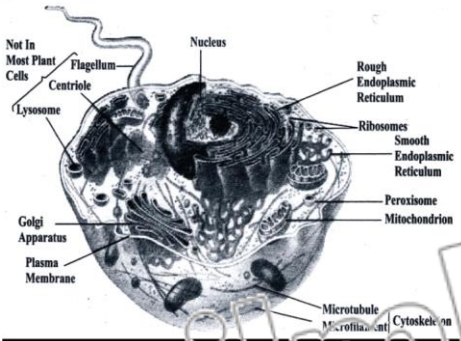



# Chapter 4
# The Cell

## 4.1 CELL

Cell is the basic structural and functional unit of life. It is the smallest unit that can carry all activities of life. Cells are building blocks of complex multicellular organisms.

### 4.1.1 Emergence and implication of cell theory

**History of Discovery of Cell**

**i) Robert Hooke**

Study of cell (cell biology) began with the discovery of cell by Robert Hooke (1665), who reported his work in his famous publication, ***Micrographia***.

- He prepared and studied thin sections of cork (consisting dead plant material) under his self-made compound microscope.
- He observed that the cork is composed of minute honeycomb like compartments, which he termed as ***cells***.
- According to Hooke, cell is an empty space bounded by thick walls.

**ii) Lorenz Oken**

Lorenz Oken (1805) was a German scientist, who believed that ***all living beings originate from or consist of vesicles or cells***.

**iii) Jean Baptist de-Lamarck**

He in 1809 expressed an idea similar to Lorenz and said ***nobody can have life if its constituent parts are not cellular tissues or are not formed by cellular tissues***.

**iv) Robert Brown**

In (1831), Robert Brown reported the presence of ***nucleus*** in the cell. Due to this discovery, Hook's idea about the cell as an empty space was changed.

**v) Schwann and Schleiden**

A German zoologist Theodor Schwann (1839) and a German botanist Schleiden (1838), working independently, came out with a theory called the ***Cell Theory***.

They divided cell into three parts i.e. nucleus, cytoplasm and cell membrane. They differentiated plant cell having cell wall from animal cells in which cell wall is absent.

**vi) Rudolph Virchow**

He was a German physician. In (1855), he hypothesized that ***new cells were formed only by the division of previously existing cells***, to put it in Virchow's words: **"Omnis cellula e cellula"** and thus rejected the idea of abiogenesis.

**vii) Louis Pasteur**

Louis Pasteur (1862), one of the greatest scientists of all times, supplied ***experimental proof for Virchow's hypothesis*** by demonstrating that microorganisms (bacteria) could be formed only from existing bacteria.

**viii) August Weismann**

In 1880, he said that **all presently living cells have a common origin because they have *basic similarities in structure and molecules*** etc. It was shown that there are fundamental similarities in the chemical composition, metabolic activities and structure, although they differ in many respects.

### 4.1.2 Importance of microscope in biology

Observations in biology can be made with naked eye or with use of microscope.

**Human Eye**

The human naked eye can differentiate between two points, which are at least ***1.0 mm*** apart. This is known as ***resolution power of the eye***. This resolution can be increased with the aid of lenses.

**Compound Microscope**

A compound microscope is a typical laboratory microscope with at least different magnifying powers.

- In a typical compound microscope, the ***resolution*** is ***2.0 µm***, which is about ***500X*** that of the naked eye.
- It consists of two lenses i.e. ocular and objective.
- Typical ***ocular lenses*** could be **5X** and **10X**, but others also exist.
- There are different type of ***objectives*** e.g. **20X**, **40X** and **100X** etc.
- The ***magnifying power*** of microscope is determined by multiplying X values of ocular lens and X values of objective lens. Therefore a microscope with **10X** ocular lens and **40X** objective lens will have **(10 X 40 = 400X) 400X** magnifying power.
- ***Source of illumination*** in compound microscope is visible light.

**Electron Microscope**

- ***Resolution*** of electron microscope ranges between ***2-4 Angstrom***.
- Resolution of electron microscope is 500X more than compound microscope and ***250,000X*** greater than that of naked eye.
- ***Source of illumination*** is beam of electrons.

### 4.1.3 The cell theory

**Introduction**

- The cell theory is one of the most fundamental generalizations in biology.
- It states that all living beings (animals and plants) are composed of cells and cell products.

**Presentation**

The cell theory was presented by a botanist named ***Schleiden*** (1838) and a zoologist named ***Schwann*** (1839).

**Salient Features**

The salient features of the cell theory in its present form are:

**1)** All organisms are composed of one or more cells.
**2)** All cells arise from pre-existing cells.
**3)** Cell is the basic structural and functional unit for all organisms.

**Importance**

- It has wide ranging effect in all fields of biological research.
- It has been established that every cell is formed by the division of another cell.
- It shows that function of whole organism is the result of the activities and interactions of the cell and its components.
- Progress in biochemistry confirmed that there are fundamental similarities in the chemical composition and metabolic activities of all cells.

### 4.1.4 Cell as a unit of structure and function

**Cell**

A cell is defined as structural and functional unit of organism.

**Division of labour**

In multicellular organism, there is a division of labour among cells. Different cells are specialized for different functions in animals.

**i) Examples in Animals**

- ***Muscle cells*** contract and relax.
- ***Nerve cells*** transmit impulses
- ***Gland cells*** secrete.
- ***Red blood cells*** carry oxygen.
- Some ***gastric cells*** secrete gastric juice.

**ii) Examples in Plants**

- ***Xylem cells*** conduct water and mineral salts from soil to the aerial parts of plants.
- ***Phloem cells*** translocate food.
- ***Sclarenchymatous cells*** give support to the plant.
- ***Chlorenchymatous cells*** carry out photosynthesis.
- ***Parenchymatous cells*** store surplus food.

As animal and plant cells mentioned above show great variation in shapes and sizes, they have a common plan of organization.

**QUESTION RELATED TO ABOVE ARTICLE**

**Explain the importance of Microscope in biology as compared to human eye.**

**State cell theory and discuss its emergence. (Exercises Question ii)**

## 4.2 STRUCTURE OF A GENERALIZED CELL

The modern technology by which we can isolate various components of cell including its organelles is called cell fractionation.

**CELL FRACTIONATION**

Following steps are involved in cell fractionation;

**i) Disruption**

The tissues are homogenized or disrupted with special instruments.

**ii) Spinning**

The homogenized or disrupted cells are made to spin in a special medium in a centrifuge at high speed.

**iii) Density Gradient Centrifugation**

The various cellular parts separate out in different layers depending upon their size, weight and density of the medium.

After this we can study their structure and function in detail under electron microscope.

A cell consists of the following basic components:

**a.** ***Plasma membrane***, also a cell wall in plant cells.

**b.** ***Cytoplasm***, containing cell organelles.

**c.** ***Nucleus***, with nuclear or chromatin material.

**Types of cells**

There are two main types of cells i.e. prokaryotic and eukaryotic cells.

**i) Prokaryotic Cell**

- A prokaryotic cell lacks a definite nucleus and their nuclear material is directly submerged in the cytoplasm and is not separated from it by membrane.
- Example is ***bacteria***.

**ii) Eukaryotic Cell**

- A eukaryotic cell has a distinct nucleus (chromatin material is bounded by a membrane)
- For example ***plants and animals***.
- These cells are complex and vary greatly in size.
- They could be as big as an Ostrich's egg
- Most of the cells are microscopic and are not visible to the naked eye. Their size is measured in micrometer (μm).
- 1 μm = 0.000,001 m = 1 x $10^{-6}$ m.

