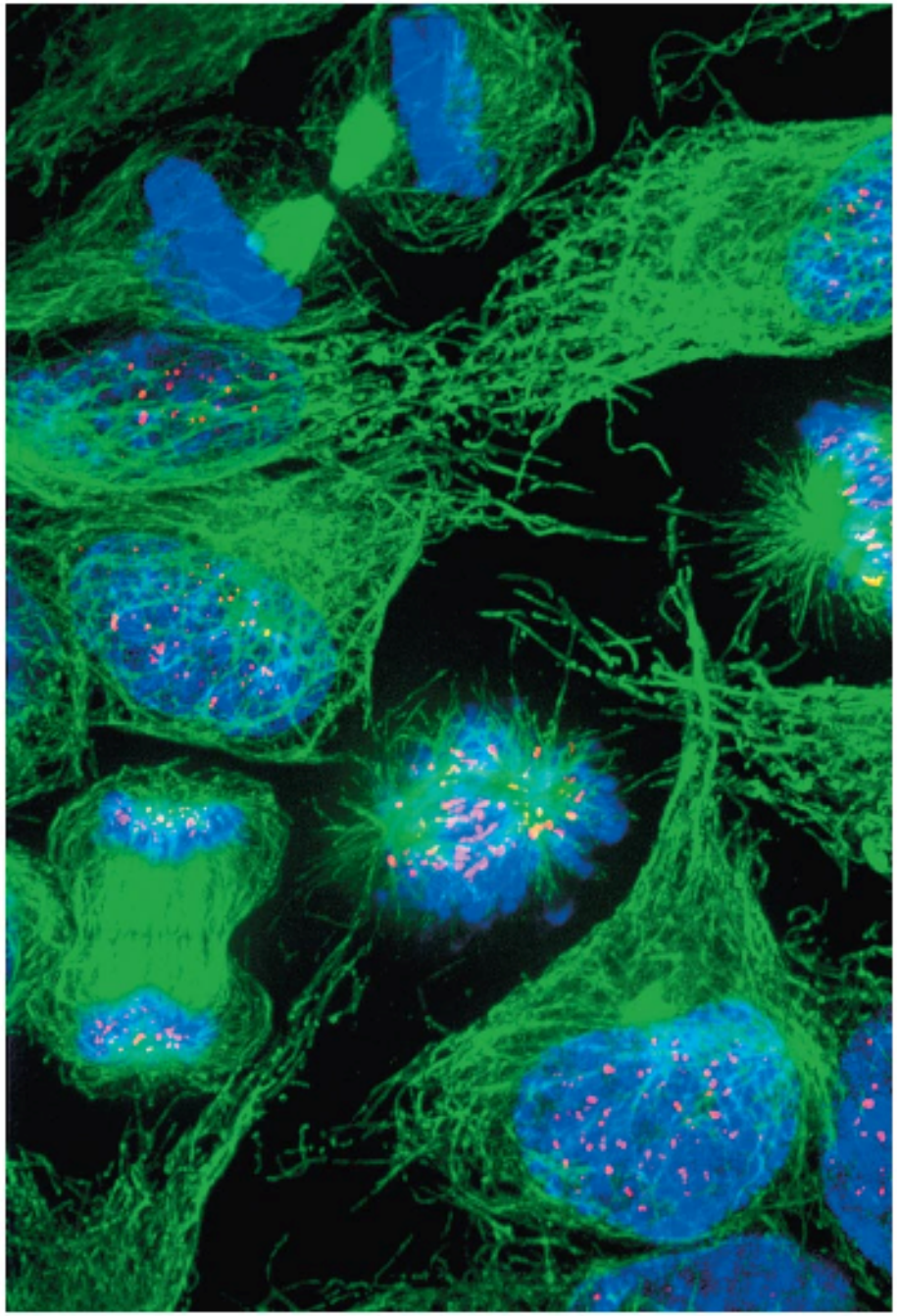
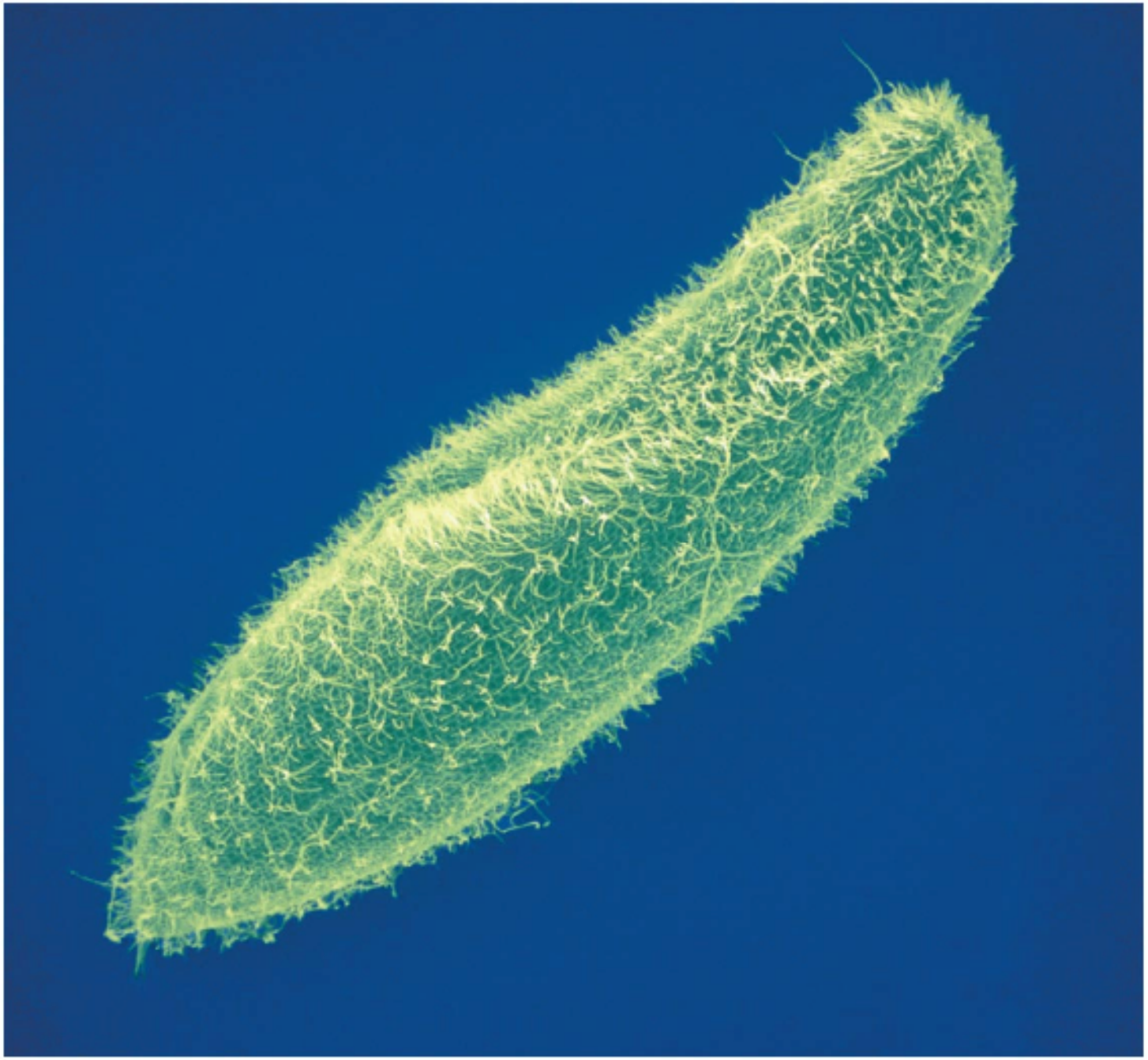
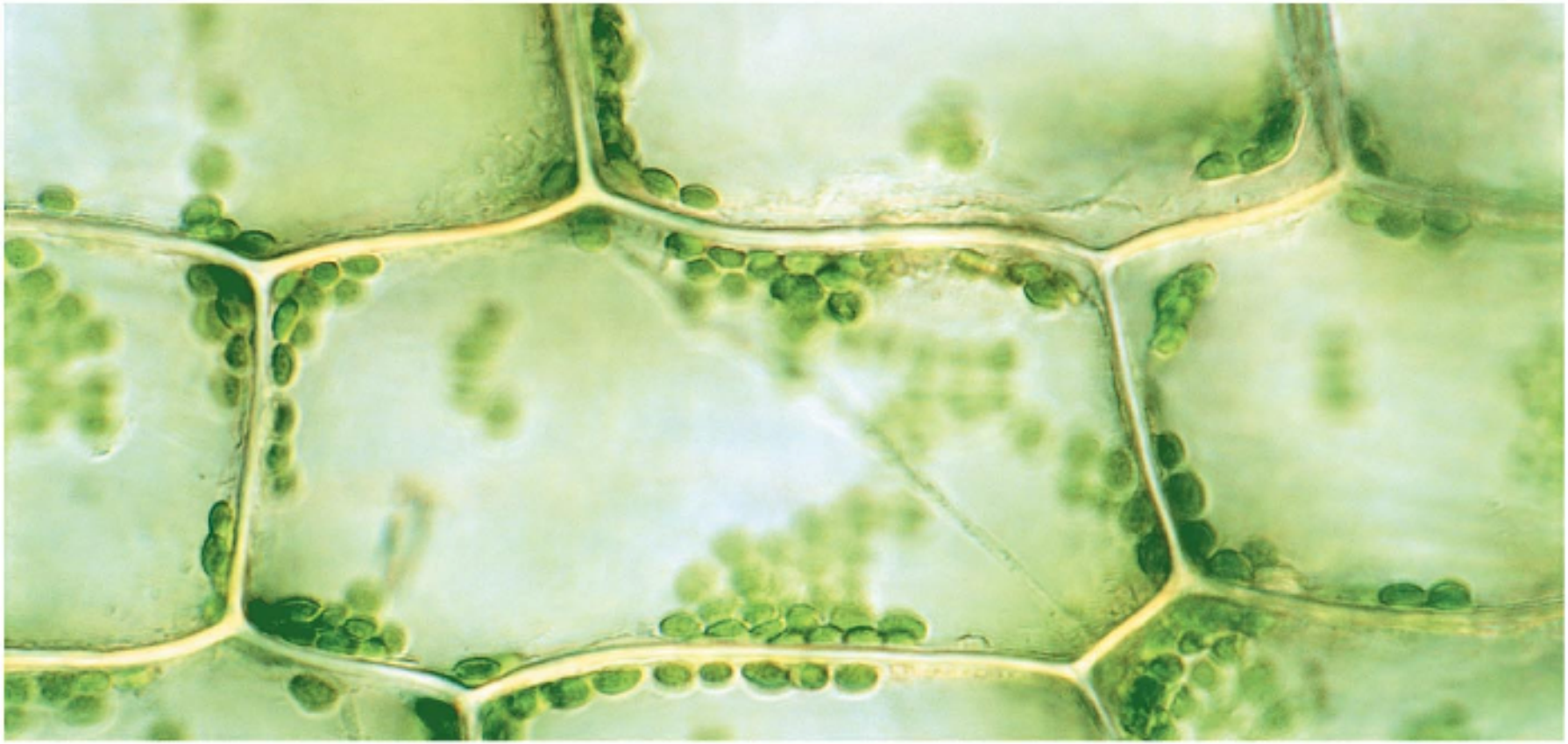
INTRODUCTION TO THE CELL

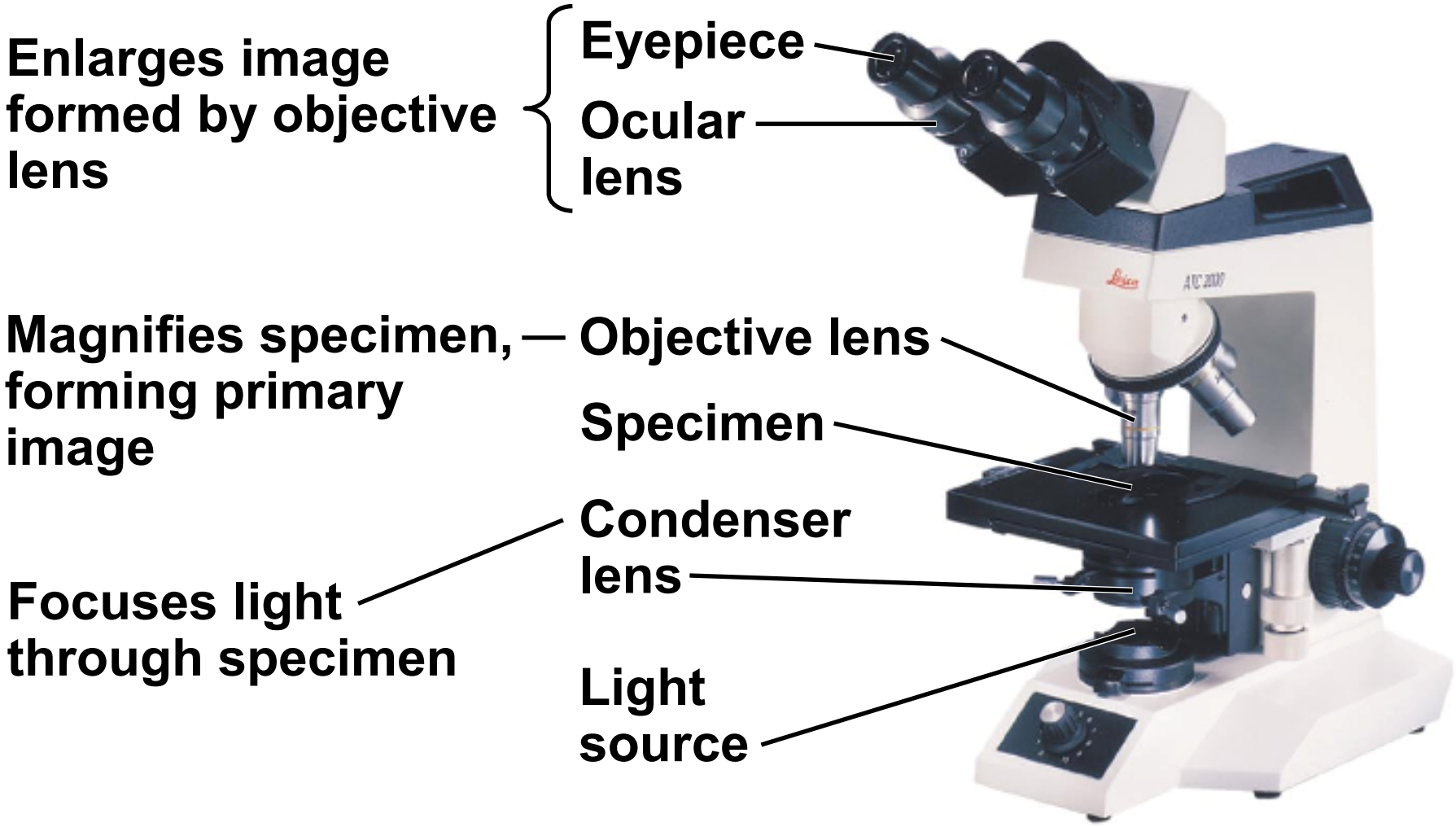






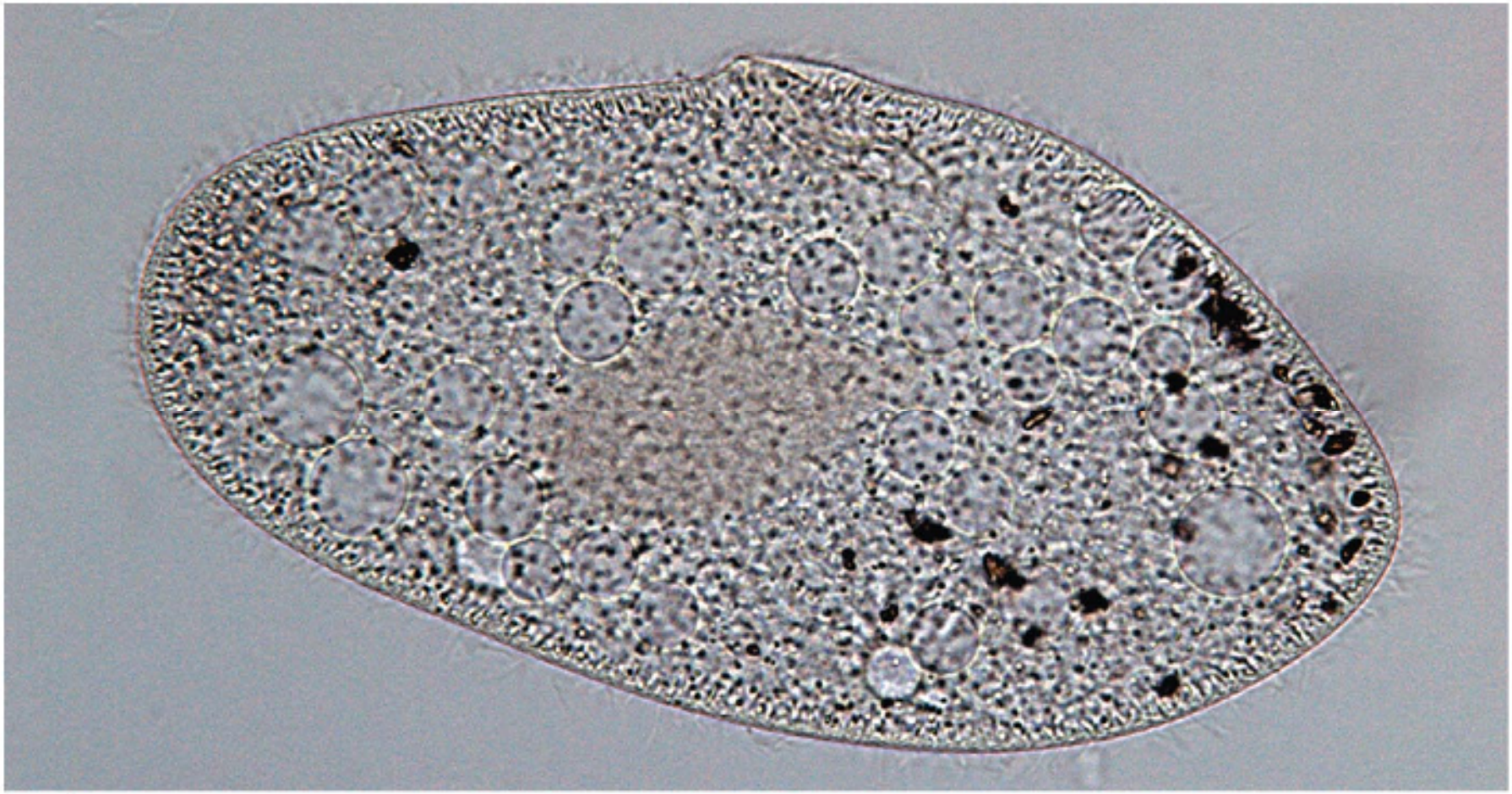
4.1 Microscopes reveal the world of the cell

- 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 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

- Microscopes have limitations
  - Both 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

- Biologists often use a very powerful microscope called the **electron microscope** (**EM**) to view the ultrastructure of cells
  - It can resolve biological structures as small as 2 nanometers and can magnify up to 100,000 times
  - Instead of light, the EM uses a beam of electrons

TABLE 4.1 MEASUREMENT EQUIVALENTS

1 meter (m) = 10^0 m = 39.37 inches

1 millimeter (mm) = 10^{-3} m (1/1,000 m) = 0.04 inch

1 micrometer (μm) = 10^{-3} mm = 10^{-6} m (1/1,000,000 m)

1 nanometer (nm) = 10^{-3} μm = 10^{-9} m (1/1,000,000,000 m)

