Chapter 1: Cell Structure and Organisation

How can we study parts of cells?

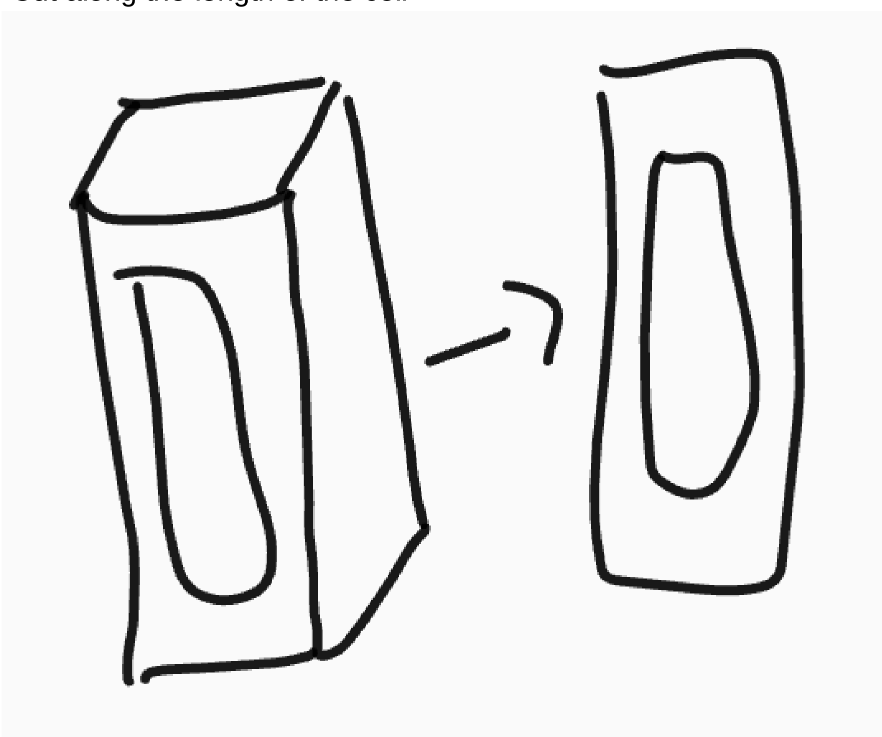
-Most cells are too small to be seen
-Microscopes are thus used to see these cells

Types of microscopes

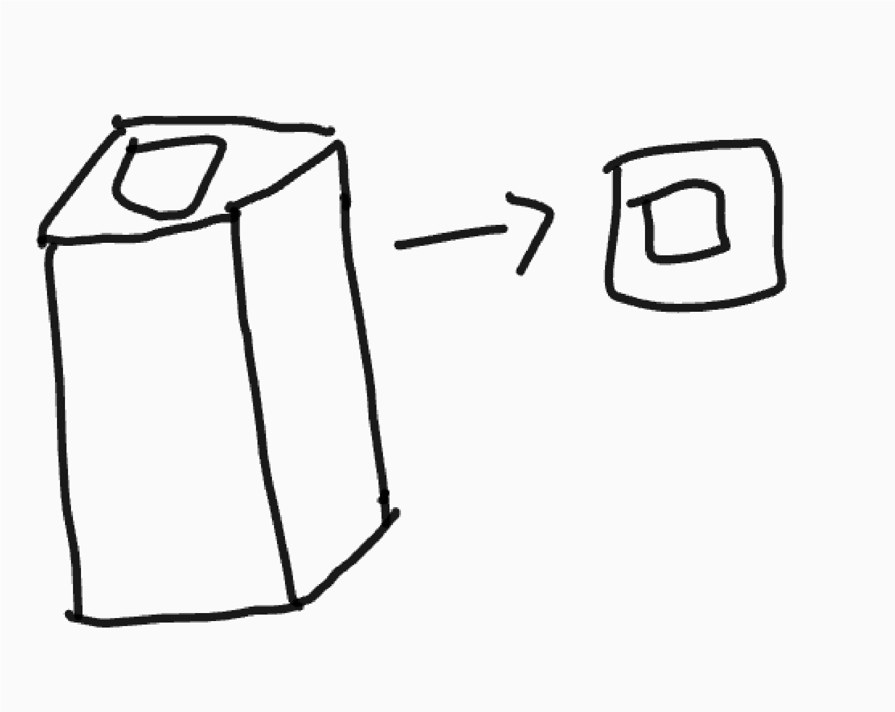
-Light microscopes (1000x)
-Electron microscope (200000x)
-The mitochondria, smooth and rough endoplastic reticulum, ribosomes, golgi apparatus and chromosomes can only be seen under an electron microscope as they are too small

Viewing cells from different perspectives

Longitudinal section (L.S.)
-Cut along the length of the cell



Transverse section (T.S.)
-Cut along the right angles of the cell



What does a cell consist of?

-A cell consists of a mass of living matter called protoplasm
-Protoplasm of a cell is made of of three parts:
-Cell membrane
-Cytoplasm
-Nucleus
-If a cell is dead there is no protoplasm

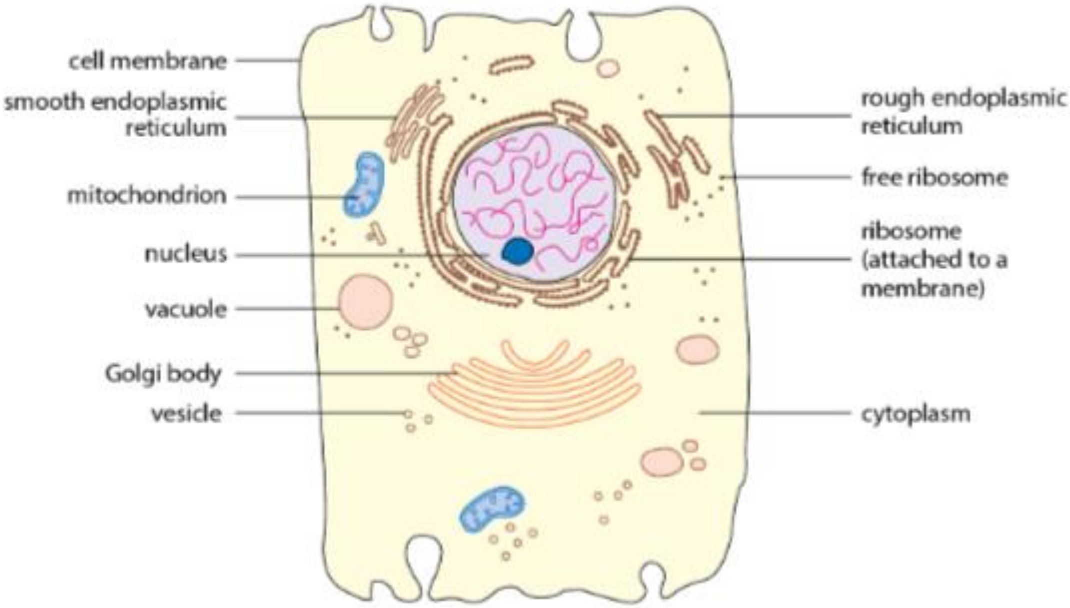
Cell membrane
-The cell membrane surrounds the cytoplasm of a cell
-It is a partially permeable membrane, thus controlling substances moving in and out of the cell

Cell wall
-Plant cells have a cell wall which fully encloses the cell
-It is fully permeable and made of cellulose, allowing all substances to move in and out of the cell
-It protects the cell from injury and gives the plant cell a fixed shape

Cytoplasm
-The cytoplasm is a jelly-like substance which fills the inside of the cell, where most cell activities occur
-It contains many organelles, which perform specific jobs inside the cell

What are the parts of the cytoplasm?

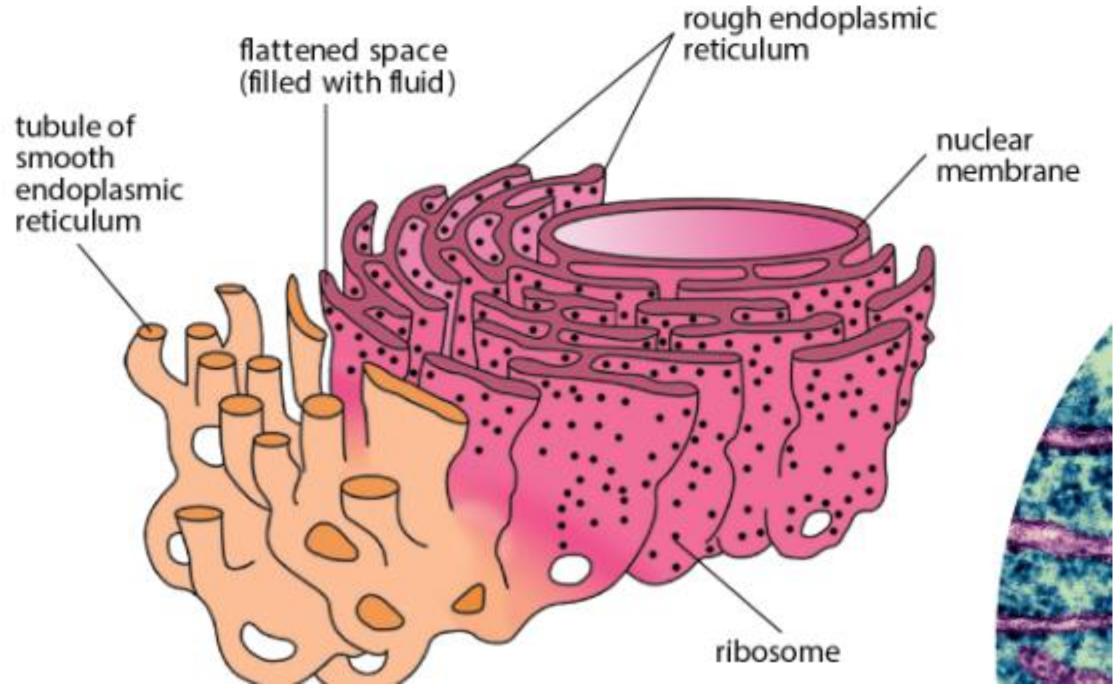
-The cytoplasm contains tiny structures called organelles, which are specialised for a specific function
-e.g. nucleus, endoplasmic reticulum, ribosomes, golgi body, mitochondria, chloroplasts, vacuoles



Nucleus
-The nucleus is surrounded by a membrane called the nuclear membrane
-It contains genetic information in the form of chromosomes
-It controls cell activities such as cell growth and the repair of worn out parts
-It is essential for cell division

Chromosomes
-Chromosomes are long thread like structures found inside the nucleus
-It is made up of proteins and deoxyribonucleic acid (DNA) which stores hereditary information and carries instructions that a cell needs while carrying out its activities
-When the cell is dividing, the chromosomes condense to form thick, rod shaped structures
-A human cell has 46 chromosomes

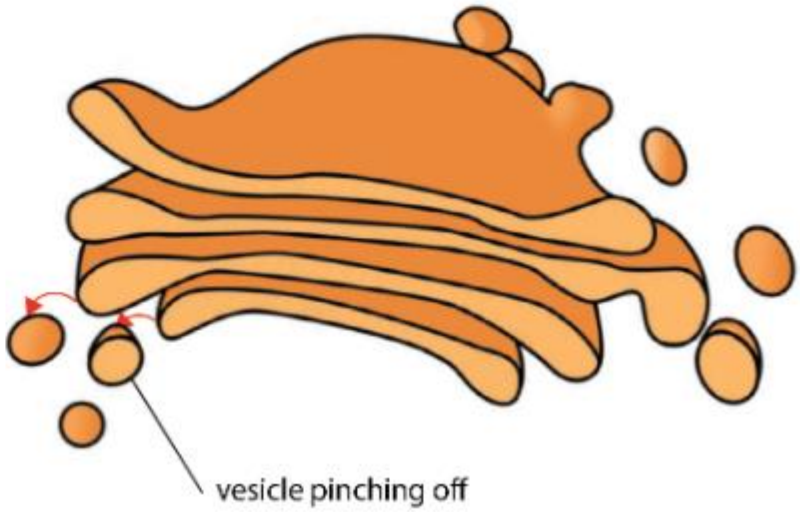
Rough Endoplasmic Reticulum (RER)
-It consists of a network of flattened spaces lined with a membrane
-Its surface appears rough when viewed under an electron microscope as small particles called ribosomes are attached to its outer surface
-The outer surface of the RER is continuous with the nuclear membrane, so it seems to be connected or very near to the nucleus under an electron microscope
-The RER transports polypeptides made by the ribosomes to the golgi body for secretion out of the cell



Ribosomes
-Ribosomes are small round structures which are either attached to the membrane of the RER or lie freely inside the cytoplasm
-They are needed to synthesise polypeptides in the cell
-The ribosomes attached to the RER make polypeptides which are usually transported out of the cell
-The ribosomes in the cytoplasm make polypeptides that are used inside the cytoplasm of the cell

Smooth endoplasmic reticulum (SER)
-The SER does not have ribosomes attached to its membrane and is more tubular than the RER
-It is connected to the RER
-It synthesises substances such as fats and steroids and converts harmful substances to harmless substances through detoxification

Golgi apparatus
-The golgi apparatus, also known as the golgi body, is shaped like a disc and contains a stack of flattened spaces surrounded by membranes
-Vesicles can be seen fusing with one side of the golgi apparatus and pinching off from the opposite side
-It chemically modifies substances made by the RER and the SER and stores and packages these substances in vesicles for secretion out of the cell



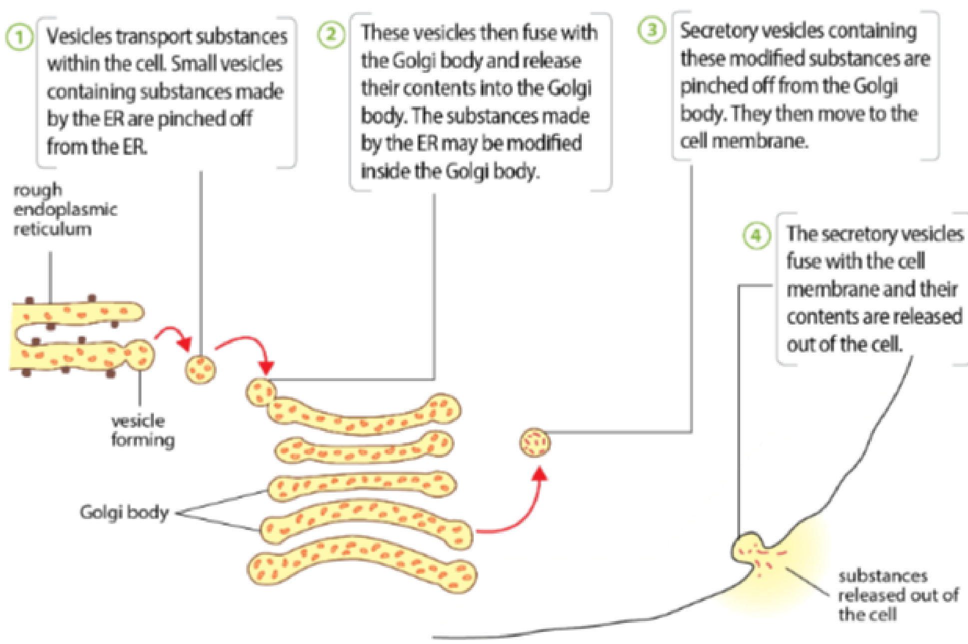


Figure 1.13 How substances made by the endoplasmic reticulum enter the Golgi body and are finally secreted out of the cell

Mitochondria (singular: mitochondrion)

-It is a small oval or sausage shaped organelle where aerobic respiration occurs

-Food substances are broken down to release energy, which may be used by the cell to perform cell activities such as growth and reproduction

-aerobic respiration equation: glucose ($C_6H_{12}O_6$) + oxygen ($6O_2$) = carbon dioxide ($6CO_2$) + water ($6H_2O$) + energy

Chloroplasts

-Chloroplasts are oval structures found in plant cells which contain a green pigment called chlorophyll

-Chlorophyll is essential for photosynthesis, the process by which plants make food

-Photosynthesis equation: carbon dioxide ($6CO_2$) + water ($6H_2O$) = glucose ($C_6H_{12}O_6$) + oxygen ($6O_2$)

Vacuole
-The vacuole is a fluid filled space enclosed by a partially permeable membrane
-The vacuole stores substances within the cell
-Plant cells contain a large, central vacuole which contains a liquid called cell sap
-Cell sap contains dissolved substances such as sugars, mineral salts and amino acids
-Animal cells contain small, numerous vacuoles which contain food and water substances
-These vacuoles usually exist temporarily

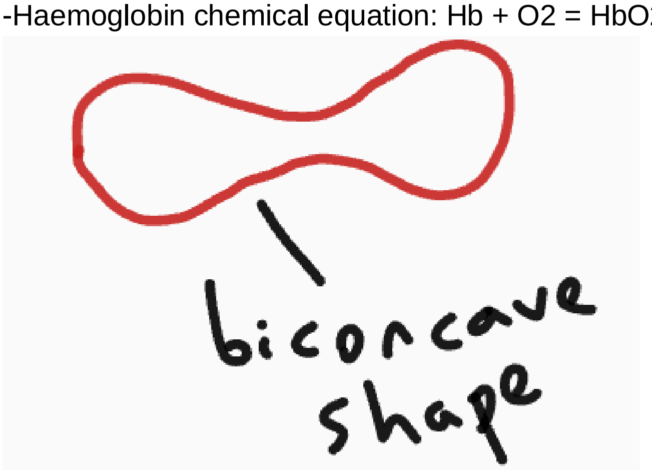
Differences between plant and animal cells

Animal cell	Plant cell
No cell wall	Has a cell wall
Many small vacuoles	One large central vacuole
No chloroplasts	Has chloroplasts

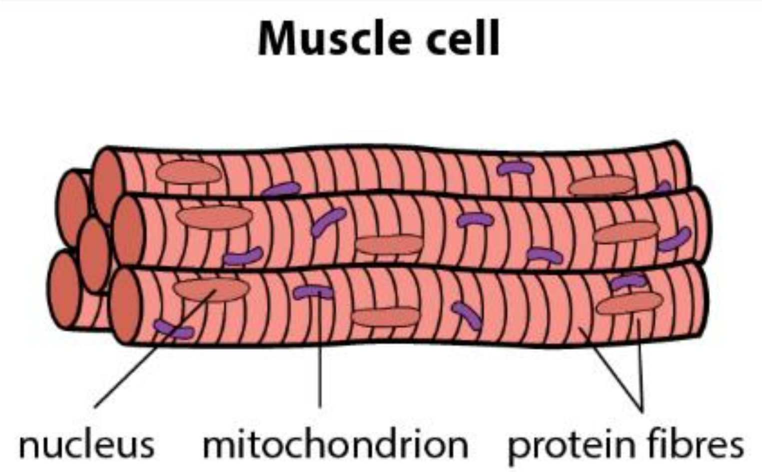
How are cells adapted to their functions?

-Some cells develop or lose certain structures to enable them to carry out specific functions
-This process of development is called differentiation

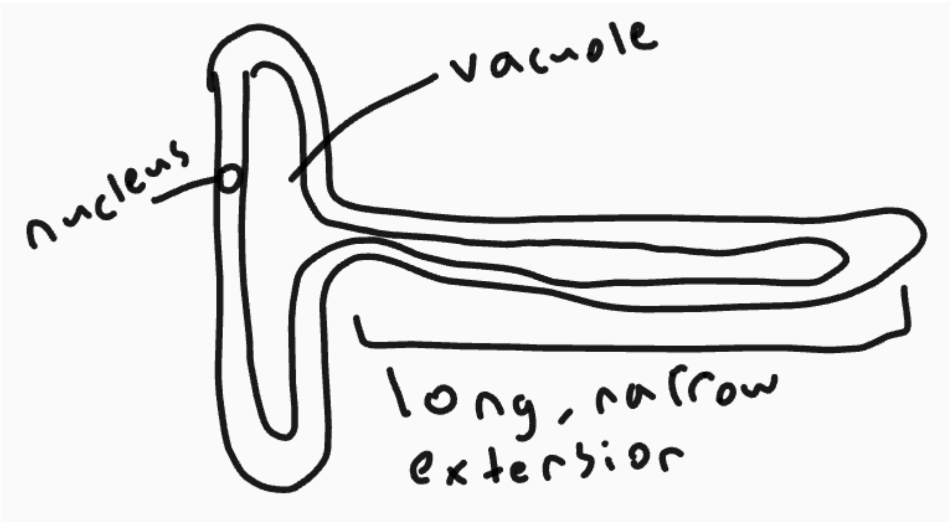
Red blood cell
-The red blood cell contains haemoglobin, which binds reversibly to oxygen and transports it around the body
-It has a biconcave shape, increasing the surface area to volume ratio so that oxygen can diffuse in and out at a higher rate
-It lacks a nucleus, allowing it to store more haemoglobin to transport more oxygen
-It is flexible to allow it to squeeze through capillaries easily
-Haemoglobin chemical equation: $Hb + O_2 = HbO_2$ (lungs) $HbO_2 = Hb + O_2$ (cells)



Muscle cell
-The muscle cell is elongated and cylindrical in shape, containing many nuclei and mitochondria
-It has many mitochondria to provide energy for the contraction of the muscle cell
-It has contractile protein fibers to allow for contraction and relaxation of the cell to bring about movement
-It has many nuclei to allow for cell division



Root hair cell
-The root hair cell has a long and narrow root hair to increase the surface area to volume ratio to absorb water and mineral salts at a higher rate
-It has a large amount of mitochondria to provide energy for the active transport of mineral sats



Chapter 2: Movement of Substances

Diffusion

-Diffusion is the net movement of particles from a region of higher concentration to a region of lower concentration without the need for energy

Concentration gradient

-A concentration gradient is the difference in concentration between two regions
-If the concentration gradient is steeper, the rate of diffusion is faster
-Two substances must have a concentration gradient in order for diffusion to occur

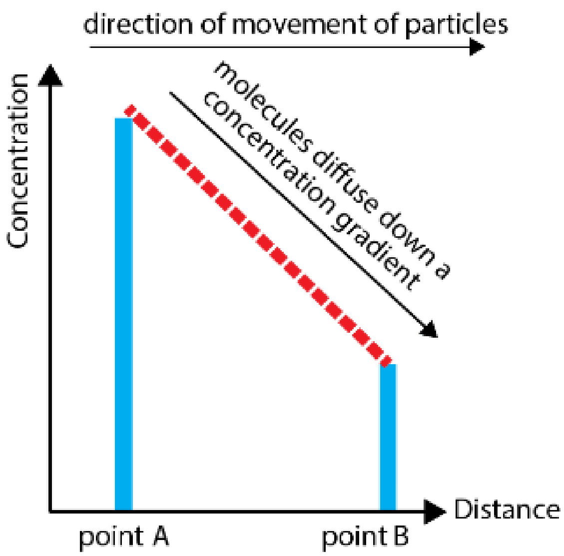


Figure 2.2 Graphical representation of diffusion

Diffusion across a membrane

-Diffusion can occur across a membrane as long as both molecules can pass through the membrane

Factors that affect the rate of diffusion

Concentration gradient
-If the concentration gradient is steeper, the rate of diffusion is faster

Diffusion distance
-Diffusion distance is the distance through which a substance diffuses
-The shorter the diffusion distance, the less time needed for the substance to travel, and thus the higher the rate of diffusion

Surface area to volume ratio

-If two cells have the same volume, the cell with the larger surface area to volume ratio will have the higher rate of diffusion

Temperature
-If the substances have a higher temperature, they will have higher kinetic energy, and thus a higher rate of collisions and a higher rate of diffusion

Osmosis

-Osmosis is the net movement of water molecules from a region of higher water potential to a region of lower water potential through a partially permeable membrane without the need for energy
-It only occurs with liquid water molecules

Partially permeable membrane

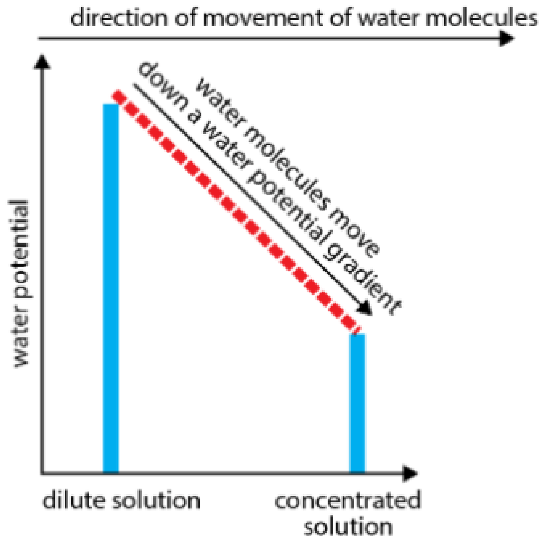
-A partially permeable membrane allows some substances to pass through while other cannot
-The substances permeate through particle size
-Osmosis requires a partially permeable membrane while diffusion does not
-Diffusion can still occur through a partially permeable membrane, if both substances can pass through the membrane
-e.g. visking tubing, cell membrane

Solute concentration

-Solute concentration is the number of solute molecules per unit volume

Water potential gradient

-Water potential is the amount of water in a mixture
-If a mixture is dilute, it has a high water potential
-If a mixture is concentrated, it has a low water potential
-A water potential gradient is the difference in water potential between two regions
-If the water potential gradient is steeper, the rate of osmosis is faster
-Two substances must have a water potential gradient in order for osmosis to occur
-Osmosis occurs with a water potential gradient while diffusion occurs with a concentration gradient



Factors that affect the rate of osmosis

Water potential gradient
-If the water potential gradient is steeper, the rate of osmosis is faster

Distance that water molecules have to move
-The shorter the distance that water molecules have to move, the less time needed for the molecules to travel, and thus the higher the rate of osmosis

Surface area to volume ratio
-If two cells have the same volume, the cell with the larger surface area to volume ratio will have the higher rate of osmosis

Temperature
-If the water has a higher temperature, it will have higher kinetic energy, and thus a higher rate of collisions and a higher rate of osmosis

Explaining the process of diffusion / osmosis

1. Contrast region of higher concentration / water potential and region of lower concentration / water potential
2. Net movement of molecules
3. Process
4. Direction of movement of molecules
5. End result

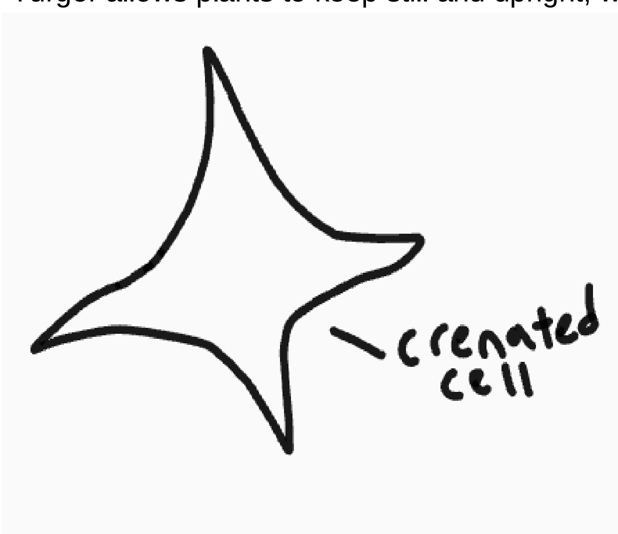
How does osmosis affect living organisms?

Higher water potential

-A plant cell with a higher water potential on the outside of the cell will expand or swell due to water entering the cell through osmosis, making it turgid as the vacuole expands and pushes against the cytoplasm
-The turgidity of the cell is called turgor, and the pressure exerted on the cell wall is called turgor pressure
-Turgor allows plants to keep still and upright, while a lack of turgidity will cause plants to wilt
-An animal cell will also expand or swell, but may burst due to the lack of a cell wall
-In the case of red blood cells, the process of bursting is called haemolyzing (base form: haemolyze)

Same water potential
-The cells remain the same as there is no net movement of water molecules in or out the cell

Lower water potential
-A plant cell with a lower water potential on the outside of the cell will have its cell membrane and cytoplasm shrink inwards as the vacuole shrinks in size, which is called plasmolysis, as water leaves the cell through osmosis
-The cell is said to be plasmolysed, and is flaccid or limp
-An entire tissue is said to be flaccid instead of plasmolyzed
-The cell wall does not change in size as it is inelastic
-An animal cell will shrink and have spikes appear on its surface through a process called crenation, before dying from dehydration in a solution with a lower water potential
-The cell is said to be crenated
-Turgor allows plants to keep still and upright, while a lack of turgidity will cause plants to wilt



What is active transport?

-Active transport is the process in which energy is used to move particles of a substance against its concentration gradient, from a region of lower to higher concentration across a partially permeable membrane

-It occurs when the microvilli of the human small intestine takes up glucose, and when the root hair cells take in mineral salts

Chapter 3: Biological Molecules

Types of nutrients

-The three organic nutrients are carbohydrates, fats and proteins
-Organic nutrients contain carbon
-Inorganic nutrients include water

Why do we need water?

-Water is an essential component of body tissues
-70% of our body is made up of water by weight
-It is a solvent in which chemical reactions take place
-It is essential for photosynthesis
-Keeps cells turgid and firm
-Helps in the transport of mineral salts in plants and water dissolves mineral salts
-Regulates body temperature due to its high specific heat capacity
-Helps to transport dissolved substances across the body

Carbohydrates

-Carbohydrates are organic molecules made up of carbon, hydrogen and oxygen
-It has the general formula of $C_nH_{2m}O_m$
-It can be classified as sugars and complex carbohydrates
-It provides energy for cell activities
-It forms supporting structures
-It is used for conversion into other organic compounds
-It can be used to form nucleic acid (DNA)
-It is used to synthesise lubricants
-It is used to synthesise nectar in flowers
-It can be found in rice, bread, potatoes and noodles

Sugars

Simple sugars
-A simple sugar, or monosaccharide, is the basic unit of carbohydrate
-It can pass through cell membranes and be absorbed into cells
-The two simple sugars are glucose and fructose, which are both $C_6H_{12}O_6$, but arranged differently
-Glucose is found in both plants and animals, while fructose is common in plants but rare in animals

Double sugars
-A double sugar, or disaccharide, is formed when two simple sugars are formed
-Common double sugars are lactose (milk sugar), maltose (malt sugar) and sucrose (cane sugar)

-Maltose is made up of two glucose molecules, while sucrose is made up of one fructose and one glucose molecule and lactose is made up of one glucose and one galactose molecule
-Double sugars can be split up into simple sugars using enzymes

Test for reducing sugar

-Glucose, fructose and maltose are known as reducing sugars
-Benedict's solution (blue) can be used to test for reducing sugars
-2 cm^3 of a food sample is placed in a test tube
-2 cm^3 of benedict's solution is then added
-The mixture is then shaken and heated in a boiling water bath for 5 minutes
-If a brick-red precipitate is formed, reducing sugar is present
-If a green precipitate is formed, traces of reducing sugar are present
-If an orange precipitate is formed, moderate amounts of reducing sugar is present

Complex carbohydrates

-A complex carbohydrate, or polysaccharide, is formed by many similar molecules to form a larger molecule
-Starch, cellulose and glycogen are common complex carbohydrates

Starch

-Starch is made up of many glucose molecules joined together
-It is a storage form of carbohydrates in plants
-It can be digested to glucose to provide energy
-It is broken down by amylase into maltose, then into glucose by maltase
-It is stored in storage organs of plants, such as potato tubers and tapioca

Glycogen

-Glycogen is a branched molecule made up of many glucose molecules joined together
-It is a storage of carbohydrates in mammals
-It is digested to glucose when needed to provide energy for cell activities
-It is stored in the liver and muscles of mammals

Cellulose

-Cellulose is made up of many glucose molecules joined together
-They are joined differently as compared to starch
-The cellulose cell wall protects plant cells from bursting or damage
-It cannot be digested by our intestines and serves as dietary fibre to prevent constipation
-It is present in the cell walls of plants

Stores of glucose

-Starch and glycogen are used as stores of glucose in plants and animals respectively
-They are both insoluble in water, so they do not change the water potential in the cells
-They are large molecules that cannot diffuse through cell membranes, so they cannot be lost from the cell
-They can be easily broken down into glucose when needed
-They have compact molecular shapes, so they occupy less space than all individual glucose molecules that make up a glycogen or starch molecule

Test for starch

-Iodine solution (brown) can be used to test for starch
-Add a few drops of iodine solution to a food sample
-If the solution turns blue-black, starch is present

Fats

-Fats are organic molecules made up of carbon, hydrogen and oxygen
-It contains less oxygen in proportion to the hydrogen and has no general formula
-The base unit of fat is one glycerol molecule and 3 fatty acid chains
-It is digested into glycerol and fatty acids by lipase
-They are also known as lipids
-They are a store of energy
-It acts as an insulating material to prevent excessive heat loss
-It is a solvent for fat soluble vitamins and some hormones
-It forms the main part of the cell membrane
-It helps reduce water loss from the skin surface
-It can be found in nuts, oil, butter and eggs

Test for fats

-2 cm^3 of food sample is placed in a test tube
-2 cm^3 of ethanol is then added into the test tube
-The mixture is then shaken and 2 cm^3 of water is added
-If a white emulsion is formed, fat is present

Proteins

-Proteins are organic molecules made up of carbon, hydrogen, oxygen, nitrogen and sometimes contains sulfur
-The base unit of protein is the amino acid
-Amino acids are made up of an amino group (-NH2), an acid group (-COOH) and a side chain (denoted by R, sometimes containing sulfur)
-Peptide bonds then link up amino acids to form a polypeptide

-Two or more polypeptide molecules are then folded into a 3D molecule, called a protein, in the rough endoplastic reticulum
-The sequence of amino acids in a polypeptide affects the structure of the protein
-This affects the function of the protein
-It synthesises new protoplasm for growth and repair of worn out cells
-It synthesises all enzymes and some hormones
-It synthesises antibodies
-It can be found in eggs, milk, meat and cheese

Test for proteins

-The biuret solution (blue) can be used to test for proteins
-2 cm^3 of a food sample is placed in a test tube
-2 cm^3 of biuret solution is then added into the test tube before being shaken
-If the solution turns violet, proteins are present

Chapter 4: Enzymes

What are catalysts and enzymes?

-A catalyst is a substance which speeds up chemical reactions while being chemically unchanged at the end of the reaction
-Catalysts may not be made out of proteins
-Enzymes are proteins that function as biological catalysts
-Enzymes are always made out of proteins
-They catalyse or speed up the rate of chemical reactions
-They remain chemically unchanged at the end of the reaction
-The active site of the enzyme is complementary to the substrate (not the same shape)
-In the lock and key hypothesis, the enzyme is the lock and the substrate is the key

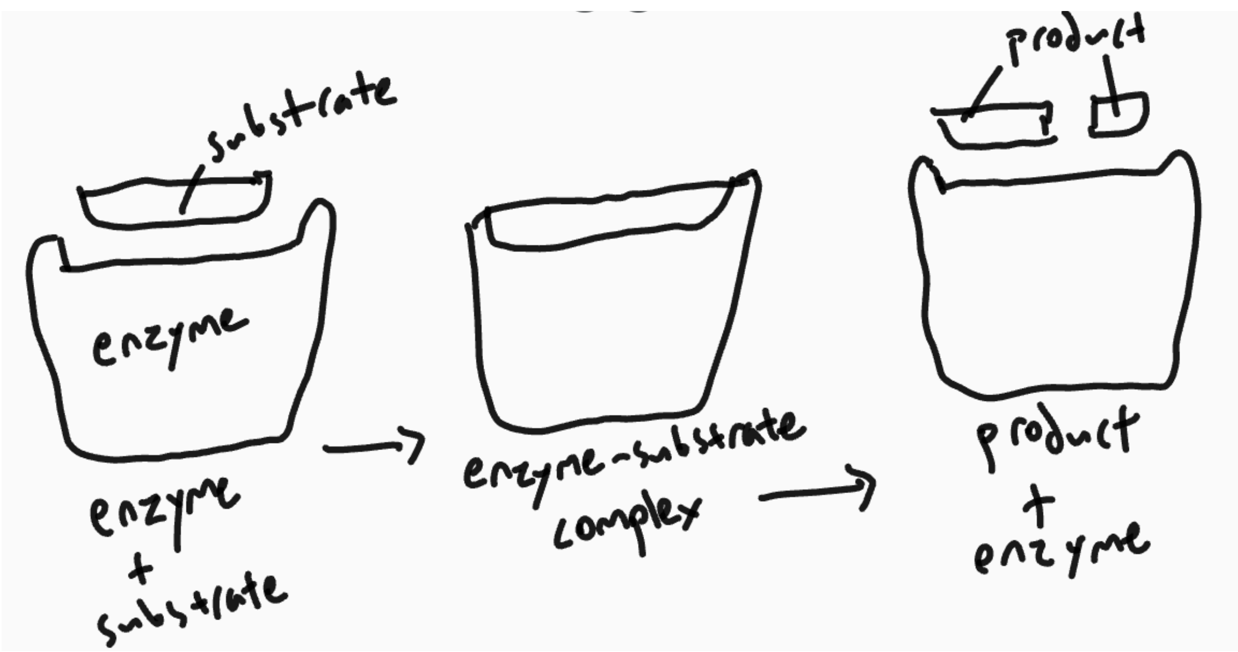
Activation energy

-Activation energy is the minimum energy needed to start a chemical reaction
-Enzymes lower the activation energy required for the chemical reaction to start

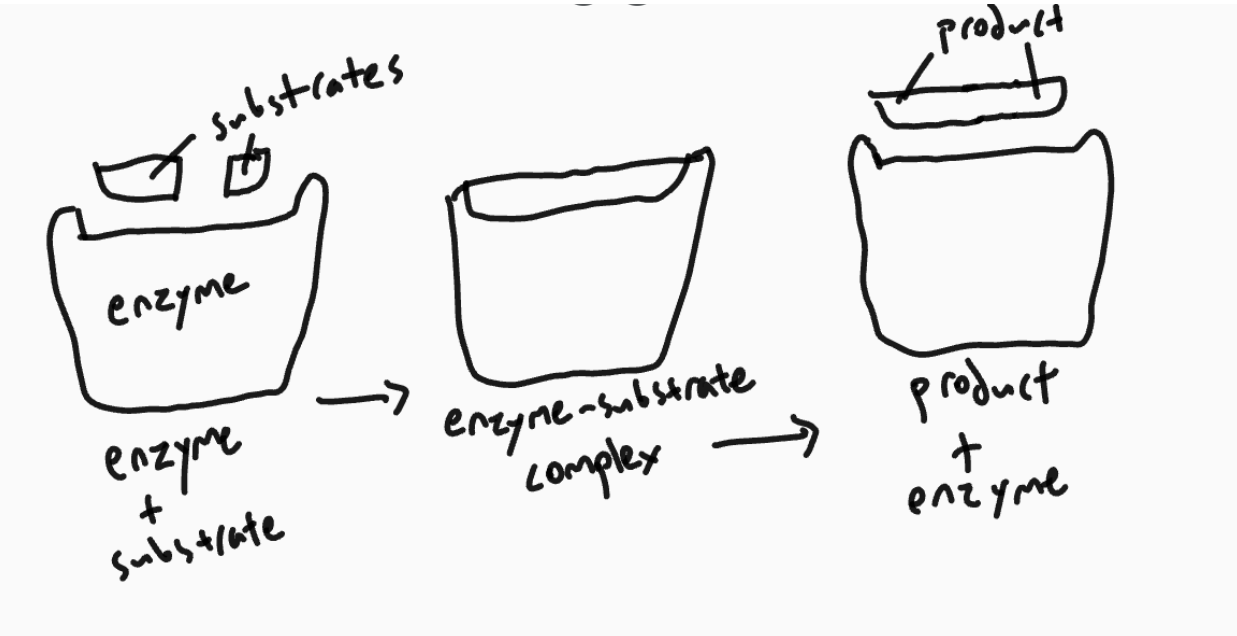
What reactions do enzymes catalyse?

-Reactions that build up complex substances
-Reactions that break down complex substances
Example of an enzyme catalysed catabolic reaction

Example of enzyme catalysed reaction that breaks down complex substances



Example of enzyme catalysed reaction that builds up complex substances



How enzymes are affected by temperature

-At low temperature, enzyme activity is low as the kinetic energy of the molecules is low
-Chances of effective collision between enzymes and substrate molecules is very low
-As the temperature increases, enzyme activity increases
-The temperature increase will increase the kinetic energy of the enzyme and substrate molecules
-This will increase the rate of effective collisions, which will increase the rate of enzyme substrate complex formation
-Enzyme activity is fastest at optimum temperature
-As temperature increases above the optimum temperature, enzyme starts to denature
-The substrate can no longer fit into the active site and is no longer complementary to the shape of the active site
-Rate of reaction decreases rapidly
-The graph of rate of reaction against temperature is asymmetrical about the optimum temperature
-The kinetic energy of the enzyme and substrate molecules is highest at the end of the graph

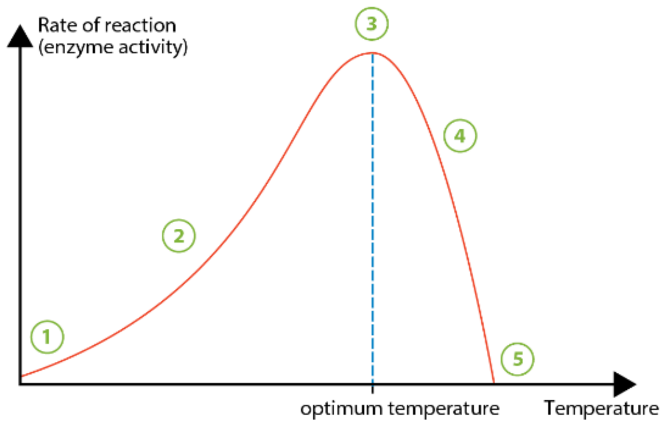


Figure 4.10 Effect of temperature on the rate of enzyme reaction

Denaturation

-Only affects things that are made of proteins
-Enzymes denature upon exposure to temperature above its optimum temperature
-This changes the enzymes' 3D structure, making the active side no longer complementary to the active site
-Enzymes do not denature at temperatures lower than the optimum temperature

How enzymes are affected by pH

-Enzymes are affected by the pH of the solutions in which they act
-Some enzymes work better in acidic solutions (low pH), while others work better in alkaline solutions (high pH)
-When enzymes are placed in pH conditions which vary from their optimum pH, they start to denature

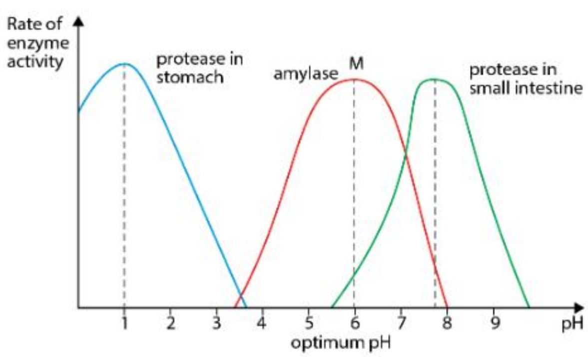


Figure 4.13 Effect of pH on the rate of reactions catalysed by different enzymes

Chapter 5: Nutrition in Humans

What is nutrition?

