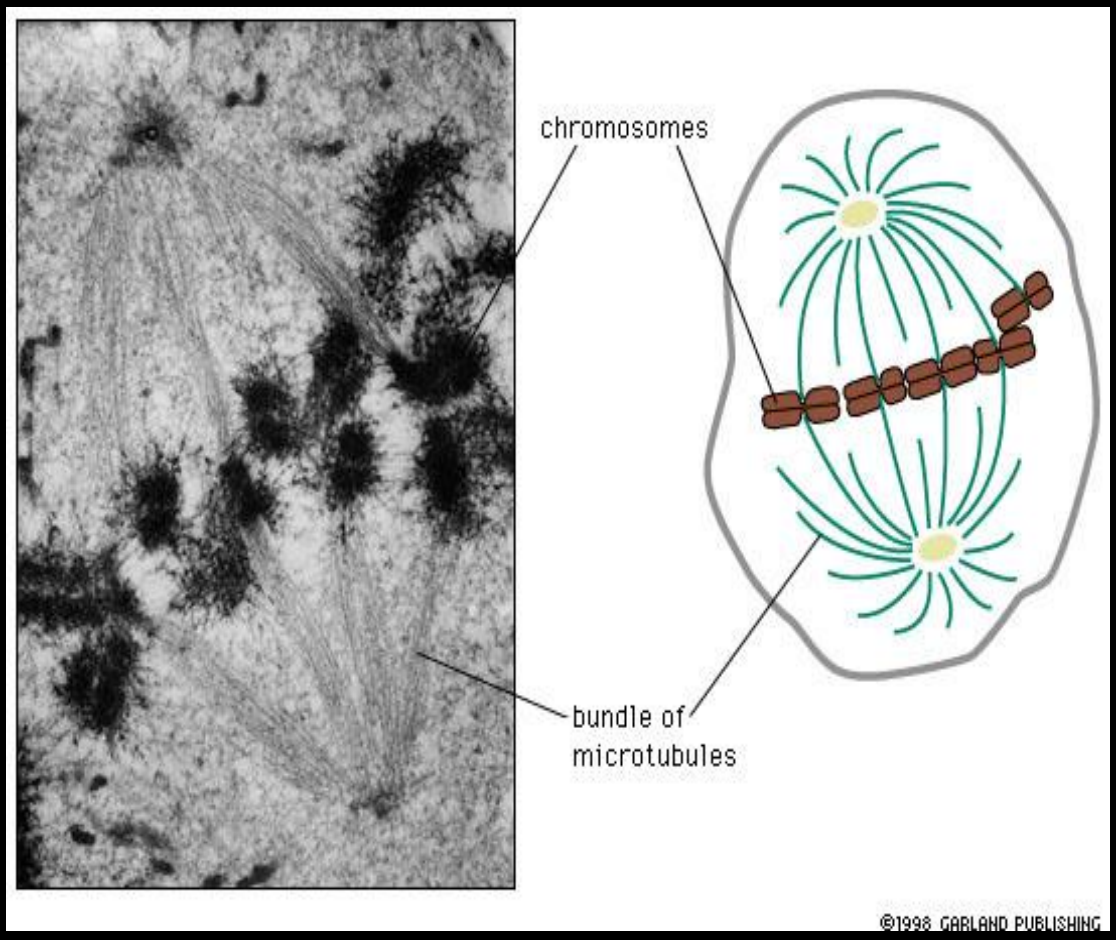
Cytoskeleton

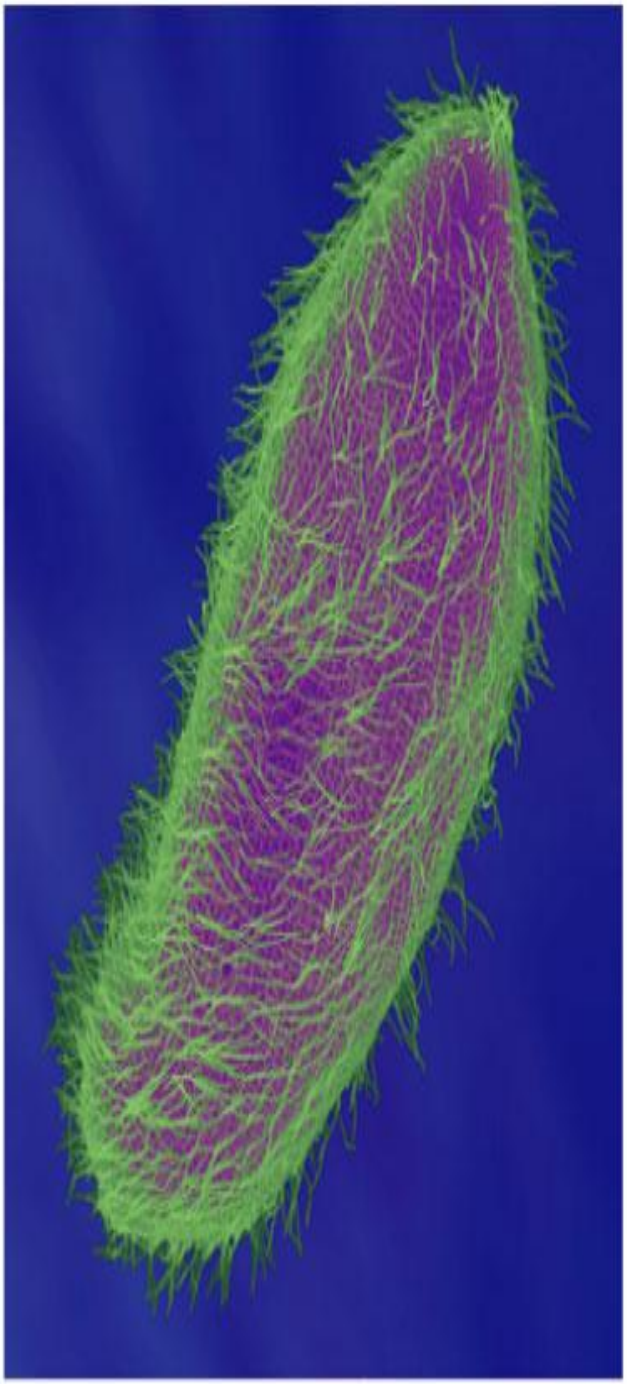
(microtubules)



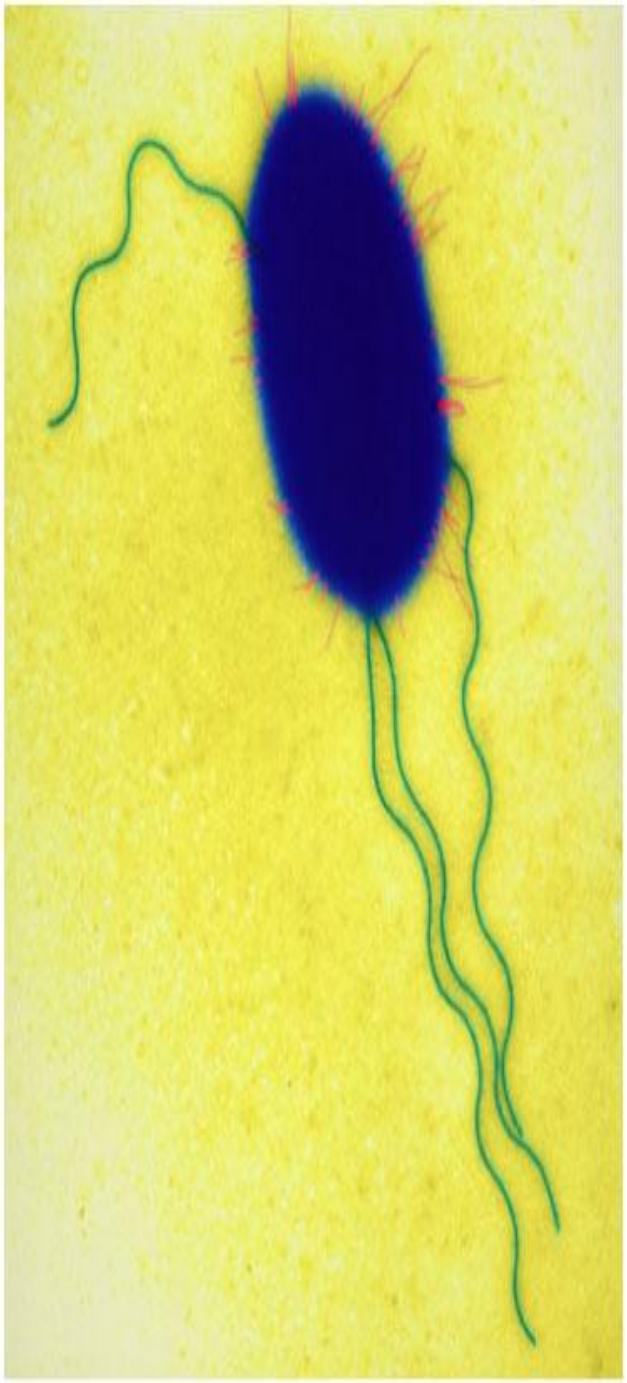
Microtubules dynamics during mitosis

CELL MOVEMENT

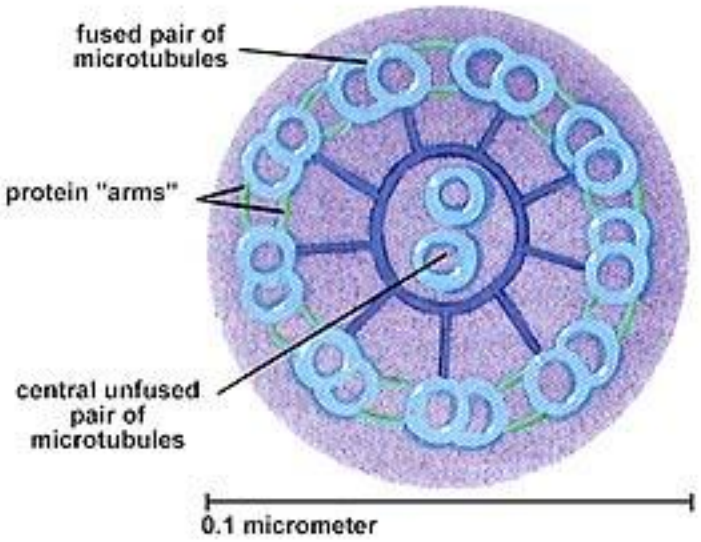
Cilia

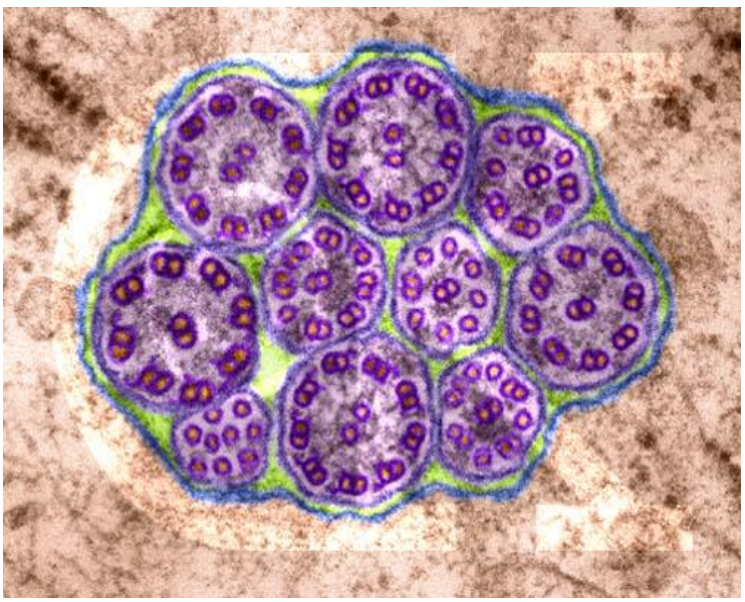


Flagella

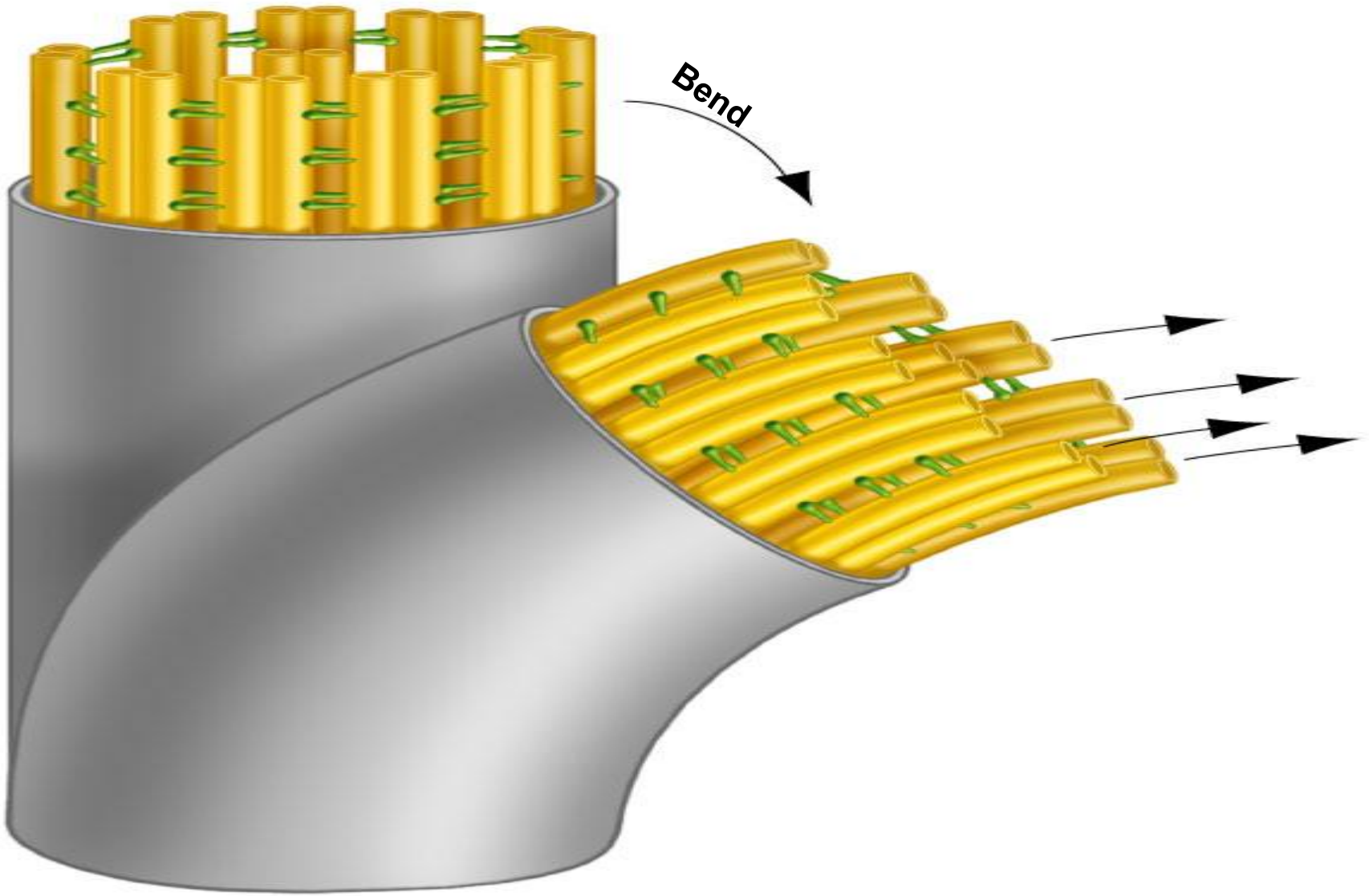


Cilia and **flagella** are similar except for length, cilia being much shorter. They both have the characteristic 9 + 2 arrangement of microtubules.

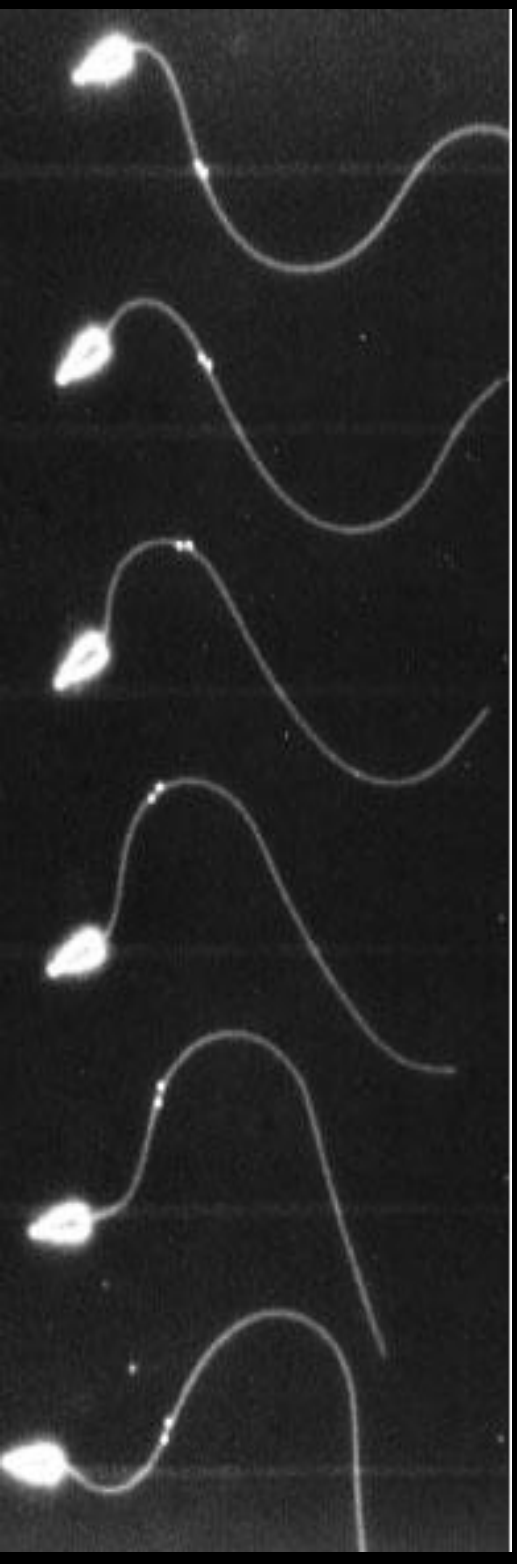




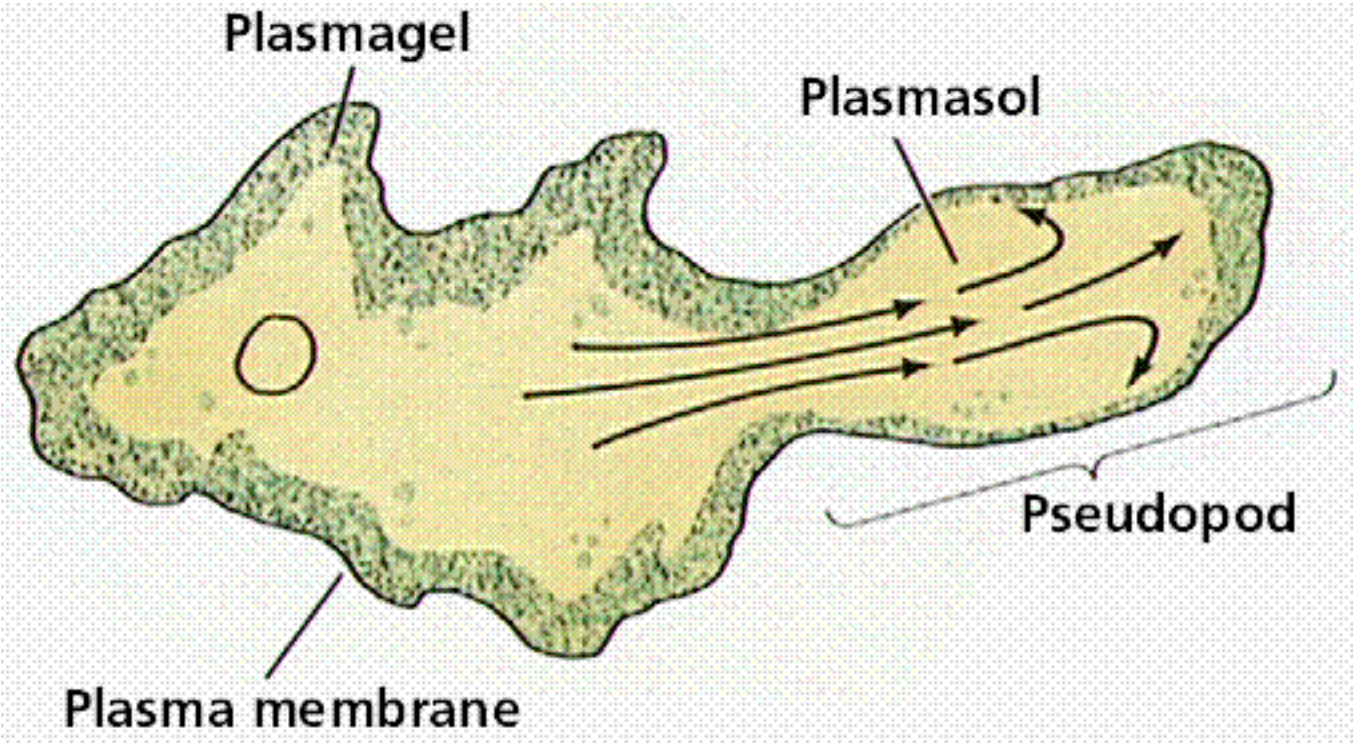
Cilia from an epithelial cell in cross section (TEM x199,500). Note the 9 + 2 arrangement of cilia.


Bend

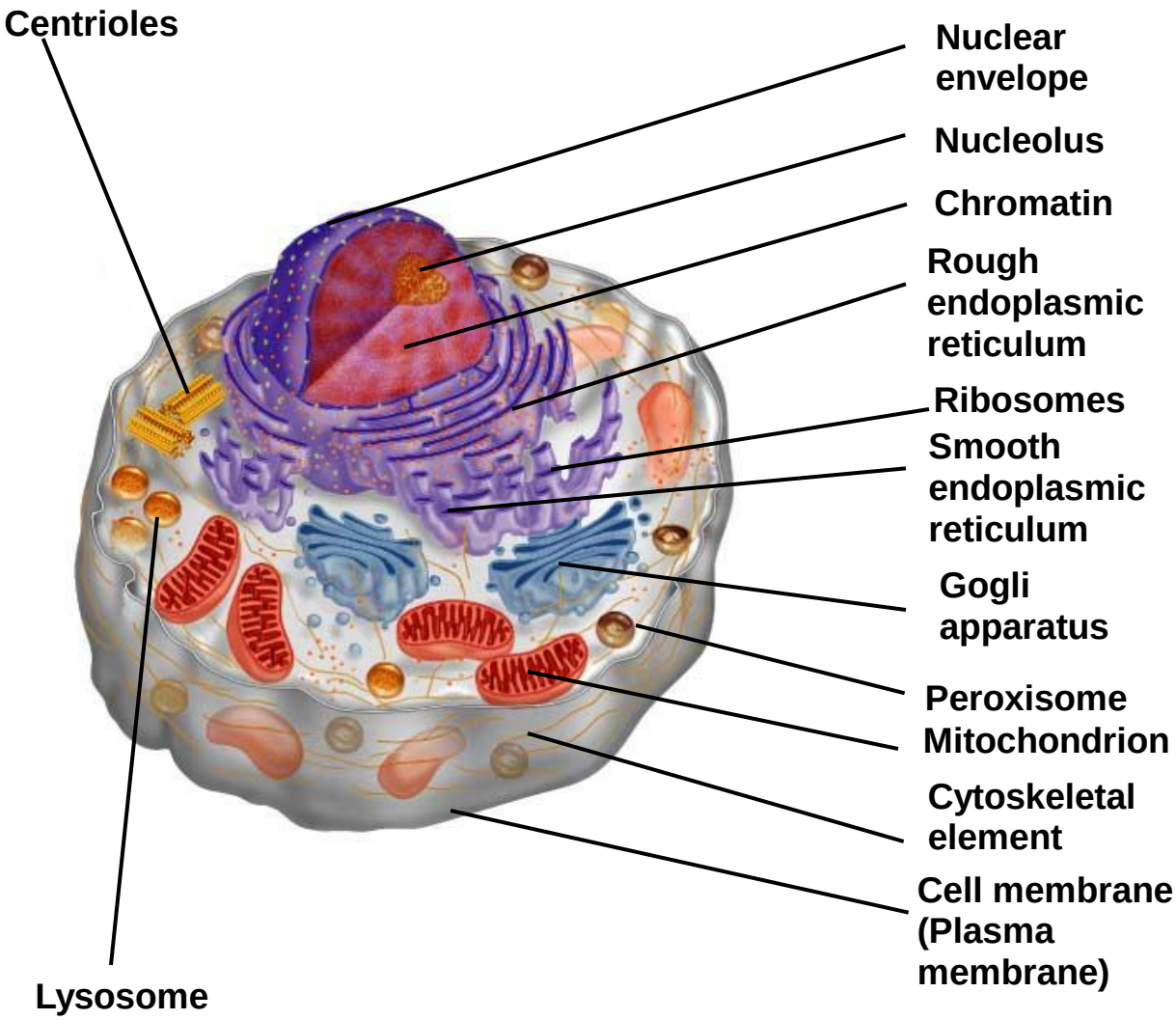
spermatozoi



Formation and functioning of a pseudopod by an amoeboid cell



Pseudopodia are used by many cells, such as *Amoeba* and human leukocytes (white blood cells). These are not structures as such but rather are associated with actin near the moving edge.

