

CYTOLOGY AND MICROSCOPY

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Syllabus extract

<i>Content</i>	SPECIFIC OBJECTIVES <i>The learner should be able to:</i>
<p>Cell structure</p> <ul style="list-style-type: none"> • Structure of the animal cell and plant cell as seen under a light microscope. • Detailed animal and plant cells. • Functions of detailed cell structures indicating the inter relationship. • Differences between plant cell and animal cell ultra-structures. • The theory behind the structure of the plasma membrane. • The fluid mosaic model-plasma membrane. 	<ul style="list-style-type: none"> • Identify plant and animal cell structures visible under the light microscope • Draw and label detailed animal and plant cells. • State functions of cell structures as seen under an electron microscope. • Distinguish between the plant cell and animal cell ultra-structures as visible under the electron microscope • Explain the theory behind the structure of the plasma membrane.
<p>Diversity of Specialized cells and tissues.</p> <ul style="list-style-type: none"> • Differences between Eukaryotic cells and Prokaryotic cells. • Specialised cells and tissues: xylem, phloem, tracheids, sclerenchyma, collenchyma, parenchyma, connective and skeletal tissue. • Function and adaptation of epithelial tissues • Levels of organization: cell, tissue, organ and organ system. • Advantages and disadvantages of being unicellular • Advantages of multicellular state. 	<ul style="list-style-type: none"> • Distinguish between prokaryotes and eukaryotes. • Explain cell and tissue specialization. • Explain how epithelial tissues are adapted to diversity of functions in the body. • Distinguish between the different levels of organization. • State the advantages and disadvantages of being unicellular. • State the advantages of being multicellular.
<p>cell structure and microscopy Practical</p> <ul style="list-style-type: none"> • The functioning principles of a light and electron microscope: resolving power, e.t.c. • Preparation of temporary mounts of cell and tissue slides. • Simple staining methods • Staining plant tissues. • Estimation of cell size. • Epithelial tissues classification. 	<ul style="list-style-type: none"> • Explain the functioning principles of a light and electron microscope • Prepare temporary mounts of cells and tissue slides. • Use simple stains in studying cells and tissues • Identify different plant tissues using different laboratory stains. • Determine cell size • Draw and label epithelial tissues.

CELL BIOLOGY

This deals with cell structure, function and cell physiology all at the unit level of a living organism called a cell. The study of the structure of cells, **cytology**, is part of a major branch of biology known as cell biology.

The main functions of the cell include

1. Basic unit of life. The cell is the smallest part to which an organism can be reduced that still retains the characteristics of life.
2. Protection and support. Cells produce and secrete various molecules that provide protection and support of the body. For example, bone cells are surrounded by a mineralized material, making bone a hard tissue that protects the brain and other organs and that supports the weight of the body.
3. Movement. All the movements of the body occur because of molecules located within specific cells such as muscle cells.
4. Communication. Cells produce and receive chemical and electrical signals that allow them to communicate with one another. For example, nerve cells communicate with one another and with muscle cells, causing them to contract.
5. Cell metabolism and energy release. The chemical reactions that occur within cells are referred to collectively as cell metabolism. Energy released during metabolism is used for cell activities, such as the synthesis of new molecules, muscle contraction, and heat production, which helps maintain body temperature.
6. Inheritance. Each cell contains a copy of the genetic information of the individual. Specialized cells are responsible for transmitting that genetic information to the next generation.

The cell of a living organism

The cell can be defined as the basic unit of structure and function in a living organism. This generalisation is known as the **cell theory** and it embraces four ideas;

- A. The cell is the building block of structures in living cells
- B. The cell is derived from other cells by cell division
- C. The cell contains hereditary information that is passed from parent cell to daughter cell
- D. The cell is the functioning unit of life i.e. the chemical reactions of life take place within cells

The cell theory states that "**a cell is the fundamental and functional unit of life**" i.e. the cell is the basic unit of the structure and function in living organisms.

Factors that limit cell size

1. Surface area to volume ratio

Small cells have large surface area: Volume ratio (SA: V ratio) while large cells have a small SA: V ratio. A large SA: V ratio enables fast rate of diffusion while a small SA: V ratio slows the rate of diffusion. Small cells have low metabolic demands and form low amount of wastes while large cells have higher metabolic demands and form much amount of wastes.

Therefore, the large SA: V ratio in small cells enables adequate supply of oxygen and nutrients and expulsion of wastes e.g. carbon dioxide via the surface of the cell by simple diffusion while the small SA: V ratio in large cells limits diffusion hence the supply of nutrients by simple diffusion is inadequate to meet the metabolic demands of the cell.

2. Nucleocytoplasmic ratio

DNA in the nucleus provides instructions for protein synthesis hence controls activities of the whole cell. Each nucleus can only control a certain volume of cytoplasm.

Specialization forms some long / large cells, therefore to overcome this limitation such cells are modified to become multinucleate / coenocyte e.g. skeletal muscle cells and fungal hyphae.

3. Fragility of cell membrane

As cell size increases, the risk of damage to the cell membrane also increases. This limits the maximum size of cells, especially animal cells. Hence;

- (i) In animals, some large sized cells take in substances in bulk by endocytosis and expel bulk substances by exocytosis to supplement on simple diffusion.
- (ii) Some animal cells increase their surface area by forming many tiny projections called microvilli.
- (iii) Some cells divide when they reach a certain size to maintain suitable SA: V ratio.

Note: SA: V ratio particularly limits the size of bacterial cells, i.e. prokaryotic cells which are incapable of endocytosis and exocytosis.

4. Mechanical structures that hold the cell together

Cells with tough cell walls e.g. plant cells are larger than cells with only the fragile cell membrane e.g. animal cells because the tough walls provide support and maintain cell shape.

Cells with complex internal cytoskeleton are larger than cells with little cytoskeleton because the cytoskeleton protects and supports the cell structure and maintains cell shape.

TYPES OF CELLS

There are two fundamentally different types of cells, the prokaryote cell and eukaryote cell.

A. Prokaryote cell (Pro, before; karyon, nucleus)

Characteristics of prokaryotic cells

- These are cells that **do not have a true nucleus**.
- They have no membrane bound organelles. An **organelle** can be defined as a membrane-enclosed structure with specialised functions, suspended in the cytosol of eukaryotic cells.
- Their nuclear material lies in a free region known as a **nucleoid** e.g. in bacteria. They were probably the first organisms on earth
- The cell has no distinct nucleus. The nucleoplasm appears scattered in the cytoplasm or the nuclear materials e.g. DNA.
- The cell lacks a nuclear membrane
- Each cell has got very few cell organelles (cell parts) e.g. they do lack the chloroplasts and mitochondria.
- The cell has a single circular chromosome in the form of a ring, of Deoxyribonucleic Acid (DNA) in the cytoplasm, not contained in a nuclear membrane
- They are extremely small, ranging in size between 1-10micrometres in diameter
- Duplication of the chromosomes occurs but not on the spindle i.e. their cells are capable of multiplication
- The cell has got a unique cell wall containing a polysaccharide

Examples include bacteria and cyanobacteria i.e. first organisms on earth.

Diagram of a generalised structure of a bacterium *Fig 2.5 pg 9 Soper*

Function of the parts
Structures which are always present

1. Cell wall

This lies external to the cell membrane, it's rigid and strengthened by presence of murein (a molecule consisting of parallel polysaccharide chains cross-linked at regular intervals by short amino acid chains)
The cell wall is a physical barrier which:

- (i) protects the internal parts from mechanical damage
- (ii) prevents the cell bursting when it takes in water by osmosis
- (iii) allows entry of some substances, such as water, ions and small molecules

The cell wall cannot grow and for growth to occur the cell wall is partly dissolved at intervals for materials to be added.

2. Cell membrane

It lies immediately below the cell wall and has a **fluid mosaic structure**. It's hydrophobic and impermeable to most water soluble molecules.

It has **enzymes** involved in the synthesis of the capsid and cell wall components. Enzymes for respiration and those which facilitate flagella mobility.

Note: a damaged cell membrane leads to the death of the cell.

3. Ribosomes

Prokaryotes have 70S ribosomes which are slightly smaller than the 80S eukaryotic ribosomes.
Ribosomes are site of protein synthesis.

4. DNA

The DNA comprises of a single circular molecule possessing the genetic information needed to replicate new cells

5. Food reserves

Food reserves include lipids and glycogen

6. Cytoplasm

This is enclosed by the cell membrane and is divided into three divisions (bacteria only) i.e.

- (i) Cytoplasmic area which contains ribosomes and it is also a site for protein synthesis.
- (ii) Chromatin area, a dense area which is rich in nucleic acid material. The nuclear region is called **nucleoid**. Bacteria have single circular strand of chromatin material.
- (iii) The fluid area, an area with dissolved substances. In the bacteria the rough endoplasmic reticulum is lacking. The ribosomes are generally smaller than in an eukaryotic cell and are free or attached to the cell membrane.

Structures sometimes present

7. Flagellum (Plural. flagella)

This occurs in many species of bacteria. They are hair like helical appendages protruding through the cell wall. They are used for propulsion. Bacterial flagella are smaller, thinner and simpler than eukaryotic flagella. Their location and number may be used in identification of bacteria.

8. Pili

Pili are numerous fine protein rods projecting from the walls of some bacteria. The pili are for attachment to specific cells or surfaces. The **F.pilus** is used in sexual reproduction.

9. Capsule

This is an enveloping layer of viscous substances around the cell wall. This layer can be detected under the light microscope after staining the bacteria with Indian ink. Its uses include;

- (i) Protecting against infecting phages
- (ii) Resist engulfment by white blood cells
- (iii) Prevents agglutination of bacteria
- (iv) Used by bacteria to stick firmly onto substances e.g. bacteria on teeth

- (v) The capsular secretions are in some cases used to unite bacteria into colonies

10. Plasmids

Plasmids are small self-replicating strands of extra DNA. Plasmids possess only a few genes, and are generally concerned with survival in adverse conditions.

Plasmids are known which;

- a) Confer resistance to antibiotics
- b) Confer resistance to disinfectants
- c) Cause disease
- d) Are responsible for fermentation of milk to cheese by lactic acid bacteria
- e) Confer the ability to use complex as chemicals such as hydrocarbons as fuel

11. Mesosomes

Bacteria lack membrane bound organelles such as mitochondria and chloroplasts. Instead they have invaginations of cell membranes forming a system referred to as mesosomes. There are 2 types; the central and the peripheral mesosomes.

(i) Central mesosomes

These are invaginations which penetrate deep into the cytoplasm. They appear to be linked to the nuclear material and play a role in cell division.

(ii) Peripheral mesosomes

These are shallow invaginations formed by infoldings of the cell membrane. They are associated with export of secretions such as cellular secretions or enzymes. They are site of respiration.

12. Photosynthetic membranes

Photosynthetic bacteria possess sac-like, tubular or sheet-like infoldings of the cell surface membrane containing photosynthetic pigments, always including **bacteriochlorophyll**

13. Spores

Some bacteria form endospores (spores produced inside cells). The spores are thick-walled, long-lived, and extremely resistant (particularly to heat, drought, and shortwave radiations)

14. Membranes for nitrogen fixation

B. Eukaryotic cell (Eu, true; Karyon Nucleus)

These are cells with a true nucleus. Their nuclear materials are found inside the nucleus surrounded by two membranes. They probably evolved about 1000 million years ago, 2 million years after the prokaryotes. There are 2 main types of eukaryotic cells; the plant cell and the animal cell.

Cells as seen with the light microscope

A light microscope is a microscope that uses light as a source of radiation. Under the microscope, cells are described as a small unit of living protoplasm and always surrounded by cell surface membrane and sometimes as in plants, surrounded by a non-living cell wall made of cellulose. The most conspicuous structure is the nucleus which contains a deeply staining material known as chromatin. When loose it is referred to as chromosome. Chromosomes appear as thread like structures just before nuclear division. The living material between the nucleus and the cell surface is known as the cytoplasm which contains a variety of organelles.

A generalised cell is a cell which shows all the typical features found in a cell.

a) Animal cell

An animal cell as seen in a light microscope contains protoplasm (nucleus and cytoplasm) surrounded by a thin plasma membrane.

Each cell has a relatively large central nucleus surrounded by the cytoplasm. The nucleus contains coiled threads called chromatin. Chromatin contains DNA and proteins called histones which together condense to

form chromosome during cell division. DNA carries genetic material which controls cell activities and determines the organism's characteristics. The cytoplasm contains organelles suspended within.

The structure of a generalised animal cell *Fig 5.1 a pg 129 Soper*

b) Plant cell

Many of the structures found in an animal cell also occur in the plant cell. A typical plant cell has additional specialised structures.

The structure of a generalised plant cell (*Fig 5.2 pg 130 Soper*)

There's a protective, rigid, cellulose cell wall surrounding the cell. Plant cells have a nucleus and cytoplasm which are usually peripheral. The cytoplasm contains chlorophyll pigments which carry out photosynthesis. A large central vacuole filled with cell sap is present in mature plant cells. The vacuole is surrounded by the tonoplast

Description of a generalised structure of a eukaryotic cell.

A cell is a small unit of living protoplasm, always surrounded by a cell surface membrane and sometimes by a non-living cell wall (as in plants and fungi).

The most conspicuous structure of the cell is the nucleus which contains chromatin. Chromatin is the loosely-coiled form of chromosomes. Chromosomes contain genetic material in the form of DNA. The nucleus is separated from the cytoplasm by its nuclear membrane

The cytoplasm contains organelles.

Comparison between prokaryotic and eukaryotic cells

Similarities	Differences	
	Prokaryotes	Eukaryotes
a. The protoplasm is surrounded by a membrane that is selectively permeable (protoplasm = nucleoplasm + cytoplasm) b. The binding protein is made up of lipid-protein complex c. The cells have got ectoplasmic and nuclear regions	The nuclear material is not enclosed by nuclear membrane	The nuclear material is enclosed by nuclear membrane
	Genetic material is circular double strand of DNA	Most DNA is linear and associated with histones proteins to form chromosomes
	No membrane bound organelles	Has membrane bound organelles
	No mitosis or meiosis	Mitosis, meiosis or both can occur
	No spindle formation	There's spindle formation
	Ribosomes are smaller (70S)	Ribosomes are bigger (80S)
	Rigid cell wall containing murein (peptidoglycan)	Cell walls of plants and algae contain cellulose, fungi contain chitin and animal cells have no cell walls
	No mitochondria (mesosomes in bacteria and plasma membrane of cyano bacteria contain respiratory enzymes)	Mitochondria present and function as sites for cellular respiration to produce ATP.
	Use mesosomes for respiration	No mesosomes
	Flagella if present, contain flagellin and lack microtubules	Flagella, if present, have a '9+2' arrangement of microtubules
	Average diameter of cell is 0.5-5µm	Average diameter of cell is 10-100µm
	Some bacteria have small circular DNA plasmids	Plasmids are absent
	Few organelles	Many organelles
No chloroplasts (some prokaryotes are photoautotrophs with the photosynthetic membranes not stacked into grana)	Chloroplasts containing grana	

NOTE: the only organelle found in animal cells which is absent from plant cells is the centriole

Advantages of having membrane bound organelles

1. Potentially harmful reactions (enzymes) can be isolated inside an organelle so that they do not harm the rest of the cell
2. The rate of any metabolic reactions inside an organelle can be controlled by regulating the rate at which the membrane allows the first reaction to occur or to enter
3. The containment of enzymes for a particular metabolic pathway within the organelle means that the products of the reaction will always be in close proximity to the next enzymes within the sequence. This increases the rate of metabolic reactions
4. Many metabolic processes which involve enzymes occur in the membrane.

Organelles such as chloroplasts (about 3000nm in diameter) are large enough to interfere with the light waves and can be seen. Ribosomes (about 20nm) are too small to interfere with the light waves and cannot be seen under a light microscope.

Phase contrast microscope

Many cell details cannot be seen using an ordinary optical microscope. This is because there is very little **contrast** between structures. They have similar transparency and are not coloured. A third important parameter in microscopy is *contrast*, which emphasizes or makes more noticeable, differences in parts of the sample. New methods of improving contrast include staining or labelling cell components to stand out visually.

Special phase contrast condensers and objective lenses are added to the optical microscope. Light rays travelling through material of different densities are bent and altered giving a better contrast (cell components having different densities show variation in the refractive index, those of a higher refractive index can bend light to greater angle than other cell components of lower refractive index).

Phase contrast microscopes enable **living, non-pigmented specimen** to be studied without fixing and staining. Phase contrast microscopes give better contrast but do not improve resolution. This is similar to the optical microscope.

Just as the resolving power of the human eye is limited, the light microscope cannot resolve detail finer than about 0.2 μ m or 200nm, the size of a small bacterium, regardless of the magnification factor. The poor resolution of the LM could only be overcome by using a form of radiation with a wave length less than of light. This led to the development of the **electron microscope (EM)**. Since electrons have a shorter wavelength than light (about 0.005nm), they couple their higher magnifying power with much greater resolution and contrast. They can resolve two objects which are only about 1nm apart.

While the light microscope uses glass lenses to focus the light rays, the electron beam of the electron microscope is focused by powerful electromagnets. The image produced by electron microscopes cannot be seen by the unaided eye. Instead the electron beam is directed onto a screen giving black and white images (photographs). A photograph taken with an electron microscope is called an **electron micrograph** or **photomicrograph**.

There are two types of electron microscopes; the **Transmission Electron Microscope (TEM)** and the **Scanning Electron Microscope (SEM)**.

A TEM is an electron microscope in which the electron beam is transmitted through the specimen before viewing. The principle is the same as in the light microscope in that a beam of radiation is focused by condenser lenses through the specimen, and the image is magnified by further lenses. The TEM has a resolving power of about 1nm. It used to study the **ultrastructure** of a cell.

The electron beam is heated using a cathode and passed through ultra-thin dehydrated sections of dead specimen. Electrons are absorbed by heavily stained (due to treatment with heavy metals) parts but pass through the lightly stained parts. This provides contrast between different parts of the specimen.

Drawing of the pathway of the electron beam in the TEM (Soper pg 133)

A SEM is an electron microscope in which the electron beam is scanned to and from across the specimen. The electrons reflected from the surface are collected and used to form a TV-like image on a cathode ray tube. This enables the studying of the surfaces of structures and gives three-dimensional images. The SEM has a resolving power of about 5nm higher than that of a light microscope, but lower than that of a TEM. Larger and thicker specimens can be examined.

