Endoplasmic Reticulum (ER): Structure, Types and Function

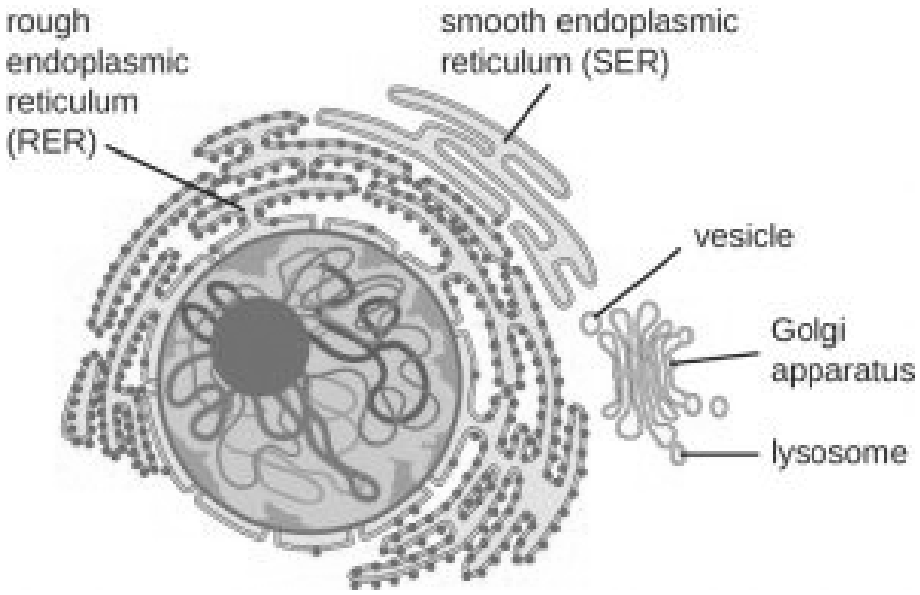
- In most animal cells, within the cytoplasm of is an extensive network (reticulum) of membrane-limited channels, collectively called the endoplasmic reticulum (or ER).

- The endoplasmic reticulum is a name derived from the fact that in the light microscope it looks like a "net in the cytoplasm." It was first reported by Porter in 1945.

- The endoplasmic reticulum is only present in the eukaryotic cells. It is generally absent in egg and embryonic cells. For example, the erythrocytes (RBC), egg and embryonic cells lack in the endoplasmic reticulum. However, the occurrence of the endoplasmic reticulum varies from cell to cell.
- Some portion of ER membranes remains continuous with the plasma membrane and the nuclear envelope. This continuous membrane system connects the nuclear membrane on one end and the cell membrane on the other end.

- ER may be rough or smooth. The outer surface of rough ER has attached ribosomes, whereas smooth ER does not have attached ribosomes.

- The endoplasmic reticulum acts as secretory, storage, circulatory and nervous system for the cell. It is also the site of the biogenesis of cellular membranes.



- The membrane of the endoplasmic reticulum is 50 to 60 Aº thickness and fluid-mosaic like the unit membrane of the plasma membrane.

- The membranes of the endoplasmic reticulum are found to contain many kinds of enzymes that are needed for various important synthetic activities. The most important enzymes are the stearases, NADH-cytochrome C reductase, NADH diaphorase, glucose-6-phosphatase, and Mg++ activated ATPase.

- The membrane of endoplasmic reticulum remains continuous with the membranes of the plasma membrane, nuclear membrane, and Golgi apparatus.
- The cavity of the endoplasmic reticulum is well developed and acts as a passage for the secretory products.

Endoplasmic Reticulum contains three different types of structure:

The Cisternae

- RER usually exists as cisternae that occur in those cells which have synthetic roles as the cells of the pancreas, notochord, and brain. The cisternae are long, flattened, sac-like, unbranched tubules having a diameter of 40 to 50 μm. They remain arranged parallelly in bundles or stakes.

The Vesicles

- The vesicles are oval; membrane-bound vacuolar structures having a diameter of 25 to 500 μm. They often remain isolated in the cytoplasm and occur in most cells but especially abundant in the SER.

The Tubules

- The tubules are branched structures forming the reticular system along with the cisternae and vesicles. They usually have a diameter from 50 to 190 μm and occur almost in all the cells. Tubular form of ER is often found in SER and is dynamic in nature, i.e., it is associated with membrane movements, fission and fusion between membranes of cytocavity network.

Types of Endoplasmic Reticulum: Smooth Endoplasmic Reticulum

- They are also called as the agranular endoplasmic reticulum.
- This type of endoplasmic reticulum possesses smooth walls because the ribosomes are not attached to its membranes.

