## ENDOPLASMIC RETICULUM

The endoplasmic reticulum (the name given by Porter, 1955), is the most fascinating discovery of the electron microscope. It is found in all living cells of plants and animals. ER (endoplasmic reticulum) arises from the outer nuclear membrane and extends up to the cell surface. In a cross-section, the whole meshwork of ER looks like organised channels but when studied with 3D techniques, it is found that to be composed of flat saccular expansions called cisternae. The cisternae may occur singly but more often they are aggregated to form a lamellae system roughly parallel to one another. These parallel running cisternae are interconnected with partitions, resulting in the compartmentalisation of ER. The peripheral region of cisternae may be entire or composed of meshed network of anastomosing tubules of

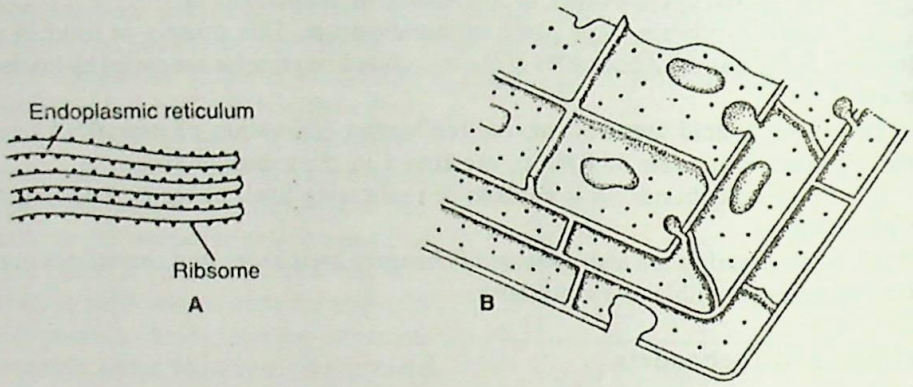


**Fig. 1.13.** Endoplasmic reticulum. A—a cross-section of the ER showing parallel and tubular appearance and B—a three–dimensional figure of ER showing flat structure with compartmentalisation.

400-700 Å dia. On the other end of tubules are found vesicles. The development of tubular, cisternae and vesicular arrangement of ER varies with the age of the cell. The ER may be entirely tubular or cisternae in a particular region.

On the basis of surface structure, two types of ER are known:

(*i*) The **granular type** or **rough surfaced** that is coated with a large number of adherent ribosomes. In classical cytology, both these structures together are called ergastoplasm. RER contains two transmembrane glycoproteins, ribophorins I and II. Ribophorins are involved in mediating the attachment of ribosomes to the membrane.

(*ii*) **Agranular type** or **smooth surfaced.** Glycosomes have been found attached to SER region. The ER contains several enzymes for various activities (see under heading Microsomes). While comparing the cell membrane with ER, the cell membranes are slightly thicker and without adherent ribosomes. The ER remains away about 200 Å from the general surface of the cell membrane, but at places in the region of a plasmodesmata, it contacts and occasionally passes through to establish connections with the branches of ER of the neighbouring cell. Thus, the extensive meshwork of ER may keep the nuclei of different cells in communication with each other, directly or indirectly.

Chemically, ER consists of proteins (40–60%), lipids (30–50%) and some RNA. The lipids are mostly phospholipids (55–66%) whereas protein is partly structural and partly enzymatic types. ER develops strongly in meristematic cells.

**Functions of ER**

The ER participates in a number of cellular activities. Some of them are:

1. It forms the skeletal-framework within the cytoplasm.
2. It helps in intracellular transport of various metabolites.
3. The compartmentalisation plays important role in keeping certain enzymes and metabolites separate.
4. Some enzymes synthesised on the surface of ER move through the supporting membranes of ER into the closed cavity and accumulate in the form of granules. The granules after travelling through the ER channels are released to the site of action.

Segregation and translocation of proteins are important functions of the ER. It can be cotranslational and post-translational translocation of proteins, *e.g.* secretory proteins furnish an example of cotranslational translocation whereas proteins of mitochondrial and chloroplast matrices are examples of post-translational translocation.