Note: the fine structure of the cell as seen with the electron microscope is called the **ultra-structure**.

Differences between the light and electron microscopes

TEM	Compound light microscope
1. Source of radiation are electrons	1. Source of radiation is light
2. Electrons have a shorter wavelength of about 0.005nm	2. Light has a longer wave length of about 400-700nm
3. Maximum resolution is greater (about 0.5nm)	3. Maximum resolution is lower (about 20nm)
4. Maximum useful magnification on screen is higher (about X250,000)	4. Magnification is low (about X1500)
5. Uses powerful electromagnets as lenses	5. Uses glass lenses
6. The specimen is dead, dehydrated and relatively small or thin	6. The specimen maybe living or non-living
7. The specimen is supported on a small copper and in a vacuum	7. The specimen is supported on a glass slide
8. The stains used contain heavy metals to reflect electrons	8. The stains used are coloured dyes
9. The image is black and white	9. The image is usually coloured

A comparison of radiation pathways in light and transmission electron microscopes

A comparison of the relative advantages and disadvantages of the light and electron microscopes

Light microscope	Electron microscope
<p style="text-align: center;"><u>Advantages</u></p> <ol style="list-style-type: none"> Cheaper to produce and operate Smaller and more portable; thus can be used almost anywhere Not affected by magnetic fields Preparation of material is relatively quicker and simpler, and requires only a little expertise and simpler equipment Material rarely distorted by preparation The natural colour of the material can be observed The specimen may be living The specimen does not deteriorate easily, allowing more study time 	<p style="text-align: center;"><u>Disadvantages</u></p> <ol style="list-style-type: none"> Much more expensive to purchase and operate Much larger and fixed, and must be operated in special rooms Affected by magnetic fields Preparation of material is lengthier and requires more expertise and more complex equipment Material is usually distorted by the preparation (preservation and staining may change or damage the structure) All images are in black and white The specimen must be dead because it is viewed in a vacuum The specimen gradually deteriorates in the electron beam, and thus photomicrographs must be taken and observed on the screen
<p style="text-align: center;"><u>Disadvantages</u></p> <ol style="list-style-type: none"> Lower magnification of up to X1,500 Has a restricted depth of field Lower resolution of about 200nm 	<p style="text-align: center;"><u>Advantages</u></p> <ol style="list-style-type: none"> Higher magnification of up to X250,000 Enables investigation of a greater depth of field Higher resolution of about 0.5nm

CELL STRUCTURE**Differences between plant and animal cells**

Plant cells	Animals cells
<ol style="list-style-type: none"> Have tough slightly elastic cellulose cell wall outside the cell surface membrane Have pits and plasmodesmata in the cell wall Have middle lamellae joining the cell walls of adjacent cells Possess plastids, such as chloroplasts Mature cells possess a large single, central vacuole filled with cell sap The cell vacuole is enclosed by a tonoplast Have a thin layer of cytoplasm confined to the edge of the cell The nucleus is located at the edge of the cell Higher plant cells lack centrioles Higher plant cells lack cilia and flagella Store food as starch grains Only some cells are capable of division Plant cells produce secretions Have a regular shape 	<ol style="list-style-type: none"> Have no cell wall, only a cell surface membrane surrounds the cell Have no cell wall, and therefore have no pits and plasmodesmata Middle lamellae are absent, the cells are joined by intercellular cement Lack plastids Possess only small vacuoles scattered throughout the cells Vacuoles lack tonoplasts Have much cytoplasm spread throughout the cell The nucleus is usually placed centrally in the cell Possess centrioles Often possess cilia and flagella Store food as glycogen granules Almost all cell are capable of division Animal cells produce a wide variety of secretion Have an irregular shape

a) **The ultra-structure of a generalised animal cell** (Soper fig 5.10 page 135)

b) **The ultra-structure of a generalised plant cell** (Soper fig 5.11 page 135)

MUGABI GODFREY

Detailed study of animal and plant cells.

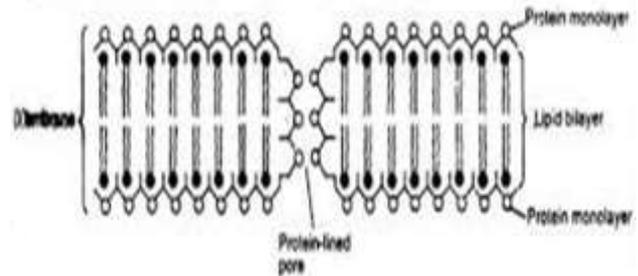
Cell membrane

The cell membrane is invisible with a light microscope.

Danielli and **Davison** proposed a membrane structure in which a lipid bilayer was coated on either side with a protein so as to provide the mechanical strength (elasticity and surface tension properties) to the cell membrane. This hypothesis proposes that the plasma membrane is made up of three layers: a bimolecular layer of lipid sandwiched between two layers of protein, the lipid molecules being set at right angles to the surface i.e. the **sandwich model** of the cell membrane

Diagram of the cell membrane based on the Danielli-Davison hypothesis

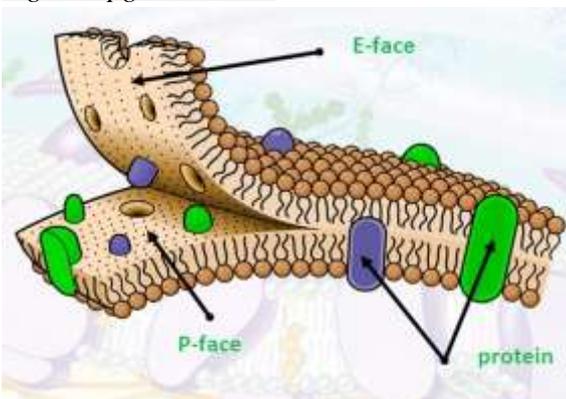
Fig 2.21 pg 27 Roberts



From the speeds at which various molecules penetrate the membrane, they predicted the lipid layer to be about 6.0nm in thickness, and each of the protein layers about 1.0nm giving a total thickness to the membrane of about 8.0nm.

Robertson (1960) used an electron microscope to observe a cell membrane and proposed that a cell membrane is actually a **unit membrane**. According to his proposal, all membranes have the same structure. A unit membrane has protein molecules with lipid molecules inside. The head of the lipid molecules are in mutual electrostatic attraction with the protein molecules, this increases on the mechanical strength of the unit membrane.

Fig 2.22 pg 27 Roberts



The unit membrane has pores that are lined with protein molecules which enable water soluble substances to enter or leave the membrane. Such substances include, water molecules, mineral salts, simple sugars, vitamins, gasses and excretory products. The membrane has got lipid layers which enable the lipid molecules to enter and leave the membrane.

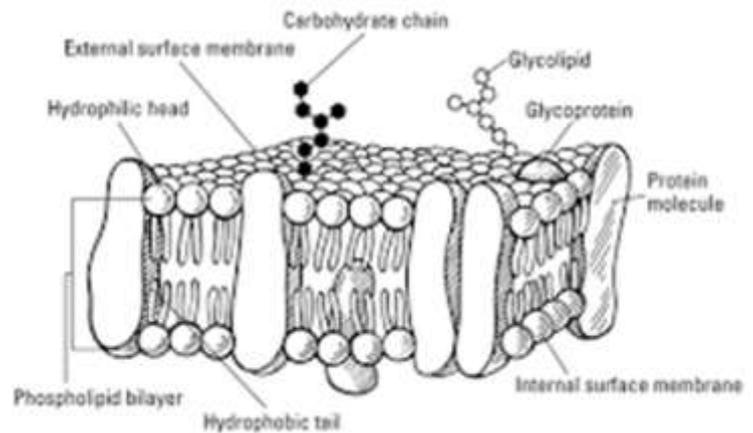
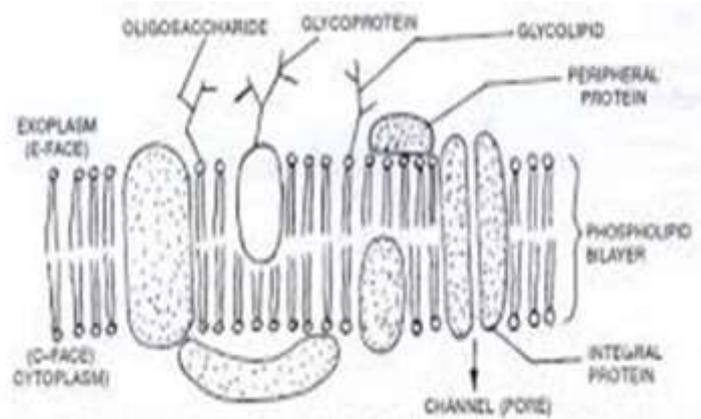
Most of the proteins on the cell membranes are called carrier proteins i.e. they enable the transport of substances across the membrane. Other proteins are enzymes in nature i.e. they catalyse biochemical reactions at the cell surface

In 1972 **Singer** and **Nicolson** suggested that the unit membrane has a **fluid mosaic model**

- The fluid mosaic model proposes that the basic structure for the unit membrane is a phospholipid bilayer with various protein molecules embedded and attached to it.
- The hydrophilic phosphate heads of the phospholipids face outwards into the aqueous environments inside and outside the cell and form hydrogen bonds with water molecules.
- The hydrocarbon tails face inwards and create a hydrophobic interior through Van der Waal forces and hydrophobic interactions. The phospholipids are fluid and move about rapidly by diffusion in their own layers. Some of the fatty acid tails are saturated and some are unsaturated. Unsaturated tails are bent and fit together more loosely. Therefore the more unsaturated the tails are, the more fluid the membrane is.
- Most protein molecules float about in the phospholipid bilayer forming a fluid mosaic pattern and these proteins stay in the membrane because they have regions of hydrophobic amino acids which interact with the fatty acid tails to exclude water.

- The membrane proteins most of which float individually in the fluid bilayer, forming the mosaic part of the fluid mosaic model. The rest of the protein is hydrophilic and faces into the cell or out into the external environment, both of which are aqueous. Some proteins penetrate only part of the way into the membrane (extrinsic proteins) while others penetrate all the way through (intrinsic proteins).
- Some proteins and lipids (phospholipids) have short branching carbohydrate (oligosaccharides) chains forming glycoproteins and glycolipids respectively, more glycoproteins are formed than glycolipids. These are important for cell recognition.
- Membranes also contain cholesterol which disturbs the close packing of phospholipids and regulates membrane fluidity. This is important for organisms living at low temperatures where membranes can solidify. Cholesterol also increases flexibility and stability of membranes, without it, membranes break up.

Fig 5.16 b pg 142 Soper OR Fig 7.15 pg 159 Cross-sectional view Clegg



A comparison of the sandwich model (Daniel-Danielli) and the fluid-mosaic model (Singer-Nicholson) of the cell membrane

a) Similarities

- (i) Both comprise of a bimolecular layer of phospholipids
- (ii) Both contain protein molecules
- (iii) In both, the phospholipids possess hydrophilic heads and hydrophobic tails
- (iv) In both, the phospholipid tails extend inwards, while the heads lie at the periphery
- (v) In both, the main structural skeleton of the membrane comprises lipids and proteins

b) Differences

Sandwich model	Fluid-mosaic model
1. Proteins regularly arranged to form a continuous layer covering both sides of the membrane	1. Proteins arranged irregularly in a mosaic pattern
2. Proteins lie on the surface, and do not get in the membrane	2. Some globular proteins lie on the surface, some extend into the lipid layer to varying degrees, and others extend through it
3. Lipids and proteins are rigid and cannot move	3. Lipids and proteins capable of much movement like a fluid
4. Protein molecules are of the same size	4. Proteins molecules are of different sizes
5. Proteins lack pores	5. Some proteins have pores
6. All proteins offer structural support only	6. Proteins may be structural, carrier proteins or enzymes

How phospholipid properties maintain cell membrane structure

1. Hydrophilic / hydrophobic layers restrict entry/ exit of substances.
2. Phospholipids are held together by hydrophobic interactions
3. Phospholipid layers are stabilized by interaction of hydrophilic heads and surrounding water
4. Phospholipids with short fatty acids and those with unsaturated fatty acids are more fluid. Fluidity is important in breaking and remaking membranes (e.g. endocytosis / exocytosis)
5. Phospholipids can move about / move laterally (horizontally) / "flip flop" (move transversely) to increase fluidity
6. Phospholipids allow for membrane fluidity/ flexibility. Fluidity/ flexibility enables membranes to be functionally stable

Membrane fluidity

Membranes are fluid, dynamic structures whose fluidity/viscosity is affected by their composition.

- a) An increase in temperature increases the fluidity of the membrane. Low temperature decreases membrane fluidity because lipids are laterally ordered, the lipid chains pack well together, mobility reduces to allow many stabilising interactions. Increase in temperature increases membrane fluidity because lipids acquire thermal energy to become mobile and reduce stabilising interactions.
- b) At moderate warm temperatures, the cholesterol molecules reduce the free movement of phospholipid molecules and make the membranes less fluid. At low temperatures, cholesterol molecules prevent the close packing of phospholipid molecules and slow down solidification of the membrane.
- c) Lipid chains with double bonds (unsaturated fatty acids) are more fluid because the kinks caused by double bonds make it harder for the lipids to pack together. Lipids that have single bonds only (saturated fatty acids) have straightened hydrocarbon chain which pack together to reduce membrane fluidity.
- d) Lipids with shorter chains are more fluid because they quickly gain kinetic energy due to their smaller molecular size and have less surface area for Van der Waals interactions to stabilise with neighboring hydrophobic chains. Lipids with longer chains are less fluid because their large surface area enables more Van der Waals interactions hence increasing the melting temperature.

Functions of the unit membrane

- 1) Surface membrane forms a protective barrier between cell contents and external environments, and determines the shape of the cell.
- 2) They form membrane organelles e.g. mitochondria, chloroplasts e.t.c.
- 3) Membranes are selectively permeable and regulate movement of substances in and out the cell
- 4) Some membrane proteins act as enzymes e.g. ATP synthase
- 5) Cell surface receptor proteins are involved in signal-transduction
- 6) Some membrane proteins act as electron carriers in the electron transport chain
- 7) Glycoproteins with branching oligosaccharides act as antigens
- 8) Glycolipids are involved in cell-cell recognition
- 9) Folding of cell membranes enables the cell to carry out phagocytosis and pinocytosis which enables the cell to obtain nutrients or to engulf and destroy foreign particles.
- 10) Folding of membranes also increases the surface area for reactions e.g. the epithelium villus of the ileum
- 11) Cell adhesion proteins join cells together forming tissues which carry out specific functions
- 12) Cholesterol molecules stabilise the membrane structure and reduce entry or exit of polar molecules through the membrane

Note; the various membranes of an eukaryotic cell are different because only certain proteins are unique to each membrane.

Molecules and ions can pass through the plasma membrane in four ways:

- a) **Directly through the phospholipid membrane.** Molecules that are soluble in lipids, such as oxygen, carbon dioxide, and steroids, pass through the plasma membrane readily by dissolving in the lipid bilayer. The phospholipid bilayer acts as a barrier to most substances that are not lipid-soluble; but certain small, nonlipid-soluble molecules, such as water, carbon dioxide, and urea, can diffuse between the phospholipid molecules of the plasma membrane.
- b) **Membrane channels.** There are several types of protein channels through the plasma membrane. Each channel type allows only certain molecules to pass through it. The size, shape, and charge of molecules determines whether they can pass through a given channel. For example, sodium ions pass through sodium channels, and potassium and chloride ions pass through potassium and chloride channels, respectively. Rapid movement of water across the cell membrane apparently occurs through membrane channels.
- c) **Carrier molecules.** Large polar molecules that are not lipidsoluble, such as glucose and amino acids, cannot pass through the cell membrane in significant amounts unless they are transported by carrier molecules. Substances that are transported across the cell membrane by carrier molecules are said to be transported by carrier-mediated processes. Carrier proteins bind to specific molecules and transport them across the cell membrane. Carrier molecules that transport glucose across the cell membrane do not transport amino acids, and carrier molecules that transport amino acids do not transport glucose.
- d) **Vesicles.** Large nonlipid-soluble molecules, small pieces of matter, and even whole cells can be transported across the cell membrane in a vesicle, which is a small sac surrounded by a membrane. Because of the fluid nature of membranes, the vesicle and the cell membrane can fuse, allowing the contents of the vesicle to cross the cell membrane.

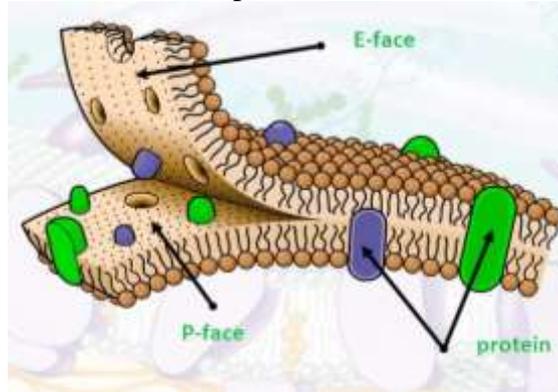
Role of proteins within the plasma membrane

1. Anchoring cells. Membrane proteins anchor cells to the cuticle membrane, and also to microfilaments within the cell.
2. Transport. Membrane proteins form channels that allow selective passage of ions or molecules, for example carrier proteins during facilitated diffusion.
 - Some carrier proteins pump solutes across membranes by active transport
3. Enzyme activity. Some membrane proteins are enzymes that catalyse reactions that are placed within or along the surface of the membrane.
4. Signal transduction. Receptor proteins bind with signal molecules such as hormones and neurotransmitters, and transmit information into the cell
5. Cell recognition. Proteins function as identification tags for cells
6. Junction between cells. Cell adhesion proteins of different cells together
7. Energy transducers and electron carriers. In photosynthesis and respiration, membrane proteins take part in energy transfer
8. Structural support. The various proteins dotted throughout the biphospholipid layer provide structural support to the cell membrane.

Evidence for the fluid-mosaic model of the cell membrane

- a. Pieces of the cell membrane treated from one side with chemicals which react with the proteins but cannot pass through the membrane behave differently.
In some cases, the reactions are confined to the side of the membrane to which the chemicals are applied, while in other cases they occur on both sides, suggesting that this particular proteins span the entire membrane.

- b. Using freeze-fracture technique, a piece of the cell membrane is frozen, then split down the middle longitudinally. If there's inner surface is then viewed in the electron microscope, globular structures of the same size as the membrane proteins can be seen scattered about as shown below



- c. Experiments on membrane viscosity suggest that it is of a fluid consistency rather like oil, and shows considerable side movements of the lipid and protein molecules within it.

