UNIT

3

Cell : Structure and Function

CELL : THE UNIT OF LIFE

- Cell is the basic unit of life and structural and functional unit of an organism. It is the smallest unit capable of independent existence and performing the essential functions of the life.
- **Anton von Leeuwenhoek** first saw and described a live cells. **Robert Brown** later discovered the nucleus. The invention of the microscope and its improvement leading to the electron microscope revealed all the structural details of the cell.

CELL THEORY

- Cell theory was jointly put forward by **Schleiden** and **Schwann** in 1839. Cell theory states that the bodies of all organisms are made up of cells and their products so that cells are units of both structure and function of living organisms.
- **Rudolf Virchow** (1855) first explained that cells divide 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.

Fundamental features of cell theory

- The fundamental features of cell theory are :

(i) All living organisms are composed of cells and their products.

(ii) Each cell is made up of a small mass of protoplasm containing a nucleus in its inside and a plasma membrane with or without a cell wall on its outside.

(iii) New cells arise from pre-existing cells.

- Viruses are exception to cell theory as they are not composed of cell. They consist of a nucleic acid (DNA or RNA) surrounded by a protein sheath and are incapable of independent existence, self regulation and self reproduction.

Table : Differences between prokaryotic and eukaryotic cells

	Prokaryotic cell	Eukaryotic cell
1.	The cell size is usually small (0.1 - 5.0 μm).	The cell size is comparatively larger (5-100 μm).
2.	A prokaryotic cell has one envelope organisation.	An eukaryotic cell has two envelope organisation.
3.	The flagella, if present, are single stranded, and without differentiation of axoneme and sheath.	The flagella, if present, are 11-stranded, (9+2 arrangement). They show differentiation of axoneme and sheath.
4.	An organised nucleus is absent. Instead a nucleoid is found.	An organised nucleus is found. It is differentiated into nuclear envelope, chromatin, one or more nucleoli, and nucleoplasm.
5.	Cell wall, if present, possesses muramic acid.	Cell wall, if present, does not contain muramic acid.
6.	DNA is naked, that is, without an association with histones. DNA is usually circular.	Nuclear DNA is associated with histone proteins. Nuclear DNA is linear while extra-nuclear DNA is circular.
7.	DNA lies freely in the cytoplasm. It is not associated with any organelle.	Most of the cell DNA lies in the nucleus. A small quantity is also found in the plastids and mitochondria.
8.	Transcription and translation occur in the cytoplasm.	Transcription occurs in the nucleus while translation takes place in the cytoplasm.
9.	Additional small circular DNA segments or plasmids may occur.	Plasmids are usually absent.
10.	Ribosomes are of 70S type.	Ribosomes are of 80S type. 70S ribosomes, however, occur in plastids and mitochondria.
11.	ER, mitochondria, Golgi apparatus, lysosomes and centrioles (centrosome, central apparatus) are absent.	ER, mitochondria, Golgi apparatus and lysosomes or their equivalents are present in all the eukaryotic cells. Centrioles are usually present in animal cells.
12.	Cell membrane may be infolded to form a complex structure called mesosome.	Mesosome-like structures are absent.

CELL SIZE AND SHAPE

- Generally the cell size ranges between **0.2–20** μ. The **smallest cell** is considered to be of **PPLO (Pleuro Pneumonia Like Organisms)** or *Mycoplasma gallisepticum*, *i.e.*, 0.1 μ. The largest cell is an egg of ostrich which measures as much as 6 inches in diameter with shell and 3 inches without shell.
- There is great variability in cell shape, *i.e.*, **spherical**, **polygonal**, **disc-like**, **cuboidal**, **columnar**, **spindle-like**, etc. The shape of cell is related to its position (flat in surface cells, polygonal in cortex) and function (*e.g.*, RBCs are biconcave to pass through capillaries and carry O_2).

