TOPIC: ENDOPLASMIC RETICULUM & RIBOSOME

LECTURE NO:06
B.SC PART-II(SUB.)-GROUP A
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Objectives:-

After reading this unit the readers will be able to:

Define endoplasmic reticulum (ER)

Discuss the structure and functions of endoplasmic reticulum Explain the importance of ER

Discuss the structure and functions of ribosome Write the importance of ribosome

Explain the structure and functions of Golgi bodies Tell the importance of Golgi bodies.

Introduction:-

The matrix of cell contains various particles of different sizes called cytoplasmic constituents or organelles. They include rounded, globular, filamentous or granular mitochondria, network of endoplasmic reticulum, elongated secretary particles of Golgi apparatus, ribosomes, plastids, centrosomes and lysosomes. Endoplasmic reticulum is a complex, finely divided vacuolar or tubular system, extending from nucleus through cytoplasm to the margins of the cells. This system is enclosed by double membrane. Ribosomes are small dense and granular ribonucleoprotein (i.e. RNA and proteins) particles found attached to outer surface of endoplasmic reticulum and nucleus as well as freely scattered in cytoplasm, mitochondrial matrix and chloroplast. Golgi bodies may consist of many flattened sacs. In

plant cells they are collectively called as **'dictyosome'**. They are found scattered throughout the cytoplasm. Golgi complex occupies different positions in different kinds of cells. In secretary and absorptive cells, it usually lies between the nucleus and the cell surface where secretion and absorption occurs. In nerve cells it surrounds the nucleus, and lies elsewhere in other cells.

Endoplasmic Reticulum

General History of Endoplasmic Reticulum:-

Early cytologists held that some sort of supporting network or cytoskeleton was present in the cells. It was given various names — **Nissil substance**, **ergastoplasm**, **basophilic bodies**, etc. In 1945, **Porter, Claude and Fullman** with the help of electron microscope noted a delicate membranous network in the cytoplasm. It was later called **endoplasmic reticulum** (ER) by **Keith Porter** in 1953. The ER originally seemed to be confined to the endoplasm of the cell, hence its name.

Structure of Endoplasmic Reticulum:-

In eukaryotic cells endoplasmic reticulum is generally the largest membrane which forms extensive system of intercommunicating membranous sacs or channels. It represents 30 to 60% of total membrane in a cell. The membrane of endoplasmic reticulum may or may not have ribosomes attached to their outer membrane. Accordingly these are classified as rough (RER) or smooth endoplasmic reticulum (SER). Rough endoplasmic reticulum is characterized by the presence of ribosomes of about 150Å in diameter and rich in protein and RNA. Smooth endoplasmic reticulum lacks ribosomes. It comprises three types of elements: cisternae, tubules and vesicles (Fig. 4.1).

Cisternae- These are flattened, unbranched, sac like elements with about 40-50µm in diameter. They lie in stacks (piles) parallel to but interconnected with one another. They are separated from one another by cytosolic spaces. The small granular structures called the ribosomes may or may not be present on the surface of cisternae.

Tubules- These are irregular, branching elements, which form a network along with other elements. They are about 50-100µm in diameter, and are often free of ribosomes.

Vesicles- These are oval, vacuole like elements, about 25-500µm in diameter. They often occur isolated in the cytoplasmic matrix. They are also free of ribosomes. A fluid called the endoplasmic matrix is present in the lumen of ER. All the elements of ER freely communicate with each other.