-Nutrition is the process by which organisms obtain food and energy for growth, repair and maintenance of the body
-In humans, nutrition consists of ingestion, digestion, absorption, assimilation and egestion

Ingestion

-Food is taken into the body
-It takes place in the mouth
-It is also known as feeding

Digestion

-Large food molecules are broken down into smaller, soluble molecules that can be absorbed into the body cells
-It takes place in the mouth, stomach and small intestine

Absorption

-Nutrients move from the small intestine into the bloodstream
-It takes place in the small intestine and large intestine
-The majority of absorption takes place in the small intestine, including water and mineral salts as only excess water and mineral salts is absorbed in the large intestine

Assimilation

-Nutrients are used by cells to provide energy to make new protoplasm for growth
-It takes place in the liver

Egestion

-Undigested matter is removed from the body
-Excretion is the removal of waste materials from the body while egestion is the removal of undigested matter
-It takes place in the anus

The human digestive system

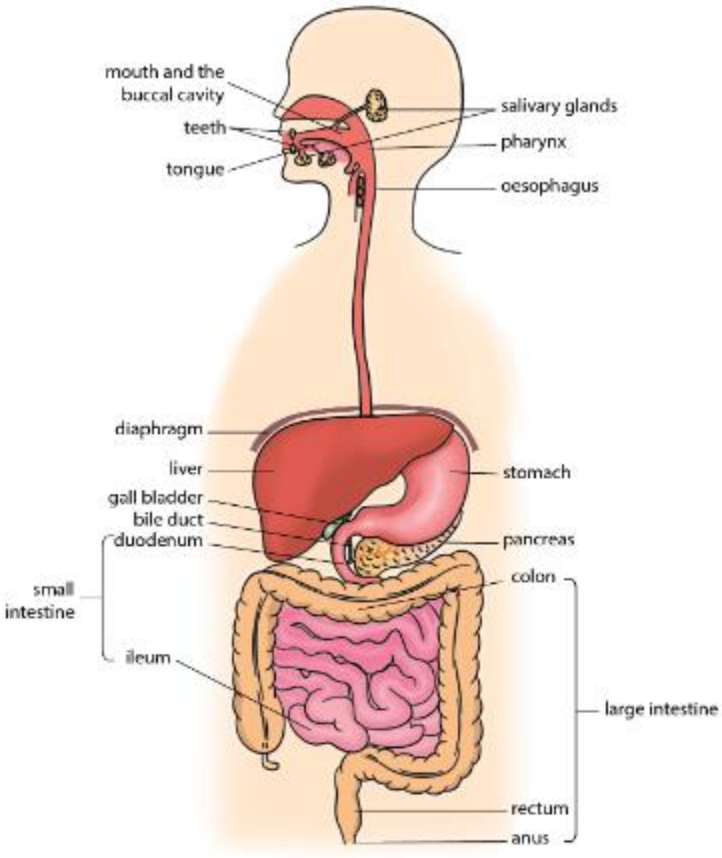


Figure 5.2 The human digestive system

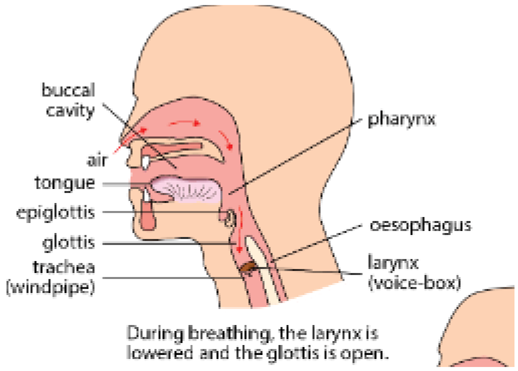
-The human digestive system consists of the alimentary canal or gut and it's accessory organs
-The mouth, oesophagus, stomach, small intestine (duodenum and ileum), large intestine (colon, rectum and anus) are part of the alimentary canal
-The salivary glands, liver, gall bladder and pancreas are the accessory organs of the alimentary canal
-Food comes into direct contact with the organs of the alimentary canal, while food does not come into direct contact with the accessory organs and instead produce and secrete juices which may contain enzymes for the breakdown of food

The mouth and the buccal cavity

-The mouth is made up of the teeth, salivary glands and the tongue, leading into the buccal cavity
-The teeth break up large pieces of food into smaller pieces which increases the surface area of the food for enzymes to act more efficiently
-The salivary glands secrete saliva into the mouth
-The tongue mixes food with saliva and moves the food to the back of the mouth during swallowing

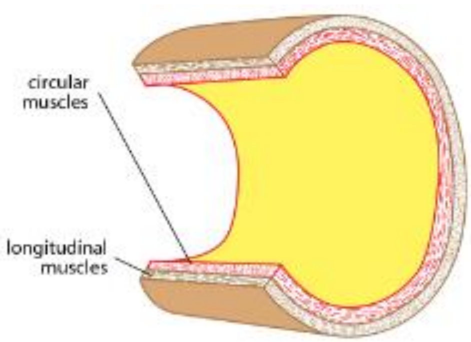
The pharynx

-The pharynx connects the buccal cavity to the oesophagus, larynx (voicebox) and trachea (windpipe)
-The glottis is a slit located at the larynx
-Both food and air pass through the pharynx when they enter the body
-Air passes through the trachea, while food passes through the oesophagus
-The epligottis closes over the glottis to prevent food from reaching the larynx and trachea when swallowing
-People tend to choke when they talk while swallowing as the epliglottis cannot fully close



The oesophagus

-The oesophagus or gullet is a narrow, muscular tube
-It passes through the thorax (chest) and diaphragm
-It connects the mouth to the stomach
-It consists of a layer of longitudinal muscles and a layer of circular muscles
-The longitudinal muscles are on the outer side of the gut wall while circular muscles are on the inner sides of the gut wall
-They are present along the gut from the oesophagus to the rectum



Peristalsis

-Peristalsis refers to the rhythmic, wave like muscular contractions in the wall of the alimentary canal
-It enables food to be mixed with digestive juices and helps to push or propel the food along the gut

-When the circular muscles contract, they constrict the lumen (volume inside of the gut wall)
-When the longitudinal muscles contract, they shorten and widen the lumen
-These muscles are antagonistic, so when one muscle contracts, the other relaxes
-When the circular muscles contract, the longitudinal muscles relax, thus the gut becomes narrower and longer (constricts) and the food is squeezed or pushed forward
-When the longitudinal muscles contract, the circular muscles relax, thus the gut becomes wider and shorter (dilates), allowing food to enter the lumen

The stomach

-The stomach lies beneath the diaphragm, to the left side of the abdomen and is partly covered by the liver
-It has numerous pits and gastric glands which secrete gastric juice which aids in digestion
-It has a pH of 2

The small intestine

-The small intestine consists of the u shaped duodenum and the coiled ileum and in humans, it is about 6 metres long
-It carries out most of the digestive process
-The lining of the small intestine contains glands which secrete digestive enzymes
-These enzymes along with enzymes from the pancreas, food is digested
-Water and nutrients from food is then absorbed into the bloodstream
-It has a pH of 8

The large intestine

-The large intestine is shorter but broader than the small intestine
-The small intestine opens into the large intestine on the right side of the abdominal cavity
-The large intestine is about 1.5 metres long and consists of the colon, rectum and anus
-Faeces are stored temporarily in the rectum and expelled through the anus when the rectum contracts
-The colon absorbs the remaining water and mineral salts not absorbed by the small intestine in the undigested food

The liver

-It is the largest gland in the body, located below the diaphragm
-Three blood vessels are attached to the lower surface of the liver; the hepatic portal vein, the hepatic vein and the hepatic artery
-Liver cells produce and secrete bile, which contains bile salts helping in the emulsification of fats

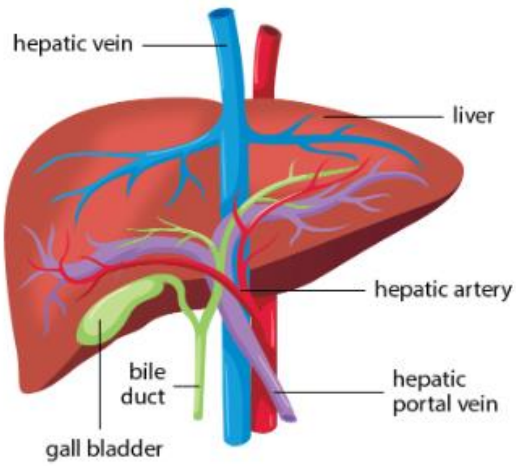


Figure 5.7 Liver and its blood vessels

The gall bladder

-The gall bladder stores bile, before releasing it into the duodenum via the bile duct
-When the gall bladder contracts, bile flows into the duodenum

The pancreas

-It is connected to the duodenum by the pancreatic duct
-The bile duct joins the pancreatic duct before the pancreatic duct opens into the duodenum
-It produces pancreatic juice, which contains digestive enzymes such as amylase, lipase and protease
-It also secretes hormones such as insulin and glucagon, which play an important role in the control of blood sugar levels in the body

What is digestion?

-Digestion is the process whereby large food molecules are broken down into smaller, soluble molecules which can be absorbed into the body cells
-It consists of two types, chemical and physical digestion

Physical digestion

-Physical digestion involves the mechanical breakdown of large food molecules into smaller food molecules
-This increases the surface area to volume ratio of the food molecules, speeding up chemical digestion by enzymes
-Food being chewed, stomach churning and emulsification of fats are all examples of physical digestion

Chemical digestion

-Chemical digestion involve the breaking down of large, complex and insoluble food molecules into smaller, simpler and soluble food molecules using enzymes to digest or hydrolyse the food molecules
-Hydrolysis is the usage of water to break down substances, with digestion being an example
-These molecules can then be absorbed into the bloodstream and then into the body cells
-When explaining chemical digestion, the substrate, enzyme and product must be stated clearly
-For example, starch is digested by amylase into maltose

Digestion in the mouth

-Salivary glands are stimulated to secrete saliva
-Saliva mixes with food and softens it
-The salivary amylase digests starch into maltose
-The optimum pH of salivary amylase is 7
-The food is also broken down into smaller pieces through chewing, increasing the surface area to volume ratio for salivary amylase to work on
-The food is then rolled into small round masses called boli
-The boli are then swallowed and passed down the oesophagus via the pharynx

Digestion in the stomach

-Gastric glands are stimulated to secrete gastric juice
-Peristalsis churns and breaks up the food and mixes the food with gastric juice
-Gastric juice contains hydrochloric acid, mucus and protease
-Hydrochloric acid stops the action of salivary amylase by denaturing it, provides a low pH environment of 2 in the stomach for protease to digest proteins and kills microorganisms in food
-The protease then digests proteins into polypeptides
-The food remains in the stomach for 3-4 hours, becoming a partially digested substance called chyme
-The chyme then passes into the duodenum in small amounts

Digestion in the small intestine

-As chyme enters the duodenum, it stimulates the pancreas to secrete pancreatic juice
-The pancreatic juice passes to the duodenum via the pancreatic duct
-Pancreatic juice contains pancreatic amylase, pancreatic lipase and pancreatic protease
-The gall bladder then releases bile into the duodenum via the bile duct
-Bile does not contain enzymes, and instead speeds up the digestion of fats by breaking up large fat molecules into smaller fat molecules through emulsification
-The small intestine also produces maltase, intestinal protease and intestinal lipase
-The acidic chyme from the stomach is neutralised by the alkaline fluids from the pancreas, gall bladder and small intestine, thus achieving a pH of 8, which is suitable for digestion in the small intestine

Digestion of carbohydrates

-Carbohydrates include starch, sucrose and cellulose
-Carbohydrates are digested by carbohydrases such as amylase and maltase
-Starch is digested into maltose by salivary amylase in the mouth and pancreatic amylase in the small intestine
-Pancreatic amylase digests the remaining starch not digested in the mouth
-Maltose is digested into glucose by maltase in the small intestine

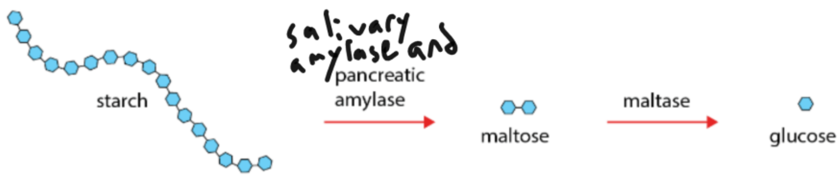


Figure 5.13 Digestion of carbohydrates

Digestion of proteins

-Proteins are digested by proteases
-Protein digestion starts in the stomach, where stomach protease digests proteins into polypeptides
-The polypeptides that enter the small intestine are further digested by pancreatic protease to smaller polypeptides
-The smaller polypeptides are then digested into amino acids by intestinal protease

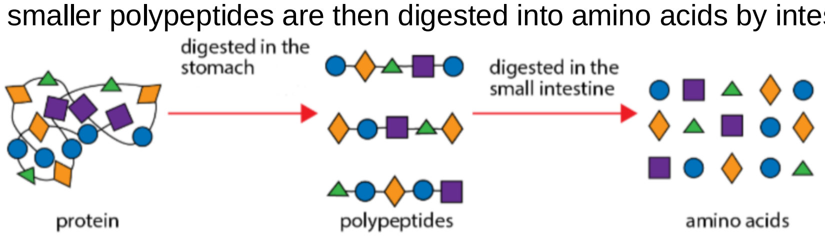


Figure 5.14 Breakdown of proteins to amino acids

Digestion of fats

-Bile is released into the duodenum, and the bile salts emulsify fats by lowering the surface tension of the fats through emulsification
-Thus, the fats break into tiny fat droplets, increasing the surface area to volume ratio for enzyme action
-Emulsification is a form of physical digestion
-Emulsified fats are digested by pancreatic and intestinal lipase into fatty acids and glycerol in the small intestine

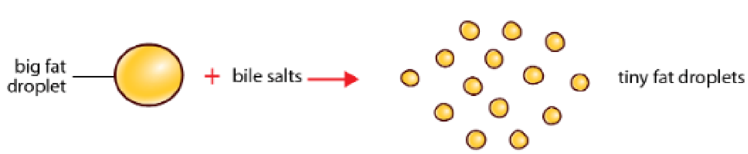
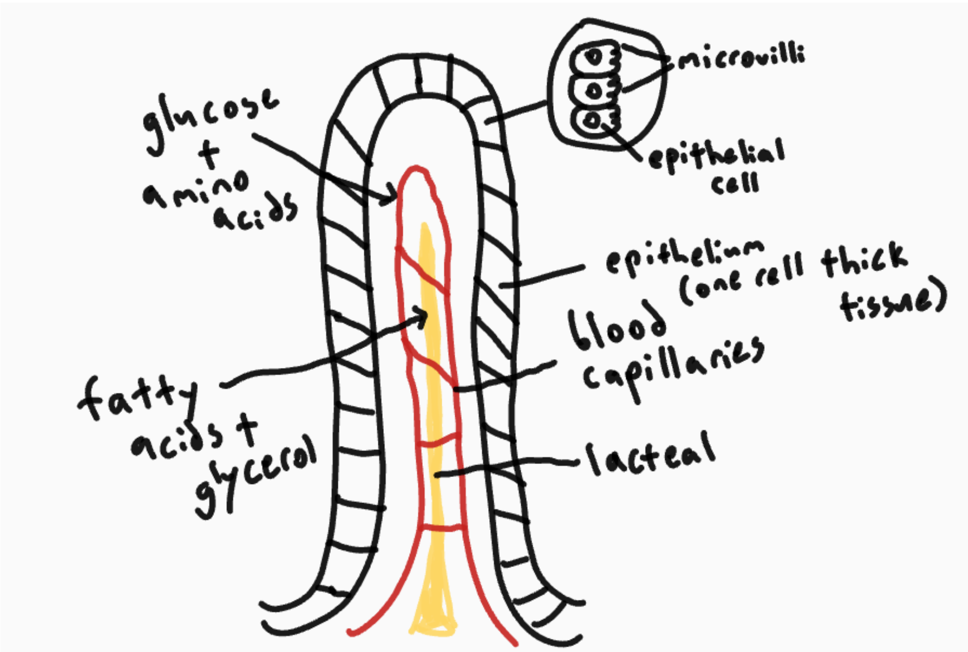


Figure 5.15 Bile salts emulsify fats into tiny fat droplets.

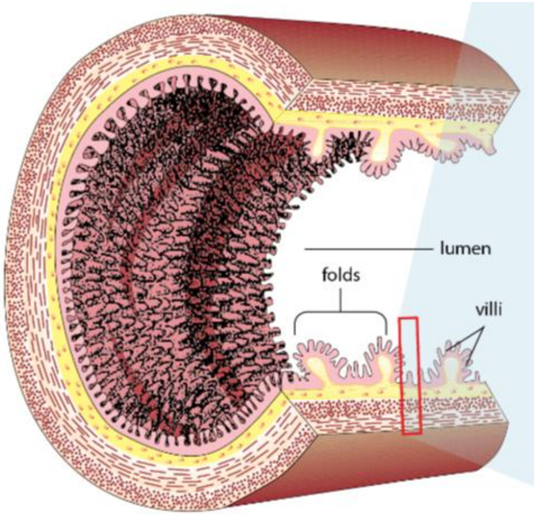
What is absorption?

-Absorption is the process by which digested food molecules are taken into the blood capillaries for amino acids and glucose and into the lacteal for fats
-This takes place in the villi of the small intestine
-The digested food move into the villi of the small intestine through diffusion or active transport
-Glucose and amino acids are absorbed by diffusion into the blood capillaries of the villi
-Glucose and amino acids are also absorbed by active transport
-This happens when there is a lower concentration of these digested food substances in the lumen of the small intestine than in the blood capillaries
-Glycerol and fatty acids diffuse into the epithelium, where they combine to form minute fat globules which enter the lacteals



Adaptations which improve absorption

-The small intestine has numerous finger like projections called villi, which increases surface area to volume ratio
-The cells of the epithelium have many microvilli, further increasing surface area to volume ratio
-The epithelium of the villus is one cell thick, which provides a shorter diffusion distance for nutrients to pass through
-Each villi has many blood capillaries, allowing blood to continually transport the absorbed glucose and amino acids away in order to maintain a steep diffusion gradient
-Each villus contains a lacteal, which allows the continual transport of absorbed fats away, so a steep diffusion gradient is maintained
-The epithelial cells contain many mitochondria, which provide energy for the active transport of nutrients into the villi
-The small intestine is long, providing sufficient time for absorption



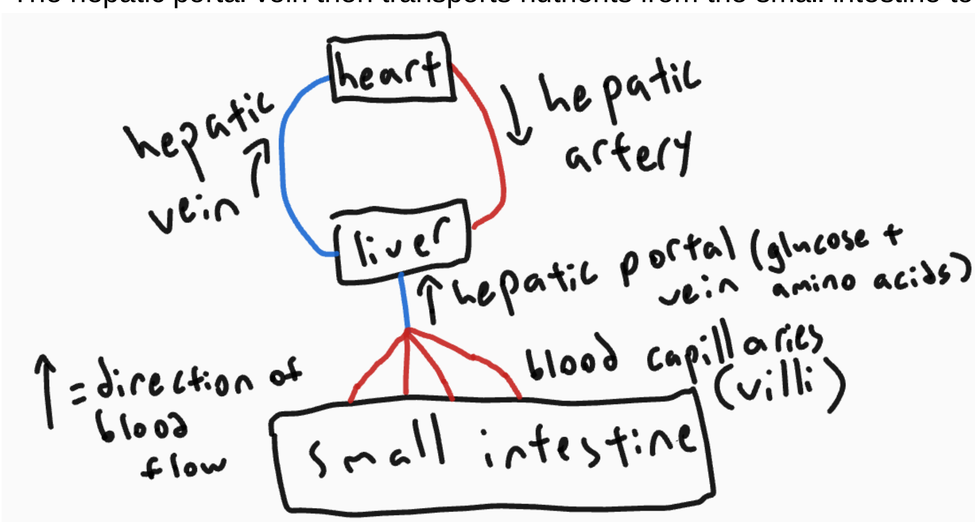
(a) Small intestine with a portion cut off to show folds and villi

What happens to unabsorbed matter?

-Undigested and unabsorbed matter is stored temporarily in the rectum
-It is the discharged through the anus through egestion

What happens to absorbed nutrients?

-Assimilation is the process by which absorbed products of digestion are used as an energy source or converted into new protoplasm needed for growth and repair of body parts
-After absorption, the blood in the villi is rich in nutrients
-The blood capillaries unite to form larger blood vessels, which then unite to form the hepatic portal vein
-The hepatic portal vein then transports nutrients from the small intestine to the liver



Glucose after absorption

-In the liver, most absorbed sugars are converted into glycogen and stored in the liver
-Some glucose is transported to the blood after leaving the liver and distributed around the body
-When blood glucose concentration is higher than normal, insulin is secreted by the islets of langerhans in the pancreas, which stimulates the liver to convert excess glucose to glycogen, reverting blood sugar concentration to normal
-When blood sugar concentration is lower than normal, glucagon is secreted by the islets of langerhans in the pancreas, which stimulates the liver to convert glycogen into glucose, reverting blood sugar concentration to normal
-Insulin does not convert glucose into glycogen, it only stimulates the liver to do so and likewise for glucagon

Amino acids after absorption

-Amino acids that enter the cells are converted into new protoplasm that is used for growth and repair of worn out parts of the body
-Amino acids are also used to form enzymes and hormones
-In the liver, excess amino acids have their amino groups removed and converted into urea, which is known as deamination
-Urea is removed from the body through urine
-The remains of the deaminated amino acids are then converted into glucose in the liver

Fat after absorption

-Fats are absorbed into the lymphatic capillaries, which join to form larger lymphatic vessels, which discharge fats into the bloodstream
-Blood carries the fats to all parts of the body, especially the liver
-When there is enough glucose, fats are not broken down and are used to build protoplasm like cell membranes
-When glucose is in short supply, fats are broken down to provide the energy needed for vital activities in the body
-Excess fat is stored in adipose tissues beneath the skin and around the heart and kidneys
-These tissues protect organs by acting as shock absorbers

Functions of the liver

-The liver produces bile to emulsify fats
-It deaminates excess amino acids
-It regulates blood glucose concentration through secretion of hormones
-When hormones have served their purpose, the liver breaks down these hormones
-Harmful substances may be absorbed into the blood from the gut
-These substances are made harmless by the liver cells
-For example, harmful hydrogen peroxide is broken down into water and oxygen by the liver
-Alcohol is also broken down by the liver into water and carbon dioxide, as alcohol can cause damage to the digestive system and slow down brain function

-Liver cells contain an enzyme which breaks down alcohol to compounds that can be used in respiration, providing energy for cell activities

Impacts of alcohol on the digestive system

-Alcohol stimulates acid secretion in the stomach
-Excess stomach acid increases the risk of gastric ulcers
-Too much alcohol may lead to liver cirrhosis
-Cirrhosis is a disease in which the liver cells are destroyed and replaced with fibrous tissue, making the liver less able to function
-Liver cirrhosis may lead to haemorrhage (heavy bleeding) in the liver, which can lead to liver failure and subsequently, death

Impacts of alcohol on the nervous system

-Alcohol slows down some brain functions
-Its effects vary from person to person
-A person can become carefree as alcohol takes away their self control
-They may do things they may regret after the effects of alcohol have worn off
-It can lead to slurred speech, blurred vision and poor muscular coordination, making a person clumsy and unable to walk steadily
-Their judgement deteriorates and they tend to underestimate speed, which can lead to car accidents
-Alcohol can also increase reaction time, leading to car accidents
-Heavy drinking can interfere with the absorption of vitamin B1 in the small intestine
-Vitamin B1 is needed to break down sugar to release energy for brain activities, so a lack of it can lead to “wet brain”, which is a type of dementia
-The brain can also become smaller than normal, especially the region associated with memory and reasoning
-Heavy consumption of alcohol during pregnancy may interfere with the the development of the fetus’ brain, which can lead to lifelong physical, mental and behavioral problems
-People can neglect their work or families, exhibit violent behavior and commit crimes when addicted to alcohol

Chapter 6: Transport in Humans

Blood

-Blood is a mixture made up of mainly plasma, red blood cells, white blood cells and platelets

Plasma

-The yellowish liquid in blood is plasma
-It mainly consists of water, which acts as a solvent to transport other substances
-These substances include excretory products such as urea and carbon dioxide from excretory organs for removal and glucose, amino acids, fatty acids and glycerol as well as hormones from the endocrine organs to target organs
-Serum is plasma with clotting factors removed

Red blood cells

-The purpose of red blood cells is to transport oxygen throughout the body
-Red blood cells contain haemoglobin which bind reversibly to oxygen and transports it from the lungs to the rest of the body
-They have a circular biconcave shape, which increases surface area to volume ratio for increased rate of absorption of oxygen
-They have no nucleus to allow for more space for haemoglobin
-They are flexible to fit through smaller blood vessels, such as the capillaries

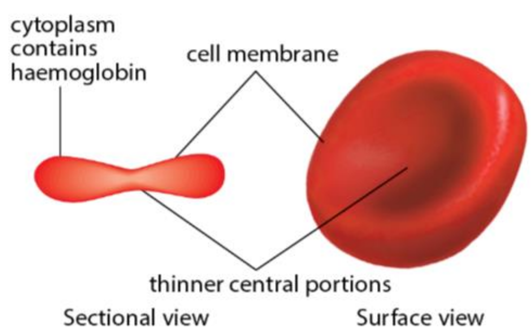
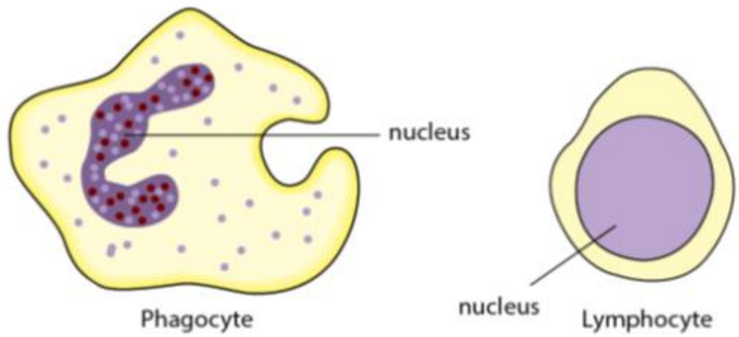


Figure 6.3 Human red blood cells

White blood cells

-There are two types of white blood cells, phagocytes and lymphocytes



-A purpose of white blood cells is to engulf and destroy pathogens such as bacteria through the process of phagocytosis
-It is performed by phagocytes

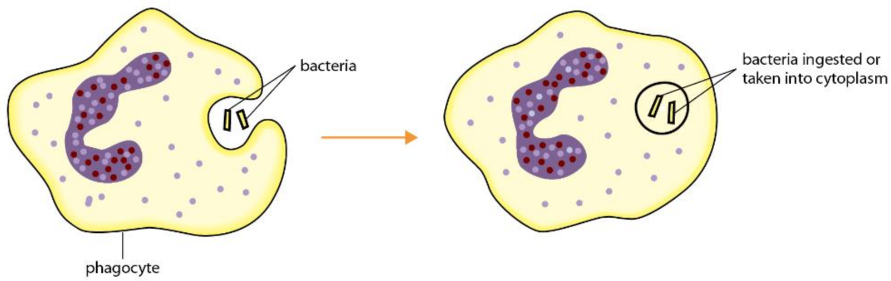


Figure 6.7 Phagocytosis

-White blood cells also produce antibodies
-These antibodies are produced by lymphocytes
-They can recognise and destroy pathogens, cause pathogens to clump together for easy digestion by phagocytes and neutralise toxins produced by bacteria

Platelets

-Platelets are cytoplasm fragments
-Platelets contain an enzyme that catalyses the conversion of fibrinogen to fibrin threads
-Fibrinogen is a soluble protein which is found in the blood, while fibrin threads are insoluble
-Fibrin threads entangle with red blood cells to form blood clots which seals a wound
-Blood clots help prevent excessive blood loss, while also preventing harmful microorganisms from entering the blood

How does blood clot?

-Blood exposed to air will soon clot or coagulate
-Platelets are involved in converting soluble fibrinogen to fibrin threads through enzymes
-These threads entangle blood cells and the whole mass forms a clot or a scab
-The clot seals the wound, preventing the entry of microorganisms and excessive blood loss

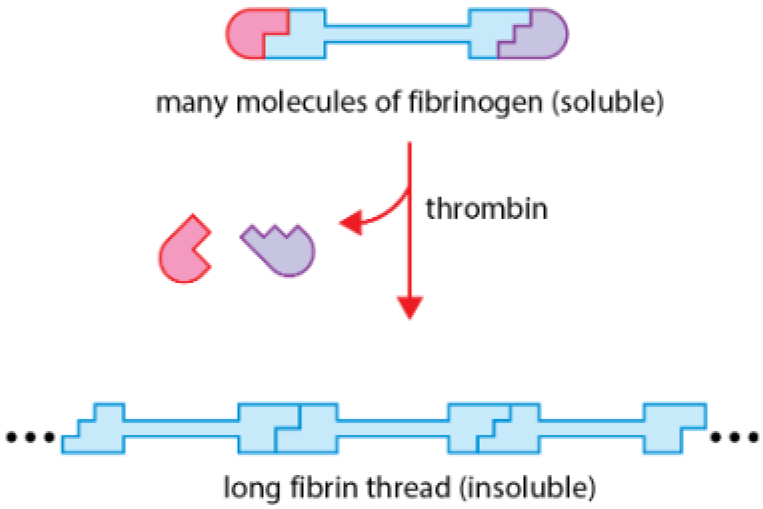


Figure 6.9 How insoluble fibrin threads are formed

Organ transplants and tissue rejection

-When a person has issues with some of their organs, an organ transplant may be needed
-However, when a donor organ is placed in another person, it may be recognised as foreign tissue and may be detected by the white blood cells which release antibodies to destroy the foreign tissue
-This is called tissue rejection

Blood groups

-There are four different blood groups, A, B, O and AB

What are antigens in blood?

-Blood antigens are special proteins found on the surface of red blood cells
-A person has the same antigens on all their blood cells, which determines their blood grounp
-For example, if a person has A antigens on their red blood cells, they have a blood group of A
-If a person has B antigens on their red blood cells, they have a blood group of B
-If they have both A and B antigens, they have a blood group of AB
-If they have no blood antigens, they have a blood group of O

What are antibodies in blood?

-Plasma contains natural antibodies which recognise and bind to specific antigens on the red blood cells
-Note that antibodies are found in plasma
-Antibody A will bind to antigen A, which will cause the clotting of the blood, which is bad to the person

-So if a person has a blood group of A, they will have antibody b
-If a person has a blood group of B, they will have an antibody of a
-If a person has a blood group of O, they will have antibodies a and b
-If a person has a blood group of AB, they will have no antibodies

Antibody reaction

-In a blood transfusion, only the red blood cells are transferred from body to body, not the plasma, white blood cells or platelets
-During a blood transfusion, if the donor's blood cells have antigens that can react with the recipient's antibodies, clumping of the blood occurs
-This process is known as agglutination and is damaging as it can block blood vessels
-This can lead to death
-If two blood groups cause agglutination, they are incompatible blood groups

Blood group compatibility table

Recipient's blood group	Antibody in recipient's plasma / serum	Donor: group A (antigen A)	Donor: group B (antigen B)	Donor: group AB (antigens A and B)	Donor: group O (no antigens, universal donor)
A	b	No agglutination, compatible	Agglutanation, incompatible	Agglutanation, incompatible	No agglutination, compatible
B	a	Agglutanation, incompatible	No agglutination, compatible	Agglutanation, incompatible	No agglutination, compatible
AB (universal acceptor)	none	No agglutination, compatible	No agglutination, compatible	No agglutination, compatible	No agglutination, compatible
O	a, b	Agglutanation, incompatible	Agglutanation, incompatible	Agglutanation, incompatible	No agglutination, compatible

Blood type profiling

-By dripping a person's blood on a serum with known blood group and seeing which blood groups react with the blood and cause agglutination, the person's blood type can be determined

The arteries

-Arteries have thicker and more elastic, more muscular walls relative to the diameter of the vessel to withstand the high pressure of the blood, and the elastic walls to stretch and recoil to push blood in spurts
-They have the highest pressure out of the major blood vessels, and the thickest, most elastic and most muscular walls out of the major blood vessels

The veins

-Veins have thinner, less elastic, less muscular walls relative to the diameter of the entire vessel as blood is flowing at low pressure, so there is no need for thick, muscular and highly elastic walls
-They have valves to prevent backflow of blood that is flowing at low pressure
-The pulmonary vein is an exception, as it has no valves
-They have a large lumen relative to the diameter of the entire vessel as the blood is already moving slowly at low pressure, so a larger lumen reduces resistance to blood flow
-They have the lowest pressure out of the major blood vessels

The capillaries

-The role of the capillaries is for exchange of substances
-Capillaries branch repeatedly to provide large surface area for exchange of substances between blood and body cell
-Since the total cross sectional area is large, the blood pressure is lowered which allows for more time for the exchange of substances with the surrounding tissue fluid
-The endothelium of the capillary is partially permeable, which allows smaller substances, such as oxygen, glucose, amino acids, water, urea and carbon dioxide to diffuse through
-The wall of the capillary is one cell thick without any muscular tissue, to provide shorter diffusion distance for exchange of substances between the blood and body cells
-There is a continuous flow of blood through the capillaries to maintain a steep concentration gradient for higher rate of diffusion
-They have the thinnest, least muscular and least elastic walls out of the major blood vessels

Tissue fluid

-Tissue fluid is the colourless liquid that fills the spaces between cells in tissue
-It is formed by the leakage of the capillaries
-It transports substances between blood capillaries and tissue cells
-Only oxygen moves from the red blood cells to the tissue fluid, all other substances move from the blood plasma
-Urea and other waste materials move from the tissue fluid into the blood plasma

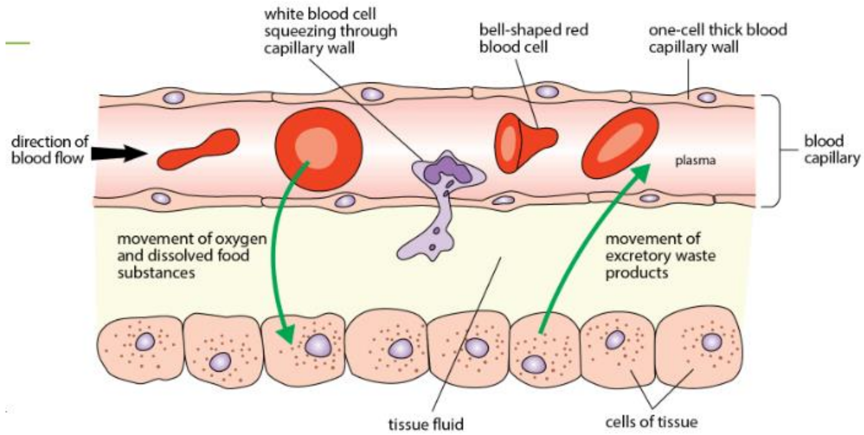
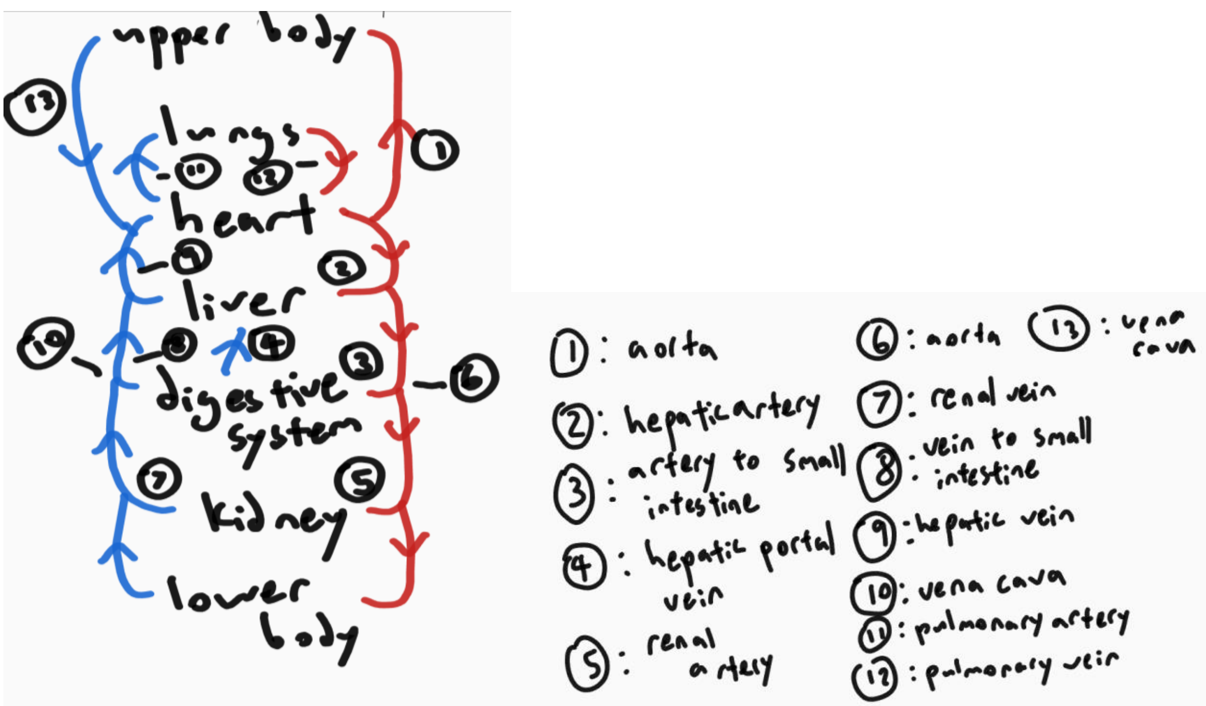


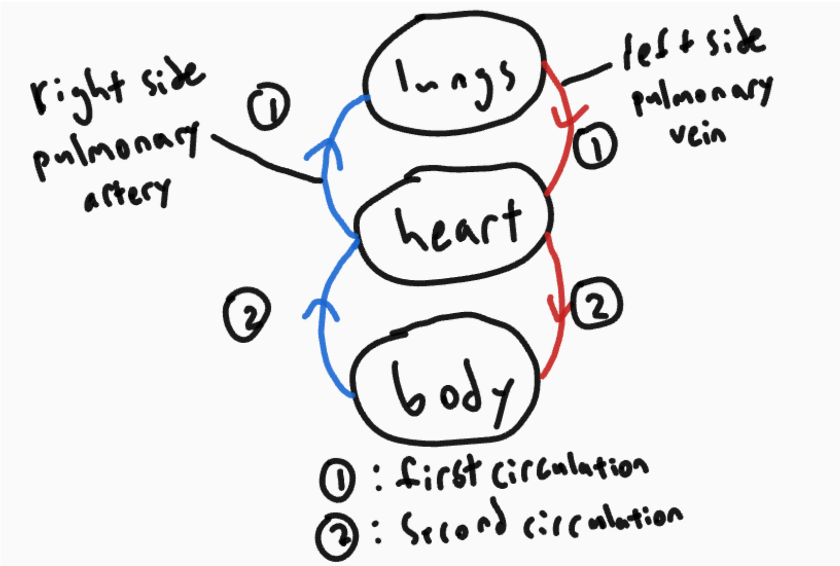
Figure 6.22 Movement of substances between the blood capillary and tissue cells via the tissue fluid

Diagram of the circulatory system



Double circulation

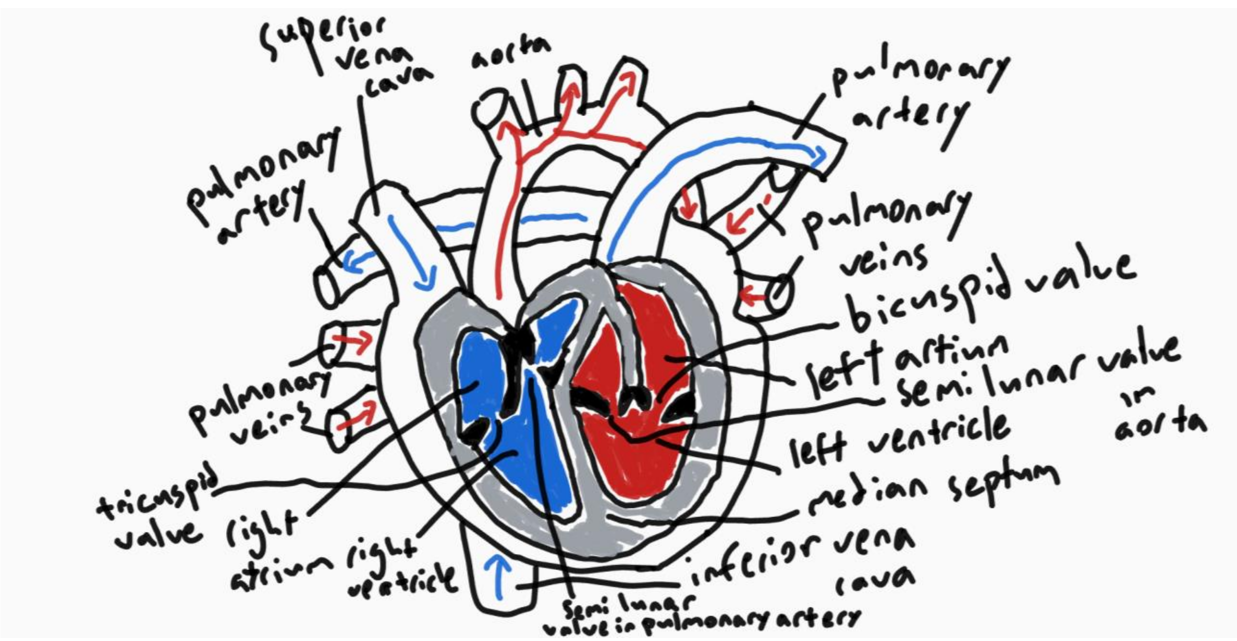
-Blood moves through the circulatory system through double circulation
-From the heart to the lungs to the heart
-From the heart to the rest of the body back to the heart
-In a double circulation, the blood has to pass through the heart twice in one complete circuit
-The first circulation is called pulmonary circulation, while the second circulation is called systemic circulation



Pressure in circulation

-Blood entering the lungs is at a lower pressure compared to blood leaving the heart via the aorta to the rest of the body
-This ensures that the blood flows more slowly through the lungs, allowing sufficient time for the blood to be well oxygenated before it is returned to the heart
-Heart pumps oxygenated blood at high pressure to the rest of the body through systemic circulation, so there is a quicker distribution of oxygen to body tissues and therefore helps maintain the high metabolic rate in mammals.

Diagram of the heart



Structure and functions of the heart

Atria
-The atria are the two upper chambers of the heart
-They receive blood from veins, and have the thinnest muscle walls in the heart as the blood they have to pump travels the least distance from the atria to the ventricles, so they require the least pressure
Ventricles
-The ventricles are the two lower chambers of the heart
-They receive blood from the atria, and the left ventricle has thicker walls than the right, as the left ventricle has to pump blood all over the body, while the right ventricle only pumps blood to the lungs
Median septum
-The median septum is a piece of muscle seperating the left and right side of the heart, separating oxygenated and deoxygenated blood
-If there is a hole in the median septum, the blood will mix and reduce the concentration gradient of oxygen, reducing the efficiency of gas exchange
-This can cause shortness of breath, dizziness and heart failure
Tricuspid valve
-The tricuspid valve is the valve located between the right atrium and right ventricle
-It prevents the backflow of blood from the right ventricle back into the right atrium
Bicuspid valve
-The biscuspid valve is the valve located between the left atrium and left ventricle
-It prevents the backflow of blood from the left ventricle back into the left atrium
Semi lunar valve in aorta
-The semi lunar valve in the aorta or the aortic valve prevents the backflow of blood from the aorta into the left ventricle
Semi lunar valve in pulmonary artery
-The semi lunar valve in the pulmonary artery or the pulmonary valve prevents the backflow of blood from the pulmonary artery into the right ventricle

Path of blood through the heart

-Deoxygenated blood from the body is returned into the right atrium by two large veins called the venae cavae
-The vena cava on top is the superior vena cava, while the inferior vena cava is the one on the bottom
-From the right atrium, the blood passes through the tricuspid valve into the right ventricle
-The pulmonary artery then transport the deoxygenated blood into the lungs
-The pulmonary veins then transport oxygenated blood into the left atirum
-Blood passes into the left atrium through the bicuspid valve into the left ventricle
-From the left ventricle, the blood leaves the heart through the aorta to all parts of the body
-Some of the blood is then transported back to the heart through the coronary arteries
-The cycle then continues again

Systole and diastole

-Systole is the process of contraction, while diastole is the process of relaxation
-Atrial systole is when the muscle of the atrium contracts
-Ventricular systole is when the muscles of the ventricle contracts
-Atrial diastole is when the muscle of the atrium relaxes
-Ventricular diastole is when the muscle of the ventricle relaxes

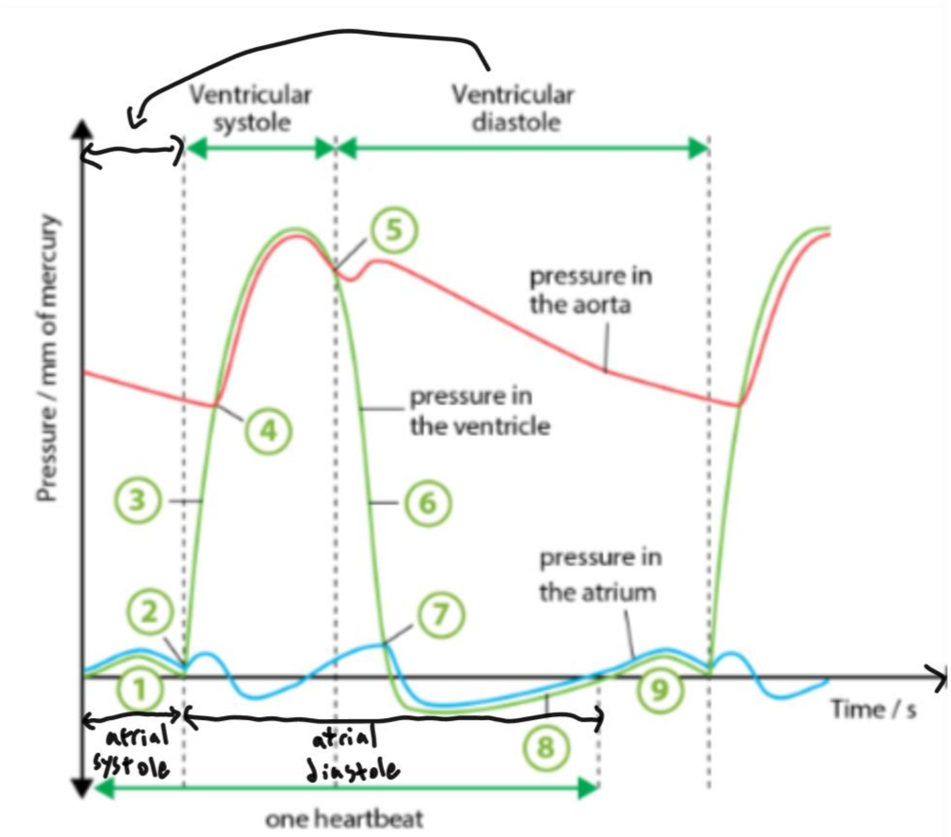
How blood moves through the heart

-Blood moves from a region of higher pressure to lower pressure, so the ventricles and atria will contract and relax to maintain the movement of blood throughout the body
-When muscles contract, pressure increases and vice versa
-So, when muscles of a chamber contracts, pressure in that region rises, so blood is forced from a region of higher pressure to lower pressure, with valves preventing backflow
-The muscles in the blood vessels are used to withstand pressure, not create pressure

What is the cardiac cycle?

-The cardiac cycle refers to the sequence of events happening in one heartbeat
-One cardiac cycle is made up of one ventricular systole and one ventricular diastole
-The ventricular muscles first contract, causing a rise in pressure in the ventricles
-The rise in pressure causes the bicuspid and tricuspid valves to close as the pressure in the ventricles is now higher than that of the atrium, preventing backflow of blood back into the atria
-The closure of the bicuspid and tricuspid valves also produces a loud ‘lub’ sound
-The semi lunar valves also open due to the rise in pressure, as the pressure in the ventricles is higher than in the blood vessels, causing blood to flow from the right ventricle and the left ventricle into the pulmonary artery and aorta respectively
-At the same time the ventricular muscles contract, the atrial muscles relax and the right atrium receives blood from the venae cavae, and the left atrium receives blood from the pulmonary veins as the pressure of the atria is lower than that of in the blood vessels
-The ventricular muscles then relax and the atrial muscles contract, causing the semi lunar valves close as the pressure in the blood vessels is now higher than that of in the ventricles to prevent backflow of blood from the pulmonary artery and aorta into the ventricles
-The bicuspid and tricuspid valves also open as the pressure in the atria is now higher than that of in the ventricles, causing blood to flow from the atria into the ventricles
-The cycle then continues as the ventricular muscles contract

Cardiac cycle graph



-Since this is a graph of the pressure in the left ventricle, the graph of pressure in the right ventricle will have the same shape but be lower as there is less pressure in the right ventricle

1: A slight increase in ventricular pressure due to the contraction of the left atrial muscles, forcing blood into the ventricle

2: The ventricular muscles begin to contract and the bicuspid valve closes

3: The ventricular muscles continue to contract without change in the volume of blood and pressure continues to rise

4: Pressure in the ventricle becomes higher than in the aorta, opening the semi lunar valve in the aorta and the volume of blood in the ventricle decreases as blood is forced into the aorta

5: Ventricular muscles begin to relax and the drop in pressure causes the semi lunar valve in aorta to close and prevent backflow of blood into the ventricle

6: Ventricular muscles continue to relax without change in volume of blood

7: Bicuspid valve opens when pressure in ventricle becomes lower than that in the atrium

8: Pressure in ventricle rises as blood continues to enter the ventricle from the atrium

	2	4	5	7
Bicuspid valve	closed	closed	closed	open
Aortic valve	closed	open	closed	closed

Coronary arteries

-The coronary arteries are arteries located on the outside of the heart
-They transport oxygenated blood and glucose from the aorta to the heart muscle cells

Coronary heart disease

-Coronary heart disease occurs due to a diet high in cholesterol and saturated fats
-This leads to these being deposited on the inner wall of the coronary arteries, which narrows the lumen of the arteries and increases the risk of formation of blood clots, which prevents oxygen and glucose from reaching the heart muscle cells
-Smoking, a sedentary lifestyle and stress can all lead to coronary heart disease as well

Preventive measures against coronary heart disease

-In order to prevent coronary heart disease, people should have regular exercise, have good stress management, not smoke and have a proper diet with unsaturated fats

Chapter 7: Respiration in Humans

What is respiration?

