Cell

It is the small mass of protoplasm bound by membrane and containing different cellular organelles in it. It is the smallest unit of living organism. It can perform the life activities and exhibit independent of any other living system.

It plays vital role in developing definite structure and conducting various functions in organisms. Hence, is known as structural and functional unit of living organism.

Cell was first observed by Robert Hooke (1665) in cork tissue after the invention of compound microscope. The word cell is derived from Latin word 'cella' which means empty room. Later in 1674, Antony Van Leeuwenhoek first observed living cells in unicellular organisms.

Cell Theory:

Matthisa Jakob Schleiden (1804-1881)(1838), a Belgian botanist and Theodore Schwann (1839), a German zoologist put forward some concept about cell independently. Both of them had common concept about cell. Hence, both of them discussed and formulated cell theory.

The cell theory comprises into following points.

a. All organisms are made up of smallest units which are the smallest living entities.
b. Each cell comprises protoplasm with nucleus and bounded by plasma membrane.
c. All cells are basically similar in their structure and function.
d. Function of an organism is the sum total of activities and interaction of its constituent cells.
e. New cells are produced from the pre-existing cells.
f. The structure and function of the cell are controlled by DNA.

Difference between unicellular and multicellular organisms:

Unicellular organism	Multicellular organism
1. They are made up of single cell.	1. They are made up of several cells.
2. They are simple and smaller in size.	2. They are larger in size.
3. All metabolic activities perform by single cell.	3. Different functions are carried by different cells.
4. They are unable to exhibit wide range of functions.	4. Various functions show by various types of cells.
5. The death of cell leads death of organism.	5. The death of any cell does not affect the organism.
6. Growth of organism is caused by the cellular growth.	6. Cell division and cellular growth result the growth of organism.

Difference between plant cell and animal cell:

Plant cell	Animal cell
1. The cell is covered by cell wall.	1. The cell is covered by cell membrane.
2. Cells are generally polygonal in shape.	2. Cells are generally oval in shape.
3. Nucleus is slightly shifted to periphery.	3. Nucleus lies centrally.
4. It contains plastids.	4. It doesn't contain plastids.
5. Mitochondria are fewer in number.	5. Mitochondria are numerous in number.
6. It lacks centrioles.	6. It contains centrioles in a pair.
7. It consists of single large vacuole.	7. It consists of numerous small vacuoles.

Difference between prokaryotic cell and eukaryotic cell:

Prokaryotic cell	Eukaryotic cell
1. These are primitive type of cell.	1. These are advance type of cells.
2. Nucleus is not covered by nuclear membrane.	2. Nucleus is covered by nuclear membrane.
3. Other cell organelles are wanting.	3. Other cell organelles are well developed.
4. Cell wall, if present, made up of peptidoglycan.	4. Cell wall, if present, made up of cellulose.
5. Mesosome is present instead of mitochondria.	5. Mitochondria are present as power house of cell.
6. Photosynthetic organism consists of thylakoid membrane.	6. Photosynthetic organism consists of plastids.
7. 70s type of ribosome is present.	7. 70s and 80s types of ribosome are present.
8. Genetic material is either DNA or RNA.	8. Genetic material is DNA.

Cell Organelles:

These are living components of cell that perform specific function for a cell. They are also known as protoplasmic bodies or organoids.

Basically, they are divided into two groups. They are membrane bound organelles and membraneless organelles.

1. **Cell wall:** It is rigid and protective covering of all plant cells. It is generally living and permeable in young stage but after getting maturity it becomes non-living and impermeable.
   It was first observed by Robert Hooke in 1665.
   A plant cell wall contains following parts.
   a. **Middle lamellae:** It is the first layer that forms during cytokinesis. It is thin, amorphous cemented layer between two adjacent cells. It is made up of calcium and magnesium pectates along with protein molecules.
   b. **Primary wall:** It is first formed wall which is produced inner to the middle lamellae. It is thin, elastic and extensively growing parts.
   c. **Secondary wall:** It is formed inner to the primary wall due to the deposition of lignin. It is thick and rigid wall. It may contain suberin, minerals, waxes, tannins, resins, gums, inorganic salts etc.

