CYTOLOGY

CONTENT BREAKDOWN

(a) Operate a light microscope to observe tissues from plants and animals under different magnifications.
- Learners prepare slides, observe under low and medium power, and determine the linear magnification of the cells observed. Make a write-up.

(b) Analyse the ultrastructure of animal/ plant cells, bacterial cells, and the plasma membrane, to distinguish prokaryotic and eukaryotic cell characteristics.
- Study and compare images of ultra-structures of animal or plant cells with a bacterium cell, and make diagrams using a suitable graphics program.
- Study images of the fluid-mosaic model of the plasma membrane, make a model and use it to explain the functions of the membrane and its parts.
- Learners search and categorize the cells as prokaryotic and eukaryotic and present their work to the rest of the groups.
- Learners search for the differences in the ultrastructure of prokaryotes, design an annotated flow diagram, and use it to explain the division of the original kingdom Monera to kingdoms eubacteria and archaebacteria.

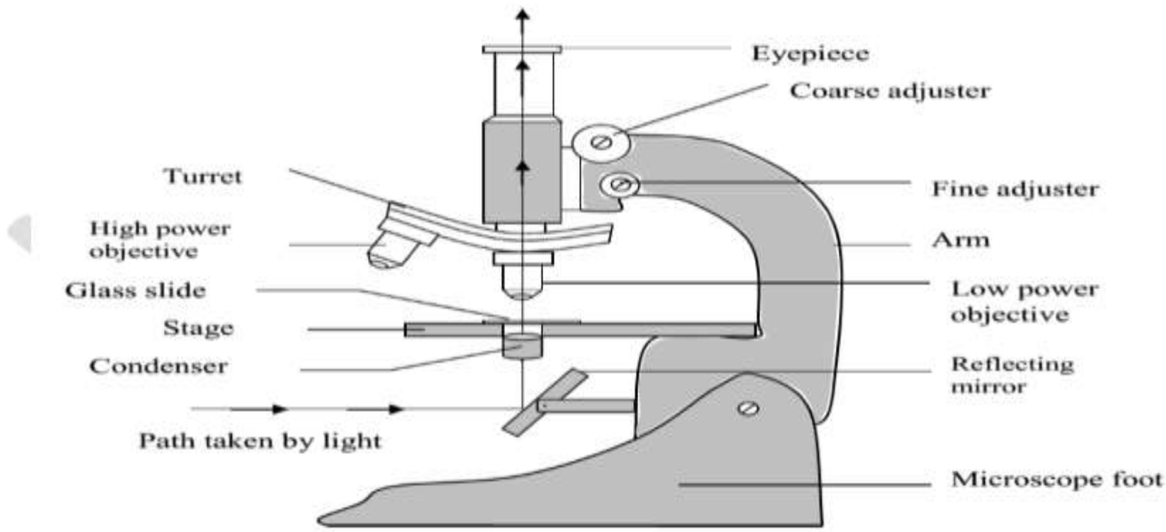
MICROSCOPY

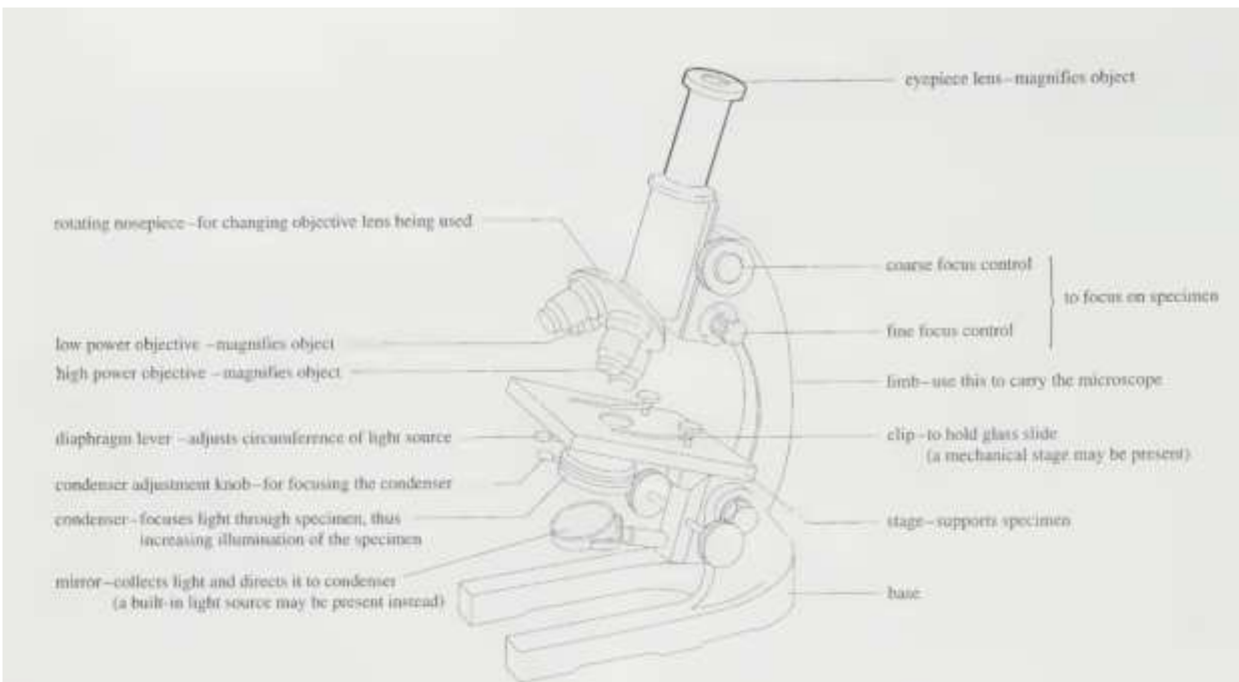
Most cells are too small to be seen with unaided human eyes, hence the need for an instrument that can magnify them so that they appear clearer.
This instrument is called the microscope. There are two types of microscopes used to study cells at this level which include;
- Light microscope
- Electron microscope

THE COMPOUND LIGHT MICROSCOPE

It is called so because it uses a beam of light to view objects and has more than one convex lens. It is used in hospitals, schools and some industries.

Structure of a compound light microscope





FUNCTIONS OF THE LABELLED PARTS

(a) Eye Piece.

- It is where the eye is placed while viewing the specimen
- It magnifies the image from the objective lens.

(b) Barrel.

- It provides support for the eye piece and objective lens.

(c) Nose piece/ turret.

- It holds the objective lenses in position
- It can be rotated to position a particular lens required for a particular magnification.

(d) Stage.

- It is where a prepared slide is placed for observation.

(e) **Mirror.**

- It reflects light from external source through the specimen

(f) **Stand / Base**.

- It supports the instrument on a flat surface.

(g) Diaphragm.

- It regulates the amount of light passing through the specimen.

(h) **Condenser.**

- It concentrates the light reflected by the mirror through the specimen on the stage.

(i) **Arm.**

- It is used for carrying the instrument.

(j) Clip.

- It keeps the slide firmly on the stage.

(k) Coarse adjustment knob.

- It is used for focusing of the object under study.

(l) Fine adjustment knob.

- It brings the specimen into a sharp clearer focus (final focusing).

(m) **Objective lens.**

Magnifies the specimen under study. They are normally two or three. Low power (shortest), medium power and high power (longest).

Care of a microscope

The microscope is very delicate, expensive instrument which is very useful in the study of biology.

Thus, it should be handled carefully by doing the following;

- It should be carried with both hands.
- Should never be dropped.
- Always kept in an upright position
- Only wipe the lens with soft lens tissue.
- It should always be kept in its special designed box

Determination of magnification of a microscope.

Magnification refers to how much larger the object appears compared to its real size.
Magnification = magnification of the eye piece lens X magnification of the objective lens.

