লাল-সবুজে দাগানো

TEXT BOOK

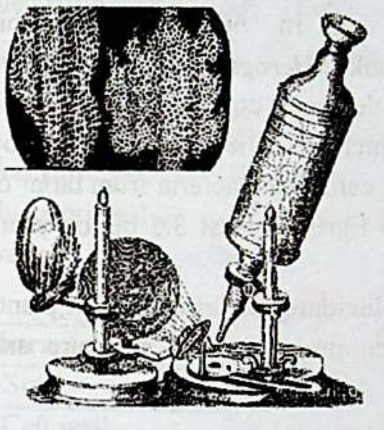
Botany

UNMESH

Medical & Dental Admission Care

1

Chapter One
Cell: Structure and Functions



Life is both wonderful and majestic. Yet for all of its majesty, all organisms are composed of the fundamental unit of life, the cell. From the unicellular bacteria to muiticellular animals, the cell is one of the basic organizational principles of biology. Secretes of complexity of the life remain concealed in these small structures. Until now, scientists have not been able to reveal all functional mysteries of cell. In this chapter, a discussion has made about the structure and function of the cells.

Key words: Cell, eukaryotic, prokaryotic, mitochondria, chromosome, DNA, RNA, replication, transcription, translation, gene, genetic code.

Period 25: After reading this chapter student should be able to (Learning output)-
☐ Describe the position, physical and chemical structure and functions of cell wall and plasma membrane.
☐ Describe the chemical nature and metabolic roles of cytoplasm.
☐ Describe the position, structure and functions of ribosome, lysosome, Golgi bodies and centriole.
☐ Differentiate between smooth and rough endoplasmic reticulum based on structure and functions.
☐ Explain the functional interrelationship of external and internal structure of the mitochondria.
☐ Explain the functional interrelaticnship of external and internal structure of the chloroplasts.
☐ Describe the structure and functions of nucleus.
☐ Compare the chemical structure of nucleoplasm and cytoplasm.
☐ Draw and label the diagram of different organelles of cell.
☐ Understand the roles of cells in different activities of organism.
☐ Describe the physical structure and chemical components of chromosome.
☐ Describe the roles of chromosome in cell division.
☐ Explain the structure and function of DNA and RNA.
☐ Explain the types of RNA.
☐ Illustrate the replication mechanism.
☐ Illustrate the transcription mechanism.
☐ Illustrate the translation mechanism.
☐ Describe the gene and genetic codes.
☐ Comprehend the role of DNA as genetic materials.

Introduction

Most of the organism's body consists of many complex and small units. Scientists have recognized these small units as cell, which are often called the "**building blocks of life** ". The word cell comes from the Latin *cellula*, meaning 'small room' in which a prisoner is locked up or in which a monk or nun sleeps. British engineer **Robert Hooke** discovered the cells in 1665 and coined this descriptive term for the smallest living biological structure in the book '***Micrographia***' he published in 1665. While examining a thin slice of bottle cork under a self-designed compound microscope Robert Hooke noticed honeycomb like compartments or units, which he called cells. **Anton von Leeuwenhoek**, a Dutch microscopist, in 1674, first observed living cells like bacteria from tartar of teeth, protozoans, erythrocytes, sperm cells etc. Cells emerged on Earth at least 3.5 billion years ago.

In 1839, **Theodor Schwann** and **Matthias Jakob Schleiden** elucidate the principle that plants and animals are made of cells, concluding that cells are a common unit of structure and development, and thus founding the *cell theory*.

Definition of cell

Several scientists have defined cell in different ways.

1. **Jean Brachet** (1961) has defined cell as **'the structural fundamental unit of organism'**.

2. According to **Loewy and Siekevitz** (1963) 'Cell is a unit of biological activities delimited by a semipermeable membrane and capable of self reproduction in a medium free of other living system'.

3. **De Roberties** (1979) defined cell as the **structural and functional unit of organism**.

4. According to **Merriam-Webster** dictionary " Cell is a small usually microscopic mass of protoplasm bounded externally by a semi permeable membrane, usually including one or more nuclei and various other organelles with their products, capable alone or interacting with other cells of performing all the fundamental functions of life, and forming the smallest structural unit of living matter capable of functioning independently".

Characteristics of Cell

All the living cells have following characteristics:-

1. Presence of a membrane around the cell, which restricts entry to only certain molecules, besides allowing free passage to water and to some of the gases such as oxygen and carbon dioxide.

2. The cell has its own energy generating system. The energy, which is produced by the cell, is conserved in the form of ATP and is utilized for various life functions.

3. A cell has its own genetic information, which it has received from its parent cell.

4. The cell has its own machinery by which it can copy, and translate the genetic information, which is present in it in the form of polymer of nitrogen bases.

5. The cell is able to produce its own kind *i.e.* the cell is capable of forming new daughter cells.

6. Cells constantly sense changes in their surroundings and make controlled response to those changes.

7. Cells can maintain the homeostatic condition.

Types of Cell

➢ On the basis of nuclear organization, **Dougherty** (1957) classified cells into the two types *i.e.* Prokaryotic cell and Eukaryotic cell.

(a) Prokaryotic cells (Gr-*pro*=primitive and *karyon*=nucleus)**:** The cells having no nucleus are called **prokaryotic cells**. These cells are comparatively small, >5 micrometer. They have no cellular organelles except the ribosomes of 70S type. Bacteria, Cyanobacteria etc. are examples of prokaryotic cells.

(b) Eukaryotic cell (Gr-*eu*=true and *karyon*=nucleus)**:** The cells having true nucleus are called **eukaryotic cells**. These cells are comparatively large, <5 micrometer. They usually have all the cellular organelles. The ribosomes of these cells are of 80S type. Except prokaryotic cells, all other lower and higher organism's cells are of eukaryotic type.

Differences between Prokaryotic and Eukaryotic cells

Characters	**Prokaryotes**	**Eukaryotes**
1. Size	The size is 0.1 – 5.0 μm.	The size is 5 – 100 μm.
2. Cell wall	If present, contains mucopeptide or peptidoglycan.	If present, contains cellulose, peptidoglycan is absent.
3. Nucleus	No real nucleus.	Real nucleus with double membrane.
4. DNA	DNA is generally circular and without histone protein.	DNA is commonly linear and with histone protein.
5. Ribosome	Ribosome is of 70S type.	Ribosome is of 80S type
6. Mitochondria	None	One to several thousand.
7. Plasmids	Plasmid may occur.	Plasmids are rare.
8. Mesosome	Cell membrane may have infolding called mesosome.	Mesosome absent.
9. Cell organelles	No cell organelles, except ribosome	Al types of cell organelles are present.
10. Pili and fimbrae	They may have pili and fimbrae.	Pili and fimbrae are absent.
11. Transcription	Transcription occurs in the cytoplasm.	Transcription occurs inside the nucleus.
12. Respiration	Anaerobic.	Aerobic.
13.Cell division	Binary fission	Mitosis and Meiosis
14. Organisms	Bacteria, Cyanobacteria.	Protists, fungi, plants, all animals.

➢ Based on position and function cells are of two types:

(a) Somatic cell: A somatic cell is a cell that makes the body tissues of multicellular organisms and does not have the ability to transfer genetic information to offspring. Somatic cells are diploid (2n), meaning that they contain two sets of chromosomes, one inherited from each parent. Epithelial cell, muscular cell, nerve cell, collenchymas cell, cell of xylem etc are the somatic cells.

(b) Germ cell: A germ cell is the sex cell that is used by sexually reproducing organisms to pass on genes from generation to generation. Germ cells are haploid (n), meaning that they contain single set of chromosomes. Eggs and sperm cells are the germ cells.

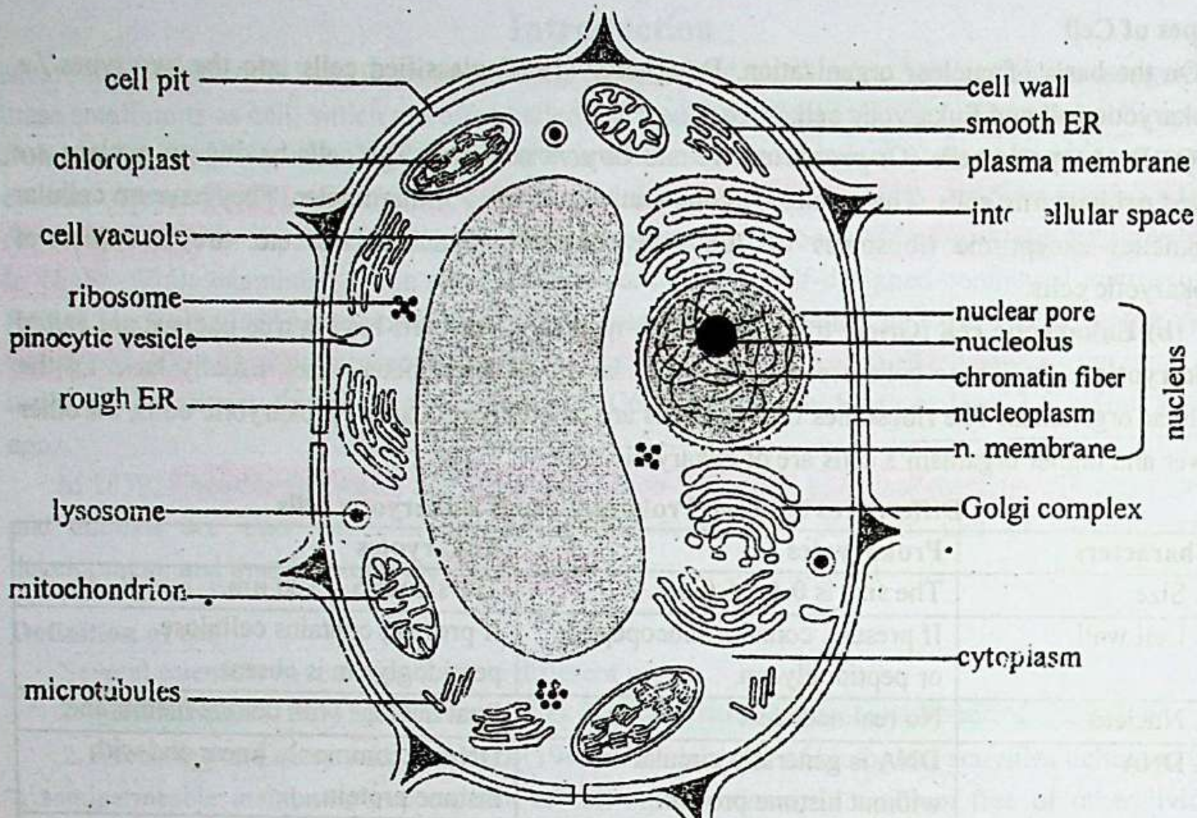


Fig1.1 Electron microscopic view of a plant cell

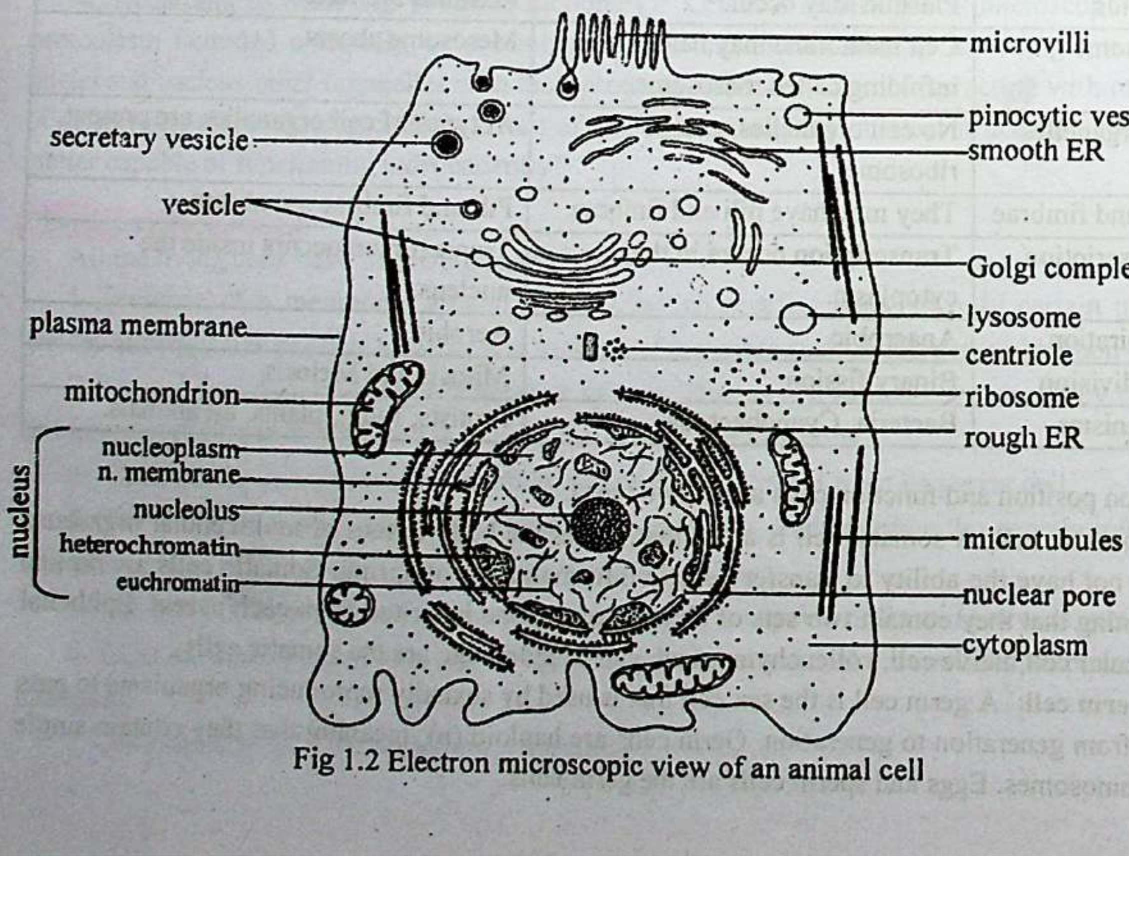


Fig 1.2 Electron microscopic view of an animal cell

Differences between Somatic cell and Germ cell

Somatic cell	Germ cell
1. A somatic cell or vegetal cell is any biological cell forming the body of an organism.	1. Germ cells are cells that give rise to gametes, *i.e.*, eggs and sperms.
2. A somatic cell has a diploid (2n) number of chromosomes.	2. A germ cell has a haploid (n) number of chromosomes.
3. Somatic cells cannot transfer their generic information to next generations.	3. Germ cells can transfer their genetic information to next generations.
4. Somatic cells are produced through the process of mitosis and cytokinesis.	4. The process of germ cells is produced through meiosis.
5. Mutations that occur in somatic cells affect only the individual and will not be passed on to the next generations.	5. Mutations that occur in germ cells can be passed to the offspring.
6. Somatic cells can be differentiated into various types of cells in the body.	6. Germ cells cannot be differentiated.

