Unit III-Cell Biology

Synopsis

Cell wall and Protoplasm

- Plant cells differ from animal cells in having cell wall. Robert Hook first observed them in cork tissues of oak tree.
- Cell wall is rigid and protects cell. It is permeable to all substances.
- Between the cells in tissues a cementing substance is present called middle lamellum.
- The cell plate formed during telophase of cell division develops into middle lamellum. Chemically it is calcium and magnesium pectins. Dissolution of middle lamellum results in separation of cells.
- Outer most layer of cell wall is primary cell wall. It is made up of cellulose, hemicelluloses and pectins. It is elastic and thin.
- Thin areas in the primary wall are called primary pit fields. Cytoplasmic connection called plasmodesmata extend from cell to cell helping in the intercellular transport of certain material from cell to cell.
- Secondary wall form inside to the primary wall. Generally it is three layered. Third layer is inner most. Secondary wall material like lignin, suberin, cutin form in the secondary wall.
- Secondary walls with secondary wall material are rigid and inelastic.
- Growth of the cell wall is by two methods- Intussusception and Opposition.
- In intussusceptions new wall material form between cellulose fibrils and increases the surface area. In Opposition wall material form on the existing fibrils resulting in thickness of the wall.
- On pit fields secondary wall material is not deposited on pit fields.
- Pit fields are simple or bordered pits. Bordered pits are found in water conducting elements (tracheids, trachea).
- In the centre of the bordered pit middle lamellum thickens to form into biconvex lens shaped structure called torus.
- Cell wall gives definite shape to the cell.
- Cell wall encloses plasma membrane. Plasma membrane chemically consisting of proteins and lipids.

- Danielli and Davson proposed Sandwich model or Trilamellar model. Lipid bilayer sandwiched between protein layers. Each protein layer is $20A^0$ and lipid bilayer is $35\ A^0$.
- Singer and Nicolson proposed Fluid Mosaic model. Protein is embedded in phospho lipid bilayer which is like viscous liquid. Protein may be, superficial, extrinsic or peripheral and partially or completely embedded Intrinsic or Integral proteins. Besides proteins glycolipids, cholesterol, oligosaccharides may be present. Proteins of the membranes are called as porters.
- Plasma membrane selectively permeable and regulate the flow of materials across. All membranes are not identical.
- It is osmoregulatory
- Inside the membrane the liquid is Protoplasm. It may be granular, colloidal (shows Tyndall effect), fibrillar, alveolar or sol-gel like in nature.
- All biological activities take place in protoplasm .Von Mohl described it as centre of biological activities.
- Chemically it consist nearly 90% water. Different organic and inorganic substances are present.
- Specific density is greater than one and slightly acidic. It coagulates when exposed to high temperatures, toxins and electric shock.
- It shows biological properties like irritability, growth, and reproduction.
- It shows Brownian movements and Tyndall effect.
- Excluding nucleus the liquid portion is Cytoplasm. Liquid without cell organelles is Cytosol.
- Protoplasm shows rotatory or circulatory motion.
- The cytoplasm encloses many sub cellular particle called cell organelles.

Cell organelles-Plastids

- They are present in all plant cells. (Fungi and blue green algae lack them).Leeuwenhoek discovered them. They are double membrane.
- They may be cloured-Chromoplasts or colourless-Leucoplasts.
- Leucoplasts store food material. Starch-amyloplasts, Protein-aleuroplasts, fats or oils-Elaioplasts.
- Green colour plastids are Chloroplasts with chlorophylls (chl a, chl b, chl c, chl d, chl e).

- Chromoplast contains carotenoids (carotenes and xanthophylls) which imparts different colours to the organs.
- These are spherical in shape. Complex in structure in Chlorophyceae and angiosperms.
- In between the outer membranes space is peri plastidial space. Matrix is colourless and called as stroma.
- Enzymes useful in carbon dioxide fixation are present in stroma.
- Matrix also contains circular DNA and ribosomes. It can self duplicate and called as semi-autonomous organelle. (Like mitochondria). Chloroplasts resemble photosynthetic bacteria
- Inside the stroma membranous discoid structures called thylokoids are present. Thylakoids are stacked to form into grana. Grana are interconnected by stroma thylakoids.Space within the thylakoid is lumen –seat of oxygen evolution during photosynthesis. Pigments concerning with photosynthesis are attached to thylakoid membranes.
- Chloroplasts and leucoplasts are inter convertible.

Mitochondria

- Mitochondria are rod shaped or spherical bodied organelles. First reported by Kolliker and Benda named them as mitochondria.
- It is a double membrane organelle. In between the membranes peri mitochondrial space is present.
- Outer membrane is smooth and inner membranes invaginate inside into finger like projections called cristae which increases the surface area of the membrane.
- On the membranes small stalked bodies (ATP synthase) are present. These are structures responsible for the formation of ATP during respiration.
- Matrix filed with liquid consisting of enzymes of Krebs cycle.
- A circular form of DNA and ribosomes are present in the matrix. They are self replicating.
- Mitochondria function is oxidation of respiratory substrate. They are called power houses of the cell.
- In green plant cells they are few in number when compares to animal cells and non-green cells.

