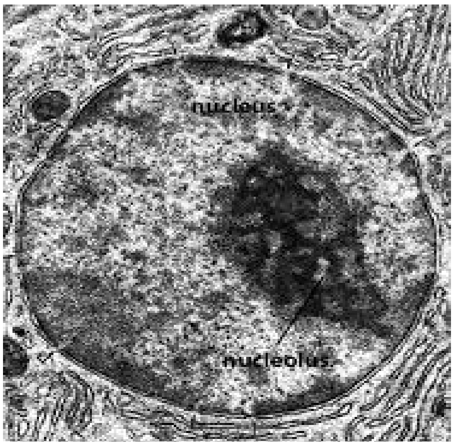
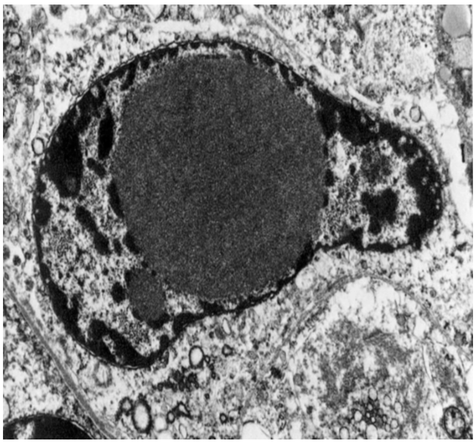
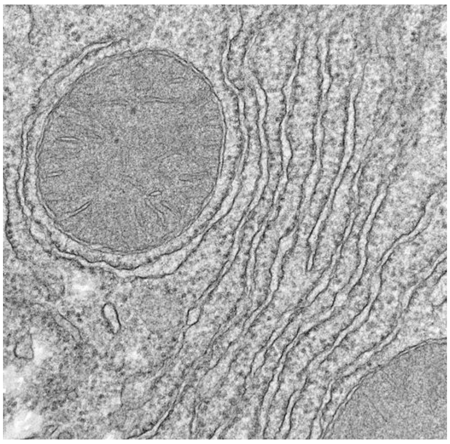
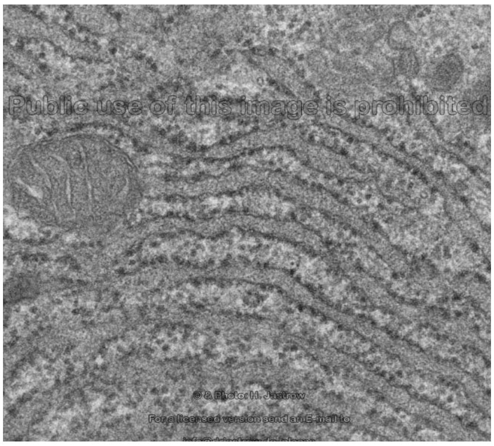
Cells

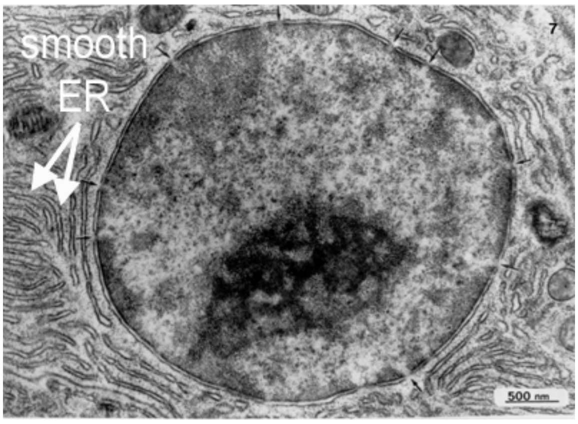
1. Organelles of a cell

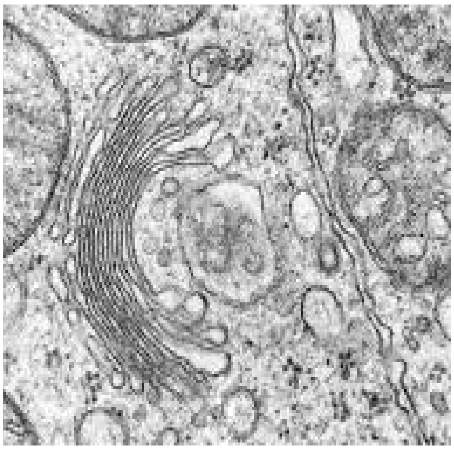
Part	Details
Cell membrane	D: partially permeable F: controls movement of food substances and oxygen into, and waste products out of the cell to maintain chemical balance with cell's surrounding medium
Cytoplasm	D: jelly-like substance F: serves as site for numerous metabolic chemical reactions and cell activities
Nucleus	D: consists of nucleoplasm, chromatin and a nucleolus; surrounded by nuclear envelope F: nucleolus: plays a role in the making of proteins; nuclear envelope: separates contents of the nucleus from rest of cytoplasm; chromatin: each chromatin thread is made of proteins and deoxyribonucleic acid (DNA), which stores hereditary information and instructions cell needs for carrying out activities
Cell wall	D: made of cellulose; fully permeable F: protects cell from injury; gives plant cell a fixed shape
Rough endoplasmic reticulum (RER)	D: ribosomes attached to outer surface; continuous with nuclear envelope F: contains ribosomes that synthesise proteins; transports proteins made by ribosomes to the Golgi body for secretion out of the cell
Smooth endoplasmic reticulum (SER)	D: does not have ribosomes attached to outer surface; more tubular than RER F: synthesises fats and steroids; carries out detoxification
Ribosomes	D: small round structures; either attached to the membrane of the RER or lie freely in the cytoplasm F: ribosomes attached to RER make proteins that are usually transported out of cell; ribosomes lying freely in cytoplasm make proteins that are used within cytoplasm of cell
Golgi body	D: consist of a stack of flattened spaces surrounded by membranes; vesicles can be seen fusing with one of the Golgi body and pinching off from opposite side F: chemically modifies substances made by ER; stores and packages these substances in vesicles for secretion out of cell
Mitochondria	D: small, oval-shaped; **has its own genetic material** F: carries out aerobic respiration to release energy
Chloroplasts	D: contain green pigment chlorophyll; **has its own genetic material** F: chlorophyll traps light energy; chloroplasts carry out photosynthesis

Vacuoles	D: in plant cells: one large and central, surrounded by tonoplast; in animal cells: small, numerous and temporary F: in plant cells: contains cell sap which contains dissolved substances such as sugars, dissolved mineral salts and amino acids; in animal cells: contains water and food substances

2. Histology of cells

Nucleus	  - Nucleus have larger sizes than other organelles
RER	  - Directly outside the nucleus - In a layered fashion, is extensive - very long stacked ‘pratas’ (too many layers for a Golgi apparatus - how to differentiate)

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

not a continuous layer, get cut off
can be continuous with rough ER</td></tr>
<tr><td>Golgi body</td><td> 
Curved
must label the vesicles around it as secretory vesicles
‘stacked-off prata’, “wi-fi” sign</td></tr>
<tr><td>Mitochondrion</td><td></td></tr>
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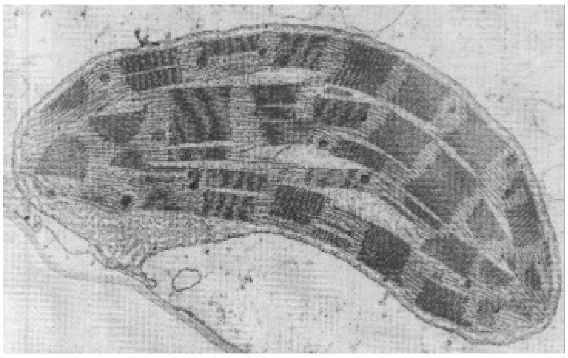
Chloroplast	

3. Protein synthesis pathway
    a. mRNA (instructions) synthesised by nucleus
    b. leaves nucleus through nuclear pores
    c. Moves to RER when ribosomes use them as templates
    d. for synthesis of polypeptides
    e. Polypeptides move within RER and are modified and assembled into proteins
    f. Proteins are transferred to Golgi apparatus for modification and packaging for transport into (secretory) vesicles which pinch off.
    g. Secretory vesicles fuse with cell membrane, releasing proteins outside the cell.

*note(s):
- Protein synthesis: may need to mention tRNA
- Products may be used within the cell (intracellular)
- Products released outside the cell: use secretory vesicles

4. Comparison between plant and animal cells

Plant cell	**Animal cell**
Cell wall present	Cell wall absent
Chloroplasts present	Chloroplasts absent
Centrioles absent	Centrioles present
A large central vacuole	Vacuoles are small, numerous and temporary

5. Differentiation
   Differentiation is the process by which a cell becomes specialised for a specific function.
    a. RBC
        i. Biconcave (and elastic)
        ii. Contains Hb
        iii. No nucleus
        iv. Elastic
    b. RHC
        i. Concentrated cell sap
        ii. Long narrow protrusion
    c. Xylem
        i. No cross walls/continuous lumen

        ii. No cytoplasm/dead
        iii. Lignified
    d. Epithelial cell
    e. Cilliated cells of trachea

Movement of Substances

1. Diffusion
    a. Diffusion is the net movement of particles from a region of higher concentration to a region of lower concentration, down a concentration gradient.
    b. Condition(s): There must be a concentration gradient.
    c. Can assume that movement of one type of particle is unaffected by the presence of other types of particles.
2. Osmosis
   Osmosis is the net movement of water molecules from a solution of higher water potential to a solution of lower water potential, through a partially permeable membrane, down a water potential gradient.
   Condition(s): p.p.m; water potential gradient.
    a. Template
        i. Compare wp.
           There is a higher wp in the __ than in the __.
        ii. Describe movement
           There is a net movement of water molecules from __ to __ by osmosis.
        iii. Result
           So ____
    b. Know how osmosis causes bending
        i. If one group of cells is unable to shrink or expand due to a waxy cuticle or is hardened, then there will be uneven expansion/contraction resulting in bending
        ii. Examples: guard cells have wall thicker on one side; cutting of strips)
    c. Sources of error for osmosis experiments
        i. Epithelial layers can *interfere (do NOT use vague language! If there is an effect, state the effect and why it occurs)* with results - e.g. affects mass measured
        ii. Evaporation (DODGY) - e.g. using test tube vs petri dish - larger exposed surface area using petri dish, solution will evaporate faster
        iii. Dilution effects (DODGY) water moving out of the potato strips will affect the concentration of the solution - better way is to use larger volumes using larger containers
        iv. Different parts of the organ may have different compositions in the tissue, leading to different results
3. Active transport
    a. Active transport is the process in which energy is used to move the particles of a substance across a **membrane** (not p.p.m/cell membrane) against its concentration gradient.
    a. Requires energy (from respiration, which requires oxygen) - show this understanding in explanations

b. Lower concentration to higher concentration - however, active transport happens when the body needs to absorb important substances, even when it is down a concentration gradient, so that these substances can be absorbed more quickly (e.g. selective reabsorption of glucose from glomerular filtrate; absorbing ions to create a concentrated cell sap; absorption of glucose, amino acids and fatty acids and glycerol from small intestine; absorption of potassium ions by guard cells, etc)
c. Active transport does not require a p.p.m, by definition (but in the syllabus, you'll usually see active transport happening across a living p.p.m since active transport requires energy)

4. Comparison

Diffusion	Osmosis
Does not require p.p.m	Requires p.p.m
Movement of any type of particles	Movement of water molecules
Higher concentration to lower concentration	Higher water potential to lower water potential

Similarities (diffusion & osmosis):

a. Both passive processes - no energy required
b. Both can occur across a p.p.m
c. Both involve the movement of substance from higher concentration of that substance to a lower concentration of that substance until dynamic equilibrium is reached (DODGY)

	Diffusion	Osmosis	Active transport
Down a concentration gradient	✓	✓	✗
Against a concentration gradient	✗	✗	✓
Energy needed	✗	✗	✓
Substance moved	Dissolved solutes	Water	Dissolved solutes
Notes	Gases and dissolved gases also diffuse	Partially permeable membrane needed	Carrier protein needed

a. Diffusion
    i. Absorption of nutrients in small intestine
    ii. Absorption of oxygen in alveoli
b. Osmosis
    i. Absorption of water in roots
    ii. Absorption of water in small intestine / large intestine
c. Active transport
    i. Absorption of nutrients in small intestine
    ii. Movement of K+ ions into guard cells

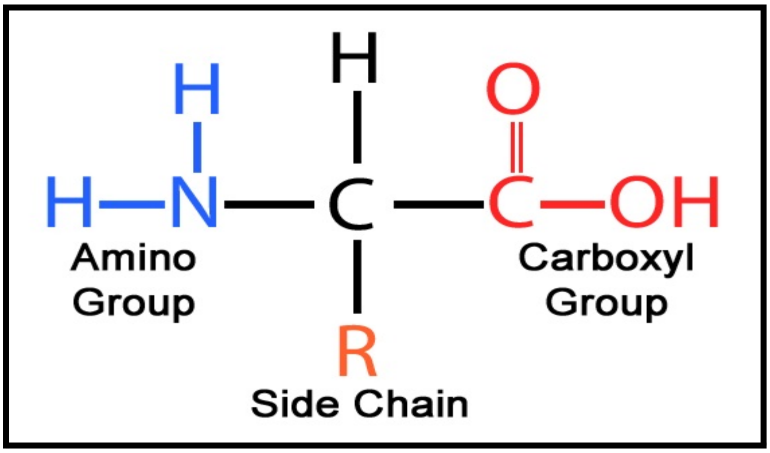
Nutrients

1. Water
    a. Transport medium
    b. Medium for chemical reactions
    c. Key component of many secretions & bodily fluids
    d. Lubricates surfaces
    e. Used in hydrolytic reactions
    f. Controlling body temperature:
        i. Water in sweat evaporates from skin surface→latent heat lost→cool body down
        ii. Maintains temperature of the body since it has high heat capacity
2. Fibre
    a. Provides roughage; adds bulk to food so that the alimentary canal can propel food along more easily through peristalsis, reducing the risk of constipation and allowing food to pass through the digestive system faster
3. Carbohydrates
    a. Made up of C, H and O
    b. Made up of monosaccharide units (glu, gal, fru) joined by glycosidic bonds to form disaccharides (maltose - glu-glu, lactose - glu - gal, sucrose - glu-fru) and polysaccharides (starch, glycogen, cellulose) through condensation reactions
    c. Monosaccharides
        i. Glucose: found in plants and animals
        ii. Fructose: common in plants, rare in animals
        iii. Galactose: present in milk sugar of mammals
    d. Disaccharides
        i. Sucrose: found in plants, not in animals, sucrose = glucose + fructose
        ii. Maltose: occurs in germinating grains, maltose = glucose + glucose
        iii. Lactose: occurs in milk of mammals, lactose = glucose + galactose
    e. Polysaccharides
        i. Starch: storage form of carbohydrates in plants; can be digested to glucose for aerobic respiration to release energy
        ii. Cellulose: found in cell walls, which protect plant cells from injury; cannot be digested in intestines of humans; enzyme that breaks down cellulose: cellulase
        iii. Glycogen: storage form of carbohydrates in mammals; can be digested to glucose for aerobic respiration to release energy
        iv. Properties that make starch and glycogen suitable storage of carbohydrates
            1. Insoluble in water: does not affect the water potential in cells; if a cell stores soluble monosaccharides, the monosaccharides will dissolve in the water of the cytoplasm of the cell→lowering the water potential of the cytoplasm of the cell, causing osmosis of water into the cell→if it is an animal cell, cell may expand and burst

        2. Large molecule: does not diffuse through the cell membrane as it is too big; will not be lost from cell
        3. Compact: more glycogen or starch can be stored in a given space
        4. Easily hydrolysed to glucose: can be used easily, can respire aerobically to release energy quickly
   f. All monosaccharides and disaccharides are reducing sugars (EXCEPT sucrose)
   g. Functions
      i. Release energy through respiration
      ii. Transport food throughout plant
      iii. Energy storage
      iv. To synthesise cellulose for cell walls
      v. Produce mucus for lubrication
   h. Found in bread, rice, noodles
   i. Tests
      - Iodine test
        1. Add a few drops of iodine solution to the food sample.
        2. If starch is present, iodine solution turns from yellowish brown to blue-black.
        3. If starch is absent, iodine solution remains yellowish brown.
      - Benedict's test
        1. Place 2 cm^3 of food sample into a clean test tube.
        2. Add an equal volume of Benedict's solution into the food sample.
        3. Shake the mixture and place the test tube in a boiling water bath for 2-3 minutes.
        4. Results:
           Remains blue: reducing sugar absent
           Green ppt. : small amount of reducing sugar
           Yellow or orange ppt. : moderate amount of reducing sugar
           Red-brick ppt. : large amount of reducing sugar
4. Fats
   a. Made up of C, H and O
   b. Made up of glycerol and fatty acids joined by ester bonds through condensation reactions
   c. Functions:
      i. Energy storage
      ii. Insulation against heat loss
      iii. Synthesis of cell membranes
      iv. Absorption of fat soluble vitamins
   d. Found in oil, butter, milk
   e. Test
      i. Ethanol emulsion test
         1. On liquid food
            a. Add 2 cm^3 of ethanol to the food sample in the test tube and shake the mixture thoroughly.
            b. Add 2 cm^3 of water to the mixture and shake the mixture.
            c. Results:
               Cloudy-white emulsion: fats present
               Solution remains clear: fats absent

2. On solid food
    a. Cut the food sample into small pieces and place the pieces in a test tube.
    b. Add 2 cm^3 of ethanol and shake thoroughly.
    c. Allow the solid particles to settle.
    d. Carefully decant (pour in a way such that you don't get the solid particles) the ethanol into another test tube containing 2 cm^3 of water.
    e. Results:
    Cloudy-white emulsion: fats present
    Solution remains clear: fats absent

5. Proteins
    a. Made up of C, H, O and N.
    b. Made up of amino acids joined by peptide bonds through condensation reactions
    c. Structure of an amino acid:



Amino acids are linked up by peptide bonds to form polypeptides.

    d. Functions:
        i. For synthesis of protoplasm to build new cells for growth, repair and maintenance.
        ii. Energy source when carbohydrates are not available
        iii. Synthesis of hormones, enzymes, antibodies
    e. Found in milk, meat, eggs
    f. Test
        i. Biuret test
            1. Add 2 cm^3 of sodium hydroxide solution (or 40% bench solution) to 2 cm^3 of the food sample in a test tube and shake it thoroughly.
            2. Add 1 % copper(II) sulfate solution, drop by drop, shaking after each drop.
            3. Results:
            Solution turns from blue to violet/purple if proteins are present.

6. Reactions
    a. Condensation reaction: chemical reaction in which two simple molecules are joined together to form a larger molecule with the removal of one water molecule

b. Hydrolysis/hydrolytic reaction: reaction in which a water molecule is needed to break up a complex molecule into smaller molecules

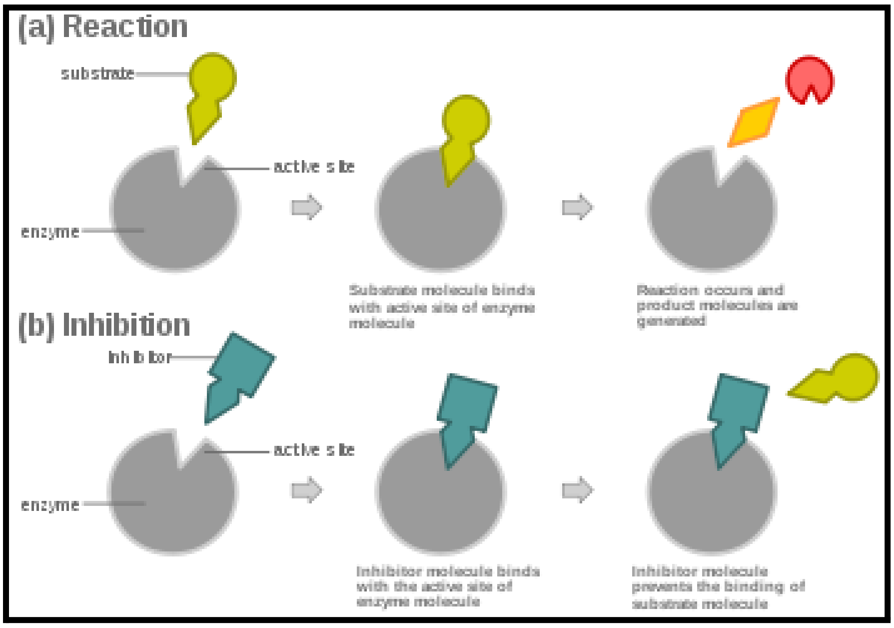
Enzymes

1. Biological catalysts that are protein in nature that increase the rate of biological reactions by decreasing the activation energy.
2. Enzyme activity is
    a. Highly specific
    3-D shape of active site of an enzyme only complementary to shape of substrate of the reaction catalysed (one enzyme one substrate - will usually test this by showing diagram of enzymes and substrates + shape of the active site)
    b. Temperature dependent (at low temp it is inactive, at optimum temp its activity is max, and above optimum temp it is denatured)
    c. pH dependent (at optimum pH its activity is max, and above and below optimum pH it is denatured)
    d. Affected by substrate concentration (higher concentration, higher rate until the active sites start becoming fully occupied)
    e. Enzymes remain chemically unchanged at the end of reactions and can be reused, so they are required in small amounts

Effect of temperature of enzymes	1. Enzymes are **inactive at low temperatures** since their **kinetic energy levels are low** and the **frequency of effective collisions** between substrate and enzyme molecules is **low**. 2. Enzyme activity increases with temperature. **For every 10°C rise in temperature, the rate of enzyme reaction doubles** until optimum temperature is reached. Raising the temperature **increases the kinetic energy levels** of the molecules, and hence more enzyme and substrate molecules have **energy levels equal to or greater than activation energy.** The **frequency of effective collisions** between enzyme and substrate molecules increases and the chances of the substrates fitting into the active sites of the enzymes increase. Thus, the **rate of formation of enzyme-substrate complexes increases**. 3. At the optimum temperature, the enzyme is the **most active** and the rate of reaction is the highest. 4. Beyond the optimum temperature, **enzyme activity decreases.** The high temperature **breaks the hydrogen bonds** that keep the enzyme protein in shape. The **active site** of the enzyme **loses its original shape** and the shape of the substrate is **no longer complementary** to that of the active site, and can no longer fit into it. The enzyme is **denatured.**
Effect of substrate concentration on enzymes	1. As the substrate concentration increases, the **rate of reaction increases** as the **frequency of effective collisions** between substrate and enzyme molecules **increases**. Thus, the chances of the substrates fitting into the active sites of the enzymes increases and the **rate of formation of enzyme-substrate complexes increases**. 2. However, after a certain point, increasing the substrate concentration no longer increases the rate of the reaction any further, since at any given

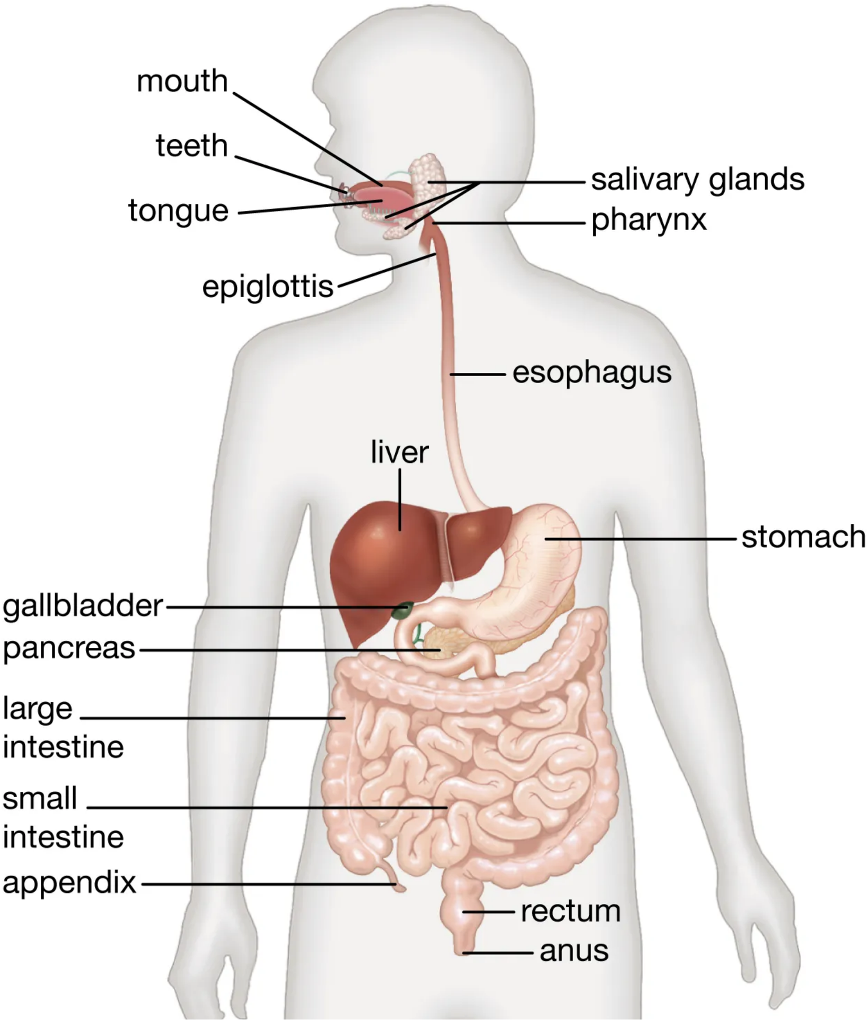
	instant, all the **active sites** of the molecules are being **binded to the substrate molecules**. The enzyme molecules are **saturated**. The number of products formed per unit time remains the same. Enzyme concentration is now the limiting factor.
Effect of pH on enzymes	1. At the optimum pH, enzyme activity is the greatest. 2. Beyond and below its optimum pH, the enzyme is **denatured**. 3. The active site of the enzyme **loses its original shape** and the shape of the substrate is **no longer complementary** to that of the active site, and can no longer fit into it.

3. Competitive inhibition



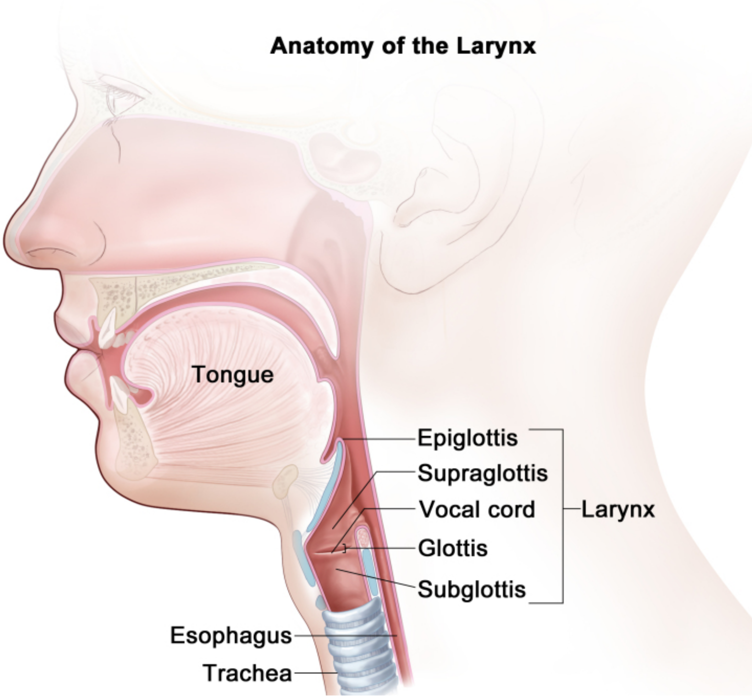
The inhibitor molecule has the same shape as the substrate molecule, but does not react.

Nutrition in Humans



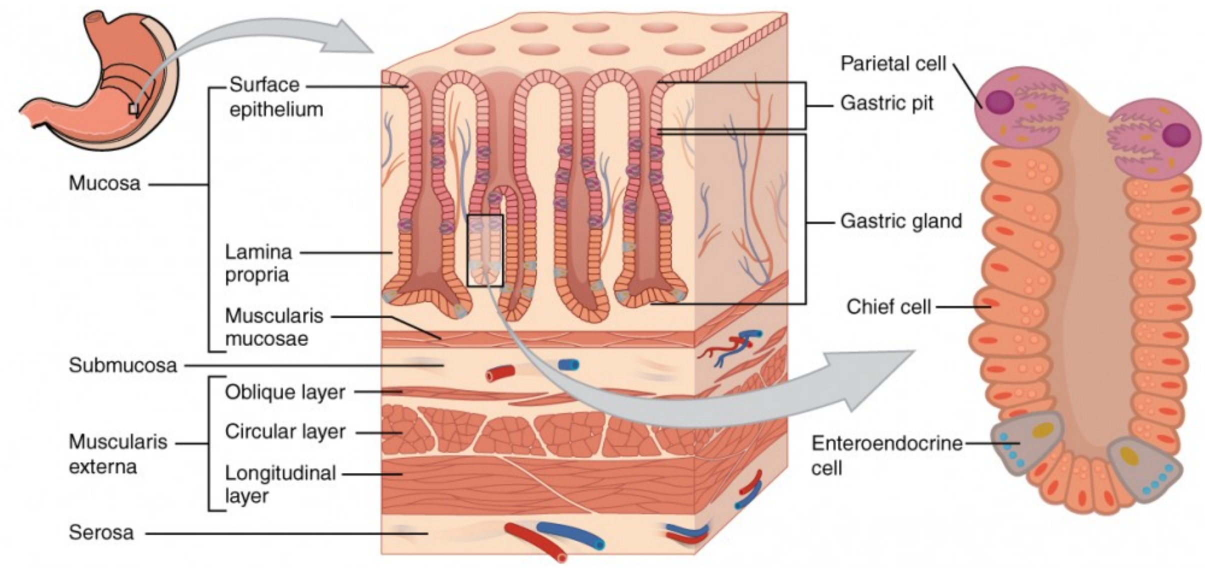
1. Digestion
    a. Types
        i. Physical: break up large pieces/droplets of food into smaller pieces/droplets to increase surface area to volume ratio for more efficient digestion by enzymes
        ii. Chemical: breakdown large insoluble food molecules into smaller soluble food molecules so that they are small enough to be absorbed through the partially permeable walls of the small intestine by diffusion/active transport
2. Parts of the digestive system
    a. Mouth
        i. Physical: Teeth cut and grind food into smaller pieces
        ii. Chemical: Starch→maltose by salivary amylase
        iii. Support processes: Tongue rolls food into a bolus; rolling action of the food helps to break up the food into smaller pieces; Salivary glands secrete saliva into the mouth
        iv. Juices: Saliva
    b. Pharynx

i. Connects buccal cavity to oesophagus and larynx
ii. Swallowing:



During swallowing, epiglottis moves downwards while glottis and larynx move upwards to close the trachea when food is swallowed

c. Oesophagus
   i. Chemical: Starch→maltose by salivary amylase
   ii. Support processes: Peristalsis
      1. Circular muscles contract, longitudinal muscles relax. Lumen of the oesophagus becomes narrower and longer and food is pushed forward.
      2. Circular muscles relax, longitudinal muscles contract. Lumen of the oesophagus to widen and shorten and food is allowed to enter.
   iii. Juices: Saliva
d. Stomach
   i. Physical:
      1. Peristaltic muscular contractions: Churn and break up the food into smaller pieces to increase its surface area to volume ratio; mixes the food well with gastric juice
   ii. Chemical:
      1. Proteins → polypeptides by proteases (pepsin)
      2. Caseinogen → casein by rennin
      3. Pepsinogen → pepsin by HCl
      4. Prorennin → rennin by HCl
   iii. Support processes:
      1. HCl in gastric juice:
         a. Kills bacteria
         b. Acidic environment activates pepsinogen into pepsin



2. Mucus producing cells: produce mucus to:
    a. prevent stomach from being corroded by strong HCl or being digested by pepsin (since stomach walls are made of proteins)
    b. serve as lubrication during peristalsis in stomach

iv. Food is temporarily stored for a few hours

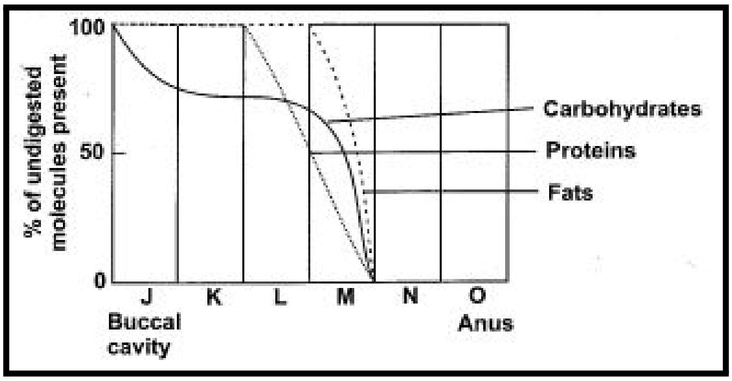
v. Rings of muscles:
1. Cardiac sphincter: closes of top end leading to oesophagus
2. Pyloric sphincter: closes of bottom end leading to small intestine

e. Pancreas
    i. Secretes pancreatic juice (contains pancreatic amylase, pancreatic lipase and trypsinogen)

f. Liver
    i. Produces and secretes bile
    ii. Vessels:
        1. Hepatic artery: carries oxygenated blood from the heart
        2. Hepatic vein: carries deoxygenated blood away from the liver; carries blood containing the remaining glucose and amino acids to be distributed around the body
        3. Hepatic portal vein: carries blood containing glucose and amino acids from the small intestine to the liver

g. Gallbladder
    i. Temporarily stores bile
    ii. Bile transported to the small intestine via the bile duct

h. Small intestine



i. Duodenum
   1. Physical:
      a. Bile emulsifies large fat globules into smaller fat droplets, increasing the surface area to volume ratio of fats for lipase to digest it into fatty acids and glycerol more quickly
   2. Chemical:
      a. (Remaining undigested) starch → maltose by pancreatic amylase
      b. Trypsinogen→ trypsin by enterokinase
      c. Proteins → polypeptides by trypsin
      d. Fats → fatty acids + glycerol by lipases (pancreatic lipase & intestinal lipase)
   3. Support processes:
      a. Bile salts and pancreatic juice neutralise acid and create alkaline conditions
   4. Juices:
      a. Bile
      b. Pancreatic juice

ii. Ileum
   1. Chemical:
      a. Maltose → glucose by maltase
      b. Sucrose → glucose + fructose by sucrase
      c. Lactose → galactose + glucose by lactase
      d. Polypeptides → amino acids by erepsin
      e. Fats → fatty acids + glycerol by lipases
   2. Juices:
      a. Intestinal juice

