Lecture Series 3

The Organization of Cells

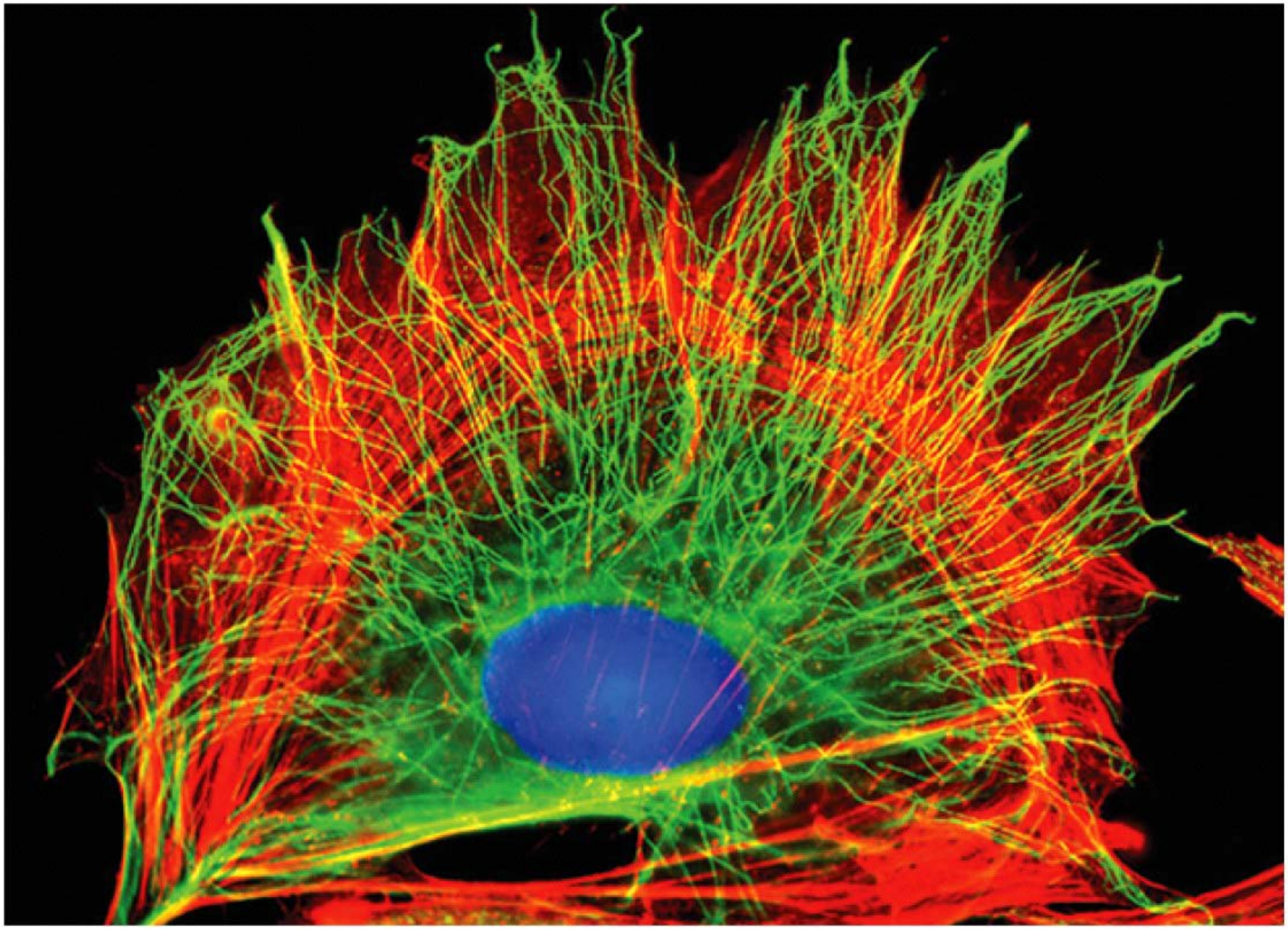
Reading Assignments

- Read Chapter 15
  Endomembrane System
- Read Chapter 17
  Cytoskeleton

A. The Cell: The Basic Unit of Life

- Cell Theory: All cells come from preexisting cells and have certain processes, molecules, and structures in common.

Fluorescent stain of cell



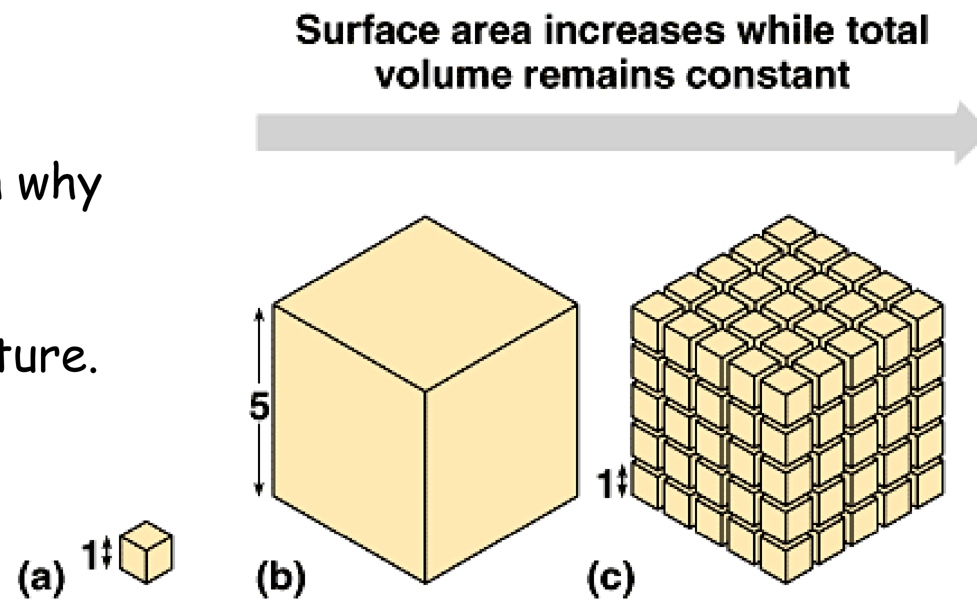
10 μm

A. The Cell: The Basic Unit of Life

- To maintain adequate exchanges with its environment, a cell's surface area must be large compared with its volume.

Geometric relationships explain why most cells are so small.

SA / V ratios measure this feature.

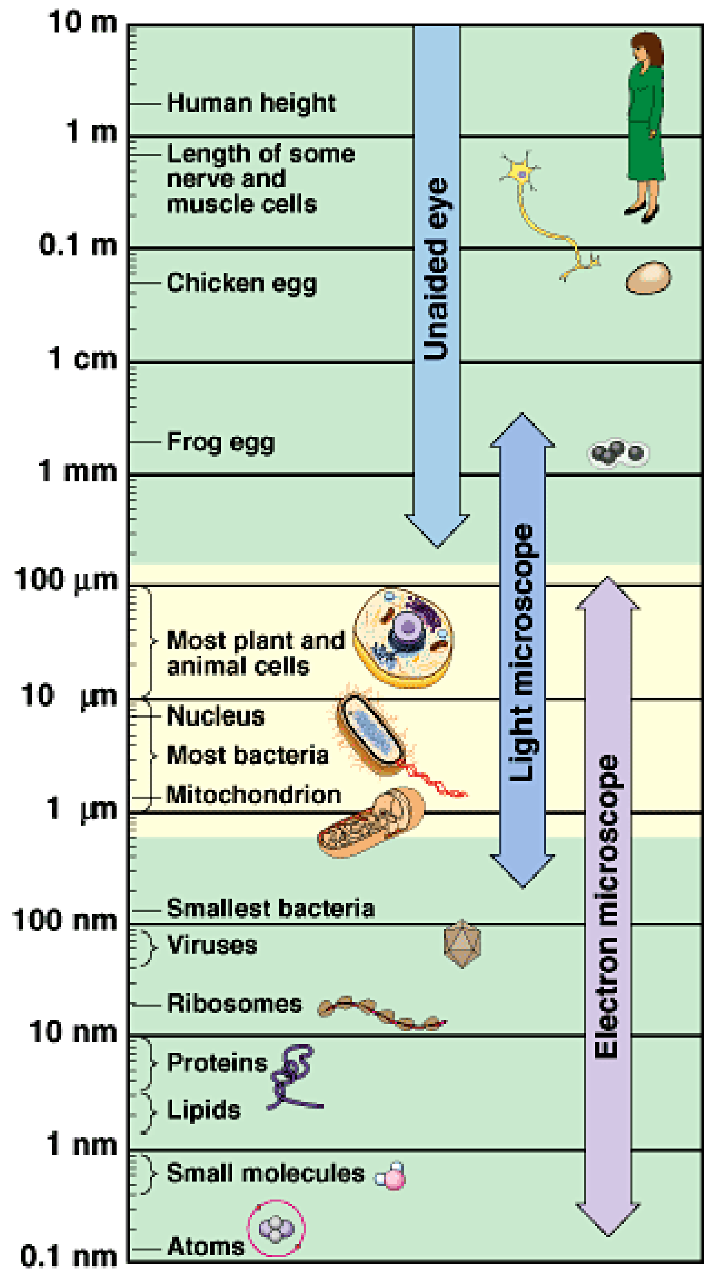


Total surface area (height × width × number of sides × number of boxes)	6	150	750
Total volume (height × width × length × number of boxes)	1	125	125
Surface-to-volume ratio (area ÷ volume)	6	1.2	6

A. The Cell: The Basic Unit of Life

- Microscopes are needed to visualize cells. Electron microscopes allow observation of greater detail than light microscopes do.

The size range of cells:



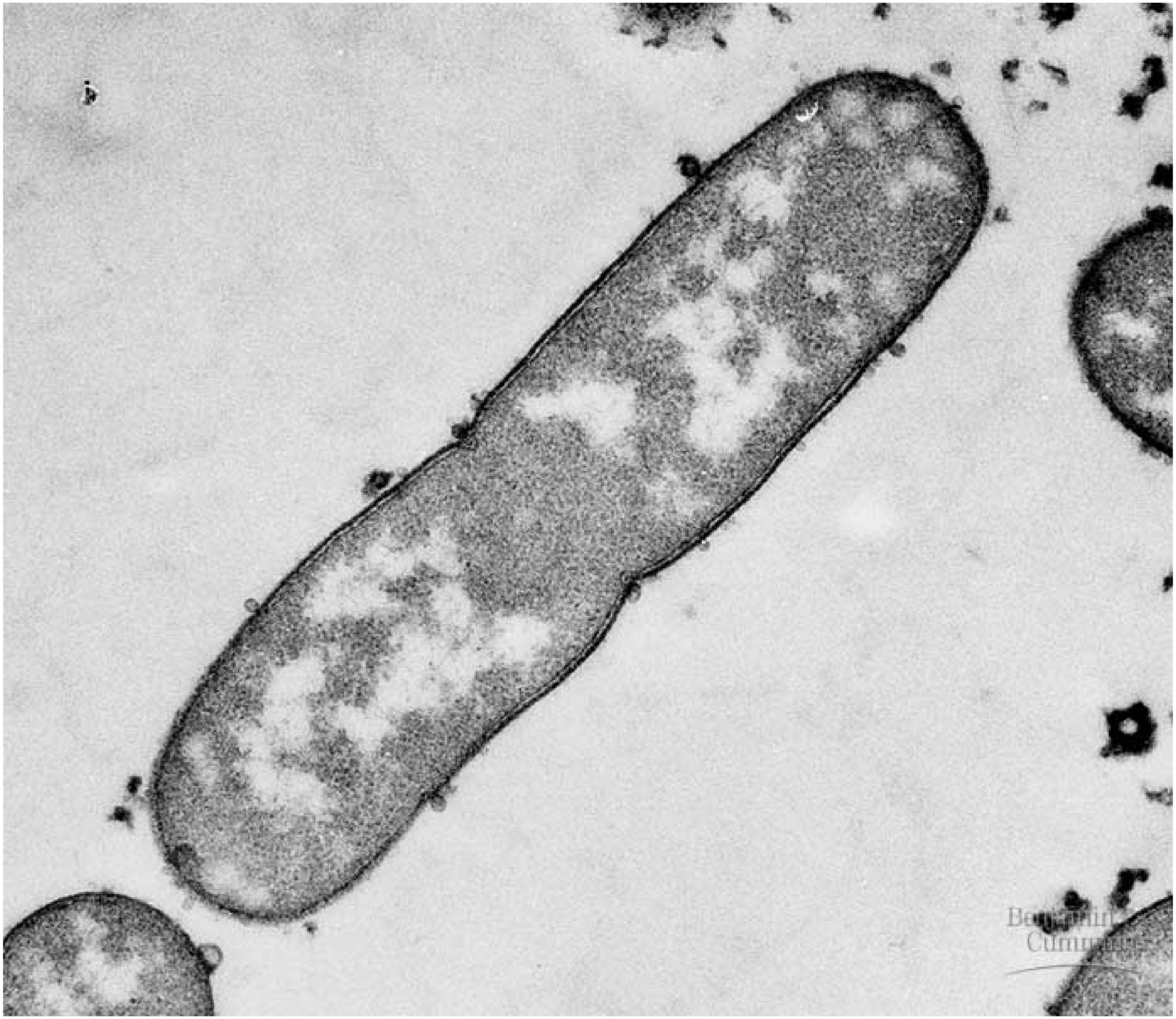
Eucarya

Bacteria & Archaea

A. The Cell: The Basic Unit of Life

- Microbial cell organization is characteristic of both the Domains *Bacteria* and *Archaea*.
- Microbial cells lack internal compartments, i.e., no bags within bags of biochemistry.

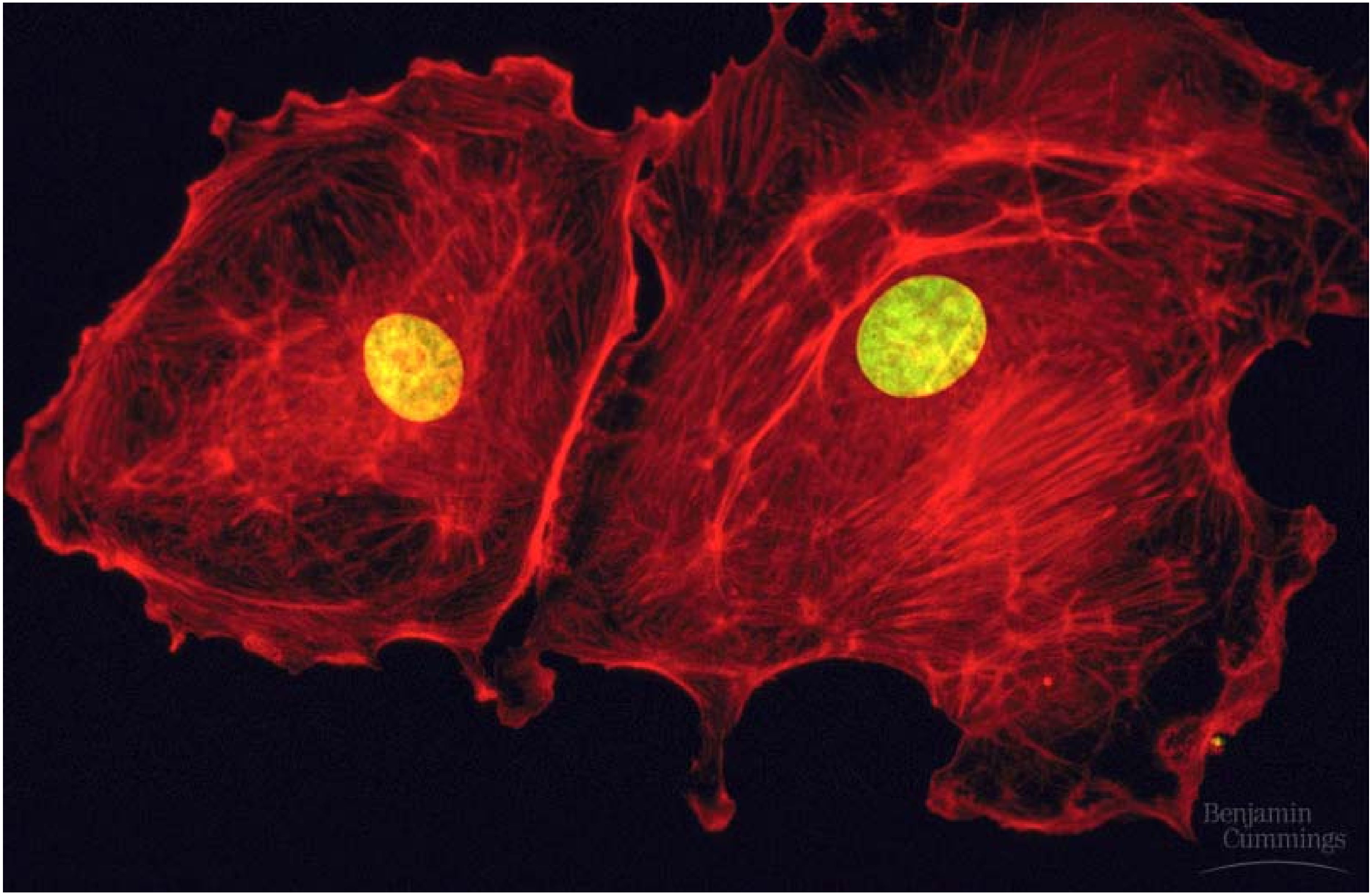
Escherichia coli



A. The Cell: The Basic Unit of Life

- Eucarya cells have many membrane-enclosed compartments, including a nucleus containing DNA.

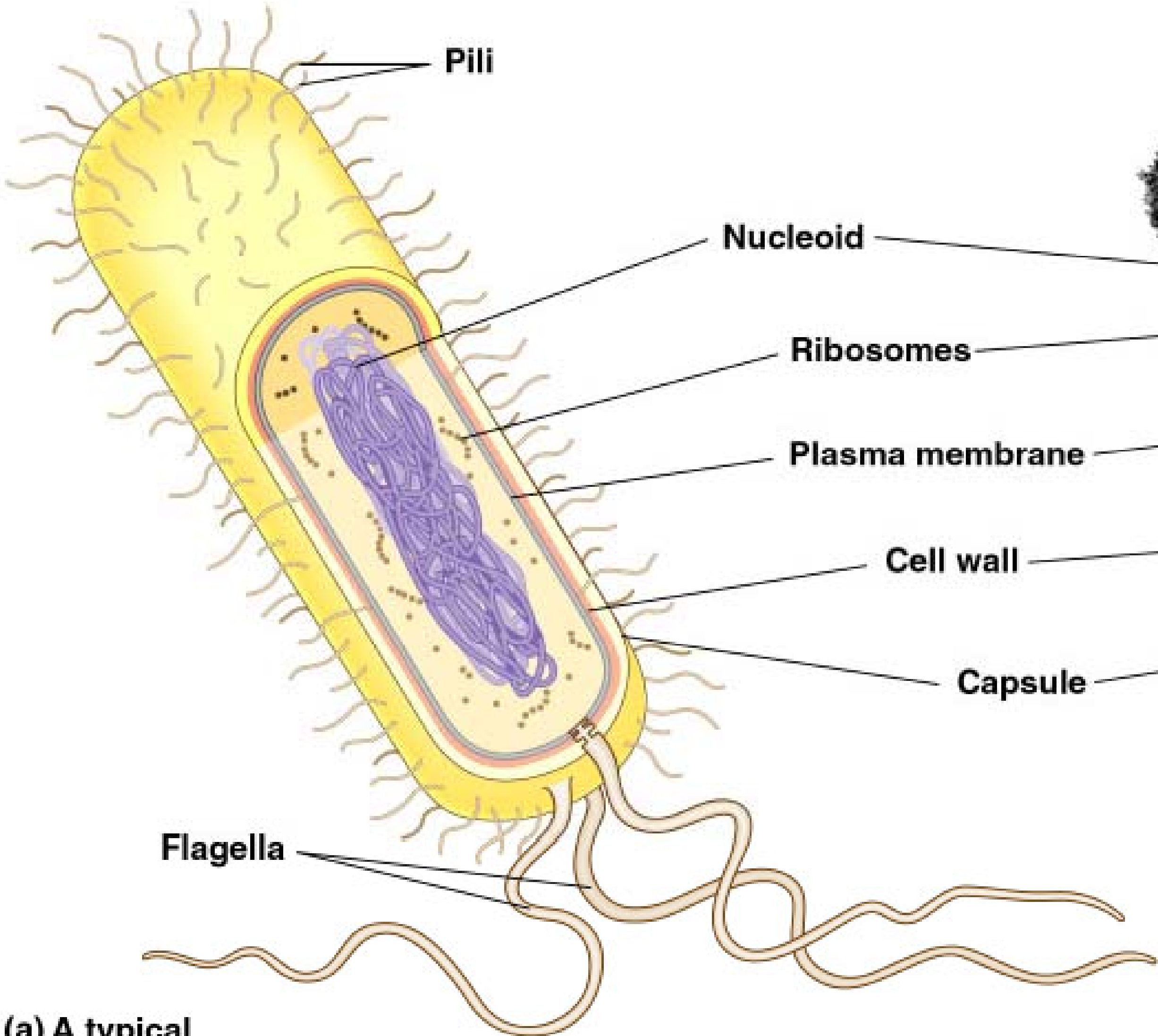
Nuclei and Actin in Animal cells



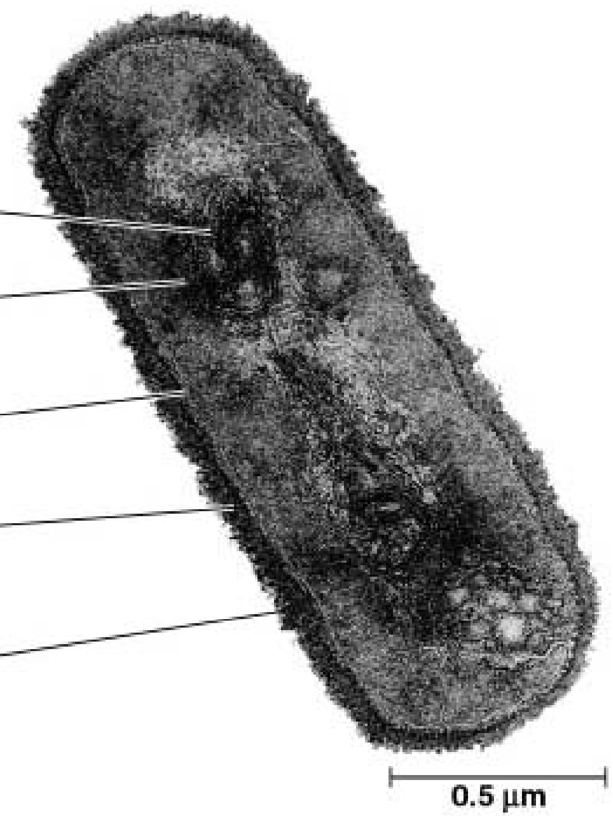
B. Microbial Cells

- All microbial cells have a plasma membrane, a nucleoid region with DNA, and a cytoplasm.
- Cytoplasm contains ribosomes and cytosol (dissolved enzymes, water, small molecules and dissolved macromolecules).
- Some microbes have a cell wall, outer membrane and capsule, some contain photosynthetic membranes, and some have mesosomes.

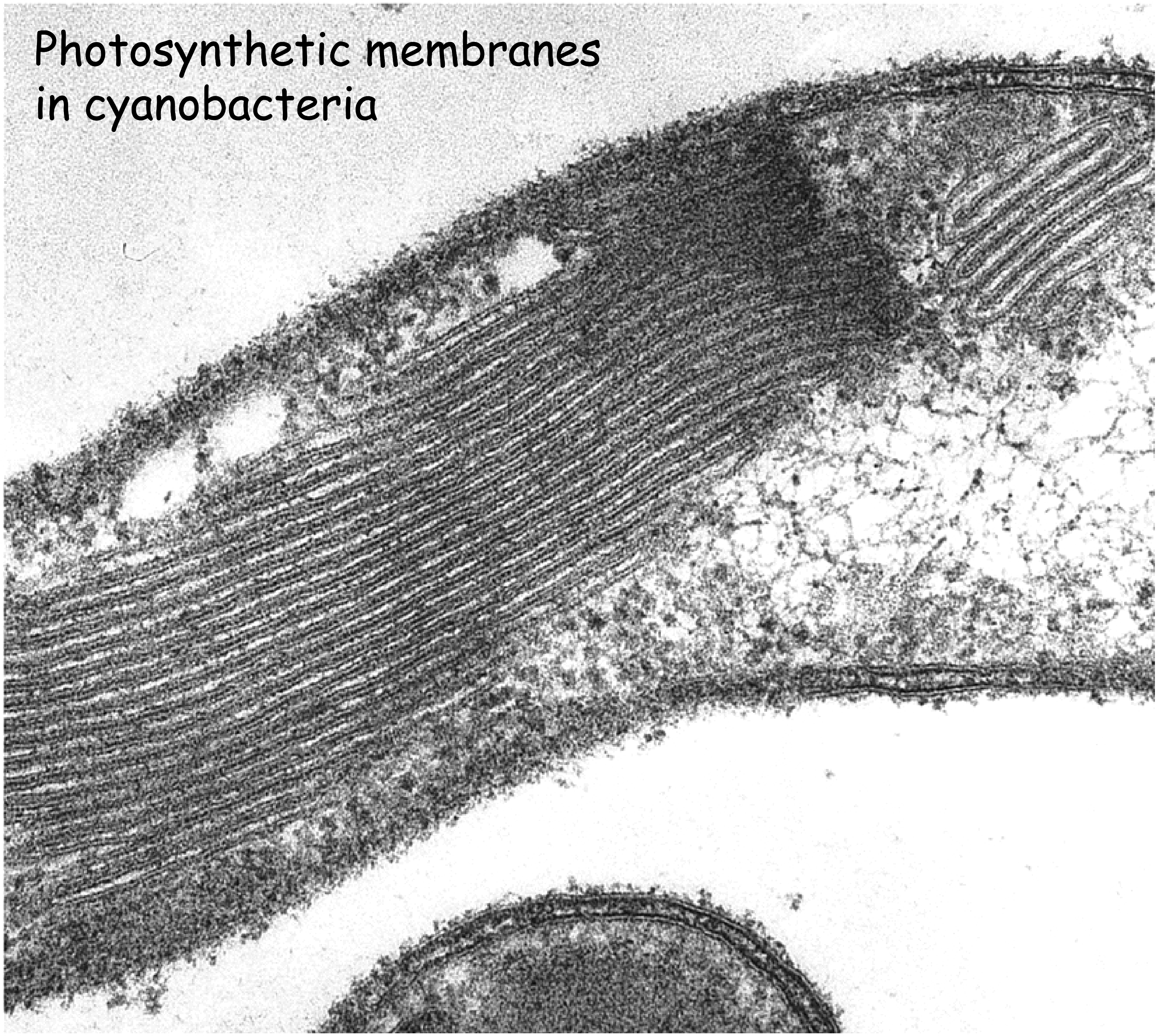
A bacterial cell

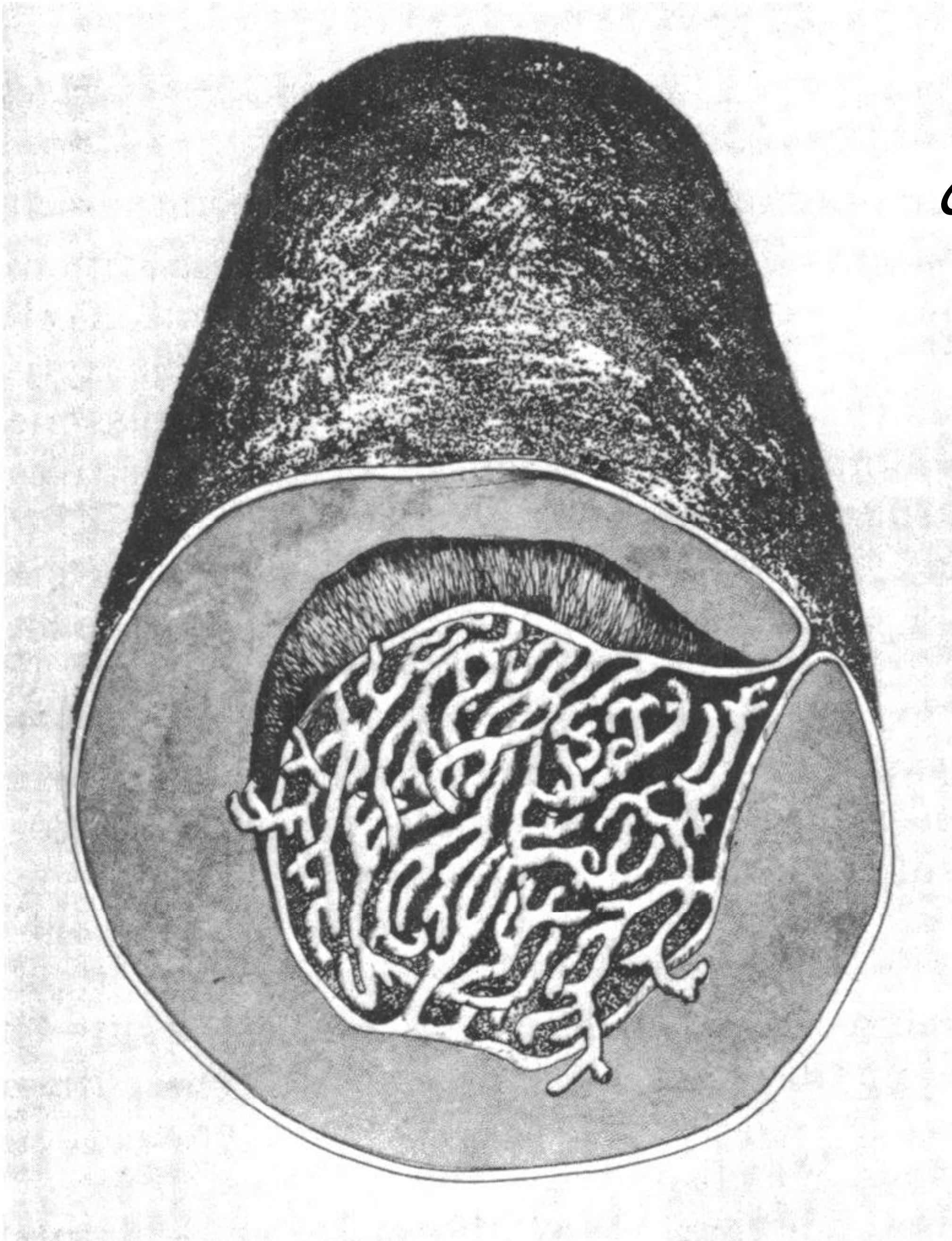


(a) A typical rod-shaped bacterium



(b) A thin section through the bacterium *Bacillus coagulans* (TEM)


