MEMBRANOUS ORGANELLES

Lecture 6&7

In

Block 102PMS

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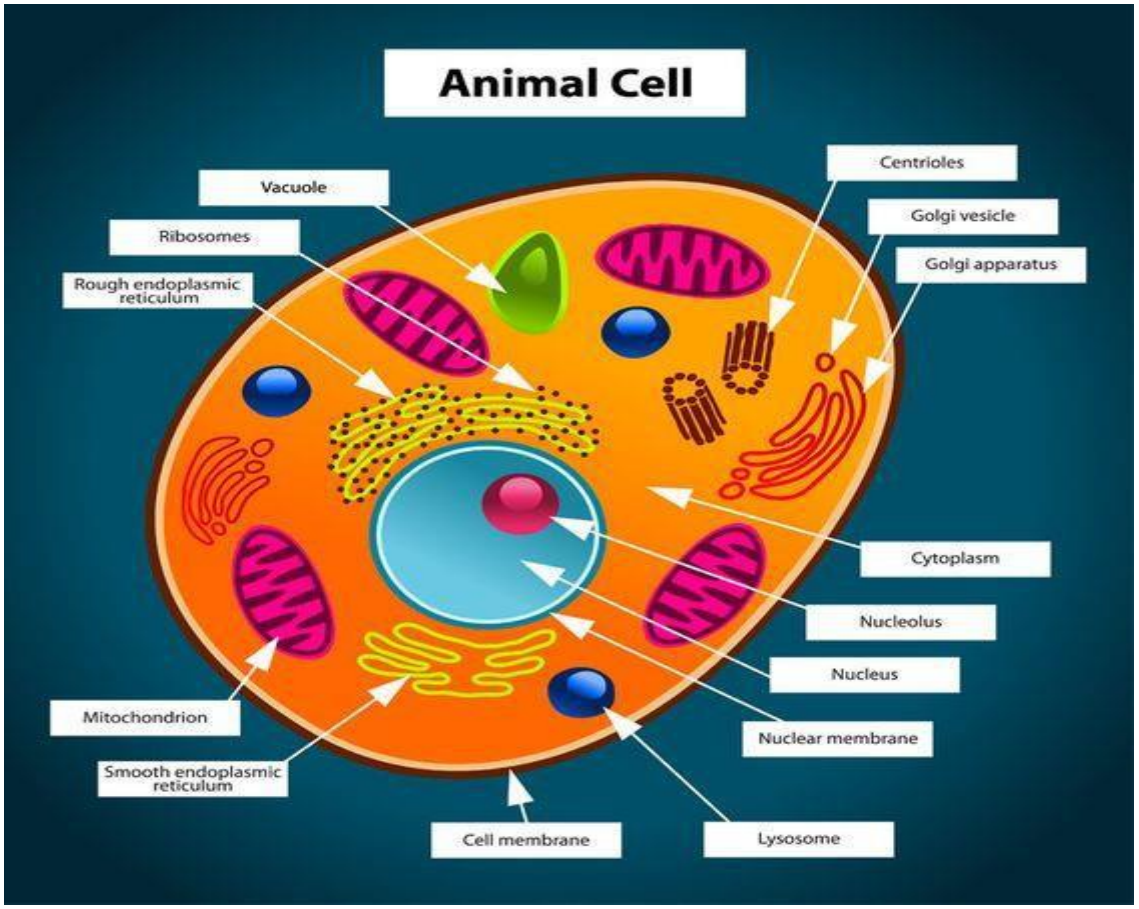


Learning objectives (*Lectures 6&7*)

After the lecture, students should be able to:

- Define cell organelles and classify them.
- Identify the types (smooth and rough), structure & function of the endoplasmic reticulum.
- Discuss the structure & function of Golgi bodies.
- Recognize the structure & types of lysosomes.
- Discriminate the structure & function of peroxisomes.
- Describe the structure of mitochondria.

Cell organelles

A-Membranous organelles

- Rough & smooth endoplasmic reticulum
- Golgi apparatus
- Lysosomes
- Microbodies (peroxisomes)
- Mitochondria

B-Non membranous organelles

- Ribosomes,
- Proteasomes,
- Centrosomes,
- Cytoskeleton, which includes microfilaments, intermediate filaments & microtubules.

