MOJZA

A Level

BIOLOGY NOTES

9700

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CONTENTS

Chapter 1: Cells

1.1 Magnification calculations

Conversions

- ➔ 1 mm = 1000 or 103 µm
- ➔ 1 µm = 1000 or 103 nm

Magnification and Resolution

- Magnification

- ➔ It is how much bigger a sample appears to be under a microscope than it is in real life.

- Resolution

- ➔ It is the ability to distinguish between 2 separate points.
- ➔ As resolution increases, image clarity and detail also increases.

Types of microscopes

- Light Microscope

- ➔ RESOLUTION is 200 nm
- ➔ SEM – 3 nm
- ➔ TEM – 0.5 nm
- ➔ MAGNIFICATION x 1500 x 250,000 – x500,00
- ➔ Limit of resolution: half the wavelength
- ➔ Ribosomes (25 nm) can't be seen with a light microscope as they don't interfere with the light waves.
- ➔ Different stains are absorbed by different cell organelles so they can be observed more clearly.

- Electron microscopes

- ➔ Vacuum (electrons cannot be focused without a vacuum as they will collide with air molecules and scatter)
- ➔ Water boils at room temperature in a vacuum, so the sample must be dehydrated (specimen has to be dead)

Advantages of a light microscope over an electron microscope

- ➔ Can observe living tissue
- ➔ More portable
- ➔ Easier to use - no technical training required
- ➔ Possible to see real/natural colours and a live specimen
- ➔ Can stain particular types of tissue for better visibility scope in cell studies

1.2 Cells as the basic units of living organisms

Definition of a cell

➔ All living things are built around cells. The relationships between these cell structures demonstrate how cells transfer energy, produce biological products, and proteins.

Eukaryotic cell structures and their functions

Golgi Body

- Structure

➔ Consist of stack of flattened membranes enclosing hollow sacs called cisternae
➔ These sacs have layered appearance with no connections between the membranes
➔ Not continuous with nuclear membrane (unlike RER)
➔ There are swellings at the end of the sacs which are regularly pinched off and are transported to the other parts of the cell

- Functions

➔ Modification and Packaging of Proteins and Lipids
➔ Proteins and lipids made by ER are sent to the Golgi for modification and packaging
    - Protein + Non Protein (Carbohydrate) = GLYCOPROTEIN. This process is known as Glycosylation.
    - Removal of 1st amino acid, methionine, from newly formed protein to make a functional protein.
    - Folding proteins into tertiary and quaternary folding.
    - Replenishes plasma membrane when lysosomes fuse with the cell surface membrane
➔ Transports, modifies & Stores Lipids
➔ In plants, enzymes in Golgi convert sugars into cell wall components
➔ Once sorted, these modified proteins and lipids are pinched off from the ends of the Golgi cisternae and are transported to other parts of the cell
➔ Some vesicles may fuse with the cell membrane, releasing their contents out of the cell by exocytosis.

Nucleus

➔ Largest organelle of Eukaryotic cells (5-20um) in diameter.
➔ Surrounded by a double membrane called nuclear envelope
➔ The outer membrane of the nuclear membrane is continuous with endoplasmic reticulum.

- Nuclear pores

➔ Nuclear membrane contains many pores (100 nm) which allows exchange of molecules (mRNA, Amino Acids, Ribosomes) between nucleus and cytoplasm.
➔ Nucleus → Cytoplasm = 1. mRNA 2.Ribosomes
➔ Cytoplasm → Nucleus = 1. Proteins 2. Hormones 3. ATP

- Chromosomes

- ➔ Nucleus contains chromosomes, thread like structures, chemically composed of DNA, which codes for a Protein.
- ➔ Chromosomes are only visible during cell division.

- Chromatin

- ➔ Chromatin = (DNA + Histones)
- ➔ Euchromatin: loosely coiled chromosomes (part of the cell cycle when no nuclear division is taking place)
- ➔ Heterochromatin: tightly coiled (during nuclear division)

- Nucleolus

- ➔ A nucleus may contains one to several tiny, rounded darkly stained bodies called nucleolus (1-2um)
- ➔ Nucleolus makes:
  - Ribosomes
  - rRNA (Ribosomal RNA)
  - tRNA (Transfer RNA)

- Functions of nucleus

- ➔ Acts as a control centre of the cell by controlling activities through
  - Producing mRNA , tRNA (Nucleolus) & rRNA (Nucleolus)
  - Ribosomes (Nucleolus)
  - Protein Synthesis
- ➔ Protects the DNA from the rest of the cells.

Endoplasmic reticulum

- ➔ An extensive system of membranes which form a network of interconnected sacs to form a complete system (reticulum).
- ➔ There are two types:
  - Rough Endoplasmic Reticulum (RER)
  - Smooth Endoplasmic Reticulum (SER)

Rough Endoplasmic Reticulum (RER)

- ➔ Form flattened sacs and called cisternae
- ➔ RER is continuous with the outer nuclear membrane of the nuclear envelope.
- ➔ More layered in terms of its arrangement
- ➔ Has ribosomes on the OUTER SURFACE
- ➔ Margins of RER have swellings which form vesicles, spherical organelles bounded by a single membrane, which buds off as they separate.
- ➔ These sacs transport proteins synthesised on the ribosomes to the Golgi bodies
- ➔ Site of protein synthesis (Translation)
- ➔ Provides pathways for transport of materials especially proteins.

Smooth Endoplasmic Reticulum (SER)

- ➔ SER contain tubular compartments or sacs called cisternae. Exam Tip: Flattened compartments is incorrect usage for SER
- ➔ NO ribosomes

- ➔ SER is more irregular and disorganised in terms of its arrangement
- ➔ Produces and stores lipids, steroids (cholesterol)
- ➔ SER is the site of storage of Ca+2 ions in relaxed voluntary muscle.

Mitochondria

- ➔ Present almost in all eukaryotic cells
- ➔ Rod shaped, length (1-7um)
- ➔ Can move, change shape and divide.

- Structure

- ➔ Have a double membrane (each membrane is a phospholipid bilayer) and the space between the two membranes is called intermembrane space.
- ➔ The inner membrane is folded to form extensions known as cristae.
- ➔ The outer membrane contains a transport protein called porin, which forms a wide aqueous channel allowing easy access of small water soluble molecules into intermembrane space.
- ➔ Cristae contain enzymes and other molecules involved in aerobic respiration
- ➔ Cristae provides a large surface area to volume ratio for aerobic respiration (oxidative phosphorylation) which makes ATP.
- ➔ Matrix, a semi rigid fluid containing
    - Proteins
    - Lipids
    - 70S Ribosomes
    - Small circular DNA
    - Enzymes involved in Krebs cycle

- Functions

- ➔ It is the site for aerobic respiration
    - Links reaction (in Matrix)
    - Krebs Cycle (in Matrix)
    - Oxidative Phosphorylation (inner membrane)
- ➔ Energy is released from the energy rich molecules to produce molecules of ATP which is the universal energy currency

- Exam tip

- ➔ Your answer should refer to the production of ATP, rather than “ATP energy”.
- ➔ DO NOT write produces energy, this is INCORRECT terminology usage

Chloroplast

- ➔ Site of Photosynthesis
- ➔ Size: 3-10 um in diameter.
- ➔ Are found in some plant cells of leaf
    - Palisade mesophyll cells
    - Spongy mesophyll cells
    - Guard cells
- ➔ Can move away (to protect from damage due to excessive sunlight) or towards (to absorb maximum light) the light in palisade mesophyll cells.
- ➔ Capable of protein synthesis and replication independently.

➔ ATP is also produced during photosynthesis.

- Double Membrane

➔ Surrounded by a double membrane, (together called envelope)
- Outer membrane (a phospholipid bilayer)
- Inner membrane (a phospholipid bilayer)

➔ This double membrane controls the entry and exit of substances in and out of the chloroplast.

Stroma

➔ A colourless mixture which is the site of Light independent reaction (Calvin Cycle) , contains the following:
- Enzymes
- 70S Ribosomes
- Small circular DNA
- Oil droplets
- Starch grains – temporary stores of carbs from photosynthesis Thylakoids & Granum

➔ Chloroplasts have an internal network of membranes, which form flattened sacs called thylakoids.
➔ Several thylakoids are stacked together are called granum (plural grana)
➔ The grana are joined together by membranes called lamella
➔ Chlorophyll is embedded in thylakoid membranes which traps light energy and converts it into chemical energy in the form of glucose. (Light dependent reaction)
➔ The proteins on the membrane are associated with chlorophyll molecules,forming complexes called photosystems (1 and 2) containing different photosynthetic pigments.

Lysosomes

➔ Found in most animal and plant cells
➔ Single membrane bound spherical sacs formed by Golgi bodies
➔ They play an important part in immune system and cell death (apoptosis) or autolysis
➔ Contain a storage of hydrolytic enzymes, which are kept separated from the rest of the cell by a single membrane.

-Exam Tip

➔ DO NOT WRITE lysosomes themselves are digestive enzymes
➔ DO NOT WRITE lysosomes ‘engulf’
➔ Hydrolytic enzymes in lysosomes digest the following
- Old organelles
- Pathogens like bacteria
- Toxinsi
- Cells and foreign objects

Ribosomes

➔ Have two types:
- 80S (22nm) = present in Eukaryotic cells
- 70S (17 nm) = present in Prokaryotic cells, Chloroplast and Mitochondria

- ➔ Found on:
  - RER
  - Free floating in cytoplasm
  - Mitochondria and chloroplast (70S)
- ➔ Not surrounded by membrane
- ➔ Made up of two subunits
  - Small subunit
  - Large sub-unit
- ➔ Chemically made up of
  - Proteins
  - RNA (a nucleic acid)
- ➔ Are sites of protein synthesis

Plasmodesmata

- ➔ Pores in plant cell wall
- ➔ Contains fine strands of cytoplasm linking the plant cell with its neighbouring cells
- ➔ Facilitates more rapid transfer, communication and signalling of the following
  - Water (Allows symplastic movement)
  - Sucrose
  - Amino acids
  - Ions
  - Minerals
  - Salts
  - Hormones
  - ATP

- Exam Tip

- ➔ Do NOT write that “substances” are transferred.
- ➔ The substances that cross through the plasmodesmata do not need to cross the cell surface membrane or the cell wall.
- ➔ Examples:
  - Diffusion of sucrose from companion cells to sieve tube (NOT between sieve tube elements)
  - Symplastic pathway of water is through plasmodesmata (unlike apoplastic which is through cell walls)
  - Mesophyll cells to companion cells

Tonoplast

- ➔ Phospholipid bilayer that surrounds the cell vacuole.
- ➔ Phosphate head are HYDROPHILIC (water loving)
- ➔ The tails made up of fatty acid chains are HYDROPHOBIC (water repelling)
- ➔ The phospholipid molecules can move within the MONOlayer
- ➔ Have protein molecules scattered, not as a complete layer.
- ➔ There are many different types of protein molecules.
- ➔ Cholesterol molecules are also found in the membrane
- ➔ Fluid Mosaic
  - FLUID: phospholipid and protein molecules move within the monolayer
  - MOSAIC: Protein molecules scattered
- ➔ Tonoplast is selectively permeable therefore controls exchange of materials between the vacuole and the cell

Cell vacuole

- ➔ A large fluid filled space contained within a membrane called tonoplast.
- ➔ Vacuole contains cell sap, which contains:
    - Water
    - Sucrose
    - Mineral salts
    - Pigments
    - Nutrients
    - Waste (products)
- ➔ Since it is very large, it pushes chloroplasts & nuclei to the edge of the plant cell.
- ➔ The vacuole full of cell sap gives the cell its turgidity, therefore supporting it with the turgor pressure.
- ➔ A full vacuole maintains the turgidity of the cell.

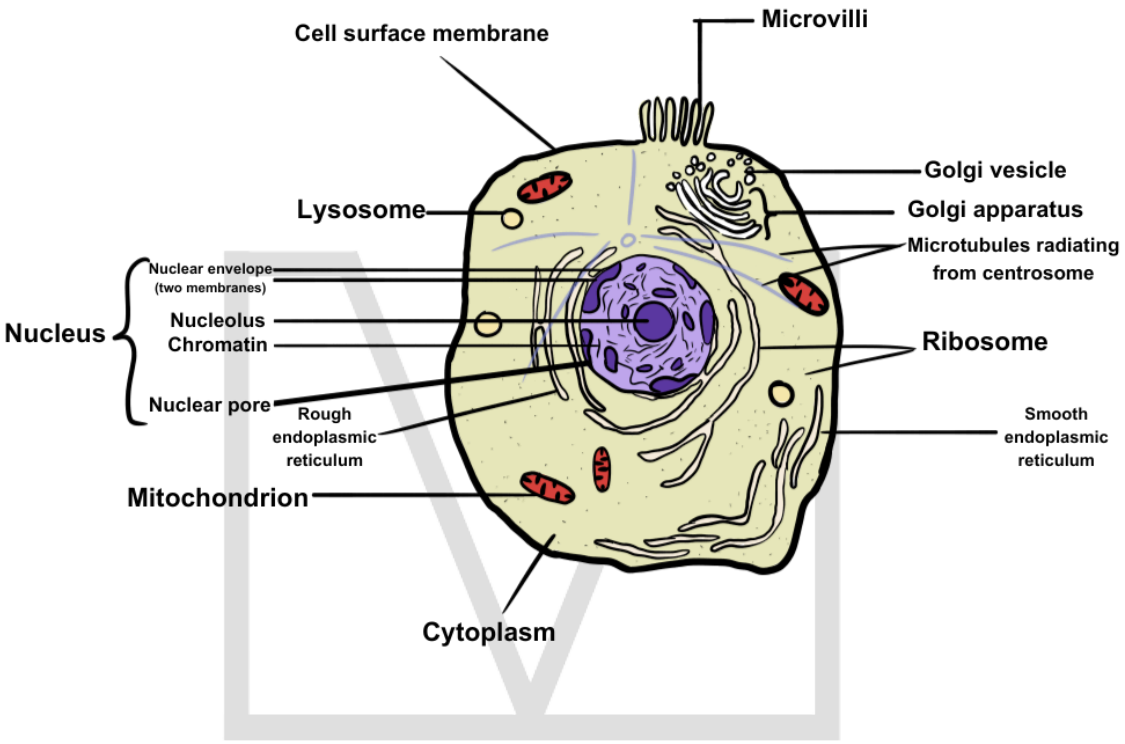
- Exam tip

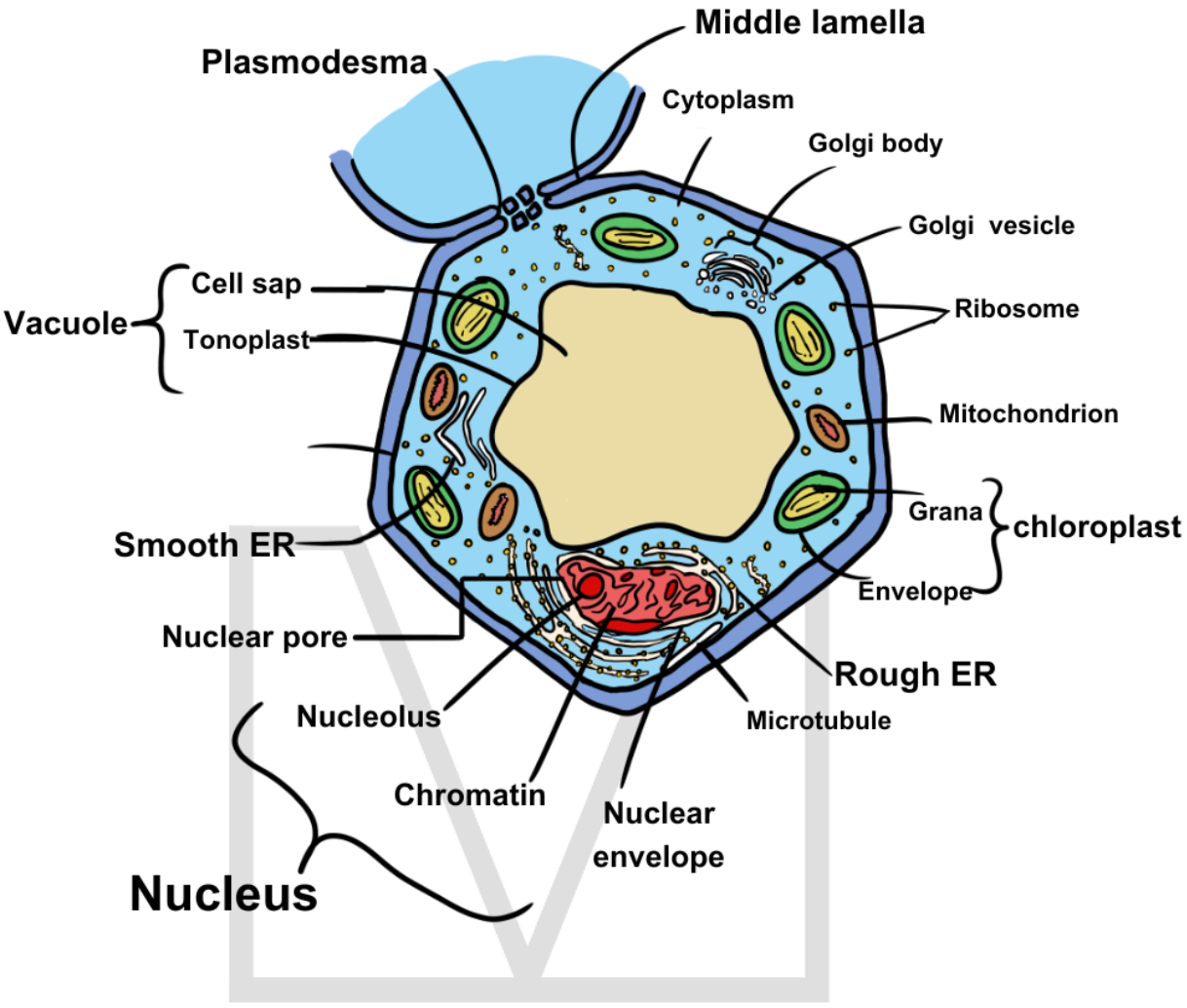
- ➔ DO NOT write ‘substances’ ‘molecules’ ‘food’ ‘food storage’
- ➔ DO NOT write ‘gives shape’ ‘strengthens’. Also DO NOT say No reaction happens inside vacuole.
- ➔ Animal cells may contain small vacuoles which are not permanent and disappear in later stages of cell life.

Cell Wall

- ➔ Made up of cellulose fibres (a carbohydrate and a polysaccharide)
- ➔ It is non-living, non-elastic and thicker than the cell membrane
- ➔ It is freely permeable which means it has no control over what enters or leaves the cell.
- ➔ Cell wall gives the plant cell its shape and prevents the cell from bursting when water enters by osmosis, allowing large pressures to develop inside the cell.
- ➔ There is a thin layer called middle lamella, which marks the boundary between adjacent cell walls and cements adjacent cells together.
- ➔ The prokaryotic cell wall is made up of peptidoglycan.

1.3 Animal and Plant cells





Compare the structure of typical plant and animal cells.

➔ The only structures found in animal cells but not plant cells are the centrioles, microvilli, cellulose cell wall, large permanent vacuoles and chloroplasts.

- Animal and Plant Cells

Key structural features of a prokaryotic cell as found in a typical bacterium, including:

➔ Unicellular
➔ Generally 1–5 μm diameter
➔ Peptidoglycan cell walls
➔ Circular DNA
➔ 70S ribosomes

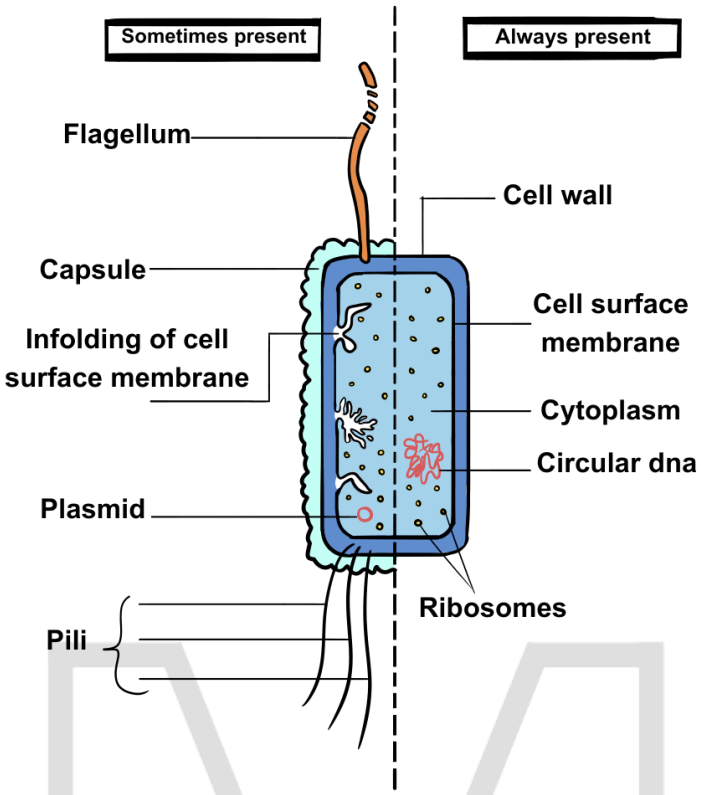
- ➔ absence of organelles surrounded by double membranes
- ➔ Animal and plant cells are types of eukaryotic cells, bacteria are prokaryotes.
- ➔ Prokaryotes have a cellular structure distinct from eukaryotes; their genetic material is not packaged with a membrane bound nucleus and is usually circular.
- ➔ They are smaller than eukaryotes.
- ➔ Their ribosomes are smaller in size (70S) in comparison to those found in eukaryotic cells (80S)

- Important note!!

