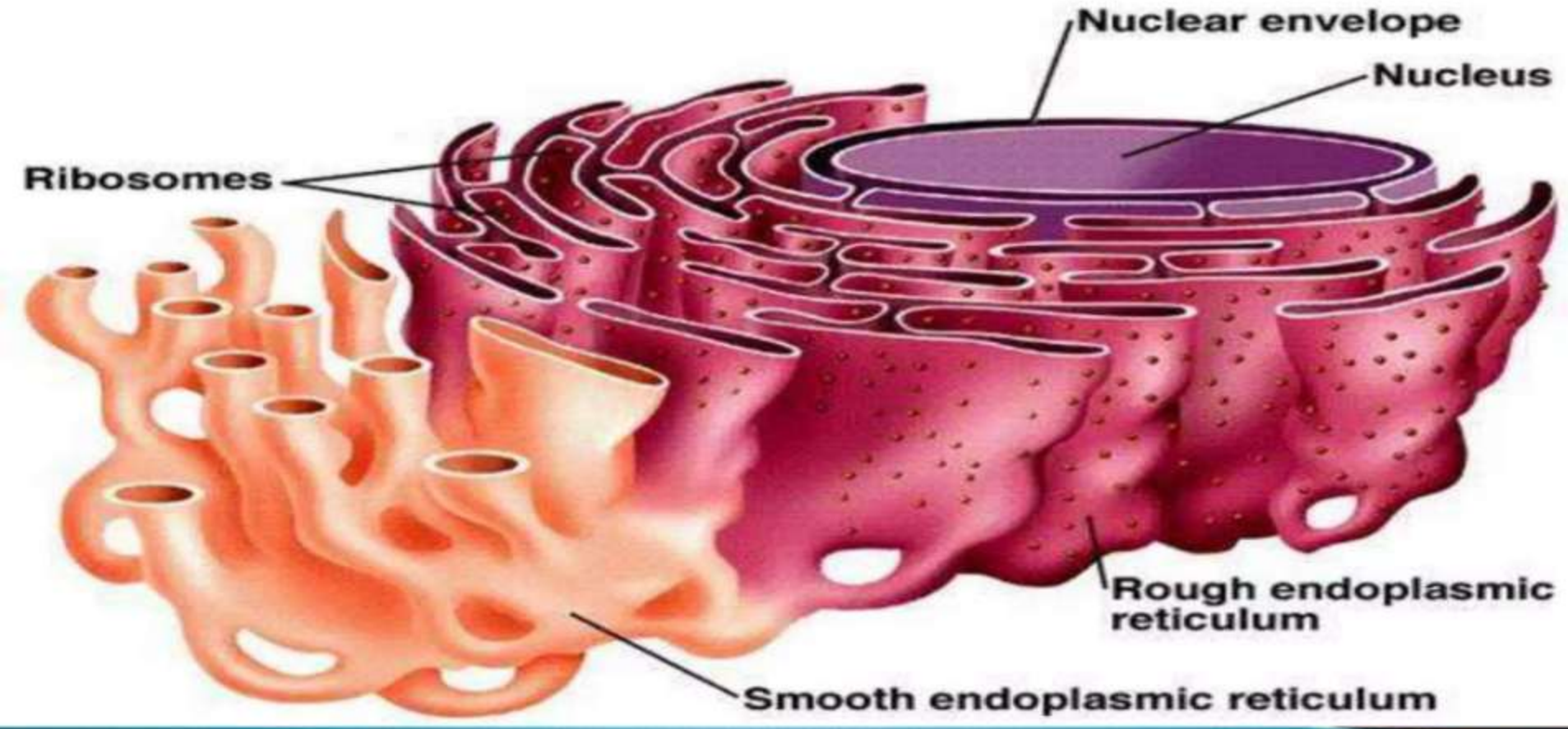
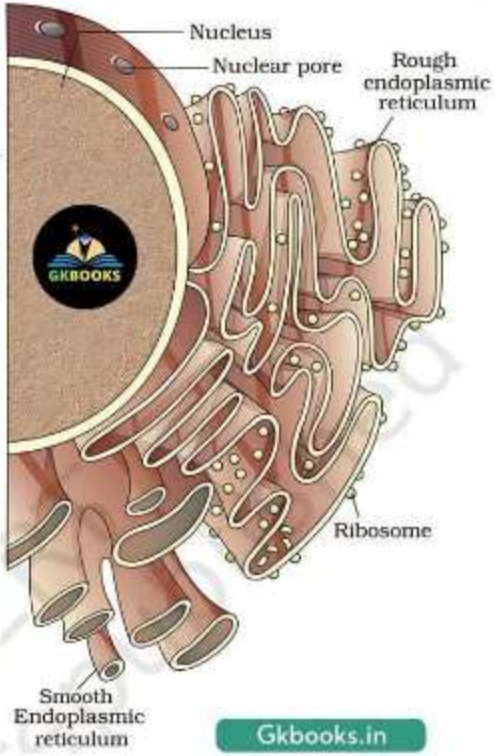
Endoplasmic Reticulum