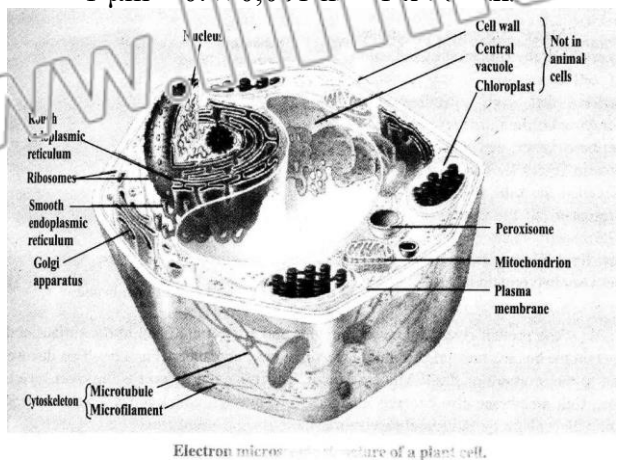



**Fig. 4.2** Electron microscopic structure of an plant cell

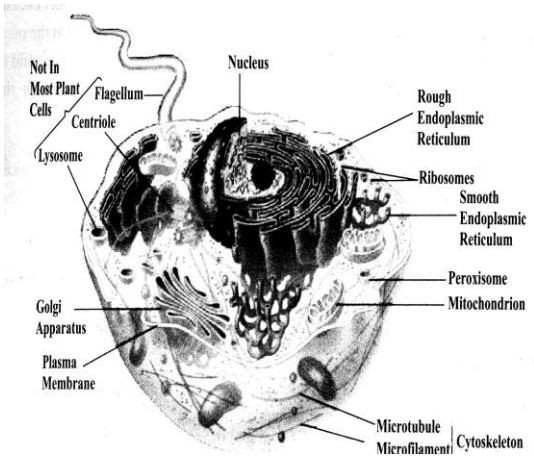



**Fig. 4.3** Electron microscopic structure of a animals cell

## QUESTION RELATED TO ABOVE ARTICLE

**What do you know about the generalized structure of cell and describe cell fractionation for study cellular structures?**

## 4.2.1 PLASMA MEMBRANE

**Introduction**

- It is also known as ***cell membrane***. It is the outermost layer in the animal cell but lies beneath the cell wall in plant cell.
- It is thin, delicate, elastic and capable of limited self-repair.

**Chemical Composition**

Cell membrane is chemically composed of lipids and proteins

- 60 – 80% are proteins.
- 20 – 40% are lipids
- Very small quantity of carbohydrate

**Physical Structure**

Many biologists contributed in describing the arrangement of lipids and proteins in cell membrane.

There are two important models about it i.e,

**(i)** Unit membrane model

**(ii)** Fluid mosaic model.

**1) Unit Membrane Model**

Generally, it was believed that plasma membrane is composed of lipid bilayer sandwiched between two protein layers. This is called unit membrane model.

This basic structure is found in all the membranes such as those of mitochondria, chloroplasts etc.

**2) Fluid Mosaic Model**

The modern technology has revealed that lipid bilayer is not sandwiched between two protein layers. Instead proteins are embedded in the lipid bilayer in a mosaic manner. This model is called fluid mosaic model and is most accepted now.

According to this cell membrane also contains ***charged pores*** through which movement of material takes place both by active and passive transport.

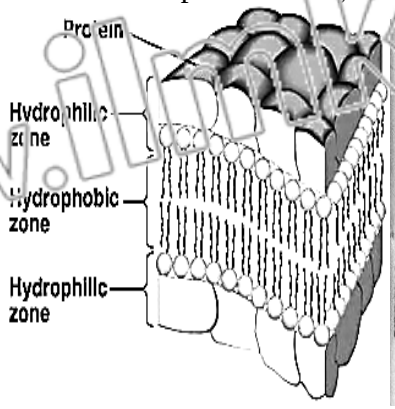



**Fig. 4.4** Unit membrane

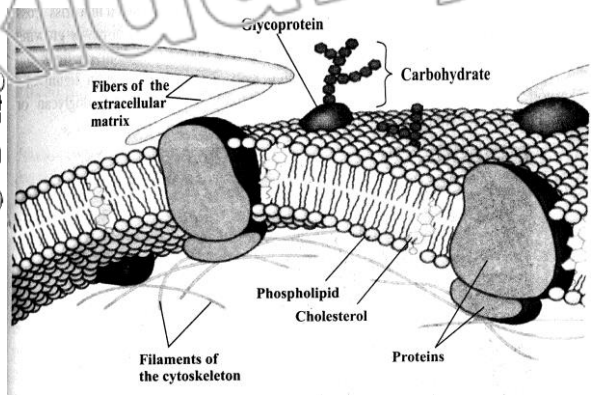



**Fig. 4.5** Fluid Mosaic Model

**Functions of Cell Membrane**

**i) Mechanical Support**

It provides mechanical support to the protoplasm.

**ii) External Form**

It provides external form to cell.

**iii) Transportation**

Transport of materials, which is vital for cell, occurs through cell membrane. It offers a barrier between the cell contents and their environment allowing only selective substances to pass through it. Thus it is also known as differentially permeable or selectively permeable membrane.

**iv) Regulation of Materials**

It regulates the flow of materials and ions to maintain definite gradient across it.

- The substances, which are lipid soluble, cross it more easily.
- Many small gas molecules, water, glucose etc being neutral can easily cross.
- Ions, beings charged particles have some difficulty in crossing.

**v) Active Transport**

Many substances, which are not needed, enter the cell by passive transport. These are then pushed out by active transport. The energy for this transport is provided by ATP.

**vi) Endocytosis**

In many animal cells, the cell membrane helps to take in materials by infoldings in the form of vacuoles. This type of intake is termed as endocytosis. It may be;

- ***Phagocytosis*** – ingestion of solid material.
- ***Pinocytosis*** – ingestion of liquid material.

**vii) Conduction**

In neuron (nerve cells), the cell membrane transmits nerve impulse from one part of the body to the other to keep coordination.

## QUESTION RELATED TO ABOVE ARTICLE

**Define cell membrane. Explain its functions. (LHR 2018)**

**Explain Structure of Plasma membrane. (BWP 2019)**

**Discuss structure and functions of plasma membrane. (LHR 2018, SWL 2019, 2022, RWP 2022)**

## 4.2.2 CELL WALL

**Characteristics**

**1)** It is the outermost boundary in plant cells.

**2)** It is absent in animal cells.

**3)** It is secreted by protoplasm of the cell.

**4)** Its thickness varies in different cells of the plant.

**5)** Cell wall of plant cell is different from that of prokaryotes both in structure and chemical composition.

**Structure**

Cell wall is composed of:

- Primary wall
- Middle lamella
- Secondary wall

**i) Primary Wall**

The primary wall is composed of:

- ***Cellulose*** whose molecules are arranged in a crisscross arrangement.
- Some amount of ***pectin*** is also present.

The primary wall is a true wall and develops in newly growing cells.

**i) Middle Lamella**

The middle lamella is first to be formed in between the primary walls of the neighboring cells.

**ii) Secondary Wall**

The secondary wall is formed on inner surface of primary wall. It is comparatively thick and rigid as compared to primary wall.

Chemically it is composed of:

- Inorganic salts
- Silica
- Waxes
- Lignin
- Cutin etc.

**Functions of Cell Wall**

Cell wall is very important. It performs following important functions:

**1)** It provides a ***definite shape*** to the cell

**2)** It makes cell ***rigid***

**3)** It provides ***protection*** to inner parts of cell.

**4)** It ***does not act as a barrier*** to the materials passing through it.

**QUESTION RELATED TO ABOVE ARTICLE**

**Describe in detail the cell wall of plant.** **(Exercise Question ii)**

## 4.2.3 CYTOPLASM

Inner to the cell membrane lies cytoplasm, which contains many organelles. The living contents of the eukaryotic cells are divided into nucleus and cytoplasm.

**Composition**

Cytoplasm contains

**i.** Cytosol

**ii.** Fundamental molecules of life

**iii.** Cell organelles

**i) Cytosol**

It is the soluble part of cytoplasm. Chemically, it is about ***90% water*** and forms a solution containing all the fundamental molecules of life.

