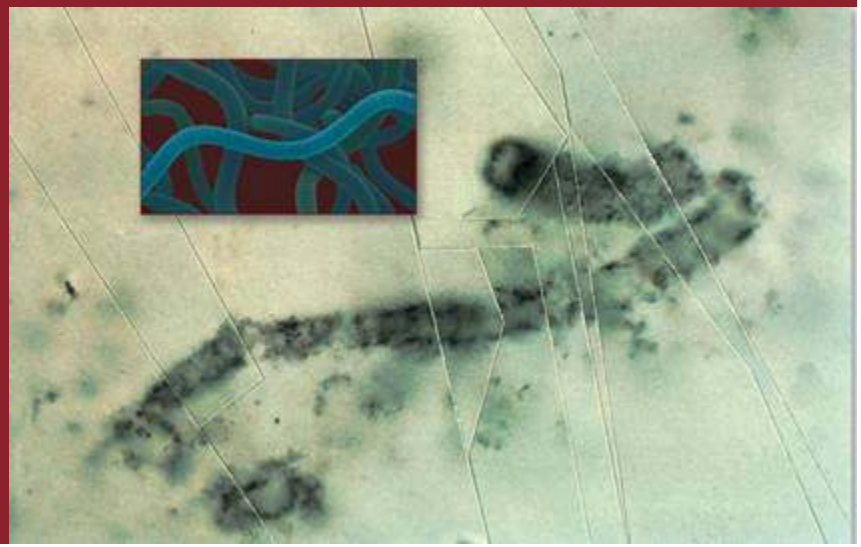
4

Cells: The Working Units of Life



4 Cells: The Working Units of Life

- 4.1 What Features of Cells Make Them the Fundamental Unit of Life?
- 4.2 What Are the Characteristics of Prokaryotic Cells?
- 4.3 What Are the Characteristics of Eukaryotic Cells?
- 4.4 What Are the Roles of Extracellular Structures?
- 4.5 How Did Eukaryotic Cells Originate?

4.1 What Features of Cells Make Them the Fundamental Unit of Life?

Cell theory was the first unifying theory of biology.

- Cells are the fundamental units of life.
- All organisms are composed of cells.
- All cells come from preexisting cells.

4.1 What Features of Cells Make Them the Fundamental Unit of Life?

Implications of cell theory:

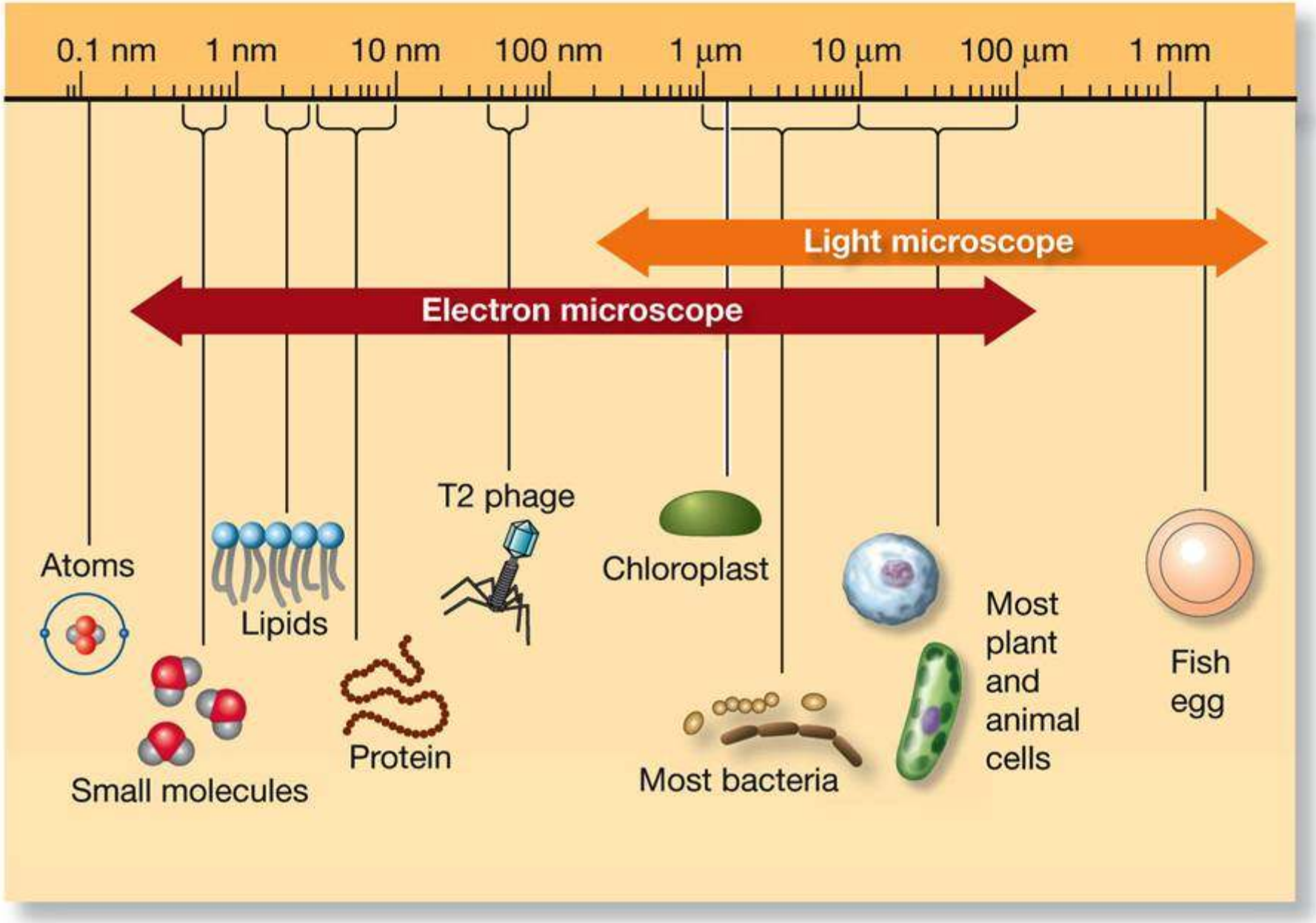
- Functions of all cells are similar
- Life is continuous
- Origin of life was the origin of cells
- What about other planets?

4.1 What Features of Cells Make Them the Fundamental Unit of Life?

Cells are small (mostly).

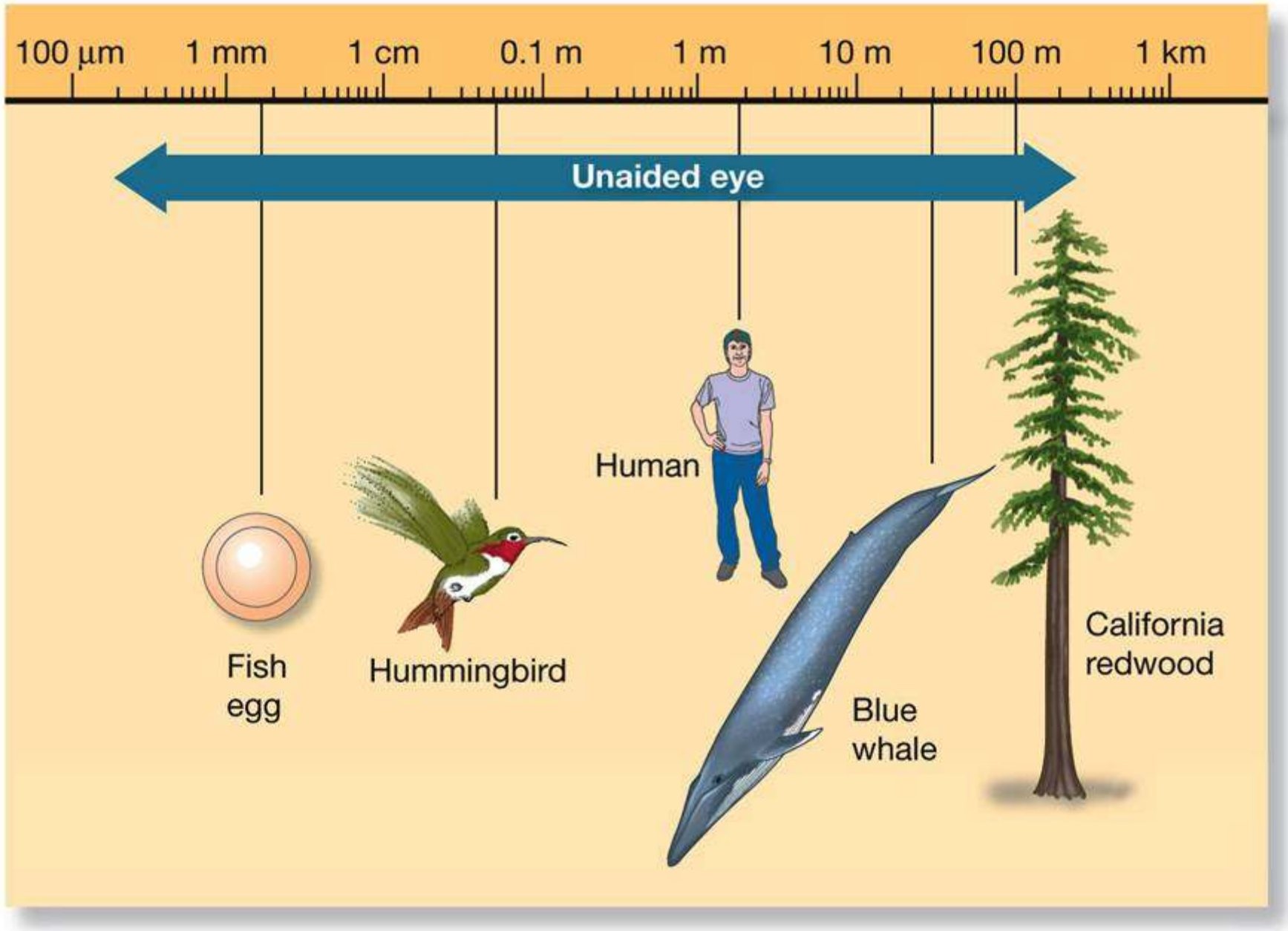
Exceptions: bird eggs, neurons, some algae and bacteria cells

Figure 4.1 The Scale of Life (Part 1)



***LIFE 8e*, Figure 4.1 (Part 1)**

Figure 4.1 The Scale of Life (Part 2)



***LIFE* 8e, Figure 4.1 (Part 2)**

4.1 What Features of Cells Make Them the Fundamental Unit of Life?

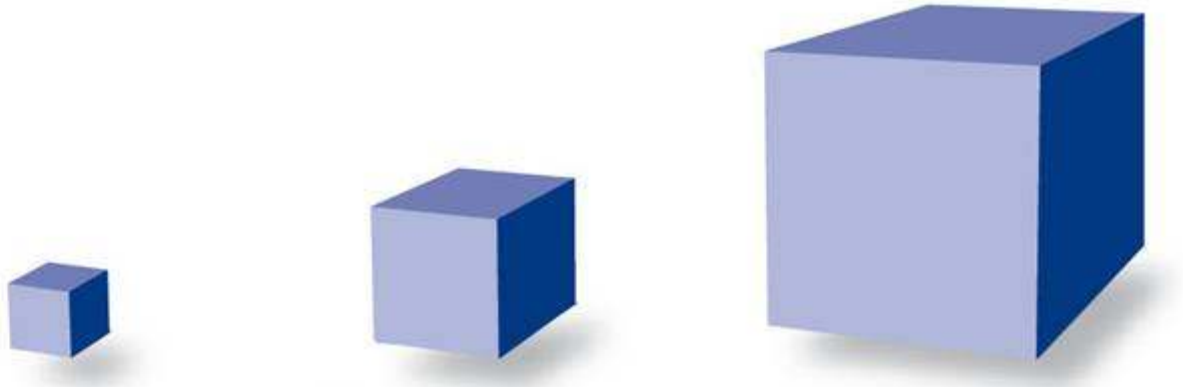
Cells are small because they need a high **surface area-to-volume ratio**.

Volume determines the amount of chemical activity in the cell per unit time.

Surface area determines the amount of substances that can pass the cell boundary per unit time.

Figure 4.2 Why Cells Are Small (Part 1)

(A) Cubes



	1-mm cube	2-mm cube	4-mm cube
Surface area	6 sides × 1^2 = 6 mm^2	6 sides × 2^2 = 24 mm^2	6 sides × 4^2 = 96 mm^2
Volume	1^3 = 1 mm^3	2^3 = 8 mm^3	4^3 = 64 mm^3
Surface area-to-volume ratio	6:1	3:1	1.5:1

***LIFE* 8e, Figure 4.2 (Part 1)**

Figure 4.2 Why Cells Are Small (Part 2)

(B) Spheres

Diameter	1 µm	2 µm	3 µm
Surface area $4 \pi r^2$	3.14 μm^2	12.56 μm^2	28.26 μm^2
Volume $4/3 \pi r^3$	0.52 μm^3	4.19 μm^3	14.18 μm^3
Surface area-to-volume ratio	6:1	3:1	2:1

***LIFE* 8e, Figure 4.2 (Part 2)**

4.1 What Features of Cells Make Them the Fundamental Unit of Life?

Most cells are < 200 μm in size.

Minimum **resolution** of human eye is 200 μm.

Microscopes improve resolution.

4.1 What Features of Cells Make Them the Fundamental Unit of Life?

All cells are surrounded by a membrane: the **plasma membrane** is made of a phospholipid bilayer.

4.1 What Features of Cells Make Them the Fundamental Unit of Life?

The plasma membrane:

- Allows cells to maintain constant internal environment
- Is a selectively permeable barrier
- Is important in communication and receiving signals
- Often has proteins for binding with adjacent cells

4.1 What Features of Cells Make Them the Fundamental Unit of Life?

Two types of cells: **prokaryotic** and **eukaryotic**

Bacteria and Archaea are prokaryotic.

The first cells were probably prokaryotic.

Eukarya are eukaryotic—DNA is in a membrane-enclosed compartment called the **nucleus**.

4.2 What Are the Characteristics of Prokaryotic Cells?

Prokaryotic cells are very small.

Individuals are single cells, but often found in chains or clusters.

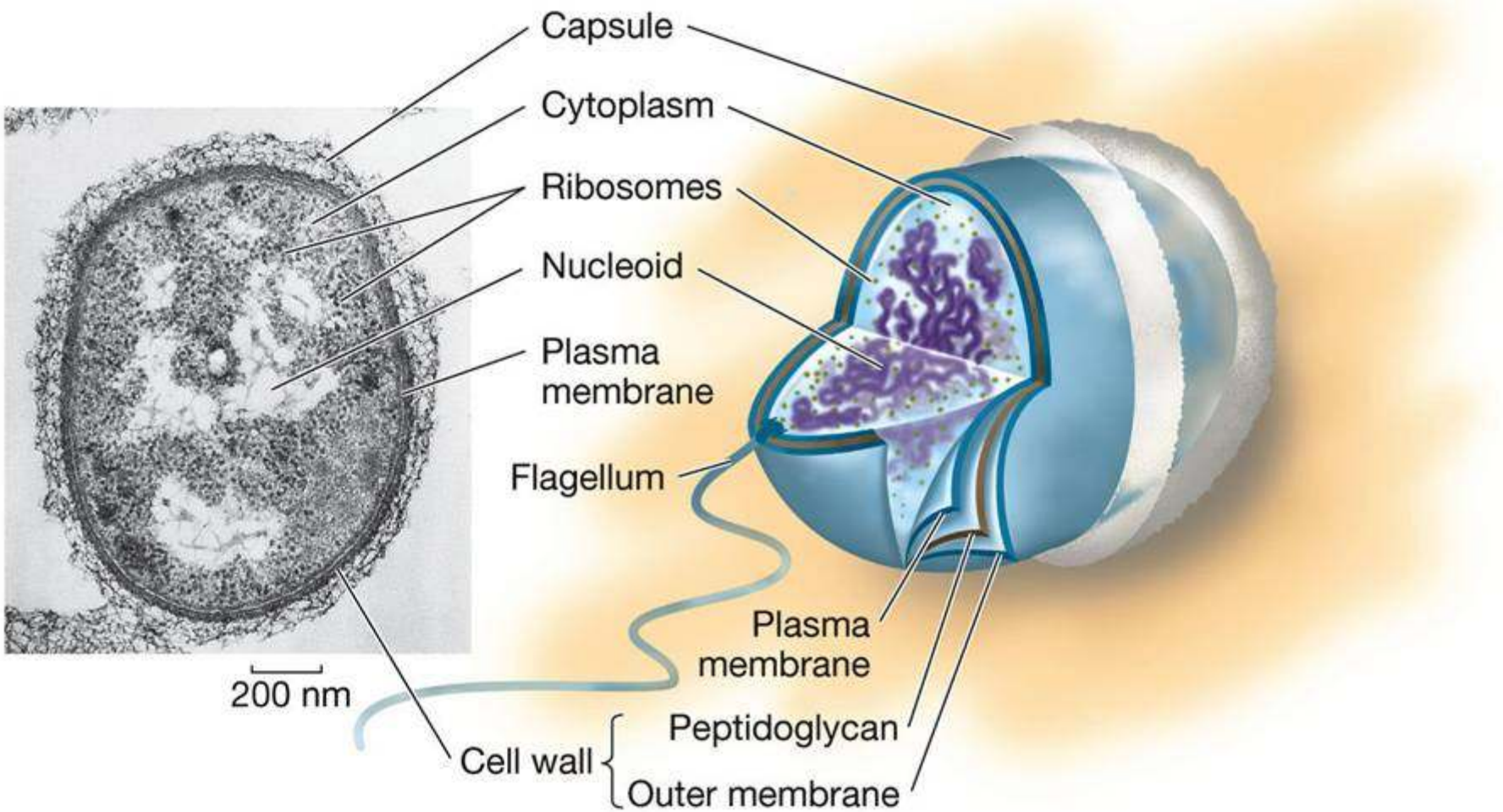
Prokaryotes are very successful—they can live on a diversity of energy sources and inhabit every environment including extreme environments.

