Cell : The Unit of Life

Prokaryotic Cell

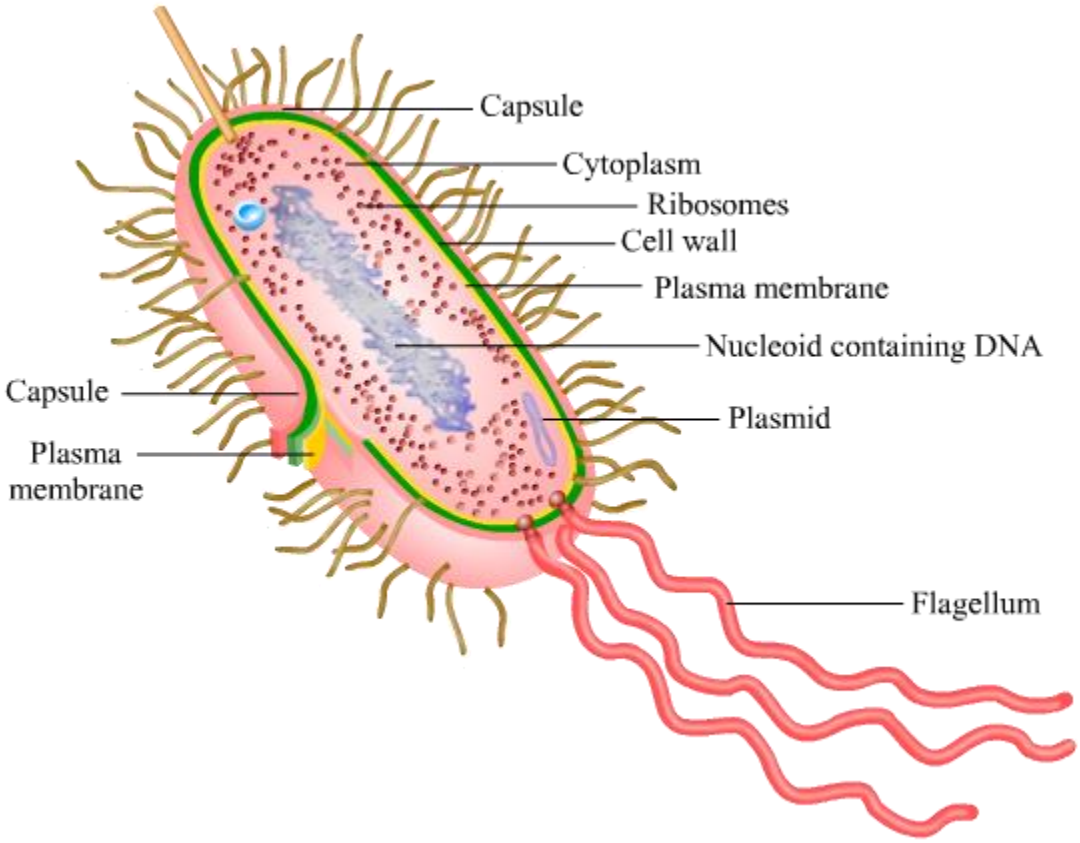
What is a Cell?

- A fundamental, structural and functional unit of all living organisms
- Anton von Leeuwenhoek first described the live cells.
- Cell theory:
- All living organisms are composed of cells and products of cells.
- All cells arise from pre-existing cells.
- Smallest cell: *Mycoplasma* (0.3 μm)
- Largest cell: Ostrich egg
- Longest cell: Nerve cell

Prokaryotic Cells

- Represented by bacteria, blue-green algae, PPLO and *Mycoplasma*
- Smaller and rapidly multiplying
- Vary greatly in shape and size
- Characteristic features:
- Have cell wall surrounding the cell membrane
- Absence of a well-defined nucleus
- May have plasmids − small, circular, extra-chromosomal DNAs present in addition to the genomic DNAs; this confers characteristics like antibiotic resistance to bacteria, and help in bacterial transformation with foreign DNA.
- Absence of organelles (only ribosomes are found in prokaryotes)
- Have mesosomes (specialised differentiated cell membranes); these are infoldings of the cell membrane

- Have inclusion bodies



Cell Envelope in Prokaryotes

- **Cell Envelope − Three-Layered Structure**
- *Glycocalyx* (Outermost): May be present in the form of loose sheath called slime layer in some bacteria, or as a thick and tough capsule in others
- *Cell wall* (middle): Determines the shape of a cell and provides a strong structural support
- *Plasma Membrane* (innermost): Semi-permeable and structurally similar to that of eukaryotes
- ***Mesosome***
- Formed by the extension of the plasma membrane into the cell
- These extensions are made up of vesicles, tubules and lamellae.