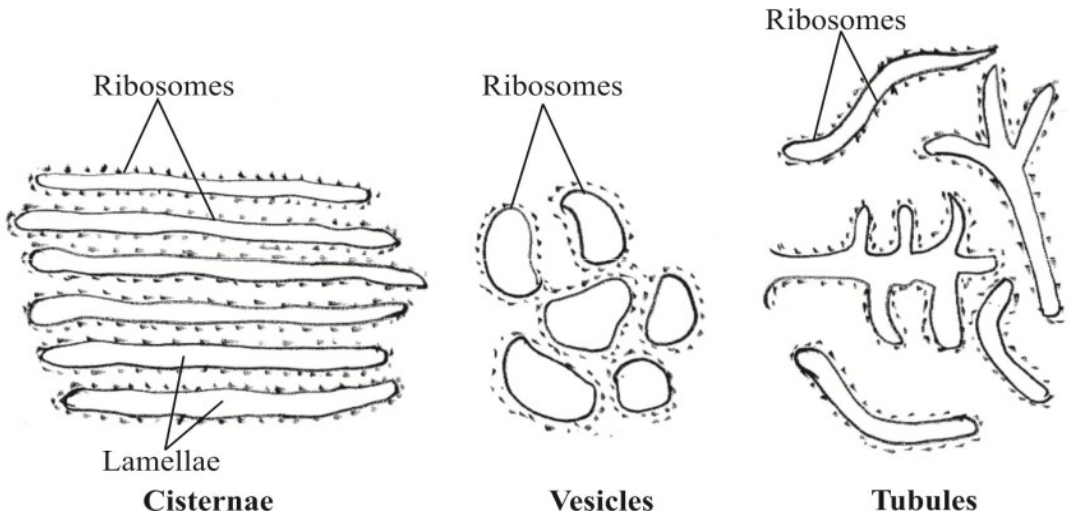

Fig. 4.1: Various forms of ER.

Ultra structure of Endoplasmic Reticulum:-

The membrane bounding the cisternae, tubules and vacuoles of the ER is similar to the cell membrane. It is 50-60Å thick. The membranes of endoplasmic reticulum are composed of two layers of phospholipids molecules sandwiched by two layers of protein molecules like other membranes in the cell (Robertson, 1959). The ER membrane has a relatively high protein/lipid ratio. It is continuous with the cell membrane, Golgi membranes and outer

membrane of the nuclear envelope. Certain cisternae open out by pores in the cell membrane. In the lumen of endoplasmic reticulum, secretary granules were observed by Palade (1956). The lumen acts as a passage for the secretary products. 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. Membrane bound endoplasmic reticulum spaces varies in shape and sizes in different cell types (Fig. 4.2).

On the basis of absence or presence of ribosomes, two kinds of ER are found in cells.

Smooth Endoplasmic Reticulum: Ribosomes are absent on the walls of ER and so it appears smooth and hence called **smooth or agranular ER**. It mainly occurs as tubular forms. The tubules forms irregular lattices and measures about 500-1000Å in diameter. Smooth ER is commonly found in the cells involved in the synthesis of **steroids or lipids i.e. non protein type of synthesis** (Christensen and Fawcett, 1961) such as adrenal or sebaceous glands, gonadial interstitial cells. Certain cells with carbohydrate metabolism (e.g. liver cells), impulse conduction (e.g. muscle cells), with pigment production (e.g., retinal pigment cell) and electrolyte excretion (e.g., chloride cells of fish gills) are also have more of SER in them.

Rough Endoplasmic Reticulum (RER): It is characterized by the presence of ribosomes on the surface of reticulum and so it is also known as **granular ER**. It is in the form of flattened cisternae with the width of 400-500Å. RER occurs 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) or mucus (goblet cells). In exocrine cells of pancreas, RER consists of reticular sheets and fenestrated cisternae in the basal region of the cell. These cisternae measures about 5-10 micron in length and their groups are

400-1000Å in diameter. In apical region of the cells, granular reticulum occurs in the form of vesicles. Granular and agranular ER are in continuity of their membranes in the regions of contact.

