Chapter 03

Cell: The Unit of Life

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- **Introduction**
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- **An overview of cell**
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INTRODUCTION:

- All organisms are composed of cells. Some are composed of a single cell and are called unicellular organisms while others, like us, composed of many cells, are called multicellular organisms.
- Unicellular organisms are capable of
  (i) independent existence
  (ii) performing the essential functions of life.
- Anything less than a complete structure of a cell does not ensure independent living.Hence, cell is the fundamental structural and functional unit of all living organisms.

Robert Hooke
Discovery Of
First Cell
(1665)

A.V. Leeuwenhoek
First Living Cell
(1674)

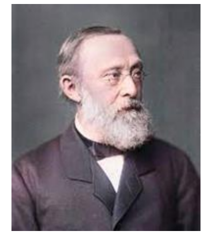
Robert Brown
Discovered Nucleus
(1831)

The invention of the microscope and its improvement leading to the electron microscope revealed all the structural details of the cell.

CELL THEORY:

- In 1838, **Matthias Schleiden,** a German botanist, examined a large number of plants and observed that all plants are composed of different kinds of cells which form the tissues of the plant.
- At about the same time, **Theodore Schwann**(1839), a British zoologist, studied different types of animal cells and reported that cells had a thin outer layer which is today known as the **'plasma membrane'**. He also concluded, based on his studies on plant tissues, that the presence of cell wall is a unique character of the plant cells.
- **Schwann** proposed the hypothesis that the bodies of animals and plants are composed of cells and products of cells.

- **Schleiden** and **Schwann** together formulated the cell theory. This theory however, did not explain as to how new cells were formed.
- **Rudolf Virchow** (1855) first explained that cells divided and new cells are formed from pre-existing cells **(Omnis cellula-e cellula).** He modified the hypothesis of **Schleiden** and **Schwann** to give the cell theory a final shape.
- **Cell theory as understood today is:**
  (i)All living organisms are composed of cells and products of cells.
  (ii)All cells arise from pre-existing cells.



Rudolf Virchow
Omnis cellula-e cellula

Unicellular organism	Multicellular organism
➢ Single celled organisms. ➢ A single cell can act as complete organism. ➢ They have ability to divide/reproduce hence they are immortal. ➢ There is no differentiation & division of labour. **Eg: *Ameoba***	➢ These are the organisms made up of many cells. ➢ In them cells organize & grouped into tissues, tissues forms organ, organ system & finally organism. **Eg: Higher Plants and Animals**

AN OVERVIEW OF CELL:

- A typical plant cell, has a distinct cell wall as its outer boundary and just within it is the cell membrane.
- Cells that have membrane bound nuclei are called eukaryotic whereas cells that lack a membrane bound nucleus are prokaryotic.
- In both prokaryotic and eukaryotic cells, a semi-fluid matrix called cytoplasm occupies the volume of the cell.
- The **cytoplasm** is the main **arena** of cellular activities in both the plant and animal cells. Various chemical reactions occur in it to keep the cell in the **'living state'**.
- Besides the nucleus, the eukaryotic cells have **other membrane bound distinct structures called organelles like the endoplasmic reticulum (ER), the Golgi complex, lysosomes, mitochondria, microbodies.**
- **The prokaryotic cells lack such membrane bound organelles.**
- **Ribosomes are non-membrane bound organelles found in all cells – both eukaryotic as well as prokaryotic cell.** Within the cell, ribosomes are found not only in the cytoplasm but also within the two organelles – chloroplasts (in plants) and mitochondria and on rough ER.
- **Animals cell also contain a non-membrane bound cell organelle called centrosome which helps in cell division.**

SIZE AND SHAPE OF CELL

Size:

- Cells differ greatly in size, shape and activities.
- *Mycoplasma* (Smallest cells): **Only 0.3 μm in length [PPLO (pleuro pneumonia like organisms) is a type of *Mycoplasma* having the size about 0.1 μm)]**
- Bacteria = 3 to 5 μm
- **Largest isolated single cell = egg of an ostrich.**
- **Human red blood cell = 7.0 μm in diameter**
- Nerve cell = One of the longest cell

Shape:

- The shape of the cell may vary with the function they perform.
- They may be disc-like, polygonal, columnar, cuboid, thread like or even irregular.

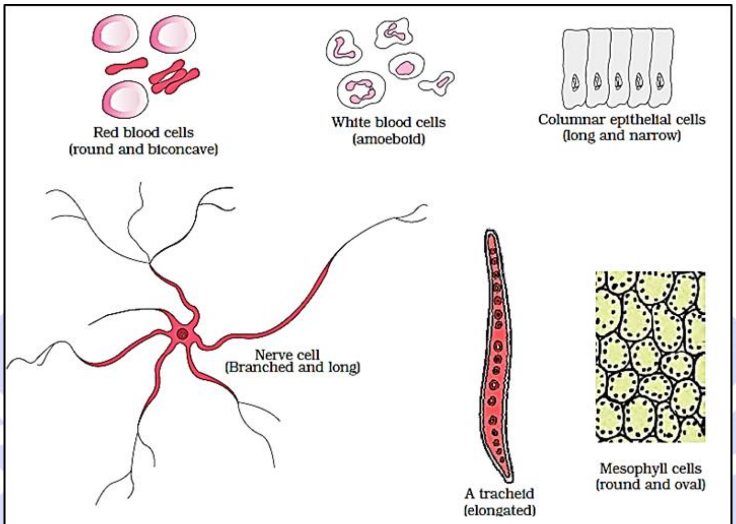


Diagram showing different shapes of the cells

PROKARYOTIC CELLS:

- These are the cells having primitive type of nucleus i.e**. well defined & membrane bound nucleus is absent.**
- **They do not have membrane bound cell organelle.**
- The prokaryotic cells are represented by **bacteria, blue-green algae, *Mycoplasma* or PPLO (Pleuro pneumonia like organisms).** They are generally **smaller in size and multiply much faster than the eukaryotic cells.** They may vary greatly in shape and size but exhibit a similar basic cellular organisation.

STRUCTURE OF PROKARYOTIC CELL :

- The organisation of the prokaryotic cell is fundamentally similar even though prokaryotes exhibit a wide variety of shapes and functions. Most prokaryotes have a cell wall surrounding the cell membrane. The fluid matrix filling the cell is the cytoplasm. There is not well-defined nucleus.

1. **Nucleoid :**
   - **The genetic material is basically naked DNA, not enveloped by a nuclear membrane.**
2. **Plasmid :**

   In addition to the genomic DNA (the single chromosome/circular DNA) **many bacteria have small circular DNA outside the genomic DNA. These smaller DNA are called plasmids.**
   - **The plasmid DNA confers certain unique phenotypic characters to such bacteria. One such character is resistance to antibiotic. The plasmid DNA is used to monitor bacterial transformation with foreign DNA.**

3. Cell Envelopes:

The cell envelope consists of a tightly bound three-layered structure i.e., **the outer most glycocalyx followed by the cell wall and the plasma membrane.**

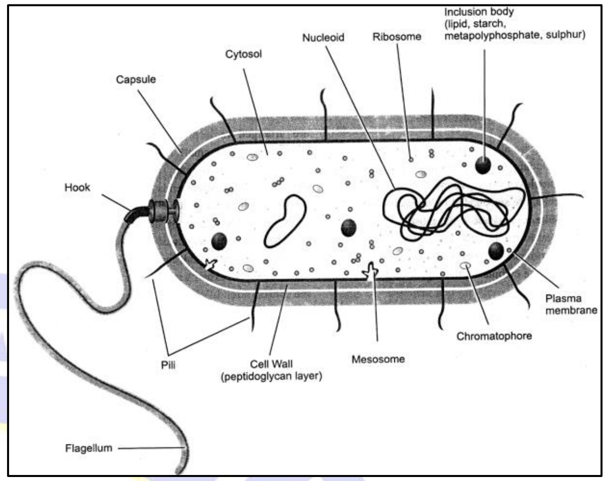


Fig: Structure of a Prokaryotic cell

(A) Glycocalyx is the outermost layer comprising a coating of mucous or polysaccharides macromolecules,

It is of two types on the basis of thickness & rigidity.

(i) Slime layer:-

a. Thin, slimy & sticky layer.

b. Mainly helps in attachment of a cell to any substratum.

(ii) Capsule:-

a. Thick, hard, rigid, protective covering.

b. Capsule provide protection against injuries, viral infection, antibiotics etc.

Glycocalyx
- Slime Layer(Elastic)
- Capsule (Rigid)

(B) Cell wall:-

(i) The **cell wall** determines the shape of the cell and provides a strong structural support to prevent the bacterium from bursting or collapsing. This layer is rigid due to a special macromolecule called **peptidoglycan** (murein or mucopeptide).

(ii) Bacteria can be classified into 2 groups on the basis of manner in which they respond to staining procedure developed by Gram viz.