The cytoplasm

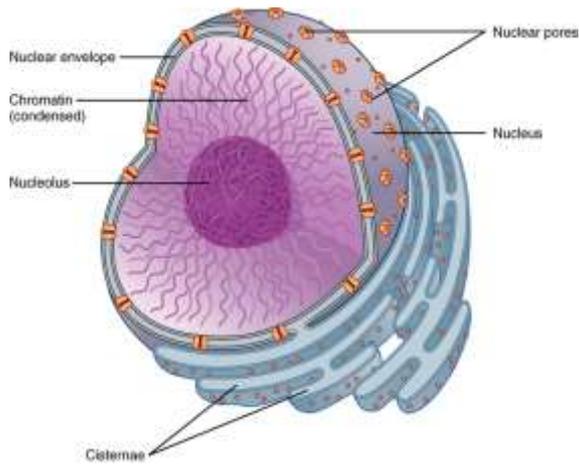
The cell organelles are contained within the cytoplasmic matrix (cytoplasm). The cytoplasm is an aqueous material forming a solution or colloidal suspension of many fundamental biochemicals of life, including ions such sodium, phosphates and chlorides; organic molecules such as amino acids, ATP, fatty acids, nucleotides, vitamins; dissolved gases and storage material such as oil droplets.

The cytoplasm is capable of mass flow in a process cytoplasmic streaming. The cytoplasm is important for important biochemical processes.

The nucleus

This is the central region in both plant and animal cells with a diameter of 4-10 μ m. In this region, all the cell activities are directed e.g. cell division and protein synthesis. A nucleus can be seen with the ordinary microscope. The nuclei have got various shapes depending on the cells e.g. oval, spherical or lobed. Mammalian red blood cells (erythrocytes) and phloem sieve tube elements don't have a nucleus. A distinct nucleus is present at some stage in the cells of all forms except in bacterial cells, blue green- algae and viruses.

- The nucleus has a double layered nuclear membrane (unit membrane). The outer membrane is continuous with the endoplasmic reticulum. The perinuclear space occurs between the two membranes.
- The nuclear membrane has got nuclear pores, which regulate exchange of substances between the nucleoplasm and the cytoplasm. The nuclear membrane pores are routes for the passage of large molecules such as mRNA, from the nucleus to the cytoplasm and this happens during protein synthesis. The nuclear pores can only be seen using an electron microscope.
- Inside the nuclear membrane, we find nucleic acids (DNA and RNA) and proteins. The nuclear DNA is bonded to a number of proteins which are called histones which appear as chromatin in a non-dividing cell. During nuclear division, the chromatins become visible as chromosomes and the nuclear membranes disappear. During Interphase, some of the chromatin strands are tightly coiled and are called heterochromatin. The remaining loosely coiled chromatin is called euchromatin. Inside the nucleus, there is a nucleolus which makes ribosomes and ribosomal RNA.
- The nucleus contains one or more small spherical bodies called nucleoli which manufacture ribosomal RNA (rRNA) and assemble ribosomes. A nucleolus contains RNA and DNA.



Functions of a nucleus

1. Chromosomes in a nucleus contain the genetic material of the cell
2. The nucleus acts as the centre to control cell activities and cell division
3. Production of ribosomes and RNAs needed for protein and enzymes synthesis
4. Formation of the ribosomal RNA by nucleolus.
5. Nuclear division gives rise to cell division hence reproduction.

Adaptations of the nucleus to its function

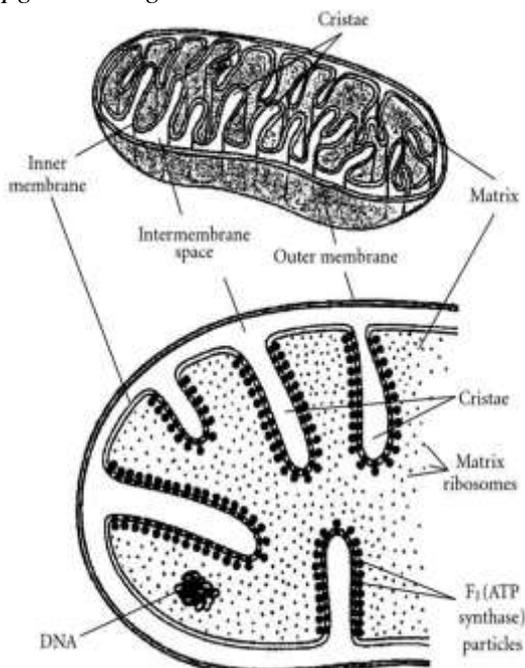
- 1) DNA is long to store many genes
- 2) Nuclear membrane has pores for exchange of DNA and RNA between the nucleus and cytoplasm
- 3) Presence of nucleolus that produces ribosomes which are protein factories
- 4) Nuclear envelope that isolates nucleus from interference by processes in cytoplasm
- 5) Nuclear pores are narrow to regulate entry and exit of substances

Mitochondria

Mitochondria appear as rod-shaped or cylindrical organelle, although occasionally they are more variable in shape with a length of about 2.5-5 μ m and a diameter of 1 μ m.

Each mitochondrion is bound by a double membrane, the outer layer being a continuous smooth boundary. Between the two membranes is the intermembrane space. The inner membrane is extensively in folded to form partitions called Cristae (consisting of a head piece, stalk and base piece), which partially divide the interior. The Cristae in plants are commonly tubular and villus-like; in animal cells they are sheet-like plates. The inner membrane holds the oxysome and encloses a fluid filled space called the matrix. The matrix contains enzymes and DNA, the DNA directs or codes the synthesis of proteins within the mitochondria i.e. mitochondria multiply during cell division.

Fig 7.21 pg 163 Clegg OR Fig 162 B & C pg 162 Monger



Functions

1. They are sites of ATP formation
2. They are sites of aerobic respiration

NOTE; Mitochondria are prominent in organs where there's a lot of metabolic activity e.g. kidney nephron, muscle fibres, neurone axons, tail of the sperm and root hairs.

Adaptations of the mitochondria to its function (energy production)

1. The double membranes separate the mitochondrion from interference by processes in the cytoplasm
2. small size gives a large surface area to volume ratio for the rapid uptake / release of materials
3. matrix contains enzymes of the Krebs cycle
4. inner membrane invaginates (in-folds) forms cristae to increase the surface area for electron transport chain (oxidative phosphorylation)
5. inner membrane has cristae with oxysomes that contain ATP synthetase (ATPase) on stalked particles that make ATP

6. narrow intermembrane space (gap between inner and outer membranes) enables pH / H⁺ / proton concentration gradient to be rapidly established / steeper chemiosmosis therefore more efficient / chemiosmosis can occur
7. inner membrane contains molecules for electron transport pathway
8. DNA is present to act as genetic material for synthesis of some protein / control of metabolism
9. Presence of many ribosomes for protein synthesis to reduce on importation of some proteins
10. Phosphate used in glycolysis thru protein carriers (not clear)

Comparison between the structure of the nucleus and the mitochondria

a. Similarities

- Both contain DNA
- Both contain RNA
- Both contain ribosomes
- Both contain enzymes
- Both are bound by a double membrane

b. Differences

Nucleus	Mitochondrion
1. Linear DNA	1. Circular DNA
2. DNA contained in chromosomes	2. DNA not contained in chromosome
3. Larger 80S ribosomes	3. Smaller 70S
4. Membrane has pores	4. Membrane has no pores
5. Inner membrane not folded	5. Inner membrane folded to form cristae
6. Oval or spherical	6. Sausage shaped, spiral or cup-shaped
7. Outer membrane continuous with endoplasmic reticulum	7. Outer membrane not continuous with any organelle
8. Ribosomes may be attached to outer membrane	8. Ribosomes not attached on outer membrane

Chloroplast

Chloroplasts are members of a group of organelles known as **plastids**. Plastids normally contain pigments such as chlorophylls and carotenoids and bound by 2 membranes. They develop from small bodies called proplastids found in the meristematic regions. There are mainly two types of plastids and they are both found in plant cells.

The **leucoplasts** are colourless and are found in plant parts which are not exposed to sunlight; these parts include roots and underground stems. They are the food storage organelles. There are three types of leucoplasts;

1. In the amyloplasts, sugar is converted into starch
2. In the elaioplasts, there's synthesis and storage of lipids
3. In the aleuroplast, there's synthesis and storage of proteins

Chromoplasts are coloured pigments containing non-photosynthetic pigments, common in fruits, carrot root tissue and in flower petals

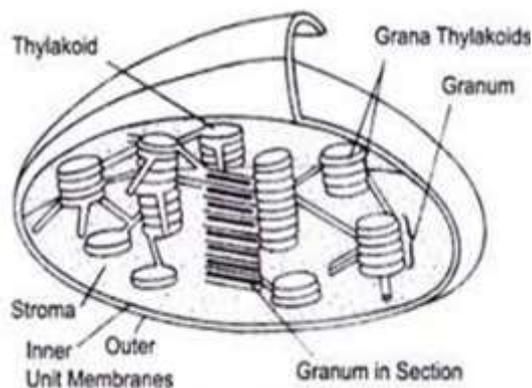
Structure

- Chloroplasts are biconvex in shape, 4-10µm in diameter, 2-3µm thick.
- They are bound by a double unit membrane, like chloroplasts, but in addition chloroplasts have a third membrane called the thylakoid membrane. This is folded into thin vesicles (the thylakoids), enclosing small spaces called the thylakoid lumen (lamellae). The thylakoid vesicles are often layered in stacks

called grana, which contain photosynthetic pigments. The thylakoid membrane contains the same ATP synthase particles found in mitochondria.

- The interior of the chloroplast is divided into the grana which are surrounded by an aqueous matrix called stroma, into which the lamella is suspended.
- Chloroplasts contain DNA, tRNA and ribosomes, and they often store products of photosynthesis as starch grains and lipid droplets.

Fig 4.5 a & b pg 56 Toole.



Adaptations of chloroplasts to their function

1. Chloroplasts of flowering plants have a biconvex shape which increases the surface area for the exposure of the photosynthesis pigments.
2. It has a double membrane with an outer membrane (surface) membrane which prevents the photosynthetic reactions from mixing with those in the cell cytoplasm.
3. The surface membrane is permeable to gases like carbon dioxide which is a raw material for photosynthesis.
4. The internal membrane also contains electron transport systems which synthesize ATP.
5. It contains chlorophyll for trapping sunlight energy.
6. It has thylakoids that increase the surface area for holding chlorophyll molecules.
7. The thylakoid granum is connected by intergrana membranes thus maintaining the thylakoids and chlorophyll stationary in position.
8. The stroma of the chloroplast has DNA and ribosomes for protein synthesis.
9. The stroma contains the necessary enzymes for protein synthesis.

Comparison of chloroplast and mitochondrion

Similarities:	Differences	
	Chloroplast	Mitochondrion
Both:		
a. are enclosed by double membrane	Site of photosynthesis	Site of respiration
b. contain DNA	Contains thylakoid membranes	Lacks thylakoid membranes
c. contain 70S ribosomes	Contains photosynthetic pigments that absorb light	Lacks photosynthetic pigments
d. have electron transport chain	There is light generated ATP production	ATP production by oxidation of organic molecules
e. produce ATP by chemiosmosis	H ⁺ gradient across thylakoid membrane	H ⁺ gradient across inner membrane
f. contain ATP synthase /ATPase	Cristae absent	Cristae present
	Larger size	Smaller size

Microvilli

Microvilli are tiny finger-like extensions of the cell surface membrane or certain animal cells, such as those of the intestinal epithelium. Microvilli are massed together forming a brush border at the edge of cell bearing them.

Each microvillus contains bundles of actin and myosin filaments, causing the microvilli to contract.

Microvilli provide a large surface area for absorption and digestion.

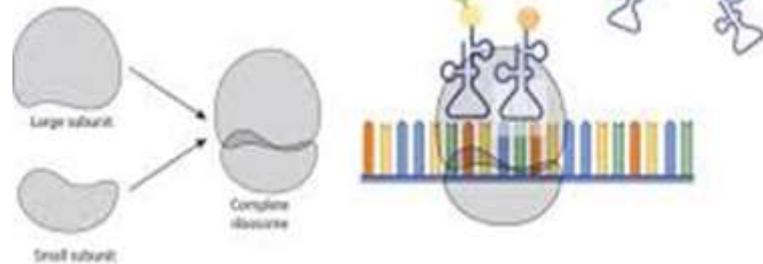
Ribosomes

Ribosomes are tiny organelles with a diameter of about 20nm, made of ribosomal RNA and protein. They carry out protein synthesis. Each ribosome consists of two sub-units, one large and one small. There are two types of ribosomes: 70s are found in prokaryotes, mitochondria, chloroplasts and are the slightly larger 80s ribosomes

occur in the cytoplasm of eukaryotes.

When several ribosomes occur along a common strand of mRNA, the whole structure is known as a polysome or a polyribosome.

Bound and free ribosomes are structurally identical, and ribosomes can alternate between the two roles.



Ribosomes lying free in the cytoplasm are the site of synthesis of proteins that are retained within the cells, e.g. enzymes that catalyse the first steps of sugar breakdown and haemoglobin in young red blood cells. Ribosomes bound to endoplasmic reticulum produce proteins that are subsequently secreted outside the cell e.g. proteins inserted into membranes for packaging within certain organelles (lysosomes) or for export from the cell.

Cells that specialise in protein synthesis have a high proportion of bound proteins and a prominent nuclei e.g. cells of the pancreas that secrete digestive enzymes.

Endoplasmic reticulum

Endoplasmic reticulum (ER) consists of a network of folded membranes forming sheets, tubes or flattened sacs in the cytoplasm. It forms a cytoplasmic skeleton called a cytoskeleton. The tubules and sacs are called cisternae.

ER is flexible and mobile since it occupies much of the cytoplasm of many cells, including those in which streaming movements of the cytoplasm occur. *It therefore forms an intracellular transport system and a cytoplasmic skeleton of the cell.*

Functions of ER

1. Offer increased surface area for cellular reactions.
2. Form part of the cell's skeletal framework
3. Transporting proteins and carbohydrates to other organelles like lysosomes, Golgi apparatus, and plasma membrane.
4. Form the nuclear membrane during cell division.

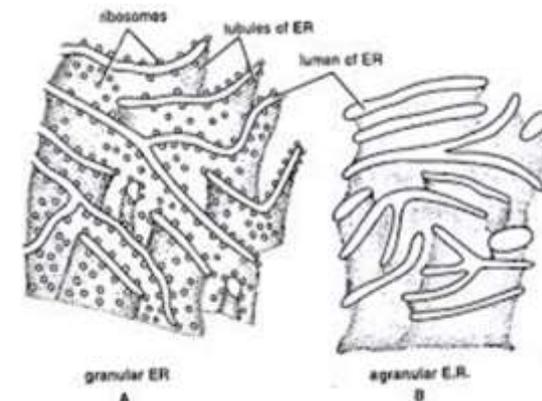


Fig. 298. Structure of endoplasmic reticulum. A, Rough ER; B, Smooth ER.

Rough ER (RER) consists of an interconnected system of membrane-bound flattened sacs. It is continuous with the outer membrane of the nucleus and has many minute globular bodies called ribosomes. The RER isolates and transports proteins manufactured by ribosomes, mainly secreted proteins for export i.e. those that the cell does not need but are needed elsewhere e.g. enzymes and hormones. RER is abundant in cells which are rapidly growing or secretory cells e.g. pancreatic cells.

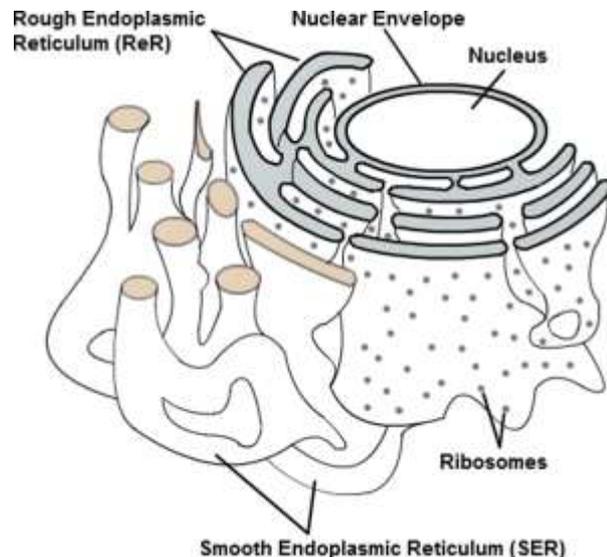
Functions of RER

1. Rough ER is concerned with the transport of proteins which are made by ribosomes on its surface
2. The protein is extensively modified as it passes through the cisternae e.g. converting it into a glycoprotein.
3. Checks the quality of proteins formed, especially correct ordering and structure.

Smooth ER (SER) is a system of interconnected tubules and it lacks ribosomes. SER is abundant in cells involved in lipid and steroid hormone synthesis e.g. cells in the testes and ovaries or cells involved in detoxification e.g. liver cells.

Functions of SER

1. Enzymes of SER are important in the synthesis of lipids including oils, phospholipids and steroids e.g. lipids from fatty acids and glycerol in the epithelium of the intestine. Testes and ovaries are rich in SER because they secrete steroid hormones
2. Other enzymes of SER detoxify drugs, alcohol and poisons, especially in the liver
3. SER becomes modified to form the sarcoplasmic reticulum surrounding the muscle myofibrils
4. SER attaches receptors to cell membrane proteins in plant cells
5. Synthesis and repair of membranes by producing cholesterol and phospholipids
6. For metabolism of glycogen in the liver e.g. glucose-6-phosphatase enzyme in SER converts glucose-6-phosphate to glucose.
7. Contains enzymes that detoxicate lipid soluble drugs, alcohol and metabolic wastes from the liver
8. The SER also stores calcium ions
9. Pathway for the transport of materials through the cell



Adaptations of ER to its function

1. The interconnected network provides the cell with skeletal framework.
2. Forming an extensive network increases the surface area for metabolic reactions e.g. protein synthesis at RER.
3. The endoplasmic reticulum membrane compartmentalizes the cytoplasm (isolates lumen from cytosol), which;
 - Enables transporting soluble and well packaged substances to their specific destinations.
 - Prevents interference of different metabolic processes taking place in the cell at the same time.
4. Contains a variety of enzymes for performing diver roles in cell metabolism.
5. The SER is modified into sarcoplasmic reticulum storage and release of calcium ions.
6. The membrane has a variety of proteins that offer unique properties including signal reception.
7. The RER membrane has sites for attachment of many ribosomes for protein synthesis

Lysosomes (suicide bag)

These are tiny membrane bound organelles that contain hydrolytic enzymes. Lysosomes occur only in animal cells and there are primary and secondary lysosomes. The primary lysosomes are tiny vesicles from the Golgi body while the larger secondary lysosomes are formed when the primary lysosomes fuse with small vacuoles of the animal cells.

