Unit III: Cell biology and Biomolecules

Chapter 6

Cell: The Unit of Life

Learning Objectives

The learner will be able to,

- *Describe the cell and contributions of early scientist towards its discovery*
- *Appreciate the use of light and electron microscopes for better understanding of the cell*
- *Understand the ideas of cell theory and the different concepts associated with it*
- *Distinguish the significant characters of various groups of life forms*
- *Recognize the basic structure of cell and differentiate the cells of animals, plants, bacteria and viruses*
- *Explain the structure and functions of cell organelles including nucleus*
- *Recognize the structure of chromosome and its types*
- *Describe the flagellar structure, types and movements*
- *Get acquainted with the cytological techniques*

Chapter Outline

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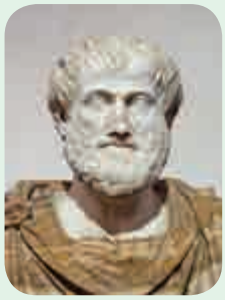
The word '*cell*' comes from the Latin word '*Celle*" which means 'a small compartment'. The word cell was first used by Robert Hooke (1662) therefore the term '*cell*' is as old as 300 years.

6.1. Discovery

Aristotle (384-322BC), was the one who first recognised that animals and plants consists of organised structural units but unable to explain what it was. In 1660's **Robert Hooke** observed something which looks like 'honeycomb with a great little boxes' which was later called as '**cell**' from the cork tissue in 1665. He compiled his work as **Micrographia**. Later, **Antonie von Leeuwenhoek** observed unicellular particles which he named as '***animacules***'. **Robert Brown** (1831-39) described the spherical body in the plant

Scientist



Aristotle (384–322BC)

Robert Hooke (1635–1703)

Antonie von Leeuwenhoek (1632–1723)

Schleiden (1804–1881) & Schwann (1810–1882)

Rudolf Virchow (1821–1902)

Figure 6.1

cells as nucleus. **H. J. Dutrochet** (1824), a French scientist, was the first to give idea on cell theory. Later, **Matthias Schleiden** (German Botanist) and **Theodor Schwann** (German Zoologist) (1833) outlined the basic features of the cell theory. **Rudolf Virchow** (1858) explained the cell theory by adding a feature stating that all living cells arise from pre-existing living cells by 'cell division'.

6.2. Microscopy

Microscope is an inevitable instrument in studying the cell and subcellular structures. It offers scope in studying

Resolution: The term resolving power or resolution refers to the ability of the lenses to show the details of object lying between two points. It is the finest detail available from an object. It can be calculated using the following formula

$$\text{Resolution} = \frac{0.61\lambda}{NA}$$

Where, λ= wavelength of the light and NA is the numerical aperture.

Numerical Aperture: It is an important optical constant associated with the optical lens denoting the ability to resolve. Higher the NA value greater will be the resolving power of the microscope.

Magnification: The optical increase in the size of an image is called magnification. It is calculated by the following formula

$$\text{Magnification} = \frac{\text{size of image seen with the microscope}}{\text{size of the image seen with normal eye}}$$

microscopic organisms therefore it is named as microscope (mikros – small; skipein – to see) in Greek terminology. Compound microscope was invented by **Z. Jansen**.

Microscope works on the lens system which basically relies on properties of light and lens such as reflection, magnification and numerical aperture. The common light microscope which has many lenses are called as **compound microscope**. The microscope transmits visible light from sources to eye or camera through sample, where interaction takes place.

6.2.1 Bright field Microscope

Bright field microscope is routinely used microscope in studying various aspects of cells. It allows light to pass directly through specimen and shows a well distinguished image from different portions of the specimen depending upon the contrast from absorption of visible light. The contrast can be increased by staining the specimen with reagent that reacts with cells and tissue components of the object.

The light rays are focused by condenser on to the specimen on a microslide placed upon the adjustable platform called as **stage**. The light comes from the Compact Flourescent Lamp (CFL) or Light Emitting Diode (LED) light system. Then it passes through two lens systems namely objective lens (closer to the object) and the eye piece (closer to eye). There are four objective lenses (5X, 10X, 45X and 100X) which can be rotated and fixed at certain point to get required magnification. It works on the principle of numerical aperture value and its own resolving power.

The first magnification of the microscope is done by the objective lens which is called **primary magnification** and it is real, inverted image. The second magnification of the microscope is obtained through eye piece lens called as **secondary magnification** and it is virtual and inverted image (Figure 6.2 a, b and c).

6.2.2 Dark Field Microscope

The dark field microscope was discovered by **Z. Sigmondy** (1905). Here the field will be dark but object will be glistening so the appearance will be bright. A special effect in an ordinary microscope is brought about by means of a special component called '**Patch Stop Carrier**'. It is fixed in metal ring of the condenser component. Patch stop is a small glass device which has a dark patch at centre of the disc leaving a small area along the margin through which the light passes. The light passing through the margin will travel oblique like a hollow cone and strikes the object in the periphery, therefore the specimen appears glistening in a dark background. (Figure 6.2 d and e).

6.2.3 Phase contrast microscope

This was invented by **Zernike** (1935). It is a modification of light microscope with all its basic principle. The objects observed by increasing the contrast by bringing about change in amplitude of the light waves. The contrast can be increased by introducing the '**Phase Plate**' in the condenser lens. Phase plate is a circular component with circular annular etching.

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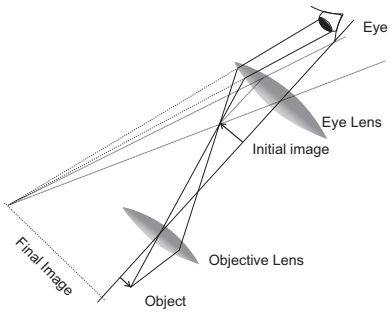

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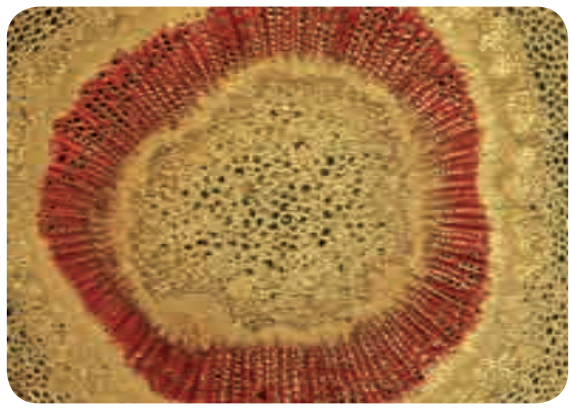

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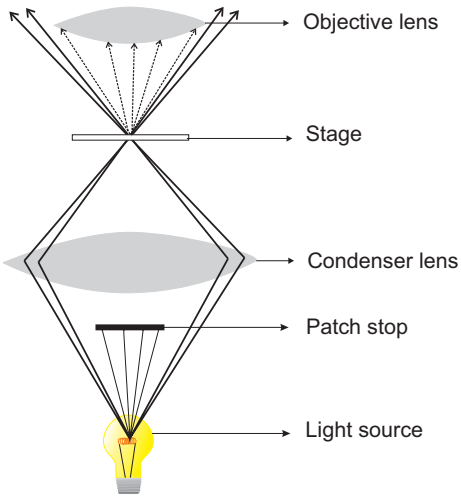

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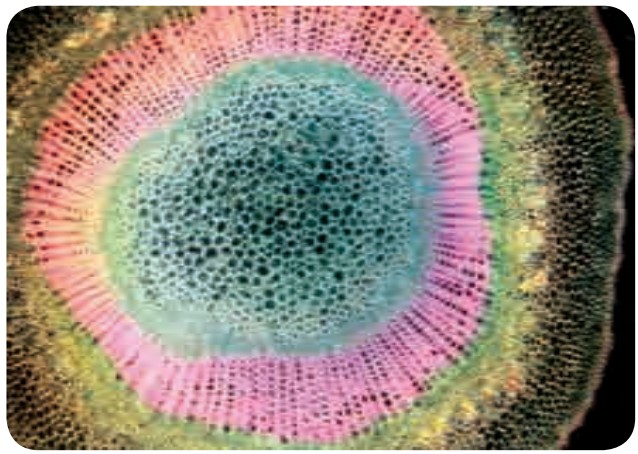

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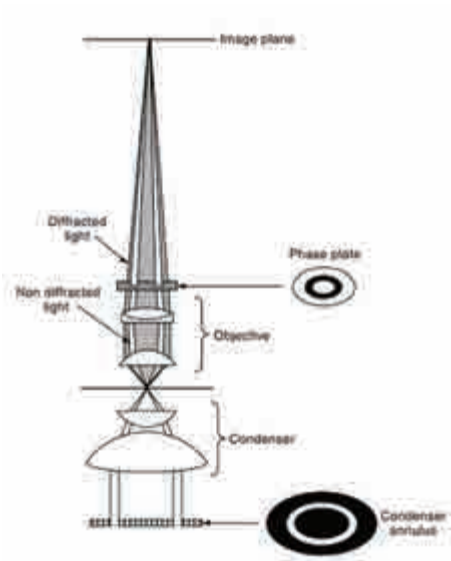

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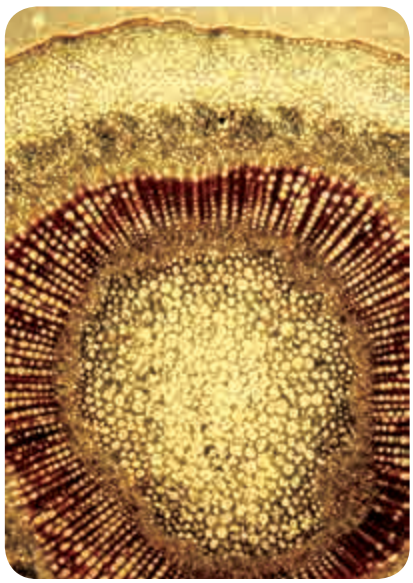


(g)

Figure 6.2: a. Light microscope; **b.** Ray diagram - light path; c. Image taken using light microscope; **d.** Light path in dark field; **e.** Image taken using dark field microscope; **f.** Light path in phase contrast microscope; **g.** Image taken using phase contrast microscope

Microscopic measurements:

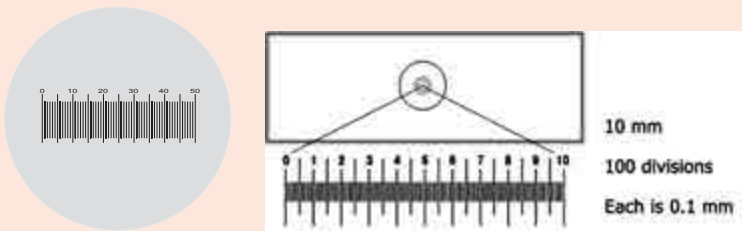
The microscope also has facility to measure microscopic objects through a technique called '**micrometry**'. There are two scales involved for measuring.

1. Ocular Micrometer
2. Stage Micrometer

Ocular Micrometer: It is fixed inside the eye piece lens. It is a thin transparent glass disc where there are lines divided into 100 equal units. The scale has no value.

Stage Micrometer: This is a slide with a line divided into 100 units. The line is about 1mm. The distance between two adjacent lines is 10 µm. The known value of the stage micrometer is transferred to the ocular micrometer, thereby the measurements can be made using ocular micrometer.

$$\text{The distance between two adjacent line of ocular meter} = \frac{\text{Number of stage divisions}}{\text{Number of ocular divisions}} \times 10$$



(a) (b)

Figure 6.3: a. Ocular micrometer; b. Stage micrometer

Light passes with different velocity after coming out of the thinnest and thickest areas of the phase plate thereby increasing the contrast of the specimen. A hollow cone of light passes through the condenser. Direct light pass through thin area of phase plate, whereas light passing from the specimen reaches thick area of phase plate. The light passing through thicker area travel at low speed, on the other hand the light passing through thin area reach fast therefore contrast is increased in the specimen. Phase contrast microscope is used to observe living cells, tissues and the cells cultured *invitro* during mitosis (Figure 6.2 f and g).

6.2.4 Electron Microscope

Electron Microscope was first introduced by **Ernest Ruska** (1931) and developed by **G Binning** and **H Roher** (1981). It is used to analyse the fine details of the cell and organelles called ultrastructure. It uses beam of accelerated electrons as source of illumination and therefore the resolving power is 1,00,000 times than that of light microscope.

The specimen to be viewed under electron microscope is dehydrated and impregnated with electron opaque chemicals like gold or palladium. This is essential for withstanding electrons and

also for contrast of the image.

