Cell structure

Cell membrane ……cont.

Membrane Carbohydrates— the Cell "Glycocalyx."

Membrane carbohydrates occur almost invariably in combination with proteins or lipids in the form of *glycoproteins* or *glycolipids.* In fact, most of the integral proteins are glycoproteins, and about one-tenth of the membrane lipid molecules are glycolipids.

The *glyco*-portions of these molecules almost invariably protrude to the outside of the cell, dangling outward from the cell surface. Many other carbohydrate compounds, called *proteoglycans*— which are mainly carbohydrates bound to small protein cores— are loosely attached to the outer surface of the cell as well. Thus, the entire outside surface of the cell often has a loose carbohydrate coat called the *glycocalyx.*

The carbohydrate moieties attached to the outer surface of the cell have several important functions:

1. Many of them have a negative electrical charge, which gives most cells an overall negative surface charge that repels other negatively charged objects.
2. The glycocalyx of some cells attaches to the glycocalyx of other cells, thus attaching cells to one another.
3. Many of the carbohydrates act as *receptors* for binding hormones, such as insulin. When bound, this combination activates attached internal proteins that in turn activate a cascade of intracellular enzymes.
4. Some carbohydrate moieties enter into immune reactions.

Cytoplasm and its organelles

The cytoplasm is filled with minute and large dispersed particles and organelles. The jelly-like fluid portion of the cytoplasm in which the particles are dispersed is called *cytosol* and contains mainly dissolved proteins, electrolytes, and glucose. Dispersed in the cytoplasm are neutral fat globules, glycogen granules, ribosomes, secretory vesicles,

and five especially important organelles—the *endoplasmic reticulum,* the *Golgi apparatus, mitochondria, lysosomes,* and *peroxisomes.*

Endoplasmic Reticulum (ER)

- It is a network of tubular and flat vesicular structures in the cytoplasm (their walls are similar to the cell membrane).
- In liver cells, for example, the total surface area of this structure can be as much as 30 to 40 times the cell membrane area.
- **Function**:
  (1) Conduct substances that are formed in some parts of the cell to other parts of the cell.
  (2) Has a major share of the metabolic functions of the cell because multiple enzyme systems are attached to its membranes.
  (3) Represents a stage for protein synthesis by ribosomes.
  (4) Synthesize essential membrane lipids.

Proteins Are Formed by the Granular ER

- The rough ER is characterized by large numbers of ribosomes attached to the outer surfaces of the ER membrane.
- Cytosolic ribosomes extrude few synthesized proteins directly into the cytosol.
- Endoplasmic ribosomes extrude many synthesized proteins through the wall of the ER to the interior of the endoplasmic vesicles and tubules, into the endoplasmic matrix.

