CELL : THE UNIT OF LIFE
EUKARYOTIC CELLS

EUKARYOTIC CELLS

- The eukaryotes include all the protists, plants, animals and fungi. In eukaryotic cells there is an extensive compartmentalisation of cytoplasm through the presence of membrane bound organelles.
- Eukaryotic cells possess an organised nucleus with a nuclear envelope. In addition eukaryotic cells have a variety of complex locomotory and cytoskeletal structures. Their genetic material is organised into chromosomes.
- All eukaryotic cells are not identical. Plant and animal cells are different as the former possess cell walls, plastids and a large central vacuole which are absent in animal cells. On the other hand, animal cells have centrioles which are absent in almost all higher plant cells.

STRUCTURE. OF BIOMEMBRANES / CELL MEMBRANE :

- It is outermost covering of the cell that is **elastic, living, pliable, hydrophilic and selective permeable membrane**.
- It is found in both prokaryotic and eukaryotic cells.

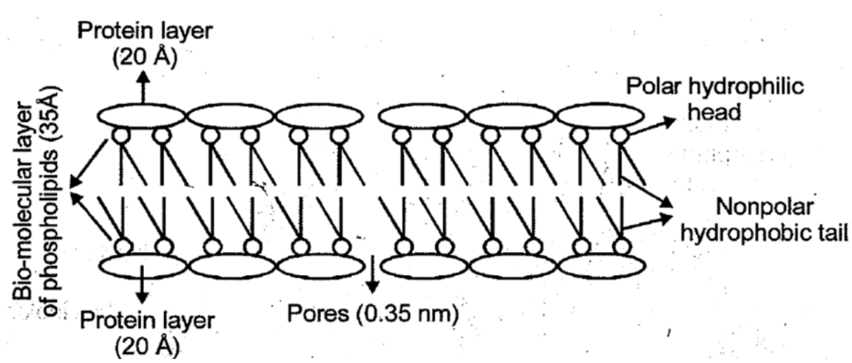
Structure

- The detailed structure of the membrane was studied only after the advent of the electron microscope in the 1950s.
- Cell membranes can be observed in electron microscope. It appears trilaminar or tripartite layer under electron microscope.
- Meanwhile, chemical studies on the cell membrane, **especially in human red blood cells (RBCs), enabled the scientists to deduce the possible structure of plasma membrane.**
- Chemically a cell membrane contains proteins, Lipids, carbohydrates, water. DNA, RNA are absent.

- **The ratio of protein and lipid in plasma membrane varies e.g. in human beings, the membrane of the erythrocyte has approximately 52 per cent protein and 40 per cent lipids.**
- Proteins are globular in nature including structural, enzymatic, carrier, permease and receptor proteins.
- **Lipids** are usually **phospholipids (**arranged in bilayer) that are **amphiatic / amphipathic** containing **polar hydrophilic heads** (outside) and **nonpolar hydrophobic tails** (inside).
- Cholesterol provides regidity and stability to the cell membrane.
- **Carbohydrates** of cell membranes are small unbranched or branched chains of **oligosaccharides.**
- They combine with both lipids and protein molecules on outer surface of the membrane and form **glycolipids and glycoproteins respectively.**

1. **Sandwitch or Trilamellar model :-** By Davson & Danielli (1935).

- According td this model, the plasma-membrane is made up of three layers in which a bimolecular layer of lipid is sandwitched between two single layers of proteins.
- According to this model each protein layer is 20Å thick and bilayer of phospholipid is 35Å thick. Thus total thickness is 75Å (PLLP – structure, range 75–100Å)
- Phospholipid molecule called as amphipathic molecule due to presence of two type of parts (hydrophilic head and hydrophobic tail).
- Hydrophilic head of the phospholipid binds with protein layer by hydrogen and ionic bonds.
- Hydrophobic tail of phospholipid are attached to each other by vanderwal force.



2. **Unit membrane model :-** By Robertson 1959.

- According to this model all the cellular and organeller membranes are structurally & functionally similar (difference in chemically & size).
- Both of the above models are rejected because they fails to explain the selective permeability of plasmalemma.
- The detailed structure of the membrane was studied only after the advent of the electron microscope in the 1950s. Meanwhile, chemical studies on the cell membrane, especially in human red blood cells (RBCs), enabled the scientists to deduce the possible structure of plasma membrane.

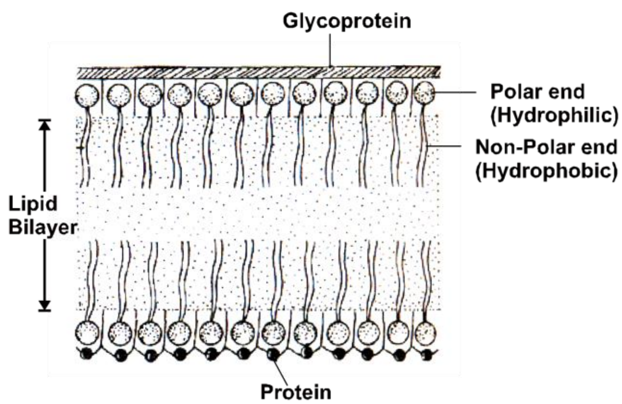


Fig:- Unit membrane model of Robertson

This model is unable to explain the selective permeability and elasticity of plasma membrane.

Fluid mosaic model:

- It was proposed by **Singer and Nicolson (1972).**
- It is most recognized model for plasma membrane.
- **According to this, the quasi-fluid nature of lipid enables lateral movement of proteins within the overall bilayer**.
- This ability to move within the membrane is measured as its fluidity.
- They stated that plasmamembrane contains lipid bilayer in which protein are found on both outer and inner side to form mosaic pattern.
- Thus they described it as **protein icebergs in sea of lipids.**
- **The fluid nature of the membrane is also important from the point of view of functions like cell growth, formation of intercellular junctions, secretion, endocytosis, cell division etc**.
- **Depending on ease of extraction, proteins of membrane are of two types.**

(a) **External or extrinsic proteins:**

- It is peripheral protein **(30% of total protein)**.
- They lie on the surface of the membrane.
- It can be easily removed **e.g. Spectrin in RBC.**

(b) **Integral or intrinsic proteins:**

- It is about **70% of total protein.**
- They are buried partially or totally in plasma membrane.
- These can not be separated easily. **e.g. Cytochrome oxidase, Porin Proteins.**
- They may function as **carriers, permeases, enzymes, receptors**.
- Some large globular intrinsic proteins pass as a helix into the lipid bilayer from outside to inside to form **tunnel proteins or transmembrane proteins.**
- The transmembrane proteins act as channels for passage of water soluble materials and water.

- The plasma membrane is **asymmetric** due to **oligosaccharides** which form glycolipids and glycoprotein alongwith lipids and proteins respectively.
- Both glycolipids and glycoproteins form **glycocalyx**.
- Oligosaccharide part in glycocalyx acts as recognition centre, site for attachment and provides antigen specificity to cell membranes, blood grouping, immune response and matching of tissues in transplantation of organs.

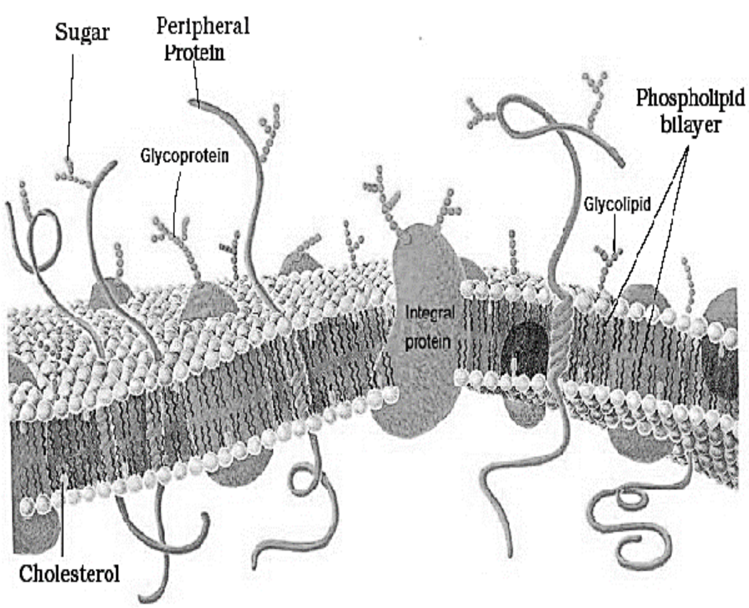
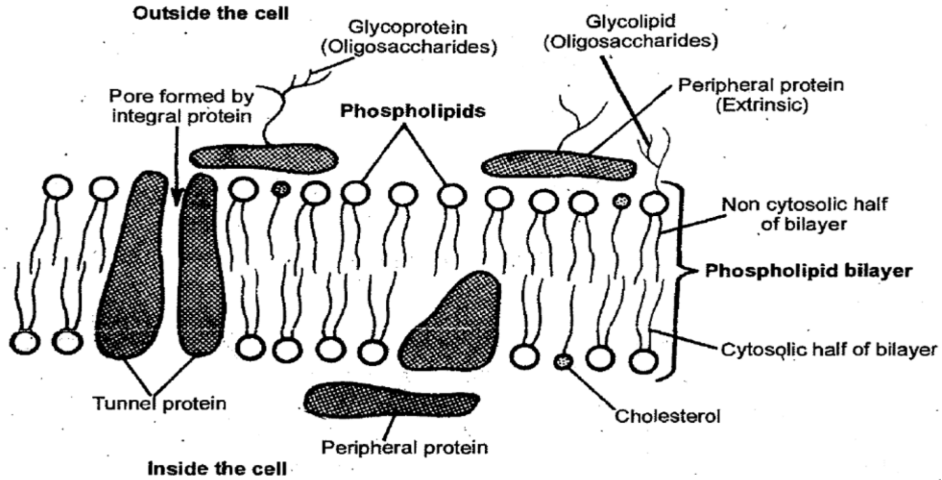


Figure: Fluid mosaic model of plasma membrane



Fluid-mosaic model of membrane

Special points of cell membrane

1. Phospholipid also show exchange of molecule from one monolayer to the monolayer of other side it is called as **flip-flop movement.**
2. Flip-flop movement is absent in protein molecules.
3. Protein and lipid both can show rotational and lateral diffusion in membrane.
4. **Eukaryotic plasma membrane contains cholesterol but in prokaryotes hopanoids are present instead of it.**
5. Lipids provide fluidity, elasticity and stability and make growth, formation of cell junctions, cell division and endocytosis possible.
6. Glycoproteins and glycolipids provide antigen specificity eg. RBC antigen, fertilizin-antifertilizin reaction

Functions of plasma membrane

Membrane transport:

- Cell membrane is considered as selective permeable membrane.
- Passage of substances across biomembranes occur by following methods.