4.2 What Are the Characteristics of Prokaryotic Cells?

Prokaryotic cells:

- Are enclosed by a plasma membrane
- The DNA is contained in the **nucleoid**
- **Cytoplasm** consists of **cytosol** (water and dissolved material) and suspended particles
- Ribosomes—site of protein synthesis

Figure 4.4 A Prokaryotic Cell



LIFE 8e, Figure 4.4

4.2 What Are the Characteristics of Prokaryotic Cells?

Most prokaryotes have a rigid **cell wall** outside the plasma membrane.

Bacteria cell walls contain *peptidoglycan*.

Some bacteria have an additional outer membrane.

Some bacteria have a slimy *capsule* of polysaccharides.

4.2 What Are the Characteristics of Prokaryotic Cells?

In photosynthetic bacteria, the plasma membrane folds into the cytoplasm to form an internal membrane system where photosynthesis occurs.

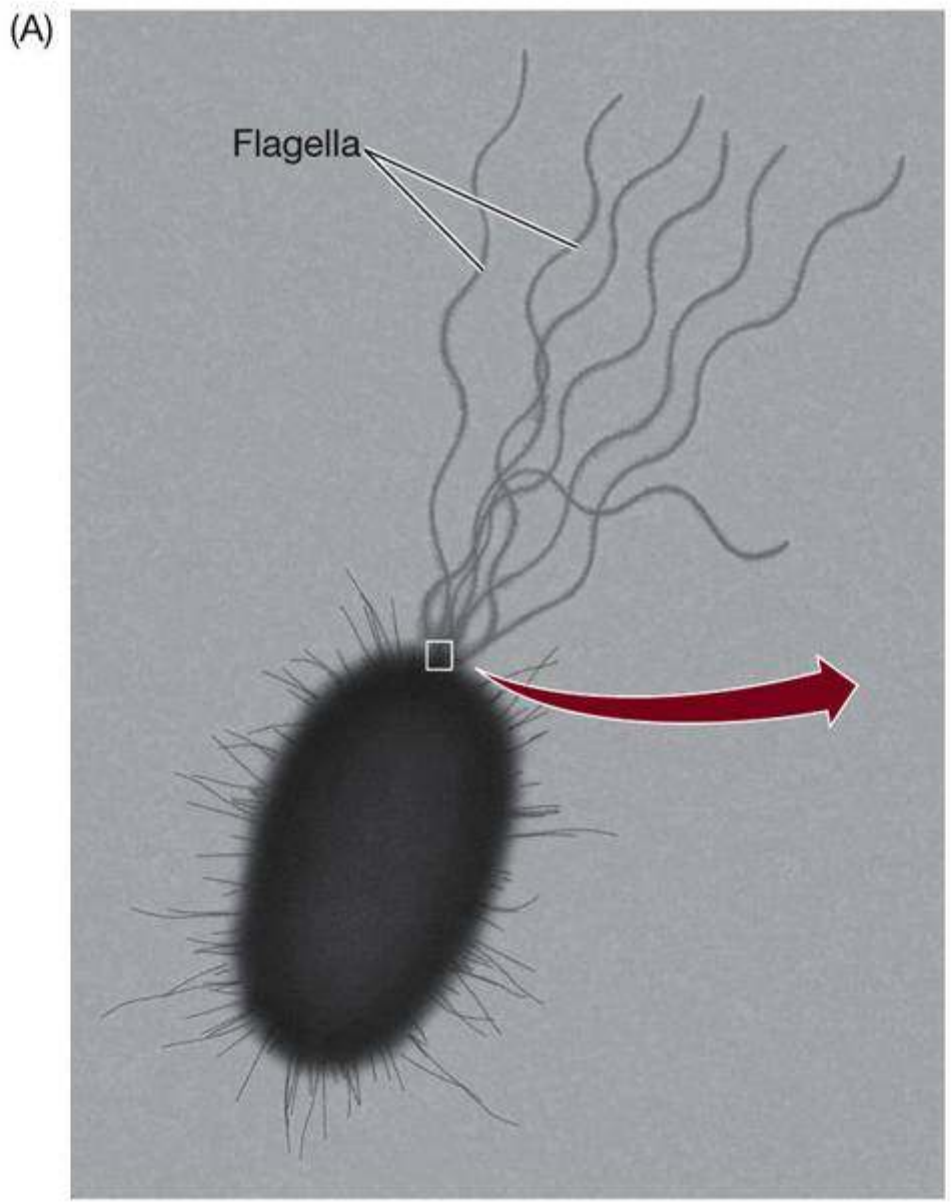
4.2 What Are the Characteristics of Prokaryotic Cells?

Some prokaryotes swim by means of **flagella**, made of the protein *flagellin*.

Some bacteria have *pili*—hair-like structures projecting from the surface. They help bacteria adhere to other cells.

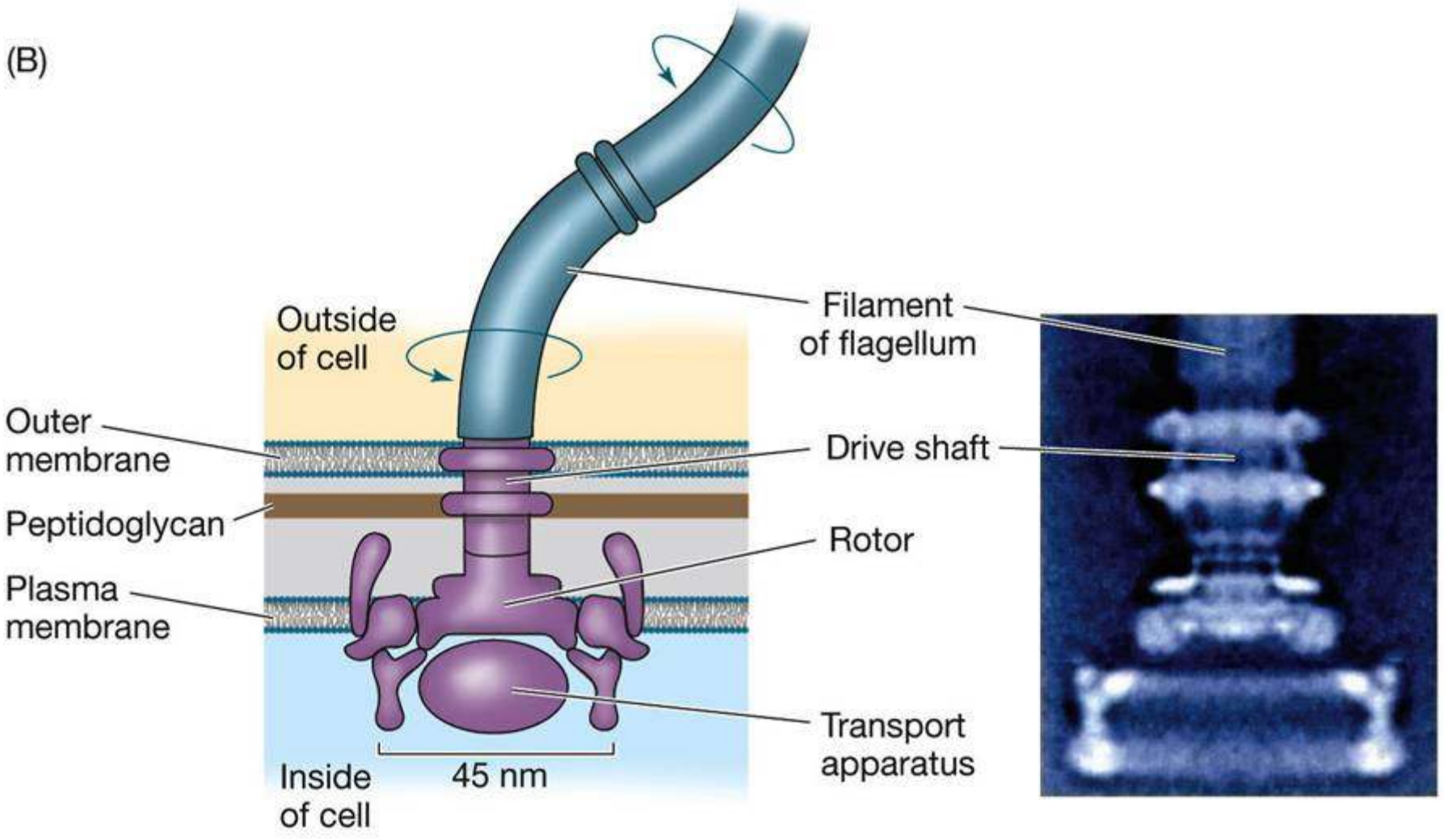
Some rod-shaped bacteria have a cytoskeleton made of the protein actin.

Figure 4.5 Prokaryotic Flagella (A)



***LIFE 8e*, Figure 4.5 (Part 1)**

Figure 4.5 Prokaryotic Flagella (B)



***LIFE 8e*, Figure 4.5 (Part 2)**

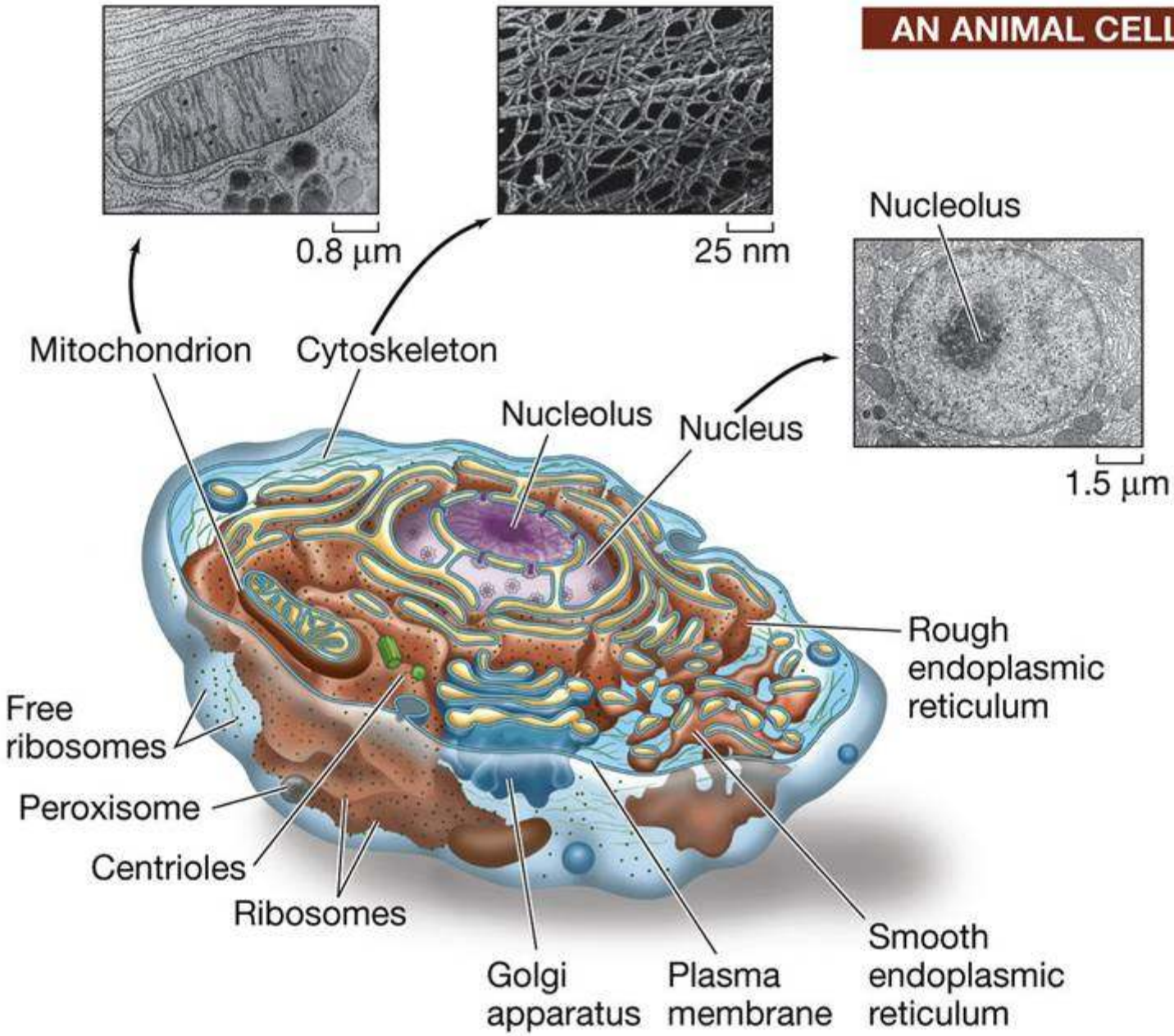
4.3 What Are the Characteristics of Eukaryotic Cells?

Eukaryotic cells are up to 10 times larger than prokaryotes.

Eukaryotic cells have membrane-enclosed compartments called **organelles**.

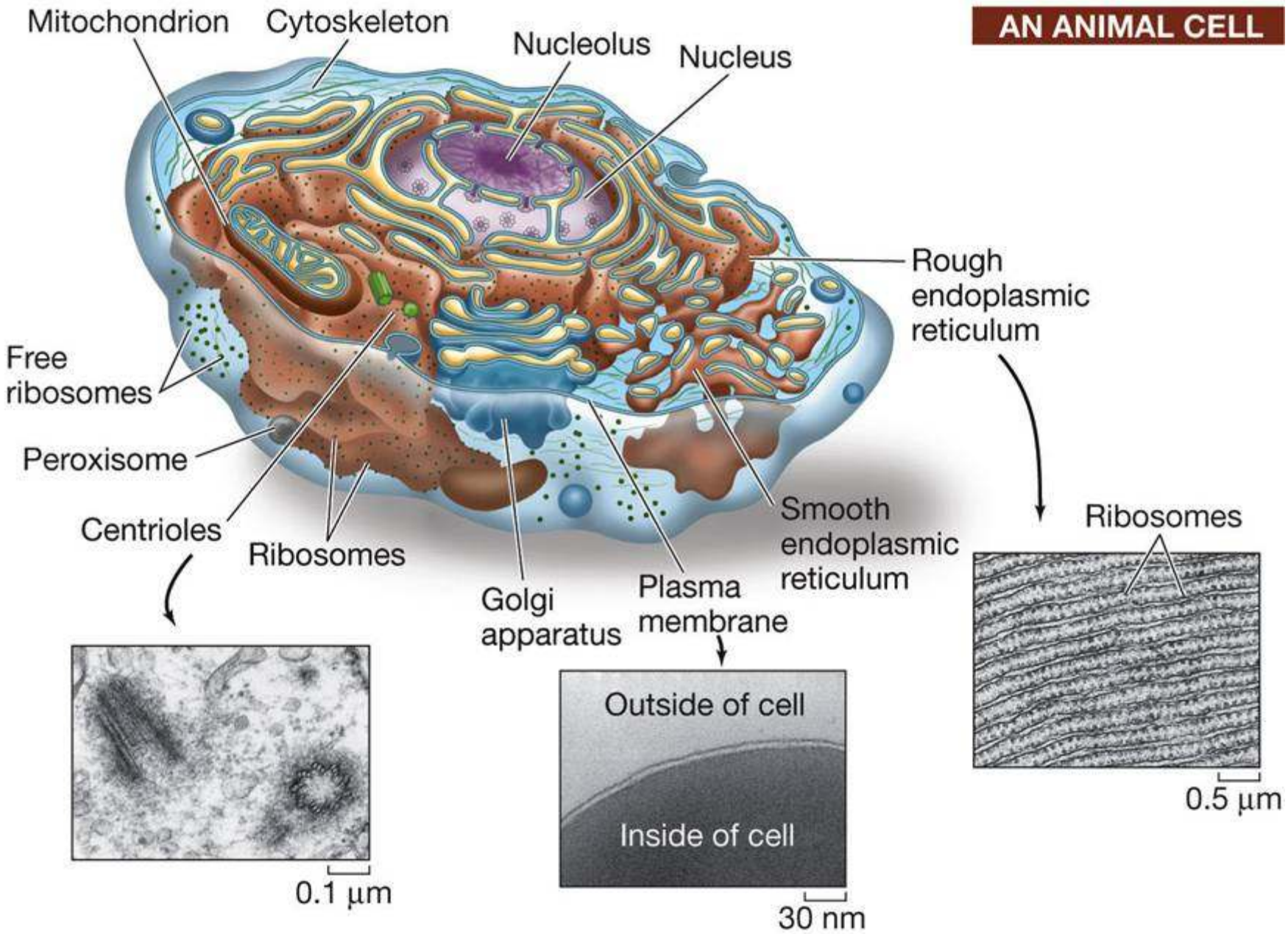
Organelles have specific functions.

