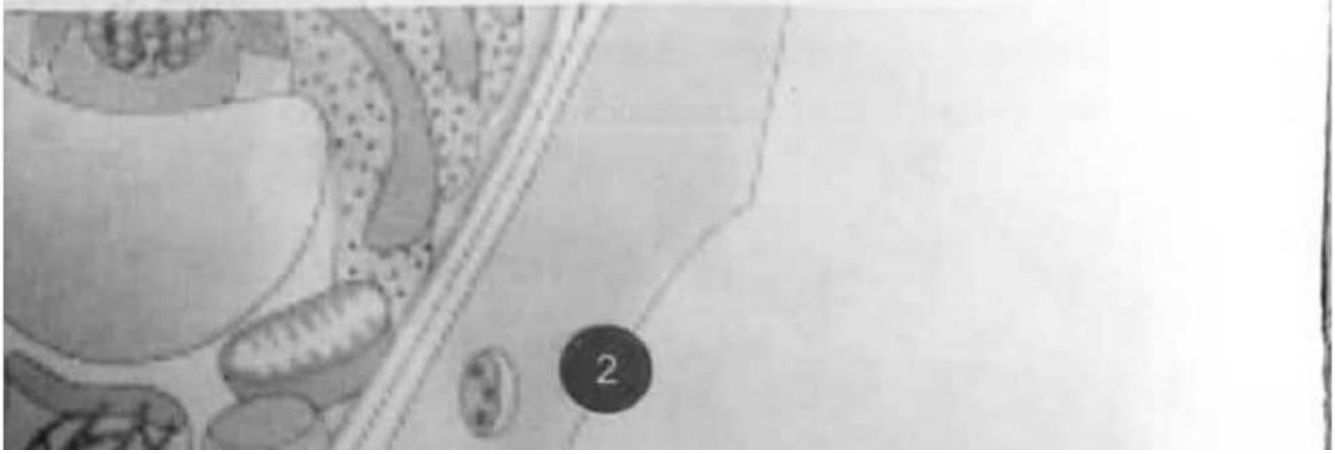
- State the structure and functions of the peroxisomes and glyoxisomes in animal and plant cells.
- Describe the formation, structure and functions of the lysosomes.
- Interpret the storage diseases with reference to the malfunctioning of lysosomes.
- Explain the external and internal structure of mitochondrion and interlink it with its function.
- Explain the external and internal structure of chloroplast and interlink it with its function.
- Describe the structure, composition and functions of centriole.
- Describe the types, structure, composition and functions of cytoskeleton.
- Explain the structure of cilia and flagella and the mechanisms of their movement.
- Describe the chemical composition and structure of nuclear envelope.
- Compare the chemical composition of nucleoplasm with that of cytoplasm.
- Explain that nucleoli are the areas where ribosomes are assembled.
- Describe the structure, chemical composition and function of chromosome.
- List the structures missing in prokaryotic cells.
- Describe the composition of cell wall in a prokaryotic cell.
- Differentiate between the patterns of cell division in prokaryotic and eukaryotic cells.
- Relate the structure of bacteria as a model prokaryotic cell.



Introduction

One of the most important concepts in biology is that the basic unit of structure and function in living organisms is the cell. It is the smallest unit that can carry out all activities of life. Cells are the building blocks of complex multicellular organism.

The modern theory of cellular organization states that,

1. All living organisms are composed of one or many cells.
2. All new cells arise from by the division of pre existing cells.
3. Cells contain the hereditary material of an organism which is passed from parent to daughter cells.
4. All metabolic processes take place within cells.

Tidbit

The oldest accurately dated life form is a microorganism, *Eubacterium isolatum* which dated back 3500 million years.

1.1 Techniques used in Cell Biology

Microscopy makes a very valuable contribution to our understanding of cells. However, techniques are also needed if the functions of organelles are to be studied. Various techniques have been used for isolating and examining various cell components. Of these, differential staining, centrifugation, tissue culture, chromatography, electrophoresis etc are the most common techniques. The examination of a cell and its component depends upon the magnification powers of two convex lenses to produce a magnified image of a very small object.

Table 1.1 Magnification of the Microscope

Objective lens	Eye piece lens	Magnification of object
x 10	x 6	x 60
x 40	x 6	x 240
x 10	x 10	x 100
x 40	x 10	x 400

1.1.1 Resolution versus magnification of microscope

The biologists who study cells, use different devices and precise techniques in their efforts to develop exact descriptions of cells and their parts. Their most important tool is the compound light microscope. It is very useful but it is limited by the nature of the energy it uses i.e light. The limitation of any microscope defined as resolving power; the ability to distinguish close objects as being separate from one another.

The resolving power of light microscopes is 250nm. This resolution power is about 500X is that of naked eye. The human naked eye can differentiate between two points at least 1.0mm apart. Different light microscopes have been developed with different resolution and magnification powers. Magnification is a mean of increasing the apparent size of the object being viewed to a reasonable size. With a light microscope a specimen could quite easily be magnified by as much as 1000 to 2000 times. Fortunately, we are not dependent only on the resolving powers of the light microscope. We now have the Transmission Electron Microscope (TEM). The TEM can magnify an object upto 1,000,000 (1 million) times. One recent innovation, the Scanning Electron Microscope (SEM) has produced three dimensional images of whole objects.

1.1.2 Staining

Most biological structures are transparent so that some techniques of obtaining contrast between different structures must be employed. The most common method is staining. It is a process of treating a specimen for examination under the microscope with a reagent or dye. This makes certain structures visible without affecting others. Some of the stains used in light microscopy are shown in table 1.2. Certain stains when used in low concentration are non-toxic to living tissues and can therefore be used on living materials. Two stains may be used in which the first stain is called principal stain and the second as counter stain. Counter stain is stain of a contrasting color used to color the components in a microscopic specimen that are not made visible by the principal stain. These stains are called **vital stains.** For example, methylene blue and neutral red. Two stains may be used in which the second is called **counter stain.**

Table 1.2 Profile of Permanent Stains

Stains	Final Colour	Suitable for
i. Aniline blue	Blue	Fungal hyphae & Spores
ii. Borax carmine	Pink	Nuclei, Obelia colony
iii. Eosin	Pink / Red	Cytoplasm / Cellulose
iv. Feulgen's stain	Red / Purple	DNA (particularly during cell division) i.e. chromosomes
v. Leishman's stain	Red / Pink / Blue	Blood cells
vi. Methylene blue	Blue	Nuclei
vii. Safranin	Red/ Purple	Nuclei, lignin & plant tissues

Table: 1.3 Profile of Temporary Stains

Stains	Final Colour	Suitable for
i. Aniline sulphate	Yellow	Lignin
ii. Iodine solution	Blue-black	Starch
iii. Schultz's solution (Chlor-zinc-iodine)	Yellow / Blue / Blue or Violet	Lignin, Cutin, Protein. / Starch / Cellulose

As revealed by the above table different cell organelles stain differently by different stains, hence increase the resolution power of a microscope.

1.1.3 Centrifugation (cell fractionation)

Dividing the cell into its parts or fractions is called cell fractionation. It is done in a centrifuge and the process is called centrifugation. Cell fractionation can isolate various components of cells including organelles according to their particular size and density. This process is accomplished in the following manner.

- The first step is grinding up the tissue in a liquid medium of proper osmotic concentration to form a homogenate, which is then put in a centrifuge and spun.
- Initially it is spun at a relatively slow rate to separate out the larger, heavier part of the homogenate, such as any remaining whole cells and the nuclei.
- When these fractions have been removed, the remaining material is again spun at a speed and cellular components of intermediate size, such as mitochondria, plastids etc precipitate out and are removed.
- The supernatant liquid can then be spun at still higher speeds and smaller, lighter cellular fractions are precipitated.

