Lectures of Histology

(1st Stage)
First Semester 2024-2025

Anatomy and Histology Department

By

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Cell Organelles

Cytoplasm represent basic inner environment of the cell, it's the part located outside the nucleus filling the space between nuclear envelop and plasma membrane, its composed mainly of water (70-80)%. It also includes a considerable number of inorganic and organic compounds. It consists of:

1. Cytosol: a semi-liquid mass, which should be in form of liquid/gel.

2. Organelles: swimming metabolically active structures.

3. Cytoskeleton: protein component determines cell shape and motility.

4. Inclusions: minor cytoplasmic structures, are usually not surrounded by a membrane. They consist of such diverse materials like crystals, pigment granules, lipids, glycogen, and other stored waste products.

Cell **organelles** (contents) are distinguished according to their composition into three basic types:

1. membranous: endoplasmic reticulum, Golgi apparatus, mitochondria, nucleus, lysosomes, peroxisomes.
2. non-membranous: ribosomes, centrosome.
3. cytoskeleton: microtubules, intermediate filaments, microfilaments.

* Endoplasmic reticulum (ER)

Is a complex finely divided vacuolar or tubular system in form of hollow tubules, cisterns (flattened folds, sheets, round sacs) or flat vesicles, extending from the cell membrane closely communicating with the nucleus and via transport vesicles with the Golgi apparatus and cytoplasm (ER generally the largest membrane which forms extensive system of intercommunicating membranous sacs or channels, it represents (30-60)% of total membrane in a cell). The ratio/quantity of ER depends on its function (cell's activity in general) (Fig.1).