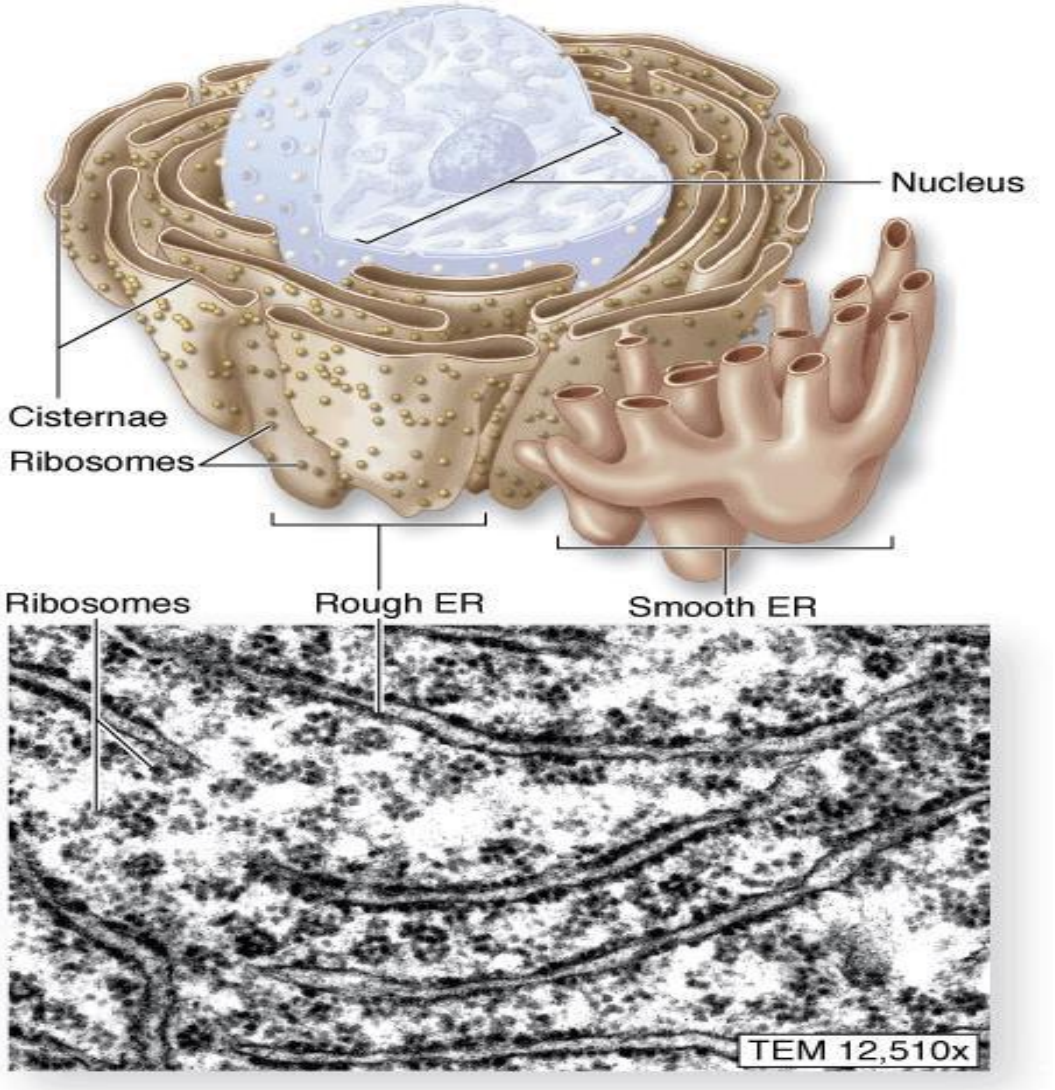
Endoplasmic Reticulum

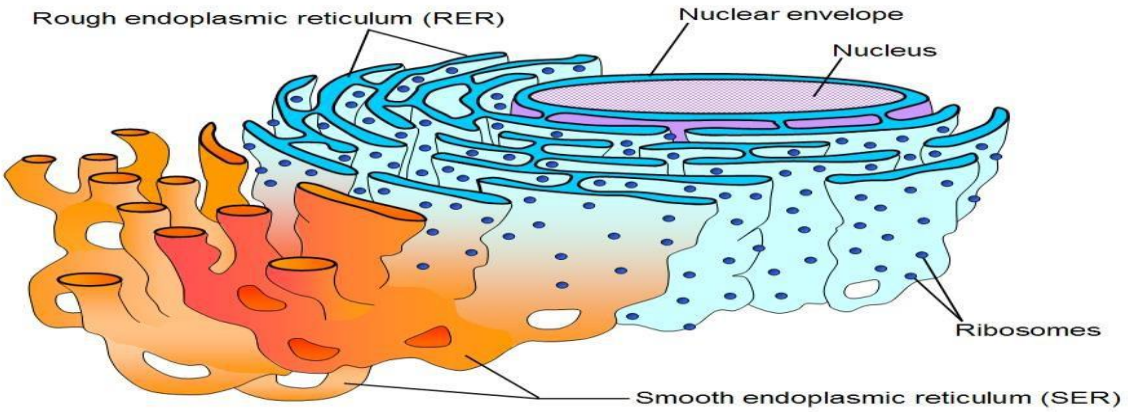
The endoplasmic reticulum (ER) is an extensive network of intracellular membranes.

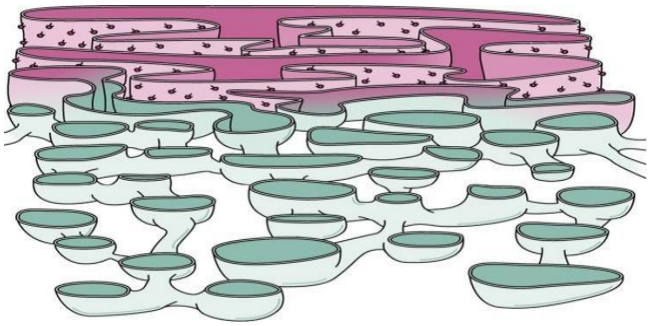
Types: The ER is classified into two major functional and morphologic categories:

1- The rough endoplasmic reticulum (rER).

2- The smooth endoplasmic reticulum (sER).







