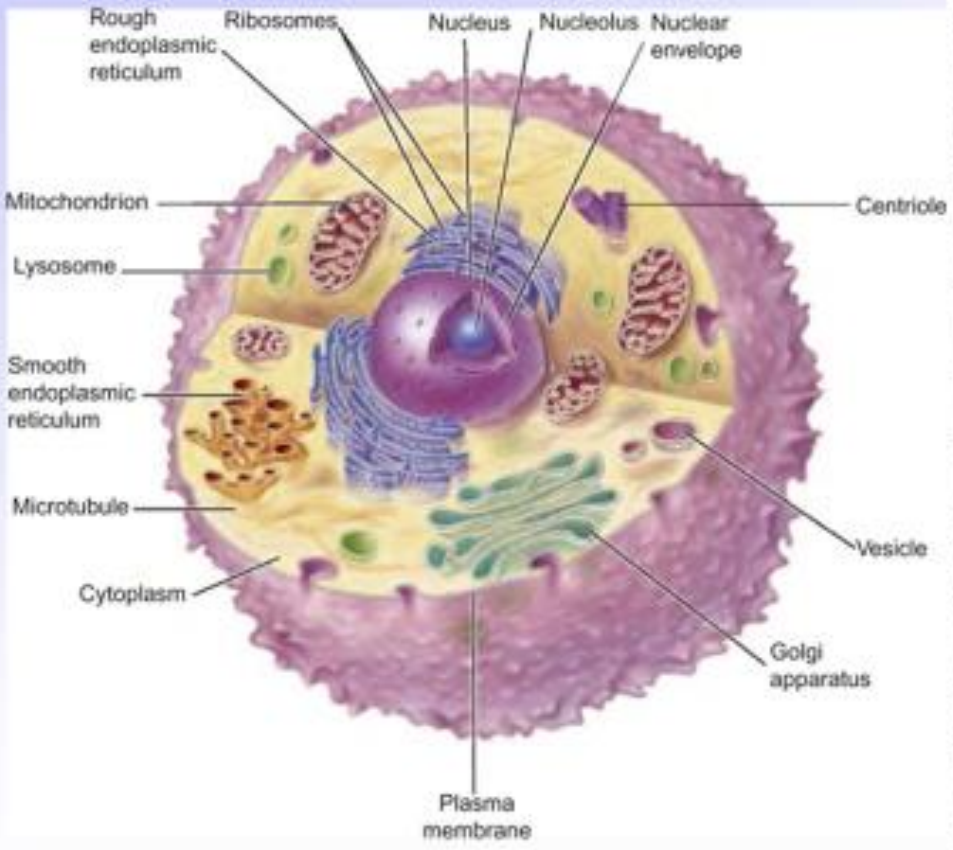
University of Teramo

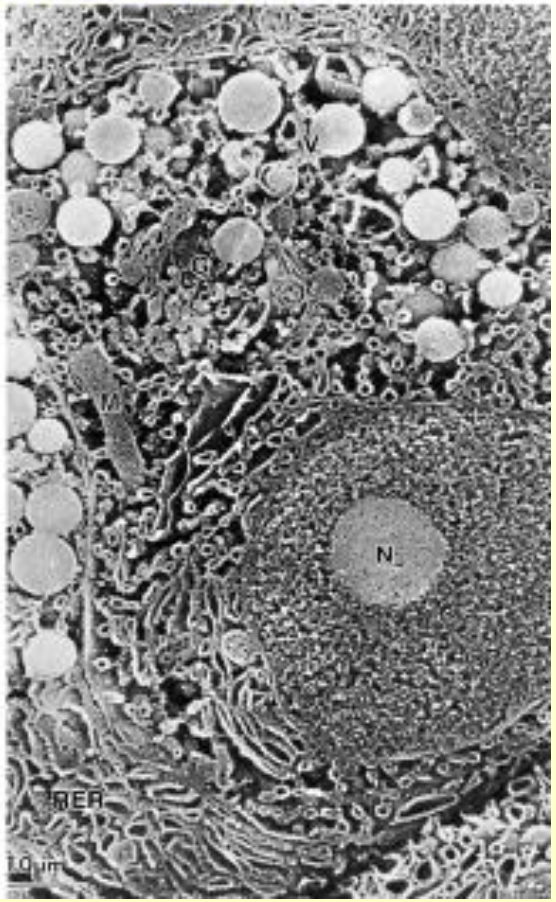
Degree Program in Biotechnology

COURSE OF CYTOLOGY AND HISTOLOGY
Prof. Mauro

CITOPLASM AND ORGANELLES

Organization of the protoplasm of a eukaryotic cell





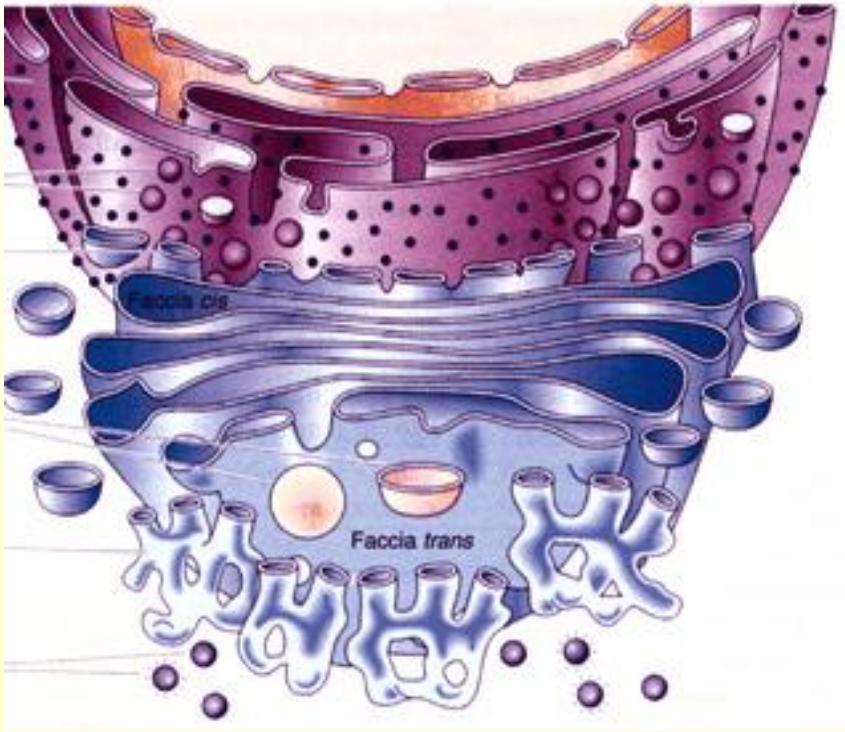
CELL ORGANELLES

Nucleus

Endoplasmic Reticulum

Golgi Apparatus

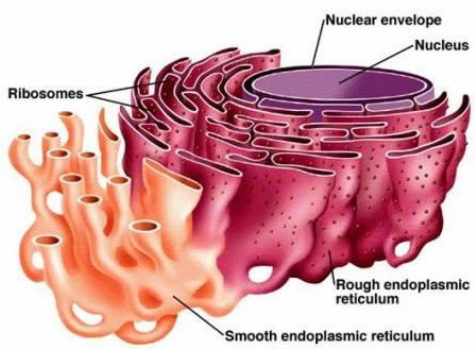
Membrane Vacuolar System



Mitochondria

Lysosomes

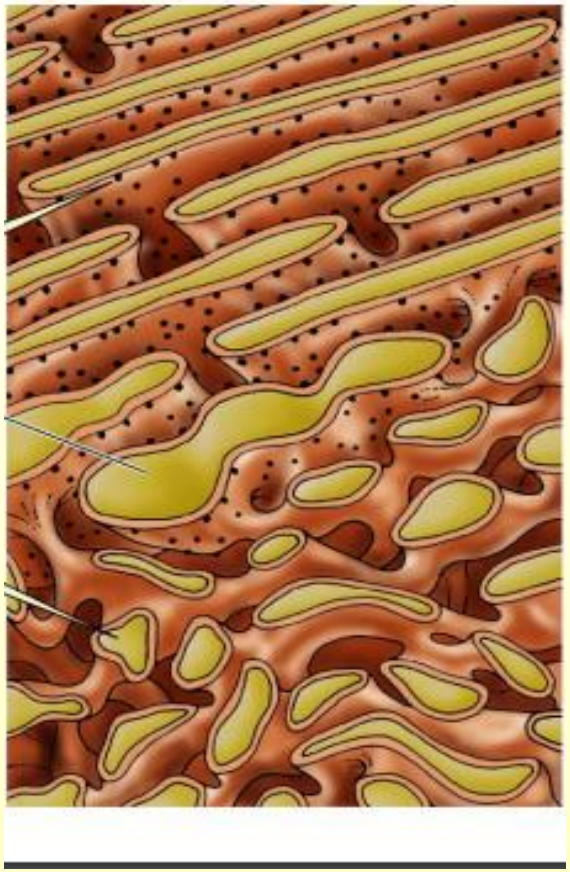
ENDOPLASMIC RETICULUM (ER)



***Endoplasmic Reticulum* (*ER*), a system of interconnected sacs and tubes of membrane that often extends throughout most of the cell**

***Rough endoplasmic reticulum* (*Rough ER, RER*)**

***Smooth endoplasmic reticulum* (*smooth ER ,SER*)**

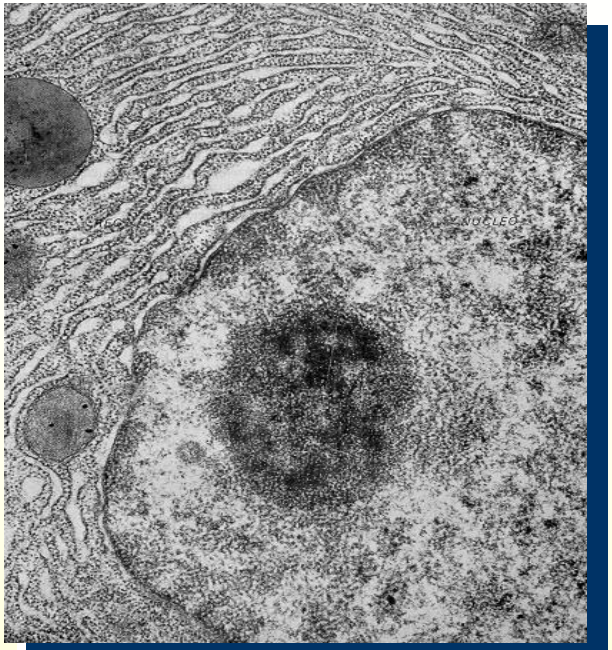


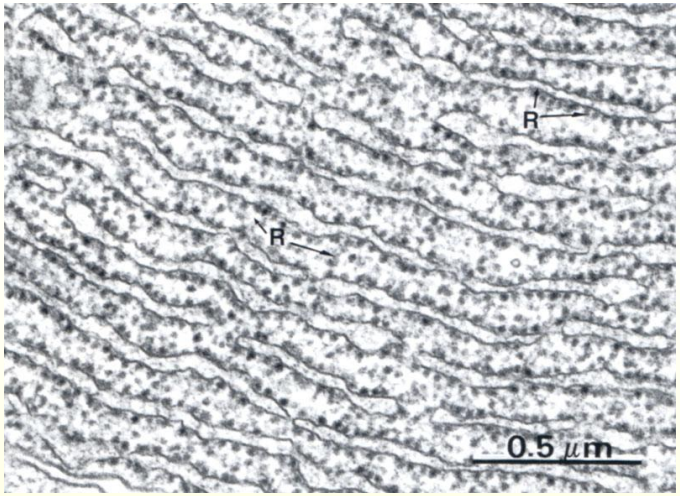
ENDOPLASMIC RETICULUM (ER)