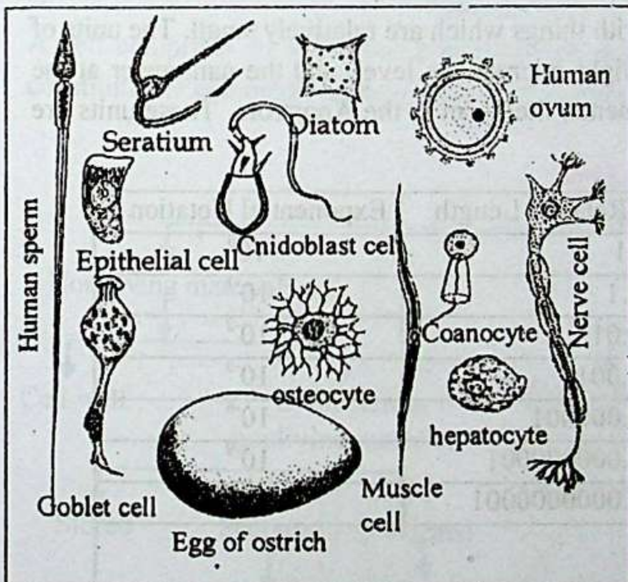


Fig 1.3 Different animal cells

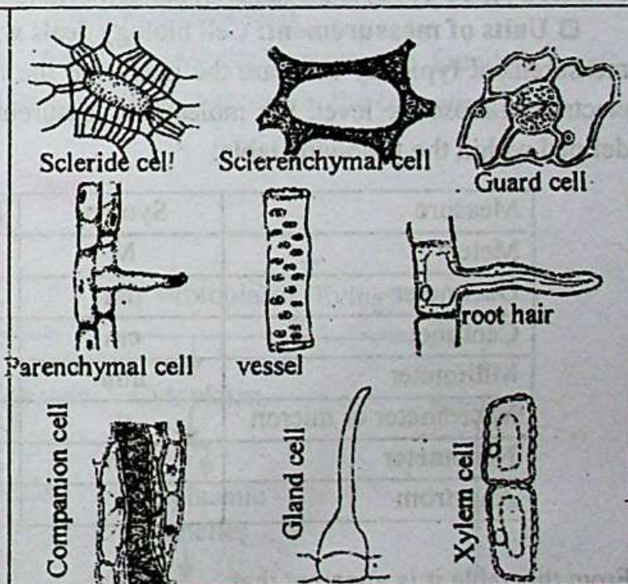


Fig 1.4 Different plant cells

❑ **Shape of cell:** The shapes of cells are quite varied and determined by the specific function of the cell. The cells may have diverse shape such as polyhedral, flattened, cuboidal, columnar, discoidal, spherical, spindle shape, elongated, or irregular shape. Some cells have branched filaments.

❑ **Size of cell:** The sizes of cells are also varied. Most of cells of multicellular organisms are microscopic and ranges between 20 to 30μm. The smallest cell is the PPLO (Pleuro Pneumonia like Organism), *Mycoplasma* (diameter is 0.1 μm) and the **largest animal cell is the egg of ostrich** (170×135mm). Human RBC being 7 to 8 μm in diameter. The largest cell in the human body is the female egg also known as 'ovum' (0.1mm in diameter) while the smallest cell is the sperm in terms of volume. The longest cell of the human body is the motor neuron which is 1.37 meter in length and extended from the base of spinal cord to the tip of leg thumb. The largest plant cell is unicellular green marine algae, *Acetabularia* (0.5 to 10cm) but longest plant cell is the fibre of rami plant (*Bochmeria nivela*) which is 55cm in length.

❑ **Cell number:** The organism made up of a single cell is called **unicellular organism.** Organisms like the *Amoeba, Paramecium* are single-celled organisms. Organisms that consist of more than one cell are known as **multicellular organisms.** The number of cells in multicellular organism depends on its size and shape. An adult human body has 100 trillions of cells.

❑ **Cell organelles:** Cell organelles are specialized subunits within a cell that have specific functions, and are usually separately enclosed within their own lipid bi-layer. There are many types of organelles, particularly in eukaryotic cells as mitochondria, ribosome, Golgi bodies, nucleus etc.

❑ **Cell inclusions:** Cell inclusions are non-living, often temporary materials in the protoplasm of a cell also called ***metaplastic bodies*** in case of animals and ***ergastic substances*** in case of plants. They include metabolic products, pigment granules, fat droplets, or nutritive substances.

❑ **Cytology:** Cytology (from *Kytos=cell* and *logia=knowledge*) is the study of cells. Cytology is that branch of life science that deals with the study of cells in terms of structure, function and chemistry. **Robert Hooke** (1635-1703) is sometimes seen as the father of cytology but **Carl P. Swanson** (1911-1996) is the father of modern cytology.

❑ **Units of measurement:** Cell biology deals with things which are relatively small. The units of measurement typically used are the micron at the light microscope level, and the nanometer at the electron microscope level. For molecular measurements, the norm is the Angstrom. These units are defined within the following table:

Measure	Symbol	Relative Length	Exponential Notation
Meter	M	1	10^{0}
Decimeter	dm	.1	10^{-1}
Centimeter	cm	.01	10^{-2}
Millimeter	mm	.001	10^{-3}
Micrometer or micron	μ	.000001	10^{-6}
Nanometer	nm	.000000001	10^{-9}
Angstrom	Å	.0000000001	10^{-10}

From this table it is apparent that:

1 meter = 100 cm = 1,000 mm = 1,000,000 μm = 1,000,000,000 nm

1 centimeter (cm) = 1/100 meter = 10 mm

1 millimeter (mm) = 1/1000 meter = 1/10 cm

1 micrometer (μm) = 1/1,000,000 meter = 1/10,000 cm

1 nanometer (nm) = 1/1,000,000,000 meter = 1/10,000,000 cm

Cell theory

In biology, **cell theory** is a scientific theory, which describes the properties of cells. The **cell theory or cell doctrine** first developed in 1839 by German Botanist **Matthias Jakob Schleiden** and Zoologist **Theodor Schwann**. The generally accepted parts of modern cell theory include:

1. All known living things are made up of one or more cells.
2. All living cells arise from pre-existing cells by division.
3. The cell is the fundamental unit of structure and function in all living organisms.

4. The activity of an organism depends on the total activity of independent cells.
5. Energy flow (metabolism and biochemistry) occurs within cells.
6. Cells contain DNA which is found specifically in the chromosome and RNA found in the cell nucleus and cytoplasm.
7. All cells are the same in chemical composition in organisms of similar species

Limitation of Cell theory:

Cell theory does not have universal application; it has many limitations, which are as follows:

1. Viruses, Viroias and Prions do not have a cellular architecture.
2. Eubacteria and archebacteria do not have an organized nucleus.
3. Certain algae (*Vaacheria*), fungi (*Rhizopus, Mucor* etc), and Ciliates are coenocytic in nature *i.e.* consists of multinucleate mass of protoplasm.
4. RBCs and mature sieve tube cells live without nucleus and other cell organelles.
5. Connective tissues contain many non-cellular ground substances called matrix.
6. Protoplasm is replaced by non-living materials in the surface cell of skin and cork.

Organization of a typical plant cell

A cell comprises of some complex structure and chemicals. All the components found in a cell constitute the **cell organization**. The organization of a plant cell is shown in the following chart:

- Plant cell
  - Non-living materials
    - Cell wall
    - Cytoplasmic nonliving materials
      - Stored
        - Proteins
        - Lipids
        - Carbohydrates
      - Secreted
        - Enzyme
        - Pigments
        - Nectar
      - Wasted
        - Tanin
        - Reign
        - Latex
        - Organic acid
        - Glue
        - Alkaloid
        - Oil
        - Minerals
  - Protoplasm (living)
    - Cell membrane
    - Cytoplasm
      - Cytomatrix
      - Cytoplasmic organelles
        - Plastids
        - Mitochondria
        - Endo. reticulum
        - Golgi complex
        - Ribosome
        - Lysosome
        - Centrosome
        - Cell vacuoles
        - Microtubules
        - Peroxisomes
    - Nucleus
      - Nuclear membrane
      - Nucleoplasm
      - Nucleus
      - Nuclear reticulum

Note that, animal cells have no cell wall in their cellular organization.

1.1 Cell wall

The cell wall is a tough, flexible or rigid layer that surrounds the plasma membrane of plant cell. A plant cell wall was first observed and named (simply as a 'wall') by **Robert Hooke** in 1665. In 1804, **Karl Rudolphi** and **J.H.F. Link** proved that cells had independent cell walls. **Cell wall is the unique characteristics of plant cell.** Each plant cell originates from a pre-existing cell thus cell wall start to develop during the **telophase of mitotic** cell division.

Physical structure

A completely developed plant cell wall comprises of three different types of layers, *viz.*,

1. The middle lamella: This outermost layer forms the interface between adjacent plant cells and glues them together. This layer enrich of **pectin.** Lonely single cell have no middle lamella.

2. The primary cell wall: It is generally a thin, flexible and extensible 1-3 micrometer thick layer. It is formed while the cell is growing. It present on both side of the middle lamella. In case of parenchyma, collenchyma, mesophyll tissue etc. the primary cell wall is only cell wall of the cell.

3. The secondary cell wall: It is a thick layer (5-10 micrometer) formed inside the primary cell wall after the cell is fully-grown. It not found in all cell types. Some cells, such as the tracheid, tracheid fiber etc. possess a secondary wall containing **lignin**, which strengthens and waterproofs the wall. The cells of vascular tissue have no secondary cell walls.

The tertiary cell wall: It is of rare occurrence in tracheid of gymnosperms. It deposited on the inner side of the secondary cell wall. It is relatively richer in xylan than cellulose.

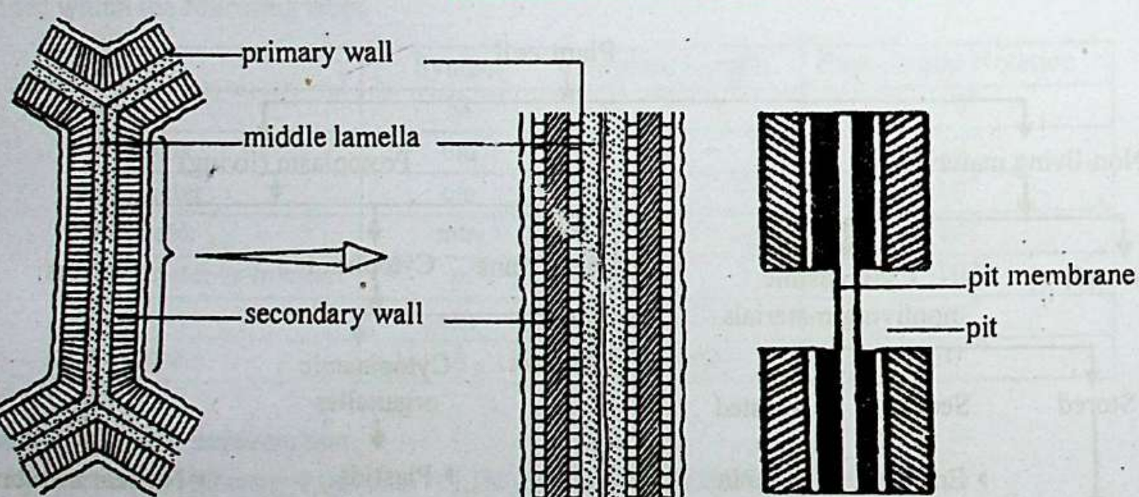


Fig 1.5 Arrangement of different layer and pit field in cell wall

Chemical composition

The chemical composition of cell wall varies in different plant species. Bacterial cell walls are made of **peptidoglycan or mucoprotein.**

Most true fungi have a cell wall consisting largely of glucosamine polymer **chitin** and other **polysaccharides**. True fungi do not have cellulose in their cell walls.

Algae possess cell walls made of **glycoproteins and polysaccharides** such as *carrageenan* and *agar* that are absent from land plants. Unicellular algae diatoms have biogenic **silicic acid** in their cell walls.

The cell walls of archaea have various compositions, and may be formed of **glycoprotein S-layers, pseudopeptidoglycan,** or **polysaccharides.**

Cell wall of higher plants mainly composed of **cellulose** and **polysaccharides**. The middle lamella of cell wall largely composed of a chemical known as **pectin**. The core component of primary cell wall is **cellulose**, but there are some depositions of hemicelluloses, pectin, glycoprotein etc. The outer part of the primary cell wall of the plant epidermis is usually impregnated with **cutin** and **wax**, forming a permeability barrier known as the **plant cuticle**. The secondary cell wall consists of cellulose (35-50%), xylan (20-35%), cutin, suberin, pectin, lignin (10-25%) etc. Cellulose exists as **micelles** units in the cell wall. Each micelles unit comprises of several thousands of β-D glucose molecules.

Plant cell wall also contains numerous enzymes, such as *hydrolases, esterases, peroxidases,* and *transglycosylases,* that cut, trim and cross-link wall polymers.

Plasmodesmata: In cell wall at many places, the cellulose layers are absent and at these places, small pits are formed. These places are called primary **pit fields**. These pits are always opposite in between the walls of adjacent cells. In such case the middle lamella is called a **pit membrane**. There are many minute pore in the middle lamella through which the protoplasm of both cells are connected together by microscopic fibrils. Each fibril is called **plasmodesma** and the group of these fibrils is called **plasmodesmata**. These structure discovered by Tangle.

Functions of cell walls

1. Cell wall maintains the structural integrity of the cell.

2. Thick walled cells provide mechanical support and acts like a skeleton of the plant by providing rigidity, strength and flexibility.

3. Cell wall provides tensile strength and limited plasticity that are important for keeping cells from rupturing from turgor pressure.

4. By impregnation of cutin and suberin cell wall reduces loss of water by transportation.

5. It provides mechanical protection from insects and pathogens.

6. It being freely permeable, helps in the absorption and transportation of water and solutions in the different parts of the plants.

7. Physiological and biochemical activities in the cell wall contribute to cell-cell communication.

Differences between primary cell wall and secondary cell wall

Primary cell wall	Secondary cell wall
1. Primary cell wall is the first formed cell wall and inner to middle lamella.	1. It is the later formed cell wall and inner to primary cell wall.
2. It is thin and present in all types of cells.	2. It is thick and not present in meristematic and parenchyma cells.
3. It is homogeneous in thickness and elastic in nature.	3. It is irregular in thickness and non-elastic.
4. It grows by intussusceptions.	4. It grows by accretion.
5. It is mainly composed of cellulose.	5. It is composed of hemicelluloses, lignin and pectin.

Protoplast

Protoplast (Gr. *protoplastos*= "first-formed") refer to the entire cell, excluding the cell wall. **Hanstein** first proposed this term in 1880. Therefore, protoplast of plant cell consists of plasma lemma and everything contained within it. **Vasil** (1980) defines that "the protoplast is a part of plant cell which lies within the cell wall and can be plasmolysed and which can be isolated by removing the cell wall by mechanical or enzymatic procedure". Experimentally produced protoplasts are known as **isolated protoplasts.** Protoplast consists of protoplasm and non-living substances within cell.

