4

Cells: The Basic Units of Life

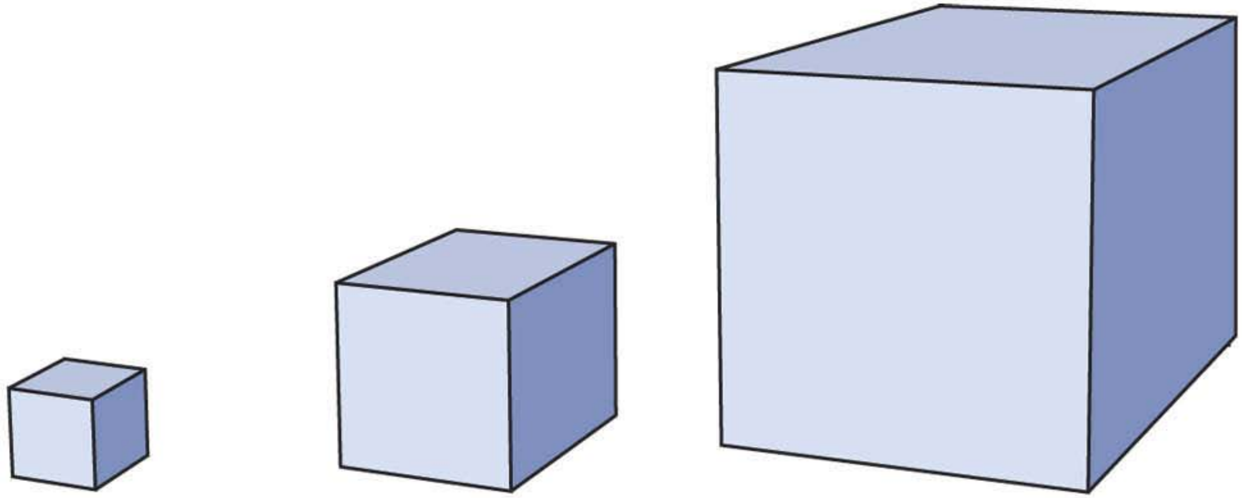
- The Cell: The Basic Unit of Life
- Prokaryotic Cells
- Eukaryotic Cells
- Organelles that Process Information
- The Endomembrane System
- Organelles that Process Energy
- Other Organelles
- The Cytoskeleton
- Extracellular Structures

- Life requires a structural compartment separate from the external environment in which macromolecules can perform unique functions in a relatively constant internal environment.
- These “living compartments” are cells.

- The **cell theory** states that:
  - Cells are the fundamental units of life.
  - All organisms are composed of cells.
  - All cells come from preexisting cells.

- Cell size is limited by the surface area-to-volume ratio.
- The surface of a cell is the area that interfaces with the cell's environment. The volume of a cell is a measure of the space inside a cell.
- Surface area-to-volume ratio is defined as the surface area divided by the volume. For any given shape, increasing volume decreases the surface area-to-volume ratio.

Figure 4.3 *Why Cells are Small*



	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: THE SCIENCE OF BIOLOGY, Seventh Edition, Figure 4.3 Why Cells Are Small
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- Because most cells are tiny, with diameters in the range of 1 to 100 μm, microscopes are needed to visualize them.
- With normal human vision the smallest objects that can be resolved (i.e., distinguished from one another) are about 200 μm (0.2 mm) in size.

Figure 4.2 The Scale of Life

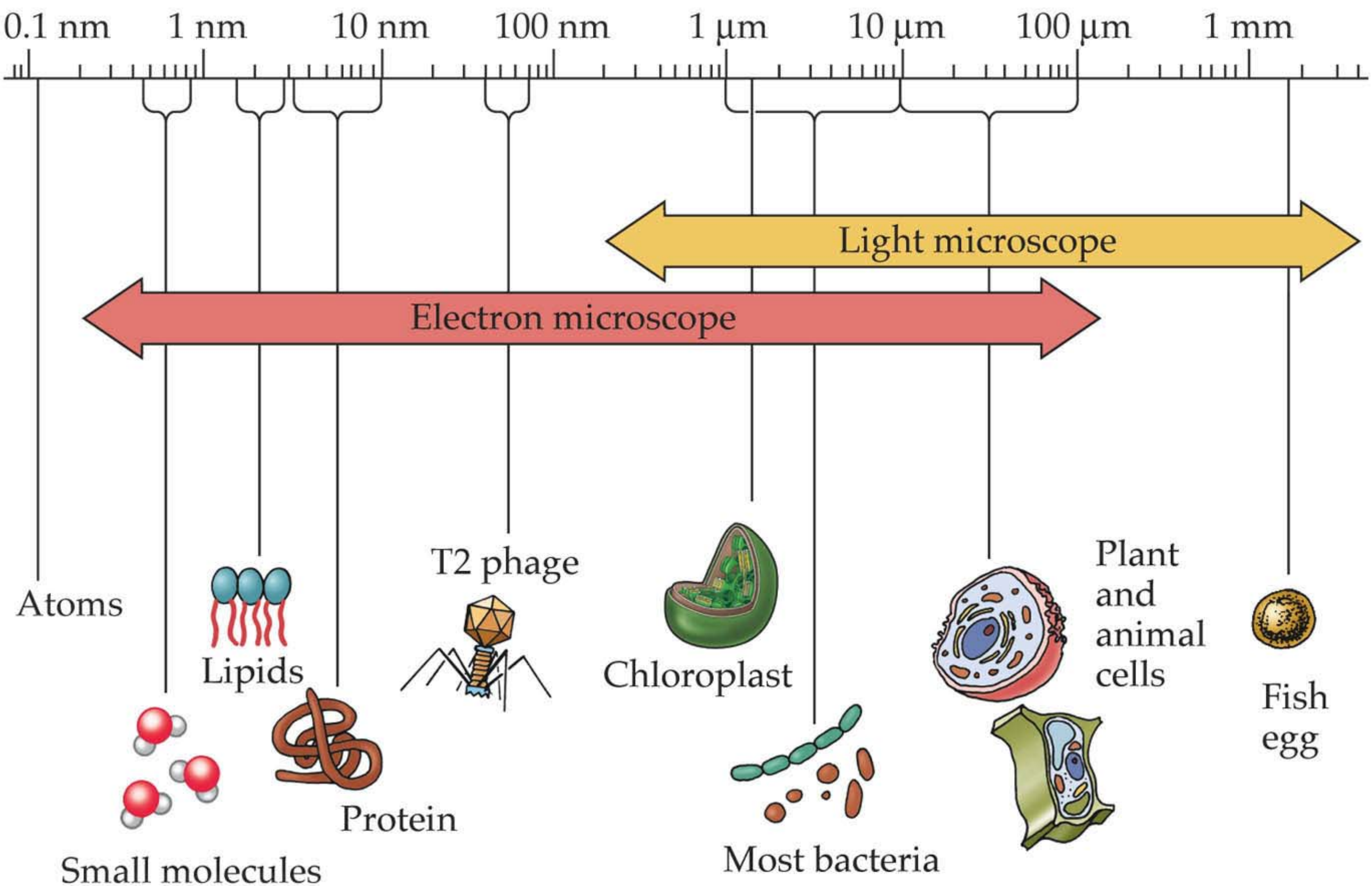

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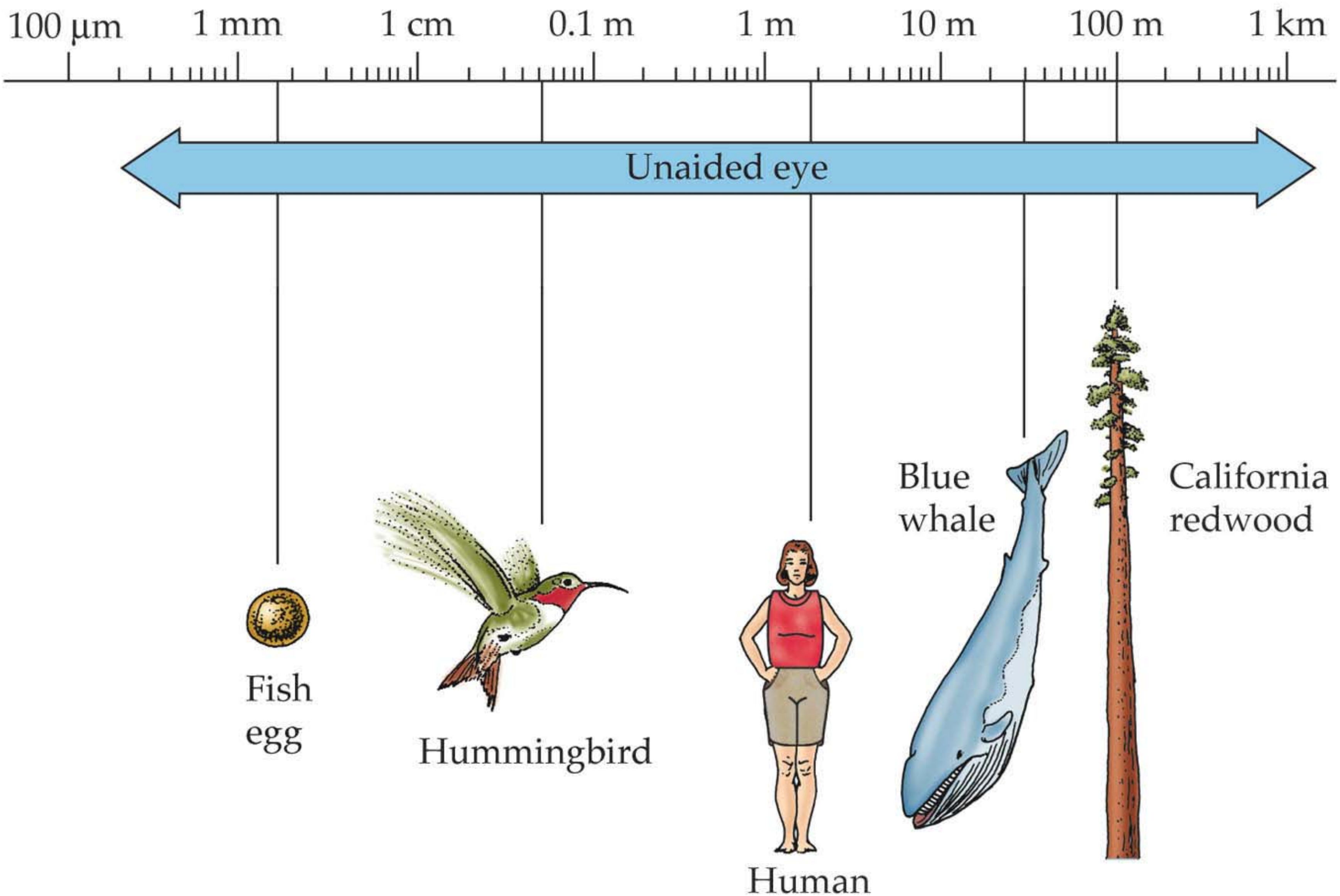
Figure 4.2 *The Scale of Life*



LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, Figure 4.2 The Scale of Life (Part 2)

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- Every cell is surrounded by a **plasma (cell) membrane**, a continuous membrane composed of a lipid bilayer with proteins floating within it and protruding from it.

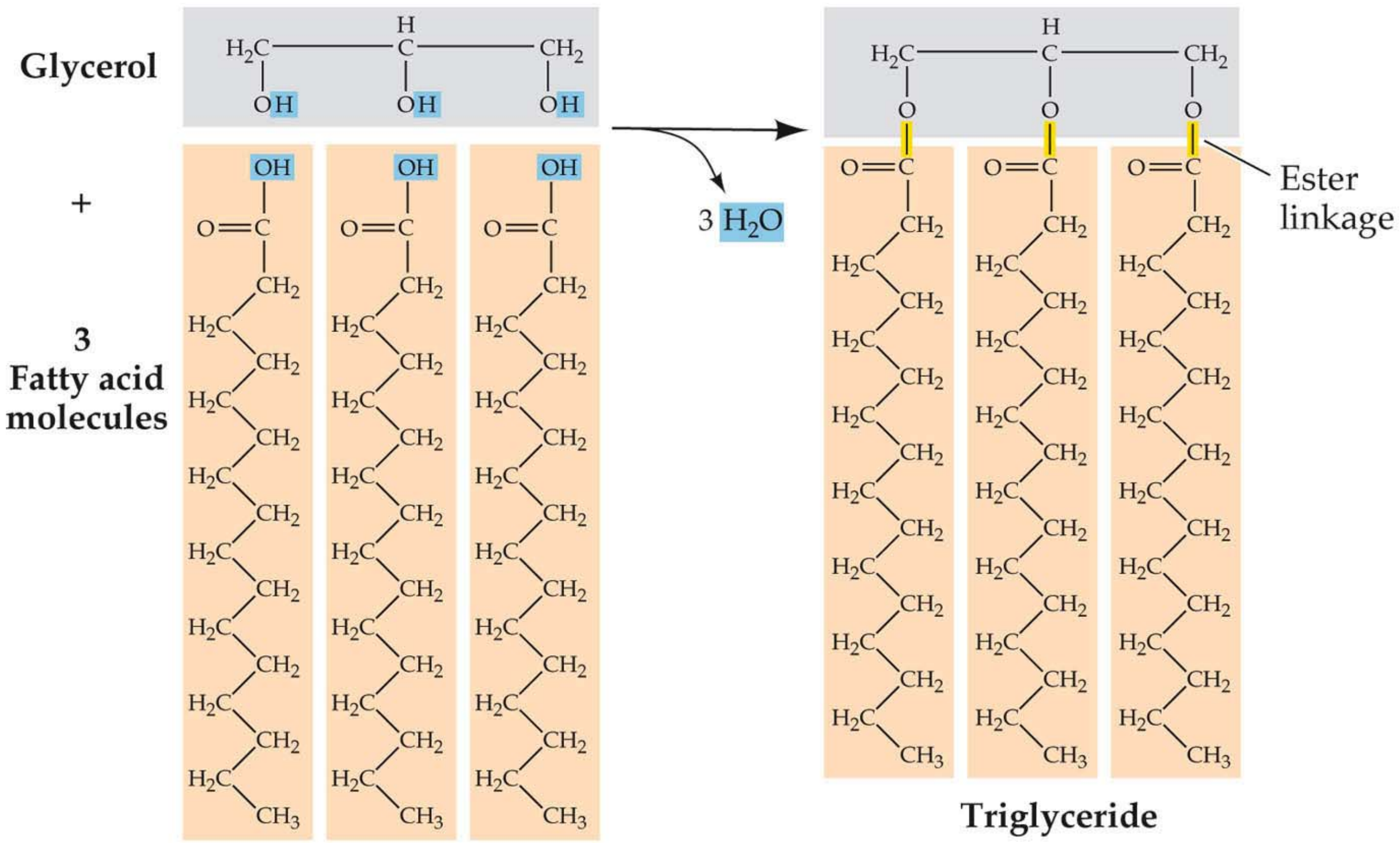
- **Lipids** are insoluble in water.

