MEDICAL EDUCATION RESOURCE

# Subcellular Organelles and Cell Membranes

## Cell Composition

• A cell is the **basic structural and functional unit** of all living organisms.
• Human cells share three fundamental components: **cell membrane**, **cytoplasm**, and **nucleus** (except mature RBCs).

### Water

• Makes up **70–80%** of a typical cell's weight.
• Serves as the medium for biochemical reactions and transport of solutes.

### Macromolecules

• **Proteins (?15%)**
– Form enzymes, structural elements, transporters, receptors, and regulatory molecules.
• **Lipids (?15%)**
– Found mainly in the plasma membrane and organelle membranes.
– Act as barriers and signaling molecules.
• **Carbohydrates (?2%)**
– Present as glycogen in some cells and as glycoproteins/glycolipids on membranes.
• **Nucleic Acids**
– DNA and RNA store genetic information and direct protein synthesis.

### Inorganic Ions

• Essential ions include **Na?, K?, Ca²?, Mg²?, Cl?, HCO??, PO?³?**.
• Maintain osmotic balance, electrical gradients, enzyme function, and signaling.

### Small Molecules & Metabolites

• Includes amino acids, glucose, fatty acids, nucleotides, and intermediates of metabolic pathways.
• Continuously synthesized, degraded, and recycled as part of metabolism.

 

### Organelles

• Specialized structures performing distinct functions:
– **Nucleus** (genetic control)
– **Mitochondria** (ATP generation)
– **ER** (protein and lipid synthesis)
– **Golgi** (sorting and packaging)
– **Lysosomes** (degradation)
– **Peroxisomes** (oxidation reactions)
• Together maintain cellular organization and homeostasis.

## Subcellular Organelles

Cells contain organized internal structures called **organelles**, each performing specific biochemical functions essential for survival and metabolism.

## Nucleus

• Largest and most prominent organelle; contains the cell's **genetic material (DNA)**.
• Surrounded by a **double nuclear membrane** with nuclear pores for controlled transport.
• DNA is packaged with proteins as **chromatin**, which condenses into chromosomes during division.
• Site of **DNA replication** and **RNA transcription**.
• Contains the **nucleolus**, the center for rRNA synthesis and ribosome assembly.

## Endoplasmic Reticulum (ER)

### Rough ER

• Studded with ribosomes.
• Site of **protein synthesis**, particularly for secretory and membrane-bound proteins.
• Helps in folding, processing, and initial glycosylation of proteins.

### Smooth ER

• Lacks ribosomes.
• Functions in **lipid synthesis**, **steroid hormone production**, and **detoxification** of drugs (via cytochrome P450).
• In muscle cells, forms the **sarcoplasmic reticulum** for calcium storage.

## Golgi Apparatus

• Stack of flattened membrane-bound cisternae: **cis**, **medial**, and **trans** regions.
• Receives newly synthesized proteins from ER, modifies them (glycosylation, sulfation), and sorts them.
• Packages proteins into vesicles for delivery to:
– Plasma membrane
– Lysosomes
– Extracellular secretion
• Essential for **protein sorting and trafficking**.

## Lysosomes

• Membrane-bound vesicles containing **acid hydrolases**.
• Enzymes work optimally at acidic pH (~5).
• Responsible for degradation of:
– Damaged organelles
– Foreign particles
– Cellular waste
• Formed by fusion of Golgi-derived vesicles with endocytic/phagocytic vesicles.
• Defects lead to **lysosomal storage disorders**.

## Peroxisomes

• Small organelles containing **oxidative enzymes** (e.g., catalase, oxidases).
• Carry out **?-oxidation of very long-chain fatty acids**.
• Detoxify hydrogen peroxide (H?O?) by converting it to water.
• Involved in plasmalogen synthesis (important in myelin).

## Mitochondria

• Double-membraned organelle; outer smooth membrane and inner membrane with **cristae**.
• Site of **oxidative phosphorylation** and **ATP generation**.
• Contains its own **DNA and ribosomes**, enabling synthesis of some mitochondrial proteins.
• Involved in **apoptosis**, **TCA cycle**, **fatty acid oxidation**, and **urea cycle (partial)**.
• Number varies with energy demand; highest in muscle, heart, and liver.

