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STRUCTURE OF EUKARYOTIC CELL

Eukaryotic cells are defined by their complex compartmentalized internal structure, with a membrane bound nucleus and various other specialized organelles. These cells make up multicellular organisms like animals, plants, and fungi, as well as unicellular protists.

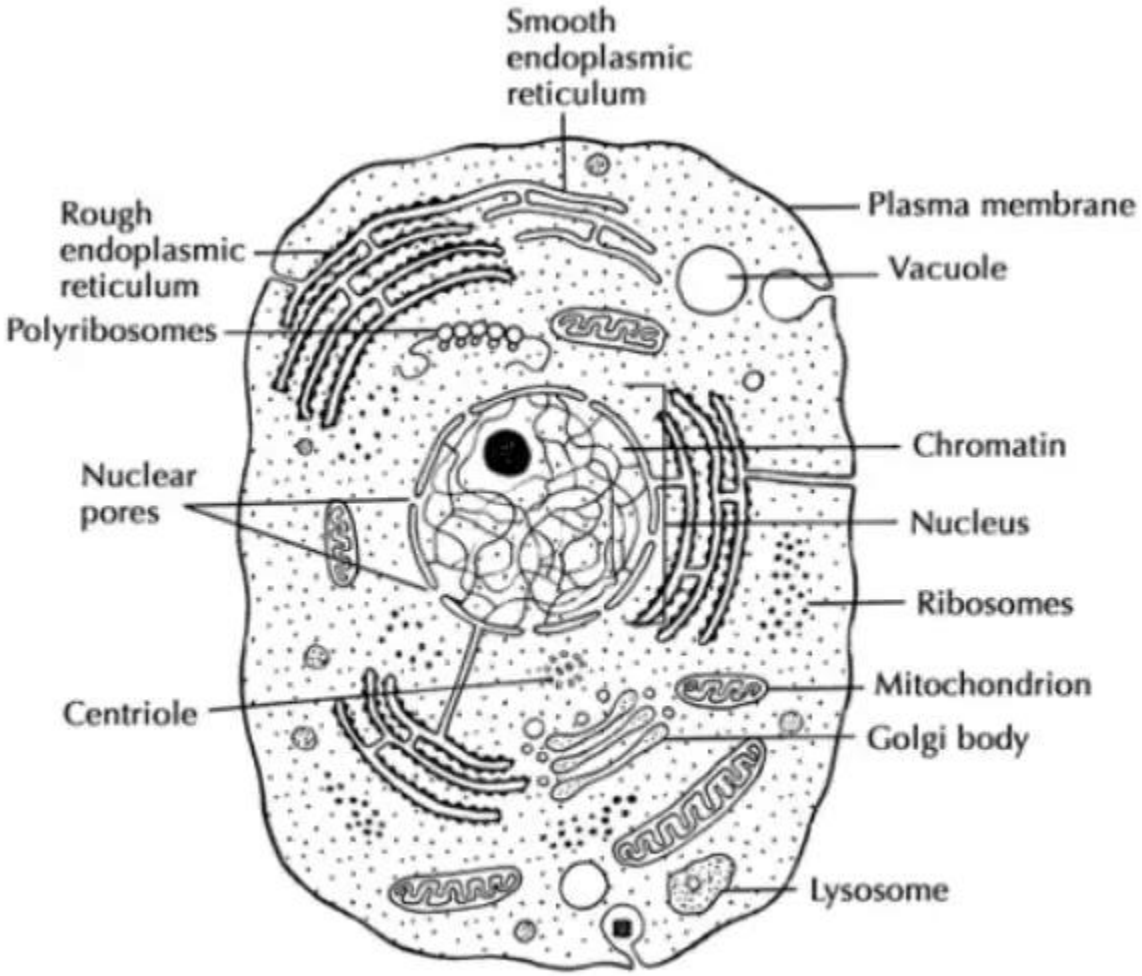

Fig.1 Structure of animal cell

Animal cell consists of following components;

1. The Nucleus:

The most prominent organelle, the nucleus serves as the "brain" of the cell.