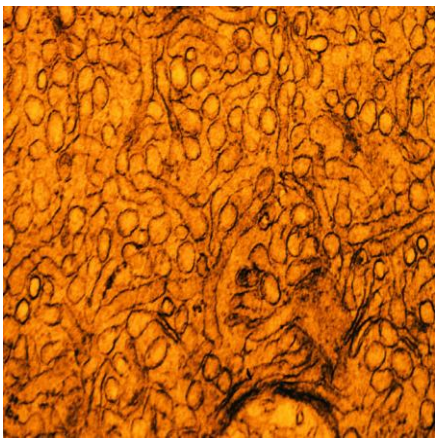


The organelles within eukaryotic cells
subdivide
the cell into functional compartments

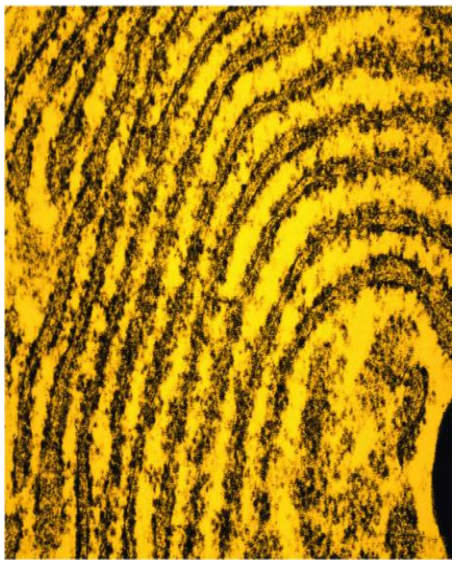
Intracellular comparment	Percentage total cell volume
Cytosol	54
Mitochondria	22
Rough ER	9
Smooth ER + Golgi	6
Nucleus	6
Peroxisomes	1
Lysosomes	1
Endosomes	1

The organelles within eukaryotic cells subdivide the cell into functional compartments

- The endomembrane system is the site of biomolecule synthesis and considerable molecular movement

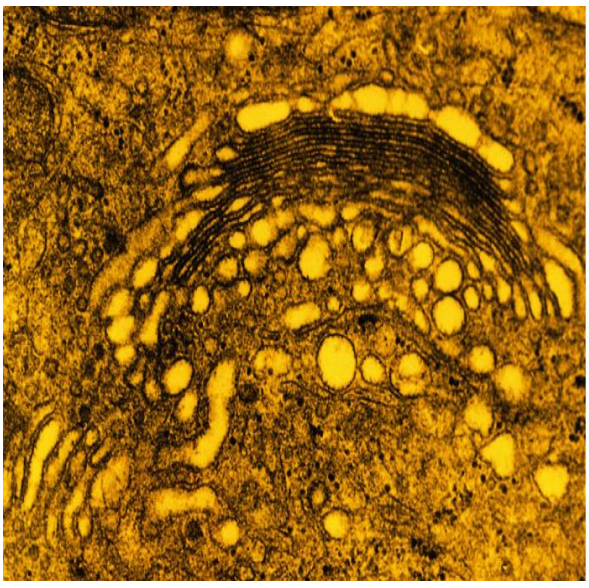


Smooth ER
(no ribosomes attached)



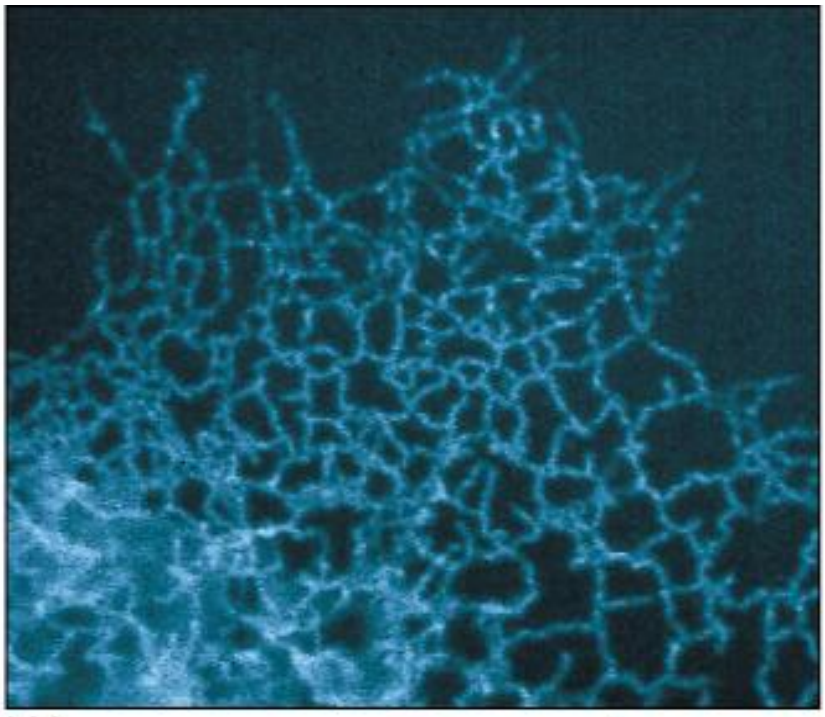
Rough ER
(with ribosomes attached)

Golgi apparatus



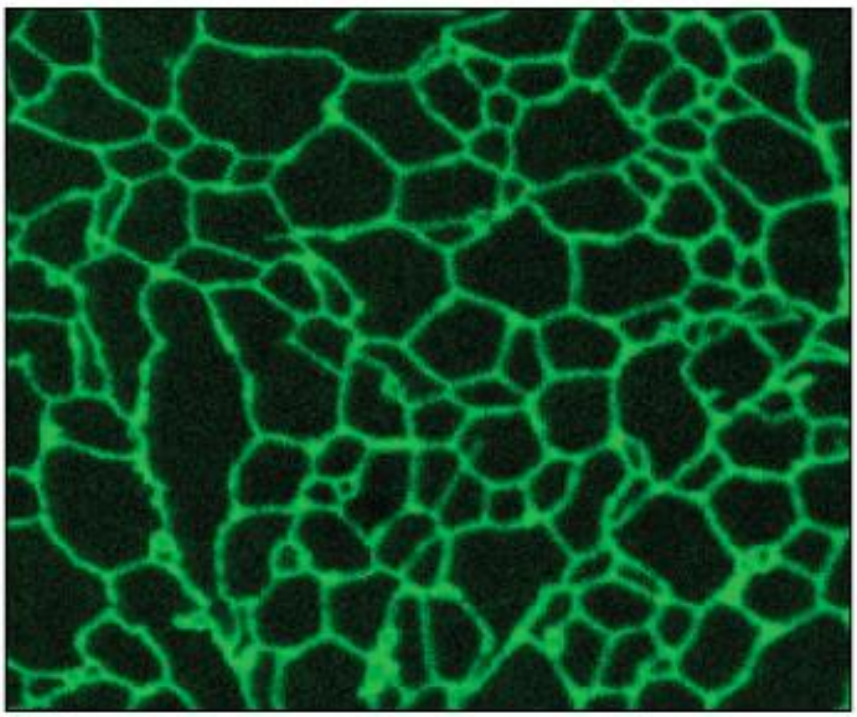
THE ENDOPLASMIC RETICULUM

is a mesh of interconnected membranes that serves a function involving protein synthesis and transport



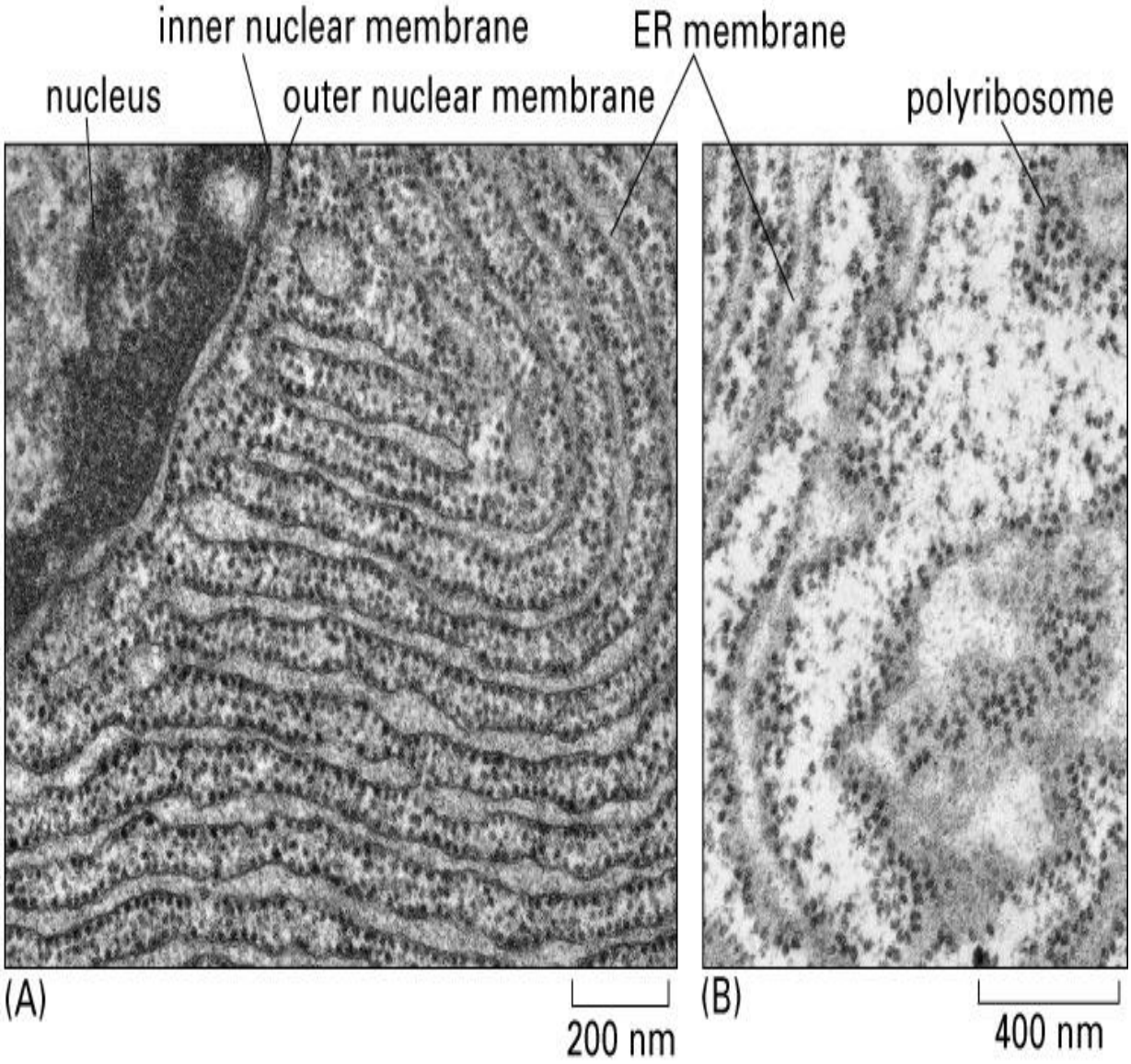
(A)

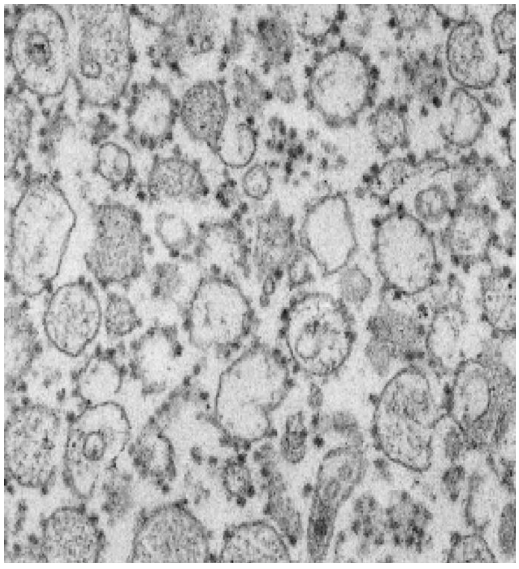
2 μm

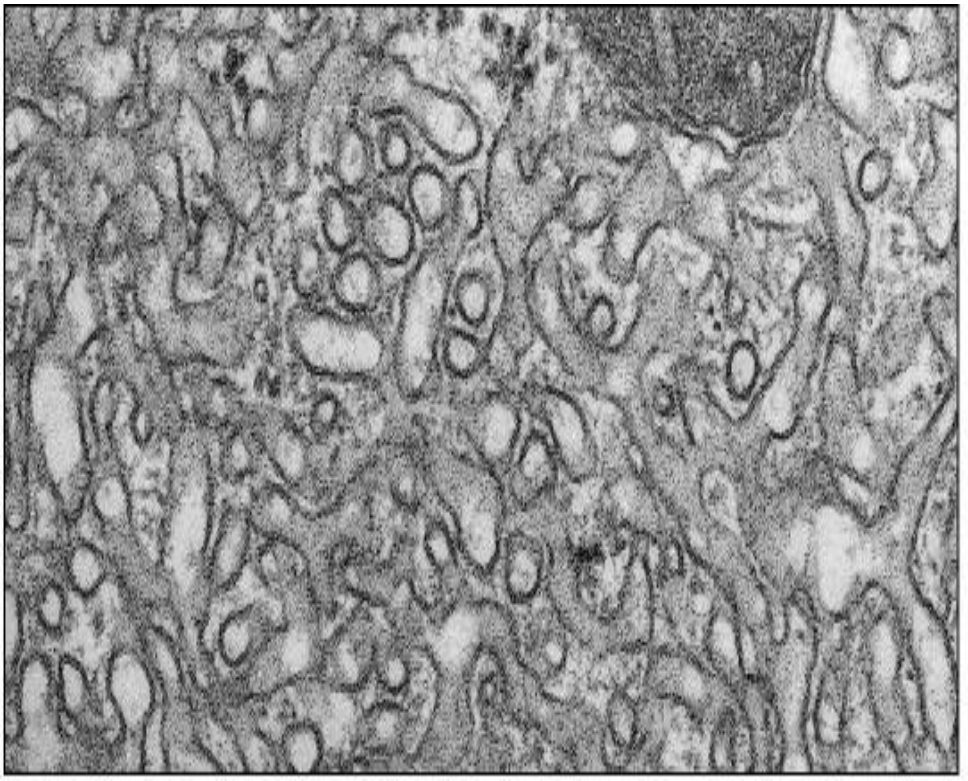


(B)

10 μm

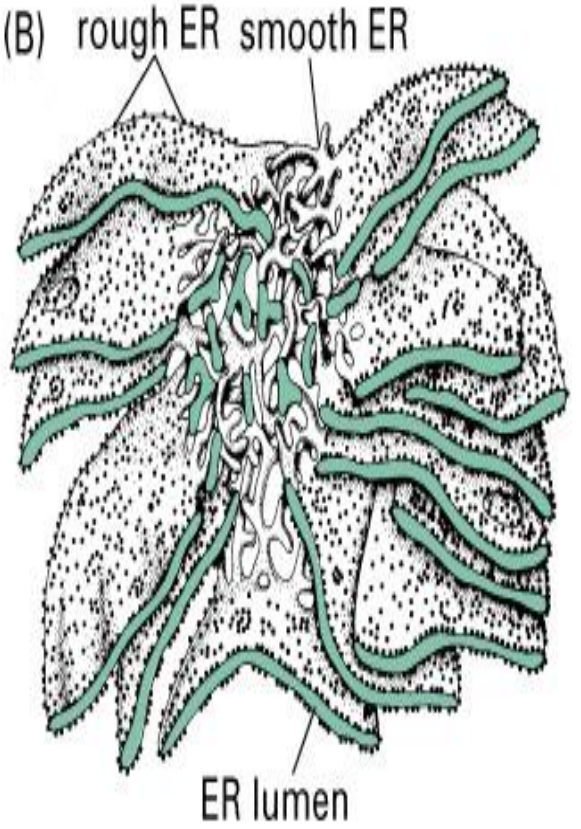

inner nuclear membrane
ER membrane
nucleus
outer nuclear membrane
polyribosome
(A)
200 nm
(B)
400 nm

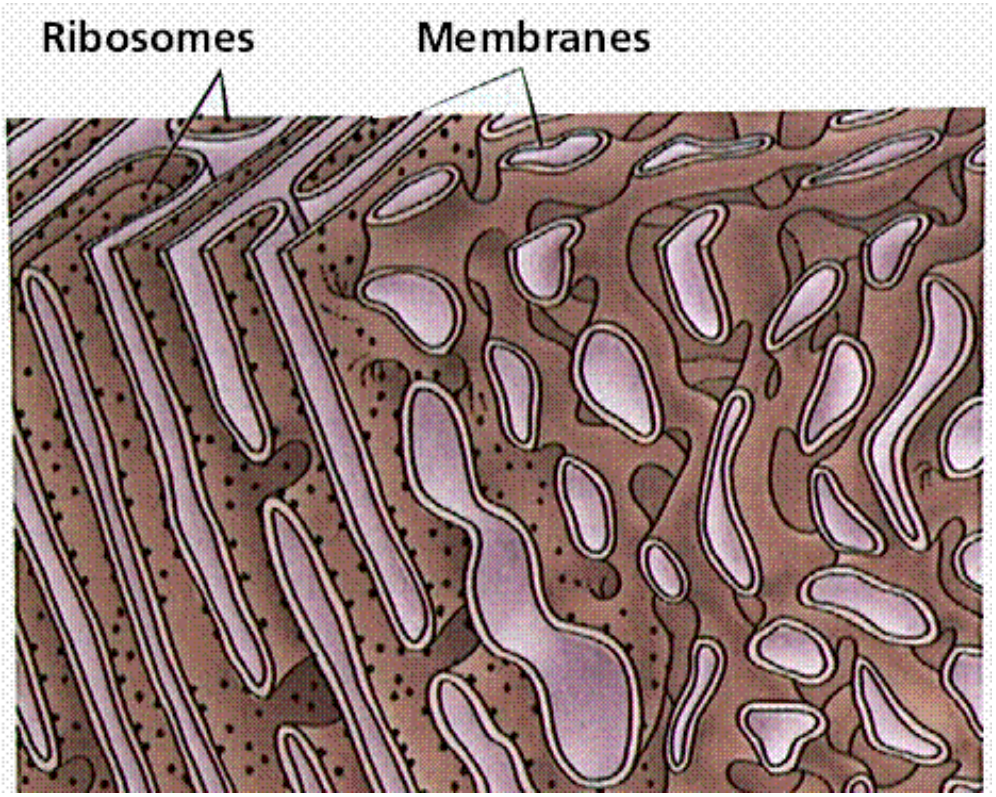


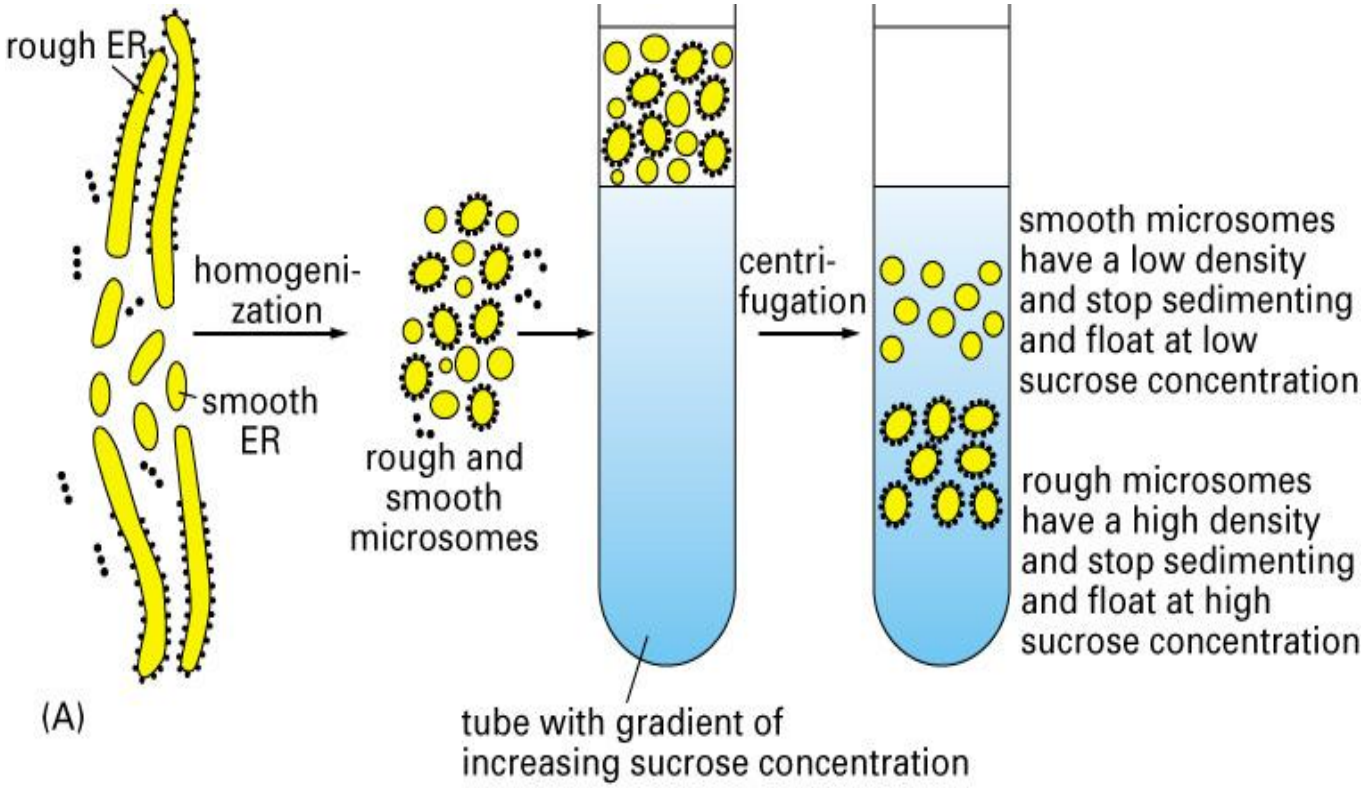


(A)

