9 Endoplasmic Reticulum

Endoplasmic reticulum is a network of ***membrane bound cavities, vesicles*** and ***tubules,*** distributed throughout the cytoplasm. It is concerned with the biosynthesis of proteins and lipids.

- It is the ***cytoskeleton*** of the cell.
- It is a cytoplasmic vesicular system.
- The term ***endoplasmic reticulum*** (ER) was introduced by ***Porter 1948.***
- According to ***Porter,*** the endoplasmic reticulum is a complex, finely divided ***vacuolar system*** extending from the nucleus throughout the cytoplasm to the margin of the cell.

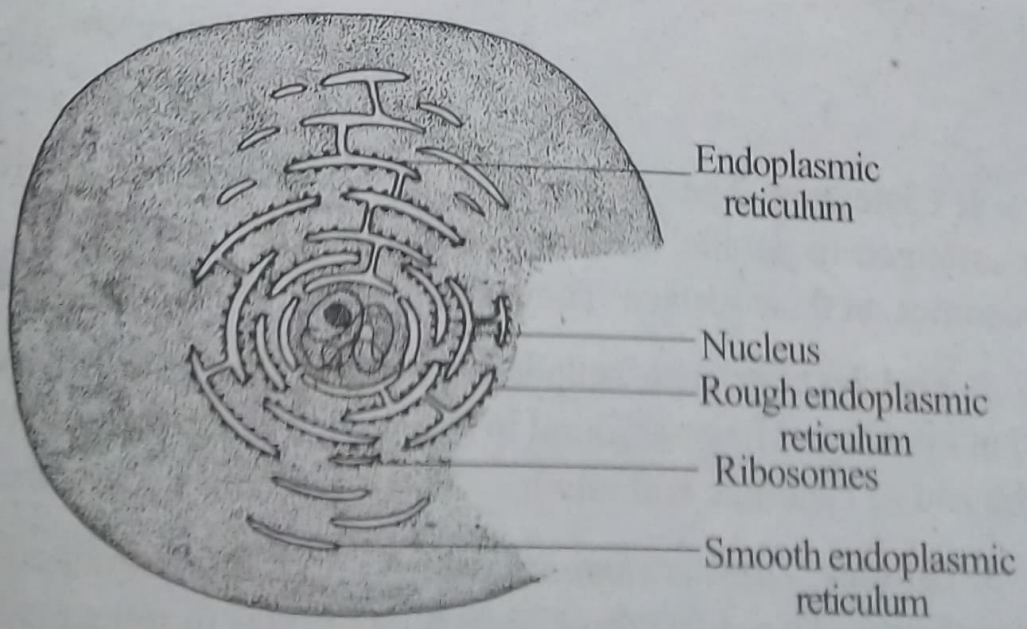

Fig.9.1: A cell showing endoplasmic reticulum.

• Since this network is more concentrated in the endoplasm of the cytoplasm, the name ***endoplasmic reticulum*** was proposed.

• ***De Robertis, Nowinski*** and ***Saez*** have coined another term, the ***cytoplasmic vacuolar system*** for these membrane bound cavities present in the cytoplasm.

• It is a ***cell organelle.***

• Endoplasmic reticulum is absent from ***eggs, embryonic cells, RBC*** and ***bacteria***. Simple type of endoplasmic reticulum is found in cells engaged in lipid metabolism. But it is well developed in cells which are active in protein synthesis.

Structure

Endoplasmic reticulum consists of three components. They are ***cisternae, vesicles*** and ***tubules.***

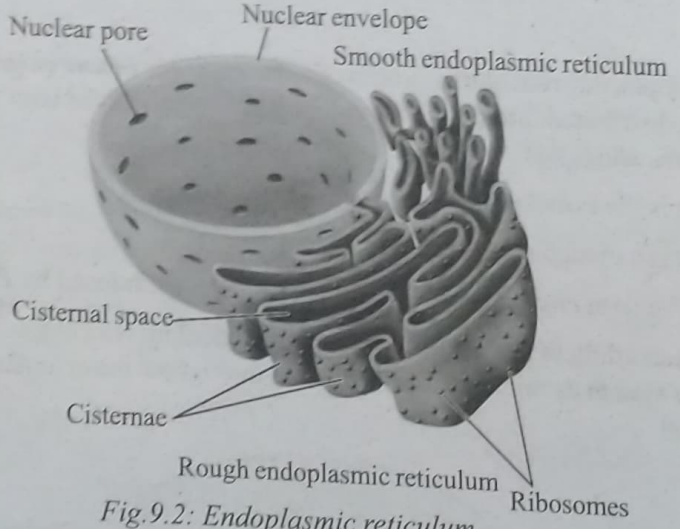

Fig.9.2: Endoplasmic reticulum.