3. Absorption

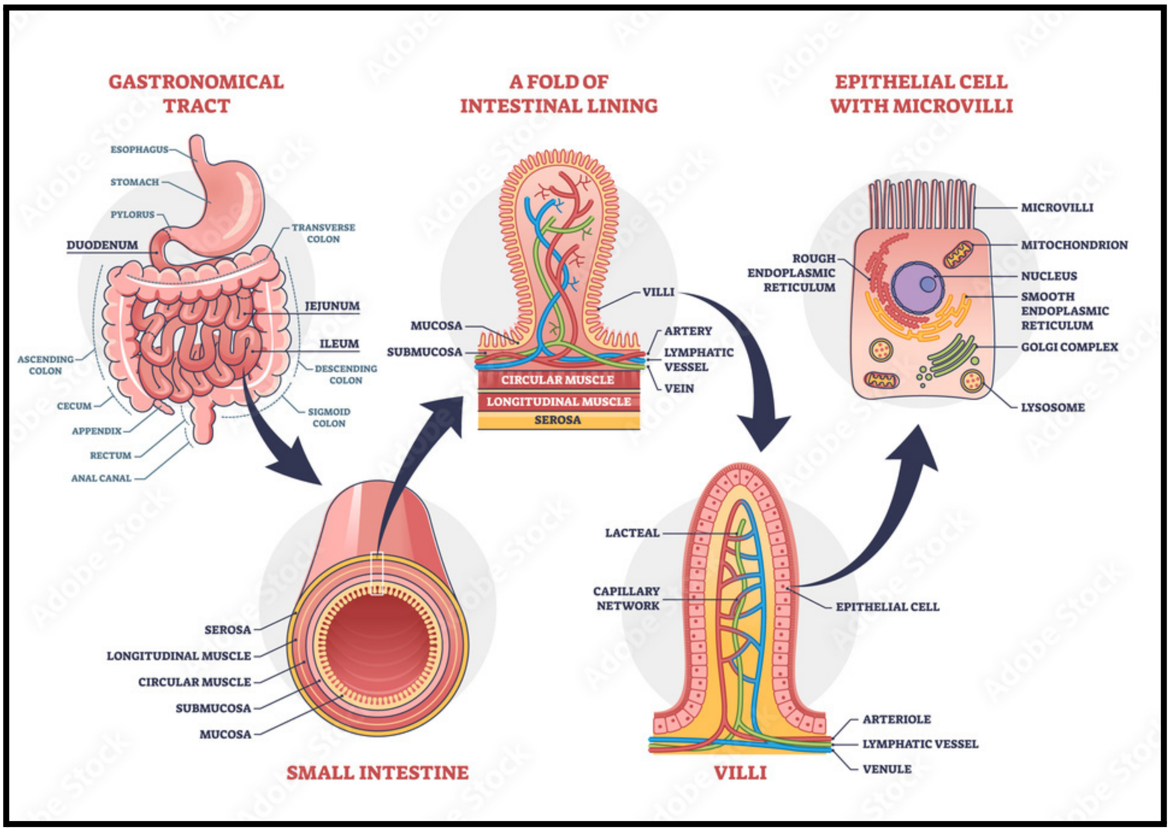
   a. Nutrients

Glucose and amino acids	Fatty acids and glycerol	Water
Glucose and amino acids diffuse into the epithelium of villi	Glycerol and fatty acids diffuse into the epithelium of villi and combine to form minute fat globules when they enter the lacteal	Water is absorbed by diffusion Dissolved mineral salts are absorbed in the ileum

When there is a lower concentration of glucose and amino acids in the lumen of the small intestine than in the blood capillaries, glucose and amino acids are absorbed by active transport		

b. Adaptations

Adaptation	**Function**
1. Inner surface of the small intestine is folded 2. Folds bear numerous villi, whose epithelial cells have numerous microvilli	Increases the surface area to volume ratio for faster absorption of digested food substances
Villi have one-cell thick epithelium	Decrease diffusion distance of digested food substances
Rich supply of blood capillaries	Allow continual transport of digested food substances to maintain a steep concentration gradient
Very long (~7m)	Provide sufficient time for absorption of digested food substances



*note: don't mistake the folds on intestinal walls as villi

3. Assimilation
    a. Assimilation of glucose
        i. Glucose is transported to the liver from the small intestine by the hepatic portal vein
        ii. Some glucose leaves the liver and is transported to cells for respiration
        iii. The islets of Langerhans of the pancreas secrete more insulin, which stimulates the liver and muscles to convert excess glucose to glycogen
        iv. When the body needs energy, the islets of Langerhans of the pancreas secrete more glucagon, stimulating the liver and muscles to convert glycogen back to glucose, which is transported by the blood to cells

    b. Assimilation of amino acids
        i. Amino acids are transported to the liver from the small intestine by the hepatic portal vein
        ii. Amino acids which enter the cells are converted into new protoplasm used for growth and repair of worn-out body parts. Amino acids are also used to form enzymes and hormones.
        iii. Excess amino acids are deaminated in the liver, where their amino groups are removed and converted to ammonia, which is toxic and is then converted to urea, which is non-toxic and excreted in urine

    c. Assimilation of fats

    i. Fats are absorbed into lacteals (lymphatic capillaries), which then join to form larger lymphatic vessels
    ii. These lymphatic vessels discharge fats into the bloodstream
    iii. Fats are used to build protoplasm, when there is sufficient supply of glucose.
    iv. When there is insufficient glucose, fats are broken down to release energy
    v. Excess fats are stored in adipose tissues beneath the skin and around the heart and the kidneys. Adipose tissues protect these organs by acting as shock absorbers.

4. Liver
    a. Liver is very active and is a large organ (makes up a large part of the body). A lot of metabolic processes take place in it, so it releases a lot of heat (balances the amount of heat lost as well) - should only use this point when desperate for the role of the liver
    b. Regulation of blood glucose concentration (refer to *Homeostasis*)
        i. Iron storage
            1. Worn-out red blood cells are destroyed in the spleen, releasing haemoglobin, which is brought to the liver
            2. The liver breaks down the haemoglobin
            3. The iron released in the process is stored in the liver for synthesis of new red blood cells
            4. Bile pigments are also released
        ii. Deamination of excess amino acids
            1. Excess amino acids are deaminated in the liver. The amino groups of the excess amino acids are removed and converted to ammonia, which is toxic to cells and is then converted to urea, which is non-toxic and excreted in urine.
            2. The carbon residues of excess amino acids are converted to glucose, which is converted to glycogen and stored in the liver and muscles
        iii. Detoxification
            1. Liver produces alcohol dehydrogenase
            2. Alcohol dehydrogenase catalyses the breakdown of alcohol into acetaldehyde
            3. Acetaldehyde can be broken down further to compounds that can be used in respiration to release energy for cellular activities
        iv. Protein synthesis
            1. Liver synthesises proteins found in the blood plasma, including prothrombin and fibrinogen, which are essential for blood clotting

5. Effects of excessive alcohol consumption
    a. Short term effects
        i. Slower reactions (longer reaction times)
        ii. Poorer coordination
        iii. Slurred speech
        iv. Lowered inhibitions

b. Long term effects
    i. Stomach ulcers
        1. Alcohol stimulates acid secretion in the stomach. Excess stomach acid increases the risk of gastric ulcers.
    ii. Liver cirrhosis
        1. Liver cells are destroyed and replaced with fibrous tissue, making the liver less able to function.
        2. This may lead to haemorrhage in the liver, which can subsequently cause liver failure and death.

Nutrition in Plants

1. Photosynthesis
    a. Light-dependent stage:
        i. Photolysis of water: light energy absorbed by chlorophyll is used to split water into hydrogen and oxygen atoms
        ii. The oxygen atoms combine to form oxygen gas
        iii. Other high-energy molecules are generated for use in the light-independent stage to convert carbon dioxide into glucose
    b. Light-independent stage:
        i. Hydrogen produced in photolysis is used to reduce carbon dioxide to glucose
        ii. The chemical energy stored during the light reactions as high-energy molecules is used in this process

    c. Other note(s):
        i. In the light-dependent stage, 12 molecules of water are split up to yield 6 molecules of oxygen and 24 atoms of hydrogen.
        ii. All the oxygen gas released during photosynthesis comes from water.
        iii. As the rate of photosynthesis increases, more oxygen is produced. The volume of oxygen produced thus indicates the rate of photosynthesis.
        iv. In the light-independent stage, the hydrogen released during photosynthesis is used to reduce 6 molecules of carbon dioxide. As a result, 1 molecule of glucose is formed.
        v. Several enzymes are involved in the light-independent stage.

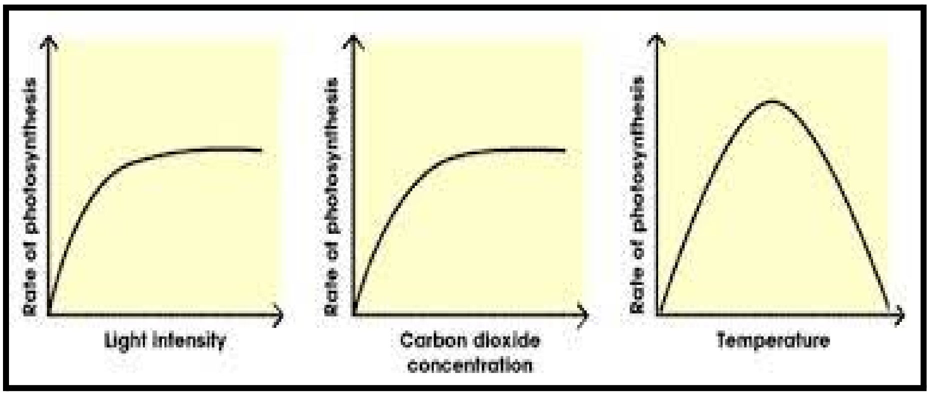
    d. Overall equation:
        i. Chemical equation:

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

        ii. Word equation:

$$\textbf{carbon dioxide + water} \xrightarrow[\textbf{chlorophyll}]{\textbf{light energy}} \textbf{glucose + oxygen}$$

2. Limiting factors of photosynthesis
    a. Limiting factors are factors that directly affect a process if its quantity is changed.
    b. Limiting factors are factors that would increase the rate of photosynthesis when they are increased. If reducing a factor reduces the rate of photosynthesis, it PROVES NOTHING. (When you reduce it, it proves that it HAS been limiting, but it doesn't mean that it WAS limiting.)



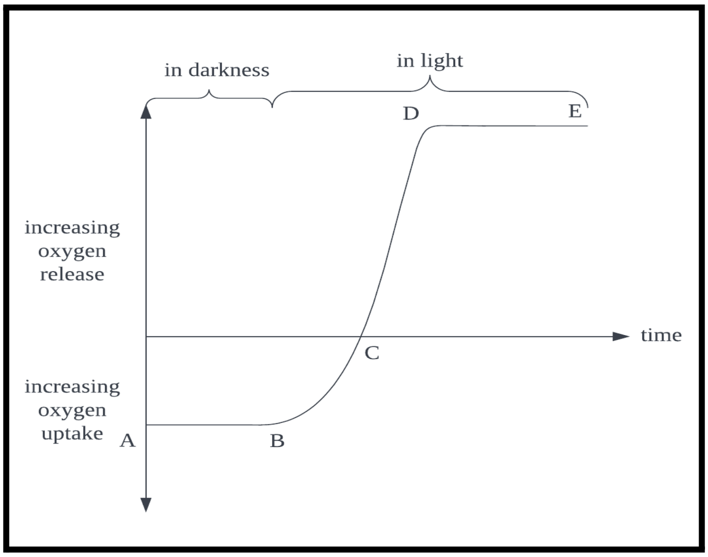
When increasing light intensity or carbon dioxide concentration no longer increases the rate of photosynthesis, then light intensity or carbon dioxide concentration is no longer the L.F. Some other factors could be causing the plateau of the graph.

In the entire rate of photosynthesis-temperature graph, temperature is the L.F except for the point at the optimum temperature.

*notes: Carbon dioxide concentration affects, since carbon dioxide is a substrate; light intensity provides the energy for photosynthesis to occur. Humidity may affect photosynthetic rate.

3. Fate of glucose
    a. Respiration
    b. Converted to cellulose to form cell walls
    c. Excess glucose stored as starch in leaves
    d. Converted to sucrose by combining it with fructose to be transported to other parts of the plant
    e. Reacts mineral salts to form to form amino acids in leaves
        i. Amino acids are used to form proteins for the synthesis of new protoplasm in leaves
        ii. Excess amino acids are transported to other parts of the plant for synthesis of new protoplasm or for storage as proteins
    f. Forms fats:
        i. for storage
        ii. for cellular respiration
        iii. for synthesis of new protoplasm

4. Graphs of photosynthesis



- At point B, there is a decrease in oxygen uptake and an increase in oxygen release. The rate of photosynthesis increases. **Photosynthesis starts at point B**, as soon as the plant starts to release oxygen. This is because oxygen used up per unit time is lower, meaning that some of the oxygen used up by respiration is being offset by small amounts of oxygen produced by photosynthesis.
- At C, the amount of oxygen released is equal to the amount of oxygen absorbed. This suggests that the rate of photosynthesis is equal to the rate of respiration. (Note: ❌ "rate of p/s is the **same as** rate of r/s")

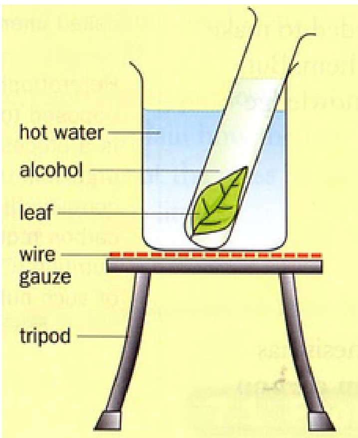
5. Photosynthesis experiments

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 are the monosaccharides, e.g. glucose.	N.A.
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. (Under the presence of light, the rate of photosynthesis is higher than the rate of respiration.) • However, starch formation is not photosynthesis – starch can be formed even in the	Test for starch using iodine test.

	roots or underground storage organs of plants.	
De-starching (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 catalyse the **conversion of starch to sucrose**, which is **transported to other parts of the plant.**

a. **Factors necessary for photosynthesis**

Experiment 1: Test for starch in a leaf:



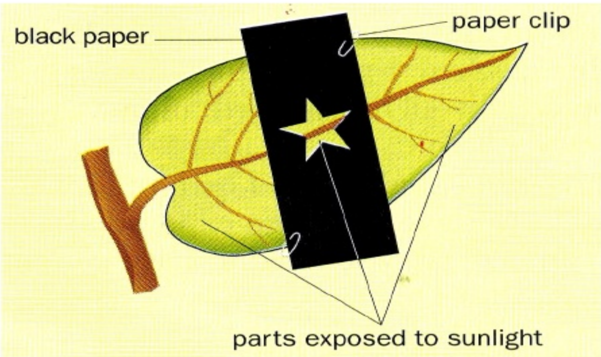
Test on leaf specimen P1.

Step	Action	Purpose
1	Plant containing P1 was placed in a dark room for 48 hours.	To destarch the plant so that any starch present in P1 later is only formed during the experiment.
2	Plant containing P1 was placed under the Sun for 5 hours before P1 was removed from the plant.	To allow the plant to carry out photosynthesis.
3	P1 was placed into a beaker of boiling water.	To denature all enzymes in P1 so that starch formed through photosynthesis is not converted to glucose. The high temperature also destroys the cell membranes of the leaf cells.

4	P1 was removed from the hot water and placed into a boiling tube containing ethanol. The boiling tube is then placed into a beaker of boiling water.	To remove chlorophyll from P1 so that the colour change caused by the iodine solution later will be more easily visible.
5	P1 was removed from the boiling water using a forcep and placed back into hot water.	To soften the leaf and make the leaf cells more permeable to iodine solution.
6	P1 was stained with iodine solution on a white tile.	To test for the presence of starch and observe its distribution in P1.

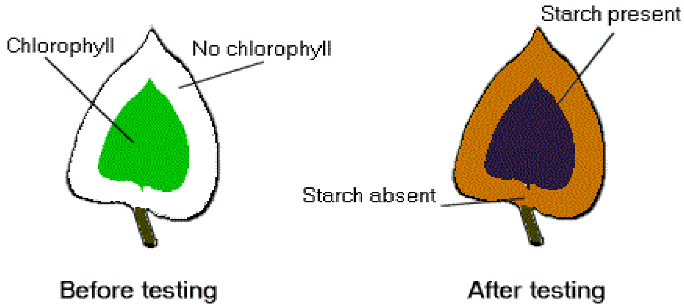
Observation: The iodine solution turns from yellowish brown to blue-black.
Conclusion: Starch is present in the leaf.

Experiment 2: Test if light is necessary for photosynthesis:



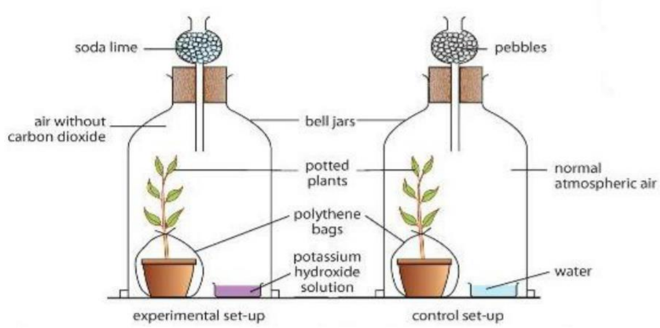
1. Destarch a potted plant by placing it in the dark for two days.
2. Remove one leaf. Test it for starch as described in Experiment 1.
3. Sandwich a leaf, which is still attached to the plant, between two pieces of black paper. Each paper has a certain pattern cut out from it. Fasten the papers with paper clips. Place the plant in strong sunlight.
4. After a few hours, remove the leaf and test it for starch.
5. Make a drawing of the leaf to show the regions that are stained blue-black.
    a. Before the treatment of the leaf with iodine solution, the leaf must be **de-starched**. This is to ensure that the formation of starch from excess glucose occurred during the experiment.
    b. When iodine solution is applied to the parts exposed to light, the iodine solution changes from yellowish-brown to blue-black. (Reason: The chlorophyll in the chloroplasts absorb light energy for photosynthesis, producing **excess** glucose which is converted to starch for storage.)
    c. When iodine solution is applied to the parts that were covered by the black paper, the iodine solution remains yellowish brown. (Reason: The chlorophyll in these parts were not exposed to light, so light energy cannot be absorbed by chlorophyll for photosynthesis to occur.)

Experiment 3: Test if chlorophyll is necessary for photosynthesis:



1. Destarch a plant with variegated leaves by placing it in the dark for two days.
2. Expose the plant to strong sunlight for a few hours.
3. Remove one leaf. Make a drawing to show the distribution of the green parts, i.e. the parts that contain chlorophyll.
4. Decolourise the leaf and test it for starch.
5. Make a drawing of the leaf to show the distribution of the blue-black colour. Compare this with your drawing in step 3.
    a. Before the treatment of the leaf with iodine solution, the leaf must be **de-starched.** This is to ensure that the formation of starch from excess glucose occurred during the experiment.
    b. When iodine solution is applied to the green parts of the leaves, the iodine solution changes from yellowish-brown to blue-black. (Reason: Only those parts containing chlorophyll will absorb light energy and photosynthesis occurs, which produces **excess** glucose, which is converted to starch for storage, so starch is present.)
    c. When iodine solution is applied to the non-green parts of the leaves, the iodine solution remains yellowish-brown. (Reason: Chlorophyll is absent in these parts of the leaves, hence, light energy cannot be absorbed and photosynthesis does not occur, so no glucose is produced. Thus, this does not give rise to excess glucose converted to starch for storage, so starch is absent.)

Experiment 4: Test if carbon dioxide is necessary in photosynthesis:



1. Destarch two potted plants by placing them in the dark for two days.
2. Enclose the pots in polythene bags. Secure the bags to the plant stems.
3. Place one pot in the bell jar. The plant does not have a supply of carbon dioxide from the air because soda lime and potassium hydroxide solution rapidly absorb carbon dioxide. Leave the whole apparatus in strong sunlight for a few hours.

4. Set up a control using pebbles and water in place of soda lime and potassium hydroxide solution respectively. Leave the control apparatus in strong sunlight for a few hours.

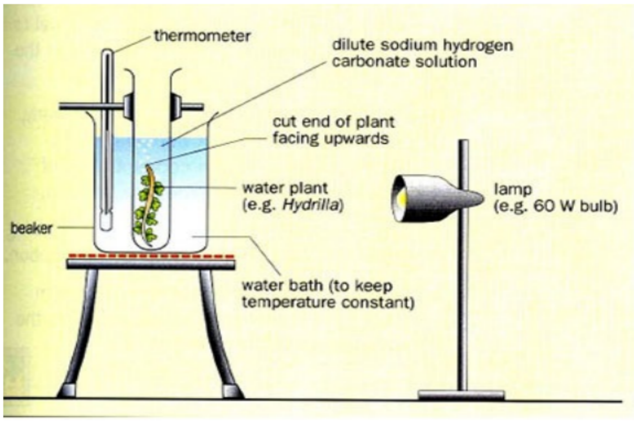
Notes:

a. Chemicals used:
    i. The soda lime serves as a “filter”. The soda lime absorbs carbon dioxide from the atmospheric air that enters the bell-jar.
    ii. The sodium hydroxide serves to remove the remaining carbon dioxide in the bell-jar.
    iii. The soda lime and sodium hydroxide hence ensure that there is no carbon dioxide present in the bell-jar.

b. The soil is covered with a polythene bag:
    i. To prevent water loss by evaporation of water in the soil.
    ii. To prevent the contribution of carbon dioxide into the air in the set-up by microorganisms living in the soil that respire.
    iii. When iodine solution is applied to the leaf exposed to air with carbon dioxide, the iodine solution changes from yellowish-brown to blue-black. (Reason: Carbon dioxide is required in photosynthesis. It is reduced by hydrogen to glucose. The excess glucose formed in photosynthesis is converted to starch for storage, so starch is present.)
    iv. When iodine solution is applied to the leaf exposed to air without carbon dioxide, the iodine solution remains yellowish-brown. (Reason: Carbon dioxide is required in photosynthesis. It is reduced by hydrogen to glucose. Without carbon dioxide, no photosynthesis occurs, so no glucose is produced. Thus, this does not give rise to excess glucose converted to starch for storage, so starch is absent.)

b. **Factors affecting the rate of photosynthesis**

Experiment 1: Effect of light intensity on the rate of photosynthesis:



1. Set up the apparatus as shown above with the cut end of the water plant positioned upwards.

2. Air bubbles are given off from the cut end of the plant. Allow some time for the plant to adapt to the conditions provided before taking readings.
3. When the bubbles are produced at a regular rate, count the number of bubbles over a period of 5 minutes. Repeat this a few times to obtain the average rate
4. Repeat step 3 with the light source closer to the plant, e.g. 80 cm, 40 cm, 30 cm, 20 cm, 15 cm and 10 cm. The nearer the light source is to the beaker, the higher the light intensity that the plant is exposed to.
5. Record your results in a table. Plot a graph to show the rate of bubbling per minute against the distance between the lamp and the plant.

- Notes:
    - ➔ Some time is allowed for the rate of bubbling to stabilise.
    - ➔ Observation: The rate of bubbling increases as the distance of the lamp from the plant decreases.
    - ➔ The dilute sodium hydrogencarbonate solution serves as a source of dissolved carbon dioxide.
    - ➔ In some experiments, sodium bicarbonate is used. Sodium bicarbonate solution spontaneously decomposes to form carbon dioxide.

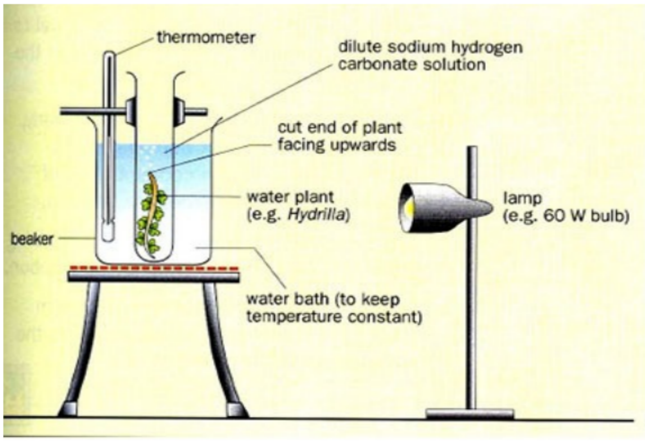
➔ The cut end of the plant faces upwards to allow bubbles containing oxygen to rise.

➔ A bubbler may be used in this experiment to serve the following purposes:
1. To ensure that all the bubbles are **of the same size.**
2. Acts as an **electronic counter.**
3. To slow down bubbling to make it **more visible** for the counting of bubbles to be more accurate.

➔ The bubbles produced contain oxygen gas, **a product of photosynthesis**. Thus, the greater the number of bubbles produced, the higher the rate of photosynthesis. The rate of gas production is **proportional** to the rate of photosynthesis.

➔ The rate of photosynthesis measured by this method may be lower than expected as:
1. Some of the oxygen gas in the bubbles might have dissolved in the water as oxygen gas is slightly soluble in water, hence the number of oxygen bubbles counted may be lower.
2. Some oxygen is used during respiration while the plant is photosynthesising.

Experiment 2: Effect of temperature on the rate of photosynthesis:

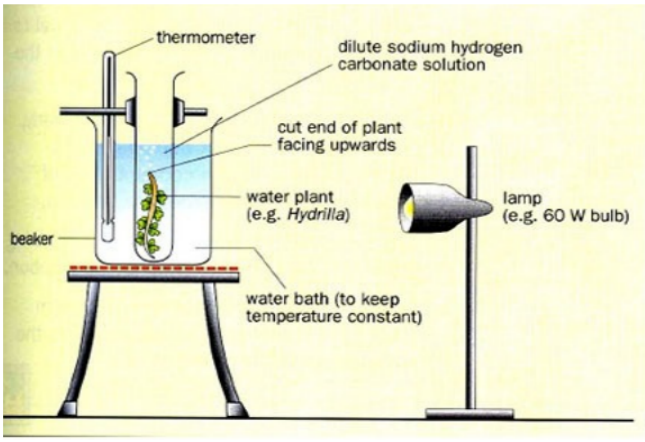


1. Set up the apparatus as shown above with the cut end of the water plant positioned upwards.
2. Place a lamp 10 cm away from the plant. Keep this distance constant throughout the experiment.
3. Add ice-cold water to the water bath to keep the temperature at 5 °C. Allow some time for the plant to adapt to the conditions provided before taking the readings.
4. Count the number of bubbles over a period of 5 minutes. Repeat this a few times to obtain an average rate.
5. Repeat step 4 at different temperatures, e.g. 15°C, 25°C, 35°C, 45°C, 55°C, 65°C and 75°C.
6. Record your results in a table. Plot a graph to show the rate of bubbling per minute against the temperature.

- Notes:

➔ The experiment starts off using cold water. This is to check if temperature is a limiting factor. If the water is too warm, the enzymes in the leaf may be denatured.
➔ It is observed that the rate of bubbling increases as the temperature is increased. The reactions in photosynthesis are enzyme-dependent.
➔ At low temperatures, enzymes are inactive.
➔ At extreme temperatures higher than optimum temperatures, enzymes are denatured.

Experiment 3: Effect of carbon dioxide on the rate of photosynthesis:

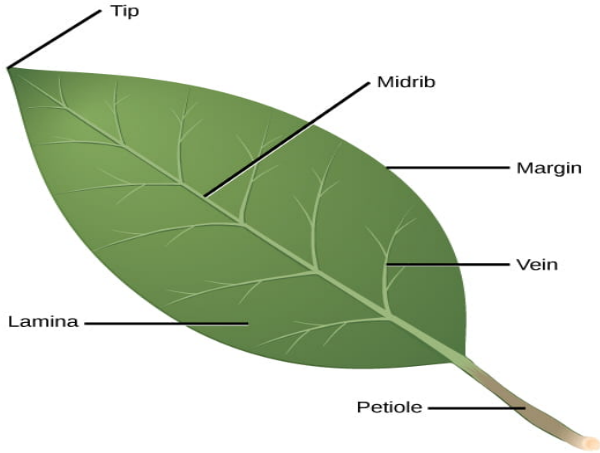


1. Set up the apparatus as shown above with the cut end of the water plant positioned upwards.
2. Place a lamp 10 cm away from the plant. Keep this distance constant throughout the experiment.
3. Conduct the experiment at room temperature.
4. Use different concentrations of sodium hydrogencarbonate solutions, e.g. 0.01 mol/dm^3, 0.02 mol/dm^3, 0.03 mol/dm^3, 0.04 mol/dm^3, 0.05 mol/dm^3, up to 0.1 mol/dm^3. (These are proportional to the carbon dioxide concentrations in the solution.)
5. When the bubbles are coming out at a regular rate, measure the rate of bubbling for each concentration of the sodium hydrogencarbonate solution.
6. Plot a graph to show the rate of bubbling against the concentration of the solution.

- Notes:
    - ➔ Different concentrations of sodium hydrogencarbonate solutions are used.
    - ➔ It is observed that the rate of bubbling increases as the concentration of the sodium hydrogencarbonate solution is increased.

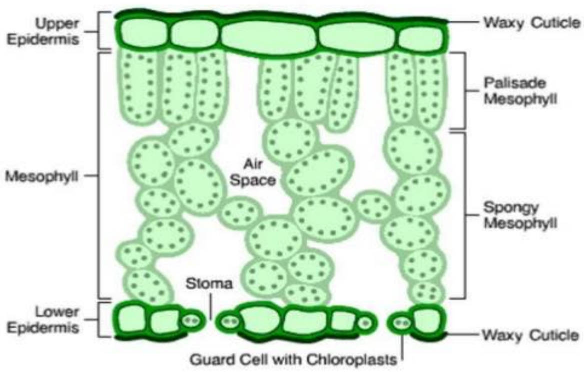
6. Leaf structure

a. External structure



Petiole	• Positions the lamina for maximum absorption of light energy. • Leaf arrangement: Leaves are always organised around the stem in a regular pattern (paired arrangement or alternate arrangement). Thus ensures that the leaves do not block each other from light and that each leaf receives sufficient light.
Thin and broad lamina	• Broad lamina provides a large surface area for maximum absorption of light energy. • Thin lamina provides a short diffusion distance for carbon dioxide to diffuse into the inner cells of the leaf quickly and for **excess** oxygen and water vapour to diffuse out of the cells of the leaf quickly. It also enables light to reach all mesophyll cells.
Veins	• Consist of the mid-rib, branch of mid-rib and branch vein. • Allow transport of dissolved mineral salts and water from the roots to the cells in the lamina. • Allow transport of manufactured food (sucrose and amino acids) from the leaf to the other parts of the plant.

b. Internal structure



Waxy cuticle on upper and lower epidermis	● Cuticle on the upper epidermis: **Prevents** water vapour loss through transpiration, as it is impermeable to water. ● Cuticle on the lower epidermis: **Reduces** water vapour loss through transpiration, as it is impermeable to water. ● Transparent for light to penetrate into the mesophyll layers. ● “Focuses” light onto the mesophyll layers. ● Protects the epidermis.
Upper epidermis	● Epidermal cells do not contain chloroplasts and are transparent to allow light to penetrate into the inner layers of the leaf. ● Has fewer stomata to reduce water loss by transpiration.
Lower epidermis	● Has numerous stomata. (Note: However, water plants are an exception. They have more stomata on the upper epidermis of their leaves, to **allow air to enter** and **allow excess water to be lost by transpiration**.) ● Guard cells contain chloroplasts and lower epidermal cells do not (important - will test)
Stomata present in the epidermal layers	● Open in the presence of light, allowing carbon dioxide to diffuse in and oxygen to diffuse out of the leaf.
Palisade mesophyll layer	● Largest concentration of chloroplasts (feature) as they receive the most sunlight so that they can maximise light absorption (important) for photosynthesis If question is to “support the plant…” → photosynthesis → produce glucose, which is used for…(other purposes) → point on photosynthesis can be developed further
Spongy mesophyll layer	● Cells are not as compact as those in the palisade mesophyll layer. ● Cells have fewer chloroplasts than those in the palisade mesophyll layer. ● Irregularly-shaped cells and their loose arrangement allow for large intercellular air spaces to occur around them to allow rapid diffusion of carbon dioxide and oxygen into and out of mesophyll cells. ● Cells are covered with a thin film of moisture

	1. Carbon dioxide can dissolve into the layer and diffuse into photosynthesising cells more quickly 2. Increased rate of evaporation for higher rate of transpiration (core purpose)
Vascular bundle	● Consists of the xylem and the phloem, allowing for the transport of water and dissolved mineral salts and sucrose and amino acids, respectively.