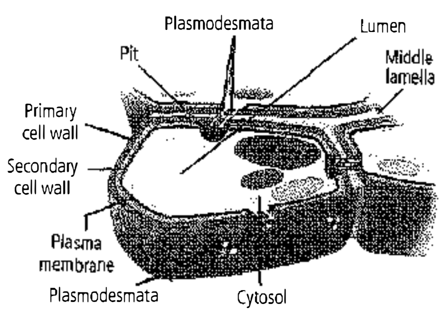
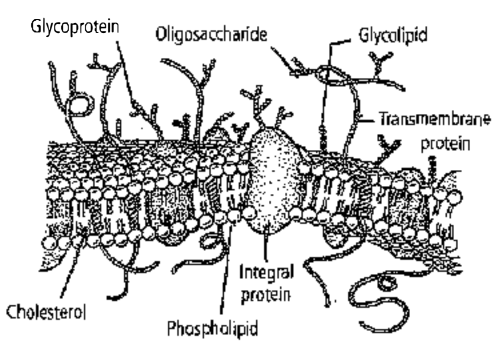
TYPES OF CELLS

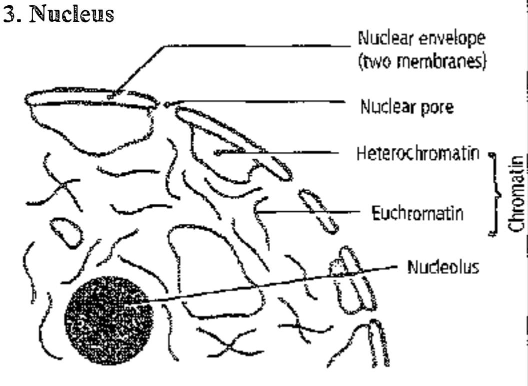
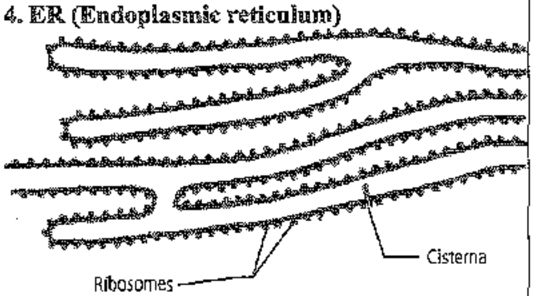
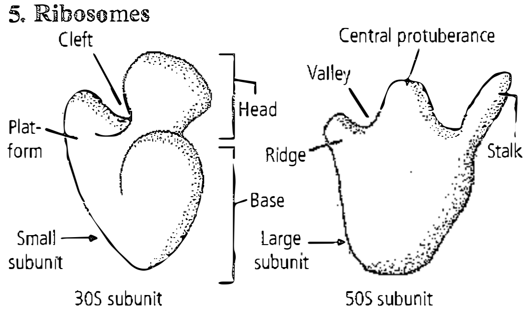
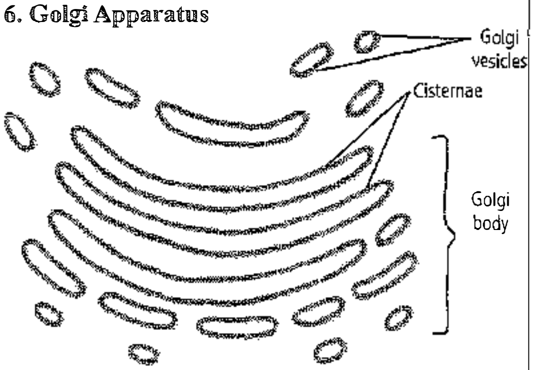
- On the basis of **nature of nucleus**, cells are of two types: prokaryotic cell and eukaryotic cell.
- A **prokaryotic cell** is the one in which the genetic material is not organised into nucleus (Greek. *pro*–before, *karyon*-nucleus) and all membrane bound organelles are absent so there is single envelope system of organisation.
- Prokaryotic cells occur in **bacteria**, **archaebacteria**, *Mycoplasma* (PPLO), **spirochaetes**, **rickettsiae**, **chlamydiae** and **cyanobacteria** (or blue green algae).
- **Eukaryotic cells** (Greek : *Eu* – true + *Karyon* – nucleus) are with true or well defined nucleus with membrane bound organelles are eukaryotic cells, *e.g.*, higher plants and animals.