- This insolubility results from the many nonpolar covalent bonds of hydrogen and carbon in lipids.

- Lipids aggregate away from water, which is polar, and are attracted to each other via weak, but additive, van der Waals forces.

- Roles for lipids in organisms include:
  - Energy storage (fats and oils)
  - Plasma (cell) membranes (phospholipids)
  - Capture of light energy (carotinoids)
  - Hormones and vitamins (steroids and modified fatty acids)
  - Thermal insulation
  - Electrical insulation of nerves
  - Water repellency (waxes and oils)

- Fats and oils store energy.
- Fats and oils are **triglycerides**, composed of three fatty acid molecules and one glycerol molecule.
- **Glycerol** is a three-carbon molecule with three hydroxyl (—OH) groups, one for each carbon.
- **Fatty acids** are long chains of hydrocarbons with a carboxyl group (—COOH) at one end.



LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, Figure 3.18 Synthesis of a Triglyceride

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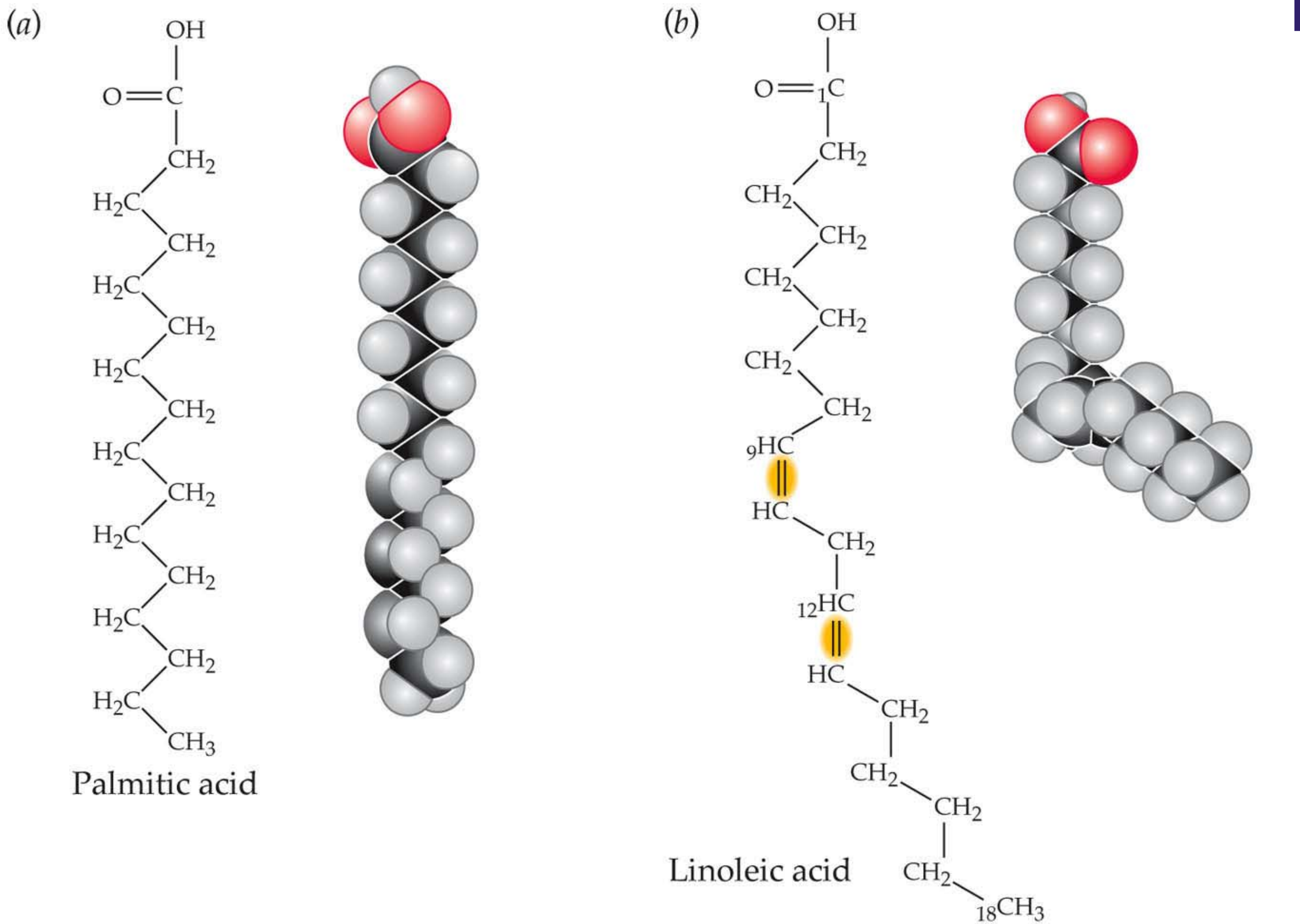
- **Saturated fatty acids** have only single carbon-to-carbon bonds and are said to be saturated with hydrogens.
- Saturated fatty acids are rigid and straight, and solid at room temperature. Animal fats are saturated (think about fat in meat)

- **Unsaturated fatty acids** have at least one double-bonded carbon in one of the chains —the chain is not completely saturated with hydrogen atoms.
- The double bonds cause kinks that prevent easy packing. Unsaturated fatty acids are liquid at room temperature. Plants commonly have unsaturated fatty acids.



LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, **Figure 3.19 Saturated and Unsaturated Fatty Acids**

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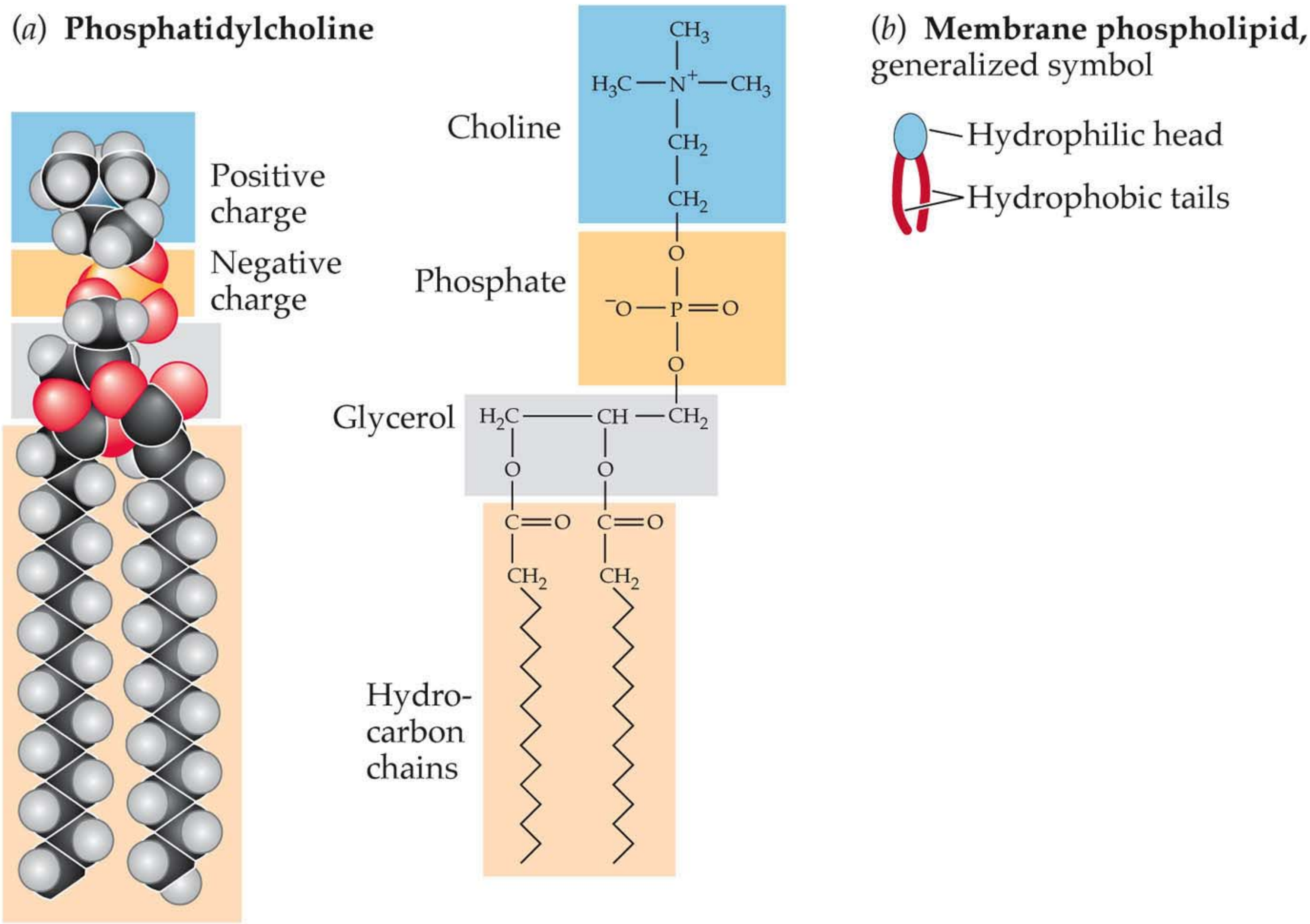
- **Phospholipids** have two hydrophobic fatty acid tails and one hydrophilic phosphate group attached to the glycerol.
- As a result, phospholipids orient themselves so that the phosphate group faces water and the tail faces away.
- In aqueous environments, these lipids form **bilayers**, with heads facing outward, tails facing inward. Cell membranes are structured this way.



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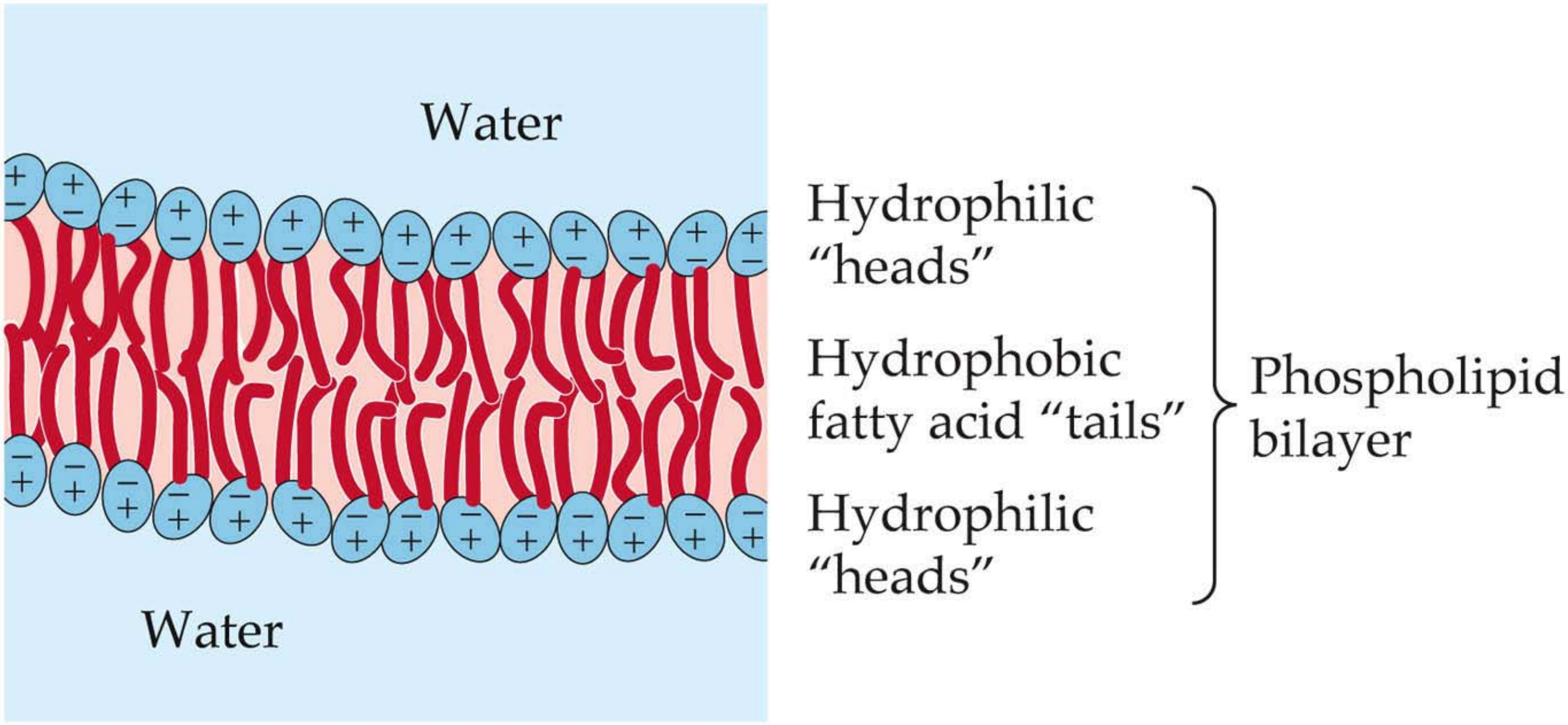

LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, **Figure 3.21 Phospholipids Form a Bilayer**

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- Roles of the plasma membrane:
  - Acts as a selectively permeable barrier.
  - Is an interface for cells where information is received from adjacent cells and extracellular signals.
  - Allows cells to maintain a constant internal environment.
  - Has molecules that are responsible for binding and adhering to adjacent cells.

- Cells show two organizational patterns:
  - **Prokaryotes** have no nucleus or other membrane-enclosed compartments. They lack distinct organelles.
  - **Eukaryotes** have a membrane-enclosed nucleus and other membrane-enclosed compartments or organelles as well.

