

**ZOOLOGY**

# **Cytology, Genetics & Infectious Diseases**

*for*

## **B.Sc. Sem. I**

**Chaudhary Charan Singh University, Meerut**

*Authors*

**Dr. Subhash Kumar**

*Assistant Professor and HOD*

*CCR (PG) College, Muzaffarnagar (U.P.)*

**Dr. Preeti Chaudhary**

*Assistant Professor*

*Dept. of Zoology, I.P. (P.G.) College, Bulandshahr (U.P.)*



First Edition : 2025

## **Cytology, Genetics & Infectious Diseases**

**Authors:** Dr. Subhash Kumar and Dr. Preeti Chaudhary

**ISBN: 978-93-49911-77-2**

Printing : Shiv Offset Printers, Meerut

DTP : Learning Media DTP Unit, Meerut

Design: Learning Media Designing Unit, Meerut

© ***Publisher***

**Publisher: Learning Media Publication, Meerut**

**Regd. Office :**

**Learning Media Publication**

A-16, Aman Vihar, Mawana Road,

Opp. J.P. Academy, Meerut- 250001

Contact No. +91-8449001390, 8791976106

E-mail : learningmediapublicationmeerut@gmail.com

Website : www.learningmedia.in

**Price : ₹210**

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# CONTENTS

## **UNIT 1. Structure and Function of Cell Organelles I** **1-20**

Plasma membrane: chemical structure, lipids and proteins, Cell-cell interaction: cell adhesion molecules, cellular junctions, Endomembrane system: protein targeting and sorting, endocytosis, exocytosis

---

## **UNIT 2. Structure and Function of Cell Organelles II** **21-38**

Cytoskeleton: microtubules, microfilaments, intermediate filaments, Mitochondria: Structure, oxidative phosphorylation, electron transport system, Peroxisome and ribosome: structure and function

---

## **UNIT 3. Nucleus and Chromatin Structure** **39-57**

Structure and function of nucleus in eukaryotes, Chemical structure and base composition of DNA and RNA, DNA supercoiling, chromatin organization, structure of chromosomes, Types of DNA and RNA

---

## **UNIT 4. Cell cycle, Cell Division and Cell Signaling** **58-82**

Cell division: mitosis and meiosis, Introduction to Cell cycle and its regulation, apoptosis, Signal transduction: intracellular signaling and cell surface receptors, via G-protein linked receptors, Cell-cell interaction: cell adhesion molecules, cellular junctions

---

## **UNIT 5. Mendelism and Sex Determination** **83-105**

Basic principles of heredity: Mendel's laws, monohybrid and dihybrid crosses, Complete and Incomplete Dominance, Clinical expressions: Penetrance and expressivity, Genic Sex-Determining Systems, Environmental Sex Determination, Sex Determination in *Drosophila*, Sex-linked characteristics and Dosage compensation

---

## **UNIT 6. Extensions of Mendelism, Genes and Environment** **106-127**

Extensions of Mendelism: Multiple Alleles, Gene Interaction, The Interaction Between Sex and Heredity: Sex-Influenced and Sex-Limited Characteristics, Cytoplasmic Inheritance, Genetic Maternal Effects, Genomic Imprinting, Anticipation, Interaction Between Genes and

Environment: Environmental Effects on Gene Expression, Inheritance of Continuous Characteristics

---

**UNIT 7. Human Chromosomes and Patterns of Inheritance 128-147**

Human karyotype, Chromosomal anomalies: Structural and numerical aberrations with examples, Pedigree analysis, Patterns of inheritance: autosomal dominant, autosomal recessive, X-linked recessive, X-linked dominant

---

**UNIT 8. Infectious Diseases 148-160**

Introduction to pathogenic organisms: viruses, bacteria, fungi, protozoa, and worms. Structure, life cycle, pathogenicity, including diseases, causes, symptoms and control of common parasites: Trypanosoma, Giardia and Wuchereria

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**Very Short Answer Type Questions with Solutions**

**Short Answer Type Questions with Solutions**

**Long Answer Type Questions with Solutions**

# UNIT 1

## Structure and Function of Cell Organelles-I

### PLASMA MEMBRANE

The plasma membrane is a complex, dynamic structure that surrounds the cell, maintaining its integrity while facilitating communication and transport of materials. Its primary components—lipids and proteins—are intricately organized to support the wide range of functions the membrane performs.

#### Lipids in the Plasma Membrane

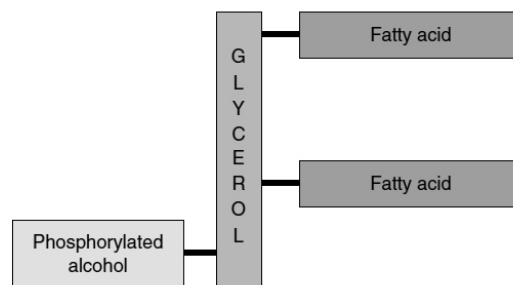
Lipids make up a significant portion of the plasma membrane and are essential for its structural integrity, fluidity, and function. The key classes of lipids in the plasma membrane are phospholipids, cholesterol, and glycolipids.

#### Phospholipids

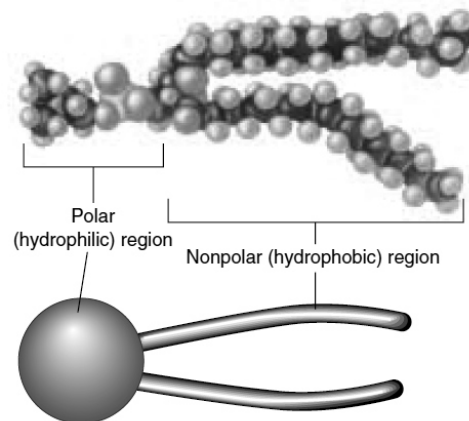
Phospholipids are the most abundant lipids in the plasma membrane and form the bilayer structure. A phospholipid molecule consists of:

- **Hydrophilic (polar) head** : This is the part of the molecule that is water-loving, composed of a phosphate group attached to a glycerol backbone. The hydrophilic head interacts with the aqueous environments both inside and outside the cell.
- **Hydrophobic (non-polar) tails** : These are typically two long fatty acid chains (either saturated or unsaturated) that are water-repelling. These fatty acid tails are oriented inward, away from water, forming the hydrophobic core of the bilayer.

- The amphipathic nature (having both hydrophilic and hydrophobic regions) of



(a)



(b)

**Phospholipid structure.** (a) A phospholipid is a composite molecule similar to a triacylglycerol, except that only two fatty acids are bound to the glycerol backbone; a phosphorylated alcohol occupies the third position on the backbone. (b) Because the phosphorylated alcohol usually extends from one end of the molecule and the two fatty acid chains extend from the other,

phospholipids drives their arrangement into a bilayer, which serves as the foundation of the plasma membrane. The bilayer allows selective permeability, controlling the movement of materials into and out of the cell.