   Plasmodesmata: The cell wall is interrupted at places by the narrow pores known as plasmodesmata. It interlinks the contents of the cells.
   Pits: Pits are the areas on cell wall where secondary wall is not formed.
   Figure:
   Functions:
   a. It gives definite shape to the cell.
   b. It provides mechanical strength to the cell.
   c. It gives rigidity to the cell.
   d. It prevents the brusting of plant cells due to endosmosis.
   e. The cell wall takes part in offense and defense.
   f. Deposition of cutin and suberin prevent excessive evaporation.

2. **Cell membrane:** It is the outermost layer of animal cell and second layer of plant cell. It is extremely delicate, thin, elastic, microscopic and trilaminar living membrane. It is semi-permeable and regenerative in nature. It is also known as plasma membrane or plasmalemma.
   The name cell membrane was given by Nageli and Crames (1855) and renamed as plasmalemma by Plowe (1931).
   It is present in both prokaryotic and eukaryotic cells. It lies on the outer side of protoplast and separates it from external environment. It is about 75A^{o} in thickness.
   Chemically it contains proteins (60-70%), lipids (20-40%) and carbohydrates (1-5%). Proteins may be structural, enzymatic or carrier. Lipids are generally phospholipids which are amphipathic molecule. It consists of polar hydrophilic heads of glycerol or its derivatives and non-polar hydrophobic tail of fatty acid. Carbohydrates are generally oligosaccharides as glycolipids and glycoproteins.

A glycoprotein may have many oligosaccharide side chains whereas a glycolipid has only one.

Regarding the structure of cell membrane, various models have been proposed. Among them, two models have been discussed below.

A) Sandwitch model: James Danielli and Hugh Davson (1935) proposed the lipid bilayer model which is also known as sandwitch model.

According to them, cell membrane is a double phospholipid layer is surrounded on either side by globular protein. The hydrophobic or non-polar tails of lipid lies towards the inner side and hydrophilic polar head lies towards outer side.

It states that:

a) Cell membrane is a lipoproteinous and trilaminar membrane.
b) It is transparent phospholipid bilayer surrounded by denser protein layer. Hence, it is protein-lipid-protein sandwitch.
c) It contains globular protein that makes cell membrane stable.
d) Phospholipid is an amphipathic molecule.
e) Cell membrane also bears pores.

Figure:

Drawbacks:

a) It doesn't mention about the functional specificity and variability in biomembranes.
b) Active transport has not been discussed.

B) Fluid mosaic model: S. Jonathan Singer and Garth Nicolson (1972) proposed this model. It is the most accepted model. It explains cell membrane as viscous lipid bilayer having proteins at mosaic on both surfaces and in the middle. According to it, cell membrane is formed of protein icebergs in a sea of lipids.

It states that:

a) Cell membrane is a lipoproteinous and trilaminar membrane.
b) Phospholipid bilayer is fluidy in nature. The molecules show transition (horizontal) and flip-flop movement.
c) Cell membrane consists of extrinsic (peripheral, 30%) and intrinsic (integral, 70%) globular proteins.
d) Phospholipid bilayer molecules are of amphipathic.
e) Carbohydrates generally oligosaccharides are present in outer surface of cell membrane in the form of glycoproteins and glycolipids.

Figure:

Functions:

a) It helps the cell in maintaining its shape.
b) It provides protection to the internal contents of the cell.

c) It helps in osmosis due to its semi-permeable nature.
d) It also intake solid and liquid materials by the process of endocytosis.
e) It can take part in active transport.
f) It helps to eliminate large sized molecules from cell by the process of exocytosis.

3. **Cytoplasm:** It is the substance present in between plasma membrane and nucleus. It is an amorphous, translucent, homogenous colloidal substance.
Chemically, cytoplasm consists of various inorganic and organic compounds including sodium, potassium, salts, nucleotides, vitamins, sugars, RNAs, amino acids, protein etc. It contains about 75-85% of water.
In eukaryotic cells, the cytoplasm shows streaming movement around vacuole which is known as cyclosis.

Functions:
a. It supplies raw materials to most of the cell organelles.
b. It helps cell organelles to exchange material between them.
c. Various types of biomolecules as lipid, proteins, nucleotides, carbohydrates are synthesize in this region.
d. It plays the role in proper distribution of various materials inside the cell.

