CHAPTER-08

CELL: THE UNIT OF LIFE

Introduction

The study of form, structure, and composition of the cell is called cytology.

The cell is the structural and functional unit of life. In unicellular organism (amoeba, paramecium, yeast, bacteria) single cell performs all the essential functions of life.
An organism consists of one or more cells, accordingly, there are two types of organisms, i.e., unicellular (composed of single-cell) and multicellular (composed of many cells).

In a multicellular organism, different kinds of tissues perform a different function and have a division of labour.

Robert Hooke discovered cell after viewing honey comb like compartments under the microscope when he took a thin slice of cork (discovered dead cell). Anton Von Leeuwenhoek first saw and described a live cell. Robert Brown later discovered the nucleus.

Cell theory

The cell theory was formulated by two German Scientists, Matthias Schneider and Theodore Schwann independently. Schleiden (1838) examined a large variety of plant tissues and observed that all plants are composed of different kinds of cells.
At about the same time, Schwann (1839), closely studied different types of animal cells and found that the animal cell had a very thin outer layer known as the plasma membrane. He also concluded, from his studies based on plant tissues that animal cells differ from plant cells in lacking a cell wall.

The two postulates of cell theory are:
(i) All living organisms are composed of one or more than one cell.
(ii) Cells are the structural and functional units of the living organism.

Rudolf Virchow in 1855 expanded cell theory and said Omnis cellula-e- cellula (cells arise from pre-existing cells.)
(iii) All cells arise from pre-existing cells.

Objections to Cell Theory

Cell theory failed to explain how and from where the new cells were formed. All these observations lead to a major expansion of cell theory that was expressed by Rudolf Virchow in 1855 modified the hypothesis of Schleiden and Schwann and explained in his statement that cells divide and new cells are formed from pre-existing cells, i.e., Omnis cellula-e-cellula.

Thus, the cell theory states that
The outer membrane, the boundary of the cell, which provides protection to the cell and controls the exchange of ions, molecules, and other components in and out of the cell. The outer membrane of a cell contains a cell wall (only in plant cells) and plasma membrane.

Microscopes allow us to study the structure of cells, two types are commonly used, i.e., light microscopes and electron microscopes,
Cells are divided into compartments that help segregate functions, leading to more efficient performance; human cells consist of two major compartments, i.e., the cytoplasmic and nuclear.

Size of a cell

The cells exhibit an endless variation in size, life span, and cellular activities, e.g., Mycoplasma (smallest cell) or PPLOs (Pleuro-Pneumonia Like Organisms) is only 0.3 µm in length and bacteria are approx. 3-5 µm in size.
An ostrich egg, which is known to be the largest isolated single cell measures about 170 X 135 mm. Human Red Blood Cells (RBCs) are about 7 µm in diameter and the nerve cell of the human being is the longest cell having length of 90-100 cm.

The shape of a cell

The cells also vary in their shapes. They may be polygonal, disc-like amoeboid, thread-like, cuboid, or irregular. The cell shape is always related and vary with the function they perform.

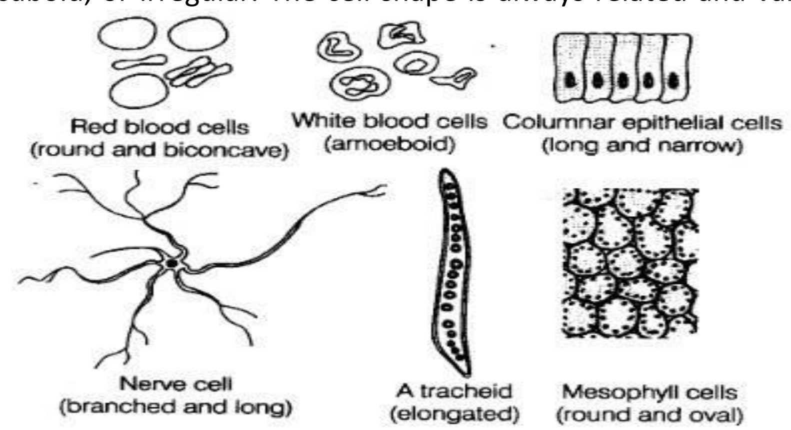


Fig. 8.1 Diagram showing different shapes of the cells

Structural outline of a cell

The onion cell, which is a typical plant cell, has a distinct cell wall as its outer boundary, and just within it is the cell membrane. The human and animal cell has an outer membrane, inside which is a dense membrane-bound structure called the nucleus. Each cell consists of (i) Nucleus, the central part of the cell, which is spherical in shape. Its number can be one or more per cell. It is denser than the surrounding cytoplasm.

The nucleus is composed of chromosomes (contains the genetic material, i.e., DNA), nuclear membrane, and centrioles (non-membrane bound organelle present in only animal cells, which helps in cell division).

(ii) Cytoplasm, a semi-fluid matrix that occupies the volume of the cell. It is mainly composed of water with free-floating molecules.

Inside the cytoplasm, all cellular activities like a gaseous exchange, elimination of wastes, hereditary mechanisms, etc occur.

Eukaryotic cells also contain another cell membrane-bound distinct structures called cell organelles, like mitochondria, vacuoles, Endoplasmic Reticulum (ER), Golgi complex, etc.

The prokaryotic cells lack all these membrane-bound organelles. It is to be noted that ribosomes are not bounded by the membrane and are found in all cells. Ribosomes are also found in chloroplasts (in plants) and mitochondria and on rough ER other than the cytoplasm.

Types of Cell

Based on the organization, complexity, and variety, all cells can be grouped into two types, i. e., prokaryotic cells, and eukaryotic cells.

Prokaryotic cell

The cell which does not have a nuclear membrane and other membrane-bound organelles is called a prokaryotic cell.

Occurrence

Prokaryotic cells are placed in the kingdom-Monera. These cells are represented by bacteria, cyanobacteria (blue-green algae), mycoplasma, or PPLO. Bacteria are the simplest and common most type of organism amongst prokaryotes.
They are generally smaller and multiply more rapidly than the eukaryotic cell.

The bacteria are found in almost every place like deep in the soil, human intestine, deep in seawater, etc.

Size

Bacteria tend to vary greatly in size. It normally ranges from 0.3-1.5 µm with some exceptions.

Shape

The four basic shapes of bacteria are bacillus (rod-like), coccus (spherical), vibrio (comma-shaped), and spirillum (spiral). All prokaryotic cells are similar in their organization although they exhibit a wide variety of shapes and functions.

Components of a Prokaryotic (Bacterial) Cell

A bacterial cell is composed of various components as genetic material, cell envelope, cytoplasm, nucleoid, inclusion bodies, ribosomes, flagella, pili, fimbriae, etc.

Genetic Material

Nucleoid represents the genetic material incase of prokaryotes that is naked, not enveloped by a nuclear membrane. Many bacteria contain a small circular DNA known as plasmid other than the chromosomal or genomic DNA.

These plasmids confer certain unique characters to the bacteria like antibiotic resistance, sex factor, etc.

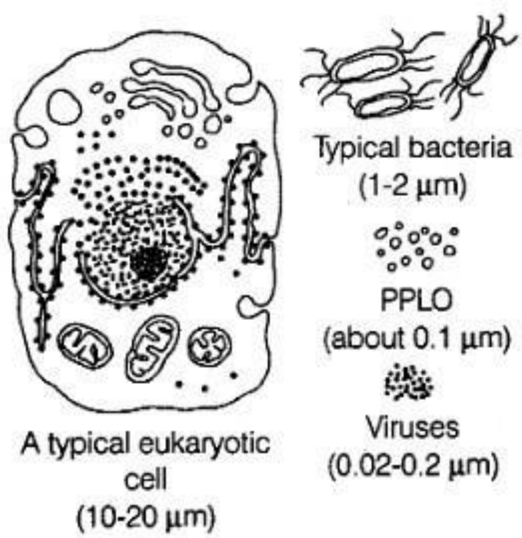


Fig. 8.2 Diagram showing comparison of eukaryotic cell with other organisms

Cell envelop and its modifications

The cell envelope is the outermost covering of the protoplasm of the bacterial cell. It is known to protect the cell from mechanical shocks and injuries.