1. Passive transport: It involves following methods **(i) Diffusion (ii) Osmosis (iii) Facilitated diffusion**

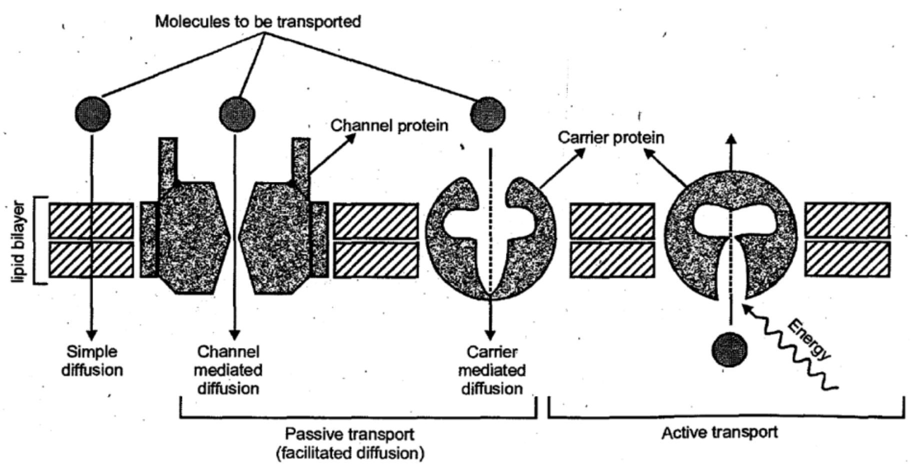
(i) Fat soluble substances can channelise directly across lipid layer.

(ii) Neutral solutes may move across the membrane by the process of simple diffusion along the concentration gradient, i.e., from higher concentration to the lower.

(iii) Water may also move across this membrane from higher to lower concentration. Movement of water by diffusion is called osmosis.

(iv) The polar molecules cannot pass through the nonpolar lipid bilayer, they require a carrier protein of the membrane to facilitate their transport across the membrane called as facilitated diffusion.

2. Active transport: Some ions or molecules are transported across the membrane against their concentration gradient, i.e., from lower to the higher concentration. Such a transport is an energy dependent process, in which ATP is utilised and is called active transport, e.g., Na+/K+ Pump.



3. **Bulk transport:** It take place by two methods.

(i) **Endocytosis:** The inward transport of material by means of carrier vesicles is called endocytosis. It includes two types.

(a) **Pinocytosis or Potocytosis (Cell drinking):** Intake of fluid substances by plasmalemma in the form of vesicles **(Pinosome)** is called pinocytosis.

(b) **Phagocytosis (Cell eating) :** Intake of solid food substances by plasmalemma in the form of vesicles **(Phagosome)** is called phagocytosis.

(ii) **Exocytosis (Cell vomitting or emiocytosis):** It is reverse of endocytosis in which waste materials are removed from the cell. It involves **reverse pinocytosis.**

Cell wall

- It was first studied by **Robert Hooke in cork cells**.
- It is outer most dead covering around plant cell. That is secreted by **cytoplasm/(Protoplasm).**
- **Cell wall not only gives shape to the cell and protects the cell from mechanical damage and infection, it also helps in cell-to-cell interaction and provides barrier to undesirable macromolecules. Algae have cell wall, made of cellulose, galactans, mannans and minerals like calcium carbonate.**
- In **plant cell** it is usually composed of **cellulose**, hemicellulose, pectins and proteins but in **bacteria and BGA** it is composed of **peptidoglycan and DAPA.** In **fungi** it consists of **chitin.** It is **absent** in **Animals, Mycoplasma**.

Structure of the cell wall

- The **diameter** of cell wall varies from **0.1–10 m.**
- A cell wall contains **(a) matrix (b) fibrils (c) depositions**

Chemical Compostion of cell wall:

Matrix: Water-60%. Hemicellulose-5-15%. Pectic Substances-2-8%. Lipids–0.5–3.0%. Proteins-1-2%

Microfibrils: Cellulose / fungus cellulose–10–15%.Other depostions 0.025%. Cellulose is a main component of cell wall.

The cell wall is formed of following layers

(i) **Middle Lamella**
(ii) **rimary wall**
(iii) **Secondary Wall**
(iv) **Tertiary wall**

(i) Middle Lamella:

- It is thin amorphous cementing layer for joining of two adjacent plant cells.
- It is composed of **pectin as calcium and magnesium pectate** (mainly calcium pactate).
- It is absent on the outer free surface of cell and plasmodesmata.

- Retting of fibres and softening of fruits are due to dissolution of calcium pectate in middle lamella by pectinase enzyme.
- The cell wall and middle lamellae may be traversed by plasmodesmata which connect the cytoplasm of neighbouring cells.

(ii) Primary wall:

- It is elastic, permeable and thin, single layered outer most wall layer of plant cell.
- Cellulose, hemicellulose and pectin contents are roughly in equal amount in primary wall.
- Root hairs, parenchymatous cells and meristematic cells are formed of only primary wall.
- It is capable of growth. Its growth takes place by **intussusception (Addition of materials with in the existing wall).**
- It generally diminshes as the cell matures.

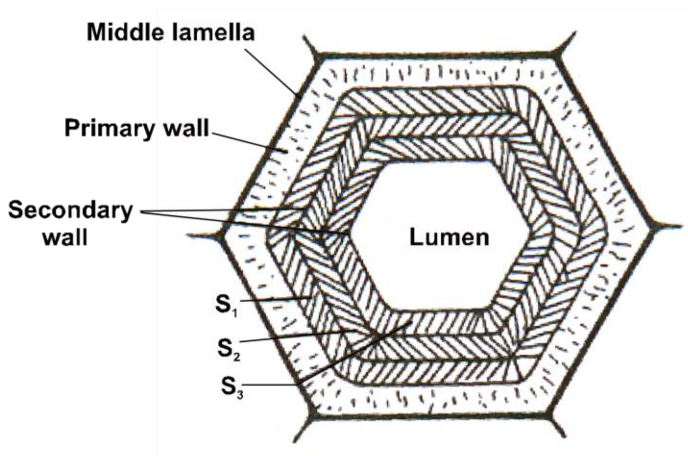


Fig:- Parts and Layers of cell wall

(iii)Secondary wall:

- It lies inside the primary wall i.e. it lies towards membrane side of the cell
- Its growth takes place by **Accretion (deposition of materials over the surface of existing structure).**
- It consists of at least **three layers–S_1, S_2, S_3,** this wall is made up of cellulose, hemicellulose and pectin.

Differences Between Primary and Secondary Walls			
S.No.	**Primary Wall**	**S.No.**	**Secondary Wall**
1	It is single layered formed in young growing cell.	1	It is three or more layered formed when the cell has stopped growing.
2	Cellulose microfibrils are shorter, wavy and loosely arranged.	2	Cellulose microfibrils are longer, closely arranged, straight and parallel.
3	Cellulose content is compartively low.	3	Cellulose content is compartively high.
4	Hemicellulose is upto 50%.	4	Hemicellulose is about 25%.
5	Pits are usually absent.	5	Pits are common.
6	It grows by intussusception.	6	It grows by accretion.
7	Lipid content is 5-10%, protein is 5%.	7	Lipid is absent, protein content is 1% or less.

Thickenings of cell wall

(a) Spiral thickenings **(b) Annular thickenings** **(c) Sclariform thickenings**

(d) Reticulate thickenings **(e) Pitted thickenings**

Pits: They represent unthickened areas in the secondary walls of plant cells that occur as depressions. A pit contains **pit chamber and a pit membrane**.

- The pit membrane composed of **primary wall and middle lamella.** Pits are two types

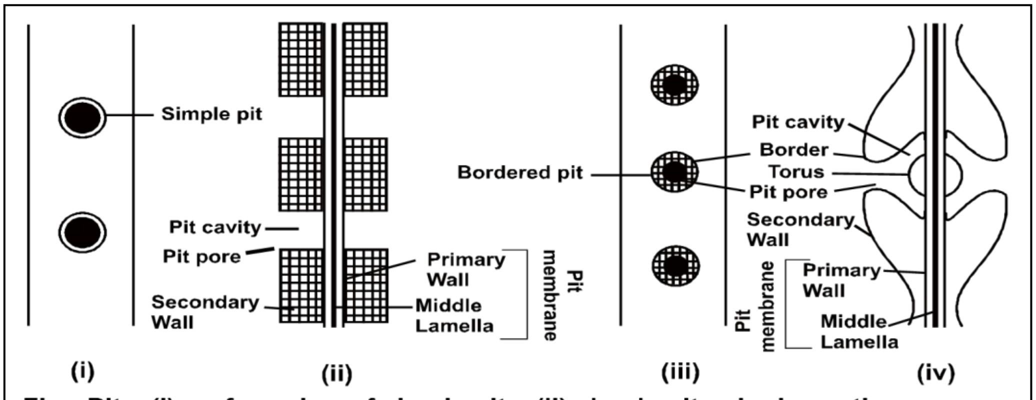


Fig:- Pits. (i) surface view of simple pits. (ii) simple pit pairs in section. (iii) Surface view of bordered pits.(iv) Bordered pit pairs in section.

- **Simple pits:** It bears uniform width of the pit chamber.
- **Bordered pits:**

  Its chamber is flask-shaped due to overarching of secondary wall on its mouth.

  Its pit membrane has thickening of suberin called **Torus**.

  In bordered pits the diffusion is regulated by torus and it functions as a valve.

  These pits are found abundantly in **tracheids of gymnosperms (have maximum number of bordered pits) and in vessels of angiosperms.**

(iv) Tertiary wall:

Sometimes innermost layer of the secondary wall is distinct both chemically as well as in staining properties due to the presence of xylans. It is called tertiary wall Eg. Tension wood in gymnosperms.

PLASMODESMATA:-

Name proposed by Strasburger (1901). These are cytoplasmic connections between two adjacent plant cells. Plasmodesmata are characteristic of multi-cellular plants. E.R. tubules (Desmotubules) help to maintain continuity of cytoplasm. The cell wall and middle lamella may be traversed by plasmodesmata which connect the cytoplasm of neighbouring cells.

Expansin: It is special protein that takes part in growth of cell wall by loosing cellulose microfibril and addition of new cell wall material in the space.

Extensin: This protein connects pectin and hemicellulose.

Cell Coat: In many animals and protistans distinct layer of glycocalyx is found in the outer surface of cells. It is fibrous and composed of oligosaccharides. It helps in cell recognition, protection etc.

FUNCTIONS OF CELL WAIL

(i) Cell wall gives shape to the cell

(ii) It protects the cell from mechanical damage and infection

(iii) it also helps in cell-to-cell interaction

(iv) it provides barrier to undesirable macromolecules.

CYTOPLASM

- Term "Cytoplasm", was given by Strasburger for the part of cell, presents between the nucleus and cell membrane. Cytoplasm can be divided into two parts :- Cytosol and Trophoplasm

Cytosol / Hyaloplasm / Ground plasm:

- Liquid part of cytoplasm except cell organelles
- It can exist in sol and gel state called plasmasol and plasma gel.

Cytoplasmic streaming: It is also called as protoplasmic streaming or cyclosis occur in eukaryotic cells.

Function:

(a) Help in movement of organelle such as chloroplast in relation to light intensity.
(b) Distribution of various substances and food vacuole in Amoeba.
(c) Formation of pseudopodia in Amoeba and in repair of membrane and in heat distribution.

Trophoplasm: It involves cell organelles and cell inclusions.