200 nm

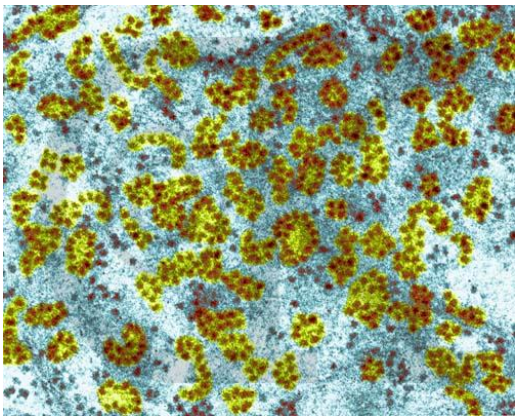


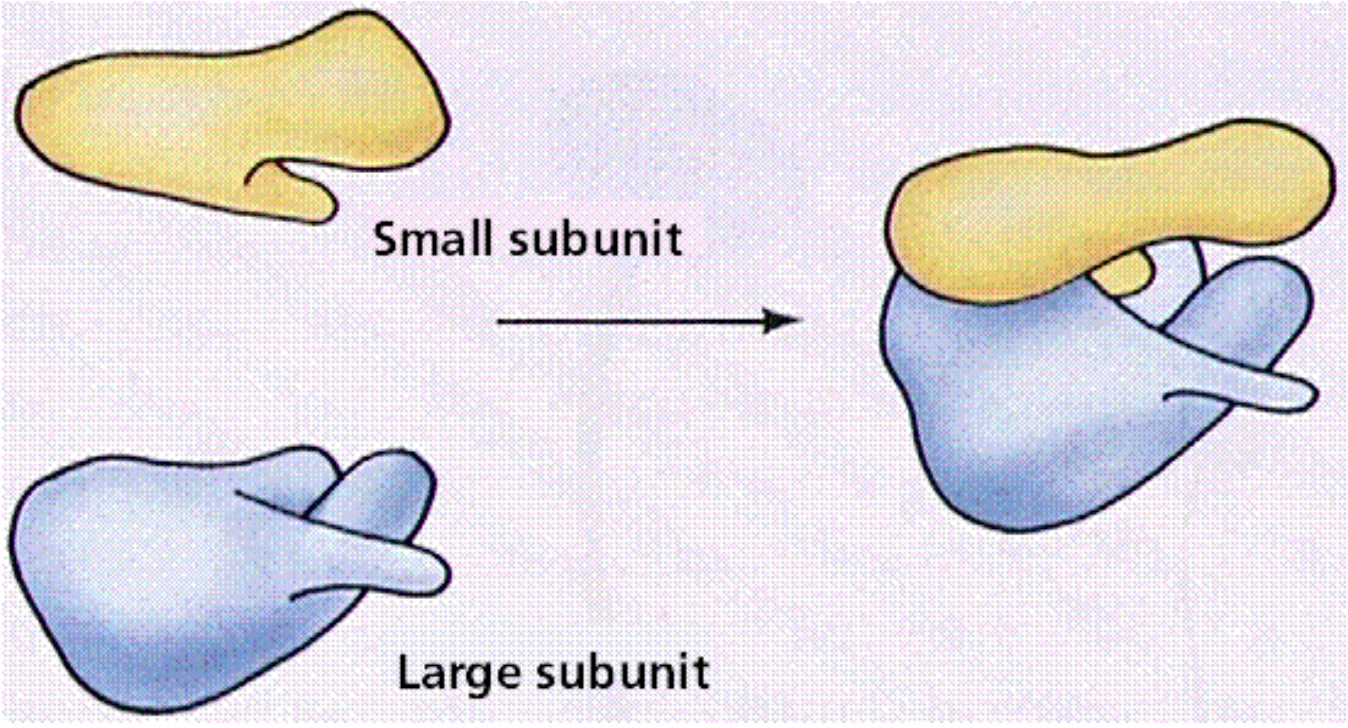

Ribosomes
Membranes

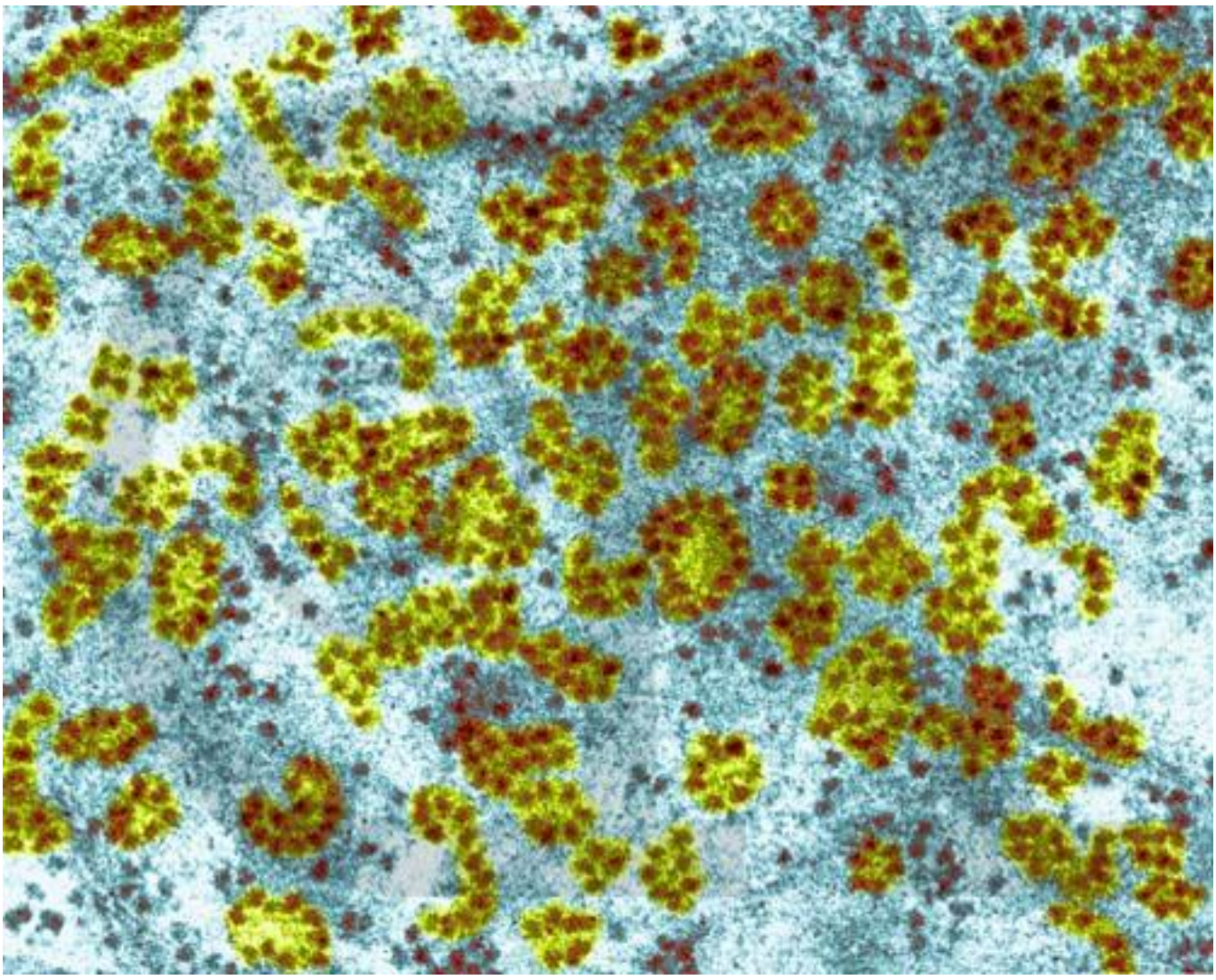

rough ER
homogeni-
zation
smooth
ER
rough and
smooth
microsomes
centri-
fugation
smooth microsomes
have a low density
and stop sedimenting
and float at low
sucrose concentration
rough microsomes
have a high density
and stop sedimenting
and float at high
sucrose concentration
(A)
tube with gradient of
increasing sucrose concentration

I RIBOSOMI

- Sites of protein synthesis.
- They are not membrane-bound
- .Occur in both prokaryotes and eukaryotes.
- Eukaryotic ribosomes are slightly larger
- Consists of a small and larger subunit.
- .Biochemically the ribosome consists of ribosomal RNA (rRNA) and some 50 structural proteins.
- .Often ribosomes cluster on the endoplasmic reticulum



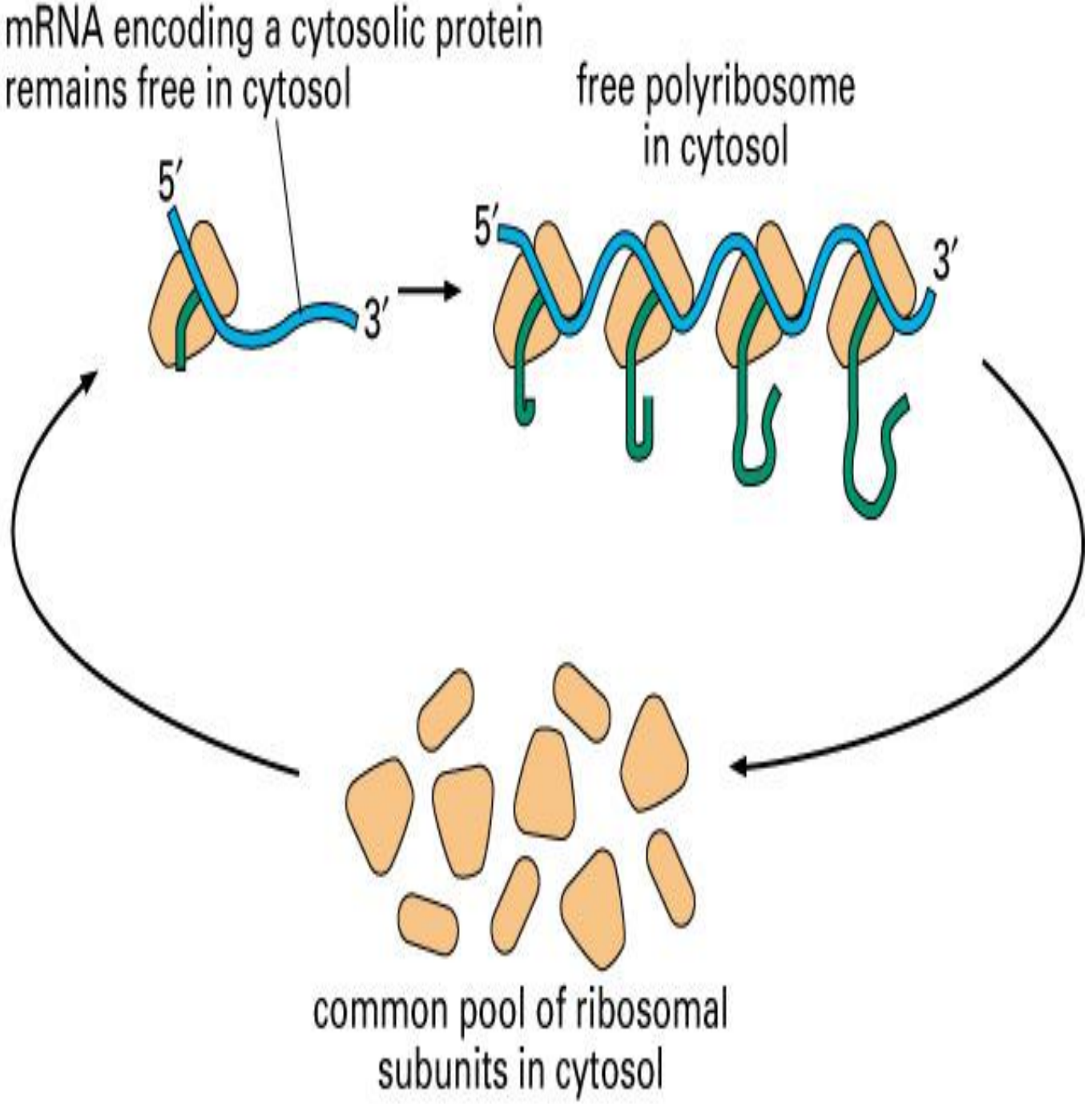

Small subunit
Large subunit

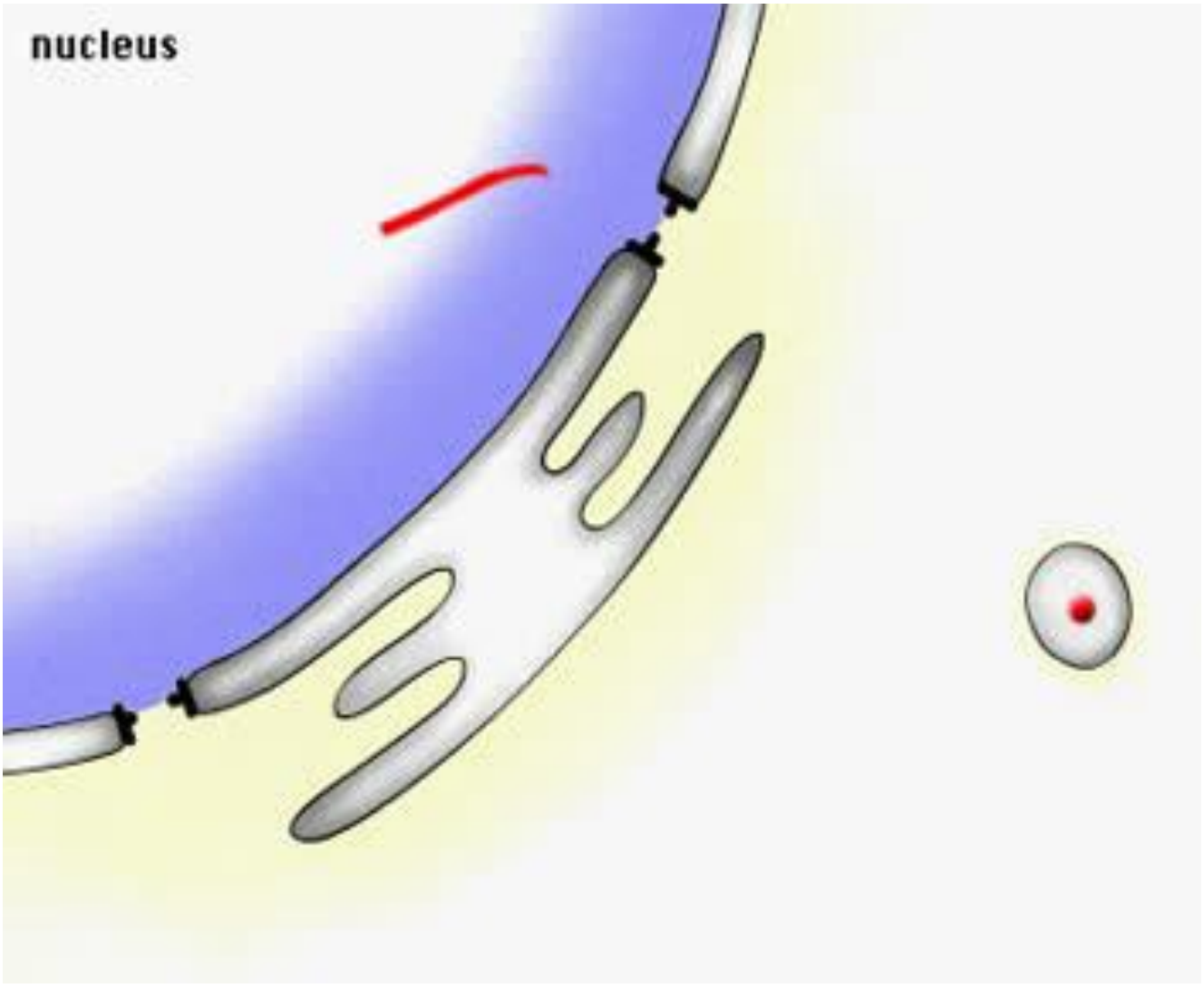


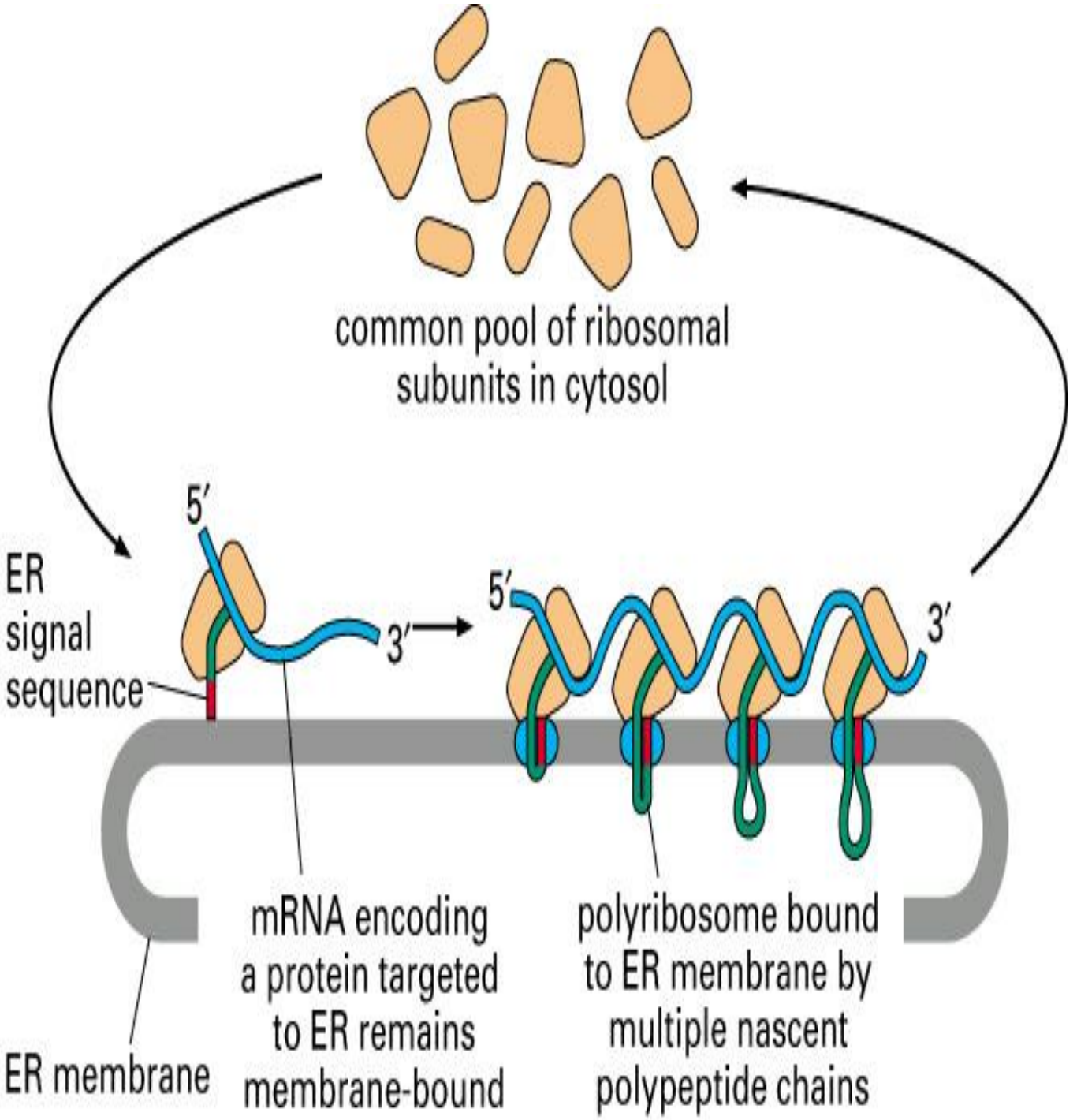
Provenienza	Ribosoma	Subunita'	Composizione
Eucarioti	80S	60S	rRNA 28S RNA 5.8S RNA 5S proteine
		40S	rRNA 18S proteine
Procarioti	70S	50S	rRNA 23S RNA 5S proteine
		30S	rRNA 16S proteine
		35S	rRNA 16S proteine

