UNIT - III

CHAPTER 8 : CELL - THE UNIT OF LIFE

All organisms are made of cells or aggregates of cells. Cells vary in their shape, size and functions. Based on the presence or absence of a membrane bound nucleus and other organelles, cells can be named as Prokaryotic or Eukaryotic.

- Cell is the fundamental structural and functional unit of all living organisms.
- Anton Von Leeuwenhoek first observed and described a liver cell.
- Robert Brown later discovered the nucleus.

Cell theory – Schleiden and Schwann (later Virchow)

- All living organism are made of cells and their products.
- All cells arise from pre – existing cells.

Prokaryotic cell : Bacteria, Blue-green algae, Mycoplasma, PPLP (Pleuro Pneumonia Like Organisms.

- Glycocalyx, cell wall, plasma membrane
- Based on staining property gram + and gram –ve bacteria.
- Mesosome, chromatophores (extension of plasma membrane)
- Motile, non motile,
- Flagellum- three parts are – filament. Hook, and basal body
- Pili, fimbriae – surface structure do not play a role in motility but helps in attachment
- Ribosomes and inclusion bodies.
- Ribosomes. 15-20 nm, 2 sub – units 50S and 30S-together form 70S. – help in Protein synthesis – polysomes / polyribosomes on m RNA
- ***Inclusion bodies***. Reserve materials: Phosphate granules, Cyanophycean , Glycogen granules, Gas vacuoles.

Eukaryotic cell :

- Protists, Fungi, Plant cell and animal cell
- Cell membrane – fluid mosaic model by Singer & Nicholson (1972) - bilipid layer of phospholipids with two types of membrane proteins called peripheral protein and integral proteins with cholestral, glycolipids and glycoproteins.

Cell wall : It gives shape, mechanical support, cell-to-cell interaction – made of cellulose, hemicelluloses, pectins (in plants) and cellulose, galactans, mannans, calcium carbonate (in algae).

- Primary cell wall – in young plant cell, capable of growing till cell matures
- Secondary cell wall – formed on the inner side of the cell.
- Middle lamellae – calcium pectate

- The cell wall middle lamellae may be traversed by plasmodesmata which connect the cytoplasm of neighbouring cells.

Endoplasmic reticulum :

- SER – no ribosomes on its surface, appears smooth (helps in lipid synthesis/ steroids)
- RER – ribosomes are present on its surface, appears rough surface (helps in protein synthesis)

Golgi apparatus – first observed by Camillo Golgi - packaging unit - makes glycoprotein and glycolipids.

Lysosomes – contain enzyme, hydrolases – help intra cellular digestion.

Vacuoles : tonoplast is vacuole membrane - contractile vacuole (for excretion) – food vacuole (engulfing).

Mitochondria – power house of the cell – sites of aerobic respiration, produce energy capsules ATP – double membrane structure, inner compartment is known as Matrix – inner membrane forms a number of infoldings called Cristae to increase the surface area – matrix possesses single circular DNA, few RNA and ribosomes (70S).

Plastids – chloroplast, chromoplast and leucoplasts - Leucoplasts - amyloplasts, (starch); Elaioplasts (oil/fat); Aleuroplasts (proteins).

Riboomes (George Palade) - Composed of RNA and proteins - Eukaryotic ribosomes are 80 S
'S' stand for the sedimentation coefficient (Svedbergs unit) - Site of protein synthesis.

Cytoskeleton: Network of filaments proteinaceous structures in the cytoplasm - made up of microtubules and micro philaments. Functions:- Mechanical support, motility, maintenance of the shape of the cell.

Cilia and flagella: Core is called axoneme - has 9 pairs of doublets of microtubules on peripheral and one pair in the centre 9+2 array emerged from centriole like structure called the Basal bodies.

Centrosome and centrioles: Centrosome contains 2 centrioles - Each centriole has a cart wheel like organization with 9 evenly spaced microtubule - triplets connected to central hub by radial spokes – produces spindle apparatus dueing cell division

Nucleus (Robert brown, 1831) :

- Chromatin named by Flemming.
- Nucleoli – active ribosomal RNA synthesis
- Nucleoplasm – nucleolus + chromatin

- Nuclear membrane – with perinuclear space
- Chromosome – DNA + histone proteins
- Centromere –primary constriction – disc is known as kinetochores
- No nucleus in erythrocytes (RBC) of mammals and sieve tube cells in vascular plants
- Based on the position of centromere
- Metacentric, sub-metacentric, acrocentric, telocentric

Microbodies: Minute vesicles containing various enzyme (in plant and animal cell).