1. **Cell Inclusions:**

- They are non-living substances also known as ergastic bodies. They are of three types–

(A) Reserve food: It includes starch, glycogen, fat droplets and aleuron grains.
(i) Starch grains
(ii) Glycogen granules: Animal cells
(iii) Fat droplets: Animal and Plant cells
(iv) Aleurone grains

(B) Excretory or secretory products:

- Mucus in several animal cells, essential oils, alkaloids, resins, gums, tanins, latex etc.

(C) Mineral matter:

- Silica found in epidermal cells of grasses.
- **Calcium carbonate crystals (cystolith)** found in epidermal cells of momordica, hypodermal leaf cells of Banyan.
- **Calcium oxalate** occurs in the form of powdery mass (crystal sand) in atropa, star shaped **sphaerophide** in Colocasia, Begonia, Chenopodium prismatic crystals in dry scales of Onion, needle shaped **raphides** in lemna, Eichhornia.

CEIL ORGANELLES

- Metabolically active and living structures of cytoplasm are called organelles.

ENDOMEMBRANESYSTEM

- While each of the membranous organelles is distinct in terms of its structure and function, many of these are considered together as an endomembrane system because their functions are coordinated.
- The endomembrance system include endoplasmic reticulum (ER). golgi complex. lysosomes and vacuoles. Since the functions of the mitochondria chloroplast and peroxisomes are not coordinated with the above components these are not considered as part of the endomembrane system.

Enodoplasmic Reticulum (E.R.)

- It was discovered by **Porter and Thompson** and the name Enodoplasmic Reticulum coined by **Porter.**
- It is 3-dimensional and interconnected system of membrane-lined channels that run through the cytoplasm, forms network.
- **It divides the intracellular space into luminal (inside ER) and extra luminal (Cytoplasm) compartments.**
- It is single membrane bound organelle.
- It is found in plasmodesmata in the form of **desmotubules**.

Components of E.R. :-

(1) Cisternae - These are long flattened and unbranched units arranged in stacks.

(2) Vesicles - These are oval membrane bound structures.

(3) Tubules- These are irregular, often branched tubes bounded by membrane. Tubules may free or associated with cisternae.

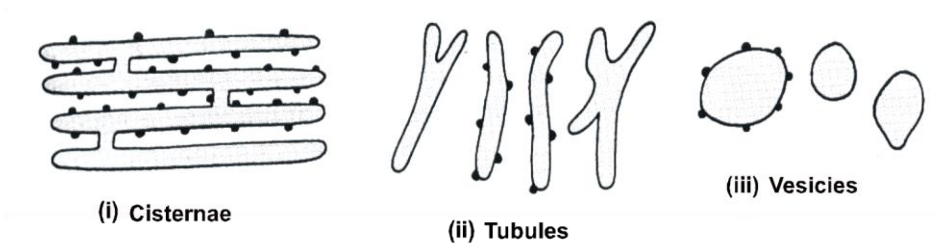


Fig:- Parts of Endoplasmic reticulum

- Structure of E.R. is like the golgi body but in E.R. cisternae, vesicles and tubules are isolated in cytoplasm and these do not form complex.
- Golgi body is localised cell organelle while E.R. is widespread in cytoplasm. E.R. is often termed as "System of Membranes"
- ER divide the intracellular space into two distinct compartment i.e. Luminal (inside ER) and extra luminal (cytoplasm) compartments.

Types of Endoplasmic reticulum

On the basis of nature of its membranes, endoplasmic reticulum is of two types.

RER – Rough Endoplasmic Reticulum

SER – Smooth Endoplasmic Reticulum

- The ER often shows ribosomes attached to their outer surface. The endoplasmic reticulun bearing ribosomes on their surface is called rough endoplasmic reticulum (RER).
- RER is frequently observed in the cells actively involved in protein synthesis and secretion.
- They are extensive and continuous with the outer membrane of the nucleus.
- In the absence of ribosomes they appear smooth and are called smooth endoplasmic reticulum (SER).
- The smooth endoplasmic reticulum is the major site for synthesis of lipid. In animal cells lipid-like steroidal hormones are synthesised in SER.

Differences between SER and RER

Rough E.R. (Granular)	Smooth E.R. (Agranular)
(1) 80s ribosomes binds by their larger subunit, with the help of two glycoproteins (Ribophorin I and II on the surface of Rough E.R.)	(1) Ribosomes and Ribophorins absent
(2) Mainly composed of cisternae.	(2) Mainly composed of tubules.
(3) Abundantly occurs in cells which are actively engaged in protein synthesis and secretion. e.g. liver, pancreas, goblet cells.	(3) Abundantly occurs in cells concerned with glycogen and lipid metabolism. ➢ In animal cell lipid like steroidal hormones are synthesized in SER. e.g. Adipose tissue, Interstitial cells, muscles, Glycogen storing liver cells and adrenal cortex.

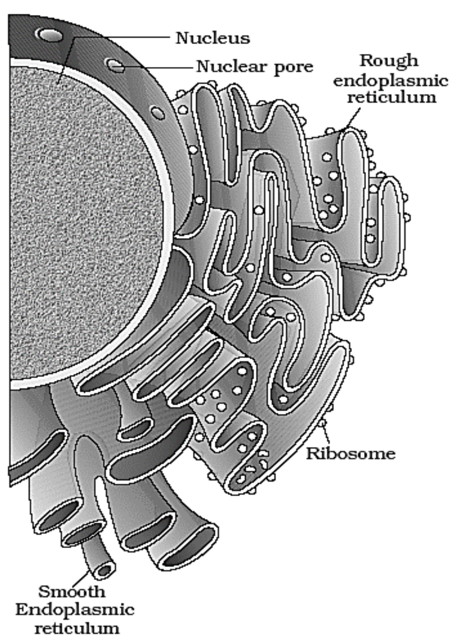


Figure: Endoplasmic reticulum

MODIFICATIONS OF E.R.

(i) **Sarcoplasmic Reticulum (S.R.) :-** These smooth E.R. occurs in skeletal and cardiac muscles. S.R. Stores Ca^{+2} and energy rich compounds required for muscle contraction.

(ii) **Microsomes :-** These are pieces of E.R. with associated ribosomal particles. These can be obtained by fragementation and high speed centrifugation of cell. They do not exist as such in the living cell. Scientist used microsome for in vitro protein synthesis study.

(iii) **Nissl granules :** RER of nerves cells are called nissl granules.

(iv) **GERL :** Golgi associated ER from which lysosomes arise

FUNCTIONS OF E.R.

1. **Mechanical support :-** Micro filaments, Microtubules and E.R. forms endoskeleton of cell.
2. **Intracellular exchange :-** E.R. forms intracellular conducting system. Transport of materials in cytoplasm from one place to another may occurs through the E.R.

- At some places E.R. is also connected to P.M. So E.R. can secrete the materials outside the cell.

3. **Rough E.R. :-** Provides site for the protein synthesis, because rough E.R., has ribosomes on its surface.
4. **Lipid Synthesis :-** Lipids (cholesterol & phospholipids) synthesized by the agranular portion of E.R. (Smooth E.R.).
5. ER also helps in the synthesis of lipoproteins and glycogen.
6. **Cellular metabolism :-** The membranes of the reticulum provides an increased surface for metabolic activities within the cytoplasm.
7. **Formation of nuclear membrane :-** Fragmented vesicles of disintegrated nuclear membrane arid ER elements arranged around the chromosomes to form a new nuclear membrane during cell division.
8. Formation of lysosomes, Golgi body & some Micro bodies.
9. **Detoxification :-** Smooth ER concerned with detoxification of drugs, pollutants and steroids. Cytochrome P_{450} in E.R. act as enzyme which function in detoxification of drugs and other toxins
10. E.R. provides the precursor of secretory material to golgi body.

GOLGI COMPLES

- Camillo Golgi (1898) first observed densely stained reticular structure near the nucleus. These were later named Gogi bodies after him.
- Golgi body also named as :-
  Lipochondria (rich in lipids)
  Dictyosome (plant golgi body)
- The cytoplasm surrounding Golgi body have fewer or no other organelles. It is called Golgi ground substance or zone of exclusion.
- It is extremely **pleomorphic** as its shape and form vary in cells.
- Golgi complex is also Known as **Dictyosome (plant golgi body),** Lipochondria **(Rich in lipids), traffic police of cell,** Idiosome, **Baker's body,** Dalton complex, Golgisome, **export house/middle man of cell.**
- A plant cell has 10 –20 dictyosomes.
- Golgi bodies mainly arise from SER.

Structure of Golgi complex

- The shape and size of Golgi complex depend upon the physiological state of the cells. Structurally Golgi complex is composed of four parts

  1. Cisternae **2. Tubules** **3. Vesicles** **4. Golgian vacuoles**

1. **Cisternae :-** These are flat disc shaped, sacs like structure many cistenae are arranged in a stack (parallel to each other). Diameter 0.5 m to 1.0 m. Dense opaque material inside cisternae is called Nodes.

- Varied number of cisternae are present in Golgi complex.
- The Golgi cisternae are concentrically arranged near the nucleus.
- Convex surface of cisternae which is towards the nucleus is called cis- face or forming face.
- Concave surface of cisternae which is towards the membrane is called Transface or maturing face.
- The cis and trans faces of the organelle are entirely different but inner connected.

2. **Tubules:** They form a complex network towards the periphery and trans face of the Golgi apparatus. They interconnect the different cisternae.

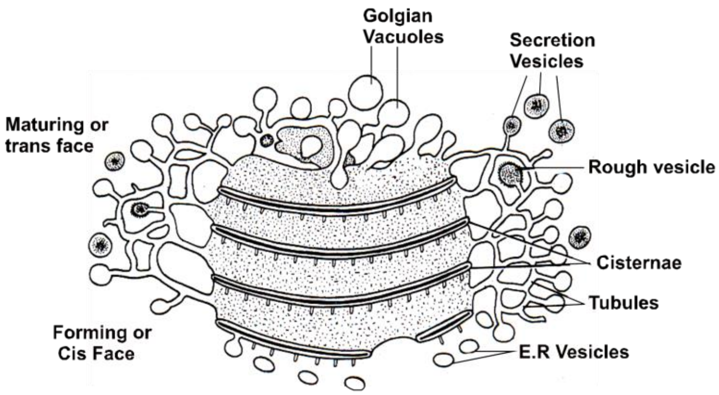


Fig. Structure of Golgi apparatus

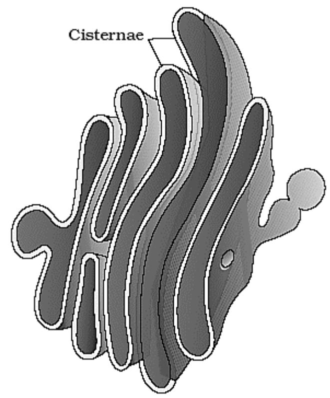


Fig. Golgi apparatus

3. **Vesicles:** They are small sacs that arise from tubules. They are of two types smooth and coated. Out of them smooth vesicles contain secretory substances hence these are called secretory vesicles.

4. **Golgian vacuoles:** These are expensions of cisternae at trans face. Some of them act as lysosomes.