Smooth endoplasmic reticulum (SER)

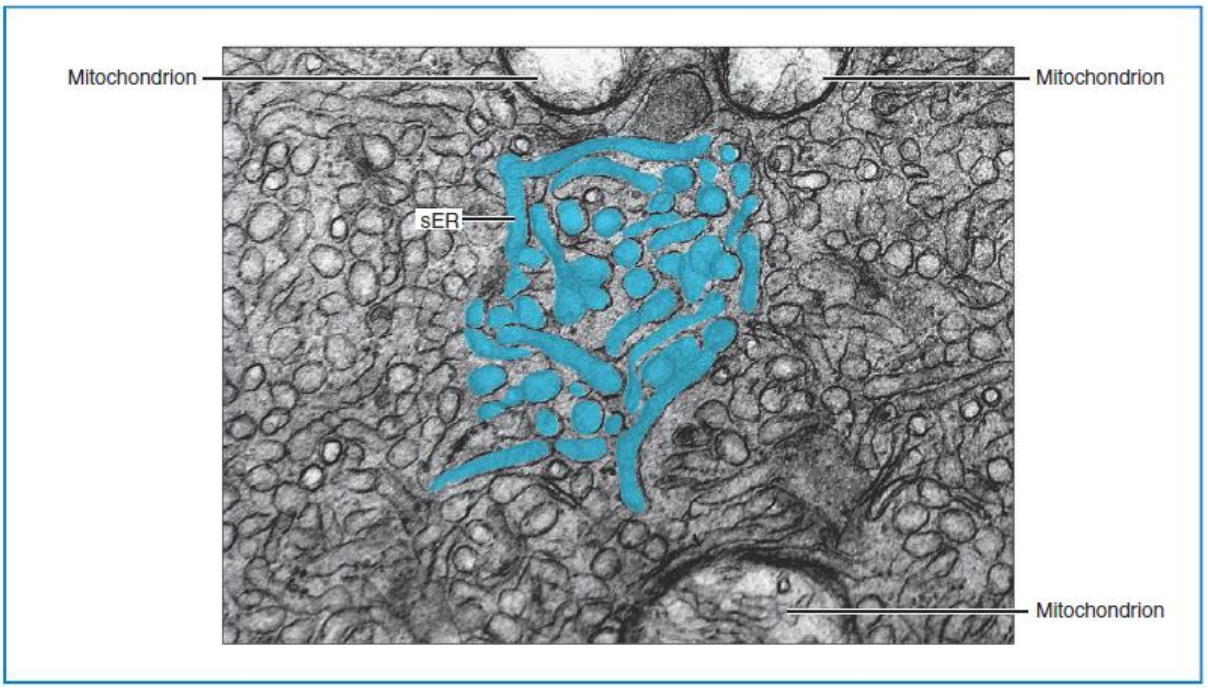
Regions of ER that lack ribosomes make up the smooth endoplasmic reticulum (SER). It contains enzymes associated with a wide variety of specialized functions.

* The sER is well developed in cells that synthesize and secrete steroids and therefore is highly developed in cells of the adrenal cortex and steroid secreting cells of the ovaries and testes. Hepatocytes also have a highly developed SER, as they are constantly detoxifying hydrophobic compounds through conjugation and excretion.

* In skeletal and cardiac muscle, the sER is called the **sarcoplasmic reticulum**.

LM: cells rich in SER are highly acidophilic due to the absence of ribosomes on their membrane.

EM: it appears as membrane-bound tubules &vesicles with no ribosomes on their surfaces.



B

B, Electron micrograph of sER in a steroid-secreting cell. Cisternal spaces are colored pale blue. Profiles of the sER are seen throughout the figure. Several mitochondria and lipid droplets typical of steroid-secreting cells are also present. (Courtesy of Don W. Fawcett.)

Functions:

1- Lipid synthesis (especially steroids), e.g., adrenal cortex cells and interstitial cells of the testis. The smooth endoplasmic reticulum (SER) is the site of fatty acid and phospholipid production.

2-Detoxification of drugs. e.g., cells of the liver

3- Helps muscular contraction (by sequester and release Ca^{2+})

4- Helps intracellular transport.

5- Glycogenolysis as in liver cells.

6- Mineral metabolism as in the parietal cell of the stomach.

Rough Endoplasmic reticulum (RER)

They are flattened cisternae, The rough in rough endoplasmic reticulum comes from the many ribosomes that stud the membrane of the RER. Ribosomes associate with transfer RNA (tRNA) to translate messenger RNA (mRNA) into amino acid sequences and, eventually, into proteins. Proteins whose functional destiny is to become part of the plasma membrane, of the extracellular environment, or of certain intracellular organelles are synthesized by the endoplasmic reticulum.

* The rER is most highly developed in active secretory cells. In those cells that synthesize proteins destined to leave the cell and in cells with large amounts of plasma membrane, such as neurons. Secretory cells include glandular cells such as pancreatic acinar cells and plasma cells .

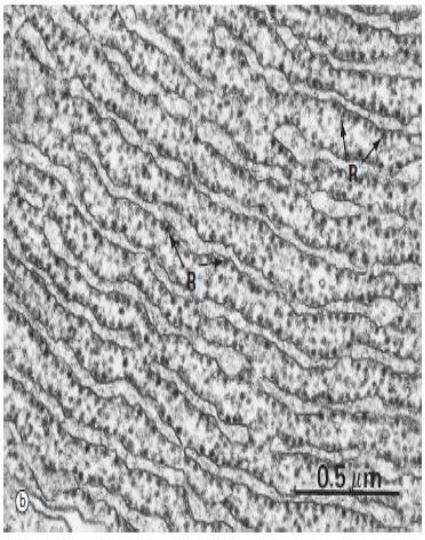
LM: it is highly basophilic due to the presence of ribosomes on its surface. All ribosomes contain RNA, that account for basophilic staining of the cytoplasm.

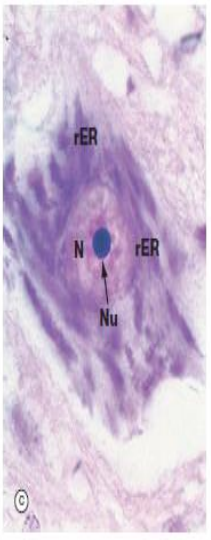
*The large basophilic bodies of nerve cells, called **Nissl bodies**, consist of both rER and large numbers of free ribosomes.