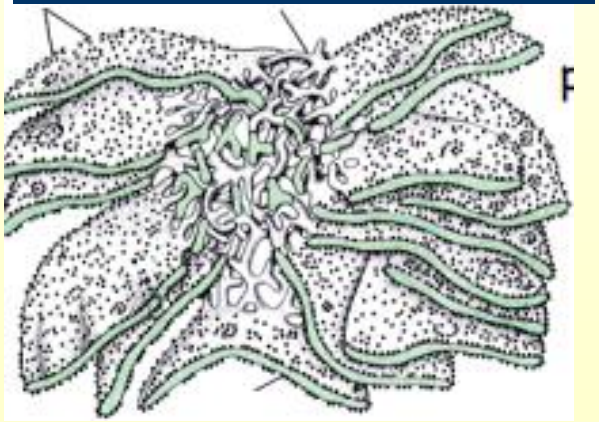
FUNCTIONS:

- Protein synthesis and remodeling (RER)
- Lipid and steroid synthesis (REL)
- Lipid degradation (REL)
- Detoxification of certain compounds (REL)
- Remodeling of all cell membranes (RER))

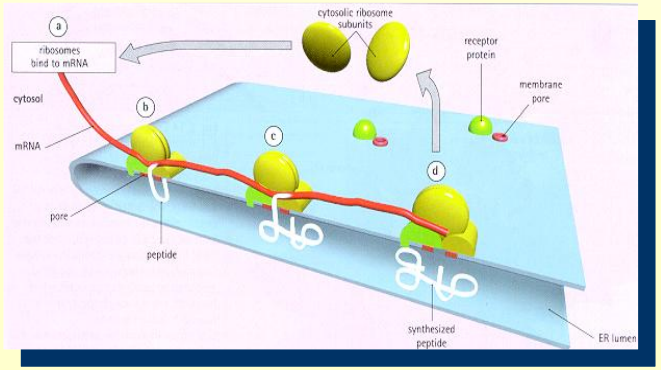
•Rough endoplasmic reticulum (RER)



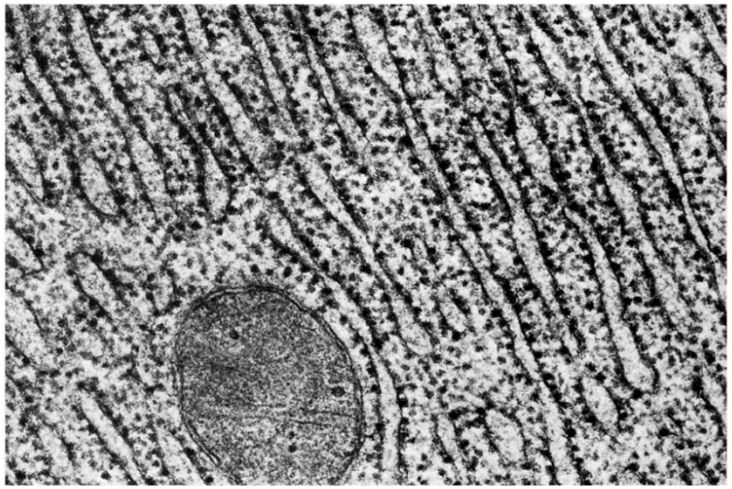


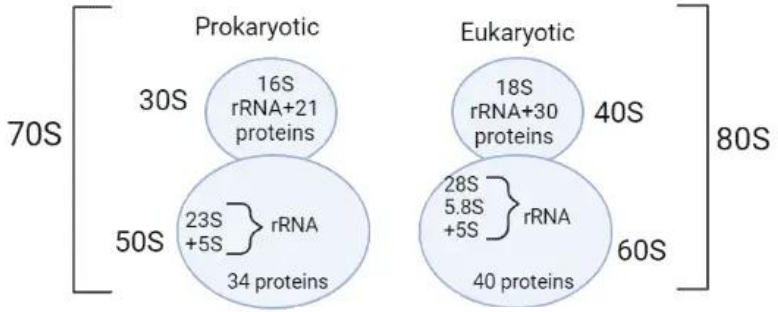


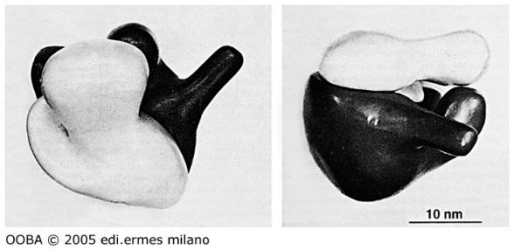
With the TEM, the RER appears as a series of interconnected, membrane-limited, flattened sacs called **cisternae**, with particles studding the exterior cytosolic surface of the membrane called **Ribosomes (15-20 nm)**

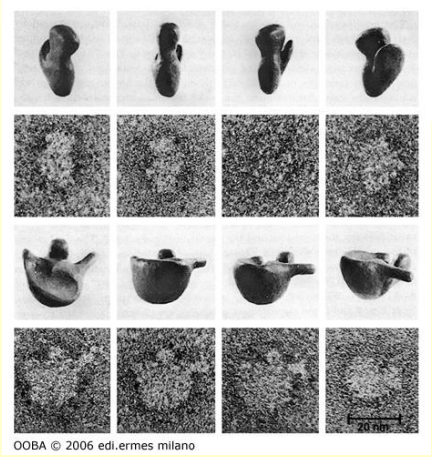


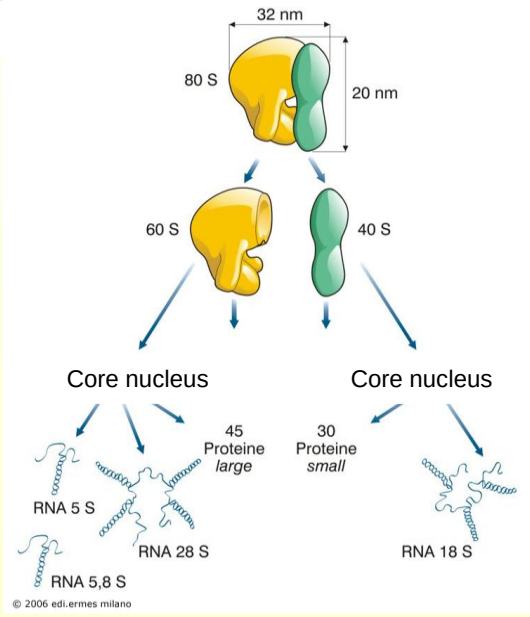
RIBOSOMES











Each Ribosome measure 15 to 20 nm in diameter and consist of a Small and Large subunit both produced in the *nucleulus*

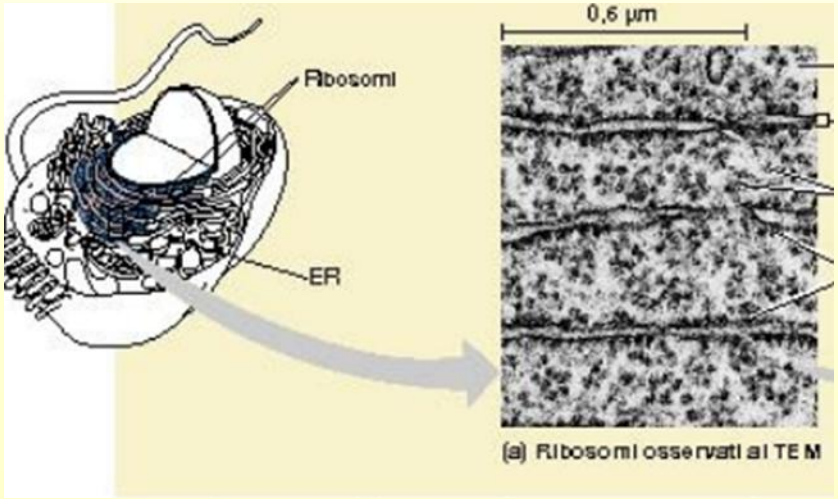
They function as a structural basis for protein synthesis.

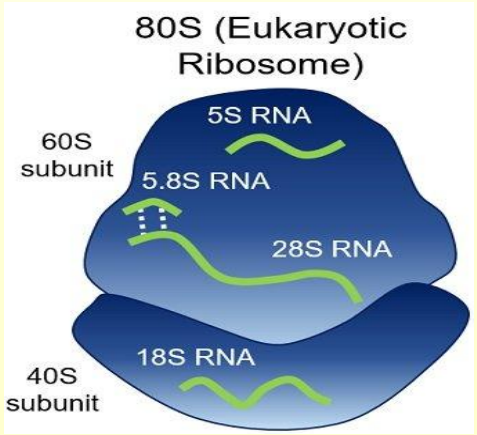
RIBOSOMES

Ribosomes are the organelles responsible for protein synthesis. In eukaryotic cells they can be:

Free ribosomes in the cytoplasm
Produce proteins:
– that are used in the cytosol

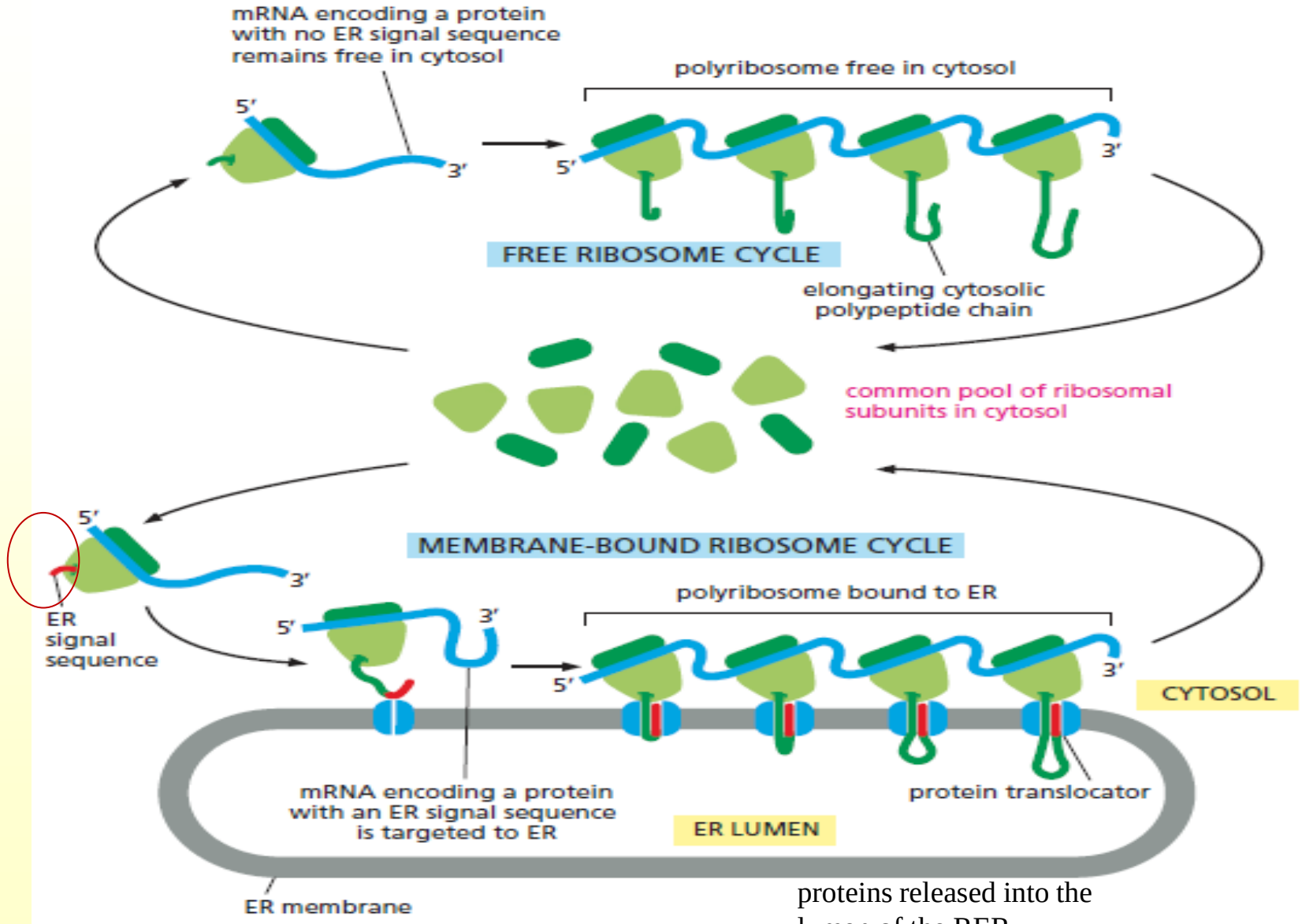
Bound ribosomes to the endoplasmic reticulum
Produce proteins:
– destined to be inserted into membranes, or
– destined to be exported from the cell (secreted)