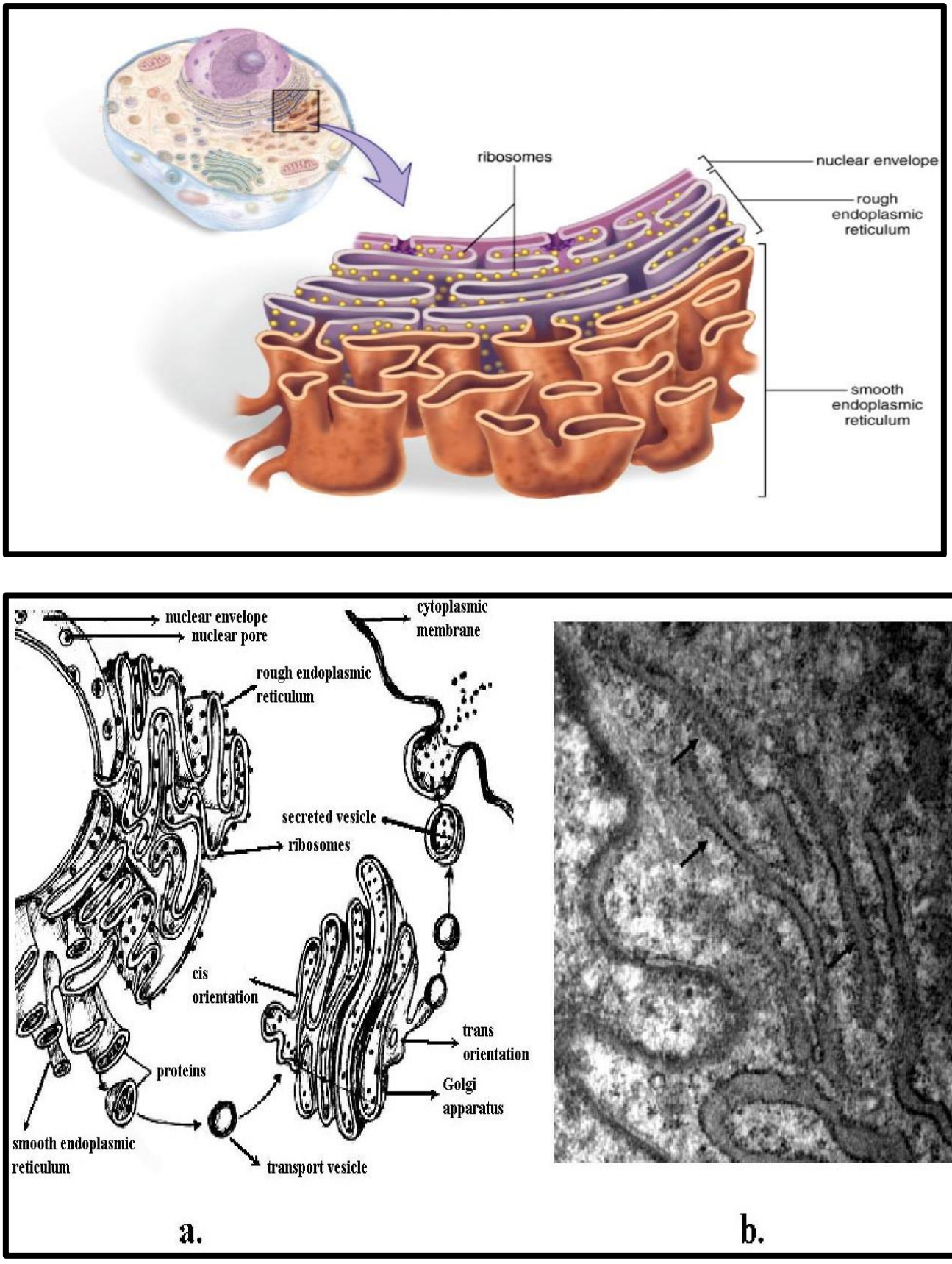

Fig. 1: **a. Scheme of endoplasmic reticulum and Golgi apparatus; b. rough endoplasmic reticulum by electron microscope.**

Structure of ER

Generally, ER comprises three types of forms/elements (Fig.2):

- **Cisternae:** flattened, unbranched, sac like elements with about (40-50)µm in diameter. They lie in stacks parallel to but interconnected with one another. They are separated from one another by cytosolic spaces.
- **Tubules:** irregular, branching elements, which form a network along with other elements. They are about (50-100)µm in diameter.
- **Vesicles:** oval, vacuole like elements, about (25-500)µm in diameter.

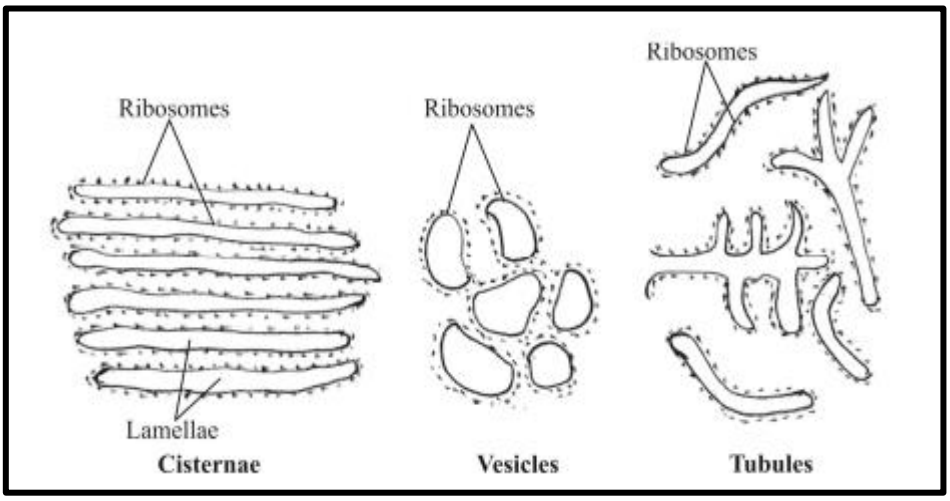

Fig. 2: Various forms of ER.

Ultrastructure of ER

Membrane bounding the cisternae, tubules and vacuoles of the ER is like cell membrane (50-60Å thick). About (30-40) different enzymes are associated with the ER for the various synthetic activities. These may be located on the cytoplasmic surface or luminal surface or both (Fig. 3).