- The smooth type of endoplasmic reticulum occurs mostly in those cells, which are involved in the metabolism of lipids (including steroids) and glycogen. Eg. adipose cells, interstitial cells, glycogen storing cells of the liver, conduction fibers of heart, spermatocytes, and leucocytes.

Rough Endoplasmic Reticulum

- It possesses rough walls because the ribosomes remain attached to its membranes.
- On their membranes, rough ER (RER) contains certain ribosome specific, transmembrane glycoproteins, called ribophorins I and II, to which are attached the ribosomes while engaged in polypeptide synthesis.
- The rough type of endoplasmic reticulum is found abundantly in those cells which are active in protein syntheses such as pancreatic cells, plasma cells, goblet cells, and liver cells.

Functions of Endoplasmic Reticulum:

The ER plays a number of roles within the cell, from protein synthesis and lipid metabolism to detoxification of the cell. Cisternae, each of the small folds of the endoplasmic reticulum, are commonly associated with lipid metabolism. This creates the plasma membrane of the cell, as well as additional endoplasmic reticulum and organelles. They also appear to be important in maintaining the Ca^{2+} balance within the cell and in the interaction of the ER with mitochondria. This interaction also influences the aerobic status of the cell.

ER sheets appear to be crucial in the response of the organelle to stress, especially since cells alter their tubules-to-sheets ratio when the number of unfolded proteins increases. Occasionally, apoptosis is induced by the ER in response to an excess of unfolded protein within the cell. When ribosomes detach from ER sheets, these structures can disperse and form tubular cisternae.

Although ER sheets and tubules appear to have distinct functions, there isn't a perfect delineation of roles. For instance, in mammals tubules and sheets can interconvert, making the cells adaptable to various conditions. The relationship between structure and function in the ER has not been completely elucidated.

Protein Synthesis and Folding:

Protein synthesis occurs in the rough endoplasmic reticulum. Although translation for all proteins begins in the cytoplasm, some are moved into the ER in order to be folded and sorted for different destinations. Proteins that are translocated into the ER during translation are often destined for secretion.

Initially, these proteins are folded within the ER and then moved into the Golgi apparatus where they can be dispatched towards other organelles.

For instance, the hydrolytic enzymes in the lysosome are generated in this manner. Alternately, these proteins could be secreted from the cell. This is the origin of the enzymes of the digestive tract. The third potential role for proteins translated in the ER is to remain within the endo-membrane system itself. This is particularly true for chaperone proteins that assist in the folding of other proteins. The genes encoding these proteins are up-regulated when the cell is under stress from unfolded proteins.

Lipid Synthesis

The smooth endoplasmic reticulum plays an important role in cholesterol and phospho-lipid biosynthesis. Therefore, this section of the ER is important not only for the generation and maintenance of the plasma membrane but of the extensive endo-membrane system of the ER itself.

The SER is enriched in enzymes involved in sterol and steroid biosynthetic pathways and is also necessary for the synthesis of steroid hormones. Therefore the SER is extremely prominent in the cells of the adrenal gland that secrete five different groups of steroid hormones that influence the metabolism of the entire body. The synthesis of these hormones also involves enzymes within the mitochondria, further underscoring the relationship between these two organelles.

Calcium Store

The SER is an important site for storage and release of calcium in the cell.

A modified form of the SER called sarcoplasmic reticulum forms an extensive network in contractile cells such as muscle fibers. Calcium ions are also involved in the regulation of metabolism in the cell and can change cytoskeletal dynamics.

The extensive nature of the ER network allows it to interact with the plasma membrane and use Ca^{2+} for signal transduction and modulation of nuclear activity. In association with mitochondria, the ER can also use its calcium stores to induce apoptosis in response to stress.

The major functions these are the following:

(a)Common to both Endoplasmic Reticulum:

(i) Forms the skeletal framework.
(ii) Active transport of cellular materials.
(iii) Metabolic activities due to presence of different enzymes.
(iv) Provides increased surface area for cellular reactions.

(v) Formation of nuclear membrane during cell division.

(b) Function of Smooth Endoplasmic Reticulum:

(i) Lipid synthesis.
(ii) Glycogen synthesis.
(iii) Steroid synthesis like cholesterol, progesterone, testosterone, etc.
(iv) Metabolism of carbohydrates .
(v) Detoxification function.
(vi) Major storage and released site of inter cellular calcium ions.

(c) Function of Rough Endoplasmic Reticulum:

(i) It provides site for protein synthesis.
(ii) Protein translocation, folding and transport of protein.
(iii) Glycosylation (this is the relation of a saccharides group with a hydroxyl or amino functional group to form a glucoside).
(iv) Disulfide bond formation (disulfide bonds stabilize the tertiary and quaternary structures of many proteins).
(v) Membrane synthesis.