CYTOLOGY

Cytology; is scientific study of cells. It is also known as **cell biology** also the two terms are slightly different.

- A cell is the smallest/tiny fundamental/basic structural and functional unit of life.
- All living organisms are composed of cells and cellular products.
- All cells arise from preexisting living cells by cell division.
- All metabolic processes occur within cells.

The four statements above constitute the modern cell theory.

- Which states that "***cells are the basic structural and functional units of life***."

However, the o**rganismal theory**; *states that an organism is the basic structural and functional entity of life.*

- And this was proved to be **WRONG**.
- Some organisms are unicellular-that is made up of a single cell while other are multicellular.
- In multicellular organisms, there are cooperatives of specialized cells which couldn't survive for long on their own.
- All cells are related to their parent cells. Since cells as well as their organelles are very small, knowing some unit measurements below is of value as far as understanding cell biology is concerned.

Unit measurements

Unit	Symbol	Size
Millimetre	mm	$1 \times 10^{-3} m$
Micrometre	μm	$1 \times 10^{-6} m$
Nanometre	nm	$1 \times 10^{-9} m$

That's;

$$1mm = 10^{-3}m$$

$$1\mu m = 10^{-6}m = 10^{-3}mm$$

$$1nm = 10^{-9}m = 10^{-3}\mu m$$

Cell size

- Cell sizes normally range between 10 to 30 μm.
- Cell size is limited by;

1. **The nucleus/nucleo-cytoplasmic ratio**

- This is the ultimate factor that determines cell size since it's the nucleus controlling all cellular activities.
- Any one nucleus can only exert control over a certain volume of cytoplasm. Thus, the volume of the cytoplasm is limited to that volume the nucleus can control effectively.
- Increase in the size of the nucleus like in tetraploids leads to an increase in the amount of cytoplasm so as to preserve the volume of nucleus to cytoplasm ratio; hence large cells.
- In some large cells like amoeba and paramecium, two nuclei have been developed.

2. **Surface area to volume ratio**

Cells depend on diffusion for movement of many materials to and from the cell interior.

- Increase in the size of the cell would reduce the surface area to volume ratio of the cell, and so diffusion of materials like oxygen and carbon dioxide is inadequate.
- Hence the cells are limited to a size at which the surface area to volume ratio is large enough for diffusion of materials to occur adequately to support cell processes.

3. **Diffusion** is also the main form of transport within the cell. This is only effective in small sized cells.

- In very large cells, the distance for which the materials have to travel is large. The rate of diffusion reduces with distance thus the movement of materials would not be as fast to keep up with the cellular activities.

How cells are studied?

Since most cells are too small to be seen with our naked/unaided eyes thus for details, they are studied using a special instrument called a **microscope**; that magnifies them so that they appear clearer.

There are 2 main/common types of microscopes used at this level to study cells namely;

1. Light microscopes.
2. Electron microscopes.

The choice of the microscope in studying cells depends on the;

- Cells to be viewed as living or dead.
- Resolution required.
- Magnification required.

Resolution and magnification

- **Resolution;** Is the ability of an optical microscope to distinguish two separate, closet entities/objects that could be observed as one entity/object.
- **Resolving power**: Is the minimum distance between two closest points on the specimen that can still be distinguished as separate entities.
- The shorter the distance, the higher is the resolving power.
- The electron microscope has a higher resolution than the light microscope because, it used a beam of electrons with a shorter wave length than light.
- **Magnification/magnifying power**: Is the ability of a microscope to enlarge the specimen(object) so as to be studied in details.
- In other words, it refers to how many times the image is larger than the actual object.
- **Contrast**: Refers to the differences in parts of the sample/specimen.
- **Staining/labeling** enhances contrast.

NOTE:

(i) At greater magnification, additional details can't be observed since resolution is inversely proportional to magnification.

(ii) Light microscopes are only limited to lower magnifications because, at higher magnification, clarity is lost; but due to its higher resolving power, the electron microscope can still give clear images at higher magnifications.

LIGHT MICROSCOPE

This uses natural or artificial light to magnify objects so as they can be studied in details.

Differences between the light microscope and electron microscope

Light microscope	Electron microscope
• Is used to view both living and dead cells.	• Is used to view only dead cells.
• Has lower resolution • Has lower magnification • Sample preparation is quick and simple, little expertise is required. • Is small and portable thus can be used from anywhere. • Specimens/materials not much distorted during preparation. • Natural colour of the specimen can be observed. • Its operation is unaffected by magnetic fields. • The depth of its field is restricted.	• Has higher resolution. • Has higher magnification. • Sample preparation is complex, much expertise is required. • Is very large and only operate from a special place. • Specimens/materials can be distorted during preparation. • Natural colour of the specimen can't be observed since all images are in black and white. • Its operation is affected by magnetic fields. • The depth of its field is not restricted-i.e. can be varied.

TYPES OF CELLS

Basically, there are two main types of cells where the various kinds of cells are categorized namely;

1. Prokaryotic cells
2. Eukaryotic cells

PROKARYOTIC CELLS

- The term *prokaryotic* comes from two Greek words i.e. **pro** which means before/false and **karyos** which means *nucleus*.
- Thus, prokaryotic cells are cells that lack a membrane-bound/true nucleus. This implies that they evolved before the evolution/formation of nucleus.
- Their hereditary material, DNA is not enclosed with a nuclear membrane/nuclear envelope.
- They also lack membrane-bound organelles.
- Prokaryotes are organisms with prokaryotic cells.

- All organisms under kingdom **monera** possess prokaryotic cells.
- Prokaryotes lack true nucleus but they possess a single circular chromosome located in a nuclear area/region called **nucleoid**.
- Bacteria belong to kingdom monera thus are prokaryotes-i.e. bacteria and blue-green bacteria.

Bacteria are broadly categorized into two major groups namely;

1. Archaebacteria.
2. Eubacteria

Archaebacteria: These existed first and are capable of living in unusual conditions like those existed in primitive earth such as Thermoacidophile that live in hot sulphur springs at 80°C and P^H of 2.

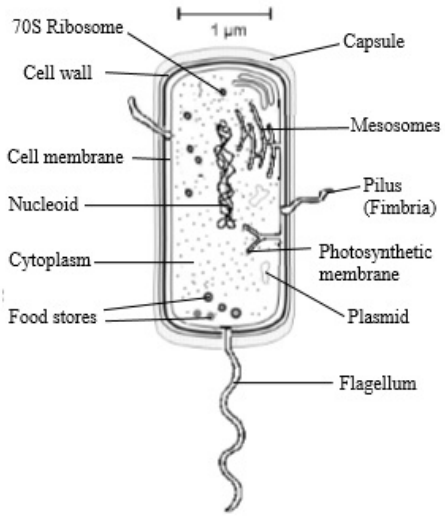
Eubactria: These live in a wide range of environment. The majority are pathogens that live in association with human. They are majorly classified according to their shape (**Refer to classification**)

Eubacteria are further grouped into two groups depending on their degree of picking/reacting with gram stain viz;

(i) **Gram positive bacteria**; these pick the gram stain.

(ii) **Gram negative bacteria**; these don't pick up gram stain.

STRUCTURE OF PROKARYOTIC CELL (BACTERIAL CELL)



- Prokaryotic cells are much smaller usually (0.2-10μm), most of them are unicellular although some are multicellular like cyanobacteria.
- They possess circular DNA which is **naked** located on single chromosome without **histones**.
- Their ribosomes are smaller 70S and a few.
- They have 9+0 microtubule arrangement in cilia, flagella and fimbriae.

NB: Some lack flagella.

- They have complex cell walls with peptidoglycan and a capsule or slime layer.
- They reproduce asexually by binary fission and sexually by conjugation.

Recall: Prokaryotic cells generally lack membrane bound organelles.

- An **organelle** is a distinct part of the cell that has a particular structure and performs a specific function.

However, eukaryotic cells possess membrane bound organelles.

EUKARYOTIC CELLS

- The term *eukaryotic* comes from two Greek words-i.e. **eu** which means after/true and **karyos** which means nucleus.
- Thus, eukaryotic cells are cells that possess a distinct/true nucleus bounded by a nuclear membrane/ nuclear envelope.
- This implies that they evolved after the evolution of nucleus.
- Apart from bacterial cells, all other cells are eukaryotic.
- Their hereditary material, DNA is enclosed in a double membrane called **nuclear envelope.**
- Eukaryotes are organisms with eukaryotic cells. For example, plant and animal cells are eukaryotic in nature.
- They have membrane-bound organelles.

SIGNIFICANCE OF HAVING MEMBRANE BOUND ORGANELLES IN EUKARYOTES

Having membrane bound organelles in eukaryotes provides a number of advantages which include the following;

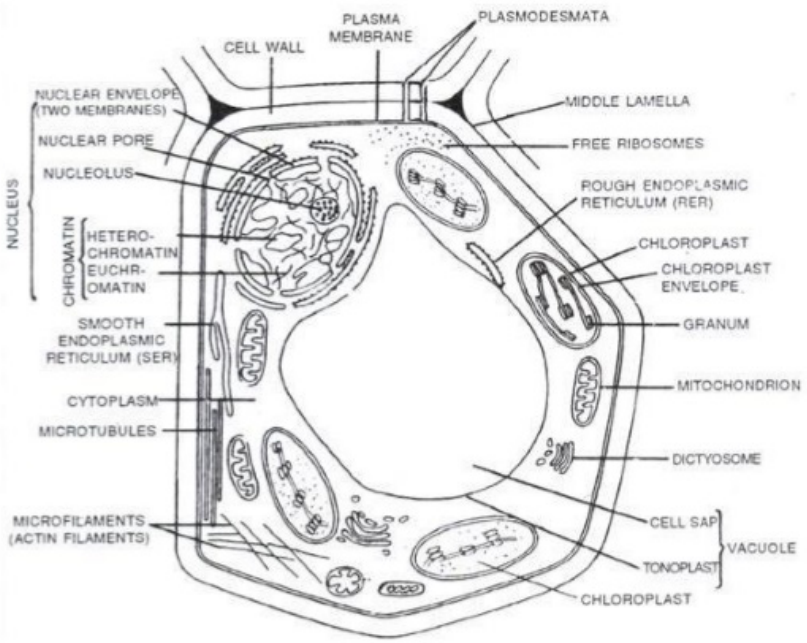
- Membranes bring about compartmentation; resulting in the formation of organelles, each specialized for a particular function. This division of labour improves the overall efficiency of the cell.
- Many metabolic processes involve enzymes being embedded in a membrane. Thus, membranes of organelles increase the surface area onto which enzymes can be embedded. This is particularly important in those large eukaryotic cells where the cell surface membrane area to cell volume is reduced.
- Within organelles, the substrate and enzymes are in close proximity. The rate of metabolic reactions thus increases.
- The rate of metabolic reactions inside the organelle can be controlled by regulating the rate at which the membrane surrounding the organelle allows the reactants to enter.
- Potentially harmful reactants, products and enzymes can be isolated inside an organelle so that the cell is not damaged.

TYPES OF EUKARYOTIC CELLS

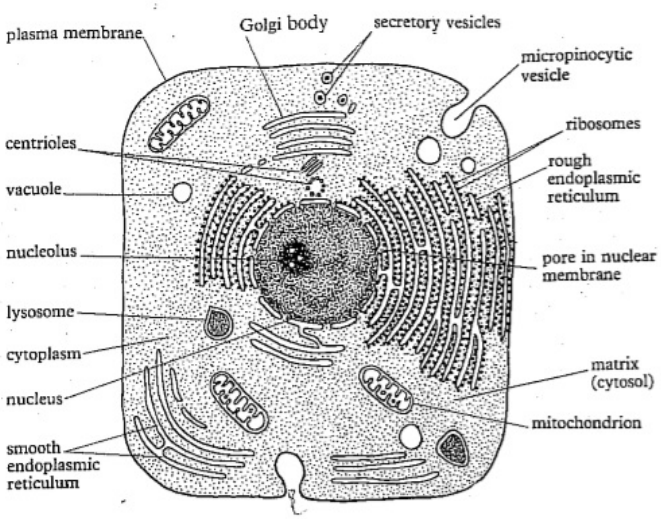
- The ***plant cells*** and ***animal cells*** are the main 2 types of eukaryotic cells.

THE FINE STRUCTURE OF A CELL

UTRASTRUCTURE OF PLANT CELL



UTRASTRUCTURE OF PLANT CELL



THE FINE STRUCTURE OF A CELL

DESCRIPTION OF CELLULAR ORGANELLES

1. **Nucleus;** The word nucleus means *centre*.

The nucleus is a largest, oval shaped cell organelle surrounded by a double membrane called nuclear envelope; perforated by nuclear pores.

- Nuclear pores allow exchange of materials between the nucleus and the cytoplasm.
- Surrounded by the nuclear envelope is a gel-like fluid called nucleoplasm; containing chromatin; made up of coils of DNA bound to proteins called histones; which two form nucleosome.
- Within the nucleoplasm is a spherical darkly stained structure called nucleolus.
- Nucleolus synthesizes rRNA from RNA & proteins; and ribosomes.
- Nucleolus disappears during cell division because the DNA is dispersed to other chromosomes.
- During cell division, chromatin condenses into chromosomes.
- Being the largest cell organelle, the nucleus is the most conspicuous cell organelle.
- Nuclei are found in all eukaryotic cells with common exceptions being sieve tube elements and mature red blood cells.
- Has two forms of chromatin; **heterochromatin** which is genetically inactive, tightly coiled and stain darkly and e**uchromatin** which is loosely packed, genetically active and enriched.
- The outer membrane of nuclear envelope is continuous with endoplasmic reticulum.

Functions of nucleus

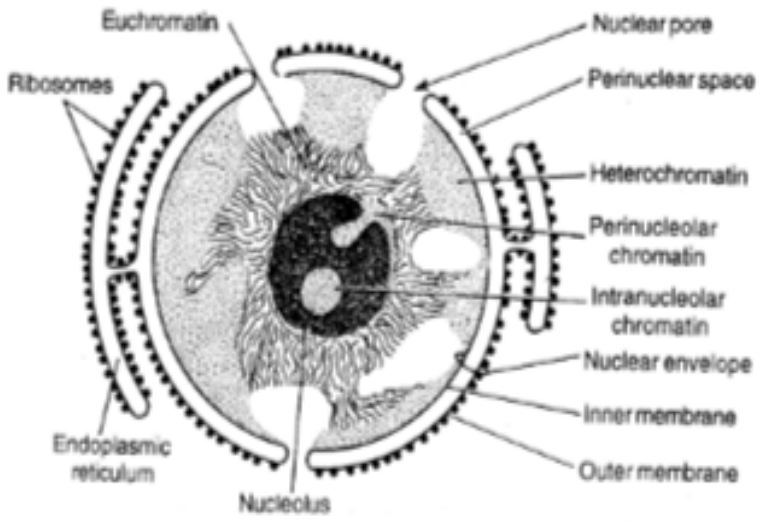
- Nuclear division is the basis of cell replication thus reproduction and growth.
- Stores DNA, the genetic/hereditary material within the chromosomes.
- Stores proteins and RNA in the nucleolus.
- Manufacture of RNA for protein synthesis.
- Synthesis of ribosomes within the nucleolus.
- Controls the heredity features of an organism/unicellular organism.

- Chromosomes are organized into genes that control all cellular activities like protein synthesis, cell division/ reproduction, growth and differentiation.

Adaptations of nucleus to its functions

- DNA is long to store many genes.
- Has nuclear pores within nuclear envelope to permit exit of RNA from the nucleus.
- Has nucleolus for synthesis of ribosomes that enhance protein synthesis.
- Has nuclear envelope to separate nucleoplasm processes from cytoplasm processes.
- Nuclear envelope perforated with nuclear pores to regulate exchange of substances between nucleoplasm and cytoplasm.

Diagram of the cell nucleus



2. Ribosomes

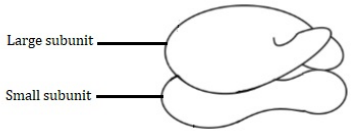
- Are small cytoplasmic granules found in all cells; composed of rRNA and proteins; each with two subunits; consisting of one large subunit and one small subunit.
- Are manufactured in the nucleolus and are important in the synthesis of proteins, where they move along mRNA in succession.
- Can occur in groups called **polysomes** or singly as free ribosomes within the cytoplasm; or associated with endoplasmic reticulum (ER) forming rough endoplasmic reticulum (rER) and nuclear envelope.

- Eukaryotic cells have 80S ribosomes; prokaryotic cells have 70S ribosomes;
- Named according to their rate of sedimentation on a special gel dufitier sedimentation; whose unit is **Svedberg** denoted "**S.**

NB: Ribosomes are the smallest and most numerous organelles.

Function of ribosomes: Sites for protein synthesis.

Structure of a ribosome



3. Endoplasmic reticulum (ER)

- Endoplasmic≡ inside cytoplasm
- Reticulum ≡ little net/tubules
- cisternae≡ reservoir of lipids

ER; Is an elaborate system of membranes found throughout the cell, forming the cytoplasmic skeleton.

- It is composed of composed of parallel flattened membrane-bound sacks called cisternae;
- The cavities are interconnected and the lining membranes are continuous with the outer nuclear membrane.
- Attached on the outer side of the membranes of some ER are numerous granules rich in ribonucleic acid called ribosomes and thus the ER is called rough endoplasmic reticulum(rER).
- The general function of rER is to isolate and transport proteins made by the ribosomes through the cisternae. ER is this a kind of intracellular transport system of facilitating the movement of materials from one part of the cell to another.
- In certain parts of the cell, the ER is not encrusted/associated with ribosomes and thus called the smooth endoplasmic reticulum(sER).
- sER is not continuous with the rER or nuclear membrane.

- Its cavities are tubular rather than flattened sacs.
- Its general function is to synthesize lipids and steroids.
- Contain lytic enzymes in liver cells/hepatocytes.
- Stores calcium ions in sarcoplasmic reticulum of muscle cells.
- The ER provides a large surface area for chemical reactions.