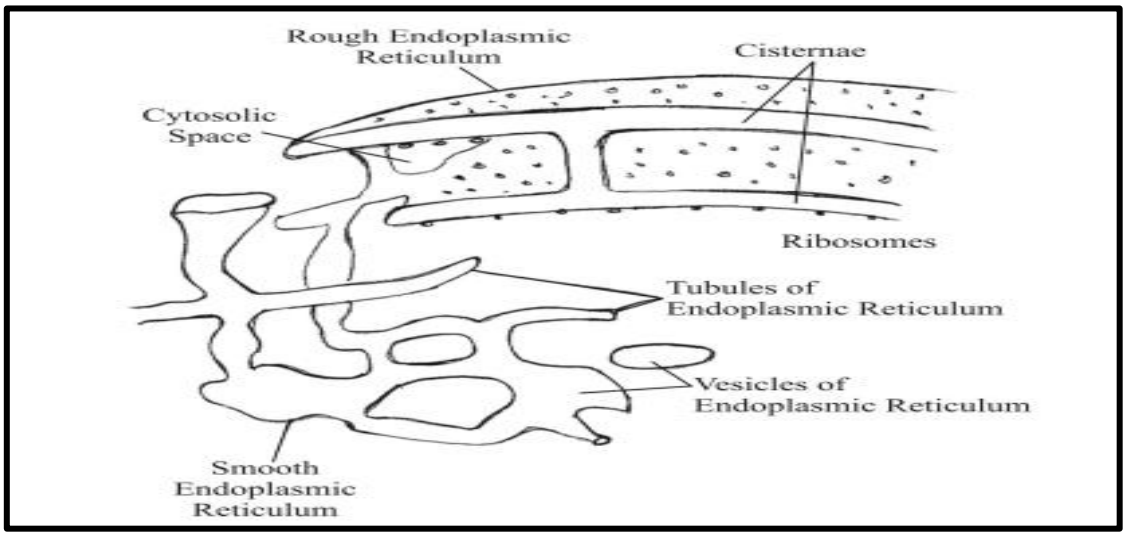

Fig. 3: Various types of elements of ER.

Based on absence or presence of ribosomes, two kinds of ER are found:

1. **Smooth ER** does not have attached ribosomes and so it appears smooth. Smooth ER is commonly found in the cells involved in synthesis of steroids or lipids (i.e., non-protein type of synthesis) such as adrenal or sebaceous glands, gonadial interstitial cells. Certain cells with carbohydrate metabolism (e.g., liver cells), impulse conduction (e.g., muscle cells) are also have more of SER in them.

2. **Rough ER** is characterized by presence of ribosomes on the surface of reticulum (side of membrane that faces the cytoplasm) and so it is also known as granular ER. RER found largely in the cells that are actively involved in the synthesis of proteins such as enzymes (e.g., pancreatic cells, plasma cells and liver cells), with pigment production (e.g., retinal pigment cell) or mucus (goblet cells).

Functions of ER

1. exchange of materials between the cytoplasm and the nucleus.

2. provides space for temporary storage of synthetic products.

3. facilitates transport of materials from one part of the cell to another thus forming the cell's circulatory system.

4. offers extensive surface for the synthesis of a variety of materials (e.g., **SER** provides surface for synthesis of fatty acids, phospholipids, glycolipids, steroids. While **RER** offers extensive surface on which protein synthesis).

5. variety of enzymes are in ER membranes to catalyze the biochemical reactions (in **SER:** glycogen metabolism, detoxification, formation of organelles, skeletal muscle contraction, while in **RER:** proteins synthesis and packaging in vesicles which have various fates, some remain in cytoplasm as storage vesicles, others migrate to plasma membrane and expel their contents by exocytosis, some fuse with Golgi apparatus for further processing to storage or release from cell).

* Golgi apparatus (complex or bodies)

The dynamic organelle that completes posttranslational modifications of proteins produced in the RER and then packages and addresses these proteins to their proper destinations.