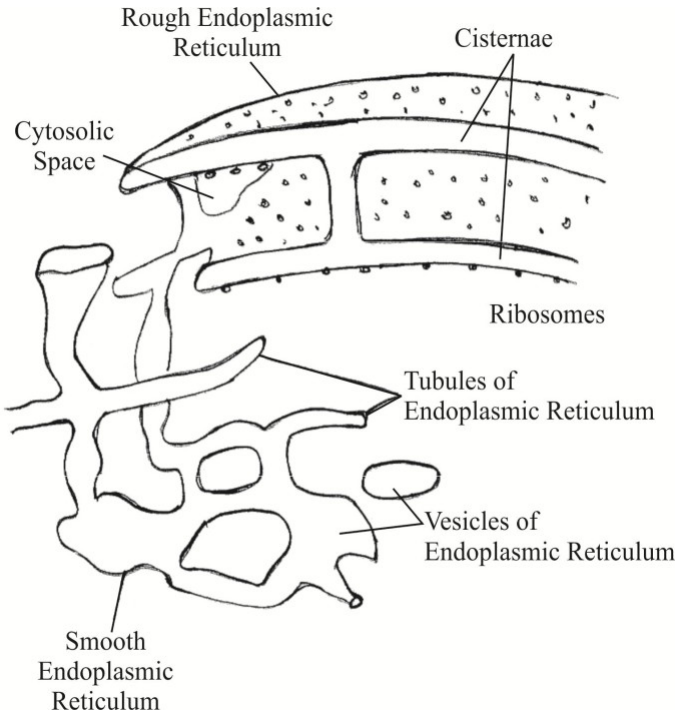

Fig. : Various types of elements of endoplasmic reticulum.

Functions of Endoplasmic Reticulum:-

ER serves many functions. These may be listed as follows.

Functions of smooth endoplasmic reticulum:-

Surface for Synthesis- The SER provides surface for the synthesis of fatty acids, phospholipids, glycolipids, steroids and visual pigments.

Glycogen Metabolism- The SER carries enzymes for glycogen metabolism in liver cells. Glycogen granules are attached in larger numbers to the outside of the SER's membranes in liver cells.

Detoxification- The SER has enzymes that are involved in the detoxification in the liver, i.e., converts harmful materials

such as carcinogens and pesticides, into harmless ones for excretion by the cell.

Formation of organelles- The SER produces Golgi apparatus, lysosomes, micro bodies and vacuoles.

Transport route- The proteins shift from RER through SER to Golgi apparatus for further processing.

Skeletal Muscle Contraction- The sarcoplasmic reticulum in skeletal muscle cells release Ca^{2+} ions to cause contraction and absorbs Ca^{2+} ions to bring about relaxation.

Fat Oxidation- The SER membranes carry out the initial reactions in the oxidation of fats.

Functions of rough endoplasmic reticulum

Surface for Ribosomes- The RER provides a large surface for the attachment of ribosomes.

Surface for synthesis- The RER offers extensive surface on which protein synthesis can be conveniently carried on by ribosomes. The newly formed proteins may enter the ER membranes, becoming a part of the membrane structure or pass into the ER lumen. The proteins becoming a part of ER membrane eventually move from the ER via membranes of other cell organelles, namely Golgi apparatus, secretary vesicles to become permanent plasma membrane proteins. The proteins entering ER lumen are packed for export.

Packaging- The proteins in ER lumen are processed and get enclosed in spherical membrane bound vesicles which get pinch off from the ER. These vesicles have various fates. Some remain in the cytoplasm as storage vesicles while others migrate to the plasma membrane and expel their contents by exocytosis. Some fuse with Golgi apparatus for further processing of their proteins for storage or release from the cell.

Smooth ER Formation- The RER gives rise to the smooth ER by loss of ribosomes.

Formation of Nuclear Envelope- The RER forms nuclear envelope around daughter cells in cell division.

Formation of Glycoproteins- The process of linking sugars to proteins to form glycoproteins starts in the RER and is completed in Golgi apparatus.

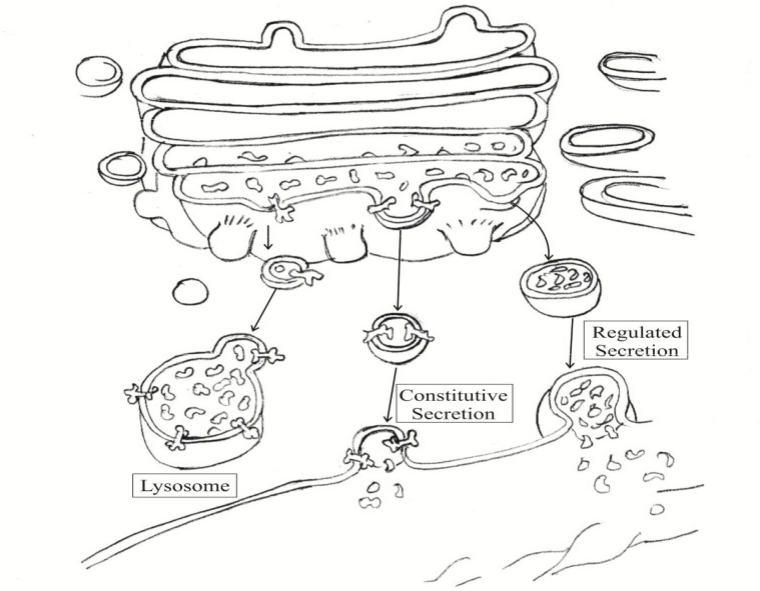

Fig: Transport of proteins from Golgi apparatus. Proteins are sorted and transformed in Golgi network and transported in vesicles to their final destination.