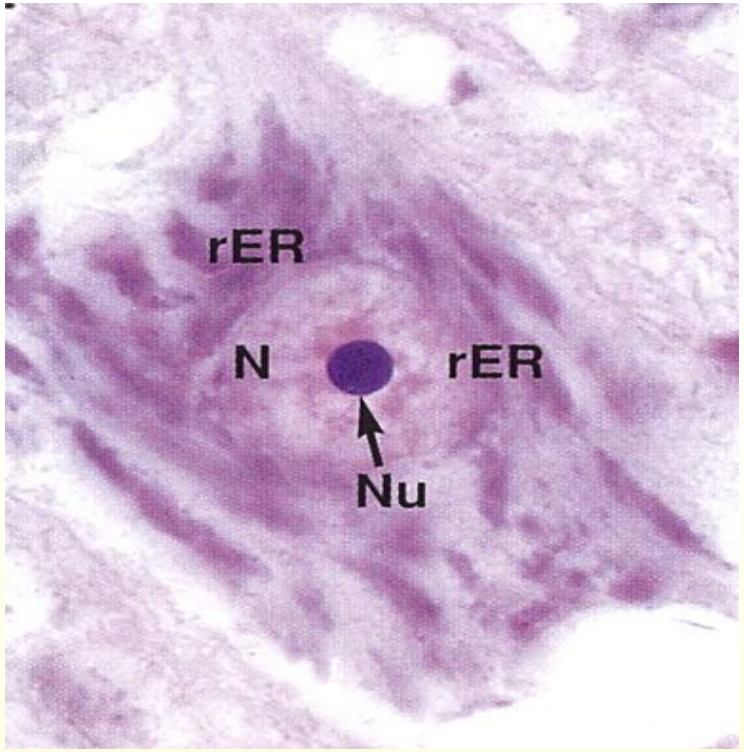


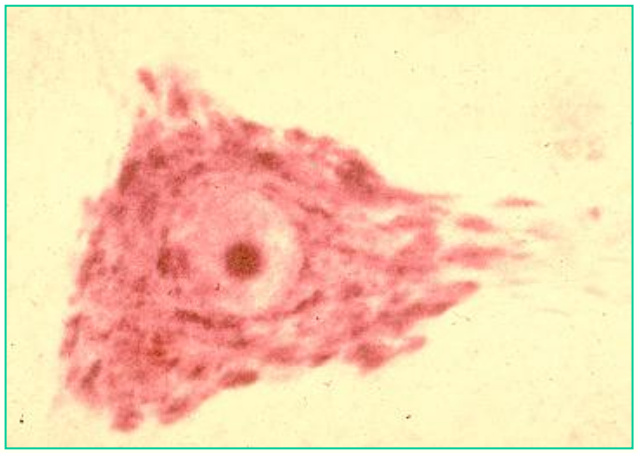
Membrane-bound ribosomes and free ribosomes are structurally and functionally identical; they differ only in the proteins they are making at any given time

RIBOSOMES: Protein synthesis mechanism



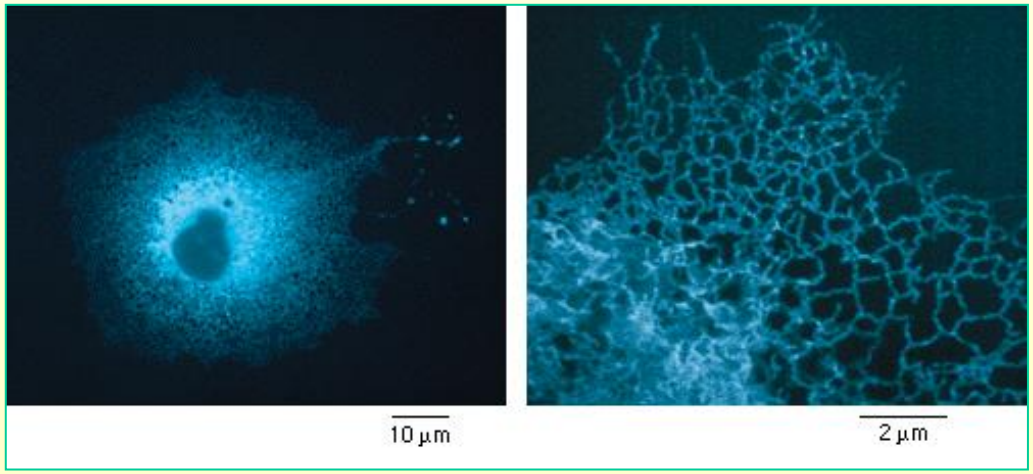
proteins released into the lumen of the RER



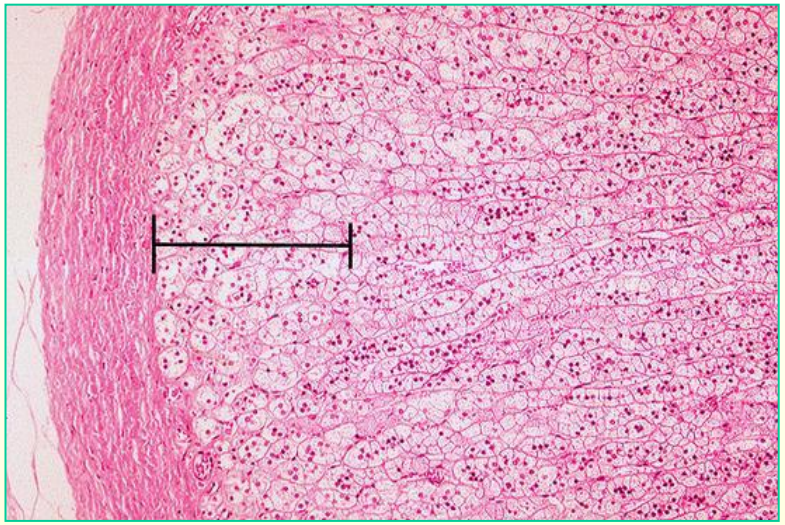


RER

Nissl bodies



•*Smooth endoplasmic reticulum (SER)*

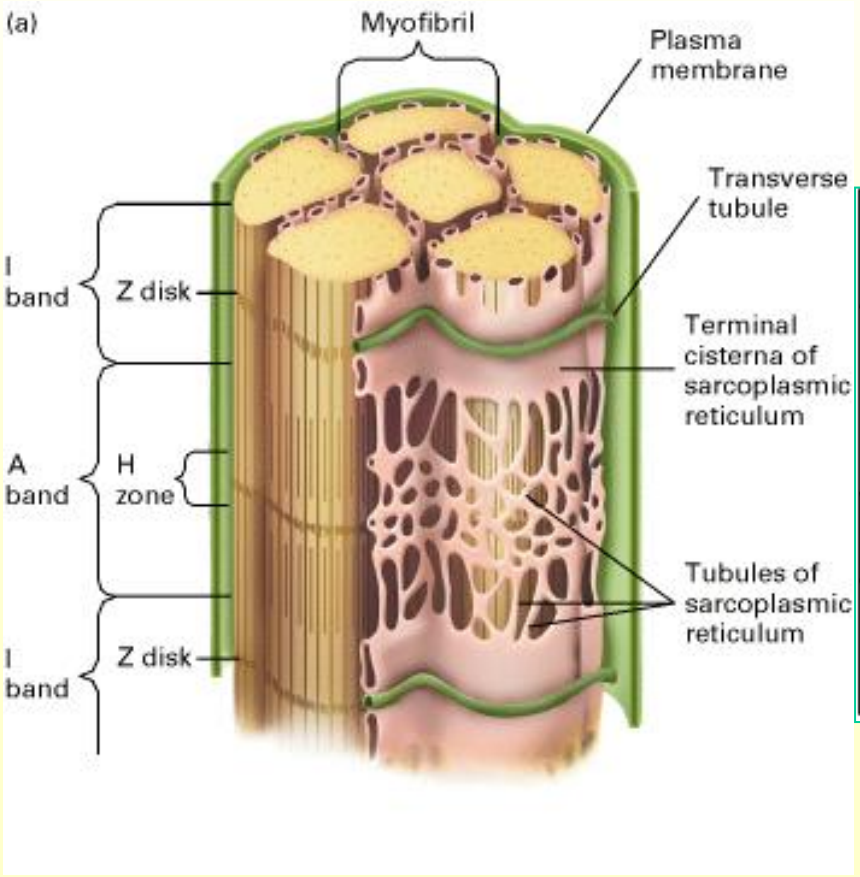


The **smooth endoplasmic reticulum (SER)** is a network of membrane-bound tubules and vesicles **without ribosomes**, hence the term *"smooth."*.

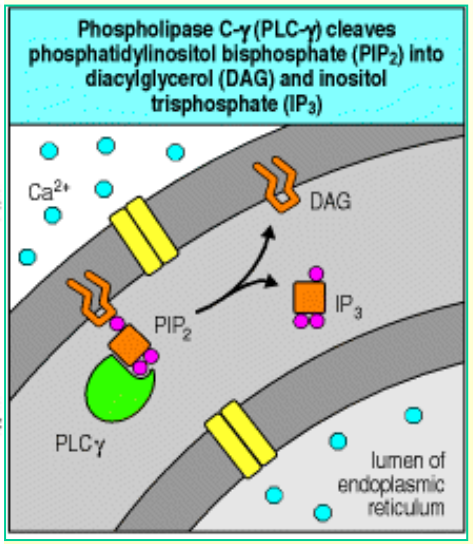
Abundant in **liver cells**, (key role in detoxifying drugs and harmful substances) and in **cells that produce steroid hormones** because it participates in lipid and steroid synthesis

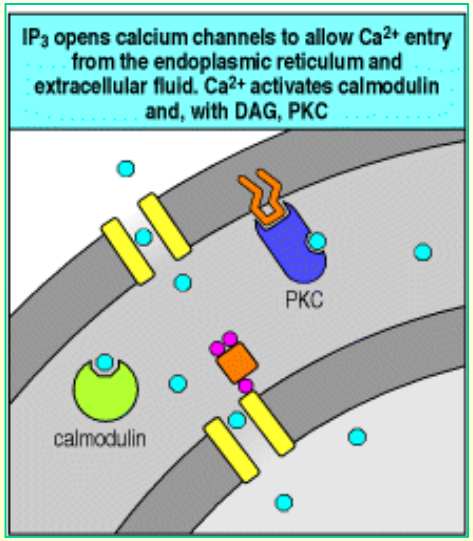
•Smooth endoplasmic reticulum (SER)

In muscle cells SER becomes highly specialized and is called the sarcoplasmic reticulum which serves as a storage site for calcium ions (Ca^{2+}).
Calcium release from this structure is essential for muscle contraction.