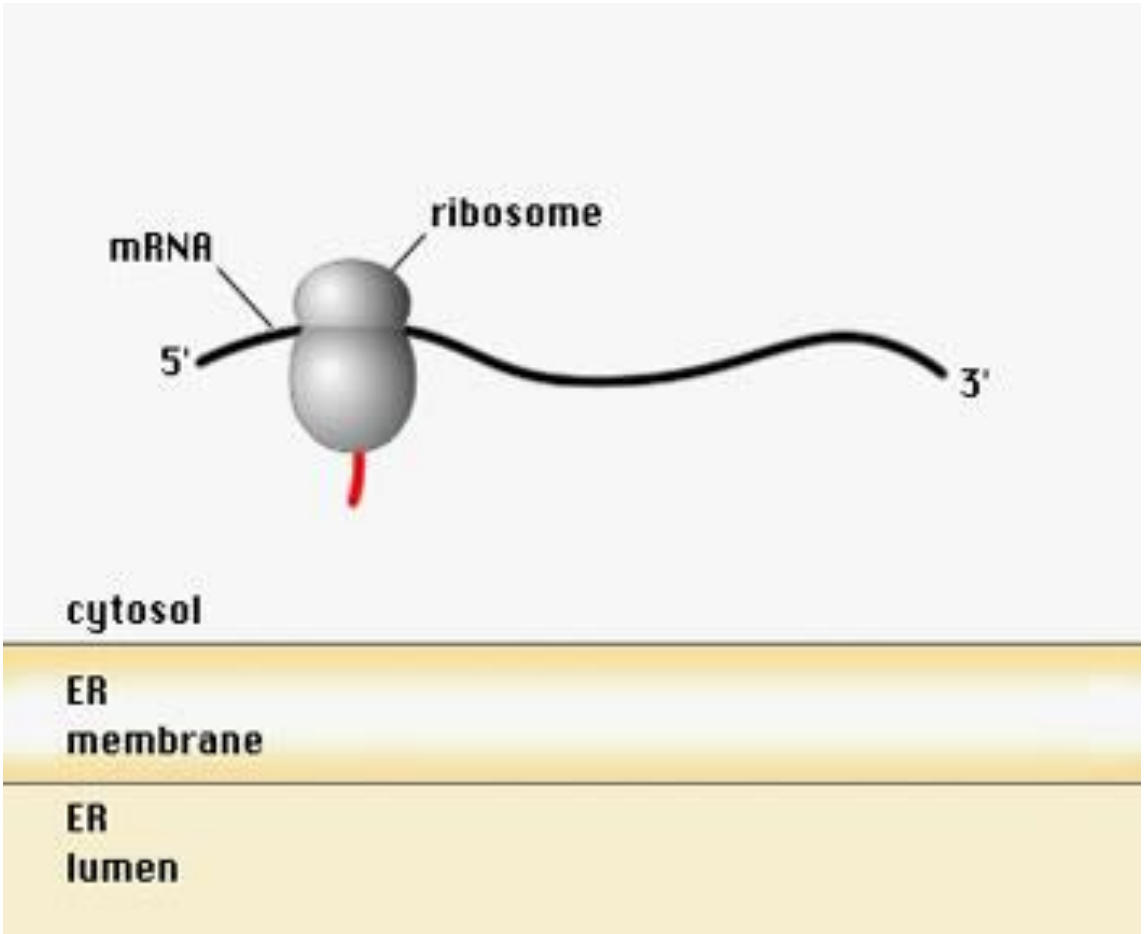
Types of proteins synthesised

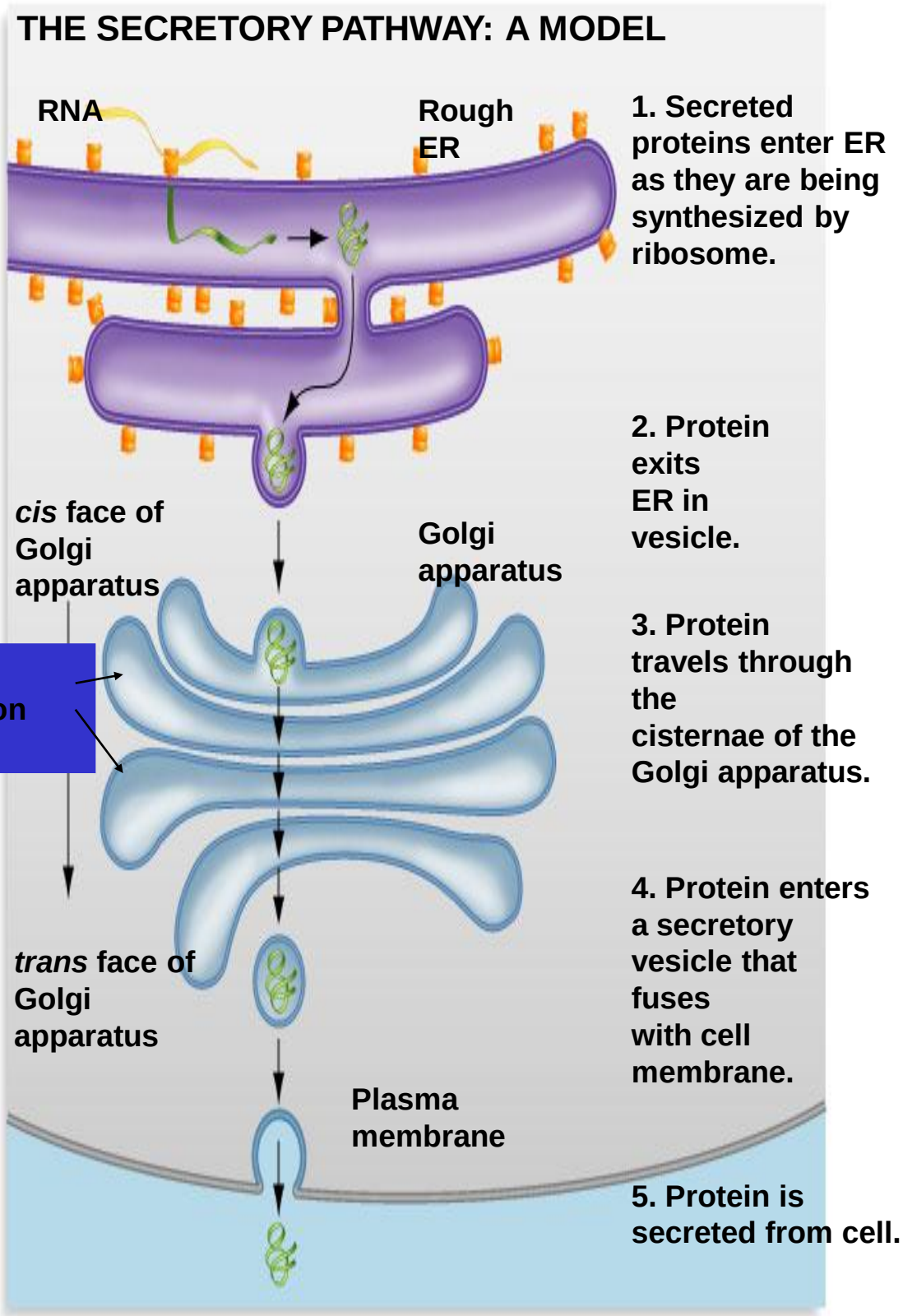
1. On ER ribosomes
    - Proteins secreted by the cell
    - Trans-membrane proteins
    - Proteins of Golgi, lysosomes, endosomes, plant vacuoles
2. On free ribosomes
    - Cytosol proteins (cytoskeleton, glycolysis enzymes)
    - Peripheral proteins of the inner plasma membrane (spectrin, ankirin etc)
    - Proteins of perossisomes, cloroplasts and mytocondria


mRNA encoding a cytosolic protein
remains free in cytosol
free polyribosome
in cytosol
5′
3′
5′
3′
common pool of ribosomal
subunits in cytosol

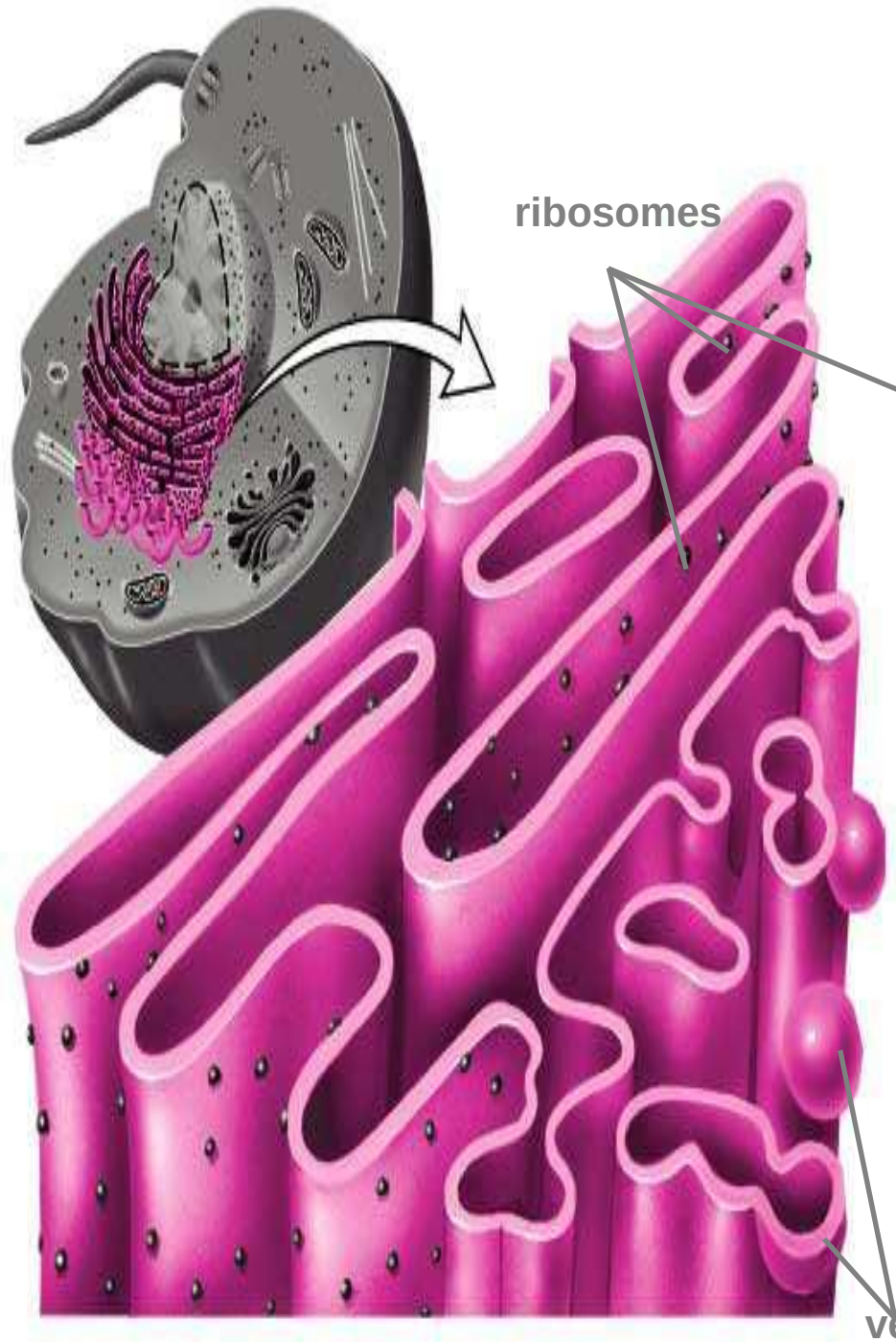

nucleus


common pool of ribosomal subunits in cytosol
5′
3′
ER signal sequence
5′
3′
ER membrane
mRNA encoding a protein targeted to ER remains membrane-bound
polyribosome bound to ER membrane by multiple nascent polypeptide chains


ribosome
mRNA
5'
3'
cytosol
ER
membrane
ER
lumen

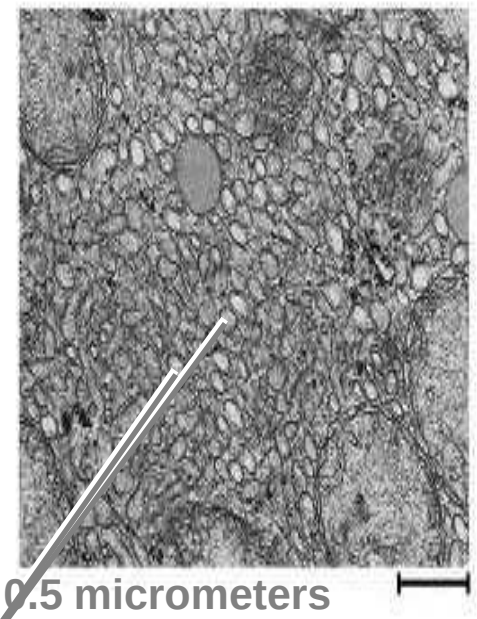

THE SECRETORY PATHWAY: A MODEL
RNA
Rough ER
1. Secreted proteins enter ER as they are being synthesized by ribosome.
2. Protein exits ER in vesicle.
cis face of Golgi apparatus
Golgi apparatus
Various glycosylation reactions
3. Protein travels through the cisternae of the Golgi apparatus.
4. Protein enters a secretory vesicle that fuses with cell membrane.
trans face of Golgi apparatus
Plasma membrane
5. Protein is secreted from cell.

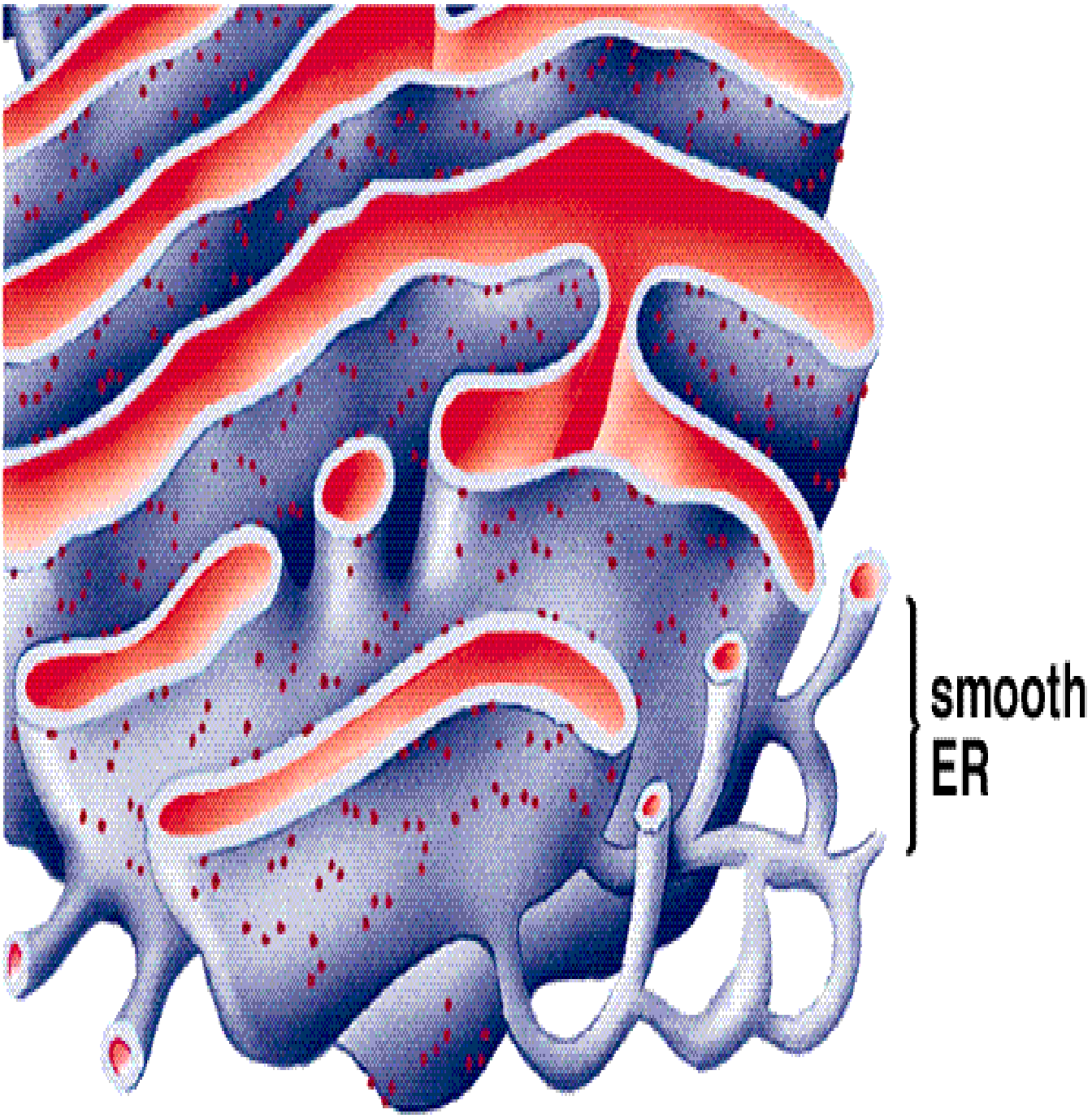
Endoplasmic reticulum



rough

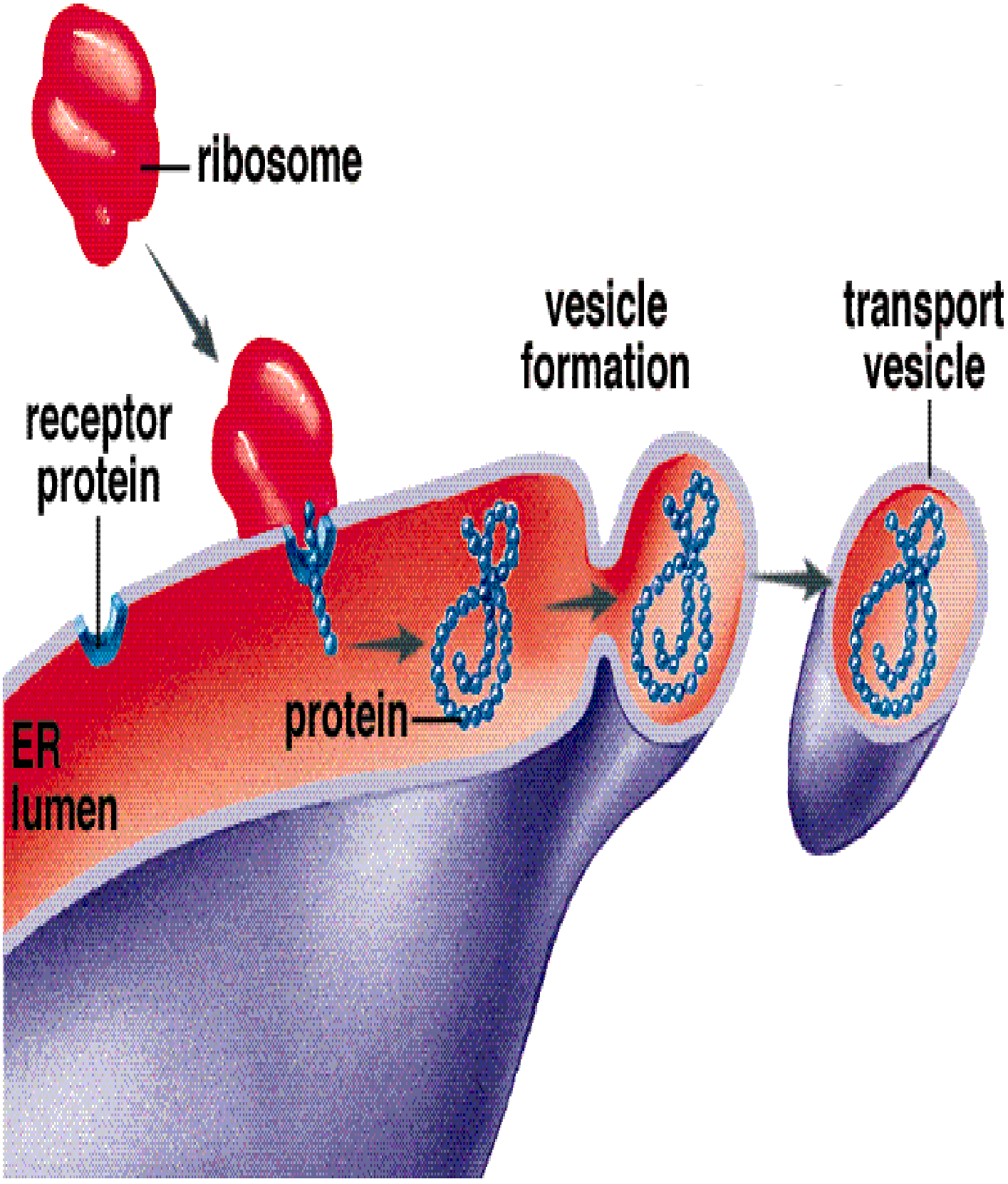
smooth




smooth
ER

Smooth Endoplasmic Reticulum

- Regions of ER that lack ribosomes are called smooth ER
- Functions:
  - **Contains ER exit sites** from which transport vesicles carrying newly synthesized lipids and proteins bud off on route to the Golgi apparatus


ribosome
receptor protein
vesicle formation
transport vesicle
protein
ER lumen

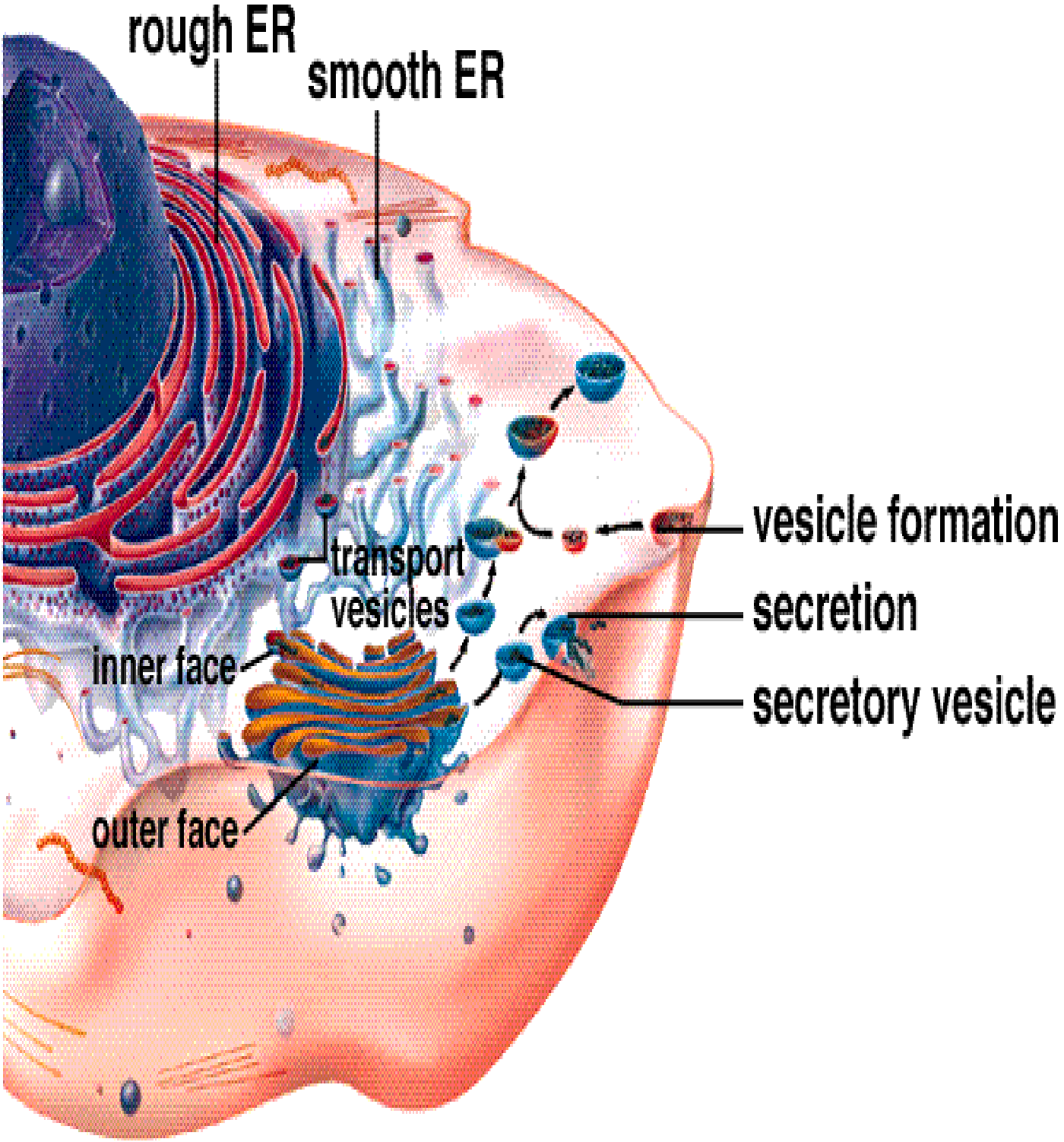
Smooth Endoplasmic Reticulum

- Functions:
  - Contains enzymes that detoxify lipid-soluble drugs (liver)
    - Carried out by cytochrome P_{450}
    - This is a family of enzymes that hydroxylate lipid-soluble drugs
    - This makes them water-soluble so they can be secreted
      - (e.g. phenobarbital)

Smooth Endoplasmic Reticulum

- **Functions:**
  - Steroid hormones synthesis in endocrine cells of the gonads and of the adrenal glands

Golgi Apparatus



Golgi complexes are flattened stacks of membrane-bound sacs. They function as a packaging plant, modifying vesicles from the Rough ER. New membrane material is assembled in various cisternae of the Golgi.