(1) Gram Positive	**(2) Gram Negative**
Takes up gram stain	Do not take up gram stain

(C) Plasma membrane

(i) Most important cell envelope, inner most living layer.

(ii) **The plasma membrane** is selective permeable in nature and interacts with the outside world.

(iii) **Cell membrane of prokaryotic cell is very similar to eukaryotic cell in structure & function.**

(iv) A special membranous structure is the **mesosome** which is formed by the invagination of plasma membrane into the cell **(They are essentially infoldings of cell membrane)**. These extensions are in the form of **vesicles, tubules and lamellae.** They help in the **cell wall formation, DNA replication and distribution to daughter cells.** They also help in respiration, secretion process, to increase the surface area of the plasma membrane and enzymatic content.

(v) **Mesosome is more prominent in gram positive bacteria.** In some photosynthetic prokaryotes like cyanobacteria, and purple bacteria, there are other membranous extensions into the cytoplasm called **chromatophores which contain pigments. (NEET 2013)**

4. Flagella:-

(i) **Bacterial cells maybe motile or none motile. If motile, they have thin filamentous extensions from the cell wall called flagella.**

(ii) It is a proteinaceous structure made up of **flagellin protein**.

(iii) Flagella helps in locomotion & movement of cell.

Structure of Flagella:-

Flagella consist of three parts-

(a) Basal body:-

Found embedded in cell wall & cell membrane and made up of four rings [L, P, S, M rings]

(b) Hook:-

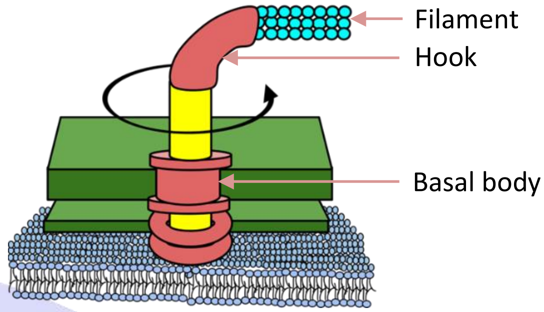
Joints basal body & filament.

(c) Filament:-

(i) Longest, Hollow, tubular structure made up of flagellin protein units.

(ii) Basal body is a rod-like structure which consists of rings.

(iii) **Besides flagella, pili and fimbriae are also surface structures of the bacteria but do not play a role in motility. (NEET 2016)**



Prokaryotic flagellum

5. Pili:-

(i) Very rare, small, non-motile, hollow, tubular structure present on surface of bacteria.

(ii) May be present or absent.

(iii) It has no role in locomotion, it helps in conjugation, act as conjugation tube & makes communication with other bacteria.

(iv) Normally only one pili act as conjugation tube & known as sex pili.

(v) Pili is made up of pilin protein.

6. Fimbrae:-

(i) Minute, thin, bristle like non-motile structure, several in no. & present on entire surface of cell.

(ii) They are known to help attached the bacteria to rocks and streams and also to the host tissues. (AIPMT-2015, NEET-2016)

7. Ribosomes :

(i) In prokaryotes, ribosomes are associated with the plasma membrane of the cell.

(ii) They are about 15 nm by 20 nm in size and are made up of two subunits – 50'S and 30'S units which when present together form 70S prokaryotic ribosomes.

(iii) Ribosomes are the site of protein synthesis. Cytoplasmic ribosomes synthesise proteins, which remain within cells but the ribosomes on the plasma membrane make proteins that are transported out. **Several ribosomes may attach to a single mRNA and form a chain called polyribosomes** or **polysome. (NEET-2016,2017,2018)**

(iv) The ribosomes of a polysome translate the mRNA into proteins.

(v) No organelles, like the ones in eukaryotic cell except for ribosomes are present in prokaryotic cell.

8. Inclusion bodies:

(i) Reserve material in prokaryotic cells are stored in the cytoplasm in the form of inclusion bodies. (NEET-2017)

(ii) These are not bounded by any membrane system and lie free in the cytoplasm, e.g., phosphate granules, cyanophycean granules and glycogen granules.

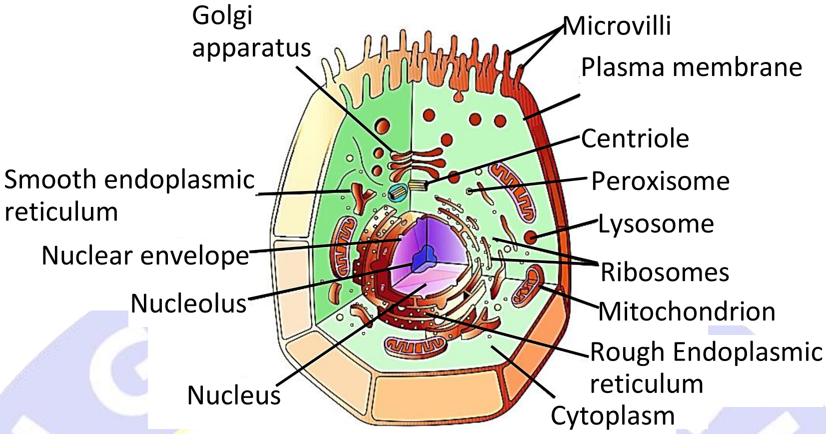
(iii) Some other inclusion bodies may be surrounded by a single layer non-unit membrane, which is 2-4 nm thick.

(iv) Gas vacuoles are found in blue-green algae, purple and green Sulphur photosynthetic bacteria.

EUKARYOTIC CELLS:

- [Eu→ True, karyon→ Nucleus]
- **Cell with true nucleus**.

- **Most advance and complex type of cell, which have a well defined membrane bound nucleus and single/ double membrane bound many cell organelles**.

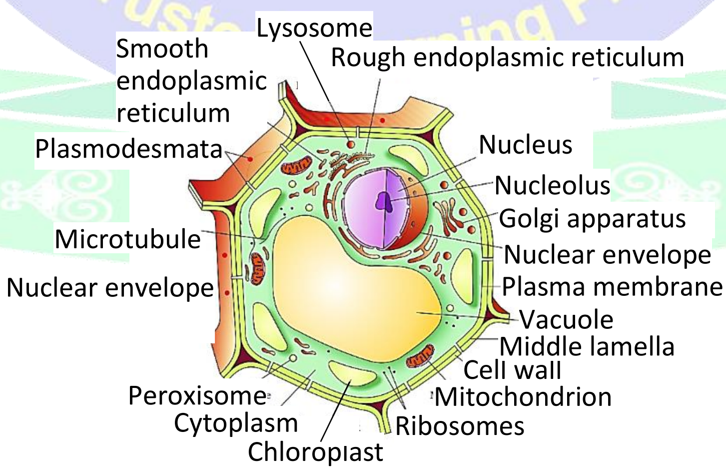


Animal cell

- 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.**
- 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 higher plant cells.**

CELL WALL

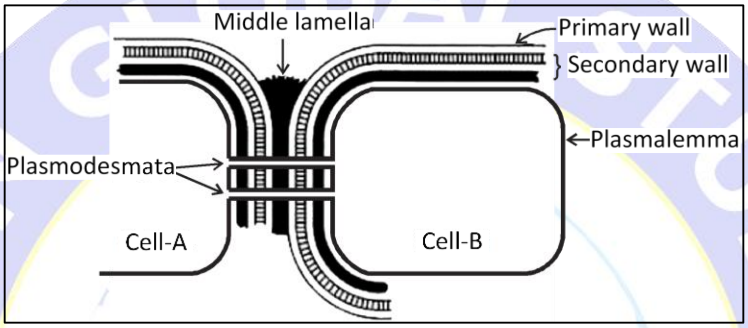
- A non-living rigid structure called the cell wall forms an outer covering for **the plasma membrane of Bacteria Fungi, Algae and Plants and absent in all animal cells.**
- **Cell wall not only gives shape to the cell and protects the cell from mechanical damage and infection, it also helps in cell-to-cell interaction and provides barrier to undesirable macromolecules.**
- **Algae have cell wall, made of cellulose, galactans, mannans and minerals like calcium carbonate.**
- In other plants it consists of cellulose, hemicellulose, pectins and proteins.
- Bacterial cell wall mainly composed of Peptidoglycans [Polymer of NAG(N-acetyle glucosamine) and NAG (N-acetylemuramic acid) + peptides].



Plant cell

- **The cell wall of Fungi is composed of Chitin and Polysaccharides.**

Cell wall
- **Primary wall:** Outermost layer, thin elastic, diminishes as cell matures, capable of growth, composed of cellulose, hemicellulose & pectin.
- **Secondary Wall:** Rigid, thick & composed of cellulose, hemi–cellulose, Pectin. **(S_1, S_2, S_3)** (absent in meristem cells) **inner side of cell (toward CM)**
- **Tertiary wall:** Present only in tracheid of Gymnosperm. Composed of hemi cellulose &xylem .