### Examples of Phospholipids

- **Phosphatidylcholine (PC)** : One of the most common phospholipids, with a choline head group, typically found in the outer leaflet of the membrane.
- **Function:** Forms the basic structure of the bilayer and contributes to membrane stability.
- **Phosphatidylethanolamine (PE)**: Found in both the inner and outer leaflets of the membrane, but more commonly in the inner leaflet.
- **Function** : Contributes to membrane curvature and the function of various membrane proteins.
- **Phosphatidylserine (PS)** : A negatively charged phospholipid, typically found on the inner leaflet.
- **Function** : Plays a role in cell signaling and apoptosis. When exposed on the outer leaflet, it signals for macrophage-mediated phagocytosis.
- **Sphingomyelin** : Contains a sphingosine backbone rather than glycerol, with a phosphocholine head group.
- **Function** : Found primarily in the outer leaflet of the membrane and contributes to the formation of lipid rafts.

### Cholesterol

- Cholesterol is an essential lipid that intercalates between phospholipids in the bilayer, affecting membrane properties.
- **Structure** : Cholesterol consists of a rigid steroid ring structure, a hydrocarbon tail, and a small hydroxyl group (OH) attached to the ring.

### Function

- **Regulates fluidity** : Cholesterol decreases membrane fluidity at high temperatures by stabilizing the membrane, while preventing it from becoming too rigid at low temperatures.
- **Forms lipid rafts** : Cholesterol contributes to the formation of specialized microdomains, called lipid rafts, which organize certain proteins and lipids for specific cellular functions, such as signal transduction.

### Glycolipids

- Glycolipids are lipids with carbohydrate chains attached to the polar head group. They are found primarily on the extracellular surface of the plasma membrane.
- **Structure** : Glycolipids consist of a lipid tail (often sphingolipid or phospholipid) with one or more sugar molecules attached to the hydrophilic head.

### Function

- **Cell recognition:** The carbohydrate portion is involved in cell-cell recognition and communication, as well as the immune response.
- **Protection** : They are components of the glycocalyx, a protective, sugar-rich layer on the membrane's exterior.

### Example of Glycolipid

- **Gangliosides:** A type of glycolipid with complex sugar chains, commonly involved in cell signaling and recognition. They are particularly abundant in neurons.

## Proteins in the Plasma Membrane

- Proteins embedded within or associated with the lipid bilayer perform most of the membrane's functions, including transport, signal transduction, structural support, and enzymatic activity.

Membrane proteins are typically classified into integral (intrinsic) and peripheral (extrinsic) proteins.

### ☞ Integral Membrane Proteins

- Integral proteins are embedded within the lipid bilayer and often span it completely (transmembrane proteins). These proteins have distinct regions:
- **Hydrophobic regions:** Interact with the hydrophobic lipid tails within the bilayer.
- **Hydrophilic regions:** Exposed to the aqueous environment inside and outside the cell.
- These proteins perform essential functions like transport, signal transduction, and enzymatic activity.

### Examples of Integral Membrane Proteins

- **Ion Channels:** Ion channels allow the passage of ions (e.g.,  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{2+}$ ) across the membrane.  
**Example :** Voltage-gated sodium channels in neurons allow the influx of  $\text{Na}^+$  during action potentials.
- **Transporters and Pumps :** These proteins facilitate the active or passive movement of molecules across the membrane.  
**Example :** Sodium-potassium pump ( $\text{Na}^+/\text{K}^+$  ATPase): Actively transports  $\text{Na}^+$  out of the cell and  $\text{K}^+$  into the cell against their concentration gradients, essential for maintaining cell volume and function.
- **Receptors :** Receptor proteins bind specific signaling molecules (ligands) and initiate cellular responses.  
**Example : Insulin receptor :** A receptor tyrosine kinase that, when bound to insulin, activates intracellular signaling pathways for glucose uptake.
- **G-Protein Coupled Receptors (GPCRs):** These are involved in a wide variety of signal transduction processes,

converting extracellular signals into intracellular actions.

**Example :**  $\beta$ -adrenergic receptors in heart cells respond to adrenaline, activating a cascade of signaling events that increase heart rate.

- **Enzymes :** Some integral proteins act as enzymes, catalyzing reactions at the membrane.

**Example :** Adenylyl cyclase, which is activated by GPCRs, catalyzes the production of cyclic AMP (cAMP) in response to extracellular signals.

### ☞ Peripheral Membrane Proteins :

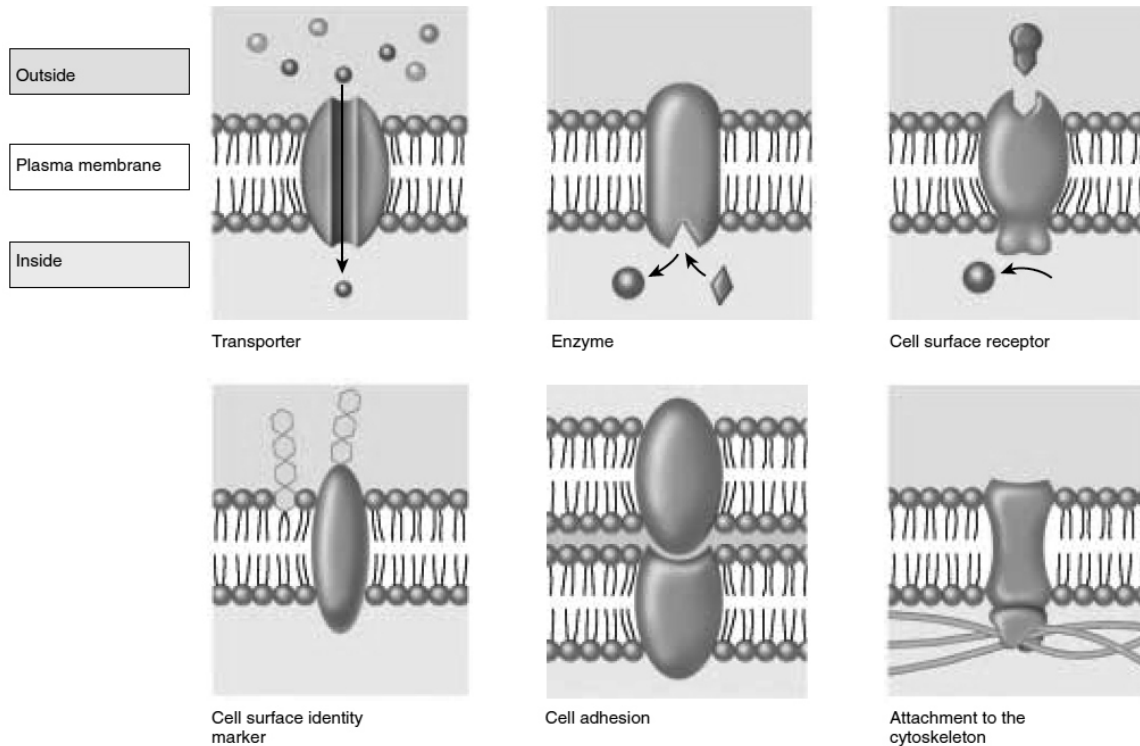
- Peripheral proteins are not embedded in the lipid bilayer but are attached to the membrane surface, often interacting with integral proteins or lipid heads. These proteins are involved in signal transduction, membrane support, and cell recognition.