Complete the table below

Eye piece lens	Objective lens	Magnification
X15	X7	
X60		X240
	X17	X340
X25	X8	

COMPARISON BETWEEN A LIGHT AND AN ELECTRON MICROSCOPE

SIMILARITIES

- Both microscopes form magnified images
- Both use lenses
- Both involve the use of stained specimens
- In both the specimen can be mounted in a vacuum
- In both the specimen is mounted on a support
- Both involve the bending of the source of radiation
- In both non-living specimens can be used

DIFFERECES

Electron microscope	Light microscope
• The specimen is mounted in a vacuum	• The specimen can be mounted in a vacuum and even in presence of air
• It is used to observe dead specimen	• It is used to observe both dead and living organisms
• It uses electrons	• It uses light
• It uses electro-magnetic lenses	• It uses glass lenses
• The specimen is mounted on a small copper grid	• The specimen is mounted on the glass slide

• It has a high resolving power	• It has a low resolving power
• It forms black and white images	• It usually forms coloured images
• It has a high useful magnification	• It has a low useful magnification
• The specimen stains with heavy metals	• The specimen stains with coloured dyes
• Radiation enters at the top and the specimen is viewed at the bottom.	• Radiation enters at the bottom and the specimen is viewed at the top
• The image is projected onto the fluorescent screen.	• The image is not projected to screen

Advantages of an electron microscope over a light microscope

- An electron microscope has a higher magnification than light microscope.
- An electron microscope has a greater resolution than light microscope.
- A greater depth of field can be investigated with an electron microscope than with a light microscope.

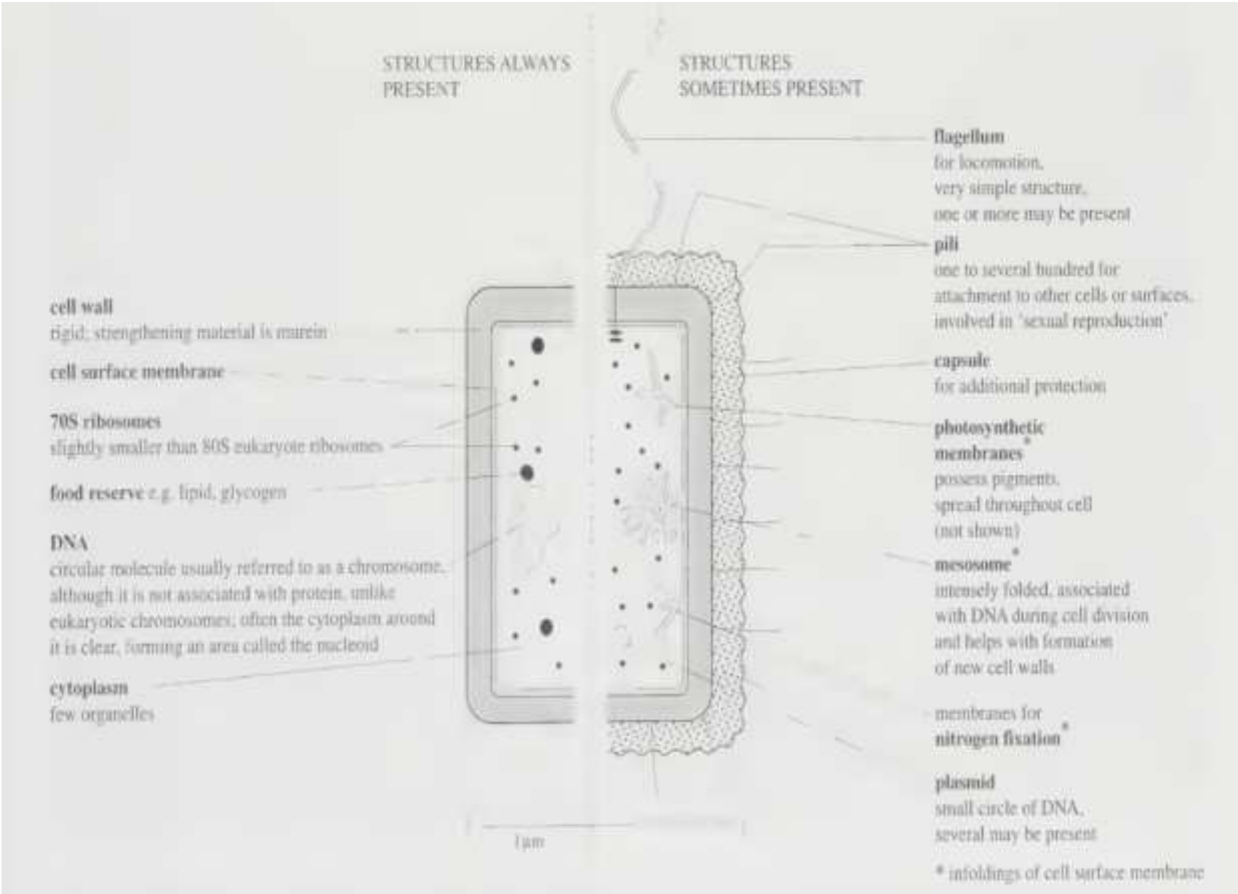
Advantages of a light microscope over an electron microscope

- The light microscopes produce coloured images but electron microscopes produce black and white images.
- Both living and non-living specimen can be viewed under a light microscope but only dead specimen can be viewed under electron microscope.
- A light microscope requires less expertise to operate as compared to electron microscope.
- A light microscope is small and portable and can be used almost everywhere but electron microscope is very large requiring a special room for operation.
- With a light microscope, the material is rarely distorted during preparation but with an electron microscope, material may be distorted during preparation.
- A light microscope is cheaper to purchase and operate than an electron microscope.

PROKARYOTIC CELLS

These are cells with no true nucleus and other membrane bound organelles. Their genetic material (DNA) is located free within the cytoplasm in a region called nucleoid.

Structure of a prokaryotic cell (Bacteria cell)



FUNCTIONS OF THE LABELLED PARTS

70S ribosomes. They are sites of protein synthesis

Cell wall. This is a peptidoglycan layer that protects and maintains cell shape

Cell membrane. This is a phospholipid layer that controls entry and exit of substances.

Nucleoid. This is a region of one free strand of DNA

Food granules. These include glycogen and lipid granules. They are used for food storage.

Cytoplasm. This acts as a centre for biochemical reactions

Mesosome. It acts as a site of respiration and cell wall synthesis

Flagellum. It is an elongated, relatively flexible cork-screw shaped structure that moves the cell

Capsule (slime layer). It is used for protection

Pili (fimbriae). These are protein filaments that facilitate cell adhesion and conjugation.

Plasmid. A plasmid is an independent small circle of DNA. Plasmids offer resistance to drugs

Photosynthetic membranes. This is where photosynthesis occurs.

NB. All prokaryotes belong **Kingdom Monera** made of bacteria and cyanobacteria (blue green bacteria).

Eukaryotic cells are mainly found in cells of plants, animals, fungi and protists

COMPARISON BETWEEN PROKARYOTIC AND EUKARYOTIC CELLS

PROKARYOTIC CELLS	EUKARYOTIC CELLS
They lack a distinct nucleus	They have a membrane-bound nucleus
Their DNA is not associated with proteins (DNA is naked)	Their DNA is associated with proteins called histones
They lack membrane-bound organelles Have	They have membrane-bound organelles
They have small (70S) ribosomes	They have large (80S) ribosomes in their cytoplasm
Their flagella lack internal 9+2 microtubule arrangement	Their flagella have internal 9+2 microtubule arrangement
Their cells divide by binary fission	Their cells divide by meiosis and mitosis
The cell wall is always present	The cell wall may or may not be present
They have circular DNA	They have linear DNA
Their DNA is single stranded	Their DNA is double stranded
Respiration occurs in mesosomes	Respiration occurs in the mitochondria

Division of Kingdom Monera

The original Kingdom Monera included all prokaryotes.

Advances in genetic studies showed two distinct groups, leading to its division into **Eubacteria** and **Archaebacteria.**
The original Kingdom Monera was divided because Eubacteria and Archaebacteria differ in genetics, cell structure, membrane composition, metabolism, and evolution.

Modern classification recognizes them as the domains Bacteria and Archaea.

Reasons for the Division

- **Genetics.** Archaebacteria have very different rRNA and are closer to eukaryotes.
- **Cell wall.** Eubacteria contain peptidoglycan in their cell wall while Archaebacteria do not.
- **Cell membrane.** Eubacteria have ester-linked lipids in their cell membrane while Archaebacteria have ether-linked lipids.
- **Habitat.** Eubacteria occur in common environments while Archaebacteria often live in extreme environments which may range from; very hot (**thermophiles**) very salty

(**Halophiles**) oxygen free environments (**methanogens**) very acidic or alkaline, high-pressure environments among others.