ENDOPLASMIC RETICULUM (ER)

▲ The ER is a **network of tiny tubular structures present in the cytoplasm of eukaryotic cells.**

- It divides the intracellular space into two compartments:
- **Luminal compartment (inside the ER).**
- **Extraluminal compartment (cytoplasm).**



■ **Nucleus** – The nucleus is the control center of the cell, containing genetic material (DNA) responsible for regulating cellular activities.

■ **Nuclear Pore** – These are openings in the nuclear envelope that allow the exchange of molecules, such as RNA and proteins, between the nucleus and the cytoplasm.

■ **Rough Endoplasmic Reticulum (Rough ER)** – This part of the ER has ribosomes attached to its surface, giving it a rough appearance. It plays a key role in protein synthesis and processing.

Based on NCERT

■ **Ribosome** – Ribosomes are small organelles found on the rough ER and freely in the cytoplasm. They are the site of protein synthesis.

■ **Smooth Endoplasmic Reticulum (Smooth ER)** – Unlike the rough ER, the smooth ER lacks ribosomes. It is involved in lipid synthesis, detoxification, and calcium ion storage.

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Rough ER

- Has ribosomes attached to its surface.
- Involved in protein synthesis and secretion.
- Found extensively in cells that actively produce and secrete proteins.
- Continuous with the outer membrane of the nucleus.

Smooth ER

- Lacks ribosomes, giving it a smooth appearance.
- Major site for lipid synthesis.
- In animal cells, it is responsible for the synthesis of steroidal hormones.

INTRODUCTION

- Endoplasmic means “within the plasm” and reticulum mean“network”
- The endoplasmic reticulum (**ER**) is a network of flat and vesicular structures which extends throughout the cytoplasm in plant and animal cells.
- These sacs and tubules are all interconnected by a single continuous membrane so that the organelle has only one large, highly convoluted and complexly arranged **lumen** (internal space).
- It takes up aproximately 12% of the total volume of a cell.
- It is connected to the double-layered nuclear envelope.