- ➔ The structures that are sometimes present in Prokaryotes are flagellum, capsule (for protection), infoldings of cell surface membrane (may allow photosynthesis or carry out nitrogen fixation), plasmid (small circle of DNA), pili(for attachment to other cells or surfaces, involved in sexual reproduction)
- ➔ The structures that are always present in Prokaryotes are cell wall, cell surface membrane, cytoplasm, circular DNA, ribosomes.

Eukaryotic Vs Prokaryotic Cell Structures

Feature	Prokaryotes	Eukaryote
Size	0.1 to 5.0 micrometres (μm) in diameter	Have diameters ranging from 10 to 100 μm.
Genome	Circular DNA, no proteins, in the cytoplasm	DNA is associated with proteins, formed into chromosomes
Ribosomes	70s Ribosomes	80s Ribosomes
Organelles	Very few no membrane bound organelles	Numerous types of membrane bound organelles
Cell wall	made up of peptidoglycan	In plant cells, it's made up of cellulose. In fungi, its made up of chitin



1.4 The Vital Role of ATP

- Adenosine Triphosphate (ATP)

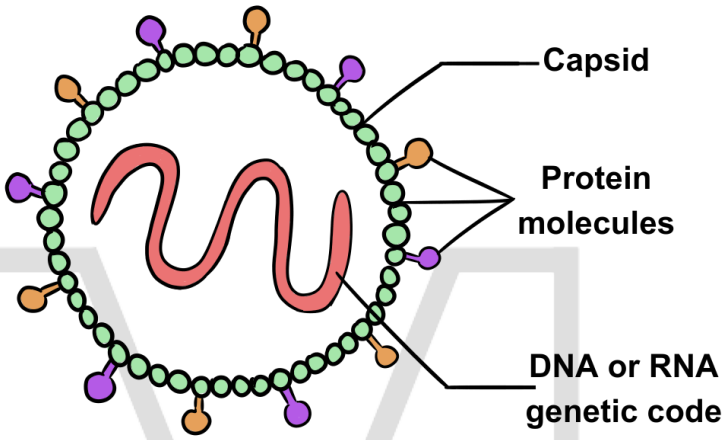
- ➔ To maintain their cells and stay alive, all organisms require a constant supply of energy.
- ➔ This energy is required because anabolic reactions involve the formation of larger molecules from smaller molecules.
- ➔ To transport substances across the cell membrane (active transport) or within the cell
- ➔ Energy is required in animals to coordinate movement at the whole-organism level, using muscle contraction.
- ➔ In the transmission of nerve impulses and many other cellular processes.
- ➔ ATP from respiration is used to transfer energy in all energy-requiring processes in cells in all known forms of life.
- ➔ This is why ATP is referred to as the universal energy currency.
- ➔ It is a type of nucleotide.
- ➔ DNA and RNA monomers are both nucleotides.

1.5 Viruses

- Viruses

- ➔ Non-cellular/acellular
- ➔ Made up of a protein coat called capsid

- ➔ Either have a DNA or RNA strand
- ➔ Replicate inside host cells only
- ➔ Show no characteristics of living organism
- ➔ Symmetrical shape the virus DNA/RNA takes over the protein synthesising machinery of the host cell which helps to make new virus particles
- ➔ All viruses are parasitic in the way that they can only reproduce by infecting living cells and using their protein building machinery (ribosomes) to produce new viral particles.



Chapter 2: Biological Molecules

2.1 Carbohydrates and Lipids

All living organisms are made of **C, H, O** and **N** molecules.

Carbohydrates

- Monosaccharide

➔ A molecule consisting of a single sugar unit and with the general formula $(CH_2O)n$. Examples include hexoses(glucose,fructose and galactose) and pentoses(ribose and deoxyribose).

- Disaccharide

➔ A sugar molecule consisting of two monosaccharides joined together by a glycosidic bond. Examples include sucrose (formed by joining of glucose and fructose), maltose (formed by joining of two glucose units).
➔ Polysaccharide: A polymer whose subunits are monosaccharides joined together by glycosidic bonds. Examples include amylose,amylopectin,glycogen and cellulose.
➔ Glycosidic bond: A C-O-C link between two sugar molecules,formed by a condensation reaction; it is a covalent bond.

- Condensation reaction

➔ A chemical reaction in which two molecules join together to form a complex molecule with the removal of a molecule of water.

- Hydrolysis

➔ A chemical reaction in which a chemical bond is broken by the addition of a molecule of water;commonly used to break down complex molecules into simpler molecules

Monomer

➔ A relatively simple molecule which is used as a basic building block for the synthesis of a giant complex molecule called polymer, many monomers bond together by covalent bonds to form the polymer(condensation reaction).
➔ Examples include:
- Monosaccharides
- Amino acids
- Nucleotides

Polymer

➔ A giant molecule made from many similar repeating subunits(monomers) joined together in a chain.
➔ Examples include:
- Polysaccharides
- Proteins

- Nucleic acids

Macromolecule

A large molecule such as a polysaccharide,protein or nucleic acid.

- Determination of general formula of disaccharides

1. Double the number of C,H and O atoms present in general formula of monosaccharide
2. Subtract 2 hydrogen and 1 oxygen atom from this formula.

➔ Example: Sucrose is made up of glucose and fructose both of which have the general formula $C_6H_{12}O_6$ so the general formula for sucrose would be $C_{12}H_{22}O_5$.

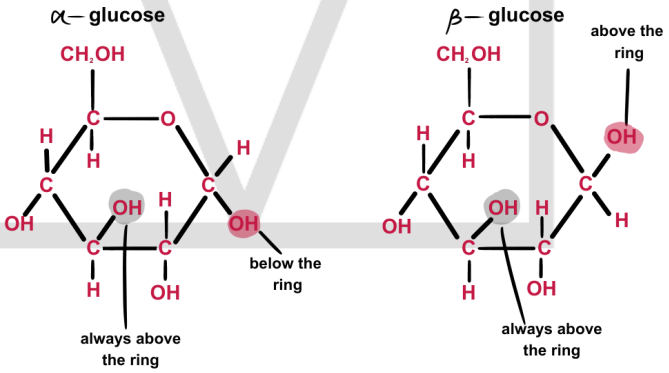
- Reducing sugars

➔ Glucose
➔ Fructose
➔ Maltose

- Non reducing sugar

➔ Sucrose

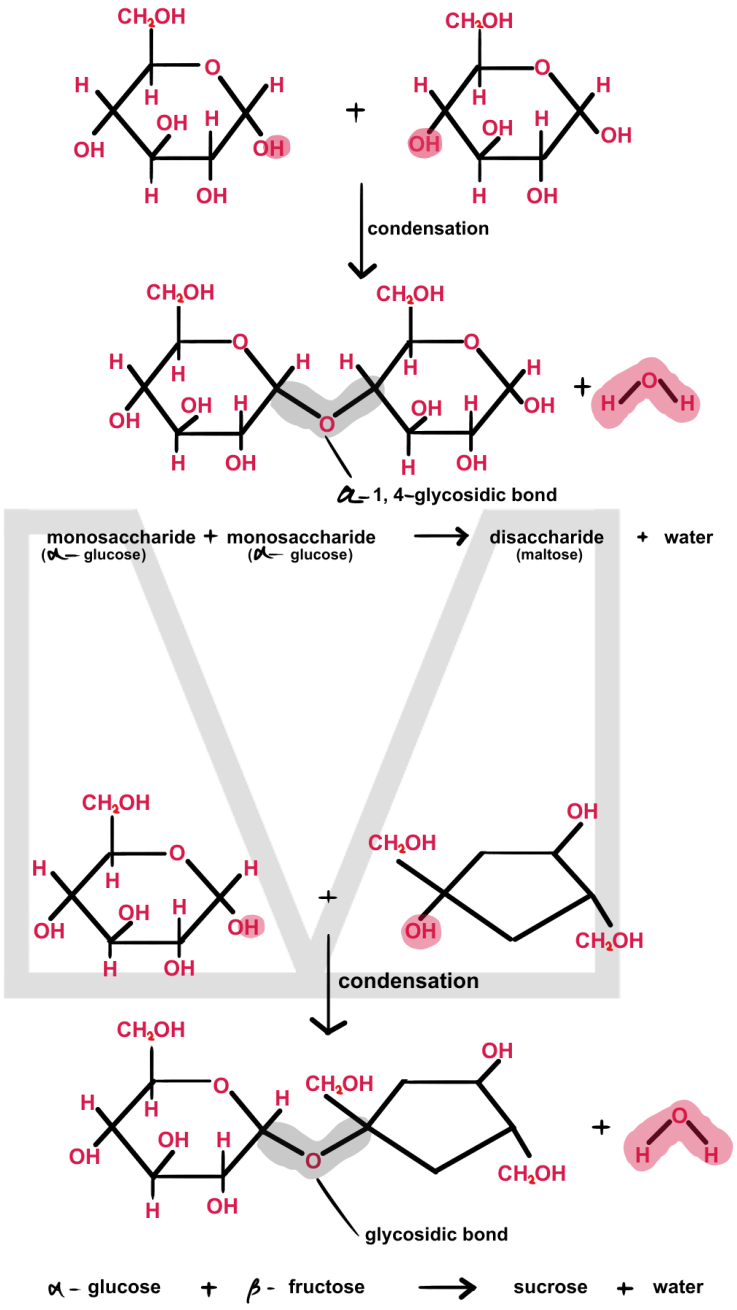
Alpha and Beta glucose units



Ring structures of glucose

➔ Alpha and beta glucose are isomers of each other which means they only differ in their structure.
➔ The form of glucose where hydroxyl group(-OH) on carbon atom 1 is below the ring is known as alpha-glucose
➔ The form of glucose where hydroxyl group(-OH) on carbon atom 1 is above the ring is known as beta-glucose.

Formation of maltose and sucrose



- ➔ Maltose is formed from two alpha-glucose molecules. A 1,4 glycosidic bond is formed between the two glucose molecules
- ➔ Sucrose is formed from one alpha-glucose and one beta-fructose molecule. A 1,2 glycosidic bond is formed between the glucose and fructose molecules.

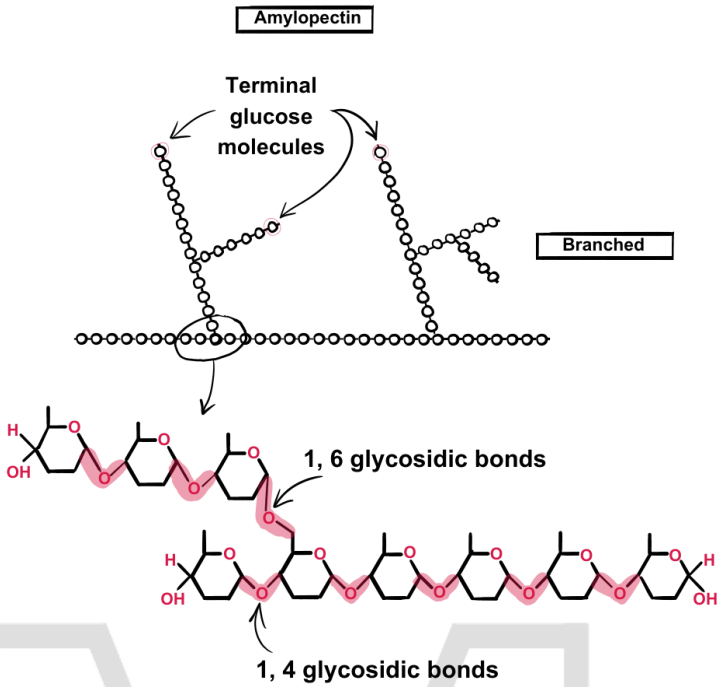
Polysaccharides

- Starch

- ➔ Starch is a mixture of two polysaccharides: amylose and amylopectin
- ➔ Amylose is made by condensations between alpha-glucose molecules.The alpha glucose molecules are joined together by 1,4 glycosidic bonds, which cause the chain to turn and coil.
- ➔ Amylopectin is made up of 1,4 linked alpha-glucose molecules as well as 1,6 linkages.Therefore amylopectin is branched.
- ➔ Starch is only found in plants(commonly in chloroplasts and storage organs) and not in animal cells.

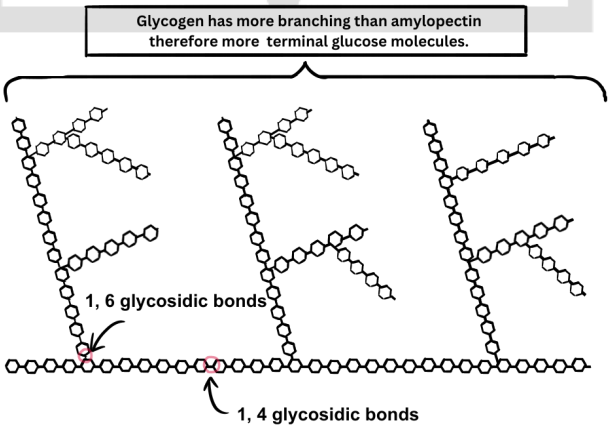
Difference between amylose and amylopectin

Amylose	Amylopectin
1,4 glycosidic bonds only	1.4 and 1,6 glycosidic bonds
Helical and unbranched structure	Branched structure
Smaller	Larger
Less compact	More compact



- Glycogen

- ➔ Glycogen is made up of chains of 1,4 linked alpha-glucose with 1,6 linkages making branched points.
- ➔ It is more branched than amylopectin, thereby making it more compact.
- ➔ It is the storage carbohydrate in animals(commonly stored in liver and muscle cells).

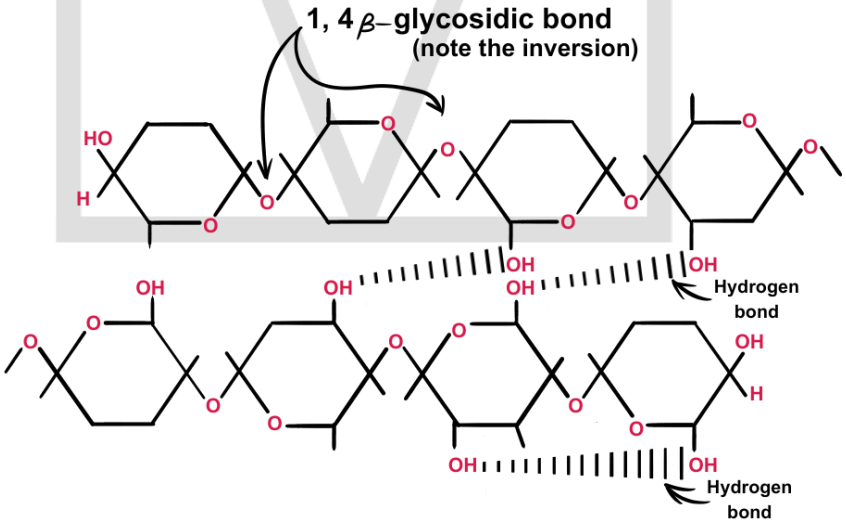


- Relation of structure of starch and glycogen to their function

- ➔ Starch is the storage carbohydrate in plants while glycogen is the storage carbohydrate in animals
- ➔ Presence of 1,4 and 1,6 glycosidic bonds make these molecules compact therefore starch and glycogen do not change the osmotic pressure in cells
- ➔ These are large molecules so cannot diffuse out of cell membrane making them suitable as storage material
- ➔ Since both are made up of glucose monomers, they can easily be hydrolysed to provide glucose for aerobic respiration. -

- Cellulose

- ➔ Cellulose is made up of beta-glucose units which are linked at 180 degrees to each other/alternately oriented.
- ➔ The glucose units are held together by 1,4 glycosidic bonds only.
- ➔ Cellulose is unbranched/has a linear structure.
- ➔ Cellulose has many hydrogen bonds between its molecules
- ➔ The molecules are arranged in a straight chain which allow them to lie parallel to each other, forming **microfibrils** which further form cellulose fibres
- ➔ Strong bonds and criss-cross arrangement of cellulose fibres gives strength to it,allowing it to withstand turgor pressure and prevent plant cells from bursting.



Summary of polysaccharides

Features	Starch	Glycogen Cellulose
Type of glucose	Alpha(α)	Alpha(α) Beta(β)
Glycosidic Bonds	1,4 and 1,6	1,4 and 1,6 1,4
Where it is found	Plants	Animals,bacteria Plant cell walls Fungi
Frequency of branching	Less	More No branching

- Test for reducing sugar

- ➔ Add Benedict's reagent to the solution being tested
- ➔ Heat the solution in water bath(to about 80 degree Celcius)
- ➔ If a reducing sugar is present, the solution will turn from blue to green/yellow/orange/red
- ➔ The intensity of colour obtained gives an idea of the concentration of reducing sugar present in the sample with green indicating a low concentration and red indicating a high concentration

- Test for non reducing sugar

- ➔ Carry out Benedict's test on the solution containing non reducing sugar
- ➔ Negative result will be obtained(colour will remain blue)
- ➔ Take a fresh sample of the solution and heat with hydrochloric acid (this breaks down the disaccharide to monosaccharide)
- ➔ Add an alkali such as sodium hydroxide until fizzing stops (this neutralises the acid)
- ➔ Add Benedict's reagent and heat in water bath
- ➔ Colour change will be observed from blue to green/yellow/orange/red

Determining whether a sample contains both reducing & non reducing sugar

- If both are present

- ➔ A colour change will be observed after adding Benedict's reagent and heating ○ There will be an increase in intensity of colour obtained after carrying out non reducing sugar test(e.g if colour changed to yellow after adding Benedict's reagent and heating for first time, now the colour should change to either orange or red)

- If only reducing sugar is present

- ➔ A colour change will be observed after adding Benedict's reagent and heating ○ There will be no change in intensity of colour obtained after carrying out non reducing sugar test

(e.g if colour changed to yellow after adding Benedict's reagent and heating for first time, it will now remain yellow)

- If none is present

➔ No colour change obtained after adding Benedict's reagent and heating.

Semi quantitative Benedict's test

➔ This is used to estimate the concentration of reducing sugar solution using colour standards made by comparing the colour against the colours obtained in tests done with reducing sugar solutions of known concentration.
➔ If the sample is between two intervals take a narrower range between these two intervals to accurately estimate readings.
➔ Time taken for the first colour change can also be measured and used for this comparison.

Test for presence of starch

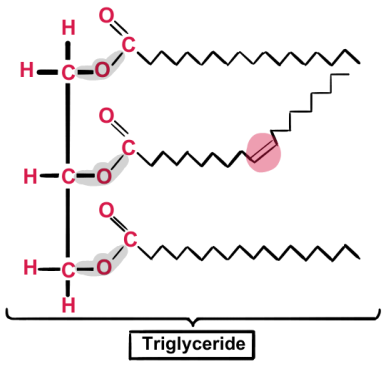
➔ Add a drop of iodine solution to the solid or liquid to be tested.
➔ A blue-black colour is quickly produced if starch is present.

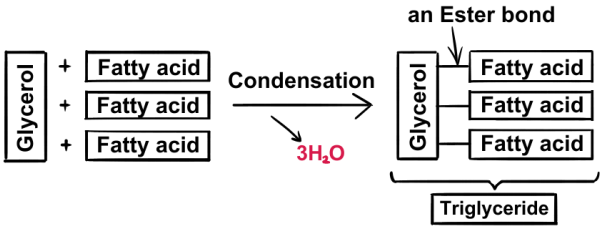
Triglycerides

➔ Triglycerides are nonpolar hydrophobic molecules, formed when three fatty acid molecules combine with glycerol by ester bonds.
➔ Glycerol has three hydroxy(OH) groups, each of which undergoes a condensation reaction with a fatty acid.
➔ Triglycerides are a type of lipids so are insoluble in water but are soluble in certain organic solvents such as ethanol
➔ The fatty acid tails of triglycerides vary in length depending on whether the fatty acid molecules are saturated or unsaturated
➔ If fatty acid tails have double bonds between neighbouring carbon atoms(—C=C—) then they are unsaturated and so form unsaturated triglycerides.
➔ If there is more than one double bond, the fatty acid or triglyceride is described as polyunsaturated.
➔ If there is no double bond between adjacent carbon atoms then the fatty acid and triglyceride is saturated.

- Function of triglycerides

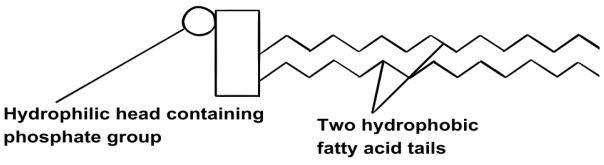
➔ Triglycerides make excellent energy stores because they are even richer in carbon-hydrogen bonds than carbohydrates.
➔ A given mass of triglyceride will yield more energy on oxidation than the same mass of carbohydrates.
➔ Triglycerides are stored in a number of places in the human body,particularly just below the skin and around the kidneys
➔ Below the skin they also act as an insulator against loss of water.