### Examples of Peripheral Membrane Proteins

- **Spectrin :** A peripheral protein that forms part of the cytoskeleton, providing structural support to the membrane. Spectrin is abundant in red blood cells, helping to maintain their shape.
- **Ankyrin :** Anchors various membrane proteins (e.g., ion channels) to the underlying cytoskeleton.
- **Caveolin :** Involved in the formation of caveolae, specialized lipid microdomains that participate in endocytosis and cell signaling.

### ☞ Glycoproteins

- While not a distinct category of membrane proteins, many integral proteins are glycosylated, meaning they have carbohydrate chains covalently attached to them. These glycoproteins are important for:
- **Cell-cell recognition :** The sugar portion of glycoproteins can serve as recognition



Functions of plasma membrane proteins. Membrane proteins act as transporters, enzymes, cell surface receptors, and cell surface markers, as well as aiding in cell-to-cell adhesion and

sites for other cells or molecules, such as during immune responses.

- **Protection** : The glycocalyx formed by glycoproteins and glycolipids provides protection against mechanical stress and enzymatic degradation.
- **Example of Glycoproteins** : Major Histocompatibility Complex (MHC) proteins: These are glycoproteins found on the surface of cells that play a role in immune system recognition of self and non-self cells.

#### The Fluid Mosaic Model

- The fluid mosaic model describes the plasma membrane as a flexible, dynamic structure, where proteins are embedded within or associated with a lipid bilayer. The mosaic refers to the diverse set of

proteins scattered within the bilayer, while the fluid aspect refers to the ability of lipids and proteins to move laterally within the membrane, allowing it to adapt to changes in the environment.

- **Fluidity** : The membrane is not static; lipids and proteins can move laterally within the bilayer, providing flexibility for processes like endocytosis and cell migration.
- **Asymmetry** : The two leaflets of the bilayer (the inner and outer layers) have different lipid and protein compositions, which is crucial for membrane function.

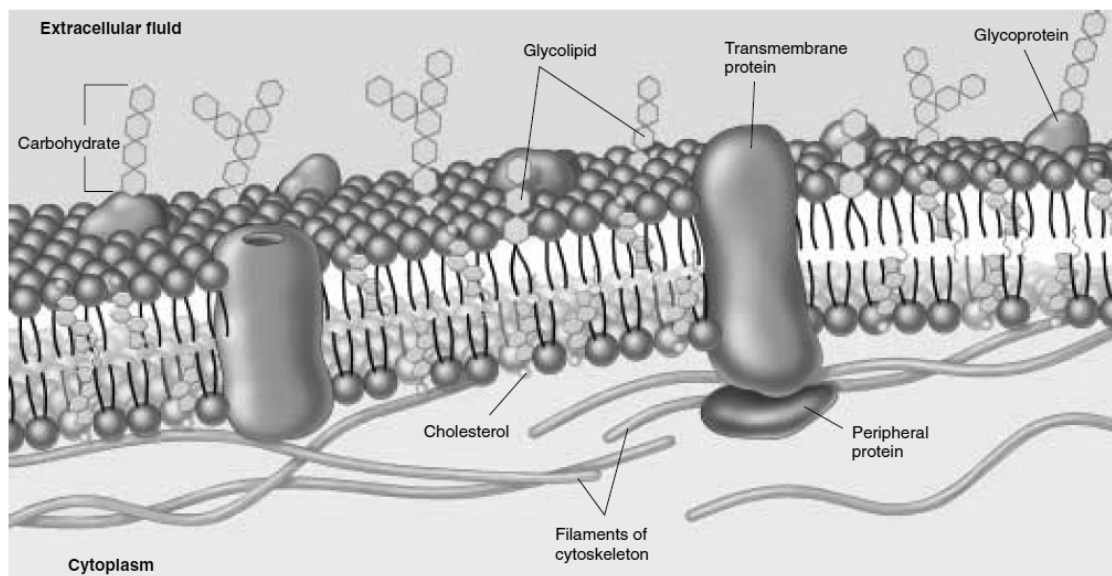
#### Conclusion

- The plasma membrane's structure is intricately designed to perform its many functions, including providing selective

### Components of Plasma Membrane

| Component                | Composition          | Function                                                                                                             | Example                                                                 |
|--------------------------|----------------------|----------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|
| Phospholipid molecules   | Phospholipid bilayer | Provides permeability barrier, matrix for proteins                                                                   | Bilayer of cell is impermeable to watersoluble molecules, like glucose. |
| Transmembrane proteins   | Carriers             | Transport molecules across membrane against gradient                                                                 | Glycophorin carrier for sugar transport                                 |
|                          | Channels             | Passively transport molecules across membrane                                                                        | Sodium and potassium channels in nerve cells                            |
|                          | Receptors            | Transmit information into cell                                                                                       | Specific receptors bind peptide hormones and neurotransmitters          |
| Interior protein network | Spectrins            | Determine shape of cell                                                                                              | Red blood cell                                                          |
|                          | Clathrins            | Anchor certain proteins to specific sites, especially on the exterior cell membrane in receptor-mediated endocytosis | Localization of lowdensity lipoprotein receptor within coated pits.     |
| Cell surface markers     | Glycoproteins        | "Self"-recognition                                                                                                   | Major histocompatibility complex protein recognized by immune system    |
|                          | Glycolipid           | Tissue recognition                                                                                                   | A, B, O blood group markers                                             |

permeability, supporting cell signaling, and maintaining cellular integrity. The lipid bilayer—composed primarily of phospholipids, cholesterol, and glycolipids—forms the



The fluid mosaic model of the plasma membrane.

foundation of the membrane, while embedded integral proteins and associated peripheral proteins carry out a variety of essential tasks such as transport, communication, and structural support. The combination of these

components allows the plasma membrane to adapt and function efficiently in a dynamic cellular environment.

## CELL-CELL INTERACTION

Cell-cell interaction is essential for the formation, maintenance, and function of tissues and organs. It ensures communication between cells and facilitates structural integrity and physiological processes.

### Cell Adhesion Molecules (CAMs)

Cell adhesion molecules are specialized proteins on the surface of cells that mediate the adhesion of cells to other cells or to the extracellular matrix (ECM). These molecules play a crucial role in tissue organization, cellular signaling, immune response, and wound healing.