DISCOVERY

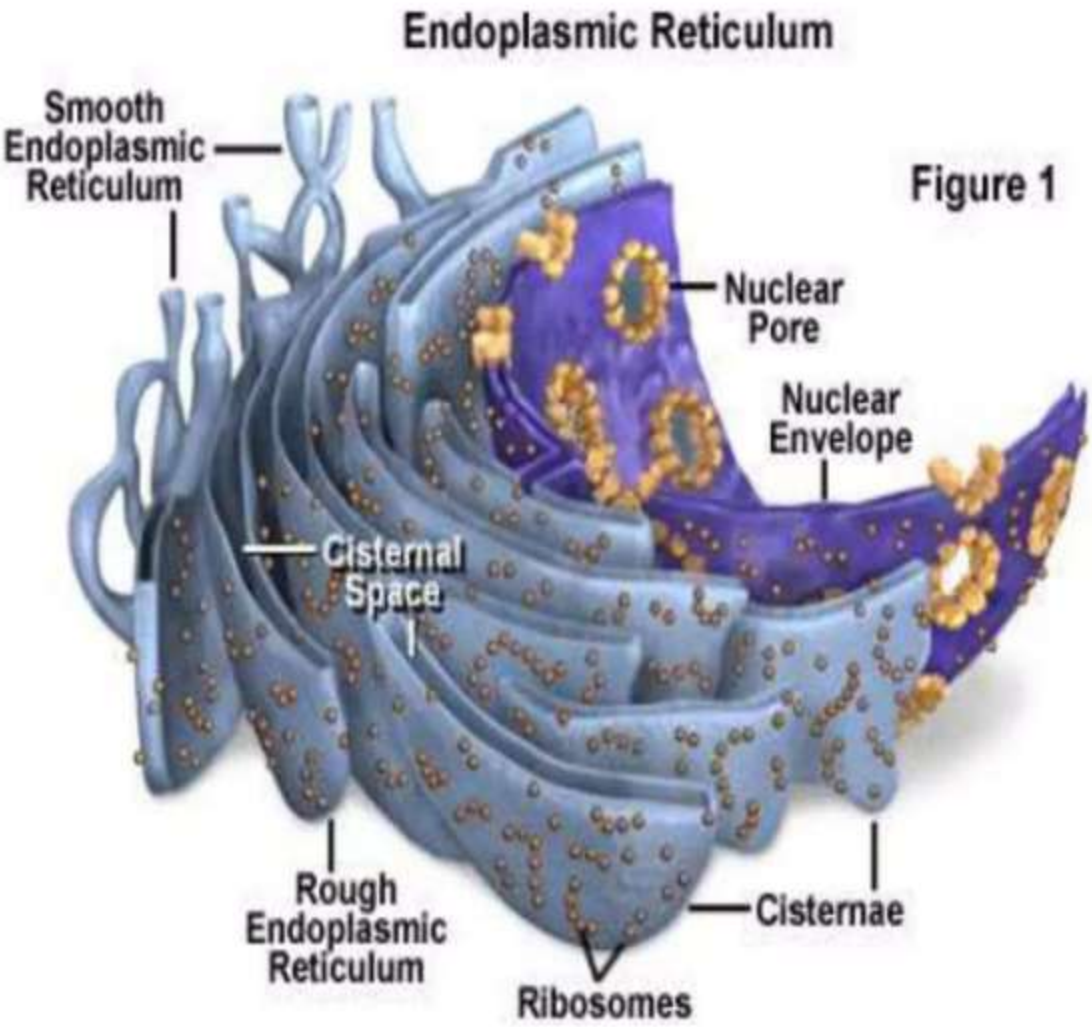
Garnier (1897) – first discovered the **Endoplasmic Reticulum** and named it **ergastoplasm,** but its ultrastructure was given by **Porter, Claude, and Fullum** in (1945).

K.R. Porter in (1953).

coined the term endoplasmic reticulum

Origin

- The most accepted view regarding origin of ER is that RER arises as an invagination of outer nuclear membrane while the SER are formed from RER by loss of ribosomes.
- Intercisternal space of ER is continuous with perinuclear space.
- Fluid present in ER and perinuclear space is of similar nature.



STRUCTURE

- The Endoplasmic Reticulum is a part of Endomembranous system and is membrane bound organalle. The membrane of endoplasmic reticulum is 50-60 Å thick.
- E.R. is connected to nuclear pore through outer membrane of nucleus.
- When we look at the ultrastructure of E.R., it is composed of three types of elements.

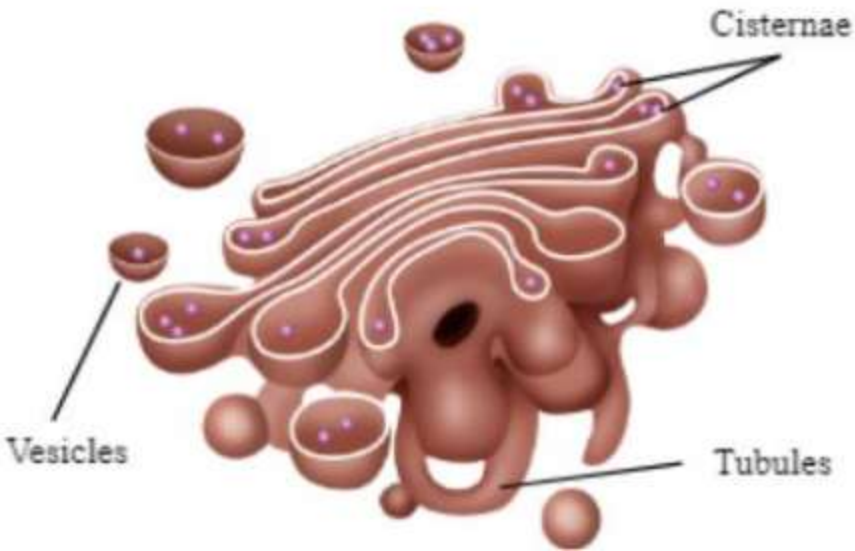
- **Cisternae** :-These are narrow, flattened and unbranched structures generally present near the nucleus. These lie parallel to each other and may be interconnected .They occur in the cells having active synthetic roles.

