Cell : The Unit of Life

8

INTRODUCTION

Cell is a basic of life and it is considered as structural and functional unit of an organism. **Robert Hooke (1665)** discovered cell. He first observed the cell in a piece of dead cork cells. He described cell in his book **"Micrographia"**.

Leeuwnehoek (1674) first observed animal cell and used the term **"Animalcule"** for it.

The study of cell structure is called **cytology**. The study of cell structure, function & Reproduction is called **Cell biology.**

Term **'cytology'** was coined by **'Hertwig'** who wrote a book entitled **'cells & tissues'**. **Robert hook is known as 'father of cytology'**.

Cell Theory :

Malthias Schleiden (German botanist) and schwann (German Zoologist) jointly proposed cell theory in 1839.

Its main features are as follows

(i) All living organism consist of cells and their products.

(ii) All cells are structurally and metabolically similar.

(iii) Cells perform Vital activities of an organism.

(vi) Each cell is unit of heredity.

(v) New cell arises from pre existing cells **"Omnis cellula e cellula"**. It is called cell lineage theory. This concept was given by Rudolph virchow (1855).

OBJECTIONS :

(1) Bacteria and cyanobacteria do not bear nucleus and membrane bound cell organelles.

(2) Viruses are acellular and do not contain cellular machineary.

(3) RBCs and sieve tube cells live without nucleus.

CELL - AN OPEN SYSTEM :

An open system is one which is separated from its surrounding by a boundary that allows transfer of material in and out of the cells. Cell is an open system because it recieves a number of materials & energy from outside and liberates energy as heat.

Difference between Prokaryotic and Eukaryotic Cell	
Prokaryotic cell	**Eukaryotic Cell**
1. The cell size is small (0.1 – 0.5 um.)	1. The cell size is comparatively larger (0.5-100 um).
2. An organized nucleus is absent instead a nucleoid is found.	2. An organized nucleus is found. It is differtntiated into nuclear envelope, chromatin one or more nucleoli and nucleoplasm.
3. Cell wall if present, contains muramic acid.	3. Cell wall, if present, muramic acid in absent
4. DNA is naked, it means histones absent	4. DNA is found with histones.
5. DNA lies freely in the cytoplasm.	5. Most of the cell DNA is found in the nucleus. A small quantity is also found in thhe plastids and mitochondrai.
6. DNA is circular.	6. Nuclear DNA is linear whereas Extra nuclear DNA is circular.
7. Trancription and translation take place in the cytoplasm.	7. Transcripition occurs in the nucleus while translation takes place in the cytoplasm.
8. Cytoplasm does not show cyclosis.	8. Cytoplasm usually shows cytoplasm.
9. Membrane bound organelles like mitchondria, Golgi apparatus, ER, Lysosomes and other microbodies are absent.	9. Mithochondria, ER, Golgi apparatus & microbodies including lysosomes are present in cell of organism.
10. Microtubules and microfilaments are commonly absent.	10. MIcrotubules and microfilaments are present.
11. 70S types of Ribosomes are found.	11. Ribosomes are of 80S types. 70S ribosomes are found in mitochondria and plastids.
12. Centriole is also absent	12. Centriole is present in animals & lower plants
13. Ex:- Bacteria, Cyanobacteria, Mycoplasma.	13. Ex:- Protists, Fungi, Plants and Animals.

Differences between PLant ande Animal Cells	
Plant cell	**Animal cell**
1. A plant cell has rigid wall on the outside.	1. A cell wall is absent.
2. Plastids are found in plant cells	2. Plastide are usually absent.
3. A mature cell has a largecentral vacuole.	3. An animal cell may have many small vacuoles.
4. Nucleus lies on one side in the peripheral cytoplasm due to central vacuole.	4. Nucles usually lies in the centre.
5. Centrioles are usually absent.	5. Centrioles are found in animals cells.
6. Golgi apparatus consists of number of distinct & unconnected units called dictyosomes.	6. Golgi apparatus is either localised or diffused & consits of a well connected single complex.
7. Reserve food is generally starch and fat.	7. Reserve food is usually glycogen and fat.
8. Adjacent cells may be connected through plasmodesmata.	8. Adjacent cells are connected through a number of cell junctions.
9. Cytokinesis occurs by cell plate.	9. Cytokinesis takes place by cleavage.

SHAPE AND SIZE OF CELLS

Cells differ greatly in size, shape and activities (Figure). For example, Mycoplasmas, the smallest cells, are only 0.3 µm in length while bacteria could be 3 to 5 µm. The largest isolated single cell is the egg of an ostrich. Among multicellular organisms, human red blood cells are about 7.0 ìm in diameter. Nerve cells are some of the longest cells. Cells also vary greatly in their shape. They may be disc-like, polygonal, columnar, cuboid, thread like, or even irregular. The shape of the cell may vary with the function they perform.

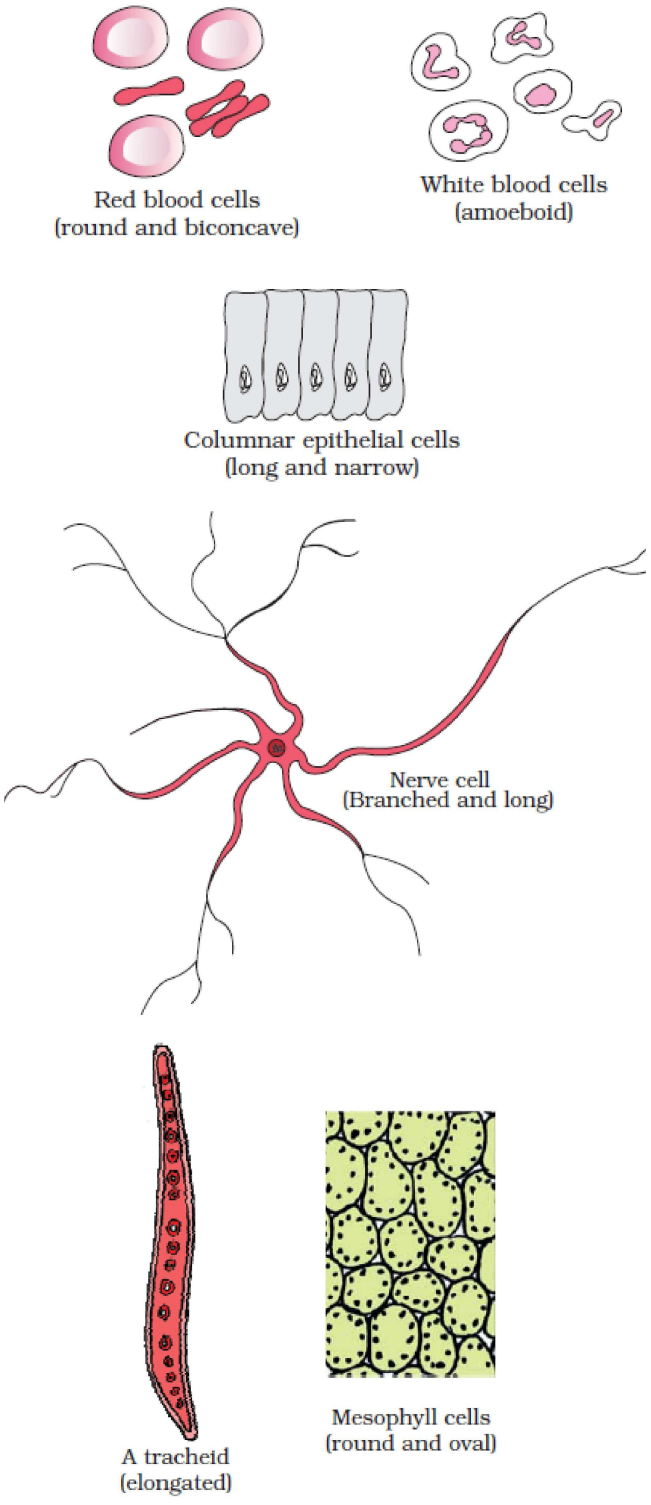


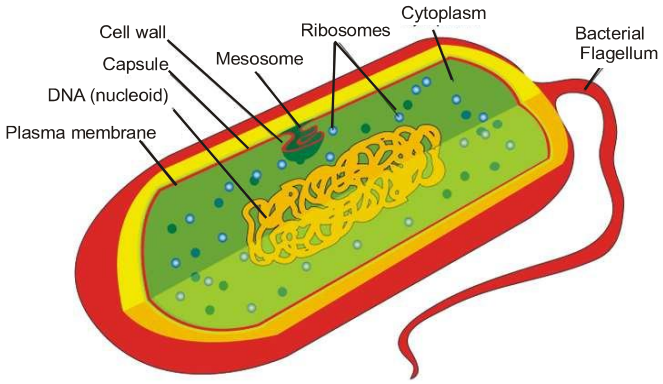
Diagram showing different shapes of the cells