4. **Mitochondria:** They are the largest cellular organelle of animal cell. They are only present in eukaryotic cell except mature and old RBC. They are variable in shape which may be granular, fibrillar, spherical, oval or discoid. The number and size of mitochondria differ on the basis of metabolic state of a cell. They are widely distributed in growing, dividing and metabolically active cells.
Mitochondrion was first discovered by Kolliker (1880) in striated muscles of insects and called sacromere. Later on Christian Benda (1898) renamed it as mitochondria (Gk: mito - thread, chondrion - granule).
Each mitochondrion is double membranous structure, inner membrane and outer membrane. Both membranes are made up of phospholipid bilayer and proteins.
The outer membrane is smooth which composed about equal amount of protein and phospholipid. It covers entire organelle. It contains large number of porin (integral proteins) that makes it permeable. The inner membrane is not smooth and impermeable. It consists about 80% of protein. It produces finger like projections towards inner sides is known as cristae. It expands the surface area of inner membrane. Cristae contain small knob-like bodies known as F_1 particles or oxysomes. Oxysomes are placed at regular intervals along the

length of cristae. Each cristae contains a spherical head, a long stalk and rectangular base. The head contains enzyme ATPase or ATP synthatase that helps in oxidation and phosphorylation process.

There is the space between inner and outer membrane which is filled by liquid. It contains ions, sugars, salts, proteins, organic acids etc. Inner to inner membrane, it is filled with dense proteinaceous material known as matrix. It is usually homogeneous but sometime contains dense granules. The matrix contains highly concentrated mixture of enzymes, 70s type ribosome, tRNA, DNA genome.

Mitochondria contain their own DNA molecule, 70s ribosome, large number of enzymes, amino-acids, minerals, sugars. Hence, they are capable to synthesize about 30 different proteins. They depend upon cytoplasmic ribosome for those proteins which cannot synthesize themselves. Due to this, they are not depend nuclear DNA completely to fulfill their protein requirement. Therefore, mitochondria are called semi-autonomous organelle.

Figure:

Functions:

a. They are primary site of ATP synthesis. Hence, are called power house of cell.
b. They control the formation of yolk.
c. They help to regulate calcium inside the cell.
d. Some amino-acids are synthesized by themselves.
e. They are the site of haeme synthesis of haemoglobin and myoglobin.

5. Plastids: It is the cell organelle which contains different colour pigments in it. It is one of the larger cell organelle found in eukaryotic plant cell. It is absent in prokaryotes, fungi and animal cell.

The term 'plastid' was given by Ernest Haeckel in 1865.

It is double membranous structure that again classified into three main groups on the basis of presence or absence of different colour pigments. These plastids have ability to interchange its form from one to another.

Types of plastids:

On the basis of colour pigments, plastids are classified into three main groups.

i. Chloroplast: It is the most common plastids present in almost all of the plants except fungi. The shape, size and number of the chloroplast vary greatly. In higher plants, they are mainly ovoid, spherical, discoid or lens shaped.

Each chloroplast is covered by two lipoproteinous membranes. The outer membrane is smooth, less proteinous and permeable. The inner membrane

is less permeable and high proteinous. The inner membrane contains a denser, colourless and granular ground material known as matrix or stroma. The stroma contains starch grains, lipids, circular double stranded DNA, 70s ribosome, numerous enzymes, water and minerals. Hence, it is also referred as semi-autonomous organelles.

There is also presence a series of internal parallel membranous sheet called lamellae. Lamellae remain suspended in stroma. The lamellae are combined to form sac like structure called thylakoid. Thylakoids are flattened vesicles. It contains all requirements of light reaction. About 20-50 thylakoids may combine like a pile of coin to form a special structure called granum (pl. grana). Their number varies in cell to cell.

Figure:

Functions:

a. It is the site of photosynthesis.
b. It evolves oxygen.
c. It balances oxygen and carbondioxide in atmosphere.
d. It reduces global warming.
e. It is responsible for maintaining natural green.

ii. Chromoplast: It is coloured pigments except green. It contains yellow, orange and red pigments. They are found in coloured parts of plant. It is again of following types:

a. Phaeoplast: It is found in brown algae, diatoms etc. Fucoxanthin is the main pigment along with chlorophyll.

b. Rhodoplast: It is found in red algae. r-phycoerythrin and r-phycocyanin are the main pigment along with chlorophyll a and chlorophyll d (instead of chl. b).

c. Chromatophores of BGA: They contain c-phycocyanin, c-phycoerythrin with chlorophyll a.

d. Chromatophores of photosynthetic bacteria: It is found in purple and non-purple photosynthetic bacteria. They contain purple red pigment.