#### Types of Cell Adhesion Molecules

CAMs are classified into four major families based on their structure and function:

##### Cadherins

###### Structure :

- Calcium-dependent glycoproteins.
- Have extracellular domains that mediate homophilic (same type) interactions.
- The intracellular domain binds to cytoskeleton proteins like actin via catenins.

###### Function :

- Maintain tissue integrity and mediate cell-cell adhesion in a calcium-dependent manner.
- Crucial during embryonic development and wound healing.

###### Example :

- **E-cadherin:** Found in epithelial cells, essential for maintaining epithelial integrity.

- **N-cadherin:** Found in neurons, promoting neural connections.

##### Integrins

###### Structure :

- Heterodimeric proteins made up of  $\alpha$  and  $\beta$  subunits.
- Recognize specific amino acid sequences like RGD (Arg-Gly-Asp) in ECM proteins.

###### Function :

- Mediate cell-ECM adhesion.
- Play a key role in signal transduction, cell migration, and immune response.

###### Example :

$\alpha_5 \beta_1$  **Integrin:** Binds fibronectin, aiding in tissue repair.

$\alpha_v \beta_3$  **Integrin :** Important in angiogenesis (formation of new blood vessels).

##### Selectins

###### Structure:

- Glycoproteins that bind to carbohydrate moieties on the surface of other cells.
- Composed of a lectin domain, EGF-like domain, and complement-binding domains.

###### Function:

- Facilitate transient cell-cell interactions.
- Key players in immune responses, particularly in leukocyte rolling on endothelial surfaces.

### Example :

- **L-selectin:** Found on leukocytes, mediates their tethering to endothelial cells during inflammation.
- **E-selectin:** Expressed on endothelial cells, binds to ligands on leukocytes.

### Immunoglobulin Superfamily CAMs (Ig-CAMs)

#### Structure:

- Contain immunoglobulin-like domains.
- Mediate homophilic or heterophilic interactions.

#### Function:

- Involved in immune response, synapse formation in neurons, and cell migration.

### Example :

- **ICAM-1 (Intercellular Adhesion Molecule-1):** Expressed on endothelial cells, binds to integrins on leukocytes during inflammation.
- **NCAM (Neural Cell Adhesion Molecule):** Found in neurons, involved in neural development.

### Role of CAMs in Biological Processes

#### Tissue Development and Maintenance:

Cadherins maintain the structural integrity of epithelial layers.

**Immune Response:** Selectins and integrins help leukocytes migrate to sites of infection or injury.

**Signal Transduction:** Integrins transmit signals from the ECM to the cell interior, regulating cell survival and differentiation.

**Wound Healing:** CAMs like integrins mediate cell migration during tissue repair.

### Examples of CAM Function

**Cancer Metastasis :** Loss of E-cadherin expression is associated with increased tumor invasiveness.

**Leukocyte Extravasation:**

- L-selectin on leukocytes interacts with P-selectin glycoprotein ligand-1 (PSGL-1) on endothelial cells.
- ICAM-1 facilitates leukocyte adhesion to the endothelium.
- Developmental Disorders: Mutations in NCAM are linked to developmental defects in the nervous system.

### Key Insights

- CAMs are indispensable for cellular adhesion, communication, and migration.
- Disruption of CAM function is implicated in diseases such as cancer, autoimmune disorders, and developmental abnormalities.
- Let me know if you'd like detailed diagrams or further discussion on a specific CAM family!

## Cellular Junctions

Cellular junctions are specialized structures that connect adjacent cells or link cells to the extracellular matrix (ECM). These junctions play critical roles in maintaining the structural integrity of tissues, enabling intercellular communication, and regulating the permeability of cellular barriers.

### Types of Cellular Junctions

- Cellular junctions can be categorized into three main types based on their function:
- Occluding Junctions (Tight Junctions)
- Anchoring Junctions
- Communicating Junctions (Gap Junctions)

### Occluding Junctions (Tight Junctions)

#### Structure:

- Comprised of proteins like claudins, occludins, and junctional adhesion molecules (JAMs).

- Arranged in a network that encircles the cell's apical surface.

**Function:**

- Prevent the passage of molecules and ions between adjacent cells, creating a selectively permeable barrier.
- Maintain cell polarity by separating the apical and basolateral surfaces.

**Location :** Found in epithelial tissues lining organs like the intestines and kidneys.

**Example :** Intestinal epithelium: Tight junctions prevent leakage of gut contents into the bloodstream.

**🔗 Anchoring Junctions**

These junctions provide mechanical strength by connecting cells to each other or to the

ECM. They are further subdivided into four types:

**Adherens Junctions**

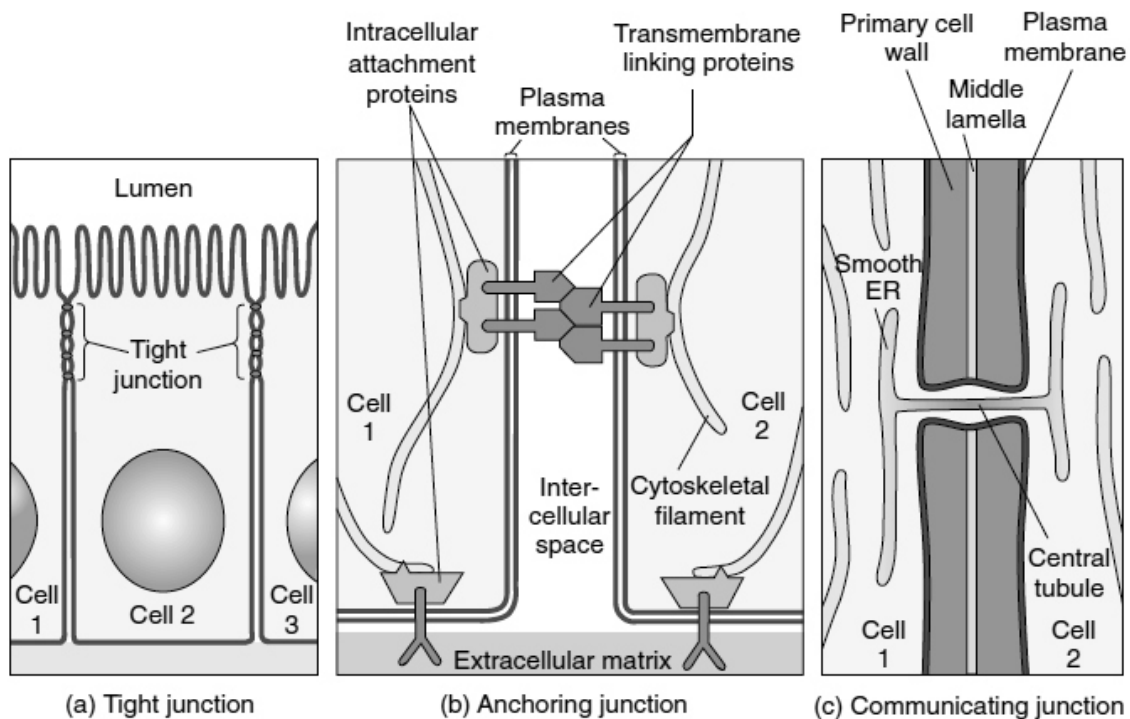
**Structure:**

- Formed by cadherins (transmembrane proteins) linked to actin filaments through adaptor proteins like catenins.
- Create a continuous adhesion belt around the cell.

