Cell structure and organization

- Chloroplasts
  - Site of photosynthesis where light energy is absorbed
  - Consist of grana which are stacked up to increase surface area for absorption of light
  - Only present in plant cells
- Cell membrane (plasma membrane)
  - Lipid bilayer that surrounds the cell, interspersed with protein molecule
  - Presence of temporary pores
  - Selectively permeable
    - Controls movement of substances
  - Diffusion, osmosis and active transport can therefore take place
  - Prevent outflowing of cytoplasm
  - Tonoplast
    - Plasma membrane surrounding the vacuole
- Cell wall
  - Made of cellulose (a polysaccharide), and may be deposited with ligin
  - Maintain cell turgidity, provide mechanical support, protect from mechanical damage
  - Freely permeable to water and most solutes
  - Only present in plant cells
- Cytoplasm
  - Protoplasm surrounding the nucleus
  - There are numerous organelles present in the cytoplasm
  - Organelle
    - Specialized membrane bound structures
- Cell vacuole
  - Fluid-filled space enclosed by a membrane
  - In animal cells, these are present as numerous small ones, and these are usually not permanent
  - In plant cells, there is usually a large central vacuole
  - Cell sap
    - Fluid in vacuoles, contains sugars, mineral salts and amino acids
  - Tonoplast
    - Membrane around the vacuole
- Nucleus
  - Nucleoplasm
    - Small spherical mass of denser protoplasm
  - Nuclear membrane
    - Nuclear envelope
  - Found in the cytoplasm
  - Control activities of the cell
    - Reproduction, repairs and maintenance
  - Chromatin
    - Network of long thread-like structures, containing the heredity materials
  - Chromatin is made up of proteins and DNA (Deoxyribose Nucleic Acid)
  - Chromosomes

        - Condensed and highly coiled chromatin threads during cell division
    - Nucleoli
        - A spherical structure that plays a part in the build up of proteins
- Endoplasmic reticulum
    - A series of flattened sheets
    - Smooth endoplasmic reticulum
        - Sites of synthesis and transport of steroids and lipids
    - Rough endoplasmic reticulum
        - Transport proteins synthesized at the ribosomes towards Golgi bodies for secretary packing
- Mitochondria
    - Rod-shaped
    - Site of aerobic respiration
    - Powerhouse
        - Release energy during cellular respiration
- Golgi bodies
    - Stacks of flattened membrane sacs
    - Involved in secretion of vesicles, formation of lysosomes
- Ribosomes
    - Tiny structures concerned with the manufacture of proteins
    - Found on rough endoplasmic reticulum
- Comparison between plant cell and animal cell

	Plant cell	Animal cell
Cell wall	√	X
Cell membrane	√	√
Chloroplasts	√	X
Mitochondria	√	√
Golgi apparatus	√	√
Endoplasmic reticulum	√	√
Nucleus	√	√
Shape	Fixed	Irregular
Centriole	X	√
Vacuoles	One large central	Many small
Granules	Starch	Glycogen
Cilia/flagella	X	√

    - All cells have cell membrane, cytoplasm, nucleus, mitochondria, endoplasmic reticulum and ribosomes
- Root hair cell
    - Function
        - Increase absorption of water and mineral salts from the soil
    - Presence of root hair
    - Long and elongated
    - Increase surface area for greater rate of absorption
- Xylem vessel
    - Function
        - Conduction of water in plants as well as to offer mechanical support
    - Narrow and cylindrical continuous tube
    - Absence of cross wall

    - Water column can move easily up the lumen of the xylem vessel
    - Lignified cell walls
    - Strengthens the wall and prevents collapse of the xylem vessel
- Red blood cell
    - Function
        - Transport of oxygen from lungs to the rest of the body
    - Contains hemoglobin
        - Oxygen carrier
    - Flat, biconcave shape (no nucleus)
    - This serves to increase surface area to volume ratio
    - Oxygen can also diffuse into or out of the cell at a faster rate
    - The absence of a nucleus also allow the red blood cell to squeeze through the narrow capillaries
- Cell
    - Basic structural unit of all organisms
    - Functional unit of all organisms where all chemical reactions necessary to maintain and reproduce the living system exist
    - Arise from pre-existing cells
    - Contain heredity material
- Simple tissue
    - Cells of the same type grouped together to carry out special function
- Complex tissue
    - Cells of different type grouped together for the same function
- Organ
    - Different tissues working together and enabling the organ to perform its function
- Organ system
    - Different organs working together for a special purpose

Movement of substances

- Diffusion
    - The random movement of molecules of a substance from a region of higher concentration to a region of lower concentration
- Osmosis
    - The movement of water (or solvent) molecules from a region of higher concentration to a region of lower concentration across a partially permeable membrane
- Active transport
    - The movement of substances into or out of cells against a concentration gradient
- Water potential
    - The measure of the free kinetic energy of water in a system, or the tendency for water to leave a system
    - High water potential = high tendency for water to leave the system/low tendency for water to enter a system/high concentration of water
- Osmotic potential
    - Low osmotic potential = low tendency for water to enter a system/high tendency for water to leave the system/high water potential/high concentration of water
- Hypertonic environment

    - Cell has high water potential
    - Cell has low osmotic potential
    - Water leaves the cell
- Hypotonic environment
    - Cell has low water potential
    - Cell has high osmotic potential
    - Water enters the cell
- Isotonic solution
    - Cell gains and lose water at the same rate
    - No net loss or gain in water

Biological molecules

- Importance of water
    - Use as a biological solvent
        - Medium where chemical reactions occur
    - As a reagent in the digestion or hydrolysis of food
    - As a transport medium for digested food like glucose, amino acids in animals
    - As a transport medium for wastes like CO_2, urea and other nitrogenous wastes like creatinine in animals
    - As a transport medium for hormones from the glands to the target organs
    - For heat loss since water has a high specific heat capacity
    - As a major component of body fluids such as blood, tissue fluid and digestive juices
    - Replaces water lost from the body in sweat, urine and in breath
    - Act as a lubricant in mucus and synovial fluid
    - Essential constituent of protoplasm
    - Essential for photosynthesis in green plants
    - Maintains turgidity of plant cells and to keep plants upright
    - Transport medium for mineral salts and manufactured sugars in plants
- Carbohydrates
    - Chemical constituents
        - Carbon
        - Hydrogen
        - Oxygen
- Fats
    - Chemical constituents
        - Carbon
        - Hydrogen
        - Oxygen
- Proteins
    - Chemical constituents
        - Carbon
        - Hydrogen
        - Oxygen
        - Nitrogen
    - Other possible constituents
        - Sulfur
        - Phosphorus
- Starch test