Functions:

(i) **Secretion:**

- **The Golgi apparatus principally performs the function of packaging materials, to be delivered either to the intra-cellular targets or secreted outside the cell.**
- **Golgi complex is a centre of reception, finishing, packaging and secreting for a variety of materials in the cells**.
- After modifications materials are packed in vesicles, the latter are budded off from maturing face of Golgi body and released outside the cell that is called **Exocytosis or revevrse pinocytosis.**

(ii) **Formation of new cell wall:** Pectic compounds of middle lamella and various polysaccharides of the cell wall are secreted by Golgi complex.

(iii) Glycosidation and Glycosylation:

- A number of proteins synthesised by ribosomes on the endoplasmic reticulum are modified in the cisternae of the golgi apparatus before they are released from its trans face.
- Golgi complex cause glycosylation of protein synthesized on RER to form glycolipids and glycoproteins.
- Golgi complex cause glycosidation (addition of oligosaccharides to phospholipids of membranes) of lipids.

(iv) Formation of acrosome: Acrosome of sperms is synthesised by Golgi complex during spermiogenesis.

(v) Formation of Lysosome: Vesicles of Golgi complex and ER take part in the synthesis of primary lysosomes **(GERL system)**.

(vi) Vitellogenesis: Golgi complex acts as the centre around which yolk is deposited.

(vii) Root cap cells are rich in Golgi bodies which secrete mucilage for lubrication of root tip.

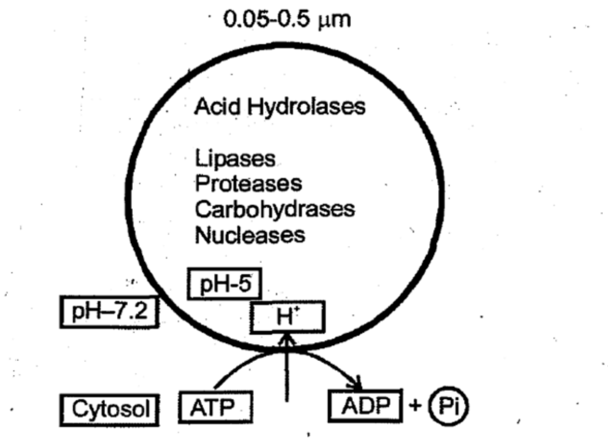
(viii) Hormones: Production of hormones by endocrine glands is mediated through it.

Note: Materials to be packaged in the form of vesicles from the ER fuse with the cis face of the golgi apparatus and move towards the maturing face. This explains, why the golgi apparatus remains in close association with the endoplasmic reticulum.

LYSOSOME

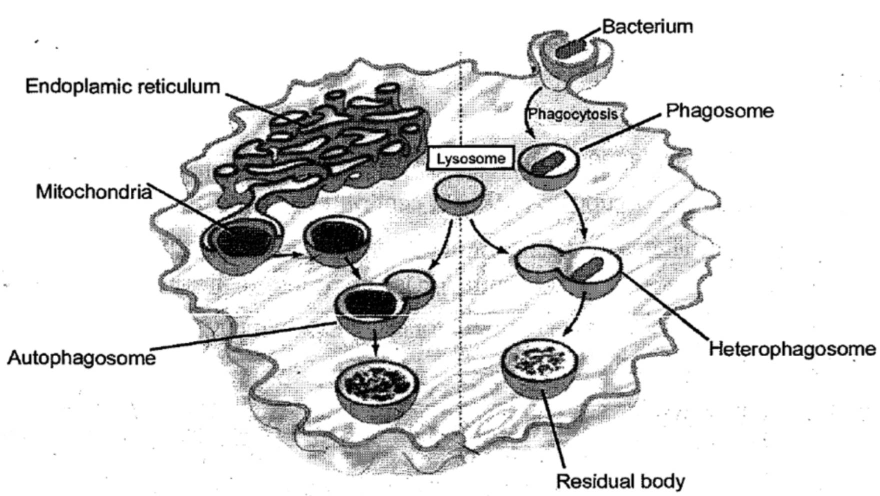
(Suicidal bags or recycling centres or scavenger of cell)

- These are membrane bound vesicular structures formed by the process of packaging in the golgi apparatus. The isolated lysosomal vesicles have been found to be very rich in almost all types of hydrolytic enzymes (hydrolases - lipases, proteases, carbohydrases) optimally active at the acidic pH (pH = 5). These enzymes are capable of digesting carbohydrates, proteins, lipids and nucleic acids.
- With the exception of mammalian RBC they were reported in all animal cells.
- In plant cells large central vacuole functions as Lysosome. So in higher plants lysosomes are less frequent. But number of lysosomes is high in fungi.
- **Periplasmic Space :-** space between cell wall and cell membrane in bacteria, may play similar role.



A lysosome containing a number of acid hydrolases that are active under acidic condition, which is maintained by an H+ ATPase in the membrane

- Lysosomes are spherical bag like structures, which is covered by single unit membrane. They are large sized in Phagocytes (WBC).
- Lysosomes are filled with 50 different type of digestive enzymes termed as Acid hydrolases for digestion of all type of macromolecules.
  These acid hydrolases function in acidic medium (pH = 5). Membrane of lysosome has an active H^+ pump mechanism which produce acidic pH in lumen of lysosome.
- Lysosomes are highly polymorphic cell organelle. Because, lysosomes have different physiological states.



Types of Lysosomes:

Lysosomes show **pleomorphism** and are of four types.

1. **Primary lysosomes:** These are newly synthesized lysosomes from Golgi complex by GERL system. They contain inactive enzymes.
2. **Secondary lysosomes (hetorophagosomes or phagolysosomes):** It is formed by the union of primary lysosome with food vacuole (Phagosome).
3. **Tertiary lysosomes (residual bodies or telolysosomes):**

- After digestion the products are absorbed in to the cytoplasm.
- The undigested remains are left in the lysosome.
- It is called residual body.
- This moves to the surface and throws the contents by exocytosis.

4. **Autophagic vacuoles (Autophagosomes or cytolysosomes):**

- Complex lysosomes formed by union of many primary lysosomes around old/dead organelle/cell and digest them.
- The phenomenon is also called autophagy or autodigestion.
- Worn out aged or injured cells are also disposed of similarly (apoptosis).
- Hence lysosomes are also called disposal bags.
- Autophagic vacuoles provide nourishment during starvation.

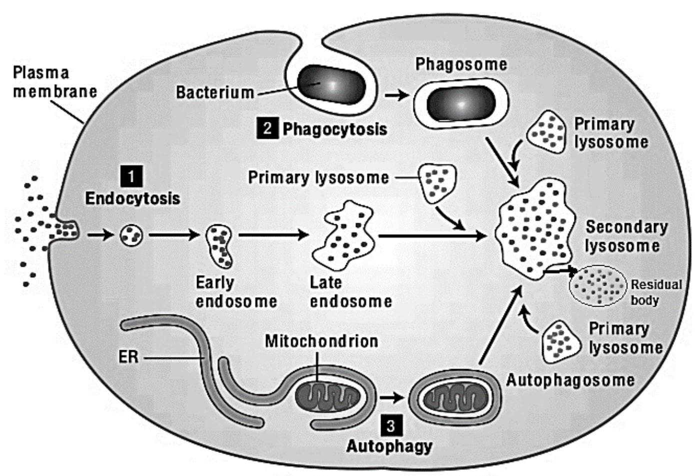


Fig. Types of Lysosomes and their function

Functions:

1. Intracellular Digestion and Extracellular Digestion
2. Body Defense (Heterophagy)
3. Autophagy
4. Mobilisation of Reserves
5. Autolysis

VACUOLES

They firstly described by **Spallangini**

- **The vacuole is the membrane-bound space found in the cytoplasm. It contains water, sap, excretory product and other materials not useful for the cell.**
- **The vacuole is bound by a single membrane called tonoplast.**
- **In plant cells the vacuoles can occupy up to 90 per cent of the volume of the cell.**
  In plants the tonoplast facilitates the transport of a number of ions and other materials against concentration gradients into the vacuole hence their concentration is significantly higher in the vacuole than in the cytoplasm.
  In Amoeba the contractile vacuole is important for excretion. In many cells as in protists, food vacuoles are formed by engulfing the food particles.

Types of vacuoles

Vacuoles are of four types.

1. **Food vacuoles:**

- In many cells, as in protists, food vacuoles are formed by engulfing the food particles.
- These vacuoles contain digestive enzymes.

2. **Gas vacuoles (Pseudovacuoles):** These are found in some prokaryotes like blue grean algae where they perform buoyancy regulation.

3. **Contractile vacuole:**

- It is found in some protists like **Amoeba, Paramecium and Chlamydomonas.**

- It expands to receive water this process is called diastole.
- When it contracts to expell water outside. It is called systole.
- It performs osmoregulation and **excretion**.
- Contractile vacuole is analogous organ to liver.

4. Sap vacuoles:

- It contains sap or water.
- In plants single large central vacuole is present whereas in animal cell several small vacuoles are found.
- Sap is non living content of cell.
- Sap contains sugar, amino acid, Tannin, esters, phenols, enzymes, calcium oxalate, organic acid - (acetic acid and fumeric acid), resin, gum, minerals (Ca, Mg, Mn, Na, K), pigments **(Anthocyanin, Anthoxanthin).**
- Sap also maintains osmotic pressure of cell.
- **pH of vacuolar cell sap is acidic and hypertonic**. Most common element and organic acid in sap vacuole are K^{+}, acetic acid.

Plastids:

- They are found in all plant cells and in Euglenoids.
- These are easily observed under the microscope as they are large.
- These are **double membrane bound**, DNA containing **largest** organelles in plant cells.
- **Origin:** All types of plastids have common origin from **proplastids** (sac like non-lamellar structures).
- They bear some specific pigments, thus imparting specific colours to the plants.

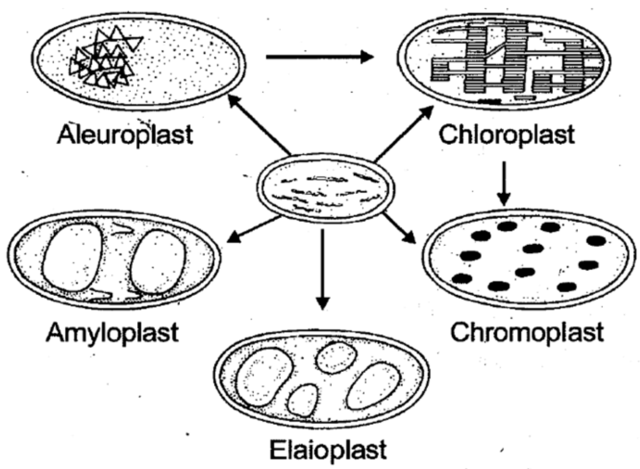
TYPES OF PLASTIDS

1. **Chromoplasts :-** In chromoplasts fat soluble carotenoid pigments like carotene, xanthophyllas and others are present. This gives yellow; orange or red colour to the part of the plant. Chlorophylls either absent or occur in very less amount. Chromoplasts occurs mainly in pericarp and petals. Red colour of tomatoes is due to the red pigment "Lycopene" of chromoplasts.