- Functions: Cell wall formation; DNA replication and distribution; respiration and secretion processes; increase surface area of plasma membrane and enzymatic content

- **Prokaryotic Cell may be − Motile or Non-Motile**

- Motile: Have flagella

- Non-motile: Lack flagella

- Flagella has three parts: Filament, Hook, Basal body

- Pili (tubular structures made of proteins) and fimbriae (bristle-like fibres) are also present along with flagella, but their function is attachment (to the substratum or the host cell).

- Depending upon the cell envelope, bacteria are of two types:

- Gram positive − take up gram stain

- Gram negative − do not take up gram stain

Ribosome

- Associated with plasma membrane

- Made up of two subunits: 50S and 30 S = 70S

- Site of protein synthesis

- Polysome: When several ribosomes attach to a single mRNA

- Help in the translation of mRNA into proteins

Inclusion Bodies

- Reserve material in prokaryotic cells is stored in the form of inclusion bodies.

- Suspended freely in the cytoplasm, e.g., phosphate granules or glycogen granules

- Gas vacuoles: found in blue-green, purple and green photosynthetic bacteria

Let us find out some more differences between gram positive and gram negative

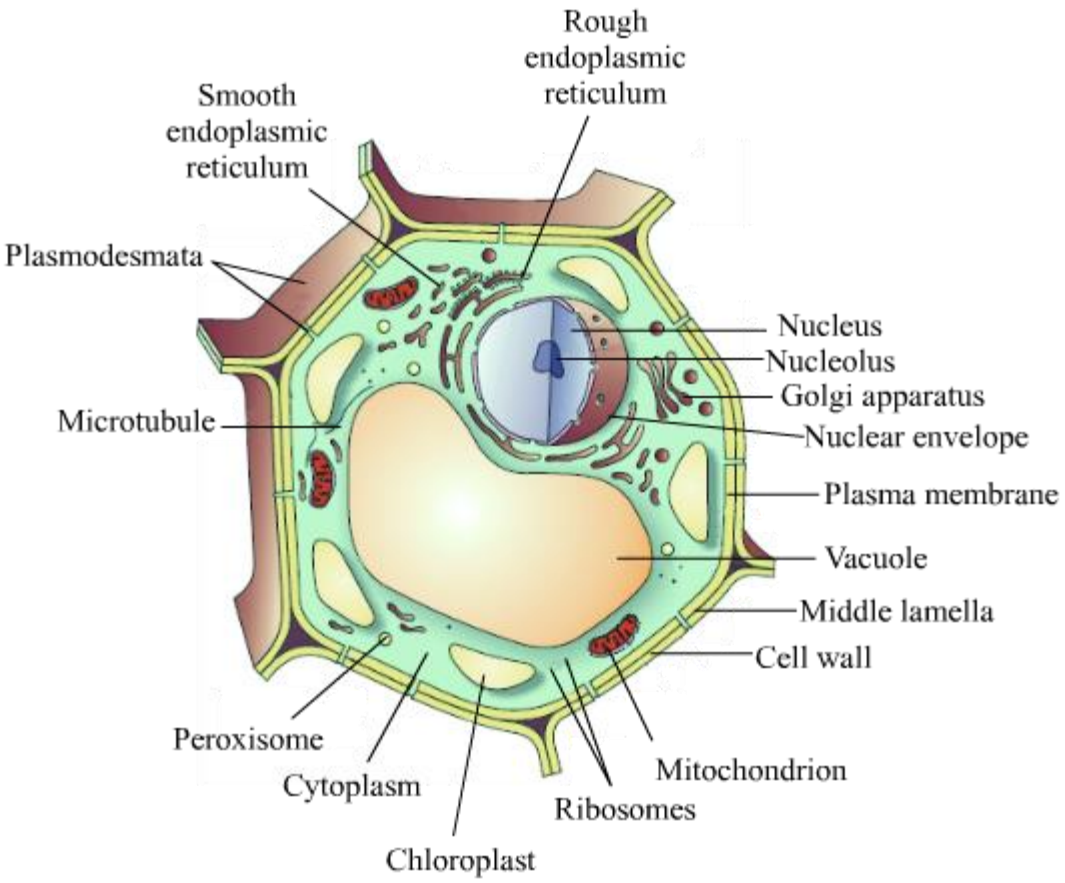
bacteria.