    - Drops of iodine
        - Blue-black color if starch is present
        - Brown color if starch is present
- Reducing sugars test
    - Benedict's solution
        - Green color mixture means traces of reducing sugars
        - Yellow or orange color precipitate means moderate amounts of reducing sugars
        - Brick-red or orange-red color precipitate means large amount of reducing sugars
- Protein test
    - Biuret solution
        - Sodium hydroxide
        - Copper (II) sulfate
    - Color change
        - Blue to violet (proteins)
        - Blue to pink (short-chain polypetides)
- Fat test
    - Ethanol
    - Water
    - Observation
        - Cloudy white emulsion if fats are present
- Synthesis
    - Glycogen from glucose
    - Polypetides and proteins from amino acids
    - Lipids such as fats from glycerol and fatty acids
- Enzymes
    - Lock and key
        - Highly specific
        - Only substrates with shapes complementary in shape to that of the enzymes can fit into the enzyme active site and be acted upon by the enzymes
    - Active site
        - Site with a specific shape where substrate will bind onto enzyme
    - Enzyme-substrate complex
        - Formed only long enough for the reaction to be complete
        - Same enzyme molecule can then catalyze the reaction with another substrate molecule
    - Activation energy
        - Reduces activation energy so that it is possible for chemical reactions to take place in cells at normal body temperature
    - Enzyme specificity
        - Only substrates with shapes complementary to that of the enzyme can fit into enzyme active site and be acted upon by the enzyme
    - Effects of temperature
        - Enzymes have an optimum working temperature often but not always close to that at which they usually function
        - An enzyme is inactive at low temperatures
        - This is because enzyme-substrate complexes are formed slowly

        - As temperature rises, it activity increases
        - The rising temperature increases the rate of metabolic reactions as the heat increases molecular motion
        - Thus the molecules move more quickly and frequency of collision between substrate and enzyme molecules increases
        - Hence, there is a greater possibility of a reaction taking place
        - Q_{10}
            - The rate of reaction double for every 10°C rise in temperature until optimum temperature is reached
            - The temperature coefficient Q_{10} varies between enzymes, depending on the activation energy of the catalyzed reaction
        - Optimum temperature
            - The temperature at which maximum reaction occurs
            - Beyond optimum temperature, enzyme activity will decrease until it is completely deactivated or destroyed
            - As enzymes are made of proteins, when they are heated to too high a temperature, they are denatured
        - Denaturation
            - The breaking of the secondary tertiary structures of proteins/enzymes due to high temperatures
            - An irreversible (≈60°C) destruction of an enzyme can be brought about by extreme heating
            - Each enzyme has its own optimum temperature
            - Most enzymes work best between 30-37°C
            - Enzymes in the human body have an optimum temperature of 37°C
    - Effects of pH
        - Extreme changes in pH of the solutions destroy the enzymes
        - Optimum pH
            - The pH at which the maximum rate of reaction occurs
            - When the pH is altered above or below the optimum pH, the rate of enzyme activity decreases as changes in pH alter the ionic charge of the acidic and the basic groups that help maintain the specific shape of the enzyme
            - pH changes lead to alterations in enzyme, particularly at the active site
            - extreme pH changes can cause denaturation of the enzyme

Animal nutrition

- Digestion
    - Mouth
        - The presence of food in the mouth or thoughts of food stimulates the three pairs of salivary glands to secrete saliva
        - Food is mixed with saliva and is softened by mucin
        - Mastication breaks down food into smaller pieces (increase in surface area/physical digestion)
        - The enzyme amylase, present in saliva, digests starch to maltose
        - Bolus

- Small, spherical mass of food formed by mastication and the rolling of the tongue
- Bolus is swallowed via the pharynx into the esophagus

- Esophagus
  - Bolus passes down the esophagus into the stomach through gravity as well as peristalsis
  - No digestion takes place in the esophagus
- Stomach
  - Food in the stomach stimulates the secretion of gastric juices into the stomach cavity by the gastric glands
  - Peristaltic movement in the stomach churns the food and mixes it well with gastric juice (as well as to break down the food substances into smaller pieces)
  - Gastric juice
    - A dilute hydrochloric acid (≈pH 2), prorenin and pepsinogen
  - The functions of hydrochloric acid
    - Stops action of salivary amylase
    - Converts inactive forms of gastric enzymes to active forms
      - Pepsinogen → pepsin
      - Prorenin → rennin
    - Provides a slightly acidic medium for the action of digestive enzymes
    - Kills germs and certain potential parasites
  - Excess production of hydrochloric acid may erode the stomach walls and thus result in gastric ulcers
  - Pepsin causes the breakdown of proteins to peptones or polypeptides
    - Proteins + pepsin → peptones
  - Since pepsin breaks down proteins, these need to be formed in the inactive state before being released, otherwise they will breakdown the proteins found in the cells that produces them
  - Renin is an enzyme characteristic of mammals
  - Renin clots or curdles milk proteins by converting the soluble protein caseinogen into insoluble casein, a process that requires calcium ions
    - Caseinogen (soluble) + renin/Ca^{2+} → casein (insoluble)
  - The insoluble casein would remain long enough in the stomach to be digested by pepsin
  - Protein digestion would be completed in the ileum
  - Food normally remains in the stomach for about three to four hours
  - Chyme
    - Liquefied, partly digested food that passes in small amounts into the duodenum through the pyloric sphincter
- Small intestine
  - The presence of chyme stimulates
    - Secretion of intestinal juice (succus entericus (which contains enzymes enterokinase), erepsin (peptidase),

maltase, sucrase (or invertase), lactase and intestinal lipase by the intestinal glands)
- Secretion of pancreatic juice (pancreatic amylase, pancreatic lipase, trypsinogen, an inactive form of protease) by the pancreas into the duodenum
- Release of bile by the gall bladder into the duodenum

- Acidic chyme comes into contact with intestinal juice, pancreatic juice and bile and is neutralized
- An alkaline environment is now created to provide a suitable alkaline medium for the action of pancreatic and intestinal enzymes
- Carbohydrate digestion in small intestine
  - Digestion of starch in the mouth is minimal
  - Also, there is no digestion of starch in the stomach
  - Remaining starch that enters the small intestine are digested by pancreatic amylase to maltose, then to glucose by maltase
  - Simple sugars are the end-products of carbohydrates digestion
- Fat digestion in small intestine
  - Bile emulsifies fat by breaking fats up into minute fat globules suspended in water to form a stable emulsion
  - Emulsification increases the surface area of fats for digestion
  - Digestion of fats sped up
  - Emulsified fats are converted by lipases to fatty acid and glycerol
- Protein digestion in small intestine
  - Some protein digestion occurs in the stomach
  - Undigested proteins in the small intestine are converted by trypsin to peptones, which are converted erepsin to amino acids
    - Trypsinogen + enterokinase → trypsin
    - Proteins + trypsin → peptones
    - Peptones + erepsin → amino acids

- Absorption
  - Digested food substances are absorbed by the villi of the small intestine, especially in the jejunum and ileum
  - The wall of the small intestine is well adapted for the absorption of digested food substances
    - Inner walls of the small intestine thrown into many transverse folds and furrows
    - Villi
      - Minute finger-like projections found on the wall of the small intestine
    - Numerous villi are found on the folds and furrows of the small intestine
    - Microvilli
      - Minute finger-like projections found on villi
    - The presence of folds and furrows, as well as villi and microvilli, serve to increase surface area for absorption