**ii) Fundamental Molecules of Life**

- Some of them are in ionic form.
- Small molecules form true solutions.
- Some large molecules form colloidal solutions. Colloidal solution may be sol (non-viscous) or gel (viscous).

**iii) Cell Organelles**

In living cells, the cytoplasm contains several cell organelles such as endoplasmic reticulum, mitochondria, Golgi complex, nucleus, plastids, ribosomes, lysosomes and centrioles

**Function of Cytoplasm**

The most important functions of cytoplasm are:

**1)** It acts as a ***store house*** of vital chemicals.

**2)** It is a ***site of certain metabolic pathways*** e.g, Glycolysis.

**3)** The free floating organelles e.g. mitochondria move about in cytoplasm due cytoplasmic streaming movement. This is an active mass movement of cytoplasm.

## 4.2.4 ENDOPLASMIC RETICULUM

**Introduction**

Endoplasmic reticulum is a network, which is continuous with plasma membrane at one end and also appears to be in contact with the nuclear envelope.

**Structure**

- Endoplasmic reticulum is visible with electron microscope as a network of channels extending throughout the cytoplasm.
- They vary widely in appearance from cell to cell.
- These channels are filled with material, which is separated from the cytoplasmic material by the spherical or tubular membranes, called ***cisternae***.

**Functions**

- ➢ It provides ***mechanical support*** to the various cellular organelles in cytoplasm.
- ➢ It plays an important role in ***transport of materials*** from one part of the cell to the other.

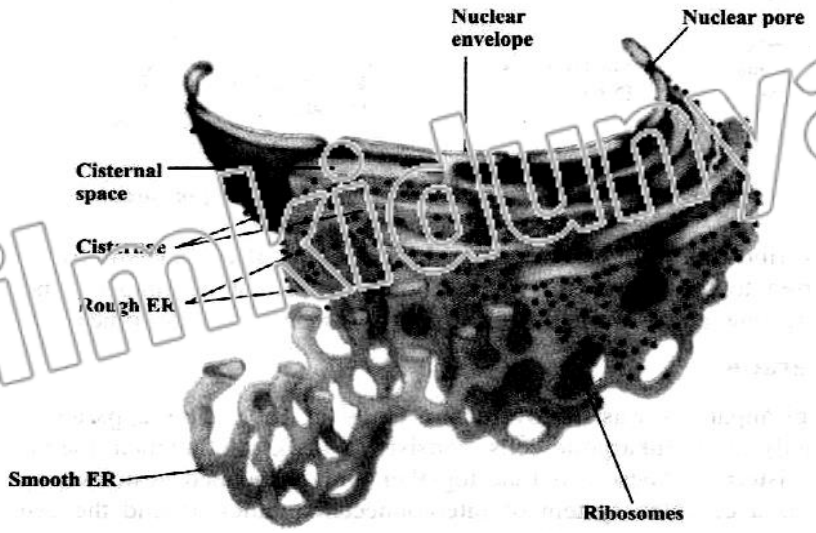



**Fig. 4.7:** Rough endoplasmic reticulum is marked by the presence of ribosomes attached to the membranes of endoplasmic reticulum. Proteins synthesized on ribosomes are pushed into channels of endoplasmic reticulum, from where they are transported to Golgi apparatus, on their way out of the cell.

**Forms**

There are two morphological forms of endoplasmic reticulum i.e,

**i)** Rough form with attached ribosomes

**ii)** Smooth form without ribosomes

**1) Rough Endoplasmic Reticulum (RER)**

On this form, ribosomes are attached, so it is called as rough endoplasmic reticulum.

**Function**

It is involved in the ***synthesis of proteins***. After synthesis, the proteins are either stored in the cytoplasm or exported out of the cell through these channels.

**2) Smooth Endoplasmic Reticulum (SER)**

This form of endoplasmic reticulum is without ribosomes, so called as smooth endoplasmic reticulum.

**Functions**

**i)** It helps in ***metabolism*** of a number of different types of molecules particularly lipids.

**ii)** It also helps to ***detoxify*** the harmful drugs.

**iii)** In some cells, it is responsible for ***transmission of impulses*** e.g. muscle cells, and nerve cells.

**iv)** It also plays an important role in ***transport of materials*** from one part of the cell to the other.

## QUESTION RELATED TO ABOVE ARTICLE

**What is endoplasmic reticulum? Explain its types and functions.**
**Write a note on endoplasmic reticulum.**
**Give structure and function of endoplasmic reticulum. (FSD 2019)**
**Describe in detail the structure and functions of Endoplasmic Reticulum. (SWL 2021)**
**What do you know about endoplasmic reticulum? Explain with diagram. (LHR 2022)**
**What is endoplasmic reticulum? Write its types and function. (FSD 2022)**

## 4.2.5 RIBOSOMES

**Introduction**

These are tiny granular structures present in cytoplasm.

**Discovery**

***Palade*** (1955) was the person, who first time discovered and studied them.

**Production**

New ribosomes are ***assembled in the nucleolus*** of the nucleus from where they are transported to the cytoplasm via the pores in the nuclear membrane.

**Chemical Composition**

Ribosomes are composed of almost an equal amount of:

- RNA
- Proteins

Due to presence of RNA and proteins, these are also called as ***ribonucleoprotein particles.***

**Existence**

Ribosomes exist in two forms:

- ***Freely*** dispersed in cytoplasm
- ***Attached*** with the endoplasmic reticulum as tiny granules.

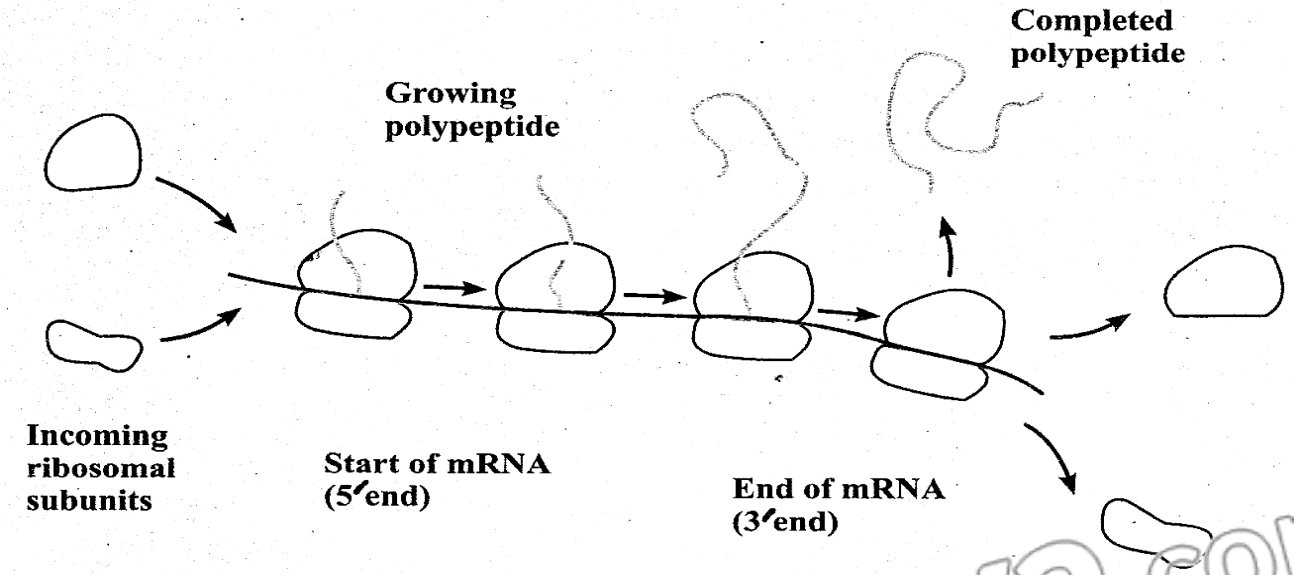



**Fig. 4.8** mRNA attached to ribosomes forming polysomes

**Structure**

Each eukaryotic ribosome consist of two sub units

- ***Larger subunits*** sediment at 60S
- ***Smaller subunits*** sediment at 40S

Two subunits on attachment, with each other form **80S** particles (S = Svedberg unit which specifies sedimentation rate). This attachment is controlled by $Mg^{2+}$ ions.