Gram Positive Bacteria	Gram Negative Bacteria
They retain the crystal violet stain during gram staining.	They do not retain the crystal violet stain during gram staining.
They lack the outer membrane.	They possess the outer membrane.
Peptidoglycan layer in cell wall is thick and multilayered.	Peptidoglycan layer in cell wall is thin and single layered.
Cell wall is smooth and is around 20-80 nm thick.	Cell wall is wavy and is around 5-10 nm thick.
Cell wall contains very less lipid content.	Cell wall contains high lipid content.
Very few bacteria are pathogenic in nature.	Most of the bacteria are pathogenic in nature.
Examples include *Bacillus, Streptococcus, Clostridium,* etc.	Examples include *Chlamydia, Pseudomonas, Salmonella,* etc.

Eukaryotic Cell, Cell Membrane and Cell Wall

Eukaryotic Cell

- Represents cells of protists, plants, animals and fungi
- Several membrane-bound organelles are present
- Nucleus has a nuclear envelope; genetic material is organised into chromosomes
- Has complex locomotory and cytoskeleton structures
- Plant cells possess cell wall, plastids and a large central vacuole, which are absent from animal cells.
- Animal cells possess centrioles, lysosomes, numerous small-sized vacuoles, which are absent from plant cells.



A eukaryotic cell (Plant cell)

Cell Membrane (Plasma Membrane)

- Composed of a lipid bilayer, with a polar head towards the outer side, and hydrophobic tails towards the inner side. So, the non-polar, hydrophobic tail is protected from aqueous environment.
- Proteins and carbohydrates are also present in the cell membrane.
- Membrane proteins can be integral (lying buried in the membrane) or peripheral (lying on the surface of the membrane).
- Fluid mosaic model (Singer and Nicolson) shows that the quasi-fluid nature of lipids enables lateral movement of proteins within the bilayer.
- Fluidity is the measure of the ability of the membrane to allow movement within itself.
- Fluid nature of the membrane is important for cell division, cell growth, the formation of intercellular junctions, secretion and endocytosis.

- Transport across plasma membrane:

- *Passive transport* − does not require energy; neutral solute moves by diffusion, along the concentration gradient;
  Water moves through osmosis; polar molecules that cannot diffuse move through facilitated diffusion, carried out by carrier proteins

- *Active transport* − requires energy for transport against the concentration gradient

Cell Wall

- Present exterior to the cell membrane in fungi and plants

- Gives shape and protection to cell

- Helps in cell to cell interactions; provides a barrier against undesirable macromolecules

- Algae cell wall: Has cellulose, galactans, mannans, minerals ($CaCO_3$)

- Plant cell wall: Has cellulose, hemicelluloses, pectins and proteins

- In a young plant cell, the primary cell wall is present; it diminishes as the cell matures and is replaced by the secondary cell wall, towards the inner side of the cell.

- Neighbouring plant cells are separated by a layer called middle lamella.

- Plasmodesmata traverses the cell wall and the middle lamella, and connects cytoplasm of the neighbouring cells.

Eukaryotic Cell Organelles, Endomembrane System and Ribosomes

Endomembrane System

- Some organelles with coordinated functions together constitute the endomembrane system.

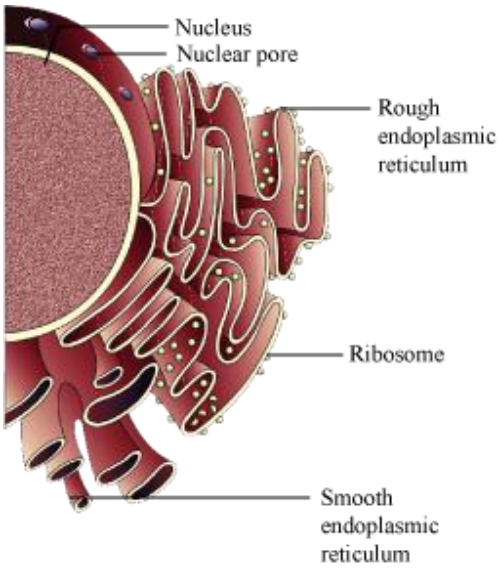
- Endomembrane system includes the endoplasmic reticulum (ER), Golgi complex, lysosomes and vacuole.