Photosynthetic membranes
in cyanobacteria

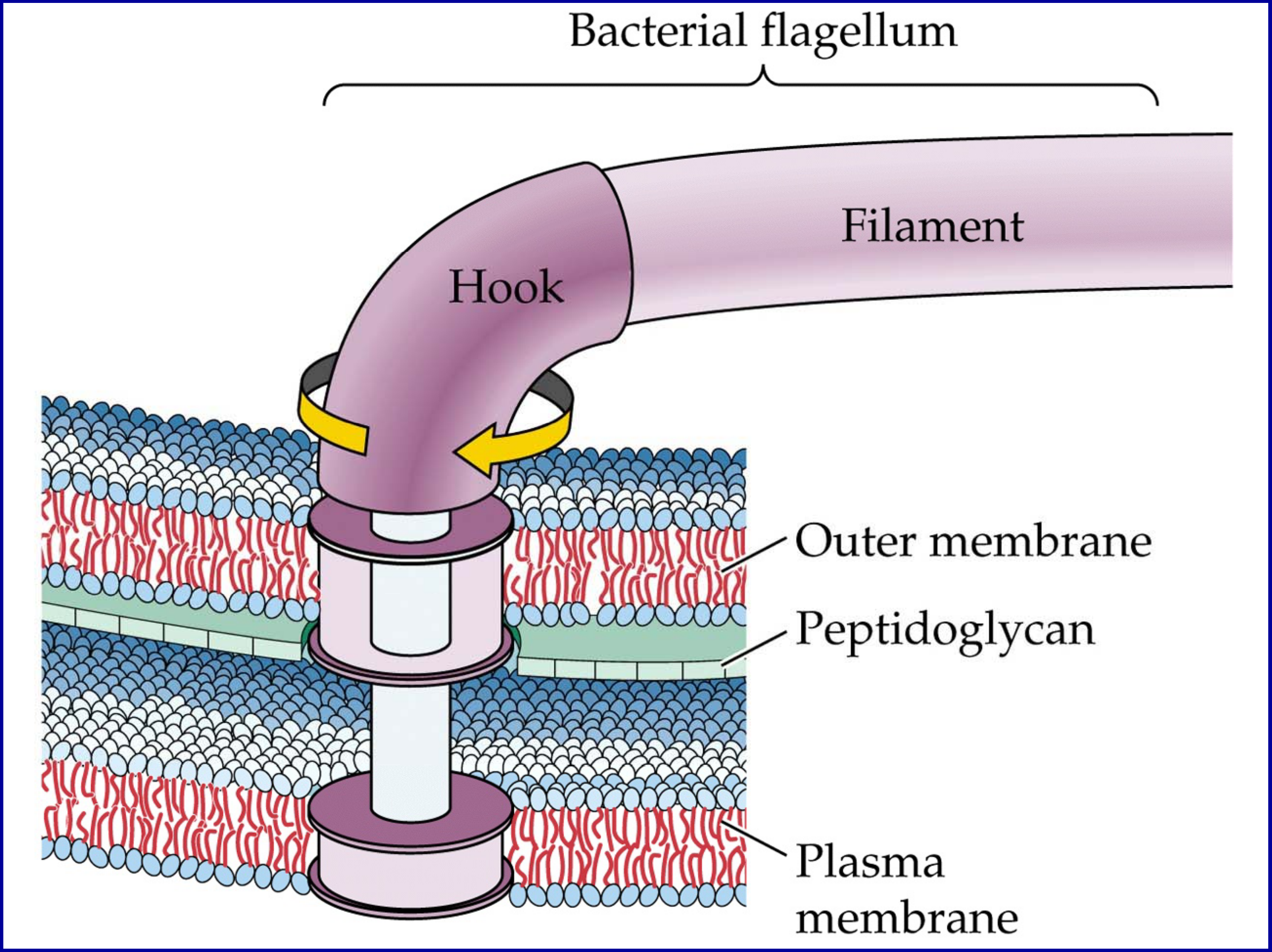


Drawing of the mesosome structure found in *Chromobacterium violaceum*

- A convoluted invagination of the cytoplasmic membrane found in some bacterial cells.

B. Microbial Cells

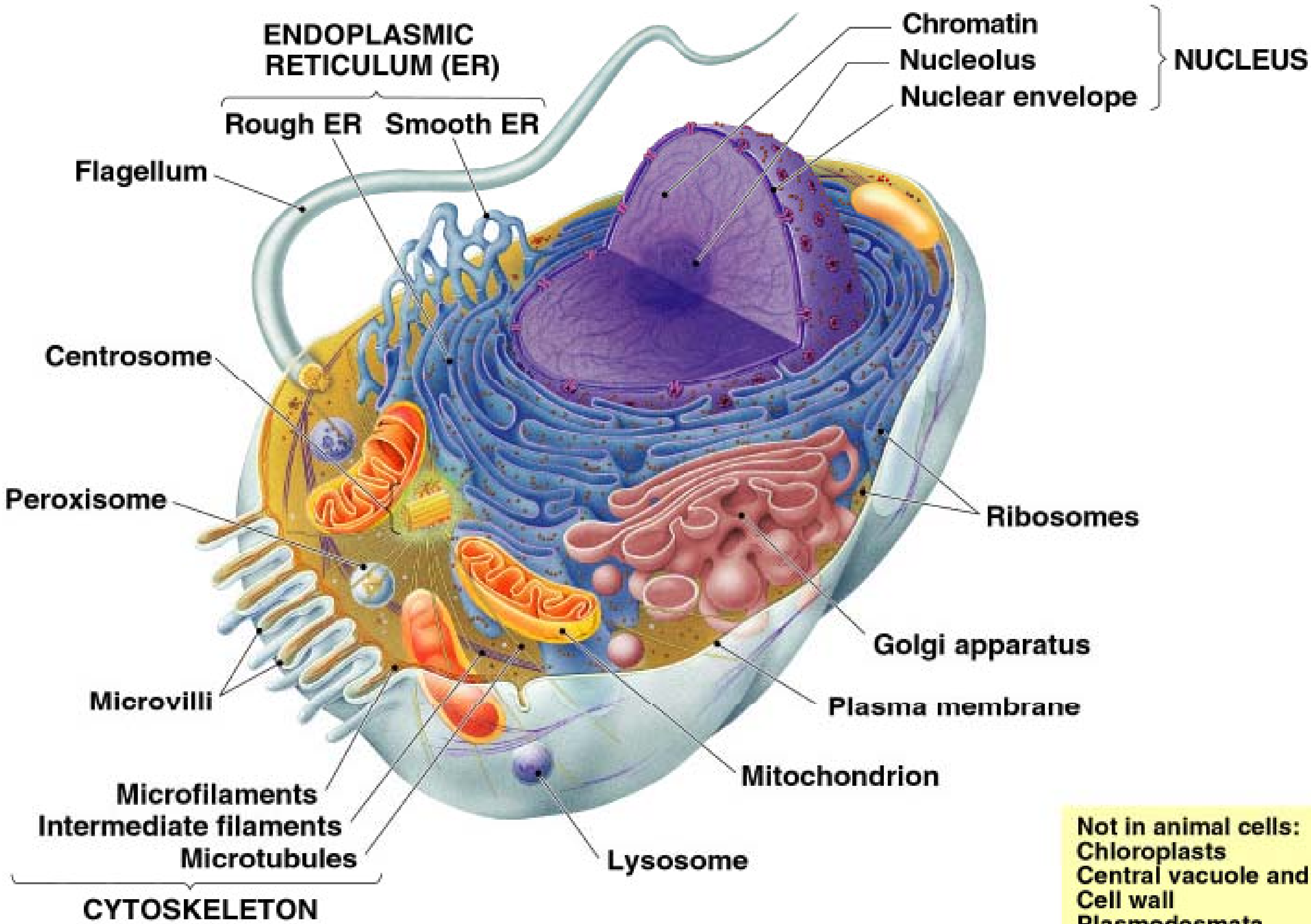
- Some microbes have rotating flagella for movement. Pili are projections by which microbial cells attach to one another or to environmental surfaces.


Bacterial flagellum
Filament
Hook
Outer membrane
Peptidoglycan
Plasma membrane

C. Eucarya Cells

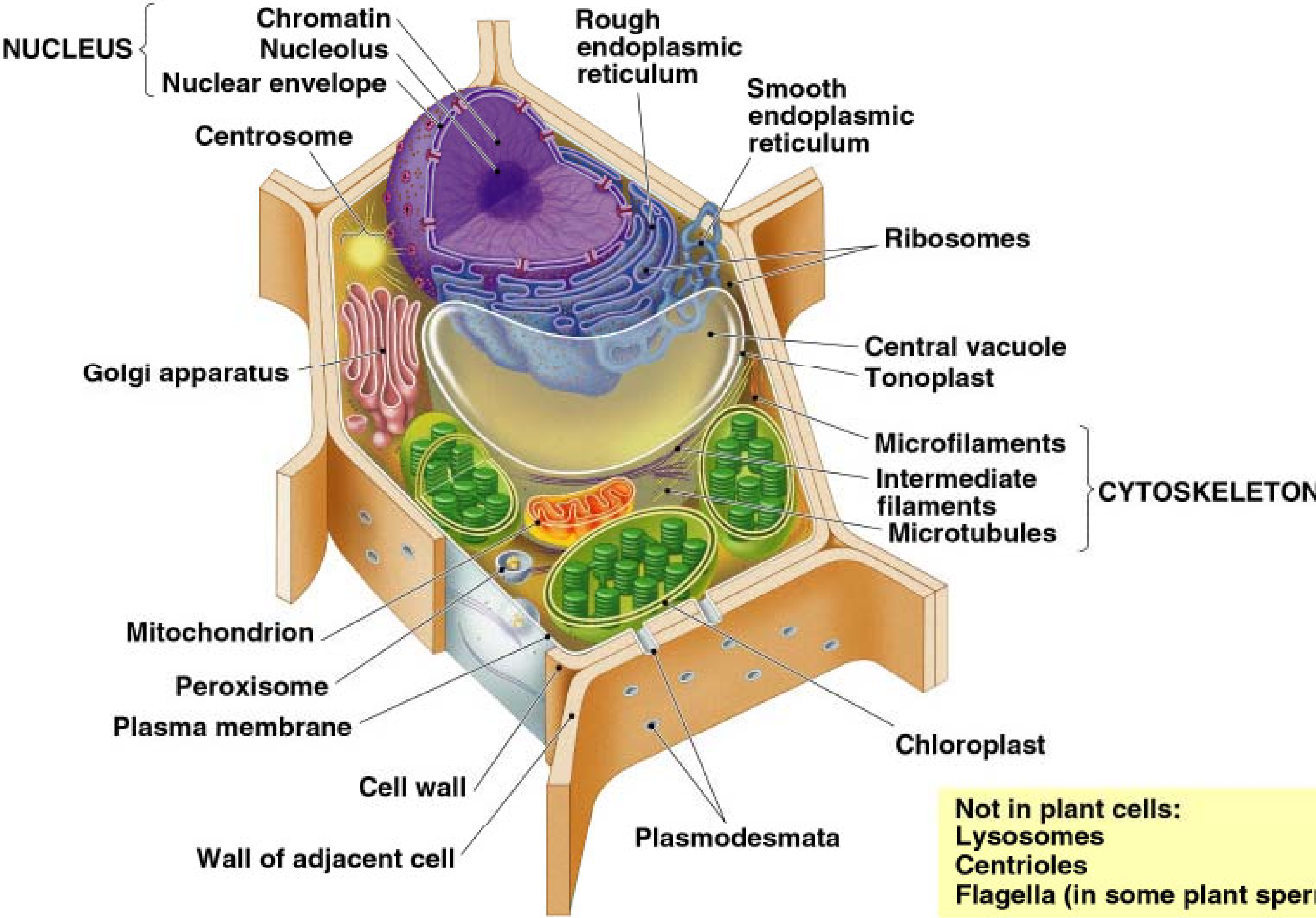
- Like microbial cells, Eucarya cells have a plasma membrane, cytoplasm, and ribosomes. However, Eucarya cells are larger and contain many membrane-enclosed organelles.
- The compartmentalization of Eucarya cells is the key to their success and ability to carry out specialized functions. Requires endosymbiotic relationships to have occurred.

Overview of an animal cell:



Not in animal cells:
Chloroplasts
Central vacuole and tonoplast
Cell wall
Plasmodesmata

Overview of a plant cell:



Not in plant cells:
Lysosomes
Centrioles
Flagella (in some plant sperm)

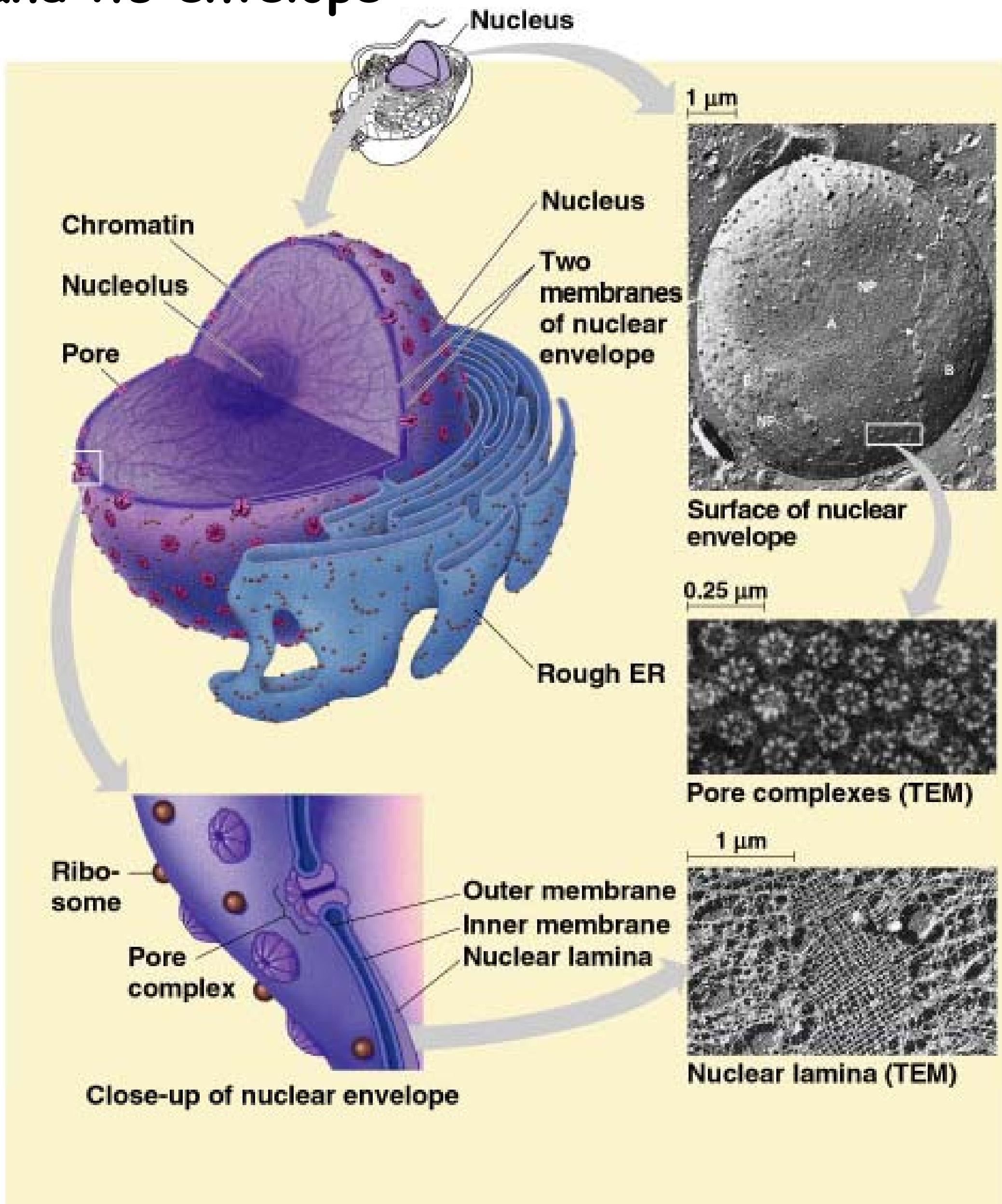
C. Eucarya Cells

- Membranes that envelop organelles in Eucarya cells are partial barriers ensuring that the chemical composition of the organelle's interior differs from that of the surrounding cytoplasm.

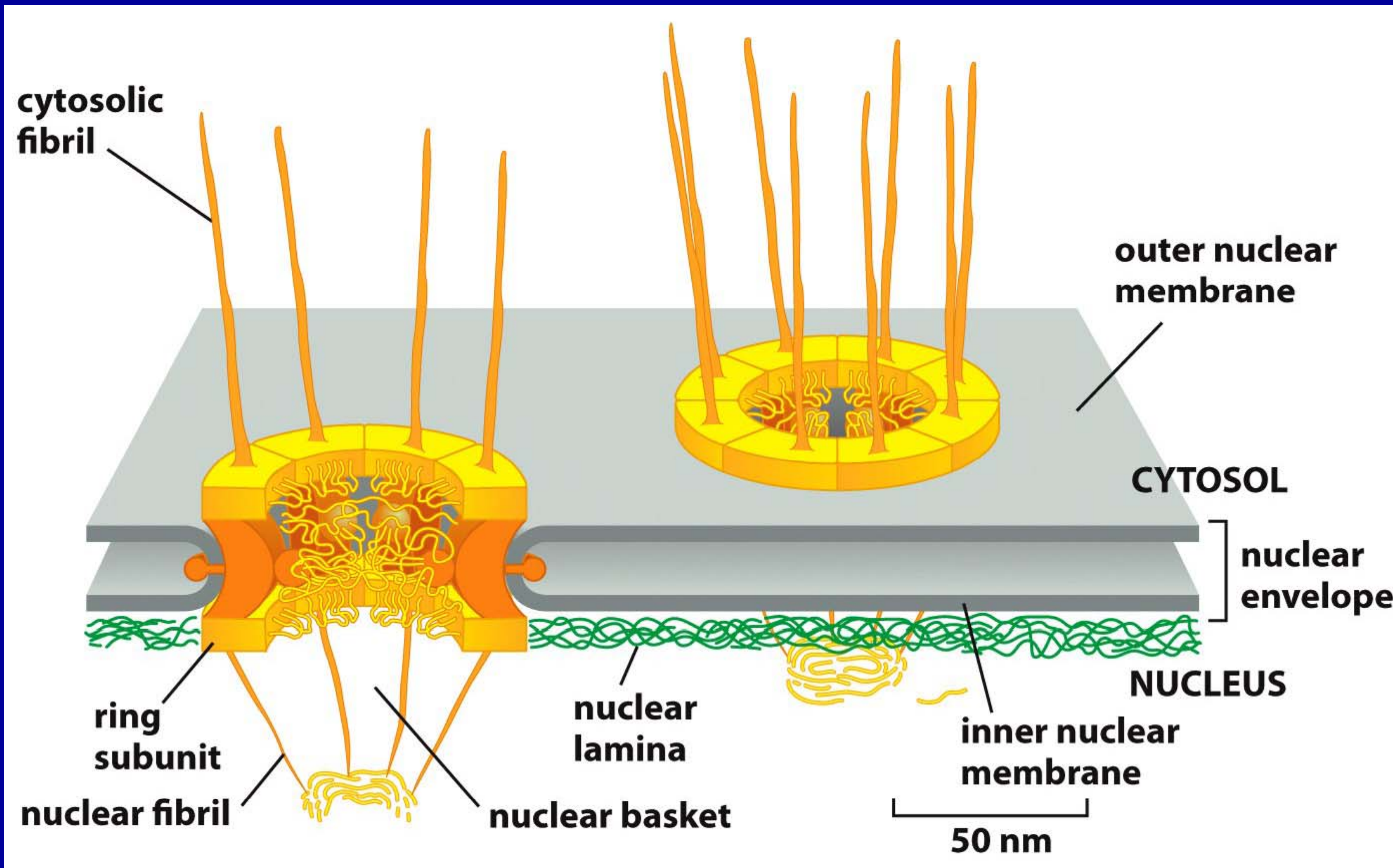
D. Organelles that Process Information

- The nucleus is usually the largest organelle in a cell. It is surrounded by the nuclear envelope.
- Nuclear pores have complex structures governing what enters and leaves the nucleus.
- Within the nucleus, the nucleolus is the source of the ribosomes found in the cytoplasm.

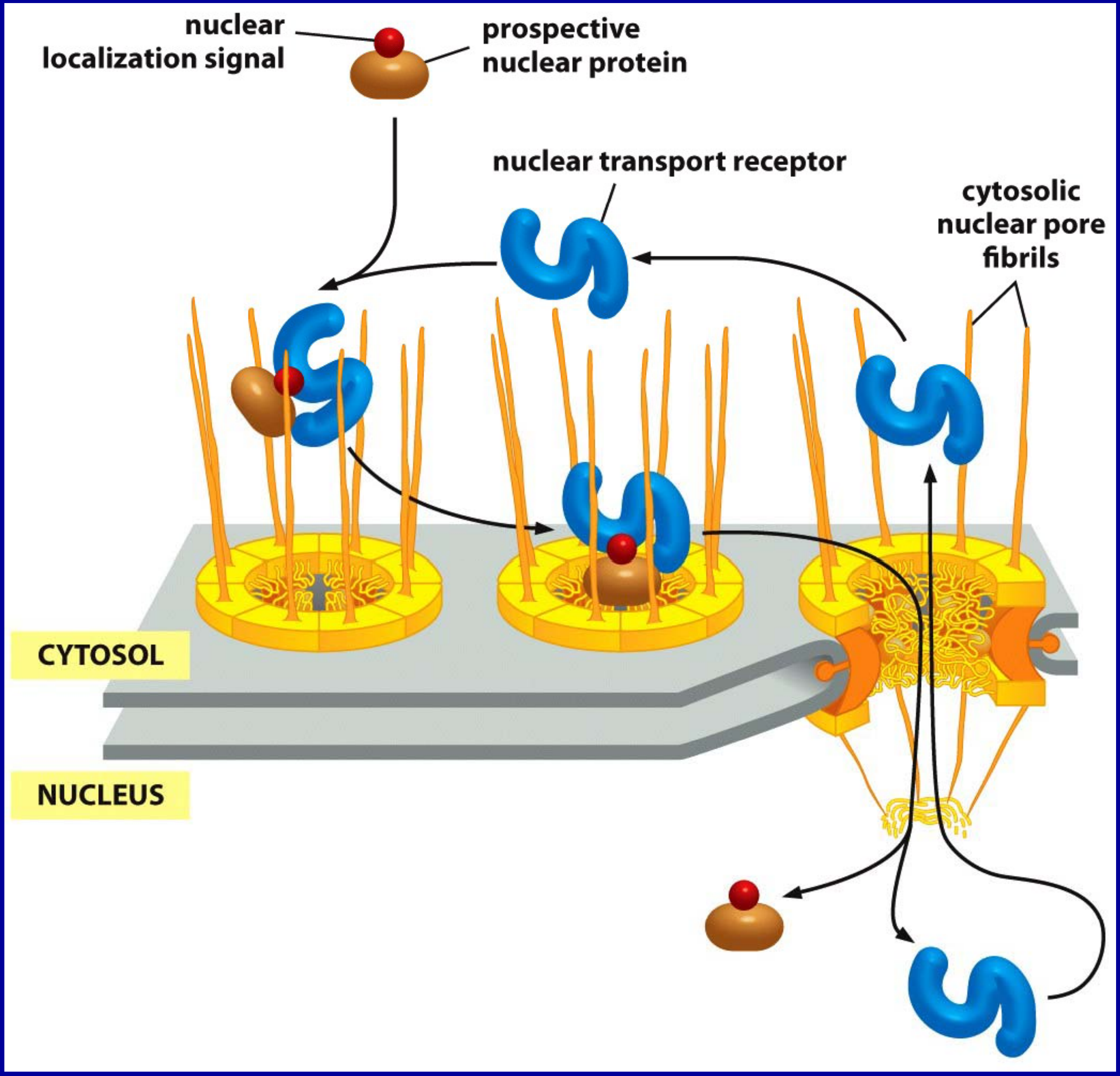
The nucleus and its envelope



The nuclear pore complex forms a gate

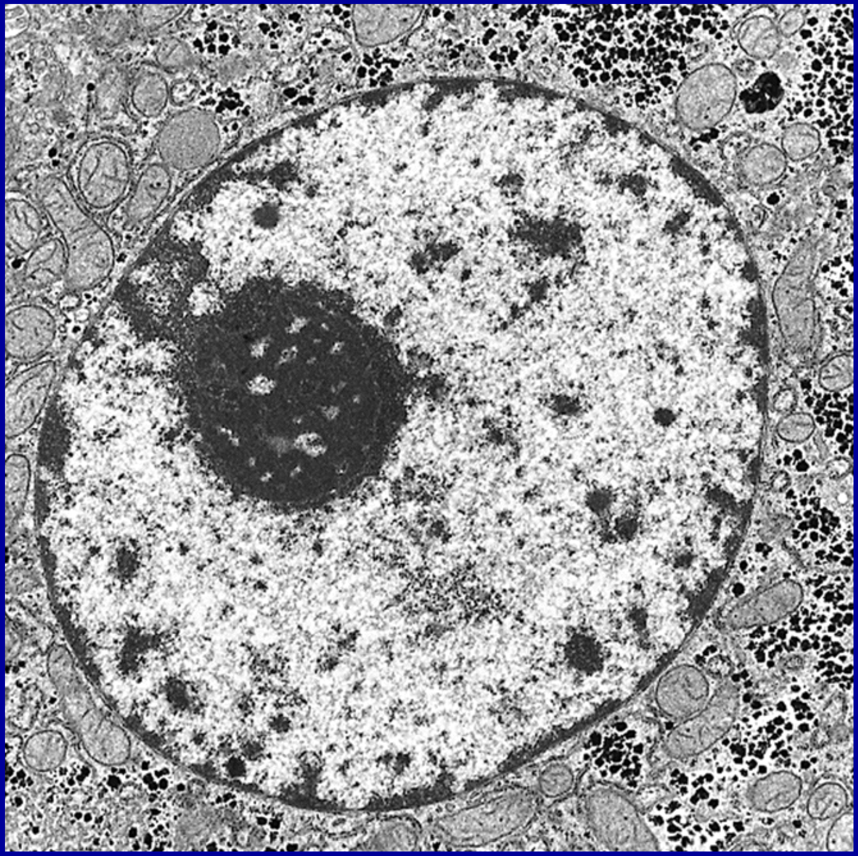


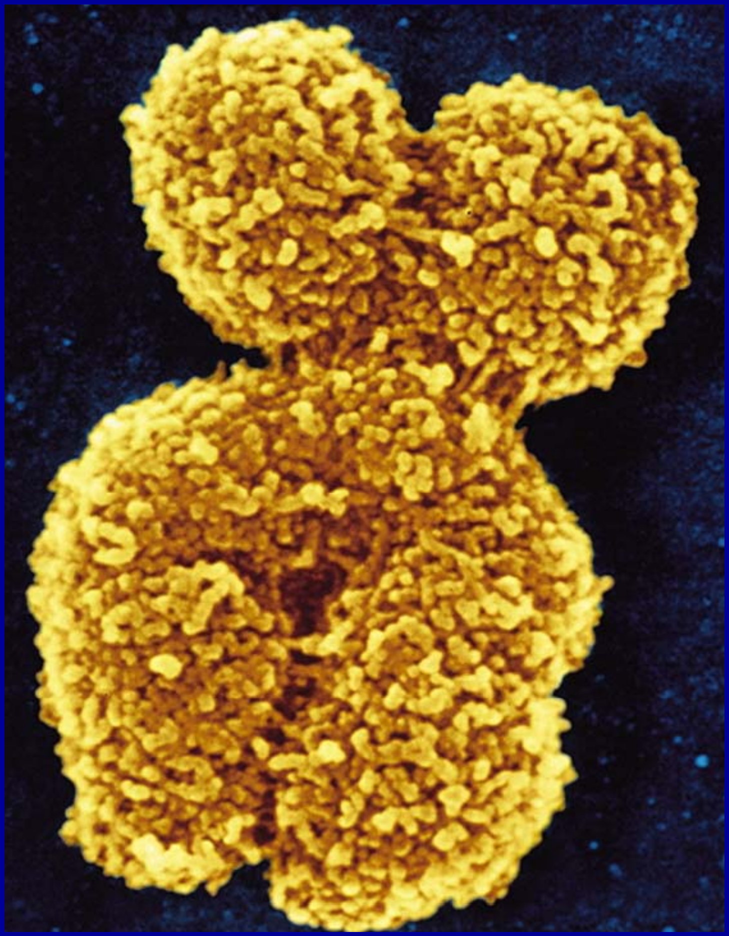
Active transport through nuclear pores via GTP



D. Organelles that Process Information

- Nuclear Lamina is a protein mesh that interacts with chromatin and supports nuclear envelope.
- The nucleus contains most of the cell's DNA, which associates with protein to form chromatin. Chromatin is diffuse throughout the nucleus. Just before cell division, it condenses to form chromosomes.
- Ribosomes are the sites of protein synthesis.