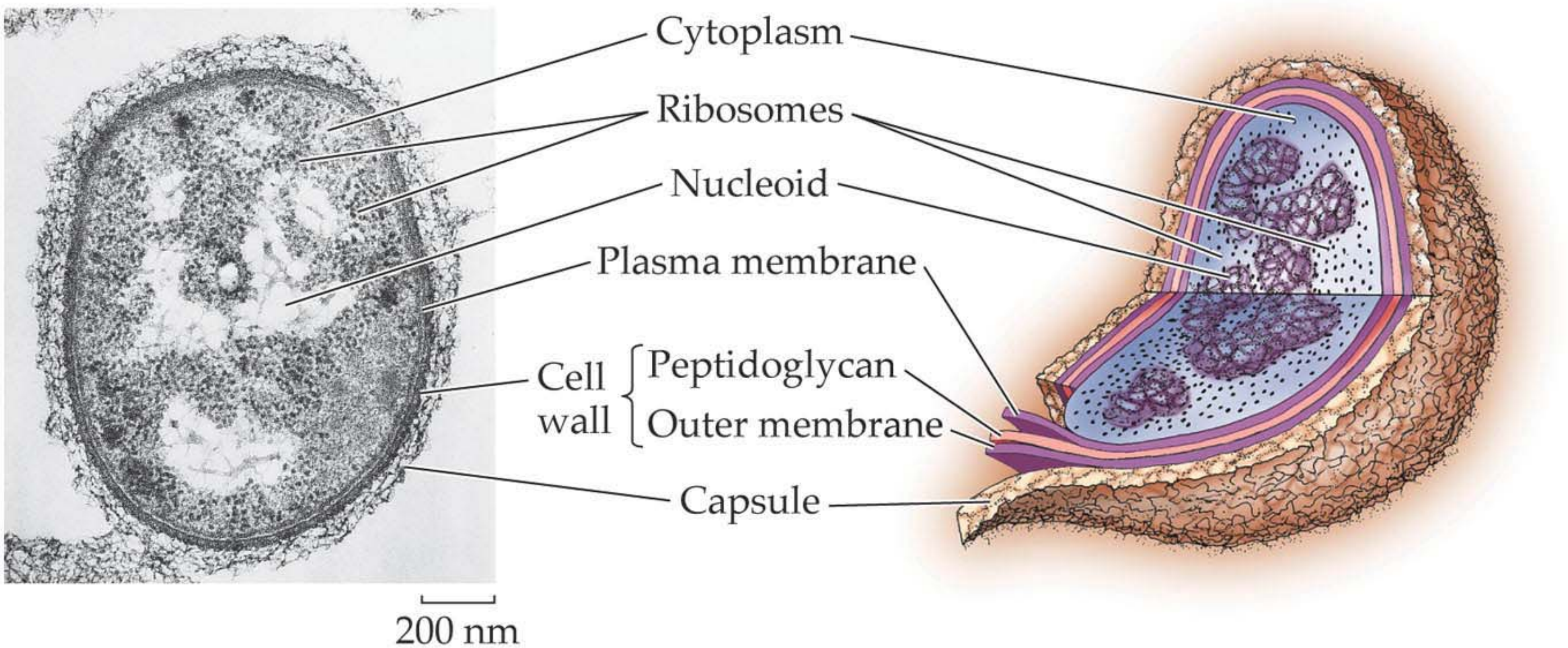
Prokaryotic Cells

- Prokaryotes inhabit the widest range of environmental extremes.
- Prokaryotic cells are generally smaller than eukaryotic cells.
- Each prokaryote is a single cell, but many types can be found in chains or clusters.

Prokaryotic Cells

- Features shared by all prokaryotic cells:
  - All have a plasma membrane.
  - All have a region called the **nucleoid** where the DNA is concentrated.
  - The **cytoplasm** (the plasma-membrane enclosed region) consists of the nucleoid, ribosomes, and a liquid portion called the **cytosol**.

Figure 4.5 *A Prokaryotic Cell*



LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, **Figure 4.5 A Prokaryotic Cell**
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Prokaryotic Cells

- Specialized features of some prokaryotic cells:
  - A cell wall just outside the plasma membrane (made of carbohydrates).
  - Some bacteria have another membrane outside the cell wall, a polysaccharide-rich phospholipid membrane.
  - Some bacteria have an outermost slimy layer made of polysaccharides and referred to as a **capsule**.
  - In lab today, you will have the opportunity to examine several different bacterial strains and look up their properties!

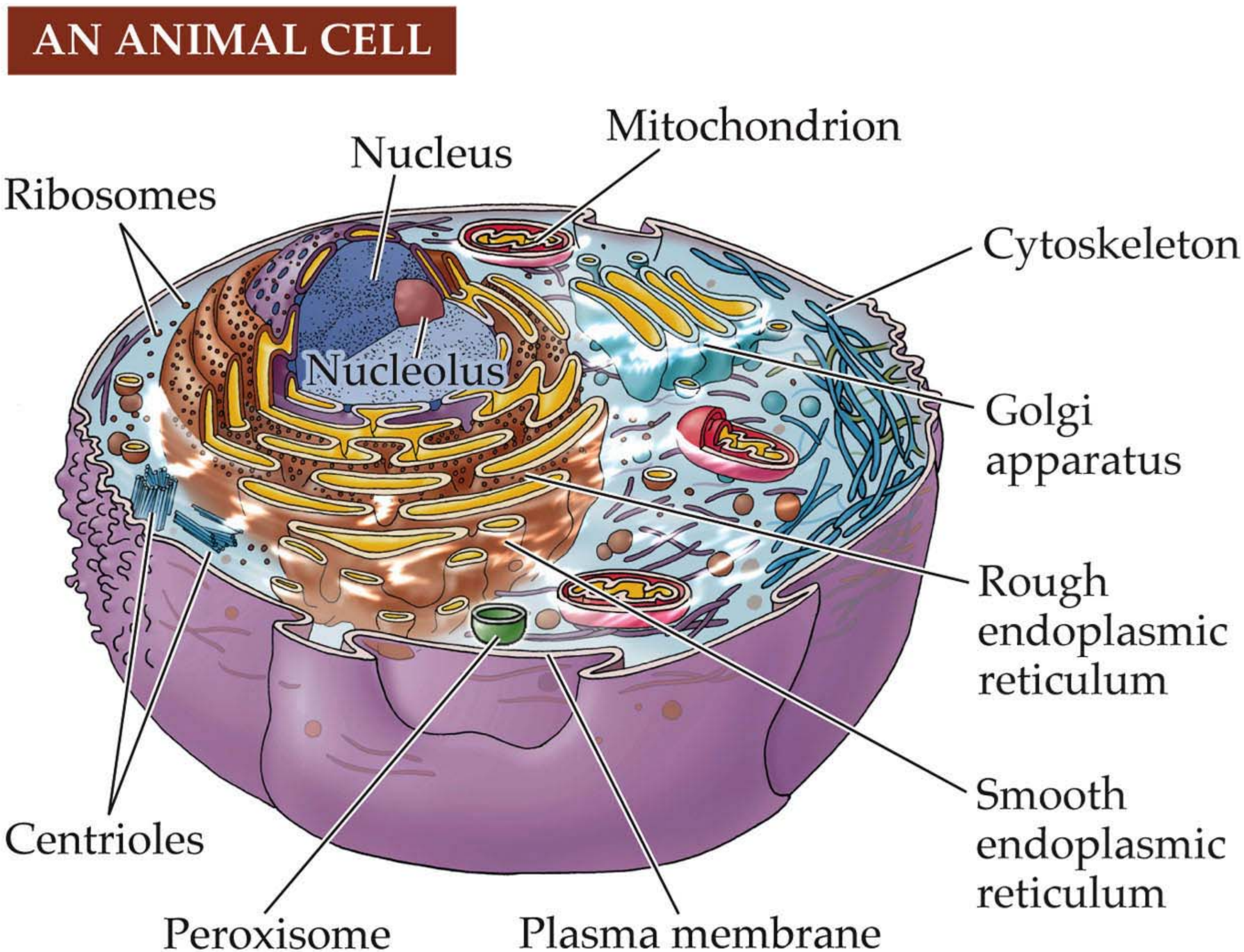
- Some bacteria, including cyanobacteria, can carry on photosynthesis. The plasma membrane is infolded and has chlorophyll.
- Some bacteria have **flagella**, locomotory structures shaped like a corkscrew.
- Some bacteria have **pili**, threadlike structures that help bacteria adhere to one another during mating or to other cells for food and protection.

Eukaryotic Cells

- **Eukaryotes**, (animals, plants, fungi, and protists), have a membrane-enclosed nucleus in each of their cells.
- Eukaryotic cells:
  - tend to be larger than prokaryotic cells.
  - have a variety of membrane-enclosed compartments called **organelles**.
  - have a protein scaffolding called the **cytoskeleton** – we mentioned this when talking about trafficking of things around the cell – molecular highways.

Eukaryotic Cells

- Compartmentalization is the key to eukaryotic cell function.
- Each organelle or compartment has a specific role defined by chemical processes.
- Membranes surrounding these organelles keep away inappropriate molecules and also act as traffic regulators for raw materials into and out of the organelle.



LIFE: THE SCIENCE OF BIOLOGY, *Seventh Edition*, Figure 4.7 Eukaryotic Cells (Part 5)

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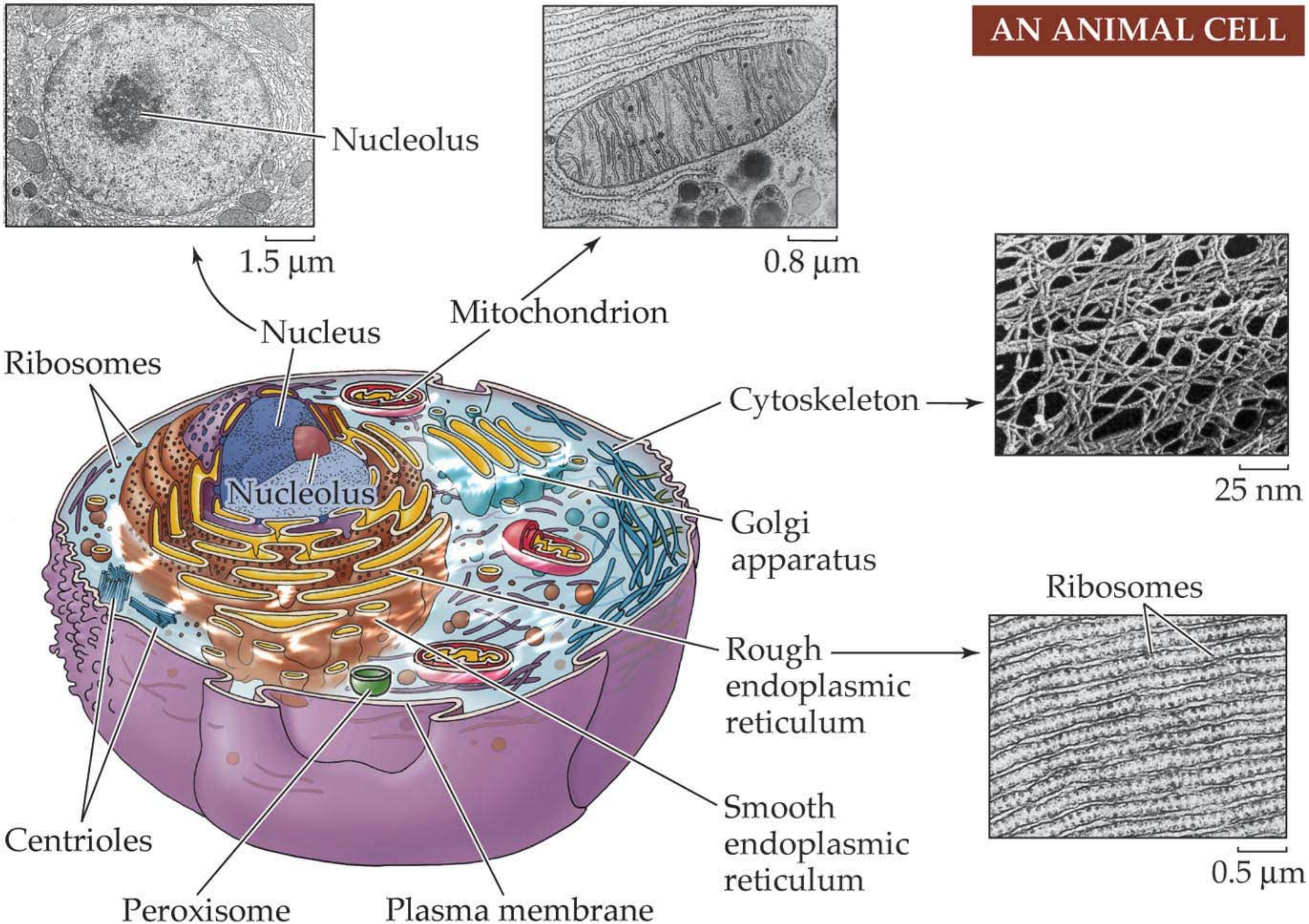
Figure 4.7 *Eukaryotic Cells* (Part 1)



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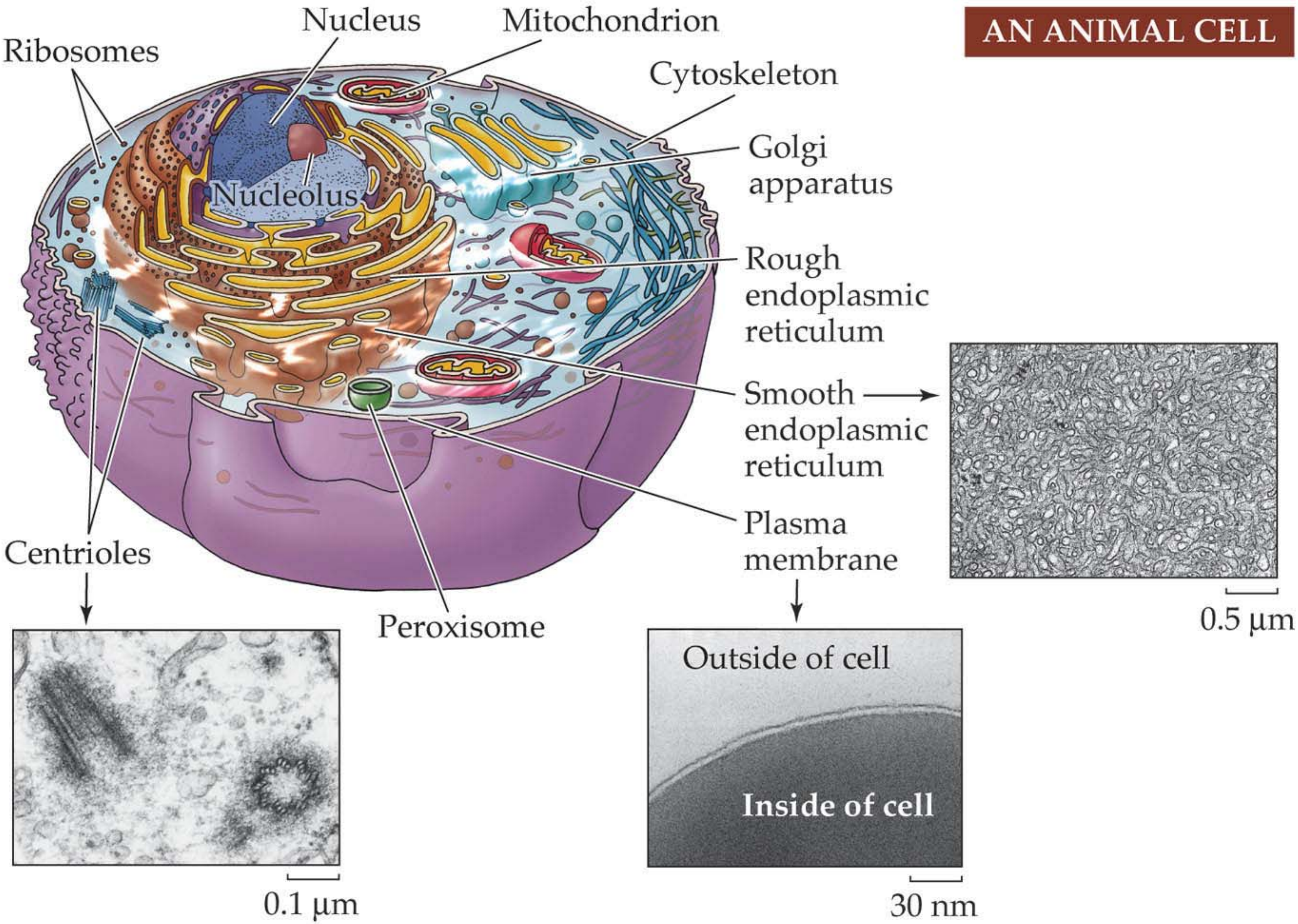