        - The long length of the small intestine also increases surface area for absorption to take place
        - The epithelium is only one cell thick
        - The intestinal wall and the villi are richly supplied with blood vessels and lymphatic vessels
        - The presence of these vessels serve to carry away digested food substances
        - Lacteal
            - A lymphatic vessel present in a villi which is surrounded by blood capillaries
            - Aid in the transport of fat
        - Blood vessels carry sugars and amino acids
        - This continuous transportation of digested materials away aids to maintain concentration gradient
    - Process
        - Simple sugars and amino acids, since they are relatively small in size, diffuse through the walls of the villi into the blood capillaries
        - Mineral salts and vitamins, since they are relatively small in size, also diffuse through the walls of the villi into the blood capillaries
        - Transport of digested food substances into the blood capillaries can be through diffusion or by active transport
        - Fats are broken down into glycerol and fatty acids
            - Glycerol is soluble in water and it diffuses through the epithelium
            - Fatty acids reacts with bile salts to form soluble soaps so that it can diffuse through the epithelium
            - In the epithelium, glycerol and the soluble soaps recombine to form minute fat globules which are absorbed by the lacteals
        - Water and mineral salts are also absorbed by the large intestines
        - The epithelium layer of the villi is one cell thick
            - This allows digested food substances to diffuse rapidly over a short distance into the blood capillaries or lacteal
        - Undigested food substances and unabsorbed digested matter are stored temporarily in the rectum before being discharged as feces through the anus
        - Egestion
            - Removal undigested matter from the body
- Transportation and utilization of absorbed foods
    - Sugars
        - Blood capillaries in the villi unite to form a large vein, the hepatic portal vein
        - The hepatic portal vein is linked to the liver
        - Simple sugars are transported to the liver, where most of these are converted to glycogen and stored

        - Conversion of glucose to glycogen is carried out in the presence of the hormone insulin, produced by the pancreas
            - Glucose + insulin (from pancreas) → glycogen
        - The unconverted sugars are transported to the other parts of the body as glucose for assimilation
        - Glucose is needed for cellular respiration
        - Hence, when the body is in need of glucose, glycogen is converted back into glucose in the liver and transported away to other parts of the body
        - The conversion of glycogen to glucose is under the action of the hormone adrenaline
            - Glycogen + glucagon (from pancreas) → glucose
    - Amino acids
        - The route of transport for amino acids is similar to that of simple sugars (after being transported to the liver, it is transported in the blood stream to other parts of the body)
        - Amino acids are assimilated for
            - New protoplasm
            - Growth and repair
            - Formation of hormones
            - Formation of enzymes
        - Excess amino acids not utilized are brought back to the liver
        - Deamination
            - Removal of the amino groups ($-NH_2$) and conversion into ammonia, then urea of excess amino acids
        - Urea is transported to the kidneys to be removed in the urine
        - The remains of amino acids are converted into glucose (and then to glycogen) in the liver
    - Fats
        - Lymph
            - A colorless fluid in lacteals
        - Chyle
            - Milky fluid obtained when fats in the lacteals are mixed with lymph
        - Lacteals linked together into larger lymphatic vessels, discharging into the thoracic duct, and ultimately opening into the subclavian vein
        - Fats are then carried to the liver and assimilated
        - When there is an inadequate supply of glucose, the fats are oxidized to provide energy
        - Under normal conditions, fats are used to build protoplasm
        - Excess fats are stored in adipose tissues
        - Adipose tissues
            - A layer of tissues beneath the skin, around the heart, the kidneys and in the mesenteries binding the intestines, where fats are stored
- Peristalsis
    - Rhythmic, wave-like contractions of the alimentary canal wall to move food along the alimentary canal
    - Brought about by the antagonistic actions of the circular and longitudinal muscles
        - Dilation

        - Circular muscles relax, longitudinal muscles contract
    - Constriction
        - Circular muscles contract, longitudinal muscles relax
- Functions of liver
    - Carbohydrate metabolism
        - Glycogen is converted to glucose in the liver in the presence of glucagon from the pancreas
    - Fat metabolism
        - Lipids are removed from the blood and broken down
        - E.g. cholesterol is excreted in the bile
    - Breakdown of red blood cells
        - The red blood cells become worn out after a period of time and are destroyed by the spleen
        - The hemoglobin of red blood cells are brought back to the liver where it is broken down and the iron released is stored
        - Bile pigments are formed from the breakdown of hemoglobin
    - Metabolism of amino acids and the formation of urea
        - The amino group is converted into urea and is removed from the body in the urine
        - The remains of the deaminated amino acids are converted to glucose in urea

Plant nutrition

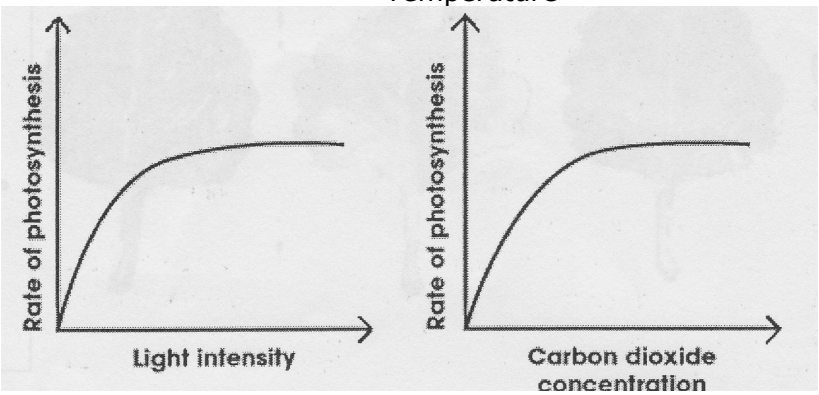
- Adaptations of dicotyledonous leaf

Part of the leaf	Structure	Function
Upper epidermis	One cell thick layer Waxy cuticle No chlorophyll Stomata may be present in small numbers	Cuticle reduces loss of water through evaporation Cuticle also protects the leaf from mechanical injury The upper epidermis and the cuticle is transparent, thus allowing light to pass through easily
Palisade mesophyll	Densely packed cylindrical-shaped cells arranged at right-angles to the upper epidermis of the leaf in one or two layers Cells have thin walls and contain many chloroplasts	Palisade mesophyll cells are the main sites where photosynthesis takes place due to high concentration of chlorophyll Thin cell wall and cytoplasm allows rapid diffusion of water and carbon dioxide into the chloroplasts
Spongy mesophyll	Irregularly-shaped cells containing fewer chloroplasts Cells are loosely packed with large intercellular air spaces between cells	Air spaces are connected with the stomata (serves as passage way for diffusion of carbon dioxide and oxygen, as well as water vapor) Some photosynthesis occurs and this causes the