**Function :** Provide mechanical stability and facilitate changes in cell shape during development and wound healing.

**Location :** Found in epithelial and endothelial tissues.

**Example :** Zonula adherens in intestinal epithelial cells.



The three types of cell junctions. These three models represent current thinking on how the structures of the three major types of cell junctions facilitate their function: (a) tight junction; (b) anchoring junction; (c) communicating junction.

### Desmosomes (Macula Adherens)

#### Structure:

Composed of desmosomal cadherins (desmogleins and desmocollins) connected to intermediate filaments via adaptor proteins like plakoglobin and desmoplakin.

**Function :** Provide resistance to mechanical stress, especially in tissues subjected to stretching.

**Location :** Found in the skin, heart, and other mechanically stressed tissues.

**Example :** Desmosomes in cardiac muscle tissue maintain structural integrity during contractions.

### Hemidesmosomes

**Structure :** Integrins anchor intermediate filaments within the cell to the ECM, particularly the basement membrane.

**Function :** Attach epithelial cells to the basement membrane, providing structural support.

**Location :** Found in epithelial cells.

**Example :** Hemidesmosomes in skin cells anchor them to the underlying dermis.

### Focal Adhesions

**Structure :** Comprised of integrins linked to actin filaments via adaptor proteins like talin and vinculin.

**Function :** Mediate cell-ECM adhesion and are involved in signal transduction during cell migration and proliferation.

**Location :** Found in migrating cells.

**Example :** Focal adhesions in fibroblasts during wound healing.

### Communicating Junctions (Gap Junctions)

**Structure :** Composed of connexins that assemble into connexons, forming channel-like structures between adjacent cells.

#### Function:

- Allow the passage of ions, metabolites, and small signaling molecules, facilitating direct intercellular communication.
- Play a role in synchronizing activities like electrical signaling in cardiac muscle.

#### Location:

- Found in nearly all tissues, especially cardiac and smooth muscle.

**Example :** Gap junctions in cardiac tissue enable synchronized heartbeats by transmitting electrical impulses.

### Specialized Junctions

**Plasmodesmata (in plants):** Channels that connect plant cells, allowing the exchange of nutrients and signaling molecules.

**Synaptic Junctions (in neurons):** Specialized gap junctions facilitating neurotransmitter release for neural communication.

### Clinical Relevance

- **Cancer:** Loss of E-cadherin in adherens junctions promotes metastasis.
- **Pemphigus Vulgaris:** Autoimmune attack on desmosomal proteins causes skin blistering.
- **Connexin Mutations:** Defects in gap junction proteins can lead to cardiac arrhythmias or hearing loss.

Summary Table

| Type               | Structure                         | Function                                    | Example                             |
|--------------------|-----------------------------------|---------------------------------------------|-------------------------------------|
| Tight Junctions    | Claudins, occludins               | Barrier, cell polarity maintenance          | Intestinal epithelium               |
| Adherens Junctions | Cadherins, actin filaments        | Mechanical stability, cell shape regulation | Zonula adherens in epithelial cells |
| Desmosomes         | Desmogleins, desmocollins         | Mechanical stress resistance                | Skin and cardiac muscle             |
| Hemidesmosomes     | Integrins, intermediate filaments | Cell-ECM anchoring                          | Skin epithelium                     |
| Focal Adhesions    | Integrins, actin filaments        | Cell migration and signal transduction      | Migrating fibroblasts               |
| Gap Junctions      | Connexins, connexons              | Intercellular communication                 | Cardiac and smooth muscle           |

## ENDOMEMBRANE SYSTEM

The endomembrane system is a network of membrane-bound organelles within eukaryotic cells that work together to modify, package, and transport lipids and proteins. This system includes the endoplasmic reticulum (ER), Golgi apparatus, lysosomes, vesicles, nuclear envelope, and plasma membrane. Key processes such as protein targeting and sorting, endocytosis, and exocytosis are central to its function.

### Protein Targeting and Sorting

The endomembrane system is responsible for ensuring that proteins are synthesized, modified, and delivered to the correct location within or outside the cell. This process involves several key steps:

#### Protein Synthesis and Transport

##### Rough Endoplasmic Reticulum (RER)

- Proteins destined for secretion, the plasma membrane, or the lysosome are synthesized on ribosomes attached to the RER.

- These proteins have signal peptides (short amino acid sequences) that direct them to the ER.

##### Signal Recognition Particle (SRP)

- The SRP binds to the signal peptide of the nascent protein and the ribosome, guiding them to the SRP receptor on the ER membrane.
- Once the SRP binds, the ribosome is transferred to a translocon, a channel in the ER membrane, where protein synthesis continues.

##### Post-translational Modifications in the ER :

Proteins are folded and undergo modifications like glycosylation (adding sugar molecules) in the ER.

##### Sorting and Transport via the Golgi Apparatus

##### Golgi Apparatus:

- After synthesis and initial processing in the ER, proteins are transported in vesicles to the Golgi for further modification (e.g., glycosylation) and sorting.

- The Golgi is divided into cis (entry), medial, and trans (exit) regions. Proteins are modified as they travel from cis to trans regions.

### Sorting:

- The Golgi sorts proteins into different vesicles based on their final destination:
- Vesicles destined for secretion: Proteins are packaged into secretory vesicles that fuse with the plasma membrane.
- **Vesicles destined for lysosomes:** Proteins are tagged with mannose-6-phosphate and transported to lysosomes.
- **Vesicles destined for the plasma membrane:** Membrane proteins are inserted into the plasma membrane.

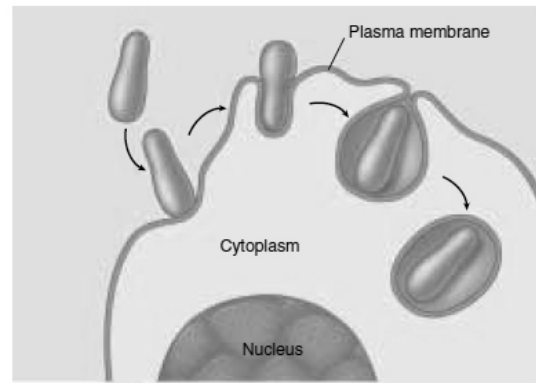
### ☞ Endocytosis

Endocytosis is the process by which cells internalize extracellular material by engulfing it in a membrane-bound vesicle. This allows cells to take in nutrients, regulate surface receptors, and remove waste.