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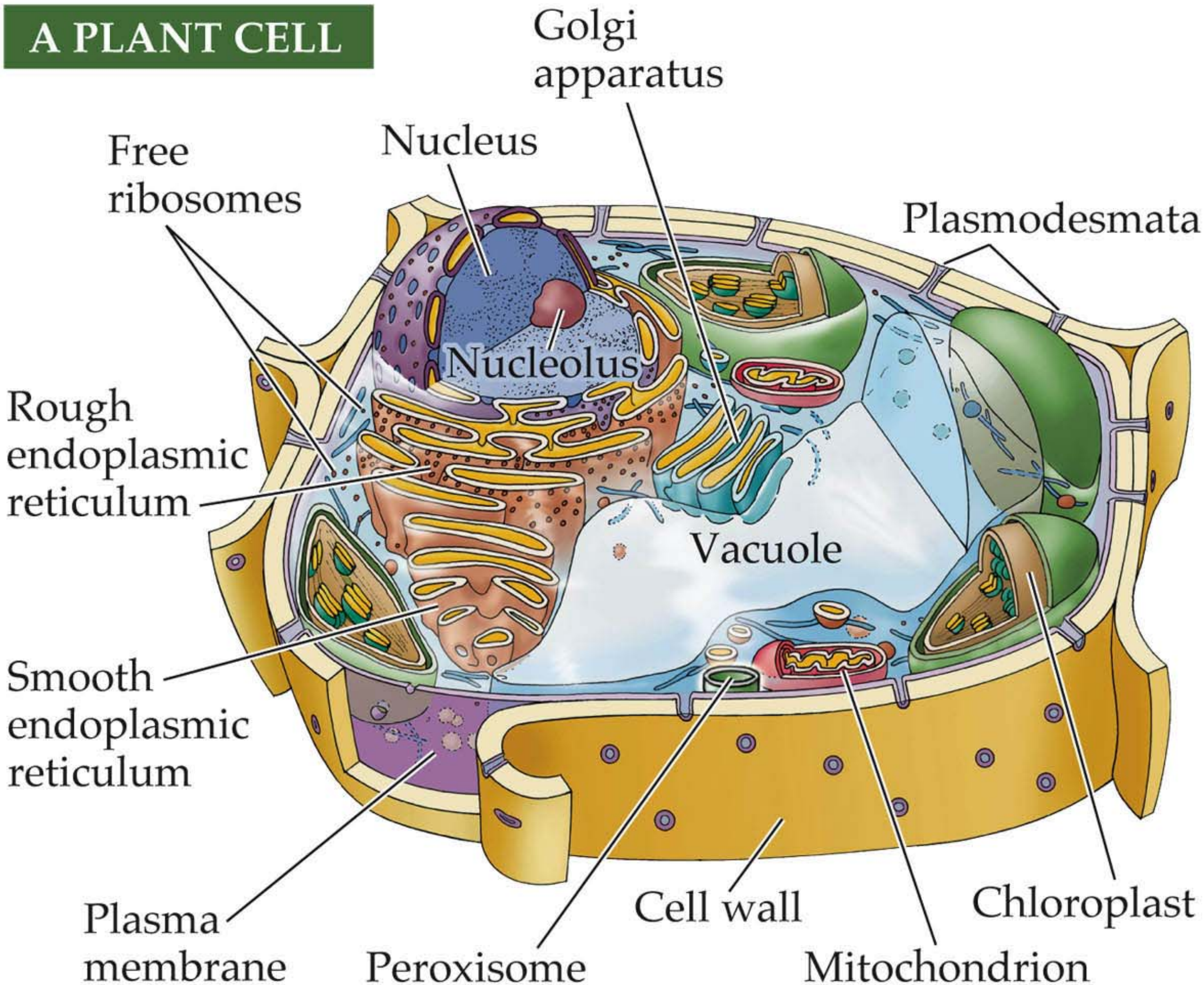

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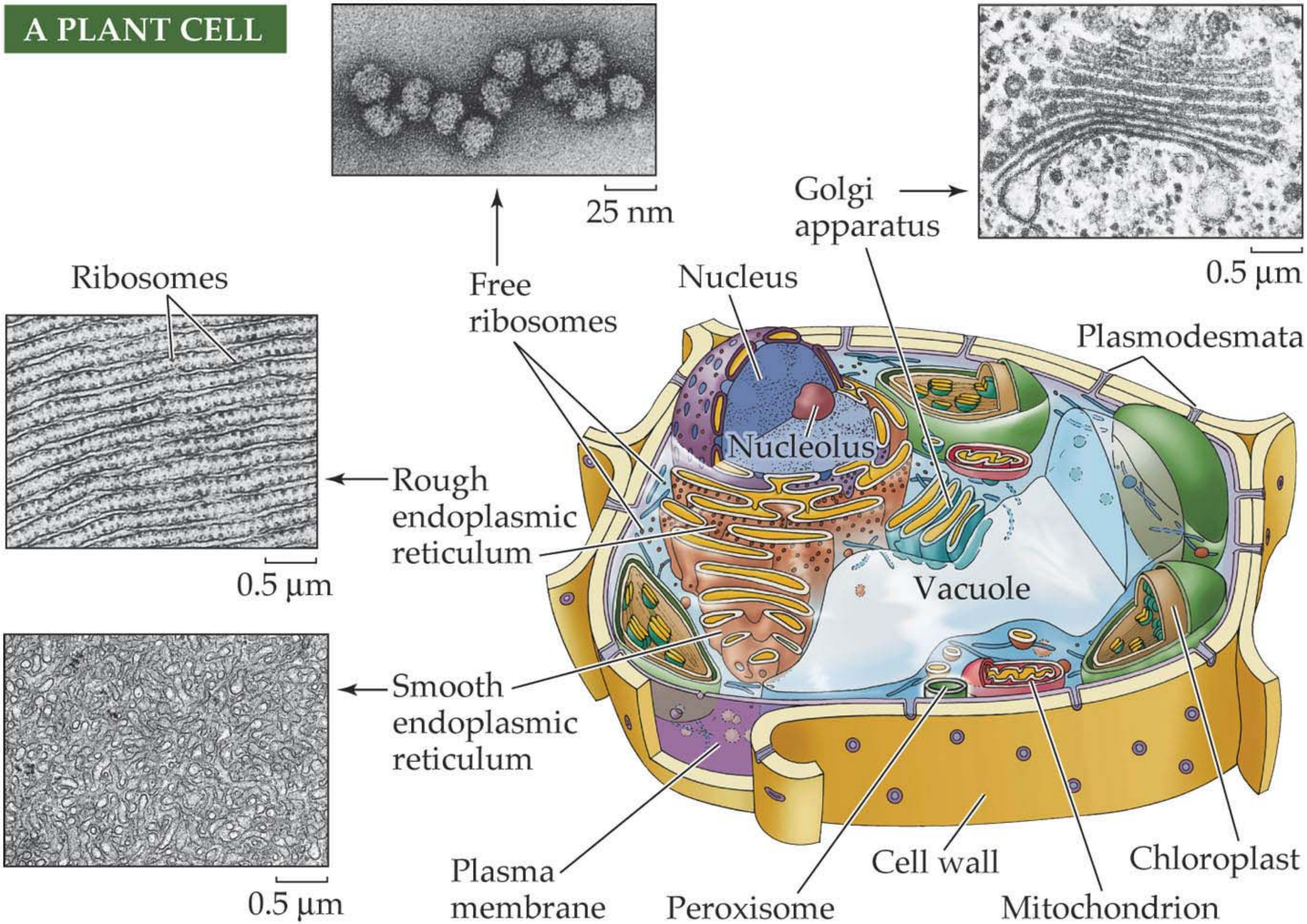

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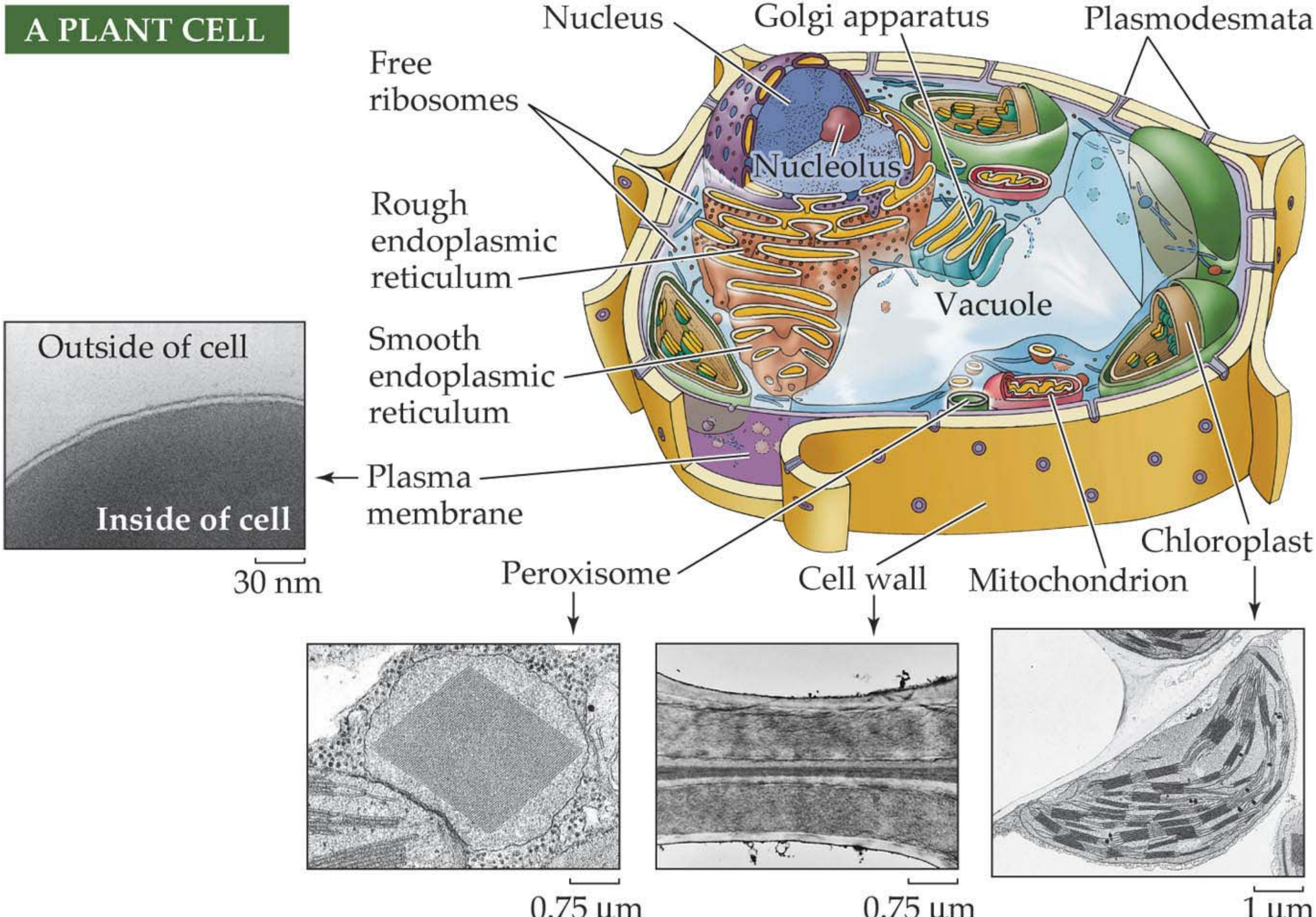