Figure 4.7 Eukaryotic Cells—Animal Cells (Part 1)



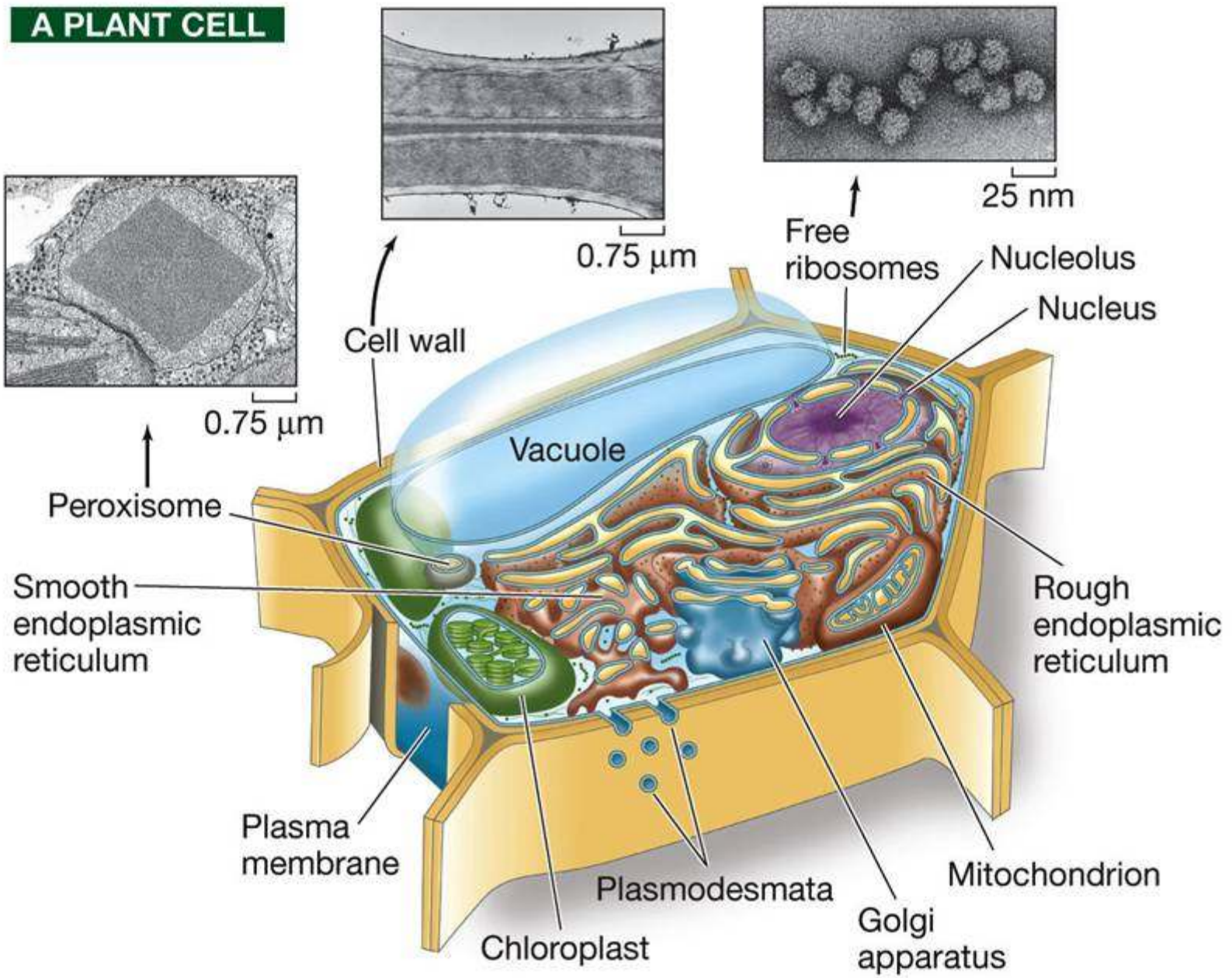
***LIFE 8e*, Figure 4.7 (Part 1)**

Figure 4.7 Eukaryotic Cells—Animal Cells (Part 2)



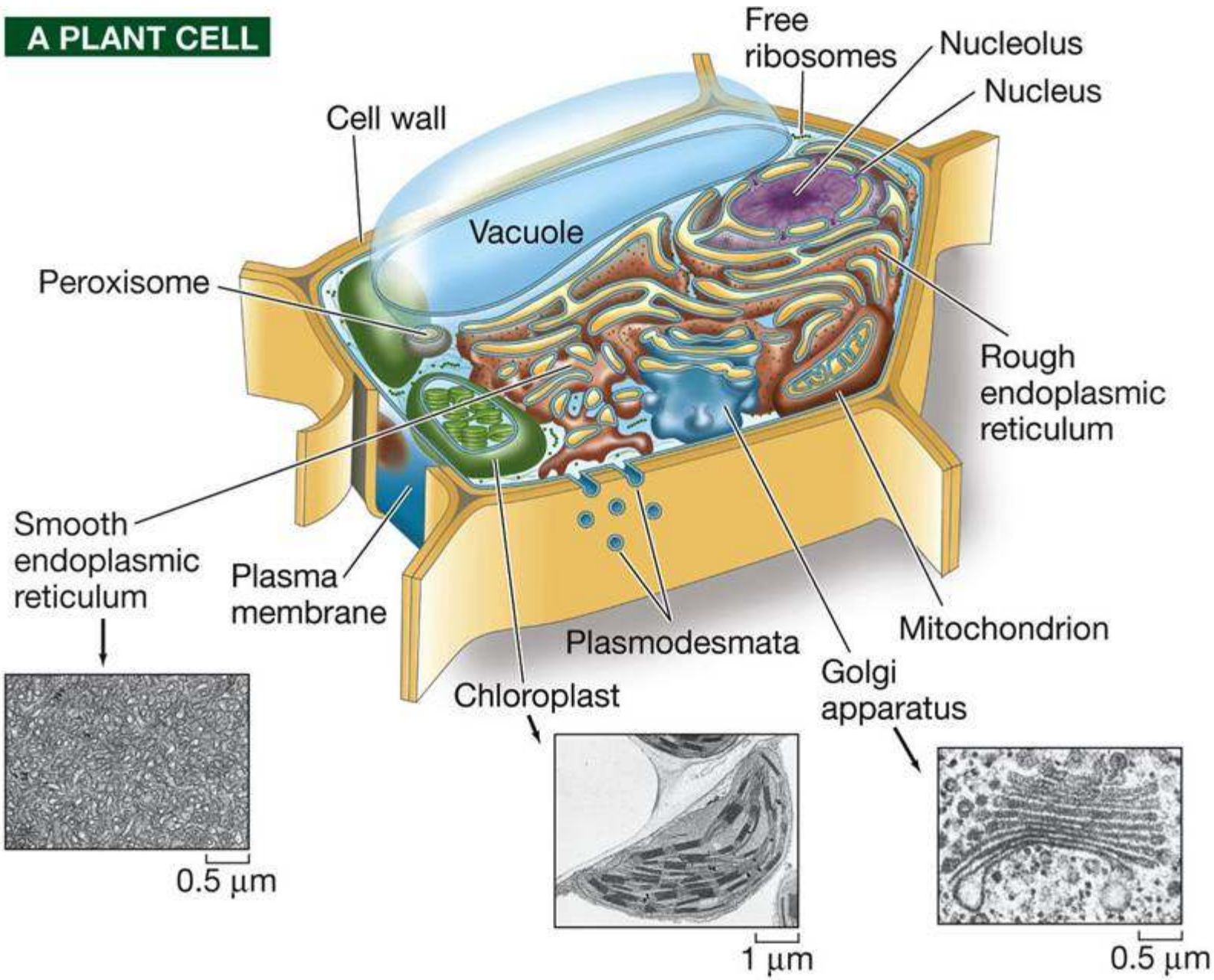
***LIFE 8e*, Figure 4.7 (Part 2)**

Figure 4.7 Eukaryotic Cells—Plant Cells (Part 3)



***LIFE 8e*, Figure 4.7 (Part 3)**

Figure 4.7 Eukaryotic Cells—Plant Cells (Part 4)



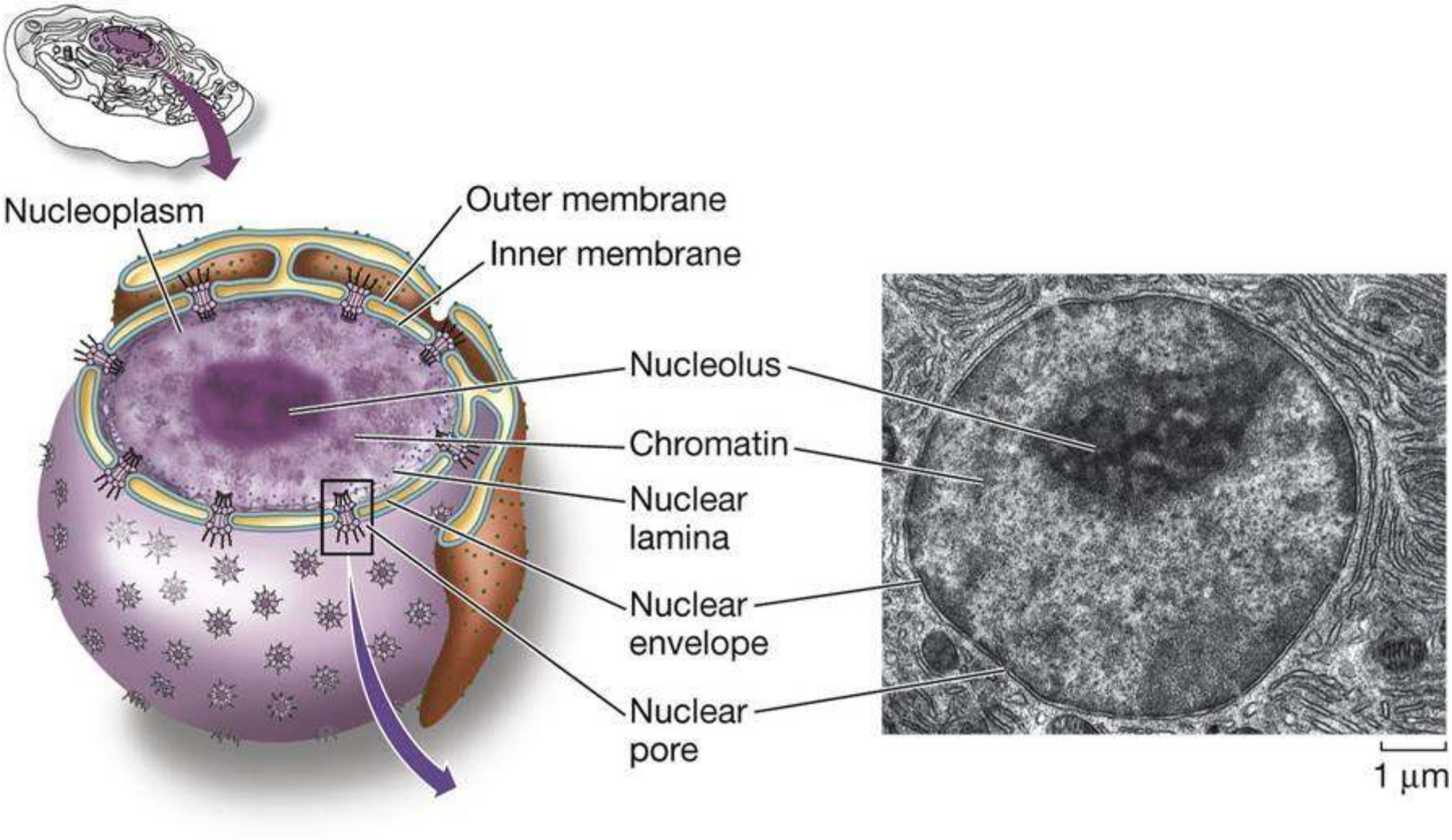
***LIFE 8e*, Figure 4.7 (Part 4)**

4.3 What Are the Characteristics of Eukaryotic Cells?

The **nucleus** is usually the largest organelle.

- Contains the DNA
- Site of DNA replication
- Site of genetic control of cell activities
- The **nucleolus** begins assembly of ribosomes

Figure 4.8 The Nucleus is Enclosed by a Double Membrane (Part 1)



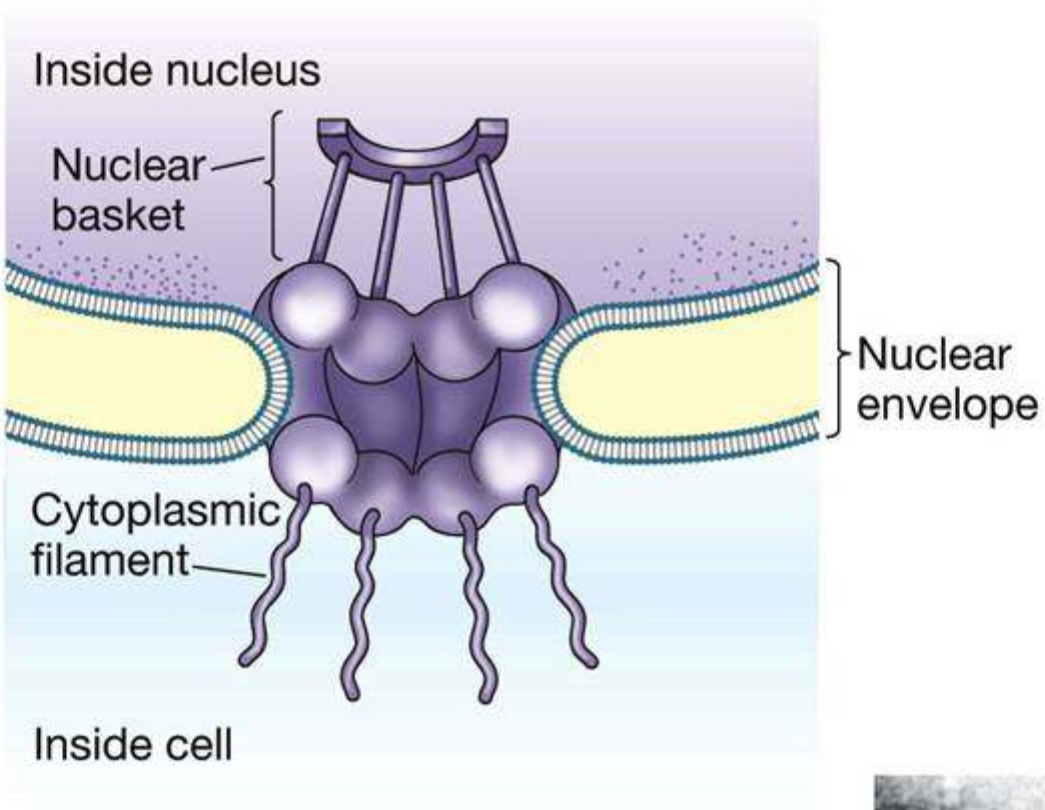
***LIFE 8e*, Figure 4.8 (Part 1)**

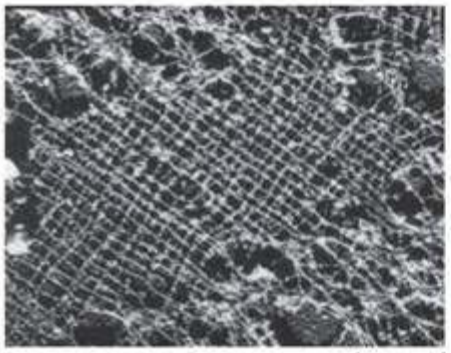
4.3 What Are the Characteristics of Eukaryotic Cells?

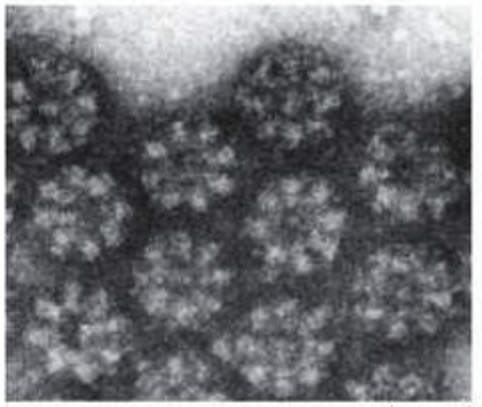
The nucleus is surrounded by two membranes—the *nuclear envelope*.

Nuclear pores in the envelope control passage of molecules. Large molecules such as proteins need a signal—a certain sequence of amino acids—to pass through.

Figure 4.8 The Nucleus is Enclosed by a Double Membrane (Part 2)







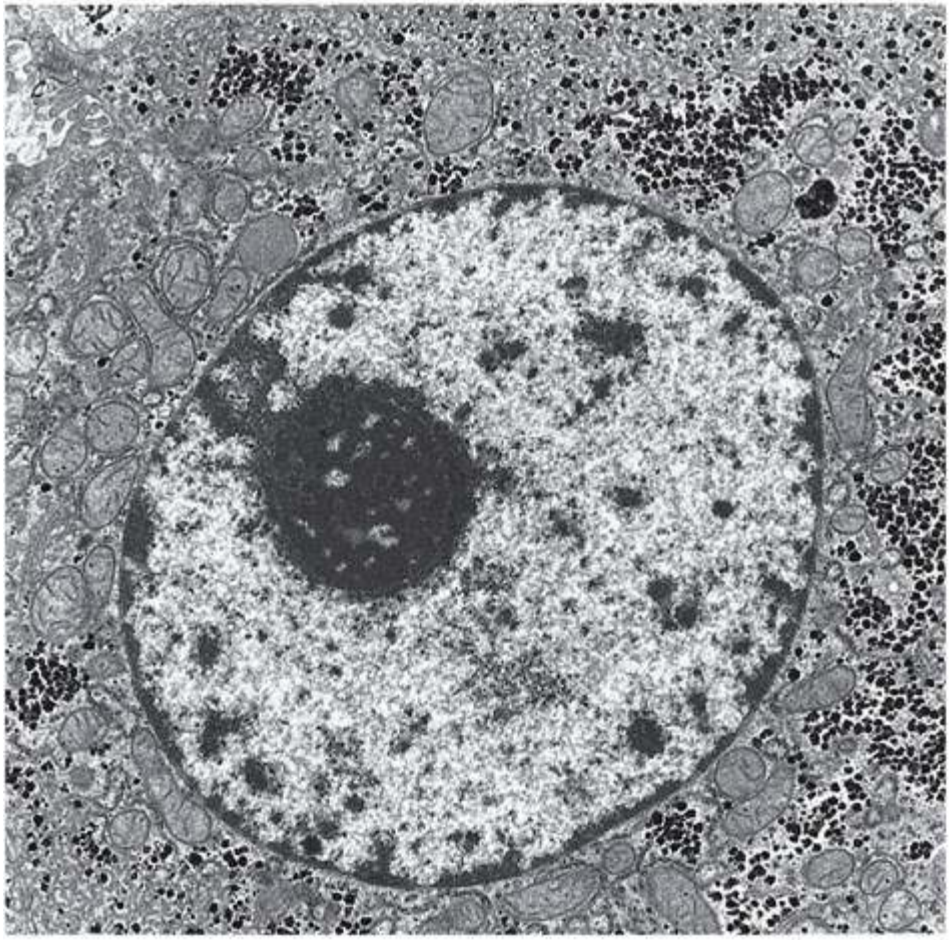
***LIFE 8e*, Figure 4.8 (Part 2)**

4.3 What Are the Characteristics of Eukaryotic Cells?

DNA combines with proteins to form **chromatin**. Before cell division, chromatin aggregates to form **chromosomes**.