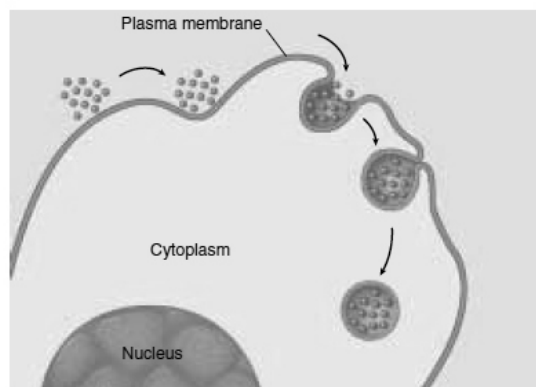
### ☞ Types of Endocytosis:

#### Phagocytosis (Cell Eating):

- Involves the ingestion of large particles (e.g., pathogens or debris) by specialized cells like macrophages and neutrophils.



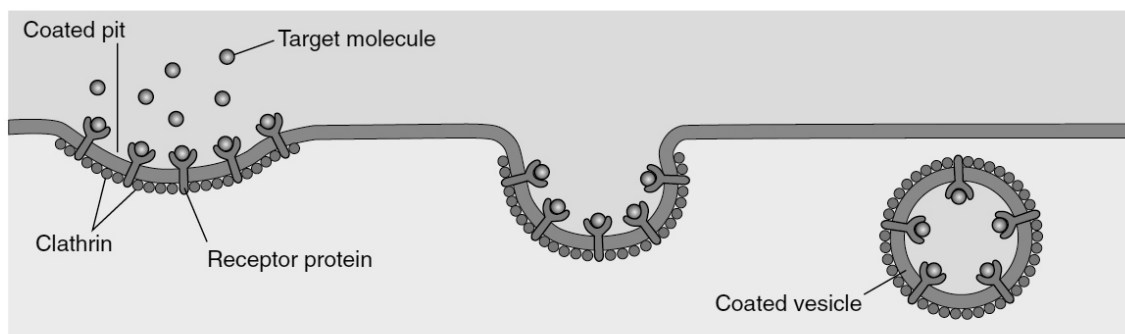
(a) **Phagocytosis**



(b) **Pinocytosis**

Endocytosis. Both phagocytosis (a) and pinocytosis (b) are forms of endocytosis.

- The cell membrane extends around the particle, forming a phagosome, which



Receptor-mediated endocytosis. Cells that undergo receptor-mediated endocytosis have pits coated with the protein clathrin that initiate endocytosis when target molecules bind to

then fuses with a lysosome for degradation.

#### **Pinocytosis (Cell Drinking):**

- The cell engulfs extracellular fluid and solutes into small vesicles.
- It is a non-specific process, meaning it internalizes whatever solutes are present in the fluid.

#### **Receptor-Mediated Endocytosis:**

- A more specific form of endocytosis, where cells internalize specific molecules by recognizing them through receptors on the cell surface.
- An example is the uptake of low-density lipoproteins (LDL), where LDL particles bind to LDL receptors on the plasma membrane, and the complex is internalized by clathrin-mediated endocytosis.

#### **Exocytosis**

Exocytosis is the process by which cells expel substances from the interior to the outside environment. This is essential for the secretion of hormones, enzymes, and neurotransmitters, as well as the recycling of membrane components.

#### **Steps of Exocytosis:**

##### **Vesicle Formation:**

Materials are packed into vesicles within the cell, often originating from the Golgi apparatus or endosomes.

##### **Vesicle Transport:**

The vesicle is transported toward the plasma membrane, often guided by the cytoskeleton (microtubules).

##### **Vesicle Fusion:**

- Upon reaching the plasma membrane, the vesicle membrane fuses with the cell

membrane, releasing its contents into the extracellular space.

- The fusion process involves proteins such as SNAREs (Soluble NSF Attachment Protein Receptors), which help the vesicle and plasma membrane to merge.

#### **Exocytosis Examples**

- **Neurotransmitter release:** In neurons, synaptic vesicles fuse with the membrane to release neurotransmitters into the synapse.
- **Insulin secretion:** Pancreatic  $\beta$ -cells release insulin via exocytosis in response to glucose stimulation.
- **Secretion of digestive enzymes:** Pancreatic cells secrete digestive enzymes into the duodenum.

#### **Interplay Between Endocytosis and Exocytosis**

##### **Recycling of Membranes:**

Endocytosis and exocytosis are interconnected and help maintain cell surface area. Membrane components internalized via endocytosis are often recycled back to the plasma membrane via vesicles after their contents have been processed.

##### **Regulation of Receptor Density:**

Cells use endocytosis and exocytosis to regulate the number of receptors on their surface. For example, receptor-mediated endocytosis removes excess receptors from the cell surface, while exocytosis can increase receptor density.

#### **Clinical Relevance**

**Endocytosis and Disease :** Some pathogens, like HIV and diphtheria toxin,

exploit receptor-mediated endocytosis to enter host cells.

**Exocytosis in Neurotransmitter Release :** Dysfunction in exocytosis can result in neurological disorders. For example, Botulinum toxin inhibits neurotransmitter release, leading to paralysis.

**Endocytosis and Cancer :** Altered endocytosis and protein sorting can contribute to cancer progression by affecting growth factor signaling or nutrient uptake.

### Summary Table

| Process                  | Key Organelles Involved          | Function                                         | Examples                                    |
|--------------------------|----------------------------------|--------------------------------------------------|---------------------------------------------|
| <b>Protein Targeting</b> | ER, Golgi, Vesicles              | Synthesis, modification, and sorting of proteins | Protein secretion, lysosomal targeting      |
| <b>Endocytosis</b>       | Plasma Membrane, Endosomes       | Internalization of extracellular material        | Phagocytosis, receptor-mediated endocytosis |
| <b>Exocytosis</b>        | Golgi, Vesicles, Plasma Membrane | Expulsion of materials from the cell             | Neurotransmitter release, insulin secretion |

## QUESTIONS



### Section A : Very Short Answer Type Questions

---

1. What are the major chemical components of the plasma membrane? (CCSU 2022)

**Ans.** The plasma membrane consists of lipids (phospholipids, cholesterol) and proteins (integral and peripheral).

2. What is the role of cholesterol in the plasma membrane? (CCSU 2021)

**Ans.** Cholesterol maintains membrane fluidity and stability by preventing fatty acid chains from packing too closely.

3. Name two types of membrane proteins. (CCSU 2020)

**Ans.** Integral proteins (embedded in the membrane) and peripheral proteins (loosely attached to the surface).

4. What is the fluid mosaic model? (CCSU 2023)

**Ans.** The fluid mosaic model describes the plasma membrane as a dynamic structure with lipids and proteins moving freely within the bilayer.