Protoplasm

Protoplasm is the complex, semifluid, colloidal, translucent substance that constitutes the interior matter of a living cell and is composed of proteins, fats, and other molecules suspended in water. The term protoplasm (Gr. *protos* = first + *plasma* = anything formed) was first used by **J. E. Purkinje** in 1840 for the material of the animal embryo. **Huxley** (1868) referred to protoplasm as the '**physical basis of life**'. It does all the activities of living beings. For this reason, protoplasm is recognized as the '**physical basis of life**' or *vivum fluidum*.

Physical properties of protoplasm:

1. The protoplasm forms a polyphase colloidal system.
2. The protoplasm exists mostly as a sol (which is semi-liquid) but sometimes it becomes rigid and is viewed as a gel (which is sem-solid).
3. The particles of the protoplasm show an erratic zig-zag movement. This **random** motion, caused by the uneven bombardment of particle is called **Brownian movement**.
4. The particles of the protoplasm cannot be filtered through ordinary filter paper but can be filtered through ultrafilters such as millipore filters.
5. The particles of the colloid carry an uniform electric charge.
6. When the particles of a colloid lose their charges they tend to aggregate and increase in size. As a result they fall out and get precipitated.
7. It has a high specific heat, thus, it provides protection against fluctuation in temperatures.

Different workers advanced different theories about the physical characteristics of the protoplasm. These theories have been represented as follows:

■ **Reticular theory:** According to **Frommann** (1865) the protoplasm is composed of reticulum of fibres or particles in the ground substance.

■ **Granular theory:** According to **Altman** (1886) the protoplasm contains many granules of smaller and larger size known as bioplasts arranged differently.

■ **Alveolar theory:** According to **Butschli** (1892) the protoplasm consists of many suspended droplets or alveoli or minute bubbles resembling the foams of emulsion

■ **Colloidal theory:** According to **Wilson and Fishar** (1894) the protoplasm is partly a true solution and partly a colloidal system.

Chemical properties of protoplasm:

1. The major constituent of the protoplasm is water which makes up 80-90% of it.

2. The dry matter has several organic and inorganic substances. Generally, the dry protoplasm shows the following constitution-Protein 45%, Carbohydrates 25%, Lipids 25% and other substances 5%.

3. Proteins and other nitrogen-containing compounds constitute the bulk of organic matter.

4. Liquids like fats and oils are present in small amounts.

5. Compounds consisting of chlorides, phosphates, sulphates and carbonates of magnesium, potassium, sodium, calcium and iron are also present.

Main parts of protoplasm:

The protoplasm made up of three main parts: cell membrane, cytoplasm and nucleus.

Functions of protoplasm:

1. It carries out all the processes necessary for life.
2. It processes nutrients and oxygen, change food into living matter, ejects used substances, renews its worn parts, and itself produces new cells.
3. It houses larger sub-cellular organelles such as mitochondria.
4. It responses well to external stimuli like electric shock, heat, cold, chemicals etc.
5. The water of protoplasm is essential for maintaining life.

1.2 Cell membrane/Plasmalema/Plasma membrane

The cell membrane or plasmalema is a living, elastic, selectively permeable and ultrathin biological membrane that separates the interior of all cells from the outside environment. In plant cell it is occurs just beneath the cell wall and in animal cell, it occurs outer margin of cytoplasm. Chemically it consists of the phospholipid bilayer with embedded proteins. The term *cell membrane* was given by **C. Nageli** and **Cramer** (1855) while the term *plasmalema* was coined by **J.Q. Plower** (1931).

Physical structure

Several theories regarding the physical structure of cell membrane have been proposed by different scientists. Some of these are as:

1. The lipid membrane model theory of **Gorter and Grendel** (1925),
2. The sandwich model theory of **Danielli and Davson** (1935)
3. The unit membrane model theory of **Robertson** (1953) and
4. The fluid mosaic model theory of **Singer and Nicolson** (1972).

Among these here described only two more acceptable theories *viz.*,

The unit membrane theory of Robertson

According to **Robertson** (1953) cell membrane consists of three layers. These layers are collectively recognized as an unit. All membranes of cell organelles are also consist of such type of unit. Hence, cell membrane and membranes of all the organelles are called as **unit membrane.** Robertson explained that a cell membrane's wide as 75Å. Each of its outer layer has 20 Å wide as well as made of protein molecule and inner layer made of bi-molecular lipid and has 35 Å wide. Actually, the cell membrane comprises of total four layers of which two are outer layers of protein and two are inner layers of lipid.

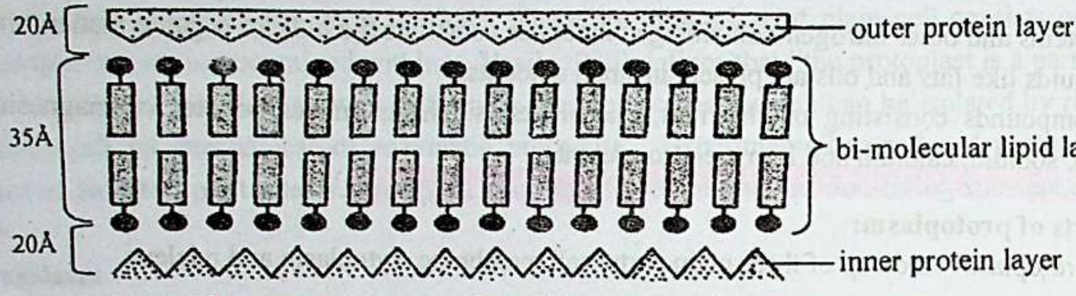


Fig 1.6 Unit membrane model of plasma membrane

Fluid Mosaic Model Theory of Singer and Nicolson

Latest and modern explanation of plasma membrane described by English scientists **S. J. Singer and Garth Nicolson** in 1972. The model of plasma membrane described by these scientists is called **Singer-Nicolson's fluid mosaic model.** According to this theory:

S.J. Singer G.L. Nicolson

1. The main component of cell membrane is a bimolecular lipid layer that actually consists of two rows of phospholipids molecules. Each phospholipid molecule has a water-soluble polar head and two fat-soluble non polar tails. The polar head of phospholipids is hydrophilic (*hydro*=water; *philic*= owing) and non-polar tail is hydrophobic (*hydro*=water; *phobic* =fearing). The hydrophobic tails always try to avoid water and face the inside of the bilayer, whereas the hydrophilic head faces the exterior and the interior.

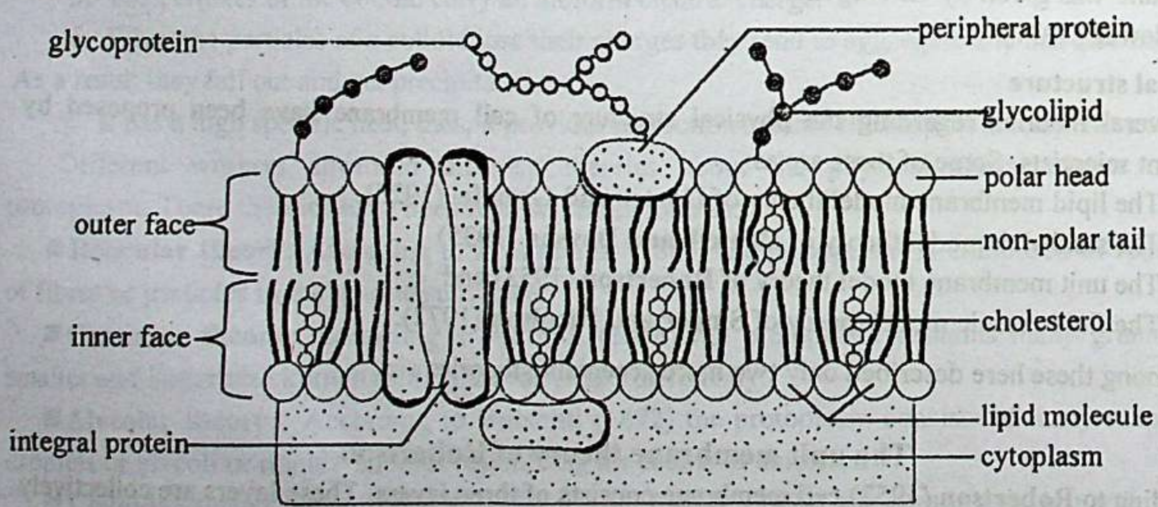


Fig 1.7 Fluid mosaic model of cell membrane

2. Within the phospholipid bilayer are many different types of embedded proteins and cholesterol molecules whose presence spawned the term **mosaic.** The plasma membrane has described to be fluid because of its hydrophobic integral components such as lipids and membrane

proteins that move laterally or sideways throughout the membrane. That means the membrane is not solid, but more like a **fluid.**

3. Few protein molecules exist outside the lipid layer, called **peripheral protein molecule** and some are partially or entirely pass across the lipid layer, called **integral protein molecules**. Integral protein molecules create **'ion channel'** through the cell membrane for passing water-soluble molecules.

4. Oligosaccharide (carbohydrate) molecules attached to some protein and lipid molecules of outer side of cell membrane to form glycoprotein and glycolipid respectively.

5. The fluid mosaic membrane is thought to be far less rigid than was originally supposed. In fact, experiments on its viscosity suggest that it is fluid consistency rather like the oil, and there is a considerable sideways movement of the lipid and protein molecules within it.

6. On account of its fluidity and the mosaic arrangement of protein molecules, this model of cell membrane is known as the **'fluid mosaic model'.** The fluid mosaic model has found to be applied to all biological membranes in general, and it is seen as a dynamic, ever-changing structure.

Chemical structure: Chemically cell membrane composed of following components:

1. Protein (60-80%): Structural protein, carrier protein, enzymes etc.
2. Lipid (20-40%): Phospholipid (lecithin, phosphotidic acid) sterol, fatty acid etc.
3. Carbohydrates (4-5%): Glycolipid, glycoprotein, galactose etc.
4. Water and minerals: Trace amount.

Functions of cell membrane:

The cell membrane performs following functions:

1. The cell membrane surrounds the cytoplasm of living cells, physically separating the intracellular components from the extra cellular environment.

2. It is also plays a role in anchoring the cytoskeleton to provide shape to the cell, and in attaching to the extra cellular matrix and other cells to help group cells together to form tissues.

3. It is **selectively permeable** and able to regulate what enters and exits the cell, thus facilitating the transport of materials needed for survival.

4. The cell membrane functions as a barrier that makes it possible for the cytoplasm to maintain a different composition from the material surrounding the cell.

5. It provides protection to the internal contents of the cell.

6. It can take in solid and liquid materials by **phagocytosis** and **pinocytosis** processes respectively.

7. In animal cells, it is involved in the formation of vesicles, cilia, flagella, microvilli, etc.

8. The cell membrane contains numerous receptor molecules that are involved in communication with other cells and the outside world in general. These respond to antigens, hormones, and neurotransmitters in various ways.

9. The cell membrane also allows cell identification.

10. It enhances the absorbing area by producing **microvilli** in animal cells.

11. It controls the molecular activity of the cell.

12. The cell membrane contains different types of enzymes.

13. It plays important roles in developing different cell organelles.

Differences between cell wall and cell membrane

Cell wall	Cell membrane
1. Non-living, only present in fungi, bacteria, algae and all other plant cells.	1. Living, present in both plant and animal cells.
2. Composed of middle lamella, primary and secondary cell wall.	2. Composed of lipid – protein- lipids layers.
3. Chemically the cell wall is made up mainly of cellulose, pectin and chitin	3. Chemically the cell membrane is made up mainly of proteins, carbohydrates and lipids.
4. Primarily permeable, but secondarily becomes non-permeable.	4. Always semi-permeable.
5. It surrounds the plasma membrane.	5. It surrounds the cytoplasm.
6. The function of the cell wall is to provide strength and rigidity to the cell.	6. The function of the cell membrane is allows the passage of certain substances through them.

Modification of cell membrane

■ **Microvilli:** These are tiny hairlike folds in the plasma membrane that extend from the surface of many absorptive or secretory cells. Each epithelial cell of small intestine and nephron having 3000 microvilli. Microvilli greatly increase total cell surface, and therefore also the absorptive capacity of cell.

■ **Desmosome:** Desmosomes are intercellular junctions with **tonofibril fibres** modified from cell membrane, provide strong adhesion between cells.

■ **Phagocytic vesicle:** A membrane-bounded intracellular *vesicle* that arises from the ingestion of particulate material by *phagocytosis*.

■ **Pinocytic vesicle:** A membrane-bounded intracellular *vesicle* that arises from the ingestion of liquid material by *pinocytosis*.

■ **Tight junction:** It is a type of cell junction formed between epithelial cells of vertebrates wherein the cell membrane of two adjacent cells fuse, thereby serving as a barrier to the passage of fluid between cells. Found in neuron of brain.

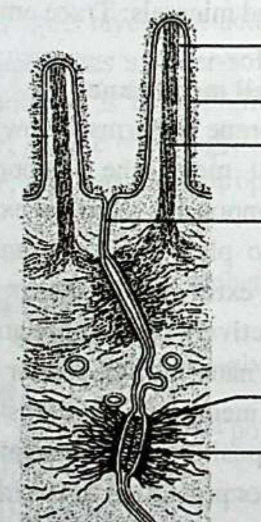


Fig 1.7: Modification of cell membrane

Cytoplasm and Cell organelles

Cytoplasm

The live, semi-transparent, granular, colloidal, colourless and flexible constituent of cell enclose by cell membrane is called cytoplasm or cytosol. American biochemist **H.A. Lardy** (1965) first introduced the term **cytosol**. The cytoplasm is found inside the cell membrane, surrounding the nuclear envelope and the cytoplasmic organelles. The main and matrix component of the cell is the cytoplasm. It contains all the cell organelles, solid non-living materials, stored foods, organic acids, water etc. Cell organelle less part of cytoplasm is called **cytomatrix** or **matrix** or **hyaloplasm**.

Comparatively less dense central area of cytoplasm is known as **endoplasm** or **cortex** and denser cell membrane adjacent area of cytoplasm is known as **ectoplasm.**

Physical properties of cytoplasm

Cytoplasm is a live, semi-transparent, colloidal, colourless, viscous and flexible matrix substance. Its 98% components is water. Different types of cell organelles and organic substance uniformly distributed throughout it.

Chemical properties of cytoplasm

The chemical components of cytoplasm classified as in two groups: organic and non-organic.

(a) Inorganic components

The foremost inorganic components of cytoplasm are water (65-85%), minerals and dissolved gases. The water is not only the key component of the cytoplasm, it has illimitable significance as a solvent of many vital substances of the cell. The quantity of water differs in different types of cells but in most case, cells contain 65-85% of water. Of cellular water, 95% is free water and numerous organic and inorganic chemicals are dissolved in it.