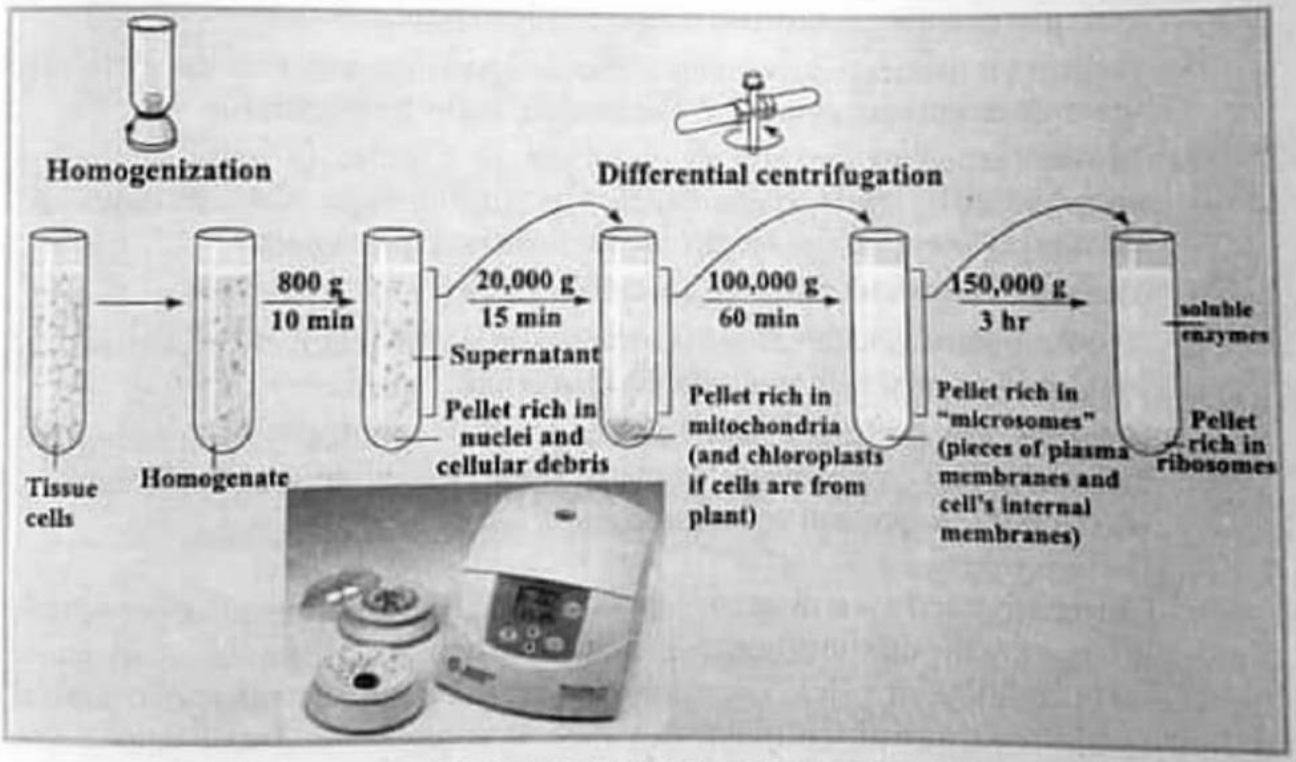


Fig 1.1 Cell fractionation technique.

1.1.4 Tissue Culture

Tissue culture is the growth of tissues and cells separate from the organism. This is typically facilitated by the use of liquid semi-solid growth medium such as broth,or agar. Tissue culture produces clones in which all the product cells have the same genotypes unless affected by mutation during culture. In the following

sections a list of apparatus and main steps of tissue culture are given:

A. Tissue Culture Apparatus

- Cell culture hood (i.e., laminar-flow hood or biosafety cabinet)
- Incubator (humid CO_2 incubator recommended)
- Water bath
- Centrifuge
- Refrigerator and freezer (–20°C)
- Cell counter
- Inverted microscope
- Liquid nitrogen (N_2) freezer or cryostorage container
- Sterilizer (i.e., autoclave)

B. Main steps in tissue culture

1. Selection of the plant tissue (explant) from a healthy vigorous mother plant. This is often the apical bud but can be other tissue.
2. This tissue must be sterilized to remove microbial contaminants.
3. Establishment of the explant in a culture medium. Medium sustains the plant cells and encourages division it can be solid or liquid.
4. Each plant species (and sometimes the variety within a species has particular medium requirements that must be established by trail and error.
5. Multiplication of the explant gives rise to a callus (a mass of loosely arranged cells) which is manipulated by varying sugar concentrations and the auxin (low) cytokinin high ratios to form multiple shoots.
6. The callus may be subdivided a number of times.
7. The shoots are transferred to a growth medium with relatively higher auxins, cytokinin ratios which results in the formation of roots.
8. Plantlets are deflasked and hardened off by gradually decreasing the humidity. This is necessary as many young tissue culture plants have no waxy cuticle to prevent water loss.

1.1.5 Chromatography

Chromatography is a mean of separating one type of molecule from others. It involves moving the mixture, normally as a liquid or a gas, over a stationary phase embedded in cellulose or silica. The separation may depend on a range of chemical and physical properties of the molecules such as solubility and molecular mass. Essentially there are two basic ways of carrying out the separation.

a. Paper Chromatography

It is used for the separation of photosynthetic pigments, sugar or amino acids. The mixture is spotted near one end of a paper strip and then dipped into a

specific solvent which moves through the paper by capillary action carrying the molecules with it. Similarly, a thin layer of silica may be used instead of paper.

b. **Column Chromatography**

It is more commonly used method which involves the mobile phase flowing over a supporting matrix held in a glass or metal tube.

1.1.6 Electrophoresis

It is a technique used to separate molecules of different electrical charge. Under the influence of different electrical field, negatively and positively charged ions (Molecules) will move towards anode (+) and cathode (-) respectively. Two factors affect the speed with which charged molecules move towards an electrode.

i) The amount of charge (greater charge, faster movement & vice versa)

ii) The size of molecules (smaller molecules, faster movement & vice versa)

1.1.7 Spectrophotometery

This technique is used to measure the change in percentage transmission of light (Optical density) of the suspension material. The cell mass is directly proportional to the optical density. The determination of amino acids by spectrophotometeric analysis is based upon specific light absorption. Such analysis of the amino acid generally depends upon absorption exhibited by their colored derivatives.

1.1.8 Microdissection

It refers to a variety of techniques in which microscope is used to aid the process of dissection cells or it organelles. Different kinds of techniques involve microdissection:

- Chromosome microdissection — use of fine glass needle under a microscope to remove a portion from a complete chromosome
- Laser micro dissection — use of a laser through a microscope to dissect selected cells
- Laser capture microdissection — use of a laser through a microscope to cause selected cells to adhere to a film.

1.2 Micrometry (measurement of size with the microscope)

It is obviously important to be able to make accurate measurement of the real size of structures seen with the microscope. Measurement of microscopic objects is called micrometry. This can be done by using specially designed scales. One of the scales is placed in eye piece (eye piece graticule) or ocular micrometer and other on the stage (stage micrometer). The micrometer has equally spaced divisions. Before using the eye piece micrometer to measure a particular structure, you will have to find out the real width of each unit on the scale at each magnification. In other words

you will have to calibrate the micrometer. This can be done by replacing the specimen with the stage micrometer, and using this to measure the eye piece units at each magnification.

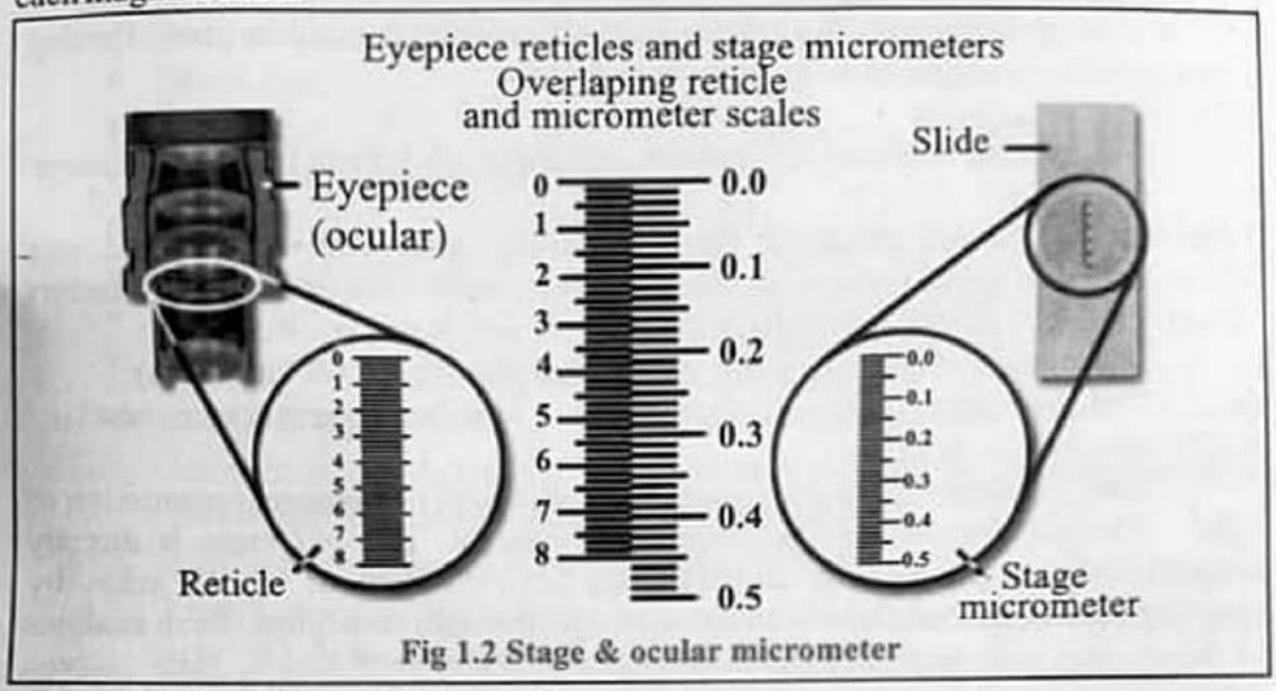


Fig 1.2 Stage & ocular micrometer

1.3 Cell Wall and Plasma Membrane

1.3.1 Cell Wall

The cell wall was discovered by Robert Hooke in 1665 earlier than the protoplast. It is the outer most boundary of the plant cells. It is secreted by the protoplasm of the cell. Its thickness varies in different cells of the plant.