7. Regulation of the size of stomata (potassium ion theory)
    a. Under the presence of light
        1. Guard cells photosynthesise, converting light energy to chemical energy.
        2. The chemical energy is used to pump potassium ions into the guard cells from neighbouring epidermal cells by active transport.
        3. Potassium ion concentration in the cell sap of the guard cells increases and its water potential decreases.
        4. Water molecules from neighbouring epidermal cells enter the guard cells by osmosis, down a water potential gradient.
        5. The guard cells expand a little and become turgid.
        6. The guard cells have a thicker cell wall on one side, causing the swollen guard cells to become more curved and pull the stoma open.
    b. Under the absence of light
        1. The potassium ions that have accumulated in the guard cells when light is present diffuse out of the guard cells.
        2. Potassium ion concentration in the cell sap of the guard cells decreases and its water potential increases.
        3. Water molecules leave the guard cells by osmosis, down a water potential gradient.
        4. The guard cells become flaccid and the stoma closes.
8. Movement of carbon dioxide through a leaf
    a. Under the presence of light, carbon dioxide in the leaf is used up rapidly for photosynthesis.
    b. Carbon dioxide concentration in the leaf becomes lower than that of atmospheric air. Carbon dioxide diffuses from the surrounding air into the air spaces in the leaf, down a carbon dioxide concentration gradient.
    c. The surfaces of the mesophyll cells are covered by a thin film of moisture so that carbon dioxide can dissolve in it.
    d. The dissolved carbon dioxide diffuses into the cells.

Transport in Humans

1. Structure and Composition of Blood
    a. Plasma (is 90% water, containing dissolved substances, such as the following)

        i. Soluble proteins such as fibrinogen, prothrombin & antibodies
        ii. Dissolved mineral salts such as hydrogencarbonates, chlorides, sulfates of calcium & sodium
        iii. Dissolved food substances such as glucose, amino acids, fats & vitamins
        iv. Waste products such as urea, uric acid & creatinine; carbon dioxide in the form of hydrogencarbonate ions
    b. Red blood cells (erythrocytes)
        i. Produced in bone marrow, destroyed at spleen
        ii. Function: to transport oxygen to body cells
        iii. Adaptations:
            1. Contains haemoglobin, which **binds reversibly with oxygen** and allow red blood cells to transport oxygen from the lungs to all cells in the body
            2. No nucleus, to carry **more haemoglobin** (must write) and transport more oxygen
            3. Biconcave in shape, to **increase surface area to volume ratio** to absorb and release oxygen at a faster rate
            4. Elastic to **squeeze through blood vessels** smaller than itself in diameter
    c. White blood cells (leucocytes)
        i. Lymphocytes
            1. Produced in lymph glands
            2. Large round nucleus
            3. Small amount of non-granular cytoplasm
            4. Produce antibodies
        ii. Phagocytes
            1. Produced in bone marrow
            2. Lobed nucleus
            3. Granular cytoplasm
            4. Ingests and digests foreign particles (e.g. bacteria)
    d. Platelets (thrombocytes)
        i. Not true cells
        ii. Membrane -bound fragments of cytoplasm
        iii. Important for blood clotting

2. Blood groups

Blood group	Antigen on red blood cell (use capital letters)	Antibody in blood plasma & serum (use small letters)
A	Antigen A	Antibody b
B	Antigen B	Antibody a
AB	Antigens A and B	No antibodies
O	No antigen	Antibodies a and b

*antibody a binds with antigen A, antibody b binds with antigen B

Blood Transfusions

Blood Type of Donor	Blood Type of Recipient			
	A	B	AB	O
A	✓	X	✓	X
B	X	✓	✓	X
AB	X	X	✓	X
O	✓	✓	✓	✓

X = Unsuccessful transfusion ✓ = Successful transfusion

- During blood transfusion, the effect of the **recipient's plasma** on the **donor's red blood cells** is considered.
- Blood type O is the universal donor: there are no antigens on the donor's red blood cells, so the antibodies in the recipient's plasma will not bind to the red blood cells
- Blood type AB is the universal acceptor. There are no antibodies in the plasma. Hence, no agglutination of red blood cells in the donor's blood will occur.

3. Functions of blood

   a. Transport function

Substances transported	Carried from	Carried to
Digested food -glucose, amino acids, dissolved mineral salts, fats, vitamins	Intestines	- Other parts of the body - Excess dissolved mineral salts are transported to the kidneys for excretion
Excretory products: Nitrogenous wastes (urea, uric acid, creatinine)	All parts of the body	Kidneys
Excretory products: Carbon dioxide (carried as hydrogencarbonate ions in plasma)	All parts of the body	Lungs, where the hydrogencarbonate ions are converted to carbon dioxide and expelled
Hormones	Glands	Target organs
Heat	Respiring body tissues	All parts of the body to maintain uniform body temperature

Oxygen (transported by haemoglobin in red blood cells)	Lungs	All parts of the body for cellular respiration

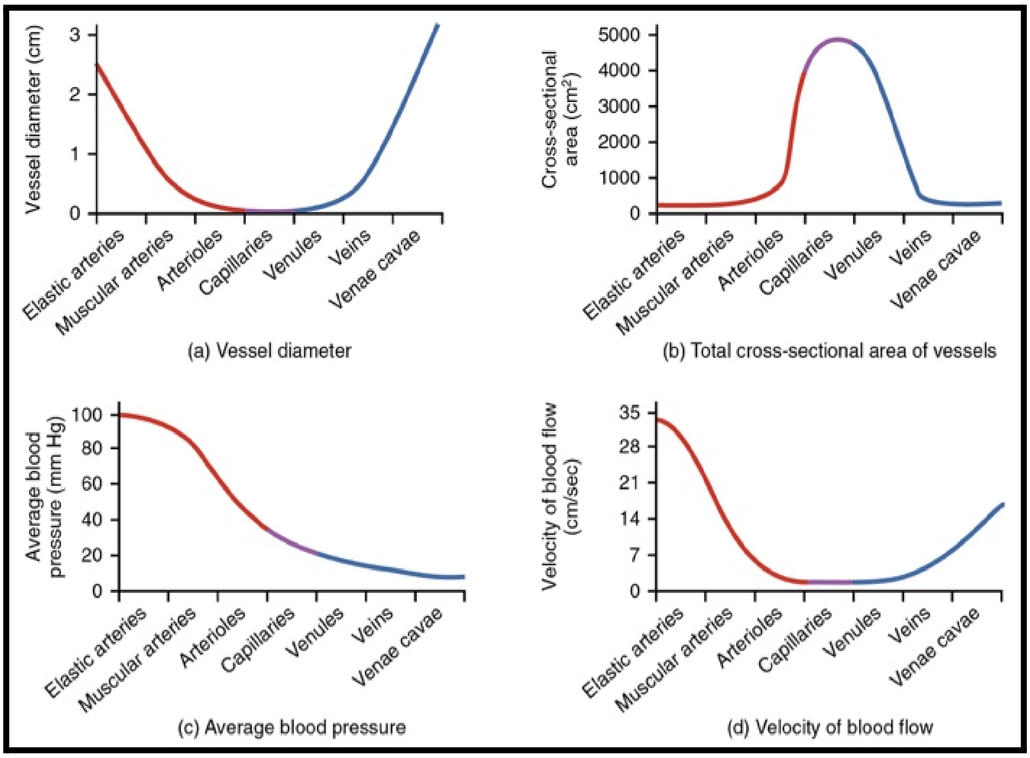
b. Protective function
    i. Blood clotting:
        1. **Damaged tissues and thrombocytes** release **thrombokinase.**
        2. Thrombokinase catalyses the conversion of **inactive prothrombin** to **active thrombin** in the **presence of calcium ions.**
        3. Thrombin catalyses the conversion of **soluble fibrinogen** to **insoluble fibrin threads.**
        4. Insoluble fibrin threads **entangle blood cells** to form a **clot**, sealing the wound and preventing **further blood loss** and **entry of pathogens** into the **bloodstream.**
    ii. Heparin, an anti-clotting substance, prevents blood in undamaged blood vessels from clotting. Thrombokinase neutralises the action of heparin for clotting to occur.
    iii. When blood clots, serum is left behind. Serum has the same composition as plasma except that it lacks clotting factors.
    iv. Leucocytes
    Lymphocytes arrive at the site of infection and recognise the antigens on the bacteria. **Lymphocytes** produce **antibodies** specific to the bacteria's antigen. The antibody **binds to the antigens** and causes the **bacterial membrane to rupture** and its organelles to leak out. The bacteria die. Antibodies that bind to the antigens on the bacteria cause **agglutination** of the bacteria, which are **ingested** and **digested** by **phagocytes** as a whole during phagocytosis.

4. Circulatory system
a. Adaptations

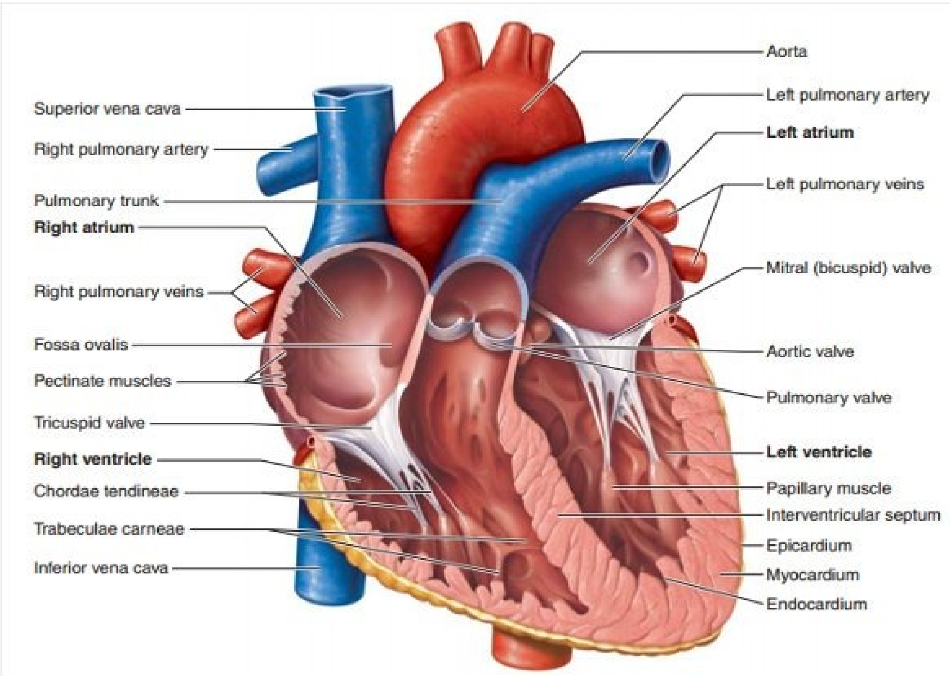
Capillaries	● wall of capillaries is a **one-cell-thick** endothelium to **decrease the diffusion distance** for substances to **diffuse quickly** through capillary walls ● capillaries **branch repeatedly** to **increase the surface area to volume ratio**, **decreasing blood pressure** and **slowing down blood flow** for more time for exchange of substances between the blood and tissue cells
Veins	● have **valves** to **prevent backflow of blood** ● **large, wide lumen** to **reduce resistance** to blood flow back to heart ● relatively **thinner, less elastic** and **less muscular wall** for deoxygenated blood to **flow slowly** through the lungs at a lower pressure for **sufficient time** for gaseous exchange ● movement of blood along the veins is assisted by the action of **skeletal muscles** on the veins - exercising the muscles **increases the pressure exerted on the veins** and moves the blood along **more quickly**

Arteries	● **thicker, more muscular** and **more elastic** walls to **withstand high pressure** of the blood directly from the heart ● **elastic** walls enable the artery walls to **recoil** to help to push blood in **spurts** along the artery, which also gives rise to the pulse.

b. Graphs of blood vessels:



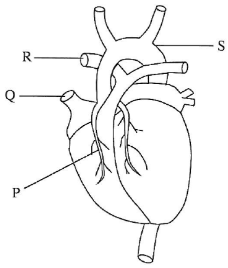
c. Heart



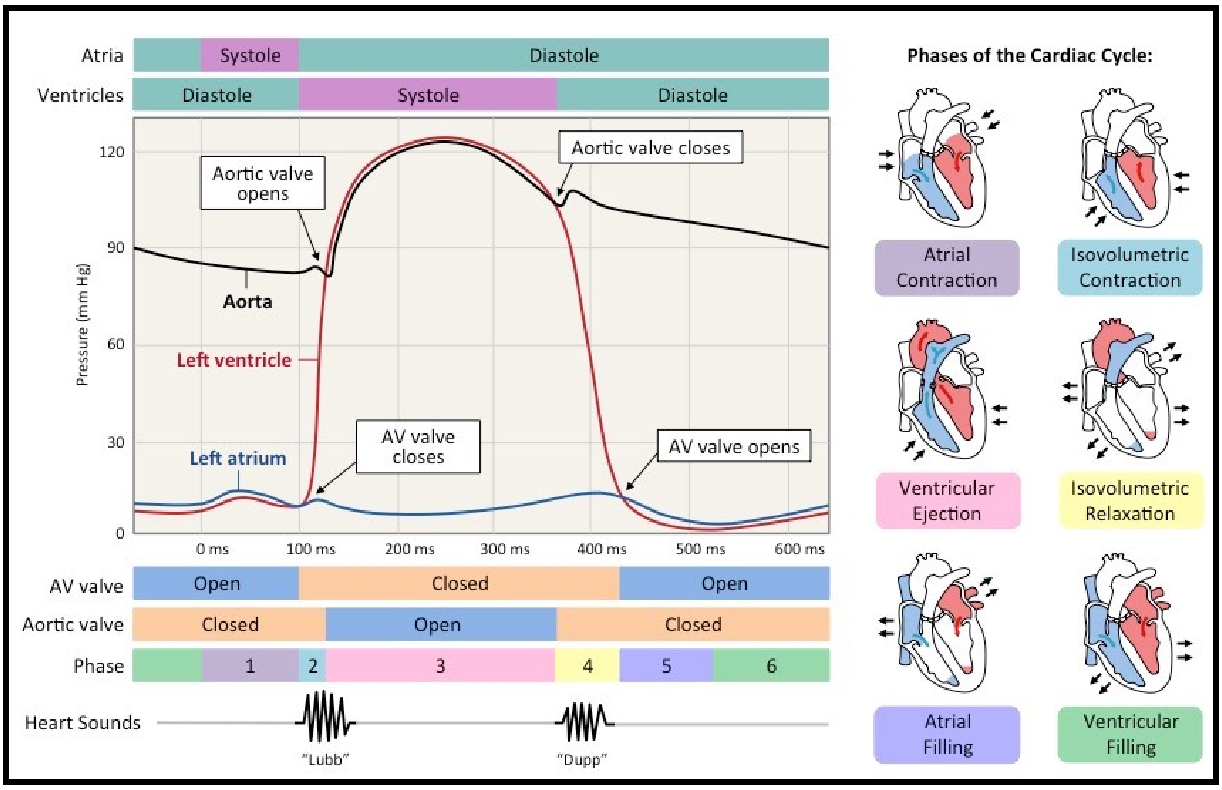
*chordae tendineae: consists of three flaps that point downwards to allow easy blood flow from the atrium into the ventricle

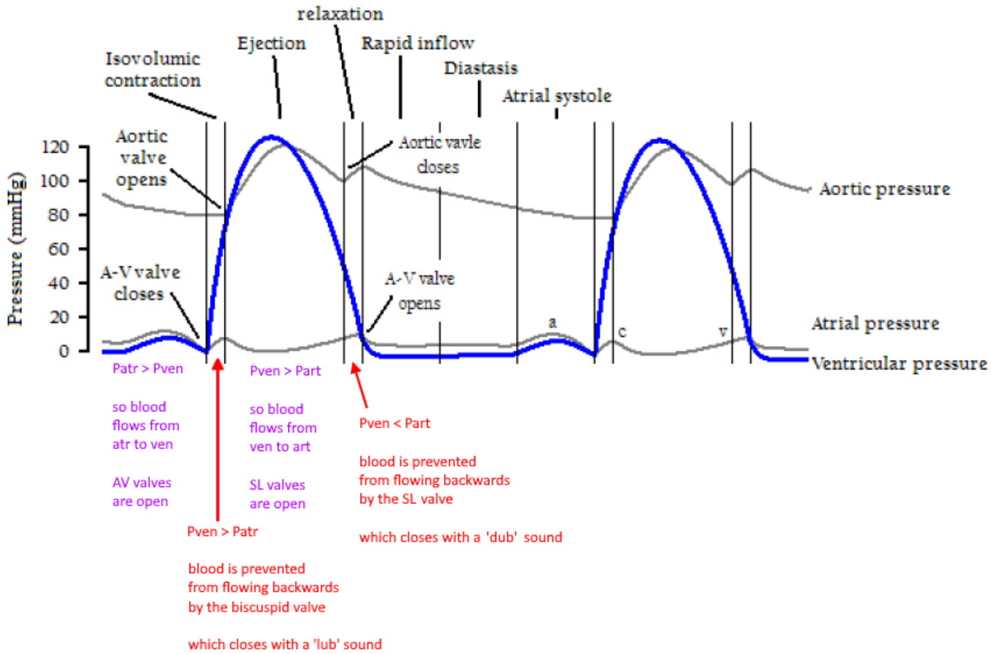
The median septum
Purpose: To keep the oxygenated blood in the left side of the heart from mixing with the deoxygenated blood from the right side of the heart.
Problem: If there is a hole in the median septum, then there will be mixing of oxygenated and deoxygenated blood, resulting in the blood going round the body being less oxygenated. Less oxygen is transported to the cells of the body, so there is less energy available from respiration, so the person feels tired more easily. Pressure in the left ventricle is also greater, so if the blood mixes, then the pressure of the blood in the right ventricle will be greater, resulting in high blood pressure in the lungs, damaging the blood vessels in the lungs over time. The blood in the lungs would also be partially oxygenated so there is a lower concentration gradient, and be moving at a higher speed so there is less time for absorption of oxygen by diffusion.

Coronary Artery Disease (CAD)
It is the building up of fatty deposits in the coronary arteries, resulting in restricted blood flow to the muscle cells downstream.
Lifestyle factors such as smoking, a diet high in saturated fats, a sedentary lifestyle, stress and being overweight can result in the formation of these deposits, which hardens these arteries and makes them less elastic (atherosclerosis).
CAD may lead to heart attacks (myocardial infarctions). They usually occur when a blood clot forms in the coronary arteries**,** blocking blood flow to sections of the heart. Oxygen is unable to reach the muscles, which are unable to respire, and die. The heart becomes unable to pump blood effectively, leading to the symptoms of a heart attack.



d. Cardiac cycle





1. Muscles of the atria contract, causing **atrial pressure to be higher** than **ventricular pressure** and **atrioventricular valves open**, allowing blood to flow from the **atria to the ventricles.**
2. Muscles of the ventricles contract, causing **ventricular pressure to be higher than atrial pressure** and **atrioventricular valves close** to **prevent backflow of blood from the ventricles into the atria**. This produces a loud "lub" sound.
3. As ventricular systole continues, **pressures in the right ventricle and left ventricle** are **higher** than **pressures in the pulmonary arch** and **aortic arch** respectively. **Semilunar valves open**, allowing blood to flow from the **ventricles into the arches**.
4. During ventricular systole, atrial diastole happens. Muscles of the atria relax. The **right atrium receives blood from the venae cavae** while the **left atrium receives blood from the pulmonary veins**.
5. During ventricular diastole, muscles of the ventricles relax, causing **pressures in the right ventricle** and the **left ventricle** to **decrease** until they are **lower than pressures in the pulmonary arch and aortic arch** respectively. **Semilunar valves close** to **prevent backflow of blood from the two arches into the ventricles**. This produces a softer "dub" sound.
6. Eventually, **ventricular pressure** decreases until it is **lower than atrial pressure**, causing the **atrioventricular valves to open**, allowing **blood to flow from the atria into the ventricles.** Muscles of the atria contract and the cycle repeats.

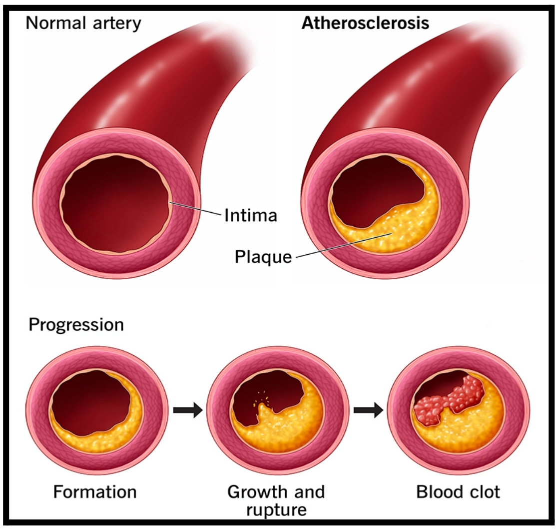
e. Blood flow

1. **Deoxygenated blood** from other parts of the body is returned to the **right atrium** by the **venae cavae**.
1. Muscles of the right atrium contract, causing **pressure in the right atrium to be higher than that in the right ventricle**. The **tricuspid valve opens**, allowing blood to flow from the right atrium into the right ventricle.
2. Muscles of the right ventricle contract, causing **pressure in the right ventricle to be higher than that in the right atrium**. The **tricuspid valve closes** to **prevent backflow of blood** from the right ventricle into the right atrium. The **pressure in the right ventricle is also higher**

than that in the pulmonary arch, causing the **pulmonary valve to open**, allowing blood to flow from the right ventricle into the pulmonary arteries. The pulmonary arteries transport blood to the lungs.
3. **Oxygenated blood** from the lungs is transported to the **left atrium** by **pulmonary veins**.
4. Muscles of the left atrium contract, causing **pressure of the left atrium to be higher than that of the left ventricle**. The **bicuspid valve opens**, allowing blood to flow from the left atrium into the left ventricle.
5. Muscles of the left ventricle contract, causing **pressure in the left ventricle to be higher than that in the left atrium**. The **bicuspid valve closes** to **prevent backflow of blood** from the left ventricle into the left atrium The **pressure in the right ventricle is also higher than that in the aortic arch**, causing the **aortic valve to open**, allowing blood to flow from the left ventricle into the aorta.
6. The aorta transports blood to all parts of the body (except the lungs).

f. Double circulation
Blood passes through the heart twice in one circuit round the body.
   1. Pulmonary circulation:
      The flow of (deoxygenated) blood from the right ventricle of the heart into the pulmonary artery and into the lungs, and the flow of (oxygenated) blood from the lungs down the pulmonary vein into the left atrium of the heart
   2. Systemic circulation:
      The flow of (oxygenated) blood from the left ventricle of the heart into the aorta and onto the rest of the body, and the flow of (deoxygenated) blood back into the vena cava and into the right atrium of the heart
   3. Advantages:
      a. Blood entering lungs is at lower pressure than blood leaving heart, ensuring that blood flows more slowly through the lungs more slowly, allowing sufficient time for blood to be well-oxygenated before being returned to heart
      b. Heart pumps oxygenated blood at high pressure to rest of body so oxygenated blood is distributed to body tissues more quickly, helping to maintain high metabolic rate in mammals

5. Coronary heart disease
   - Atherosclerosis is the **accumulation of fatty deposits** on the **inner wall of coronary arteries**, which harden to form **plaque**.
      a. **narrowed lumen** and **reduced blood flow** to heart tissue.
      b. narrowed lumen of arteries causes **blood pressure to increase,** causing the arteries to develop a **rough inner surface**, increasing the risk of formation of a **thrombosis** (a blood clot), which reduces blood flow to the heart



c. heart muscle cells receive **less or no oxygen** and are unable to respire aerobically to release energy for cellular activities
d. heart muscle cells **start to die** and heart muscles lose their function to contract and relax, which may lead to a heart attack

- Factors that increase the risk of atherosclerosis & coronary heart disease:
  1. Diet rich in cholesterol & saturated animal fat
  2. Emotional stress
  3. Smoking
  4. Sedentary lifestyle
- Preventive measures against coronary heart disease:
  1. Healthy diet: animals fats replaced with polyunsaturated plant fats + more vegetables
  2. Manage stress
  3. Avoid smoking
  4. Exercise regularly: strengthen the heart & maintain elasticity of arterial wall to reduce risk of high blood pressure (hypertension)

Transport in Plants

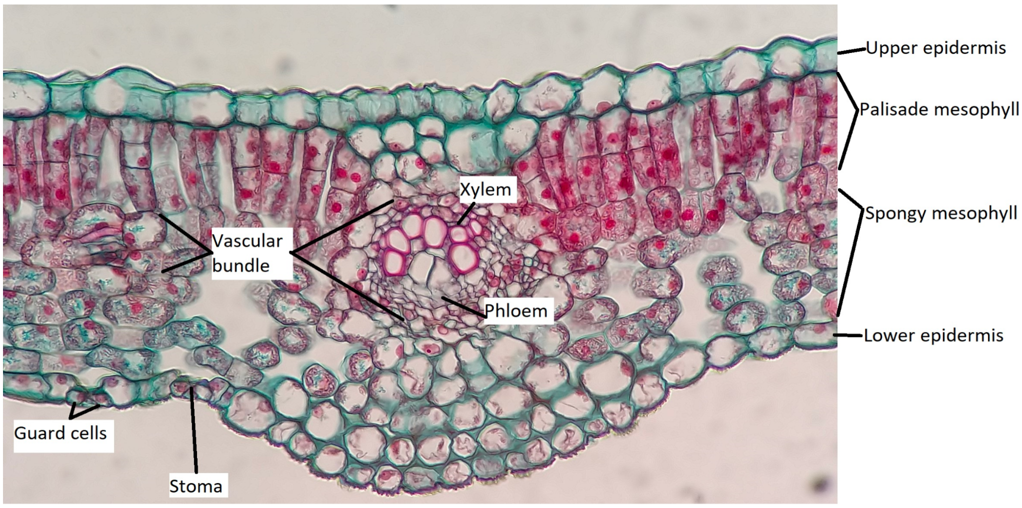
1. Transport structure

	xylem	phloem
What it transports	Water and dissolved mineral salts	Sucrose and amino acids
Direction of movement of substances	● From the roots to the aerial parts of the plant ● Unidirectional	● From green parts of the plant to other parts of the plant ● Bidirectional
Adaptations	● Continuous, hollow lumen with no cross-walls or protoplasm/vessel is made up of longitudinal fusion of cells without nucleus and cytoplasm to reduce resistance to flow of water and dissolved mineral salts for them to be transported more quickly ● Long and narrow lumen so that capillary action can act to draw water up the xylem vessels ● **Walls** of xylem (NOT xylem) are thickened with lignin to provide mechanical support for the plant to resist compression and prevent	● Companion cells contain numerous mitochondria to release more energy by respiring aerobically for the active transport of sucrose and amino acids through sieve tubes ● Phloem sieve tube elements/sieve tube cells have very little protoplasm (lost central vacuole, nucleus & most organelles; only has thin layer of cytoplasm) and are arranged to form a continuous column to reduce resistance to the flow of sucrose and amino acids

	collapse under tension forces ● Pits allow lateral flow of water and dissolved mineral salts to overcome air locks	● Pores within sieve plates allow rapid flow of sucrose and amino acids
Location	● Centre in roots ● Centre in stem ● Above in leaf	● In between xylem ● Outside of stem ● Below in leaf

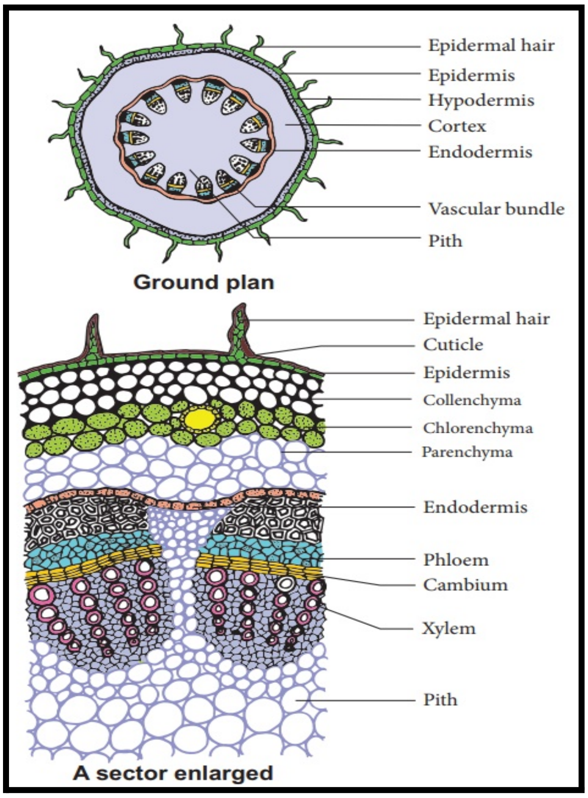
*xylem is made up of dead cells at maturity, sieve tube elements are dead while companion cells are alive in phloem

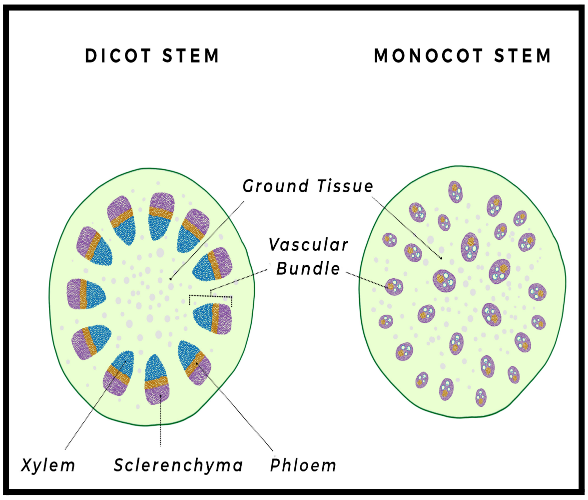
2. Arrangement of vascular tissue (focus is on dicots)
    a. Leaf

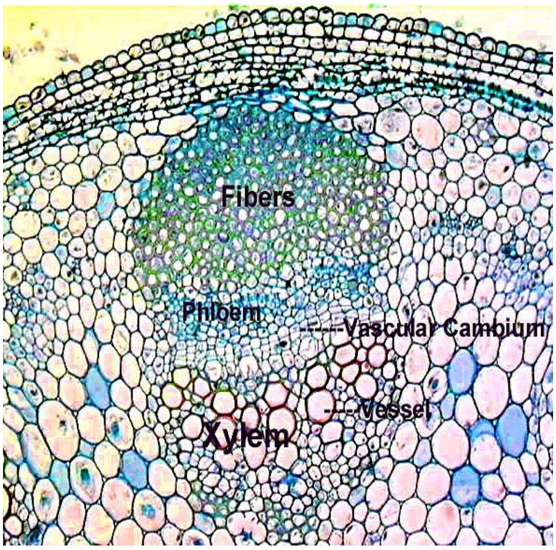


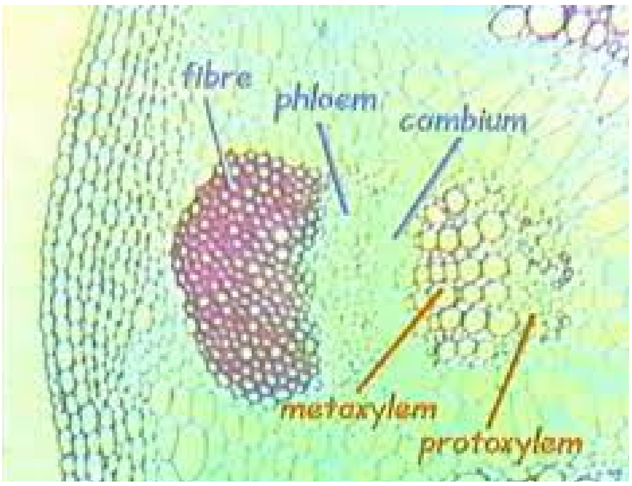
- Xylem vessels are found neared to the top of the leaf (further from stomata to reduce rate of water vapour loss by evaporation + closer to palisade mesophyll cells & spongy mesophyll cells for these cells to obtain water more easily for photosynthesis)
- Phloem vessels are found nearer to the bottom of the leaf

    b. Stem



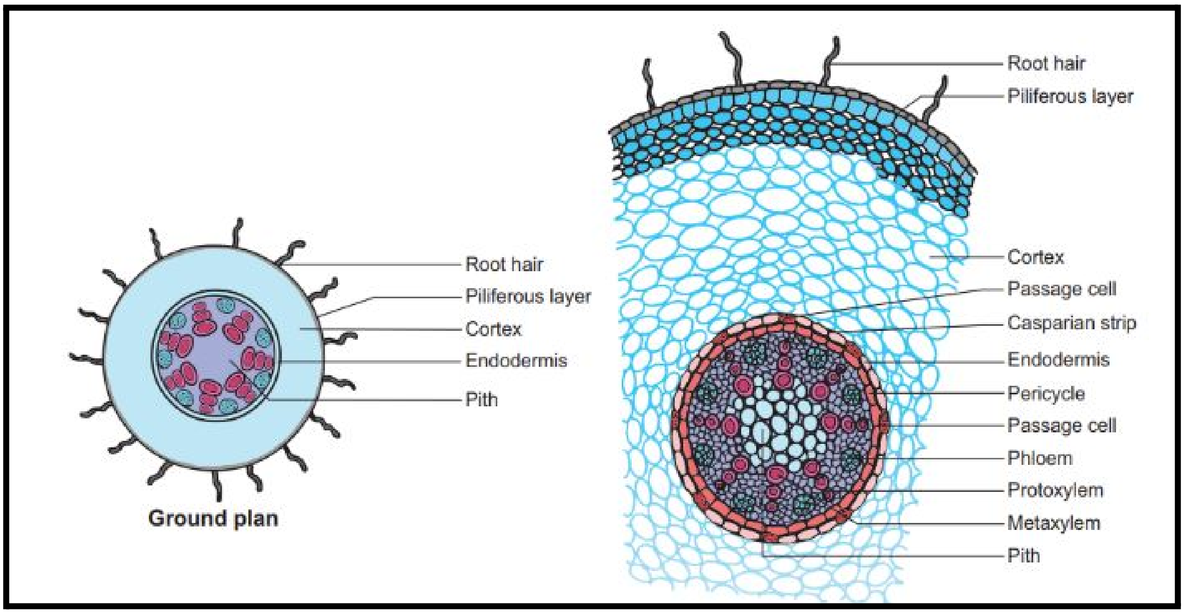


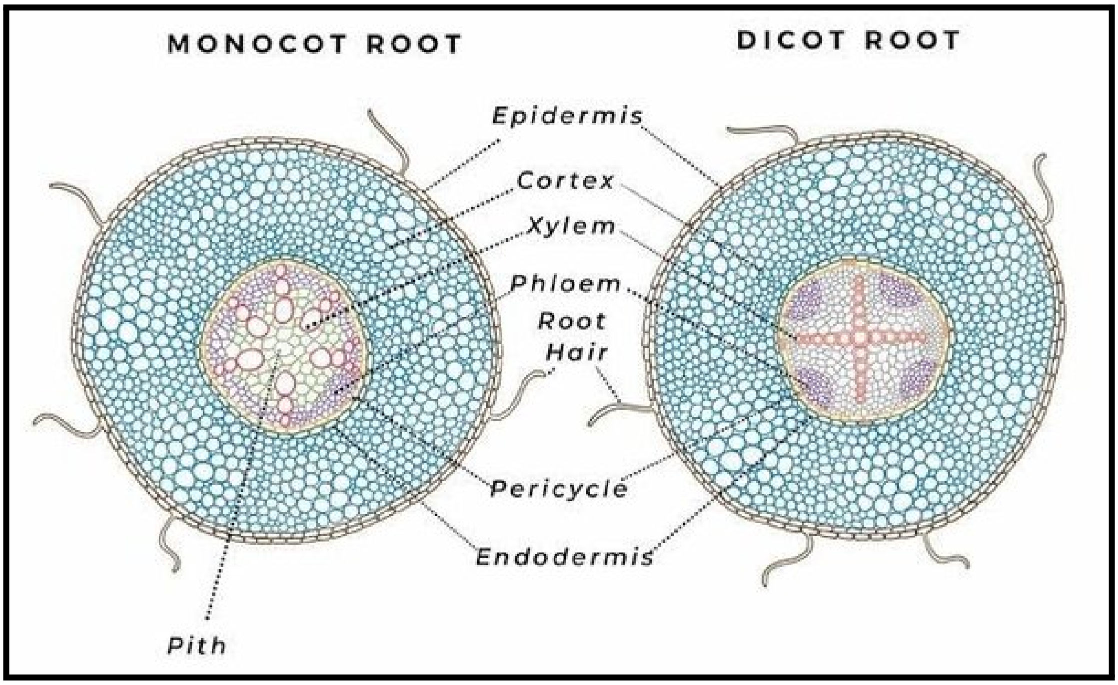




- Xylem and phloem form vascular bundles
- The phloem lies outside the xylem with the cambium between them
- The region between the pith and the epidermis is the cortex
- Stem is covered by the epidermis
- Epidermal cells are protected by a layer of waxy, waterproof cuticle
- Functions:
    1. Cambium cells: divide and differentiate to form new xylem & phloem tissue, giving rise to the thickening of the stem
    2. Cortex & pith: store food substances such as starch
    3. Cuticle: is impermeable to water, reducing water loss by evaporation

c. Root



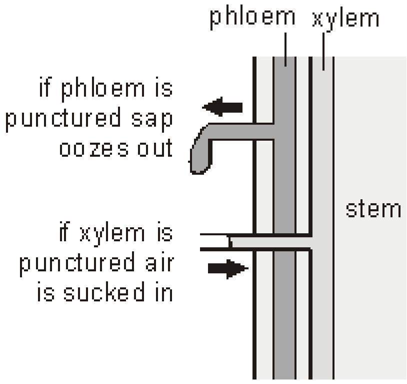


- Xylem and phloem are not bundled together. Instead, they alternate with each other.
- Epidermis/piliferous layer: outermost layer of cells; cuticle absent
- Endodermis: innermost layer of cortex
- Cortex: stores food such as starch
- Root hair: each root hair is a tubular outgrowth of an epidermal cell to increase the surface area to volume ratio of the root hair cell for faster absorption of water and dissolved mineral salts

3. Translocation

Translocation is the transport of manufactured food substances such as sucrose and amino acids from the leaves to the other parts of the plant through the phloem.