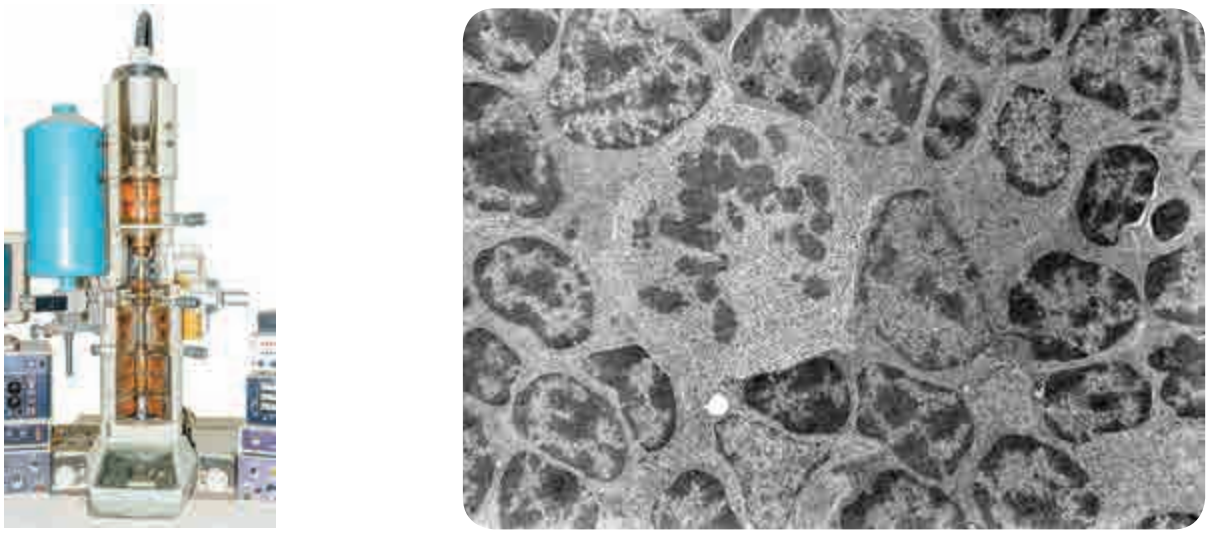
There are two kinds of electron microscopes namely

1. Transmission Electron Microscope (TEM)
2. Scanning Electron Microscope (SEM)

1. Transmission electron microscope:

This is the most commonly used electron microscope which provides two dimensional image. The components of the microscope are as follows:

a. Electron Generating System
b. Electron Condensor
c. Specimen Objective
d. Tube Lens
e. Projector



(a) (b)

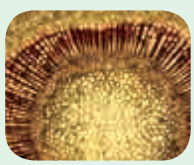
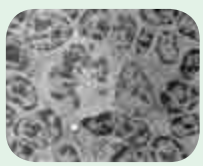
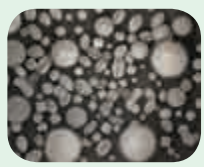
Figure 6.4: a. Transmission electron microscope; b. Image of TEM

(a) (b)

Figure 6.5: a. Scanning electron microscope; b. Image of SEM

A beam of electron passes through the specimen to form an image on fluorescent screen. The magnification is 1–3 lakhs times and resolving power is 2–10 Å. It is used for studying detailed structrue of viruses, mycoplasma, cellular organelles, etc (Figure 6.4 a and b).

Comparison of Microscopes

Features	Light Microscope	Dark Field Microscope	Phase Contrast Microscope	Transmission Electron Microscope	Scanning Electron Microscope
Source of illumination for Image Formation	Visible light	Visible light	Visible light	Electrons	Electrons
Types of cells visualized	Individual cells can be visualised, even living ones.	Individual cells can be visualised, even living ones.	Individual cells can be visualised, even living ones.	Thin sections of the specimen are obtained. The electron beam pass through the sections and form an image with high magnification and high resolution.	The specimen is coated with gold and the electrons are reflected back and give the details of surface topography of the specimen.
Image	2-D	2-D	2-D	2-D	3-D
Nature of Lenses	Glass lenses	Glass lenses	Glass lenses	One electrostatic lens with few electromagnetic lenses	One electrostatic lens with few electromagnetic lenses
Medium	Air/oil	Air/oil	Air/oil	Vacuum	Vacuum
Specimen mounting	Glass slides	Glass slides	Glass slides	Mounted on coated or uncoated copper grids	Mounted on aluminium stubs and are coated in gold
Focusing and Magnification Adjustments	Changing objectives	Changing objectives	Changing objectives	Electrical, using deflection coil	Electrical, using deflection coil
Means for obtaining specimen Contrast	Light diffraction	Through patch stop	Through phase plate	Electron scattering	Electron scattering
Microscope picture					

2. Scanning Electron Microscope:

This is used to obtain three dimensional image and has a lower resolving power than TEM. In this, electrons are focused by means of lenses into a very fine point. The interaction of electrons with the specimen results in the release of different forms of radiation (such as auger electrons, secondary electrons, back scattered electrons) from the surface of the specimen. These radiations are then captured by an appropriate detector, amplified and then imaged on fluorescent screen. The magnification is 2,00,000 times and resolution is 5–20 nm (Figure 6.5 a and b).

6.3. Cell Theory

In 1833, German botanist **Matthias Schleiden** and German zoologist **Theodor Schwann** proposed that all plants and animals are composed of cells and that cells were the basic building blocks of life.

These observations led to the formulation of modern cell theory.

- All organisms are made up of cells.
- New cells are formed by the division of pre-existing cells.
- Cells contains genetic material, which is passed on from parents to daughter cells.
- All metabolic reactions take place inside the cells.

6.3.1 Exception to Cell Theory

Viruses are puzzle in biology. Viruses, viroids and prions are the exception to cell theory. They lack protoplasm, the essential part of the cell and exists as obligate parasites which are sub-cellular in nature.

6.3.2 Cell Doctrine (Cell Principle)

The features of cell doctrine are as follows:

- All organisms are made up of cells.
- New cells are produced from the pre-existing cells.
- Cell is a structural and functional unit of all living organisms.
- A cell contains hereditary information which is passed on from cell to cell during cell division.
- All the cells are basically the same in chemical composition and metabolic activities.
- The structure and function of cell is controlled by DNA.
- Sometimes the dead cells may remain functional as tracheids and vessels in plants and horny cells in animals.

6.3.3 Protoplasm Theory

Corti first observed protoplasm. **Felix Dujardin** (1835) observed a living juice in animal cell and called it "**Sarcode**". **Purkinje** (1839) coined the term protoplasm for sap inside a plant cell. **Hugo Van Mohl** (1846) indicated importance of protoplasm.

Max Schultze (1861) established similarity between Protoplasm and Sarcode and proposed a theory which later on called "**Protoplasm Theory**" by **O. Hertwig** (1892). **Huxley** (1868) proposed Protoplasm as a "**physical basis of life**".

Protoplasm as a Colloidal System

Protoplasm is a complex colloidal system which was suggested by **Fisher** in 1894 and **Hardy** in 1899. It is primarily made of water contents and various other solutes of biological importance such as glucose, fatty acids, amino acids, minerals, vitamins, hormones and enzymes.

These solutes may be homogeneous (soluble in water) or heterogeneous mass (insoluble in water) which forms the basis for its colloidal nature.

Physical Properties of Protoplasm

The protoplasm exist either in semisolid (jelly-like) state called '**gel**' due to suspended particles and various chemical bonds or may be liquid state called '**sol**'. The colloidal protoplasm which is in gel form can change into sol form by **solation** and the sol can change into gel by **gelation**. These gel-sol conditions of colloidal system are prime basis for mechanical behaviour of cytoplasm.

1. Protoplasm is translucent, odourless and polyphasic fluid.
2. It is a crystal colloid solution which is a mixture of chemical substances forming crystalloid i.e. true solution (sugars, salts, acids, bases) and others forming colloidal solution (Proteins and lipids)
3. It is the most important property of the protoplasm by which it exhibits three main phenomena namely Brownian movement, amoeboid movement and cytoplasmic streaming or cyclosis. Viscosity of protoplasm is 2–20 centipoises. The Refractive index of the protoplasm is 1.4.
4. The pH of the protoplasm is around 6.8, contain 90% water (10% in dormant seeds)
5. Approximately 34 elements are present in protoplasm but only 13 elements are main or universal elements i.e. C, H, O, N, Cl, Ca, P, Na, K, S, Mg, I and Fe. Carbon, Hydrogen, Oxygen and Nitrogen form the 96% of protoplasm.
6. Protoplasm is neither a good nor a bad conductor of electricity. It forms a delimiting membrane on coming in contact with water and solidifies when heated.
7. **Cohesiveness:** Particles or molecules of protoplasm are adhered with each other by forces, such as **Van der Waal's bonds**, that hold long chains of molecules together. This property varies with the strength of these forces.
8. **Contractility:** The contractility of protoplasm is important for the absorption and removal of water especially stomatal operations.
9. **Surface tension:** The proteins and lipids of the protoplasm have less surface tension, hence they are found at the surface forming the membrane. On the other hand the chemical substances (NaCl) have high surface tension, so they occur in deeper parts of the cell protoplasm.

6.3.4 Cell sizes and shapes

Cell greatly vary in size, shape and also in function. Group of cells with similar structures are called **tissue** they integrate together to perform similar function, group of tissue join together to perform similar function called **organ**, group of organs with related function called **organ system**, organ system coordinating together to form an **organism**.

Shape

The shape of cell vary greatly from organism to organism and within the organism itself. In bacteria cell shape

DO YOU KNOW?

1 cm = 1/100 meter

1 mm = 1/1000 meter =1/10 cm

1 µm = 1/1000,000 meter = 1/10,000 cm

1 nm = 1/1,000,000,000 meter = 1/10,000,000 cm

1 Å = 1/10,000,000,000 meter =1/100,000,000 cm

or

$1\ m = 10^2 cm = 10^3 mm = 10^6 \mu m = 10^9 nm = 10^{10} Å$

m = meter cm = centimetre mm = millimeter µm = micrometer

nm = nanometer Å=Angstrom

vary from round (**cocci**) to rectangular (**rod**). In virus, shape of the envelope varies from round to hexagonal or 'T' shaped. In fungi, globular to elongated cylindrical cells and the spores of fungi vary greatly in shape. In plants and animals cells vary in shape according to cell types such as parenchyma, mesophyll, palisade, tracheid, fiber, epithelium and others (Figure 6.6).

Size:

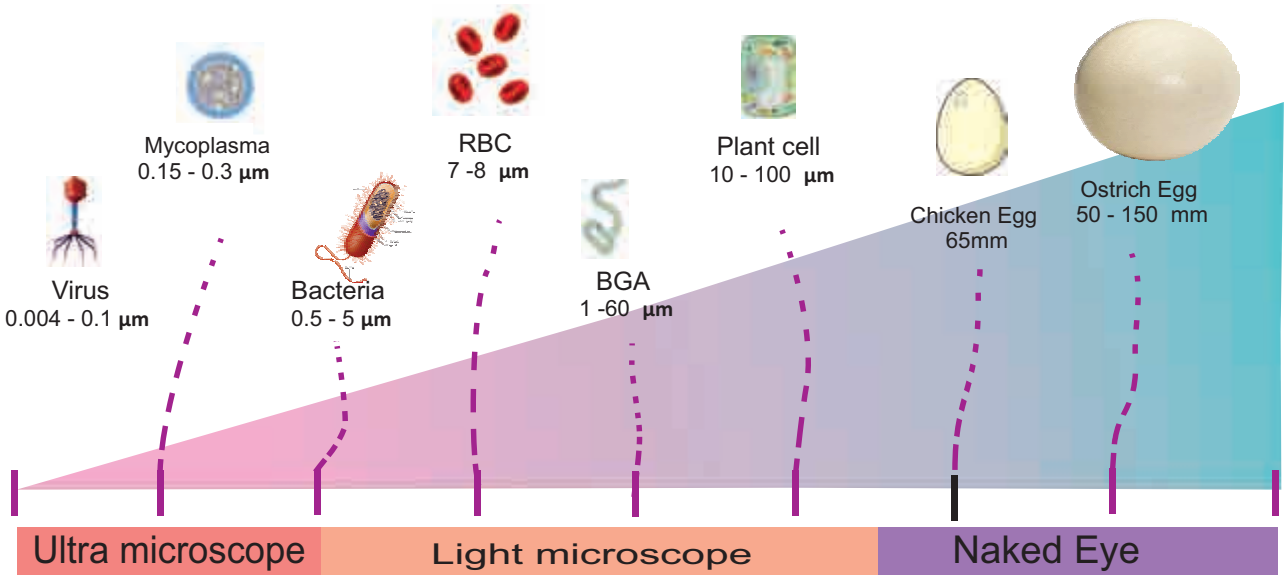


Figure 6.6: Cell size variation of few organisms

6.4. Types of cells

On the basis of the cellular organization and the nuclear characteristics, the cell can be divided into

- Prokaryotes
- Mesokaryotes and
- Eukaryotes

6.4.1 Prokaryotes

Those organisms with primitive nucleus are called as **prokaryotes** (*pro* – primitive; *karyon* – nucleus). The DNA lies in the 'nucleoid' which is not bound by the nuclear membrane and therefore it is not a true nucleus and is also a primitive type

of nuclear material. The DNA is without histone proteins. Example: Bacteria, blue green algae, Mycoplasma, Rickettsiae and Spirochaetae.