- **Nuclear Envelope:** A double membrane (two phospholipid bilayers) that separates genetic material from the cytoplasm.
- **Nuclear Pores:** Openings in the envelope that regulate the exchange of RNA and proteins.
- **Chromatin & Chromosomes:** Genetic material (DNA) is wrapped around **histone proteins**. It exists as loosely packed **chromatin** during growth and condenses into **linear chromosomes** during cell division.
- **Nucleolus:** A dense region within the nucleus where **ribosomal RNA (rRNA)** is synthesized and ribosome subunits are assembled.

2. The Endomembrane System

This network of membranes works together to modify, package, and transport lipids and proteins.

- **Endoplasmic Reticulum (ER):**
    - **Rough ER:** Studded with ribosomes; its primary role is protein synthesis and modification.
    - **Smooth ER:** Lacks ribosomes; synthesizes lipids, metabolizes carbohydrates, detoxifies poisons, and stores calcium ions.
- **Golgi Apparatus:** A stack of flattened sacs (cisternae) that modifies, sorts, and packages proteins and lipids into vesicles for transport.
- **Lysosomes:** Membrane-bound sacs containing digestive enzymes (active at low pH) that break down waste, cellular debris, and foreign pathogens.

3. Energy Organelles

Mitochondria and chloroplasts are unique as they contain their own DNA and double membranes, likely originating through **endosymbiosis**.

- **Mitochondria:** The "powerhouse" where **ATP** is generated through cellular respiration. The inner membrane is folded into **cristae** to increase surface area for reactions.
- **Chloroplasts (Plants/Algae only):** Conduct photosynthesis, converting light energy into glucose. They contain green **chlorophyll** within stacked membrane sacs called **thylakoids** (forming **grana**).

4. Cytoplasm and Support Structures

- **Plasma Membrane:** A selectively permeable phospholipid bilayer with embedded proteins and cholesterol that regulates the passage of substances.
- **Cytoskeleton:** A network of protein fibers (microfilaments, intermediate filaments, and microtubules) that maintains cell shape, anchors organelles, and facilitates movement.
- **Ribosomes (80S):** Large complexes made of RNA and protein responsible for protein synthesis; found freely in the cytoplasm or bound to the rough ER.
- **Cytoplasm:** The entire region between the plasma membrane and nuclear envelope, consisting of the gel-like **cytosol**, organelles, and cytoskeleton.

ENDO MEMBRANE SYSTEM: PROTEIN TARGETING AND SORTING, ENDOCYTOSIS, EXOCYTOSIS

Endomembrane System (Endo = inner; membrane – thin layers; system- combination of two or more components)

The Endomembrane system is a group of membranes and organelles present within the eukaryotic cell. This system includes plasma membrane, nuclear membrane, endoplasmin reticulum, Golgi complex, lysosome, vesicles and vacuoles. The major function of endo membrane system is to modify, package, and transport lipids and proteins within and outside the cell. It also plays an important role in maintaining the internal organization and forms various compartments of the cell.

Components of Endomembrane System

1. Nuclear membrane: The nucleus of the cell is surrounded by double layered membranes. This membrane is called nuclear membrane. This membrane separate nucleoplasm to cytoplasm. It has pores. These pores allow the transport of cellular materials like RNA and proteins between nucleus and cytoplasm. Nuclear membrane is also connected with endoplasmic reticulum on outer surface.
2. Endoplasmic Reticulum (ER): It is a network of membrane-bound cisternae, tubules and sacs present in cytoplasm of eukaryotic cells. ER is of two types: Rough Endoplasmic Reticulum (RER) and smooth Endoplasmic Reticulum (SER). On the outer surface of rough ER, ribosomes are present. RER is involved in protein synthesis and transport. The outer surface of smooth ER is without ribosomes and involved in lipid synthesis, detoxification, and calcium storage.
3. Golgi Complex: Golgi complex is a double membranous cell organelle and composed of cisternae, tubules and vesicles. This organelle is present in cytoplasm of eukaryotic cells near the nucleus. The main function of Golgi complex is modification, sorting,

and packaging of proteins and lipids for secretion and transport within and outside the cell. It also forms lysosomes and vesicles.

4. Lysosomes are small vesicles present in cytoplasm of cell. These lysosomes contain digestive enzymes such as proteases, nucleases, lipases, and glycosidases, that work together to break down a variety of biological molecules including digestion of useless organelles, food particles, and foreign bodies.
5. Vesicles and Vacuoles: Vesicles are small membrane bound sacs that transport materials between organelles. Vacuoles are large vesicles present in plant cells for storage (e.g., water, nutrients, waste).
6. Plasma Membrane: This is the outer membrane of the cell made up of mainly phospholipids and proteins. Plasma membrane controls the entry and exit of substances of cell and helps in communication with the external environment.