Study 1: Puncture experiment

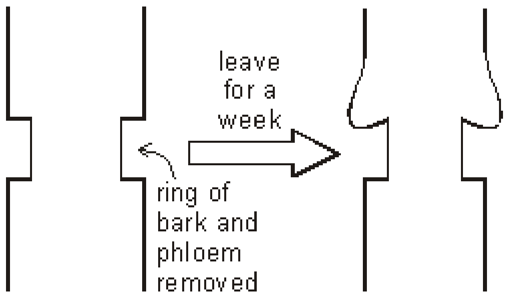


If the phloem is punctured with a hollow tube, sap oozes out. This shows that there is high pressure (compression) inside the phloem.

If the xylem is punctured, air is sucked in. This shows that there is low pressure (tension) inside the xylem.

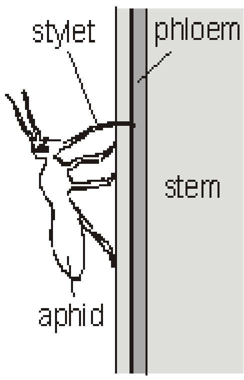
The results show that water and dissolved mineral salts are pulled up in the xylem, while sap is pushed down the phloem.

Study 2: Ringing experiment



The removal of phloem prevents the translocation of sugars to the region below the ring. The accumulation of sugars in the region just above the ring lowers the water potential of the cells in that region. Water enters the region by osmosis, causing the swelling.

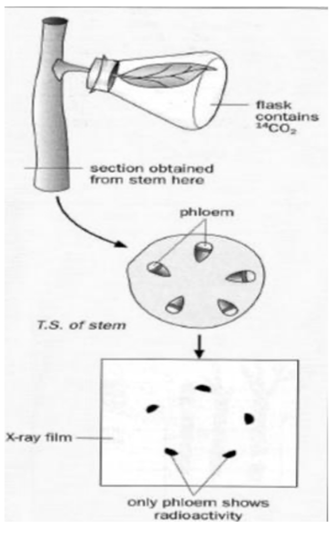
Study 3: Aphid stylets experiment



Steps:
S1: Anaesthetise the aphid with carbon dioxide while it is feeding on the stem. This is to enable the body of the aphid to be cut off while it is feeding, ensuring that the proboscis remains in the phloem sieve tube. If the aphid moves, there will not be an accurate penetration of the phloem.
S2: Cut off its body such that the proboscis remains in the plant tissue.
S3: Analyse the liquid that oozes out from the cut end of the proboscis.
S4: Section the portion of the stem that contains the proboscis and examine it under a microscope to determine which vascular tissue the proboscis was inserted into.

Study 4: Radioactive carbon isotope

Steps:
S1: Supply radioactive carbon (carbon-14, ^{14}C) to an intact leaf enclosed in a sealed chamber.
S2: Allow photosynthesis to occur.
S3: Cut a section of the stem and expose it onto an X-ray photography film.



Radioactivity would be detected in the phloem. When the plant is exposed to carbon dioxide containing radioactive carbon, the glucose made by the leaves would be radioactive (since carbon dioxide is reduced by hydrogen into glucose during the light-independent stage). Glucose is then combined with fructose to form sucrose to be transported in the phloem.

4. Transpiration
    a. Study of pathway of water
        1. Allow a plant to stand in a dilute red ink solution.
        2. After a few hours, cut a transverse section of the stem and a transverse section of the root that was not immersed in ink.

       Results: Xylem would be stained red.

       Explanation: Transpiration removes water from the xylem vessels, causing a suction force that pulls water containing the red ink against gravity. Hence, the red ink enters the stem and up the xylem vessels.
    b. Movement of water into root hairs
        1. The concentrated cell sap of root hair cells has a lower water potential than the soil solution. Water molecules enter the root hair cells from the soil solution by osmosis.
        2. The entry of water dilutes the root hair cell's cell sap, which now has a higher water potential than the next cell. Water molecules move by osmosis from the root hair cell to the inner cell.
        3. Water molecules move from one cell to another by osmosis until water molecules enter the xylem vessels.
        4. Water that reaches the xylem will be transported away up the plant immediately (to maintain a low water potential of the root hair cells).
    c. Movement of water through a leaf
        1. Water that moves out of mesophyll cells by osmosis forms a thin film of moisture around the cells.
        2. Water evaporates from the thin film of moisture. The water vapour moves into the intercellular air spaces and accumulates in the sub-stomatal spaces.
        3. Water vapour diffuses through the stomata to the drier air outside (transpiration).
        4. Movement of water out of mesophyll cells to replace the thin film of moisture that has evaporated decreases the water potential of the cell sap of the cells.
        5. Water molecules from cells deeper in the leaf move by osmosis into the mesophyll cells.
        6. Water molecules, in turn, move from xylem vessels into these cells.
        7. This results in a suction force that pulls the column of water in the xylem vessels up.
    d. Entry of ions and dissolved mineral salts into root hairs
        - By diffusion, when concentration of ions is higher in the soil solution that in the root hair cells
        - By active transport, when concentration of ions is lower in the soil solution than in the root hair cells

e. Adaptations of root hair cells

- Each root hair is a tubular outgrowth of a RHC, making the root hair cell long and narrow, increasing the SAVR of the RHC for faster absorption of water and dissolved mineral salts.
- The vacuoles in RHC contain cell sap, which is a concentrated solution of sugars and dissolved mineral salts. This creates a lower water potential than the soil solution and thus a steep water potential gradient for water to enter the root hairs more quickly.
- The presence of a cell membrane prevents leakage of the concentrated cell sap to maintain the steep water potential gradient.
- RHCs contain many mitochondria to carry out aerobic respiration at a higher rate to release energy for the active transport of ions and dissolved mineral salts into the cells.

f. Moving water against gravity

Name of process	Root pressure/guttation	Capillary action	Transpiration
Definition	Root pressure: pressure resulting from the constant entry of water into the roots	Capillary action: the tendency of water to move up inside very narrow tubes (capillary tubes)	Transpiration: the loss of water vapour from the aerial parts of the plant, mainly through the stomata of leaves
Process	- Living cells around xylem vessels in the roots use active transport to pump ions into the vessels, lowering the water potential in xylem vessels - Water moves from the living cells into the xylem vessels by osmosis and is transported up the plant by the xylem	- Since the xylem vessels are very narrow tubes, capillary action helps to move water up the vessels - Depends on forces of cohesion and adhesion - Note: Capillary action also applies to transport of dissolved mineral salts (As water moves up by capillary action, it carried the salts up with it)	*refer to movement of water through a leaf*

g. Importance of transpiration

- Transpiration pull draws water and dissolved mineral salts from the roots to the aerial parts of the plant

- Evaporation of water from the thin film of moisture on mesophyll cells removes latent heat of vaporisation, which helps to cool the plant
- Water transported to the leaves is:
    1. used in photosynthesis
    2. to keep cells turgid to keep the leaves spread out widely to trap light energy for photosynthesis

h. Factors affecting rate of transpiration

Factor	Explanation
Light intensity	Potassium ion theory: 1. As light intensity increases, the rate of photosynthesis in guard cells increases. 2. The guard cells convert more light energy into chemical energy. More chemical energy is available to pump potassium ions into the guard cells from neighbouring epidermal cells by active transport. 3. As the potassium ion concentration in guard cells increases, the water potential of the cell sap of the guard cells decreases. This causes the net movement of water molecules from adjacent epidermal cells into the guard cells by osmosis. 4. The guard cells expand and little and become turgid, causing the stomata to become wider and the rate of transpiration to be higher.
Humidity	1. As humidity increases, the water vapour concentration in the air surrounding the plant increases. 2. The water vapour concentration gradient between the air surrounding the plant and the intercellular air spaces in the leaf becomes less steep. 3. Water vapour diffuses out of the leaf less quickly and the rate of transpiration decreases.
Temperature	1. As the temperature increases, the rate of evaporation of water from the thin film of moisture around mesophyll cells increases. 2. There is a higher water vapour concentration in the intercellular air spaces. 3. This causes the water vapour concentration gradient between the air surrounding the plant and the intercellular air spaces in the leaf becomes steeper. 4. Water vapour diffuses out of the leaf more quickly and the rate of transpiration increases.

Wind speed	1. When there is a higher wind speed, the wind blows away the water vapour that accumulates outside the stomata more quickly. 2. This causes the water vapour concentration in the air surrounding the leaf to decrease. 3. This maintains a steep water vapour concentration gradient between the intercellular air spaces in the leaf and the air surrounding the leaf. 4. Water vapour diffuses out of the leaf more quickly and the rate of transpiration increases.

i. Potometer

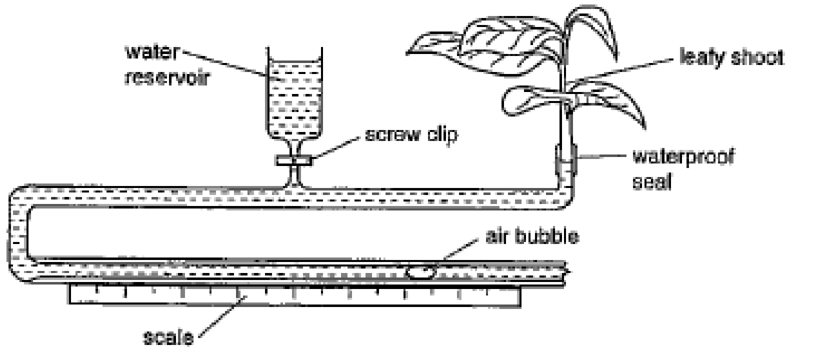


Fig. 5

How the potometer can be used to measure the rate of water loss from the leafy shoot:
As leafy shoot loses water (through the aerial parts of the plant by transpiration),
water is taken in by transpiration pull (through the xylem vessels)
resulting in the air bubble moving to the left.
The distance moved by the air bubble to the left represents the amount of water taken in, (and, by extension, the water lost).

Purpose of waterproof seal:
It prevents water loss from the sides of the apparatus through evaporation
reducing error and ensuring that any water loss from the apparatus is only through transpiration in the leaf.

Purpose of water reservoir:
It is used to replenish the water in the tube and
pushes the air bubble back to the right, resetting the apparatus.

Purpose of cutting the shoot underwater:
To ensure that no bubbles are formed.

Assumption:
The rate of water absorption is proportional to the rate of transpiration. (However, some water is also used in photosynthesis, so amount of water lost < amount of water absorbed. Hence, a potometer is used to directly measure the rate of absorption of water by the plant and NOT the rate of transpiration.)

j. Wilting
- Loss of turgidity in plant tissues

- Caused by rate of water loss by transpiration and other processes (such as photosynthesis) being greater than the rate of water uptake in the roots.
- Wilting causes leaves to droop so they have lower exposed surface area so water loss decreases since less photosynthesis occurs, and less light is absorbed so less water evaporates from the leaves. Loss of turgidity causes the stomata to close, reducing transpiration rate and preventing excess water loss.
- However, water becomes LF and as the stomata close, the intake of carbon dioxide decreases and carbon dioxide becomes LF as well. When the leaves droop, there is reduced surface area and the rate of absorption of light energy is lower. Hence, the rate of photosynthesis decreases.

Respiration

1. Types of respiration
    a. Aerobic respiration
        i. Aerobic respiration is the breakdown of food molecules in the presence of oxygen, resulting in the release of a large amount of energy and giving off carbon dioxide and water as waste products.
        ii. Chemical equation: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + energy
        iii. Word equation: glucose + oxygen → carbon dioxide + water + **large amount** of energy released
    b. Energy-consuming processes:
        i. Synthesis of new protoplasm for growth & repair
        ii. Synthesis of proteins from amino acids
        iii. Active transport in the absorption of digested food substances by small intestine
        iv. Muscular contractions such as heartbeats & respiratory movements (both voluntary & involuntary)
        v. Transmission of nerve impulses
        vi. Cell division
    c. Anaerobic respiration
        i. Anaerobic respiration is the breakdown of food molecules in the absence of oxygen, releasing less energy than aerobic respiration.
        ii. Alcoholic fermentation (in yeast):
            1. Yeast respires aerobically in the presence of oxygen, but respire anaerobically in the absence of oxygen. The glucose is only partially broken down and the ethanol produced still contains energy
            2. Chemical equation: $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$ + energy
            3. Word equation: glucose → ethanol + carbon dioxide + **small amount** of energy released
        iii. Lactate fermentation (in humans):
            1. Chemical equation: $C_6H_{12}O_6 \rightarrow 2C_3H_6O_3$ + energy
            2. Word equation: glucose→lactic acid + **small amount** of energy released

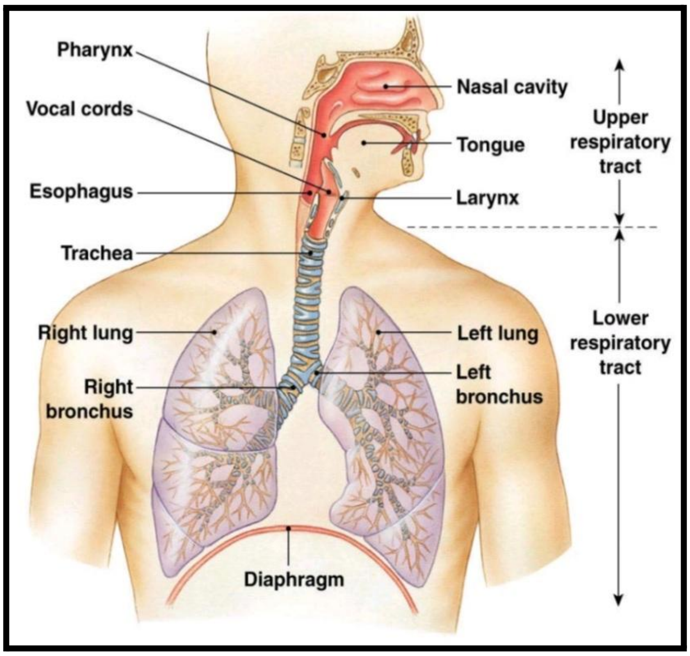
Exercise:

During exercise	1. Rate of aerobic respiration increases: Muscles in the body require **more energy** to **contract and relax more vigorously.** The **rate of aerobic respiration increases** to increase the amount of energy released. **More oxygen** needs to be inhaled to be used by respiring cells while **more carbon dioxide** needs to be expelled. 2. Breathing rate and depth increases: As such, **breathing rate and depth increases** to facilitate efficient gaseous exchange. **Rate of blood flow to the lungs increases** to release carbon dioxide more quickly. 3. Heart rate increases: Muscles in the body require more glucose and oxygen to respire aerobically at a higher rate. So, **muscles of the heart contract more forcefully and rapidly** to **pump oxygenated blood around the body faster,** thus **increasing heart rate.** Also, more blood is transported to the muscles, lungs and liver and less blood is transported to other organs in the body so that there is sufficient glucose and oxygen for working muscles and organs.
After exercise	1. **Accumulation** of **lactic acid** (NOT just "lactic acid") causes **fatigue** and the body can only sustain anaerobic respiration for a short time before it needs to rest. 2. During rest, **breathing rate remains high** to provide **sufficient oxygen** to muscle cells to repay oxygen debt. 3. **Lactic acid** is gradually **removed** from the **muscles** and transported to the **liver**. In the liver, some lactic acid is **completely oxidised** to **carbon dioxide** and **water** to **release energy** to **convert the remaining lactic acid into glucose**. 4. Glucose is then transported and **stored as glycogen** in the liver and muscles. When all lactic acid has been converted, oxygen debt is repaid. The amount of oxygen required for this process is called oxygen debt.

Respiration vs Photosynthesis

Respiration	**Photosynthesis**
Energy released	Energy stored in carbohydrate molecules
Oxygen used; carbon dioxide & water produced	Carbon dioxide & water used; oxygen produced
Catabolic process, where carbohydrate molecules are broken down	Anabolic process, where carbohydrate molecules are formed
Occurs all the time, independent of chlorophyll & availability of light	Occurs only in cells containing chlorophyll & in presence of light
Results in loss of dry mass	Results in gain of dry mass

2. Human respiratory system
    a. Parts of the human respiratory system



Part	Details
Nasal passages	- Walls of nostrils bear a fringe of hair - Nostrils lead to two nasal passages lined with a moist mucous membrane - Air is warmed & moistened: a. Moisture lining alveoli evaporates & moistens air b. Nasal cavity has numerous foldings that expose inspired air to a larger surface area to warm the air faster - Harmful chemical may be detected by small sensory cells in mucous membrane (smell cannot be detected if breath through mouth)
Trachea	- Supported by C-shaped rings of cartilage to ensure that the lumen of the trachea is always open - Epithelium consists of two types of (epithelial) cells: a. Gland cells: secrete mucus to trap dust particles & bacteria b. Ciliated cells: have cilia that sweep the mucus with trapped particles & bacteria up the bronchi & trachea, into the pharynx
Pharynx	Common passage for opening of oesophagus & trachea
Larynx	Voice box containing vocal cords
Bronchi (singular: bronchus)	- Trachea divides into two bronchi, one to each lung - Each bronchi branches repeatedly to produce bronchioles - Each bronchioles ends in clusters of alveoli (singular: alveolus)
Alveoli (air sacs)	- Numerous to provide a large SAVR

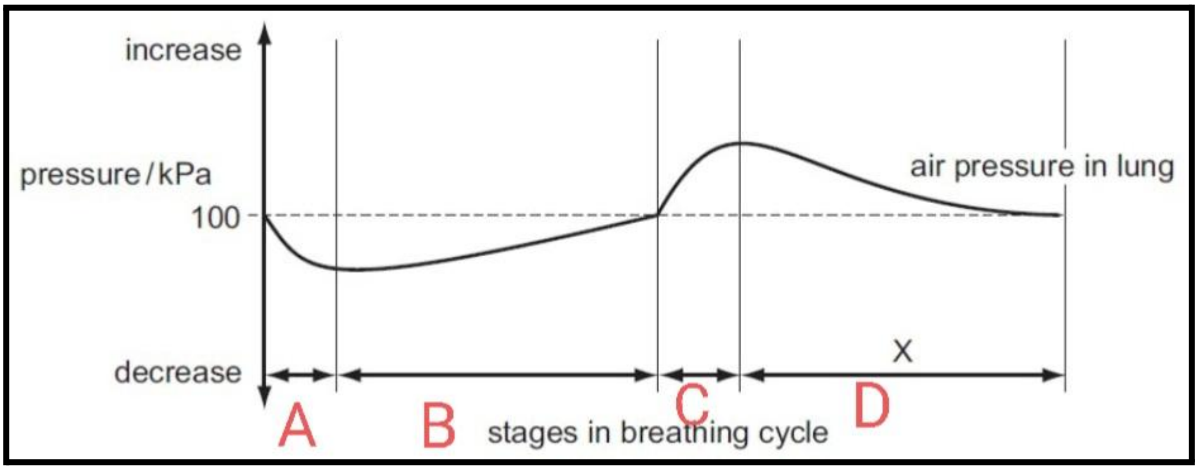
	- Wall of alveolus is one-cell thick: Provide short diffusion distance of gases, allowing faster rate of diffusion of gases - Thin film of moisture covers surface of alveolus: Allows gases to dissolve in it for faster rate of diffusion of gases - Walls are richly supplied with blood capillaries: Continuous flow of blood maintains steep concentration gradients of gases (oxygen and carbon dioxide)

*path of air: nasal passage→pharynx→larynx→trachea→bronchi→bronchioles→alveoli

b. Processes of gaseous exchange

Transport of oxygen	1. Alveolar air has a **higher oxygen concentration** than in blood capillary. 2. Oxygen **dissolves in a thin film of moisture** lining the alveolar walls and diffuses into the blood through the blood capillary walls. 3. Oxygen molecules diffuse into **red blood cells** through their cell membranes. 4. In the lungs where **oxygen concentration is high**, oxygen combines with haemoglobin to form **oxyhaemoglobin.** 5. When blood passes through **oxygen-poor tissues,** oxyhaemoglobin releases oxygen molecules, which diffuse out of red blood cells through their cell membranes. Oxygen diffuses through the walls of blood capillaries into tissue cells.
Transport of carbon dioxide	1. Carbon dioxide from aerobically respiring cells diffuses into the blood in blood capillaries before diffusing into red blood cells. 2. **Carbonic anhydrase** in red blood cells **catalyses** the conversion of **carbon dioxide** with **water** into **carbonic acid**. 3. Carbonic acid **dissociates into hydrogencarbonate ions** and **hydrogen ions**. Hydrogencarbonate ions diffuse out of red blood cells. Most carbon dioxide is carried as **hydrogencarbonate ions in blood plasma**, while a small amount of carbon dioxide is dissolved and carried in red blood cells. 4. In the lungs, hydrogencarbonate ions diffuse back into red blood cells and **combine with hydrogen ions** released from haemoglobin to form **carbonic acid.** 5. **Carbonic anhydrase** catalyses the conversion of **carbonic acid** into **carbon dioxide** and **water.** The carbon dioxide diffuses out of red blood cells into the blood plasma, before diffusing out of blood capillaries into the **alveoli**, where it is **expelled during expiration.**

c. Breathing mechanisms



Inhalation	A: **Muscles of the diaphragm contract** and the **diaphragm flattens**. The **external intercostal muscles contract** while the **internal intercostal muscles relax**. The **ribs move upwards** and **outwards** while the **sternum moves up** and **forward.** The **thoracic volume increases** and **air pressure in the lungs decreases** until it is **lower than atmospheric pressure**. B: Air flows into the lungs until **air pressure in the lungs is equal to atmospheric pressure.**
Exhalation	C: **Muscles of the diaphragm relax** and the **diaphragm arches upwards.** The **external intercostal muscles relax** while the **internal intercostal muscles contract.** The **ribs move downwards and inwards** while the **sternum moves downwards** to its original position. The **thoracic volume decreases** and **air pressure in the lungs increases** until it is **higher than atmospheric pressure**. D: Air flows out of the lungs until **air pressure in the lungs is equal to atmospheric pressure.**

*1 breathe=1 exhalation + 1 inhalation

3. Tobacco smoke

Chemical	Properties	Effects
Nicotine	- Addictive drug that stimulates adrenaline release - Makes blood clot easily	- Increases heart rate and blood pressure - Blood clots in arteries leads to increased risk of heart attack - Blood clots in blood capillaries in the brain increases risk of stroke
Carbon monoxide	- Combines irreversibly with haemoglobin to form carboxyhaemoglobin - Increases the rate of fatty	- Reduces ability of red blood cells to transport oxygen - Narrows lumen of arteries and leads to increase in blood

	deposits on the inner arterial wall, increasing the risk of coronary heart disease	pressure
Tar	- Causes uncontrolled cell division - Paralyses cilia lining air passages	- Increases risk of cancer - Dust and irritants are trapped in the mucus cannot be removed, increasing risks of chronic bronchitis and emphysema
Irritants	- Paralyses cilia lining the air passages	- Dust particles trapped in the mucus cannot be removed, increasing risks of chronic bronchitis and emphysema

- Chronic bronchitis:
  Cause: Prolonged exposure to irritant particles
1. Epithelium lining of airways becomes inflamed
2. Excessive mucus is secreted by the epithelium.
3. Cilia on the epithelium are paralysed. Mucus and dust particles cannot be removed.
4. Airways become blocked, making breathing difficult.
5. Persistent coughing is needed to clear air passages, in order to breathe. This increases the risk of getting lung infections.

- Emphysema:
  Cause: Persistent and violent coughing due to bronchitis
1. Partition walls between alveoli break down due to persistent and violent coughing. This decreased surface area for gaseous exchange.
2. Lungs lose their elasticity and become inflated with air
3. Breathing becomes difficult, leading to wheezing and severe breathlessness

*chronic bronchitis + emphysema = chronic obstructive lung disease

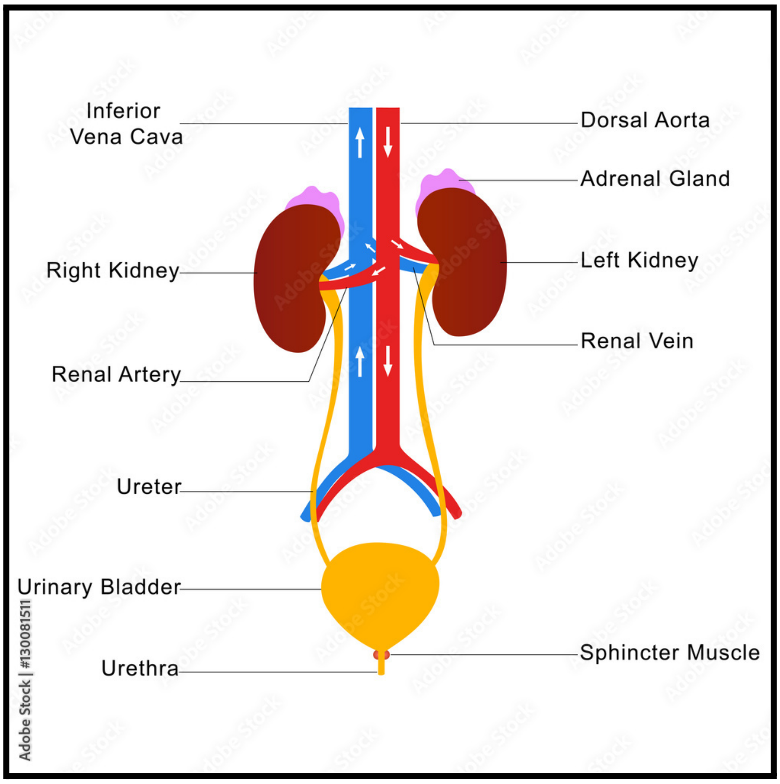
- Lung cancer
  Cancer: uncontrolled cell division producing tumours

Excretion

1. Metabolism
   a. Metabolism = catabolism + anabolism
   b. Catabolic reactions: complex substances are broken done into simpler ones
   c. Anabolic reactions: simpler substances are built up into more complex substances
2. Excretion
   a. Excretion: the process by which metabolic waste products and toxic substances are removed from the body of an organism by excretory organs
   b. Excretory products:

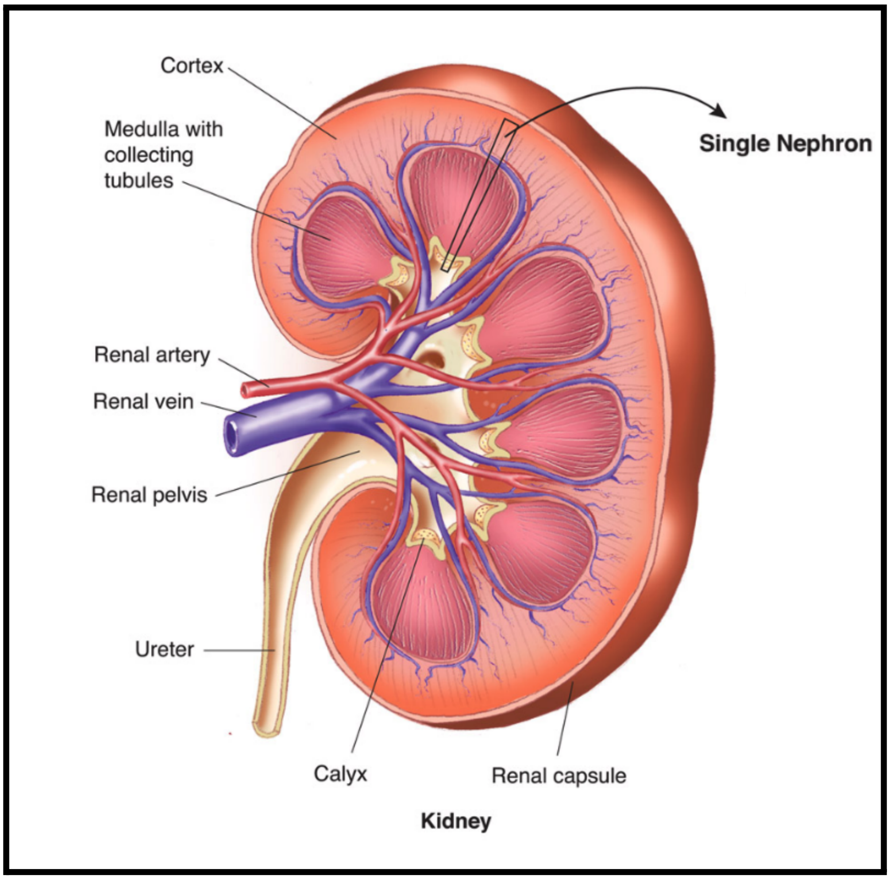
What is the product	How is it produced	Where is it excreted	How it it excreted
Carbon dioxide	From aerobic respiration in body cells	Lungs	Removed from the blood in the lungs, through diffusion into the air in the lungs followed by exhalation
Urea	Deamination of excess amino acids in liver		Removed from the blood in kidneys, through ultrafiltration in the nephron resulting in the formation and subsequent removal of urine Removed as constituent of sweat at the skin from sweat production by sweat glands
Uric acid	Breakdown of nucleic acids		
Creatinine	Breakdown of muscle proteins		
Excess mineral salts			
Excess water		Kidney Skin Lungs	Main constituent of urine Main constituent of sweat Water vapour in expired air
Bile pigments (from breakdown of haemoglobin)		Liver	Constituent of faeces, via the intestines

3. Human urinary system



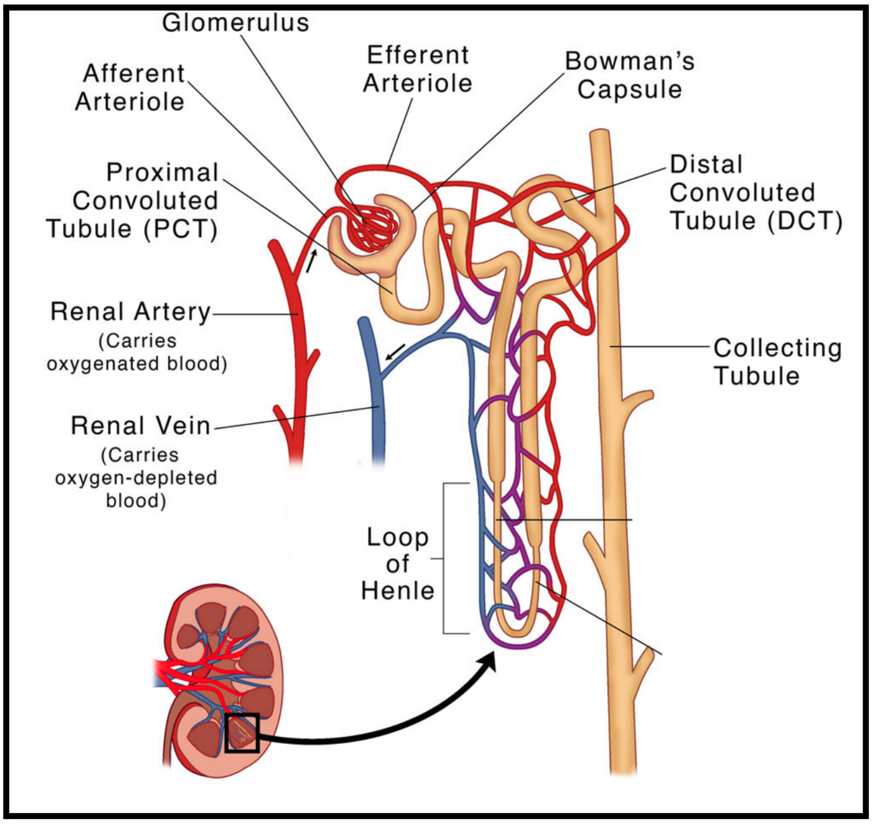
Ureter	Connects the kidney to urinary bladder and transports urine from kidneys to urinary bladder
Urinary bladder	Stores urine temporarily
Urethra	Allows urine to pass from the urinary bladder to outside of the body
Kidneys	Remove waste products from blood
Sphincter muscle	Controls urination: a. When bladder is full: sensory neurones send nerve impulses to the brain b. To urinate, brain sends nerve impulses to sphincter muscle to cause it to relax for urine to flow into the urethra and out of the body
Hilus	Area where ureter, renal artery, renal vein and nerves are connected to the kidneys
Aorta	Transports blood from the heart to all parts of the body except the lungs
Renal artery	Transports blood rich in excretory products to the kidneys
Renal vein	Transports blood without excretory products away from the kidneys
Vena cava	Transports blood from all parts of the body to the heart

4. Structure of a kidney



Cortex	The outer region of kidney, covered by protective fibrous renal capsule
Medulla	The inner region of kidney consisting of a number of renal pyramids
Renal pyramids	● Conical structures consisting of nephrons, which are the urine-producing units of the kidney ● Empty urine into the renal pelvis, which will collect urine from all the pyramids to deliver to the ureter
Renal pelvis	Enlarged portion of ureter inside the kidney

5. Structure of a nephron



a. Blood enters the kidney by renal artery, which branches out into arterioles.
b. Each arteriole further branches into glomerulus. (Bowman's capsule + glomerulus = renal corpuscle/Malpighian corpuscle)
c. Blood leaving the glomerulus enters blood capillaries surrounding the nephron.
d. These blood capillaries then unite to form venules, which in turn join to form a branch of the renal vein.