STRCUTURE OF A PROKARYOTIC CELLS

The prokaryotic cells are represented by bacteria, blue-green algae, mycoplasma and PPLO (Pleuro Pneumonia Like Organisms). They are generally smaller and multiply more rapidly than the eukaryotic cells.

1. Shape and size of cell :

They may vary greatly in shape and size. The four basic shapes of bacteria are bacillus (rod like), coccus (spherical), vibrio (comma shaped) and spirillum (spiral).



2. Cell Envelope and its Modifications :

Most prokaryotic cells, particularly the bacterial cells, have a chemically complex cell envelope. The cell envelope consists of a tightly bound three layered structure i.e., the outermost glycocalyx followed by the cell wall and then the plasma membrane. Although each layer of the envelope performs distinct function, they act together as a single protective unit. Bacteria can be classified into two groups on the basis of the differences in the cell envelopes and the manner in which they respond to the staining procedure developed by Gram viz., those that take up the gram stain are Gram positive and the others that do not are called Gram negative bacteria.

Glycocalyx differs in composition and thickness among different bacteria. It could be a loose sheath called the slime layer in some, while in others it may be thick and tough, called the capsule. The cell wall determines the shape of the cell and provides a strong structural support to prevent the bacterium from bursting or collapsing. The plasma membrane is semi-permeable in nature and interacts with the outside world. This membrane is similar structurally to that of the eukaryotes.

3. Nucleoid :

All prokaryotes have a cell wall surrounding the cell membrane. The fluid matrix filling the cell is the cytoplasm. There is no well-defined nucleus. The genetic material is basically naked, not enveloped by a nuclear membrane. In addition to the genomic DNA (the single chromosome/circular DNA).

4. Plasmid :

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 antibiotics. In higher classes you will learn that this plasmid DNA is used to monitor bacterial transformation with foreign DNA.

5. Mesosome :

A special membranous structure is the mesosome which is formed by the extensions of plasma membrane into the cell. These extensions are in the form of vesicles, tubules and lamellae. They help in cell wall formation, DNA replication and distribution to daughter cells. They also help in respiration, secretion processes, to increase the surface area of the plasma membrane and enzymatic content. In some prokaryotes like cyanobacteria, there are other membranous extensions into the cytoplasm called chromatophores which contain pigments.

6. Flagella :

Bacterial cells may be motile or non-motile. If motile, they have thin filamentous extensions from their cell wall called flagella. Bacteria show a range in the number and arrangement of flagella. Bacterial flagellum is composed of three parts – filament, hook and basal body. The filament is the longest portion and extends from the cell surface to the outside.

7. Pili and fimbriae :

Besides flagella, Pili and Fimbriae are also surface structures of the bacteria but do not play a role in motility. The pili are elongated tubular structures made of a special protein. The fimbriae are small bristle like fibres sprouting out of the cell. In some bacteria, they are known to help attach the bacteria to rocks in streams and also to the host tissues.

8. Ribosomes :

In prokaryotes ribosomes are associated with the plasma membrane of the cell. They are about 15 nm by 20 nm in size and are made of two subunits - 50S and 30S units which when present together form 70S prokaryotic ribosomes. Ribosomes are the site of protein synthesis. Several ribosomes may attach to a single mRNA and form a chain called polyribosomes or polysome. The ribosomes of a polysome translate the mRNA into proteins.

9. Inclusion bodies:

Reserve material in prokaryotic cells are stored in the cytoplasm in the form of inclusion bodies. These are not bounded by any membrane system and lie free in the cytoplasm, e.g., phosphate granules, cyanophycean granules and glycogen granules. Gas vacuoles are found in blue green and purple and green photosynthetic bacteria.

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 plant cells .

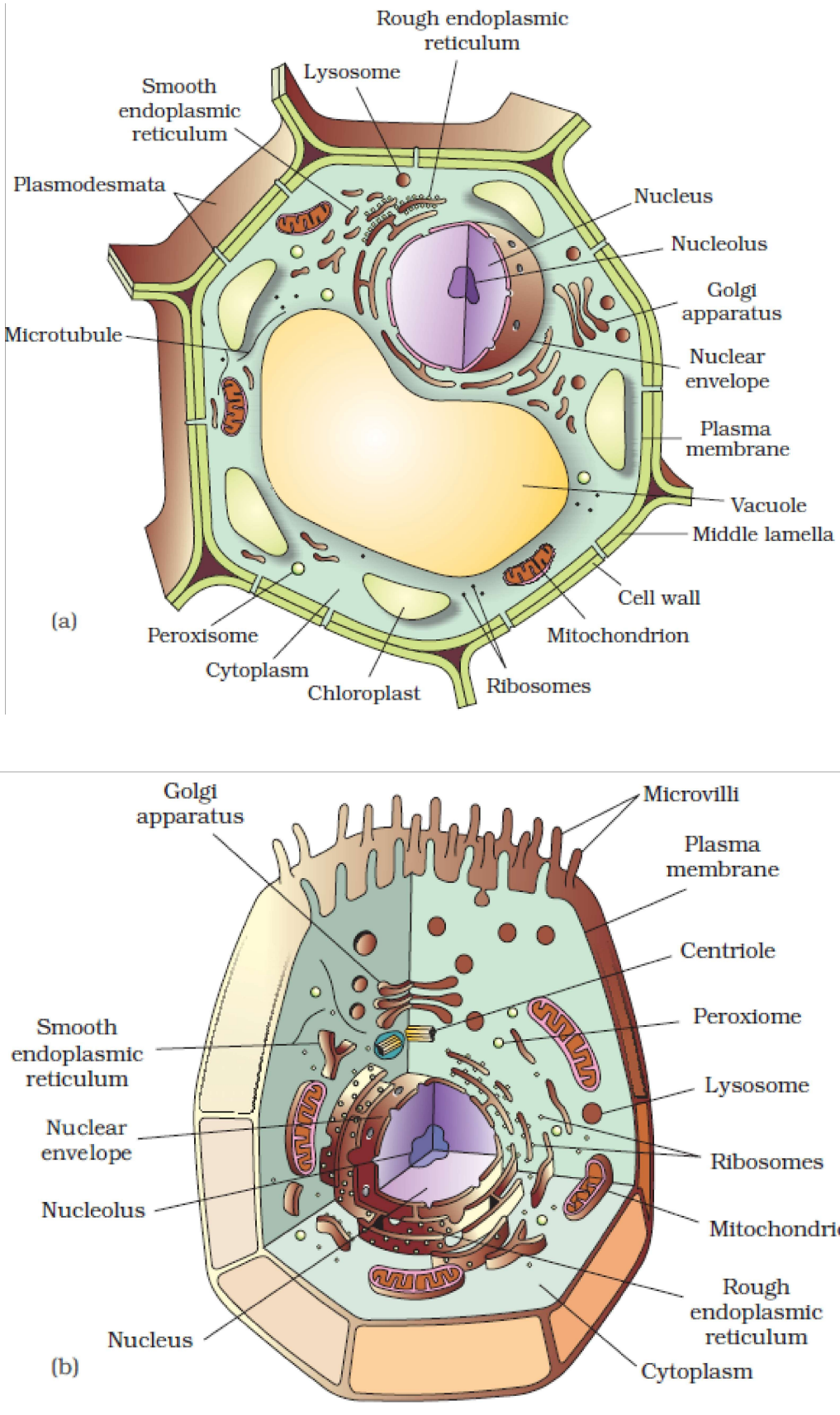
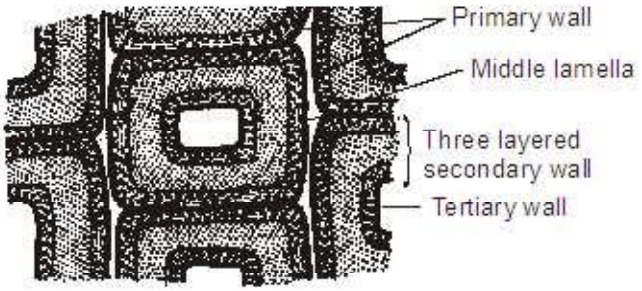