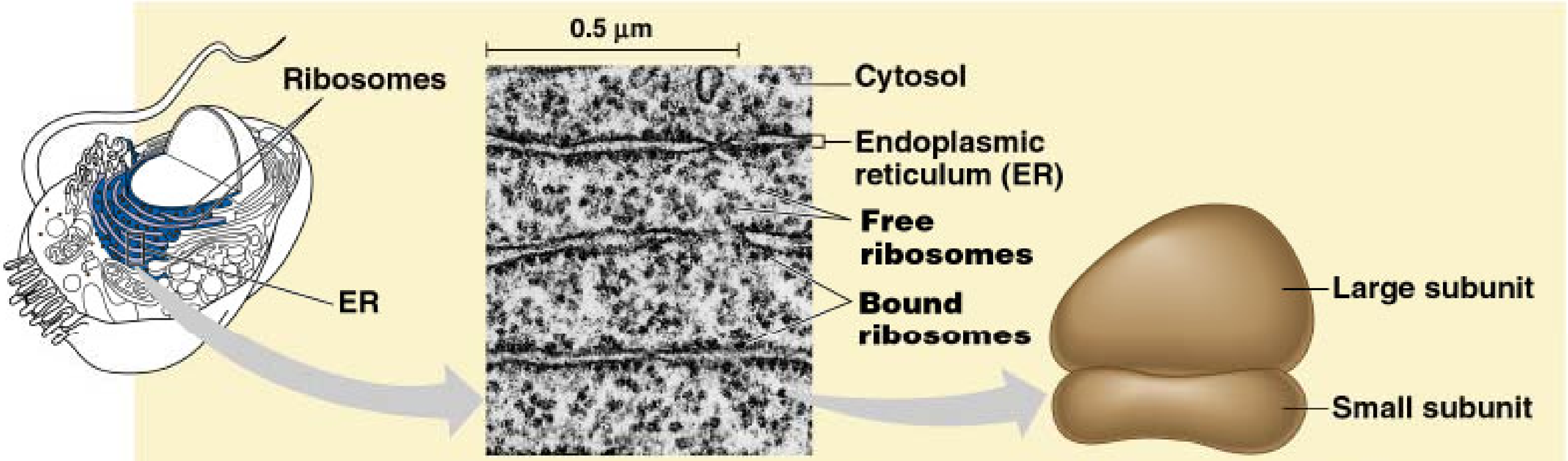




Chromatin: diffuse (in nucleoplasm) and dense (attached to nuclear lamina)

Chromosome: very dense packed bodies

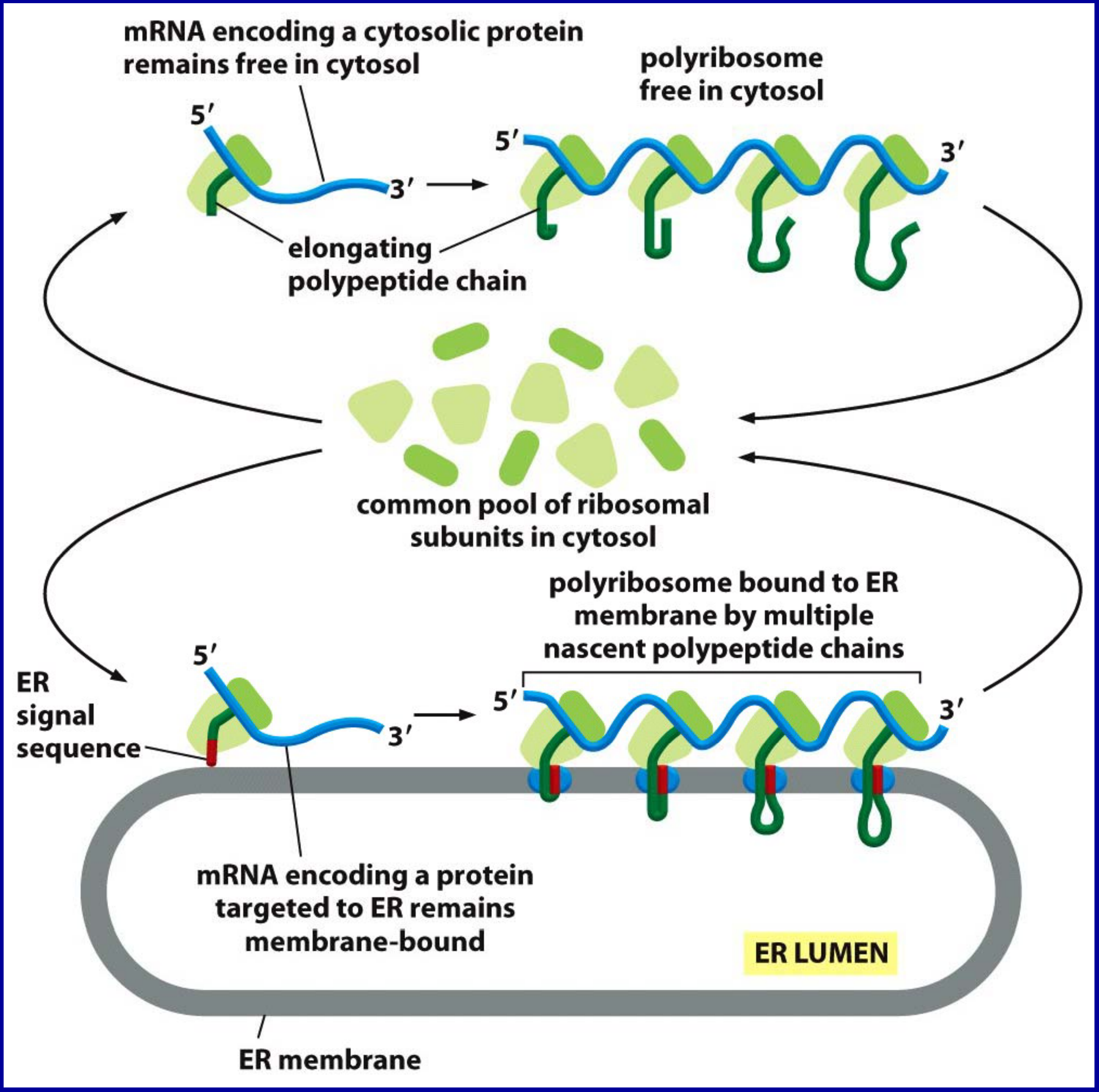
Ribosomes: Free and Bound



(a) TEM showing ribosomes

(b) Diagram of a ribosome

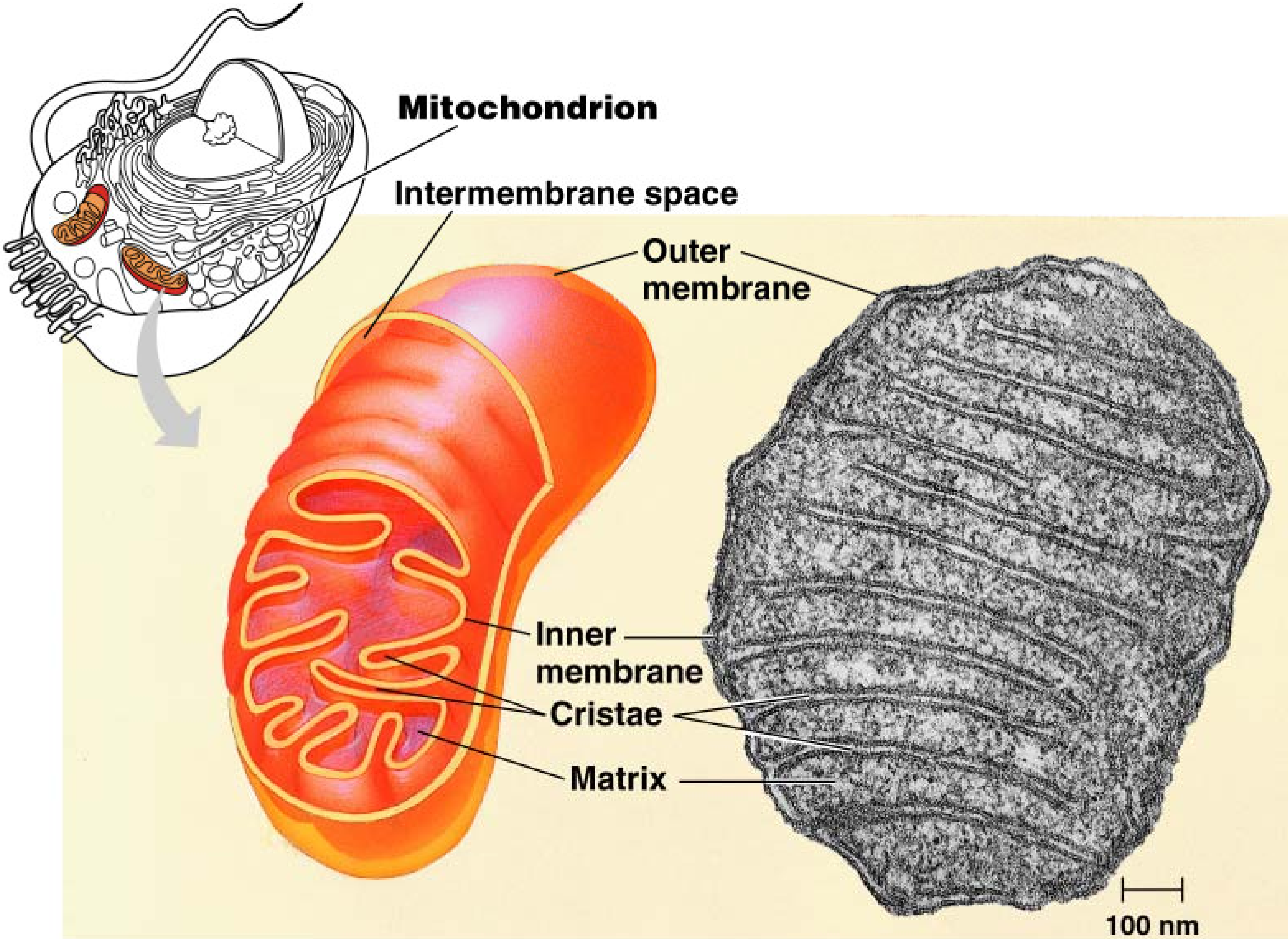
Common pool of ribosomes used in translation



E. Organelles that Process Energy

- Mitochondria are enclosed by an outer membrane and an inner membrane that folds inward to form cristae.
- Mitochondria contain proteins needed for cellular respiration and generation of ATP.
- They are the energy transformers in terms of performing cellular respiration.

The mitochondrion, site of cellular respiration



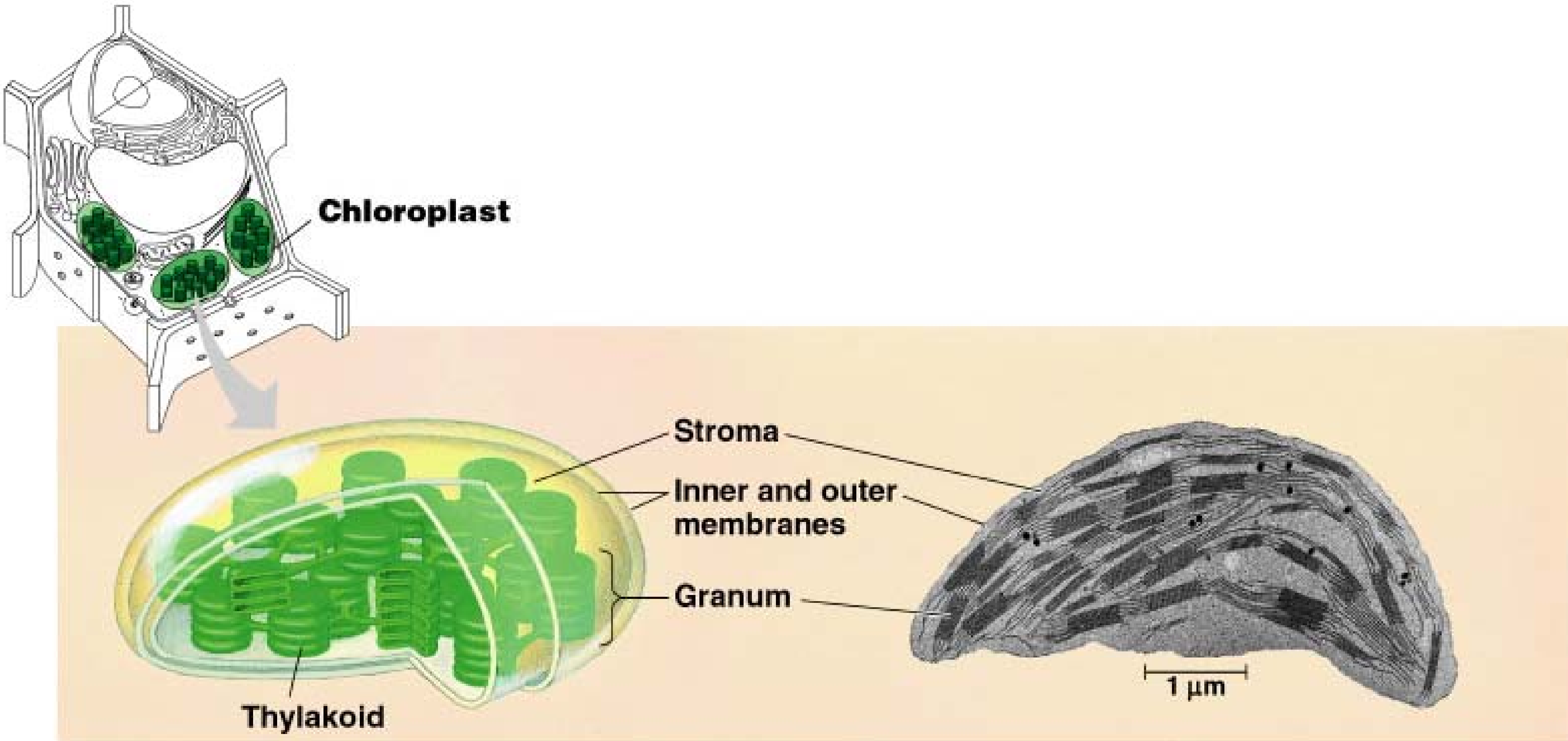
E. Organelles that Process Energy

- Plastids are another class of organelles used for photosynthesis or storage of materials.
  - Amyloplasts
  - Chromoplasts
  - Chloroplasts

E. Organelles that Process Energy

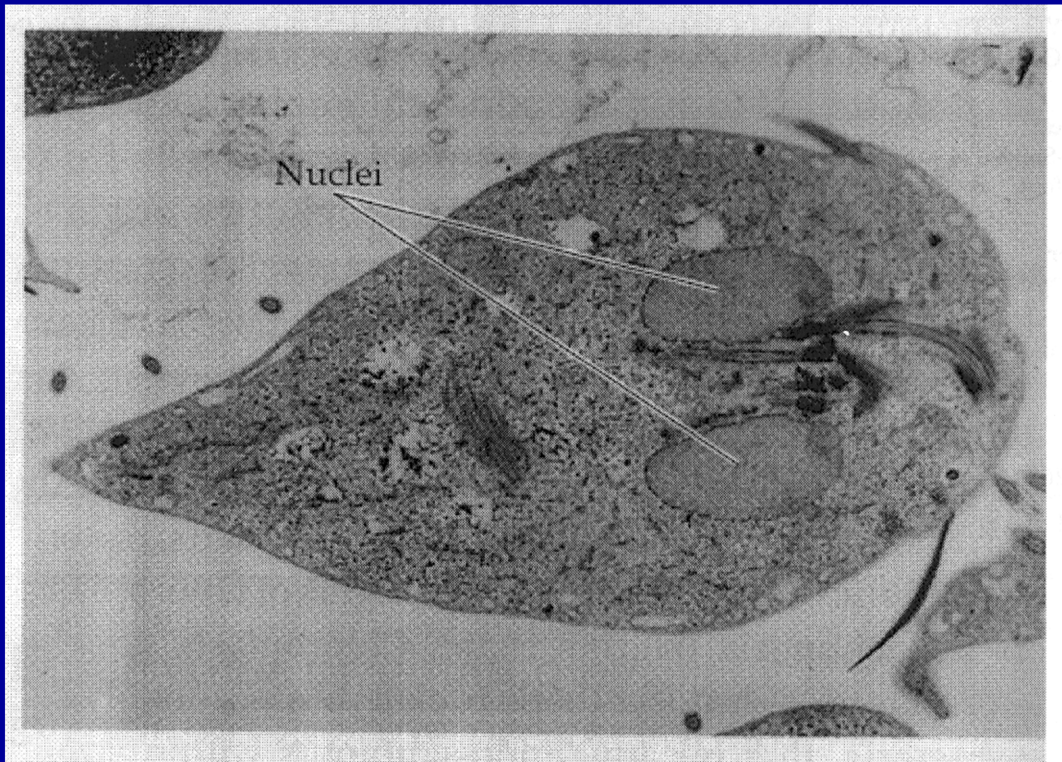
- Chloroplasts have a triple membrane system containing an internal system of thylakoids organized as stacks of grana.
- Thylakoids within chloroplasts contain the chlorophyll and proteins that harvest light energy for photosynthesis.

The chloroplast, site of photosynthesis



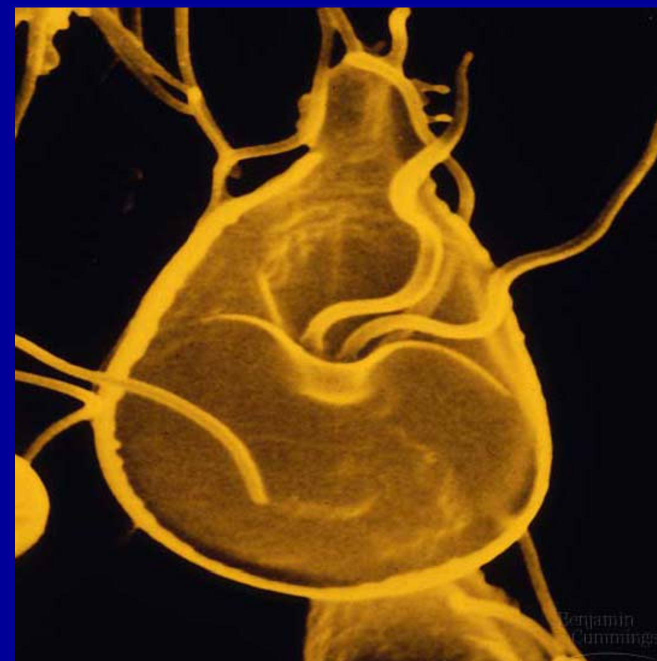
E. Organelles that Process Energy

- Mitochondria and chloroplasts contain their own DNA nucleoid and ribosomes and can make some of their own proteins.
- The endosymbiosis theory of the evolutionary origin of mitochondria and chloroplasts states that they originated when large cells engulfed, but did not digest, smaller ones. Mutual benefits permitted this symbiotic relationship to evolve into eucaryotic organelles of today.



1 μm

Giardia: A key to evolutionary history?



Archezoans

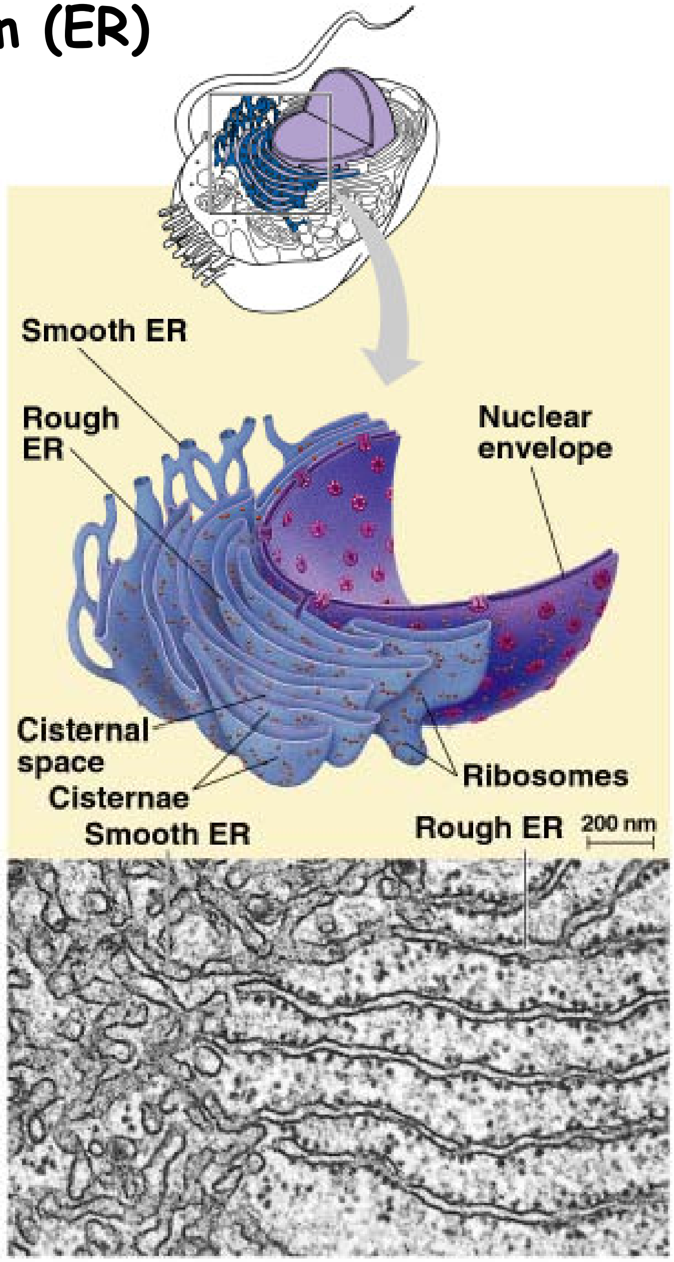
F. The Endomembrane System

- The endomembrane system is made up of a series of interrelated membranes and compartments.
- Is continuous with the nuclear envelope.
- This complex factory has a direction of flow in terms of the production of various cellular components and their further processing from the nuclear membrane to the plasma membrane.
- May accounts for more than half the total membrane in many eucaryotic cells.