Structure of Golgi Bodies

Golgi bodies vary in size and form in different types of cells (Fig.4). Golgi bodies are compiled as a central stack/pile from one of three forms following:

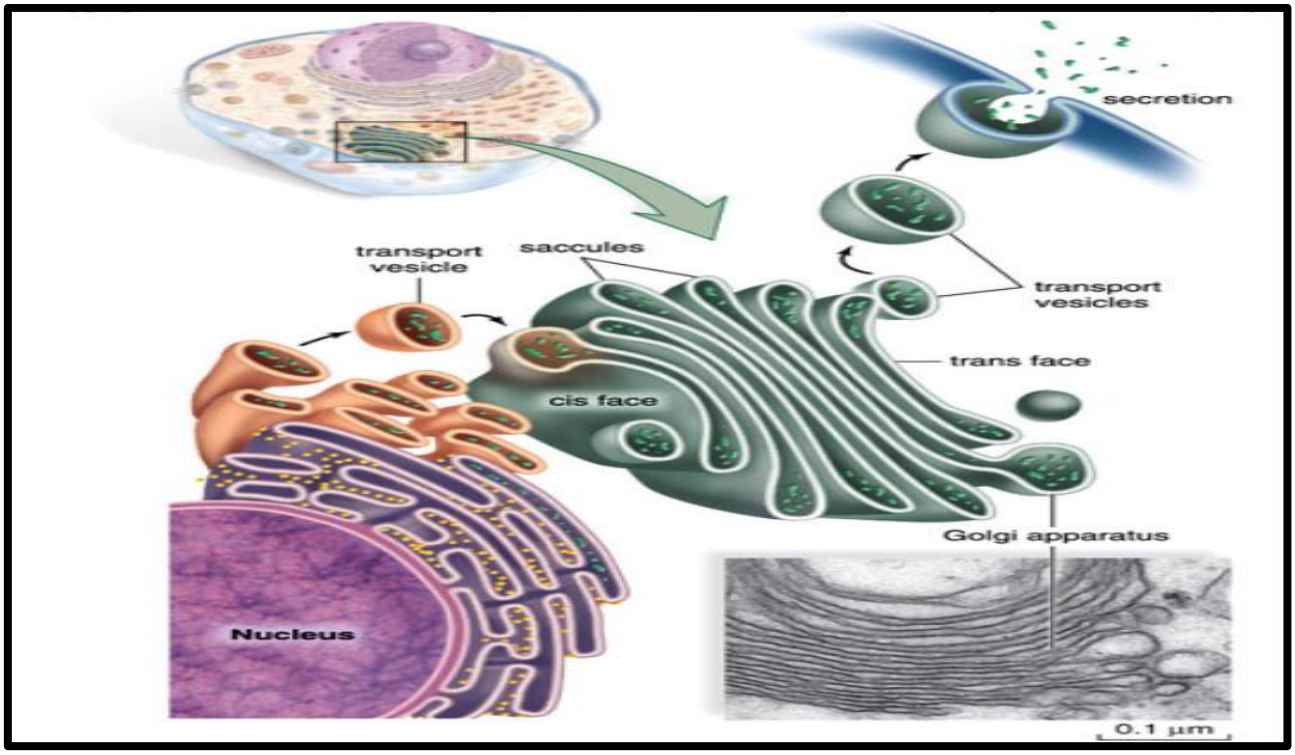

Fig. 4: Golgi apparatus.

1. Cisternae: they are usually equally spaced in pile (nearly parallel) containing parallel fibers support cisternae and maintain regular spacing between them. Cisternae may be flat but are often curved (having a convex/cis or formation face, and concave/trans or maturing face) are free of ribosomes and have swollen ends. They look like SER and are continuous with it at certain places, this suggests that the Golgi apparatus is derived from SER.

2. Tubules: short tubules arise from the periphery of the cisternae. Some of these enlarge at their ends to form vesicles.

3. Vesicles: lie near the ends and concave surface of Golgi complex (pinched off from the tubules of cisternae). They are of two types:

a. transitional vesicles are small outgrowths formed from ER, migrate to merge with **cis face** of Golgi, where they form new cisternae.

b. mature vesicles arise from trans face of Golgi, contain secretions, so they are also called secretory vesicles, that carry complete protein products to organelles or out of cell.

Importance of Golgi Bodies

Is often referred to as the "traffic police or post office" of the cell because its enzymes sort out, modify and packages then labels cell's secretory proteins passing through its lumen and directs them to their proper destination inside or outside the cell. The principal modification is: **glycosylation** (i.e., addition of sugars to proteins, forming glycoproteins), **liposylation** (i.e., addition of lipids to proteins, forming lipoproteins).