Each cell whether isolated or occurring in tissues has its own cell wall. Cell walls of neighboring cells are held together by an intercellular substance called middle lamella.

Cell wall varies greatly in morphology and chemical composition but its characteristics have a close relation with the age and function of the cell on the basis of development and structure.

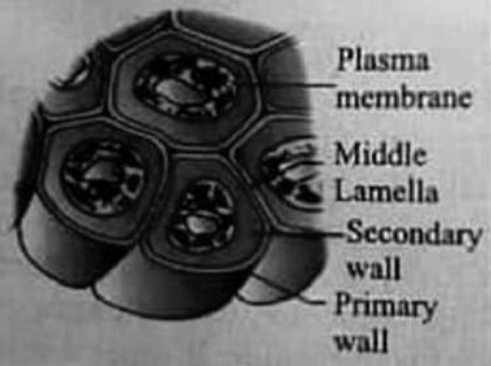


Fig 1.3 Cell wall

For your information

Cellulose, a cell wall component, can be used in Industries in the following ways:

1) Nitrocellulose (Explosives)
2) Rayan (Textile fiber)
3) Cellophane (Partially permeable membrane)
4) Plastics including celluloid's & cinematography
5) Paper making

The cell walls have three fundamental parts namely i) Middle lamella ii) Primary wall iii) Secondary wall.

Middle lamella cements together the walls of the neighboring cells. It is usually thin and about 1 μm in thickness. In woody tissues the middle lamella is commonly lignified.

Primary wall is the first wall formed in a developing cell. It is usually 1-3 μm in thickness. More or less elastic and extendable, crystalline and optically active. It is composed of cellulose, pectic compounds mostly polysaccharides and hemicellulose.

The secondary wall follows the order of primary wall in development. It is laid down inside the primary wall. Its thickness is about 5-10 μm, more or less rigid, crystalline, and strongly optically active. It is mainly composed of lignin, cellulose, non-cellulosic polysaccharides, hemicelluloses and mineral salts of Ca, Mg, K, and some silica.

A major role of the cell wall is to form a framework for the cell to prevent over expansion. Cellulose fibers, structural proteins, and other polysaccharides help to maintain the shape and form of the cell.

1.3.2 Plasma Membrane

Plasma membrane or cell membrane is the outer most boundary of the animal cells and inner to cell wall in plant cells. Cell membrane is chemically composed of lipids (20-40%) and proteins (60-80%). In addition there is small quantity of carbohydrates present.

Many biologists contributed to establish the structural organization of cell membrane. The modern technology has revealed that lipid bilayer is not sandwiched between two protein layers. In 1972, Singer and Nicholson proposed a most acceptable model for membranes called **Fluid Mosaic Model**. This model is in agreement with photograph of cell membrane by electron microscope. This model explains that "the membrane is like a sea of lipids in which protein are floating".

a. Role of Proteins

The proteins are not arranged in sheet but as globes of proteins which are floating about in the sea of lipid molecules. Some proteins extend completely through the double layer of lipids from one side to the other and are called intrinsic proteins. Some other proteins are smaller and are placed among the phospholipids molecules. These are on one side of the membrane and are called extrinsic proteins. Carbohydrates extend out from the outer surface of the membrane and are attached either to membrane lipids as glycolipids or to proteins as glycoproteins.

b. Role of Glycolipids and Glycoprotein

Lipids, proteins and carbohydrates are responsible for functional diversity of the membranes. Lipid bilayer makes the membrane differentially permeable barrier that allows the transport of non-polar materials across it and prevents ionic materials. Membrane proteins on the other hand makes it selectively permeable barrier that select materials according to cell's need. If glucose concentration inside the cell is proper, no more glucose can enter the cell. Extrinsic proteins function as receptor that receives the stimuli from the environment and thus inform the cell to respond. Integral proteins also called as "permeases" regulate diffusion, osmosis and active transport of ionic materials.

For your information

Chronological developments towards Fluid Mosaic Model of Plasma Membrane

- Gorter & Grendel 1925: -Two layers of lipid molecules only
- J F Danielle & Davson 1935:-Lipid bilayer is covered with proteins & protein pores
- Robertson 1959: - Unit membrane model
- S J Singer & G L Nicholson 1972: - Fluid mosaic model

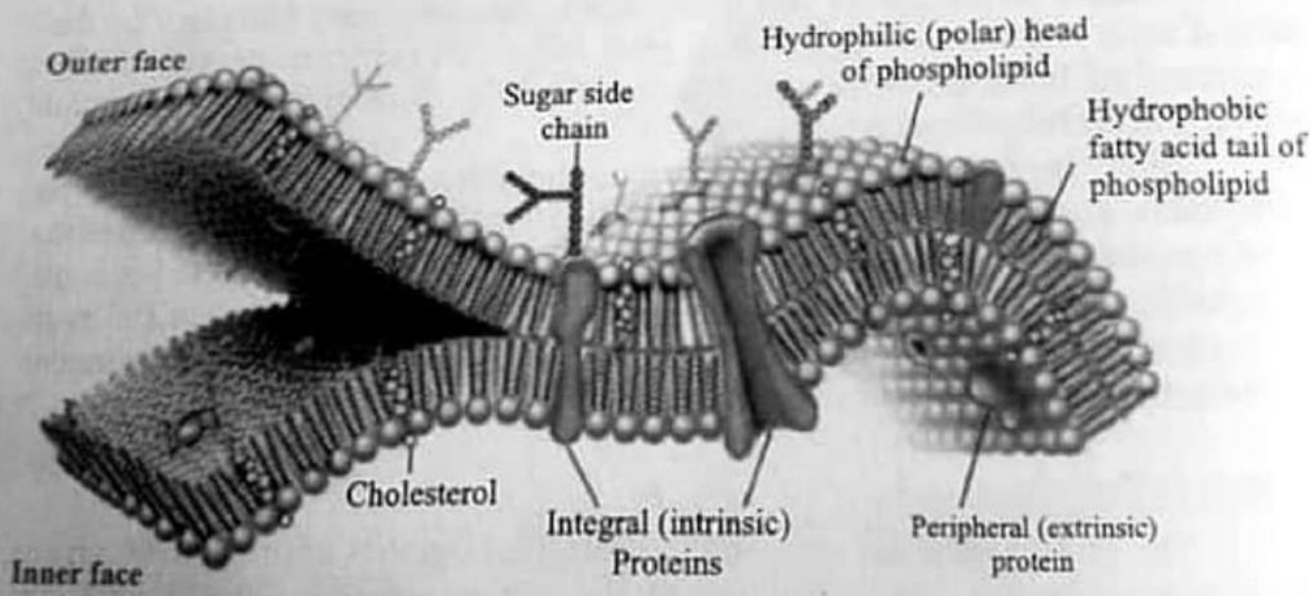


Fig: 1.4 Fluid mosaic Model

Membrane carbohydrates such as glycolipids and glycoproteins provide receptor sites that receives different types of stimuli like Hormone Receptor Sites (HRS), receives nerve impulses, recognition of antigen and food materials thus inform the cell for response. Membrane carbohydrates are also responsible for Endocytosis i.e. phagocytosis (eating of the cell) and pinocytosis (drinking of the cell). Thus glycolipids and glycoproteins act as cell surface markers.

1.3.3 Role of Plasma membrane

Plasma membrane is a dynamic structure only about 7 nm wide but it present barrier to the movement of ions and molecules, particularly polar (water soluble) molecules such as glucose and amino acids, which are repelled by the non-polar, hydrophilic lipids. This prevents the aqueous contents of the cell from escaping.

However, transport or maintenance across membranes must still occur for a number of reasons, for example

- To obtain nutrients.
- To excrete waste substances (urea, uric acid etc).
- To secrete useful substances (hormones, enzymes, etc).
- To generate the ionic gradients essential for nervous & muscular activity.
- To maintain a suitable pH and ionic concentration with in the cell for enzyme activity.

1.4 Cytoplasm

The living contents of eukaryotic cells are divided into nucleus and cytoplasm, the two together forming the protoplasm. Cytoplasm is aqueous (water containing) substance containing a variety of cell organelles and other structures such as insoluble wastes and storage products.

The soluble part of the cytoplasm forms the ground substance between the cell organelles and is called cytosol. It is formed of about 90% water and forms a solution which contains all the fundamental biochemicals of life. In cytosol, small molecules and ions may form true solutions, and some large molecules form colloidal solutions. A colloidal solution may be a **sol** (non-viscous) or a **gel** (jelly like or viscous). Often the outer region of cytoplasm is more gel like.