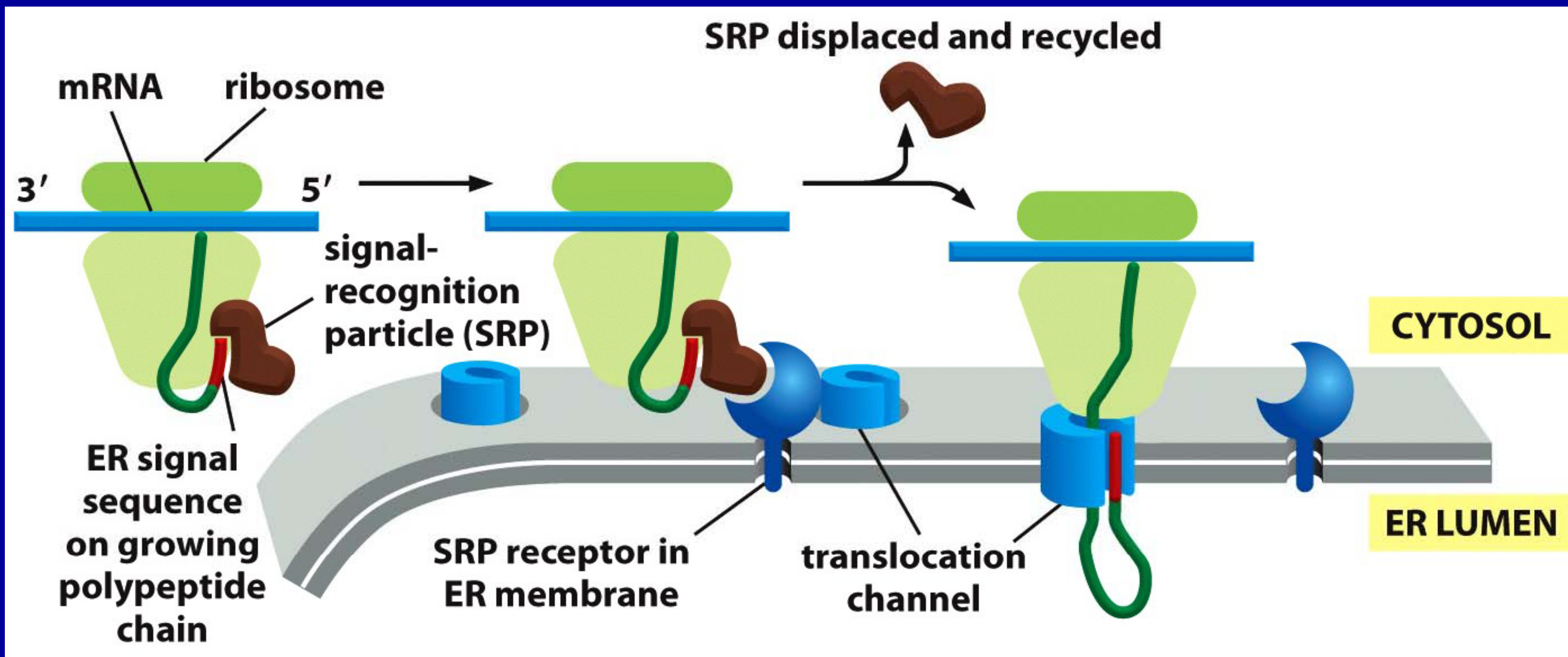
F. The Endomembrane System

- The rough endoplasmic reticulum has ribosomes that synthesize proteins.
  - RER produces proteins and membranes, which are distributed by transport vesicles.
- The smooth endoplasmic reticulum lacks ribosomes and is associated with synthesis of lipids. SER also:
  - Metabolizes carbohydrates
  - Stores calcium
  - Detoxifies poison

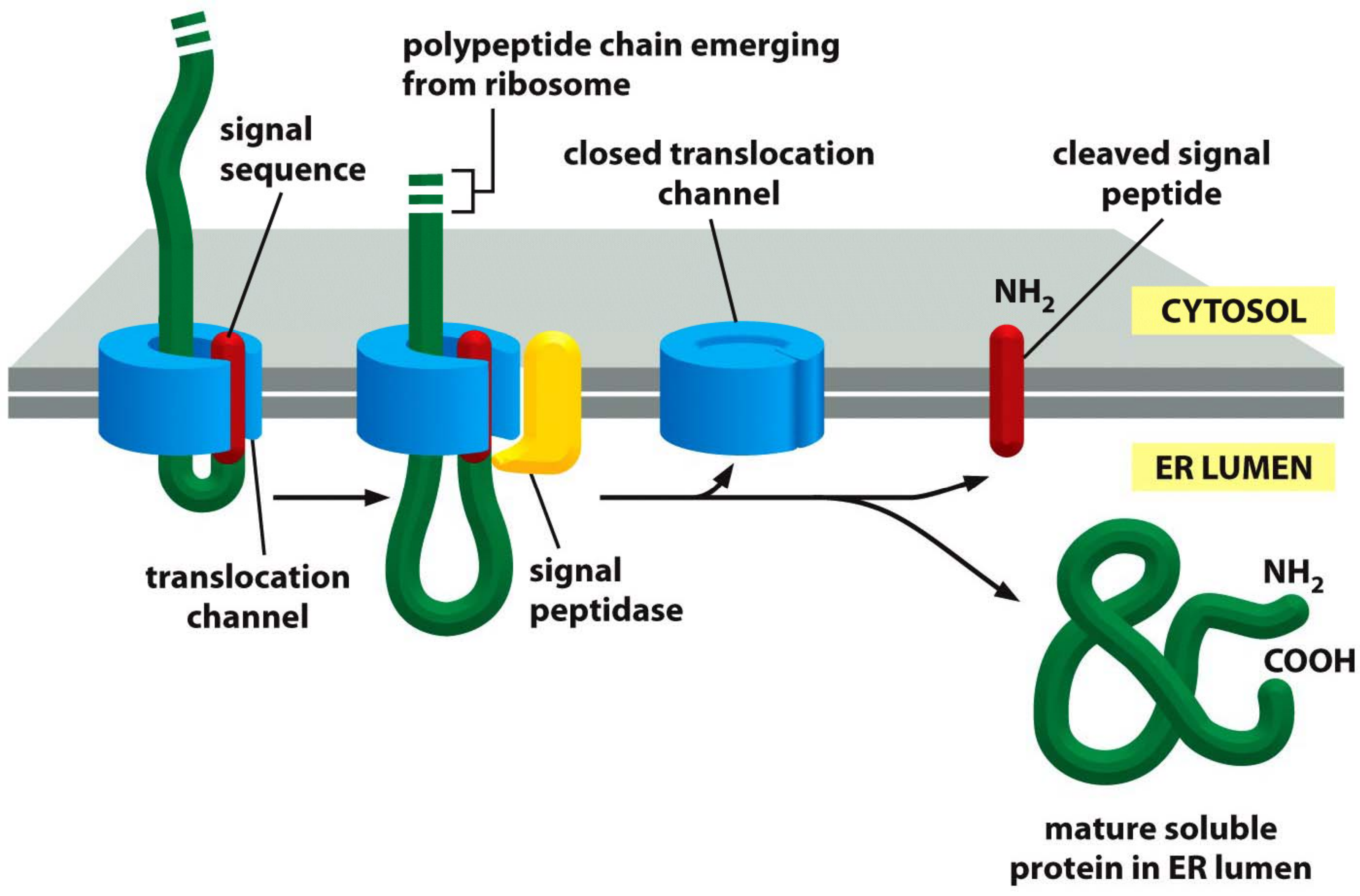
Endoplasmic reticulum (ER)



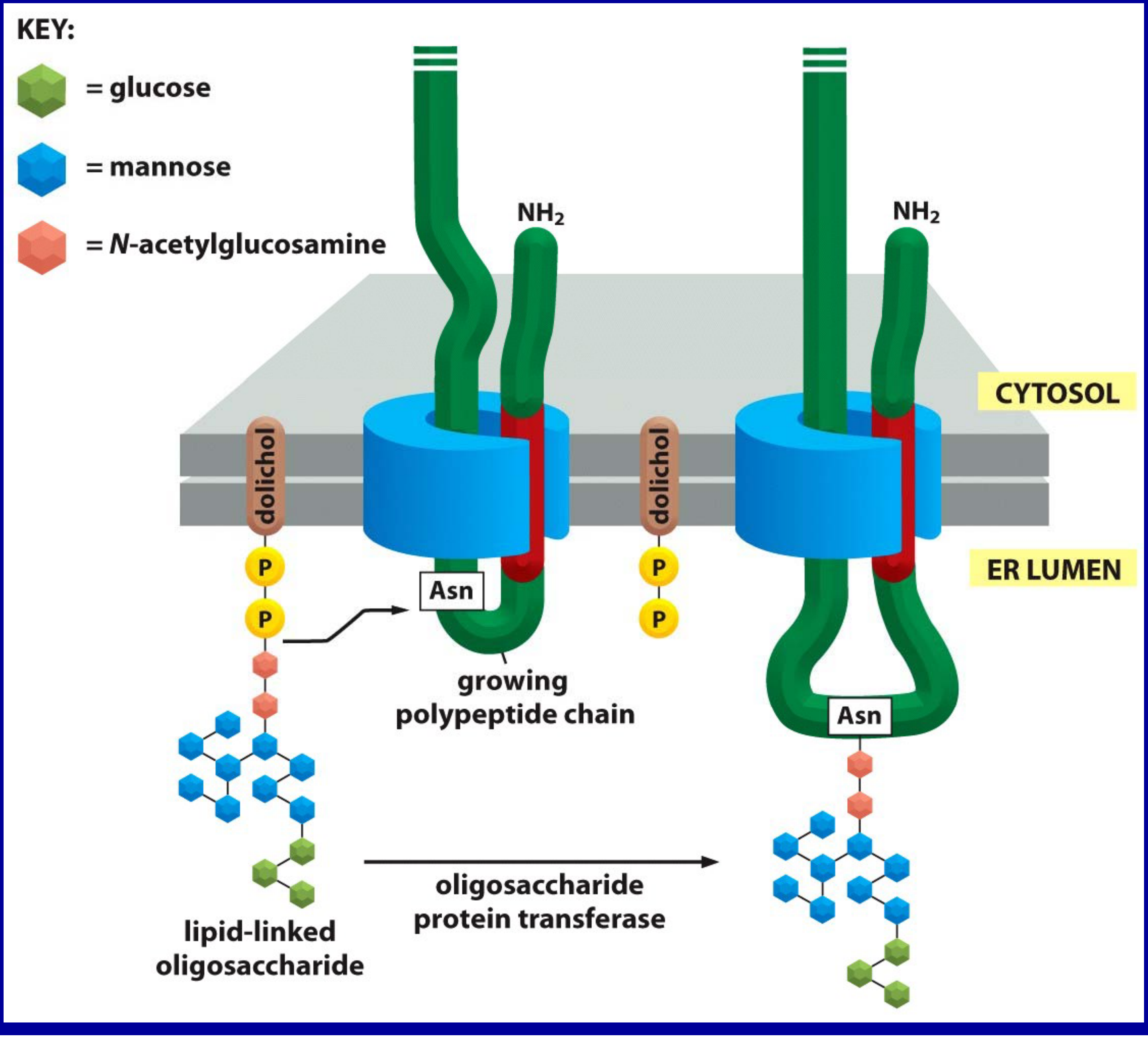
Signal Recognition Proteins



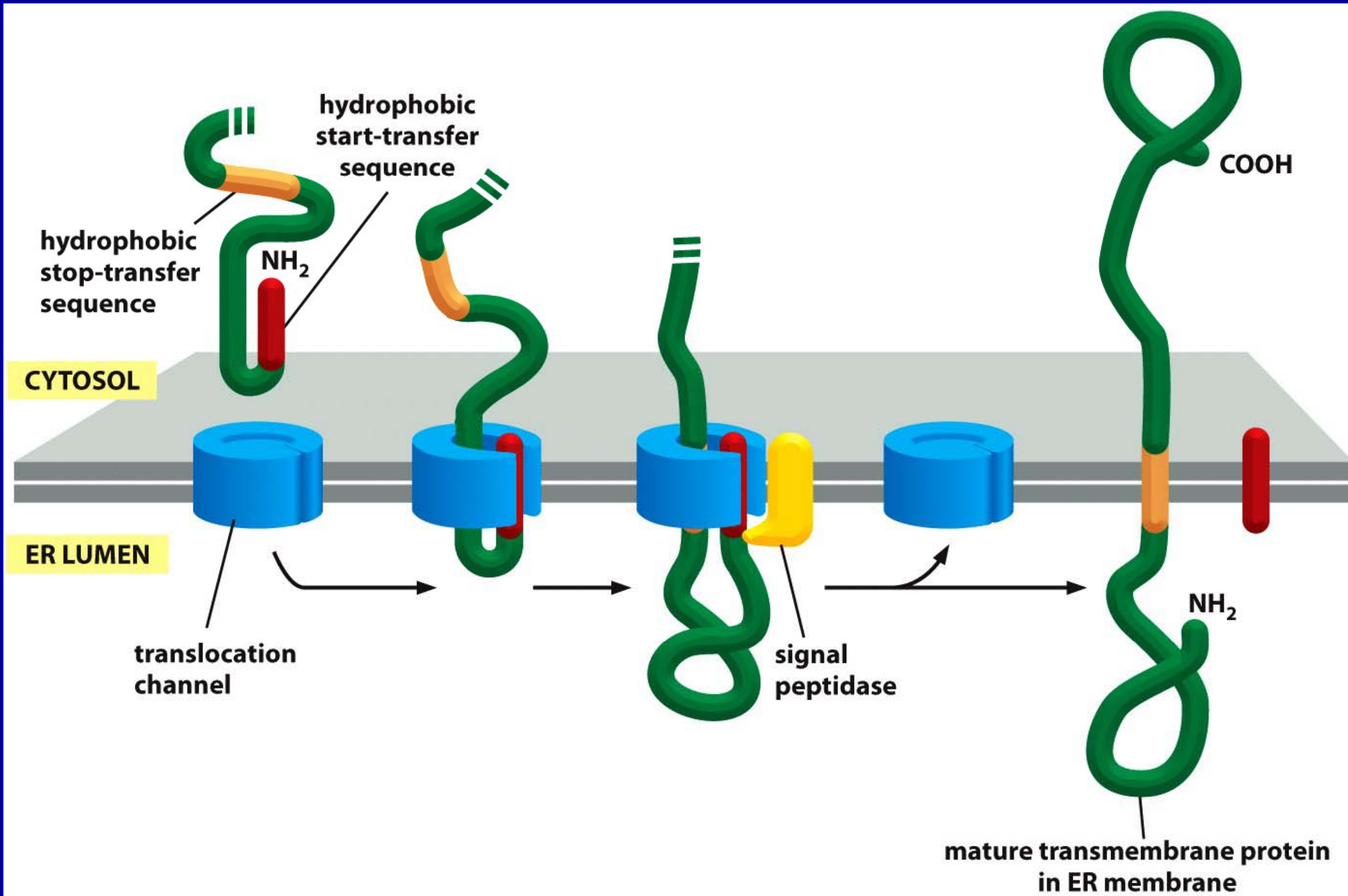
Soluble protein crosses ER to lumen



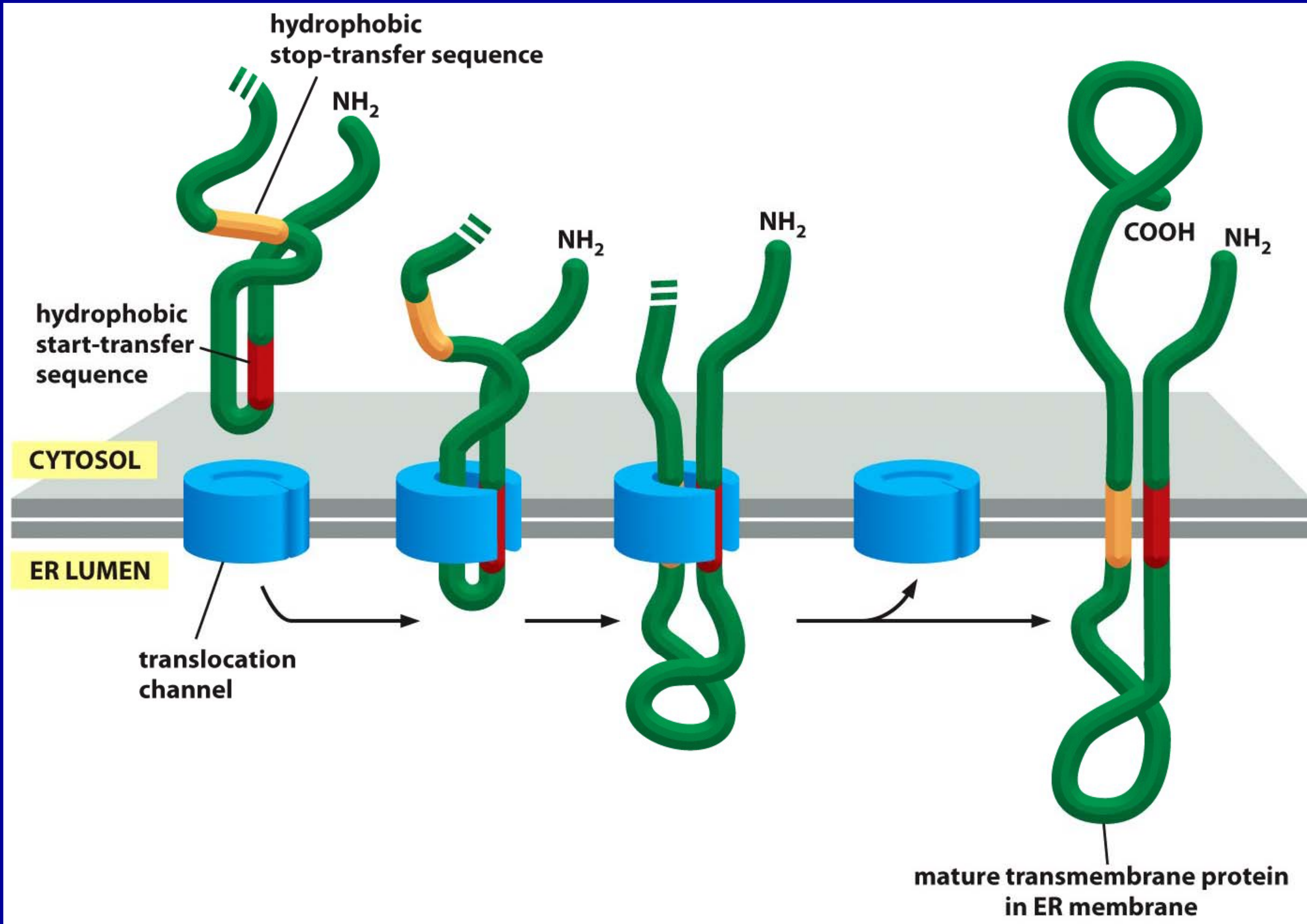
Glycosylation of Proteins in ER



Single-pass transmembrane protein



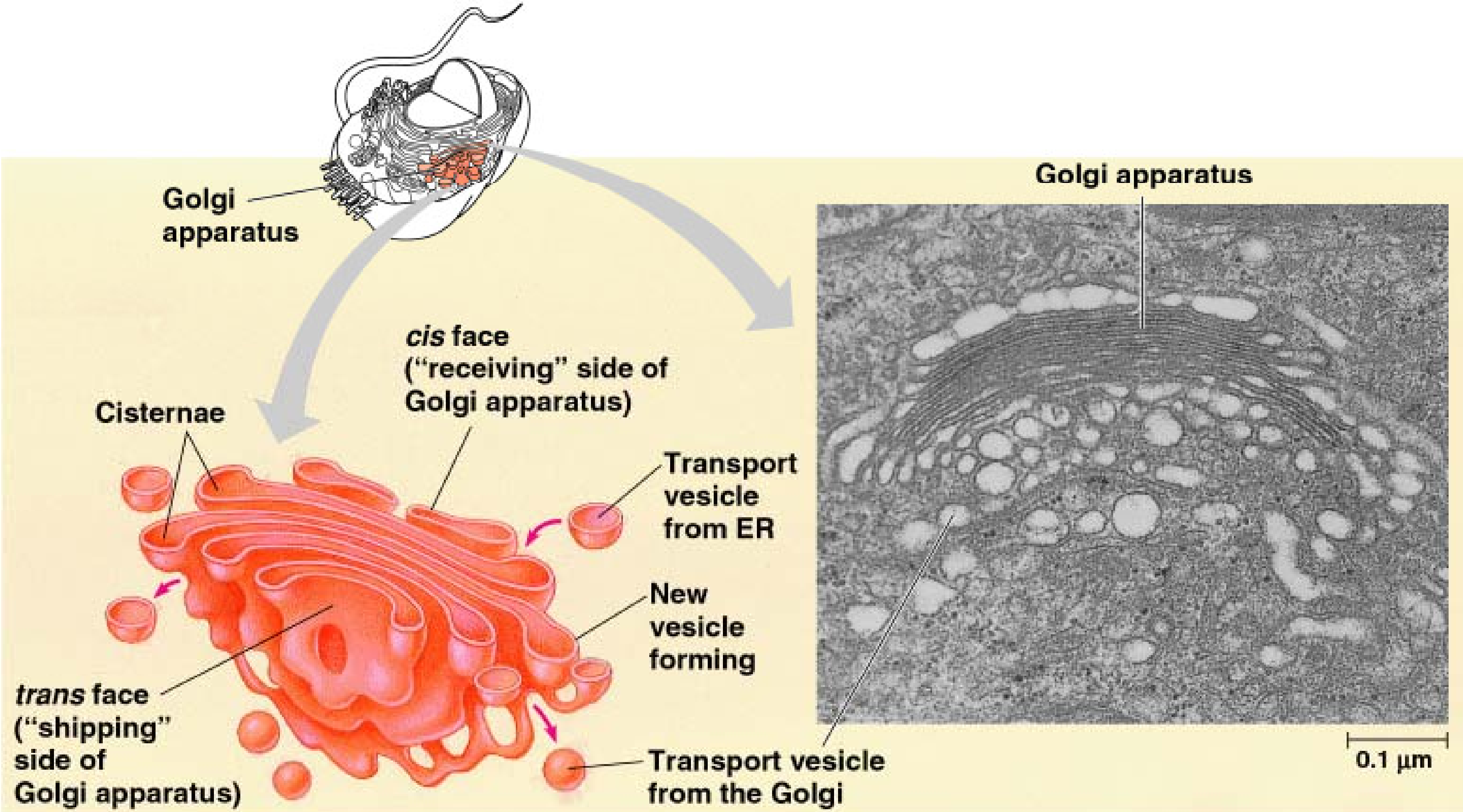
Double-pass transmembrane protein



F. The Endomembrane System

- The Golgi apparatus is the cellular post office; storing, modifying and packaging proteins.
- It receives materials from the rough ER via vesicles that fuse with the *cis* region of the Golgi.
- It adds signal molecules to proteins, directing them to various destinations.
- Vesicles originating from the *trans* region of the Golgi contain proteins for different cellular locations. Some fuse with the plasma membrane and release their contents outside the cell.

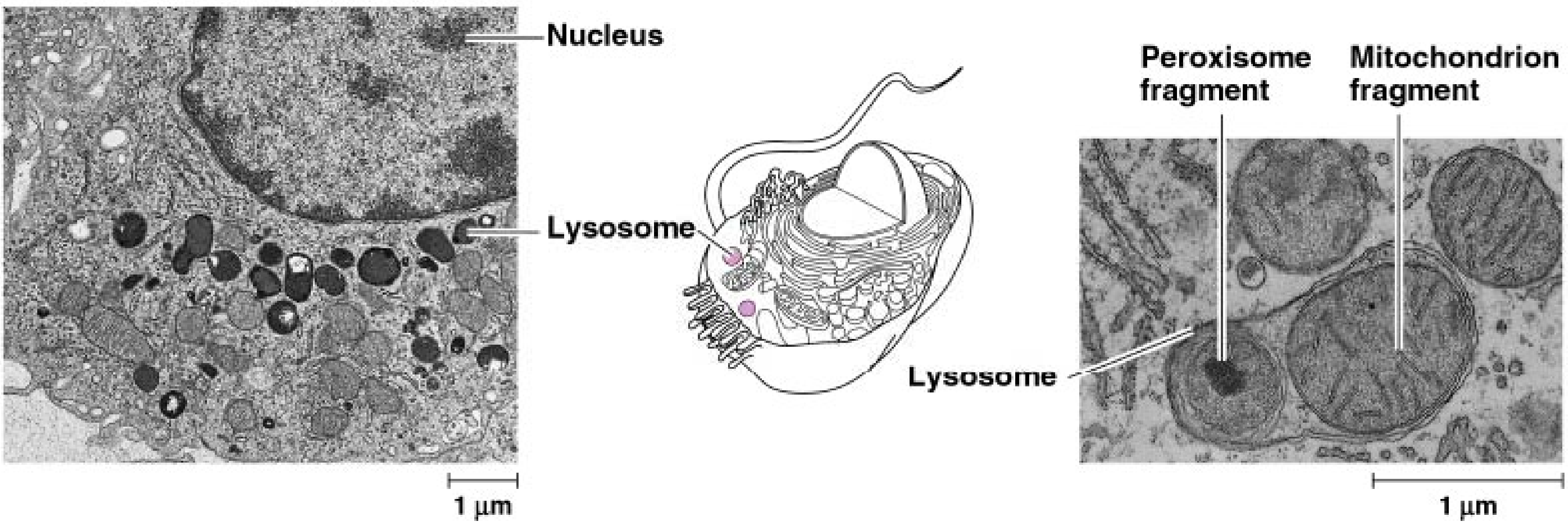
The Golgi apparatus



F. The Endomembrane System

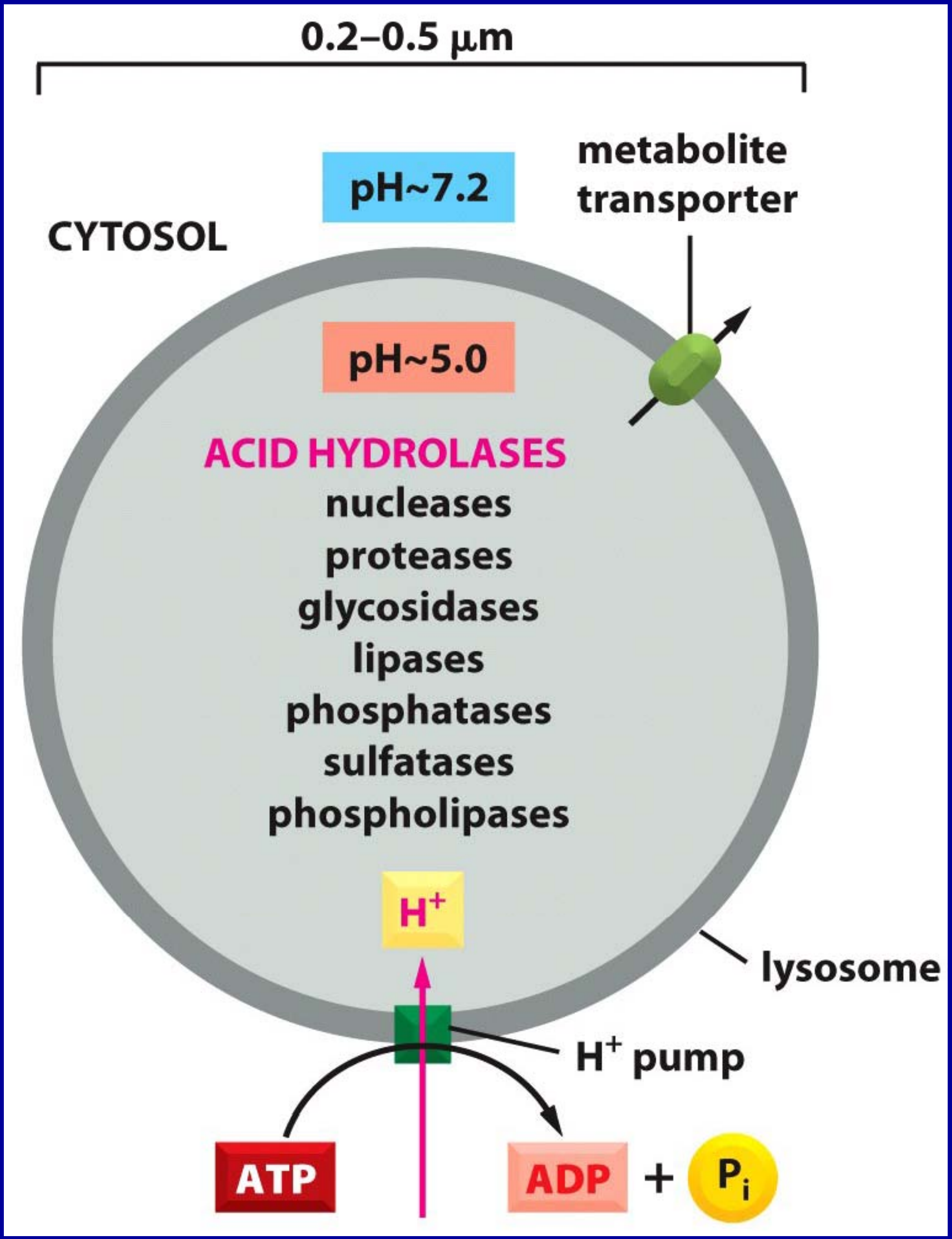
- Lysosomes fuse with transport vesicles produced by endocytosis to form endosomes, in which digestion occurs.
- Undigested materials are secreted from the cell when the endosome fuses with the plasma membrane.
- Hydrolysis reactions occur inside.
- Cell's recycling center.
- Programmed cell destruction or apoptosis.