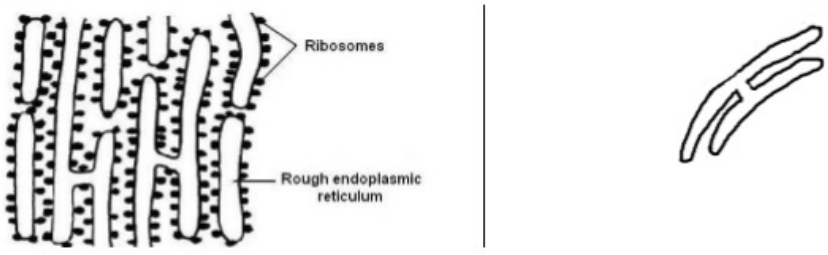
NB: The ends of this system (ER) pinch off into secretory vesicles. ER delivers substances to Golgi body.

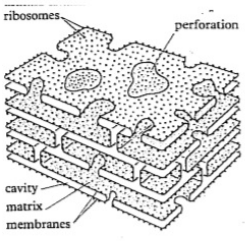
Functions of ER

- Synthesis of steroids, lipids and proteins.
- Transport of steroids, lipids and proteins.
- Modification of proteins and lipids to form glycoproteins, lipoproteins, phosphoproteins, glycolipids, phospholipids etc.
- Detoxification of alcohols, drugs (fat soluble ones) and metabolic wastes.
- Secretion of synthesized, modified/processed lipids and proteins.

Structure of ER

rER sER





FOOD FOR THOUGHT 1.0: Research and brainstorm on adaptations of ER to its functions.

4. Vacuoles and vesicles

- These are fluid-filled sacs in the cytoplasm, bound by a single membrane.
- In plant cells, the semi-permeable membrane surrounding the vacuole is called a **tonoplas**t and the fluid inside is the **cell sap**.
- Vesicles are small sacs while vacuoles are big sacs. They are majorly for storage of substances.

Types of vacuoles

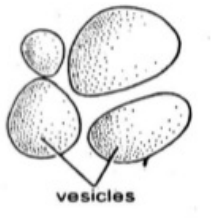
- **Food vacuole**; storage of food substances.
- **Contractile vacuole**; removal of excess water, osmoregulatory device in amoeba and other protists.
- **Central vacuole**; stores water, maintains turgidity/tonicity of the cell.

Generally, cell vacuoles store water, amino acids, mineral salts/ions, sugars, wastes among others.

Functions of vacuoles

1. Sugars and amino acids in the sap serve as temporary food stores.
2. Pigments in the vacuoles like anthrocyanins give colours to flower petals to attract pollinating agents.
3. Serve as temporary stores for organic wastes like tannins; which are removed form the plant when the leaf/fruit falls.
4. Contain hydrolytic enzymes thus function as lysosomes.
5. Provide a basis for support in herbaceous plants by providing an osmotic system which creates a pressure potential.

Illustration of vesicles



5. Golgi body/complex/apparatus

Cytoskeleton: Is a network of fibres extending throughout the cytoplasm. These include microfilaments (3-6nm), intermediate filaments (8-12nm) and microtubules (20-25nm).

General functions

- For mechanical support, strength, mobility like motor proteins≡ "**feet**".

6. **Microfilaments**: Are solid unbranched, fine thread-like fibres (rod-like fibrils); mainly composed of contractile protein; actin associated with protein myosin for muscle contraction; cellular movements; gliding, contraction, cytokinesis. Are 3-6nm in diameter, with varying lengths.

7. **Intermediate filaments**: Are 10nm in diameter; provide tensile strength.

8. **Microtubules**

- Are slender, cylindrical, hollow, unbranched tubes; composed of helically arranged subunits of protein **tubulin.**

- Commonly found in eukaryotic cells but not in prokaryotes.

- Are arranged in microtubule organizing centre (MTOC) called **centrosome** near the nucleus.

- They radiate form centrosome to plasma membrane.

Functions

- Form centrioles and spindle fibres in nuclear division that control separation of chromosomes during cell division. Plant cells lack centrioles.

- Intracellular transport; are involved in the movement of other cell organelles like Golgi vesicles, materials by cytoplasmic streaming since they form cell tracts. Such movements stop if the microtubule system is disrupted because the routes along which they move are destroyed.

- Cytoskeleton; are long, fairly rigid structures and this provide an internal skeleton for cells and so determine and maintain shape of the cell during development.

- Form a framework along which the cellulose cell wall of plant cells is laid down.

- Form basal bodies, cilia and flagella; where they are arranged **in 9+2 microtubule arrangement**. Basal bodies are found at the base of every cilium and flagellum functioning as microtubule organizing centres (MTOCs).

9. Cilia and flagella

- These are identical structures although flagella are longer than cilia.
- Have 9+2 microtubule arrangement in eukaryotes but 9+0 in prokaryotes.
- In prokaryotic cells, flagella are made up of flagellin but tubulin in eukaryotic cells.

Functions of cilia in organisms

- Movement of materials over cells like ovum in oviducts; trapped dust in the respiratory pathways.
- Locomotion in organisms like paramecium.

NOTE:

- ❖ The primary microtubule organizing centre is **centrosome** that organizes the microtubules thus enhancing organelles' positioning.
- ❖ The centrosome is near the nucleus in a package of 2-4 centrioles; and perpendicular to one another.
- ❖ Microfilaments, intermediate filaments and microtubules form **cytoskeleton** that give cell shape and coherence.

10. Mitochondria

- Is an oval shaped/cigar shape organelle with variable length; bound by a double membrane.
- The inner membrane is highly folded to give rise the cristae.
- The surface of the cristae has stalked particles along its length.
- The ground substance called mitochondrial matrix is rigid and contains proteins, lipids, traces of circular DNA and mitochondrial ribosomes.

Summary of structural description

Mitochondrion is a roughly spherical, double membrane organelle; 0.5-1μm in diameter and 1-10μm in length; each with phosholipid bilayer and a unique collection of proteins embedded; outer membrane is smooth; inner membrane is infolded into cristae; increasing surface are for enzyme activity thus ATP synthesis; each crista possess cytochromes and enzymes for respiratory chain/ETS; the envelope encloses fluid-filled cavity called mitochondrial matrix; within which circular DNA, ribosomes, lipid droplets, enzymes are

embedded. In- between the outer and inner membrane; there is intermembranal space, important in synthesis of energy by chemiosmosis.

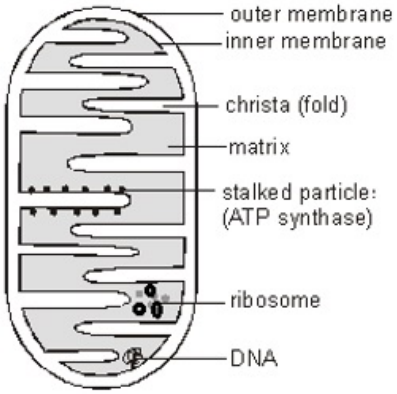
Functions

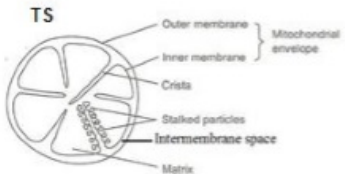
- Site for energy (ATP) synthesis/cellular respiration.
- Has a role in programmed cell death/apoptosis.

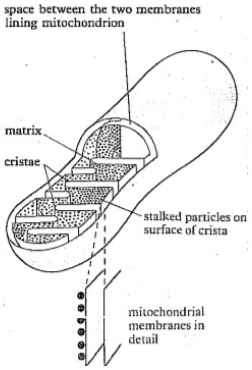
ADAPTATIONS OF MITOCHONDRION TO ITS FUNCTION(S)

- The mitochondrion is able to change shape, and move to areas in a cell where a lot of energy consuming activities occur to provide the cell with a high concentration of mitochondria in areas where energy/ATP is most needed.
- Has mitochondrial envelope that isolates the reactions of mitochondrion from other cellular activities.
- Its outer membrane is selectively permeable providing a control on the entry and exit of materials to and from the mitochondrion.
- Its inner membrane is folded into cristae, increasing the surface area for energy synthesis/on which respiratory process occur.
- Its inner membrane has stalked particles with ATPase activity that couples energy into ATP synthesis.
- Has a mitochondrial matrix with a number of respiratory enzymes for energy synthesis and interconversion of metabolites.
- Has a number of co-enzymes/hydrogen carriers like NAD and FAD, which carry hydrogen atoms from the mitochondrial matrix/Krebs cycle to the respiratory chain for synthesis of a lot of ATP.
- Has intermembranal space with mitochondrial envelope where protons accumulate to establish electrochemical gradient for energy/ATP synthesis during chemiosmosis.
- Its inner membrane has proton pumps which actively pump protons from the matrix into the intermembrane space for energy production.
- **Question:** How the mitochondrion is suited for its function? (10 marks)

Structure of mitochondrion







11. Chloroplast

- This belongs to group of pigmented organelles called **plastids**.
- It is bound by a double membrane called **chloroplast envelope**.
- The inner membrane is folded into a series of lamellae and is highly selective in what it allows in and out of the chloroplast.
- Within the chloroplast envelope is the gelatinous matrix called **stroma** in which other structures are embedded.
- It contains stacks of closed flattened sacs called **thylakoids**. Each stack of thylakoids is called **granum** (singular of grana).

- Within the thylakoid membranes, are the photosynthetic pigments like chlorophylls.
- Some thylakoids have tubular extensions connecting adjacent grana, called intergranal lamellae.
- Other structures in the stroma include starch granules which serve as temporary stores of photosynthetic products, a small amount of circular DNA and oil droplets.

Summary of structural description

Is a roughly spherical/lens-shaped, double membraned organelle 3-6μm in length; with a gel-like fluid-filled matrix; stroma with free ribosomes, starch granules, lipid droplets, circular DNA and interconnected system of flattened sacs called **thylakoids** stacked like pocker chips (platy-like) to form grana; embedded in it; intergranal lamella connects granum to another. In other words, each granum is composed of stalks of platy-like structures called thylakoid membranes containing photosynthetic pigments like chlorophyll pigment. The membranes divide into 3 comportments i.e. intermembranal space, stroma and thylakoid space.

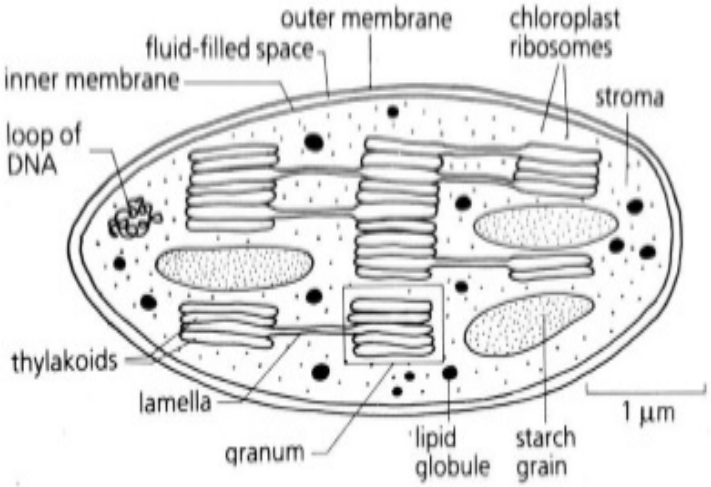
Function: Site for photosynthesis

ADAPTATIONS OF CHLOROPLAST TO ITS FUNCTION

- It's bound by a double membrane that isolates the photosynthetic reactions for other cellular activities.
- Contains numerous thylakoids to hold chlorophyll in large quantities for trapping of much light energy.
- Has grana with thylakoids stacked on top of each other; to provide a large surface area for light absorption in a small space.
- Has colourless stroma; not to filter out light reaching the chloroplast.
- Has thylakoid membranes containing numerous enzymes that catalyse the chemical reactions of energy production and carbon dioxide reduction.
- Contains different types of light harvesting molecules/photosynthetic pigments like chlorophyll a, b and carotenoids; that increase the range of light spectrum absorbed.
- Has accessory pigments like carotenoids which protects chlorophyll from excessive light and thus bleaching and from oxidation by the oxygen produced during photosynthesis.

- Has highly folded inner membrane into series of lamellae which increases the surface area for synthesis of substances like lipids.
- Has highly selective inner membrane ; to regulate the entry and exit of materials in and out of the chloroplast.
- Has starch granules and oil droplets for temporary storage of photosynthetic products.

Structure of a chloroplast



NOTE: Chloroplasts are examples of plastids in plant cells

PLASTIDS: These are pigmented self replicating organelles surrounded by envelopes.

Type of plastids

There are 2 main types of plastids namely;

(i) **Primary plastids**; with 2 membranes like chloroplasts.

(ii) **Secondary plastids**; with 3/4 complex membranes like planktons, diatoms, dinoflagellates.

Examples of plastids in photosynthetic eukaryotes include;

- **Chloroplasts**; green pigmented.
- **Chromoplasts**; yellow/red/orange coloured; contain carotenoids like in fruits, flowers, roots(carrots) that attract pollinators and seed dispersal agents(animals).
- **Leucoplasts**; colourless like in stem tubers and root tubers.

- **Amyloplasts**; store starch (amylose).
- **Elaioplasts**; store lipids.
- **Proteinoplasts**; store proteins.
- **Etioplasts**; are pale yellow/colourless organelles; responsible for etiolation in case of stress or mechanical damage.
- **Proplastids**; are progenitors/precursors of all other plastids and are amoeboid in shape.

FOOD FOR THOUGHT 1.4: In pairs, compare chloroplast and mitochondrion.

NOTE: The origin of mitochondria and chloroplasts in eukaryotic cell is explained by **endosymbiotic theory.**

ENDOSYMBIOTIC THEORY

- Is an evolutionary theory that explains the origin of eukaryotic cells from prokaryotes.
- It states that, several organelles of eukaryotes like mitochondria and plastids such as chloroplasts originated as a symbiosis between separate single-celled organelles. Such organelles were take in/engulfed by another cell as an endosymbiont; with which they evolved to be dependent on each other.

In brief: It suggests that mitochondria and chloroplasts were once free living small aerobic bacteria and photosynthetic bacteria respectively that were engulfed by a larger anaerobic eukaryotic cell by phagocytosis but digestion failed. Thus, lived inside the larger cell as parasites or phagocytotic vesicles. Later a mutually benefiting relationship called ***endosymbiosis*** was established whereby the larger (host) cell provided protection and shelter while smaller cells removed oxygen which was toxic to the larger anaerobic cell.

Hint:

- **Secondary endosymbiosis** is the engulfing of smaller eukaryotic cells by a larger eukaryotic cell.
- Plant cells engulfed both aerobic and photosynthetic bacteria that gave rise to mitochondria and chloroplasts respectively but animal cells engulfed only aerobic bacteria thus they possess mitochondria only.

Evidence of endosymbiotic theory

MODELS OF CELL MEMBRANE

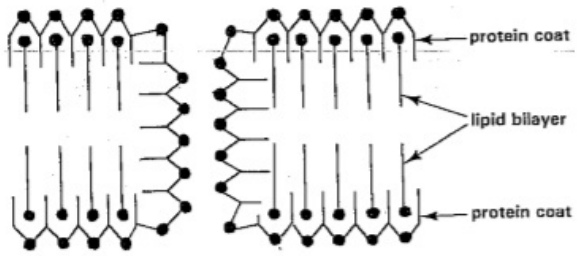
There are two models that were put forward to explain the structure of cell membrane viz;

1. Davison-Daniell's model
2. Fluid-mosaic model

DAVISON-DANIELL'S MODEL OF CELL MEMBRANE

It suggests that the cell membrane consists of a phospholipid bilayer sandwiched between two globular protein layers; globular proteins surround the pores. The phospholipid hydrophilic "heads" are oriented towards proteins forming hydrophilic zone while phospholipid hydrophobic "tails" are oriented away from the proteins(centre) constituting to hydrophobic zone.

Illustration



FOOD FOR THOUGHT 1.5: In pairs, research and brainstorm on the weaknesses of this model.

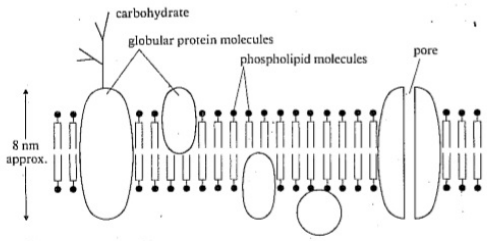
This model was disproved due to its weaknesses and thus fluid-mosaic model was adopted.

FLUID-MOSAIC MODEL OF CELL MEMBRANE

It suggests that the cell membrane is a bimolecular layer; consisting of two layers of phospholipids interspersed with globular proteins. Phospholipids are composed of phosphate "heads" which are polar; hydrophilic and form hydrogen bonds with water thus oriented towards aqueous solution of extracellular fluids and cytosol/cytoplasm; fatty acid "tails" of lipids which are non-polar, hydrophobic; attracted to each other by hydrophobic interactions and Vander Waal's forces of attractions thus facing towards each other due to repulsion from water. Globular proteins include integral proteins and extrinsic(peripheral) proteins; some integral proteins(integrins) are intrinsic proteins; partly embedded in hydrophobic core of one of phospholipid layers; while others are transmembranal proteins; that span across the two phospholipid layers and porous; some transmembranal proteins contain ionic channels; called channel proteins; others have binding sites; called

carrier proteins; capable of changing conformation. Some intrinsic proteins are conjugated with short branched carbohydrates forming glycoproteins; others with lipids forming lipoproteins. Extrinsic proteins are at the inner and outer surfaces. Some phospholipids conjugate with short branched carbohydrates forming glycolipids. Cholesterol molecules are squeezed in between phospholipids mainly in animals; which maintain membrane fluidity; globular proteins are individually and mosaically embedded in the cell membrane thus giving the membrane a fluid a mosaic structure.

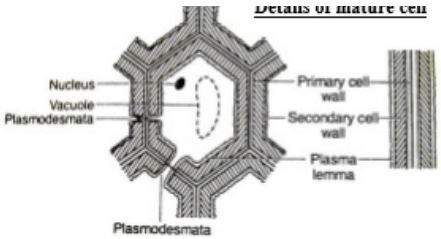
Illustration



Question: Describe the structure of a cell wall.