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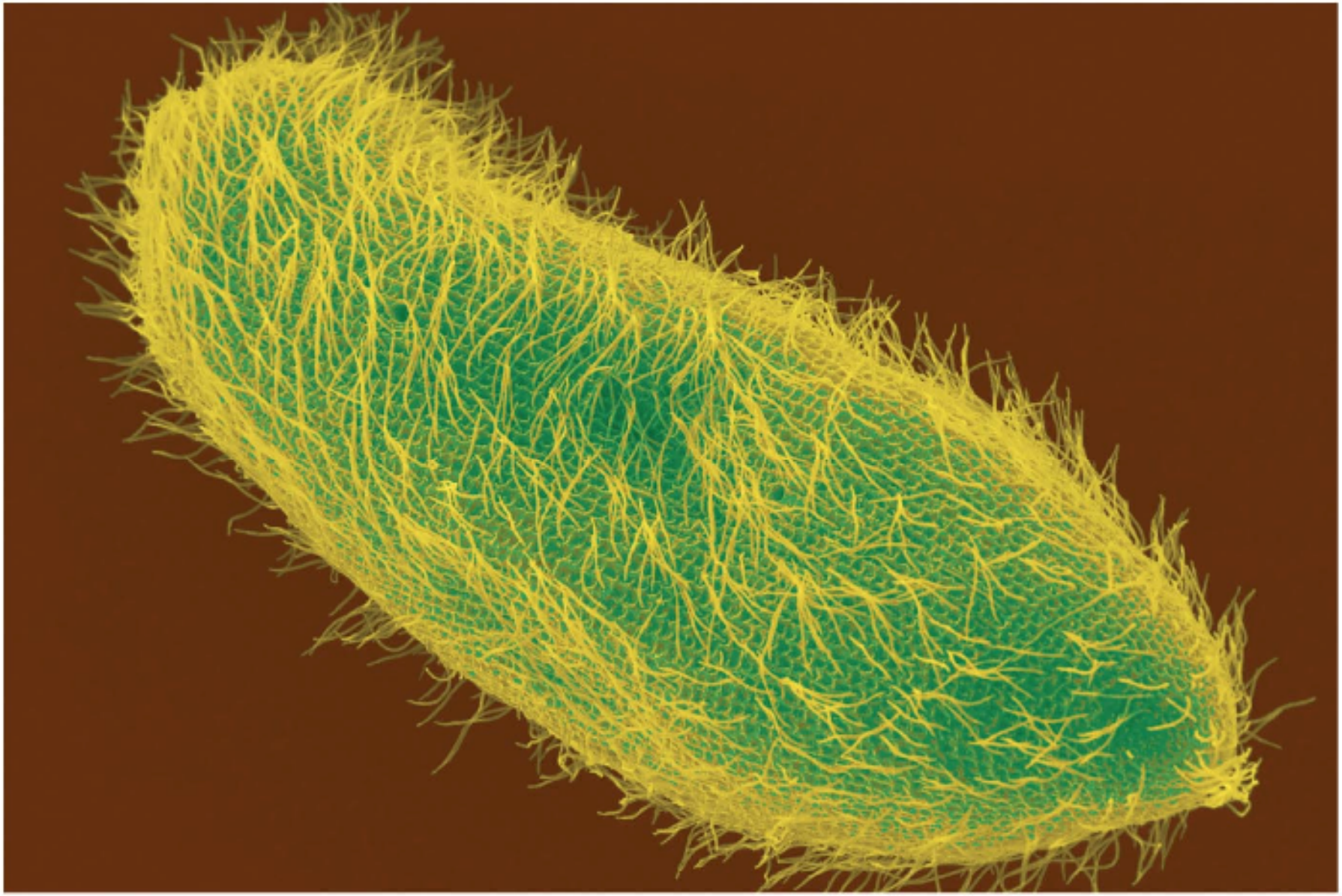
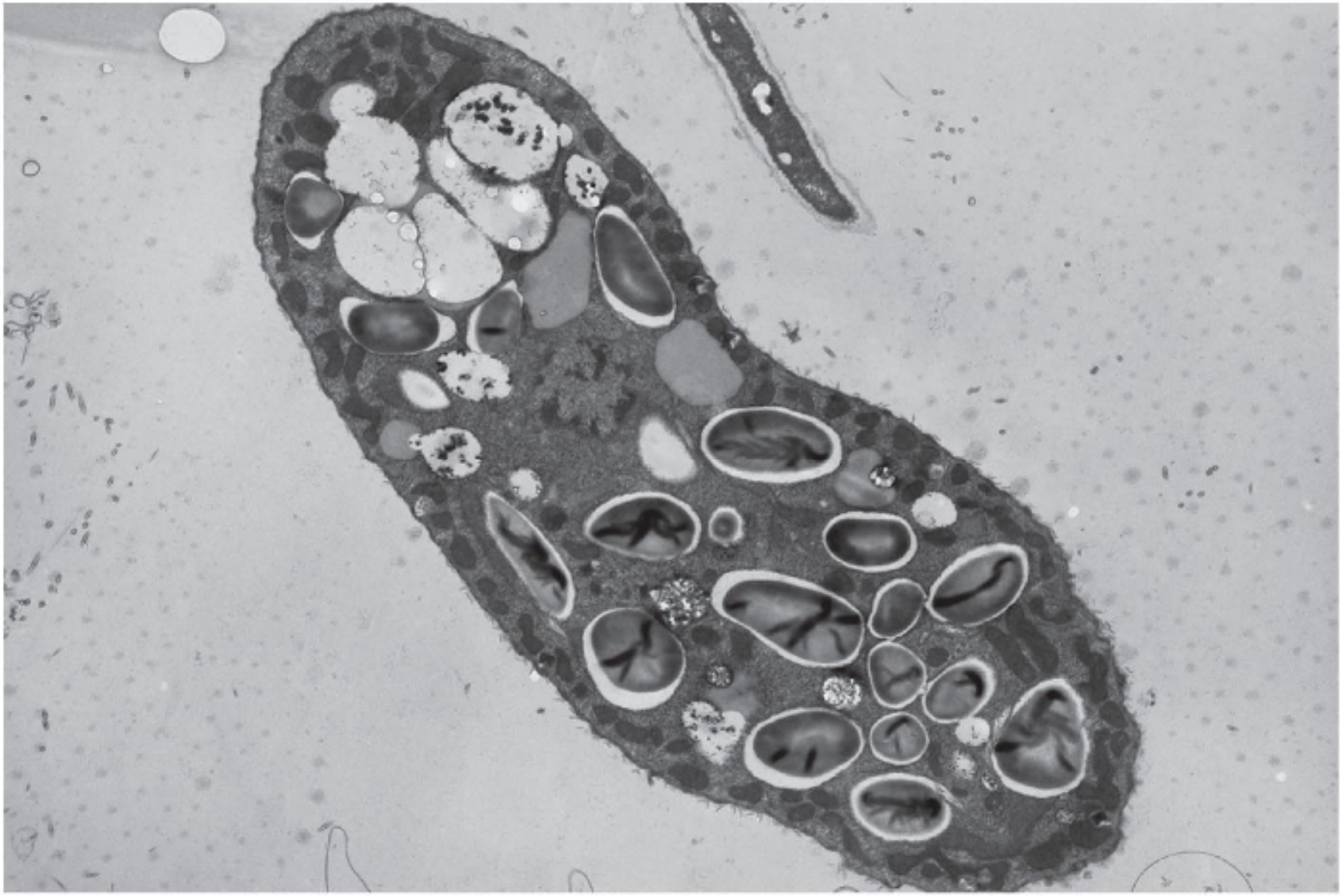
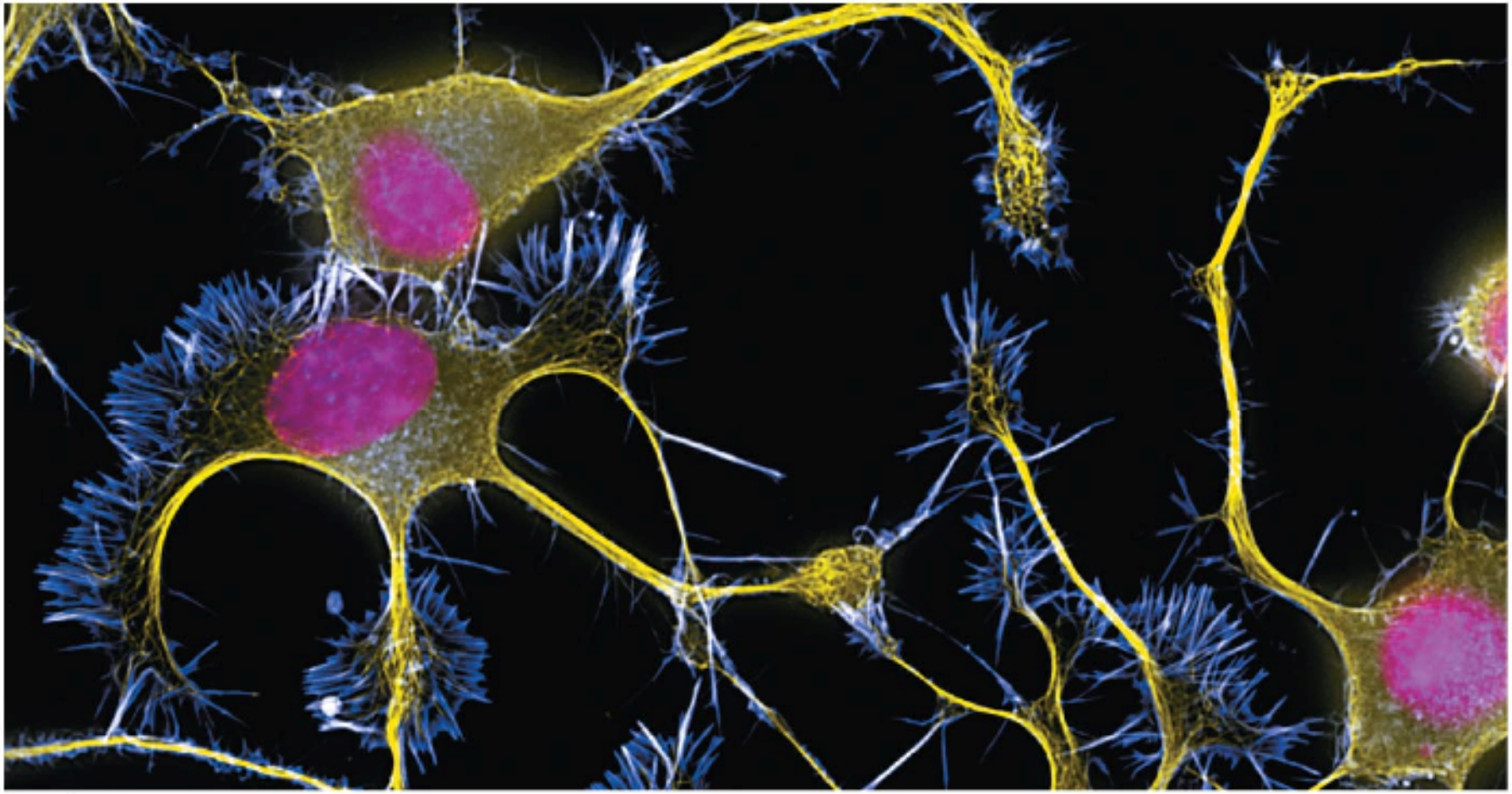
1 meter = 10^3 mm = 10^6 μm = 10^9 nm

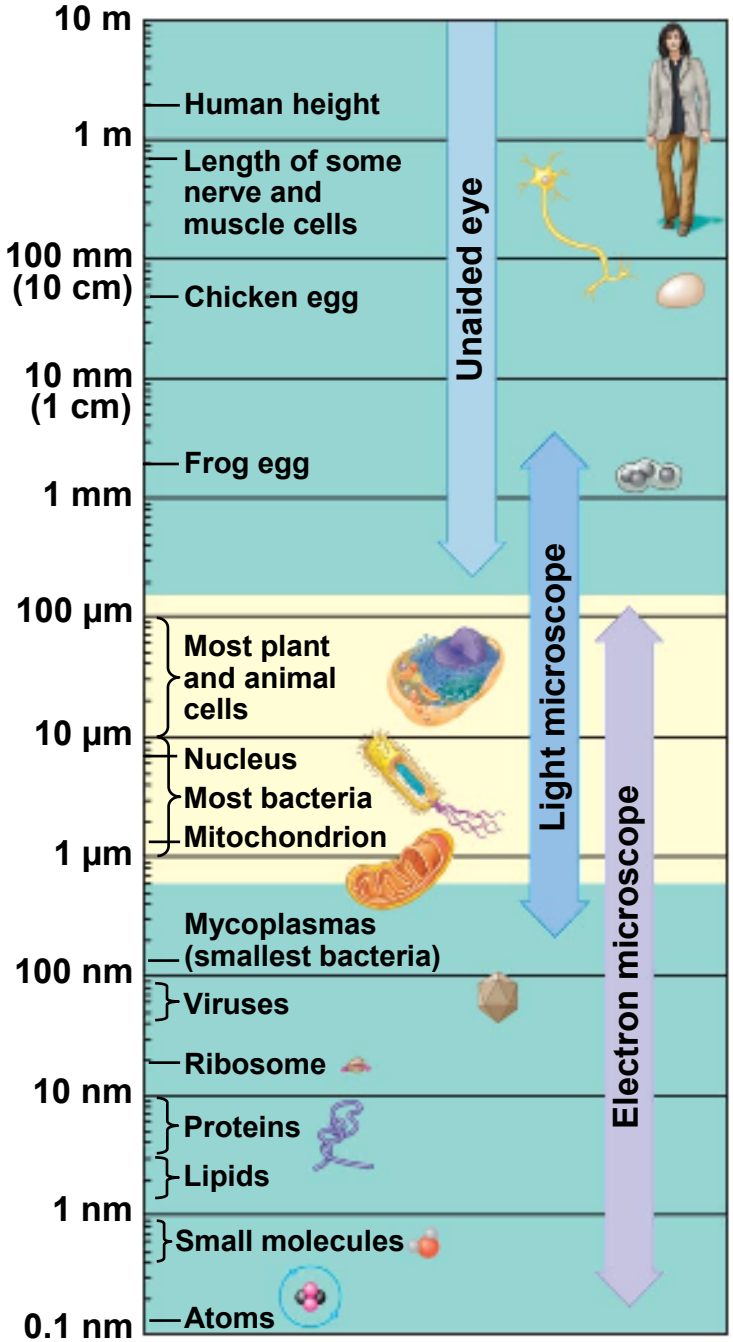






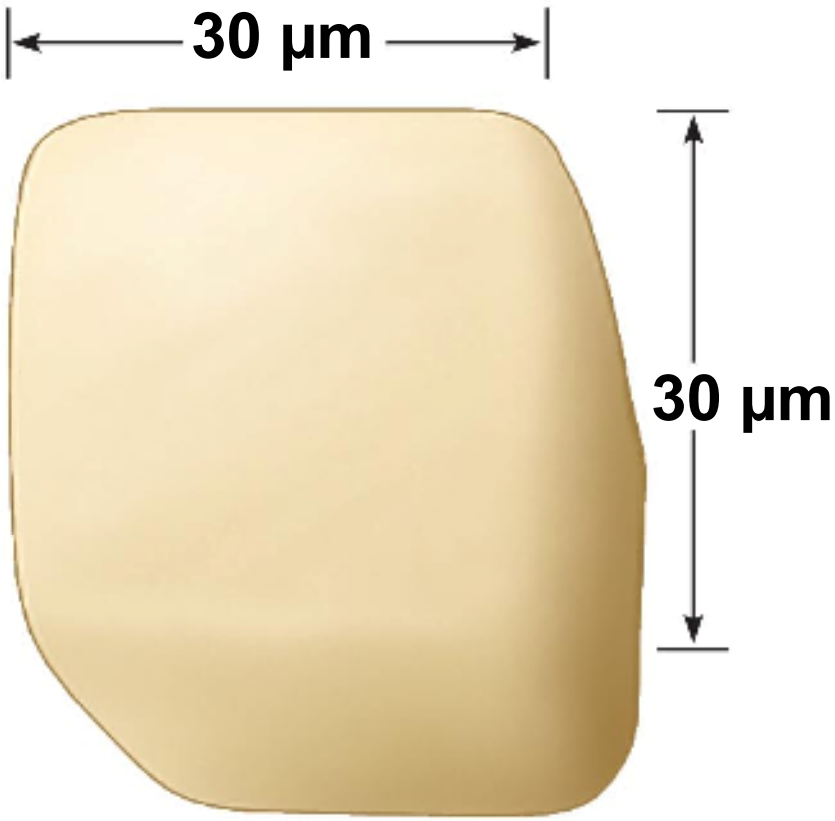
4.2 Most cells are microscopic

- Most cells cannot be seen without a microscope
  - Bacteria are the smallest of all cells and require magnifications up to 1,000X
  - Plant and animal cells are 10 times larger than most bacteria

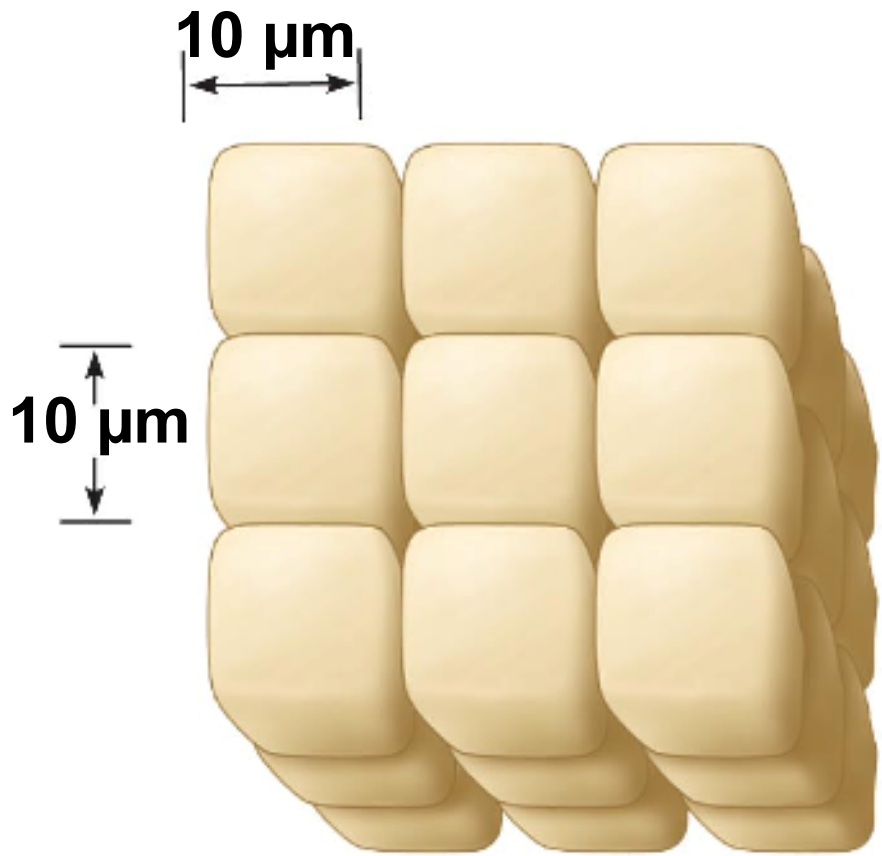


4.2 Most cells are microscopic

- The surface area of a cell is important for carrying out the cell's functions, such as acquiring adequate nutrients and oxygen
  - A small cell has more surface area relative to its cell volume and is more efficient



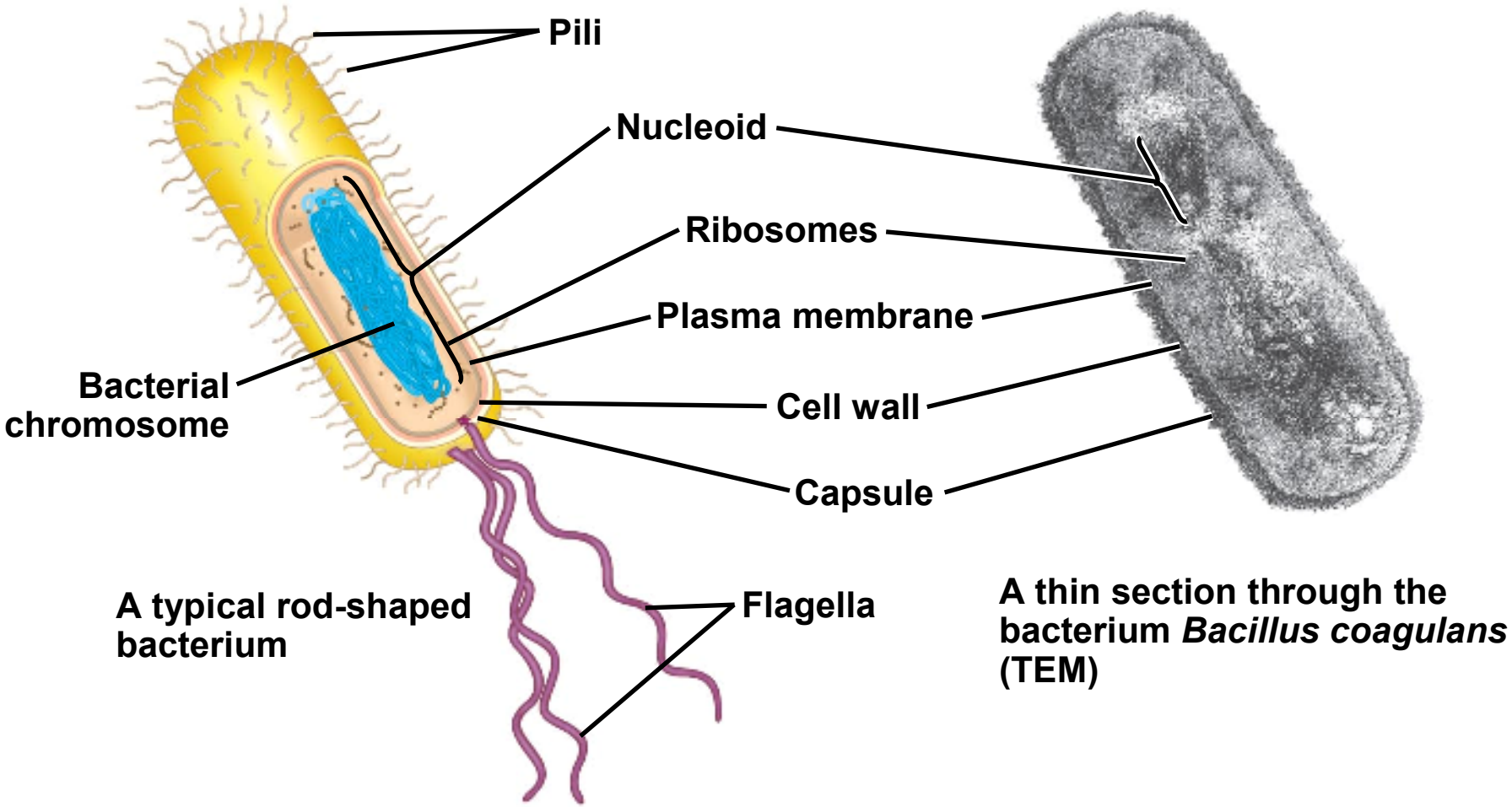
Surface area of one large cube = 5,400 µm²



Total surface area of 27 small cubes = 16,200 µm²

4.3 Prokaryotic cells are structurally simpler than eukaryotic cells

- Bacteria and archaea are **prokaryotic** cells
- All other forms of life are **eukaryotic** cells
  - Both prokaryotic and eukaryotic cells have a plasma membrane and one or more chromosomes and ribosomes
  - Eukaryotic cells have a membrane-bound nucleus and a number of other organelles, whereas prokaryotes have a nucleoid and no true organelles



A typical rod-shaped bacterium

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

4.4 Eukaryotic cells are partitioned into functional compartments

- There are four life processes in eukaryotic cells that depend upon structures and organelles
  - Manufacturing
  - Breakdown of molecules
  - Energy processing
  - Structural support, movement, and communication

4.4 Eukaryotic cells are partitioned into functional compartments

- Manufacturing involves the nucleus, ribosomes, endoplasmic reticulum, and Golgi apparatus
  - Manufacture of a protein, perhaps an enzyme, involves all of these