Importance of Endoplasmic Reticulum:-

Transport of Materials- The ER facilitates transport of materials from one part of the cell to another thus forming the cell's circulatory system.

Formation of Desmotubule- Tubular extension, called desmotubule, extends through plasmodesmata to make ER continuous in the two adjacent plant cells.

Support- The ER acts as an intracellular supporting framework, the cytoskeleton that also maintains the form of the cell.

Localization of Organelles- It keeps the cell organelles properly stationed and distributed in relation to one another.

Surface for Synthesis- The ER offers extensive surface for the synthesis of a variety of materials.

Storage of Materials- The ER provides space for temporary storage of synthetic products such as proteins and glycogen.

Exchange of materials- The ER helps in the exchange of materials between the cytoplasm and the nucleus.

Location of Enzymes- A variety of enzymes is located in the ER membranes to catalyze the biochemical reactions.

Ribosomes

General History of Ribosome

George E. Palade (1953) was the first to observe dense particles or granules in animal cells under electron microscope. These were thus called as Palade's Particles. Later **Richard B. Roberts** named them "**ribosomes**" in 1958. **Tissieres and J.D. Watson** (1958) isolated ribosomes from E. coli for the first time. It was shown that ribosomes contain approximately equal amount of RNA and proteins.

4.4.2 Structure of Ribosome:-

Ribosomes are of two types **70S and 80S. 'S'** is **Svedberg unit**, a measure of particle size dependent on the speed with which the particles sediment in the ultracentrifuge. The **70S** ribosomes are found in the **prokaryotic cells** and in the **mitochondria and plastids** of eukaryotic cells. The **80S** ribosomes occur in the cytoplasm of the eukaryotic cells. Both the 70S and 80S ribosomes are similar in structure. They are small, spherical structures of which 70S ribosomes are around 200Å in diameter, while 80S are 250 to 300Å in diameter. They are porous and hydrated having two subunits, one is larger (140-160Å in diameter) having dome shaped structure and the other is smaller in size, found over the larger subunit, forming a cap like structure. The two subunits are separated by clefts (Palade and Kuff, 1966). **Membrane is absent around them**. The subunits occur separately in the cytoplasm, and join to form ribosomes only at the time of protein synthesis. Many ribosomes line up and join the mRNA chain. After the synthesis of protein, the ribosomes leave the mRNA chain and dissociate into subunits.

70S Ribosome: These are found in bacterial cells and have the molecular wt. 2.7×10^{-6} daltons and sedimentation coefficient 70S. 70S ribosome consists of a large 50S subunit

and a small 30S subunit. Each subunit is composed of rRNA and several basic proteins. The 50S subunit has two species of RNA: 23S and 5S and about 34 different ribosomal proteins. The 30S subunit has only one species of rRNA, i.e., 16S and about 21 different ribosomal proteins. They also occur in mitochondria and chloroplasts of eukaryotic cells (Fig. 4.4a).

80S Ribosome: Having the sedimentation coefficient 80S, these are somewhat larger

and contain more RNA and proteins than 70S ribosomes. An 80S ribosome is over 250 to 300Å in diameter. Their mol. wt. is 4×10^{-6} daltons. It consists of a large 60S subunit and a small 40S subunit. Each subunit is composed of rRNA and several specific basic proteins. The 60S subunit has three species of rRNA: 28S, 5.8S and 5S and over 45 different ribosomal proteins. The 40S subunit has only one species of rRNA, i.e., 18S and over 33 different ribosomal proteins. They are found in eukaryotic cells (Fig. 4.4b).