When many ribosomes get attached to the same stretch of mRNA they form a structure called ***'Polysome'***.

**Function**

Ribosomes are involved in the ***synthesis of proteins***.

**QUESTION RELATED TO ABOVE ARTICLE**

**Write note on ribosomes.**

## 4.2.6 GOLGI APPARATUS

**Introduction**

Golgi apparatus is also known as Golgi bodies or Golgi complex. In plants, these are also called as '***Dictyosomes***'

**Discovery**

Golgi apparatus was discovered by ***Golgi*** in 1898.

**Production**

These are produced by budding of SER and are gathered around cisternae.

**Structure**

Golgi complex is formed by cisternae along with associated vesicles.

- ***Cisternae*** are stacks of flattened, membrane-bounded sacs.
- ***Associated vesicles*** are complex system of interconnected tubules around the central stacks.
- The whole stack consists of a number of cisternae.
- Their outer convex surface is the ***forming face***, while the inner concave surface is the ***maturing face***. Vesicles are separated from cisternae from maturing face.

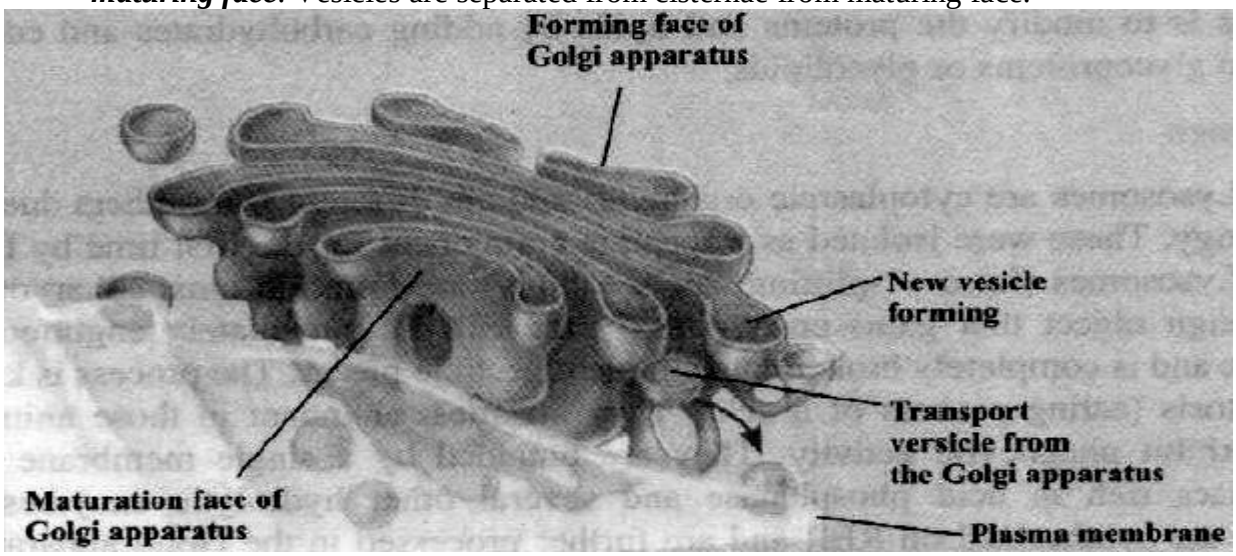



**Fig. 4.9** Golgi complex

**Functions**

**i) Cell Secretions**

Golgi complex is concerned with cell secretions. Mechanism of formation of these products is as; Formation of products on ribosomes, transport to Golgi apparatus for conversion into finished products, packing of finished products, export to outside through Golgi bodies or endoplasmic reticulum. *For example* in mammals, the pancreas secretes granules containing enzymes that help in digestion. The Golgi complex has a role in formation of these granules.

**ii) Transport outside the Cell**

The proteins or enzymes which have to be transported out of the cell, pass through the Golgi apparatus.

**iii) Modification in Molecules**

The most important function is to modify the proteins and lipids by adding carbohydrates and converting them into glycoproteins and glycolipids.

**QUESTION RELATED TO ABOVE ARTICLE**

**Explain the Golgi bodies in detail.**

## 4.2.7 LYSOSOMES

**Introduction**

The word 'Lysosome' has been derived from two words i.e.

- ***'Lyso'*** means splitting.
- ***'Soma'*** means body.

These were isolated as separate components for the first time by ***De Duve*** (1949).

These are mostly found in eukaryotic cells and are most abundant in these animal cells which exhibit phagocytosis.

**Structure**

They are bound by a single membrane and are simple sacs rich in **acid phosphates** and several other **hydrolytic** enzymes. These enzymes are synthesized on RER and are further processed in the Golgi apparatus. The processed enzymes are budded off as Golgi vesicles and are called as primary lysosomes

**Functions**

**i) Phagocytosis**

Lysosomes contain those enzymes which can digest the phagocytosed food. Any foreign object that gains entry into the cell is completely broken into simple digestible pieces. This process is known as phagocytosis (eating process of cell). They also contain enzymes, which can digest the phagocytosed food particles.

**ii) Autophagy**

They are also involved in autophagy (self-eating). During this process, some old, worn out parts of cell, such as old mitochondria are digested. In this way, materials of cell may be recycled and cell may be renewed.

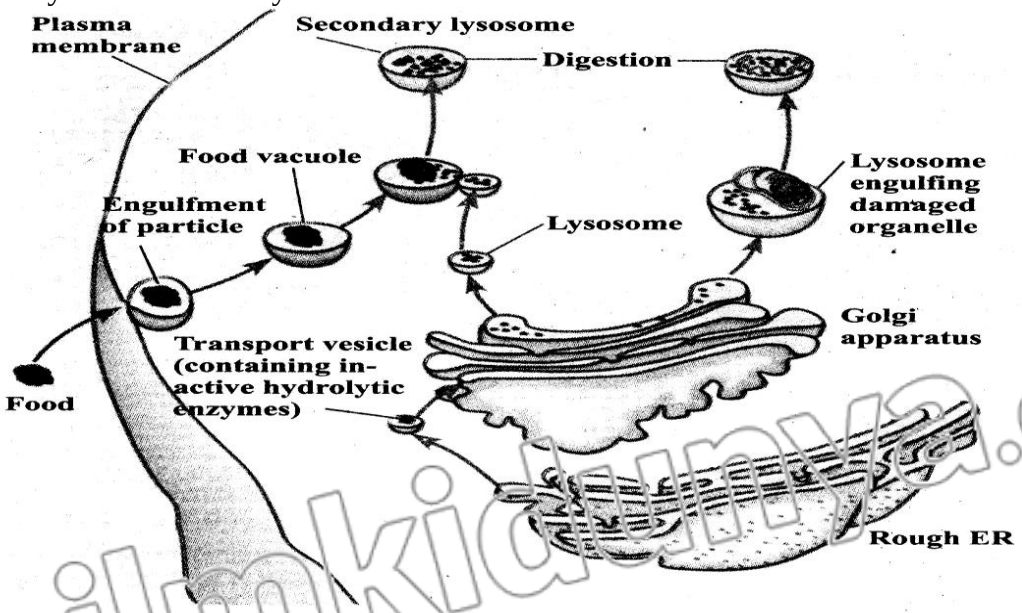



**Fig. 4.11** Lysosomes protect the cells from invading organisms or any other foreign object, (food) which are engulfed in the cell as phagocytic vacuoles. These fuse with primary lysomes to form digest various components of the vacuole. Sometimes, under abnormal circumstances, e.g. starvation, or as a normal physiological process the parts of the cell are engulfed by primary lysomomes and digested to generate energy. The lysosomes which eat parts of their own cell are known as autophagosomes. The digestive vacuoles and autophagosomes are also known as secondary Lysosomes.