Diagram showing : (a) Plant cell (b) Animal cell

Cell wall →	**Primary wall**	:	Outermost layer, thin elastic composed of cellulose, hemicellulose & pectin.
	Secondary Wall (S_1, S_2, S_3)	:	Rigid, thick & composed of cellulose, hemi–cellulose, Pectin. (absent in meristem cells)
	Tertiary wall	:	Present only in tracheids of Gymnosperm. Composed of hemi cellulose & xylan.
	Middle lamella	:	Common layer between two cells.

* Cell wall was discovered by **Robert–Hooke.**
* Outer most but dead boundary of plant cell is cell wall.
* Bacteria included in plants because they have cell wall.
* Middle lamella is consist of Ca & Mg pectates (Plant cement). Amount of Ca is more.
* Fruits become soft and juicy due to dissolve of middle lamella.
* Cellulose is a main constituent of cell wall but addition to cellulose – Hemicellulose, cutin, Pectin, Lignin, Suberin are also presents in cell wall.
* Cell wall worked as frame or protective layer of cell.
* Cellulose microfibrils and macrofibrils arranged in layers to form skeleton of cell wall. In between these layers other substances like pectin, hemicellulose may be present. These form **matrix of cell wall**.



A few cells showing gross structure of cell wall

STRUCTURE OF BIOMEMBRANES :

* All these models are rejected because they fails to explain the elasticity and selective permeability of plasmalemma.

Fluid mosaic model : By **Singer** & **Nicolson** (1973)

* This is **latest & most widely accepted** model for the structure of plasmalemma.
* According to fluid mosaic model protein are arranged in phospholipid layer as mosaic pattern.
* Thus membrane is termed as **"protein icebergh in a sea of phospholipid"** or **"Gulab Jamun (protein)** in a concenterated solution **(phospholipid)** of sugar".

(1) Phospholipids :

* Phospholipid is the **main component of cell membrane** because it forms continous structural frame of cell membrane. Main type of phospholipids are phosphatidyl serine, phosphatidyl choline (Lecithin), P-ethanol amine (cephalin)
* Phospholipid layer provides fluidity to plasma membrane because phospholipids are rich in unsaturated fatty acid which are liquid in nature.
* Cholesterol is also present in plasmamembrane. Cholestrol are more rigid than phospholipid. So it helps in stability of membrane structure.
* Cholesterol is absent in membrane of prokaryote. Thus **Hopanoides** (Pentacyclic sterol) provides stability to prokaryotic cell membrane.

(2) Proteins :

Two types of protein are present in plasma membrane.

(a) Integral or intrinsic protein (70%)

* These protein are tightly binds with phospholipid. Thus not easily released from membrane.
* Some intrinsic protein are confined in lipid bilayer (Stable protein).
* Some integral proteins traverse the complete thickness of membrane. These type of protein are called as **tunnel protein** which passage water soluble material across the membrane.
* Some intrinsic protein extending from outside to inside are called as **transmembrane** protein eg. glycophorin, porins. Porins founds in outer mitochondrial Membrane and Bacterial Memberane.

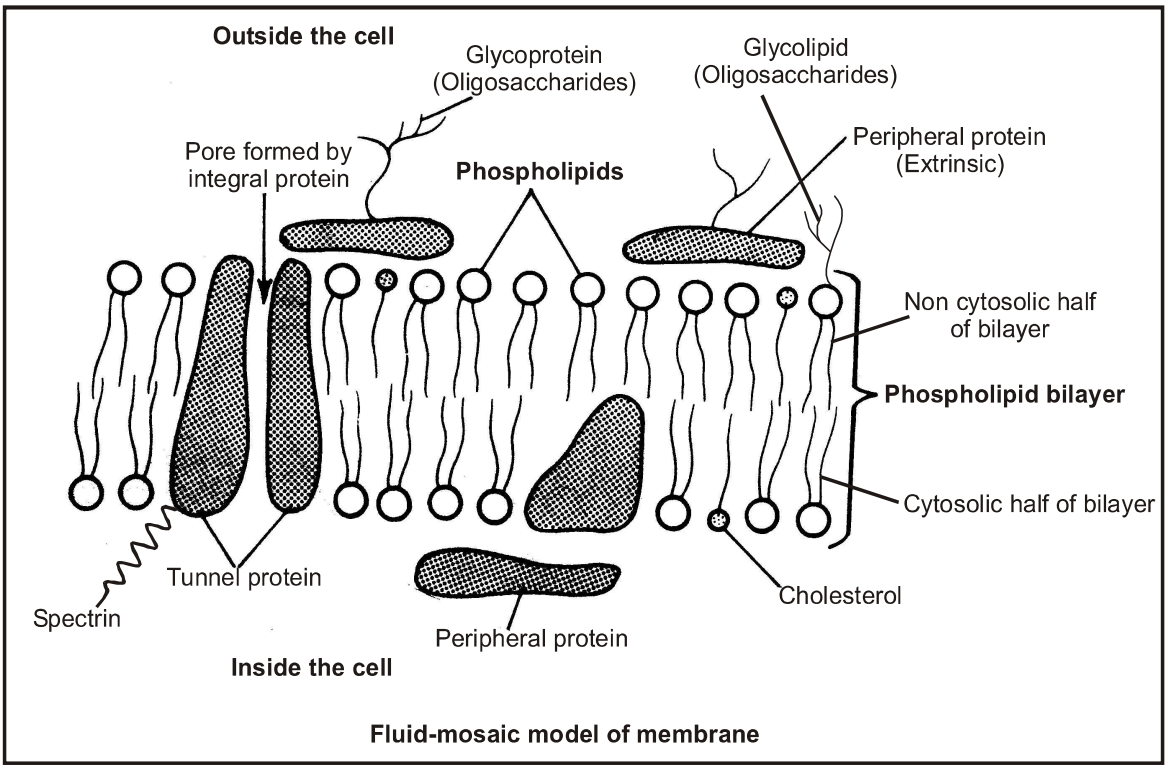
(b) Peripheral or extrinsic protein (30%)

* These are superficially arranged on outer side and can be seperate easily. These protein have enzymatic activity. Extrinsic protein can move freely on membrane structure.
* Some protein like permeases and translocase function as **carriers** for the transport of materials. **Spectrin** are helical type of extrinsic protein founds on cytosolic face of membrane and attached to intrinsic protein. Spectrins are part of cytoskeleton.
* However phospholipid bilayer has fluid property but no evidence of **flip flop mechanism** for protein molecule (**Flip Flop means** exchange of molecules from one monolayer with those in the monolayer on the other side).
* Rotational diffusion and lateral diffusion of protein and lipids is possible in membrane.
* Absence of flip flop movement detected by electro spin resonance (ESR) spectroscopy.

