# Chapter 4

## A Tour of the Cell

PowerPoint Lectures for

***Campbell Biology: Concepts & Connections,*** ***Seventh Edition***

***Reece, Taylor, Simon, and Dickey***

**Lecture by Edward J. Zalisko**

# Introduction

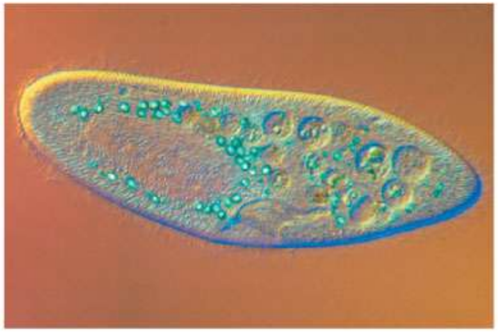
- Cells are the simplest collection of matter that can live.
- Cells were first observed by Robert Hooke in 1665.
- Working with more refined lenses, Antoni van Leeuwenhoek later described
  - blood,
  - sperm, and
  - organisms living in pond water.

# Introduction

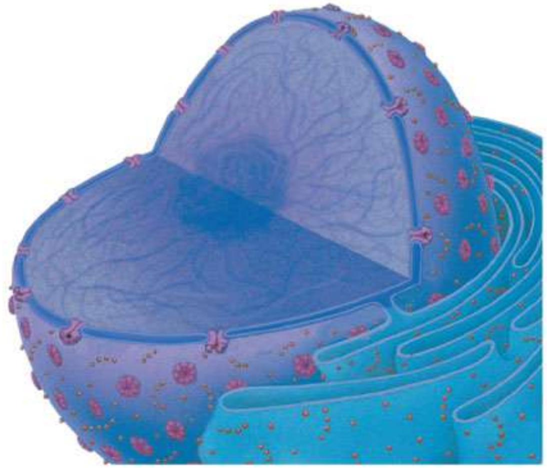
- Since the days of Hooke and Leeuwenhoek, improved microscopes have vastly expanded our view of the cell.

Figure 4.0_1

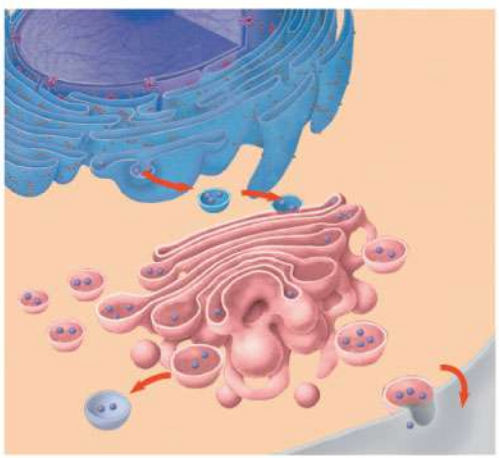
# Chapter 4: Big Ideas



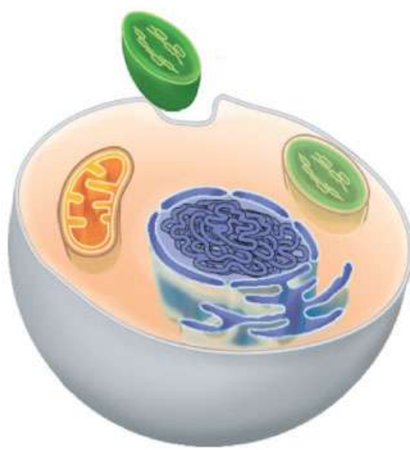
Introduction to the Cell



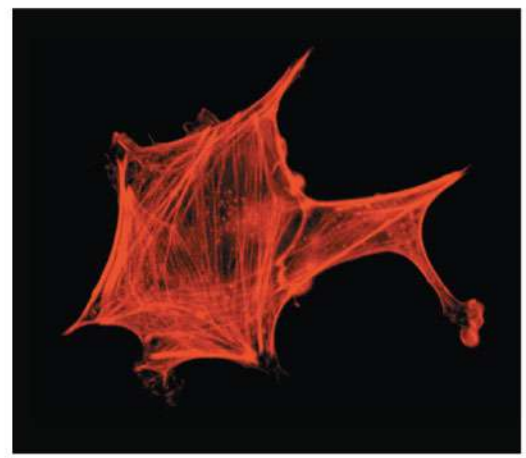
The Nucleus and Ribosomes



The Endomembrane System

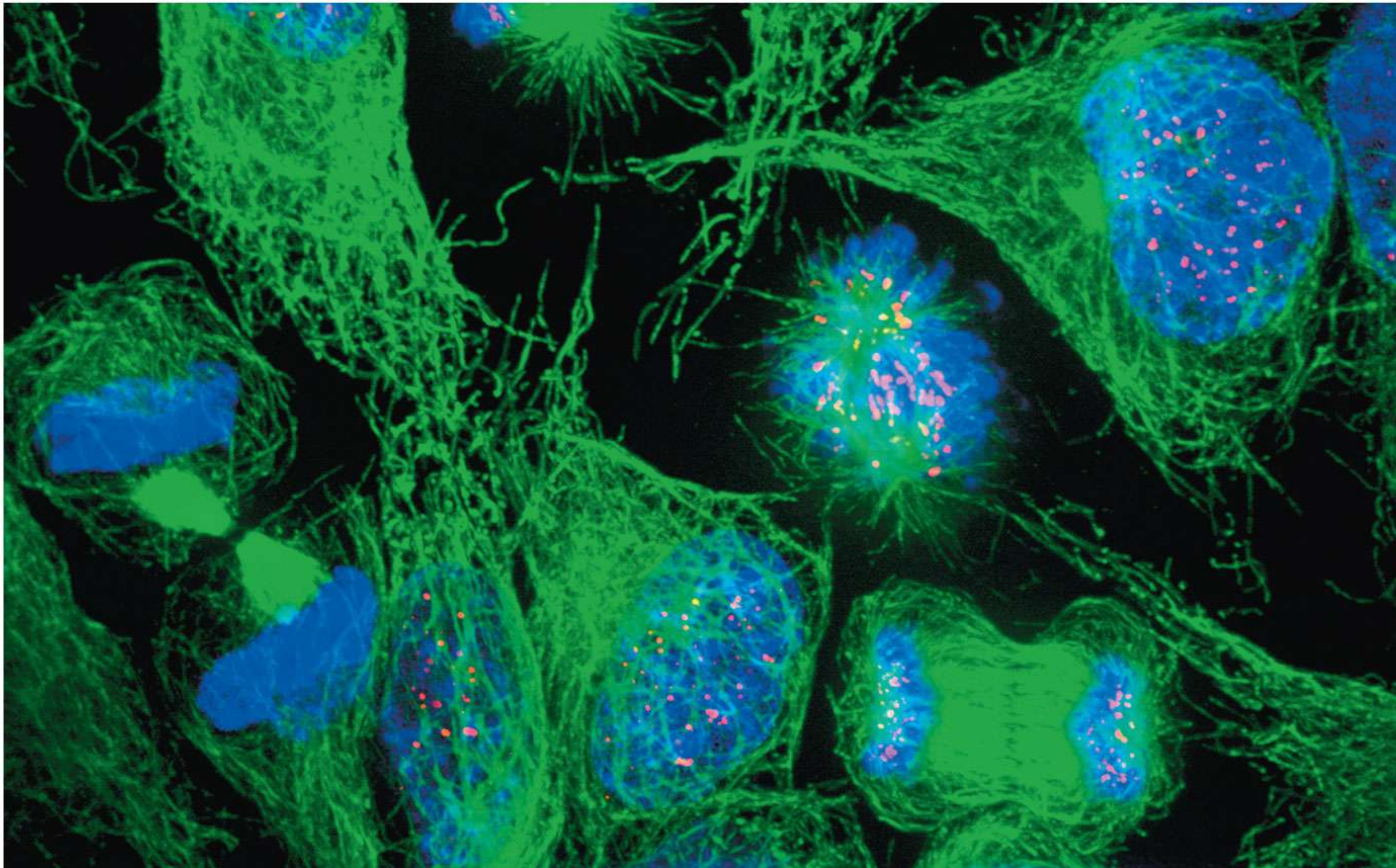


Energy-Converting Organelles



The Cytoskeleton and Cell Surfaces

Figure 4.0_2



# INTRODUCTION TO THE CELL

# 4.1 Microscopes reveal the world of the cell

- A variety of microscopes have been developed for a clearer view of cells and cellular structure.
- The most frequently used microscope is the **light microscope** (**LM**)—like the one used in biology laboratories.
  - Light passes through a specimen, then through glass lenses, and finally light is projected into the viewer's eye.
  - Specimens can be magnified up to 1,000 times the actual size of the specimen.

# 4.1 Microscopes reveal the world of the cell

- *Magnification* is the increase in the apparent size of an object.
- *Resolution* is a measure of the clarity of an image. In other words, it is the ability of an instrument to show two close objects as separate.

# 4.1 Microscopes reveal the world of the cell

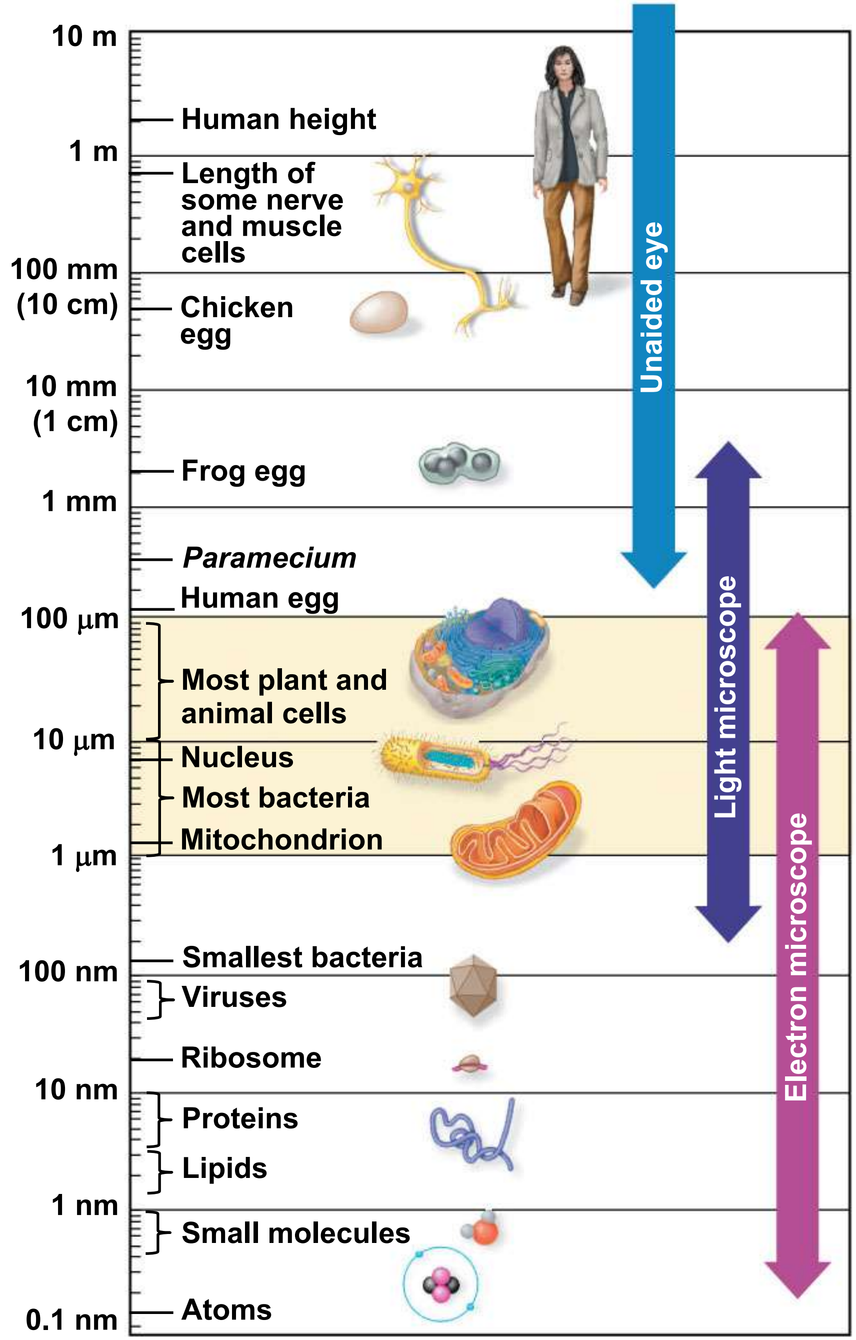
- Microscopes have limitations.
  - The human eye and the microscope have limits of resolution—the ability to distinguish between small structures.
  - Therefore, the light microscope cannot provide the details of a small cell’s structure.

# 4.1 Microscopes reveal the world of the cell

- Using light microscopes, scientists studied
  - microorganisms,
  - animal and plant cells, and
  - some structures within cells.
- In the 1800s, these studies led to **cell theory**, which states that
  - all living things are composed of cells and
  - all cells come from other cells.

Figure 4.1A

Figure 4.1B



10 m
Human height
1 m
Length of some nerve and muscle cells
100 mm (10 cm)
Chicken egg
10 mm (1 cm)
Frog egg
1 mm
*Paramecium*
Human egg
100 µm
Most plant and animal cells
10 µm
Nucleus
Most bacteria
Mitochondrion
1 µm
Smallest bacteria
100 nm
Viruses
Ribosome
10 nm
Proteins
Lipids
1 nm
Small molecules
Atoms
0.1 nm
Unaided eye
Light microscope
Electron microscope