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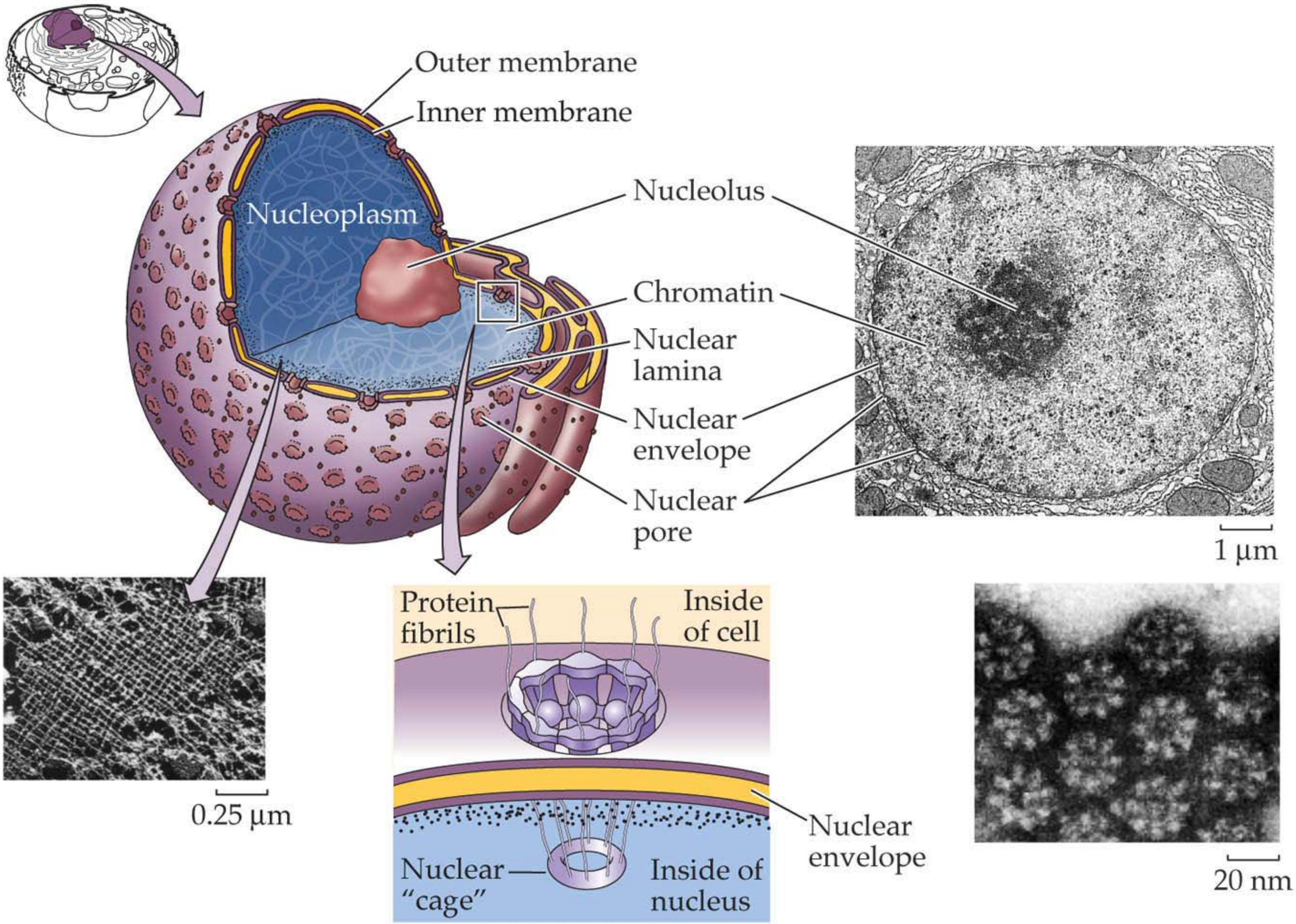
- Cell organelles can be studied by light and electron microscopy.
- Stains are used to target specific macromolecules and determine chemical composition.
- Cell fractionation is used to separate organelles for biochemical analyses. We will do a lab to isolate mitochondria next week

- The **nucleus** contains most of the cell's DNA and is the site of DNA duplication to support cell reproduction.
- The nucleus also plays a role in DNA control of cell activities.
- Within the nucleus is a specialized region called the **nucleolus**, where ribosomes are initially assembled.

- Two lipid bilayers form the **nuclear envelope** which is perforated with **nuclear pores**.
- The nuclear pores connect the interior of the nucleus with the rest of the cytoplasm.
- A pore complex, consisting of eight large protein granules, surrounds each pore.
- RNA and proteins must pass through these pores to enter or leave the nucleus.

Figure 4.9 *The Nucleus is Enclosed by a Double Membrane*



LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, **Figure 4.9 The Nucleus Is Enclosed by a Double Membrane**

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Organelles that Process Information

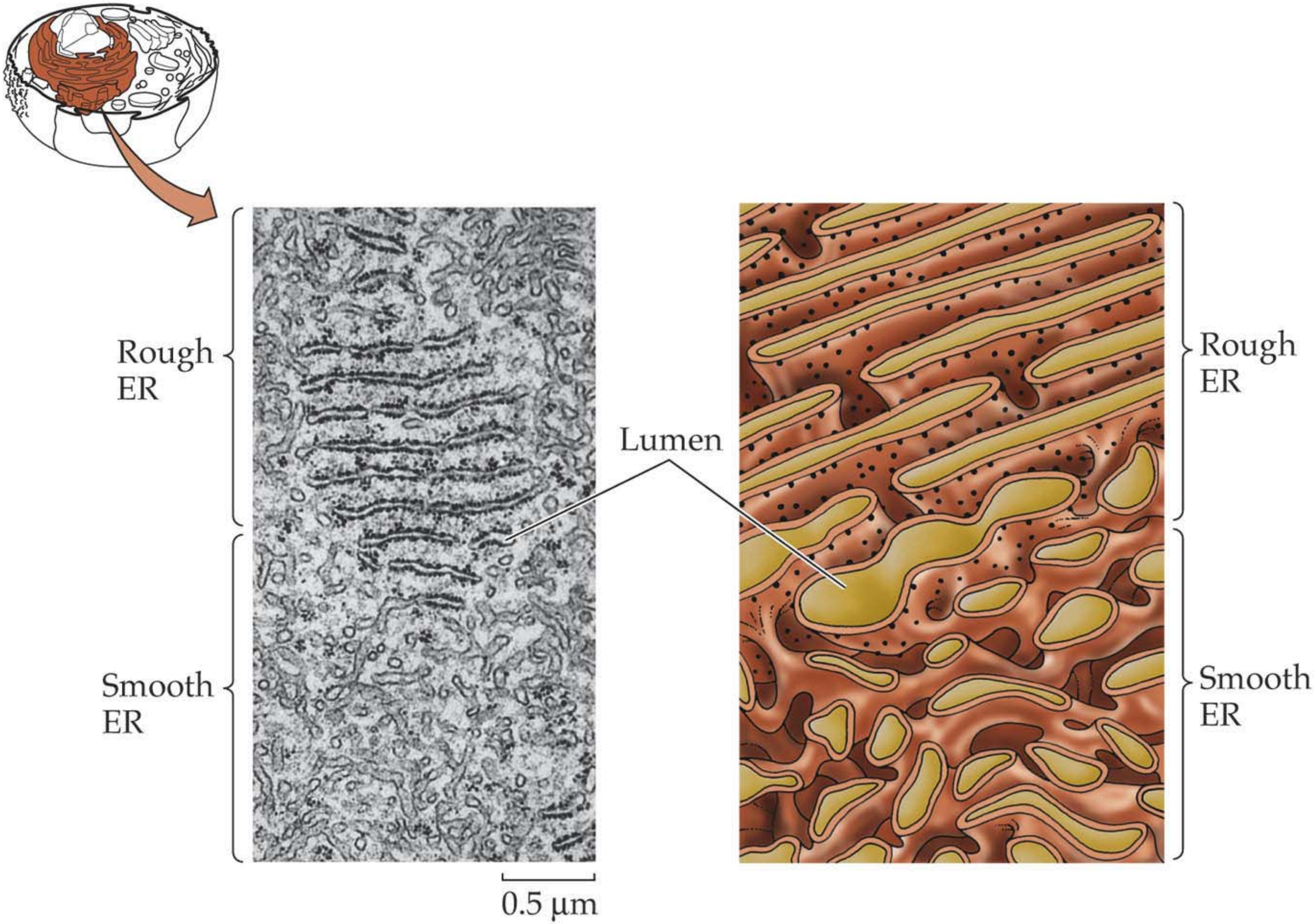
- The **chromatin** consists of diffuse or very long, thin fibers in which DNA is bound to proteins.
- Prior to cell division these condense and organize into structures recognized as **chromosomes**.
- Surrounding the chromatin is the **nucleoplasm** – bascially the nuclear cytoplasm.
- The **nuclear lamina** is a meshwork of proteins which maintains the shape of the nuclear envelope and the nucleus.

- **Ribosomes** are the sites of protein synthesis.
- In eukaryotes, functional ribosomes are found free in the cytoplasm, in mitochondria, bound to the endoplasmic reticulum, and in chloroplasts.
- They consist of a type of RNA called ribosomal RNA, and more than 50 other proteins.

- The **endoplasmic reticulum** (ER) is a network of interconnecting membranes distributed throughout the cytoplasm.
- The internal compartment, called the lumen, is a separate part of the cell with a distinct protein and ion composition.
- The ER’s folding generates a surface area much greater than that of the plasma membrane.
- At certain sites, the ER membrane is continuous with the outer nuclear envelope membrane.

- The rough ER (RER) has ribosomes attached is one of the places proteins are synthesized.
- The smooth ER (SER) is a ribosome-free region of the ER. It doesn’t synthesize ribosomes. It functions to synthesize lipids, detoxification.
- Cells that are specialized for synthesizing proteins for extracellular export have extensive ER membrane systems.

Figure 4.11 *The Endoplasmic Reticulum*



LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, Figure 4.11 The Endoplasmic Reticulum

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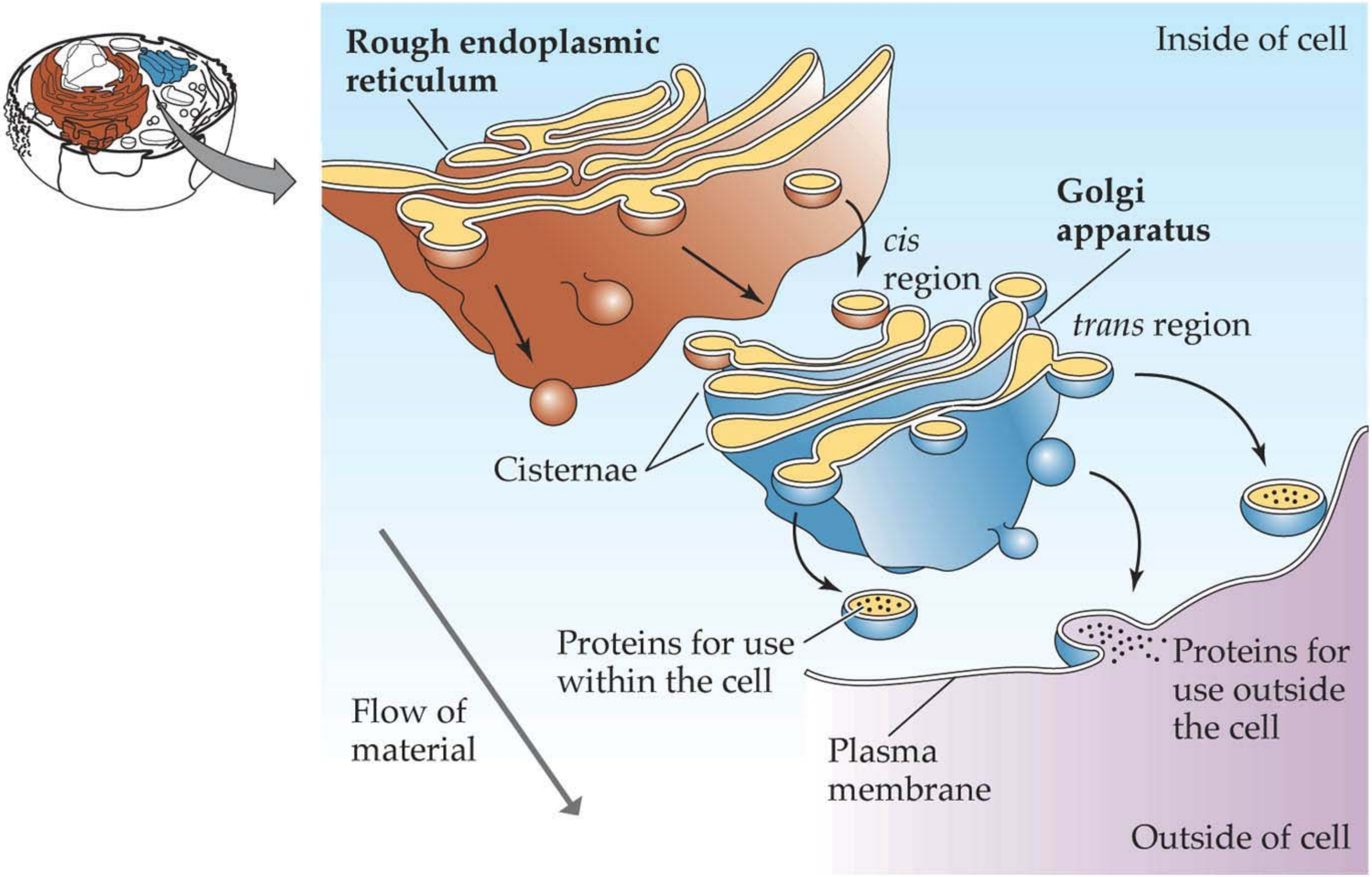
- The **Golgi apparatus** consists of flattened membranous sacs and small membrane-enclosed vesicles.
- The Golgi apparatus has three roles:
  - Receive proteins from the ER and further modifies them.
  - Concentrate, package, and sort proteins before they are sent to their destinations.
  - Some polysaccharides for plant cell walls are synthesized.

Figure 4.12 *The Golgi Apparatus*



LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, Figure 4.12 The Golgi Apparatus

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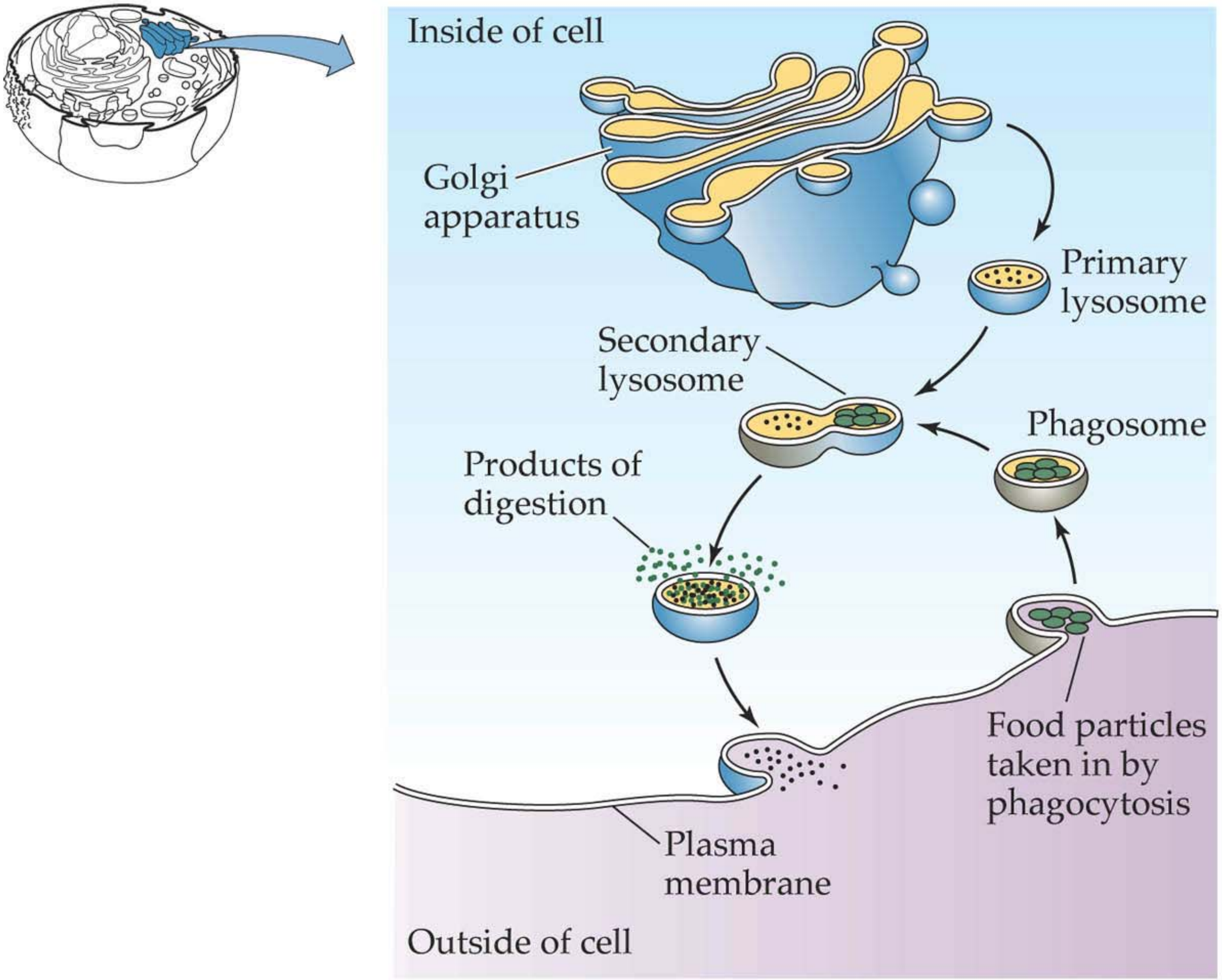
- **Lysosomes** are vesicles containing digestive enzymes that come in part from the Golgi.
- Lysosomes are sites for breakdown of food and foreign material brought into the cell by **phagocytosis**.
- Lysosomes are also the sites where digestion of spent cellular components occurs, a process called **autophagy**.

