GOVERNMENT OF TAMILNADU

Department of Employment and Training

Course : TNPSC Group-II Mains Material

Subject : Biology

Topic : The Cell - Unit of Life

THE CELL - UNIT OF LIFE

INTRODUCTION

- The word 'cell' comes from the Latin word 'Cellus' which means 'a small compartment'. The word cell was first used by Robert Hooke (1662), therefore the term 'cell' is as old as 300 years.
- Aristotle (384–322 BC), was the one, who first recognised that animals and plants consists of organised structural units but unable to explain what it was.
- In 1660's, Robert Hooke observed something which looks like 'honeycomb with a great little boxes' which was later called as 'cell' from the cork tissue in 1665.
- He compiled his work as Micrographia. Later, Antonie van Leeuwenhoek observed unicellular particles, which he named as 'animalcules'.
- Robert Brown (1831–1839) described the spherical body in the plant cells as nucleus. H.J. Dutrochet (1824), a French scientist, was the first to give idea on cell theory.

Microscopy

- Compound microscope was invented by Z. Jansen.
- The dark field microscope was discovered by Z. Sigmondy (1905).
- Phase contrast microscope was invented by Zernike (1935). It is a modification of light microscope with all its basic principle.
- Phase contrast microscope is used to observe living cells, tissues and the cells cultured in-vitro during mitosis.

- Later, Matthias Schleiden (German Botanist) and Theodor Schwann (German Zoologist) (1833) outlined the basic features of the cell theory.
- Rudolf Virchow (1858) explained the cell theory by adding a feature stating that all living cells arise from pre-existing living cells by 'cell division'.

ELECTRON MICROSCOPE

- Electron Microscope was first introduced by Ernst Ruska (1931) and developed by G. Binning and H. Roher (1981). It is used to analyse the fine details of the cell and organelles called ultrastructure.
- It uses beam of accelerated electrons as source of illumination and therefore the resolving power is 1,00,000 times than that of light microscope.
- The specimen to be viewed under electron microscope is dehydrated and impregnated with electron opaque chemicals like gold or palladium.
- This is essential for withstanding electrons and also for contrast of the image. There are two kinds of electron microscopes namely,
  1. Transmission Electron Microscope (TEM).
  2. Scanning Electron Microscope (SEM).

1. Transmission Electron Microscope

- This is the most commonly used electron microscope which provides two dimensional image.
- The magnification is 1–3 lakh times and resolving power is 2−10 Å. It is used for studying detailed structure of viruses, mycoplasma, cellular organelles, etc.,

2. Scanning Electron Microscope

- This is used to obtain three dimensional image and has a lower resolving power than TEM. The magnification is 2,00,000 times and resolution is 5–20 nm.

CELL THEORY

- In 1833, German botanist Matthias Schleiden and German zoologist Theodor Schwann proposed that all plants and animals are composed of cells and that cells were the basic building blocks of life. These observations led to the formulation of modern cell theory.
  1. All organisms are made up of cells.
  2. New cells are formed by the division of pre-existing cells.
  3. Cells contains genetic material, which is passed on from parents to daughter cells.
  4. All metabolic reactions take place inside the cells.

Exception to Cell Theory

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

Cell Doctrine (Cell Principle)

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

PROTOPLASM THEORY

1. Corti first observed protoplasm. Felix Dujardin (1835) observed a living juice in animal cell and called it "Sarcode".
2. Purkinje (1839) coined the term protoplasm for sap inside a plant cell.
3. Hugo Von Mohl (1846) indicated importance of protoplasm.
4. Max Schultze (1861) established similarity between Protoplasm and Sarcode and proposed a theory which later on called "Protoplasm Theory" by O. Hertwig (1892).
5. Huxley (1868) proposed Protoplasm as a **"Physical basis of life".**

Physical Properties of Protoplasm

1. The pH of the protoplasm is around 6.8, contain 90% water (10% in dormant seeds).
2. Approximately 34 elements are present in protoplasm. But, only 13 elements are main or universal elements **i.e.,** C, H, O, N, Cl, Ca, P, Na, K, S, Mg, I and Fe. Carbon, Hydrogen, Oxygen and Nitrogen form the 96% of protoplasm.