Figure 4.1C

Figure 4.1D

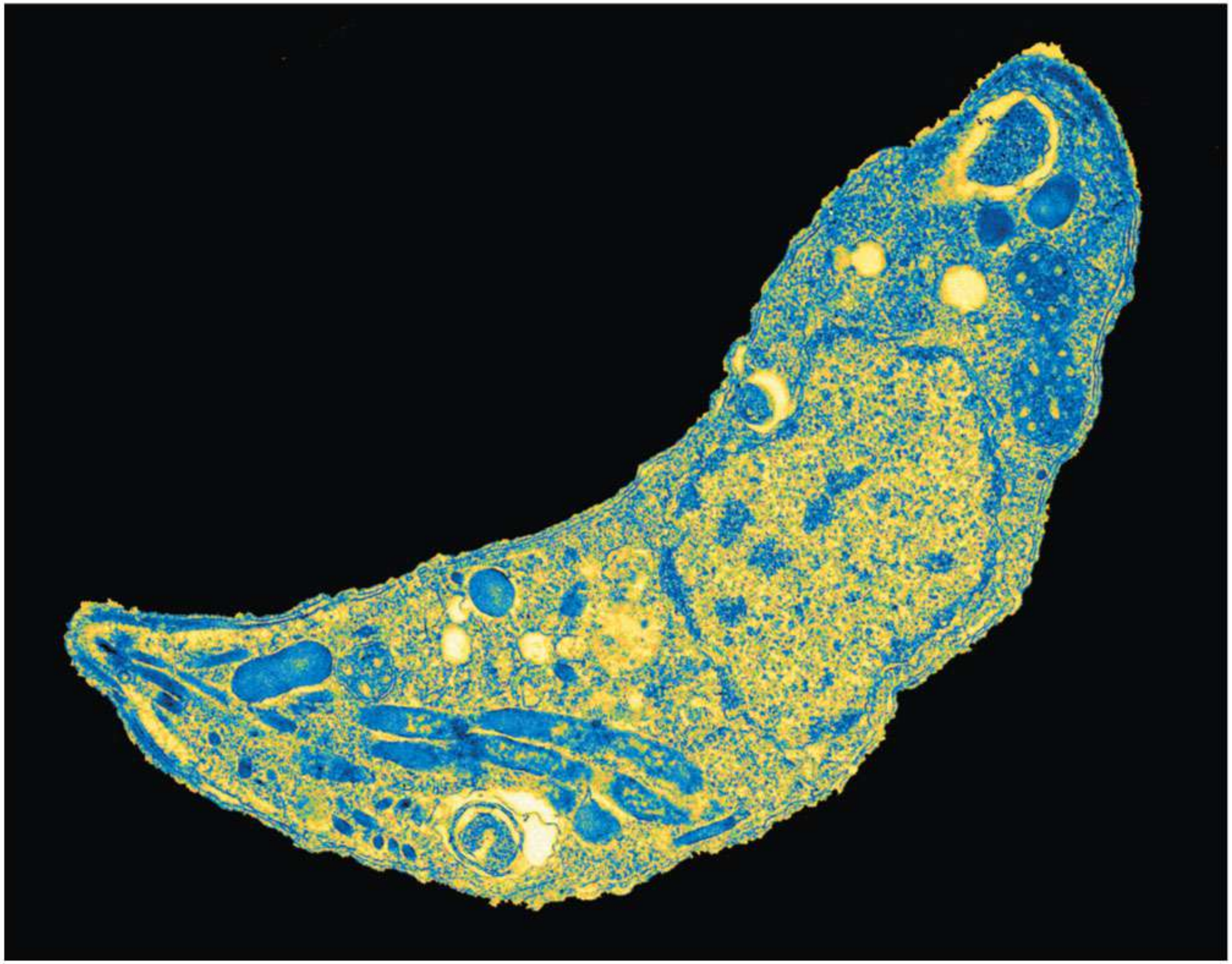
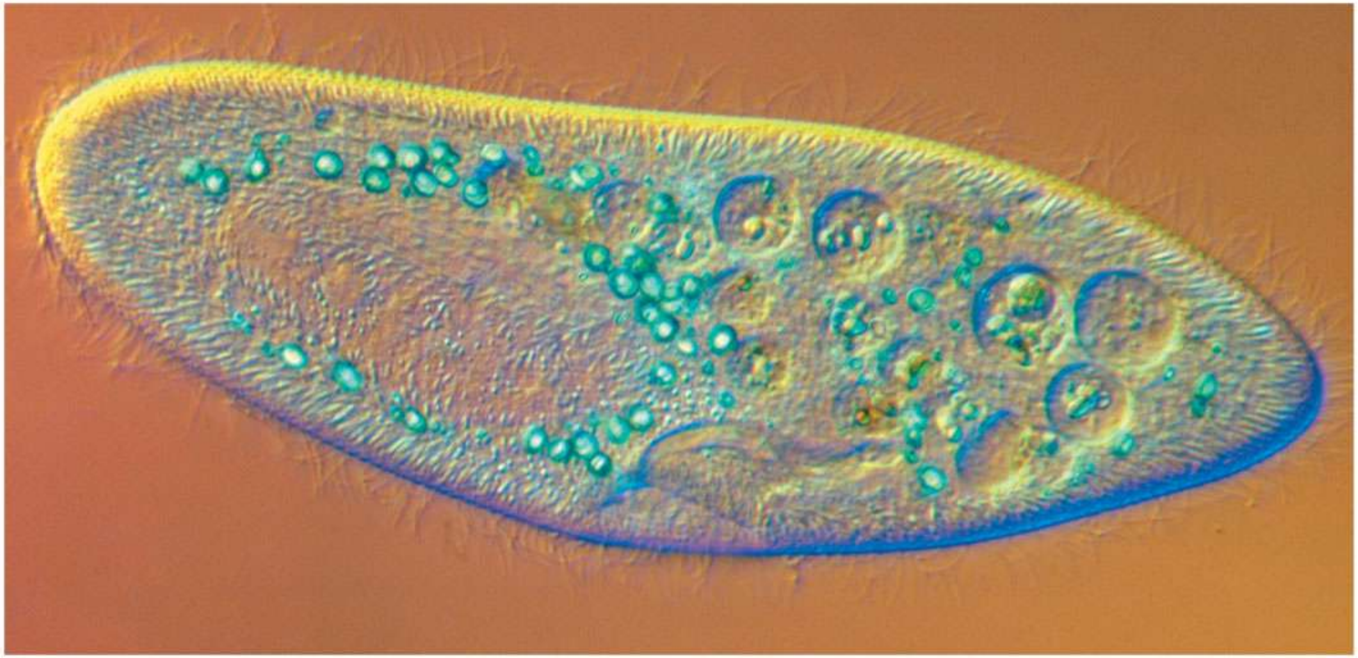


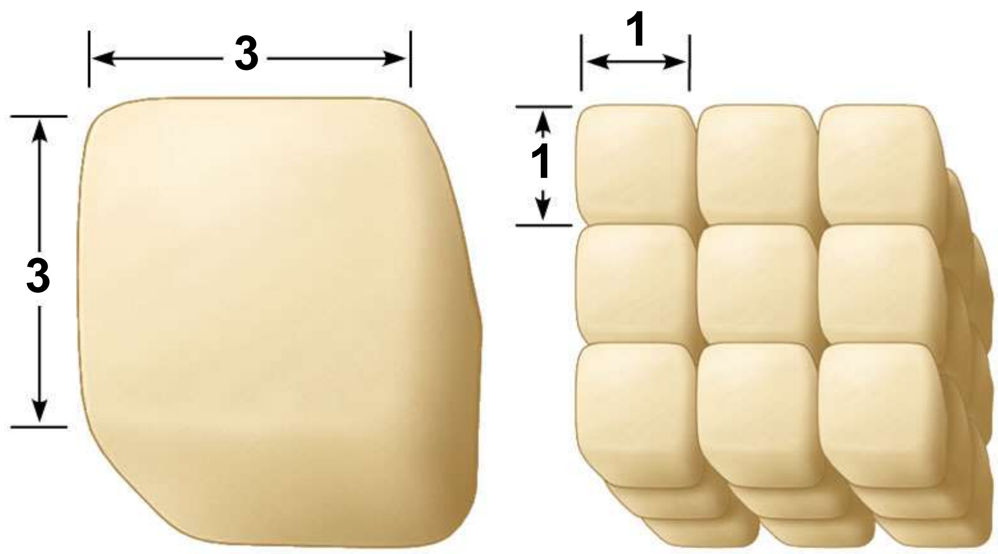
Figure 4.1E



# 4.2 The small size of cells relates to the need to exchange materials across the plasma membrane

- Cell size must
  - be large enough to house DNA, proteins, and structures needed to survive and reproduce, but
  - remain small enough to allow for a surface-to-volume ratio that will allow adequate exchange with the environment.

Figure 4.2A




| | | |
|---|---|---|
| Total volume | 27 units$^3$ | 27 units$^3$ |
| Total surface area | 54 units$^2$ | 162 units$^2$ |
| Surface-to-volume ratio | 2 | 6 |

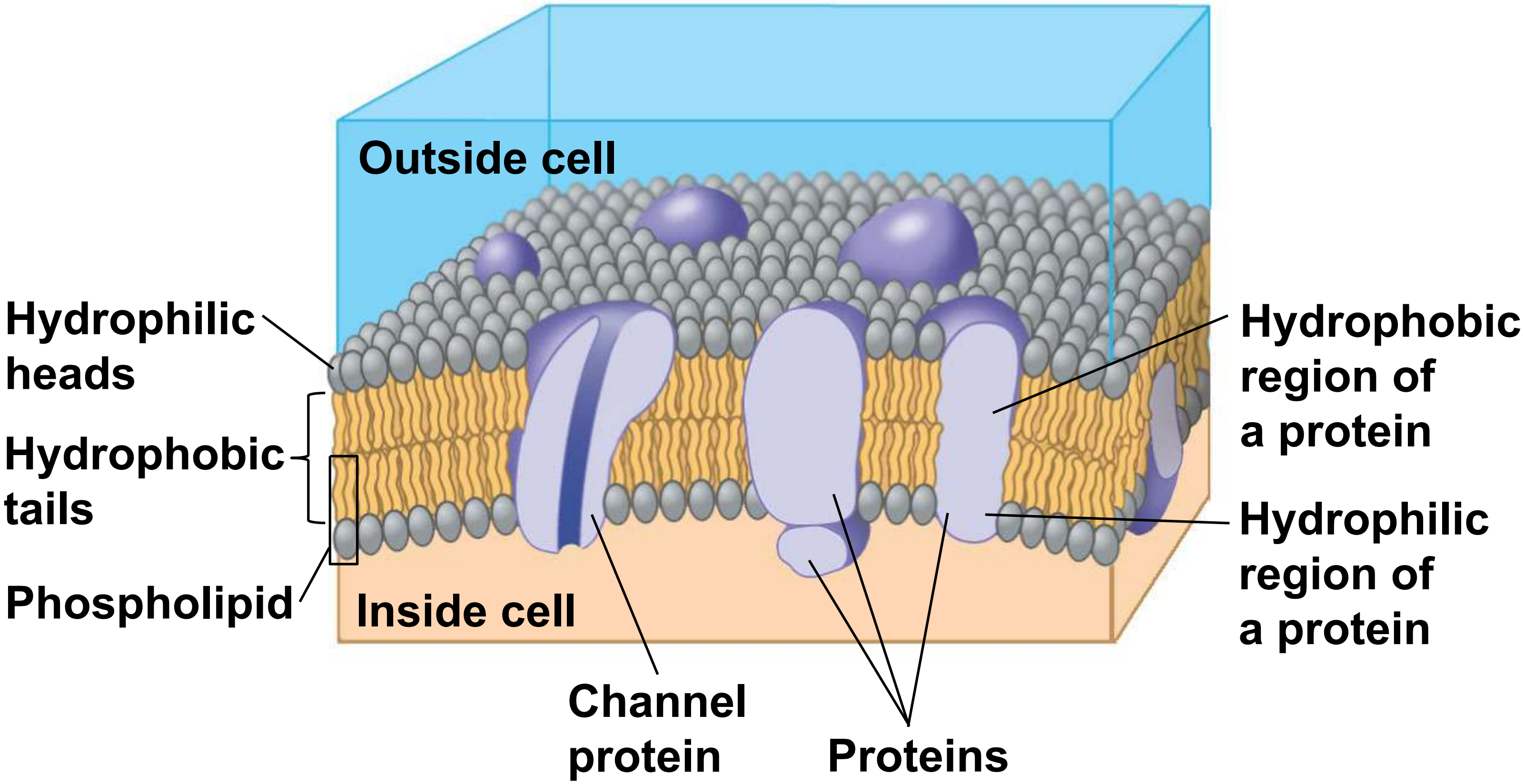
# 4.2 The small size of cells relates to the need to exchange materials across the plasma membrane

- The **plasma membrane** forms a flexible boundary between the living cell and its surroundings.
- Phospholipids form a two-layer sheet called a phospholipid bilayer in which
  - hydrophilic heads face outward, exposed to water, and
  - hydrophobic tails point inward, shielded from water.

# 4.2 The small size of cells relates to the need to exchange materials across the plasma membrane

- Membrane proteins are either
  - attached to the membrane surface or
  - embedded in the phospholipid bilayer.
- Some proteins form channels or tunnels that shield ions and other hydrophilic molecules as they pass through the hydrophobic center of the membrane.
- Other proteins serve as pumps, using energy to actively transport molecules into or out of the cell.

Figure 4.2B



Outside cell
Hydrophilic heads
Hydrophobic tails
Phospholipid
Inside cell
Channel protein
Proteins
Hydrophobic region of a protein
Hydrophilic region of a protein

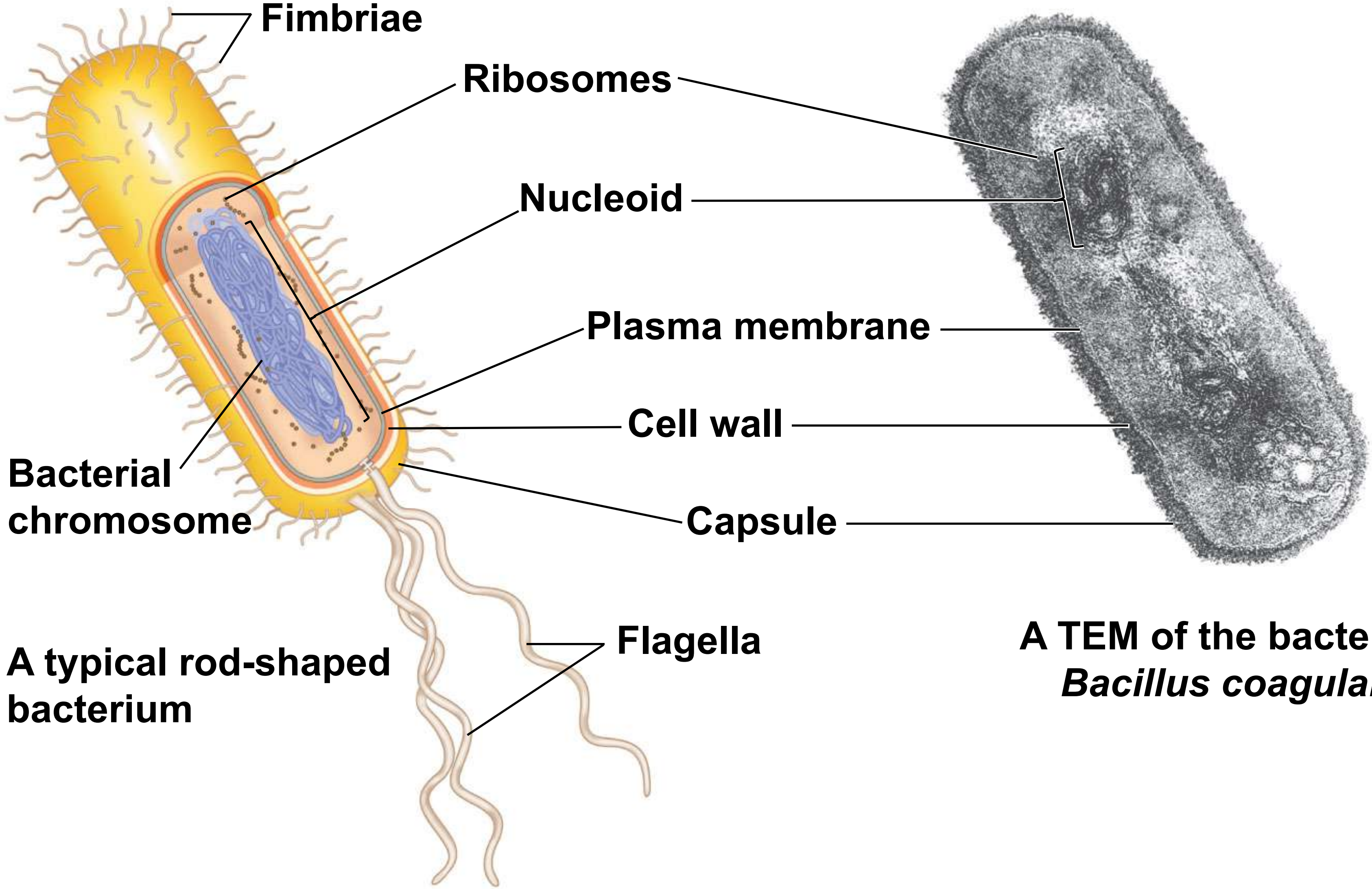
# 4.3 Prokaryotic cells are structurally simpler than eukaryotic cells

- Bacteria and archaea are **prokaryotic** cells.
- All other forms of life are composed of **eukaryotic** cells.
  - Prokaryotic and eukaryotic cells have
    - a plasma membrane and
    - one or more chromosomes and ribosomes.
  - Eukaryotic cells have a
    - membrane-bound nucleus and
    - number of other organelles.
  - Prokaryotes have a nucleoid and no true organelles.

# 4.3 Prokaryotic cells are structurally simpler than eukaryotic cells

- The DNA of prokaryotic cells is coiled into a region called the **nucleoid**, but no membrane surrounds the DNA.
- The surface of prokaryotic cells may
  - be surrounded by a chemically complex cell wall,
  - have a capsule surrounding the cell wall,
  - have short projections that help attach to other cells or the substrate, or
  - have longer projections called **flagella** that may propel the cell through its liquid environment.

Figure 4.3




A typical rod-shaped bacterium

A TEM of the bacterium *Bacillus coagulans*

# 4.4 Eukaryotic cells are partitioned into functional compartments

- The structures and organelles of eukaryotic cells perform four basic functions.
  1. The nucleus and ribosomes are involved in the genetic control of the cell.
  2. The endoplasmic reticulum, Golgi apparatus, lysosomes, vacuoles, and peroxisomes are involved in the manufacture, distribution, and breakdown of molecules.

# 4.4 Eukaryotic cells are partitioned into functional compartments

3. Mitochondria in all cells and chloroplasts in plant cells are involved in energy processing.
4. Structural support, movement, and communication between cells are functions of the cytoskeleton, plasma membrane, and cell wall.

# 4.4 Eukaryotic cells are partitioned into functional compartments

- The internal membranes of eukaryotic cells partition it into compartments.
- **Cellular metabolism**, the many chemical activities of cells, occurs within organelles.

# 4.4 Eukaryotic cells are partitioned into functional compartments

- Almost all of the organelles and other structures of animals cells are present in plant cells.
- A few exceptions exist.
  - Lysosomes and centrioles are not found in plant cells.
  - Plant but not animal cells have
    - a rigid cell wall,
    - chloroplasts, and
    - a central vacuole.