- Chromoplasts occur in petals but colour in petals is mainly due to water soluble pigments which are found in cell sap. eg. :- Anthocyanin

2. **Chloroplasts :-** The chloroplasts contain chlorophyll and carotenoid pigments which are responsible for trapping light energy essential for photosynthesis.
3. **Leucoplasts :-** The leucoplasts are the colourless plastids of varied shapes and sizes with stored nutrients: Amyloplasts store carbohydrates (starch). e.g. potato; elaioplasts store oils and fats whereas the aleuroplasts store proteins. Pigments and lamellar structure absents in Leucoplasts. Generally occurs in non green and underground plant cells.

- Different types of plastids may transform from one form to another. Because genetic meteral is similar.



Interconversion of plastids

Number, Shape & Size of chloroplasts :

- Majority of the chloroplasts of the green plants are found in the mesophyll cells of the leaves.
- Number varies from 1 per cell of the Chlamydomonas a green alga to 20-40 per cell in the mesophyll.
- These are lens-shaped, oval, spherical, discoid, or even ribbon shaped.
- Length and width are also variable.

  Length = 5-10 μm

  Width = 2-4 μm

Plant	Shape of chloroplasts
Chlamydomonas	Cup shaped
Ulothrix	Girdle shaped
Spirogyra	Spiral (Ribbon like)
Zygnaema	Stellate
Oedogonium	Reticulate
Higher plants	Discodial / oval / Lens / spherical

STRUCTURE OF CHLOROPLAST

Each chloroplast contains three parts

(i) Envelope **(ii) Stroma** **(iii) Lamellar system**

(i) Envelope

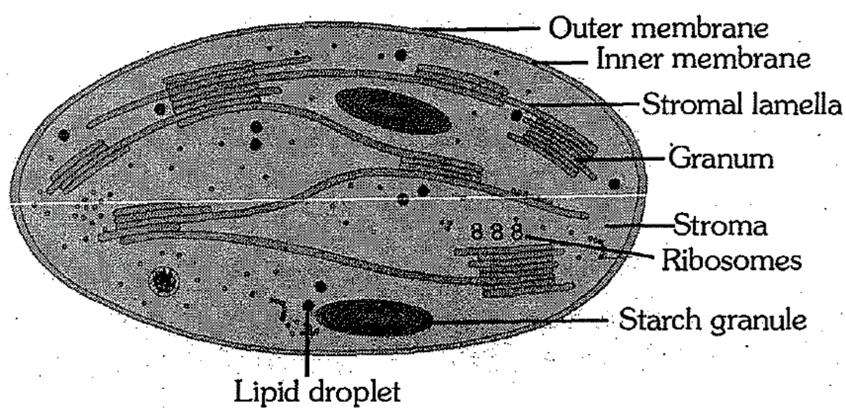
- It contains two lipoprotein unit membranes.
- The space between these two membranes is called intermembrane space or periplastidial space.
- Outer membranes freely permeable and whereas inner membrane is **selective permeable** or releatively less permeable.

(ii) Stroma (Matrix)

- The space limited by the inner membrane of the chloroplast is called the stroma.
- It is highly proteinaceous.
- The stroma of the chloroplast contains enzymes required for the synthesis of carbohydrates and proteins.
- It also contains small, doublestranded circular DNA molecules called **cp-DNA or plastidome.** and ribosomes.
- The ribosomes of the chloroplasts are smaller (70S) than the cytoplasmic ribosomes (80S). Chlorophyll pigments are present in the thylakoids.

(iii) Lamellar system:

- A number of organised flattened double membrane bound sacs called the thylakoids, are present in the stroma.
- Thylakoids (2-100) are arranged in stacks like the piles of coins called grana (singular: granum) or the intergranal thylakoids. Each chloroplast has 40–60 grana.
- Intergranal thylakoids: flat membranous tubules called the stroma lamellae or fret lamellae connecting the thylakoids of the different grana.
- The membrane of the thylakoids enclose a space called a lumen.
- **The granum is absent in the chloroplasts of algae and bundle sheath chloroplasts of C_4 plants. These chloroplasts are called Agranal chloroplasts.**
- Inner membrane of thylakoid contains **Quantasomes i.e. photosynthetic functional units**.
- Each of them consists of **230 chlorophyll molecules (160 chl a + 70 chl b) and about 50 carotenoid molecules.**



Chloroplast

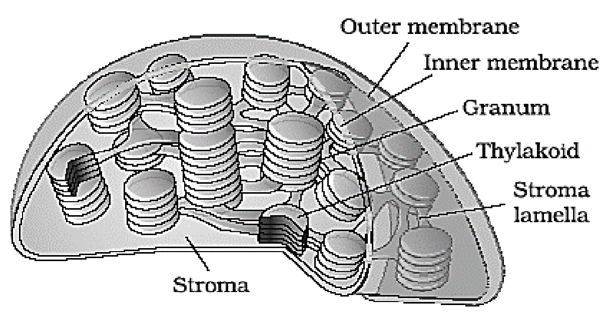


Fig.: Sectional View of Chloroplast

FUNCTION :-

Photosynthesis : The chloroplasts trap the light energy of sun and transform it into the chemical energy in the form glucose.

BIOGENESIS

(1) From Proplastid

(2) From binary fission of pre-existing plastids.

ORIGIN : Endosymbiotic origin by a cyanobacterium.

Mitochondria (Sing-mitochondrion):

- Mitochondria first observed in **striated flight muscles of insect** as granular structure by **Kolliker.**
- The term mitochondria used by **Benda.**
- Unless specifically stained, are not easily visible under the microscope.
- The number of mitochondria per cell is variable depending on the physiological activity of the cells.
- It is also called **power house of cell**.
- Number of mitochondria depends upon physiological activity of cell.
- One in Microasterias, Chlorella fusca (alga).
- All the mitochondria present in a cell are collectively called chondriome.
- Usually plant cells have fewer mitochondria as compared to animal cell.
- In higher animals maximum mitochondria are found in flight muscles of birds.
- Mitochondria are differ in size and shape and can make its shape sausage or cylindrical.
- Diameter 0.2–1.0 μm (average 0.5 μm), length 1.0–4.1 m.

Mitochondria is also named as –

- Power house of cell or ATP-mill in cell
- Cell within cell
- Most busy and active organelle in cell
- Semi autonomous cell organelle

- Endo-symbionts of cell

Origin:

- They have originated from the symbiosis of a prokaryotic organism (aerobic bacteria) with a host cell that was anaerobic and derived its energy only from glycolysis (Endosymbiotic hypothesis).

Shape and size:

- In terms of shape and size also, considerable degree of variability is observed.
- **Typically it is sausage-shaped or cylindrical.**
- **Diameter of mitochondria is 0.2-1.0 m (average 0.5 m) and length 1.0-4.1 m.**

Number:

- The number of mitochondria per cell is variable depending on the physiological activity of the cell.

Structure of mitochondria:

- Mitochondria is double membrane bound cell organelle.
- The two membranes are seperated by a broad space that is called **perimitochondrial space (Outer chamber)**.
- **Both the membranes have its own specific enzyme.**
- Inner membrane is folded to form **cristae (Palade)** that increase surface area.
  The two membranes have their own specific enzymes associated with mitochondrial functions.
- Enzymes like **succinate dehydrogenase, ATPase and cytochrome oxidase** are found in inner membrane of mitochondria.
- Mitochondria are rich in **Manganese (Mn).**
- Outer surface of inner membrane is called **C- face** whereas inner surface called **M-face**.

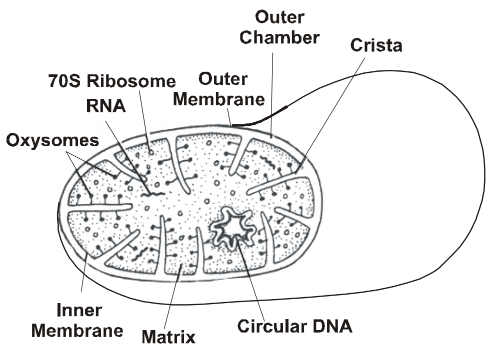


Fig:- Structure of mitochondrion

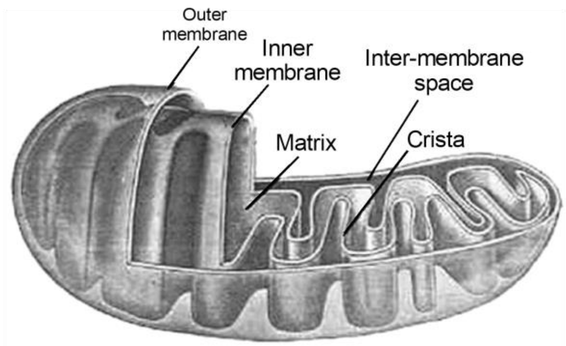


Fig : Structure of mitochondrion (Longitudinal section)

- The inner membrane and cristae bear electron transport chain and particles called **Oxysomes or Elementary particles, F_0–F_1 particles or ETP (Electron transport particles) or ATP synthase particles.**
- These are considered as **functional unit of mitochondria** and they are the site of **oxidative phosphorylation.**
- Head part of oxysomes contains **ATP synthase enzymes** for **oxidative phosphorylation.**

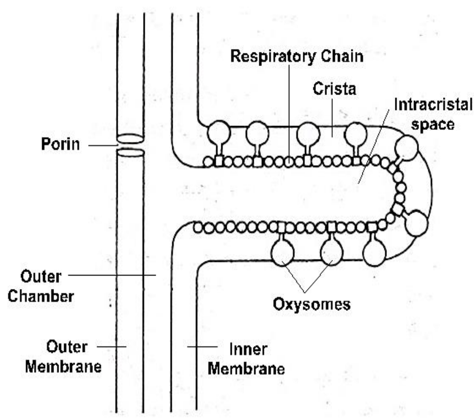


Fig. Inner membrane with oxysome

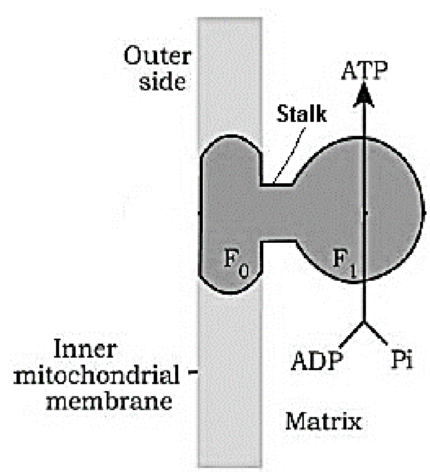


Fig. Diagramatic presentation of ATP synthesis in mitochondria

- The inner compartment is filled with a dense homogeneous substance called the matrix.
- The matrix also possesses single circular DNA molecule, a few RNA molecules, ribosomes (70S) and the components required for the synthesis of proteins.
- **Mitochondrion** is considered as **semi-autonomous cell organelle** due to **presence of DNA (rich in G–C ratio), RNA, 70S ribosomes and proteins synthesis systems.**
- **The mitochondria divide by fission.**

Functions of mitochondria

1. It is the site of aerobic respiration. Most of the ATP are produced by mitochondria during respiration. Thus mitochondrion is called **power house of cell**.
2. Enzymes of **krebs cycle, fattly acids synthesis, amino acids synthesis** are found in matrix.
3. Mitochondria help in **Vitellogenesis in oocytes**.
4. **Heme protein** required for **haemoglobin, cytochrome and myoglobin** is synthesized in mitochondria.
5. In bacteria the **Mesosomes** bear enzymes of aerobic respiration hence these are called **Chondrioid**. Thus **Mesosome and Mitochondria are analogous organelles.**
6. The **gene for male sterility in maize** plants is found in **mt DNA**. Thus it helps in **cytoplasmic inheritance.**

RIBOSOMES (ENGINE OF CELL)

- Ribosomes are the granular structures first observed under the electron microscope as dense particles by George Palade (1953). They are composed of ribonucleic acid (RNA) and proteins and are not surrounded by any membrane.
- Except mammalian RBC all living cells have ribosomes. (Both prokaryotes & Eukaryotes)
- Ribosomes are smallest cell organelles
- Ribosomes are also called as "Organelle within organelle" and "Protein factory of cell"

Types of Ribosomes :-

1. Eukaryotic ribosomes :- 80 S - Occur in cytoplasm of eukaryotic cells.
2. Prokaryotic ribosomes :- 70 S - Occur in cytoplasm and associated with plasma membrane of prokaryotic cell. Their size is 15 to 20 nanometer.