- Endoplasmic Reticulum:

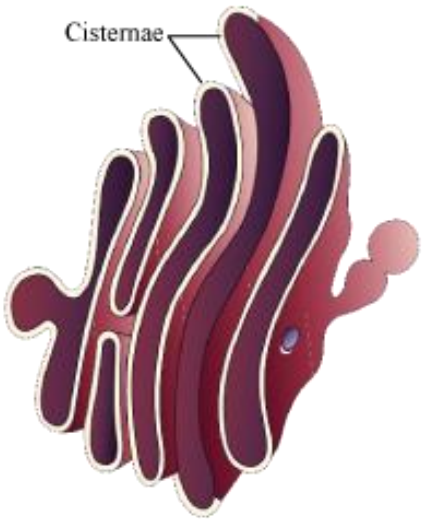
- Reticulum (network) of tiny tubular structures scattered in the cytoplasm

- ER divides the intracellular space into luminal (inside ER) and extra-luminal (cytoplasm) compartments

- ER is of two types − rough ER (has ribosomes attached to its outer surface) and smooth ER (ribosomes absent, so it appears smooth)



- RER is found in cells involved in proteins synthesis.
- SER is the major site for lipid synthesis.
- Golgi Apparatus:
- Reticular structure consisting of many disc-shaped sacs (cisternae), stacked parallel to each other



- Cisternae have 2 distinct faces −
  Convex (*cis*) − forming face

Concave (*trans*) − maturing face
Cis and *trans* faces are interconnected.

- Function − packaging of materials, either to be delivered to the intracellular targets or to be secreted outside the cell
- Materials to be packaged in the form of vesicles from ER fuse with the cis face of the golgi apparatus and move towards the trans face.
- Glycolipids and glycoproteins are also synthesised in the Golgi apparatus.
- Lysosomes:
- Lysosomes are vesicles formed as a result of the packaging in the Golgi apparatus.
- These are rich in all types of hydrolytic enzymes (optimally active at acidic pH), and are capable of digesting all types of molecules, such as carbohydrates, lipids, proteins and nucleic acid.
- Vacuole:
- Membrane-bound space in cells; containing water, sap, excretory products and other waste materials
- Vacuole membrane − Tonoplast
- Tonoplast has the ability to pump ions into the vacuole against the concentration gradient. So, the concentrations of ions in the vacuole are greater than in the cytoplasm.
- E.g., Contractile vacuole is found in *Amoeba* for excretion; food vacuole is found in protists formed by the engulfment of food particles

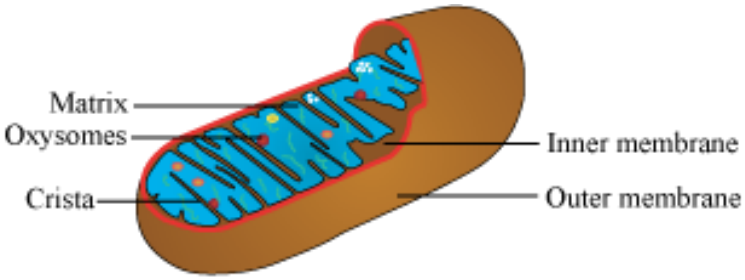
Ribosomes

- Granular structures, first observed by George Palade under an electron microscope
- Composition: RNA and proteins
- Not surrounded by any membrane
- Prokaryotic cells have ribosomes 70S. Eukaryotic ribosomes are 80S. S stands for Svedberg's Unit, and is indicative of density and size.

Semi Autonomous Cell Organelles: Mitochondria and Chloroplast

Mitochondria

- Sausage-shaped or cylindrical cell organelles, visible only with specific staining under the microscope
- Have *double-membrane system*: Inner membrane and Outer membrane
- These membranes divide the lumen of the mitochondria into two compartments − the outer compartment and the inner compartment (*matrix*)
- Outer membrane − forms the boundary of the organelle
- Inner membrane − forms the infoldings called *cristae*; this increases the surface area of the inner membrane
- Both membranes have specific enzymes associated with them.