**iii) Degeneration**

Their enzymes can also result in degeneration of cell, as may occur during some developmental processes.

**iv) Extracellular Digestion**

They also release enzymes for extra cellular digestion.

**DISEASES RELATED TO LYSOSOMES**

Several congenital diseases have been found to be due to accumulation within the cell of substance such as glycogen or various glycolipids. These are also called ***storage diseases*** and are produced by a mutation that affects one of the lysosomal enzymes involved in the catabolism of a certain substance.

**For example**

- ***About twenty*** such diseases are known these days, which are because of absence of a particular enzyme.
- In ***glycogenosis type II disease***, the liver and muscles appear filled with glycogen within membrane-bounded organelles. In this disease, an enzyme that degrades glycogen into glucose is absent.
- ***Tay-Sach's disease*** is because of absence of an enzyme that is involved in the catabolism of lipids. Accumulation of lipids in brain cells lead to mental retardation and even death.

**QUESTION RELATED TO ABOVE ARTICLE**

**What are lysosomes? Explain its types and its function.**

**Explain the structure and functions of lysosomes. (LHR 2017)**

**What are lysosomes? Give their functions. (LHR 2017)**

**What are lysosomes and explain its phagocytic role with the help of diagram? (LHR 2018)**

**Write a complete note on lysosome. Explain its phagocytic role with the help of diagram. (DGK 2021)**

## 4.2.8 PEROXISOMES

The name peroxisome (Peroxi = Peroxide and Soma = body) has been given because this organelle is specifically involved in the formation and decomposition of hydrogen peroxide in the cell.

**Discovery**

These were isolated by ***De-Duve*** and his coworkers in 1965 from liver cells and other tissues, which were enriched with some **oxidative enzymes**, such as peroxidase, catalase, glycolic acid oxidase and some other enzymes.

**Characteristics**

- These are ***single membrane*** enclosed cytoplasmic organelle found both in animal and plant cells.
- They are characterized by containing ***$H_2O_2$ producing oxidases and catalases***.
- They are approximately ***0.5 µm in diameter***.
- They have also been found in protozoa, yeast and many cell types of higher plants.

**Function**

These are involved in the ***formation and decomposition of hydrogen peroxide*** in the cell, which is used in various metabolic reactions.

## 4.2.9 GLYOXISOMES

**Introduction**

These are found *only in plant cells* and absent in animal cells.

- These are most ***abundant in plant seedlings.***
- They appear for only short period of time ***during germination*** of the lipid-rich seed such as castor oil, bean and soyabean and are absent in lipid-poor seed such as the pea.

**Composition**

These are single membranous organelle, which in addition to ***glycolic acid oxidase*** and ***catalase,*** also possess a number of enzymes that are not found in animal cells.

**Function**

- In plants, they play important role in both ***catabolic*** and ***anabolic*** activities.
- In germinating seedlings, enzymes of glyoxisome are important in conversion of ***stored fatty acids*** to carbohydrates especially succinate through a cycle called ***glyoxylate cycle***.

**QUESTION RELATED TO ABOVE ARTICLE**

**Write note on Peroxisome and Glyoxysomes.**

**Write notes on. (Exercise Question iii (a))**

**Peroxisomes and Glyoxisomes**

## 4.2.10 VACUOLES

**Introduction**

Vacuole are present both in animal and plant cells.

- ***In plant cells***, vacuole are large and few in number, often occupying a major portion of cell and pushing intracellular structures into a thin peripheral layer.
- ***In animal cells***, these are small but numerous in numbers.

**Formation**

The vacuoles are bounded by a single membrane and are formed during growth and development of cells. In plants, smaller vacuoles combine to form a larger vacuole.

**Function**

- They serve to ***expand the plant cell without diluting its cytoplasm.***
- They function as ***sites for the storage*** of water and cell products or metabolic intermediates.
- The plant vacuole is involved in ***turgor*** that provides ***support*** for the individual plant cell and contributes to the rigidity of the leaves and younger parts of the plants.

**QUESTION RELATED TO ABOVE ARTICLE**

**Describe the vacuoles in detail.**

## 4.2.11 CYTOSKELETON

Cytosol contains cytoskeletal fabrics formed of microtubules, microfilaments and intermediate filaments, all constituting cytoskeleton.

**Composition**

Cytoskeleton is made by different proteins. The main proteins that are present in cytoskeleton are tubulin, actin, myosin, tropomyosin and others, which are also found in muscles.

**Types of Cytoskeletal Fibers**

**i) Microtubules**

- These are long, unbranched and slender ***tubulin protein*** structures.
- Their important role is in assembly and disassembly of the ***spindle*** structure during mitosis. They are also involved in formation of ***cilia, flagella*** and ***basal bodies***.

**ii) Microfilaments**

- These are more slender cylinders made up of contractile ***actin protein***, linked to inner face of the plasma membrane.
- They are involved in ***internal cell motion*** e.g. movement of cyclosis and amoeboid movement.

**iii) Intermediate Filaments**

- They have diameter in between those of microtubules and microfilaments.
- They play role in ***maintenance of cell shape*** and ***integration of cellular compartment***.

## QUESTION RELATED TO ABOVE ARTICLE

**What is Cytoskeleton? Give its functions.** **(MTN 2019)**
**Write a note on Cytoskeleton.** **(GRW 2018, BWP 2022)**
**Write notes on.** **(Exercise Question iii (a))**
**Cytoskeleton**

## 4.2.12 CENTRIOLE

**Introduction**

Animal cell and the cells of some microorganisms and lower plants contain two centrioles located near the exterior surface of the nucleus and ***absent in higher plants.*** They are usually placed at right angle to each other.

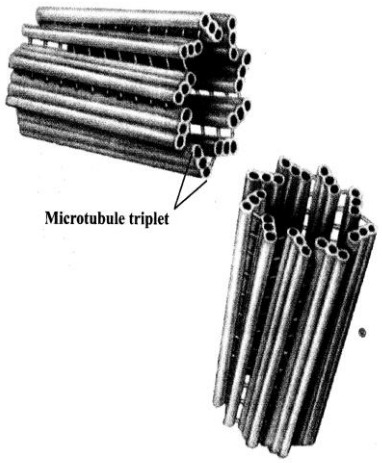



**Fig. 4.12.** Centrioles are made up of nine microtubule triplets

**Structure**

In cross-section, each centriole consists of a cylindrical array of ***9 microtubules***. Each of the 9 microtubules is further composed of ***three tubules***.

**Function**

Centrioles are involved in ***cell division***. Just before cell divides, its centrioles duplicate and one pair migrates to the opposite side of the nucleus. The spindle then forms between them.

## QUESTION RELATED TO ABOVE ARTICLE

**Explain the centriole in detail.**

## 4.2.13 MITOCHONDRIA

**Introduction**

- Mitochondria are very important organelle of the eukaryotic cell because they are involved in the manufacture and supply of energy to the cell. They are also known as ***power-house of the cell***.
- Mitochondria are ***self-replicating organelles***.

**Structure**

- ***Under compound microscope,*** they appear to be vesicles, rods or filaments.
- ***Under electron microscope***, they show a complex morphology.

**Characteristics**

- Their ***number and size*** varies and depends on the physiological activity of the cell.
- It is bounded by two membranes. ***Outer membrane*** is smooth. ***Inner membrane*** forms infoldings into the inner chamber or ***mitochondrial matrix***. These infoldings are called ***cristae***.
- The inner surface of cristae has small knob like structures known as ***$F_1$ particles***
- Mitochondrial membranes are similar in structure to other membranes.
- Mitochondria also contain some ***DNA*** and ***ribosomes***.

