14. Which type of transport of molecules across the plasma membrane requires energy?
(1) Facilitated diffusion (2) Simple diffusion
(3) Osmosis (4) Active transport

15. Which part of the cell wall is chiefly made up of calcium pectate?
(1) Primary wall (2) Middle lamella
(3) Secondary wall (4) Middle lamella and primary wall

Endomembrane System

The interior of a eukaryotic cell is composed of many membrane bound organelles. Each of the membrane-bound organelles has a distinct structure and function. But some of these organelles function in a coordinated manner and constitute an **endomembrane system**. The organelles included in this system are endoplasmic reticulum, golgi complex, lysosomes and vacuoles. The functions of the mitochondria, chloroplast and peroxisomes are not coordinated with the above mentioned organelles hence, these are not considered as a part of the endomembrane system.

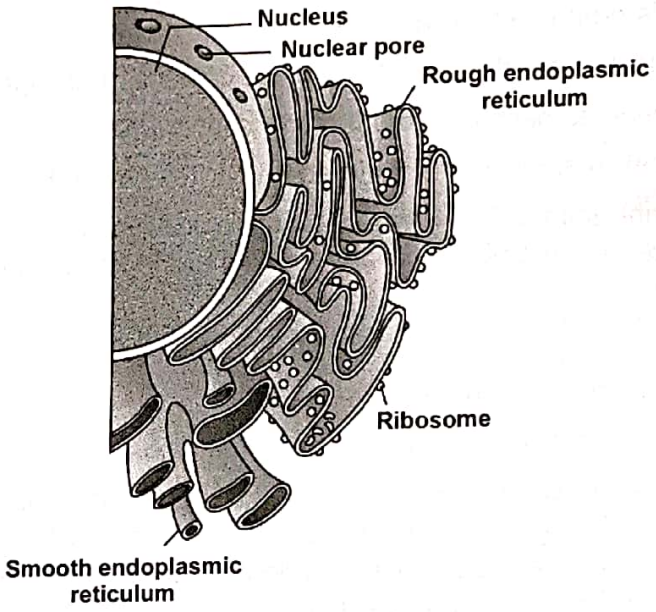

Fig. : Endoplasmic reticulum

1. **Endoplasmic Reticulum (ER) :** Electron microscopic studies of eukaryotic cells reveal the presence of a network of reticulum of tiny tubular structures scattered in the cytoplasm that is called the endoplasmic reticulum (ER).

Ultrastructure : The endoplasmic reticulum is composed of the following three kinds of structures, viz., cisternae, tubules and vesicles.

(a) Cisternae : The cisternae are long, flattened, parallel, sac-like, interconnected structures. These are found in cells which are actively involved in protein synthesis. The cisternae usually occur in those cells which have synthetic roles, *e.g.*, cells of pancreas and brain. They are usually associated with large subunit (60 S) of ribosomes.

(b) Tubules : The tubules are branched or unbranched structures forming the reticular system alongwith the cisternae and vesicles. They are free of ribosomes and are common in cells involved in lipid and sterol synthesis.

(c) Vesicles : The vesicles are oval, membrane bound vacuolar structures. They are also free of ribosomes. They are abundant in the pancreatic cells and these are the only ER structures found in spermatocytes.

ER divides the intracellular space into two distinct compartments:

(i) **Luminal compartment :** It is the internal space enclosed by ER membrane.

(ii) **Extra luminal compartment :** It is the space, present outside the ER in the cytoplasm.

Types : On the basis of presence or absence of ribosomes on the surface of endoplasmic reticulum, it is of two types:

(i) **Smooth endoplasmic reticulum (SER) :** The endoplasmic reticulum which is free of ribosomes is known as SER. When it is observed under the electron microscope it appears as smooth tubular structures. The muscle cells are also rich in smooth type of endoplasmic reticulum which is known as **sarcoplasmic reticulum.**

Function :

(a) It is specialised in the synthesis of lipids and steroids,

(b) Detoxification of drugs,

(c) Associated with muscle contraction by release and uptake of Ca^{2+} ions.