Figure 4.4A

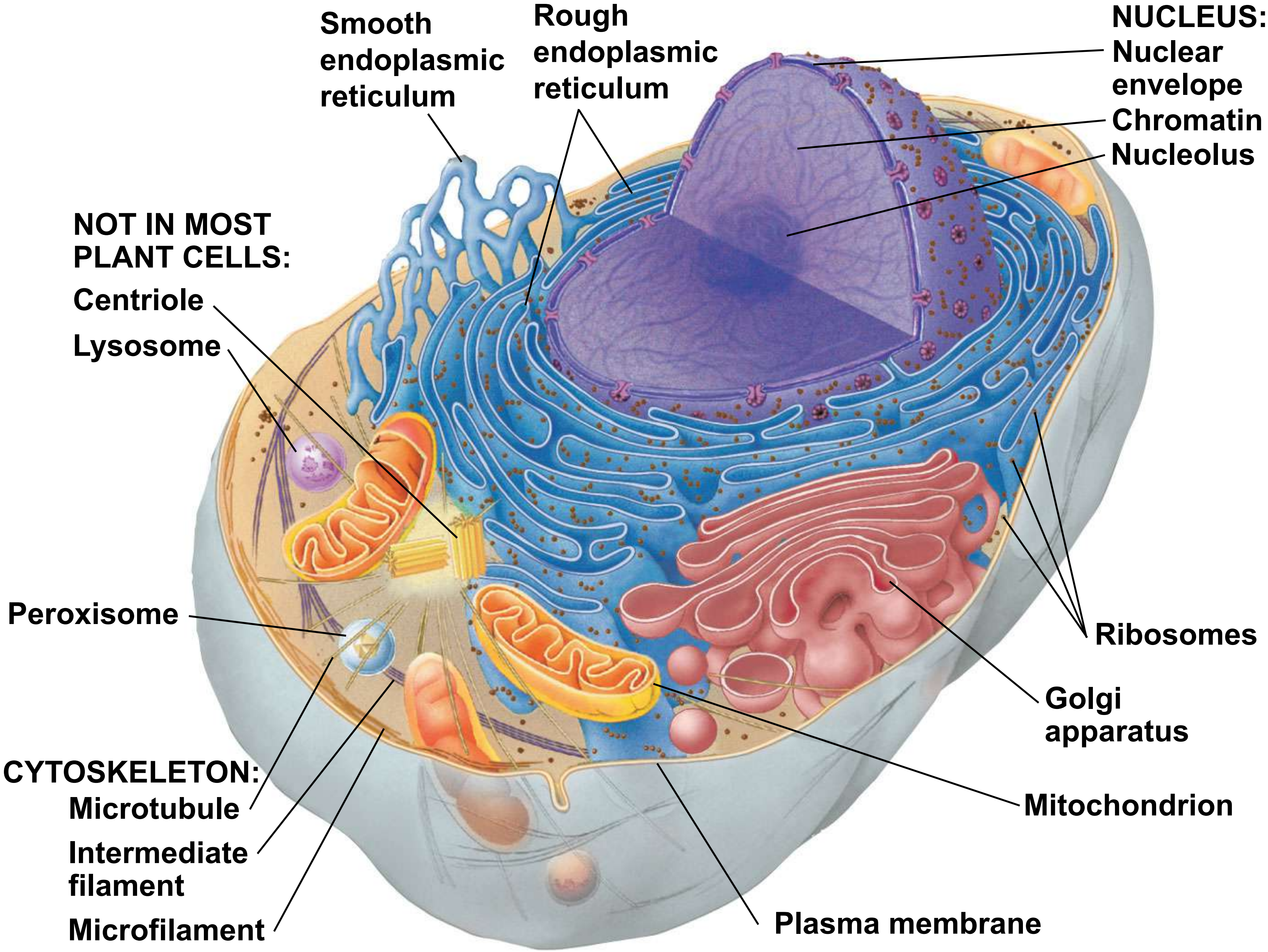
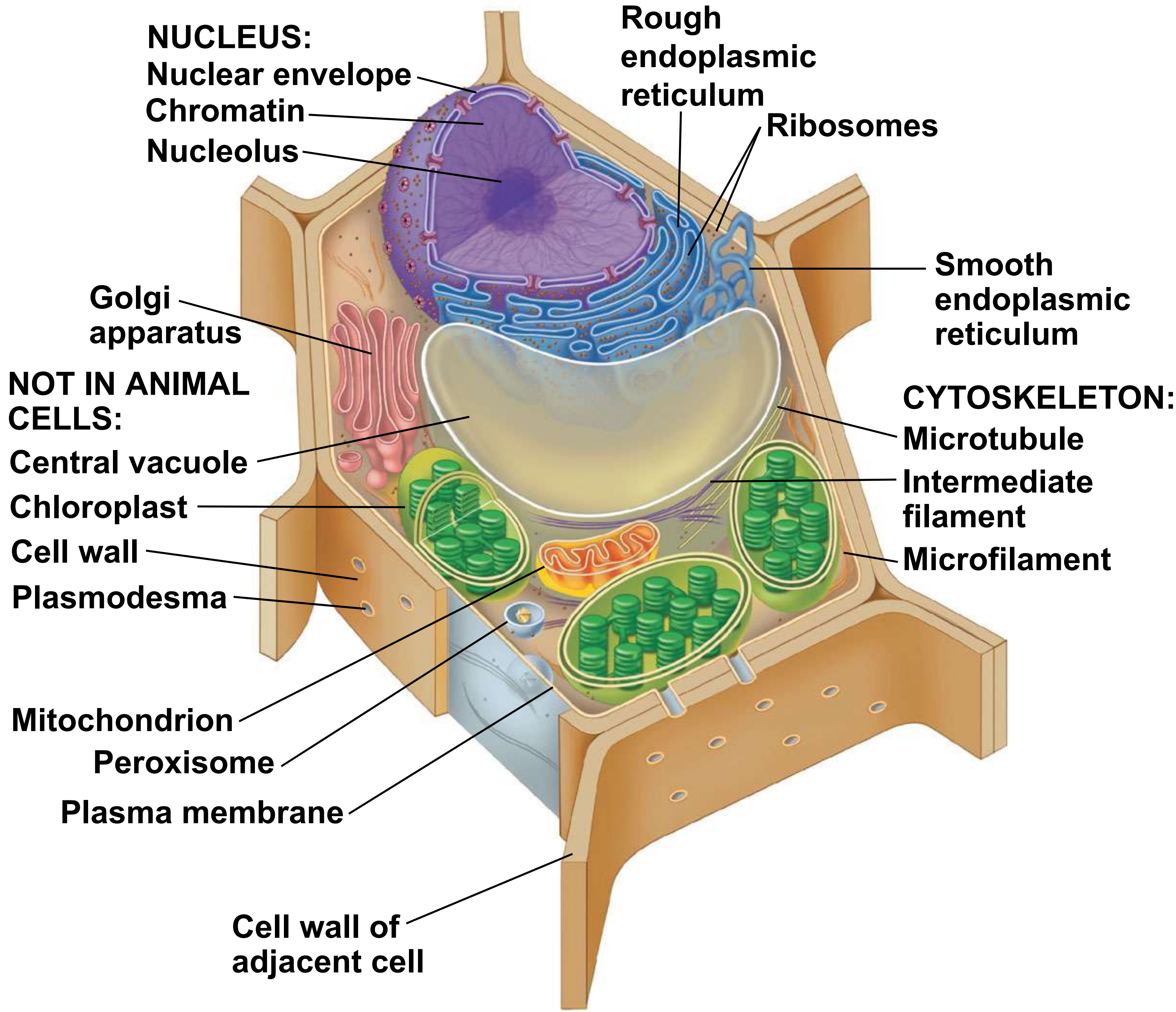

Smooth endoplasmic reticulum
Rough endoplasmic reticulum
NUCLEUS:
Nuclear envelope
Chromatin
Nucleolus
NOT IN MOST PLANT CELLS:
Centriole
Lysosome
Peroxisome
Ribosomes
Golgi apparatus
Mitochondrion
CYTOSKELETON:
Microtubule
Intermediate filament
Microfilament
Plasma membrane

Figure 4.4B


NUCLEUS:
Nuclear envelope
Chromatin
Nucleolus
Rough endoplasmic reticulum
Ribosomes
Smooth endoplasmic reticulum
Golgi apparatus
NOT IN ANIMAL CELLS:
Central vacuole
Chloroplast
Cell wall
Plasmodesma
CYTOSKELETON:
Microtubule
Intermediate filament
Microfilament
Mitochondrion
Peroxisome
Plasma membrane
Cell wall of adjacent cell

# THE NUCLEUS AND RIBOSOMES

# 4.5 The nucleus is the cell's genetic control center

- The **nucleus**
  - contains most of the cell's DNA and
  - controls the cell's activities by directing protein synthesis by making messenger RNA (mRNA).
- DNA is associated with many proteins in structures called **chromosomes**.

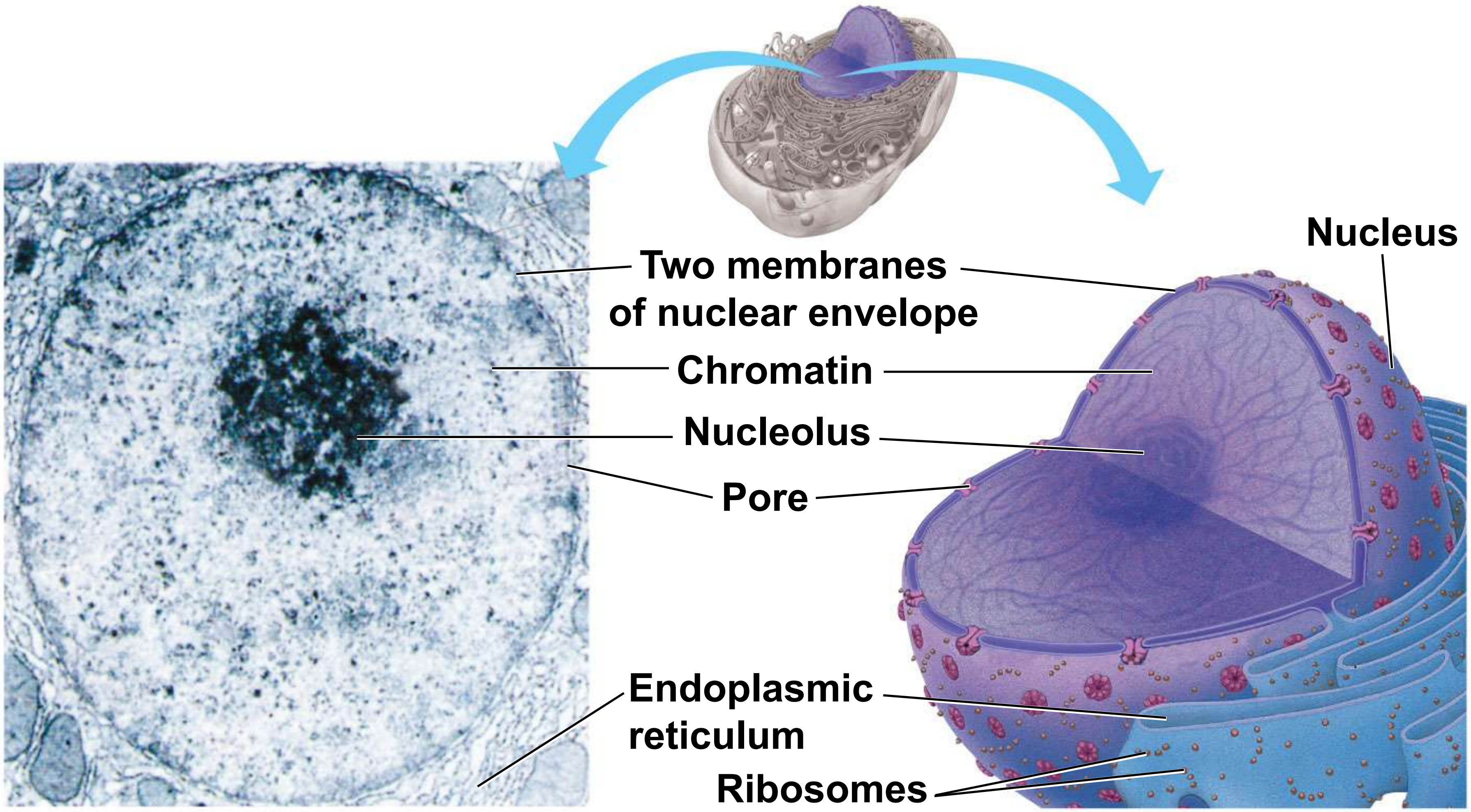
# 4.5 The nucleus is the cell's genetic control center

- The **nuclear envelope**
  - is a double membrane and
  - has pores that allow material to flow in and out of the nucleus.
- The nuclear envelope is attached to a network of cellular membranes called the endoplasmic reticulum.

# 4.5 The nucleus is the cell's genetic control center

- The **nucleolus** is
  - a prominent structure in the nucleus and
  - the site of ribosomal RNA (rRNA) synthesis.

Figure 4.5



Two membranes of nuclear envelope
Chromatin
Nucleolus
Pore
Endoplasmic reticulum
Ribosomes
Nucleus

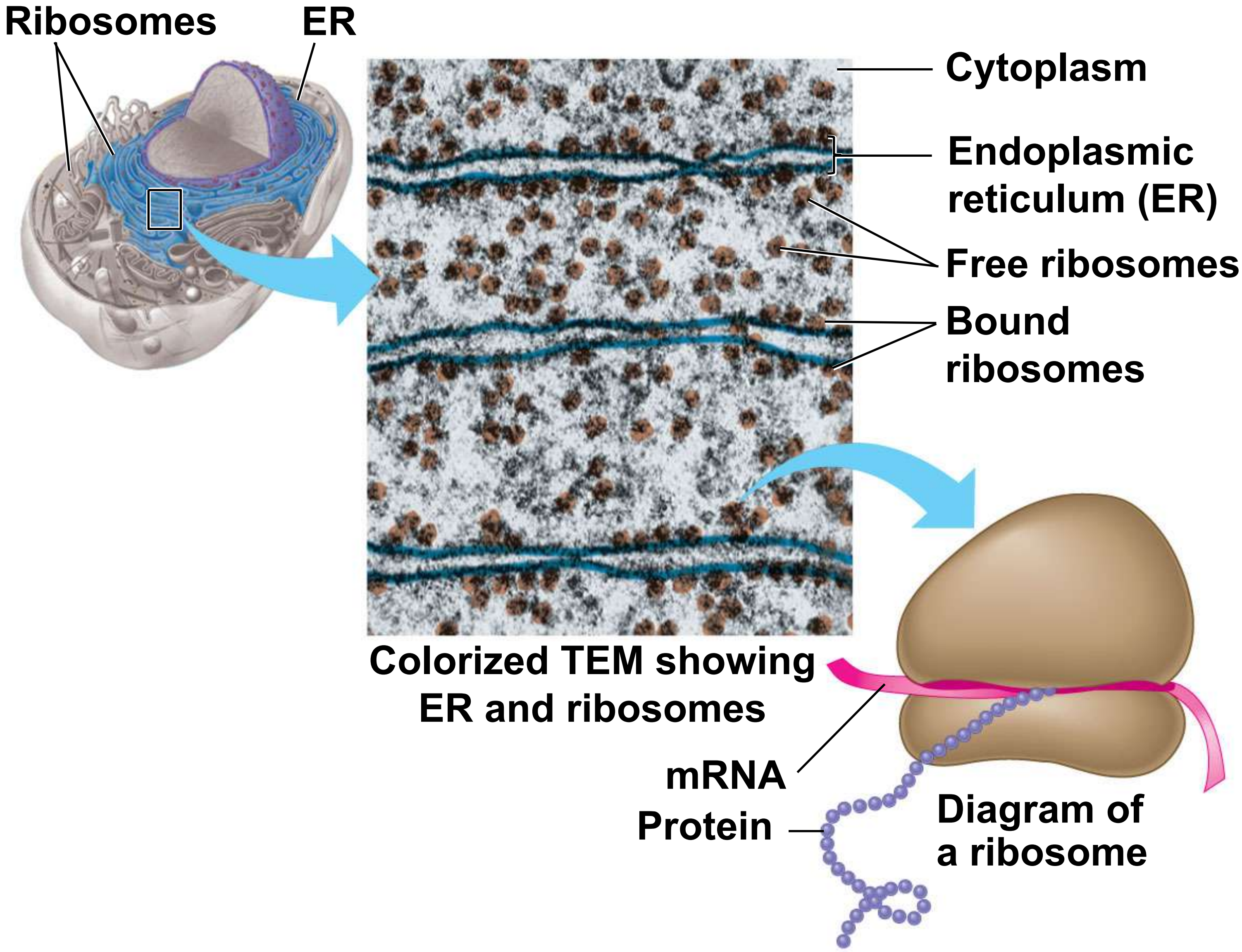
# 4.6 Ribosomes make proteins for use in the cell and export

- **Ribosomes** are involved in the cell's protein synthesis.
  - Ribosomes are synthesized from rRNA produced in the nucleolus.
  - Cells that must synthesize large amounts of protein have a large number of ribosomes.