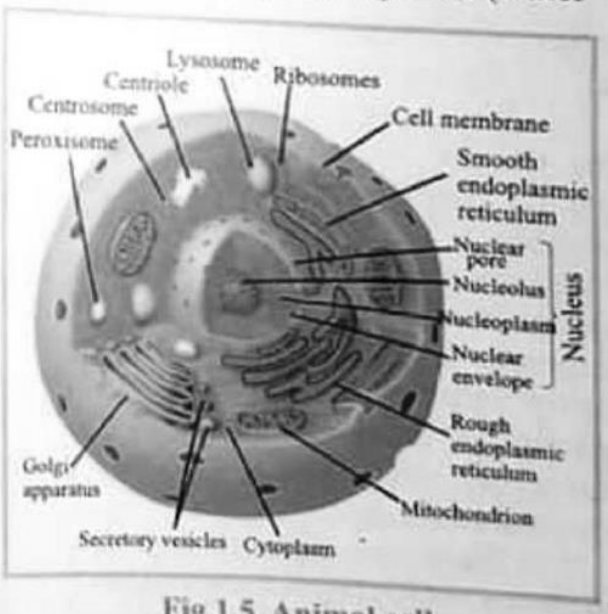


Fig 1.5 Animal cell

Apart from acting as storage of vital chemicals, the ground substance (cytosol) is the site of certain metabolic pathways, such as glycolysis. In living cells the cytoplasm contains several cell organelles such as endoplasmic reticulum, mitochondria, Golgi complex, nucleus, plastids, ribosomes, lysosomes, centrioles and various others. In the cytosol mitochondria move about in cytoplasm due to

cytoplasmic streaming movements. This is an active mass movement of cytoplasm which is called cyclosis.

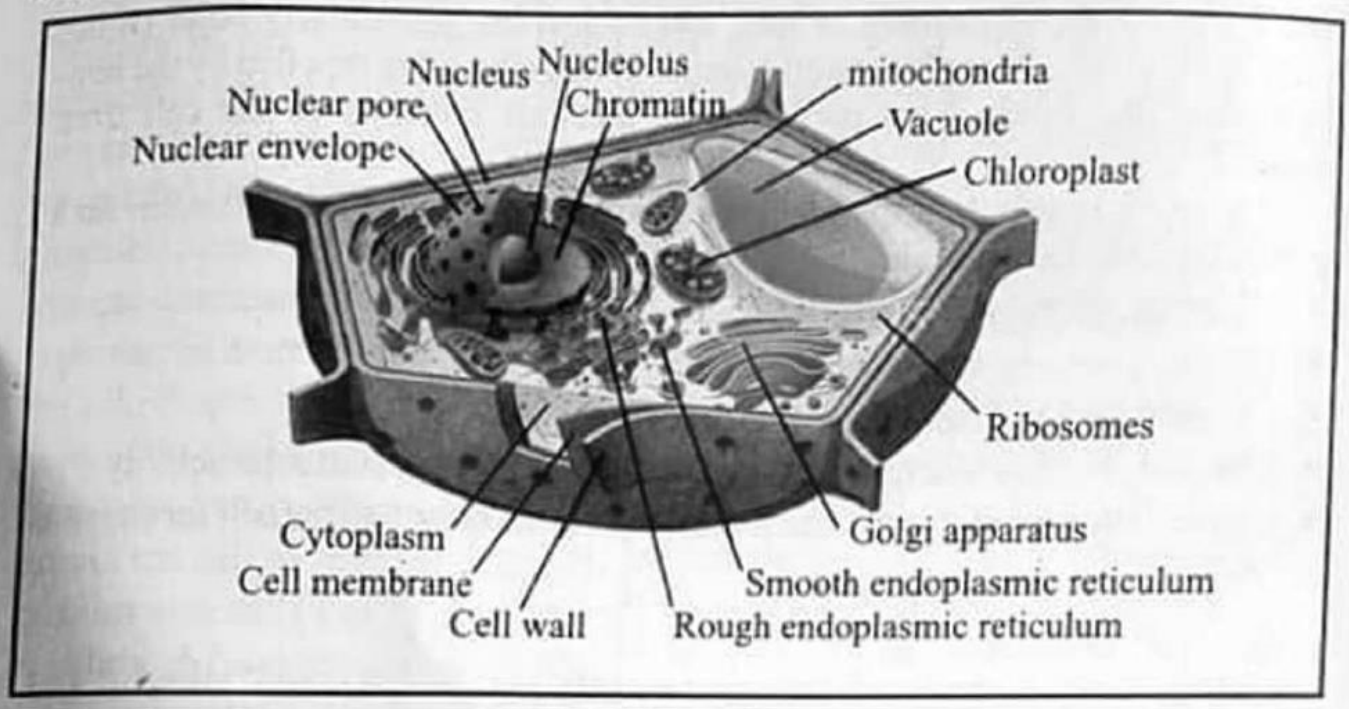


Fig: 1.6 Plant cell

1.4.1 Cytoplasmic Organelles

I. Endoplasmic Reticulum

Under the electron microscope a net work of channels is seen running through the cytoplasm of all the eukaryotic cells. These channels are often continuous with plasma membrane and also appear to be in contact with the nuclear membrane. The whole system of channels is said to be endoplasmic reticulum. These membranes vary widely in appearance from cell to cell. These channels are separated from the cytoplasmic materials by the spherical or tubular membranes one above the other, called cisternae (singular: cisterna).

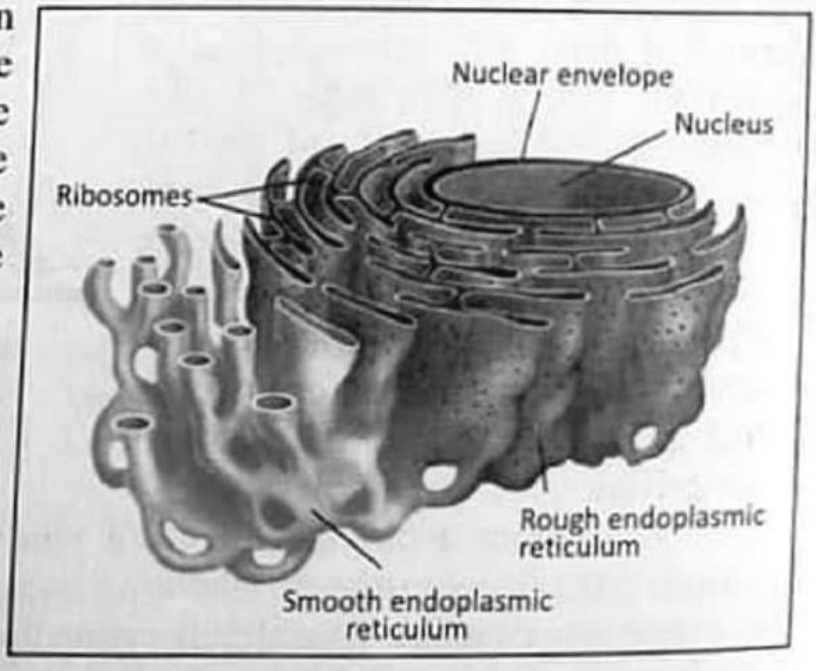


Fig 1.7 Endoplasmic reticulum

There are two morphological forms of endoplasmic reticulum; rough form with attached ribosome and a smooth form without ribosome. Rough endoplasmic reticulum (RER) are mostly present outside the nuclear membrane and thus involved in protein synthesis. After synthesis the proteins are either stored in the cytoplasm or exported out of the cell through

these channels.

Do you know?

SER makes lipids from fatty acid & glycerol absorbed in the gut & passes them to the Golgi bodies for export. Hormone corticosteroids made in adrenal cortex & sex hormones testosterone, estrogen are also initiated by endoplasmic reticulum.

The Smooth Endoplasmic Reticulum (SER) helps in metabolism of a number of different types of molecules particularly lipid synthesis. They also help to detoxify the harmful drugs. In some cells SER is responsible for the transmission of impulses, for example, muscle cells, nerve cells etc. In addition, SER play an important role in the transport of materials from one part of the cell to the other. It provides mechanical support to the cell so that its shape is maintained.

ii. Ribosomes

These are tiny cell organelles, about 20 nm in diameter and were first studied by Palade (1955). Eukaryotic ribosomes are composed of almost equal amount of RNA (ribonucleic acid) and protein; hence they are ribonucleoprotein particles.

The RNA present in ribosomes is ribosomal-RNA. Ribosomes exist in two forms; either freely dispersed in the cytosol or attached with RER as tiny granules and are the site of protein synthesis. Ribosomes are synthesized in nucleolus of the nucleus. An example of protein synthesized by free ribosomes is Haemoglobin in young RBCs. Each ribosome consists of two subunits; one large and one small as shown in fig 1.8.

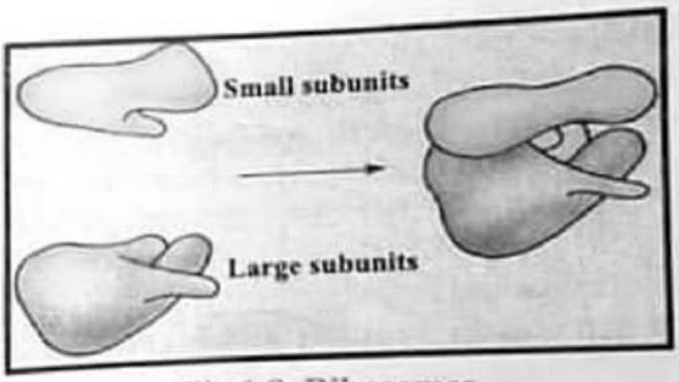


Fig 1.8 Ribosomes

Tidbit

Due to small size ribosomes are the last organelle to be sedimented in a centrifuge requiring a force of 150,000 times gravity for 3 hours. Chloroplast and mitochondria contains 70S ribosomes, showing their prokaryotic origin.