Functions of the Endomembrane System

- Transport of molecules within the cell.
- Synthesis, modification and packaging of proteins and lipids.
- Formation of lysosomes and secretory vesicles.
- Intracellular digestion and waste disposal.
- Maintains cell shape and various compartments of cell.

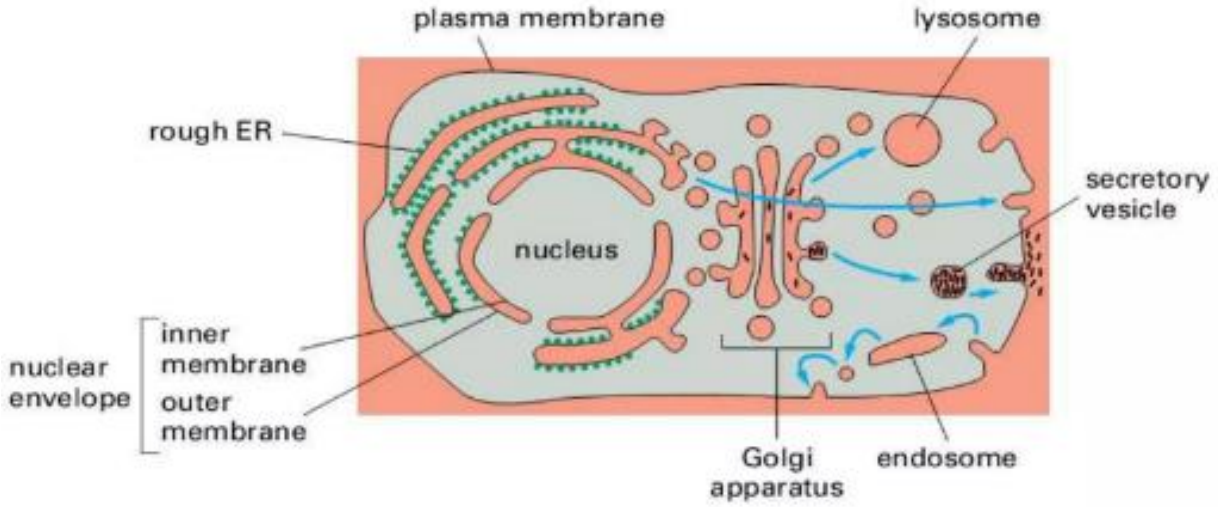

Fig.2 Endomembrane system of animal cell

Protein Targeting or Sorting - Protein targeting means transport of newly synthesized proteins to their proper destination inside or outside the cell. Or in other words, protein targeting or sorting is the process by which a cell transports proteins to the appropriate places inside or outside the cell. It ensures that each protein (enzymes and structural proteins) reaches the correct organelle or membrane, where it can perform its correct function. Protein targeting also supports processes like secretion, membrane repair, and signal transduction and maintains cellular organization and function.

Targeting process is directed by specific signal sequences, present on the protein. Signal sequences are specific amino acid sequences on the protein that act as an "address label" to guide it for correct destination There is two main pathways for transport of proteins; co-translational targeting (during translation) for the endoplasmic reticulum and secretory pathway, and post-translational targeting (after translation) for destinations like the nucleus, mitochondria, and peroxisomes. The correct protein sorting is crucial for proper cell function. The misplaced protein in cell can cause various harmful effects in body.

Protein Synthesis: - In cell, all proteins are synthesized by ribosomes. These ribosomes are found in cytoplasm as free form or attached to rough endoplasmic reticulum. After synthesis, proteins need to reach their appropriate site for structure and function. The final destination of protein depends on the site of protein synthesis and targeting signal present on it.

Protein Targeting - Types

Depending on the site of target, protein targeting is of following types;

1. Cytoplasmic targeting protein
2. Organelle targeted proteins
3. Secretory pathway proteins

A. Cytoplasmic Proteins: The protein synthesized by free ribosomes, remain in the cytoplasm (e.g., enzymes of glycolysis).