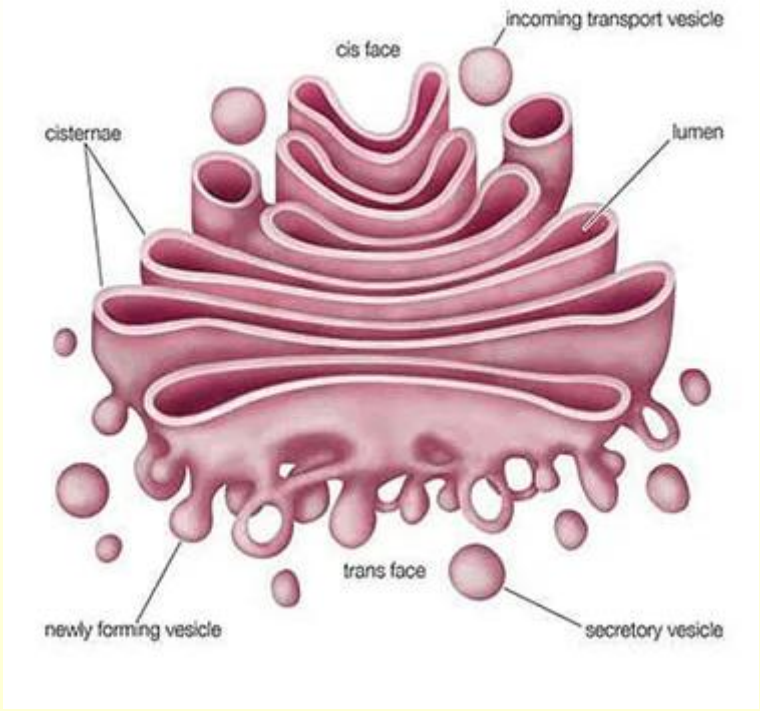


storage site for calcium ions (Ca^{2+})..





Golgi Apparatus



It consists of one or more series of flattened and slightly curved cisterns (Golgi stacks) and vesicles connected to each other.

Golgi Apparatus

Main functions:

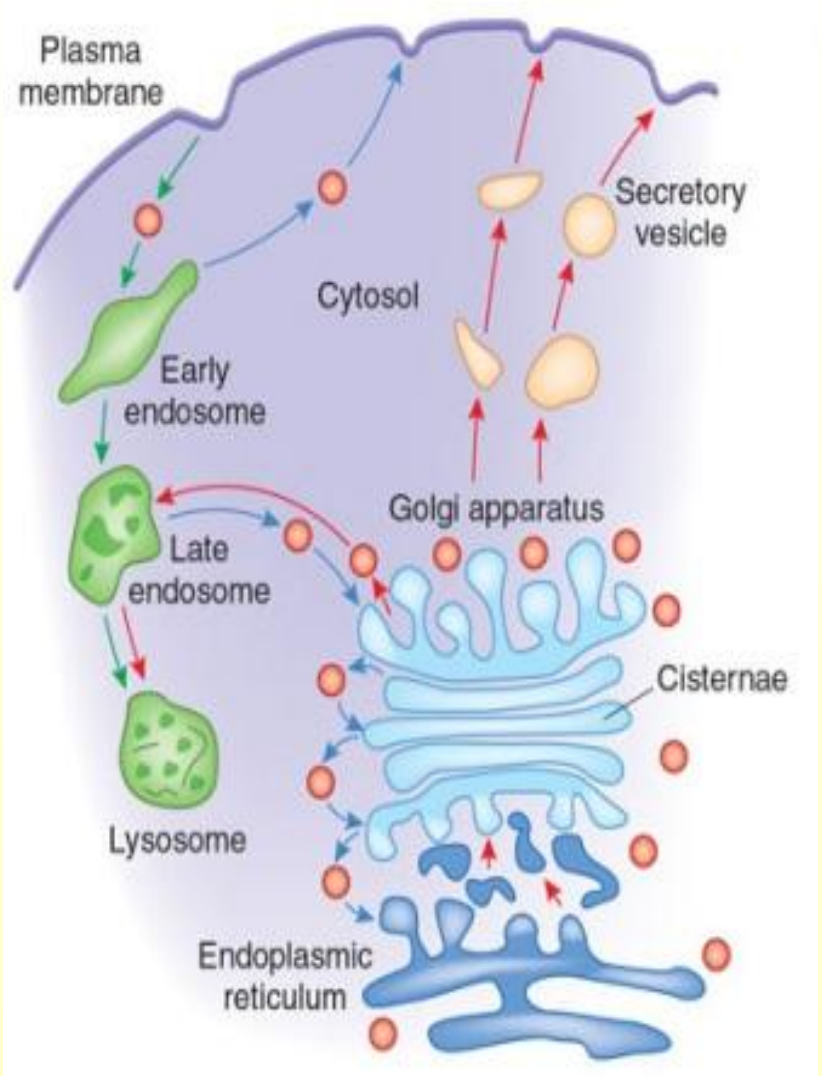
1.Modifies molecules that pass through its cisternae:

- **-Amino acid modification**
- **-Glycosylation:** Modification of the carbohydrate portion of a glycoprotein synthesized in the rough endoplasmic reticulum
- **-Modification of glycoproteins and glycolipids** synthesized as follows:
  a) Solvation
  b) Acetylation
  c) Deamination

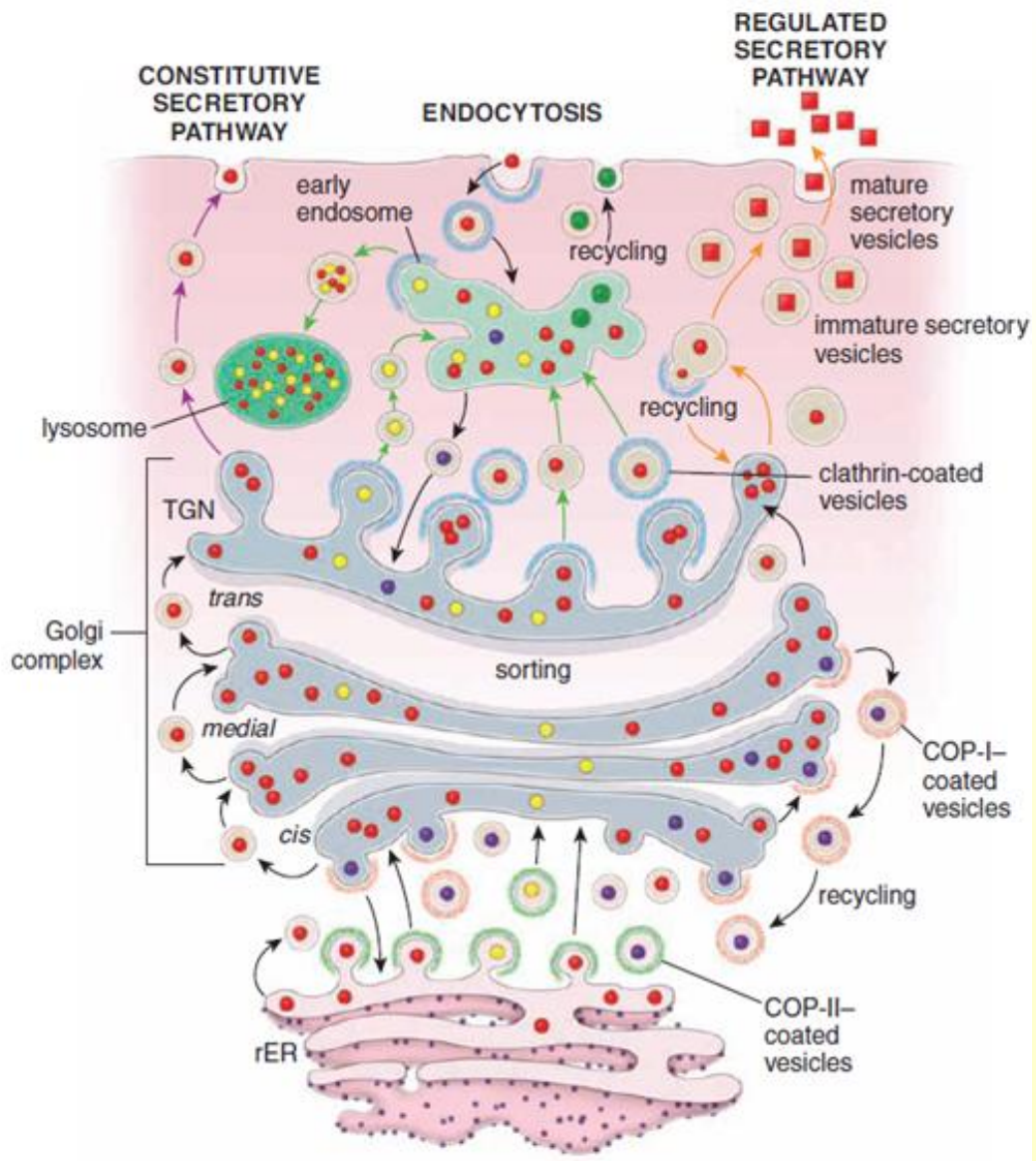
2.Remodeling of lipids: glycolipids and sphingomyelin

3.Synthesis of complex polysaccharides

4.Stores, packages, and distributes molecules already synthesized in different regions of the cell



Golgi Apparatus



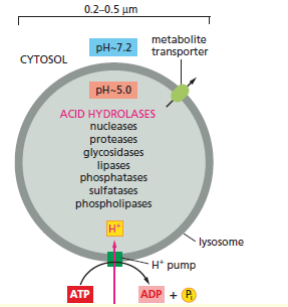
The proteins that leave the Golgi apparatus are enclosed in vesicles coated with plasma membrane and can have different destinations.

LYSOSOMES

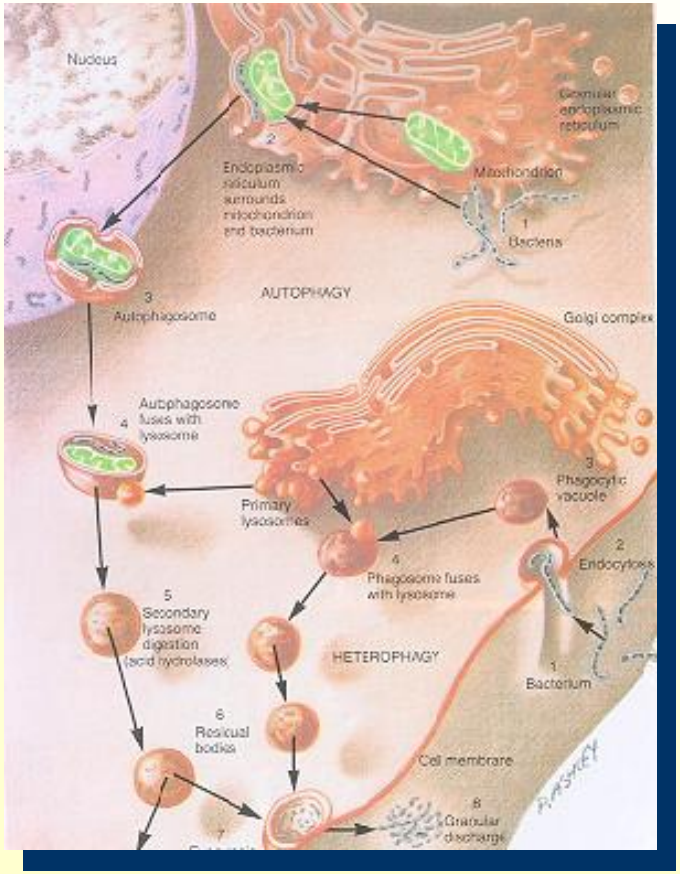
Lysosomes are the primary "degradation centers" that break down macromolecules

They contain about forty types of **hydrolytic enzymes**, including those that degrade **proteins, nucleic acids, polysaccharides, and phospholipids**.