# 4.6 Ribosomes make proteins for use in the cell and export

- Some ribosomes are free ribosomes; others are bound.
  - *Free ribosomes* are
    - suspended in the cytoplasm and
    - typically involved in making proteins that function within the cytoplasm.
  - *Bound ribosomes* are
    - attached to the endoplasmic reticulum (ER) associated with the nuclear envelope and
    - associated with proteins packed in certain organelles or exported from the cell.

Figure 4.6



Ribosomes
ER
Cytoplasm
Endoplasmic reticulum (ER)
Free ribosomes
Bound ribosomes
Colorized TEM showing ER and ribosomes
mRNA
Protein
Diagram of a ribosome

# THE ENDOMEMBRANE SYSTEM

# 4.7 Overview: Many cell organelles are connected through the endomembrane system

- Many of the membranes within a eukaryotic cell are part of the **endomembrane system**.
- Some of these membranes are physically connected and some are related by the transfer of membrane segments by tiny **vesicles** (sacs made of membrane).
- Many of these organelles work together in the
  - synthesis,
  - storage, and
  - export of molecules.

# 4.7 Overview: Many cell organelles are connected through the endomembrane system

- The **endomembrane system** includes
  - the nuclear envelope,
  - endoplasmic reticulum (ER),
  - Golgi apparatus,
  - lysosomes,
  - vacuoles, and
  - the plasma membrane.

# 4.8 The endoplasmic reticulum is a biosynthetic factory

- There are two kinds of endoplasmic reticulum—smooth and rough.
  - **Smooth ER** lacks attached ribosomes.
  - **Rough ER** lines the outer surface of membranes.
  - Although physically interconnected, smooth and rough ER differ in structure and function.

Figure 4.8A

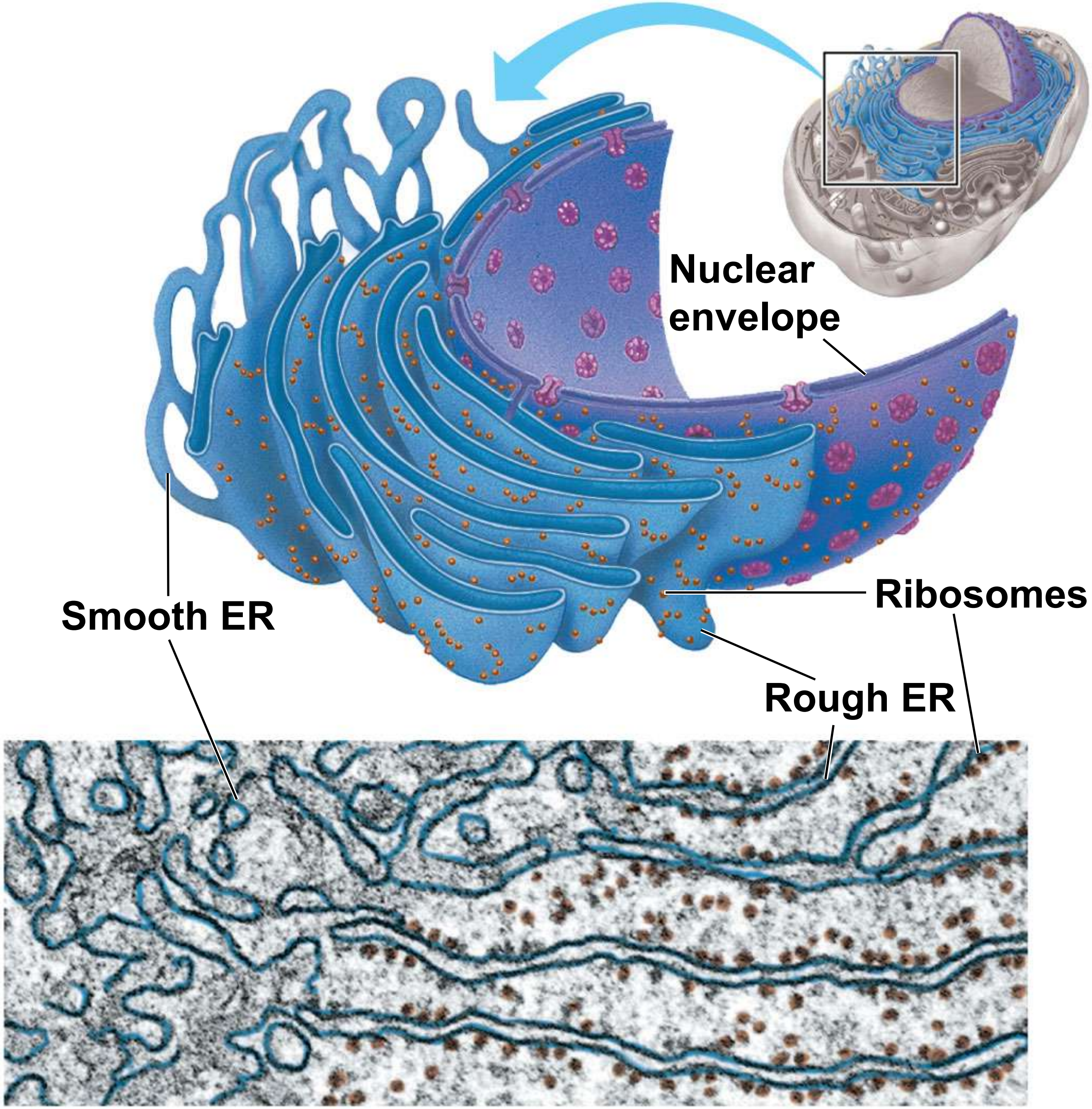
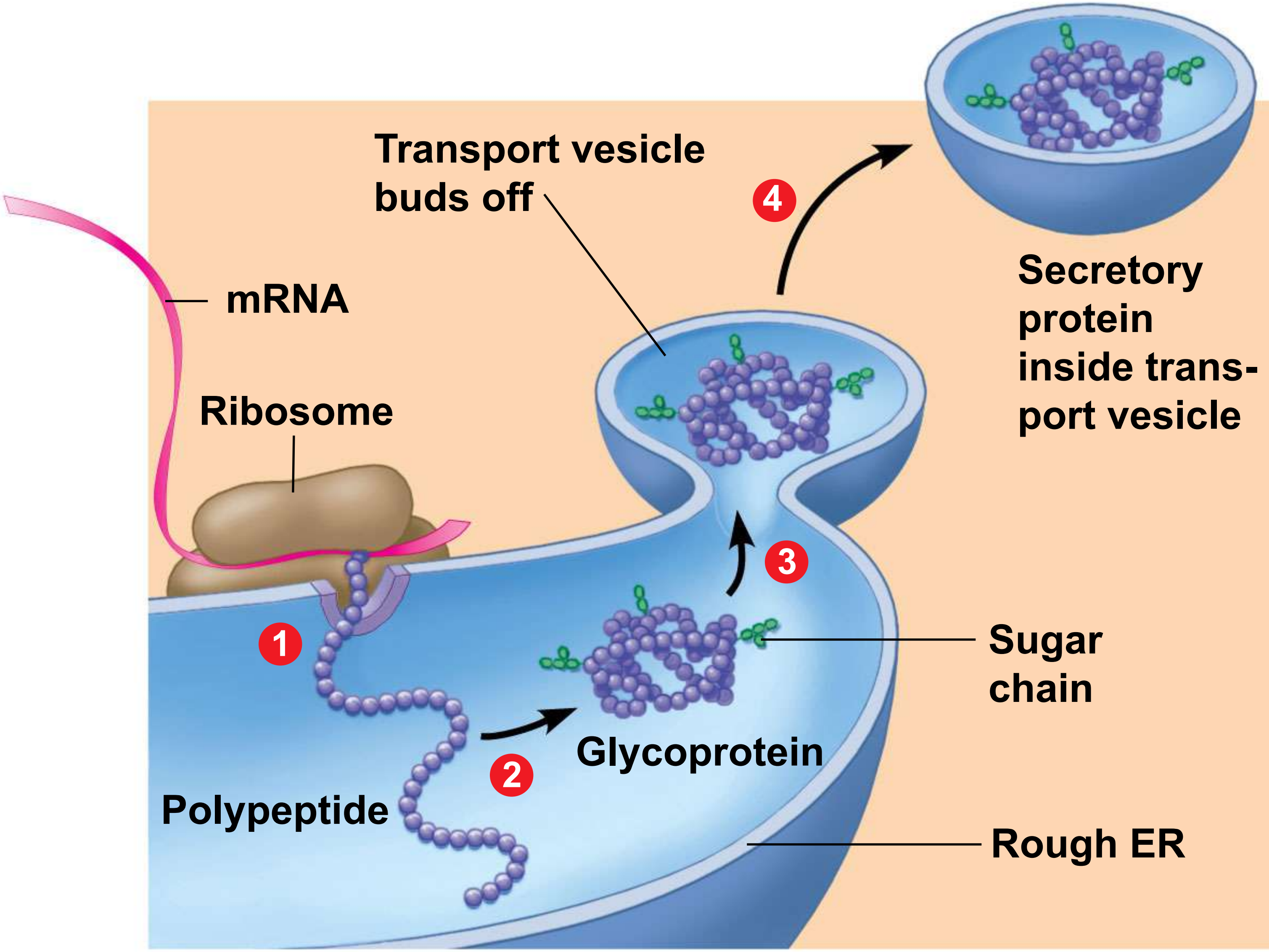


Figure 4.8B


Transport vesicle buds off
4
Secretory protein inside transport vesicle
mRNA
Ribosome
3
1
Sugar chain
Glycoprotein
2
Polypeptide
Rough ER

# 4.8 The endoplasmic reticulum is a biosynthetic factory

- Smooth ER is involved in a variety of diverse metabolic processes.
  - Smooth ER produces enzymes important in the synthesis of lipids, oils, phospholipids, and steroids.
  - Other enzymes help process drugs, alcohol, and other potentially harmful substances.
  - Some smooth ER helps store calcium ions.

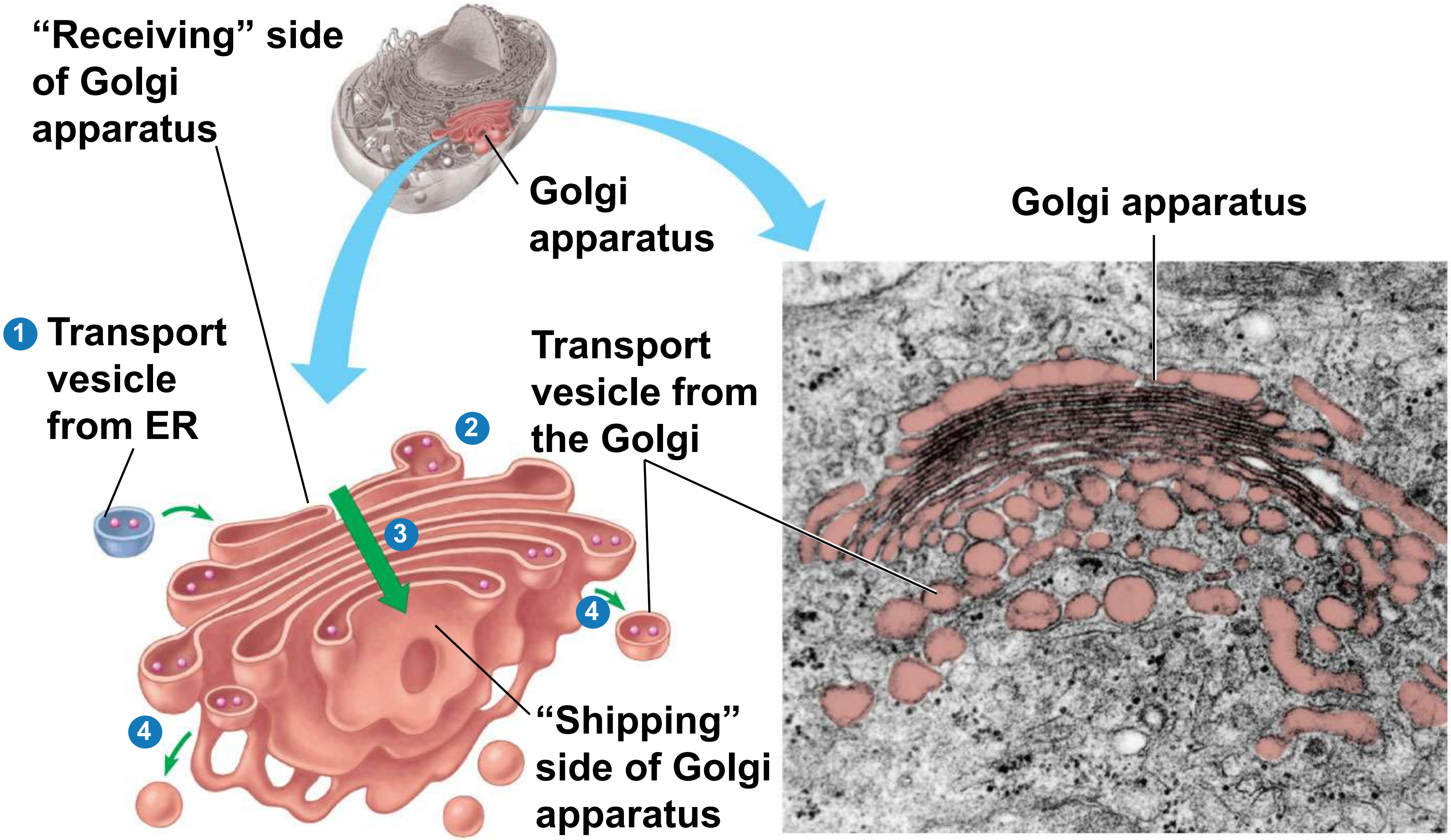
# 4.8 The endoplasmic reticulum is a biosynthetic factory

- Rough ER makes
  - additional membrane for itself and
  - proteins destined for secretions.

# 4.9 The Golgi apparatus finishes, sorts, and ships cell products

- The Golgi apparatus serves as a molecular warehouse and finishing factory for products manufactured by the ER.
  - Products travel in transport vesicles from the ER to the Golgi apparatus.
  - One side of the Golgi apparatus functions as a receiving dock for the product and the other as a shipping dock.
  - Products are modified as they go from one side of the Golgi apparatus to the other and travel in vesicles to other sites.

Figure 4.9



“Receiving” side of Golgi apparatus
Golgi apparatus
Golgi apparatus
1 Transport vesicle from ER
2
3
4
4
Transport vesicle from the Golgi
“Shipping” side of Golgi apparatus

# 4.10 Lysosomes are digestive compartments within a cell

- A **lysosome** is a membranous sac containing digestive enzymes.
  - The enzymes and membrane are produced by the ER and transferred to the Golgi apparatus for processing.
  - The membrane serves to safely isolate these potent enzymes from the rest of the cell.

# 4.10 Lysosomes are digestive compartments within a cell

- Lysosomes help digest food particles engulfed by a cell.
  1. A food vacuole binds with a lysosome.
  2. The enzymes in the lysosome digest the food.
  3. The nutrients are then released into the cell.