Types of Cells

- On the basis of the cellular organization, nuclear characteristics, the cell can be divided into
  1. Prokaryotes.
  2. Mesokaryotes.
  3. Eukaryotes.

1) Prokaryotes (Undeveloped Primitive Cell)

- Those organisms with primitive nucleus are called as prokaryotes (Pro – Primitive; Karyon – Nucleus).
- The DNA lies in the 'nucleoid' which is not bound by the nuclear membrane and therefore it is not a true nucleus and is also a primitive type of nuclear material.
- The DNA is without histone proteins. Example: Bacteria, blue green algae, Mycoplasma, Rickettsiae and Spirochaetae.

2 Mesokaryotes

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

3. Eukaryotes (True Nucleated Cells)

- Those organisms, which have true nucleus are called Eukaryotes (Eu – True; karyon – nucleus). The DNA is associated with protein bound histones forming the chromosomes.
- Membrane bound organelles are present. Few organelles may be arisen by endosymbiosis which is a cell living inside another cell. The organelles like mitochondria and chloroplast well support this theory.
- The first cell might have evolved approximately 3.8 billion years ago. The primitive cell would have been similar to present day protists.

1. Cell Wall

- Cell wall is the outermost protective cover of cell. It is present in bacteria, fungi and plants whereas it is absent in animal cell. It was first observed by Robert Hooke ***(Table 9.2)***.
- It is an actively growing portion. It is made up of different complex material in various organism.
- In bacteria, it is composed of peptidoglycan, in fungi chitin and fungal cellulose, in algae cellulose, galactans and mannans.
- In plants it is made up of cellulose, hemicellulose, pectin, lignin, cutin, suberin and silica. In plant, cell wall shows three distinct regions a) Primary wall, b) Secondary wall, c) Middle lamella.

Plasmodesmata and Pits

- Plasmodesmata act as a channel between the protoplasm of adjacent cells through which many substances pass through. Moreover, at few regions the secondary wall layer is laid unevenly whereas the primary wall and middle lamella are laid continuously such regions are called pits.

Functions of Cell Wall

1. Offers definite shape and rigidity to the cell.
2. Serves as barrier for several molecules to enter the cells.
3. Provides protection to the internal protoplasm against mechanical injury.

4. Prevents the bursting of cells by maintaining the osmotic pressure.
5. Plays a major role by acting as a mechanism of defence for the cells.

2. Cell Membrane

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

Fluid Mosaic Model

- Jonathan Singer and Garth Nicolson (1972) proposed fluid mosaic model. It is made up of lipids and proteins together with a little amount of carbohydrate.
- The lipid membrane is made up of phospholipid. The phospholipid molecule has a hydrophobic tail and hydrophilic head. The hydrophobic tail repels water and hydrophilic head attracts water.
- The proteins of the membrane are globular proteins which are found intermingled between the lipid bilayer most of which are projecting beyond the lipid bilayer. These proteins are called as integral proteins. Few are superficially attached on either surface of the lipid bilayer which are called as peripheral proteins.
- The proteins are involved in transport of molecules across the membranes and also act as enzymes, receptors (or) antigens.
- The Carbohydrate molecules of cell membrane are short chain polysaccharides. These are either bound with **'glycoproteins'** or **'glycolipids'** and form a **'glycocalyx'.**
- The movement of membrane lipids from one side of the membrane to the other side by vertical movement is called flip flopping or flip flop movement. This movement takes place more slowly than lateral diffusion of lipid molecule.
- The phospholipids can have flip flop movement because the phospholipids have smaller polar regions, whereas the proteins cannot flip flop because the polar region is extensive.