Phospholipids

- ➔ Phospholipids are a special type of lipids formed when one of the three fatty acid molecules is replaced by a phosphate group.
- ➔ The phosphate group is hydrophilic(polar) and makes the head of the phospholipid molecule hydrophilic.
- ➔ The two remaining hydrocarbon tails are still hydrophobic
- ➔ This allows phospholipid to form a membrane around a cell;two rows of phospholipids are arranged with their hydrophilic heads in the watery solutions on either side of the membrane and their hydrophobic tails forming a layer that is impermeable to hydrophilic substances(further detail in chapter 4)



- Test for lipids

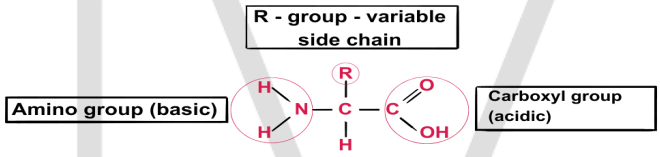
- ➔ Add ethanol to the sample and shake vigorously
- ➔ Pour the ethanol into a tube containing water
- ➔ If lipid is present,a cloudy white emulsion is formed.

2.2 Proteins and Water

Proteins

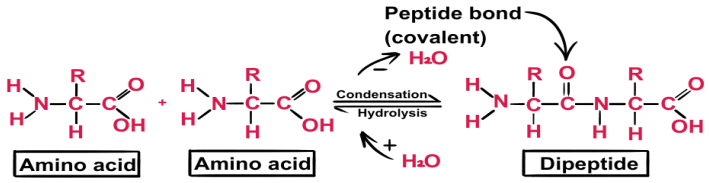
- ➔ Proteins are polymers made from the same basic monomers, amino acids.
- ➔ Enzymes,some hormones like insulin,antibodies,haemoglobin,collagen are all proteins.
- ➔ Proteins are also essential components of cell membranes.

- Amino acids



- ➔ All amino acids have amino(-NH3) and carboxylic acid (-COOH) groups
- ➔ A hydrogen atom is always attached to the central carbon atom
- ➔ Amino acids differ from each other due to different R groups.
- ➔ R groups are specific for each amino acid and determine its properties,they also help to identify the amino acid (e.g glycine,which is the smallest amino acid has H as its R group while alanine has CH3 as its R group).

- Peptide bond



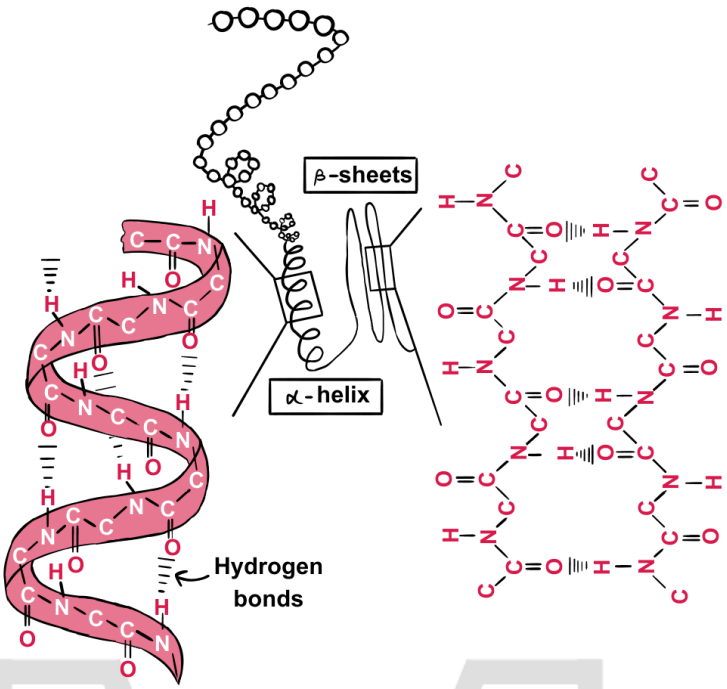
- ➔ The covalent bond joins neighbouring amino acids together in proteins;it is a C-N link between two amino acid molecules, formed by condensation reaction.
- ➔ The oxygen and two hydrogen atoms removed from the amino acids form a water molecule
- ➔ The molecule formed when two amino acids join together is known as dipeptide.(the number of peptide bonds is always one less than the number of amino acids so if n represents the number of amino acids, n-1 will represent the number of peptide bonds).
- ➔ A molecule made up of many amino acids linked together by peptide bonds is called a polypeptide.
- ➔ A protein may have just one polypeptide chain or it may have two or more chains.

- Primary structure of proteins

- ➔ The particular amino acids contained in the chain, and the sequence in which they are joined, is called the primary structure of the protein.
- ➔ A change in a single amino acid in a chain made up of thousands may completely alter the properties of the polypeptide or protein.

- Secondary structure of proteins:

- ➔ The structure of a protein molecule resulting from the regular coiling or folding of the chain of amino acids(an α-helix or β-pleated sheet)
- ➔ α-helix is a helical structure formed by a polypeptide chain. It arises due to hydrogen bonding between the oxygen of the C=O group of one amino acid and the hydrogen of the -NH group of another amino acid four places ahead of it
- ➔ β-pleated sheet is a loose,sheet like structure formed by hydrogen bonding between parallel polypeptide chains
- ➔ Some proteins or parts of proteins show no regular arrangement are all.It all depends on which R groups are present and what attractions occur between amino acids in the chain.



- Tertiary structure

- ➔ The compact structure of a protein molecule resulting from the three-dimensional coiling of the chain of amino acids.
- ➔ The amino acids interact with each other due to hydrogen bonds, disulfide bonds,ionic bonds or hydrophobic interactions between R groups
- ➔ Hydrogen bonds form between strongly polar R groups e.g -NH, -CO- and -OH groups.
- ➔ Disulfide bonds form between R groups containing sulphur, they are the strongest of the bonds in the tertiary structure
- ➔ Ionic bonds form between R groups containing ionised amino groups and ionised carboxylic acid groups.
- ➔ Weak hydrophobic interactions occur between non polar R groups.

- Quaternary structure

- ➔ The overall three-dimensional structure formed by two or more polypeptides chains.
- ➔ Quaternary structure does not exist if there is only one polypeptide chain
- ➔ The polypeptide chains in quaternary structure are held together by the same four types of bond as in tertiary structures
- ➔ Examples include Haemoglobin and Collagen

- Globular proteins

- ➔ A protein whose molecules are folded into a relatively spherical shape.
- ➔ They are water soluble
- ➔ Have physiological roles
- ➔ Have hydrophobic R groups on the inside and hydrophilic R groups on the

outside.
- ➔ Enzymes, haemoglobin and insulin are globular proteins

- Fibrous proteins

- ➔ A protein whose molecules have a relatively long,thin structure.
- ➔ Generally insoluble in water.
- ➔ Have structural roles.
- ➔ Collagen and keratin are fibrous proteins

- Haemoglobin

- ➔ Haemoglobin is the oxygen carrying pigment in the red blood cells.
- ➔ The quaternary structure of haemoglobin is made up of four polypeptide chains, two of the chains are made up of α-globin (called the α chains) and the other two chains are made up of β-globin (called the β chains).
- ➔ Each of the four polypeptide chains of haemoglobin contains a haem group,each haem group contains an iron atom.
- ➔ One oxygen molecule can bind with each iron atom so a haemoglobin molecule can carry four oxygen molecules/eight oxygen atoms at a time.
- ➔ The hydrophobic R groups point in towards the centre of the molecule, and their hydrophilic ones point outwards.
- ➔ The interactions between the hydrophobic R groups inside the molecule are important in holding it in the correct three-dimensional shape.
- ➔ The outward-pointing hydrophobic R groups on the surface of the molecule are important in maintaining its solubility
- ➔ Having a non-polar R group on the outside of the molecule makes the haemoglobin much less soluble, and causes the dangerous and unpleasant symptoms associated with sickle cell anaemia.

- Collagen

- ➔ Fibrous protein
- ➔ It is the main structural protein of vertebrates
- ➔ Found in skin,tendons,cartilage,bones,teeth and the walls of blood vessels.
- ➔ A collagen molecule is made up of three helical polypeptide chains wound around each other,forming a ‘triple helix’ with a high tensile strength.
- ➔ The three strands are held together by hydrogen bonds and some covalent bonds.
- ➔ Almost every third amino acid in each polypeptide is glycine,the smallest amino acid.
- ➔ Small size of glycine allows the three strands to lie close together and so form a tight coil.Any other amino acid would be too large.
- ➔ Each complete,three-stranded molecule of collagen interacts with other collagen molecules running parallel to it.Covalent bonds form between R groups of amino acids lying next to each other.
- ➔ These cross-links hold many collagen molecules side by side,forming fibrils.
- ➔ The ends of the parallel molecules are staggered.
- ➔ Finally many fibrils lie alongside each other, forming strong bundles called fibres.

- Test for proteins

- ➔ Biuret reagent used for this test is prepared by mixing a dilute solution of potassium hydroxide and a dilute solution of copper(II) sulphate.
- ➔ Add biuret reagent to solution that is being tested
- ➔ Colour changes from blue to purple if protein is present in the sample.

Water

- ➔ Physical properties of water are affected by hydrogen bonding.
- ➔ Water molecules are dipoles.
- ➔ Each water molecule has partial positive(δ+) hydrogen atoms and a partial negative(δ-) oxygen atom.
- ➔ The positively charged hydrogen atom of one water molecule is attracted to the negatively charged oxygen atom of another water molecule which results in hydrogen bonding.
- ➔ Each oxygen atom forms two hydrogen bonds/each hydrogen atom forms one hydrogen bond

Important properties of water

- Solvent action

- ➔ Water is an excellent solvent for ions and polar molecules.
- ➔ Since ions are charged, water molecules are attracted to them.
- ➔ The attraction occurs because δ- oxygen atoms of water molecules face positive ions while δ+ hydrogen atoms face negative ions.
- ➔ Non-polar molecules like lipids are insoluble in water and,if surrounded by water,tend to be pushed together by the water,since water molecules are attracted to each other.

- High specific heat capacity

- ➔ The hydrogen bonds that tend to make water molecules stick to each other make it more difficult for the molecules to move about freely.
- ➔ The bonds must be broken to allow free movement.
- ➔ Hydrogen bonding allows water to store more energy for a given temperature rise than would otherwise be possible, hence making water more resistant to changes in temperature.

- High latent heat of evaporation

- ➔ The fact that water molecules tend to stick to each other by hydrogen bonds means that relatively large amounts of energy are needed for evaporation to occur, because hydrogen bonds have to be broken before molecules can escape as a gas.
- ➔ The energy transferred to water molecules during evaporation results in corresponding loss of energy from their surroundings, which therefore cool down
- ➔ This is biologically important because it means living organisms can use evaporation as a cooling mechanism,as in sweating or panting in mammals.

Chapter 3: Enzymes

3.1 Mode of action of enzymes

Enzymes

- ➔ Enzymes are globular proteins that increase the rate of reaction by lowering the activation energy of the reaction they catalyse.
- ➔ The active site is the area of the enzyme where the reaction with the substrate takes place.
- ➔ Each enzyme has a specific shape that must be complementary to the substrate, meaning that only one type of substrate fits into the active site of each enzyme.
- ➔ Enzymes are also known as protein molecules. enzymes are coiled into a precise 3D shape, with hydrophilic (water loving) R groups which are outside the molecules, and this ensures that they are soluble.
- ➔ Enzymes can be intracellular (function inside cells), for example DNA polymerase.
- ➔ They can also be extracellular, such as the enzymes used in digestion.

- Induced Fit Model

- ➔ For this model, the active site is not complementary to the substrate, before the reaction can occur.
- ➔ The active site undergoes conformational changes, so it then becomes complementary to the substrate, hence allowing it to fit into the active site.
- ➔ An enzyme substrate complex is formed, which allows products to be formed and are then released.
- ➔ Enzymes help to lower the activation energy by providing alternative routes, which hold the substrates in such a way that they react more easily.

- Lock and Key hypothesis

- ➔ This model suggests that the substrate fits into the enzyme's active site in the same way in which a key fits into a lock.
- ➔ The shape of the substrate and the active site are perfectly complementary to each other. Catalysis happens in the following stages:
    1) The substrate binds to the enzyme's active site, forming an enzyme-substrate complex (ES complex).
    2) The enzyme converts the substrate into product, forming an enzyme-product complex (EP complex).
    3) The product is released from the enzyme's active site.

3.2 Factors that affect enzyme action

The rate of enzyme catalysed reactions can be affected by the following factors,

- Temperature

- ➔ The reactions speed up when the temperature rises because the substrate and enzymes have more kinetic energy and are moving more quickly as a result.
- ➔ This leads to more successful collisions that result in the conversion of substrate into products.

- ➔ The enzyme at its optimum, and so, all of its active sites are occupied by substrates at the ideal temperature.
- ➔ The reaction pace will be faster. Higher temperatures will, however, eventually lead to the structure of the enzymes, particularly their active areas, changing.
- ➔ Denaturation is the term for this. The tertiary structure of the protein is harmed by high temperatures, which prevents it from continuing the reaction and causes the bonds between the R groups to dissolve.
- ➔ An enzyme's optimum temperature is around 37 degrees Celsius, anything over that will lead to its denaturation.

- pH

- ➔ pH is the measure of H+ ions in a solution. the lower the pH, the more the H+ ion concentration. the H+ ions can interact with the R groups of amino acids (e.g. ionisation of groups).
- ➔ This has an impact on the ionic bonding between the R groups, which has an influence on the enzyme's three-dimensional structure and its ability to denature.
- ➔ There is a pH where enzymes work at their best. A change in pH has an impact on the hydrogen ion concentration surrounding the enzyme molecule, which ultimately causes the ionisation of R groups on the protein's amino acid residues.
- ➔ As a result, it affects the shape of the active site, and the ease formation of an enzyme substrate complex. At the optimum pH, the shape of the active site is complementary to the shape of the substrate.

- Enzyme Concentration

- ➔ As the enzyme concentration increases, the rate of reaction also increases, which means more active sites are available.
- ➔ The increased concentration of enzyme will lead to an increase in collisions between the enzyme and the substrate, resulting in a faster rate of reaction.
- ➔ However, at a high concentration of enzymes, the concentration of substrates can become a limiting factor and the rate will level off, but this won't happen if there are plenty of substrates available.

- Substrate Concentration

- ➔ As the substrate concentration increases, the initial rate of reaction also increases.
- ➔ But after some time, enzymes are working continuously with no free active sites.So the substrate molecules queue up.
- ➔ This will lead to a slow rate. However, if the concentration of substrate is increased, there will be more frequent collisions between the enzyme and substrate molecules, more enzyme substrate complexes are formed and this will result in a faster rate of reaction.

Vmax

- ➔ This is the theoretical maximum rate (velocity) of a reaction an enzyme catalyses, and at Vmax all the enzymes are occupied by substrate molecules.
- ➔ At high substrate concentrations, the enzyme concentration will become the limiting factor and at this point, the curve will level off.

- Michaelis-Menten constant (Km)

- ➔ The substrate concentration at which an enzyme works at halves its maximum rate (½ Vmax)

➔ It is also used as a measure of affinity of enzyme for its substrate or efficiency of an enzyme.

- How to determine the Km from the graph?

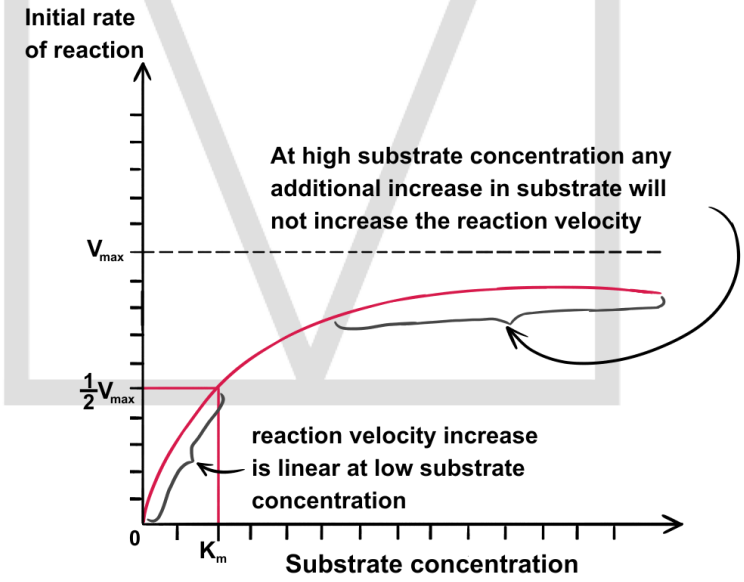
➔ Take half of Vmax.
➔ Reconcile this with substrate concentration on the x axis.

- High Low Km values

➔ When Km is high, affinity will be low.
➔ This will result in less effective collisions, as enzymes form fewer enzyme substrate complexes, as the active sites of these enzymes are less good fit for the substrates, so the reaction will take longer to get to Vmax.
➔ And a higher concentration of substrate is required to reach Vmax.

- Low Km value

➔ There will be more effective collision, as enzymes form more enzyme substrate complexes.
➔ The active sites of these enzymes are a very good fit for the substrate so the reaction will take lesser time to get to Vmax.
➔ Less concentration of substrate is required to reach Vmax.



Inhibitors

There are two types of inhibitors, known as Competitive and Non Competitive Inhibitors.

- Competitive Inhibitors

➔ Have a similar shape to substrate

- ➔ They can fit temporarily in the active site to prevent the substrate from entering, this reduces the enzyme substrate complexes being formed and slows down the reaction.
- ➔ The greater the concentration of an inhibitor to substrate in a mixture, the more effect the inhibitor will have in reducing the activity of the enzyme.
- ➔ The competitive inhibitors graph will be downwards, towards the right side. The Km increases and Vmax stays the same. Regardless of the concentration of a competitive inhibitor, the effects of concentration can be overcome by increasing concentration of substrates.

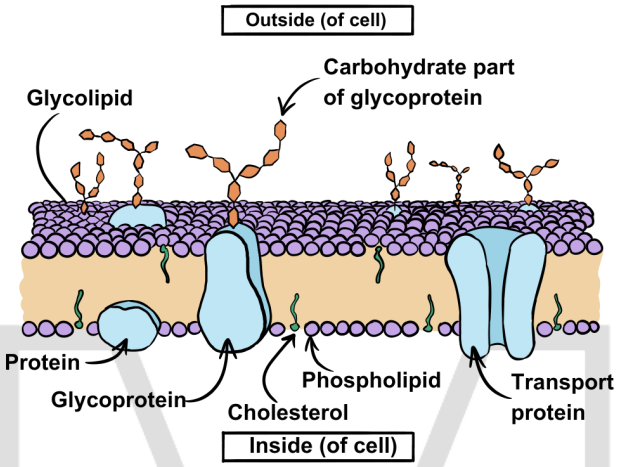
- Non Competitive Inhibitor

- ➔ The shape does not resemble the substrate.
- ➔ It binds to the allosteric site, which is any other place other on the enzyme, other than the enzyme.
- ➔ This causes a change in the structure of the active site and so it is no longer complementary.
- ➔ It is irreversible.

Chapter 4: Cell Transport

- Fluid Mosaic Model

➔ Fluid refers to the movement of the phospholipids moving around the bilayer, while mosaic is referred to as the proteins and glycolipids scattered throughout the bilayer.



- Phospholipids

➔ Phospholipids are made up a hydrophilic head (water loving) and a hydrophobic tail (water hating)
➔ If we add water into the phospholipid, it forms a ball like structure which is called micelles the heads will point to the water making a ball.and the tails will be facing inside, cause they don't like water
➔ It can also form sheets called bilayers, which is the basic structure of the membrane the phospholipids and proteins can move around by diffusion; fluid
➔ They move sideways in their own layer

Membrane fluidity

Membrane fluidity is affected by:

- Tail length

➔ The longer the tail is, the less fluid the membrane

- Saturation of fatty acids

➔ The more unsaturated they are, the more fluid the membrane will have, as unsaturated fatty acid tails are bent and fit together more loosely

- Cholesterol

- ➔ It regulates the fluidity of membranes.
- ➔ At low temperatures, cholesterol increases the fluidity of the membrane preventing it from being too rigid, this is because it prevents close packing of phospholipid tails
- ➔ At high temperatures, cholesterol decreases the fluidity of membrane and stabilises the cell

Roles of the molecules found in membranes

- ➔ Phospholipids form a bilayer, which is the basic structure of the membrane and the fluidity of the membrane is affected by the length of the fatty acid tails and how saturated or unsaturated they are.
- ➔ As the tails of phospholipids are nonpolar (hydrophobic) it is difficult for polar molecules or ions to pass through the membranes. membranes therefore act as a barrier to most water soluble substances. This means that water soluble molecules such as sugars, amino acids and proteins can not leak out of the cell and unwanted sugar soluble molecules cannot enter the cells.
- ➔ Some phospholipids can be modified to act as signalling molecules.

Cholesterol

- ➔ It is a small molecule
- ➔ Just like phospholipids, they have hydrophilic heads and hydrophobic tails
- ➔ Cell surface membranes in animal cells contain almost as much cholesterol as phospholipids, its less common in plants and is absent from prokaryotes
- ➔ Cholesterol is important for the mechanical stability of membranes, it strengthens membranes by getting in-between the phospholipid molecules and reduces fluidity. without cholesterol, membranes would quickly break and cells would burst open.
- ➔ The hydrophobic regions of cholesterol help to prevent ions or polar molecules from passing through the membrane
- ➔ At low temp, the phospholipid tails tend to pack closer together, but cholesterol prevents this from happening too much.
- ➔ Maintaining the correct fluidity of the membrane means cells can survive colder temperatures.