The **acidic pH** inside lysosomes is maintained by a **proton pump (H^+ pump)** powered by ATP, which transfers protons into the lumen and keeps the internal environment acidic.



The **lysosomal membrane proteins** are highly **glycosylated** to protect them from the proteolytic activity of the enzymes they contain.



In cells that are destined for programmed death (apoptosis), lysosomes release their contents into the cell, causing AUTOLYSIS.

Mitochondria

ENERGY

Plants and Prokaryotes → Solar light
Fungi and Animals → Organic molecules

Cells Obtain Most of Their Energy by a Membrane-based Mechanism

In **eukaryotic cells**, the organelles responsible for **energy production** are the

MITOCHONDRIA

Mitochondria

They are cytoplasmic organelles present in all animal and plant eukaryotic cells and absent in prokaryotic cells.

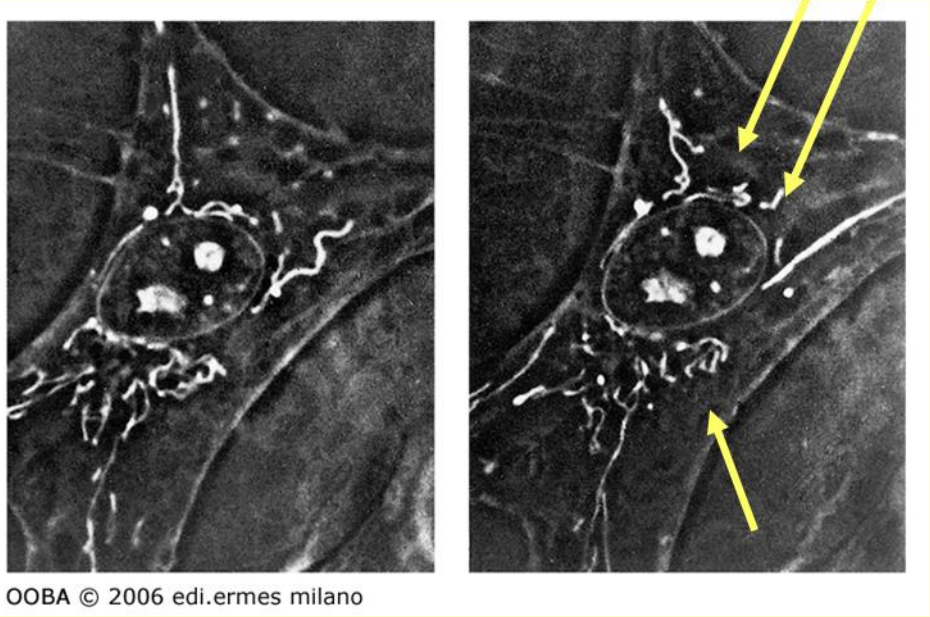
The collection of all mitochondria in a cell is called ***chondrioma***.

Mitochondria evolved from aerobic bacteria that were engulfed by eukaryotic cells.

Mitochondria

They are **dynamic**: they quickly change from a granular to a filamentous form, and can lengthen and shrink, shorten and swell thanks to the involvement of specific mitochondrial proteins

Movement in the cytoplasm depends on classic cellular motors:
microtubules and microfilaments.



Mitochondria

The number, shape, and internal structure of mitochondria are often characteristic for specific cell types.

•**Shape and size** (length 1-6 mm, diameter 0.2-1 mm) are related to the functional state and energy requirements of the cell. Shapes, include spheres, rods, elongated filaments, and even coiled structures.

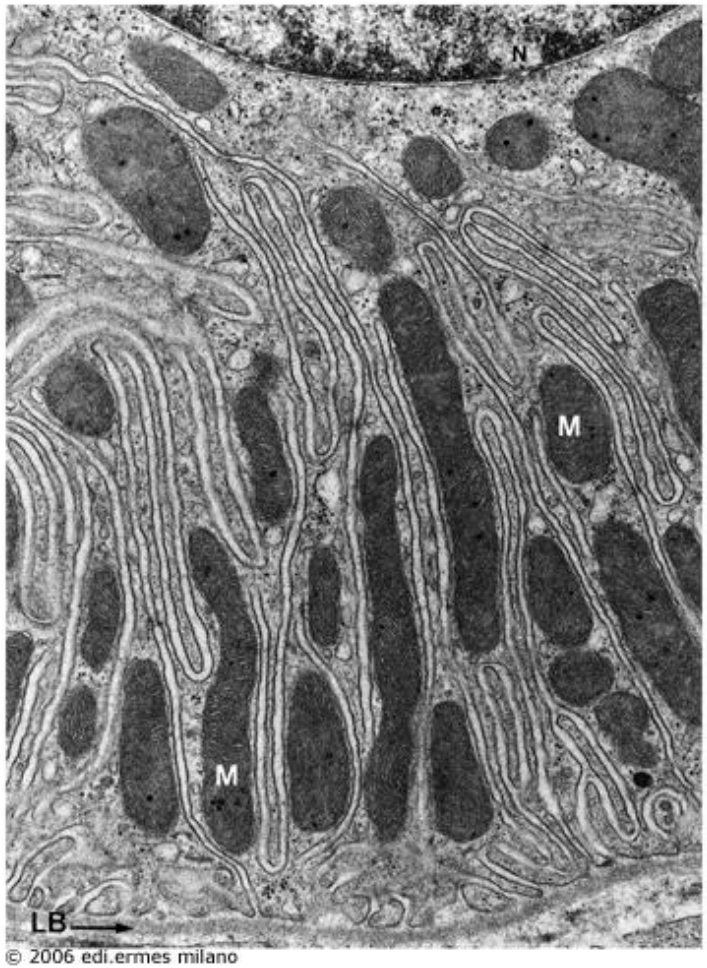
Number varies from cell to cell

From 1000-2000 in a normal cell

To 30.000 in the oocyte of some animal species

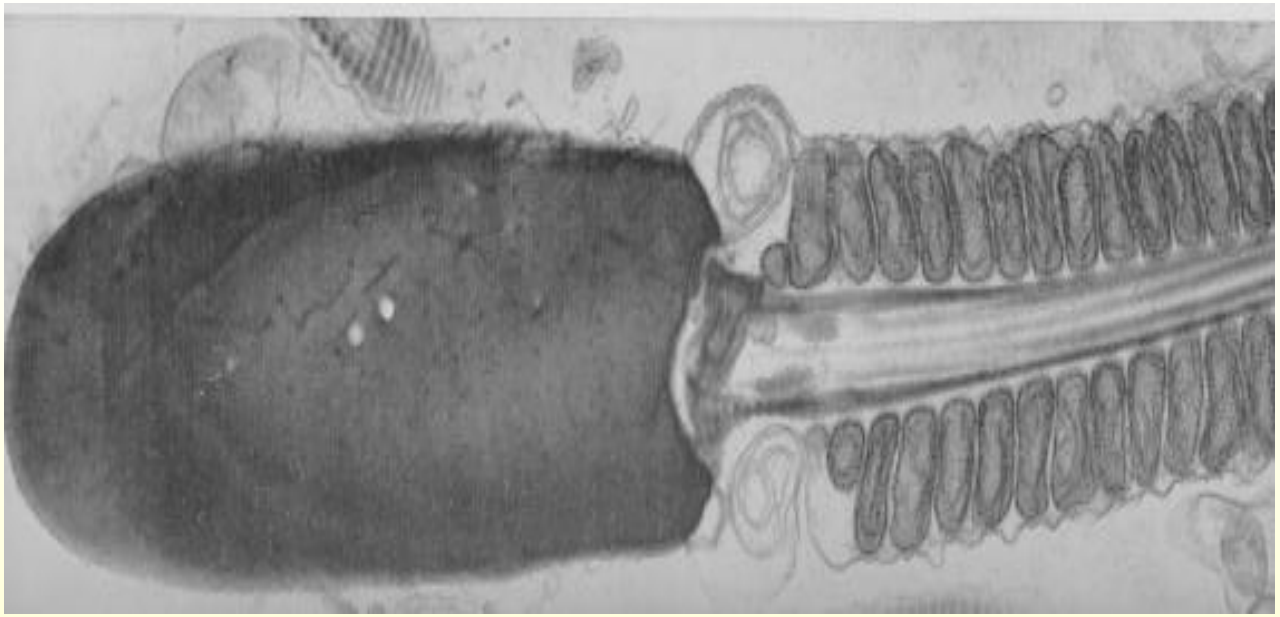
Distribution, generally uniformin the cytoplasm, however in some cells **localization** in relation to the areas where more energy is needed

Glandular cells at the base, epithelial cells at both poles,muscle cells aligned between the myofibrils,



Mitochondria located in the invaginations of the plasma membrane in cells of the distal convoluted tubule of the kidney

Mitochondria



In spermatozoa, mitochondria form a helical sheath in the middle part of the tail.