It is composed of the following three layers, which perform a specialized function i- Glycocalyx (Mucilage Sheath)

It is the outermost layer, made up of macromolecules that give sticky character to the cell. Glycocalyx differs in composition and thickness among different bacteria. It could be in the form of a loose mucilaginous sheath called a slime layer or thick and tough covering called the capsule.
Function help in resisting phagocytosis.

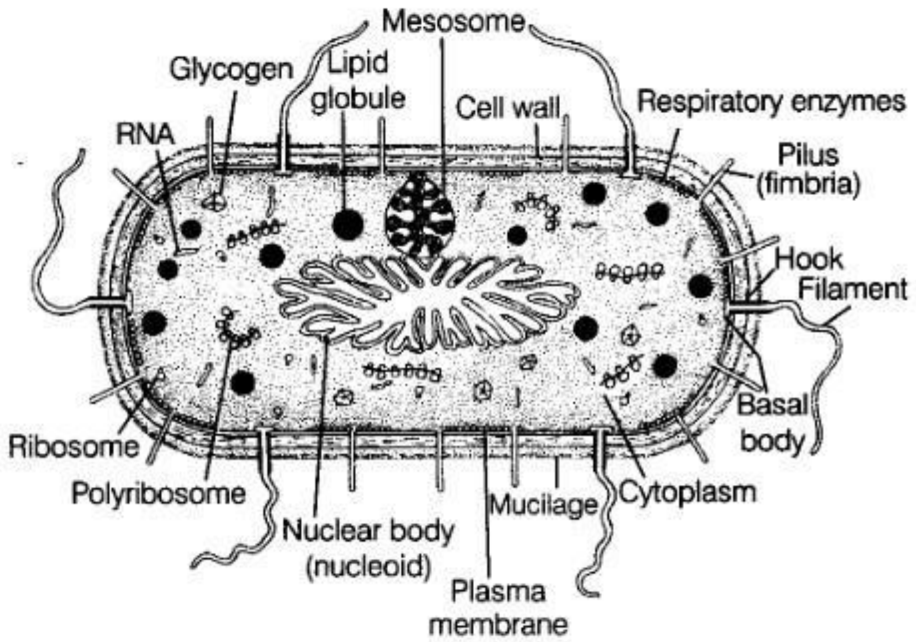
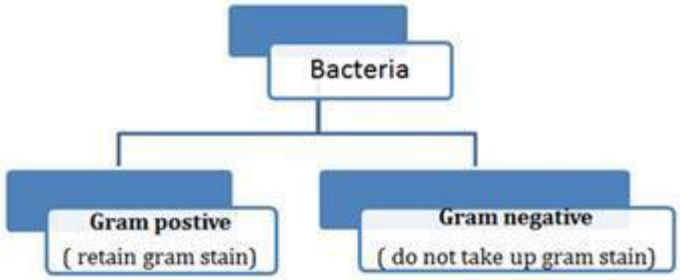


Fig. 8.3 Diagrammatic representation of a typical bactèrial cell

Gram-Positive and Gram-Negative Bacteria

According to Christian Gram (1884), various types of reactions are shown by the cell walls of different bacteria. Thus, based on the differences in the cell wall and the | response to the staining procedure developed by Gram, bacteria are classified into the following two types
(i) Gram-positive (+ve) bacteria are those that take up the Gram stain and retain blue or purple colour, e.g., Bacillus subtilis, Clostridium, etc.

(ii) Gram-negative (-ve) bacteria are those that do not take up Gram stain and loose the blue or purple colour, e.g., Escherichia coli, (E.coli), Acetobacter, etc.



Membranous Structures

Prokaryotic cells lack the complex membrane-bound organelles (such as chloroplast, mitochondria, etc). However, some other special membranous structures are found in them (i.e., mesosomes and chromatophores).

Mesosomes

These are formed by the extensions of the plasma membrane into the cell in the form of vesicles, tubules, and lamellae.

Mesosomes are equal to mitochondria in eukaryotes, as these structures participate in aerobic cellular respiration in prokaryotes.

Mesosomes perform the following junctions in the bacterium

- Helps in respiration, cellular secretion, etc.
- Helps in increasing the enzymatic content and surface area of the plasma membrane. (c) Helps in the formation of a cell wall.
- Helps in the replication of DNA and distribution of genetic material to daughter cells during fission.

Chromatophores

They are other membranous structures present in some prokaryotes like cyanobacteria, etc. They are internal membrane systems of photosynthetic forms, which possess photosynthetic pigments. These pigments are light-reflecting.

Flagella

Bacteria can be motile or non-motile. Thus, motile bacteria possess one or more thread-like appendages extending from their cell wall called flagella (sing, flagellum). Bacteria are also classified according to the number and arrangement of the flagellum in them. Each flagellum is about 1-7 nm long covered by a protein coat. The bacterial flagellum is differentiated into the following three parts

- Filament, the longest portion, extending from the cell surface to the outside. It is made up of a protein called flagellin.
- Hook, a curved and tubular structure made up of protein subunits.
- Basal body, the most complex part of the flagellum.

Pili and Fimbriae

Similarities Between Fimbriae and Pili

- Fimbriae and pili are two filamentous structures that extend from the surface of the bacteria.
- Both are made up of proteins.
- Also, both are shorter than a flagellum.
- Furthermore, both structures help in the attachment of the bacterial cell to various structures.
- Gram-negative bacteria contain both fimbriae and pili.
- Besides, both fimbriae and pili are antigenic; hence, they can evoke an immune response in the host.

Some of the differences between fimbriae and pili are as follows:

S.N.	Characteristics	Fimbriae	Pili
	Definition	Fimbriae are tiny bristle-like fibres arising from the surface of bacterial cells.	Pili are hair-like microfibers that are thick tubular structure made up of pilin.
	Length	Shorter than pili	Longer than fimbriae.
	Diameter	Thin	Thicker than fimbriae.
	Number	No. of fimbriae are 200-400 per cell.	No of pili are less 1-10 per cell.
	Made up of	Fimbrillin protein.	Pilin protein.

Ribosomes and inclusion bodies

The cytoplasm in prokaryotes appear granular, due to the presence of the following structures:

Ribosomes

Like eukaryotes, ribosomes are also found in prokaryotes and serves a common function, i.e., acts as a site of protein synthesis. Ribosomes are small but are complex both in structure and chemical composition. They are about 15-20 nm in size.
In prokaryotes, ribosomes are found in association with the plasma membrane of the cell (as it lacks endoplasmic reticulum) in the cytoplasmic matrix. The prokaryotic ribosomes are of 70S type.

It has the following two sub-units

- Smaller subunit (the 30S)
- Larger subunit (the 50S)

Ribosomes generally occur in helical groups called polysome or polyribosomes. In each polysome, 4-8 ribosomes are attached to a single strand of mRNA. The ribosomes of a polysome help in the translation (mechanisms to synthesize several copies of the same protein) of mRNA into protein.

Inclusion Bodies

They are non-living structures present in the cytoplasm and not bound by any membrane system. They may either lie free in the cytoplasm (e.g., Cyanophycean granules, glycogen granules) or may be covered by 2-4 nm thick, non-protein membrane (e.g., Gas vacuoles, sulphur granules, etc).

Note:
* Gas vacuoles are gas storing vacuoles that do not have any covering of their own. They are found in cyanobacteria (blue-green algae), purple and green photosynthetic bacteria.
* These are named so because they are permeable to atmospheric gases but not to water.

Eukaryotic cell

A cell that has a well-organized nucleus with a nuclear envelope and several membrane-bound organelles is called a eukaryotic cell.