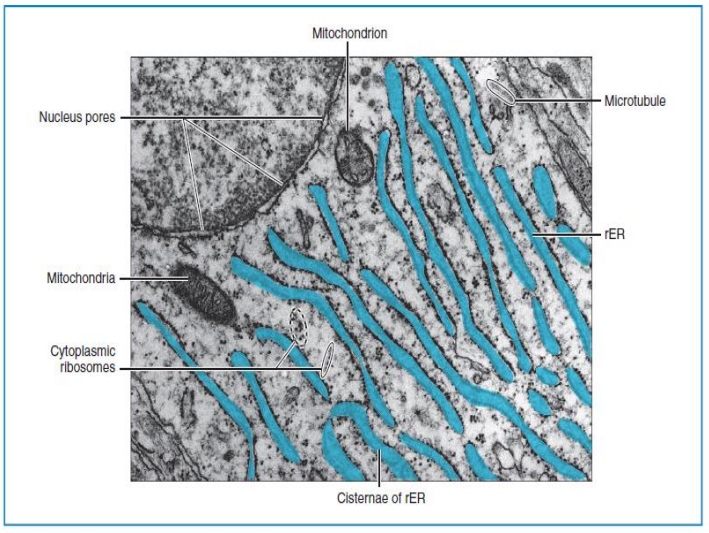
EM: it appears as membrane-bound cisternae with ribosomes on their surfaces and concentrated material in their lumens. In many instances, the rER is continuous with the outer membrane of the nuclear envelope.

The function:

The RER is the location of membrane and secretory protein production.







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Golgi complex (Golgi apparatus)

Golgi apparatus is a morphologically complex system of membrane vesicles and cisternae in which proteins and other molecules made in the ER undergo modification and maturation. They are sorted into specific vesicles for different roles in the cell.

*****The Golgi apparatus is well developed in secretory cells. It is active both in cells that secrete protein by exocytosis and in cells that synthesize large amounts of membrane and membrane-associated proteins such as nerve cells.

LM: - The Golgi is seen as a light-staining or unstained area in the light microscope, usually near the nucleus.

With H&E stain, secretory cells that have a large Golgi apparatus (e.g., plasma cells, osteoblasts, and cells of the epididymis) typically exhibit a clear area in the cytoplasm near the nucleus.

-After silver or osmic impregnation, the Golgi appears as a dark structure taking different shapes and sites.

Site: It is perinuclear (around the nucleus) in nerve cells, whereas in secretory cells, it lies between the nucleus and the secretory surface, and in liver cells, it is scattered in the cytoplasm.

EM: The Golgi is formed of a series of stacked, flattened cisternae with dilated edges as well as small and large vesicles.

-The array of cisternae is curved, giving the Golgi convex and concave sides.

- There are 3-8 cisternae per Golgi depending on the activity of the cell.

-The vesicles are of various sizes being larger at the concave (Trans-or maturation) surface and smaller at the convex (cis or formation) surface.

-The small vesicles from RER and carry secretory material towards the formation surface.

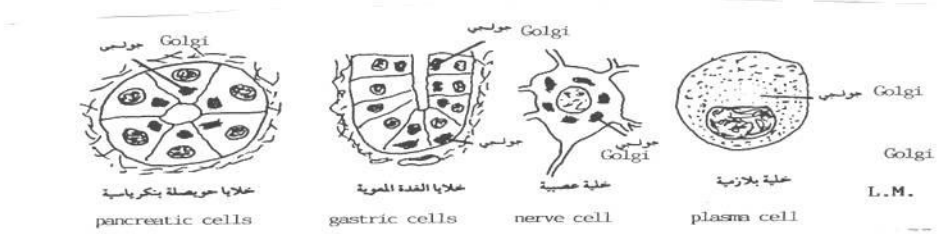
Functions:

1. It is the site for the condensation and packing of proteins that come from the rER.

2-Formation of lysosomes by packing hydrolytic enzymes.

3. In the Golgi, carbohydrates are added to proteins to form the proteoglycans.

4.The Golgi adds specific chemical groups to protein molecules (modification).