- **Antibiotics.** Many antibiotics affect Eubacteria but not Archaebacteria.

EUBACTERIA	ARCHAEBACTERIA
Their cell walls contain peptidoglycan	Their cell walls lack peptidoglycan
Their cell membrane contains Ester-linked lipids	Their cell membrane contains Ether-linked lipids
They occur in common environments	They often live in extreme environments
They are less related to eukaryotes	They are more related to eukaryotes
They are usually sensitive to antibiotics	They are usually resistant to antibiotics

EUKARYOTIC CELLS

These are cells that have a distinct (true) nucleus bounded by a nuclear membrane (envelope).

Their DNA is enclosed within the nucleus.

Examples of eukaryotic cells include; animal cells, plant cells, fungal cells, algal cells, protist cells and protozoan cells.

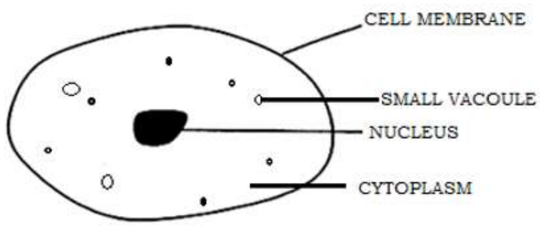
Having membrane-bound organelles in eukaryotes provides a number of advantages which include:

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

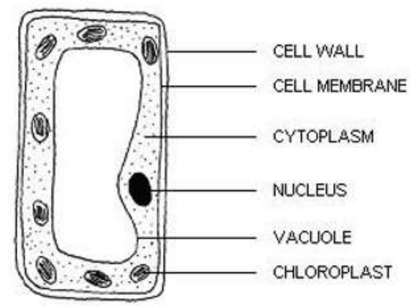
Note: An organelle is a distinct part of a cell which has a particular structure and function.