Ans: It consists of three (3) main layers/regions; middle lamella; primary cell wall; and secondary cell wall. It is tough, flexible/bendable/fairly rigid; of variable thickness; surrounding plant cells; the outermost layer, middle lamella cements/binds/glues adjacent plant cells together; and is rich in calcium and magnesium pectates; and proteins; the primary cell wall (next layer) is thin; flexible and extensible. It consists of cellulose; microfibrils; hemicellulose; pectin; water; and protein. In plant epidermis, it is impregnated with cutin; and wax to form impermeable barrier called plant cuticle; the various chemical components are tightly/closely bound together. In some cells there is secondary cell wall inside the primary cell wall; is thick; with 3 layers; contains several proteins and polymers like cellulose; hemicelluloses and lignin in wood and xylem; suberin in cork and root casparian strips; silica crystals in grass; certain small areas of the cell wall remain unthickened to form pits; which coincide in adjacent cells to form pit pairs in which the cells are separated only by the middle lamella and through which plasmodesmata/cytoplasmic strands pass.

Diagrammatic illustration



Functions of a cell wall

(i) Provides mechanical strength and skeletal support for the individual cells and plant as a whole. Lignification increases the mechanical strength.

(ii) Is fairly rigid and resistant to expansion and thus allow development of turgidity when water enters the cell by osmosis. This provides support to non-woody plants/herbaceous plants and plant organs like leaves and flowers which donot undergo secondary growth.

(iii) Arrangement of cellulose fibrils in the cell wall determine the pattern of growth and thus overall cell shape.

(iv) The system of interconnected cell walls called **apoplast** is the major pathway for movement of water and dissolved mineral salts.

(v) Some cell walls are modified as food reserves like storage of hemicelluloses in some seeds.

(vi) Is impregnated with cutin, suberin or lignin thereby making cells less permeable to substances;

- ✓ Lignified cell walls of the xylem keep water within the xylem;
- ✓ Suberin in the endodermal cells of the roots prevents water movement through the apoplast, channeling it to a different path called symplast route;
- ✓ Cutin in the epidermis of the leaves prevent excessive water loss from the plant.

DIFFERENCES BETWEEN PLANT AND ANIMAL CELL

Plant cell	**Animal cell**
• Has cellulose cell wall.	• Lacks cell wall
• Has plastids like chloroplasts and leucoplasts	• Lacks plastids
• Has a single prominent central cell vacuole filled with cell sap.	• Has many small and scattered cell vacuoles throughout the cell.
• Has a tonoplast around the cell vacuole.	• Lacks tonoplast around the vacuole.
• Has starch granules for food storage.	• Has glycogen for food storage.
• Centrioles absent	• Centrioles present
• Cilia and flagella absent	• Cilia and flagella present
• Has nucleus at the edge of the cell	• Nucleus often at the central although can be anywhere in the cell.
• Cytoplasm often confined to a thin layer at the edge of the cell.	• Cytoplasm present throughout the cell.
• Has pits and plasmodesmata in the cell wall.	• Lacks pits and plasmodesmata due to absence of cell wall
• Has middle lamellae joining cell walls of adjacent cells	• Has intercellular cement joining adjacent cells instead of middle lamellae

DIFFERENCES BETWEEN PROKARYOTIC CELLS AND EUKARYOTIC CELLS

QUICK CHECK

1. Give the comparison between a chloroplast and a mitochondrion. (10 marks)
2. Describe how the following organelles are adapted to their functions. (20 marks)
   (i) Mitochondrion
   (ii) Chloroplast
   (iii) Nucleus
3. Describe the functions of the following organelles. (20 marks)
   (i) Lysosome
   (ii) Endoplasmic reticulum
   (iii) Golgi body
   (iv) Cell vacuole
4.
   (a) Briefly describe the fluid mosaic model of the plasma membrane. (10 marks)
   (b) Compare the above model with Davison-Danielli's model of cell membrane. (10 marks)
5.
   (a) Describe the structure of a ribosome. (02 marks)
   (b) Describe the role of proteins in the plasma membrane. (06 marks)
   (c) How is the plasma membrane suited to its functions? (12 marks)
6. Compare the cell membrane with cell wall. (08 marks)
7. Give an account of the cell cycle. (10 marks)
8.
   (a) Name and describe the components of cytoskeleton. (15 marks)
   (b) Outline the function(s) of each of the components named above. (05 marks)

9.

(a) Name and describe the components of endomembrane system. (15 marks)

(b) Give the function(s) of each of the components named above. (05 marks)

10.

(a) Briefly describe the endosymbiotic theory. (10 marks)

(b) Give the evidence for the theory described above. (10 marks)

MOVEMENT IN & OUT OF CELLS

OUTLINE

- Definition
- Necessity
- Processes involved
- Diffusion
- Osmosis
- Active transport
- Phagocytosis
- Pinocytosis
- Receptor mediated transport.

Definition: Movement of materials in and out of cells.

Necessity

- To supply oxygen for respiration.
- To supply nutrients/raw materials for cellular metabolism/anabolism.
- To excrete toxic waste products of metabolism out of cells.
- To secrete useful substances for cellular activities like hormones, enzymes etc.
- To regulate cellular P^H and solute concentration for maintenance of a stable internal environment for optimal functions of enzymes.

Movement across the cell membrane

Nature of the cell membrane

1. **Membranes are partially permeable**

- Cell membrane do not behave simply like semi-permeable membranes that allow only the passage of water and other small molecules like gases.
- Instead, they are described as <u>partially permeable</u> since other substances like glucose, amino acids. Fatty acids, glycerol and ions can diffuse slowly through them.

2. **Membranes contain proteins and lipids**

- Organic solvents like alcohols, ether and chloroform penetrate the membrane even more rapidly than water.
- This suggests that membranes are have non-polar portions and contain lipids.
- Chemical analysis confirmed the presence of proteins.

The need for transport across the cell membrane

- Transport across the cell membrane must occur in order for the cell to;
  - (i) Obtain nutrients from its surrounding necessary for its metabolism.
  - (ii) To excrete waste products from the cell which if allowed to accumulate cause harm to cell.
  - (iii) To secrete useful substances like hormones for cell-cell communication; enzymes for extracellular digestion etc.
  - (iv) Maintain a suitable pH and ionic concentration within the cell for proper enzyme activities.

There are four basic mechanisms by which movement across the cell membrane occurs, viz;

1. Diffusion
2. Osmosis
3. Active transport
4. Bulk transport

1. DIFFUSION

Definition: Is the net movement of molecules or ions from a region of their higher concentration to a region of their lower concentration via a fully permeable membrane.

OR

- Is the net movement of materials(particles) from a region of their higher concentration to a region of their lower concentration across a fully permeable membrane.
- It occurs along the diffusion/concentration gradient randomly till a dynamic equilibrium is established. At the dynamic equilibrium random movement continues to occur not net movement of molecules/ions in either side.
- Diffusion is possible because substances are made of molecules and ions which are in constant random motion.

- Diffusion is passive, hence does not require energy for it to occur. It occurs spontaneously.
- It occurs in both living and non-living systems.

Types of diffusion

1. **Simple diffusion** (for small and non-polar molecules e.g. oxygen + carbon dioxide)
2. **Facilitated diffusion**

FACILITATED DIFFUSION

- Is the net movement of molecules or ions (particles) from a region of their higher concentration to a region their lower concentration across a permeable membrane with the aid of channel proteins.
- Respiratory gases; oxygen and carbon dioxide are small and non-polar thus diffuse rapidly through membranes.
- Water molecules, although very polar, are small enough to pass through the membrane without interference.
- However, ions and larger, polar molecules like glucose and amino acids are repelled by the hydrophobic region of the membrane and simple diffusion occurs extremely very slowly to satisfy the cell's needs.
- Thus, for faster rates of diffusion, ions like chloride ions and large polar molecules diffuse through special transport proteins called **channel proteins** and **carrier proteins**.
- Basically, fat-insoluble, polar molecules/ions like glucose, water, nucleic acids and small proteins are transported by this process.
- **Channel proteins** are globular proteins with water-filled hydrophilic pores along which materials (molecules or ions) diffuse across the plasma membrane.
- The channels connect the two sides of the hydrophobic lipid bilayer of cell membrane.
- These channels/pores only allow ions of specific charge and/or size to pass through thus they are describe as being **selectively permeable**.
- The hydrophilic pores/channels are either ligand-gated/voltage gated(closed/opened).

FACTORS AFFECTING THE RATE OF DIFFUSION

(i) **Concentration gradient**; is the difference in concentration between the two sides of the diffusing substances/ is the difference in concentration of a substance between two points.

- The greater the difference in concentration between two regions of a diffusing substance (the steeper/greater the concentration gradient), the faster the rate of diffusion and the less steep the concentration gradient, the slower the rate of diffusion. This is due to greater pressure exerted by molecules in the region of higher concentration which forces them to diffuse across the membrane into their region of low concentration where the pressure is low.
- Cells must therefore maintain a steep diffusion gradient if rapid transport by diffusion is required.
- This can be achieved into 2 ways;
  - ✓ By rapidly transporting away the substance from the site of absorption like in the lungs, numerous blood vessels increase blood flow through it.
  - ✓ By maintaining a fresh supply of the substance to be absorbed. This ensures that the dynamic equilibrium between the either side of the cell membrane is never established like constant breathing renews the air in the lungs.

(ii) **Diffusion distance**; time of diffusion used to explain.

- The rate of diffusion increases with the decrease in the distance between the two regions of the different concentrations for a given substance.i.e.;
- The shorter the distance between two regions of the diffusing substance, the faster the rate of diffusion and the longer the diffusion distance, the slower the rate of diffusion. This is because molecules/ions take long time to diffuse across the longer distance thus slow rate of diffusion but molecules/ions take short time to diffuse across a short distance thus faster rate of diffusion.
- Diffusion is therefore only effective over very short distances.
- Thus, it's essential that membranes are thin so that molecules or ions can cross them rapidly.

Hint: For this reason, body structures where diffusion often occurs are thin for instance, cell membranes$= 75\text{nm}$; alveolar membranes$0.3\mu\text{m}$.

The influence of diffusion distance on diffusion rate was summarized in inverse square law which states that "*the rate of diffusion is proportional to the reciprocal of the square of the distance over which it occurs."*

OR

Law of diffusion which states that "*the rate of diffusion is inversely proportional to the distance over which it occurs*."

(iii) **Temperature**

- The higher the temperature, the faster the rate of diffusion and the lower the temperature, the slower the rate of diffusion. This is because, increase in temperature increases the kinetic energy gained by the diffusing molecules, thus move at higher velocities/speed leading to increase in rate of diffusion. Decrease in temperature; decrease the kinetic energy gained by diffusing molecules/ions thus move at low velocities/speed thus low rate of diffusion.

(iv) **Size and nature of diffusing molecules/ions(particles)**

- Small and light; big & heavy; big & light etc.

Size of diffusing molecules

- Small molecules diffuse faster than big(large) ones. This is because small particles have less inertia than heavy, big ones. Thus, diffuse faster since they can easily diffuse through the pores of the membrane(partition).

Nature of the diffusing molecules

- Fat-soluble molecules diffuse more rapidly through cell membranes than water-soluble molecules. This is because the interior core of the cell membrane is made up of phospholipids (fatty acid tails) which are hydrophobic and thus repel water soluble molecules to the expense of fat-soluble molecules since they are non-polar.

(v) **Nature of diffusion medium**

- Rate of diffusion is highest in gaseous medium followed by in liquid medium and lowest in solids. i.e. Gases < liquids <solids

(Highest) (lowest)

This is because gas molecules are well spaced; diffusing molecules meet less resistance thus fastest diffusion rate; liquid molecules are less spaced, diffusing molecules meet moderate resistance thus moderate

Generally, the rate of diffusion is;

- ✓ Directly proportional to surface area.
- ✓ Directly proportional to the concentration gradient.
- ✓ Inversely proportional to the diffusion distance.

These are summarized in **Fick's law** which states that "*rate of diffusion is proportional to ratio of product of surface area and diffusion gradient to diffusion distance*."

i.e. Rate of diffusion$\propto \frac{Surface\ area \times Concentration\ gradient}{\text{Diffusion distance}}$

This law is applicable to situations where there's no barrier to movement of a substances.

In nature

1. In the alimentary canal; particles are broken down for easy uptake by diffusion in ileum.
2. In lungs, numerous blood capillaries carry oxygenated blood away rapidly to regions of low oxygen partial pressures (respiring tissues) to maintain a steep concentration gradient for rapid diffusion of respiratory gases; conversion of less osmotically active substances.
3. Thin linings in alveoli; even in capillary walls (endothelium, squame cells) provide a short diffusion distance.
4. In lungs, the alveoli have a larger surface area to volume ratio; being small; for fast diffusion of gases;
5. Only villi & microvilli on cells where diffusion occurs; increase surface area for faster diffusion rate.

   NB: The infolding of the ileum; is to allow food to take time to go through being digested fully but doesn't increase surface are for diffusion.
6. Flattened body in flatworms(platyhelminths); increase surface area for rapid diffusion of materials.

Qn: Describe the adaptations possessed by tissues/cells to maximize rate of diffusion.

Solutions

- Lung ventilation of respiratory tract; maintain a steep concentration gradient for rapid diffusion.

- Rich blood supply of respiratory surfaces like alveoli, intense epithelial lining by numerous blood capillaries; for efficient transport of materials to maintain a steep concentration gradient thus faster diffusion rate.
- Covered by thin epithelial lining; providing a short diffusion distance for rapid diffusion of materials.
- Epithelial lining of alveoli & ileum lumen are permeable to allow easy diffusion of materials across them.
- Numerous alveoli, microvilli & villi increase surface area for rapid diffusion of materials.
- Flattened body e.g. platyhelminths, increase surface area for rapid diffusion of materials.
- Some organisms (unicellular organisms) are small in size; to surface to volume ratio for rapid diffusion of materials.

Significance of diffusion

1. Allows exchange of gases at the alveoli in lungs, through stomata etc; Oxygen from air enters the blood capillaries and carbon dioxide from blood into alveolar air by diffusion, according to their concentration gradients.
2. Enhances absorption of digested food materials in the ileums e.g. glucose; Absorption of the digested food substances in addition to other mechanisms also involves diffusion.
3. Enhances movement of hormones from endocrine glands within blood to target cells/organs.
4. Facilitates nerve impulse generation and transmission/propagation; Movement of sodium ions when sodium ion gates open during transmission of nerve impulses; Diffusion of neurotransmitter substances at synapse; thus, enhancing synaptic transmission.
5. Harnesses absorption of some mineral salts by plant roots.
6. Enhances exchange of materials at capillary bed between blood capillaries and respiring tissues; Exchange of materials between blood and tissue cells occurs by diffusion.
7. Enhances excretion of metabolic waste products like ammonia in fresh water fishes; selective reabsorption of substances in the kidney tubules during urinification involves diffusion.
8. Harnesses transportation of materials within cellular cytoplasm.

Simple and facilitated diffusion compared

EXOSMOSIS

- Is the osmotic flow of water out of the cell/Is the loss of water by a cell by osmosis/ Is the osmotic exflux of water out of a cell by osmosis.

Terminologies in osmosis

1. **Water potential**; is the tendency/ability/capacity of a cell/solution to lose water by osmosis. At stp, it is measured in KPa. It is denoted by Ψ/Ψ_{Cell} which is a Greek letter **psi.** Pure water has the highest water potential of zero (0).

Two main factors affect water potential viz;

- Solute potential
- Pressure potential

Effect of solutes on water potential

Adding solute molecules to pure water ("free water") lowers water potential i.e. makes it negative. This is because solute molecules attract the water molecules; water molecules cluster around the solute molecules; as the concentration of solutes increase; clustering also increases; reducing the number of collisions water molecules make with the membrane thus less pressure exerted; leading to further lowering in water potential i.e. becomes more negative.

The more concentrate a solution is, the more negative(lower) is its water potential. Therefore, water flow osmotically from a region of less negative(higher) water potential to one of more negative(lower) water potential.

Hint:

- The tendency of water to move increases with increase in "*free water*" i.e. water; not bonded to solute molecules; Thus, water molecules have high free kinetic energy hence move very freely.
- The negative sign on water potential values is to confuse for clarity consider temperature of −20°C and -10°C; A system with -10°C has more heat than that with -20°C. Thus, heat moves from -10°C to−20°C . The same applies to water potential systems.

2. **Solute potential**; is a measure of the tendency to reduce the water potential of a system(cell/solution) by adding solutes to it.

In other words, it is the ability to a solution to attract water molecules due to dissolved solutes in the solution/ the amount of lowering of water potential due to presence of solute particles.

It's value is always negative since the solute always lowers the water potential and it becomes more negative as more solutes are added to the system.

3. **Osmotic potential**; is the ability of a cell/solution to attract (take in) water by osmosis. Solute potential/osmotic potential is denoted by $\boldsymbol{\Psi_S}$ and always negative since it lowers water potential.

4. **Osmotic pressure**; is the pressure applied to a solution to stop the osmotic inflow of water from the solvent side across a semipermeable membrane/Is the minimum pressure that must be applied to a solution to prevent water molecules from entering the solution by osmosis. The higher the concentration of a solution, the higher the osmotic pressure.

5. **Pressure potential** (cell wall pressure/wall pressure); is the backward pressure exerted by cell wall onto the protoplasm (cell contents) to resist further entry of water by osmosis.it is denoted by $\boldsymbol{\Psi_P}$**.**

It is always a positive pressure except in the xylem when water is under tension.

6. **Turgor pressure;** is the pressure exerted onto cell wall by cell contents (protoplast) due to osmotic intake of water by cell vacuole.

As water continues to flow into the cell vacuole by osmosis, internal hydrostatic pressure builds up; which presses the protoplast against the cell wall thus turgor pressure. When protoplast makes contact with the cell walls; pressure potential develops.

For a plant cell, the effect of cell membrane is so small thus is ignored. Turgor pressure reaches its maximum at full turgor when the cell wall cannot stretch any more.