Cytoplasm contains several types of inorganic salts (minerals). Among these Na, K, Ca, Mg etc. are especially significant. These minerals play important role in maintaining ionic balance of different physiological activities.

(b) Organic components

The organic components of cytoplasm are proteins (7-10%), lipids (1-3%), carbohydrates (1-1.5%), pigments etc. All types of protein such as **simple, conjugated** and **derived proteins** are present into cytoplasm. Among the simple proteins albumin, globulin, histon and protamin are notable. The major conjugated proteins are nucleoprotein, glycoprotein, lipoprotein, chromoprotein etc. Proteose, peptone etc. are the derived proteins of cytoplasm. These proteins produced from natural protein through digestion, hydrolysis or any other chemical reaction.

Lipid components of cytoplasm differ in different cells (1-3%). Glycerides, phospholipids, lypolipids, cholesterols etc are the principal lipids of cytoplasm. The amount of carbohydrates in cytoplasm ranges 1-1.5%. They exist freely or conjugated in the cytoplasm as *mono*, *di* or different types of polysaccharides. These components are the key sources of chemical energy in the cell. Glucose, galactose and fructose are prime monosaccharide. Maltose, lactose, sucrose, etc. are the disaccharides and starch, glycogen are the polysaccharides of cytoplasm. In cytoplasm carbohydrates conjugated with other compounds to form some essential components of the cell like nucleic acid, co-enzyme etc.

Metabolic roles of Cytoplasm

1. The cytoplasm holds all of the cellular organelles outside of the nucleus and maintains the shape and consistency of the cell.

2. It is also a storage place for chemical substances indispensable to life, which are involved in vital metabolic reactions, such as anaerobic glycolysis and protein synthesis.

3. The cytoplasm is the site of protein synthesis and most of the cell's intermediary metabolism.

4. It has thousands of enzymes involved in metabolic activities.

5. In bacteria, chemical reactions take place in the cytoplasm and all of the genetic material has suspended in it.

6. The enzymes in the cytoplasm break down large molecules, thereby helping the organelles to use them.

7. Exchange of chemicals between the organelles is also one among the different cytoplasm functions.

8. Cytoplasm is the binding factor for the organelles inside the cell and it synchronizes the various cellular functions.

9. The cytoplasm contains many salts and is an excellent conductor of electricity, which therefore creates a medium for the vesicles, or mechanics of the cell.

10. Water of cytoplasm carry several chemical compound which essential for life. Most of the metabolic reaction of cell held in cytoplasmic water.

CYTOPLASMIC ORGANELLES

1. Plastid

In the cytoplasm of plant and algal cell there are numerous spherical or discoidal or fibrous living double-membrane organelles called the plastids. In 1883, **W. Schimper** (1856-1901) coined the name plastids for these structures. These are the **second largest** organelles of the cell and exist slatternly in the cytoplasm. Plastids are found in almost all the cells of the plant body either in the form of colourless plastids or colour plastids or proplastids. Plastids are the site of manufacture and storage of important chemical compounds used by the cell. They have a common evolutionary origin and possess a double-stranded DNA molecule that is circular, like that of prokaryotic cells. Plastids are thought to have originated from **endosymbiotic cyanobacteria**. This symbiosis evolved around 1.5 billion years ago and enabled eukaryotes to carry out oxygenic photosynthesis.

Types of Plastid

Based on presence or absence of colour and pigments plastids are classified into leucoplasts, chromoplasts and chloroplasts.

1. Leucoplast (Gr. *leuco*=white, *plast*=living)

Leucoplasts are colourless plastids. They occur most commonly in the embryonic cells, gametes, merestematic cells, seed cells, storage cells of roots and underground stems. These are spherical or discoidal or rod shape structures. In touch of light leucoplast become chloroplasts.

Functions: Leucoplasts store the food of the plant body in the form of starch, protein and lipids. The leucoplast of tuber, cotyledons and endosperm are responsible for the synthesis and storage of starch granules are known as **amyloplast** and the leucoplasts of seeds responsible for the synthesis and storage of oil and fat are known as **elioplasts.** In some cases they synthesis fatty acids and amino acids which are called **aleuroplast.**

2. Chromoplast (Gr. *Chroma*=colour)

Chromoplasts are red, yellow, orange or brown in colour and are found in petals of flowers, in colourful fruit and seed, roots of carrots etc. Their colour is due to two pigments, orange-red **carotene** and yellow **xanthophylls**. The brown and red plastids are called **pheoplasts** and **rodoplasts** respectively. All chromoplasts are modified chloroplasts.

Functions: The primary function of chromoplasts in the cells of flowers is to attract agents of pollination and in fruit to attract agents of dispersal.

3. Chloroplast (Gr. *Chloros*=green)

The green coloured plastids are called chloroplasts. Their discovery inside plant cells is usually credited to **Julius von Sachs** (1832–1897), an influential botanist familiar as '**Father of Modern Plant Physiology**'. Chloroplasts are probably the most important among the plastids since they are directly involved in photosynthesis. They are usually situated near the surface of the cell and occur in those parts that receive sufficient light, e.g. the palisade cells of leaves, tender green stem, green fruits etc. The green colour of chloroplasts is due to the green pigment **chlorophyll.** Normally there are 20-50 chloroplasts in a plant cell, but in algae, just one chloroplast may be present in a cell. In the moss *Mnium*, approximately 106 chloroplasts are present in each cell.

Physical Structure: In higher plants, the chloroplasts are **lens shaped.** However, their shape in higher plants is usually ovoid, discoid or ellipsoid in higher plants. **In algae, the chloroplasts have very unusual shape and size.** In *Chlamydomonas* the chloroplast is **disc** shaped, in *Spirogyra* it is **ribbon** shaped, in *Oedogonium* it forms a **network**, in *Desmids* and *Zygnema* the chloroplasts are like **radiating plates**. A typical chloroplast of higher plant's leaf has the following structure:

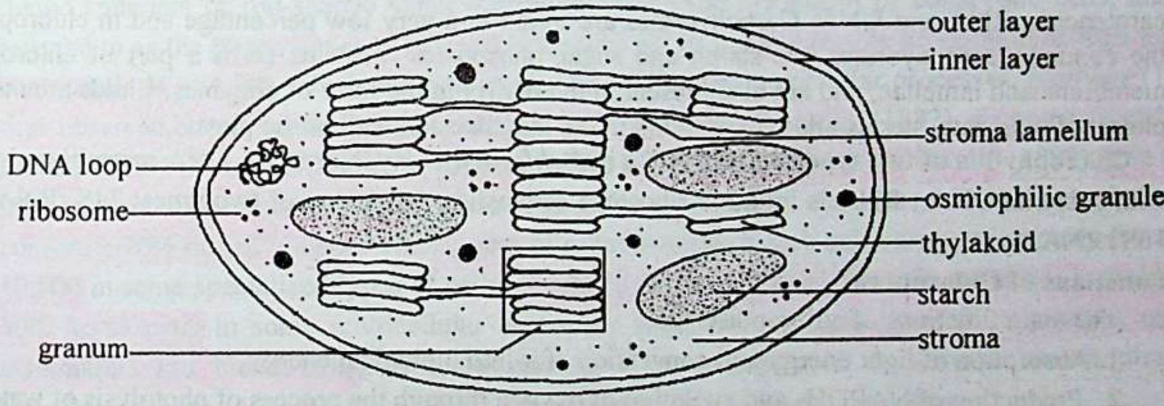


Fig 1.8 Ultrastructure of a chloroplast

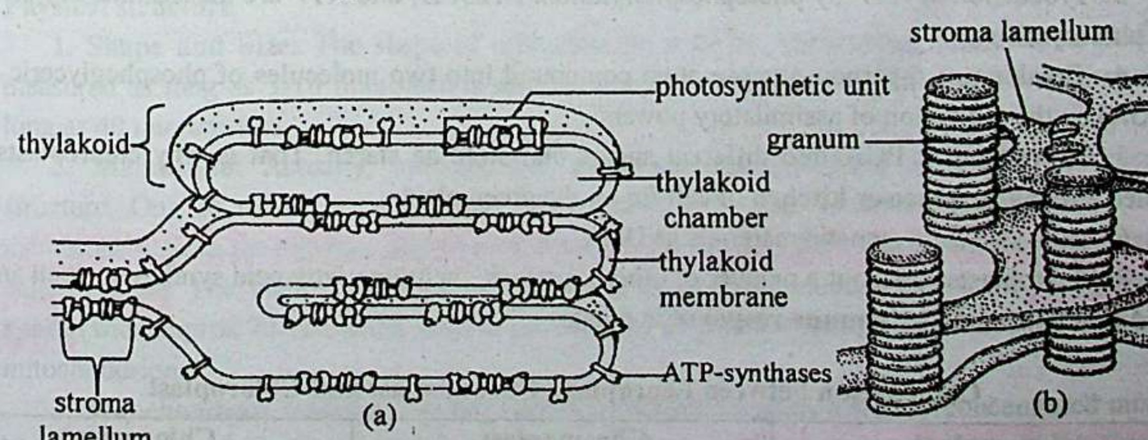


Fig 1.9 The (a) ultra structure and (b) three dimensional of granum

(a) Membrane: Each chloroplast is surrounded by a double membrane. Each membrane is a unit membrane of 60 Å thicknesses comprises of protein-lipid molecules. The space between outer and inner membranes is called as **periplastidal space** of 100-300 Å.

(b) Stroma: Inside the inner membrane there is a watery protein-rich ground substance called the **stroma** or **matrix.** The stroma contains fat globules, starch grain, osmiophilic granules, pyrenoids, and enzymes of dark reaction. It also contains RNA, DNA, 70S ribosome and several plasmids.

(c) Thylakoids: In the stroma embedded a continuous membrane system, the granal network. This network forms a three-dimensional arrangement of membrane-bound vesicles called **thylakoids** of 100-300 Å wide. The inner chamber of thylakoid contains the photosynthetic pigments **chlorophyll a** and b and the yellow to red **carotenoids,** lipid and enzymes. These components collectively known as **quantasome.** Thylakoid membranes hold the **photosynthetic units** and **ATP-synthases.**

(d) **Grana:** The thylakoids usually lie in stacks called **grana.** A granum may be of 0.3-1,7 micrometer height and comprises of 50-100 thylakoids. In a chloroplast, usually 40-60 grana are found.

(e) Stroma lamellae: The grana are interconnected by tubular membranes called the **intergranal frets or stroma lamellae.** These structure also contain chlorophyll.

Chemical composition: Chemically the chloroplasts contain proteins, lipids, and chlorophyll, carotenoids, RNA and DNA. Carbohydrates are found in a very low percentage and in chloroplasts the common carbohydrates are starch and sugar phosphates. Proteins form a part of chloroplast membrane and lamellae, and are also present in the matrix in the form of enzymes. Lipids are mainly phospholipids, fats, sterols and waxes found in the lamellae and wall of the plastid.

Chlorophyll is of two types-*chlorophyll a* and *chlorophyll b*. Chloroplast DNA resembles closely with bacterial DNA. RNA is found in ribosome of plastids. RNAs are of two types: 24S rRNA and 16S rRNA.

Functions of Chloroplast

The main functions of chloroplasts are:

1. Absorption of light energy and conversion of it into biological energy.
2. Production of $NAPDH_2$ and evolution of oxygen through the process of photolysis of water.
3. Production of ATP by photophosphorylation. $NADPH_2$ and ATP are the assimilatory powers of photosynthesis.
4. Breaking of 6-carbon glucose atom compound into two molecules of phosphoglyceric acid (PGA) by the utilization of assimilatory powers.
5. Conversion of PGA into different sugars and store as starch. That is why chloroplasts are called as **cooking place** or **kitchen of cell** for all the green plants.
6. They also carry genetic materials as DNA.
7. Chloroplasts carry out a number of other functions, including fatty acid synthesis, much amino acid synthesis, and the **immune response** in plants.

Comparison between Leucoplast, Chromoplast and Chloroplast

Leucoplast	Chromoplast	Chloroplast
1. They are colourless plastids.	1. Chromoplasts are orange-red plastids.	1. Chloroplasts are green coloured plastids.
2. Leucoplasts usually occur in unexposed parts of plants.	2. They are commonly found in exposed parts of plants like flowers and fruits.	2. They are present in all green parts of the plants.

3. Internal lamellae are present.	3. Internal lamellae degenerate.	3. Internal lamellae are well developed.
4. They help in storage s of minerals, starch, protein and lipid.	4. Chromoplasts are rich in carotenoid and lipids.	4. They take part in photosynthesis.
5. The shape is more regular, mostly rounded.	5. They have variable shapes.like elongated, angular,spherical etc.	5. The chloroplasts are **lens** shaped.
6. They can change to other types of plastids.	6. They do not get changed to other types.	6. Do not undergo transformation.
7. They have no role to play in the process of pollination and fertilization.	7. They attract insects and animals for pollination and fertilization.	7. They play key role in pathogen defense as part of immune response.

2. Mitochondria

Mitochondria (Sing: Mitochondrion; Gr-*mitos,* warp thread + *khondrion*- granule) are membrane-bound spherical or rod-shaped small organelles within the cytoplasm of eukaryotic cells, and are referred to as the **powerhouse** of the cell since they act as the site for the production of high-energy compounds (e.g. ATP), which are vital energy source for several cellular processes. **Kolliker** (1880) first observed mitochondria in flight muscle of insects. **W. Fleming** (1882) observed thread like mitochondria and called the as *fila.* **Altman** (1890) called them as *bioblast.* **Benda** (1898) gave them their present name mitochondria. These organelles dispersedly distributed in the cytoplasm and constitute 20% of cell volume. The number of mitochondria in each cell varies enormously from 1 to 10,000 in some specialized types of cells. A typical number of mitochondria per cell is around 200-300. Some cells in some multicellular organisms may however lack them (for example, mature mammalian red blood cells). Mitochondria have been implicated in several human diseases, including mitochondrial disorders, cardiac dysfunction, heart failure and autism.

Physical structure

1. Shape and Size: The shape of mitochondria may be filamentous, granular, or oval. They measured as long as 3-10 micrometers and wide as 0.2-1 micrometer. In some case, they may be long as 40 micrometers.

2. Membrane: Actually, mitochondria are organelles that have a double unit membrane structure. One of them is called **outer membrane** and other is **inner membrane.** The outer membrane defines the external shape of the mitochondrion while the inner membrane has many folds called **cristae.** The volume between the inner and outer membranes is called the **intermembrane space** (wide approx 70Å) and the volume enclosed by the inner membrane is called the **matrix** of the mitochondrion.

3. Mitochondrial matrix: The mitochondrial matrix contains a highly concentrated mixture of hundreds of enzymes. These include most of the enzymes that participate in the TCA Cycle. The matrix also contains other structures and molecules including ribosomes, matrix granules and mitochondrial DNA.

