1 (a) Write at least one contribution of the following scientists (Attempt any five):

- (i) Maurice Wilkins
    - Contributed to the determination of the structure of DNA, particularly through his X-ray diffraction studies.
- (ii) Singer and Nicolson
    - Proposed the fluid mosaic model of the cell membrane.
- (iii) Robert Brown
    - Discovered the nucleus in plant cells and described Brownian motion.
- (iv) Fritz Lipmann
    - Discovered coenzyme A and elucidated its role in metabolism, especially in the breakdown of carbohydrates and fats, and emphasized the central role of ATP in energy transfer.
- (v) Gunter Blobel and David Sabatini
    - Gunter Blobel: Proposed the signal hypothesis for protein targeting to organelles.
    - David Sabatini: Contributed to the understanding of the function of the endoplasmic reticulum and ribosomes in protein synthesis and membrane biogenesis.
- (vi) George Palade
    - Identified ribosomes as the sites of protein synthesis and elucidated the secretory pathway within cells.

(b) State whether the following statements are true or false (any ten):

- (i) Tertiary structure of proteins involves more than one polypeptide.

  - False. Tertiary structure refers to the three-dimensional folding of a *single* polypeptide chain. Quaternary structure involves more than one polypeptide.

- (ii) Sucrose is a disaccharide and has alpha (1-4) bond.
  - False. Sucrose is a disaccharide, but it has an alpha (1-2) glycosidic bond between glucose and fructose.
- (iii) Nucleus communicates with the cytoplasm through nucleopores.
  - True. Nuclear pore complexes embedded in the nuclear envelope regulate the transport of molecules between the nucleus and the cytoplasm.
- (iv) Cell membranes are composed of amylose and amylopectin.
  - False. Cell membranes are primarily composed of phospholipids and proteins, not amylose and amylopectin (which are components of starch).
- (v) Cellulose form the lipid component of the cell walls.
  - False. Cellulose is a polysaccharide that forms the primary structural component of plant cell walls; it is not a lipid.
- (vi) Phosphodiglycerides are a part of cell membranes.
  - True. Phosphodiglycerides (also known as phosphoglycerides or glycerophospholipids) are a major class of lipids that form the basic structure of cell membranes.
- (vii) Golgi bodies are seat of N-glycosylation of lipids.
  - False. While the Golgi apparatus is involved in glycosylation, N-glycosylation of lipids (specifically, glycosylphosphatidylinositol anchors) and proteins largely begins in the endoplasmic reticulum, and is then further modified in the Golgi. O-glycosylation is more characteristic of the Golgi.
- (viii) Cholesterol is major constituent of plant cell membrane.

  - False. Cholesterol is a major constituent of animal cell membranes. Plant cell membranes contain sterols, but primarily phytosterols, not cholesterol.

- (ix) Pectin is a constituent of bacterial cell wall.
  - False. Pectin is a constituent of plant cell walls. Bacterial cell walls are primarily composed of peptidoglycan.
- (x) Phosphodiester bonds link nitrogenous bases to sugars.
  - False. Glycosidic bonds link nitrogenous bases to sugars. Phosphodiester bonds link the 5' phosphate of one nucleotide to the 3' hydroxyl of another nucleotide within a DNA or RNA strand.
- (xi) Ribosomes are single membrane bound organelles.
  - False. Ribosomes are not membrane-bound organelles. They are composed of ribosomal RNA and proteins.
- (xii) Lysosome helps in protein folding.
  - False. Lysosomes are primarily involved in the degradation and recycling of cellular waste, organelles, and macromolecules. Protein folding is primarily assisted by chaperones in the ER and cytoplasm.

(c) Fill in the blanks (Attempt any five):

- (i) **Cysteine** amino acid participates in the formation of disulfide bonds.
- (ii) Enzymes for oxidative phosphorylation are present on the **inner membrane** of mitochondria.
- (iii) The reticular network which traverses the cytoplasm is known as **Endoplasmic Reticulum**.
- (iv) Digestion of old cell organelles like mitochondria is called **autophagy**.

- (v) The stage at which crossing over of chromosomes takes place during meiosis I is called **Pachytene**.
- (vi) Hydrophobic proteins tend to have **a globular or compact** structure.