Therefore, water potential is the algebraic sum of solute/osmotic potential and pressure potential.

i.e. water potential=solute potential+ pressure potential

$$\boldsymbol{\Psi/\Psi_{Cell}} = \boldsymbol{\Psi_S} + \boldsymbol{\Psi_P}$$

$$(\text{Usually} - \text{ve}) \quad (-ve) \quad (usually + ve)$$

7. **Tonicity**: This refers to the degree of concentration of a solution/cell relative to adjacent/nearby cell/solution. It is described using the following terms as described herein;
   (a) **Hypotonic solution**: Is a solution whose osmotic pressure is lower than that of the cell sap. i.e. Is the solution is more dilute compared to the cell sap.

(b) **Isotonic solution**: Is the solution whose osmotic pressure is equal to that of cell sap. i.e. is the solution whose concentration is similar to that of cell sap.

(c) **Hypertonic solution:** Is a solution whose osmotic pressure is higher than that of the cell sap /Is the solution which is more concentrated (less dilute) than the cell sap. i.e. the solution is more concentrated than the cell sap.

NB: The direction of net osmotic flow is governed by difference in water potential of a cell and water potential of a solution/another cell.

E.g. In a dilute solution, if $\boldsymbol{\Psi_S} = -1000KPa$ and $\boldsymbol{\Psi_P} = +500KPa$

Then $\boldsymbol{\Psi_{solution}} = -1000KPa + 500KPa$

$= -500KPa$

If $\boldsymbol{\Psi_{Cell}} = -300KPa$

The; $\Delta\boldsymbol{\Psi} = -500 — 300$

$= -500 + 300$

$\Delta\boldsymbol{\Psi} = -200KPa$

The negative water potential gradient means that water will enter into the cell osmotically.

In a concentrated solution, if $\boldsymbol{\Psi_{Cell}} = -500KPa$ and $\boldsymbol{\Psi_{solution}} = -600KPa$

Then $\Delta\boldsymbol{\Psi} = -500 — (-600)$

$= -500 + 600$

$\Delta\boldsymbol{\Psi} = +200KPa$

The positive water potential gradient means that water will flow out of the cell osmotically.

CELLS AS OSMOMETERS

(a) **Animal cells**

- When an animal cell like a red blood cell is placed in hypotonic solution/distilled water; water potential of red blood cell is lower/more negative than solution/distilled water; water flows into the cell by osmosis; red blood cell swells; to a point when the membrane cannot resist swelling; finally bursts. This is process is called lysis but for red blood cells, it is called haemolysis (blood splitting) due to bursting and oozing out of haemoglobin. However, some animal cells like amoebae don't burst because they possess contractile vacuoles that collect and get rid of excess water as soon as it enters.
- When an animal cell like red blood cell is placed in a strong/hypertonic solution; water potential of RBC is less negative/higher than that of strong solution; water flow out of the cell by osmosis; cell shrinks, shrivels and cell membrane crinkles thus becomes crenated. This process is called crenation.
- In isotonic solution, no net movement of water in or out of the cell by osmosis thus remains unchanged.

Illustrations

Plasmolysis is the shrinking away of protoplast from the cell wall due to osmotic loss of water from the cell to its surrounding.

- At incipient plasmolysis; the cell membrane(protoplast) begins to leave/pull away due to water loss from the cell to the surrounding. **OR** Protoplasts just lose contact with cell walls.
- Wilting is the shrinking of the whole cell including the cell wall, due to evaporation of water from cell surface more than it can be replaced; leading to the collapsing of the whole plant. i.e. is the loss of rigidity of non-woody parts of the plant; no gaps are left between the plasma membrane and cell wall.
- At full turgidity; the cell vacuole has maximum volume and no more osmotic intake of water.

Applications of plasmolysis

- Weed control.
- Food preservation e.g. stem tubers.
- Water conservation in plants due to stomatal closure.

Significance of osmosis

- Promotes absorption of water by root hairs of plant roots.
- Controls opening and closure of stomata in leaves of plants.
- Provides support to herbaceous (non-woody) plants due to turgidity developed as a result of osmotic intake of water.
- Enhances opening and closure of flowers.
- Provides support to leaves due to turgidity developed within the petiole/leafstalks.
- Enhances imbibition of water by osmosis i.e. initial absorption of water by the seed during seed germination.
- Reabsorption of water from kidney tubules into blood stream thus osmoregulation.
- Maintains form and position of plants organs like leaves for maximum sunlight absorption during photosynthesis.
- Controls opening and closure of stomata.
- Harnesses absorption of water in the gut/colon.

- Enhances movement of water across the root cortex.

Osmosis and diffusion compared

(i) **Similarities**

- Both are passive; don't require energy (ATP) to occur.
- Both occur along the concentration gradient.
- Both occur in living and non-living systems

(ii) **Differences**

Osmosis	Diffusion
• Involves movement of solvent molecules. • Occurs across a semipermeable membrane. • Doesn't require channel proteins. • Solvent molecules flow from dilute to concentrated solution.	• Involves movement of molecules or ions. • Occurs across a fully permeable membrane. • Facilitated diffusion requires channel proteins. • Molecules/ions flow from concentrated solution to dilute solution.

ACTIVE TRANSPORT

Defn: Is the movement of materials(molecules/ions) from their region of lower concentration to their region of higher concentration with expenditure of metabolic energy from hydrolysis of ATP.

OR

Is the movement of substances against a concentration gradient with the expenditure of energy.

It involves carrier proteins with ATP binding site and substance binding site.

Cells/tissues where active transport occurs are characterized by;

- Presence of numerous mitochondria.
- High ATP concentration.
- High respiratory rate.

Thus, any factor which affects respiration also affects active transport e.g. temperature, substrate concentration like glucose and oxygen concentration.

Hint: If a cell cannot carry out active transport, it dies as concentration in & out of cell become equal. This can be due to metabolic poisons like cyanide or lack of oxygen.

- Like facilitated diffusion, active transport depends on carrier proteins which have specific receptor sites for the substance to be transported.
- Active transport unlike facilitated diffusion requires the input of metabolic energy; Thus any factor that increases the rate of respiration increases the rate of active transport.

Why cells need active transport?

- The concentration gradient of some substances across the cell membrane at times is not high enough for diffusion to occur at such rates as required by the cell. Energy is thus used to transport such substances by active transport.
- To increase/decrease the concentration of a substance on one side of the cell membrane to a given level even when it is the side with the higher/lower substrate concentrate in comparison to the opposite side.

How active transport occurs?

Mechanism of active transport

During active transport, ATP is either directly or indirectly used to span/shuttle materials across the plasma membrane.

(a) <u>Direct active transport e.g. sodium-potassium pump.</u>

- The substance to be transported attaches on the carrier protein on one side. The carrier protein is phosphorylated by ATP and its configuration changes shape so that the substance is taken to the opposite side of the membrane. Dephosphorylation of the protein occurs so that it returns to its original configuration.

Diagrammatic illustration

FACTORS AFFECTING ACTIVE TRANSPORT

1. **Temperature**

   Increase in temperature, increase the rate of active transport; provided the temperature increase is not beyond optimum. This is because increase in temperature, increases molecular motion of substrate and enzymes due to increased kinetic energy of these molecules; increasing frequency of molecular collision; chances of forming enzyme-substrate complexes increased; thus, end products which are ATP molecules formed more rapidly to power active transport.

   Beyond optimum temperature, respiratory enzymes within carrier proteins are denatured; ATP production reduced thus a decrease in rate of active transport.

   At very low temperatures; respiratory enzymes within carrier proteins are inactive since they move slowly due to reduced kinetic energy gained leading to reduce frequency of collision; ATP production reduced; thus, a decrease in the rate of active transport.

2. **Oxygen availability**

   Increase in oxygen concentration increases the rate of active transport; decrease in oxygen concentration, decreases the rate of active transport. This is because oxygen is required for aerobic production of ATP; increase in oxygen concentration increases ATP production to power active transport thus increase in active transport.

   In absence/ presence of little oxygen; anaerobic respiration occurs; no/little ATP produced thus decrease in rate of active transport.

3. **Respiratory substrate concentration** e.g. glucose.

   Increase in respiratory substrate concentration increases the rate of active transport; decrease in respiratory substrate concentration, decreases the rate of active transport. This is because increase in respiratory substrate concentration increases ATP production since are used in cellular respiration; decrease in respiratory substrate concentration, decreases ATP production due to limiting of cellular respiration thus decrease in rate of active transport.

4. **Availability of enzyme inhibitors/metabolic poisons** e.g cyanide.

   Presence of inhibitors lowers the rate of active transport due to inhibition of respiratory enzymes/carrier proteins by altering the active/binding sites of enzymes/carrier proteins or stoppage of ATP synthesis.

Significance of active transport

(i) Active absorption of digested food end products from ileum into blood stream.

(ii) Active absorption of mineral salts/ions by plant root hairs from soil solution into the plant.

(iii) Enhances excretion of metabolic waste products from cells into extracellular fluids.

(iv) Enhances muscular contraction & relaxation due to pumping out of calcium ions at neuromuscular junction and from sarcoplasmic vesicles.

(v) Harnesses loading and offloading of photosynthates in & out of phloem tissue.

(vi) Facilitates unidirectional transmission of nerve impulses due to repolarization (maintenance of resting potential) by sodium-potassium pump mechanism

(vii) Enhances stomatal opening in plants thus promotes carbon dioxide fixation and photosynthesis.

Diffusion and active transport compared

Similarities

- Both occur in living organisms (involve movement of materials across the cell membrane)
- Both involve solutes (molecules or ions)
- Both facilitated diffusion and active transport involve use globular proteins to move materials.

Differences

Diffusion	Active transport
• Doesn't involve use of energy (ATP) • Materials move along(down) a concentration gradient. • Is non-selective process/ any state of molecules is moved • No need for carrier molecules (for simple diffusion)	• Involve use of energy (ATP). • Materials move against concentration gradient. • Is a selective process (movement of solute molecules only) • Use of carrier molecules involved.

NB: **CYTOSIS**; is a form of active transport involving infoldings of cell membrane into vesicles/vacuoles that move material in and out of cells.

In other words, is a form of active transport involving infolding or outfolding of sections of cell membrane.

It involves bulk transport of materials.

Types of cytosis

(i) Endocytosis

(ii) Exocytosis

- These are active processes involving the bulk movement of materials through the cell membrane either into the cell (endocytosis) or out of the cell (exocytosis).

ENDOCYTOSIS

Defn: Is the bulk transport of materials into the cell by use of cell membrane.

- It occurs by infloding/invagination of the cell surface membrane which encloses the material being take in . the 2 ends of the cell membrane then fuse to form a vacuole within the cell cytoplasm.

Forms/types of endocytosis

(a) Phagocytosis (solid substances)

(b) Pinocytosis (liquid droplets)

(c) Receptor mediated endocytosis(transport)

PHAGOCYTOSIS ("cell eating")

- This involves taking in a material in solid form by use of plasma membrane.
- Cells specializing in the process are called phagocytes like white blood cells that ingest bacteria and amoeba where it is a means of feeding.

Description

During this; plasma membrane invaginates to form a flask-like depression; enclosing the solid/food particles within; the neck of flask-like invagination closes/seals off and pinches off as phagocytic vesicle/food vacuole; which migrates towards the cell centre in cytoplasm; lysosomes move and fuse with phagocytic vesicle/food vacuole; secreting hydrolytic enzymes into the phagocytic vesicle/food vacuole; food particles are digested; soluble products of digestion like amino acids and glucose(simple sugars) are

absorbed into the surrounding cytoplasm; while the indigestible food particles remain in the vesicle/vacuole; vesicle/vacuole moves towards the cell membrane, fusing with it releasing out the indigestibles out of the cell exocytosis.

- It is a selective process e.g. Amoeba takes in nutritional food particles but not non-nutritional particles; white blood cells take in certain bacteria with specific complements.

NB: Materials in food vacuole are not yet part of cell but still bound by cell membrane.

Mechanism of phagocytosis in white blood cells

White blood cell forms cytoplasm extensions called pseudopodia; engulf microbes/bacteria; to form phagocytic vesicle/vacuole called phagosome; which pinches off the cell membrane into the cytoplasm; as phagosome migrates towards the centre; lysosome move and fuse with it forming phagolysosome; hydrolytic enzymes release into; the microbe is digested and products expelled out by exocytosis.

PINOCYTOSIS ("cell drinking")

- This involves taking up a material in liquid form.
- The vesicles formed are usually very small and are called pinocytic vacuoles.
- Similar to phagocytosis but liquid droplets (small particles/proteins) replace the solid particles.
- Pinocytic channels give off pinocytic vesicles which may fuse to form pinocytic vacuole.
- It's highly specific process involving binding of molecules to their specific receptor molecules/sites on the cell membrane.

RECEPTOR MEDIATED TRANSPORT

- Specific substance from extracellular fluid binds to a specific receptor sites on the cell membrane; once receptor sites are filled, the surface falls inwards until a coated vesicle finally separates from the cell membrane.

EXOCYTOSIS

Questions

1. Why organisms take in by phagocytosis?
2. (a) What is active transport? (01 mark)

(b) How is the occurrence of active transport in cells related with the structure of the plasma membrane? (02 marks)

(c) What **evidence** is there to account for the fact that active transport requires energy and it is selective? (02 marks)

(d) Summarize the events that occur in a plant when it achieves full turgidity.

(02 marks)

3. (a) Briefly explain why most cells are spherical in shape. (04 marks)

(b) Give a brief account for the small size of most cells in nature. (06marks)

HISTOLOGY

OUTLINE

- Definition
- Tissue definition
- Advantages & disadvantages of being multicellular
- Plant tissues
  - Simple tissues
    - ✓ Meristematic tissue
    - ✓ Parenchyma tissue
    - ✓ Collenchyma tissue
    - ✓ Sclerenchyma
    - ✓ Modified parenchyma tissues
      - Mesophyll
      - Epidermis
      - Pericycle
      - Endodermis
  - Compound tissues
    - ✓ Xylem tissue
    - ✓ Phloem tissue
- Animal tissues
  - ✓ Epithelial tissues
    - Simple tissues
    - Compound tissues
    - Glands
  - ✓ Connective/skeletal tissues
  - ✓ Muscular tissue
  - ✓ Nervous tissue
  - ✓ Blood
  - ✓ Reproductive tissue

Definition: Branch of biology that deals with the study of tissues.

Tissue: Is a group of similar cells physically linked with associated intercellular substance (connective substances) like hyaluronic acid; to perform a specific function.

OR

- Is a group of similar cells which perform a particular function; physically linked and share intercellular substances/ a group of physically linked cells and associated intercellular substances that is specialized for a particular function(s).
- The cells of a tissue generally have a similar origin in the embryo.
- Tissues improve efficiency with which the body functions by allowing division of labour; with each tissue being specialized for a particular function.
- In unicellular organisms; one cell performs all the functions which are essential to life but not efficiently at all.

NB: Each function requires a different type of cellular organization for efficiency.

- Multicellular organisms; organisms whose body comprises of many specialized cells to perform particular functions.

NB:

- ✓ Groups of cells with similar structure and function=Tissue.
- ✓ Tissues link together and form large functional units called organs.
- ✓ A number of organs working together in a coordinated manner form a system.
- ✓ Organs working=system/organ system.
- ✓ Cooperative and integrated activities of various organ system=organism.

i.e. Cells⟶Tissues⟶Organs ⟶systems⟶Multicellular organism

Advantages of being multicellular (of multicellular state)

(i) Ensures growth of an organism since individual cell with low life expectancy instead of death may just divide.
(ii) Increased efficiency due to cell specialization.
(iii) Greater strength to move and catch prey due to better muscles and skeleton due to increased size and specialization.
(iv) Improved physiological mechanisms due to cell specialization.
(v) Avoidance of predation due to increased size.

Disadvantages of being multicellular (of multicellular state)

(i) Difficulty in obtaining body requirements thus need for development of transport system/Food and oxygen acquisition difficulties thus need for transport system.
(ii) Increased food consumption due to increase in size.
(iii) Need to maintain a constant internal environment of PH, temperature, wastes etc.
(iv) Bulky organisms thus more energy demand.

Question: Explain any four (4) advantages of multicellularity over unicellularity. (04 marks)

Solution

- Cells become differentiated to perform a particular function leading to greater efficiency compared to unicellular organisms;
- It's possible to store more materials to be able to better withstand periods of their scarcity compared to unicellular organisms;
- It's easier to separate the regions of opposing conditions in a multicellular organism like digestion often has acidic and alkaline phases; which is not possible in unicellular organisms;
- If some cells are damaged enough may still remain to carry out the repair compared to unicellular organisms;
- Large organisms have a better competitive advantage like larger plants favourably compete for sunlight compared to small ones;
- Large size also offers a protective advantage from predators since organisms are too large to ingest;

PLANT TISSUES

- Plant tissues are categorized as **simple tissues**; if they are made up of only one type of cell. Like parenchyma tissue or **compound tissues;** if they comprise of a mixture of different cell types like xylem.

1. **Simple tissues**
   - Meristematic tissue
   - Parenchyma tissue
   - Collenchyma tissue
   - Sclerenchyma tissue
   - Modified parenchyma tissues
     - Epidermis

- Mesophyll
- Pericycle
- Endodermis
- Transfer cells

2. **Compound tissues**
   - Xylem tissue
   - Phloem tissue

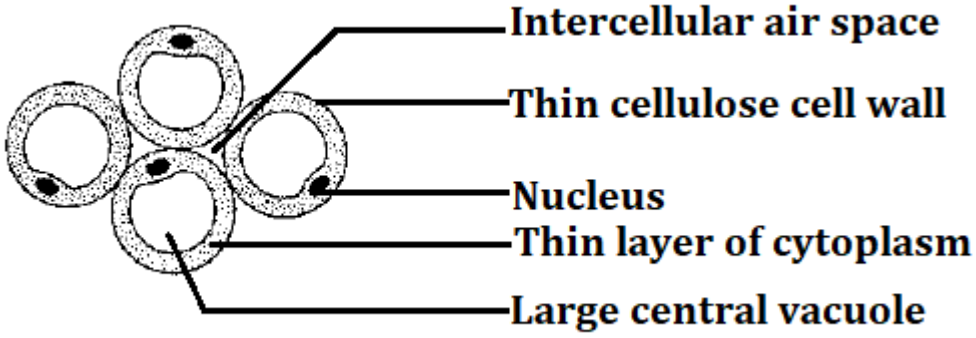
NOTE: For each tissue, try to understand the following;

- ❖ Structure of tissue cells
- ❖ Characteristics
- ❖ Distribution/location.
- ❖ Functions
- ❖ Adaptations to the function(s)

1. **PARENCHYMA TISSUE**

Structure

- Parenchyma tissue is comprising of roughly spherical cells; with large central vacuole, and thin layer of cytoplasm at the periphery/edges.
- The unspecialized parenchyma tissue also possesses many intercellular airspaces.
  Transverse section through the parenchyma tissue



Characteristics

- Spherical/isodiametric cells; elongated longitudinally.
- Cells are packed together.
- Have intercellular air spaces; gaseous exchange.
- Thin cell wall; allowing expansion; impregnated with cellulose, pectin, hemicellulose.
- Unspecialized cells.
- Living cells & metabolically active.
- Dense peripheral cytoplasm; large vacuole.