4.4 Eukaryotic cells are partitioned into functional compartments

- Breakdown of molecules involves lysosomes, vacuoles, and peroxisomes
  - Breakdown of an internalized bacterium by a phagocytic cell would involve all of these

4.4 Eukaryotic cells are partitioned into functional compartments

- Energy processing involves mitochondria in animal cells and chloroplasts in plant cells
  - Generation of energy-containing molecules, such as adenosine triphosphate, occurs in mitochondria and chloroplasts

4.4 Eukaryotic cells are partitioned into functional compartments

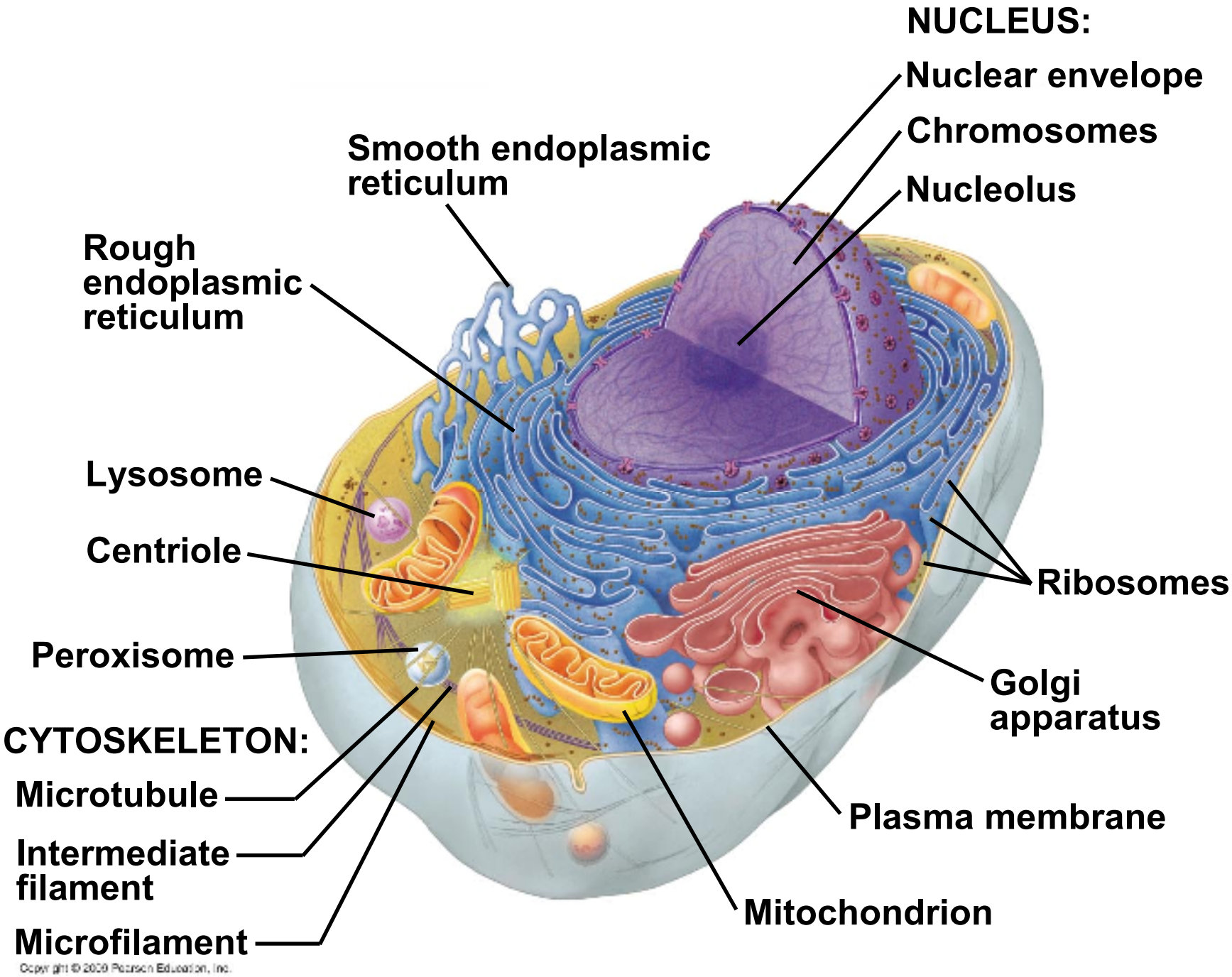
- Structural support, movement, and communication involve the cytoskeleton, plasma membrane, and cell wall
  - An example of the importance of these is the response and movement of phagocytic cells to an infected area

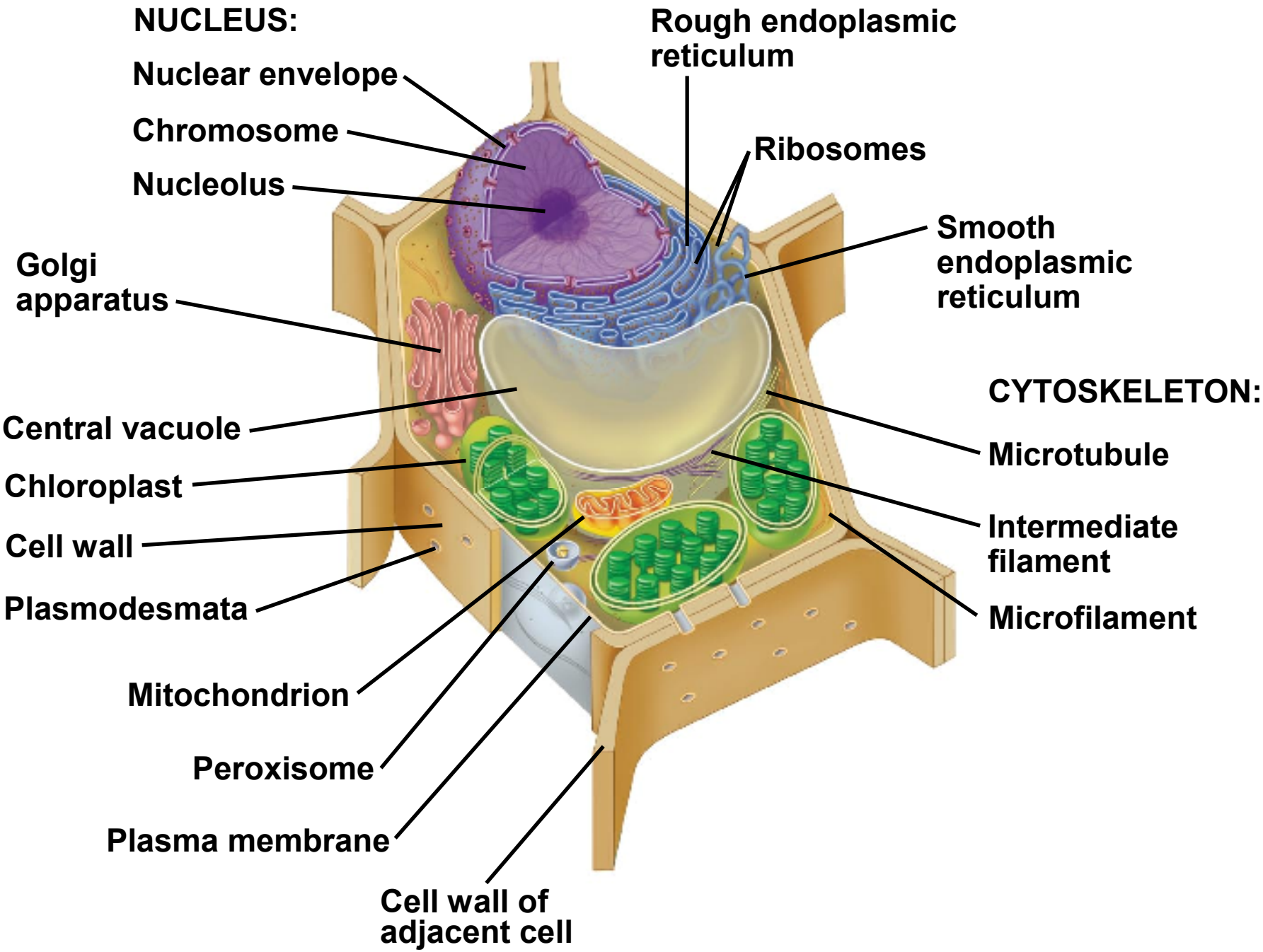
4.4 Eukaryotic cells are partitioned into functional compartments

- Membranes within a eukaryotic cell partition the cell into compartments, areas where cellular metabolism occurs
  - Each compartment is fluid-filled and maintains conditions that favor particular metabolic processes and activities

4.4 Eukaryotic cells are partitioned into functional compartments

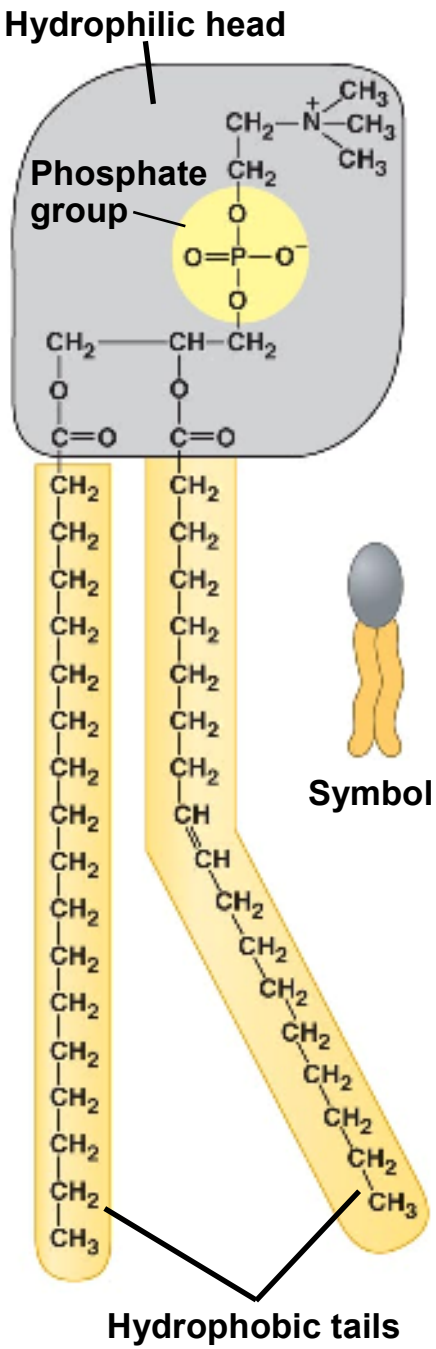
- Although there are many similarities between animal and plant cells, differences exist
  - Lysosomes and centrioles are not found in plant cells
  - Plant cells have a rigid cell wall, chloroplasts, and a central vacuole not found in animal cells





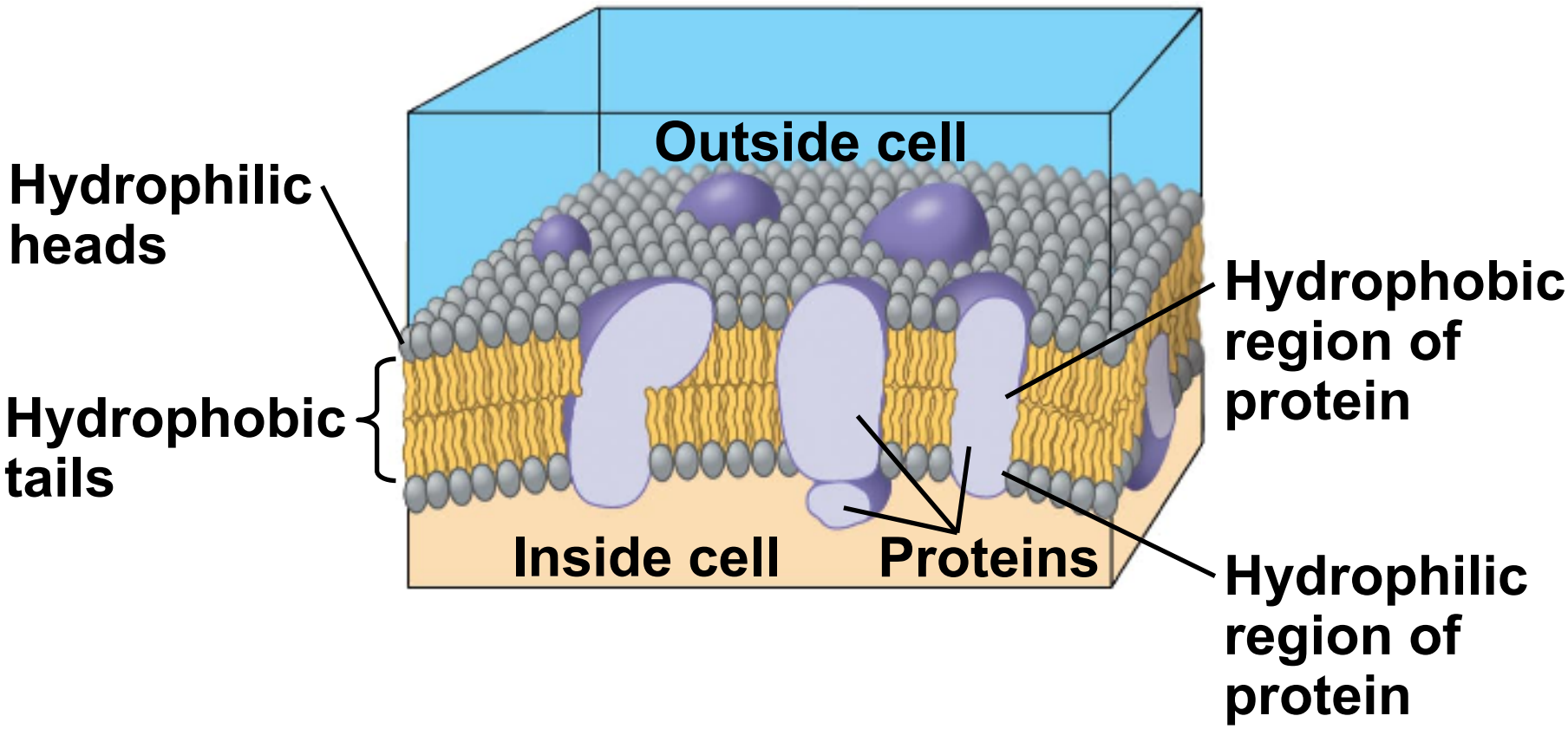
4.5 The structure of membranes correlates with their functions

- The plasma membrane controls the movement of molecules into and out of the cell, a trait called selective permeability
  - The structure of the membrane with its component molecules is responsible for this characteristic
  - Membranes are made of lipids, proteins, and some carbohydrate, but the most abundant lipids are phospholipids



4.5 The structure of membranes correlates with their functions

- Phospholipids form a two-layer sheet called a phospholipid bilayer
  - Hydrophilic heads face outward, and hydrophobic tails point inward
  - Thus, hydrophilic heads are exposed to water, while hydrophobic tails are shielded from water
- Proteins are attached to the surface, and some are embedded into the phospholipid bilayer



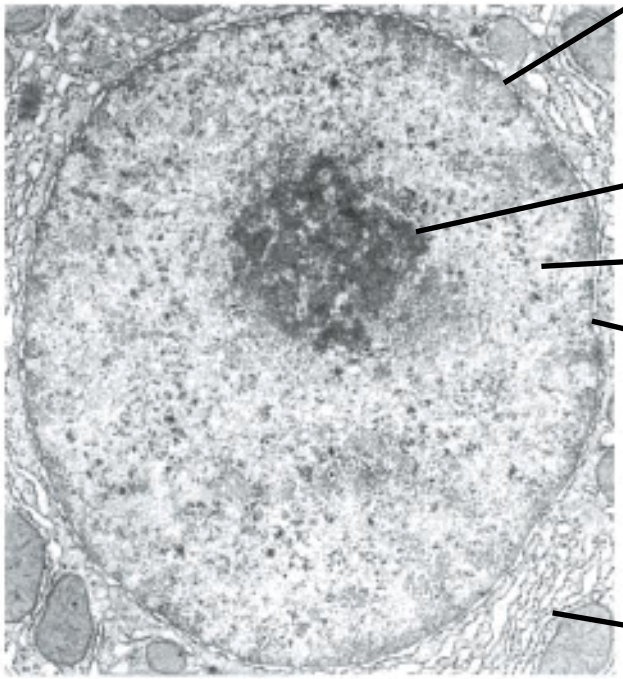
CELL STRUCTURES INVOLVED IN MANUFACTURING AND BREAKDOWN

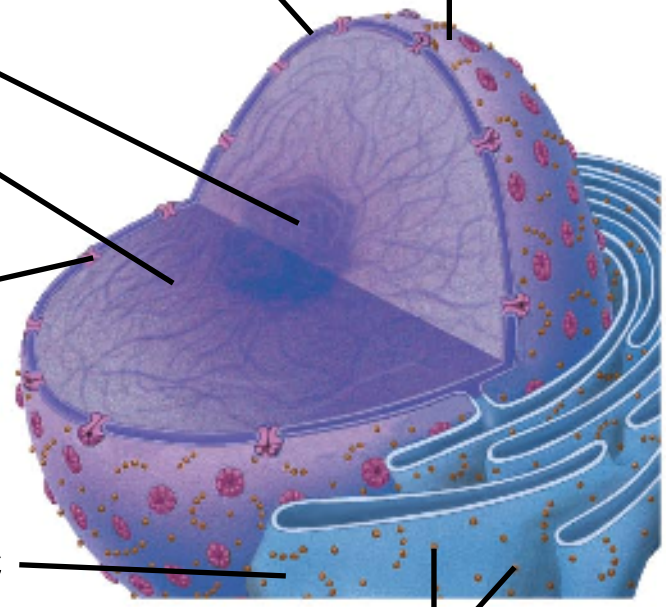
4.6 The nucleus is the cell's genetic control center

- The **nucleus** controls the cell's activities and is responsible for inheritance
  - Inside is a complex of proteins and DNA called **chromatin**, which makes up the cell's chromosomes
  - DNA is copied within the nucleus prior to cell division

4.6 The nucleus is the cell's genetic control center

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





Two membranes of nuclear envelope

Nucleus

Nucleolus

Chromatin

Pore

Endoplasmic reticulum

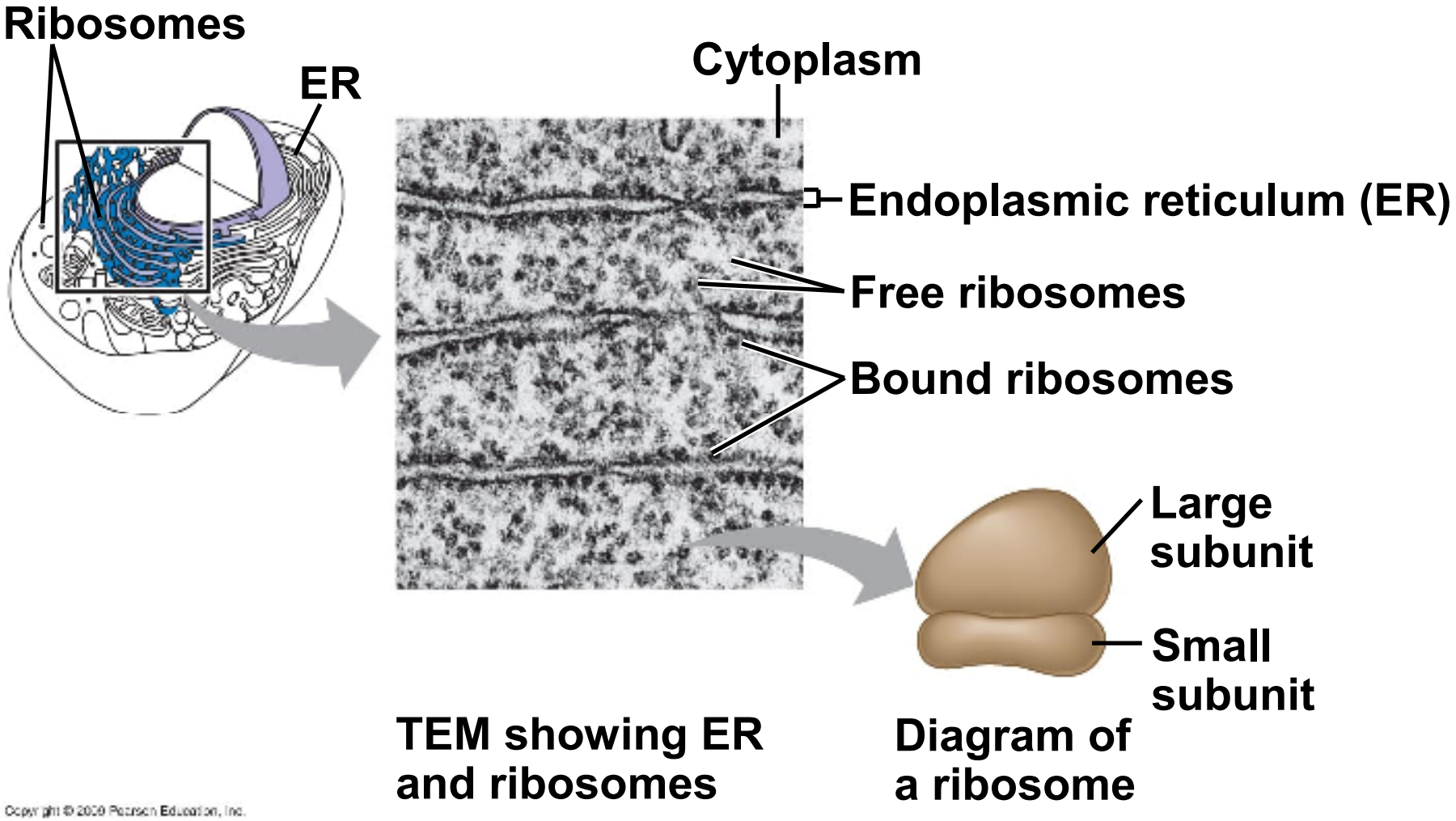
Ribosomes

4.7 Ribosomes make proteins for use in the cell and export

- **Ribosomes** are involved in the cell's protein synthesis
  - Ribosomes are synthesized in the nucleolus, which is found in the nucleus
  - Cells that must synthesize large amounts of protein have a large number of ribosomes

