CELL STRUCTURE AND FUNCTION

Chapter 3

Major Concept

In this Unit you will learn:

- Techniques used in Cell-Biology
- Cell-Wall and Plasma membrane as boundary wall
- Cytoplasm and Organelles
- Prokaryotic and Eukaryotic Cells

Introduction:

We are studying cell from our early classes and know that it is the basic structural and functional unit of all living organisms. As a student of biology we must study cell in detail. For this study we must know about the techniques of its studies because it is a microscopic structure. The isolation, magnification and other basic needs should understand clearly before this study.

3.1 TECHNIQUES USED IN CELL BIOLOGY

To study cell, its organelles and functions following procedure are required.

(i) Cell fractionation – Centrifugation and sedimentation.
(ii) Differential staining
(iii) Microdissection
(iv) Chromatography
(v) Electrophoresis
(vi) Spectrophotometry
(vii) Tissue culture
(viii) Microscopy
(ix) Measurement of cell and their organelles size.

i) Cell fractionation

Isolation of cellular components to determine their structure and chemical composition is called cell fractionation. It is a combination of various procedures to separate cell organelles on the basis of size and density. It consists of two steps:

(a) Homogenization
(b) Sedimentation

(a) Homogenization:

It is the first step of cell fractionation, where large number of similar type of cells breaks in an ice cold suitable medium with proper pH and ionic composition. These cells are placed in homogenizer or mortar and pestle. For plant cells an enzyme pectinase is also used in medium to separate cells by digesting middle lamella.

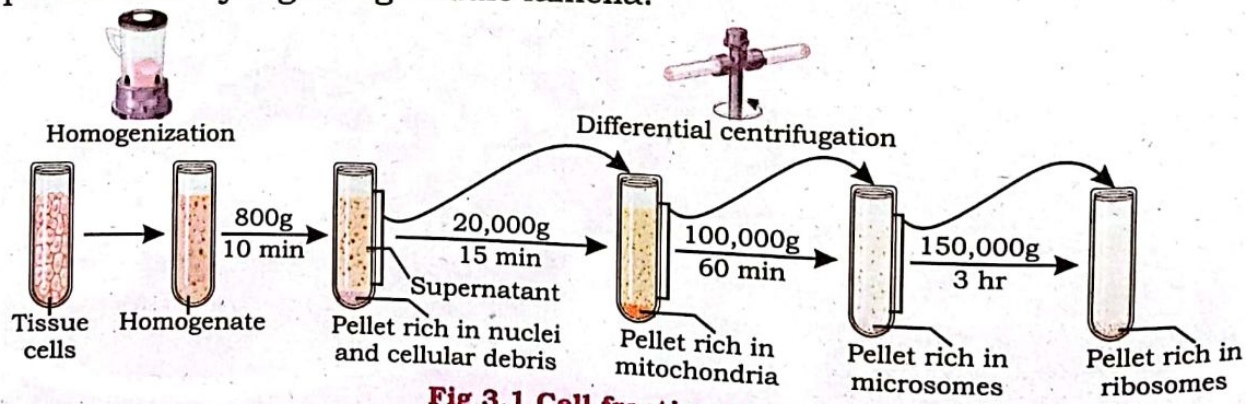

Fig 3.1 Cell fractionation

(b) Sedimentation:

The process of setting down cell organelles on the basis of density and mass by the process of centrifugation is called sedimentation. Smaller the particle (organelles or molecules) the higher will be the gravitational force required for the separation. It requires ultra centrifuge instrument (its rotation can be up to 60,000 cycles per minutes). Centrifugation method is used for the isolation of cell organelles and components. It is very common method in cell biology where separation is based on sedimentation rate. It is stepwise process by increasing in the centrifugation speed. In the beginning lower speed of centrifuge is used to separate the heavier and bigger organelle from sample and then gradually the speed and size of rotator increases stepwise until the target achieve. At low speed large particles like cell nuclei, settle down as sediment. Smaller particle are still in the supernatant (fluid) which can be poured into a fresh tube and subjected to centrifugation at higher speed until the smallest particles have been separated out. The various cell fractions are now available for cytological and biochemical analysis.

ii) Differential Staining

In cell or tissues some structures are transparent. To study the differences between these structures some dyes are used which are absorbed differentially due to their chemical composition for example, for different types of WBCs we use different dyes. This technique is called staining, and the process where different dyes are used at the same time to distinguish them from one another called differential staining.

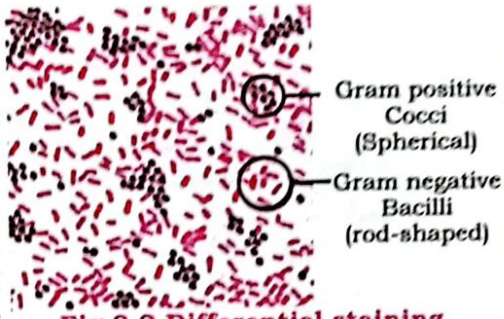

Fig 3.2 Differential staining

iii) Microdissections

Microdissection is a technique to isolate specific cells with the help of microscope. It is used in biological research to find out the role of embryonic cells in development, role of different chemicals on cell development and treatment of different diseases. So it is a collection of different techniques where a microscope is used during studies.

iv) Tissue Culture

It is a technique of cloning where cell or tissues or an organ grow on artificial medium in a test tube or Petri dish. It was first started from plant cell because plant cells are totipotent (totally potential) i.e. each cell has complete genetic potential to grow in a plant. In 1958 F.C Steward grew a complete carrot plant from a tiny piece of phloem on a medium containing sugar, minerals and vitamins. With these he also added coconut milk (containing plant hormone) these cells began dividing, they produced a

callus (an undifferentiated group of cells). That callus differentiated later on into shoot and root and developed into a new plant. Now a day this technique is also used to grow some tissues for transplantation to find abnormality in cells like cancer cells.

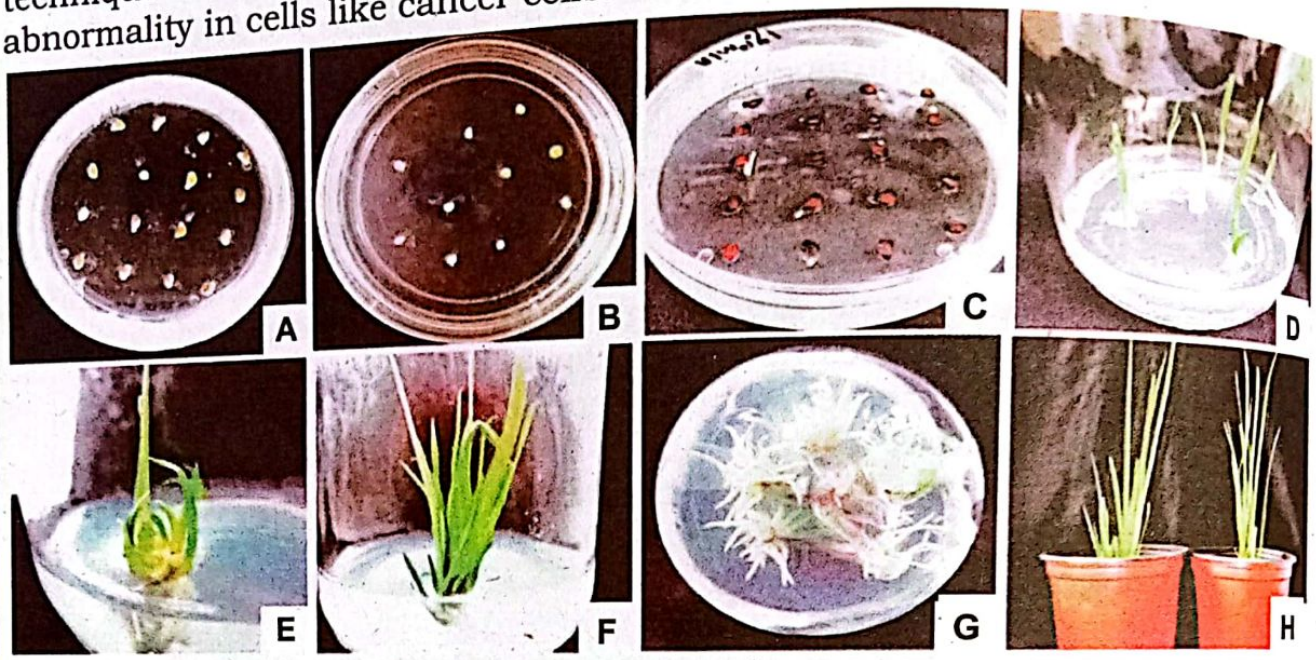

Fig 3.3 Tissue culture from seed to plant

v) Chromatography (Chroma = colour, graphic = lines or pictures)

It is a technique used for separating different components of mixture. The speed of molecular movement is also depend on its molecular size, so different components of mixture travel through the stationary phase at different speed. There are four different types of chromatography techniques used for qualitative analysis.

a) Paper chromatography
b) Thin-layer chromatography
c) Gas chromatography
d) High performance liquid chromatography.

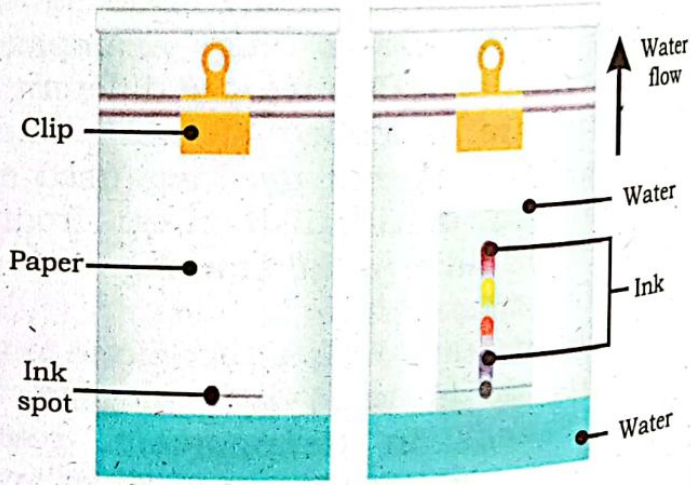

Fig 3.4 Paper chromatography

Paper chromatography is a simple and mostly used in analytical chemistry. In this method there are two phases. One is stationary phase and other is mobile phase. The cellulose sheet i.e. filter paper works as stationary phase while sample mixture within a solvent work as mobile phase. The component of sample (mixture) starts separating on paper according to their rate of movement.

vi) Electrophoresis:

A technique used to separate charged molecule based on their size and electrical charge in an electrolytic cell is called electrophoresis. It is mainly used to separate DNA, RNA or protein molecules.