- **The middle lamella is a layer mainly of calcium pectate which holds or glues the different neighbouring cells together. The cell wall and middle lamellae may be traversed by plasmodesmata which connect the cytoplasm of neighbouring cells.**

DETECTIVE MIND

- **Formation of cell wall occurs by two methods:**
  (1) Intussusception: This is a deposition of wall material in the form of fine grains.
  (2) Apposition: Deposition of layers.
- Primary wall is formed mainly by intussusception, while secondary wall formed by both methods. Growth of already formed cell wall occurs by only intussusception.

	Primary wall		Secondary wall
(1)	Cellulose microfibrils are arranged in a dispersed manner.	(1)	Microfibrils are parallel to long axis of cell.
(2)	Hemicellulose more (50%)	(2)	Hemicellulose less (25%)
(3)	Primary wall has lipids (5-10%) and proteins (5%)	(3)	Proteins and lipids either absent or in little amount.
(4)	Form by Intussusception	(4)	By both methods.
(5)	Primary wall is universal layer	(5)	Absent in meristem cells

- A special protein called **expansin** helps in growth of cell wall by loosening the cellulose microfibril and addition of new cell wall material takes place in the space. Thus expansin is called as "cell wall loosening factor".

CELL–MEMBRANE

- All the living cells are covered by a thin, delicate, elastic, **selectively–permeable** and **living boundary,** which is called as – **cell membrane** or **plasmalemma** or **bio membrane** or **plasma membrane.**
- Biochemical investigation clearly revealed that the cell membranes possess lipid, protein and carbohydrate. The ratio of protein and lipid varies considerably in different cell types. In human beings, **the membrane of the erythrocyte has approximately 52 percent protein and 40 percent lipids**
- Lipids = 40% (Phospholipid, Cholesterol, Glycolipids)
- Proteins = 58-59% (Arginine, Lysine rich)
- Carbohydrates = 1-2%

Structure of Cell–Membrane:

Fluid mosaic model: By **Singer** &**Nicolson** (1972)

- This is **latest & most widely accepted** model for the structure of plasmalemma.
- According to fluid mosaic model, proteins are arranged in phospholipid layer as mosaic pattern.
- Thus membrane is termed as **"protein iceberg in a sea of lipid".**

(1) Phospholipids:

- Phospholipid is the **main component of cell membrane** because it forms continuous structural frame of cell membrane.
- The studies showed that the cell membrane is composed of lipids that are arranged in a bilayer. Also, the lipids are arranged within the membrane with the polar head towards the outer sides and the hydrophobic tails towards the inner part. This ensures **that the nonpolar tail of saturated hydrocarbons is protected from the aqueous environment.** The lipid component of the membrane mainly consists of phosphoglycerides (Phospholipids).
- Phospholipid layer provides fluidity to plasma membrane because phospholipids are rich in unsaturated fatty acid which are liquid in nature.
- **The Quasifluid nature of lipid enable lateral movement of protein with in the overall bilayer.** This ability to move within the membrane is measured as its, **fluidity.**
- **The fluid nature of the membrane** is also important in various function like **cell growth, formation of intercellular junction, secretion, endocytosis, cell division etc.**

DETECTIVE MIND

- **Cholesterol** is also present in plasma membrane. Cholesterol are more rigid than phospholipid. So it helps in **stability of membrane structure.**
- **Cholesterol is absent in membrane of prokaryote.** Thus **Hopanoids** (Pentacyclic sterol) provides stability to prokaryotic cell membrane.

(2) Proteins:

- Two types of proteins are present in plasma membrane. (On the basis of ease of extraction)

(a) Integral or intrinsic proteins

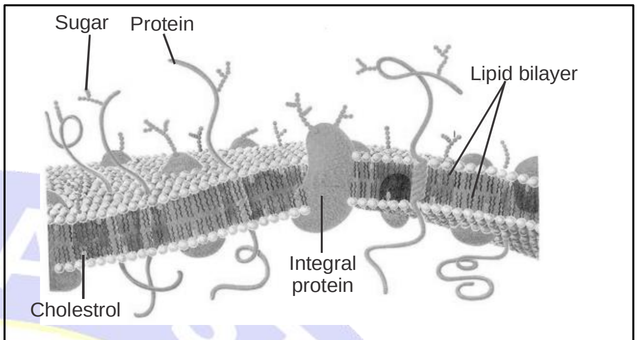
- These proteins tightly bind with phospholipid. Thus, they can not easily remove from membrane.
- Integral proteins are of 2 types:

  (i) Partially buried (ii) Totally buried
- Some integral proteins which are totally buried through the complete thickness of membrane. These types of protein are called as **tunnel (channel) protein** which provide a passage for movement of water-soluble material across the membrane.

(b) Peripheral or extrinsic proteins

- These are superficially arranged on outer side and can be separate easily. These proteins have enzymatic activity.

- However, phospholipid bilayer has fluid property. Sometime shows **flip flop movement** (**Flip Flop means** exchange of molecules from one monolayer with those in the monolayer on the other side) but no evidence of **flip flop mechanism** for protein molecule
- Rotational diffusion and lateral diffusion of protein and lipids are possible in membrane.
- Oligosaccharides of the **glycolipids & glycoproteins** on the outer surface of plasma membranes are involved in cell to cell recognition mechanism. Best example of cell recognition is **fertilization**, (where sperm & egg recognize to each other) and **blood - Antigens.**
- Plasma membrane have approximately 30 types of enzymes in which ATPase (ATP hydrolysing) is more important. ATPase enzyme helps in active transport of materials.



Fluid mosaic model of plasma membrane

DETECTIVE MIND

- **Spectrin** are helical type of extrinsic protein found on cytosolic face (towards cytoplasm) of membrane and attached to intrinsic protein. Spectrins are part of cytoskeleton.
- Plasma membrane is an **asymmetrical structure** because carbohydrates are present only on outer surface.

Transport through plasma membrane:

- One of the most important functions of the plasma membrane is the transport of the molecules across it. The membrane is selectively permeable to some molecules present on either side of it. Many molecules can move briefly across the membrane without any requirement of energy and this is called the **passive transport.**
- **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. Water may also move across this membrane from higher to lower concentration. Movement of water by diffusion is called osmosis.**
- **As 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.**
- **A few 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.**

DETECTIVE MIND

Bulk transport:

A. **Endocytosis:** It involves intake of materials in the form of carrier vesicles formed by invagination of small regions of plasma membrane. Endocytosis of two types:

(a) **Pinocytosis:** In take of liquid substance from outside, It is also called **cell drinking process**. Globules of fluid materials are called **pinosomes** which are pinched off from the plasma membrane inside the cytoplasm in the form of **small pinocytic vesicles**.

(b) **Phagocytosis:**It is bulk intake of large sized solid particles by the cell using the plasma membrane. It is also called **cell eating process**. It is pinched off from the plasma membrane inside the cytoplasm in the form of food vacuole or phagocytic vesicle. This will further be digested by lysosomes.

B. **Exocytosis/Emiocytosis/Cell vomiting /Ephagy:** Egestion of **waste materials** from cell through plasma membrane.

CYTOPLASM

- **Term "Cytoplasm"**,was given by ***Strasburger*** for the part of cell, present between the nucleus and cell membrane. Cytoplasm can be divided into two parts.
- **Ground plasm** / **Hyaloplasm** / **Cytosol**→ Liquid matrix of cytoplasm except organelles.
- **Trophoplasm**→ Part of cytoplasm containing organelles &non living Inclusions.

CELL ORGANELLES

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

ENDOMEMBRANE SYSTEM

- 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 endomembrane system **includes 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 (NEET 2023)**.

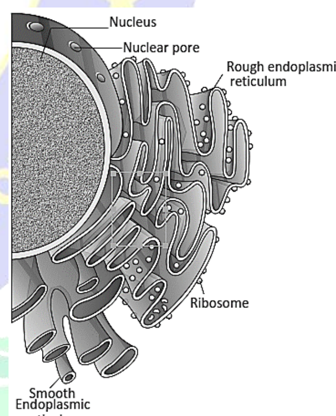


Fig. : Endoplasmic reticulum

ENDOPLASMIC RETICULUM

- Electron microscopic studies of eukaryotic cells reveal the presence of a network of reticulum of tiny tubular structures scattered in the cytoplasm that is called the endoplasmic reticulum (ER).
- Usually present in almost all eukaryotic cells, but absent in Prokaryotic cells, some eukaryotic cells like RBC.

  Components of ER:

  (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.

- Structure of ER is like the Golgi body but in ER cisternae, vesicles and tubules are isolated in cytoplasm and these do not form complex.
- Golgi body is localised cell organelle while ER is widespread in cytoplasm. ER is often termed as "**System of Membranes**".