Functions of Golgi Bodies

1. **formation of glycoproteins:** links the sugars with proteins coming from RER to form glycoproteins.
2. **formation of lipoproteins:** lipids and proteins coming from ER are complexed into lipoproteins in Golgi apparatus.
3. **synthesis of carbohydrates:** synthesizes certain mucopolysaccharides from simple sugars.
4. **acrosome formation:** gives rise the acrosome in a sperm.
5. **addition to cell membrane:** provides membrane material for plasma membrane when later must enlarge for the formation of pinocytotic and phagocytotic vesicles, as the secretory vesicles discharge their contents by exocytosis, their membranes are incorporated into the cell membrane.

* Vesicles

Small, spherical compartments made in the Golgi apparatus and ER, they are chemical reaction chambers (basic tools of the cell for organizing metabolism, transport, and storage of molecules). They can be classified by their contents and function into lysosomes and peroxisomes.

- Lysosomes

Are small principal sites of intracellular digestion (Fig.5), may be spherical, rounded, elliptical or highly irregular in shape. They are membrane-limited vesicles that contain different enzymes. Lysosomes, which are usually spherical, range in diameter from (0.05 to 0.5)µm and present a uniformly granular, electron- dense appearance in the electron microscope. Lysosomal hydrolases are synthesized and segregated in the RER and then transferred to the Golgi apparatus, where the enzymes are further modified (where acid phosphatase reaction takes place) and packaged in vacuoles that form lysosomes.

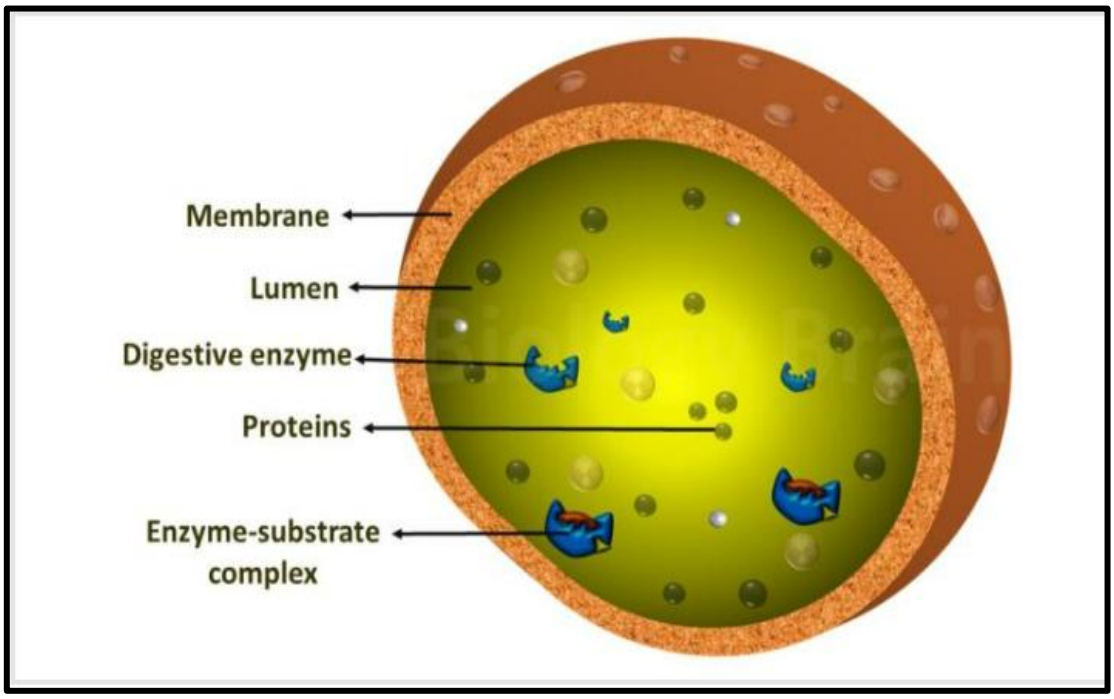

Fig. 5: Diagram of Lysosome.