Functions:

a. It provides different colouration in plants.
b. It makes flower and fruit attractive.
c. It helps in pollination.
d. It helps in dispersal of fruit and seeds.

iii. **Leucoplast:** It is colourless plastids that donot bear grana. They are mostly found in underground part of plants. It is oval, spherical or filamentous in shape.

Based on the nature of food storage, it is categorized into three groups.

a. **Amyloplast:** The plastids that store starch. It is found in potato tuber, grains of wheat and rice.
b. **Elaioplast:** The plastids that store fats and oils. It is found in seeds of mustard, castor, sunflower etc.
c. **Proteinoplast:** The plastids that store protein. It is found in maize grains.

Function:

a. Its chief function is storage of foods.

6. **Endoplasmic Reticulum (ER):** It is the cellular organelle extended from nucleus to the cell membrane. It is irregular branched sac like structure. It is present in all eukaryotic cells except germinal cells and RBC. It is totally absent in prokaryotes.

It was first observed by Garnier in 1897 who called it as ergastoplasm. The present name was given by Porter in 1953.

ER composed of three different types of structure. They are cisternae, vesicles and tubules.

a. **Cisternae:** These are long, flat and unbranched lamellae arranged in parallel rows. These are double layered membranous structure that are interconnected and lies near nuclear membrane. It contains ribosome on it.
b. **Vesicles:** These are normally round or ovoid sacs separated from cisternae. It is found in isolated form in cytoplasm.
c. **Tubules:** It is irregularly branched tube-like structures. The lumens of tubules are filled with secretory products. It forms reticular system with cisternae and vesicles.

Figure:

There is found two types of ER in a cell. Both ER may be present in the same cell or different cell.

a. **Smooth ER:** ER that lacks ribosome on its outer surface is called smooth ER. It mainly composed of tubules. It lies towards cell membrane that helps in synthesis of glycogen, fats and detoxification (removal of harmful substances).
b. **Rough ER:** ER that contains ribosome on its outer surface is called rough ER. It mainly composed of cisternae. It lies towards nuclear membrane that helps in production and excretion of protein.

Functions:

a. It provides mechanical support to cell.
b. It helps active transport of cellular materials.
c. It increases the surface area for cellular reaction.
d. It is involved in genetic information transferring process.
e. It produces primary lysosomes from its tubules.
f. It helps in detoxification.
g. It provides the site for different protein synthesis.
h. It also helps in transport of proteins.

7. **Golgi Bodies:** It is curved or rod shaped cellular organelles present near centriole in the living cell. It is usually present in all eukaryotic cells except mature RBCs, cells of fungi, male gamete of bryophytes and pteridophytes and sieve tubes. It is totally absent in prokaryotic cells.

   It was first observed by George (1867) but studied by Camillo Golgi (1898). Hence, the name was given as golgi bodies after the name of Camillo Golgi. It is also known as golgi complex, golgi apparatus, lipochondria, idiosome or dictyosomes. It is found in large number in mature, functional and secretory cells.

   It is composed of three different structures.

   a. Cisternae: These are elongated, double layered, flat and curved sacs arranged in parallel to each other. Hence, are also called flattened sacs. The end of these structures are swollen which are called golgian vacuoles.

   b. Vacuoles: These are spherical membranous structure lies toward concave side of cisternae.

   c. Vesicles: These are small, oval and membranous structure lies toward convex side of cisternae.

   Figure:

   The convex side is the front or receiving side directs toward nuclear membrane. It is also called cis-face through which materials transport for further processing. The concave side is back or maturing side directs toward cell membrane. It is also called trans-face from where materials discharged outside in secretory vesicles.

   Functions:

   a. The chemicals like protein, lipid, sterols, etc are modified and condensed.
   b. They synthesize and secrete cell wall materials like pectin.
   c. It plays main role in the formation of primary lysosomes.
   d. It takes part in yolk synthesis in egg.

e. It transforms one type of membrane to another.