-Respiration is the breaking down of food molecules such as glucose to release energy
-Energy is not produced but released, due to the law of conservation of energy
-Respiration is not breathing, as respiration is a chemical process while breathing is a physical process
-There are two types of respiration, aerobic and anaerobic respiration
-In general, breathing and heart rate increases during vigorous activities to increase the rate of respiration to provide more energy for the body

Aerobic respiration

-Involves the breakdown of glucose in the presence of oxygen
-Produces carbon dioxide and water as waste products
-Releases a large amount of energy
-Chemical equation: $C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O$ + a lot of energy
-Word equation: glucose + oxygen = carbon dioxide + water + a lot of energy
-The energy is released due to the breaking of the carbon bonds within the glucose molecule, releasing the energy stored in these bonds
-This energy is mostly released by heat, and is also used up by the cells
-Aerobic respiration occurs in the mitochondria
-Aerobic respiration occurs all the time

Anaerobic respiration

-Involves the breakdown of glucose in the abscence of oxygen
-Releases a relatively small amount of energy
-Chemical equation: $C_6H_{12}O_6 = 2C_3H_6O_3$ + a little bit of energy
-Word equation: glucose = lactic acid + a little bit of energy
-Anaerobic respiration mostly occurs in muscle cells
-Anaerobic respiration occurs in the cytoplasm of a cell
-Anaerobic respiration occurs only sometimes when needed

Respiration during exercise

-During exercise, more energy is needed for muscle contractions compared to the normal amount needed for day to day activities
-Aerobic respiration in muscle cells increases, leading to increased breathing rate to supply oxygen and increased heart rate to transport the oxygen
-The amount of energy that can be supplied by aerobic respiration is limited by heart rate and rate of ventilation, so after a certain point, no more energy can be produced through aerobic respiration
-This is when the body starts releasing energy through anaerobic respiration to make up for the energy not released through aerobic respiration

-This is until a point where there is too much lactic acid produced as waste products which is called incurring an oxygen debt
-This is bad as lactic acid can affect the body's pH, which can affect many enzymatic processes in the body
-This is when you should stop exercising
-After exercise, this lactic acid is transported to the liver to be oxidised, or repaying the oxygen debt
-This requires oxygen, which is why heart rate and breathing rate still remains high for a while after exercise to transport oxygen and lactic acid to the liver and to absorb more oxygen respectively
-So, oxygen debt is the amount of oxygen needed to remove lactic acid through oxidation
-Lactic acid is only oxidised after exercise, not during exercise

How do organisms take in oxygen for aerobic respiration?

-Unlike simple organisms, such as amoeba, who rely on diffusion for gaseous exchange due to their large surface area to volume ratio, we have a small surface area to volume ratio, so diffusion is not enough for gaseous exchange, thus we requite a special system of organs for gaseous exchange

The human gas exchange system

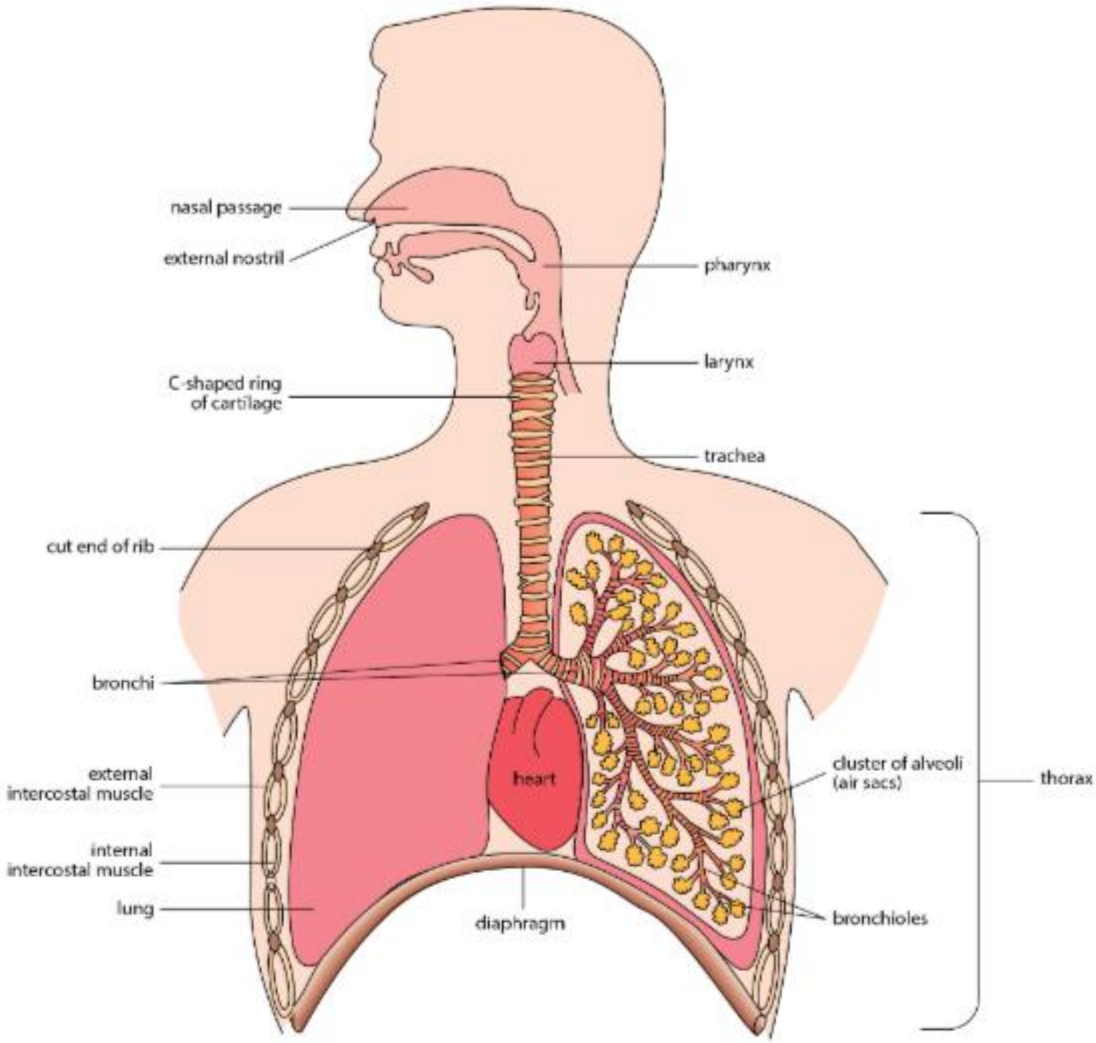


Figure 7.8 The human gas exchange system

-Oxygen starts at the nasal passages, before moving to the pharynx, then the larynx, then the trachea, then the bronchi, then the bronchioles then lastly the alveoli
-At the alveoli, the oxygen is dissolved in the thin film of moisture lining the inner walls of the alveolus, before diffusing into the surrounding capillaries
-The bronchi, bronchioles and alveoli are part of the lungs

The trachea

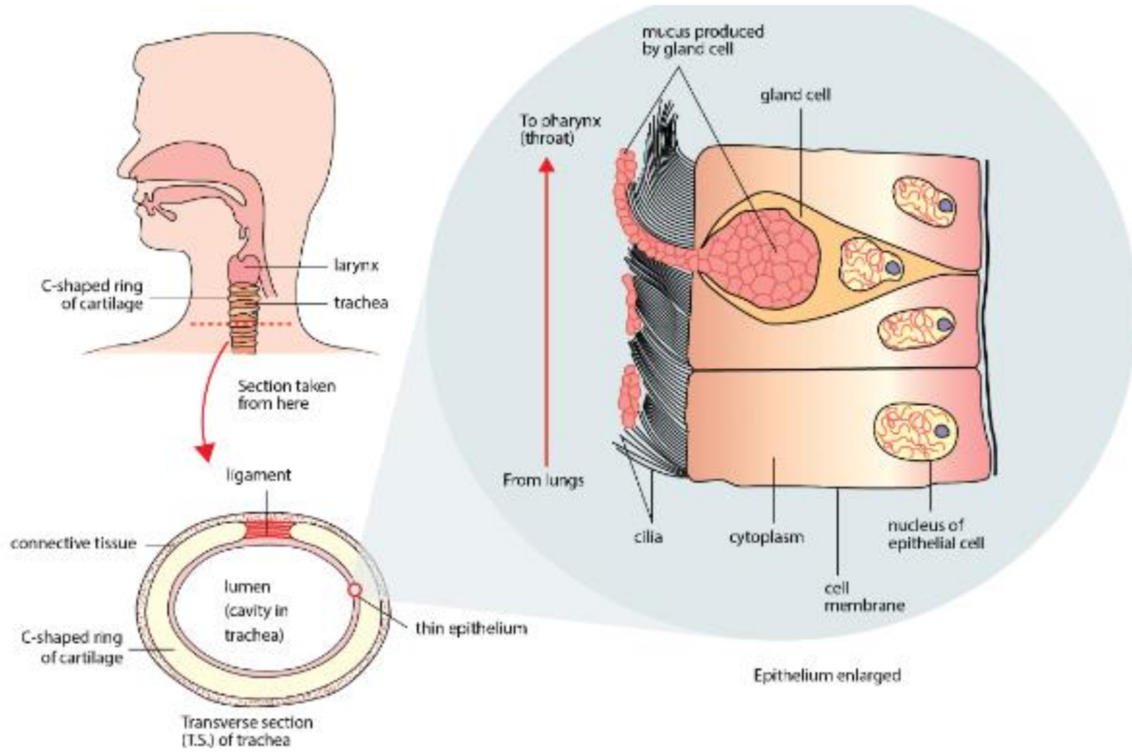
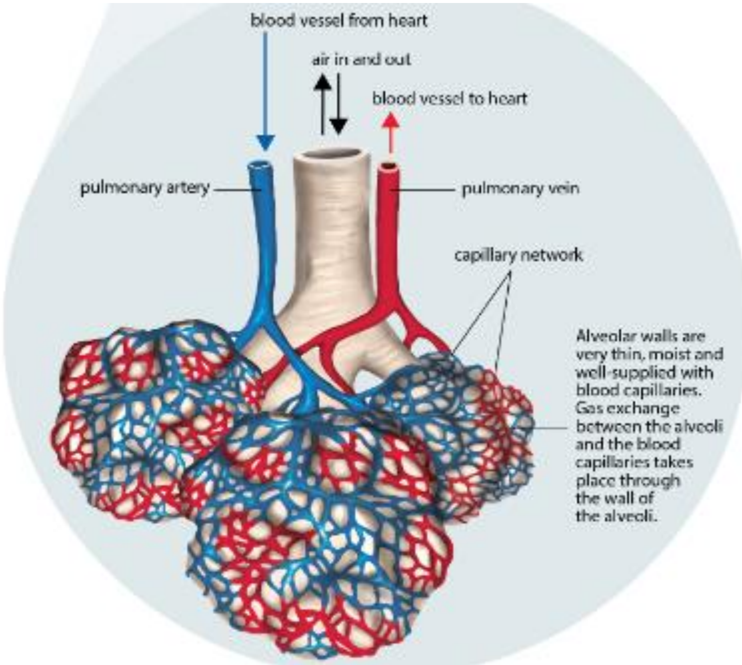


Figure 7.9 Features of the air passages

-The C shaped ring of cartilage keeps the trachea open and prevent it from collapsing
-The cells with cilia are called ciliated cells
-The purpose of the cilia is to sweep dust trapped mucus upwards towards the pharynx, where it is either coughed out or swallowed
-The cells without cilia are called gland cells
-The purpose of the gland cell is to secrete mucus
-The purpose of mucus is to trap dust particles in the cilia, as it is sticky
-Cells in the trachea are also present in the bronchi

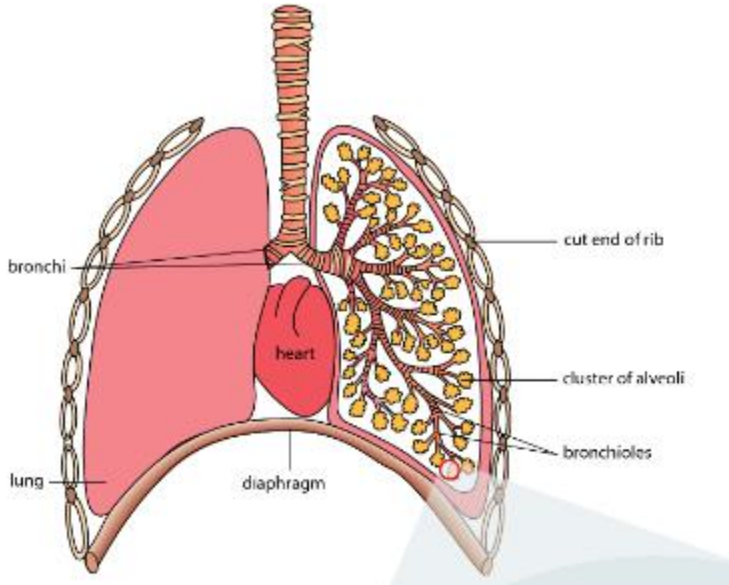
The alveoli



Nutrients	Pulmonary vein	Pulmonary artery
Oxygen	higher	lower
Carbon dioxide	lower	higher
Glucose	lower	higher

-The glucose level in the pulmonary vein is lower as glucose is used by the cells in the lungs for aerobic respiration

Adaptations of the lung



-There is a lot of alveoli for a large surface area for gas exchange
-The walls of the alveoli are one cell thick, for a short diffusion distance
-There is also a thin film of moisture on the inner walls, to allow for oxygen to dissolve
-The walls of the alveoli are surrounded by numerous blood capillaries, to create a steep concentration gradient

Gas exchange in the alveolus

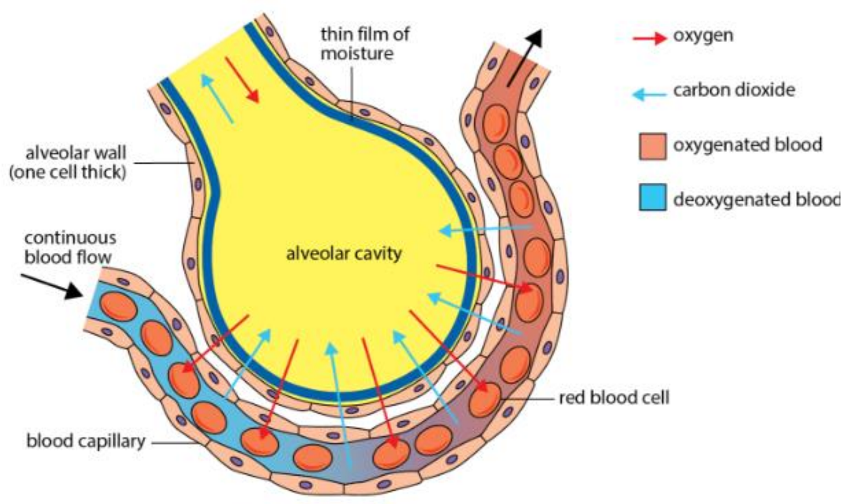


Figure 7.11 A section of an alveolus

-The oxygen and carbon dioxide concentration gradients are maintained by a continuous flow of blood capillaries and continuous breathing, causing air in the lungs to be constantly refreshed

How is oxygen transported around the body?

-Haemoglobin binds reversibly with oxygen to form oxyhaemoglobin in the red blood cell, which transports oxygen around the body
-Oxygen binds with haemoglobin in the lungs, and oxyhaemoglobin reverts to oxygen and haemoglobin in the tissue cells

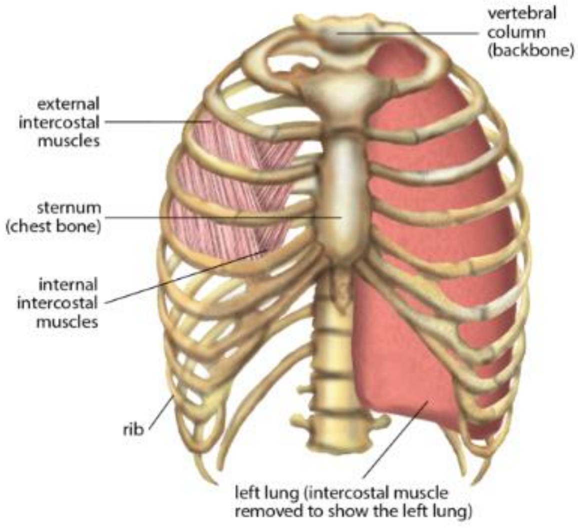
How do we breathe?

-Inhalation or inspiration is the breathing in of air, while exhalation and expiration is the breathing out of oxygen
-Air is forced from a higher pressure to lower pressure during breathing

Gaseous exchange vs aerobic respiration

Features of comparison	Gaseous exchange	Aerobic respiration
Location	Lungs	Mitochondria of cells
Type of reaction	Physical reaction, is just the movement of air	Chemical reaction, from glucose and oxygen to carbon dioxide and energy

The thoracic cavity



-The thoracic or chest cavity is the area surrounded by the ribs
-The ribs supports the chest wall
-Between the ribs, two sets of muscles, the external and internal intercostal muscles can be found
-They are antagonistic, so when one contracts the other relaxes

The diaphragm

-It is a dome shaped muscular elastic tissue which separates the thorax from the abdomen
-Flattens when diaphragm muscles contract
-Arches when the diaphragm muscles relax

Inhalation

-Air is forced into the lungs during inhalation
-The diaphragm muscles contract, and the diaphragm flattens
-The internal intercostal muscles relax, and the external intercostal muscles contract, as they are antagonistic
-This causes the ribs to move out and up
-This increases the volume of the thoracic cavity, thereby expanding the lungs, reducing lung pressure
-Lung pressure is now lower than atmospheric pressure, which causes air to be forced in the lungs

Exhalation

-Air is forced out of the lungs during exhalation
-The diaphragm muscles relax, and the diaphragm arches up
-The internal intercostal muscles contract, and the external intercostal muscles relax, as they are antagonistic
-This causes the ribs to move in and down
-This decreases the volume of the thoracic cavity, thereby compressing the lungs, increasing lung pressure
-Lung pressure is now higher than atmospheric pressure, which causes air to be forced out of the lungs

How does inspired air differ from expired air?

Component	Inspired	Expired
O_2	higher	lower
CO_2	lower	higher
N_2	same	same
H_2O	variable	saturated
Dust	variable, but present	little, if any
Temperature	variable	38C

Chemicals in tobacco smoke and their effects

Nicotine
-Very addictive, increases risk of blood clots in arteries, leading to increased risk of coronary heart disease
-Increases heartbeat rate and blood pressure
-Increases the risk of arteries to narrow
-In a pregnant mother, narrowed arteries decrease the amount of food substances reaching the fetus, thereby affecting fetal development and may cause miscarriage

Carbon monoxide
-Binds irreversibly with haemoglobin to form carboxyhaemoglobin
-It binds at a higher affinity to haemoglobin than oxygen, so it will want to bind to carbon monoxide more than to oxygen
-This reduces the ability of blood to transport oxygen around the body
-In a pregnant mother, less oxygen reaches the fetus through the placenta which can affect fetal development

Tar
-It increases the risk of cancer as it can cause uncontrolled cell division
-It increases the risk of chronic bronchitis and emphysema

Chronic bronchitis

-Chronic bronchitis occurs when the lungs are exposed to irritants over a prolonged period
-This inflames the linings of the bronchus, and they secrete excess mucus
-The cilia on cells of linings also become paralysed
-Dust trapped mucus cannot be removed, blocking the airways
-This can lead to persistent coughing and an increased risk of lung infection

Emphysema

-Persistent and violent coughing due to bronchitis can lead to the breakdown of partition walls of alveoli
-This reduces the surface area to volume ratio for gaseous exchange
-This reduces the elasticity of the lungs, which cause the lungs to be inflated
-This can lead to wheezing and severe breathlessness

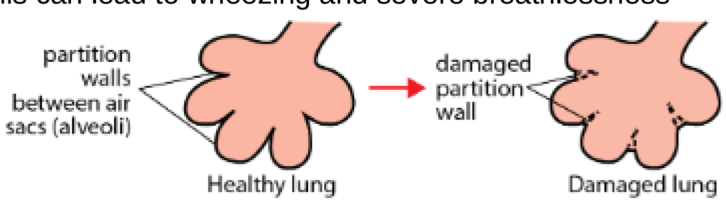


Figure 7.27 Diagram showing a healthy lung damaged by emphysema

Chapter 8: Excretion in Humans

What is excretion?

-Excretion is the removal of metabolic waste products, toxic substances and excess substances produced from bodily functions
-Egestion is the process by which undigested food is expelled from the body through the anus, while excretion is the removal of waste products from the body

Why is excretion necessary?

-Chemical or metabolic activities occur within our body all the time
-These metabolic activities produce substances which are toxic or harmful to the body
-These are called metabolic waste products
-Excretion is important to prevent the accumulation of metabolic waste products in the body to toxic levels

Metabolic waste products

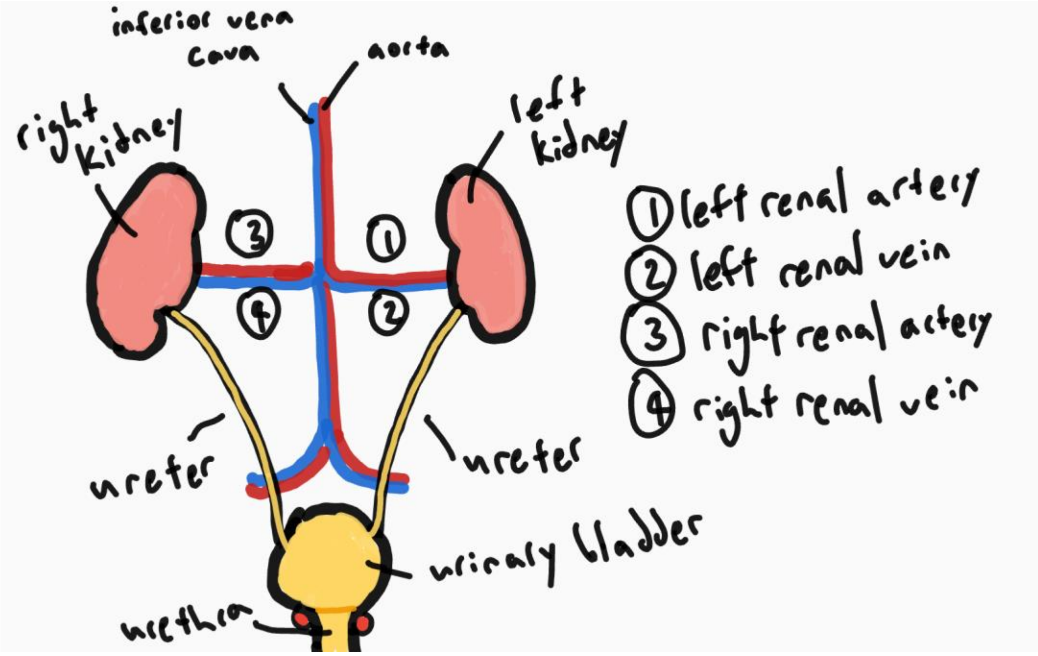
Carbon dioxide
-Carbon dioxide is a waste product from aerobic respiration
-It is excreted through the lungs, through expired air
-Excess carbon dioxide can lead to a condition called hypercarbia, where the patient may suffer from headache, confusion, rapid breathing or premature heartbeats

Urea
-Urea is produced through the deamination of excess amino acids
-It is excreted from the body through the kidneys and skin, through urine and some from sweat
-Eating high protein foods can increase the amount of urea excreted

Mineral salts or ions
-Mineral salts or ions are a waste product from the food we eat
-It is excreted through the kidneys and skin, through urine and sweat
-Excess mineral salts in the bloodstream will decrease the blood plasma water potential, which will cause water to leave the blood cells, causing them to become crenated

Water
-Water is a waste product from aerobic respiration
-It is excreted through the kidneys and skin, through urine and sweat
-Excess water potential in the bloodstream can cause water to enter the blood cells through osmosis, causing them to burst

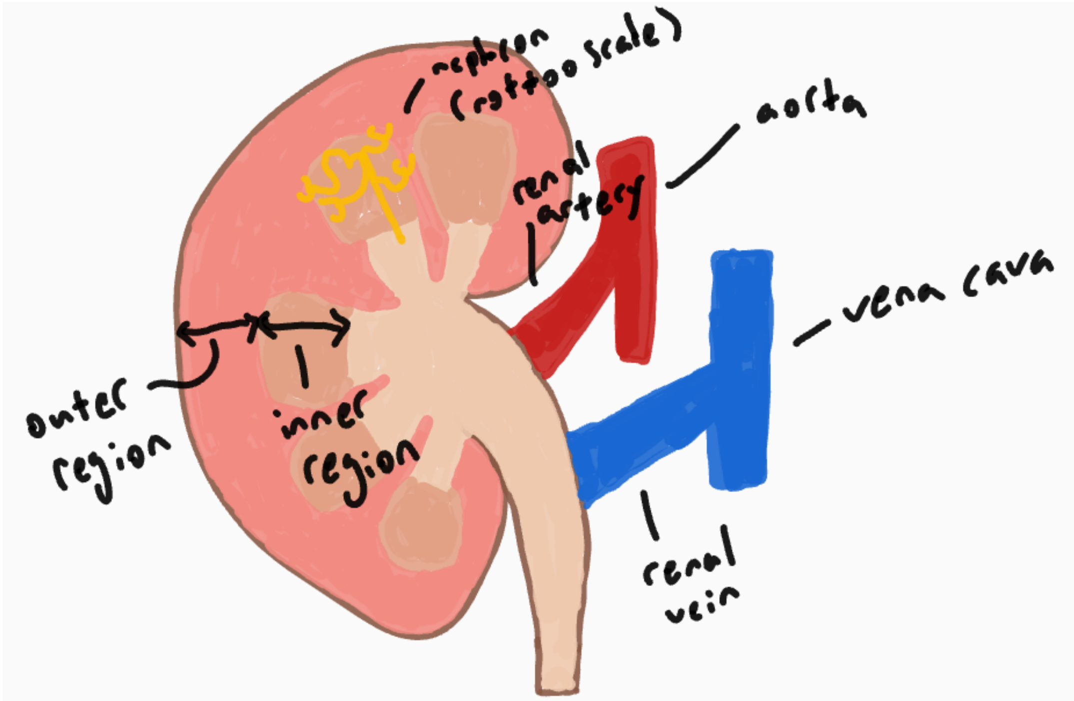
The human urinary system



-The human urinary system consists of a pair of kidneys, a pair of ureters, the urinary bladder and the urethra

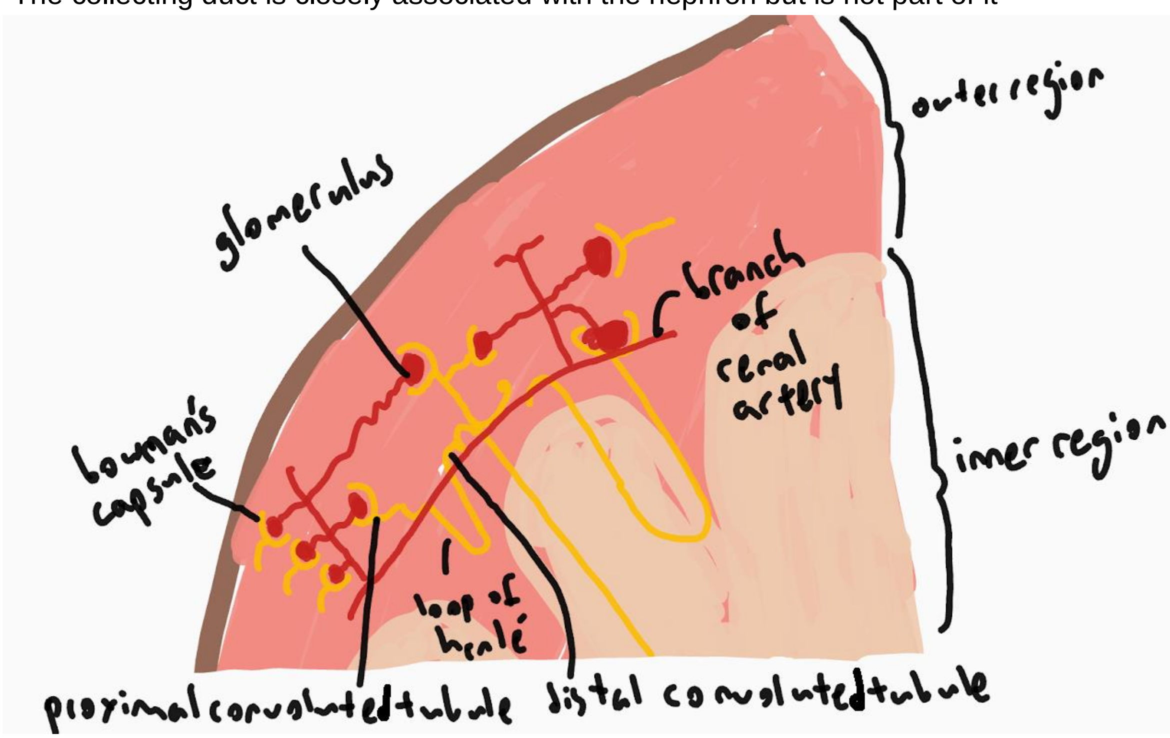
The kidney

-The kidney is bean shaped
-It has a visible dark outer region and a pale inner region
-It receives blood through the renal artery
-It returns blood through the renal vein
-The basic functional unit of the kidney tubule is called the nephron



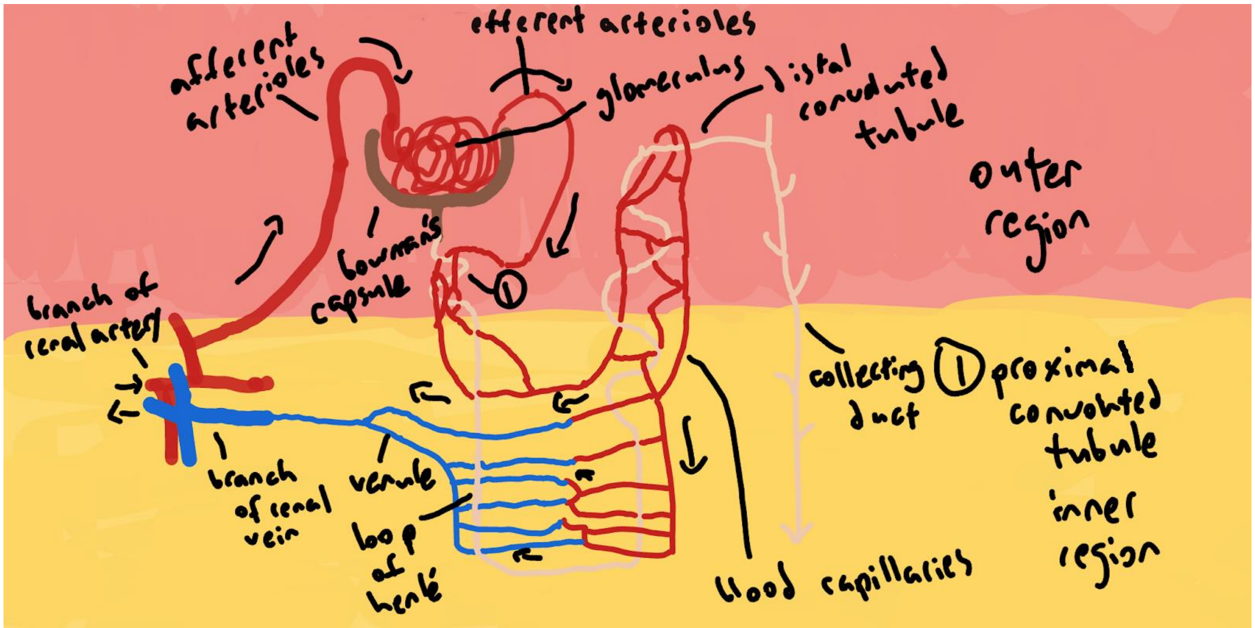
The nephron

-The nephron is responsible for the production of urine
-It is made up of the bowman's capsule, the proximal convoluted tubule, the loop of henle and the distal convoluted tubule
-The collecting duct is closely associated with the nephron but is not part of it



Blood capillaries around the nephron

-They consist of the afferent arteriole, the glomerulus, the efferent arteriole and the blood capillaries surrounding the nephron



How is urine formed?

-Urine is formed through ultrafiltration and selective reabsorption

Ultrafiltration

-Ultrafiltration is the first stage of urine formation
-It is the process by which small molecules are filtered out of the blood by the glomerulus into the bowman's capsule
-In order for ultrafiltration to take place, a force and filter is needed
-The force is provided by a high hydrostatic blood pressure from the diameter of the afferent arteriole becoming smaller as it passes through the glomerulus
-The filter is the partially permeable membrane surrounding the glomerulus, as all capillaries are partially permeable

How is the glomerulus adapted for urine formation?

-It is a network of blood capillaries to provide a large surface area for filtration
-It has a partially permeable membrane to allow for small substances such as glucose, amino acids, mineral salts and urea to pass through, while bigger substances such as blood cells, platelets and proteins cannot pass through
-The walls of the capillaries are one cell thick, so there is a shorter distance for small substances to be forced out

-The afferent arterioles have a larger diameter than the efferent arterioles to create a high hydrostatic blood pressure for ultrafiltration at the glomerulus

Selective reabsoprtion

-It is the second stage of urine formation
-It is the process by which useful substances that the body needs is reabsorbed into the blood capillaries through a partially permeable membrane
-It takes place mostly at the proximal convoluted tubule
-All glucose, amino acids and most mineral salts are selectively reabsorbed through diffusion and active transport
-Most of the water is reabsorbed through osmosis

Why are the kidneys important?

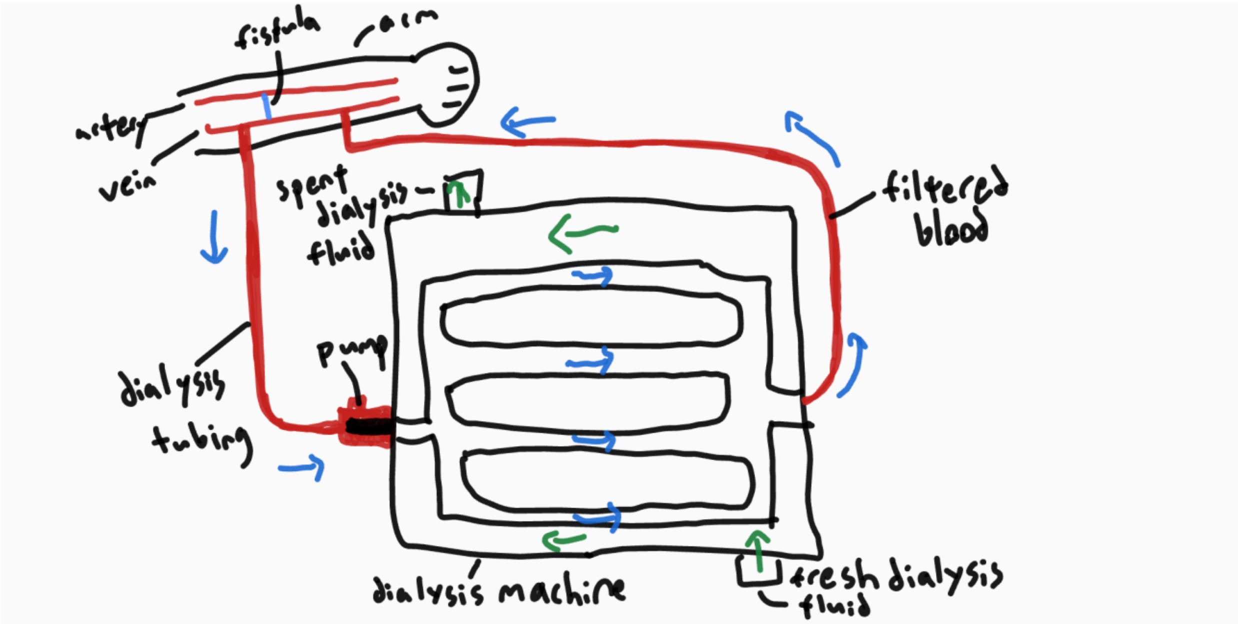
-They excrete metabolic waste products, such as urea, excess water and mineral salts
-They regulate water potential and solute concentration to maintain a constant water potential level in the body as an osmoregulator

What is kidney dialysis?

-A patient with kidney failure will undergo dialysis when there are not enough kidney donors to donate a kidney
-Common causes of kidney failure include high blood pressure, diabetes, alcohol abuse, severe accidents and complications from major surgeries
-They undergo treatment 3 times per week, with each session lasting 4 hours

How does a dialysis machine work?

-Blood is drawn from the vein in the patients arm and is allowed to be pumped through the tubing into the dialysis machine
-Blood is drawn from the vein as it is closer to the surface of the skin and is thus easier to locate
-The tubing is bathed in a specially controlled dialysis fluid in the dialysis machine
-The walls of the tubing in the dialysis machine are partially permeable
-Small molecules such as urea and other excretory waste products diffuse out of the tubing into the dialysis tubing into the dialysis fluid
-Blood cells, platelets, other essential molecules and large molecules such as proteins remain in the tubing
-Glucose and other important molecules do not diffuse out as there is no concentration gradient between the dialysis fluid and blood
-The filtered blood is then returned to a vein in the patients arm



Features of a dialysis machine

-The dialysis fluid contains the same concentration of essential substances as a healthy individuals blood
-This is so that these essential substances such as glucose, amino acids and mineral salts do not diffuse out of the blood, and if there is a lack of these substances, they will diffuse into the blood
-The dialysis fluid does not contain metabolic waste products
-This sets up a steep concentration gradient between the dialysis fluid and blood of urea, excess water and mineral salts, to allow for a higher rate of diffusion of these substances, maintaining a correct solute concentration and water potential in the patients blood
-The tubing in the machine is narrow
-This increases the surface area to volume ratio which helps to speed up the rate of diffusion between the blood and dialysis fluid
-The tubing in the machine is long
-This provides sufficient time for diffusion
-The direction of blood flow is opposite to the flow of the dialysis fluid, to maintain a concentration gradient for the removal of waste products as the waste products are always removed after diffusing out of the blood

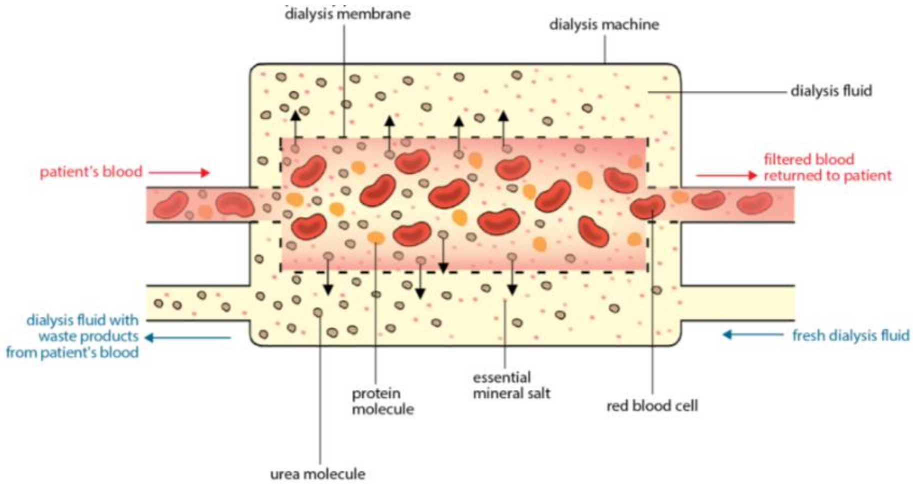


Figure 8.18 How substances are exchanged between the blood and the dialysis fluid in a dialysis machine

Kidney dialysis vs kidney transplant

-A kidney transplant allows a patient not to spend extra time doing dialysis that that causes disruption to daily activities
-Periods of feeling unwell due to kidney dialysis are absent
-A patient who undergoes a kidney transplant will likely live longer than a patient on kidney dialysis, as he has a fully functional kidney
-The patient does not need to eat a restricted diet if he undergoes a kidney transplant
-The transplanted kidney may however be at risk of tissue rejections, hence the patient would need to consume long term immunosuppressant drugs, which lowers their immunity
-There is a risk of death, infection and damage to surrounding organs during the transplant operation

Osmoregulation

-The antidiuretic hormone, or ADH acts on the kidneys to help regulate water potential in blood plasma through osmoregulation
-This is done through homeostatic control
-When the water potential of blood increases, the hypothalamus is stimulated
-Less ADH is then released by the pituitary gland into the bloodstream, decreasing the amount of ADH transported to the kidneys, which makes cells in the walls of the collecting ducts less permeable to water, leading to less water being reabsorbed into the bloodstream, increasing the amount of water excreted through urine
-More urine is produced and it is more diluted
-The water potential then decreases to the normal level
-When the water potential of blood decreases, the hypothalamus is stimulated
-More ADH is then released by the pituitary gland into the bloodstream, increasing the amount of ADH transported to the kidneys, which makes cells in the walls of the collecting ducts more permeable to water, leading to more water being reabsorbed into the bloodstream, decreasing the amount of water excreted through urine

-Less urine is produced and it is more concentrated
-The water potential then increases to the normal level

Chapter 9: Homeostasis and Hormonal Control

What is homeostasis?

-Homeostasis is the maintenance of a constant internal environment
-Some examples of homeostasis in humans include thermoregulation, osmoregulation and blood glucose regulation

How does homeostasis work?

-In homeostatic control, your body reacts to bring about an opposite effect to changes detected
-If your body is disturbed, the disturbance sets in motion a sequence of events that tends to restore the body to its original state
-This is called the negative feedback process
-Organs and structures in the body that detect changes in body condition are called receptors or sense organs, and any change in body condition is called the stimulus

Negative feedback

-In order for negative feedback to tack place, there must be a normal level or set point to be maintained, a stimulus, a receptor to detect the stimulus, a control center to receive signals from the receptor, and a corrective mechanism which brings about the reverse effect of the stimulus, in order to maintain the set point

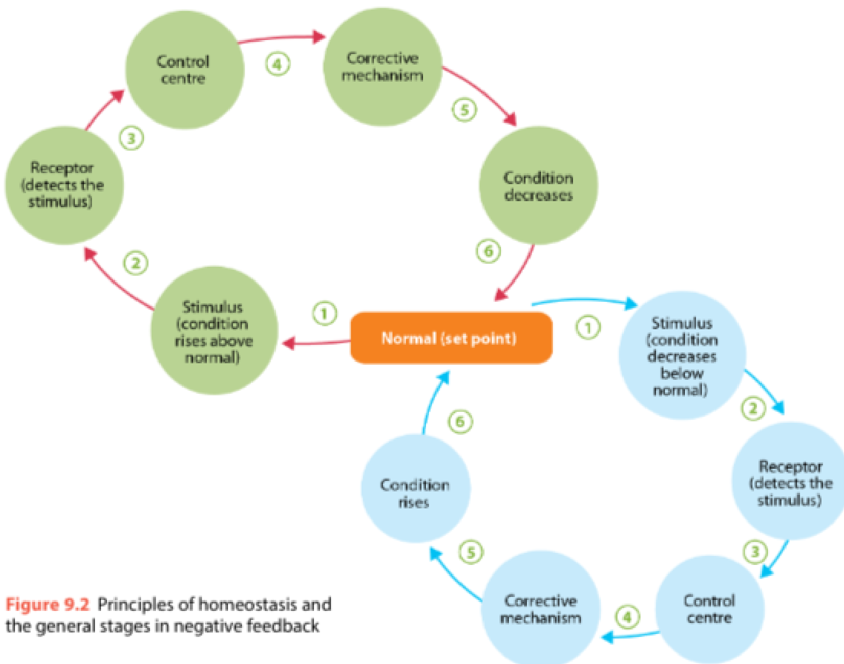


Figure 9.2 Principles of homeostasis and the general stages in negative feedback

Osmoregulation

-The antidiuretic hormone, or ADH acts on the kidneys to help regulate water potential in blood plasma through osmoregulation
-This is done through homeostatic control
-When the water potential of blood increases (stimuli), the hypothalamus (receptor) is stimulated
-Less ADH is then released by the pituitary gland into the bloodstream, reducing the amount of ADH transported to the kidneys, which makes cells in the walls of the collecting ducts less permeable to water, leading to less water being reabsorbed into the bloodstream, increasing the amount of water excreted through urine (corrective mechanism)
-The water potential then decreases to the normal level (set point)
-The opposite occurs when the water potential of blood decreases

What is a hormone?

-A hormone is a chemical substance produced in minute quantities by an endocrine gland, which is transported in the bloodstream to alter the activity of one or more target organs and is destroyed in the liver and excreted in the kidneys
-They are produced by glands

Endocrine glands

-Most glands, such as the salivary glands and sweat glands, have a duct or tube to carry away their secretions
-These glands are known as exocrine glands

-However, hormones are produced by ductless glands, where the hormone is directly secreted into the bloodstream, where it is then transported around the body
-Ductless glands are also known as endocrine glands
-Some glands are purely endocrine glands, producing only hormones, such as the pituitary gland, while other glands such as the pancreas produce both hormones and other secretions
-Hence, the pancreas can be considered both an endocrine and exocrine gland

Examples of endocrine glands

Pituitary gland
-It secretes many hormones which control the secretion of other hormones by targeting mostly endocrine glands
-It also secretes ADH
-It is located in the head

Hypothalamus
-It secretes some hormones
-it is located in the head

Pancreas
-The islets of langerhans in the pancreas secrete insulin and glucagon
-It is located in the lower body, above the crotch

Ovary
-The ovary in females secretes oestrogen and progesterone
-It is located in the female reproductive system

Testes
-The testes in males secretes testosterone
-It is located in the male reproductive system

Effects of insulin

-The islets of langerhans secrete insulin when blood glucose concentration rises above normal levels
-It decreases blood glucose concentration by making cell membranes more permeable to glucose, allowing more glucose to diffuse into the liver and muscle cells
-It also stimulates the liver and muscle cells to convert excess glucose into glycogen for storage, and increases the use of glucose for respiration
-When not enough insulin is secreted and blood glucose concentration is high, glucose cannot be stored or utilised by tissue cells and some glucose is lost through urine, leading to a disease called diabetes mellitus
-The muscles cells also have no reserves of glycogen, and the body grows weak and continuously loses weight

-When too much insulin is secreted, the abnormal decrease in blood glucose concentration can lead to shock, seizures, fits, collapsing or passing out
-The target organ of insulin are the muscles, fats and liver

Effects of glucagon

-The islets of langerhans secrete glucagon when blood glucose concentration drops below normal levels
-It increases blood glucose concentration by stimulating the conversion of glycogen to glucose and the conversion of amino acids and fats into glucose in the liver
-The target organ of glucagon is only the liver

What is diabetes mellitus?