The Nobel Prize in Physiolog
Medicine 190

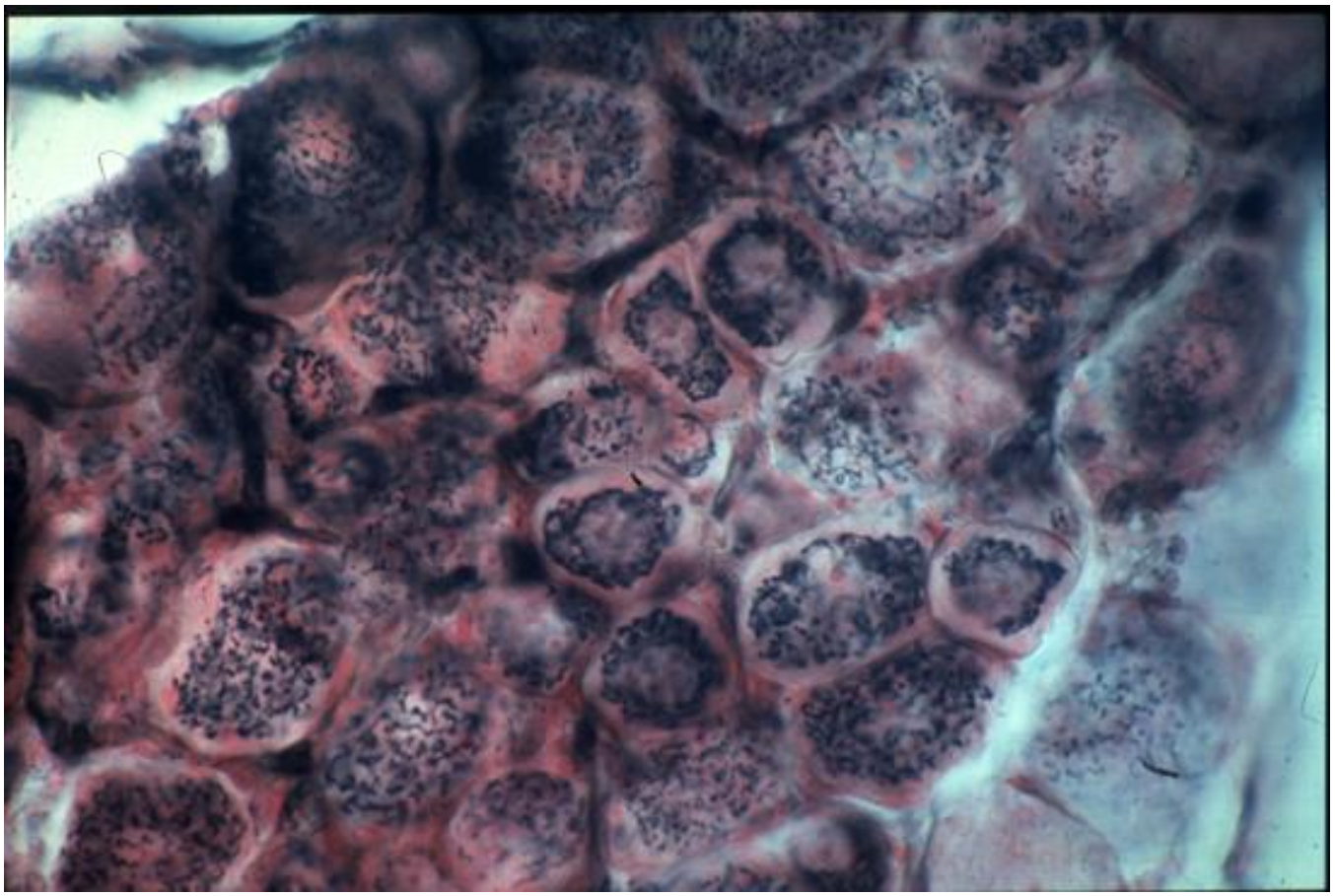
"in recognition of their work on the structure of the nervous system"

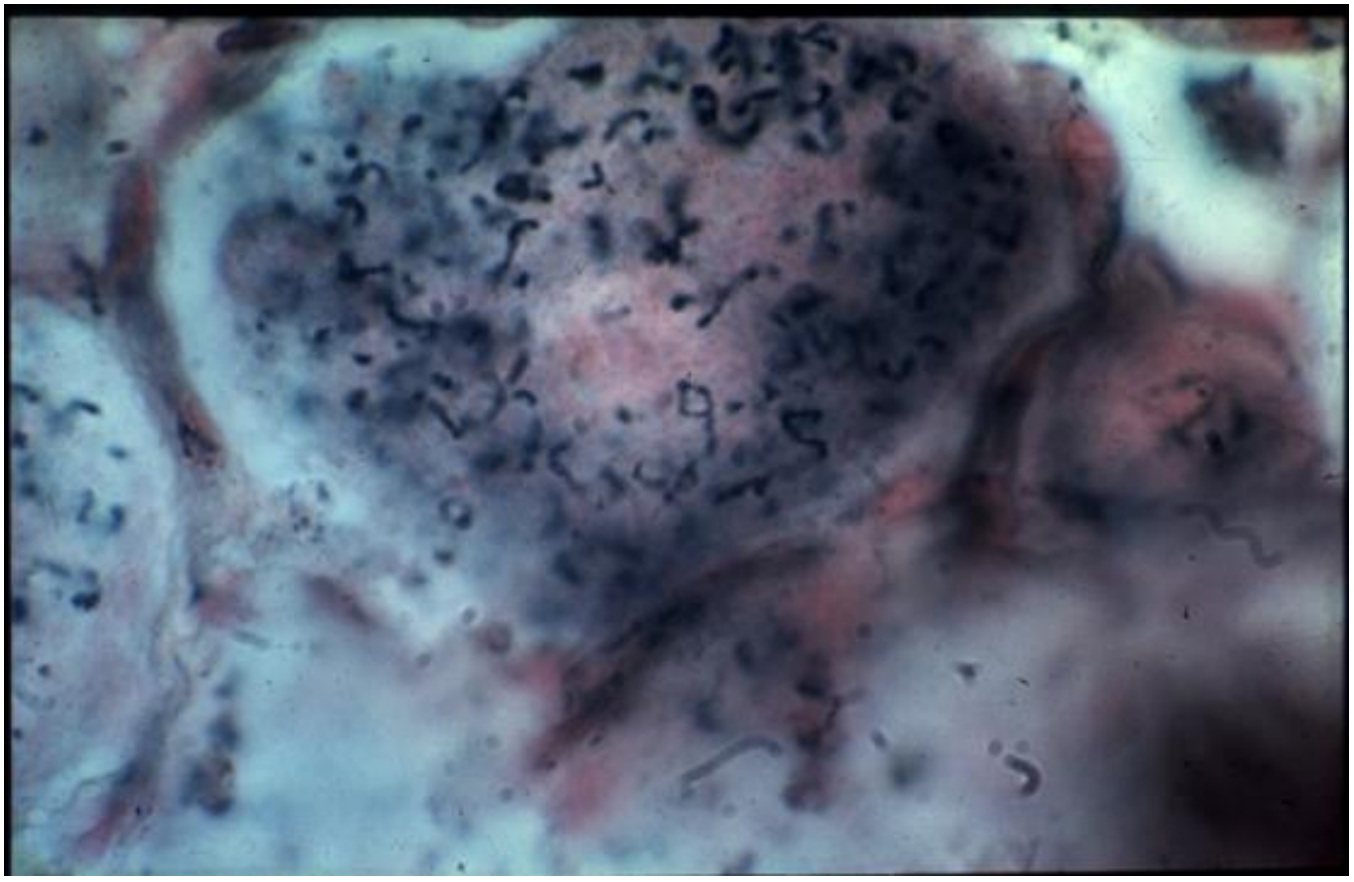
Camillo Golgi

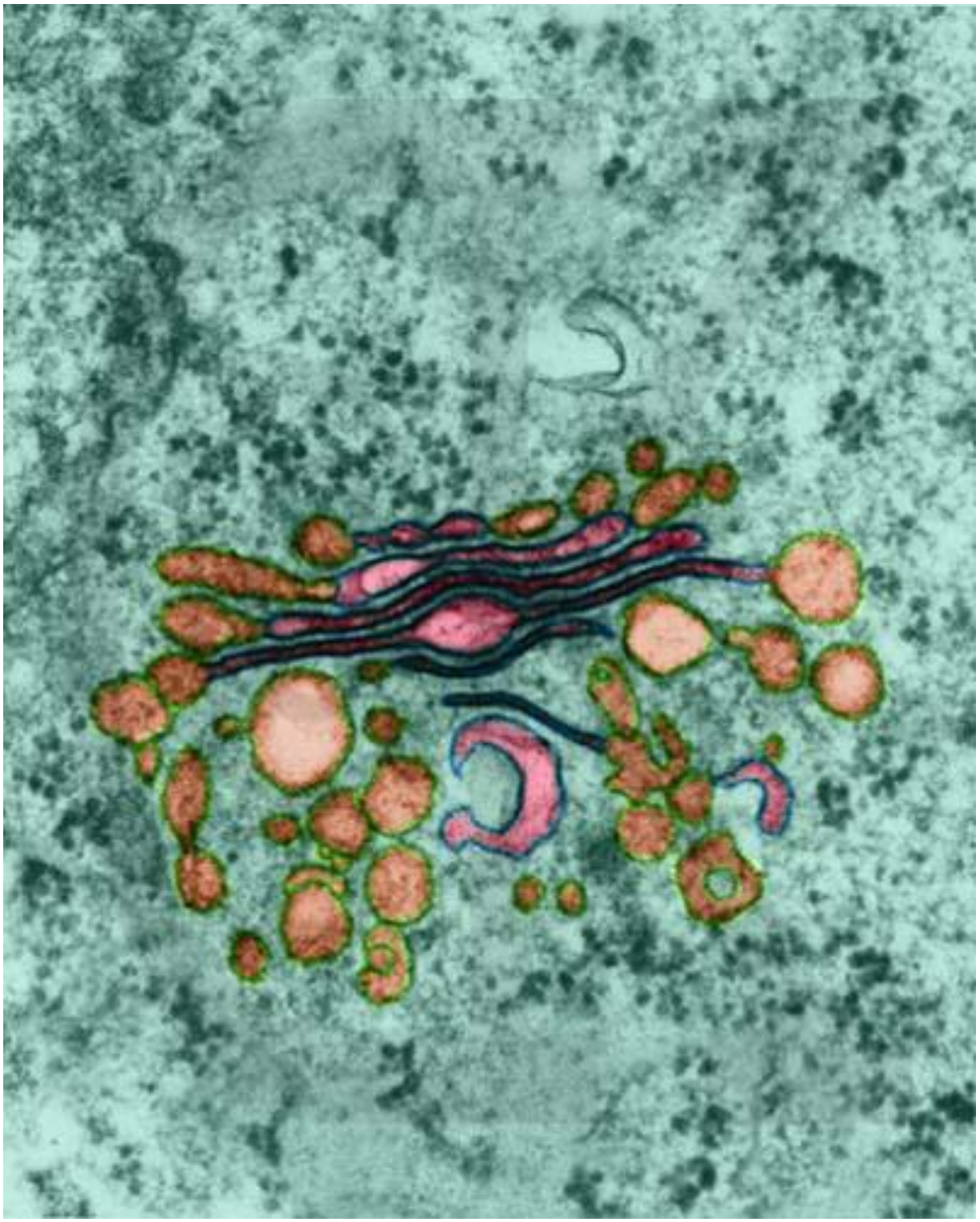
Pavia University
Pavia, Italy
1843 - 1926

Santiago Ramón y Caj

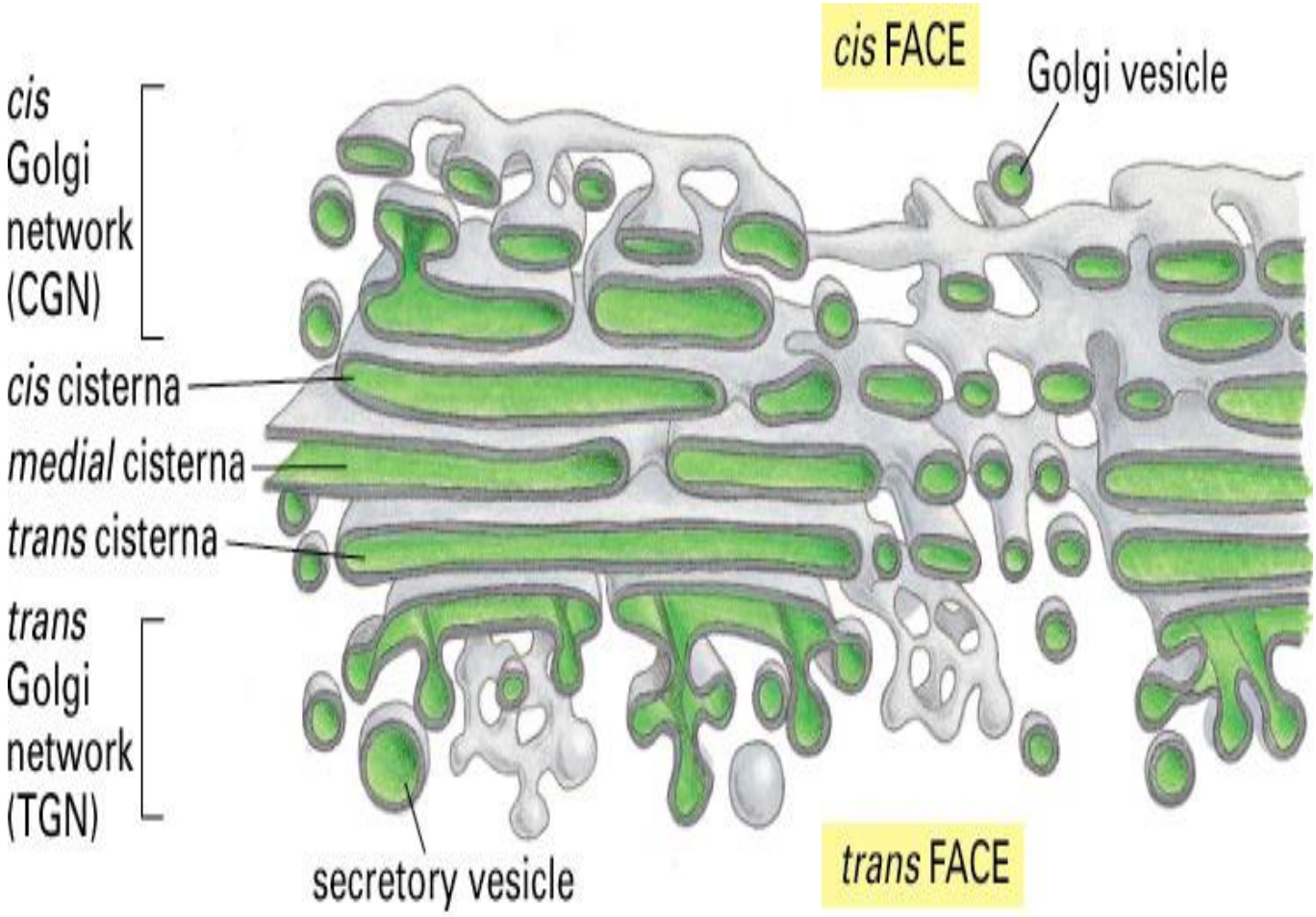
Madrid University
Madrid, Spain
1852 - 1934







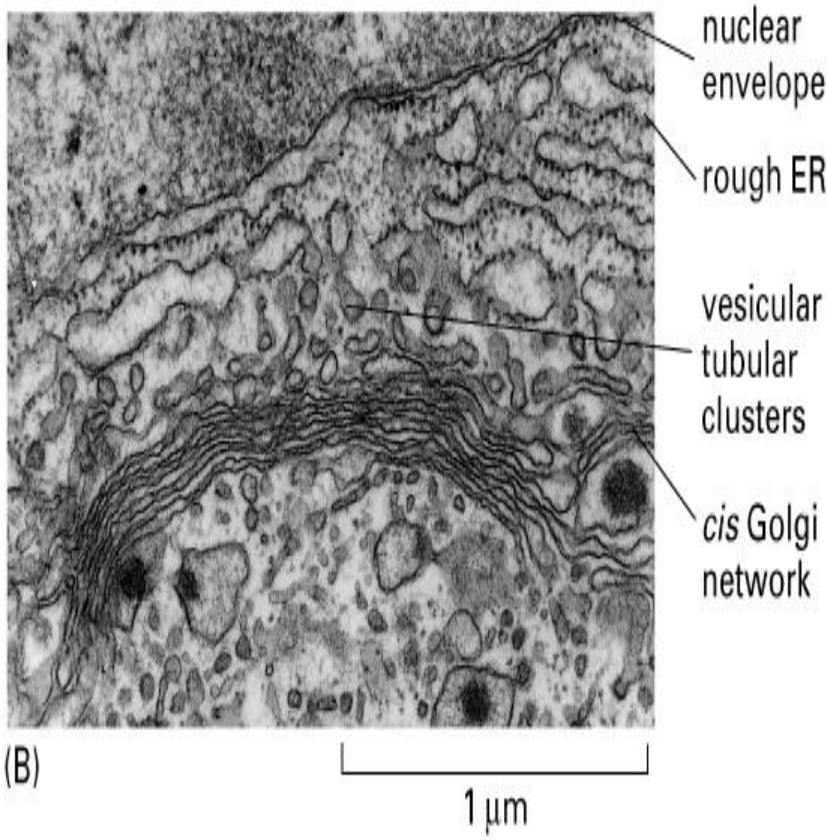
Golgi Apparatus in a plant parenchyma cell from *Sauromatum guttatum* (TEM x145,700).
Note the numerous vesicles near the Golgi.

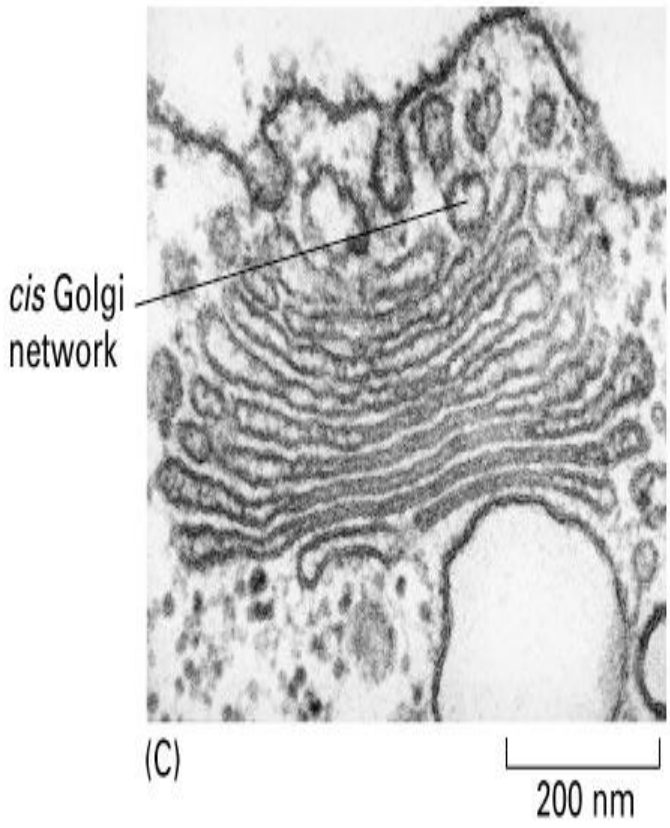

cis FACE
Golgi vesicle
cis Golgi network (CGN)
cis cisterna
medial cisterna
trans cisterna
trans Golgi network (TGN)
secretory vesicle
trans FACE

TEMs of Golgi Apparatuses. In an animal secretory cell

an algal cell Chlamydomonas

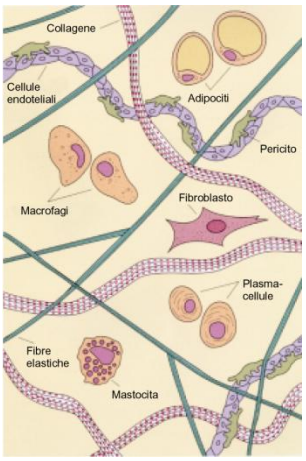
Note convex cis face and concave trans face.

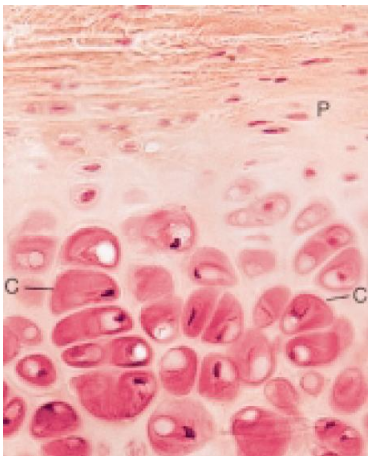


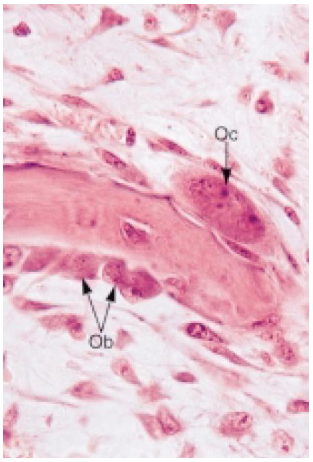


Attivita' dell'apparato del Golgi

• elaborazione di polisaccaridi e glicosaminoglicani (polisaccaridi solforati: eparina) presenti nella sostanza fondamentale del tessuto connettivo (fibroblasti), cartilagineo (condroblasti) ed osseo (osteoblasti)