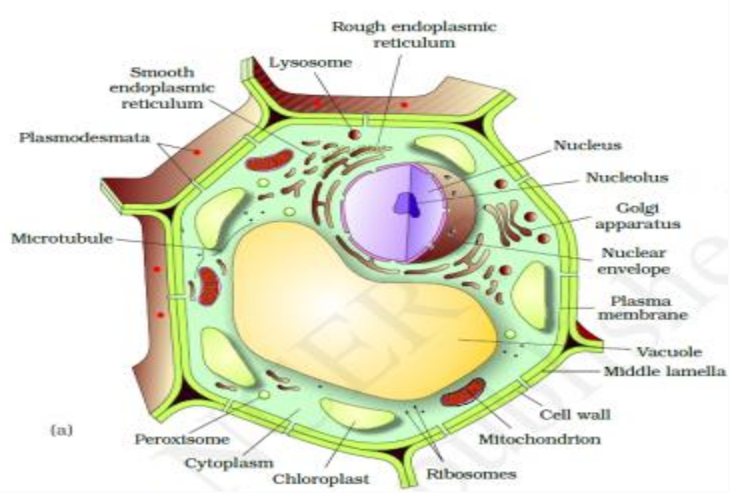
The internal organization of eukaryotic cells is more advanced and elaborate than the prokaryotic cells. All eukaryotic cells are not identical. Except for monerans, the eukaryotic organization is seen in all the protists, plants, fungi, and animals. The eukaryotic cell is larger than the prokaryotic cell (i.e., around 10-100 cm in size).

BASIS FOR COMPARISON	PROKARYOTIC CELLS	EUKARYOTIC CELLS
Size	0.5-3um	2-100um
Kind of Cell	Single-cell	Multicellular
Cell Wall	The cell wall present, comprise of peptidoglycan or mucopeptide (polysaccharide).	Usually cell wall absent, if present (plant cells and fungus), comprises cellulose (polysaccharide).
Presence of Nucleus	The well-defined nucleus is absent, rather 'nucleoid' is present which is an open region containing DNA.	A well-defined nucleus is presently enclosed within the nuclear membrane.
Shape of DNA	Circular, double-stranded DNA.	Linear, double-stranded DNA.
Mitochondria	Absent	Present
Ribosome	The 70S	The 80S
Golgi Apparatus	Absent	Present
Endoplasmic Reticulum	Absent	Present
Mode of Reproduction	Asexual	Most commonly sexual
Cell Divison	Binary Fission, (conjugation, transformation, transduction)	Mitosis
Lysosomes and Peroxisomes	Absent	Present
Chloroplast	(Absent) scattered in the cytoplasm.	Present in plants, algae.
Transcription and Translation	Occurs together.	Transcription occurs in the nucleus and

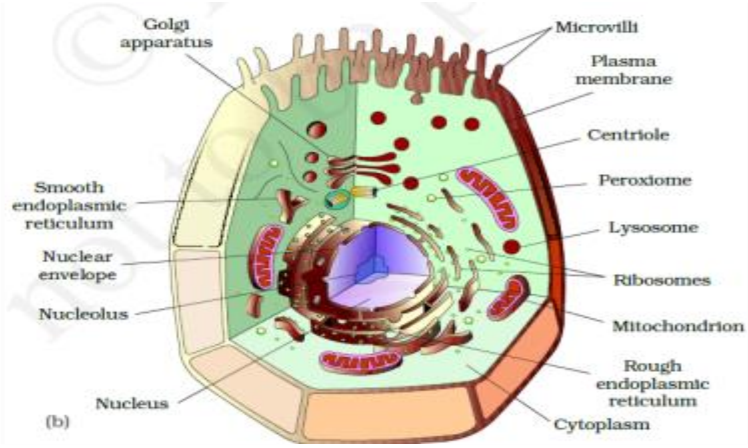
		translation in the cytosol.
Organelles	Organelles are not membrane-bound, if present any.	Organelles are membrane-bound and are specific in function.
Replication	Single-origin of replication.	Multiple origins of replication.
Number of Chromosomes	Only one (not truly called a plasmid).	More than one.
Examples	Archaea, Bacteria.	Plants and Animals.

Generalized Structure

Extensive compartmentalization of cytoplasm is seen through the presence of membrane-bound organelles. Eukaryotic cells also possess a variety of locomotory and cytoskeletal structures.
All eukaryotic cells are not-identical, instead, they differ from each other based on structure and function. The cell wall is a special membrane, being present in plants, fungi, and some protists. Plants cells also contain a large vacuole and plastids, which are absent in animal cells, while animal cells possess centrioles, which are absent in plant cells.



Plant cell



Animal cell

BASIS FOR COMPARISON	PLANT CELL	ANIMAL CELL
Meaning	The fundamental and functional unit of Kingdom Plantae of the Eukaryotic cells, having a true nucleus along with the many organelles, especially the cell wall, chloroplast, and the vacuoles.	Animal cells are also the basic unit of life of Kingdom Animalia of the Eukaryotic cells, having all the necessary organelles with specified functions.
Cell Size	Usually larger, which is fixed.	Smaller in size and irregular.
Cell Shape	Rectangular.	Round.
Enclosed by	A plant cell is enclosed by a rigid cell wall along with the plasma membrane.	The animal cell is enclosed by a flexible, thin plasma membrane only.
Nucleus	Present and lies on one side of the cell.	Present and lies in the centre of the cell wall.
Centrosomes/Centrioles	Absent	Present
Plastids	Present with chloroplast in them.	Plastids are absent.
Cilia	Absent.	Usually present.

Glyoxysomes	May be present.	Absent.
Plasmodesmata	Present.	Absent.
Desmosomes/Tight junction	Absent.	Present.
Mitochondria	Present in fewer numbers.	Present in large numbers.
Vacuoles	Only one huge vacuole.	Animal cells contain many in numbers.
Lysosomes	Rarely noticed in plant cells.	Present.
Chloroplast	Plant cell contains chloroplast, which they use in storing energy.	Animal cells lack chloroplast and use mitochondria for energy storing purpose.
Reserve food	Present as starch.	Present as glycogen.
Synthesis of nutrients	They can synthesize all amino acids, vitamins, and coenzymes.	They are not able to synthesize any amino acids, vitamins, and coenzymes required by them.
Cytokinesis	Occurs by cell plate only.	Occurs by furrowing or constrictions.
Hypotonic/Hypertonic Solutions	Plant cell does not burst if placed in a hypotonic solution.	Animal cells burst in hypertonic solution as they do not have the cell wall.

Components of a eukaryotic cell

A eukaryotic cell is composed of various cell components like the cell membrane, cell wall (only in plants), mitochondria, chloroplast, Golgi bodies, ribosomes, centrioles (only in animals), etc.

Cell membrane

Every living cell is covered by a thin, elastic, transparent, semi-permeable and regenerative membrane called cell membrane also called plasma membrane or plasmalemma. The plasma membrane separates the internal environment of the cell from the external environment. This membrane helps in regulating the entrance and exit of molecules into and out of the cell.

In the 1950s with the advancement of the electron microscope, the detailed structure of the membrane was studied. Most of the initial studies on cell membrane structure, i.e., especially on the human Red Blood cells (RBCs), which enabled the scientists to deduce the possible structure of the plasma membrane

Human RBCs are considered to be the best material for the: study of the biochemical composition of the cell membrane because they lack nucleus as well as cytoplasmic organelles. Studies on human RBCs concluded that the cell membrane is composed of lipid which forms a bilayer with protein molecules embedded in it at places. Later it was revealed that cell membranes also possess protein and carbohydrates.

It is the innermost layer of the cell envelope. It is semi-permeable in nature and is responsible for the interaction of the cell with the outside environment.

It performs some functions as follows

- It helps in the regulation of the exchange of specific materials between the cytoplasm and the extracellular medium.
- Selectively permits particular molecules to pass and prevent others.
- Prevents loss of components from the cells through the leakage.