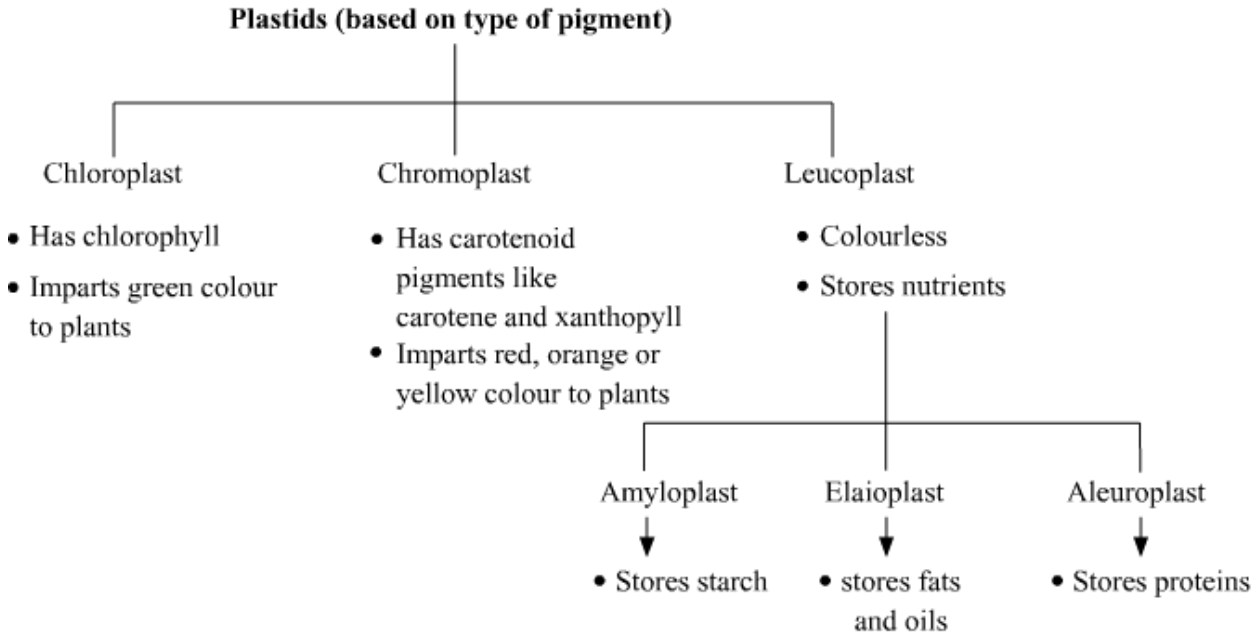
Structure of mitochondrion

- Importance: Mitochondria are called the ‘power houses of cells’ since they are the site for aerobic respiration, and form ATP (source of cellular energy).
- Matrix contains components like the single circular DNA, RNA, ribosomes (70s) and the components needed for protein synthesis.
- Mitochondria divide by fission.

Plastids

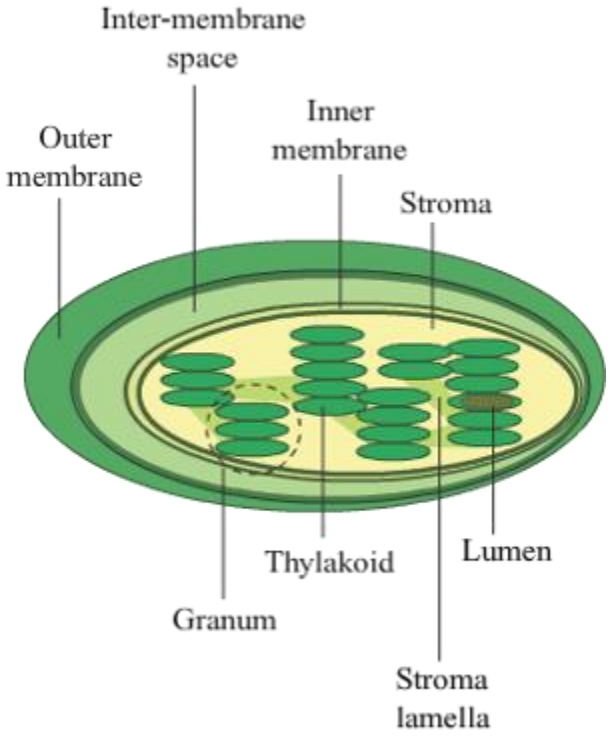
- Found in plant cells and euglenoids
- Bear pigments and impart colours to plants