1. Cisternae: These are long flattened, unbranched sac-like structures. They are arranged in parallel bundles. Their diameter is 40-50 m micron. They have ribosomes on their surface. They are normally found in secretory cells.

2. Vesicles: These are rounded or ovoidal structures having the diameter of 25-500 m microns. They are found in abundance in ***pancreatic cells.*** They are found at the end of cisternae and tubules. Many vesicles are left free in the cytoplasm.

3. Tubules: These are ***smooth*** walled and highly branched tubular spaces having ***diverse*** forms. They have the diameter of 50-100 m microns. They normally occur in ***non-secretory cells*** like striated muscle cells. They arise from the cisternae.

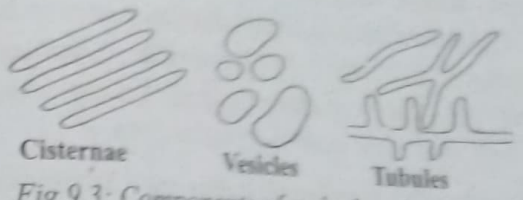

Fig.9.3: Components of endoplasmic reticulum.

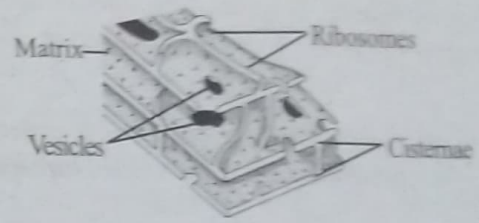

Fig.9.4: 3D-View of endoplasmic reticulum.

• The membrane of endoplasmic reticulum is a ***trilaminar structure***. It is an ***unit membrane.*** It consists of two ***protein*** layers with a ***lipid*** layer in between. It is 50-60A° in thickness. The membranes of endoplasmic reticulum constitutes more than half of the total membranes of an animal cell.

• The membrane of endoplasmic reticulum is continuous with the plasma membrane, Golgi membrane and nuclear membrane.

• The lumen of the endoplasmic reticulum acts as a passage for the intracellular transport of secretory products.

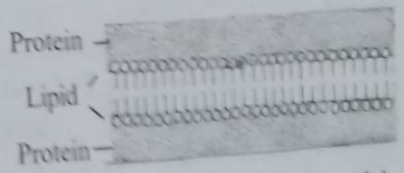

Fig.9.5: Unit membrane model.

• These membranes provide increased surface area for metabolic activity.

• Endoplasmic reticulum is classified into two types. They are-

1. Granular or *rough endoplasmic reticulum*

2. Agranular or *smooth endoplasmic reticulum*

1. Granular or Rough Endoplasmic Reticulum: In some endoplasmic reticulum, spherical granular structures called ***ribosomes*** are attached on the surface. This type of endoplasmic reticulum is called ***granular endoplasmic reticulum.*** It occurs in almost all cells which are actively engaged in protein synthesis, such as liver cells, goblet cells, pancreatic cells and plasma cells.

2. Agranular or Smooth Endoplasmic Reticulum: Ribosomes are not attached with the membranes of this type of endoplasmic reticulum. So the surface of this endoplasmic reticulum is ***smooth***. It occurs especially in those cells which are almost inactive in protein synthesis. It is well developed in cells that synthesize steroid hormones.

The endoplasmic reticulum present in retinal cells is called ***myeloid bodies.*** The endoplasmic reticulum present in muscle cells is called ***sarcoplasmic reticulum.***

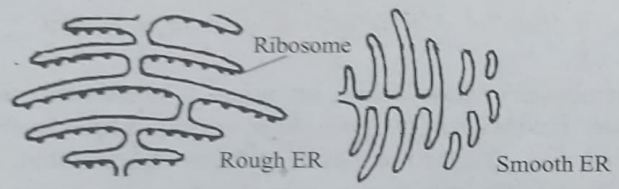

Fig.9.6: Rough and smooth endoplasmic reticulum.

Chemical Composition

Endoplasmic reticulum is composed of lipoprotein like that of plasma membrane and other membranes. Lipid fraction of the reticulum comprises of phospholipids, inositol, lecithin, cephalin, etc. Most of the proteins are represented in the form of enzymes such as stearases, NADH-cytochrome C reductase, NADH diaphorase, glucose 6-phosphatase and Mg -activated ATPase. The granules present on the reticulum are composed of RNA combined with protein. About 25% of cytoplasmic RNA is associated with endoplasmic reticulum.

Microsomes

Microsome is a *heterogeneous small particle fraction obtained by high speed centrifugation of cell homogenate.* It was first discovered by ***Claude*** in 1951.