4.7 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
  - Bound ribosomes are attached to the endoplasmic reticulum (ER) associated with the nuclear envelope



4.8 Overview: Many cell organelles are connected through the endomembrane system

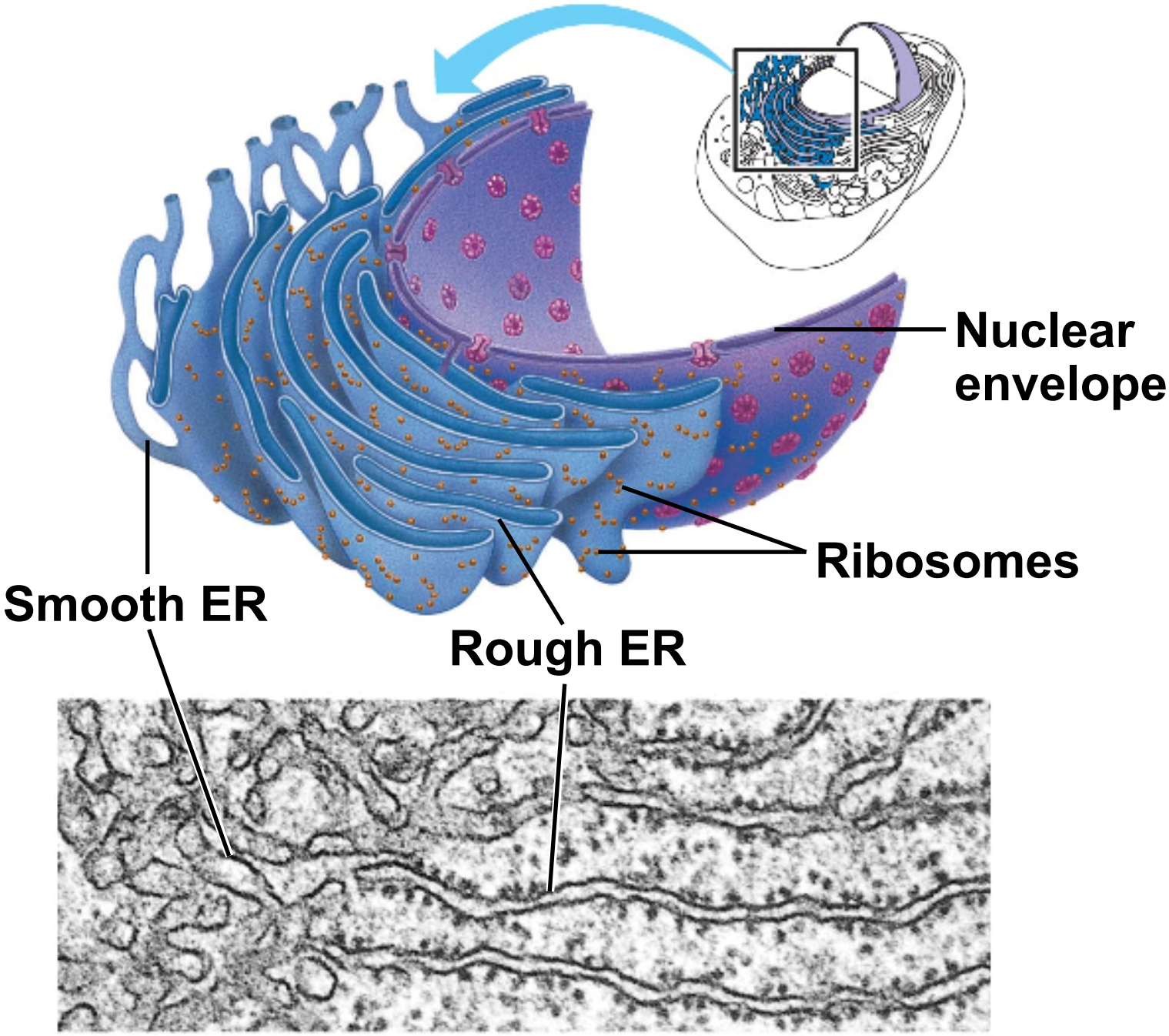
- The membranes within a eukaryotic cell are physically connected and compose the **endomembrane system**
  - The endomembrane system includes the nuclear envelope, endoplasmic reticulum (ER), Golgi apparatus, lysosomes, vacuoles, and the plasma membrane

4.8 Overview: Many cell organelles are connected through the endomembrane system

- Some components of the endomembrane system are able to communicate with others with formation and transfer of small membrane segments called **vesicles**
  - One important result of communication is the synthesis, storage, and export of molecules

4.9 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
  - They differ in structure and function
  - However, they are connected

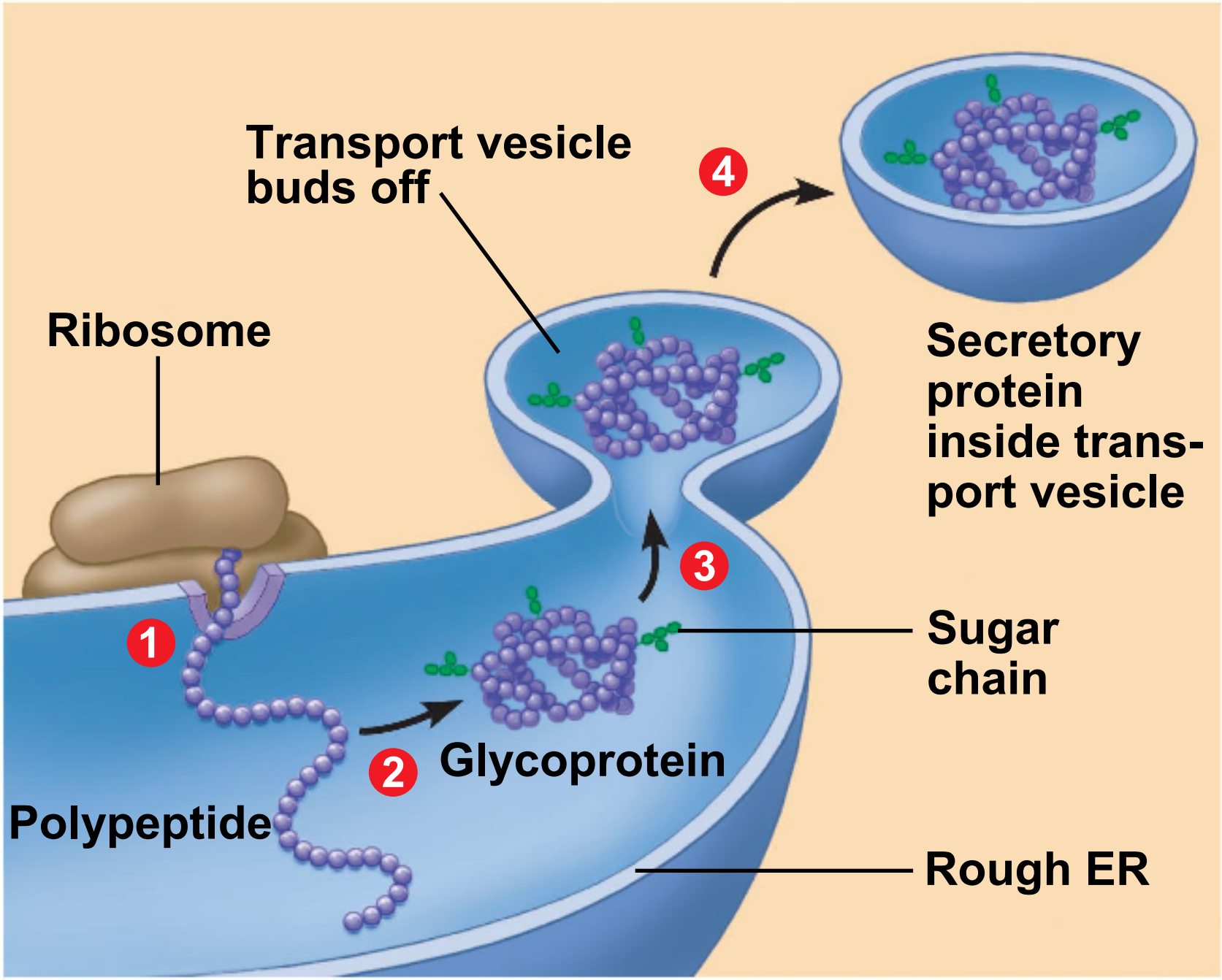


4.9 The endoplasmic reticulum is a biosynthetic factory

- Smooth ER is involved in a variety of diverse metabolic processes
  - For example, enzymes produced by the smooth ER are involved in the synthesis of lipids, oils, phospholipids, and steroids

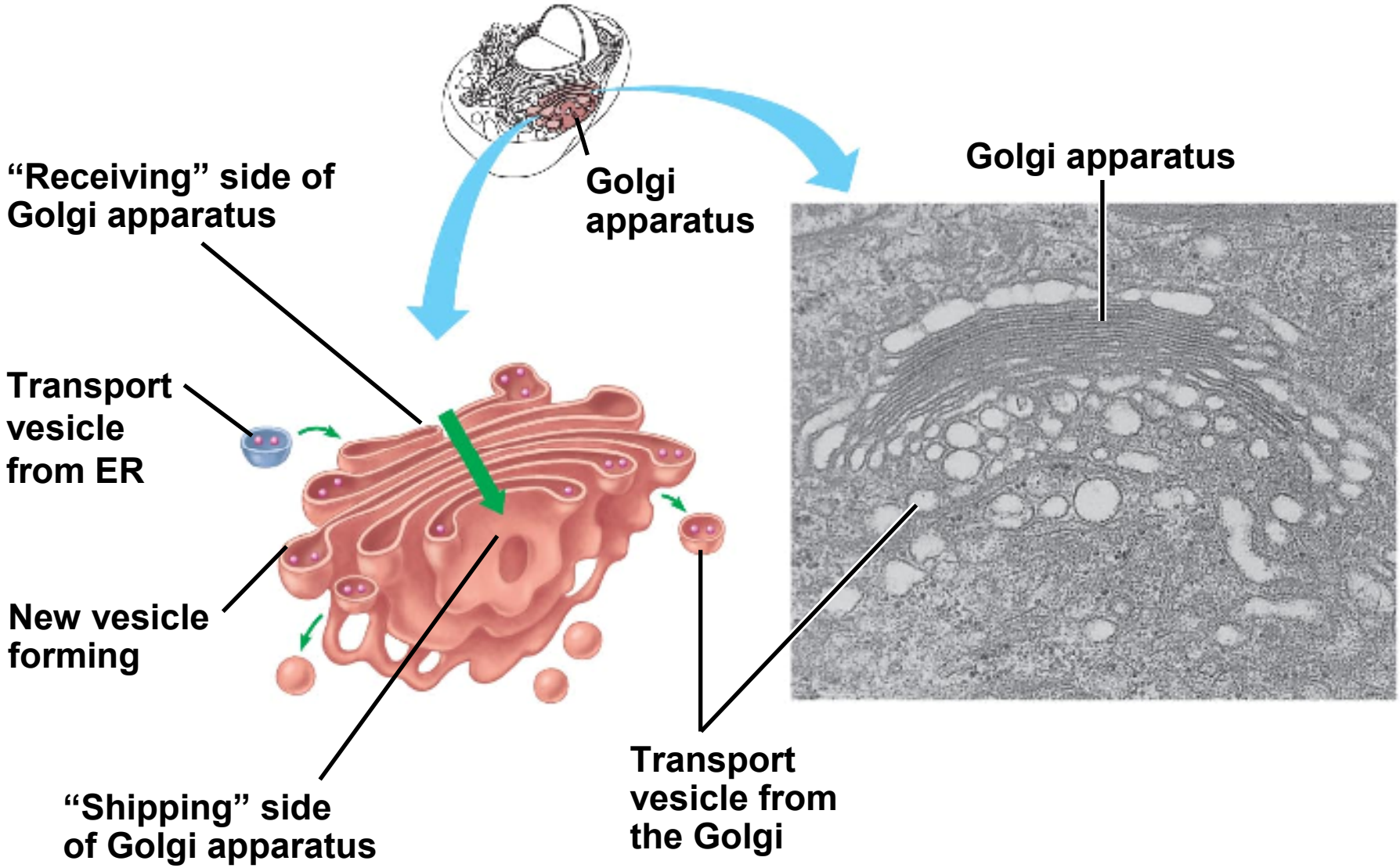
4.9 The endoplasmic reticulum is a biosynthetic factory

- Rough ER makes additional membrane for itself and proteins destined for secretion
  - Once proteins are synthesized, they are transported in vesicles to other parts of the endomembrane system



4.10 The Golgi apparatus finishes, sorts, and ships cell products

- The Golgi apparatus functions in conjunction with the ER by modifying products of 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



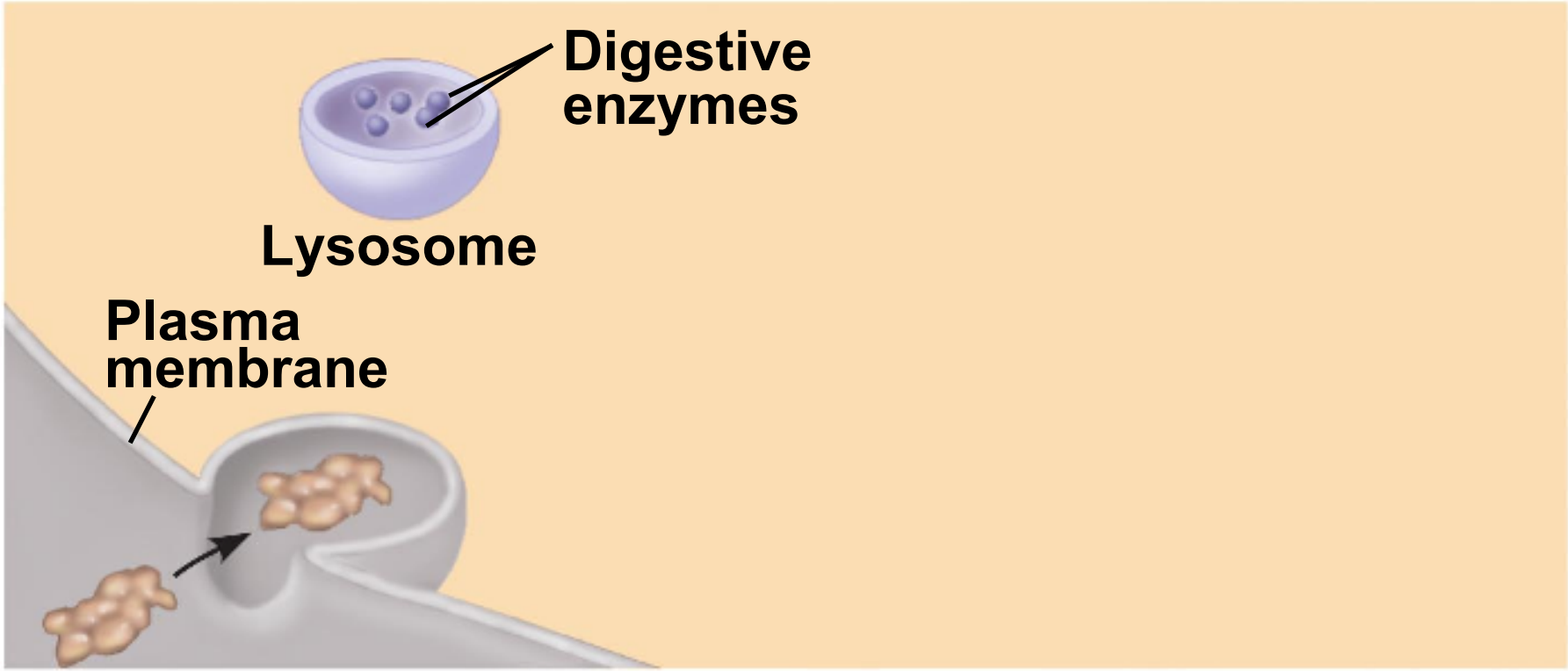
4.11 Lysosomes are digestive compartments within a cell

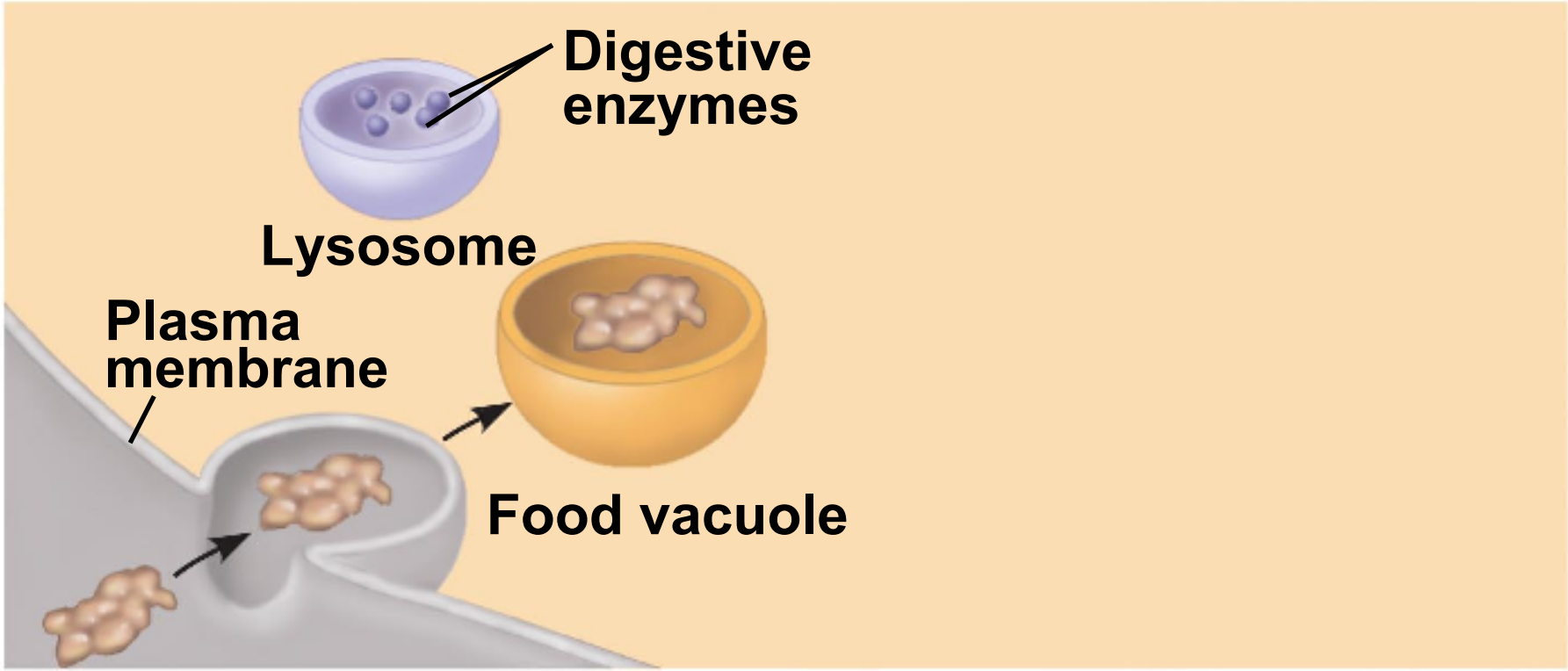
- A lysosome is a membranous sac containing digestive enzymes
  - The enzymes and membrane are produced by the ER and transferred to the Golgi apparatus for processing
  - The membrane serves to safely isolate these potent enzymes from the rest of the cell

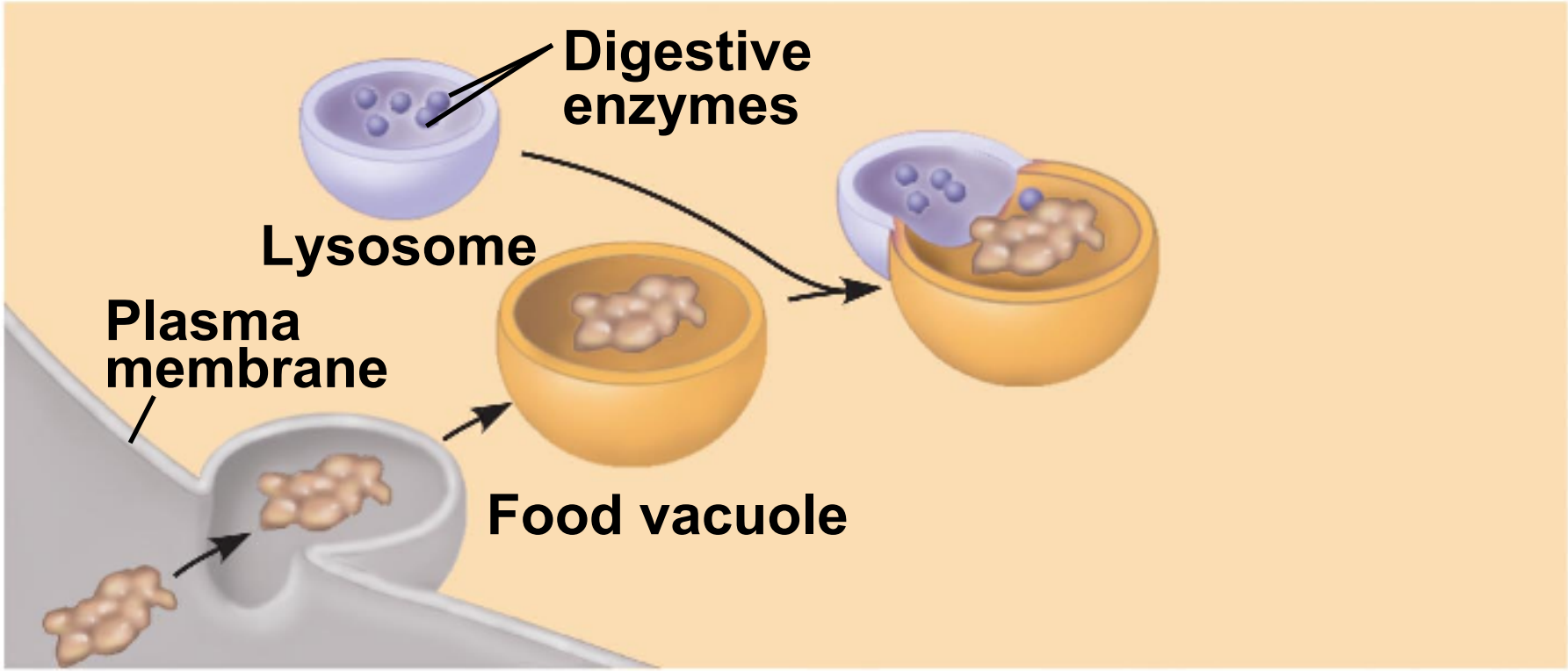
4.11 Lysosomes are digestive compartments within a cell