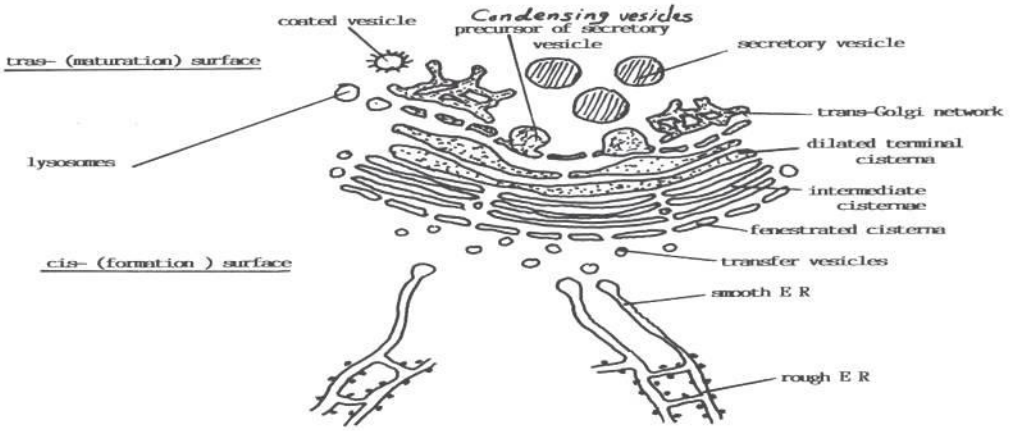
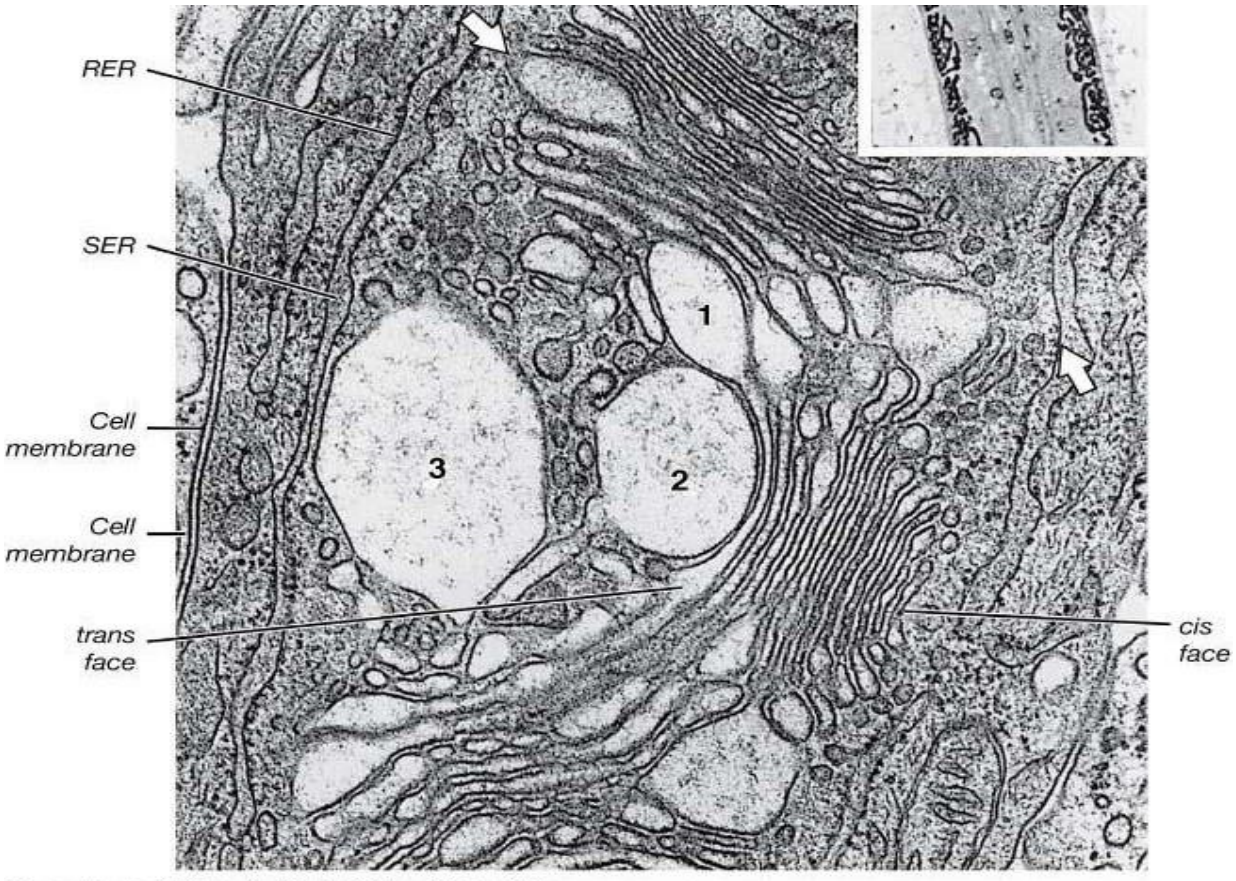


Fig. (11): ***Golgi body with L.M. and E.M.***



Lysosomes

Lysosomes are small, membrane-bounded vesicles rich in **hydrolytic enzymes.** Lysosomes are considered the digestive apparatus of the cell. They are responsible for hydrolytic degradation of obsolete cellular components. Lysosomal enzymes (nucleases, proteases, and phosphatases) are active only at an acidic pH (between pH 4.5 and 5.0). To maintain this pH, the membrane of the lysosome contains a hydrogen ion pump, that generate an internal acid environment to function in hydrolysis of cell contents.

Origin: from the Golgi region while their enzymes are synthesized in rER.

***Lysosomes are particularly abundant in cells with great phagocytic activity (e.g., macrophages,neutrophils)**.

LM: They are usually spherical can be demonstrated by special histochemical methods for detection of their enzymes (e.g. the acid phosphatase test).