-Diabetes mellitus or diabetes is a disease in which the body is unable to control its blood glucose concentration, causing blood glucose concentration to rise to a level that exceeeds the kidney's ability to completely reabsorb the glucose, after which te unabsorbed glucose is excreted through urine
-There are two main types od diabetes, type 1 and type 2
-Type 1 diabetes develops in the early stages of one's life, hence being known as juvenile or early onset diabetes
-Type 1 diabetes occurs when the islets of langerhans are unable to produce or secrete sufficient insulin, and is inherited
-Type 2 diabetes develops in the laterstages of one's life, hence being known as late onset diabetes
-Type 2 diabetes occurs when the target cells of insulin do not respond well to insulin, and is more common among overweight people
-Signs of diabetes include a persistently high blood glucose concentration, frequent urination, the presence of glucose in urine, weight loss, thirst and slow or difficult healing of wounds

How can diabetes by treated?

-Diabetics have to measure their blood glucose concentration and test their urine regularly, as well as watching their diet carefully, making sure they don't eat too many carbohydrates
-People with type 1 diabetes have to regularly inject insulin into the fat tissue under their skin, but if they use too much insulin, exercise too much or eat too little, their blood glucose concentration may drop too low
-Hence, they should always have a supply of sugary foods on hand
-They also take medication to increase the uptake of glucose from the bloodstream into the cells

What are the risk factors of type 2 diabetes?

-In type 2 diabetes, the liver and muscle cells do not respond well to insulin, which is called insulin resistance, hence they are unable to take in excess glucose in the blood

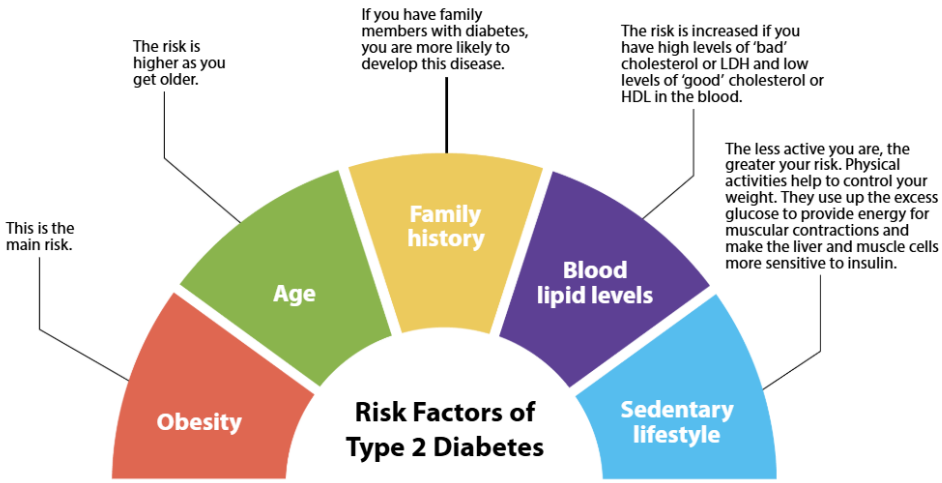


Figure 9.9 Factors that may increase the risk of type 2 diabetes

-To help reduce the risk of developing type 2 diabetes, a person should lead a healthy lifestyle involving eating healthily, exercising more and maintaining a healthy body weight

Structures involved in thermoregulation

-Thermoregulation is the maintanence of a constant body temperature

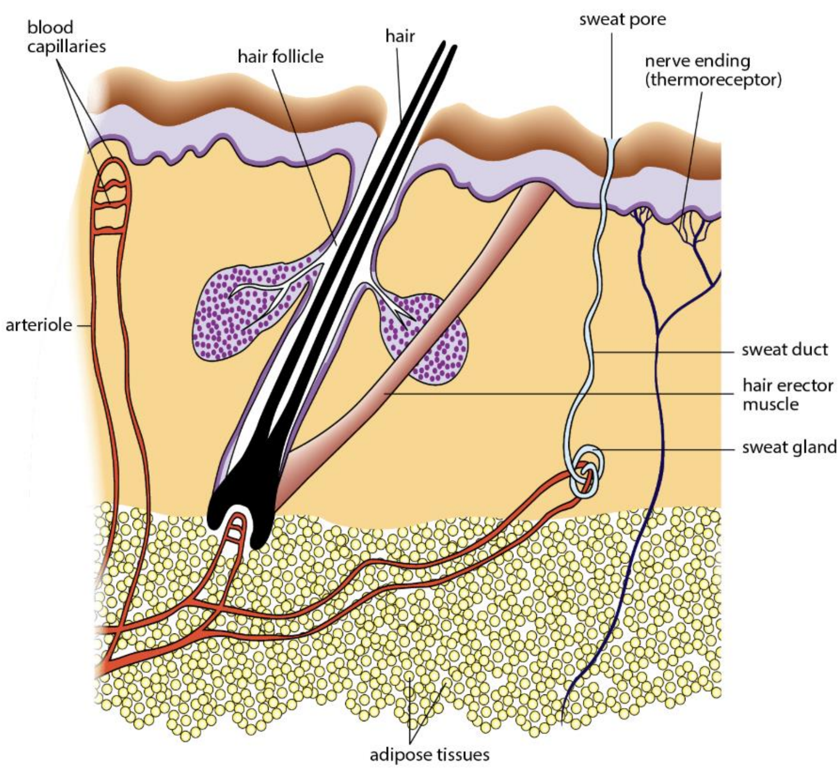


Figure 9.13 Section of the human skin

Blood vessels

-The arterioles and blood capillaries under the skin help with thermoregulation

-The arterioles constrict and dilate due to the muscles present in the arteriole walls to help regulate body temperature
-The dilation of the arterioles is called vasodilation, and with it, more blood is sent to the blood capillaries in the skin, resulting in the blushing or flushing of the skin, which helps to reduce body temperature as more heat is lost
-The constriction of the arterioles is called vasoconstriction, and with it, less blood is sent to the blood capillaries in the skin, resulting in the skin turning pale, which helps to increase body temperature as less heat is lost

Sweat glands
-Secreted sweat flows through a sweat duct to a sweat pore that opens at the skin surface
-Secreted sweat is mainly made up of water and it contains dissolved salts and small amounts of urea
-Since it contains metabolic waste products, the skin is considered an excretory organ
-Sweat is secreted continuously, but the amount of sweat secreted varies depending on internal and external conditions
-Sweat is a way the body regulates body temperature, and more sweat is produced in a hot environment and vice versa

Thermoreceptors
-The thermoreceptors under the skin detect temperature changes

How is heat gained by the body?

-Heat is released within the body as a result of metabolic activities such as cellular respiration, and since high amounts of respiration take place in the muscles and liver, a large amount of heat is released there, and the heat is then redistributed to the rest of the body via the bloodstream
-The body also gains heat through vigorous exercise, eating hot food or being in warm environments

How is heat lost by the body?

-Heat is lost through the skin through blood vessels under the skin, through the evaporation of water in sweat from the surface of the skin, through faeces and urine, or through air that is exhaled

Thermoregulation

-The hypothalamus in the brain monitors and regulates body temperature
-It receoves information from two sources, the thermoreceptors in the skin and hypothalamus, which detect changes in environmental temperature and blood temperature respectively
-On a hot day, the rate of heat loss of the body decreases, leading to a higher internal body temperature, which is detected by the thernoreceptors in the hypothalamus, and the higher external temperature is detected by the thermoreceptors in the skin

-The hypothalamus then sends out nerve impulses to relevant body parts
-The arterioles in the skin dilate, allowing more blood to flow through the capillaries in the skin, increasing the amount of heat lost through the skin
-The sweat glands become more active and produce more sweat and as more water in the sweat evaporates from the surface of the skin, more heat is lost from the body
-The metabolic rate of the body is decreased, reducing heat gained within the body
-This all leads to a decrease in body temperature, eventually decreasing to a regular body temperature
-This is a form of homeostatic control, and the opposite happens when body temperature drops
-However, when the body temperature is too low, shivering occurs, where the rapid contraction and relaxation of skeletal muscles help increase the amount of heat released
-The adipose tissues also help regulate body temperature by acting as an insulator

Chapter 10: The Nervous System and the Eye

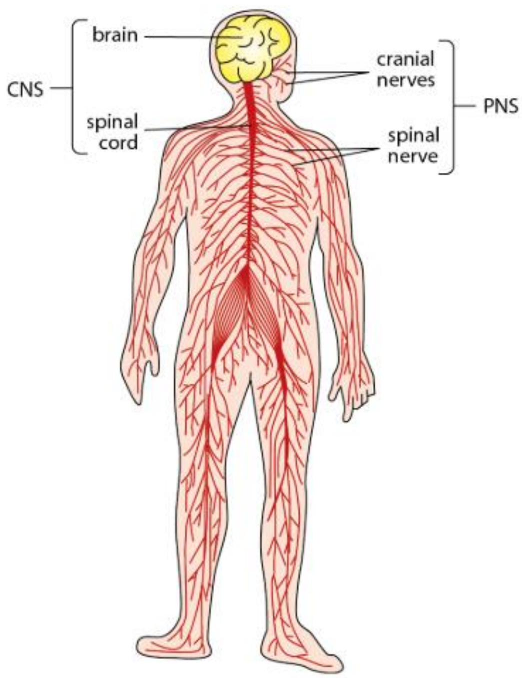
What is sensitivity?

-An organism can react to changes in its environment
-Any changes in the environment that causes an organism to react is called a stimuli
-An organism's reaction to a stimulus is called a response

Voluntary and involuntary actions

-Voluntary actions are activities that are controlled consciously
-Examples include walking, studying and eating
-Involuntary actions are activities that are not controlled consciously
-Examples include breathing, peristalsis and our heart beating

Components of the nervous system



-The nervous system is made up of the central nervous system (CNS) and the peripheral nervous system (PNS)
-The nervous system coordinates and regulates body functions, maintains body processes and allows the body to respond to stimuli appropriately.
-The central nervous system is made up of the brain and spinal cord
-The peripheral nervous system is made up of the cranial and spinal nerves, as well as the sense organs

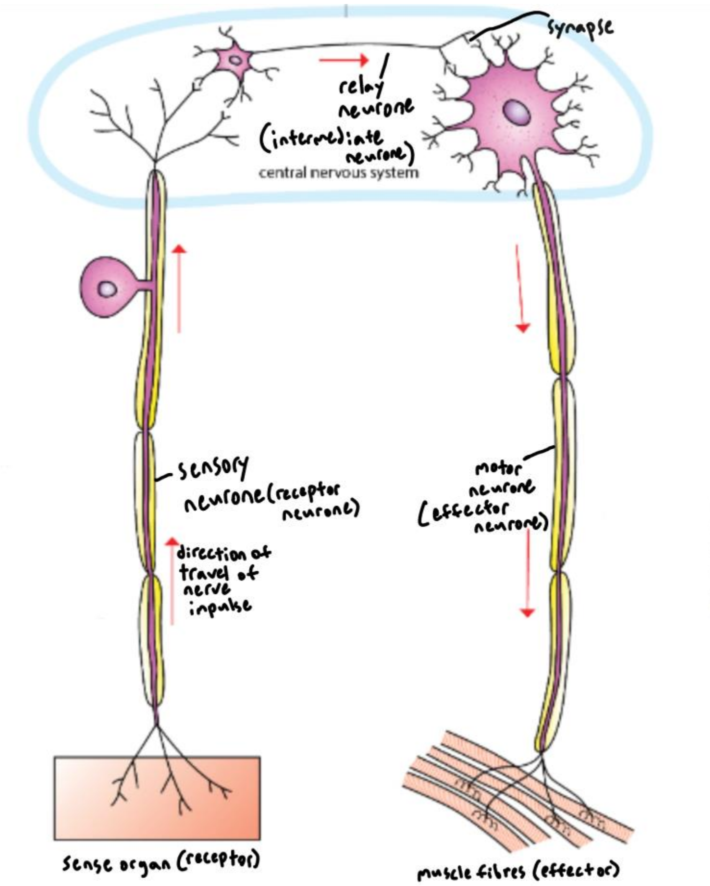
How do the CNS and PNS work together?

-When there is a stimulus, the receptors in our sense organs are stimulated to produce nerve impulses

-These nerve impulses are transmitted by nerves to the central nervous system
-The central nervous system then sends the nerve impulses to the effectors, which are either muscles or glands

Neurones

-Nerve cells are called neurones



-The sensory neurone transmits nerve impulses from the receptors to the central nervous system
-The relay neurone transmits nerve impulses from the sensory neurone to the motor neurone, located in the central nervous system
-The motor neurone transmits nerve impulses from the central nervous system to the effectors
-The junction between the neurones is called the synapse
-Nerve impulses are transmitted by a chemical called a neurotransmitter released by the neurones as the nerve impulses cannot directly travel from one neurone to another due to the tiny space between them

Structure of neurones

-Although the size and shape of neurones differ in different parts of the nervous system, they are very similar

-Each neurone consists of a cell body containing a nucleus and cytoplasm, and a number of nerve fibers
-A nerve fiber is a strand of cytoplasm extending from the cell body
-A nerve is a bundle of nerve fibers
Motor neurone

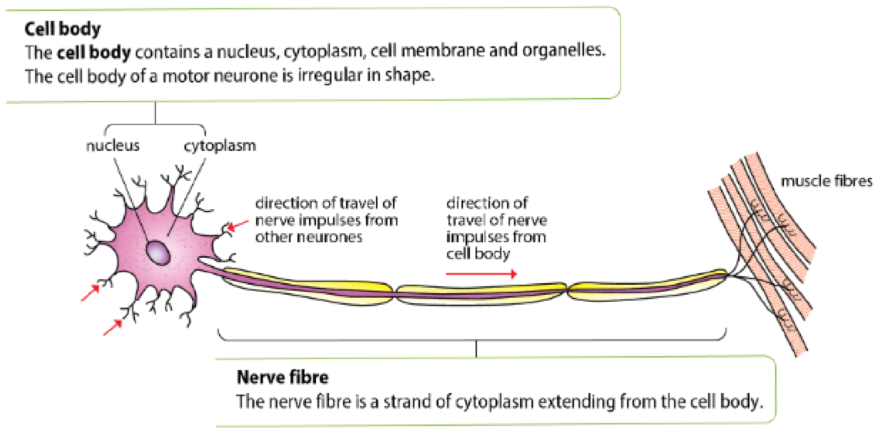


Figure 10.4 Structure of a motor neurone

Sensory neurone

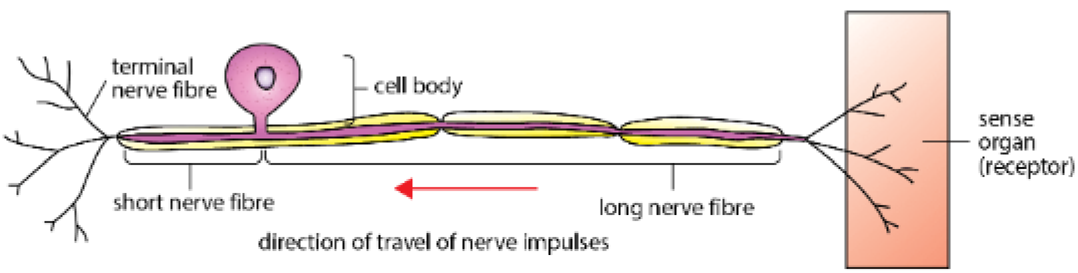


Figure 10.5 Structure of a sensory neurone

-The sensory neurone has a circular cell body

How do the brain, spinal cord and spinal nerves work together?

-The brain which is contained in and protected by the skull, has a spinal cord running from it down the back of the body
-The spinal cord passes through the vertebral column, or backbone, which protects it
-Spinal nerves connect the spinal cord to various parts of the body

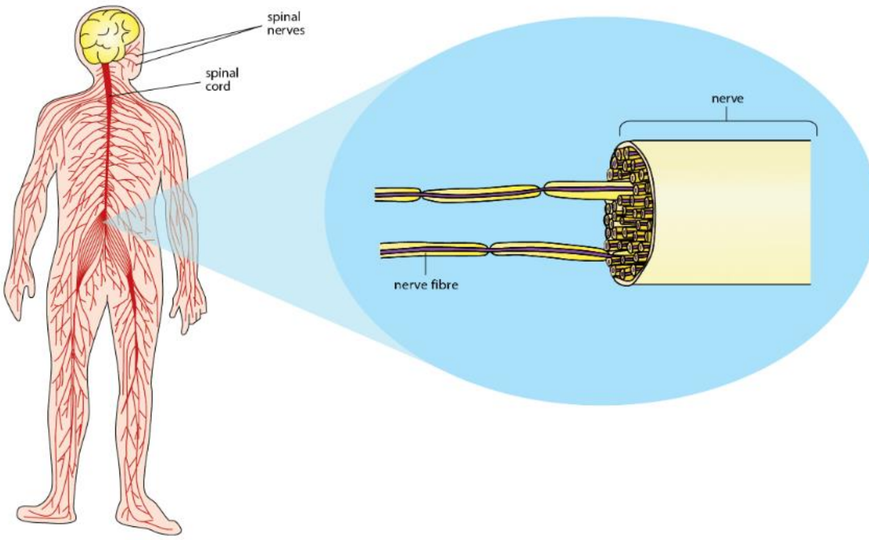
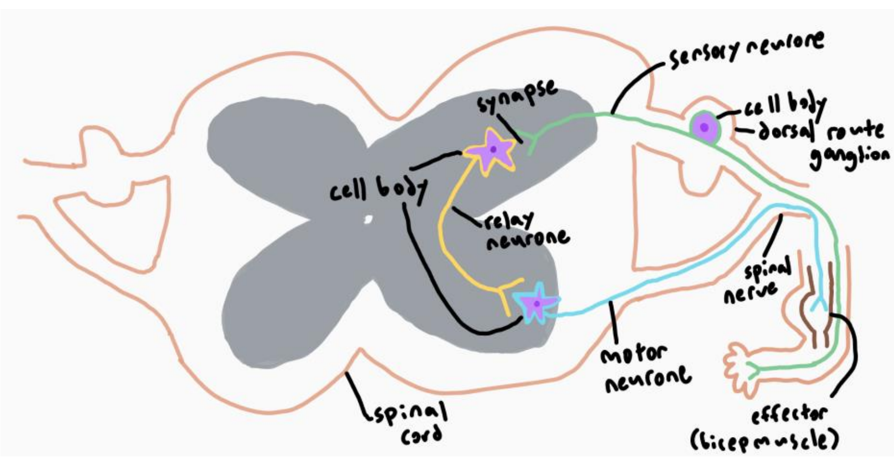


Figure 10.7 Spinal cord and spinal nerves in the human body

What is a reflex action?

-A reflex action is an immediate response to a specific stimulus without conscious control by the brain.
-There are two types of reflex actions, cranial and spinal reflexes
-Cranial reflexes are controlled by the brain and spinal reflexes are controlled by the spinal cord
-The brain and spinal cord are reflex centres
-Different reflexes have different reflex centres depending on their distance from the reflex centre



Describing the pathway involved in a named receptors

-(Receptors) are stimulated by the (stimulus)
-A nerve impulse is generated which is transmitted along the sensory neurone to the (central nervous system)
-Where it is transmitted across another synapse to the motor neurone to reach the (effector)
-The (action of effector) will cause an (appropriate response)

-An example of this is the knee jerk reflex

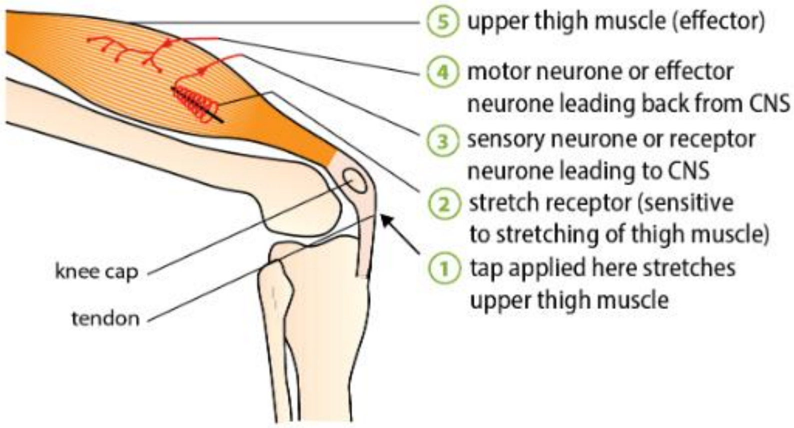
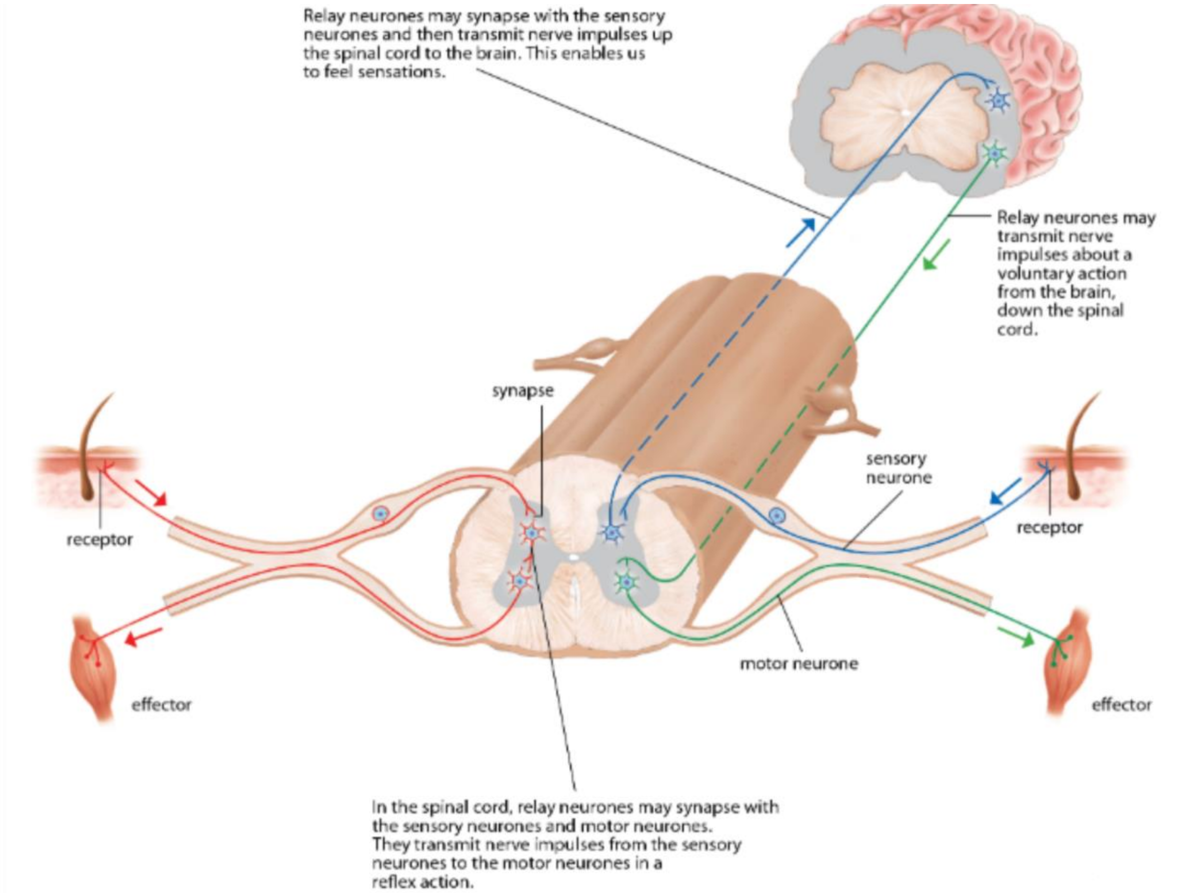


Figure 10.15 Knee-jerk reflex

Reflex arc

-A reflex arc is the shortest pathway by which nerve impulses travel from the receptor to effector in a reflex action
-The nervous pathway in a reflex arc can be written as receptor -> sensory neurone -> relay neurone (CNS) -> motor neurone -> effector
-Nerve impulses are always transmitted to the brain, even if they are not part of the reflex arc

Different pathways of nerve impulses



-The red pathway is a reflex arc
-The blue pathway is when nerve impulses produced by receptors are transmitted to the brain
-The green pathway is when nerve impulses from the brain are transmitted to effectors

Voluntary vs reflex actions

Voluntary	Reflex
Controlled by conscious will	Not controlled by conscious will
Specific stimulus is not required	Specific stimulus is required
May not involve sensory neurones	Involves sensory neurones
Nerve impulses are generated in either the brain or receptor	Nerve impulses are generated at the receptor
Regulated by the brain	Regulated by the brain or spinal cord
Both involve nerve impulses transmitted along motor neurones	

Both involve the central nervous system

External structure of the eye

-The human eye is made up of the conjunctiva, eyelash, eyelid, tear gland, iris, pupil and rectus muscles
-The eyeball lies in a hollow in the skull called the orbit

Conjunctiva
-The conjunctiva is a thin transparent membrane that covers the sclera in the front
-It is a mucous membrane, secreting mucus to help keep the front of the eyeball moist

Eyelash
-The eyelashes help shield the eye from dust particles

Eyelid
-The eyelid protects the cornea from mechanical damage and can be partially closed in a process called
squinting
-Squinting prevents too much light from entering the eyelid and damaging the retina
-Blinking spreads tears over the cornea and conjunctiva, and wipes dust particles off the cornea

Tear gland
-The tear gland lies at the corner of the upper eyelid and secretes tears that wash away dust particles, keep the cornea moist for oxygen to dissolve so that oxygen can diffuse into the cornea, and to lubricate the conjunctiva, to help reduce friction when the eyelids move

Iris
-The iris is a circular sheet of muscles which controls the size of the pupil and therefore the amount of light entering the eye, and contains a pigment giving the eyes its colour

Pupil
-The pupil is a hole at the centre of the iris, which allows light to enter the eye

Rectus muscles
-The rectus muscles are responsible for moving the eye
-The eyeball is also attached to the skull by the rectus muscles
-They are antagonistic, so when one relaxes, the other contracts
-There are 3 sets of rectus muscles in each eye

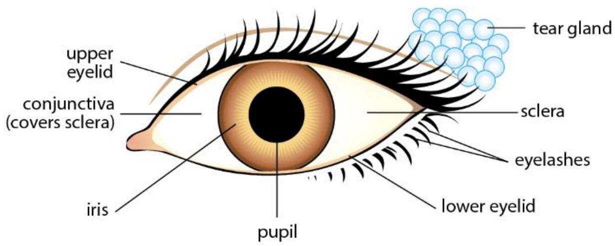


Figure 10.19 Parts at the front of the eye

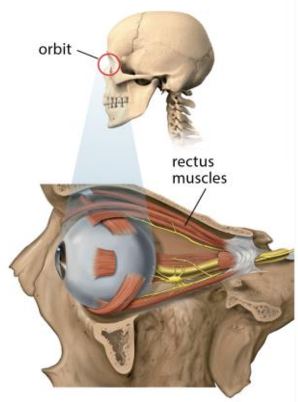


Figure 10.18 Rectus muscles of the eyeball

Internal wall of the eye

-The wall of the eyeball has three layers, the sclera, choroid and retina

Sclera
-The sclera, or sclerotic coat is a tough, white outer covering of the eyeball which is continuous with the cornea, which is a dome shaped transparent layer at the front of the eyeball
-It protects the eye from mechanical damage
-It is the uppermost layer of the eyeball

Choroid
-The choroid is the black pigmented middle layer which prevents the internal reflection of light
-It also contains blood vessles that brings oxygen and nutrients to the eyeball, while removing metabolic waste products from the eyeball
-It is the middle layer of the eyeball

Retina
-The retina is the light sensitive layer on which images are formed
-It contains light sensitive cells called photoreceptors, which are connected to the nerve endings from the optic nerve
-It is the innermost layer of the eyeball

Internal structure of the eye

-The eye is also made up of the cornea, fovea, optic nerve, ciliary body, suspensory ligament, vitreous chamber, blind spot, lens and aqueous chamber

Cornea
-A dome shaped transparent layer continuous with the sclera
-It refracts light rays into the eye, and it causes the greatest refraction of light into the eye

Fovea
-It is a small yellow depression in the retina, situated directly behind the lens, and is where images are usually focused
-The fovea contains the greatest number of cones but do not contain rods
-It enables people to have detailed colour vision in bright light

Optic nerve
-It is the nerve that transmits nerve impulses to the brain when photoreceptors in the retina are stimulated

Ciliary muscles
-Controls the curvature and thickness of lens

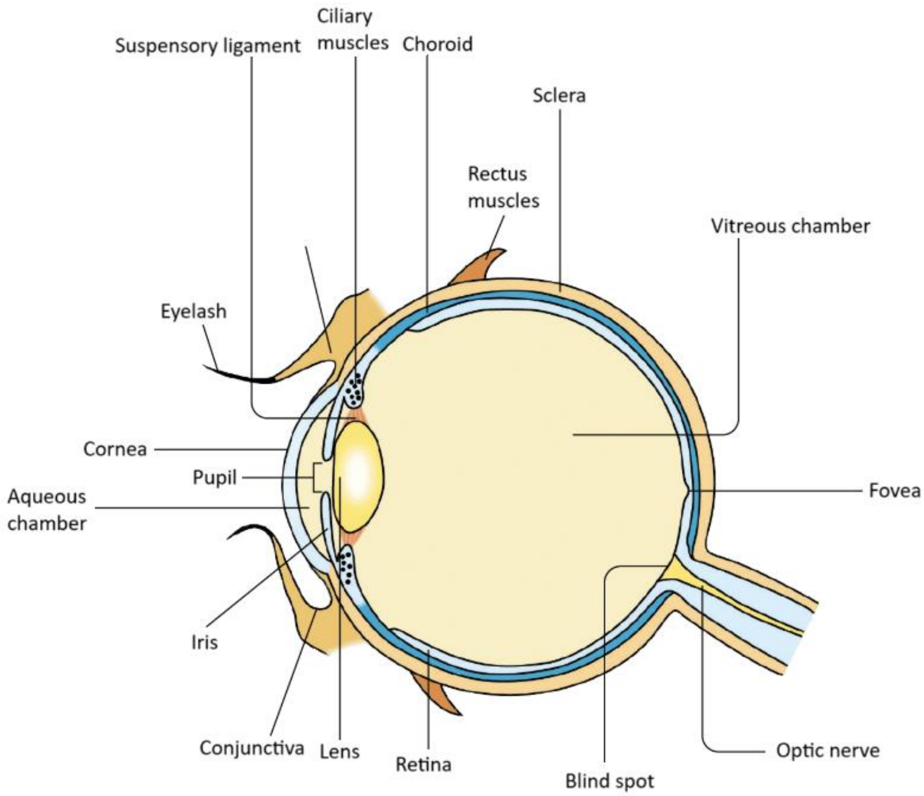
Suspensory ligament
-It is the connective tissue that attaches the edge of the lens to the ciliary muscles

Vitreous chamber
-Space behind the lens
-Filled with vitreous humour, a transparent, jelly like substance
-It helps keep the eyeball firm and helps to refract light onto the retina

Blind spot
-It is the region where the optic nerve leaves the eye
-It does not contain any rods or cones, hence it is not sensitive to light
-An object cannot be seen if its image falls on the blind spot

Lens
-It is a transparent, circular and biconvex structure
-It changes its curvature or thickness to focus light onto the retina

Aqueous chamber
-Space between the lens and cornea
-Filled with aqueous humour, a transparent, watery fluid
-It helps keep the front of the eyeball firm and helps refract light into the pupil



Rods and cones

-Cones enable us to see colours in bright light, but do not work well in dim light, and rods are more sensitive to light than cones, allowing us to see in dim light, but only in black and white
-Rods are found everywhere in the retina except the fovea

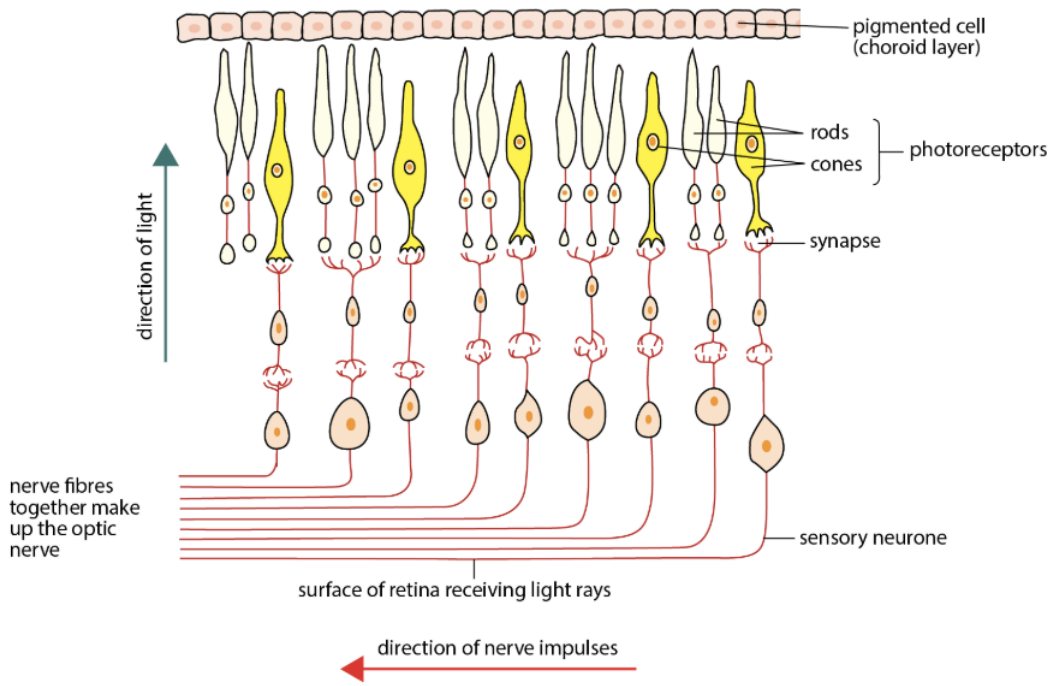


Figure 10.21 A section through the retina

Pupil reflex

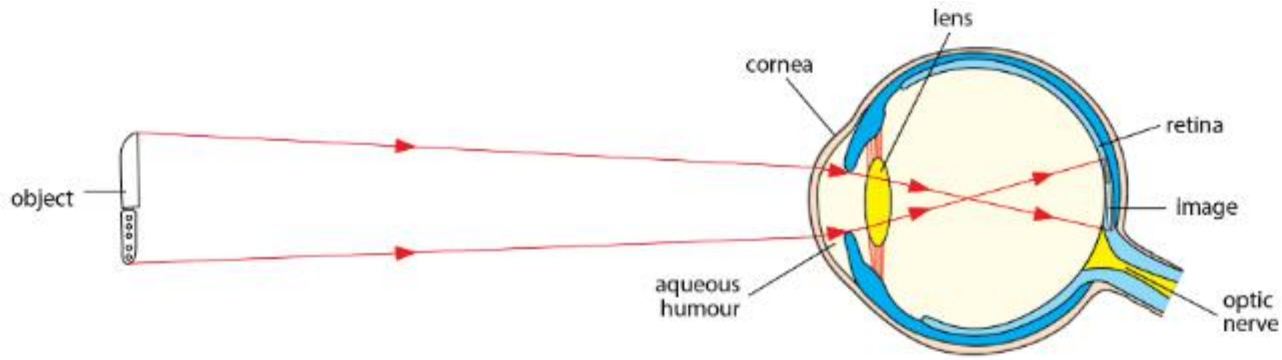
-To see clearly, an appropriate amount of light must enter the eye
-Hence, when there is not enough light, the pupil will dilate, and when there is too much light, the pupil will constrict
-This is known as the pupil reflex
-The photoreceptors in the retina are stimulated
-A nerve impulse is then produced and the sensory neurone in the optic nerve transmits the nerve impulse across a synapse to the relay neurone in the brain
-The motor neurone then transmits the nerve impulses to the iris muscles to dilate and contract the pupil

Muscles in the iris

-There are two muscles in the iris, the radial and circular muscles
-They are antagonistic
-When the circular muscles contract from a relaxed state, the radial muscles relax from a contracted state, and the pupil constricts
-When the circular muscles relax from a contracted state, the radial muscles contract from a relaxed state, and the pupil dilates

Seeing

-In order to see, light rays are refracted through the cornea and the aqueous humour and onto the lens
-The lens causes further refraction and the rays are brought to a focus on the retina
-The image on the retina stimulates either rods or cones, for dim and bright light respectively
-The image formed on the retina are upside down, laterally inverted, and diminished (smaller than actual object)



Focusing

-Focusing, also called accommodation, is the adjustment of the lens of the eye so that clear images of objects at different distances are formed on the retina
-Focusing is necessary so that objects at different distances can be seen

Focusing on a distant object

-When a person is focusing on a distant object, the light rays reflecting off the object are almost parallel to each other when they reach the eye
-These light rays are then refracted through the cornea and aqueous humour into the pupil
-Since the rays are almost parallel, the lens needs to be thinner as only a little refraction is needed
-The ciliary muscles relax from a contracted state, pulling on the suspensory ligaments
-The suspensory ligaments become taut from a slackened state, pulling on the edge of the lens
-The lens becomes thinner and less convex and light rays from the distant object are sharply focused on the retina

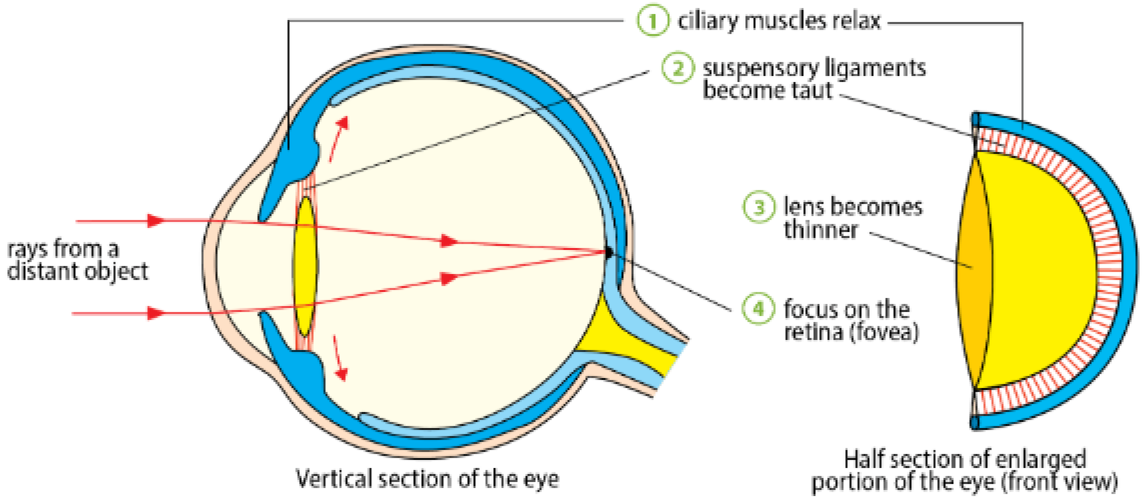


Figure 10.29 Focusing on a distant object

Focusing on a nearby object

-When a person is focusing on a nearby object, the light rays reflecting off the object are diverging when they reach the eye
-These light rays are then refracted through the cornea and aqueous humour into the pupil
-Since the rays are diverging, the lens needs to be thicker to bend the light rays more
-The ciliary muscles contract from a relaxed state, relaxing their pull on the suspensory ligaments
-The suspensory ligaments slacken from a taut state, relaxing their pull on the edge of the lens
-The lens becomes thicker and more convex and light rays from the nearby object are sharply focused on the retina

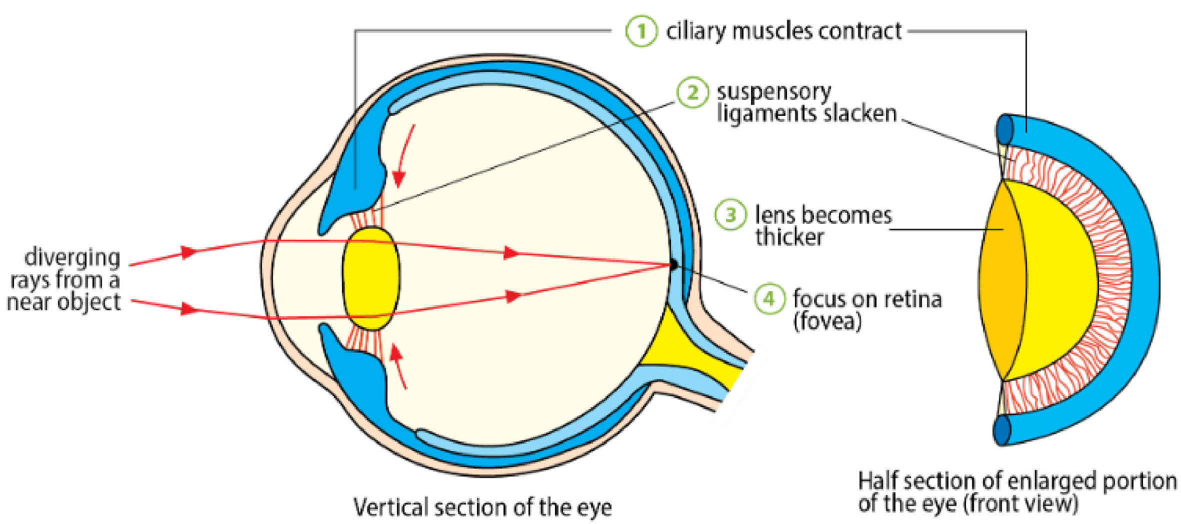


Figure 10.30 Focusing on a near object

Chapter 11: Infectious Diseases in Humans

Signs and symptoms

-A sign of a disease can be observed and measured
-Examples include rashes, fever, coughing and vomiting
-A symptom of a disease can be described or felt by the patient
-Examples include headaches, fatigue and nausea
-Not all signs and symptoms are caused by the same pathogen

Infectious and non infectious diseases

-Infectious diseases are caused by pathogens and can be spread from one person to another
-Examples of pathogens include bacteria and viruses
-Examples of infectious diseases include influenza, HIV or pneumoccal disease
-Non infectious diseases are not caused by pathogens and cannot be spread from one person to another
-They can be inherited or may be caused by factors such as malnutrition, environmental factors or lifestyle choices
-Examples of non infectious diseases include liver cirrhosis, coronary heart disease, atherosclerosis, type 2 diabetes or sickle cell anaemia

How are infectious diseases spread?