Glycolipids, glycoproteins and proteins

- ➔ The carbohydrate chains help the glycoproteins and glycolipids to act as receptor molecules.
- ➔ The function of receptor molecules is to bind with particular substances at the cell surface.
- ➔ One group of receptors are called signalling receptors.
- ➔ Signalling receptors recognize messenger molecules like hormones and neurotransmitters.
- ➔ When the messenger molecule binds to the signalling receptor, a series of chemical reactions has started inside the cells.
- ➔ Only cells that have glucagon receptors are affected by glucagon

Transmembrane Protein (Intrinsic)	Extrinsic Protein
Proteins which are found embedded within the membrane	They are present inside or outside of the cell membrane
Can be found in the inner layer, outer layer or could even be spanning the whole membrane	Extracellular peripheral proteins – are used for communication, receptors, and recognition proteins
It also helps in movement in and out of cell	Intracellular peripheral proteins offer more of a structural function, attached to the cytoskeleton of the cell

Transport proteins

- ➔ Many proteins act as transport proteins, these provide hydrophilic channels or passageways for ions and polar molecules to pass through the membrane.
- ➔ Each transport protein is specific for a particular kind of ion or molecules.
- ➔ There are two types of transport protein, Carrier and Channel Proteins. (both channel and carrier proteins are highly specific, allowing only one type of molecule or ion to pass through it)

- Channel proteins

- ➔ These have water filled pores as part of their structure
- ➔ The pores allow charged substances (usually ions) to diffuse through the membrane most channel proteins are gated, this means that part of the protein molecule on the inside surface of the membrane can move to close or open the pore
- ➔ This allows control of ion exchange
- ➔ Two examples are the gated proteins found in nerve cell surface membrane
- ➔ One type allows entry of sodium ions
- ➔ Another type allows exit of potassium ions during the recovery phase
- ➔ Some channels occur in a single protein, others are formed by several proteins combined while some gated channel proteins require energy (in the form of atp) to operate the gate

- Carrier proteins

- ➔ Whereas channel proteins have a fixed shape, carrier proteins can flip between two shapes
- ➔ As a result, the binding site is open to one side of the membrane, and then the other
- ➔ Allows the molecule or ion to cross the membrane
- ➔ Some carrier proteins change shape spontaneously
- ➔ These are the ones that allow facilitated diffusion
- ➔ Some carrier proteins, known as pumps require energy and are involved in active transport

Cell surface receptors

- ➔ Cell surface receptors (membrane receptors, transmembrane receptors) are receptors that are embedded in the plasma membrane of cells.
- ➔ They act in cell signalling by receiving extracellular molecules.

Cell surface antigen

- ➔ These act as cell identifying markers
- ➔ Each type of cell has its own antigen, just like how each country has its own flag
- ➔ Hence, this allows cells to recognise other cells and behave in an organised way

Cell to cell recognition

- ➔ Some glycolipids and glycoproteins act as cell markers or antigens, which allows cells to recognise each other
- ➔ The carbohydrate chains bind to complementary sites on other cells.
- ➔ Cell to cell recognition is important in growth and development and for immune responses

- If the signalling molecules are hydrophobic

- ➔ They will diffuse directly across the cell membrane and bind to the receptors present in the cytoplasm or the nucleus.

- If the signalling molecules are water soluble

- ➔ A stimulus causes cells to secrete a specific chemical, this is called a ligand. The hormone glucagon is an example of a ligand.
- ➔ It is a specific chemical secreted by certain cells in the pancreas in response to a drop in blood sugar levels
- ➔ The ligand is transported to the target cells. signalling molecules are usually relatively small for easier transport.
- ➔ In the case of hormones, the transport system is the blood system
- ➔ The ligand binds to cell surface receptors on the target cells. The receptors are protein molecules which are located in the cell surface membrane.
- ➔ The cell surface receptor is a specific shape and recognizes the ligand.
- ➔ Only cells with this receptor can recognize the ligand.
- ➔ The receptor spans the membrane, so that the message is passed to the inside of the cell changing the shape of the receptor will allow it to interact with the next component of the signalling pathway, so the message gets transmitted.
- ➔ Conversion of the original signal to a message that is then transmitted is called transduction.
- ➔ The next component in the signalling pathway is often a G protein, which acts as a switch to bring about the release of a second messenger.
- ➔ The second messenger is a small molecule which diffuses through the cell which relays the message.
- ➔ G proteins are called G proteins because the switch mechanism involves binding to GTP which is guanosine triphosphate.
- ➔ GTP is similar to ATP but with guanine in place of adenine.
- ➔ The stimulation of one receptor molecule results in many second messenger molecules being made in response
- ➔ This represents an amplification (magnification) of the original signal, a key feature of signalling.

- ➔ The second messenger typically activates an enzyme, which in turn activates more enzymes, which increases the amplification at each stage
- ➔ Finally, enzymes are produced, which bring about the required change in cell metabolism
- ➔ The sequence of events triggered by G protein is called a signalling cascade.

Cytoskeleton

- ➔ Some proteins on the inside of the cell surface membrane are attached to a system of protein filaments inside the cell which is known as the cytoskeleton.
- ➔ These proteins help to maintain and decide the shape of the cell. they may also be involved in changes of shape when the cells move.

Movement of substances across membranes

These are the ways exchange can be done,

Diffusion

- ➔ It is the net movement of a substance from a region higher concentration to lower concentration /down a concentration gradient
- ➔ Because of diffusion, molecules or ions tend to reach an equilibrium where they are evenly spread
- ➔ Some molecules or ions are able to pass through living cell membranes by diffusion. For example, the respiratory gases, oxygen and carbon dioxide cross membranes by diffusion.
- ➔ They are uncharged and nonpolar, so they can cross through the phospholipid bilayer between the phospholipid molecules. water molecules, despite being very polar, can diffuse rapidly across the phospholipid bilayer because they are small enough
- ➔ Hydrophobic molecules can cross membranes because of the interior of the membrane, which is hydrophobic.

- The rate at which a substance diffuses across a membrane depends on

- ➔ **The steepness of the conc gradient:** The steeper the conc gradient of a substance across a membrane, the faster the rate of diffusion of that substance
- ➔ **Temperature:** High temp means more kinetic energy, they move faster so diffusion is faster too
- ➔ **The nature of the molecules or ions:** Large molecules require more energy to get them moving, rather than small ones. large molecules then tend to diffuse more slowly than small molecules. mom polar molecules such a glycerol, alcohol and steroid hormones, diffuse much more easily through membranes than polar ones, as they are soluble in the non polar phospholipid tails
- ➔ **The surface area across which diffusion is taking place:**
    - The greater the surface area of a surface, the more molecules or ions can cross it at any moment and therefore, diffusion will be faster
    - The surface area of a cell membrane can be increased by foldings
    - The larger the cell, the smaller its surface area in relation to its volume.
    - Cells rely on diffusion because it is the main method by which molecules move about inside cells.
    - This results in a limit on the size of the cells, because the time taken to travel any distance by diffusion increases much faster than the distance does.

- Facilitated diffusion

- ➔ Large polar molecules such as glucose and amino acids cannot diffuse through the phospholipid bilayer, nor can ions such as sodium and chloride
- ➔ These can only cross the membrane with the help of certain protein molecules diffusion that needs help in this way is called facilitated diffusion

- Rate of diffusion through channel and carrier proteins

- ➔ If molecules are diffusing across a membrane, the direction of movement depends on their relative concentration on each side of the membrane
- ➔ They move down a conc gradient from a higher to a lower conc

Osmosis

- ➔ It is the movement of water from high to low water potential conc across a partially permeable membrane until equilibrium is achieved. Water potential is described as the tendency of water to move out of solution.
- ➔ Water will always move down a water potential gradient, this will continue to happen till water potential is the equal throughout the solution
- ➔ Water potential is denoted by psi (Ψ)
- ➔ Water potential becomes negative if the solute concentration becomes very high

	Red Blood cells/Animal cells	Plant cells
Water loss	Crenated	Flaccid
Water gain	Lysed	Turgid

Active Transport

- ➔ It is defined as a process that involves the movement of molecules from a region of lower concentration to a region of higher concentration against a gradient, with the use of ATP.

- Sodium/Potassium Pump

- ➔ For every ATP molecules used, 3Na+ -are given out of the cell, whereas 2K+ are taken into the cell

- Bulk transport

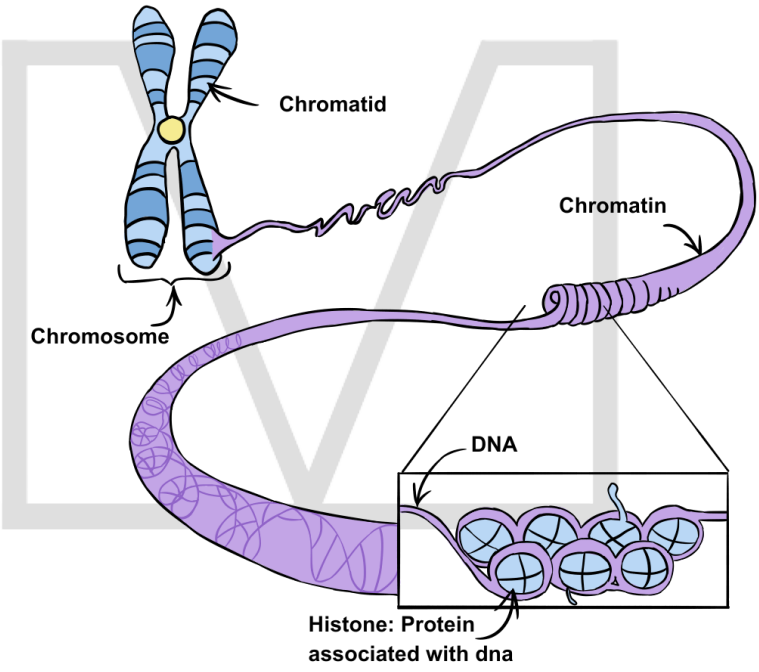
- ➔ It is when large molecules are transported across the cell surface membrane, while using ATP.

Endocytosis	Exocytosis
It's a process by which cells absorb material by engulfing external material alongside its cell membrane	Its a process that expels secretory vesicles containing nanoparticles (or other chemicals) out of the cell membranes into the extracellular space

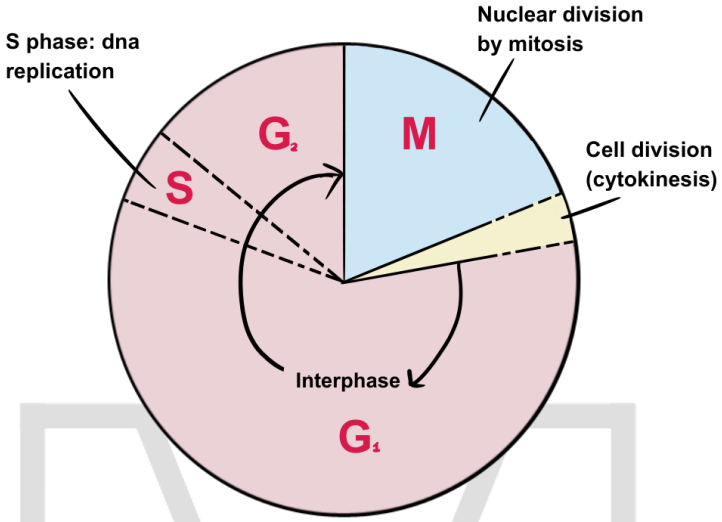
Chapter 5: The Mitotic Cell Cycle

5.1 Chromosomes

- ➔ A chromosome is a structure in the nucleus that is composed of two identical chromatids.
- ➔ These two chromatids are held together by a narrow region called the centromere. Each chromatid contains one DNA molecule.
- ➔ The number of chromosomes is a characteristic of the species; human cells have 46 chromosomes.
- ➔ When cells divide, each of the daughter cells get one chromatid from each chromosome. Hence, the daughter cells are genetically identical.
- ➔ Chromosomes are made of chromatin. Chromatin is the combination of DNA and protein molecules. The DNA is wound around the outside of protein molecules. Most of these proteins are histone proteins.



5.2 Cell Cycle



- ➔ The cell cycle is a sequence of events that takes place between one cell division and the next.
- ➔ It consists of three phases: interphase, nuclear division (mitosis) and cell division (cytokinesis).

- Interphase: consists of G1, S and G2

- ➔ The cell grows to its normal size during interphase, and carries out its normal functions. Cells make RNA, enzymes and proteins needed for growth. This is the G1 phase.
- ➔ The cell receives a signal to divide again. Then, the DNA in the nucleus replicates, so that each chromosome consists of two identical chromatids. This is the S phase.
- ➔ The cell then continues to grow and new DNA is checked and repaired. Preparations for division begin. This is the G2 phase.

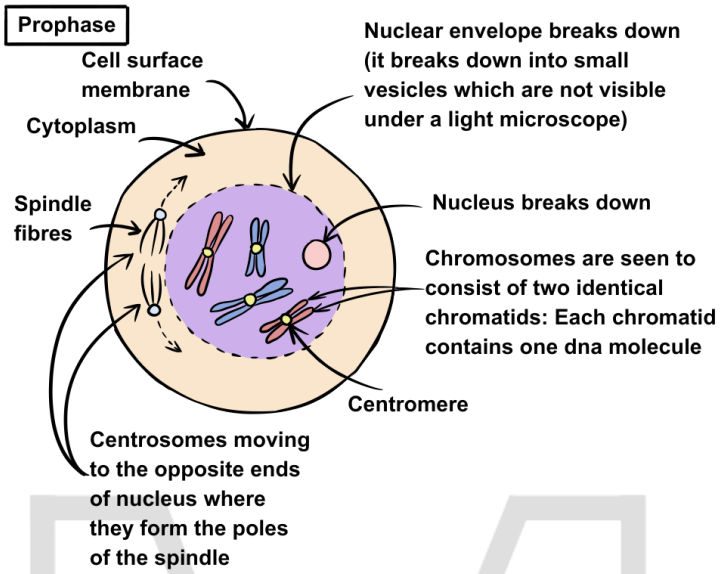
Nuclear Division (Mitosis)

- ➔ During mitosis, cell growth stops temporarily.
- ➔ It has 4 stages: prophase, metaphase, anaphase and telophase.

- Prophase

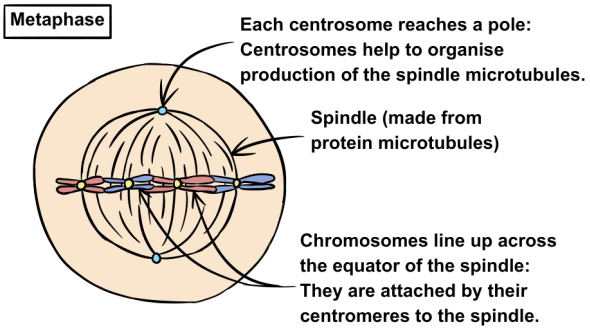
- ➔ Centrosomes replicate just before prophase. They then move to opposite ends of the nucleus to form the poles of the spindle.
- ➔ Chromosomes start to appear, and are visible when stained. Later, they are seen to consist of two chromatids.
- ➔ Nuclear envelope and nucleolus disappear.

➔ By the end of prophase, a spindle is formed.



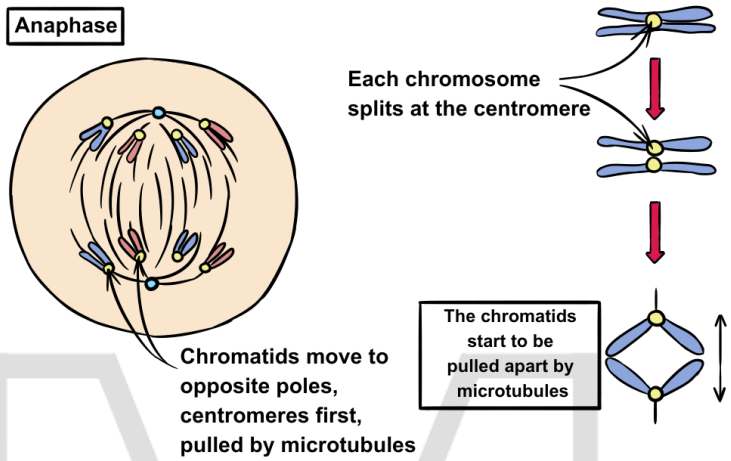
- Metaphase

➔ Each centrosome reaches a pole and spindles are formed from microtubules.
➔ Chromosomes line up across the equator of the spindle, and are attached to the spindle by their centromeres.



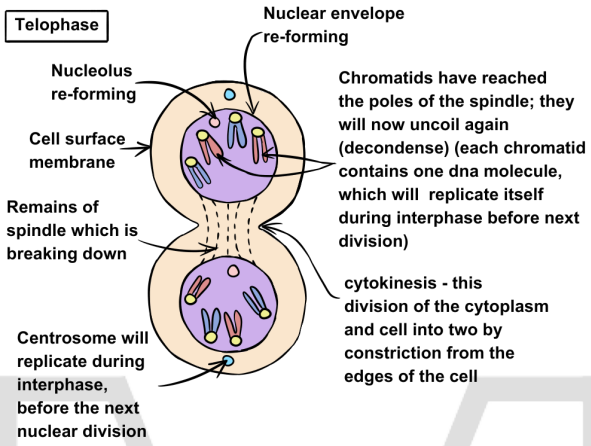
- Anaphase

- ➔ Each chromosome splits at the centromere and the chromatids are pulled apart by the microtubules.
- ➔ Chromatids move to opposite poles, pulled by the microtubules.



- Telophase

- ➔ At this point, two nuclei are present in one cell.
- ➔ Nuclear envelope and nucleolus begin reforming.
- ➔ Remains of the spindle break down.
- ➔ Chromatids have reached the poles of the spindle at this point, and will uncoil again.



Cytokinesis

- ➔ The cytoplasm and cell divide into two.
- ➔ At the end of cytokinesis, two cells are formed, each with identical nuclei

Telomeres

- ➔ The ends of chromosomes have structures called telomeres.
- ➔ Telomeres are made of DNA with base sequences that are repeated multiple times.
- ➔ The enzyme that copies DNA during replication cannot run to the end of the DNA strand. Basically, it cannot replicate the entire DNA strand as it stops a little short of the end.
- ➔ If important parts of the DNA are not copied, the information stored by that part is lost. Eventually, after many subsequent divisions, the loss of vital genes would result in cell death.
- ➔ The main function of telomeres is to prevent the loss of vital genes during replication, and to allow continued replication of a cell. Telomeres themselves do not contain any vital information, so they ensure that the important DNA is copied.
- ➔ Telomerase is an enzyme that adds extra DNA during each cell cycle. This extra DNA is the telomere. Some cells, typically specialised cells, do not regenerate their telomeres. So, with each cell division, their telomeres get shorter and shorter until the vital DNA is no longer protected and the cell dies.
- ➔ Telomeres permit continued replication
- ➔ Telomeres prevent loss of genes

Stem Cells

- ➔ A stem cell is a relatively unspecialised cell that can divide an unlimited number of times.

➔ Each new cell has the potential to remain a stem cell or to develop into a specialised cell.

Cancer

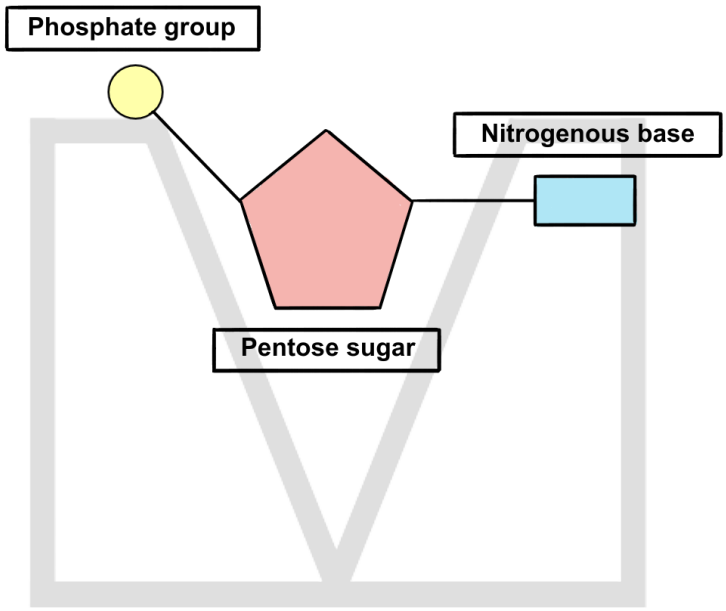
➔ When uncontrolled cell division/mitosis takes place, a mass of cells, called a tumour, is formed. Cancer is a group of diseases caused by the uncontrolled growth and spread of cells.
➔ Cancers are a result of mutation in genes that control cell division. A change in genes is called a mutation.
➔ These mutations are caused by agents called carcinogens. Examples of carcinogens are UV light, tar, and asbestos.

Chapter 6 : Protein Synthesis

6.1 DNA Structure and Replication of DNA

- Nucleotide:

A molecule consisting of a nitrogen containing base, a pentose sugar and a phosphate group.