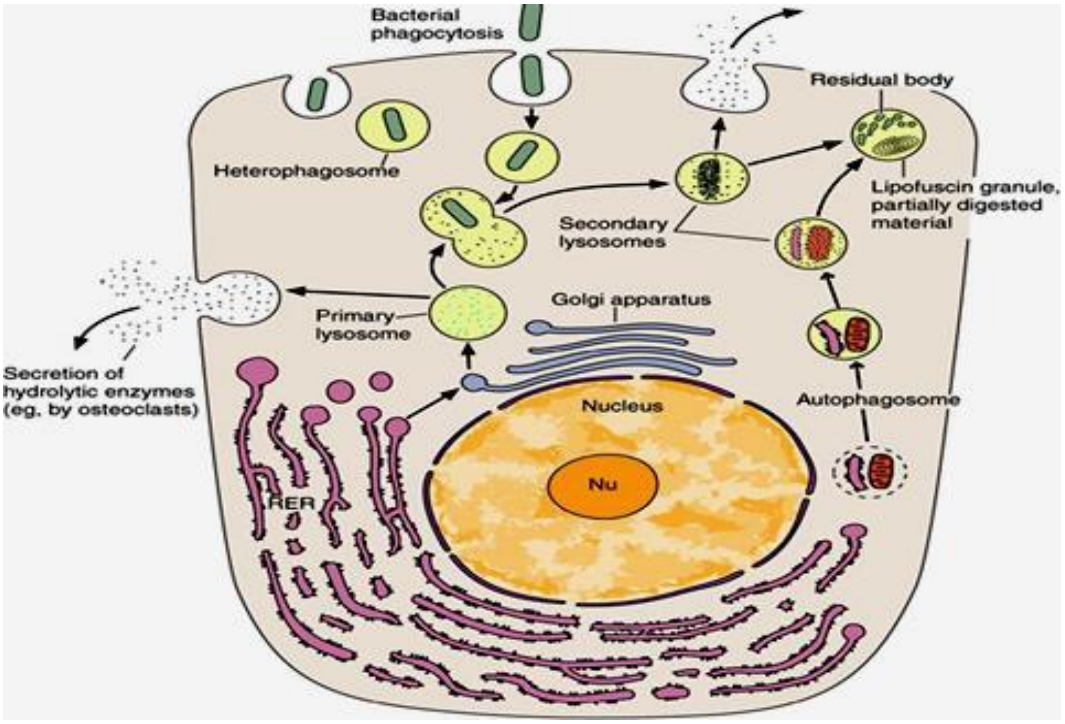
EM: Are membrane-bound vesicles. The primary lysosome presents a uniformly granular, electron-dense appearance.

Types:

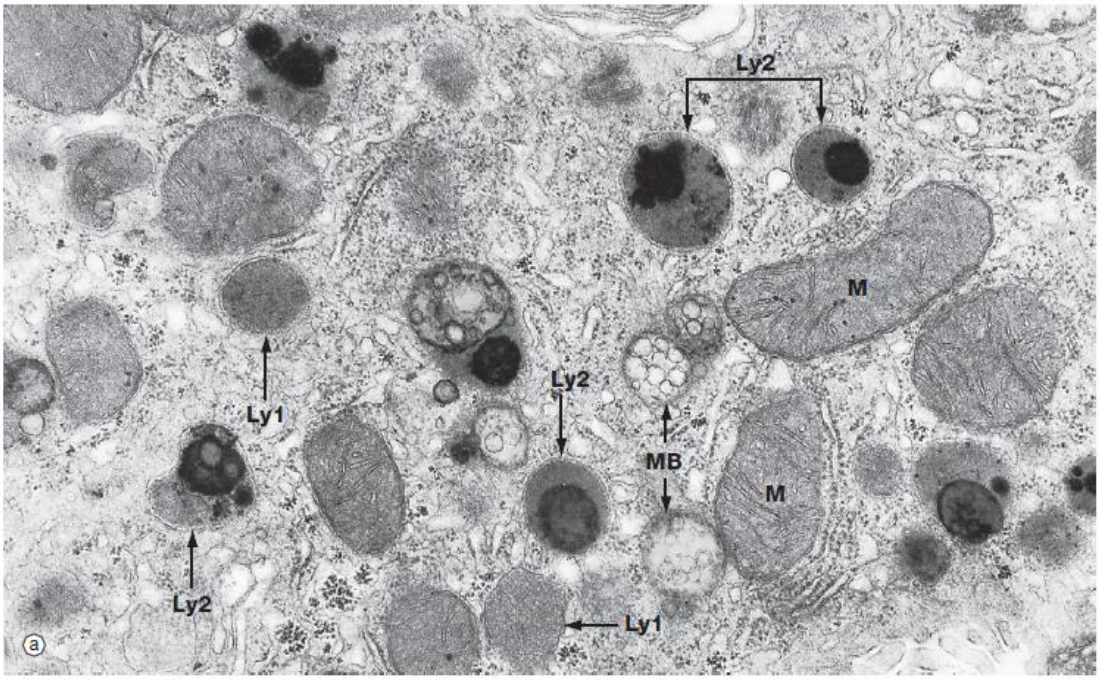
1- Primary lysosomes: are newly formed ones not yet engaged in any digestive activity.

2- Secondary lysosomes: are primary lysosomes that have been involved in the digestive activity.

3- Residual bodies: are secondary lysosomes containing indigestible materials**.** In some long-lived cells (e.g., neurons, heart muscle), residual bodies can accumulate over time as **granules of lipofuscin**.



Types of Lysosomes



EM of lysosome

Functions:

1- Digestion of materials entering the cell either by phagocytosis (Extracellular large particles such as bacteria, cell debris, and other foreign), pinocytosis and receptor-mediated endocytosis (Extracellular small particles)