Endoplasmic Reticulum

- Endoplasmic reticulum(ER) is membranous net work like structure dividing the cells into compartments. It is discovered by K.R. Porter.
- Membranes are attached to inner nuclear membrane and extend into other cells through plamodesmata.
- They are of two types. 1. Rough endoplasmic reticulum with ribosomes attached
  2. Smooth endoplasmic reticulum without ribosomes attached.
- It shows three distinct membranous structures –Cisternae (flattened discs), Tubules, Vesicles.
- Vesicles single membranous sacs that are pinching off from the tubules or cisternae,
- ER major function is intracellular transport of cell materials.
- Rough ER associated with protein synthesis (by ribosomes) and smooth ER with lipid synthesis.
- Golgi apparatus, peroxisomes, glyoxysomes and lysosomes are synthesized from membranes of ER.
- It plays a role cell plate formation along with Golgi complex during cell division.
- Ribosomes are smallest cell organelles present in all living cells (primitive cell organelles). Discovered by Palade, they also called as palade granules.
- These are not bounded by any membrane and made up of ribonucleic acids and proteins.
- They are of rat liver shape with two separable units. (Large and small).
- Precursors of ribosomes form in nucleolus.
- Svedberg's sedimentation co-efficient of prokaryotic ribosomes is 70S that can be separated into sub-units 50S and 30S. In eukaryotes 80S that can be separated into 60S and 40S.
- Two cavities are present extending in two sub unit. One is 'A' site or amino acid site .Second one is 'P' site or peptidyl site.
- The two units separate in the presence of proteins called .initiation factors'. Ribosomes exist as integrated structures with the help of Magnesium ions.
- During protein synthesis ribosomes are seen attached to mRNA and are called as polysomes.
- Major function of ribosomes is protein synthesis.

Golgi complex

- Golgi complex discovered by Camillo Golgi.
- Structural components of Golgi is like that of ER (cisternae, tubules, vesicles) .
- They also called as idiosomes, bakers' body, and lipochondria.
- The stack of cisternae may be referred as dictyosomes. They are slightly curved.
- They are nearer to the nucleus with convex portion towards nucleus.
- They are involved in the synthesis of cell wall materials – cellulose, hemicelluloses etc.
- It is generally referred as secretary body as they help in the synthesis of lipids, hormones and enzyme.

Lysosomes, Peroxisomes, Glyoxysomes

- They help in the formation of glycolipids and glycoproteins. And also during cell division 'the cell plate'.Lysosomes are also synthesized from Golgi besides ER.
- Lysosomes are single membrane bodies. Discovered first by Christian de Duve in animal.
- In plants they are present in meristems.
- These spherical bodies help in the digestion of food or dying cells and cellular components (autophagy). As primary host defense organelles they ingest and digest foreign pathogens.
- Sometimes they digest cell components. Because of this activity they are called as suicidal bags of the cell.
- Peroxisomes are single membrane structure discovered by Rhodin in liver cells of animals.
- They also present in plant cells.
- They help in oxidation of fatty acids (β oxidation pathway) and synthesis of phospholipids.
- In plants along with chloroplasts and mitochondria participate in photorespiration.
- They enclose enzymes required for the photorespiration reactions. They contain peroxidase that breaks down hydrogen peroxide formed during photorespiration.
- Glyoxysomes are single membrane structures discovered by Breidenbach.
- They are present only in plants. During the germination of oil rich seeds they form as bags enclosing enzymes required for the conversion of fats into carbohydrates.

Vacuoles

- Vacuoles are considered by some cytologists as cell organelle as they covered by a membrane 'tonoplast'. The solution inside the vacuole is called as cell sap or tonoplast.
- It acts as repository of the cell. As the age of the cell increases the size of the vacuole also increases and occupies most of the cell pushing the cytoplasm to the periphery. This peripheral cytoplasm is called as 'primordial utricle'.
- In animal cells it functions as osmoregulatory body.
- In plant cells vacuoles are filled with pigments (anthocyanins) and other non-living inclusions (ergastic bodies) like gums, latex, alkaloids etc.

Nucleus

- Nucleus enclosed in double membrane and controlles all the activities of the cells. Membrane shows pores in it. In prokaryotic cells membrane is absent. It encloses nucleoplasm.
- Generally a single nucleus per cell is present in all organisms. Red blood cells and mature sieve cells are anucleate. Due to dikaryotization two nucleii are present in the cells of Ascomycotina and Basidiomycotina of fungi. In primitive fungi acellular or coenocytic condition is present like in Zygomycetes. Xanthophyceae of algae also coenocytic.
- Nucleus is visible only during the interphase of the cell cycle.
- During the staining with acetocarmine or aceto orcein or Feulgen ,a thin thread is visible called chromatin net work. Chromatin condenses during cell division and forms into chromosomes.
- In the nucleoplasm one or two granular bodies are present called nucleolus. Fontana discovered it. They are attached to nucleolar organizer or secondary constriction of the chromosomes.