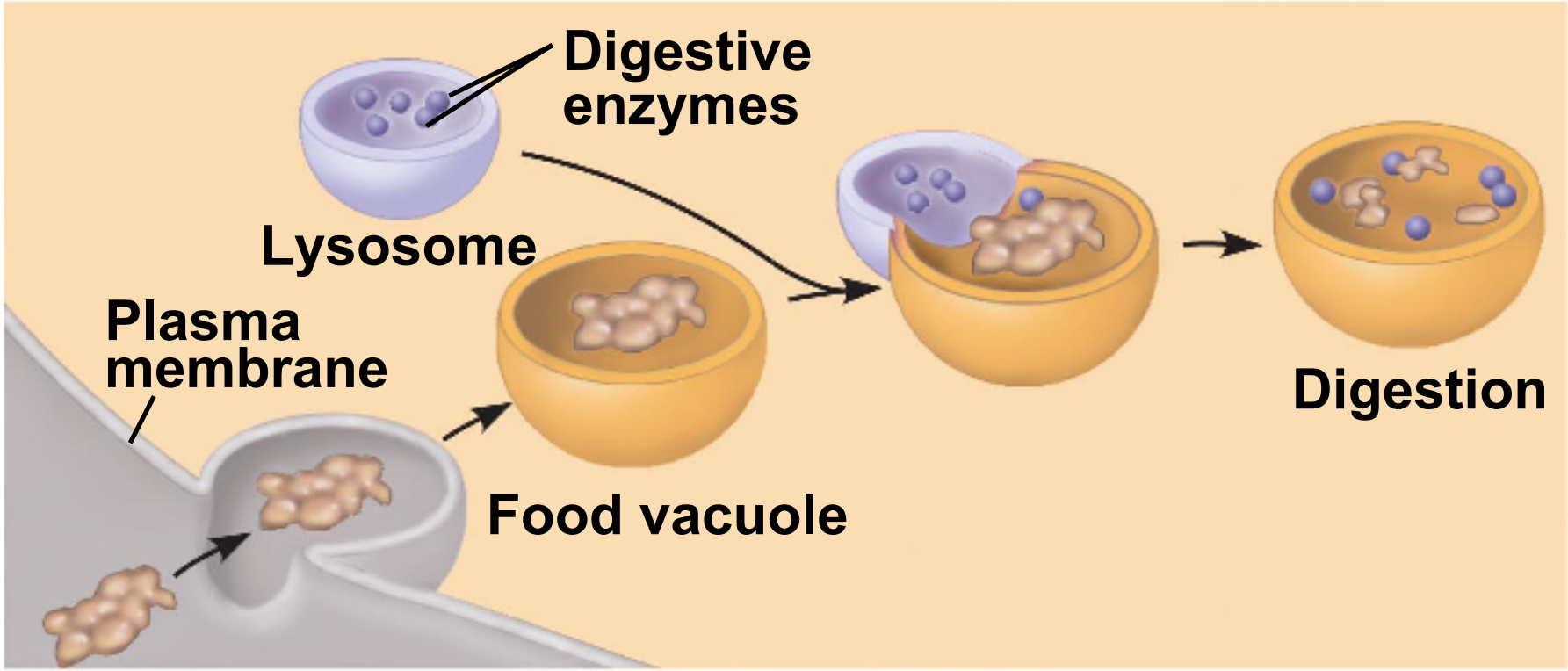
- One of the several functions of lysosomes is to remove or recycle damaged parts of a cell
  - The damaged organelle is first enclosed in a membrane vesicle
  - Then a lysosome fuses with the vesicle, dismantling its contents and breaking down the damaged organelle

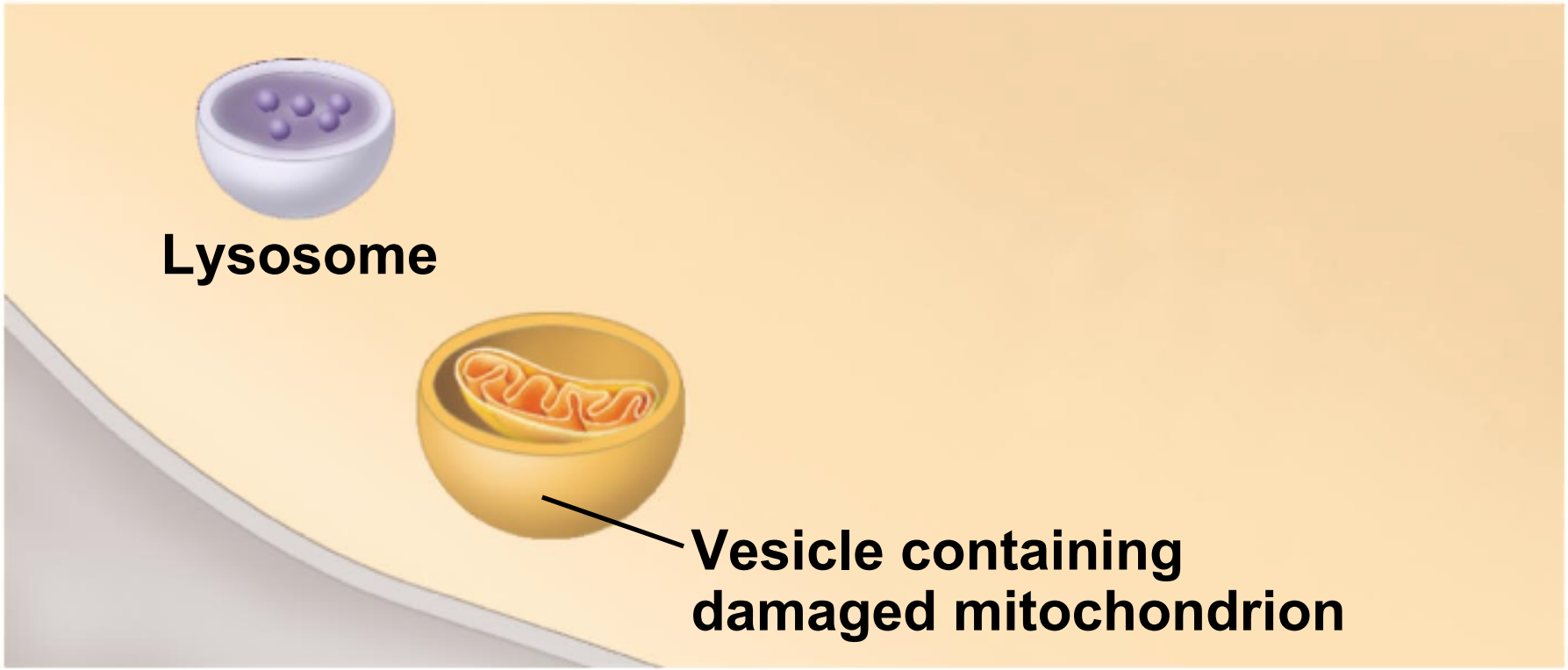
PLAY Animation: Lysosome Formation

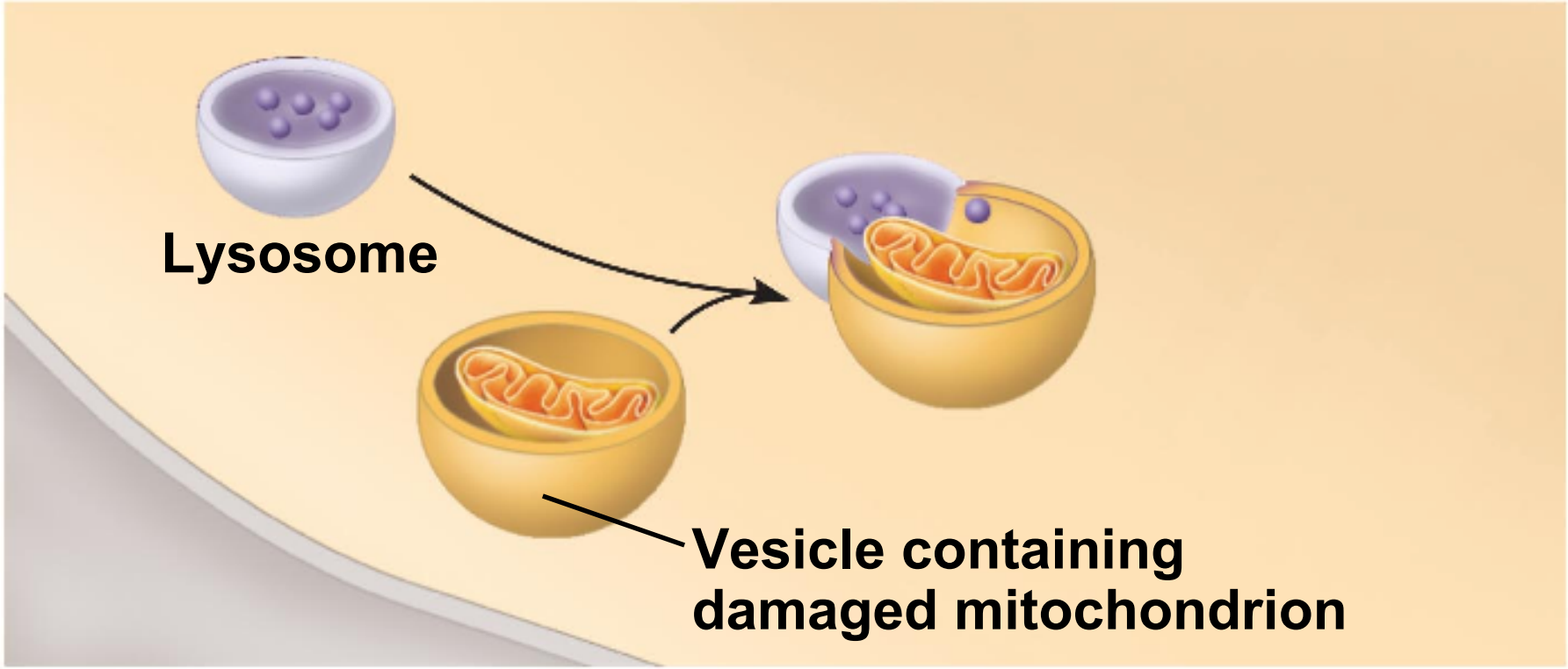


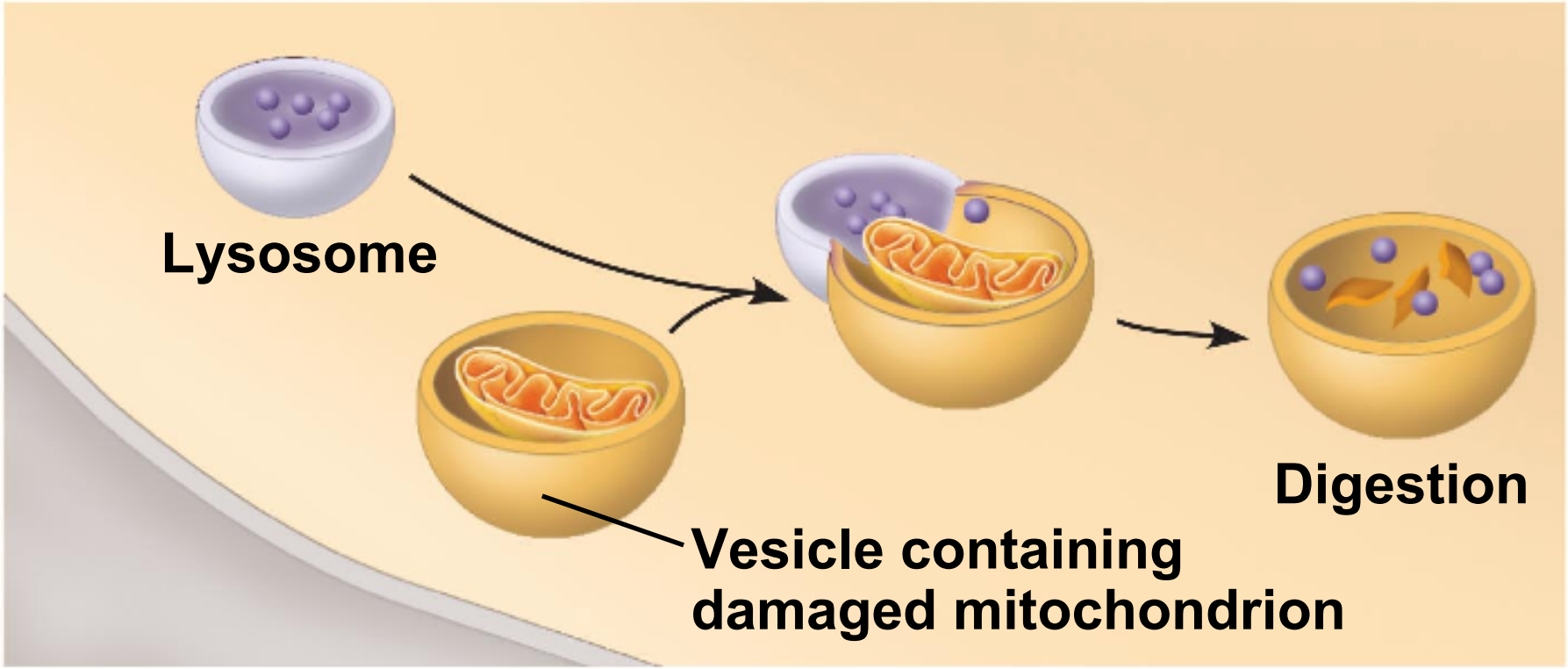










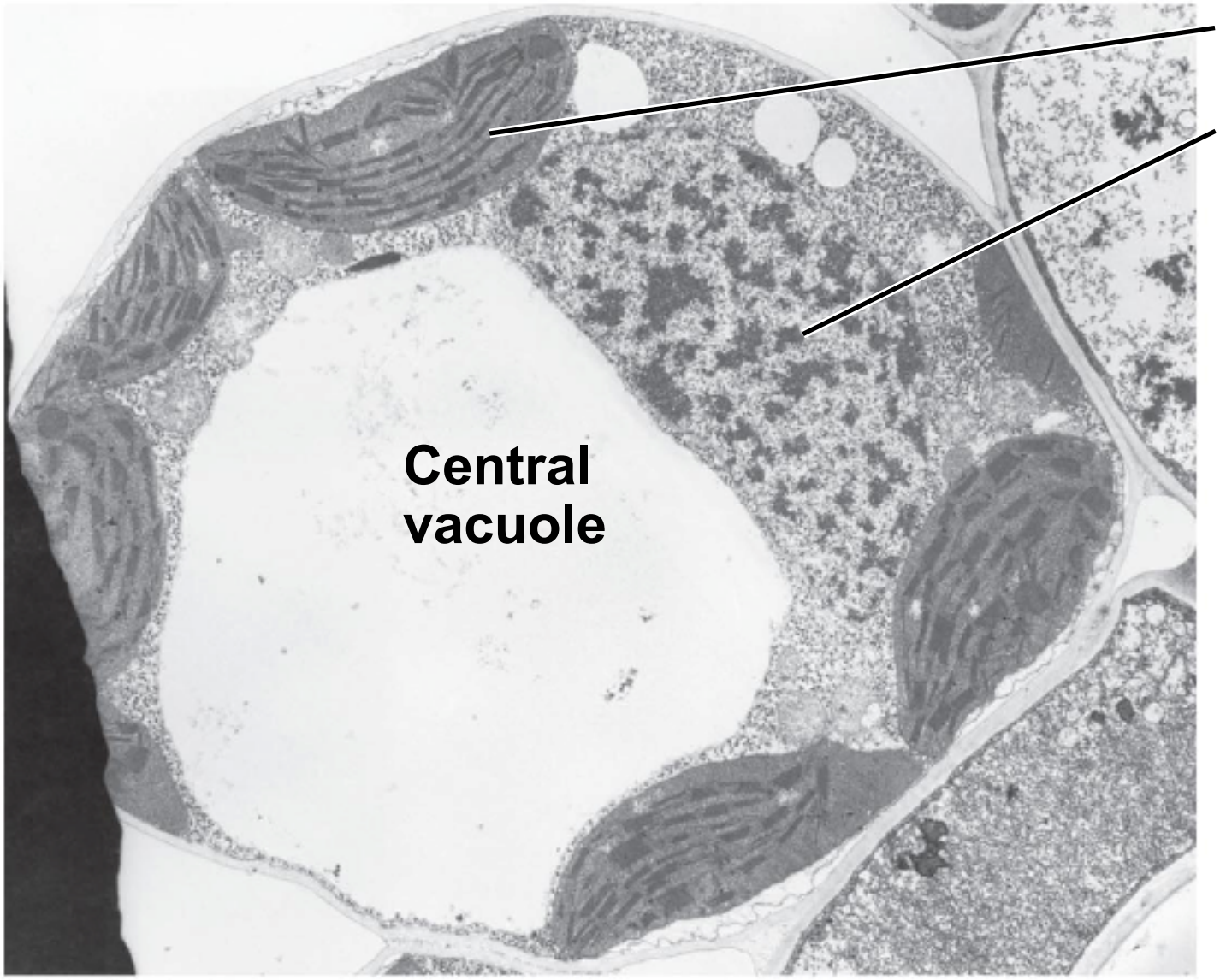


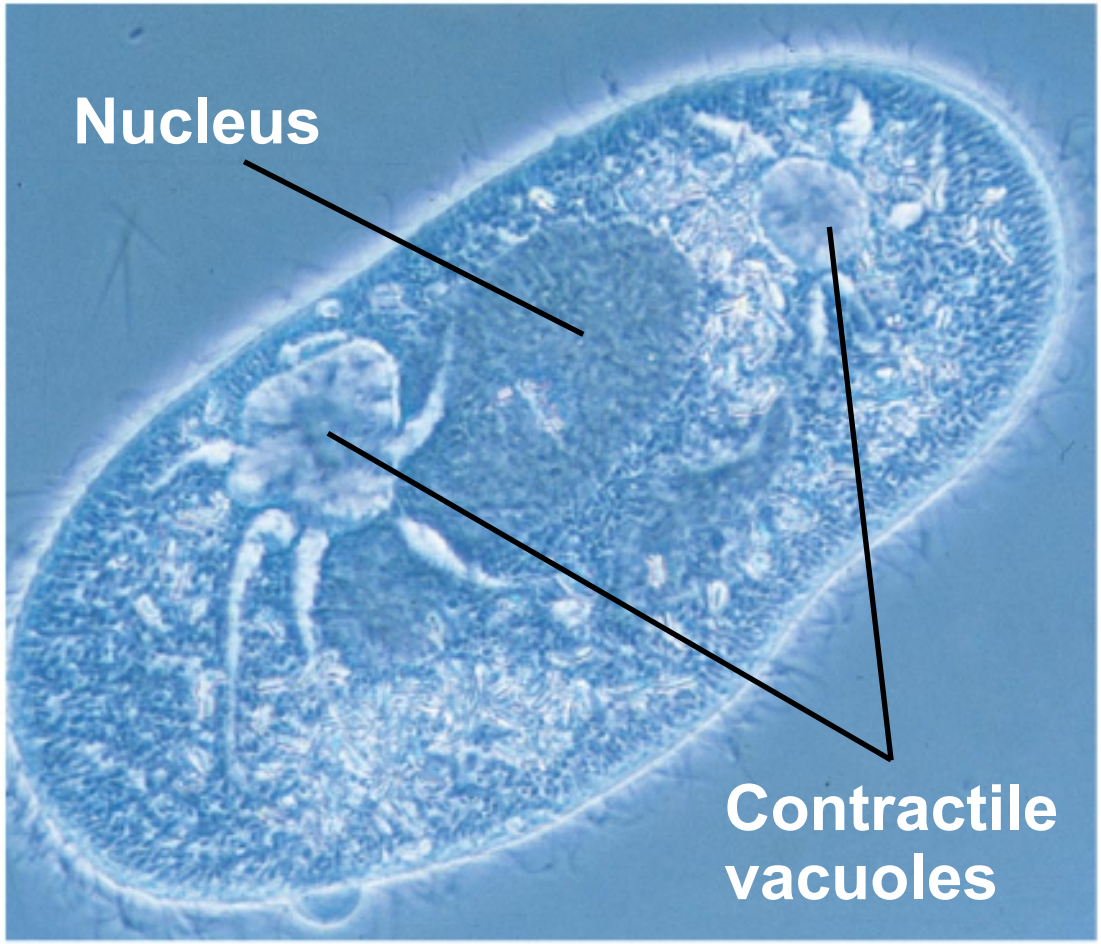
4.12 Vacuoles function in the general maintenance of the cell

- **Vacuoles** are membranous sacs that are found in a variety of cells and possess an assortment of functions
  - Examples are the central vacuole in plants with hydrolytic functions, pigment vacuoles in plants to provide color to flowers, and contractile vacuoles in some protists to expel water from the cell