Sedimentation has revealed two basic types of ribosomes called 70S (50Sand 30S) and 80S(60S and 40S) ribosomes (S = Svedberg unit used in ultracentrifugation). The 70S ribosomes are found in prokaryotes while slightly larger 80S in eukaryotes. The two subunits on attachment with each other require Mg^{++} ions. The ribosomes are attached to mRNA through small ribosomal units. A group of ribosomes attached to mRNA are called polysomes.

iii. Golgi apparatus (Dictyosomes)

The Golgi apparatus was discovered by Camillo Golgi in 1898, using special staining techniques. This apparatus which was found virtually in all eukaryotes consists of stacks of flattened, membrane bounded sacs called cisternae. These cisternae together with associated vesicles are called Golgi-complex. It is a complex system of interconnected tubules around the central stack.

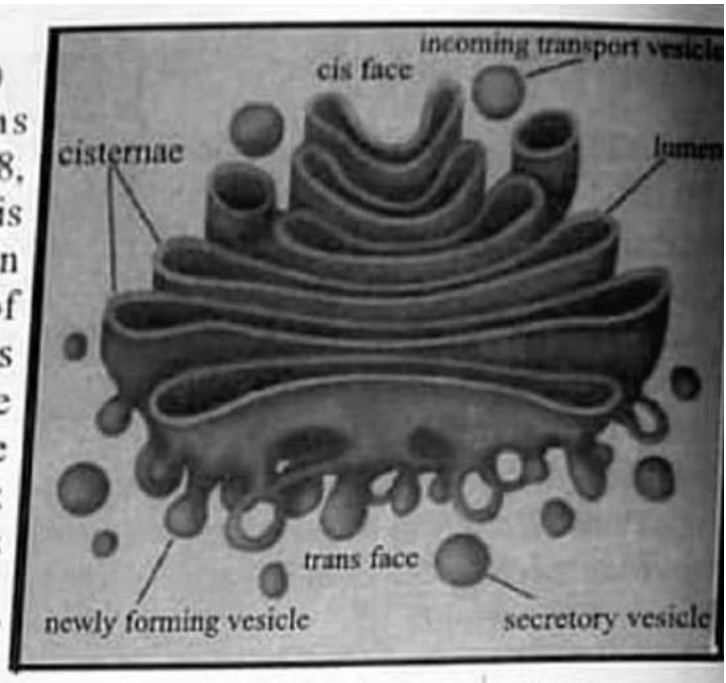


Fig: 1.9 Golgi Apparatus

The Golgi complex consists of units called dictyosomes. Each dictyosome is formed of bundles of curved and flattened cisternae, associated tubules and secretary vesicles. Dictyosome has two distinct faces. The proximal (cis) or forming face present close to nucleus and a distal (trans) or maturing face located towards the cell membrane. Vesicles and tubules pinched off from RER, flow, converge and fuse with the forming face to form new cisterna.

a. Functions of Golgi Apparatus

Golgi aaparatus helps in the storage of secretory products and in the modification and packaging of secretory products. In some cases polysaccharides may be synthesized from simple sugars in the Golgi apparatus. These polysaccharides may then be attached to proteins and lipids to form glycoproteins and glycolipids. Secretory vesicles produced by the Golgi apparatus may play an important role in adding surface area to the plasma membrane.

iv. Lysosomes

Lysosomes (lyso – splitting; soma – body) are cytoplasmic organelles found in most eukaryotes and are different from others cytoplasmic organelles due to their morphology. These were isolated as separate components for the first time by De Duve in 1949. They are surrounded by a single membrane and are simple sacs that contain very large variety of food digesting enzymes called hydrolases. Any foreign objects that gain entry with in the cell are immediately engulfed by the lysosomes and are completely broken down into digestible pieces. This process is known as phagocytosis. They are very abundant in those animal cells which exhibit phagocytic activity e.g neutrophils.

Lysosomes are bounded by single membrane and contain numerous hydrolytic and acid phosphatase 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 primary lysosomes. These contain those

enzymes which can digest the phagocytosed food particles.

During autophagy (self eating) some old worn out parts of the cell are also digested. In this way, materials of cell may be recycled and cell may be renewed. Their enzymes can also result in degeneration of cell, as may occur during the developmental processes.

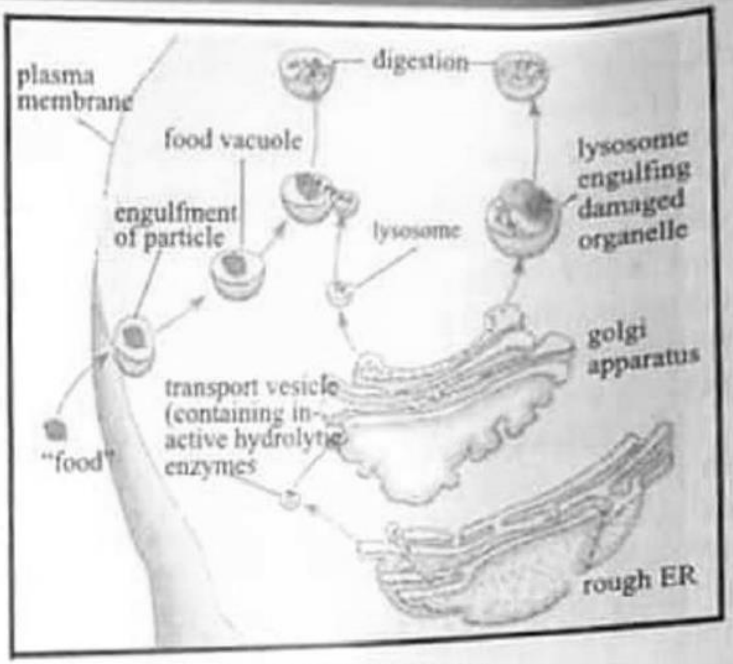


Fig: 1.10 Lysosomes

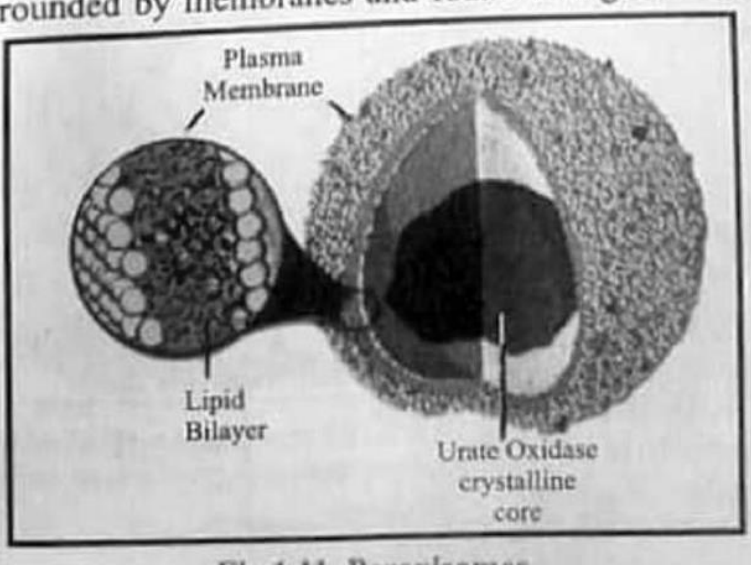
a. Malfunctioning of Lysosomes

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

For example, in **glycogenosis type II** disease, the liver and muscles cells appear filled with glycogen with in membrane bound organelles. In this disease, an enzyme that converts glycogen to glucose, is absent. Similarly **Tay-Sach's** disease is involved in the catabolism of lipids. Accumulation of lipids in brain cells lead to mental retardation and even death.

v. Peroxisomes and Glyoxisomes

The peroxisomes are small sub-cellular bodies approximately 0.5*u*m in diameter, surrounded by membranes and found in a great variety of organisms,



including plants and animals which are also called microbodies. In animals they are most common in liver and kidney cells. They are similar to lysosomes, but they are somewhat more dense and have different enzyme systems. For example, the enzymes of peroxisomes are known to break down hydrogen peroxide into oxygen and water, protecting cells from its corrosive effects. In the leaves of green plants, photorespiration may occur in peroxisomes.

Glyoxisomes are present only in plant cells It contains a number of enzymes including glycolic acid oxidase and catalase .These organelles are most abundant in plant seedlings. The primary activity of the glyoxisomes is the conversion of fatty acids to carbohydrates. In lipid rich seeds such as soyabeens, glyoxisomes provide sites for the breakdown of lipids. These organelles are absent in seeds poor in lipid.

fldbjf

Glyoxisomes only present during a short period in the germination of the lipid rich seed (castor oil seed) and is absent in lipid poor seed such as pea.

vi) Cytoskeleton

Koltzoff in 1928, by his microscopic studies suggested the existence of an organized fibrous network of skeleton in the cytoplasm of eukaryotic cells. Later on, Cohen (1977) confirmed the views of Koltzoff, by his electron microscopic studies.