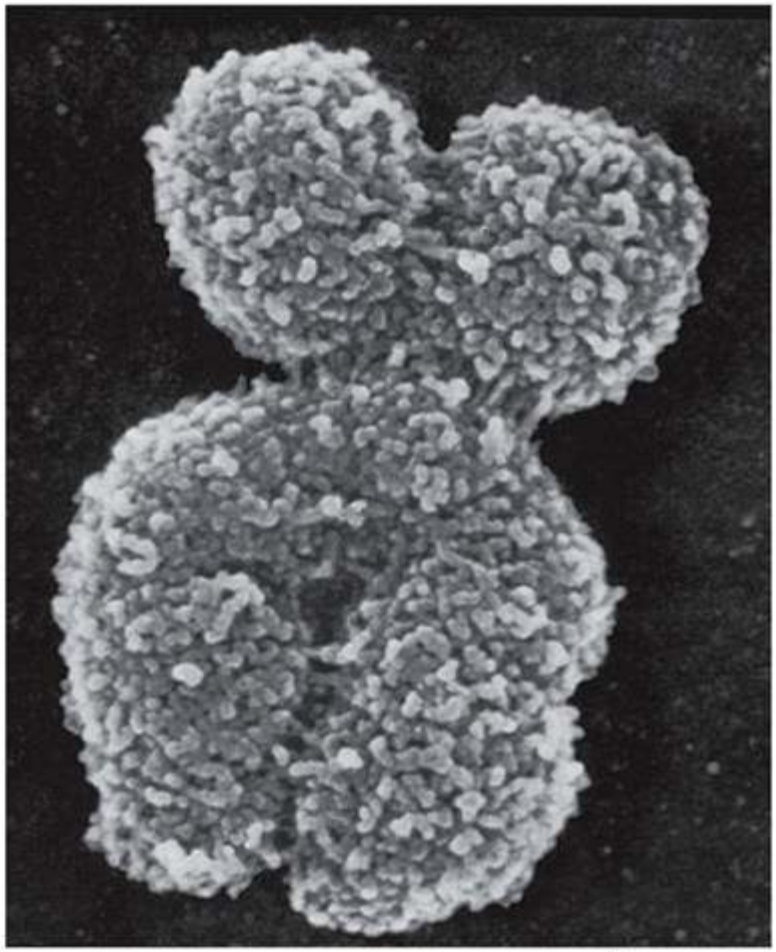
Figure 4.9 Chromatin and Chromosomes

(A)



1 µm

(B)



0.5 µm

***LIFE 8e*, Figure 4.9**

4.3 What Are the Characteristics of Eukaryotic Cells?

Ribosomes—sites of protein synthesis.

Occur in both prokaryotic and eukaryotic cells.

In eukaryotes, ribosomes are free in the cytoplasm, attached to the endoplasmic reticulum, or inside mitochondria and chloroplasts.

4.3 What Are the Characteristics of Eukaryotic Cells?

The **endomembrane system** includes the endoplasmic reticulum and the Golgi apparatus.

The outer membrane of the nuclear envelope is continuous with the endomembrane system.

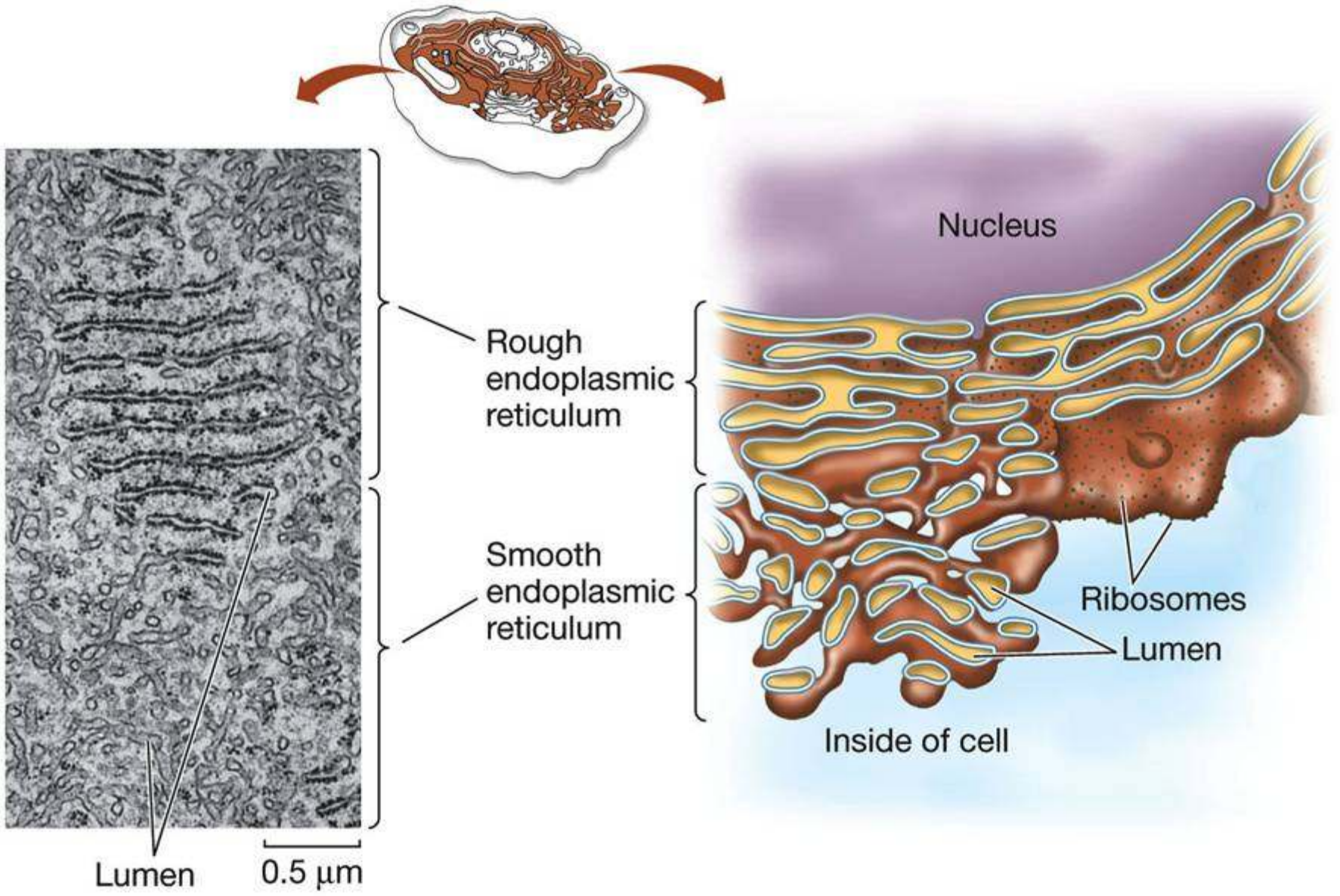
4.3 What Are the Characteristics of Eukaryotic Cells?

Endoplasmic reticulum (ER): a network of interconnected membranes—large surface area

Rough endoplasmic reticulum (RER): ribosomes are attached

RER segregates newly made proteins—they enter the *lumen* and can be modified and transported.

Figure 4.10 Endoplasmic Reticulum



***LIFE 8e*, Figure 4.10**

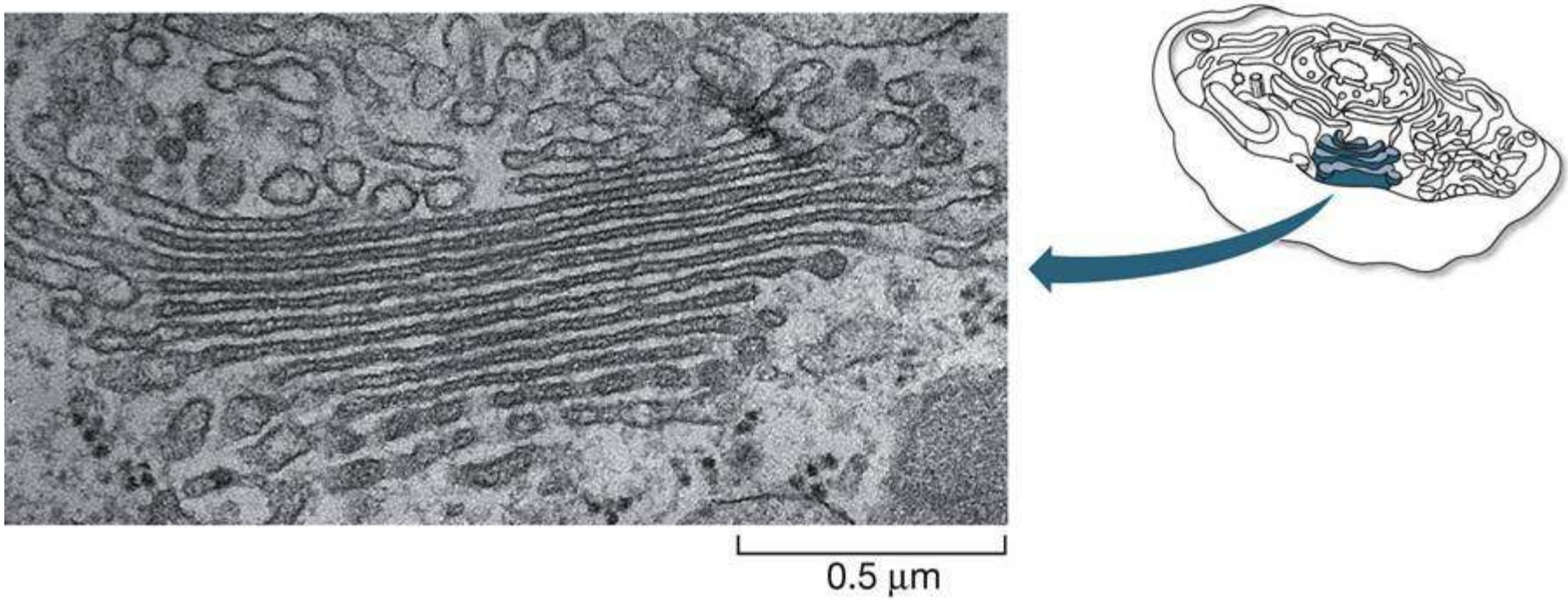
Smooth endoplasmic reticulum (SER): more tubular, no ribosomes

- Chemically modifies small molecules such as drugs and pesticides
- Hydrolysis of glycogen in animal cells
- Synthesis of lipids and steroids

The **Golgi apparatus**:

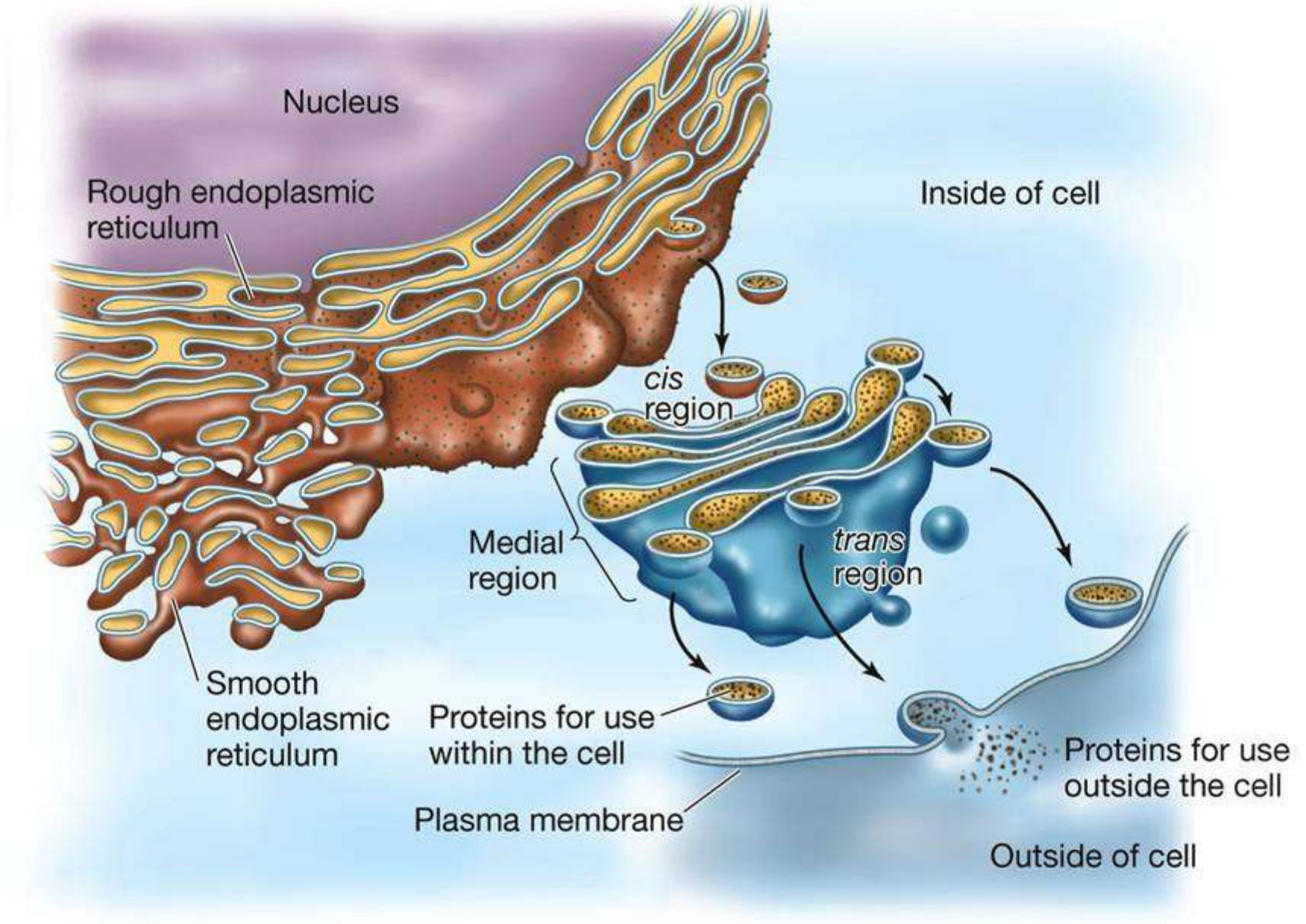
- Receives proteins from the ER—can further modify them
- Concentrates, packages, sorts proteins
- In plant cells, polysaccharides for cell walls are synthesized

Figure 4.11 The Golgi Apparatus (Part 1)



***LIFE 8e*, Figure 4.11 (Part 1)**

Figure 4.11 The Golgi Apparatus (Part 2)



***LIFE 8e*, Figure 4.11 (Part 2)**

The *cis* region receives vesicles (a piece of the ER that "buds" off) from the ER.

At the *trans* region, vesicles bud off from the Golgi apparatus and are moved to the plasma membrane.

Lysosomes originate from the Golgi apparatus.

They contain digestive enzymes—macromolecules are hydrolyzed into monomers.