5. What are cell adhesion molecules (CAMs)? (CCSU 2022)

**Ans.** CAMs are proteins (e.g., cadherins, integrins) that help cells stick together and communicate.

6. Give one example of a tight junction. (CCSU 2021)

**Ans.** Tight junctions (e.g., in intestinal epithelial cells) prevent leakage between cells.

7. What is the function of gap junctions? (CCSU 2020)

**Ans.** Gap junctions allow direct exchange of ions and small molecules between adjacent cells.

8. Name a disease caused by defective cell adhesion. (CCSU 2023)

**Ans.** Pemphigus vulgaris (an autoimmune disorder affecting desmosomes).

9. What is the function of the Golgi apparatus? (CCSU 2022)

**Ans.** The Golgi apparatus modifies, sorts, and packages proteins for secretion or transport.

10. Define endocytosis. (CCSU 2021)

**Ans.** Endocytosis is the process by which cells engulf external materials (e.g., phagocytosis, pinocytosis).

11. What is lysosomal storage disease? Give an example. (CCSU 2020)

**Ans.** A disorder due to lysosomal enzyme deficiency (e.g., Tay-Sachs disease).

12. How are proteins targeted to the endoplasmic reticulum (ER)? (CCSU 2023)

**Ans.** Proteins with a signal sequence are recognized by SRP (Signal Recognition Particle) and directed to the ER.

## 13. What is exocytosis?

(CCSU 2022)

**Ans.** Exocytosis is the release of cellular contents (e.g., hormones, enzymes) via vesicle fusion with the plasma membrane.

## Section B Short Answer Type Questions

## 14. Describe the fluid mosaic model of the plasma membrane.

(CCSU 2021, 2023)

**Ans.**

- The fluid mosaic model describes the plasma membrane as a fluid lipid bilayer with proteins embedded or attached, creating a mosaic pattern.
- Lipids and proteins can move laterally, allowing membrane flexibility and dynamic functions like transport, signaling, and cell recognition.

## 15. What are cell adhesion molecules (CAMs)? Give two examples.

(CCSU 2020)

**Ans.** CAMs are proteins located on the cell surface involved in binding cells to each other or to the extracellular matrix.

- Examples: Cadherins (mediate cell-cell adhesion), Integrins (mediate cell-ECM adhesion).

## 16. Differentiate between tight junctions and gap junctions.

(CCSU 2019)

**Ans.**

| Feature   | Tight Junctions                                     | Gap Junctions                                         |
|-----------|-----------------------------------------------------|-------------------------------------------------------|
| Function  | Seal adjacent cells to prevent leakage of molecules | Allow direct communication between cells via channels |
| Structure | Continuous belt-like seals                          | Clusters of connexon channels                         |
| Location  | Epithelial layers                                   | Many tissues, including heart and liver               |

## 17. Explain the role of the endomembrane system in protein sorting.

(CCSU 2022)

**Ans.** The endomembrane system (ER, Golgi, vesicles) synthesizes, modifies, and sorts proteins to their correct destinations like lysosomes, plasma membrane, or secretion.

## 18. What is receptor-mediated endocytosis?

(CCSU 2018)

**Ans.** A selective process where cells internalize specific molecules by binding them to receptors on the membrane, forming vesicles for uptake (e.g., LDL uptake).

## 19. Name two lipids found in the plasma membrane and their functions.

(CCSU 2021)

**Ans. Phospholipids:** Form the bilayer structure, providing fluidity and barrier.

- **Cholesterol:** Stabilizes membrane fluidity and permeability.

## 20. How does exocytosis differ from endocytosis?

(CCSU 2020)

**Ans. Exocytosis:** Vesicles fuse with the plasma membrane to release substances outside the cell.

- **Endocytosis:** The cell membrane engulfs substances to bring them inside the cell.

**21. What is the significance of the Golgi apparatus in protein trafficking?** (CCSU 2019)

**Ans.** The Golgi modifies, sorts, and packages proteins from the ER, directing them to their correct cellular locations or secretion.

**22. List two contributions of Prof. G.N. Ramachandran to cell biology.** (CCSU 2022)

**Ans.** Developed the Ramachandran plot for protein structure validation.

- Contributed to understanding of collagen structure.

**23. How did Prof. Lalji Singh contribute to genetic research in India?** (CCSU 2018)

**Ans.** Pioneer in DNA fingerprinting technology in India.

- Led the Centre for DNA Fingerprinting and Diagnostics (CDFD) advancing forensic and medical genetics.

## Section C Long Answer Type Questions

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**24. Explain the chemical composition and functions of the plasma membrane.** (CCSU 2021, 2023)

**Ans. Chemical Composition:**

- **Lipids:** Mainly phospholipids arranged in a bilayer, with hydrophilic heads facing outward and hydrophobic tails inward. Other lipids include cholesterol (modulates fluidity) and glycolipids (involved in cell recognition).
- **Proteins:** Integral (transmembrane) and peripheral proteins. Integral proteins act as channels, transporters, receptors; peripheral proteins provide structural support and signaling functions.
- **Carbohydrates:** Attached to lipids (glycolipids) and proteins (glycoproteins), forming the glycocalyx involved in cell recognition and protection.

**Functions:**

- **Selective permeability barrier:** Controls movement of substances in and out of the cell.
- **Communication:** Receptor proteins detect signals from the environment and initiate cellular responses.
- **Cell adhesion:** Membrane proteins help cells adhere to each other and extracellular matrix.
- **Transport:** Facilitates passive and active transport of molecules.
- **Signal transduction:** Converts extracellular signals to intracellular actions.
- **Maintains cell shape:** Interacts with cytoskeleton to maintain structural integrity.

**25. Describe the types of cellular junctions (tight, gap, desmosomes) with diagrams.** (CCSU 2020)

**Ans. Tight Junctions:**

- Seal adjacent epithelial cells tightly, preventing leakage of extracellular fluid.
- Form continuous belts around cells near their apical surface.
- Important in maintaining distinct compartments within tissues.

**Diagram:** [Imagine two adjacent cells with tightly fused membranes forming a seal near their top surfaces.]

**Gap Junctions:**

- Specialized channels (connexons) allow direct cytoplasmic exchange of ions and small molecules between cells.
- Facilitate cell-to-cell communication in tissues like heart and smooth muscle.

**Diagram:** [Two adjacent cells connected by small channels formed by protein complexes spanning both membranes.]

**Desmosomes:**

- Spot-like adhesions that provide mechanical strength by anchoring intermediate filaments of adjacent cells.
- Important in tissues exposed to mechanical stress like skin and heart.