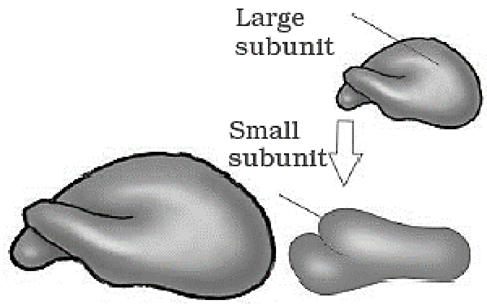


Fig. Ribosome

- 70 Sribosome also present in mitochondria and chloroplast of eukaryotes.
- Each ribosome composed of two subunits i.e. larger and smaller subunits.

  80 S = 60 S + 40 S

  70 S = 50 S + 30 S
- Magnesium ion is essential for the binding the ribosome sub units. Mg^{+2} form ionic bond with phosphate groups of r– RNA of two subunits. Minimum 0.001 M Mg^{+2} concentration is required for structural formation of ribosomes.

Chemical Composition of Ribosomes :

70 S	-	60% r-RNA + 40% proteins
80 S	-	40% r-RNA + 60% proteins
60 S	-	r-RNA 28 S, 5.8 S, 5 S
40 S	-	r-RNA 18 S
50 S	-	r-RNA 23 S, 5 S
30 S	-	r-RNA 16 S

- At the time of protein synthesis, several 70 S ribosomes become attached to m-RNA with the help of smaller subunits. This structure is called polyribosome or polysome or Ergosome. Larger subunit (50s) contains peptidyl transferase enzyme (23S rRNA) which helps in the formation of peptide bond during protein synthesis.

  This is an example of Ribozyme. (Noller 1992)

Functions

- Ribosomes are the sites of protein synthesis.
- Free ribosomes form structural and enzymatic proteins that are used inside the cell whereas attached ribosomes forms proteins for transport.

Note

1. **Cytoplasmic ribosomes:**

- In prokaryotes, they freely lie in cytoplasm and 70S type whereas in eukaryotes, they are freely attached to ER and nuclear membrane and 80S type.

2. **Organelle ribosomes:**

- These are found in organelle of eukaryotic cells like mitochondria, plastids, and nucleus.
- Size and density of the ribosomes depends upon sedimentation coefficient in the ultra-centrifuge. It is mesured in Svedberg units (S).

CYTOSKELETION

- An elaborate network of filamentous proteinaceous structures present in the cytoplasm is collectively referred to as the cytoskeleton. The cytoskeleton in a cell are involved in many functions such as mechanic motility, maintenance of the shape of the cell.

MICROTUBULES

- Microtubules are composed of protien, Tubulin [Size 25 nm.]
- In plants microtubules often found associated with cell wall. Probably these transport cell wall material from Golgi body to outside of cell. During cell division these microtubules form spindle fibers.

MICRO FILAMENTS

They are composed of contractile protien, Actin which concern with muscle contraction, Microtubules and microfilament are part of cytoskeleton-base of cell. [Size 6-7 nm]

INTERMEDIATE FILAMENT

Intermediate filaments has size/diameter in between microfilaments and microtubules. These filaments form basket like structure around the nucleus. [Size 8-12 nm]

Structure of Cilia and Flagella

- Structurally cilia or flagella is composed of four parts.
- Basal body
- Both the cilium and flagellum emerge from centriole-like structure called the basal bodies.
- It is also known as Blepharoplast, Basal granule or kinetosome.
- The arrangement of microtubules is 9 + 0 similar as centriole. It forms cilia and flagella.

A. Rootlets

- They originate from outer surface of basal part of cilia or flagella. Each of them consists of bundles of microfilaments.
- They provide mechanical support to the basal body.

B. Basal plate

- It lies between basal body and shaft. One subfibril is disappeared from peripheral triplet in this plate.
- Two central singlet fibrils originate from basal plate.

C. Shaft:

- It is elongated part composed of three parts.

1. Covering membrane (Extension of plasmalemma) **2. Matrix** **3. Axoneme**

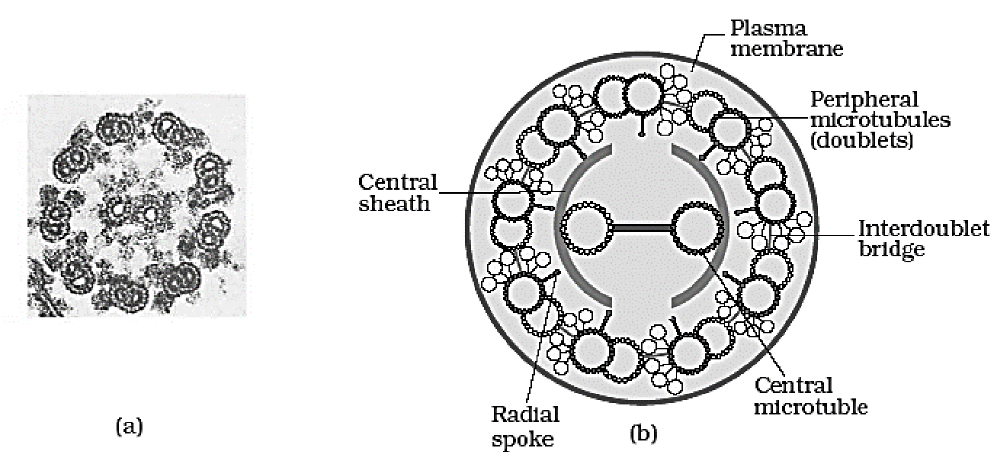


Fig. Section of cilia/flagella showing different parts: (a) Electron micrograph (b) Diagrammatic representation of internal structure

- Axoneme is the main part which possesses a number of microtubules running parallel to the long axis.
- **Nine peripheral doublet fibrils** are **tilted at 10º. Nine peripheral doublet fibrils and two central singlet fibrils** are composed of **tubulin protein.**
- Such an arrangement of axonemal microtubules is referred to as the **9+2** array.
- The central tubules are connected by bridges and is also enclosed by a central sheath, which is connected to one of the tubules of each peripheral doublets by a radial spoke. Thus, there are nine radial spokes.
- Each peripheral doublet fibril contain **subfibrial A and B.**
- A subfibril has two side arms or **lateral arms** composed of **dynein protein**. Out of them outer arm has hook. **Inner arm show ATPase activity**. It also generates force for the movement of cilia thus it is considered as locomotory motor for cilia.
- Two peripheral doublet fibrils are connected by **A–B linker** composed of **nexin protein.**
- A spoke originates from each subfibril A and grows towards central part.
- The tip of each spoke is swollen that is called head which is connected with central proteinaceous sheath by transitional junction.
- Cilia and flagella are different in number, length, distribution and function.

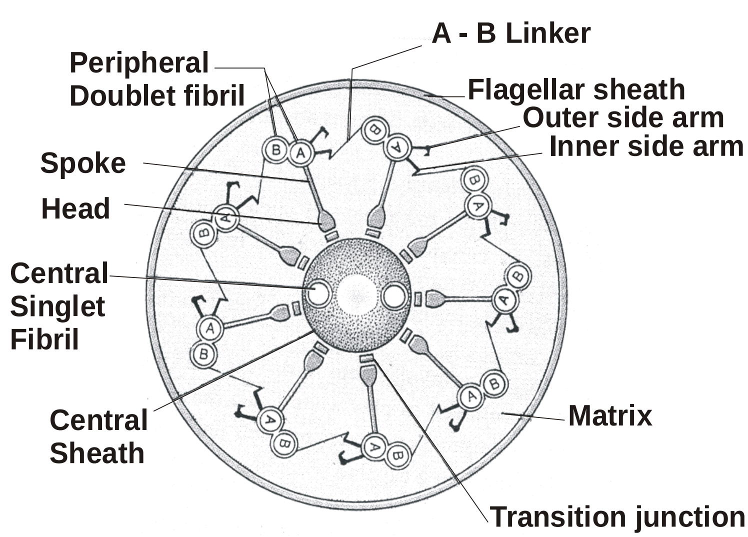


Fig :- Ultrastructure of flagellum in T.S.

Differences between Cilia and Flagella

Differences between Cilia and Flagella		
S.No.	**Cilia**	**Flagella**
1.	Only Eukaryotic cell has Cilia.	The prokaryotic bacteria also possess flagella but these are structurally different from that of the eukaryotic flagella.
1.	No of cilia is 3000–14000.	No. of Flagella is 1–4 .
2.	Length is 2–10 m.	Length is about 150 m.
3.	They are found at most of the part of organ/body.	It is present at one end of an organ/body.
	Cilia are small structures which work like oars, causing the movement of either the cell or the surrounding fluid.	Flagella are comparatively longer and responsible for cell movement.
4.	They beat in coordinate manner that is either synchronous (isochronous beat simultaneously) or matachronous (beat one after other).	They beat independently.
5.	They show pendular movement	They show undulatory motion.
6.	Cilia perform locomotion, aeration, Feeding, circulation.	Flagella perform Locomotion only.

Centrioles:

- **Centrosome is an organelle usually containing two cylindrical structures called centrioles.**
- They are membraneless structures.
- **They are surrounded by amorphous pericentriolar materials.**
- The clear cytoplasm **(Zone of exclusion)** around centriole is called **centrosphere or kinoplasm or cytocentrum.** Both centrioles are commonly called **Diplosomes.**

- Centriole does not bear intracellular compartment.
- Centrioles are usually found in all the animal cells except Amoeba.
- Centrioles are absent in higher plants. Although centriole is found in those plants that bear flagellate stage in the life cycle. **e.g. Many green algae, Bryophytes, pteridophytes, cycads.**
- **Both the centrioles in a centrosome lie perpendicular to each other in which each has an organisation like the cartwheel.**

Structure of centriole

- Each centriole is composed of 9 peripheral triplet fibrils of microtubules but in the central part these are absent. Thus centriole has **9 + 0** arrangement of tubules.
- The size of each peripheral triplet fibril is 25nm and It consists of three **subfibrils – C, B, A** from outside towards innerside.