6.4.2 Mesokaryotes

In the year 1966, scientist **Dodge** and his coworkers proposed another kind of organisms called **mesokaryotes**. These organisms which shares some of the characters of both prokaryotes and eukaryotes. In other words these are organisms intermediate between pro and eukaryotes. These contains well organized nucleus with nuclear membrane and the DNA is organized into chromosomes but without histone protein components divides through amitosis similar with prokaryotes. Certain Protozoa like **Noctiluca**, some phytoplanktons like *Gymnodinium*, *Peridinium* and Dinoflagellates are representatives of mesokaryotes.

6.4.3 Eukaryotes

Those organisms which have true nucleus are called **Eukaryotes** (*Eu* – True; *karyon* – nucleus). The DNA is associated with protein bound histones forming the chromosomes. Membrane bound organelles are present. Few organelles may be arisen by **endosymbiosis** which is a cell living inside another cell. The organelles like mitochondria and chloroplast well support this theory.

Comparison between types of cellular organisation

Features	Prokaryotes	Mesokaryotes	Eukaryotes
Size of the cell	~1-5µm	~5-10µm	~10-100µm
Nuclear character	Nucleoid, no true nucleus,	Nucleus with nuclear membrane	True nucleus with nuclear membrane
DNA	Usually circular without histone proteins	Usually linear but without histone proteins	Usually linear with histone proteins
RNA/Protein synthesis	Couples in cytoplasm	Similar with eukaryotes	RNA synthesis Inside nucleus/ Protein synthesis in cytoplasm
Ribosomes	50S+ 30S	60S + 40S	60S + 40S
Organelles	Absent	Present	Numerous
Cell movement	Flagella	Gliding and flagella	Flagella and cilia
Organization	Usually single cell	Single and colony	Single, colonial and multicellular
Cell division	Binary fission	Binary fission	Mitosis and meiosis
Examples	Bacteria and Archaea	Dinoflagellate, Protozoa	Fungi, plants and animals

Origin of Eukaryotic cell:

Endosymbiont theory: Two eukaryotic organelles believed to be the descendants of the endosymbiotic prokaryotes. The ancestors of the eukaryotic cell engulfed a bacterium and the bacteria continued to function inside the host cell.

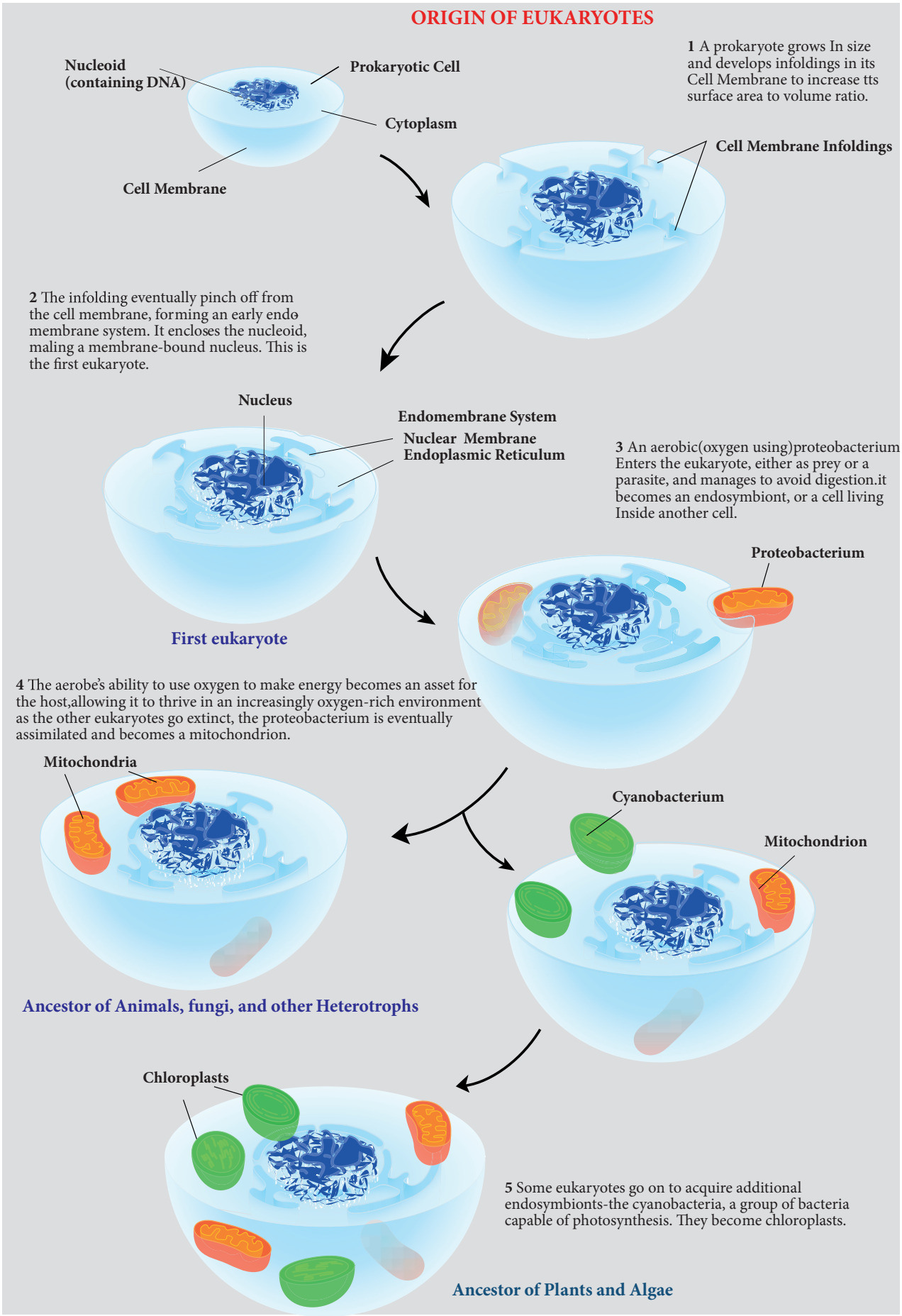


Figure 6.7: A model of endosymbiotic theory

The first cell might have evolved approximately 3.8 billion years ago. The primitive cell would have been similar to present day protists (Figure 6.7).

6.5. Plant and Animal cell

6.5.1 Ultra Structure of Eukaryotic Cell

The eukaryotic cell is highly distinct in its organisation. It shows several variations in different organisms. For instance, the eukaryotic cells in plants and animals vary greatly (Figure 6.8).

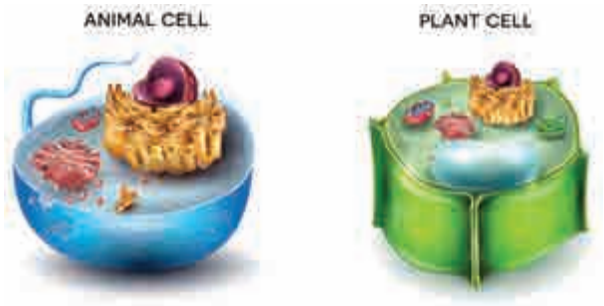


Figure 6.8: Animal and Plant cell

Animal Cell

Animal cells are surrounded by cell membrane or plasma membrane. Inside this membrane the gelatinous matrix called **protoplasm** is seen to contain nucleus and other organelles which include the endoplasmic reticulum, mitochondria, golgi bodies, centrioles, lysosomes, ribosomes and cytoskeleton.

Plant cell

A typical plant cell has prominent cell wall, a large central vacuole and plastids in addition to other organelles present in animal cell (Figure 6.9 and 6.10).

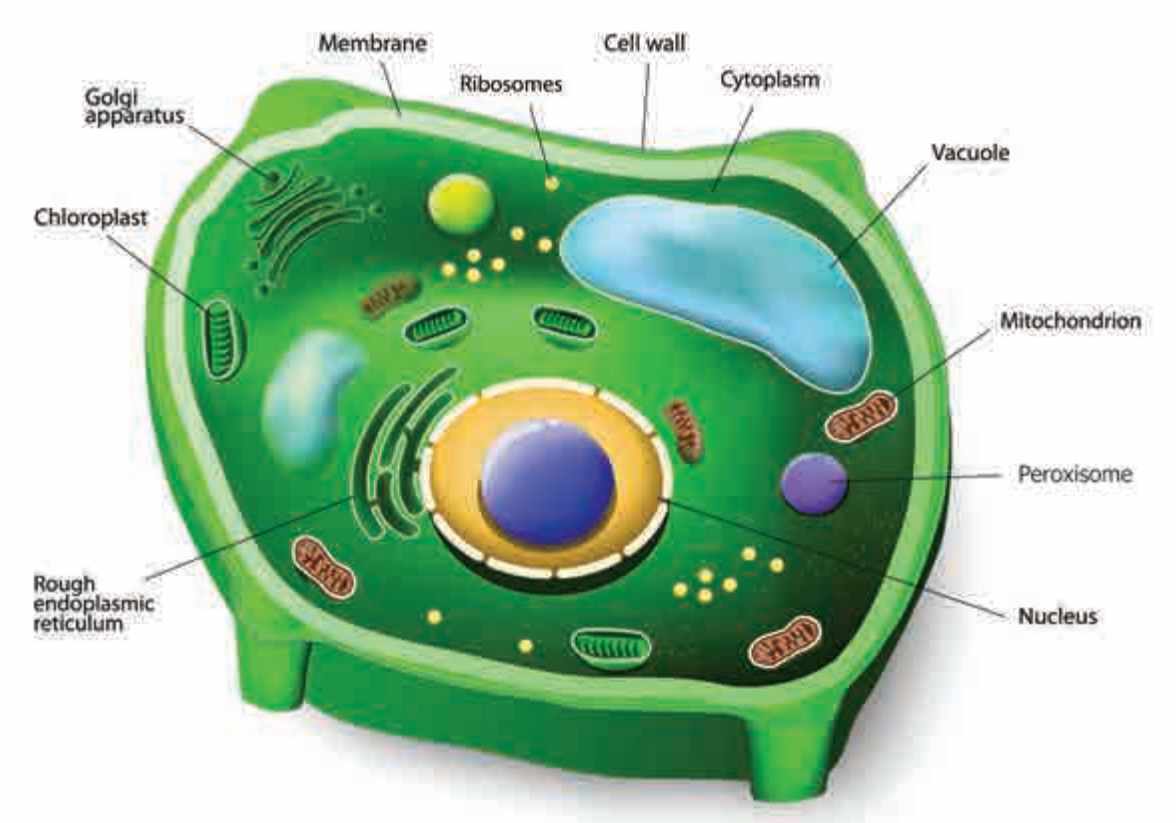


Figure 6.9: Ultra Structure of Plant Cell

Difference between plant and animal cells

S. No	Plant cell	Animal Cell
1	Usually they are larger than animal cells	Usually smaller than plant cells
2	Cell wall present in addition to plasma membrane and consists of middle lamellae, primary and secondary walls	Cell wall absent
3	Plasmodesmata present	Plasmodesmata absent
4	Chloroplast present	Chloroplast absent
5	Vacuole large and permanent	Vacuole small and temporary
6	Tonoplast present around vacuole	Tonoplast absent
7	Centrioles absent except motile cells of lower plants	Centrioles present
8	Nucleus present along the periphery of the cell	Nucleus at the centre of the cell
9	Lysosomes are rare	Lysosomes present
10	Storage material is starch grains	Storage material is a glycogen granules

6.5.2 Protoplasm

Protoplasm is the living content of the cell that is surrounded by plasma membrane. It is a colourless material that exists throughout the cell together with the cytoplasm, nucleus and other organelles. Protoplasm is composed of a mixture of small particles, such as ions, amino acids, monosaccharides, water, macromolecules like nucleic acids, proteins, lipids and polysaccharides. It appears colourless, jelly like gelatinous, viscous elastic and granular. It appears foamy due to the presence of large number of vacuoles. It responds to the stimuli like heat, electric shock, chemicals and so on.

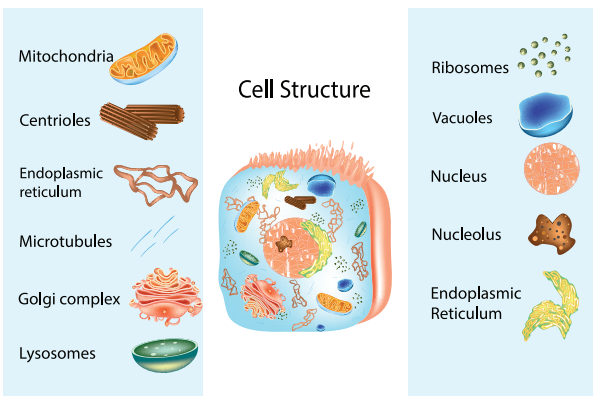


Figure 6.10: Cell structure and components

6.5.3 Cell Wall

Cell wall is the outermost protective cover of cell. It is present in bacteria, fungi and plants whereas it is absent in animal cell. It was first observed by **Robert Hooke**. It is an actively growing portion. It is made up of different complex material in various organism. In bacteria it is composed of peptidoglycan, in fungi chitin and fungal cellulose, in algae cellulose, galactans and mannans. In plants it is made up of cellulose, hemicellulose, pectin, lignin, cutin, suberin and silica.