Distribution and function

- The unspecialized cells serve as a packing tissue between more specialized tissues like in the central pith of stems, and outer cortex of stems and roots. It makes the bulk of young stems.
- Osmotic functions of parenchyma cells ensure that when turgid, they become tightly packed and provide support for the organs in which they are found. Like in stems of herbs.
- The cells are living thus transport of materials and remain metabolically active and are sites of many vital activities of the plant body.
- They are often sites of food storage like in storage organs such as stem tubers which store starch.
- Walls of parenchyma are important pathways for water and mineral salts through the plant.

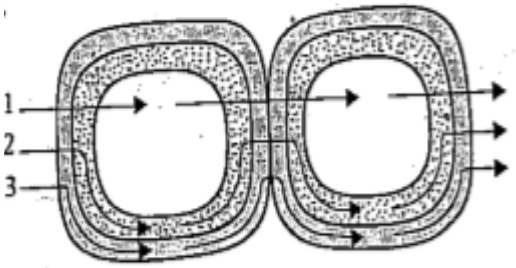
Summary of location/distribution

- Cortex
- Pith
- Medullary rays; occur during secondary growth; differentiated into xylem & phloem.
- Xylem tissue } packing tissue
- Phloem tissue }

Summary of functions

- Packing tissue
- Storage tissue; root tubers, stem tubers, fruits, seeds etc.
- Can be modified into other cells.
- Provide support when turgid to the herbaceous plants(herbs)
- Gaseous exchange
- Transport of materials; apoplast; symplast; vacuolar pathways.

Illustration of pathways



Where; 1= Vacuolar pathway

2=Symplast pathway

3=Apoplast pathway

Adaptations of parenchyma tissue

- Living cells for transportation of materials and remain metabolically active.
- Intercellular airspaces for gaseous exchange/transport of materials.
- Chloroplasts with chlorophyll for photosynthesis.
- Starch granules/amyloplasts for food/starch storage.
- Isodiametric/roughly spherical cells/elongated cells for packing materials between specialized cells/for storage of much food/starch.
- Thin/transparent cell walls to enhance transport of materials/expansion/ easy light penetration.
- Large vacuoles for storage of much materials.
- Undifferentiated cells to perform a variety of functions.

Modification of the parenchyma tissue

- Parenchyma cells can be modified to form;

(i) **Epidermis/epidermal tissue;** is a one (1) layer of cells; cover whole primary plant body; external surface.

- This is formed by modified parenchyma cells which secrete **cutin**, a waxy substance that forms a layer of **cuticle** around the plant. This reduces water loss by the evaporation from the plant and prevents entry of pathogens.
- Guard cells are specialized epidermal cells with a pore called **stoma**. The turgidity of the guard cells adjusts the size of the stoma allowing **gaseous exchange** and **transpiration**.
- Epidermal cells can grow hair-like extensions called **root-hairs**. They serve to <u>absorb water</u> and <u>mineral salts</u> for the plant.

Functions

- Protection of internal organs against;
  - Desiccation
  - Infection
  - Mechanical damage

  } secrete <u>cutin</u>; forms cuticle; water proof.
- Specialized epidermal cells; guard cells; control stomatal opening and closure.
- Hair-like structures on epidermis; like root hairs; increase surface area for water and mineral salts absorption in roots.

- Hooked hairs of climbing stems; prevents slipping off the supports.
- Epidermal hairs of leaves; reduce water loss; reflect sun's radiations.
- Allow light penetration to mesophyll cells due to transparency.
- Glandular cells on cuticle; secrete sticky substance for trapping and killing insects; secrete scent for attraction of pollinators;

Question:

(a) State the functions of epidermal tissue. (05 marks)
(b) Describe how the structure of the epidermal tissue relates to its roles/functions. (10 marks)

Solution

(a)

- Minimizes water loss by transpiration thus preventing desiccation;
- At times, cells have hairs, trichomes for trapping a layer of moisture/root hairs for absorption of water and mineral salts;
- Permits gaseous exchange through stomata on leaves;
- Offers protection by preventing entry of pathogens;
- Performs a secretory function like some epidermal cells contain glands that secrete sticky fluids in insectivorous plants for trapping insects;
- Etc **@01MK, 05MKS**

(b)

- Has a waxy cuticle that prevents desiccation by reducing waterloss via transpiration;
- Has a hairy cuticle that traps a layer of moisture thus reducing waterloss by transpiration;
- Has 1 layer of cells; provide a short diffusion distance for rapid diffusion of materials in and out of epidermal cells;
- Has cells with thin permeable cell wall; that permit materials diffuse in and out of epidermal cells;
- In leaves, it is perforated by stomata for gaseous exchange;
- On roots, has root hairs for absorption of water and dissolved mineral salts from soil, essential for plant growth;
- In leaves, it is transparent to allow easy sunlight penetration to photosynthetic tissue thus enhancing photosynthesis; **@02MKS; 14MKS,10MAX**

(ii) **Mesophyll cells (chlorenchyma tissue)**

- A mass of cells between the two epidermal layers of the leaves. i.e. Packing tissue between upper and lower epidermis of leaves. The parenchyma cells have been modified to carry out photosynthesis, thus called <u>chlorenchyma</u>.

- Photosynthesis is mostly carried out in the palisade mesophyll with high amount of chloroplasts while the larger intercellular air spaces between the spongy mesophyll allows efficient gaseous exchange.

Question:

(a) Describe how parenchyma tissue is modified to its functions. (10 marks)
(b) Structure and function are closely related. By reference to a parenchyma tissue, discuss how far this statement is true. (10 marks)

OR

Describe the adaptations of the parenchyma tissue for its function. (10 marks)

Solution

(a)

- Parenchyma cells are modified into epidermis, chlorenchyma, endodermis, pericycle, companion cells, mesophyll cells and transfer cells;
- Epidermis has one layer of flattened elongated living cells covering external surface of plant body; with cell wall impregnated with cellulose, pectins and hemicellulose; for protection of underlying tissues against mechanical damage; provision of mechanical support; covered by a waxy cuticle at times to reduce water loss/desiccation;
- Chlorenchyma, parenchyma cells contain numerous chloroplasts for photosynthesis; fills the gap between lower and upper epidermis in the mesophyll of leaves thus serving as packing tissue; have starch granules for storage of starch;
- Endodermis, has living flattened cells whose cell walls impregnated with pectin and water proof fatty suberin; forming casparian strip that prevents entry of pathogens; exerts root pressure for ascent of water and dissolved mineral salts due to stoppage of water flow by apoplast pathway; forms innermost layer of cortex around the vascular tissue.
- Pericycle has living cells with retained meristematic activity/ability to divide by mitosis; produce lateral roots thus contribute to secondary growth in roots;
- Companion cells, living modified parenchyma cells with a prominent nucleus, dense cytoplasm and numerous mitochondria thus a high metabolic activity; generating a lot of ATP needed for loading and offloading sugars in the sieve tube/element.

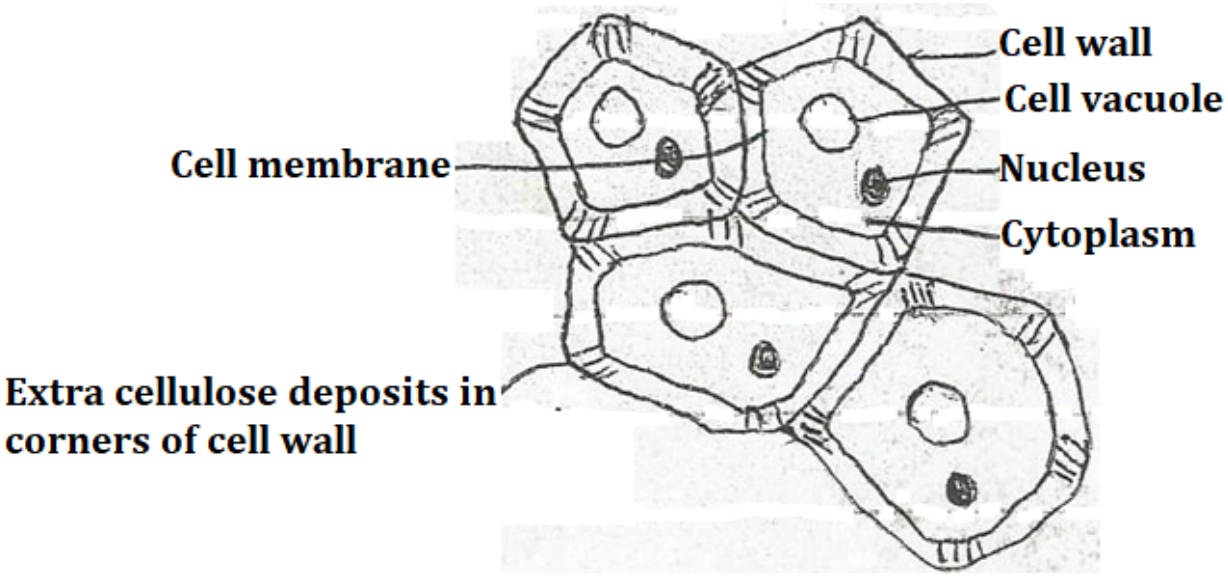
(b) See Adaptations

Question: Describe the distribution and function of parenchyma tissue in a plant body. (14 marks)

2. **COLLENCHYMA TISSUE;** Mechanical tissue, 1st develop; "*closed shape*".
   - It consists of living cells usually modified to give support and mechanical strength.

- The cells are polygonal in outline, with thickened corners due to deposition of extra cellulose at the corners of these cells (in transverse section).
- In longitudinal section, the cells appear elongated and parallel to each other with pointed end walls. The side walls have thick and thin parts(regions).

Structure



Characteristics

- Cells are elongated longitudinally.
- Cells are pentagonal/hexagonal (polygonal).
- Cells are living and can stretch.
- Have extra cellulose depositions at corners.
- Closely packed with very little/no intercellular airspaces.
- Cell walls impregnated with cellulose, pectin, hemipectin, hemicellulose; strengthening materials.

Distribution and function

- Is a mechanical tissue, providing support for organs in which it is found.
- Its important in young plants, herbaceous plants and organs like leaves where secondary growth does not occur. In these conditions, it strengthens the organ supplementing on the effects of turgid parenchyma tissue.
- It is the first strengthening tissue to develop in primary plant body because it is living and therefore can grow and stretch without imposing limitations on the growth of other cells around it.
- In stems and petioles, its value in support is increased by its location just on the periphery of the organs below the epidermis.

- In leaves of dicots, it appears as a solid mass running the length of the midrib providing support for vascular bundles.
  Summary of location/distribution; Organs where secondary growth doesn't occur like;
  - ✓ Stems of herbaceous plants.
  - ✓ Midribs of leaves
  - ✓ Petioles of leaves
  - ✓ Fruit stalks etc
- **Function emphasis**: Mechanical support; together with turgid parenchyma.
  Adaptations to the function
  - Deposition of extra cellulose at corners for support/mechanical strength.
  - Living cells, can grow/stretch; mechanical strength without imposing limitations; on growth of other cells around it, allowing continued growth in young stems/leaves.
  - Cells towards periphery of organs; below epidermis; for increased support valve in stems & petiole.

3. SCLERENCHYMA TISSUE

COMPOUND TISSUES

- These plant tissues consist of more than one type of cell. And these are, the xylem and phloem and together they constitute to the vascular tissue whose function is in translocation.

XYLEM TISSUE

- This has 2 major functions; conduction of water & mineral salts and support. Thus, it has both a physiological role and a structural role in the plant.
- It consists of 4 cell types; tracheids, vessel elements, parenchyma and fibres.

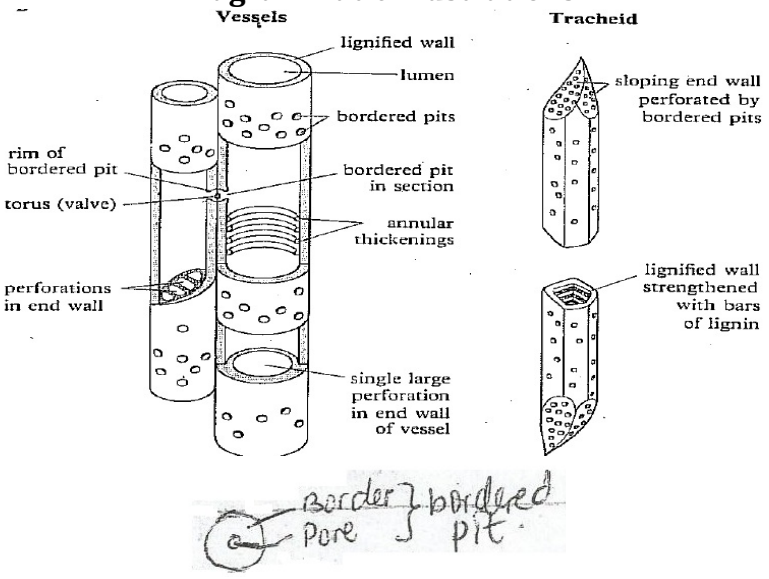
Tracheid

- These are single cells that are elongated and lignified.
- They have tapering endwalls that overlap with adjacent tracheids. They are dead cells, with empty lumens and perforated endwalls when mature.
- Have mechanical strength and give support to the plant.
- Are the only conducting vessels in conifers as water can pass through the empty lumens without being obstructed by living contents and passes from tracheid to tracheid through pits.

Vessels

- These are the characteristic conducting units of angiosperm xylem.
- Are long, tubular structures formed by the fusion of several cells end to end in a row as a result of their endwalls breaking down. Each cell of the xylem vessel is called a vessel element.
- Vessel elements are however, shorter and wider than tracheids and are open ended.

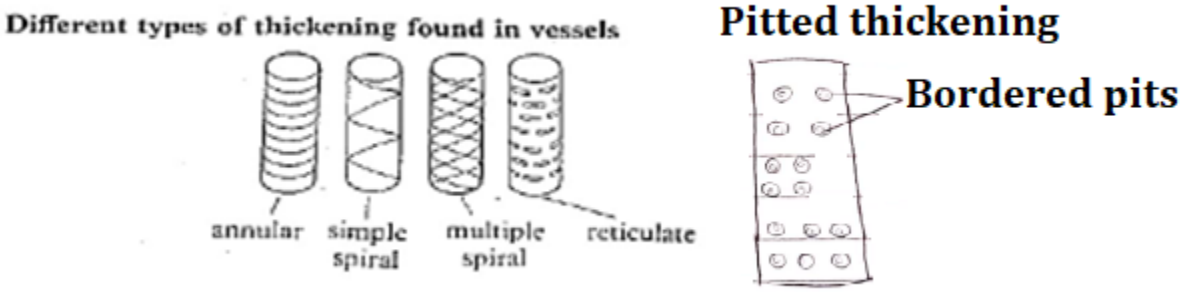
Diagrammatic illustrations



Tracheid with bordered pits

Protoxylem and metaxylem

- The first vessels form the protoxylem, located in the part of the apex, where elongation of surrounding cells is still occurring.
- Mature protoxylem vessels can be stretched as the surrounding cells elongate because lignin is not deposited over the entire cellulose cell wall, but only in rings or spirals as shown below.
- These act as reinforcement for the tubes during elongation of the stem or root.
- Metaxylem is formed when more vessels are formed and undergo extensive lignification completing their development in the mature regions of organ.
- Mature metaxylem vessels cannot stretch or grow because they are dead, rigid, fully lignified tubes. If they developed before the living cells around them had finished elongating, they would limit the elongation of such organs and thus the plant.
- Metaxylem vessels show 3 basic patterns of lignification-that is scalariform, reticulate and pitted.



The role of xylem in plant support

- One of the functions of the xylem is support. It is fulfilled by a collection of lignified tubes.
- In the plant primary plant body, the xylem distribution is central in roots. Thus, they are able to withstand the tagging strains of the aerial parts as they bend or lean over.
- In the stems, xylem is peripherally arranged, in a ring in dicots or scattered in monocots so that in both, separate rods of xylem run through the xylem to provide support.
- This is reinforced by secondary growth with extensive xylem taking over from collenchyma and sclerenchyma as the chief mechanical tissue.