Function of Cell Membrane

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

Cell Transport

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

Endocytosis & Exocytosis

- Cell surface membrane are able to transport individual molecules and ions. Through, this special process Large quantity of solids and liquids are taken into cell **(Endocytosis)** or out of cell **(Exocytosis).**

1. Endocytosis

- During endocytosis the cell membrane infolds around the material to form a vacuole and brings it into cytoplasm. There are two types of endocytosis:
  1. **Phagocytosis:** Solid Particles are engulfed by membrane, which folds around it and forms a vesicle. The enzymes digest the material and products are absorbed by cytoplasm.
  2. **Pinocytosis:** Fluid droplets are engulfed by membrane, by forming vesicles around them.

2. Exocytosis

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

Signal Transduction

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

3. Cytoplasm

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

CELL ORGANELLES

1. Endomembrane System

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

2. Endoplasmic Reticulum

- The largest of the internal membranes is called the endoplasmic reticulum. The name endoplasmic reticulum was given by K.R. Porter (1948).
- It consists of double membrane. Morphologically the structure of endoplasmic reticulum consists of:
  1. Cisternae are long, broad, flat, sac like structures arranged in parallel bundles or stacks to form lamella. The space between membranes of cisternae is filled with fluid.
  2. Vesicles are oval membrane bound vacuolar structure.
  3. Tubules are irregular shape, branched, smooth walled, enclosing a space.
- Endoplasmic reticulum is associated with nuclear membrane and cell surface membrane. It forms a network in cytoplasm and gives mechanical support to the cell.
- Its chemical environment enables protein folding and undergo modification necessary for their function. When ribosomes are present in the outer surface of the membrane it is called as Rough Endoplasmic Reticulum (RER).
- When the ribosomes are absent in the endoplasmic reticulum it is called as Smooth Endoplasmic reticulum (SER).
- Rough endoplasmic reticulum is involved in protein synthesis and smooth endoplasmic reticulum are the sites of lipid synthesis.
- The smooth endoplasmic reticulum contains enzymes that detoxify lipid soluble drugs, certain chemicals and other harmful compounds.

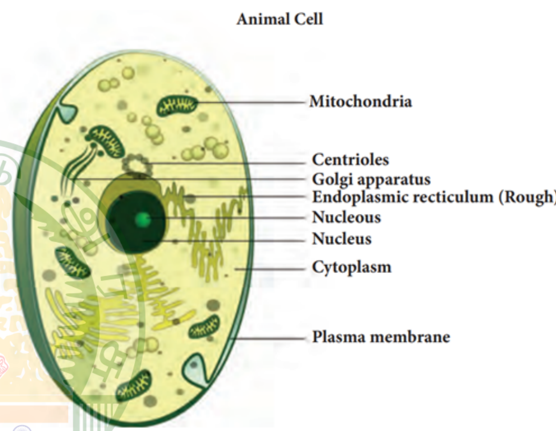
3. Golgi Body (Dictyosomes)

- In 1898, Camillo Golgi visualized a netlike reticulum of fibrils near the nucleus, were named as Golgi bodies. In plant cells they are found as smaller vesicles termed as dictyosomes. Golgi apparatus is a stack of flat membrane enclosed sacs.

- It consist of cisternae, tubules, vesicles and golgi vacuoles. In plants the cisternae are 10-20 in number placed in piles separated from the cytoplasm of the cell.
- Peripheral edge of cisternae forms a network of tubules and vesicles. Tubules interconnect cisternae and are 30−50 nm in dimension.
- Vesicles are large round or concave sac. They are pinched off from the tubules. They are smooth/secretary or coated type. Golgi vacuoles are large spherical filled with granular or amorphous substance, some function like lysosomes.
- The Golgi apparatus compartmentalises a series of steps leading to the production of functional protein. Golgi complex plays a major role in post translational modification of proteins and glycosidation of lipids.