2 Differentiate between any three:

- (a) B DNA and Z DNA
    - B-DNA:
        - Most common and stable form of DNA under physiological conditions.
        - Right-handed helix.
        - Has a regular, smooth backbone.
        - Contains major and minor grooves.
        - Approximately 10-10.5 base pairs per turn.
    - Z-DNA:
        - A less common, left-handed helix.
        - Has an irregular, zig-zag backbone.
        - Appears to lack distinct major and minor grooves.
        - Approximately 12 base pairs per turn.
        - Can form in regions of alternating purine-pyrimidine sequences (e.g., GCGCGC).
        - Its biological role is still under investigation, but it's thought to be involved in gene regulation and recombination.
- (b) Microfilament and Intermediate Filament
    - Microfilament:

        - Composed of actin protein.
        - The thinnest filaments of the cytoskeleton (around 7 nm diameter).
        - Highly dynamic, constantly assembling and disassembling.
        - Involved in cell shape changes, muscle contraction, cell division (cytokinesis), and cell motility (e.g., pseudopods).
        - Can be rapidly remodeled.
    - Intermediate Filament:
        - Composed of various proteins depending on the cell type (e.g., keratin in epithelial cells, vimentin in fibroblasts, lamins in the nucleus).
        - Intermediate in size (around 8-12 nm diameter).
        - More stable and less dynamic than microfilaments and microtubules.
        - Provide mechanical strength to cells and tissues, anchoring organelles, and maintaining cell shape.
        - Forms a strong, rope-like structure.
- (c) Primary, Secondary and Tertiary Lysosome
    - Primary Lysosome:
        - Newly formed lysosome, budded off from the Golgi apparatus.
        - Contains digestive enzymes (hydrolases) but has not yet fused with a substrate.
        - pH is acidic but slightly less so than secondary lysosomes.

- Secondary Lysosome (or Phagolysosome/Autophagolysosome):
  - Formed by the fusion of a primary lysosome with an endosome (containing engulfed material from outside the cell) or an autophagosome (containing internal cellular components to be degraded).
  - Site where active digestion of macromolecules occurs.
  - Characterized by a highly acidic internal pH, optimal for hydrolase activity.
- Tertiary Lysosome (or Residual Body):
  - Formed after digestion is complete in the secondary lysosome.
  - Contains undigested, residual waste material.
  - Can remain in the cell as lipofuscin granules or be expelled from the cell.

- (d) Heterochromatin and Euchromatin
  - Heterochromatin:
    - Highly condensed and densely packed chromatin.
    - Transcriptionally inactive or silenced.
    - Replicates late in the S phase.
    - Stains darkly with DNA dyes.
    - Found in regions like centromeres and telomeres.
    - Rich in repetitive DNA sequences.
  - Euchromatin:
    - Less condensed and loosely packed chromatin.

- Transcriptionally active, contains most of the expressed genes.
- Replicates early in the S phase.
- Stains lightly with DNA dyes.
- Dispersed throughout the nucleus.
- Rich in gene-coding sequences.

3 Write short notes on any three:

- (a) Semiautonomous Organelles
  - Semiautonomous organelles are cellular organelles that possess their own genetic material (DNA), ribosomes, and some components of the machinery needed for protein synthesis, allowing them to carry out some functions independently of the nucleus, yet they still rely on the rest of the cell for many essential proteins and materials. The two main examples in eukaryotic cells are mitochondria and chloroplasts. They divide by binary fission, similar to bacteria, and contain circular DNA molecules. Their ability to synthesize some of their own proteins, coupled with their bacterial-like features, supports the endosymbiotic theory, which posits that these organelles originated from free-living prokaryotes that were engulfed by ancestral eukaryotic cells.
- (b) Cell Wall
  - The cell wall is a rigid, protective layer found outside the plasma membrane in plant cells, fungi, algae, and bacteria, but absent in animal cells. Its primary functions include providing structural support and protection to the cell, maintaining cell shape, preventing excessive water uptake by osmotic lysis, and acting as a barrier against pathogens. In plants, the cell wall is primarily composed of cellulose microfibrils embedded in a matrix of hemicelluloses, pectins, and lignin. In fungi, it's mainly

chitin, while in bacteria, it's peptidoglycan. The cell wall is permeable, allowing water and small molecules to pass through, but its structural integrity is crucial for the survival and turgor of the cell.