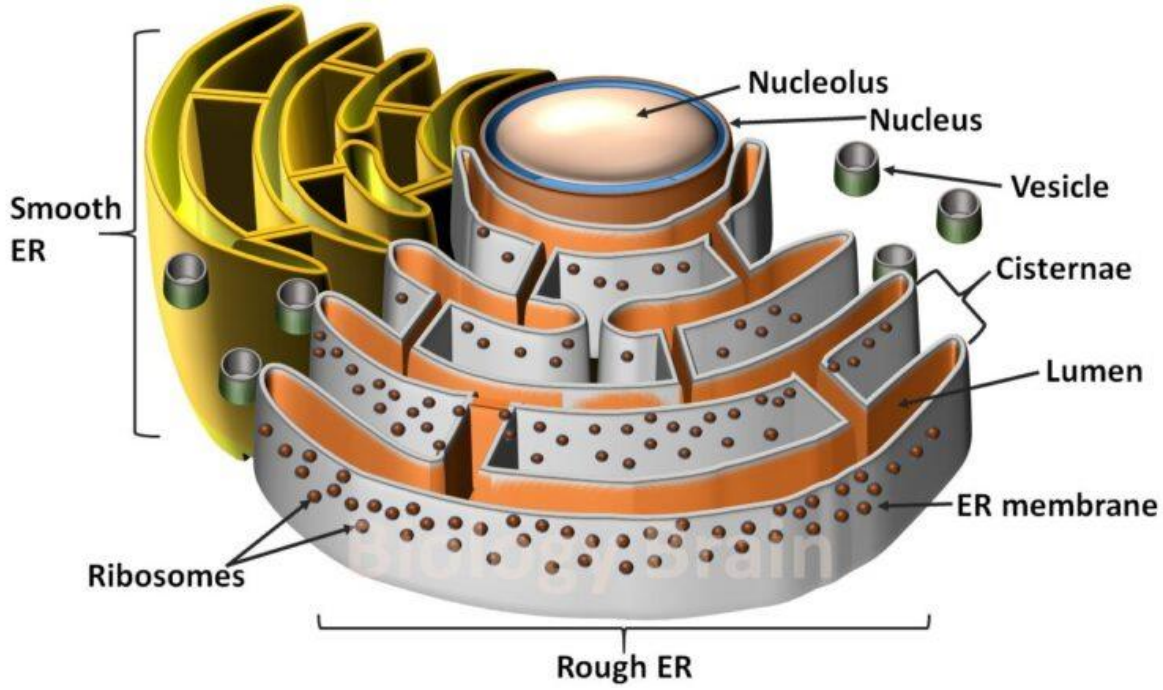
Synthesis of Lipids by the Smooth ER

- The smooth ER synthesizes lipids, especially phospholipids and cholesterol.
- These are rapidly incorporated into the lipid bilayer of the ER itself, thus causing the ER to grow more extensive.
- To keep the ER from growing beyond the needs of the cell, small vesicles called ER vesicles or transport vesicles continually break away from the smooth ER; most of these vesicles then migrate rapidly to the Golgi apparatus.

Other Functions of the ER

- ER, especially the smooth ER provides:
  - ✓ Enzymes that control glycogen breakdown when glycogen is to be used for energy.
  - ✓ Large number of detoxifying enzymes that is capable of detoxifying substances, such as drugs, that might damage the cell.

It achieves detoxification by coagulation, oxidation, hydrolysis, conjugation with glucuronic acid, and in other ways.



Golgi Apparatus

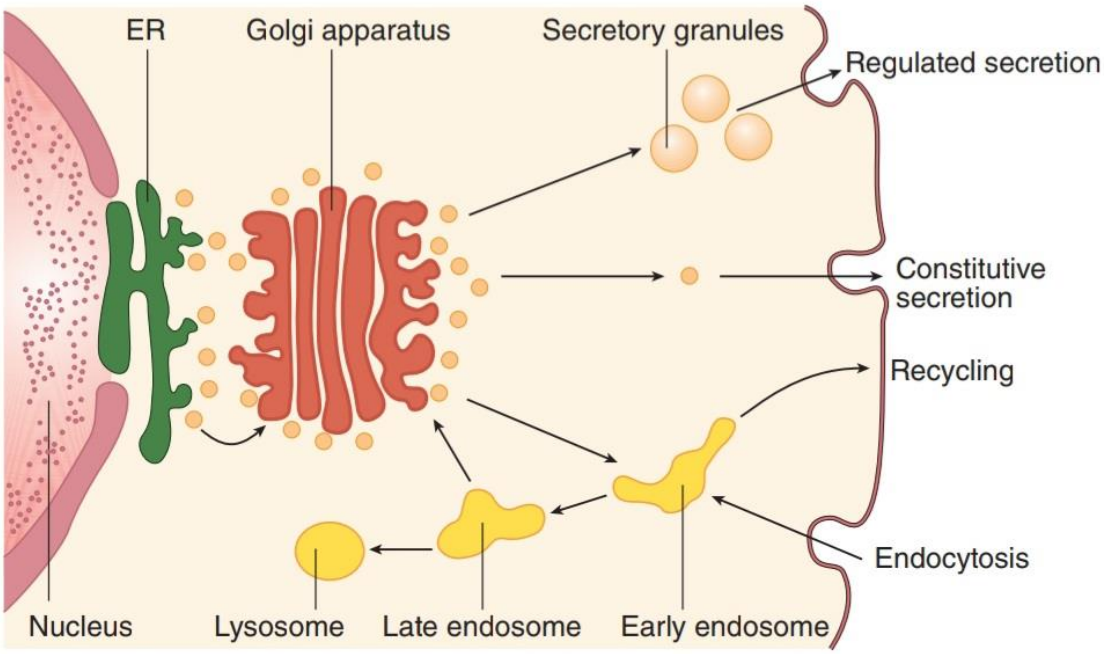
- The Golgi apparatus is closely related to the ER.
- It has membranes similar to those of the smooth ER.
- It is prominent in secretory cells, where it is located on the side of the cell from which the secretory substances are extruded.
- **Functions**