In plant, cell wall shows three distinct regions (a) Primary wall (b) Secondary wall (c) Middle lamellae (Figure 6.11).

a. Primary wall

It is the first layer inner to middle lamellae, primarily consisting of loose network of cellulose microfibrils in a gel matrix. It is thin, elastic and extensible. In most plants the microfibrils are made up of cellulose oriented differently based on shape and thickness of the wall. The matrix of the primary wall is composed of hemicellulose, pectin, glycoprotein and water. Hemicellulose binds the microfibrils with matrix and glycoproteins control the orientation of microfibrils while pectin serves as filling material of the matrix. Cells such as parenchyma and meristems have only primary wall.

b. Secondary wall

Secondary wall is laid during maturation. It plays a key role in determining the shape of a cell. It is thick, inelastic and is made up of cellulose and lignin. The secondary wall is divided into three sublayers termed as S_1, S_2 and S_3 where the cellulose microfibrils are compactly arranged with different orientation forming a laminated structure and the cell wall strength is increased.

c. Middle lamellae

It is the outermost layer made up of calcium and magnesium pectate, deposited at the time of cytokinesis. It is a thin amorphous layer which cements two adjacent cells. It is optically inactive (isotropic).

Plasmodesmata and Pits

Plasmodesmata act as a channel between the protoplasm of adjacent cells through which many substances pass through. Moreover, at few regions the secondary wall layer is laid unevenly whereas the primary wall and middle lamellae are laid continuously such regions are called **pits**. The pits of adjacent cells are opposite to each other. Each pit has a pit chamber and a pit membrane. The pit membrane has many minute pores and thus they are permeable. The pits are of two types namely simple and bordered pit.

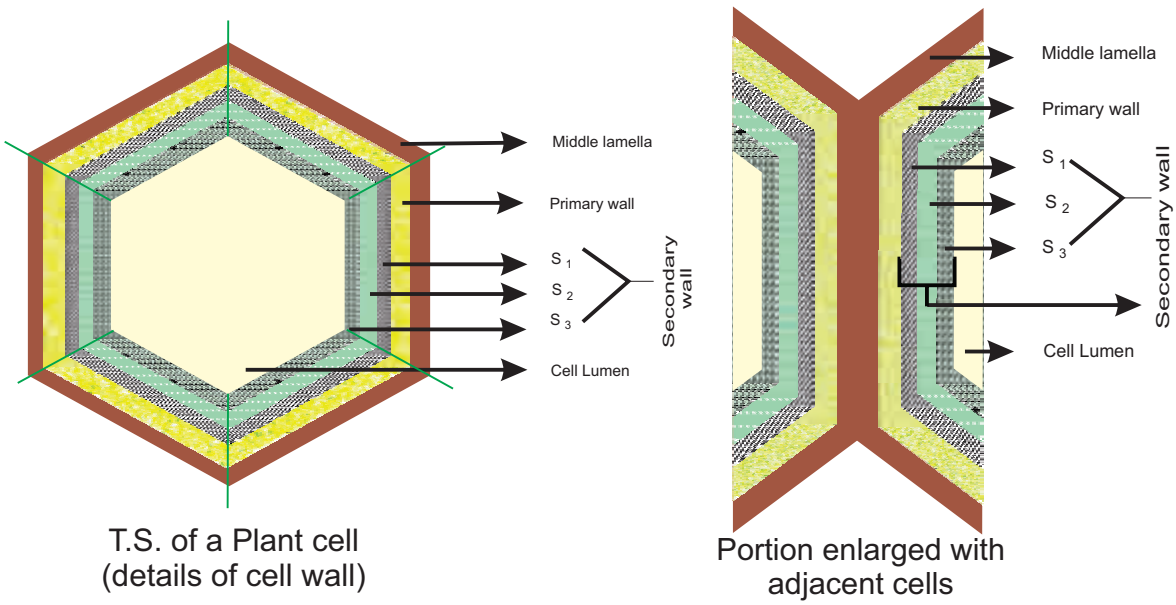


Figure 6.11: Plant cell wall

Functions of cell wall

The cell wall plays a vital role in holding several important functions given below

1. Offers definite shape and rigidity to the cell.
2. Serves as barrier for several molecules to enter the cells.
3. Provides protection to the internal protoplasm against mechanical injury.
4. Prevents the bursting of cells by maintaining the osmotic pressure.
5. Plays a major role by acting as a mechanism of defense for the cells.

6.5.4 Cell Membrane

The cell membrane is also called **cell surface** (or) **plasma membrane**. It is a thin structure which holds the cytoplasmic content called '**cytosol**'. It is extremely thin (less than 10nm).

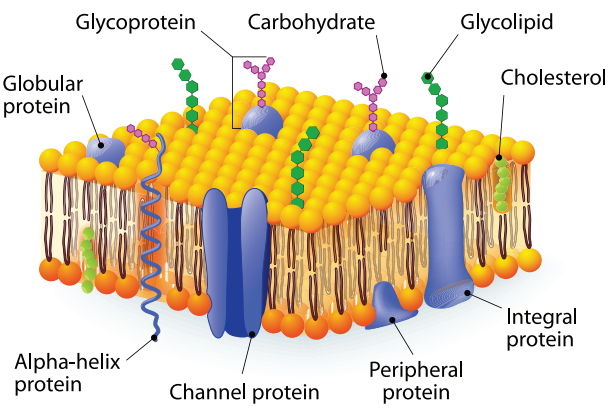


Figure 6.12: Model of Cell membrane

Fluid Mosaic Model

Jonathan Singer and **Garth Nicolson** (1972) proposed fluid mosaic model.

It is made up of lipids and proteins together with a little amount of carbohydrate. The lipid membrane is made up of phospholipid. The phospholipid molecule has a hydrophobic tail and hydrophilic head. The hydrophobic tail repels water and hydrophilic head attracts water. The proteins of the membrane are globular proteins which are found intermingled between the lipid bilayer most of which are projecting beyond the lipid bilayer. These proteins are called as **integral proteins**. Few are superficially attached on either surface of the lipid bilayer which are called as **peripheral proteins**. The proteins are involved in transport of molecules across the membranes and also act as enzymes, receptors (or) antigens.

The Carbohydrate molecules of cell membrane are short chain polysaccharides. These are either bound with '**glycoproteins**' or '**glycolipids**' and form a '**glyocalyx**' (Figure 6.12).

The movement of membrane lipids from one side of the membrane to the other side by vertical movement is called **flip flopping** or **flip flop movement**. This movement takes place more slowly than lateral diffusion of lipid molecule. The phospholipids can have flip flop movement because the phospholipids have smaller polar regions, whereas the proteins cannot flip flop because the polar region is extensive.

Water-loving polar molecule are called hydrophilic molecule. They have polar phosphate group responsible for attracting water.

Water hating non-polar molecule are called as hydrophobic molecule. They have fatty acid which is non-polar which cannot attract water

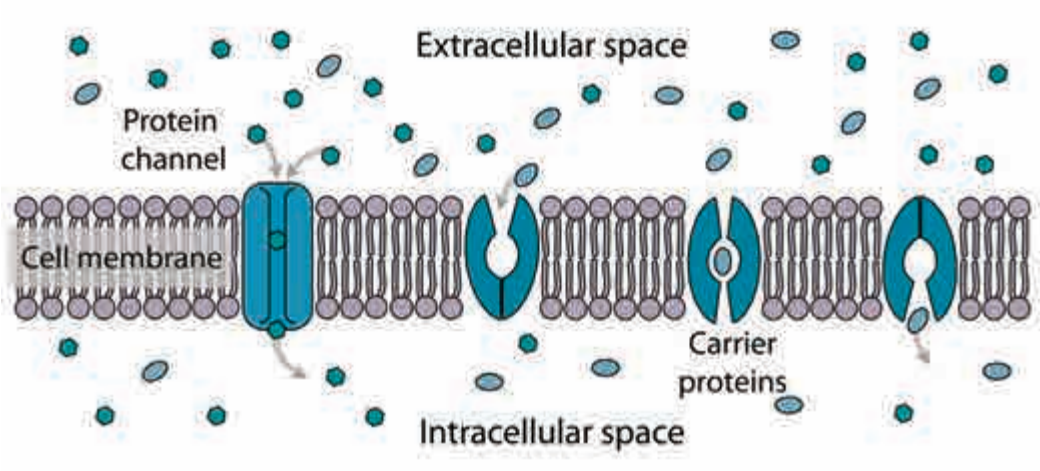


Figure 6.13: Transport of molecules through cell membrane

Function of Cell Membrane

The functions of the cell membrane is enormous which includes cell signalling, transporting nutrients and water, preventing unwanted substances entering into the cell, and so on.

Cell Transport

Cell membrane act as a channel of transport for molecules. The membrane is selectively permeable to molecules. It transports molecules through energy dependant process and energy independent process. The membrane proteins (channel and carrier) are involved in movement of ions and molecules across the membrane (Figure 6.13).

Endocytosis and Exocytosis

Cell surface membrane are able to transport individual molecules and ions. Through this special process Large quantity of solids and liquids are taken into cell (**endocytosis**) or out of cell (**exocytosis**) (Figure 6.14).

Endocytosis: During endocytosis the cell membrane infolds around the material to form a vacuole and brings it into

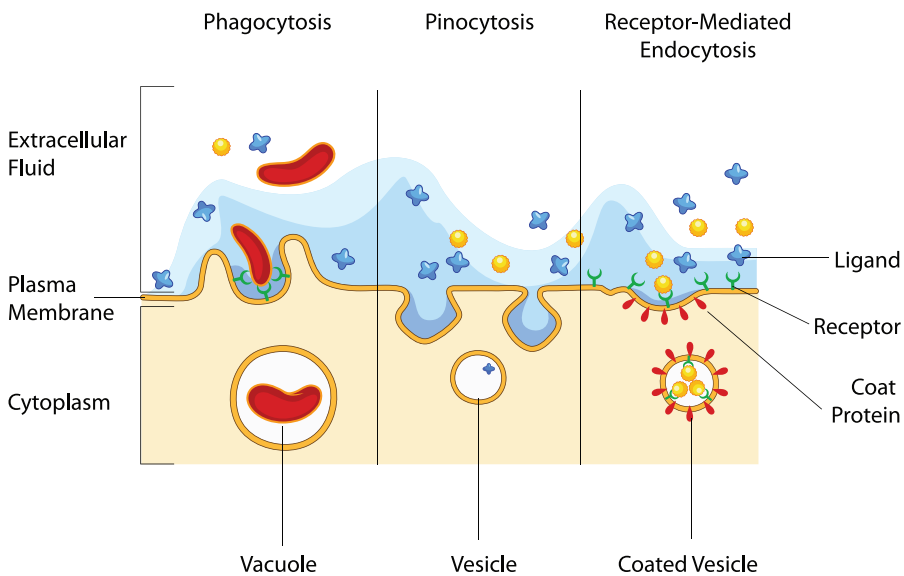


Figure 6.14: Endocytosis and exocytosis

cytoplasm. There are two types of endocytosis:

1. **Phagocytosis** – Solid Particles are engulfed by membrane, which folds around it and forms a vesicle. The enzymes digest the material and products are absorbed by cytoplasm.
2. **Pinocytosis** – Fluid droplets are engulfed by membrane, by forming vesicles around them.

Exocytosis: Vesicles fuse with plasma membrane and eject contents. This passage of material out of the cell is known as **exocytosis**. This material may be a secretion in the case of digestive enzymes, hormones or mucus.

Signal Transduction

The process by which the cell receive information from outside and respond is called **signal transduction**. Plants, fungi and animal cell use nitric oxide as one of the many signalling molecules. The cell membrane is the site of chemical interactions of signal transduction. Receptors receives the information from first messenger and transmit the message through series of membrane proteins. It activates second messenger which stimulates the cell to carry out specific function.

Cytoplasm

Cytoplasm is the main arena of various activities of a cell. It is the semifluid gelatinous substance that fills the cell. It is made up of eighty percent water and is usually clear and colourless. The cytoplasm is sometimes described as non nuclear content of protoplasm. The cytoplasm serves as a molecular soup where all the cellular organelles are suspended and bound together by a lipid bilayer plasma membrane. It constitutes dissolved nutrients, numerous salts and acids to dissolve waste products. It is a very good conductor of electricity. It gives support and protection to the cell organelles. It helps movement of the cellular materials around the cell through a process called **cytoplasmic streaming**. Further, most cellular activities such as many metabolic pathways including glycolysis and cell division occur in cytoplasm.