This technique is familiar with the name of Gel electrophoresis because the charged molecules of different size move through a gel made up of a compound i.e. Acrylamide, this movement of charged molecule occur when an electric current is passed across it. The Gel consists of a permeable matrix, like sieve, through which molecules can travel when an electric current is passed across it. The Gel is suspended in an electrolytic solution and it is placed between two electrodes. At one end the gel has positive electrode i.e. positively charged and the other end has a negative electrode i.e. negatively charged.

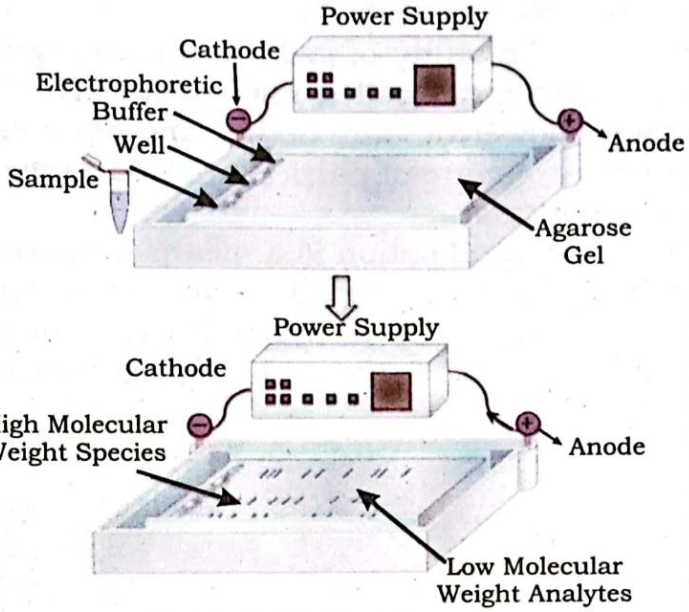

Fig 3.5 Electrophoresis

The movement of charged molecules is called migration molecules. They migrate towards opposite charge. A molecule of negative (-) charge will migrate towards positive (+) end. Smaller molecule migrates more quickly through the pores of gel and travel faster than large molecules. As a result different molecules are separated.

vii) Spectrophotometry

Each compound absorbs visible light of a certain range and wave length. We can recognize the compound from this range of absorption septrum. This method of measuring light absorption by a particular substance is called spectrophotometry. The instrument used is called **spectrophotometer**. This instrument uses a light beam which passes through the sample where each compound of sample solution absorbs or transmits light of a certain wavelength. This emitted or absorbed wave length is measured by spectrophotometer. It is used to determine growth of bacteria, rate of photosynthesis and minute quantity of (DNA) etc.

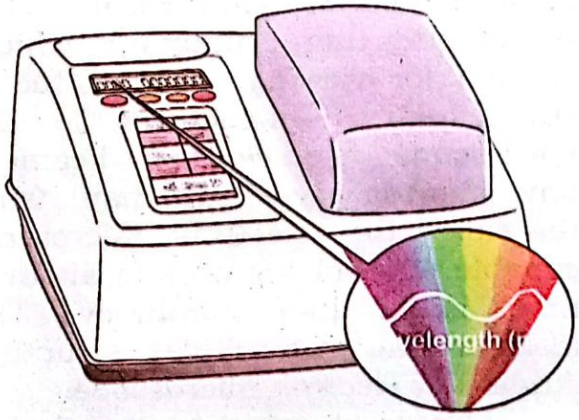

Fig 3.6 Spectrophotometer

viii) Microscopy

The study of cell and micro-organisms is dependent upon the use of an instrument called microscope. To study cell and its organelles properly more powerful and better microscopes are required. Three attributes of microscope are of particular importance, these are magnification, resolution and contrast.

Magnification is a means of increasing the apparent size of an object, with a light microscope a specimen could quite easily be magnified by as much as 10,000 x. Magnification power of a microscope is calculated by multiplying the power of its eye piece with its magnifying power of its objective.

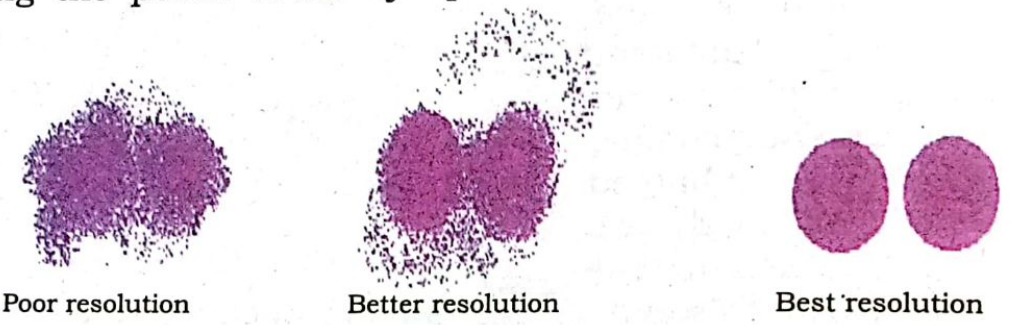

Fig 3.7 Microscopy

When we magnify the object beyond a limit its image become blurred i.e. loose its clarity. This clarity of image is generally known as **resolution,** we can say that it is the capacity of an instrument to separate adjacent form or object i.e. minimum distance at which two distinct point of a specimen can still be seen by observer.

A very high magnification can be obtained by light microscope, but their resolution power is limited. It is about 500 times better than human eye, which is not enough for viewing some of the smaller sub-cellular structures. Electron microscope use electron beams which have shorter wavelength than visible light therefore the electron microscope are capable of resolving objects about 10,000 times better than human eye. Therefore most of the sub-cellular structures are studied by electron microscope.

Contrast refers to the darkness of the background relative to the specimen. In order to see colorless or transparent specimen, a special type of microscope is

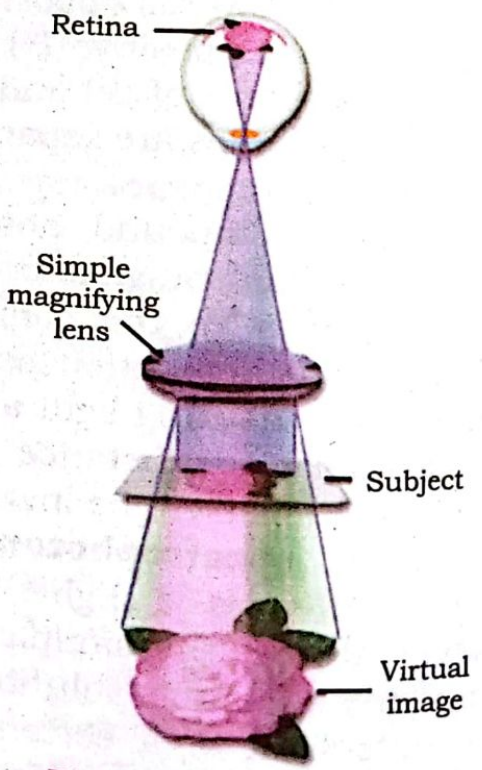

Fig 3.8 Magnification with a simple thin lens

required called phase contrast microscope. It is important to distinguish one part of cell from another. In light microscope contrast is often obtained by fixing and staining the material.

3.1.2 Micrometry

It is the science related to measurement of dimensions and size of an object observing under microscope. It requires special device of measurement called micrometer, this instrument is attached or put into the microscope. There are two types of micrometer i.e. an ocular micrometer and stage micrometer. The ocular micrometer is a disc, made up of glass. It has 100 equal divisions with no absolute value. It is placed in the eye piece of microscope. A stage micrometer is a calibrating device. It is a glass slide with proper scale like ruler. To calibrate and estimate the size of a given object, the image of ocular micrometer is super imposed on stage micrometer.

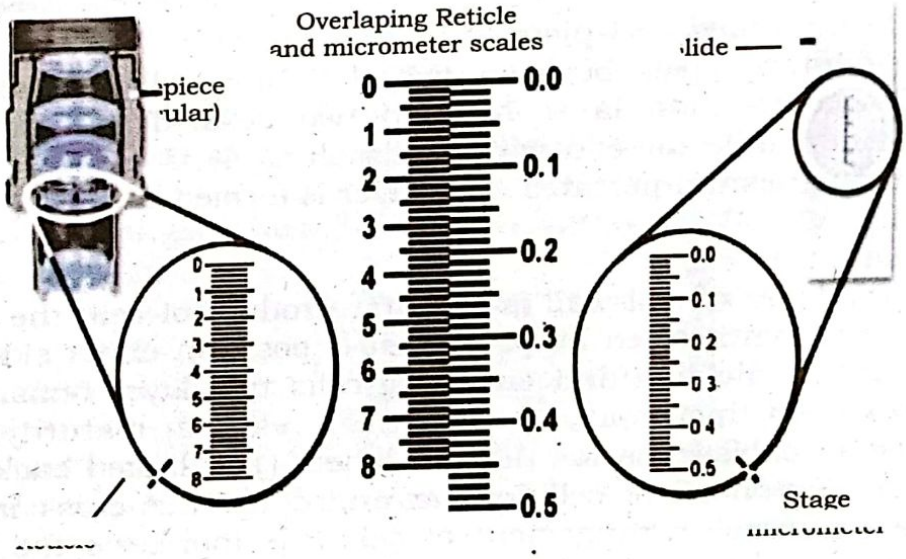

Fig 3.9 Eyepiece reticles and stage micrometers

Micrometer is a also called micron, so the unit of micrometer is micron for length i.e.0.001 mm or about 0.000039 inches. It is symbolized by μm.

3.2 CELL WALL AND PLASMA MEMBRANE

Cell Wall

The outer surface of some cells is covered with non-living, stiff layer called cell-wall. This cell wall is present at bacterial, fungal, algal and plant cells. Bacterial cell-wall is made up of peptidoglycan, and fungal cell wall is made up of modified polysaccharide chitin, while plant and algal cell wall is made up of (cellulose) already discussed in chapter of Biomolecules.

Cell wall is composed of mainly cellulose, pectin and other polysaccharides. These materials of cell-wall are always synthesized by protoplasm, secreted out of the cell and deposited around outer surface of plasma membrane. We will discuss only plant cell wall here.