- **ER divide the intracellular space into two distinct compartments i.e. Luminal (inside ER) and extra luminal (cytoplasm) compartments.**
- On the basis of structure and function ER is of two types.

Rough ER(Granular)	Smooth ER(Agranular)
It has rough surface due to the presence of ribosome.	It have smooth surface due to the absence of ribosomes.
80s ribosomes bind by their larger subunit, with the help of two glycoproteins (**Ribophorin I** and **II** On the surface of Rough ER)	Ribosomes and Ribophorins are absent
More stable structure	Less stable structure
Mainly composed of cisternae and vesicles	Mainly composed of tubules.
Abundantly occurs in cells which are actively engaged **in protein synthesis metabolism** and **secretion**. **e.g.** liver, pancreas, goblet cells.	Abundantly occurs in cells concerned with **glycogen** and **lipid** synthesis. **In animal cell lipid like steroidal hormones are synthesied in SER. e.g.** Adipose tissue, Interstitial cells, muscles, Glycogen storing liver cells, and adrenal cortex.

DETECTIVE MIND

Modifications of ER:

(1) Sarcoplasmic Reticulum (SR): These smooth ER occur in skeletal and cardiac muscles. SR Stores Ca^{+2} and energy rich compounds required for muscle contraction.

(2) Ergastoplasm: When the ribosomes are accumulated on the small parallel cisternae of ER, then called **Ergastoplasm**. Ergastoplasm of nerve cells is called as ***Nissl's bodies***.

(3) Microsomes: These are pieces of ER with associated ribosomal particles. These can be obtained by fragmentation and high speed centrifugation of cell. They do not exist as such in the living cell. Scientist used microsome for invitro protein synthesis study.

DETECTIVE MIND

Functions of ER:

(1) Mechanical support: Microfilaments, Microtubules and ER form **endoskeleton** of cell.

(2) Intracellular exchange: ER forms intracellular conducting system. Transport of materials in cytoplasm from one place to another may occurs through the ER

- At some places ER is also connected to PM So ER can secrete the materials outside the cell.

(3) Rough ER: Provides site for the protein synthesis, because rough ER, has ribosomes on its surface.

(4) Lipid Synthesis: Lipids (cholesterol & phospholipids) synthesized by the agranular portion of ER (**Smooth ER**). The major lipids synthesized by SER are phospholipids and cholesterol.

(5) Cellular metabolism: The membranes of the reticulum provide an increased surface for metabolic activities within the cytoplasm.

(6) Formation of nuclear membrane: Fragmented vesicles of disintegrated nuclear membrane and ER elements arranged around the chromosomes to form a new nuclear membrane during cell division.

(7) Formation of lysosomes, Golgi body & some Micro bodies: All the organelles are form by ER which have membrane except chloroplast and mitochondria (semi autonomous organelles).

(8) Detoxification: Smooth ER concerned with detoxification of **drugs, pollutants and steroids.**

(9) ER provides the precursor of secretory material to golgi body.

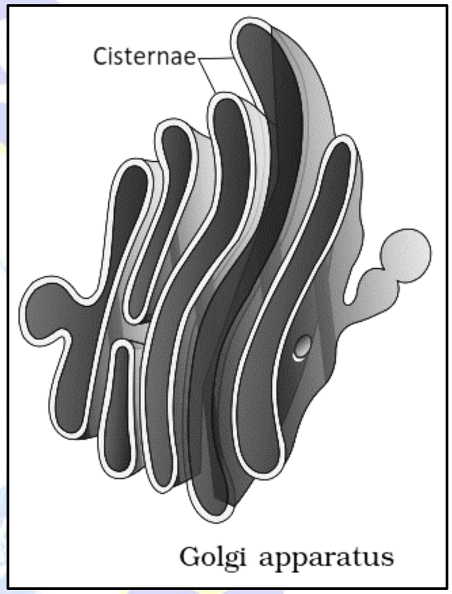
GOLGI APPARATUS

- **Camillo Golgi** (1898) first observed densely stained reticular structure near the nucleus. These were later named Golgi bodies after him.
  Golgi apparatus is also named as:
  - Golgi complex
  - Golgi bodies
  - Dictyosome (plant Golgi body)
- The cytoplasm surrounding Golgi body has fewer or no other organelles. It is called Golgi ground substance or **zone of exclusion**.

STRUCTURE:

Structural components of Golgi body are similar to ER. It consists of three components.

(1) **Cisternae:**It is the main structural component of Golgi body.
These are flat disc shaped, sacs like structure many cisternae are arranged in a stack (parallel to each other).



- Varied number of cisternae are present in Golgi complex.
- 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 **Trans face** or **maturing face**.
- The cis and trans faces of the organelle are entirely different but inter connected.

(2) **Tubules:** These are branched and irregular tube like structures associated with cisternae.

(3) **Vesicles**: Spherical structures arise by budding from tubules. Vesicles are filled with secretory materials.

Functions of Golgi Body:

(1) **Cell Secretion:** Chief function of Golgi body is secretion (export) of macromolecules.
Secretion involve three steps:

(a) Golgi body receives the materials from ER through it's cis - face.

(b) These materials are chemically modified by Golgi body. (For e.g. glycosylation of proteins and **glycosidation** of lipids takes place in Golgi body and it yields **glycoproteins** and **glycolipids respectively**).

(c) After chemical modifications materials are packed in vesicles. These vesicles are pinched off from trans face of Golgi body and discharged out side the cell (**Reverse pinocytosis**).

- This explains, why the Golgi apparatus remains in close association with the endoplasmic reticulum. 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.

(2) **Golgi apparatus is the important site of formation of glycoproteins and glycolipids.(NEET-2020)**

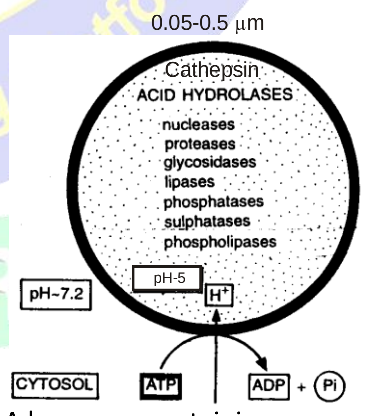
- All the macromolecules which are to be sent out side the cell, move through the Golgi body. So Golgi body is termed as ***"Director of macromolecular traffic in cell"*** or **middle men of cell**.

(3) ***Synthesis of cell wall Material***(Polysaccharide synthesis).

(4) ***Formation of Lysosome*** = It is collective function of Golgi body and ER in animal cells.

(5) ***Cell plate formation***

(6) ***Formation of acrosome during sperms formation.***



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

LYSOSOME

- **Lysosomes are membrane bound Vesicular structures (0.1-0.8 μm) which is covered by single unit membrane.**
- **Lysosome is formed by the process of packaging in the Golgi apparatus.**
- They are very rich in almost 50 types of hydrolytic enzymes (**acid hydrolases – lipases, proteases, carbohydrases)** optimally active at the acidic pH. These enzymes are capable of digesting carbohydrates, proteins, lipids and nucleic acids.
- 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.
- Lysosomes are **highly polymorphic** cell organelle. Because, during functioning, lysosomes have different morphological and physiological states.

DETECTIVE MIND

Types of lysosomes:

(1) **Primary Lysosomes or storage granules:** These lysosomes store enzyme *Acid Hydrolases* in the inactive form. (Enzymes synthesized on ribosomes in cytoplasm) these are newly formed lysosome.

(2) **Digestive vacuoles or Heterophagosomes:**These lysosomes formed by the fusion of primary lysosomes and phagosomes. These are **secondary Lysosomes**.

(3) **Residual bodies:**

- Lysosomes containing undigested material are called residual bodies.
- These are also called as ***Telolysosomes***. **(Tertiary lysosomes)**.
- Residual bodies pass outwardly, come in contact with plasmalemma and throw their contents to the outside through **ephagy**or**exocytosis**. However, in certain cells the residual bodies do not discharge their contents to the outside. Instead, they load the cells and bring about ageing, e.g., liver cells, muscle cells.

(4) **Autophagic Lysosomes or Cytolysosomes or autophagosomes:** Lysosomes containing cell organelles to be digested are known as **Autophagosomes**.

Functions:

(1) **Intracellular digestion:** This is digestion of foreign materials received in cell by phagocytosis and pinocytosis.