6.6 Cell Organelles

6.6.1 Endomembrane System

The system of membranes in a eukaryotic cell, comprising the plasma membrane, nuclear membrane, endoplasmic reticulum, golgi apparatus, lysosomes and vacuolar membranes (tonoplast). Endomembranes are made up of phospholipids with embedded proteins that are similar to cell membrane which occur within the cytoplasm. The endomembrane system is evolved from the inward growth of cell membrane in the ancestors of the first eukaryotes (Figure 6.15).

6.6.2 Endoplasmic Reticulum

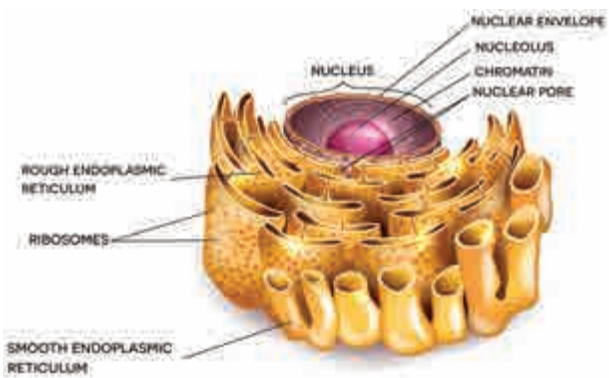


Figure 6.15: Structure of Endoplasmic reticulum

The largest of the internal membranes is called the **endoplasmic reticulum** (ER). The name endoplasmic reticulum was given by **K.R. Porter** (1948). It consists of double membrane. Morphologically the structure of endoplasmic reticulum consists of:

1. **Cisternae** are long, broad, flat, sac like structures arranged in parallel bundles or stacks to form lamella. The space between membranes of cisternae is filled with fluid.
2. **Vesicles** are oval membrane bound vacuolar structure.
3. **Tubules** are irregular shape, branched, smooth walled, enclosing a space

Endoplasmic reticulum is associated with nuclear membrane and cell surface membrane. It forms a network in cytoplasm and gives mechanical support to the cell. Its chemical environment enables protein folding and undergo modification necessary for their function. Misfolded proteins are pulled out and are degraded in endoplasmic reticulum. When ribosomes are present in the outer surface of the membrane it is called as **rough endoplasmic reticulum(RER)**, when the ribosomes are absent in the endoplasmic reticulum it is called as **smooth Endoplasmic reticulum(SER)**. Rough endoplasmic reticulum is involved in protein synthesis and smooth endoplasmic reticulum are the sites of lipid synthesis. The smooth endoplasmic reticulum contains enzymes that detoxify lipid soluble drugs, certain chemicals and other harmful compounds.

6.6.3 Golgi Body (Dictyosomes)

In 1898, **Camillo Golgi** visualized a netlike reticulum of fibrils near the nucleus, were named as **Golgi bodies.** In plant cells they are found as smaller vesicles termed as **dictyosomes**. Golgi apparatus is a stack of flat membrane enclosed sacs. It consist of cisternae, tubules, vesicles and golgi vacuoles. In plants the cisternae are 10-20 in number placed in piles separated from the cytoplasm of the cell. Peripheral edge of cisternae forms a network of tubules and vesicles. Tubules interconnect cisternae and are 30-50nm in dimension. Vesicles are large round or concave sac. They are pinched off from the tubules.They are smooth/secretary or coated type. Golgi vacuoles are large spherical filled with granular or amorphous substance, some function like lysosomes. The Golgi apparatus compartmentalises a series of steps leading to the production of functional protein.

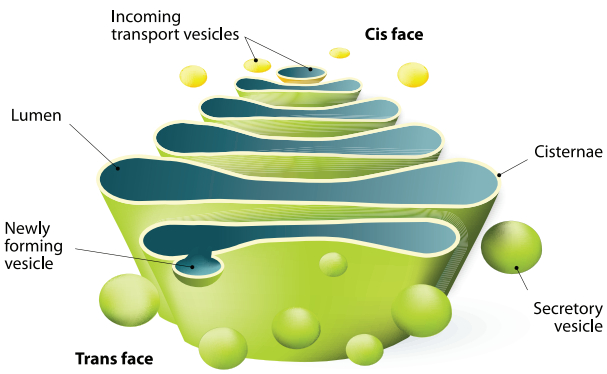


Figure 6.16: Structure of Golgi apparatus

Small pieces of rough endoplasmic reticulum are pinched off at the ends to form small vesicles. A number of these vesicles then join up and fuse together to make a Golgi body. Golgi complex plays a major role in post translational modification of proteins and glycosidation of lipids (Figure 6.16 and 6.17).

Functions:

- Glycoproteins and glycolipids are produced
- Transporting and storing lipids.

- Formation of lysosomes.
- Production of digestive enzymes.
- Cell plate and cell wall formation
- Secretion of Carbohydrates for the formation of plant cell walls and insect cuticles.
- **Zymogen granules** (proenzyme/precursor of all enzyme) are synthesised.

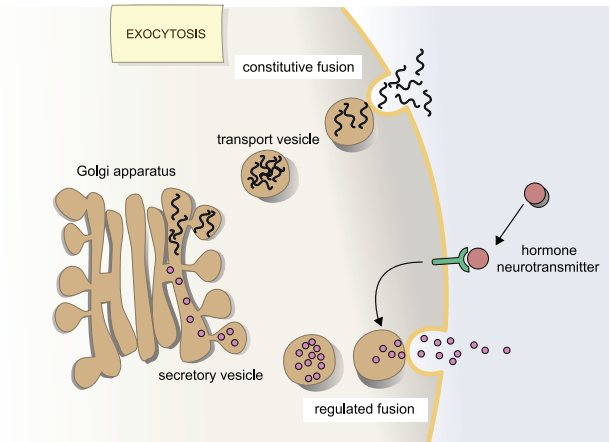


Figure 6.17: Exocytosis

6.6.4 Mitochondria

It was first observed by **A. Kolliker** (1880). **Altmann** (1894) named it as Bioplasts. **Later Benda** (1897, 1898), named as mitochondria. They are ovoid, rounded, rod shape and pleomorphic structures. Mitochondrion consists of double membrane, the outer and inner membrane. The outer membrane is smooth, highly permeable to small molecules and it contains proteins called **Porins**, which form channels that allows free diffusion of molecules smaller than about 1000 daltons and the inner membrane divides the mitochondrion into two compartments, outer chamber between two membranes and the inner chamber filled with matrix.

The inner membrane is convoluted (infoldings), called **crista** (plural: cristae). Cristae contain most of the enzymes for electron transport system. Inner chamber of the mitochondrion is filled with proteinaceous material called **mitochondrial matrix**. The inner membrane consists of stalked particles called **elementary particles** or **Fernandez Moran particles**, F1 particles or Oxysomes. Each particle consists of a base, stem and a round head. In the head ATP synthase is present for oxidative phosphorylation. Inner membrane is impermeable to most ions, small molecules and maintains the proton gradient that drives oxidative phosphorylation (Figure 6.18).

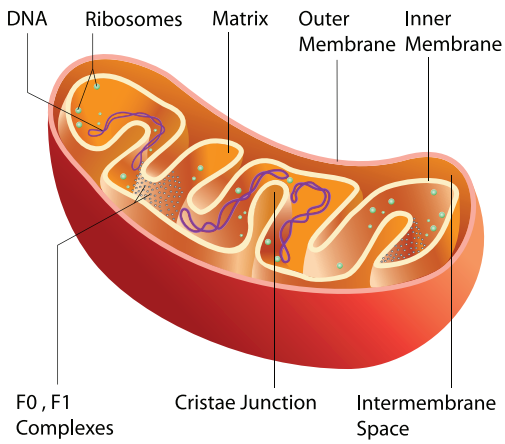


Figure 6.18: Structure of Mitochondria

Mitochondria contain 73% of proteins, 25-30% of lipids, 5-7 % of RNA, DNA (in traces) and enzymes (about 60 types). Mitochondria are called **Power house of a cell**, as they produce energy rich ATP.

All the enzymes of Kreb's cycle are found in the matrix except succinate dehydrogenase. Mitochondria consist of circular DNA and 70S ribosome. They multiply by fission and replicates by strand displacement model. Because of the presence of DNA it is semi-autonomous organelle. Unique characteristic of mitochondria is that they are inherited from female parent only. Mitochondrial DNA comparisons are used to trace human origins. Mitochondrial DNA is used to track and date recent evolutionary time because it mutates 5 to 10

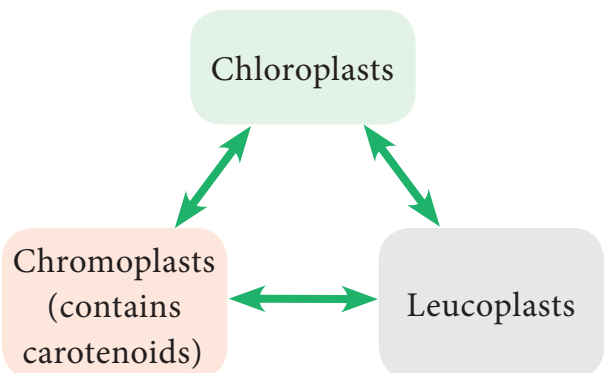
time faster than DNA in the nucleus.

6.6.5 Plastids

The term plastid is derived from the Greek word ***Platikas*** (formed/moulded) and used by **A.F.U. Schimper** in 1885. He classified plastids into following types according to their structure, pigments and function. Plastids multiply by fission.

Plastids	
Chromoplasts	**Leucoplasts**
(Coloured Plastids)	(Colourless Plastids store food materials)
Chloroplast Occurs in green algae and higher plants Pigments chlorophyll *a* and *b*	**Amyloplast** – stores – starch
Phaeoplast Brown algae and dinoflagellates Pigment fucoxanthin	**Elaioplast** – store – lipids (oils) Seed of monocot and dicots.
Rhodoplast Red algae Pigment Phycoerythrin	**Aleuroplast** (or) **Proteoplast** store – Protein

According to Schimper, different kind of plastids can transform into one another.



6.6.6 Chloroplast

Chloroplasts are vital organelle found in green plants. Chloroplast has a double membrane the outer membrane and the inner membrane separated by a space called **periplastidial space**. The space enclosed by the inner membrane of chloroplast is filled with gelatinous matrix, lipo-proteinaceous fluid called **stroma**. Inside the stroma there is flat interconnected sacs called **thylakoid**. The membrane of thylakoid enclose a space called **thylakoid lumen**.

Grana (singular: Granum) are formed when many of these thylakoids are stacked together like pile of coins. Light is absorbed and converted into chemical energy in the granum, which is used in stroma to prepare carbohydrates. Thylakoid contain chlorophyll pigments. The chloroplast contains osmophilic granules, 70s ribosomes, DNA (circular and non histone) and RNA. These chloroplast genome encodes approximately 30 proteins involved in photosynthesis including the components of photosystem I & II, cytochrome bf complex and ATP synthase. One of the subunits of Rubisco is encoded by chloroplast DNA. It is the major protein component of chloroplast stroma, single most abundant protein on earth. The thylakoid contain small, rounded photosynthetic units called **quantosomes**. It is a semi-autonomous organelle and divides by fission (Figure 6.19).

Functions:

- Photosynthesis
- Light reactions takes place in granum,
- Dark reactions take place in stroma,
- Chloroplast is involved in photo-respiration.

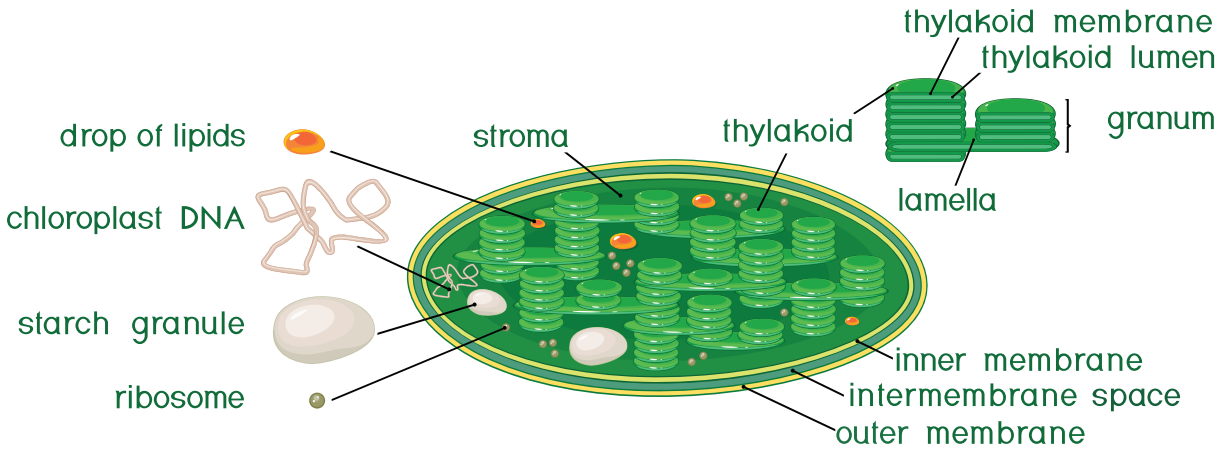


Figure 6.19: Structure of Chloroplast

6.6.7 Ribosome

Ribosomes were first observed by **George Palade** (1953) as dense particles or granules in the electron microscope. Electron microscopic observation reveals that ribosomes are composed of two rounded sub units, united together to form a complete unit. Mg^{2+} is required for structural cohesion of ribosomes. Biogenesis of ribosome are *denova* formation, auto replication and nucleolar origin. Each ribosome is made up of one small and one large sub-unit Ribosomes are the sites of protein synthesis in the cell. Ribosome is not a membrane bound organelle (Figure 6.20).