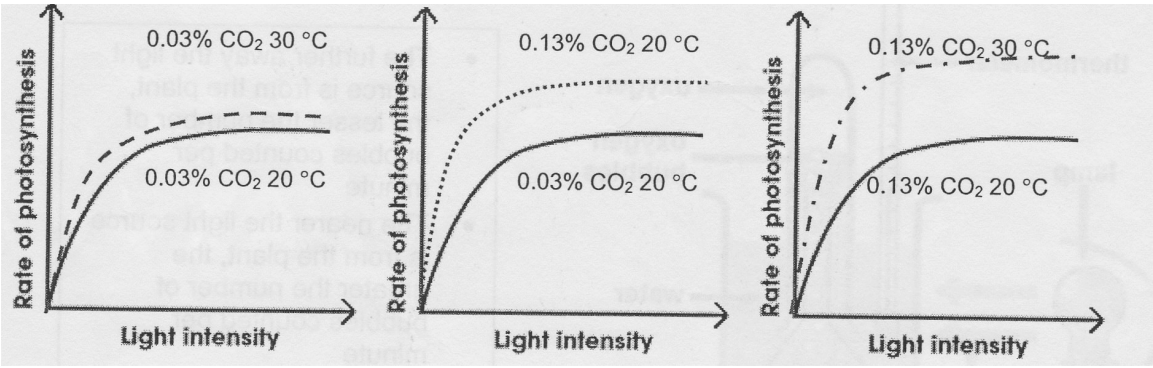
		cells to be turgid (support)
Vascular bundles	Lignified xylem vessels and tracheids Phloem tissues with sieve tubes and companion cells	Xylem aids in the conduction of water and mineral salts from the roots to the leaves Provides support for the leaf lamina Phloem aids in transport of products of photosynthesis from the leaves to other parts of the plant, especially to the roots, in the form of sucrose
Lower epidermis	One cell thick layer Waxy cuticle Presence of many stomata	Stomata allow gaseous exchange between external environment and the intercellular air spaces in the spongy mesophyll
Stomata	A pair of curved guard cells surrounding a stomatal pore	Gaseous exchange occurs through the stomatal pore Opening or closure of guard cells regulates gaseous exchange

- Photosynthesis
  - Equations
    - Word equation
      - Carbon dioxide + water → glucose + oxygen + water
    - Chemical equation
      - $6CO_2 + 12H_2O \rightarrow C_6H_{12}O_6 + 6O_2 + 6\ H_2O$
  - Intake of carbon dioxide
    - Carbon dioxide from the atmosphere diffuses into the leaf through the stomata
    - Once the carbon dioxide enters the leaf, it dissolves in the thin film of water surrounding the spongy mesophyll cells and palisade mesophyll cells and finally diffuse into the chloroplasts within the cells and used in photosynthesis
  - Effects of varying light intensity
    - In the absence of light, photosynthesis does not occur and only respiration continues
    - As light intensity increases, the rate of photosynthesis increases until the amount of carbon dioxide released from respiration is equal to the amount of carbon dioxide absorbed for photosynthesis
    - As higher light intensities, a net uptake of carbon dioxide and release of oxygen is reached and the amount of sugar in the plant will increase
    - The rate of photosynthesis increases with increasing light intensity up to the light saturation point
    - Beyond the light saturation point, further increase in light intensity has no effect on the rate of photosynthesis

        - At very high light intensities, the rate of photosynthesis slows down as excessive amounts of ultraviolet rays damages chlorophyll molecules
        - Blue light and red light are most strongly absorbed by chlorophyll pigments
        - Thus, the highest photosynthetic rate is obtained when leaves are illuminated with blue and red light
    - Effects of temperature
        - The reaction in dark stage of photosynthetic process are catalyzed by enzyme
        - Increasing temperature up to 40°C will increase the rate of photosynthesis due to increased enzyme activity
        - At temperatures above 40°C, the rate of photosynthesis slows down as the enzymes are denatured gradually
    - Effects of carbon dioxide
        - The normal percentage of carbon dioxide in atmospheric air is 0.03%
        - Increasing carbon dioxide level increases the rate of photosynthesis up to the carbon saturation point
        - Further increase in carbon dioxide levels had no effect on the rate of photosynthesis
        - Carbon dioxide levels of greater than 0.1% have no effect on rate of photosynthesis
    - Limiting factor
        - Definition
            - Any factor that directly affects a process if the quantity of this factor is changed
        - In the case of photosynthesis
            - Light
            - Carbon dioxide concentration
            - Temperature



        - Graphs show the effect of light and carbon dioxide concentration on photosynthesis rates
        - In each case, the rates increase rapidly at first, then reach a ceiling, indicating that they are being affected by another limiting factor, for example, temperature



- For example, in the first graph, by increasing the temperature, the rate of photosynthesis showed only a small increase
- It is likely that temperature may not be an important limiting factor in this example
- In the second graph, carbon dioxide concentration is increased instead
- There is a significant increase in the rate of photosynthesis
- It is likely that carbon dioxide is an important limiting factor in this example
- This is true in nature as there only is 0.03% CO_2 in air
- Thus, carbon dioxide concentration is the limitation factor
- Carbon dioxide levels can only be raised under laboratory conditions
- The constant rate of photosynthesis even when carbon dioxide concentration is raised implies that there is another limiting factor at work
- In the third graph, with raised carbon dioxide concentration, temperature is increased
- Again, there is a significant increase in the rate of photosynthesis
- This shows that temperature was a limiting factor
- Compensation point
    - At certain light intensity, the rate of photosynthesis and the rate of respiration is equal
    - This means that the amount of CO_2 taken in and O_2 released is the same

Transport in flowering plants

- Xylem
    - Functions
        - Conducts water and its dissolved mineral salts from the roots to the stems
        - Provide mechanical support to the plant
- Phloem
    - Functions
        - Conducts manufactured nutrients (sucrose and amino acids) from the leaves to other parts of the plant
- Root
    - Structure
        - The root consists of various regions or zones
        - Growing zone

            - Small young cells that are actively dividing to form new cells
        - Zone of elongation
            - Cells elongate here to bring about increase in length of the root
        - Root cap
            - Several layers of protective cells to protect the young cells from injury during elongation
        - Zone of root hairs/maturation
            - Absorption of minerals and water occurs here
        - The region of the root about the zone of root hairs has an outer skin which is impregnated with suberin
        - This allows it to be air proof as well as waterproof
    - Structure of a young dicotyledonous root
        - Xylem and phloem are not bundled together
        - Cortex present as a storage tissue
        - Piliferous layer
            - Epidermal layer of the root which bears root hair cells
        - Root hairs serve to increase surface area to volume ratio for the adaptation of absorbing water and mineral salts
        - Cuticle is missing
    - Movement of water
        - Absorption of water and mineral salts takes place mainly in the zone of root hairs
        - Root hairs increase surface area for uptake of water
        - Sap in root hair is a relatively concentrated solution of sugars and various salts
        - Thus the sap has a lower water potential than the soil water
        - Water enters the root hair cells by osmosis
        - Cell sap and soil water is separated by a partially-permeable plasma membrane
        - Entry of water dilutes the root hair cell sap
        - This causes water to move into the inners cell by osmosis
        - As water moves into these cells, they have a higher water potential than cells further in, thus water will move in further into the roots
        - The process continues until the water enters the xylem vessels and moves up the plant
    - Pathway of water from root to leaves
        - Root hair cells → epidermis of root → cortex of root → endodermis → xylem vessels
- Transpiration
    - Definition
        - The loss of water vapor from the aerial parts of a plant, especially through the stomata of the leaves
    - A consequence of gaseous exchange
        - There are numerous mesophyll cells present within a leaf, and these are surrounded by intercellular air spaces
        - Water continually moves out of the mesophyll cells to form a thin film of moisture over their surface