- Polynucleotide:

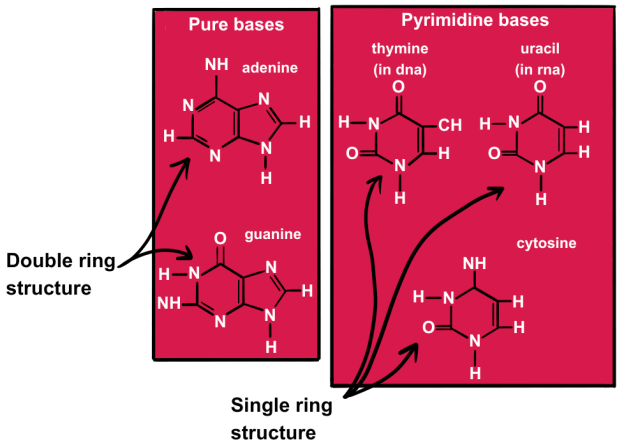
A chain of nucleotides joined together by phosphodiester bonds.

- ➔ Two pentose are found in nucleic acids, ribose and deoxyribose
- ➔ DNA and RNA are polynucleotides, made up of long chains of nucleotides. In RNA, the sugar is ribose; in DNA, it is deoxyribose
- ➔ The structure of ATP has three components which are adenine, ribose and phosphate. Adenine plus ribose forms a sugar–base called adenosine.
- ➔ Two nucleotides can be joined together by a condensation reaction.
- ➔ The molecule formed by joining two nucleotides is called a dinucleotide.
- ➔ The bond formed is called a phosphodiester bond.
- ➔ The term diester is used because the phosphate group involved now has two ester bonds.
- ➔ A nucleic acid containing ribose is called a ribonucleic acid (RNA). One containing deoxyribose is called a deoxyribonucleic acid (DNA). As the name suggests, deoxyribose is almost the same as ribose except that it has one fewer oxygen atom in its molecule.

- ➔ A DNA molecule consists of two polynucleotide chains, linked by hydrogen bonds between the bases. The overall structure is a double helix. In DNA there are four bases – adenine (A) always pairs with thymine (T), and guanine (G) always pairs with cytosine (C).
- ➔ The two antiparallel DNA polynucleotide strands that make up the DNA molecule are held together by hydrogen bonds between the nitrogenous bases.
- ➔ These hydrogen bonds always occur between the same pairs of bases:
- ➔ The purine adenine (A) will always pair up with the pyrimidine thymine (T) and two hydrogen bonds are formed between these two bases.
- ➔ The purine guanine (G) always pairs with the pyrimidine cytosine (C) and three hydrogen bonds will be formed between these bases.

Properties	DNA	RNA
Bases	Adenine Thymine Cytosine Guanine	Adenine Uracil Cytosine Guanine

- ➔ **Important Note!** You need to learn the different groups that they are made up of (phosphate groups, pentose sugars and nitrogenous bases). Remember that adenine is a nitrogenous base whereas adenosine is a nucleoside (a base – adenine, attached to a pentose sugar).
- ➔ The two ends of a DNA strand are called the 5′ end and the 3′ end. At the 5′ end is phosphate and at the 3′ end is sugar.
- ➔ RNA has only one polynucleotide chain, although this may be twisted back on itself, as in tRNA.
- ➔ In RNA the base thymine is replaced by uracil.
- ➔ Adenine and guanine are purines with a double ring structure and thymine, cytosine and uracil are pyrimidines with a single ring structure.



Semi-conservative replication of DNA

- ➔ DNA molecules replicate during the S phase of interphase by semi-conservative replication. Each of the two new molecules formed contains one parent strand and one new strand.
- ➔ The sequence of nucleotide bases in a DNA molecule codes for the sequence of amino acids in a polypeptide. Each amino acid is coded for by three bases. A length of DNA coding for one polypeptide is a gene.
- ➔ DNA Replication is controlled by enzymes. It starts by the unwinding (separation) of the two strands of DNA by the breaking of the hydrogen bonds that normally hold the two strands together. This is the process of 'unzipping' which is done by the enzyme helicase.
- ➔ The enzyme DNA polymerase is then used for the copying process. A molecule of DNA polymerase attaches to each of the single strands. It adds one new nucleotide at a time, which is held by hydrogen bonding to the strand being copied. DNA polymerase can only copy in the 5′ to 3′ direction along each strand
- ➔ DNA polymerase: an enzyme that copies DNA; it runs along the separated DNA strands lining up one complementary nucleotide at a time ready for joining by DNA ligase
- ➔ The DNA genetic code has the following features.
- ➔ It is a three-letter code, otherwise known as a triplet code. This means that three bases make the code for one amino acid.
- ➔ The code is universal. This means that each triplet codes for the same amino acid in all living things.
- ➔ The code is described as redundant or degenerate. This means that some amino acids are coded for by more than one triplet.
- ➔ DNA makes RNA and RNA makes protein.' This shows that protein synthesis is a two-stage process. The process by which DNA makes mRNA is called transcription. The process by which the message carried by mRNA is decoded to make protein is called translation.
- ➔ The main enzymes involved in DNA Replication are helicase, primase, DNA polymerase, and ligase.
    - Helicase unwinds the double helix
    - Primase synthesises RNA primers
    - DNA polymerase adds nucleotides to the template strand
    - Ligase seals the gaps between the nucleotides.

6.2 Proteins

- Protein synthesis

- ➔ **Transcription** takes place in the nucleus (where the DNA is). The enzyme responsible for transcription is called RNA polymerase. RNA polymerase attaches to the beginning of the gene to be copied. It starts to unwind the DNA of the gene and another enzyme breaks the hydrogen bonds between the two strands ('unzips' the DNA).
- ➔ Only one of the exposed strands is copied. This is called the template/ transcribed strand. A complementary RNA copy of the template strand is made.
- ➔ mRNA is made from nucleotides found free in solution in the nucleus. As the RNA polymerase moves along the gene, the nucleotides approach and hydrogen bond with their complementary nucleotides in the DNA. As each nucleotide arrives RNA polymerase joins it to the growing mRNA molecule with a phosphodiester bond. Once phosphodiester bonds are formed, hydrogen bonding of that part of the mRNA to the DNA is no longer necessary and the hydrogen bonds are broken. The mRNA leaves the nucleus through a nuclear pore in the nuclear envelope.

- ➔ The process of modification is called RNA processing. One step in this processing is RNA splicing. Splicing is the removal of sections of the primary transcript. The sections removed are called introns (as are the sections of DNA that code for them). The nucleotide sequences that remain after the introns are removed are called exons. They have to be joined together after removal of the introns.
- ➔ During **Translation**, each amino acid has a different tRNA molecule to carry it. The amino acid is attached at one end of the molecule. At the other end of the molecule three projecting bases form an anticodon. This is complementary to the codon for the amino acid carried by that tRNA. Enzymes are responsible for making sure that each tRNA carries the correct amino acid.
- ➔ When an mRNA molecule arrives at a ribosome, it enters a groove between the two subunits of the ribosome where it is held ready to receive the first tRNA molecule. The ribosome moves along the mRNA molecule one codon at a time. The sequence of codons determines the sequence of amino acids joined together to form a polypeptide.
- ➔ Enzymes play a key role in protein synthesis by facilitating the processes of transcription and translation. RNA polymerase is an enzyme which is responsible for catalysing the transcription of DNA into RNA, while ribosomes and tRNA molecules are enzymes that catalyse the translation of RNA into proteins.

- Differences between Translation and Transcription

Translation	Transcription
Translation takes place in the cytoplasm of the cell	Transcription takes place in the nucleus of the cell
mRNA, tRNA, and rRNA are involved.	Only mRNA is involved
Translation is the decoding of the mRNA into proteins.	Transcription is the copying down of genes in the genome into RNA pieces.

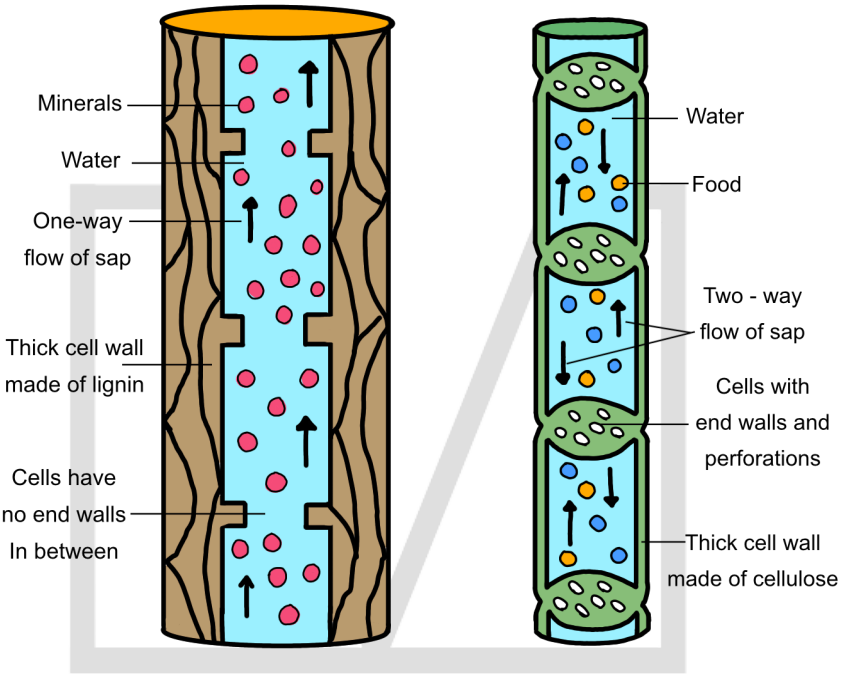
- ➔ **Codon:** sequence of three bases on an mRNA molecule that codes for a specific amino acid or for a stop signal
- ➔ **Anticodon:** sequence of three unpaired bases on a tRNA molecule that binds with a codon on Mrna
- ➔ Start codon: AUG
- ➔ Stop codon: UAA, UAG or UGA
- ➔ Gene mutation: a change in the base sequence in part of a DNA molecule
- ➔ Chromosome mutation: a random and unpredictable change in the structure or number of chromosomes in a cell
- ➔ A change in the base sequence of the DNA may cause a change in the amino acid sequence of the polypeptide coded for by the mutated DNA. Something that can cause mutations is called a mutagen. X-ray radiation is an example of a mutagen.
- ➔ Such a change may affect the way the polypeptide folds up and in turn change the tertiary structure of the protein.
- ➔ **Substitution** – a base is replaced by a different base
- ➔ **Deletion** – a base is lost and not replaced
- ➔ **Insertion** – a base is added.
- ➔ An amino acid being coded for by more than one triplet is an example of the fact that the genetic code is degenerate.

- ➔ **Frame-shift mutation:** a type of gene mutation caused by insertion or deletion of one or more nucleotides, resulting in incorrect reading of the sequence of triplets in the genetic code due to a shift in the reading frame
- ➔ Note that for both insertion and deletion the whole of the rest of the code is altered. Therefore, all the amino acids coded for will probably be incorrect, so the polypeptide or protein made as a result is likely to be non-functioning

Chapter 7: Transport In Plants

- ➔ Flowering plants do not have compact bodies like those of many animals.
- ➔ Leaves and extensive root systems spread out to obtain the light energy, carbon dioxide, mineral ions and water that plants gain from their environment to make organic molecules, such as sugars and amino acids.
- ➔ Transport systems in plants move substances from where they are absorbed or produced to where they are stored or used.

7.1 Vascular System: Xylem and Phloem

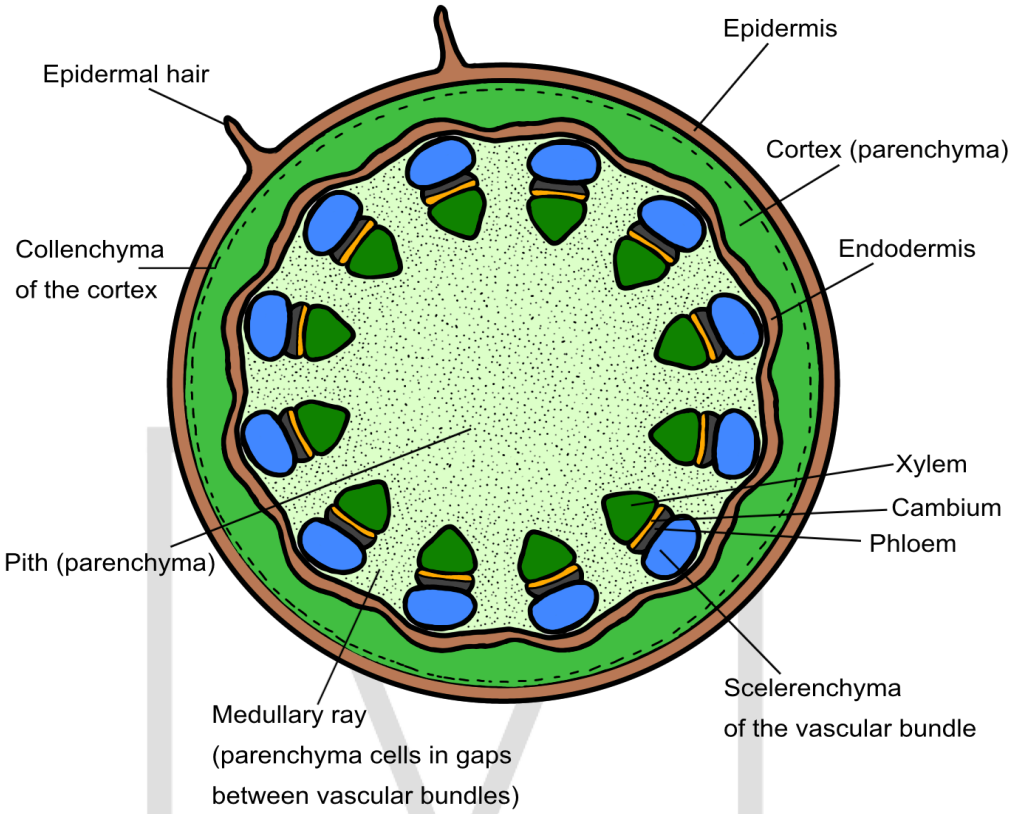


-Xylem and Phloem

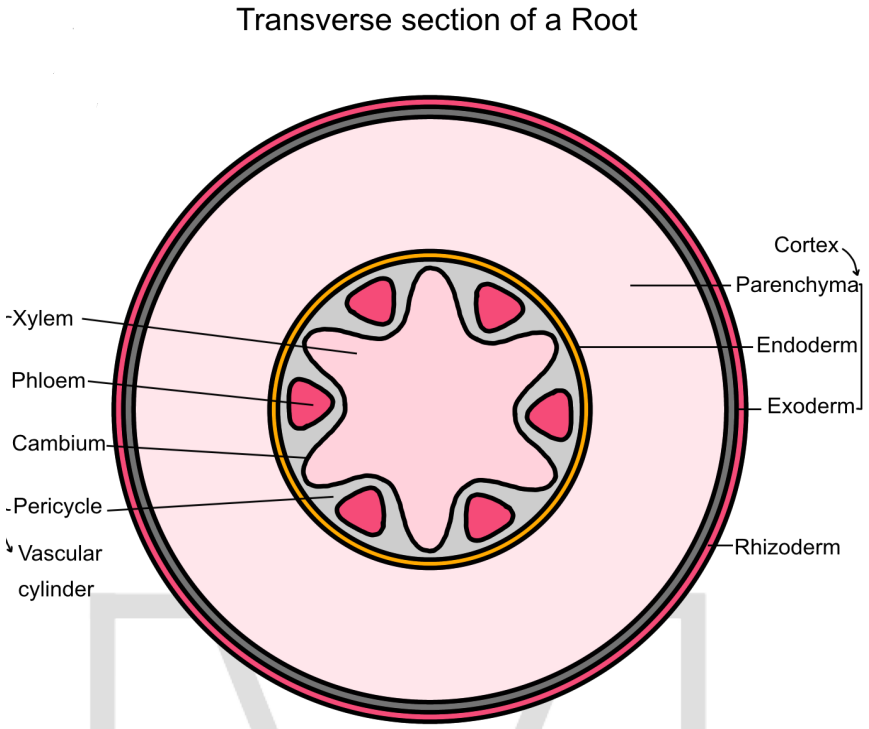
- ➔ The substances transported, such as mineral ions and organic compounds, dissolve in water to form solutions and these solutions are moved through specialised tubes.
- ➔ The tubes form a system called the vascular system.
- ➔ In plants, the vascular system contains two tissues, xylem and phloem.
- ➔ Both xylem and phloem contain specialised tubes for transporting fluid called sap.
- ➔ Xylem sap moves in tubes called xylem vessels.
- ➔ Phloem sap moves in tubes called sieve tubes.
- ➔ Xylem carries mainly water and inorganic ions(mineral salts) from roots to parts above the ground.
- ➔ Xylem sap can move in only one direction, from roots to the rest of the plant.
- ➔ Phloem sap carries organic solutes(assimilates) such as sucrose from the leaves to other areas of the plant.
- ➔ Phloem sap can move in both directions(bi-directional movement) up or down the plant.

7.2 Structure of transport tissues

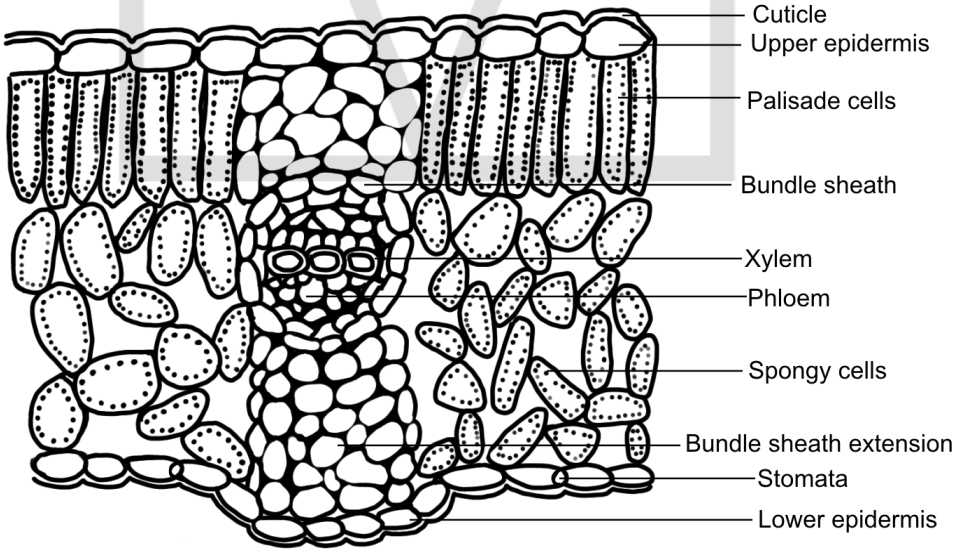
- Distribution of xylem and phloem in transverse section of dicot stem



- Distribution of xylem and phloem in transverse section of dicot root



- Distribution of xylem and phloem in transverse section of dicot leaf



- Identification of xylem, phloem and other tissues in photomicrographs or under microscope slides

- ➔ Phloem is usually stained green and has small cells.
- ➔ Xylem is usually stained red and usually contains a few large vessels.
- ➔ In stem and leaves, the xylem and phloem are found in structures called vascular bundles which also contain other types of cells.
- ➔ In roots, the xylem and phloem are found at the centre of the root.
- ➔ Many of the cells outside the vascular tissue are parenchyma cells.These have thin cell walls and vary in size.The outer region of stems and roots is known as cortex and it is mainly made of parenchyma.
- ➔ Zones of cells with thicker cell walls are called collenchyma and are found around the outside of the stem just below the epidermis and in the midrib of the leaves.
- ➔ Vascular bundles in stems have a cap of fibres called sclerenchyma for extra strength in the stem.These are usually stained red because, like xylem, their walls contain the strengthening material lignin.

7.3 The transport of water

- ➔ The movement of water through the plant is driven by evaporation from the leaves.
- ➔ The energy from the sun causes water to evaporate from the leaves, a process called transpiration.
- ➔ This reduces water potential in the leaves and sets up a water potential gradient throughout the plant.
- ➔ Water moves down this gradient from the soil into the plant.
- ➔ Water then moves across the root into the xylem tissue in the centre of the root.
- ➔ Once inside the xylem, the water moves upwards through the root to the stem and from there into the leaves.

- Transpiration (Movement of water from leaf to atmosphere)

- ➔ Loss of water vapour from aerial parts of plants is called transpiration.
- ➔ Water evaporates from cell walls of mesophyll cells into the substomatal air space.
- ➔ Sub stomatal air space becomes saturated so a diffusion gradient develops between air space and external environment.
- ➔ Water vapour diffuses from the substomatal air space into the external environment through the open stomata, down the water potential gradient.
- ➔ Stomata open during the day and close at night, so most transpiration takes place during the day.

- Structure of xylem

- ➔ Xylem contains more than one type of cell, but the ones of particular importance in transport are the xylem vessel elements.
- ➔ Lignin is deposited on the wall of xylem vessel elements for waterproofing.It provides strength to the xylem vessel and prevents inward collapse of the vessel.
- ➔ Xylem vessel elements have no cell contents (dead cell). This prevents any resistance to flow of water, ensuring a smooth flow.
- ➔ The xylem vessel elements are quite elongated and they line up end to end.
- ➔ The end walls of xylem vessel elements break down completely, to form a continuous tube.
- ➔ Xylem vessel is formed from these xylem vessel elements which are lined up end to end.

- ➔ In those parts of the original cell walls where groups of plasmodesmata are found, no lignin is laid down.These non-lignified areas appear as ‘gaps’ and are called pits.
- ➔ Pits in the walls of xylem vessel elements allow lateral movement of water (into and out of the tubes).