B. Organelle-targeted Proteins: Contain specific signal sequences that direct them to organelles:

- Nucleus → nuclear localization signal (NLS).
- Mitochondria → mitochondrial targeting signal.
- Chloroplasts → Transit peptide sequence.
- Chloroplasts → Transit peptide sequence.
- Peroxisomes → Peroxisomal targeting signal (PTS).

C. Secretory Pathway Proteins: Synthesized on RER bound ribosomes and include:

- Secreted proteins (e.g., hormones, enzymes).
- Membrane proteins (e.g., receptors).
- Lysosomal proteins.

Process of secretory pathway

1. Signal peptide on the growing protein directs ribosome to the RER membrane.
2. Protein enters RER lumen for folding and modification.
3. Transported to Golgi apparatus for further processing.
4. Sent to lysosomes, plasma membrane, or secreted outside the cell.

Mechanism of Protein Targeting

1. Signal sequence recognition – short amino acid sequence acts as an "address tag."
2. Transport – protein is moved through vesicles or pores.
3. Processing and modification – cleavage of signal, folding, and addition of sugar or lipid groups.
4. Delivery – protein reaches the target organelle or cell surface.

Mis-targeting of Proteins: Misplacing of proteins can cause cell damage or diseases, such as cystic fibrosis (defective transport of a membrane protein) and zelweger syndrome (failure in peroxisomal protein import).

Table 1. Protein sorting – destination, signal and transport mechanism.

Sl. No.	Protein destination	Site of synthesis	Signal Sequence	Transport Mechanism
1	Cytoplasm	Free ribosome	None	Diffusion
2	Nucleus	Free ribosome	NLS	Through nuclear pores
3	Mitochondria	Free ribosome	Mitochondrial signal	Across mitochondrial membranes
4	Peroxisome	Free ribosome	PTS	Transport protein complex
5	Plasma Membrane / Secreted	RER-bound ribosome	Signal peptide	Vesicle transport via Golgi complex

Endocytosis

Endocytosis is a cellular process. In this process, cell takes substances inside cell from the outside by engulfing them. In this way cell absorbs nutrients, pathogens, and other necessary materials from outside environment. The process involves cell membrane invagination, or folds inward, around the material to be ingested. The membrane then pinches off, creating a membrane-bound sac called an endocytic vesicle within the cell. The vesicle transports the contents to other parts of the cell, such as a lysosome for breakdown.

The two main types of endocytosis are phagocytosis (cellular eating) and pinocytosis (cellular drinking). Phagocytosis process is the ingestion of large particles, such as microorganisms and dead cells. It is often performed by specialized cells like white blood cells. The pinocytosis involves the uptake of fluids and dissolved solutes in small vesicles. Most eukaryotic cells perform this continuously. Receptor-mediated Endocytosis is a more specific form of Endocytosis. In this process, cell takes in particular molecules after they bind to specific receptors on the cell surface. Certain viruses and hormones can be taken into cells by this method.