- **Tubules** :-Tubules are wider, tubular and irregulary branched elements mainly present near the cell membrane. Each is about 50-100µm diameter.

  These are without ribosomes and are actively involved in glycogen metabolism, lipid and steroid synthesis

- **Vesicles** :- These are spherical or oval bodies scattered in the cytoplasm whose diameter ranges from 25-500 µm. These are also studded with ribosomes and are present mainly in cells that are involved in protein synthesis.

  In spermatocytes vesicles are the only ER structures found

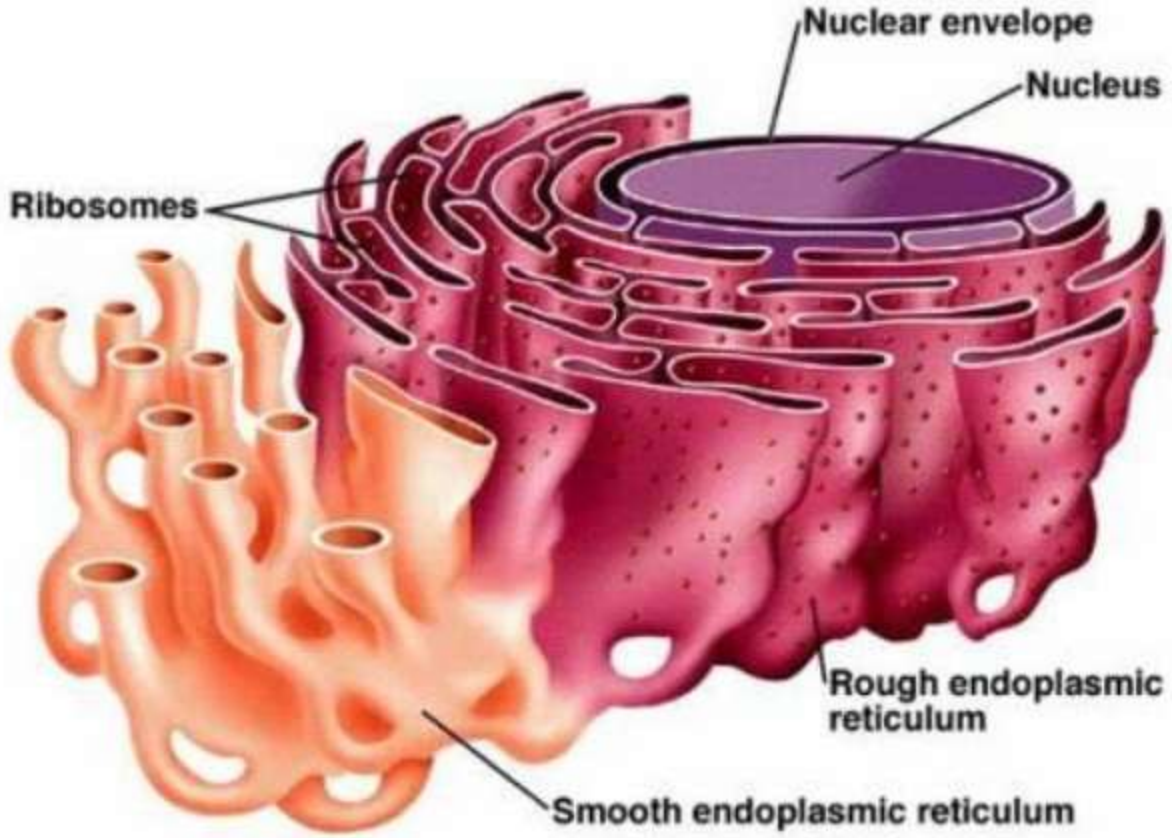


Endoplasmic reticulum enzymes and their roles

Enzyme	Type/Location	Function/Role
Protein Disulfide Isomerase (PDI)	Lumenal	Catalyzes formation and rearrangement of disulfide bonds in nascent proteins.
BiP (Binding Immunoglobulin Protein)	Lumenal chaperone	Assists in protein folding and assembly; part of the unfolded protein response.
Calnexin/Calreticulin	Lumenal chaperones	Bind glycoproteins and assist in proper protein folding (calcium-dependent).
ERp57	Lumenal	Works with calnexin/calreticulin to form correct disulfide bonds in glycoproteins.