**Function**

**i)** Presence of ribosomes and DNA indicates that some ***proteins*** are also synthesized in it.

**ii)** Mitochondrial matrix contains a large number of enzymes, coenzymes and organic and inorganic salts which help in several ***metabolic processes*** like Krebs cycle, aerobic respiration, fatty acid metabolism etc. As a result of these metabolic processes, the energy present in the food stuff is transformed into energy rich compound known as adenosine triphosphate abbreviated as **ATP** which then provides energy to cell on demand.

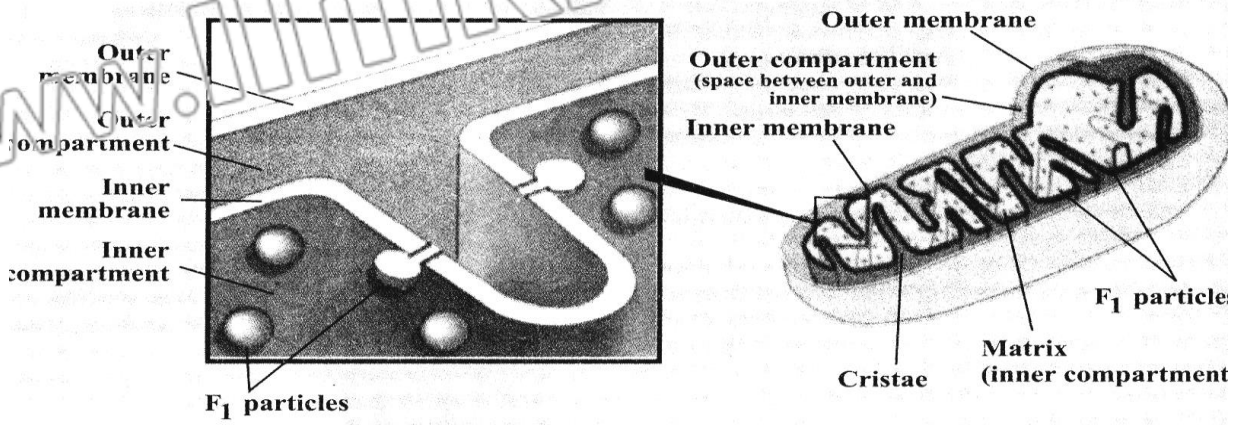



**Fig. 4.13** Diagrammatic representation of a mitochondrion cut longitudinally. The main features are shown. A crista is made of lipoprotein membrane containing different enzymes as well as $F_1$ Particles embedded in it. After a special processing the inner mitochondrial membrane is ruptured and the $F_1$ particles come out on the surface.

## QUESTION RELATED TO ABOVE ARTICLE

**Explain the mitochondria in detail.**

**Compare structure and function of chloroplast and mitochondria.**

**Write down a note on mitochondria.** **(GRW 2017, 2021)**

**Write a comprehensive note on mitochondria.** **(LHR2021, MTN 2021)**

**Explain structure and functions of mitochondria.**

**(LHR 2019, GRW 2021, MTN 2021, DGK 2022)**

## 4.2.14 PLASTIDS

Membrane bounded, mostly pigment containing bodies present in the cells are called plastids. These are present in plant cells only.

**Types**

There are three main types of plastids.

**i.** Chloroplast

**ii.** Chromoplast

**iii.** Leucoplast

**1) Chloroplast**

***Green colored*** plastids are called as chloroplasts. These are ***self-replicating organelle***.

**Structure**

- Their green colour is due to presence of a pigment, which is an organic compound called chlorophyll. ***Chlorophyll*** resembles haem group of haemoglobin. The main difference between these two molecules is that chlorophyll has $Mg^{++}$ while haem has $Fe^{++}$ as the central atom.
- Chloroplasts vary in their shape and size with a diameter of about ***4-6 µm***.
- **Under light microscope,** they appear to be heterogeneous structures with small granules known as ***grana*** embedded in the ***matrix***.
- **Under electron microscope,** it shows three components i.e. envelope, stroma and thylakoid

**i)** ***Envelope*** is formed by double membrane.

**ii)** ***Stroma*** covers most of the volume of the chloroplast. It is a fluid, which surrounds the thylakoids. It contains proteins, some ribosomes and a small **circular** DNA. In it $CO_2$ is fixed to carbohydrates during photosynthesis.

**iii)** ***Thylakoids*** are the flattened vesicles, which arrange themselves to form grana and intergrana. On the layer of thylakoid, chlorophyll molecules are arranged.

**iv)** A ***granum*** appears to be a pile of thylakoids, in which on an average 50 or more thylakoids may be present.

- Grana look green due to presence of chlorophyll on thylakoid.
- Each granum is interconnected with others by the non-green part called intergranum.
- These are the sites where sunlight is trapped.

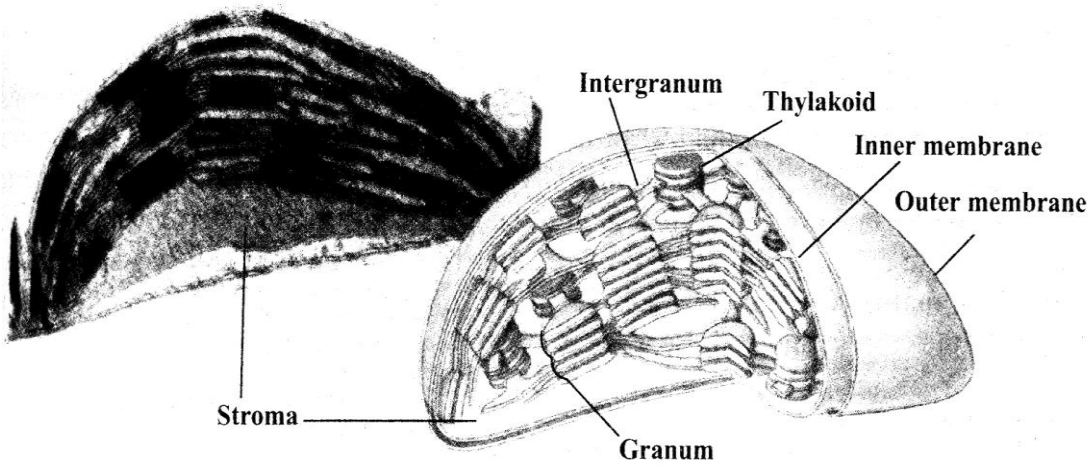



**Fig. 4.14 Diagram of Chloroplast showing the main structural components**

**Function**

Process of ***photosynthesis*** by which plants manufacture their food takes places in chloroplast.

**2) Chromoplast.**

They are present in the petals of the flowers and in the ripened fruit.

**Function**

- They impart colours to the plants ***other than green***.
- They help in ***pollination*** and ***dispersal of seeds***.

**3) Leucoplast**

- They are ***colourless***.
- They are triangular, tubular or of some other shape.
- They are found ***in underground parts*** of the plant and stored food.

## QUESTION RELATED TO ABOVE ARTICLE

**What are plastids? Explain the structure and function of chloroplast. Draw figure.**
**What are plastids? (LHR 2021)**
**What are plastids? Describe structure and function of chloroplast?**
**(RwP 2019, LHR 2019, DGK 2021, RWP 2021)**
**Define Plastids, give its types, and also draw its diagram. (MTN 2022)**
**What are plastids? Write their type in detail? (GRW 2019, SGD 2022)**

## 4.3 NUCLE

**Introduction**

Nucleus is the most important organelle of cell, which controls all the activities of cell.

**Discovery**

***Robert Brown*** discovered nucleus first time in 1831.

**General Features**

**i)** In ***animal cells***, it generally occupies the central space, while in the case of ***plant cells*** it is pushed towards periphery due to the presence of a large vacuole.

**ii)** Generally the cells have one nucleus and are called ***mononucleate***. On the other hand, the cells with two nuclei are ***binucleated*** and with more than two as ***multinucleated***.

**iii)** Nucleus is ***only visible*** when the cell is ***in non-dividing stage***. It contains chromatin network and soluble sap called nucleoplasm. In dividing cells, the nucleus disappears and chromosomes replace the chromatin material in it.