(d) Synthetic products of RER pass onto Golgi complex through SER.

(ii) **Rough endoplasmic reticulum (RER) :** The endoplasmic reticulum bearing ribosomes on its surface is called RER, it gives a rough granular appearance under the electron microscope. They are extensive and continuous with the outer membrane of the nucleus.

RER contains two types of glycoproteins *i.e.,* Ribophorin-I and Ribophorin-II for the attachment of 60 S subunit of 80 S ribosome.

Function :

(a) Ribosomes are the site of protein synthesis and thus, RER are present in the cells which are actively involved in the protein synthesis and secretion.

(b) It provides precursors of enzymes for the formation of lysosomes in Golgi complex.

(c) It gives rise to SER.

2. **Golgi Apparatus :** Golgi apparatus was first observed by **Camillo Golgi** in 1898. He described it as a densely stained reticular structures present near the nucleus of the cell. Therefore, these were given the name Golgi bodies, after his name. It is present in eukaryotic cells, **except** in mature sieve tubes of plants, mature RBCs of mammals, sperm cells of bryophytes and pteridophytes, etc. It is also absent in prokaryotic cells. In plants, it is called **dictyosomes** as Golgi apparatus is made up of unconnected units.

Structure : There are four parts of Golgi complex, viz. cisternae, tubules, vesicles, golgian vacuoles.

(a) Cisternae

(i) These are flattened sac-like structures stacked on one another. There are usually 4–8 cisternae present in a stack. These cisternae resemble with smooth endoplasmic reticulum.

(ii) Cisternae form an extensive network and are arranged near the nucleus in a concentric pattern.

(iii) The shape, size and number of cisternae may vary in different cells but have a similar organisation in one type of cells. Their size may range from 0.5 μm to 1.0 μm in diameter.

(iv) The Golgi cisternae are concentrically arranged near the nucleus with distinct convex *cis* or the forming face and concave *trans* or the maturing face. The *cis* and the *trans* faces of the organelles are entirely different, but interconnected.

(b) Tubules : These are small, flat, interconnecting structures arising from the periphery of cisternae due to fenestrations.

(c) Vesicles : These are large rounded sacs present at the edges of cisternae in clusters. These are pinched off from the tubules.

These are of two types:

(i) Smooth vesicles : These are smooth surfaced secretory vesicles and contain secretory granules.

(ii) Coated vesicles : These are rough surfaced, spherical protuberances arising from the tubules of cisternae.

(d) **Golgian Vacuoles :** These are large, spherical vacuoles produced at maturing face. These are filled with some granular or amorphous substances. Some of them function as lysosomes.

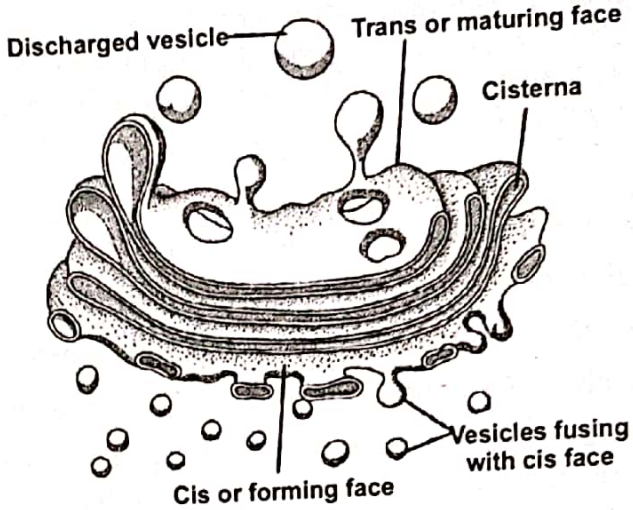

Fig.: Golgi apparatus

Functions :

(i) The important function of Golgi apparatus is to **process, package and transport** the materials for secretions. The packaged material is delivered either to the intracellular targets *i.e.*, within the cell or secreted to extracellular targets *i.e.*, outside the cell. The material to be secreted moves from ER to the Golgi apparatus in the form of transitional vesicles. These vesicles then fuse with the *cis* face and move towards the maturing face of the golgi apparatus. Therefore, Golgi apparatus is closely associated with ER in structural as well as functional aspects.