****

CHAPTER 9 : BIOMOLECULES

Living cells are composed of both organic and inorganic components.

How to analyse chemical composition:
For organic compounds:

- Living tissue + trichloro acetic acid and grind it to form slurry.
- Filter the slurry to obtain 2 fractions like Filtrate/ acid soluble and Retentate/ acid insoluble

For inorganic compounds:

Sample of tissue should be burnt to obtain ash and different kinds of inorganic compounds were identified.

Types of biomolecules - Micro molecules and Macro molecules

- Micro molecules are known as monomers
- Macromolecules are known as polymers

Primary and Secondary metabolites: These are biomolecules in living cells metabolites.

Primary metabolites are those which have identifiable functions and play specific roles in normal physiological processes. Eg. Amino acids, nitrogenous bases, proteins and nucleic acid.

Secondary metabolites are product of certain metabolic pathways from primary metabolites.

- Pigments – anthocyanin, carotenoids
- Drugs – vinblastin, curcumin
- Alkaloids - morphine, codeine
- Essential oils – lemon grass oil
- Polymeric compounds - rubber gum, cellulose, resins

Biomacromolecules

It is molecules with weight greater than 1000 dalton found in acid insoluble fraction.
Eg- polysaccharides, nucleic acid, proteins and lipids.

Polysaccharides :

- Long chain of polymers of monosaccharides – 2 types of Mono-polysaccharides (cellulose, starch – made of only Glucose monomers).
- Heteropolymer – chitin
- Inulin -is a polymer of fructose
- Glycogen – polymer of glucose in animal tissues
- Monosaccharides are joined by Glycosidic acid bond, right end is reducing and left end is non reducing.
- Starch forms helical secondary structures. Starch can hold Iodine molecules in helical portion and form blue colour. But Cellulose does not contain complex helices and cannot hold iodine.
- Complex polysaccharide: .Plant cell wall (cellulose), Paper (plant pulp), Cotton, Fibre (cellulose) Exoskeleton of animals, building blocks, amino-sugars and chemically modified Sugars like, Eg. – Giucosamine (N – acetyl galactosamine).

Nucleic acids:

- DNA – Polynucleotide chain, double stranded (deoxy ribose sugar) – nitrogenous bases are A, G, C and T
- RNA – single stranded Polymer of ribo-nucleotides (ribose sugar) – A, G, C and U
- Nucleotides – nitrogenous base + pentose sugar + phosphate group
- Nucleoside – nitrogenous base + pentose sugar
- Nitrogenous bases
    1. Adenine (A)
    2. Guanine(G)
    3. Cytosine(C)
    4. Thymine (T)

Phospho-diester bonds – covalent bond formed between nucleotides.

Proteins:

- Polymer of amino acids (peptide bonds)
    1. Primary structure – linear chain of aminoacids linked by peptide bonds – non functional.
    2. Secondary structure – alpha-helix or beta-pleated structure with peptide and hydrogen bonds.
    3. Tertiary structure – long chain of coiled structure with peptide, hydrogen, disulphide and ionic bonds – functional structurte of protein.
    4. Quaternary structure – group of more than two tertiary structured proteins (eg- haemoglobin – made of two alpha and two beta chains).

Nature of bonds linking monomers in a polymer:

1. Amino acids are linked by Peptide bonds
2. Monosaccharides are linked by Glycosidic bond
3. Nucleotides are linked by Phosphodiester bond between 3-C of one nucleotide with 5-C of another - Each helix of DNA contains 10 base pairs with the length of 3.4 nm (34 A^{o}).

Concept of Metabolism:

- Biomolecules have turn over (because constantly changing from one form to another)
- Chemical reactions are called metabolism.

Examples:

- Amino acids can be formed by the removal of amino group in a nucleotide base.
- Hydrolysis of disaccharides – 2 monosacharides
- Linked chemical reactions are called Metabolic pathways, it is a catalysed reaction by enzymes.

Metabolic pathways in living system:

- Anabolic pathways - making / constructing big molecules from micromolecules (eg – photosynthesis)
- Catabolic pathways – breaking down of big molecules in to smaller ones (eg – respiration)
- For both ATP is required (energy currency)

The living state

- Blood glucose – should be 4.5 -5.0mM
- Hormones – in nanograms/mL
- System at equilibrium cannot perform work
- As living organisms work constantly, it is non equilibrium.
- Hence the living state is non equilibrium steady state to be able to perform work.