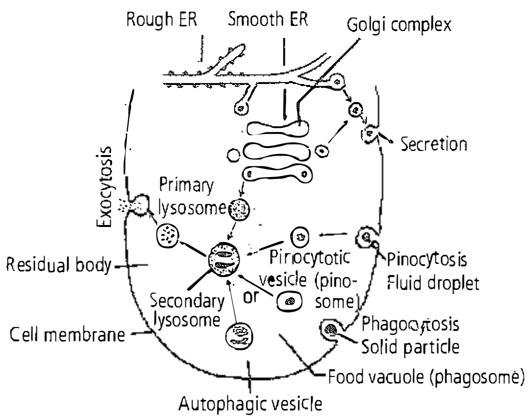
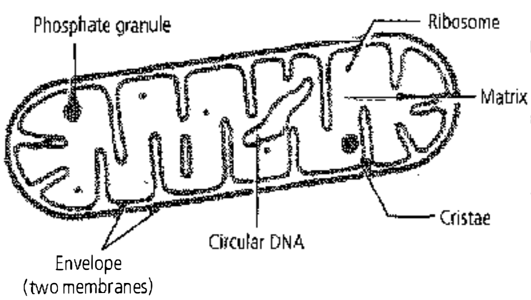
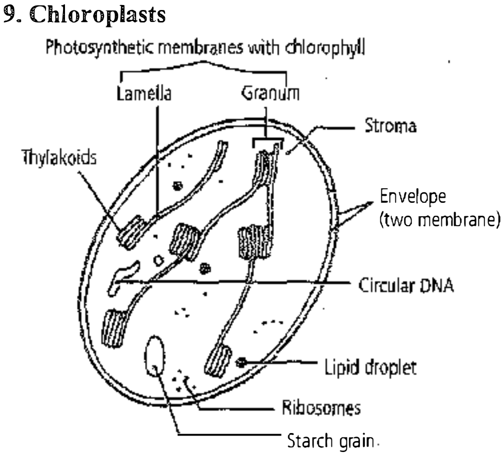
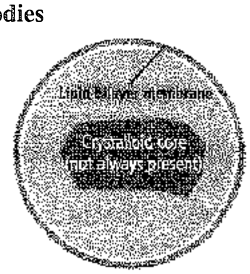
PROKARYOTIC CELLS

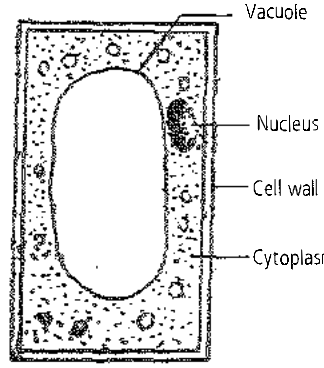
- Most prokaryotic cells, particularly the bacterial cells, have a chemically complex cell envelope. The cell envelope consists of a tightly bound three layered structure *i.e.*, the outermost glycocalyx followed by the **cell wall** and then the **plasma membrane.** Bacterial cell walls are made of **peptidoglycan.**
- 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.** Those that take up the Gram stain are **Gram positive** and the others that do not are called **Gram negative** bacteria.