Lipids – 40% (Phospholipids, cholesterol, glycolipids)

Proteins – 58–59% (Arginine, Lysine rich)

Carbohydrates – 1–2%



Fluid-mosaic model of membrane

TRANSPORT THROUGH PLASMA MEMBRANE

* Plasma membrane now consider as **selectively** or **differentially permeable** because it allows certain solutes to pass through it and prevents others.

  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.

CYTOPLASM

* **Term "Cytoplasm"**, was given by ***Strasburger*** for the part of cell, presents between the nucleus and cell membrane. Cytoplasm can be devided 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.**

MITOCHONDRIA

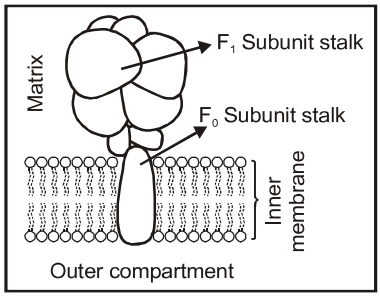
* 5 lakhs mitochondria in an Amoeba ***Chaos Chaos.***
* All the mitochondria present in a cell are collectively called **chondriome**.
* Usually plant cells have fewer mitochondria as compared to animal cell.
* In higher animals maximum mitochondria are found in flight muscles of birds.
* Mitochondria can make its shape as ellipsoidal, oval, spherical or spiral.

Mitochondria

* Power house of cell or ATP-mill in cell
* **Cell within cell**/second largest organelle
* Cell furanaces or storage batteries
* Most busy and active organelle in cell
* Semi autonomous cell organelle.

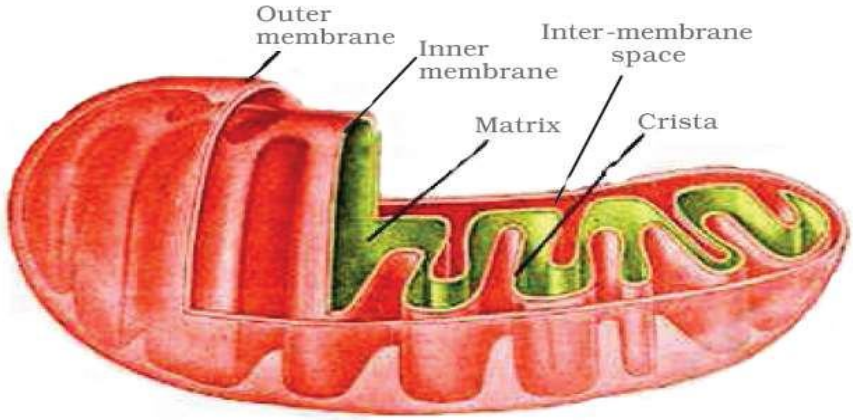
STRUCTURE :

* Mitochondria is covered by double unit membrane. Outer membrane has more phospholipids (Phosphatidyl choline) and cholesterol as compared to inner membrane.
* Inner membrane is folded into a number of finger like ***cristae***. Cristae are tubular finger like but in fungi cristae are plate like.
* 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)** for oxidative phosphorylation.
* 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 composed of ATPase (ATP synthase) enzymes and concerned with ***Oxidative phosphorylation***
* Matrix have a complete protein synthesis apparatus (**Ribosome-** 70-s, **DNA**, few **RNA's & enzymes**) so mitochondria called as semi autonomous **cell organelles**.
* Enzymes for replication and transcription of DNA like ***DNA-polymerase*** and ***RNA-polymerase*** are found in mitochondrial matrix.



FUNCTIONS OF MITOCHONDRIA

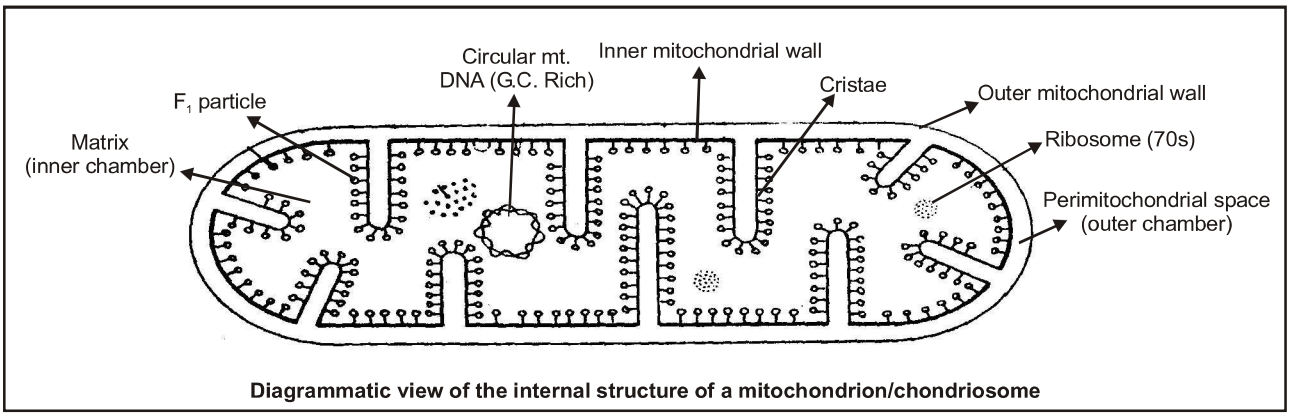
(1) Most of the oxidative metabolism and ATP production occurs in mitochondria, thus mitochondria are the **power house of cell**, where organic compounds are broken down to release & store metabolic energy in the the form of ATP molecules. (Resp. metabolism).



Structure of mitochondrion (Longitudinal section)

(2) Mitochondria help in vitellogenesis in oocytes.

(3) In cytoplasmic inheritance.



Diagrammatic view of the internal structure of a mitochondrion/chondriosome

GOLGI COMPLEX :

* Discovered by **C.Golgi** (1898) - In nerve cells of owl and named "internal reticular apparatus" (Golgi body first observed by L.S. George)
* Golgi body also named as
  * Golgi body
  * Golgi complex
  * Dalton complex
  * Dictyosome

STRUCTURE

Golgi complex is made up of four parts –

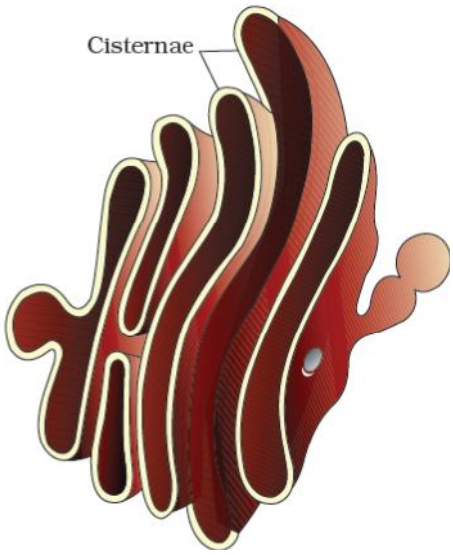
(1) **Cisternae :–** These are unbranched saccules likes smooth E.R., many cistenae are arranged in a stack. Dense opaque material inside cisternae is called **Node s**.

* 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**.

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

(3) **Vacuoles :–** Large spherical structures associated to tubules.

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



Golgi apparatus

* Golgibody1 is single membrane bound cell organelle.
* About 60% proteins and 40% phospholipid occur in golgi body.

FUNCTIONS :

(1) **Cell Secretion :–** Chief function of golgi body is secretion (export) of macromolecules.

Secretion involve three steps :

(a) Golgi body recieves the materials from E.R. through it's cis - face.

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

(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**)

* Golgi complex involves secretion of zymogen granules from pancreas, secretion of lactoprotein from mammary Glands.
* The secretion of hormone by endocrine glands is mediated through golgibodies.

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**.

(2) ***Synthesis of cell wall Material*** (Polysaccharide synthesis)

(3) ***Cell plate formation*** (Phragmoplast) during cell formation.