- Large-sized, and hence, easily observable



Chloroplast

- Location: Mesophyll cells in leaves
- Can be variable in shape (oval/spherical/discoid/ribbon-like), variable in length and in number (1 per cell in *Chlamydomonas* to 20−40 per cell in green algae)
- Have *double membrane*: Outer membrane and Inner membrane (less permeable)
- *Stroma*: Space enclosed by the inner membrane; contains enzymes required for carbohydrate and protein synthesis
- Thylakoids: Flattened, membrane-bound sacs present in the stroma; contains chlorophyll pigment
- *Grana*: Integranal thylakoids; like piles of coins, where thylakoids are arranged in stacks
- *Stroma Lamella*: Flat, membrane-bound tubules; connect thylakoids present in the different grana
- *Lumen*: Space present in thylakoid, i.e., the space enclosed by the thylakoid membrane
- Stroma of the chloroplast has small, double stranded circular DNA molecules and ribosomes (70S).



Small Organelles of Eukaryotic Cell

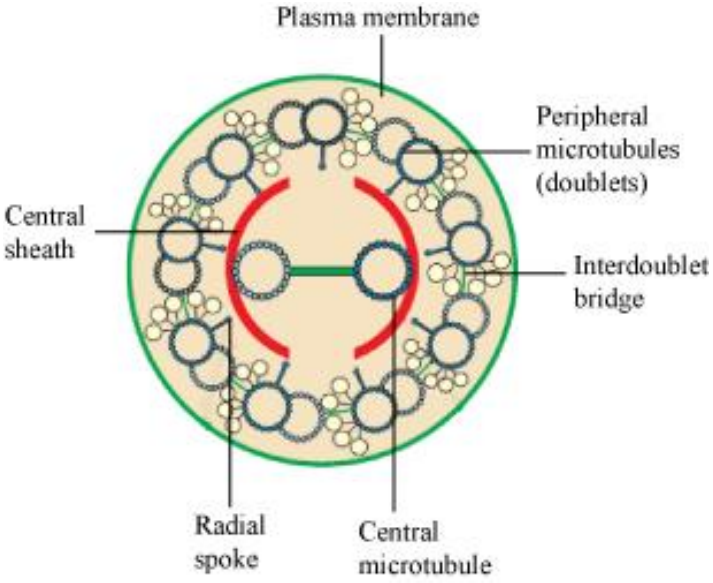
Cytoskeleton

- Filamentous, proteinaceous structures present in cytoplasm
- Functions:
- Mechanical support
- Motility
- Maintenance of the shape of a cell

Cilia and Flagella

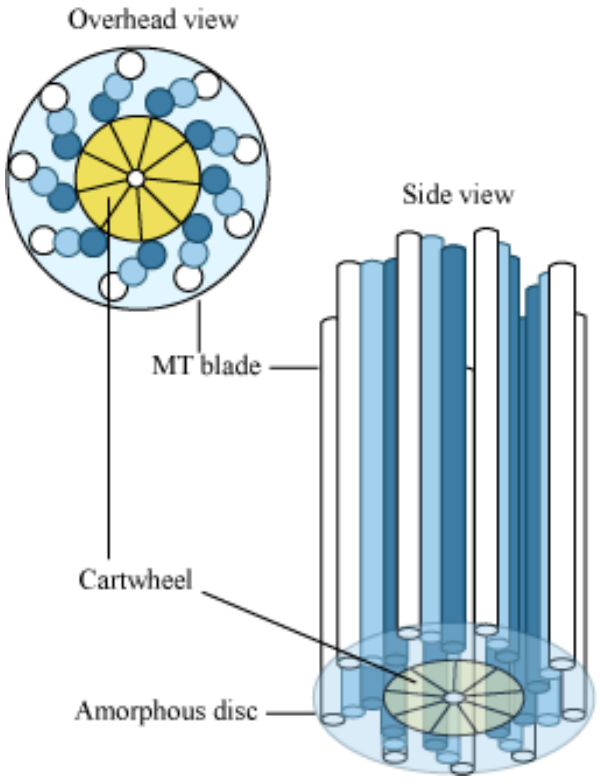
- These are hair-like outgrowths of the plasma membrane.
- *Cilia*: Structures working as oars; help in motility
- *Flagella*: Comparatively longer and fewer than the cilia
- Electron microscope study of the cilia and the flagella:

- They are covered by the plasma membrane.
- Axoneme − core of the internal portions of the cilia and the flagella
- Axoneme contains microtubules. There are 9 pairs of peripheral microtubules and one pair of central microtubules.
- This arrangement is called 9 + 2 array.
- Central tubules − connected by bridges and enclosed within the central sheath
- Radial spoke − connects one of the tubules of each of the nine peripheral microtubules with the central sheath
- Linkers − interconnect the peripheral tubules
- Basal body − centriole-like structure from where the cilia and the flagella emerge



Centrosome and Centrioles

- Centrosome: Organelle that contains two cylindrical structures called centrioles.
- Both centrioles in a centrosome lie perpendicular to each other. Centrioles have a cartwheel-like organisation.
- A centriole is made up of nine peripheral fibrils of tubulin protein. Also, each of the peripheral fibrils is a triplet.



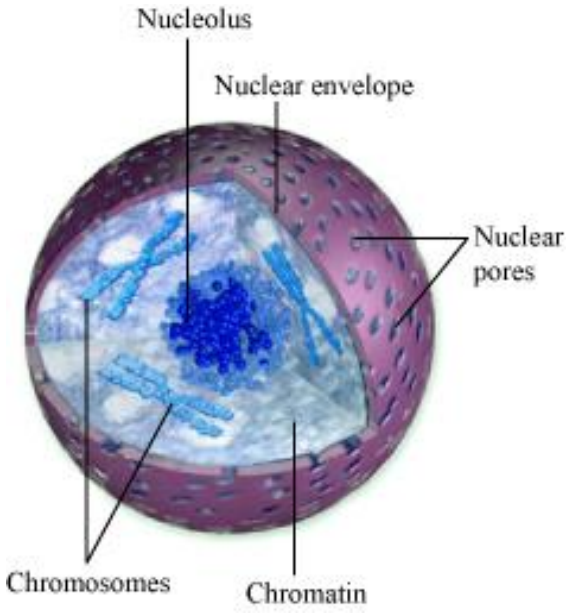
- *Hub*: Central part of the proximal region of the centriole
- *Radial spokes*: Connect the hub with the tubules of the peripheral triplets
- Importance of centriole: Forms the basal body of the cilia and the flagella, and the spindle fibre

Microbodies

- Membrane-bound minute vesicles
- Present in both plant and animal cells
- Contain enzymes

Nucleus and Chromosomes

Nucleus



- Every cell has a nucleus, except some such as the RBCs of mammals and the sieve tube cells in vascular plants.

  A cell usually has one nucleus, except some variations.

- Nucleus is bound by a *nuclear envelope* which consists of two membranes with *perinuclear space* (10 − 50 nm) between them

- Perinuclear space acts as a barrier for the flow of materials between the inside of the nucleus and the cytoplasm. So, to facilitate the transfer of RNA and proteins, *nuclear pores* are present. Nuclear pores are formed at places where the two membranes fuse.

- *Nuclear matrix* (*Nucleoplasm* consists of the nucleolus and the chromatin.)

- Nucleolus (pl. nucleoli): Site of active rRNA synthesis; not bound by membrane; its contents are continuous with the nucleoplasm

- Chromatin: Loose, indistinct network of nucleoprotein fibres (present in the interphase)

- Chromosomes: Chromatin structures develop into distinct chromosomes during cell division.

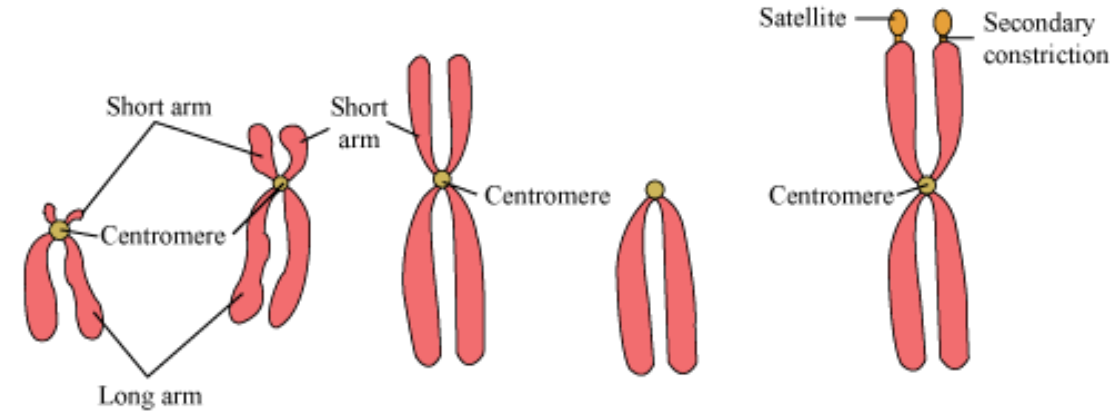
- Contains DNA, histone proteins, non-histone proteins, and also RNA

- DNA is distributed among 23 pairs (46) of chromosomes

- A chromosome has a primary constriction called *centromere***.** On the sides of the centromere, disc-shaped kinetochores are present.