PLAY

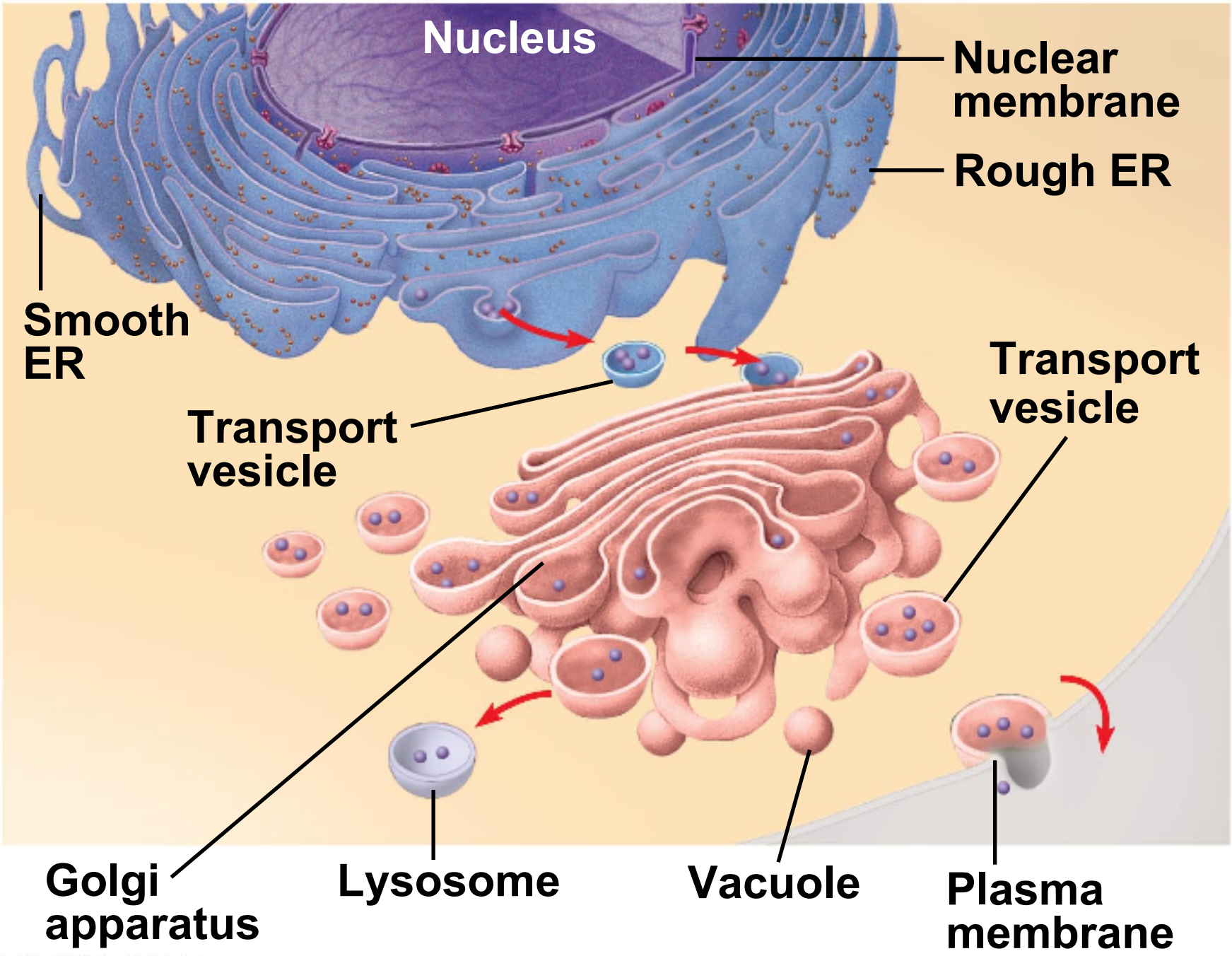
Video: *Paramecium* Vacuole





4.13 A review of the structures involved in manufacturing and breakdown

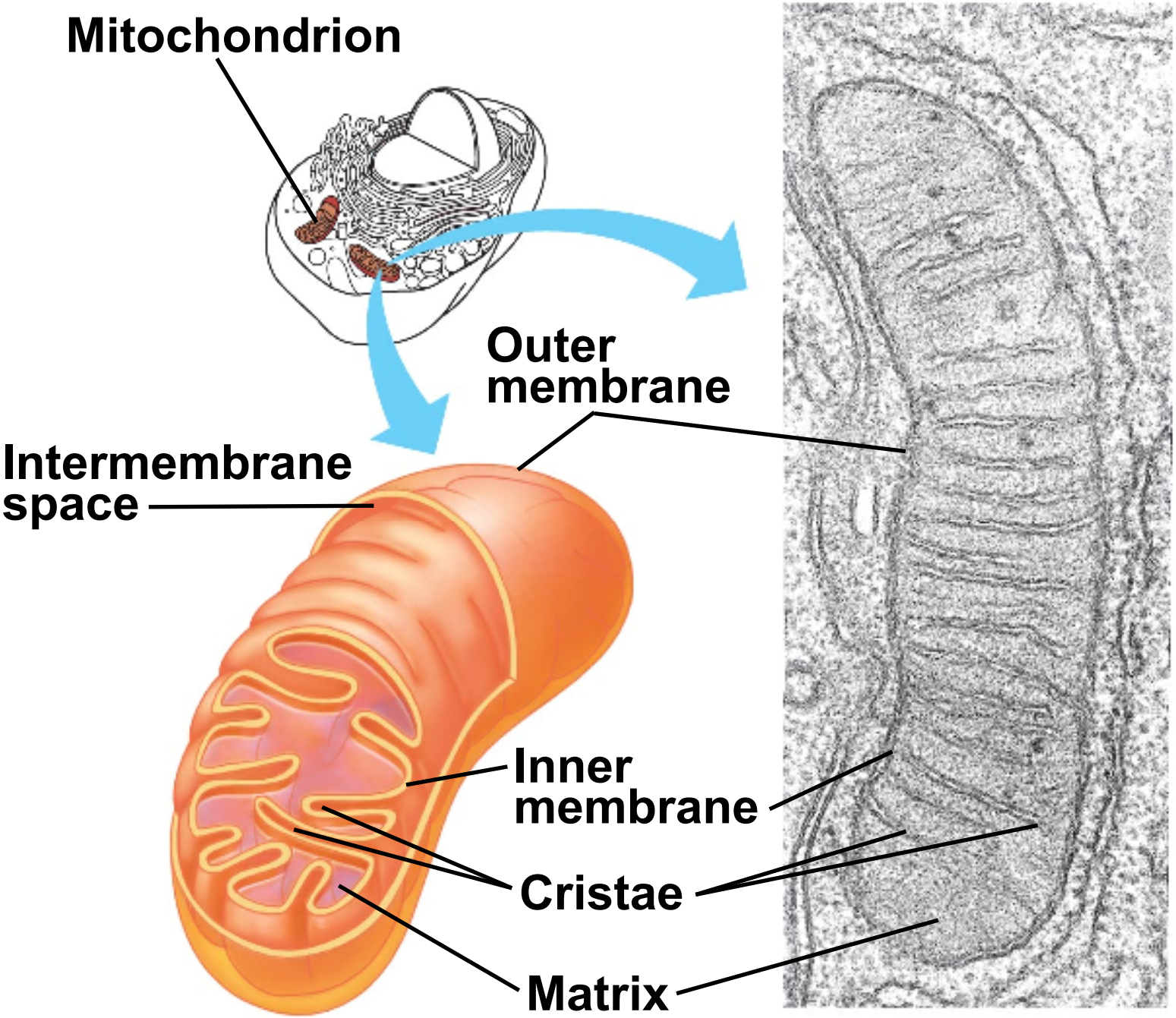
- The following figure summarizes the relationships among the major organelles of the endomembrane system



ENERGY-CONVERTING ORGANELLES

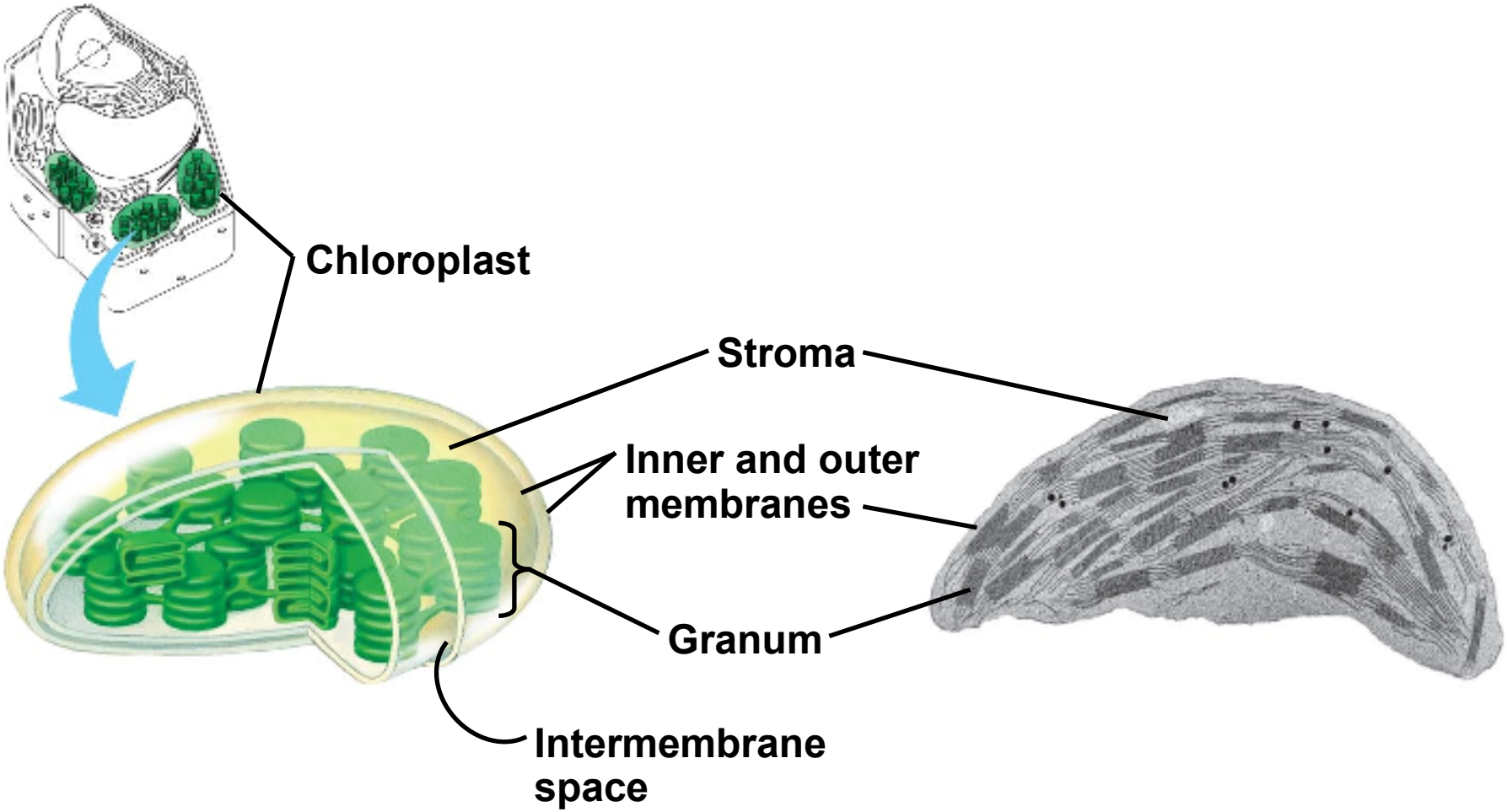
4.14 Mitochondria harvest chemical energy from food

- Cellular respiration is accomplished in the **mitochondria** of eukaryotic cells
  - Cellular respiration involves conversion of chemical energy in foods to chemical energy in ATP (adenosine triphosphate)
  - Mitochondria have two internal compartments
    - The **intermembrane space**, which encloses the **mitochondrial matrix** where materials necessary for ATP generation are found



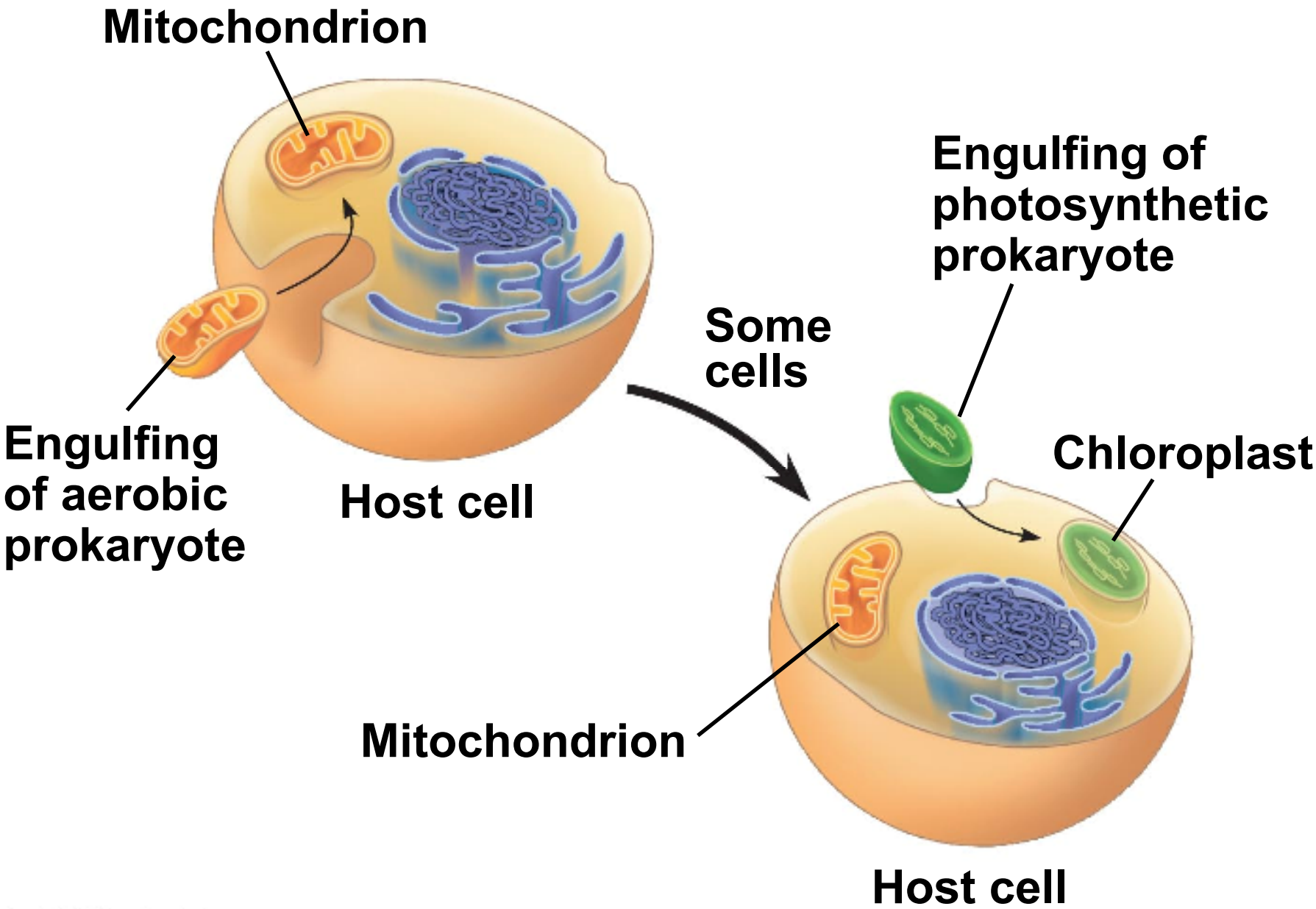
4.15 Chloroplasts convert solar energy to chemical energy

- **Chloroplasts** are the photosynthesizing organelles of plants
  - **Photosynthesis** is the conversion of light energy to chemical energy of sugar molecules
- Chloroplasts are partitioned into compartments
  - The important parts of chloroplasts are the stroma, thylakoids, and grana



4.16 EVOLUTION CONNECTION: Mitochondria and chloroplasts evolved by endosymbiosis

- When compared, you find that mitochondria and chloroplasts have (1) DNA and (2) ribosomes
  - The structure of both DNA and ribosomes is very similar to that found in prokaryotic cells, and mitochondria and chloroplasts replicate much like prokaryotes
- The hypothesis of **endosymbiosis** proposes that mitochondria and chloroplasts were formerly small prokaryotes that began living within larger cells
  - Symbiosis benefited both cell types

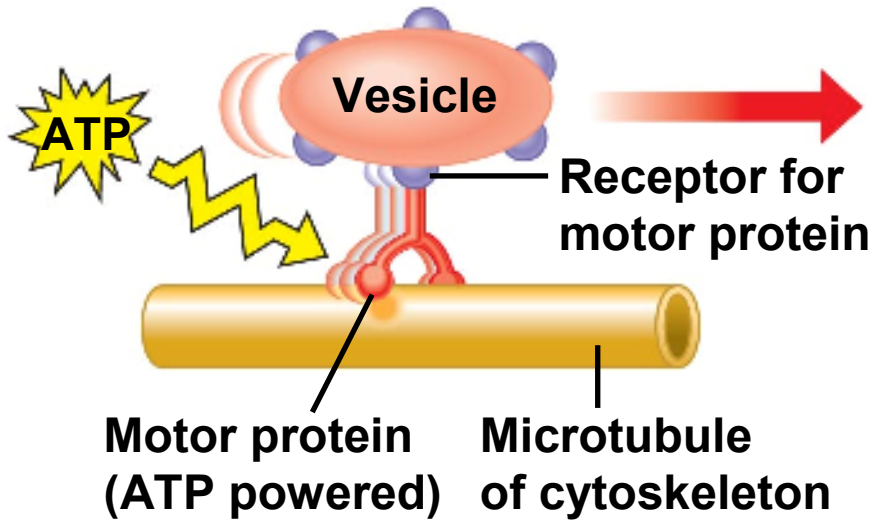


INTERNAL AND EXTERNAL SUPPORT: THE CYTOSKELETON AND CELL SURFACES

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

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

PLAY Video: Cytoplasmic Streaming



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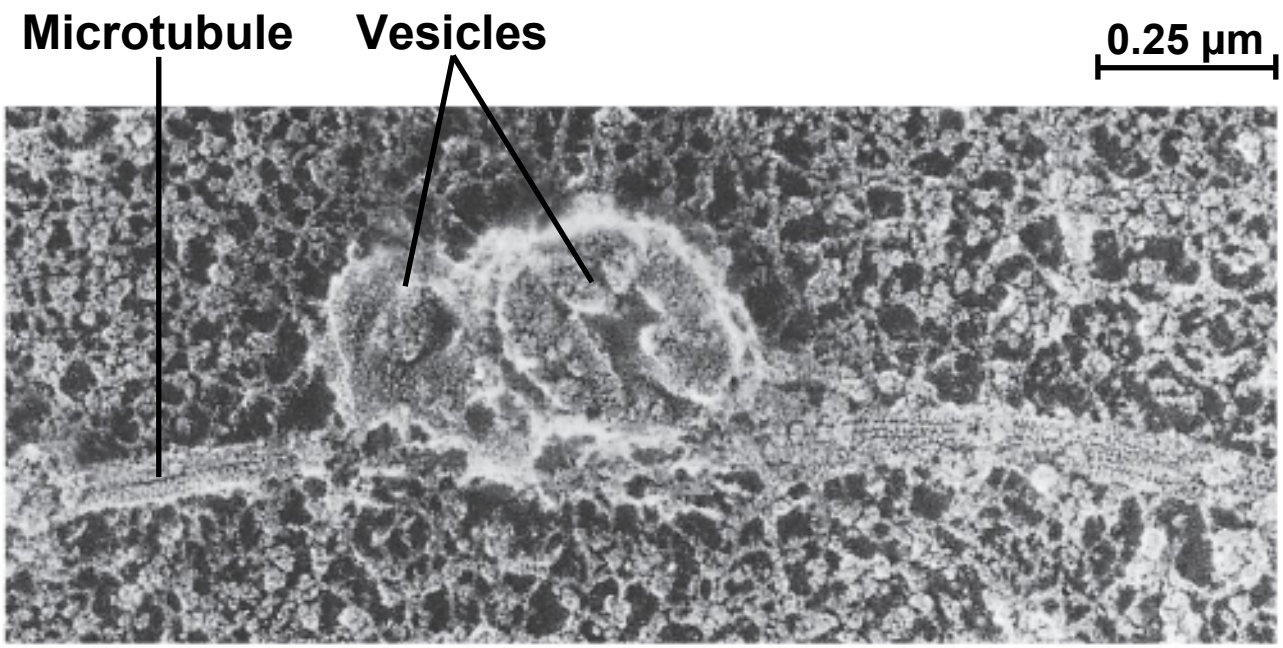
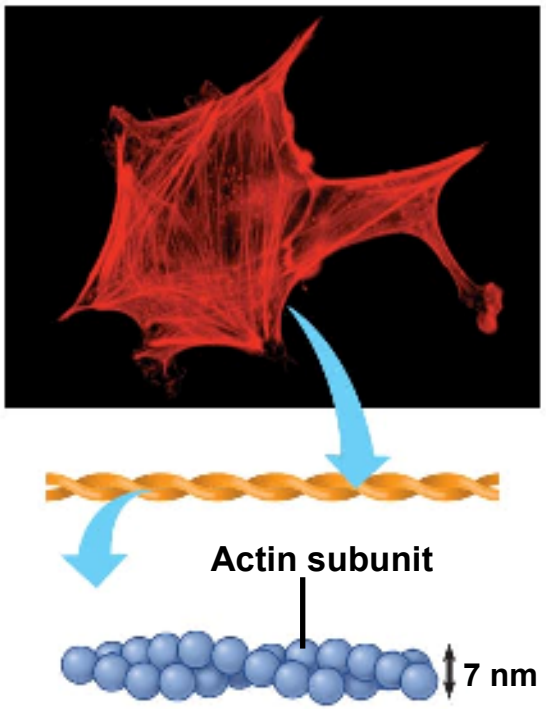