Question: Describe how xylem tissue is suited to its functions. (15 marks)

- Has lignified dead cells; thus, don't use up water in transit;
- Has dead cells with no protoplasm thus empty lumens; to permit easy flow of water;/to prevent impediment of water flow;
- Has long and tubular/hollow vessel elements; thus, able to maintain a transpiration stream for continuous flow of water over long distances;
- Has open ended vessel elements/elongated cylindrical cells joined/connected end to end forming pipe-like vessels/tubes/hollow pipes; suitable for material transportation;/to enhance continuous flow of water column;/has cells with dissolved end walls to form a continuous hollow pipe; for continuous flow of water over long distances;
- Has cells with lignified walls; to prevent water leakage/ensuring no escape/loss of water and mineral salts;
- Has cells strengthened by lignin/lignified walls; to prevent collapsing when pressure inside reduces;/bursting when pressure inside increases;
- Has cells with bordered pits; for lateral conduction/movement of water and dissolved mineral salts/minerals; some vessels have torus; to control lateral flow of materials/water; on transit.
- Has tracheids with narrow lumens; to maintain/cause water flow by capillarity; OR to increase the pressure of materials on transit; **@01MK, 20MKS, 15MAX**

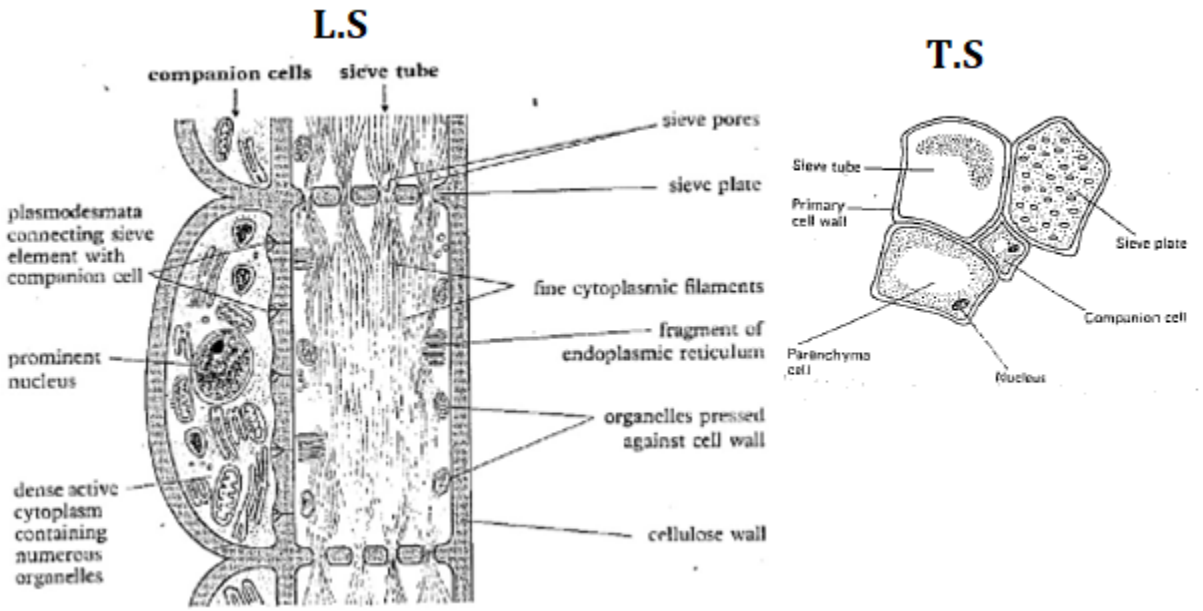
PHLOEM TISSUE

- This is a living tissue, composed of tubular structures modified for translocation. The tissue has no mechanical function.
- It is composed of mainly sieve tube elements and companion cells.

Sieve tubes and companion cells

- Sieve tubes are long tubular structures that translocate solutions of organic solutes like sucrose, throughout the plant.
- Are formed by end-to-end fusion of cell called sieve elements which in turn develop from procambium.
- The first phloem formed is called protophloem; produced in the zone of elongation of the growing root or stem. As tissues around in elongate, it becomes stretched and much of it eventually collapses. It is replaced by the metaphloem after elongation has ceased.
- Sieve tubes have a cellulose cell wall, without a nucleus which degenerate during development, with a thin layer of cytoplasm around the periphery of the cell.
- Also, they lack nuclei, the sieve elements remain living but are dependent on the adjacent companion cells which have dense, very metabolically active cytoplasm.

- Sieve tubes have sieve plates derived from the two adjoining endwalls of the neighbouring sieve elements which are perforated by large pores called sieve pores which allow the flow of solution from one element to the next.
  Diagram of phloem tissue in LS



QUICK FACTS ON PHLOEM TISSUE

Functions

- Translocation of manufactured food/ hormones/ photosynthates from leaves to other parts.

Cells present

1. Sieve tube elements
2. Companion cells
3. Phloem parenchyma (transfer cells)
4. Phloem fibres
5. Sclereids

SIEVE TUBE ELEMENTS

- Joined end to end forming; sieve tubes; no living cells
- No nucleus; numerous fine cytoplasmic filaments.
- Peripherial cytoplasm
- It's believed that mitochondria exist in peripherial cytoplasm; provide energy for translocation.

- Perforated sieve plates; at end of sieve elements important in translocation.
- Believed that fine cytoplasmic filaments exist and are important in translocation by cytoplasmic streaming.

ANIMAL TISSUES (RCMEN)

(i) Epithelial tissues; protection, absorption, secretions, sensory, absorption (PASS)
(ii) Connective/skeletal tissues; binding, support, protection, transport & circulation (BSc.P)
(iii) Muscular tissues; movement & locomotion.
(iv) Nervous tissues; conduct impulses, control, coordination (IC^2).
(v) Reproductive tissues; reproduction.

A. EPITHELIAL TISSUES (GCS)

- Epithelial tissue/epithelium is a lining tissue. In its simplest form, it consists of a single layer of cells covering the surface of animal and organs, cavities and tubes within it.
- It is arranged in single or multilayered sheets of cells. Typically, the individual cells are firmly attached to each other and rest on a basement membrane; which is composed of a network of fibres (protein). It is not a barrier to diffusion and it is produced by the epithelial cells themselves.
- Epithelial tissues are not supplied by blood vessels and the cells are nourished through diffusion of substances.
- They can be classified as **simple** if they bear only one cell thick or **compound** if they have more than one cell thick**.**

QUICK FACTS ON EPITHELIAL TISSUES

- Cover external and internal surfaces (endothelium) of the animal body and organs.

Structure

- Closely packed cells, lack intercellular space.
- Non-cellular basement membrane with network of collagen fibres for layers of cells to rest on.
- Cells held (Cemented) together by a carbohydrate derivative cementing substance; g hyaluronic acid.
- Not supplied by blood vessels (with blood), obtain nutrients/materials from lymphatic vessels/tissue fluid by diffusion.
- Free surface modified into cilia, stereocilia and microvilli (MSC).
- Cells with glands, sensory cells and nerve endings (SGN)
- Are innervated.

Location

(i) Cover all internal and external surfaces of body and body organs.
(ii) Line body cavities of hollow body organs and cavities; e.g. digestive system.
(iii) Form inner lining of blood vessels though it is not considered as true epithelium.

1. SIMPLE EPITHELIAL TISSUES/EPITHELIA

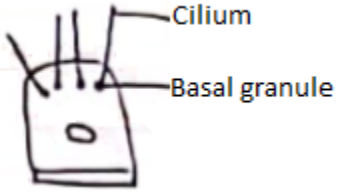
- ✓ Single layer of cells.
- ✓ All cells rest on basement membrane.
- ✓ Very effective at secretory/absorptive role.
- ✓ Very thin thus less/not effective at protecting.
- ✓ Cuboidal and columnar at times with cilia.
- ✓ Cilia set up current and move materials in a particular direction.
- ✓ Free surface of cuboidal/columnar may be modified also as microvilli; to increase surface area for absorption.
- ✓ Epididymis and vasa deferens in man; free surface modified into stereocilia; taper at top.
- ✓ Types of simple epithelial tissue; squamous; cuboidal, columnar and pseudostratified.

NB: Hyaluronic acid cements epithelial cells together.

- ✓ Stress of epithelial tissues combated by being thickened and keratinized.
- ✓ Free surface may be used for absorptive, secretory, excretory or even sensory function to detect stimuli if with nerves.

(a) **Modifications of epithelial free surface**

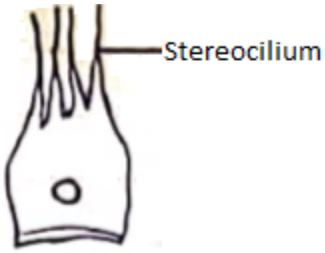
(i) Cilia



Nature

- Thin, motile hair-like protoplasmic extensions.
- Have basal granule in cytoplasm.
- In respiratory system and reproductive tract.
- Associated with flow of materials in a particular direction.

(ii) Stereocilia

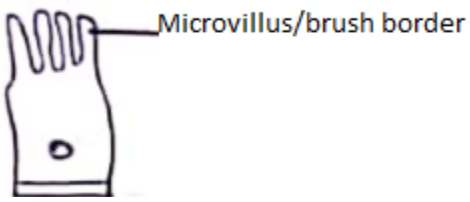


Nature

- Elongated non-motile cytoplasmic extensions.

- Broad at base, taper at top.
- In epididymis and vasa deferentia.
- Associated with spermal(sperms) flow.

(iii) Microvilli (brush bordered)



Nature

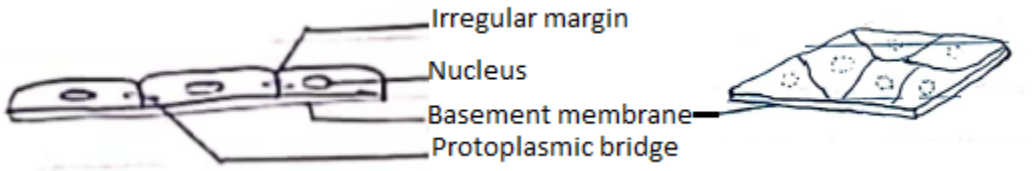
- Thin, short, closely packed invaginations.
- Brush border appearance.
- In nephrons and intestines.
- Increase surface for absorption of materials.

(b) **Types of simple epithelial tissues/epithelia**

(i) Simple squamous epithelium/epithelial tissue(pavement)

Structure

Side view **surface view**



Description

- It is made up of thin, flattened cells, with an irregular outline.
- There are special tight junctions between neighbouring cells which aid in binding them firmly together.
- Occur in areas like the renal capsules of the kidney, the alveoli of lungs and the blood capillary walls where its thinness permits diffusion of materials through it.
- In blood vessels, it is referred to as endothelium.
- It also provides smooth linings to hollow structures like blood vessels and chambers of the heart; where it allows the relatively friction-free passage of fluids through them.

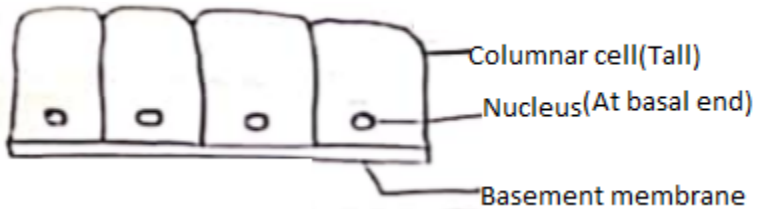
QUICK FACTS ON SQUAMOUS/PAVEMENT EPITHELIUM

(ii)

(iii) **Simple columnar epithelium**

- These are tall and narrow. Each cell has a nucleus situated at its basal end. Goblet cells which secrete mucus are often interspersed among the epithelial cells.
- The epithelium can be secretory or absorptive.
- Some of the cells have a brush border of microvilli at the free surface end. They line the stomach, small intestines and kidney ducts and it is a component of thyroid gland.

Structure



Quick facts on columnar epithelium

Description

- Tall, column-like narrow cells, nucleus at basal end, interspersed by goblet cells often.
- i.e. Elongated cells perpendicular to the basement membrane, narrow cells with oval shaped nuclei located near basement membrane.

Location

- Line; stomach, intestines, gall bladder and kidney ducts.
- Present in gastric and intestinal, salivary, thyroid glands.

Function: Secretion, absorption, mucus release for protection and lubrication (SAM)

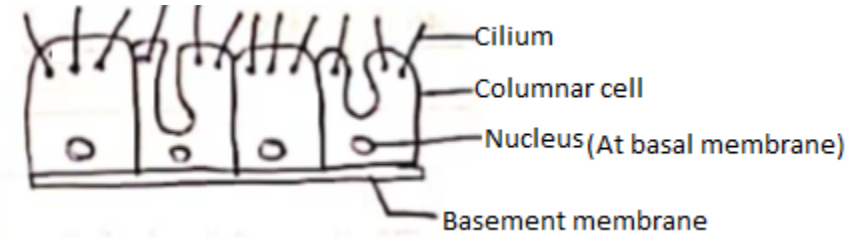
Accessory structures: Cilia, goblet cells.

Modifications

(a) Ciliated columnar epithelium/ciliated epithelium

- Cells of this tissue are often columnar in shape, but bear numerous cilia at their free surfaces. They are always associated with goblet cells, producing fluids in which the cilia set up currents.
- The epithelium lines the inside of oviducts, ventricles of the brain, spinal canal and respiratory passages where it serves to move materials from one location to another.
- In the respiratory tract, the mucus traps bacteria, dust and other small particles preventing them from reaching the lungs.

Structure



QUICK FACTS ON CILIATED EPITHELIUM

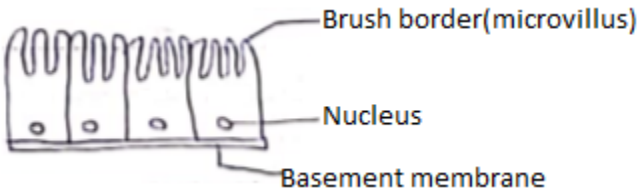
Description: Cilia at free surface/end, mucus secreting goblet cells between.

Function: Flow of fluids in particular direction; removal of dust particles in air tracts; movement of ova in oviduct.

Location: Oviducts, respiratory passages (tracheal & bronchi) in ventricles of brain and spinal cord (SORV).

(b) Brush bordered columnar epithelium

Structure



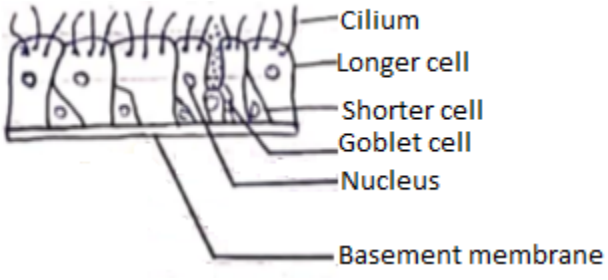
Description: Microvilli at free ends.

Location: Intestinal mucosa.

Function: Increased surface area for nutrients' absorption.

(iv) Pseudostratified epithelium

Structure



Description

- One layer of columnar cells but appears 2 layered.
- Nuclei at different levels.
- Some cells do not reach free surface and lack cilia.
- Longer cells reach free surface and have cilia.
- Shorter cells secrete mucus.
- All cells rest on basement membrane.

Location: Part of nosal epithelium (olfactory mucosa), line trachea and primary bronchi; urinary tract.

Function:

- Mucus traps germs and dust.
- Cilia expel them outwards.
- i.e. Removal of pathogens & dust particles in air tracts.

Accessory structure: Cilia, goblet cells.

2. **Compound epithelial tissues**
   - ✓ Many layers of cells only lower layer rests on basement membrane.
   - ✓ Could be stratified or transitional.

(i) **Stratified epithelium** (protective)

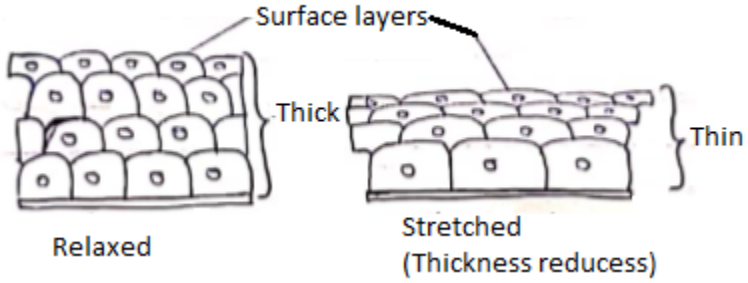
- The tissue is made up of a number of cell layers. It is thus thicker than simple epithelium and forms a relatively tough impervious barrier.
- The cells arise by mitotic division of cells in the germinal layer which rests on a basement membrane.
- The first formed cells are cuboid in shape, but as they are pushed outwards towards the free surface end, they become flattened and, in this condition, they are called **squames**.
- They can remain uncornified like in the oesophagus, where the epithelium protects the underlying tissue against mechanical damage by friction with food just swallowed.
- In some areas of the body, the squames can be transformed into a dead horny layer of **keratin** which eventually flakes away. In this

condition, the epithelium is said to be **cornified** and is found in particular abundance of external skin surfaces, lining the buccal cavity/mouth and vagina, where it affords protection against **abrasion**.

(ii) Transitional epithelium

- It consists of layers of cells all of similar size and shape except those of the outermost/superficial layer which are more flattened.
- The surface cells do not slough off and all cells are able to change shape depending on the degree of distension.
- This property is important in locations where structures are subjected to stretching like urinary bladder and ureters.
- The cells have a highly keratinized cellular membrane which makes the epithelium relatively impermeable to water and salts. On addition, the cells are connected by tight junctions which prevent urine escaping into the surrounding tissue.

Structure



Quick facts on transitional epithelium

Description

- ✓ 3-4 layers of cells, all of similar size and shape.
- ✓ Except at free surface; more flattened.
- ✓ Superficial cells do not slough off.
- ✓ Cells modify their shape on stretch.

Location: Areas subjected to considerable distention like urinary bladder, ureter and pelvic region of kidney.

Function

- ✓ Thickness prevents escape of materials to surrounding tissues.
- ✓ Distention enables expansion to accommodate more materials and prevents rapturing like in urinary bladder.

3. Glandular epithelium
   - ✓ Consists of modified epithelium into secretory glands.
   - ✓ Glands have cuboidal or columnar epithelium.
   - ✓ A gland is a cell or group of cells that is specialized to secrete particular chemical substances for use in the body of the organism or for discharge into the surroundings

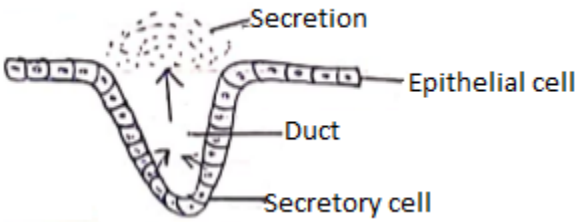
Types of glands

(i) Basing on ducts and kind of secretion.