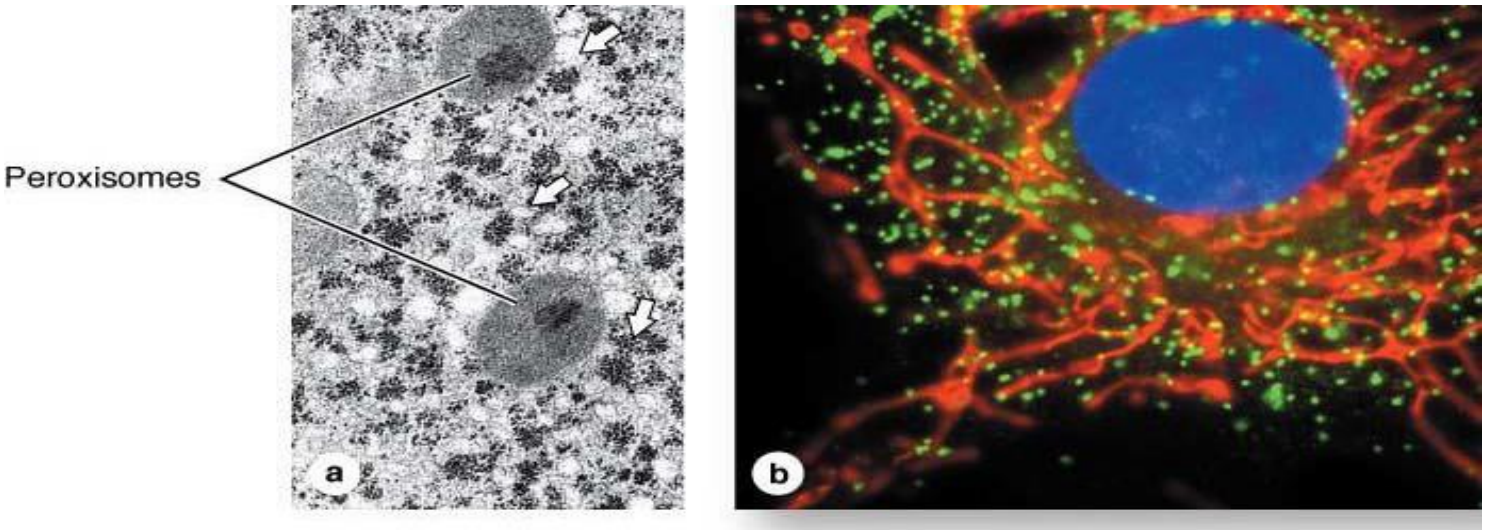
2- Responsible for the disposal of worn-out or damaged cell components, e.g., old mitochondria (removal of nonfunctional organelles or excess cytoplasmic structures, a process called **autophagy**)

3-In some cells (e.g., osteoclasts involved in bone resorption and neutrophils involved in acute inflammation) may release lysosomal enzymes directly into the extracellular space to digest components of the extracellular matrix.

*The absence of certain lysosomal enzymes can cause the pathologic accumulation of undigested substrates in residual bodies. This can lead to several disorders collectively termed **lysosomal storage diseases**.

Microbodies (peroxisomes)

- Peroxisomes are another group of vesicular organelles found in the cytoplasm of cells.They are specialized to carry out oxidative reactions via a group of oxidative enzymes (oxidases) that utilize molecular O2 to produce H2O2. Excess H2O2 is removed by catalase, of which peroxisomes contain considerable quantities. The catalase (and general protein) concentration of the peroxisome is so high that it is often seen as a crystalline inclusion in the peroxisome, which can serve as a useful marker to recognize this organelle in electron micrographs.
- Peroxisomes contain no DNA or RNA and are self-replicating; new organelles arise by fission of preexisting organelles.
- They are numerous in liver cells.



Source: Mescher AL: *Junqueira's Basic Histology: Text and Atlas, 12th Edition:* http://www.accessmedicine.com

Mitochondria (power houses of the cell)

- **M**itochondria are membrane cytoplasmic-enclosed organelles**.**
- The shape of a typical mitochondrion is an elongated oval, but mitochondria may also be spherical, branched, coiled, or filamentous.When living cells are observed in tissue culture, mitochondria are highly dynamic—they are in constant motion and undergo fission and fusion.
- ***Mitochondria are present in all cells except red blood cells and the outermost layers of the skin.** The number of mitochondria is related to the cell's energy needs. Thus, cells with a high-energy metabolism (e.g., cardiac muscle, cells of some kidney tubules) have abundant mitochondria, whereas cells with a low-energy metabolism have few mitochondria. Mitochondria also localize at sites where energy is needed. In the middle piece of the sperm, the intermyofibrillar spaces in striated muscle cells, and adjacent to the basolateral plasma membrane infoldings in the cells of the proximal convoluted tubule of the kidney.
- Number in a specific cell type may range from 10 or 20 to thousands.

- The main function of mitochondria is to provide energy, in the form of ATP, to drive the metabolic reactions of the cell. ATP is a major form of energy that the cell uses for nearly all its metabolic work. Mitochondria are also responsible for generating the heat that maintains body temperature.
- -**LM:**

Mitochondria typically appear as numerous eosinophilic (red) structures in Hx.&E stain. Mitochondria contribute to the acidophilia of the cytoplasm because of the large amount of membrane they contain.

Staining of mitochondria:

a) Stained by special stain: iron haematoxylin.

b) Vital stain: Janus green.

c) Histochemical method by detection of cytochrome oxidase enzyme.

- **EM**.

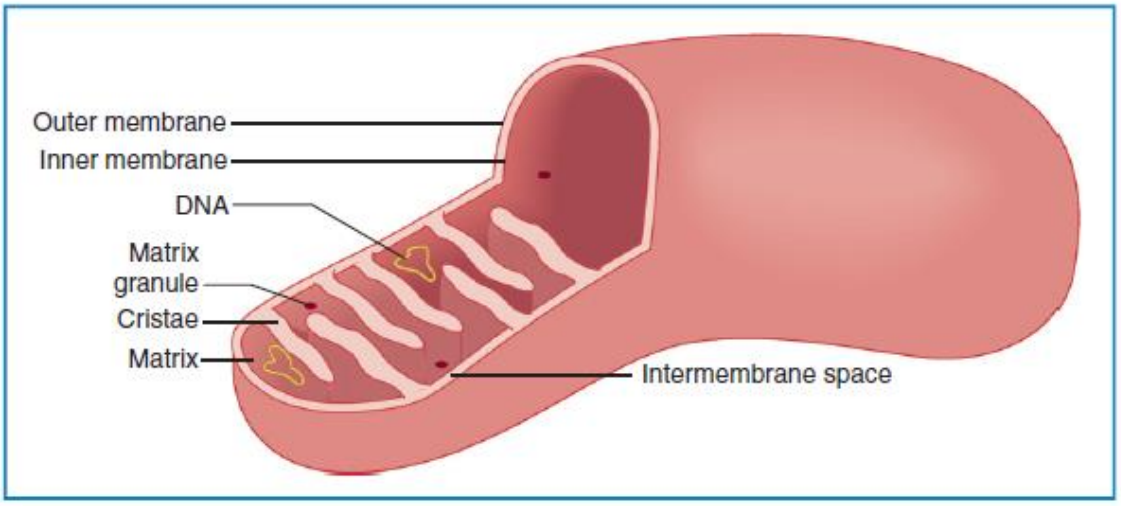
Mitochondria are surrounded by two membranes outer and inner membranes. Both mitochondrial membranes contain a higher density of protein molecules than other membranes in the cell. The outer membrane of the mitochondrion; next is an intermembrane space; then an inner mitochondrial membrane; and finally the mitochondrial matrix