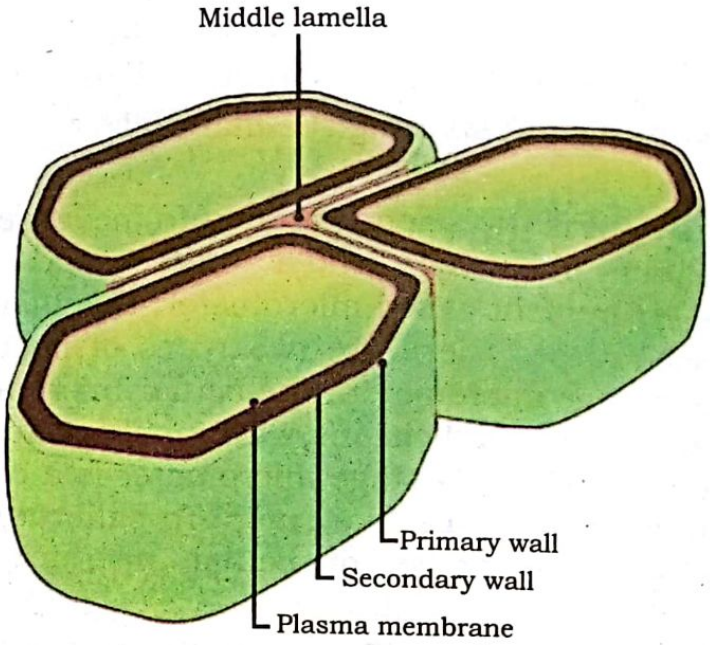

Fig 3.10 Cell wall

A plant cell-wall is mainly differentiated into three layers,

i) Middle lamella,
ii) Primary wall,
iii) Secondary wall.

i) Middle lamella

The first formed cell-plate work as cementing layer between two daughter cells is called middle lamella. It is a common layer between two cells. These two cells will separate when middle lamella will be dissolved. It is mainly made up of calcium and magnesium pectates. This layer is formed during cytokinesis of cell-division.

ii) Primary cell wall

Primary layer of cell-wall is the first product of cell, the material of primary layer is synthesized by protoplast deposit on either side of middle lamella. In young dividing and enlarging cells this layer remain thin and elastic. It becomes thick and rigid when cell reach at maturity. It contain hemicellulose (a polysaccharide that have beta (1-4) linked backbones with cross linked) microfibril of cellulose arranged in criss-cross manner and pectin. The crisscross arrangement of cellulose increases the strength of cell-wall. At some places in the cell-wall, the deposition of wall material does not take place. These places known as **plasmodesmeta** (singular, plasmodesma) through which cellular content of neighbor cells remain in communication with each other.

iii) Secondary cell wall

The layer of wall developed in between plasma membrane and primary cell-wall. It does not deposit in every plant cell, only deposited in hard tissues i.e. sclerenchyma. The cells become dead at their maturity.

Secondary wall deposits after complete maturation of primary cell-wall. It is very thick and rigid due to deposition of lignin, inorganic salts and some waxes. It plays important role in support of plant i.e. sclerenchyma fiber, scleroids, xylem vessels, tracheids, which contain secondary cell-wall.

Function of cell-wall

It performs two important functions. Firstly it provides mechanical support, gives definite shape and protection to cell. It acts like a skeletal frame work of plants particularly in vascular plants. Secondly, being hydrophilic in nature it is capable of imbibing water and thus helps in the movement of water and solutes toward protoplast i.e. cell-wall acts as permeable structure.

3.2.2 Plasma membrane or cell membrane

All cells either prokaryotic or eukaryotic cells are enclosed in a membrane which serves as their outer most living boundary, called plasma membrane. It separates the cytoplasm from the external environment.

(i) Chemical composition of cell membrane

All biological membranes have the same basic molecular organization. They are made up of double layer (Bilayer) of phospholipids interspersed with proteins.

The phospholipids molecules in the plasma membrane are arranged in two parallel layers. Their non-polar hydrophobic ends face each other whereas their polar hydrophilic ends are associated with carbohydrates protein etc. Plasma membrane also contains several types of lipids like cholesterol sterol etc. In some animal cells cholesterol may contain 50% of lipid molecules in plasma membrane. It is absent in the cell membrane of most plant cells.

Most of the plasma membrane consists of approx 50% lipids and 50% protein by weight, while the carbohydrates portion of glycolipids and glycoprotein constituting 5 to 10% of the membrane mass.

(ii) Structure of Plasma membrane

Number of biologists presented different models of cell-membrane. One of the models is sandwich model. According to this model the cell-membrane is composed of lipids bilayer sandwiched between inner and outer layer of protein. This basic structure is called the unit membrane and is present in all the cellular organelles. The modern technology has revealed that lipid bilayered is not sandwiched between two protein layers.

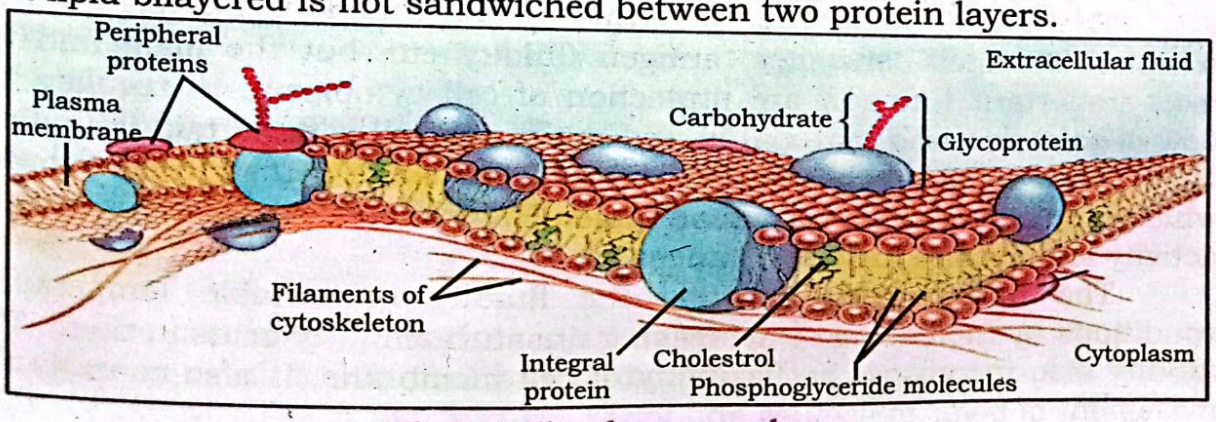

Fig 3.11 The plasma membrane

Fluid Mosaic Model

In 1972 Singer and Nicolson proposed a working model of plasma membrane known as fluid mosaic model. In the fluid mosaic model the lipid bilayer is retained as the core of the membrane. These lipid molecules are present in a fluid state able to rotate, translate and vibrate these molecules moving laterally within their layers of membrane. Proteins are also present in bilayer of phospholipids.

The structure and arrangement of membrane protein in the fluid mosaic model are like ice bergs in the sea. The protein occurs as a "mosaic" of discontinuous particles that penetrate deeply into and even completely through the lipid sheet. The components of plasma membrane are mobile and capable of coming together to engage in various type of transient or semipermanent interaction.

The proteins associated with the lipid bilayer can be divided into two groups.

a) Integral proteins
b) Peripheral proteins

(a) Integral proteins (Intrinsic proteins):

A class of proteins that are directly incorporated within the lipid bilayer. Some of these proteins are believed to provide a channel through which water-soluble substances, such as ions, can pass back and forth between the extracellular and intracellular compartment.

(b) Peripheral proteins (Extrinsic proteins):

A class of proteins located entirely outside the lipid bilayer on either the extracellular or cytoplasmic surface, exhibit a loose association with membrane surface.

These proteins which may possess lipid (lipoprotein) or carbohydrates (glycoprotein) side chains are arranged as mosaic within the cell-membrane.

Function of Plasma membrane

The plasma membrane performs several functions like platform for receptor, channels, enzymes, antigen fluidity etc, but the main and the most important function are protection of cell cytoplasm, to regulate the flow of solutions and material in and out of the cell with certain limitation. These limitations are checked by in flow of materials across the membrane which is necessary to maintain suitable pH, ionic concentration for enzyme activity and excrete toxic substances etc.

The lipid bilayer controls the fluidity in variable temperature conditions by increasing or decreasing unsaturated fatty acids in them. The fluidity also increases the flexibility of cell-membrane. It also controls the movement of polar molecules and ions.

The differentially or selective permeability is due to presence of specific channel proteins which permit only specific molecule to pass through them. The protein is carrier protein embedded in phospholipid layer. Some extrinsic proteins also work as enzymes e.g. ATPase complex to synthesize ATP.

Some proteins are conjugated proteins work as receptor for different hormones and other molecules. While other proteins work as antigen like R^H protein of RBCs.

Role of plasma membrane in regulating cells interaction with its environment

For entry and exit there are two main process of transport. i). Passive transport. ii). Active transport. They are discussed as follows.

(i) Passive transport:

It is a transport of molecules by diffusion and osmosis without consumption of ATP.

(ii) Active Transport:

Movement of molecules against concentration gradient by using energy of ATP.

There are two other phenomena i.e. endocytosis and exocytosis. Endocytosis is the process of intake of material in bulk by infolding cell membrane. It may be intake of solid material i.e. phagocytosis or intake of fluid or liquid i.e. pinocytosis, whereas exocytosis is the process of membrane fusion and exfolding to exit the material from the cell.

Cholestrol helps to regulate membrane fluidity over the range of temperature. It also prevents the passage of proton and sodium ions across the plasma membrane.

Role of Glycolipids and Glycoproteins as cell surface markers

The Glycolipids formed on the outer side of phospholipids bilayer of plasma membrane in eukaryotic cells. Its main function is to maintain stability of the membrane and facilitate cell-cell interaction i.e. cell adhesion to form a tissue. They also help cellular identification during immune responses. It also acts as receptor for viruses and other pathogens.

Specific glycoproteins present on the surface of red blood cells determine blood group type A,B, AB, and absence in O.

> The Glycolipids on the plasma membrane of R.B.C are of particular importance, it plays important role in blood transfusion. These glycolipids form AB antigen.

3.3 CYTOPLASM

The term cytoplasm was introduced by Rudolf Von Kolliker in 1868 for the material which is filled in between cell-membrane and nuclear membrane of eukaryotic cell and whole material inside cell-membrane in

prokaryotic cell. In some cells the cytoplasm is distinguish into two regions, the outer clear part near plasma-membrane is viscous called **cytogel** (previously called ectoplasm) and the inner part near nucleus is less viscous like solution called cytosol (previously called endoplasm).

3.3.1 Chemical nature and metabolic role of cytoplasm

Cytoplasm is a translucent granular liquid. It consists of an aqueous ground substance called cytosol. Chemically it contains about 90% water. It forms a solution containing all the fundamental molecules of life i.e. salts, sugar, amino acids, fatty acids, nucleotides, vitamins, hormones, inorganic ions. The large molecule like proteins and lipids are also present in the form of colloidal semi-fluid.