They are usually absent in plants except insectivorous plants e.g. *Nepenthes*, *Dionaea*.

Lysosomal enzymes work best in the acidic environment found in lysosomes. If a lysosome breaks open or leaks its contents, the released enzymes are not very active because the cytosol has a neutral pH. However, excessive leakage from a large number of lysosomes can destroy a cell by *autodigestion*.

Particles taken in by cells or made in the cell are digested on the lysosome. Lysosomes contain enzymes e.g. lipase which hydrolyses lipids to fatty acids and glycerol, carbohydrases which hydrolyse carbohydrates to simple sugars, peptidases which hydrolyse peptides to amino acids, RNA-ase, DNA-ase, and others.

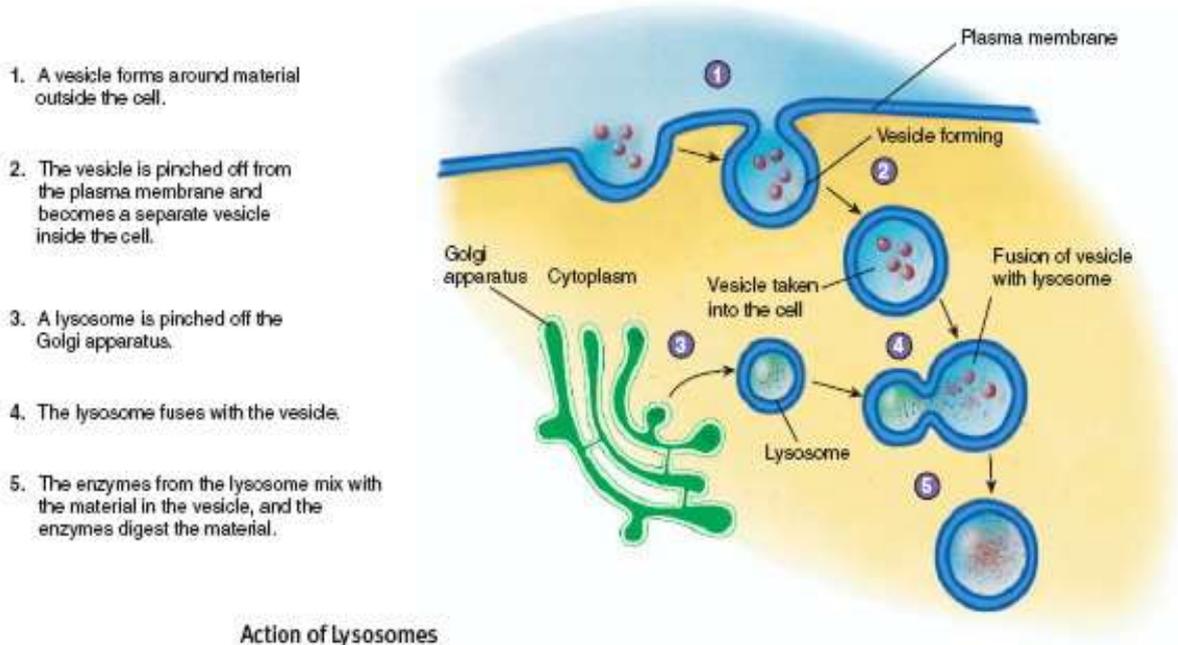


Fig 5.32 pg 155 Soper OR Fig 7.20 pg 162 Clegg

Functions

1. Digestion of materials taken in by endocytosis. The digestion may be for nutrition or defensive purposes. After its action, the products of digestion are absorbed, assimilated and the vacuole migrates to the cell surface membrane and releases its contents.
2. Release of enzymes outside the cell. This occurs during replacement of cartilage by bone during development or bone remodeling after injury.
3. On the sperm head is an organelle called acrosome which is actually a lysosome, it contains enzymes that enable the sperm to penetrate the ova.
4. Autolysis. This is the process by which the lysosome releases its contents into the cell i.e. a suicide bag. Autolysis occurs during reabsorption of the tail of a tadpole and returning the nucleus to its normal size after delivery
5. Autophagy. This is the process by which unwanted structures within the cell are engulfed and digested within the lysosomes.



1. Cleavage of organic substances.
2. The destruction of dead cell organelles.
3. The destruction of cells fulfilled.

Golgi apparatus/body

It is called a dictyosome in plants.

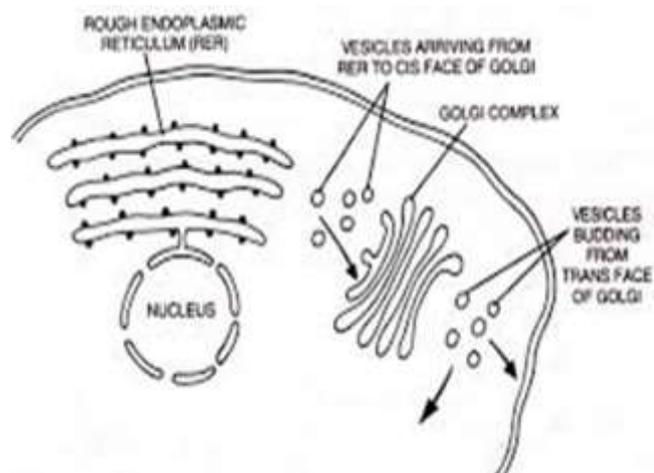
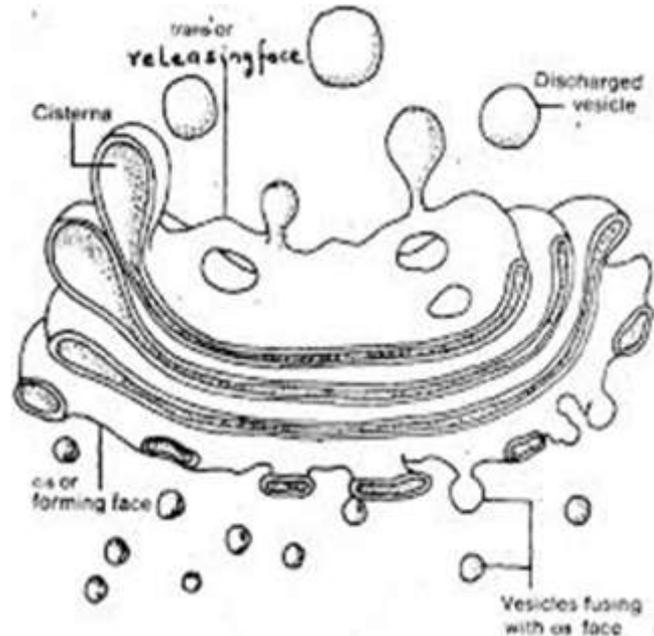
Golgi consist of a stack of flattened, membrane bound sacs called cisternae, together with a system of associated vesicles called Golgi vesicles. They are abundant in secretory cells and in rapidly dividing cells e.g. pancreatic cells, goblet cells, cells in testes and ovaries.

NOTE: at one end of the stack, new cisternae are constantly being formed by vesicles from the SER.

Mode of action of the Golgi

- i. Proteins made at RER have, as part of their amino acid sequence, a signal that directs them where to go:
- ii. Proteins arriving at cis-Golgi but having RER retention signal (were wrongly sent), are repackaged into vesicles then returned to RER.
- iii. Soluble or properly folded macromolecules (proteins, lipids and polysaccharides) from RER enter cis-Golgi network via transport vesicles
- iv. Within cis-cisternae, macromolecules are partly modified i.e. carbohydrates are added to proteins (glycosylation), phosphate is added to protein (phosphorylation) e.t.c.
- v. After partial modification, coated vesicles bud (pinch) off the swollen ends of cis-cisternae and fuse with ends of medial cisternae.

Fig 4.10 pg 60 Toole OR Fig 2.10 pg 19 Roberts OR Fig 2.19 pg 162 Clegg



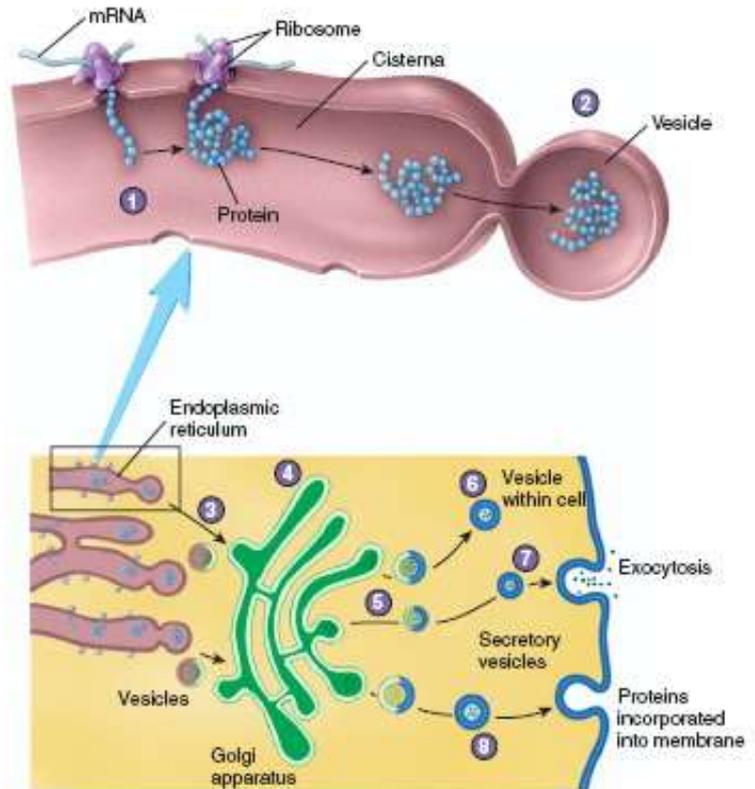
From trans-cisternae, the transformed macromolecules exit the Golgi and are sorted into different transport vesicles destined for lysosomes, plasma membrane or storage vesicles for secretion.

Within medial-cisternae, different enzymes further transform macromolecules differently, depending on their structures and destination i.e. some are modified for secretion, others for the membrane, and some for lysosomes.

After further modification within the medial-cisternae, coated vesicles bud (pinch) off the swollen ends of the medial-cisternae and fuse with the ends of trans-cisternae for further transformation

- a) Vesicles containing hydrolase enzymes fuse with membranes of growing lysosomes so that the contents of both structures fuse.
- b) Vesicles containing hormones e.g. insulin remain until when signaled by the cell, the vesicles then fuse with plasma membrane to release (secrete) the hormone outside the cell by exocytosis.
- c) Vesicles containing membrane proteins fuse with the cell membrane and some of the modified proteins become part of the cell membrane e.g. protein receptors.

1. Some proteins are produced at ribosomes on the surface of the rough endoplasmic reticulum and are transferred into the cisterna as they are produced.
2. The proteins are surrounded by a vesicle that forms from the membrane of the endoplasmic reticulum.
3. The vesicle moves from the endoplasmic reticulum to the Golgi apparatus, fuses with its membrane and releases the proteins into its cisterna.
4. The Golgi apparatus concentrates and, in some cases, modifies the proteins into glycoproteins or lipoproteins.
5. The proteins are packaged into vesicles that form from the membrane of the Golgi apparatus.
6. Some vesicles, such as lysosomes, contain enzymes that are used within the cell.
7. Secretory vesicles carry proteins to the plasma membrane, where the proteins are secreted from the cell by exocytosis.
8. Some vesicles contain proteins that become part of the plasma membrane.



Function of the Golgi Apparatus

Functions

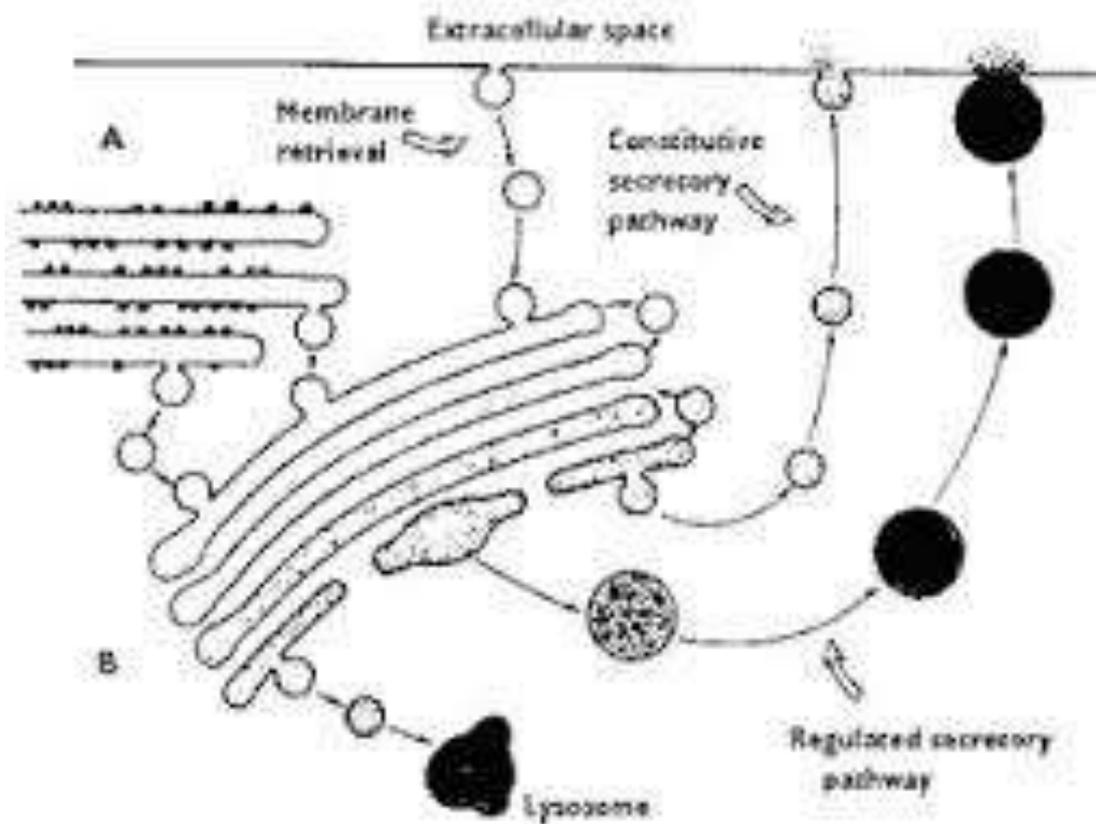
1. The function of the Golgi apparatus is to transport and chemically modify the materials contained within it.
2. Golgi apparatus forms lysosomes containing hydrolytic enzymes
3. Golgi is involved in the formation of peroxisomes
4. Golgi apparatus in the leaf glands of some insectivorous plants e.g. sundews secrete a sticky slime and enzymes which trap and digest insects
5. The membranes of the vesicles from the Golgi apparatus form the first layer of the new cell wall that develops between the two daughter cells as they divide.
6. Golgi is sometimes involved in the secretion of carbohydrates e.g. polysaccharides are attached to a protein to form proteoglycans present in the extracellular matrix of the animal cell
7. To form carbohydrates.
8. Transport of lipid molecules around the cell.
9. Secretory vesicles produced by Golgi contain a variety of important substances e.g.

neurotransmitters, hormones, mucin, zymogen e.g. pepsinogen, etc.

10. Fusion of Golgi vesicles with cell membrane maintains the membrane which is used to form phagocytic vacuoles and Pinocytic vesicles
11. They form lysosomes if or when they contain digestive enzymes

Adaptations of the Golgi

- a) Cisternae are enclosed by permeable membranes, which isolate the inside cavity from cytosol for efficient functioning.
- b) Tubular structure enables transportation of soluble protein and lipids from the endoplasmic reticulum for modification.
- c) Variety of enzyme systems for modifying proteins by adding carbohydrates and phosphate by the process of glycosylation and phosphorylation respectively.
- d) Many cisternae increase the surface area for modifying synthesised macromolecules.
- e) There are many compartments at the cis, located at the beginning of the Golgi apparatus to facilitate passage of proteins through the Golgi apparatus



Plant cell wall

It has fibres of cellulose that contain several units of glucose cellulose fibres. Each fibre has several microfibrils. These are strands of cellulose in a crystalline state and these cellulose molecules are held in a matrix by hydrogen bonds. The matrix consists of pectic acid, calcium and magnesium pectate and hemicelluloses. Hemicelluloses are polymers of various pectose and hexose sugars. Pectic substances also make up most of the middle lamella. The middle lamella binds adjacent plant cells to one another. The cell wall is interrupted by pores which carry strands of cytoplasm called plasmodesmata. This cytoplasm facilitates the movement of substances between adjacent cells as well as the deposition of cellulose during the thickening of secondary cell wall.

The young plant cells are made up of the primary wall. These cells are usually found in the growing regions of plants i.e. the meristems e.g. the shoot and root apex. The primary wall is thin, plastic and it allows the cell to grow. Inside the primary wall develops the secondary wall which is thicker due to more cellulose fibres being laid down as the cell grows. The cellulose fibres are closely packed and are laid down in an orderly way. The secondary wall is impregnated with lignin which is an alcohol polymer and this lignin gives strength to cells of the xylem and the sclerechyma. The secondary cell wall tends to be rigid and tangile. This characteristic brings about the death of the cell because the essential nutrients from the cytoplasm can no longer move across the pores through the cell wall.

In the cork tissue, the tissue between primary and secondary wall, is a fatty substance called suberin. The cork (phloem) cells are formed by the cork cambium (phellogen) prevents the passage of water and gases into and out of the woody plants.

The outer walls of the leaves and young stems are made up of cells called epidermal cells. These cells are covered by a waxy polymer called cutin. Which is secreted by the cytoplasm and it passes through the primary

wall and the middle lamella to appear on the epidermis. Cutin provides a water proof covering to the aerial surface of the plant.