5. Rough ER provides larger surface for the attachment of ribosomes which act as a working table during protein synthesis.
6. Biosynthesis of fatty acids and phospholipids takes place with the help of smooth ER.
7. The metabolism of steroids including oxidation and reduction reactions also occur in smooth ER.
8. Smooth ER also participates in carbohydrate metabolism by providing intimate surface for certain enzymes, *e.g.* degradative enzymes such as *glucose, 6-phosphatase* and enzymes related to glycogen synthesis.
9. Smooth ER have been involved in electron transport and related processes. It is substantiated by the presence of NAD, cytochromes and ATPase complex in this region.
10. It is believed that the ER in general provides limited mechanical strength to the cytoplasm.
11. The ER is involved in the formation of protein bodies, glyoxysomes and the vacuoles.
12. The cytoplasms of two cells remain interconnected with the ER and thus play an important role in maintaining cytoplasmic continuity between the two cells.

## MICROSOMES

Microsome is not any natural cell organelle. These are small or microfractions of endomembrane systems obtained by differential centrifugation. These are called microsomal fractions or microsomes. By further gradient centrifugations of microsomal fractions, RER, SER, Golgi complexes, ribosomes etc. may also be separated. Microsomal membranes have a complex lipid and protein composition.

The ER contains enzymes for the synthesis of triglycerides, phospholipids and cholesterol. Two electron transport systems that contain two flavoproteins (*i.e.* NADH cyt. c-reductase and NADH-cyt. $b_5$-reductase) and two hemoproteins (*i.e.* cytochrome $b_5$ and cytochrome P-450) are also present. Other enzymes of the *ER*

are *peptidases, glycosyl transferases* and *hydroxylases*. These modify nascent polypeptides. *Glucose-6 phosphatase* produces the degradation of glycogen in smooth ER. $Mg^{++}$-activated *ATPase* are also found.

Some microsomal enzyme activities include:

(*i*) Synthesis of glycerides.
(*ii*) Fatty acid synthesis.
(*iii*) Steroid biosynthesis.
(*iv*) Aromatization.
(*v*) Hydroxylation.
(*vi*) Deamination and desulfuration.
(*vii*) L-ascorbic acid synthesis.
(*viii*) UDP-glucose dephosphorylation etc.

## GOLGI COMPLEX

Golgi complex was discovered by Camillo Golgi (1898) in the neural tissue, where it appeared as an extensive network of dark strands. He called it internal reticular apparatus but his students, Raman and Cajal referred it after his name as Golgi bodies. These were also called Golgi apparatus or Golgi complex. Occasionally, the term lipochondria has been used for Golgi complex.

### Ultra Structure of Golgi Complex

Golgi complex is an assemblage of flat or curved saccules or cisternae lying one above the other in close parallel array. Each cisternal unit corresponds to an individual lamella which surrounds a thin closed cavity of about 15 Å across and of variable length. Four to eight such cisternal units are commonly spaced 200 to 300 Å apart and thus form multi-layered cisternae. On their convex outer surface are present several myriad small vesicles, 440–800 Å in dia. which evolve from the edges of cisternae.

The cisternae are the smallest functional units separated from each other by an inter-cisternal region in a regular fashion. In this region are present several inter-cisternal elements composed of more or less parallel fibrous elements. The cisternae appear as fenestral plates composed of tubules which branch and rejoin to form highly fenestrated and anastomosed system. They do not appear as flattened sacs. The cisternae are so organised as to enclose several small young vesicles.

The young vesicles are the smooth surfaced and the older ones are rough surfaced. In classical cytology, the peripheral lamellar system is referred to as *dictyosomes* or *Golgi externum* and the vacuolar elements in the centre as *archoplasm* or *Golgi internum*. Because of morphological heterogeneity due to its vesicular, vacuolar, tubular and cisternal components, the term Golgi complex is now-a-days preferred to older terms.

More recently *dictyosomes* are considered as units of Golgi complex. Dictyosomes are formed by stacks of flattened disc-shaped cisternae and associated secretory vesicles.