(4) ***Formation of acrosome during spermiogenesis.*** (formation of male gametes)

(5) ***Vitelline membrane of egg*** *is secreted by golgi body.*

LYSOSOME

* **Christian De Duve** (1955) discovered lysosome as cell organelle and also named ***Lysosomes***.
* With the exception of mammalian RBC they were reported from all 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.*
* **Lysosomes** are spherical bag like structures (0.1-0.8 μm) which is covered by single unit membrane. They are larger in Phagocytes (WBC) (0.8 to 2 μm).
* Lysosomes are filled with 50 different type of digestive enzymes termed as ***Acid hydrolases.***

FUNCTIONS

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

(2) **Autophagy :–** Digestion of old or dead cell organelles. Autophagy also takes place during starvation of cell.

(3) **Extracellular digestion :–**

Lysosomes of osteoclast (bone eating cells) dissolve unwanted part of bones.

(Extracellular digestion also occurs by fungal lysosomes.)

(5) **Cellular digestion (Autolysis)** :– Sometimes all lysosomes of a cell burst to dissolve the cell completely. *Old cells are removed by **autolysis.*** unwanted organs of embryo are destroyed by autolysis **Cathepsin** of lysosome digests the tail of tadpole of frog during metamorphosis.

* **Biogenesis of Lysosome** Lyosomes originates from G E R L - (Golgi associated Endoplasmic Reticulum from which Lysosomes arise).

E.R. ⟶ Golgi body ⟶ Lysosome

ENDOPLASMIC RETICULUM :

* "Garnier" (1897) first observed them and called **Ergastoplasm**. E. R. name proposed by **"Porter"** (1961). (Credit for discovery of ER goes to **Porter**)

Components of E.R. :–

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

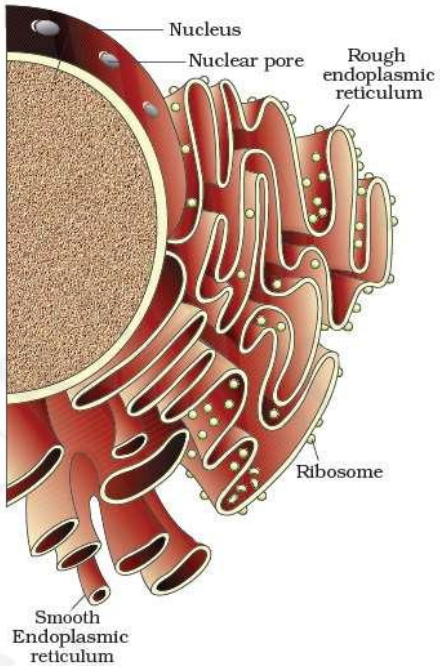
(2) ***Vesicles*** - These are oval membrane bound structures.

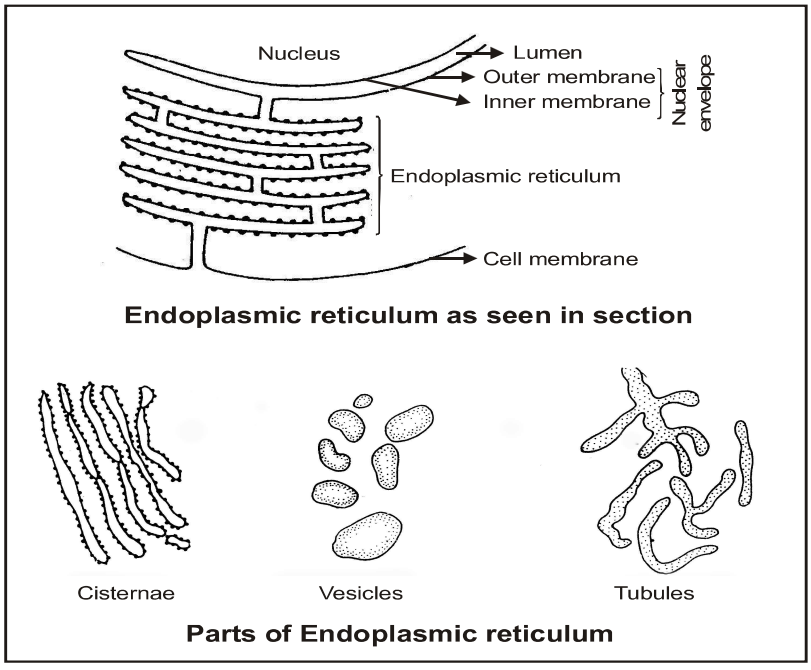
(3) ***Tubules*** - These are irregular, often branched tubes bounded by membrane. Tubules may free or associated with cisternae.

* 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**"

	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)	*More Stable* structure	(2)	*Less Stable* structure
(3)	Mainly Composed of cisternae and vesicles	(3)	Mainly composed of tubules.
(4)	Abundantly occurs in cells which are actively engaged **in protein synthesis** e.g. liver, pancreas, Goblet cells.	(4)	Abundantly occurs in cells concerned with **glycogen** and **lipid metabolism**. e.g. Adipose tissue, Interstitial cells, Muscles, Glycogen storing liver cells, and adrenal cortex.





FUNCTIONS OF E.R.

(1) **Mechanical support :–** Microfilaments, 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.**). The major lipids synthesized by S. E. R. are phospholipids and Cholesterol.

(5) **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.

(6) **Formation of lysosomes, Golgi–body & Micro–bodies.** All the organelles are form by E.R. which have membrane except chloroplast and mitochondria (semi autonomous organelles)

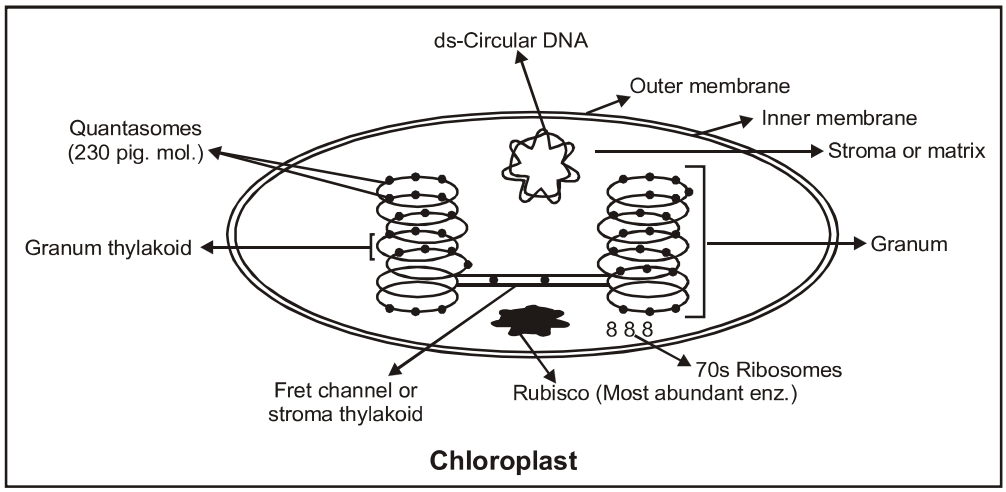
PLASTIDS

* The term **"Plastid"** first used by **Haeckel .**

Types of Plastids :

(1) **Chromoplasts :–** These are plastids, which contain different types of pigments (carotenes, Xanthophylls etc.). Chlorophylls either absent or occur in very less amount. Chromoplasts occurs mainly in **pericarp** and petals. Red colour of chillies and red tomatoes is due to the red pigment **"Lycopene"** of chromoplasts,. Lycopene is a type of carotene. Yellowish - orange colours of fruits are due to α-carotene, β-carotene and γ–carotene. β–carotene is precursor of vitamin-A. Richest source of β-carotene are carrot roots.

(2) **Chloroplasts :–** Green plastids with chlorophylls and other photosynthetic pigments.