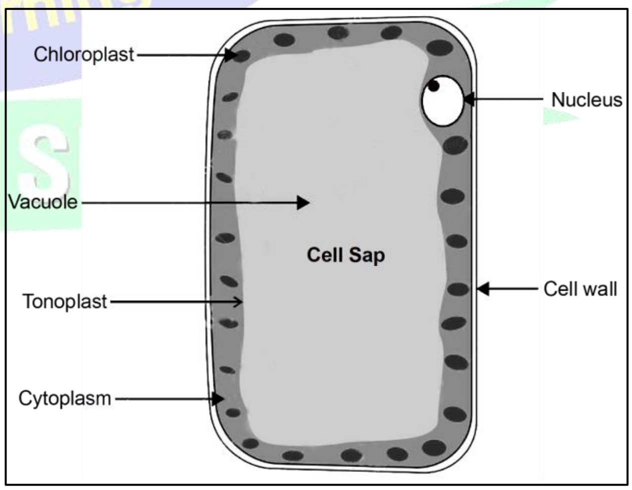
- Digestion of old or dead cell organelles. Autophagy also takes place during starvation of cell.

(2) **Extracellular digestion:**

(3) Sometimes all lysosomes of a cell burst to dissolve the cell completely. (so, Lysosome called as **suicidal bags** of cell).

VACUOLES

- Single membrane bound, chamber or sac like structure found in cytoplasm of eukaryotic cell.
- They are small or large, variable in number & not a permanent structure
- In animal cell vacuole are very small, less in number or may be absent. While in plant & fungi cell large & well developed vacuoles are found.
- 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 percent 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 osmoregulation and excretion. In many cells, as in protists, food vacuoles are formed by engulfing the food particles.**

  Types of vacuoles

  (1) Sap vacuoles (2) Contractile vacuoles (3) Food vacuoles (4) Gas vacuoles

  Functions of vacuoles
- Maintains cellular turgidity.
- Act as dustbin of cell, where cellular waste is deposited.
- Act as site for storage of food.

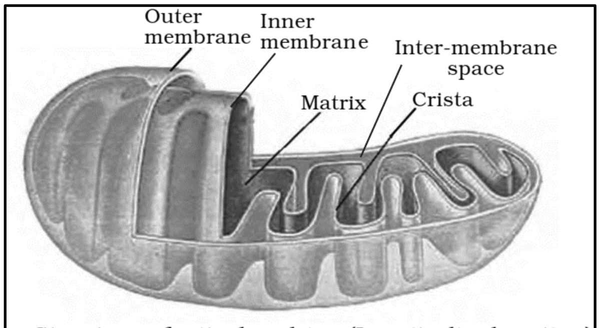
MITOCHONDRIA

- Term '**Mitochondria**, was given by **C. Benda**.
- Number depends upon physiological activity of cell.
- About 50,000 mitochondria in an ***Amoeba***.
- All the mitochondria present in a cell are collectively called **chondriome**.
- Usually plant cells have fewer mitochondria as compared to animal cell.
- **In higher animal's maximum mitochondria(5 lakhs/cell) are found in flight muscles of birds.**
- Mitochondria can make its shape **sausage or cylindrical**.
- **Diameter** of a **mitochondrion** is **0.2-1.0μm (average 0.5μm) and length 1.0-4.1μm.**

Structure:

- Mitochondria unless specifically **stained (Janus green B)** are not easily visible under the microscope.
- **Mitochondria is covered by double unit membrane.**
- **The outer membrane and the inner membrane dividing its lumen distinctly into two aqueous compartments, i.e., the outer compartment and the inner compartment.**
- **The inner compartment is called the matrix. The outer membrane forms the continuous limiting boundary of the organelle.**
- The two membranes have their own specific enzymes associated with the mitochondrial function.
- Each membrane is thick and separated by a space called **peri-mitochondrial space or inter membrane space**. This space has enzymes required for oxidation of fats.
- Inner membrane is folded into a number of fingers like ***cristae*** which increase the surface area.
- In metabolically active mitochondria number of cristae is higher.
- Many electron carrier cytochromes are arranged in a definite sequence in Inner membrane of mitochondria, which forms **Electron transport system (ETS).**
- Inner membrane is studded with pin head particles called **oxysomes** or **elementary particles** or **$F_1 – F_0$ particles** (10^4 to 10^6 in number).
- Head of Oxysomes or $F_1$is concerned with ***Oxidative phosphorylation*** **(formation of ATP by energy of oxidation).**
- Mitochondrial matrix has enzyme for kreb's cycle (Aerobic respiration). Beside these enzymes, matrix have a complete protein synthesis apparatus (**Ribosome-** 70S, **DNA**, few **RNA's & enzymes**) so mitochondria called as semi autonomous **cell organelles**.

- A double stranded and circular **naked DNA** present in mitochondrial matrix.



Structure of mitochondrion (Longitudinal section)

Functions of mitochondria:

(1) Mitochondria is the site of aerobic respiration. Most of the oxidative metabolism and ATP production occurs in mitochondria, thus mitochondria is known as **power house of cell**, where organic compounds are broken down to release & store metabolic energy in the the form of ATP molecules. (Resp. metabolism).

(2) Bring about the oxidation of carbohydrates, proteins and β-oxidation of fats. **Maximum enzymes are present in Mitochondria.**

(3) Participate in photorespiration in mesophyll cells of C_3 plant.

(4) In cytoplasmic inheritance.

SPOT LIGHT
- **Mitochondria divide by fission.**
- **The number of mitochondria per cell is variable depending on the physiological activity of the cells.**

PLASTIDS
- Plastids are found in all plant cells and in Euglenoids. They can be easily observed under the microscope because they are large.
- They bear some specific pigments, thus imparting specific colors to the plants.
- Based on the presence or absence of type of pigments plastids can be classified into **chloroplasts, chromoplasts** and **leucoplasts**.

Types of plastids:

(1) **Chromoplasts:** In chromoplasts fat soluble carotenoid pigments like carotene, xanthophylls and others are present. This gives yellow, orange or red colour to the part of the plant. Chromoplasts occurs mainly in **pericarp** and petals.

- Chromoplasts also occurs in petals but colour of petals are mainly due to water soluble pigments occur in cell sap.

DETECTIVE MIND

(1) Red colour of chilies and red tomatoes is due to the red pigment **"Lycopene"** of chromoplasts.

(2) **Anthocyanin** - (Blue or violet or red pigment) **Anthochlor**(yellow pigment).

(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:

- Generally it is present in non-green and underground plant cells.
- All types of plastids have common origin from ***proplastids,*** sac like non-lamellar structures.

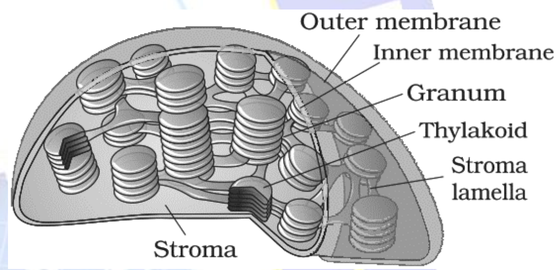
- Plastid
  - Chromoplast (except green all colour)
  - Chloroplast (Green Colour)
  - Leucoplast (Colourless)
    - Amyloplast Stores (Carbohydrate)
    - Elaioplast Stores (Oils and fat)
    - Aleuroplast Stores(Protein)

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**

Structure of Chloroplast:

Membrane:



- Like mitochondria the chloroplast are also **double membrane bound**.
- Out of the two, the inner membrane is relative less permeable. (Outer membrane has more porins and less porins are found in inner membrane).
- The space limited by the inner membrane is called the stroma (matrix).

Component of stroma:

(a) Thylakoids:

- In the stroma a number of organised **flatted membranous sacs are present called thylakoids**.
- **Thylakoids are arranged in stacks like the piles of coins called grana (singular: granum) or the intergranal thylakoids.**
- Each chloroplast contains about 20-100 granum.
- Stroma lamellae are flat membranous tubules (Fret channel or Stroma thylakoids) connecting the thylakoids of the different granum.
- The membrane of the thylakoids encloses a space called a lumen.
- **Chlorophyll (photosynthetic pigments) are present in the thylakoid's membrane.**
- A photosynthetic functional unit (Located in thylakoids membrane) contains about 250 to 400 molecules of various pigments (Chl-a, Chl-b, Carotenes, Xanthophylls etc.) is called as **Quantasomes**

(b) Enzymes:

- The stroma of the chloroplast contains enzymes required for the synthesis of carbohydrate. e.g. starch grains (i.e. enzymes of **Calvin cycle** or **Dark reaction**) and protein synthesis.

(c) DNA:

- Stroma contains small double-stranded circular DNA molecules.
- Chloroplast have more genes as compared to mitochondria.

(d) Ribosome:

- The Ribosomes of the chloroplast are smaller (70S) than the cytoplasmic ribosomes (80S).
- Chloroplast has their own genetic system & complete protein synthesis machinery (ds - DNA, RNA, Ribosome, Enzymes, Amino acids) therefore chloroplast is also called as **semi autonomous organelle** of the cell.