Cytochrome P450 enzymes	Membrane-bound (smooth ER)	Involved in drug metabolism, steroid synthesis, and detoxification.
UDP-glucuronosyltransferase (UGT)	Membrane-bound (smooth ER)	Adds glucuronic acid to substances for detoxification and excretion.
Oligosaccharyltransferase (OST)	Lumenal	Transfers oligosaccharides to nascent proteins (N-linked glycosylation).
Glucosidase I and II	Lumenal	Trims glucose residues during glycoprotein processing.
ER α-glucosidase	Lumenal	Involved in glycoprotein quality control by trimming N-glycans.
Sterol regulatory element-binding proteins (SREBPs)	Membrane-bound precursors	Regulate cholesterol and lipid biosynthesis; activated in ER stress.
SERCA (Sarco/Endoplasmic Reticulum Ca^{2+}-ATPase)	Membrane-bound	Pumps Ca^{2+} into ER lumen, maintaining calcium homeostasis.
Phospholipid synthases	Membrane-associated	Involved in synthesis of phospholipids for membranes.

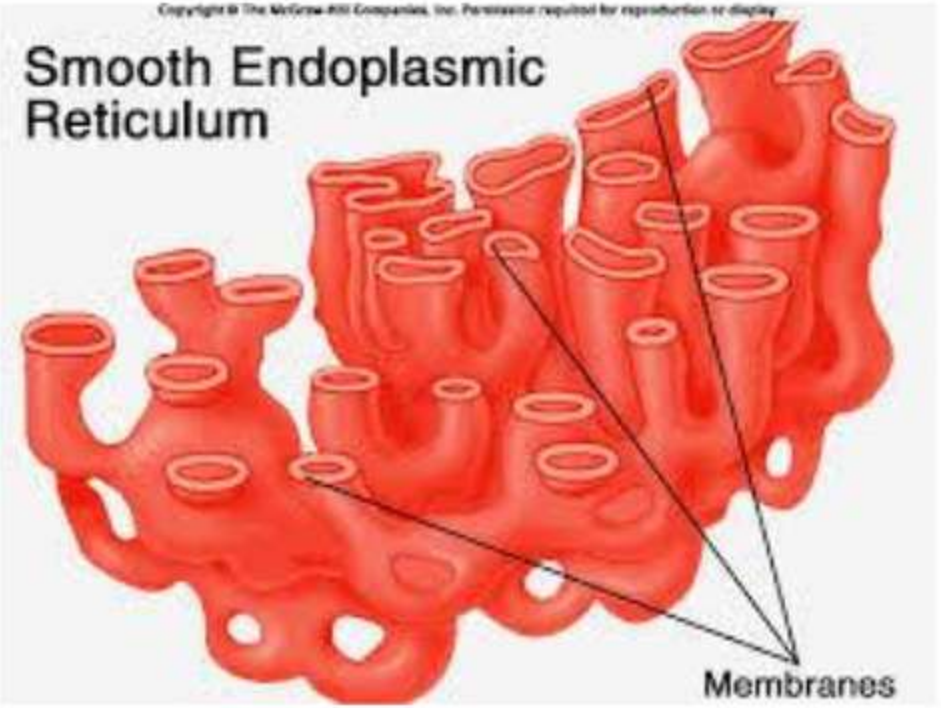
TYPES OF ENDOPLASMIC RETICULUM

- E.R.is of Two types
- Smooth endoplasmic reticulum(S.E.R.)
- Rough endoplasmic reticulum(R.E.R.)
- Smooth ER- which don't have ribosomes on their surface. The have smooth surface.
- Rough ER- which is coated with ribosomes Rough ER is the site of protein synthesis