4. Cristae: Cristae are folds of the inner mitochondrial membrane. The quantity and shape of the cristae may vary. For example, although the shape of cristae within mitochondria is often either flat or tubular, in some cases (e.g. in certain nerve cells) cristae take the form of prisms while in other cases (e.g. in some photoreceptor cone cells) they have a whorl-like shape.

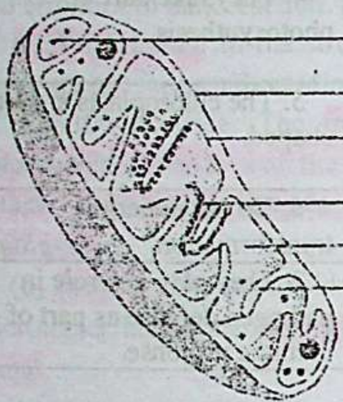


Fig 1.10 T S of mitochondrion

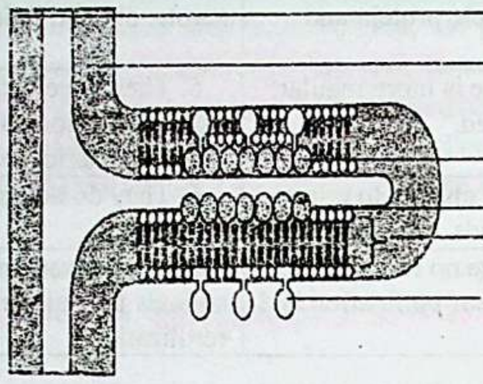


Fig 1.11 Ultra structure of cristae of mitochondria

5. Oxisomes or F_1 particles: Cristae are covered with many tiny 'stalked particles' called **inner membrane spheres or the F_1 particles**. Each stalked particle has a head diameter of 8-9 nm and a stalk 30-35Å wide and 45-50Å long.

6. ETS and ATPase complex: The inner membrane of mitochondria contains the electron transport system (ETS) and ATPase complex. The ETS generates a proton gradient and the ATPase complex uses proton gradient to produce adenosine triphosphate (ATP) from adenosine diphosphate (ADP).

Chemical structure: The chemically mitochondria composed of the following components:

(i) Protein 60 to 70 %, (ii) Lipid-25 to35%, (iii) DNA, RNA 0.5% and (iv) Trace amount of sulfur, iron, copper, vitamins E etc.

Functions: The mitochondria perform following functions:

1. The main function of the mitochondrion is the production of energy, in the form of adenosine triphosphate (ATP). So, mitochondria are considered as the **powerhouse** of the cell as their main function is to provide energy to the cell.

2. Mitochondria are involved in building, breaking down, and recycling products needed for proper cell functioning. For example, some of the building blocks of DNA and RNA occur within the mitochondria.

3. They are required for cholesterol metabolism, neurotransmitter metabolism, and detoxification of ammonia in the urea cycle.

4. Mitochondria help to maintain proper concentration of calcium ions within the various compartments of the cell.

5. Mitochondria storage the ions of Ca^{2+}, S^{2+}, Fe^{2+}, Mn^{2+}.

6. Mitochondria help in the formation of blood components and hormones such as testosterone and oestrogen.

7. Production of heat is another function of mitochondria.

8. Mitochondria help in the regulation of membrane potential, cell proliferation and cell metabolism.

9. Mitochondria cause apoptosis or programmed cell death.

10. Mitochondria help in the biosynthesis of heme and steroids.

11. Mitochondria synthesis DNA and RNA. According to **Benda** they contribute in heredity.

Endosymbiont : The mitochondria and chloroplasts in eukaryotic cells supposed to evolve from certain types of bacteria that eukaryotic cells engulfed through endophagocytosis. Hence, they are considered as **endosymbiont** of the cell.

Differences between chloroplasts and mitochondria

Chloroplasts	Mitochondria
1. Chloroplasts are found in only specific types of plant cells.	1. Mitochondria are found in all animal and plant cells.
2. Chloroplasts contain pigments such as chlorophyll a, chlorophyll b and carotenoids.	2. Mitochondria do not contain any such pigments.
3. Chloroplasts are involved in photosynthesis.	3. Mitochondria are involved in cellular respiration.
4. Chloroplasts use light to convert carbon, derived from carbon dioxide into sugar.	4. Mitochondria break down simple sugars into carbon dioxide and release energy.
5. The electron acceptors in chloroplast is NADP.	5. The electron acceptors in mitochondria are NAD and FAD.
6. In chloroplast, ATP synthesizing energy comes from light hence called photo phosphorylation.	6. In mitochondria, ATP synthesizing energy comes from the oxidation of glucose, hence called oxidative phosphorylation.
7. Chloroplasts function under only light conditions.	7. Mitochondria function under both light and dark conditions.

3. Endoplasmic reticulum

Endoplasmic reticulum (ER) is a membrane-bounded organelle that occurs in endoplasm of eukaryotic cell, interconnected flattened sacs or tubules that is connected to the nuclear membrane, runs through the cytoplasm, and may well extend into the cell membrane. In the light microscope, it looks like a net in the cytoplasm hence named as endoplasmic reticulum. The name endoplasmic reticulum was coined in 1953 by **Keith R. Porter**, but it had first observed by **Keith R. Porter, Albert Claude**, and **Ernest F. Fullam** in 1945 in electron micrographs of liver cells. The endoplasmic reticulum occurs in most types of eukaryotic cells, but is absent from red blood cells and spermatozoa. They are present in huge number in liver, pancreatic and gland cells.

Physical structure: Morphologically endoplasmic reticulum occurs in the three forms:

1. Lamellar form or cisternae,
2. Vesicular form or vesicle and
3. Tubular form or tubules.

1. The Cisternae: Cisternae are flattened, unbranched, sac like elements with a diameter of 40-50 micron. They lie in stacks parallel to one another and the sacs in the stack are interconnected with one another. They coated with ribosomes.

2. The Vesicles: Vesicles are small, oval or rounded structure with a diameter of 25-50 micron.

3. The tubules: These are elongated and branched tube like structure with a diameter of 40-190 micron. Tubules are tube like extensions which may be connected with cisternae or vesicles to form a reticular system in the cytoplasm.

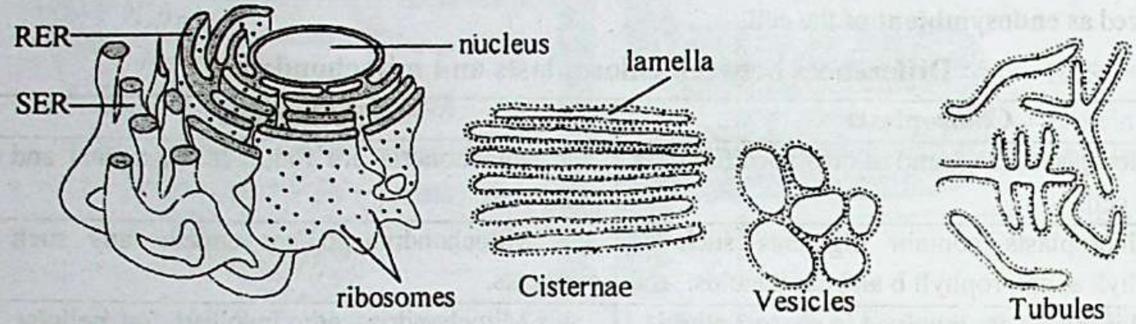


Fig 1.12 Different structures of endoplasmic reticulum

Chemical structure: The chemically endoplasmic reticulum composed of the following components:

(i) Protein 60 to70%, (ii) Lipid 30 to 40%, (iii) Enzymes of several types (more than 15) etc.

Most important ER enzymes include stearates, NADH-cytochrome C reductase, NADH-diapnoresis, glucose-6-phosphatase, glycosyl transferase and Mg^{++} activated ATPase.

Types: According to the structure, the endoplasmic reticulum is classified into two types, **rough endoplasmic reticulum** (RER)- is coated with ribosomes and **smooth endoplasmic reticulum** (SER)- without any ribosomal coating.

Differences between Smooth and Rough Endoplasmic Reticulum

Smooth Endoplasmic Reticulum (SER)	Rough Endoplasmic Reticulum (RER)
1. SER is not associated with ribosomes.	1. RER has ribosomes on the surface.
2. SER is observed as smooth in the microscope.	2. RER is observed as rough in the microscope.
3. These are mainly composed of tubules.	3. These are mainly composed of cisternae.
4. Generally, these are associated with plasma membrane.	4. Generally associated with nuclear membrane.
5. Main function is lipid synthesis and hence mostly seen in cells associated with synthesis of steroid hormones.	5. Main function is protein synthesis and hence mostly seen in cells associated with secretion of proteins.
6. SER responsible for liberating calcium during the contraction of muscles.	6. RER helps store up minerals such as calcium.

Functions: Endoplasmic reticulum performs following function in the cell:

1. The ER acts as an **intracellular supporting framework** that also maintains the form the cell.

2. It facilitates transport of materials from one part of the cell to another, thus forming the cells **circulatory systems.** The route of circulation is as follows:

RER → SER → Golgi complex → Lysosome

3. It keeps the cell organelles proper stationed and distributed in relation to one another.

4. It provides space for temporary storage of synthetic products such as glycogen.

5. Tubular ER extensions called **desmotubules** extend to the plasmadesmata to make ER continue in the two adjacent plant cells.

6. In muscle cells ER helps in muscle contraction by regulating calcium ions concentration in the sarcoplasm.

7. The smooth ER is responsible for a variety of vital cell processes that include carbohydrate metabolism, lipid synthesis, calcium storage, and drug and poison detoxification.

8. The smooth ER is the source of many important enzymes that important in lipid synthesis.

9. The smooth ER is responsible for **hydroxylating** drug or poison molecules to increase their solubility and aid removal of these harmful molecules from the system.

10. Ribosomes attached to the rough ER synthesize proteins that are secreted by a wide variety of cells including pancreatic cells, which produce and export insulin.

11. The rough ER is responsible for the covalent attachment of certain carbohydrates to specific proteins to form glycoproteins.

12. The rough ER is responsible for a great deal of membrane production in the cell and continues to grow by adding phosphlipids and proteins to itself.

4. Golgi apparatus


C. Golgi (1843-1926)

A major organelle dispersedly distributed in the cytoplasm of most eukaryotic cells is the structure of membrane-bound sacs called the **Golgi apparatus** or **Golgi body** or **Golgi complex** or **dictyosome.** It was identified in 1897 by the Italian physician **Camillo Golgi** during an investigation of the nervous system of an owl and named after him in 1898.

Their number per plant cell can vary from several hundred as in tissue of corn root and algal rhizoids to a single organelle in some algae. In animal cells, there usually occurs a single Golgi apparatus; however, its number may vary from animal to animal and from cell to cell. Golgi apparatus not found in mature sperm, red blood cell and prokaryotes.

Physical structure

Typically Golgi apparatus appears as a complex array of interconnecting cisternae, vesicles and tubules.

1. Cisternae: These are central, flattened, plate or saucer-like closed compartments which held in parallel stacks one above the others. Each cisterna with a diameter of 0.5-1 micrometer is bounded by a smooth unit membrane having a lumen of 500-1000 nanometer wide. In the stack cistern has a *cis face* on the rough ER side.and a *trans face* opposite of the rough ER. Based on position in the stack the cisternae are of three types- (i) last cisterna of trans face is **trans cisterna,** (ii) last cisterna of cis face is **cis-cisterna** and (iii) all middle cesternae of the stack is **medial cisternae.** The cisternae vary in number from 3-7 in most animal cells and from 10-20 in plant cells.

2. Vacuoles: Golgian vacuoles are expanded part of the cisternae which have become modified to form vacuoles. The vacuoles develop from the concave or maturing face. Golgian vacuoles contain amorphous or granular substance.

3. Vesicles: The Golgi apparatus works closely with the rough ER. When a protein is made in the ER, something called a **transition vesicle** is made. This vesicle or sac floats through the cytoplasm to the Golgi apparatus and is absorbed. After the Golgi does its work on the molecules inside the sac, a **secretory vesicle** is created and released into the cytoplasm. Most of the vesicles associated with cisternae and form **trans-Golgi network** (TGN).

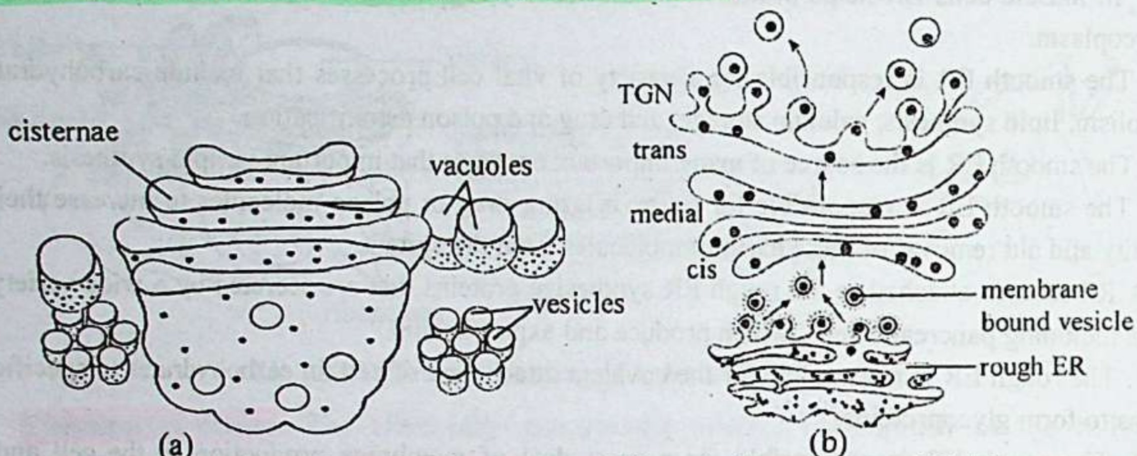


Fig 1.13 (a) Three dimensional structure and (b) vesicular transport of Golgi apparatus

Chemical structure

The membrane of the Golgi apparatus comprises of 60% protein and 40% lipid. It also carry fatty acid, Vitami K, carotinoid etc. Within their sacs there are several types of enzymes such as ADPase, ATPase, NADPH cytochrome-C-reductase, glycosyl transferases, thiamine pyrophosphatase etc.

Functions

Golgi apparatus is metabolically very active and many functions have been assigned to it. The main functions of Golgi apparatus are as below:

1. It acts to **process and package** the macromolecules such as proteins and lipids that are synthesized by the cell. The Golgi processes proteins and lipids made by the endoplasmic reticulum (ER) as lipoproteins before sending them out to the cell. Hence, these are called as **traffic police** of cell.

2. It is also involved in creation of lysosome and cell wall.

3. The Golgi apparatus synthesizes some simple carbohydrates such as galactos, sialic acid and certain polysaccharides, pectin compounds from simple sugars.

4. The Golgi apparatus links carbohydrates with proteins coming from ER to form glycol proteins. This process is called **glycolsylation.**

5. The production of hormones by endocrine glands is mediated through Golgi apparatus.

6. In many mammalian tumour and cancer cells the Golgi apparatus has been described as the site of origin of pigment granules (melanin).