Functions:

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

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.**
- They are membrane less. **(AIPMT-2015)**
- Except mammalian RBC all living cells have ribosomes. (Both prokaryotes & eukaryotes).
- Ribosomes are **smallest cell organelles** Ribosomes are **organelle without membranes**.
- Ribosomes are also called as *''**Organelle within an organelle**'' (also present inside chloroplast and mitochondrion) &**"Protein factory of cell"**.*

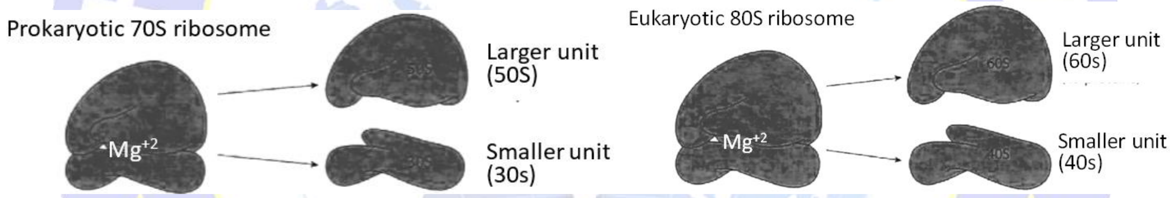
Types of Ribosomes:

(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.

- 70S ribosome also present in mitochondria and chloroplast of eukaryotes. (55 S ribosome present in mitochondria of mammals).
- **S = Svedberg unit or Sedimentation rate. It indirectly is a measure of density and size.**
- **Each ribosome composed of two subunits i.e. larger and smaller subunits.**

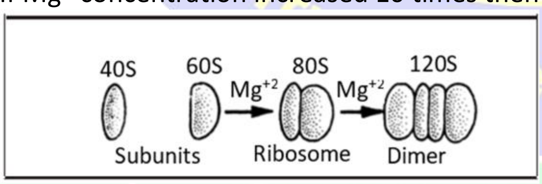
  ➢80S = 60S + 40S **➢70S = 50S + 30S**



DETECTIVE MIND

After synthesis of ribosomes, protein are transported in cytoplasm and organelles
The proper folding and transport of proteins is assisted by specific proteins called Chaperons.

- 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.
- If Mg^{+2}concentration increased 10 times then ribosome dimer is formed.



- 80S +80S = 120S (Dimer) ➢70S + 70S = 100S (Dimer)
- At the time of protein synthesis, several ribosomes become attached to **m-RNA** with the help of smaller subunits. This structure is called ***polyribosome or polysome***. Ribosomes move along the m-RNA like beads on a string, during protein synthesis. Larger subunit 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).

CYTOSKELETON

- An elaborate network of filamentous proteinaceous structures present in the cytoplasm is collectively referred to as the **cytoskeleton** consisting of **microtubules, microfilaments and intermediate filaments**.

The cytoskeleton in a cell are involved in many functions such as **mechanical support, motility, (NEET-2023) maintenance of the shape of the cell.**

CILIA AND FLAGELLA

➢ **Cilia (sing.: cilium) and flagella (sing.: flagellum) are hair-like outgrowths of the cell membrane.** 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. Some prokaryotes also possess flagella but these are structurally different from that of the eukaryotic flagella.

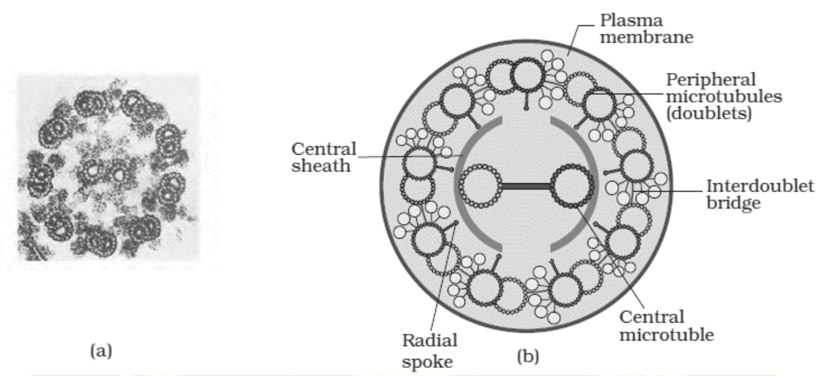
➢ **Flagellar apparatus consists of following Parts.**

(a) **Shaft or ciliary part:** It is projecting hair like part of ciliary apparatus. Cilium is composed of 11 microtubules. (9 doublet + 2 singlet)

➢ The electron microscopic study of a cilium or the flagellum show that they are covered with plasma membrane. **Their core called the axoneme, possesses a number of microtubules running parallel to the long axis**. The axoneme usually has nine doublets of radially arranged peripheral microtubules, and a pair of centrally located microtubules. **Such an arrangement of axonemal microtubules is referred to as the 9+2 array. (9 double + 2 singlet).**

➢ Arms of a tubules consist of an enzymatic protein **dynein** similar to myosin of muscle cells. **Dyenin** has ability of hydrolysis of ATP & liberates energy for ciliary or flagellar movement.

➢ **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 radial spoke. Thus, there are nine radial spokes. The peripheral doublets are also interconnected by linkers. Both the cilium &flagellum emerge from centriole-like structure called the basal bodies.



Electron micrograph and Diagrammatic representation of internal structure of Cilia of Flagella

➢ Cilia and Flagella are similar in structure but some differences may be observe which are:

Cilia		Flagella	
1.	The cilia are small in size (5–10μm)	1.	Flagella are long (up to 150 μm)
2.	Very large in number.	2.	Few in number
3.	Cilia beat in a coordinated manner (sweeping or pendular move)	3.	Flagella beats independently (Non-coordinated manner)
4.	They take part in locomotion, attachment, feeding and sensation.	4.	Flagella involved only in locomotion
5.	Cilia usually occur throughout or major part of surface of a cell.	5.	Flagella are commonly found at one of the cell

CENTROSOME & CENTRIOLES

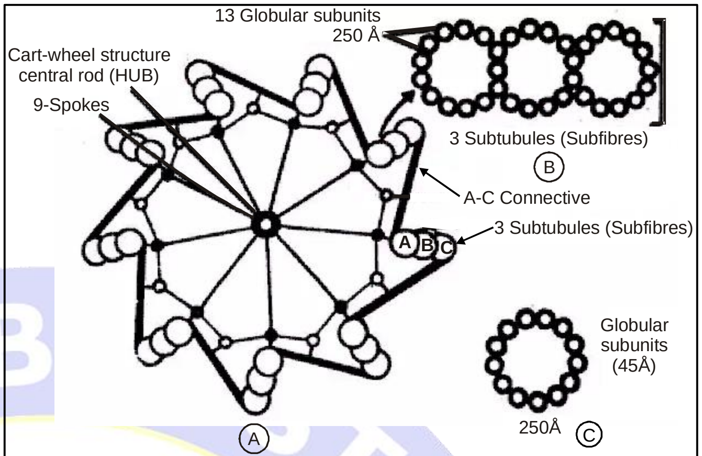


Fig. : (A) T.S. Centriole (B) Three subtubues (C) A subtubule

- Centrosome was discovered by **Benden. Boveri** named it as centrosome. Centrosome is absent in almost all plant cell. **Exception - *Chlamydomonas***.
- **Two Cylindrical shaped centrioles** (diplosome) located just outside the nucleus and lie at right angle (90°) to each other. Cytoplasm which surrounds centrioles called as "**Centrosphere**". Centrioles and centrosphere collectively called **centrosome**.
- Each centriole is surrounded by amorphous peri centriolar mass, which is called as **massules or crown or satellite.**
- Centrioles are **membrane less** elongated structure which exhibit **cart wheel structure** (Just like Basal body of cilia). Basal body is also a type of centriole.
- Centriole mainly consist of 9 peripheral triplet fibers of tubulin. **(9 + 0 arrangement)**.
- Centrioles are self duplicating units.
- Replication of centriole occur in **S-phase in cytoplasm.**

Function:

(i) **The centrioles form the basal body of cilia and flagella.**

(ii) **The centrioles form spindle fibres that give rise to spindle apparatus during cell division in animal cells.**

MICRO–BODIES

- **Many membrane bound minute vesicles called microbodies that contain various enzymes, are present in both plant and animal cells.**

DETECTIVE MIND

- The cells of **protozoa**, **fungi**, **plants**, **liver** and **kidney cells** contain certain membrane bounded spherical bodies of 0.3 to 1.5 μ diameter, filled with enzymes are called as *''Micro–Bodies''*.

Types of Microbodies

On the basis of functions microbodies are of following types:

(1) Spherosomes:
- Spherosomes occur only in plant cells. They are major site of lipid storage and synthesis in plants.
- Spherosomes contain hydrolytic enzymes hence also have lysosome like activity so considered as **plant lysosomes**.
- They are produced from SER.