Figure 4.10A_s1

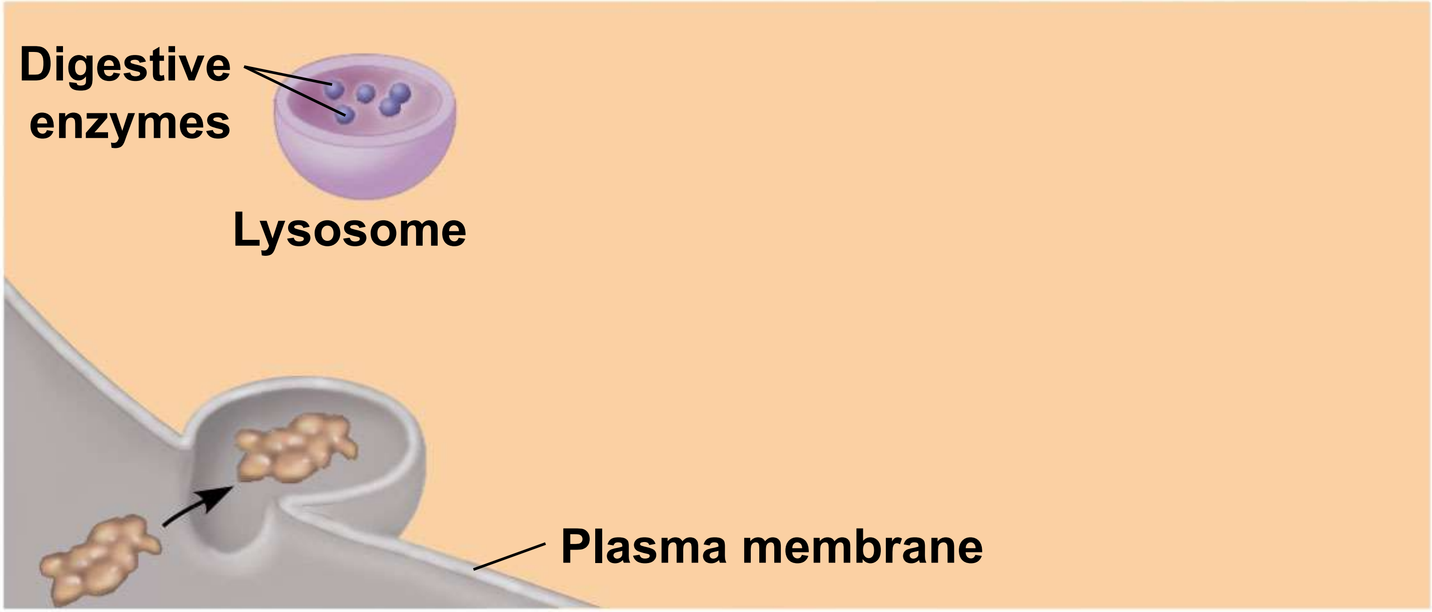


Figure 4.10A_s2

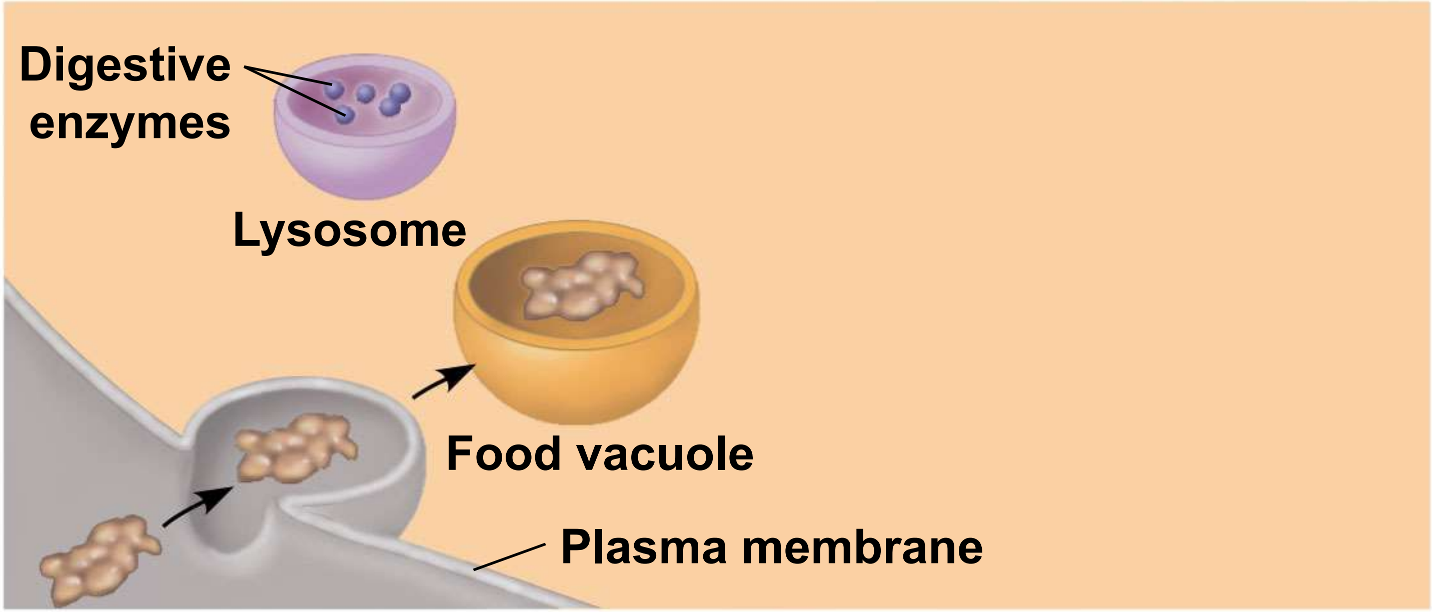


Figure 4.10A_s3

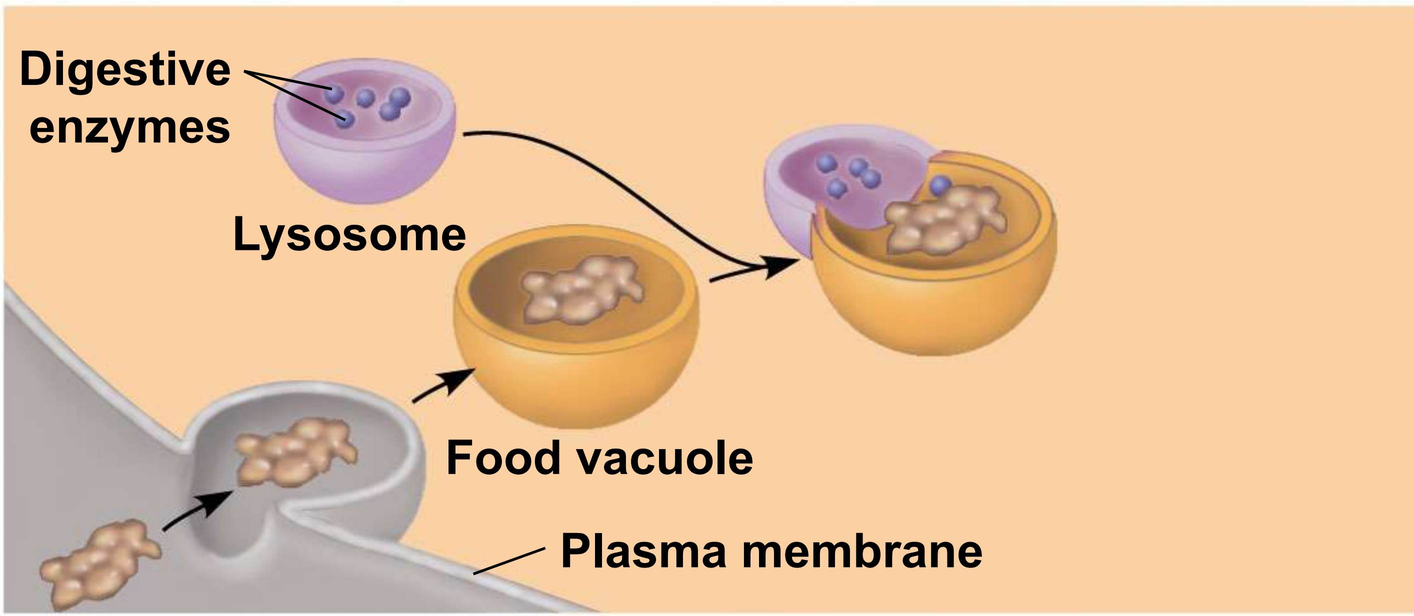
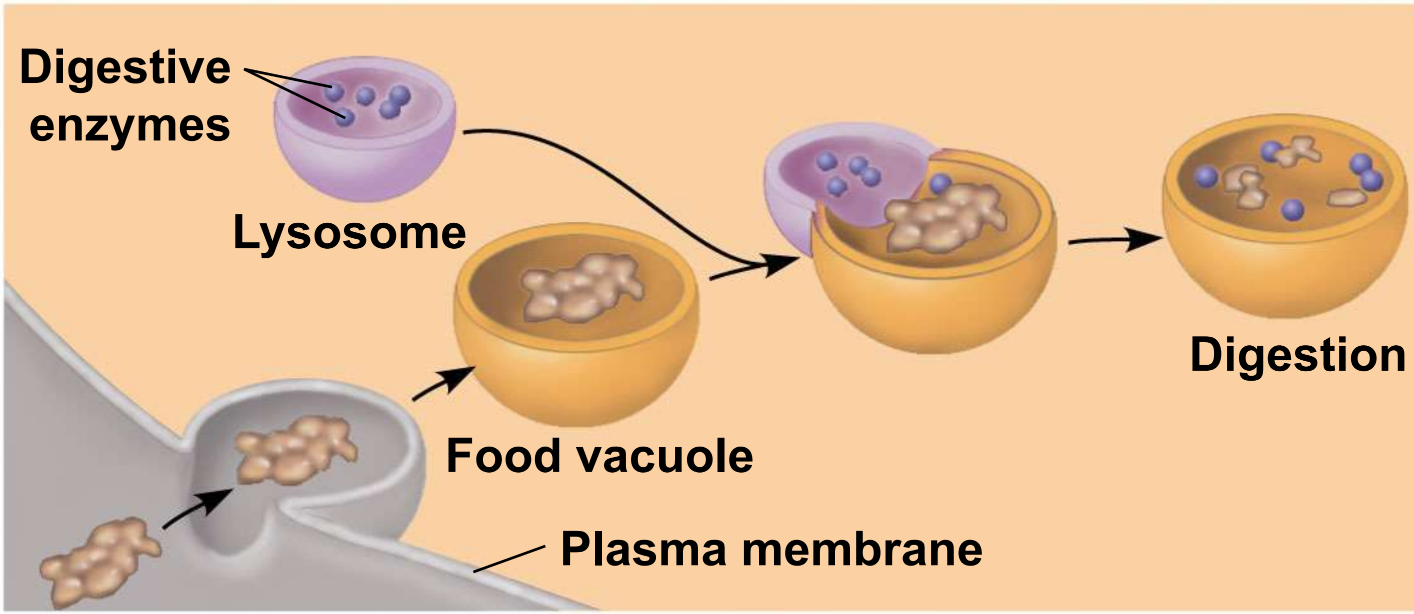


Figure 4.10A_s4



# 4.10 Lysosomes are digestive compartments within a cell

- Lysosomes also help remove or recycle damaged parts of a cell.
  1. The damaged organelle is first enclosed in a membrane vesicle.
  2. Then a lysosome
     – fuses with the vesicle,
     – dismantles its contents, and
     – breaks down the damaged organelle.

Figure 4.10B_s1

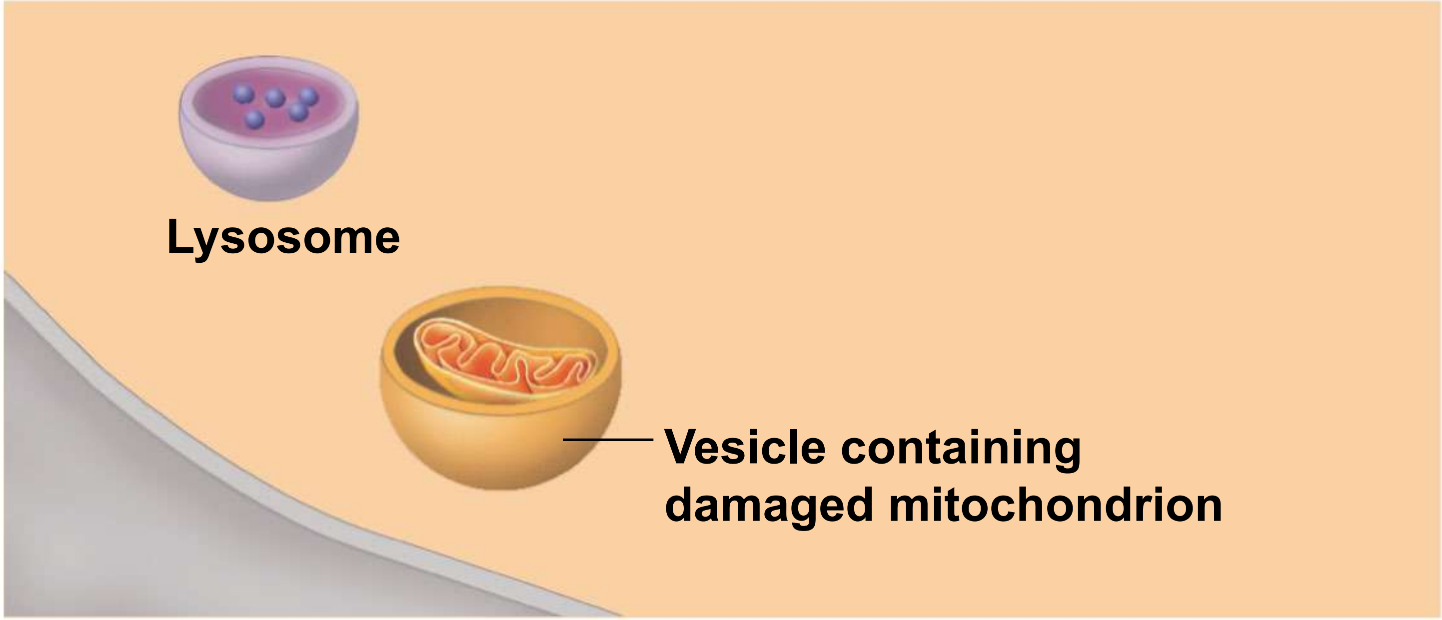


Figure 4.10B_s2

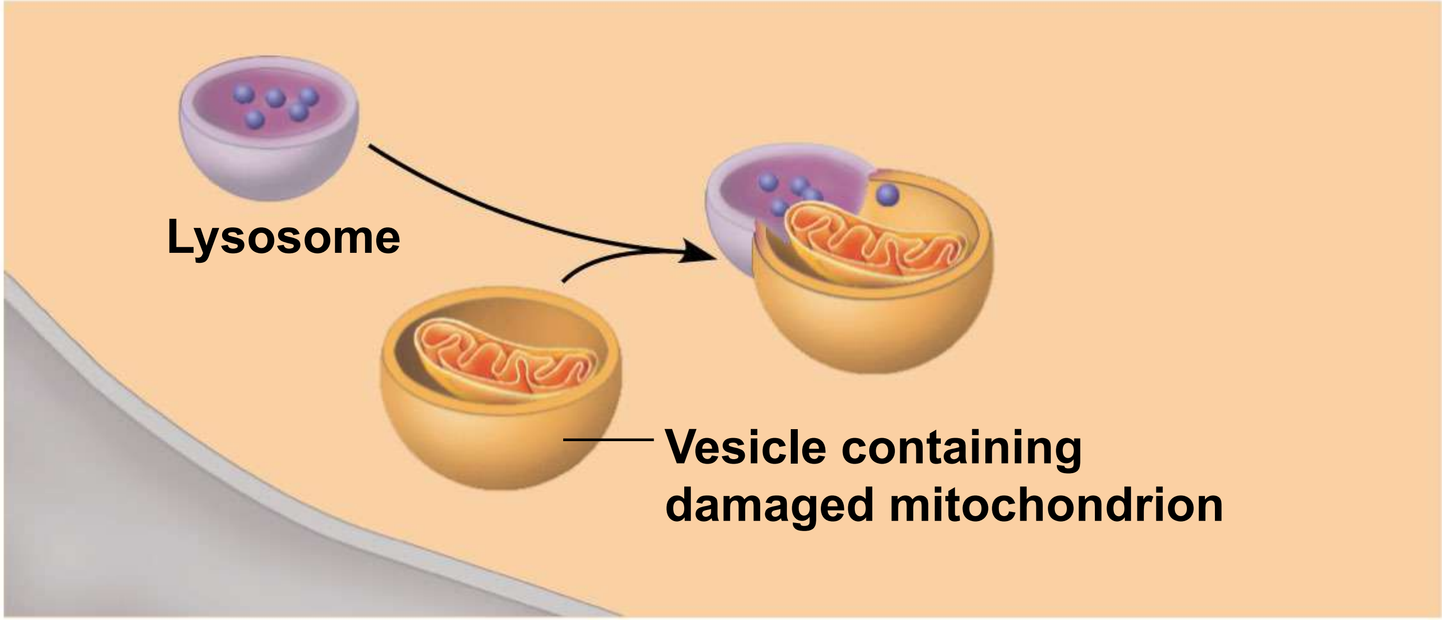
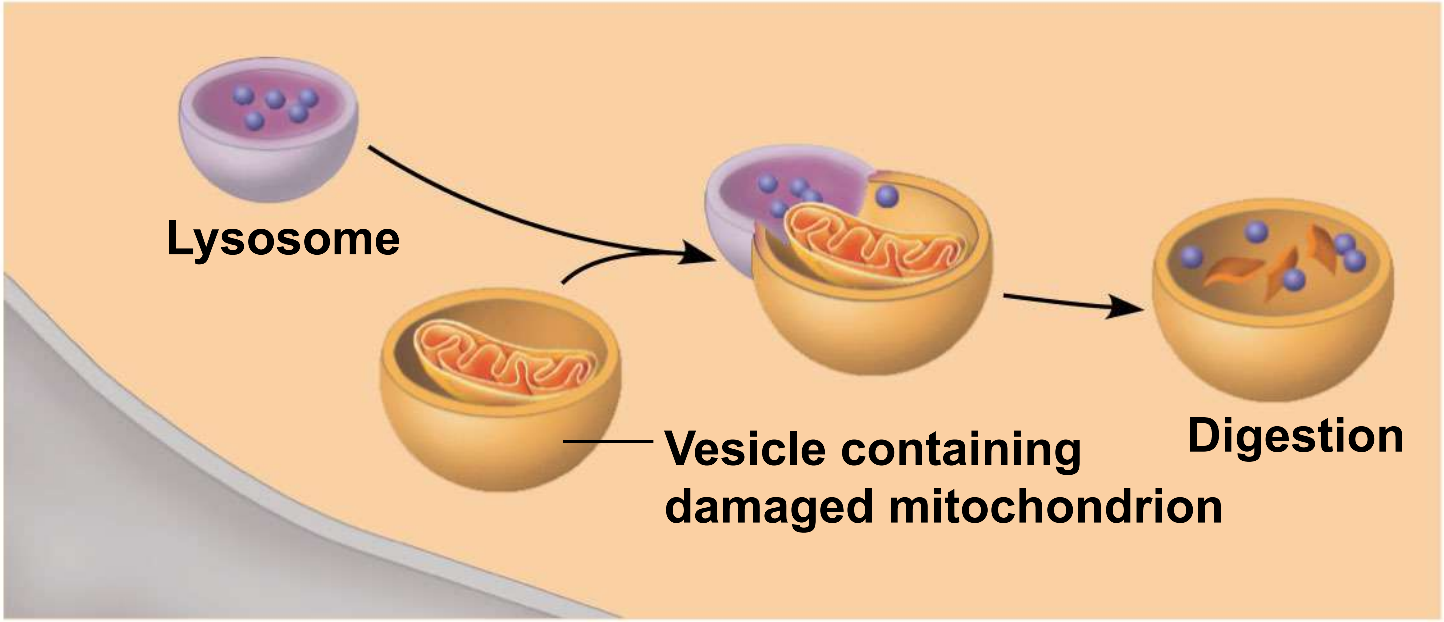