Functions

1. Mechanical strength and skeletal support is provided for individual cells and for the plant as a whole
2. Cell walls are fairly rigid and resistant to expansion and therefore allow development of turgidity when water enters by osmosis
3. Orientation of cellulose microfibrils limits and controls cell growth and shape because the cell's ability to stretch is determined by their arrangement
4. The system of interconnected cell wall (apoplast) is a major pathway of movement for water and dissolved salts
5. Cell walls develop a coating of waxy cutin, the cuticle, on exposed epidermal surfaces reducing water loss and risk of infection
6. The walls of xylem vessels and sieve tubes are adapted for long distance translocation of materials through the cells
7. The cell wall of root endodermal cells are impregnated with suberin that forms a barrier to water movement
8. Some cells walls are modified as food reservoirs as in storage of hemicelluloses in some seeds.
9. The cell walls of transfer cells develop an increased surface area and the consequent increase in surface area of the cell surface membrane increases the efficiency of transfer by active transport
- 10.

Adaptation of the cell wall to its function

- a) The cell wall has cellulose polymers associate through very many H-bonds whose cumulative bonding energy provides high tensile strength of the cell wall for providing support and preventing rupturing
- b) The cell wall has relatively thick multiple wall layers provide mechanical support
- c) The cell wall has secondary walls which may be cutinized / suberinised for preventing water loss
- d) The variety of functional proteins like oxidative enzymes (peroxidases), hydrolytic enzymes (pectinases, cellulases) enable performing several functions like protection against pathogens, cell expansion, cell wall maturation
- e) The cell wall has extremely rigid secondary walls that provide compression strength
- f) Deposition of cellulose fibrils in alternating layers enables some degree of flexibility
- g) The cell wall is semi-permeable in nature to allows exchange of water, dissolved salts and small protein molecules

Comparison between plant cell wall and plasma membrane		
Similarities	Differences	
(Group assignment)	Cell wall	Plasma membrane
	Number of main layers / regions varies (2 or 3)	Number of main layers / regions constant
	Skeleton mainly made of carbohydrates / polysaccharides	Skeleton mainly made of phospholipids
	More permeable to molecules	Less permeable to molecules
	Lacks transmembrane proteins	Transmembrane proteins present
	Plasmodesmata present	Plasmodesmata absent
	May be lignified and suberinised	Lacks lignification and suberinisation
	Has middle lamella	Lacks middle lamella
Secondary thickening occurs	Lacks secondary thickening	

Flagella and cilia

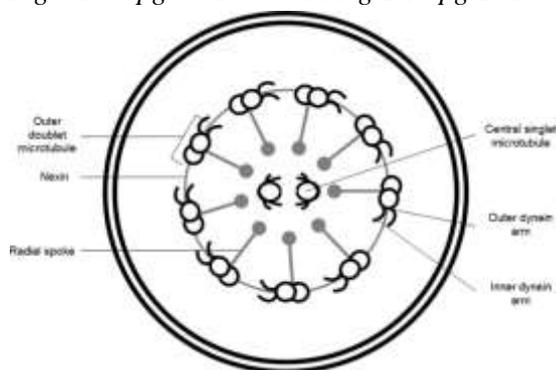
These are organelles that project from the surface of cells but are connected to a basal body just below the membrane.

Flagella occur singly or in small numbers, whereas cilia occur in large numbers on larger cells, and are typically shorter than flagella.

Flagella and cilia are enclosed by a plasma membrane. Internally, they consist of microtubules arranged in an outer ring of nine pairs surrounding two central pairs ('9 + 2' arrangement).

Flagella and cilia move by means of sliding movements of one member of a microtubule pair relative to the other.

Fig 4.15 b pg 63 Toole OR Fig 2.16 pg 23 Roberts



Functions

1. In moving cells e.g. sperm, chlamydomonas spp e.t.c.
2. To propel fluids across cells of ciliated cells that move mucus along the brachial lining
3. To acquire food e.g. the feeding current generated by paramecium in its oral groove
4. To sense the environment e.g. sensory hair cells

Microbodies

These are small spherical membrane-bound bodies of 0.5-1.5µm in diameter. The two common types of microbodies are peroxisomes and glyoxysomes.

Peroxisomes contain oxidative enzymes e.g. catalase. Glyoxysomes are found in the fat tissues of germinating seedling such as those of peanut plants. Glyoxysomes contain enzymes that catalyse the conversion of fats and oils into sugars until the germinating seedlings can produce their own sugars through photosynthesis.

Middle lamella

This is a membrane that holds adjacent plant cells together. It is called the basement membrane in animal cells to form a tissue. The middle lamella is made up of calcium pectate.

Vacuoles

Vacuoles are fluid cavities bound by a single membrane. They are formed either by infolding or pinching off of part of the cell membrane, or by enlargement of a vesicle cut off by the Golgi apparatus.

Young plant cells usually contain several small vacuoles which, in the mature cell, have united to form a large permanent, central vacuole. The plant vacuole is filled with a liquid known as a cell sap, an aqueous solution

Centrioles

Centrioles are found in animal cells. The centrioles are located outside the nucleus in a material of poorly defined structure called the centrosome. Centrioles are paired cylinders of about 0.3-0.5µm long and 0.24µm in diameter which are held at right angle to each other. Each cylinder consists of nine triplets of microtubules in a '9+0' arrangement.

Functions

- a. Centrioles act as organizers of spindle fibres and are involved in the separation of chromosomes or chromatids during cell division
- b. In some cells, centrioles divide to produce basal bodies from which flagella and cilia develop.

Microfilaments

These are long fibres of about 6-7nm in diameter. They are made up of two actin protein strands intertwined together.

Functions

1. Component of cytoskeleton; give support and maintain cell shape
2. Actin and myosin filaments are needed for muscle contraction
3. Constriction of filaments causes cleavage and furrow formation in cytokinesis of animal cells
4. They play a role in cellular movements e.g. cytoplasmic streaming, cell motility, involved in phagocytosis and pinocytosis.

of dissolved food materials, ions, waste products and pigments. The membrane around this type of vacuole is known as the tonoplast.

The vacuoles of animal cells are usually very small and less permanent, called vesicles. They may contain engulfed solids or liquids.

Functions of vacuoles

1. In plants, the vacuole functions to store food substances e.g. sugars
2. The concentrated cell sap causes water to enter by osmosis and the cell becomes turgid. Turgidity brings about support in herbaceous plants and plays a role in enlargement and growth of young plant cells
3. Vacuoles of some plant cells e.g. petals of flowers; contain coloured pigments to attract insects for pollination.
4. Vacuoles in leaves accumulate waste products e.g. tannins and are removed when the leaves fall
5. Food vacuoles formed by endocytosis enable bulk intake of large food particles
6. Contractile vacuoles in unicellular organisms e.g. amoeba and paramecium, regulate water content in the cell.

Protoplasm

This is the living material that comprises of the cytoplasm and the nucleoplasm. The cytoplasm is the protoplasm outside the nucleus and it has all other organelles e.g. mitochondria, RER and other cell contents e.g. glycogen in animal cells, liquid droplets, starch granules in plant cells, salts e.g. NaCl.

The nucleoplasm is the cytoplasm bound by the nuclear membrane. Chromatins are found within the nucleoplasm and later form the chromosomes.

The protoplasm is a colloidal system i.e. a solution with suspended particles in it e.g. cell organelles and food nutrients

Microtubules

These are straight unbranched hollow cylinders, 25nm wide and usually short in strength. They are made of protein and constantly being built up and broken down.

Functions

1. They are involved in the movement of cytoplasmic components within the cell.
2. Microtubules appear to direct the passage of Golgi vesicles to deposition sites.
3. Along with the microfilaments, the microtubules constitute the cytoskeleton, which controls the shape and movement of the cell
4. They are used in cell wall formation
5. They also occur in basal bodies, centrioles, in the spindle, in cilia and flagella

Distribution and function of membranes of cells

- a) Membranes of cells is not limited only to the cell membrane (plasma membrane), which forms the cell boundary plus its various modifications, it also includes all other membranes enclosing some organelles and some cytoplasmic inclusions within cells.
- b) Plasma membrane: Forms a protective barrier between the cell inside and outside. Determines cell shape and provides cell stability. Selectively regulates entry and exit of substances.
- c) Nuclear envelope: Separate nuclear contents from cytoplasm hence limits DNA within the nucleoplasm but allows exit of RNA. Controls flow of information to nucleus and DNA that are carried by the macromolecules.
- d) Outer mitochondrial membrane: Allows entry of ATP, NADH and from glycolysis
- e) Inner mitochondrial membrane: Contains electron carriers in electron transport chain
- f) Rough Endoplasmic Reticulum: Intracellular transport and sites for ribosome attachment
- g) Smooth Endoplasmic Reticulum: intracellular transport
- h) Outer chloroplast membrane: Allows photosynthetic products out and substrates in

- i) Thylakoid membranes of chloroplasts: Store photosynthetic pigments e.g. chlorophyll. Contains electron carriers
- j) Golgi complex membrane. Storage of glycoprotein. Synthesis of polysaccharides e.g. cellulose in plants
- k) Lysosomes. Isolates autolytic enzymes from unnecessary digestion of cell components
- l) Tonoplast. Limits cell sap within the vacuole
- m) Membranes surrounding vesicles: Limit the contents of the vesicles within until when ready for exit e.g. calcium ions and neurotransmitters in neurones, undigested materials in phagocytic vesicles, etc.
- n) Neurilemma of neurones. Contains protein pumps for Na^+ and K^+ which bring about impulse propagation
- o) Myelin sheath membrane. Insulates nerve fibre to increase transmission speed.

Advantages of having membrane-bound organelles (importance of possession of numerous internal membranes)

1. Internal membranes maintain pH and temperature of internal membranes for reactions to proceed optimally
2. Increases proportion of membrane area to cell volume, increasing surface area over which metabolic reactions occur, for metabolic pathways with membrane-embedded enzymes.
3. Internal membranes partition the cell into compartments, providing different local environments for specific metabolic pathways so that incompatible processes can proceed simultaneously inside the same cell
4. Inner membranes provide attachment sites for specific enzymes, metabolites and molecules, regulating the occurrence of specific metabolic processes.
5. Enzymes and metabolites for particular metabolic pathways are enclosed within organelles, causing close proximity of products of one reaction to the next enzyme in the sequence, thereby increasing the rate of metabolic reactions
6. Internal membranes regulate the entry of metabolites into the organelle, controlling the rate of metabolic activity
7. Potentially harmful metabolites and enzymes are isolated inside organelles, preventing damage to the rest of the cell, such as lytic enzymes in lysosomes.
8. Internal membranes provide a supporting cytoskeleton to the cell, and serve as an intracellular transport system
9. Internal membranes protect the genetic material (DNA) from digestion and chemical alteration, preventing harmful mutations
10. Internal membranes maintain optimal conditions in specific organelles for specific metabolic pathways to proceed optimally

HISTOLOGY

Histology is the study of tissue structure, largely by various methods of staining and microscopy.

A tissue is a group of cells of similar appearance and a common function. Broadly tissues consist of cells physically linked and associated intracellular substances that is specialised for particular function.

There are both plant and animal tissues to be looked at in this study;

HISTOLOGY OF PLANTS

Plant tissues can be divided into;

- a) Meristems, these include apical meristems, lateral meristems and intercalary meristems.
- b) Permanent tissues, which are divided into two major groups;
 - i. Ground tissues, which include;
 - Parenchyma tissues
 - Collenchyma tissue
 - Sclerenchyma tissue
 - ii. Vascular tissues, they include;
 - Xylem
 - Phloem

MERISTEMS

A plant meristem is a group of cells which retain the ability to divide by mitosis. These are three types of meristems namely; apical, lateral & intercalary meristems.

- a) Apical meristems
Are located at the growing shoot and root apex and are responsible for primary growth
- b) Lateral meristems (cambium)
Occur as cylinders into the older parts of the plants are responsible for secondary growth of dicotyledonous plants
- c) Intercalary meristems
These meristems occur at the nodes of the plants

Functions of meristematic cells

Meristematic cells retain the ability to divide by mitosis to produce new cells. The cells elongate and differentiate to form specialised cells to carry out specific functions. Some examples are growth, reproduction and replacement of old and damaged cells.

- i. Apical shoot and root meristems produce new cells for growth of shoot and root
- ii. Vascular cambium produces new cells to increase the diameter of stems and roots during secondary growth
- iii. Cork cambium (phellogen) produces the outer cork layer (phellem) which consists of suberized cells.
The cork layer reduces evaporation of water from the plant and protects against entry of pathogens.
- iv. The intercalary meristems allow growth and increase in length in regions other than the tip

PERMANENT TISSUES

Parenchyma

Parenchyma tissue consist of living cells. They are usually isodiametric or elongated cells. However, their shape may be distorted by pressure from adjacent cells.

Parenchyma cells have thin cell walls containing cellulose, hemicellulose and pectin. There are no secondary walls. The walls are permeable to water and permit the passage of solutes.

The cells have a large central vacuole with a nucleus and a thin layer of cytoplasm pushed to the membrane.

Transverse section of parenchyma cells
(Roberts fig 3.8A page 40 OR Soper fig 6.2a page 169)

Functions of parenchyma tissue

- i. They are unspecialized tissues which form major component of tissue of stems and roots especially in herbaceous plants.
- ii. When the cells are turgid and tightly packed, they provide support for herbaceous plants
- iii. Some parenchyma cells, like mesophyll cells, contain chloroplasts and carry out photosynthesis
- iv. They store food substances such as starch and malic acid that are stored temporarily in the vacuoles of CAM parenchyma cells
- v. The parenchyma cells in flowers and pericarps contain chromoplasts to attract pollinating agents and dispersal agents of seeds and fruits.
- vi. The parenchyma tissues can be modified or differentiated to form specialised cells to carry out specific functions. These include epidermis, mesophyll, endodermis, pericycle, aerenchyma and secretory cells.

Modifications of the parenchyma tissue

Epidermis

This is a layer of flattened cells, one cells thick. The cells secrete cutin which forms a layer of waxy cuticle on the outer surface of the epidermis.

Functions of the epidermis

- i. It's a protective layer to the inner tissue
- ii. The waxy cuticle reduces water loss through evaporation from the plant and entrance of pathogens
- iii. Stomatal pores in the epidermis allow gaseous exchange
- iv. Epidermis is transparent and allows light to reach the mesophyll layers of leaves for photosynthesis.

• **Endodermis**

It consists of a single-celled ring which is a selective barrier between the outer cortex and the inner pericycle tissues.

In roots the endodermis is impregnated with suberin to form a distinct casparian strip and prevent the movement of water via the apoplast pathway. Non-suberized passage cells in the endodermis permit lateral movement of water and mineral salts.

- **Pericycle**
This is made up of one to several layers of parenchyma cells.
Pericycle is found between the endodermis and central vascular tissues.
It can divide to produce the lateral roots and it is involved in the secondary growth of roots.
- **Palisade mesophyll**
This is made up of column shaped cells and its found below the upper epidermis.
Function
It contains many chloroplasts that enable a leaf to carry out photosynthesis.
- **Aerenchyma**
Parenchyma tissues that surround large air spaces form reservoirs of oxygen and permit gaseous exchange in submerged parts. The large air spaces also provide buoyancy.
- **Secretory cells**
Some parenchyma tissues are modified to form secretory tissue for example nectary glands, hydathodes and resin ducts.
- **Spongy mesophyll**
It has isodiametric or irregular shaped cells.
They are loosely packed with many intracellular space for gaseous exchange.
They have fewer chloroplasts than the palisade cells to carry out photosynthesis

Collenchyma

These consist of living cells. Cells are polygonal shaped and they are elongated. They are closely packed together with very small intracellular air spaces.
The cell walls are unevenly thickened at the corners of cell walls (angular collenchyma). Pits are present in the cell walls.
Collenchyma tissues are usually found in herbaceous plants below the epidermis, midrib of the leaves and leaf petioles.

Functions of collenchyma tissues

It acts as a supporting tissue to provide support to herbaceous plants. With mechanical strength and flexibility.

It allows the cell to expand and be stretched as the young stem grows.

Some of the collenchyma cells contain chloroplasts which carry out photosynthesis

Diagram showing a transverse section of collenchyma cells

Soper fig 6.5a page 173

Diagram showing a longitudinal section of the collenchyma cells

(Roberts fig 3.8B page 40 OR Soper fig 6.5b page 173)

Sclerenchyma

They are two types of sclerenchyma

- i. Sclerenchyma fibres
- ii. Sclereids (stone cells)

Diagram showing transverse section through sclerenchyma cells (Soper fig 6.5a page 173)

Sclerenchyma fibres

These are polygonal shaped cells with tapering ends. Mature sclerenchyma cells have thick lignified secondary cell wall impermeable to water, solutes and gases. (Acidified phloroglucinol can be used for staining lignin red). The cells have protoplast with narrow empty lumen. Pits are present in cell walls. Sclerenchyma fibres are found below the epidermis of the stems or roots or around the vascular bundles and in the midrib of the leaves.

Functions

- i. It acts as a supporting tissue. Collectively the tightly packed sclerenchyma fibres with thick lignified walls provide the plant with mechanical strength and rigidity.
- ii. The tapering ends of sclerenchyma fibres overlap and interlock with one another, further increasing their combined strength

Sclereids (stone cells).

They have different shapes but are usually shorter than sclerenchyma fibres. They consist of dead cells with thicker lignified walls. Simple branching pit are present in the walls.

Drawing of the structure of the sclerenchyma sclereids
(Roberts fig 3.8C page 40 OR Soper fig 6.6b page 175)

A simple pit is formed in an area where lignin is not deposited on the primary wall. A bordered pit is formed when lignin arches over the area.

Sclereids are found singly or in groups in stems, leaves, fruits e.g. pears, guavas and in the hard endocarp of coconuts and seeds e.g. testa of beans.

It is a protective tissue which gives strength and support to the plant structures or organs.

Drawing of the structure of a bordered pit (Soper fig 6.12 page 180)

THE VASCULAR TISSUE

Vascular tissue consists of xylem and phloem which are specialised for the internal transport of substances in the plant.

THE XYLEM

The xylem tissue is made up of two conducting tissues or cells known as xylem vessels and xylem tracheids.