7. Golgi apparatus takes part in formation of **sperm's acrosome** in mammals.

8. It accelerates mitochondria to synthesize ATP.

Difference between Golgi apparatus and Endoplasmic Reticulum

Golgi apparatus	Endoplasmic Reticulum
1. Golgi apparatus is an arrangement of few fluid-filled dishes.	1. Endoplasmic reticulum is a network of tubules and vesicles.
2. Cisternae in Golgi apparatus are not interconnected.	2. Cisternae in ER are interconnected with each other.
3. Golgi apparatus sorts, modifies, and delivers the components in a cell.	3. ER is much a structurally aiding organelle for metabolic activities.
4. Lysosomes are formed at the Golgi apparatus.	4. The enzymes in lysosomes are synthesized at RER.

5. Ribosome

Albert Claude
(1899-1983)

The ribosomes are minute, rounded, granular and dense particles that contain RNA and protein. They occur either freely in the matrix of mitochondria, chloroplast and cytoplasm or remain attached with the membrane of ER and nucleus. In 1940s **Albert Claude** obtained tiny particles of ribonucleoprotein and lipid what he called **microsomes.** Latter in 1955, Romanian cell biologist **George Palade** discovered these particles as ribosomes and described them as dense particles or granules in the cytoplasm. Actually, scientist **Richard B. Roberts** proposed the name 'ribosome' in 1958.

Types: According to the size and the sedimentation coefficient (S) two types of ribosome have been recognized, 70S ribosomes and 80S ribosomes.

(i) 70S Ribosome: These are comparatively smaller and have sedimentation coefficient 70S and molecular weight 2.7×10^6 Daltons. They occur in all prokaryotic cells (bacteria) and in mitochondria and chloroplast of eukaryotic cells.

(ii) 80S Ribosome: These are comparatively larger and have sedimentation coefficient 80S and molecular weight 40×10^6 Daltons. They occur in all eukaryotic cells.

Physical structure: The ribosomes are tiny particles **without a covering membrane** and have oblate spheroid structure of 150Å-200Å in diameter. Each ribosome consists of larger and smaller subunits. The larger and smaller subunits of 70S ribosome are respectively 50S and 30S. Similarly, the larger and smaller subunits of 80S ribosome are respectively 60S and 40S. The smaller subunit of ribosome occurs above the larger subunit like a cap.

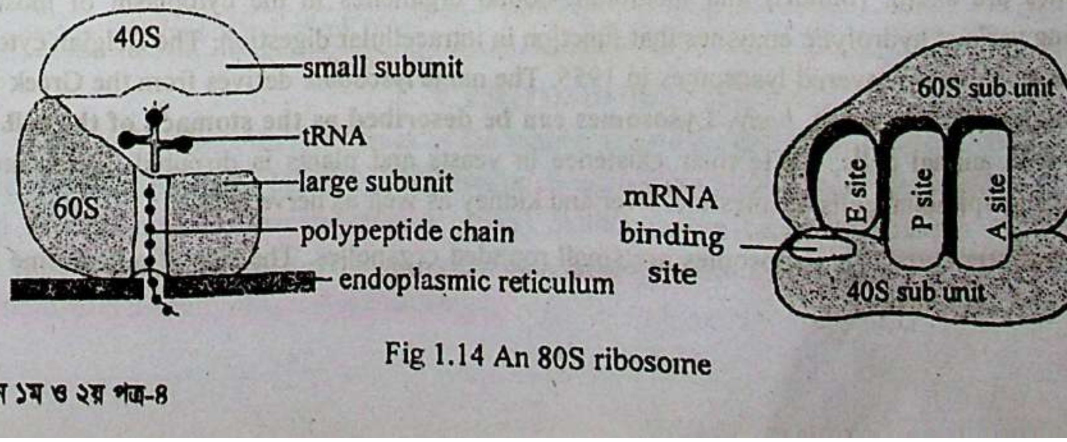


Fig 1.14 An 80S ribosome

The subunits of ribosome occur separately when ribosomes are not involved in protein synthesis. The two subunits join when protein synthesis starts, and during this time there are four sites are seen in ribosome. These are-A site (aminoacyl site), P site (peptidyl site), E site (exit site) and mRNA binding site. Many ribosomes line up on the mRNA chain during protein synthesis. Such a group of active ribosomes is called a **polyribosome**, or a **polysome**.

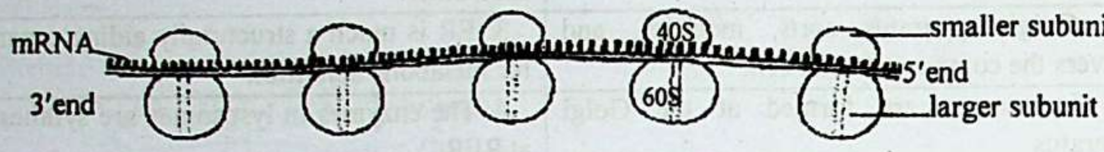


Fig 1.15 Polyribosome

A eukaryotic ribosome has a groove at the junction of the two subunits. From this groove, a tunnel extends through the large subunit and opens into a canal of the endoplasmic reticulum. The polypeptides are synthesized in the groove between the two ribosomal subunits and pass through the tunnel of the large subunit into the endoplasmic reticulum.

Svedberg unit/Sedimentation coefficient: A Svedberg unit (symbol S) is a unit for sedimentation rate. The unit is named after the Swedish chemist **Theodor Svedberg** (1884–1971), winner of the 1926 Nobel Prize in chemistry for his work on colloids and his invention of the ultracentrifuge.

Chemical structure: The prime chemical components of ribosome are 50% RNA and 50% protein at the ratio of 1 : 1. There are trace amounts of Mg^{++}, Ca^{++} and Mn^{++} present in the ribosome.The 80S ribosome contains 28S, 18S, 5.8S and 5S valued rRNA as well as 80 types of protein molecules. The 70S ribosome, on the other hand contains 23S, 16S and 5S valued rRNA as well as 50 types of protein molecules.

Functions:

1. Ribosomes are the sites in a cell in which **translation of protein synthesis** takes place.
2. They produced cytochrome, which transports electrons during cellular respiration.
3. According to **Laninger** (1959) the phosphorilation of glucose held in ribosomes.

6. Lysosomes

Lysosomes are small, rounded and membrane-bound organelles in the cytoplasm of most cells containing various hydrolytic enzymes that function in intracellular digestion. The Belgian cytologist Christian de Duve discovered lysosomes in 1955. The name *lysosome* derives from the Greek words **lysis,** *to separate*, and **soma,** *body*. **Lysosomes can be described as the stomach of the cell.** They are found in animal cells, while their existence in yeasts and plants is disputed. Lysosomes are abundance in epithelial cells of intestine, liver and kidney as well as nerve cells.

Physical structure: The lysosomes are small rounded organelles. The size of a lysosome varies from 0.2–0.8 micrometers.

Chemical structure: The membrane of lysosomes composed of protein, lipids and trace amount of carbohydrates. There lumens have dense liquid which contain more than 40 types of enzymes. The main enzymes are acid phosphatase, acid lipase, aryl salphatase, esterase, lysozyme etc.

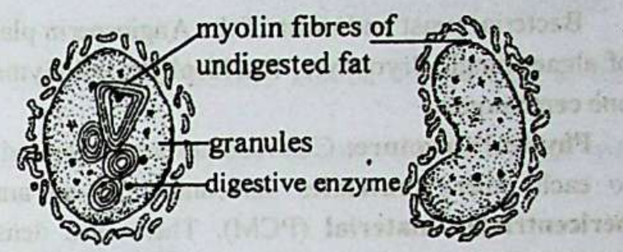


Fig 1.16 Two different lysosomes

Functions

1. Lysosomes digest excess or worn-out organelles, food particles, and engulf viruses or bacteria through the process of **phagocytosis.**

2. They fuse with autophagic vacuoles and dispense their enzymes into the autophagic vacuoles, digesting their contents.

3. They are frequently nicknamed **suicide-bags** or **suicide-sacs** by cell biologists due to their autolysis.

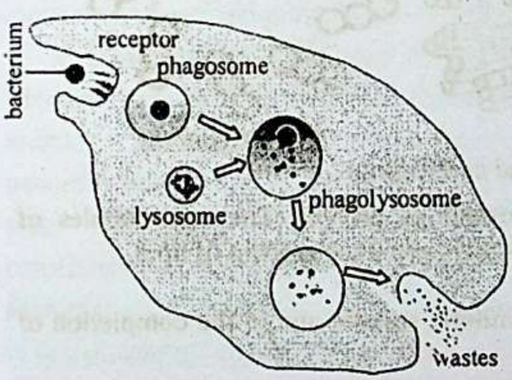


Fig 1.17 Phagocytosis process

4. They helping repair damage to the plasma membrane by serving as a membrane patch, sealing the wound.

5. They help in breaking the cellular and nuclear membrane during cell division.

6. They produce keratin within cells.

7. The enzymes they contain are so powerful that they can kill their host cell if released. This process is called **autophagy.**

8. In normal cells they enclosed different autophagal enzymes and thus save the cells.

Difference between Ribosome and Lysosome

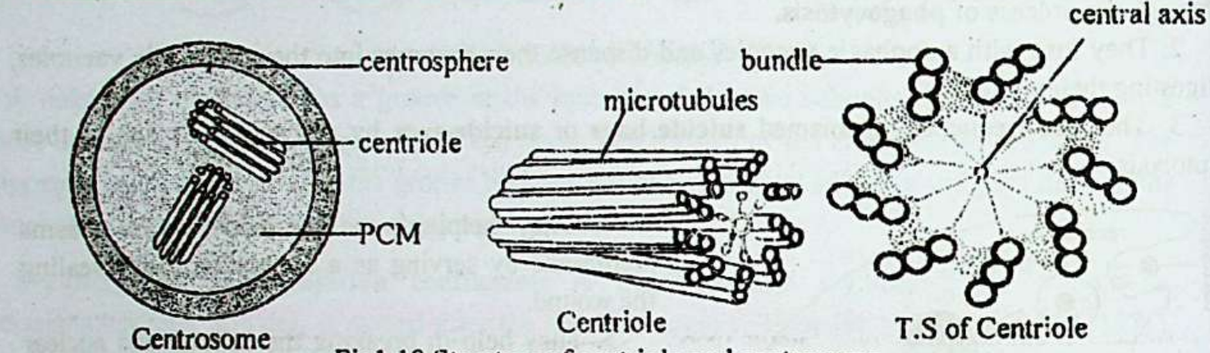
Ribosome	Lysosome
1. Ribosomes are found in bacteria, plant cell as well as animal cells	1. Lysosomes can be found in eukaryotic animal cells.
2. Not enclosed by a membrane	2. Enclosed by a membrane
3. Comparatively small, 20-30 nm in size.	3. Comparatively large, 0.1-1.2 μm in size.
4. Composed of rRNA and ribosomal proteins.	4. Composed of membrane protein and digestive enzymes.
5. Involved in the translation of mRNAs.	5. Involved in intracellular digestion.

7. Centrosomes

The centrosome is an organelle that serves as the main microtubule-organizing centre of the animal cell as well as a regulator of cell-cycle progression. **Edouard Van Beneden** discovered it in 1887, described and named by **Theodor Boveri** (1988). Although the centrosome has a key role in efficient mitosis in animal cells, it is not essential. Although the centrosome has a key role in efficient mitosis in animal cells, it is not essential.

Bacteria, yeast and most of the Angiosperm plant cells do not have centrosomes. However, cells of algae, fungi, Bryophyte, Pteridophyte and Gymnosperm have centrosomes. A cell contains only one centrosome.

Physical structure: Centrosomes are composed of two orthogonally arranged (lie at right angles to each other) **centrioles** surrounded by an amorphous mass of protein, referred to as the **pericentriolar material** (PCM). There is a dense solid area around the centrosome is called **centrosphere.** Each centriole is a long hollow cylinder about 0.3-0.5 micrometer long and about 0.2 micrometer diameter. The wall of each centriole is usually composed of nine triplets of microtubules that radiate from the central axis like spokes of wheel.



Figl.18 Structure of centriole and centrosome

Chemical structure: The prime component of centrosome is protein. The microtubules of centrioles contain the structural protein **tubulin.** Besides this there are trace amount of lipid.

Functions:

1. Centrosomes are involved in the organization of the mitotic spindle and in the completion of cytokinesis.
2. They form the basal bodies of cilia and flagella.
3. They play role in formation of the tail of sperm.

8. Cell Vacuole

A cell vacuole is a membrane-bound organelle, which is present in all plant and fungal cells and some protist, animal and bacterial cells. Vacuoles are essentially enclosed compartments which are filled with water containing inorganic and organic molecules including enzymes in solution. In a mature plant the large vacuole is surrounds by a membrane called **tonoplast.**

Vacuoles are formed by the fusion of multiple membrane vesicles and are effectively just larger forms of these. The organelle has no basic shape or size; its structure varies according to the needs of the cell.

Functions: The function and importance of vacuoles varies greatly according to the type of cell in which they are present. In general, the functions of the vacuole include:

1. Isolating materials that might be harmful or a threat to the cell.
2. Containing waste products.
3. Containing water in plant cells.
4. Maintaining internal hydrostatic pressure or turgor within the cell.
5. Maintaining an acidic internal pH.
6. Containing small molecules.

7. Allows plants to support structures such as leaves and flowers due to the pressure of the central vacuole.

8. In seeds, stored proteins needed for germination are kept in 'protein bodies', which are modified vacuoles.

9. Cytoskeleton

The cytoskeleton is a network of fibers composed of proteins contained within a cell's cytoplasm. Although the name implies the cytoskeleton to be stable, it is a dynamic structure, parts of which are constantly destroyed, renewed or newly constructed. The cytoskeleton of eukaryotes has three major components: microfilaments, microtubules and intermediate filaments.

1. Microfilaments: Microfilaments are one of the thinnest filaments of the cytoskeleton. They are composed of linear polymers of G-actin subunits, and generate force when the growing end of the filament pushes against a barrier, such as the cell membrane. They also act as tracks for the movement of myosin molecules that attach to the microfilament and walk along them.

2. Intermediate filaments: Intermediate filaments are a part of the cytoskeleton of all animals. These filaments, averaging 10 nanometers in diameter, are more stable than actin filaments, and heterogeneous constituents of the cytoskeleton. Like actin filaments, they function in the maintenance of cell-shape by bearing tension. Intermediate filaments organize the internal tridimensional structure of the cell, anchoring organelles and serving as structural components of the nuclear lamina. They also participate in some cell-cell and cell-matrix junctions.