## Fluid Mosaic Model

• The plasma membrane is described by the **fluid mosaic model**, which states that the membrane behaves like a **flexible, dynamic lipid sheet** with proteins embedded in it.

### Phospholipid Bilayer

• Composed of **amphipathic phospholipids** arranged in two layers:
– Hydrophilic heads facing outward
– Hydrophobic tails facing inward
• Lipids move freely within the plane of the membrane, giving it **fluidity**.

### Membrane Proteins

• Proteins are distributed throughout the lipid bilayer like a **mosaic**.
• Two main types:
– **Integral (transmembrane) proteins:** span the bilayer, act as transporters, receptors, channels.
– **Peripheral proteins:** loosely attached to the surface, involved in signaling and structural support.

### Cholesterol

• Inserted between phospholipids.
• Maintains membrane stability by:
– Reducing fluidity at high temperatures
– Preventing rigidity at low temperatures

### Carbohydrates

• Present as **glycoproteins** and **glycolipids** on the extracellular side.
• Important for cell recognition, adhesion, and immune response.

### Lateral Mobility

• Lipids and many proteins move laterally within the membrane, enabling:
– Rapid distribution of molecules
– Flexibility
– Membrane repair

### Description of Membrane Organization

The membrane is shown as a double layer of phospholipids with their hydrophobic tails facing inward. Proteins of various sizes are embedded within this layer, some spanning across it and others positioned only on one surface. Cholesterol molecules are interspersed among the lipids, while carbohydrate chains extend outward from proteins and lipids on the outer side.

## Lipid Rafts

• Lipid rafts are **specialized microdomains** within the plasma membrane that are richer in **cholesterol**, **sphingolipids**, and certain **proteins** compared to the surrounding membrane.

### Composition

• Contain tightly packed **sphingomyelin**, **glycosphingolipids**, and **cholesterol**.
• More ordered and less fluid than the rest of the lipid bilayer.
• Host selected proteins such as receptors, G-proteins, and signaling molecules.

### Structure and Properties

• Appear as small, dynamic “islands” that can cluster together during signaling events.
• Their ordered lipid environment provides a stable platform for assembling signaling complexes.
• Resistant to detergent solubilization due to tight lipid packing.

### Functions

• Act as **signaling hubs**, organizing receptors and intracellular signaling proteins.
• Facilitate **membrane trafficking**, assisting in endocytosis and sorting.
• Important in **immune cell activation**, **hormone signaling**, and **nerve function**.
• Help in clustering proteins required for **viral entry**, making them biologically significant.

### Description of Lipid Raft Visualization

A membrane area is shown enriched with cholesterol and sphingolipids, forming a thicker, less fluid patch compared to the surrounding phospholipid bilayer. Specific membrane proteins cluster within this patch while others remain outside, illustrating selective organization of molecules.

## Caveolae

• Caveolae are small **flask-shaped invaginations** of the plasma membrane.
• Rich in **cholesterol**, **sphingolipids**, and the protein **caveolin**.
• Represent a **specialized subtype of lipid rafts**.
• Common in endothelial cells, adipocytes, muscle cells.

### Functions

• Involved in **endocytosis**, especially receptor-mediated internalization.
• Play a role in **signal transduction**, clustering receptors and signaling molecules.
• Help in **mechanotransduction** — sensing stretch or tension in the membrane.
• Important in **cholesterol transport** and lipid regulation.

### Description of Caveolae Structure

Small pouch-like membrane invaginations enriched with caveolin proteins form a pocket dipping into the cytoplasm. These pockets contain concentrated signaling receptors and cholesterol-rich lipids.

## Tight Junction

• Tight junctions are **seal-forming contacts** between adjacent epithelial cells.
• Located at the **apical region** of cell–cell boundaries.
• Formed by proteins such as **claudins**, **occludins**, and junctional adhesion molecules.

### Functions

• Create a **selective barrier** that prevents free movement of solutes between cells.
• Maintain **cell polarity** by separating the apical and basolateral membrane domains.
• Regulate **paracellular transport**, allowing controlled ion and water movement.
• Essential for organs like the intestine, kidney, and blood–brain barrier.