According to Cohen, the cytoplasm of eukaryotic cells contains a cytoskeletal network of different types of microtubules, microfilaments and intermediate filaments.

The main proteins that are present in the cytoskeleton are tubulin (in microtubules), actin, myosin, tropomyosin and others which are also found in muscles. Several cell organelles are derived from special assemblies of microtubules, e.g. cilia, flagella,

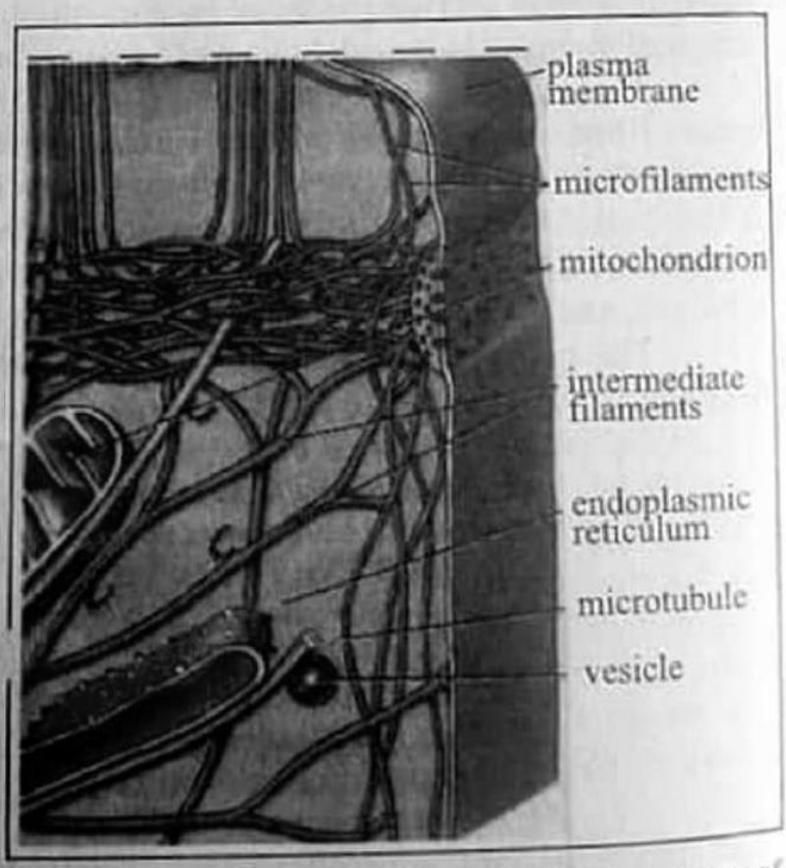


Fig 1.12 Cytoskeletal network of different types of microtubules, microfilaments and intermediate filaments.

basal bodies and centrioles. Cyclosis and amoeboid movements are because of microfilaments, where as intermediate filaments are involved in determination of cell shape and integration of cellular components.

a. Microtubules

These are long, unbranched slender tubulin protein structures. One very important function of microtubules is their role in the assembly and disassembly of the spindle structures during cell division.

b. Microfilaments

These are considerably more thin cylinders made up of contractile actin proteins, linked to the inner face of the plasma membrane. They are involved in cyclosis.

c. Intermediate filaments

They have diameter in between those of microtubules and microfilaments. They help in maintaining the cell shape.

vii. Centrioles

Animal cells, cells of some microscopic organisms and lower plants for example mosses, liverworts etc. contain two centrioles located near the surface of the nucleus. These are small hollow cylinders (about 0.3-0.5 μm long & about 0.2 μm in diameter) that occur in pair.

In cross section each centriole consists of cylindrical array of nine microtubules. However each of the nine microtubules is further composed of three tubules (fig 1.13).

The two centrioles are usually placed at right angle to each other. Just before cell division, its centrioles duplicate and one pair migrates to the opposite side of the nucleus. The spindle fibers formation takes place by using centrioles as MTOCs (microtubule organizing center) located outside the nucleus. They are absent in higher plants. Centrioles play an important role in the location of furrowing during cell division and in the formation of cilia and flagella.

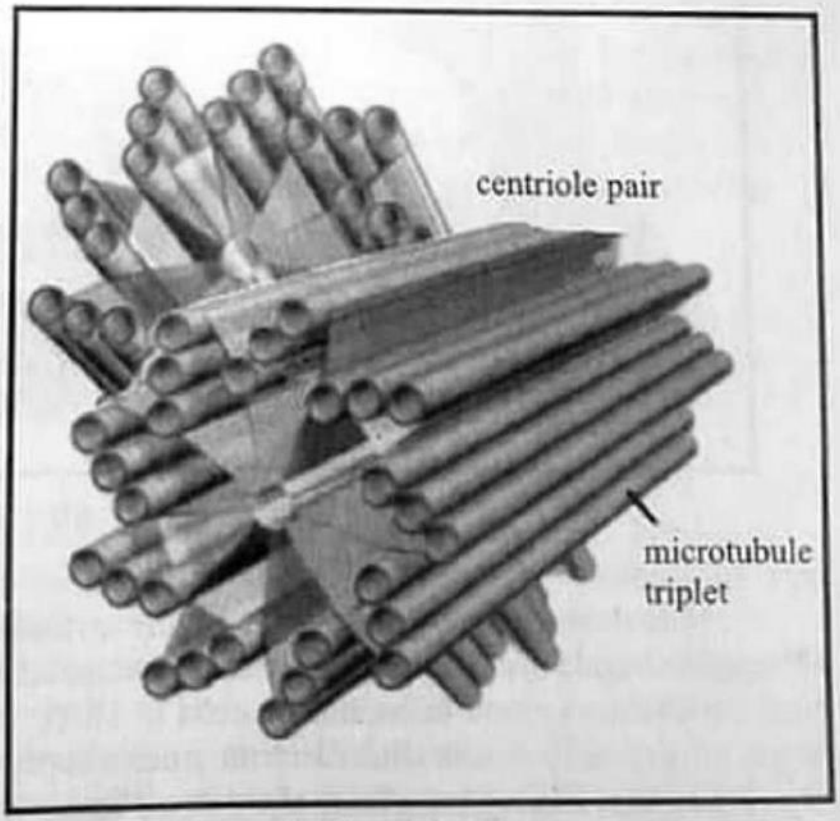


Fig 1.13 Centrioles

viii. Cilia and Flagella

Tidbit

In higher plants, cells seem to organize microtubules at sites distributed all around the nuclear envelope. However, they do use the special tubulin (gamma tubulin) to nucleate microtubules, just like the centrioles do in animal cells.

Although cilia and flagella are the same, they were given different names before their structures were studied. Typically, cells possess one or two long flagella, whereas ciliated cells have many short cilia. For example, the mammalian spermatozoon has a single flagellum, the unicellular green alga *Chlamydomonas* has two flagella, and the unicellular protozoan *Paramecium* is covered with a few thousand cilia. Ciliary and flagellar beating is characterized by a series of bends, originating at the base of the structure and propagated toward the tip. Virtually all eukaryotic cilia and flagella are remarkably similar in their organization, possessing a central bundle of microtubules, called the axoneme, in which nine outer doublet microtubules surround a central pair of singlet microtubules. The bundle of microtubules comprising the axoneme is surrounded by the plasma membrane.