Enzymes Vs Catalysts:

- Enzyme – helps in chemical reactions
- Inorganic reaction :- $Ba(OH)_2 + H_2SO_4 \rightarrow BaSO_4 + 2\ H_2O$ – No enzyme used.
- Organic reaction - Enzyme used
- Carbonic anhydrase – fastest enzyme - without enzyme 200 molecules / hr - with enzyme 600,000 molecules / sec.
- Activation energy is the energy needed to do work.

Nature of enzyme action:

Enzyme + Substrate --> ES complex --> Enzyme + Product

	ENZYME	CATALYST
1.	It is produced by living cells and made of protein.	It is chemical substances and help in chemical reactions.
2.	It can work well at optimum temperature of 40^{o} C.	It can work even at 80 – 90^{o} C.
3.	It reduces the activation energy.	It requires different level of energy.

Properties of Enzymes:

1. All enzymes are proteins, but all proteins are not enzymes.
2. Enzymes are specific with their substrates as their active sites are different for different substrates.
3. Enzymes are of 2 types 1. Builders. 2. Breakers
4. Enzyme does not get used up during the reaction, as it does not change its shape – hence less enzymes are required.

Denaturation:

The enzyme changes its shape and the substrate cannot bind with the enzyme - affect tertiary structure of the protein.

Factors affecting enzyme activity:

- Effect of temperature: temperature at which the enzyme gives its maximum rate of reaction is known as optimum temperature (40^{o} C).
- Effect of pH - different enzymes work at different pH, for example, enzyme pepsin works at pH 2, and enzyme amylase at pH 7, it is called optimum pH.
- Substrate concentration -

Enzyme inhibition – enzyme action can be inhibited by other chemical molecules called inhibitors.

Competitive inhibition: Inhibitor chemical molecule resembles the structure of substrate and bind with the active site of enzyme instead of substrate, hence there is no production of products.

Eg. Inhibition of Succinic dehydrogenase by Malonate (inhibitor), which resembles the substrate Succinate in structure.

- All enzymes are proteins but all proteins are not enzymes. Eg. Heamoglobin is a protein but not an enzyme.
- Enzymes at low temperature become inactive, enzymes at high temperature denatures.

Classification and nomenclature of enzymes: Based on type of reaction they classified into 6 classes.

1. ***Dehydrogenases/ oxidoreductases*** -
   S reduced + S' oxidized ------ S oxidized + S' reduced
2. ***Transferases*** -
   S-G + S'------- S+S'-G
3. ***Hydrolases*** -
   Hydrolysis of ester ether, peptide and glycoside
   C –C , C- halides , P-N bonds
4. ***Lyases*** -
   Removal of group from substrates other than hydrolysis (from double bond)
   X Y
   I I
   C C ------ X-Y+C =C
5. ***Isomerases*** - Inter-conversion of optical geometrical or positional isomers.
6. ***Ligases*** – linking two compounds. C-O, C-S, C-N, P-O

Co-factors:

- It is a non – protein part, makes enzyme more active – protein part is called *Apoenzyme*.

- There are 3 kinds of factors:
  1. Prosthetic group - tightly bound with apoenzyme. Eg. Peroxidase, Catalases.
  2. Co-enzyme – bound transient form. Eg. NAD, NADP (Nicotinamide Adenine Dinucleotide Phosphate)
  3. Metal ions - Form coordination bonds. Eg. Fe, Zn.

****

CHAPTER 10 : CELL CYCLE AND CELL DIVISION

Cell cycle

It is a series of events that takes place in a cell, leading to the formation of two daughter cells from a single mother cell.

Cell cycle is divided into two basic phases**: Interphase and M phase** Phases of cell cycle.

- Interphase
- M phase (mitosis phase) karyokinesis and cytokinesis

Interphase

- G1 phase
- S phase
- G2 phase
- Go phase-quiescent stage

Mitotic phase

- Karyokinesis (nuclear division): – Prophase, Metaphase, Anaphase and Telophase.
- Cytokinesis (division of cytoplasm)

Interphase

Interphase involves a series of changes that prepares the cell for division. It involves the period of cell growth and cell division in an orderly manner.

It is divided into three phases:

- **G1 phase** – It involves growth of cell and preparation of DNA for replication.
- **S phase** – It involves DNA synthesis. The amount of DNA doubles, but the chromosome number remains the same.
- **G2 phase** – It involves protein synthesis and further growth of cell, which prepares it for division.
- **G0 pha**se or Quiescent phase – It is the stage when metabolically active cell remains quiescent for long period of time.