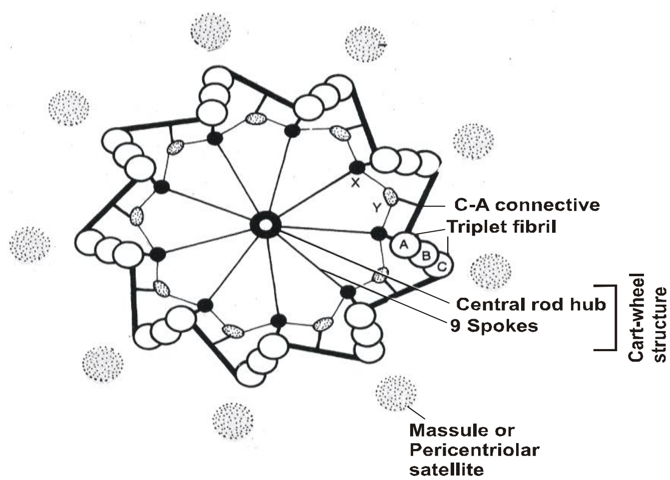


Fig :- Ultrastructure of centriole in T.S.

- A is spherical or tubular shaped whereas B and C are C–shaped. A consists of 13 protofilaments.
- A linker connects two peripheral triplet fibrils in such a way that A subfibril of a peripheral triplet fibril is connected with C sub fibril of adjacent peripheral triplet fibril. This linker is called **C– A linker**.
- In the central part a proteinecious **Hub** is present. Nine radial spokes arise from Hub.

- The main function of centriole is locomotion and the role of centriole in cell division is secondary function.
- Centriole is surrounded by amorphous structures called **massules or perecentriolar satellite.** Massules act as nucleating centre for the growth of microtubules during Aster formation. Occurs in **S-phase.**
- Thus **new centriole arises from pre-existing centriole in S phase (NEET-2021) without presence of DNA due to massules.**

Functions: The centrioles form

1. **The basal body of cilia or flagella**
2. **Spindle fibres that give rise to spindle apparatus during cell division in animal cells.**
3. Distal centriole of sperm synthesizes Axial filament of sperm.
4. Proximal centriole of sperm stimulate cleavage in fertilized egg after fertilization.

Micorobodies

- Many membrane bound minute vesicles called microbodies that contain various enzymes, are present in both plant and animal cells.
- These are smallest single membrane bounded organelles that participate in oxidation reactions other than those of respiration.

It is a following types–

1. Sphaerosomes (Oleosomes):

- They originate from SER.
- These are abundant in cotyledon and endosperm of oily seeds.
- The major function of sphaerosomes is synthesis and storage of fat.

2. Peroxisomes (uricosomes):

- They are found in both plant and animal cells.
- A photosynthetic cell contains 70–100 peroxisomes.
- They contains oxidative enzymes like urate oxidase, D-amino acid oxidase, -hydroxy acid oxidase and -hydroxy acid oxidase.

- **Catalase** performs detoxification of H_2O_2. In plants, peroxisomes are the site of **photorespiration**.
- Peroxisomes also take part in -oxidation of fat.

3. Glyoxysomes:

- These are largest microbodies.
- They were observed from endosperm of germinating castor bean seeds. These are common in Neurospora. Germinating oily seeds of castor, groundnut and cucumbers, Yeast.
- These are the sites of **β-oxidation of fat** and **Glyoxylate cycle** they are highly specialized peroxisomes.

4. Lomasomes:

- They lie between cell membrane and cell wall and were discovered in **fungi**.
- They help in cell proliferation and elongation for diffusion of substances required in cell wall formation.

Cytoskeletal structures

- **An elaborate network of filamentous proteinaceous structures present in the cytoplasm is collectively referred to as the cytoskeleton.**
- **The cytoskeleton in a cell are involved in many functions such as mechanical support, motility, maintenance of the shape of the cell.**
- In eukaryotic cell, these are of three types

1. **Microtubules**
2. **Microfilaments**
3. **Intermediate filaments**

Differences among Microtubules, microfilaments and intermediate filaments

Property	Microtubules (Tubulin Polymers)	Microfilaments (Actin filaments)	Intermediate filaments
Structure	Hollow tubes; wall consists of 13 columns of tubulin molecules	Two interwined strands of actin, each a polymer of actin subunits	Fibrous proteins supercoiled into thicker cables
Diameter	25 nm with 15 nm lumen	7 nm	8 - 12 nm
Protein subunits	□□ Tubulin, consisting of □□ tubulin and tubulin	Actin	One of several different proteins of the keratin family, depending on cell type.
Main functions	Maintenance of cell shape. Cell motility (as in cilia or flagella) Chromosome movements in cell division Organelle movements	Maintenance of cell shape Changes in cell shape Muscle contraction Cytoplasmic streaming Cell motility (as in pseudopodia) Cell division (cleavage furrow formation)	Maintenance of cell shape Anchorage of nucleus and ceratin other organelles Formation of nuclear lamina

NUCLEUS

INTRODUCTION :

- Nucleus as a cell organelle was first described by Robert Brown as early as 1831. Later the material of the nucleus stained by the basic dyes (Acefocarmine) was given the name chromatin by Flemming.

- "Nucleus is double membrane bound dense protoplasmic body, which controls all cellular metabolism and encloses the genetic information of cell".
- Nucleus is consider as controller or director of cell. Importance of nucleus in control of heredity, growth and metabolism was experimentally proved by Hammerling. (Experiment was on Acetabularia a single cell largest alga).
- Generally eukaryotic cell contain at least one nucleus but nucleus is absents in mature phloem sieve tube elements and mature RBCs of mammals.
- Dikaryotic (Paramoecium) and multikaryotic cells are also known.

Occurence:

- It is found in all eukaryotic cells except mature mammalian erythrocyte and in mature sieve tube of higher plant.
- In prokaryotic cell the nucleus is without distinct nuclear membrane that is called **nucleoid**.

Number:

- Usually single nucleus is found in a cell.
- **In Paramecium two nuclei are present.**
- Multinucleated condition is found in some organisms this condition is called **syncytium** (arises due to fusion of cells) **E.g. Ascaris** or **coenocytic** (due to repeated nuclear divisons without cytokinesis) **E.g. Vaucheria, Rhizopus**.

Shape and size:

The size of nucleus is 5μm – 25μm. The size of the nucleus depends on the volume of cell, amount of DNA protein and metabolic activity of cell.

STRUCTURE OF INTERPHASE NUCLEUS :

Interphase nucleus : Nucleus of cell when it is not dividing.

1. Nuclear membrane or karyotheca.
2. Nuclear matrix / Nucleoplasm / Karyolymph / Karyoplasm.
3. Chromatin net
4. Nucleolus / little nucleus / Ribosome factory

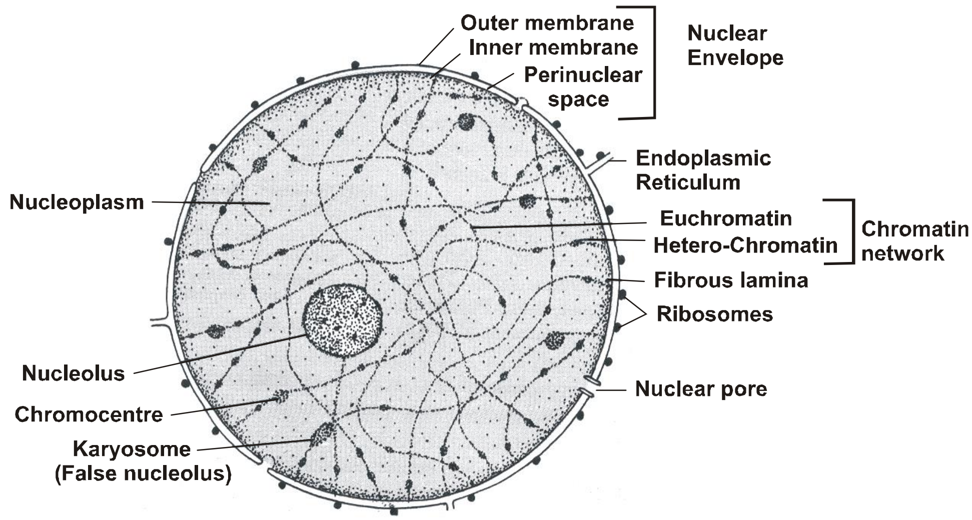


Fig:- Ultrastructure of interphase nucleus

1. **Nuclear membrane:**

- Electron microscopy has revealed that the nuclear envelope is consist of two parallel membranes.
- **The two membranes are seperated by a space of (10 to 50 nm) called the perinuclear space.**
- The perinuclear space forms a barrier between the materials present inside the nucleus and that of the cytoplasm.
- The outer membrane usually remains continuous with the endoplasmic reticulum and also bears ribosomes on it.
- At a number of places the nuclear envelope is interrupted by minute pores, which are formed by the fusion of its two membranes.
- These nuclear pores are the passages through which movement of RNA and protein molecules takes place in both directions between the nucleus and the cytoplasm.

2. **Nucleoplasm or Karyolymph :-**

- Nucleoplasm or Nuclear sap is a ground substance of nucleus, which is a complex colloidal formed of a number of chemicals like nucleotides, nucleosides, ATPs, proteins & enzymes.
- Chromatin net and nucleolus are components of nucleoplasm.

3. **Chromatin net :-** (Term given by Flemming)

- Interphase nudes has a loose and indistinct network of nucleoprotein fibers called chromatin, which embeded in nucleoplasm. Chromatin net is mainly formed of DNA and histone protein complexes.
- Chromatin fibres contain genetic information and condensed to form chromosomes during cell division.
- During different stages of cell division cells show structured chromosomes in place of nucleus.
- Chemically chromatin consists of DNA, RNA, Histone protein (basic proteins, rich in arginine and lysin) and non histone proteins.

Chromatin net has two type of chromatins :-

I. **Euchromatin :-** This is lightly stained and diffused part of chromatin. Which is transcriptionally or genetically more active.

II. **Heterochromatin :-** This is dark stained, thick and condensed part of chromatin. Heterochromatin is genetically less active or inactive chromatin.

(i) **Constitutive heterochromatin :-** Occurs in all cells in all stages e.g. centromeric region.

(ii) **Facultative heterochromatin:-** Occurs in some cells in some stages e.g. barr body in females.

4. **Nucleolus:** It was discovered by **Fontana.**

- The nucleoli are spherical structures present in the nucleoplasm.
- It is absent in RBC, sperm, Yeast, muscle fibres, young embryo cells and Procaryotes.
- It is largest part of nucleus (35%) and it is dense, DNA free subcellular structure and content of nucleolus is continuous with rest of the nucleoplasm is it is not membrane bound structure.
- Usually **1–4 nucleoli,** are found in a nucleus of diploid cell. At least one nucleolus is found. **1600 nucleoli** have been reported in the oocytes of **xenopus (An amphibian).**

Functions of Nucleolus

- **Nucleolus is a site for active ribosomal RNA synthesis. Larger and more numerous nucleoli are present in cells actively carrying out protein synthesis.**

Origin: Nucleolus is connected with **NOR (Nucleolar organizer Region)** of chromatin. **NOR** synthesizes nucleolus at the end of cell division.

Functions of Nucleus

1. It stores genetic information in its DNA molecules that can be passed on the daughter cells.
2. Nucleus controls all metabolic activites of the cell.
3. All variations are caused by changes in genetic material present in the nucleus.
4. It helps in cell differentiation by allowing certain particular sets of genes to operate.
5. It directs the synthesis of some structural proteins and chemicals required for cell growth and maintenance with the help of RNA.