Microsomal fraction consists of fragments of ***smooth endoplasmic reticulum, rough endoplasmic reticulum, ribosomes*** and ***Golgi membranes.***

Microsomes constitute 15 to 20% of the total mass of the cell.

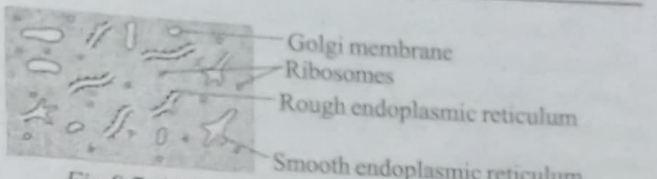

Fig.9.7: Microsomes.

It contains a large amount of RNA which makes upto 50-60% of the total RNA of the cell.

It also contains high concentrations of ***phospholipids, inositol, acetylphosphatides*** and ***gangliosides.***

It contains a large number of enzymes such as ATPase, uridine disphosphatase, stearase, NADPH-cytochrome-C reductase, glucose-6-phosphate, Mg^{++} activated reductase, etc.

It has enzymes used for the synthesis of triglycerides, phospholipids and cholesterol.

Annulate Lamellae

Annulate lamellae are *membranous flattened sacs containing annuli and pores.* They are ***endoplasmic reticulum containing annuli*** and ***pores*** similar to those of nuclear membrane.

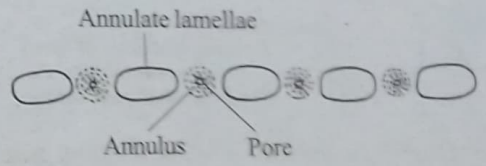

Fig.9.8: Annulate lamellae.

The annulate lamellae were first described by ***Me Cullock*** in 1952.

They are found in the cytoplasm of oocytes, spermatocytes, embryonic cells, tumour cells and invertebrates.

The annulate lamellae frequently contain ribosomes.

Hruban (1965) suggested that annulate lamellae may represent an intermediate stage in the formation of the endoplasmic reticulum. In some instances, there is continuity between endoplasmic reticulum and annulate lamellae. So the annulate lamellae are ***transitory cytoplasmic organelles.***

The annulate lamellae originate from the nuclear membrane. The outer nuclear membrane forms finger like processes. They are pinched off into the cytoplasm to form vesicles. Rows of vesicles fuse together to form cisternae. Matrix materials become associated with the pores to form ***annuli.*** This results in the formation of annulate lamellae.

The annulate lamella has the following functions:

1. It helps in the formation of endoplasmic reticulum.

2. It increases the cytoplasmic membranes in times of increased metabolic needs as in embryonic cells.

Origin of Endoplasmic Reticulum

Several theories have been forwarded to explain the origin of endoplasmic reticulum. But the exact nature of origin of the endoplasmic reticulum has not yet been clearly known.

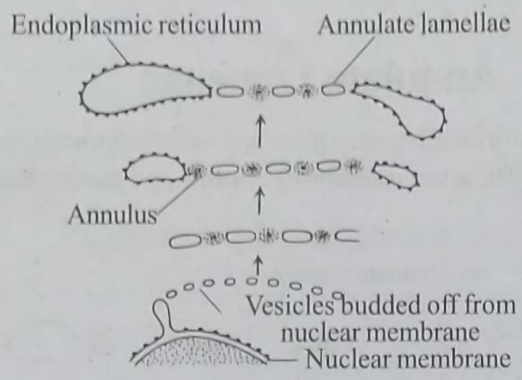

Fig.9.9: Origin of endoplasmic reticulum from annulate lamellae.

1. It has been suggested that the endoplasmic reticulum is formed from the ground substance or ***hyaloplasm.***

2. It may originate as the infoldings of plasma membrane (***Palade***).

3. Endoplasmic reticulum may be formed from the evagination of nuclear membrane (***Gay*** 1955, ***Rebhun*** 1956) through the formation of ***annulate lamellae.***

Functions of Endoplasmic Reticulum

Endoplasmic reticulum performs the following functions:

1. Mechanical support

The endoplasmic reticulum divides the fluid content of the cell into different compartments by which it gives ***mechanical support*** to the cell. Hence it is known as the ***cytoskeleton*** of the cell.

2. Transport

Endoplasmic reticulum acts as a kind of circulatory system, involved in the import, export and intracellular circulation of various substances. By this process, proteins, lipids, enzymes, etc. are transported to the various parts of the cell.

Thus the endoplasmic reticulum functions as a ***cellular circulatory system.***

3. Protein Synthesis

Ribosomes are ***protein factories.*** Amino acids are assembled on ribosomes to produce polypeptide chains. The ribosomes attached to the endoplasmic reticulum are more efficient in protein synthesis than the free ribosomes lying in the cytoplasm.

The endoplasmic reticulum provides space for the attachment of ribosomes.