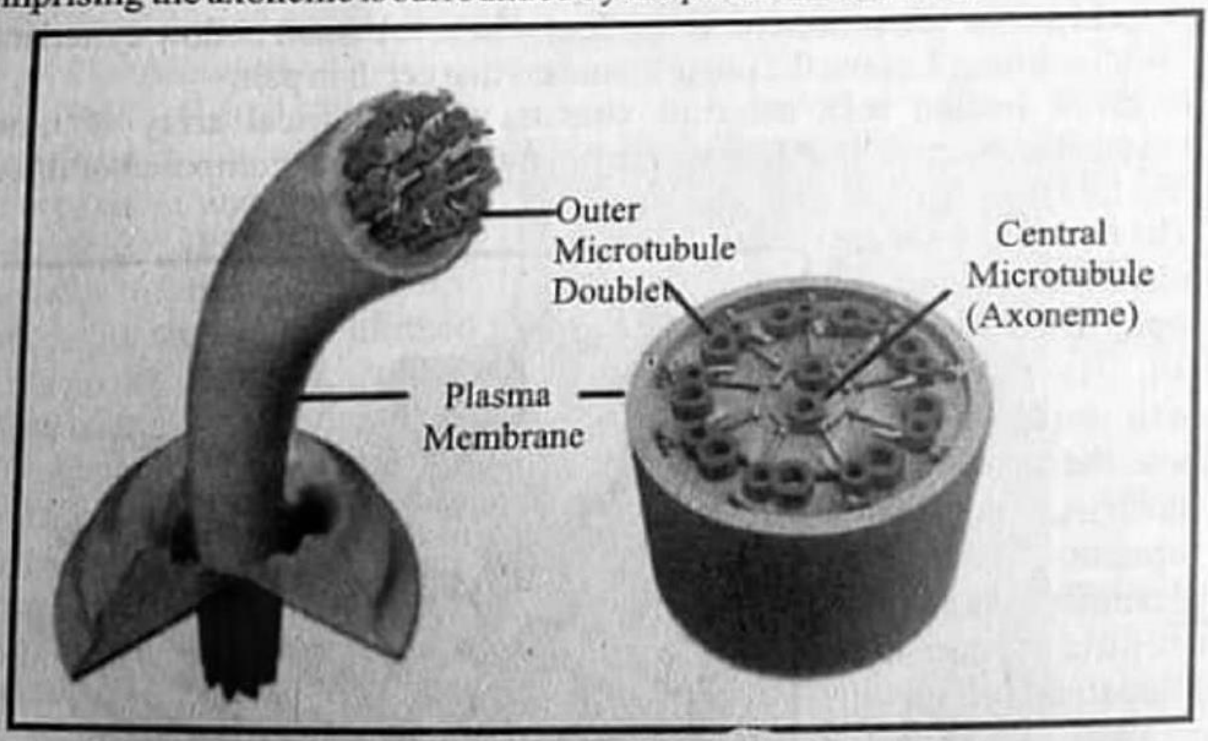


Fig 1.14 Internal organization of cilia

ix. Mitochondria

Mitochondria are found with in the cytoplasm of all eukaryotic cells, although in highly specialized cells such as mature RBCs, they may be absent. They were first seen as granules in muscle cells in 1850. They are known as the power house of the cell. Under the electron microscope, mitochondria appear to be vesicles, rods or filaments and also show complex morphology.

Although their number, shape and internal structure vary widely, a tochondrion is bounded by two membranes, the outer one is smooth, while the ner membranes form infolding into the inner chamber called mitochondrial atrix. These in folds are called cristae (sing: crista). The membranes have the same emical nature as that of cell membrane. The presence of **ribosomes** and **DNA** side mitochondria indicate that some proteins are synthesized in it, so it is a **self plicating** organelle.

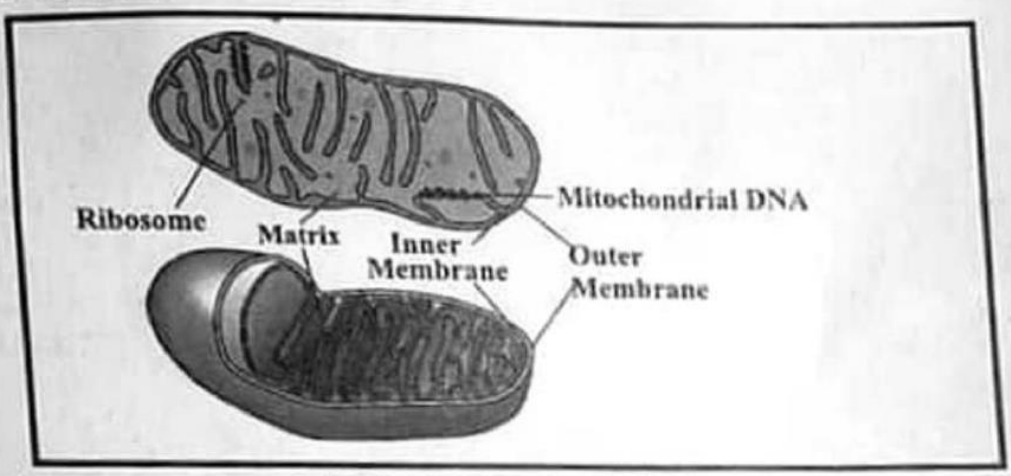


Fig: 1.15 Mitochondrium

The inner surface of cristae in the mitochondrial matrix has small knob like structures known as elementary particles (F_0 , F_1 particles). As mitochondrion is a site for all the reactions of aerobic respiration. Its matrix contains a large number of oxidative enzymes, co-enzymes, organic and inorganic salts, vital for aerobic respiration (Krebs cycle, Fatty acid metabolism etc). As a result of these metabolic processes the energy extracted from the organic food is transformed into energy rich compounds ATP (adenosine tri-phosphate) and in turn this energy is provided to the cells on demand.

x. Plastids

Membrane bounded, mostly pigment containing bodies present in the cell are called plastids. Plastids are the unique organelles found only in plant cells. There are three main types of plastids: a) Chloroplasts b) Chromoplasts c) Leucoplasts

a. Chloroplasts

In photosynthetic plant cells, these are membrane bounded structures containing a green pigment, chlorophyll. Chlorophyll is an organic compound which helps the cell to absorb sunlight and utilize it to manufacture food.

Chloroplasts vary in their shape and size with a diameter of about 4-6 μm. Under electron microscope they appear to be heterogeneous structures with small granules known as grana embedded in the matrix. Chloroplast shows three main components, the envelope, stroma and the thylakoid (fig 1.16). The envelope is

formed by a doubled membrane, while stroma covers most of the volume of the chloroplast. Stroma is a fluid which surrounds the thylakoids. It contains proteins, some ribosomes and a small circular DNA. It is in this part of the chloroplast where carbondixoide is fixed to manufacture sugars.

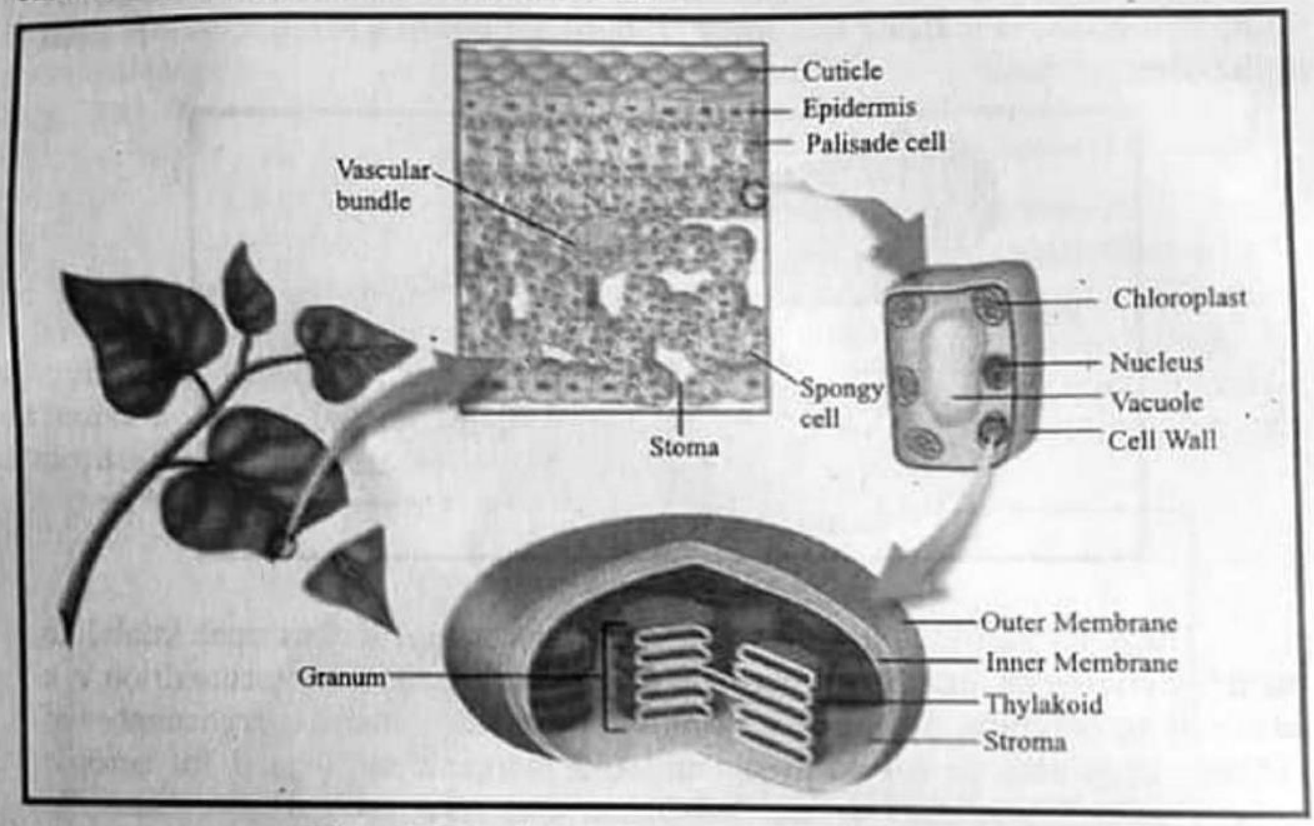


Fig 1.16 Location and structure of Chloroplast

Thylakoids are the flattened vesicles which arrange themselves to form grana. A granum appears to be a pile of thylakoids stacked on each other like coins. On average there are 50 or more thylakoid piled to form one granum. On the layers of the thylakoids, chlorophyll molecules are arranged and that is why granum appears to be green. Each granum is inter-connected with other by the non green part called intergranum. Chloroplasts are also self replicating organelle like mitochondria.

b. Chromoplasts

Chromoplasts impart colour to the plant parts other than green. They are present in the petals of the flower and in the ripened fruits. They help in pollination and dispersal of seeds.

c. Leucoplasts

Leucoplasts are colorless. They are triangular, tubular or of some other shape. They are mostly found in the underground parts of the plants and store food.

xi. Nucleus

Presence of cell nucleus was reported in 1838 by Robert Brown. Its early

discovery was due to its prominence in many cells, where it stands out as slightly darker than the surrounding cytoplasm. They are typically about 10 μm in diameter.