CHROMOSOMES

GENERAL INTRODUCTION :

- At the time of cell division the chromatin material get condensed to form chromosomes, thus chromosome is highly condensed form of the chromatin. Chromosomes are not visible during interphase stage but during different stages of cell division, cells show structured chromosomes in place of the nucleus.
- Chromosomes can be best studied at metaphase stage because size of chromosomes is the shortest during metaphase (Shape of chromosome is studied at Anaphase stage)

Chromosome Numbers in Meiocytes (diploid, 2n) and

Gametes (haploid, n) of Some Organisms

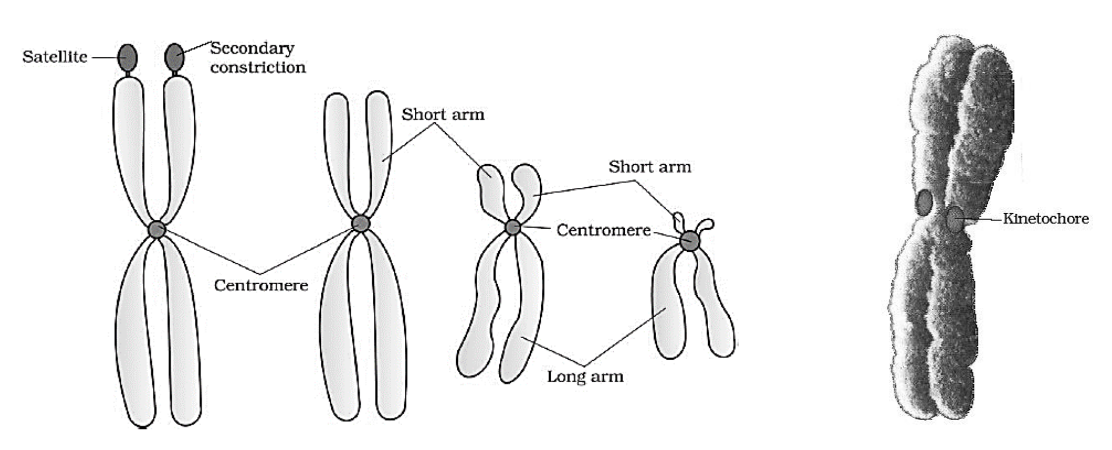
Name of organism	Charomosome number in meiocyte (2n)	Chromosome number in gamete (n)
Human beings	46	23
House fly	12	6
Rat	42	21
Dog	78	39
Cat	38	19
Fruit fly	8	4

Ophioglossum (a fern)	1260	630
Apple	34	17
Rice	24	12
Maize	20	10
Potato	48	24
Butterfly	380	190
Onion	16	8

- The number of chromosomes in a gamete is called "Genome" or "A complete set (n) of chromosomes inherited as a unit from one parent is known as genome.
- A single human cell has approximately two meter long thread of DNA distributed among its 46 (23 pairs) chromosomes.

- On the basis of position of the centromere, chromosomes are of following types.

1. **Metacentric:** Centromere is found in middle and at anaphase chromosome is **V-shaped.**
2. **Sub-metacentric:** The position of the centromere is subcentral. Anaphasic stage **L-shaped.**
3. **Acrocentric:** The position of the centromere is subterminal. Anaphasic stage **J-shaped.**
4. **Telocentric:** Centromere terminal, anaphasic stage is **I- shaped.**



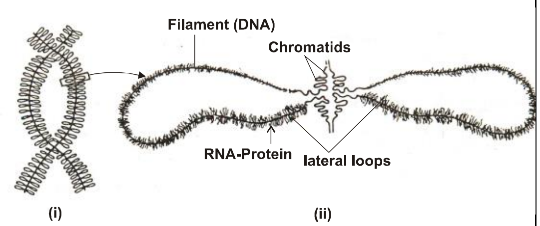
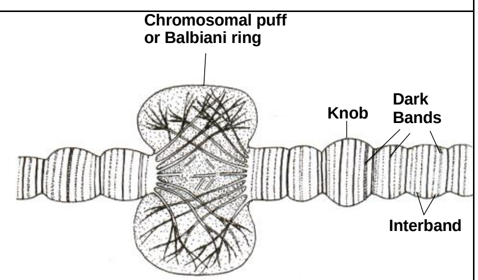
Ultrastructure of Chromosome:

Eukaryotic chromosome contains following parts

1. **Pellicle:** Outermost thin covering of chromosome.
2. **Matrix:** It consists of proteins, lipids and RNA in which chromonemata remain embedded.
3. **Chromonema:** There is two chromonemata when chromosome has two chromatids. Chromonemata is coiled structure.
4. **Centromere (Primary constriction):** Narrow non stainable area where two chromatids are joined.The surface has disc or **kinetochore** on either side for attachment of microtubules belonging to chromosomal fibre.
5. **Secondary constriction:** They are narrow areas of two types. **NOR and joints. NOR or nucleolar organiser region is secondary constriction-I** capable of forming **nucleolus in telophase. It is found on chromosome number 13, 14, 15, 21, 22. Joints or secondary constriction-II** are areas involved in breaking and fusion of chromosome segments.
6. Sometimes a few chromosomes have non-staining secondary constrictions at a constant location. This gives the appearance of a small fragment called the satellite.
7. **Satellite:** It is knob like part distal to NOR. The chromosome that bears satellite is called **SAT (Sine acid Thymonucleinico) chromosome.**
8. **Telomeres:** These are nonsticky terminal ends of chomosome or seal ends of chromosomes. They prevent the sticking of one chromosome with other. They are rich in guanine base. Telomerase enzyme is (required for replication of) this part of chromosome.

Special type of chromosomes

S.No.	Lampbrush chromosomes	Polytene chromosomes
1.	They firstly observed by **Flemming.**	They discovered by **Balbiani.**
2.	These are found in yolk rich **primary oocytes of Amphibians like Newt (Triturus), spermatocytes of many animals, giant nucleus of Acetabularia.**	They were observed in the cell of **salivary glands** of **Chironomus larva** of **Dipterian insect**. These are also found in **malpighian tubules,**

		endosperm, antipodal cells and salivary glands of Drosophila.
3.	They are found in **permanent diplotene stage of meiosis**.	They are found in **permanent prophase stage**.
4.	The size upto **5.9 mm (5900 m)**.	The size of polytene chromosomes is **2000 m.**
5.	<u>Special Characteristic:</u> The axis of lamp-brush chromosome is composed of **DNA** and **matrix of RNA and proteins Its lateral loops help in synthesis of RNA and yolk.**	<u>Special Characteristic:</u> They become **giant** due to **endomitosis or endoduplication**. **Large swellings** are found on some places of each strand that are called **puffs (Balbiani rings)**. In puffs DNA is uncoiled for rapid transcription of RNA.
	 Fig:- (i) Lampbrush chromosome (ii) One loop of a lampbrush chromosme	 Fig:- Structure of polytene chromosome

Karyotype:

- Chromosomes have some specific features

1. **Number of chromosomes**
2. **Relative size**
3. **Position of centromere**
4. **Length of arm**
5. **Secondary constriction**
6. **Satellites.**

- All such features by which a particular set of chromosomes (chromosomal complement) can be identified, is called **karyotype** of a species or it is chromosomal complement of organism providing description of various aspects of all the chormosomes like number, relative size, position of centromere, length of arms and centromeric ratio, secondary constriction and satellites.

Idiogram:

- A diagrammatic representation of karyotype of a species showing morphological chraracteristics of the chromosome is called idiogram.

IMPORTANT

- Virus is acellular and connecting link between living and non-living.
- Smallest cell– Mycoplasma laidlawii (PPLO) (0.1 -0.3 m)
- Largest unicellular eucaryotic cell - Acetabularia alga - (10cm).
- Longest animal cell –Human nerve cell (90cm).
- Longest plant cell –Ramie (Boehmaria)–55cm, jute fibre–30–90cm, hemp–1metre.
- Largest animal cell–Ostrich egg cell (170mm×150mm)
- Small cell has higher surface volume ratio than the larger cell.
- Number of different materials may be deposited in the wall.
  - **Lignin:** It is formed by polymerisation and dehydrogenation of aldehydes and alcohols of coniferyl and coumaryl. It reduces the water content of the wall matrix and increases its hardness. The deposition of lignin on the cell wall is called **lignification** that provides strengthening to the cell wall.
  - **Suberin: It is fatty substance that makes the wall impermeable. It reduces the transpiration rate in plants. It is found in the cork and casparian strips of endodermal cells. The deposition of suberin is called suberisation.**
  - **Cutin:** It lies as a distinct layer on the outside of the epidermal cell wall. It is fatty substance that reduces the rate or epidermal or surface transpiration. Other substances may also be deposited in the cell wall such as silica **(E.g. grasses)**, minerals waxes, tannins, resins, gums.
- Spectrin, a helical extrinsic protein used to attach with intrinsic protein at the inner side of membrane and make cytoskeleton with microtubule and microfilament
- Porins the intrinsic protein found in the outer mitochondrial and bactrial membrane
- Permease, translocase etc. act as carriers for the transport of materials.

- Through ESR (electro spin resonance), it is revealed that **flip-flop mechanism is absent in protein molucules**
- Other than phospholipids the cell membranes have cholesterol, cerebrosides, gangliosides and sphingomyelins.
- Gas vacuoles protect the cell from UV radiation.
- Anthocyanin is water soluble pigment. It provides colour to the petals of flowers (Blue, Purple or violet, Black and Pink colour).
- The Na^+ ions of sap vacuole maintain turger pressure.
- K^+ are abundantly present is sap of sap vacuole.
- **Chaperons:** These are specific proteins that help in folding and transport of proteins into organelles and are synthesized on ribosomes.
- Cilia or flagella are absent in Red algae, Blue green algae or cyanobacteria, Angiosperms, Pinus, Arthropods.
- Cilia or flagella performs power stroke and recovery stroke for locomation .
- Flagella are either whiplash type (smooth surface) or Tinsel type (hairy surface). The microscopic hairs are called flimmers
- Chemically nucleolus contains 10% rRNA, 5% DNA and 85% non-histone proteins.
- It is believed that **Ca^{++} ions** are responsible for the maintenance of organisation of nucleolus.
- The **structural and functional unit of chromatin** is **nucleosome**.
- Chemical composition of chromosome

  DNA–40%, Histone –50%, Non-histone proteins–8.5%, RNA–1.5%, trace amount of Ca^{++}, Fe^{++}, Mg^{++}, lipids. Acentric chromosome : Chromosome without centromere.
- **In human chromosomes are metacentric, submetacentric and Acrocentric. But telocentric chromosome are absent.**
- Nucleus is largest extra cytoplasmic inclusion.
- Fluidity of cell membrane is due to non-polar ends of phospholipids.
- **Protoplast:** It includes all the living constituents of the protoplasm. Naked cell without cell wall is also called protoplast.

- **Calmodulin:** Calcium protein complex often associated with microtubules and microfilaments, taking part in motility and regulation of certain enzyme systems.
- Cells of WBC, skin cell, oral mucosa are taken for Karyotyping.