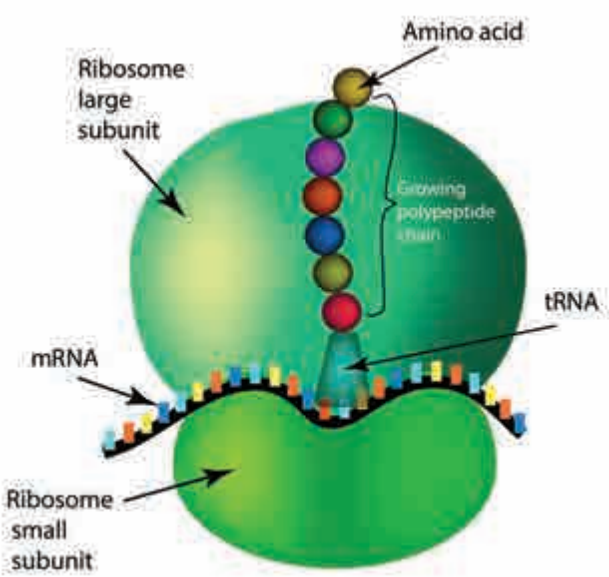


Figure 6.20: Structure of Ribosomes

Types of Ribosomes

70S Ribosomes (sub unit 30S and 50S)	80S Ribosomes (sub units 40S and 60S)
3 RNA molecule (i) 16SrRNA in 30S subunit (ii) 23S and 5S in 50S large subunit **(Prokaryotic cells of Bluegreen algae Bacteria, Mitochondria and Chloroplast of many Algae and higher plants)**	4 RNA molecule (i) 18SrRNA in 40S small subunit (ii) 28S, 5.8S and 5S in larger 60S subunit **(Eukaryotic cells of Plants and animals)**

Svedberg unit (s).

The size of ribosomes and their subunits are usually given in Svedberg unit (named after Theoder Svedberg, Swedish Chemist Noble Laureate 1929), a measure of a particle size dependent on the speed with which particle sediment in the ultracentrifuge.

Ribosome consists of RNA and protein: RNA 60 % and Protein 40%. During protein synthesis many ribosomes are attached to the single mRNA is called **polysomes** or **polyribosomes**. The function of polysomes is the formation of several copies of a particular polypeptide during protein synthesis. They are free in non-protein synthesising cells. In protein synthesising cells they are linked together with the help of Mg^{2+} ions.

6.6.8 Lysosomes (Suicidal Bags of Cell)

Lysosomes were discovered by **Christian de Duve** (1953), these are known as **suicidal bags**. They are spherical bodies enclosed by a single unit membrane. They are found in eukaryotic cell. Lysosomes are small vacuoles formed when small pieces of golgi body are pinched off from its tubules.

They contain a variety of hydrolytic enzymes, that can digest material within the cell. The membrane around lysosome prevent these enzymes from digesting the cell itself (Figure 6.21).

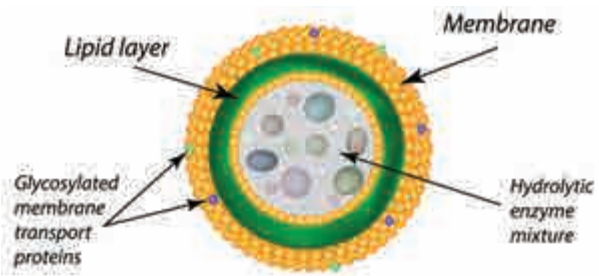


Figure 6.21: Structure of Lysosome

Functions:

- **Intracellular digestion:** They digest carbohydrates, proteins and lipids present in cytoplasm.
- **Autophagy:** During adverse condition they digest their own cell organelles like mitochondria and endoplasmic reticulum
- **Autolysis:** Lysosome causes self destruction of cell on insight of disease they destroy the cells.
- **Ageing:** Lysosomes have autolytic enzymes that disrupts intracellular molecules.
- **Phagocytosis:** Large cells or contents are engulfed and digested by macrophages, thus forming a phagosome in cytoplasm. These phagosome fuse with lysosome for further digestion.
- **Exocytosis:** Lysosomes release their enzymes outside the cell to digest other cells (Figure 6.22).

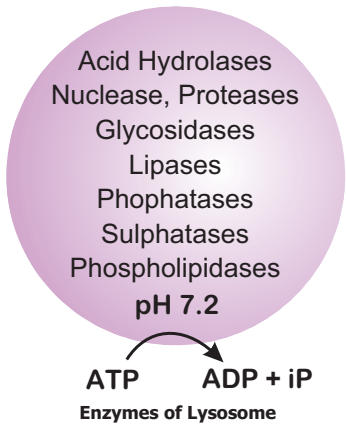


Figure 6.22: Enzymes of Lysosome

6.6.9 Peroxisomes

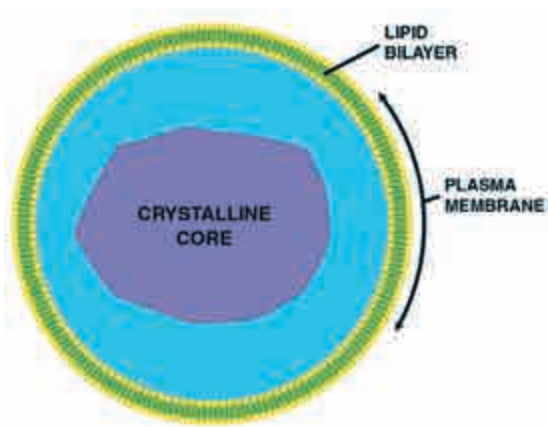


Figure 6.23: Structure of Peroxisome

Peroxisomes were identified as organelles by **Christian de Duve** (1967). Peroxisomes are small spherical bodies and single membrane bound organelle. It takes part in photorespiration and associated with glycolate metabolism. In plants, leaf cells have many peroxisomes. It is also commonly found in liver and kidney of mammals. These are also found in cells of protozoa and yeast (Figure 6.23).

6.6.10 Glyoxysomes

Glyoxysome was discovered by **Harry Beevers** (1961). Glyoxysome is a single membrane bound organelle. It is a sub cellular organelle and contains enzymes of glyoxylate pathway. β-oxidation of fatty acid occurs in glyoxysomes of germinating seeds Example: Castor seeds.

6.6.11 Microbodies

Eukaryotic cells contain many enzyme bearing membrane enclosed vesicles called **microbodies**. They are single unit membrane bound cell organelles: Example: peroxisomes and glyoxysomes.

6.6.12 Sphaerosomes

It is spherical in shape and enclosed by single unit membrane. Example: Storage of fat in the endosperm cells of oil seeds.

6.6.13 Centrioles

Centriole consist of nine triplet peripheral fibrils made up of tubulin. The central part of the centriole is called **hub**, is connected to the tubules of the peripheral triplets by radial spokes (9+0 pattern). The centriole form the basal body of cilia or flagella and spindle fibers which forms the spindle apparatus in animal cells. The membrane is absent in centriole (non-membranous organelle) (Figure 6.24).

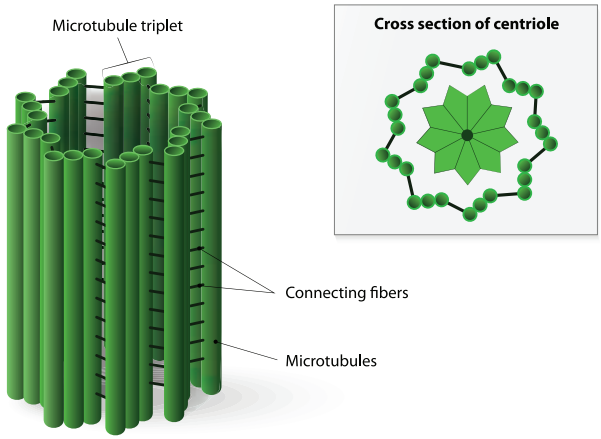


Figure 6.24: Structure of Centriole

6.6.14 Vacuoles

In plant cells vacuoles are large, bounded by a single unit membrane called **Tonoplast**. The vacuoles contain cell sap, which is a solution of sugars, amino acids, mineral salts, waste chemical and anthocyanin pigments. Beetroot cells contains anthocyanin pigments in their vacuoles. Vacuoles accumulate products like tannins. The osmotic expansion of a cell kept in water is chiefly regulated by vacuole and the water enters the vacuoles by osmosis.

The major function of plant vacuole is to maintain water pressure known as **turgor pressure**, which maintains the plant structure. Vacuoles organises itself into a storage/sequestration compartment. Example: Vacuoles store, most of the sucrose of the cell.

i. Sugar in *Sugar beet* and *Sugar cane*.
ii. Malic acid in Apple.
iii. Acids in *Citrus* fruits.
iv. Flavonoid pigment Cyanidin 3 rutinoside in the petals of *Antirrhinum*.

v. Tannins in *Mimosa pudica*.

vi. Raphide crystals in *Dieffenbachia*.

vii. Heavy metals in Mustard (*Brassica*).

viii. Latex in Rubber tree and *Dandelion stem*.

Cell Inclusions

The cell inclusions are the non-living materials present in the cytoplasm. They are organic and inorganic compounds.

Inclusions in prokaryotes

In prokaryotes, reserve materials such as phosphate granules, cyanophycean granules, glycogen granules, poly β-hydroxy butyrate granules, sulphur granules, carboxysomes and gas vacuoles are present. Inorganic inclusions in bacteria are polyphosphate granules (volutin granules) and sulphur granules. These granules are also known as **metachromatic granules.**

Inclusions in Eukaryotes

- Reserve food materials: Starch grains, glycogen granules, aleurone grains, fat droplets
- Secretions in plant cells are essential oil, resins, gums, latex and tannins
- **Inorganic crystals** – plant cell have calcium carbonate, calcium oxalate and silica
- **Cystolith** – hypodermal leaf cells of *Ficus bengalensis*, calcium carbonate
- **Sphaeraphides** – star shaped calcium oxalate, *Colocasia*
- **Raphides** – calcium oxalate, *Eichhornia*
- **Prismatic crystals** – calcium oxalate, dry scales of *Allium cepa*

6.7. Nucleus

Nucleus is an important unit of cell which control all activities of the cell. Nucleus holds the hereditary information. It is the largest among all cell organelles. It may be spherical, cuboidal, ellipsoidal or discoidal.

It is surrounded by a double membrane structure called **nuclear envelope**, which has the inner and outer membrane. The inner membrane is smooth without ribosomes and the outer membrane is rough by the presence of ribosomes and is continues with irregular and infrequent intervals with the endoplasmic reticulum. The membrane is perforated by pores known as **nuclear pores** which allows materials such as mRNA, ribosomal units, proteins and other macromolecules to pass in and out of the nucleus. The pores enclosed by circular structures called **annuli**. The pore and annuli forms the **pore complex**. The space between two membranes is called **perinuclear space**.

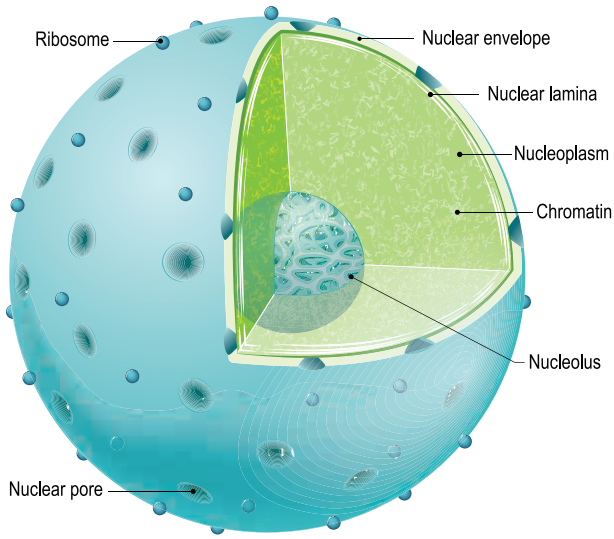


Figure 6.25: Structure of a Nucleus

Nuclear space is filled with **nucleoplasm**, a gelatinous matrix has uncondensed

chromatin network and a conspicuous **nucleoli**. The chromatin network is the uncoiled, indistinct and remain thread like during the interphase. It has little amount of RNA and DNA bound to histone proteins in eukaryotic cells (Figure 6.25).