**iv)** DNA, RNA and proteins including enzymes form the ***chemical composition*** of the nucleus.

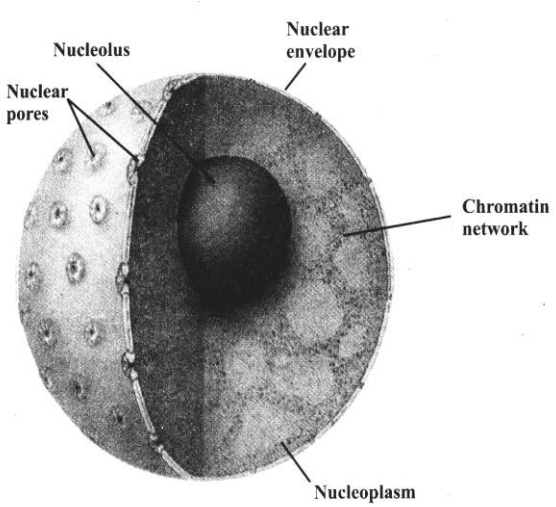



**Fig. 4.16** Structure of nucleus

**Structure**

Nucleus consists of three important components i.e.

**(i)** Nuclear membrane
**(ii)** Nucleolus
**(iii)** Chromosomes

**i) Nuclear Membrane**

Nucleus is surrounded by a nuclear membrane, which separates the nuclear material from the cytoplasm.

- Nuclear membrane acts as ***nuclear envelope***, which is composed of two membranes.
- ***Outer membrane*** is at places continuous with the endoplasmic reticulum.
- ***Inner membrane*** encloses the nuclear contents.
- Outer and inner membranes are continuous at several points, giving rise to ***nuclear pores***.
- They allow exchange of materials between the nucleus and cytoplasm.
- Their number is highly variable. The undifferentiated cells e.g, eggs have numerous pores (about 30,000 per nucleus), whereas differentiated cells e.g, erythrocytes have only 3 or 4 pores per nucleus.
- Each pore has a specific structure, which controls the traffic of substances passing through them.

**ii) Nucleolus**

It is a darkly stained body within the nucleus, and is without any membranous boundary to separate it from the rest of the nuclear material.

**Abundance**

- There may be ***one or more*** nucleoli in the nucleus.

**Physical Structure**

- It is composed of ***two regions***, the ***peripheral granular area*** composed of precursors of ribosomal subunits and the ***central fibrillar*** consisting of large molecular weight RNA and rDNA.

**Function**

- It is involved in the ***synthesis*** and ***storage of ribosomal RNA***. It is the site where ribosomes are assembled and exported to the cytoplasm via nuclear pores.

**iii) Chromosomes**

Nucleus is deeply stained with basic dyes because of the chromatin material. During cell division chromatin material is converted into darkly stained thread like structures known as chromosomes.

**Physical Structure**

Under compound microscope, chromosomes appear to be made of arms and centromere. Each chromosome consists of;

- Two identical ***chromatids*** at the beginning of cell division (chromatid is exact replica of the chromosome), which are held together at centromere.
- ***Centromere*** is the place on the chromosome where spindle fibers are attached during cell division.

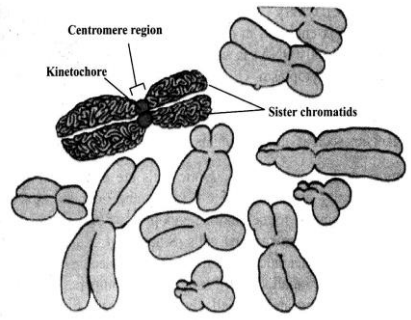



**Fig. 4.15** Structure of chromosome and its shape

**Chemical Structure**

A chromosome is composed of ***DNA*** and ***proteins***. All the information necessary to control the activities of the cell is located on the chromosomes in the form of genes, which are transferred from one generation to the other.

**Number of Chromosomes**

- The number of chromosomes in all individuals of the same species remains ***constant generation after generation***.

**For example**

- In man, each cell contains 46 chromosomes
- Frog cell has 26
- Chimpanzee has 48
- Fruitfly Drosophila has 8
- Onion cell has 16
- Potato cell has 48
- Garden pea has 14

- The number of chromosomes in normal body cells is ***diploid (2n),*** whereas ***haploid number (n)*** is present in germ cells e.g. human sperm and eggs have 23, while those of Drosophila have 4 chromosomes.

## QUESTION RELATED TO ABOVE ARTICLE

**Write detail note on nucleus.**

**Give structure and function of nucleus.** **(SGD 2019, FSD 2019)**

## 4.4 PROKARYOTIC AND EUKARYOTIC CELL

| DIFFERENCE | PROKARYOTE | EUKARYOTE |
|---|---|---|
| **1) CELL TYPE** | They are composed of prokaryotic cells. | They are composed of eukaryotic cells. |
| **2) NUCLEUS** | Nucleus is absent in them. | They have well defined nucleus. |
| **3) DNA** | DNA is without any nuclear membrane covering and is directly submerged in cytoplasm. | DNA is enclosed inside the nucleus. |
| **4) MEMBRANE-BOUNDED STRUCTURES** | Membrane-bounded structures are absent. | Membrane-bounded structures are present. |
| **5) RIBOSOMES** | They have small sized 70S ribosomes | They have large sized 80S ribosomes. |
| **6) CELL WALL** | Their cell wall is composed of polysaccharide chain covalently bonded with shorter chains of amino acids forming peptidoglycan or murein. | Cell wall of plants is generally composed of cellulose. |
| **7) CELL DIVISION** | They reproduce by binary fission. | They reproduce by mitosis and meiosis. |
| **8) EXAMPLE** | Bacteria and blue green algae | Multicellular animals and plants are examples. |

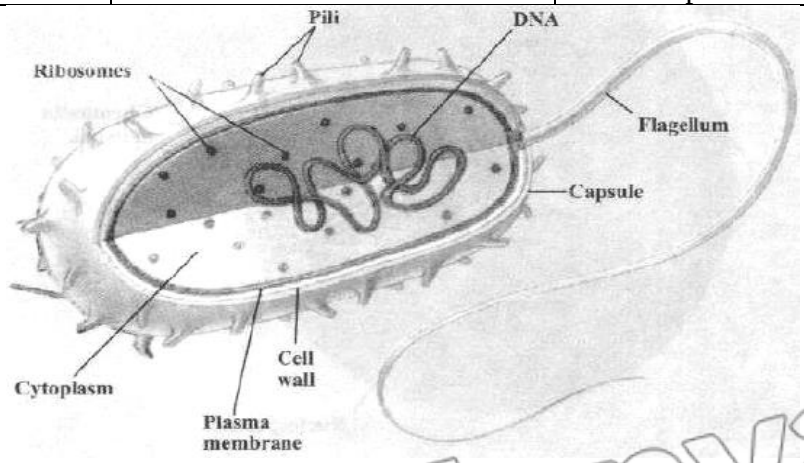



**Fig. 4.17** Generalized Prokaryotic cell

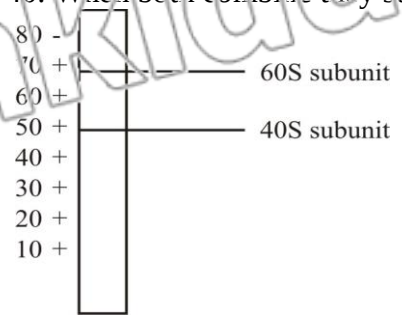
### QUESTION RELATED TO ABOVE ARTICLE

**Compare Eukaryotic and prokaryotic cell**
**Differentiate between Prokaryotes and Eukaryotes. (BWP 2021)**
**Differentiate between prokaryotic and eukaryotic cell. (DGK 2019, RWP 2021)**

## KEY POINTS

**Svedberg Unit(s)**

It is the rate of sedimentation (layers) formation during centrifugation. In this case ribosomes are centrifuged in a special centrifuge tube. Different points like 10, 20, 30, 40, 50, 60 etc are present on this tube. Different layers with different points. 60S settle at point 60 and 40S at point 40. When both combine they settle in the layer at 80S.