Note:
* The plasma membrane is vital to cellular homeostasis and therefore, the health and welfare of all living organisms.
* Molecules move through membranes either passively, flowing down concentration gradients or actively, being pumped in or out of cells.
* Membrane in prokaryotes is. structurally similar to eukaryotes.

Lipid
The lipid molecules are amphipathic in nature and are arranged within the membrane with the help of two types of ends. These are as follows

- Polar Hydrophilic End This region is in the form of (water-loving) head, which faces towards the outer sides of the cell membrane to interact with the aqueous environments on both sides.
- Non-polar Hydrophobic End This region is in the form of (water-repelling) tail, both ends of which face each other that occur towards the centre of the cell membrane

The proportion of lipid molecules varies in the plasma membrane of different cell types. These are formed of cholesterol (25-32%) and mainly of phosphoglycerides or phospholipids (55-75%).

Proteins
Depending upon the ease of extraction, the ratio of protein and lipid varies considerably in different cell types. In human beings, the membrane of the erythrocytes (RBCs) has approximately 52% protein and 40% lipid.

The membrane proteins can be classified as

- Integral Proteins (intrinsic protein) They have a stronger association and are bound firmly to the membrane. These proteins are buried partially or totally in the phospholipid bilayer.

- Peripheral Proteins (extrinsic protein) They have a weaker association and are bound to lipids of the membrane by electrostatic interactions.

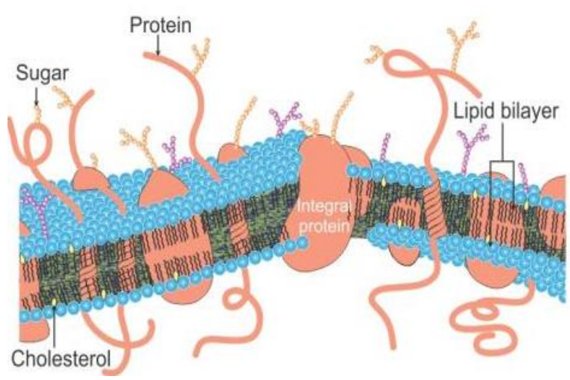
Carbohydrates

These constitute about 1-5% of the chemical composition of the plasma membrane. These are associated with the phospholipids or with the peripheral proteins to form glycolipids and glycoproteins respectively.

To understand the structure of the plasma membrane various models are given out of which the most accepted model is the Fluid Mosaic Model.

Fluid Mosaic Model

This model was given by Singer and Nicholson (1972). According to this model, the lipid bilayer and integral proteins appear like a mosaic arrangement and the quasi-fluid nature of lipid enables the lateral movement of the proteins within the overall bilayer. This ability of proteins to move within the membrane indicates the fluidity of the lipid part.



Fluidity of Membrane

The fluid nature of the membrane is important for interactions of molecules within the membrane as well as other functions like the formation of intercellular junctions, cell growth, secretion, endocytosis, cell division, etc.

Passage of substances across the membrane occurs mainly by two methods

Active Transport

Active transport is the movement of the molecules across the membrane against their concentration gradient, i.e., from lower to the Tighter concentration. It is an energy-dependent process, in which ATP is utilized. It occurs in few ions and molecules, e.g., Na+ / K+ pump.

Polar molecules require a carrier protein of the membrane to facilitate their transport across the membrane because they cannot pass through the non-polar lipid bilayer.

Passive Transport

Passive transport is the mode of movement of molecules or substances across the membrane without any requirement of energy.

It can be further of the following three types

- Osmosis is the process by which water molecules pass through a membrane from a region of higher concentration to a lower concentration.
- Simple Diffusion In this process, neutral molecules move across the membrane along the concentration gradient (from higher to lower concentration), e.g., Gases and small molecules.
- Facilitated Diffusion In this process, the molecules are transported along the concentration gradient with the help of ion channels and permeases. Energy is not required in this process.

Differences between Active and Passive Transport

Active Transport	Passive Transport
1. The transport involves an expenditure of energy by the cells. 2. It occurs against the concentration gradient. 3. It is a rapid process.	1. The cells do not spend energy on passive transport. 2. This transport is always along the concentration gradient. 3. It is a comparatively slow process.

Functions

Cell membrane possess the following functions

- It is a selectively permeable or semi-permeable membrane, allows only selected substances to pass inwardly.
- It protects the cell from injury.
- Membranes have carrier proteins for active transport.
- The cell membrane contains enzymes which perform certain reaction on their surface, e.g., ATPase, phosphatase, etc.

Cell wall

It was first discovered by Robert Hooke (1665). It is a rigid and non-living structure that forms an outer covering of the plasma membrane in plants and fungi. It is absent in animal cells. The cell wall is metabolically active and is capable of growth. Its thickness varies from 0.1-10 pm.

Cell wall not only gives shape to the cell and protects the cell from mechanical damage and infection, but it also helps in the cell to cell infraction and provides a barrier to undesirable macromolecules.

Chemical Composition

The cell wall of algae is made up of cellulose, galactans, mannans, and minerals like calcium carbonate, etc., while the cell wall of the plant is composed of cellulose, hemicellulose, pectins, and proteins.

Structure of the Cell Wall

Based on the structure, the cell wall is differentiated into the following three parts

Middle Lamella

It is the layer mainly made up of calcium and magnesium pectates. It cements the cell walls of two adjoining cells together. It is absent on the outer side of surface cells middle lamella along with a cell wall transversed by plasmodesmata which connect the cytoplasm of neighbouring centre cells.

Primary Cell Wall

It is produced inner to the middle lamella in a young and growing cell. It is capable of growth and extension. It tends to diminish gradually as the cell attains maturity.

Secondary Cell Wall

The thick secondary wall is formed inner towards the membrane to the primary wall. As the cell gets fully matured. Its composition is similar to the primary wall.

Functions

Cell wall possess the following Junctions

- It helps in providing a definite shape to the cell and also protects protoplasm against any mechanical injury, i.e., damage and infection.
- It also helps in cell-to-cell interaction
- It provides a barrier to undesirable macromolecules and the attack of pathogens.

Endomembrane system

The endomembrane system consists of the nuclear envelope, Endoplasmic Reticulum (ER), Golgi complex, lysosomes, and vacuoles suspended in the cytoplasm. These are considered together as an endomembrane system because their functions are coordinated with each other, despite this that each membranous organelles are distinct in terms of its structure and functioning.

Endoplasmic reticulum (ER)

The endoplasmic reticulum is a complicated system of membranous channels and flattened vesicles. It is physically continuous with the outer membrane of the nuclear envelope. It is revealed from the electron microscopic studies of eukaryotic cells that there is a presence of a network or reticulum of tiny tubular structures that are being scattered in the cytoplasm.

ER is known to be absent in prokaryotes but is present in all eukaryotic cells except germinal cells and mature human RBCs.

Endoplasmic reticulum divides the intracellular space into two main compartments

- Luminal (inside ER) compartment
- Extra-luminal (cytoplasm) compartment,

Types of Endoplasmic Reticulum

The endoplasmic reticulum is mainly of two types, depending upon the nature of its membranes

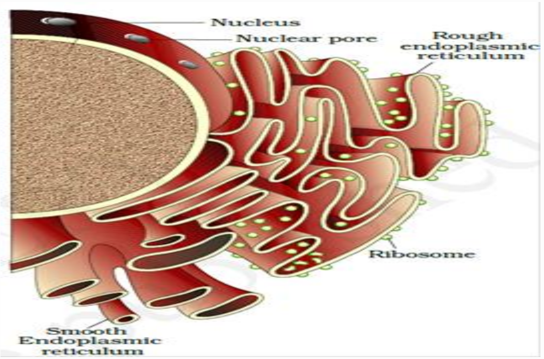
Smooth Endoplasmic Reticulum (SER)

These are smooth because they do not bear ribosomes in the form of granules on their surfaces. It is present in cells where they act as a major site for the synthesis of lipid and also helps in the synthesis of steroidal hormone in animal cells.