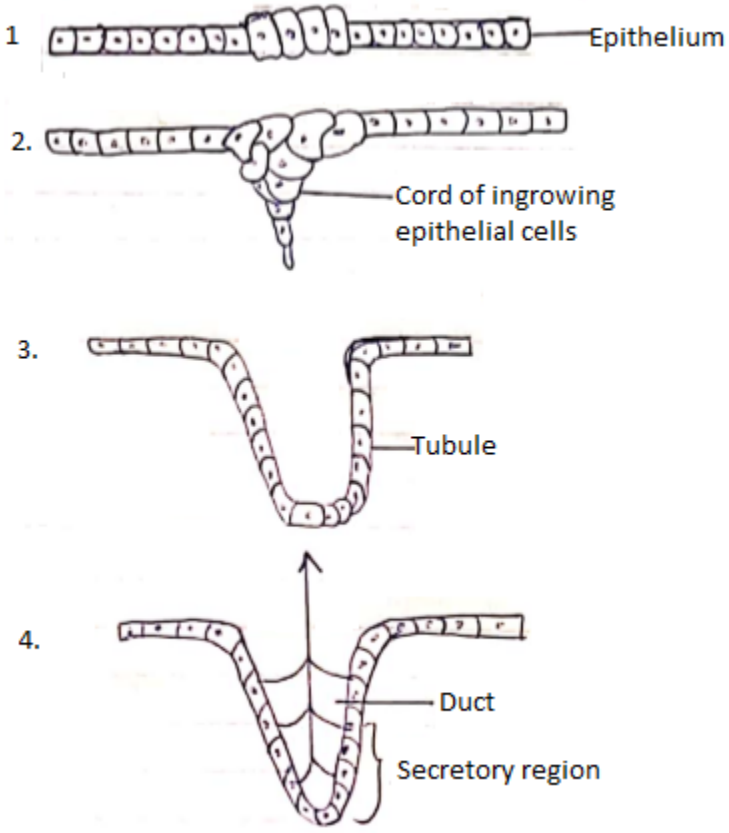
(a) **Exocrine glands;** these discharge their secretions through a duct into/out of the body. i.e. Pour their secretions through ducts to the respective sites of action.

- ✓ Secretions are mainly enzymes.
- ✓ Glands could be simple or compound like salivary, tear, gastric and intestinal glands.

Illustration



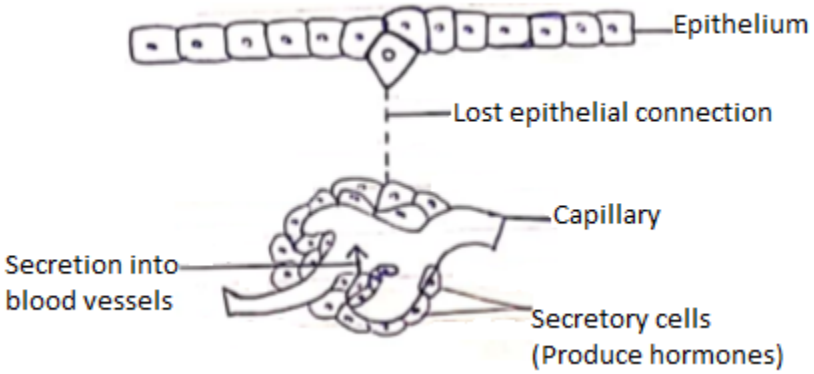
Formation of an exocrine gland



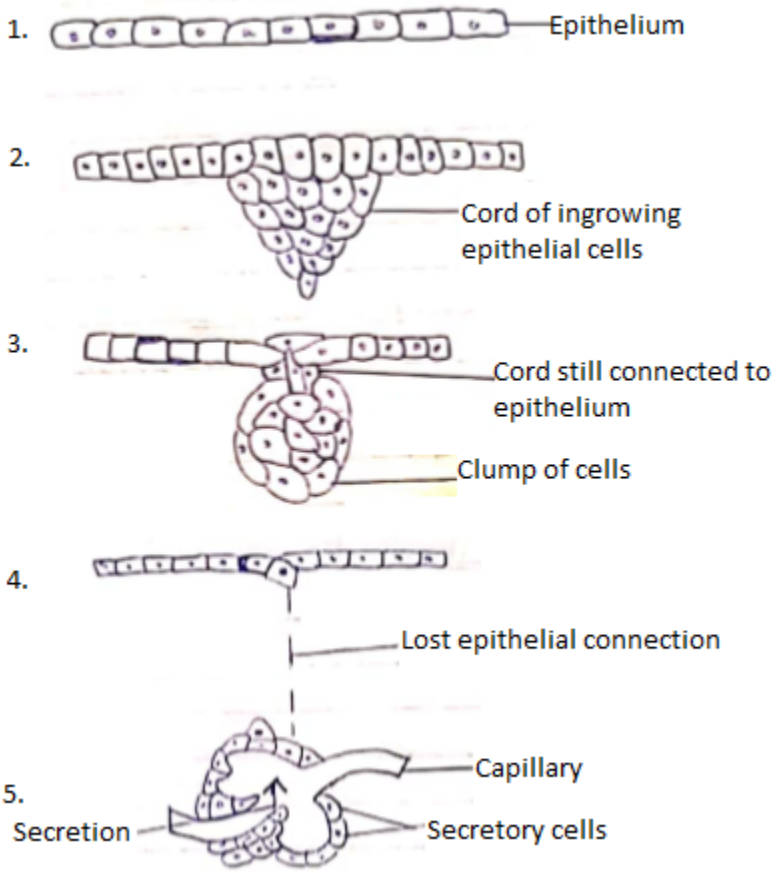
(b) Endocrine glands

- ✓ Pour their secretions directly into the blood stream because they lack ducts.
- ✓ Secretions are hormones.
- ✓ Hormones thus have effects far away from production areas.
- ✓ Like pituitary , thyroid, parathyroid and adrenal glands etc,

Diagram showing an endocrine gland



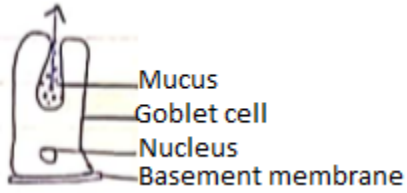
Formation of and endocrine gland



(ii) Basing on number of cells making the gland

(a) Unicellular gland

- ✓ Individual epithelial cell modified into a glandular cell like goblet cell.
- ✓ Often interspersed between cuboidal epithelium.
- ✓ Produce mucus; eases food movement.
- ✓ Hence mucus epithelium.



- ✓ Goblet between cuboidal; mucus.

(b) Multicellular gland

- ✓ Formed from aggregation of a number of glandular cells like sweat glands, gastric glands etc; Endocrine and exocrine glands.

(1) Simple glands; 1 layer of cells.

(2) Compound glands; many layers of cells.

(iii) Basing on shape and complexity

- ✓ For exocrine glands.

Different forms of multicellular exocrine glands/ Types of exocrine glands

Gland type	Structure	Location
(a) Simple tubular	 ▪ Elongated ▪ Tube-like	❖ Crypts of Leiberkuhn in ileum of higher vertebrates/in the wall of the mammalian intestine.
(b) Simple coiled tubular	 ✓ Coiled secretory tubule.	❖ Sweat glands in human skin.

(c) Simple branched tubular	 ✓ Branches into tubules with single duct.	❖ Gastric glands in gastric wall. ❖ Brunner's glands of intestines.
(d) Compound tubular	 ✓ Many ducts form branching system.	❖ Brunner's glands. ❖ Salivary glands.
(e) Simple branched alveolar	 ✓ Number of sacs open in same duct.	❖ Sebaceous glands in mammalian skin.
(f) Compound alveolar	 ✓ Many ducts form branching pattern from sac-shaped secretory cells.	❖ Exocrine parts of pancreas. ❖ Mammary glands.
(g) Compound tubular alveolar	 ✓ Many branched ducts possessing a mixture of tubular and	❖ Submaxillary salivary glands. ❖ Mammary glands. ❖ Salivary glands.

	alveolar secretory region.	
(h) Simple alveolar	 ✓ Sac-shaped secretory region.	❖ Mucus secretory glands in skin of frog.

(iv) Basing on mode of secretions; Exocrine glands (HAM)

(a) Holocrine glands;

✓ Entire cell breaks down in order to release its secretions which extrude from the epithelial surface. Like sebaceous glands in mammalian skin.

(b) Apocrine glands;

✓ Cell loses part of its cytoplasm while releasing its secretions.

✓ Secretions stored in apical part of cell which bursts open to release secretions like mammary glands.

(c) Merocrine glands;

✓ Secretions within cell discharged on cell surface without losing any of its cytoplasm –i.e. cells remain intact. Like goblet cells, pancreatic glands and sweat glands.

(v) Basing on nature of secretions

(a) Mucus glands; secretion is a viscous mucus fluid. Like goblet cells in intestines.

✓ Cells called mucocytes.

(b) Serous glands; secretion is a clear watery fluid containing enzymes. Like sweat glands.

✓ Cells termed as serocytes.

(c) Mixed glands; with both mucocytes and serocytes producing both kinds of secretions.

✓ Like gastric glands and pancreatic glands.

General functions of epithelial tissues

i) Protection; underlying tissue from injury by chemicals, pressure, abrasion and infection (CAPI).

ii) Secretion; many modified to produce secretions inform of mucus, enzymes or hormones.

iii) Excretion; epithelial cells of kidney tubules and sweat glands remove toxic metabolic wastes from the body.

iv) Absorption; free surface of cuboidal and columnar epithelia modified into microvilli and villi which increase surface are for absorption of materials like in intestines.

v) Exchange of materials; thin squamous epithelium permits diffusion of gases through alveoli lining, blood capillaries, Bowman's capsule.

vi) Sensory; epithelial lining bearing sensory cells and nerve endings is specialized to receive stimuli and respond to environment like skin and retina.

Questions

1. Describe the structure, functions and distribution of epithelial tissues. (20 marks)

1.

(a) What is meant by;
   (i) Merocrine gland. (04 marks)
   (ii) Apocrine gland. (03 marks)
   (iii) Holocrine gland (02 marks)
   Giving an example in each case.

(b) Give the various forms of multicellular exocrine glands and indicate the location of each. (11 marks)

Solutions

CONNECTIVE TISSUES (supporting, BSc.P & Binds)

- They are the major supporting tissues of the body and they include; the skeletal tissues, bones and cartilages etc
- Also bind other tissues together like epithelia of mesenteries.
- They also form sheaths like bags around the organs of the body, separating them so that they do not interfere with each other's activities, as well as surrounding and protecting blood vessels and nerves where they enter or leave organs.

(a) **The 3 basic components**

(i) Cells;

- Widely separated living components.
- i.e. Large intercellular spaces between them.
- They have a mesodermal origin.

(ii) Fibres;

- Several types scattered between cells.
- Non-living products of cells.
- Form extracellular material and blood is devoid of them.

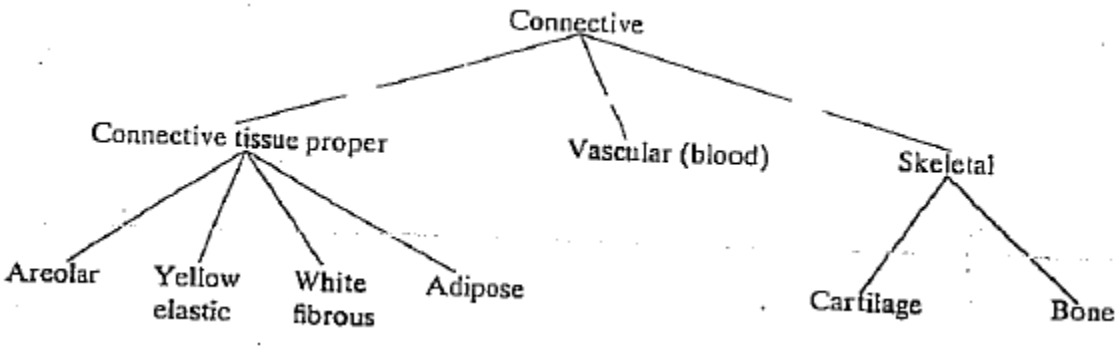
(iii) Matrix

- Forms basic ground tissue in which both cells and fibres are suspended.
- Non-living and could be amorphous, transparent, fluid or semifluid.
- Contain organic and inorganic substances.
- Most important is hyaluronic acid.
- Matrix varies in different tissues.

(b) Location

- Between different tissues and organs.
- In and around body organs.
- Skeletal tissue in form of bone and cartilage.
- Fluid connective tissue throughout body.

(c) Types of connective tissues.



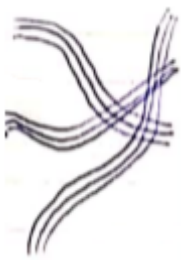
(d) Functions of connective tissues

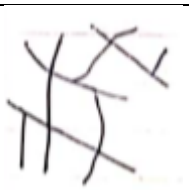
i) Bind various tissues together like skin, muscles and bones.
ii) Making packaging tissues in form of sheaths around body organs.
iii) Areolar tissue protects body against wounds and infections.
iv) Adipose tissue stores fat and insulates body against heat loss.
v) Supportive tissues form shape and body frameworks.
vi) Haemopoitic tissue produces blood.
vii) Lymphatic tissue produces lymphocytes for immunity build up and transports fatty acids and glycerol.

(e) Types of cells in connective tissues; [FM^2P]

Cell type	Characteristics	Structure	Function(s)
(i) Fibroblasts	▪ Spindle shaped ▪ Flattened cells ▪ Oval nucleus ▪ Long process		▪ Produce fibres. ▪ Close to fibres
(iii) Macrophages	▪ Large ▪ Amoeboid ▪ Kidney shaped nucleus		▪ Engulf bacteria. ▪ Ingest damaged tissues
(iv) Mast cells [Allergic reactions]	▪ Large ▪ Oval ▪ Granular cytoplasm		▪ Secretes heparin & histamine. ▪ Heparin; anticoagulant. ▪ Histamine; anti-inflammatory.
(v) Plasma cells	▪ Small ▪ Round/irregular		▪ Produce antibodies.

(f) Types of fibres in connective tissues

Fibre type	Characteristics	Structure	Function
(i) Collagen/white fibres	▪ Long ▪ Wavy ▪ Unbranched ▪ Inelastic ▪ Contain collagen		▪ Tensile strength and resilience.

(ii) Elastic/yellow fibres	▪ Long ▪ Straight ▪ Branched ▪ Present not in bundles but singles. ▪ Fine network ▪ Flexible & elastic. ▪ Contain elastin		▪ Tensile strength. ▪ Resilience ▪ Elasticity
(iii) Reticulate fibres	▪ Very fine ▪ Short ▪ Thread-like ▪ Around blood vessels/nerves ▪ Rigid		▪ Tensile strength. ▪ Resilience

(a) Details of connective tissue types

1. CONNECTIVE TISSUE PROPER (LOOSE & DENSE)

They can be grouped as;

- Loose connective tissue; comprising of mainly areolar tissue and adipose tissue.
- Dense connective tissue/ fibrous connective tissue; comprising of white fibrous and yellow elastic tissue.
    - Soft matrix.
    - Connects and supports various tissues and organs.
    - To resist strain and displacement.

i. Loose connective tissue [areolar & Adipose]

- Loosely woven fibres and matrix, cells widely distributed.
- Resist strain and displacement.

(a) Areolar connective tissue

- This represents the typical structure of a connective tissue.
- The tissue consists of a gelatinous glycoprotein matrix containing 4 main types of cells and 2 types of protein fibres.
  The cells include;
- Fibroblasts; large fat cells that secrete fibres.
- Mast cells; which secrete anticoagulant.
- Phagocytic macrophages; which engulf foreign materials and fat cells.
  It's the fibres that give the areolar tissue its strength and toughness.

QUICK FACTS ON ADIPOSE TISSUE

Description

- Modified form of areolar tissue.
- Large number of fat cells.
- Almost cell entirely filled with fat.
- In each adipocyte, the cytoplasm, nucleus and organelles shifted to periphery.

Types of adipocytes

I. White fat cells; one large fat droplet.
II. Brown fat cells; many small fat droplets.

Location

- In dermis beneath skin, mesenteries, around kidney, heart and eyeballs.

Functions

- Synthesizes stores and metabolizes fat.
- Source of energy on oxidation.
- Cushions kidneys, heart and eyeballs.
- Insulates body against heat loss.

Question

a) Why do adults have little/no brown fat while new born mammals have much brown fat. Explain. (03 marks)
b) Describe the functions of adipose tissue. (06 marks)
c) Describe how the structure of areolar tissue is related to its roles. [requires adaptations] (11marks)

Solution

(a) New born mammals being small in size, have a large surface area to volume ratio; thus lose heat faster than adults; so they possess much brown fat because brown adipose tissue produces a lot of heat to replace the lose heat;; since its fats/lipids are respired with release of little/no adenosine triphosphate(ATP); as most energy is lost as heat; unlike adults with a smaller surface area to volume ratio being big-sized/have well developed heat insulator mechanisms, so they lose heat slowly;; thus no need of much heat generation from brown fats therefore have little/no brown fat; **@0.5MK,04.5MKS, 03MAX**

(b)

- For insulation against heatloss; being a bad conductor of heat; insulates the body against heat loss;
- Provision of energy; fats are oxidized to release a lot of energy in form of adenosine triphosphate (ATP);
- For storage of fat-soluble vitamins; like vitamin A, D, E and K;

Differences between tendons and ligaments

Tendons	Ligaments
▪ Predominance of collagen fibres ▪ Fibres regularly arranged in parallel bundles. ▪ Fibroblasts arranged in neat rows along fibres ▪ Join skeletal muscles to bones	▪ Predominance of elastic fibres. ▪ Fibres irregularly arranged. ▪ Fibroblasts scattered all over matrix. ▪ Join bones to bones at joints.

2. SUPPORTIVE CONNECTIVE TISSUES

- Form shape and body framework-i.e. bones and cartilages.

i) Cartilages (hyaline, elastic, fibrous)

- Tough, hard but flexible connective tissues.
- Can resist strain and absorb mechanical shock.
- Consist of solid or semi-solid matrix.
- In which are embedded chondrocytes and fibres (C/E).