- (c) Biological Significance of Hydrogen Bonds
    - Hydrogen bonds are weak intermolecular forces formed between a hydrogen atom covalently bonded to a highly electronegative atom (like oxygen, nitrogen, or fluorine) and another electronegative atom. Despite being individually weak, their collective strength provides crucial stability to biological macromolecules and processes. They are fundamental to the structure of water, allowing it to act as an excellent solvent and moderating temperature. In proteins, hydrogen bonds stabilize secondary structures like alpha-helices and beta-sheets, and contribute to tertiary and quaternary structures. In nucleic acids, hydrogen bonds between complementary base pairs (A-T/U, G-C) are essential for maintaining the double helix structure of DNA and RNA, facilitating accurate replication, transcription, and translation, and allowing for reversible strand separation.
- (d) Structure and Function of ATP
    - ATP (Adenosine Triphosphate) is the primary energy currency of the cell, providing energy for most cellular processes.
    - Structure: ATP consists of an adenine base, a ribose sugar, and three phosphate groups linked in series. The last two phosphate bonds, known as phosphoanhydride bonds, are high-energy bonds.
    - Function:
        - Energy Coupling: Energy released from the hydrolysis of the terminal phosphate bond of ATP (ATP $\rightarrow$ ADP + Pi) is used to drive energy-requiring cellular reactions, such as muscle contraction, active transport across membranes,

and synthesis of macromolecules (e.g., DNA, RNA, proteins).

- Phosphorylation: The terminal phosphate group can be transferred to other molecules (phosphorylation), activating them or changing their conformation, which is crucial for signal transduction pathways.
- Precursor: ATP serves as a precursor for the synthesis of RNA.
- Allosteric Regulator: It can act as an allosteric regulator of enzyme activity, modulating metabolic pathways.

4 Draw well labelled ultrastructure of any three:

- (a) Fluid mosaic model
- (b) Chloroplast
- (c) Nuclear Pore complex
- (d) Flagella

5.(a) Garbage disposal or suicidal bags is a popular expression for one of the cell organelle. Name the organelle and comment on its function.

- The organelle referred to as "garbage disposal" or "suicidal bags" is the **lysosome**.
- Function:
  - Lysosomes are membrane-bound organelles containing a wide array of hydrolytic enzymes (hydrolases) that are active under acidic conditions (optimal pH around 4.5-5.0).
  - They serve as the cell's primary digestive and recycling centers.
  - **Degradation of macromolecules:** They break down various macromolecules, including proteins, nucleic acids, carbohydrates, and lipids, into their simpler building blocks

(amino acids, nucleotides, monosaccharides, fatty acids) which can then be recycled by the cell.

- **Digestion of extracellular material (Heterophagy):** Lysosomes fuse with endosomes or phagosomes (containing material taken up from outside the cell, like bacteria or cellular debris) to form secondary lysosomes, where the engulfed material is digested.
- **Digestion of old or damaged organelles (Autophagy):** They enclose and break down worn-out or dysfunctional cellular components, such as mitochondria or ribosomes, through a process called autophagy, which is vital for cellular renewal and homeostasis.
- **Autolysis (Suicidal function):** In certain pathological conditions or during programmed cell death (apoptosis), lysosomes can rupture and release their enzymes into the cytoplasm, leading to the self-digestion of the cell. This is why they are sometimes called "suicidal bags."
- **Role in cellular processes:** Lysosomes play crucial roles in nutrient sensing, immune response, and bone resorption.

(b) Golgi apparatus is the export house of the cell. Comment.

- The statement "Golgi apparatus is the export house of the cell" is an apt description because the Golgi apparatus (also known as the Golgi complex or Golgi body) is a central organelle in the endomembrane system responsible for modifying, sorting, and packaging proteins and lipids synthesized in the endoplasmic reticulum (ER) for secretion out of the cell or delivery to other cellular destinations.
- **Key functions that support this description:**
  - **Further Processing and Modification:** Proteins and lipids arriving from the ER are further processed within the Golgi's distinct compartments (cis, medial, trans-Golgi cisternae). This

includes extensive glycosylation (adding and modifying carbohydrate chains), phosphorylation, and sulfation, which are crucial for the proper function and targeting of molecules.

- **Sorting and Packaging:** The trans-Golgi network (TGN) acts as a crucial sorting station. Here, modified proteins and lipids are sorted into different vesicles destined for specific locations.
- **Vesicular Transport and Export:**
  - **Secretion:** Proteins and lipids destined for secretion outside the cell (e.g., hormones, enzymes, extracellular matrix components) are packaged into secretory vesicles that bud off from the TGN and move to the plasma membrane, where they fuse and release their contents (exocytosis).
  - **Lysosomal Delivery:** Hydrolases destined for lysosomes are sorted and packaged into specific vesicles that fuse with endosomes to form lysosomes.
  - **Membrane Integration:** Proteins and lipids intended for the plasma membrane or other organelles within the endomembrane system are also sorted and delivered by Golgi-derived vesicles.
- **Quality Control:** The Golgi also participates in quality control, ensuring that only properly folded and modified molecules are sent to their destinations.

- In essence, the Golgi acts like a cellular post office or a distribution center, taking in raw materials from the ER, processing them, sorting them with specific "address labels," and then dispatching them to their final destinations, thus facilitating the "export" of cellular products.