Lysosomes



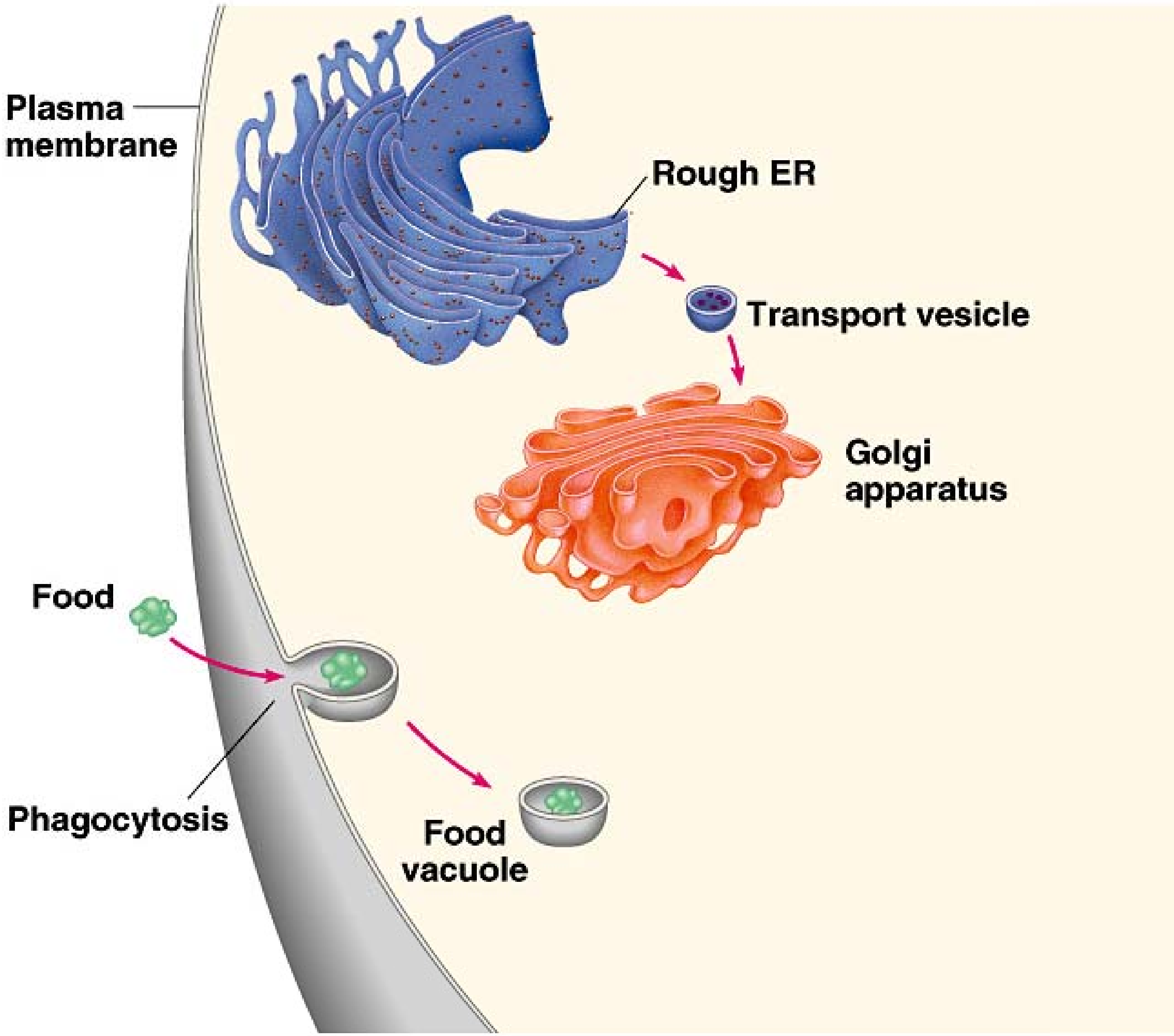
(a) Lysosomes in a white blood cell

(b) A lysosome in action

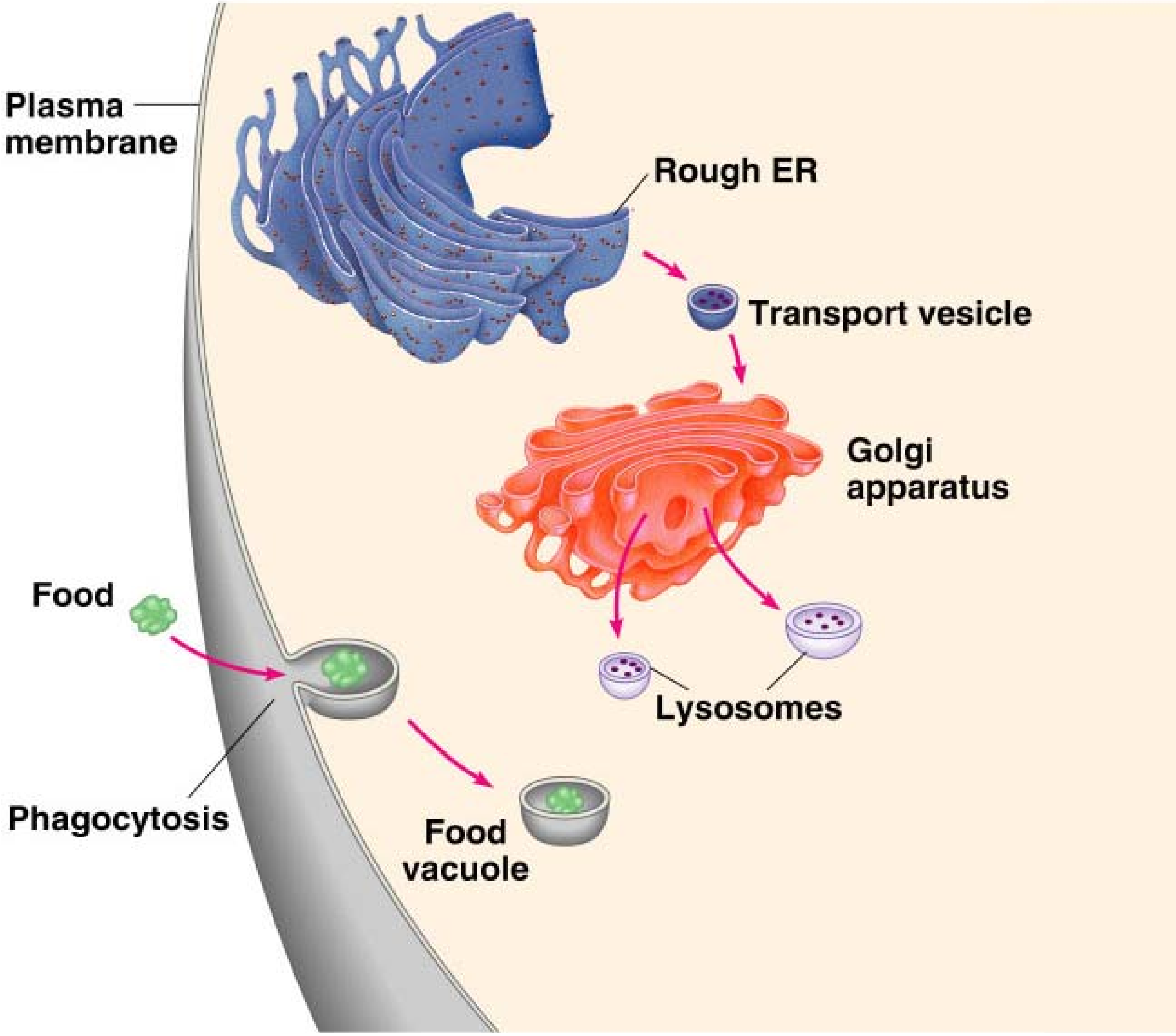


Lysosome Contents
(havoc for the cytoplasm)

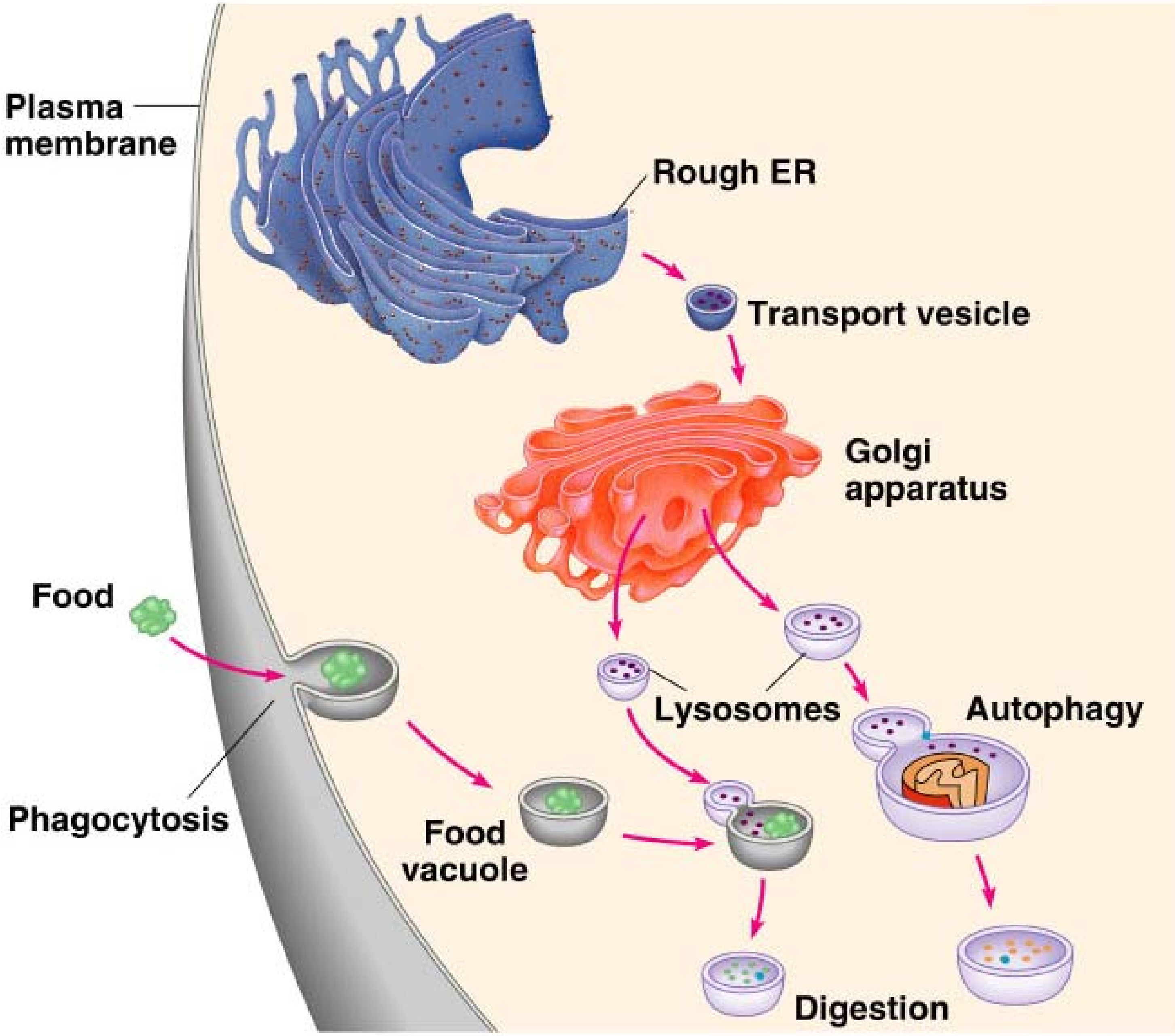
The formation and functions of lysosomes (Step 1)



The formation and functions of lysosomes (Step 2)



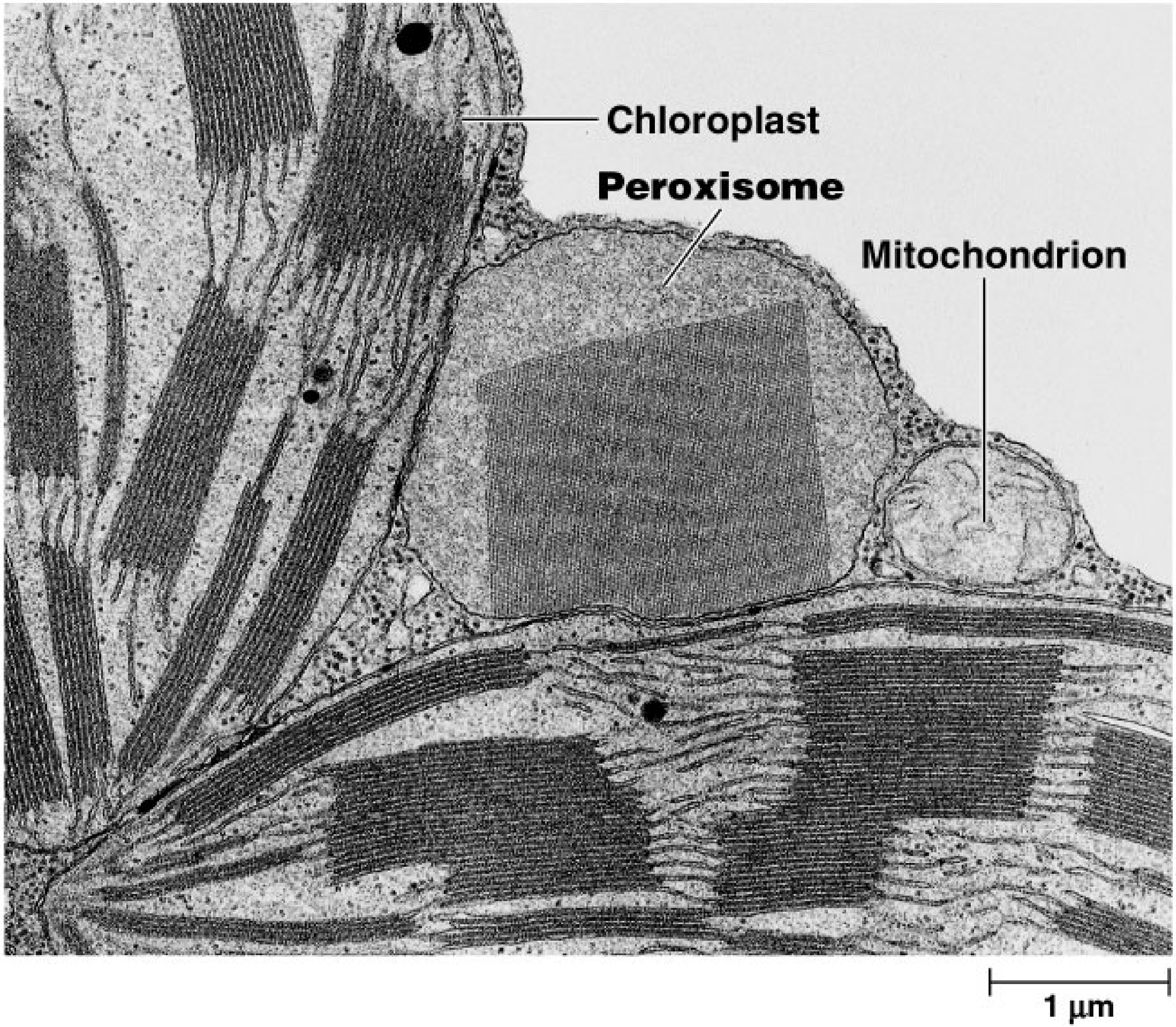
The formation and functions of lysosomes (Step 3)



G. Other Organelles Enclosed by Membranes

- Peroxisomes and glyoxysomes contain special enzymes and carry out specialized chemical reactions inside the cell.
- Peroxisomes deal with excess hydrogen peroxide.
- Glyoxysomes break down stored lipids to sugars in mostly young plant cells.

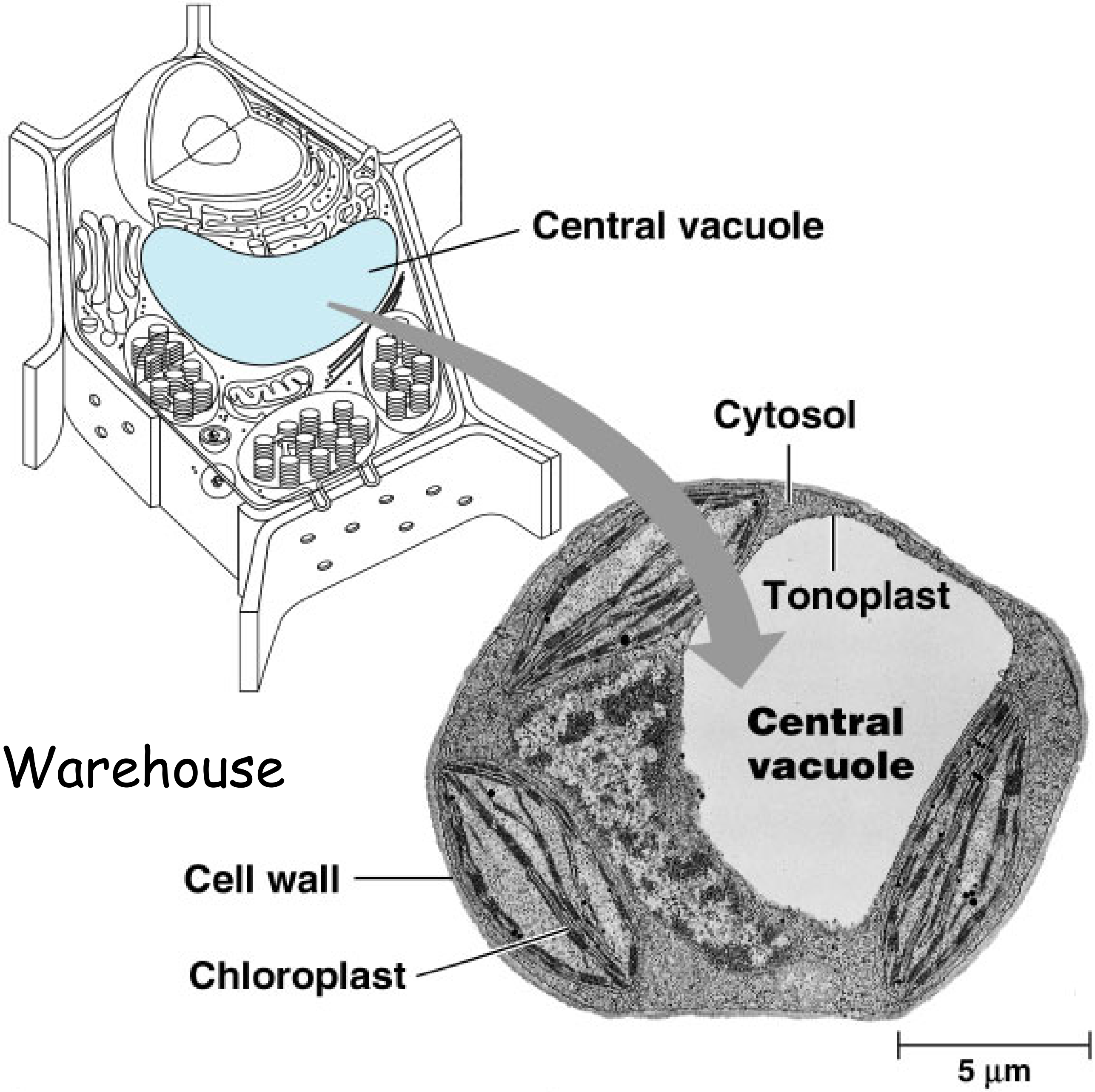
Peroxisomes



G. Other Organelles Enclosed by Membranes

- Vacuoles consist of a membrane-enclosed compartment of water and dissolved substances. They take in water and enlarge, providing pressure to stretch the cell wall and structural support for a plant.
- Tonoplast is part of endomembrane system.
- Various types:
  - Food Vacuole
  - Contractile Vacuole
  - Central Vacuole

The plant cell vacuole

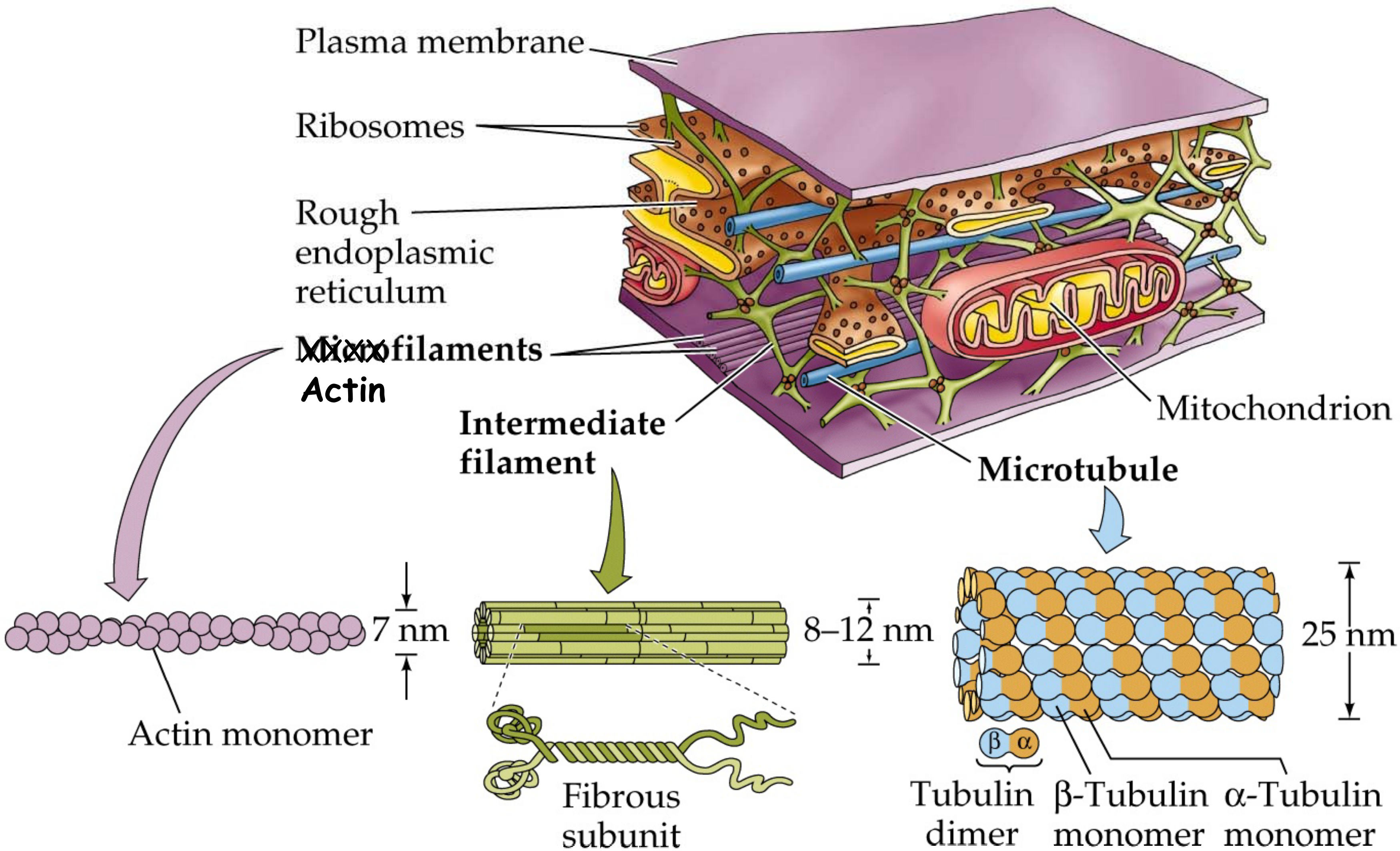


Cellular Warehouse

H. The Cytoskeleton

- The cytoskeleton within the cytoplasm of eukaryotic cells provides shape, strength, and movement. It consists of three interacting types of protein fibers.
  - **Actin filaments** (tension-bearing)
  - **Intermediate filaments** (tension-bearing)
  - **Microtubules** (compression-resistant)

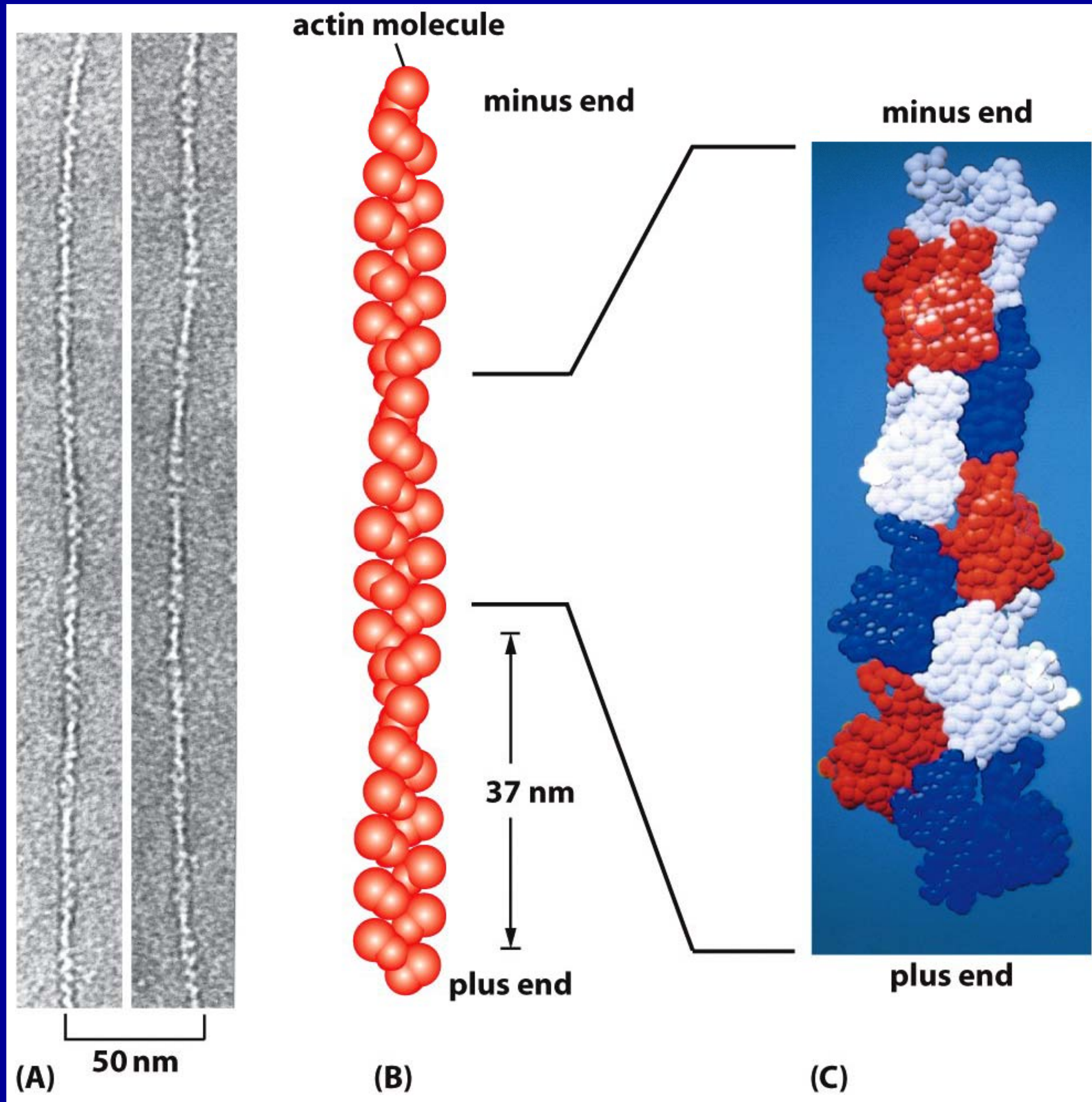
Cytoskeleton Components



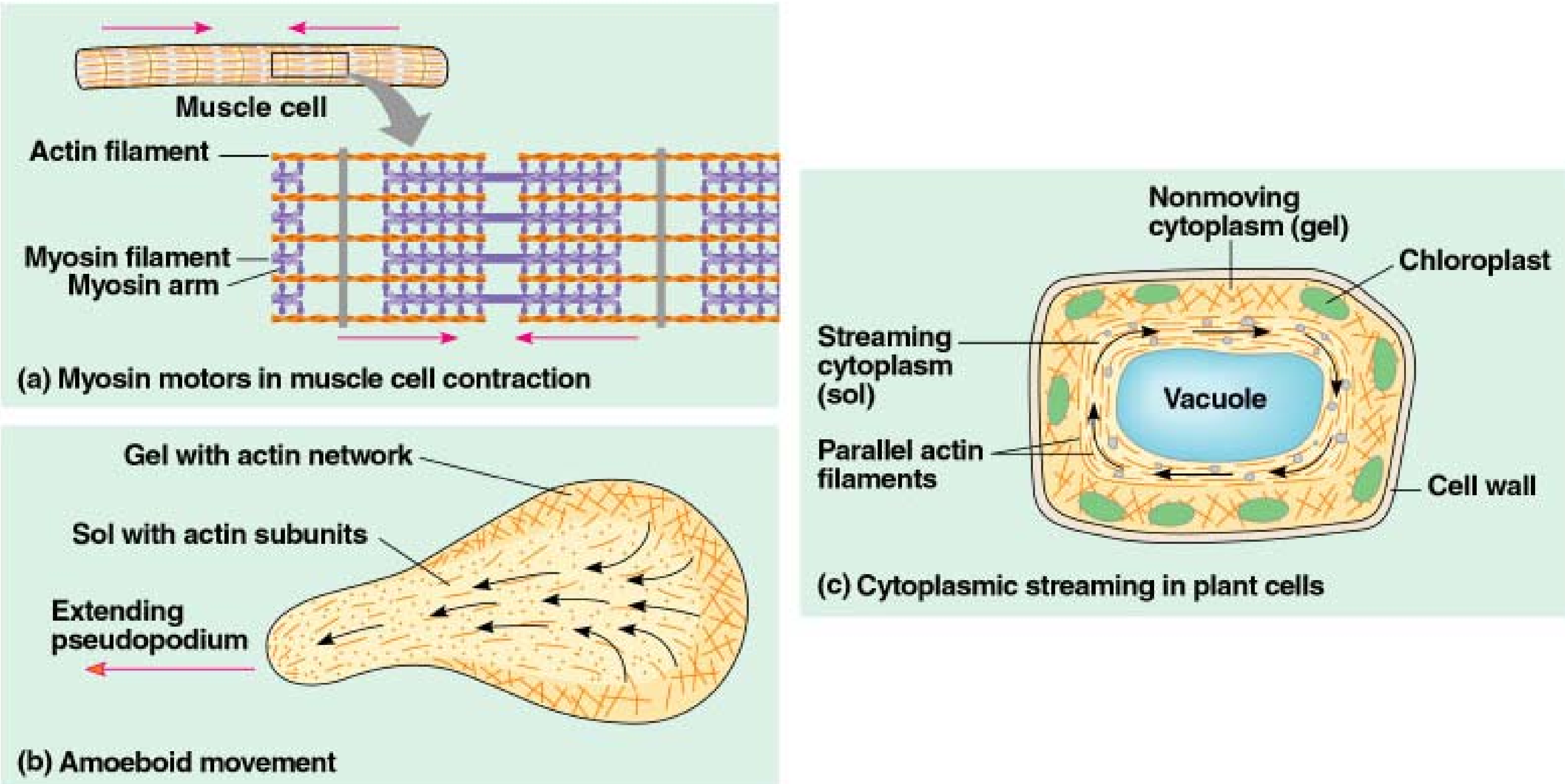
H. The Cytoskeleton

- Actin filaments consist of two chains of actin units forming a double helix.
- Actin filaments strengthen cellular structures and maintain cell shape.
- Involved with the protein myosin in muscle contraction.
- In animal cell division, forms cleavage furrow.
- Also used in cytoplasmic streaming and pseudopod extension (cell motility).