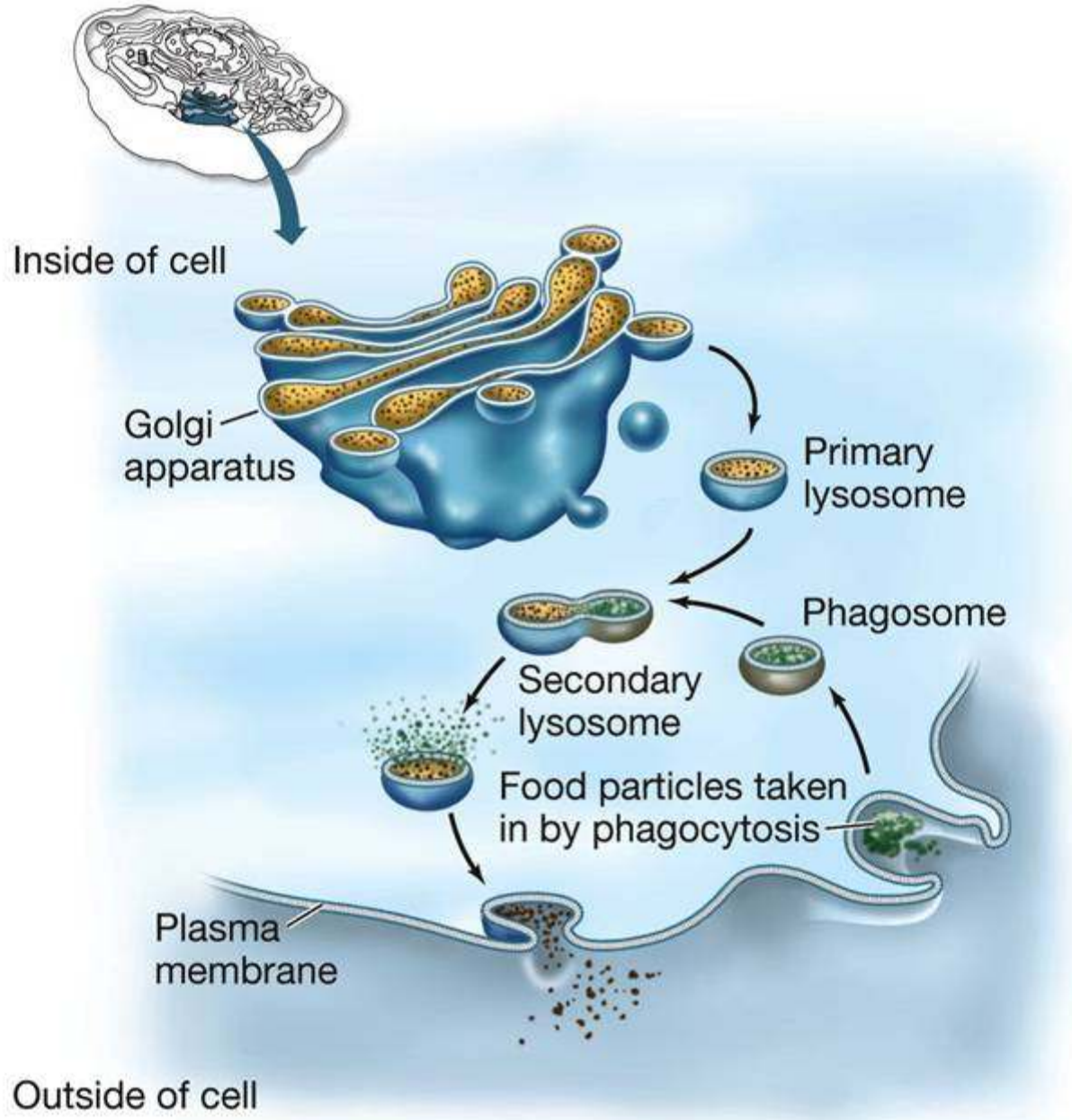
4.3 What Are the Characteristics of Eukaryotic Cells?

Food molecules enter the cell by *phagocytosis*—a *phagosome* is formed, which fuses with a *primary lysosome*, forming a *secondary lysosome*.

Enzymes in the secondary lysosome hydrolyze the food molecules.

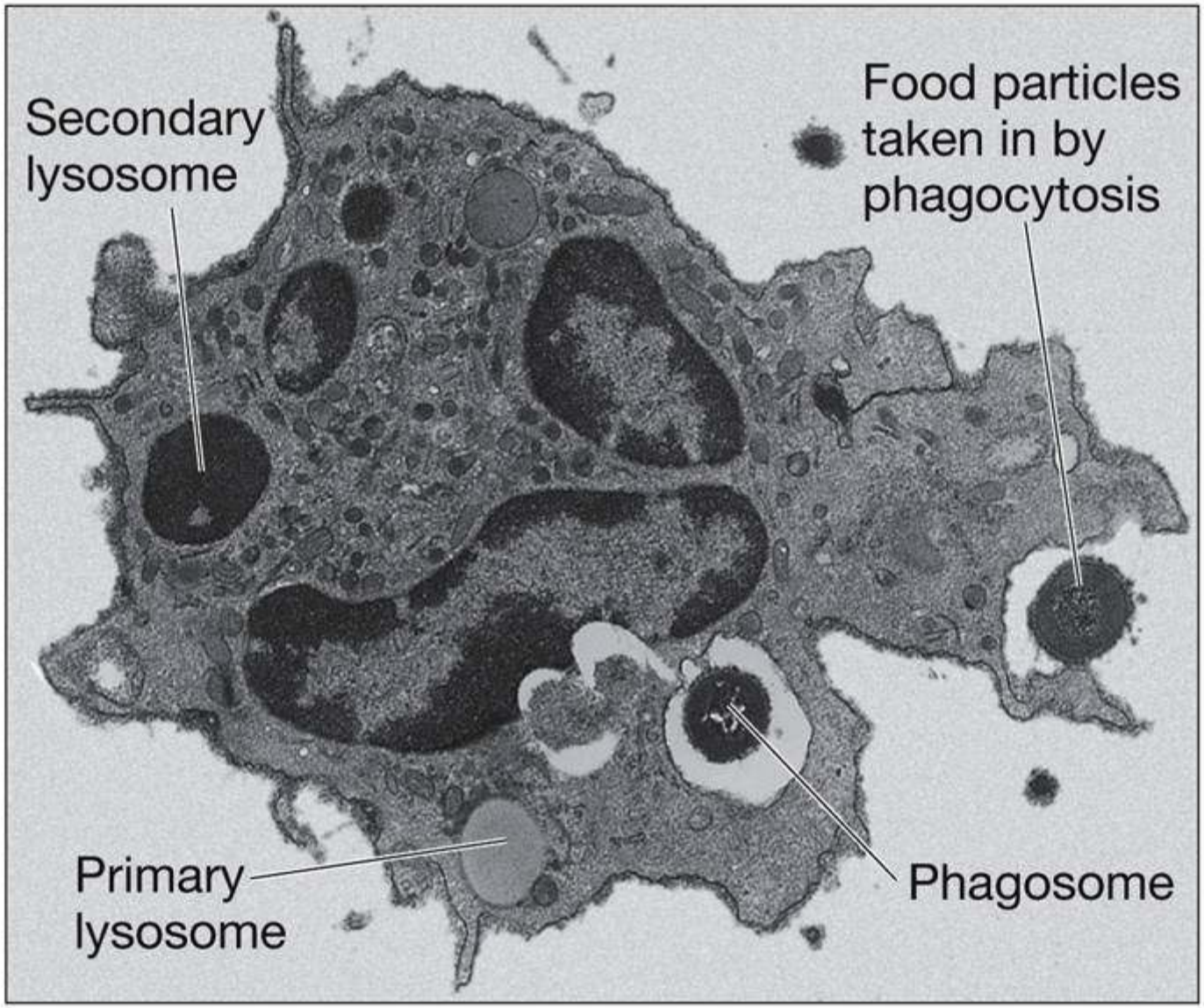
Lysosomes also digest cell materials—*autophagy*

Figure 4.12 Lysosomes Isolate Digestive Enzymes from the Cytoplasm (Part 1)



***LIFE 8e*, Figure 4.12 (Part 1)**

Figure 4.12 Lysosomes Isolate Digestive Enzymes from the Cytoplasm (Part 2)



***LIFE 8e*, Figure 4.12 (Part 2)**

4.3 What Are the Characteristics of Eukaryotic Cells?

In the **mitochondria**, energy in fuel molecules is transformed to the bonds of energy-rich ATP: *cellular respiration*.

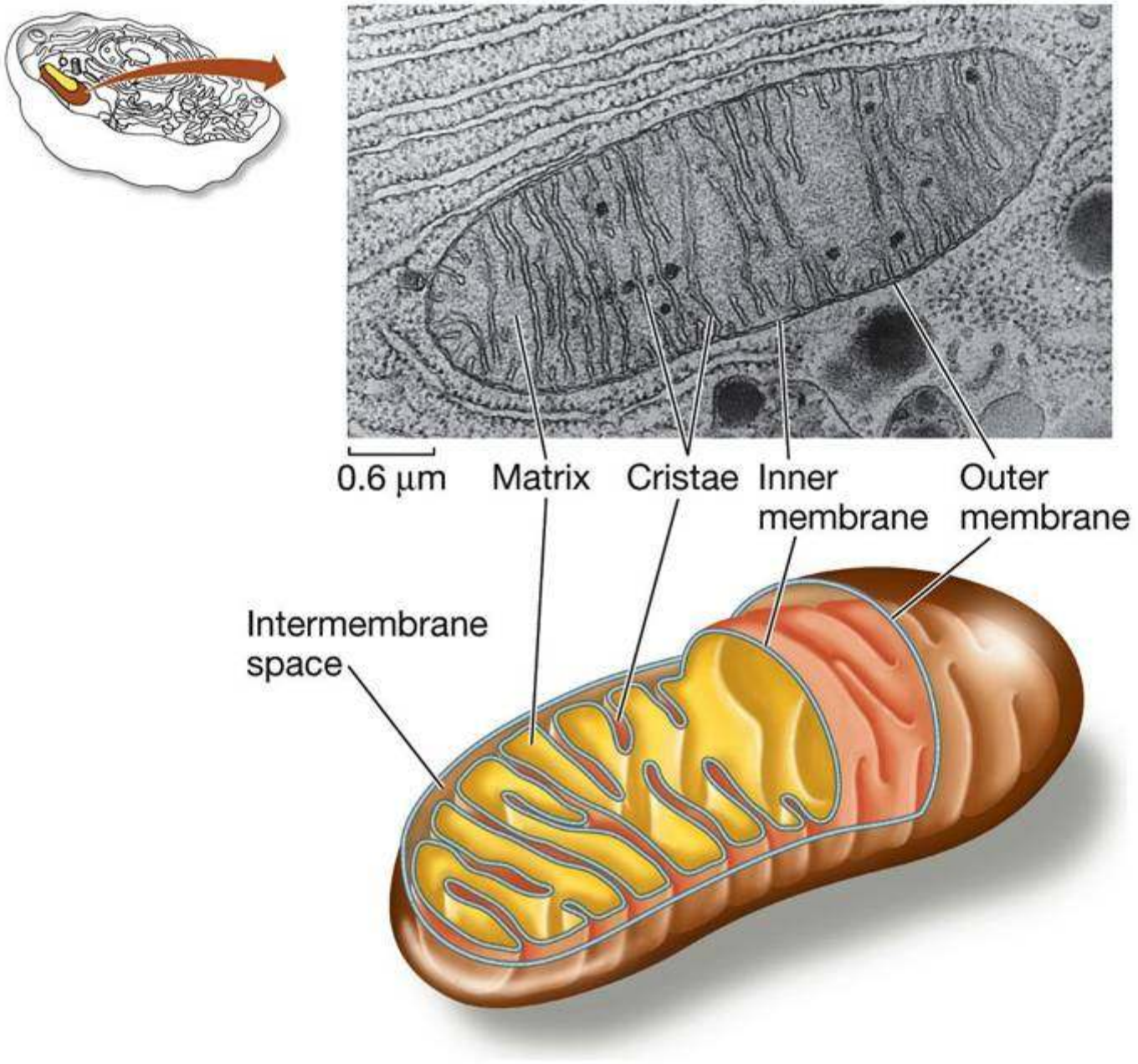
Cells that require a lot of energy have a lot of mitochondria.

4.3 What Are the Characteristics of Eukaryotic Cells?

The inner membrane of a mitochondrion folds inward—creating a large surface area for proteins that participate in cellular respiration reactions.

The mitochondrial matrix contains DNA and ribosomes.

Figure 4.13 A Mitochondrion Converts Energy from Fuel Molecules into ATP



***LIFE 8e*, Figure 4.13**

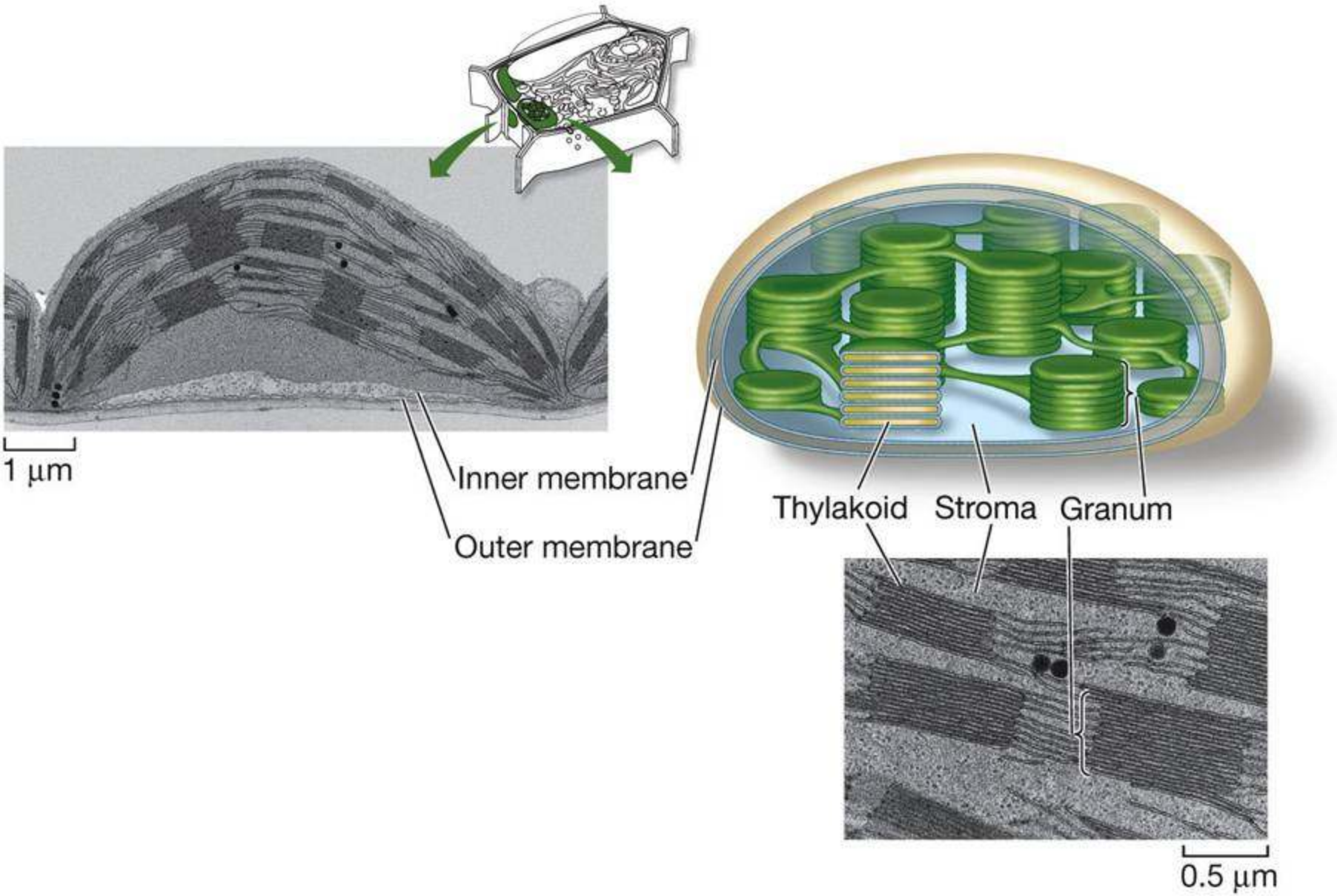
4.3 What Are the Characteristics of Eukaryotic Cells?

Plastids occur only in plants and some protists.

Chloroplasts: Site of photosynthesis—light energy is converted to the energy of chemical bonds.

Chloroplasts have a double membrane.

Figure 4.14 Chloroplasts Feed the World



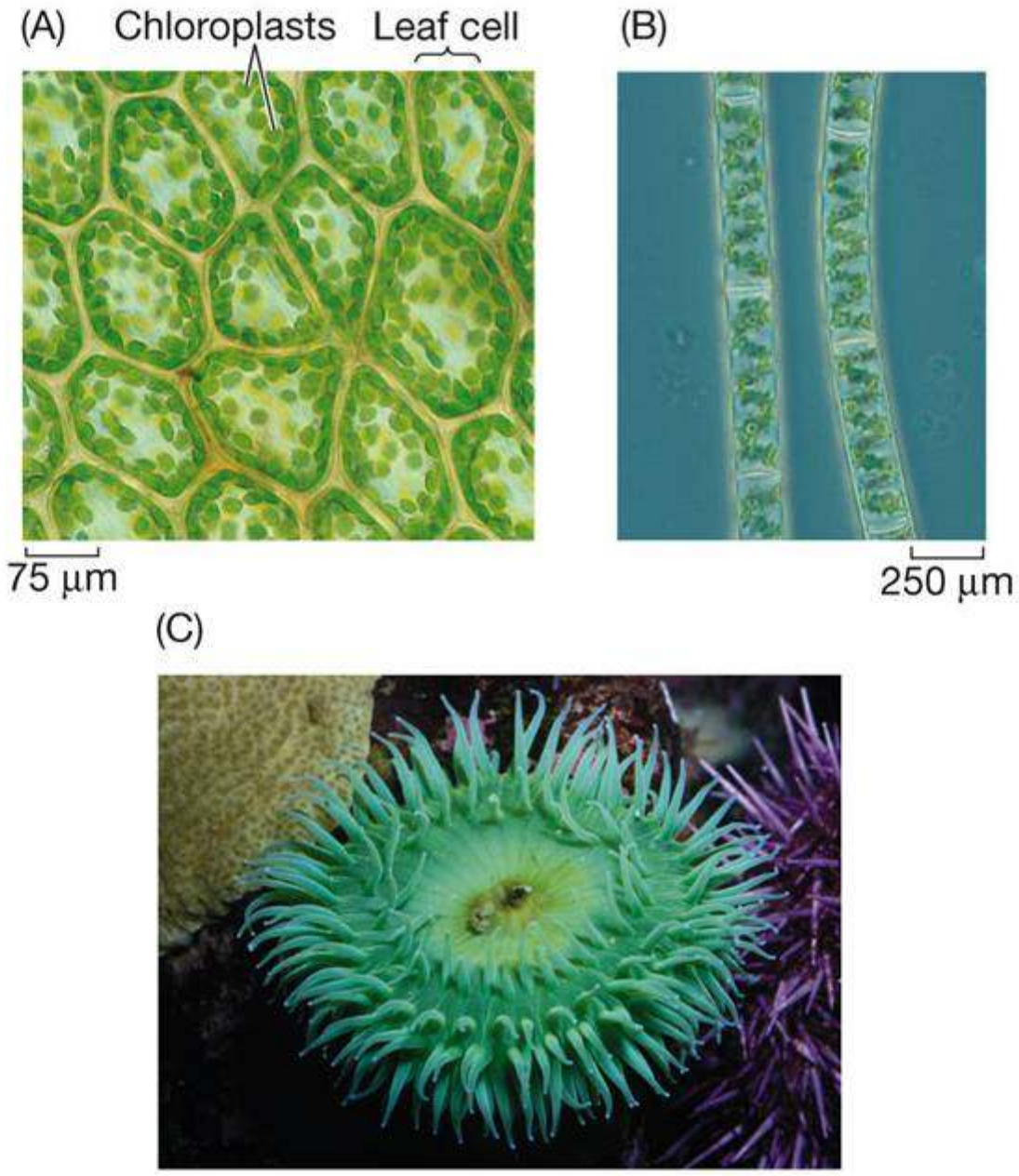
***LIFE 8e*, Figure 4.14**

4.3 What Are the Characteristics of Eukaryotic Cells?

Grana—stacks of **thylakoids**—made of circular compartments of the inner membrane.