I Mitosis

- It is a process of cell division where chromosomes replicate and get equally distributed into two daughter cells. Hence, it is also called equational division.
- The process of mitosis keeps the chromosome number equal in daughter as well as parental cell.
- Mitosis usually takes place in somatic cells.

Mitosis involves four stages:

Prophase

- It involves initiation and condensation of chromosomes.
- Nucleolus and nuclear membrane disappears.

Metaphase

- Chromosomal material condenses to form compact chromosomes that get aligned in the middle of nucleus at equatorial plate.

Anaphase

- Centromere splits and chromosomes move apart towards two opposite poles due to shortening of spindle fibres.

Telophase

- Chromosomes finally reach their respective poles.
- Nuclear envelope assembles around each chromosome clusters.
- Nucleolus and other organelles reform.

Karyokinesis and Cytokinesis

- Karyokinesis is the division of nucleus during mitosis or meiosis which is followed by cytokinesis.
- Cytokinesis involves the division of cytoplasm of a cell.
- Cytokinesis is achieved in animal cell by cleavage, which deepens and divides the cell into two.
- It is achieved in plant cell by cell plate formation.
- When karyokinesis is not followed by cytokinesis, a multinucleated condition arises. This is called *Syncytium*.

Significance of mitosis

- Results in formation of diploid genetically identical daughter cells
- Growth of the body takes place by mitosis.
- Cell repair and replacement of worn out tissues
- Maintenance of nucleo-cytoplasmic ratio
- Vegetative reproduction in plants takes place by mitosis.

II Meiosis

- It is the process which involves the reduction in the amount of genetic material.
- It mainly occurs in germ cells.
- At the end of meiosis II, four haploid cells are formed.
- It is comprised of two successive nuclear and cell division with a single cycle of DNA replication.
- The phases of meiosis are as shown below-

Meiosis I

1. Prophase I – It comprises of 5 stages:

i. Leptotene

- Chromosomes start condensing.

ii. Zygotene

- Pairing of chromosomes called synapsis occurs.
- A pair of synapsed homologous chromosomes is called bivalent or tetrad.

iii. Pachytene

- Exchange of genetic material (crossing over) between non-sister chromatids occurs.
- Chiasmata formation

iv. Diplotene

- Bivalents formed during pachytene separate from each other (except at chiasmata) due to dissolution of synaptonemal complex.

v. Diakinesis

- Terminalisation of chiasmata can be observed.
- By the end of this stage, the nucleolus disappears and the nuclear envelope breaks.

2. Metaphase I

- Bivalents (tetrad) get aligned along metaphase plate through spindle fibres.

3. Anaphase I

- Homologous chromosomes separate while chromatids remain attached at their centromere.

4. Telophase

- Nucleolus and nuclear membrane reappear around chromosome clusters at each pole.
- Inter-kinesis – It is the stage between two meiotic divisions.

Meiosis II

1. Prophase II

- Chromosomes become compact.
- Nuclear membrane disappears.

2. Metaphase II

- Chromosomes align at the equator.
- Kinetochores of sister chromatids attach to spindle fibres at each pole.

3. Anaphase II

- Chromatids separate by splitting of centromere.
- As a result, chromatids move towards their respective poles in the cell.

4. Telophase II

- Nuclear envelope and nucleolus reform around the chromosome clusters.

Cytokinesis:

- After meiosis II, the process of cytokinesis results in the formation of four haploid cells.

Significance of meiosis:

- It results in reduction of chromosome number by half in gametes, which again doubles during fertilization. Therefore, it helps to conserve the chromosome number of species from generation to generation.
- Crossing-over, occurring in pachytene stage of meiosis I, is a source of genetic variation in sexually reproducing organisms.
- The variation thus formed helps in evolution.

Differences between Mitosis and Meiosis:

	MITOSIS	MEIOSIS
1.	It occurs in Somatic cells.	It occurs in Sex cells.
2.	It gives 2 daughter cells	It gives 4 gametes.
3.	Cells formed are diploid (2n)	Cells formed are haploid (n)
4.	During Metaphase, chromosomes are not lined in pair.	During Metaphase I, homologous chromosomes are lined up in pairs.
5.	During Prophase no recombination takes place.	During Prophase I, recombination / crossing over occur between homologous chromosomes.
6.	During Anaphase, centromere splits and chromatids move towards opposite poles.	During Anaphase I, homologous chromosomes separate and Anaphase II, centromere splits and chromatids move towards opposite poles.
7.	It takes very short duration.	It takes very long duration.
8.	Only one division occurs and forms two diploid daughter cells	Two divisions occur and form 4 haploid cells.