Table : Different types of cell organelles

Cell organelles	Features	Functions
1. Cell wall  **Fig.:** T.S. of a cell showing cell wall and plasmodesmata	• Consisting of cellulose microfibrils running through a matrix of other complex polysaccharides. • Mainly composed of **middle lamella, primary** and **secondary cell wall.** • **Middle lamella** is made up of pectates of calcium and magnesium. • **Plasmodesmata,** linking the cytoplasm of adjacent plant cells is present in the cell wall. It encloses tubular extension of ER (endoplasmic reticulum) called **desmotubules.** • Plasmodesmata form channels for controlled passage of small sized particles between adjacent cell as well as transfer of some specific signals.	• Provides mechanical support and protection. • Prevents osmotic bursting of the cell. • Pathway for the movement of water and mineral salts. • Cements neighbouring cells together. • Provides a protoplasmic continuum called symplast for transport of substances between cells.
2. Cell membrane  **Fig.:** Fluid-mosaic model of a biomembrane	• It has trilaminar appearance (3 layers), a pale layer sandwiched between 2 dark layers. • **Danielli** and **Davson** have proposed bilayer model of plasma membrane. • Unit membrane concept was proposed by **Robertson** (1959). • Fluid mosaic model was proposed by **Singer** and **Nicolson** in 1972.	• A partially permeable barrier controlling exchange between the cell and its environment. • Promote compartmentalisation. • The cell membrane may present regional differentiations that are related to specialised functions like absorption, secretions, fluid transport, electric coupling and other physiological processes.

3. Nucleus  **Fig.**: Nucleus	• Largest cell organelle, enclosed by an envelope of two membranes that is perforated by nuclear pores. • **Robert Brown** (1831) first described nucleus and saw it in an orchid root cell. • It contains chromatin which is the entended form taken by chromosomes during interphase. It also contains a nucleolus. • Chemically, it is composed of **DNA** – 9-12%, basic proteins (histones) – 15%, **enzymes**, **acid proteins** and **neutral proteins** – 65%, **RNA** – 5%, **lipids** – 3% and **minerals**, (Ca^{2+}, Mg^{2+}, K^+, Na^+) – in traces.	• Chromosomes contain DNA, the molecule of inheritance. DNA is organised into genes which control all the activities of the cell. • Nuclear division is the basis of cell replication and hence reproduction. • The nucleolus manufactures ribosomes.
4. ER (Endoplasmic reticulum)  **Fig.**: Endoplasmic reticulum (ER)	• It is a system of flattened, membrane bounded sacs called cisternae, forming tubes and sheets. Discovered by **Porter** and **Thompson.** • It is of two types : SER and RER • SER (Smooth endoplasmic reticulum) consists mainly of tubules and vesicles. It is free of ribosomes. • RER (Rough endoplasmic reticulum) consists of cisternae and has ribosomes attached on its surface.	• Transports proteins made by the ribosomes through cisternae. • SER is the site of lipid and steroid synthesis. • SER brings about detoxification. • Participates in membrane biogenesis.
5. Ribosomes  **Fig.**: Parts of ribosomes	• Discovered by **Robinson** and **Brown** in plant cell and by **Palade** in animal cell. • Very small organelles consisting of a large and small sub-unit. • Eukaryotic ribosomes are of 80S (60S and 40S), while prokaryotic ribosomes are of 70S (50S and 30S). • Non-membranous organelles. • Mg^{2+} is required for binding the two sub-units. • Made up of proteins and *r*RNA.	• Sites for protein synthesis. • May form polyribosomes, polysomes or ergosomes; collection of ribosome strung along *m*RNA. • Larger sub-unit contains enzyme peptidyl transferase needed for the formation of polypeptides.
6. Golgi Apparatus  **Fig.**: Golgi Apparatus	• Discovered by **Camillio Golgi** in 1898. • A stack of flattened membrane -bounded sacs, called cisternae, continuously being formed at one end of the stack and budded off as vesicles at the other. • One face of the apparatus is convex called **forming** or **formative** or ***cis*-face** while the other is **concave** known as **maturing face** (***trans*-face**). • The expanded form of cisternae modified to form vacuoles.	• Internal packaging and transportation. • Synthesis of carbohydrates, cell wall, hormones, pigments, acrosomes, lysosomes etc. • Secretion of substances. • Transformation of membranes of one type to another.