GENERALISED STRUCTURES OF EUKARYOTIC CELLS AS OBSERVED UNDER LIGHT MICROSCOPE

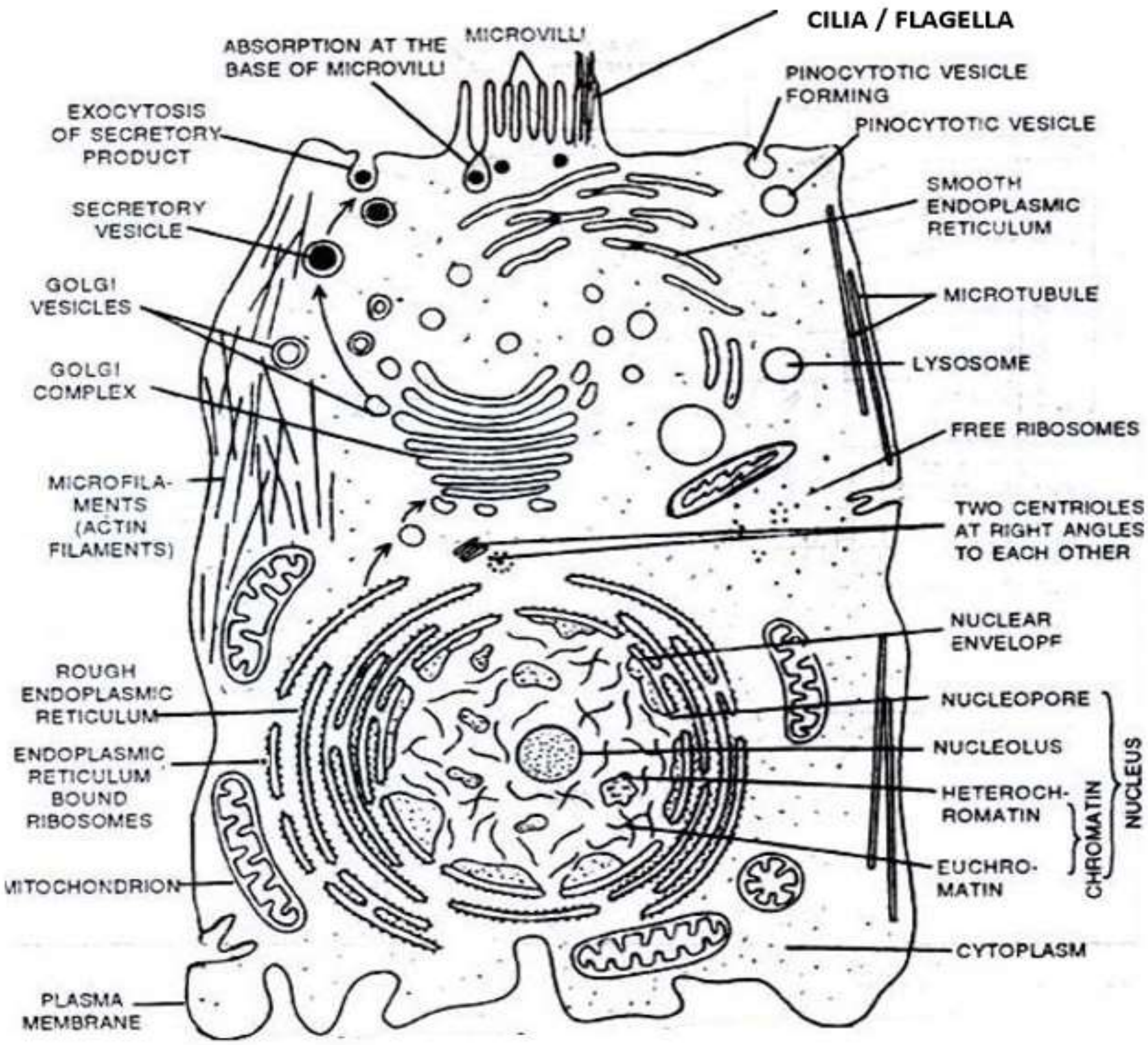
Animal cell



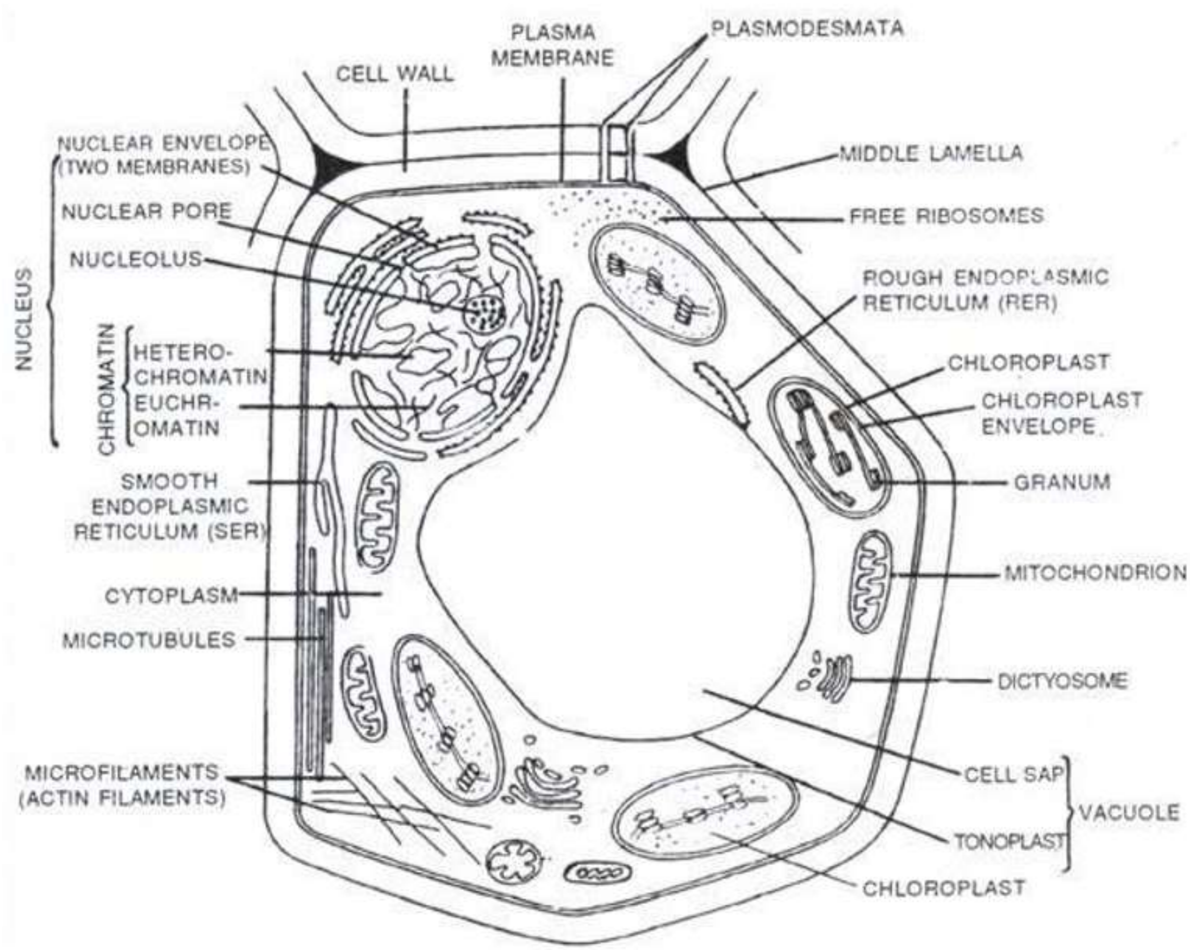
Plant cell



ULTRASTRUCTURE OF AN ANIMAL CELL



ULTRASTRUCTURE OF PLANT CELL



COMPARISON OF PLANT AND ANIMAL CELLS

SIMILARITIES

- Both are eukaryotic cells, meaning they have a defined nucleus
- Both have a cell membrane that is selectively permeable, controlling the movement of substances in and out of the cell.
- Both contain cytoplasm, which holds organelles and provides a medium for chemical reactions
- Both have ribosomes, which are responsible for protein synthesis
- Both contain mitochondria, the site of cellular respiration and energy production

- Both have endoplasmic reticulum, (Rough endoplasmic reticulum and smooth endoplasmic reticulum) for transport and synthesis of molecules.
- Both possess a Golgi apparatus, which packages and modifies proteins and other substances.
- Both have a nucleus, which contains DNA, and controls all cell activities.
- Both contain Vacuoles, although plant cells usually have a large central vacuole, while animal cells have smaller scattered vacuoles.
- Both are capable of cell division, such as mitosis and in some cases meiosis.

Differences between a plant cell and an animal cell.

Plant cell	**Animal cell**
It has a cell wall	It lacks a cell wall
It has a cell membrane present beneath the cell wall	It has a cell membrane present as the outer most boundary.
It has starch granules for storage	It has glycogen granules for storage
Its nucleus is located at the edge of the cell	Its nucleus is located anywhere in the cell, most often centrally
It has plastids (chloroplasts, leucoplasts and chromoplasts)	It lacks plastids
Its cytoplasm is confined to a thin layer at the edge of the cell	Its cytoplasm is present throughout the cell

NB. Plastids are double membrane-bound organelles found in the cells of plants and algae. They are responsible for making and storing food, pigments, and other important substances.

Main Types of Plastids

Chloroplasts. These are green plastids that contain chlorophyll and carry out photosynthesis.

Chromoplasts. These are colored plastids (red, yellow, or orange) that store pigments and give color to fruits and flowers.

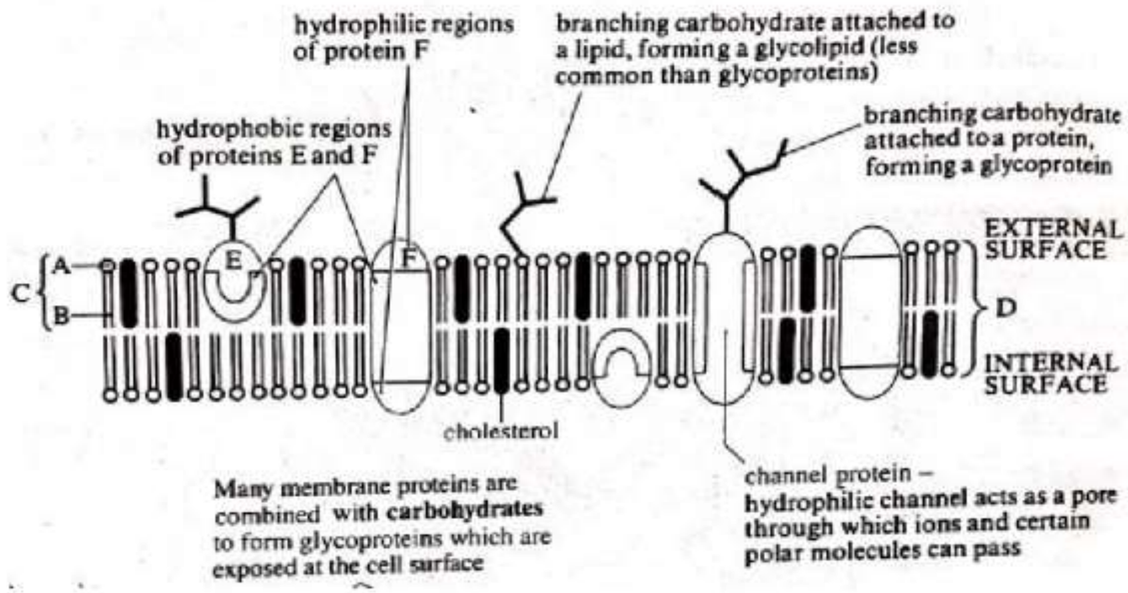
Leucoplasts. These are colorless plastids that store food such as starch, oils, and proteins.

Simple Definition

Plastids are specialized organelles in plant cells that produce and store food and pigments.

THE PLASMA MEMBRANE

The fluid mosaic model of the cell membrane



The cell membrane consists of a bilayer of phospholipids (two phospholipid layers).
The phosphate heads are hydrophilic and face outwards into the internal or external environments of the plasma membrane while hydrophobic hydrocarbon tails face inwards forming a hydrophobic interior.
The phospholipids can move laterally across the membrane making it flexible and thus fluid.
Proteins are embedded in the phospholipid bilayer in a dotted pattern resulting into a mosaic pattern.
Some proteins are located on the surface of the membrane and are called **extrinsic/peripheral proteins**, some penetrate only part of the way into the membrane and are called **intrinsic/integral proteins** while others span the membrane completely from one side to the other and are called **transmembrane proteins.**
Some proteins and phospholipids have short carbohydrate chains attached forming glycoproteins and glycolipids respectively.
The membrane also contains cholesterol between phospholipids which maintains membrane fluidity.

Functions of the cell surface membrane

The basic function of the cell membrane is to serve as a boundary between the cell and its environment and hence protecting the cell from its surroundings and controlling the exchange of materials between the cell and the external environment. The functions of the cell surface membrane are given below:

- It provides protection to the cytoplasm and the organelles.
- It controls the exchange of substances between the cell and its environment since its selectively permeable.
- It maintains shape and size of cell.
- It is required for absorption of nutrients into the cell.
- It is required for secretion of substances from the cell.
- It is required for transmission of nerve impulses in neurones.
- It provides receptor sites for hormones, neurotransmitters and other chemicals.
- It provides cell to cell recognition sites.

Functions of components of the cell membrane

(a) Phospholipids

- They provide a barrier to passage of polar molecules and ions.
- They allow passage of lipid soluble (non-polar) molecules.
- They make the membrane flexible since they are fluid.

(b) Proteins

- Channel proteins and carrier proteins are used for selective transport of ions and polar molecules across the membrane.
- Some proteins act as enzymes.
- Some proteins act as receptor sites for hormones and neurotransmitters.
- Surface proteins provide attachment to cytoskeleton.
- They provide structural support to the membrane. By various forms of molecular interactions, they anchor the bimolecular phospholipid layer.
- The assist in active transport of materials across the membrane
- In combination with carbohydrates as glycoproteins, they act as cell recognition sites.
- They act as electron carriers in many redox reactions

(c) Glycoproteins.