Stroma—fluid in which grana are suspended. The stroma contains DNA and ribosomes.

Figure 4.15 Being Green



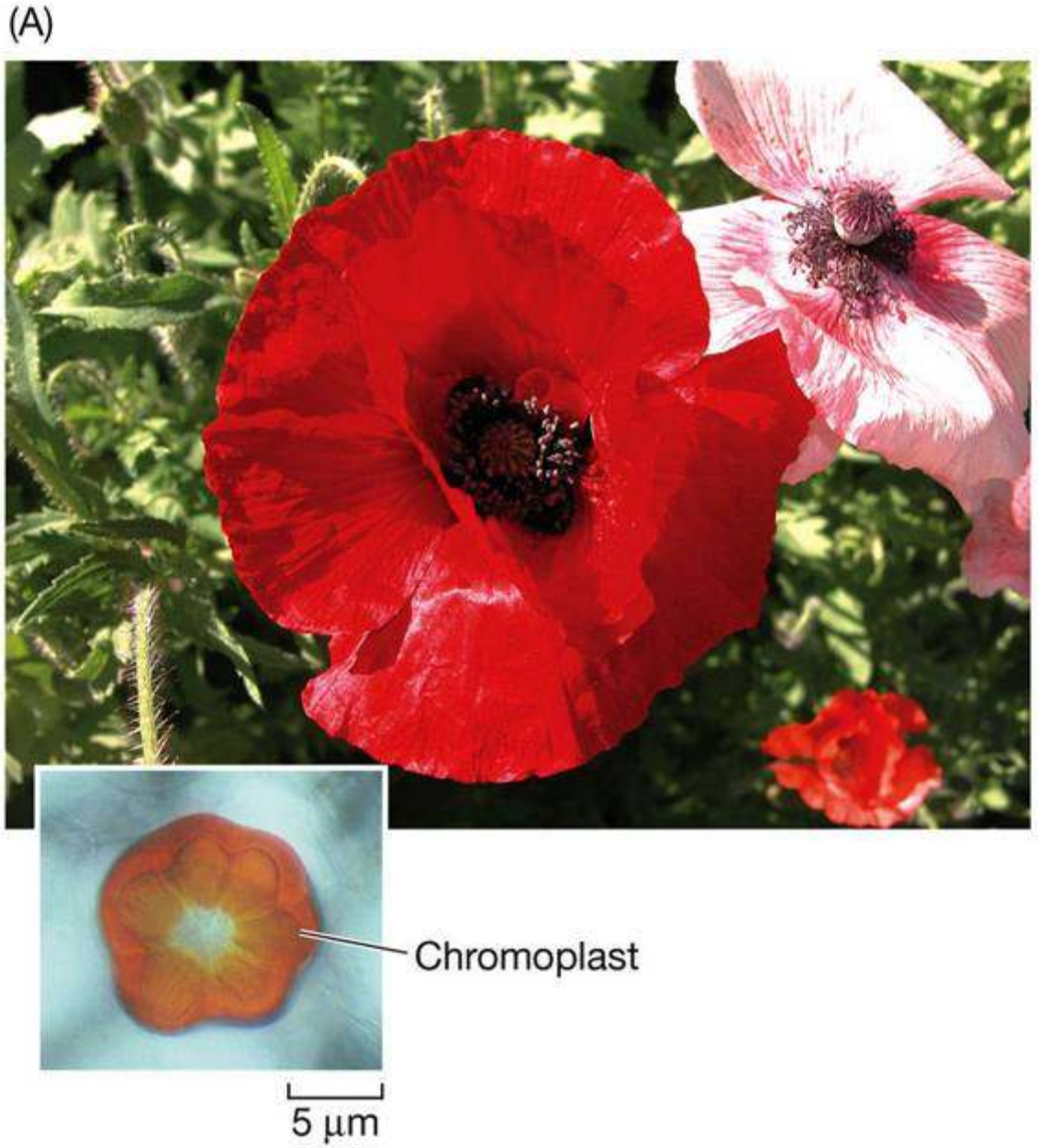
LIFE 8e, Figure 4.15

Other plastids:

Chromoplasts contain red, orange, and yellow pigments—gives color to flowers.

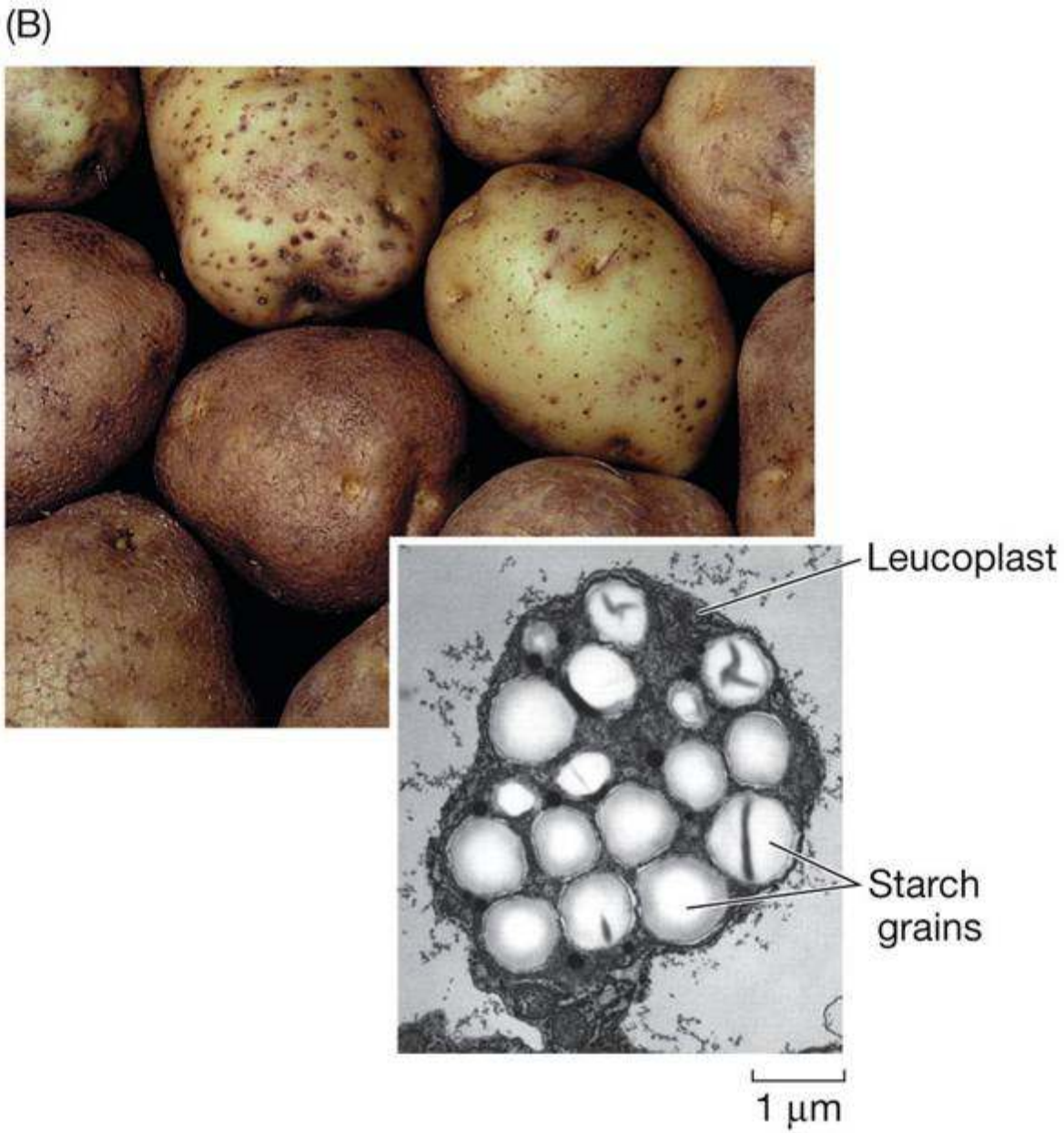
Leucoplasts store starches and fats.

Figure 4.16 Chromoplasts and Leucoplasts (Part 1)



***LIFE 8e*, Figure 4.16 (Part 1)**

Figure 4.16 Chromoplasts and Leucoplasts (Part 2)



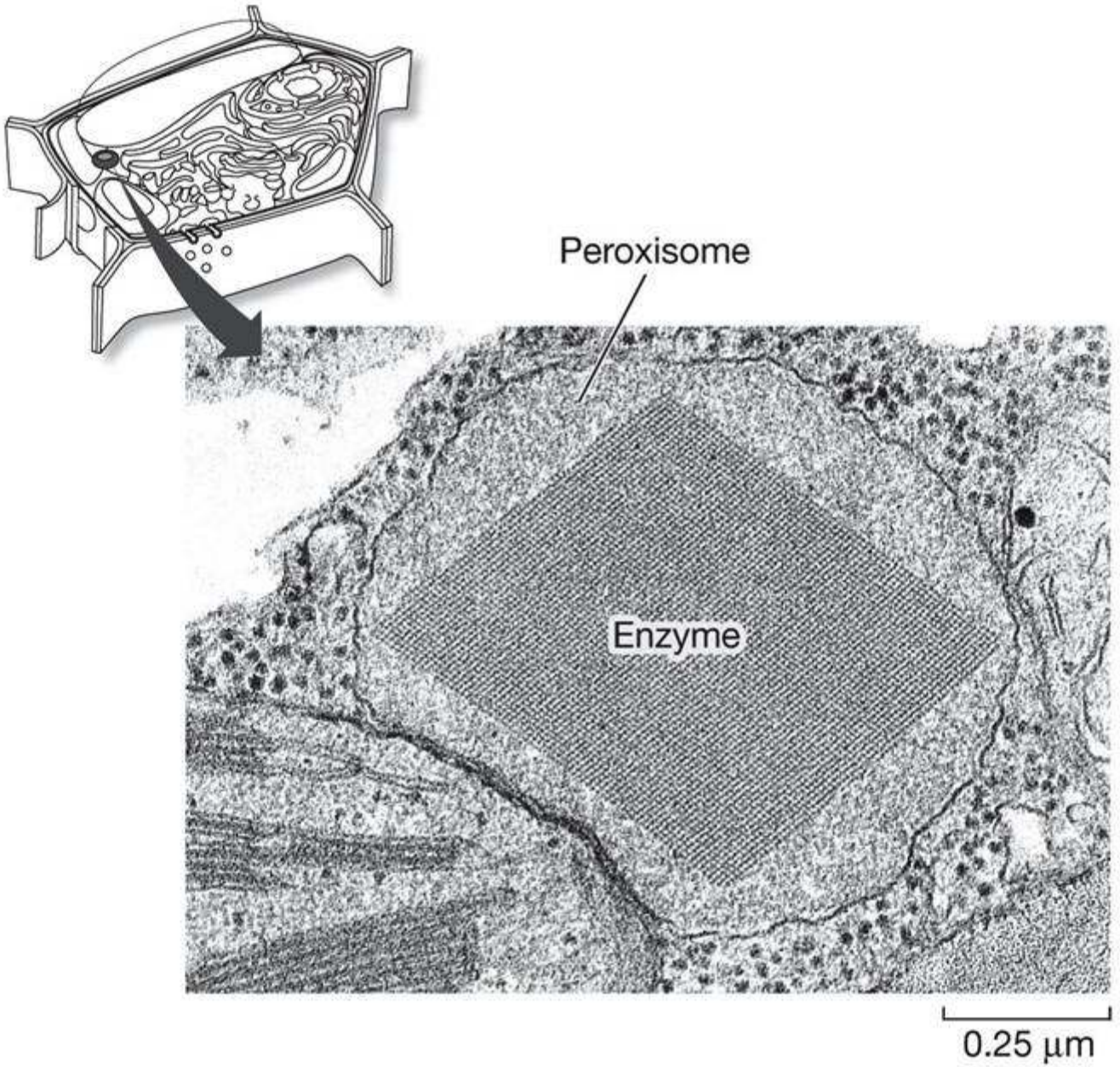
***LIFE 8e*, Figure 4.16 (Part 2)**

4.3 What Are the Characteristics of Eukaryotic Cells?

Peroxisomes: collect toxic by-products of metabolism such as H_2O_2, using specialized enzymes.

Glyoxysomes: only in plants—lipids are converted to carbohydrates for growth

Figure 4.17 A Peroxisome



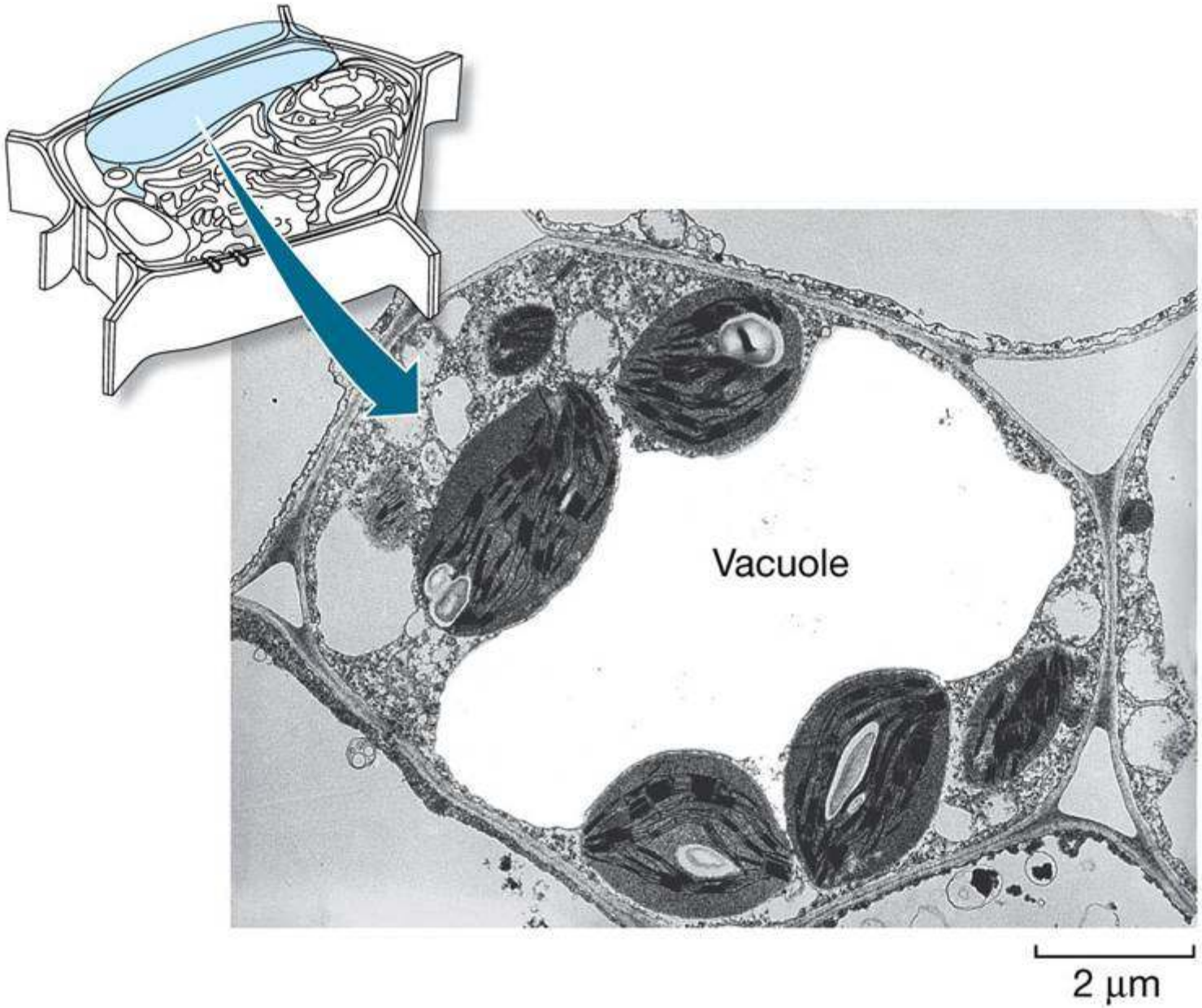
***LIFE 8e*, Figure 4.17**

4.3 What Are the Characteristics of Eukaryotic Cells?

Plant and protist cells have **vacuoles**:

- Store waste products and toxic compounds—may deter herbivores
- Provide structure for plant cells—*turgor*
- Store anthocyanins (pink and blue pigments) in flowers and fruits
- Digestion in seeds—vacuoles have enzymes to hydrolyze stored food for early growth

Figure 4.18 Vacuoles in Plant Cells Are Usually Large



***LIFE 8e*, Figure 4.18**

4.3 What Are the Characteristics of Eukaryotic Cells?

Many protists have *food vacuoles*—formed by phagocytosis.