Figure 4.10B_s3



# 4.11 Vacuoles function in the general maintenance of the cell

- **Vacuoles** are large vesicles that have a variety of functions.
  - Some protists have contractile vacuoles that help to eliminate water from the protist.
  - In plants, vacuoles may
    - have digestive functions,
    - contain pigments, or
    - contain poisons that protect the plant.

Figure 4.11A

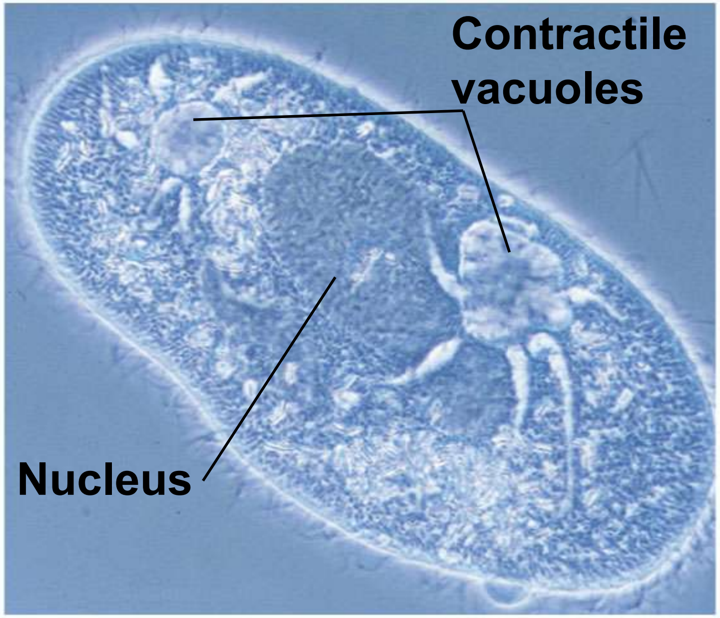
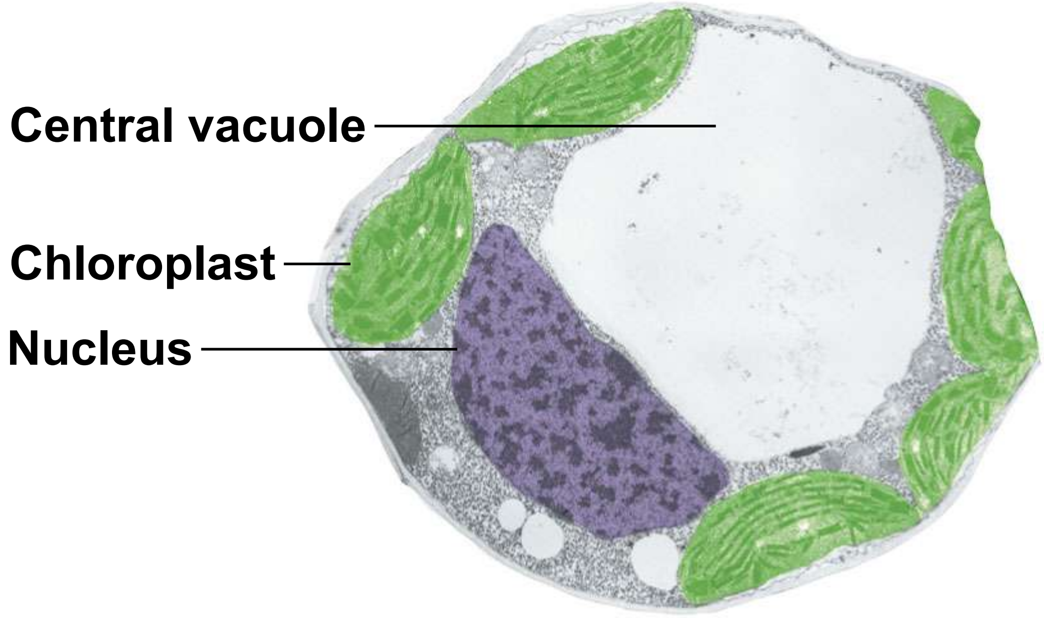


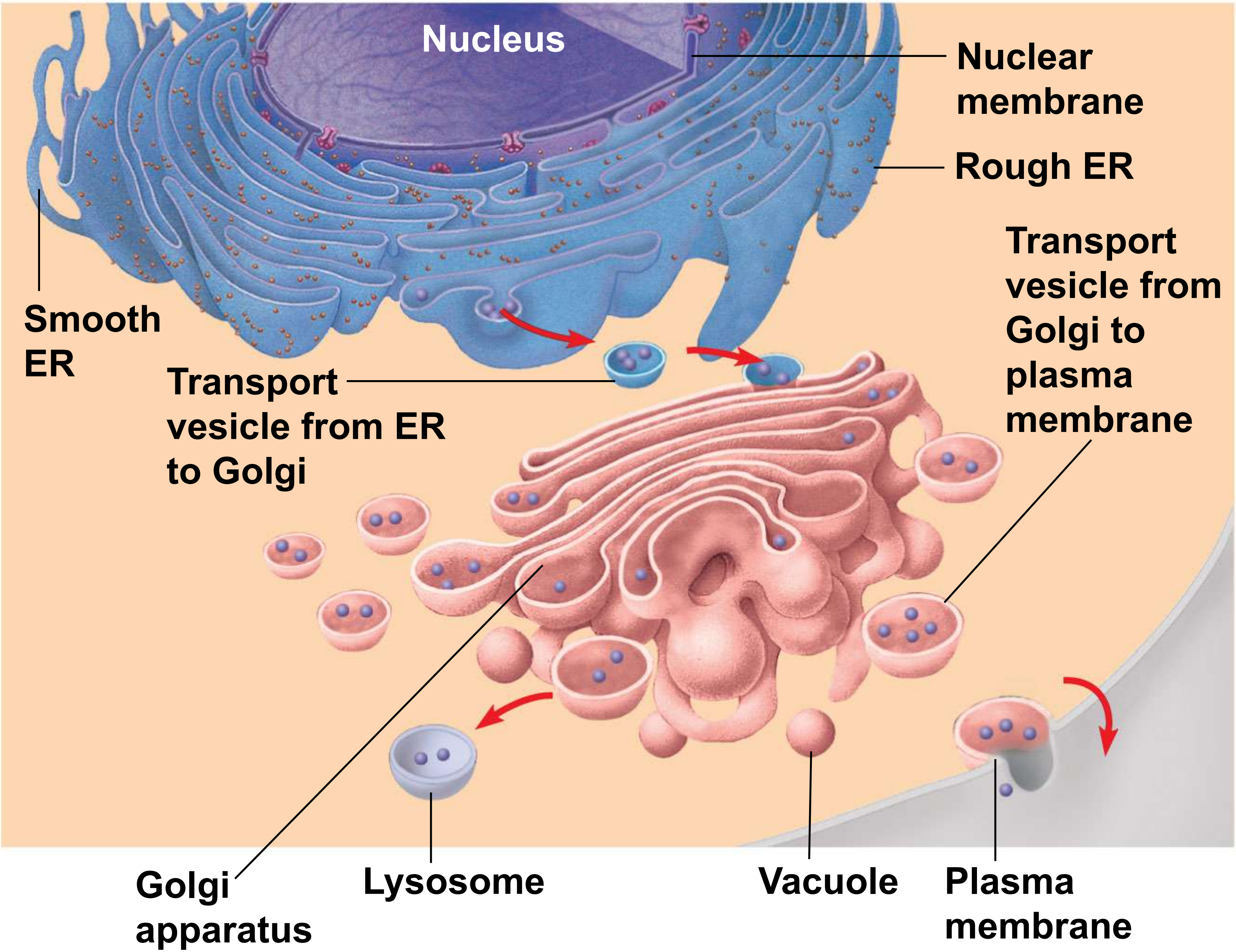
Figure 4.11B



# 4.12 A review of the structures involved in manufacturing and breakdown

- The following figure summarizes the relationships among the major organelles of the endomembrane system.

Figure 4.12


Nucleus
Nuclear membrane
Rough ER
Smooth ER
Transport vesicle from Golgi to plasma membrane
Transport vesicle from ER to Golgi
Golgi apparatus
Lysosome
Vacuole
Plasma membrane

# ENERGY-CONVERTING ORGANELLES

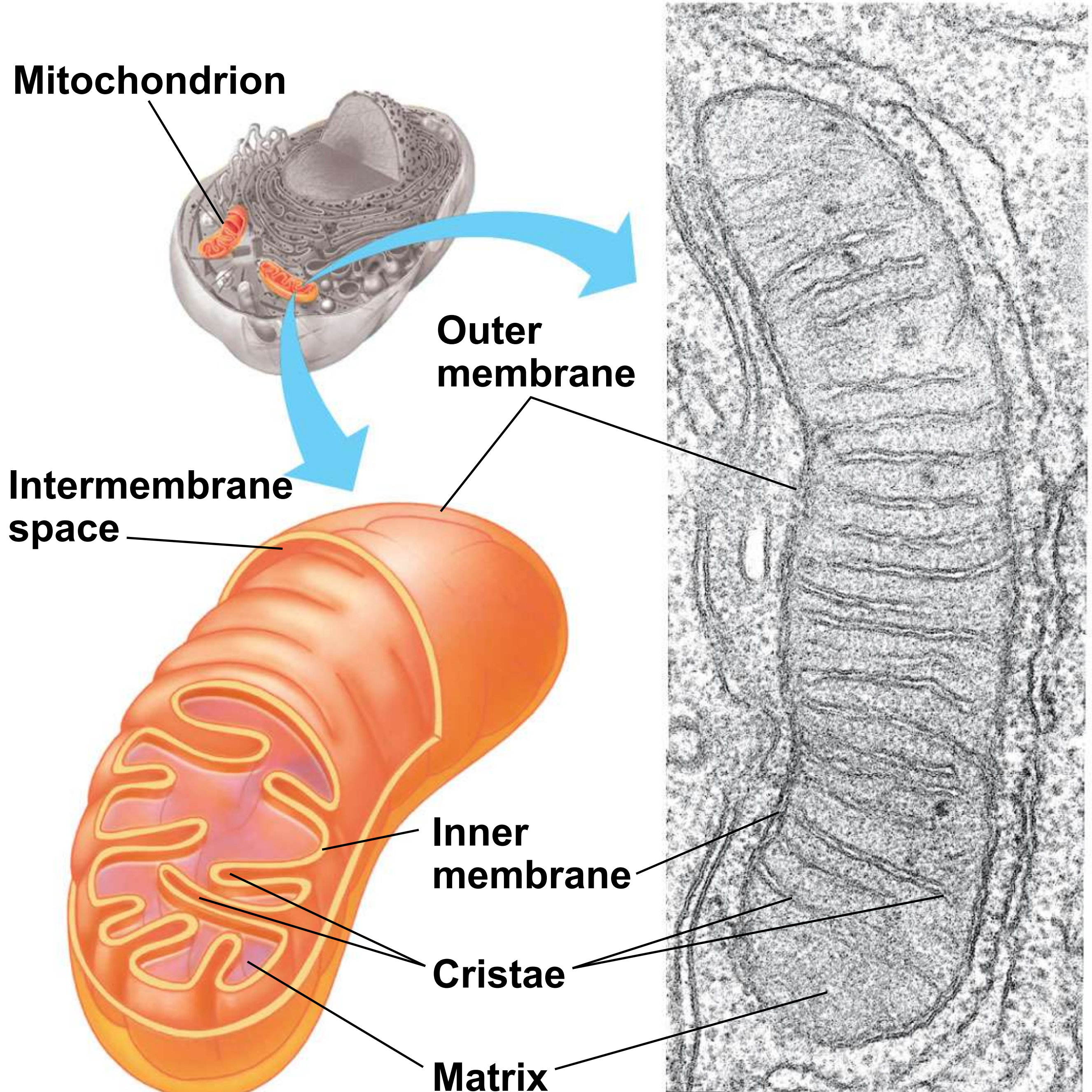
# 4.13 Mitochondria harvest chemical energy from food

- **Mitochondria** are organelles that carry out cellular respiration in nearly all eukaryotic cells.
- Cellular respiration converts the chemical energy in foods to chemical energy in **ATP** (adenosine triphosphate).

# 4.13 Mitochondria harvest chemical energy from food

- Mitochondria have two internal compartments.
  1. The intermembrane space is the narrow region between the inner and outer membranes.
  2. The **mitochondrial matrix** contains
     - the mitochondrial DNA,
     - ribosomes, and
     - many enzymes that catalyze some of the reactions of cellular respiration.