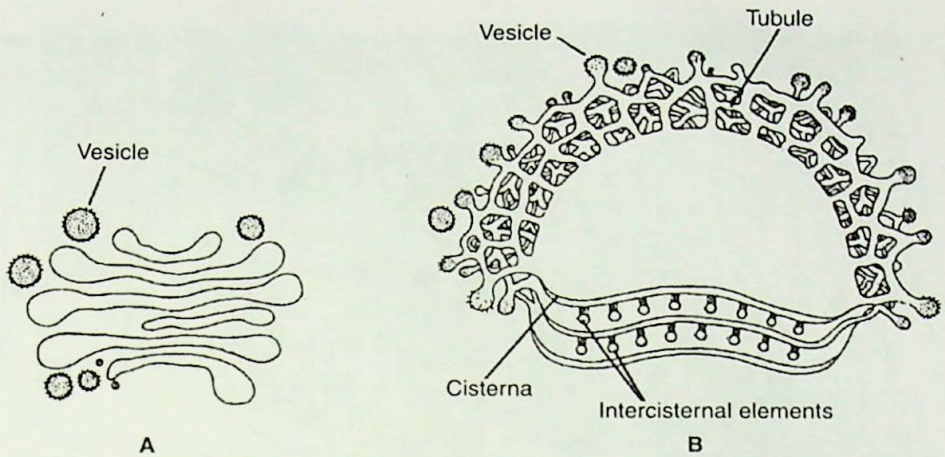


**Fig. 1.14.** Golgi bodies. A—as appear in cross-section and B—a three-dimensional figure showing details.

Plant dictyosomes consist of 2 to 7, sometimes upto 20 or more cisternae. In pea roots, the number of dictyosomes per cell is approximately 30; in root tips of maize, several hundred and in the rhizoidal apex of *Chara foetida* about 25,000. Most plant dictyosomes do not show polarity.

Farquhar (1985) stated that Golgi complex exhibits polarity and proposed *Stationary Cisternae Model.* Of the Golgi complex, the side which faces ER is called *cis* side and the side opposite to it through which mature vesicles are released is called *trans* side. By *cis* side, it receives vesicles released from ER which contain immature enzymes. These enzymes are processed step by step in different cisternal elements and ultimately mature enzymes are released from *trans* side.

According to the recent studies, the **cis** or **forming face** is characterised by the presence of small transitional vesicles of tubules, that converge upon the Golgi cisternae.

These transition vesicles are thought to form blebs from the ER and migrate to the Golgi complex where they coalesce to form new cisternae. Accordingly, a new concept of the mechanism of membrane flow has been proposed in which new cisternae are formed at the proximal end and thus compensate for the loss at the *trans* or maturing face that occurs with the release of secretory vesicles.

*Glucose-6-phosphatase* is the marker enzyme of ER but it is also found in Golgi fractions. Besides, some other enzymes such as *NADH-cytochrome-$b_5$-reductase, NADH-cytochrome-c-reductase* and *5-nucleotidase* are found both in ER and Golgi bodies.

The most characteristic enzymes of Golgi bodies are related to the transfer of oligosaccharides to proteins *(e.g. glycosyl transferases)* forming glycoproteins. Glycoproteins are carried out by small vesicles formed by Golgi bodies.

Associated with *trans* or maturing face there is often a saccular structure that is rich in *acid phosphatase.* This region has been called the GERL (*i.e.* Golgi-ER-Lysosome). This term indicates that it has been interpreted as a region of smooth ER, near the Golgi which is involved in the production of lysosmes. More recently, it relates to *Golgi condensing vacuoles* or *presecretory granules.*