7. Lysosomes  **Fig.:** Types of lysosomes and their functions	• A simple spherical sac surrounded by a single membrane. • First reported by Christian de Duve in 1955. • They contain **digestive** or **hydrolytic enzymes** synthesised by RER. • No internal structure visible.	• Called "suicidal bags" of the cell because they digest the incoming food materials and remove the foreign bodies, toxic molecules and debris. • Helps in thyroxine formation, in fertilisation and renewal of worn out cells and organelles.
8. Mitochondria  **Fig.:** Mitochondria	• Double membranous organelle, first observed by **Kolliker.** The term was coined by **Benda.** • Inner membrane folded to form cristae small stalked particles or F_0 - F_1 particles or elementary particles are present on cristae. • Mitochondria are called **semi-autonomous organelles** as they contain their own DNA, ribosomes and can synthesise some of their own structural proteins.	• Main sites of **cell respiration.** • Cristae are the sites of oxidative phosphorylation and electron transport. Matrix is the site of **Krebs' cycle.** • Provide intermediates for the synthesis of chlorophyll, cytochromes, pyrimidines etc. • Synthesis of many amino acids.
9. Chloroplasts  **Fig.:** Chloroplast	• **Schimper** called the green plastids the chloropalsts. • Double membranous and contains a gel-like **stroma** through which runs a system of membranes that are stacked in places to form **grana.** • A granum is composed of 20-50 **thylakoids** in the chloroplasts of higher plants and a chloroplast may have 40-100 grana in its matrix. • Thylakoid membrane contains photosynthetic pigments (photosystems). • Stroma also contains ribosomes, circular DNA molecule and lipid droplets.	• Photosynthesis takes place. • Light energy is converted to chemical energy; "energy transduction". • Synthesis of fatty acids, storage of lipids. • Like mitochondria, called semi-autonomous organelle, which can synthesise few of its own protein.
10. Microbodies  **Fig.:** Microbodies	• Roughly spherical organelles bounded by a single membrane. • Contents appear finely granular except for occasional filamentous deposits. • First seen by **Rhodin** in 1954 in mouse kidney tubule cells. • These are of two types : **peroxisomes** and **glyoxysomes.**	• Peroxisomes metabolize a number of toxic substances, performs photorespiration, synthesizes peroxide. • Glyoxysomes contain enzyme for β-oxidation of fatty acids and glyoxylate pathway.

11. Vacuoles  Fig.: Vacuole	• Sacs surrounded by single membrane called tonoplast and contain cell sap. • Occurs in all type of cells; are small in animal cells and large in fungal and plant cells. Typically large in mature cells.	• Storage of various substances including waste products. • Important contribution to the osmotic properties of the cell. • Sometimes function as lysosomes. • Functions as contractile vacuoles, food vacuoles, gas vacuoles etc.

- **Gram-positive bacteria** possess a thick cell wall containing many layers of peptidoglycan and teichoic acids. In contrast, **Gram-negative bacteria** have a relatively thin cell wall consisting of a few layers of peptidoglycan surrounded by a second lipid membrane containing lipopolysaccharides and lipoproteins.
- A special membranous structure is the **mesosome** which is formed by the extensions of plasma membrane into the cell.
- 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.
- Bacterial cells may be motile or non-motile. If motile, they have thin **filamentous extensions** from their cell wall called **flagella.**
- **Pili** are longer, fewer and thicker tubular outgrowths which develop in response to F^+ or **fertility factor** in **Gram–ve bacteria.** So they are also called **sex pili.** They help in attaching to recipient cell and forming conjugation tube.
- **Fimbriae** are formed in large numbers. They help in attaching bacteria to solid surfaces or host tissues.
- Each ribosome (70S) has two subunits, larger 50S and smaller 30S. Ribosomes take part in protein synthesis.

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.
- All eukaryotic cells are not identical. Plant and animal cells are different as the former possess cell walls, plastids and a larger central vacuole which are absent in animal cells.