Figure 4.13



Mitochondrion
Outer membrane
Intermembrane space
Inner membrane
Cristae
Matrix

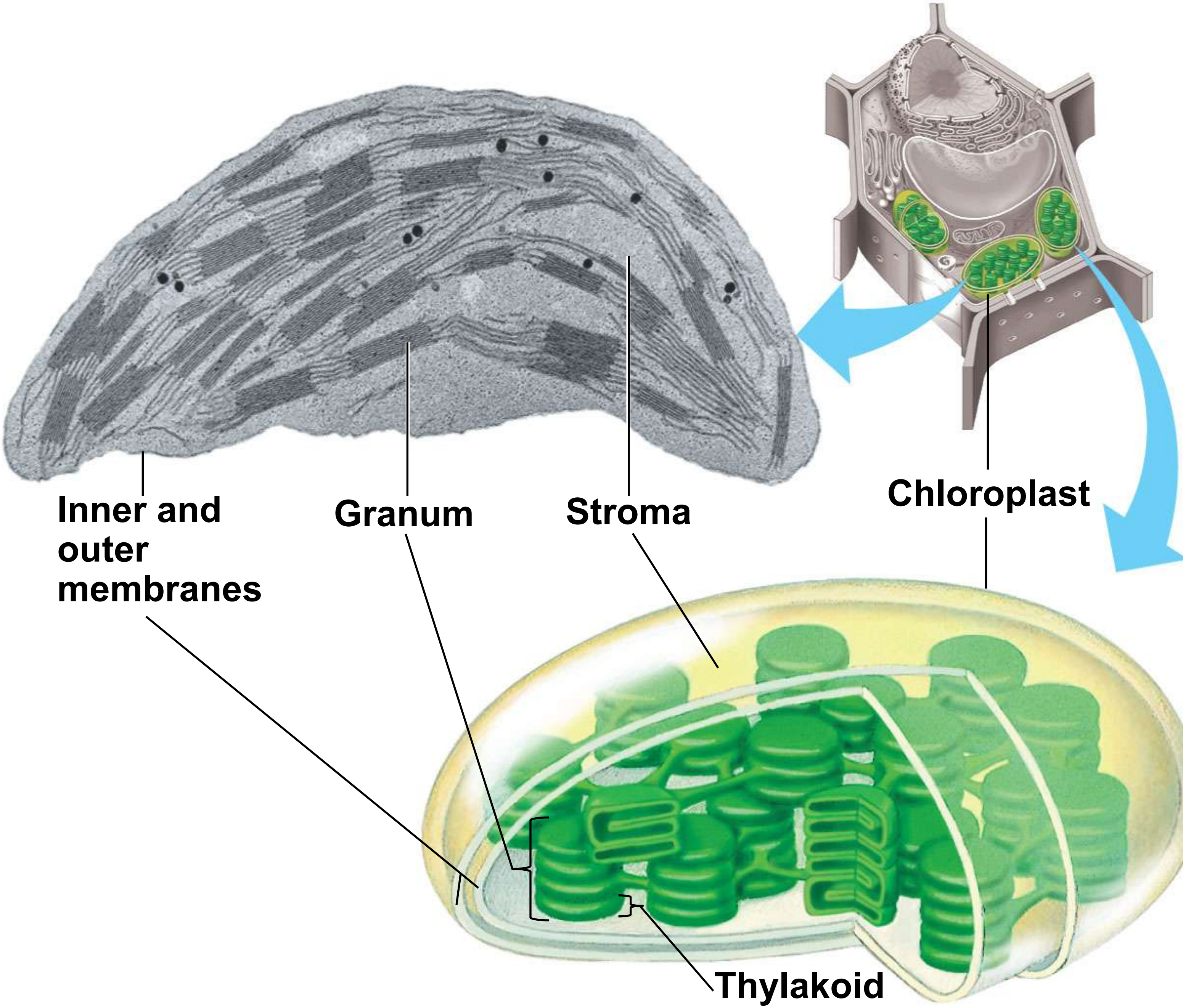
# 4.14 Chloroplasts convert solar energy to chemical energy

- **Chloroplasts** are the photosynthesizing organelles of all photosynthesizing eukaryotes.
- Photosynthesis is the conversion of light energy from the sun to the chemical energy of sugar molecules.

# 4.14 Chloroplasts convert solar energy to chemical energy

- Chloroplasts are partitioned into compartments.
  - Between the outer and inner membrane is a thin intermembrane space.
  - Inside the inner membrane is
    - a thick fluid called **stroma** that contains the chloroplast DNA, ribosomes, and many enzymes and
    - a network of interconnected sacs called **thylakoids**.
    - In some regions, thylakoids are stacked like poker chips. Each stack is called a **granum**,where green chlorophyll molecules trap solar energy.

Figure 4.14



Inner and outer membranes
Granum
Stroma
Chloroplast
Thylakoid

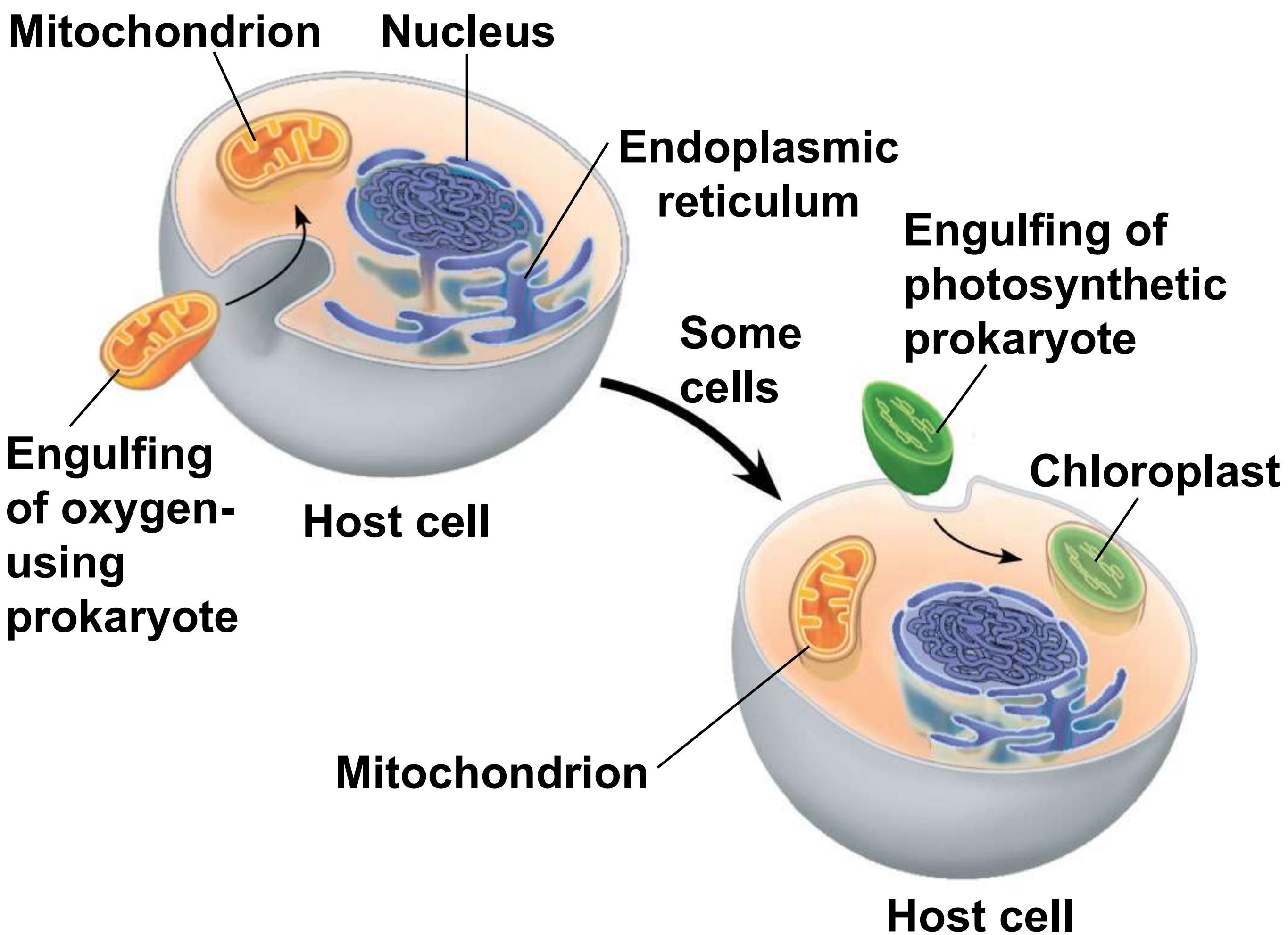
# 4.15 EVOLUTION CONNECTION: Mitochondria and chloroplasts evolved by endosymbiosis

- Mitochondria and chloroplasts have
  - DNA and
  - ribosomes.
- The structure of this DNA and these ribosomes is very similar to that found in prokaryotic cells.

# 4.15 EVOLUTION CONNECTION: Mitochondria and chloroplasts evolved by endosymbiosis

- The **endosymbiont theory** proposes that
  - mitochondria and chloroplasts were formerly small prokaryotes and
  - they began living within larger cells.

Figure 4.15



Mitochondrion
Nucleus
Endoplasmic reticulum
Engulfing of oxygen-using prokaryote
Host cell
Some cells
Engulfing of photosynthetic prokaryote
Chloroplast
Mitochondrion
Host cell

# THE CYTOSKELETON AND CELL SURFACES

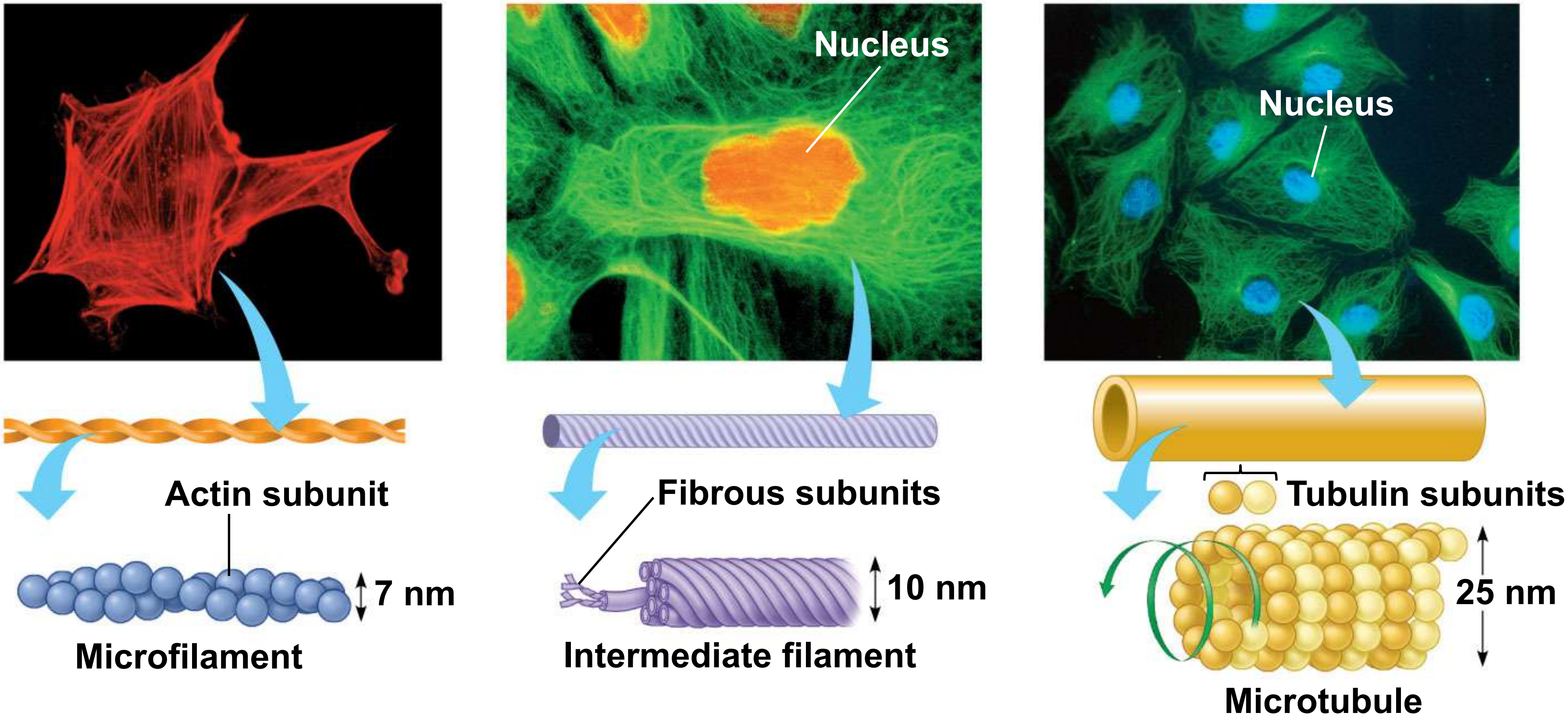
# 4.16 The cell's internal skeleton helps organize its structure and activities

- Cells contain a network of protein fibers, called the **cytoskeleton**, which functions in structural support and motility.
- Scientists believe that motility and cellular regulation result when the cytoskeleton interacts with proteins called motor proteins.

# 4.16 The cell's internal skeleton helps organize its structure and activities

- The cytoskeleton is composed of three kinds of fibers.
  1. **Microfilaments** (actin filaments) support the cell's shape and are involved in motility.
  2. **Intermediate filaments** reinforce cell shape and anchor organelles.
  3. **Microtubules** (made of tubulin) give the cell rigidity and act as tracks for organelle movement.

Figure 4.16


Nucleus
Nucleus
Actin subunit
7 nm
Microfilament
Fibrous subunits
10 nm
Intermediate filament
Tubulin subunits
25 nm
Microtubule

# 4.17 Cilia and flagella move when microtubules bend

- While some protists have flagella and **cilia** that are important in locomotion, some cells of multicellular organisms have them for different reasons.
  - Cells that sweep mucus out of our lungs have cilia.
  - Animal sperm are flagellated.

Figure 4.17A

Figure 4.17B

Figure 4.17C

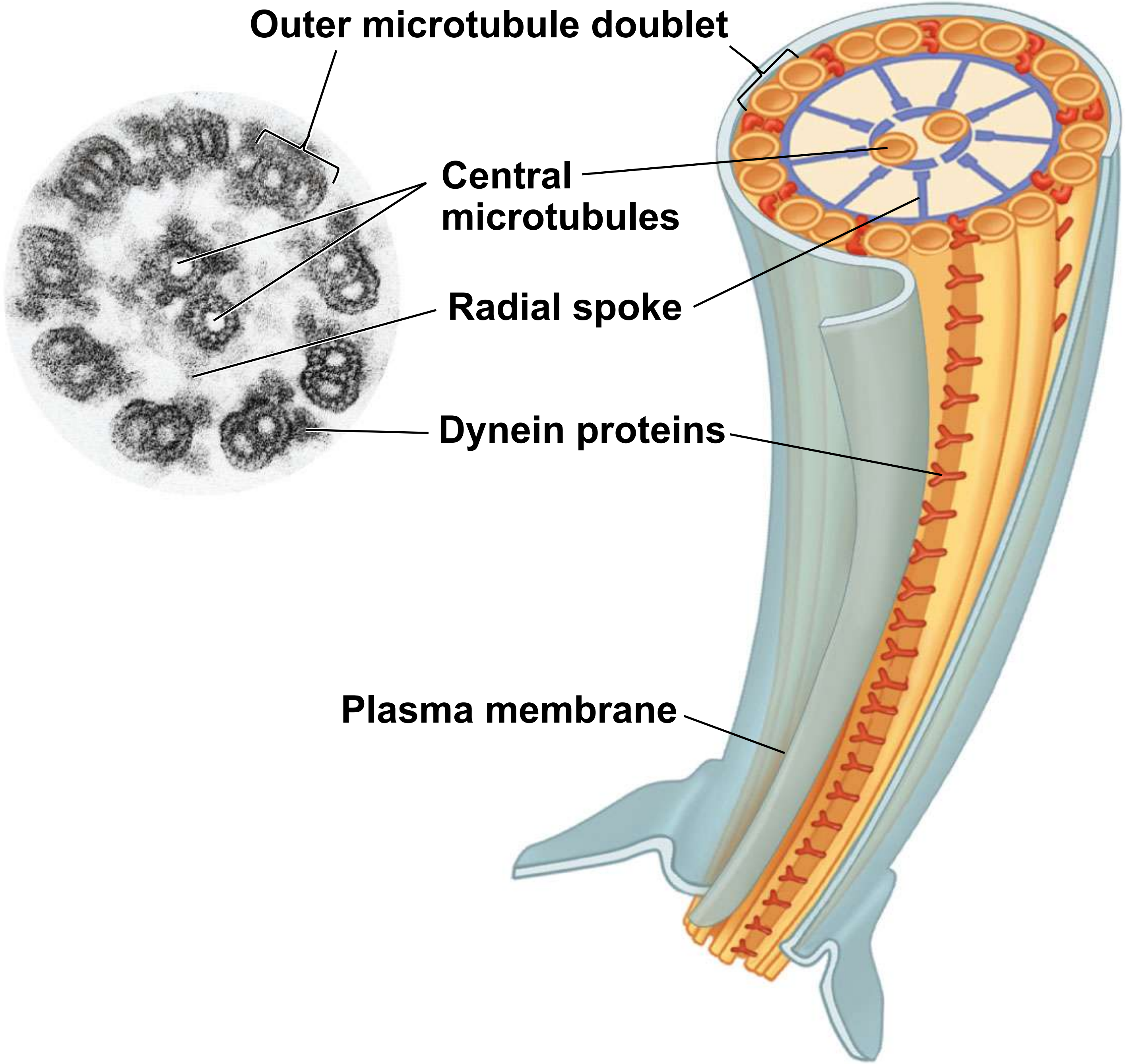
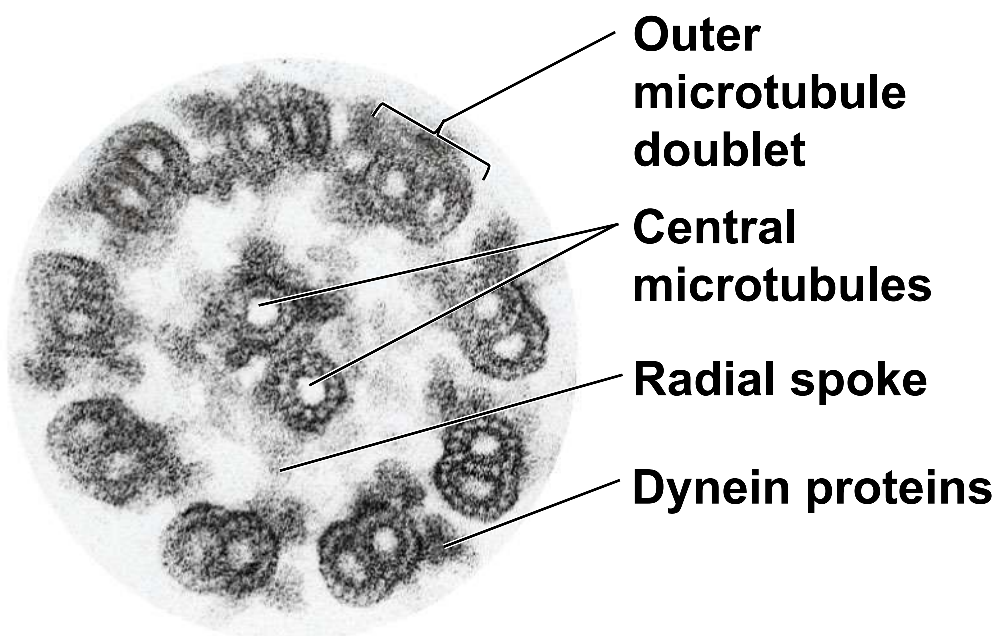