Freshwater protists may have contractile vacuoles to expel excess water.

The **cytoskeleton:**

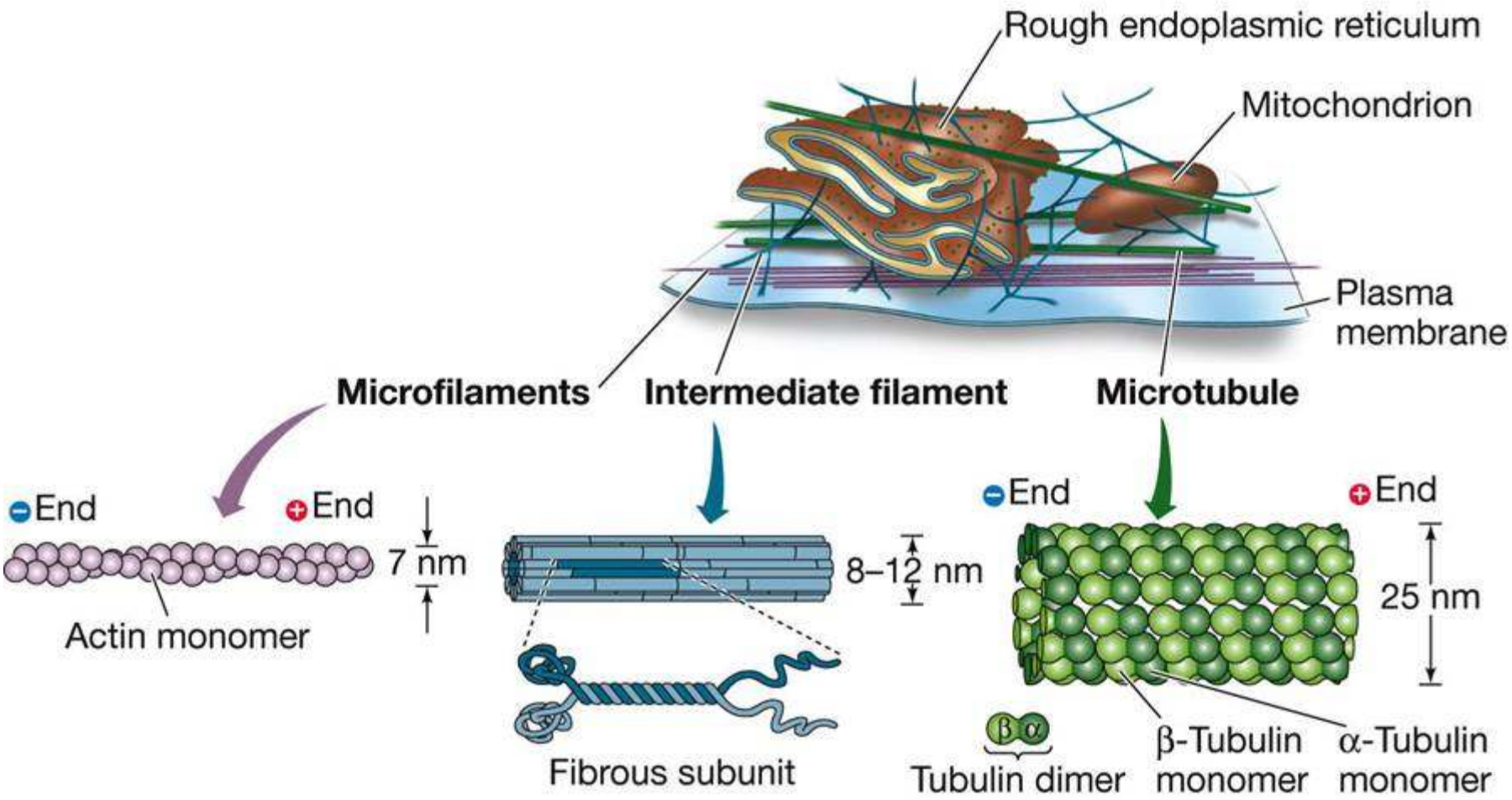
- Supports and maintains shape
- Allows some types of movement
- Positions organelles
- Some fibers act as support for motor proteins
- Interacts with extracellular structures to hold cell in place

4.3 What Are the Characteristics of Eukaryotic Cells?

The cytoskeleton has three components:

- Microfilaments
- Intermediate filaments
- Microtubules

Figure 4.20 The Cytoskeleton (Part 1)

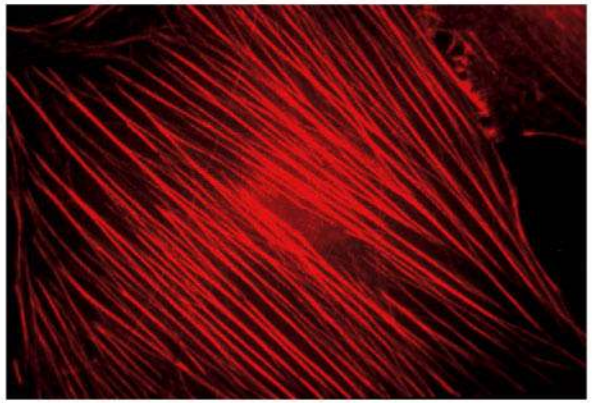


***LIFE 8e*, Figure 4.20 (Part 1)**

Microfilaments:

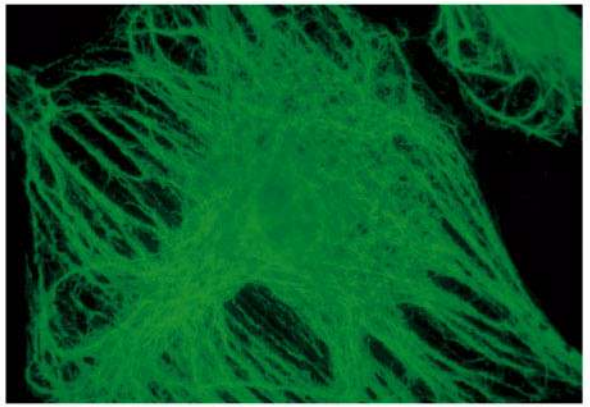
- Help a cell or parts of a cell to move
- Determine cell shape
- Made from the protein *actin*
- Actin has + and – ends and polymerizes to form long helical chains (reversible).

Figure 4.20 The Cytoskeleton (Part 2)



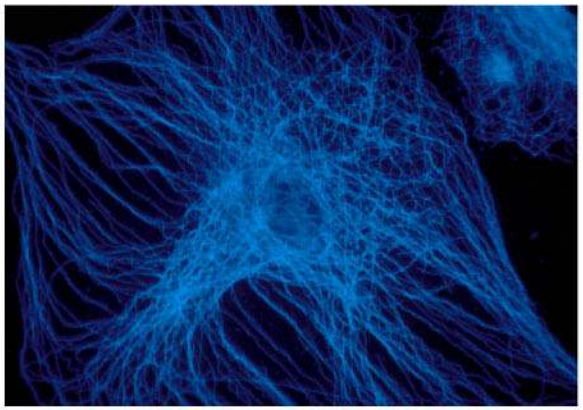
20 μm

(A) Microfilaments



10 μm

(B) Intermediate filaments

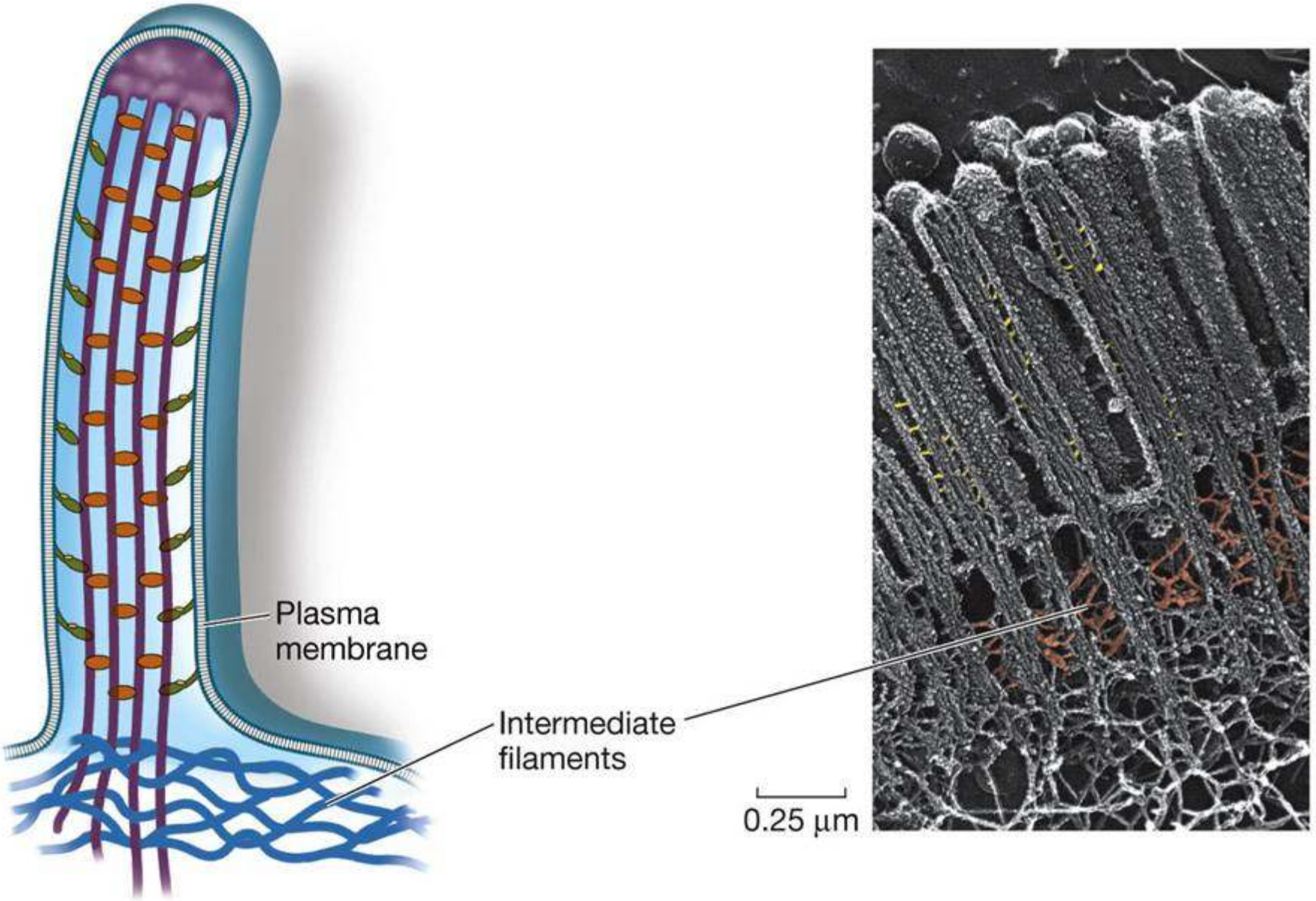


10 μm

(C) Microtubules

***LIFE 8e*, Figure 4.20 (Part 2)**

Figure 4.21 Microfilaments for Support

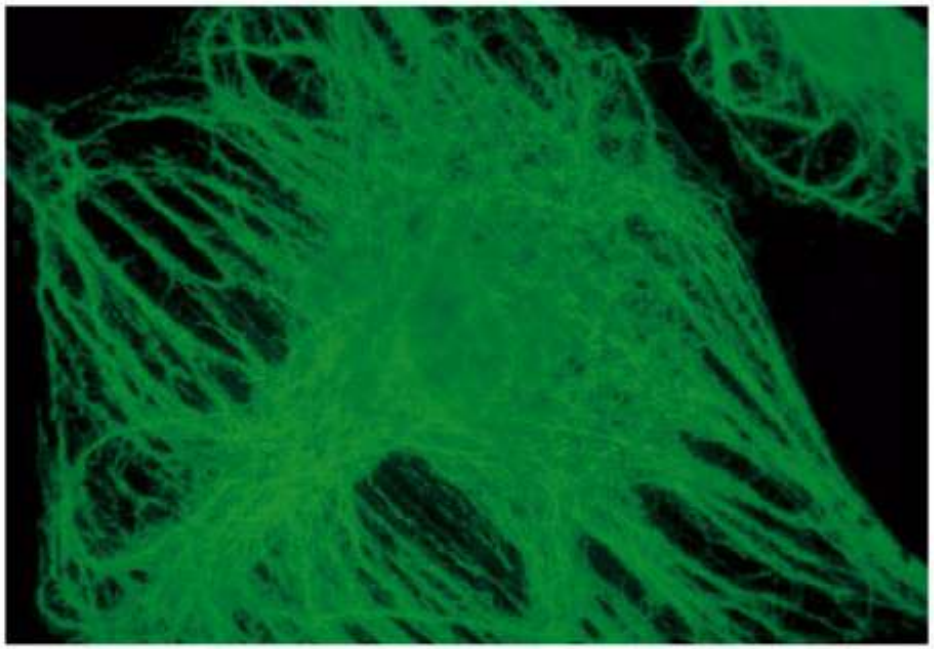


***LIFE 8e*, Figure 4.21**

Intermediate filaments:

- Many different kinds
- Made of fibrous proteins of the keratin family
- Stabilize cell structure and resist tension

Figure 4.20 The Cytoskeleton (Part 3)



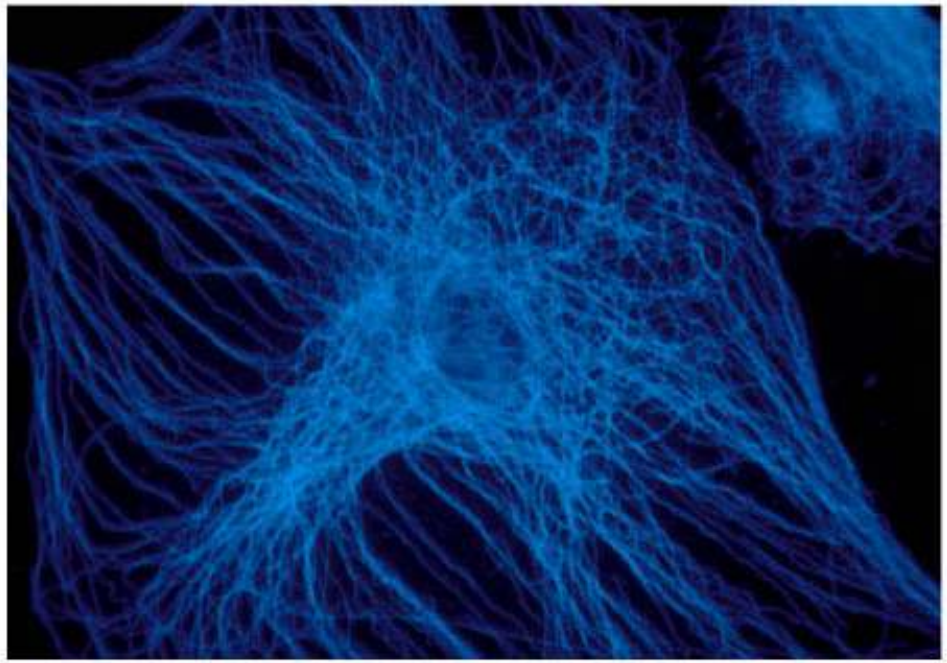
10 µm

(B) Intermediate filaments

Microtubules:

- Form rigid internal skeleton in some cells
- Act as tracks along which **motor proteins** move
- Made from the protein *tubulin*—a *dimer*
- Have + and – ends
- Can change length rapidly by adding or losing dimers

Figure 4.20 The Cytoskeleton (Part 4)



10 µm

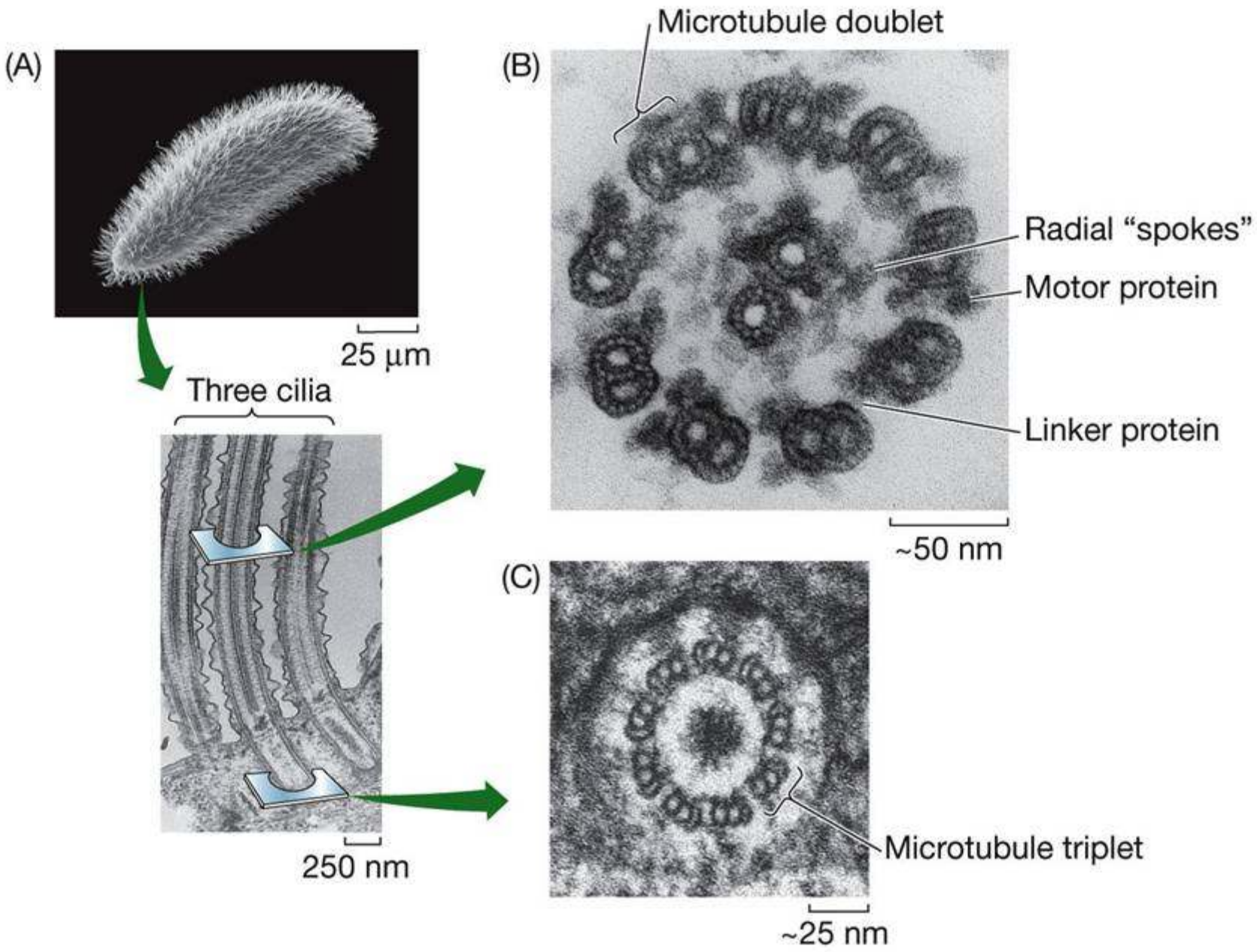
(C) Microtubules

4.3 What Are the Characteristics of Eukaryotic Cells?

Cilia and **eukaryotic flagella**: made of microtubules in “9 + 2” array

- Cilia—short, usually many present, move with stiff power stroke and flexible recovery stroke
- Flagella—longer, usually one or two present, movement is snake-like

Figure 4.22 Sliding Microtubules Cause Cilia to Bend



***LIFE 8e*, Figure 4.22**

The nine microtubule doublets extend into the basal body in the cytoplasm.