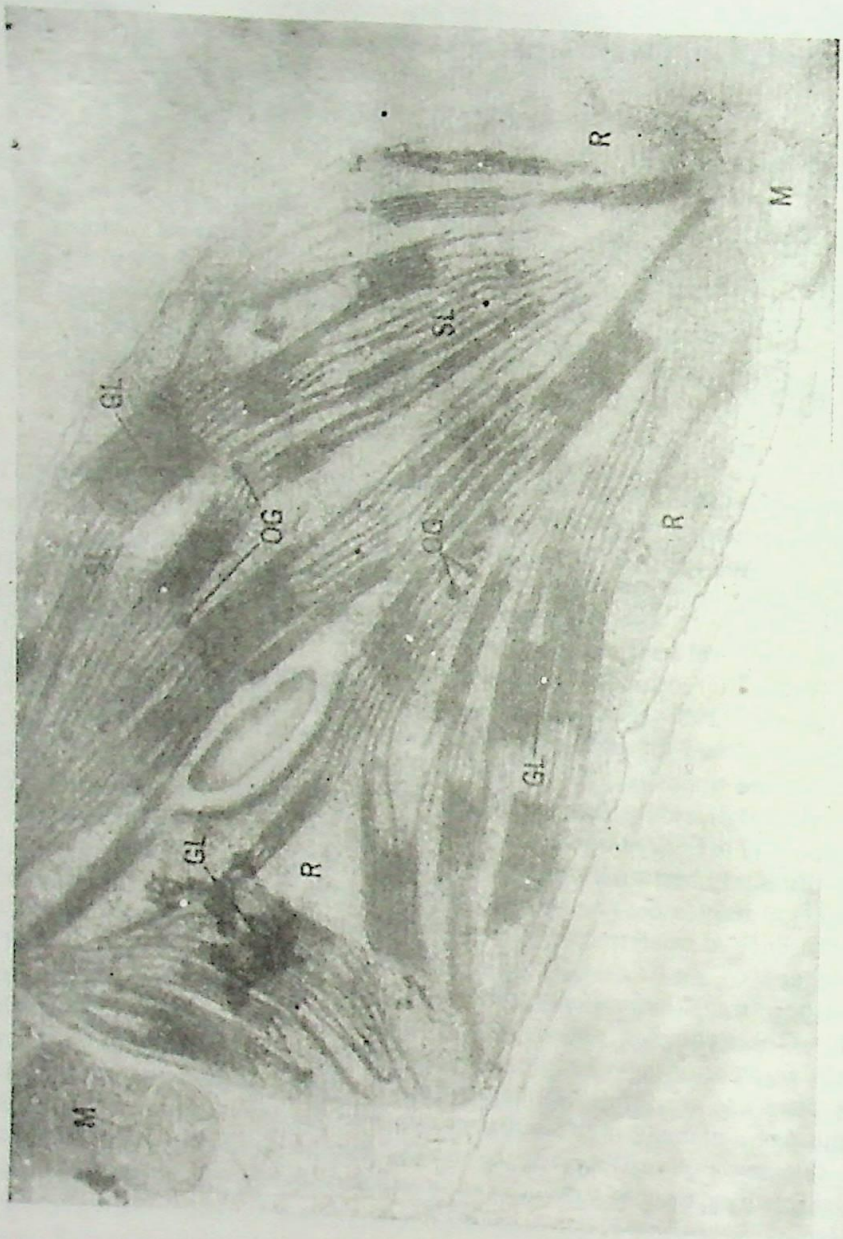


**Fig. Plate 1.1.** Fine structure of chloroplast showing details [abbreviations used are – GL = Grana Lamellae; SL = Stroma Lamellae; OG = Osmiophilic granules; R = Ribosomes (in Stroma); M = Mitochondria] (*Courtesy*: Dr. E. Weier).