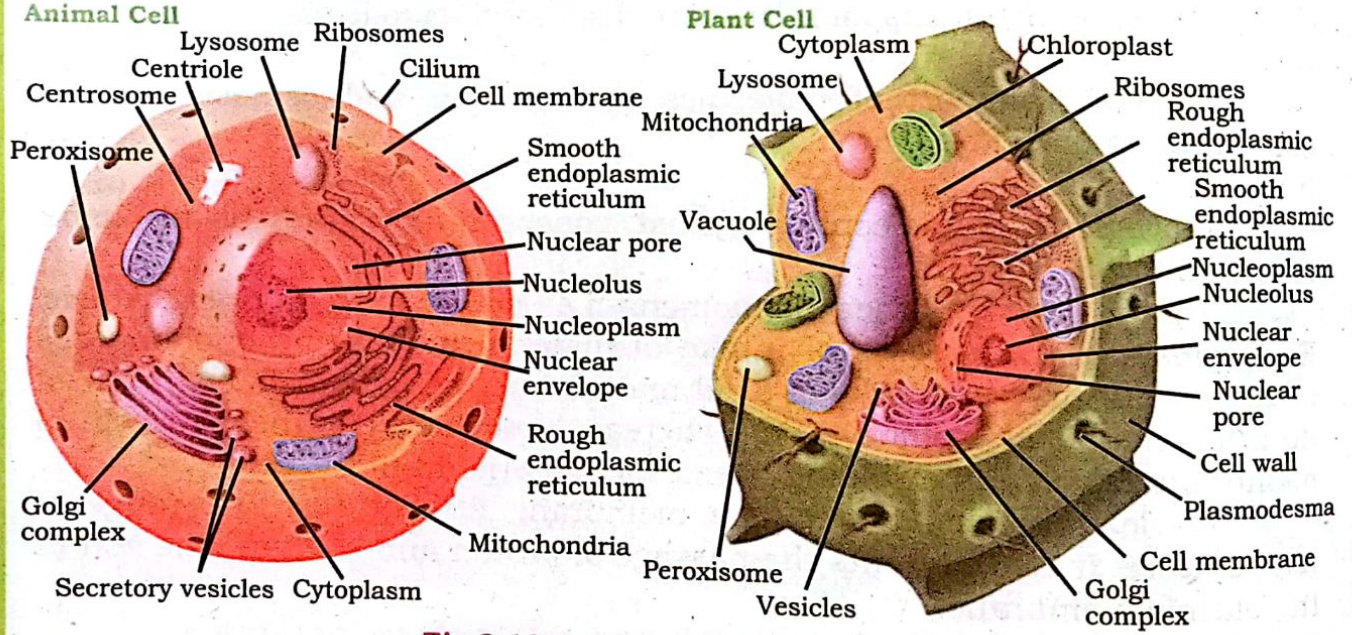

Fig 3.12 Animal cell and Plant cell

Observation under electron microscope revealed that the cytoplasm is not consists of liquid part only, it also contains granular part called cytoplasmic organelles, with this granular part a mesh of tiny filaments, the microfibrils which form a type of skeleton, giving rigidity to cell and help unicellular organism in movement. Most of the cytoplasmic organelles are tough to be attached with this cytoskeleton.

The cytoplasm exhibits active streaming movement around the inner surface of the cell called **cyclosis**. This movement is responsible for even distribution of cell content in cytoplasm. It is considered the seat of all metabolic activities from gene expression to energy production processes like glycolysis and Kreb's cycle. The energy is captured and conveted here in chloroplast. It also performs the function of molecular modification to detoxification, storage in vacuole and other organelles.

3.3.2 Cytplasmic organelles

In living eukaryotic cell, variety of organelles are present in cytoplasm such as endoplasmic reticulum, mitochondria, nucleus, plastids, ribosomes, lysosomes, centriole and vacuole. They perform their own functions. On the basis of these organelles and their functions the cell is considered as basic unit of life.

3.3.3 Endoplasmic reticulum (Endo = inside, plasma = formed substance, reticulum = network).

The elaborated, tube like system of lipoprotein form a complex network of channels, extended from plasma membrane to nuclear membrane called **endoplasmic reticulum**. This network is present throughout the cytoplasm like network of roads of a country. There are two types of endoplasmic reticulum.

a) Agranulated or smooth endoplasmic reticulum (SER)
b) Granulated or rough endoplasmic reticulum (RER)

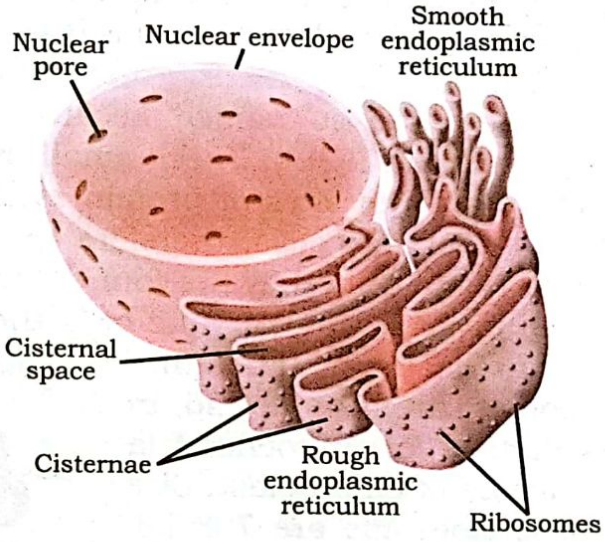

Fig 3.13 Endoplasmic reticulum

Usually cell contains both the type of endoplasmic reticulum in different ratios according their function. Although, some cells have only one type like fibrous cells of skeletal muscles, which have only smooth type of endoplasmic reticulum with the name of sarcoplasmic reticulum.

Rough Endoplasmic Reticulum (RER)

It is a type of endoplasmic reticulum which is heavily coated with ribosomes on its outer surface towards cytoplasmic face. It occurs mostly in protein synthesizing cells in high proportion. The process of translation during protein synthesis takes place here. After synthesis, the protein is either stored in the cytoplasm or exported out of the cell through these channels.

Smooth Endoplasmic Reticulum (SER)

The smooth endoplasmic reticulum named due to smooth surface i.e. ribosomes are not present on it. It is found in steroid producing cells like adipose cells, interstial cells, glycogen storing cells of liver and muscles. It is involved in the synthesis of oil, phospholipids and different types of steroids. The smooth E.R also provides mechanical support to cell.

Function of Endoplasmic Reticulum

The endoplasmic reticulum performs many important functions in the cell. It serves as supporting platform for the ribosome (RER). It forms a structural framework of the cell with increased surface of the various metabolic reactions (especially SER). It also provides conducting pathways for import, export and intercellular circulation of various substances. it provides passage for RNA to pass from nucleus to various organelles of cytoplasm.

It helps in detoxification of harmful drugs, storage, and release of Ca^{++}, manufacture of lipids and formation of Golgi apparatus (SER). The S.E.R transport protein from R.E.R to Golgi bodies through themselves.

3.3.4 Ribosome (RNA containing bodies)

These are so named because they contain high concentration of ribonucleic acid (RNA). These small spherical, granular, non-membranous structure are the sites of protein synthesis in cell type i.e. prokaryotic as well as eukaryotic cells, therefore they are regarded as "Protein factories". In prokaryotic cells they are found freely dispersed in the cytoplasm due to absence of E.R. In eukaryotic cells they are found free as well as attached to endoplasmic reticulum. Ribosomes are also found in the matrix of mitochondria and stroma of chloroplast. Size of these ribosome are 70S i.e. prokaryotic. It is good evidence that eukaryotic cells evolved from prokaryotic cells. The size of ribosome of eukaryotic cell is little larger than prokaryotic cells i.e. 80S while the prokaryotic ribosome is 70S. (S=Svedberg unit)

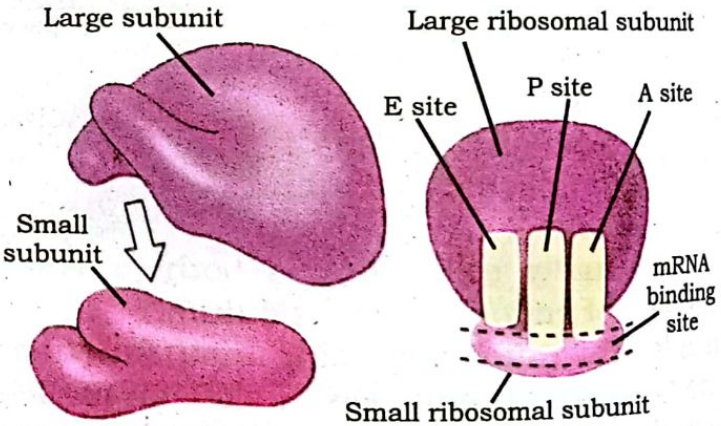

Fig 3.14 Ribosome

Each ribosome is consists of two unequal units. The larger sub-unit is dome shaped and smaller one form a cap on the flat surface of larger sub-unit. Eukaryotic ribosome has a larger sub-unit of 60S and smaller sub-unit of 40S particles, on attachment as single unit it becomes 80S particle. Both the unit are attached by magnesium ions. The ribosome is chemically made of nucleoprotein i.e. RNA (40 %) and protein (60%). They are made up of 50 or more different kind of proteins. Mg^{++} form bond between phosphates group of RNA and amino group of amino acids to attach both units at the time of protein synthesis. Recent investigation revealed that the ribosomes are manufactured in nucleolus in eukaryotic cells from where they are transferred to the cytoplasm through nuclear pores via E.R.

During protein synthesis several ribosome are attached to a single mRNA to synthesize number of identical protein molecules. This group of ribosome attached to a single mRNA is known as **polysome**.

3.3.5 Golgi complex

After the name of its discoverer an Italian physician **Camilo Golgi** in 1898. It was name Golgi apparatus or Golgi bodies or Golgisome or Golgi complex. Like endoplasmic reticulum it is a canalicular system with sacs, but unlike the endoplasmic reticulum it has parallel arranged, flattened membrane bound vesicles without ribosome. It is basically developed from S.E.R

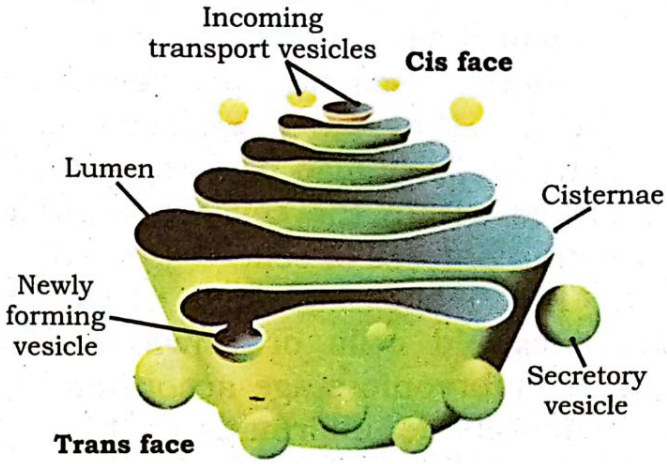

Fig 3.15 Golgi apparatus

The Golgi-bodies are found in all eukaryotic cells. It has basically same morphology in plants and animal cells. Each of them is disc shaped and consists of central flattened, plate like compartments called **cisternae**, perephral network of inter connecting tubules and peripherally occurring vesicles called Golgian vesicles. In Golgian system interconnected tubules are formed around the central stock, this process of forming cistarnae tubules remain continue at one end, if this outer or forming face in convex it is called cis - face, generally face towards nucleus, while the inner face which is called maturing face is concave also termed as trans face.