### Description of Tight Junction Appearance

Adjacent cells are shown sealed together along their edges, forming continuous ridges that block substances from passing between them, ensuring directional movement of molecules.

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## Cytoskeleton

• A dynamic network of protein filaments that supports cell shape, organization, and movement.

### 1. Microfilaments (Actin Filaments)

• Composed of **actin**.
• Provide structural support, enable **cell movement**, **cytokinesis**, and muscle contraction (with myosin).
• Found beneath the plasma membrane forming the **cell cortex**.

### 2. Intermediate Filaments

• Provide **tensile strength** to cells.
• Different types depending on tissue:
– Keratin (epithelium)
– Desmin (muscle)
– Vimentin (connective tissue)
– Neurofilaments (neurons)

### 3. Microtubules

• Hollow tubes made of **?- and ?-tubulin**.
• Form the **mitotic spindle**, **cilia**, **flagella**, and serve as tracks for intracellular transport using motor proteins (**kinesin**, **dynein**).
• Help maintain cell shape and internal organization.

**Description of Cytoskeletal Network**

A meshwork of actin filaments lines the cell's periphery, thicker intermediate filaments run throughout the cell for stability, and long microtubule tracks radiate from the centrosome toward the membrane, guiding vesicle transport and organizing cell structure.

## Transport Mechanisms

Cells use several mechanisms to move substances across the plasma membrane depending on size, charge, and concentration gradients.

**Passive Transport**

• Does **not require energy**.
• Movement occurs **down** the concentration gradient.
• Includes simple diffusion, facilitated diffusion, and osmosis.

**Active Transport**

• Requires **ATP or other energy source**.
• Moves substances **against** their concentration gradient.
• Utilizes carrier proteins or pumps.

**Vesicular Transport**

• Large particles are transported via membrane-bound vesicles.
• Includes **endocytosis**, **exocytosis**, **pinocytosis**, and **phagocytosis**.

## Facilitated Diffusion

• A passive process where substances move from **high to low concentration** with the help of membrane proteins.

• Does **not require ATP**.

### Carrier Proteins

• Bind specific molecules (e.g., glucose, amino acids) and undergo a **conformational change** to move them across the membrane.
• Saturable — maximum transport rate depends on number of carriers.

### Channel Proteins

• Form **hydrophilic pores** allowing ions or water to move rapidly across.
• Highly selective for ions such as Na?, K?, Ca²?, Cl?.
• Can be gated (voltage-gated, ligand-gated, mechanically gated).

### Specificity

• Transport is highly selective: each carrier/channel moves **a particular molecule or ion**.

### No Energy Requirement

• Occurs only when a **concentration gradient** exists.
• Movement stops when equilibrium is reached.

### Description of Facilitated Diffusion Diagram

A membrane protein is shown with a binding site. A molecule such as glucose binds on the high-concentration side, the protein changes shape, and the molecule is released on the low-concentration side, without any energy usage.

## Ion Channels

• Ion channels are **membrane proteins** that create hydrophilic pathways for ions to cross the lipid bilayer.
• Allow rapid movement of **Na?, K?, Ca²?, Cl?**, and other ions.
• Movement is **passive**, driven by concentration and electrical gradients.
• Highly **selective** due to precise pore size and charge distribution.
• Essential for neuronal conduction, muscle contraction, hormone release, and maintaining

membrane potential.

## Ligand-Gated Channels

• Open or close in response to **binding of a specific chemical ligand**.
• Ligand may be extracellular (e.g., neurotransmitters) or intracellular.

### Examples

• **Nicotinic acetylcholine receptor** (opens Na?/K? channel).
• **GABA-A receptor** (Cl? influx ? inhibition).
• **Glutamate receptors** (NMDA, AMPA).

### Functions

• Mediate **synaptic transmission** in the nervous system.
• Provide rapid response to chemical signals.

### Description of Ligand-Gated Mechanism

A receptor protein on the membrane binds a neurotransmitter; this binding causes a conformational change, opening the channel so ions can flow across the membrane.

## Voltage-Gated Channels

• Open or close in response to changes in **membrane potential**.
• Critical for **action potentials** in neurons, skeletal and cardiac muscle.