        - From the wet cell walls, water evaporates into the intercellular spaces, and from there it diffuses through the stomata to the drier air outside the leaf
    - Effects
        - Air movement
            - The higher the air movement, the higher the rate of transpiration
        - Temperature
            - A rise in temperature will result in a rise in rate of evaporation (transpiration)
        - Humidity of air
            - The more humid the air, the slower the rate of transpiration
        - Light intensity
            - High light intensity will cause stomata opening
            - This will increase the rate of transpiration
    - Wilting
        - The turgor pressure in the mesophyll cells in the leaf
            - Supports the leaf
            - Keep the leaf firm and widely spread out to absorb sunlight for photosynthesis
        - In strong sunlight, excessive transpiration causes the cells to lose their turgor
        - They become flaccid and the plant wilts
    - Translocation
        - Definition
            - The transport of manufactured substances like sugars and amino acids in plants
        - Translocation of sugars and amino acids occurs in the phloem
            - Experiment with aphids
            - Ringing experiment
            - Use of ^{14}C isotopes

Transport in humans

- Main blood vessels
    - Pulmonary artery
        - Heart to lungs
    - Pulmonary vein
        - Lungs to heart
    - Hepatic artery
        - Heart to liver
    - Hepatic vein
        - Liver to heart
    - Renal artery
        - Heart to kidneys
    - Renal vein
        - Kidneys to arteries
- Functions of blood
    - Red blood cells
        - Contains hemoglobin
            - A red pigment

                - Special kind of protein containing iron
                - Oxygen carrier
        - White blood cells
            - Two main kinds
                - Lymphocytes
                    - Produces antibodies
                - Phagocytes
                    - Phagocytosis
                    - Tissue rejection
        - Platelets
            - Aids in the clotting of blood
                - Fibrinogen → fibrin
        - Plasma
            - Transport medium
                - Blood cells
                - Ions
                - Soluble food substances
                - Hormones
                - Carbon dioxide
                - Urea
                - Vitamins
                - Plasma proteins
- Blood groups
    - Types
        - A
        - B
        - AB
        - O
    - Possible combinations for the donor and recipient

	O (donor)	A (donor)	B (donor)	AB (donor)
O (recipient)	√			
A (recipient)	√	√		
B (recipient)	√		√	
AB (recipient)	√	√	√	√

- Arteries
    - Arteries have walls that are thick, muscular and elastic to withstand the high pressure of blood coming out from the heart
    - Strength of an artery to resist the pressure comes largely from its elastic fibres
    - Thick elastic walls also help to maintain the high blood pressure in the artery
    - Elastic layer is much thicker in arteries near the heart
    - Elasticity allows the arteries to stretch and recoil, thus propelling the blood along the blood vessel
    - The constriction and dilation of an artery is brought about by the contraction and relaxation of the muscles in the arterial walls
- Veins
    - Blood in veins are at a lower pressure and flows more slowly and smoothly
    - The walls of veins are not as thick and muscular as those of arteries
    - Veins contains less elastic tissue

    - Semi-lunar valves
        - Folds of the inner walls in veins that aids in preventing back flow of blood
    - Prevention of back flow is important in returning the blood to the heart
    - Presence of semi-lunar valves ensures unidirectional blood flow of blood
    - The movement of blood along the veins is assisted by the action of the skeletal muscles on the veins → muscular contractions and relaxation exert a pressure on the veins, thus moving blood along
- Capillaries
    - Microscopic blood vessels found between cells of almost all tissues
    - Endothelium
        - A single layer of flattened cells that makes up the wall of capillaries
    - The endothelium is partially permeable to ensure rapid diffusion of substances through it
    - Capillaries branch repeatedly to increase surface area for exchange of substances
    - Blood pressure in capillaries is also lowered, thus blood flow is slowed down, allowing more time for exchange of substances
- Transfer of materials between capillaries and tissue cells
    - High blood pressure at the arterial end of capillaries forces out blood plasma into spaces between cells
    - White blood corpuscles can also squeeze through, but no red blood corpuscles
    - Tissue fluid
        - Diluted plasma containing white corpuscles
    - Tissue fluid is a colorless liquid
    - Some cells do not have direct contact with blood vessels
    - However, these cells are bathed by tissue fluid
    - Tissue fluid carries substances in solution between the tissue cells and the blood capillaries
    - Dissolved food substances and oxygen diffuse from the blood into the tissue fluid and then into the cells
    - Waste products diffuse from the cells into the tissue fluid and then through the capillary walls into the blood
    - As capillaries are small, erythrocytes can only move through them in single file
        - Red blood cells may even become bell-shaped
    - The advantages of this are
        - The diameter of the erythrocyte is decreased so that it can pass easily through the lumen of the capillaries
        - The cell increases its surface area to speed up absorption of waste products and release of oxygen
        - Rate of blood flow is reduced, giving more time for efficient gaseous exchange
- Heart
    - Size is about the size of a clenched fist in man
    - Lies in the thorax, behind the sternum and between the two lungs, displaced to the left side of the body

    - Conical in shape and slants with its apex directed slightly towards the left side of the body
    - Pericardium
        - A two-layered bag surrounding the heart
        - The inner membrane being in contact with the heart while the pericardial fluid lies between the two membrane
    - Made up of four chambers
        - Two upper atria and two lower ventricles
    - Median septum
        - Muscular wall that separates the right chambers from the left chambers, thus preventing mixing of oxygenated and deoxygenated blood
    - Blood is returned to the right and left from the vena cava and the pulmonary vein respectively
    - Contraction of the atria will cause the blood in the atria to be pumped into the right and left ventricles accordingly
    - Blood is pumped out of the heart by the ventricles
        - Pulmonary arch and pulmonary arteries carry blood to the lungs, aortic arch carries blood to the other parts of the body
    - Backflow is prevented due to the presence of valves
        - Tricuspid valve in the right side, bicuspid valve on the left side
- Blood clotting
    - Clotting of blood seals up a wound to prevent excessive loss of blood
    - Clotting also prevents entry of foreign particles into the blood stream
    - Hemophilia
        - A genetic disease where the clotting mechanism is greatly impaired, thus hemophilics may bleed to death
    - Damaged tissues and platelets → thrombokinase
    - Prothrombin + thrombokinase + Ca^{2+} → thrombin
    - Fribinogen + thrombin → insoluble fibrin threads
    - When blood vessels are damaged, an enzyme (thrombokinase) is released by the damaged tissues and blood platelets
    - Thrombokinase converts the protein prothrombin normally present in the plasma to thrombin, which is an enzyme
    - Calcium ions are required for the conversion of prothrombin to thrombin
    - Thrombin catalyzes the conversion of the soluble protein fibrinogen to a meshwork of insoluble threads of fibrin
    - Fibrin threads entangle blood corpuscles and the whole mass forms a clot
    - Vitamin K is also essential for the process of blood clotting
    - In undamaged blood vessels, the blood does not clot due to the presence of heparin, an anti-clotting substance produced by the liver
    - During blood clot, thrombokinase released neutralizes the action of heparin so that clotting can take place
    - When blood clots, serum is left behind
    - Serum
        - A yellowish liquid that has the same composition as plasma except that it lacks the clotting constituents
- Cardiac cycle