(2) Peroxisomes:
- In animal cells **peroxisomes** concerned with peroxide (H_2O_2) metabolism. **Catalase** degrade the H_2O_2into water and oxygen.
- In plants, **peroxisomes** occur in cells of green tissues and concerned with **photorespiration** (glycolate pathway).
- Peroxisomes involved in **β-oxidation** of fatty acids in animal cells.

(3) Glyoxysomes:
- Glyoxysomes occur in yeast cells and in plants especially in **fatty seeds** (castor seed, ground nut seed etc.), guard cells of stomata and **unripe fruits**. They are related with **β-oxidation** of fatty acids and glyoxylate cycle in plant cells.

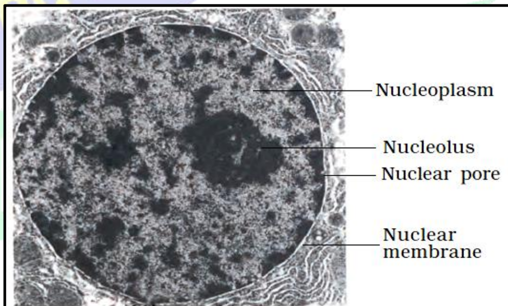
NUCLEUS

Introduction:
- "Nucleus is double membrane bound dense protoplasmic body, which controls all cellular metabolism and encloses the genetic information of cell".
- 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 (Acetocarmine) was given the name **chromatin** by **Flemming**.
- Generally eukaryotic cell contains at least one nucleus but nucleus is absent in mature phloem **sieve tube** elements and **mature RBCs** of mammals. **(exceptionally nucleus is present in RBCs of camel & lamma).**
- **Dikaryotic *(Paramoecium)* and multikaryotic cells (*Opalina*) are also known**.

Structure of nucleus:

When Nucleus is not dividing Nucleus of cell contains.

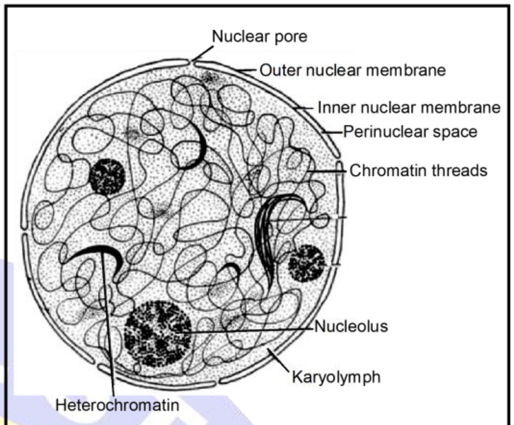
(i) Nuclear membrane or nuclear envelope.
(ii) Nuclear matrix / Nucleoplasm/Karyolymph.
(iii) Chromatin network.
(iv) Nucleolus/little nucleus/Ribosome factory.



Sturcture of nucleus

(i) Nuclear membrane: Electron microscopy has revealed that the nuclear envelope, which consists of two parallel membranes called the **perinuclear space(10nm - 50 nm).**
- This membrane 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.
- Each nuclear pore is guarded by an octagonal discoid structure of **nucleoplasmin protein** this structure is called as **annulus** or **Bleb**. (Annulus + Pore = Nuclear Pore complex).
- **Pore complex** provides the **main channel**, between nucleoplasm and cytoplasm, while **nucleoplasmin** regulates nucleo cytoplasmic traffic.



Ultrastructure of a nucleus

(ii) 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 of RNA & DNA polymerases, endonucleases, minerals, (Ca^{++}, Mg^{++}) etc.

Nucleoplasm contains high concentration of Nucleotides in the form of triphosphate. (NTPs and dNTPs).

- **Chromatin network** and **nucleolus** are embedded in nucleoplasm.

(iii) Chromatin network: (Term given by **Flemming**)

- Interphase nucleus has a loose and indistinct network of nucleoprotein fibers called chromatin, which embedded in nucleoplasm. Chromatin net is mainly formed of DNA and histone protein complexes. Chromatin fibres contain genetic information and condensed to form constant number of chromosomes during cell division.
- During different stages of cell division cells show structured chromosomes in place of nucleus.
- **Chromatin network has two type of chromatins:**

(a) Euchromatin: This is lightly stained and diffused part of chromatin, which is transcriptionally or **genetically more active**. Generally, euchromatin lies at central part of nucleus.

(b) Heterochromatin: This is dark stained, thick and condensed part of chromatin this part has more histone and less acidic protein. Heterochromatin is **genetically less active** chromatin. Heterochromatin occurs near nuclear membrane.

Differences between Euchromatin and Heterochromatin.

	Euchromatin		**Heterochromatin**
(i)	Consists of thin, extended, light stained part of chromatin.	(i)	Consists of thick **solid**, condensed part of Chromatin and dark stained.
(ii)	Genetically more active chromatin	(ii)	Less active or inert chromatin.
(iii)	Less histone protein	(iii)	More histone protein
(iv)	Replicates in early S phase	(iv)	Replicates in late S phase

(iv) Nucleolus:

- Nucleoplasm also contain nucleolus.
- The nucleoli are spherical and membrane less structure so that the content of nucleolus is continuous with the rest of the nucleoplasm.
- **It is a site for active ribosomal RNA synthesis.(NEET-2020)**
- Nucleolus disappears during prophase and reappears in telophase.
- **Ribosome formation** is the chief role of nucleolus, thus it called as **Ribosome factory of cell**, the proteins of ribosomes are synthesised in cytoplasm but it diffused in to nucleus and reach at nucleolus. Here rRNA and ribosomal proteins are assembled to form ribosomes which move to cytoplasm through nuclear pores.

- **Larger and more numerus nucleoli are present in cells actively carrying out protein synthesis.**

- **Functions of nucleus:**

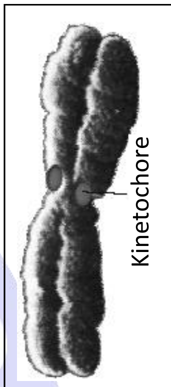
(i) Nucleus contains genetic information in its chromatin.
(store house of genetic material).

(ii) Nucleus takes part in transmission of genetical information from parent cell to daughter cell or the one generation to next.

(iii) Division of nucleus is pre-requisite to cell division.

(iv) Nucleus controls metabolism of cell by sending m-RNA in cytosol
(Basically, biomolecule DNA controls cellular activities through directing synthesis of enzyme).

(v) Variation develops due to change in genetic material of nucleus. (Evolutionary role).



Chromosome with Kinetochore (Metaphasic chromosome)

CHROMOSOMES

General introduction:

- **You may recall that the interphase nucleus has a loose and indistinct network of nucleoprotein fibres called chromatin.**
- **But during different stages of cell division, cells show structured chromosomes in place of the nucleus.**
- **Chromatin contains DNA and some basic proteins called histones, some non-histone proteins and also RNA.**
- **A single human cell has approximately two metre long thread of DNA distributed among its forty six (twenty three pairs) chromosomes.**
- **Every chromosome (visible only in dividing cells) essentially has a primary constriction or the centromere on the sides of which disc shaped structures called kinetochores are present Centromere holds two chromatids of a chromosome.**

Types of chromosomes on the basis of position of centromere:

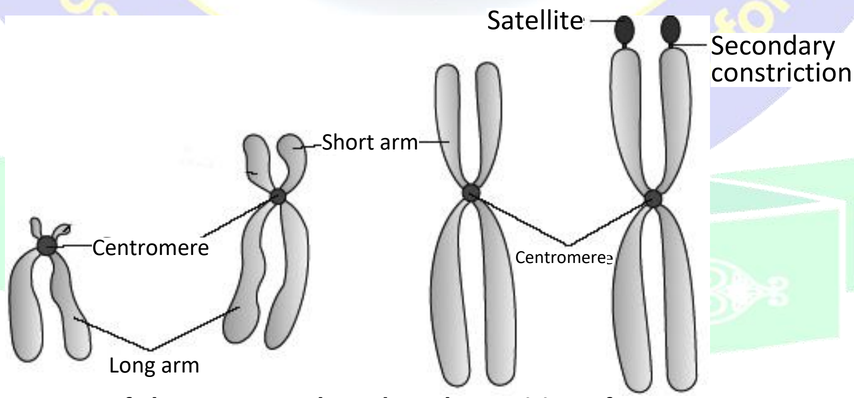
(i) **Telocentric:** When centromere is terminal or located at the tip of chromosome.

(ii) **Acrocentric:** When the centromere is **sub-terminal** or located near the tip.

(iii) **Metacentric:** When the centromere is located at mid of the chromosome.

(iv) **Sub metacentric:** When the centromere located near centre or mid point of chromosome.

- The ratio of length of the long arm to the short arm of a chromosome is called **arm ratio**. Arm ratio is maximum in acrocentric chromosome.