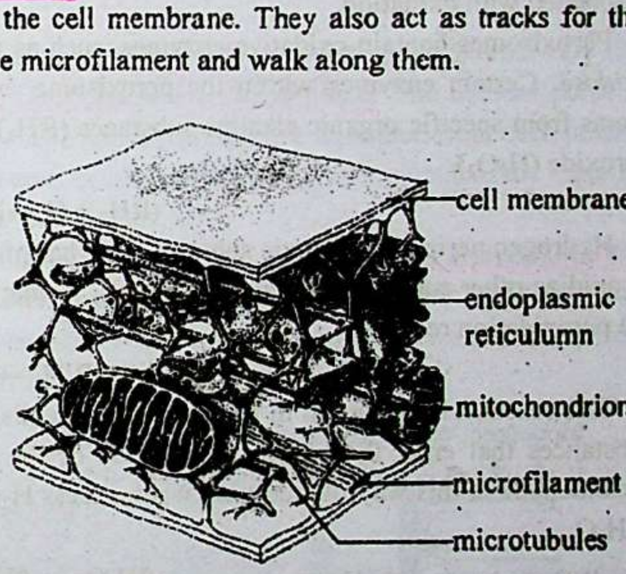


Fig 1.19 Cytoskeleton

3. Microtubules: Microtubules are hollow cylinders about 23 nm in diameter, most commonly comprising 13 protofilaments that, in turn, are polymers of alpha and beta tubulin. They have a very dynamic behavior, binding GTP for polymerization. They are commonly organized by the centrosome. In nine triplet sets, they form the centrioles and in nine doublets oriented about two additional microtubules (wheel-shaped), they form cilia and flagella.

Functions: There is a multitude of functions the cytoskeleton can perform:

1. It gives the cell shape and mechanical resistance to deformation.

2. Through association with extracellular connective tissue and other cells it stabilizes entire tissues.

3. It can actively contract, thereby deforming the cell and the cell's environment and allowing cells to migrate.

4. It is involved in many cell signaling pathways.

5. It is involved in the uptake of extracellular material.

6. It segregates chromosomes during cellular division.

7. It is involved in cytokinesis - the division of a mother cell into two daughter cells.

8. It provides a scaffold to organize the contents of the cell in space and for intracellular transport.

9. It can be a template for the construction of a cell wall.

10. It forms specialized structures such as flagella, cilia, lamellipodia and podosoms.

10. Peroxisome

Peroxisomes also called microbodies are very small (0.2-17 µm), enzyme filled organelles found in virtually all eukaryotic cells. Peroxisomes were identified as organelles by the Belgian cytologist **Christian de Duve** in 1967. Peroxisomes can be derived from the endoplasmic reticulum and replicate by fission. **A major function of peroxisomes is the breakdown of fatty acid molecules into acetyl CoA, through the process called β oxidation.** The peroxisomes, which take part in β oxidation are called **glyoxysomes.** Peroxisomes contain about 50 types oxidative enzymes which associated with oxidation.

Peroxisomes contain oxidative enzymes, such as *Catalase*, *D-amino acid oxidase*, and *uric acid. oxidase*. Certain enzymes within the peroxisome, by using molecular oxygen, remove hydrogen atoms from specific organic alkaline substance (RH_2), in an oxidative reaction, producing hydrogen peroxide (H_2O_2).

$$(RH_2 + O_2 \rightarrow R + H_2O_2)$$

Hydrogen peroxide is a toxic substance and harmful to the body. *Catalase* enzyme uses this H_2O_2 to oxidize other substrates, including phenols, formic acid, formaldehyde, and alcohol, by means of the peroxidation reaction.

$$H_2O_2 + R'H_2 \rightarrow R' + H_2O$$

This reaction is important in liver and kidney cells, where the peroxisomes detoxify various toxic substances that enter the blood. About 25% of the ethanol alcohol humans drink is oxidized to acetaldehyde in this way. In addition, when excess H_2O_2 accumulates in the cell, *catalase* converts it to H_2O.

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

In higher plants, peroxisomes contain also a complex battery of antioxidative enzymes such as superoxide dismutase and the NADP-dehydrogenases which take part in different important reactions.

11. Nucleus

The nucleus is a membrane bounded compact organelle found in the cytoplasm of all eukaryotic cells that control biological activity of the cell and contains the genetic materials. Most of the cells have a central nucleus but in some exceptional cases, there is more than one nucleus (*Paramecium, Opalina*). Although nucleus was observed first time by **Antonie van Leeuwenhoek**, but the actual credit for discovery of cell nucleus goes to Scottish botanist **Robert Brown** (1831).

Shape: The shape of the nucleus varies considerably. In most of the cells it is spherical in shape.

Size: Nucleus is the **largest organelle** of the cell. However, size of the nucleus is variable. The size of the nucleus is directly proportional to the cytoplasm. The more the volume of the cytoplasm the larger is the size of the nucleus. **R. Hertwig** has formulated a relationship between the nuclear volume and the cytoplasmic volume which is called the **nucleoplasmic index** (NP). The NP ratio acts as a stimulus to the cell division.

Chemical structure: The chemical structure of nucleus is very complex. The prime chemical components of nucleus are protein and nucleic acid. Besides these, there are water, lipid, enzyme, minerals etc. in trace amount.

Structure of an ideal Nucleus

In the interphase stage of cell division, the following four structures of nucleus have been observed:

1. Nuclear membrane: It is a double-layered membrane enclosing the nucleus of a eukaryotic cell and also called **nuclear envelope** or **nucleolemma** or **karyotheca.** It is penetrated by large **nuclear pores**. Endoplasmic reticulum and ribosomes are attached to the outer layer of nuclear membrane.

■ **Nuclear pores:** The nuclear membrane possesses a number of nuclear pores, which vary from 40 to 145 per square micro-meter in nuclei of various plants and animals. The nuclear pores are octagonal in shape, their diameter varies from 400-1000Å, and they are separated from each other by a space of 1500Å. The nuclear pores are enclosed by circular annuli. At the annulus, the inner and outer membranes of the nuclear envelope fuse.

The pores and annuli collectively form the **pore complex.** Each annulus consists of eight peripheral protein granules of about 15 nm, which are present on both the nuclear and cytoplasmic surfaces. Inside the pore is a central granule. Fine fibrils (about 30Å in diameter) extend from central protein granule to the peripheral granules, forming a cartwheel structure.

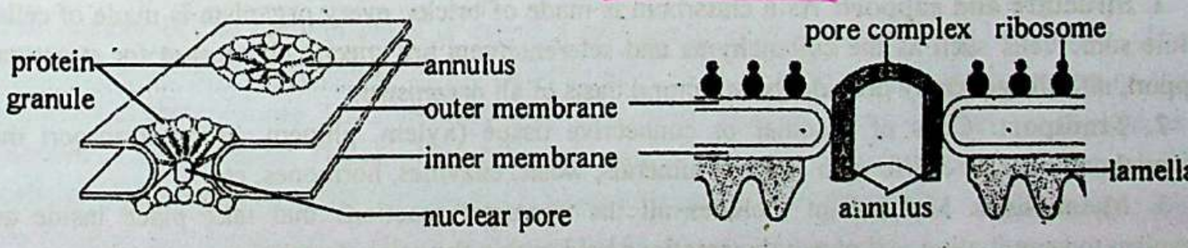


Fig 1.20 Different parts of nuclear membrane

2. Nucleoplasm: Nucleoplasm, also called nuclear sap or **karyolymph,** is the fluid usually found in the nucleus. This fluid contains primarily water, dissolved ions, nucleic acids, phosphoproteins, enzymes and a complex mixture of molecules.

3. Chromatin fibers: These are elongated thread like structures exist as coiled networks within nucleoplasm of nucleous also known as **nuclear reticulum**. They got the name chromatin (Gr, *chroma*=colour) because of their colourful nature during cell staining when viewing with the microscope. During cell division, these structures become condense into more tightly coiled wide threads called the **chromosomes**.

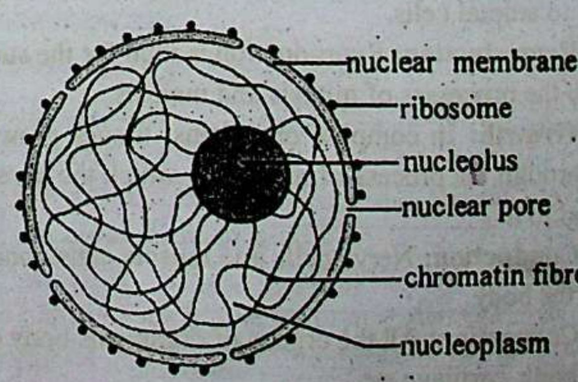


Fig 1.21 Structure of a nucleus

Actually, chromatins are composed of histon protein and DNA. However, trace amount of RNA is also present. Histon protein and DNA exist in chromatin in 1:1 ratio.

4. Nucleolus: The nucleolus is a discrete densely stained structure found in the nucleus. It is not surrounded by a membrane, and is sometimes called a sub-organelle. It forms around tandem repeats of rDNA, DNA coding for ribosomal RNA (rRNA). These regions are called **nucleolar organizer regions** (NOR). Chemically nucleolus composed of protein, lipid, DNA and RNA.

Functions of Nucleus

The nucleus is considered the brain of the cell. It directs all processes. That is where the vast majority of the cell's DNA is located, and that controls all of the cell's functions by directing protein synthesis. The main functions of nucleus of a cell are:

1. Metabolism: Nucleus controls majority of the cell activities. It is a regulatory organelle in cell metabolism.

2. Heredity: Since the nucleus contains DNA molecules in its chromosomes, it plays a significant role in heredity.

3. Differentiation: It controls cell differentiation during the embryonic development.

4. Exchange of materials: Nuclear membrane is concerned with the exchange of materials between the cytoplasm and nucleoplasm.

5. Support: Nuclear membrane provides a surface for the attachment of structural elements of the cytoplasm such microtubules and microfilaments.

6. RNA Synthesis: The synthesis of RNA occurs with in nucleus. From these RNAs ribosome, :RNA and various proteins are formed.

Role of cells in different activities of organisms

1. Structure and support: As a classroom is made of bricks, every organism is made of cells. While some cells such as the collenchyma and sclerenchyma are specifically meant for structural support, all cells generally provide the structural basis of all organisms.

2. Transport: Cells of vascular or connective tissue (xylem, phloem, blood) transport the essential components of life such as food, minerals, water, enzymes, hormones, etc.

3. Metabolism: Metabolism includes all the chemical reactions that take place inside an organism to keep it alive. All metabolic reactions held within the cells of organism.

4. Energy production: An organism's survival depends upon the thousands of chemical reactions that cells carry out relentlessly. For these reactions, cells require energy. Most plants get this energy through the process of photosynthesis whereas respiration is the mechanism that provides energy to animal cells.

5. Reproduction: Reproduction is vital for the survival of a species. A cell helps in reproduction through the processes of mitosis and meiosis.

6. Growth: In complex organisms, tissues grow by simple multiplication of cells. This takes place through the process of mitosis in which the parent cell breaks down to form two daughter cells identical to it.

7. Conduction: Nerve cells and muscle cells conduct electric impulses from one part to another part of the body.

8. Connection: All the organs of organisms body stay connected with the help of vascular tissue, blood, bone, cartilage etc.

9. Secretion: Cells of different glands always secrete enzymes, hormone and other essential components of organisms

10. Vision: Vertebrate vision accomplished by rod cell and cone cell of the eye.

11. Digestion and absorption: Cells of digestive system participate in digestion and absorption of food materials.

12. Excretion: Nephroidal cells of kidney play key roles in discharge nitrogenous excretory wastes from the body.

13. Defense: WBC and other phagocytes engulf microbes and produced antibody and thus take part in defense of the body.

14. Homeostasis: All cells of the body perform different tasks and thus maintain physiological and biochemical homeostasis of the body of organism.

1.4 Chromosome

Chromosome is an organized structure of DNA and protein that is found in the nucleus of eukaryotic cell. It is a single piece of coiled DNA containing many genes, regulatory elements and other nucleotide sequences. Chromosomes also contain DNA-bound proteins, which serve to package the DNA and control its functions. **Karl Nagli** (1842) first of all observed chromosomes in the nuclei of plant cells. **E. Strasburger** (1875) discovered thread-like structures which appeared during cell division. **Walter Flemming** (1878) introduced the term **chromatin** to describe the thread-like structures of nucleus. The present name chromosome (Greek *chroma-* colour and *soma-* body) was coined by **W. Waldeyer** (1888) to darkly stained bodies of nucleus. **W. S. Sutton and T. Boveri (1902) suggested that chromosomes are the physical structures which act as messengers of heredity.** The number of human chromosomes was published in 1921 by **Theophilus Painter.**

The number of the chromosomes is constant and unchangeable for a particular species. The number or set of the chromosomes of the gametic cells such as sperms and ova is known as the **haploid** sets of chromosome. The somatic or body cells of the most organism contain two haploid set and known as **diploid** cells. The number of chromosome of the most organisms is undetermined. In the cells of higher organisms the number of chromosome ranges from 20 to 50. Among animal the lowest number of chromosome is found in the nematode, *Ascaris megalocephalus* which has only 2 chromosome (2n=2) and the highest number is found in protozoa, *Aulacantha* which have, 2n=1600 hromosomes. Among angiospermic plants, lowest chromosome number found in *Haplopappus gracilis* (2n=4) and highest in *Poa littarosa* (2n=506-530). The fern species, *Ophioglossum reticulatum* have the highest number, 1200 chromosomes per cell.

Following table demonstrates the number of chromosome of some organisms:

Common name	Scientific name	Chromosome (2n)	Common name	Scientific name	Chromosome (2n)
Maize	*Zea mays*	20	Roundworm	*Ascaris megalocephalus*	2
Wheat	*Triticum aestivum*	42	Silkworm	*Bombyx mori*	46
Tomato	*Lycopersicon esculentum*	24	Gueinipig	*Cavia porcellus*	64
Cabbage	*Brassica oleracea*	18	Gorilla	*Gorilla gorilla*	48
Potato	*Solanum tuberosum*	48	Human	*Homo sapiens*	46

Physical structure: The size of chromosome is normally measured at mitotic metaphase. Most metaphase chromosomes fall within a range of 3 micrometer in fruit fly *Drosophila*, to 4-6 micrometer in man and 8-12 micrometer in maize. Normally chromosomes are not visible in light microscope, but in the metaphase of cell division, these structures are visible in a compound microscope. Compounds microscopic view of chromosome reveals the following structures:

1. Pellicle: It is the outer thin but doubtful covering or sheath of the chromosome.

2. Matrix: Matrix or ground substance of the chromosome is made up of proteins, small quantities of RNA and lipid.

3. Chromonemata: They are coiled threads that form the bulk of chromosomes. A chromosome may have one or two chromonemata. **Vejdovsky** (1912) called the coiled filament as chromonema. The coils may be of the following 2 types

(i) Paranemic coils: When the chromonemal threads are easily separable from their coils then such coils are known as paranemic coils.

(ii) Plectonemic coils: When the chromosomal threads remain inter-twined so intimately that they cannot be separate easily is known as plectonemic coils.

4. Chromomeres: Chromomeres are linearly arranged bead-like and compact segments described by **J. Bellings.** They are identified by their characteristic size and linear arrangement along a chromosome.