8. **Lysosomes:** Lysosomes are tiny bag like structures whose form, size and density are extremely variable.
It was discovered by Christian de Duve in 1955. They are found in all eukaryotic animal cell (except RBC), some fungi and meristematic cells of plant. They are mostly present in secretory cells like pancreatic cells, spleen cells etc. They are generally originated from Golgi cisternae or tubules of Endoplasmic Reticulum.

Types of Lysosomes:
On the basis of morphology, internal contents and function, they are of four different types.

a. Primary lysosome: It is small vesicle like structure produce from golgi complex. It contains powerful lytic enzymes (digestive enzymes). It stores the enzyme which is synthesized in the ER. Hence, is also known as 'storage granules'.

b. Secondary lysosome: It is formed by the fusion of primary lysosome and injested food or micro-organisms for digestion. Therefore, it is also known as 'digestive vacuole'.

c. Autophagosome: It is formed by the fusion of primary lysosome and old, damaged cell organelles. The lysosome release hydrolase enzymes to digest them. This process is called autolysis and lysosomes are autophagic vacuoles.

d. Residual bodies: The lysosome that contain unhydrolysed residues due to incomplete digestion. This type of lysosome is also known as telolysosome or tertiary lysosome.

Polymorphism: Lysosomes may occur in different forms in a cell and they can perform different functions simultaneously. Hence, are called polymorphic organelle.

Functions:

a. Primary lysosome breaks macro-molecules inside the cells supporting the intracellular digestion.
b. It helps cell in self defense against microbes and provide nutrition.
c. It helps to digest the aging cell organelle. Due to this phenomenon, it is also known as suicidal bag of cell.
d. It helps organism in natural defense with the help of their enzymes.

e. The lysosomal enzyme of seed digests protein and starch to provide nutrition for germinating seeds.

9. **Ribosome:** Ribosome is small, subspherical granular organelles that lack any membranous covering. They are composed of ribonucleoproteins and they are the site of protein synthesis.
   It was first isolated by Claude (1943) and named it microsome. It was renamed as ribosome by G. Palade (1955).
   They are found in large number in both eukaryotes and prokaryotes except mature sperm and RBC. Their number in a cell depends upon the RNA content.
   Depending upon size (sedimentation coefficient 's'), they are of two types; 70s and 80s. 70s type is found in all prokaryotic cell and in the cell organelles of eukaryotes whereas 80s type is found in cytoplasm of eukaryotic cell. Hence, 70s type is known as organelle ribosome and 80s type is known as cytoplasmic ribosome.
   Each ribosome is 150 – 250 A^o in diameter and consists of two unequal subunits. A larger dome shaped and a smaller ovoid shaped. The smaller subunit fits over the larger one like a cap. These subunits lie separately in the cytoplasm and join only at the time of protein synthesis. The 80s ribosome has 60s and 40s subunits whereas 70s ribosome has 50s and 30s subunits.

   Functions:
   a. They play important role in protein synthesis. Hence, are also called protein factories.
   b. They also produce non-secretory protein that play enzymatic role within the cell.
   c. Some ribosome produces secretory proteins from pancreas, liver etc.
   d. Ribosome may store protein temporarily.
   e. They store tRNA for protein synthesis.

10. **Microbodies:** They are single membrane covered small cell organelles which take part in oxidation reactions. They often possess a crystalline cone and granular matrix. They are of different types.
    a. Sphaerosomes: They were discovered by Perner (1953) which contain many hydrolytic enzymes as ribonucleases, esterases, proteases, hydrolases, phosphotases etc. They are formed in SER. They occur in plant cells especially in endosperm cells of oil seeds.
    b. Peroxisomes: They were first discovered by J. Rhodin (1954). Later on, de Duve (1965) suggested the name peroxisomes. They are found in higher

plants, liver and kidney cells of vertebrates. They have enzymes for peroxide biosynthesis.

c. Glyoxysomes: They were discovered by Beever (1963). They occur in fat rich seeds of higher plants. They contain various enzymes of bioxidation of fatty acid and glyoxylate cycle.

Functions:

a. Sphaerosome helps in synthesis and storage of fats.
b. Peroxidase helps the cell in detoxification of peroxide.
c. Peroxisomes involve in purine metabolism and conversion of fat to carbohydrate.
d. Glyoxysome involved in conversion of fatty acid to carbohydrate by bioxidation of fatty acid.