Types of chromosomes based on the position of centromere

- **Sometimes a few chromosomes have non-staining secondary constrictions at a constant location. This gives the appearance of a small fragment called the satellite.**

EXTRA INFORMATION:–

- ***Karyotype*⇒** Karyotype is external morphology of all Chromosomes of a cell which is specific for each species of living organisms. Karyotype can be studied in metaphase of mitosis.
- Karyotype includes the number of chromosomes, relative size, position of centromere, length of the arms, secondary constrictions and banding patterns.
- **Idiogram:** Diagrammatic representation of Karyotype. In idiogram chromosomes are arrangedin decreasing order of size. Sex chromosomes are placed in last .

Use of Karyotyping and idiogram:

(i) It suggests primitive or advanced features of an organism. If karyotype shows a large size difference between the smallest and the largest chromosome of the set and having fewer metacentric chromosomes then it is called ***asymmetric karyotype***, which is a relatively advance feature. Symmetric karyotype is primitive feature.

(ii) The karyotype of different species are compared and similarities in them represent the evolutionary relationships.

(iii) Karyotype is helpful in detection of chromosomal aberrations and polyploidy.

(iv) In research of **medical genetics Forensic science cytogenetics and Anthropogenetics.**

Structure of chromosome: (Parts which appears in metaphase chromosome)

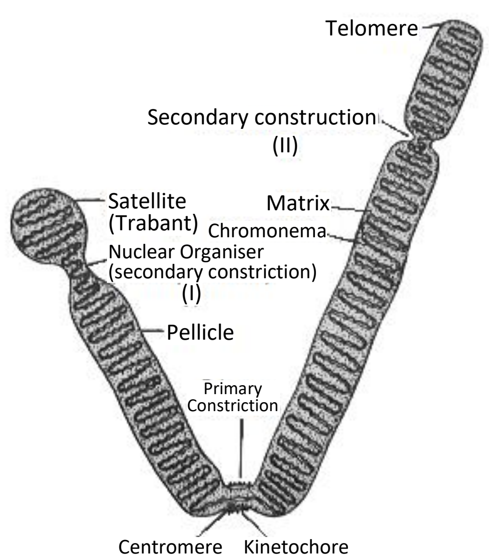
1. **Pellicle:** This is outermost, thin proteinaceous covering or sheath of chromosome.
2. **Matrix:** This is a liquid nongenetic achromatic ground substance of chromosome, which has different type of enzymes, minerals, water, proteins.
3. **Chromatid:** At metaphase stage each chromosome is consist of two cylindrical structures - called **chromatids**. Both sister chromatids are joined together by a common **centromere**.

- Each chromatid consists of a single long thread of DNA associated with histone. Non histone proteins and RNA are also present.

4. **Centromere/Kinetochore:** (Primary constriction)

- Each chromosome (at metaphase) is consist of two chromatids. Both the chromatids of a chromosome are joined or connected by a structure called **Centromere**. At this point or centromere two protein discs are present which is called **Kinetochore.**
- **Kinetochores** constitute the actual site of attachment of spindles to chromosomes during cell division.
- At the region of centromere, the chromosome is comparatively narrower than remaining part of chromosome, thus it is termed as **Primary constriction**.

5. **Secondary constriction:** Besides primary constrictions, other constriction may also occur on some chromosome, which are known as secondary constriction. These constrictions are non staining and found at a constant location.
6. **Satellite:** part of chromosome remains after the NOR is known as chromosomes **satellite/ Trabent**.



Structure of chromosome at anaphase

- Chromosomes with satellite part are called as **SAT chromosome** (SAT = Sine Acid Thymonucleinico).

7. **Telomere:** Chromosomes have polarity and polar ends of chromosomes are known as Telomeres.

- Telomere prevents fusion of one chromosome to another chromosome.
  According to Richard Kathan (2003) telomeres of chromosomes become shorter during ageing process as telomerase becomes less active.

Special types of chromosomes or giant chromosomes:

In some organisms, the chromosomes assume special structures in some specific tissues, e.g.

1. **Lampbrush chromosomes:**These were described by Ruckert (1892).
   These are observed in diplotene stage.
   These are present in primary oocyte nuclei of vertebrates as well as invertebrates.

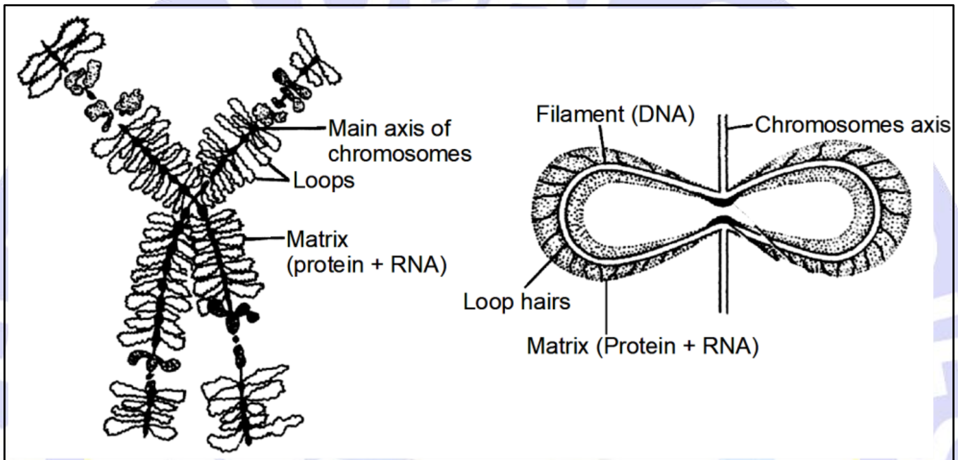


Fig. : Lampbrush chromosomes : A. Enlarged view B. One extended loop

- Their main axis is formed by DNA. Many of the chromosomes give out lateral projections or loops.
  Loops are extended parts of chromosomes, participating in transcription,

2. **Salivary gland chromosomes or Polytene chromosomes:**
   In salivary gland cells of insects of order Diptera (dipteran insects), some special chromosomes were reported by **E.G. Balbiani** (1881). It is due to the presence of these giant chromosomes that maximum cytological studies have been made in ***Drosophila***.

3. **RNA and protein synthesis take place in Balbiani rings.**

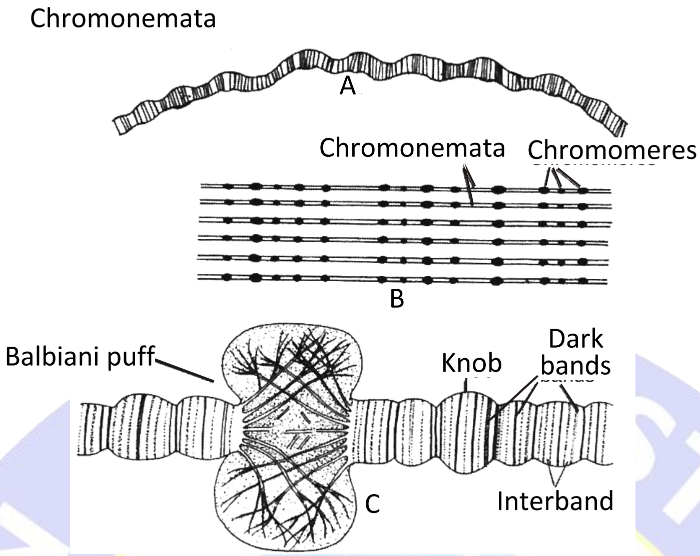


Fig. : Polytene chromosomes :
A. A typical polytene chromosome.
B. Schematic representation of formation of polytene chromosome and its dark bands by coming together of a number of chromonemata and their chromomeres.
C. An enlarged portion of polytene chromosome showing a puff.

The Structure and Function of the Cytoskeleton			
Property	**Microtubules (Tubulin Polymers)**	**Microfilaments (Actin Filaments)**	**Intermediate Filaments**
Structure	Hollow tubes	Two interwined strands of actin	Fibrous protein coiled into cables
Diameter	25 nm with 15-nm lumen	7 nm	8-12 nm
Protein subunits	Tubulin, a dimer consisting of α-tubulin and β-tubulin	Actin	One of several different proteins (such as keratins)
Main functions	Maintenance of cell shape (compression-resisting "girders"); cell motility (as in cilia or flagella); chromosomes movements in cell divison; organelle movements	Maintenance of cell shape (tension-bearing elements); changes in cell shape; muscle contraction; cytoplasmic streaming in plant cells; cell motility (as in amoeboid movement); division of animal cells	Maintenance of cell shape (tension-bearing elements); anchorage of nucleus and certain other organelles; foration of nuclear lamina
Fluorescence micrographs of fibroblast. Fibroblasts are a favorite cell type for cell biology studies. In each, the structure of interest has been tagged with fluorescent molecules. The DNA in the nucleus has also been tagged in the first micrograph (blue) and third micrograph (orange).