- They are required for cell-to-cell recognition.
- They are involved in sticking cells together to form tissues.
- They act as receptor sites for some hormones and neurotransmitters.

(d) Glycolipids

- They are required for cell-to-cell recognition.
- They are involved in sticking cells together to form tissues.
- They act as receptor sites for chemical signals.

(e) Cholesterol.

- It acts as a barrier to passage of ions and polar molecules.
- It regulates membrane fluidity, making it more fluid at low temperatures and less fluid at high temperatures.
- It increases flexibility and mechanical stability of the membrane.

Adaptations of the cell membrane to its functions

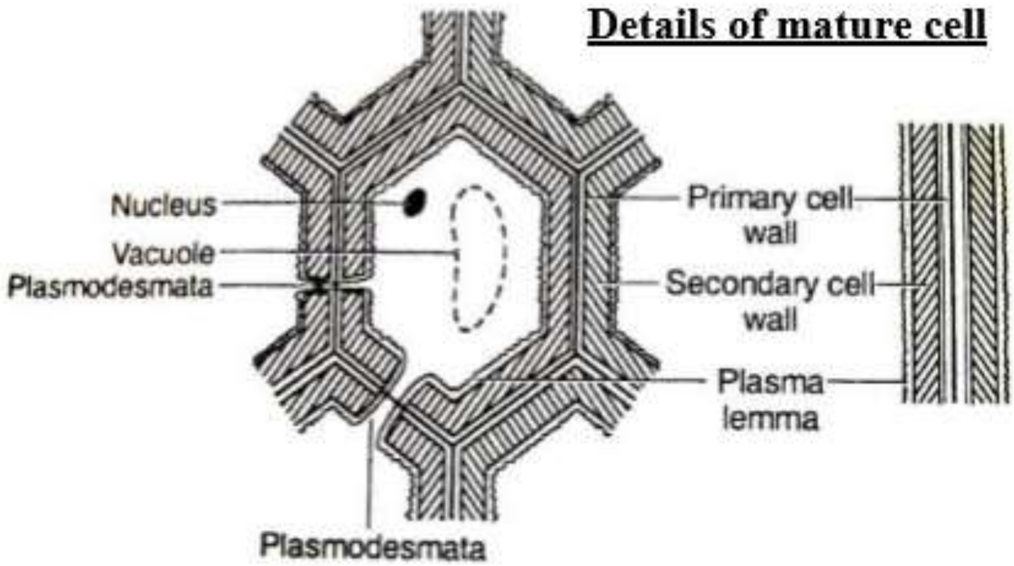
- The cell membrane is thin allowing rapid transport of substances across it.
- It contains phospholipids which are fluid making it flexible and hence cannot easily break down.
- Proteins and phospholipids in the cell membrane provide selective permeability to the membrane and thus controlling what enters and leaves the cell.
- Cholesterol in the membrane disturbs the close packing of phospholipids keeping them more fluid such that the membrane does not solidify at low temperatures.
- Some proteins span the membrane from one side to the other allowing selective transport of polar molecules and ions across the membrane.
- Proteins are embedded in the phospholipid bilayer to provide structural support to the membrane.
- Cholesterol in the membrane increases the flexibility and stability of the membrane such that it does not break up.
- Some proteins in the membrane are enzymes making the membrane metabolically active.
- Short carbohydrate chains added to phospholipids and proteins are involved in sticking cells together to form tissues and in cell-to-cell recognition.

THE CELL WALL

The cellulose cell wall is the outer most layer in plant cells.

The cell wall is interrupted at intervals by narrow pores containing fine strands of cytoplasm called plasmodesmata.

Young plant cells have only a thin primary cell wall but as they grow, a secondary cell wall may be laid down, consisting of many layers of cellulose which may be impregnated with lignin, suberin or cutin.



Functions of the plant cell wall

It maintains cell shape since it is rigid.

It allows plant cells to develop turgidity since it is rigid and resistant to expansion and thus providing support to herbaceous plants.

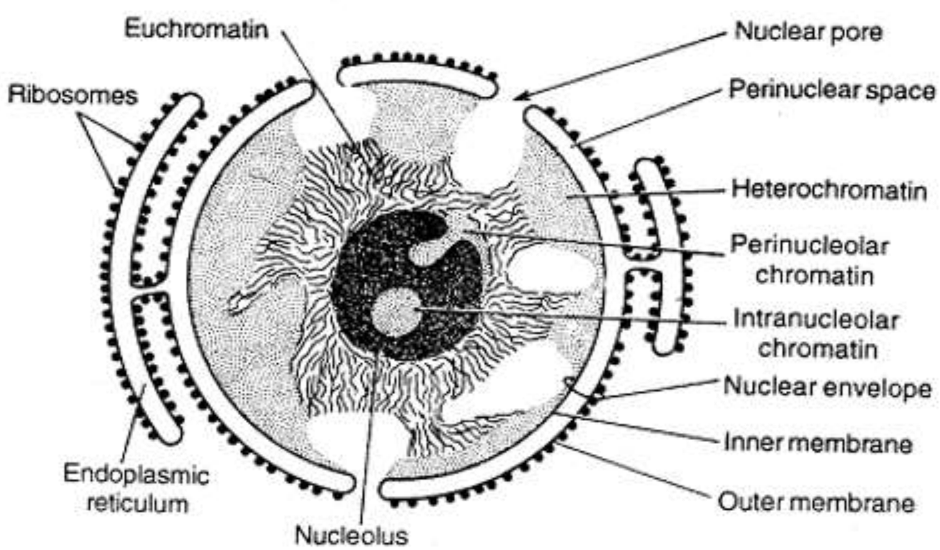
It provides support and mechanical strength to the cell (plant) against gravity.

It acts as a pathway for water and dissolved mineral salt movement by the apoplast pathway.

It prevents excessive entry of water to the cell in a hypotonic solution (resists turgor pressure of the cell).

In suberized cells, it acts as physical barrier to pathogens; and water loss.

Membrane-bound organelles
THE NUCLEUS



This is the largest cell organelle, hence the most conspicuous.
Nuclei are found in all eukaryotic cells with common exceptions being the sieve tube elements and red blood cells.

Structure of the nucleus

The nucleus is surrounded by a double membrane called nuclear envelope.
A fluid-filled space called perinuclear space exists between the inner and outer membrane.
The nuclear envelope is perforated with nuclear pores. These allow exchange of materials between the nucleus and the cytoplasm.
The outer membrane is continuous with endoplasmic reticulum and may be covered with ribosomes on its outside surface.
Within the nucleus is the nucleoplasm containing chromatin made up of coils of DNA bound to proteins called histones.
Within the nucleus is one or more nucleoli which are darkly staining structures.

Functions of the nucleus

It stores DNA which is the molecule of inheritance.
It controls all the activities of the cell through the genes located in DNA.
Nuclear division is the basis of cell division and hence reproduction.
The nucleolus manufactures ribosomes which are a site of protein synthesis

Adaptations of the nucleus to its function

The nuclear membrane has pores; for exchange of RNA and other molecules between the nucleus and the cytoplasm.

It has a nucleolus which produces ribosomes which are sites for protein synthesis.