Classification of Chromosomes

- Based upon the position of the centromere, chromosomes are of four types:
- *Metacentric* − centromere located in the middle, forming two equal arms of the chromosome
- *Sub-metacentric* − centromere located slightly away from the middle, resulting in one arm being longer than the other
- *Acrocentric* − centromere located close to the end, resulting in one arm being extremely longer than the other
- *Telocentric* − centromere located at the terminal point

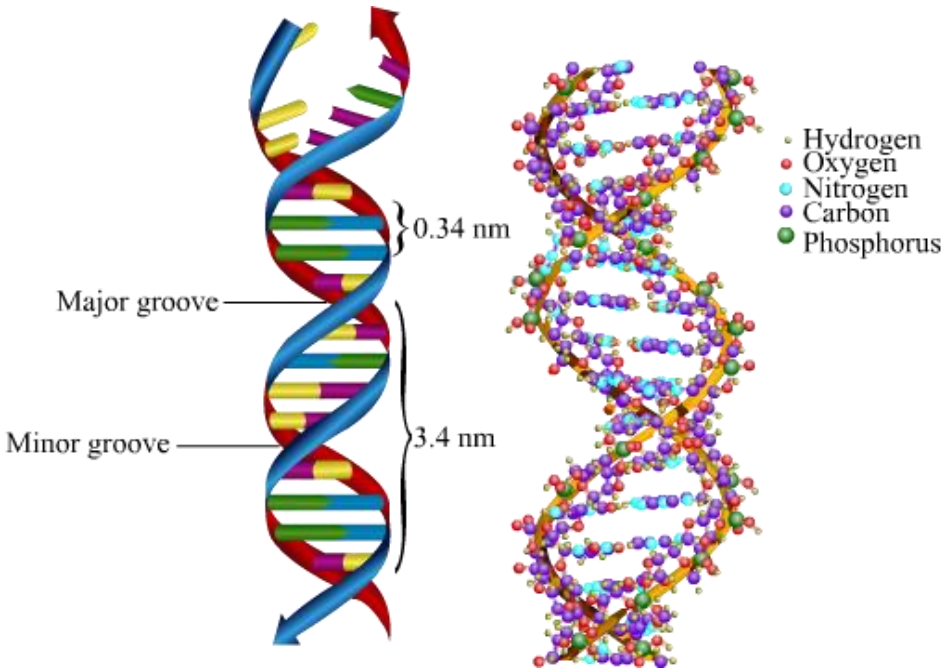


Types of chromosomes

- *Satellites*: Small fragments that appear due to the non-staining secondary constrictions present at a constant location on the chromosomes

DNA and Its Structure

Deoxyribonucleic acid or DNA is a macromolecule found inside the nucleus. It has a double helical structure, similar to a ladder, which is twisted at both ends. A DNA molecule is made up of repeating units of **nucleotides.** Each nucleotide is made up of three components :



- A pentose sugar (ribose)
- Phosphate group
- A nitrogen base

There are four nitrogenous bases found in DNA. These are :

- Adenine (A)
- Guanine (G)
- Cytosine (C)
- Thymine (T)

Adenine pairs with Thymine with the help of two hydrogen bonds, while Guanine pairs with Cytosine with the help of three hydrogen bonds.

Each DNA molecule has a property to duplicate, or **replicate**, itself. This replication process takes place during mitosis, in which the helical structure of DNA gets open at one end and the free strands give rise to new, complementary strands.

Genes

A gene is a functional unit of DNA. It is located on a chromosome and controls the development of one or more traits through proteins encoded by it. It is the basic unit through which the genetic information is transferred from parent to their offspring. Every person has two copies of each gene, one inherited from each parent. Genes can acquire mutations in their sequence that lead to different variants, known as **alleles**, in population.