**Diagram:** [Two cells connected by dense protein plaques with filaments anchored inside cells.]

## 26 Discuss the endomembrane system (ER, Golgi, lysosomes) and its role in protein targeting. (CCSU 2019)

**Ans. Endoplasmic Reticulum (ER):**

- Rough ER (RER): Studded with ribosomes; synthesizes membrane-bound and secretory proteins.
- Smooth ER (SER): Involved in lipid synthesis and detoxification.

**Golgi Apparatus:**

- Modifies proteins from ER (glycosylation, folding).
- Sorts and packages proteins into vesicles targeted to lysosomes, plasma membrane, or secretion.

**Lysosomes:**

- Contain hydrolytic enzymes for digestion of macromolecules and cellular debris.
- Involved in intracellular digestion and recycling.

**Role in Protein Targeting:**

- Proteins synthesized in RER are transported in vesicles to the Golgi.
- Golgi tags proteins with molecular signals directing them to their final destinations (e.g., lysosomes, secretion).
- This system ensures proteins reach correct locations, maintaining cellular function and homeostasis.

## 27. Compare and contrast endocytosis and exocytosis.

(CCSU 2021)

**Ans.**

| Aspect            | Endocytosis                                                                                   | Exocytosis                                                                            |
|-------------------|-----------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| <b>Definition</b> | Process by which cells internalize substances from the outside by engulfing them in vesicles. | Process by which cells expel substances by merging vesicles with the plasma membrane. |

|                           |                                                                                                     |                                                                                        |
|---------------------------|-----------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|
| <b>Purpose</b>            | Uptake of nutrients, fluids, large molecules, and particles.                                        | Secretion of hormones, neurotransmitters, waste products, and enzymes.                 |
| <b>Mechanism</b>          | Plasma membrane folds inward forming a vesicle containing extracellular material.                   | Vesicles formed inside the cell fuse with plasma membrane to release contents outside. |
| <b>Types</b>              | Phagocytosis (cell eating), Pinocytosis (cell drinking), Receptor-mediated endocytosis.             | Constitutive exocytosis (continuous) and regulated exocytosis (triggered by signals).  |
| <b>Energy Requirement</b> | Requires energy (ATP).                                                                              | Requires energy (ATP).                                                                 |
| <b>Examples</b>           | White blood cells engulfing bacteria (phagocytosis); uptake of LDL cholesterol (receptor-mediated). | Release of insulin from pancreatic cells; neurotransmitter release at synapses.        |

**28. Explain the contributions of ancient Indian biologists (Sushruta, Charak) to life sciences. (CCSU 2022)**

**Ans.**

- **Sushruta:** Known as the "Father of Surgery." Authored the Sushruta Samhita, a comprehensive ancient text on surgery and medicine. Pioneered surgical techniques such as rhinoplasty (nose reconstruction), cataract surgery, and the use of surgical instruments. Described detailed anatomy, wound management, and surgical procedures.
- **Charak:** Regarded as the "Father of Medicine" in Ayurveda. Authored Charak Samhita, a foundational text on internal medicine (Kayachikitsa). Emphasized the importance of diagnosis, treatment, and preventive medicine. Introduced concepts of metabolism, digestion, and immunity, and categorized diseases systematically.

Both laid the groundwork for holistic approaches in health care and had a lasting influence on traditional medicine systems.

**29. Discuss the work of Prof. H.G. Khurana in molecular biology. (CCSU 2018)**

**Ans.**

- Prof. Har Gobind Khorana was an Indian-American molecular biologist awarded the Nobel Prize in Physiology or Medicine in 1968 (shared with Marshall Nirenberg and Robert Holley).

● **Major Contributions:**

Deciphered the genetic code by demonstrating how nucleotide triplets (codons) specify amino acids.

Synthesized the first artificial gene, proving that DNA sequences could be chemically synthesized.

His work laid the foundation for understanding how genetic information is translated into proteins.

Advanced molecular biology techniques and recombinant DNA technology.

His research fundamentally transformed genetics and biotechnology.

### 30. How did Prof. Salim Ali contribute to zoology in India?

(CCSU 2020)

**Ans.** Prof. Salim Ali, known as the "Birdman of India," was a pioneering ornithologist and naturalist.

- Contributions:

- Conducted extensive studies on Indian birds, publishing the landmark book *The Book of Indian Birds*.

- Initiated systematic ornithological surveys and bird censuses across India.

- played a key role in bird conservation and establishment of several bird sanctuaries and national parks.

- Helped develop modern ornithology and wildlife biology as scientific disciplines in India.

- Raised public awareness about biodiversity and environmental protection.

His work remains foundational in Indian zoology and conservation biology.

### 31. Explain the significance of Prof. M.K. Chandrashekharan's research in cell biology.

(CCSU 2019)

**Ans.** Prof. M.K. Chandrashekharan is known for his pioneering work in cell biology, particularly in the area of membrane biology and cell signaling.

- His research significantly contributed to understanding the fluid mosaic model of cell membranes, focusing on membrane dynamics and transport mechanisms.
- He studied the role of membrane proteins and lipid interactions in cellular processes such as endocytosis and exocytosis.
- His work helped clarify how cells communicate and transport molecules, which is crucial for understanding diseases like cancer and neurodegeneration.
- He also contributed to the development of advanced microscopy techniques for studying live cells.

His research has had a lasting impact on both basic and applied cell biology, influencing drug delivery and therapeutic strategies.

### 32. Discuss the role of Prof. J.P. Thapliyal in environmental zoology.

(CCSU 2021)

**Ans.** Prof. J.P. Thapliyal is recognized for his contributions to environmental zoology and wildlife conservation.

- He conducted extensive studies on the impact of pollution and habitat degradation on wildlife, especially in aquatic ecosystems.
- His work emphasized the bioindicators approach—using certain animal species to monitor environmental health.
- He contributed to understanding the effects of pesticides, heavy metals, and other pollutants on the physiology and behavior of animals.
- Prof. Thapliyal advocated for sustainable environmental management and biodiversity conservation through education and policy.

His research helped shape conservation practices and environmental awareness in India.

**33. How has Prof. R. Mishra advanced biological sciences in India?**

**(CCSU 2022)**

***Ans.***

- Prof. R. Mishra is a distinguished biologist noted for his work in molecular genetics and biotechnology.
- He has advanced research in gene regulation, genetic engineering, and plant molecular biology, focusing on crop improvement.
- His studies on stress tolerance genes have contributed to developing genetically modified plants that can withstand drought and salinity.
- Prof. Mishra has mentored numerous students and helped establish state-of-the-art research facilities in India.
- He played an active role in promoting biotechnology education and research policy, enhancing India's position in global biological sciences.
- Through his research and leadership, Prof. Mishra has greatly contributed to the growth of modern biological sciences in India.