(c) Explain the process of regulation of cell cycle in eukaryotes.

- The eukaryotic cell cycle is a tightly regulated process that ensures accurate DNA replication and segregation, leading to the production of two genetically identical daughter cells. This regulation is primarily controlled by a sophisticated system of checkpoints and key protein complexes, most notably Cyclin-Dependent Kinases (CDKs) and cyclins.
- **Key Regulators:**
    - **Cyclin-Dependent Kinases (CDKs):** These are enzymes that phosphorylate (add phosphate groups to) specific target proteins, thereby activating or inactivating them to control cell cycle progression. CDKs are constitutively present but are inactive on their own.
    - **Cyclins:** These are proteins whose concentrations fluctuate throughout the cell cycle. They bind to and activate CDKs. Different cyclins are expressed at different phases, activating specific CDKs needed for that phase.
    - **CDK-Cyclin Complexes:** The binding of a cyclin to a CDK forms an active complex (e.g., G1-CDK, S-CDK, M-CDK) that drives the cell through specific phases of the cycle.
- **Checkpoints:** The cell cycle is monitored by "checkpoints" that ensure critical events (e.g., DNA replication, chromosome segregation) are completed accurately before proceeding to the next phase. These checkpoints prevent errors that could lead to mutations or aneuploidy.
    - **G1 Checkpoint (Restriction Point):**
        - Often considered the most important checkpoint.
        - The cell assesses its size, nutrient availability, growth factors, and DNA integrity.

- If conditions are favorable and there is no DNA damage, the cell commits to entering S phase. If not, it may enter a quiescent state (G0) or undergo apoptosis.
- Regulation: Activated G1-CDK-cyclin complexes (e.g., Cyclin D-CDK4/6, Cyclin E-CDK2) phosphorylate the Rb (retinoblastoma) protein, releasing E2F transcription factors to promote expression of S-phase genes.

- **G2/M Checkpoint:**
  - Ensures that DNA replication is complete and any DNA damage is repaired before mitosis begins.
  - Regulation: MPF (Maturation-Promoting Factor), which is a Cyclin B-CDK1 complex, is crucial. It is kept inactive by phosphorylation until all conditions are met. Once activated, MPF phosphorylates proteins involved in chromosome condensation, nuclear envelope breakdown, and spindle formation.

- **Metaphase-Anaphase Checkpoint (Spindle Assembly Checkpoint - SAC):**
  - Occurs during metaphase of mitosis.
  - Ensures that all sister chromatids are correctly attached to microtubules from opposite poles of the spindle.
  - If any kinetochore is unattached or improperly attached, the checkpoint delays anaphase onset.
  - Regulation: Unattached kinetochores activate the SAC, which inhibits the Anaphase-Promoting Complex/Cyclosome (APC/C). Once all attachments are correct, APC/C is activated, leading to the ubiquitination and degradation of securin (which inhibits separase) and cyclins, allowing separase to cleave cohesin and initiate anaphase.

- **Other Regulators:**
    - **Ubiquitin Proteasome System (UPS):** Important for degrading cyclins and other regulatory proteins at specific times, which is essential for irreversible progression through the cell cycle (e.g., APC/C targets cyclins for degradation).
    - **Tumor Suppressor Genes (e.g., p53):** Act to halt the cell cycle or induce apoptosis in response to DNA damage, preventing the proliferation of abnormal cells.
    - **Growth Factors:** External signals that stimulate cell proliferation by activating signaling pathways that lead to cyclin and CDK production.

6 (a) What is the role of mitosis in living organisms?

- Mitosis is a fundamental process of cell division in eukaryotic cells that results in two daughter cells each having the same number and kind of chromosomes as the parent nucleus, typically for growth, tissue repair, and asexual reproduction.

- **Key roles of mitosis:**
    - **Growth:** For multicellular organisms, mitosis is essential for increasing the number of cells, leading to the growth and development of the organism from a single zygote to a mature adult.
    - **Tissue Repair and Regeneration:** It replaces damaged or worn-out cells, allowing for the repair of injuries and the maintenance of tissues and organs (e.g., skin cells, blood cells, gut lining cells are constantly being replaced).
    - **Asexual Reproduction:** In many single-celled eukaryotic organisms (e.g., yeast, amoeba) and some multicellular organisms (e.g., plants, hydra), mitosis is the primary method of asexual reproduction, producing genetically identical offspring.

- **Development:** During embryonic development, repeated rounds of mitosis are crucial for forming different tissues and organs from a fertilized egg.
- **Genetic Stability:** Mitosis ensures that each daughter cell receives an exact and complete set of chromosomes, thus maintaining the genetic integrity and chromosome number across generations of cells within an organism.