Chloroplast

(3) **Leucoplasts :–** These store food in different forms like **starch** (Amyloplasts), **Fat and oil** (Elaioplasts) and **protein** (Aleuroplasts). Pigments and lamellar structure absents in Leucoplasts. Generally occurs in non green and underground plant cells.

* Chloroplast is a **double membrane** bound cell organelle, and is the **largest organelle of cell**.

(4-6 μm x 1-3 μm). (largest component is nucleus)

* Internally chloroplast contains **stroma** (Matrix) and thylakoids or lamellae. Matrix part of chloroplast contains **circular** or rarely linear **DNA, RNA**, **70-s Ribosomes**, **starch grains**, **enzymes of calvin cycle** or **dark reaction**. Rubisco is the most abundant enzyme on the earth. It made 16% protein of the chloroplast.

* The number of chloroplast in cell of higher plants 20-40.(One in chlamydomonas)

* **Thylakoids** (Term by **Menke** 1962) are membrane lined **flattend sacs,** which forms stacks called **granum** (**Plu. grana**). Each chloroplast contains about 20-100 granum. **Fret channel** or **stromal thylakoids** is connection between two granum. Photosynthetic pigments (chlorophylls) are located in the thylakoid membranes.
* Chloroplasts has their own genetic system & complete protein synthesis machinary (**ds-DNA, RNA, Ribosomes, enzymes, Amino Acids**), thus chloroplasts are called as **semiautonomous 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 glucose.

(2) Balancing of O_2 & CO_2 in nature.

(3) Chloroplasts impart the pleasing greenary to the earth.

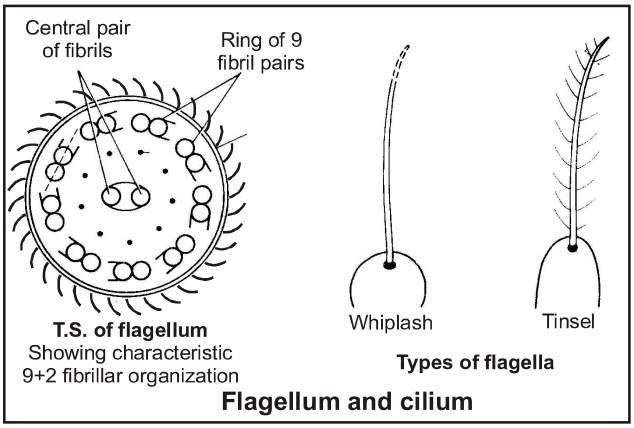
(4) Chloroplasts store vitamin K, E, Rubisco protein and **Fe** etc.

CILIA AND FLAGELLA :

* Cilia & Flagella are mechanical, hair like cellular appendages and locomotory structure. Flagellar apparatus is consist of following Parts.

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

* Bundle of microtubules is called as **axonema**. Nine microtubules are peripheral and each composed of two small tubules i.e. A tubule with two arms and **B-Tubules** without arms.
* Microtubules is consists of a contractile protein **tubulin** similar to actin of muscles.
* **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.



(b) Kinetosome or basal granule or Blepheroplast or Basal body : It is **membraneless structure**, lies immediately below the plasmamembrane. Basal body exhibit **cart wheel structure** similar to centriole. (9 triplet fibriles connected to a central hub in basal body).

* Arrangement of microtubules is 9 (triple) +0. In basal granule there occurs 9 microtubules on periphery and each microtubule is composed of three tubules i.e. A-tubule, B-tubule and C-tubule
* Central part of basal granule is composed of semisolid cytosol called **"Central Hub"**.
* Microtubules connected to central hub with the help of protein fibres called **primary fibres or spokes.**
* **Secondary fibres** connect microtubules with each other.

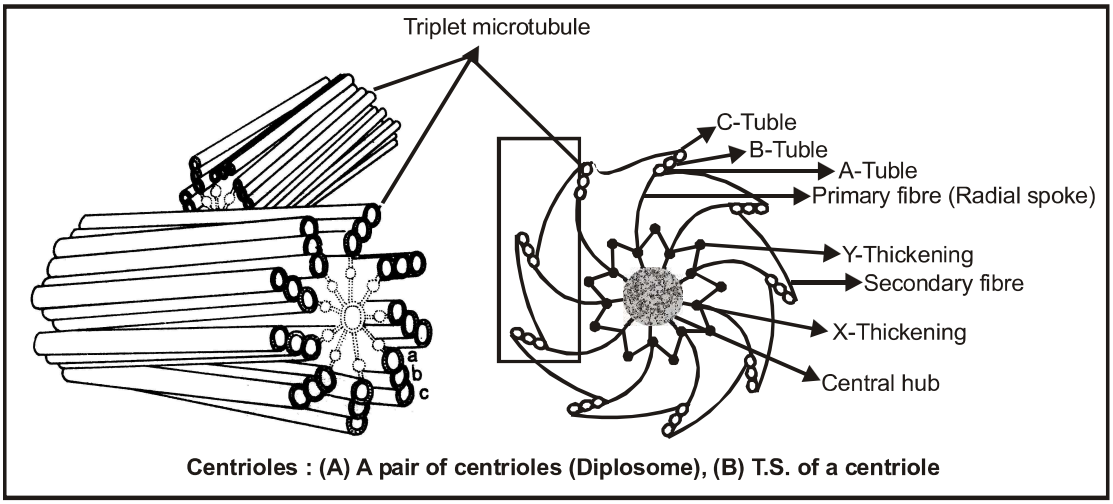
(c) Rootlet or Rhizoplast : This is a conical bundle of protein fibers which arises from basal body to different directions. Rootlet have **dark bands** composed of **ATPase**.

* Cilia and Flagella are simialr in structure but some differences may observed –

Cilia	Flagella
1. The cilia are small in size (5–10μm)	1. Flagella are long (up to 150 μm)
2. Number of cilia per cell is very large.	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

CENTROSOME :

* Centrosome was discovered by ***Benden. Boveri*** named as centrosome. Centrosome is absent in higher plants.
* Two centrioles 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** or **Microcentrum** or **diplosome**. Each centriole is surrounded by peri centriolar mass, which is called as **massules or crown or satellite.**
* Centrioles are **membraneless** 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 triplet fibers of tubulin. (9 + 0 arrangement)
* Centrioles are self duplicating units, which contains DNA, RNA and protein synthesis machinary.



Centrioles : (A) A pair of centrioles (Diplosome), (B) T.S. of a centriole

Function :– In animal cells centrioles play important role in initiation of cell division by arranging spindle fibres between two poles of cell. The location of centrioles during cell division decides the plane of division. The plane of division is always at right angle to the long axis of spindle. Thus centrioles is also termed as ***"cell centers".***

RIBOSOMES (ENGINE OF CELL) :

* **Claude** first observed them. Palade (1955) coined the term ***Ribosome***.
* In plants Robinson and Brown (1953) first observed them in bean roots.
* Except mammalian RBC all living cells have ribosomes. (Both prokaryotes & Eukaryotes)
* Ribosomes are **smallest cell organelles** (150 x 250 A^0) Ribosomes are **organelle without membranes**.
* Ribosomes are also called as ***"Organelle with in an organelle" & "Protein factory of cell"***.