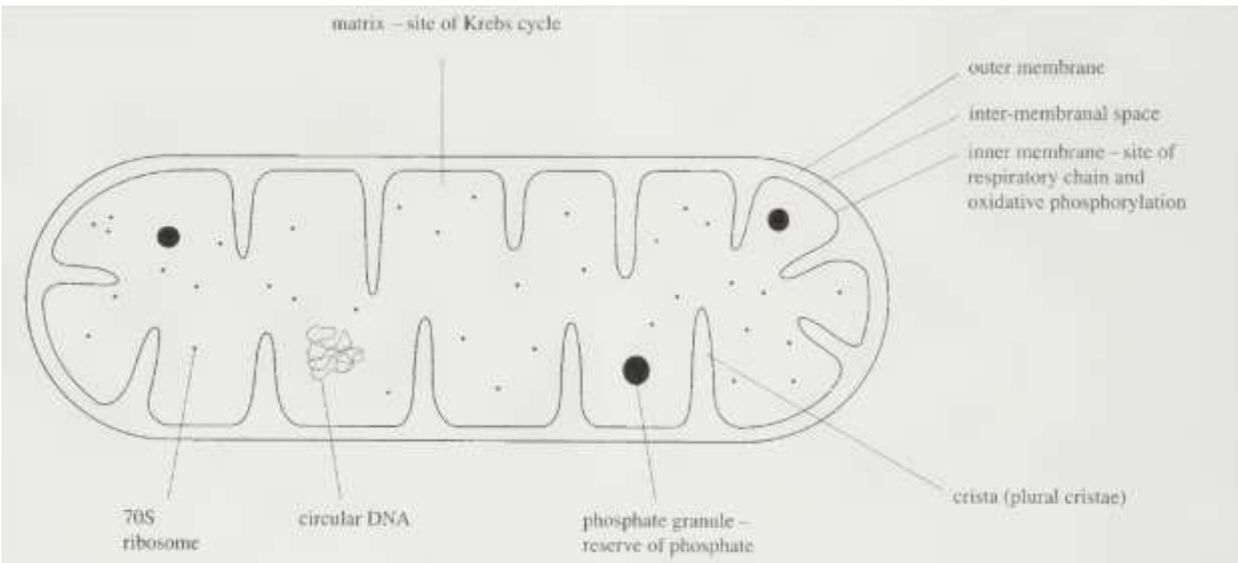
It has a nuclear envelope which isolates the nucleus from interference by processes in cytoplasm.

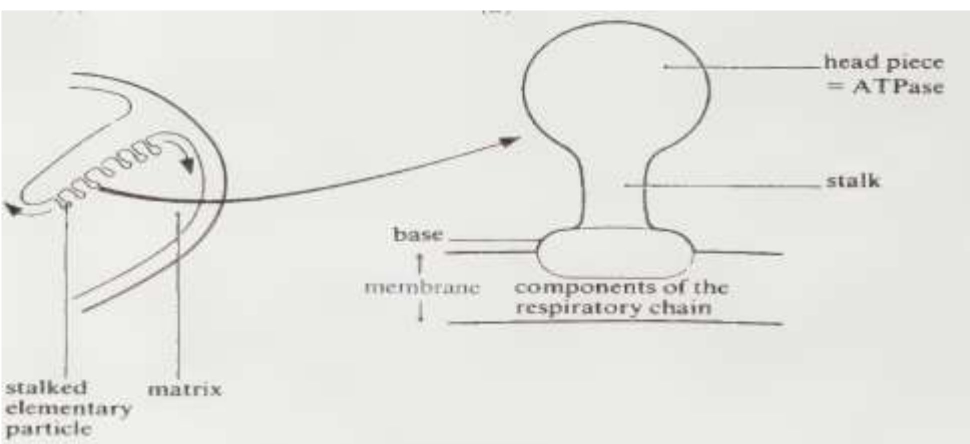
The nuclear pores are narrow to regulate entry and exit of substances

THE MITOCHONDRION

It is the site for aerobic respiration for production of ATP that powers cell activities.

Description of the structure of a mitochondrion





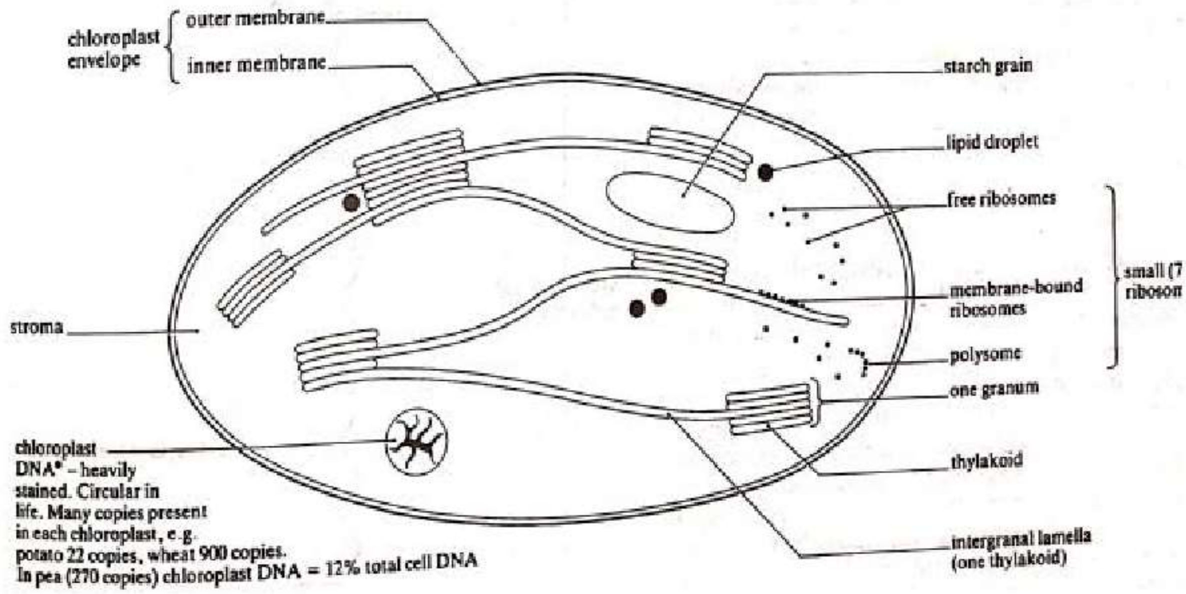
The mitochondrion is bounded by two membranes.
The outer membrane is entire and the inner membrane folds into the mitochondrial matrix to form cristae;

The outer membrane is separated from the inner by a narrow space, the intermembranal space.
The inner membrane is folded inwards into a number of shelf-like cristae
The cristae increase its surface area, providing space for the components of the respiratory chain which are located in the membrane.
Attached to each crista are stalked particles
The mitochondrial matrix is fluid filled, with several enzymes, 70s ribosomes and circular DNA
Each membrane is a phospholipid bilayer, with variable phospholipid compositions and protein-to-lipid (PTL) ratios.

Adaptations of a mitochondrion to its functions

- It is bounded by double membranes which isolate the mitochondrion from interference by processes in the cytoplasm
- It is small in size giving it a large surface are to volume ratio for rapid uptake and release of materials
- Its matrix contains enzymes of the Krebs cycle.
- The inner membrane forms cristae to increase the surface area for electron transport chain reactions.
- The inner membrane contains stalked particles that make ATP
- It has a narrow intermembrane space which enables H+ ion concentration gradient to be rapidly established for chemiosmosis to occur
- The inner membrane contains molecules for electron transport pathway
- It contains DNA which acts as genetic material for synthesis of some protein
- It has many ribosomes for protein synthesis to reduce on importing proteins from cytoplasm.

THE CHLOROPLAST (SITE FOR PHOTOSYNTHESIS)



Adaptations of a chloroplast to its functions

- It contains chlorophyll molecules which trap sunlight energy to be used in the process of photosynthesis.
- The stroma contains enzymes necessary for fixation of carbon dioxide in the light independent reactions of photosynthesis.
- It has a thin Outer membrane for faster diffusion of gases like carbon dioxide which is a raw material for photosynthesis
- It contains thylakoid membranes arranged into coin-like stacks called grana to increase the surface area for packaging of chlorophyll molecules.
- Chloroplasts within the mesophyll cells can move towards light, arranging themselves in the best position within the cells for maximum absorption of light.
- It is bound by a double membrane, to isolate the photosynthetic reactions from other cell activities.
- It contains numerous closed, flattened, fluid-filled sacs, called thylakoids, to hold chlorophyll and accessory pigments in a structured way, in a suitable position to trap maximum light.
- Thylakoids are stacked on top of each other forming grana, interconnected by lamellae to provide a large surface area within the small volume for maximum light absorption
- A chloroplast is transparent due to the thin envelope and the colourless stroma, allowing maximum absorption of light by photosynthetic pigments.

- The arrangement of chlorophyll in the thylakoids brings it into close proximity to other molecules necessary for its functioning in light harvesting photosystems.
- The inner membrane of envelope is highly selective in what it allows in and out of the chloroplasts, regulating the conditions of the internal chloroplast environment for optimum rate of photosynthesis.

LYSOSOMES

These are surrounded by a single membrane. They are spherical sacs that contain lytic enzymes in acidic solution.