6. Ultrafiltration
   a. Blood flows from the branches of the renal artery into the glomeruli in the renal corpuscles. Most of the blood plasma is forced out of the glomerular blood capillaries into the Bowman's capsule.
   b. The afferent arteriole that brings blood into the glomerulus is wider than the efferent arteriole. This creates a high hydrostatic blood pressure in the glomerulus,
   c. which forces small molecules such as water, glucose, amino acids, dissolved mineral salts and nitrogenous waste products out of the glomerulus through the partially permeable basement membrane into the Bowman's capsule, forming the glomerular filtrate. Large molecules such as blood cells, platelets, proteins and fats are retained in the glomerular capillaries.

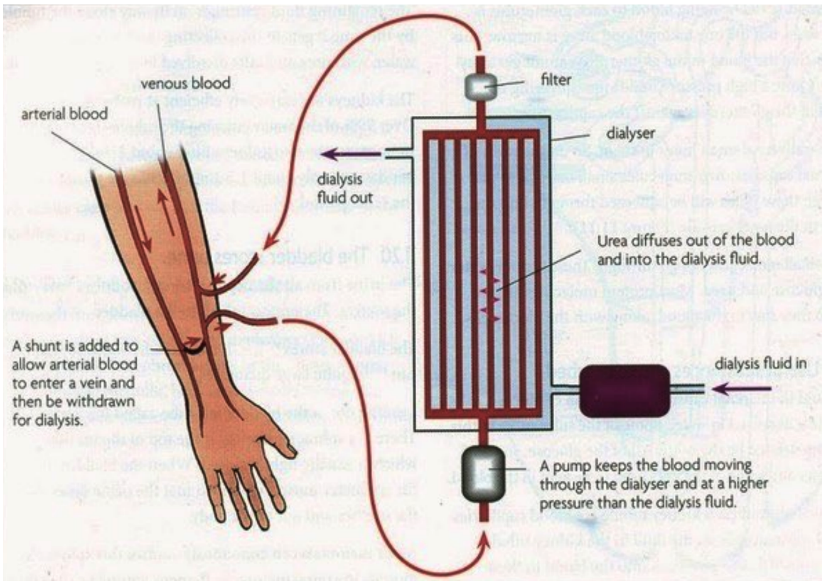
7. Selective reabsorption
   a. At the proximal convoluted tubule, most of the dissolved mineral salts and, in a healthy person, all of the glucose and amino acids are reabsorbed through the walls of the tubule into the surrounding blood capillaries by diffusion and active transport. Most of the water in the filtrate is reabsorbed by osmosis here.
   b. At the loop of Henle, some of the water is reabsorbed.

c. At the distal convoluted tubule, some water and dissolved mineral salts are reabsorbed.
d. At the collecting duct, some water is reabsorbed. Excess water, excess dissolved mineral salts and metabolic waste products such as urea, uric acid and creatinine pass out of the collecting duct into the renal pelvis as urine.

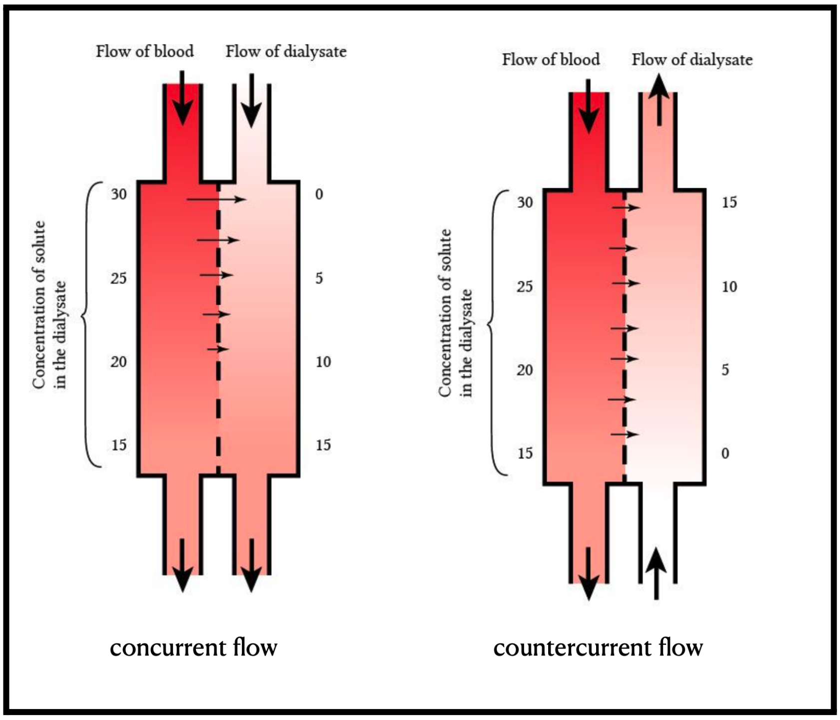
8. Structural adaptations of the kidney tubule in selective reabsorption
   a. The epithelial cells of the walls of the proximal convoluted tubule (PCT) have numerous mitochondria to carry out aerobic respiration to release energy for the selective reabsorption of glucose and amino acids by active transport.
   b. The PCT and DCT are coiled to increase the surface area to volume ratio for faster reabsorption of essential substances.
   c. There are numerous microvilli on the walls of the kidney tubule to increase the SAVR for faster reabsorption of essential substances.
   d. The kidney tubule has a one-cell-thick wall to decrease the diffusion distance of essential substances.

9. Osmoregulation (elaborated in *Homeostasis)*

10. Dialysis



   a. Blood is drawn from the vein in patient's arm and is pumped through tubing in dialysis machine.
   b. Small molecules such as urea and other metabolic waste products diffuse out of the tubing into the dialysis fluid. Blood cells, platelets and other large molecules remain in the tubing.
   c. Blood is then returned to the vein in the patient's arm



Dialysis fluid contains same concentration of essential substances as healthy blood	Ensures that these substances do not diffuse out of the blood and into the dialysis fluid. If person lacks these substances, these substances will diffuse from the dialysis fluid into the blood.
Dialysis fluid does not contain any metabolic waste products	Sets up concentration gradient that allows waste products such as urea, uric acid and creatinine, and excess water and dissolved mineral salts to diffuse out of the tubing into the dialysis fluid.
Tubing is narrow, long and coiled	Increases surface area to volume ratio to increase rate of exchange of substances between patient's blood and dialysis fluid by diffusion.
Direction of blood flow is opposite to direction of flow of dialysis fluid (concurrent flow)	Maintains concentration gradient of waste products for maximum removal of waste products.
Wall of the tubing is partially permeable	Small molecules such as urea and other metabolic waste products can diffuse out of the tubing into the dialysis fluid, while large molecules such as blood cells and plasma proteins are retained.
Fresh dialysis fluid is continuously supplied	Maintains a low concentration of waste products in the dialysis fluid compared to that in the blood plasma.

11. Differences between dialysis and ultrafiltration

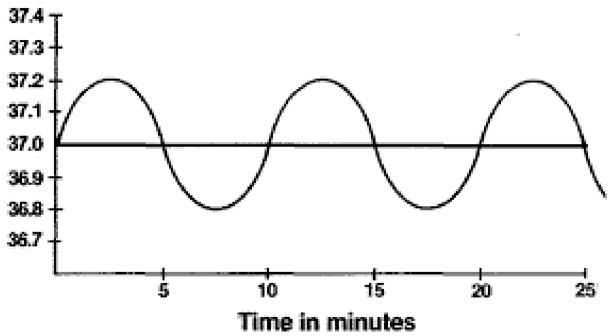
Dialysis	Ultrafiltration

Dialysate's composition is the same as the composition of normal blood to prevent net diffusion of useful substances such as dissolved mineral salts and glucose out of the blood into the dialysate	Glomerular filtrate contains both useful and waste molecules
Involves diffusion of waste molecules such as urea out of blood into the dialysate down a concentration gradient	Small molecules are forced out of the blood plasma into the Bowman's capsule by high hydrostatic blood pressure to form the glomerular filtrate
Selection of molecules in dialysis is based on concentration gradient for waste molecules to diffuse into dialysate from blood	Selection of molecules is based on size since the basement membrane is partially permeable

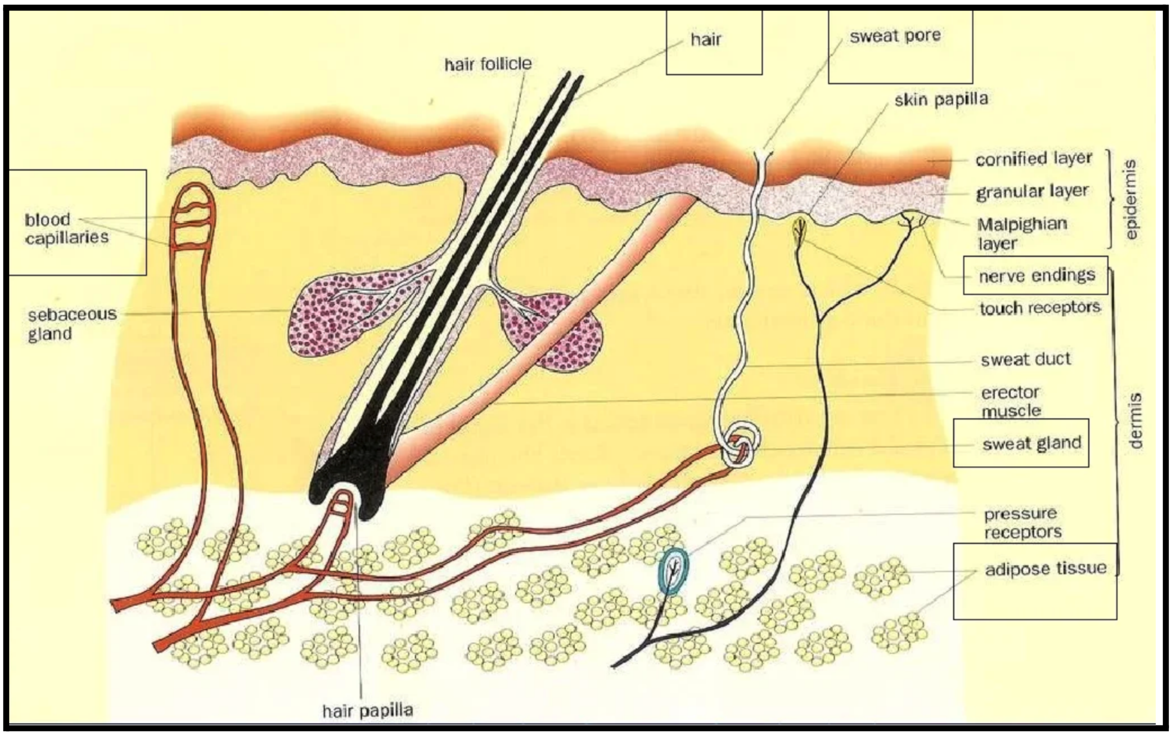
12. Comparison between dialysis fluid & blood plasma
    a. Similarities:
        i. Both the dialysis fluid and the blood plasma have equal concentrations of essential substances such as glucose, amino acids and dissolved mineral salts.
    b. Differences:
        i. The dialysis fluid does not have any metabolic waste products but the blood plasma contains metabolic waste products such as urea, uric acid, creatinine and excess water and excess dissolved mineral salts.
        ii. The dialysis fluid does not contain proteins while the blood plasma contains proteins such as hormones.

Homeostasis

1. Negative feedback
    a. Homeostasis: the maintenance of a constant internal environment
    b. Negative feedback:
        1. A **stimulus** is a change in the internal environment from set point
        2. **Receptors** detect change and send signals to **control centre**
        3. Control centre triggers **corrective mechanism** to reverse effect of stimulus
        4. A **negative feedback** is sent to receptor when condition is back to normal
        5. Corrective mechanism is stopped



2. Human skin



Part	Function
Cornified layer (outermost layer)	a. Water resistant; prevents uncontrolled water loss by evaporation b. Consists of dead dry cells with keratin deposits; dead cells continuously shed from skin surface; forms a protective layer over the body surface to prevent mechanical injury or microorganisms entering body
Granular layer (middle layer)	Consists of living cells that move upwards; cells eventually become dry and dead to form cornified layer
Malpighian layer (innermost layer)	Consists of actively dividing cells that contain melanin; melanin protect skin cells against ultraviolet light
Blood capillaries	a. Vasodilation b. Vasoconstriction *note: 'vaso' is related to blood vessels; vasodilation and vasoconstriction cannot be used to describe capillaries as there are no muscles in one-cell-thick capillary wall
Hairs	a. Hair erector muscles contract and cause hairs to stand on their ends to trap more air, which is a poor conductor of heat and helps to reduce heat loss from the body b. Hair erector muscles relax and cause hairs to lie down to trap less air, which is a poor conductor of heat. This helps to reduce the amount of body heat retained.

Sebaceous glands	Secrete sebum which lubricates the hair; keeps skin soft and prevents microbial growth
Sweat glands	Secrete sweat which flows through sweat duct and sweat pore to skin surface
Subcutaneous fat	Consists of adipose cells which store fats; serve as an insulating layer that reduces heat loss to the surroundings

3. Regulation of blood glucose level
    a. Blood glucose level rises above normal,
        1. stimulating the islets of Langerhans in the pancreas to secrete more insulin into the bloodstream.
        2. Insulin is transported by the blood to the liver and muscles.
        3. Insulin increases the permeability of the cell membranes of the liver cells and muscle cells to glucose,
        4. causing glucose to be absorbed more quickly by the cells.
        5. Insulin stimulates the liver to convert excess glucose to glycogen, which is stored in the liver and muscles.
        6. Blood glucose level decreases,
        7. providing a feedback to the islets of Langerhans to secrete less insulin into the bloodstream.
        8. Blood glucose level decreases back to normal.

    b. Blood glucose level falls below normal,
        1. stimulating the islets of Langerhans in the pancreas to secrete more glucagon into the bloodstream.
        2. Glucagon is transported by the blood to the liver and muscles.
        3. Glucagon stimulates the liver and muscles to convert stored glycogen to glucose, which enters the bloodstream.
        4. Blood glucose concentration increases,
        5. providing a feedback to the islets of Langerhans to secrete less glucagon into the bloodstream.
        6. Blood glucose level rises back to normal.

4. Regulation of blood water potential (osmoregulation)
    a. Blood water potential rises above normal,
        1. stimulating the hypothalamus to stimulate the pituitary gland to secrete less anti-diuretic hormone (ADH) into bloodstream.
        2. This decreases the permeability of cells in the distal convoluted tubules (DCT) and the collecting ducts in kidneys tubules to water
        3. Less water is reabsorbed into bloodstream.
        4. A larger volume of more dilute urine is produced.
        5. Blood water potential decreases back to normal.

    b. Blood water potential falls below normal,

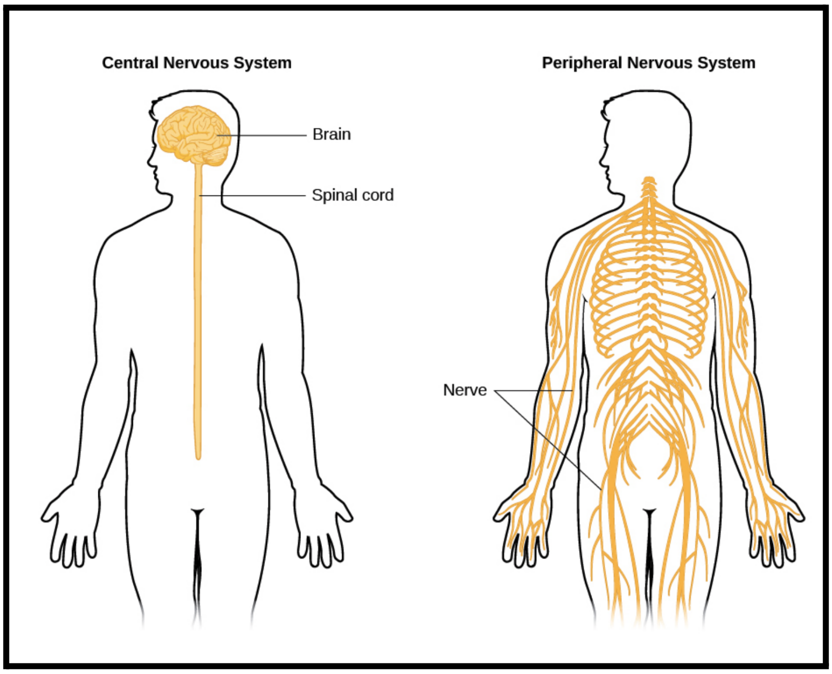
1. stimulating the hypothalamus to stimulate the pituitary gland to secrete more ADH into the bloodstream.
2. This increases the permeability of cells in the DCT and collecting ducts in the kidney tubules to water.
3. More water is **reabsorbed** into bloodstream.
4. A smaller volume of more concentrated urine is produced.
5. Blood water potential increases back to normal.

5. Thermoregulation
    - Thermoreceptors in **hypothalamus** detect **temperature of blood**
    - Thermoreceptors in **skin** detect **temperature from environment**
    a. Surrounding temperature increases,
        1. thermoreceptors in the skin detect rise in temperature and send nerve impulses to brain.
        2. Hypothalamus is stimulated and sends impulses to relevant body parts.
        3. Vasodilation occurs. Arterioles in skin dilate, shunt vessels constrict so that more blood flows through blood capillaries in skin, increasing heat loss by conduction, convection and radiation.
        4. Sweat glands become more active and more sweat is produced. As more water in sweat evaporates from skin surface, more latent heat of vaporisation is lost.
        5. Hair erector muscles relax and hairs lie down, trapping less air to retain less body heat.
        6. Metabolic rate decreases to reduce the amount of heat released within the body.
        7. Body temperature decreases back to normal.
    b. Surrounding temperature decreases,
        1. thermoreceptors in the skin detect drop in temperature and send nerve impulses to brain.
        2. Hypothalamus is stimulated and sends impulses to relevant body parts.
        3. Vasoconstriction occurs. Arterioles in skin constrict, shunt vessels dilate so that less blood flows through blood capillaries in skin, decreases heat loss by conduction, convection and radiation.
        4. Sweat glands become less active and less sweat is produced. As less water in sweat evaporates from skin surface, less latent heat of vaporisation is lost.
        5. Hair erector muscles contract and hairs are raised to trap air, which helps to retain more body heat.
        6. Metabolic rate increases to increase the amount of heat released within the body.
        7. Shivering occurs if the above reactions are insufficient to prevent a further drop in body temperature. The spasmodic contraction of skeletal muscles increases the amount of heat released.
        8. Body temperature rises back to normal.

Nervous System

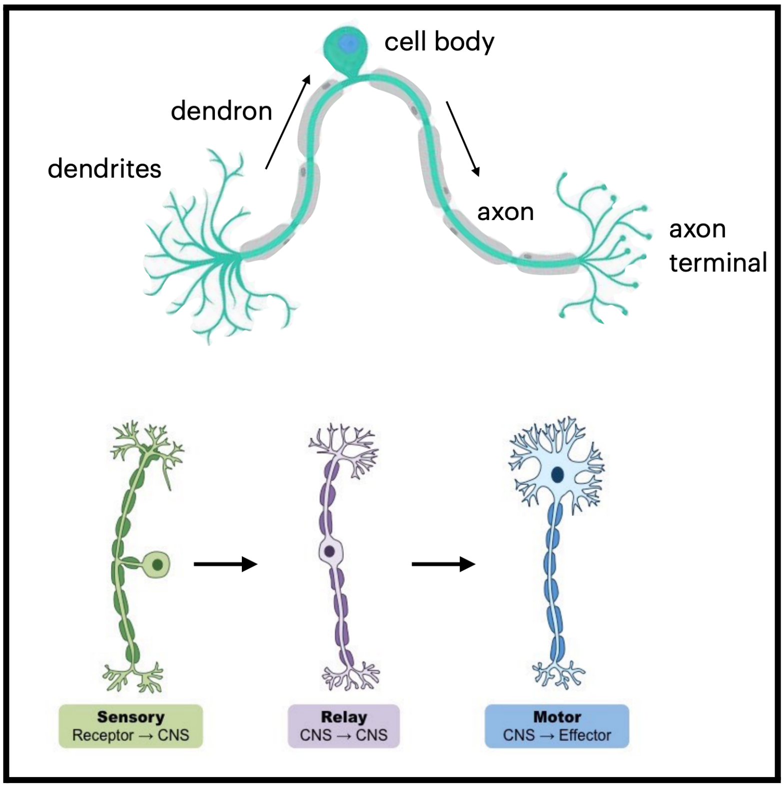
1. The role of nervous system:
    a. Help the body to adjust rapidly to any changes in the environment
    b. Enable the various parts of the body to coordinate with one another quickly
    c. Control involuntary actions, automatic actions that cannot be consciously controlled, such as heartbeat, peristalsis, vasoconstriction and reflex actions
    d. Control voluntary actions, actions that are consciously controlled

2. Human nervous system

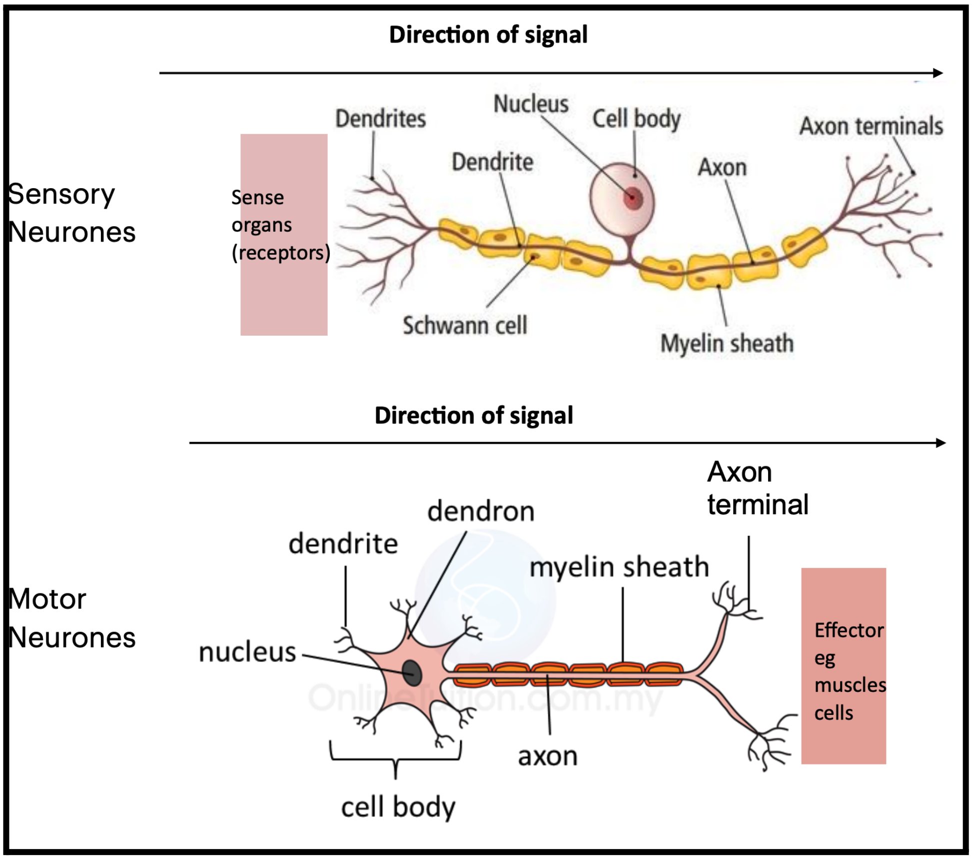


    a. Central nervous system (CNS) consists of the brain and spinal cord
    b. Peripheral nervous system (PNS) consists of cranial nerves (from the brain), spinal nerves (from the spinal cord) and sense organs

3. Nervous tissue

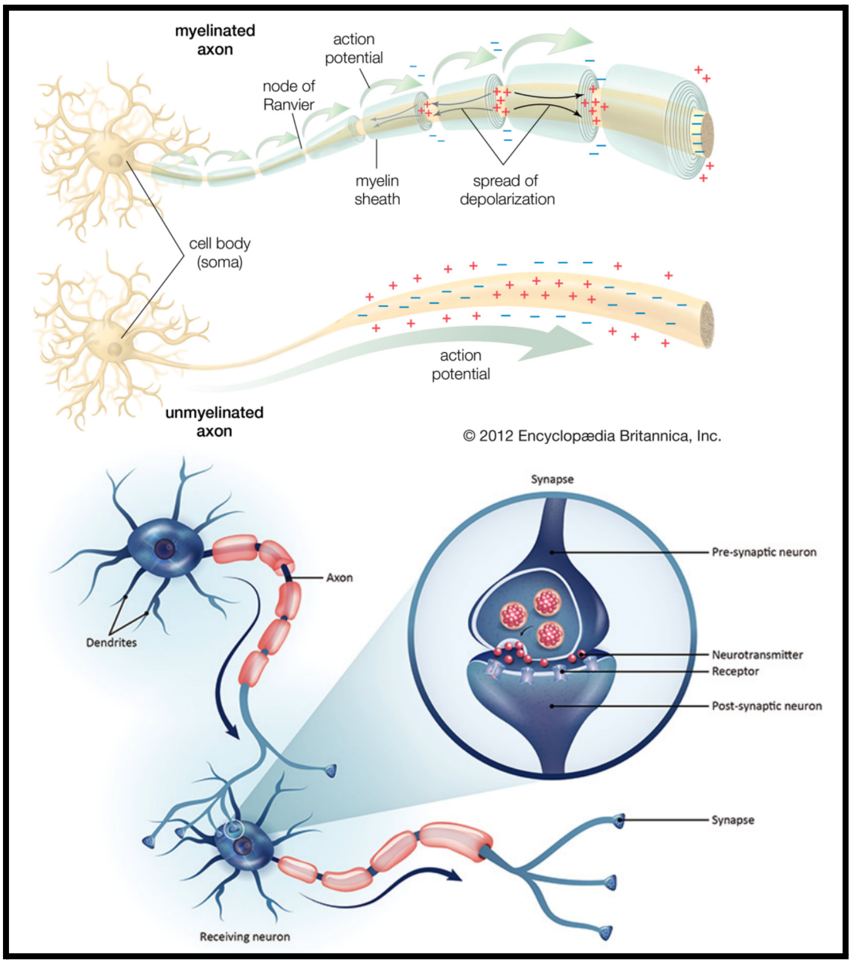


a. Nervous system is made of nervous tissue, which is made of neurones (nerve cells)
b. Nerve is a bundle of neurones that transmit nerve impulses. They may contain:
    1. Sensory nerve fibres only
    2. Motor nerve fibres only
    3. Mixed fibres (both sensory and motor nerve fibres - spinal nerves contain mixed fibres)
c. Parts of a neurone:
    1. Cell body: Contain the nucleus and organelles
    2. Dendrons: Nerve fibres that transmit nerve impulses towards the cell body.
    3. Axons: Nerve fibres that transmit nerve impulses away from the cell body.
    4. Dendrites: Nerve fibre branches at the terminal ends of axons and dendrons. Where the axon is connected to muscles, these branches are also known as motor end plates.
    5. Myelin sheath: Layer of fatty substance enclosing many nerve fibres; surrounded by a thin membrane called the neurilemma; insulates the nerve fibres
    6. Node of Ranvier: Region where the myelin sheath is absent; speed up transmission by allowing impulses to ‘jump’ from node to node
    7. Synapse: Junction between two neurones or a junction between a neurone and an effector
d. Three types of neurones:
    1. Sensory neurone: Transmits nerve impulses from receptors to CNS
    2. Relay neurone: Transmits nerve impulses from sensory neurone to motor neurone; found within CNS
    3. Motor neurone: Transmits nerve impulses from CNS to effectors
e. Comparison between sensory neurone and motor neurone:



	Sensory neurone	Motor neurone
Cell body	Circular	Irregular in shape
Dendrons	Long	Short
Axons	Short	Long
Direction of transmission	Transmits impulses from receptors to CNS	Transmits impulses from CNS to effectors

f. Transmission of nerve impulses:



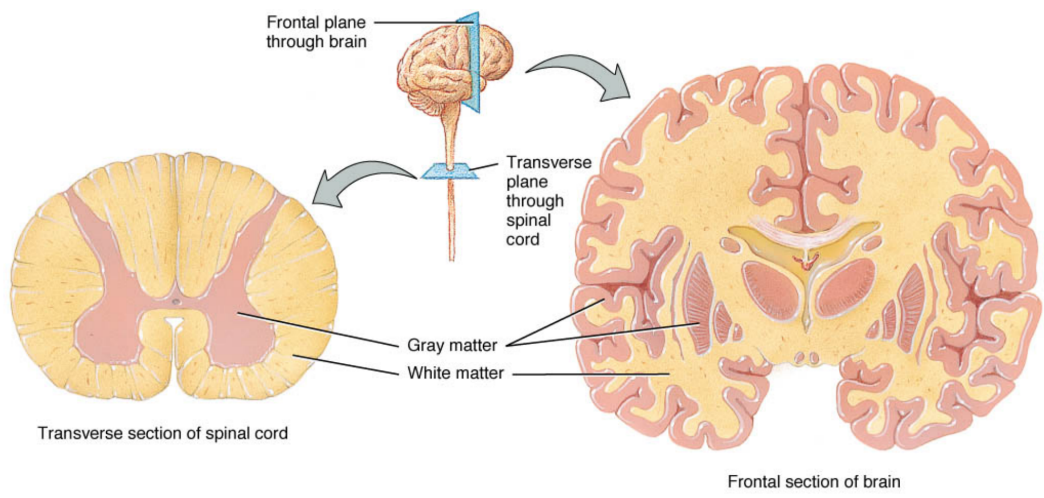
Along axons of neurones,

- Myelin sheath is made up of schwann cells which are fats. It provides insulation to the nerve impulses which are electrical signal
- Nodes of Ranvier are regions where myelin sheath is absent
- Nerve impulses which are electrical signals cannot be transmitted through the myelin sheath, so they "jump" from one node to the next, speeding up transmission of impulses