Figure 4.13 *Lysosomes Isolate Digestive Enzymes from the Cytoplasm*



LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, **Figure 4.13 Lysosomes Isolate Digestive Enzymes from the Cytoplasm**

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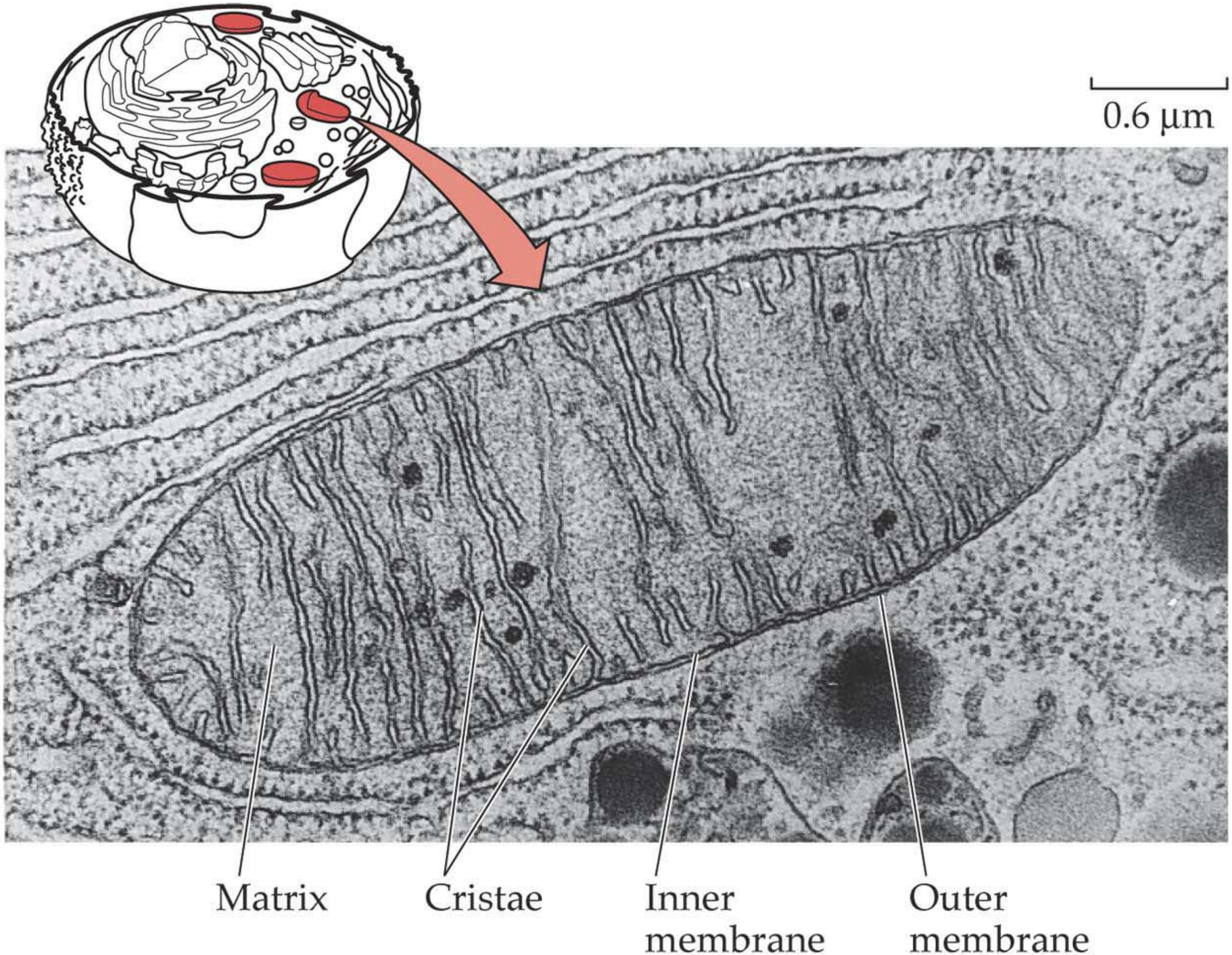
Organelles that Process Energy

- The primary function of **mitochondria** is to convert the potential chemical energy of fuel molecules into a form that the cell can use (ATP).
- The production of ATP is called **cellular respiration.**
- *We will study this in depth later in the course.*

- Mitochondria have an outer lipid bilayer and a highly folded inner membrane.
- Folds of the inner membrane give rise to the **cristae**, which contain large protein molecules used in cellular respiration.
- The region enclosed by the inner membrane is called the **mitochondrial matrix.**



LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, Figure 4.14 A Mitochondrion Converts Energy from Fuel Molecules into ATP (Part 1)

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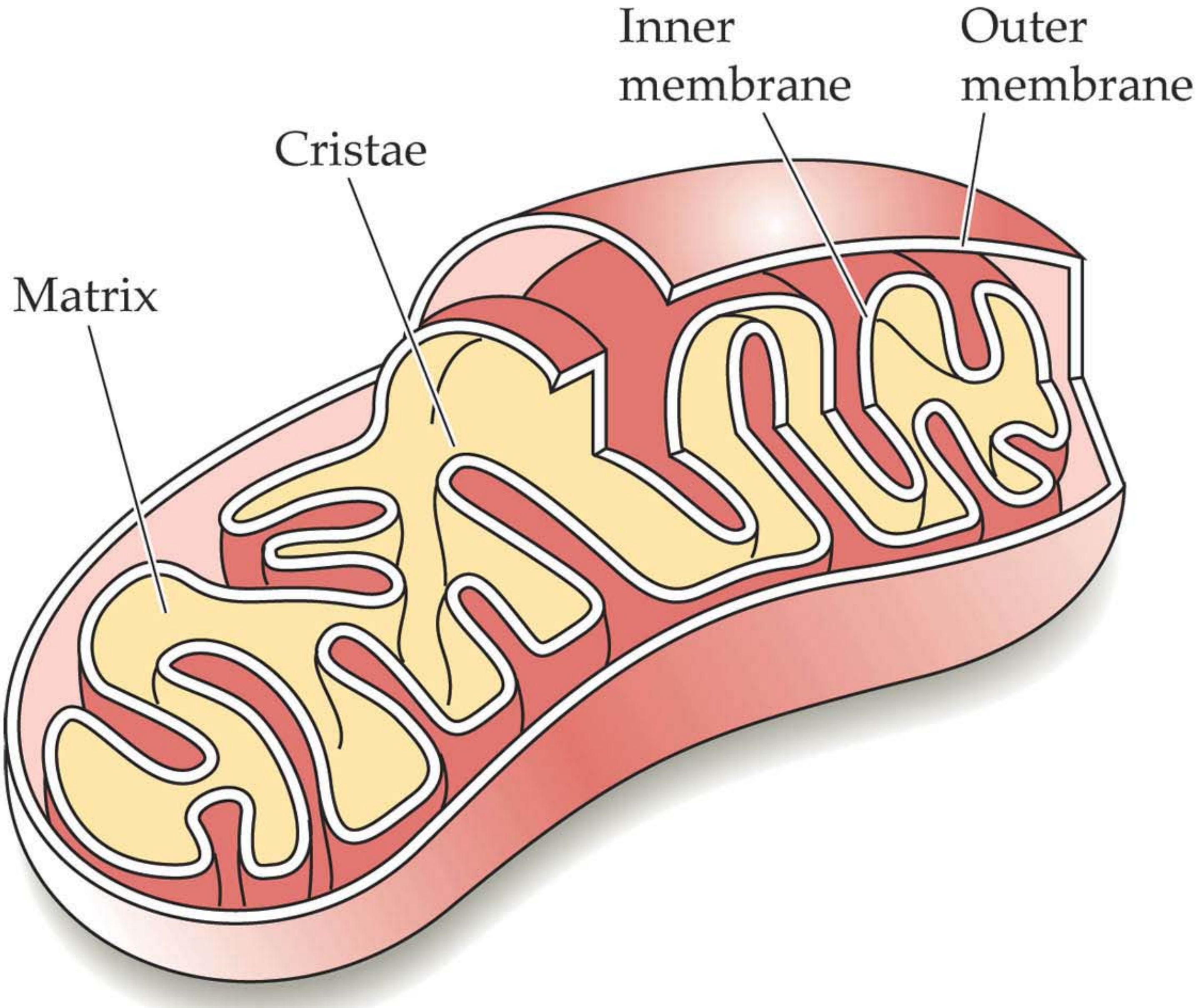
Figure 4.14 *A Mitochondrion Converts Energy from Fuel Molecules into ATP* (Part 2)



LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, **Figure 4.14 A Mitochondrion Converts Energy from Fuel Molecules into ATP (Part 2)**

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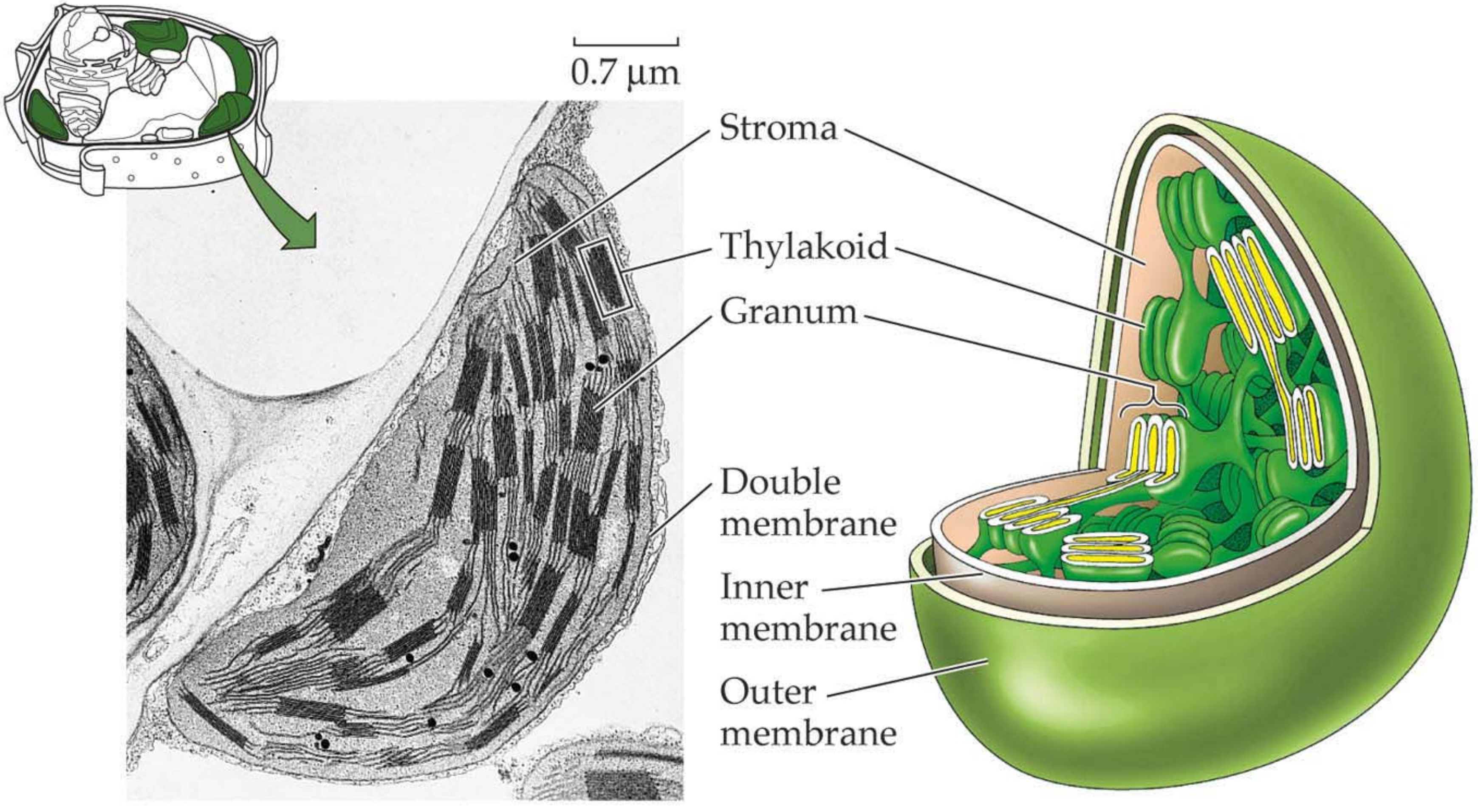
Organelles that Process Energy

- **Plastids** are organelles found only in plants and some protists.
- **Chloroplasts**, the sites where photosynthesis occurs, are one type of plastid.