Function

Golgi complexes are especially prominent in glandular cells. The products of E.R are modified, stored and then sent to other destination. They perform the function of collection, packaging, processing of cell secretions. These secretions are mainly proteins which they collect from R.E.R transport to S.E.R, modifies to perform specific function and then export in the form of vesicles. It manufactures certain macromolecules by itself. Many polysaccharides secreted by cells like cellulose, chitin to form cell-wall and cell plate are Golgi products. Certain organelles such as lysosome, peroxisome and Glyoxysome develop from Golgi-complex. It is also involved in the formation of different conjugated molecules.

3.3.6 Lysosome (Lysis = breakdown; soma = bodies)

These are spherical, single, membrane bounded bodies, a few micrometers in diameter, originated by Golgi-bodies, containing hydrolytic enzymes. They occur only in the cytoplasm of animal cells and function in the digestion of material taken into cells by phagocytosis. Normally, they function as destroyers of foreign particles and worn out cellular component.

The newly formed lysosome before start its functions called primary lysosome. They contain about 40 different types of hydrolytic enzymes.

The lysosme during performing their function attach with the membrane of ingested material like endocytosis, phagocytosis or autophagocytosis.

These lysosome are generally called secondary lysosome but specifically they are endosomes, phagosome and autophagosomes respectively. They also perform autophagy, the process by which unwanted structures within the cell are engulfed and digested by lysosome. This is self-eating process of cell.

The body some time eliminates old cells or unwanted cells at embryonic stage according to their genetic information, this process is called **apoptosis**. During this self destruction process the membrane of lysosome is ruptured at a particular time. As a result the hydrolytic enzyme become free in cell and cell undergoes chemical breakdown or lysis, which cause a cell to destroy itself by digesting its own macromolecules, so the lysosome is referred as "**suicidal sac**" and this process is called **autolysis**.

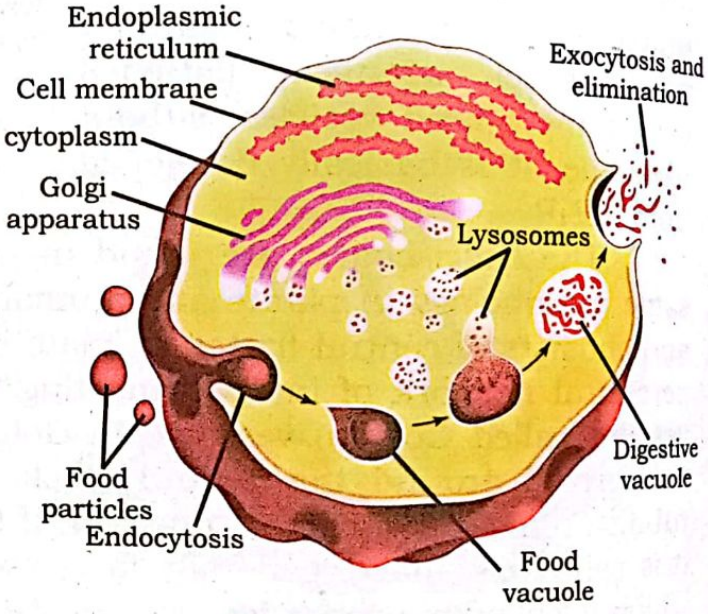

Fig 3.16 lysosome

Lysosome is also important in a way that it contains variety of enzyme which maintains metabolic balance of cell. If cell becomes unable to synthesize any one of these enzyme due to heredity and congenital reason. The substrate of that enzyme accumulates in these cells as well as organs which lead to metabolic imbalance at last become fatal at early childhood. These type of diseases cause due to lack of lysosomal enzymes are called **lysosomal storage diseases.** More than 30 diseases are reported as lysosomal storage disease some of them are given below.

Some lysosomal storage diseases

Diseases	Symptoms and problems
• Tay-Sachs disease	• Mental retardation, blindness, death by age of 3
• Gaucher's disease	• Liver and spleen enlargement, erosion of long bones, mental retardation in infantile form only.
• Krabbe's disease	• Loss of myelin, mental retardation death by the age of 2.

3.3.7 Peroxisome

Peroxisomes are the single membrane bounded organelles like lysosome but smaller in size than lysosome. It is mainly involves in the formation and decomposition of toxic molecules i.e. hydrogen peroxide (H_2O_2) so named peroxisome. It also originates from Golgi-complex. It contains variety of enzymes i.e. peroxidase, catalase, glycolic acid oxidase etc. It is found both in animal and plant cells. In animal cell it is involved in lipid metabolism i.e. fatty acid oxidation, either phospholipid synthesis, isoprenoid biosynthesis. It also produces and export cholesterol and an important group of phospholipids called plasmalogen to cytoplasm. Plasmalogen are found in brain and heart tissues.

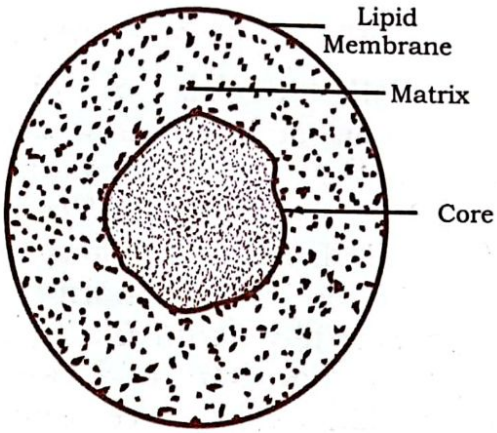

Fig 3.17 Peroxisome

Peroxisome are mainly concerned with the detoxification of alcohol where alcohol is oxidized and form another toxic compound H_2O_2 (Hydrogen peroxide) that is immediately breakdown to H_2O (detoxify) by an enzyme **catalase**. They are found abundantly in liver cells as well as in the cells of organisms (like camel, Kangaroos and number of reptiles) which store fats as reserve food and water.

In plants it converts glycolate an acid produced during photorespiration into amino acid glycine. It occurs with the help of an enzyme called Glycolic acid oxidase.

> Peroxisome contain enzyme that break down toxic compounds e.g. peroxysome within liver and kidney cells breakdown and detoxify fully, half of the alcohol of a person drink.

3.3.8 Glyoxysome

Another single membrane bounded micro body found in plant also originate from Golgi complex like lysosome and peroxisome. These are also considered as specialized peroxisome. They are found in fats storing tissues i.e. seeds endosperm. Each glyoxysome has a single layer bounding membrane enclosing a fine granular stroma. Glyoxysome contain enzymes that initiate the conversion of fatty acid into sugar. So the germinating seedlings convert stored fatty acids to carbohydrate. This process takes place in cyclic manner, which is called **Glyoxylate cycle**.

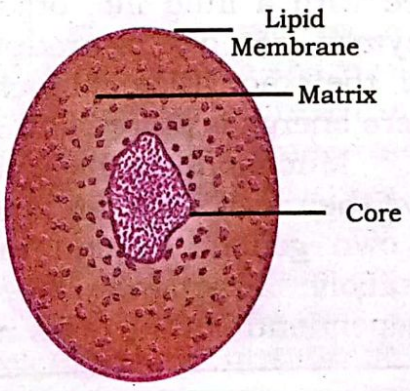

Fig 3.18 Glyoxysome

Mitochondria (Power house of the cell)

Gr: Mitos = thread. khondrion = small grain.

Mitochondria or chondriosome are universily present in the cytoplasm of eukaryotic cells. They appear minute grannular, vesicle, rodlets, thread or strings, depending on the nature of cells, but usually it is considered that it found in bean shaped. They are seen to be in constant motion in living cells. These are the centers of aerobic respiration.

Each mitochondrion is approximately about 0.5 to 1.0 nm in diameter and about 10µm long. They are double membrane bounded organelles. Both membranes are formed of lipids and proteins. The outer membrane is smooth and having pores like sieve made up of proteins called **Porins**. These pores are responsible for the transport of molecules across the membrane; therefore this outer membrane is permeable for all. The inner membrane forms irregular, incomplete partition due to inward folding. These folds are called **cristae** which increase the surface area to attach number of proteins containing molecules. These molecules are ATPase complex, variable types of cytochrome, NAD, FAD etc. These complexes and molecules serves as electron carrier, which metabolize carbohydrates (starch), fatty acid (lipids) and amino acids (protein) into CO_2 and H_2O with energy in the form of ATP which is stored in mitochondria. The folds formed by inner membrane is filled with a fluid like organic matrix, with a number of compounds and enzymes in it, due to production of high amount of energy for all cell organs and their activities. Mitochondria is known as power house of the cell, where energy is stored and released wherever required by an organism.

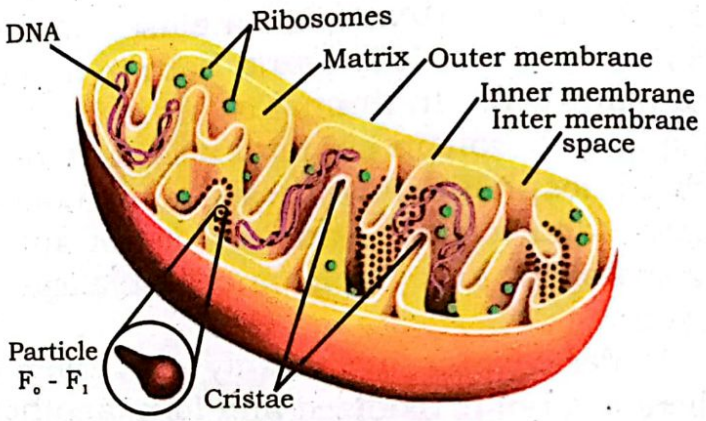

Fig 3.19 Mitrochondria structure

Mitochondria have a semi-autonomous existence in the cell. They have their own DNA, all kinds of RNA and ribosomes of 70s. It means it has its own genetic system to synthesize its own enzyme (proteins) for its metabolic function. They can divide in half and thus reproduce independently of the cell's normal cell-division.