Structure of Lysosomes

Lysosomes are round tiny bags filled with dense material rich in acid phosphatase (tissue dissolving enzymes) and other hydrolytic enzymes (Fig.6). Lysosomal enzymes (about 40 different enzymes) can break down/ hydrolyses proteins, nucleic acids, polysaccharides, lipids, organic sulfurate and organic phosphates (capable of digesting all kinds of materials inside or outside the cell, could break down/digest even the cell thus they called suicidal bags).

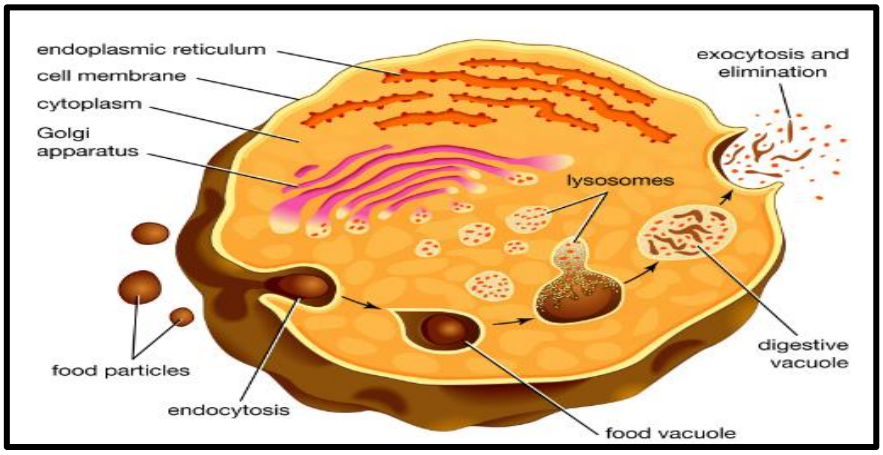

Fig. 6: Diagram of digestion within lysosome.

Kinds of Lysosomes

(1) primary lysosome (protolysosome, storage granule): it is a small sac-like body. Its enzymatic contents are synthesized by ribosomes and accumulated in ER then in Golgi apparatus. As primary lysosomes formed 'recently' they considered virgin, because their enzymes haven't taken place their role in hydrolysis yet.

(2) secondary lysosome (digestive vacuole or heterophagosome): these are produced either from phagosome or pinosomes, which ultimately fuse with primary lysosomes, thus forming secondary lysosome where the digestion occurs. The digested material of these lysosomes passes through lysosomal membrane, then they will be reused in metabolic pathways or may be elimination by exocytosis.

(3) residual body (dense body, telolysosome): these are formed in case the digestion is incomplete due to lack of certain enzymes in lysosomes. So, they will be rejected by exocytosis or sometime remain in cells for long time and cause diseases such as fever, hepatitis, polynephritis, hypertension, congested heart failure etc.

(4) autophagic vacuole (cytolysosome or autophagosome): in this case, lysosome digests a part of cell (e.g., mitochondria or portion of ER) by the process of autophagy (liver cell shows numerous autophagosome during starvation). This is a mechanism by which cell can achieve degradation of its own constituents without irreparable damage. Autophagy of organelles, cell, or tissue during the process of growth and differentiation or cell death is important and necessary (Fig.7).

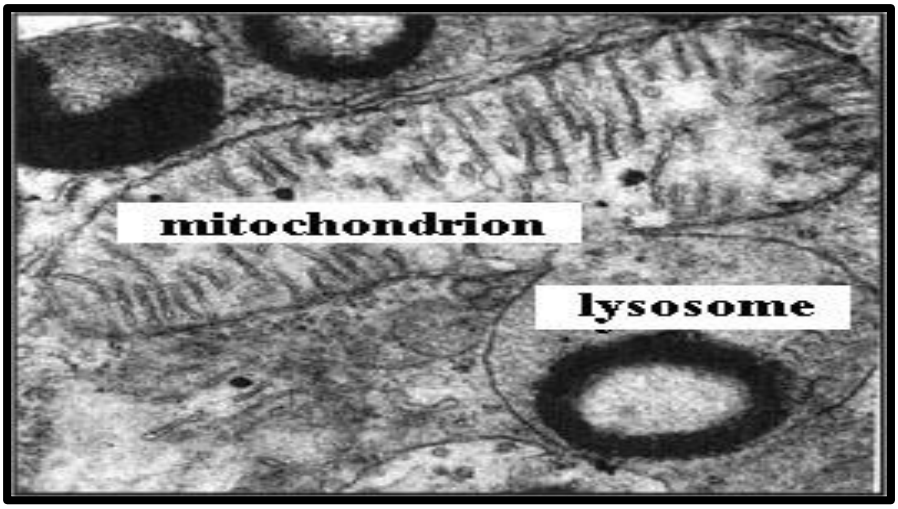

Fig. 7: Mitochondrion digested by lysosome (electron microscope).