Organelles that Process Energy

- Chloroplasts are surrounded by two layers, and have an internal membrane system similar to mitochondria.
- The internal membranes are arranged as **thylakoids** and **grana**. These membranes contain chlorophyll and other pigments.
- The fluid in which the grana are suspended is called the **stroma.**

Figure 4.15 *The Chloroplast: The Organelle That Feeds the World*



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Organelles that Process Energy

- **Endosymbiosis** may explain the origin of mitochondria and chloroplasts.
- According to the endosymbiosis theory, both organelles were formerly prokaryotic organisms that somehow became incorporated into a larger cell.
- Today, both mitochondria and chloroplasts have DNA and ribosomes, and are self-duplicating organelles.

Other Organelles

- **Peroxisomes**, also called microbodies, are small organelles that are specialized to compartmentalize toxic peroxides and break them down.
- **Glyoxysomes** are structurally similar organelles found in plants.

Other Organelles

- **Vacuoles**, found in plants and protists, are filled with an aqueous solution and are used to store wastes and pigments.
- Vacuoles may develop turgor pressure, a swelling that helps the plant cell maintain support and rigidity.
- Food vacuoles are formed in single-celled protists.
- Many freshwater protists have a contractile vacuole that helps eliminate excess water and restore proper salt balance.

- The **cytoskeleton:**
  - maintains cell shape and support.
  - provides the mechanisms for cell movement.
  - acts as tracks for “motor proteins” that help move materials within cells.
- There are three major types of cytoskeletal components: microfilaments, intermediate filaments, and microtubules.

- **Microfilaments** are made of the protein **actin**, and may exist as single filaments, in bundles, or in networks.
- Microfilaments are needed for cell contraction, as in muscle cells, and add structure to the plasma membrane and shape to cells.
- They are involved in cytoplasmic streaming, and the formation of pseudopodia.

- **Intermediate filaments** are found only in multicellular organisms, forming ropelike assemblages in cells.
- They have two major structural functions: to stabilize the cell structure, and resist tension.
- In some cells, intermediate filaments maintain the positions of the nucleus and other organelles in the cell.

- **Microtubules** are hollow cylinders made from **tubulin** protein subunits.
- Microtubules provide a rigid intracellular skeleton for some cells, and they function as tracks that motor proteins can move along in the cell.
- They regularly form and disassemble as the needs of the cell change.

Figure 4.21 *The Cytoskeleton* (Part 1)

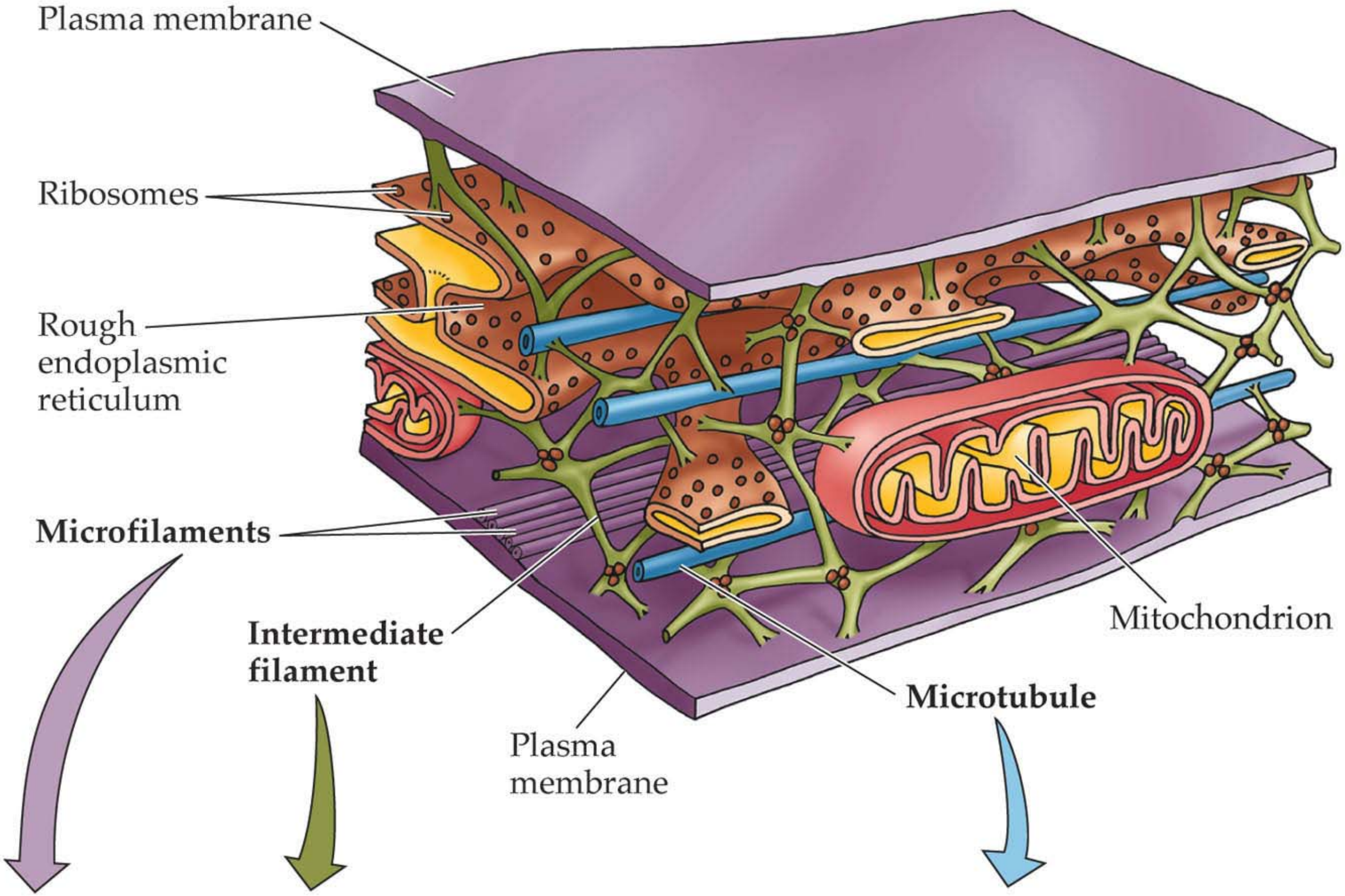

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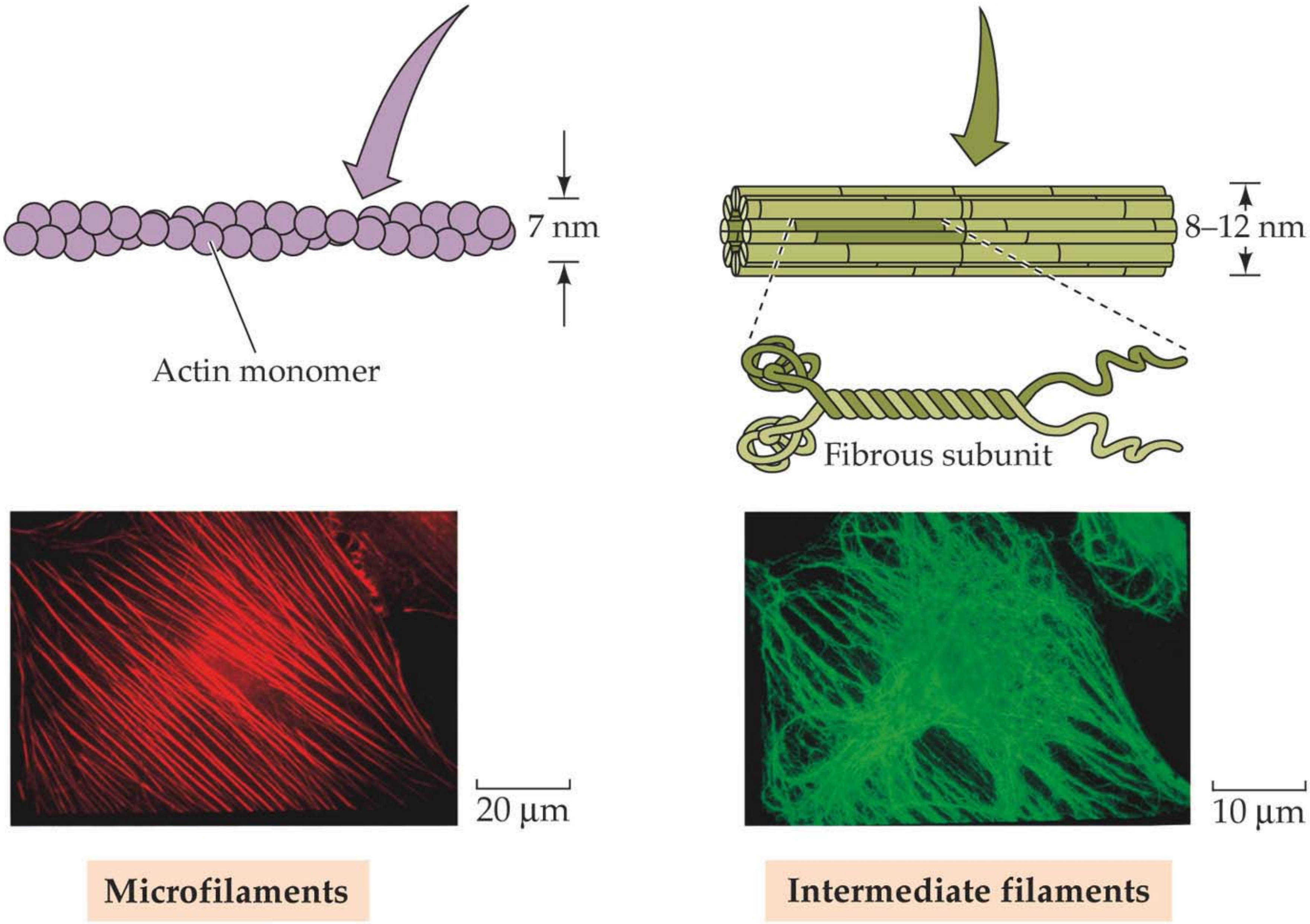
Figure 4.21 *The Cytoskeleton* (Part 2)



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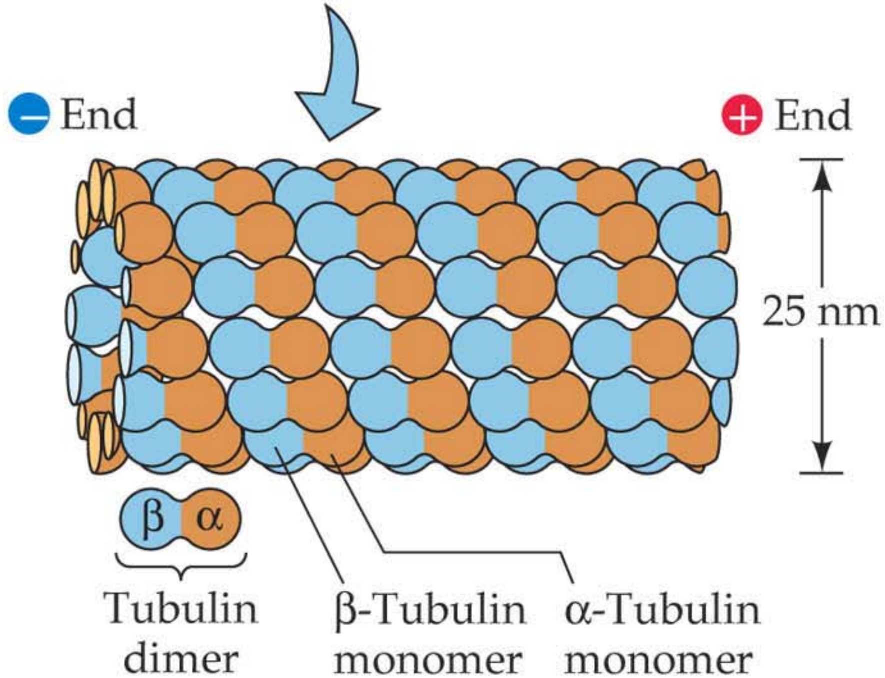

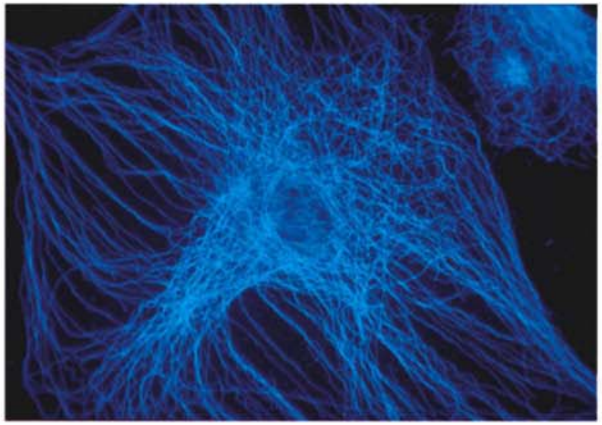

Microtubules

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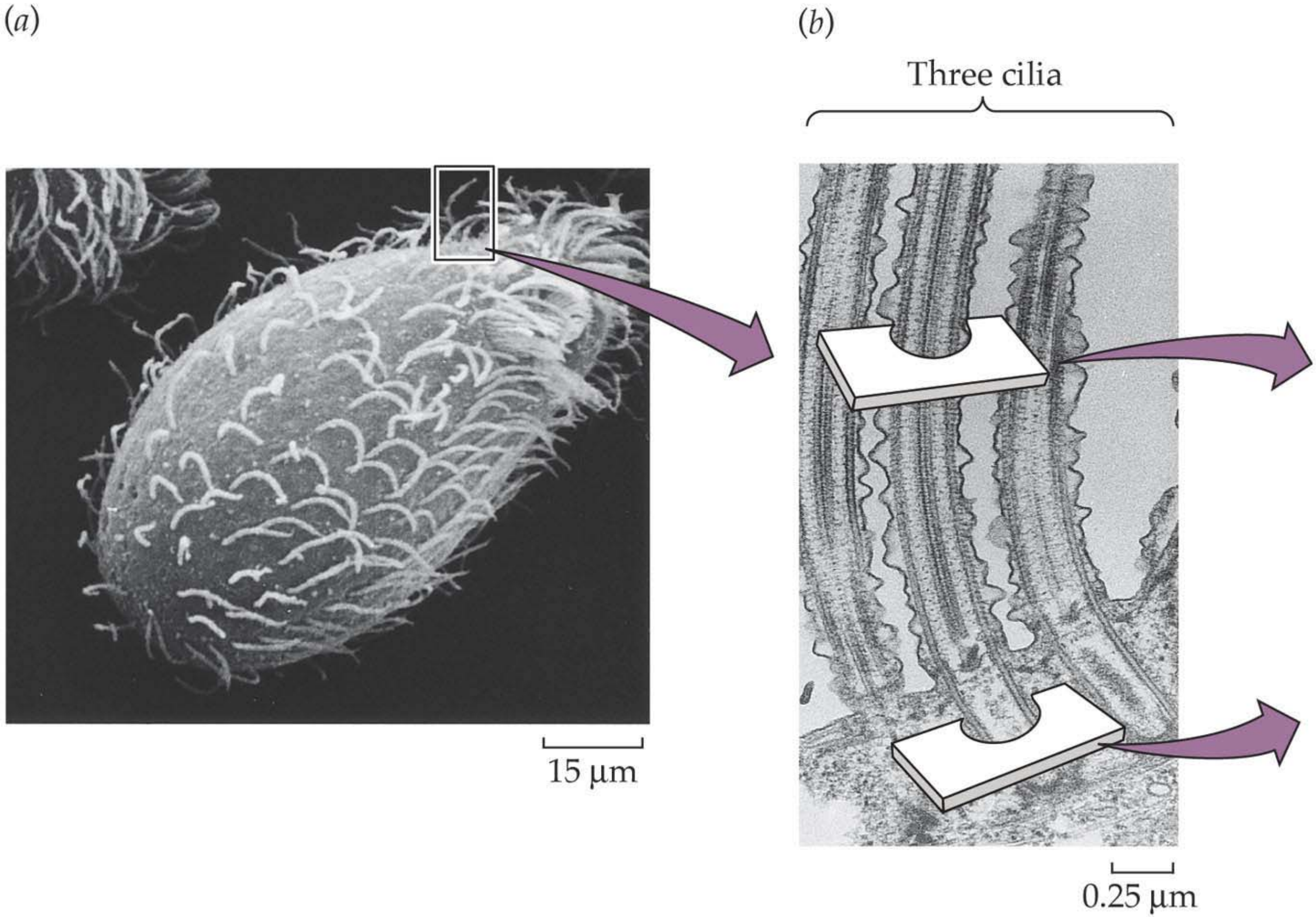
- Cilia and flagella, common locomotary appendages of cells, are made of microtubules.
- **Flagella** are typically longer than cilia, and cells that have them usually have only one or two.
- **Cilia** are shorter and usually present in great numbers.