11. Microtubules: They were first observed by De Roberties and Franchi (1953) in animal cells. Later on, Ledbetter and Porter (1963) observed it in plant cell.
They are present in different cellular organelle in eukaryotic cells like flagella, cilia, centrioles, spindle fibre, sperm tails etc. It is totally absent in amoeba, slime moulds and prokaryotic cells.
The microtubule is a hollow, cylindrical and stiff structure. The wall is made up of 13 proto-tubules arrange parallel to each other. Each proto-tubule is formed by globular tubulin protein molecule.

Functions:

a. It maintains the form of the cells and provides mechanical support.
b. It helps in intracellular transportation of materials.
c. Microtubules of cilia and flagella responsible for their movements.
d. It helps in proper orientation of cellulose microfibrils.
e. It also helps in skin colouration by playing role in pigment distribution in chromatophore.

12. Microfilaments: They are cylindrical filamentous structure with indefinite length.
It was reported by Paleviz *et. al*. (1974).
They are long, narrow cylindrical and contractile protein filaments found in cytoplasm of eukaryotic cells. They are formed by special protein molecule named as actin.

Functions:

a. It provides shape and strength to the cell.

b. They help in developing cyclosis.
c. They generate locomotion in WBC and amoeba.
d. They form cleavage furrows at the time of cytokinesis.
e. They help in intracellular movement of cell organelles.

13. **Centrioles:** They are small, cylindrical structures found in all animal cells and flagellated plant cells likes antherozoids, zoospores etc. It is absent in prokaryotes, fungi, gymnosperms and angiosperms.
It was discovered by Edouard Van Beneden (1883). The term centriole was introduced by Theodor Boveri (1888).
They are hollow, cylindrical structures. Each centriole consists of nine triplet fibres equally spaced around an imaginary axis. They occur in pairs at right angles to one another near one pole of the dividing nucleus. It is called centrosome. Centrioles are surrounded by a transparent cytoplasmic area in centrosome known as centrospheres or kinplasm.
Figure:

Functions:
a. It functions as centres for spindle fibre organization.
b. They move to the periphery of the cell and act as basal bodies.
c. Centriole of sperm gives rise to asoneme of axial filament of sperm tail.

14. **Vacuoles:** It is an area which includes a transparent or rarely coloured watery substance.
It is reported by Lazzaro Spallanzani in 17^{th} century. These organelles were renamed as vacuoles by Felix Dujardin (1841). Later on Matthias Schleiden (1842) introduced the term vacuole in botany.
It is present in all plant and fungal cell, some protists and animal cells. A young or growing plant cell contains many small vacuoles which fuse to form a large central vacuole. Hence, a large central vacuole is present in a mature plant cell. It has no definite shape or size. Its structure varies according to the need of the cell.
It is non-cytoplasmic area bounded by a single membrane bilayer present in the cytoplasm. It basically contains two parts.
a. Tonoplast: It is outer, single layered, lipoproteinous and semi-permeable membrane. It regulates the movement of ions and metabolites into the vacuole.
b. Cell sap: The liquid present inside the vacuole is called cell sap. It consists of large quantity of water with inorganic and organic molecules as

enzymes, minerals, sugars, amino acids, proteins, esters, glucosides, alkaloids, organic acids etc.

Functions:

a. It acts as storage of reserve food like sucrose.
b. It stores and maintains the concentration of minerals inside the cell.
c. It store waste products and expels out from the cell.
d. Some plant vacuoles have hydrolytic enzymes that function like lysosome.
e. Secondary metabolites like tannin, latex etc are stored in vacuoles.

15. Nucleus: It is a membrane bound cell organelle found in all eukaryotic cells except sieve tube and RBC. It is located almost at the centre of cell.

It was first discovered by Robert Brown (1831).

It is the principle organelle of the cell. It directs and controls all the cellular activities and carries the hereditary information of the cell. Hence, is called 'master organelle of the cell'. The shape and size of nucleus varies greatly.

There is absent of membrane bound true nucleus in prokaryotes. Such type of nucleus is called incipient nucleus.