(a) General structure

- Enclosed in white fibrous tissue sheath perichondrin/perichondrium.
- Layer of chondroblasts forming chondrocytes dispersed in matrix.
- Chondrocytes occur in fluid filled spaces; lacunae.
- Each lacuna with 2/3 chondrocytes.
- Each chondrocytes; large angular cartilage cell with distinct nucleus.
- No process from lacunae to matrix.
- Lacks blood vessels.
- Exchange of materials by diffusion only.
- Matrix with protein chondrin.

(b) Types (depending on matrix nature)

1. Hyaline cartilage

Structure

DEVELOPMENT OF THE MAMMALIAN BONES (OSSIFICATION)

Types of ossification

i) Endochondrial ossification; replacement of cartilage by bone.

ii) Intramembranous ossification; bone formation from embryonic connective tissue; mesoderm.

ENDOCHONDRIAL OSSIFICATION

- Cartilaginous skeleton of mammalian embryo gradually replaced by bone in growing organisms.
- Existing cartilage removed and bone constructed in its place.
- In long bone diaphysis ossified first.
- Diaphysis is the hollow shaft (long) part.
- Layer of membrane bone laid down in perichondrium.
- Complete ring of bone formed around diaphysis.
- When complete layer is periosteum.
- Chondrocytes internal to periosteum increase in size.
- Matrix between becomes calcified and cells disintegrate.
- Creates series of hollow corridors in the cartilage.
- Gradually get filled with embryonic bone marrow cells and blood vessels.
- Bone marrow cells and blood vessels arise from the layer of membrane bone in outlying regions of diaphysis.
- Some bone marrow cells differentiate into osteoblasts.
- They position themselves around remaining bone marrow.
- Secrete layers of bony material.
- End product is a strong hollow tube of bone surrounding marrow cavity.
- Ossification extends towards epiphysis but tip cartilage persists.
- Growth in length of bone occurs at same time as ossification.
- Cartilage continues to be produced and ossified into new bone on either side of growth regions.
- When growth regions get ossified, no further cell divisions occur and growth in length ceases.
- Further deposition of bone in periosteum increases bone girth.
- Old bone tissue in centre reabsorbed by osteoclasts forming bone marrow cavity.

Illustration

Questions

1.

(a) Describe how each of the following structures relate to its roles/functions.

(i) Collagen tissue (03 marks)

(ii) Elastic tissue (02 marks)

(iii) Stratified tissue (02 marks)

(b) Describe the structure of a compact bone. (08 marks)

2.

(a)

(i) Describe the structure of a cartilage. (06 marks)

(ii) Compare a cartilage and a bone. (08 marks)

(b) State the areas in the body where the following types of cartilage are found;

(i) Hyaline cartilage. (02 marks)

(ii) Yellow cartilage (02 marks)

(iii) White fibrous cartilage. (02 marks)

Solutions

3. FLUID CONNECTIVE TISSUES [BLOOD & LYMPH]

- Consist of both myeloid and lymphoid tissue from which blood and lymph respectively are formed.

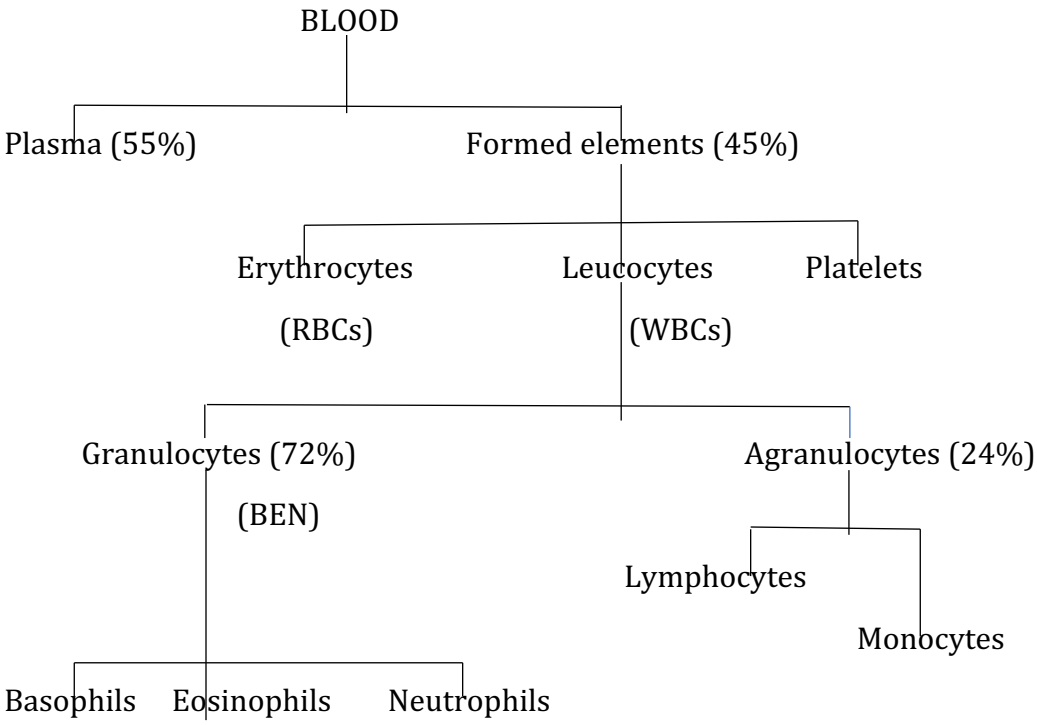
a) BLOOD

- Fluid connective tissue that circulates in the entire body.

Nature of blood

- Fluid connective tissue circulating in body.
- Extracellular without fibres; outside cells.
- Consists of pale yellow coloured/straw coloured plasma.
- 55% plasma; 45% formed blood elements.
- Formed elements include RBCs, WBCs and platelets.
- Adult with approximately 5 litres of blood.

COMPOSITION OF BLOOD



i) Blood plasma

- Pale yellow; 55% of blood by volume; slightly alkaline; organic and inorganics in solution.

Composition

- Water (90-92%)
- Plasma proteins 7% (albumins, globulins and fibrinogen; [FAG])
  - ✓ Albumins; osmotic level, retain water(FGAP)

- ✓ Globulins; α, β & γ
  α −Bind with thyroxine; bilirubin + transport.
  β − Bind with iron (III), vitamin A, D, E, K+ Transport.
  γ − Antibodies
- ✓ Prothrombin;
- ✓ Fibrinogen; form blood clot; fibrin.

- Inorganic compounds 1%; chloride, bicarbonate, sulphate, phosphate, sodium, calcium, potassium & magnesium ions [$C^2P^2S^2HM$]
- Organic compounds (1%); glucose, amino acids, glycerol, fatty acids; wastes like urea, vitamins.

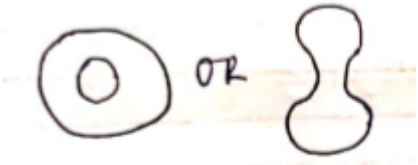
Functions of blood plasma [T^3OPIC]

1. Transport; nutrients, excretory wastes, oxygen, carbon dioxide and hormones.
2. Immunity; antibodies build immune system.
3. Maintenance of osmotic pressure; albumins.
4. Maintenance of optimum blood PH; buffers.
5. Prevention of blood loss; prothrombin; clotting factors + fibrinogen.
6. Regulation of body temperature; heat distribution-i.e distributes heat.
7. Tissue fluid formation for exchange with other body cells.

ii) Formed elements of blood

(a) Erythrocytes (RBCs)

- Most highly adapted cells in body.
- 4.5-5M/mm^3 of blood.
- Lack nucleus(mammals)
- Haemoglobin in cytoplasm.
- Transport oxygen & carbon dioxide; $CO_2 + HHbNH_2$
  $\rightarrow HHbNHCOOH$(carboaminoHb)
- Circular + biconcave in side view.
- Separated from plasma by centrifugation.
- Mature lacks all cell organelles thus decrease oxygen consumed.



Formation of RBCs (Haemopoiesis)

- From haemopoietic tissue.

NB:

- ✓ Leucocytosis; increase in number of leucocytes approximately $10000/cm^3$; often due to infection.
- ✓ Leukemia; uncontrolled abnormal increase in number of leucocytes due to the failure of the homeostatic mechanism regulating their production; blood cancer.
- ✓ Leucopenia; abnormal fall in count of WBCs; below $4000/mm^3$ due to starvation, medication of folic acid deficiency (FMS).

(b) Thrombocytes/blood platelets

- Irregularly shaped i.e.
- Smaller than even the RBCs
- No nucleus often.
- Cytoplasm contains distinct granules.
- Are fragments of protoplasm broken from large bone marrow cells; megakaryocytes.
- $250000/mm^3$
- Lifespan approximately 7days.
- Aggregate at site of blood flow to stop it.
- Release platelet factor which initiate blood clotting.

Summary of blood clotting

- See transport in animals.

NB:

- ✓ Serum; Blood plasma after removal of fibrinogen; it can't clot.
- ✓ Thrombosis; formation of a clot in the blood vessels as a result of endothelium damage which breakdown the platelets; treated with heparin from liver of mammals.
- ✓ Haemophilia; hereditary disorder resulting in failure of blood to clot due to absence of an essential clotting factor due to a gene mutation.

Differences between;

Blood plasma	Serum
✓ Blood part in which formed elements clot. ✓ Contains fibrinogen. ✓ Straw/pale yellow coloured ✓ Can clot	✓ Blood part left after blood clot is formed. ✓ Lacks fibrinogen. ✓ Colourless ✓ Can't clot

LYMPH

- Fluid flowing in lymph vessels.
- Like plasma except; lacks RBCs, blood platelets, plasma proteins & macromolecules.
- Refer to transport in animals for details.

C. MUSCULAR TISSUE

- ✓ Tissues made up of highly specialized thin and elongated cells with capability to contract and relax.
- ✓ The thin and elongated cells called muscle fibres.
- ✓ Contractility due to presence of protein filaments of myosin and actin in their cytoplasm.
- ✓ Muscles make up 40% of mammalian body weight.
- ✓ Well supplied with blood vessels for nourishment and wastes removal.
- ✓ Each muscle with own blood supply.
- ✓ **Basing on structure, function and location; 3 types**;
  i) Striated muscles
  ii) Unstriated muscles
  iii) Cardiac muscle.

I. Basic structure of muscles

- Made up of thin elongated cells called muscle fibres.
- Specialized cytoplasm called sarcoplasm.
- Network of membranes in cytoplasm; sarcoplasmic reticulum.
- Muscle fibre often bound by cell membrane called sarcolemma.
- Each muscle fibre contains numerous myofibrils.

II. Types of muscles

(a) Striated/stripped/skeletal/voluntary muscle

Location

- Attached to skeleton in head, trunk and limb regions.

Structure of the muscle

- Cross striations in form of light and dark bands or I and A bands respectively.

NB:

- ✓ I=Isotropic i.e. Allows light through.
- ✓ A=Anisotropic i.e. Doesn't allow light through.

- Comprises of muscle fibres.
- Each muscle fibre comprises of numerous myofibrils.

NB:

- A-band; region with both actin and myosin filaments.
- H-zone; region of only myosin filaments
- Z-line; membrane to which actin filaments are attached on both sides.
- M-line; membrane to which myosin filaments are attached on both sides.

HINT: Key units in a skeletal muscle;

- Muscle fibre
- Myofibril
- Sarcomere

Filaments' differences

Actin filaments	Myosin filaments
✓ Made of thinner & lighter protein actin ✓ Found in both I & A bands. ✓ Cross bridge lacking	✓ Made of thicker and heavier protein myosin. ✓ Found in A bands only. ✓ Contain cross bridges.

Differences between A and I bands

A band	I band
✓ Anisotropic i.e. doesn't allow light to pass through. ✓ Appears as dark band under a microscope. ✓ Has lighter region called Henson's disc or H-band in the middle. ✓ Contains both actin and myosin filaments.	✓ Isotropic i.e. allows light to pass through. ✓ Appears as light band under a microscope. ✓ Has a darker line called Z line in the middle. ✓ Contains only actin filaments.

b) **Unstriated/unstrapped/smooth/involuntary muscle**

Location

- In walls of visceral organs like stomach, intestines, ureters, kidneys and blood vessels.
- Also found at hair base, iris of eye and in the reproductive system.

Diagrammatic illustration

Question

a) State any 3 examples of muscular tissue in a mammalian body. (03 marks)
b) Describe the structure of a cardiac muscle. (06 marks)
c) Describe how the structure of the skeletal muscle relates to its functions. (11 marks)

Solution

(a) Cardiac muscle
Skeletal muscle
Smooth muscle **@01MK, 03MKS**

(b)

- It consists of uninucleated/binucleated short, cylindrical, branched muscle fibres; joined end to end into rows; by intercalated discs;
- Muscle fibres contain numerous mitochondria; myofibrils, sarcomeres, cytoplasm and glycogen granules; with cross faint, regular striations; due to presence of actin and myosin filaments; giving the muscle a striated appearance;
- In between muscle fibres is collagen and a connective tissue;

@01MK,07MK,06MAX

(c)

- Has elongated muscle fibres to allow considerable contraction;
- Has actin and myosin filaments; slide over each other to cause contraction in the muscle;
- Has numerous mitochondria to provide enough energy inform of ATP for muscular contraction;
- Has a rich supply of blood vessels to provide adequate supply of oxygen and glucose; for energy production needed for muscular contraction;
- Has parallel muscle fibres for maximum contractile effect;
- Has muscle fibres with tapering and interwoven ends to provide strength to the muscle thus no risk of muscle breakage;
- Has a motor end plate that stimulates the muscle to contract;
- Contains myoglobin which stores oxygen needed for energy generation;
- Has endoplasmic reticulum to stimulate transmission of nerve impulses**;**

@01MK, 10MKS

D. **NERVE TISSUE**

- Made up of millions of nerve cells called neurons.
- Neurons; highly specialized cells forming the nervous system.

Parts of the nervous system

- Central nervous system (CNS)
- Peripheral nervous system (PNS)
- Autonomic/autonomous nervous system (ANS)

NB: They provide quickest means of in-body communication and effect response to stimuli.

Basic properties of neurons

i) Excitability; on stimulation, the pre-existing potential difference across their membrane undergoes a change and the neuron is said to be excited. This change is transmitted like a wave along membrane.

ii) Conductivity; transmitted electrochemical message along an axon is called a nerve impulse.
The impulse is conducted as an electrochemical message in a wave-like form along the axon. Always from cell body towards axon.

Structure of a neuron

1. 2 distinct regions; cell body and cytoplasmic extensions.
2. Cell body contains nucleus and abundant granular cytoplasm.
3. Cytoplasm is embedded with mitochondria, Golgi apparatus, rER and neurofibrils.
4. Cytoplasm also with Nissl's granules rich in RNA for protein synthesis but are absent in axon.
5. From cell body/some extend cytoplasmic extensions –i.e. dendrones/dendrites and the axon.
6. Dendrons are wide processes that break into fine branches carrying impulses to cell body.
7. Axons/nerve fibres are long processes that conduct impulses away from cell body.
8. At terminal ends of axons are swollen ends which secrete acetylcholine and adrenaline.
9. Axons communicate with other neurons through synapses.
10. Each axon is filled with the cytoplasm called axoplasm continuous with cell body cytoplasm.
11. Axoplasm contains, mitochondria, rER and neurofibrils.
12. Lacks Nissl's granules, Golgi apparatus and nucleus.

Differences between myelinated and non-myelinated nerve fibres

Myelinated(medullated)	Non-myelinated(non-medullated)
• Myelin sheath on axon. • Nodes of Ranvier. • Relatively thick. • Faster impulse speed • In cranial and spinal nerves in CNS & PNS.	• Lack myelin sheath on axon. • Lack nodes of Ranvier. • Thinner. • Much slower impulse speed • Present in the ANS.

NB: In CNS instead of connective tissue in the interneuron spaces; Neuroglia cells fill the spaces.

Functions of neuroglia cells

- **Bind** nervous tissue together.
- For memory, store information in their RNA.
- Nourish surrounding tissues.
- Specialized to engulf germs like phagocytic microglia.
- Repair injured tissues.
- Unfortunately causes of brain tumours.
- Form myelin sheath since schwann cells absent in CNS, cligodendrocytes.

Differences between neurons and neuroglia cells

Neuron	Neuroglia cell
• Conduct impulses • Incapable of division • Specialized for impulse transmission • Much less in number	• Bind nerve tissue. • Capable of division + regeneration. • Phagocytic, nutritive & regenerative functions. • X10 more in number.

CHEMICALS OF LIFE

INTRODUCTION

- The protoplasm of living organisms' cells is made up of chemicals structurally and the metabolism of these chemicals maintain life.
- These chemicals are known as chemicals of life.
- They are grouped into organic and inorganic chemicals of life.
- The study of chemicals of life and the chemical reactions in which they take place is **biochemistry**.

TYPES OF CHEMICALS OF LIFE

(i) **Inorganic chemicals of life**
These lack carbon-hydrogen bonds in their structures. E.g. Water, salts, acids and bases.

(ii) **Organic chemicals of life**
These contain carbon-hydrogen bonds in their structures. E.g. Carbohydrates, lipids, proteins, nucleic acids and vitamins.

NB:

- Apart from nucleic acids all other chemicals of life need to be supplied in appropriate quantities in the diet thus the need for a balanced diet.
- 92 elements exist in nature but only 16 contribute to chemicals of life thus Bio-elements.
- Most used ones are C, H, O, N, P and S(CHNOPS).

A. **INORGANIC CHEMICALS OF LIFE** i.e. Lack carbon-hydrogen bonds.

1. WATER
Is the most abundant & most important chemical of life in the organism's body accounting for approximately 70% of the total body weight.

GENERAL FUNCTIONS OF WATER IN ORGANISMS

- Photosynthesis reagent.
- Cools the body since its evaporation carries heat away from the body like by sweating, painting and transpiration.
- Used for dispersal of seeds and fruits.
- Medium for gametes fusion/ fertilization for swimming gametes.
- Habitat for aquatic organisms.
- Cleans atmosphere i.e. when it rains.

FOR MORE OF SUCH GRAB YOUR COPY OF "ESSENTIALS OF 'A' LEVEL BIOLOGY"

NB: The contents on the blank pages have been removed intentionally!

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