Figure 4.23 *Cilia are Made up of Microtubules* (Part 1)



LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, **Figure 4.23 Cilia are Made up of Microtubules (Part 1)**

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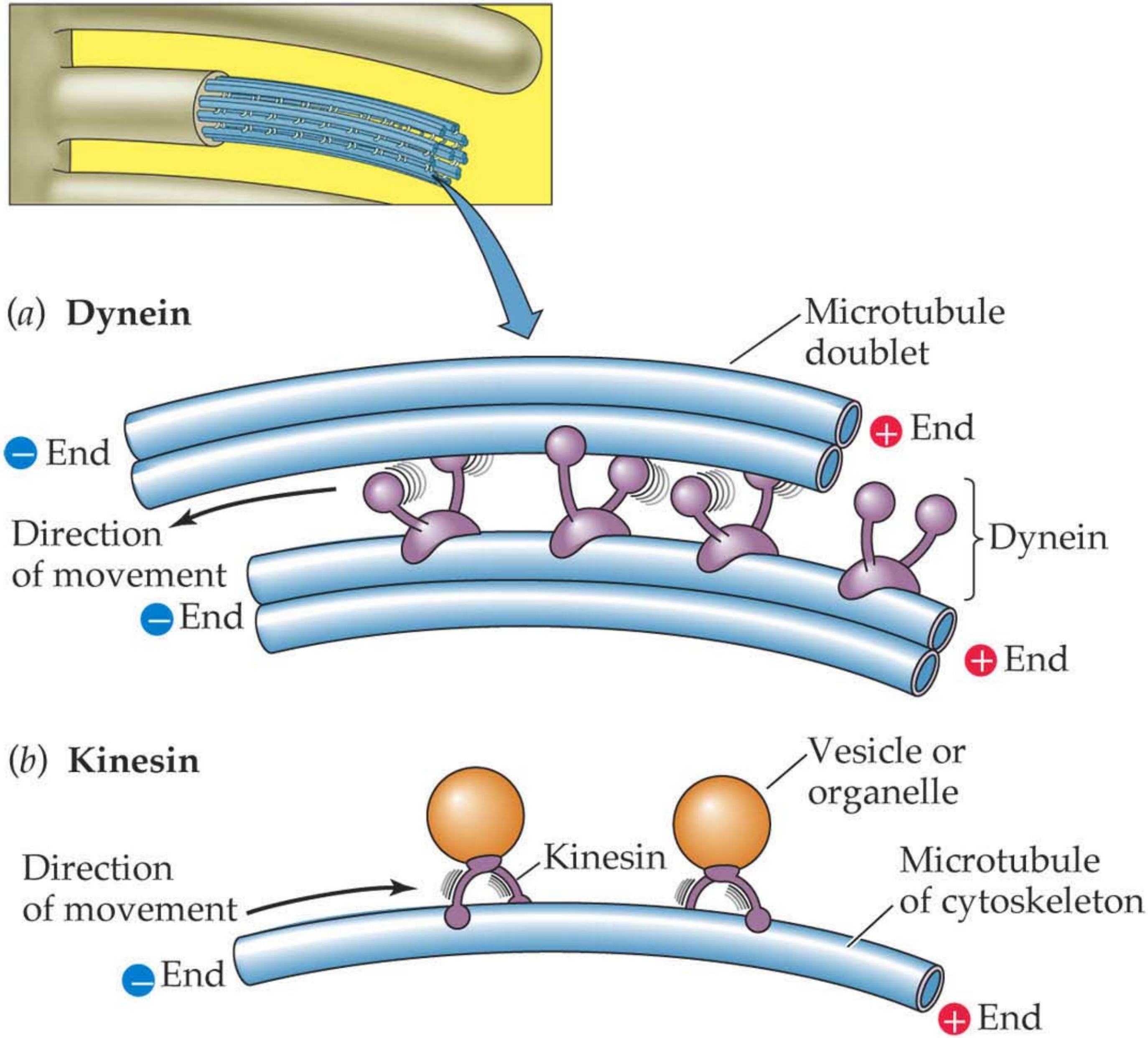
- Motor proteins move along microtubules.
- In both cilia and flagella, the microtubules are cross-linked by spokes of the motor protein called **dynein**.
- Dynein changes its shape when energy is released from ATP. Many dynein molecules associate along the length of the microtubule pair.
- Dynein moves vesicles toward the minus end of the microtubule. **Kinesin**, another motor protein, moves them toward the plus end.

Figure 4.24 *Motor Proteins Use Energy from ATP to Move Things* (Part 1)



LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, Figure 4.24 Motor Proteins Use Energy from ATP to Move Things (Part 1)

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Extracellular Structures

- The plant **cell wall** is composed of cellulose fibers embedded in a matrix of other complex polysaccharides and proteins.
- The cell wall provides a rigid structure for the plasma membrane under turgor pressure, giving important support.
- It is a barrier to many fungi, bacteria, and other organisms that may cause plant diseases.

Extracellular Structures

- Multicellular animals have an **extracellular matrix** composed of fibrous proteins, such as collagen, and glycoproteins.
- Functions of the extracellular matrix:
  - Holds cells together in tissues.
  - Contributes to physical properties of tissue.
  - Helps filter material passing between tissues.
  - Helps orient cell movements.
  - Plays a role in chemical signaling.
- Epithelial cells, which line the human body cavities, have a basement membrane of extracellular material called the basal lamina.

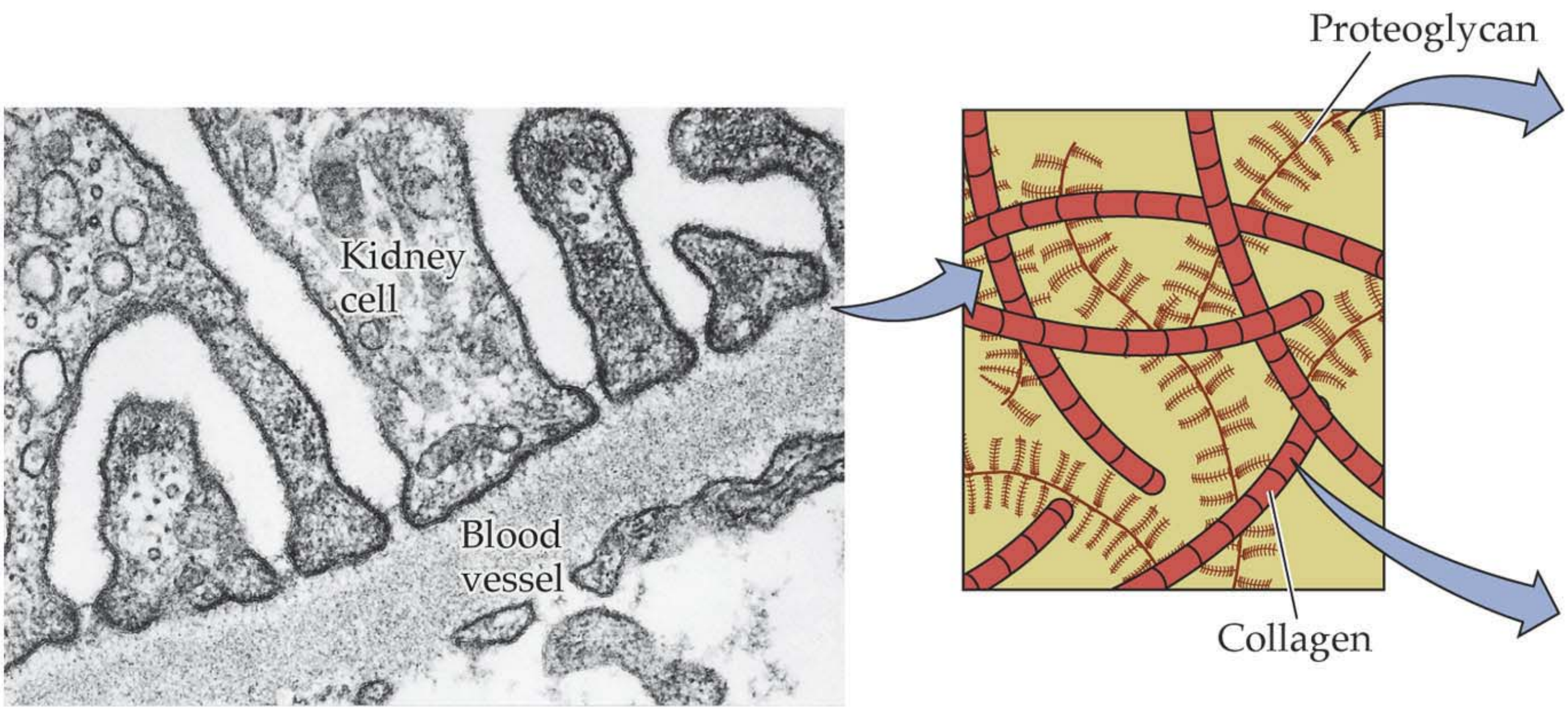

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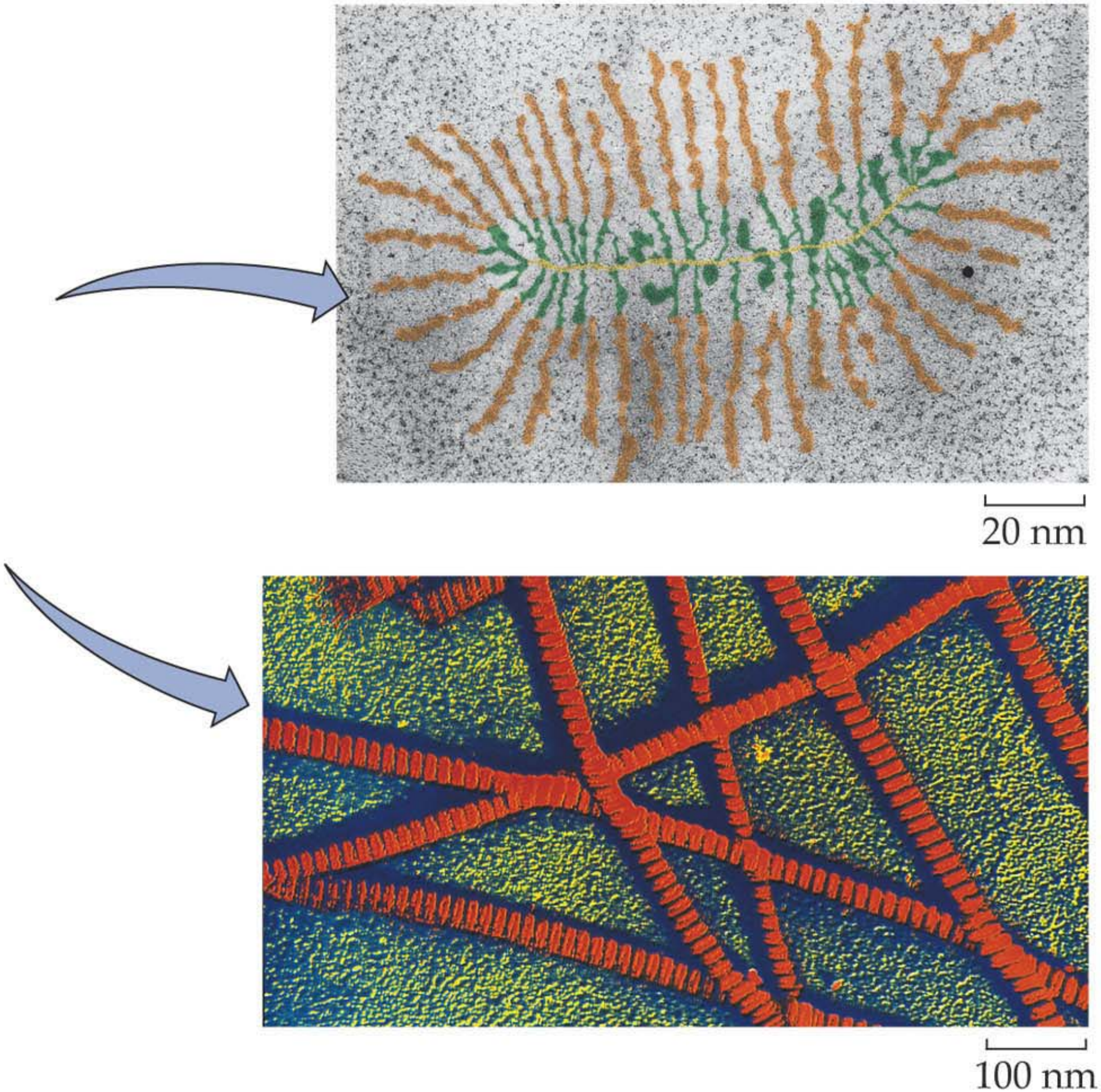
Figure 4.26 *An Extracellular Matrix* (Part 2)



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