Through droplets in the air
-When a person coughs or sneezes, numerous tiny respiratory droplets are expelled, which may contain pathogens
-Anyone within a close range of around 1 metre can become infected
-Examples include influenza or COVID-19
-To try and prevent the spread of infectious diseases through droplets in the air, people are advised to wear a mask, practice social distancing, and staying indoors

By direct contact
-Some diseases can only be spread through direct contact, such as through transmitting bodily fluids during sexual intercouse in the case of sexually transmitted infections (STIs), from mother to baby when breastfeeding, or when blood from an infected person comes into contact with the mucous membrane or bloodstream of an infected person
-Examples include human immunodeficiency virus (HIV), syphillis or hepatitis B
-To try and prevent the spread of infectious diseases through direct contact, people can practice safe sex using condoms, or by not sharing razors or needles

By contaminated food and water
-Food and water can be contaminated by pathogens
-This can occur when food and water are not properly handled, such as when food is undercooked
-Examples include cholera or salmonella

-To try and prevent the spread of infectious diseases through contaminated food and water, people can practice hygienic food preparation and storage, having good personal hygiene, maintaining a clean water supply and maintaining proper sewage treatment

Structure of bacteria

-Bacteria do not have a membrane bound nucleus
-They have a single circular DNA as their genetic material
-They have a cell wall, ribosomes, small circular DNA molecules called plasmids and one or more flagella
-The single DNA is essential for the bacteria's survival, but the plasmids are not
-Some bacteria are pathogenic and can cause diseases, while some are non pathogenic and do not cause diseases

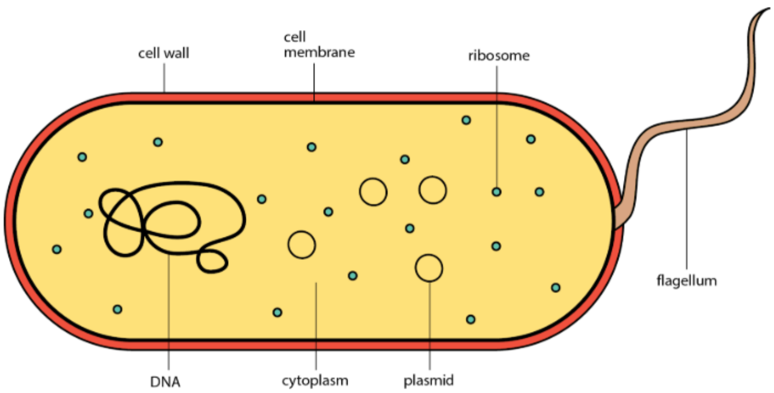


Figure 11.9 Section of a bacterial cell

Structure of a virus

-Viruses have a protein coat enclosing their genetic material, which is either DNA or RNA
-They do not have any cellular structures, such as a cell membrane or organelles
-Unlike living things, they do not grow, feed, respire or excrete
-They can only reproduce when they enter a living cell, which acts as their host, as the host cell contains the necessary materials for reproduction, such as enzymes and organells like ribosomes

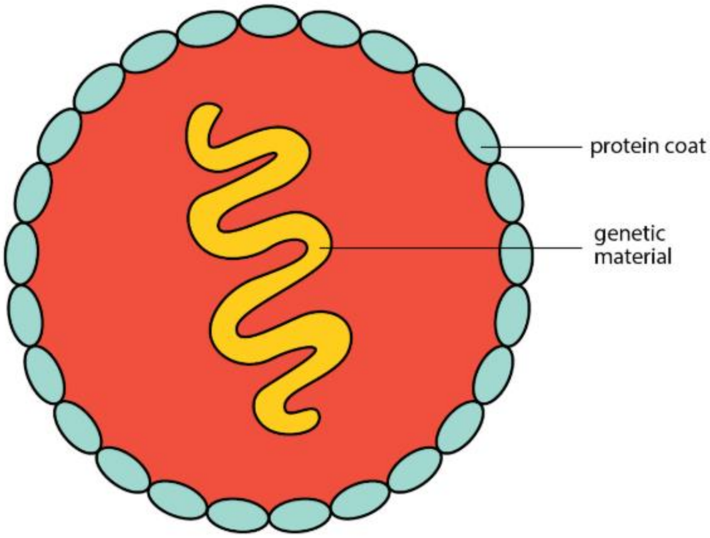


Figure 11.10 Section of a typical virus

Influenza

-Influenze, or flu, is a disease that attacks the respiratory system
-Most people recover from influenza within two weeks, but it can lead to complications such as pneumonia (infection of the lungs)
-Influenza is caused by the influenza virus
-Influenza is transmitted through droplets in the air
-Influenza symptoms include, high fever, headache, stuffy nose, cough, sore throat and muscle aches

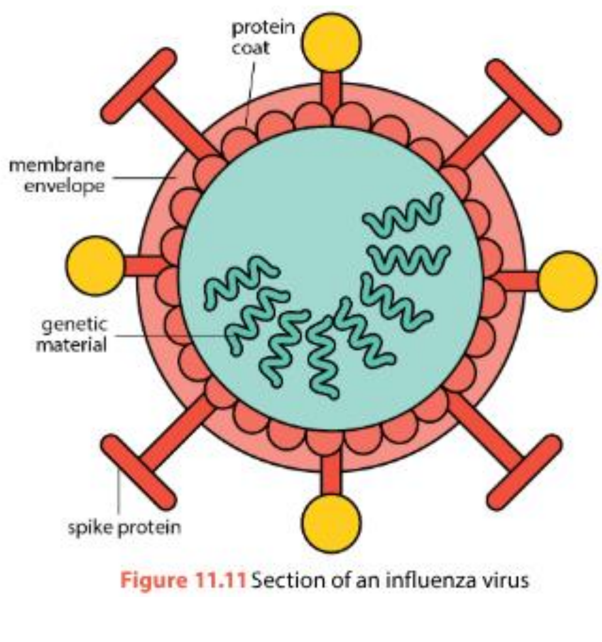


Figure 11.11 Section of an influenza virus

Pneumococcal disease

-Pneumococcal disease is caused by the pneumococcus bacteria, also known as Streptococcus pneumoniae
-The bacteria can attack different parts of the body, such as by causing middle ear infection, pneumonia, inflammation of the membranes in the brain and spinal cord, and sepsis (infection of the blood)
-Pneumococcal disease is transmitted through droplets in the air
-Pneumococcal disease symptoms include high fever, headache, vomiting, cough, chest pain and shortness of breath

Reducing transmission of diseases

<table>
<tr><td>Influenza</td><td>Pneumococcal disease</td></tr>
<tr><td colspan="2">-Taking their respective vaccination
-Avoiding close contact with sick people
-Covering your mouth and nose with a tissue when coughing or sneezing when sick
-Wearing a mask when not feeling well
-Frequent hand washing
-Avoiding touching your eyes, nose and mouth</td></tr>
<tr><td>Taking antiviral drugs as prescribed by a doctor</td><td>Taking antibiotics as prescribed by a doctor</td></tr>
</table>

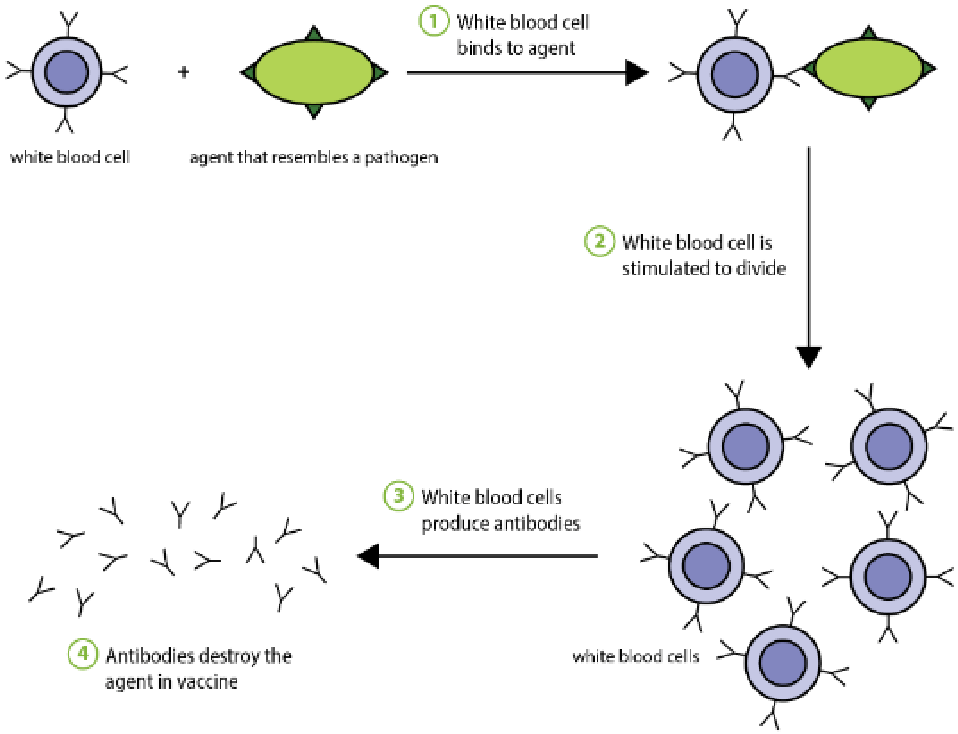
What are vaccines?

-A vaccine contains an agent that resembles a pathogen and prevents infectious diseases by stimulating white blood cells to quickly produce antibodies when the pathogen invades
-The process of receiving a vaccine is called vaccination
-Some vaccines are administered orally, while others are taken as an injection
-Vaccines can be used against all pathogenic infections, not just viral infections

How do vaccines work?

-Substances that can trigger the formation of antibodies are called antigens
-When foreign particles such as pathogens enter our bloodstream, they stimulate our white blood cells to produce antibodies against them
-Proteins on the surface of pathogens are examples of antigens
-When a vaccine enters the body, it stimulates the white blood cells to produce antibodies as white blood cells binds to the agent from the vaccine
-The white blood cells are then stimulated to divide and these white blood cells then produce antibodies

-These antibodies then destroy the agent in the vaccine
-Some of these white blood cells remain in the bloodstream as memory cells, so in the future, if live pathogens enter the bloodstream, the white blood cells will quickly recognise them and produce antibodies to destroy the pathogens by binding to them before they can infect our cells
-Antibodies are proteins that are produced to destroy pathogens
-They are specific in action, hence antibodies that destroy one pathogen will be ineffective against another pathogen
-Antibodies can also tag a pathogen for destruction by white blood cells



What are antibiotics?

-Antibiotics are drugs used to treat bacterial infections
-They are made by microorganisms and are used to kill or inhibit the growth of bacteria or fungi
-They intefere with the growth and metabolic activities of the bacteria
-Antibiotics are ineffective against viruses
-Many antibiotics are chemically modified to make them more effective in treating diseases

How do antibiotics work?

Inhibits the synthesis of bacterial cell wall
-Some antibiotics prevent the synthesis of bacterial cell walls
-When these cell walls are weakened, water enters the cell by osmosis
-The bacterial cell then expands, bursts and dies

Inhibit cell membrane function
-Some antibiotics inhibit cell membrane function by breaking up the bacterial cell membrane
-Without the cell membrane, the bacterial cell is no longer protected from its environment as any substances can move into the bacterial cell

Inhibit protein synthesis in ribosome
-Some antibiotics bind to bacterial ribosomes, preventing the ribosomes from taking part in protein synthesis and thereby inhibiting growth

Inhibiting enzyme action in cytoplasm
-Bacteria require a vitamin called folic acid for growth
-Some antibiotics inhibit the enzyme needed for the synthesis of folic acid
-This inhibits the growth of the bacteria

Why are antibiotics ineffective against viruses?

-Antibiotics act on bacterial cell walls, but viruses do not have cell walls, instead having a protein coat
-Antibiotics break up cell membranes, but viruses do not have cell membranes
-Antibiotics act on ribosomes, inhibiting protein synthesis and growth, but viruses do not have ribosomes and do not grow
-Therefore, a person with a viral infection can only recover through rest, or through antiviral drugs which help the body fight the viruses

Antibiotic resistance

-Antibiotic resistance is when a bacteria becomes increasingly resistant to antibiotics
-This occurs when in a population of bacteria, some are more sensitive to an antibiotic, while some are less sensitive
-When the antibiotic is taken, the sensitive cells are killed off, while those that are less sensitive have a higher chance of surviving
-If the prescribed antibiotic dose is completed, there is a higher chance these less sensitive bacteria are killed
-If the prescribed does is not completed, the less sensitive bacteria will multiply and increase in numbers
-Over time, subsequent generations of these bacteria will become less sensitive to this antibiotic, and eventually these bacteria will become resistant to this antibiotic and the antibiotic cannot kill these bacteria

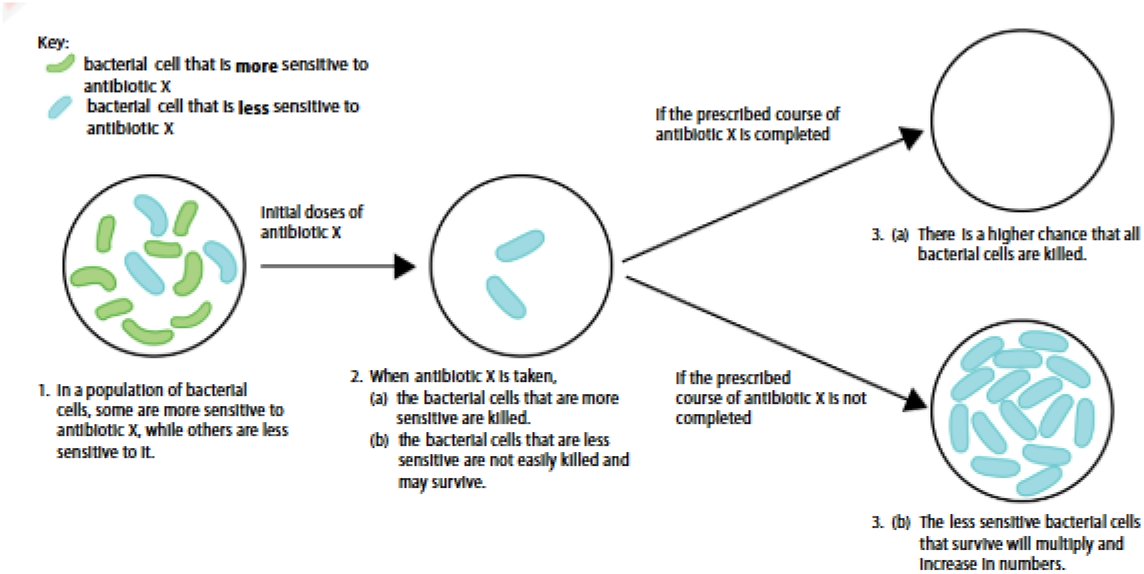


Figure 11.20 Possible outcomes when antibiotic X is taken to treat a bacterial infection

Preventing antibiotic resistance

-In order to reduce antibiotic resistance, we can do the following
-Not misusing or overusing antibiotics
-Completing the full course of prescribed antibiotics
-Using antibiotics only for bacterial infections and only when necessary

Chapter 12: Nutrition and Transport in Plants

Photosynthesis

-Photosynthesis is a process in which light energy is absorbed by chlorophyll and converted into chemical energy
-Chemical energy is used to synthesise glucose from water and carbon dioxide and oxygen is released as a by product of this reaction
-Word equation: carbon dioxide + water (light energy absorbed by chlorophyll) -> glucose + oxygen
-Chemical equation: $6CO_2 + 6H_2O$ (light energy absorbed by chlorophyll) -> $C_6H_{12}O_6 + 6O_2$

How can we study photosynthesis?

-Glucose is formed during photosynthesis
-If there is starch in the leaves, it indicates that photosynthesis has taken place
-Destarching of plant must be carried out before the experiment
-This can be done by placing the experimental set up in the dark for 2 days
-This ensures that no starch is left in the leaves as it is used up
-To study if light is necessary for photosynthesis, only one leaf is needed, instead of the whole plant
-To study if carbon dioxide is necessary for photosynthesis, soda lime and potassium hydroxide is used to absorb the carbon dioxide gas
-A polyethylene bag is put around the pot of the plant as there are decomposers in the soil which release carbon dioxide during respiration
-To study if gas if given out during photosynthesis, an aquatic plant is placed in the set up shown below
-The gas produced during photosynthesis is collected in the test tube
-When this gas is tested with a glowing splint, it will reignite as the gas is oxygen and oxygen is needed for combustion
-Sodium hydrogencarbonate or sodium bicarbonate is added to the water to provide carbon dioxide for the plants]
-In order to study the effect of light intensity, carbon dioxide concentration and temperature, the distance between the lamp and the set up, the concentration of sodium bicarbonate solution and the temperature of the water bath is changed respectively
-The volume of oxygen gas released is then measured with a gas syringe

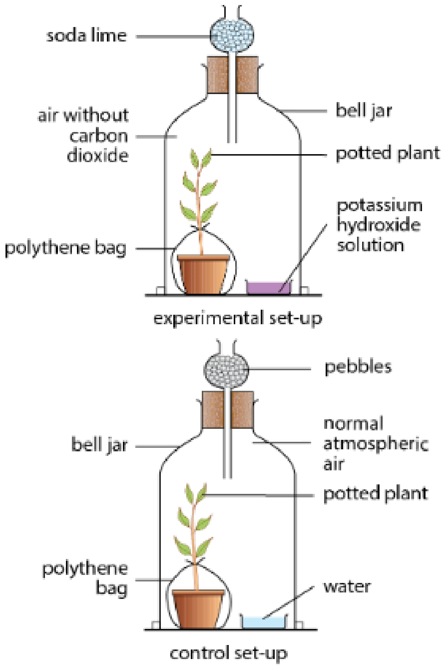


Figure 12.30 Experimental set-up to find out whether carbon dioxide is necessary for photosynthesis

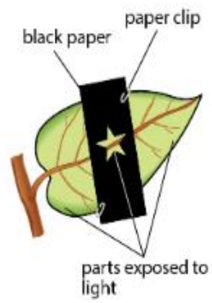


Figure 12.27 Place a leaf between two pieces of black paper.

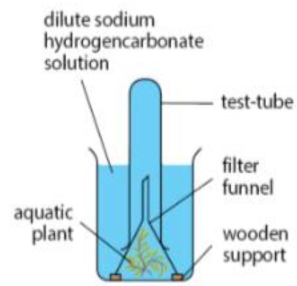


Figure 12.31 Experimental set-up to find out what gas is given off during photosynthesis

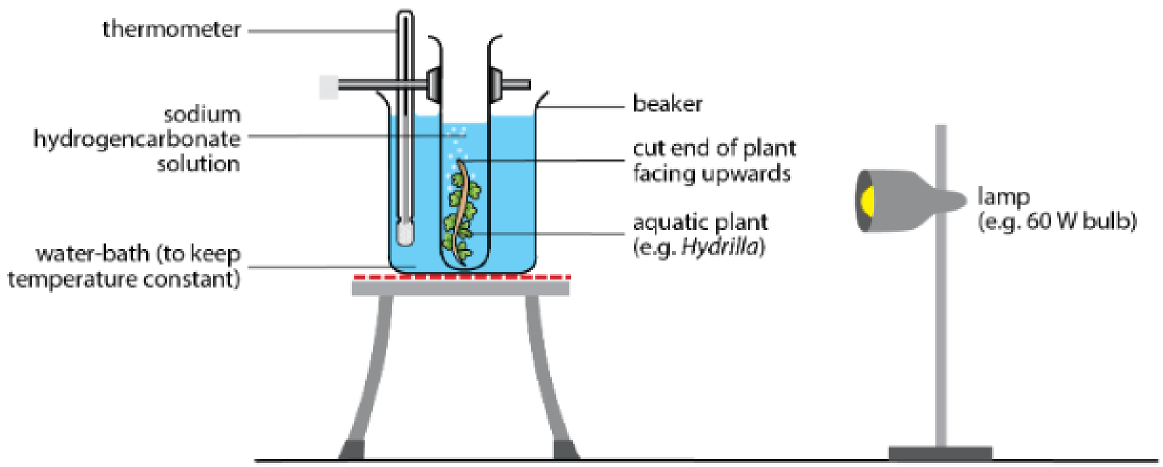
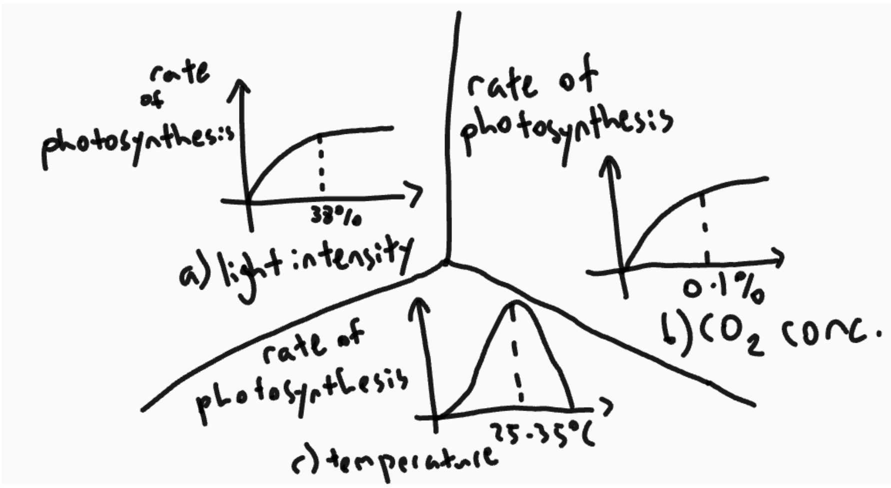


Figure 12.33 Experimental set-up to investigate the effect of different light intensities on the rate of photosynthesis

What is a limiting factor?

-A limiting factor is a factor that affects the rate of a reaction
-The rate of reaction cannot increase unless the value of the limiting factor is increased
-In photosynthesis, the limiting factors are usually light intensity, carbon dioxide concentration and temperature
-Since a suitable temperature is required, photosynthesis is an enzyme dependent reaction
-Thus, light intensity, carbon dioxide concentration and outside temperature can all affect photosynthesis

-When there is more light energy absorbed by the chlorophyll, there is more light energy converted to more chemical energy, which helps to synthesise glucose, increasing the rate of photosynthesis
-However, when the light intensity reaches a constant point, the rate of photosynthesis remains constant, which is called the light saturation point
-It is the same for carbon dioxide concentration
-When the temperature is too high, the enzymes responsible for photosynthesis start to denature, reducing the rate of photosynthesis



What happens to glucose after photosynthesis?

-Glucose is used in aerobic respiration for energy immediately
-It can also be converted to starch and stored temporarily
-Or it is converted into sucrose and transported away to be stored
-It is also converted to amino acids to form proteins
-It can also become fats

Why is photosynthesis important?

-It converts energy from the sun into chemical energy, which is needed by other organisms down the food chain
-It removes carbon dioxide from the atmosphere which helps prevent global warming as carbon dioxide is a greenhouse gas which traps heat
-It produces oxygen needed for respiration by other organisms
-It contributes to the energy stored in fossil fuels

External features of a leaf

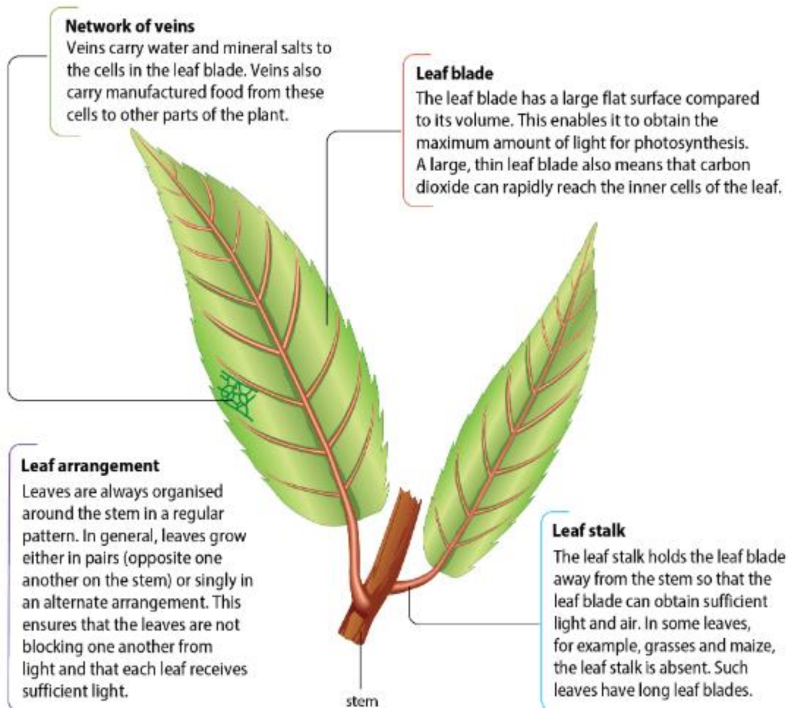
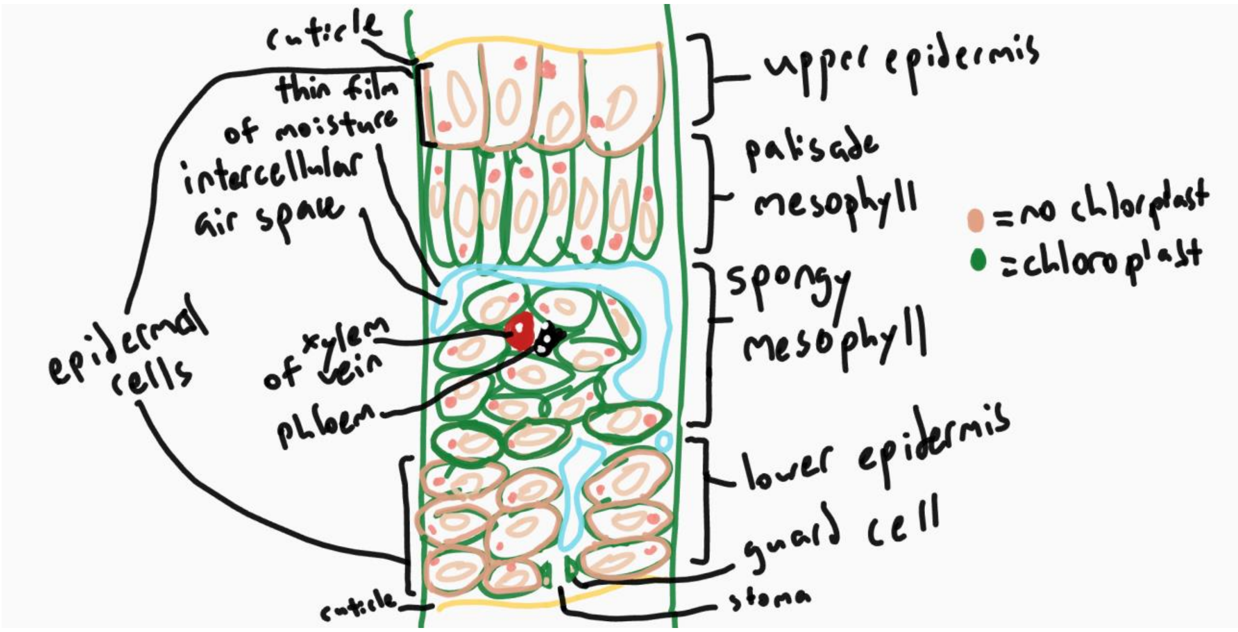


Figure 12.1 External features of a simple leaf

Internal structure of a leaf

-The internal structure of a leaf can be divided into 4 distinct layers
-The upper epidermis is the uppermost layer of the leaf
-It is responsible for protection of the leaf
-The next layer is the palisade mesophyll
-It contains a lot of chlorophyll as it is specialised for photosynthesis
-The next layer is the spongy mesophyll
-The last layer is the lower epidermis
-It is also responsible for protection of the leaf
-The leaf also contains vascular bundles, which contain xylem and phloem, which are responsible for transporting water and food respectively



How is a leaf adapted for photosynthesis?

-The guard cells, palisade mesophyll cells and spongy mesophyll cells all contain chloroplasts
-The palisade mesophyll cell contains the most chloroplasts as it is the nearest to the sun so it can trap as much light energy as possible
-The palisade mesophyll cells are positioned with its longitudinal axis, so that more cells can be packed beneath the epidermis to capture maximum light energy for photosynthesis
-The numerous large intercellular air spaces in the spongy mesophyll layer allows for higher rate of diffusion of carbon dioxide into the leaf
-The thin film of moisture around the palisade and spongy mesophyll cells allows carbon dioxide to dissolve in it
-The numerous stomata on the lower epidermis open in the presence of light for carbon dioxide to diffuse in
-Veins containing xylem and phloem situated close to the mesophyll cells to transport water to mesophyll cells, and to transport sucrose away from the leaf
-There are no chloroplasts in the upper epidermal cell, to allow for light rays to penetrate to reach the mesophyll cells for photosynthesis

How does carbon dioxide, water and mineral salts enter the leaf?

-In the presence of sunlight, the guard cells become turgid and open as water is used up during photosynthesis, decreasing the water potential and causing water to move into the cell through osmosis, allowing carbon dioxide to enter through the stomata
-When it is too hot, the guard cells become flaccid as water is lost to the heat and in order to prevent excess water loss, the stomata are closed
-Carbon dioxide diffuses into the leaf through the stomata
-It dissolves in the thin film of moisture around the mesophyll cells
-It then diffuses into the cells

-In order to demonstrate the presence of stomata in a leaf, a leaf is placed in very hot water
-Bubbles will then form on the leaf, with more bubbles on the underside
-This is because heat causes the air in the intercellular air space to expand, allowing it to escape through the stomata
-Water and mineral salts are transported through the xylem vessels from the roots to the leaf
-Once out of the veins, the water and mineral salts move from cell to cell right through the mesophyll of the leaf

The xylem

-The xylem transports water and mineral salts from the roots to the other parts of the plant
-It also provides mechanical support for the plant

Adaptations of the xylem

-Xylem tissue consists of xylem vessels
-Xylem vessels are a long hollow tube made up of dead cells without cross walls or protoplasm
-This helps to reduce resistance to the flow of water and mineral salts through the xylem
-Lignin is deposited in the inner walls
-It can be deposited in rings, spiral or the whole vessel is lignified except in regions called pits
-All the xylem vessels together provide mechanical support for the plant
-The more lignin there is in a xylem vessel, the older the plant

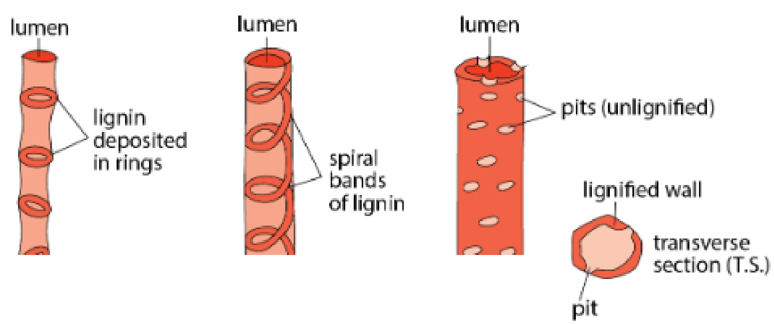


Figure 12.13 Xylem vessels showing the different patterns of lignification (three-dimensional view). Note how the whole wall of some vessels may be lignified except in regions called pits.

The phloem

-The phloem transports sucrose and amino acids from the leaves to the other parts of the plant

Adaptations of the phloem

-It consists of a column of sieve tube cells or sieve tube elements which forms a long sieve tube
-The sieve plates, which are cross walls between the cells have many minute pores
-The companion cell of each sieve tube cell provides nutrients and helps it to transport food
-Sieve tube cells have a thin layer of cytoplasm connected to cells above and below
-This allows for rapid flow of manufactured food substances through the sieve tube
-Companion cells have many mitochondria

-This provides energy though aerobic respiration, to load sugars from mesophyll cells into the sieve tubes by active transport
-This only occurs when there is not enough glucose in the leaves for it to be transported into the phloem through diffusion

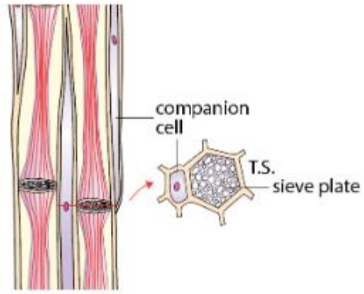


Figure 12.14 Some components of phloem tissue (three-dimensional view)

Vascular tissues in stems

-The xylem and phloem form a vascular bundle
-The xylem is the inner part as it is providing mechanical support for the plant
-The phloem is the outer part
-The cambium lies between the xylem and the phloem
-The xylem is usually thicker than the phloem in diagrams due to the lignin
-The cambium is much thinner than the phloem and xylem

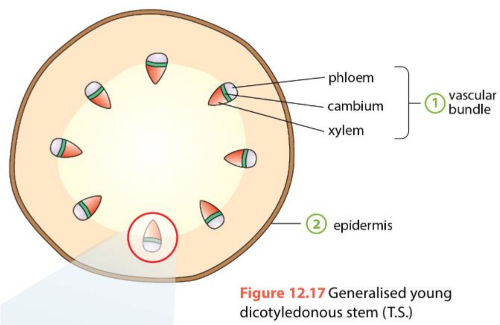
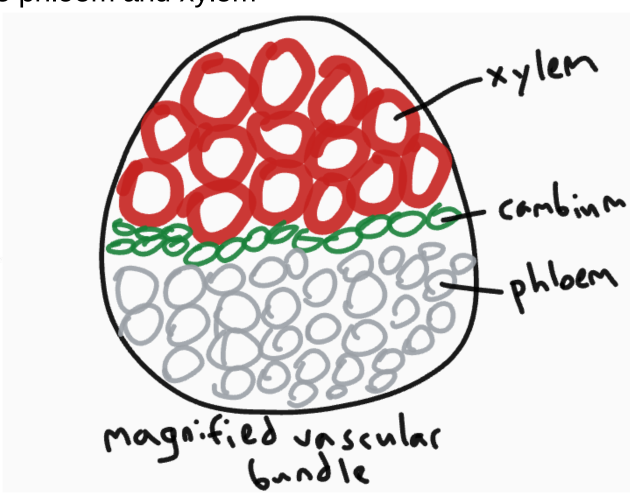
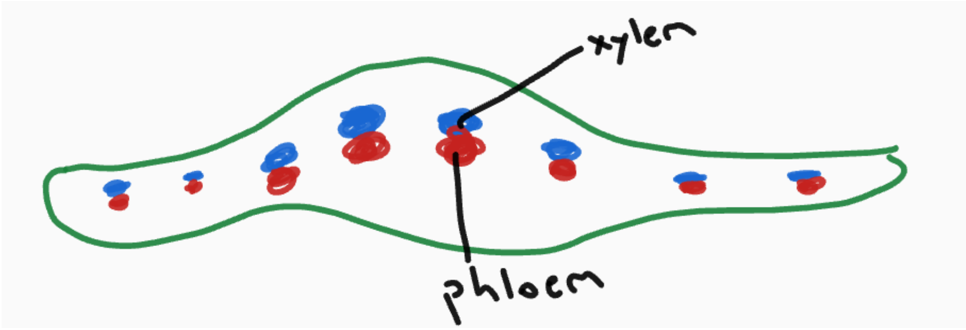


Figure 12.17 Generalised young dicotyledonous stem (T.S.)



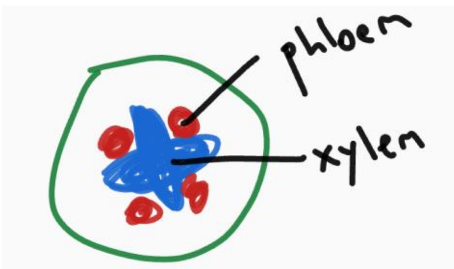
Vascular tissues in leaves

-Vascular bundles are in the spongy mesophyll layer
-The xylem is nearer to the upper surface of the leaf



Vascular tissues in roots

-In the roots, the phloem would be located on the outside, while the xylem would be located onm the inside as it is used for mechanical support



Translocation in plants

-Translocation is the transport of sucrose and amino acids, from leaves to other parts of the plants, which happens in the phloem
-Translocation is bidirectional, as sucrose and amino acids are transported upwards and downwards

Aphids and translocation

-Aphids are pests which rely on nutrients from plants for energy
-They stick their long proboscis into the phloem, as sucrose and amino acids are located in the phloem
-In order to study where the aphid is feeding on, the aphid is first anaesthised, then it is cut off with the proboscis still left in the stem
-SInce there is a higher pressure below the proboscis than above, liquid from the phloem will start flowing out
-Food tests can then be conducted on the liquid to determine the contents of the liquid
-The result for the iodine, benedict’s, biuret and ethanol emulsion test will all be negative
-This is because sucrose is not a reducing sugar, there is no starch or fats, and there are no peptide bonds within the amino acids
-This proves that the phloem only contains sucrose and amino acids

Radioactive isotopes and translocation

-A leaf is provided with CO2 containing the radioactive carbon 14 isotope
-Photosynthesis is allowed to take place
-A section of the stem is then cut off and exposed onto an x ray photographic film
-Only the phloem shows radioactivity under the x ray

Entry of water into a plant

-Each root hair grows between soil particles
-A thin film of dilute solution containing mineral salts surrounds the salt particles
-Water then moves into the root hair cells through osmosis
-The water potential of water is 0 kPa
-Water then moves from cell to cell by osmosis through the cell sap until it reaches the xylem vessels
-Mineral salts are transported through diffusion when the concentration of ions is higher than in the root hair cells
-If the concentration is lower, ions enter the root hair cell through active transport

Adaptations of the root hair cell

-The root hair cell has a long and narrow protrusion, which helps increase surface area to volume ratio to increase the rate of absorption of water and mineral sals by the root hair cell
-The root hair cell contains many mitochondria to release energy through aerobic respiration for active transport of ions into the cell
-There is the presence of partially permeable root hair cell membrane, to prevent the leakage of cell sap, which allows the root hair cell to maintain a lower water potential than the soil solution, so that water can enter the root hair by osmosis

Transpiration in plants

-Transpiration is the loss of water vapour from the aerial parts of a plant, mainly through the stomata of the leaves
-In order to demonstrate transpiration in leaves and stems, a potted plant is placed in a bell jar with a polyethylene bag around the pot
-Water will condense onto the bell jar due to transpiration
-In order to test for water, white anhydrous (no water) copper (II) sulfate is added to the liquid
-If it turns blue, water is present as hydrated (got water) copper (II) sulfate is blue
-To demonstrate transpiration in only the leaves, the leaves are cut off and the same experiment is done with the cut off leaves
-A leaves are placed in a beaker with water, along with a layer of oil on the water
-The oil and polyethylene bag is to prevent water from the soil or beaker from condensing
-In order to demonstrate that the stomata is responsible for transpiration, dry cobalt chloride paper is placed on the bottom and top of the leaf
-anhydrous cobalt (II) chloride is blue, while hydrated cobalt (II) chloride is pink

-Since the stomata is located on the underside of the leaf, the cobalt (II) chloride paper on the underside of the leaf will turn pink faster than the one on the top

Water movement in a plant

-Transpiration pull is the suction force due to transpiration pulling water up the xylem
-Water from the xylem vessels moves into the spongy mesophyll cells through osmosis
-Water evaporates from the thin film of moisture around the mesophyll cells
-Water vapour diffuses out into the atmosphere though the stomata in the process of transpiration
-It is able to diffuse as there is a lower concentration of water vapour outside the leaf compared to inside the leaf
-More water moves out of the mesophyll cells
-The water potential of the cell sap of the mesophyll cells drops, and becomes lower than the water potential of cell sap of neighbouring mesophyll cells
-Water is drawn from the cells deeper inside the leaf by osmosis
-Water is eventually drawn from the xylem vessels, and this creates a transpiration pull
-Formula for rate of transpiration: rate of transpiration = loss in mass (g) / time taken (hour)
-The loss in mass can be measured with a spring balance

Using a potometer

-A potometer measures the rate of absorption by a plant
-The rate of transpiration can be measured assuming the rate of absorption is proportional to it
-The effect of different environmental conditions can also be determined using a potometer
-The rate of absorption of water is not equal to the rate of transpiration as water taken in by the plants is used for other cellular activities like photosynthesis, thus not all the water absorbed is lost through transpiration
-Formula for rate of transpiration: rate of transpiration = difference in volume (cm^3) / time taken (min)

What affects the rate of transpiration in a plant?

Wind or air movement
-In still air, water vapur that diffuses out of the leaf accumulates, making the concentration gradient of water vapour between the inside and outside of the leaf less steep, decreasing the rate of transpiration
-However, in windy air, water vapour that diffuses out of the leaf is blown away, so the concentration gradient of water vapour between the inside and outside of the leaf increases, increasing the rate of transpiration

Temperature of air
-A rise in air temperature increases the rate of evaporation of water from the cell surfaces, thus increasing the rate of transpiration

Light
-Light affects the size of the stomata of the leaf, as when there is high amounts of light, the guard cells become turgid due to photosynthesis, so the stomata open and become wider, increasing the rate of transpiration and vice versa

Humidity of the air
-When then air outside the leaf is drier or less humid, the concentration gradient of water vapour between the inside and outside of the leaf increases, increasing the rate of transpiration and vice versa

When explaining factors affecting transpiration

1. Brief description of the factor (keywords if necessary)
2. Water vapour concentration gradient between intercellular air space and atmosphere become steeper / less steep
3. Rate of diffusion of water vapour out of leaf increases / decreases
4. Rate of transpiration increases / decreases

Wilting

-Wilting occurs when the rate of water transpiration occurs when the rate of transpiration is higher than the rate of water absorption by the roots
-It decreases the rate of transpiration and rate of photosynthesis
-The leaves will droop, reducing the exposed surface area of the leaf to light
-This reduces the rate of photosynthesis
-This also reduces exposure of stomata to the atmosphere, reducing the rate of water loss through the stomata, reducing the rate of transpiration
-The guard cells become flaccid as they lose turgor pressure, thus causing the stomata to close
-This reduces the rate of water loss through the stomata, reducing the rate of transpiration
-This also reduces the amount of carbon dioxide diffusing into the leaf, reducing the rate of photosynthesis

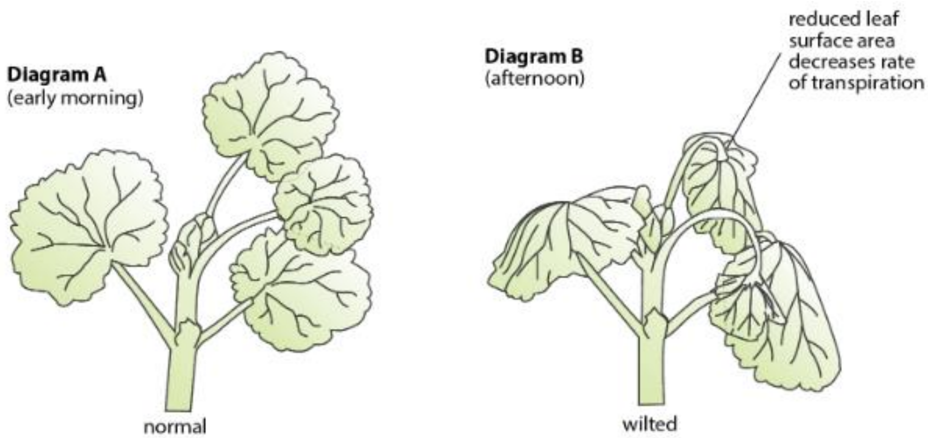


Figure 12.66 Parts of the same plant at different times of the day

Chapter 13: Organisms and Their Environment

Nutrient and energy flow in an ecosystem

-Living organisms in any ecosystem can be categorised as producers, consumers or decomposers, based on their mode of production
-Energy and nutrients are transferred from producers to consumers to decomposers through feeding

Producers

-Producers are organisms that make their own food
-They make their own food through photosynthesis, absorbing carbon dioxide to convert it along with water into glucose and oxygen in the prescence of chemical energy converted from light energy absorbed by chlorophyll
-Examples include plants, algae and phytoplankton

Consumers

-Consumers are organisms that are unable to make their own food, obtaining energy and nutrients by feeding on other organisms
-Consumers can be classified as primary, secondary and tertiary consumers, where primary consumers feed on only consumers, secondary consumers feed only on primary consumers, and tertiary consumers feed on secondary consumers
-Examples include all herbivores, omnivores and carnivores

Decomposers

-Decomposers are organisms that get their energy by breaking down dead organisms, faeces and excretory products
-Their activites then return nutrients such as mineral salts to the environment
-Examples include most bacteria and fungi

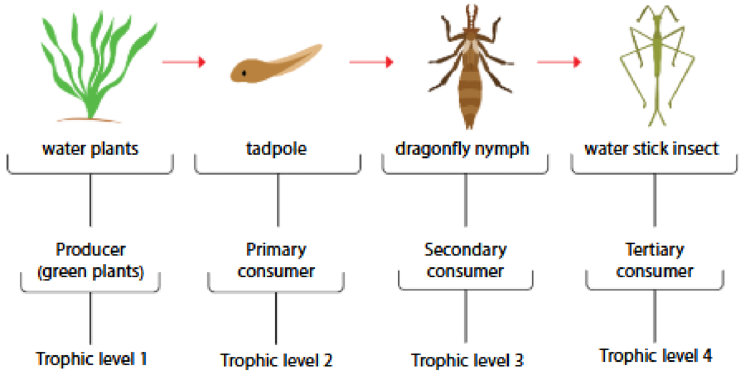
Levels of organisation

-Organisms can form various levels of organisation when interacting with one another
-A population is a group of organisms of the same species living in a habitat
-A community is made up of different populations of different species in a single habitat
-An ecosystem is made up of the community of organisms in a habitat, as well as the physical, non living environment in which they live in

Food chains

-Food chains are a series of organisms, beginning with the producer through which energy and nutrients are transferred
-In a food chain, each arrow represents the flow of energy

-The position an organism occupies in a food chain is called its trophic level, and a food chain usually does not have more than 4 trophic levels



Food webs

-Food webs consist of interconnected food chains
-Note that organisms can have different trophic levels in a food web, depending on which food chain is being looked at

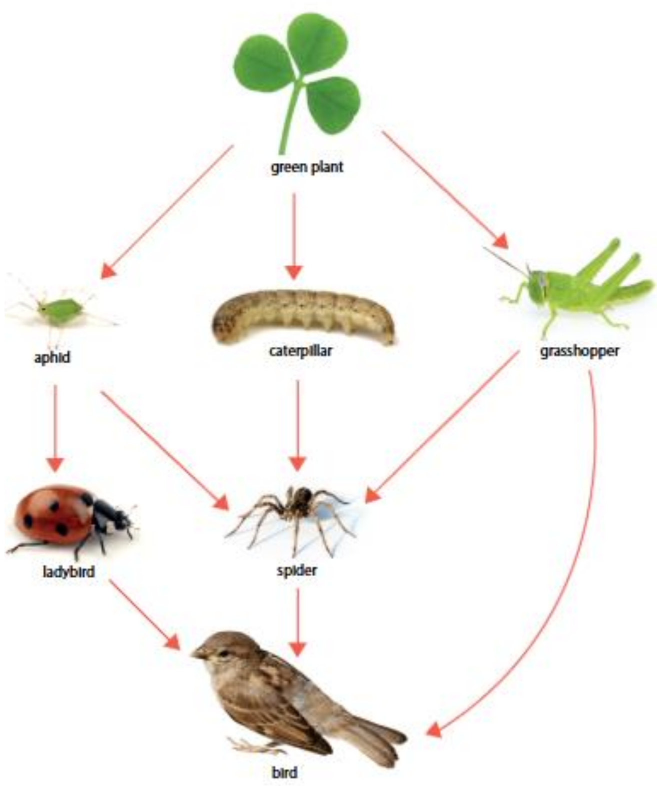
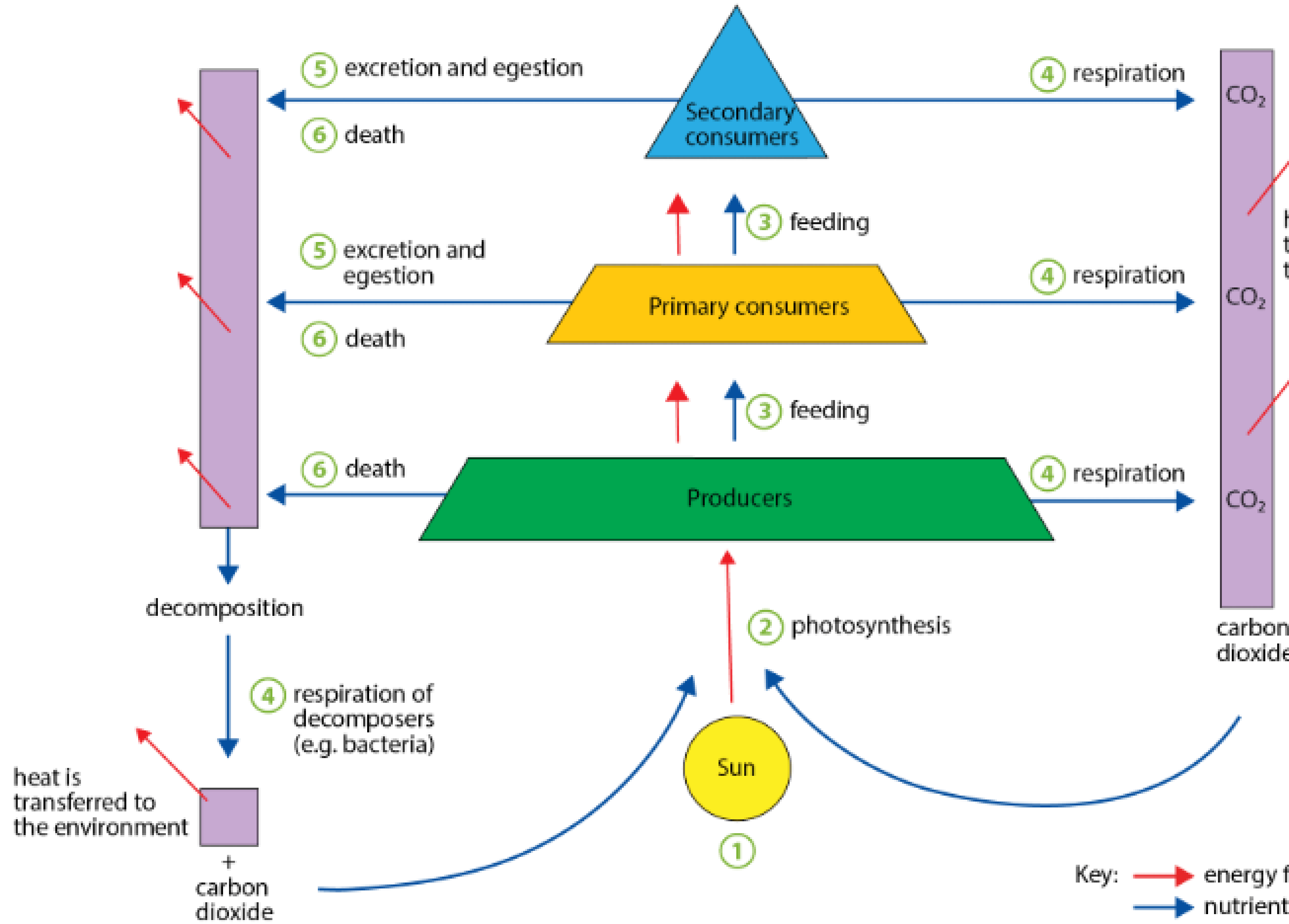