It is one of the most important organelle because it controls all the metabolic activities and has the genetic information in the form of chromosomes and DNA. They may be irregular or spherical in shape.

Generally, the cells having one nucleus are called mono-nucleate, those with two nuclei are bi-nucleate and with more than two nuclei are said to be multi-nucleate.

Parts of Nucleus: Nucleus consists of the following parts:

a. Nuclear membrane
b. Nucleolus
c. Nucleoplasm
d. Chromosomes

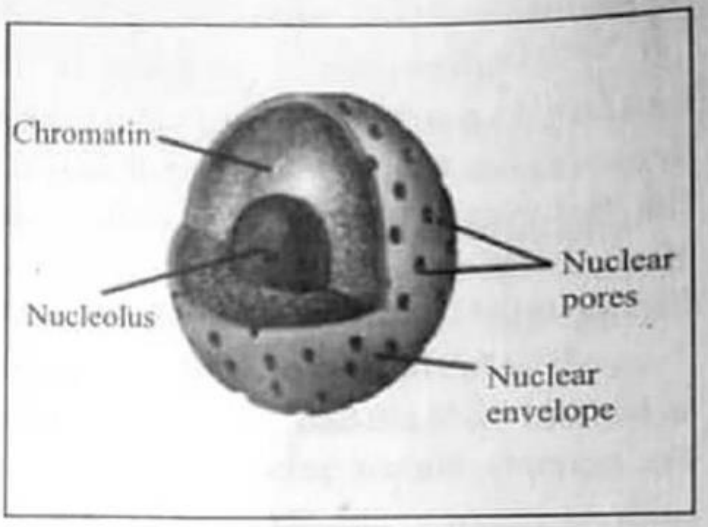


Fig: 1.17 Parts of a nucleus

a. Nuclear membrane

The outer membrane of the nucleus is the nuclear membrane which separates the nucleus from the cytoplasm (eukaryotic cells). The nuclear membrane is actually the nuclear envelop, composed of two membranes. The outer membrane is continuous with the endoplasmic reticulum (RER), while the inner membrane encloses the nuclear contents. These membranes are not continuous, leaving certain pores at points, the nuclear pores. Nuclear pores allow the exchange of materials between the nucleus and the cytoplasm.

b. Nucleolus

It is darkly stained body within the nucleus and is without any membranous boundary to separate it from the rest of nuclear material. There may be one or more nucleoli in the nucleus. The rRNA (ribosomal RNA) is synthesized and stored in the nucleolus. It is composed of two regions; the peripheral granular area composed of precursor of ribosomal subunits, and the central fibrillar area consisting of large molecular weight RNA and rDNA.

c. Nucleoplasm

The nucleoplasm is a colloidal mixture of organic and inorganic salts and ions. It serves as a matrix in which nucleoprotein complex (chromatin) is suspended. It also serves as storage place for enzymes, raw material needed for DNA replication and synthesis of RNA.

d. Chromosomes

During cell division chromatin material is stained as dark thread like

directly submerged in the cytoplasm. Prokaryotes include bacteria and blue green algae, while eukaryotes include all other unicellular or multicellular organisms such as protists (amoeba, paramecium, and euglena etc), animals, plants and fungi.

Detailed studies show that prokaryotic cells generally lack many of the membrane bounded structures which are present in eukaryotic cells. For example, mitochondria, endoplasmic reticulum, chloroplasts, Golgi complex etc are absent in prokaryotes. Since there is no nuclear membrane a prokaryotic cell has no distinct nucleus and it DNA molecule is directly suspended in the cytoplasm. Prokaryotes have small sized ribosomes i.e. 70S. In prokaryotes mitosis is missing and the cells divide by binary fission.Because of the simpler structure of prokaryotes, it was widely accepted for a long time that prokaryotic cell represents a more primitive stage of evolution than eukaryotes. Perhaps the most distinctive features of the prokaryotic cell is its cell wall, composed of polysaccharides chain bound covalently to shorter chain of amino acids forming peptidoglycan or murein.

Tid-bit

Undifferentiated cells such as **egg** have about 30,000 pores per nucleus where as differentiated cells (**erythrocytes**) have only 3 to 4 pores per nucleus.

The entire cell wall is often regarded as a single huge molecule or molecular complex called murein. The cell wall of plants (eukaryotes) is generally made of cellulose and is differently structured than that of a bacterium (prokaryotes) .

1.5.1 Structure of Bacteria as a Model Prokaryote

Bacteria as mentioned earlier are prokaryotes. These are the smallest cellular organisms and are the most abundant in the universe. Bacteria along with cyanobacteria (blue green algae) which are included in kingdom prokaryotae are the only living prokaryotic organisms.

The cell wall of bacteria has murein (as mentioned earlier), it is rigid structure and determines the shape of the bacterium. It also protects the cells from osmotic lysis. Bacterial cell unlike eukaryotic organisms lacks discrete chromosome and nuclear membrane. The nuclear material (DNA) in bacterial cells occupies a position near to the center of the cell. This material is a single, circular and double stranded DNA molecule.

Bacteria only have ribosomes, composed of RNA and proteins. There are thousands of ribosomes in each healthy growing cell. Sexual reproduction in bacteria involves the exchange of DNA. This process occurs in three different ways:

EXERCISE

A. Choose the correct answers in the following questions.

1. Which of the following is best suited stain in order to study chromosomes?
   a. Iodine solution b. Leishman's stain
   c. Feulgen 's stain d. Aniline blue

2. The 'Scavengers' or 'Digestive bags' of a cell are _____.
   a. chromosomes b. centrosomes
   c. lysosomes d. ribosomes

3. Following are the functions of cytoskeleton EXCEPT:
   a. Maintaining cell shape b. Movement
   c. Contraction d. Respiration

4. Identify the mismatch in the following pairs:
   a. Mitochondria – cellular respiration
   b. Lysosome- intra cellular digestion
   c. Microfilament- cyclosis
   d. Glyoxisome- deamination

5. The most prominent cell organelle of a bacterial cell other than DNA is:
   a. Mesosome b. Ribosome
   c. Lysosomes d. Nucleosome

6. The cell wall of prokaryotic cell (bacterial) is composed of:
   a. Pectin b. Lignin
   c. Cellulose d. Murein

7. The cell organelle in eukaryotic cell which is NOT bounded by the membrane is:
   a. Lysosomes b. Centriole
   c. Peroxisomes d. Mitochondrion

8. In which part of the chloroplast the fixation of CO_2 results in the formation of sugars?
   a. Envelope b. Stroma
   c. Thylakoid d. Intergranum

9. The organelle which is absent in animals cell:
   a. Plastids
   b. Centriole
   c. Lysomes
   d. Nucleolus

10. The special proteins which carry lipid –insoluble large molecules through pores of plasma membrane are called :
   a. Permeases
   b. Catalases
   c. Arginases
   d. Amylases

11. The membrane enclosed spaces of endoplasmic reticulum are called:
   a. Lamellae
   b. Cisternae
   c. Stroma
   d. Cristae

12. All of the following refers to lysosomes EXCEPT:
   a. Slightly larger than mitochondria
   b. Roughly spherical
   c. Single membrane bounded
   d. Contain powerful digestive enzymes

13. Lysosomes are also called as:
   a. Peroxisomes
   b. Mesosomes
   c. Phagosomes
   d. Glyoxisomes

14. In the leaves of green plants, peroxisomes are the sites of:
   a. Respiration
   b. Photosynthesis
   c. Photorespiration
   d. Phototropism

B. Write short answers of the following questions.

1. List four main functions of a nucleus.
2. What do you know about peroxisomes?
3. Write two differences between rough endoplasmic reticulum and smooth endoplasmic reticulum.
4. What is cytoskeleton? Why it is consider to be important organelle in the cell.
5. Cell is called structural and functional unit of life. Justify the statement.
6. Why are chloroplast found only in plant cells?
7. What are the consequences of cell losing cell membrane?

C. Write the answers of the following questions.

1. Differentiate between a prokaryotic and eukaryotic cell.
2. Describe the fluid mosaic model of plasma membrane.
3. What do you know about Golgi apparatus. Describe its functions.
4. Explain critically the role of lysosomes in human body.
5. Write a note on cytoskeleton.
6. What do you mean by tissue culture? What are the main steps involved in the process of tissue culture?
7. How do the cell organelles work together to keep us alive.
8. Discuss how the structure of specialized animal cells is related to their functions?

Projects:

- Make a fluid mosaic model of plasma membrane.
- Take a material of your choice and measure the size of its cells by micrometry.
- Compare in tabular form, the functions of organelles with the processes occurring in animals and plants on a chart and share it in the class.