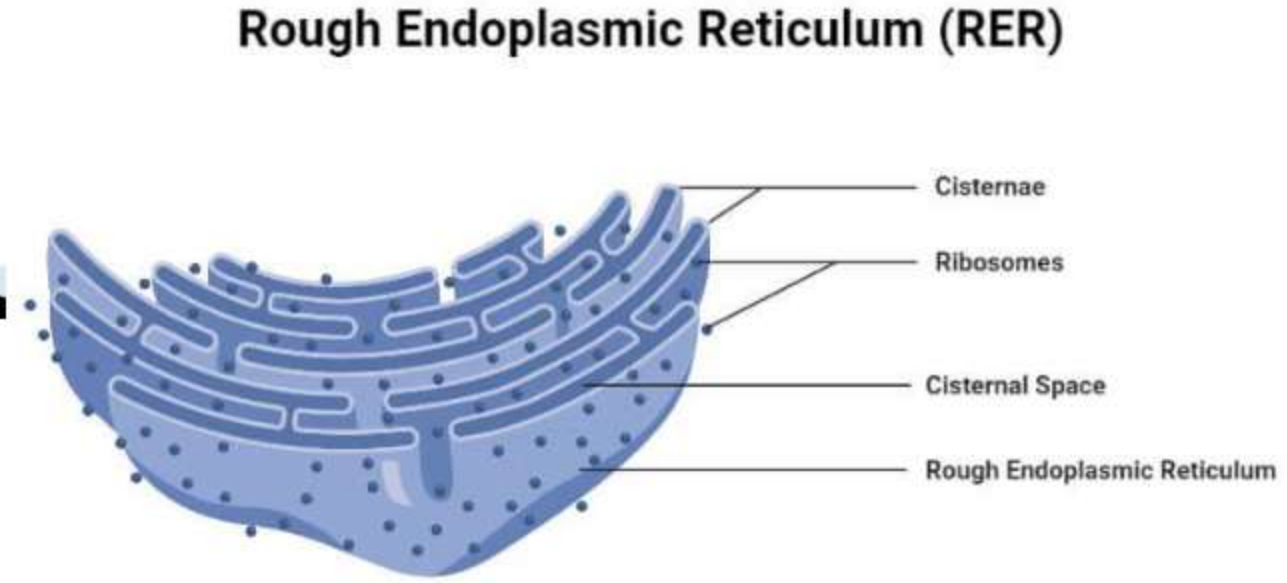
Smooth E.R.

- SER consist of a long network of a folded, tube like structure.
- It is more abundant in mammalian liver cells and gonad cells
- SER is formed from RER when it loses ribosomes



Rough E.R.

- It is composed of membranes that are folded into one another to provide maximum space.
- More abundantly found in hepatocytes.
- Nuclear envelop is formed from the cisternae of RER during telophase of cell division.



Roles of the Smooth Endoplasmic Reticulum (SER):

Function	Description
Lipid Synthesis	Produces phospholipids and cholesterol, essential for cell membrane formation.
Steroid Hormone Production	Synthesizes steroid hormones in endocrine cells (e.g., adrenal glands, gonads).
Detoxification	Detoxifies drugs and harmful chemicals, especially in liver cells.
Carbohydrate Metabolism	Involved in glycogen breakdown and glucose release (especially in liver cells).
Calcium Ion Storage	Regulates calcium ion concentration, crucial in muscle contraction.
Membrane Production	Supplies membrane components for other organelles and for cell expansion.

Role of smooth endoplasmic reticulum in lipid synthesis and detoxification

1. Lipid Synthesis:

Phospholipids:

The SER is the primary site for synthesizing phospholipids, which are essential components of cell membranes. This process involves the condensation of two fatty acyl coenzyme A (CoA) molecules with glycerol phosphate to form phosphatidic ac a precursor for phospholipids.

Cholesterol:

The SER also synthesizes cholesterol, another crucial lipid involved in cell membran structure and hormone production.

Lipoproteins:

The SER is involved in the production of lipoprotein particles, which transport lipids the bloodstream.