Figure 13.5 A food web

Non-cyclic energy flow

-In an ecosystem, energy does not flow in a cycle, and instead is non cyclic, or linear
-Living organisms cannot use heat to do work, and instead can only use light and chemical energy, so light energy has to be constantly supplied to the ecosystem
-Hence the sun is the principle source of energy input to biological systems

Energy flow in an ecosystem



-In any ecosystem, the principal source of energy is the sun
-During photosynthesis, energy from the sun is absorbed by chlorophyll in producers and transferred to chemical stores of energy in glucose molecules
-Energy in producers is then passed on by feeding
-Energy in each trophic level decreases as only some energy from each trophic level is transferred to the next one
-The rest of the energy is transferred to the environment as heat through respiration
-Since the energy does not return back to the same system as the organisms, it cannot be recycled in this ecosystem and thus energy flow is non cyclical

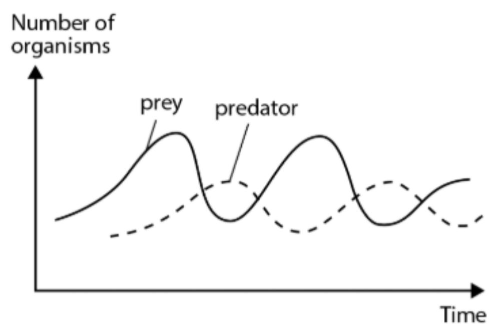
-Egested and excreted materials as well as dead organisms contain trapped chemical energy, which is released through the activities of decomposers
-Some of this energy is used by the decomposers for their own survival, while the rest is transferred as heat to the environment
-Note that while energy can be lost through heat, nutrients cannot as they are continually recycled

Energy flow in a food chain

-For each trophic level, only around 10% of energy is transferred to the next trophic level
-This could be because of heat lost through respiration, undigested matter, excretory waste products and uneaten body parts
-This is why shorter food chains are more energy efficient, and why food chains have fewer than 5 trophic levels, as there is just not enough energy for the 4th consumer

Predator prey relationship

-An animal that feeds on another is called a predator, and the animal being fed on is called the prey
-An increase in population size of prey means more food available for predators, resulting in an increase in population size of the predators
-This decreases the population size of the prey, which in turn decreases the population size of the predators
-This then increases the population size of the prey, repeating the cycle
-In general, the population size of the prey will be greater than that of the predators



Pyramid of numbers

-A pyramid of numbers allows us to compare the number of organisms present in each trophic level at a particular point in time
-The trophic level in a pyramid of numbers increases with height

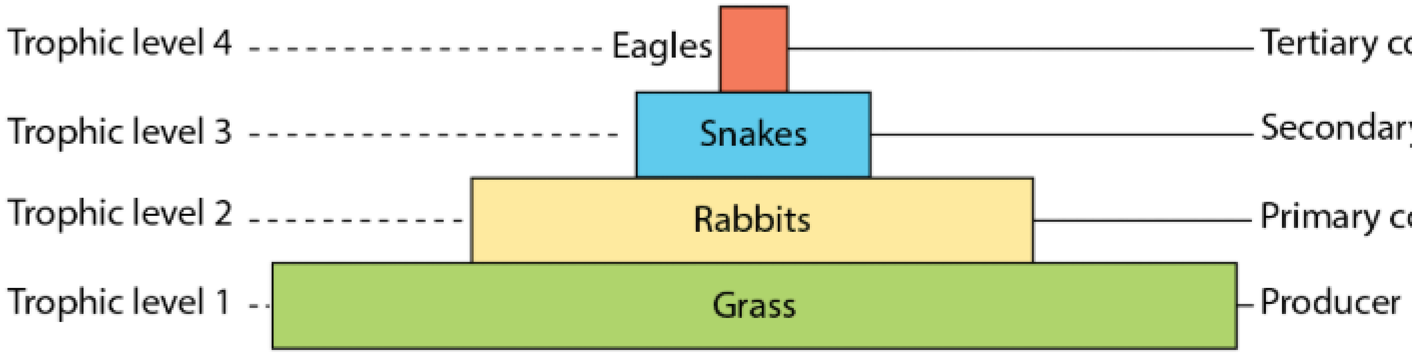
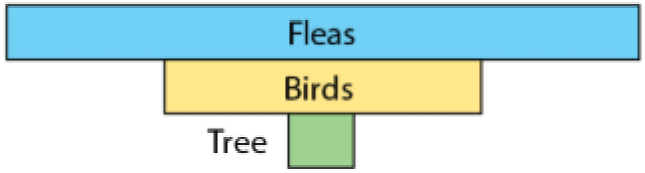


Figure 13.11 A pyramid of numbers

-This shape is not always the same, as some trophic levels can have only one or two organisms per food chain, such as in a tree, or when an organism is parasitic on another, such as for fleas on a bird



-The pyramid of numbers does not consider the size and mass of the organisms, as well as whether the organism is an adult or a juvenile (young organism)

Pyramid of biomass

-A pyramid of biomass allows us to compare the mass of organisms present in each trophic level at a particular time
-They use the dry mass of organisms, where all the water has been removed from the organism

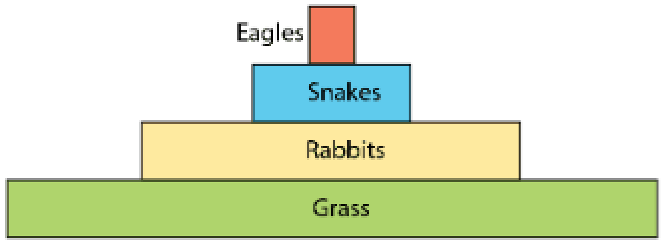


Figure 13.12
Pyramid of biomass

-This shape is almost always the same, except for the food chain phytoplankton -> zooplankton -> small fish -> large fish, as the pyramid of biomass has lesser phytoplankton than zooplankton, as phytoplankton reproduces so fast that it can replace the phytoplankton eaten by the zooplankton while maintaining a low biomass
-The pyramid of biomass considers the size and mass of organisms, hence it is a more accurate representation of energy flow in a food chain

-However, organisms have to be killed to obtain the pyramid of biomass, and it does not take into acocunt the rate of reproduction of the organisms

Nutrient cycling in an ecosystem

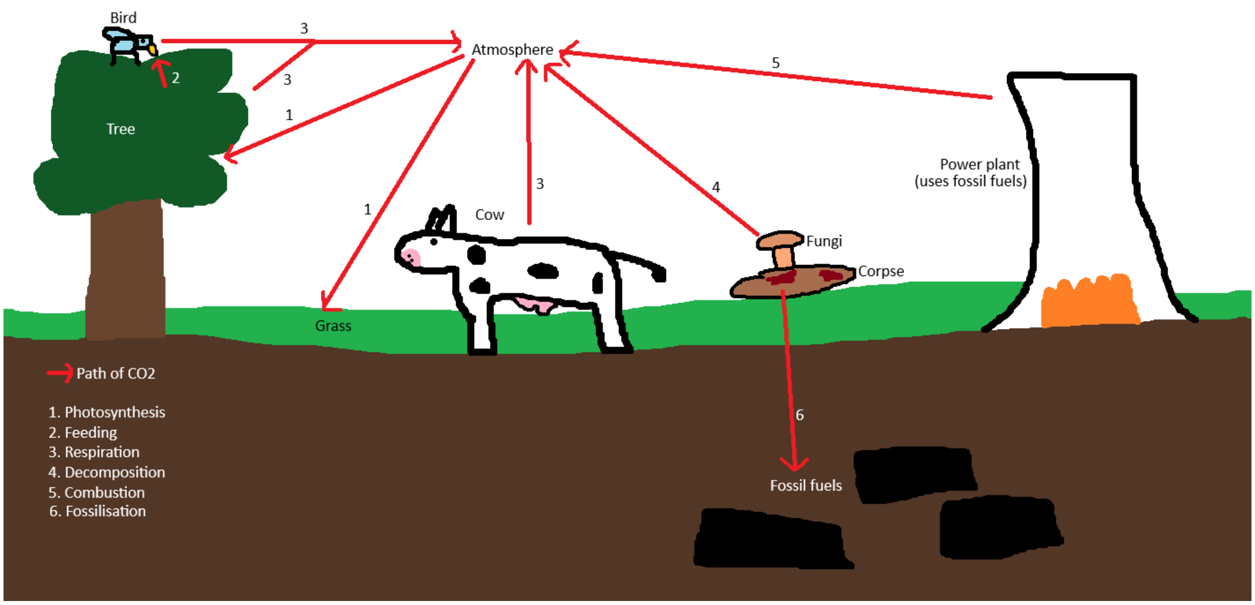
-Carbon, oxygen, nitrogen and water are all essential substances in nutrients needed for life
-These nutrients are released into the soil when organisms die, and decomposers return these nutrients to the environment to be used by green plants
-This means that in a balanced ecosystem, nutrients are not lost but are continuously recycled

Carbon cycle

-Carbon is constantly being removed from and released into the environment in the form of carbon dioxide
-Hence the concentration of carbon dioxide in the environment remains relatively constant
-The processes where carbon is removed from and released into the environment make up the carbon cycle

Processes in the carbon cycle

-During photosynthesis, plants absorb carbon dioxide and use it to synthesise carbohydrates, some of which are converted into proteins and fats
-Animals obtain carbon compounds through feeding on plants and other animals
-Plants and animals respire, releasing carbon dioxide into the atmosphere
-Decomposers break down dead organic matter and release carbon dioxide into the atmosphere
-Dead bodies of plants and animals may be buried deep into the earth, where they are subjected to high pressure and temperature and converted into fossil fuels such as coal, natural gas and oil
-Combustion of these fossil fuels then releases carbon dioxide into the environment



-The carbon cycle ensures that there is a continuous supply of carbon dioxide for plants to carry out photosynthesis
-It enables energy to flow through the ecosystem as carbon compounds store energy
-It regulates atmospheric carbon dioxide

Carbon sinks

-Carbon sinks are areas that store carbon from the atmosphere for as long period of time, storing more carbon than it releases

Oceans

Take in	Release
Photosynthesis	Respiration
Feeding (food chain)	Death
Fossil fuels	Decomposition
Solubility of CO_2 in water	
Take in > release, so ocean absorbs more CO_2 than releasing it, hence its a carbon sink	

Forests

Take in	Release
Photosynthesis	Respiration
Feeding (food chain)	Death
Trees becomes coal after dying	Decomposition
Take in > release, so forests absorb more CO_2 than releasing it, hence its a carbon sink	

How do we affect the ecosystem?

-Natural resources are those supplied by nature, and can be grouped into renewable natural resources and non renewable natural resources
-Renewable natural resources can be replaced by the ecosystem through natural cycles as long as we do not overuse them
-Examples include air, water, soil, forests and wildlife
-Non renewable natural resources cannot be replaced quickly enough for human usage
-Examples include fossil fuels
-Humans are constantly using and depleting earth’s natural resources, causing a lot of environmental damage

Deforestation

-The clearing of forests is known as deforestation
-Forests are cleared for land, as well as for materials such as wood
-Clearing forests leads to habitat destruction for many species of animals, and the remaining amount of forested land may not be big enough to support a breeding population of these animals,leading to these animals becoming endangered or extinct, resulting in a loss of biodiversity
-When trees in forests are growing, photosynthesis occurs at a higher rate than respiration
-When trees are cut down, atmospheric carbon dioxide levels increase, as less carbon dioxide can be trapped within these trees
-When trees are burnt down, excess carbon in tree trunks and roots are releasedc into the atmosphere as carbon dioxide
-This all results in a higher concentration of carbon dioxide in the atmosphere, leading to global warming as carbon dioxide is a greenhouse gas

Effect of carbon dioxide pollution

Greenhouse effect
-Carbon dioxide is a greenhouse gas and forms a layer over earth’s surface, in it’s atmosphere
-Heat is then trapped within this layer around earth, leading to the greenhouse effect which causes global warming
-This can lead to climate change
-Ice sheets in greenland and antarctica can melt, resulting in rising sea levels and flooding in many countries
-It can also lead to coral bleaching and death of corals in coral reefs, as when corals are stressed by changes in light, water or temperature, they expel the algae living in them and turn white as these colourful algae live in their tissue and produce food for the corals
-When these corals are bleached, they lose their ability to support as many species, leading to a loss in biodiversity as coral reefs are habitats for many marine organisms

Effect on aquatic ecosystems
-High levels of atmospheric carbon dioxide results in more atmospheric carbon dioxide dissolving in sea water to from carbonic acid, making the sea more acidic
-This dissolves calcium compounds in the shells of shellfish, weakening them and making them more vulnerable to predators

Global warming vs climate change

-Global warming is the rise in global temperatures, accelerated by human activities that increases concentrations of greenhouse gases in the atmosphere
-Climate change refers to the changes in temperature and weather patterns over a long period of time, where some effects of climate change include rising sea levels, unpredictable weather changes, more frequent and intense hurricane and winter storms, or shifts in flowering or blooming times of plants

How we can reduce global warming

-We can reduce the use of fossil fuels and use renewable sources of energy such as solar energy, as well as reducing our consumption of energy by using more energy efficient devices
-We can replace petrol powered vehicles with hybrid or electric vehicles, as well as reducing our daily consumption of electricity, water and plastic
-We should advocate for the conservation of forests by preventing the indiscriminate felling of trees, planting of new trees, controlling man made forest fires, as well as educating people on the importance of forests and their conservation

What is pollution?

-Pollution is the process by which harmful substances are added to the environment, making it undesirable or unfit for life
-Substances which cause pollution are called pollutants, and examples include plastic or sewage
-Some causes of pollution are natural, such as through volcanic eruptions and forest fires, while most other forms of pollution are caused by human activities

Sewage

-Water carried waste matter from homes or industries is known as sewage
-Untreated sewage contains disease carrying organisms such as bacteria, and if these disease carrying organisms get into drinking water, they can infect many people with diseases such as cholera and typhoid
-Untreated sewage can also lead to eutrophication

Eutrophication

-Eutrophication is the process by which water receives excess nutrients like phosphates and nitrates, causing excessive growth of algae and water plants
-When untreated sewage and fertilisers are discharged or washed into rivers or lakes, the nitrates and phosphates in them enhance the growth of algae and water plants
-This leads to an increased growth and multiplication of algae and floating plants in the water bodies
-Overgrowth of algae and floating water plants prevent sunlight from reaching the submerged plants
-Submerged algae and water plants then die due to lack of sunlight, and the dead algae and water plants are decomposed by aerobic bacteria and fungi
-As these decomposers feed on the decaying organic matter, they grow and multiply rapidly, using up oxygen in the water
-Other marine organisms then die due to a lack of oxygen

Insecticides

-Insecticides are substances used to kill insects, but they may be carried by rainwater into streams, rivers or lakes, and accumulate in high concentrations in the bodies of marine organisms
-Since most insecticides are toxic to marine life, this is bad
-For example, dichlorodiphenyltrichloroethane (DDT) is a non biodegradable insecticide, and hence remains in soil or water for many years
-Since the DDT is insoluble in water, it is not excreted and is instead stored in the fatty tissues of organisms that consume it, and since DDT is non biodegradable, it accumulates in the bodies of consumers
-DDT usually is first absorbed by aquatic plants and algae, and when consumers continue to feed on these contaminated plants and algae, the concentration of DDT in their bodies continue to increase in a process called bioaccumulation
-Bioaccumulation is the accumulation of chemical substances in a single organism
-When consumers of a higher trophic level feed on this contaminated prey, the concentration of DDT in their bodies also increase in a process called biomagnification
-Biomagnification or bioamplification occurs when certain chemicals are passed along the food chain, increasing in concentration in the bodies of organisms along the trophic levels
-Hence, apex predators in a food chain can accumulate large amounts of DDT from eating affected prey, and hence may suffer toxic effects

Plastics

-Harmful chemicals from plastic waste buried in landfills may be leached into rivers or seas, poisoning wildlife in these rivers or seas
-Plastic waste can be broken down into tiny pieces of plastics, known as microplastics, which can be ingested by marine organisms and accumulate in their bodies, leading to biomagnification of microplastics along the food chain as plastics (and microplastics) are non biodegradable
-Plastic waste can also block up the stomachs and intestines of turtles and dolphins as plastics are indigestible

Conservation

-Due to human intervention, the rich biodiveristy of earth is threatened, hence conservation is necessary to maintain earth's biodiversity
-Biodiversity refers to the range of species present in a particular ecosystem
-Conservation is the protection and preservation of natural resources in the environment

Reasons for conservation

Maintaining biodiversity
-Maintainence of a large gene pool is important as many wildlife possess favourable genes
-Hence by cross breeding different varieties of plants and animals, we can improve agricultural produce

-Many tropical plants are also sources of medicinal drugs, such as quinine derived from the bark of cinchono which is used to treat malaria, and vinblastine, derived from the madagascar rosy periwinkle, used to treat leukemia
-In order to prevent extinction of a species, genetic diveristy must be maintained, so that any change in environmental conditions is less likely to wipe out the whole species

For scientific research
-The study of wildlife provides usefull information to humans
-For example, we learn about evolution by studying wildlife

For economic purposes
-Marine life needs to be conserved as they are a major source of human food
-Tropical rainforests also provide food such as rice, pineapple and banana
-Tropical rainforests also provide raw materials for industries, such as rattan for furniture, rubber for tyres and fibres from cotton plants for cloth

To maintain a stable and balanced ecosystem
-This prevents disruptions of natural cycles such as the carbon cycle, and prevents global warming
To preserve natural scenery and wildlife for people to appreciate
-Natural resources enable outdoor recreational activities such as fishing, hiking or skiing

Conservation of ecosystems

Conservation of mangrove swamps
-We can help conserve mangrove swamps by taking part in mangrove restoration projects organised by countries, where volunteers plant mangrove seedlings over a portion of the mangrove swamp
-This is so that the trees that develop will protect low lying areas against strong wind, waves and tides

Conservation of coral reefs
-We can help preserve coral reefs by practising safe and responsible diving when visiting coral reefs, such as by not touching the reefs or not anchoring boats on the reefs
-People should also avoid using sunscreen in coral reefs, avoid purchasing live corals and avoid polluting the coastline with trash, especially non biodegradable plastics as this marine debris can be blown or washed away into the ocean, which can be harmful to coral reefs

Chapter 14: Molecular Genetics

What is DNA?

-Deoxyribonucleic acid, or DNA, is a molecule that carries genetic information, which is important for all cellular functions

Structure of DNA

-Small segments of DNA carry genes which store information to make a single polypeptide, which are responsible for determining the characteristics of an organism
-Each DNA molecule consists of two strands twisted around each other to form a double helix
-A molecule of DNA wraps around special proteins to form a chromatin, which then condenses and coils to form chromosomes

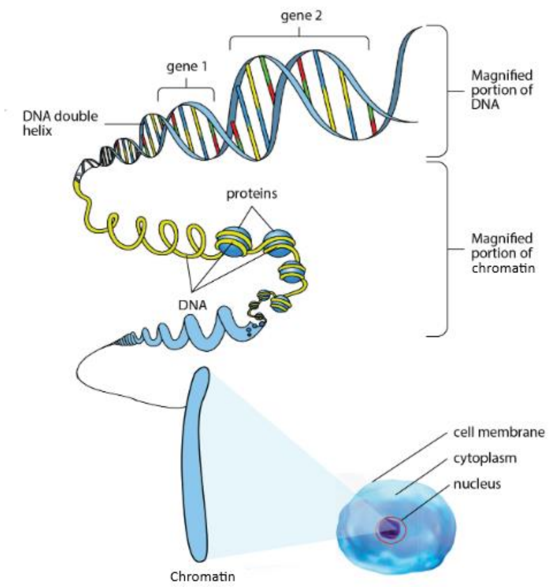


Figure 14.1 How DNA is packaged inside a cell nucleus

Basic units of DNA

-The basic unit of DNA is called a nucleotide, and each nucleotide is made up of a deoxyribose sugar, a phosphate group, and a nitrogenous base
-The deoxyribose sugar and phosphate group form a sugar phosphate backbone
-There are four nitrogenous bases, adenine, thymine, cytosine and guanine
-These nucleotides then join together to form long chains called polynucleotides, where each gene is made up of a sequence of nucleotides, and the sequence of nitrogenous bases in these nucleotides can vary, resulting in different genes

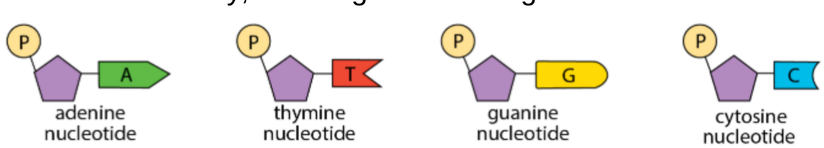


Figure 14.4 Nucleotides

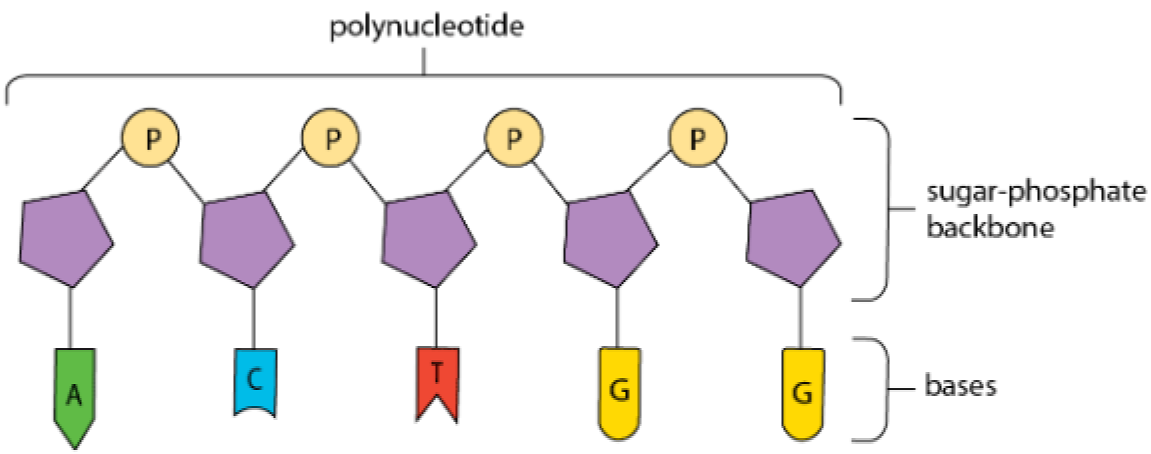


Figure 14.5 Polynucleotide

Complementary base pairing

-A DNA molecule is made up of two anti parallel polynucleotide chains, which means that one points downwards and the other points upwards
-The nitrogenous bases project into the DNA molecule from the sugar phosphate backbone, so the bases of one chain bond to the other according to the rule of base pairing
-Adenine will always bond with thymine, and cytosine will always bond with guanine, as they have complementary shapes, and are also known as complementary bases
-These bases bind through hydrogen bonds, and since they are complimentary, the ratio of complimentary bases in any given gene or DNA molecule is always 1:1, so for example in a gene, the ratio of adenine:thymine is always 1:1 and cytosine:guanine is also 1:1
-However, the ratio of thymine:cytosine could be 3:2 or 4:5 depending on the gene

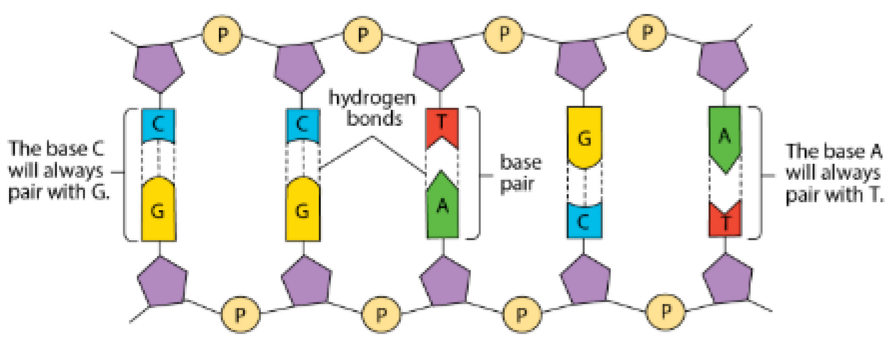


Figure 14.7 Complementary base pairing

What are genes?

-A DNA molecule can carry many genes along its length
-A gene is the basic unit of inheritance in a living organisms, and is a sequence of DNA nucleotides (bases) that control the formation of a single polypeptide
-This polypeptide can then be used to make proteins

-Each gene stores a message that determines how a protein should be made in a cell, known as genetic code
-Note that while a gene is a basic unit of inheritance, it is not a building block of DNA, as the individual nucleotides are more like the building blocks of DNA

How are polypeptides made?

-When a polypeptide is to be made, a molecule called messenger RNA or mRNA goes into the DNA, and copies the message in the gene onto itself, in a process called transcription
-This message is in the form of base pairs, so if the gene has the information CCTGA, the mRNA copies the opposite base pairs, so GGACT
-The mRNA then travels from the nucleus to the cytoplasm and attaches itself to a ribosome
-The ribosome then moves along the mRNA, synthesising a polypetide, in a process called translation
-The polypeptide is then released when the ribosome leaves the mRNA
-The sequence of amino acids in the polypeptide is determined by the sequence of bases copied my the mRNA
-Three bases together make up a codon, where each codon codes for one acid, so for example a codon of CAA will code for a different amino acid than a codon of CGG
-This means that depending on the order of bases on a gene, different orders of bases are copied onto the mRNA, resulting in different polypeptides formed

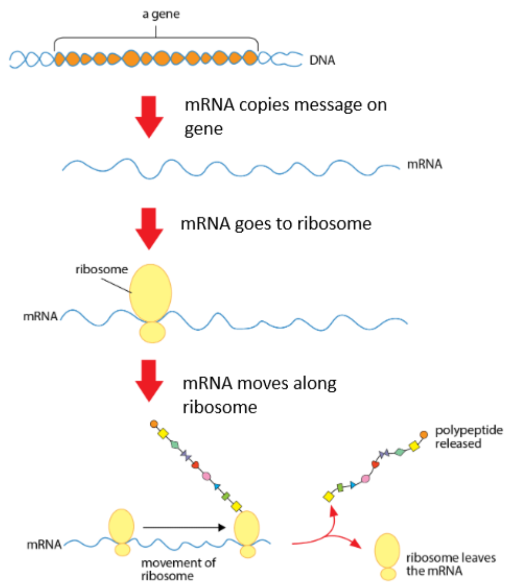
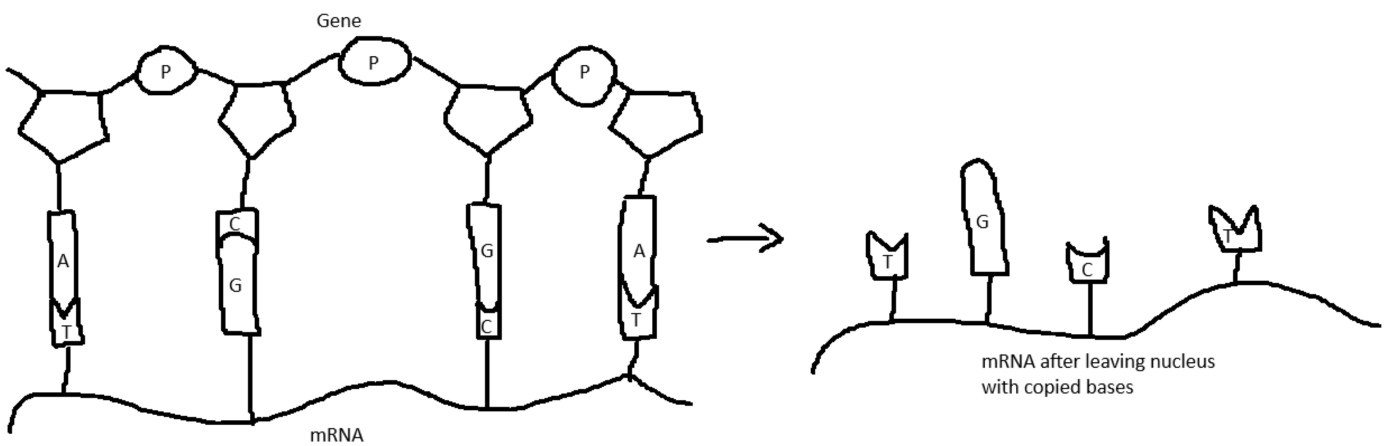


Figure 14.10 Production of a polypeptide



Genetic engineering

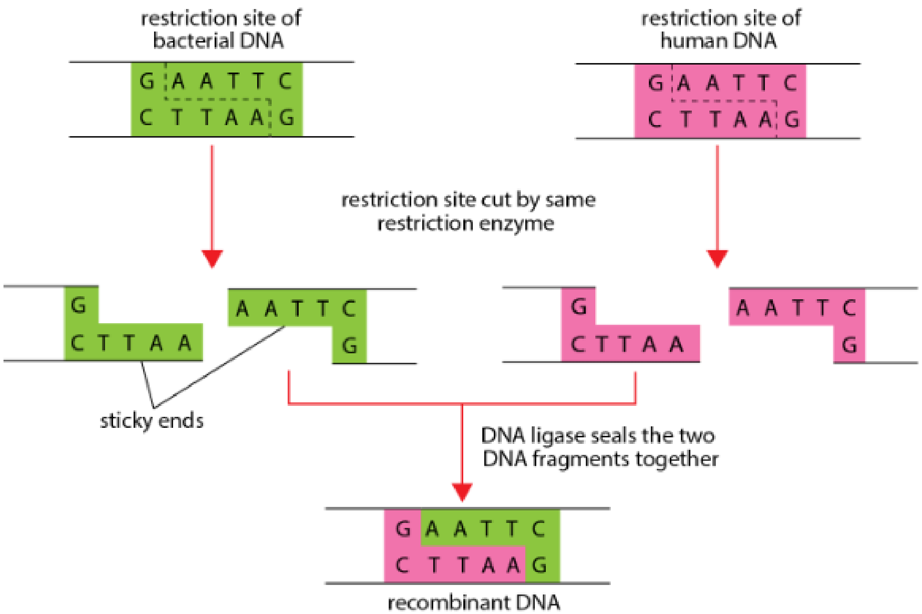
-Genetic engineering is a technique used to transfer genes from one organism to another, where individual genes may be cut off from the cells of one organism and inserted into the cells of another organism of the same or different species, so that the transferred gene can express itself in the recipient organism to make a new protein product
-A vector is required for the transfer of genes, and can be another DNA molecule, a small bacterium or a virus that is used to carry the genes of one organism to another
-Small circular DNA called plasmids, obtained from bacteria, can be used to transfer genes, and a plasmid is an example of a vector
-A gene of interest is the gene we want to transfer

Transferring a human insulin gene

-To treat diabetics, insulin is usually required, and used to be obtained from the pancreas of slaughtered animals
-However, animal insulin is different from human insulin, and many diabetics develop antibodies against it, and diseases can be transferred from animal to human through animal insulin
-However, we can use genetic engineering toi produce bacteria which can express the gene in humans which is responsible for producing insulin in order to manufacture insulin on a large scale
-This is good as it does not induce an allergic reaction as human insulin is produced, it is cheaper and easier to produce insulin in large quantities, there is a smaller risk of contamination, and it can overcome the ethical and religious concerns surrounding the use of animal insulin
-An organism that has a foreign gene inserted into its genome or DNA to express that gene and produce new protein products is called a transgenic organism, and in this case the bacteria is the transgenic organism

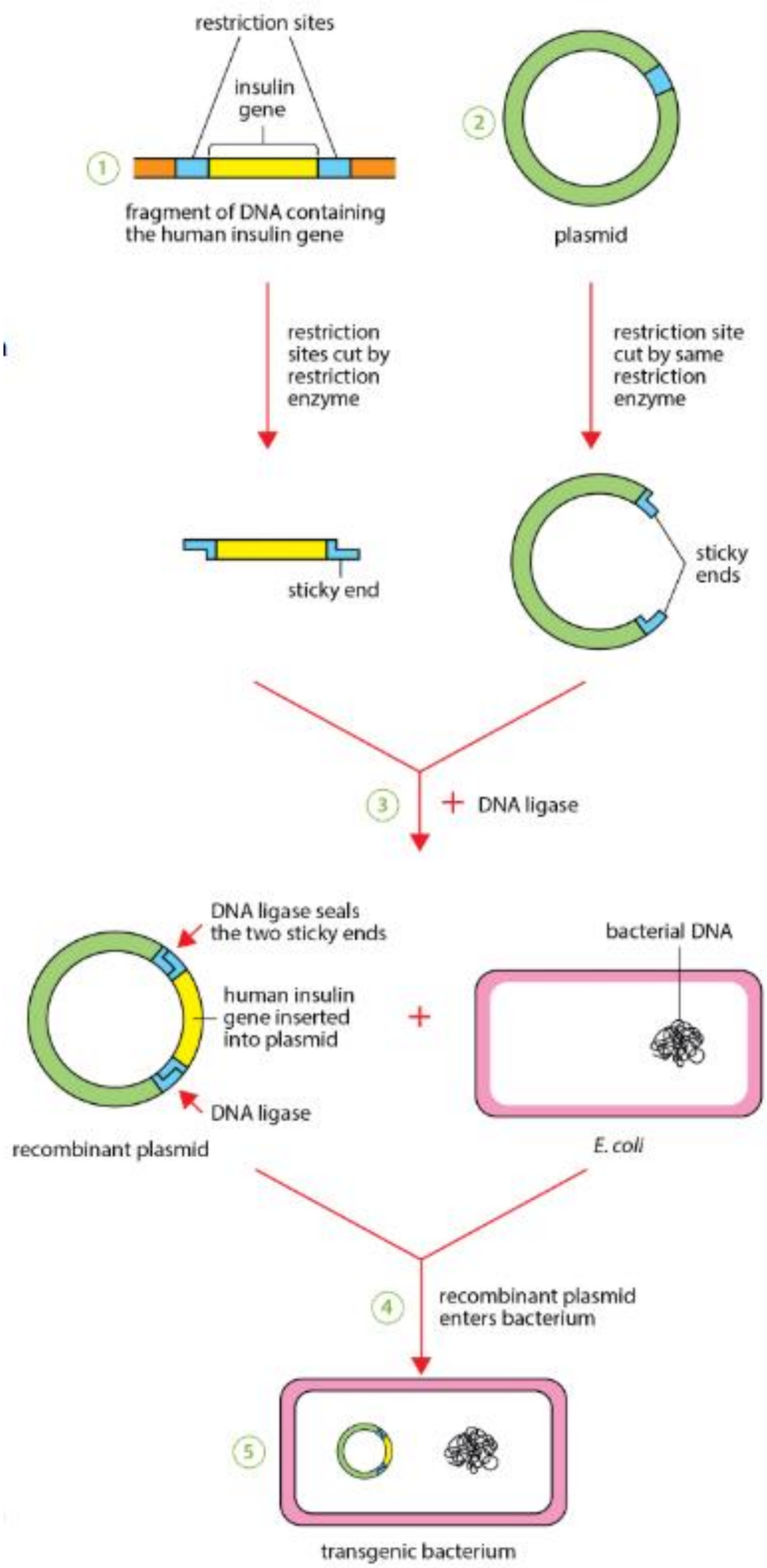
Restriction enzyme and sticky ends

-A gene is a segment in a DNA molecule, and on each side of the gene there is a segment called the restriction site
-An enzyme called the restriction enzyme recognises and cuts the restriction site to produce sticky ends as shown below
-DNA strands from two different organism are cut by the same restriction enzyme to produce complementary sticky ends
-These DNA fragments from the two sources are then mixed together with an enzyme called DNA ligase
-The two different DNA fragments will bind together by complementary base pairing, and are then sealed together by the DNA ligase to form recombinant DNA



Producing transgenic bacteria to produce insulin

-Note that transgenic bacteria is just a more specific way of saying transgenic organism
-A fragment of DNA from a human chromosome that contains the insulin gene is obtained and cut out using a restriction enzyme to produce sticky ends
-A plasmid from a bacterium is then obtained, and is cut with the same restriction enzyme to produce complementary sticky ends
-The DNA fragment and plasmid are then mixed together, and they will bind together through complementary base pairing
-DNA ligase is then added to seal the human gene to the plasmid, and the plasmid now containing DNA from two organisms is called a recombinant plasmid
-The recombinant plasmid is then mixed with a bacterium e.g. escherichia coli (E.coli), and temporary heat or electric shock is applied to open up the pores in the cell membrane of the bacterium for the plasmid to enter
-The recombinant plasmid enters the bacterium, producing a transgenic bacterium which will use the new gene to make insulin
-This bacteria can then be isolated and grown in a fermenter for mass production of human insulin
-The insulin is extracted and purified before use


restriction sites
insulin gene
1
fragment of DNA containing the human insulin gene
2
plasmid
restriction sites cut by restriction enzyme
restriction site cut by same restriction enzyme
sticky end
sticky ends
3
+ DNA ligase
DNA ligase seals the two sticky ends
human insulin gene inserted into plasmid
DNA ligase
recombinant plasmid
+
bacterial DNA
E. coli
4
recombinant plasmid enters bacterium
5
transgenic bacterium

Benefits of using bacteria

-Bacterial plasmid has a simple circular structure which makes cutting and inserting genes easier
-Bacteria multiplies rapidly given optimal conditions, resulting in mass production of insulin in a short time period, decreasing costs

Considerations of genetic engineering

Consideration	Example (if any)
-Genetic engineering can allow for the low cost production of medicines -This allows more patients to get access to these drugs and medicines to be treated	-Insulin has become much more affordable
-Genetic engineering can produce crops which are more resistant to the environment, such as drought resistant crops, salt tolerant crops, and more nutrient efficient crops -This allows farmers to grow crops even in unsuitable environments, improving crop yield, hence making crops cheaper and more widely available	-Flavr savr tomatoes which add genes which inhibit rotting enzymes, to improve shelf life and increase fungal resistance, to reduce food waste from rotted tomatoes during transport
-Genetic engineering can also produce crops that produce toxins that kill pests, as well as pesticide resistant crops -This can reduce the price of crops as less costly pesticide needs to be used by farmers, as well as through increasing crop yields -It also has environmental benefits, as it reduces pollution from environmentally damaging pesticides such as DDT	-The Bt gene from bacteria is inserted to corn to produce the Bt toxins in corn to kill insect pests
-Genetic engineering can also develop foods designed to meet nutritional goals, to improve the nutritional quality of foods, or to increase the availability of food	-Some genes are inserted into rice plants to produce rice plants, which has a higher vitamin A content -Aquadvantage salmon is genetically modified to grow faster, from 32-26 months to 16-18 months to produce more salmon and make it more available, thereby reducing the cost of salmon
-New proteins in genetically modified food can cause allergies in humans that consume them	N/A

-Note that this should not be used for known genetically modified products already in the market	
-Some biotech companies have engineered plants that produce seeds that do not germinate, which means farmers have to buy these seeds every year, posing a problem to poorer societies and farmers -These biotech companies may also have a monopoly over these seeds	N/A
-Genetically engineered animals are often used in medical research to study diseases -This can result in animal exploitation -Genetically modifying animals to produce better products can also lead to exploitation of animals	-The oncomouse is a transgenic mouse into which a cancer causing gene is introduced -The mouse develops cancer to test potential cancer curing drugs -However, these mice will usually die from the cancer -If a cow was genetically modified to produce breast milk to provide for mothers who cannot lactate (produce milk), these cows may be over exploited for the production of this milk for profit
-People can create new combinations of genes which can be used in chemical and biological warfare	N/A
-Genes which code for antibiotic resistance can be used in genetic engineering, which raises a concern that these genes may be incorporated into bacteria which cause diseases in huamns, making antibiotics ineffective against treating these diseases	N/A
-Genetic engineering may not be accessible to everyone, as only individuals with sufficient financial means can afford certain gene technologies -Genetic engineering companies can also have a monopoly over their genetically modified products	N/A

-Note that a social consideration involves people, such as extending lifespan etc, while ethical considrations involve morality, such as animal exploitation

Chapter 15: Modes of Reproduction

Asexual reproduction

-Asexual production is the process that results in the production of genetically identical offspring from one parent, without the fusion of nuclei of gametes
-Note that the adult offspring formed by asexual reproduction has identical genotypes but may have different phenotypes
-Asexual reproduction involves mitosis
-Stem tubers, rhizomes and runners are all examples of asexual reproduction in plants

Advantages	Disadvantages
-Offspring are genetically identical, so that all the beneficial qualities are passed on to the offspring, allowing a species to colonize a habitat quickly if it is well adapted -Relatively quicker method of reproduction, as since only one parent is involved and there is no need to source for a mate and no fusion of nuclei of gametes	-There is no genetic variation in the offspring, so species are not well adapted to changes in the environment -For example, if the parent does not have a resistance to a particular diseases, the offspring also would not have resistance and the whole population could be wiped out

Mitosis

-Mitosis is a type of cell division giving rise to genetically identical cells in which the chromosome number is maintained
-Before mitosis occurs, the chromosomes in the cell replicate, and the cell then splits to form two genetically identical daughter cells

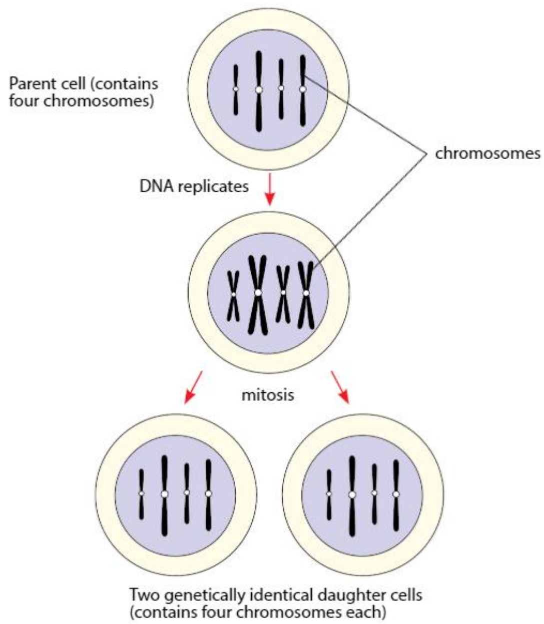


Figure 15.1 Mitosis results in two identical daughter cells.

-It occurs not only in asexual reproduction but also in the growth of multicellular organisms and when damaged tissues are repaired
-Mitosis is important as it produces new cells to aid in these processes

Sexual reproduction

-Sexual reproduction is a process involving the fusion of nuclei of two gametes to form a zygote, producing genetically dissimilar offspring
-Gametes contain half the number of chromosomes as normal body cells, and in humans, the sperm is the male gamete and the egg is the female gamete
-Gametes are also known as the sex cells
-During sexual reproduction, the zygote will have double the chromosome number of the gametes
-Hence, the gametes are haploid cells, with one set of chromosomes
-The zygote is a diploid cell, with two sets of chromosomes, one set from the male parent and one set from the female parent

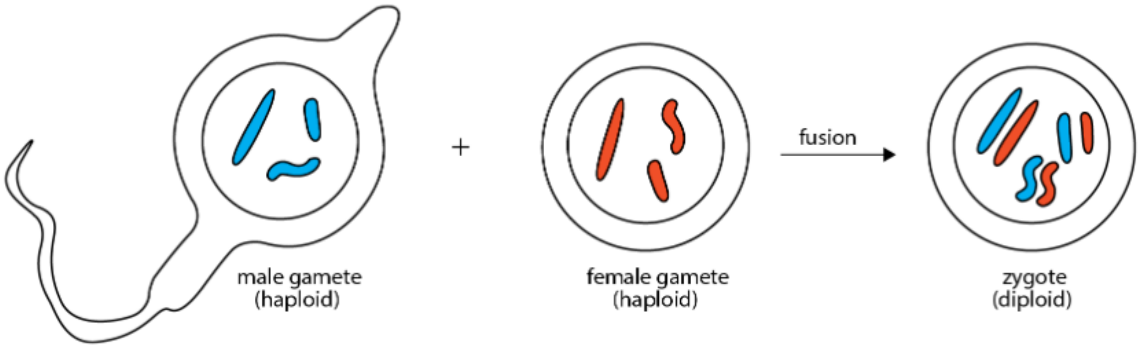


Figure 15.5 Fertilisation of male and female gametes

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Meiosis

-Meiosis is a type of cell division tat gives rise to genetically dissimilar cells in which the chromosome number is halved due to the separation of homologous chromosomes
-Homologous chromosomes are chromosomes which have the same shape, size, length and sequence of genes
-During meiosis, a parent cell with two pairs of homologous chromosomes splits to form four cells, each with one chromosome from each pair of homologous chromosomes
-Gametes are produced through meiosis

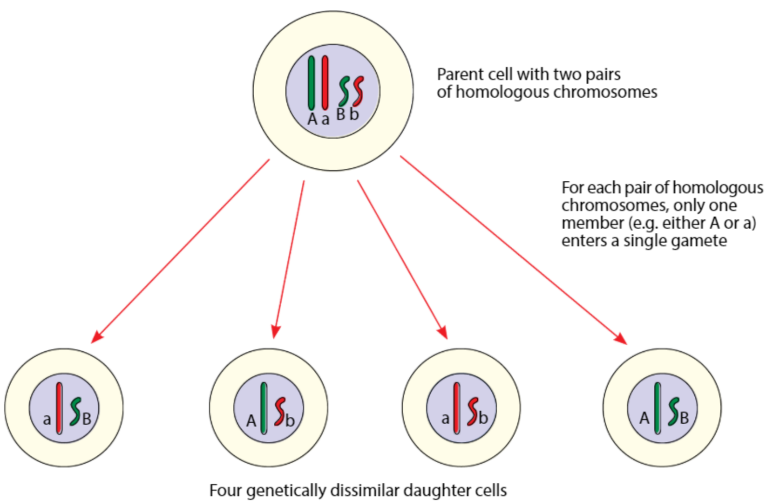


Figure 15.3 Meiosis results in four genetically dissimilar daughter cells.