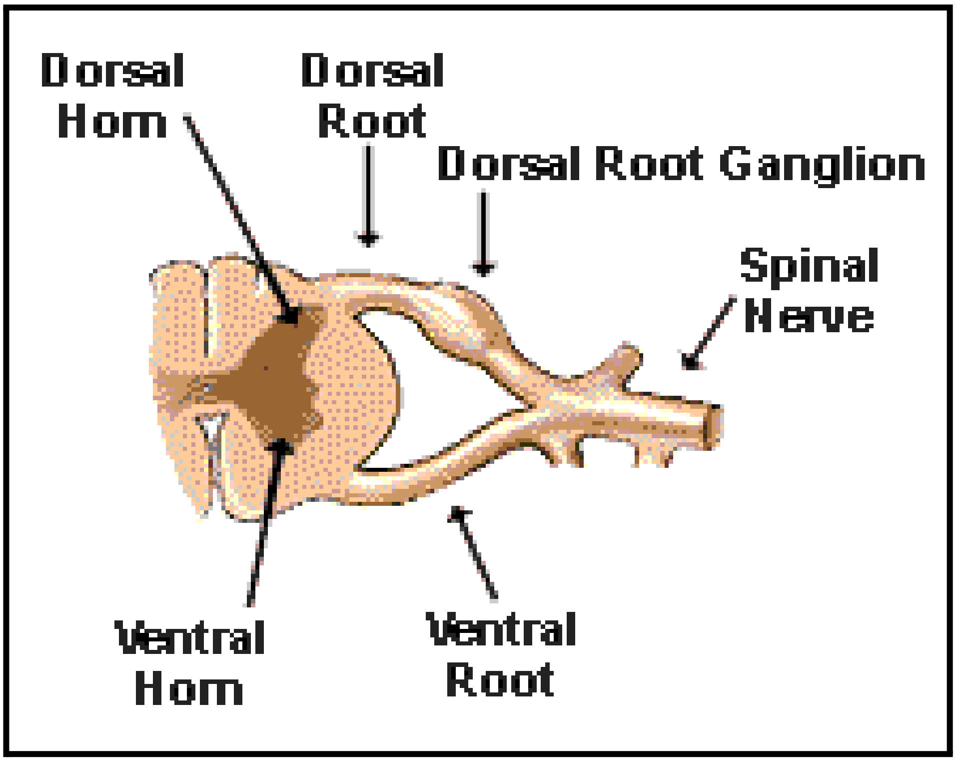
Across neurones,

- A synapse is a junction between two neurones or between a neurone and an effector
- Impulses from the axon of one neurone are transmitted to the dendrites of another neurone or to effector cells
- Nerve impulses are transmitted across the tiny space of a synapse by chemicals called neurotransmitters

4. Brain and spinal cord

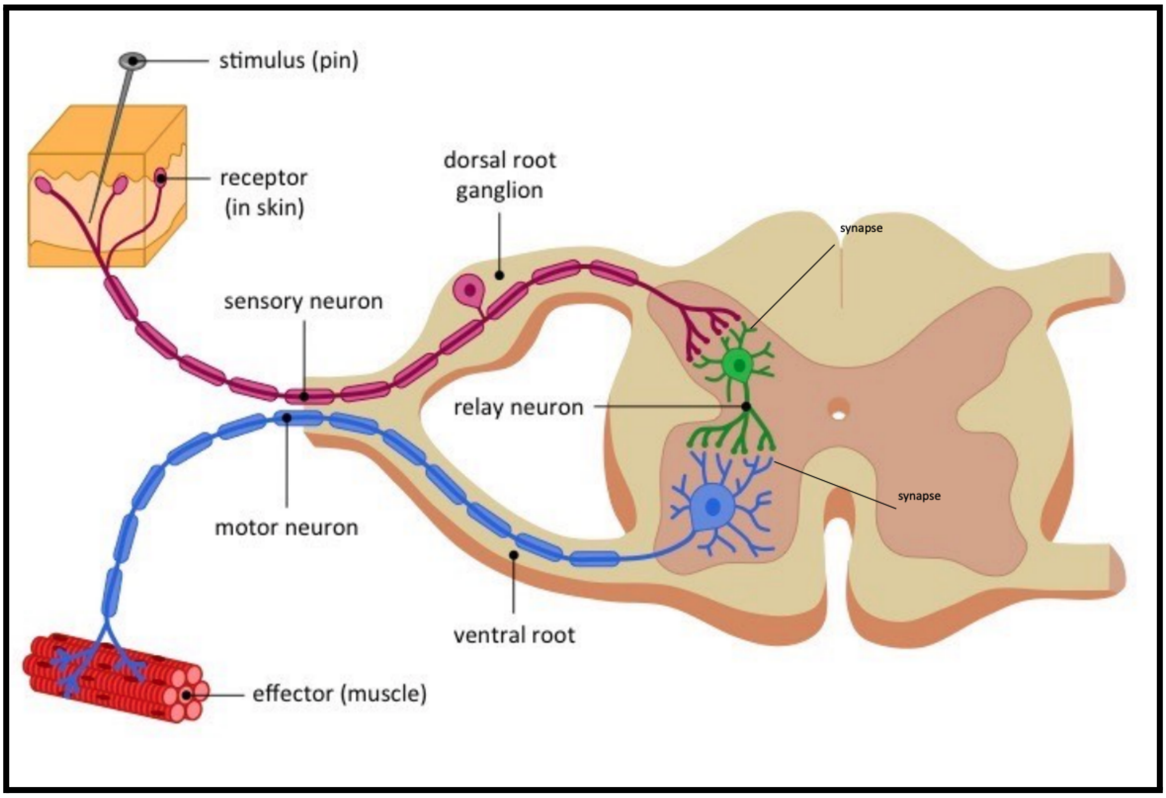


Region	Composition	Location
Grey matter	Mainly cell bodies of motor and relay neurones	- Outer layers of brain - Central parts of spinal cord
White matter	Mainly nerve fibres of sensory and motor neurones	- Central parts of brain - Outer layers of spinal cord
Central canal	Cerebrospinal fluid (CSF) that brings nutrients to spinal cord and ensures that the brain is supported	- White matter of brain - Grey matter of spinal cord



Part	Function
Dorsal root	- Joins the dorsal part (towards the back) of the spinal cord - Contains only nerve fibres of sensory neurones that transmit impulses TO the spinal cord (CNS)
Dorsal root ganglion	Small swelling in the dorsal root that contains cell bodies of sensory neurones
Ventral root	- Joins ventral part (towards the front) of the spinal cord - Contains only nerve fibres of motor neurones that transmit impulses FROM the spinal cord (CNS)
Spinal nerve	Dorsal root and ventral root may join to form the spinal nerve. Hence, the spinal nerve contains both sensory and motor neurones, and is a 'mixed' nerve.

5. Reflex action
    a. Reflex action: an immediate response to a specific stimulus without conscious control
    b. Reflex arc: the shortest pathway by which nerve impulses travel from receptor to effector in a reflex action



- Receptors in the skin detect the stimulus
- Nerve impulses are produced which are transmitted by the sensory neurone to the spinal cord
- In the spinal cord, the nerve impulses are transmitted across a synapse to a relay neurone and then across another synapse to the motor neurone
- Nerve impulses travel along the motor neurone to the motor end plate, then the effector
- The effector effects an action

c. 2 types of reflexes:

1. Cranial reflexes: reflexes controlled by the brain
2. Spinal reflexes: reflexes controlled by the spinal cord

6. Comparison between reflex action and voluntary action

Similarities:

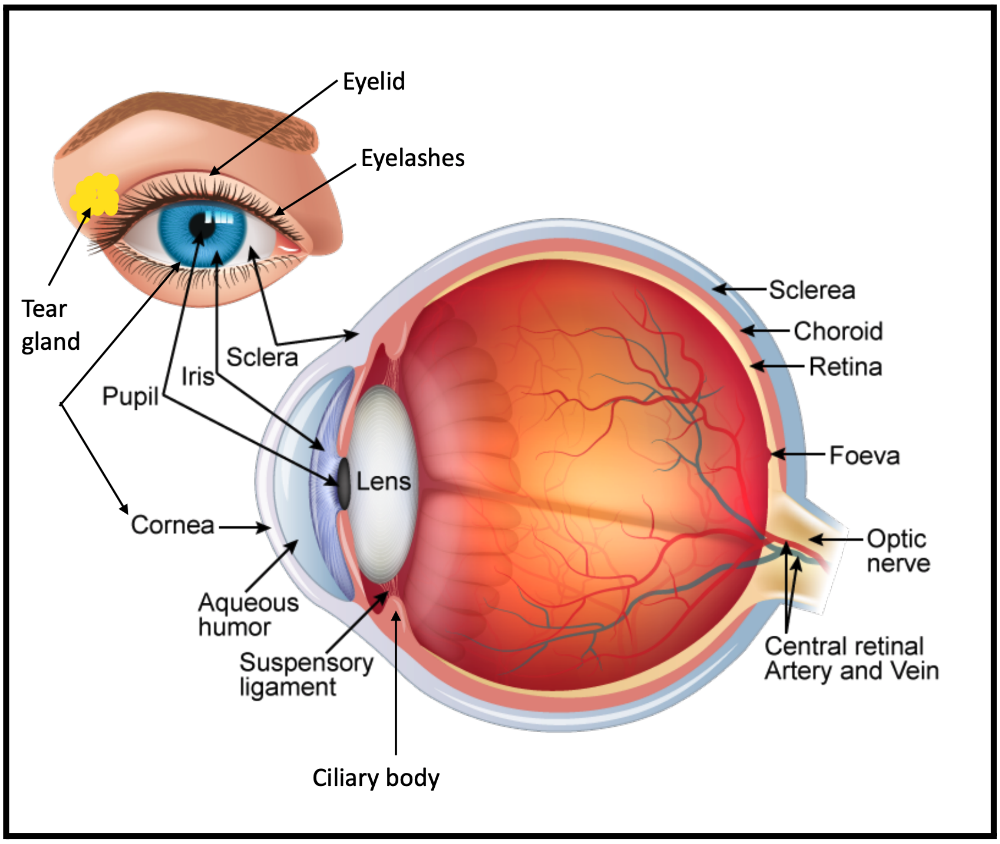
1. Nerve impulses are transmitted from the relay neurone in the CNS to the motor neurone
2. Nerve impulses are transmitted from the motor neurone to the effector

Differences:

Reflex action	**Voluntary action**
Immediate	Takes a longer time to complete
Nerve impulses are generated by the receptors	Nerve impulses are generated by the brain
Involves only one relay neurone	Involves usually more than one relay neurone

The Human Eye

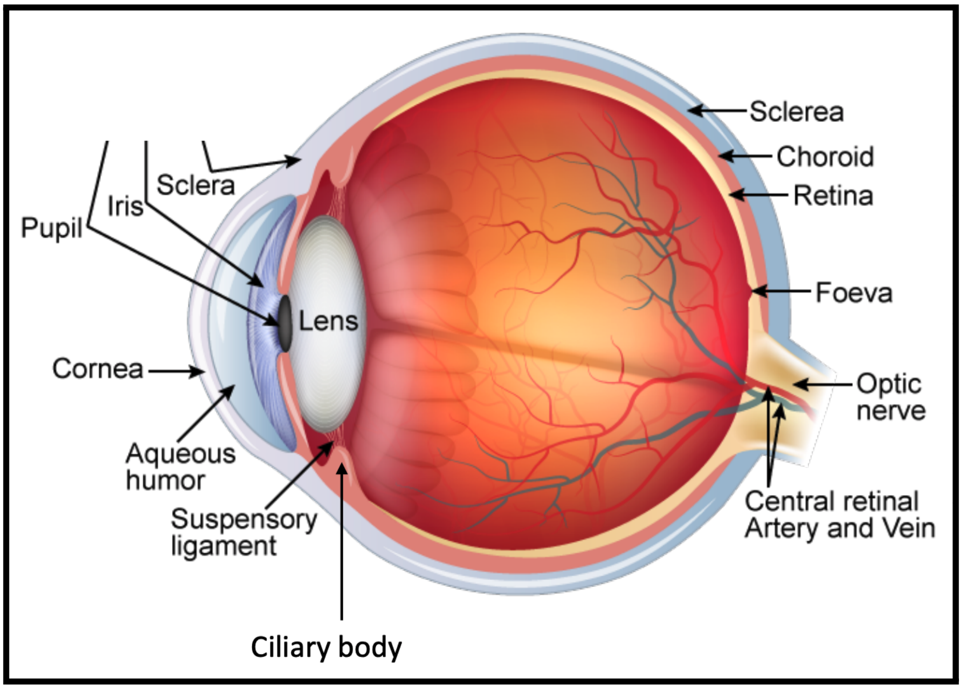
1. External structure of the eye



Part	Function
Iris	- Pigment of iris gives the colour of eyes - Two sets of involuntary muscles in the iris (circular and radial muscles) control the size of the pupil and thus the amount of light entering the eye
Pupil	Is hollow and allows light to enter the eye
Sclera/Scelerotic coat	- Tough white outer covering of eyeball; continuous with cornea - Protects the eyeball from mechanical damage - Eye rectus muscles attached to the sclera facilitates movement of the eyeball
Conjunctiva	- Thin transparent membrane covering the sclera - Secretes mucous to keep the front of the eyeball moist - Continuous with the skin of the eyelids
Eyelashes	- Shield eyes from dust particles - Squinting (the partial closure of eyelids) prevents excessive light from entering the eye and damaging the light-sensitive tissues - Blinking spreads tears over the cornea and conjunctiva and wipes dust

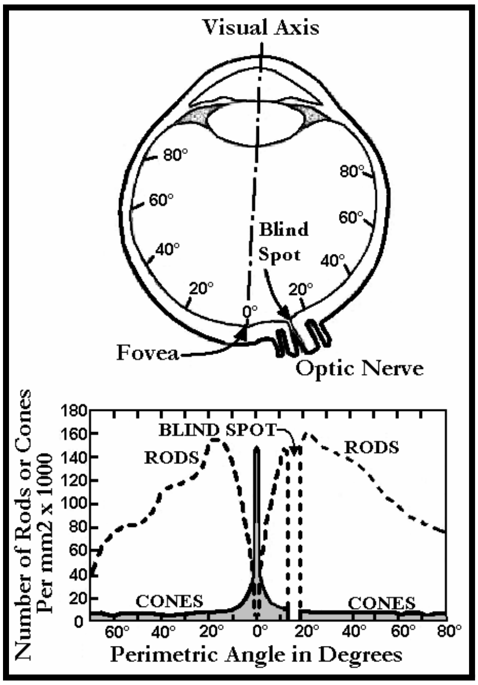
	particles off the cornea
Eyelids	- Protects the cornea from mechanical damage
Tear gland	- Secretes tears which: a. wash away dust particles b. keep the cornea moist for atmospheric oxygen to dissolve and diffuse into the cornea

2. Internal structure of the eye

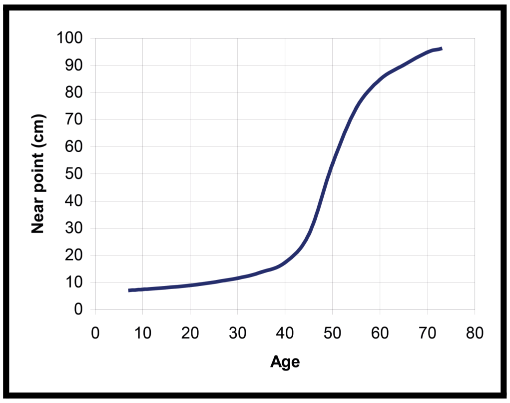


Part	Function
Choroid	- Middle layer of the eyeball, between the sclera and retina - Contains blood vessels that supply oxygen and nutrients, and remove metabolic waste products - Pigmented black to prevent an internal reflection of light
Retina	Innermost layer of the eyeball which contains photoreceptors, which are connected to the optic nerve
Lens	- Transparent biconvex structure that refracts light onto the retina - Can change its curvature to focus light onto retina
Fovea/yellow spot	- Where images are usually focused - Contains the greatest concentration of cones, but no rods
Ciliary body	- Contains ciliary muscles which control the curvature of the lens - Also responsible for producing aqueous humour (not in tb.)

Suspensory ligament	Connects the ciliary body to the lens
Aqueous chamber	- Contains transparent aqueous humour that keeps the front of the eyeball firm and helps to refract light into the pupil
Vitreous chamber	- Contains transparent vitreous humour that keeps the eyeball firm and helps to refract light onto the retina
Optic nerve	- Transmits impulses from the retina to the brain
Blind spot	Does not contain any rods or cones; not sensitive to light



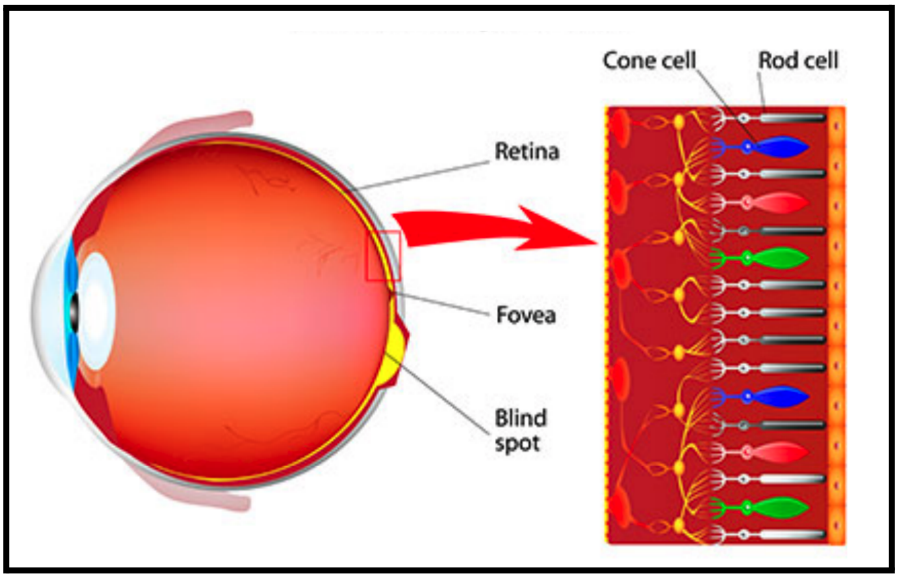
At the blind spot, the optic nerve consists of sensory neurones that carry nerve impulses from the retina to the brain. Thus, there are zero photoreceptors found.



The near point of an eye is the point nearest to the eye at which an object can be placed and there is still a sharp image forming on the retina. As people age, the lens becomes less elastic.

Also, the ciliary muscles are less able to contract enough to thicken the lens sufficiently, so the lens is not convex enough to accurately focus light rays from a very close object.

3. Photoreceptors in the retina



- Photoreceptors in the retina consist of rods and cones.
- The photoreceptors are connected to the nerve endings from the optic nerve.
    a. Cones:
        - Enable us to see colours in bright light.
        - Three types of cones: Red, blue, and green (RBG) that allow us to see a wide variety of colours by containing different pigments which absorb light of different wavelengths.
        - Do not work well in dim light.

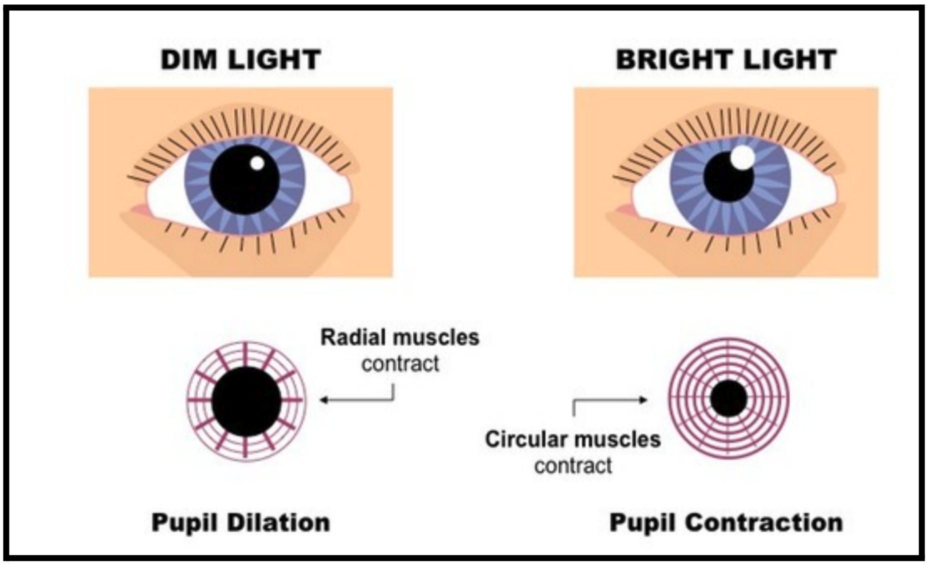
    b. Rods:
        - Enable us to see in dim light, but only in black and white.
        - Sensitive to light of low intensity as they contain pigment called visual purple.
        - When the eye is exposed to bright light, all the visual purple is bleached. Visual purple must be reformed for a person to see in the dark. Therefore, it takes awhile for one to see in dark after being in a bright environment as time is taken for visual purple to reform.
        - Formation of visual purple requires vitamin A.

4. How we see
    a. When light falls on an object, light rays are reflected from the object.
    b. Light rays are refracted through the cornea and the aqueous humour onto the lens.
    c. The lens causes further refraction and the rays are brought to a focus on the retina.
    d. The image on the retina stimulates the photoreceptors, either the rods or cones, depending on the light intensity.
    e. Nerve impulses are produced by the photoreceptors and transmitted to the brian by the optic nerve. The brain interprets the impulses and the person sees the object.

5. Accomodation: the adjustment of the lens of the eye so that clear images of objects at different distances are formed on the retina.
    a. Distant object:
        - Light rays reflected off distant objects are nearly parallel and enter the eyes.
        - Ciliary muscles relax, causing suspensory ligaments to become taut and pull on the edge of the lens.
        - The lens becomes thinner and less convex, increasing its focal length, causing less refraction of the light rays.
        - Light rays from the distant object converge on the fovea of the retina to produce a clear image.

    b. Near object:
        - Light rays reflected off near objects are diverging and enter the eyes.
        - Ciliary muscles contract, causing suspensory ligaments to slacken and relax their pull on the lens.
        - The lens becomes thicker and more convex, decreasing its focal length, causing more refraction of the light rays.
        - Light rays from the near object converge on the fovea of the retina to produce a clear image.

6. Pupil reflex



    a. Dim light:
        - In the iris, radial muscles contract and shorten while circular muscles relax and lengthen.
        - The pupil dilates and the amount of light entering the eye increases.
    b. Bright light:
        - In the iris, circular muscles contract and shorten while radial muscles relax and lengthen.
        - The pupil constricts and the amount of light entering the eye decreases.

Hormones

1. Definition
   Hormones are chemical messenger molecules
   usually protein in nature
   secreted by endocrine glands
   in minute amounts
   directly into the bloodstream
   and carried by the blood
   to one or more specific target organs
   and affect their cellular processes
   until destroyed by the liver

2. Types of glands
   a. Endocrine glands: Ductless glands; secrete their products directly into the bloodstream
   b. Exocrine glands: Glands that secrete their products via ducts

3. Hormones
   a. Insulin/Glucagon: homoeostatic control of blood glucose
      - Produced in the islets of Langerhans in the pancreas
      - When there is a lack of secretion of insulin,
        1. Glucose cannot be stored or used by cells, so blood glucose level rises; some glucose is lost in urine (diabetes mellitus)
        2. Muscle cells have no reserves of glycogen, so body grows weak + loses weight continuously
        3. Body oxidises fats instead of glucose to release energy; results in production of ketones which are poisonous and excreted in urine (ketonuria)
      - When there is over-secretion,
        1. Abnormal decrease in blood glucose level
        2. Results in shock
        3. Coma and death may follow

   b. Anti-diuretic hormone (ADH): homeostatic control of blood water potential
      Produced in hypothalamus, stored and secreted by the pituitary gland.

   c. Adrenaline
      - Released when a person is in danger.
      - Produced in the adrenal glands (situated above kidneys)
      - Function: Produces the fight or flight response
      - Increases heart rate (increase transport of blood to muscles)
      - Increases respiratory rate (increase oxygen absorption)
      - Stimulates the liver and skeletal muscles to convert glycogen to glucose (increase blood glucose concentration)
      - Blood flow is shunted away from digestive system by constricting arterioles to gut (increase transport of blood to muscles)
      - Blood flow is shunted away from skin by constricting arterioles in skin
      - Increases rate of blood clotting
      - Increases metabolic rate (release more energy during respiration)

These changes increase the transport of oxygen and glucose to the muscles so that there is an increase in the rate of cellular respiration, which makes more energy available for muscular contraction. So that the person is more able to fight or run.

Other effects:
- Sweat glands release more sweat, in preparation to cool down the body due to heat that is about to be produced in physical activity.
- Pupils dilate to allow more light to enter the eye.

4. Diabetes
   Types:
   a. Type I (juvenile or early onset diabetes) - caused by genetic factors
      Islets of Langerhans are unable to secrete sufficient insulin.
      Treatment is regular insulin injections.
   b. Type II (late-onset diabetes) - caused by genetic and lifestyle factors such as obesity, smoking, lack of exercise, too much stress, not enough sleep.
      Target cells do not respond well to insulin.
      Treatment is medication and for late stages, regular insulin injections. Lifestyle modification is often necessary to prevent further progress of the disease and to control the condition.
   c. Symptoms
      i. Excessive thirst
      ii. Frequent urination
      iii. Glucose in urine
      iv. High blood glucose
      v. Weight loss
      vi. Fatigue
      vii. Wounds take a longer time to heal
      viii. Kidney/eye damage

   Insulin injection and insulin pills:
   a. Insulin is injected into a diabetic patient rather than taken orally because insulin, being a protein, can be digested by proteases in the alimentary canal
   b. Insulin pills also take some time to pass through the digestive system to reach the small intestine, where it is absorbed into the bloodstream.
      Administering insulin via injection allows the insulin to be released into the bloodstream more quickly, allowing a quicker effect on the liver and muscles to reduce blood glucose levels in a shorter time.

5. Nervous control vs Endocrine control

   Similarities:
   - Both are means of coordination within the body
   - A stimulus causes transmission of a message to effector which carries out response

Endocrine control	**Nervous control**
Involves hormones (chemical substances)	Involves nerve impulses (electrical signals)
Hormones are transported by the blood	Impulses are transmitted by neurones
Usually slow responses	Usually quick responses

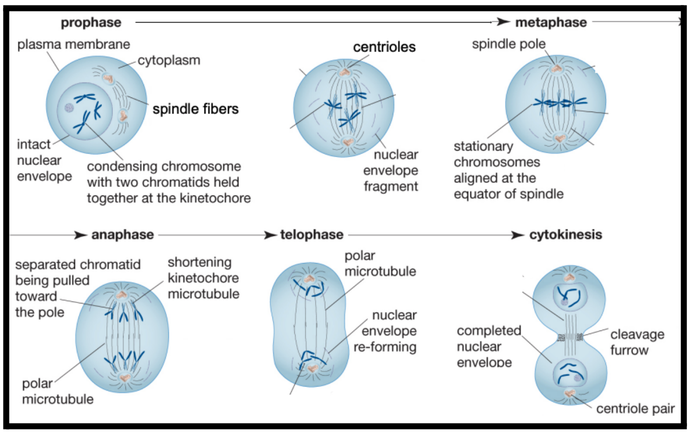
Responses may be short-lived (e.g. adrenaline) or long-lived (e.g. growth hormone)	Responses are short-lived
Always involuntary	May be voluntary or involuntary
May affect more than one target organ	Usually localised

6. Enzymes vs Hormones

Enzymes	Hormones
Always proteins	May be proteins, shorter polypeptides or steroids/cholesterol-based substances
Specific to their respective substrates	Target a wider range of cells, tissues and organs
Secreted by exocrine glands through a duct into target organ	Secreted by endocrine glands directly into bloodstream
Act very quickly and generally has short-term effects	Act more slowly and over a longer period of time
Work at specific locations	Act over a wider area and affect a large number of tissues, sometimes of different types
Catalyse reversible reactions	Control reactions that are irreversible
Speed up reactions	Regulate metabolic processes in the body

Cell Division

1. Mitosis
    a. Mitosis is a form of **nuclear division** that produces **genetically identical daughter nuclei** containing the **same number of chromosomes** as the parent nucleus
    b. Stages



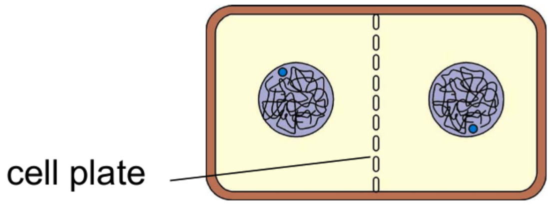
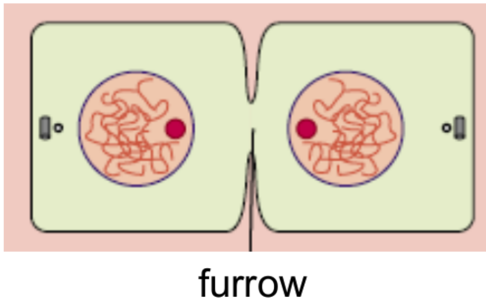
Stage	Process

Interphase	● Cell absorbs nutrients and synthesises new organelles ● Centrioles replicate and divide **in animal cells** ● Each chromatin thread replicates, producing two identical chromatin threads joined at a centromere, forming sister chromatids and DNA doubles
Prophase	● Chromatin threads condense and coil to form chromosomes ● Spindle fibres form ● Asters form around centrioles ● Centrioles move to opposite poles of the cell ● Nucleolus and nuclear envelope disappear
Metaphase	● Chromosomes line up along equatorial plane of the spindle ● Centromere of each chromosome is attached to both sides of a spindle fibre
Anaphase	● Centromeres divide ● Spindle fibres shorten to pull the sister chromatids apart to opposite poles of cell to form daughter chromosomes
Telophase	● Spindle fibres break down ● Nuclear envelope and nucleolus reform around each nucleus ● Chromosomes **decondens**e and **lengthen** to form chromatin threads
Cytokinesis	● **Cleavage of furrows appear** in cytoplasm **of animal cells** ● Furrows deepen and the cytoplasm divides ● Two identical daughter cells produced

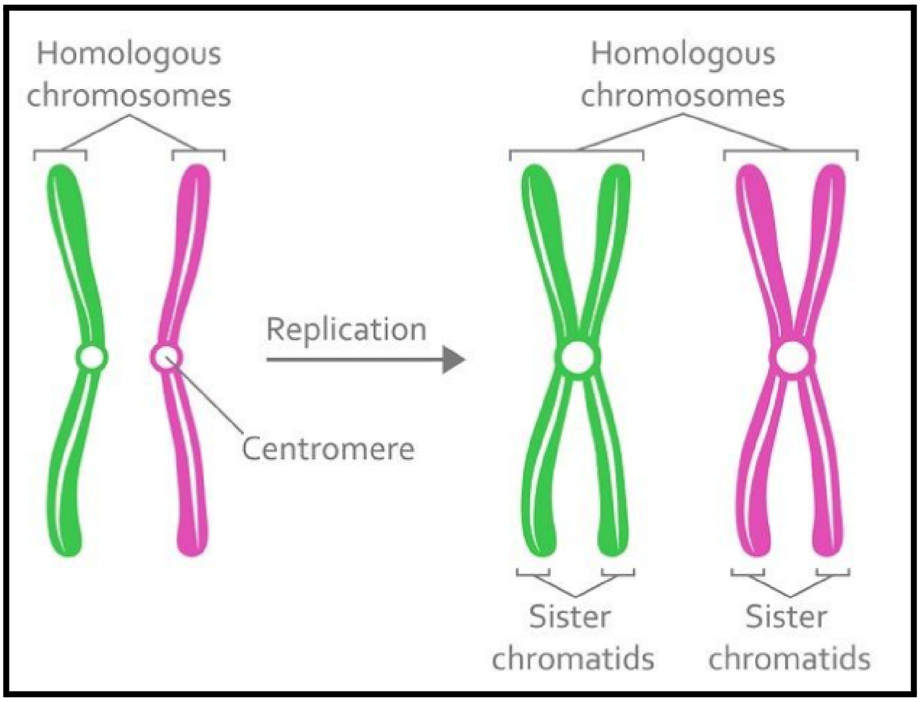
c. Importance of mitosis
   i. Growth and repair:
      Mitosis allows growth as it produces new cells.
      Mitosis allows repair by replacing new cells with worn-out cells that have been shed or to heal from wounds.
   ii. Asexual reproduction:
      Produces offspring genetically identical to one another as well as to parents.

d. Need for production of genetically identical daughter cells
   i. DNA replication copies all the information stored within the chromosomes, ensuring that daughter cells produced by mitosis contain all genes needed for subsequent cell division and differentiation.
   ii. Changes in the genes during DNA replication may cause abnormal proteins to be produced. Cells containing these proteins may be rejected or destroyed by the body's immune system.
   iii. In adult humans, mistakes made in DNA replication or mitosis may cau uncontrolled cell division (cancer). Cancer can be fatal as the cells lose the ability to control the way they divide and cannot perform their normal functions.

e. Differences between mitosis in plant and animal cells

Plant cells	Animal cells
Centrioles absent	Centrioles present
Cleavage of cytoplasm does not occur during cytokinesis. A cell plate forms between two daughter nuclei by fusion of fluid-filled vesicles. 	Cleavage of furrows form in cytoplasm during cytokinesis. 