2. Steroid Hormone Synthesis:

- The SER contains enzymes that catalyze the reactions involved in the synthesis o steroid hormones, such as cortisol and testosterone, from cholesterol. This proce is particularly important in endocrine glands like the adrenal gland and gonads.

3. Lipid Detoxification:

- The SER plays a vital role in metabolizing lipid-soluble compounds, including drug and toxins. The SER's enzymes can modify these compounds, making them more water-soluble for easier excretion. This detoxification function is particularly important in the liver.

In essence, the smooth endoplasmic reticulum is a crucial hub for lipid metabolism, playing a vital role in synthesizing essential lipids, producing steroid hormones, and detoxifying lipid-soluble substances.

Role of smooth endoplasmic reticulum in detoxification

Detoxification Enzymes:

The SER contains various enzymes, including cytochrome P450, that are essential for detoxifying drugs and other harmful compounds. These enzymes can modify lipid-soluble substances, making them less toxic and more easily excreted.

Liver Cells:

Liver cells, which are rich in SER, are particularly important for drug detoxification due to their high metabolic activity.

Xenobiotic Metabolism:

The SER plays a crucial role in xenobiotic metabolism, which is the body's process of eliminating foreign substances, including drugs and pollutants.

Water-Soluble Products:

The detoxification process in the SER often converts lipid-soluble substances into more water-soluble forms, making them easier to excrete through urine or bile.

Drug Induction:

Certain drugs and chemicals can induce the synthesis of SER and its associated enzymes, leading to increased detoxification capacity.

Role of smooth endoplasmic reticulum in calcium regulation

Calcium Storage:

The SER acts as a reservoir for calcium ions within the cell.

Active Transport:

Calcium is pumped into the SER lumen (the space inside the SER) by specialized proteins called Ca2+-ATPases.

Calcium Release:

The stored calcium can be released from the SER in response to various signals, such as hormonal or nerve signals.

Muscle Cells:

In muscle cells, the SER is highly specialized and called the sarcoplasmic reticulum (SR). The SR plays a critical role in regulating muscle contraction by releasing calcium to initiate muscle fiber contraction and by pumping calcium back into the SR to allow muscle relaxation.

Signaling:

The release of calcium from the SER is a key signaling mechanism in various cellular processes, including muscle contraction, neurotransmitter release, and other cellular activities.

Regulation:

The concentration of calcium ions within the SER is tightly regulated, ensuring proper cellular function.

Roles of the Rough Endoplasmic Reticulum (RER)

Function	Description
Protein Synthesis	Ribosomes on the RER synthesize proteins destined for secretion or organelles.
Protein Folding	Newly synthesized proteins are folded into their correct 3D shapes.
Post-translational Modification	Proteins undergo modifications such as glycosylation (addition of sugars).
Quality Control	Misfolded or defective proteins are identified and sent for degradation.
Transport of Proteins	Transports proteins to the Golgi apparatus via vesicles for further processing.
Membrane Protein Production	Synthesizes integral membrane proteins for the cell and organelle membranes.

Role of Rough endoplasmic reticulum in protein synthesis

The endoplasmic reticulum (ER) plays a vital role in protein synthesis, particularly the rough endoplasmic reticulum (RER). RER, studded with ribosomes, is the site where many proteins, especially those destined for secretion or for incorporation into cellular membranes, are synthesized and processed. The ER also functions in protein folding, modification, and quality control, ensuring that proteins are correctly shaped and functional before they are shipped to other parts of the cell.

Here's a more detailed breakdown:

Protein Synthesis:

Ribosomes on the RER translate mRNA into proteins, which are then translocated into the ER lumen (the space inside the ER).

Protein Folding and Modification:

Within the ER, proteins can fold into their proper 3D structures, and they may undergo modifications like glycosylation (adding sugar groups).

Protein Quality Control:

The ER monitors the quality of proteins and can help eliminate misfolded or damaged proteins.

Protein Transport:

Proteins synthesized in the ER are packaged into transport vesicles and moved to other organelles, like the Golgi apparatus, for further processing and sorting.

Membrane Protein Synthesis:

The ER also synthesizes transmembrane proteins, which are embedded in the membranes of various organelles, including the cell membrane.

In summary, the ER, especially the RER, is a crucial hub for protein synthesis, processing, and trafficking within the cell.