Surprisingly, mitochondria are passed an animal only by mother since mitochondria are present in eggs but not in the part of sperm that enters the egg. Thus people can trace their mitochondria back to their mother, grandmother and great grandmother cells.

3.3.10 Plastids

They are special protoplasmic, double membrane bound organelles which function as chemical synthesizers and storage bodies. They are found in plants and algal cells mainly. Basically all plastids are originated from specialized structure called proplastids. They are immature, colorless plastids occurring in cells of meristematic tissues. It consists of double membrane enclosing granular stroma. They multiply by division in meristematic cell and distributed to different cell where they become develop as different types, depending upon environmental conditions i.e. intracellular factor and exposure to light. They develop as chloroplast, chromoplast and leucoplast.

(i) Chloroplast (Chloros = green, plast = living)

The most common type of plastid, containing chlorophyll which gives green colour to plants and is the site of photosynthesis.

(ii) Chromoplast (Chroma = colour)

It is the type of plastid which contain different pigments except chlorophyll i.e. xanthophyll, carotene etc. The chromoplasts are responsible for the various color combinations in flowers, fruits and other colour parts except green. The chloroplast after loosing their green pigments may convert into chromoplast. They help in pollination and dispersal of seeds.

(iii) Leucoplast (Leucos = colorless)

These are colorless plastids, which usually develop in the absence of light, they are found in all – underground parts and storage organs of plant. They store food material as carbohydrate, lipids and proteins on the basis of their storage material. They are further classified into amyloplast – carbohydrate (starch) storing elaioplast; lipid storing and proteioplast; protein storing leucoplasts.

Structure of chloroplast and its function as energy converting organelles:

Chloroplasts are formed only in green parts of plant and some protist. They vary in shape, surrounded by two membranes; a little space is present between them. The outer membrane is permeable due to presence of protein porins like mitochondria, while the inner membrane is differentially permeable. The inner membrane encloses a semi fluid material called **stroma**. Stroma contain various enzymes, DNA, RNA, ribosome(70S), ATP, NADP etc. The inter connected stacks of hollow membranous sacs are also embedded in stroma. The individual sac is called **Thylakoids** and a stack of sacs is called **granum** (Plural grana). The thylakoid membrane contains green pigment chlorophyll as well as other pigments like xanthophylls and carotene. There is another thylakoid which connect the grana with each other and called **intergrana**. Fifty or more than fifty

thylakoids piled to form a granum. The intergrana are usually colorless due to absence of pigments.

The chloroplast is also a semi-autonomous structure due to presence of its DNA, RNA and ribosome (70s). The chloroplast is special type of energy converting organelle. It converts light energy into chemical or food energy by the process of photosynthesis, therefore called "site of photosynthesis". During photosynthesis chlorophyll captures energy of sunlight and transfer it to other molecule in the thylakoid membranein. These molecules in turn transfer the energy to ATP and other energy carrier molecule like $NADPH_2$. These molecules differentiate stroma where their energy is used to drive the synthesis of sugar from carbon dioxide. Due to this flow of energy from one form to another, chloroplast is an energy converting organelle.

3.3.11 Cytoskeleton

A network of different protein fibers which provide three dimensional shapes to cell called **cytoskeleton**. It maintains and change the shape of the cell, secure some organelles at their specific position, enable movement of cytoplasm and vesicle within cell and cell to move in response to stimuli.

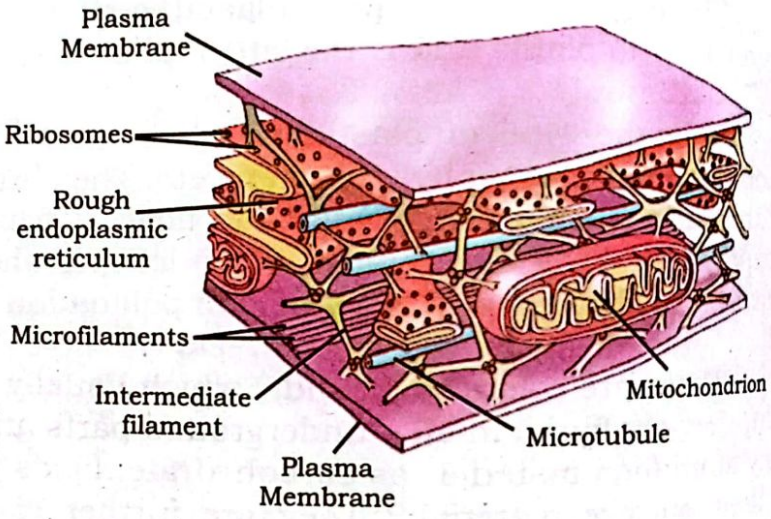

Fig 3.20 Cytoskeleton

There are three types of cytoskeletal elements found in cells.

a) Microfilament, b) Microtubules, c) intermediate filament.

(a) Microfilament:

They are solid strands of about 7 nm in diameter. They consist of two actin chains that intertwine in a helical fashion. Some microfilaments also contain myosin, tropomyosin and troponin at intervals. They form myofibrils in muscle cells, perform function of muscle contraction. They also perform function of change in cell shape, division of cytoplasm among daughter cells, cyclosis, movement of pseudopodia etc.

Fig 3.21 Microfilament

(b) Microtubules:

These are hollow tubes with an outer diameter of about 25nm. They are composed of protein tubulin. A single microtubule consists of hundreds of thousands of tubulin sub-units usually arranged in 13 columns. Each column is called **proto-filament**. In plant cells freely dispersed microtubule arrange at the time of cell division form spindle fibers whereas in animal cell they form centriole. It means microtubules are responsible for the movement of chromosomes during cell-division, movement of organelles within cytoplasm, movement of cilia and flagella.

(c) Intermediate filaments:

They are solid strands of 8 to 12 nm in diameter i.e. intermediate between microfilaments and microtubules. They are made up of at least five different types of proteins collectively called **vimentin**, form rope like polymer. Unlike the other two types of cytoskeleton intermediate filaments do not assemble and disassemble. They usually form network in cytoplasm to provide mechanical support to plasma and nuclear membrane. They are important in maintaining the shape of the cell, attachment of muscle cells and support of nerve cell processes axon.

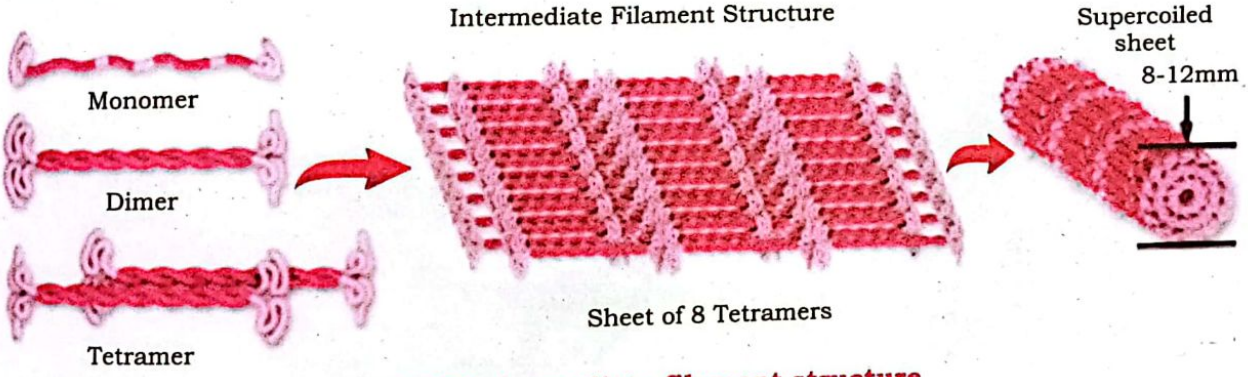

Fig 3.22 Intermediate filament structure

3.3.12 Cilia and flagella

Cilia and flagella are slender extension of plasma membrane in eukaryotic cell. The flagella are longer and few in number perform independent movement while cilia are smaller in size, and many in numbers. They perform function in synchronized manner i.e. one after the other. Both cilia and flagella share common internal structure, each contains a ring of nine fused pairs of microtubules, with an unfused pair in the center of the ring as shown in Fig 3.23. This pattern of microtubules is produced by a basal body kinetosome, located just beneath the plasma membrane.

The main difference between cilia and flagella lies in their number, length and the direction of force they generate. Cilia (Latin = eyelash) are short i.e. 10 to 25 μm long and numerous. They exert force only toward

plasma membrane. Flagella (Latin = whiplash) are long 50 to 75 μm, usually few in numbers, they exert force perpendicular to plasma membrane. Flagella perform upward and downward movement with a continuous bending wave like motion with distinct power.

Movement mechanism of Cilia and Flagella

Flagellary movement occur as planner waves, it is contracting wave that passes either from the base to the tip of flagellum or in the reverse direction to produce forward or backward movement. Movement mechanism of cilia and flagella.

A question arises here how cilia and flagella bends? it is because of the tiny protein "arms". These arms project out from each pair of microtubules in outer ring. These arms attach to neighboring pair of microtubules and flex, thereby moving the first pair along relative to the second. However the basal body firmly anchor the bottom of all microtubules in the entire celium and flagellum. Therefore, adjacent microtubule can slide past one another only if the whole cilium or flagellum bends.

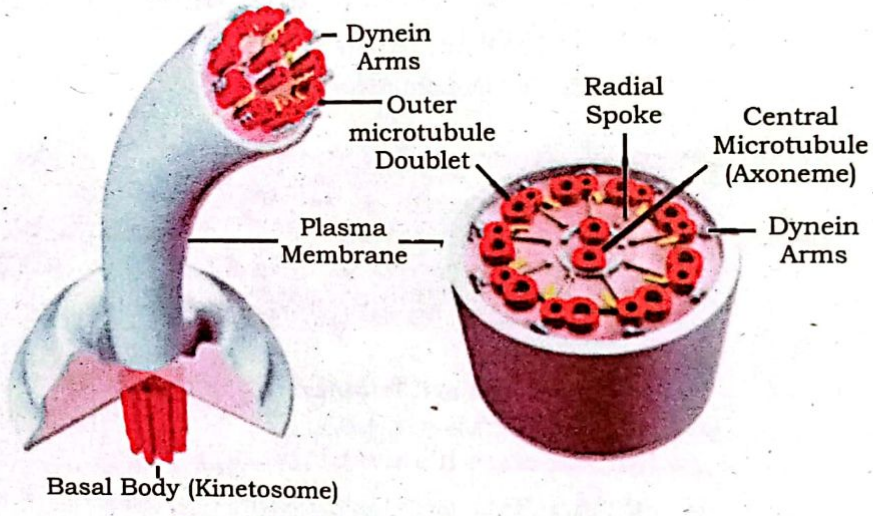

Fig 3.23 Cilia and flagella structure

3.3.13 Centrioles

Centrioles are short, barrel shaped structure of microtubules, which are non-membranous, lying perpendicular to one another. Each centriole is composed of nine sets of triplet microtubules, arranged in a ring. They appeared in animal cell and fungi like protoctist before cell-division near outer membrance of the nucleus, therefore the place where they are present in

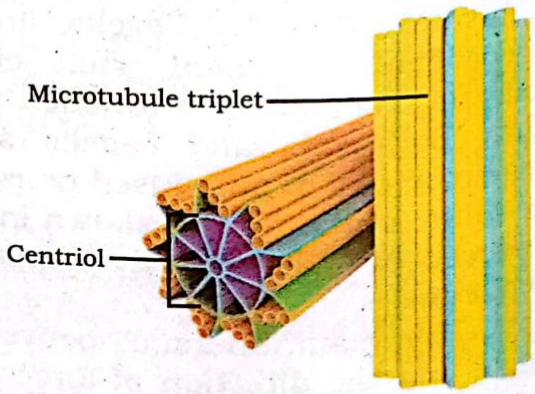

Fig 3.24 Centriole

cytoplasm is called **centrosome** (Centro = nucleus, soma = body). At the time of cell division the centriole duplicates and became two pairs, move to opposite sides of the cell and thread like fiber began to radiate from centriole in all directions called **astral rays**. The centriole also forms basal body (kinetosome) which form cilia and flagella.