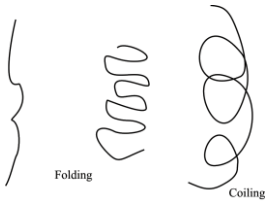

**Glycolysis and Krebs cycle**

During oxidation (break down) glucose, three processes take place.

- Glycolysis. It takes place in cytosol of cytoplasm. In this case, glucose is broken into two molecules of pyruvic acids.
- Krebs cycle: It takes place in mitochondria. In this case the pyruvic acid broken to release $CO_2$. It forms NADH.
- Electron transport chain: It also takes place in mitochondria. During this process, ATP molecules are synthesized and water is released.

**Chromatin material and Chromosome**

During non-dividing stage of cell, the nucleus has chromatin material. It is thin thread like structure. It cannot be seen with compound microscope. During dividing stage of cell, this thread of chromatin material condenses by folding and coiling and become much thick. This is called chromosome. It can be seen with compound microscope.




Thread of chromatin material. Chromosome

**Solution and colloidal solutions**

**True Solution:**

In true solution, the solute and solvent molecules are present in single phase (homogenous). The solute particles have very small size. The solute and solvent particles cannot be differentiated. e.g. Water + Sugar.

**Mixture:**

In this case, the solute and solvent particles from two phases (heterogeneous). The solute particle can be easily differentiated form the solvent molecules. The solute particles have large size, e.g. Water + Sand.

**Colloidal solution:**

It is solution in which the size of particles of solute is intermediate between true solution and mixture. In this case the solute particles can be seen in solvent but cannot be differentiated from solvent particles. In this case the size of solute particles is intermediated between solution and mixture e.g. Water + clay.

## EXERCISE

**Q.1. Fill in the blanks**

**i)** In eukaryotic cell, chromatin material is bounded by_____.

**ii)** A group of ribosomes attached to mRNA is known as_____.

**iii)** _____is the place chromosomes where spindle fibres are attached during cell division.

**iv)** The endoplasmic reticulum with attached ribosomes is known as _____.

**v)** The soluble part of the cytoplasm is called _____.

**Ans:**

i) Nuclear membrane
ii) Polysomes
iii) Centromere
iv) Rough endoplasmic reticulum
v) Cytosol

**Q.2. Write whether the statement is 'true' or 'false' and write the correct statement, if it is false.**

**i)** Cell membrane is present in all eukaryotic cells. **(True)**

**ii)** Chloroplast and mitochondria do not have hereditary material. **(False)**
Chloroplast and mitochondria have hereditary material

**iii)** Centriole is involved in cell secretions. **(False)**
Golgi complex is involved in cell secretions.

**iv)** Sometimes many ribosomes get attached to the same strand of mRNA forming a structure called cytosome. **(False)**
Sometimes many ribosomes get attached to the same strand of mRNA forming a structure called Polysome.

**v)** Mitochondria are very important organelles of the eukaryotic cells. **(True)**

**Q.3. Each question has four options. Encircle correct answer.**

**i) Which statement about the nuclear envelope is not true?**
**(a)** It has pores
**(b)** It is double membrane structure
**(c)** Its inner membrane bears ribosomes
(d)RNA and some proteins pass through it.

**ii) Which statement about plastids is true?**
**(a)** They are surrounded by a single membrane
**(b)** They are the powerhouse of the cell
**(c)** They are found in all organelles
**(d)** They contain DNA and ribosomes.

**iii) Which type of cell would most probably be most appropriate to study lysosomes?**
**(a)** Phagocytic white blood cells
**(b)** Nerve cell
**(c)** Mesophyll cell of leaf
**(d)** Muscle cell

**iv) Which of the following pairs of structure-function is mismatched:**
**(a)** Ribosomes: protein synthesis
**(b)** Nucleolus: ribosome production
**(c)** Golgi: muscle contraction
**(d)** Lysosome: intracellular digestion

**v) Which of the following statements about ribosomes is correct?**
**(a)** They are structurally different from free ribosomes.
**(b)** They are enclosed in their own membrane.
**(c)** They are concentrated in the cisternae space of rough ER.
**(d)** They are attached to cisternae surface.

**Answer Key:**

| | |
|---|---|
| i | c |
| ii | d |
| iii | a |
| iv | c |
| v | a |

**Q.4. Short Questions**

**i) Describe various movements involved in the transport of materials across the cell membrane.**

**Ans:**
**(1)** Passive transport
**(2)** Diffusion
**(3)** Osmosis
**(4)** Carrier mediated transport (Facilitated diffusion)
**(5)** Endocytosis

**ii) State various structural modifications in a cell involved in secretions.**

**Ans:** Secretions are the products produced within the cell on ribosomes and then passed to the outside through endoplasmic reticulum and Golgi apparatus. The secretions are converted into finished product and are packed inside membrane, before passing out. These involve formation of glycoproteins and glycolipids.

**iii) List the processes blocked by mitochondrial failure in a cell.**

**Ans:** **(i)** Krebs cycle
**(ii)** Electron transport chain
**(iii)** Fatty acid metabolism
**(iv)** Active transport

**iv) What will happen if a chromosome loses its centromere?**

**Ans:** It will become a functionless degenerated chromosome. It will not attach with spindle fibers during cell division and will not be able to divide properly.

**v) How does autophagy help in converting a tadpole larva into an adult amphibian?**

**Ans:** **Autophagy:**
Autophagy is the breakdown of cell organelles. During this process some old and worn-out parts of a cell are digested. In this way old cell material are used and cell is renewed.

**Role in Amphibian:**
Same way tail and some other structures are broken down and disappear and an adult amphibian appears.

**vi) Is there any similarity between bacterial and plant cell wall?**

**Ans:** Plant cell wall and bacterial cell wall are totally different both in structure and function.
For example bacterial cell wall is made up of peptidoglycan mainly while plant cell wall mainly contains cellulose. Similarly bacterial cell wall shows permeability variably while plant cell wall is permeable to water and minerals.

**Q.5. Extensive Questions.**

**i)** Compare structure and function of chloroplasts and mitochondria.

| FEATURE | CHLOROPLAST | MITOCHONDRIA |
|---|---|---|
| **Introduction** | They are found only in plant cells. | They are found both in plant and animal cells. |
| **Structure** | Their outer and inner membranes are smooth. | Their inner membrane forms infoldings called cristae. |
| **Matrix** | Their matrix is called stroma. | Their matrix is called mitochondrial matrix. |
| **Inner structures** | Grana are present in stroma. | Cristae are present in mitochondrial matrix. |
| **Enzymes** | Enzymes present in stroma are concerned with photosynthesis. | Enzymes present in mitochondrial matrix are concerned with respiration. |
| **Function** | These are involved in process of photosynthesis. | These are involved in process of respiration. |

**ii)** State cell theory and discuss its emergence.

**Ans:** (See article 4.1.1 & 4.1.3)

**iii)** Write notes on.

**(a)** Cytoskeleton

**Ans:** (See article 4.2.11)

**(b)** Peroxisomes and Glyoxisomes

**Ans:** (See article 4.2.8 & 4.2.9)

**iv)** What might happen if some lysosomal enzymes are absent? Explain with examples.
As lysosomal enzymes are involved in various processes. So absence of lysosomal enzymes will result in loss of these processes. For example;

- Lysosomes are involved in intracellular digestion through their enzymes. Absence of these enzymes will result in loss of digestion.
- Lysosomal enzymes are involved in degeneration of various structures e.g. frog tail during metamorphosis. Absence of these enzymes will result in loss of this process.
- Lysosomal enzymes of WBCs are involved in killing of microorganisms. Absence of these enzymes will result in loss of immunity and killing of these microorganisms.