Functions

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



4. Mitochondria

- It was first observed by A. Kolliker (1880), Altmann (1894) named it as Bioplasts.
- Benda (1897, 1898), named as mitochondria. They are ovoid, rounded, rod shape and pleomorphic structures.
- Mitochondrion consists of double membrane, the outer and inner membrane. The outer membrane is smooth, highly permeable to small molecules and it contains proteins called Porins, which form channels that allows free diffusion of molecules smaller than about 1000 daltons.
- The inner membrane is convoluted (Infoldings) called Crista (Plural: cristae). Cristae contain most of the enzymes for electron transport system. Inner chamber of the mitochondrion is filled with proteinaceous material called mitochondrial matrix.
- The inner membrane consists of stalked particles called elementary particles or Fernandez Moran particles, F1 particles or Oxysomes.
- Each particle consists of a base, stem and a round head. In the head ATP synthase is present for oxidative phosphorylation.
- Inner membrane is impermeable to most ions, small molecules and maintains the proton gradient that drives oxidative phosphorylation.

- Mitochondria contain 73% of proteins, 25–30% of lipids, 5–7% of RNA, DNA (in traces) and enzymes (about 60 types). Mitochondria are called power house of a cell, as they produce energy rich ATP.
- All the enzymes of Kreb's cycle are found in the matrix except succinate dehydrogenase.
- Mitochondria consist of circular DNA and 70S ribosome. They multiply by fission and replicates by strand displacement model. Because of the presence of DNA it is semi-autonomous organelle. Unique characteristic of mitochondria is that they are inherited from female parent only.
- Mitochondrial DNA comparisons are used to trace human origins. Mitochondrial DNA is used to track and date recent evolutionary time because it mutates 5–10 time faster than DNA in the nucleus.

5. Plastids

- The term plastid is derived from the Greek word Platikas (Formed/moulded) and used by A.F.U. Schimper in 1885. He classified plastids into following types according to their structure, pigments and function. Plastids multiply by fission. According to different kind of plastids can transform into one another.

Chloroplast

- Chloroplast is called kitchen of the cell.
- Chloroplast has a double membrane the outer membrane and the inner membrane separated by a space called periplastidial space.
- The space enclosed by the inner membrane of chloroplast is filled with gelatinous matrix, lipoproteinaceous fluid called stroma.
- Inside the stroma there is flat interconnected sacs called thylakoid. The membrane of thylakoid enclose a space called thylakoid lumen.
- Grana (singular: Granum) are formed when many of these thylakoids are stacked together like pile of coins.
- Light is absorbed and converted into chemical energy in the granum, which is used in stroma to prepare carbohydrates.
- Thylakoid contain chlorophyll pigments. The chloroplast contains osmophilic granules, 70s ribosomes, DNA (circular and non-histone) and RNA.
- These chloroplast genome encodes approximately 30 proteins involved in photosynthesis including the components of photo system I & II, cytochrome bf complex and ATP synthase.
- One of the subunits of Rubisco is encoded by chloroplast DNA. It is the major protein component of chloroplast stroma, single most abundant protein on earth.
- The thylakoid contain small, rounded photosynthetic units called quantasomes. It is a semi-autonomous organelle and divides by fission.

Functions

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

6. Ribosome

- Ribosomes were first observed by George Palade (1953) as dense particles or granules in the electron microscope.
- Electron microscopic observation reveals that ribosomes are composed of two rounded sub units, united together to form a complete unit. Mg^{2+} is required for structural cohesion of ribosomes.
- Biogenesis of ribosome are denova formation, auto replication and nucleolar origin. Each ribosome is made up of one small and one large sub-unit Ribosomes are the sites of protein synthesis in the cell.
- Ribosome is not a membrane bound organelle. It consists of RNA and protein: RNA 60% and Protein 40%. During protein synthesis many ribosomes are attached to the single mRNA is called polysomes or polyribosomes.
- The function of polysomes is the formation of several copies of a particular polypeptide during protein synthesis.