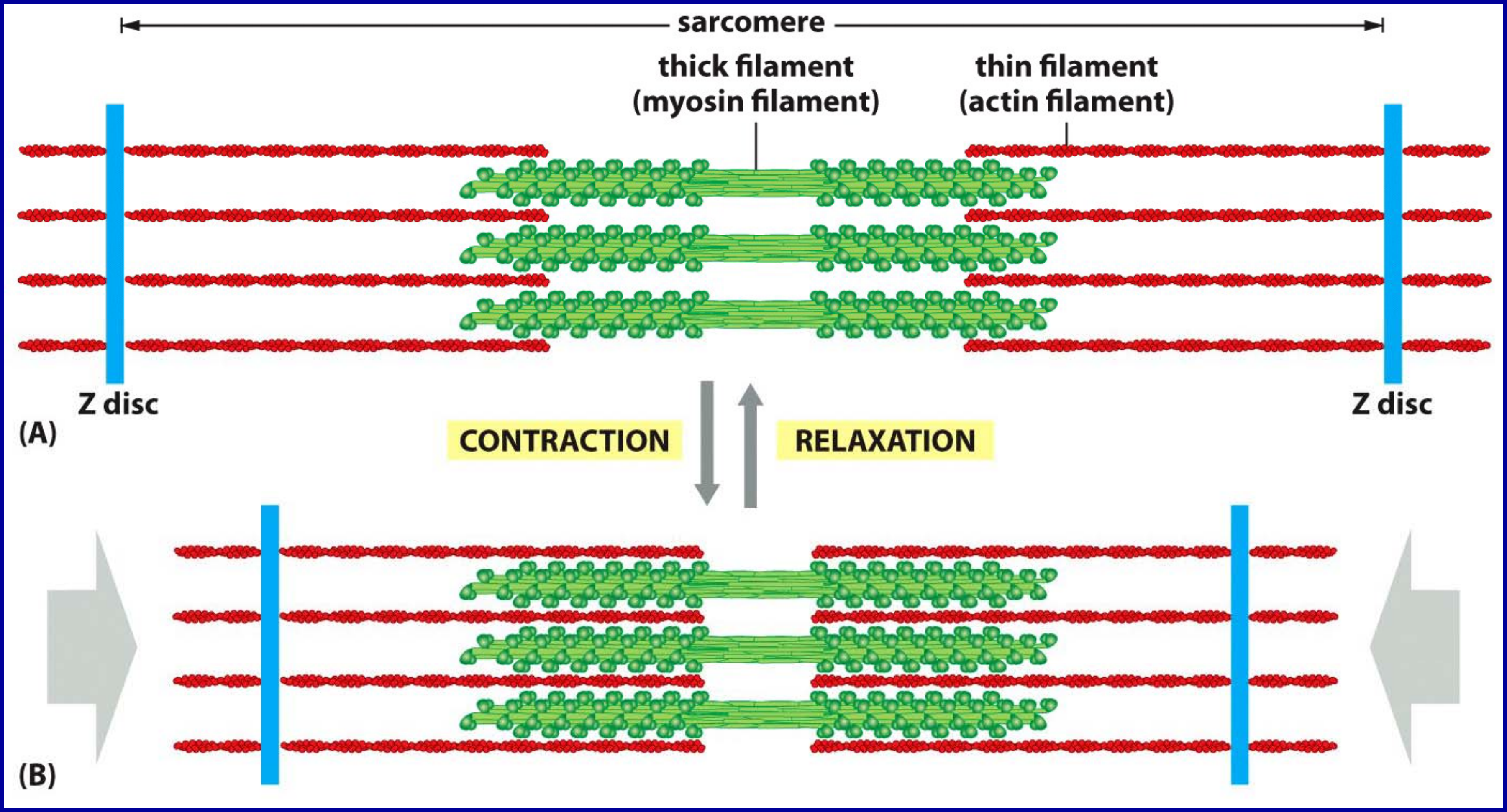
Actin filaments are thin, flexible protein threads



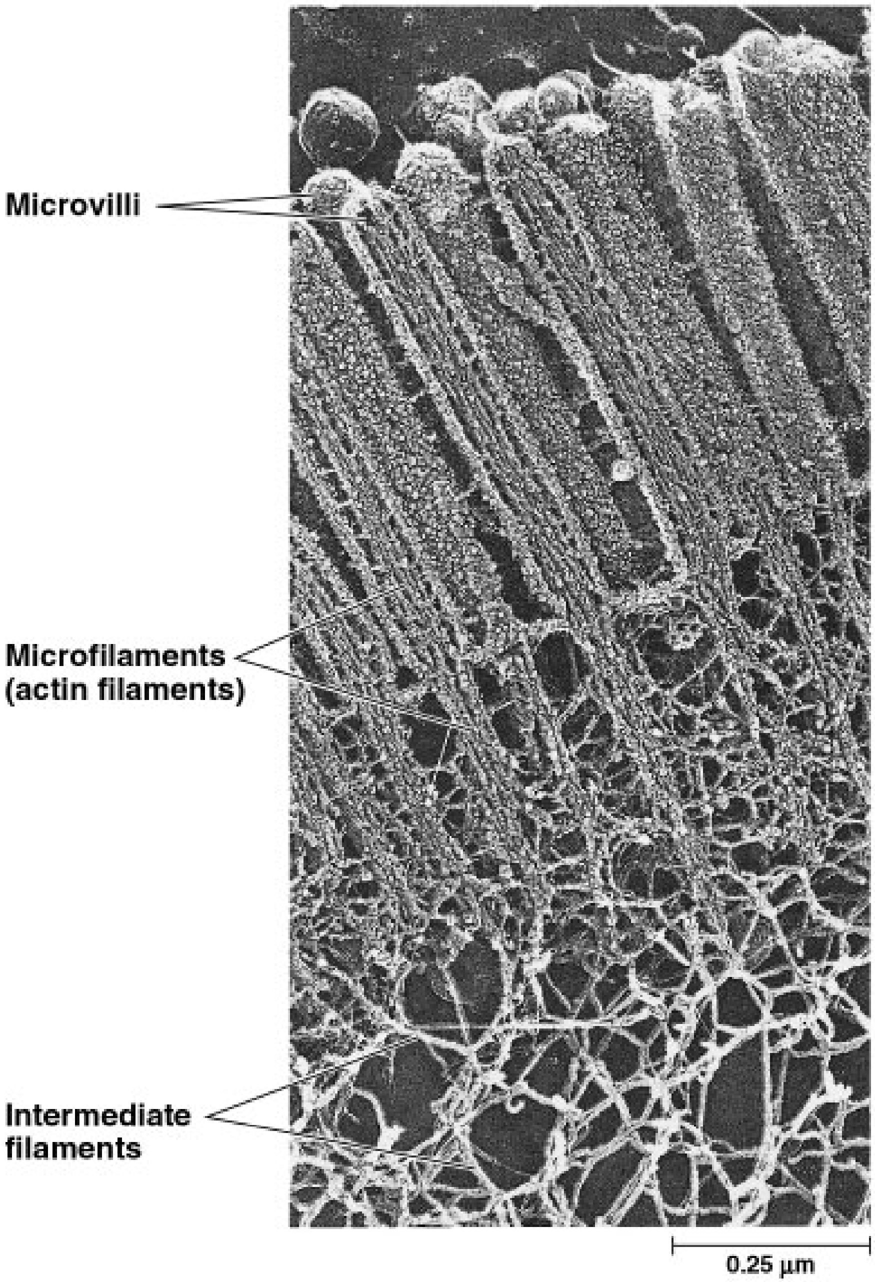
Actin filaments and motility

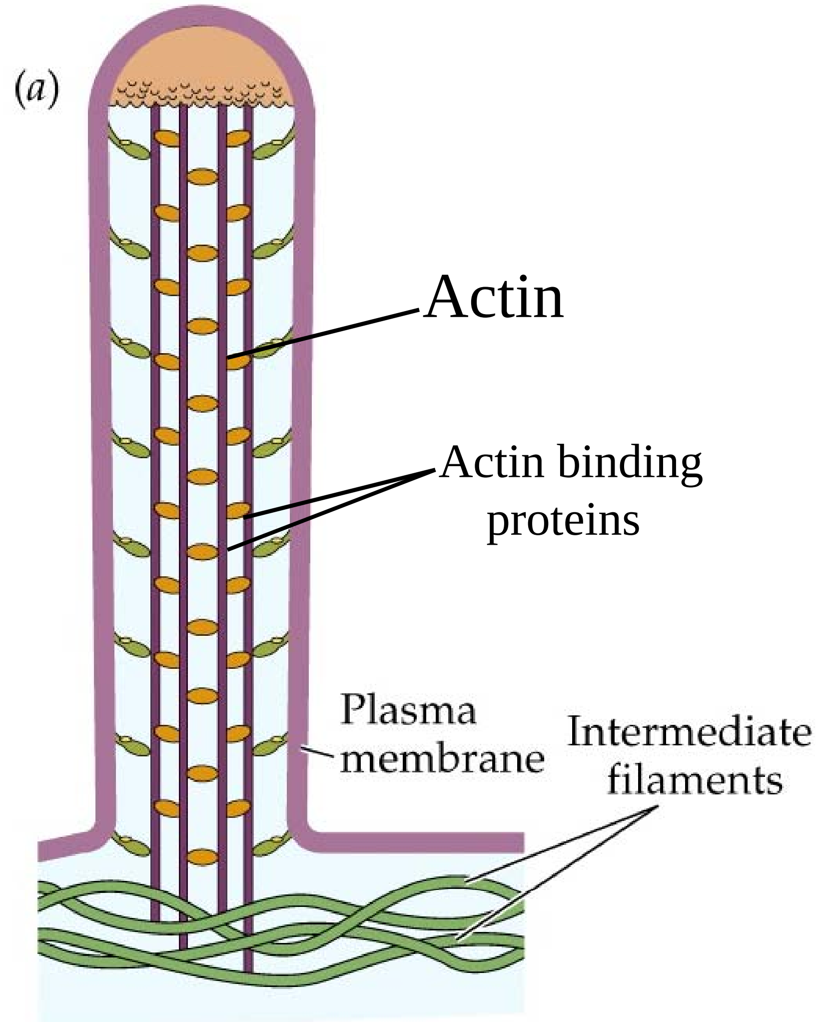


Muscles also contract by a sliding-filament mechanism



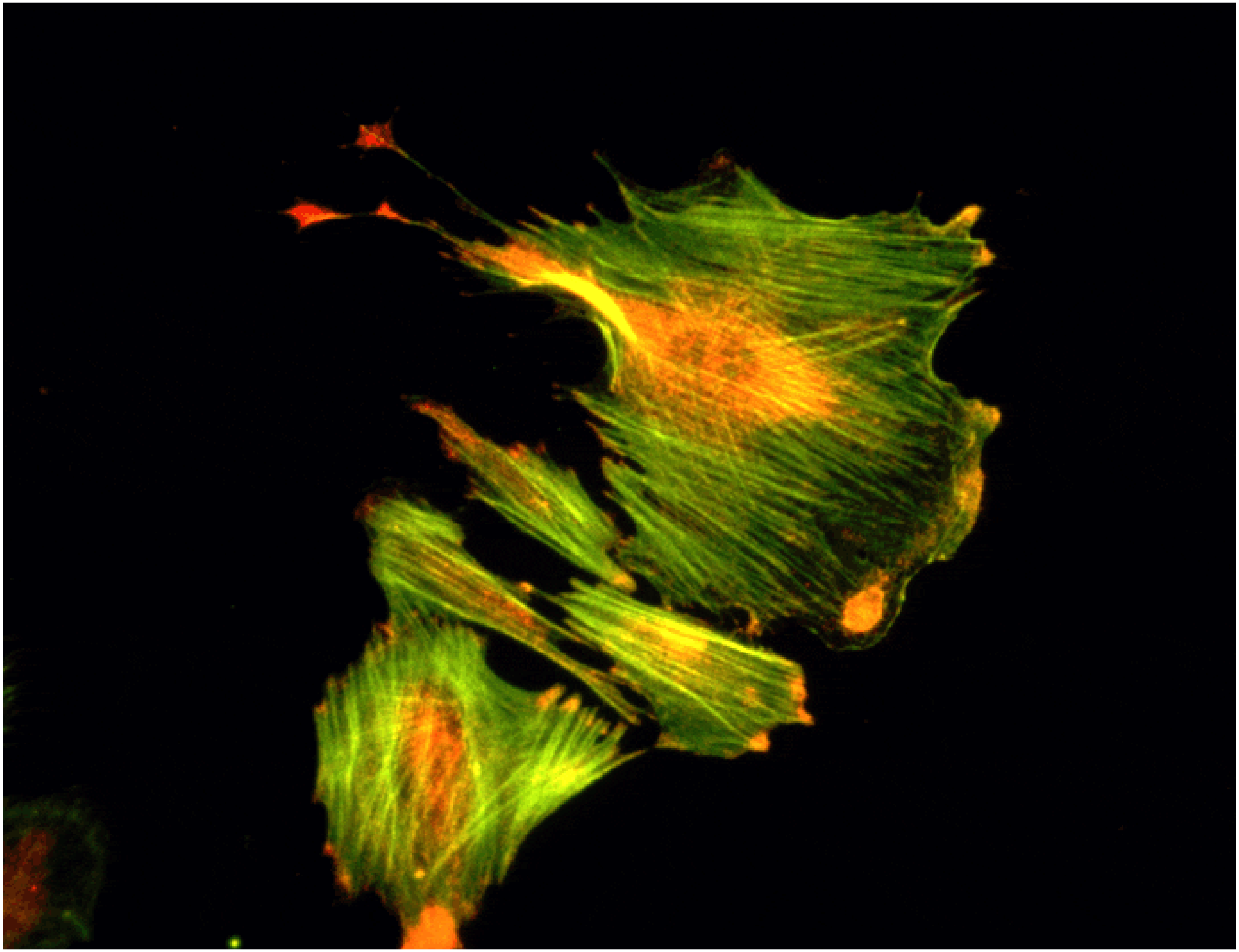
A structural role of Actin filaments





Intestinal microvillis

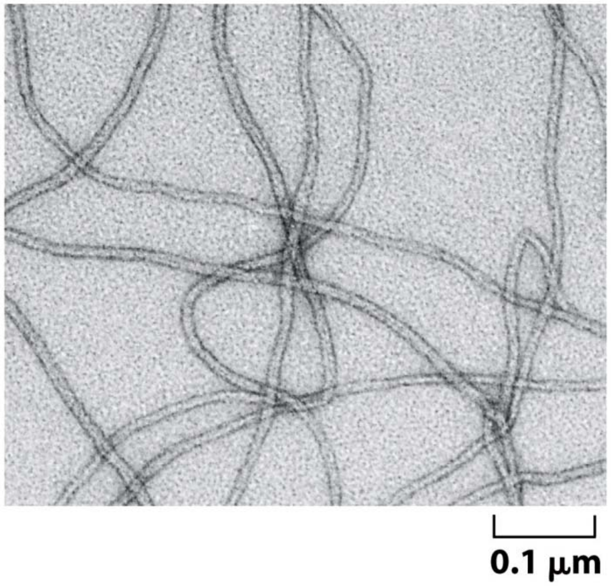
Actin

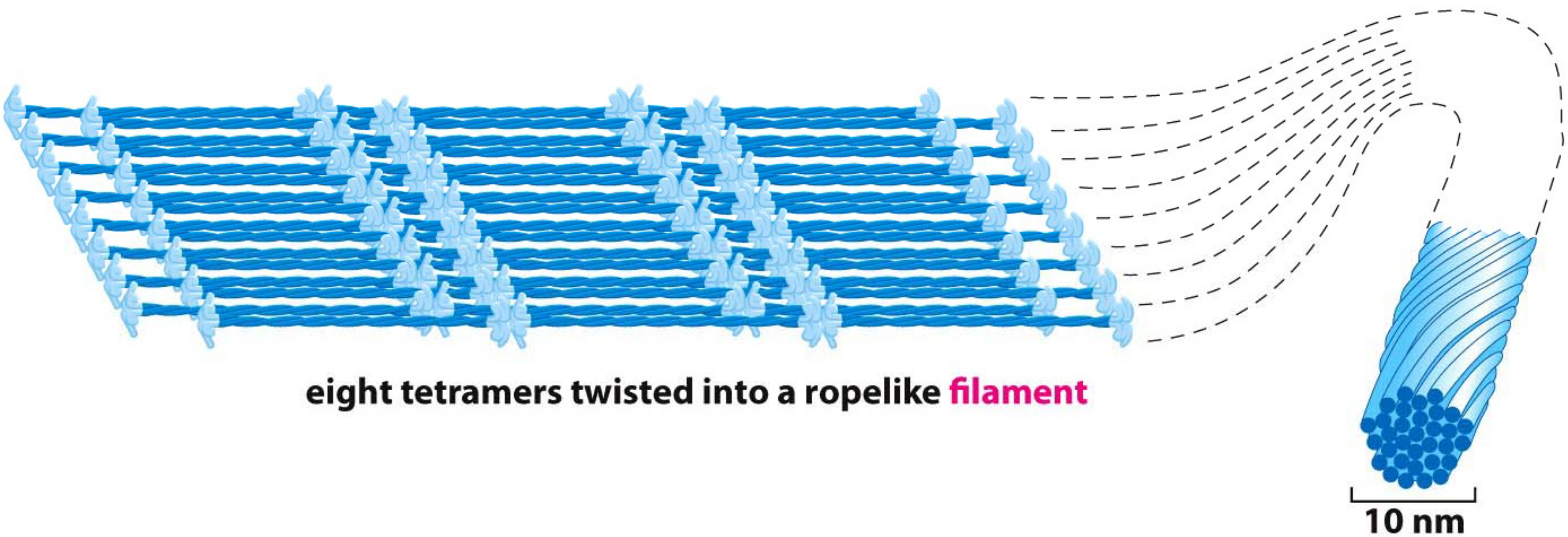


H. The Cytoskeleton

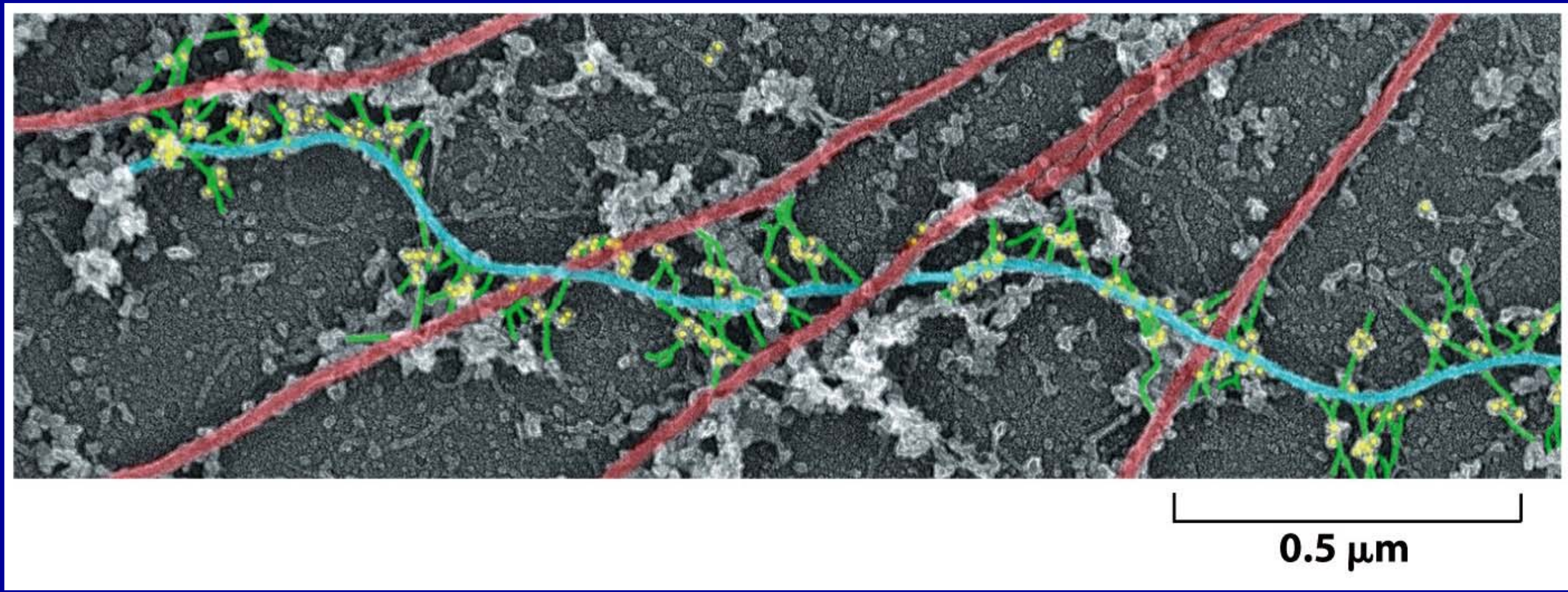
- Intermediate filaments are formed of keratins and add strength to cell structure.
- Anchorage of nucleus and other organelles.
- Formation of nuclear lamina, foundation under nuclear envelope.
- Maintain attachments in multicellular organisms through desmosome anchoring.