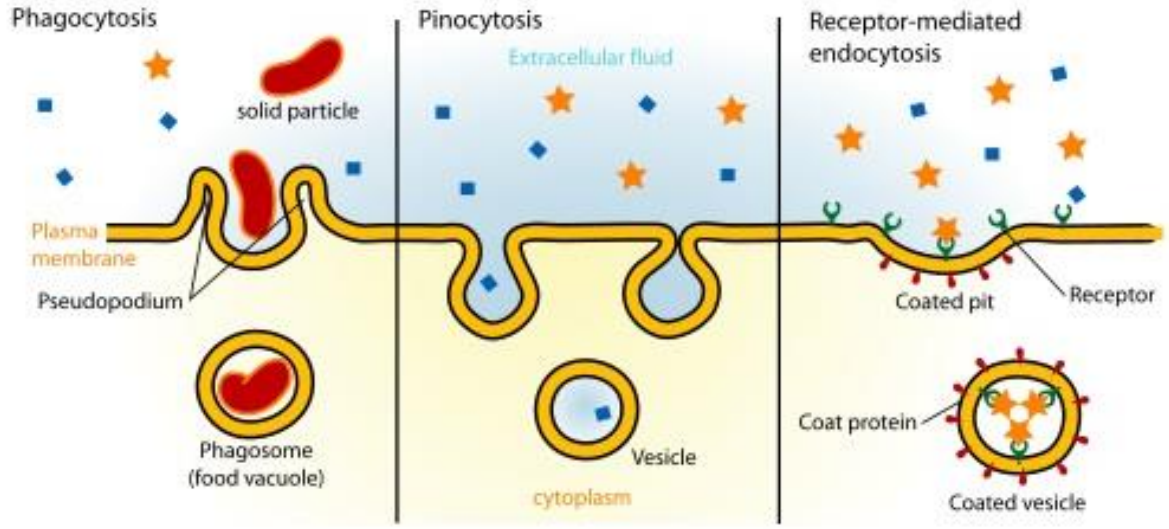

Fig. 3 Different types of Endocytosis; Phagocytosis, Pinocytosis and receptor-mediated Endocytosis.

Exocytosis

Exocytosis is a cellular process in which a cell transports molecules from inside to out of the cell. Inside the cell, substances like proteins, hormones, enzymes or waste are packed into small sacs called vesicles. These vesicles fuse with the cell membrane. The contents of the vesicle are released outside the cell. After releasing, the vesicle membrane becomes part of the cell membrane again. This active transport mechanism uses energy to move large molecules like hormones and waste products out of the cell. For example; nerve cells release neurotransmitters by exocytosis to send signals for communication with other cells and gland cells release hormones or enzymes outside the cell for various physiological functions.

Types of Exocytosis: Exocytosis occurs in two ways; constitutive exocytosis and regulated exocytosis. Constitutive exocytosis occurs continuously in all cells for constant delivery of proteins to cell membrane. The regulated exocytosis is triggered by specific signals like calcium ions. This is used by specialized cells like neurons and endocrine cells to release hormones or neurotransmitters.

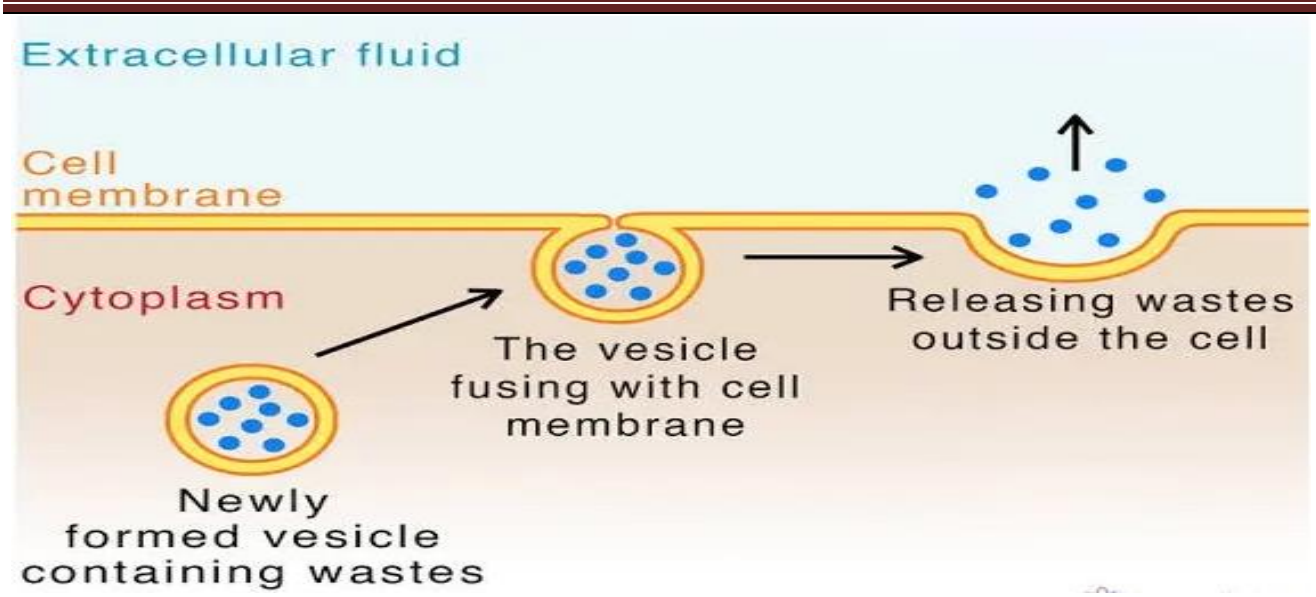

Fig.4 Exocytosis process in cell.

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