3.3.14 Vacuole

Generally vacuole is non protoplasmic liquid filled vesicle in cytoplasm especially in plant cells. In young cell of plant many small vacuole are present but at maturity of cell they unite to form a large vacuole called **central vacuole**. In plant cell it is surrounded by a membrane called **tonoplast**. The tonoplast is selectively permeable; tono means tension and keep tension on the vacuole. The vacuole in plant cell is filled with cell-sap and acts as store house. The main function of central vacuole is to maintain turgor pressure inside plant cell. Turgor pressure helps the plant cell to keep its shape by pressing the plasma membrane against cell-wall. It maintains a nice rigid structure of plant.

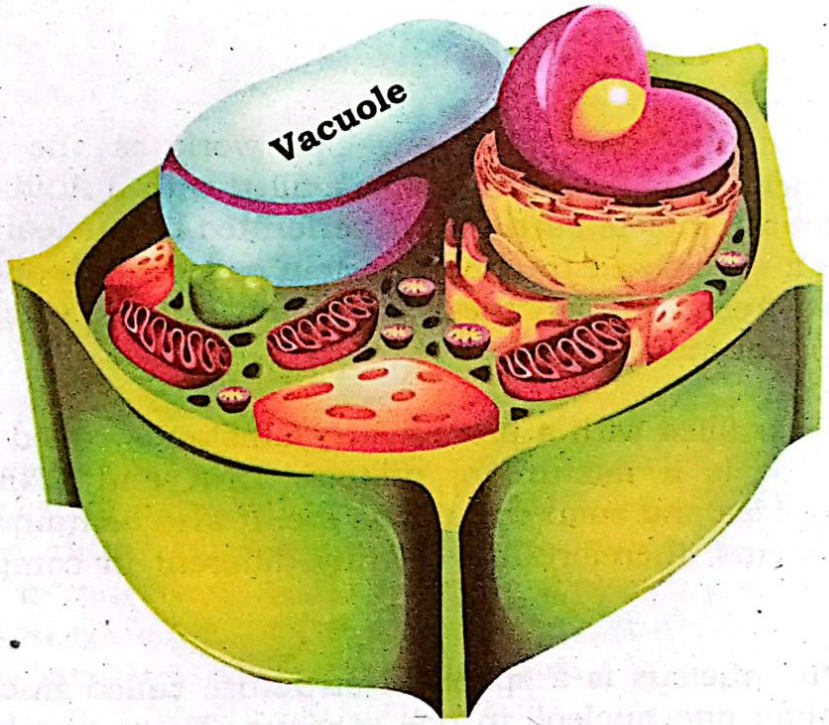

Fig 3.25 Vacuole

3.3.15 Nucleus

Nucleus was discovered by Robert Brown in 1831. It is the most important and prominent part of the cell which controls all the activities of the cell. It is commonly spherical in shape, in some cells it is lobed in

structure. In eukaryotic cell it consists of outer nuclear membrane, **nucleoplasm** (the fluid filled in it) nucleoli and chromatin.

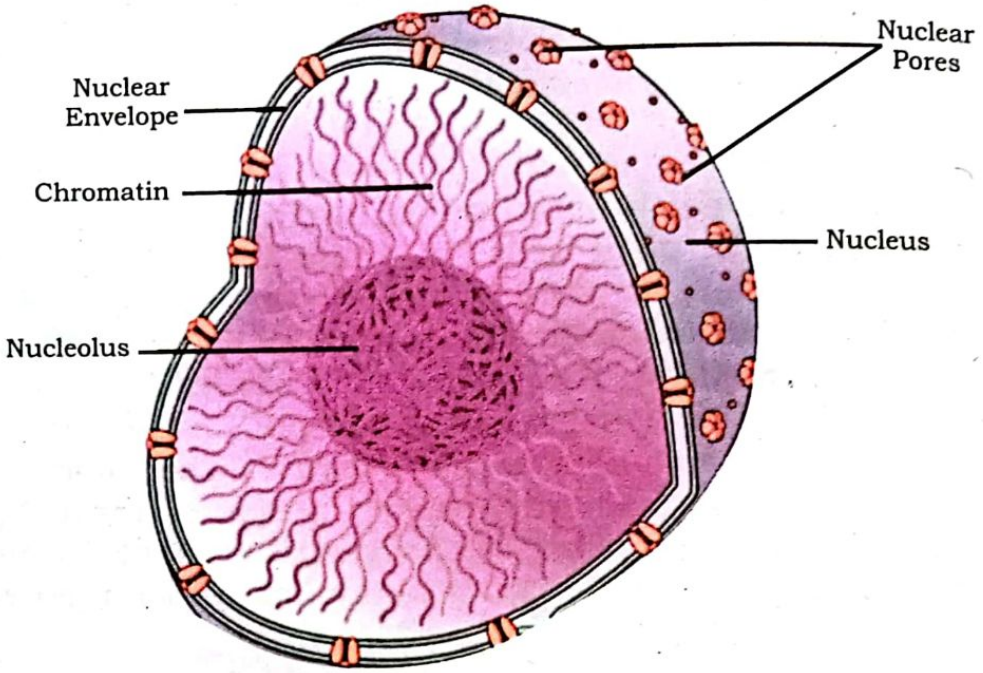

Fig 3.26 Nucleus of cell

Nuclear membrane

It is the double membrane envelope work as the boundary of nucleus. Both membrane have a thin space filled with a fluid. The nuclear membrane is not a complete barrier. It is perforated by nuclear pores which are made up of a specialized transport protein called **nucleoporin**. Certain substances pass freely through these pores between the nucleus and the surrounding cellular substances.

Nucleoplasm

The nucleus filled with a protein rich substance called nucleoplasm or karyolymph. It is a mixture of protein, DNA and RNA polymerase enzymes, nucleotides and some metal ions etc. It also contains histone and non histone proteins, therefore it is slightly different in composition from cytoplasm.

Nucleolus

Within the nucleus is a spherical structure called nucleolus. There may be more than one nucleoli in one nucleus. There numbers varies in different kind of cells. It disappears during cell-division and reappear afterward. It is made up of different type of RNA and responsible to synthesize ribosomes.

The nucleus contains numerous fine strands in the form of network throughout nucleoplasm called **chromatin network** or **nuclear reticulum**. It can be seen only in non-dividing cell. This network is made up of

chromatin material i.e. DNA and histone protein. During cell division the chromatin network break into specific number of threads; which start coiling and condensation. After condensation it becomes chromosome. The chromosomes are thick threads, made up of highly condensed chromatin material at the time of cell-division. A chromosome in the beginning of cell-division consists of two genetically identical threads attached at least at centromere called **chromatids or sister chromatids**, chromosome consist of two parts, Arms and Centromere the part of chromosome or chromatids from centromere to end is called **arm**. The arms or chromatids are joined at a constriction called primary constriction or **centromere**.

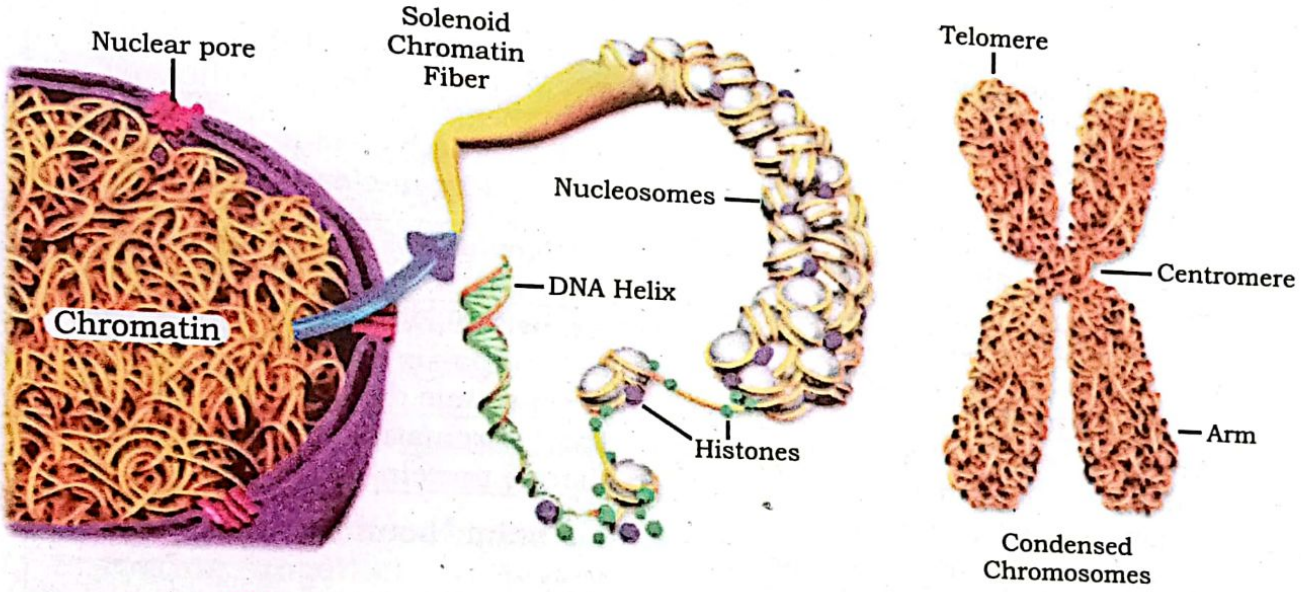

Fig 3.27 Chromatin and condensed chromosome structure

Chromosome contains the heredity units called **genes**. The position of genes on chromosome called **gene locus** (plural – loci). Chromosome carry the heredity information from generation to generation. The chromosomes number vary from species to species e.g. 8 in fruit fly, 14 in sweet pea, 20 in corn cells, 46 in human etc. On the basis of shapes and the position of centromere. The chromosomes are of different types, they are as follows.