Intermediate filaments are rope-like twisted strands of protein

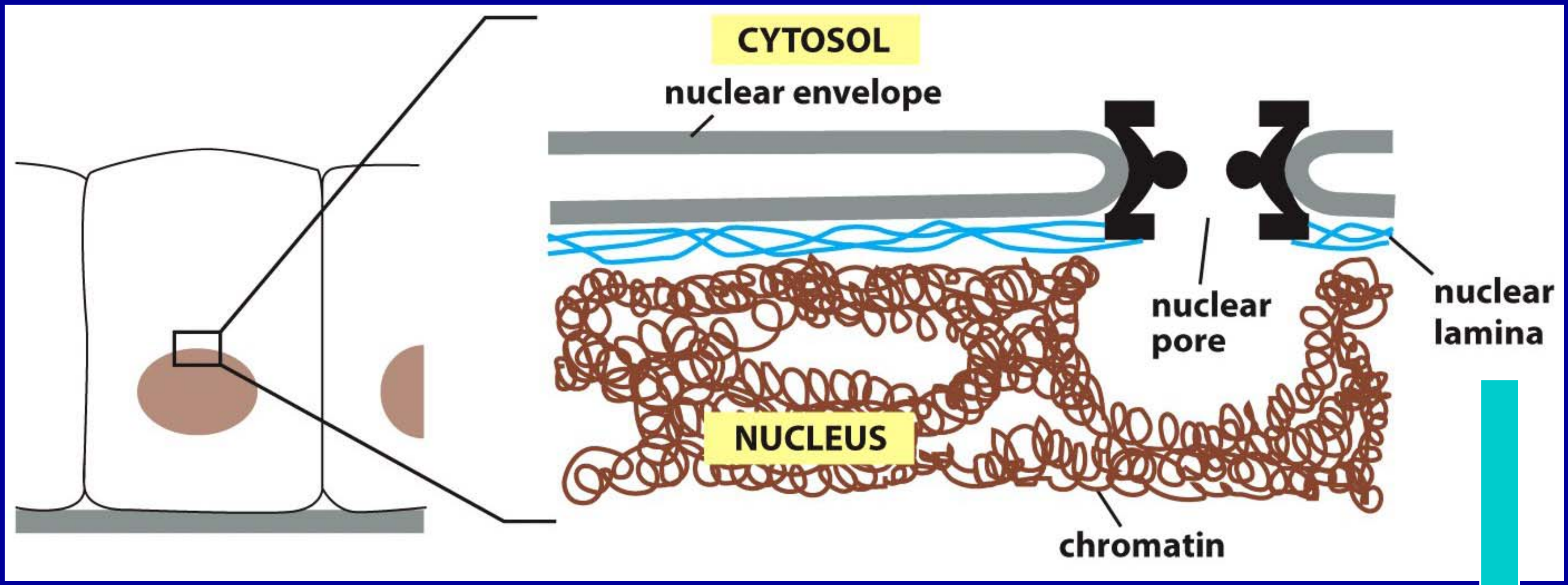


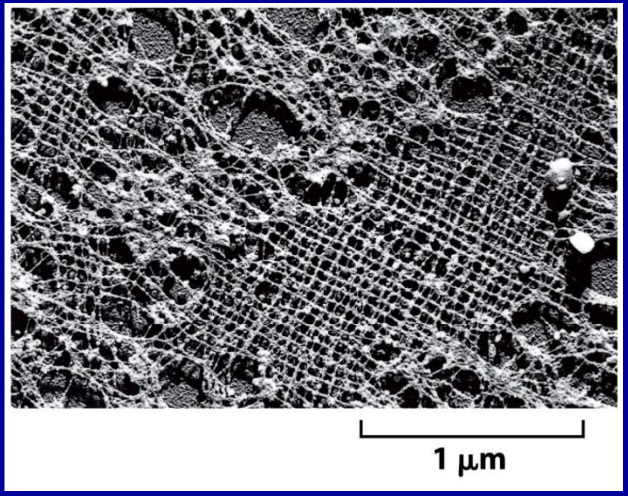


Plectin (green) is a cross-linking protein that binds intermediate filaments (blue) to other cytoskeleton networks like microtubules (red)



Intermediate filaments support and strengthen the nuclear envelope via the nuclear lamina

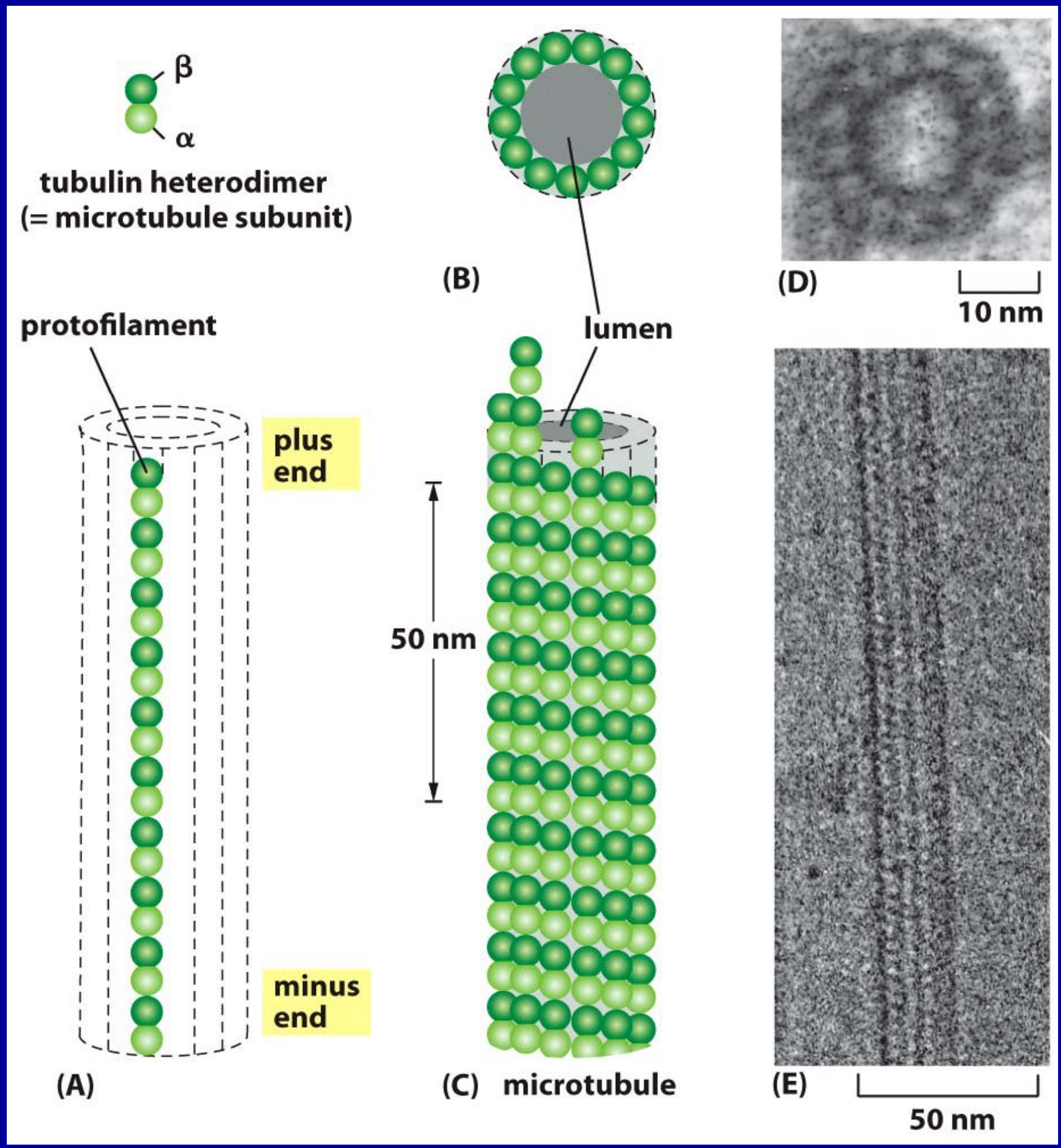




H. The Cytoskeleton

- Microtubules are composed of dimers of the protein tubulin, and can lengthen and shorten.
- Eukaryotic Cilia and flagella both have a characteristic 9 + 2 pattern of microtubules.
- They usual grow out of an organized structure, like a basal body or centrosome.

Microtubules are hollow tubes of tubulin

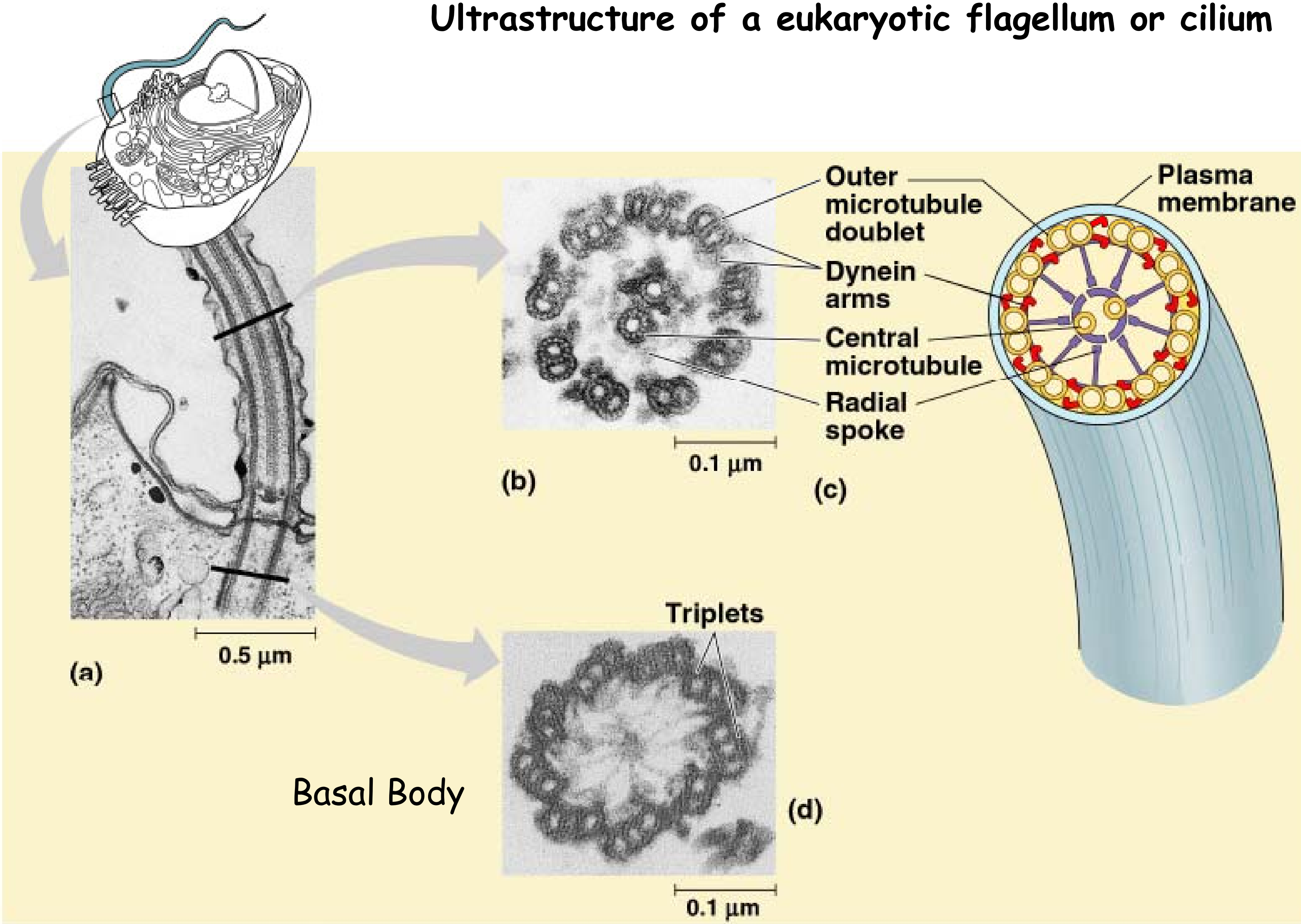


H. The Cytoskeleton

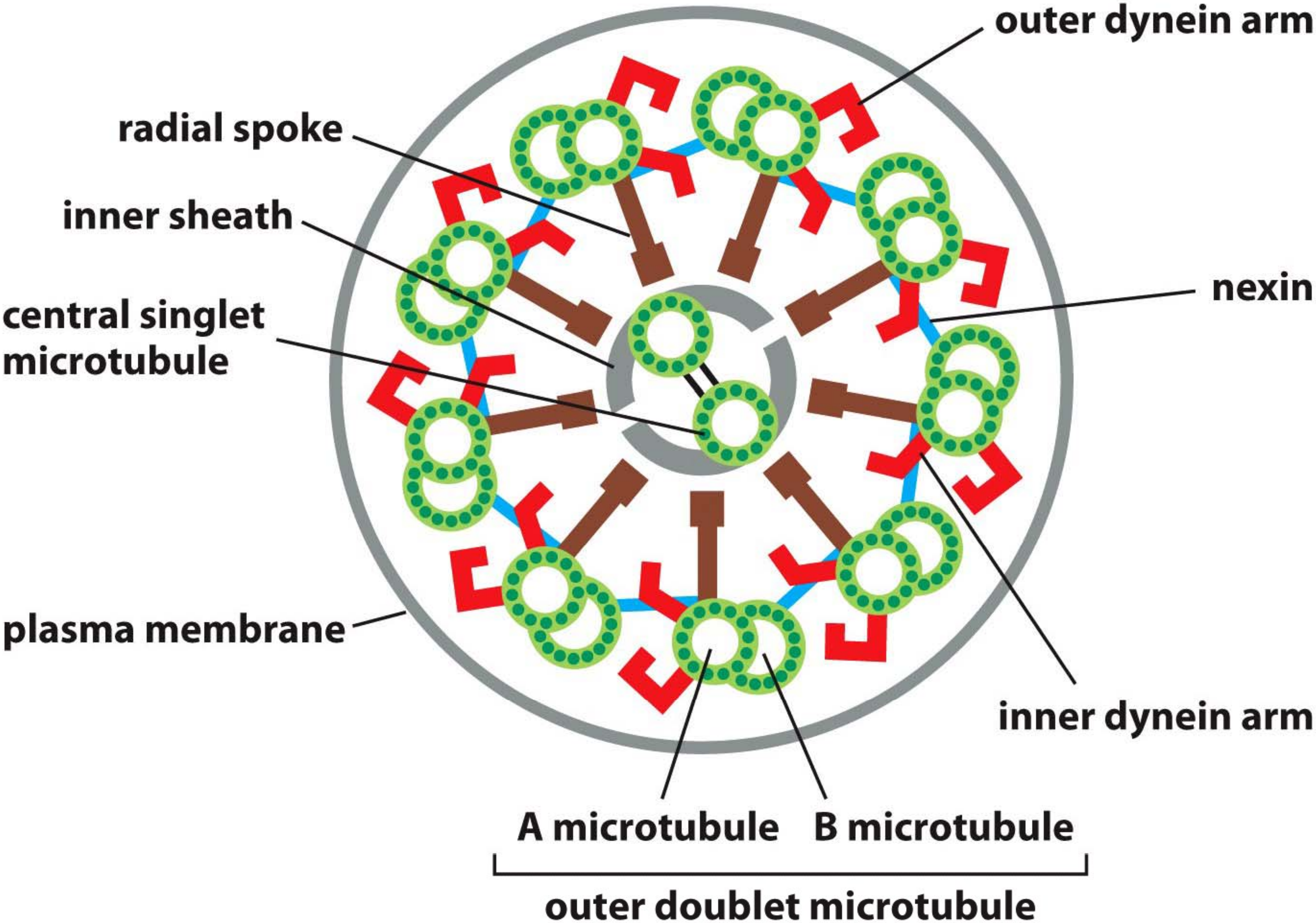
- Movements of cilia and flagella are due to binding of the motor protein dynein to microtubules.

- Microtubules also bind motor proteins that move organelles through the cell.

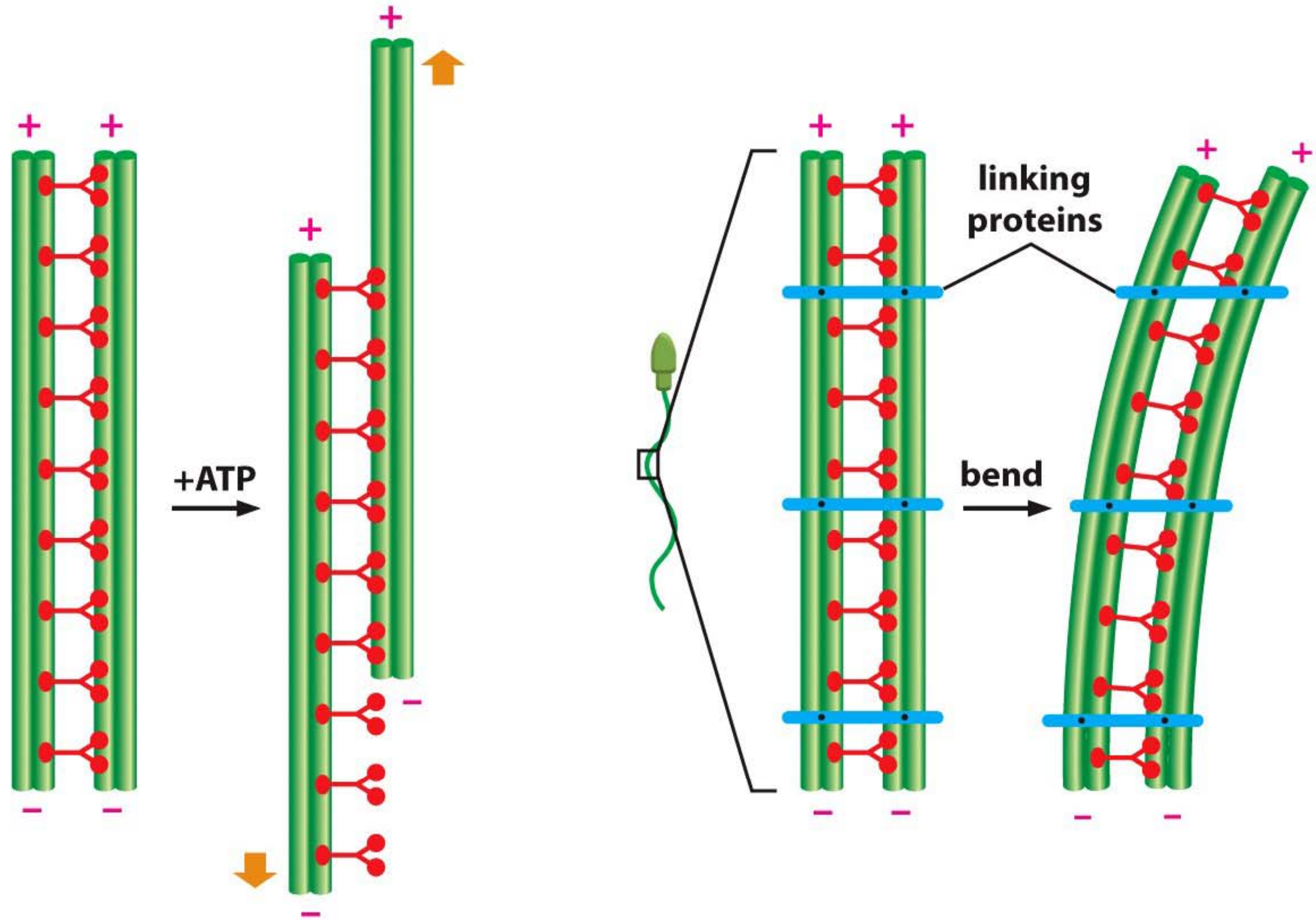
Ultrastructure of a eukaryotic flagellum or cilium



Basal Body

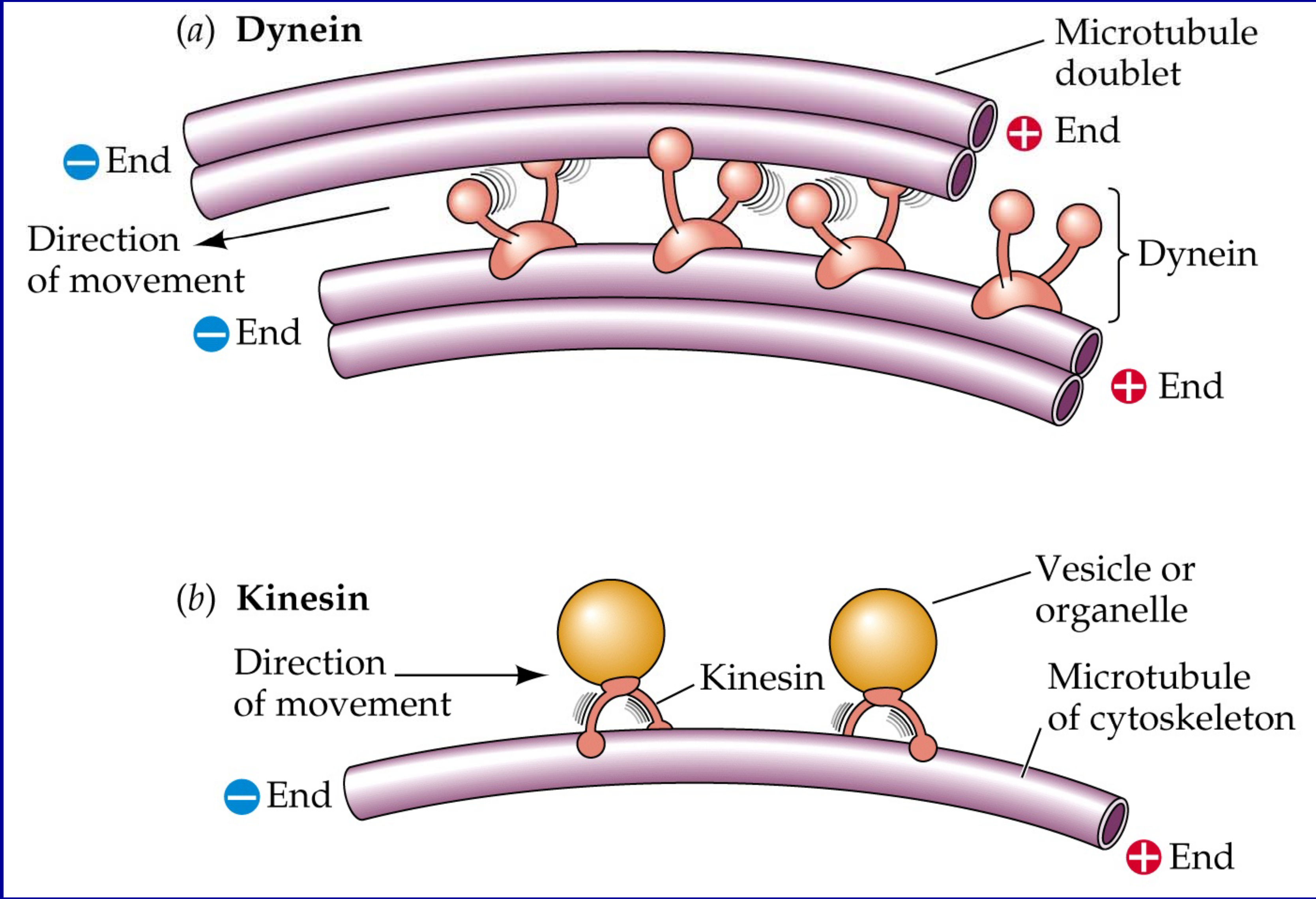

outer dynein arm
radial spoke
inner sheath
nexin
central singlet
microtubule
plasma membrane
inner dynein arm
A microtubule
B microtubule
outer doublet microtubule

How dynein "walking" moves cilia and flagella



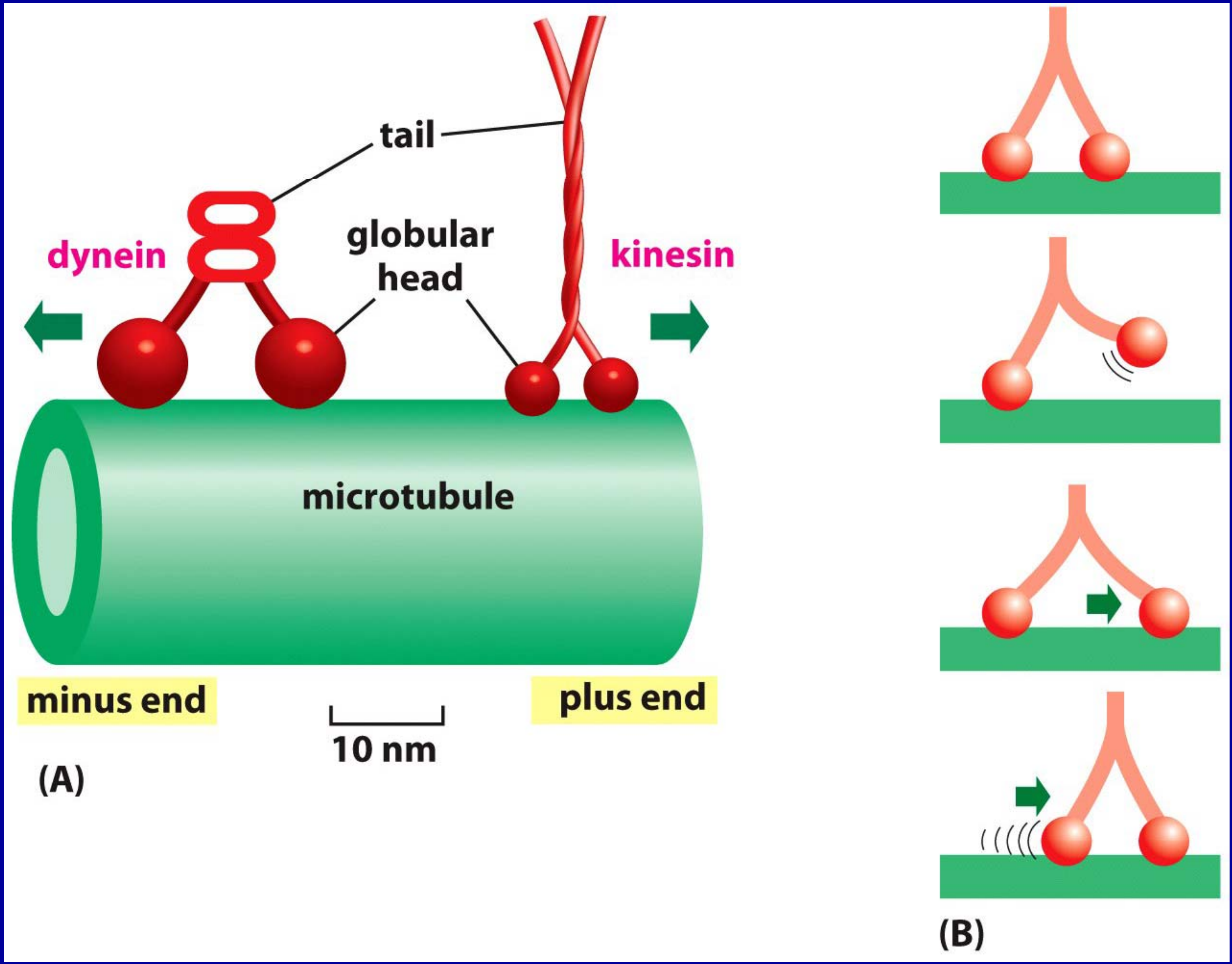
(A) IN ISOLATED DOUBLET MICROTUBULES: DYNEIN PRODUCES MICROTUBULE SLIDING

(B) IN NORMAL FLAGELLUM: DYNEIN CAUSES MICROTUBULE BENDING



(a) Dynein
Microtubule doublet
End
End
Direction of movement
Dynein
End
End
(b) Kinesin
Vesicle or organelle
Direction of movement
Kinesin
Microtubule of cytoskeleton
End
End

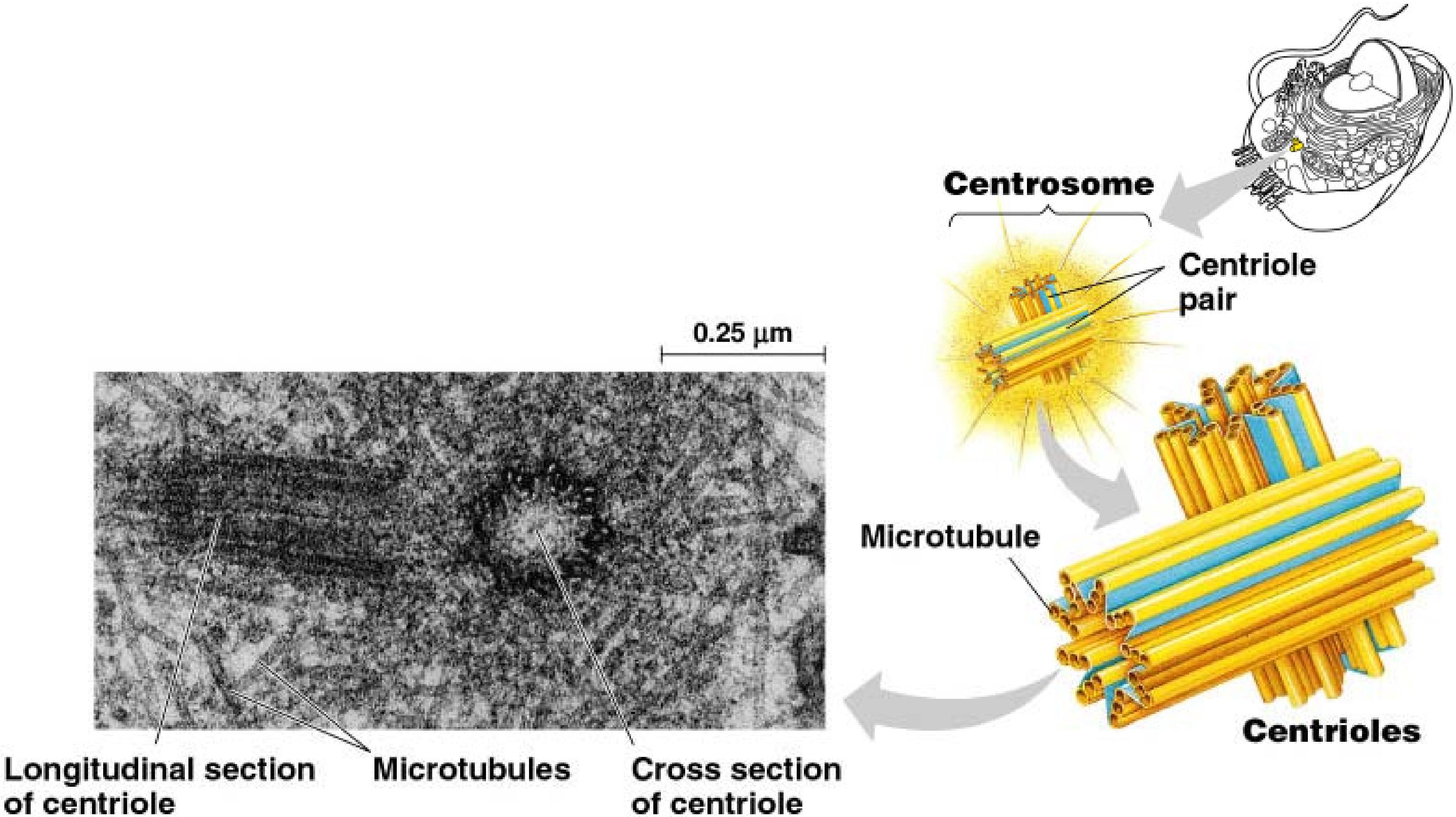
Two classes of Motor Proteins



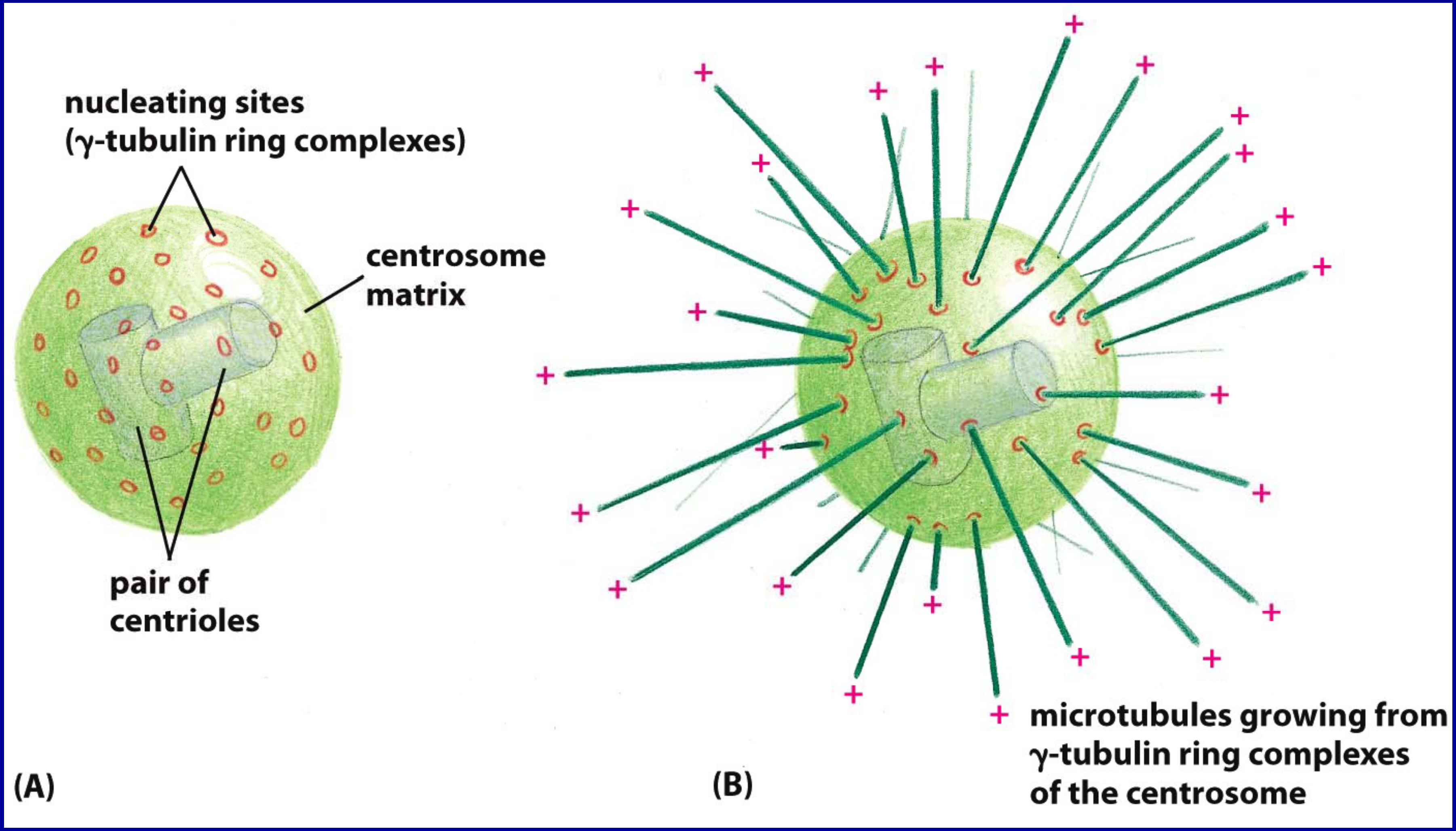
H. The Cytoskeleton

- Centrioles, made up of fused triplets of microtubules, are involved in the distribution of chromosomes during nuclear division.
- Dynamic Instability occurs until cell becomes polarized via capping proteins.