Rough Endoplasmic Reticulum (RER)

They are found extensive and continuous with the outer membrane of the nucleus. These have rough membrane because they bear ribosomes being attached to their surfaces.

They are actively being seen in the cells which have their involvement in the synthesis and secretion of proteins.



The other major difference between the smooth endoplasmic reticulum and rough endoplasmic reticulum are summarized below:

Rough Endoplasmic Reticulum (RER)	Smooth Endoplasmic Reticulum (SER)
It possesses ribosomes attached to its membrane.	It does not have ribosomes on its membrane.
Formed of cisternae and a few tubules.	Formed of vesicles and tubules.
It participates in the synthesis of enzymes and proteins.	Synthesises glycogen, lipids, and steroids.
It helps in the formation of lysosomes.	Gives rise to Spherosomes/ Oleosomes
It is internal and connected with the nuclear envelope.	It is peripheral and may be connected to plasmalemma.
Ribophorins are present and help ribosomes attach to ER	Devoid of Ribophorins.
It might develop from the nuclear envelope	Develops from Rough Endoplasmic Reticulum.
Provides proteins and lipids for the Golgi apparatus.	Provides vesicles for cis-face of the Golgi apparatus.

The most apparent difference between smooth and rough endoplasmic reticulum is the presence of ribosomes. Only the rough endoplasmic reticulum has ribosomes on its surface, and that gives it its characteristic rough appearance.

Functions

Endoplasmic reticulum possess the following functions

- It provides support to the colloidal cytoplasmic matrix.
- Helps in the rapid intracellular transport of the material.
- ER membranes contain a variety of enzymes for various metabolic processes, e.g., ATPase, phosphatases, etc.

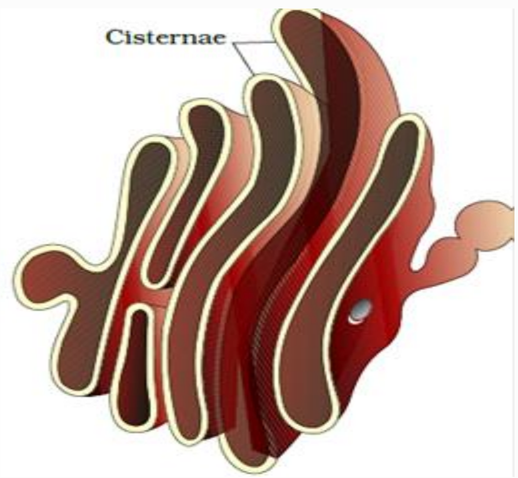
Golgi apparatus

It was first discovered by Camillo Golgi (1898) when he was observing the densely stained reticular structures being present near the nucleus of the cell. These structures were named Golgi bodies after his discovery.

Golgi complex or Golgi apparatus is a major complex protoplasmic structure being made up of many flat, disc-shaped sacs or cisternae (0.5-1.0 nm) in diameter.

Occurrence

Golgi complex occurs in all cells except prokaryotes (i.e., PPLO, bacteria, cyanobacteria) and some eukaryotes such as human RBCs, sieve tubes of plants, etc.



Cisternae of the Golgi apparatus are found stacked parallel to each other. They vary in number in a Cell. They are often curved-like shallow bowls to give Golgi complex a definite polarity. They are concentrically arranged near the nucleus with two distinct faces

Cis face {forming face) This is convex in shape that lies towards the cell membrane and is responsible for receiving secretory materials through the transitional vesicles, which are pinched off from the SER.

Trans face (maturing face) This is concave in shape that lies towards the nucleus and is responsible for releasing the material, which is being secreted by cis face and modified in the cisternae.

Note:

* Although the cis and the trans faces of the organelle are entirely different in origin, they interconnect each other.

* Proteins that are synthesized by ribosomes on ER are first modified in cisternae before they are released from its trans face.

The Golgi apparatus acts as a site where the material to be released is being packaged in the form of vesicles delivered either to the intracellular targets or secreted outside the cell.

Functions
Golgi apparatus possess the following functions

- The Golgi apparatus is involved in the formation of lysosomes, vesicles that contain proteins, and remains within the cell.
- It performs the function of packaging material.
- It acts as an important site for the formation of glycoproteins and glycolipids.
- It helps in the production of complex carbohydrates other than glycogen and starch.
- It helps in the formation of the cell wall.

Lysosomes

These are membrane-bounded vesicles that are produced by the Golgi apparatus. They are rich in several hydrolytic digestive enzymes (hydrolases-lipases, proteases, carbohydrates, etc). As these are optimally active at the acidic pH (less than 7). Therefore, are also called acid hydrolases and are capable of digesting macromolecules from various sources like carbohydrates, lipids, and nucleic acids.

Functions
Lysosomes possess the following junctions

- They digest the food contents (intracellular digestion).
- They also perform extracellular digestion.

- They also digest the old and useless organelles of the cells.
- They also have functioned in cell division

These are called suicidal bags due to the presence of hydrolytic enzymes.
De Duve observed the rounded bodies in liver cells and called them pericanalicular dense bodies (1949).

Vacuoles

The vacuole is a large membranous sac found in the cytoplasm. These store substances that are not essentially useful for the cell (like water, sap, excretory product and other materials). Plant vacuoles contain not only water, sugars, cells, and salts but also contain pigments and toxic molecules and also occupy up to 90% of the volume of the cell.

The vacuole is bounded by a single membrane structure known as tonoplast which in plant cells, facilitates the transport of materials and some ions against the concentration gradient inside the vacuole. Thus, the concentration of material tends to be higher in the vacuole, than to be in the cytoplasm.

Animal cells also have vacuole, but they are much more prominent in the case of plant cells. Thus, plant cells have typically large central vacuole filled with a watery fluid that gives added support to the cell.

Following types of vacuoles are being found in different organisms

Contractile Vacuole: They play an important part in osmoregulation and excretion in Amoeba, etc. It occurs mostly in protistan and algal cells that are found mainly in water.

Food Vacuole: They occur in the cells of mainly protozoan protists. These are formed by engulfing the food particles, i.e., by the fusion of lysosome and phagosome. The digested material thus passes out into the surrounding cytoplasm.
Air vacuoles and sap vacuoles are the types of vacuoles being formed by the cells.

Mitochondria

Mitochondria are membrane-bound cell organelles, essential for aerobic respiration of eukaryotic cells. These are also known as the powerhouse of the cell. Thus, they produce cellular energy in the form of ATP.

Occurrence

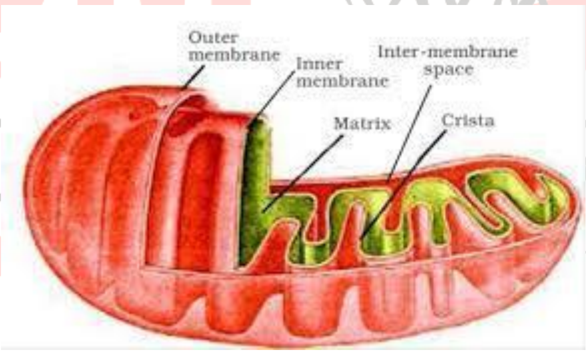
Mitochondria are present in all living cells except, prokaryotic cells and certain specialized eukaryotic cells such as anaerobic cells and mature RBCs.
It is revealed from the studies that mitochondria are not easily visible unless it is specifically stained.

Shape and Size

Mitochondria vary considerably according to shape and size. They have a varying shape such as granular fibrillar, spherical, oval, discoidal, etc. The average size of mitochondria is 2-6 |im in length and 0.5 pm in diameter (typical cylindrical or sausage-shaped mitochondria has a diameter of 0.2-1.0 Jim).