-As shown above, the number of chromosomes in the gamete is half of the number of chromosomes in the parent cell, hence meiosis is a reduction division
-Reduction division happens before fertilisation as the production of sperm and egg need meiosis
-Meiosis produces haploid gametes as each daughter cell only receives one copy of the homologous chromosome, which means that during fertilisation, the normal diploid number of chromosomes is restored in the zygote

-Meiosis produces genetically dissimilar gametes, and the greater the genetic variation, the better the species is adapted to changes in the environment
-This means that a change in the environment is unlikely to destroy the whole species, and allowing surviving species to pass down favourable genes to their offspring, allowing for greater resistance to these environmental changes

Advantages	Disadvantages
-Offspring may inherit identical qualities from both parents -Genetic variation in the offspring allows for better adaptation to the environment	-Two parents are required, except for self pollinated plants -Fusion of gametes is required -Slower than asexual reproduction

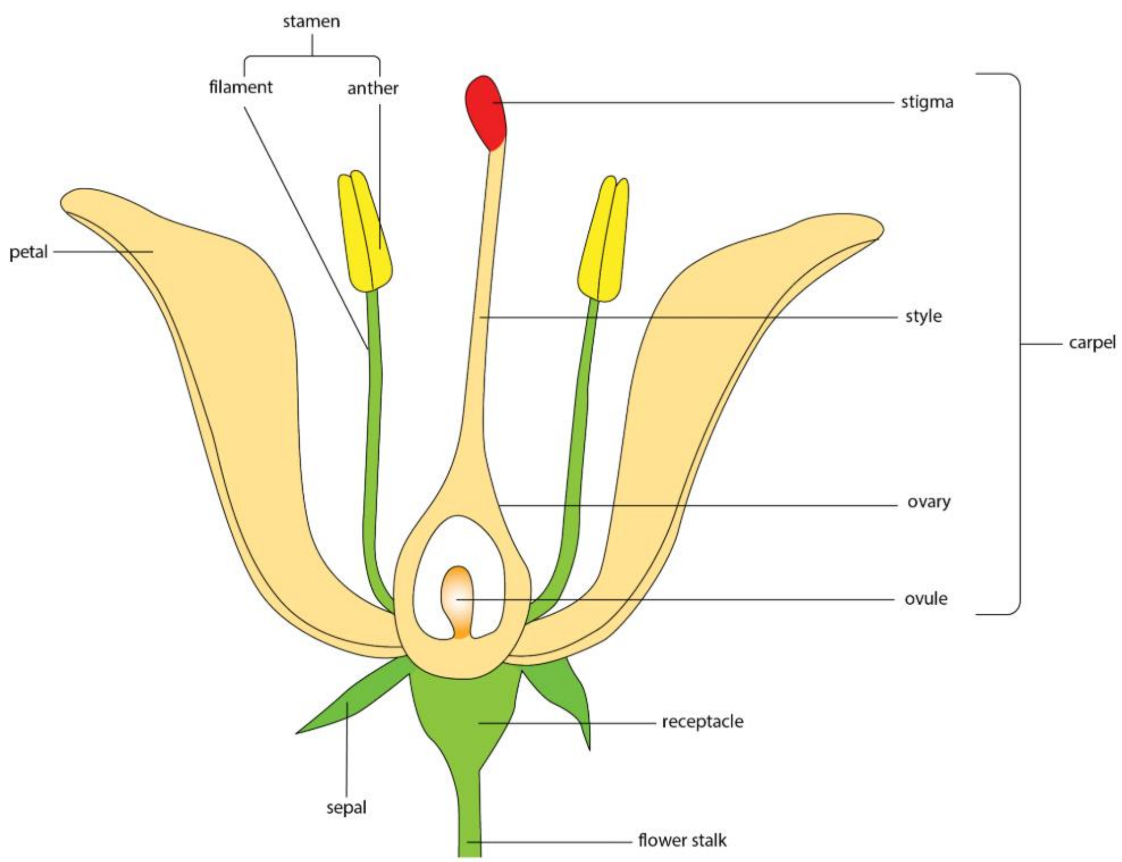
Differences between asexual and sexual reproduction

Asexual reproduction	Sexual reproduction
Does not involve fusion of gametes	Involves the fusion of a male and female gamete to form a zygote
Requires only one parent	Generally requires two parents
Offspring are genetically identical to the parent	Offspring are genetically dissimilar to the parent
Relatively quicker method of producing offspring	Slower method of producing offspring

Chapter 16: Reproduction in Plants

Structure of a flower

-The flower consists of a flower stalk, receptacle, sepals, petals, stamens and carpels or pistils



Petal
-Petals are modified leaves forming the most obvious part of the flower
-In insect pollinated plants, petals are brightly coloured to attract insects for pollination
-They also provide a platform for insects to land on and have lines that guide insects to the base of the petals to obtain nectar

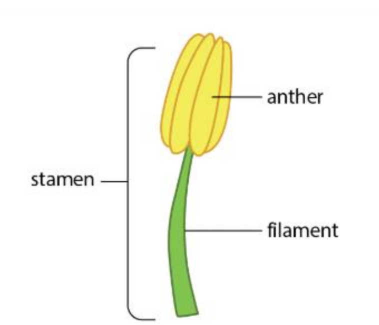
Sepal
-Sepals are modified leaves which enclose and protect the other parts of the flower in the bud stage
-The sepals usually form the outermost layer of floral leaves

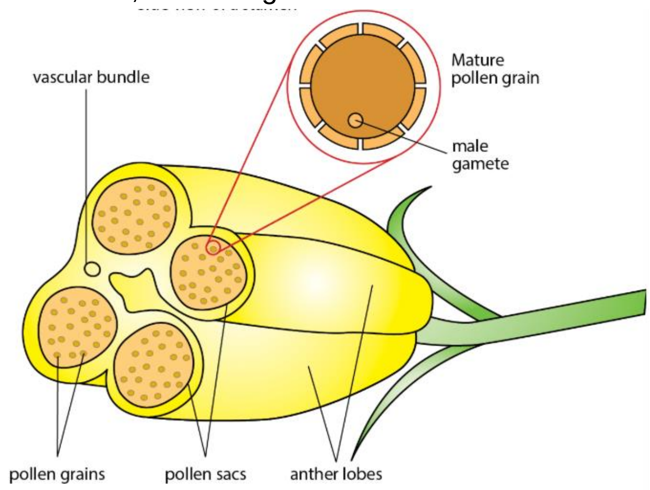
Flower stalk
-The flower stalk attaches the flower to the stem
-Some flowers have no stalks and these flowers are attached to the plant directly at the base

Receptacle
-The receptacle is the swollen end of the flower stalk

Stamen

-The stamen is the male part of the flower, consisting of an anther and a filament

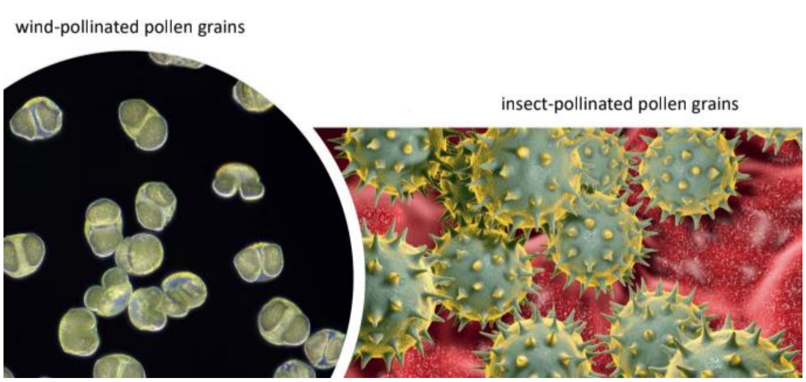




Filament
-The filament is the stalk that holds the anther in a suitable position to distribute pollen

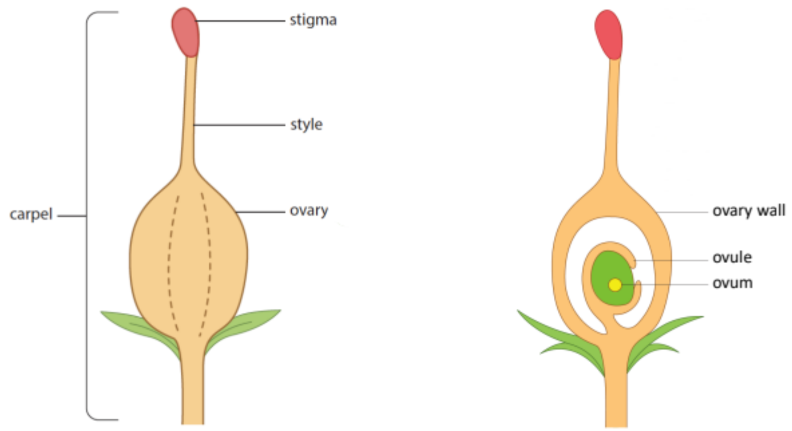
Anther
-The anther produces pollen grains and splits open when mature to release the pollen grains

Pollen grains
-Pollen grains contain the male gametes, produced through meiosis and are haploid cells
-The pollen sacs contain the pollen grains
-There are different types of pollen grains depending on how the plant is pollinated, as shown below
-Note that pollen is the collective noun for a lot of pollen grains



Carpel

-The carpel or pistil is the female part of the flower, consisting of an ovary, a style and a stigma



Stigma
-The stigma is a swollen structure at the end of the style
-It receives the pollen grains, and the mature stigma secretes a sugary fluid that stimulates pollen grains to germinate

Style
-The style is a stalk that connects the stigma to the ovary, holding the stigma in a suitable position to trap pollen grains

Ovary
-The ovary contains one or more ovules
-Within each mature ovyule is a female gamete or egg cell known as the ovum
-The ovum is produced by meiosis and is a haploid cell

Pollination

-In order for flowering plants to reproduce sexually, the pollen grains must be transferred from the anthers to the stigmas so that the male gametes in the pollen grain can meet the female gamete in the ovule, in a process known as pollination
-Pollination is the transfer of pollen grains from the anther to the stigma
-There are two types of pollination, self pollination and cross pollination

Self pollination

-Self pollination is the transfer of pollen grains from the anther to the stigma of the same flower or of a different flower on the same plant

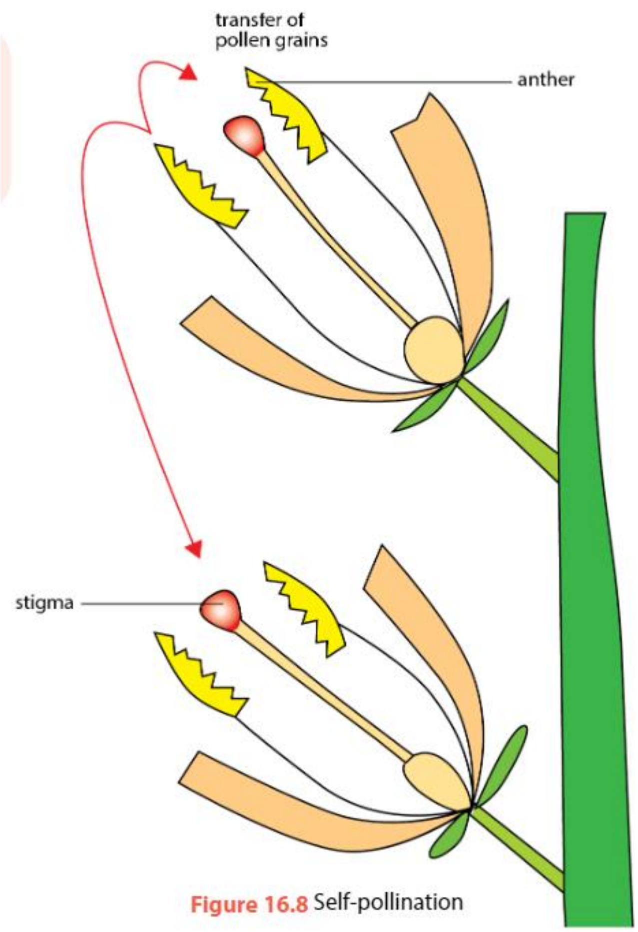
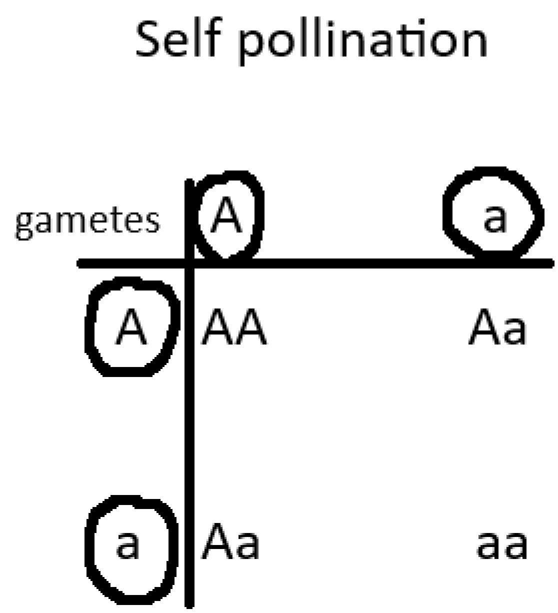


Figure 16.8 Self-pollination

-The flowers on self pollinating plants are bisexual woth anthers and stigmas maturing at the same time
-The stigma is situated directly below the anthers
-In certain plants with bisexual flowers, some flowers never open to ensure only self pollination occurs
-These are all features favouring self pollination to ensure it occurs

Advantages	Disadvantages
-Only one plant is required -The offspring inherits its genes from the parent plant after fertilisation, hence beneficial qualities are more likely to be passed down to the offspring -It does not depend on external factors such as wind or insects -Since the anthers are close to the stigmas of the same flower, there is a higher likelihood that pollination will occur as opposed to cross pollination -Less pollen and energy are wasted in self	-Should fertilisation occur, there will be less genetic variation in the offspring compared to cross pollination, and is hence less well adapted to changes in the environment -Note that it still has more genetic variation than a plant reproducing asexually, as offspring produced through self pollination are genetically similar but still slightly different from the parent plant, however plants reproducing through asexual reproduction are identical to the parent plant -This means that self pollinated plants may

pollination as compared to cross pollination	inherit more beneficial traits and less detrimental ones, while those reproducing through asexual reproduction will inherit all traits, whether good or bad -For example, if A represents a detrimental dominant allele while a represents a beneficial recessive allele, the self pollinated plant has a 25% chance to have the beneficial phenotype, while the plant reproducing through asexual reproduction will have a 0% chance to have the beneficial phenotype, as shown below  -Continued self pollination can also lead to the offspring becoming weaker, smaller and less resistant to diseases

Cross pollination

-Cross pollination is the transfer of pollen grains from one plant to the stigma of a flower in another plant of the same species
-This is done through external agents, usually insects or wind

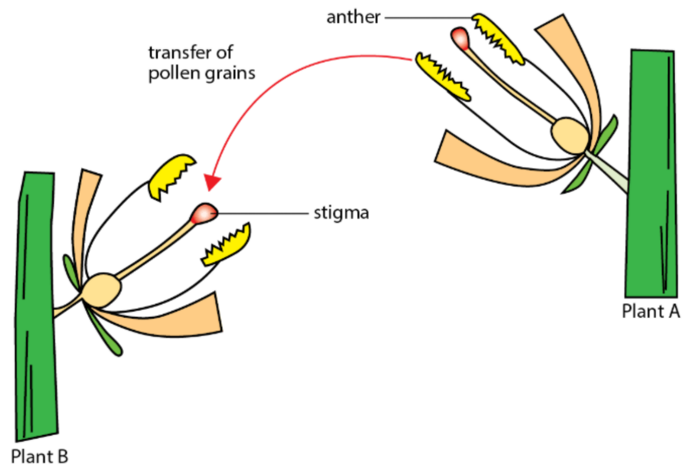


Figure 16.9 Cross-pollination

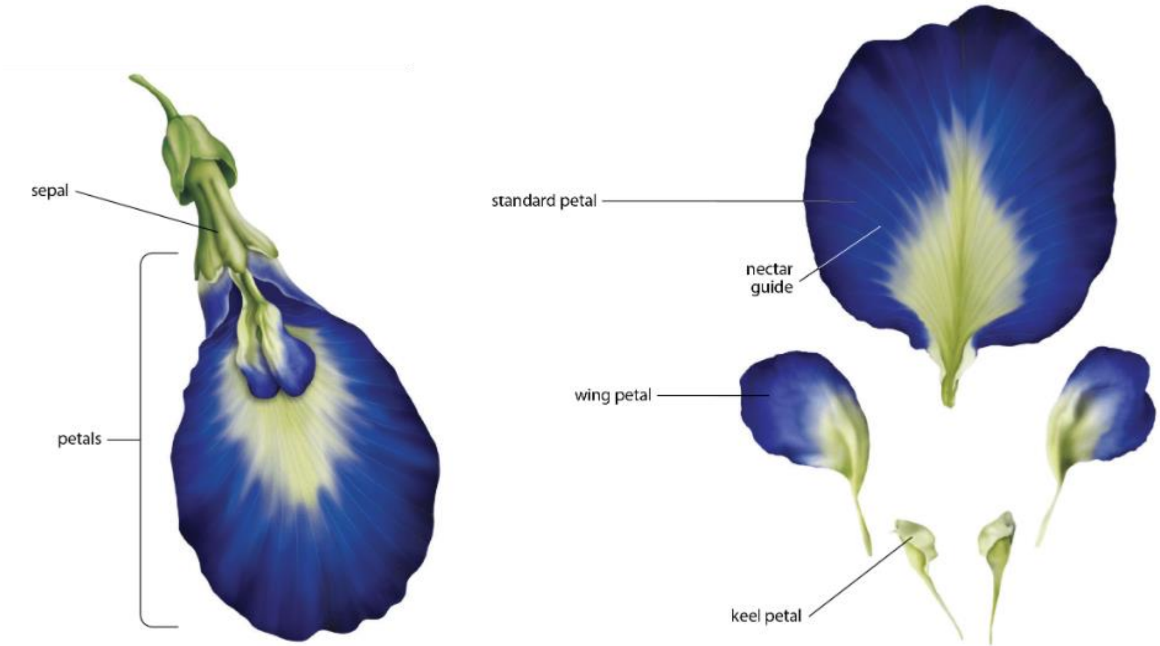
-Some plants bear either male or female flowers, and hence cannot undergo self pollination
-In plants with bisexual flowers, the anthers and stigmas may mature at different times
-The stigmas of plants with bisexual flowers may be situated some distance away from the anthers to that self pollination is unlikely
-These are all features favouring cross pollination to ensure it occurs

Advantages	Disadvantages
-The offspring produced may have inherited beneficial qualities from both parents -Should fertilisation occur, there will be greater genetic variation in the offspring produced as compared to self pollination, increasing the chance of the species surviving changes in the environment because any change in the environment is less likely to destroy the whole species -Again to the previous example where A represents a detrimental dominant allele while a represents a beneficial recessive allele, since a cross pollinated plant can have gametes with different genotypes, the cross pollinated plant has a 50% chance to have the beneficial phenotype, as shown below gametes | a | a A | Aa | Aa a | aa | aa -Hence, a cross polinated plant has the greatest genetic variation -More viable seeds are also produced which are	-Two plants are required -Depends on external factors such as wind and insects -Since the pollen grains have to be transferred from the anther of one plant to the stigma of another, there is a lower probability of pollination occurring as compared to self pollination -More energy and pollen are wasted as compared to self pollination

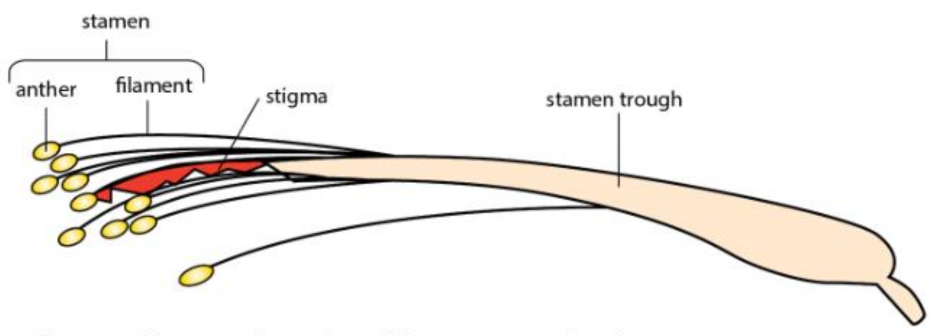
capable of surviving longer before germination	

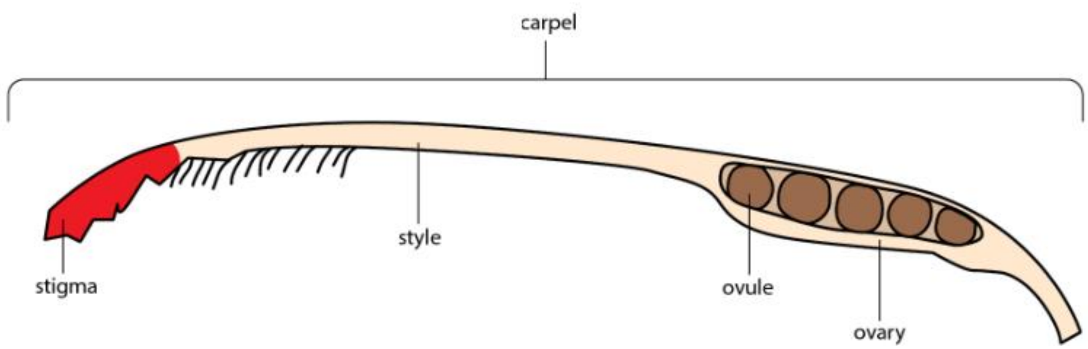
Insect pollinated flowers

-The clitoria or blue pea flower shown below is specially adapted for pollination by insects, and is bisexual



-The flower has five green sepals
-The flower has five brightly coloured petals of different shapes and sizes
-The large petal also has lines that guide insects to where nectar is located, known as the nectar guides
-The stamen and carpel of the clitoria flower is shown below





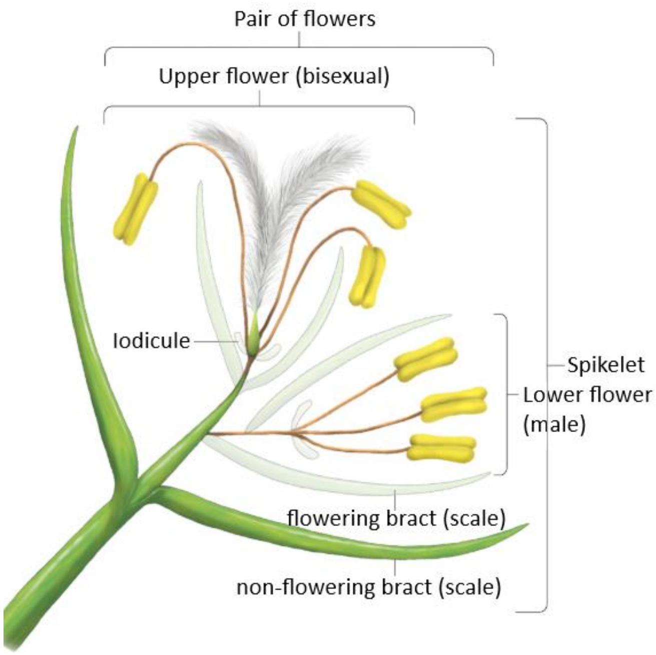
-The flower has stamens with long filaments
-Nectar, secreted by the flower, collects at the bottom of the stamen trough
-Thus, the nectar can only be reached by an insect with a long tubular mouth or proboscis, such as a bee or butterfly
-The carpel consists of a small and compact stigma, a long, curved and hairy style, and a long, narrow ovary with a single row of ovules

Insect pollination

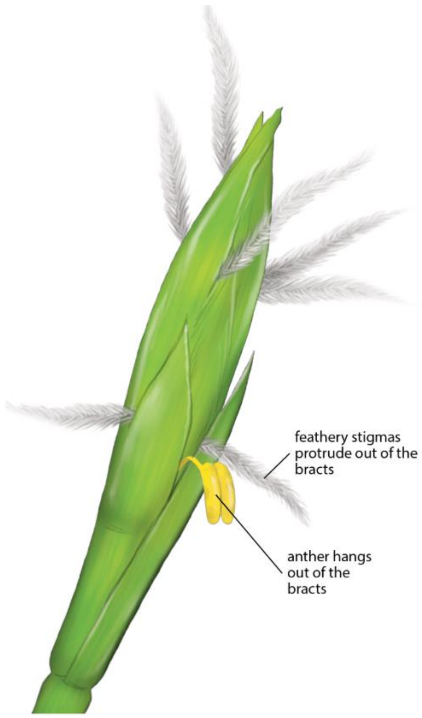
-When an insect visits the clitoria flower, it lands on a petal, which acts as a landing platform
-The insect follows the nectar guide into the flower, and forces its way and moves in to collect the nectar
-As the insect moves in, the stigma and anthers brush against the hairy back of the insect
-This results in pollen grains from the anther sticking to the hairy back of the insect
-At the same time, pollen grains already on the insect's back from a previous plant are transferred to the sticky stigma
-Although the flower is well adapted for insect pollination, self pollination can still occur

Wind pollinated flowers

-Grasses are good examples of wind pollinated flowers as grass flowers are usually small and grouped in influorescences which are dull coloured, scentless and without nectar
-They are also usually enclosed and protected by leaf like structures called bracts or scales
-The grass flower of ischaemum muticum shown below is specially adapted for pollination by wind, and consists of both male and bisexual flowers



-The flowers occur only in pairs, and each flower is enclosed by two transparent flowering bracts
-The upper flower is bisexual, consisting of an ovary with two long feathery stigmas, three stamens and two tiny structure called iodicules at the base of the ovary
-When the plant is ready to reproduce, the iodicules swell and force the two flowering bracts slightly apart, allowing the stigmas and anthers to emerge
-The lower flower is unisexual and male, consisting of only three stamens with long filaments and two iodicules
-Each pair of flowers, together with a short stal, form a spikelet
-At the base of each spikelet is a pair of empty or non flowering bracts to protect the flowers in the spikelet
-The stamens of the male flower shown above are not fully mature and are still enclosed by the flowering bracts to reduce chances of self pollination
-A few pairs of spikelets make up an inflorescence, as shown below



Wind pollination

-The stamens of ischaemum muticum have long filaments and protruding anthers, so when the filaments sway in the wind, the dust like pollen is shaken free and dispersed by the wind
-The stigmas are large, extended and feathery, hence they provide a large surface area to receive any pollen floating around in the wind

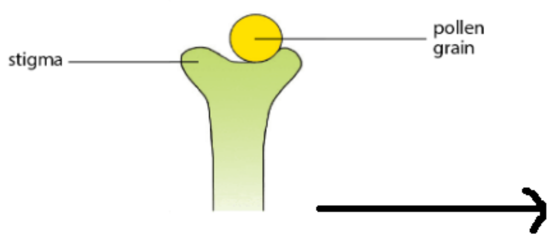
Insect vs wind pollinated flowers

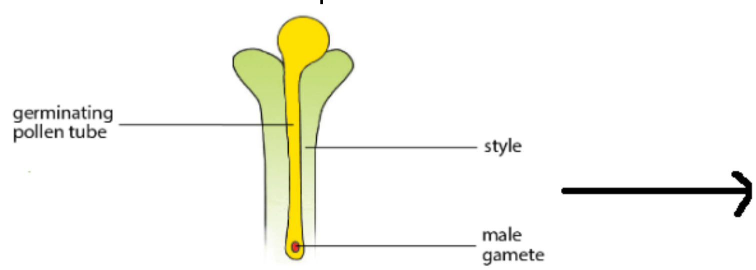
Feature	Insect pollinated	Wind pollinated
Petals	Flowers are usually large with brightly coloured petals to attract insects	Flowers are usually small and dull coloured, without petals
Nectar	Nectar is present	Nectar is absent
Scent	Flowers are fragrant or sweet smelling	Flowers are odourless
Stigmas	Stigmas are usually small, compact, and do not protrude out of the flower	Stigmas are large, feathery and usually protrude out of the flower to provide a large surface area to trap pollen
Stamens	Stamens are not loose and cannot swing side to side, and usually do not protrude out of the flower	Stamens have long, loose filaments that swing side to side, with protruding anthers so that pollen grains are easily shaken out from the anthers
Pollen	Pollen is fairly abundant, and are usually	Pollen is more abundant, and have smooth

	larger with rough surfaces to cling to insect bodies	surfaces that are tiny and light so that they are easily blown about by the wind
Nectar guide	Nectar guide may be present to guide insects towards nectar	Nectar guide is absent

The fertilisation process

-After pollination, the pollen grain germinates after coming into contact with the stigma, in response to the sugary fluid secreted by the mature stigma
-A pollen tube then grows out from each pollen grain and the male gamete enters the pollen tube
-As the pollen tube grows, it secretes enzymes to digest the surrounding tissue of the stigma, style and ovary, and thus the pollen tube grows down the style into the ovary
-The pollen tube enters the ovule through an opening in the ovule wall called the micropyle
-Within the ovule, the tip of the pollen tube absorbs sap and bursts, releasing the male gamete
-The nucleus of the male gamete fuses with the nucleus of the ovum to form the zygote, and this is known as fertilisation
-After fertilisation, the ovary develops into the fruit and the ovule develops into the seed





Post fertilisation

-After fertilisation, the ovary becomes the fruit and the ovule becomes the seed
-The zygote becopmes the embryo, which consists of the embryonic root, embryonic shoot and cotyledons as shown below

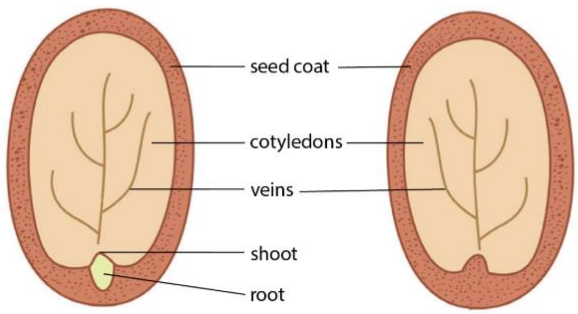


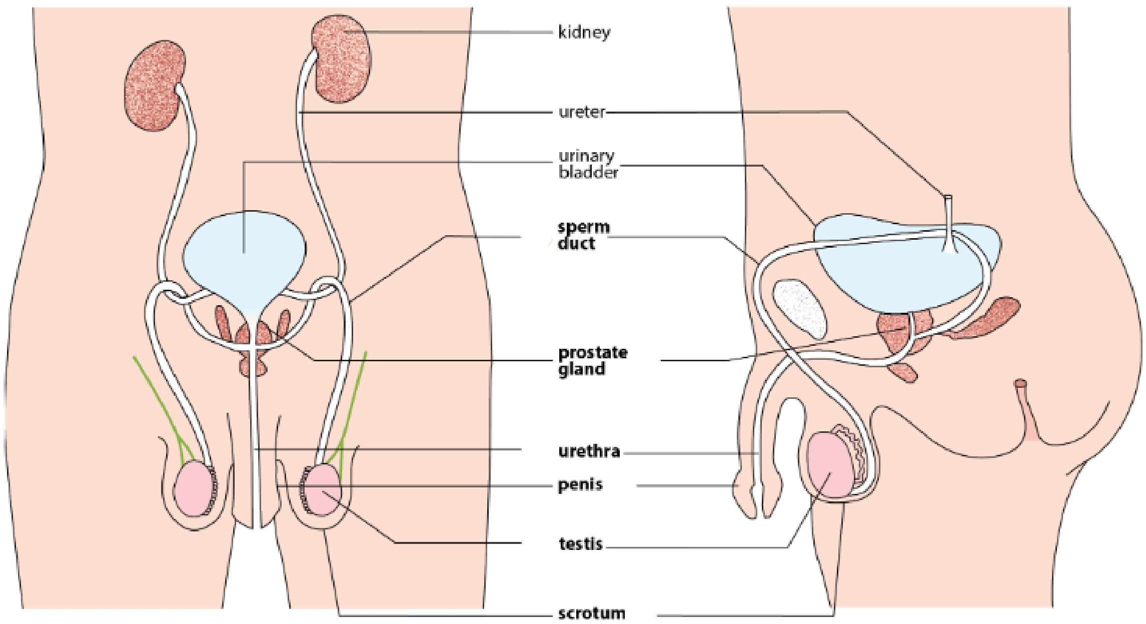
Figure 16.17 Seed cut open and separated into two halves

-The petals, style, stigma and anthers all wither and drop off

Chapter 17: Reproduction in Humans

The male reproductive system

-The male reproductive system consists of the testis, scrotum, sperm duct, prostate gland, urethra and penis



(a) Front view (b) Side view

-Note that parts of the urinary system are shown as the reproductive system is closely associated with the reproductive system

Testis
-There are two testes, and each testis produces sperm
-Each testis also produces male sex hormones such as testosterone
-The male hormones are responsible for the development and maintenance of the secondary sexual characteristics in males
-Note that testes is plural for testis

Scrotum
-The testes lie between the thighs, and both testes lie in a puch like sac called the scrotum
-The scrotum is outside the main body cavity, hence it is at a slightly lower temperature than body temperature, and this temperature is essential for sperm to develop properly

Sperm duct
-Each sperm duct loops over a ureter and then opens into the urethra
-After sperm are released from a testis, they travel through a sperm duct

Prostate gland
-The prostate gland is at the base of the urethra, where the two sperm ducts join it

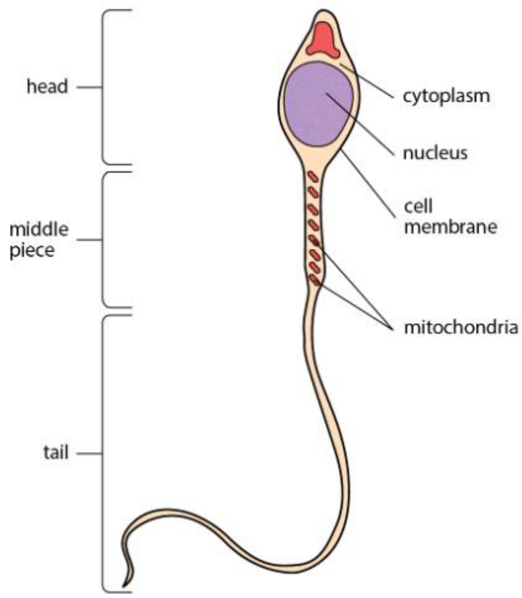
-The prostate gland secretes a fluid which mixes with the sperm, containing nutrients and enzymes which nourish the sperm and stimulate them to swin actively
-The mixture of this fluid and sperm is called semen

Urethra
-The urethra is a tube which passes from the bladder through the center of the penis to the outside of the body
-Both semen and urine pass through the urethra, but not at the same time

Penis
-The penis is an erectile organ, which means it can become rigid and upright
-The penis enters the vagina of a woman during sexual intercourse to deposit semen, containing sperm

Sperm

-The sperm is the male gamete, about 60 µm long
-Numerous sperm are produced throughout the life of a human male after he has become physically mature
-The sperm consists of the head, middle piece and tail or flagellum



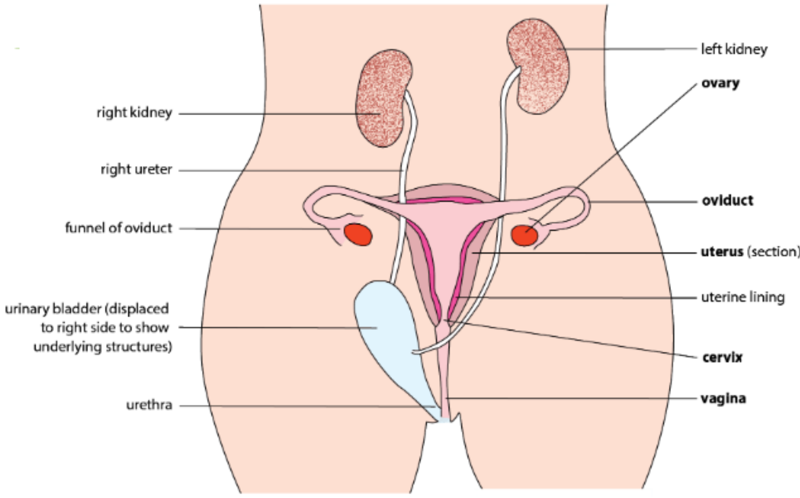
-The head is about 2.5 µm wide, and contains a large nucleus with a small amount of cytoplasm, and this nucleus carries a haploid set of chromosomes, and contains either an X or Y chromosome
-The middle piece contains numerous mitochondria to provide energy through aerobic respiration for the sperm to swin towards the egg
-The beating movement of the tail or flagellum enables the sperm to swin towards the egg, and hence allows the sperm to be able to move

-The sperm travels from the testis out of the penis in this order: testis → sperm duct → urethra → outside the body

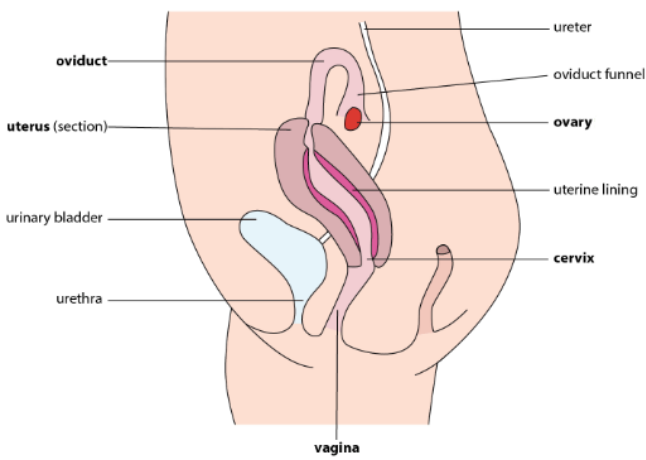
-Note that the release of semen containing sperm is known as ejaculation

The female reproductive system

-The female reproductive system consists of the ovary, oviduct, uterus, cervix and vagina



(a) Front view



(b) Side view

-Note that like males, parts of the urinary system are shown as the reproductive system is closely associated with the reproductive system

Ovary

-The two ovaries produce ova, or eggs

-Each ovary also produces hormones such as oestrogen and progesterone

-The female sex hormones are responsible for the development and maintenance of the secondary sexual characteristics in femals
-When the eggs become mature, they are released from the ovaries
-Only one ovary releases one egg per menstrual cycle

Oviduct
-Each ovary releases mature eggs into the oviduct
-Each oviduct is a narrow muscular tube leading from the ovary to the uterus, and has a funnel like opening lying close to the ovary to make it easier for the egg to enter the oviduct
-The egg is usually fertilised in the oviduct
-The inner surface of the oviduct is lined with cilia, and the movement of cilia helps to move the egg along the oviduct

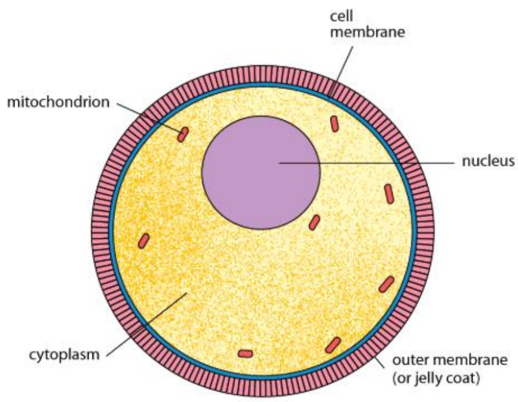
Uterus
-The uterus or womb is where the fetus or unborn baby develops during pregnancy
-The uterus is shaped like an upside down pear and has elastic muscle walls
-The smooth muscle tissue in the walls of the uterus contract to push the fetus out during birth
-The soft, smooth inner lining of the uterus is called the uterine lining, and is where the embryo is implanted

Cervix
-The cervix is the ring of muscles at the lower portion of the uterus where it joins the vagina
-The opening of the cervix allows menstrual blood to flow out into the vagina during menstruation

Vagina
-The vagina or birth canal leads from the cervix to the outside, and semen is deposited into the vagina during sex

Egg

-The ovum or egg is the female gamete
-A female is born with all the potential eggs she will ever have, and at birth around 70000 potential egg cells are present in the ovaries
-However, only about 500 will ever mature in the ovaries
-Usually, one mature egg is released every month from the time the female becomes physically mature until around 45-55 years of age, known as menopause
-The egg consists of a cell membrane, nucleus, mitochondria, cytoplasm and outer membrane or jelly coat



-The egg is spherical and about 120 µm to 150 µm wide, and is the largest cell in the human body
-The egg has abundant cytoplasm which may contain a small amount of yolk
-The nucleus of the egg contains one X chromosome
-It is also surrounded by a cell membrane which in turn is surrounded by an outer membrane or jelly coat, which changes during fertilisation to prevent other sperm from entering the egg

Male vs female gametes

Feature	Male gamete (sperm)	Female gamete (egg)
Structure	-Has a head, middle piece and tail -Nucleus contains either X or Y chromosome -About 60 µm long with a diameter of 2.5 µm for the head	-Spherical in shape -Nucleus has one X chromosome -Diameter of 120 µm to 150 µm
Motility (ability to move)	-Has a tail to allow it to swin towards the oviduct	-Passive movement of the egg along the oviduct is due to the movement of cllia along the oviduct and peristalsis of the oviduct wall
Numbers	-A large number of sperm is released per ejeculation	-Only one egg is released per month -Both ovaries produce around 500 eggs totalµ

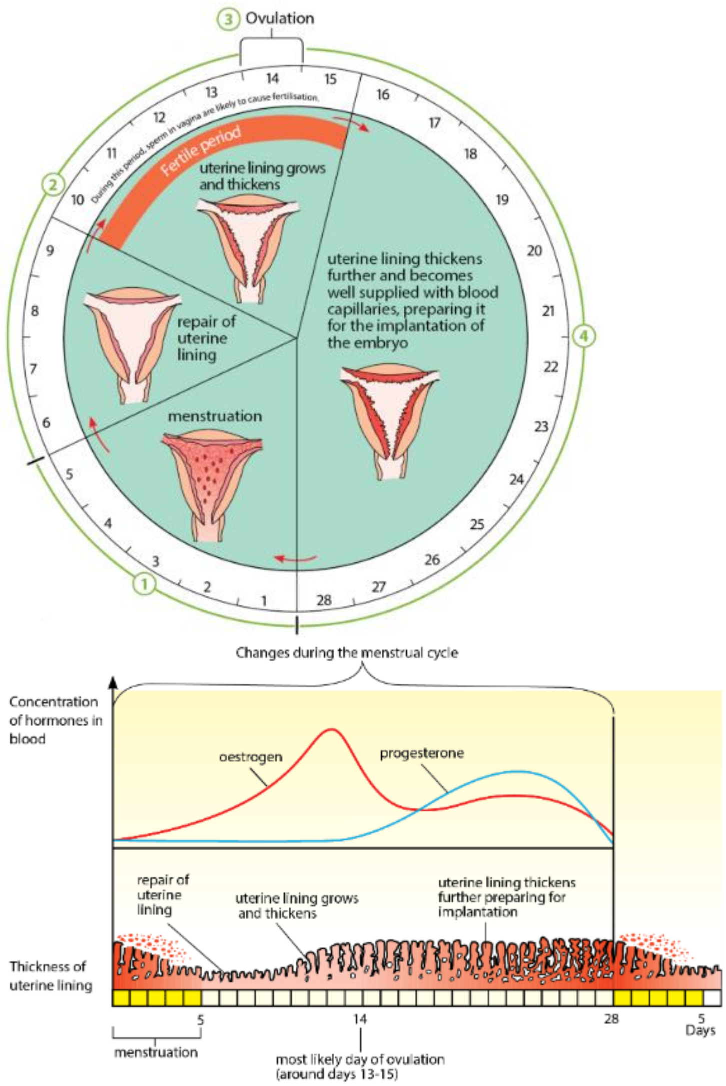
What is the menstrual cycle?

-For a female, the first sign of puberty is usually the monthly discharge of blood or menses from the uterus via the vagina, in a process known as menstruation
-The menstrual period or time of menstruating lasts about five days, but can vary
-Menstruation is a part of a cycle of events that takes place in the female reproductive system every month, and this cycle is called the menstrual cycle

-The average menstrual cycle for a female is 28 days, but can range from 21-33 days
-The length of the menstrual cycle can be affected by many factors, including stress, tiredness, illness, an unbalanced diet or malnutrition
-As a female ages, the ovaries will eventually stop releasing eggs and the menstrual cycle will pause, called menopause and taking place between 45 and 55 years of age

Stages in the menstrual cycle

-The image below shows the stages of the menstrual cycle, as well as showing the concentration of hormones and thickness of uterine lining throughout the menstrual cycle
-For the first image, 1 is menstruation, 2 is after menstruation, 3 is ovulation and 4 is after ovulation



Menstruation (Day 1-5)
-During menstruation, the uterine lining and unfertilised egg break down and are shed with some blood

After menstruation (Day 6-13)
-The ovary produces a hormone called oestrogen
-Oestrogen causes the uterine lining to repair and thicken, causing it to be thick, spongy and full of blood capillaries
-High oestrogen concentration leads to ovulation
-After menstruation, oestrogen production increases significantly

Ovulation (Day 14)
-On the 14th day, an ovary releases an egg into the oviduct in a process known as ovulation
-The two ovaries take turns releasing an egg

After ovulation (Day 15-28)
-After ovulation, the ovary produces a hormone called progesterone
-Progesterone prevents ovulation and further development of eggs, and causes the uterine lining to thicken further as well as maintaining it
-This is to prepare it for the implantation and growth of the embryo
-Oestrogen production decreases after ovulation, while progesterone production increases significantly after ovulation
-If no fertilisation occurs, progesterone production decreases
-The uterine lining then breaks down and the whole cycle repeats

What happens if no fertilisation occurs?

-When fertilisation does not occur, the egg breaks down and blood progesterone level decreases
-On the 28th day, without progesterone, the uterine lining begins to break down, and menstruation begins again, and the whole cycle repeats

What happens if fertilisation occurs?