(1) Packaging

- *Substances entrapped in the ER vesicles are transported from the ER to the Golgi apparatus which then processed "packaged" in the Golgi apparatus to form lysosomes, secretory vesicles, and other cytoplasmic components.*

(2) Synthetic Functions

- Synthesizing certain carbohydrates that cannot be formed in the ER (Formation of large saccharide polymers bound with small amounts of protein; important examples include hyaluronic acid and chondroitin sulfate).



Lysosomes:

- Lysosomes are vesicular organelles form by breaking off from the Golgi apparatus and then dispersing throughout the cytoplasm.
- **Size**: quite different in different cell types, but it is usually 250 to 750nm in diameter.
- **Membrane**: surrounded by a typical lipid bilayer membrane
- **Internal contents**: filled with large numbers of small granules (5 to 8nm), which are as many as 40 different hydrolase (digestive) enzymes.
- **Internal pH**: ~5.
- **Function**: They provide an intracellular digestive system that allows the cell to digest:
  - *Damaged cellular structures,*
  - *Food particles that have been ingested by the cell, and*
  - *Unwanted matter such as bacteria*

- **Mechanism of digestion**: a hydrolytic enzyme splitting an organic compound into two or more parts by combining H^+ (from H_2O) with one part of the compound and combining OH^- with the other part of the compound (at acidic pH around 5)
  - *Protein - hydrolyzed → amino acids,*
  - *Glycogen - hydrolyzed → glucose,*
  - *Lipids - hydrolyzed → fatty acids and glycerol.*
- The membrane surrounding the lysosome prevents the enclosed hydrolytic enzymes from coming in contact with other substances in the cell and, therefore, prevents their digestive actions.
  - *Some conditions of the cell break the membranes of some of the lysosomes, allowing release of the digestive enzymes that hydrolyze organic substances into small, highly diffusible substances such as amino acids and glucose.*

Peroxisomes

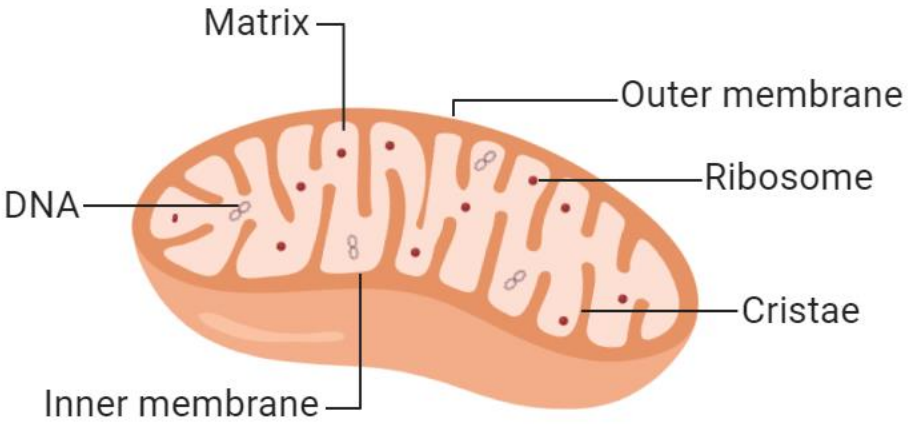
- Peroxisomes are vesicular organelles form by breaking off from the ER and then dispersing throughout the cytoplasm.
- **Size**: Smaller than lysosomes ~ 0.5-1.5nm in diameter.
- **Membrane**: surrounded by a typical lipid bilayer membrane
- **Internal contents**: filled with large numbers of oxidase "*rather than hydrolase*" enzymes.
- **Mechanism of digestion***:*
  - *Oxidases are capable of combining O_2 with H^+ ions derived from different intracellular chemicals to form hydrogen peroxide (H_2O_2).*
  - H_2O_2 is a highly oxidizing substance and is used in association with catalase (another oxidase enzyme present in large quantities in peroxisomes) to oxidize many substances (proteins, lipids) that might otherwise be poisonous to the cell.
  - For *instance, about half the alcohol a person drinks is detoxified by the peroxisomes of the liver cells in this manner.*

Secretory Vesicles:

- One of the important functions of many cells is secretion of special chemical substances.
- Almost all such secretory substances are formed by the ER-Golgi apparatus system and are then released from the Golgi apparatus into the cytoplasm in the form of storage vesicles called ***secretory vesicles*** or ***secretory granules***.