Ultrastructure

A mitochondrion contains two membranes, i.e., outer and inner. Out of which outer membrane is smooth and forms the continuous boundary of the organelle. The inner membrane is semipermeable to some metabolites. It is infolded into the matrix as an incomplete partition called cristae.
The cristae are responsible for increasing the physiological active area or surface area. The density of cristae determines the intensity of respiration.



The outer and the inner membranes divide its lumen into two aqueous compartments separately, i.e., the outer and the inner compartment.

The inner compartment is also called the matrix, which forms the inner core of the mitochondrion. The matrix also possesses a single circular DNA molecule, a few RNA molecules, ribosomes (the 70S), and the components required for the synthesis of proteins. The mitochondria divide by fission.
The two membranes of mitochondria have their specific enzymes associated with mitochondrial function.

Functions

Mitochondria possess the following functions

- Mitochondria provide important intermediates for the synthesis of several biochemicals like pyrimidines, alkaloids, etc.
- The inner chamber matrix of the mitochondria has enzymes for the synthesizes of fatty acids.
- Helps in the regulation of cellular metabolism.
- Helps in apoptosis (programmed cell death).
- Each of membrane potential.

The mitochondrion is the second-largest cell organelle and is more in animal cells than in plant cells.

Plastids

These are semi-autonomous organelles that have a double-membrane envelope. Plastids have their genetic material (i.e., DNA). Due to their large size, they are easily seen under the microscope.

Occurrence

Plastids are found in all plant cells and euglenoids except in some protistans (e.g., Euglena, Dinophyceae, etc).

Types

Plastids are differentiated into three different types based on the colour, i.e., type of pigments found in them.

Leucoplasts

These are the colourless plastids of varied shapes and sizes with stored nutrients in the form of carbohydrates lipids and proteins.

These are of following three types

Amyloplasts are the carbohydrates (starch) containing leucoplast, e.g., Rice, wheat, potato, etc. Amyloplasts are larger than the normal/original size of leucoplast. **Elaioplasts** are the leucoplast which stores oils and fats, e.g, Tuberose endosperm of castor seeds, etc.

Aleuroplasts are the protein storing leucoplast.

e.g., Maize (aleurone cells).

Chromoplasts

These are the leucoplast, which is yellow or reddish in appearance because of the presence of fat-soluble carotenoid pigment carotene.

Xanthophyll and some other pigments are also present as the fat-soluble carotenoid pigment other than carotene, e.g., the Orange colour of a carrot, etc.

Chloroplasts

These are the plastids that are greenish containing photosynthetic pigments chlorophyll and carotenoids. These pigments are responsible for trapping the light energy, essential for photosynthesis, i.e., the synthesis of organic food from inorganic raw materials in the presence of sunlight.

Occurrence

Chloroplasts occur in major numbers in the photosynthetic mesophyll cells of leaves and green stem.

Shape and Size

They may be lens-shaped, oval, spherical, discoid, or even ribbon-like organelles. They also have variable length (5-10 mm) and width (2-4 mm).

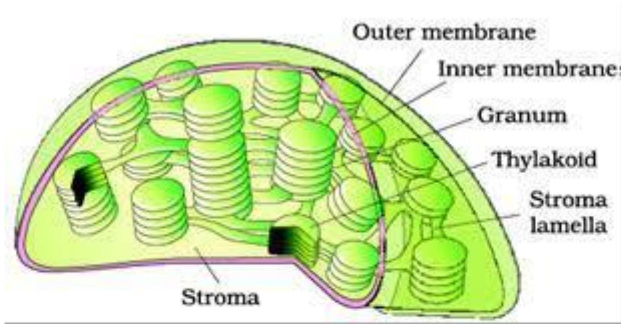
Number

Their number also varies from one per cell of the Chlamydomonas (a green alga) to 2-40 per cell in the mesophyll.

Infrastructure

Chloroplasts are also bounded by double-membrane envelope like mitochondria, the two membranes are smooth and are thick of about 90-100 A. The inner membrane of chloroplast is less permeable than the other one.

The inner membrane is grounded by a space known as stroma or matrix, a dense, colourless, and a granular substance mainly formed of soluble proteins. It also contains enzymes that are essential for the synthesis of carbohydrates, lipids, and proteins.



Thylakoids are the number of membranous like flattened structures that run throughout the matrix or stroma. When several thylakoids are arranged or organized in the stack (like the piles of coins), called grana or the intergranal thylakoids. Many flat membranous tubules interconnect the thylakoids of different grana known as stroma lamellae.

Functions

Chloroplasts possess the following functions

- Helps in photosynthesis, i.e., the formation of organic compounds. In consumption of C02 and release of 02 in photosynthesis.
- May also change into chromoplast to provide colour to many flowers and fruits. Helps in storing fat and lipids.
- Functions in the transduction of energy.

Note:

* The total of all plastids in a cell is called plastidome.

* The chloroplast with nitrogen-fixing genes are called nitroplast.

* The space between the two membranes is called intermembrane space, which separates the two membranes. This space contains a narrow fluid. Stroma also contains small, double-stranded circular DNA, molecules, and ribosomes.

Ribosomes

Ribosomes of chloroplasts are smaller (the 70S) than the ribosomes of eukaryotic cytoplasm (80S). These are the small sub-spherical granular organelles, not bounded by any membrane.

Ribosomes were first observed by George Palade (1953), as the dense particles under the electron microscope. Hence, are also called Palade particles. Ribosomes are mainly composed of ribonucleoproteins (i. e., RNA-t- proteins) and are also known as protein factories,

As they are primarily involved in the synthesis of proteins or polypeptides. As studied earlier, the prokaryotic ribosomes are 70S type, while the eukaryotic ribosomes are 80S type. Here, 'S' (Svedberg's unit) stands for the sedimentation coefficient (a measure of density and size).

Both 70S and 80S ribosomes contain two subunits, i.e., the smaller and the larger sub-unit. Differences between the 70S and 80S Ribosomes

80S Ribosomes:

- They occur only in eukaryotic cells.
- They occur inside the cytoplasm of eukaryotes either freely or attached to the ER.
- The ribosomes are larger in size with a length of (300—340 A) and breadth (200—240 A).
- The sedimentation coefficient is 80.
- They are comparatively heavier, 4.0—4.5 million Daltons.
- The two subunits are the 40S and 60S.

70S Ribosomes:

- 70S ribosomes are found both in prokaryotes and eukaryotes.
- The ribosomes are found freely inside the cytoplasm of prokaryotes and matrix of plastids and mitochondria of eukaryotes.
- They are comparatively smaller with a length of (200—290 A) and a diameter of (170—210 A).
- The sedimentation coefficient is 70.
- 70S ribosomes are comparatively lighter, 2.7—3.0 million daltons.
- The two subunits are the 30S and 50S.
- The rRNAs of 70S ribosomes are 23S + 5S (larger subunit) and 16S (smaller subunit).

Cytoskeleton

The network of interconnected proteinaceous filaments and tubules, which extends from the nucleus to the plasma membrane in eukaryotic cells.

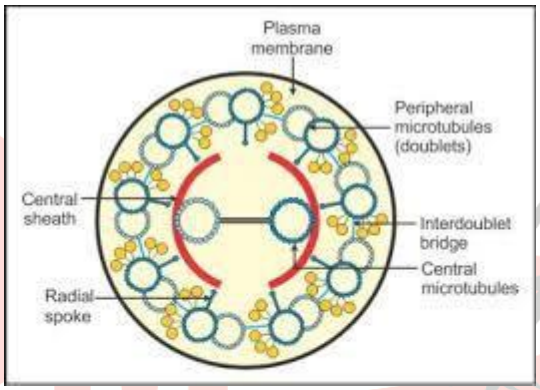
Functions

The cytoskeleton possesses, the following functions

(i) The cytoskeletal structures maintain the shape of the cell and its extensions.
(ii) It is also involved in many functions in a cell as mechanical support, motility, etc.