7. Lysosomes (Suicidal Bags)

- Lysosomes were discovered by Christian de Duve (1953), these are known as suicidal bags. They are spherical bodies enclosed by a single unit membrane and they are found in eukaryotic cell.
- Lysosomes are small vacuoles formed when small pieces of golgi body are pinched off from its tubules. They contain a variety of hydrolytic enzymes, that can digest material within the cell. The membrane around lysosome prevent these enzymes from digesting the cell itself.

Functions

- **Intracellular Digestion:** They digest carbohydrates, proteins and lipids present in cytoplasm.
- **Autophagy:** During adverse condition they digest their own cell organelles like mitochondria and endoplasmic reticulum
- **Autolysis:** Lysosome causes self destruction of cell on insight of disease they destroy the cells.
- **Ageing:** Lysosomes have autolytic enzymes that disrupts intracellular molecules.

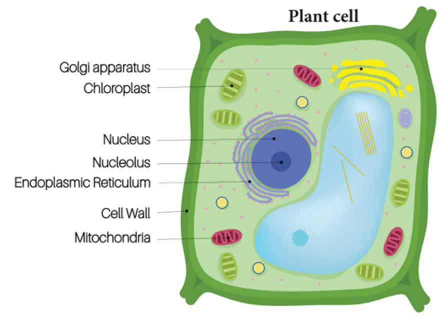
Peroxisomes

- Peroxisomes were identified as organelles by Christian de Duve (1967). Peroxisomes are small spherical bodies and single membrane bound organelle. It takes part in photo respiration and associated with glycolate metabolism.

- In plants, leaf cells have many peroxisomes. It is also commonly found in liver and kidney of mammals. These are also found in cells of protozoa and yeast.

Glyoxysomes

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



Microbodies

- Eukaryotic cells contain many enzyme bearing membrane enclosed vesicles called microbodies. They are single unit membrane bound cell organelles: **E.g.,** Peroxisomes and Glyoxysomes.

Sphaerosomes

- It is spherical in shape and enclosed by single unit membrane. **E.g.,** Storage of fat in the endosperm cells of oil seeds.

8. Centrioles

- Centrosome- it was discovered by Theodor Boveri. It is composed to set of centrioles
- Centriole consist of nine triplet peripheral fibrils made up of tubulin. The central part of the centriole is called hub, is connected to the tubules of the peripheral triplets by radial spokes (9 + 0 Pattern).
- The centriole form the basal body of cilia or flagella and spindle fibers which forms the spindle apparatus in animal cells. The membrane is absent in centriole (Non-membranous organelle).

9. Vacuoles

- In plant cells, vacuoles are large, bounded by a single unit membrane called Tonoplast. The vacuoles contain cell sap, which is a solution of sugars, amino acids, mineral salts, waste chemical and anthocyanin pigments.
- Beetroot cells contains anthocyanin pigments in their vacuoles. Vacuoles accumulate products like tannins. The osmotic expansion of a cell kept in water is chiefly regulated by vacuole and the water enters the vacuoles by osmosis.
- The major function of plant vacuole is to maintain water pressure known as turgor pressure, which maintains the plant structure. Vacuoles organises itself into a storage/sequestration compartment. E.g., Vacuoles store, most of the sucrose of the cell.