Figure:

Generally nucleus is divided into four parts.

a. Nuclear membrane: It is thin, transparent membrane which separates nucleoplasm from the cytoplasm. It is composed two units of lipoproteinous and trilaminar membranes. The outer membrane of the nucleus is often continuous with the membranes of ER and inner membrane surrounds the nuclear content. The nuclear membrane contains nuclear pores that sere for the passage of materials between cytoplasm and nucleoplasm.

b. Nucleoplasm: It is a transparent, homogenous, semi-fluid, granular ground substance. It is also known as nuclear sap, karyolymph or karyoplasm.

It is generally made up of water, sugars, nucleic acids, proteins, enzymes, nucleotides, minerals etc.

c. Nucleolus: It is a roughly rounded, darkly stained structure found inside the nucleus. It lacks membranous envelope. It is prominent in nucleus. The number of nucleoli varies.

d. Chromatin fibre: It is dark stained network of long and fine threads which intermingle with one another to form a network. It is also known as nuclear reticulum.

Generally it contains two parts.

i. **Heterochromatin:** It is dark stained and dense region of chromatin. It consists less amount of DNA and high amount of RNA. Hence, it is metabolically and genetically inactive.
ii. **Euchromatin:** It is light stained and diffused region of chromatin. It contains high amount of DNA and low amount of RNA. Hence, it is genetically active.

Functions:

a. It is the site of various enzymatic activities.
b. It helps in the formation of spindle fibre.
c. It controls all the activity of cell. Hence, it is called master organelle of cell.
d. It transfers genetic materials from parents to offspring.
e. It is the site of DNA, tRNA, mRNA and ribosomal subunit formation.
f. It controls cellular differentiation.

16. **Chromosomes:** They are dark stained thread like structures found inside the nucleus. It is made up of DNA and protein molecules along with small amount of RNA. It carries genes which are found in fixed number in any particular organism.

Figure:

It contain following parts.

a. Chromosomal envelope: It is the outermost layer of chromosome. It is made up of phospholipid and protein.
b. Matrix: It is the liquid material found inside the chromosomal envelope.
c. Chromonemata: A filamentous structure runs along the length of each chromatids is called chromonemata.
d. Centromere: The point where two chromatids of each chromosome remain joined is called centromere. It is also called primary constriction.
e. Secondary constriction: The constrictions found in chromosome except primary constriction is called secondary constriction. These are the sites of breakage and subsequent fusion.
f. Satellite: It is the part of chromosome which is separated by constriction at its terminal end. It is small, spherical body. Chromosome with satellite is called 'SAT chromosome'.
g. Telomere: It lies at the end of chromosome. It prevents ends of the chromosomes from sticking together.

Types of chromosome:

A. On the basis of number of centromere, it is of following types.
   a. Monocentric: Chromosome with only one centromere.

b. **Diacentric:** Chromosome with two centromeres.
c. **Polycentric:** Chromosome with many centromeres.
d. **Acentric:** Chromosome without centromere.
e. **Holocentric:** The whole chromosome behaves as a centromere.

B. On the basis of position of the centromere, it is of following types.
   a. **Metacentric:** Chromosome where centromere lies exactly middle is called metacentric chromosome. It appears V shaped having approximately equal arms.
   b. **Sub-metacentric:** The chromosome where centromere lies near the centre is called sub-metacentric chromosome. It appears L shaped having unequal arms.
   c. **Acrocentric:** The chromosome where centromere lies sub-terminal position is called acrocentric chromosome. It appears J shaped.
   d. **Telocentric:** The chromosome where centromere lies terminal position is called telocentric chromosome. It appears I shaped.

Functions:

a. It consists of DNA which carries genetic information
b. Chromosomes coordinate and control cell activities by controlling protein synthesis.

Cell Inclusions: These are non-living components present in cytoplasm. These are usually metabolically inactive. They are produced as the result of various metabolic activities. There are found various types of cell inclusions inside the cell. Among them some are as follows:

1. **Reserve food:** These are organic compounds that are present in liquid or solid state at room temperature. They may soluble or insoluble in water. eg: protein, amino-acids, starch, cellulose, fats, glycogen, sugar etc.

2. **Secretory materials:** The product that donot carry any nutritional value but plays role in various cellular activities. eg: plant pigments, enzymes, nector etc.

3. **Excretory materials:** They are useless byproducts of plant metabolism. eg: alkaloids, resins, gums, tannins, latex, organic acids etc.