Cilia and flagella

These are hair-like projections of the cell membrane. Both cilia and flagella are almost identical in structure but differ somewhat in length. As cilia are small structures, working as oars (causing the movement of either the cell or the surrounding fluid), while flagella are comparatively longer in size than cilia and are responsible for the movement of the cell.



According to the electron microscopic studies, it is predicted that the cilium or the flagellum are covered with the plasma membrane. Their core called the axoneme, contains some microtubules, running parallel to the long axis.

Usually, the axoneme has nine pairs of doublets of peripheral microtubules that are radially arranged and a pair of centrally located microtubules. This arrangement of axonemal microtubules is referred to as the (9 + 2) array.

The central tubules are connected by bridges and are also enclosed by a central sheath, which is connected to one of the tubules of each peripheral doublets by a radial spoke. Thus, it has been estimated that there are nine radial spokes. The peripheral doublets are also interconnected by linkers. Both the cilium and flagellum emerge from centriole like structure called the basal bodies.

Difference Between Cilia And Flagella	
Cilia	Flagella

The number of cilia is comparatively more (typically ranges in the thousands)	The number of flagella is comparatively less (usually ranges from 1 to 8)
Cilia is usually shorter in length	Flagella is comparatively longer
Beating pattern of cilia is very complicated – Can move in a wide range of motions	Beating pattern of Flagella involves circular, wave-like or propeller-like motion
Found in Eukaryotic cells	Found in prokaryotic cells and eukaryotic cells
Cilia are of two types: Non-motile cilia and Motile cilia	Flagella are of three types: Bacterial flagella, Archaeal flagella, and Eukaryotic flagella

Flagella are also present in prokaryotic bacteria but these are ' structurally different from that of eukaryotic flagella.

Centrosomes and Centrioles

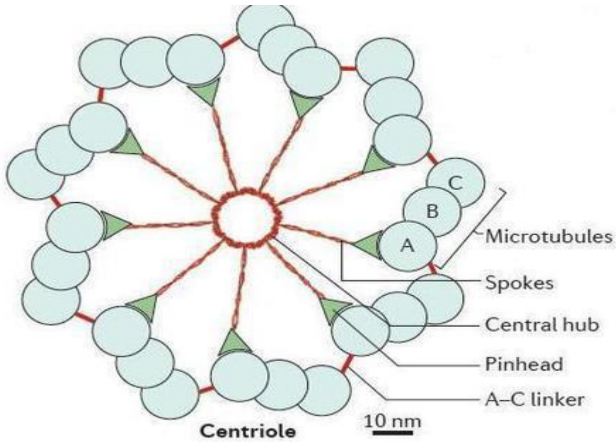
The centrosome is an organelle that generally has two cylindrical structures known as centrioles. They are surrounded by an amorphous pericentriolar material. Both the centrioles in a centrosome lie perpendicular to each other in which each has an organization like the cartwheel.

They are usually made up of nine evenly spaced peripheral fibrils (triplet in nature) of tubulin protein. With which adjacent triplets are also being linked.
The centre part of the proximal region of the centriole possesses a rod-shaped proteinaceous mass known as the hub, which is connected with tubules of the peripheral triplets fibrils known as radial spokes (made up of protein).

From the basal body of cilia or flagella, the centrioles and spindle fibres give rise to spindle apparatus during cell division in animal cells.

Centriole

"centriole is an organelle, cylindrical in shape, that is composed of a protein called tubulin."
All animal cells have two centrioles. They help the cell during cell division. They work during the process of mitosis and meiosis. They could be found in some lower plants such as Chlamydomonas, although they are not present in many of the fungi, angiosperms (flowering plants), and rhinophymaspecialized (conifers). They are usually present near the nucleus but are not visible when the cell is not dividing.



Functions

Centrosomes and centrioles possess the following functions

- These forms spindle fibres and move to the poles, at the time of cell division, which thus, help in the movement of chromatids in daughter cells.
- Help in the formation of cilia and flagella of the cells.

Nucleus

It is a specialized and principle cell organelle of the cell, which contains all the genetic information for controlling all essential processes related to metabolism and transmission. Nucleus was first described by Robert Brown as early as 1831. Later the name chromatin was given by Flemming when the material of the nucleus was stained by the basic dyes.

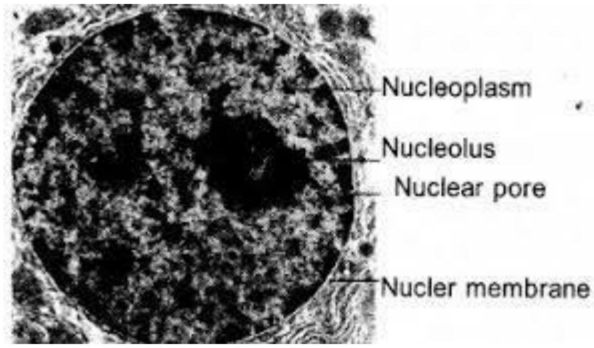
The nucleus is known to be the largest cell organelle also known as the brain of the cell. Occurrence

A nucleus is known to be present in all eukaryotic cells except a few cell types such as RBCs of humans, sieve cells of vascular plants, etc.

Prokaryotic cells lack a well-organized nucleus, instead, they have a nucleoid.

Ultrastructure

The interphase nucleus (the nucleus of a cell when it is not dividing) has highly extended and elaborate nucleoprotein fibres called chromatin, nuclear matrix, and one or more spherical bodies called nucleoli.



Microscopic Structure

It has been revealed from the studies of electron microscopy that the nuclear envelope, consists of two parallel membranes with a space between 10-50 nm called the perinuclear space, which forms a barrier between the materials present inside the nucleus and that of the cytoplasm.
The outer membrane usually bears ribosomes on it and remains continuous with the endoplasmic reticulum. The nuclear envelope is interrupted by minute nuclear pores, at a number nuclear of places, which are produced by the fusion of its two membranes. These nuclear pores are the passages through which the movement of RNA and protein molecules takes place in both directions between the nucleus and the cytoplasm.

Normally, there is only one nucleus per cell, but variations in the number of nuclei can also be seen in various organisms.

The nucleus is differentiated into the following four parts

Nuclear Envelope

It is a double membrane-bound envelope that surrounds the nucleus and separates the latter from the cytoplasm.

Nucleoplasm

It is a clear, non-staining, fluid material present in the nucleus, which contains raw materials (nucleotides), enzymes (DNA/RNA polymerases) and metal ions for the synthesis of RNAs and DNA. The nuclear matrix or the nucleoplasm is composed of nucleolus and chromatin (spherical structures present in the nucleoplasm).

Nucleolus

It is a naked, round, and slightly irregular structure, which is attached to the chromatin at a specific region. The content of the nucleolus is continuous with the rest of the nucleoplasm as it is not a membrane-bound structure.

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

Chromatin

It is named so because it can get stained with certain basic dyes. It is known to be the hereditary DNA protein fibrillar complex. The chromatin fibres are distributed throughout the nucleoplasm.

It has two distinct regions

Euchromatin (lightly stained)

Heterochromatin (darkly stained)

Functions

Nucleus possess the following functions

- It stores information that controls cellular functions.
- It controls the synthesis of structural proteins.
- It also stores the genetic information for development reproduction and behaviour.
- It also induces genetic variations.

Chromosomes

It has been already studied in the chapter that the nucleus in the interphase has a loose and indistinct network of nucleoprotein fibres called chromatin. But during different stages, of*cell division cells show structured chromosomes in place of the nucleus. The chromosomes are meant for the equal distribution of genetic material. Their number is fixed and is the same in all individuals of a species.

Chromatin is composed of DNA and some basic proteins called histones. Some non-histone proteins and RNA are also present in the chromatin.

A single human cell has the approximately two-meter-long thread of DNA distributed among its 46 (23 pairs) chromosomes.