CELL INCLUSIONS

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

1. Inclusions in Prokaryotes

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

2. Inclusions in Eukaryotes

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

3. Nucleus

- Nucleus is an important unit of cell which control all activities of the cell. Nucleus holds the hereditary information. It is the largest among all cell organelles. It may be spherical, cuboidal, ellipsoidal or discoidal.It is surrounded by a double membrane structure called nuclear envelope, which has the inner and outer membrane.
- The inner membrane is smooth without ribosomes and the outer membrane is rough by the presence of ribosomes and is continues with irregular and infrequent intervals with the endoplasmic reticulum.
- The pores enclosed by circular structures called annuli. The pore and annuli forms the pore complex. The space between two membranes is called perinuclear space.
- Nuclear space is filled with nucleoplasm, a gelatinous matrix has uncondensed chromatin network and a conspicuous nucleoli.
- The chromatin network is the uncoiled, indistinct and remain thread like during the interphase. It has little amount of RNA and DNA bound to histone proteins in eukaryotic cells. During cell division chromatin is condensed into an organized form called Chromosome.
- The portion of Eukaryotic chromosome which is transcribed into mRNA contains active genes that are not tightly condensed during interphase is called Euchromatin.
- The portion of a Eukaryotic chromosome that is not transcribed into mRNA which remains condensed during interphase and stains intensely is called Heterochromatin.
- Nucleolus is a small, dense, spherical structure either present singly or in multiples inside nucleus and it's not membrane bound. Nucleoli possesses genes for rRNA and tRNA.

Functions of the Nucleus

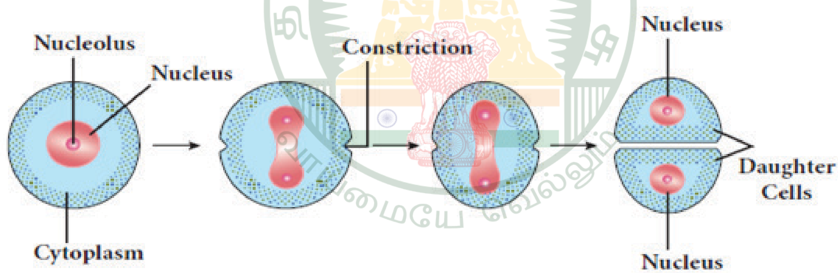
- Controlling all the cellular activities.
- Storing the genetic or hereditary information.
- Coding the information in the DNA for the production of enzymes and proteins.
- DNA duplication and transcription takes place in the nucleus.
- In nucleolus ribosomal bio-genesis takes place.

Types of Cell Division

- The three types of cell division that occur in animal cells are:
  I. Amitosis - Direct Division
  II. Mitosis - Indirect Division
  III. Meiosis - Reduction Division

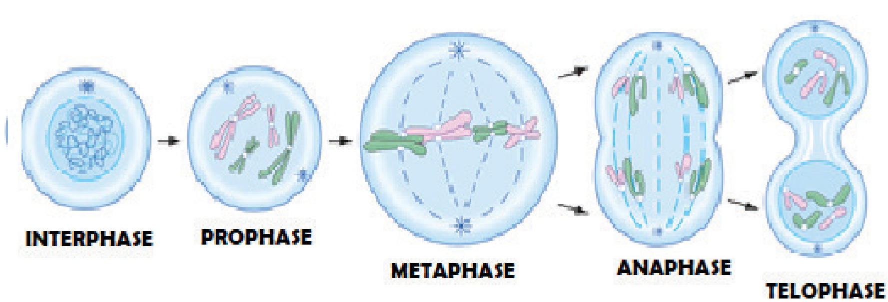
I. Amitosis

- It is the simplest mode of cell division and it occurs in unicellular animals, ageing cells and in foetal membranes. During amitosis, nucleus elongates first, and a constriction appears in it which deepens and divides the nucleus into two.
- Followed by this cytoplasm divides resulting in the formation of two daughter cells.



II. Mitosis

- It was first discovered by Fleming in 1879. In this cell division one parent cell divides into two identical daughter cells, each with a nucleus having the same amount of DNA, same number of chromosomes and genes as the parent cells. It is also called as equational division.



- Mitosis consists of two events, they are: 1. Karyokinesis 2. Cytokinesis
- Interphase: It is the resting phase of the nucleus. It is the interval between two successive cell divisions. The cell prepares itself for the next cell division.