    - Contraction of the atria will cause the blood in the atria to be pumped into the right and left ventricles accordingly
    - Ventricular contraction is also known as ventricular systole (producing 'lubb' sound due to the closing of the tricuspid and bicuspid valves)
    - Semi-lunar valves are present to prevent back flow of blood into the ventricles
    - Ventricular relaxation is also known as ventricular diastole (producing the 'dubb' sound due to the closing of the semi-lunar valves)
    - A systole and a diastole makes up one heartbeat
    - The rate of heartbeat varies between people
- Coronary heart disease
    - Two coronary arteries bring oxygen to the cardiac muscles
    - Obstruction to blood flow in these two arteries may bring about cardiac arrest or angina pectoris
    - Coronary thrombosis
        - Formation of blood clot in the artery
    - If thrombosis occurs in the coronary arteries, blood is prevented from reaching the heart → cardiac arrest
    - Heart attack/heart failure
        - Sudden slowing or stoppages of the heartbeat due to severe damage or death of cardiac muscles
    - Coronary thrombosis is more likely to occur in narrow arteries with fatty deposits
    - Atherosclerosis
        - The narrowing and hardening of artery due to fatty deposits on the walls of the artery
    - Walls of artery with atherosclerosis are thick and hard, with the rough inner surfaces increasing the risk of thrombosis
    - What happens leading up to coronary heart disease
        - Cholesterol and polysaturated fats are deposited on the walls of the artery, narrowing and hardening the artery
        - As the narrowing of lumen would result in rougher inner surfaces, a blood clot is likely to be formed
        - The blood clot would inhibit the blood from reaching the heart and cause heart attacks or heart failure
    - Coronary heart disease can be caused by
        - Diet
            - Diet rich in cholesterol and saturated animal fats results in high blood cholesterol level
        - Lack of exercise/being overweight
        - Stress
            - Hormone adrenaline secreted under stress conditions increases heart beat rate and blood pressure
        - Drinking
        - Smoking
            - Nicotine
                - Increases the rate of heart beat by increasing secretion of the hormone adrenaline
                - Causes the blood vessels to constrict, increasing the blood pressure
                - Causes blood to clot more easily

- Carbon monoxide
    - Increases the rate of fatty deposition on inner surfaces of the arteries and decreases oxygen supply to the heart
- Preventive measures can be taken as atherosclerosis begins early in life
    - Avoid diets rich in saturated animal fats
        - Substitute with polyunsaturated vegetable fats
        - Regular exercising
            - Strengthens the heart and maintains elasticity of the arterial walls
        - Minimal or no smoking and drinking
        - Low-stress lifestyle or proper stress management

Respiration

- Alveoli
    - The walls of the alveoli are the respiratory surfaces, and these are one cell-thick
    - Numerous capillaries are closely wrapped around outside of the alveoli
    - Oxygen can diffuse across the walls of the alveoli into the blood
    - Carbon dioxide can diffuse the other way
- Removal of carbon dioxide from the lungs
    - Blood entering the lungs is rich in carbon dioxide in the form of hydrogen carbonate ions
        - $H_2O + CO_2 \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$
    - This is also a reversible reaction
    - As tissue cells respire, carbon dioxide is evolved
    - Carbon dioxide diffuses into the blood and dissolves in the water in the red blood cells to form carbonic acid
    - This reaction is catalyzed by the enzyme carbonic anhydrase
    - Carbonic acid is converted to hydrogen carbonates in the red blood cells
    - Much of hydrogen carbonates formed will diffuse back into the plasma
    - Thus, hydrogen carbonates are carried both in the red blood cells as well as in the plasma
    - When blood passes through the lungs, alveolar carbon dioxide concentration is low
    - Carbonic anhydrase will catalyze the backward reaction and hydrogen carbonates are converted to water and carbon dioxide in the red blood cells
    - Carbon dioxide will diffuse out of the blood in the alveoli to be exhaled out to the external environment
    - Some moisture and heat will also be exhaled out in this manner
- Cilia
    - Cilia are hair-like structures which lines the trachea, moves to and fro in a wave-like rhythm to sweep the 'dirty' mucus up the larynx and into the pharynx to be swallowed down the esophagus
- Diaphragm
    - To increase volume of the thorax during inspiration (inhalation)
    - To decrease volume of the thorax during expiration (exhalation)
- Ribs

    - Ribs are pulled upwards and outwards during inspiration (inhalation) to increase volume of the thorax
    - Ribs are dropped to its normal position during expiration (exhalation) to decrease volume of the thorax
- Intercostal muscles
    - During inspiration (inhalation), the external intercostal muscles contract, while the internal intercostal muscles relax, pulling the rib cage upwards and outwards, and pulling sternum upward and forward
    - This is done to increase volume of the thorax
    - During expiration (exhalation), the external intercostal muscles relax, while the internal intercostal muscles contract, causing the rib cage to drop again to its normal position
    - This is done to decrease volume of the thorax
- Effects of tobacco smoke
    - Cigarette smoke contains more than 4000 chemicals, many of which are carcinogenic
    - Smoking can cause harmful diseases in man
    - Chemicals in tobacco smoke
        - Nicotine
        - Carbon monoxide
        - Tar
    - Effects of nicotine on the body
        - Increase in heartbeat and blood pressure
        - Increased risk of blood clots in arteries
    - Effects of carbon monoxide on the body
        - Death
        - Increased risk of atherosclerosis
        - Increased risk of blood clots in arteries
    - Effects of tar on the body
        - Blockage in alveoli reduces gas exchange efficiency
        - Mucus cannot be removed
        - Increase risk of chronic bronchitis
        - Increased risk of emphysema
- Aerobic respiration
    - The breakdown of food substances in the presence of oxygen with the release of a large amount of energy
    - Word equation
        - Glucose + oxygen → carbon dioxide + water + energy
    - Chemical equation
        - $C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O$ (38 ATP)
- Anaerobic respiration
    - The breakdown of food substances with the release of a comparatively small amount of energy in the absence of oxygen
    - Word equation
        - Glucose → carbon dioxide + ethanol + energy
    - Chemical equation
        - $C_6H_{12}O_6 \rightarrow 2CO_2 + 2C_2H_5OH$ (2 ATP)
- Effects of lactic acid on muscles
    - This will cause muscle fatigue and the body will need to rest to recover

Excretion

- The process by which metabolic waste products are removed from the body of an organism
- Importance of removing nitrogenous and other compounds
    - Ensure that chemical reactions proceed in the correct direction
    - Certain metabolic wastes are toxic
- Ultrafiltration
    - Blood from the renal artery brings metabolic wastes and useful substances to the kidney tubules
    - Most of the blood plasma is forced out of the glomercular blood capillaries into the Bowman's capsule
    - Is the process of small molecules being forced into the nephron due to high blood pressure
    - Factors of ultrafiltration
        - Hydrostatic blood pressure
            - Blood pressure in the glomerulus is high because the efferent arteriole is narrower than the afferent arteriole, hence providing the main force required for filtrate to leak through the porous capillary wall of glomerulus
        - Partially permeable membrane
            - Allowing only small molecules to diffuse across
    - Filtrate
        - Glucose, vitamins, amino acids, hormones, bicarbonate ions, mineral salts and other nitrogenous waste products
    - Remnants
        - Blood cells and all large molecules like blood platelets, blood corpuscles, proteins and fats
    - The filtrate trickles down into the proximal convoluted tubule, the loop of Henlé and then to the distal convoluted tubule, then down into the collecting duct
- Selective reabsorption
    - About 120cm^3 of filtrate are formed in the kidney every minute
        - There is a need to reabsorb useful materials
        - Selective reabsorption takes place to take back useful materials
    - At the proximal convoluted tubule, mineral salts, glucose, amino acids, and other useful substances are reabsorbed through the walls of the tubules into the blood capillaries through active transport and diffusion
    - Highly selective
        - Receptors only pumps in those that are needed by the body
    - The large molecules that remain in the blood capillaries act osmotically to reabsorb water in the tubule
    - Most of the water is reabsorbed mainly by osmosis
    - Some of the water is reabsorbed in the loop of Henlé, distal convoluted tubule and collecting duct into the surrounding blood capillaries
    - Some salts are also reabsorbed from the distal convoluted tubule
    - Excess water, mineral salts and nitrogenous waste products are allowed to pass through along the uriniferous tube and out through the collecting tubule into the renal pelvis and into the ureter as urine
    - Blood that flows away from the kidney tubule contains very little urea and less excess water
    - The fluid in the nephron flows in one direction while the capillaries flow in the opposite direction