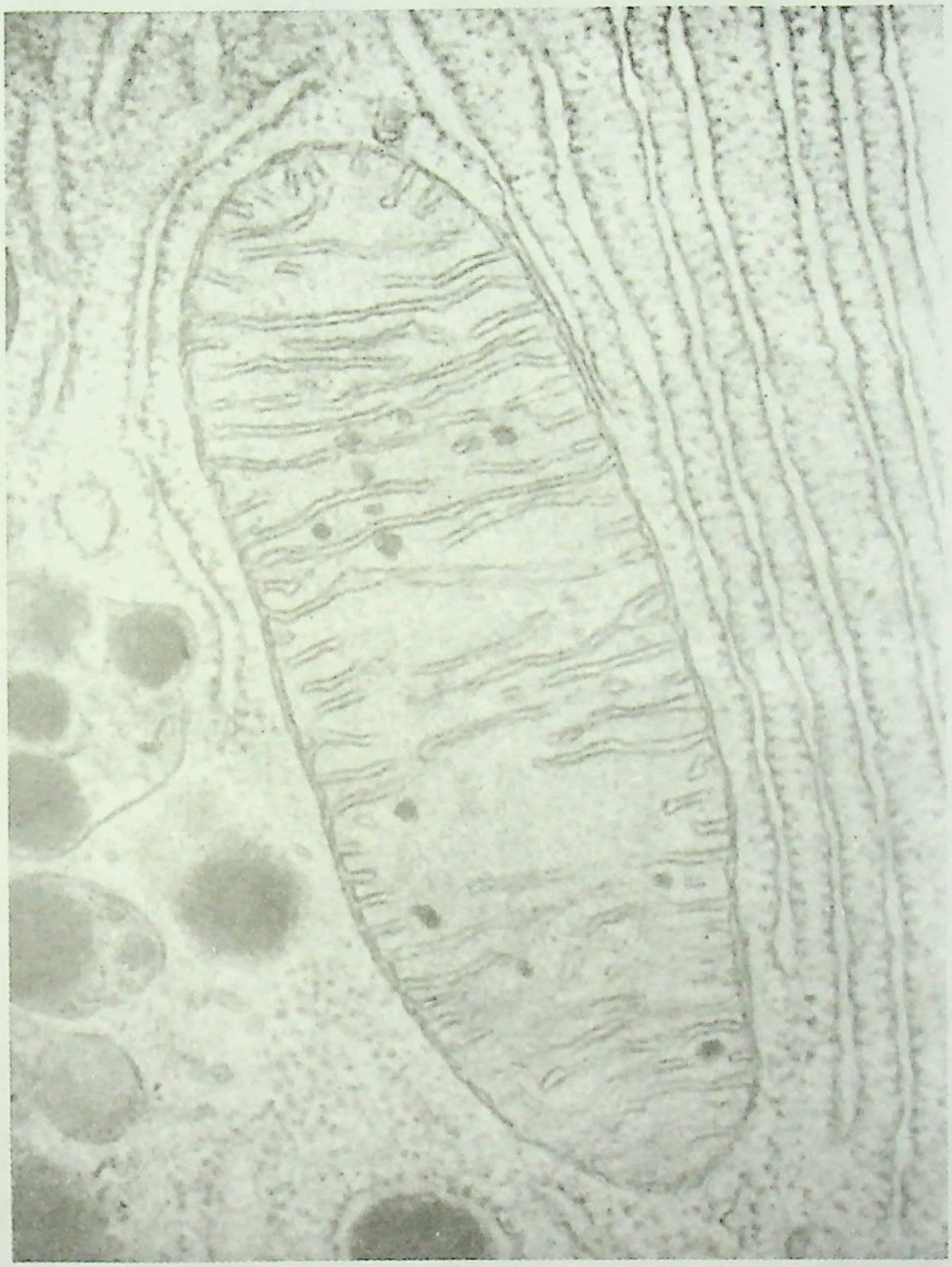

**Fig. Plate 1.2.** Longitudinal section of a mitochondrium and surrounding cytoplasm. The cristae are of variable length and form a series of incomplete transverse septa. Ribosomes attached on endoplasmic reticulum are also seen in the cytoplasm. On the left a few dark-stained spherical bodies are lysosomes, probably.
(Micrograph with Courtesy from Dr. K.R. Porter) Magnification–95.000X.

**Fig. Plate I.3.** The cisternae (ER) at the periphery are in close array and generally parallel to cell surface. It is not well known that what forces determine their even spacing. At top right mitochondria and surrounding endoplasmic reticulum are seen. The plasma membrane of two adjacent cells cross the lower left corner (at arrows) and can be distinguished from the pairs of membrane bounding cisternae of ER, by their closure apposition and the absence of associated ribosomes. (Micrograph with Courtesy from Dr. D.W. Fawcett) Magnification—46,000X.