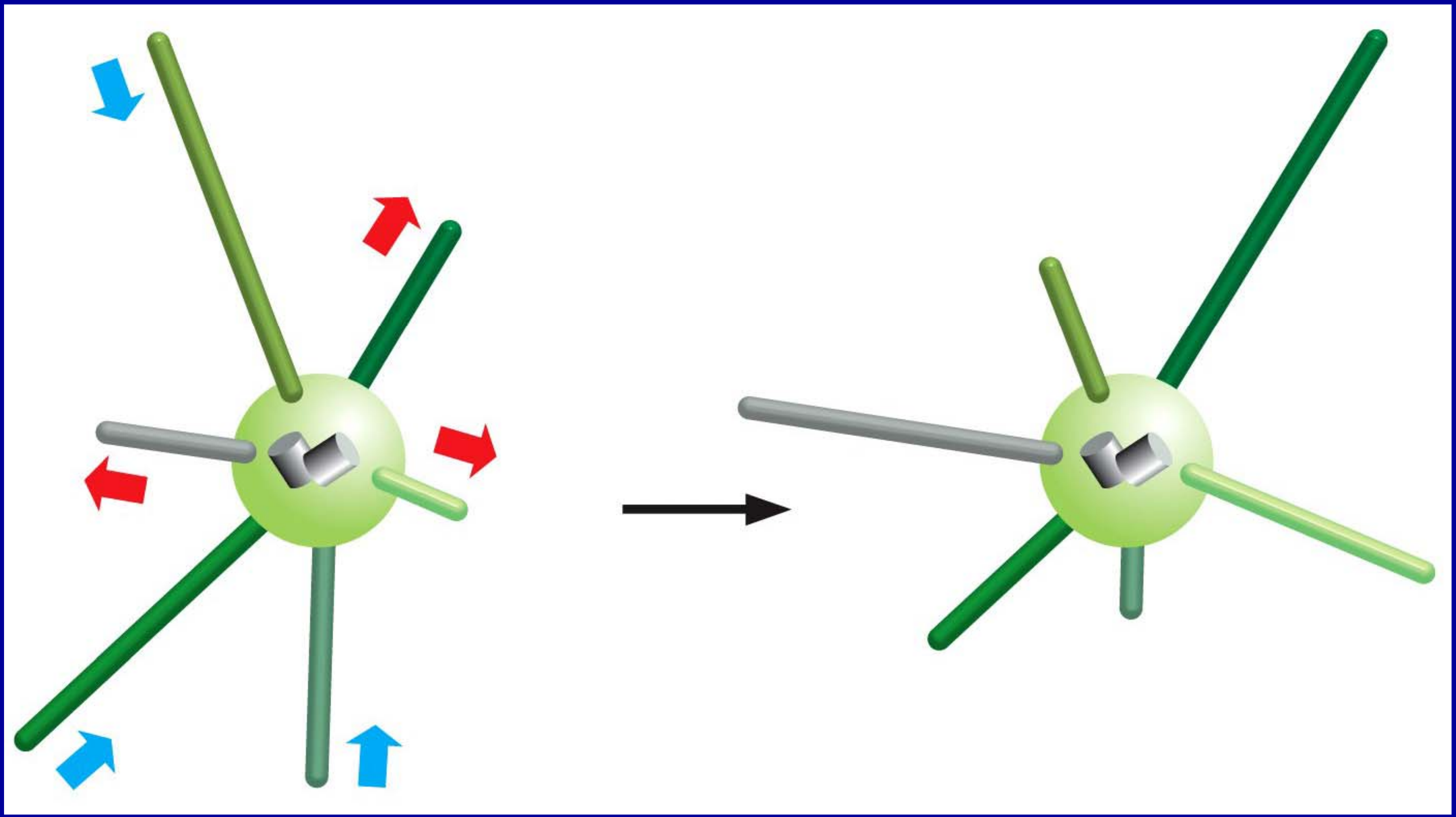
Centrosome containing a pair of centrioles



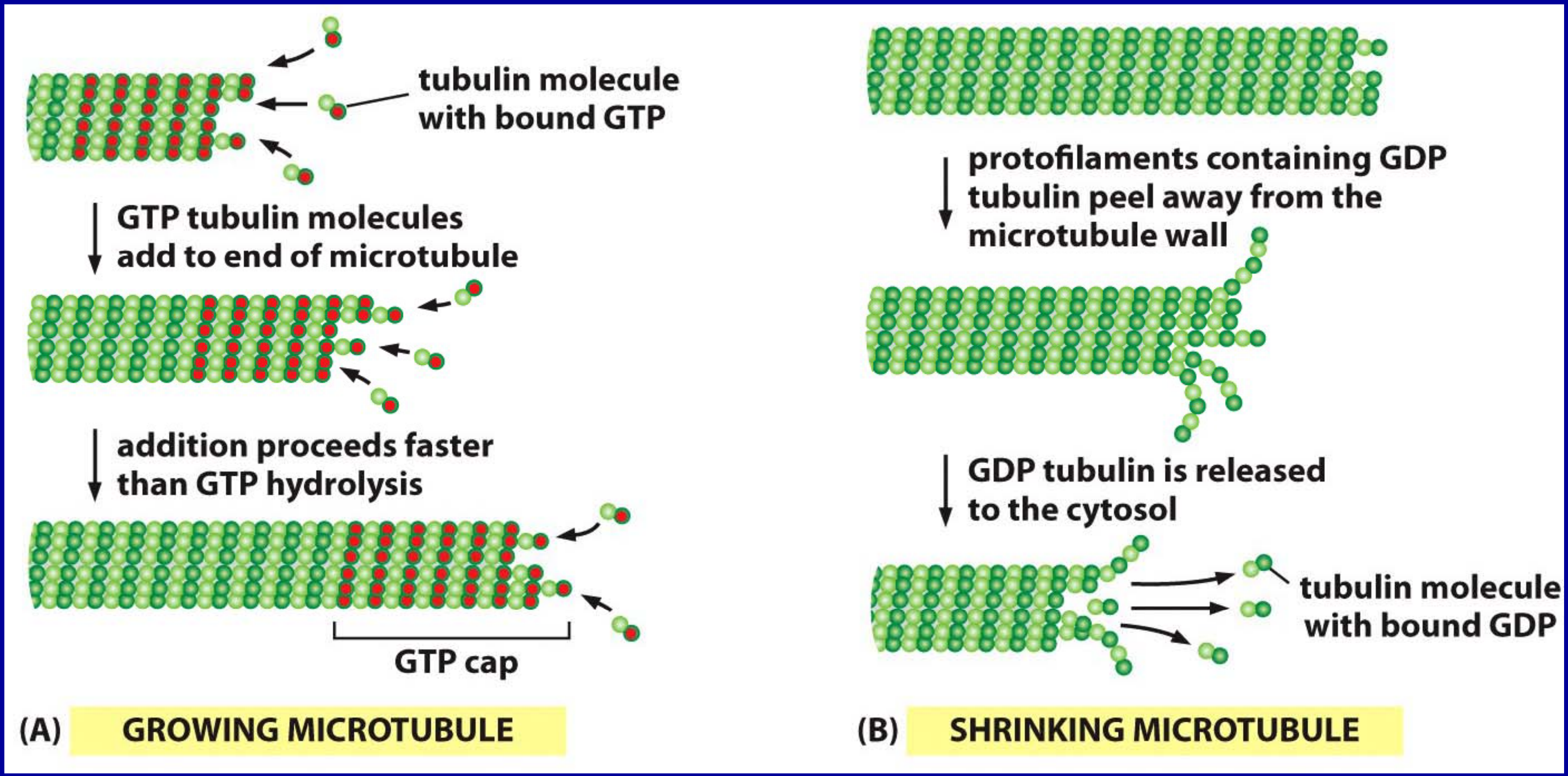
Tubulin polymerizes from nucleation sites



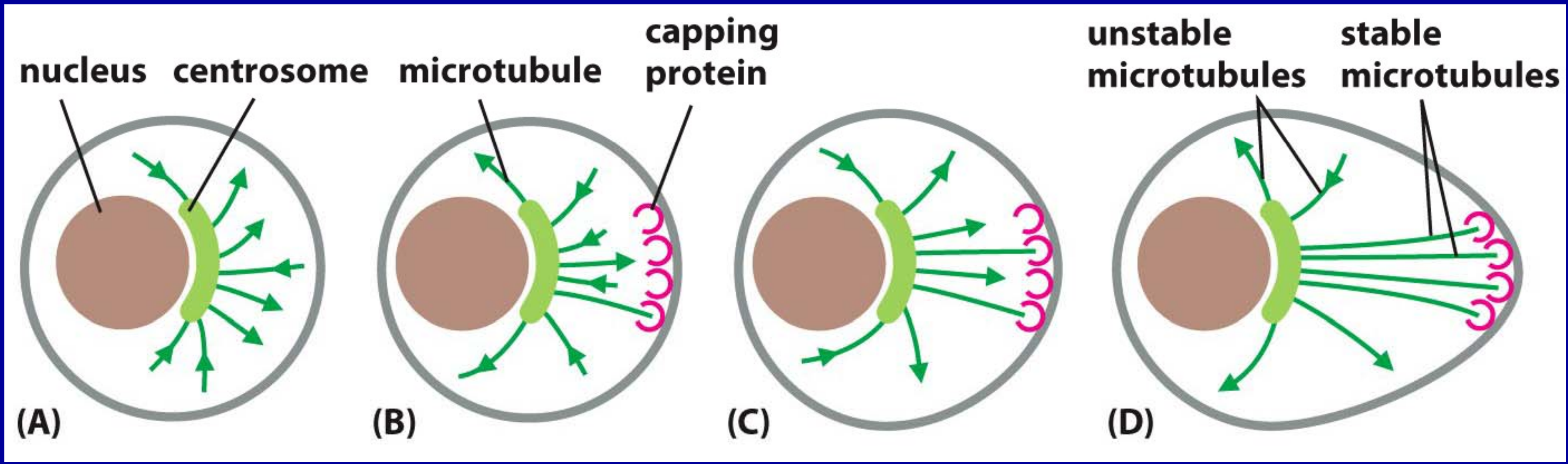
Dynamic Instability of Microtubules



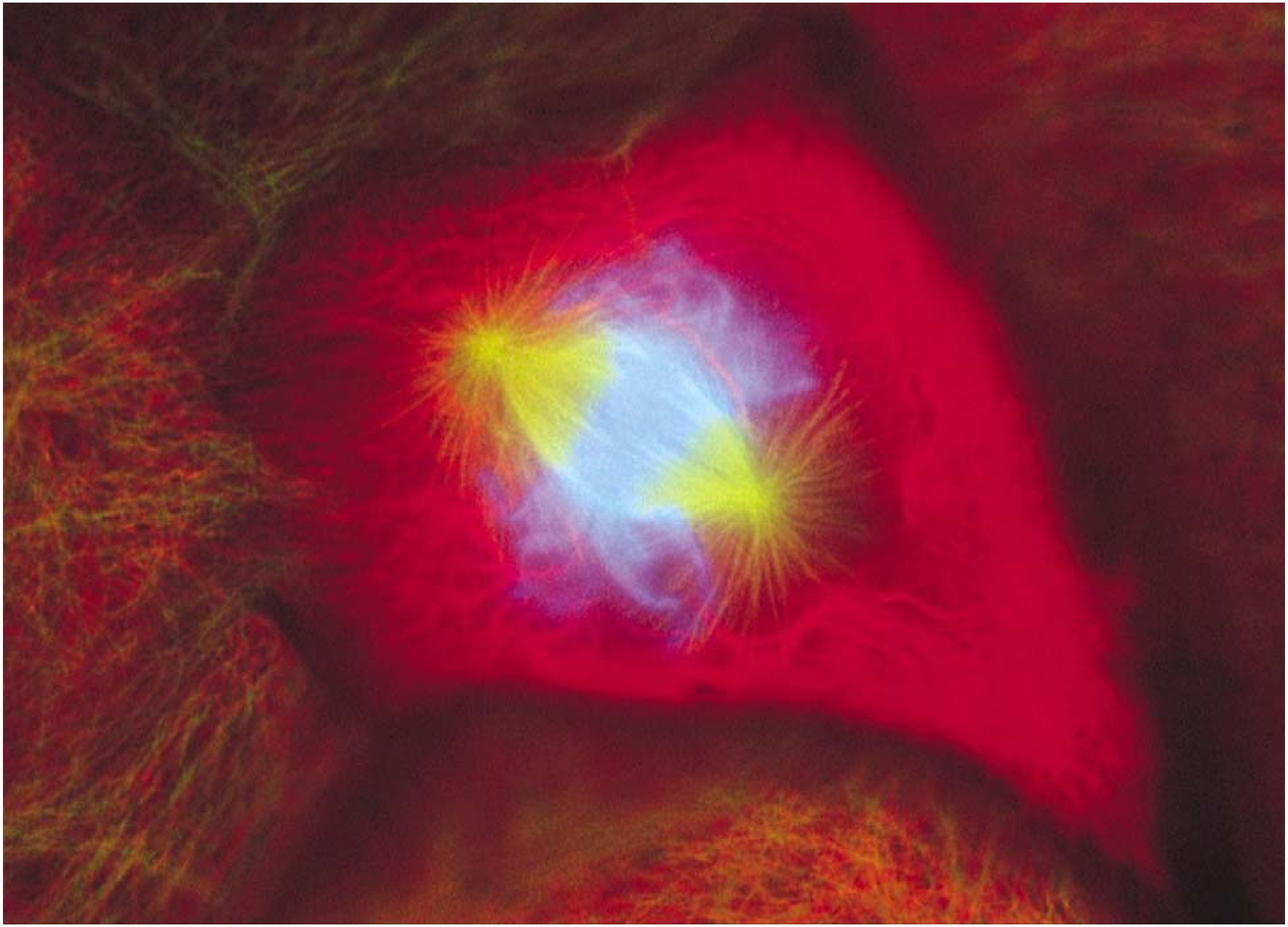
GTP Hydrolysis controls growth of Microtubules



Selective Stabilization of Microtubules



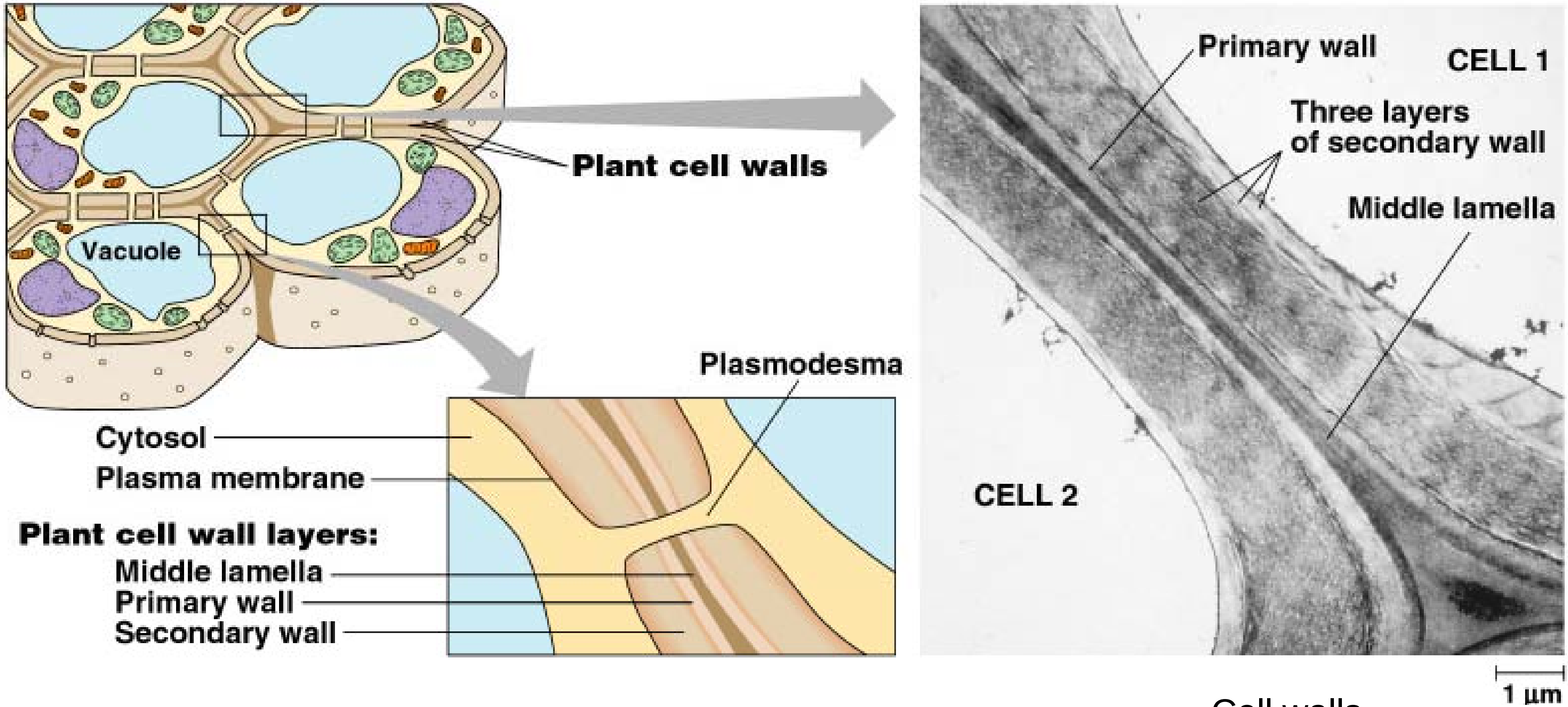
Spindle formation during mitosis

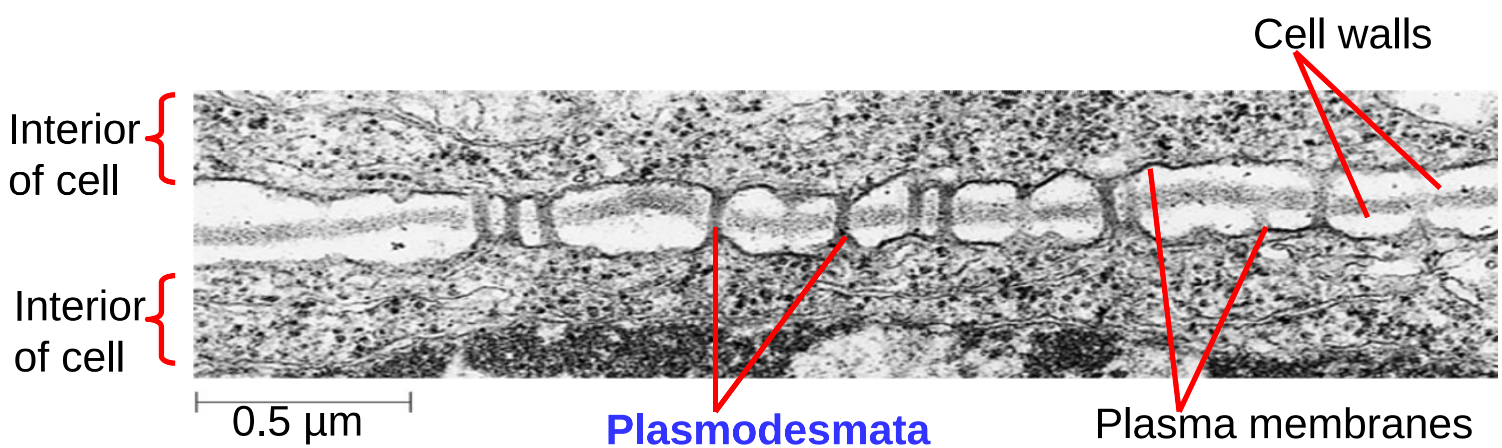


I. Extracellular Structures

- Materials external to the plasma membrane provide protection, support, and attachment for cells in multicellular systems.
- Cell walls of plants consist principally of cellulose embedded in other polysaccharides and proteins forming multiple layers.
- They are pierced by plasmodesmata that join the cytoplasm of adjacent cells.

Plant cell walls

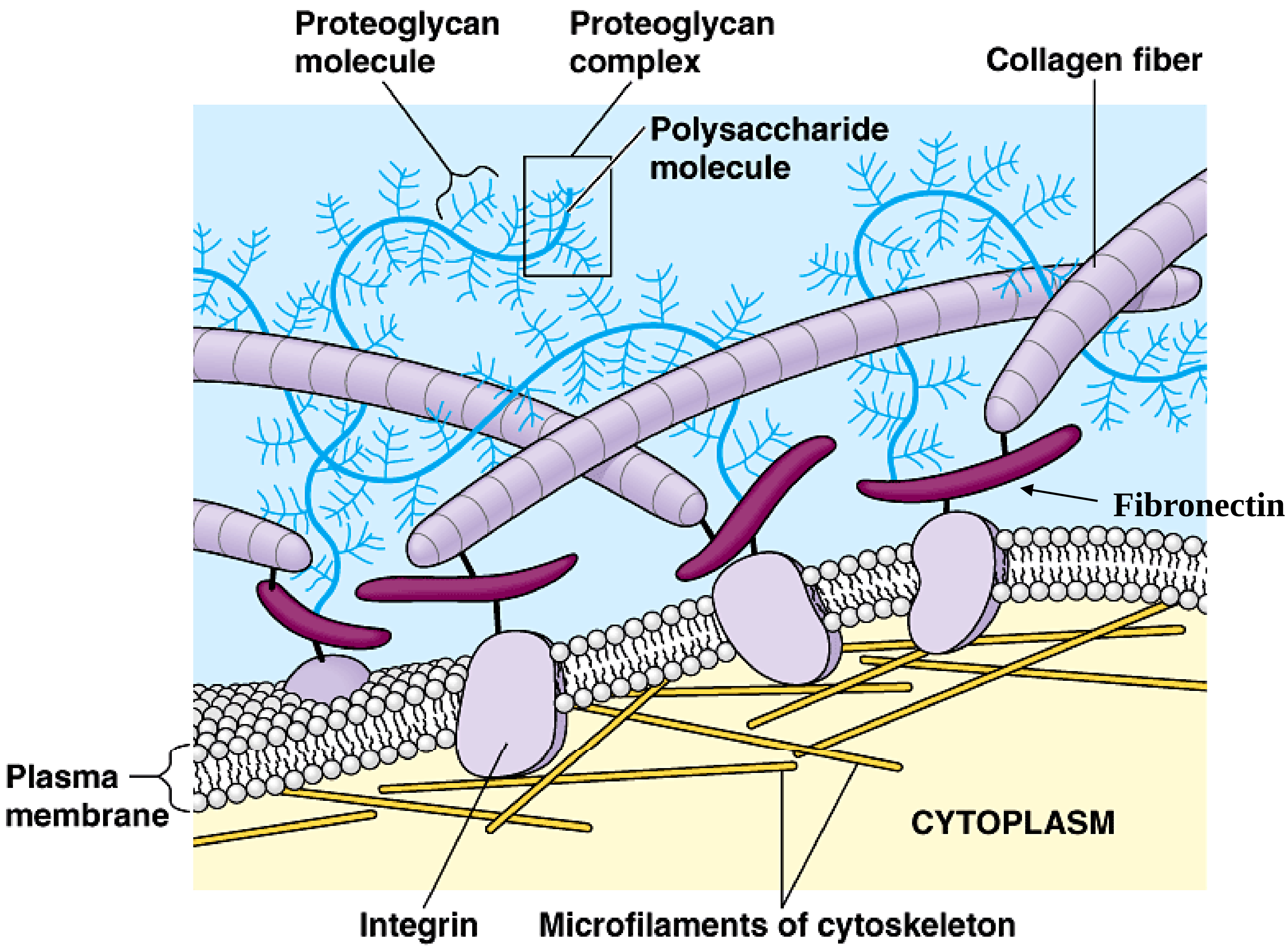




I. Extracellular Structures

- In multicellular animals, the extracellular matrix consists of different proteins, including proteoglycan. In bone and cartilage, collagen predominates.

Extracellular matrix (ECM) of an animal cell



ECMs contain glycoproteins (e.g., collagen, proteoglycan and fibronectin)