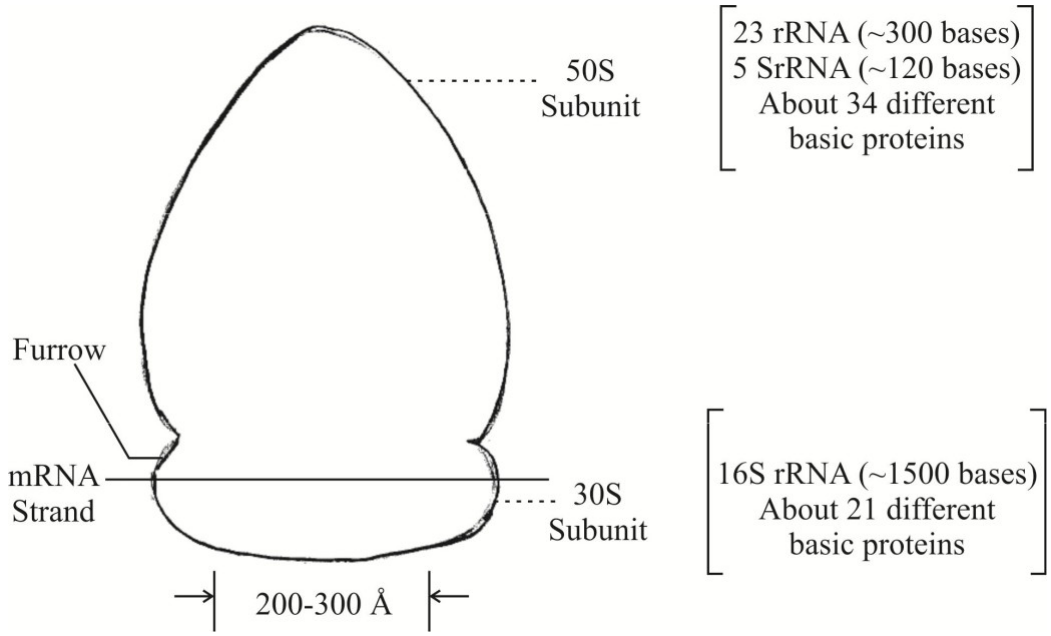

Fig. 4.4a: Structure of 70S ribosome of Escherichia coli, a colon bacilia

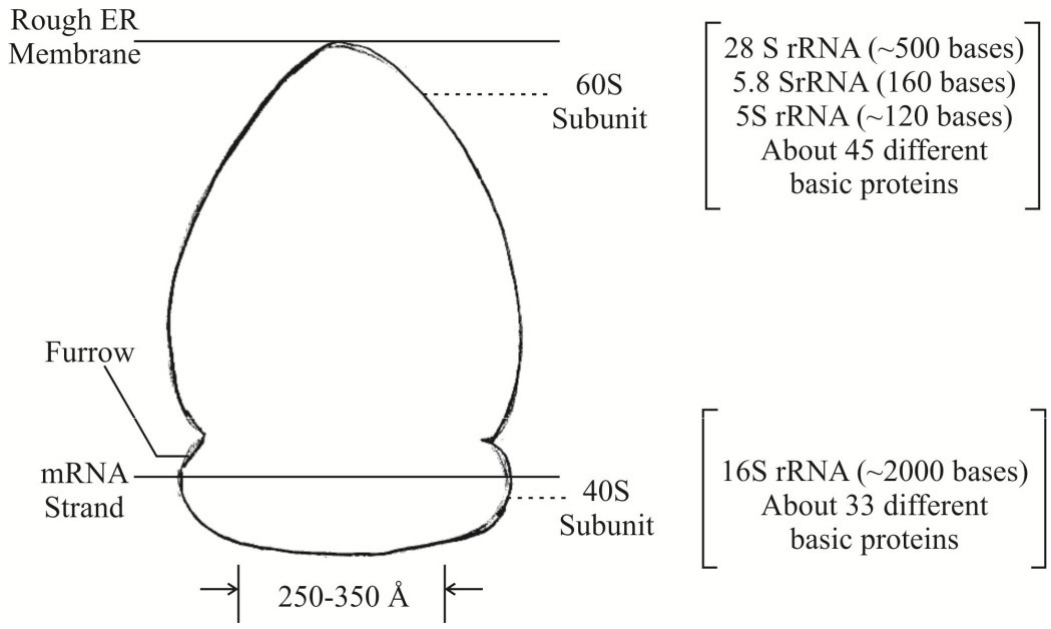

Fig. 4.4b: Structure of 80S ribosome of eukaryotic cell

Ultra structure of ribosome

The ribosomes are composed of two subunits (one subunit is almost twice in size than the other) fitted together to form a