### Examples

• **Voltage-gated Na? channels** (rapid depolarization).
• **Voltage-gated K? channels** (repolarization).
• **Voltage-gated Ca²? channels** (neurotransmitter release, muscle contraction).

### Properties

• Have voltage sensors that detect electrical changes.
• Open and close within milliseconds.

### Description of Voltage-Gated Mechanism

When the membrane depolarizes, the voltage sensor in the channel moves, shifting the protein into an open state and allowing rapid ion entry.

## Ionophores

• Small **lipid-soluble molecules** that transport ions across membranes.
• Produced by microorganisms; often used experimentally.

### Two Types

1. **Carrier Ionophores**
   • Bind an ion, shield its charge, and carry it across the membrane.
   • Example: **Valinomycin** (selective for K?).

2. **Channel-Forming Ionophores**
   • Create hydrophilic pores allowing ions to flow through.
   • Example: **Gramicidin**.

### Functions

• Disrupt ion gradients.
• Useful for studying membrane potential, mitochondrial functions, and metabolic pathways.

### Description of Ionophore Action

A lipid-soluble molecule binds to an ion like K?, surrounds it, and diffuses through the hydrophobic membrane core, releasing the ion on the opposite side.

## Active Transport

• Movement of molecules **against** their concentration gradient (low ? high).
• Requires **energy**, usually from **ATP hydrolysis** or an ion gradient.
• Highly **specific** and involves carrier proteins.

• Essential for maintaining ionic balance, nutrient uptake, and membrane potential.

### Primary Active Transport

• Uses **direct ATP hydrolysis**.
• Example: Na?/K? ATPase, H? ATPase, Ca²? ATPase.

### Secondary Active Transport

• Uses the **energy stored in ion gradients** created by primary active transport.
• Does not directly use ATP but depends on ATP-driven pumps.

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## Sodium Pump (Na?/K? ATPase)

• A classic **primary active transport pump**.
• Located in almost all cell membranes.
• Maintains **resting membrane potential**, cell volume, and ionic balance.

### Mechanism

• Pumps **3 Na? out** of the cell and **2 K? in** per ATP hydrolyzed.
• Creates a **high extracellular Na?** and **high intracellular K?** environment.
• Electrogenic — contributes to the negative charge inside the cell.

### Functions

• Drives secondary active transport (glucose, amino acids).
• Maintains osmotic stability.
• Essential for nerve and muscle excitability.

### Description of Sodium Pump Cycle

The pump binds intracellular Na?, uses ATP to change shape and release them outside, then binds extracellular K? and returns to its original conformation to bring K? inside.

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## Uniport

• Transports **one type of molecule** across the membrane.
• Can be passive (facilitated diffusion) or active (ATP-driven).
• Example: GLUT1 transporter (glucose transport).

**Key Feature**

• Moves **only one substance** at a time, in one direction.

## Symport

• Moves **two different molecules** in the **same direction** across the membrane.
• Often used in **secondary active transport**.

**Examples**

• **Na?–glucose cotransporter (SGLT)** in intestine and kidney.
• **Na?–amino acid symporters**.

**Key Feature**

• One molecule moves down its gradient, driving the other against its gradient.

## Antiport

• Moves **two different molecules in opposite directions**.
• Also commonly part of secondary active transport.

**Examples**

• **Na?–Ca²? exchanger** (NCX).
• **Cl?–HCO?? exchanger** (important in acid–base regulation).
• Mitochondrial **ADP–ATP exchanger**.

**Key Feature**

• One substance enters the cell while the other leaves.

## Exocytosis

• Process by which cells **expel materials** through fusion of vesicles with the plasma membrane.
• Used for secretion of **hormones, neurotransmitters, enzymes**, and membrane proteins.
• Requires energy (ATP) and is highly regulated.

### Steps

• Vesicles form inside the cell ? move along cytoskeletal tracks ? fuse with the membrane ? release contents outside.
• Also helps in **membrane recycling and growth**.

### Description

A vesicle moves to the surface, merges with the membrane, and discharges its molecules outside the cell while adding new membrane material.

## Endocytosis

• Process of **internalizing extracellular material** by forming vesicles from the plasma membrane.
• Helps in nutrient uptake, receptor internalization, and removal of membrane components.