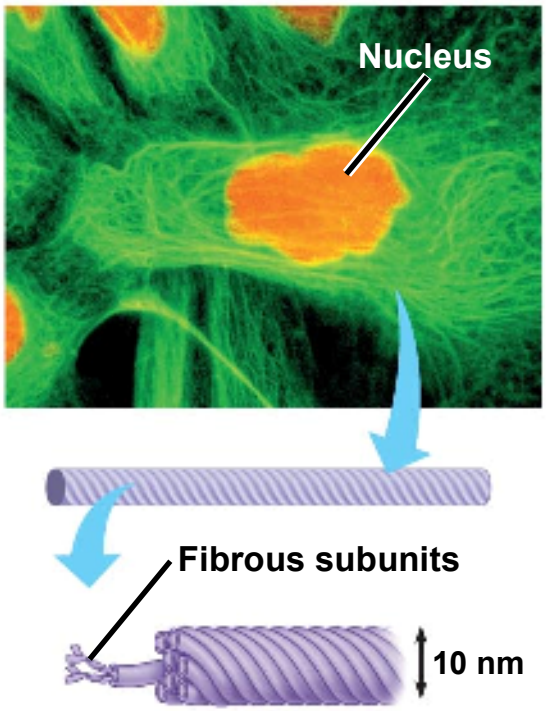
(b)

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

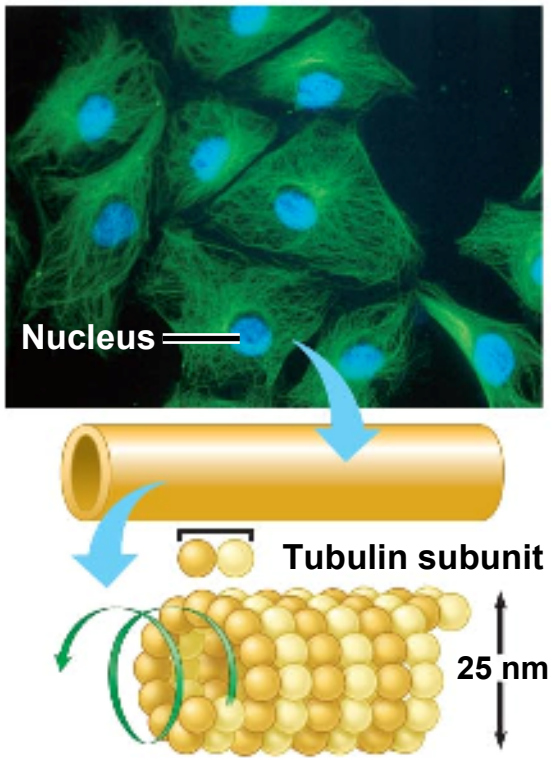
- The cytoskeleton is composed of three kinds of fibers
  - **Microfilaments** (actin filaments) support the cell's shape and are involved in motility
  - **Intermediate filaments** reinforce cell shape and anchor organelles
  - **Microtubules** (made of tubulin) shape the cell and act as tracks for motor protein



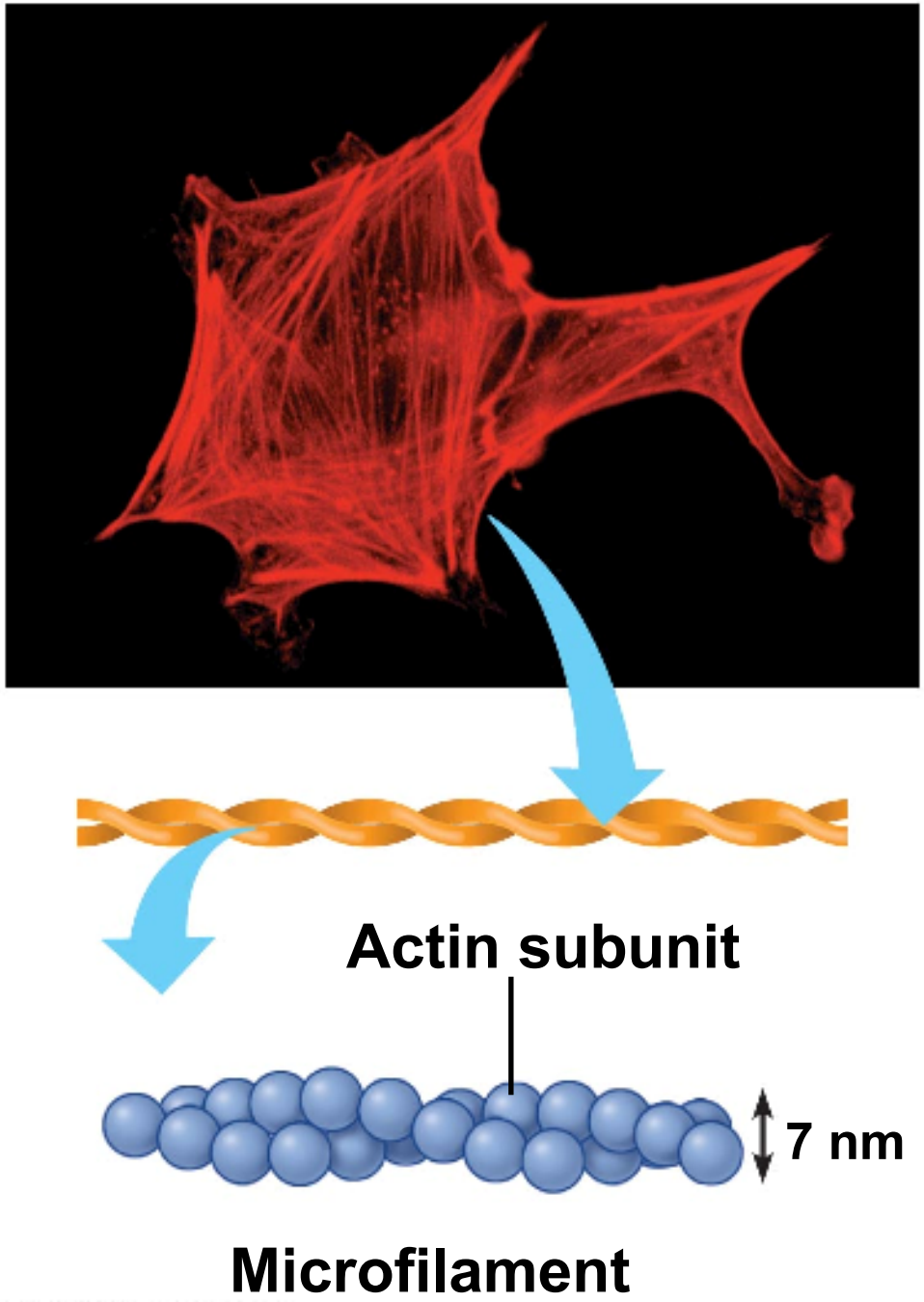
Microfilament

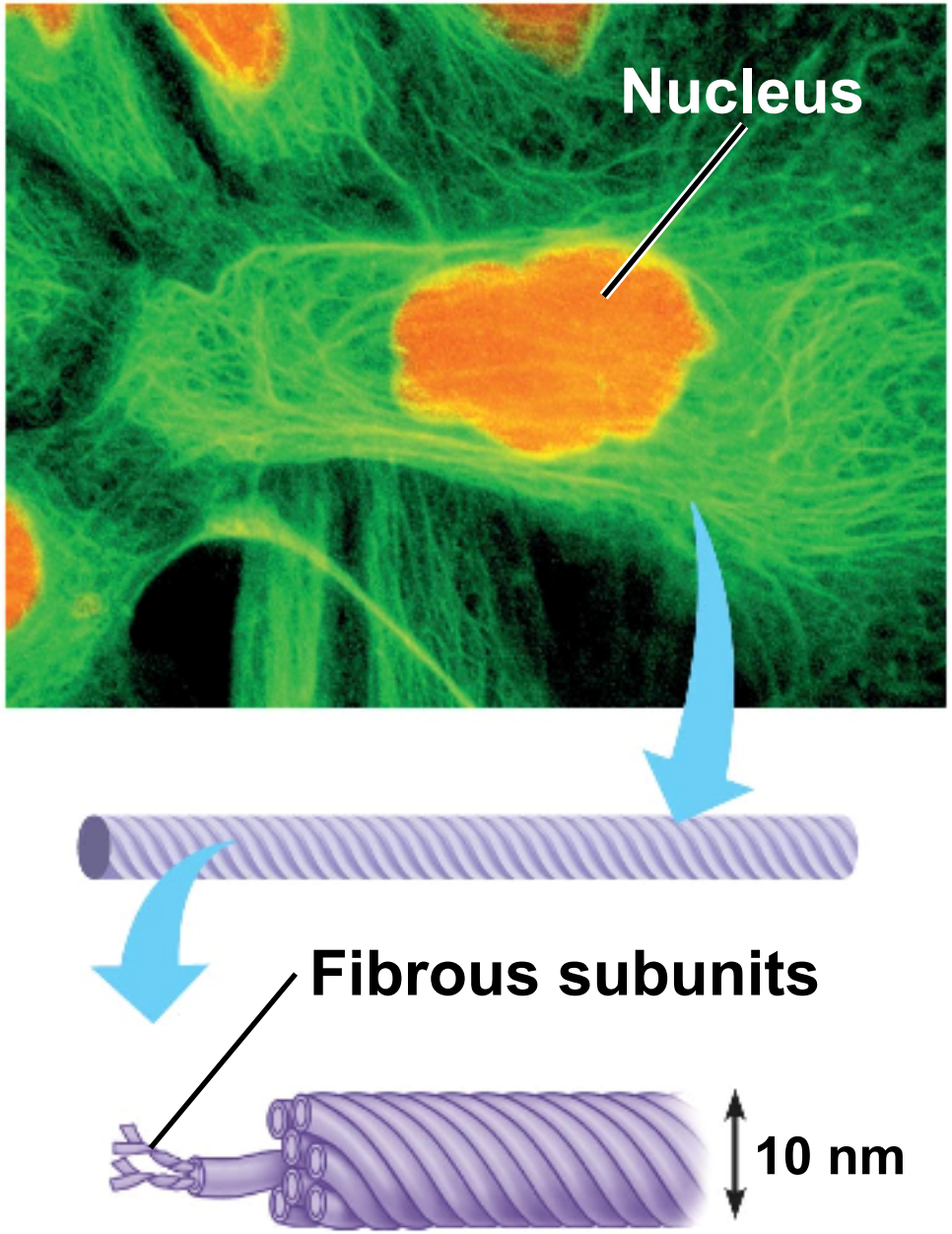


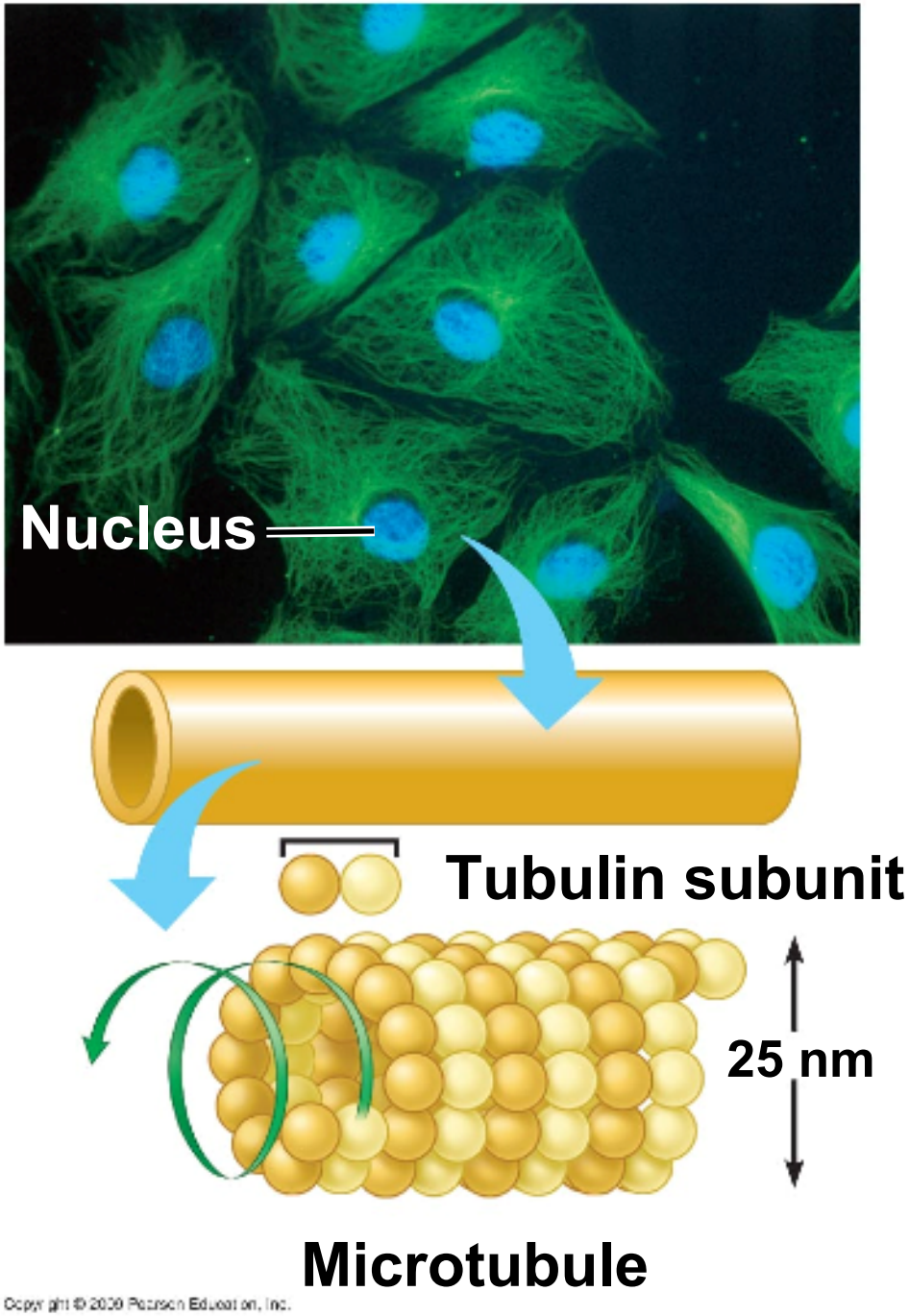
Intermediate filament



Microtubule





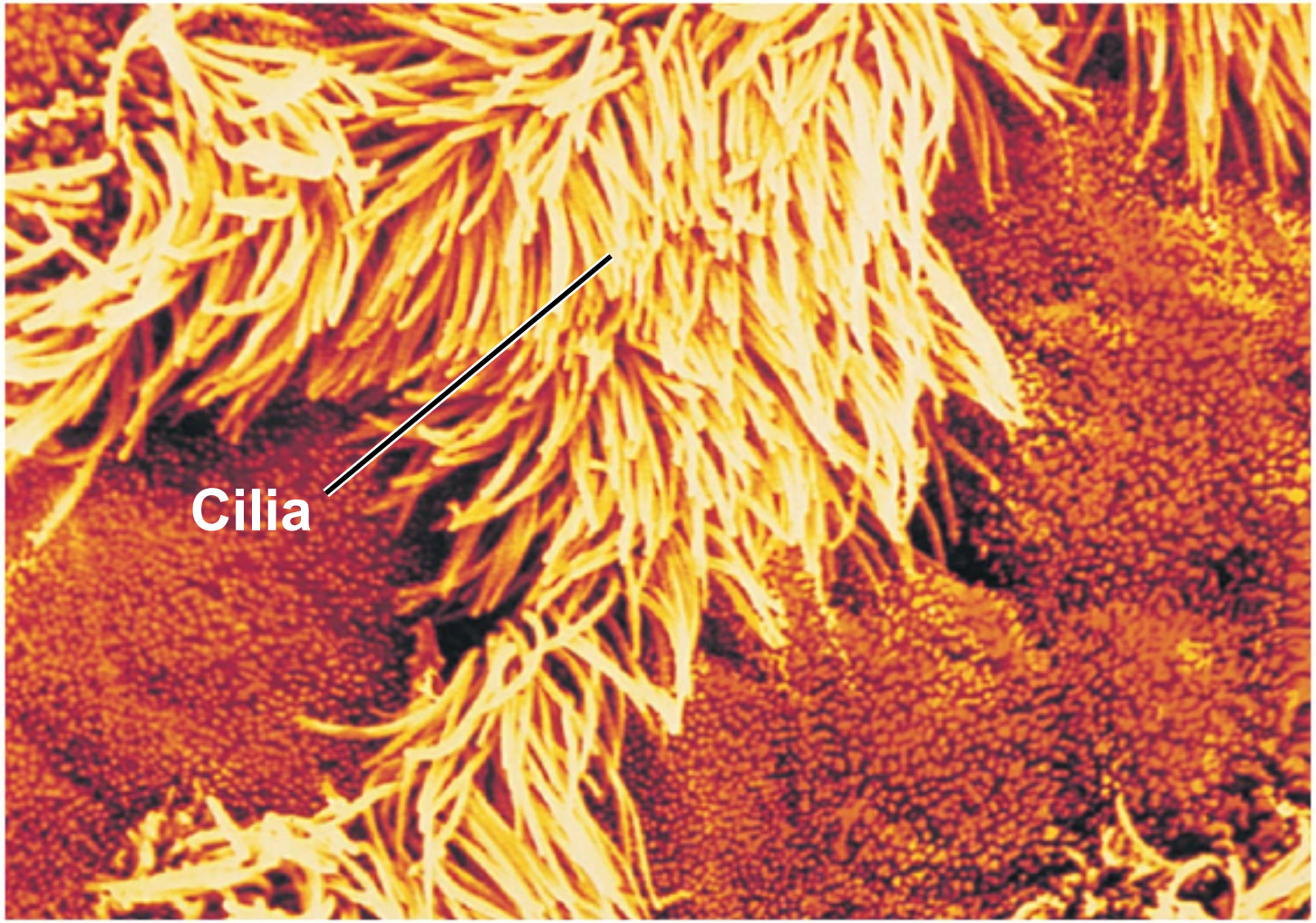


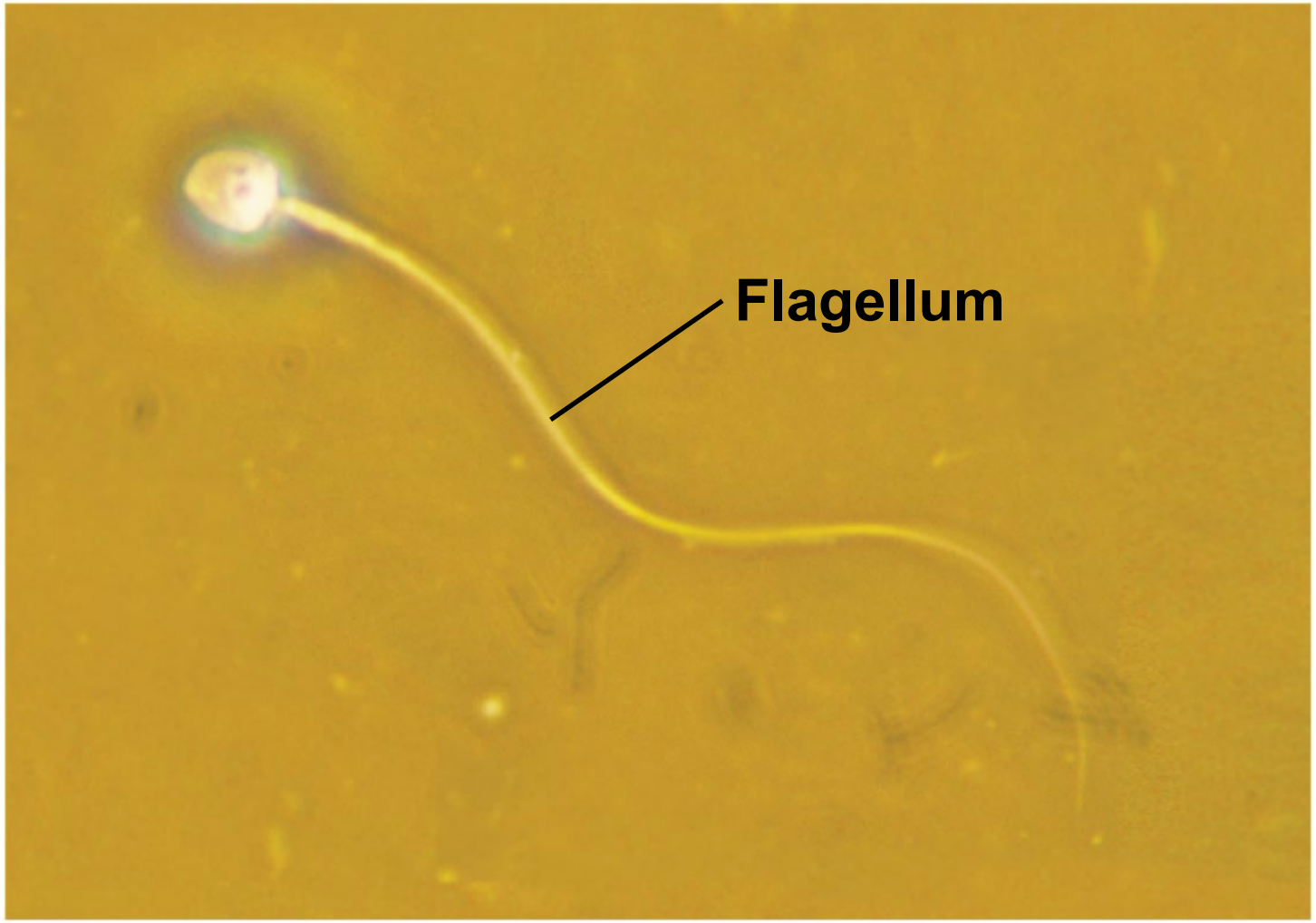
4.18 Cilia and flagella move when microtubules bend