1-The outer membrane is smooth. It is in contact with the cytoplasm of the cell.

2-The inner is thrown or folded into tubules called cristae or crests, which project into the matrix and greatly increase the membrane's surface area. The number of cristae in mitochondria also corresponds to the energy needs of the cell. This membrane is thinner than the outer mitochondrial membrane. The inner membrane of the cristae shows small particles known as elementary particles, which represent special ionic pores involved in electron transfer.

New mitochondria originate by growth and division (fission) of preexisting mitochondria. Protein synthesis occurs in mitochondria, but because of the reduced amount of mitochondrial DNA, only a small subset of mitochondrial proteins is produced locally.

- The innermost compartment, the mitochondrial matrix, contains the mitochondrial DNA, mitochondrial ribosomes, and enzymes of the tricarboxylic acid cycle and of fatty acid metabolism and mitochondrial transfer RNAs.



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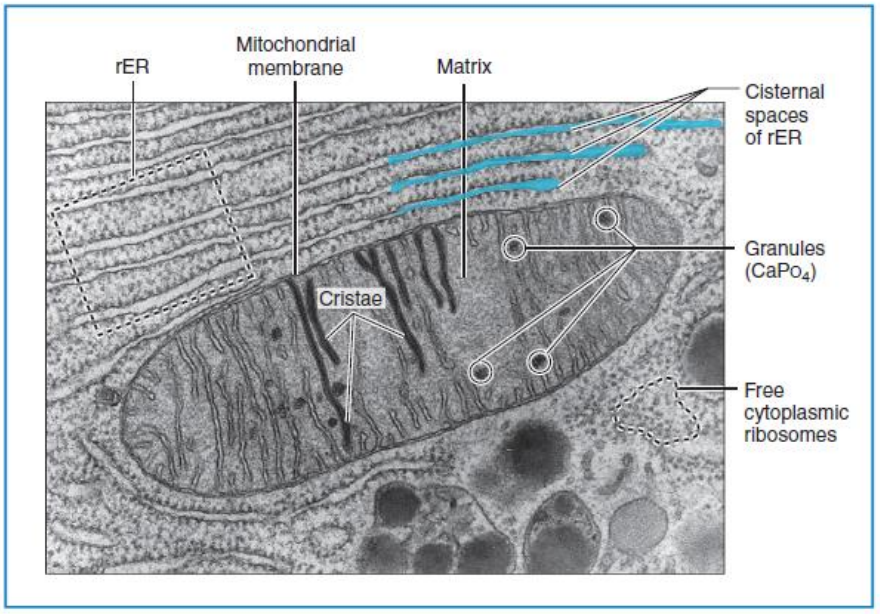

A

Figure 1-15. **A**, Electron micrograph of a mitochondrion. (Courtesy of Keith R. Porter and Don W. Fawcett.) **B**, Diagram of a typical eukaryotic mitochondrion.

Functions

1- Cell respiration and production of energy for the cell.
2- They can form proteins for themselves and undergo self-replication. (They have their DNA, ribosomes and can make their proteins)

References

- Elsevier's Integrated Histology (2007) 1st Edition. Page 19-24.

-Lippincott Illustrated Reviews: Integrated Systems (2016), 24th ed. Page 41.

- First aid for the Basic sciences, General principles. Third Edition. P: 3-5.

Self Assessment of Lectures 6&7

1- Function of RER is:
a) Synthesis of fatty acids and lipids.
b) Synthesis cytoplasmic matrix proteins.
c) Synthesis of secreted proteins
d) Synthesis of lipofuscin pigments.

2- Residual bodies:
a) Are the digested material in the secondary lysosome.
b) Are the undigested material in the secondary lysosome.
c) Are the undigested material in multivesicular bodies.
d) Are primary lysosomes.

3- Which of the following is NOT a membranous organelle?
a) Lysosomes.
b) Filaments.
c) Peroxisomes.
d) Mitochondria.

4- In the mitochondria:
a) The outer membrane projects inside to form cristae.
b) The inner membrane projects inside to form cristae.
c) The surface of the outer membrane is much greater than that of the inner membrane.
d) No space between inner and outer membranes.

5- All the statements concerning SER are true EXCEPT:
a) Found in lipid synthesizing cells.
b) Responsible for detoxification of toxins and drugs.
c) It contains ribosomes on its surface.
d) In the muscle, it is called sarcoplasmic reticulum

6- Golgi have the following functions EXCEPT:
a) Synthesis of proteins.
b) Packing of proteins.
c) Condensation of proteins.
d) Modification of proteins.