- Movement of water through xylem from root to leaf

- ➔ The removal of water from xylem vessels in the leaf creates a tension in the water left in the xylem vessels (the water potential at the top of the xylem vessel becomes lower than the water potential at the bottom).
- ➔ The tension causes water to move up the xylem vessels. This tension is called transpirational pull.
- ➔ The movement of water and mineral ions up through xylem vessels is by mass flow.
- ➔ Mass flow is helped by the fact that water molecules are attracted to each other by hydrogen bonding; this attraction is called cohesion.
- ➔ The water molecules are also attracted to the cellulose and lignin in the walls of the xylem vessels, which are hydrophilic.This attraction is called adhesion.
- ➔ Cohesion and adhesion help to keep the water in a xylem vessel moving as a continuous column.

- Movement of water across the root from root hairs to xylem

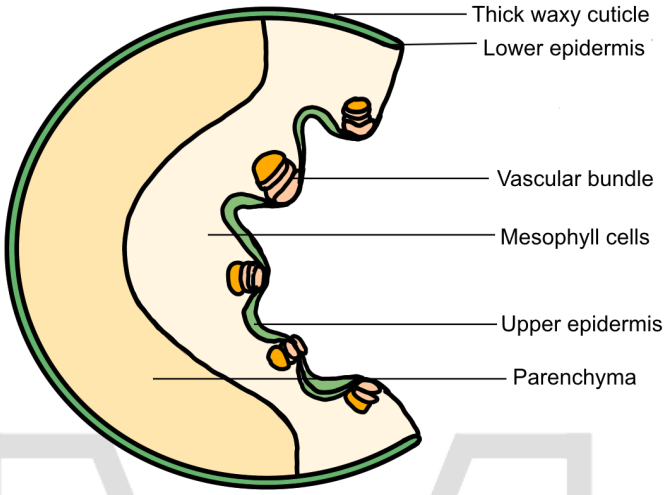
- ➔ Water is taken up by root hairs, which are on the outside of the root, growing from the epidermis.
- ➔ The root hairs increase surface area for absorption of water(and mineral ions).
- ➔ After entering the root hair, water crosses the cortex of the root and enters the xylem in the centre of the root.Water moves down a water potential gradient down the root.
- ➔ Water takes two routes through the cortex: the apoplast pathway and the symplast pathway.
- ➔ Water can soak into cell walls of cortex cells and can move across the root from cell wall to cell wall without even entering the cytoplasm of the cortex cells.This is the **apoplast pathway.**
- ➔ Water can move into the cytoplasm or vacuole of a cortex cell by osmosis, and then into neighbouring cells through interconnecting plasmodesmata.This is the **symplast pathway.**
- ➔ When the water reaches the endodermis, the apoplast pathway is blocked.
- ➔ The cells in the endodermis have a thick, waterproof, waxy band of suberin in their cell walls.
- ➔ This band is called the Casparian strip and it goes right around the cell.It stops water moving through the apoplast.
- ➔ The only way for water coming across the cortex to cross the endodermis is through the unthickened parts of the wall into the cytoplasm of the endodermis cells.
- ➔ As the endodermis cells get older, the suberin deposits become more extensive until, except in certain cells called passage cells
- ➔ Passage cells still have a Casparian strip but water can continue to pass using the symplast.
- ➔ Once across the endodermis, water continues to move down the water potential gradient towards the xylem vessels through either the symplast or apoplast pathway.
- ➔ Water moves into the xylem vessels through the pits or non-lignified regions of their walls.

- Movement of water from the soil into root hairs

- ➔ Water moves into root hairs by osmosis down a water potential gradient.

➔ The large number of very fine root hairs provides a large surface area in contact with the soil surrounding the root, thus increasing the rate at which water can be absorbed.

7.4 Xerophytes



➔ Xerophyte is a plant adapted to survive in conditions where water is in short supply.

Adaptations of xerophytes

Features	Function
Trichomes	➔ Trap water vapour, thereby maintaining humidity inside the plant. ➔ This makes the water potential gradient less steep between substomatal air space and outside environment.
Thick cuticle	➔ Greater layer of impermeable wax. ➔ Increases distance of diffusion of water vapour.
Stomata in grooves/sunken stomata	➔ Creates still/non-moving air in enclosed area hence maintaining humidity ➔ Makes water potential gradient less steep between substomatal air space and outside environment
Extensive network of roots	➔ Maximises water uptake
Curled/Rolled leaves	➔ Traps water vapour inside the enclosed area ➔ Maintains humidity and reduces steepness of water potential gradient for diffusion of water vapour

7.5 Transport of assimilates

- ➔ Assimilates are the chemical compounds made by the plant itself as a result of assimilation.Sucrose and amino acids are two of the common assimilates that are transported over long distances in the phloem.
- ➔ Assimilates are transported from sources to sinks in phloem.

- Source

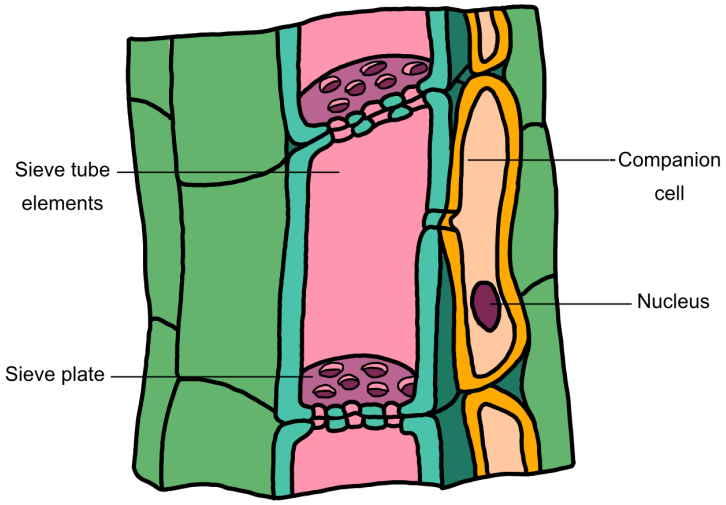
- ➔ A site in a plant which provides food to another part of the plant, the sink.Common sources are leaves and storage organs, such as tubers.

- Sink

- ➔ A site where assimilation is needed for growth and development or for storage.Common sinks are buds, flowers, fruits, roots and storage organs.

- Structure of phloem

- ➔ Two most important types of cells for transport are sieve tube elements and companion cells.
- ➔ Phoem contains tubes called sieve tubes that are made from cells called sieve tube elements.
- ➔ Sieve tube elements are elongated in shape.The cells are joined end to end vertically to form a continuous tube.
- ➔ Sieve tube element has a cell wall containing cellulose, a cell surface membrane and cytoplasm containing endoplasmic reticulum and mitochondria.
- ➔ However, very little cytoplasm(peripheral cytoplasm) is present in sieve tube elements.
- ➔ Sieve tube elements have no nucleus,tonoplast or ribosomes.
- ➔ Where the end walls of two sieve tube elements meet,a sieve plate is formed with pores.
- ➔ Each sieve tube element has at least one companion cell lying close beside it.
- ➔ Companion cells have the structure of a typical plant cell, with a cell wall containing cellulose, a surface membrane, cytoplasm, a small vacuole and a nucleus
- ➔ Number of mitochondria and ribosomes is greater than normal, and the cells are metabolically very active.
- ➔ Numerous plasmodesmata are present between sieve tube elements and companion cells.



- Adaptations of structure of phloem sieve tube elements to their function

Structure	Function
Elongated cells joined end to end	To form long tubes
Little cytoplasm(peripheral cytoplasm) / few cell organelles/no nucleus	To reduce resistance to flow
Sieve plates	Stop collapse of sieve tube elements
Sieve pores	Allow phloem sap to move easily from cell to cell
Plasmodesmata between sieve tube elements and companion cells	For ease of loading and unloading of sucrose

- Adaptations of structure of companion cells to their function

Structure	Function
Greater number of mitochondria & ribosomes	Produce large amounts of proton pumps (ribosomes) & ATP (mitochondria) for loading of sucrose. More here
Plasmodesmata between sieve tube elements and companion cells	For diffusion of sucrose from companion cells to sieve tube elements.

- Loading of sucrose into phloem

➔ Hydrogen ions (protons,H+) are pumped out of the companion cell into its cell walls (apoplast) through a proton pump which requires ATP as an energy source

- ➔ This creates an electrochemical gradient as concentration of H+ ions is higher inside the cell wall than companion cell
- ➔ Hydrogen ions therefore move back into the companion cell by facilitated diffusion, through a co-transporter protein which carries a sucrose molecule along with a hydrogen ion into the companion cell.
- ➔ The sucrose molecules are carried through this cotransporter protein into the companion cell, against the concentration gradient for sucrose, but down the concentration gradient for hydrogen ions.
- ➔ Once inside the companion cell, the sucrose molecules can move by diffusion, through the plasmodesmata, into the sieve tube.

- Transport in sieve tubes

- ➔ Loading of sucrose into sieve tube element decreases water potential of phloem sap but increases the volume of solution
- ➔ As a result water enters from the xylem vessel into a sieve tube element,moving down a water potential gradient by osmosis.
- ➔ This increases the hydrostatic pressure at the source,thereby,creating a pressure difference between the source and sink
- ➔ Phloem sap is transported down a hydrostatic pressure gradient towards the sink.
- ➔ At the sink, sucrose is removed which increases the water potential of phloem sap, as a result water moves out by osmosis.
- ➔ As a result, the volume of solution inside phloem decreases.
- ➔ The loss of water from the tube reduces pressure inside the tube, thus maintaining the hydrostatic pressure gradient.

Chapter 8: Transport in humans

8.1 The circulatory system

➔ Mammalian circulatory system is a closed double circulation consisting of a heart, blood and blood vessels including arteries, arterioles, capillaries, venules and veins.

1. Closed: blood is contained in blood vessels
2. Double circulation means blood passes the heart twice in one complete circuit

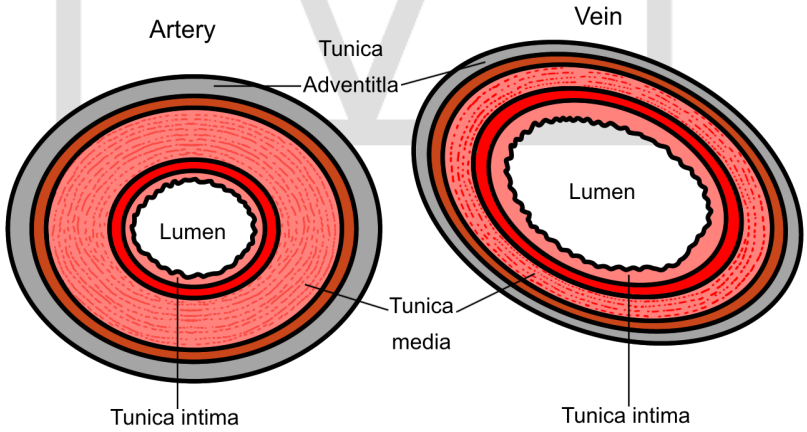
- Blood vessels

Arteries → Arterioles → Capillaries → Venules → Veins

Both arteries and veins are made up of three layers:

➔ **Tunica Intima**, made up of a layer of flat cells called squamous epithelium. It is very smooth so it minimises friction with the movement of blood.
➔ **Tunica media**, middle layer contains:
- Smooth muscles (in both arteries and veins)
- Elastic fibres (in both arteries and veins
- Collagen fibres (just in arteries)

➔ **Tunica externa**, the outer layer containing:
- Elastic fibres (just in arteries)
- Collagen fibres (in both arteries and veins)



- Arteries

➔ Narrow lumen to maintain high (blood) pressure
➔ Inner lining is wrinkled or wavy
➔ Thick middle wall (tunica media), to withstand high (blood) pressure and so prevent bursting

➔ Endothelium (tunica intima) is smooth so offering little friction to blood flow

- Role of Elastic Fibres

➔ Allow the walls to stretch as the high-pressure blood surges into them so the artery becomes wider, reducing the pressure a little.
➔ And then recoil inwards as the pressure drops giving the blood a small push and raising the pressure a little resulting in evening out the flow of blood.

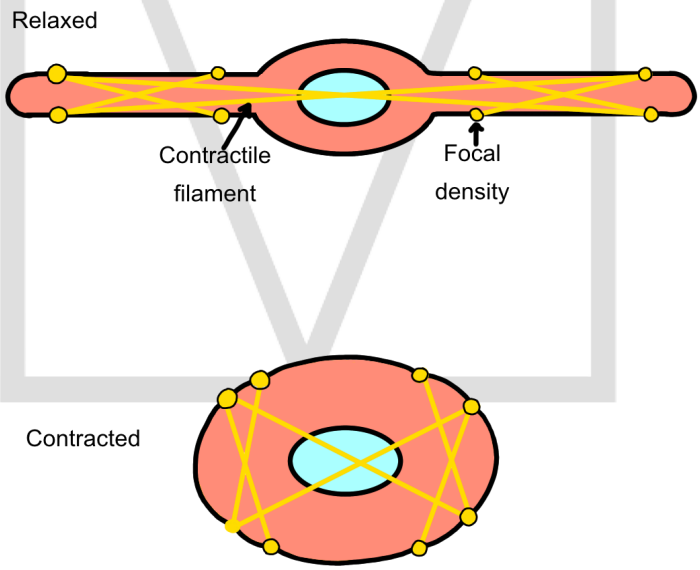
- Role of Collagen

➔ Withstand high pressure
➔ Prevents rupture of vessels

- Role of smooth muscles:

➔ Can contract slowly and steadily to alter the internal diameter of the artery and therefore control the volume of blood that can flow through it
➔ In arterioles, nerve supply receives impulses from the brain causing them to contract–vasoconstriction

- Role of smooth muscles

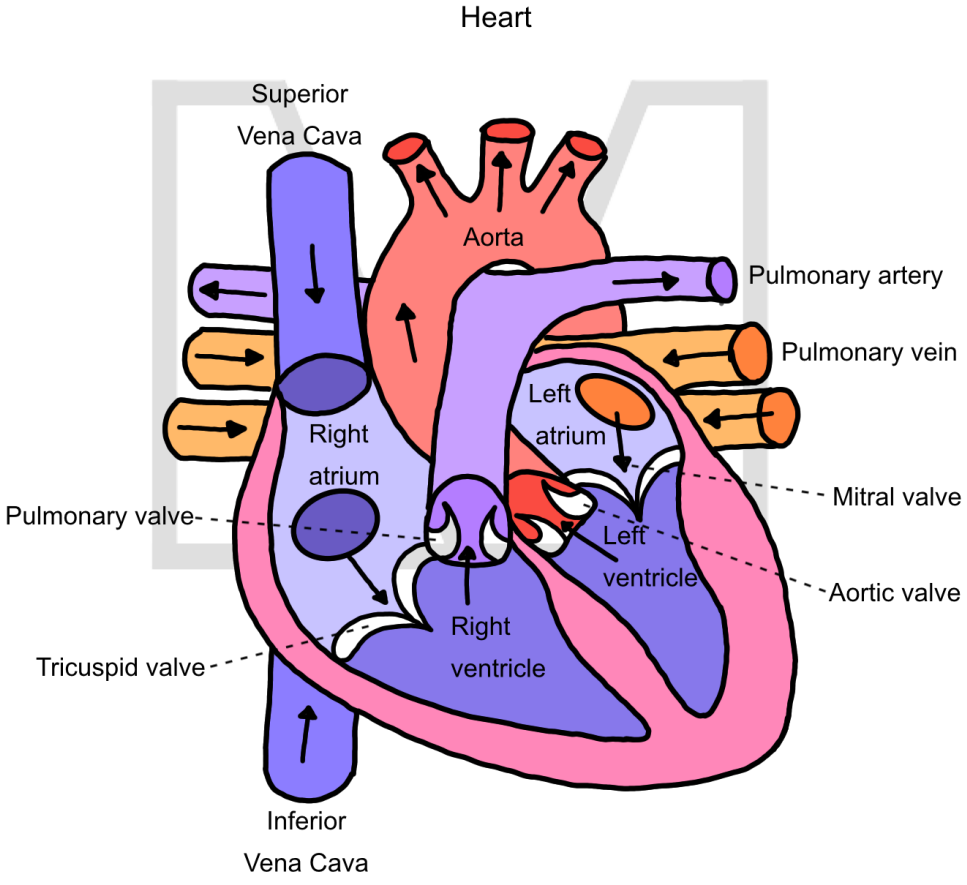


➔ Can contract slowly and steadily to alter the internal diameter of the artery and therefore control the volume of blood that can flow through it
➔ Relaxation of smooth muscles in the walls of arterioles causes widening of the muscular arteriole–vasodilation
➔ Smooth muscles also respond to hormones in the blood

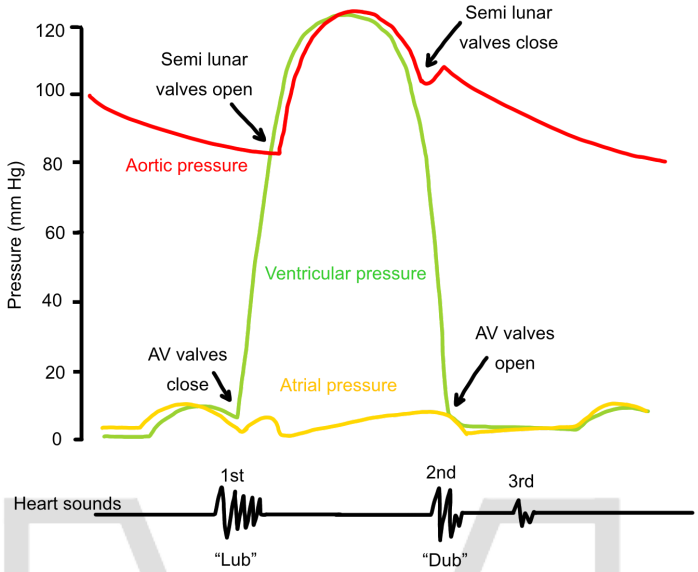
- Elastic arteries and muscle arteries

- ➔ Elastic arteries are relatively large arteries, which have a lot of elastic tissue in their middle layer and less muscle tissue. They are closer to the heart.
- ➔ Muscular arteries are further from the heart and closer to the final destination of the blood inside them than elastic arteries with more smooth muscles in their walls which allows them to constrict and dilate
- ➔ Muscular arteries become narrower so blood slows down allowing more time for exchange of gases and nutrients with tissues

8.2 The heart



Cardiac cycle



Differences in thickness of ventricles:

- ➔ To generate a higher blood pressure during systole
- ➔ To overcome higher resistance in the systemic circuit than in the pulmonary circuit
- ➔ To transport blood to a greater distance in the systemic circuit
- ➔ Right ventricle generating low pressure to avoid damaging capillaries in the lungs

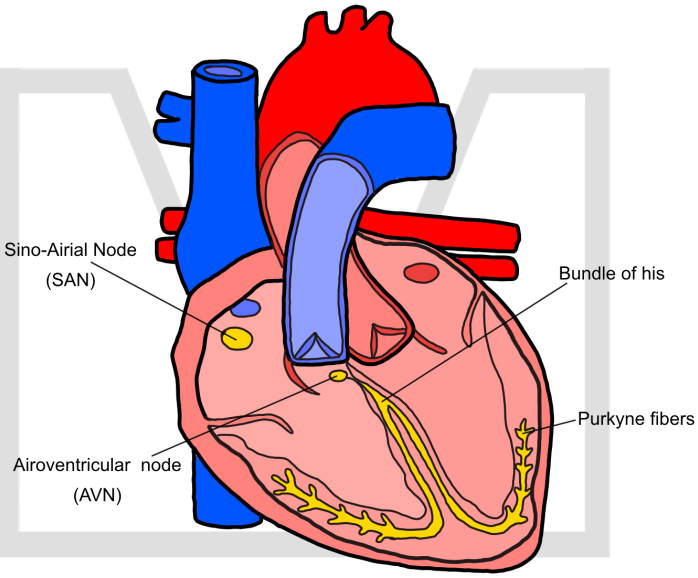
Cardiac Cycle

(SYSTOLE – CONTRACTION, DIASTOLE – RELAXATION)

- ➔ Atrial contraction begins
- ➔ Blood enters ventricles
- ➔ Ventricular systole begins; AV valves close
- ➔ Ventricles contract
- ➔ Semilunar valves open; blood flows to arteries
- ➔ Semilunar valve closes
- ➔ Ventricles empty and relax
- ➔ AV valves open; blood starts to fill the atria
- ➔ Blood trickles into the ventricle
- ➔ Pressure slightly increases when a valve closes

Heart action

- ➔ Cardiac muscles are myogenic which means contraction is initiated by the muscle itself and not the nerve impulses from the outside
- ➔ Wave of excitation passes through
  - SAN
  - AVN
  - Purkyne tissue
- ➔ SAN situated in the wall of right atrium, sends out waves of excitation or impulses
- ➔ Spread across both atria causing them to contract
- ➔ Some non-conducting tissues in the heart muscles prevent the impulses from going into the ventricle
- ➔ There is a time delay of about 0.1-0.2 seconds
- ➔ AVN sends out waves of excitation which pass through purkyne fibres reaching the apex of the ventricles and then spread upwards



Capillaries

- ➔ Made up of squamous epithelial cells and vessel diameter is almost 7um
- ➔ Wall thickness is one-celled so offering a short diffusion distance
- ➔ Has pores between some endothelial cells which allows the exchange of nutrients etc. also allows the formation of tissue fluid
- ➔ Have a small lumen diameter which slows down blood flow bringing RBCs close to the body tissues
- ➔ The network of capillaries offers a high surface area which allows more exchange

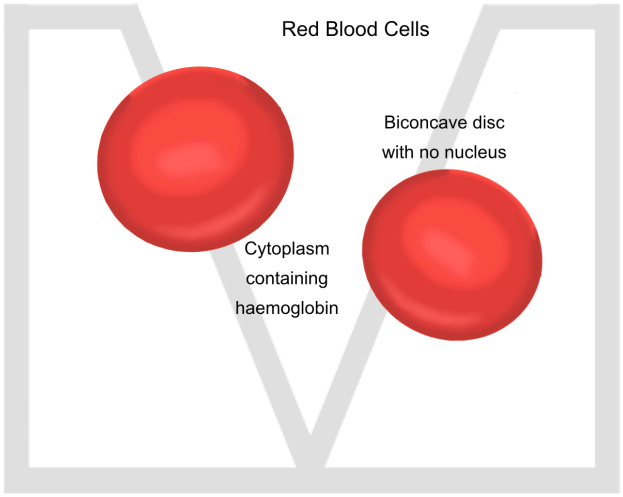
Veins

- ➔ Return blood to the heart

- ➔ Low blood pressure with lower blood flow than in the artery
- ➔ Also has 3 layers (outer, middle, and inner)
- ➔ Irregular and flattened oval shape with a wide lumen in relation to the thickness of the wall
- ➔ Thin tunica media with less elastic tissue and less smooth muscle and endothelium not wavy
- ➔ Presence of valves to prevent backflow of blood
- ➔ Ensure blood flows toward the heart
- ➔ Valves close the pathway when blood travels the opposite direction
- ➔ Surrounded by skeletal muscles which when contracted, push blood towards the heart

Components of blood

- ➔ 55% plasma
- ➔ 1% platelets and white blood cells
- ➔ 44% red blood cells



Different types of WBCs

Two main groups of white blood cells:

- ➔ Phagocytes (Neutrophil, Monocyte & Macrophage)
- ➔ Lymphocytes

- Neutrophil

- ➔ A type of phagocytic cell
- ➔ Lobed nucleus
- ➔ Granular cytoplasm

- Monocyte

- ➔ Largest type of WBC
- ➔ Bean-shaped nucleus
- ➔ Leave the blood (entering cells and tissues) and develop into macrophage

Tissue fluid

- ➔ Tissue fluid is almost a colourless fluid that fills the spaces between body cells. It forms from the fluid that leaks from blood capillaries
- ➔ There are gaps in the walls of capillaries called fenestrations
- ➔ There is higher hydrostatic pressure of blood at the start of the capillary (arteriole end) resulting in pressure filtration of blood.
- ➔ The plasma leaks (not diffuses) out of these fenestrations and flows into spaces between the cells of the tissues
- ➔ RBCs and some large plasma proteins are too large to pass out and stay in the blood; some WBCs can squeeze through and move around in tissue fluid.