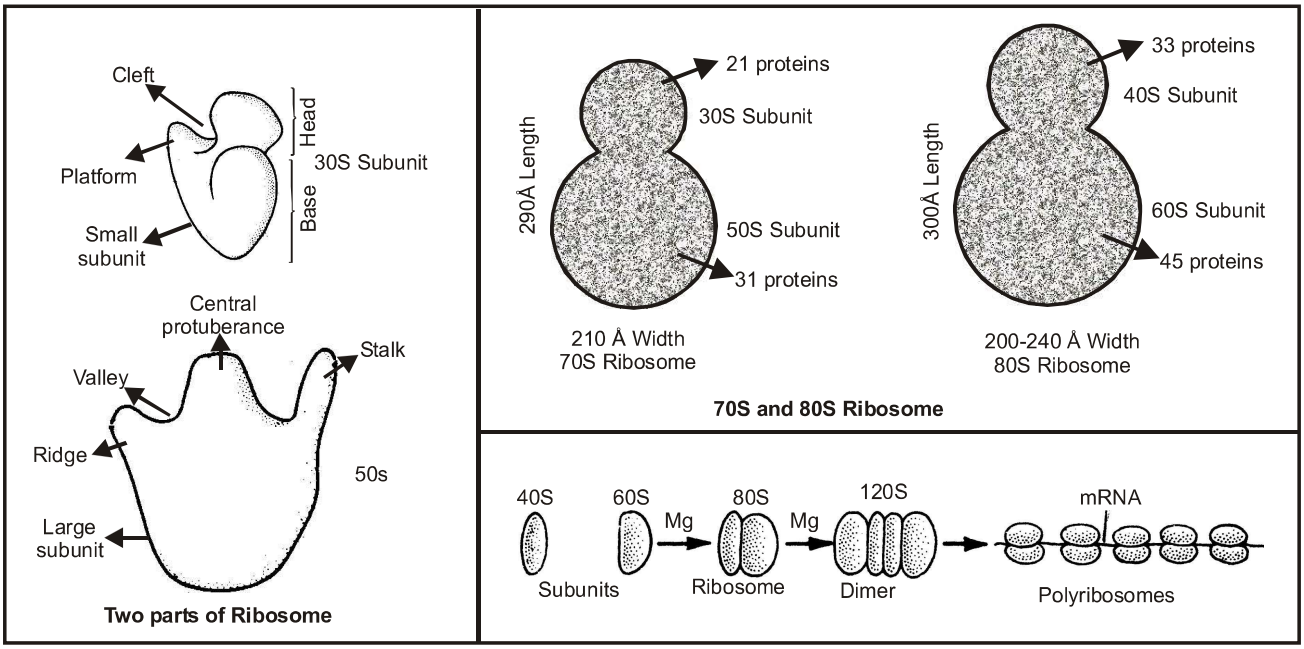
Types of Ribosomes :–

(1) **Eukaryotic ribosomes :–** 80 s - Occur in cytoplasm of eukaryotic cells.

(2) **Prokaryotic ribosomes :–** 70 s - Occur in cytoplasm of prokaryotes, and also in mitochondria, and Chloroplast of eukaryotes. (55 S ribosome present in mitochondria of mammals)

* Each ribosome composed of two subunits i.e. larger and smaller subunits. Larger subunit is dome shaped and smaller unit is ovoid. **Smaller subunit** has a platform, a cleft, a head and a base. The **larger subunit** has a protuberance, a ridge and a stalk. Larger subunit also contains a tunnel which opens in cavity of E.R.

  80s = 60s + 40s 70s = 50s + 30s
* 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*** or ***Ergosome***.
* S= Svedberg unit or Sedimentation rate



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

MICRO–BODIES :

* 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"*.

MICROTUBULES

* *Microtubules* are composed of contractile protein, **Tubulin**.
* 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.**

MICROFILAMENTS

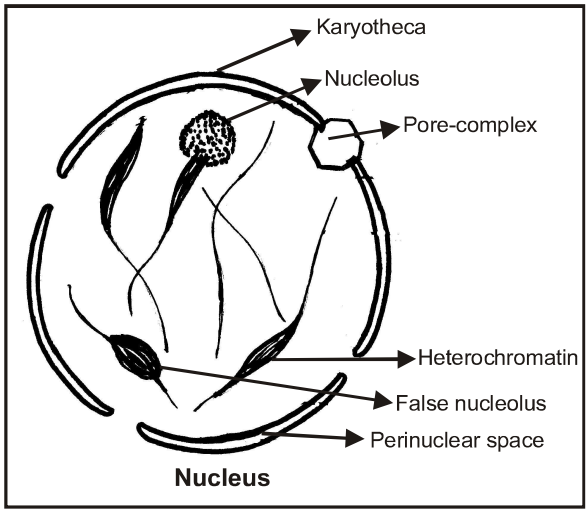
Microfilaments are long rods 40-50A^0 in thickness and distributed throughout the cytoplasm. They are composed of contractile protein, **Actin** which concern with **muscle contraction**, **and cyclosis**. Microtubules and microfilament provides cytoskeleton-base of cell.

NUCLEUS :

Introduction :

* Detail studied in orchid root cells and named by **Robert Brown** in 1831. Credit of discovery goes to Robert Brown.
* "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.
* Generally eukaryotic cell contain at least one nucleus but nucleus is absents in mature phloem **sieve tube** elements and **mature RBCs** of mammals. **(exceptionaly nucleus of RBCs of camel & lamma remains for longer time and degenerates later on)**
* Dikaryotic (Paramecium) and multikaryotic cells are also known.

Structure of Nucleus :



(i) Nuclear membrane or nuclear envelope or karyotheca.

(ii) Nucleoplasm/Karyoplasm/Karyolymph.

(iii) Chromatin net

(iv) Nucleolus/little nucleus/Ribosome factory

(i) Nuclear membrane :- Nucleus is surrounded by two unit membranes, thus nucleus is double membranous component of cell. Space (150 to 300 Å) between two membranes is known as **perinuclear space**. Outer membrane, of nucleus may connected with E.R. at several places and ribosome also may found on it.

* Nuclear membrane is perforated by minute **nuclear pores** of size, 300 to 1000Å diameter.

(ii) Nucleoplasm or Karyolymph :- (Term by **Strasburger** 1882)

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 also have enzymes for glycolysis, thus nucleus may obtain energy by glycolysis.

* **Chromatin net** and **nucleolus** are embeded in nucleoplasm. Nucleoplasm provides site for process of transcription.

(iii) Chromatin net :- (Term given by **Flemming**)

* It is an intranuclear, (stained with basic dyes) long, thread like fine fibres, which embeded 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.

* Chemically chromatin consists of DNA (31%), RNA (2-5%), Histone protein (36%) and non histone(28%). 20 to 30% part of histone is made up of arginine and lysine amino acids.

* Chromatin net has two type of chromatins (by **Emil Heitz**).

(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 have more histone and less acidic protein. Heterochromatin is **genetically less active** chromatin and forms stop point in transcription. Heterochromatin occurs near nuclear membrane.

(iv) Nucleolus :- Discovered by **Fontana** and Term by **Bowman**.

* Nucleolus is naked or **membraneless**, rounded or slightly irregular structure present in nucleus and usually attached to chromatin (or chromosomes) of specific site called **Nucleolar organiser** region/NOR.

* **Chemistry of nucleolus :-**

Proteins	85%
RNA	10%
DNA	5%

FUNCTIONS OF NUCLEOLUS :

Ribosome formation is the chief role of nucleolus, thus its called as **Ribosme factory of cell**, the proteins of ribosomes are synthesised in cytoplasm but it diffused in to nucleus and reach at nucleolus. Here r-RNA and ribosomal proteins are assembled to form ribosomes which move to cytoplasm through nuclear pores.

FUNCTIONS OF NUCLEUS :

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

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

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

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

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

CHROMOSOMES :

* 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.
* First of all, chromosomes was observed by Hofmeister (1818) and Karl Nageli in pollen mother cells (PMC) of Tradescantia.
* Strasburger (1875) described chromosome structure appeared in nucleus during cell division. **(Credit of discovery of chromosomes goes to Strasburger)**
* Term "**Chromosome**" was proposed by **Waldeyer** in 1889. (Term **'Chromatin**, was suggested by **Flemming**)
* Generally chromosomes are rod-shaped, elongated or dot like in shape with size of 0.5 to 32μ (Trillium plant has longest chromosome)
* Chromosomes can be best studied **at metaphase** stage because size of chromosomes is the shortest during metaphase due to highly condensation of chromatin threads by gelation, dehydration and coiling.

  (Shape of chromosome (V.L.J.I.) is studied at Anaphase stage)
* Generally chromosomes in plants are larger than chromosomes of animals, but number of chromosome is high in animals as compared to plants.
* The number of chromosomes has no relation with any specific feature like size, complexity of organism.