### Types

• Pinocytosis
• Phagocytosis
• Receptor-mediated endocytosis

### General Mechanism

• Membrane invaginates ? surrounds material ? pinches off to form an internal vesicle.

## Pinocytosis

• Called “**cell drinking**.”
• Uptake of **fluids and small solutes** in small vesicles.
• Occurs continuously in most cells.
• Important for nutrient absorption and routine membrane turnover.

**Description**

The membrane forms small pits that enclose extracellular fluid, creating tiny vesicles inside the cell.

## Phagocytosis

• Called “**cell eating**.”
• Uptake of **large particles** such as bacteria, dead cells, and debris.
• Performed mainly by specialized cells: **macrophages, neutrophils, dendritic cells**.

**Mechanism**

• Cell extends pseudopodia ? engulfs the particle ? forms a large vesicle (phagosome) ? fuses with lysosome for digestion.

**Description**

Large outward extensions from the cell engulf a particle, close around it, and deliver it to a digestive compartment.

## Clinical Correlation of Membrane Transport

### 1. Cystic Fibrosis (CF) – Defective Chloride Channel

• Caused by mutation in **CFTR**, a chloride channel.
• Impaired Cl? secretion ? thick, sticky mucus in lungs and pancreas.
• Leads to recurrent respiratory infections, malabsorption, infertility.
• Demonstrates the importance of **ion channels** in epithelial transport.

### 2. Hyponatremia & Hypernatremia – Na? Transport Imbalance

• Abnormal extracellular sodium alters **osmotic balance** across membranes.
• Water shifts into or out of cells ? neurological symptoms (confusion, seizures).
• Rapid correction can cause **osmotic demyelination syndrome**.

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### 3. Digitalis Toxicity – Na?/K? ATPase Inhibition

• Digitalis drugs inhibit the **sodium pump**.
• Increased intracellular Na? reduces Na?–Ca²? exchange ? ? intracellular Ca²?.
• Useful in heart failure (? contractility) but toxic at high levels.

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### 4. Glucose Uptake Disorders

• **Type 2 diabetes:** defective insulin signaling ? impaired **GLUT4 translocation** ? reduced glucose uptake in muscle and fat cells.
• **GLUT1 deficiency:** low glucose transport into the brain ? seizures, developmental delay.

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### 5. Channelopathies

• Disorders caused by defective ion channels.

Examples:
• **Long QT syndrome:** abnormal K? or Na? channels ? arrhythmias.
• **Episodic ataxia:** defective voltage-gated K? channels.
• **Hyperkalemic periodic paralysis:** dysfunctional Na? channels in muscle.

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### 6. Proton Pump Inhibitors (PPIs)

• Drugs like omeprazole inhibit the **H?/K? ATPase** in gastric parietal cells.
• Reduce acid secretion ? treat GERD, ulcers.
• Illustrate therapeutic targeting of **active transporters**.

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### 7. Cholera – Excessive Cl? Secretion

• Cholera toxin activates CFTR, causing massive **Cl? and water efflux** into the intestine.
• Leads to severe dehydration and electrolyte imbalance.
• Treated with ORS to restore Na?, Cl?, glucose-coupled cotransport.

### 8. Familial Hypercholesterolemia – Receptor-Mediated Endocytosis Defect

• LDL receptor malfunction ? reduced LDL uptake by cells.
• Causes severely elevated LDL ? premature atherosclerosis and heart disease.
• Shows the role of **endocytosis** in lipid clearance.

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### 9. Phagocytic Defects (Chronic Granulomatous Disease)

• Impaired NADPH oxidase in neutrophils ? defective killing of ingested organisms.
• Patients suffer from recurrent fungal and bacterial infections.
• Demonstrates importance of **phagocytosis** in innate immunity.

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### 10. Edema – Disruption of Ion & Water Transport

• Failure of ion pumps or increased capillary permeability causes excessive fluid buildup in tissues.
• Seen in heart failure, renal disease, liver failure.

## Frequently Asked Questions (FAQs)

### 1. Why is the plasma membrane called the “fluid mosaic model”?

Because it is made of a **fluid phospholipid bilayer** with proteins scattered throughout like a **mosaic**, and both lipids and many proteins can move laterally.

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### 2. What are lipid rafts and why are they important?