Energy production for cell motility

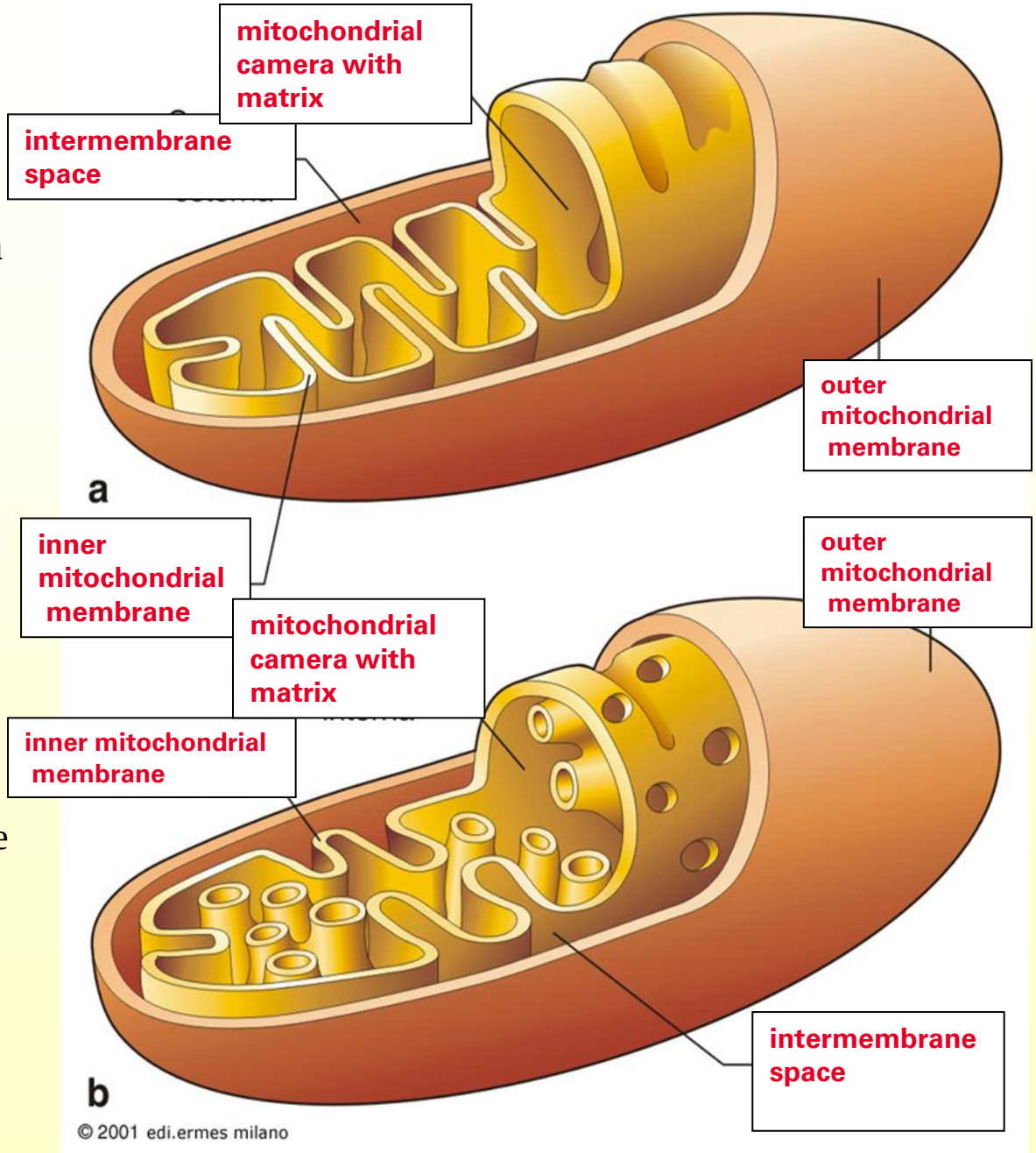
Mitochondria

Ultrastructure diagram

-Outer membrane
-Inner membrane
- mitochondrial camera with cristae

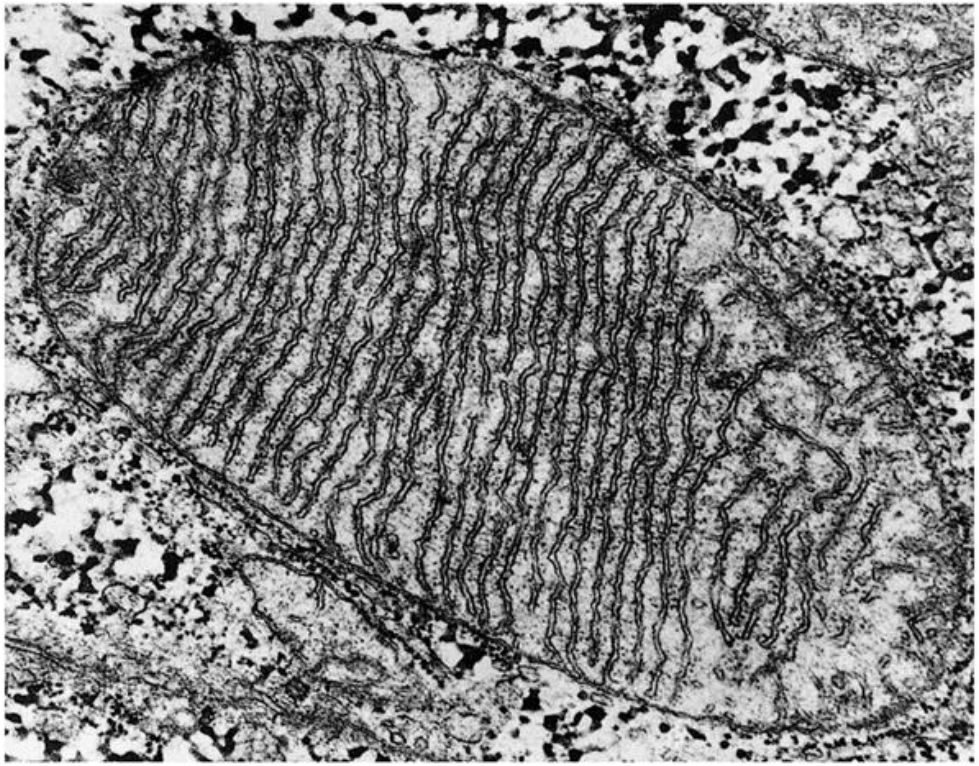
a) Mitochondria with flattened cristae perpendicular to the longitudinal axis