- 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

PLAY Video: *Paramecium* Cilia

PLAY Video: *Chlamydomonas*





4.18 Cilia and flagella move when microtubules bend

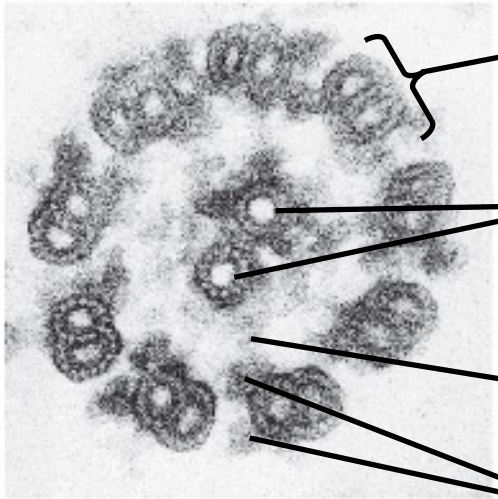
- A flagellum propels a cell by an undulating, whiplike motion
- Cilia, however, work more like the oars of a crew boat
- Although differences exist, flagella and cilia have a common structure and mechanism of movement

4.18 Cilia and flagella move when microtubules bend

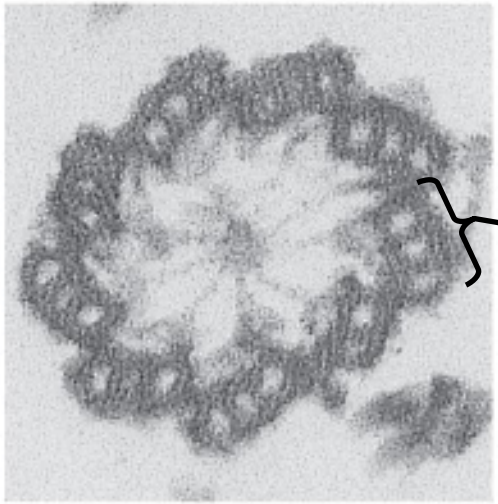
- Both flagella and cilia are made of microtubules wrapped in an extension of the plasma membrane
- A ring of nine microtubule doublets surrounds a central pair of microtubules
  - This arrangement is called the 9 + 2 pattern and is anchored in a basal body with nine microtubule triplets arranged in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

PLAY Animation: Cilia and Flagella

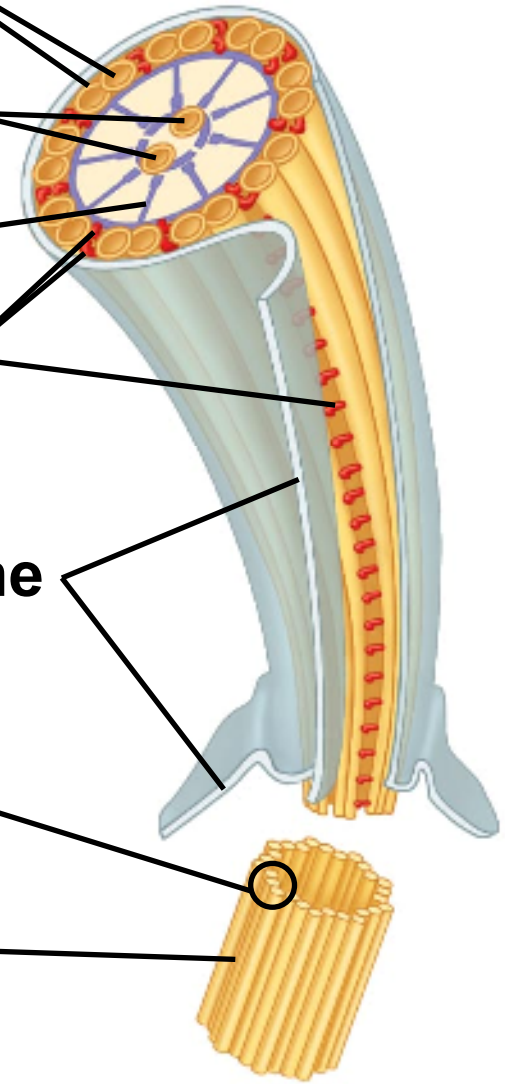
Cross sections:



Flagellum



Basal body

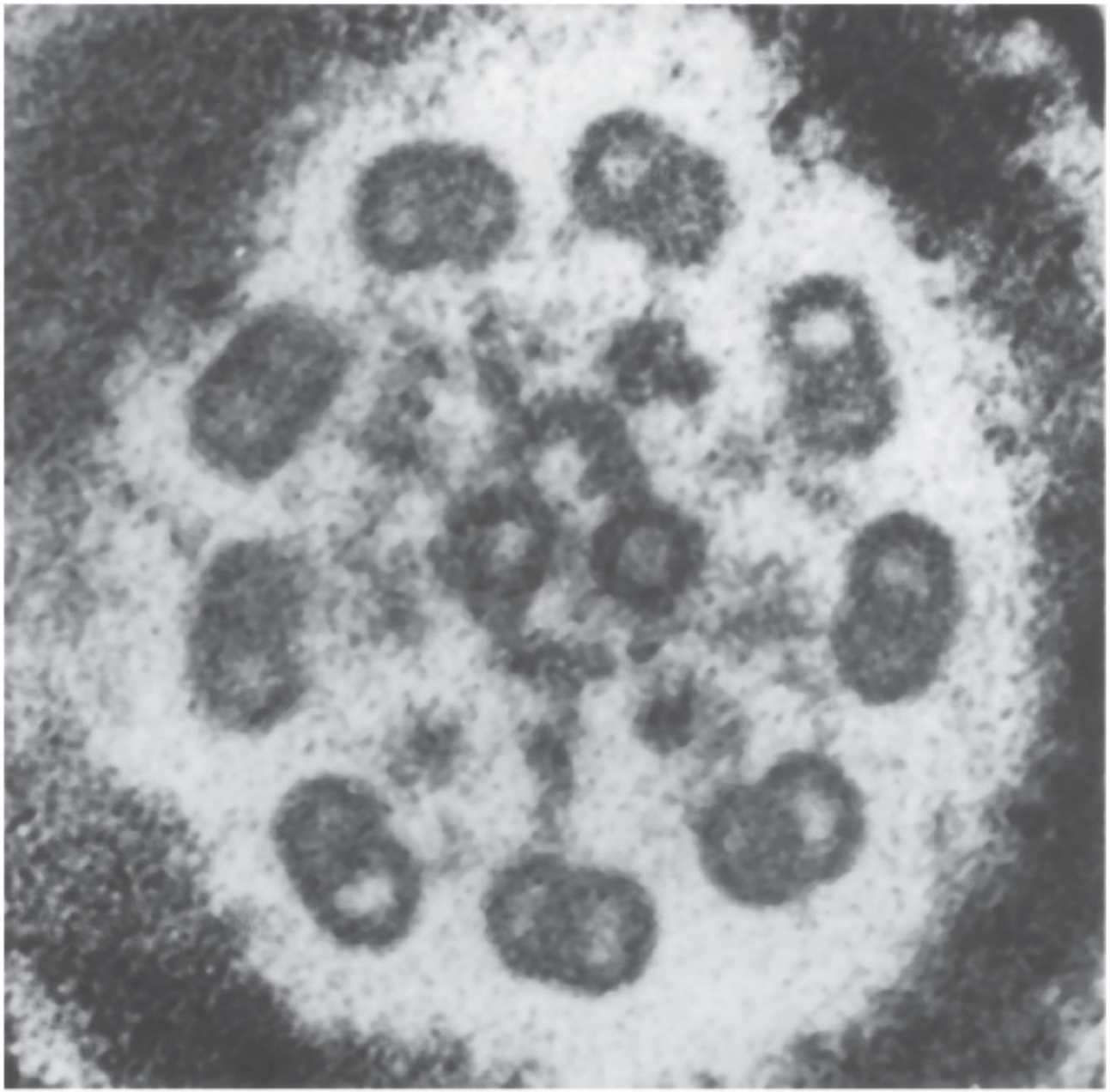


4.18 Cilia and flagella move when microtubules bend

- Cilia and flagella move by bending motor proteins called dynein arms
  - These 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

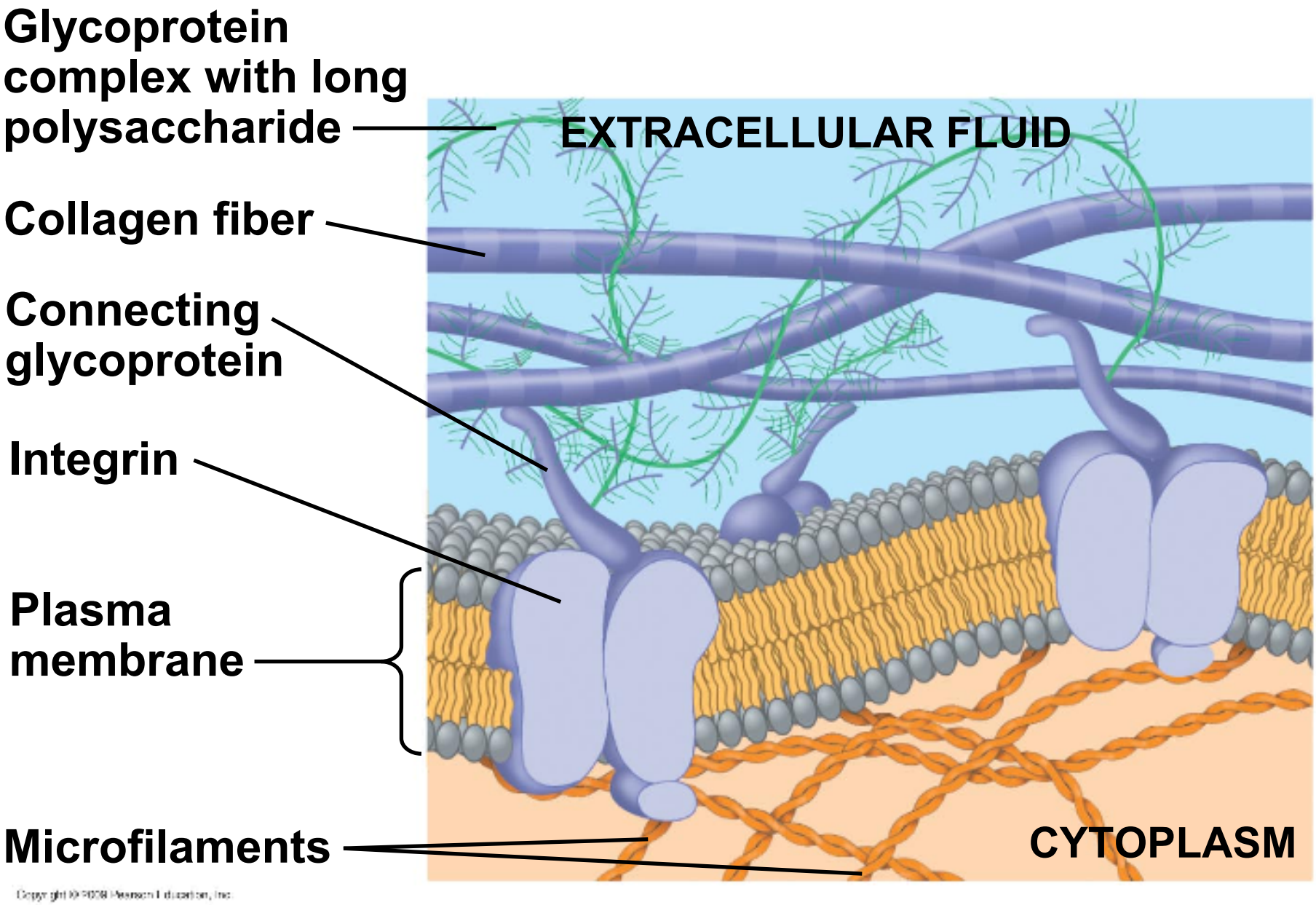
4.19 CONNECTION: Problems with sperm motility may be environmental or genetic

- There has been a decline in sperm quality
  - A group of chemicals called phthalates used in a variety of things people use every day may be the cause
- On the other hand, there are genetic reasons that sperm lack motility
  - Primary ciliary dyskinesia (PCD) is an example



4.20 The extracellular matrix of animal cells functions in support, movement, and regulation

- Cells synthesize and secrete the **extracellular matrix** (**ECM**) that is essential to cell function
  - The ECM is composed of strong fibers of collagen, which holds cells together and protects the plasma membrane
  - ECM attaches through connecting proteins that bind to membrane proteins called **integrins**
    - Integrins span the plasma membrane and connect to microfilaments of the cytoskeleton



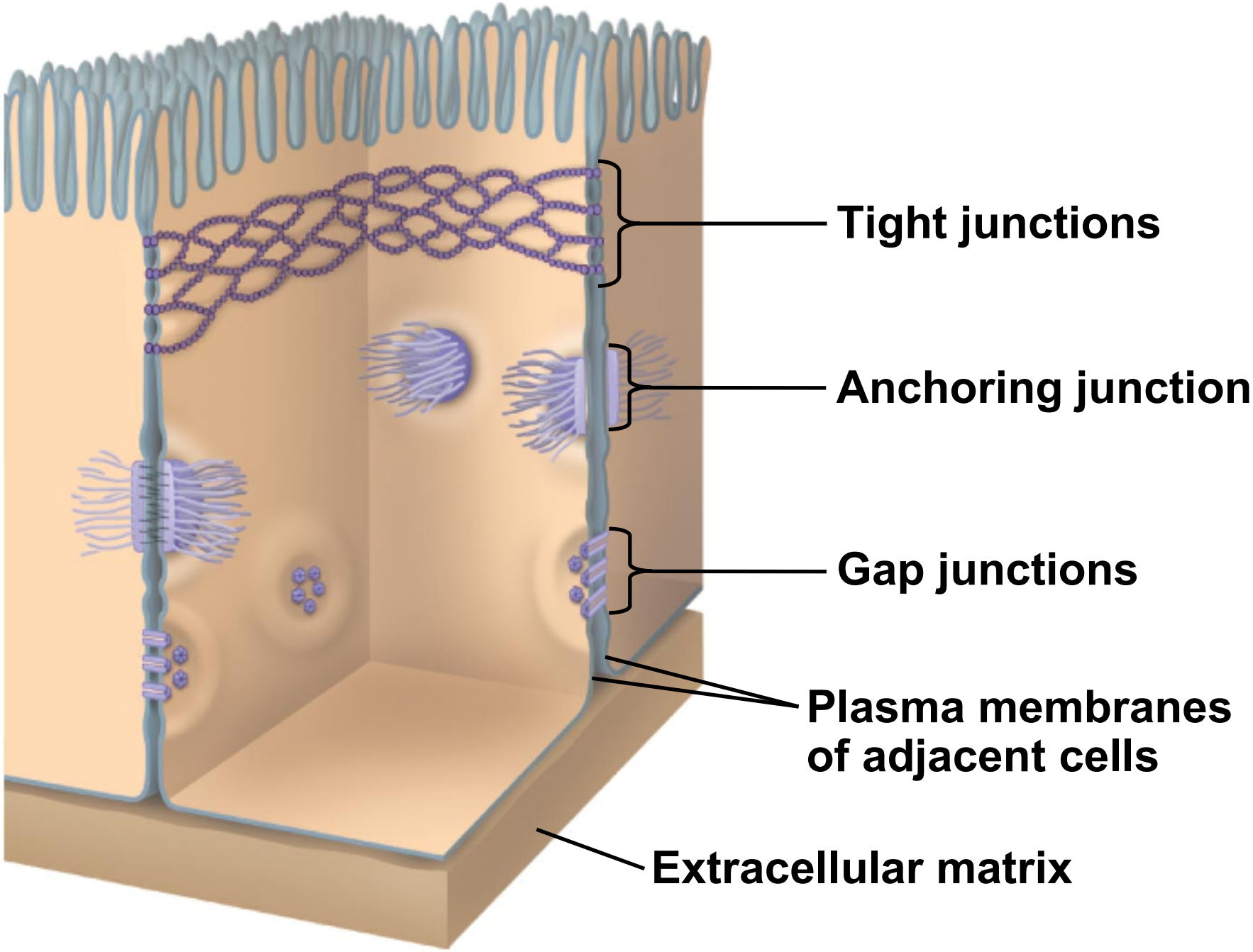
4.21 Three types of cell junctions are found in animal tissues

- 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

PLAY Animation: Desmosomes

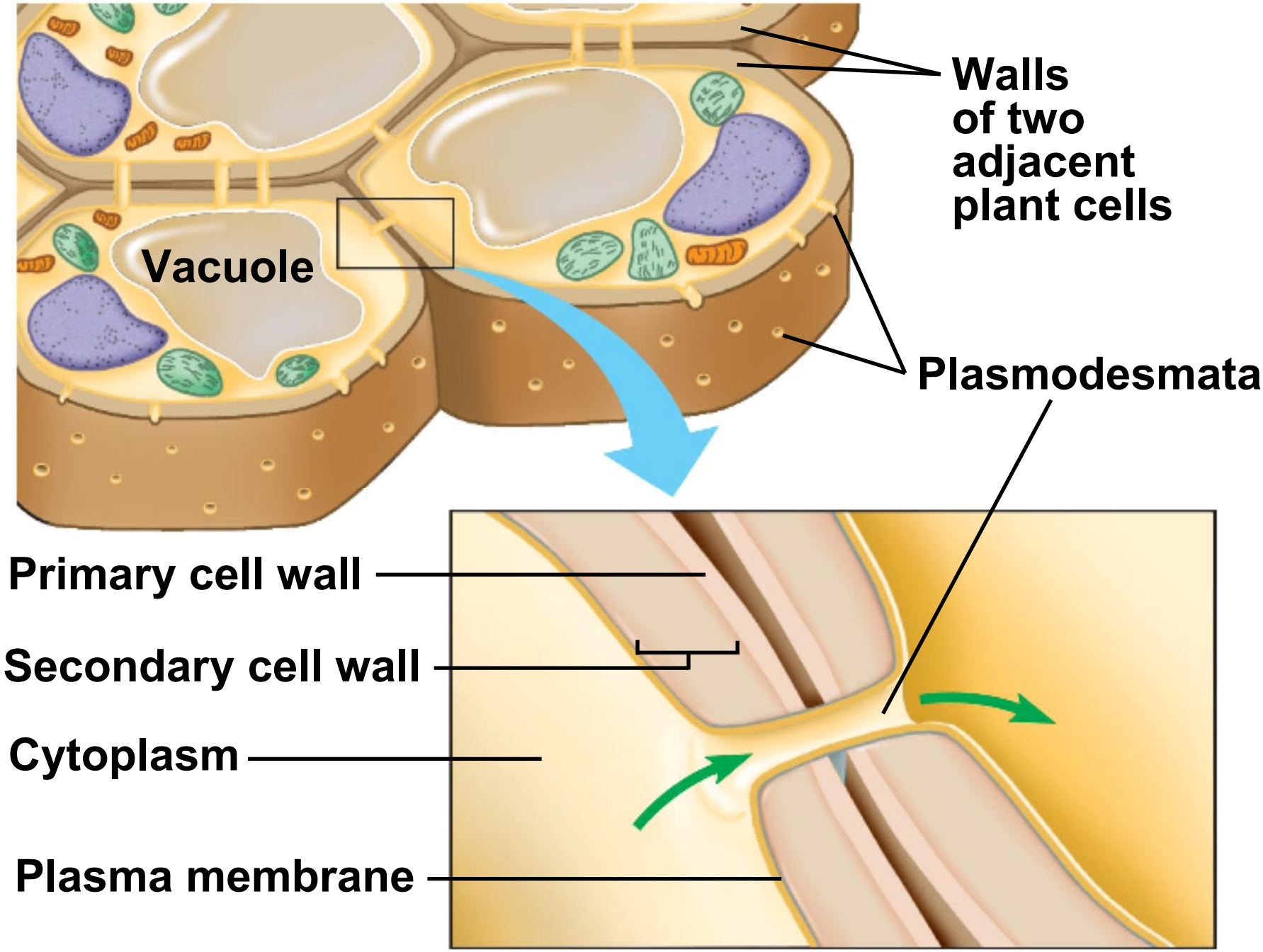
PLAY Animation: Gap Junctions

PLAY Animation: Tight Junctions



4.22 Cell walls enclose and support plant cells

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



FUNCTIONAL CATEGORIES OF CELL STRUCTURES

4.23 Review: Eukaryotic cell structures can be grouped on the basis of four basic functions

- It is possible to group cell organelles into four categories based on general functions of organelles
  - In each category structure is correlated with function

TABLE 4.23 EUKARYOTIC CELL STRUCTURES AND FUNCTIONS

1. Manufacturing	
Nucleus	DNA synthesis; RNA synthesis; assembly of ribosomal subunits (in nucleoli)
Ribosomes	Polypeptide (protein) synthesis
Rough ER	Synthesis of membrane lipids and proteins, secretory proteins, and hydrolytic enzymes; formation of transport vesicles
Smooth ER	Lipid synthesis; detoxification in liver cells; calcium ion storage
Golgi apparatus	Modification and transport of macromolecules; formation of lysosomes and transport vesicles
2. Breakdown	
Lysosomes (in animal cells and some protists)	Digestion of ingested food, bacteria, and a cell's damaged organelles and macromolecules for recycling
Vacuoles	Digestion (like lysosomes); storage of chemicals; cell enlargement; water balance
Peroxisomes (not part of endomembrane system)	Diverse metabolic processes, with breakdown of H_2O_2 by-product
3. Energy Processing	
Mitochondria	Conversion of chemical energy of food to chemical energy of ATP
Chloroplasts (in plants and some protists)	Conversion of light energy to chemical energy of sugars
4. Support, Movement, and Communication Between Cells	
Cytoskeleton (including cilia, flagella, and centrioles in animal cells)	Maintenance of cell shape; anchorage for organelles; movement of organelles within cells; cell movement; mechanical transmission of signals from exterior of cell to interior
Extracellular matrix (in animals)	Binding of cells in tissues; surface protection; regulation of cellular activities
Cell junctions	Communication between cells; binding of cells in tissues
Cell walls (in plants, fungi, and some protists)	Maintenance of cell shape and skeletal support; surface protection; binding of cells in tissues