Lipid rafts are **cholesterol- and sphingolipid-rich microdomains** that organize signaling molecules.
They help in **signal transduction, endocytosis, immune activation, and membrane trafficking.**

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### 3. How do caveolae differ from lipid rafts?

Caveolae are **flask-shaped invaginations** containing the protein **caveolin**, whereas lipid rafts are flat microdomains.
Both are cholesterol-rich, but caveolae specialize in **endocytosis** and **mechanosensing**.

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**4. What is the role of the nucleus?**

It stores **DNA**, directs **gene expression**, and contains the **nucleolus**, which forms ribosomes.

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**5. What is the function of rough ER?**

Rough ER synthesizes **secretory and membrane proteins** due to ribosomes attached to its surface.

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**6. What does the smooth ER do?**

Smooth ER is responsible for **lipid synthesis**, **steroid hormone formation**, and **detoxification** via cytochrome P450.

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**7. Why is the Golgi apparatus important?**

It modifies, sorts, and packages proteins into vesicles for **secretion**, **lysosomes**, or the **plasma membrane**.

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**8. What is the main function of lysosomes?**

Lysosomes contain **acid hydrolases** that break down cellular debris, old organelles, and ingested pathogens.

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**9. What are peroxisomes used for?**

They perform **?-oxidation of very-long-chain fatty acids** and detoxify **hydrogen peroxide** using catalase.

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**10. Why are mitochondria called the powerhouse of the cell?**

Because they carry out **oxidative phosphorylation**, producing the majority of cellular **ATP**.

**11. What is facilitated diffusion?**

Passive transport of molecules down their concentration gradient with the help of **carrier or channel proteins**; no ATP required.

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**12. What is the sodium pump (Na?/K? ATPase)?**

A primary active transporter that pumps **3 Na? out** and **2 K? into** the cell using **ATP**, helping maintain membrane potential and osmotic stability.

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**13. What is the difference between uniport, symport, and antiport?**

• **Uniport:** one molecule moves in one direction.
• **Symport:** two molecules move in the same direction.
• **Antiport:** two molecules move in opposite directions.

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**14. What is endocytosis?**

Process of internalizing extracellular material by forming vesicles from the plasma membrane.

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**15. What is the difference between pinocytosis and phagocytosis?**

• **Pinocytosis:** uptake of fluids and small molecules (“cell drinking”).
• **Phagocytosis:** ingestion of large particles like bacteria (“cell eating”).

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**16. What is exocytosis?**

Process of vesicles fusing with the plasma membrane to **release materials outside** the cell.

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**17. What clinical disease is linked to defective chloride channels?**

**Cystic fibrosis**, caused by mutations in the **CFTR** chloride channel.

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**18. What is the significance of receptor-mediated endocytosis?**

It allows **selective uptake** of molecules such as LDL, transferrin, and hormones.
Defects cause **familial hypercholesterolemia**.

## Multiple Choice Questions (MCQs)

**1. The “fluid mosaic model” describes which of the following?**

A. Cytoskeleton organization
B. Plasma membrane structure
C. Nuclear pore complex
D. Ribosomal assembly
**Answer: B**

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**2. Lipid rafts are rich in which components?**

A. Phosphatidylcholine and RNA
B. Sphingolipids and cholesterol
C. Actin and myosin
D. ATP and NADH
**Answer: B**

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**3. Caveolae contain which structural protein?**

A. Clathrin
B. Caveolin
C. Tubulin
D. Vinculin
**Answer: B**

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**4. Which organelle is responsible for detoxification via cytochrome P450?**

A. Rough ER
B. Smooth ER

C. Golgi apparatus

D. Lysosomes

**Answer: B**

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**5. Which organelle contains hydrolytic enzymes active at acidic pH?**

A. Mitochondria

B. Peroxisomes

C. Lysosomes

D. Smooth ER

**Answer: C**

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**6. ?-oxidation of very long-chain fatty acids occurs in:**

A. Lysosomes

B. Peroxisomes

C. Mitochondrial matrix

D. Cytosol

**Answer: B**

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**7. Which organelle has its own DNA and ribosomes?**

A. Nucleus

B. Golgi apparatus

C. Mitochondria

D. Rough ER

**Answer: C**

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**8. Facilitated diffusion requires:**