(i) **Metacentric** – Chromosomes with equal arms. Centromere is present exact in centre.

(ii) **Sub – metacentric:** Chromosomes with slightly unequal arms. Centromere slightly away from centromere.

(iii) **Acro or sub – Telocentric:** Chromosomes with one very long and the other is very short arm. Centromere is far away from centromere.

(iv) **Telocentric:** Centromere is in the end of arms.

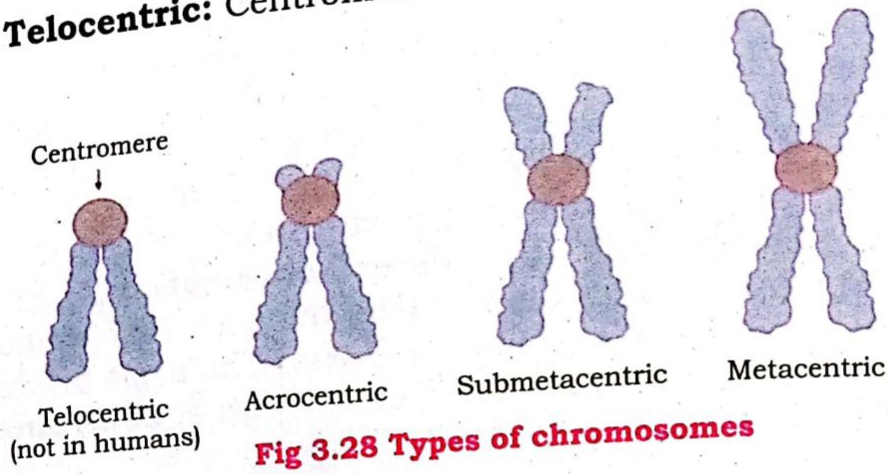

Fig 3.28 Types of chromosomes

3.4 Prokaryotic and Eukaryotic cell

Prokaryotic (Pro = first or early, Karyon = Nucleus)	Eukaryotic (Eu = proper, karyon = nucleus)
1. Cell has primitive type of nucleus i.e. does not bounded by nuclear membrane	1. Cell has true type of nucleus i.e. It is bounded by nuclear membrane
2. Nucleoplasm and nucleolus are absent	2. Nucleoplasm and nucleolus are present
3. Only one circular, long, interwoven DNA is present as chromatin material.	3. Number of DNA are present which may appear in the form of chromosome during cell-division.
4. The chromatin material does not contain histone protein	4. The chromatin material contain histone protein with DNA.
5. All membrane bounded organelles are absent i.e. E.R, golgisome, mitochondria, plastids etc.	5. Membrane bounded organelles are present.
6. Mesosomes are present.	6. Mesosomes are absent.

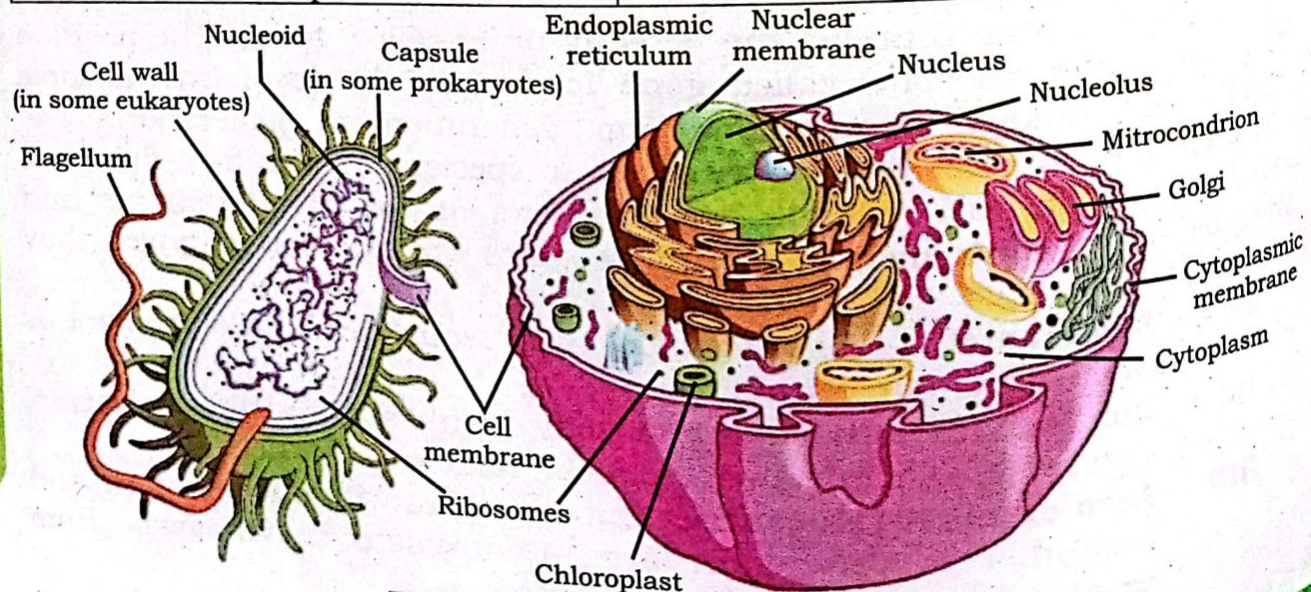

Fig 3.28 Prokaryotes and Eukaryotes

SUMMARY

- Isolation of cellular components to determine the structure and chemical composition is called cell fractionation.
- The process of setting down cell organelles on the basis of density and mass by the process of centrifugation is called sedimentation.
- Microdissection is a technique to isolate specific cell with the help of microscope.
- Chromatography is a technique used for separating different components of mixture.
- A technique used to separate charged molecule based on their size and electrical charge in an electrolytic cell is called electrophoresis.
- Method of measuring light absorption by a particular substance is called spectrophotometer.
- The study of cell and micro-organisms is dependent upon the use of an instrument called microscope.
- Micrometry is the science related to measurement of dimensions and size of an object observing under microscope.
- Cell wall is composed of mainly cellulose, pectin and other polysaccharides.
- All biological membranes have the same basic molecular organization.
- The components of plasma membrane are mobile and capable of coming together to engage in various type of transient or semipermanent interaction.
- Cytoplasm is a translucent, granular liquid. It consists of an aqueous ground substance called cytosol.
- Tube like system of lipoprotein form a complex network of channels, extended from plasma membrane to nuclear membrane called endoplasmic reticulum.
- Each ribosome consists of two unequal units. The larger sub-unit is dome shaped and smaller one forms a cap on the flat surface of large sub-unit.
- Golgi complex is especially prominent in glandular cells. The products of ER are modified, stored and then sent to other destination.
- The newly formed lysosome before starts its functions called primary lysosome.
- Peroxisome are mainly concerned with the detoxification of alcohol.

- Glyoxysome contain enzymes that initiate the conversion of fatty acid into sugar.
- Mitochondria have a semi-autonomous existence in the cell.
- The most common type of plastid, containing chlorophyll which gives green colour to plants is the site of photosynthesis.
- A network of different protein fibers which provide three dimensional shapes to the cell called cytoskeleton.
- Centrioles are short, barrel shaped structure of microtubules.
- The main function of central vacuole is to maintain turgor pressure inside plant cells.

EXERCISE

1. Encircle the correct choice

(i) A primary objective of cell fractionation is to
- (a) View the structure of cell membranes.
- (b) Identify the enzymes outside the organelles.
- (c) Determine the size of various organelles.
- (d) Separate the major organelles so that their particular functions can be determined.

(ii) The volume enclosed by the plasma membrane of plant cells is often much larger than the corresponding volume in animal cells. The most reasonable explanation for this observation is that
- (a) Plant cells are capable of having a much higher surface to volume ration than animal cells.
- (b) Plant cells have a much more highly convoluted plasma membrane than animal cells.
- (c) Plant cells contain a large vacuole that reduces the volume of the cytoplasm.
- (d) Animal cells are more spherical, while plant cells are elongated.

(iii) Large numbers of ribosomes are present in cells that specialize in producing which of the following molecules?
- (a) Lipids
- (b) Starch
- (c) Proteins
- (d) Steroids

(iv) In animal cells, hydrolytic enzymes are packed to prevent general destruction of cellular components. Which of the following organelles functions in the compartmentalization?
- (a) Chloroplast
- (b) Lysosome
- (c) Peroxisome
- (d) Glyoxysome

(v) Tay-Sachs disease is a human genetic abnormality in cells accumulating and becoming clogged with very large and complex lipids. Which cellular organelle must be involved in this condition?
(a) Endoplasmic reticulum (b) Golgi complex
(c) Lysosome (d) Mitochondria

(vi) Which is one of the main energy transformers of cells?
(a) Endoplasmic reticulum (b) Golgi complex
(c) Lysosome (d) Mitochondria

(vii) Organelles other than the nucleus that contain DNA
I. Ribosomes II. Chloroplast III. Mitochondria
(a) I only (b) II only
(c) II and III (d) I and II

(viii) Which structure is common to plant and animal cells?
(a) Chloroplast (b) Cell wall
(c) Central vacuole (d) Mitochondria

(ix) Cell organelle mainly concerned with the detoxification of alcohol.
(a) Chloroplast (b) Peroxisome
(c) Central vacuole (d) Mitochondria

(x) Clarity of image is generally known as
(a) Magnification (b) Contrast
(c) Resolution (d) Sedimentation

2. Write short answers of the following questions:

1. Why lysosome is called suicidal sacs?
2. Why plasma membrane is differentially permeable in nature?
3. Why plant cell wall is rigid?
4. Why chloroplast is called energy converting cell organelle?
5. How prokaryotic ribosome is different from eukaryotic ribosome.
6. How mitochondria is similar to bacteria?
7. Why mitochondria is called power house of cell?
8. Differentiate between peroxisome and glyoxysome.

3. Write detailed answers of the following questions:

1. Describe structure and functions of rough and smooth endoplasmic reticulum.
2. Explain the chemical composition and functions of plasma membrane in regulating cell's interactions with environment.
3. Explain the structure and functions of lysosomes.
4. Describe structure of mitochondria with suitable diagram.
5. Explain the structure and composition of cell wall.
6. Describe the structure and functions of Golgi complex.
7. Describe the types, structure, composition and functions of cytoskeleton.