    - This is known as countercurrent flow
    - Countercurrent flow occurs to allow for maximum reabsorption of substances
    - Most water is reabsorbed by diffusion, followed by osmosis according to the control of the anti-diuretic hormone (ADH) made in the hypothalamus of the brain
    - ADH is stored in the pituitary gland of brain
    - The osmoreceptors in the hypothalamus of the brain monitors the osmotic pressure of the blood passing through
    - If the osmotic pressure of the blood rises, more ADH released from the pituitary will increase the permeability of the tubule wall and more water will be reabsorbed, hence less urine will be formed
    - The production of a large quantity of water urine is known as diuresis
    - ADH serves to counter this condition, and thus the name
- Kidney dialysis
    - An artery is joined to a vein, creating a arteriovenous fistula
    - Blood is then drawn from the vein in the arm of a patient and allowed to flow through the dialysis tubing in the machine
    - This tubing is narrow, long and coiled to increase surface area
    - Its walls are selectively permeable
    - The dialysis tubing is bathed in a dialysis liquid similar to blood plasma
    - Small molecules that are waste products like urea diffuse out of the tubing into the dialysis liquid
    - Big particles like blood cells and plasma protein remain in the tubing
    - The blood is not only cleansed but the amount of salt and water is adjusted before it is returned to the patient
    - The "cleansed" blood is returned to the patient through a tube connected to a vein in the arm
    - Countercurrent flow is observed to maintain concentration gradient

Homeostasis

- Definition
    - The maintenance of a constant internal environment
- Process of homeostasis
    - A change in the internal environment (stimulus)
    - A corrective mechanism
    - A negative feedback
    - In general, if some factor becomes excessive or too little, a control system initiates a feedback mechanism, which consists of a series of changes that return the factor toward a certain mean value, thus maintaining homeostasis
    - Negative feedback serves to prevent the self-regulatory corrective mechanism from over-compensation
- Maintenance of body temperature
    - Insulation
        - The thicker one's skin is, the higher the insulation, thus he or she loses or gains heat at a slower rate
    - Temperature receptors in the skin
        - The temperature receptors in the skin sense changes in the environment and transmit a signal to the hypothalamus to start the corrective mechanism to effect a change

- Sweating
  - Another characteristics of mammals
  - Each sweat glands is a coiled tube formed by a down-growth of the epidermis
  - It forms a tight knot in the dermis and is richly surrounded by blood capillaries
  - These secrete a liquid called sweat
  - Sweat is mostly water, with small amounts of salt and urea dissolved in it
  - It travels up the sweat ducts, and out onto the surface of the skin through the sweat pores
  - Sweat is secreted continuously but sometimes in very small quantities which evaporate almost immediately
  - Sweat helps in temperature regulation (removal of latent heat)
- Shivering
  - A very fast random contraction and relaxation of muscles, which generates heat to warm the blood
- Blood vessels near the skin surface
  - When one is too warm
    - Vasodilation is brought about
      - More blood is brought to the surface of the skin and more heat is lost through radiation, conduction and convention
    - Constriction of shunt vessels to allow more blood to be brought to the surface
  - When one is too cold
    - Vasoconstriction is brought about
      - This prevents blood from flowing to the surface of the skin
      - Instead it has to go through the capillaries which lie below the fat layer
      - This reduces the amount of heat lost by radiation from the blood to the air
    - Dilation of shunt vessels to direct blood away from the surface
- Coordinating role of brain
  - The hypothalamus in the brain is responsible to prevent over-compensation
  - In other words, the brain controls when compensation is to be ceased

Co-ordination and response

- Relationship between receptors, central nervous system and effectors
  - The receptors send impulses to the central nervous systems, which transmits another impulse to the effectors, which response to the stimuli
- Structure of the eye
  - Cornea
    - Dome-shaped transparent layer continuous with the sclera
    - Specialized form of conjunctiva
    - Refracts light rays into the eye
      - Causes most of the refraction of light

- Iris
  - Circular sheet of muscles that controls the amount of light into the eye
  - Pigmented to give the eye its color (it may vary from blue to grey or green to brown)
  - Two sets of involuntary muscles present
    - Circular muscles and radial muscles
- Pupil
  - Hole in the centre of the iris
  - Allows light to enter into the eye
- Sclera
  - Outermost layer, tough, white, fibrous coat
  - Forms a protective layer round the eyeball and continues as a transparent cornea which forms a small bulge at the front of the eye
  - Cornea
    - Transparent part of the sclera
  - The cornea allows light to enter
  - The cornea is denser than the air medium, thus light rays falling onto it are refracted inwards towards the lens
- Conjunctiva
  - A thin transparent membrane covering the exposed part of the eyeball
  - It is a mucous membrane that secretes mucus to keep the eye moist
  - The conjunctiva is continuous with the skin of the eyelids
- Eyelids
  - Serve to protect the eyeball against mechanical injury
  - Act as a shutter and help control the amount of light intensity entering the light
- Lachrymal gland
  - Secretes tears to lubricate the conjunctiva
  - The tear gland lies in the outer corner of the upper eyelid
  - Tears flow between the eyelids and the exposed part of the eyeball, helping to reduce friction when the eyelids move
  - Dust particles entering the eyes will cause a great production of tears to wash them away
  - Tears contain an enzyme called lysozyme, which can kill bacteria
  - Blinking spreads tears over the cornea and conjunctiva and wipes dust particles off the cornea
- Naso-lachrymal duct
  - Duct where excess tear drains into
  - The naso-lachrymal duct runs from the inner corner of the eye to the nose
  - Emotion may cause excess tears to be secreted and passed into the naso-lachrymal duct
- Eyelashes
  - Help to shield the eye from dust particles
- Choroid coat
  - The middle layer of the eyeball