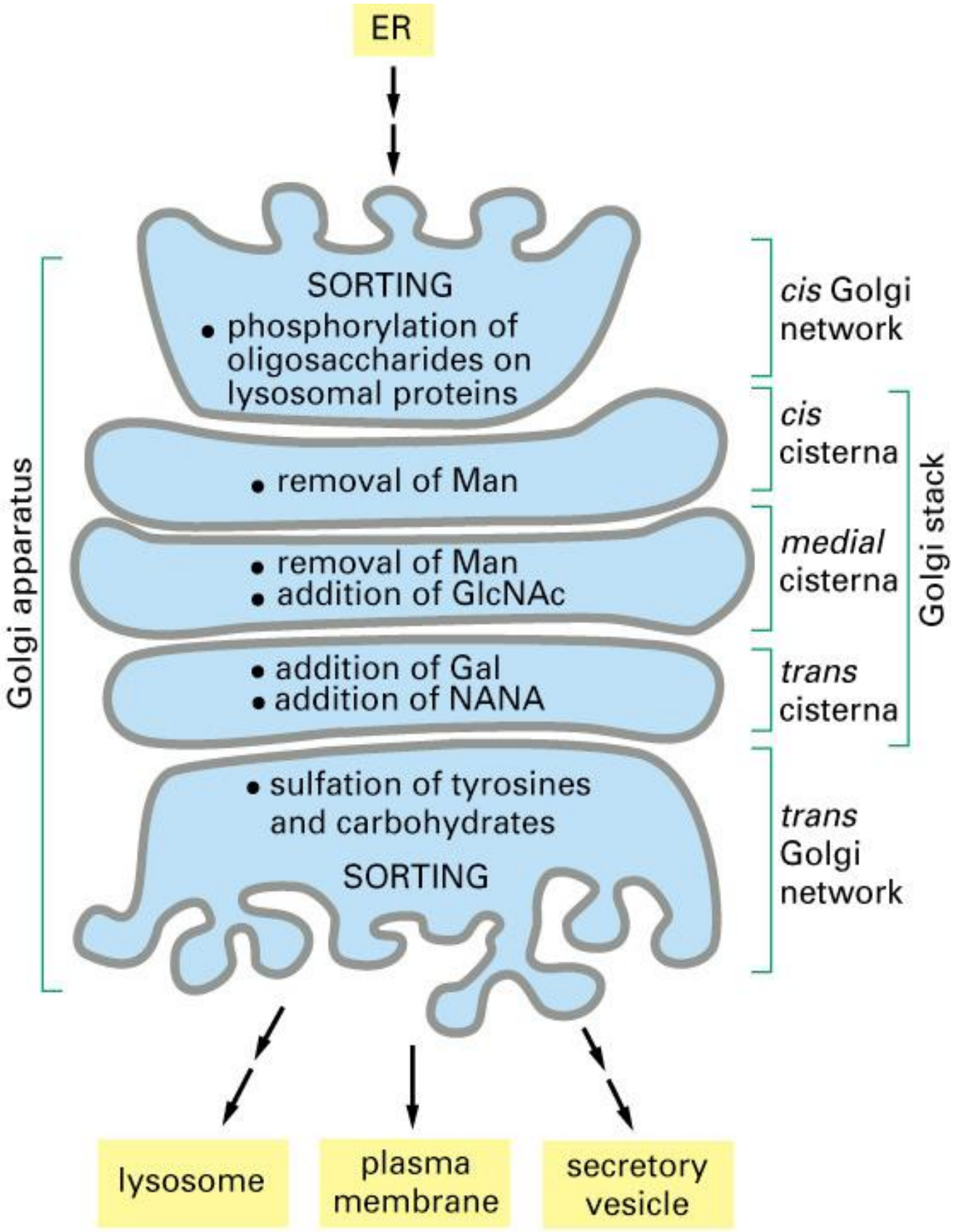


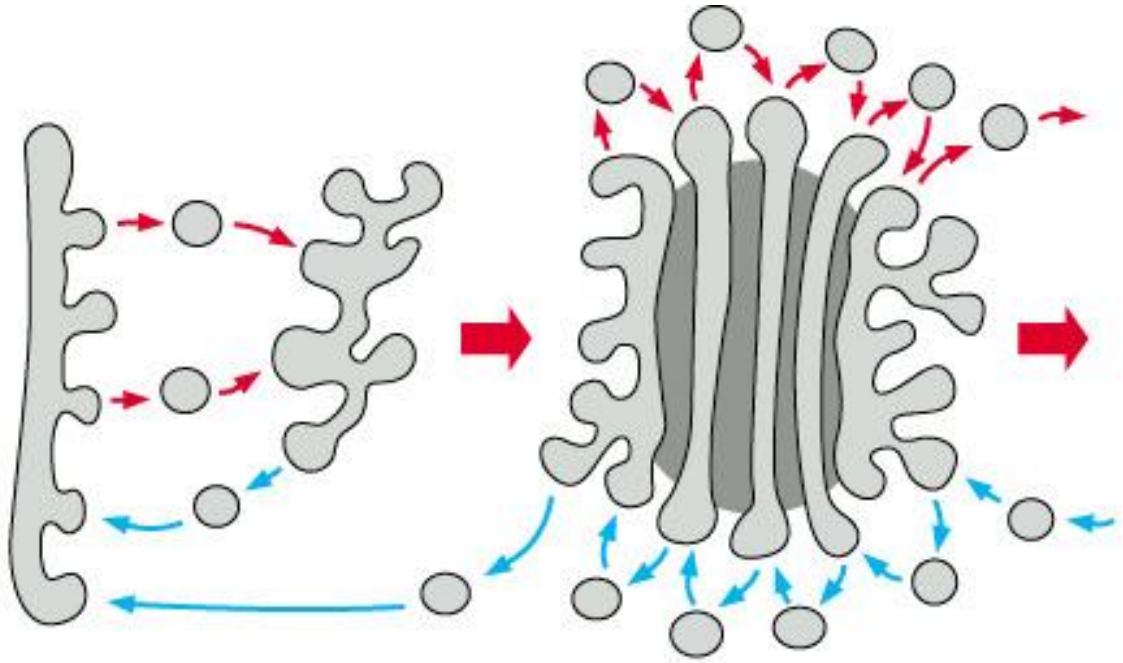




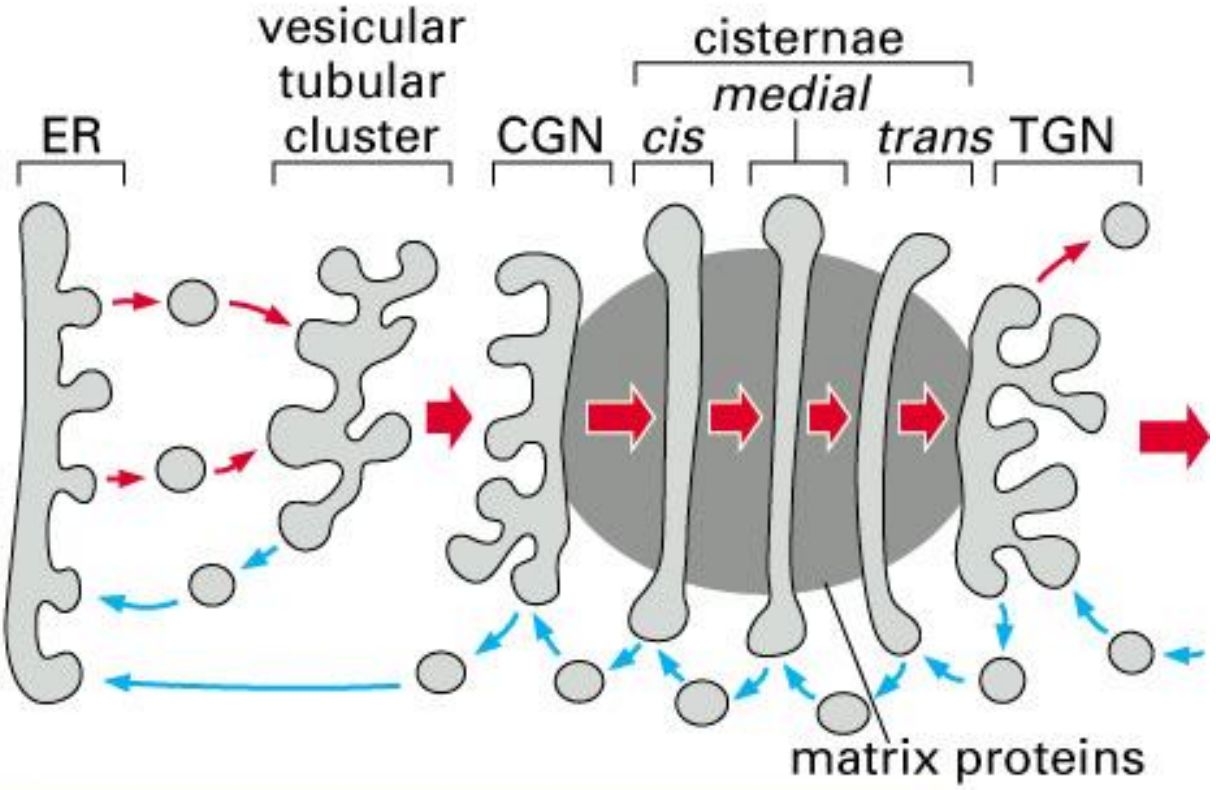
• associazione tra carboidrati e proteine a formare glicoproteine (tropocollagene, enzimi, ormoni, anticorpi) o proteoglicani (proteine + glisoaminoglicani)

• fosforilazione delle glicoproteine destinate ai lisosomi

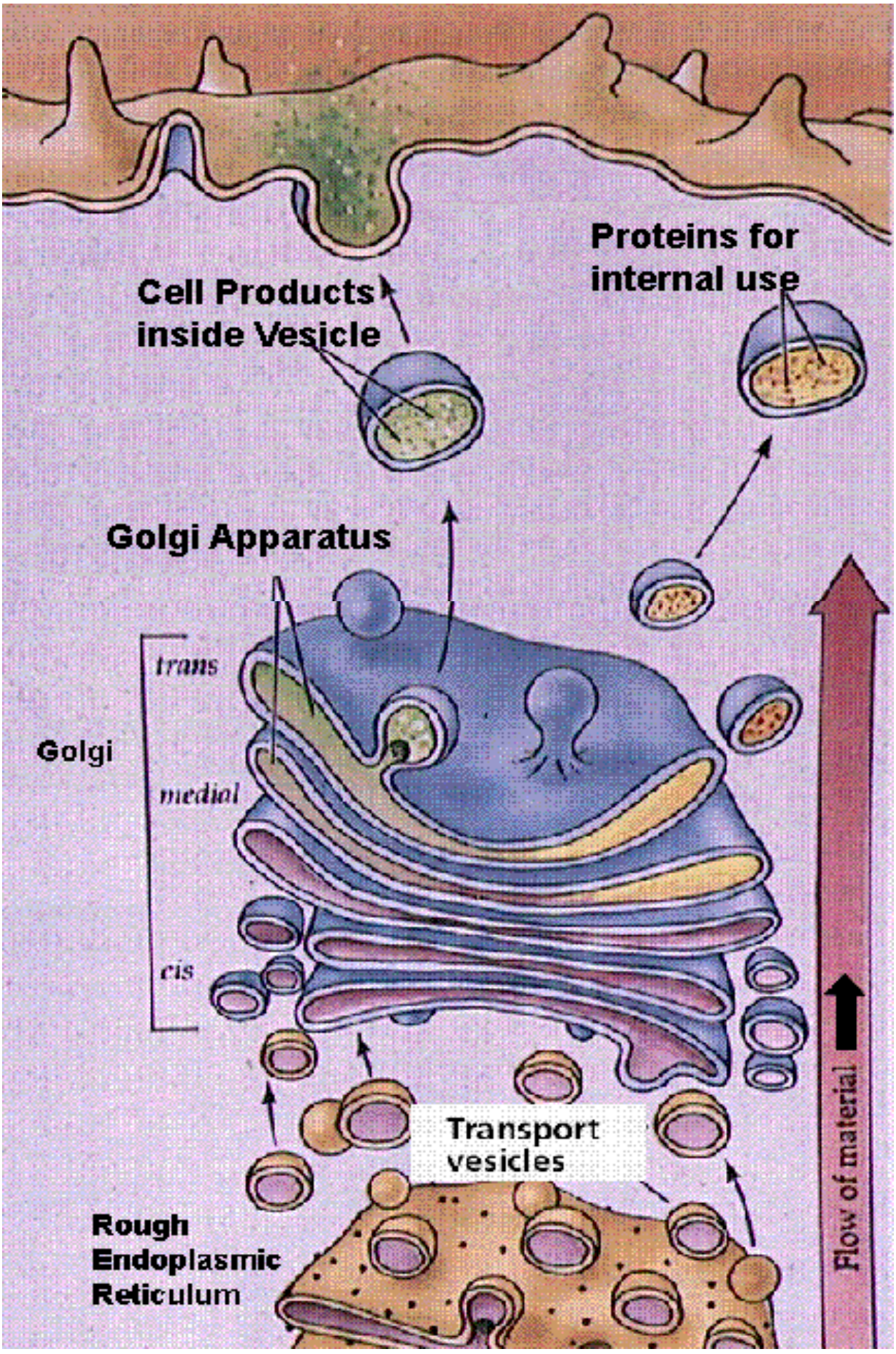

ER
SORTING
• phosphorylation of oligosaccharides on lysosomal proteins
• removal of Man
• removal of Man
• addition of GlcNAc
• addition of Gal
• addition of NANA
• sulfation of tyrosines and carbohydrates
SORTING
Golgi apparatus
cis Golgi network
cis cisterna
medial cisterna
trans cisterna
Golgi stack
trans Golgi network
lysosome
plasma membrane
secretory vesicle



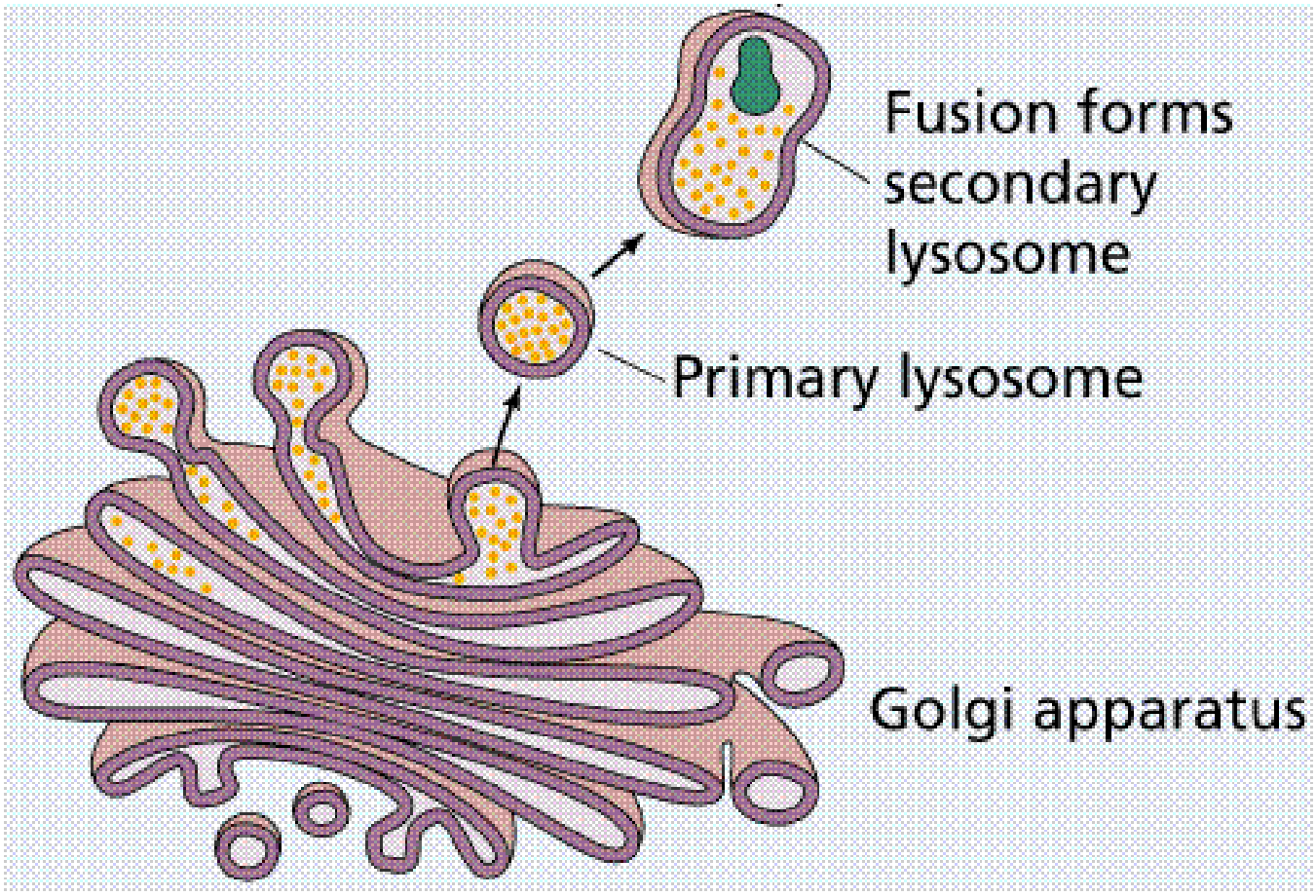
(A) VESICULAR TRANSPORT MODEL



(B) CISTERNAL MATURATION MODEL

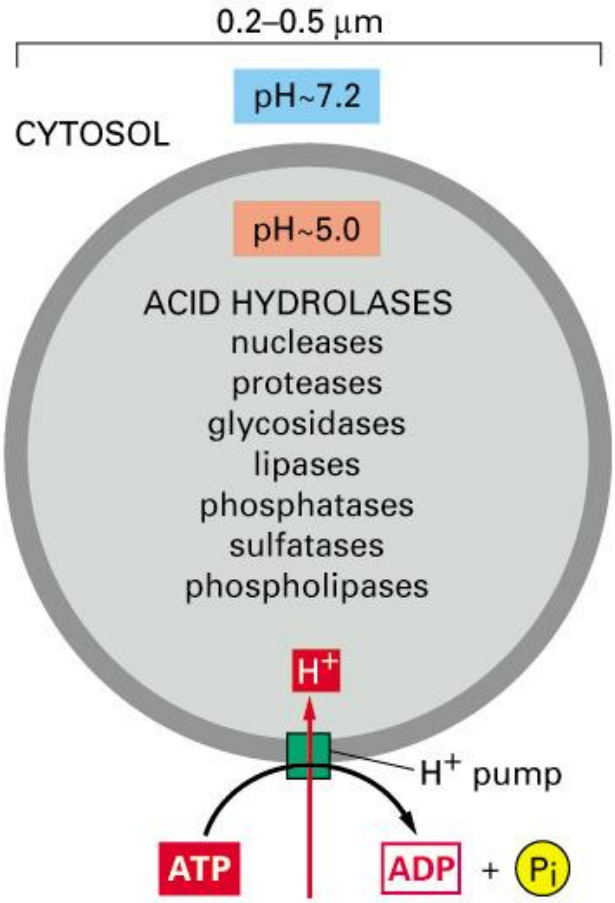

Proteins for internal use
Cell Products inside Vesicle
Golgi Apparatus
trans
Golgi
medial
cis
Transport vesicles
Rough Endoplasmic Reticulum
Flow of material

Lysosomes are relatively large vesicles formed by the Golgi. They contain **hydrolytic enzymes** that could destroy the cell. Lysosome contents function in the breakdown of materials.



Role of the Golgi in forming lysosomes

Lysosomes are the sites of intracellular digestion



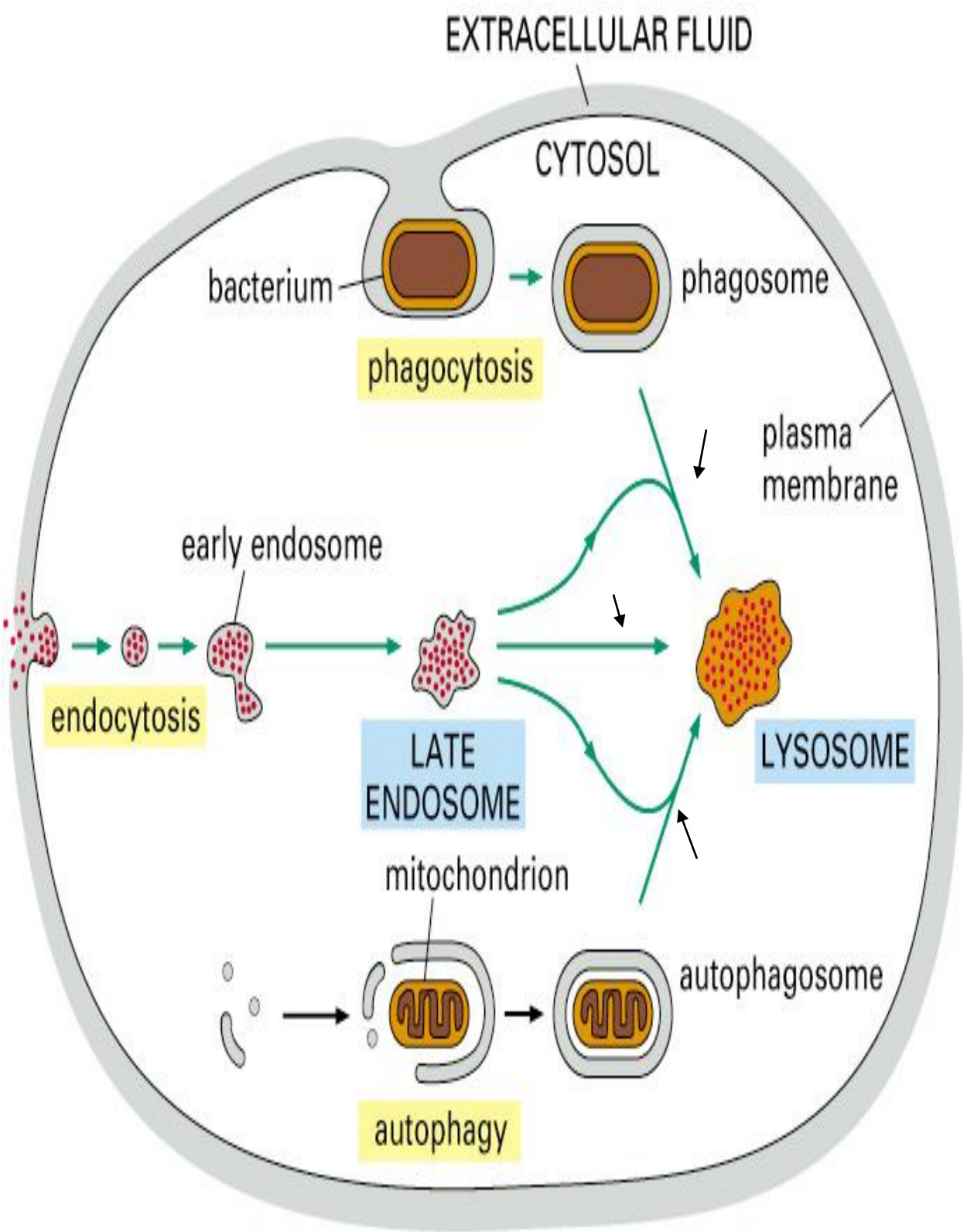
I lisosomi sono coinvolti nel turnover degli organuli cellulari (autofagia). Al termine del processo digestivo:

- formazione dei corpi residui

esocitosi

granuli lipofuscina mantenuti nel citoplasma

Material from 3 different sources end up in lysosomes



The Golgi apparatus plays a central role in vesicular traffic within cells; the post office of the eukaryotic cell.