(ii) A number of proteins synthesised by ribosomes present on the ER are transferred to golgi apparatus. These proteins are then modified in the cisternae of Golgi apparatus before they are released from its *trans* face.

(iii) Golgi apparatus is the important site of formation of glycoproteins (glycosylation of proteins) and glycolipids (glycosidation of lipids).

(iv) Root cap cells are rich in Golgi bodies which secrete mucilage for the lubrication of root tip.

(v) Acrosome of the sperm is modified Golgi apparatus.

(vi) Formation of plasma membrane during cytokinesis.

Knowledge Cloud

The eukaryotic cells posses Golgi apparatus but, many fungi and ciliated protozoans lack well-formed Golgi bodies. In fungi, it is unicisternal.

3. **Lysosomes :** Lysosomes are simple tiny spherical sac-like structures evenly distributed in the cytoplasm. These are formed by the process of packaging in the Golgi apparatus. They are bounded by a single membrane. They are rich in hydrolytic enzymes (hydrolases – lipases, proteases, carbohydrases).

Optimally active at the acidic pH : These enzymes are capable of digesting carbohydrates, proteins, lipids and nucleic acid. Acidic conditions are maintained inside the lysosomes by pumping of H^+ ions into them.

This organelle shows polymorphism : On the basis of morphology, their contents and functions, lysosomes are divided into following four forms :

(i) **Primary lysosomes :** These are small, vesicle-like newly formed structures produced from the golgi apparatus, at trans face. Primary lysosomes contain inactive enzymes.

(ii) **Secondary lysosomes :** These are also called **heterophagosomes** or **digestive vacuoles**. Secondary lysosomes are formed when phagosomes fuse with already existing primary lysosomes. These contain the enzymes against the material to be digested.

(iii) **Residual bodies :** These are secondary lysosomes containing undigested substances. Residual bodies pass outwardly, come in contact with plasmalemma and throw their contents to the outside through **ephagy** or **exocytosis**. However, in certain cells the residual bodies do not discharge their contents to the outside. Instead, they load the cells and bring about ageing, *e.g.,* liver cells, muscle cells. **Polynephritis** may occur due to absence of ephagy from residual bodies. A number of other diseases are linked to malfunctioning of lysosomes-**arthritic joints, gout** and **lung fibrosis**. Some 20 genetic or congenital diseases occur in human beings due to deficiency of certain lysosomal enzymes, *e.g.,* Hunter's syndrome, Niemann-Pick disease, Farber's disease.

(iv) **Autophagic vacuoles:** They are formed by union of many primary lysosomes around old or dead organelles which surround them with vacuolar membrane and digest them by **autolysis** or **autodigestion**. These are also called suicidal bags. The disappearance of larval organs during metamorphosis (*e.g.,* tail in frog) is due to autolysis.

4. **Vacuoles :**

(i) Vacuole is the membrane-bound space found in the cytoplasm. It contains water, sap, excretory products and other material not useful for the cell. These are also called sap vacuoles.

(ii) In plant cells, the vacuoles can occupy upto 90 percent of the volume of the cell. They are bounded by a single, semipermeable membrane called **tonoplast**. This membrane facilitates the transport of a number of ions and other materials against concentration gradients into the vacuole. Thus, their concentration is significantly higher in the vacuole than in the cytoplasm.

Types of vacuoles :

(a) **Contractile vacuole :** In *Amoeba*, it helps in excretion.

(b) **Food vacuoles :** In many cells, as in protists, food vacuoles are formed by engulfing the food particles.

(c) **Gas vacuoles (Pseudovacuoles):** These are membraneless vacuoles found in prokaryotes to provide buoyancy.

xample 11 : *Which cell organelles constitute an endomembrane system?*

olution : ER, Golgi complex, lysosomes and vacuoles.

xample 12 : *Give an important function of Golgi complex.*

olution : It is responsible for packaging, modifying the material and prepare it for secretion.