(Roberts fig 12.7A page 187 OR Soper fig 6.9B page 77)

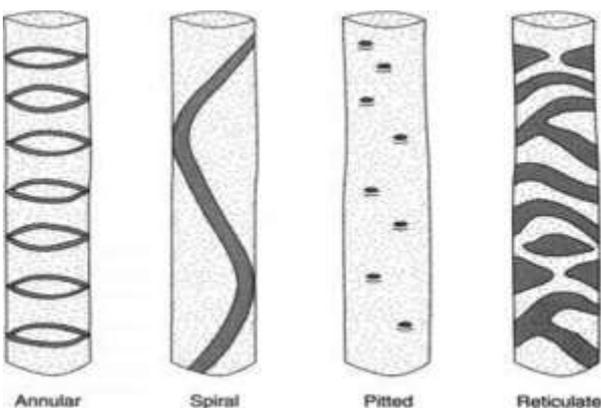
A xylem vessel is formed from a chain of elongated cylindrical cells formed end-to-end. The horizontal end-walls break down partially or completely during the course of development to allow open communication between cells. During development of the xylem tissue, the cellulose side walls of this tissue become impregnated or coated with lignin, a very hard layer which makes them impermeable to water, solutes and gases hence leading to the death of the protoplasm of the tissue. This leads to the formation of a hollow tube called xylem vessel hence more water can flow through the hollow continuous tube with less friction.

The lignified walls are perforated by numerous pits which allow horizontal movement of the lumen of water in and out of the lumen of vessels. Most pits are bordered by a lignified rim. In conifers, the bordered pits contain a valve-like plug called **torus** which controls the passage of water through the pits.

Lignification of the side walls (replacing cellulose with lignin) gives the xylem vessel extra mechanical strength, which prevents its walls from curving in or collapsing during the passage of water under a high tension. This lignification of the side walls occurs in four different patterns which include, annular lignification, simple spiral lignification, multi spiral lignification and reticular lignification

The protoxylem is the first xylem vessel to develop, just behind the apical meristem in the shoot and root. There is incomplete lignification in the walls of protoxylem vessels. Lignin is deposited in rings to form annular vessels in spirals to form spiral vessels. These annular and spiral vessels can be stretched to provide support for vessels during elongated and growth of the young stems and roots.

Different types of thickenings



As growth proceeds, new vessels are formed with more extensive lignification, these are called metaxylem. Metaxylem have bigger lumen and are able to transport more water and mineral ions to the older plant. The presence of pits in the metaxylem vessels allow lateral movement of water and mineral ions to the surrounding living cells (from one tracheid to another). Secondary xylem is formed from the activity of the vascular cambium of dicotyledonous plants during secondary growth.

Although the vessels and tracheids of the xylem tissues are meant for transportation of mineral salts from roots to leaves. They also provide mechanical strength and greatly offer support to the plant.

The table below shows a comparison between the xylem and the tracheids.

Similarities	Differences	
	Xylem vessels	Tracheids
	Cylindrical shape	Are 5 to 6 sided in cross section
	Have open ends at their sides	Perforated end walls
	Have non tapering (pointed) ends	Have tapering ends
	Offers less resistance towards water passage	Offer more resistance towards water passage

Adaptations of the xylem tissue for water transport

1. Xylem vessels have a narrow lumen which enables the upward movement of water from roots to leaves due to the high capillarity
2. Xylem vessels and tracheids have lignified cell walls which enable upward movement of water through them at a high tension as lignin prevents curving in of the walls due its tensile strength and it makes the xylem water proof.
3. Xylem vessels and tracheids lack living protoplasmic contents which enable them to remain hollow so that they allow water to move through with minimum resistance.
4. Xylem vessels and tracheids have partially or completely broken down to allow open communication of one cell to another such that there's free passage of water through them.
5. Xylem vessels and tracheids side walls are perforated by lateral pits to allow horizontal movement of water in and out of the xylem tubes.
6. In some plants like conifers, the bordered pits of the tracheids have a plug-like torus which controls the lateral passage of water through the pits
7. In the protoxylem, annular and spiral thickenings allow the stretching of the walls and further elongation of the stem is possible. In the metaxylem, scalariform, reticulate and pitted thickenings provide additional mechanical strength to older stems. Metaxylem vessels have bigger lumens than protoxylem to transport more water.

Roberts fig 12.7b page 187

THE PHLOEM

The phloem tissue consists of sieve tube elements, companion cells, parenchyma cells, fibres and sclereids.

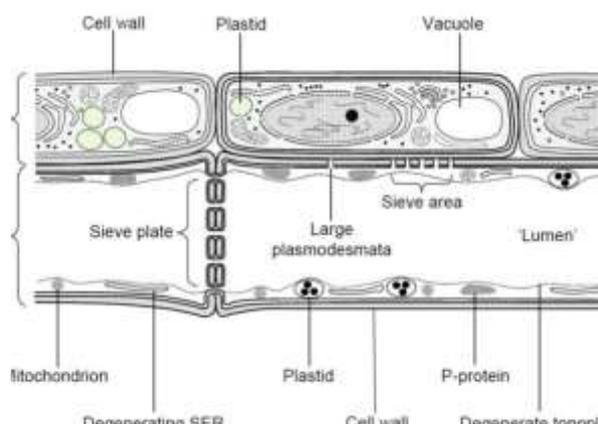
Translocation of organic food molecules from the leaves where they are manufactured takes place through sieve tubes of the phloem. The sieve tubes are long tubes formed from the fusion of end to end sieve tube elements, where end walls break down to a greater or lesser extent to allow the passage of materials.

Roberts fig 12.5A page 293

Sieve tube elements are mature sieve tubes without a nucleus. When still young, the sieve tube cells contain a nucleus and other organelles such as ribosomes, mitochondria, endoplasmic reticulum e.t.c.

At maturity, the cell organelles of the sieve tube elements including the nucleus degenerate, though some few such as the mitochondria, plastids, endoplasmic reticulum e.t.c persist immediately adjacent to the cell walls only.

During differentiation i.e. specialisation for a particular function, the end walls of the adjacent sieve tube elements get coated with cellulose, and form a sieve plate that is perforated by sieve pores. Through the sieve pores are cytoplasmic filaments or trans-cellular strands which run across and are continuous with all the sieve tube elements in the tissue. The cytoplasm of these trans-cellular strands is structurally very simple without organelles because all the organelles degenerate during its development. The side walls of the sieve tube elements are impregnated or coated with a lot of cellulose and pectic acid.



Alongside each sieve tube element is one or more companion cells made of thin cellulose walls, enclosing a protoplast with a dense cytoplasm. The companion cells are the metabolically active cells of this tissue with a prominent nucleus, numerous mitochondria, ribosomes and many other organelles. Therefore most important processes which involve active metabolism are conducted within the companion cells and all the required materials for these processes and all the required materials for these processes are passed via plasmodesmata from the companion cells or to the sieve tube elements and vice versa. The sieve tube elements are therefore living cells.

Adaptations of the phloem tissues for its function

1. It has sieve plates which are perforated to enable a continuous of food
2. The sieve tubes have large pits (plasmodesmata) for lateral movement of organic substances.

3. Companion cells have numerous mitochondria so as to produce large quantities of energy in form of ATP needed for transport of food.
4. Sieve tube elements have fewer cell organelles so as to provide more space for the flow of food materials
5. Some sieve tube elements have cytoplasmic strands or filaments (trans-cellular strands) which allow peristaltic movement of food through the sieve tubes

Phloem collenchyma cells have thick cellulose fibres for providing mechanical support to avoid collapse.

HISTOLOGY OF ANIMALS

Animals are multicellular and they need to have a combination of the individual cells so as to form tissues. This enables the animal to function properly. Animals have a small surface area to volume ratio as compared to unicellular organisms. Therefore, simple processes of diffusion, osmotic uptake of molecules, phagocytosis e.t.c. are not adequate in their function and therefore, there's need for the cells to combine together to form tissues and even in the complex animals, tissues form organs so as to carry out the various functions over a surface with a small surface area to volume ratio.

Animal tissues fall into four main categories;

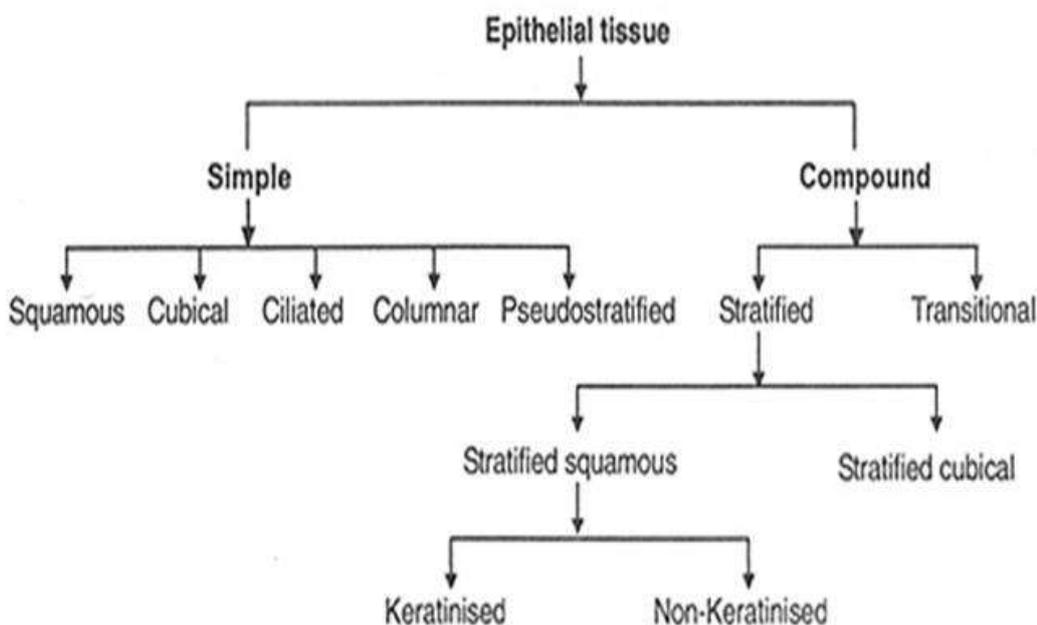
1. Epithelial tissues
2. Connective tissues
3. Muscle tissues
4. Nervous tissues

EPITHELIAL TISSUE

This is the tissue found lining the free surface of animal internally and externally. If the tissue is internal, then it's called an endothelium. The endothelium is found lining all the internal body cavities and lumen. Such activities include the mouth lining, trachea, blood vessels, tubules, oviducts e.t.c.

Epithelial cells are attached to the underlying tissue by a basement membrane, made of a network of white wavy, non-elastic collage fibres.

Classification of Epithelial Tissues



Epithelial tissues are mainly protective and secretory. However, they are of a variety of forms and differ in shape and number of layers and may perform different functions e.g. in the

- a. skin they are protective
- b. lungs they are respiratory
- c. gut they are secretory
- d. kidney they are excretory
- e. tongue they are sensory
- f. gonads they are reproductive where they form the germinal epithelium

Characteristics of epithelial tissue cells

- a. they are attached to the basement membrane which is produced by the cells themselves
- b. the adjacent cells are joined by intracellular cement
- c. there may be interconnecting bridges of cytoplasm within cells
- d. they undergo rapid cell division to resist wearing away (abrasion)
- e. they may build up large numbers of layers to resist wearing away e.g. in the epidermis of the skin

Epithelial tissues are classified according to the number of cell layers and the shape of the individual cells in longitudinal section. They are usually classified into two categories;

- a. **Simple epithelium**, this is usually one cell thick. It includes;
 - i. Squamous epithelium
 - ii. Columnar epithelium
 - iii. Ciliated epithelium
 - iv. Cuboidal epithelium
 - v. Pseudostratified epithelium

Simple squamous epithelium

This is the simplest type of epithelial tissue, sometimes called the *pavement epithelium*. It has the following characteristics;

- The cells are very thin and contain little cytoplasm
- It consists of delicate cells usually less than 20mm thick.
- The cells are loosely packed
- The nucleus is centrally placed
- The cells are flat in nature and fixed on a basement membrane.
- They have little intercellular substance (matrix) in which the cells are embedded.

Surface view (Roberts fig 3.1
page 33)

The above characteristics enable the epithelium to perform the following functions;

- i. In the lumen or blood vessels, the tissue offers a smooth surface for the efficient passage of fluids.
- ii. In the Bowman's capsule and glomerulus, the tissue is permeable to fluids and there's quick diffusion of the fluids
- iii. Between the two surfaces that slide over each e.g. between the ribs, the epithelium reduces friction

Simple columnar epithelium

The characteristics of the columnar epithelium include;

- Cells which are found at right angles to the basement membrane.
- The cells are tall and narrow in shape (elongated with a length much more than the width)
- The nuclei of the cells are at the base of the cells
- Sometimes the cells have microvilli at their end and this makes the cells have a striated or divided border
- The cells may at times have the mucus secreting cells (goblet cells) interspersed among them and the tissue is known as glandular columnar epithelium.
- The micro villi increase the surface area of the cells which are in contact with the fluids
- The goblet cells produce mucus for the reducing friction and for protection against digestive enzymes

The columnar epithelium offers an extensive surface area and it is often found where there's absorption of materials in the form of gases and solutions e.g. lining the small intestines and stomach.

It is a component of the gall bladder and thyroid gland and it protects many kidney ducts.

<p style="text-align: center;">Longitudinal view</p> <p>Soper fig 6.16a page 185 OR Roberts fig 3.1 page 33</p>	<p style="text-align: center;">Diagram of a goblet cell</p> <p>Soper fig 6.17 page 185</p>
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Simple ciliated Columnar epithelium

The cells of the tissue have the same characteristic as those of the columnar epithelium except that they have cilia instead of the micro villi and are associated with mucus secreting goblet cells.

The ciliated epithelium is found;

- i. Lining cavities in charge of movement or those of in charge of tiny particles.
- ii. In the respiratory tract (trachea) where dust particles are trapped by mucus and then waffled or moved by cilia into the pharynx.
- iii. In the oviduct where they transport the ova
- iv. In the brain cavities and the spinal cord where they keep the fluids in motion

Longitudinal section

Roberts fig 3.1 page 33 OR Soper fig 6.17a page 185

Simple cuboidal epithelium

Longitudinal view

Roberts fig 3.1 page 33 OR Soper fig 6.15 page 184

This is the least specialised of all epithelia.

- The cells are cuboid in shape
- The nucleus is usually centrally positioned
- Some cells may have microvilli in the surface to increase surface area

Such cells perform the following functions;

- i. Excretion of waste products in the human kidney i.e. lining the Loop of Henle and collecting duct
- ii. It is also found in the salivary glands, sweat glands, collecting duct of the pancreas, mucus glands, germinal epithelium of the ovary and the thyroid gland

NOTE: such epithelia is located in areas where there's secretion of fluid

Longitudinal view

Soper fig 6.18a page 186

Pseudo-stratified epithelium

Stratified means layers. This epithelium has the following characteristics;

- Its cells don't reach the free surface uniformly
- The cells are of unequal size
- The nuclei of the epithelium appear at different levels
- The cells are usually columnar in shape and ciliated

This type of epithelia is found lining the cavities e.g. the urinary bladder and nasal passages.

b. **Compound epithelium**, this is more than one cell thick. They include;

- i. Transitional epithelium
- ii. Stratified epithelium
- iii. Glandular epithelium

Transitional epithelium

It consists of three to four layers of cells thick. Its cells can alter or change shape when put under pressure i.e. they are intermediate between stratified and cuboidal (when relaxed) and stratified squamous (when contracted or stretched)

This type of epithelium is found lining/covering organs that constantly experience pressure and distensions e.g. in the urinary bladder, ureter and in the pelvic region of the kidney.

Drawing of longitudinal view

Note: epithelial cells are frequently interspaced with secretory cells and in this case they form a glandular epithelium which secrete materials like mucus, hormones, enzymes into cavities, spaces which it is lining

Stratified epithelium

It has got layers/strata of cells with only one layer resting on the basement membrane. The cells continue to divide by mitosis and push other layers of cells outwards which look thin and flattened. The epithelium is very thick, consisting of more than four layers of cells.

Roberts fig 3.1 page 33 OR Soper fig 6.19a page 186

In some stratified epithelium, the outer most cells (squamous) may be transformed into a dead horny layer of keratin and in this case the epithelium is said to be cornified which makes it tough and impervious to water and gases.

Its superficial/surface cells wear off from the surface while new cells are regenerated from the basement membrane.

Location

This type of epithelia is found covering regions/surfaces that are exposed to constant wear and tear. It's the thickest and toughest regions that experience friction most often, such regions include the sides of the feet and palms, outer skin, linings of the oesophagus, anus and vagina.

Note: stratified cuboidal epithelium consists of more than one layer of cuboidal cells and it is found lining the excretory ducts of exocrine glands such as salivary glands, sweat glands and the pancreas.

Glandular epithelium

Glandular cells are secretory in function. They produce secretions such as sweat by the sweat glands, sebum by the sebaceous glands, tears by the tear glands e.t.c.