Red=

foreward

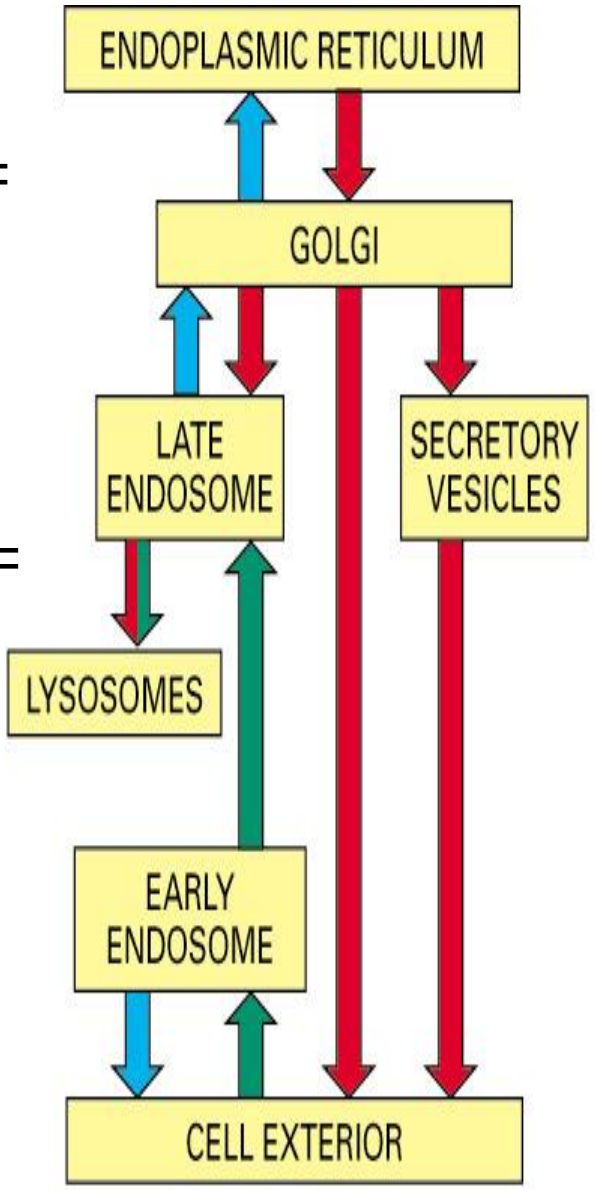
Blue=

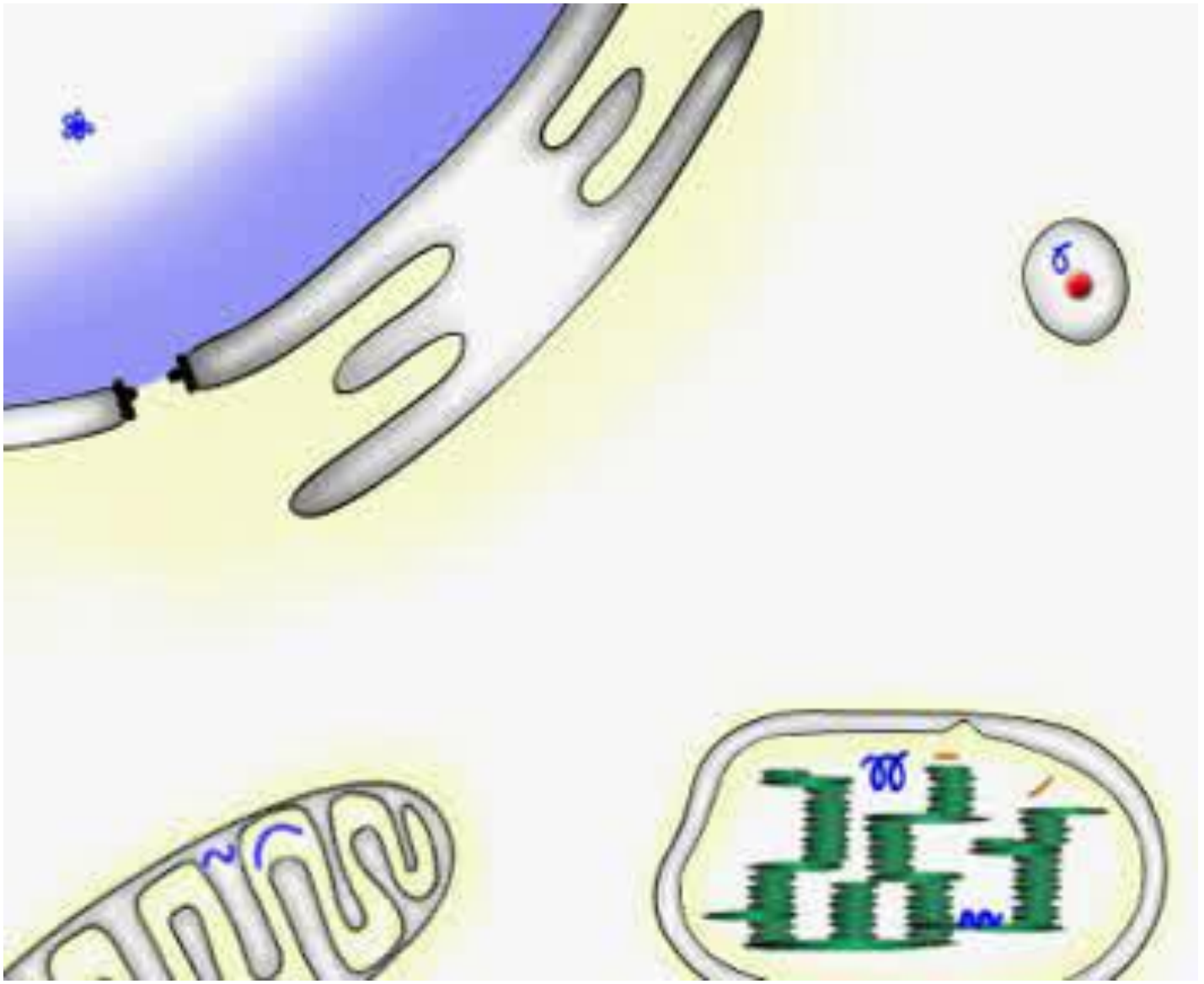
retrieval

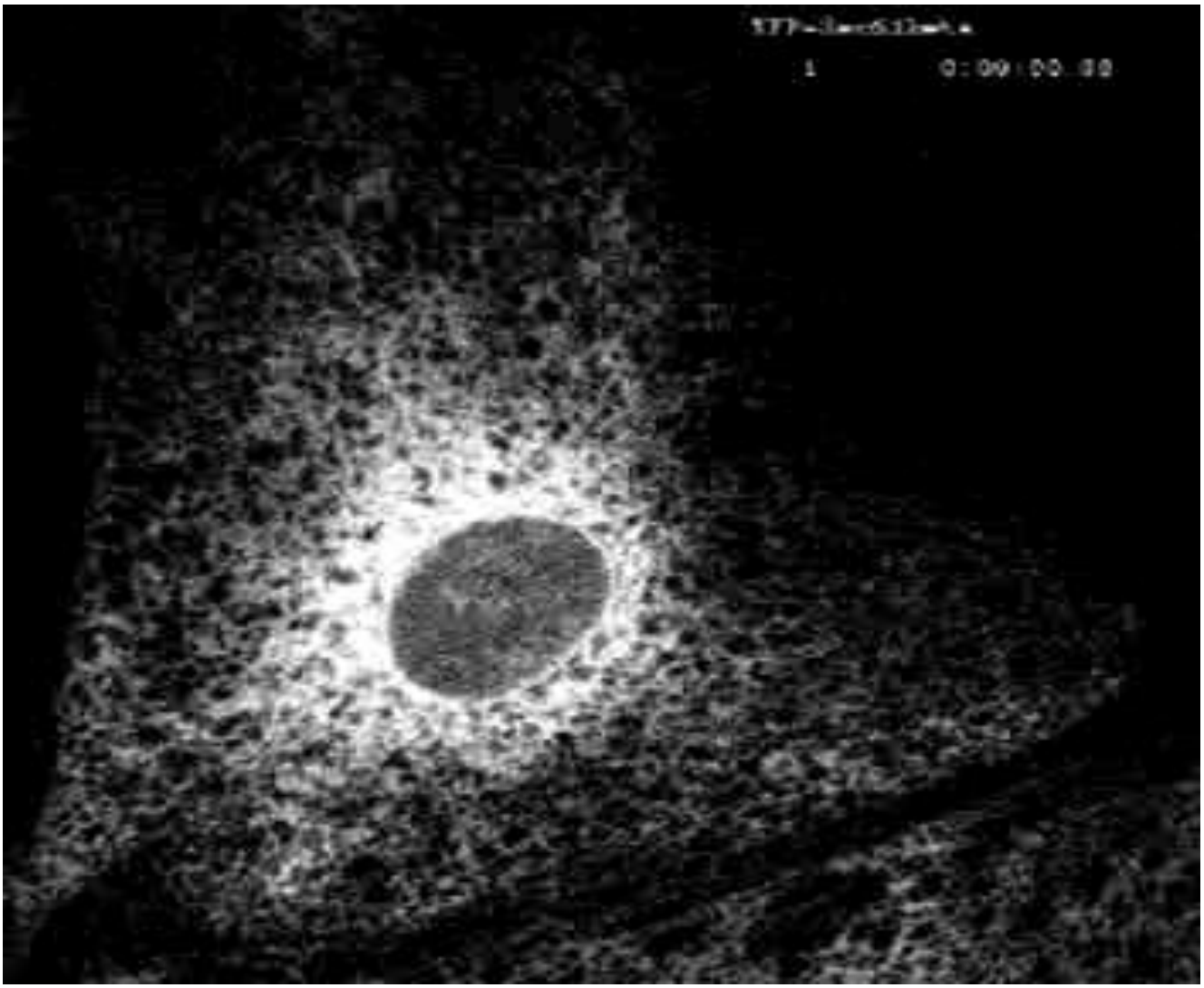
Green=

endocytic

pathways

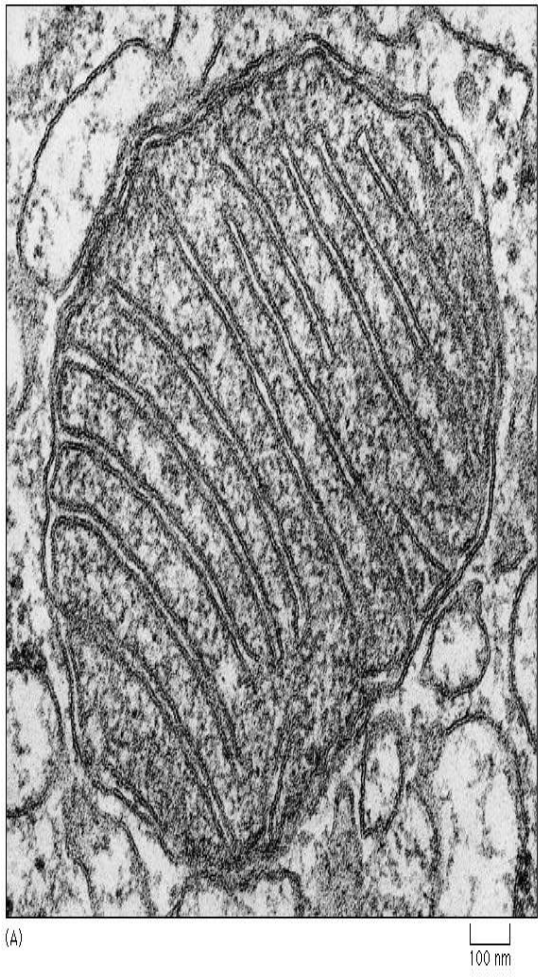


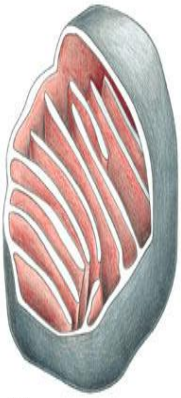


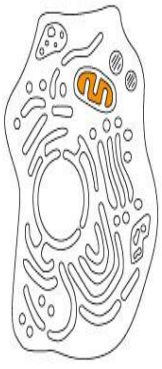


THE MITOCHONDRIA

The mitochondrion



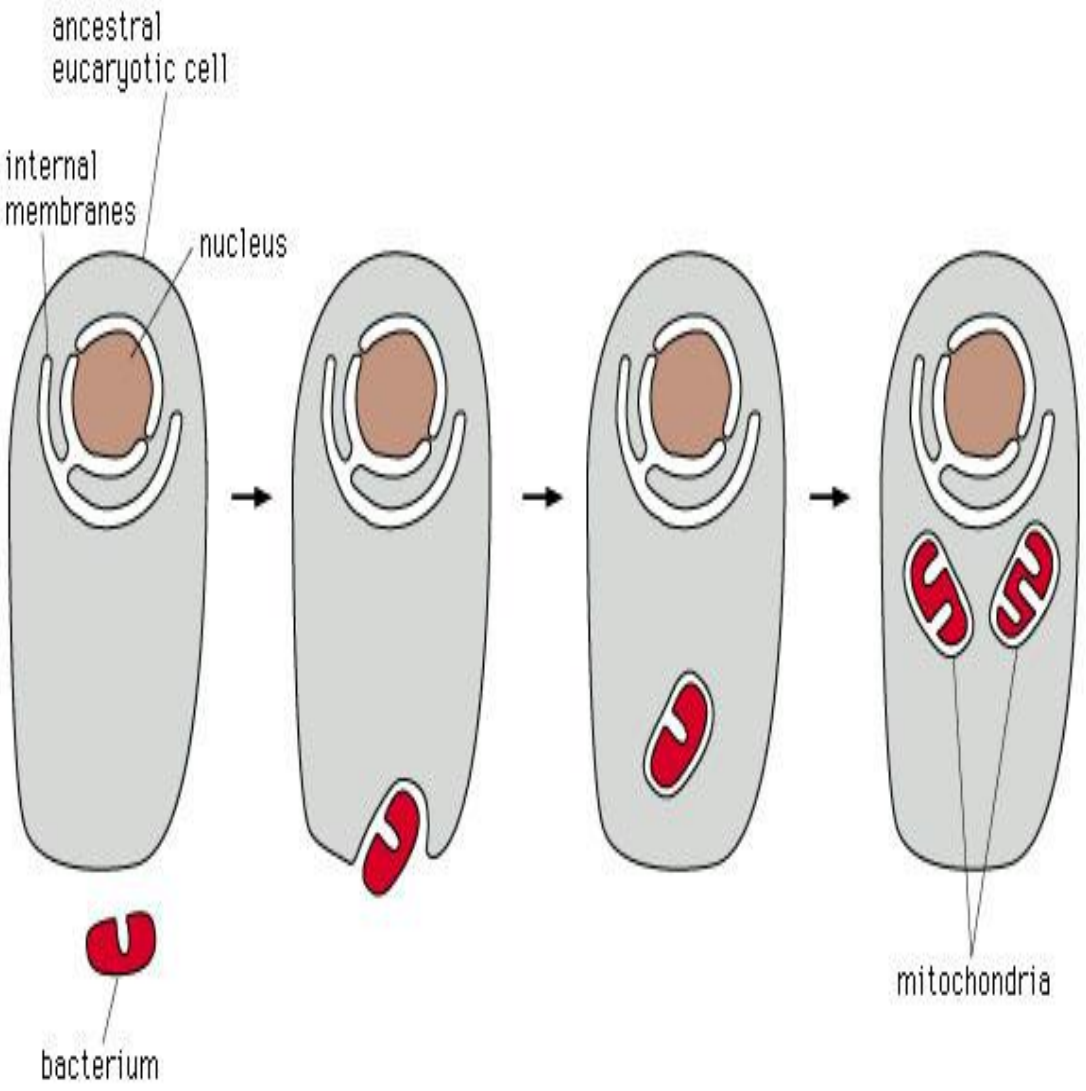




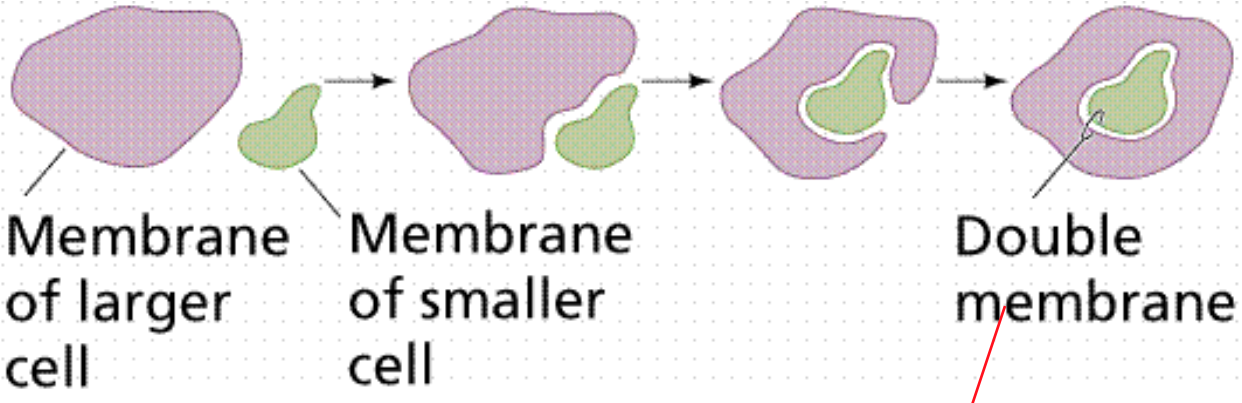
During the 1980s, Lynn Margulis proposed the theory of endosymbiosis to explain the origin of mitochondria and chloroplasts from permanent resident prokaryotes.

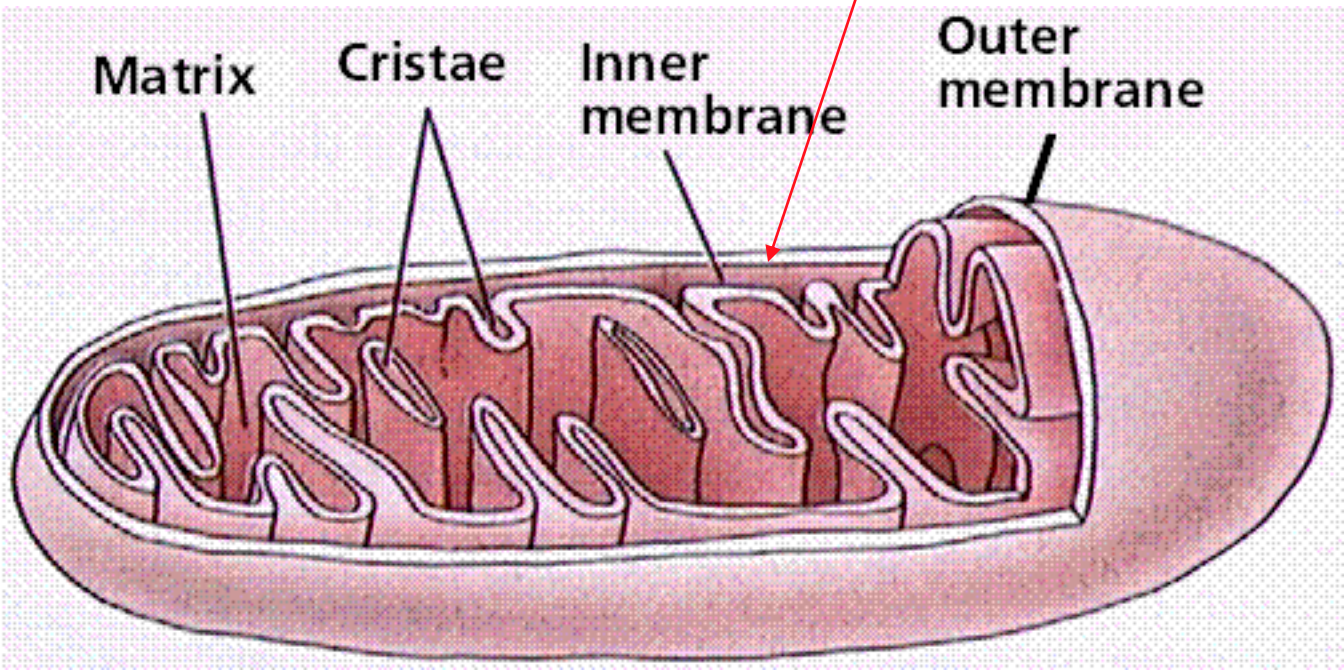
According to this idea, a larger prokaryote (or perhaps early eukaryote) engulfed or surrounded a smaller prokaryote some 1.5 billion to 700 million years ago.