Formation of tissue fluid

- ➔ There are two forces to be considered at the arteriole end:
  - High hydrostatic pressure of blood pushing the plasma out into the tissue
  - Water potential gradient from tissue fluid into the blood plasma (due to greater concentration of dissolved proteins in blood plasma than in tissue fluid)
- ➔ Overall water moves from the capillaries into the tissue fluid
- ➔ At the venule end the blood pressure inside the capillaries is lower and the water potential gradient is still similar to that of the arteriole end so water moves back into the capillary and down its water potential gradient
- ➔ If the blood pressure is too high, too much fluid is forced out and may accumulate in the tissues – edema
- ➔ One of the roles of arterioles is to reduce the pressure of the blood that enters the capillaries in order to avoid edema

Functions of tissue fluid

- ➔ Tissue fluid forms the environment of individual body cells
- ➔ Exchange of materials between cells and blood occurs through the tissue fluid
- ➔ Homeostatic process maintain the composition of the tissue fluid at a constant level

Haemoglobin

- ➔ RBCs do the loading of oxygen in the lungs and unloading of oxygen at respiring tissues
- ➔ Concentration of oxygen is also known as the partial pressure of oxygen

- Haemoglobin dissociation curve

- ➔ When haemoglobin combines with the first oxygen molecule, the entire haemoglobin molecule is slightly distorted.
- ➔ This in turn makes it easier for the second molecule to combine and so and so forth.
- ➔ This is known as the cooperative effect.

Bohr's shift

- ➔ It is the decrease in the affinity of haemoglobin for oxygen that occurs when carbon dioxide is present.
- ➔ The graph is 's-shaped due to the cooperative nature of oxygen binding
- ➔ **At the lungs:** haemoglobin is saturated with oxygen hence high affinity and thus O2 loads
- ➔ **At the tissues**: haemoglobin is less saturated so oxygen has a low affinity and unloads higher levels of CO2 such as during exercise lower blood pH and hence change the shape of haemoglobin.
    - This reduces its affinity for oxygen and thus oxygen unloads at respiring tissues.
    - This causes the graph to shift right. This shift is known as Bohr's shift.

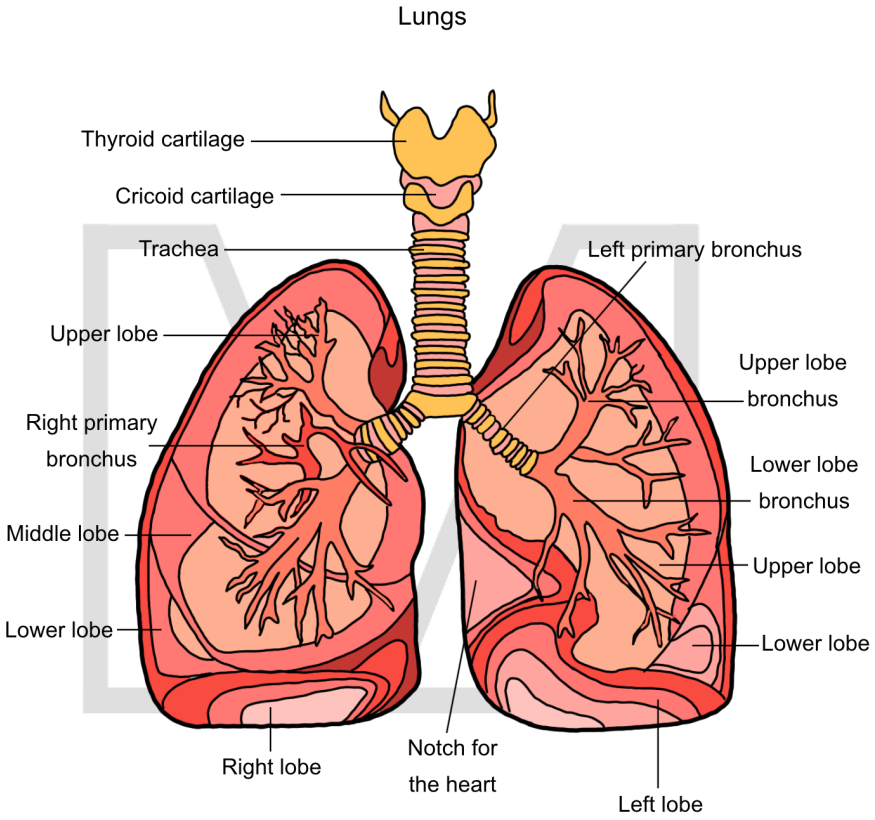
Carbon dioxide:

- ➔ Carbon dioxide exists in three forms:
    - In simple solution form dissolved in plasma (5%)
    - As carbaminohemoglobin CO2 + Haemoglobin (10%)
    - As hydrogen carbonate ions HCO3 (85%)

Chapter 9: Gas Exchange

9.1 The Human Gas Exchange System

- ➔ Most organisms require oxygen to carry out respiration.
- ➔ In single-celled organisms, oxygen simply diffuses into the cell.
- ➔ However, multicellular organisms, such as humans, require a specialised gas exchange system as most of the cells are a considerable distance away from the external environment from which oxygen is obtained.



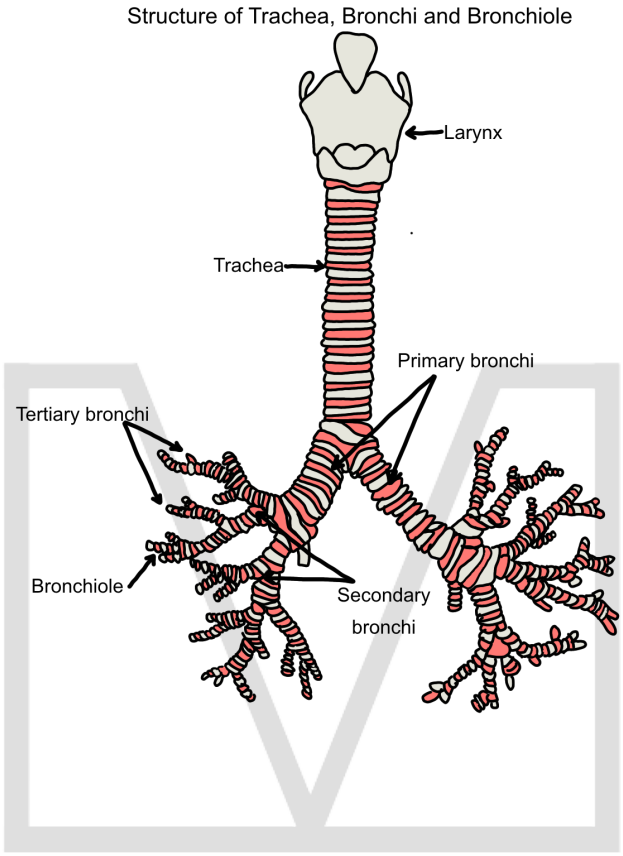
The human gas exchange system:

- ➔ Cleans and warms the air that enters during breathing
- ➔ Maximises the surface area for diffusion of oxygen and carbon dioxide between the blood and atmosphere
- ➔ Minimises the distance for diffusion
- ➔ Maintains adequate gradients for this diffusion

- Lungs

- ➔ The lungs are in the thoracic cavity surrounded by membranes, which enclose an airtight space.
- ➔ The space contains a small quantity of fluid to allow friction-free movement as the lungs are ventilated by the movement of the diaphragm and ribs.

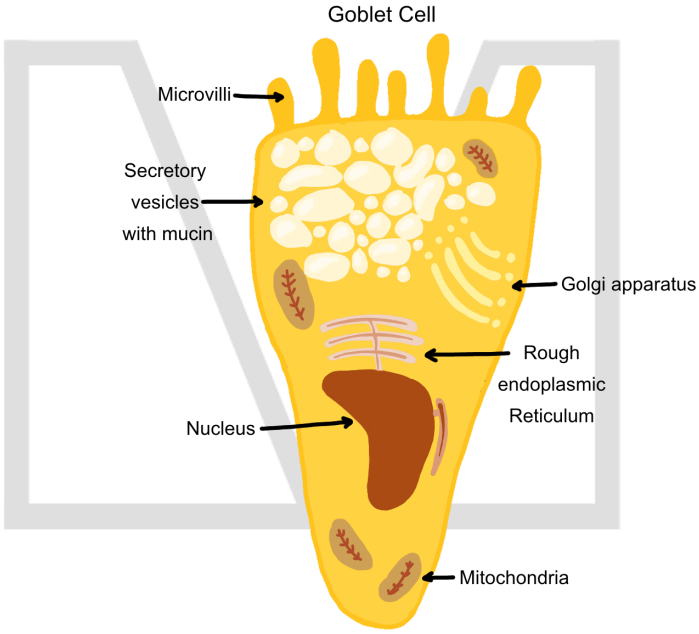
- Trachea, bronchi and bronchioles



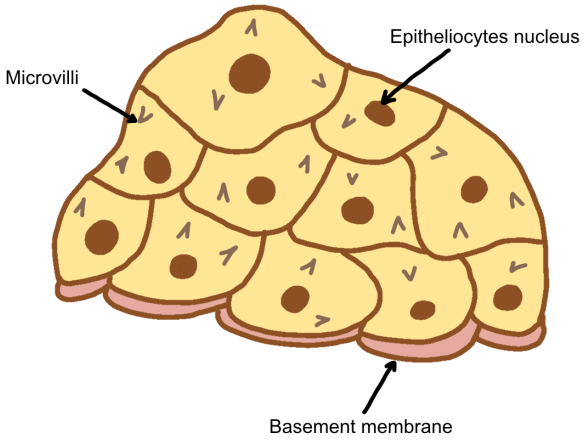
- ➔ The lungs are ventilated with air that passes through a branching system of airways.
- ➔ The trachea leads from the throat to the lungs.
- ➔ The trachea branches into two bronchi, which then subdivide and branch extensively to form bronchiole 'trees' in each lung.
- ➔ Terminal bronchioles divide to form even narrower respiratory bronchioles that supply alveoli with air.
- ➔ Trachea and bronchus both have cartilage, goblet cells, smooth muscle and cilia. Cartilage in the trachea and bronchi keeps the airways open and air resistance low, and prevents them from collapsing or bursting as the air pressure changes during breathing.
- ➔ There is a regular arrangement of C-shaped rings of cartilage.
- ➔ There are irregular blocks of cartilage in the bronchi.
- ➔ Bronchioles are surrounded by smooth muscle, which can contract or relax to adjust the diameter of these tiny airways.
- ➔ During exercise, these muscles relax to allow a greater flow of air into the alveoli.
- ➔ The absence of cartilage makes these adjustments possible.

- Warming and cleaning the air

- ➔ As air flows through the nose and trachea, it is warmed to body temperature and moistened by evaporation from the lining.
- ➔ Hence preventing the delicate surfaces inside the lungs from drying out.
- ➔ Small particles are caught on the hairs inside the nose and mucus lining the nasal passages and other airways.
- ➔ In the trachea and bronchi, mucus is produced by goblet cells of the ciliated epithelium.
- ➔ Mucus is a slimy solution of mucin, which is composed of glycoproteins.
- ➔ This enables mucus to trap inhaled particles.
- ➔ Some chemical pollutants can dissolve in the mucus to form an acidic solution that irritates the airways.
- ➔ Between the goblet cells are ciliated cells. The continual beating of the cilia carries the carpet of mucus upwards towards the larynx.
- ➔ When mucus reaches the top of the trachea, it is swallowed so that the pathogens are destroyed by the acid in the stomach.
- ➔ Phagocytic white blood cells, known as macrophages, patrol the surfaces of the airways scavenging small particles such as bacteria.

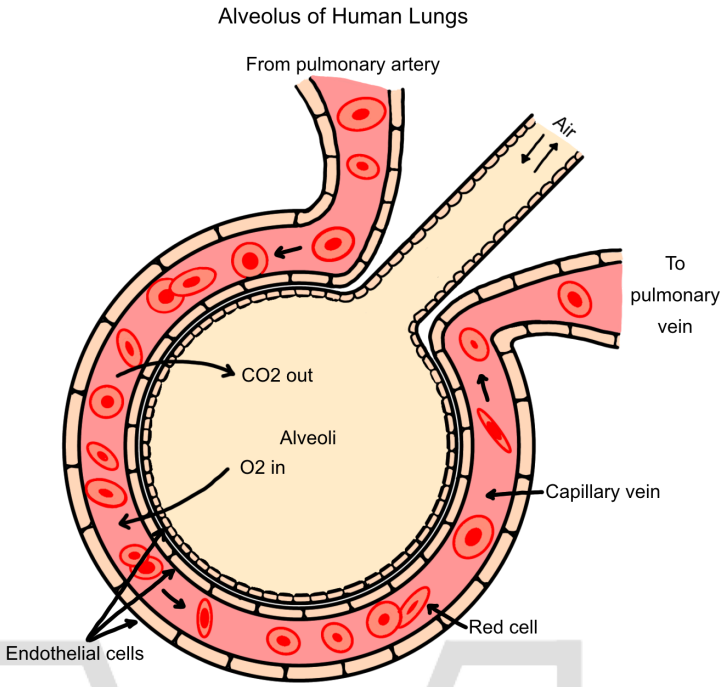


Squamous Epithelium



- Alveoli

- ➔ In humans, the gas exchange surface is the alveoli in the lungs.
- ➔ Alveoli have a huge surface area, which allows a large number of oxygen and carbon dioxide molecules to diffuse through the surface at any one moment to give a high rate of gas exchange.
- ➔ Alveolar walls contain elastic fibres, which stretch during inspiration and recoil during expiration to help force out air. This elasticity allows the alveoli to expand according to the volume of air breathed in.
- ➔ Alveoli have extremely thin walls, each consisting of a single layer of squamous epithelial cells.
- ➔ Blood capillaries, with single-celled walls, are pressed closely against the alveoli walls.
- ➔ This means that the distance between the air and blood is very small, so oxygen and carbon dioxide molecules diffuse quickly.
- ➔ For gas exchange to take place rapidly, a steep concentration must be maintained.
- ➔ This is done by breathing and by the movement of blood.
- ➔ Breathing brings supplies of fresh air into the lungs, with a relatively high oxygen concentration and a relatively low carbon dioxide concentration.
- ➔ The blood brought to the lungs has a relatively low oxygen concentration and a relatively high carbon dioxide concentration.
- ➔ Oxygen diffuses down its concentration gradient, and moves from the air in the alveoli to the blood.
- ➔ Carbon dioxide also diffuses down its concentration gradient, and moves from the blood to the air in the alveoli.



Summary of structures in the gas exchange system

	Cartlidge	Goblet Cells	Smooth Muscle	Cilia
Trachea	✔	✔	✔	✔
Bronchus	✔	✔	✔	✔
Terminal Bronchiole	✘	✘	✔	✔
Respiratory Bronchiole	✘	✘	✘	✔
Alveoli	✘	✘	✘	✘

Chapter 10: Infectious Diseases

10.1 Infectious Diseases

- ➔ **Disease:** Abnormal condition affecting an organism that reduces the effectiveness of the function of the organism
- ➔ **Infectious disease:** A disease caused by a pathogen, is transmissible and reduces the effectiveness of functions of the organism e.g., tuberculosis, cholera, etc
- ➔ **Non-infectious disease**: Long-term, degenerative diseases not caused by pathogens and not transmissible e.g., lung cancer, sickle cell anaemia, etc
- ➔ **Disease transmission**: The transfer of a pathogen from a person infected with that pathogen to an uninfected person; transmission may occur by direct contact, through the air or water or by animal vectors, such as insects.

10.2 Diseases

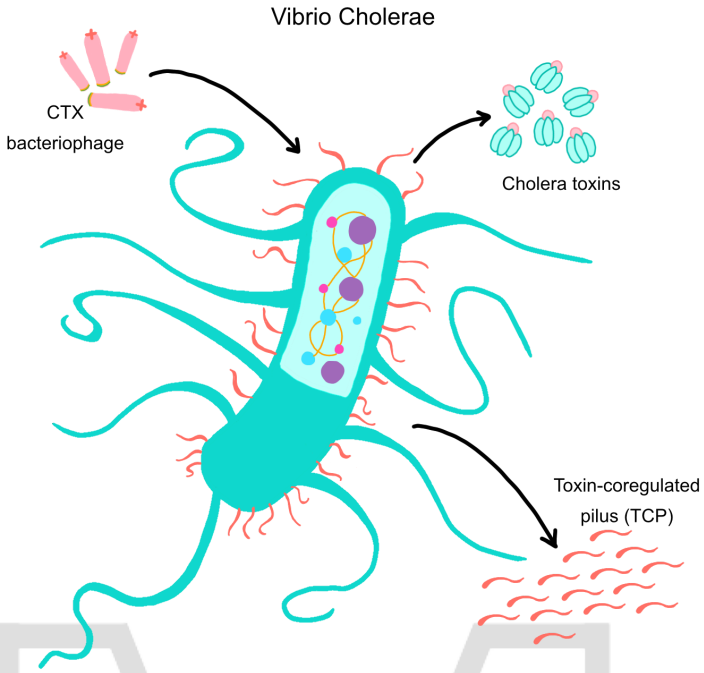
Cholera

- Transmission

- ➔ To reach their site of action in the small intestine, the bacteria have to pass through the stomach.
- ➔ If the contents are sufficiently acidic (pH less than 4.5), the bacteria are unlikely to survive.
- ➔ However, if the bacteria do reach the small intestine, they multiply and secrete the toxin choleragen.
- ➔ This toxin disrupts the functions of the epithelium lining the intestine, so that salts and water leave the blood. The loss of salts and water causes severe diarrhoea.