2. Meiosis
    a. Meiosis is a form of **reduction nuclear division** that produces **genetically dissimilar** daughter nuclei containing **half the number of chromosomes** as the parent nucleus.
    b. Homologous chromosomes

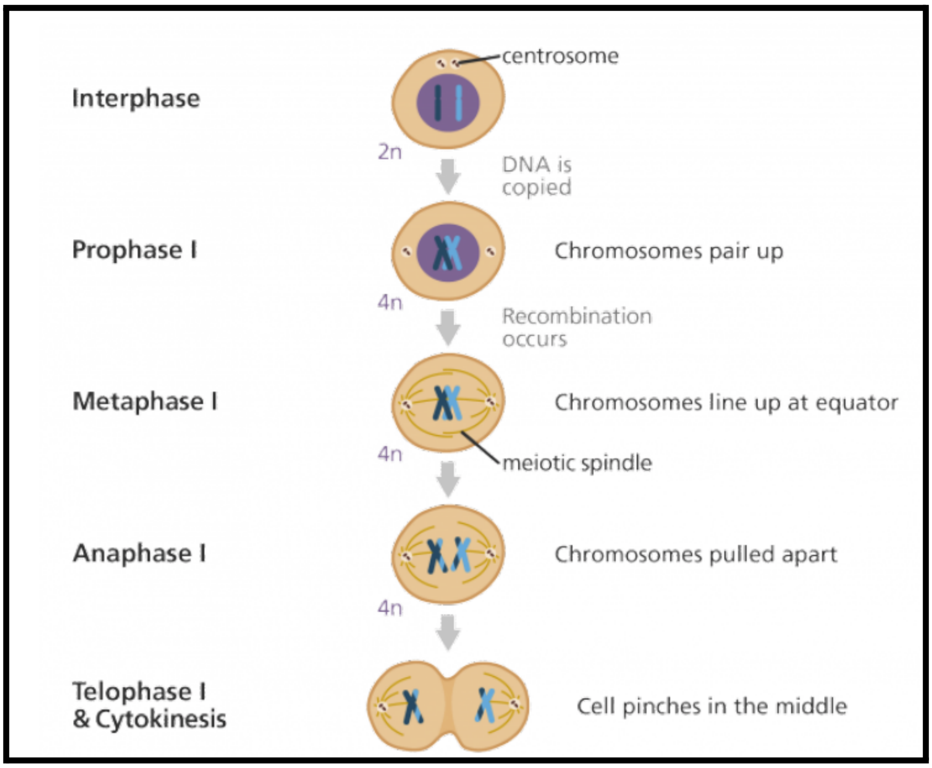


What is meant by homologous pairs of chromosomes:

- Exist in pairs - one chromosome comes from the male parent and the other from the female parent.
- Are similar in shape and size - except **sex chromosomes.**
- Have the same order of gene loci - but the alleles in those gene loci may not be the same.

c. Stages

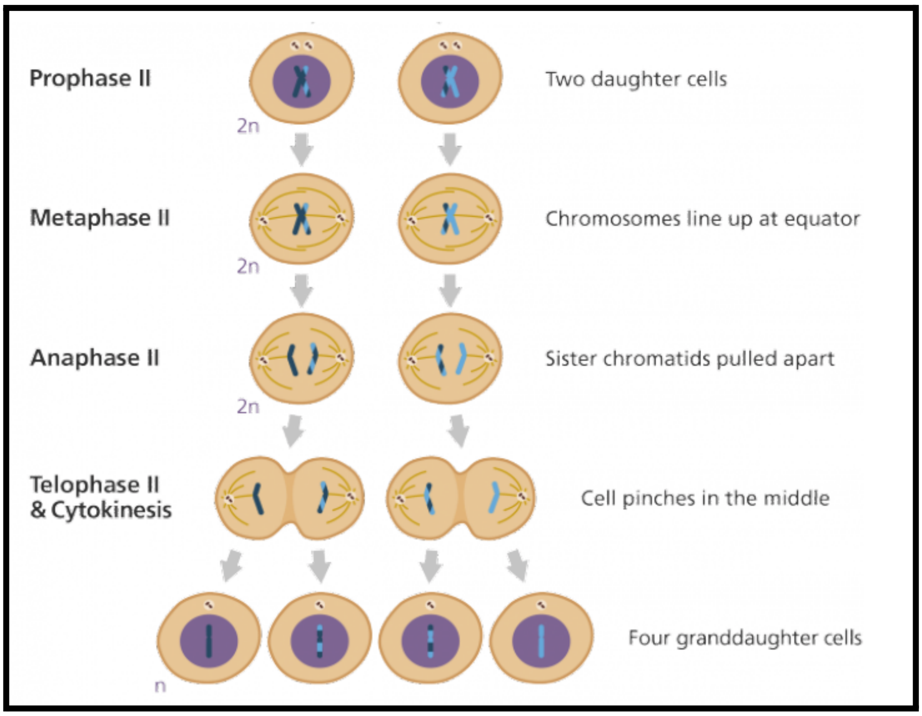
Meiosis I:



Stage	Process
Interphase	• Cell synthesise new protoplasm and absorbs nutrients • Centrioles divide and replicate in animal cells • Each chromatin thread replicates, producing two identical chromatin threads and DNA doubles
Prophase I	• Chromatin threads coil and condense to form chromosomes • Synapsis occurs, where homologous chromosomes pair along their whole length • Crossing over occurs, where chromatids of homologous chromosomes cross and twist around each other at a chiasma. The strength of their coiling causes them to break and exchange parts of their genetic material to form recombinant chromatids. • Asters form around centrioles • Centrioles move to opposite poles of the cell • Spindle fibres formed • Nuclear envelope and nucleolus disappear
Metaphase I	• Homologous chromosomes line up in pairs along the equatorial plane of the spindle
Anaphase I	• Spindle fibres shorten and homologous chromosomes separate and are pulled to opposite poles of the cell
Telophase I	• Nuclear envelope reforms around the chromosomes at each pole • Spindle fibres break down

	• Chromosomes uncoil and lengthen to form chromatin threads
Cytokinesis I	• Cleavage of furrows appear in the cytoplasm of animal cells. • Furrows deepen and the cytoplasm divides. • Two daughter cells with a haploid number of chromosomes are formed. • Centrioles divide **in animal cells**

Meiosis II:

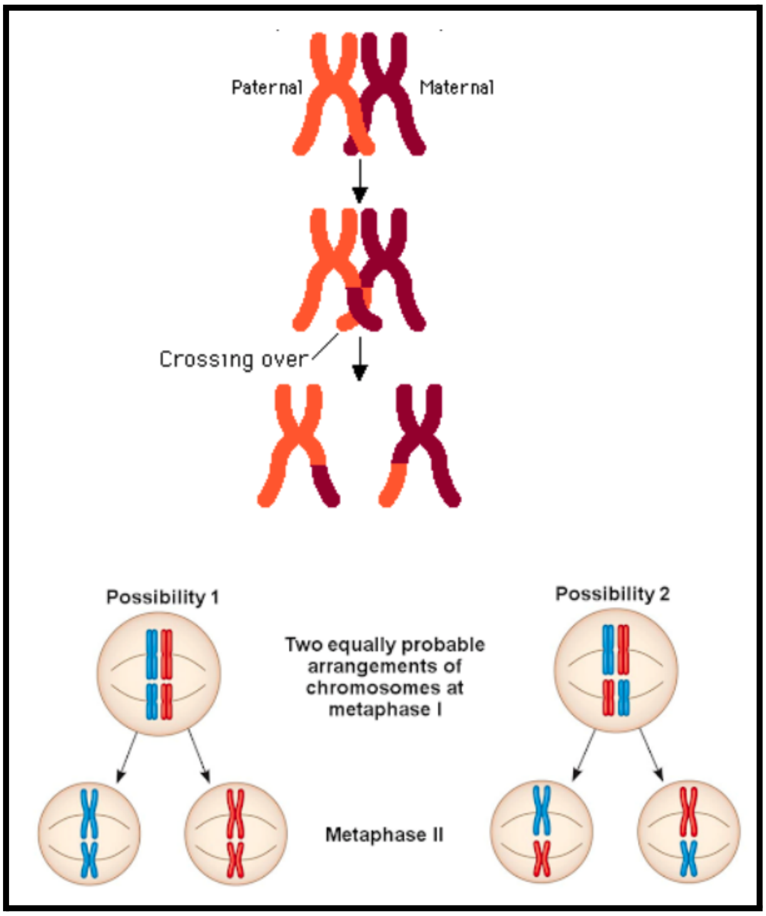


*ignore the "granddaughter" cells

Stage	Process
Prophase II	• Chromatin threads condense and coil to form chromosomes • Spindle fibres form • Asters form around centrioles • Centrioles move to opposite poles of the cell • Nuclear envelope disappears
Metaphase II	• Chromosomes line up along equatorial plane of the spindle • Centromere of each chromosome is attached to both sides of a spindle fibre
Anaphase II	• Centromeres divide • Spindle fibres shorten to pull the sister chromatids apart to opposite poles of cell to form daughter chromosomes
Telophase II	• Spindle fibres break down

	● Nuclear envelope and nucleolus reform around each nucleus ● Chromosomes **uncoil** and **lengthen** to form chromatin threads
Cytokinesis II	● **Cleavage of furrows appear** in cytoplasm **of animal cells** ● Furrows deepen and the cytoplasm divides ● Four daughter cells with a haploid number of chromosomes are formed

d. Importance of meiosis



i. Produces haploid gametes
   1. During meiosis, diploid cells undergo two nuclear divisions - meiosis I and meiosis II to give 4 haploid gametes.
   2. During fertilisation, normal diploid number of chromosomes is restored when the nucleus of male gamete fuses with nucleus of female gamete. This ensures the maintenance of chromosome number of offspring.

ii. Gives rise to genetic variation
   1. Meiosis produced **haploid** gametes, and thus when the nucleus of the male gamete fuses with the nucleus of the female gamete, the **diploid number of chromosomes** is **restored** in the **zygote**. There is no chromosomal doubling after every generation and the **chromosome number is maintained** throughout successive generations in a species.

2. **Crossing-over** between homologous chromosomes during **prophase I** of meiosis results in **exchange of genetic material** between **paternal and maternal chromosomes**, producing **new combinations of genes along the chromosomes.**
3. **Independent assortment** of homologous chromosomes during metaphase I of meiosis produces **different combinations of genetic material** in **gametes**.
4. **Random fertilisation** produces variation due to the many **different combinations of genes** from the **male and female gametes** as the nucleus of any sperm can fuse with the nucleus of any egg, producing offspring of different combinations of genotypes and thus phenotypes.
5. **Genetic variation** from meiosis and fertilisation increases the chances of survival of the species during environmental changes.

3. Differences between mitosis and meiosis

Mitosis	Meiosis
Daughter cells contain same number of chromosomes as parent cell	Daughter cells contain half the number of chromosomes as parent cell
Pairing of homologous chromosomes does not occur	Homologous chromosomes pair at prophase I
No crossing over	Crossing over may occur
Daughter cells are genetically identical to parent cell	Daughter cells are genetically dissimilar to parent cell
Two daughter cells produced from one parent cell	Four daughter cells produced from one parent cell
Involves on nuclear division	Involves two nuclear divisions
Occurs in all body cells	Occurs in gonads during gamete formation
Sister chromatids line up in a single file in metaphase	Homologous chromosomes line up in pairs in metaphase I

*suggested definitions of ploidy:
- Haploid: *'Having one set of chromosomes from each homologous pair'*
- Diploid: *'Having two sets of chromosomes, each set inherited from one parent'*

Plant Reproduction

1. Reproduction
    a. Asexual reproduction

        i. Asexual reproduction is the process resulting in the production of genetically identical offspring from one parent, without the fusion of nuclei of gametes.
        ii. Advantages:
            1. Only one parent is required as fusion of nuclei of gametes is not required.
            2. All beneficial qualities passed onto offspring.
            3. Faster method of producing offspring as compared to sexual reproduction.
            4. Since organisms are already in a suitable habitat, they can colonise the area rapidly.
        iii. Disadvantages:
            1. No genetic variation in offspring. Species are not well adapted to environmental changes and may be wiped out.
    b. Sexual reproduction
        i. Sexual reproduction is the process involving the fusion of the nucleus of the male gamete and nucleus of the female gamete to form a zygote, producing genetically dissimilar offspring.
        ii. Advantages:
            1. Offspring may inherit beneficial qualities from both parents.
            2. Greater genetic variation in offspring. Species are better adapted to environmental changes.
        iii. Disadvantages:
            1. Two parents are required (except in plants with bisexual flowers) as fusion of nuclei of gametes is required.
            2. Slower method of producing offspring as compared to asexual reproduction.

2. Parts of a flower
    a. Sepal
        i. Modified leaves found on the outermost ring of floral leaves
        ii. Enclose and protect the flower when it is in bud stage
        iii. All the sepals together form the **calyx**
    b. Petal
        i. Modified leaves which form the most conspicuous part of the flower
        ii. Large and brightly coloured in insect-pollinated plants
        iii. Form a platform for insects to land on
    c. Pedicel:
        i. The flower stalk
    d. Receptacle
        i. The enlarged end of the flower stalk which bears the other parts of the flower
    e. Anther
        i. Consists of two lobes and a vascular bundle
        ii. Each lobe contains two pollen sacs, which contain pollen grains
        iii. When mature, the anther splits up to release pollen grains containing a male gamete
    f. Filament
        i. Stalk that holds the anther in a suitable position to disperse pollen
    g. Stigma
        i. Receives pollen grains

    ii. When mature, it secretes a sugary fluid that stimulates germination of pollen grains

h. Style
    i. Holds the stigma in position to trap pollen grains

i. Ovary
    i. Contains one or more ovules, which contains the female gamete (ovum)

3. Self pollination
    a. Self pollination is the transfer of pollen grains from the anther to the stigma of the same flower or from the anther of a flower to the stigma of another flower on the same plant.
    b. Favoured when
        i. Bisexual flowers with anthers and stigmas mature at the same time
        ii. Stigma is located directly below the anthers
        iii. Flowers that never open
    c. Advantages
        i. Non-dependent on external agents of pollination such as insects or wind
        ii. Less wastage of pollen and energy. During wind and insect pollination, a great number of pollen grains are lost as only a few pollen grains come into contact with a stigma of a flower of the same species.
        iii. Only one parent plant is required.
        iv. Beneficial qualities are more likely to be passed down from parent plant to offspring.
        v. More likely for pollination to occur since stigmas are close to anthers.
    d. Disadvantages
        i. Less genetic variation. Offspring is less adapted to environmental changes.
        ii. Probability of harmful recessive alleles being expressed in offspring is higher as compared to cross-pollination. Offspring become weaker, smaller and less resistant to diseases.

4. Cross pollination
    a. Cross pollination is the transfer of pollen grains from the anther of a flower to the stigma of a flower of another plant belonging to the **same species**.
    b. Favoured when
        i. Plants bear only male or female flowers
        ii. In plants with bisexual flowers, anthers and stigmas mature at different times
        iii. Stigmas and anthers are located very far away
    c. Advantages
        i. Greater genetic variation. Offspring is more likely to survive environmental changes.
        ii. Offspring may have inherited beneficial qualities from both parents.
        iii. Increased probability of offspring being heterozygous, so probability of harmful recessive alleles being expressed in offspring is lower as compared to self-pollination.
        iv. Seeds produced are more viable and capable of surviving longer before germination.
    d. Disadvantages
        i. Energy-consuming as a large amount of energy is required to make large amounts of pollen grains.
        ii. More pollen is wasted due to the randomness of dispersal methods.

    iii. External agents of pollination such as wind and insects are required.
    iv. Two parent plants are required.

5. Insect pollination vs Wind pollination

Feature	Insect-pollinated flowers	Wind-pollinated flowers
Petals	Large and brightly coloured	Small and dull-coloured
Scent	Fragrant	Scentless
Nectar	Present	Absent
Nectar guide	Present	Absent
Stamens	Not pendulous and do not protrude out of the flower so that pollen grains can only be picked up and **dispersed** by insects that visit the flower.	Long pendulous filaments and protruding anthers so that pollen grains are easily shaken off and **dispersed** by the wind.
Stigmas	Small and compact, do not protrude out of the flower so that only pollen grains from visiting insects are transferred to it.	Large, feathery and protrude out of the flower to provide a large surface area to trap pollen grains.
Pollen grains	Fairly abundant. Large and sticky with a rough surface to readily stick to bodies of insects.	Very abundant. Small and light to be easily carried by the wind.

6. Pollination and fertilisation
    a. The pollen grains germinate in response to the sugary fluid secreted by the mature stigma.
    b. A pollen tube grows out of each pollen grain.
    c. The cytoplasm and the two nuclei of the pollen grain pass into the pollen tube.
    d. The pollen tube grows down the stigma and secretes enzymes to digest the surrounding tissue of the stigma and style.
    e. The generative nucleus divides to form two male gametes. The pollen tube nucleus disintegrates.
    f. The pollen tube enters the ovule through the micropyle. Within the ovule, the **tip** of the pollen tube absorbs sap and bursts, releasing the two male gametes.
    g. The nucleus of one male gamete fuses with the nucleus of the ovum to form a zygote. The nucleus of the other male gamete fuses with the definitive nucleus to form the endosperm nucleus.

Human Reproduction

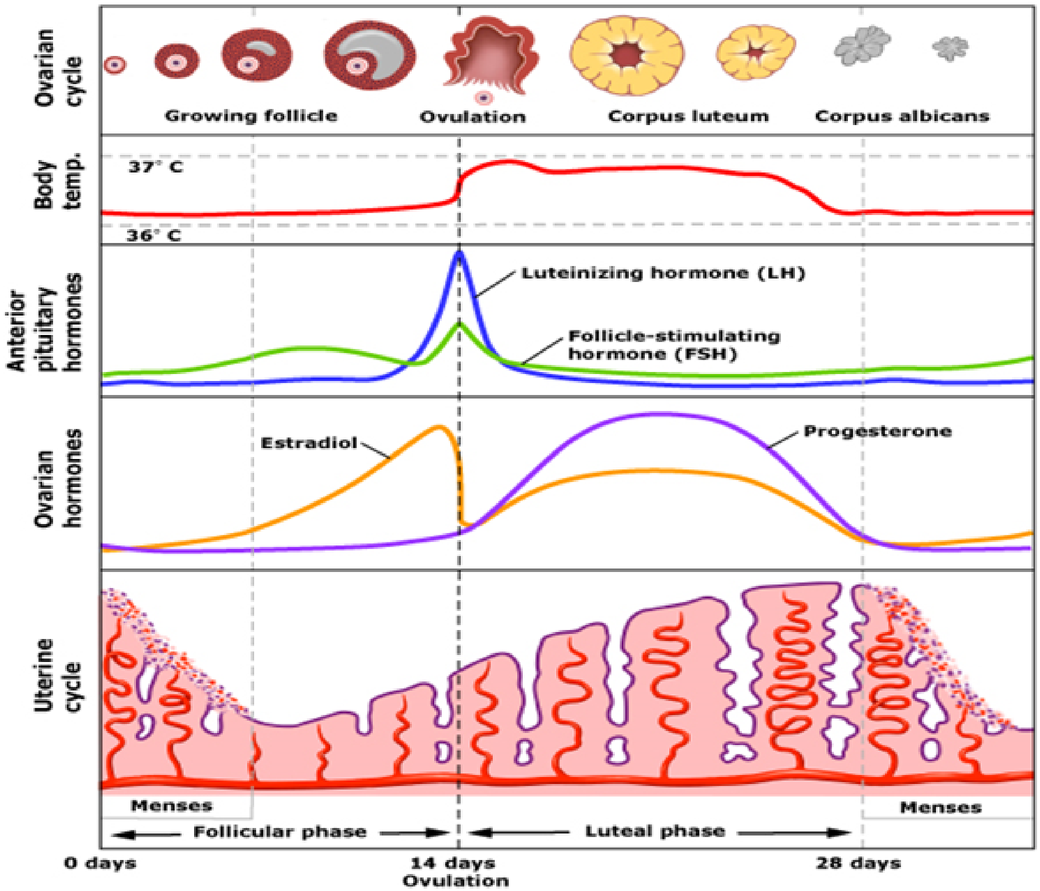
1. Male reproductive system
    a. Testes
        i. Produces sperms (male gametes)

        ii. Produce male sex hormones e.g. testosterone. Male sex hormones are responsible for development and maintenance of secondary sexual characteristics.
        iii. Sperm cell
            1. Around 60 µm long
            2. Head
                a. About 2.5 µm wide
                b. Contains a large nucleus with small amounts of cytoplasm.
                c. The nucleus carries a haploid number of chromosomes. (22 chromosomes + 1 X or Y chromosome)
                d. Acrosome contains enzymes that break down part of the egg membranes so that the sperm can penetrate the egg during fertilisation.
            3. Middle piece
                a. Contains numerous mitochondria, which provides energy for the sperm to swim towards the egg.
            4. Tail (flagellum)
                a. Carries out beating movement to swim towards the egg
                b. Sperm is motile
            5. Quantity
                a. Numerous sperms produced throughout lifetime from puberty onwards
                b. Large number of sperms released per ejaculation
    b. Epididymis
        i. Where inactive sperms are stored
    c. Scrotum
        i. Testes are held in the scrotum, which are pouch-like sacs outside the body. This allows the scrotum to be at a **slightly** lower temperature than body temperature, which is essential for sperm production
    d. Sperm ducts / Vas deferens
        i. Transport sperms from the epididymis to the urethra.
    e. Glands (Prostate gland, seminal vesicle and Cowper's gland)
        i. Secrete fluid that is mixed with sperms to make semen
        ii. The fluids contain nutrients and enzymes which nourish and activate the sperm, allowing them to swim actively
    f. Urethra
        i. A tube which passes from the bladder
        ii. Passage for urine and semen to pass out of the body
    g. Penis
        i. An erectile organ, containing erectile tissue, which allows the spaces within the tissue to be filled up with blood
        ii. When filled with blood, the penis becomes erect and hard, allowing it to enter the vagina of a woman during sexual intercourse to deposit semen

2. Female reproductive system

a. Ovaries
    i. Release mature eggs called ova (singular: ovum) into the oviduct
    ii. Produce female sex hormones e.g. estrogen and progesterone. Female sex hormones are responsible for development and maintenance of secondary sexual characteristics.
    iii. Ovum
        1. Spherical
        2. About 120 µm - 150 µm wide in diameter
        3. Has a large nucleus containing a haploid set of chromosomes (22 chromosomes + 1 X chromosome)
        4. Has abundant cytoplasm which may contain a small amount of yolk
        5. Surrounded by a plasma membrane and an outer membrane
        6. Non-motile
            a. Passive movement of egg along the oviduct is due to action of cilia in oviduct and peristalsis of oviduct wall
        7. Quantity
            a. Only one egg is released per month
            b. Both ovaries together release 500 ova
b. Oviducts / Fallopian tubes
    i. Narrow muscular tube where ovary releases the ovum into and leads to uterus
    ii. Cilia on the inner lining help move the ovum to the uterus.
    iii. Where fertilisation happens
c. Uterus
    i. A thick muscular organ.
    ii. Lined by uterine lining or endometrium
    iii. Endometrium is richly supplied with blood vessels. It is the site of implantation of the embryo post-fertilisation.
    iv. Uterus is where foetus develops during pregnancy
d. Cervix
    i. A circular ring of muscle that opens into the vagina
    ii. Enlarges during birth to allow the passage of the foetus
    iii. Opening of cervix allows menstrual blood to flow out into the vagina during menstruation
e. Vagina
    i. Birth canal through which the baby is born
    ii. Where penis is injected and sperm is deposited during sexual intercourse

3. Menstrual cycle



Day 1 - 5	Menstruation • The uterine lining breaks down and flows from the uterus out of the body through the vagina. • The pituitary gland secretes follicle-stimulating hormone (FSH) into the bloodstream.
Day 6 - 13	• FSH stimulates the development and maturation of follicles in the ovaries. Usually, one primary follicle develops into a Graafian follicle, which contains a mature egg surrounded by follicles and a fluid-filled space. • FSH stimulates the follicles in the ovaries to secrete oestrogen. • Oestrogen causes the repair and growth of the uterine lining by causing it to become thick and spongy with blood vessels. • Oestrogen at high concentration inhibits FSH secretion to prevent the development and maturation of more follicles. • Oestrogen at high concentration also stimulates the pituitary gland to secrete luteinising hormone (LH).
Day 14	Ovulation • Luteinising hormone causes ovulation, whereby the Graafian follicle ruptures and releases the mature egg into the oviduct. • LH also causes the formation of the corpus luteum from the remains of the Graafian follicle.

Day 15 - 28	• Corpus luteum secretes progesterone and some oestrogen. • Progesterone maintains the uterine lining by causing it to thicken further and be richly supplied with blood capillaries, preparing it for the implantation of an embryo. • Progesterone inhibits ovulation and FSH secretion.

If no fertilisation occurs	The egg breaks down. LH production is inhibited by high concentration of progesterone in the blood. The drop in LH level causes the corpus luteum to break down. When the corpus luteum breaks down, no progesterone is secreted. Without progesterone, the uterine lining cannot be maintained, so it breaks down. The lining flows from the uterus together with some blood through the vagina and menstruation occurs. The cycle repeats.
If fertilisation occurs	The fertilised egg becomes a zygote, which develops into an embryo. The embryo implants itself in the uterine lining. The embryo secretes a hormone which prevents the corpus luteum from breaking down until a placenta is formed. The corpus luteum continues to secrete progesterone and oestrogen until the placenta is able to take over the production of progesterone and oestrogen.

4. Fertilisation
    a. The acrosome of the sperm releases an enzyme to disperse the follicle cells and break down part of the egg membranes.
    b. As soon as one sperm enters the egg, the membrane of the egg changes so that no other sperms can enter.
    c. The haploid sperm nucleus fuses with the haploid egg nucleus, forming a diploid zygote.
    d. The remaining sperms which do not fertilise the egg eventually die.
5. Pregnancy
    a. Development of embryo
        i. Cilia lining the inner surface of the oviduct sweep the zygote along the oviduct. Peristaltic movements in the oviduct wall also help move the zygote to the uterus.
        ii. The zygote divides by mitosis to form an embryo.
        iii. It takes about 5 days for the embryo to reach the uterus. The embryo may float freely in the uterus for about 2 days.
        iv. Eventually, the embryo becomes embedded in the uterine lining. Implantation occurs about 7 days after fertilisation.
    b. Development of placenta
        i. Villi begins to grow from the embryo into the uterine lining. They contain the blood capillaries of the embryo.
        ii. The villi and the uterine lining in which the villi are embedded make up the placenta.
        iii. An umbilical cord attaches the embryo to the placenta.
    c. Development of amniotic sac/amnion

        i. The amniotic sac encloses the embryo in the amniotic cavity, which is filled with amniotic fluid
    d. Functions of placenta
        i. Provide nutrients such as glucose, amino acids and mineral salts and oxygen from maternal blood to the embryo
        ii. Remove waste materials such as urea and carbon dioxide from the foetus
        iii. Allows protective antibodies to diffuse from maternal blood into embryonic blood
        iv. Provides a barrier preventing the mixing of maternal blood and embryonic blood because
            1. Maternal blood pressure is much higher than embryonic blood pressure and would damage vital tissues
            2. The embryo might have a different blood group, which can resulting in agglutination when blood is mixed which is fatal
        v. Produces progesterone which maintains the endometrium during pregnancy
    e. Functions of umbilical cord
        i. Attaches the embryo to the placenta
        ii. One umbilical vein transports oxygenated blood and food substances from the placenta to the foetus
        iii. Two umbilical arteries transport deoxygenated blood and metabolic waste products from the foetus to the placenta
    f. Functions of amniotic fluid
        i. Acts as a cushion to absorb shock and protect the foetus against mechanical injury
        ii. Allows foetus a certain degree of movement, which promotes muscular development
        iii. Acts as lubricating fluid for the passage of the baby during birth
6. Spread of HIV
    a. Sexually transmitted infections (STIs) are transmitted through the following means:
        i. Through semen when it comes into contact with the mucous membrane in the vagina
        ii. Through fluid in the vagina when it comes into contact with the mucous membrane of the urethra
        iii. When blood from an infected person gets into the bloodstream of an uninfected person
    b. Acquired Immune Deficiency Syndrome (AIDS) is caused by Human Immunodeficiency Virus (HIV), which destroys the body’s immune system
    c. Symptoms
        i. Chronic fever
        ii. Severe diarrhoea lasting for months
        iii. Pneumonia
        iv. Cancer of blood vessels
    d. Modes of transmission of HIV
        i. Sexual intercouse with an infected person
        ii. Sharing hypodermic needles with an infected person

iii. Blood transfusion from an infected person
iv. During pregnancy, the virus may pass from the infected mother to the foetus
e. Prevention and control
i. Keep to one sex partner or do not have sex
ii. Use of condoms
iii. Do not share instruments that are likely to break the skin and be contaminated with blood

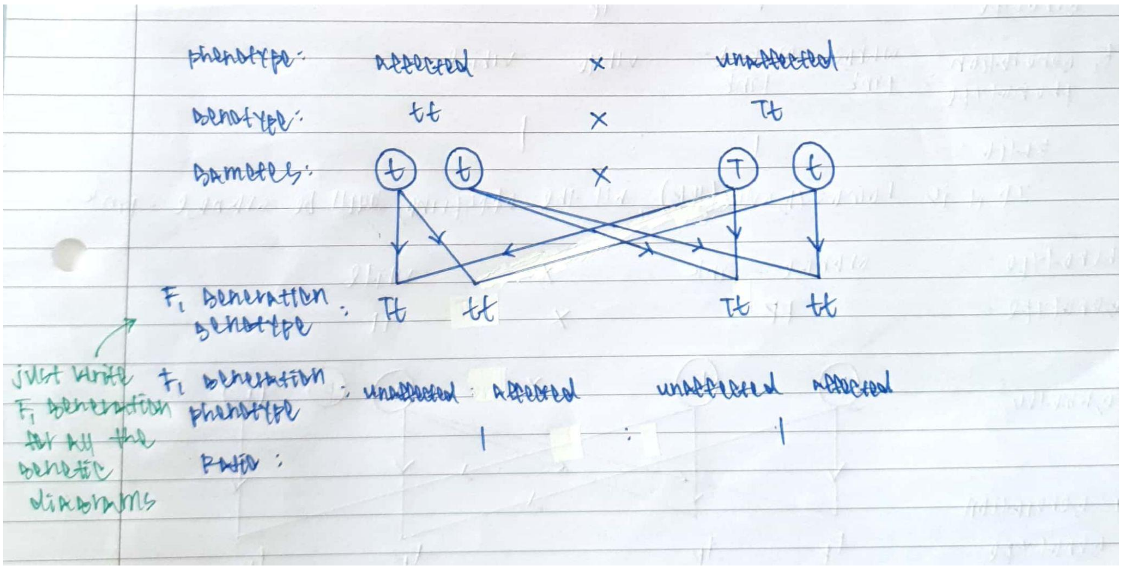
Heredity

1. Terminology

Term	Definition
Chromosome	A chromosome is a a. rod-like structure visible in the nucleus during cell division b. made up of the molecule deoxyribonucleic acid (DNA)
Gene	A gene is a a. unit of inheritance, born on a particular locus of a chromosome b. a small segment of DNA in a chromosome that controls a particular characteristic or protein in an organism
Alleles	Alleles are a. different forms of the same gene b. that occupy the same relative positions on a pair of homologous chromosomes
Homologous chromosomes	Homologous chromosomes a. exist in pairs - one chromosome comes from the male parent and the other from the female parent b. are similar in shape and size - except **sex chromosomes** c. have the same order of gene loci - but the alleles in those gene loci may not be the same
Phenotype	Phenotype is a. the expressed trait in an organism b. is influenced by: i. Genotype ii. Environment
Genotype	Genotype is the genetic make-up (pairs of alleles) of an organism
Dominant allele	A dominant allele a. expresses itself b. and gives the same phenotype in both the homozygous and heterozygous conditions
Recessive allele	A recessive allele a. does not express itself in the heterozygous condition b. and only expresses itself in the homozygous condition

Homozygous	An organism is homozygous for a trait if the two alleles controlling the trait are the same.
Heterozygous	An organism is heterozygous for a trait if the two alleles containing the trait are different.

2. Genetic diagrams



*Note: The gametes must be circled

3. Punnett square

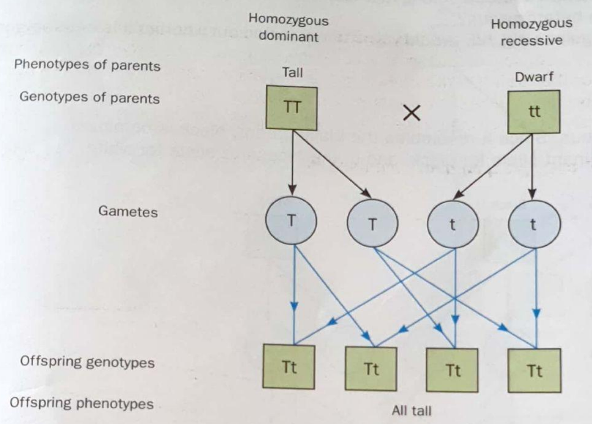
Let T be the allele that codes for the tall phenotype
Let t be the allele that codes for the short phenotype

	T	t
T	TT tall	Tt tall
t	Tt tall	tt short

Ratio 3 Tall : 1 short

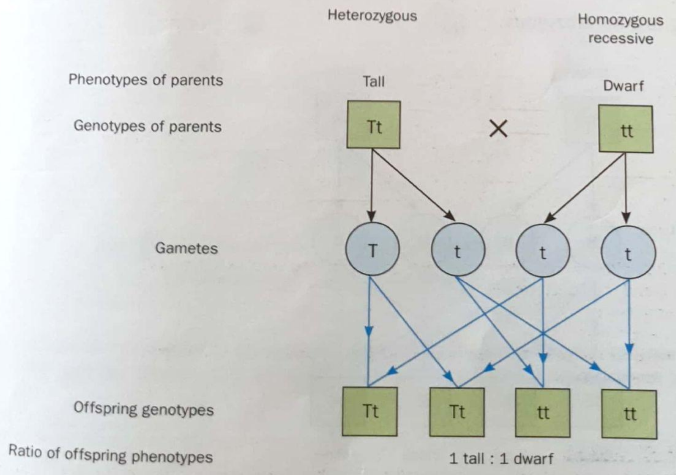
4. Determining genotype

If the organism is homozygous dominant, then all the offspring should show the dominant trait.