Chromatin is a viscous gelatinous substance that contains DNA, histone & non–histone proteins and RNA. H1, H2A, H2B, H3 and H4 are the different histones found in chromatin. It is formed by a series of repeated units called nucleosomes. Each nucleosome has a core of eight histone subunits.

During cell division chromatin is condensed into an organized form called **chromosome**. The portion of Eukaryotic chromosome which is transcribed into mRNA contains active genes that are not tightly condensed during interphase is called **Euchromatin**. The portion of a Eukaryotic chromosome that is not transcribed into mRNA which remains condensed during interphase and stains intensely is called **Heterochromatin.** I **Nucleolus** is a small, dense, spherical structure either present singly or in multiples inside nucleus and it's not membrane bound. Nucleoli possesses genes for rRNA and tRNA.

Functions of the nucleus

- Controlling all the cellular activities
- Storing the genetic or hereditary information.
- Coding the information in the DNA for the production of enzymes and proteins.
- DNA duplication and transcription takes place in the nucleus.
- In nucleolus ribosomal biogenesis takes place.

6.7.1 Chromosomes

Strasburger (1875) first reported its present in eukaryotic cell and the term 'chromosome' was introduced by **Waldeyer** in 1888. **Bridges** (1916) first proved that chromosomes are the physical carriers of genes. It is made up of DNA and associated proteins.

Structure of chromosome

The chromosomes are composed of thread like strands called **chromatin** which is made up of DNA, protein and RNA. Each chromosome consists of two symmetrical structures called **chromatids**. During cell division the chromatids forms well organized chromosomes with definite size and shape. They are identical and are called **sister chromatids**. A typical chromosome has narrow zones called **constrictions**. There are two types of constrictions namely primary constriction and secondary constriction. The **primary constriction** is made up of **centromere** and kinetochore. Both the chromatids are united at centromere, whose number varies. The **monocentric** chromosome has one centromere and the **polycentric** chromosome has many centromeres. The centromere contains a complex system of protein fibres called **kinetochore**. Kinetochore is the region of chromosome which is attached to the spindle fibre during mitosis.

Besides primary there are **secondary constrictions,** represented with few occurrence. Nucleoli develop from these

secondary constrictions are called **nucleolar organizers**. Secondary constrictions contains the genes for ribosomal RNA which induce the formation of nucleoli and are called **nucleolar organizer regions** (Figure 6.26).

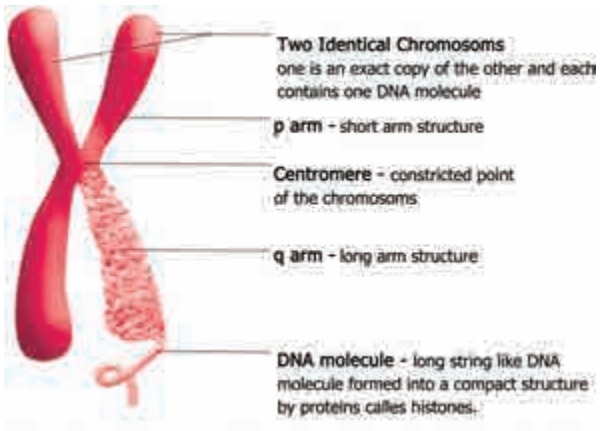


Figure 6.26: Structure of a Chromosome

A **satellite** or SAT Chromosome are short chromosomal segment or rounded body separated from main chromosome by a relatively elongated secondary constriction. It is a morphological entity in certain chromosomes.

Based on the position of centromere, chromosomes are called **telocentric** (terminal centromere), **Acrocentric** (terminal centromere capped by telomere), **Sub metacentric** (centromere subterminal) and **Metacentric** (centromere median). The eukaryotic chromosomes may be rod shaped (telocentric and acrocentric), L-shaped (sub-metacentric) and V-shaped (metacentric) (Figure 6.27).

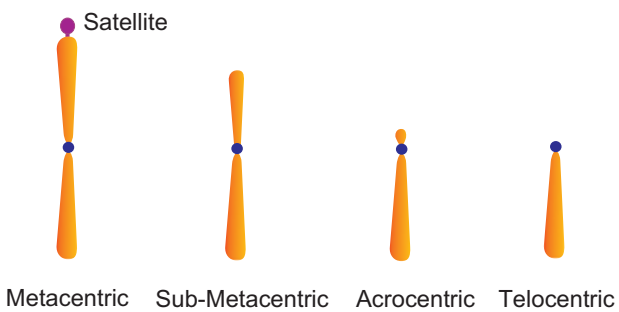


Figure 6.27: Types of chromosomes based on centromere

Chromonema fiber: It is a chromatin fibre, 100 – 130 nm in diameter thought to be an element of higher order packing of chromatin within chromosome. During prophase the chromosomal material becomes visible as very thin filaments called chromonemata, which is called as chromatids in early stages of condensation. Chromatid and chromonema are the two names for the same structure a single linear DNA molecule with its associated proteins

Chromomeres: Chromomeres are bead like accumulations of chromatin material which are visible along interphase chromosomes. They can be seen in polytene chromosomes. At metaphase they are not visible.

Telomere is the terminal part of chromosome. It offers stability to the chromosome. DNA of the telomere has specific sequence of nucleotides. Telomere in all eukaryotes are composed of many repeats of short DNA sequences (**5'TTAGGG3'** sequence in *Neurospora crassa* and human beings). Maintenance of telomeres appears to be an important factor in determining the life span and reproductive capacity of cells so studies of telomeres and telomerase have the promise of providing new insights into conditions such as ageing and cancer. Telomeres prevents the fusion of chromosomal ends with one another.

Holocentric chromosomes have centromere activity distributed along the whole surface of the chromosome during mitosis. Holocentric condition can be seen in *Caenorhabditis elegans* (nematode) and many insects. There are three types of centromere in eukaryotes. They are as follows:

Point centromere: the type of centromere in which the kinetochore is assembled as a result of protein recognition of specific DNA sequences. Kinetochores assembled on point centromere bind a single microtubule. It is also called as **localized centromere**. It occurs in budding yeasts

Regional centromere: In regional centromere where the kinetochore is assembled on a variable array of repeated DNA sequences. Kinetochore assembled on regional centromeres bind multiple microtubules. It occurs in fission yeast cell, humans and so on.

Holocentromere- The microtubules bind all along the mitotic chromosome. Example: *Caenorhabditis elegans* (nematode) and many insects.

Based on the functions of chromosome it can be divided into **autosomes** and **sex chromosomes**.

Autosomes are present in all cells controlling somatic characteristics of an organism. In human diploid cell, 44 chromosomes are autosomes whereas two are sex chromosomes. Sex chromosomes are involved in the determination of sex.

Special types of chromosomes are found only in certain special tissues. These chromosomes are larger in size and are called **giant chromosomes** in certain plants and they are found in the suspensors of the embryo. The polytene chromosome and lamp brush chromosome occur in animals and are also called as **giant chromosomes.**

Polytene chromosomes observed in the salivary glands of Drosophila (fruit fly) by **C.G. Balbiani** in 1881. In larvae of many flies, midges (*Dipthera*) and some insects the interphase chromosomes duplicates and reduplicates without nuclear division. A single chromosome which is present in multiple copies form a structure called **polytene chromosome** which can be seen in light microscope. They are genetically active. There is a distinct alternating dark bands and light inter-bands. About 95% of DNA are present in bands and 5% in inter-bands. The polytene chromosome has extremely large puff called **Balbiani rings** which is seen in Chironomous larvae. It is also known as **chromosomal puff**. Puffing of bands are the sites of intense RNA synthesis. As this chromosome occurs in the salivary gland it is known as **salivary gland chromosomes**. Polyteny is achieved by repeated replication of chromosomal DNA several times without nuclear division and the daughter chromatids aligned side by side and do not separate (called **endomitosis**). Gene expression, transcription of genes and RNA synthesis occurs in the bands along the polytene chromosomes. Maternal and paternal homologues remain associated side by side is called somatic pairing.

Lampbrush chromosomes occur at the diplotene stage of first meiotic prophase in oocytes of an animal **Salamandar** and in giant nucleus of the unicellular alga *Acetabularia*. It was first observed by **Flemming** in 1882. The highly condensed

chromosome forms the chromosomal axis, from which lateral loops of DNA extend as a result of intense RNA synthesis.

6.8. Flagella

6.8.1 Prokaryotic Flagellum

Check your grasp ?

When E-coli are cultured in medium rich in glucose they lack flagella. When grown in nutritionally poor medium they possess flagella. What does this indicate about the value of flagella?

Flagella is essential to seek out a nutritionally more favourable environment

Bacterial flagella are helical appendages helps in motility. They are much thinner than flagella or cilia of eukaryotes. The filament contains a protein called **flagellin**. The structure consists of a basal body associated with cytoplasmic membrane and cell wall with short hook and helical filament. Bacteria rotates their helical flagella and propels rings present in the basal body which are involved in the rotary motor that spins the flagellum.

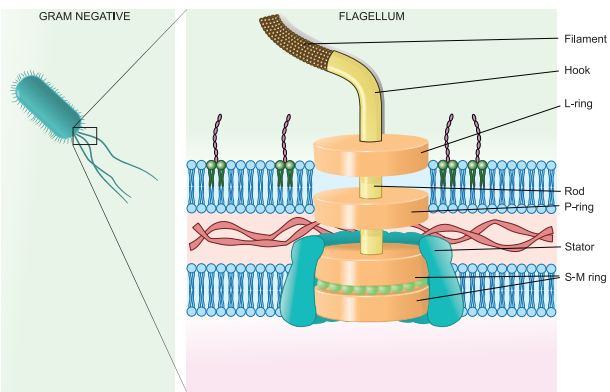


Figure 6.28: Structure of Bacterial Flagellum

Structure of flagella in Bacteria

The gram positive bacteria contain only two basal rings. S-ring is attached to the inside of peptidoglycan and M-ring is attached to the cell membrane. In Gram negative bacteria two pairs of rings proximal and distal ring are connected by a central rod. They are L-Lipopolysaccharide ring P-Peptidoglycan ring, S-Super membrane ring and M-membrane ring. The outer pair L and P rings is attached to cell wall and the inner pair S and M rings attached to cell membrane (Figure 6.28).

Mechanism of flagellar movement – proton motive force

In flagellar rotation only proton movements are involved and not ATP. Protons flowing back into the cell through the basal body rings of each flagellum drives it to rotate. These rings constitute the rotary motor. The proton motive force (The force derived from the electrical potential and the hydrogen ion gradient across the cytoplasmic membrane) drives the flagellar motor. For the rotation of flagellum the energy is derived from proton gradient across the plasma membrane generated by oxidative phosphorylation. In bacteria flagellar motor is located in the plasma membrane where the oxidative phosphorylation takes place. Therefore, plasma membrane is a site of generation of proton motive force.

6.8.2 Eukaryotic Flagellum– Cell Motility

Structure

Eukaryotic Flagella are enclosed by unit membrane and it arises from a basal body.

Flagella is composed of outer nine pairs of microtubules with two microtubules in its centre (9+2 arrangement). Flagella are microtubule projection of the plasma membrane. Flagellum is longer than cilium (as long as 200µm). The structure of flagellum has an axoneme made up microtubules and protein tubulin (Figure 6.29).

Movement

Outer microtubule doublet is associated with axonemal dynein which generates force for movement. The movement is ATP driven. The interaction between tubulin and dynein is the mechanism for the contraction of cilia and flagella. Dynein molecules uses energy from ATP to shift the adjacent microtubules. This movement bends the cilium or flagellum.