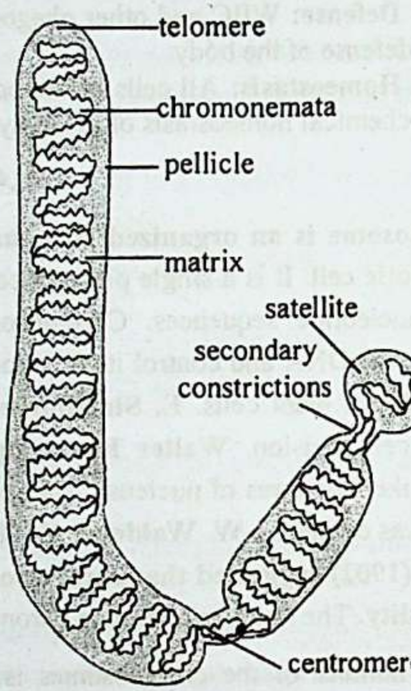


Fig 1.22 A chromosome

5. The primary constriction or Centromere: A part of the chromosome is marked by a constriction. It is comparatively narrow than the remaining chromosome. It is known as primary constriction or centromere. The centromere divides the chromosome into two arms. The centromere is associated with the chromosomal movement during cell division.

6. The secondary constrictions: Besides centromere, which produces a primary constriction in chromosomes, a **secondary constriction** observe in some chromosomes. In some cases secondary constriction take part in organize nucleolus, than it is called **nucleolar organizer.**

7. Satellite: Such a secondary constriction if present in the distal region of an arm would pinch off a small fragment called **trabant** or **satellite**. Chromosomes having a satellite are marker chromosomes and are called **SAT-chromosomes.**

8. Telomeres: The chromosome extremities or terminal regions on either side are called **telomeres.** If a chromosome breaks, the broken ends can fuse due to lack of telomeres. A chromosome, however, can not fuse at the telomeric ends, suggesting that a telomere has a polarity which prevents other segments from joining with it.

Types of chromosome

➤ Based on the number of centromeres, the chromosomes may be of the following types-

(1) Monocentric- with one centromere.

(2) Dicentric- with two centromeres, one in each chromatid.

(3) Polycentric- with more than two centromeres.

(4) Acentric- without centromere. Such chromosomes represent freshly broken segments of chromosomes, which do not survive for long.

(5) Diffused or non-located- with indistinct throughout the length of chromosome.

➤ Based on the location of centromere the chromosomes are categorized into following types-

(1) Telocentric: These are I or rod-shaped chromosomes with centromere occupying a terminal position. One arm is very long and the other is absent.

(2) Acrocentric: These are J or rod-shaped chromosomes having subterminal centromere. One arm is very long and the other is very small.

(3) Submetacentric: These are L shaped chromosomes with centromere slightly away from the mid-point so that the two arms are unequal.

(4) Metacentric: These are V shaped chromosomes in which centromere lies in the middle of chromosomes so that the two arms are almost equal.

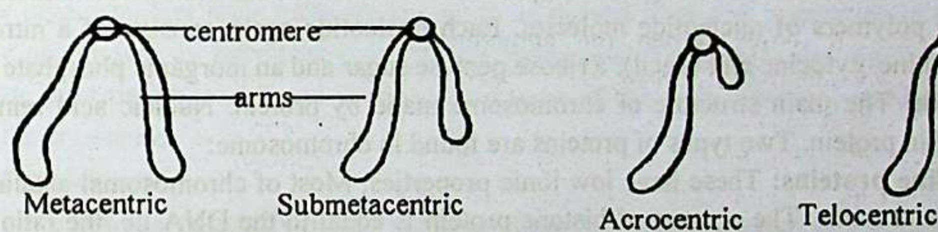


Fig 1.23 Different types of chromosome

➤ **Giant chromosomes:** There are some chromosomes, which are extremely large compared to normal chromosomes. Such chromosomes, called **giant chromosomes** occur in some animal cells. Two types of giant chromosomes are known as:

1. Lamp brush chromosomes: These chromosomes occur in the oocytes (germcells in the ovary) of amphibians and in some insects. They measure about 1500 to 2000 µm in length. A lamp brush chromosome consists of an axis from which paired loops extend in opposite directions, giving the appearance of a lamp brush. The axis consists of chromomeres and interchromomere regions. The loops consist of transcriptionally active DNA which can synthesize large amount of mRNA, necessary for the synthesis of yolk.

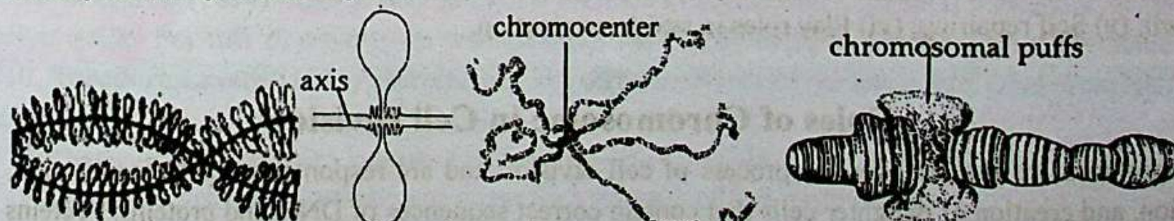


Fig 1.24 The giant chromosomes (a and b Lamp brush; c and d Polytene)

2. Polytene Chromosomes: The giant chromosomes, which found in the salivary gland cells of the fruit fly *Drosophila*, is called **polytene chromosome** or **salivary gland chromosome.** They are many times larger than the normal chromosomes reaching a length of 2000 µm and are visible even under a compound microscope. The polytene chromosomes appear to contain five long and one short arm radiating from a central point called chromocentre. The arms show characteristic dark bands and light bands. The dark bands are euchromatic regions. Some of the dark bands temporarily swell up and form enlargements called **chromosomal puffs** or **Balbiani rings**. These regions contain actively transcribing DNA involved in the synthesis of RNA types.

Chemical structure of chromosome: Chemically chromosomes are mainly composed of nucleic acids and protein. There are trace amount of lipid, enzymes, Ca^{2+} and Mg^{2+} are exist in the chromosome.

1. Nucleic acid: The largest molecule of the cell is the nucleic acid. Chromosomes have two types of nucleic acids *viz;* (i) Deoxyribo Nucleic Acid or DNA and (ii) Ribo Nucleic Acid or RNA.

(i) DNA: This is the permanent component of chromosome. Among all components DNA contribute 45%. Actually, this is a double-strand polymers of nucleotide molecles. Each nucleotide again consists of a nitrogen bases (adenine, guanine, cytocine and thymine), a deoxyribose pentose sugar and an inorganic phosphate molecule.

(ii) RNA: This is temporary component of eukaryotic chromosome but permanent genetic components of some virus. Among all components RNA contribute 0.2-1.4%. Actually this is a single-strand polymers of nucleotide molecles. Each nucleotide again consists of a nitrogen bases (adenine, guanine, cytocine and uracil), a ribose pentose sugar and an inorganic phosphate molecule.

2. Protein: The main structure of chromosome made by protein. Nucleic acid remains linear arranged within protein. Two types of proteins are found in chromosome:

(i) Alkaline proteins: These have low ionic properties. Most of chromosomal alkaline proteins are of histone protein. The amount of histone protein is equal to the DNA i.e. the ratio of histone protein and DNA is 1:1 in chromosome. Another type of alkaline protein protanmine is found only in sperm.

(ii) Acidic proteins: These are non-histone proteins having high ionic properties. Chromosomes have several types of acidic proteins but they content more DNA polymerase and RNA polymerase.

Functions of chromosome:

Chromosomes carry all necessary information to carry out different functions of the cell or incense it is the genes in the chromosomes, which guide the cell in performing different functions like-

(i) Guiding the cell in cell division; (ii) Plays an important role in inheritance of characters from generation to generation; (iii) Guiding protein synthesis; (iv) Control all the metabolic functions of the cell; (v) Self repairing; (vi) Play roles in sex determination.

Roles of Chromosome in Cell Division

Chromosomes are essential for the process of cell division and are responsible for the replication, division, and creation of daughter cells that contain correct sequences of DNA and proteins. Proteins make up for one of the most important components of the human body. They are responsible for building muscles and tissues, growth and repair, as well as the synthesis of thousands of enzymes, like DNA replication enzymes produced by the body. Protein synthesis steps and their successful completion is the responsibility of genes that are contained in chromosomes.

Cell division is a continuous process that must occur for an organism to function, whether for growth, repair, or reproduction. During cell division stages, the chromosome is responsible for the replication and distribution of DNA amongst new cells.

It is also crucial that reproductive cells, such as eggs and sperm, contain the right number of chromosomes and that those chromosomes have the correct structure. If not, the resulting offspring may fail to develop properly. For example, people with **Down syndrome** have three copies of chromosome 21, instead of the two copies found in other people. In humans, defective chromosomes made up of joined pieces of broken chromosomes cause one type of **leukaemia** and some other **cancers.**

For an organism to grow and function properly, cells must constantly divide to produce new cells to replace old, worn-out cells. During cell division, it is essential that DNA remains intact and evenly distributed among cells. Chromosomes are a key part of the process that ensures DNA is accurately copied and distributed in the vast majority of cell divisions.

1.5 Genetic materials or Hereditary materials

Heredity is the passing of traits to offspring from its parents or ancestors. This is the process by which an offspring cell or organism acquires or becomes predisposed to the characteristics of its parent cell or organism. Heritable traits are known to be passed from one generation to the next via the materials are known as **hereditary** or **genetic materials.** The molecules **nucleic acids** that encode genetic information and found in the chromosome of the cells are recognized as hereditary materials of the organisms.

Definition of nucleic acid

Nucleic acids are the naturally occurring long chain polymers present in the nucleus of the cell, capable of being broken down to yield phosphoric acid, sugars and a mixture of organic bases and play the prime role in inherited characteristics of every living organisms by directing the process of protein synthesis.

These are the largest and significant biomolecules of the cell and carrying all the traits of heredity, hence known as **master molecules**. Although nucleic acids are mainly present in the nucleus of the cell, they also found in mitochondria, plastid, ribosome and cytoplasm.

Discovery:

Nucleic acid was discovered as **nuclein** by Swiss physician and biologist **Friedrich Miescher** in 1869 from the nuclei of white blood cells. **Altmann** (1889) named the nuclein as nucleic acids. **Albrecht Kossel** (1894) isolated and described the nitrogenous bases, sugar and phosphoric acids of nucleic acids. For this discovery, he was awarded the Nobel Prize in Physiology or Medicine in 1910. **Theodore Levene** (1921) characterized the different forms of nucleic acids, DNA from RNA.

Functions:

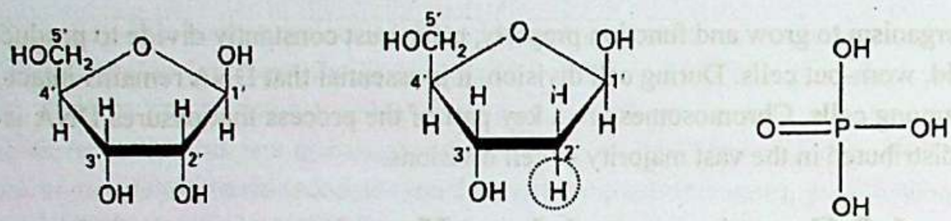
- The main functions is to store and transfer genetic information.
- To use the genetic information to direct the synthesis of new protein.

Chemical structure

Chemically nucleic acid is a polymer of nucleotide molecule. Each nucleotide composed of the following molecules:

1. One molecule of pentose sugar,
2. One molecule of inorganic phosphoric acid and
3. One molecule of nitrogenous base.

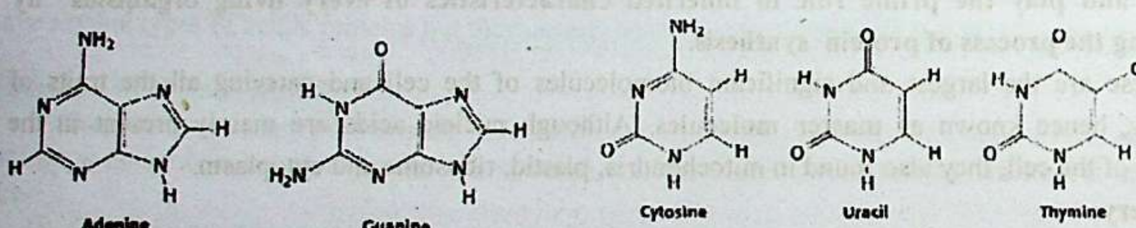
1. Pentose sugar: Each nucleic acid has a 5-carbon sugar as a part of its polymer backbone called pentose sugar. Nucleic acid has two types of pentose sugar, *viz.,* ribose and deoxyribose. β-D ribose or deoxyribose sugar of cyclic structure contribute to form nucleic acid. Both have the similar molecular structure but in deoxyribose sugar an oxygen atom is lacking in carbon 2 position of pentose structure (*deoxy*=lack of oxygen). Hence, it is also known as 2-β-D deoxyribose sugar.



ribose sugar deoxyribose sugar phosphoric acid

2. Inorganic phosphoric acid: The another part of the nucleic acid is a phosphoric acid (H_3PO_4). It is attached to the sugar molecule in place of the -OH group on the 5' carbon.

3. Nitrogenous base: Nucleic acid has two types of nitrogenous base,- purine bases and pyrimidine bases. Purine bases have two rings of atoms and chemical formula $C_5H_4N_4$.Nucleic acid has two purine bases as adenine and guanine. Pyrimidine bases have a single ring of atoms and chemical formula $C_4H_4N_2$. Nucleic acid has three pyrimidine bases as Cytosine, Thymine and Uracil. The nitrogen bases of nucleic acid are abbrebiated with their first letter (- A=Adenine, G=Guanine, C=Cytosine, T= Thymine and U= Uracil) when to write genetic codes. A nucleic acid of any type (DNA or RNA) has any four of nitrogen bases.



PURINES PYRIMIDINES

❐ Nucleoside: One molecule pentose sugar bounds to a nitrogenous base (adenine, guanine, cytosine, thymine, or uracil) with β-glycosidic likage to form a nucleoside molecule. The nucleosides with ribose and deoxyribose sugar are called **ribonucleoside** and **deoxyribonucleoside,** respectively. Based on the sugar and nitrogenous bases the nucleosides are of following types:

Nitrogen bases	Ribonucleoside	Deoxyribonucleoside
Adenine (A)	Adenosine	Deoxyadenosine
Guanine (G)	Guanosine	Deoxyguanosine
Cytosine (C)	Cytidine	Deoxycytidine
Thymine (T)	-	Deoxythymidine
Uracil (U)	Uridine	-

❐ Nucleotide: One molecule inorganic phosphate bounds to a nucleoside to form a nucleotide. Actually, nucleotide consists of a nitrogenous base, a sugar (ribose or deoxyribose) and a phosphate.