Outer microtubule doublet
Central microtubules
Radial spoke
Dynein proteins
Plasma membrane

Figure 4.17C_1



# 4.17 Cilia and flagella move when microtubules bend

- A flagellum, longer than cilia, propels a cell by an undulating, whiplike motion.
- Cilia work more like the oars of a crew boat.
- Although differences exist, flagella and cilia have a common structure and mechanism of movement.

# 4.17 Cilia and flagella move when microtubules bend

- Both flagella and cilia are made of microtubules wrapped in an extension of the plasma membrane.
- A ring of nine microtubule doublets surrounds a central pair of microtubules. This arrangement is
  - called the 9 + 2 pattern and
  - anchored in a basal body with nine microtubule triplets arranged in a ring.

# 4.17 Cilia and flagella move when microtubules bend

- Cilia and flagella move by bending motor proteins called dynein feet.
  - These feet attach to and exert a sliding force on an adjacent doublet.
  - The arms then release and reattach a little further along and repeat this time after time.
  - This “walking” causes the microtubules to bend.

# 4.18 CONNECTION: Problems with sperm motility may be environmental or genetic

- In developed countries over the last 50 years, there has been a decline in sperm quality.
- The causes of this decline may be
  - environmental chemicals or
  - genetic disorders that interfere with the movement of sperm and cilia. Primary ciliary dyskinesia (PCD) is a rare disease characterized by recurrent infections of the respiratory tract and immotile sperm.

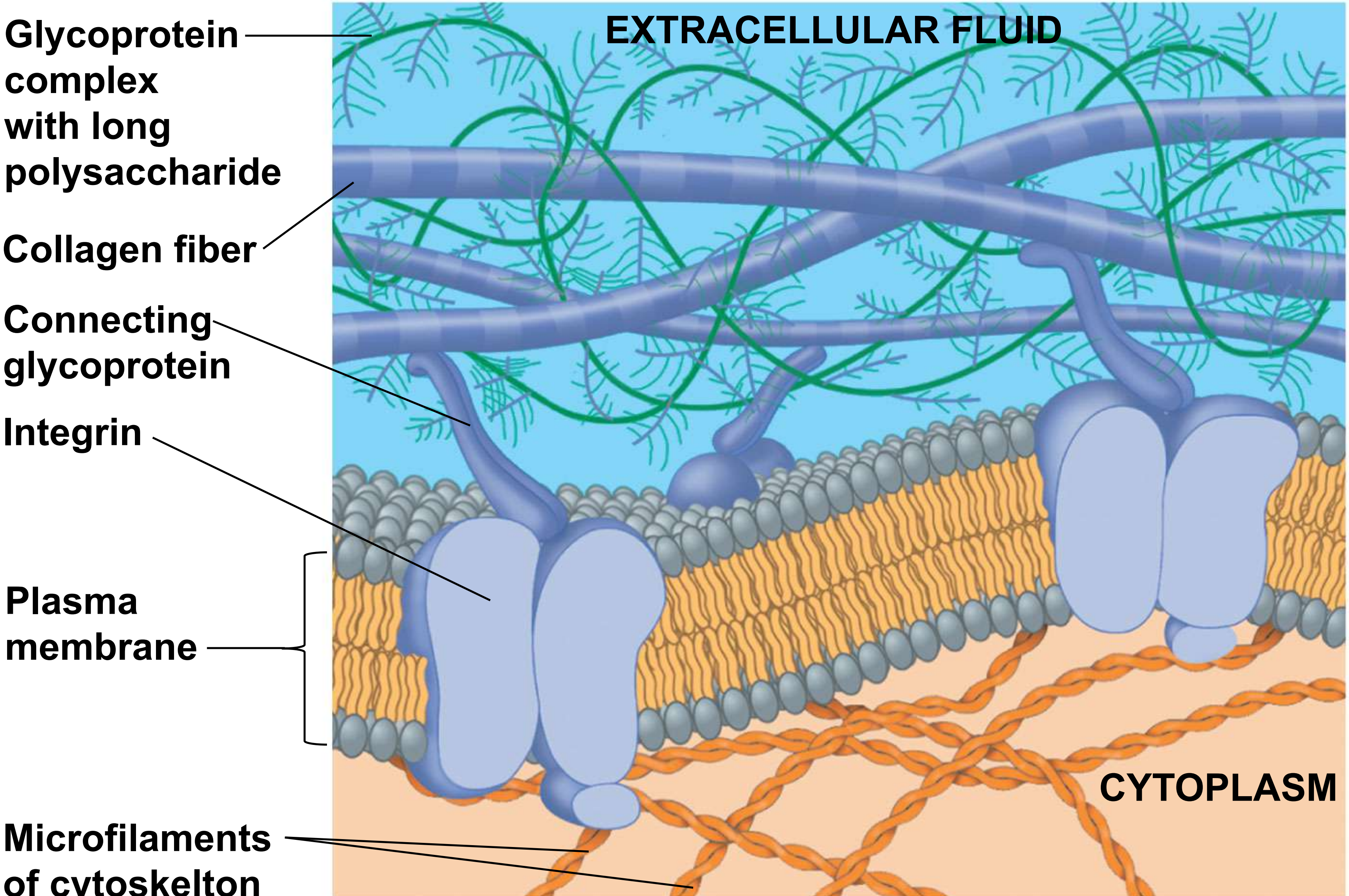
# 4.19 The extracellular matrix of animal cells functions in support and regulation

- Animal cells synthesize and secrete an elaborate **extracellular matrix** (**ECM**) that
  - helps hold cells together in tissues and
  - protects and supports the plasma membrane.

# 4.19 The extracellular matrix of animal cells functions in support and regulation

- The ECM may attach to a cell through glycoproteins that then bind to membrane proteins called **integrins**. Integrins span the plasma membrane and connect to microfilaments of the cytoskeleton.

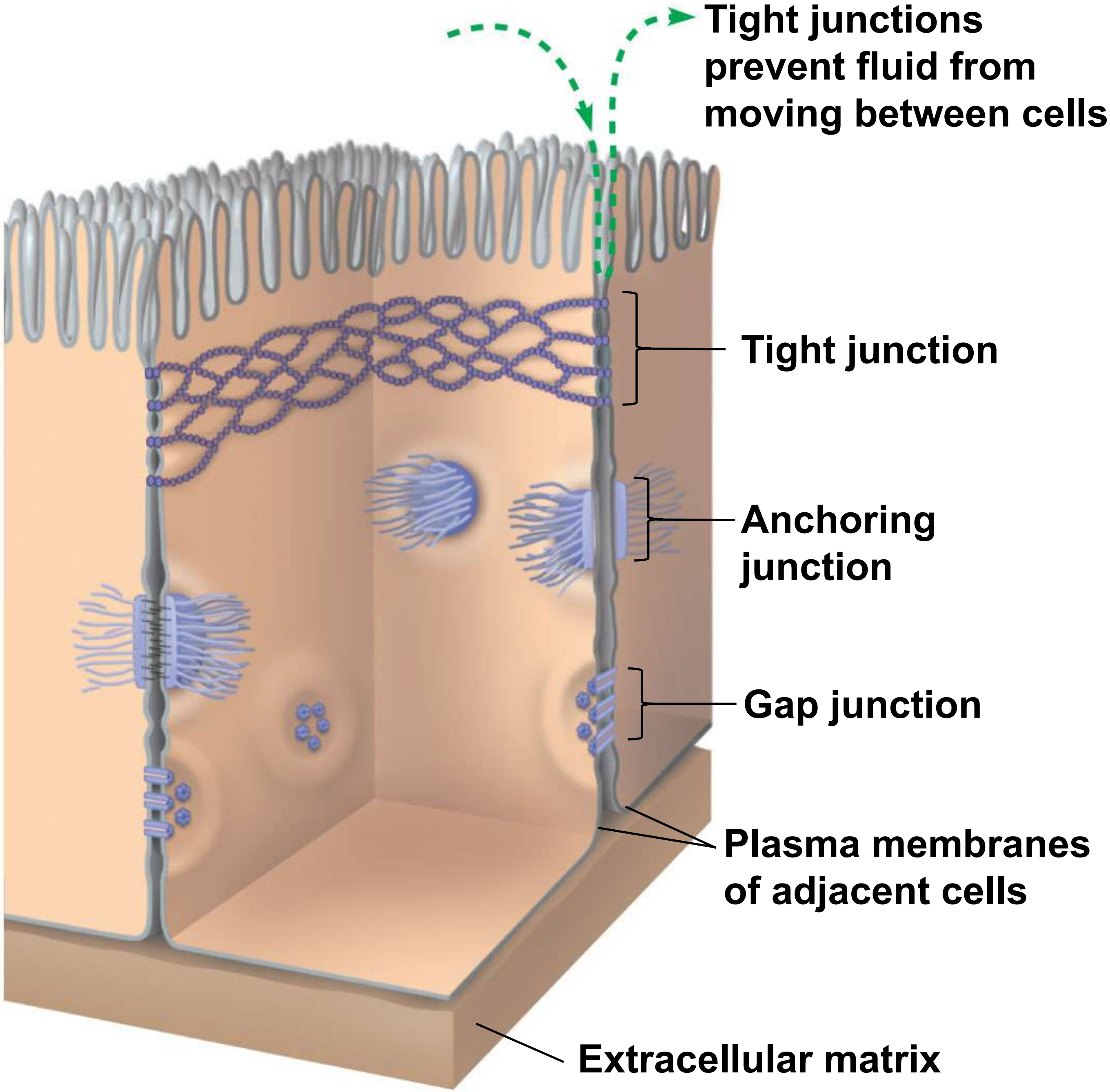
Figure 4.19


EXTRACELLULAR FLUID
Glycoprotein complex with long polysaccharide
Collagen fiber
Connecting glycoprotein
Integrin
Plasma membrane
Microfilaments of cytoskelton
CYTOPLASM

# 4.20 Three types of cell junctions are found in animal tissues

- Adjacent cells communicate, interact, and adhere through specialized junctions between them.
  - **Tight junctions** prevent leakage of extracellular fluid across a layer of epithelial cells.
  - **Anchoring junctions** fasten cells together into sheets.
  - **Gap junctions** are channels that allow molecules to flow between cells.

Figure 4.20

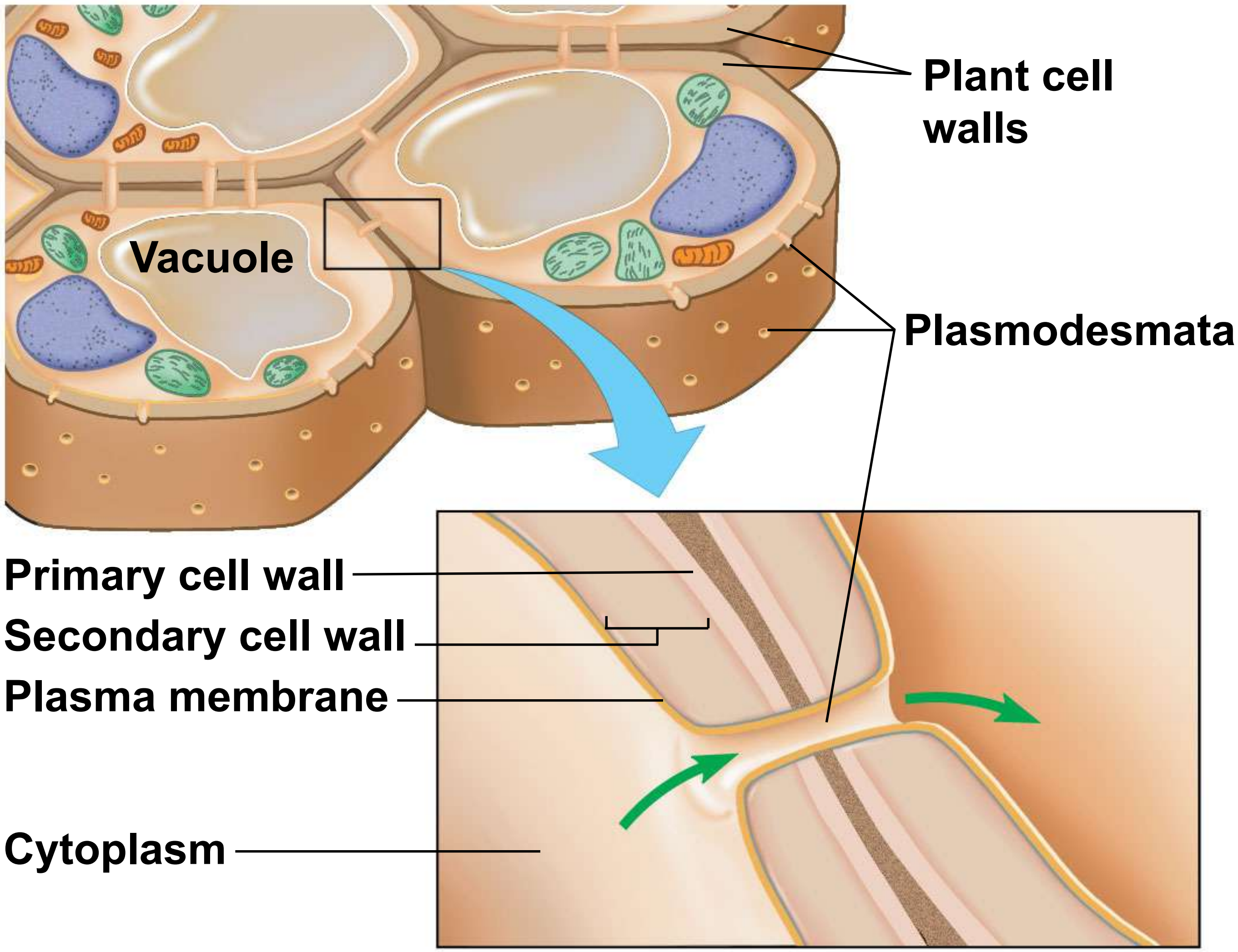


Tight junctions prevent fluid from moving between cells
Tight junction
Anchoring junction
Gap junction
Plasma membranes of adjacent cells
Extracellular matrix

# 4.21 Cell walls enclose and support plant cells

- A plant cell, but not an animal cell, has a rigid **cell wall** that
  - protects and provides skeletal support that helps keep the plant upright against gravity and
  - is primarily composed of cellulose.
- Plant cells have cell junctions called **plasmodesmata** that serve in communication between cells.

Figure 4.21


Plant cell walls
Vacuole
Plasmodesmata
Primary cell wall
Secondary cell wall
Plasma membrane
Cytoplasm