Functions of lysosomes

They are involved in autophagy a process by which unwanted structures in the cell are digested within the lysosome. The unwanted structure is first enclosed by a single membrane, then fuses with the lysosome forming an autophagic vacuole in which hydrolytic enzymes of the lysosome are released and the unwanted structure is digested.

They are involved in autolysis which involves self-destruction of a cell, where lysosomes burst open releasing hydrolytic enzymes within the cell and the cell is digested. For example; reabsorption of tadpole tail during metamorphosis and return of the uterus to its normal size after birth involves autolysis.
They are involved in release of hydrolytic enzymes by exocytosis to digest other cells. For example, release of enzymes from the acrosome of sperm which digest a path through layers of cells surrounding the egg before fertilization.
They are involved in digestion of materials taken in by endocytosis. Lysosomes fuse with vesicles or vacuoles formed during endocytosis and release their digestive enzymes into them and thereby digesting the material inside them.

ENDOPLASMIC RETICULUM

The endoplasmic reticulum (ER) is composed of parallel, flattened membrane-bound sacs called cisternae. It is found within eukaryotic cells, except mammalian red blood cells.
The cavities are interconnected.

TYPES OF ENDOPLASMIC RETICULUM

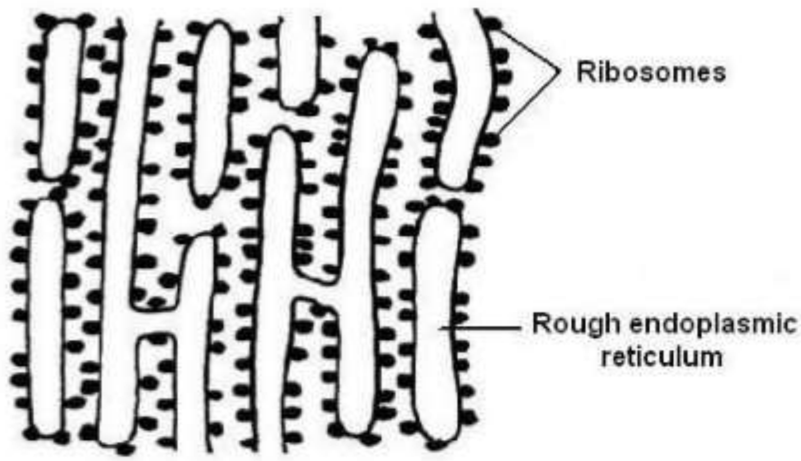
(a) **Rough Endoplasmic Reticulum** (RER), studded with ribosomes.
(b) **Smooth Endoplasmic Reticulum** (SER), without ribosomes attached.

RER is more prominent in cells concerned with protein synthesis. For example; liver cells.
SER is prominent in cells concerned with the production of lipids

NOTE:
The rough and smooth endoplasmic reticulum can transform from one type to another, depending on especially the enzymatic needs of the cell.

ROUGH ENDOPLSMIC RETICULUM

The surface of the rough endoplasmic reticulum is studded with ribosomes, which give it a rough appearance hence the name rough endoplasmic reticulum.
The RER is bound by a phospholipid membrane enclosing a fluid-filled space known as cisternal space or lumen.
Part of the RER is continuous with the outer nuclear membrane.



Functions of RER

- The ribosomes on the rough endoplasmic reticulum are a site for protein synthesis.
- It transports proteins in its cisternae.
- It modifies proteins as they are being transported. For example; addition of a carbohydrate chain to from a glycoprotein.
- It folds proteins into three dimensional shapes, for example, haemoglobin for further processing. It transports ready proteins to the sites where they are required.

SMOOTH ENDOPLASMIC RETICULUM

The smooth endoplasmic reticulum (SER) has no ribosomes attached.
The SER is a folded structure composed of a network of interconnected disc-like sacs and tubules called cisternae which are held in their place by the cytoskeleton.
The SER is bound by a phospholipid membrane enclosing a fluid-filled space known as cisternal space or lumen.

Structure of the smooth-endoplasmic reticulum

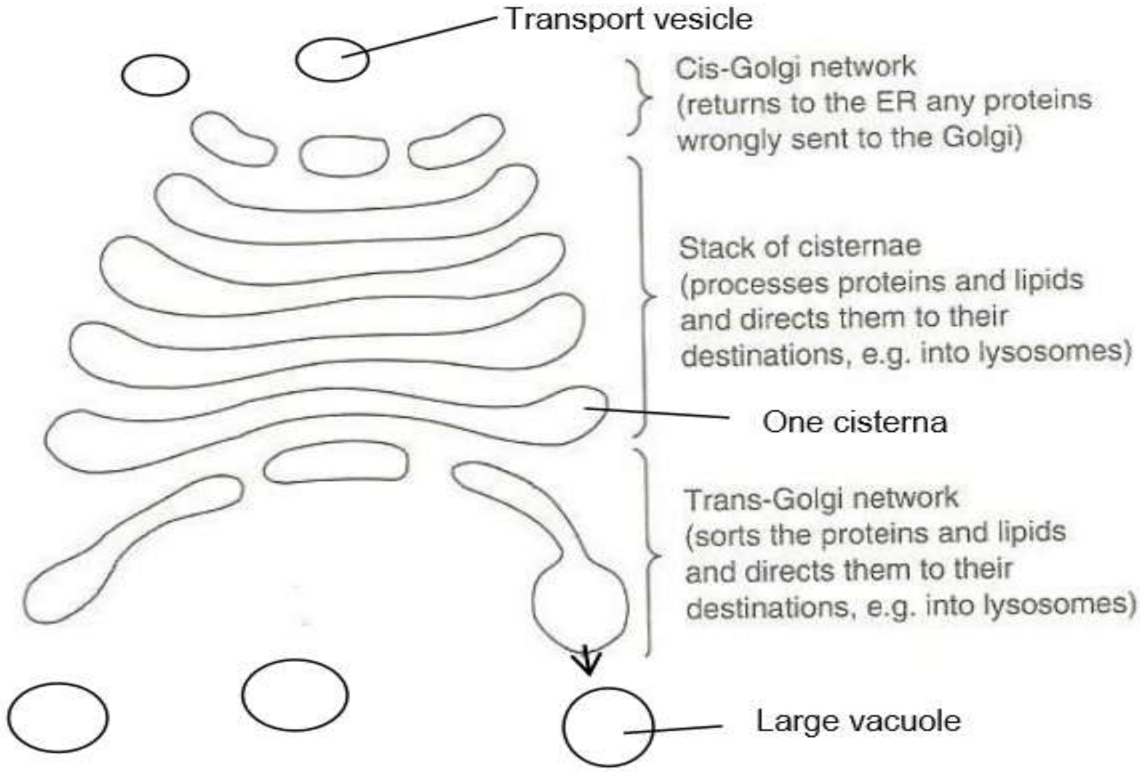
Functions of the SER

- It is a site for synthesis of lipids and other steroids like cholesterol, progesterone and testosterone.
- The smooth endoplasmic reticulum in liver cells contains enzymes for detoxification of drugs and poisons.
- The smooth endoplasmic reticulum in muscle cells stores calcium ions which are used to trigger muscle contraction.
- It is used for synthesis and repair of membranes by producing cholesterol and phospholipids.
- It is used in the metabolism of glycogen in the liver. For example; glucose-6-phosphatase enzyme in SER converts glucose-6-phosphate to glucose and a phosphate group.
- It contains enzymes that detoxicate lipid soluble drugs, alcohol and metabolic wastes from the liver.
- The sarcoplasmic reticulum regulates muscle contraction through storage and release of calcium ions.

GOLGI APPARATUS/GOLGI BODY

The Golgi body consists of piles (stacks) of flattened, membrane-bound sacs called cisternae (singular cisterna) with vesicles pinching off at edges of the sacs.
One cisterna is a flattened sac, with a lumen enclosed by a single membrane.
Between 4-8 cisternae pile up to form a stack which bends to form a semi-circle. An individual stack of the cisternae is sometimes referred as dictyosome.
Each stack of cisternae has the cis face where new cisternae are being formed by fusion of vesicles from endoplasmic reticulum and the trans face where vesicles pinch off the cisternae.

Structure of the Golgi apparatus



The *cis* face is adjacent to the endoplasmic reticulum and the **trans** points towards the plasma membrane.