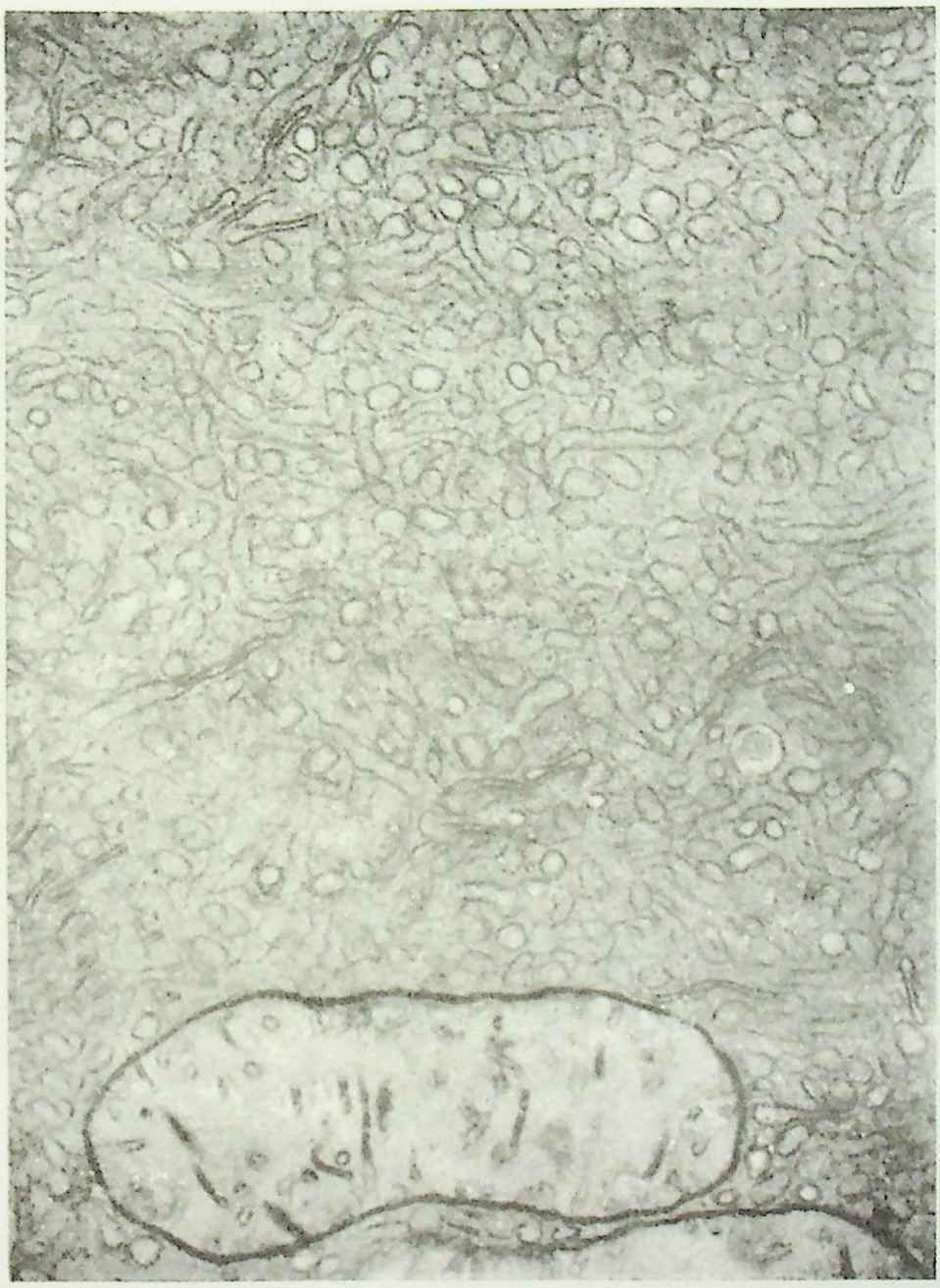

**Fig. Plate 1.4.** Micrograph showing agranular reticulum which varies not only in its morphology in different types of cells, but also in thickness and stability of its membrane. The reticulum are quite thin as compared to those of neighbouring mitochondria. (Micrograph with Courtesy from Dr. D.W. Fawcett) Magnification 51,000X