(b) What is the importance of protein glycosylation and where does it take place?

- **Importance of Protein Glycosylation:**
  - **Protein Folding and Stability:** Glycans (carbohydrate chains) can assist in the proper folding of proteins in the endoplasmic reticulum and can enhance the stability of proteins against denaturation or proteolysis.
  - **Cell-Cell Recognition and Adhesion:** Glycoproteins on the cell surface act as molecular tags, enabling cells to recognize and bind to each other. This is crucial for processes like immune responses (e.g., ABO blood groups), embryonic development, and tissue formation.
  - **Cell Signaling and Receptor Function:** Glycans can modulate the activity of cell surface receptors, influencing how cells receive and respond to external signals.
  - **Immune Response:** Glycans on pathogens are recognized by the host immune system, and conversely, glycans on host cells can modulate immune cell interactions.
  - **Barrier Function:** Glycocalyx (a carbohydrate-rich layer on the cell surface formed by glycoproteins and glycolipids) provides protection to the cell membrane from chemical and mechanical damage.

- **Protein Sorting and Targeting:** Specific glycans can act as signals that direct proteins to their correct cellular destinations (e.g., mannose-6-phosphate tag for lysosomal enzymes).

- **Where does it take place?**
  - Protein glycosylation primarily takes place in two main organelles within the endomembrane system:
    - **Endoplasmic Reticulum (ER):** N-linked glycosylation (attachment of carbohydrates to the nitrogen atom of asparagine residues) begins in the ER. A pre-formed oligosaccharide chain is transferred from a lipid carrier (dolichol phosphate) to the nascent protein.
    - **Golgi Apparatus:** Both N-linked and O-linked glycosylation (attachment of carbohydrates to the oxygen atom of serine or threonine residues) undergo extensive modifications and further additions in the Golgi. The Golgi contains a series of glycosyltransferases and glycosidases that modify the sugar chains in a stepwise manner as proteins move through its cis, medial, and trans compartments.

(c) Write an account of structure and function of nucleolus.

- The nucleolus is a prominent, non-membrane-bound organelle found within the nucleus of eukaryotic cells. It is the primary site of ribosome synthesis and assembly.

- **Structure:**
  - The nucleolus is typically spherical and appears as a dense, granular structure under an electron microscope. Its size and number can vary depending on the metabolic activity of the cell.
  - It is organized into several distinct sub-regions, although these are not separated by membranes:

        - **Fibrillar Center (FC):** Contains the ribosomal DNA (rDNA) genes. These are the regions where rRNA genes are transcribed.
        - **Dense Fibrillar Component (DFC):** Surrounds the FC and is the site where nascent rRNA transcripts are processed and associated with ribosomal proteins.
        - **Granular Component (GC):** The outermost region where the assembly of ribosomal subunits (large and small) occurs before their export to the cytoplasm.
    - It is rich in ribosomal RNA (rRNA), ribosomal proteins (imported from the cytoplasm), enzymes involved in rRNA processing, and snoRNAs (small nucleolar RNAs) which guide rRNA modification.
- **Function:**
    - **Ribosome Biogenesis:** The primary and most well-understood function of the nucleolus is the synthesis and assembly of ribosomes. This involves:
        - **rRNA Transcription:** The ribosomal DNA (rDNA) genes are transcribed by RNA Polymerase I to produce a large precursor rRNA molecule (e.g., 45S pre-rRNA in mammals).
        - **rRNA Processing and Modification:** This precursor rRNA is then cleaved, trimmed, and chemically modified (e.g., methylation, pseudouridylation) with the help of snoRNAs and associated proteins.
        - **Ribosomal Protein Import and Assembly:** Ribosomal proteins, synthesized in the cytoplasm, are imported into the nucleolus. Here, they associate with the processed rRNAs to form the nascent large and small ribosomal subunits.

- **Ribosomal Subunit Export:** Once assembled, these ribosomal subunits are exported individually through nuclear pores to the cytoplasm, where they combine to form functional ribosomes for protein synthesis.

- **Other Functions (Emerging Roles):** Beyond ribosome biogenesis, the nucleolus is increasingly recognized for its involvement in various other cellular processes, including:
  - **Stress Response:** It can alter its structure and function in response to cellular stress.
  - **Cell Cycle Regulation:** Some nucleolar proteins are involved in regulating cell cycle progression.
  - **RNA Processing and Transport:** Involvement in the processing and transport of other non-coding RNAs.
  - **Modulation of Chromatin Structure:** Interaction with chromatin organization.