Each chromosome is composed of a primary constriction of the centromere. On the sides of which the disc-shaped structures are presently known as kinetochores.

Based on the position of the centromere, the chromosomes can be classified into four following types

Metacentric Chromosome

It has a chromosome with equal arms and centromere lies in the centre.

Sub-metacentric Chromosome

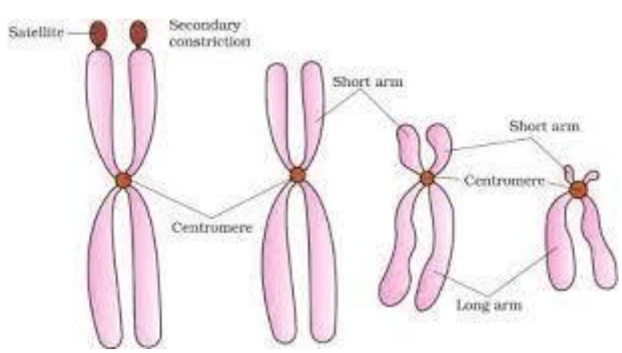
It has one shorter arm and one long arm with a centromere slightly away from the middle of the chromosome.

Acrocentric

It forms one extremely short and one very long arm and the centromere is located near the end of the chromosome.

Telocentric

It has the terminal centromere, i.e., the centromere is placed at an end. Telocentric chromosomes are not present in humans.



Few chromosomes have a non-staining secondary constriction being present at a constant location at some of the other times which gives that appearance of a small fragment known as a satellite.

Chromosomes possess the following functions

- Control cellular differentiation.
- Contains all hereditary information located in the genes.
- Forms a link between the offspring and the parents.
- Introduce variations, through the process of crossing over.
- Control cell metabolism.

Microbodies

These are the membrane-bound cytoplasmic elements that are composed of enzymes and other substances. These are minute vesicles found in both plant cells and animal cells, e.g., In the liver, kidney, Protozoa, yeast, and many other types of cells. Their shape can be ovoid, spherical, granular, etc.

Peroxisomes and glyoxysomes are the types of microbodies being found in plant cell and animal cell respectively.

Important terms

Cell

In biology, the basic membrane-bound unit that contains the fundamental molecules of life and of which all living things are composed.

Cell theory

In biology, cell theory is the historic scientific theory, now universally accepted, that living organisms are made up of cells, that they are the basic structural/organizational unit of all organisms, and that all cells come from pre-existing cells.

Cell membrane

The cell membrane is a biological membrane that separates the interior of all cells from the outside environment which protects the cell from its environment. The cell membrane consists of a lipid bilayer, including cholesterols that sit between phospholipids to maintain their fluidity at various temperatures.

Cell wall

A cell wall is a structural layer surrounding some types of cells, just outside the cell membrane. It can be tough, flexible, and sometimes rigid. It provides the cell with both structural support and protection, and also acts as a filtering mechanism.

Cytoplasm

The cytoplasm is a thick solution that fills each cell and is enclosed by the cell membrane. It is mainly composed of water, salts, and proteins. In eukaryotic cells, the cytoplasm includes all of the material inside the cell and outside of the nucleus.

Endomembrane system

The endomembrane system is composed of the different membranes that are suspended in the cytoplasm within a eukaryotic cell. These membranes divide the cell into functional and structural compartments or organelles.

Mitochondrion

The mitochondrion is a semi-autonomous double-membrane-bound organelle found in most eukaryotic organisms. Some cells in some multicellular organisms may, however, lack mitochondria.

Plastid

The plastid is a membrane-bound organelle found in the cells of plants, algae, and some other eukaryotic organisms. They are considered endosymbiotic Cyanobacteria, related to the Gloeomargarita. Plastids were discovered and named by Ernst Haeckel, but A. F. W. Schimper was the first to provide a clear definition.

Chloroplast

Chloroplasts are organelles that conduct photosynthesis, where the photosynthetic pigment chlorophyll captures the energy from sunlight, converts it, and stores it in the energy-storage molecules ATP and NADPH while freeing oxygen from water in plant and algal cells.

Semi autonomous organelles

Semi-autonomous organelles are organelles with DNA. In a eukaryotic cell, mitochondria and chloroplast are semi-autonomous organelles as it possesses its DNA.

Endoplasmic reticulum

The endoplasmic reticulum is a type of organelle made up of two subunits – rough endoplasmic reticulum, and smooth endoplasmic reticulum.

Ribosome

Ribosomes are macromolecular machines, found within all living cells, that perform biological protein synthesis. Ribosomes link amino acids together in the order specified by the codons of messenger RNA molecules to form polypeptide chains.

Cytoskeleton

The cytoskeleton is a complex, dynamic network of interlinking protein filaments present in the cytoplasm of all cells, including bacteria and archaea. It extends from the cell nucleus to the cell membrane and is composed of similar proteins in the various organisms.

Vacuole

A vacuole is a membrane-bound organelle that is present in all plant and fungal cells and some protist, animal, and bacterial cells.

Golgi apparatus

The Golgi apparatus, also known as the Golgi complex, Golgi body, or simply the Golgi, is an organelle found in most eukaryotic cells. Part of the endomembrane system in the cytoplasm, it packages proteins into membrane-bound vesicles inside the cell before the vesicles are sent to their destination.

Lysosome

A lysosome is a membrane-bound cell organelle that contains digestive enzymes. Lysosomes are involved with various cell processes. They break down excess or worn-out cell parts. They may be used to destroy invading viruses and bacteria.

Nucleus

The nucleus is a membrane-bound organelle that contains genetic material (DNA) of eukaryotic organisms. As such, it serves to maintain the integrity of the cell by facilitating transcription and replication processes. It's the largest organelle inside the cell taking up about a tenth of the entire cell volume.

Chromosome

A chromosome is a DNA molecule with part or all of the genetic material of an organism. Most eukaryotic chromosomes include packaging proteins which, aided by chaperone proteins, bind to and condense the DNA molecule to prevent it from becoming an unmanageable tangle.

Chromatin

Chromatin is a complex of DNA and protein found in eukaryotic cells. Its primary function is packaging long DNA molecules into more compact, denser structures.

Kinetochore

A kinetochore is a disc-shaped protein structure associated with duplicated chromatids in eukaryotic cells where the spindle fibres attach during cell division to pull sister chromatids apart.

Centromere

The centromere is the specialized DNA sequence of a chromosome that links a pair of sister chromatids. During mitosis, spindle fibres attach to the centromere via the kinetochore. Centromeres were first thought to be genetic loci that direct the behaviour of chromosomes.

Microbody

A microbody is a type of organelle that is found in the cells of plants, protozoa, and animals. Organelles in the microbody family include peroxisomes, glyoxysomes, glycosomes, and hydrogenosomes. Invertebrates, microbodies are especially prevalent in the liver and kidney.

Peroxisome

Peroxisome (IPA: [pɛɜˈɹɒksɪˌsoʊm]) is a membrane-bound organelle (formerly known as a microbody), found in the cytoplasm of virtually all eukaryotic cells. Peroxisomes are oxidative organelles. Frequently, molecular oxygen serves as a co-substrate, from which hydrogen peroxide (H_2O_2) is then formed.

Glyoxysome

Glyoxysomes are specialized peroxisomes found in plants and also in filamentous fungi. Seeds that contain fats and oils include corn, soybean, sunflower, peanut, and pumpkin. As in all peroxisomes, in glyoxysomes, the fatty acids are oxidized to acetyl-CoA by peroxisomal β-oxidation enzymes.

Active transport

In cellular biology, active transport is the movement of molecules across a cell membrane from a region of lower concentration to a region of higher concentration—against the concentration gradient. Active transport requires cellular energy to achieve this movement.

Passive transport

Passive transport is a movement of ions and other atomic or molecular substances across cell membranes without the need for energy input. Unlike active transport, it does not require an input of cellular energy because it is instead driven by the tendency of the system to grow in entropy.