▲ **Figure 19.10** A test cross involving a homozygous dominant genotype

If the organism is heterozygous, then half the total number of offspring should show the dominant trait. The remaining half should show the recessive trait.



▲ **Figure 19.11** A test cross involving a heterozygous genotype

a. If parents are different (phenotypically), and the offspring ALL follow one parent, that parent is expressing the dominant trait.
   - Both parents are homozygous.

b. If parents are different (phenotypically), and the offspring are 50:50 following either parent, we won't be able to figure out which is dominant.
   - Parent showing dominant trait is heterozygous.

c. If the parents are the same (phenotypically), and the offspring have at least one that's different from both, both parents are expressing the dominant trait.
   - Both parents must be heterozygous. (The heterozygous parents each contributed a recessive allele to produce a homozygous recessive offspring.)

d. Probability
   Due to probability, the larger the sample size, the more closely the actual numbers should match the expected ratio. *(Since the sample size is small, the actual ratio may differ significantly from the expected ratio due to the laws of probability.)*

e. Human Sex Determination
   i. Humans have 23 pairs of chromosomes. 22 of them are made up of homologous pairs. **The last pair is NOT homologous** (has the same genes). XX genotype produces females, XY produces males.
   ii. Human cells contain 22 pairs of autosomal chromosomes and a pair of sex chromosomes.
   iii. During gamete production, the female eggs contain an X chromosome each.
   iv. Males will produce two types of sperm - one containing an X chromosome, and the other containing the Y chromosome.

5. Multiple alleles and co-dominance
   a. Co-dominance
      i. Co-dominance occurs when both alleles are equally expressed in the heterozygous condition.
      ii. The human ABO blood group system displays co-dominance.
   b. Multiple alleles is a term used for a gene that exists in more than two alleles.
   c. When there is more than one dominant allele, we say that they are codominant. There are two types of “codominance” - **incomplete dominance** and **codominance**.

The human ABO blood group system displays co-dominance and has multiple alleles

The I^A allele codes for the A phenotype.
The I^B allele codes for the B phenotype.
The I^O allele codes for the O phenotype.

I^OI^O results in blood type O
I^AI^A results in blood type A
I^AI^o results in blood type A
I^BI^B results in blood type B
I^BI^O results in blood type B
I^AI^B results in blood type AB

6. Discontinuous and Continuous Variations

	Discontinuous	Continuous
Phenotypes	Distinct	Not-distinct, characteristic occurs within a range
Genes	Do not show additive effect	Show additive effect
Affected by environment	Not, generally	Yes
Examples	Tongue rolling Eye colour Earlobes Type I diabetes Hair curliness	Type II diabetes Height Skin colour Weight

7. Mutation

a. Mutation is a sudden random change in the structure of a gene or in the chromosome number.
b. Causes of mutation:
    i. Exposure to radiation
    ii. Exposure to chemicals called carcinogens
c. Gene mutation
    i. Change in the structure of DNA
    ii. Produces variation between individuals as it results in new alleles of genes
        1. Albinism (gene mutation)
            a. Individuals who are homozygous for the albinism alleles are albinos.
            b. Albino individuals do not have pigments in the skin, hair and eyes, but instead have reddish-white skin and white hair.
            c. Since the iris does not contain any pigment, it appears red because of the colour of blood vessels in it.
            d. Albinos are very sensitive to sunlight and their skin is easily sunburnt.
        2. Sickle-cell anaemia (gene mutation)
            a. The gene controlling haemoglobin production is mutated. It produces haemoglobin S (HbS), which is almost the same as the normal haemoglobin A (HbA) except in one amino acid.
            b. This causes a change in the three-dimensional shape of the haemoglobin molecule. HbS molecules clump together, making the cell sickle-shaped.
            c. The mutated gene is only expressed in the homozygous recessive condition.
            d. When the oxygen concentration in the blood of homozygous recessive individuals decreases, their red blood cells become sickle-shaped.
        3. Malaria and sickle-cell anaemia
            a. Individuals who are heterozygous for the sickle-cell allele are more resistant to malaria than individuals who have two copies of the normal haemoglobin allele.
            b. Individuals who are homozygous for the sickle-cell allele have shorter life spans.
            c. Heterozygous individuals have a better chance of surviving and reproducing in regions where malaria is prevalent since they do not fully contract either disease. This ensures that the recessive allele persists in the population.

d. Chromosome mutation
    Down's syndrome
    1. Humans normally have 46 chromosomes in each of their body cells
    2. People with Down's syndrome have 47 chromosomes - an extra copy of chromosome 21
    3. Mutation causes chromosome 21 to not separate during gamete formation, resulting in an egg with 2 copies of chromosome 21. After fertilisation, the zygote would have 3 copies of chromosome 21.

e. Mutagenic agents
    Mutagenic agents (mutagens) greatly increase the rate of mutation.

Radiation	Chemicals
- Ultraviolet light, X-ray - Gamma rays	- Mustard gas - Formaldehyde

8. Evolution by natural selection
    a. Variation and competition lead to differential survival of, and reproduction by, those organisms best fitted to the environment
    b. Environmental factors that act as forces of natural selection: Predation, food shortage, disease
    c. Template:
        i. *The variation*
        ii. Individuals with (so-and-so) traits are **more likely to survive longer,** resulting in a **higher rate of reproduction**
        iii. and are more likely to pass on the genes for that trait to their offspring,
        iv. resulting in **increased genetic variation**
        v. The offspring that **inherit the beneficial traits** are able to **adapt** to the environment and will be more likely to survive and reproduce.
        vi. This process repeats itself over many generations, leading to a population with a **higher proportion** of individuals with (so-and-so) traits.

E.g. 1. When the environment has mainly dark coloured tree trunks, the darker coloured variety of melanic moths are less likely to be spotted and eaten by predators. More of the darker coloured variety will survive and reproduce, and are more likely to pass on the genes for that trait to their offspring. The offspring that express that trait will be more likely to survive and reproduce. Over many generations, this will result in a population that has a higher proportion of darker coloured moths.

E.g. 2. Spontaneous mutation of genes from common ancestor W would have produced birds with various beak lengths. Competition for food would have resulted in survival of the fittest. The birds with the longest beaks would have been naturally selected since they are able to get food more easily. These birds reproduce and pass on their favourable allele to offspring while other birds with shorter beaks are outcompeted and die out. This results in long beaked birds becoming the dominant species on the island over time.

9. Mutation by artificial selection (selective breeding)
    a. In artificial selection, those with traits that are desirable to humans are **selected to reproduce.**
    b. They are **more likely to pass on the genes** for that trait to their offspring.
    c. The offspring that have the traits will be **more likely to be selected to reproduce.**
    d. Over many generations, the organism will have **more of the selected trait.**

E.g. 1: Cows that produce more milk are selected for breeding, so they produce more offspring than those that do not. And more likely to pass on the genes for that trait to their offspring. The offspring that produce more milk are also selected for breeding. Over many generations, the cows of that breed become better at producing more milk.

E.g. 2: For antibiotic resistance, populations of bacteria that are resistant to an antibiotic are more likely to survive and reproduce when exposed to antibiotics. They are more likely to pass on the genes for that trait to their offspring. The offspring that have the traits will be more likely to be selected to reproduce. Over many generations, the populations of bacteria will be more antibiotic resistant.

Natural selection	Artificial selection
Selection occurs when natural environmental conditions change	Humans select the varieties of organisms that suit their needs
Varieties are produced by mutations	Varieties are produced by selective breeding

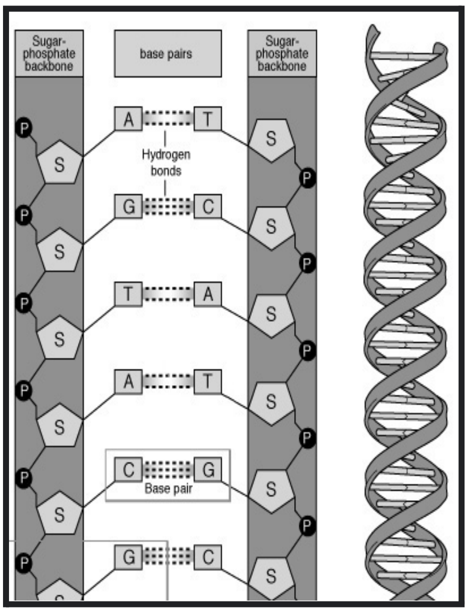
Molecular Genetics

1. DNA
    a. DNA (deoxyribonucleic acid): a molecule that carries the genetic code which is used to synthesise specific polypeptides

    b. Organisation of DNA inside nucleus
        i. Each DNA molecule consists of two strands twisted around each other to form a double helix
        ii. A molecule of DNA is wrapped around proteins to form a single chromatin thread
        iii. During cell division, chromatin threads condense, coil and shorten to form chromosomes

    c. Basic units of DNA
        i. DNA is made of nucleotides
        ii. A nucleotide is made of:
            1. Deoxyribose (sugar) molecule
            2. Phosphate group
            3. Nitrogen-containing base
                a. Cytosine
                b. Thymine
                c. Adenine
                d. Guanine

    d. Rule of (complementary) base pairing:
        i. adenine (A) + thymine (T) /uracil (U) (A & T/U are complementary bases)
        ii. cytosine (C) + guanine (G) (C and G are complementary bases)



Nucleotides are joined together to form polynucleotides.

A DNA molecule is made of two anti-parallel polynucleotide strands. These two strands coil to form a double helix structure.

Complementary bases are joined together by hydrogen bonds.

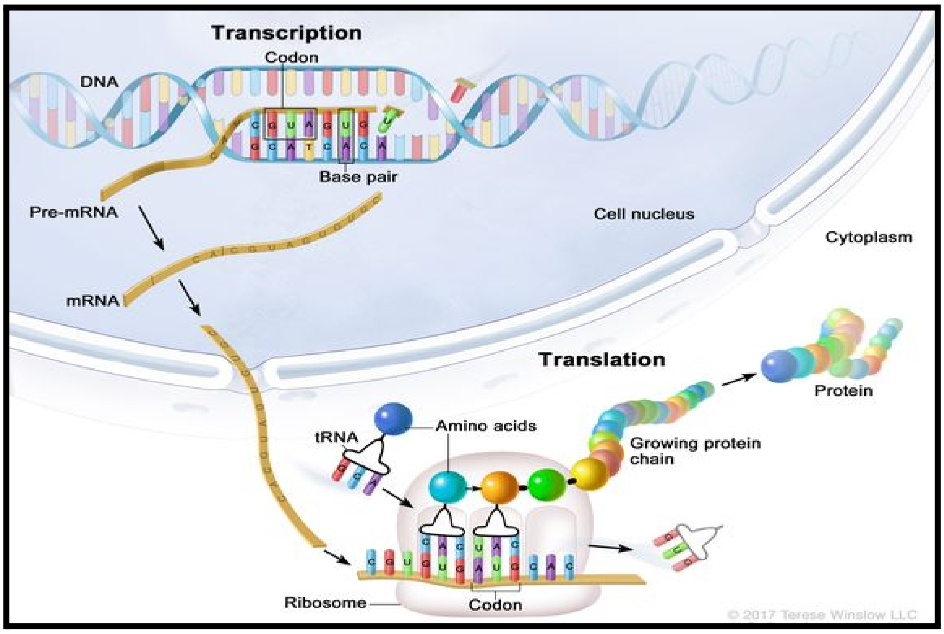
C and G are paired by 3 hydrogen bonds. A and T are paired by 2 hydrogen bonds.

2. Genes
   Gene: A sequence of DNA nucleotides that controls the formation of a single polypeptide, which can be used to make proteins

Transcription	**Translation**
The process by which the DNA template is used to make a single-stranded molecule called messenger RNA (mRNA)	The process by which the sequence of mRNA codons is used to make a polypeptide
Occurs in nucleus	Occurs in cytoplasm

DNA	RNA
Sugar unit is deoxyribose	Sugar unit is ribose
Nitrogen-containing bases are adenine (A), thymine (T), guanine (G) and cytosine (C)	Nitrogen-containing bases are adenine (A), uracil (U), guanine (G) and cytosine (C)
Double-stranded molecule	Single-stranded molecule
Ratio of A:T and C:G is 1:1	No fixed ratio between A and U or G and C
Permanent molecule	Temporary molecule; made only when needed
Cannot move out of nucleus	Can move out of the nucleus
Large insoluble molecule	Small soluble molecule

Process of making polypeptides/proteins



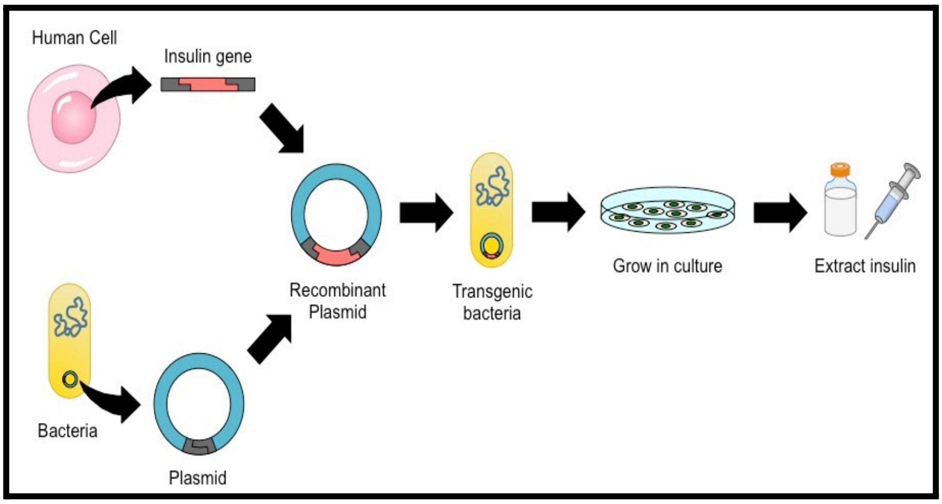
i. Transcription:
   1. The region of DNA carrying the gene unwinds and unzips.

2. The two DNA strands are separated. One of the DNA strands called the template is used to make the mRNA.
3. mRNA leaves the nucleus through the nuclear pore.
4. mRNA attaches to a ribosome.

ii. Translation:
1. Ribosome translates the message in mRNA into a sequence of amino acids joined together to form a polypeptide.
2. The amino acids attached to tRNA bind to the bases on the mRNA.
3. The amino acids are joined together by **peptide bonds**.
4. The chain elongates until it reaches the stop codon.
5. At the end of the mRNA strand, the ribosome detaches from the mRNA, and the polypeptide is released.

3. Genetic engineering

a. Process



1. Isolate the desired gene: Obtain the DNA fragment containing the desired gene in the chromosome by cutting the gene at the restriction site of the gene at its two ends using restriction enzymes (RE) to produce sticky ends
2. Insert the gene into the vector DNA: Restriction enzymes that were used to cut the desired gene are used to cut the vector DNA (e.g. plasmid of bacteria) to produce complementary sticky ends
3. Mix cut out plasmid with cut out gene: Both the plasmid and gene are mixed together with DNA ligase to to allow the gene to bind to the plasmid by complementary base pairing between their sticky ends to form a recombinant plasmid
4. Insert the recombinant plasmids into bacteria: Mix recombinant plasmids with bacteria and apply temporary heat **or** electric shock to open up the pores in the cell membranes of the bacteria for the plasmids to enter
5. Transgenic bacteria formed

b. Transferring the human insulin gene into bacteria
i. Type 1 diabetes is caused by the inability of the islets of Langerhans to produce sufficient insulin
ii. Mass production of transgenic bacteria to produce insulin is carried out using fermenters

iii. Advantages:
1. Does not induce allergic response in the patient as the insulin produced is identical to human insulin
2. Easier and cheaper to produce insulin in large quantities
3. Less risk of contamination by disease-causing microorganisms as compared to insulin obtained from pancreases of animals
4. Ethical concerns of vegetarians or religious groups can be overcome

c. Selective breeding vs genetic engineering

Selective breeding	**Genetic engineering**
Organisms involved must be closely related or of the same species	Genes from an organism can be inserted into non-related species or different species
Defective genes may be transferred along with the healthy genes to the offspring	Selection of genes before transfer reduces the risk of transferring a defective gene to the offspring
Slow process that involves several generations and large amounts of land	Fast process that uses individual cells that reproduce rapidly using a small space
Less efficient; organisms grow more slowly and require more food	More efficient; transgenic organisms grow faster and require less food
Selected organisms with a combination of desired genes are bred with one another	Specific genes are transferred from one organism to another
No vector required	A vector is required to transfer the genes from one organism to another
Enzymes are not required	Specific enzymes are required to cut out and ligate the desired gene to the vector DNA

d. Advantages of genetic engineering

Applications of genetic engineering	**Benefits to society**
Low cost production of medicines	Important drugs such as human insulin become more affordable. More patients have access to them and be treated.
Production of crops that grow in extreme conditions	Farmers are able to grow crops even in unfavourable environmental conditions for cultivating most crops.
Development of pesticide-resistant crops	Use of costly pesticides that damage the environment is reduced.
Development of foods designed to meet specific nutritional goals	Nutritional quality of foods improved.

e. Disadvantages of genetic engineering

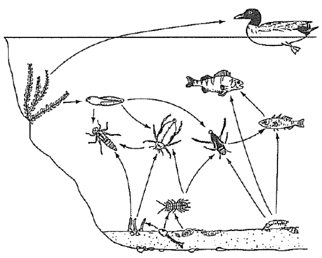
Aspect	Hazards
Environment	1. GM crop plants that produce insect toxins may cause the deaths of insects that feed on them, resulting in a loss of biodiversity. 2. A farmer may choose to grow only the seeds of crops with desirable qualities. However, this reduces the genetic diversity of the population of crops and the crops are less able to survive during environmental changes.
Economic	1. If prices of seeds of GM crop plants are not regulated, poorer farmers may not have the financial capacity to benefit from this technology while richer farmers continue to get richer through the technology. 2. Some biotechnology companies have engineered crop plants such that these plants produce seeds that cannot germinate. Farmers have to buy special seeds from these companies every year. This causes economic burden to poorer societies.
Health	1. New proteins in genetically-modified (GM) food may cause allergies in humans that consume them. 2. GM food may be toxic or cancer-causing since modifying a single gene in plants could result in a change in some metabolic processes within the plant, causing production of toxins not usually found within these plants. 3. Genes that code for antibiotic resistance may be accidentally incorporated into bacteria that cause human diseases.
Social and ethical	1. There are objections to the consumption of animal genes in plants or vice versa. Vegetarians may object to the transfer of animal genes into crop plants. 2. Some people feel that it is morally wrong to exploit animals for medical research since the animals are designed to suffer. 3. Some people may create new combinations of genes to be used in chemical or biological warfare. 4. Genetic engineering may lead to class distinctions. Only individuals with sufficient financial means can afford certain gene technologies.

Ecology

1. Energy flow
    a. Energy transfer is non-cyclic
        i. Light energy from the Sun is absorbed by chlorophyll and converted into chemical energy by producers during photosynthesis, producing and storing glucose
        ii. Glucose is used to synthesise molecules such as starch, fats and cellulose
        iii. Energy from producers is passed from one trophic level to another by feeding
        iv. The flow of energy in an ecosystem is non-cyclic as energy is lost in uneaten parts, dead bodies, faeces and egestion and excretion of consumers

v. Energy released from glucose during respiration is used for various life processes such as muscular contraction, nerve impulse transmission, and anabolic reactions such as protein synthesis
vi. Heat released during respiration is lost to the surroundings and cannot be returned to the producers or the Sun. Only **around** 10% of the energy consumed is passed on to the next trophic level

2. Food chains and food webs
    a. A food chain represents energy transfer in an ecosystem
    b. Each link/position in a food chain is called a trophic level
    c. Hierarchy of trophic levels
        i. First trophic level: Producers
            1. They are USUALLY green plants that produce their own food by photosynthesis and so do not depend on other organisms for their energy needs
        ii. Consumers do not produce their own food, and depend on other organisms for their energy needs
            1. Primary consumers feed on producers
            2. Secondary consumers feed on primary consumers
            3. Tertiary consumers feed on secondary consumers
        iii. Organisms may occupy multiple trophic levels in a food web. They usually only occupy one trophic level in each food chain in a food web.
    d. In food webs, a change in population of any trophic level will affect the trophic levels above or below it. The amount of change on the affected trophic levels is dependent on the availability of other interconnected food chains. For example
        i. If the tadpole population has a drastic decrease due to disease, then there will be fewer tadpoles to feed on the hydrilla, so the hydrilla population would increase.
        ii. This would result in more food (and thus energy) being available to the duck population, so the duck population would eventually increase. (This is a second order change, so we would rarely ask for it. We would NOT ask for a third order change).
        iii. There will be less prey available for the dragonfly nymph, the great diving beetle and the water boatman, so their populations would decrease.
        iv. If there is a decrease in the population of the small fish, the population of the larger fish would decrease, but not by much as it is also able to feed on blood worms.



3. Efficiency of energy transfer
    a. Energy transfer in an ecosystem is inefficient. Only ABOUT 10% of energy in a trophic level is transferred onto the next trophic level. AROUND 90% is lost as heat, used in respiration and lost as waste such as faeces.
        i. There are very few food chains that have more than 4 trophic levels in nature. This is because only ABOUT 10% of energy in a trophic level is transferred onto the next trophic level. AROUND 90% is lost as heat, used in respiration and lost as waste such as faeces. After four trophic levels, very

little energy is available to support the energy needs for another trophic level.

   ii. Humans should eat from lower trophic levels
   Humans usually farm primary consumers for meat.
   Humans should be more vegetarian in order to be more sustainable.
   Only ABOUT 10% of energy in a trophic level is transferred onto the next trophic level. AROUND 90% is lost as heat, used in respiration and lost as waste such as faeces. So if humans eat from a lower trophic level, more energy is available for their energy needs, so less farmland is needed to grow crops to provide for them.

b. Principal energy source for food chains is the sun, NOT producers.
c. Decomposers
   i. They neither feed on producers nor consumers directly.
   ii. Get their energy from waste that is usually written off as waste in a typical food chain
   iii. Sometimes they appear as primary consumers with the waste or dead material in the "producer" position. We do NOT consider the waste as producers, and will avoid talking about the dead matter's position.

4. Ecological Pyramids
   a. Pyramid of Numbers
      i. The width of the bar is proportional to the size of the population.
      ii. Since energy transfer in an ecosystem is inefficient, it GENERALLY takes a larger population of organisms of a lower trophic level to provide for the energy needs of a higher trophic level.
      iii. If a lower trophic level has a narrower bar, it suggests that the smaller population will not be able to sustain the energy needs of the trophic level above it.
      iv. This would result in an unstable ecosystem where the population of organisms above it would decrease eventually.
      v. A pyramid of numbers with a smaller population of a lower trophic level organism CAN be stable if the lower trophic level organism is much larger in size compared to the organisms it is providing the energy for. "The tree is much larger in size compared to the caterpillars, so it is able to provide for the energy needs of a much larger population of caterpillars." *This kind of situation is resolved using pyramids of biomass/energy.*

   b. Pyramid of Biomass
      i. The width of the bar is proportional to the biomass of the population. Eg. If each tree has a biomass of 1000 kg and there are only 5 trees in that population, the biomass of the population is 5000kg.
      ii. Since energy transfer in an ecosystem is inefficient, it GENERALLY takes a larger biomass of organisms of a lower trophic level to provide for the energy needs of a higher trophic level.
      iii. If a lower trophic level has a narrower bar, it suggests that the smaller biomass will not be able to sustain the energy needs of the trophic level above it.
      iv. This would result in an unstable ecosystem where the population of organisms above it would decrease eventually.
      v. A pyramid of biomass with a smaller biomass of a lower trophic level organism CAN be stable if the lower trophic level organism is much faster in

reproduction rate compared to the organisms it is providing the energy for. "The phytoplankton has a very high reproductive rate and is thus able to generate enough biomass to provide for the energy needs of the zooplankton above it." *(Not likely to appear.)*

5. Carbon cycle
    a. During photosynthesis, plants absorb carbon dioxide and use it to synthesise carbohydrates. Some of the carbohydrates are converted to proteins and fats.
    b. Animals obtain carbon compounds by feeding on plants or other animals. Plants and animals respire, releasing carbon dioxide into the atmosphere.
    c. Decomposers break down dead organic matter and release carbon dioxide.
    d. Dead bodies of organisms buried in the Earth for millions of years are subjected to high pressure, gradually forming fossil fuels such as coal, natural gas and oil.
    e. Fossil fuels such as coal are extracted from the ground by mining and undergo combustion in industries, releasing carbon dioxide into the atmosphere.
    f. Carbon sinks are places where carbon is stored indefinitely (*on pause with no time limit. Not destroyed, just not in circulation*).
        i. Forests
            1. Plants in forests absorb carbon dioxide from the atmosphere during photosynthesis, producing carbohydrates. These carbohydrates can be stored in the plants for a long time.
            2. When plants and animals in the forest die, they are sometimes buried deep underground, and not decomposed. These dead organisms undergo fossilisation over millions of years. The carbon in these fossils could be stored underground for a long period of time.
        ii. Oceans
            1. Carbon dioxide dissolves in ocean water to form bicarbonate ions. Bicarbonate ions are absorbed by sea creatures to form shells and skeletons such as corals (shells are mainly calcium carbonate)
            2. Marine organisms, such as phytoplankton, algae and water plants take in carbon dioxide during photosynthesis, producing carbohydrates. These carbohydrates can be stored in the plants for a long time.
            3. When these organisms die, their bodies could sink to the bottom of the ocean and undergo fossilisation for millions of years. The carbon in these fossils can be stored in the seabed for a long period of time. Carbon can also be stored in the shells of shellfish, which accumulates at the bottom of the ocean.

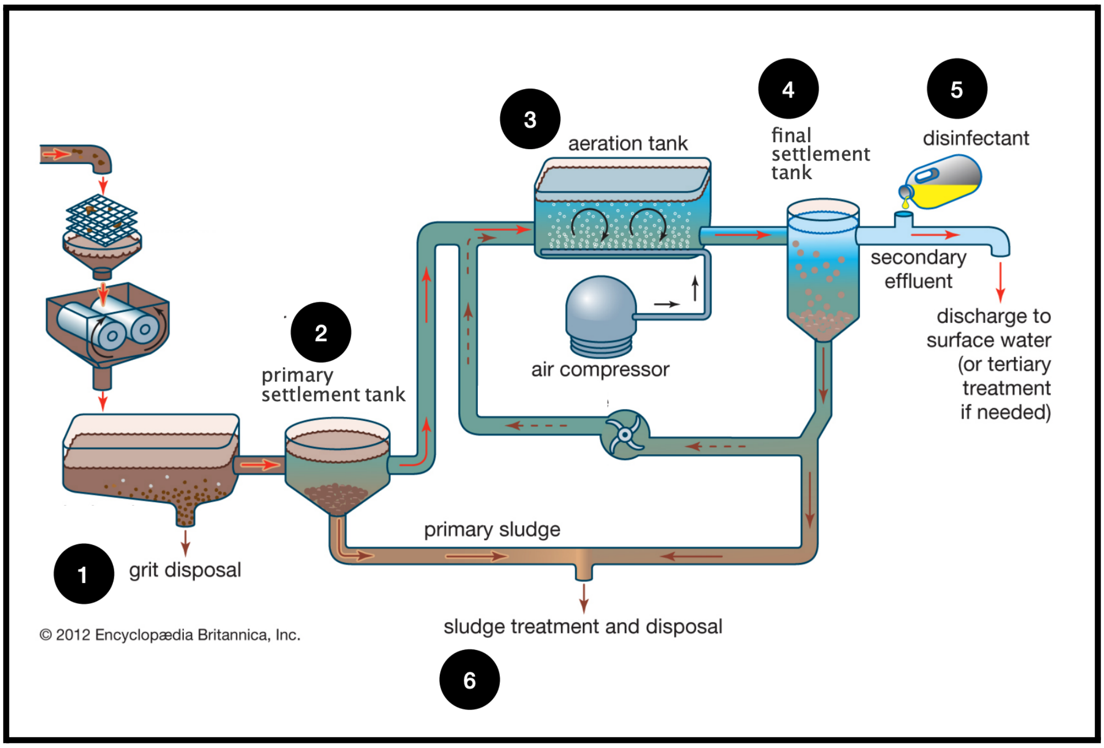
Our Impact on the Ecosystem

1. Effects of Man on the Ecosystem
    a. Water pollution by sewage and by inorganic waste (eutrophication)
        i. Fertilisers that are not absorbed by crops may be washed by rainwater into nearby rivers or lakes.
        ii. Nitrates and phosphates in untreated sewage or fertilisers are used in the synthesis of proteins and nucleic acids. This leads to increased growth and multiplication of algae and floating water plants.

iii. Overgrowth of algae and floating water plants prevent sunlight from reaching submerged plants.
iv. Submerged algae and water plants are unable to receive sufficient light energy for photosynthesis and die. The dead algae and water plants are decomposed by bacteria and fungi.
v. As the bacteria feed on decaying organic matter, they grow and multiply rapidly, using up the dissolved oxygen in the water.
vi. At night, when plants and animals respire only, there can be lack of oxygen for respiration causing animals and plants to suffocate. Eventually the dead plants and animals will also use up more oxygen in the water as they decay, causing further population decline.
vii. Eventually, dilution from other water sources, and the decay of organic matter into simpler or harmless substances restores the water quality, and the ecosystem is able to recover.

b. Bioaccumulation and bioamplification/biomagnification
    i. Pollutants are absorbed by organisms and **cannot be excreted**, so they build up in the **fatty tissues** of the organism. Over time, the **concentration** of these harmful substances **increases**. (Bioaccumulation)
    ii. Each consumer trophic level will consume a much larger biomass from the trophic level below it. The concentration of these harmful substances will therefore increase by a lot up the food chain. (Bioamplification)
    iii. At higher trophic levels, the concentration of these substances can become high enough to cause health problems that cause population decline.

2. Environmental biotechnology: Sewage treatment (water reclamation plants)



a. Outline:
    1. Primary treatment - to settle out solids
    2. Secondary treatment - use of microbial biofilms and biomats to digest organic substances
    3. Tertiary treatment - disinfection by UV, chlorination and ozonation

b. Process
    1. Sewage is passed through **bar screens** to remove large, coarse materials.
    2. Primary treatment:
       The screened liquid is sent to the **primary settlement tank.**
       The liquid flows through the tank very slowly to allow the solid suspensions to settle to the bottom of the tank as **primary sludge**.
       The sludge is removed and fed into an **anaerobic digester**.
       The top liquid from this tank flows into an **aeration tank**.
    3. Secondary treatment:
        a. **Activated sludge process** occurs.
           In the **aeration tank**, the liquid is mixed with aerobic microorganisms.
           Bubbles of compressed air are pumped into the liquid.
           The dissolved oxygen is used by the microorganisms for aerobic respiration.
           The microorganisms absorb and break down organic pollutants in the water into harmless substances.
        b. The treated water, together with the microorganisms, is channelled into the **final settlement tank**.
           In the **final settlement tank**, the microorganisms settle to the bottom of the tank as sludge.
           A portion of this sludge is returned to the **aeration tank** for reuse.
           The **excess** sludge is sent to the **anaerobic digester**.

The clean water at the top of the tank is discharged as effluent into nearby rivers, streams or lakes.

4. Anaerobic digester
   No oxygen is supplied to the anaerobic digester.
   Anaerobic bacteria decompose the sludge, producing **biogas**, mainly methane. The biogas is used as a fuel to generate electricity for the functioning of the reclamation plant.
   The remaining solid material is removed from the tank. It may be used as fertiliser or burnt in an incinerator.
5. Tertiary treatment
   The treated water is disinfected by chlorination, UV and ozonation.

3. Conservation
   a. Reason for conservation of species: To maintain biodiversity
      i. Maintenance of a large gene pool: cross-breeding different varieties of wild plants and animals with favourable genes can improve agricultural produce
      ii. Maintenance of a stable and balanced ecosystems: prevents disruption of natural cycles such as carbon cycles and reduces the effects of global warming
   b. Methods for conservation:
      i. To reduce eutrophication
         1. Control the amount of fertilisers we use in agriculture, and also have proper water management techniques.
         2. Sewage needs to be treated before discharged into rivers (water reclamation plants).
      ii. To reduce overfishing and overharvesting:
         1. Ban the use of drift nets
         2. Limit period of fishing in fishing grounds
         3. Raise endangered species of fish in hatcheries
      iii. To reduce pollution from factories
         1. Ensure that discharges are treated
      iv. To conserve forests
         1. Manage timber production through enforcement of laws that ensure that trees felled for timber are cut down selectively and at a regulated rate (young trees are not felled)
         2. Carry out reforestation
         3. Designate lands as forest reserves