Mitochondria:

- ✓ Over a billion years ago, ***aerobic bacteria*** were engulfed by eukaryotic cells and evolved into mitochondria → providing the eukaryotic cells with the ability to form the ATP (energy-rich compound) by oxidative phosphorylation (the most crucial function).
- ✓ Other functions, including a role in the regulation of apoptosis (programmed cell death)
- ✓ Each eukaryotic cell can have 100s to 1000s of mitochondria.
- ✓ Each mitochondrion has an outer membrane, an intermembrane space, an inner membrane, which is folded to form shelves (cristae), and a central matrix space.



Transport across cell membranes

Endocytosis and exocytosis

- ✓ If a cell is to live and grow and reproduce, it must obtain nutrients and other substances from the surrounding fluids.
- ✓ Most substances pass through the cell membrane by diffusion and active transport.
  - ***Diffusion*** *involves simple movement through the lipid matrix of the membrane.*
  - ***Active transport*** *involves the use of an energy-expending carrier that penetrates all the way through the membrane.*
- ✓ Very large particles enter the cell by a specialized function of the cell membrane called endocytosis.
- ✓ In general, three general types of endocytosis may occur in a cell: (1) pinocytosis ("cell drinking"), (2) phagocytosis ("cell eating"), and (3) receptor-mediated endocytosis.

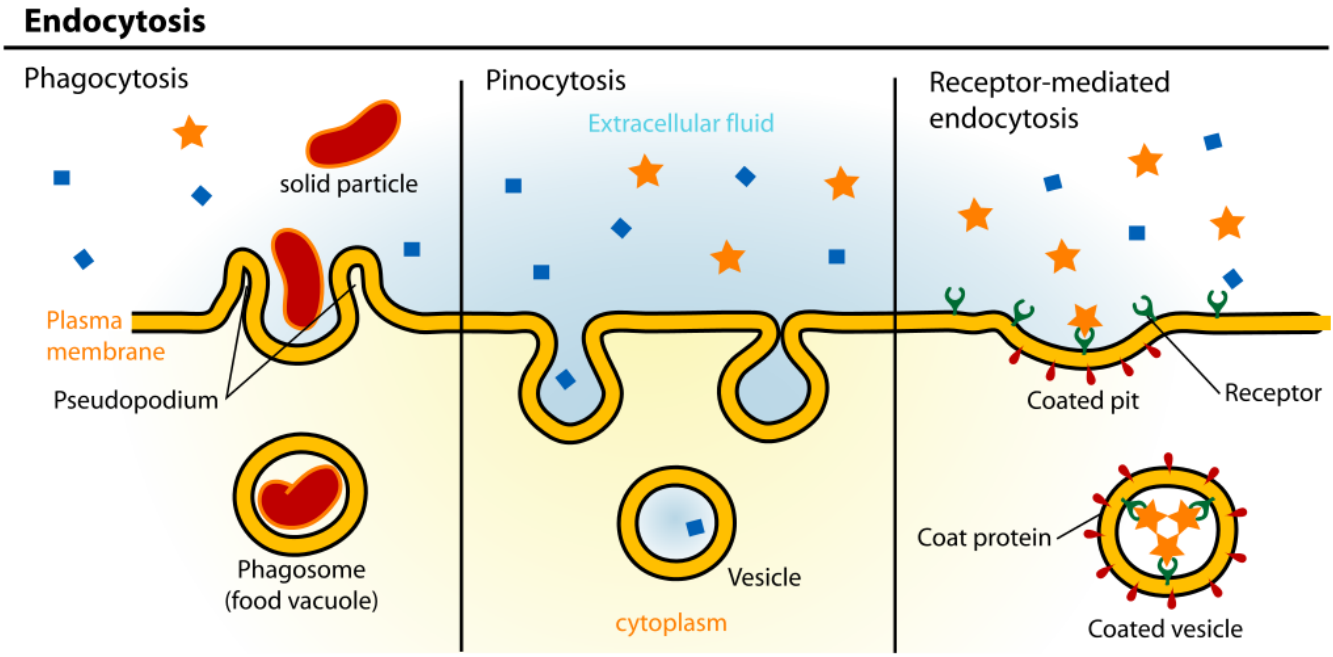
<u>Pinocytosis</u>:

- ✓ In this way, most cells ingest minute particles by forming vesicles of extracellular fluid inside the cell cytoplasm.
  For instance, it occurs so rapidly in macrophages that about 3% of the total macrophage membrane is engulfed in the form of vesicles each minute.
- ✓ Most large macromolecules (e.g.; most protein molecules) are ingested by pinocytosis.
- ✓ In fact, the rate at which pinocytotic vesicles form is usually enhanced when such macromolecules ***<u>attach</u>*** to the cell membrane.

<u>Phagocytosis:</u>

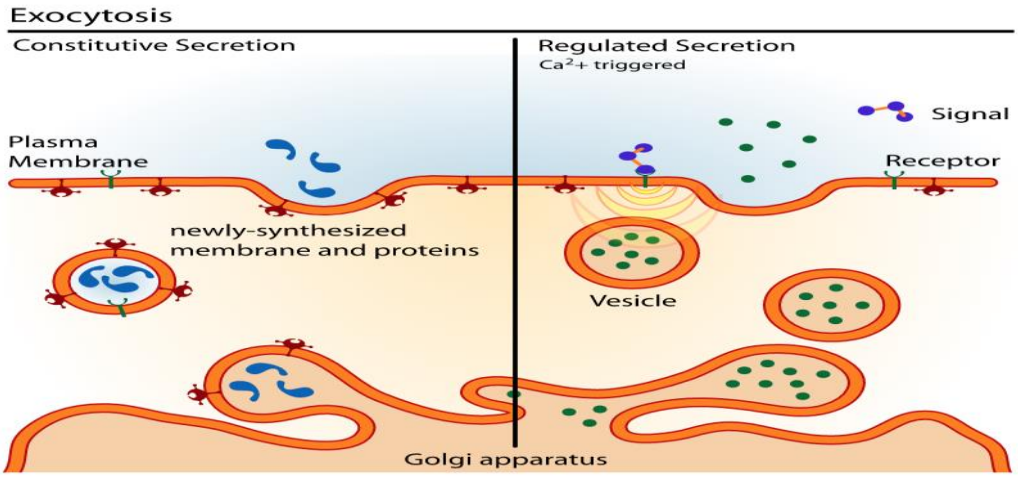
- ✓ In this way, few cells like phagocytic cells (e.g.; WBCs and macrophages) ingest large particles, such as bacteria, whole cells, or portions of degenerating tissue.
- ✓ It occurs in much the same way as pinocytosis, except that it involves large particles rather than molecules.
- ✓ It is initiated when a particle such as a bacterium, a dead cell, or tissue debris ***<u>binds</u>*** with receptors on the surface of the phagocyte.

Each bacterium is usually already attached to a specific antibody, and it is the antibody that attaches to the phagocyte receptors, dragging the bacterium along with it. This intermediation of antibodies is called opsonization.



Exocytosis

Exocytosis is defined as the transport and fusion of secretory vesicles with the plasma membrane and the extracellular space. There are three exocytosis pathways that deliver vesicles to the plasma membrane. Found in all cells, the constitutive secretory pathway operates continuously to deliver freshly synthesized membrane lipids and proteins, and soluble secretory proteins from the Golgi network directly to the plasma membrane. The regulated secretory pathway is found in specialized cells whose role it is to secrete specific cargo, such as hormones, neurotransmitters or enzymes. In these cells, secretory vesicles accumulate and concentrate their cargo through a process of retrograde movement through the Golgi. Once the vesicles are loaded to the correct concentration, they are transported via cytoskeleton tracks near the site of secretion (e.g. the synapse in neurons) to await the signal to fuse and release their contents. The third sorting pathway involves fusion of lysosomes with the plasma membrane. This lysosomal exocytosis can deliver extra membrane for repair, eject undigested debris out of the cell, and secrete cargo such as pigment


Exocytosis
Constitutive Secretion
Regulated Secretion
Ca2+ triggered
Signal
Plasma Membrane
Receptor
newly-synthesized membrane and proteins
Vesicle
Golgi apparatus