complete unit of about 300Å in diameter. In 70S ribosome the 50S subunit is pentagonal compact particle of 160 to 180Å bearing a round concave area in its center of about 40 to 60Å that accommodates the small subunit. A small pore like transparent area is also present that inhibits the entrance of enzyme ribonuclease. Similar pores are present in 60S subunit of 80S ribosomes. The smaller subunits 30S of 70S and 40S of 80S ribosomes have irregular forms and are often divided into two portions which areinterconnected by a strand of 30 to 60 Å thicknesses. Ribosomes have a groove at the junction of large and small subunits. The mRNA is seated in the gap between both ribosomal subunits, where the ribosome protects a stretch of some 25 nucleotides of mRNA from degradation by ribonuclease. From this groove, a canal or tunnel extends through the large subunit and opens into the lumen of the endoplasmic reticulum. Polypeptides are synthesized in the groove between the two ribosomal subunits and pass through the tunnel of the large subunit into the endoplasmic reticulum (Fig. 4.5).

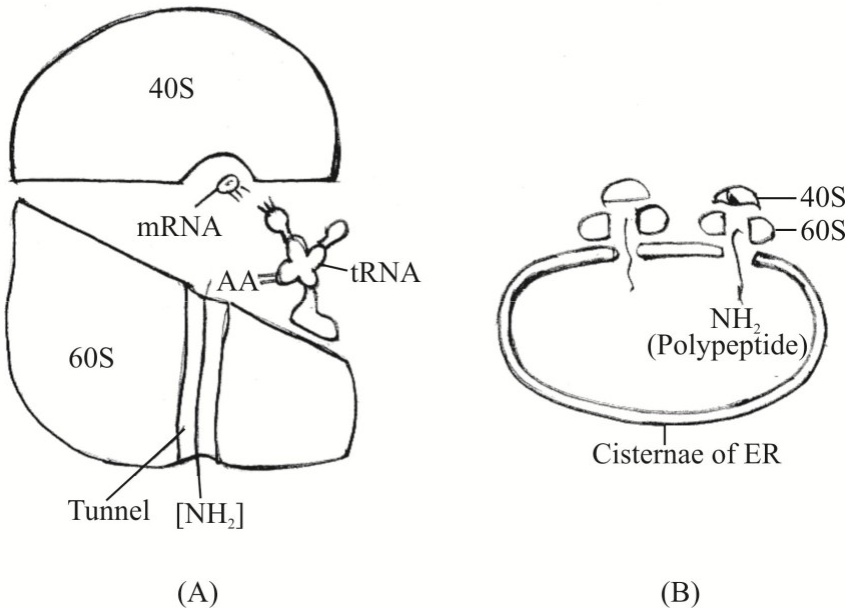

Fig. 4.5: Ultra structure of ribosomes showing two subunits

4.4.3 Functions of Ribosome

Attached Ribosomes- The ribosomes provide space and enzymes for the synthesis of proteins in the cell. The ribosomes bound to the ER membranes synthesize: (i) integral proteins for cellular membranes, (ii) lysosomal proteins and (iii) secretary proteins for export as secretions.

Free Ribosomes- The free ribosomes produce structural and enzymatic proteins for use in the cell itself. These proteins include glycolytic enzymes and most extrinsic membrane proteins, such as spectrin.

Importance of Ribosome

Ribosomes are known as protein factories. Ribosomal RNA molecules possibly serve as a skeletal framework in the ribosomes.

Smaller ribosomal subunit is required for the formation of initiation complex at the start of the protein synthesis. Whereas larger ribosomal subunit is necessary for peptide bond formation and the elongation for the polypeptide.

The ribosome function as a template in order to bring together various components involved in the synthesis of proteins. Ribosomes co-ordinate the interaction of t-RNA-amino acid complex with m-RNA. This co-ordination results in the translation of genetic code forming specific proteins.

Since free ribosomes are not involved in protein synthesis, they are transported through endoplasmic reticulum membranes and assembled into globules within the cisternae and canals in the cells that produce 'proteins for transport'. Proteins later appear in the form of granules outside the Golgi complex.

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