Functions of the Golgi body

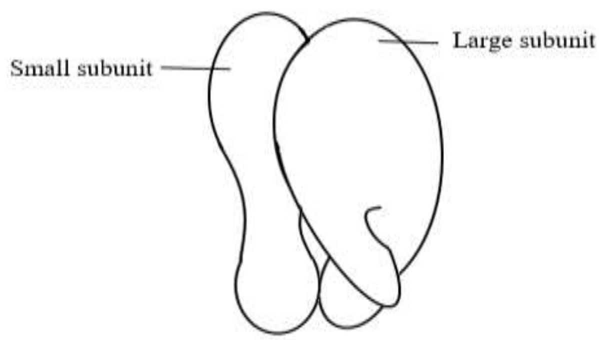
- It modifies, sorts and packages proteins that are made at the rough endoplasmic reticulum for secretion or for use within the cell.
- It transports and stores lipids.
- It forms carbohydrates. For example; polysaccharides are attached to a protein to form proteoglycans present in the extracellular matrix of the animal cell.
- It forms lysosomes containing hydrolytic enzymes.
- In plant cells, Golgi produces vesicles that join to form the cell plates during cell division.
- It replenishes cell surface membranes. When Golgi vesicles empty their contents to the exterior, their membrane fuse with and become part of the cell membrane.
- It produces materials for making plant cell walls and cuticle of insects.

Note. Golgi complex is the cell's **"post office"** or **"shipping department"** where molecules are packaged, labelled and sent to different parts of the cell.

Adaptations of Golgi apparatus

- The cisternae are enclosed by selectively permeable membranes, which isolate the inside cavity from the cytosol for efficient functioning.
- The tubular structure enables transportation of soluble proteins and lipids from the endoplasmic reticulum for modification.
- It has a variety of enzyme systems for modifying proteins by adding carbohydrates and phosphate by the process of glycosylation and phosphorylation respectively.
- Many cisternae increase the surface area for modifying synthesized macromolecules.
- There are many compartments at the cis, located at the beginning of the Golgi apparatus to facilitate passage of proteins through the Golgi apparatus

RIBOSOMES



These are small non-membranous cytoplasmic granules found in all cells. They may occur in groups called polysomes and may be associated with RER or occur freely within the cytoplasm.

Each ribosome consists of two subunits, one large and one small subunit and are made up of RNA called ribosomal RNA (rRNA) and protein.

They are manufactured in the nucleolus and are important in the synthesis of protein.

Prokaryotes have 70S ribosomes (small subunit of 30S and large subunit of 50S) while Eukaryotes have mainly 80S ribosomes which are larger and more complex, each consisting of small (40S) and large (60S) subunit. S stands for the Svedberg unit for sedimentation velocity.

VACUOLES

A vacuole is a fluid-filled sac bound by a single membrane.

Plant vacuoles are large, sac-like structures in which a single membrane called tonoplast encloses a fluid called cell sap, containing water and various dissolved substances.

In animal cells, vacuoles, when present are smaller in size.

Functions of vacuoles

- The tonoplast isolates the vacuolar sap from the cytosol, enabling vacuolar pathway of water.
- Vacuoles in some flowers have coloured pigments that give petals bright coloured for attracting pollinators.
- They serve as stores of reserve food, secretory products and waste product.
- It stores salts, nutrients, minerals, pigments, proteins among others.
- It maintains cell turgor by osmotic uptake of water since vacuolar sap has a higher solute concentration than cytosol.
- In meristematic cells, vacuoles bring about growth by initiating cell elongation.
- They serve as stores of waste products like tannins, which are excreted when leaves fall.
- In fresh water protozoans like amoeba and paramecium, contractile vacuoles regulate the water content of cells.
- Food vacuoles formed by phagocytosis (endosomes) enable bulk intake of food.

CILIA AND FLAGELLA

Cilia and flagella are structurally identical structures.

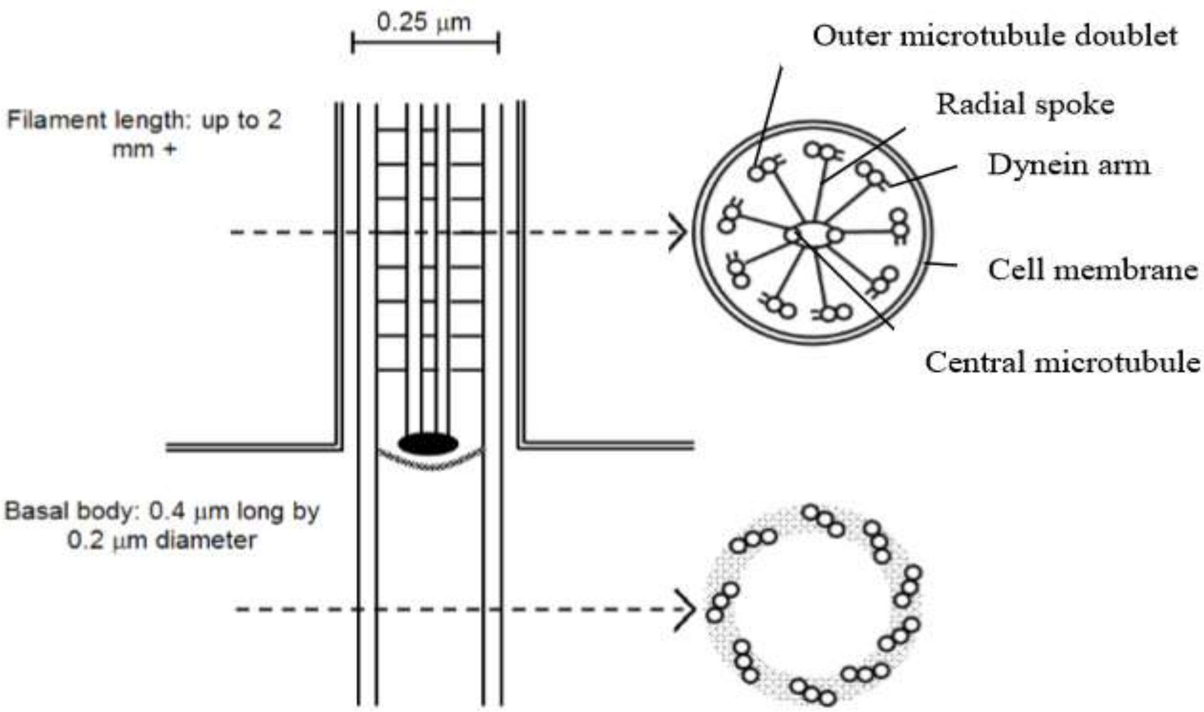
Structure of the cilium/Flagellum

Both the cilium and flagellum arise from a small granular structure called basal body. Cilia and flagella are covered by a unit membrane, which is an extension of the cell membrane.

There is a central filament called axoneme formed of 11 microtubules arranged in the pattern of 9+2

It is made of 9 pairs of peripheral microtubules;✓ and two centrally located microtubules;✓ thereby forming 9+2 pattern of arrangement;✓ 2 central singlets (single microtubules) and 9 peripheral doublets (pairs of microtubules). The cilia is thin;✓ small;✓ cylindrical;✓ and short;✓

Each cilium is supported or borne on a basal body;✓ made of nine triplets of microtubules arranged in a ring (9+0 pattern)



Cilium	**Flagellum**
Numerous	Less in number
Short hair-like organelle	Long whip-like organelle
Occur throughout the cell surface	Present at one end
Beat in coordination	Beat independently
Show sweeping movement or pendular stroke	Undulatory movement

Function of the flagellum

- It is mainly used for locomotion in unicellular organisms

Functions of cilium

- It transports materials within the body;✓
- It causes movement and feeding of certain unicellular animals;✓
- It wafts the egg through the oviduct to the uterus for implantation;✓
- It wafts dust particles from the trachea to the pharynx;✓
- It creates a current of flow of coelomic fluid into the nephrostome of the earthworm;✓
- It creates a current of flow of cerebrospinal fluid within the ventricles of the brain and median canal of central nervous system;✓
- Cilia create a propulsive force for forward movement of certain materials of the body and the entire body of ciliated unicellular organisms;✓