        - Contains a network of blood capillaries that nourishes the eye as well as removes waste
        - Pigmented black to prevent internal reflection of light
        - Anterior end of the choroid is modified to form the ciliary body and the iris
        - Ciliary body
            - Thickened region at the front end of the choroids that contains many involuntary circular muscles called ciliary muscles
            - Intrinsic eye muscles since they are inside the eyeball
            - Ciliary muscles control the curvature or the thickness of the lens
            - Ciliary muscles pay an important part in focusing and accommodation
        - Iris
            - Circular sheet of muscles with a round hold in the centre
        - Pupil
            - The central hole in the iris which allows light to pass into the eye
        - Lens
            - Transparent, elastic, biconvex crystalline lens
            - Situated behind the iris and in contact with the iris
            - The lens is attached to the ciliary body by the suspensory ligaments
            - Divides the eyeball into two chambers
                - The small chamber in front of the iris and the lens is filled with a water fluid known as aqueous humour
                - The larger chamber behind the lens is filled with a transparent jelly-like fluid, the vitreous humour
            - Both aqueous humour and vitreous humour serve to keep the eyeball firm and to refract light
    - Retina
        - Innermost layer of the eyeball
        - Light-sensitive layer on which images are formed
        - Presence of photoreceptors
            - Rods and cones
        - These cells are connected to the nerve-endings from the optic nerve
    - Rods
        - Contains visual purple
            - The pigment concerned with vision in dim light
        - Light causes bleaching of visual purple which is involved in light detection
        - In bright light, all the visual purple is bleached
        - It takes a short time for visual purple to be formed again in the rods
        - Thus, when a person enters a dark place from a bright one, he may not be able to distinguish the objects around him for some time
        - Formation of visual purple requires Vitamin A

        - A person with deficiency in Vitamin A may not be able to see in dim light, a condition known as night-blindness
        - Rods are sensitive to dim light, but only let one see in black and white
    - Cones
        - Less sensitive than rods, thus it is inefficient in dim light
        - Concerned with bright light and color vision
        - Three types of cones, each possessing a different pigment
            - Red, green and blue
        - Thus, cones enable one to see light at different colors
        - Fovea centralis (yellow spot)
            - A shallow yellow depression in the retina in line with or on the optical axis of the lens
            - Place where images are normally focused
            - Contains only cones
            - Thus vision is keenest in bright light when images are focused onto the yellow spot
        - Optic nerve
            - Nerve that transmit impulses to the brain when the photoreceptors are stimulated
        - Blind spot
            - On the retina immediately over the optic nerve
            - Absences of any photoreceptors, thus this area is insensitive to light
- Accommodation for near objects
    - Light rays from a near object are diverging
    - Refraction by cornea and aqueous humour into the pupil
    - Contraction of the ciliary muscles
    - Pull on the suspensory ligaments is released
    - Lens becomes thicker and more convex → contracted
    - Light rays from near objects are sharply focused on the retina
    - Photoreceptors stimulated
    - Nerve impulses transmitted to brain via the optic nerve
    - Brain interprets the impulses and near object is seen
    - The nearer the objects, the more the circular muscles will contract and the thicker the lens will be
    - Near point
        - Point where the object is so close to the eye that in order to see it, the ciliary muscle must contract fully and the lens become most convex
        - If the object is moved nearer to the eye, the image formed on the retina will be blurred as the lens cannot adjust any further
- Accommodation for a distant vision (≥7m)
    - For a distant object, the light rays are almost parallel to each other when they reach the eye
    - Parallel rays are refracted by cornea and aqueous humour into the pupil
    - Relaxation of ciliary mscles
    - Pull on suspensory ligaments increase → becomes taut, pulling on the edge of the elastic lens
    - The lens become flatter and less convex → relax

    - Light rays from the distant object are sharply focused on the retina
    - Photoreceptors stimulated
    - Nerve impulses transmitted to brain via the optic nerve
    - Brain interprets the impulses and far object is seen
- Light and pupil reflex
    - The size of the pupil changes to allow a suitable amount of light to pass into the eye
        - This protects the inner layer of the eye from damage
        - And in dim light, allows more light to enter the eye in order to see clearly
    - The size of the pupil is controlled by two sets of involuntary muscles in the iris
        - Circular muscles and radial muscles
    - When the circular muscles contract, the radial muscles relax → pupil becomes smaller
    - When the circular muscles relax, the radial muscles contract → pupil becomes larger
    - Thus, the size of the pupil will control the amount of light entering the eye
    - The pupil becomes smaller in light of high intensity
    - The pupil becomes larger in low light intensity
    - This is a reflex action
        - Contraction and relaxation of these involuntary muscles are automatic and immediate in response to the stimulus of light
    - Sometimes, the light intensity is so bright that decreasing the size of the pupil is not enough
    - The eyelids have to come closer together to screen off part of the light
    - The pupil reflex arc
        - Stimulus (change in light intensity) → receptor (retina) → sensory neurone in optic nerve → brain → motor neurone → effector (iris)
- Nervous system
    - Function
        - Co-ordinate and regulate bodily functions
- Sensory neurons
    - Afferent/receptor neurons
    - Transmit impulses from the receptors to the central nervous system
- Relaying neurons
    - Intermediate neurons
    - Transmit impulses from the afferent neurons to the efferent neurons and are found within the central nervous system
- Efferent neurons
    - Motor/effector neurons
    - Transmit impulses from the central nervous system to the effectors
- Reflex actions
    - The nervous pathway for reflex action is the reflex arc
    - A stimuli stimulates the nerve endings (receptor/sense organ) in the skin
    - Impulses are produced
        - These travel along the sensory neurone to the spinal cord or the brain

    - In the spinal cord or the brain (reflex centre), the impulses are transmitted first across a synapse to the intermediate or relaying neurone, and then across another synapse to the motor neurone (an impulse may also be transmitted to the brain at the same time)
    - Motor impulses leave the spinal cord along the motor neurone to the effector
    - The effector (muscles or glands) brings about a respond to the stimuli
- Hormone
    - Chemical substances produced in minute quantities by certain parts of the body and transported in the bloodstream to other parts where they exert an effect
- Endocrine gland
    - Glands without ducts or glands of internal secretions
    - The islets of Langerhans in the pancreas secrete the hormone insulin into the blood stream
- Adrenaline
    - It increases the rate of conversion of glycogen to glucose in the liver, thus increasing blood sugar level so that more glucose is available for energy production
    - Stimulus includes fear, anger, anxiety or stress
- Insulin
    - Stimulates absorption of glucose by cells so that they can break it down to release energy
    - Directing the conversion of excess glucose to glycogen for storage in liver or muscles
    - Increasing oxidation of glucose during tissue respiration
    - Thus, decreasing blood glucose concentration
- Glucagon
    - Conversion of glycogen into glucose
    - Conversion of fats and amino acids into glucose
    - Conversion of lactic acid into glucose
    - Thus, increasing blood glucose concentration
- Diabetes mellitus
    - Symptoms
        - High blood glucose level
            - Lack of secretion of insulin, the body cannot use or store glucose
            - This brings about a rise in blood glucose concentration
        - Glucose in urine
            - As insulin is not secreted, blood glucose is not reabsorbed by the body and is lost in the urine
    - Treatment
        - People with Type 1 diabetes have to inject insulin into their bodies daily.
        - They also need to ensure that they have a ready supply of sugary food as their blood glucose concentration can drop drastically (either from over-dosage of insulin, exercising too much or eating too little)
        - People with Type 2 diabetes need to control their blood glucose concentration by regulating intake of carbohydrates in their diet and by regular exercising

- If lifestyle changes fail, then the patients may need to take medication (e.g. metformin tablets) or insulin injection