b) Mitochondria with tubular type cristae

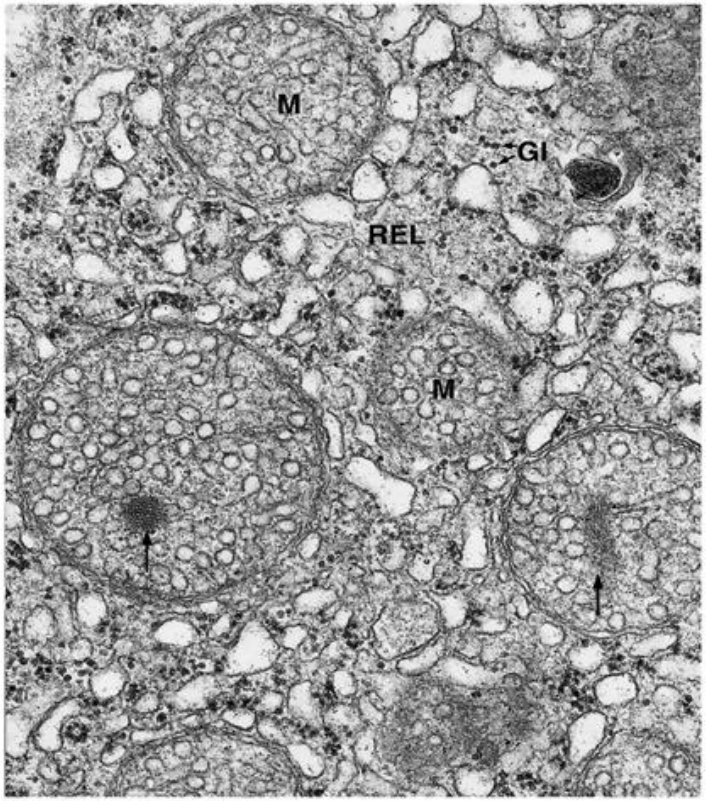


Mitochondria

TEM images of mitochondria

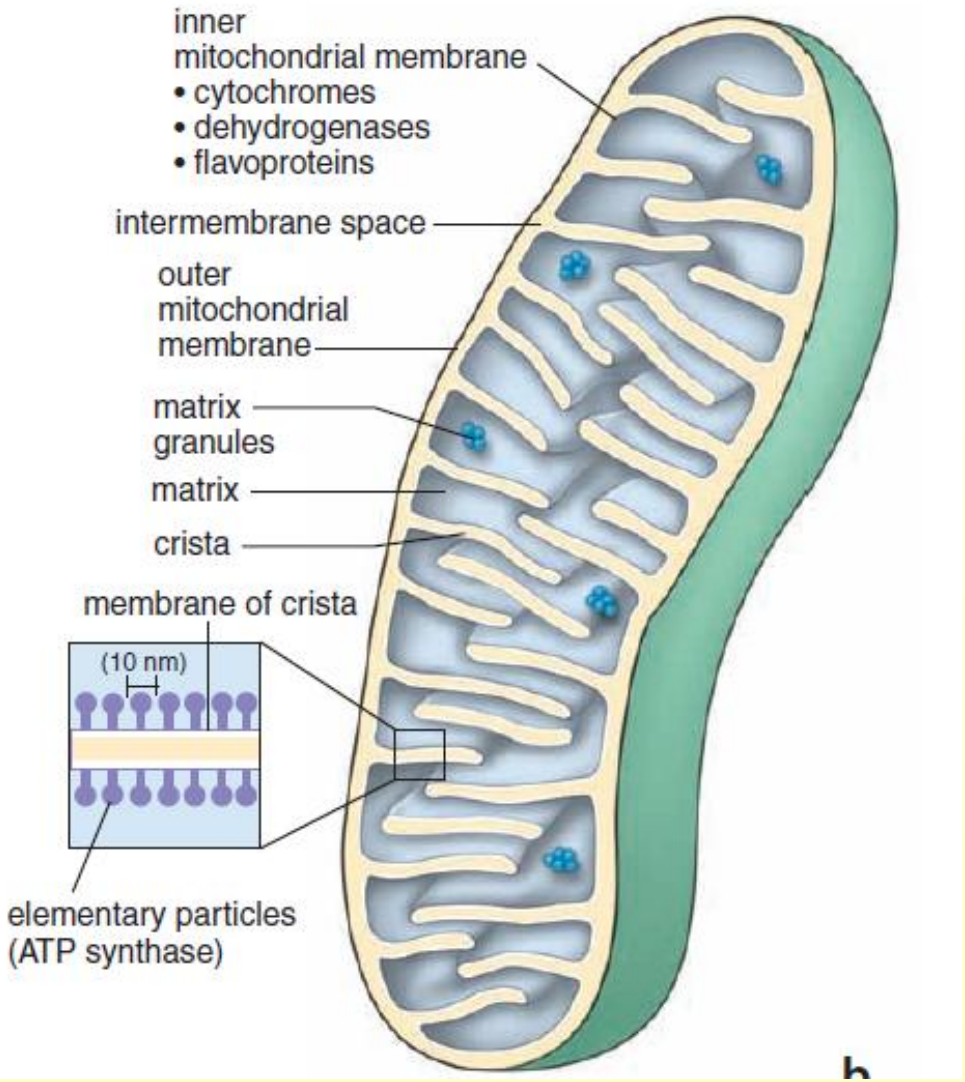


Mitochondria with flattened cristae perpendicular to the longitudinal axis

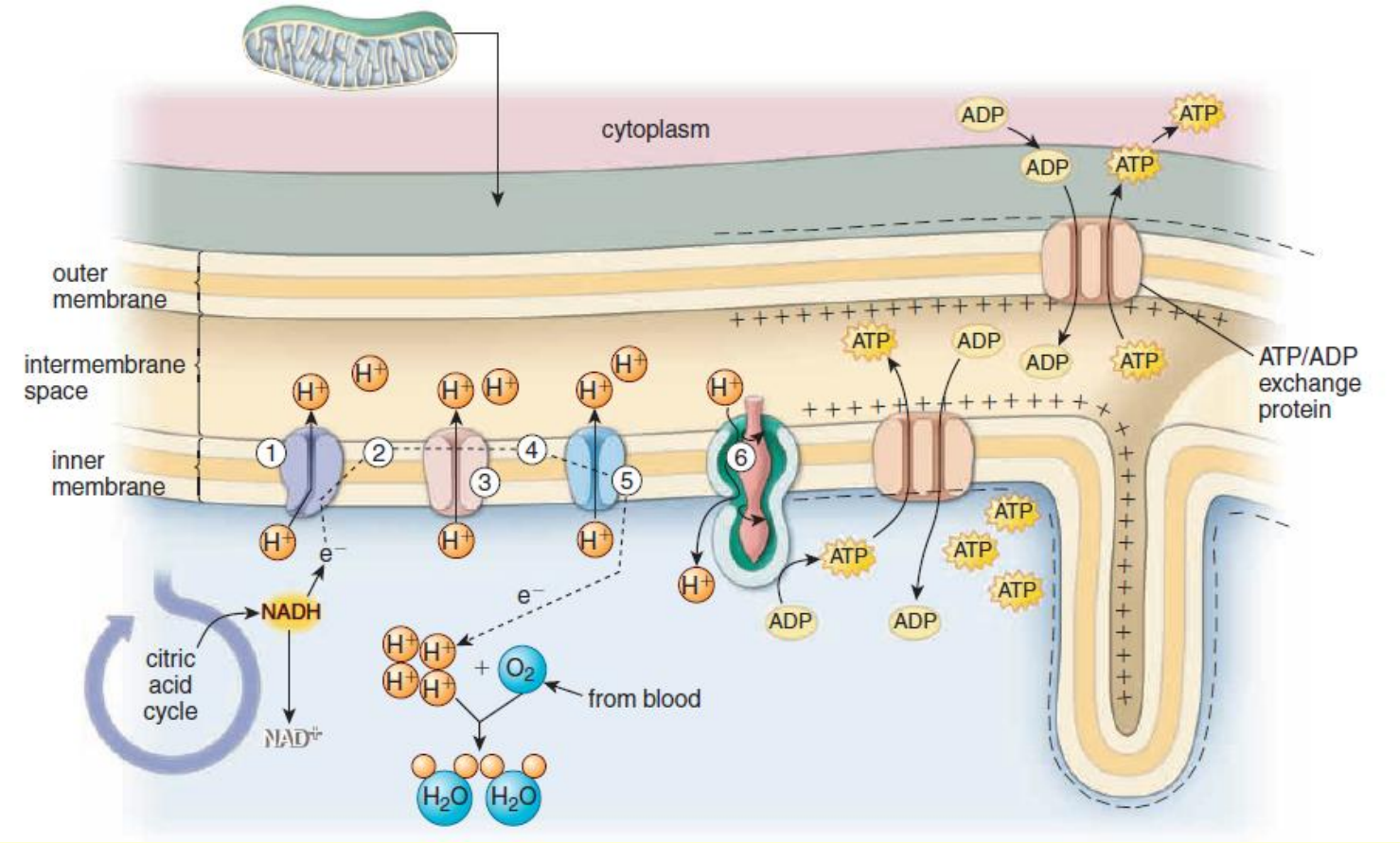


Mitochondria with tubular type cristae

Mitochondria



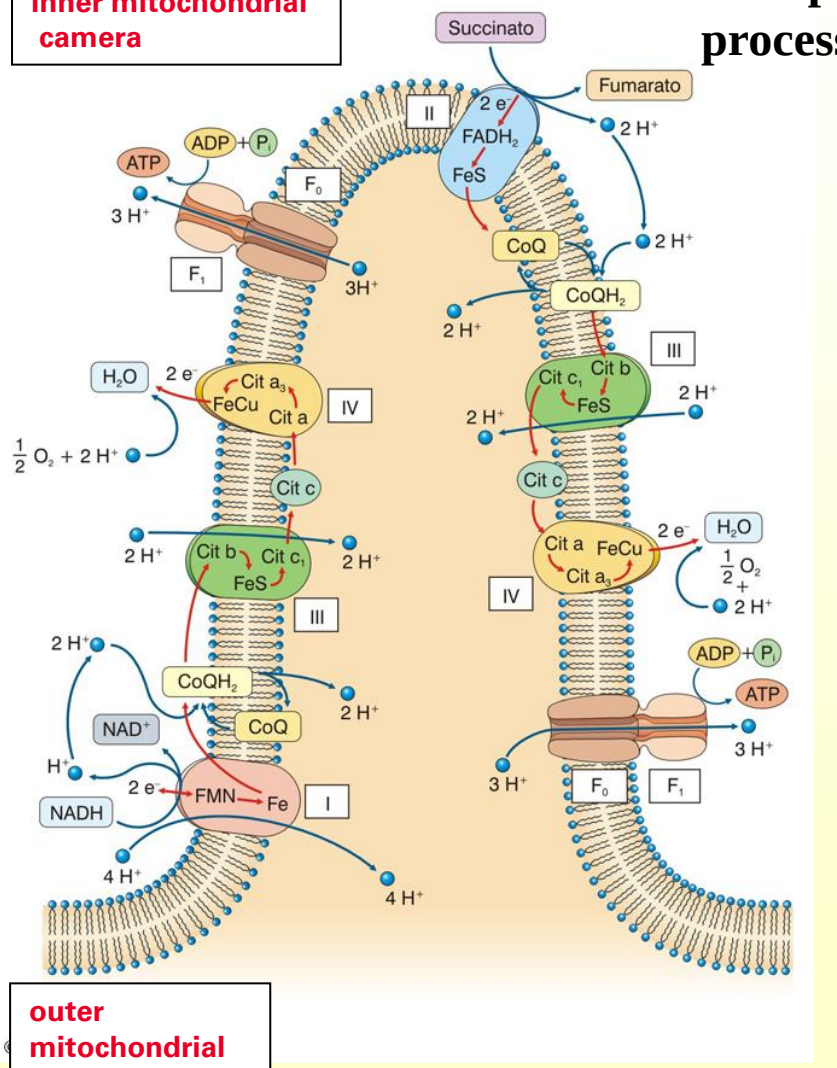
Mitochondria



Schematic diagram illustrating how mitochondria generate energy. The diagram indicates the ATP synthase complex and the electron-transport chain of proteins located in the inner mitochondrial membrane. The electron-transport chain generates a proton gradient between the matrix and intermembrane space that is used to produce ATP. *Numbers* represent sequential proteins involved in the electron-transport chain and ATP production: *1*, NADH dehydrogenase complex; *2*, ubiquinone; *3*, cytochrome *b*-*c*1 complex; *4*, cytochrome *c*; *5*, cytochrome oxidase complex; and *6*, ATP synthase complex.

Mitochondria

inner mitochondrial camera



outer mitochondrial camera

Inner Membrane

transport proteins involved in oxidative phosphorylation processes and electron transport

-NADH-CoQ reductase complex

Receives electrons from NADH and transfers them to coenzyme Q.

CoQ10-Cytochrome c reductase complex

Receives electrons from reduced coenzyme Q and transfers them to cytochrome c, a protein soluble in the membrane.

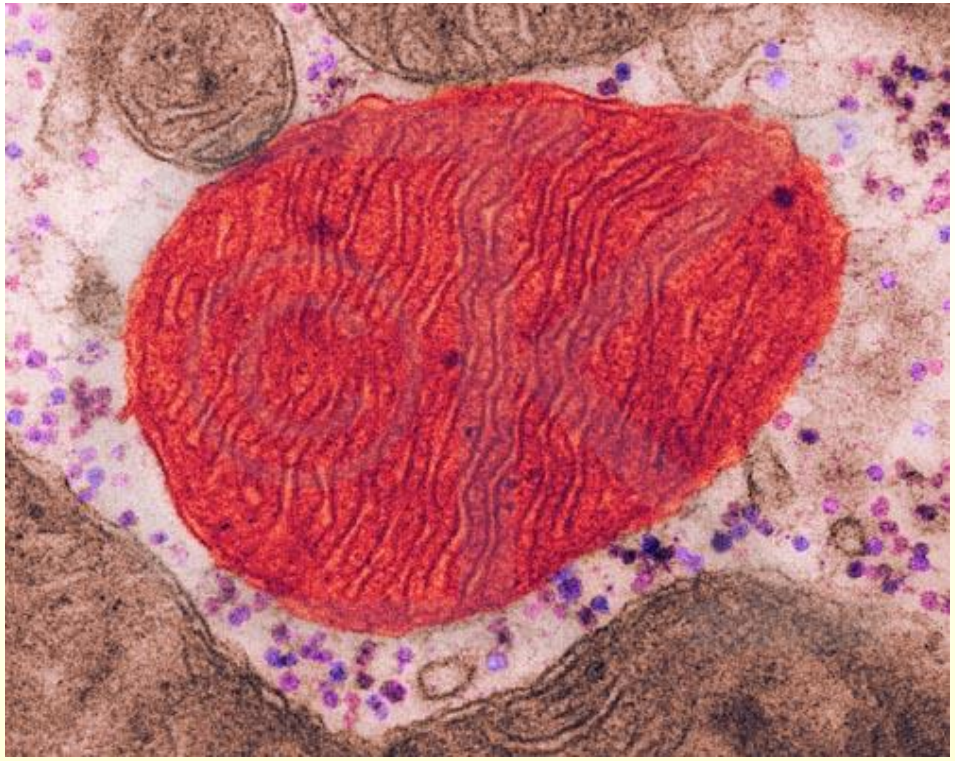
Cytochrome c oxidase complex

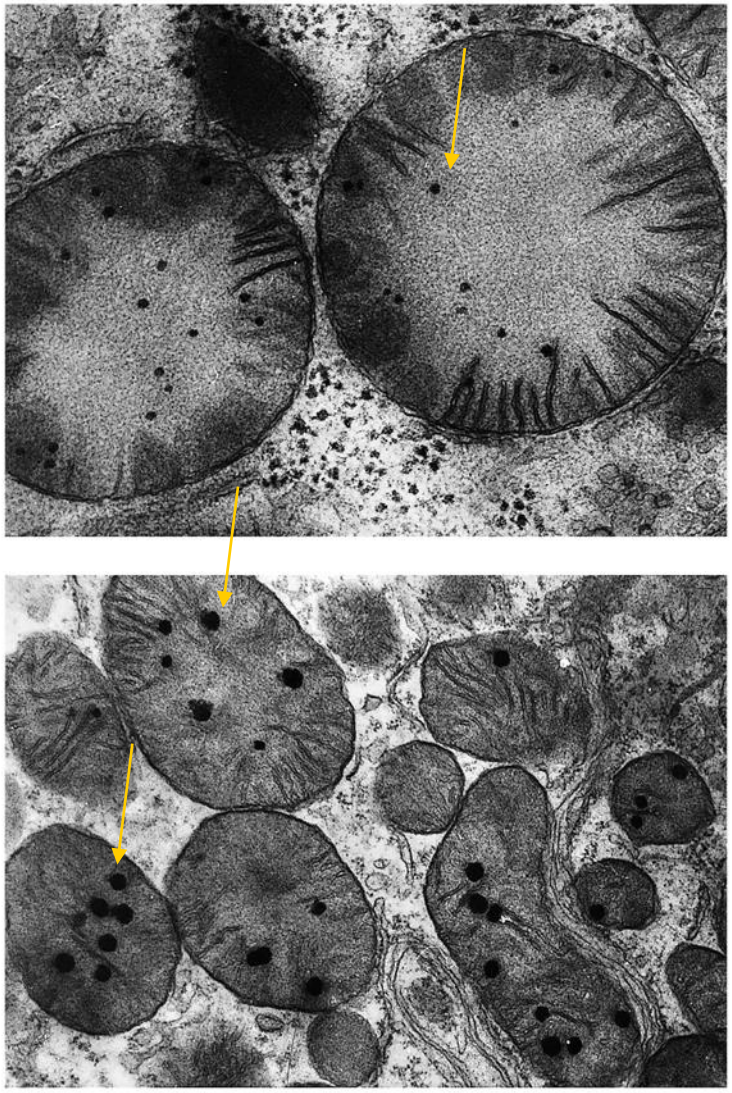
Receives electrons from cytochrome c oxidase and transfers them to oxygen

ATP synthase complex

Consisting of two components, F0 (proton channel)and F1 (globular complex that protrudes into the inner chamber and synthesizes ATP from ADP and phosphate

Mitochondria





Different parts of the mitochondria are linked todifferent functions **accumulation of Ca++ ions**.