A. ATP

B. Carrier proteins or channel proteins

C. Vesicle formation

D. Movement against the gradient

**Answer: B**

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**9. The sodium pump transports ions how?**

A. 2 Na? in and 3 K? out
B. 3 Na? in and 2 K? out
C. 3 Na? out and 2 K? in
D. 2 Na? out and 3 K? in
**Answer: C**

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**10. Symport refers to:**

A. One molecule moving across the membrane
B. Two molecules moving in opposite directions
C. Two molecules moving in the same direction
D. Transport without proteins
**Answer: C**

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**11. Which process is known as “cell drinking”?**

A. Phagocytosis
B. Endocytosis
C. Pinocytosis
D. Exocytosis
**Answer: C**

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**12. Which of the following is an example of receptor-mediated endocytosis?**

A. Glucose absorption by SGLT
B. LDL uptake into cells
C. Water reabsorption in kidney
D. Sodium reabsorption in intestine
**Answer: B**

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**13. Ionophores function by:**

A. Blocking voltage-gated channels
B. Directly hydrolyzing ATP

C. Carrying ions across membranes or forming pores

D. Enhancing RNA synthesis

**Answer: C**

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**14. Cholesterol in the membrane primarily:**

A. Increases fluidity at all temperatures

B. Prevents membrane melting at high temperature and freezing at low temperature

C. Only stiffens the membrane

D. Only increases permeability

**Answer: B**

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**15. Which organelle is responsible for protein sorting and packaging?**

A. Golgi apparatus

B. Smooth ER

C. Lysosome

D. Peroxisome

**Answer: A**

## Viva Voce

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**1. What is the basic structure of the plasma membrane?**

A phospholipid bilayer with embedded proteins, cholesterol, and surface carbohydrates.

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**2. Why is it called the fluid mosaic model?**

Because lipids and many proteins move laterally, forming a dynamic “mosaic” of components.

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**3. What is the main lipid in the cell membrane?**

Phospholipids.

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**4. What is the role of cholesterol in the membrane?**

Stabilizes membrane fluidity — prevents excessive fluidity at high temperature and rigidity at low temperature.

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**5. What are lipid rafts?**

Cholesterol- and sphingolipid-rich microdomains for signaling and membrane trafficking.

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**6. What protein characterizes caveolae?**

Caveolin.

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**7. Name the two types of ER.**

Rough ER and Smooth ER.

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**8. What is the main function of rough ER?**

Synthesis of secretory and membrane proteins.

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**9. What is the function of smooth ER?**

Lipid synthesis, steroid formation, and detoxification (cytochrome P450).

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**10. What is the role of the Golgi apparatus?**

Modification, sorting, and packaging of proteins.

---

**11. What are lysosomes?**

Vesicles containing acid hydrolases for degradation of cellular waste.

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**12. What is the main function of peroxisomes?**

Oxidation of very-long-chain fatty acids and detoxification of hydrogen peroxide.

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**13. Why do mitochondria have their own DNA?**

They originate from endosymbiotic bacteria and can synthesize some of their proteins.

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**14. What is the function of mitochondria?**

ATP production through oxidative phosphorylation.

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**15. What is facilitated diffusion?**

Passive transport of molecules down their gradient using carrier or channel proteins.

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**16. What is active transport?**

Movement of molecules against their concentration gradient using energy (ATP).

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**17. What does the sodium pump do?**

Pumps 3 Na? out and 2 K? in per ATP hydrolyzed.

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**18. What is a uniport?**

Transport of a single molecule in one direction.

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**19. What is a symport?**

Transport of two molecules in the same direction.

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**20. What is an antiport?**

Transport of two molecules in opposite directions.

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**21. What is endocytosis?**

Internalization of extracellular material by membrane invagination.

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**22. What is the difference between pinocytosis and phagocytosis?**

Pinocytosis takes in fluid; phagocytosis takes in large particles.

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**23. What is exocytosis?**

Release of cellular contents by vesicle fusion with the membrane.

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**24. Give a clinical disorder related to chloride transport.**

Cystic fibrosis.

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**25. What is receptor-mediated endocytosis?**

Selective uptake of molecules using receptors — e.g., LDL uptake.