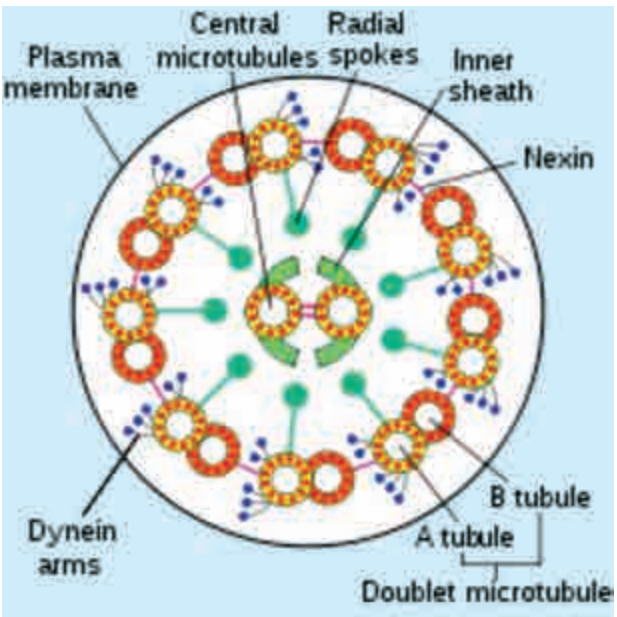


Figure 6.29: Structure of Eukaryotic flagellum

6.8.3 Cilia

Cilia (plural) are short cellular, numerous microtubule bound projections of plasma membrane. Cilium (singular) is membrane bound structure made up of basal body, rootlets, basal plate and shaft. The shaft or **axoneme** consists of nine pairs of microtubule doublets, arranged in a circle along the periphery with a two central tubules, (**9+2**) arrangement of microtubules is present. Microtubules are made up of tubulin. The motor protein **dynein** connects the outer microtubule pair and links them to the central pair. Nexin links the peripheral doublets of microtubules (Figure 6.30).

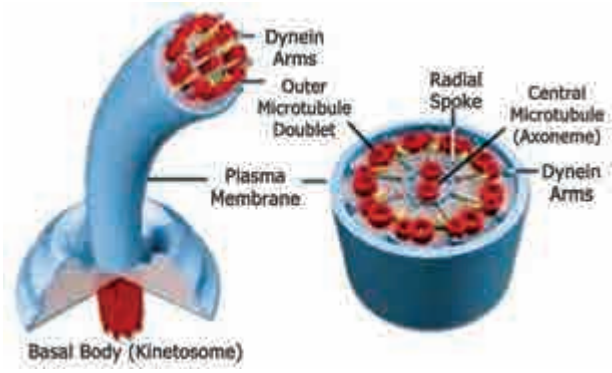


Figure 6.30: Structure of Cilia & flagella

6.9. Cytological Techniques

6.9.1 Preparation of Slides

There are different types of mounting based on the portion of a specimen to be observed

a. **Whole mount:** The whole organism or smaller structure is mounted over a slide and observed.

b. **Squash**: Is a preparation where the material to be observed is crushed/ squashed on to a slide so as to reveal their contents. Example: Pollen grains, mitosis and meiosis in root tips and flower buds to observe chromosomes.

c. **Smears:** Here the specimen is in the fluid (blood, microbial cultures etc.,) are scraped, brushed or aspirated from surface of organ. Example: Epithelial cells.

d. **Sections:** Free hand sections from a specimen and thin sections are selected, stained and mounted on a slide. Example: Leaf and stem of plants.

6.9.2 Recording the Observations

The observations made through a microscope can be recorded by hand diagrams or through microphotographs.

Hand diagrams: Hand diagrams are drawn using ordinary pencil by observing the slide and drawing manually.

Microphotograph: Images of structures observed through microscopes can be further magnified, projected and saved by attaching a camera to the microscope by a microscope coupler or eyepiece adaptor. Picture taken using a inbuilt camera in a microscope is called **microphotography** or **microphotograph**.

6.9.3 Staining Techniques

Staining is very important to observe different components of the cell. Each component of the cell has different affinity towards different stains. The technique of staining the cells and tissue is called '**histochemical staining'** or '**histochemistry**'.

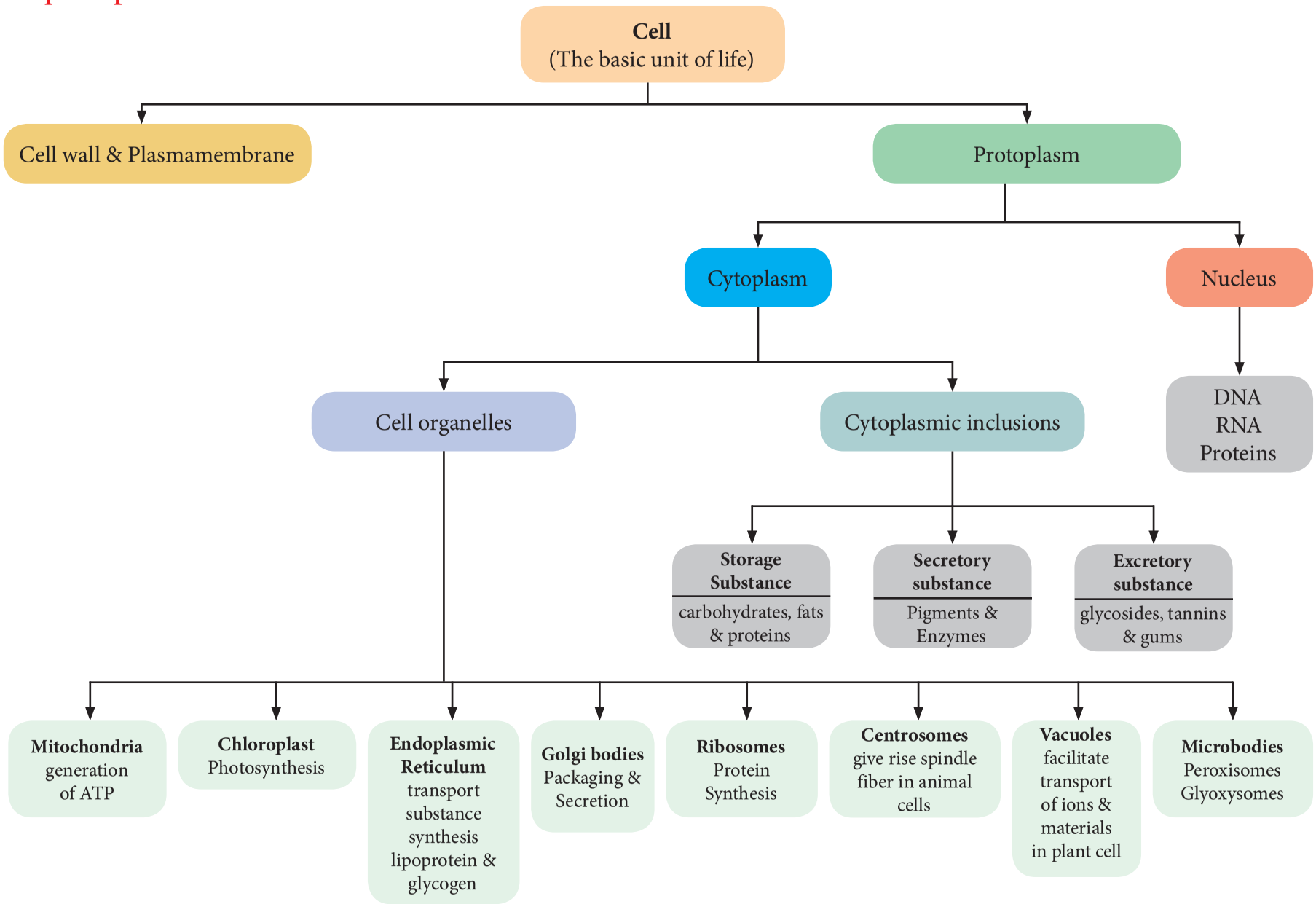
Common stains used in Histochemistry

S. No.	Stain	Colour of staining	Affinity
1.	Eosin	Pink, Red	Cytoplasm, cellulose
2.	Acetocarmine/ Haematoxylin	Pink/ Red	Nucleus, Chromosomes
3.	Methylene Blue	Blue	Nucleus
4.	Saffranine	Red	Cell wall (Lignin)
5.	Cotton blue	Blue	Fungal Hyphae
6.	Sudan IV, Sudan Black	Scarlet Red/Black	Lipids
7.	Coomasie brilliant Blue	Blue	Protein
8.	Janus Green	Greenish Blue	Mitochondria
9.	I_2KI	Bluish black to brown	Starch
10.	Toluidine blue	Blue, greenish blue	Xylem, Parenchyma & Epidermis

Summary

Cell is the fundamental unit of all organisms which was identified 300 years ago. Microscope offers scope for observing smaller objects and organisms. It works on the principle of light and lenses. Different microscope offers clarity in observing objects depending on the features to be observed. Micrometric techniques are used in measurement of microscopic objects. Electron microscopes are used in understanding the ultra-structural details of cell. Cell theory and doctrine states that all organism are made up of cell and it contains genetic material. Protoplasm theory explains nature and different properties of protoplasm. Cell size and shape differ from type of tissue or organs and organisms. Based on cellular organization and nuclear characters the

Concept Map


Cell
(The basic unit of life)
Cell wall & Plasmamembrane
Protoplasm
Cytoplasm
Nucleus
Cell organelles
Cytoplasmic inclusions
DNA
RNA
Proteins
Storage Substance
carbohydrates, fats & proteins
Secretory substance
Pigments & Enzymes
Excretory substance
glycosides, tannins & gums
Mitochondria
generation of ATP
Chloroplast
Photosynthesis
Endoplasmic Reticulum
transport substance synthesis lipoprotein & glycogen
Golgi bodies
Packaging & Secretion
Ribosomes
Protein Synthesis
Centrosomes
give rise spindle fiber in animal cells
Vacuoles
facilitate transport of ions & materials in plant cell
Microbodies
Peroxisomes
Glyoxysomes

organisms are classified into prokaryote, eukaryote and mesokaryote.

The eukaryotic cells originated by endosymbiosis of prokaryotic organism. Key difference between plant cell and animal cell is the cell wall. Protoplasm is the colourless mass includes the cytoplasm, cell organelles and nucleus. Cell wall is the outermost protective covering with three regions primary, secondary wall and middle lamellae. Cell membrane holds the cytoplasmic content called **cytosol**. Cytoplasm includes the matrix and the cell organelles excluding nucleus. Endomembrane system includes endoplasmic reticulum, golgi apparatus, chloroplast, lysosomes, vacuoles, nuclear membrane and plasma membrane. Nucleus is the control unit of the cell, it carries hereditary information. Chromosomes are made up of DNA and associated proteins. Bacterial flagella are made up of helical polymers of a protein called **flagellin**. Proton motive force are involved in flagellar rotation. In Eukaryotes flagella are made up microtubules and protein called **dynein** and **nexin** and the movement is driven by ATP. Cytological techniques include preparation of slides, staining and recording the observation.

5RKECJ

Evaluation

1. The two subunits of ribosomes remain united at critical ion level of
   a. Magnesium b. Calcium
   c. Sodium d. Ferrous
2. Sequences of which of the following is used to know the phylogeny
   a. mRNA b. rRNA
   c. tRNA d. Hn RNA
3. Many cells function properly and divide mitotically even though they do not have
   a. Plasma membrane b. cytoskeleton
   c. mitochondria d. Plastids
4. Keeping in view the fluid mosaic model for the structure of cell membrane, which one of the following statements is correct with respect to the movement of lipids and proteins from one lipid monolayer to the other
   a. Neither lipid nor proteins can flip-flop
   b. Both lipid and proteins can flip flop
   c. While lipids can rarely flip-flop proteins cannot
   d. While proteins can flip-flop lipids cannot
5. Match the columns and identify the correct option:

Column-I	Column-II
(a) Thylakoids	(i) Disc-shaped sacs in Golgi apparatus
(b) Cristae	(ii) Condensed structure of DNA
(c) Cisternae	(iii) Flat membranous sacs in stroma
(d) Chromatin	(iv) Infoldings in mitochondria

	(a)	(b)	(c)	(d)
(1)	(iii)	(iv)	(ii)	(i)
(2)	(iv)	(iii)	(i)	(ii)
(3)	(iii)	(iv)	(i)	(ii)
(4)	(iii)	(i)	(iv)	(ii)

6. Bring out the significance of phase contrast microscopy
7. State the protoplasm theory
8. Distinguish between prokaryotes and eukaryotes
9. Difference between plant and animal cell
10. Draw the ultra structure of plant cell

Cell structure

Cell-The unit of Life →

Steps

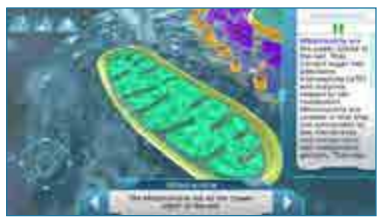
- Scan the QR code & install the app from Android app store
- Open the app & move the cell organelles by moving left bottom button
- Select the cell organelles by pointer
- Play the audio notes of cell organelles by click the right center button
- Use pointer & observe the structure of cell organelles

Activity

- Observe the structures of cell organelles and record it.

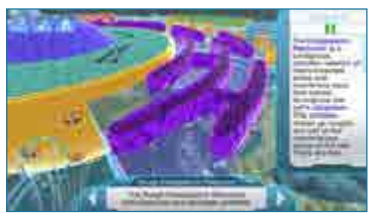
Step 1

Step 2



Step 4

Step 3



Step 5

URL:

https://play.google.com/store/apps/details?id=com.VIEW.CellWorld&hl=en

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* Pictures are indicative only