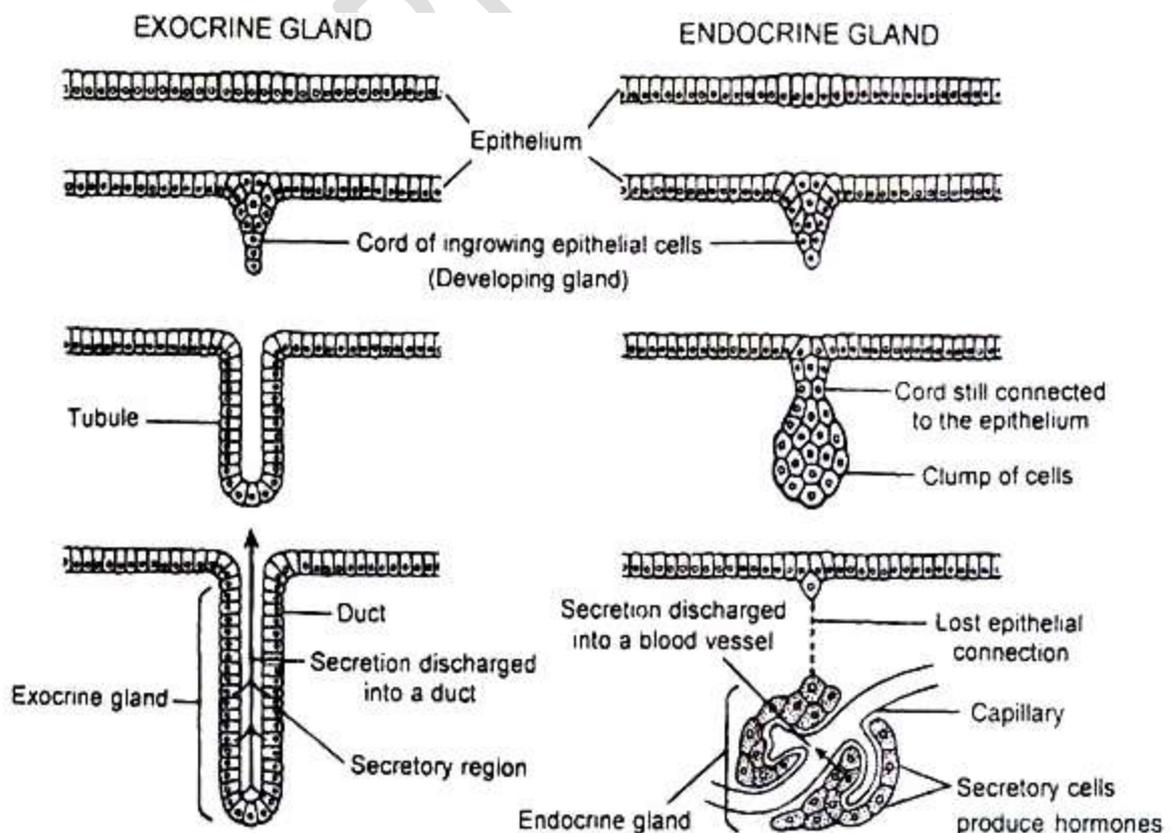
Roberts fig 3.1 page 33

Glandular epithelia can exist in two ways i.e. the epithelia can bear a single layer of cells or it can bear an aggregate or group of glandular cells in one place forming a multicellular gland

An example of a single glandular epithelia is the goblet gland. If the gland discharges its secretions into a duct, then it is described as an exocrine gland e.g. the pancreas. If there's no duct in the gland, so that the secretions are discharged directly into the blood stream, then it is called an endocrine gland (ductless gland). Most hormone producing glands are endocrine glands while those producing enzymes and secretions are exocrine glands.

NOTE; the pancreas and the stomach are both exocrine and endocrine.

Diagrams showing formation of endocrine and exocrine glands



Secretions produced by glandular cells are released in three different ways;

a) Merocrine

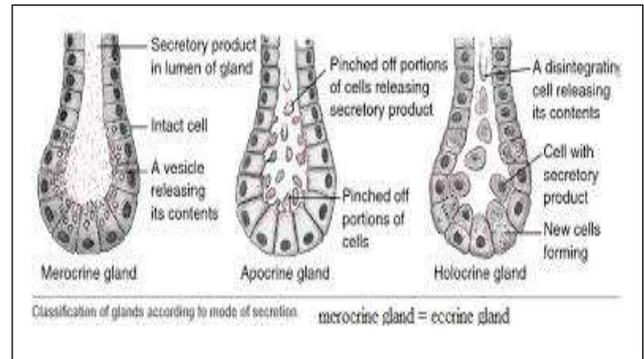
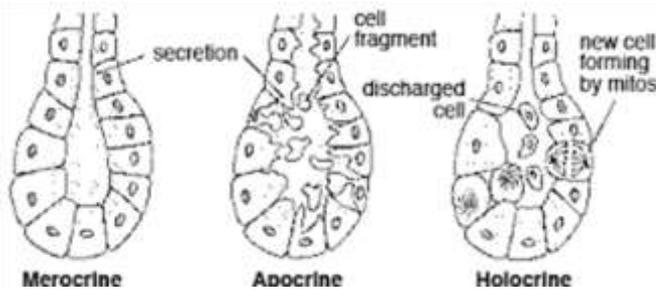
In **merocrine** glands, the secretions produced in cells are passed through the cell membrane at the cell's surface and there is no loss of cytoplasm. This occurs in the simple goblet cells, sweat glands and vertebrate pancreas.

b) Apocrine

In **apocrine** glands, the portion of cell's distal cytoplasm is lost as the secretion is lost e.g. in the secretion of the mammary glands.

c) Holocrine

In **holocrine**, the cell(s) breaks down to release its secretions (secretory products) and the cell is excluded from the epithelial layer e.g. in the sebaceous glands which produce sebum for the softness of hair.



Sometimes a cell may secrete different materials each by a different method e.g. in a mammary glands, the lipid is secreted by apocrine mechanism and the protein secretion is by merocrine or mucocyte. If the secretion produced is clear/watery and contains enzymes, the gland is called a serocyte. If both secretions are produced from within the same glands, then it is called a mixed gland.

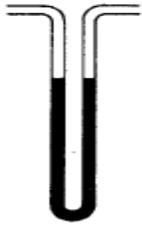
Certain glandular epithelia contain so many densely packed secretory cells that are folded in various ways to increase the surface area from which secretions takes place. Folding of glandular epithelia results in the formation of glands whose sole function secretion. The different types of exocrine glands include;

Glandular epithelia can exist in two ways i.e. the epithelia can bear a single layer of cells or it can bear an aggregate or group of glandular cells in one place forming a multicellular gland. An example of a single glandular epithelia is the goblet gland. If the gland discharges its secretions into a duct, then it is described as an exocrine gland e.g. the pancreas. If there's no duct in the gland, so that the secretions are discharged directly into the blood stream, then it is called an endocrine gland (ductless gland). Most hormone producing glands are endocrine glands while those producing enzymes and secretions are exocrine glands.

NOTE; the pancreas and the stomach are both exocrine and endocrine.

Certain glandular epithelia contain so many densely packed secretory cells that are folded in various ways to increase the surface area from which secretions takes place. Folding of glandular epithelia results in the formation of glands whose sole function secretion using either tube-shaped or sac-shaped portions of the epithelia for secretion. The different types of exocrine glands include;

Simple tubular gland e.g. crypts of Lieberkühn in the ileum and the fundic regions of the stomach



Compound tubular gland e.g. salivary glands



Simple saccular gland e.g. mucus glands in the skin of the frog and other amphibians



Simple branched saccular gland e.g. the oil-secreting sebaceous glands in mammalian skin



Simple branched tubular gland e.g. Brunner's gland and gastric glands



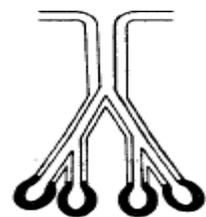
Compound tubulosaccular gland e.g. salivary glands



Coiled tubular gland e.g. the sweat gland in the skin of man



Compound saccular gland e.g. mammary glands and the part of the pancreas which secrete digestive enzymes



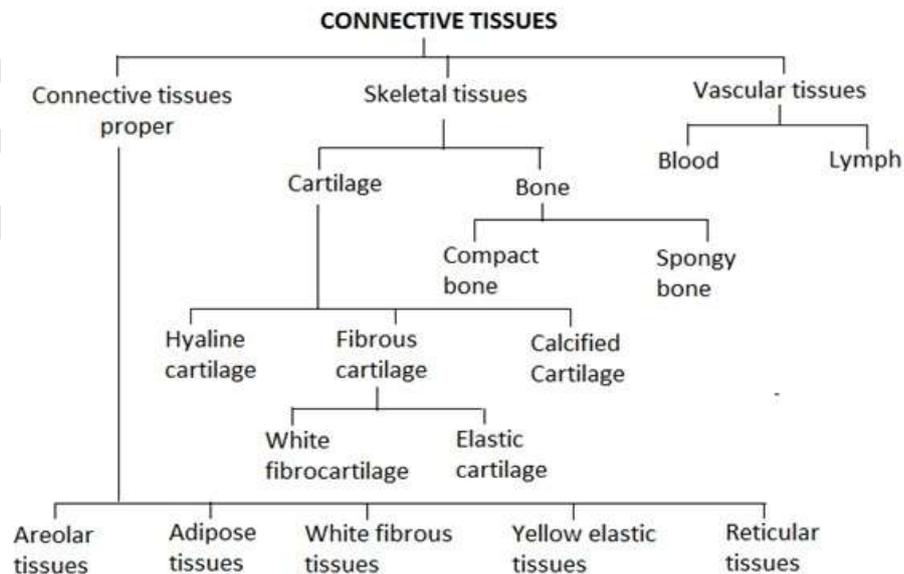
The secretory portions are black

CONNECTIVE TISSUE

These are tissues which bind other tissues together e.g. in the muscles. They include the adipose (fat) tissue, collagen tissue, and skeletal tissue which is composed of bones and cartilage. They bind or support other tissues of the body.

Main characteristics of connective tissue

- They possess a considerable number of fibres in the intercellular substances
- They have a large amount of intercellular substances
- They are all developed from the mesoderm



AREOLAR TISSUE

This tissue contains cells which are widely dispersed in the matrix and has fibres that are loosely woven in a random manner. The matrix is a transparent semi-fluid which consists of gelatinous glycoproteins containing many types of cells and protein fibres. The fluid also contains abundant mucin, hyalorinic acid and chondroitic sulphate.

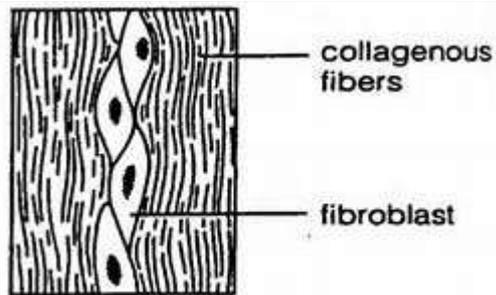
Structure of areolar connective tissue
(Roberts fig 3.5 page 36)

The areolar tissue is strong and tough due to two types of fibres i.e.

- a) The unbranched collagen (white) fibres which run parallel to each other in a bundle
 - b) The branched elastic (yellow) fibres which form a dense network in the matrix
- Some of the areolar tissue matrix,
- i. Cells responsible for synthesis and maintenance of extracellular material e.g. the **fibroblasts** which secrete both collagen and elastic fibres and are usually associated with the fibres they secrete
 - ii. Cells responsible for storage and metabolism of fats e.g. the **fat cells**
 - iii. Cells which defend and have immune functions e.g. phagocytes/phagocytic **macrophages**
 - iv. Amoeboid **mast cells** which are oval shaped and they secrete a matrix and anticoagulants such as heparin and histamine
 - v. Plasma cells which produce antibodies that are important components in the body's immune system
 - vi. **Chromatophores** which are present in some specialised areas of the skin and eye. The cells are densely packed with melanin which gives the skin its characteristic colour and in the retina of the eye they prevent back reflection of light
 - vii. Mesenchyme cells which act as reservoirs of undifferentiated cells in the tissue. They can be stimulated to transform into any one of the above cells when need arises.

THE COLLAGEN (white fibrous) TISSUE

This consists of glycoprotein matrix which contains mainly densely packed collage fibres. Each collagen strand has three chains of *tropocollagen* plaited together as in a rope. The tissue is comparatively inelastic and has great tensile strength. They are located in areas with great tension such as tendons, sclerotic and cornea of the eye, the kidney capsule, in some ligaments and in the perichondrium.



ELASTIC TISSUES (yellow elastic tissue)

This consists of glycoprotein matrix containing only elastic fibres and they combine strength with elasticity.

They are found in ligaments, walls of arteries, lungs and in the neck chords.

ADIPOSE TISSUE (fatty tissue)

The matric contains densely packed fat cells. The tissue is important in storage and in the skin it insulates the body against heat loss.

They are found around the heart and kidney and act as energy reservoirs and shock absorbers.

SKELETAL TISSUES

The vertebrate skeletal tissue is composed of **cartilage only** like in elasmobranch fishes e.g. dogfish and sharks or **both cartilage and bone** covered by a muscular system. It also includes **ligaments and tendons**. Bones form the larger component of the skeleton and cartilage is only found at joints. Ligaments connect bones together and fit them in position while tendons connect muscles to bones. All skeletal tissues consist of living cells surrounded by a non-living matrix secreted by the cells themselves.

FEATURES OF CARTILAGE

It consists of a firm translucent matrix of muco-polysaccharide called **chondrin**. The matrix is produced by cells called **chondroblasts** which are distributed in the matrix in groups of single pairs or fours.

The cartilage is surrounded by a connective tissue made up of a dense network of fibres and cells called **perichondrion** from where new chondroblasts are produced.

Cartilage is non vascularised i.e. not supplied with blood and therefore materials and nutrients diffuse in and out via the matrix.

Each chondroblast occupy its own space called **lacuna** and this chondroblast enclosed in a lacuna is referred to as a **chondrocyte**.

The matrix may be impregnated with collagen as in the vertebral disc and elastic fibres as in the ear and the nose

Cartilage tissue is of three types; **Hyaline, Yellow / elastic** and **White/ fibro-cartilage**.

Hyaline cartilage

It's the most common type of cartilage, its matrix is translucent and contains very fine collagenous fibres.

Location: nose, ends of long bones, ribs, trachea rings, foetal skeleton.

- It's a solid flexible connective tissue composed of a translucent mucopolysaccharide matrix (chondrin) in which are distributed cartilage cells (chondroblasts) and many intercellular substances like fibres.
- Each chondroblast lies in a small chamber called lacuna surrounding by a capsule.
- Chondrin lacks direct blood supply except in the Perichondrium; a tough fibrous membrane surrounding cartilage.
- In some cases chondroblasts occur in cell nests i.e. a pair or 2 pairs of cells encased by one capsule.

NB: Chondroblasts that become embedded in the matrix are called chondrocytes.

Roberts, et.al Adv. Biol. Pg. 67 fig. 4.9

Yellow / elastic cartilage

It's more flexible than hyaline cartilage because the matrix contains many elastic fibres in addition to collagen fibres.

Location: frame work of Pinna (outer ear), epiglottis.

White / fibro-cartilage

Contains dense collagenous fibres embedded in matrix, it absorbs shock and reduces friction between joints and can withstand tension and pressure.

Location: intervertebral discs, wedges in the knee joint, insertion of tendon on patella.

THE MAIN FUNCTIONS OF CARTILAGE TISSUE

Reducing friction at the joints; supporting tracheal and bronchial tubes; acting as shock absorbers between vertebrae; maintaining the shape and flexibility of ear and nose.

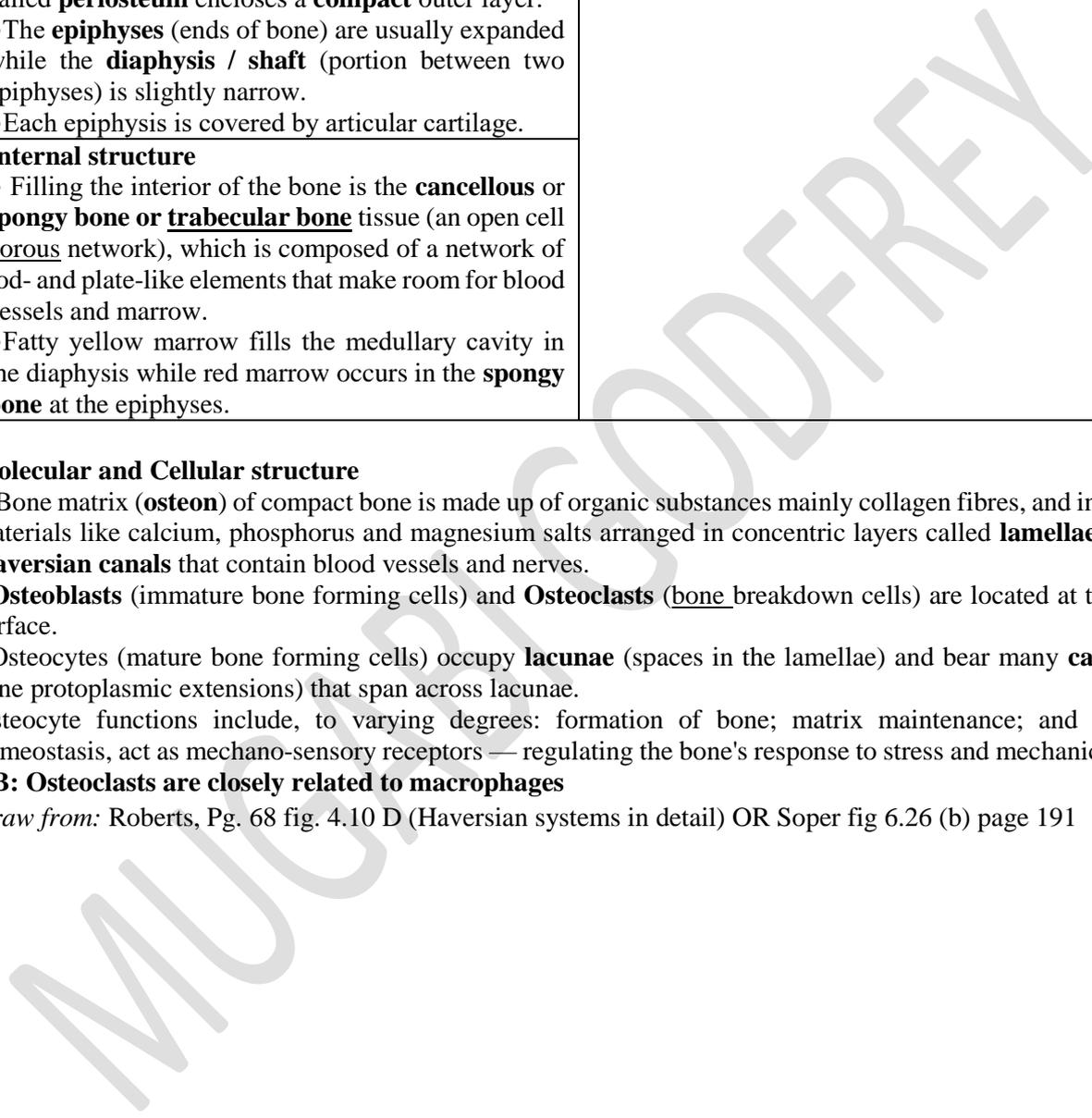
Main features of bone tissue

- It's a rigid, tough, connective tissue composed mainly of calcified substance.
- Bones occur in a variety of shapes, have complex internal and external structures, are lightweight yet strong.

- Several tissue types make up bone; including the mineralized bone tissue that gives it rigidity and brittleness, collagen fibres that provide slight elasticity, marrow, endosteum, periosteum, nerves, blood vessels and cartilage.

- All bones consist of living and dead cells embedded in the mineralized organic matrix called osteon that makes up the bone tissue.