…….Other functions of Mitochondria

-Calcium ion accumulation

-Participation, together with SER, in the synthesis of steroid hormones

-Gluconeogenesis (production of glucose from non-carbohydrate precursors)

-Fatty acid oxidation-Heat production in brown adipose tissue cells of hibernating animals

Mitochondria

The Matrix contains:

1.Enzymes

1. for the **oxidation of pyruvate** and **fatty acids**
2. for the **citric acid cycle**

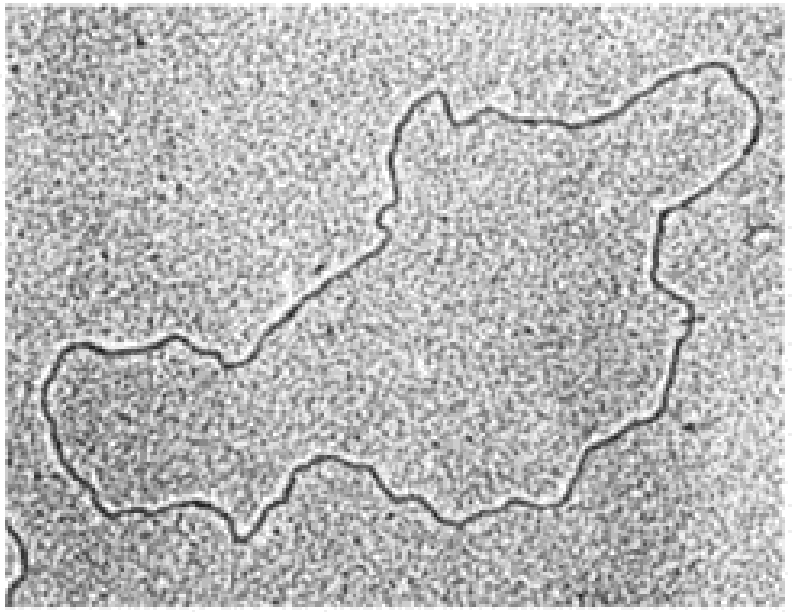
2.many identical copies of the DNA of the **mitochondrial genome**

3.special **mitochondrial ribosomes**

4.tRNA

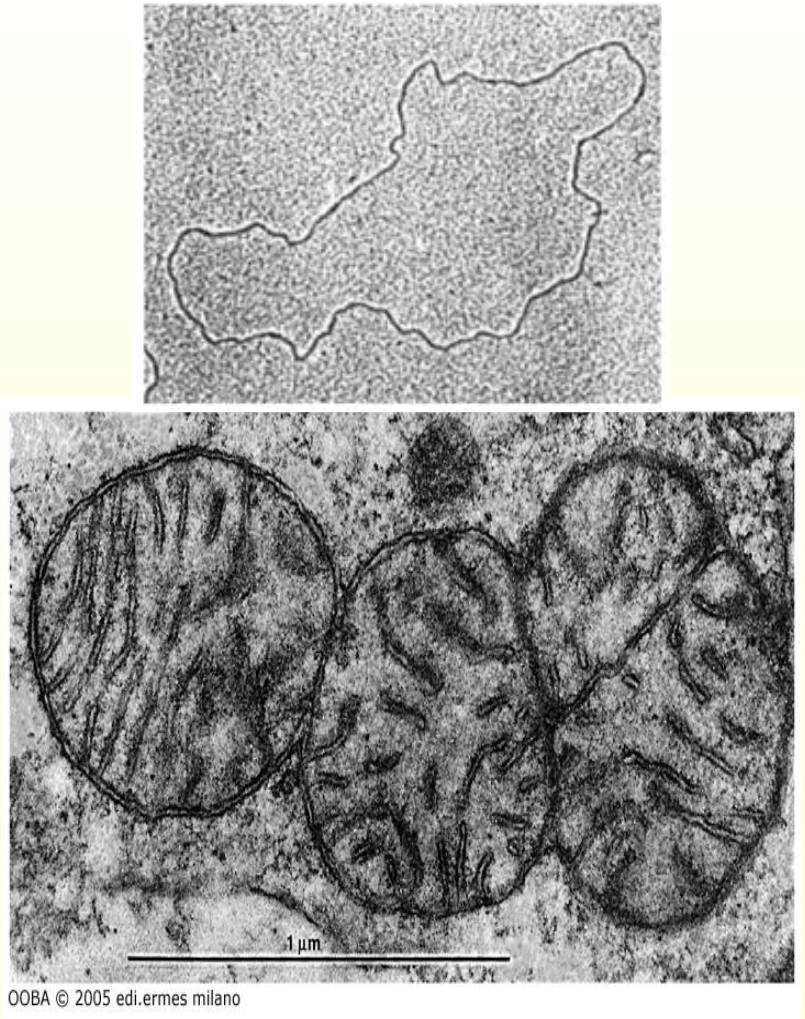
5.enzymes necessary for the **expression** of mitochondrial genes

mitochondrial genome



Mitochondria have their own genome and their own synthetic apparatus.

Most mitochondrial proteins are synthesized in the cytoplasm under the control of the nuclear genome.

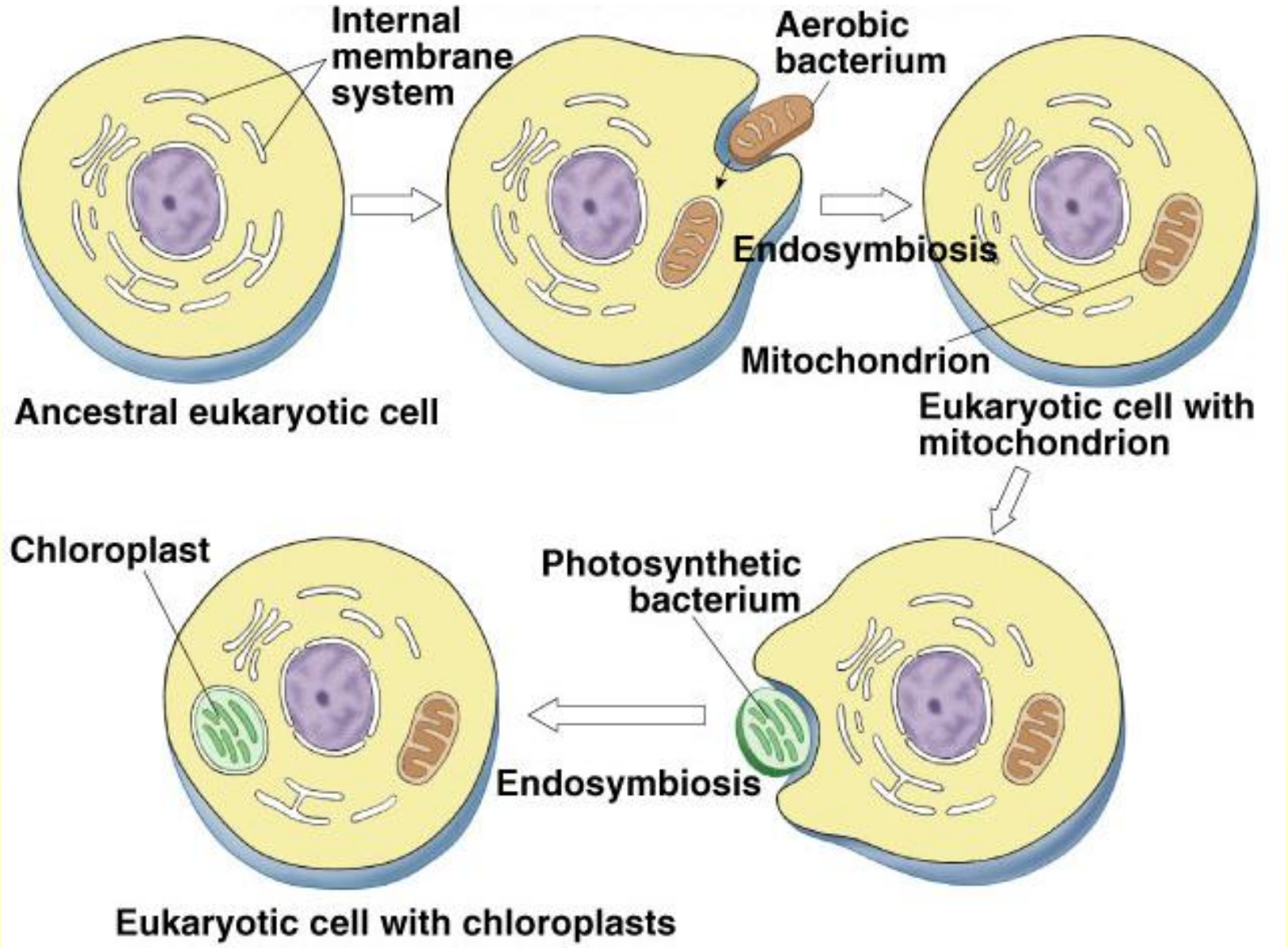


Mitochondria in rat cell division

At the moment of division, the mitochondria are equally distributed between the two daughter cells. At the end of cytokinesis, they have half the mitochondrial content.

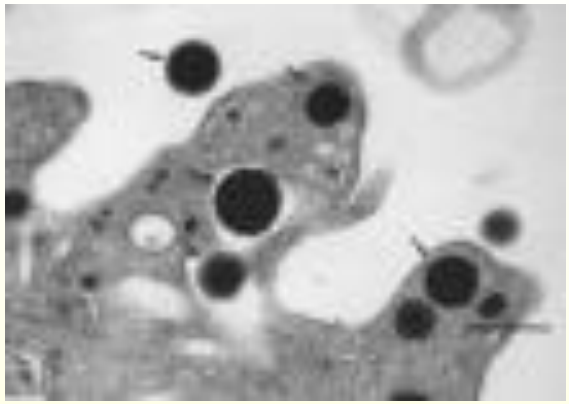
In the G1 phase, the mitochondria undergo a process of **scission** division that restores their original content and returns them to their original size thanks to the synthesis of all their components, which almost always occurs under the control of the nuclear genome and only partly under that of the mitochondrial genome.

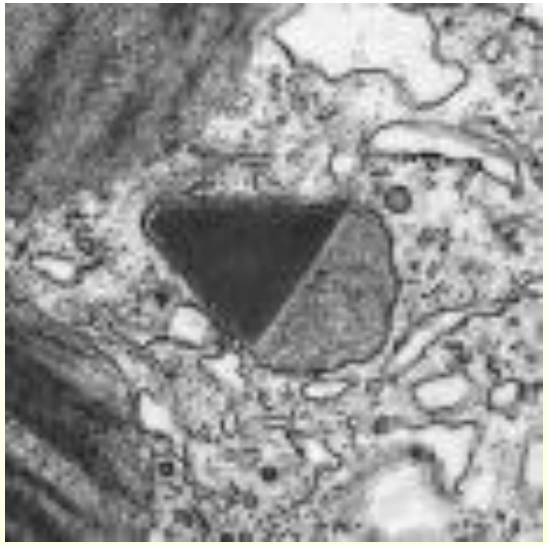
EVOLUTIONARY THEORY OF MITOCHONDRIA
ENDOSYMBIONTIC ORIGIN



Peroxisomes (Microbodies)

- **Peroxisomes are single membrane–bounded organelles containing oxidative enzymes.**





Present in all animal cells and involved in the catabolism of long-chain fatty acids: acetyl CoA and hydrogen peroxide **(H_2O_2)** as a product of the oxidation reaction are formed.

Hydrogen peroxide is a toxic substance. The catalase universally present in peroxisomes carefully regulates the cellular hydrogen peroxide content by breaking down hydrogen peroxide, thus protecting the cell