- Prevention and control:

- ➔ Treatment is via oral rehydration therapy (a mixture of glucose and salts)
- ➔ Drink bottled water or chlorinated water
- ➔ Wash utensils and vegetables properly
- ➔ Raise awareness
- ➔ Improve sanitation services and sewage treatment plants
- ➔ Global distribution – Asia, Africa, Latin America



Malaria

➔ Disease vector: an organism which carries a pathogen from one person to another or from an animal to a human

- Transmission

➔ The female Anopheles mosquito is the disease vector of malaria and she transmits the disease when she passes the infective stages into an uninfected person.
➔ Malaria may also be transmitted during blood transfusion and when unsterile needles are re-used.
➔ Plasmodium can also pass across the placenta from mother to foetus.
➔ Female Anopheles mosquitoes feed on human blood to obtain the protein they need to develop their eggs.
➔ If the person they bite is infected with Plasmodium, they will take up some of the pathogen's gametes with the blood meal.
➔ Male and female gametes fuse in the mosquito's gut and develop to form infective stages, which move to the mosquito's salivary glands.
➔ When the mosquito feeds again, she injects an anticoagulant from her salivary glands that prevents the blood meal from clotting, so that it flows out of the host into her body.
➔ The infective stages pass from the mosquito's salivary glands into the human's blood together with the anticoagulant in the saliva. The parasites enter the red blood cells, where they multiply

- Prevention and control

➔ Control of breeding of mosquitoes (e.g., drainage of stagnant water, aerial spraying of insecticide, oil on water, stocking ponds)

- ➔ Reduction of contact between vector and humans (e.g., bed nets impregnated with insecticide / insect repellents)
- ➔ Earlier identification of cases (introduction of dipstick tests ensuring diagnosis can be done quickly)
- ➔ Use of new drugs to prevent transmission or using drugs in combination to reduce chances of drug resistance arising
- ➔ Better awareness
- ➔ Better screening of blood before transfusion

Tuberculosis

- Transmission

- ➔ When infected people with the active form of the disease cough or sneeze
- ➔ The Mycobacterium Tuberculosis bacteria enter the air in tiny droplets of liquid.
- ➔ TB is transmitted when uninfected people then inhale these droplets.
- ➔ TB therefore spreads more quickly among people living in overcrowded conditions.
- ➔ The form of TB caused by Mycobacterium bovis occurs in cattle but is spread to humans through contaminated meat and unpasteurised milk.
- ➔ Very few people in developed countries now acquire TB in this way, although meat and milk can still be a source of infection in some developing countries

- Prevention and control

- ➔ The process of contact tracing (and the subsequent testing of those contacts for the bacterium) is an important method of controlling the spread of TB
- ➔ Contacts are screened for symptoms of TB infection, although the diagnosis can take up to two weeks
- ➔ Prevention for TB occurs through the use of the BCG vaccine (the only vaccine for TB)
- ➔ The vaccine protects up to 70-80% of those who receive it, although its effectiveness decreases with age unless the person is exposed to TB
- ➔ The form of TB that can be transmitted between cattle and humans (caused by Mycobacterium bovis) can be prevented by:
- ➔ Routinely testing cattle for TB and destroying those that test positivePasteurising milk (kills any TB-causing bacteria present in the milk)
- ➔ Ensuring meat is cooked properly

HIV/AIDS

- Transmission

- ➔ HIV is a retrovirus, which means that its genetic material is RNA, not DNA. Once inside a host cell, the viral RNA is converted ‘back’ to DNA (hence ‘retro’) to be incorporated into human chromosomes.
- ➔ The virus infects and destroys cells of the body’s immune system so that their numbers gradually decrease. These cells, known as T-helper lymphocytes, control the immune system’s response to infection
- ➔ When the numbers of these cells are low, the body is unable to defend itself against infection, allowing a range of pathogens to cause a variety of opportunistic infections.
- ➔ AIDS isn’t a disease, it’s a collection of opportunistic diseases associated with the immunodeficiency caused by HIV infection

- Prevention and control

- ➔ Spread awareness
- ➔ Use condoms, femidoms and dental dams ‘
- ➔ Don’t have many sexual partners
- ➔ Don’t share needles
- ➔ Contact tracing
- ➔ Blood collected by donors screened and heat treated
- ➔ Reduce mother to child transmission by using formula milk
- ➔ Drug therapy (e.g., zidovudine)
- ➔ It binds to viral enzyme reverse transcriptase and blocks its action
- ➔ This stops the replication of viral genetic material and blocks its action and leads to an increase in the body’s lymphocytes

10.2 Antibiotics

Antibiotics

- ➔ Antibiotics are drugs that kill or stop the growth of bacteria (prokaryotes) but do not harm the cells of the infected organism
- ➔ Some antibiotics are derived from living organisms (eg. penicillin is produced by certain fungi in the genus Penicillium), whilst other are made synthetically (in a laboratory)
- ➔ Antibiotics work by interfering with the growth or metabolism of the target bacterium.
- ➔ Antibiotics target a variety of processes including:
- ➔ Synthesis of bacterial cell walls
- ➔ Activity of proteins in bacterial cell
- ➔ Surface membrane
- ➔ Bacterial enzyme action
- ➔ Bacterial DNA synthesis
- ➔ Bacterial protein synthesis
- ➔ Antibiotics target areas of the bacterium such as its cell wall or other organelles. Viruses do not possess such organelles and therefore are immune to the effects of antibiotics. This is why antibiotics do not affect viruses.

- How penicillin acts on bacteria

- ➔ Penicillin prevents the synthesis of cross links which hold together a bacterium's peptidoglycan walls (so penicillin is only effective when bacteria are growing)
- ➔ Enzymes autolysins secreted create small holes that allow the wall to stretch so new peptidoglycan chains can link
- ➔ Penicillin prevents linking but holes continue to appear making the cell wall weaker
- ➔ When bacteria take up water via osmosis, it cannot withstand the pressure potential exerted due to the weakened cell wall and bursts

- Reasons for Bacterial resistant to antibiotics

- ➔ People not completing course of antibiotics causing a reservoir of bacteria to remain
- ➔ Remaining bacteria mutate to become resistant which survives.
- ➔ When they reproduce they pass on the allele for resistance to their offspring

- Consequences of antibiotic resistance

- ➔ Decreased ability to treat infections
- ➔ Increased human illness and mortality
- ➔ Increased cost and length of treatments
- ➔ Adverse effects from alternate treatments
- ➔ Lack of availability of clinically effective antibiotics

- Steps that can be taken to reduce the impact of antibiotic resistance

- ➔ Don't use antibiotics for trivial reasons or to treat viral infections
- ➔ Complete the course
- ➔ Use a combination of antibiotics
- ➔ Don't use as preventative medicine
- ➔ Only use wide-spectrum antibiotics when the pathogen is not known
- ➔ Rotate antibiotics so the same ones aren't used all the time
- ➔ Don't use the same antibiotics for animals and humans
- ➔ Don't use cell antibiotics without a doctor's prescription

Chapter 11 : Immunity

11.1 The Immune System

Phagocytes: Origin & Mode of Action

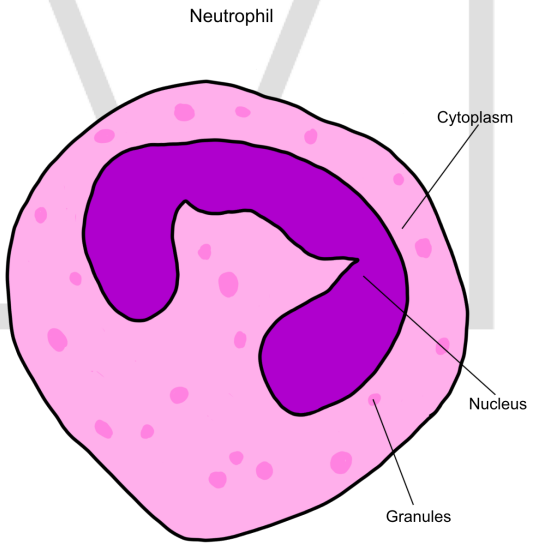
- ➔ White blood cells that are produced continuously in the bone marrow
- ➔ Stored in the bone marrow before being distributed around the body in the blood
- ➔ Responsible for removing dead cells and invasive microorganisms
- ➔ Carry out what is known as a non-specific immune response
- ➔ There are two types of phagocytes.

- The two types are

- ➔ Neutrophils
- ➔ Macrophages

As both are phagocytes, both carry out phagocytosis (the process by which a pathogen is engulfed)

Neutrophils

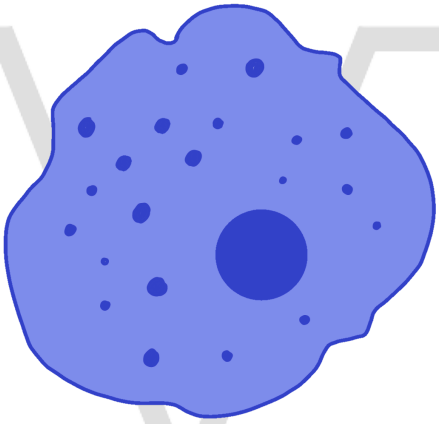


- ➔ Travel throughout the body and often leave the blood by squeezing through capillary walls to monitoring' the body tissues
- ➔ When an infection occurs, they are released in large number
- ➔ Are short-lived cells

- Mode of action

- ➔ When a pathogen attacks the body cells, they secrete chemicals, these chemicals attract the neutrophils towards the site where the pathogen is located (the response to the chemical stimuli is called chemotaxis)
- ➔ The neutrophils go to the pathogen and are covered by antibodies
- ➔ Antibodies act as a trigger to help stimulate the neutrophil to attack the pathogens (the neutrophils often have receptor proteins on their surfaces which recognise the antibody molecules and attach to them)
- ➔ They are attached to a pathogen, the cell surface membrane of a neutrophil extends around the pathogen, and engulfs it, which traps the pathogen within a phagocytic vacuole.
- ➔ It is also known as endocytosis
- ➔ Neutrophil contains enzymes, which are secreted and these enzymes basically digest the pathogen inside the vacuole
- ➔ The neutrophils then die, after killing the pathogen

Macrophages



- ➔ Larger than neutrophils and are long-lived cells
- ➔ They move into organs including the lungs, liver, spleen, kidney and lymph nodes
- ➔ After being produced in the bone marrow, macrophages travel in the blood as monocytes, and then later on develop into macrophages once they leave the blood to settle in the various organs

- Mode of action

- ➔ Play a very important role in initiating an immune response
- ➔ They do not destroy pathogens completely
- ➔ They cut up the pathogens up the display the antigens of the pathogens on their surface
- ➔ These displayed antigens are recognised by lymphocytes.

- Antigens, Self & Non-Self

- ➔ Every cell in the human body has markers that identify it, just like how every country has its own flag.
- ➔ Both pathogenic and non-pathogenic, micro organisms such as bacteria and viruses also have their own markers.

- ➔ These markers are called antigens and they (which are macromolecules)
- ➔ Allow cell-to-cell recognition
- ➔ Are found on cell surface membranes, bacterial cell walls, or the surfaces of viruses
- ➔ Sometimes, glycolipids and glycoproteins on the outer surface of cell surface membranes can also act as antigens

- Antigens can be either self antigens or non-self antigens

- ➔ Antigens produced by the organism's own body cells are known as self antigens
- ➔ Self antigens can not stimulate an immune response, as the body's immune system does not regard them as non self antigen
- ➔ Antigens that are not produced by the organism's own body cells, are known as non-self antigens
- ➔ These antigens can stimulate an immune response

Primary Immune Response

- ➔ Another type of white blood cells are lymphocytes
- ➔ Play an important part in the specific immune response
- ➔ Are smaller than phagocytes
- ➔ Have a large nucleus that fills most of the cell
- ➔ Are produced in the bone marrow before birth
- ➔ Two types of lymphocytes (with different modes of action).
- ➔ The two types of lymphocytes are:
- ➔ B-lymphocytes (B cells)
- ➔ T-lymphocytes (T cells)

- B-lymphocytes

- ➔ Remain in the bone marrow until they are mature and then spread through the body,
- ➔ As they mature the genes coding for antibodies are changed to code for different antibodies
- ➔ Each type of mature B-lymphocyte cell can make one type of antibody molecule
- ➔ The antibody molecules do not leave the B-lymphocyte cell but remain in the cell surface membrane in this stage
- ➔ Part of each antibody molecule forms a glycoprotein receptor that can combine specifically with one type of antigen
- ➔ During an immune response, these B-lymphocytes then form two types of cell:
- ➔ Some B-lymphocytes become plasma cells which secrete a lot of antibody molecules (which specific to the antigen) into the blood.
- ➔ Plasma cells are short-lived (their numbers drop off after several weeks) but the antibodies they have secreted stay in the blood for a longer time
- ➔ The other B-lymphocytes become memory cells that remain circulating in the blood for a long this response is relatively slow and is known as the primary immune response

- T-lymphocytes

- ➔ T-lymphocytes leave the bone marrow to mature in the thymus
- ➔ Mature T-lymphocytes have specific cell surface receptors called T cell receptors
- ➔ The receptors have a similar structure to antibodies and are each specific to one antigen
- ➔ The maturation of T-lymphocytes, some of them become helper T cells and others become killer T cells

- ➔ T-lymphocytes become activated when they come into contact with (and bind to) their specific antigen, which is presented by one of the host's cells (host cells are the human's own cells).
- ➔ This antigen-presenting host cell could be a macrophage or a body cell infected by a pathogen and displaying the antigen on its cell surface membrane.
- ➔ These activated T-lymphocytes (those with antigen-specific receptors) divide through mitosis to increase in number (which is similar to clonal selection and clonal expansion of B-lymphocytes).
- ➔ These T-lymphocytes develop into two types of T cells:
    - T cells that provide assistance
    - T cells that kill
- ➔ Helper T cells secrete cytokines, which stimulate B-lymphocytes to divide and develop into antibody-secreting plasma cells. Some helper T cells secrete substances.

Memory Cells & Long-Term Immunity

- ➔ B-lymphocytes divide into two types of cells during an immune response: plasma cells and memory cells.
- ➔ Memory cells are the foundation of immunological memory; they can live for many years, if not a lifetime.

- Immune responses are classified into two types

- ➔ Primary immune response (responding to a new antigen)
- ➔ Secondary immune response (response to an antigen previously encountered)

Primary immune response

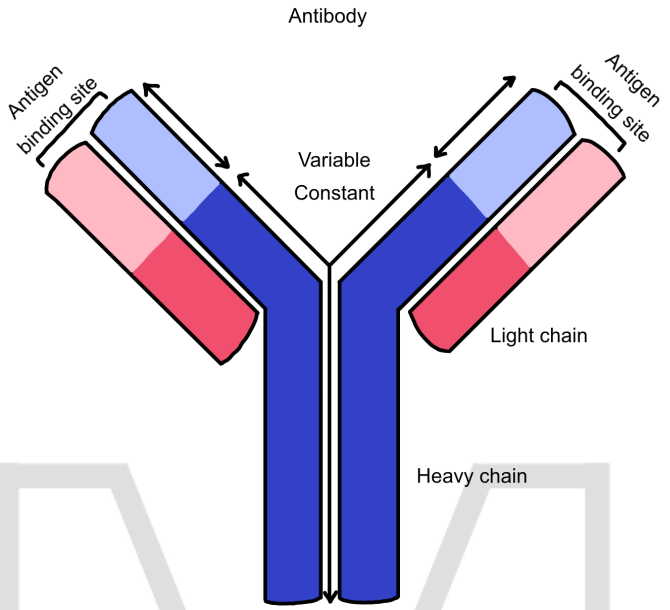
- ➔ When an antigen enters the body for the first time, a small number of B-lymphocytes with antigen-specific receptors are stimulated to divide through mitosis.
- ➔ This is referred to as clonal selection.
- ➔ As these clones divide repeatedly through mitosis (the clonal expansion stage), a large number of identical B-lymphocytes are produced over the course of a few weeks.
- ➔ Some of these B-lymphocytes develop into plasma cells, which secrete large amounts of antibody molecules (specific to the antigen) into the blood, lymph, or lungs and gut linings.
- ➔ These plasma cells have a short lifespan (they die after a few weeks), but the antibodies they secrete last longer in the blood.
- ➔ The other B-lymphocytes become memory cells that remain circulating in the blood for a long time
- ➔ This response to a newly encountered pathogen is relatively slow

Secondary Response

- ➔ T-lymphocytes also play a part in the secondary immune response
- ➔ Differentiate into memory cells, producing two main types:
    - Memory helper T cells
    - Memory killer T cells
- ➔ These memory T cells remain in the body for a long time
- ➔ If the same antigen is found in the body a second time, these memory T cells become active very quickly

11.2 Antibodies: Structure & Functions

- Structure



- ➔ Antibodies are immunoglobulins, which are globular glycoproteins.
- ➔ Antibodies have a quaternary structure (shown as a Y) with two 'heavy' (long) polypeptide chains bonded by disulfide bonds to two 'light' (short) polypeptide chains.
- ➔ Each polypeptide chain contains a constant and variable region.
- ➔ The constant regions of antibodies do not differ within a class (isotype), but they do differ between classes.
- ➔ The mechanism used to destroy the antigens is determined by the constant region.

- Function

- ➔ Each antibody has a unique amino acid sequence in the variable regions of the antibodies (the tips of the **Y**). In the variable region, the antibody binds to the antigen to form an antigen-antibody complex.
- ➔ The antigen-binding site is located at the end of the variable region. Each antigen-binding site is typically made up of 110 to 130 amino acids and includes both the light and heavy chain ends.
- ➔ The antigen-binding sites vary greatly, giving the antibody antigen specificity. The sites are antigen-specific (the part of the antigen that binds to the antibody).
- ➔ As a pathogen or virus may present multiple antigens, different antibodies must be produced.
- ➔ The 'hinge' region (where the disulfide bonds join the heavy chains) gives the antibody molecule flexibility, allowing the antigen-binding site to be positioned at various angles when binding to antigens.
- ➔ This region is not found in all antibody classes.
- ➔ Antibodies are produced by B-lymphocytes

- ➔ Antibodies bind to specific antigens, causing an immune response. There is only one antibody for each antigen.
- ➔ Pathogens and their toxins, pollen, blood cell surface molecules, and surface proteins found on transplanted tissues are examples of antigens.

- Antibodies perform a variety of functions

- ➔ Antibodies can bind to viruses and pathogen toxins (such as bacteria) to prevent them from entering or damaging cells.
- ➔ Antibodies can act as anti-toxins by binding to pathogen-produced toxins (for example, bacteria that cause diphtheria and tetanus), neutralising them and rendering them harmless.
- ➔ Antibodies can attach to bacteria making them readily identifiable to phagocytes, this is called opsonization.
- ➔ Once identified, the phagocyte has receptor proteins for the heavy polypeptide chains of the antibodies, allowing phagocytosis to occur.
- ➔ Antibodies can attach to bacteria's flagella, making them less active and making phagocytosis easier.
- ➔ Antibodies act as agglutinins, causing pathogens carrying antigen-antibody complexes to clump together (agglutination). This reduces the likelihood of pathogens spreading throughout the body and allows phagocytes to engulf multiple pathogens at the same time.
- ➔ When water is absorbed by osmosis, antibodies (along with other molecules) can cause holes in pathogen cell walls, causing them to burst (lysis).

The Hybridoma Method

- ➔ Monoclonal antibodies are antibodies that are created artificially from a single B cell clone.
- ➔ The hybridoma method is a technique for producing monoclonal antibodies (mAbs).
- ➔ Monoclonal antibodies bind antigens similarly to naturally produced antibodies.
- ➔ The method allows for the production of large quantities of identical antibodies.
- ➔ The hybridoma method addressed the issue of B cells that could divide by mitosis but did not produce antibodies and plasma cells that could produce antibodies but did not divide.
- ➔ This method was developed in the 1970s.
- ➔ Injecting mice with an antigen that stimulates the production of antibody-producing plasma cells is the hybridoma method.
- ➔ Isolated mouse plasma cells are fused with immortal tumour cells, resulting in hybridoma cells.
- ➔ The fusion of plasma and tumour cells can be assisted with the use of fusogens such as polyethylene glycol or an electric current
- ➔ These hybrid cells are grown in a selective growth medium and tested for antibody production.
- ➔ They are then cultured in order to generate a large number of monoclonal antibodies.
- ➔ Monoclonal antibodies have a wide range of applications, including diagnostics, disease treatment, food safety testing, and pregnancy testing.

Types of Immunity

- Active immunity

- ➔ When an antigen enters the body, it causes a specific immune response (the production of antibodies).
- ➔ Active immunity can be acquired naturally through microbe exposure or artificially through vaccinations.
- ➔ In both types of active immunity, the body produces memory cells as well as plasma cells, providing the individual with long-term immunity.
- ➔ In active immunity, the antibody concentration in the blood takes one to two weeks to increase during the primary response to a pathogen (natural) or a vaccination (passive). If the body is invaded by the same pathogen or the pathogen against which the person was vaccinated again, the antibody concentration in the blood increases much faster and is higher than during the primary response.
- ➔ The primary and secondary response to the same antigen

- Passive immunity

- ➔ Passive immunity is acquired without an immune response.
- ➔ Antibodies are not produced by the infected person
- ➔ As the person's immune system has not been activated then there are no memory cells that can produce antibodies in a secondary response. If a person is reinfected they would need another infusion of antibodies
- ➔ Depending on the disease a person is infected with (eg. tetanus) they may not have time to actively acquire the immunity, that is, there is no time for active immunity.
- ➔ So passive immunity occurs either artificially or naturally
- ➔ Artificial passive immunity occurs when people are given an injection /transfusion of the antibodies.

- Natural passive immunity occurs when

- ➔ Foetuses receive antibodies across the placenta from their mothers
- ➔ Babies receive the initial breast milk from mothers which delivers a certain antibody.(IgA)
- ➔ Active immunity is when the body produces the antibodies whereas in passive immunity the body is given the antibodies.
- ➔ A vaccine is a suspension of antigens that is deliberately injected into the body in order to induce artificial active immunity, a type of immune response in which plasma cells release antibodies.

A Note from Mojza

These notes for Biology 5700 have been prepared by Team Mojza, covering the content for AS Level 2022-24 syllabus. The content of these notes has been prepared with utmost care. We apologise for any issues overlooked; factual, grammatical or otherwise. We hope that you benefit from these and find them useful towards achieving your goals for your Cambridge examinations.

If you find any issues within these notes or have any feedback, please contact us at support@mojza.org.

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Acknowledgements