The synthesized proteins are collected by the endoplasmic reticulum. They are processed and transported to other parts of the cell by the endoplasmic reticulum.

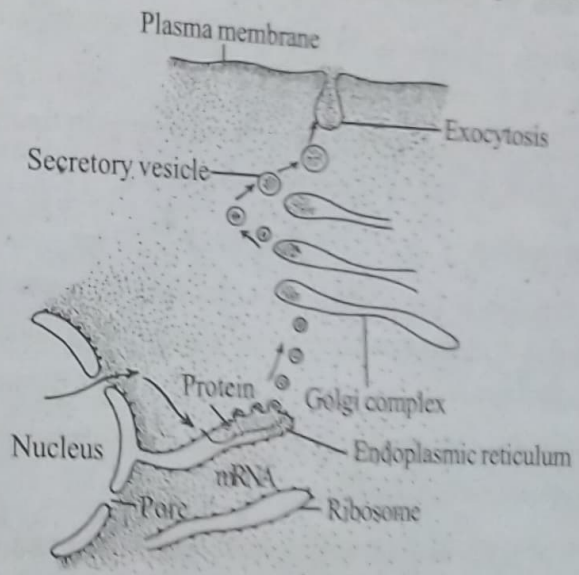

Fig.9.10: Transport and membrane flow.

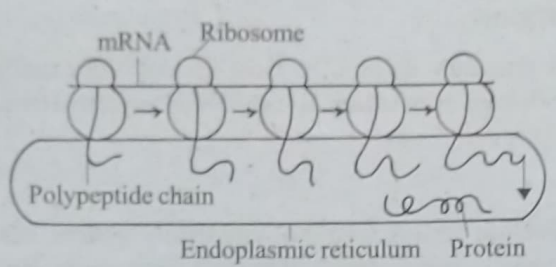

Fig.9.11: Endoplasmic reticulum collects and transports the protein synthesized on ribosomes.

4. Formation of Microbodies

Microbodies are small granular bodies filled with an electron dense granule rich in ***peroxidase.*** They include ***peroxisomes*** and ***glyoxysomes.*** They are formed in protozoa, yeast, liver, kidney and higher plants.

Microbodies remain in close association with endoplasmic reticulum. Endoplasmic reticulum buds off microbodies. In some instances, microbodies show connections with endoplasmic reticulum.

5. Synthesis of Cholesterol and Steroid Hormones

Endoplasmic reticulum is the major site for the synthesis of cholesterol, the precursor for steroid hormones.

In the testis, ovary and adrenal cortex, the smooth endoplasmic reticulum plays the major role in the synthesis of ***steroid hormones.***

6. Glycosylation

Glycosylation is the addition of carbohydrate units to other cellular macromolecules. It leads to the formation of glycoproteins, mucopolysaccharides, glycolipids, glycogen, etc.

Almost all secretory proteins are in the form of glycoproteins. Glycoprotein is formed of proteins and carbohydrates.

Proteins are synthesized on the ribosomes attached to the endoplasmic reticulum. The proteins are transferred to the lumen of endoplasmic reticulum. In the endoplasmic reticulum, carbohydrate units are linked to the polypeptide chain by ***glycosylation.*** The glycosylation is catalyzed by the enzyme ***glycosyl transferase.***

The glycosylation can take place even when protein synthesis is going on. Thus endoplasmic reticulum converts proteins into glycoproteins by glycosylation.

7. Detoxification

Detoxification *refers to the reduction of toxic properties of chemicals such as drugs and pollutants.* Detoxification occurs in the endoplasmic reticulum of liver cells.

Detoxification involves biochemical reactions by which harmful materials are converted into harmless substances suitable for excretion by the cell. The detoxification reactions include oxidations, reductions, hydrolysis or conjugation to ***soluble molecules.***

Metabolic waste products such as ***fatty acids, bile salts, steroids*** and ***haem*** are also detoxified by the smooth endoplasmic reticulum.

8. Lipid Synthesis

ER synthesizes ***triglycerides*** and ***phospholipids***. It also stores lipids.

9. Glycogenolysis

The conversion of glycogen into glucose is called ***glycogenolysis***. It takes place inside the ER. The ER contains an enzyme called ***glucose-6-phosphatase***. It converts glucose-6-phosphate into glucose which is transported to the blood.

10. Storage of Calcium ions (Ca^{++})

ER stores ***calcium ions.*** In ***sarcoplasmic reticulum*** (ER of muscle cell), the calcium ion concentration is higher than that of cytosol. When the muscle is stimulated, ER releases rapidly large amount of Ca^{++} into the cytosol. This brings about muscle contraction.

During relaxation, Ca^{++} ions are pumped into the ER from the cytosol.