PLASTIDS

- The term plastid was introduced by **E. Haeckel** in 1866. Plastids are semiautonomous organelles having DNA and double membrane envelope which store or synthesize various types of organic compounds. Plastids are present in all living plant cells and some protistans (*e.g.*, *Euglena*, dinophyceae and diatoms).
- According to their structures, pigments and functions, plastids are of three types – **leucoplasts, chromoplasts** and **chloroplasts.**
- Leucoplasts are **colourless plastids.** There are three types of special leucoplasts. **Amyloplasts** are starch containing leucoplasts, *e.g.*, potato tuber. **Elaioplasts** are colourless plastids which store lipids, *e.g.*, tube rose. **Aleuroplasts** are protein storing plastids, *e.g.*, aleurone cells of maize grain.
- **Chromoplasts** are yellow or reddish in colour because of the presence of carotenoid pigments. Chlorophyll are absent in chromoplasts. Chromoplasts are formed either from leucoplasts or chloroplasts.
- Chloroplasts : *Refer to table on page 126.*

CYTOSKELETON

- An elaborate network of filamentous proteinaceous structures present in the cytoplasm is collectively referred to as the cytoskeleton. The cytoskeleton in a cell are involved in many functions such as **mechanical support, motility,** maintenance of the **shape of the cell.**
- They are of three types : **microfilaments, intermediate filaments** and **microtubules.**

CILIA AND FLAGELLA

- The cilia and flagella are microscopic, contractile and filamentous processes of the cytoplasm which are capable of producing a current in fluid medium for locomotion and passage of substances, act as sensory organs and perform many mechanical functions of the cell.
- Both arise from the basal bodies, are similar in chemical composition, have basically identical ultrastructure, and serve the same purpose, *i.e.*, their movements either propel the organism or move the medium past a fixed cell. However, the two are distinguishable by their number, size, mode of beating.
- Cilium or the flagellum 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 pairs of 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.** The central tubules are connected by bridges and is also enclosed by a central sheath, which is connected to one of the tubules of each peripheral doublets by a radial spoke. Thus, there are nine radial spokes. The peripheral doublets are also interconnected by linkers. Both the cilium and emerge from centriole-like structure called the **basal bodies.** Movements of cilia and flagella are brought about by sliding of doublet fibrils against each other rather than by their contraction.

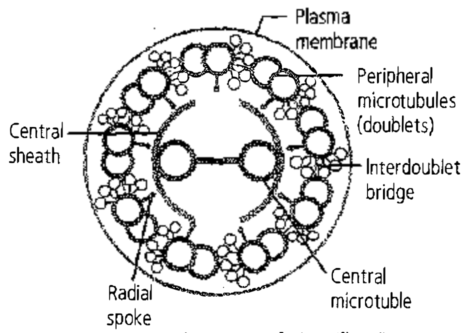


Fig.: Internal structure of cilium/flagellum

CENTRIOLES

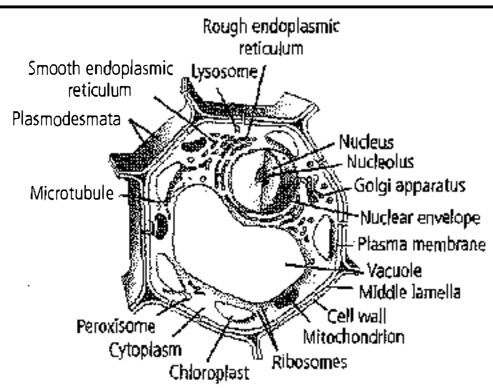
- Cytoplasm of some eukaryotic cells contains two cylindrical, rod-shaped, microtubular structures, called **centrioles,** near the nucleus.
- Centrioles lack limiting membrane and DNA or RNA and form microtubule organizing centre (cell division) and sometimes get arranged just beneath the plasma membrane to form flagella or cilia in flagellated or ciliated cells.
- The centrioles commonly occur in pairs. A pair of centrioles is called a **diplosome.** They lie in a small masses of specialized, distinctly staining cytoplasm that lacks other cell organelles and is called **centrosphere,** or **kinoplasm** or **cytocentrum.** The centrioles and the centrosphere are together referred to as centrosome.
- A centriole possesses a whorl of nine peripheral fibrils. Fibrils are absent in the centre. The arrangement is, therefore, called **9 + 0** which run parallel to one another but at an angle of 40°. Each fibril is made up of three sub-fibres called **triplet fibril.** The centre of centriole possesses a rod-shaped proteinaceous mass known as **hub.** From the hub, develops 9 proteinaceous strands towards the peripheral triplet fibrils called **radial fibres or spokes.**