1. Karyokinesis

- The division of the nucleus into two daughter nuclei is called Karyokinesis. It consists of four phases. They are: Prophase, Metaphase, Anaphase and Telophase.
- Prophase (pro-first): During this stage chromosomes become short and thick and are clearly visible inside the nucleus. Centrosome splits into centrioles and occupy opposite poles of the cell. Each centriole is surrounded by asterrays. Spindle fibres appear between the two centrioles. Nuclear membrane and nucleolus disappear gradually.
- Metaphase (meta – after): The duplicated chromosomes arrange on the equatorial plane and form the metaphase plate. Each chromosome gets attached to a spindle fibre by its centromere. The centromere of each chromosome divides into two each being associated with a chromatid.
- Anaphase (ana – up, back): The centromeres attaching the two chromatids divide and the two daughter chromatids of each chromosome separate and migrate towards the two opposite poles.
- Telophase (tele – end): Each chromatid (or) daughter chromosome lengthens, becomes thinner and turns into a network of chromatin threads. Spindle fibres breakdown and disappear. Nuclear membrane and nucleolus reappear in each daughter nucleus.

2. Cytokinesis

- The division of the cytoplasm into two daughter cells by constriction of the cell membrane is called cytokinesis.

III. Meiosis

- The term meiosis was coined by Farmer in 1905. It is the kind of cell division that produces the sex cells or the gametes. It is also called reduction division because the chromosome number is reduced to haploid (n) from diploid (2n). Meiosis produces four daughter cells from a parent cell. Meiosis consists of two divisions. They are:

I. Heterotypic division

- It divides the diploid cell into two haploid cells. The daughter cells resulting from this division are different from the parent cell in the chromosome number (Heterotypic). This consists of 5 stages:

1. **Prophase I**

- Prophase I takes a longer duration and is sub divided into five stages. They are: Leptotene, Zygotene, Pachytene, Diplotene and Diakinesis.

- Leptotene: The chromosomes become uncoiled and assume long thread like structures and take up a specific orientation inside the nucleus. They form a bouquet stage.
- Zygotene (Zygon-adjoining): Two homologous chromosomes approach each other and begin to pair. Pairing of homologous chromosomes is called as synapsis.
- Pachytene (Pachus-thick): The chromosomes are visible as long paired twisted threads. The pairs so formed are called bivalents. Each bivalent now contains four chromatids (tetrad stage).
- Diplotene: Each individual chromosome of each bivalent begins to split longitudinally into two similar chromatids. The homologous chromosomes repel each other and separate. Chiasmata begin to move along the length of the chromosome from the centromere towards the end resulting in terminalization.
- Diakinesis: The paired chromosomes are shortened and thickened. The nuclear membrane and nucleolus begin to disappear. Spindle fibres make their appearance.

2. **Metaphase I**

- The chromosomes move towards the equator and finally they orient themselves on the equator. The two chromatids of each chromosome do not separate. The centromere does not divide.

3. **Anaphase I**

- Each homologous chromosome with its two chromatids and undivided centromere move towards the opposite poles of the cell. This stage of the chromosome is called Diad.

4. **Telophase I**

- The haploid number of chromosomes after reaching their respective poles become uncoiled nucleolus reappear and thus two daughter nuclei are formed.

5. **Cytokinesis I:** The cytoplasmic division occurs and two haploid cells are formed.

II. Homotypic Division

- In this division, the two haploid cells formed during first meiotic division divide into four haploid cells. The daughter cells are similar to parent cell in the chromosome number (Homotypic). It consists of five stages.

1. **Prophase II**: The centriole divides into two, each one moves to opposite poles. Asters and spindle fibres appear. Nuclear membrane and nucleolus disappear.
2. **Metaphase II**: The chromosomes get arranged on the equator. Two chromatids are separated.
3. **Anaphase II:** The separated chromatids become daughter chromosomes and move to opposite poles
4. **Telophase II:** The daughter chromosomes are centered. The nuclear membrane and the nucleolus appear.
5. **Cytokinesis II:** Two cells are formed from each haploid daughter cell, resulting in the formation of four cells with haploid number of chromosomes.