Chromosomes

- Chromosomes are dark stained bodies present in the nucleus. Hofmeister forst observed these dark stained bodies in the nucleus of pollen mother cells of *Tradescantia* .
- Sutton and Boveri proposed chromosome theory. They are physical basis of heredity.
- During metaphase of the division chromosomes are very short and clear.

- Each chromosome has two DNA molecules each formed into one chromatid. Chromatids are held together at centromere (Primary constriction). Centromere is included on either side by protein called kinetochore.
- Some chromosomes show a small portion called satellites. These portions contain repetitive DNA.
- Karyotyping is characterization of chromosome complement of the cell. Diagrammatic representation is 'Ideogram'.
- Chromosome number is specific for a species.(**E.g**. Allium cepa chromosome number is 16).
- Sporophytes show two sets of chromosomes (diploid)
- Based on the position of centromere chromosomes may be metacentric, sub-metacentric, acrocentric and telocentric. Acentric or multicentric forms are aberrations.
- Beaded portions in the chromosomes are nucleosomes consisting of basic proteins called histone proteins.
- Chemically Four different histone protein are present - H_1, H_{2A}, H_{2B}, H_3 , H_4 . In nucleosome is an octamer of histone proteins wrapped around with 200 base pairs of DNA. These histones are two copies of each H_{2A}, H_{2B}, H_3, H_4. In between nucleosomes H_1 protein is present.
- Chromosomes are polymers of nucleotides.
- Each nucleotide consisting of pentose sugar, Phosphate and nitrogen base. Without phosphate they are nucleosides.
- Sugars are two different types; consequently nucleotides are deoxy ribose or ribose nucleotides.
- Nitrogen Bases are purines and pyramidines. Purines always pair with pyramidines by hydrogen bonds.
- The two purines are Adenine (A) and Guanine (G). Pyramidines are Cytocine(C), Thyamine(T), Uracil(U). Uracil present only in RNA.
- DNA and RNA are polymers of nucleotides. Watson and Crick elucidated the structure of DNA with inputs from Chargaff, Franklin and Wilkins.
- Chargaff- purines and pyramidins in DNA are equal.
- Wilkins – weak bonds (hydrogen) were observed.
- Rosalind Franklin- Crystallographic studies. Density of the DNA is double the expected values.

- DNA molecule shows polarity. Two strands are antiparallel. Strands are made up of chain of nucleotides with sugar back bone. Phosphates are attached to nucleosides by ester bonds.
- Different types of DNA s are present in cells. B- being prominent.
- DNA can undergo replication and transcription producing mRNA.
- mRNA carries genetic information and short lived with 5-10% in a cell. tRNA is the smallest with 10-15 % and rRNA is large molecule with 75- 80 %.

Cell Division

- Cell division is of two major types- Mitosis and Meiosis
- Mitosis occurs mostly in vegetative cells and meiosis occurs only in sex cells (diploid).
- Mitosis is equational division with daughter cells are similar to their parents in chromosome number.
- It is discovered by Walther flemming in animals and Strasburger in plants.
- During the division single nucleus divides into two and cell divides into two cells.
- The different phases are Prophase – condensation of chromatin to form chromosomes. Nuclear membrane and nucleolus disappears. Metaphase- Chromosomes are short and arranged on the equatorial plate. Spindle fibres form. Anaphase- separation of chromosomes into chromatids (daughter chromosomes) Telophase- reversal of prophase.
- Same number of chromosomes is present in daughter cell but the DNA amount is halved.
- In the interphase i.e. G_1, S, G_2 phases it regains its original size and components. S phase is longest in cell cycle where DNA synthesis takes place.
- Meiosis occurs in sex cells. Chromosome number is reduced to half hence it is called reduction division.
- After division 4 cells are formed called gametes in animals or spores in plants.
- It takes much longer time than mitosis. Genetic variations take place due to meiosis. It keeps the same chromosome number in a life cycle of a species. (Gametophyte ↔ sporophyte).
- Meiosis is divided into two major stages- Meiosis-I and Meiosis-II.
- Meiosis -I is longer. In the four phases prophase is longest. At different stages in prophase: Leptotene- condensation starts, chromosomes are thin thread like. Zygotene- pairing of homologous chromosomes (bivalent) and formation of synaptonemal complex. Spindle fibres appear. Pachytene – genetic exchange between non-sister

chromatids, tetravalent stage, and crossing over takes place after chiasma formation. It is the longest stage.(50 years in human females). Diplotene – synaptonemal complex dissolved by repulsion. Diakinesis – terminalization.

- During metaphase bivalents are arranged rigidly at the centre.
- During anaphase bivalents are separated thus reducing chromosome number.
- Meiosis –II is like mitosis.