- Peroxisomes

- Small membrane-bounded organelle. Like lysosome but less dense and contain several types of oxidases and catalases enzymes.
- Named for their enzymes which is degrading hydrogen peroxide H2O2 that is harmful to cell (break down into water (H2O) and oxygen (O2) molecules).
- Breaks down a variety of molecules, including toxins, alcohol.
- Form in two ways: budding of precursor vesicles from the ER, or division of preexisting peroxisomes (Fig. 8).

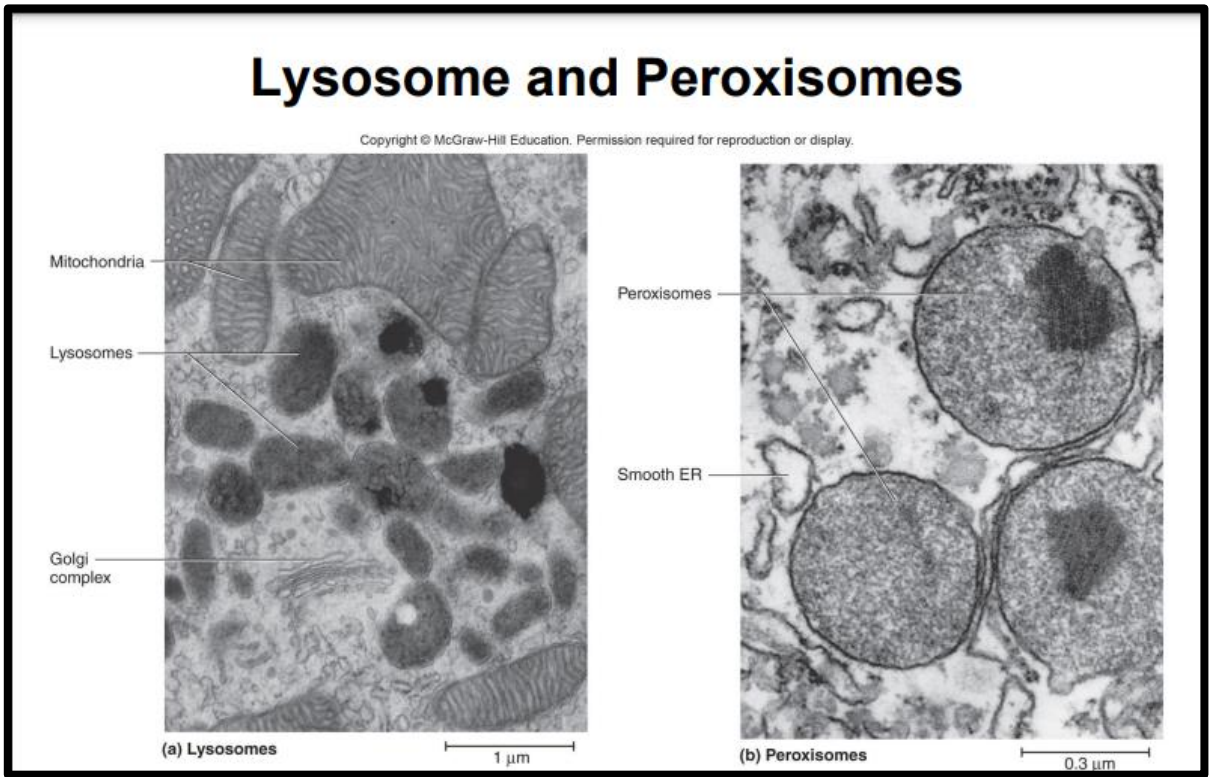

Fig. 8: Lysosome and Peroxisomes.