-When fertilisation occurs, a zygote is formed and the zygote develops into an embryo
-The ovary secretes progesterone and oestrogen, causing the maintenance and thickening of the uterine lining for implantation of the embryo
-The embryo embeds itself in the uterine lining until a structure called the placenta is formed
-The ovary continues to secrete progesterone and oestrogen until the placenta can take over production of the two hormones

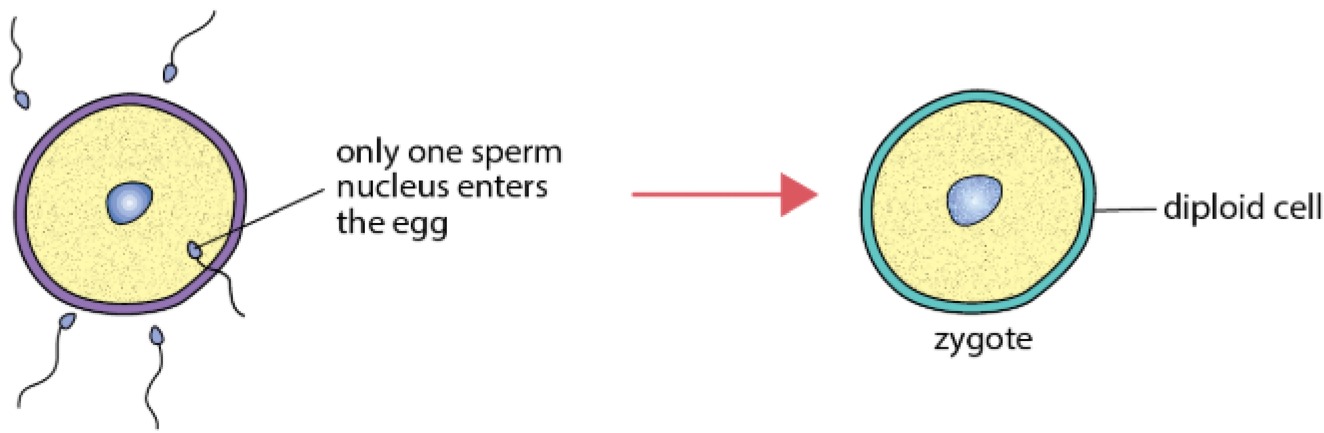
Fertile period

-An egg can survive in the oviduct for up to 24 hours, hence if ovulation occurs on the 14th day in a 28 day menstrual cycle, the egg can survive from day 14 to 15
-Sperm can survive in the female reproductive system for about 3 to 5 days
-This means that sperm deposited in the vagina around day 10 can fertilise the egg released on day 14 to bring about pregnancy

-Hence fertilisation is possible if sexual intercouse occurs from day 10 to 15 of the menstrual cycle, and this period is known as the fertile period
-The rest of the days are known as infertile periods

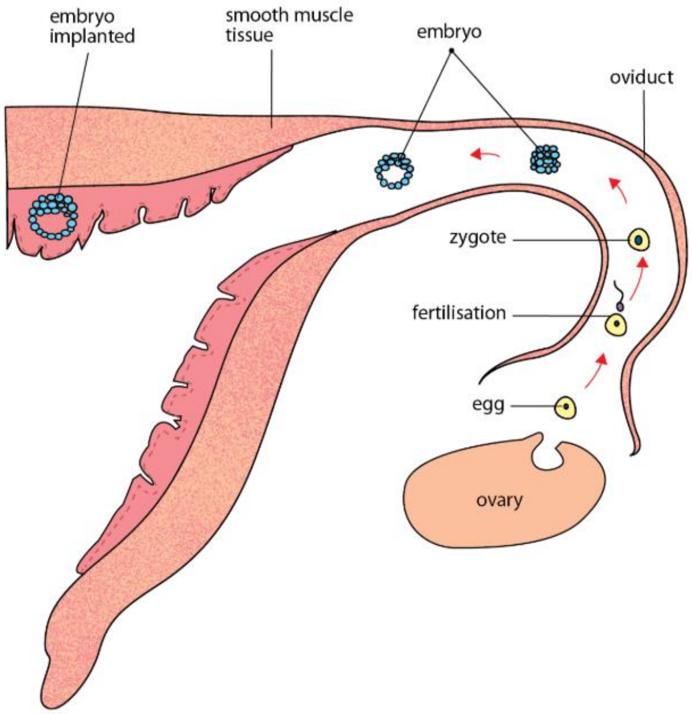
How does fertilisation occur?

-Fertilisation is the process by which the nucleus of the male gamete fuses with the nucleus of the female gamete to produce a zygote
-When sperm is deposited into the vagina during the fertile period, the sperm swims up to the oviducts of the female
-At the oviduct, only one sperm nucleus enters the egg
-The sperm nucleus then fuses with the egg nucleus, and a zygote is formed, and this process is known as fertilisation
-As soon as the sperm has entered the egg, no other sperm can enter, and the remaining sperm which do not fertilise the egg eventuallly die



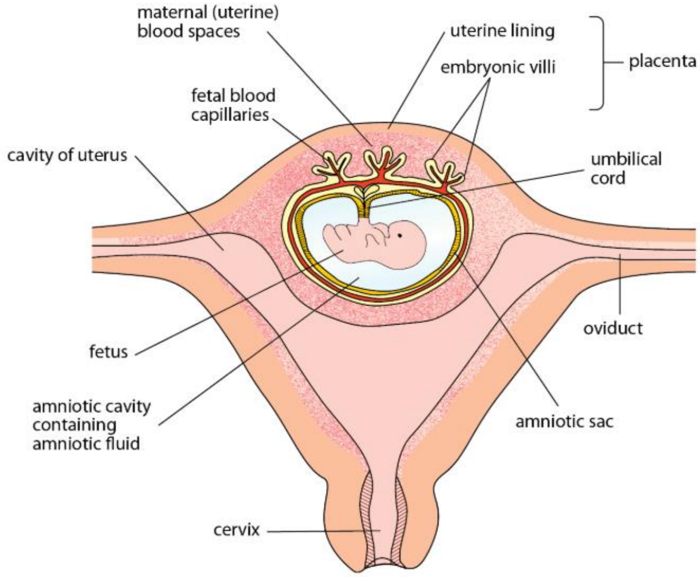
Implantation

-After fertilisation, the cilia lining the inner surface of the oviduct sweep the zygote along the oviduct, and peristaltic movements in the wall of the oviduct also aid in this process
-While the zygote moves through the oviduct, it divides through mitosis to form a ball of cells called the embryo
-The energy needed for this early stage of cell division is provided by the nutrients stored in the egg, and it takes about five days for the embryo to reach the uterus
-The embryo may then float freely in the uterus for around two days, before eventually sinking into or becoming embedded in the uterine lining, in a process called implantation, occuring about seven days after fertilisation
-The embryo implants itself into the uterine lining to receive nutrients and oxygen from the mother’s blood for continued development



Developments after implantation

-Soon after implantation, finger like projections called villi begin to grow from the embryo into the uterine lining, and they contain the blood capillaries of the embryo
-The villi and uterine lining, in which the villi are embedded, make up the placenta
-A tube known as the umbilical cord attaches the embryo to the placenta, which starts providing nutrients for the embryo instead of the uterine lining at this point
-At the same time the placenta is developing, a membrane called the amniotic sac begins to develop
-The amniotic sac encloses the embryo in a fluid filled space known as the amniotic cavity, which contains amniotic fluid
-The embryo continues to develop in the amniotic sac, and in humans, around 10 to 12 weeks after fertilisation, all the major organs in the embryo are formed, and it is now known as the fetus
-After 9 months, the fetus is fully formed and ready to be born



Placenta

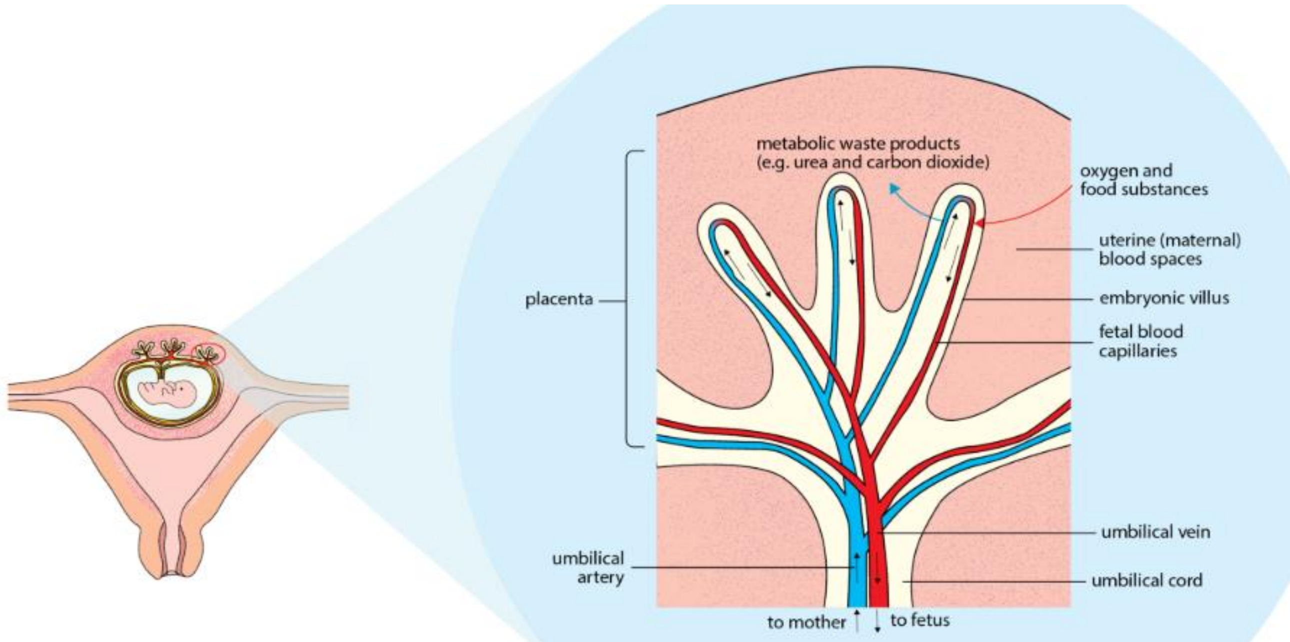
-The placenta has multiple functions, mainly imvolving the transport of substances to and from the fetus
-Most of these substances move through diffusion from maternal (mother) blood to fetal (fetus) blood or vice versa

Substance	Direction	Purpose
Oxygen	Maternal blood → Fetal blood	-Oxygen allows aerobic respiration to release energy for growth
Dissolved food substances (amino acids, glucose, mineral salts)	Maternal blood → Fetal blood	-The amino acids are used in the formation of protoplasm -The glucose is used in aerobic respiration to release energy for growth
Excretory waste products or metabolic waste (carbon dioxide, urea)	Fetal blood → Maternal blood	-To prevent excretory waste products from accumulating to toxic levels
Protective antibodies	Maternal blood → Fetal blood	-To protect the fetus against certain diseases
Oestrogen and Progesterone	Maternal blood → Fetal blood	-To maintain the uterine lining in a healthy state during pregnancy -Note that these hormones act on

		the uterine lining, not on the fetus

Umbilical cord

-The umbilical cord attaches the fetus to the placenta, and contains the blood vessels of the fetus
-It contains two umbilical arteries that transport deoxygenated blood and metabolic waste products from the fetus to the placenta
-It also contains one umbilical vein that transports oxygenated blood and food substances from the placenta to the fetus



Amniotic fluid

-The amniotic sac encloses the fetus in the amniotic cavity, which contains amniotic fluid
-The amniotic fluid supports and cushions the fetus before birth, acting as a shock absorber
-Since it cannot be compressed, it protects the fetus against physical injury
-It allows the fetus a certain degree of movement, which promotes muscular development
-During birth, it lubricates and reduces friction in the vagina and birth canal, as the amniotic sac breaks around birthtime to release the amniotic fluid

Fetal and maternal blood

-In the placenta, fetal blood capillaries are seperated from the maternal system by only a thin layer of tissue, where diffusion of dissolved substances can occur across
-This is so that the fetal blood system is not continuous with the maternal blood system
-This is because the blood pressure of the mother would kill the fetus as it is much higher than that of the fetus

-The blood group of the fetus may not be the same as the mother's, so if the two have different blood groups and the two blood systems mixed, antibodies in either the fetus or mother can cause blood cells to agglutinate, endangering the fetus and the mother
-It also prevents potential harmful substances and pathogens from entering the fetal bloodstream
-However, some toxins such as nicotine, caffeine, alcohol and lead can still enter the fetal bloodstream from the maternal bloodstream

STIs

-STIs, or sexually transmitted infections, are bacterial or viral diseases spread or transmitted through sexual intercourse
-They can be transmitted through semen from males, vaginal fluid from females or blood from an infected person

HIV and AIDS

-HIV, or human immunodeficiency virus, is an STI
-HIV can develop into AIDS, or acquired immune deficiency syndrome
-HIV attacks white blood cells and is hence harmful as it means that the body is unable to produce sufficient antibodies to protect itself from diseases
-Some symptoms of AIDS are pneumonia, brain infection, widespread tuberculosis affecting multiple organs, chronic or persistent fever, diarrhoea lasting several months and kaposi's sarcoma, which is cancer of the blood vessels
-AIDS is known as a syndrome as it is a disease with many signs and symptoms occuring at the same time
-HIV is usually transmitted through sexual intercouse, sharing of needles and blood transfusions with infected people
-It can also be transmitted from an infected mother to the fetus
-To control HIV transmission we can have only one sexual partner, abstain from sexual intercourse, use a condom, not share personal care items and use new or sterile needles.

Chapter 18: Inheritance

What is inheritance?

-Inheritance refers to the transmission of traits from one generation to another
-This is also why we can have the same eye colour as our mother or the same hair colour as out father
-Some traits in humans that can be inherited include hair type (straight, wavy or curly), hair colour (black, brown, blond etc), earlobe type (attached or detached), skin colour (fair, dark etc), eye colour (brown, blue black, green etc), eyelid type (single or double) and dimples
-Hereditary factors are responsible for the transmission of characteristics, and are known as genes
-A gene is the basic unit of inheritance in a living organisms, and is a sequence of DNA nucleotides that control the formation of a single polypeptide, and is also a unit of inheritance
-Each characteristic is controlled by a pair of factors in the cells of the organism, and the two factors in each pair separate during gamete formation
-This is so that each gamete only contains one factors
-The fusion of gametes during fertilisation then restores the diploid condition in the zygote, that is, the zygote contains two factors for a particular characteristic
-Gametes unite at random so that the ratio of characteristics among the offspring can be predicted

Alleles

-Our normal body cells contain two haploid sets of chromosomes, each inherited from one parent
-Hence, each chromosome is represented as a pair in each cell
-The different forms of the same gene are called alles, and alleles occupy the same relative position on a pair of homologous chromosomes
-If a person has two different alleles, the allele that expresses itself is called the dominant allele while the other is called the recessive allele
-The trait of a recessive allele can only be expressed if a person has two recessive alleles
-For example, if the allele for double eyelids is dominant and the allele for single eyelids is recessive, a person with both alleles would have double eyelids

Genotypes and phenotypes

-The combination of alleles for a particular gene is called the genotype, while the expressed trait or outward appearance is called the phenotype
-When writing genotypes, the dominant allele is usually written as an uppercase letter while the recessive allele is written as a lowercase letter
-For example, in the example above, let D be the dominant allele and d be the recessive allele
-The different genotypes and corresponding phenotypes of the person is hence shown below

Genotype	Phenotype
DD	Double eyelids

Dd	Double eyelids
dd	Single eyelids

Homozygous and heterozygous

-The terms homozygous and heterozygous are used to describe the allele combination or genotype of an organism
-Homozygous refers to having two identical alleles of a particular gene
-An organism can be homozygous dominant if it has two dominant alleles for a gene while it can be homozygous recessive if it has two recessive alleles for a gene
-In the previous example, a person with a DD genotype is homozygous dominant while one with a dd genotype is homozygous recessive
-Heterozygous refers to having two different alleles of a particular gene
-In the previous example, a person with a Dd genotype is heterozygous
-Hence, the dominant allele is expressed in both homozygous and heterozygous conditions, while the recessive allele is only expressed in homozygous conditions
-An organism is considered pure bred if it is homozygous and contains identical alleles

Genetic diagrams

-Scientists use genetic diagrams to explain how alleles are passed onto an offspring and what traits will be expressed by the offspring
-For example, in the genetic diagram shown below, T is the dominant tall allele while t is the recessive dwarf allele for plants

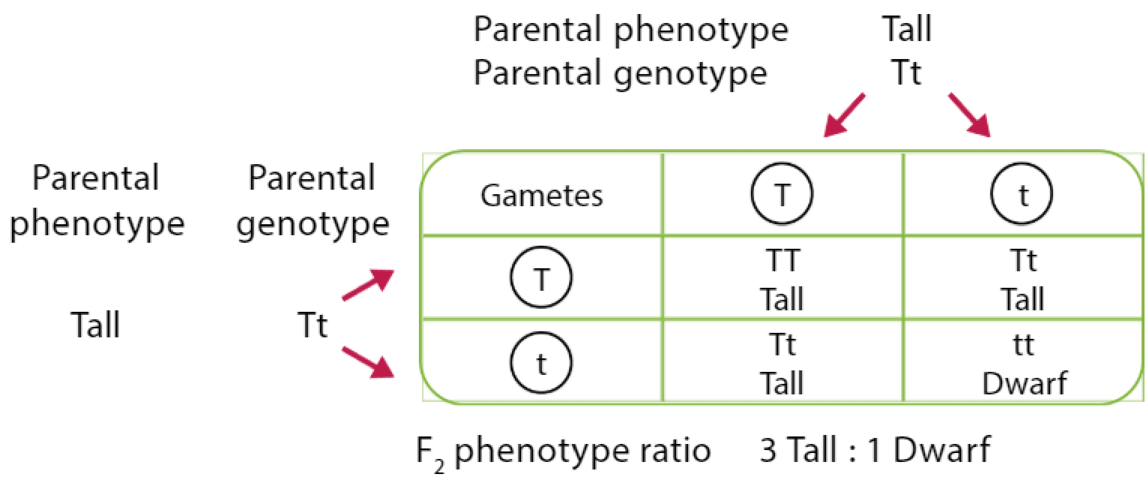
Parents phenotype	Pure tall	x	Pure dwarf
Parents genotype	TT	x	tt
Gametes	T , T	x	t , t
F1 genotype		Tt, Tt, Tt, Tt	
F1 phenotype		tall, tall, tall, tall	
Phenotypic ratio		tall:dwarf 4:0	

-At the start, an organism that is pure bred for a trait is homozygous for that trait
-Meiosis then separates a pair of allele by splitting up each pair of homologous chromosomes so that each gamete only receives one copy of each allele

-The F1 generation offspring thus all have the Tt genotype
-Note that for the parents phenotype, if they have for example a Tt genotype, they will be heterozygote tall and not pure tall
-Note that in small numbers, the probability of the observed ratio deviating from the expected genetic ratio is high for the phenotypic ratio
-Note that the F1 generation is the first generation and the F2 generation is the second generation, so if the parents are the F1 generation, it would be F2 instead of F1 for the diagram above

Punnet square

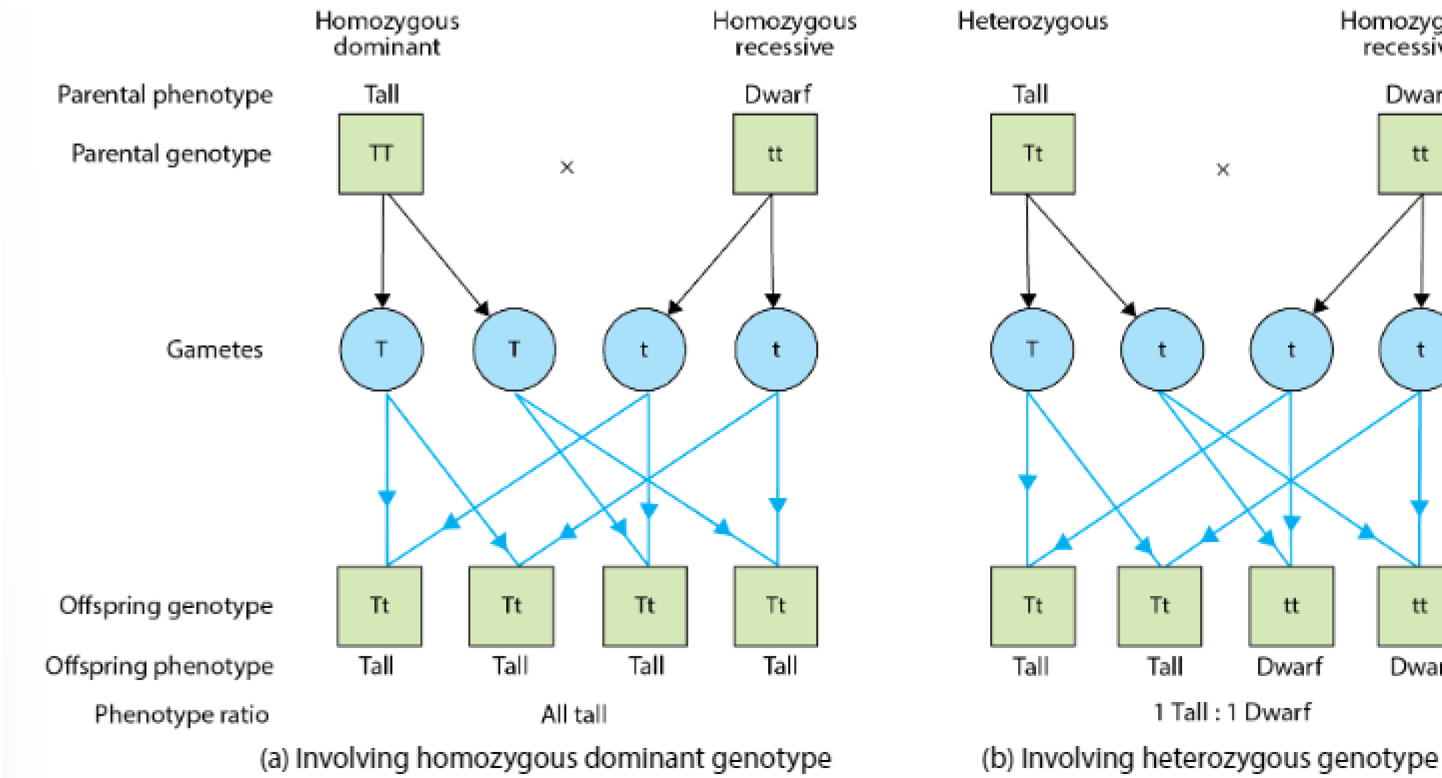
-A punnet square can also be used to show the inheritance of traits



-Note that a punnet square is not a genetic diagram

Test cross

-If an organism expresses the dominant trait, we cannot tell if it is heterozygous or homozygous dominant
-Hence to find out the genotype of an organism showing the dominant characteristic, we carry out a test cross
-A test cross is always carried out with a homozygous recessive organism
-If the organism is homozygous dominant, all the offspring will have the dominant trait
-However if the organism is heterozygous, the offspring will have the ratio of 1 dominant : 1 recessive, and offspring with the recessive trait will appear



Codominance

-When a red haired bull mates with a white haired cow, their offspring will have both red and white hairs, in an example of codominance
-In codominance, both alleles express themselves in the heterozygote, which has a phenotype intermediate between that of its pure bred parents, and the alleles are said to be codominant
-For the example above, the the red haired allele be C^R and the white haired allele be C^W
-The genetic diagram for the example is shown below

Parents phenotype	Pure red hair	x	Pure white hair
Parents genotype	C^RC^R	x	C^WC^W
Gametes	C^R , C^R	x	C^W , C^W
F1 genotype	C^RC^W, C^RC^W, C^RC^W, C^RC^W		
F1 phenotype	red-white hair, red-white hair, red-white hair, red-white hair		
Phenotypic ratio	red hair: white hair: red-white hair 0:0:4		

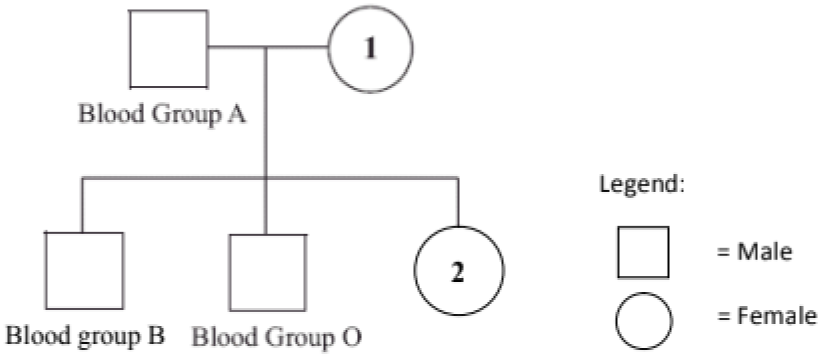
How are ABO blood groups inherited?

-A gene that exists in more than two different forms is said to have multiple alleles
-An individual can only have two alleles, one from each parent, but with multiple alleles, there can be different combinations of the two alleles
-This means that it is possible to have more than two phenotypes expressed based on the alleles in the trait
-The gene for human blood group is an example of a gene with multiple alleles
-There are 4 blood groups, A, B, O and AB, and the alleles for A, B and O are I^A, I^B, and I^O respectively
-I^A and I^B are dominant over I^O, but I^A and I^B also exhibit codominance
-Hence, individuals with both I^A and I^B alleles will have the blood group AB

Blood group	Allele
A	I^AI^A or I^AI^O
B	I^BI^B or I^BI^O
AB	I^AI^^B
O	I^OI^O

Determining blood groups

-You can determine the blood groups of a parent by knowing the blood group of their offspring and the other parent
-For example, in the image below, individual 1 has an unknown blood group



-Individual 1 has a child who has a blood group O, which means that he must have the recessive allele I^O, as the child received one copy of the I^O allele from each parent
-Individual 1 also has a child of blood group B, hence one of the parents must have a dominant I^B allele
-However, since the father has a blood group of A and the I^A allele is dominant, individual 1 must have the I^B allele
-Hence, individual 1 has a genotype of I^BI^O and a blood group of B
-This also works for other traits such as hair colour, eye colour etc

How is sex determined?

-In a human body cell, there is one pair of sex chromosomes and 22 pairs of non sex chromosomes or autosomes
-This means that each human body cell has one pair of each type of chromosome, and are diploid with 23 pairs of chromosomes
-Males have a pair of sex chromosome consisting of one X chromosome and one shorter Y chromosome in their body cells, so XY
-Females have a pair of two X chromosomes in their body cells, so XX

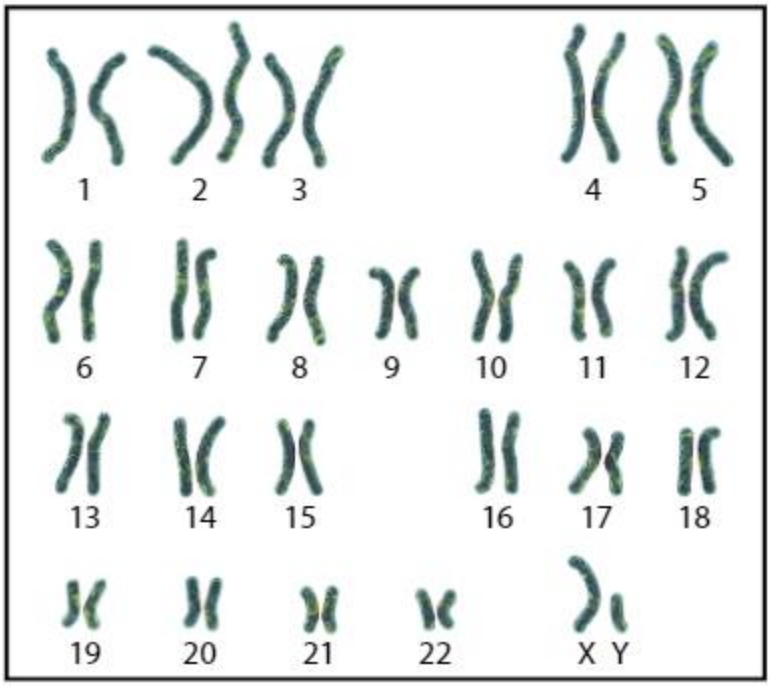


Figure 18.14 Chromosomes of a male

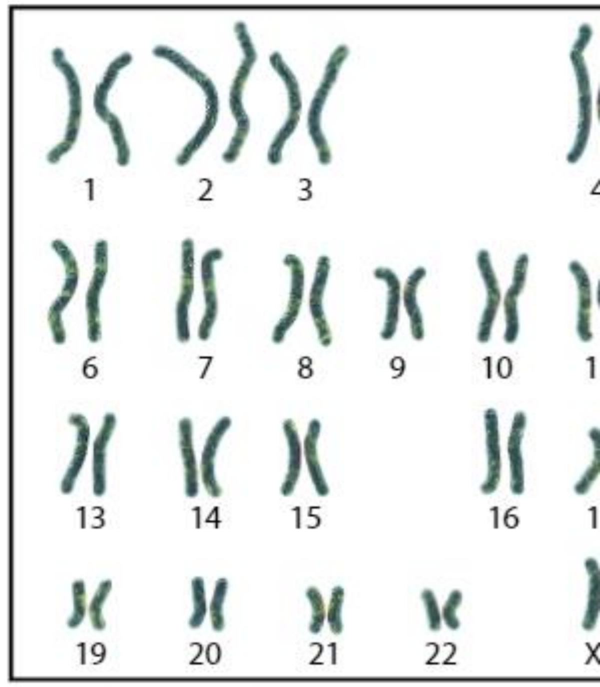


Figure 18.15 Chromosomes of a f

-During gamete formation, each gamete produced can only have one chromosome from each pair of chromosomes
-Hence, in males the sperm produced contains either an X or Y chromosome, while in females each egg will contain one X chromosome
-Random fertilisation will enable a couple to have equal chances of producing a boy or a girl, as shown below

XX

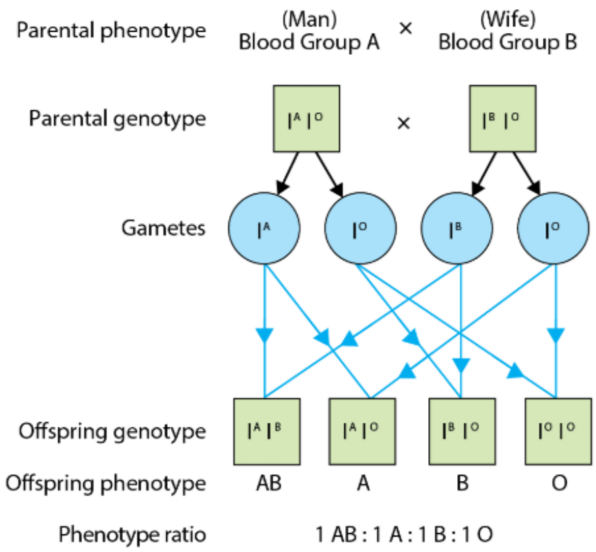
XY

Gametes	X	X
X	XX Female	XX Female
Y	XY Male	XY Male

Offspring ratio 1 Female : 1 Male

Probability

-When finding the probability or chance of an offspring having a certain trait, you use the formula: (ratio of wanted trait / total ratio of traits) x 100%
-Hence in the example below, the probability of the offspring having a blood group of AB is 1/4 x 100% = 25%



-Note that when comparing the probability of two traits occurring, you multiply them
-For example since the ratio of male:female offspring is always 1:1, to calculate the probability of the offspring being female and having a blood type of A, you do (1/2 x 1/4) x 100% = 12.5%

Variation

-Variation refers to the differences in traits between individuals of the same species
-Theres are two types of variation, discontinuous and continuous variation

	Discontinuous variation	Continuous variation
Phenotypes	-Involves a few clear cut phenotypes -For example green or yellow seeds in pea plants	-Involves a range of phenotypes -For example, human skin colour can range from dark to medium to fair
Number of genes	-Controlled by one or a few genes	-Controlled by many genes
Additive effect	-Genes show no additive effect -For example, if G is a dominant allele representing green seeds while g is a recessive allele representing yellow seeds, a plant with a Gg genotype won't have a seed colour in the middle of green or yellow but rather just a pure green seed	-Genes show additive effect -For example if D and B are both alleles making skin darker while d and b are alleles making skin fairer, a person with a DdBb genotype will have a medium skin colour as the D and B alleles add on to the d and b alleles to darken the skin colour -Note that codominance is not an additive effect
Environmental conditions	-Relatively unaffected by environmental conditions -For example, environmental conditions generally won't affect the colour of seeds	-Greatly affected by environmental conditiond -For example, greater exposure to sunlight can cause a person to have darker skin
Examples	-ABO blood groups, double or single eyelids and the ability to roll the tongue	-Height, skin colour, shoe size and body type

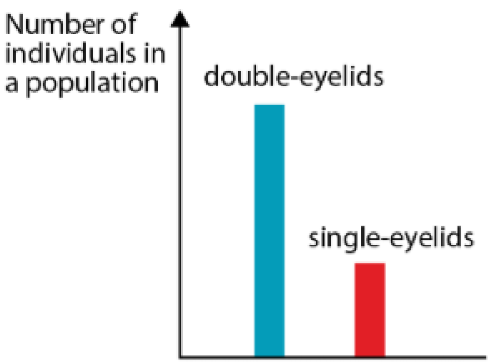


Figure 18.19 Graph showing discontinuous variation

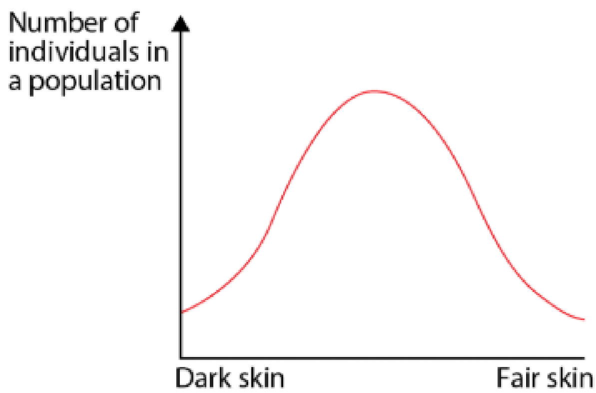


Figure 18.20 Graph showing continuous variation

Sources of genetic variation

-There are many sources of genetic variation, mainly from meiosis, random fertilisation and mutations

Meiosis
-Meiosis produces genetically dissimilar gametes with different combinations of the parent chromosomes
-This results in offspring produced that are genetically different

Random fertilisation
-Random fertilisation also contributes to variation among the offspring
-During fertilisation, any one of the millions of sperm released can randomly fuse with an egg to form a unique zygote
-Sinc each gamete is unique, the offspring produced from the fusion of gametes during fertilisation will also be genetically different

Mutation
-When genes are passed from one generation to another, the genes usually remain unchanged
-This is because before a cell divides, chromosomes replicate and the genes they carry are copied exactly
-However, an error can sometimes occur and the gene can be modified or the chromosome may be altered, and this is called mutation
-Mutation is a spontaneous change in the sequence of a gene or chromosome or in the chromosome number in the nucleus of a cell
-Diversity in species is the outcome of mutations
-Gene mutation produces variation between individuals as it results in new alleles of genes and if a mutation occurs during gamete production, the resulting genetic change can be inherited by the offspring

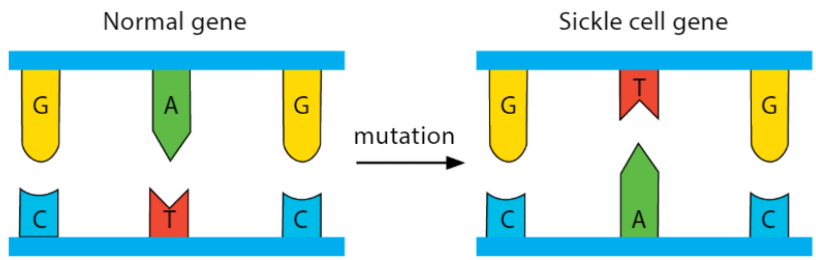
-Chromosome mutation occurs when a mutation results in a change in chromosome number in an organism
-Mutations can be inherited

Gene mutations

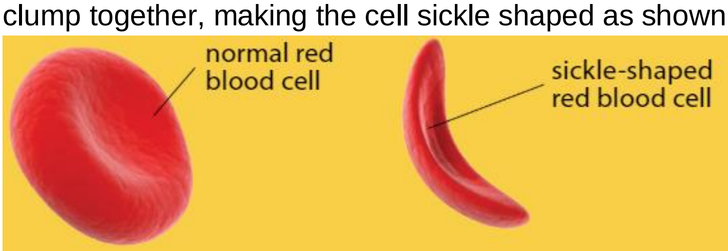
-Examples of conditions that result from gene mutations include albinism and sickle cell anaemia

Albinism
-Albinism is an example of recessive gene mutation
-Individuals who are homozygous for the albinism allele are albinos
-Albinism is characterised by the absence of pigments in the skin, hair and eyes
-An albino individual has reddish white skin and white hair, and since the iris does not contain pigment, it will appear red due to the blood vessels in it
-Albinos are very sensitive to sunlight and can get sunburnt easily

Sickle cell anaemia
-Sickle cell anaemia is another example of a gene mutation
-The mutation results in a change in the structure of the gene, involving the change in sequence of bases in the DNA, as shown below



-The gene controlling haemoglobin production is involved in sickle cell anaemia
-The mutated gene encodes the haemoglobin S or HbS protein in red blood cells
-HbS is almost the same as regular hameoglobin A or HbA, except in one amino acid
-This results in a change in the 3D shape of the hameoglobin molecule, as HbS molecules clump together, making the cell sickle shaped as shown below

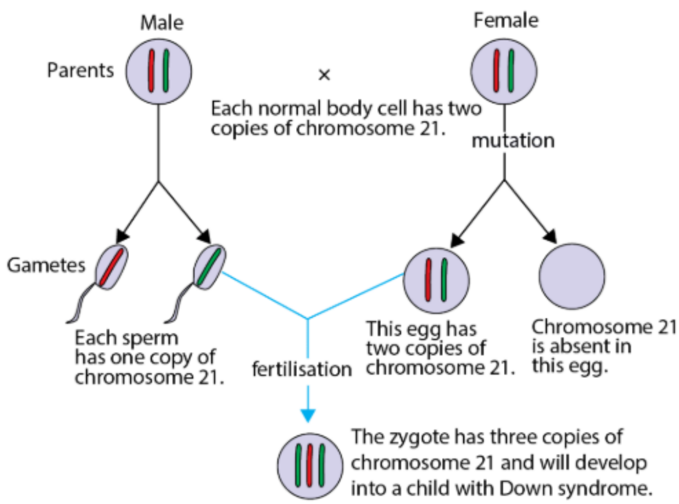


-The mutated gene is recessive, hence it is only expressed in homozygous recessive individuals
-People who have sickle cell anaemia have abnormal haemoglobin in their red blood cells, where when blood oxygen concentration drops, the red blood cells become sickle shaped
-Sickle shaped cells lose their ability to transport oxygen, and are also fragile and sticky and can get stuck in narrow blood vessels

-This slows or blocks the flow of oxygen to parts of the body, hence sickle cell anaemia can be fatal

Chromosome mutations

-An example of a chromosome that results from a chromosome mutation is down syndrome
-Humans normally have 46 chromosomes, but some people have one extra chromosome
-Normally, zygotes with extra chromosomes will fail to develop, but an exception is a zygote with an extra copy of chromosome 21, and this condition is known as down syndrome
-The way this extra chromosome is formed is shown below



-The older the mother, the higher the chance that chromosome 21 will not separate during gamete formation
-It is also possible for the mutation to occur in sperms, resulting in a sperm with an extra chromosome 21

Mutagens

-The rate of spontaneous mutations is very low
-However, this rate can be greatly increased by certain environmental agents, and such mutagenic agents are called mutagens
-Ionising radiation such as ultraviolet (UV) light, alpha and beta radiation, and gamma rays are all mutagens
-Some chemicals in certain concentrations, mainly tar and formaldehyde in cigarette smoke and a drug called lysergic acid diethylamide (LSD) are also mutagenic

Natural selection

-Natural selection refers to a process in which organisms with desirable genes and characteristics are 'selected' or 'favoured' to survive and pass on their genes to their offspring
-Mutation provide new genes or alleles for natural selection to operate on
-After thousands or millions of years, more beneficial qualities may accumulate in a species

-This new breed of organisms may be better adapted to their new environment, and may even change so much that they become an entirely new species

Evolution

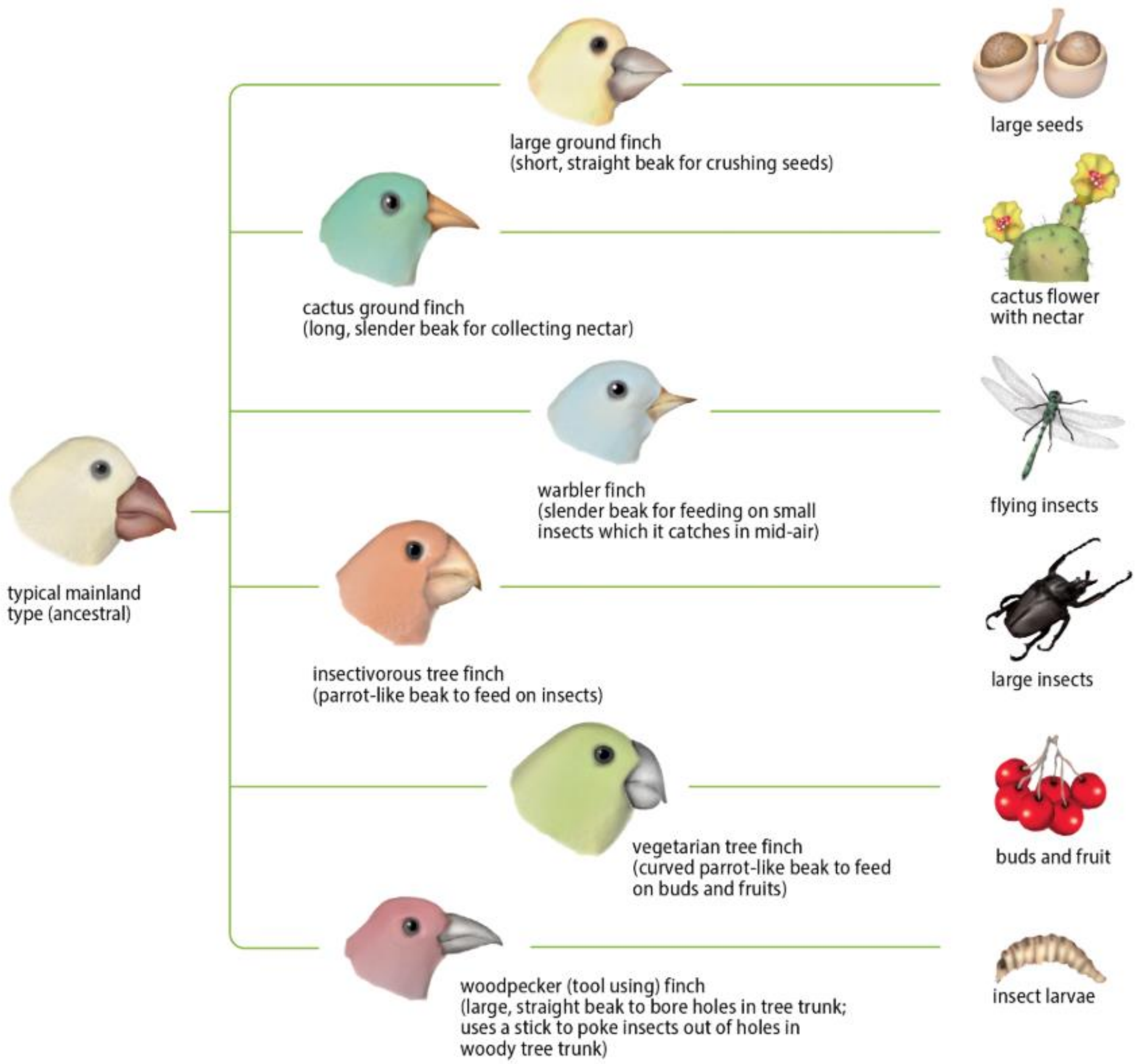
-The gradual change in the inheritable characteristics of a population over time is called evolution
-In a group of organisms, random mutations lead to different genes, alleles or traits arising in the population, where some varieties have more advantageous traits
-These advantageous traits can be anything from different fur colours to camouflage better or longer legs to run faster from predators
-Competition among the different varieties results in the survival of the fittest, where nature selects the varieties with the favourable genes and characteristics to survive, and the other varieties may die or decrease in number due to competition for food, diseases or predation
-Individuals with the more beneficial qualities are hence more likely to survive predation and reproduce to pass one these advantageous or beneficial traits to the next generation
-Over many generations, there is a shift in the genetic make-up of the population to one with more individuals possessing these beneficial traits
-These individuals may also have shifted so much from their original species that they become a new species
-Note that this process of evolution takes a long time to occur, from thousands to millions of years

Examples of natural selection

Dark peppered moths
-In 1848, the dark peppered moth was a rare sighting in england but by 1900, it became very common in the country
-This was because during that period, england was experiencing industrialisation, and many factories that were built used coal for fuel
-The burning of coal produced dark smoke that covered the environment and as a result, the trunks of trees were covered with soot from the smoke
-These dark peppered moths were hence able to camouflage better on the blacked tree trunks compared to light peppered moths and hence avoided being eaten and were able to reproduce
-Over time, the population of dark peppered moths increased due to natural selection

Antibiotic resistant bacteria
-Indiscriminate use of antibiotics has resulted in the evolution of bacteria that are resistant to certain types of antibiotics
-Genetic variations occur in bacteria due to mutation, causing some bacteria to become more resistant to antibiotics
-These bacteria will then be able to survive and pass their alleles to their offspring and over time, antibiotic resistant bacteria emerge

Darwin’s finches
-On the south american mainland, finches have short straight beaks to crush seeds
-However, on the galapagos islands, there are six major types of beaks each suited to a particular diet, as shown below



-Darwin's explanation for this is that ancestral finches from the mainland managed to get to the islands

-Once separated, the island finches began toi evolve along different lines from the mainland finches

-The island finches reproduced rapidly and competition arose

-Variations occurred among the finches and natural selection began to take place

-The finches with beaks suited for a particular diet on the islands survived and reproduced

-Eventually, six major types of finches evolved, each of which adapted to a particular food source