In the basal body, each doublet is joined by another microtubule, making nine triplets.

Centrioles are identical to basal bodies.

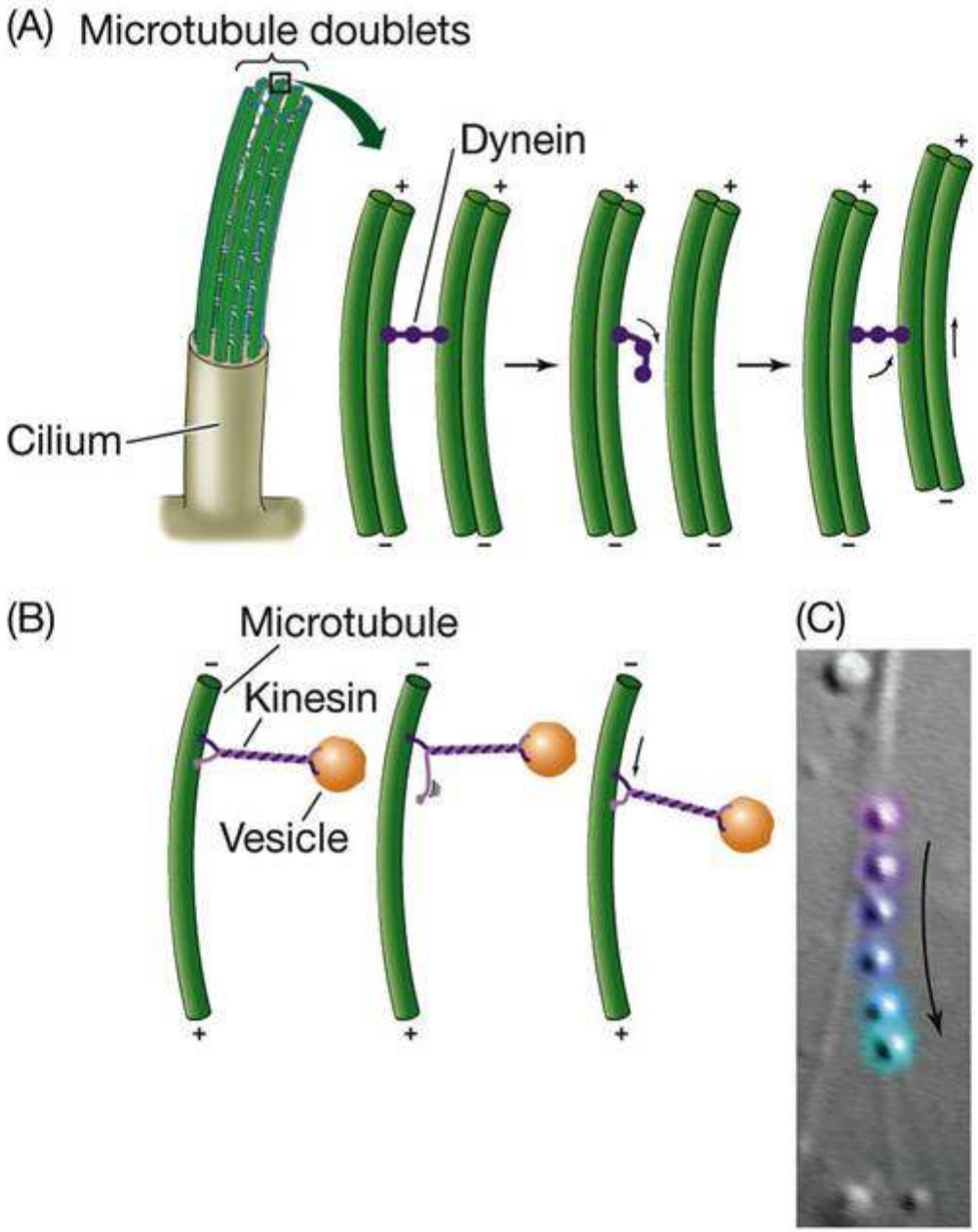
Involved in formation of the *mitotic spindle*.

Motor proteins: undergo reversible shape changes powered by ATP

Dynein binds to microtubule doublets and allows them to slide past each other.

Kinesin binds to a vesicle and “walks” it along by changing shape.

Figure 4.23 Motor Proteins Drive Vesicles along Microtubules



***LIFE 8e*, Figure 4.23**

4.4 What Are the Roles of Extracellular Structures?

Extracellular structures are outside the plasma membrane

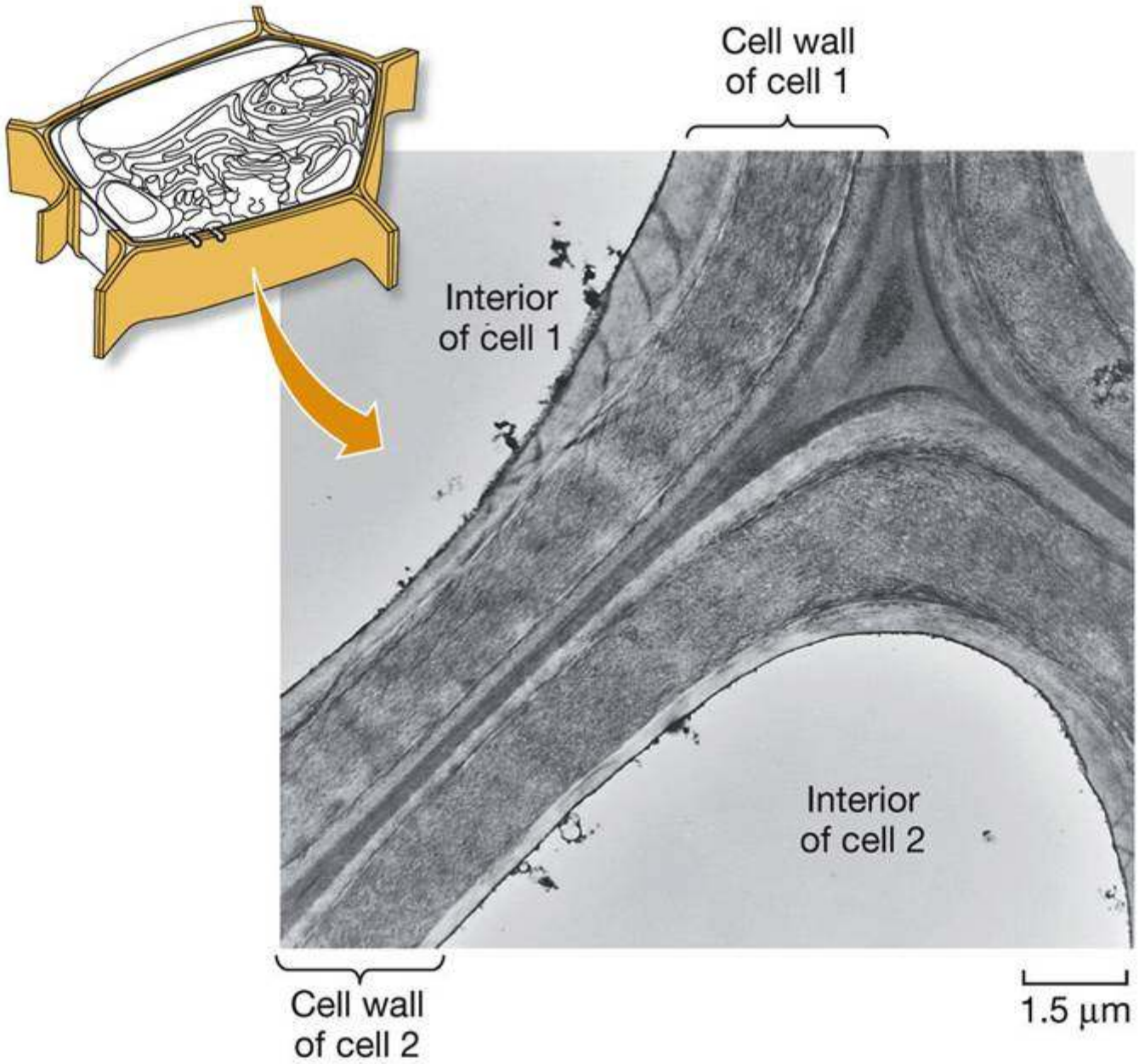
- Example: peptidoglycan cell wall of bacteria

4.4 What Are the Roles of Extracellular Structures?

Plant **cell walls**: cellulose fibers embedded in other complex polysaccharides and proteins

Adjacent plant cells are connected by plasma membrane-lined channels called **plasmodesmata**.

Figure 4.24 The Plant Cell Wall

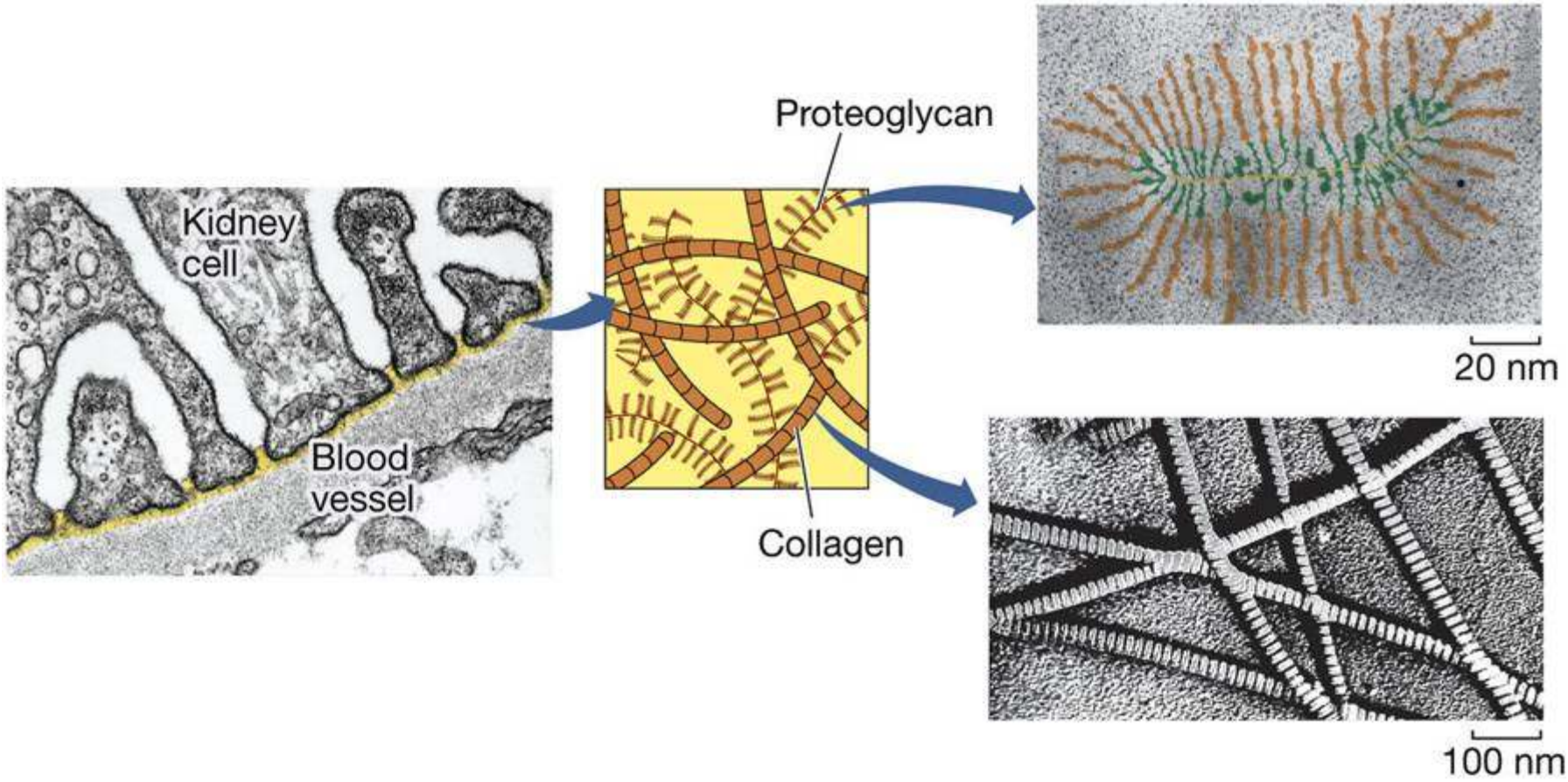


***LIFE 8e*, Figure 4.24**

4.4 What Are the Roles of Extracellular Structures?

Many animal cells are surrounded by an **extracellular matrix**, composed of fibrous proteins such as **collagen**, gel-like **proteoglycans** (glycoproteins), and other proteins.

Figure 4.25 An Extracellular Matrix



***LIFE 8e*, Figure 4.25**

4.4 What Are the Roles of Extracellular Structures?

The extracellular matrix:

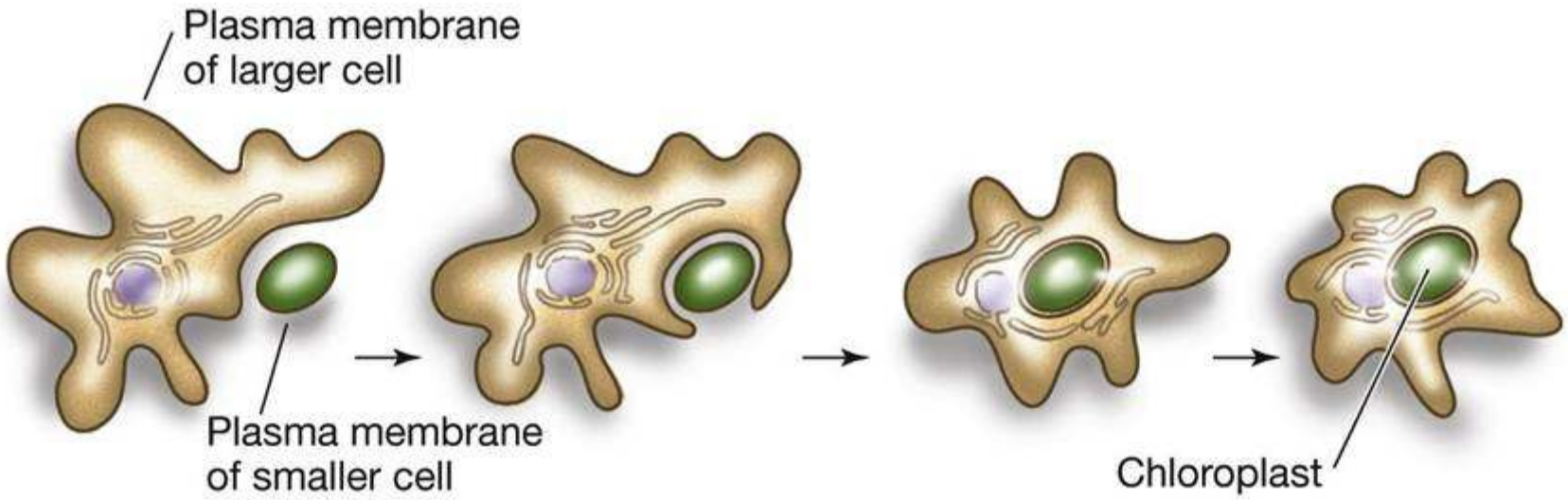
- Holds cells together in tissues
- Contributes to properties of bone, cartilage, skin, etc.
- Orient cell movements in development and tissue repair
- Plays a role in chemical signaling

4.5 How Did Eukaryotic Cells Originate?

Eukaryotic cells appeared about 1.5 billion years ago.

Endosymbiosis theory explains how eukaryotes could evolve from prokaryotes. Cells engulfed other cells that became mitochondria and chloroplasts.

Figure 4.26 The Endosymbiosis Theory



***LIFE 8e*, Figure 4.26**