Description of bone structure

<p>External structure</p> <ul style="list-style-type: none"> • A tough, fibrous, vascularised connective tissue called periosteum encloses a compact outer layer. • The epiphyses (ends of bone) are usually expanded while the diaphysis / shaft (portion between two epiphyses) is slightly narrow. • Each epiphysis is covered by articular cartilage. 	<p><i>Draw from: Soper (VS of femur head)</i></p> 
<p>Internal structure</p> <ul style="list-style-type: none"> • Filling the interior of the bone is the cancellous or spongy bone or trabecular bone tissue (an open cell porous network), which is composed of a network of rod- and plate-like elements that make room for blood vessels and marrow. • Fatty yellow marrow fills the medullary cavity in the diaphysis while red marrow occurs in the spongy bone at the epiphyses. 	

Molecular and Cellular structure

- Bone matrix (**osteon**) of compact bone is made up of organic substances mainly collagen fibres, and inorganic materials like calcium, phosphorus and magnesium salts arranged in concentric layers called **lamellae** around **Haversian canals** that contain blood vessels and nerves.

- **Osteoblasts** (immature bone forming cells) and **Osteoclasts** (bone breakdown cells) are located at the bone surface.

- Osteocytes (mature bone forming cells) occupy **lacunae** (spaces in the lamellae) and bear many **canaliculi** (fine protoplasmic extensions) that span across lacunae.

Osteocyte functions include, to varying degrees: formation of bone; matrix maintenance; and calcium homeostasis, act as mechano-sensory receptors — regulating the bone's response to stress and mechanical load.

NB: Osteoclasts are closely related to macrophages

Draw from: Roberts, Pg. 68 fig. 4.10 D (Haversian systems in detail) OR Soper fig 6.26 (b) page 191

HOW STRUCTURE IS RELATED TO FUNCTION IN COMPACT BONE

- Bone matrix (**osteon**) is made up of organic substances mainly collagen fibres, and inorganic materials which provide great tensile strength.
- There is continual remodeling which enables compact bone to respond to mechanical stress of varying loads placed on it.
- **Haversian canals** contain blood vessels for efficient supply of nutrients to and draining of wastes from bone cells.
- Osteocytes (mature bone forming cells) bear many **canaliculi** (fine protoplasmic extensions) that span across lacunae to improve on material exchange between the bone cells.
- Bundles of collagen fibres originate from the bone surface and act as a firm base for tendon insertions.

MAIN FUNCTIONS OF BONES

A. Mechanical

- They protect internal organs, e.g. the skull protects the brain, the rib cage protects the heart and lungs
- They provide a frame work to keep the body supported.
- Bones, skeletal muscles, tendons, ligaments and joints function together to generate and transfer forces to cause movement.
- Bones in the ear (ossicles) transmit vibrations that result in hearing.

B. Synthetic

- Bone marrow, located within the medullary cavity of long bones and interstices of cancellous bone, produces blood cells in a process called haematopoiesis.

C. Metabolic

- Bones act as reserves of minerals important for the body, most notably calcium and phosphorus.
- Mineralized bone matrix stores important growth factors such as insulin-like growth factors, transforming growth factor, etc.
- The yellow bone marrow acts as a storage reserve of fatty acids.
- Bone buffers the blood against excessive pH changes by absorbing or releasing alkaline salts.
- Bone tissues can also store heavy metals and other foreign elements, removing them from the blood and reducing their effects on other tissues. These can later be gradually released for excretion
- Bone controls phosphate metabolism by releasing fibroblast growth factor – 23, which acts on kidneys to reduce phosphate reabsorption. Bone cells also release a hormone called osteocalcin, which contributes to the regulation of blood glucose and fat deposition. Osteocalcin increases both the insulin secretion and sensitivity, in addition to boosting the number of insulin-producing cells and reducing stores of fat

COMPARISON OF BONE AND CARTILAGE

Similarities

- Both bone and cartilage consist of living cells and extracellular matrix
- Cells reside in lacunae in both.
- Both are capable of growth.
- Both have collagen fibres

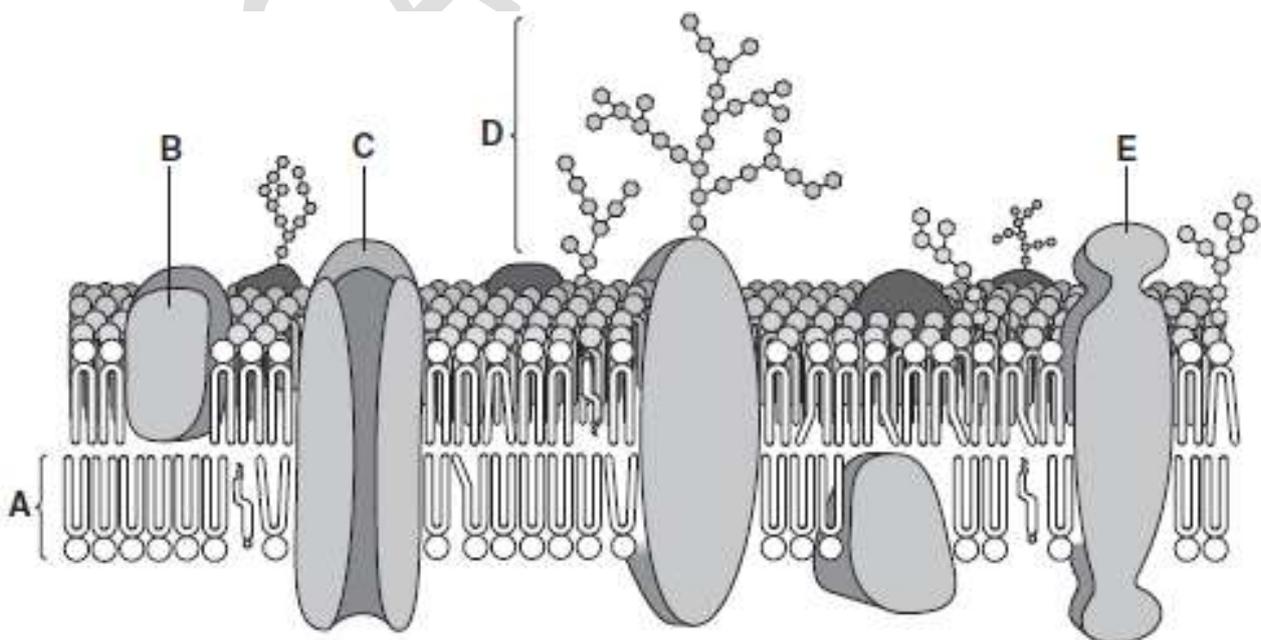
Differences

CHARACTERISTIC	CARTILAGE	BONE
<i>Mechanical properties</i>	● Stiff but flexible and incompressible	● Rigid and brittle.

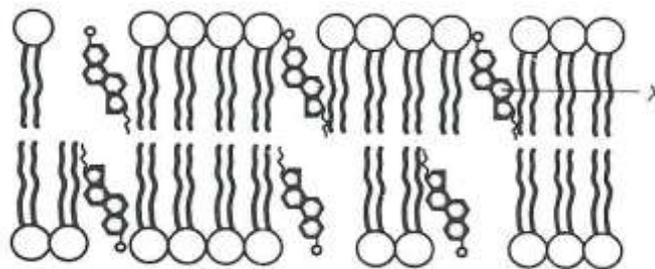
<i>Innervation</i>	<ul style="list-style-type: none"> ●Lacks nerve stimulation 	<ul style="list-style-type: none"> ●Has nerve fibers
<i>External covering</i>	<ul style="list-style-type: none"> ●Covered by perichondrium 	<ul style="list-style-type: none"> ●Covered by periosteum
<i>Nature of growth</i>	<ul style="list-style-type: none"> ●There is both appositional growth (addition of new cells and matrix onto the outside of the growing structure) and interstitial growth (cell division and secretion of new matrix within an established structure). ●Mature cartilage is relatively permanent. 	<ul style="list-style-type: none"> ●There is only appositional growth (addition of new cells and matrix onto the outside of the growing structure) ● Internal <u>remodelling</u> (continual destruction and renewal) occurs throughout life.
<i>Internal anatomy</i>	<ul style="list-style-type: none"> ●Cartilage is compact, no marrow ● Occurs in 3 forms; hyaline, fibro-cartilage and elastic cartilage. ●No lamellae, no Haversian canals. ●No Haversian systems. ●Matrix is gel-like and non-calcified ● Chondrocytes are spherically-shaped. ● Avascular (no blood vessels). ● Matrix allows tissue fluid diffusion. 	<ul style="list-style-type: none"> ● Most mature bones have a marrow-filled cavity. ●Occurs in 2 forms; compact and spongy bone. ●Organic and inorganic substances are arranged in concentric layers called lamellae around Haversian canals ●Compact bone has lamellae organized into sets of Haversian systems. ● Matrix is highly calcified. ●Osteocytes bear canaliculi (fine protoplasmic extensions). ● Vascular (has blood vessels). ● Matrix impermeable to tissue fluid diffusion.

SAMPLE QUESTIONS

1. Figure one below shows the structure of the plasma membrane

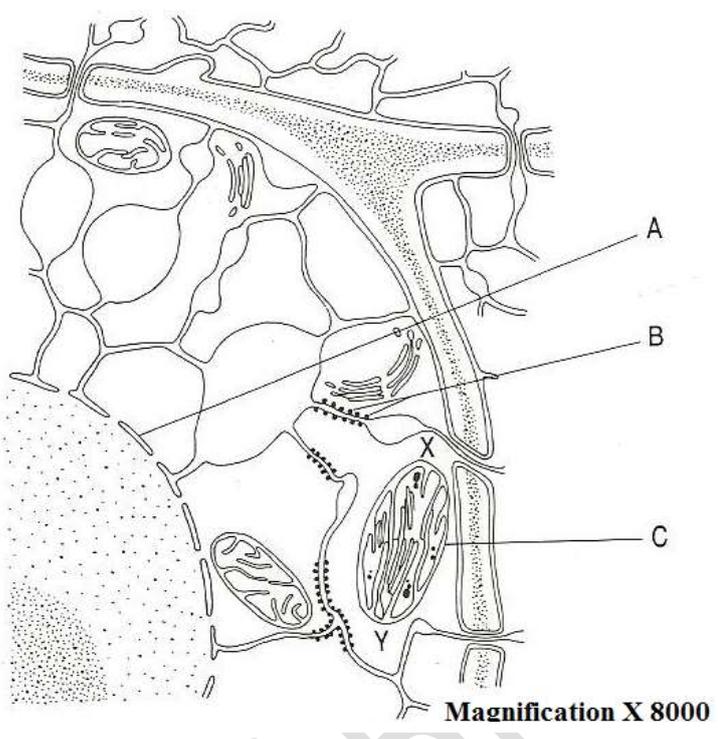


- (a) Name molecules **A, B and E** (03 marks)
- (b) Explain how the features of **molecules of A** cause them to form a layer in the membrane as seen in the figure above (03 marks)
- (c) State the functions of **C and D** (02 marks)
2. a) State the **physiological importance** of the following structural components of the plasma membrane.
- Proteins (03 marks)
 - Carbohydrates (02 marks)
 - Cholesterol (03 marks)
- b) Explain why non polar (lipid soluble) molecules diffuse more rapidly through membranes than polar (lipid insoluble) molecules. (02 marks)
3. (a) Describe the formation of Golgi bodies in the cell (06 marks)
- (b) What are the functions of this organelle to the cell? (04 marks)
4. a) State the components of the **cell theory**? (04 marks)
- (b) The figure below shows part of a membrane



- (i) Name the structure labelled **X** (01 mark)
- (ii) Explain briefly the role of **X** in the membrane when the surrounding temperature is low or at moderately warm conditions (05 marks)
5. Mitochondria and chloroplasts are cell organelles that change energy from one form to another
- a) What is meant by the term cell **organelle**? (02 marks)
- b) Describe how the **membranes** of the two enable them to carry out their respective functions
- Mitochondria (03 marks)
 - Chloroplasts (03 marks)
6. (a) Give three properties of the cell membrane (03 marks)
- (b) Name two other membranes in the cell with similar properties as the cell membrane
- (c) (i) What is the name given to membrane bound cell inclusions (01 marks)
- ii) What purpose is served by membranes in such cell inclusions? (02 marks)
- (d) (i) What constitutes the cell's protoplast? (01 marks)
- ii) List three processes carried out by the cell's protoplast? (03 marks)
7. a) State the physiological importance of the following structural components of the plasma membrane.

- i. Proteins (03 marks)
 - ii. Carbohydrates (02 marks)
 - iii. Cholesterol (03 marks)
- b) Explain why non polar (lipid soluble) molecules diffuse more rapidly through membranes than polar (lipid insoluble) molecules. (02 marks)
8. The diagram below is drawn from an electron micrograph and shows the structure of parts of a cell and the barrier between it and two of its neighbours.



- (a) (i) Identify the structures **A** and **B** (02 marks)
- (ii) What role do structures **A** and **B** play in the life of the cell?
- (b) Give **two** features of the cell which show that it is **NOT** a prokaryotic cell (02 marks)
- (c) (i) Is it a plant cell or animal cell? (1 mark)
- (ii) Give **two** reasons for your identification in (c) (i) above (2 marks)

Measure the length **XY** of the organelle **C** and calculate the actual length in μm . Show your working. (2mks)

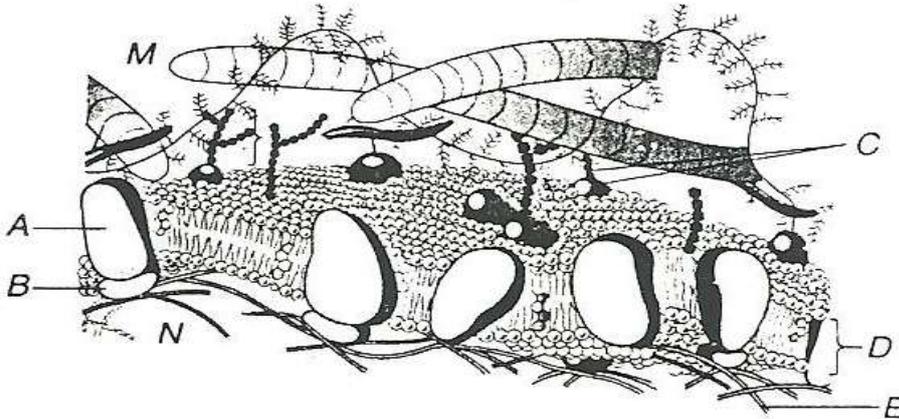
- 9. (a) Briefly describe the structure of the mitochondrion, without drawing (04 marks)
- (b) How are mitochondria suited for their functions? (02 marks)
- (c) State two structural differences between mitochondria and chloroplasts (02 marks)
- (d) Mitochondria and chloroplasts are said to be semi-autonomous. Explain this statement. (02 marks)
- 10. (a) Distinguish between prokaryotic and eukaryotic cells (01 mark)

(b) State eight (8) structural and two (2) functional major differences between prokaryotic and eukaryotic cells.

(i) Structural differences (08 marks)

(ii) Functional differences (02 marks)

11. The diagram below shows the structure of the cell surface membrane of an animal cell



(a) (i) State the name given to this model of the plasma membrane (1 Mark)

(ii) Give two reasons why it is so called (2 Marks)

(b) (i) State where the cytoplasm can be found, on side M or N?

(ii) Give a reason for your answer in (i) above

(c) (i) Name the structures labelled A to E

(ii) Give the average value for the width of D

(d) (i) State one function each of structures C, D and E

12. Explain how the following are suited for their functions

a) nucleus (3 marks)

b) Chloroplast (3 marks)

c) Mitochondrion (3 marks)

d) Endoplasmic reticular (1 mark)

13. (a) How do the components of the plasma membrane ensure its fluidity? (06 marks)

(b) Relate the function(s) of each of the following to the fluidity and porosity of their membranes?

(i) Plasma membrane (06 marks)

(ii) Rough Endoplasmic Reticulum (05 marks)

(iii) Golgi apparatus (03 marks)

14. In an investigation pea plants were dug up from the field and washed thoroughly. The nodules were removed surface sterilized and transferred aseptically to a sterile liquid culture medium. After two weeks incubation, small samples of culture media were removed and added to trays each containing a batch of pea plants growing in an inert medium. Each batch was watered regularly with a nutrient solution containing a particular concentration of sodium nitrate for four weeks, at the end of four weeks the mean number of root nodules and biomass were obtained from the investigation are shown in the table below.

Nitrate concentration of nutrient solution (arbitrary units)	Mean number of nodules per plant	Biomass of pea plants /gm ⁻²
0	82	140
1	70	200
2	68	230
3	40	350
3.5	20	400
4	10	460
5	0	440
5.5	0	400
6	0	350

- (a) Represent the results of the table above graphically (08 marks)
- (b) Explain the changes in mean number of nodules per plant and changes in the biomass of pea plants with increasing nitrate concentration of nutrient solution (20 marks)
- (c) How was accuracy of results to be obtained ensured throughout the experiment (05 marks)
- (d) (i) on the graph draw a graph to represent the plot for biomass you would expect if the experiment was repeated and in this case the sample culture medium was not added to the trays containing pea plants (02 marks)
- (ii) Suggest reason(s) for the appearance of the graph drawn in d (i) above (03 marks)
- (e) How can the information from the investigation be beneficial in crop production? (02 marks)
15. (a) Describe the structure of a chloroplast (08 marks)
- (b) Compare the structure of a chloroplast with that of a mitochondrion. (12 marks)
16. a) With the help of well labelled diagrams, describe the structures of the following:
- bone
 - cartilage
 - areolar tissue
- b) (i) How is cartilage replaced by bone? (05 marks)
- (ii) Describe how locomotion instabilities are overcome in a bony fish such as Tilapia (marks)
17. a) Describe the structure of meristematic tissue in plants (06 marks)
- b) Explain the role of each of the following in the formation of meristematic tissue in higher plants
- Vascular cambium (07 marks)
 - Cork cambium (07 marks)
18. Relate the structure and function of these tissues
- voluntary muscle (08 marks)
 - parenchyma (06 marks)
 - xylem (06 marks)
 - phloem
19. (a) Describe how each of the following tissues are related to their functions.
- Parenchyma (03 marks)
 - Collenchyma (03 marks)
 - Sclerenchyma (06 marks)
- (b) Explain the distribution pattern of mechanical tissue in a stem and root of a dicotyledonous plant

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7. **J.SIMPKINS** & **J.I.WILLIAMS**. ADVANCED BIOLOGY

END

MUGABI GODFREY