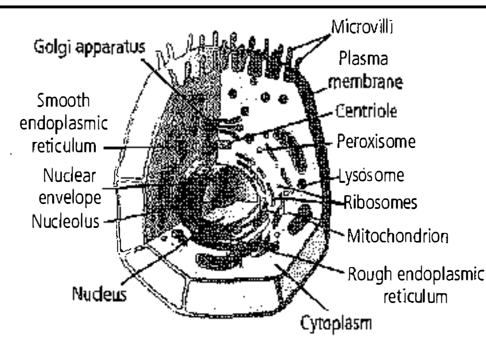
CHROMOSOMES

- During prophase of nuclear division, the chromatin fibres condense to form a definite number of thread like structures called **chromosomes.**
- A single human cell has approximately two metres long thread of DNA distributed among its **forty six** (twenty three pairs) **chromosomes.**
- The given table shows the differences between plant and animal cell :

Table : Differences between plant cell and animal cell

	Plant cell	Animal cell
1.	A plant cell has a rigid cell wall on the outside.	A cell wall is absent (Schwann 1838). Cell is enclosed by plasma membrane.
2.	Plastids are found in plant cells.	Plastids are usually absent.
3.	A mature plant cell contains a large central vacuole.	An animal cell often possesses many small vacuoles.
4.	Mitochondria are comparatively fewer.	Mitochondria are generally more numerous.
5.	Centrioles are usually absent except in lower plants.	Centrioles are found in animal cells.
6.	Spindle formed during nuclear division is anastral.	Spindle formed during nuclear division is amphiastral.
7.	Lysosomes are rare. Their activity is performed by specialised vacuoles.	Typical lysosomes occur in animal cell.
8.	Glyoxysomes may be present.	They are absent.
9.	Reserve food is generally starch and fat.	Reserve food is usually glycogen and fat.
10.	Adjacent cells may be connected through plasmodesmata.	Adjacent cells are connected through a number of junctions.





- Every chromosome essentially has a primary constriction or the centromere on the sides of which disc shaped structures called **kinetochores** are present.
- Based on the position of the centromere, the chromosomes can be classified into four types. The **metacentric chromosome** has middle centromere forming two equal arms of the chromosome. The **sub-metacentric chromosome** has centromere slightly away from the middle of the chromosome resulting into one shorter arm and one longer arm. In case of **acrocentric chromosome** the centromere is situated close to its end forming one extremely short and one very long arm, whereas the telocentric chromosome has a terminal centromere.
- All eukaryotic cells are not identical. Plant and animal cells are different as the former possess cell walls, plastids and a larger central vacuole which are absent in animal cells.
- Mitochondria can synthesise 12 different structural proteins, which are incorporated into the inner mitochondrial membrane. The mitochondrial protein synthesis is inhibited by antibiotic **chloramphenicol.**
- An individual gets mitochondria and mitochondrial genes from its mother because the middle piece of a sperm that contains mitochondria does not enter the egg during fertilisation. This inheritance pattern of mitochondrial genes is called uniparental inheritance.
- Taxol, an anticancer drug, increases the formation of microtubules and stabilises them so that there is no free tubulin for the formation of mitotic spindles. **Vinblastin** causes disassembly of formed microtubules and causes the aggregation of crystalline tubulin. Colchicine, binds to microtubules resulting in their breakdown by inhibiting microtubules formation.

CONCEPT MAP