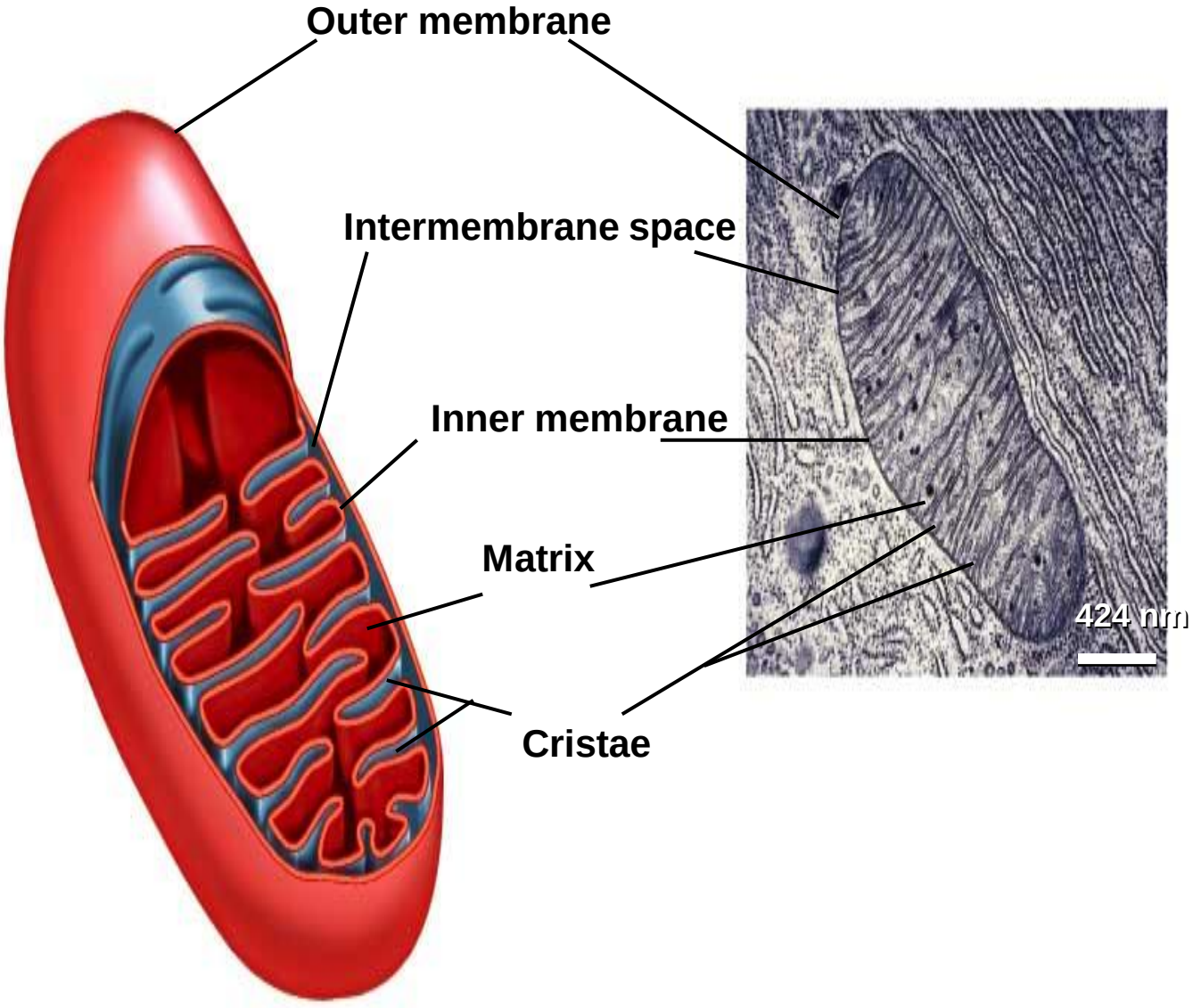
The mitochondrion

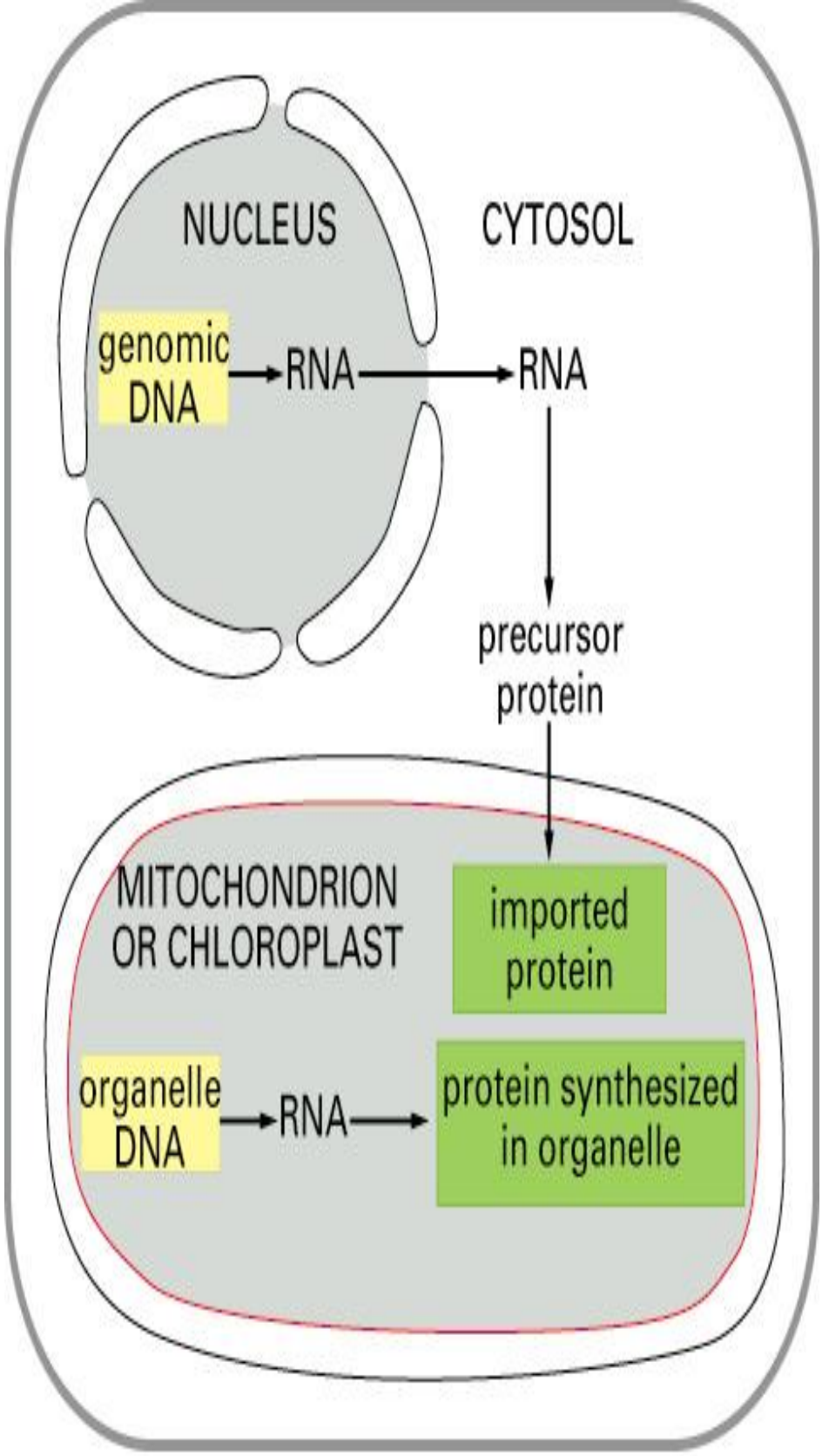


The basic events in endosymbio

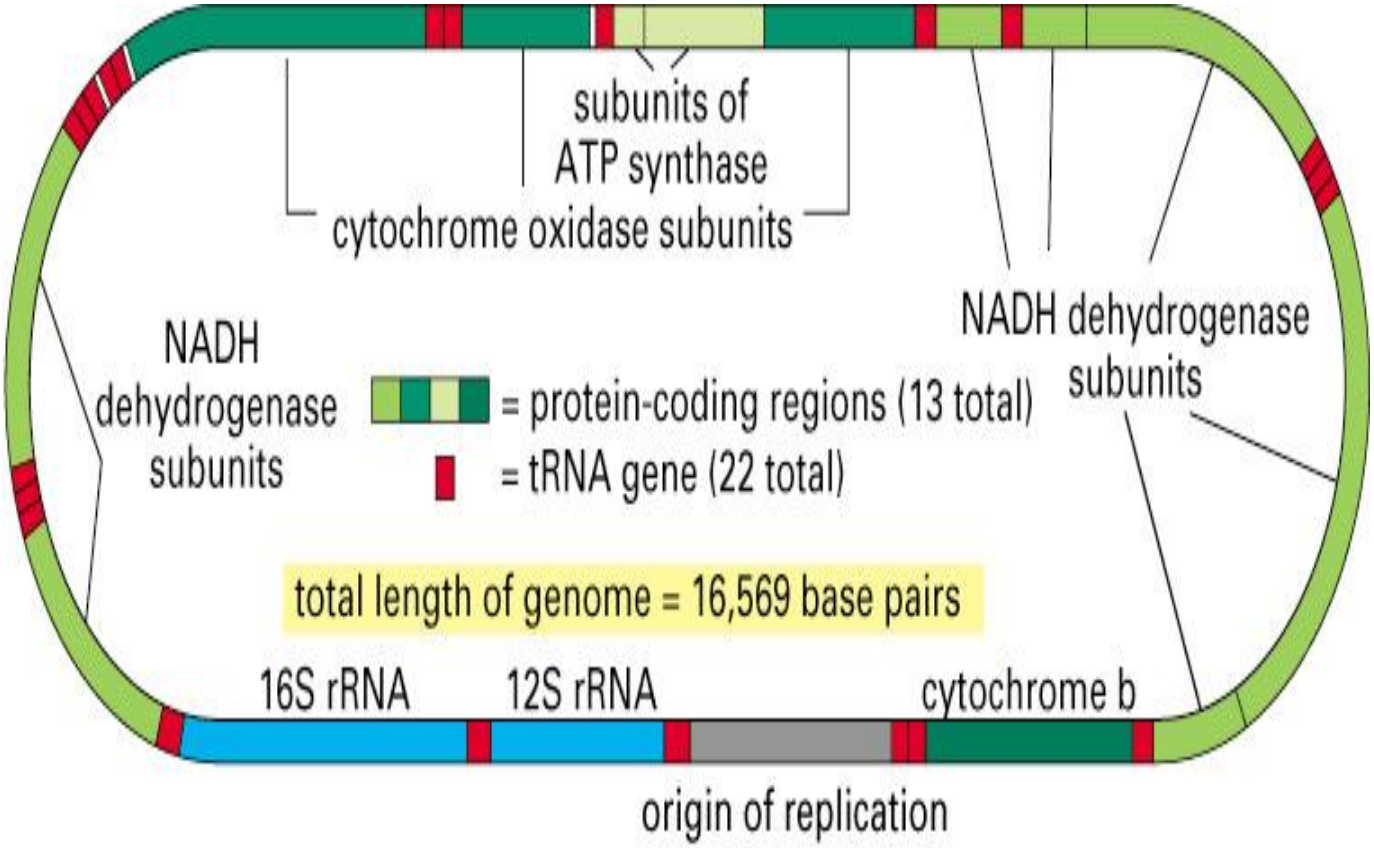





Outer membrane
Intermembrane space
Inner membrane
Matrix
Cristae
424 nm


NUCLEUS
CYTOSOL
genomic DNA
RNA
RNA
precursor protein
MITOCHONDRION OR CHLOROPLAST
imported protein
organelle DNA
RNA
protein synthesized in organelle

The human mitochondrial genome



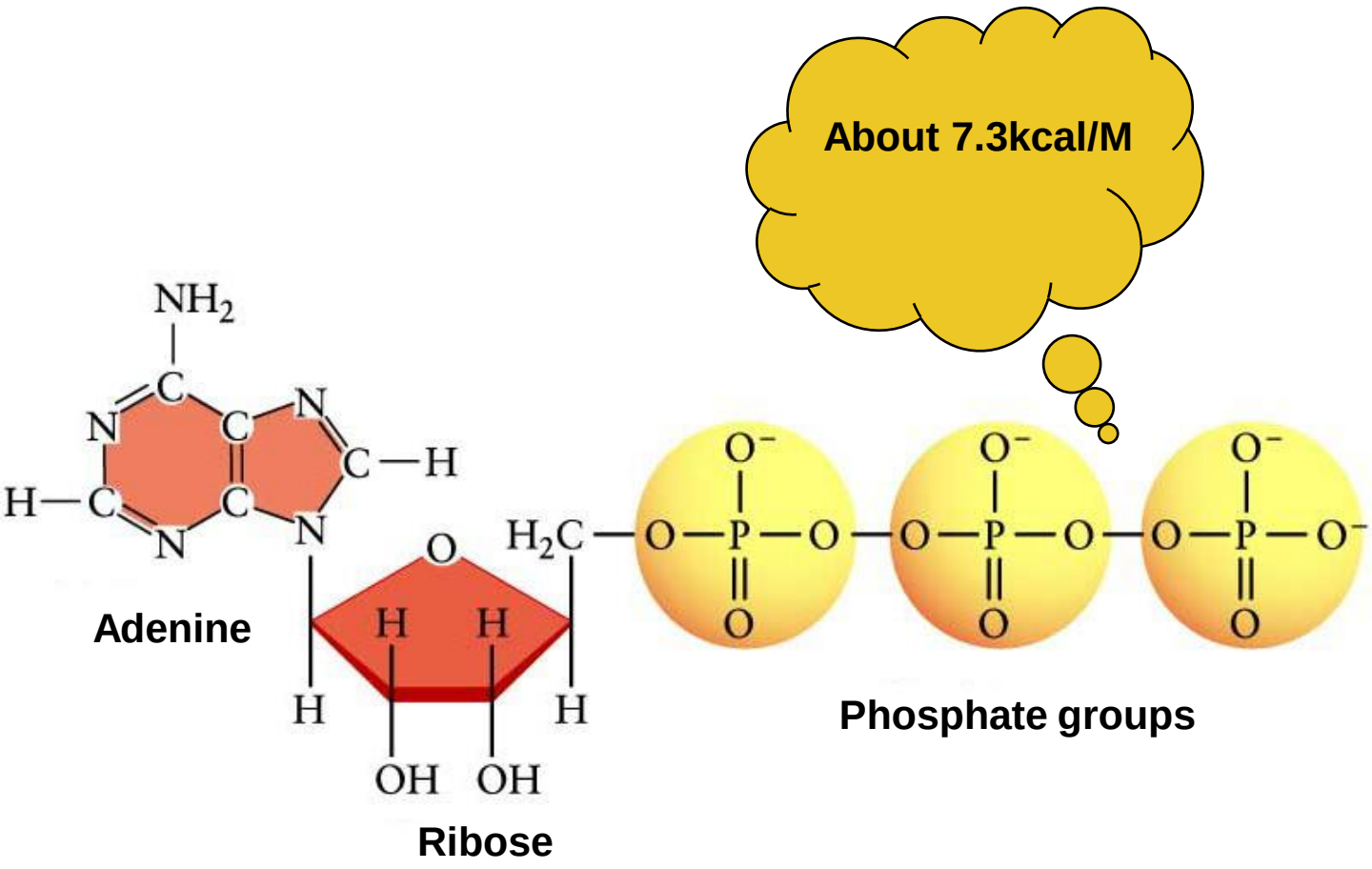
STRUCTURE AND FUNCTION

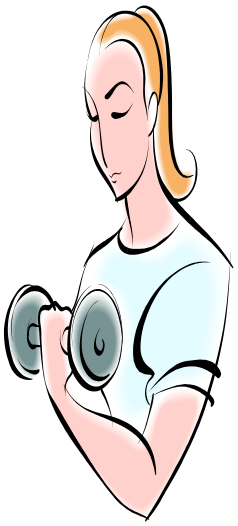
* Approximately 0.2 to 1.0 μm in diameter and 1-4 μm in length

* Mitochondrial size, number and intracellular location vary from one type of cell to another

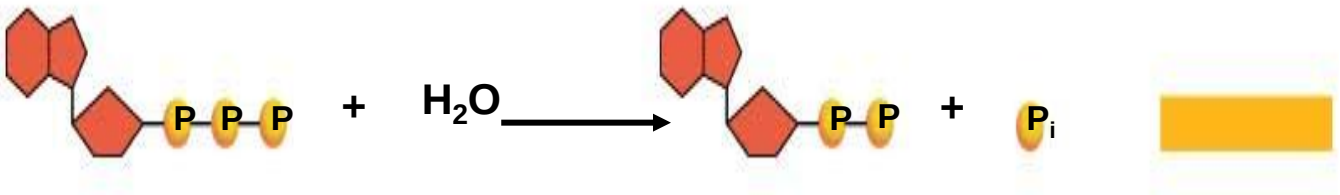
Respiration and fermentation provide energy for the formation of ATP

ATP consists of adenine, ribose, and three phosphate groups.





Energy is released when ATP is hydrolyzed.



Ruolo dell'ATP nella cellula

• **Rappresenta la piu' importante riserva di energia sotto forma di un legame chimico fosforico altamente energetico.**

• **L'energia accumulata nell'ATP viene liberata mediante riconversione dell'ATP in ADP ad opera dell'enzima adenosintrifosfatasi (ATPasi).**

• **Utilizzata per tutte le attivita' funzionali:**

- **sintesi proteica**
- **sintesi di polisaccaridi**
- **sintesi di lipidi**
- **contrazione muscolare**
- **movimenti cellulari**
- **conduzione degli impulsi**
- **trasporto attivo attraverso le membrane**
- **etc…..**

• **I processi di utilizzazione dell'energia si verificano:**

- **nel citoplasma (attivazione degli aminoacidi)**
- **ribosomi (sintesi proteica)**
- **miofibrille (contrazione muscolare)**
- **membrana plasmatica (trasporto attivo ed**
- **endocitosi)**
- **reticolo endoplasmatico e complesso del Golgi**
- **(processi di sintesi e trasporto)**

Principali vie metaboliche del glucosio

La glicolisi inizia nella matrice citoplasmatica con la formazione di piruvato

Glicolisi

↓

Glucosio

(ciclo di Embden-Meyerhof)

↓

Acido piruvico

↙ ↘

Fermentazione

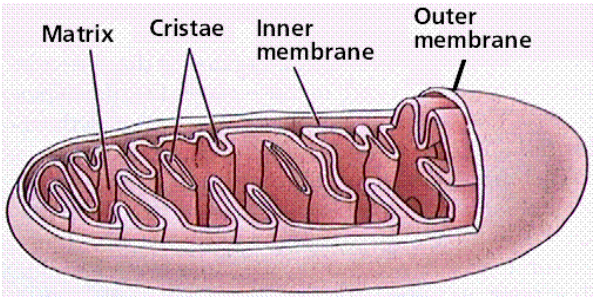
(via anaerobica)

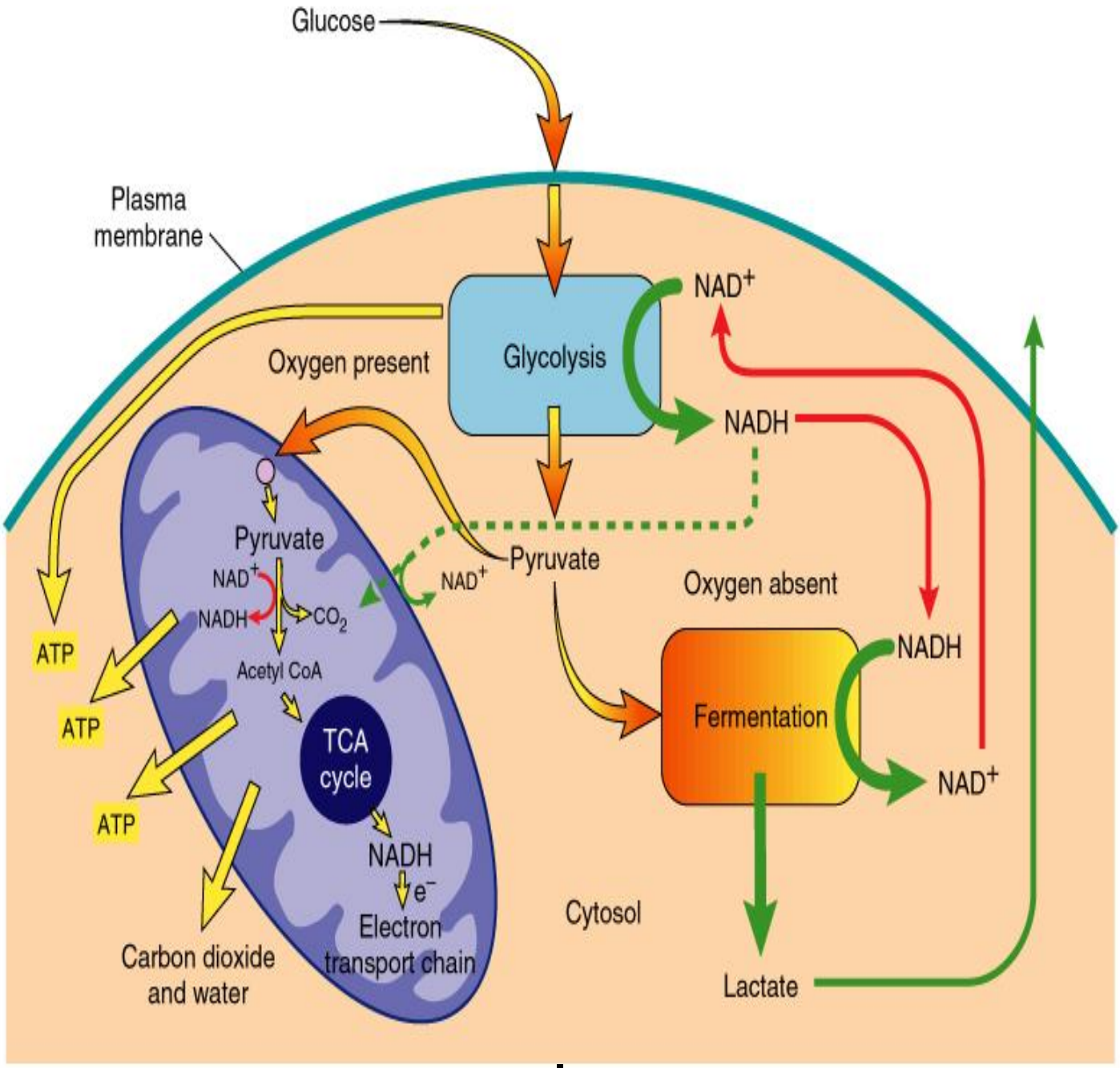
(acido lattico)

Respirazione

(via aerobica)

(ciclo di Krebs)





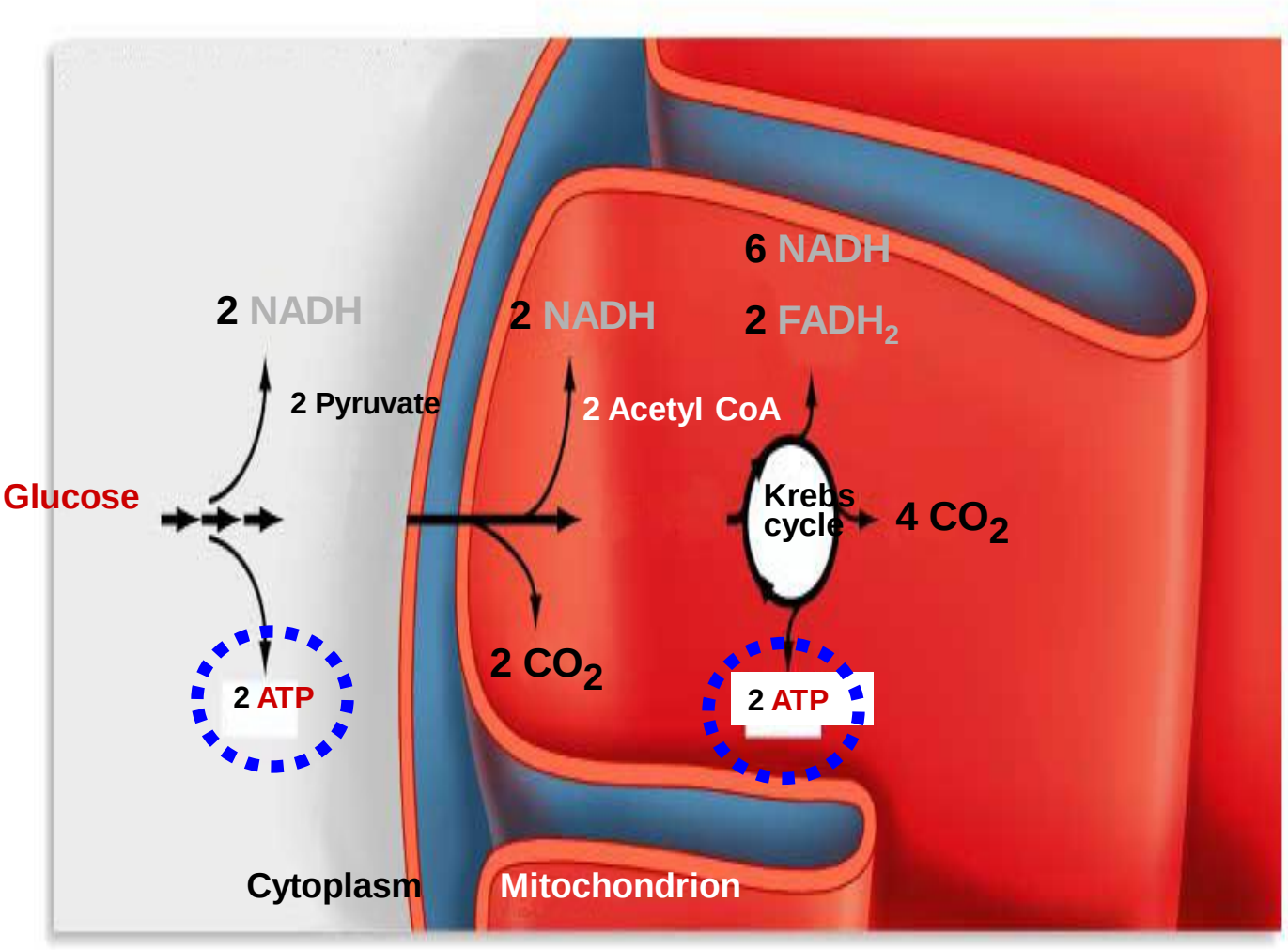
aerobi la glicolisi seguita dalla respirazione cellulare produce:

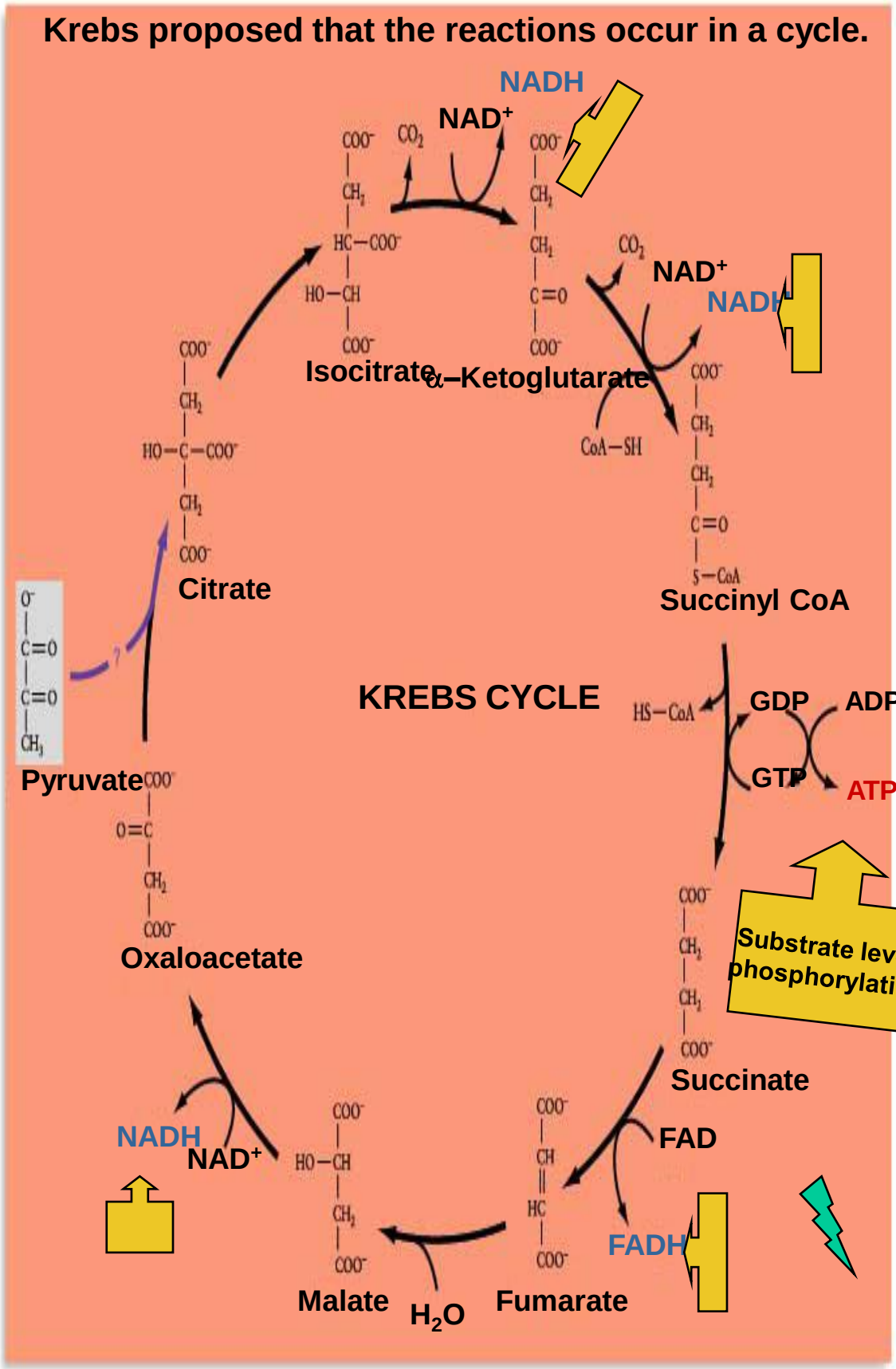
- ossidazione completa
- prodotti i rifiuto (H_2O - CO_2)
- 36 ATP

anaerobi la glicolisi seguita dalla fermentazione:

- ossidazione incompleta
- prodotti i rifiuto (acido lattico o etanolo e CO_2)
- 2 ATP

SUMMARY OF GLUCOSE OXIDATION




Krebs proposed that the reactions occur in a cycle.
NADH
NAD+
CO2
Isocitrate
α–Ketoglutarate
NAD+
NADH
CO2
CoA–SH
Citrate
Succinyl CoA
KREBS CYCLE
HS–CoA
GDP
ADP
GTP
ATP
Pyruvate
Oxaloacetate
Substrate level phosphorylation
Succinate
FAD
FADH
NADH
NAD+
Malate
H2O
Fumarate

Rese energetiche

La glicolisi ha un resa di 2 molecole di ATP per ogni molecola di glucosio

Il ciclo dell'acido citrico e della catena respiratoria producono altre 34 molecole di ATP

$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6CO_2 + 6\ H_2O + 36\ ATP$