Chromosome number in some organisms :

Plants	**2n**	**n**
Mucor hemelis (Fungi)	2	1
Haplopappus gracilis (Family compositae) & Brachycome plant	4	2
Takakia (Bryophyta)	4	2
Pisum sativum (Pea)	14	7
Maize (Zea mays)	20	10
Wheat (Triticum)	42	21
Ophioglossum reticulatum (Pteridophyta)	1262	631

Animals	**2n**	**n**
Ascaris megalocephala (Round worm)	2	1
Drosophila melanogaster (Fruit fly)	8	4
Chimpanzee/Gorilla	48	24
Homo sapiens	46	23
Aulocantha (a protozoan)	1600	800

* 2n = number of chromosome in diploid cell.
  n = number of chromosome in haploid cell.
* The number of chromosome is definate for each species. For example every normal human being has 46 chromosomes in each body cell.

* Gametes of all organisms contain only one of each chromosome. The number of chromosomes in a gamete is called **"Genome"** or haploid chromosome. (Human 23) "A complete set (n) of chromosomes (all genes) inherited as a unit from one parent is known as genome,,.

* ***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. ***Banding technique*** is used to study of the specific pattern of bands and interbands on chromosome. This includes the use of **fluorochromes** (fluorescent dyes).

(i) **Q–banding :** It is obtained when chromosomes are stained with ***quinacrine mustard***. It stains A–T rich areas (developed by **casperson** for Y chromosomes).

(ii) **G–banding :** Chromosomes are stained with ***Giemsa***. It stains **sulphur rich** protein parts.

A variety of different bands are obtained by the modification of Q–banding and G–banding like C, T and N–bands. Q, C, G and R banding used for animal karyotypes while **C and N banding** used in plants.

(iii) **C-banding :-** It is used to stain constitutive **heterochromatin** , usually in centromeric region of the chromosome. The process involves denaturation of chromosome by heat or trisodium citrate and then apply giemsa stain.

(iv) **R-banding :-** The process involved incubation of the chromosomes in a buffer at high temperature followed by use of Giemsa stain. This brings about the visualization of sulphur deficient region of chromosomes thus named as **reverse giemsa**.

NEW TECHNIQUES FOR IDIOGRAM PREPARATION

Modern techniques used in karyotype preparation are ***ISH, FISH (Fluorescence in Situ Hybridisation)***, ***Mc FISH (Multicolour fluorescence in situ Hybridisation)*** and ***flow cytometry***.

* **Idiogram :–** Diagrammatic representation of Karyotype. In idiogram chromosomes are arranged in decreasing order of size. Sex chromosomes are placed in last but in idiogram of **Drosophila** sex chromosomes are placed first. Idiogram is specific for every species.

USE OF KARYOTYPING OR 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 abberrations and polyploidy.

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

1. **In Situ Hybridization :** Using DNA probe labelled with radioactive molecule to locate the position of DNA sequence on chromosome.

2. **Fluorescence in Situ Hybridization (FISH) :** DNA may also be labelled with fluorochrome to locate the position of DNA sequence on chromosome.

3. **Multicolour Fluorescence in Situ Hybridization (Mc FISH) :** More fluorochrome colour to locate the position of DNA sequence on chromosome.

4. **Flow cytometry :** This is recent technique. In this technique a suspension of many thousands of chromosome is made and the suspended chromosome are stained with a DNA binding flurochrome.

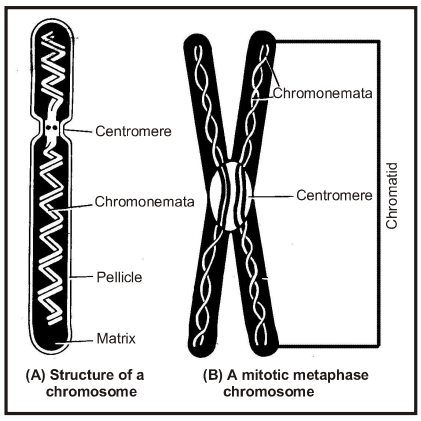
* These chromosome pass through the cytometer the fluorescence is measured for individual chromosome and the result is represented in the form of **histogram.**
* Each peak in this histogram represent, chromosome or a group of chromosome of same size.
* This technique allow detection of difference as small as 1.5 to 4.0 Mega base pair.
* This technique allow detection of aneuploidy/ duplication or deletion.

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. **Chromonema (singular Chromonemata)** → Term by **Vejdovsky.**

   This is an important, genetical, highly coiled thread, throughout the length of a chromosome or chromatid. It was called **chromonema**. Chromonema lie embeded in matrix.



* Each chromonemata is consist of a single long thread of DNA associated with histone.
* Sometimes bead like structure are seen on chromonema fibres, which are called as **chromomeres**.

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

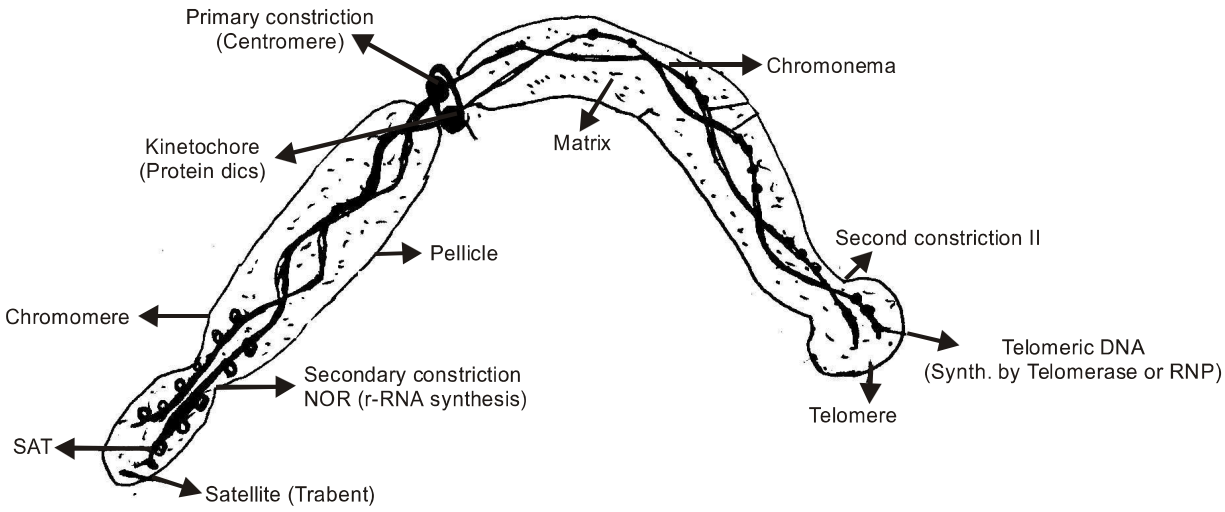
* Each chromosome (at metaphase) is consist of two half chromosome or two chromatids. Both the chromatids of a chromosome are joined or connected by a structure called **Centromere**. At this point or centromere two protein discs are present which is called **Kinetochore.**
* **Kinetochores** constitute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

5. **Chromatid –** At metaphase stage each chromosome is consist of two cylindrical structures - called **chromatids**. Both sister chromatids or longitudinal half chromosome are joined together by a common **centromere**. A chromosome, may have single chromatid (in Anaphase or Telophase) or two chromatid. (as in metaphase)
6. **Secondary constriction :** Besides primary constrictions one or two, other constriction may also occurs on some chromosome, which are known as secondary constriction.

* Secondary constriction is also known as **NOR** (**Nucleolar organizer region**)(13,14,15,21,22 chromosomes in human)

7. **Satellite :** part of chromosome remains after the NOR is known as chromosomes **satellite/Trabent**.

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



A schematic diagrammatic representation of 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 acrocenteric chromosome.