Essentials of Biology

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Chapter 4
Lecture Outline

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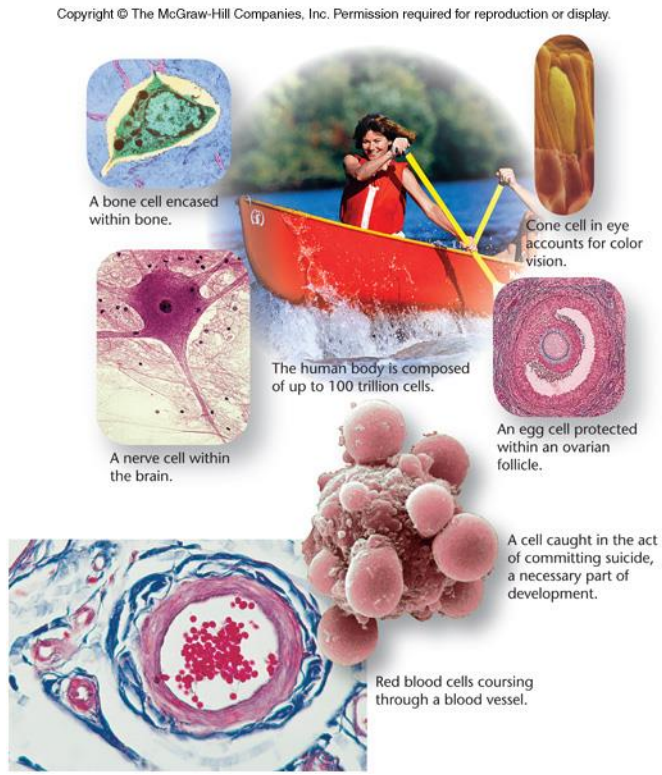


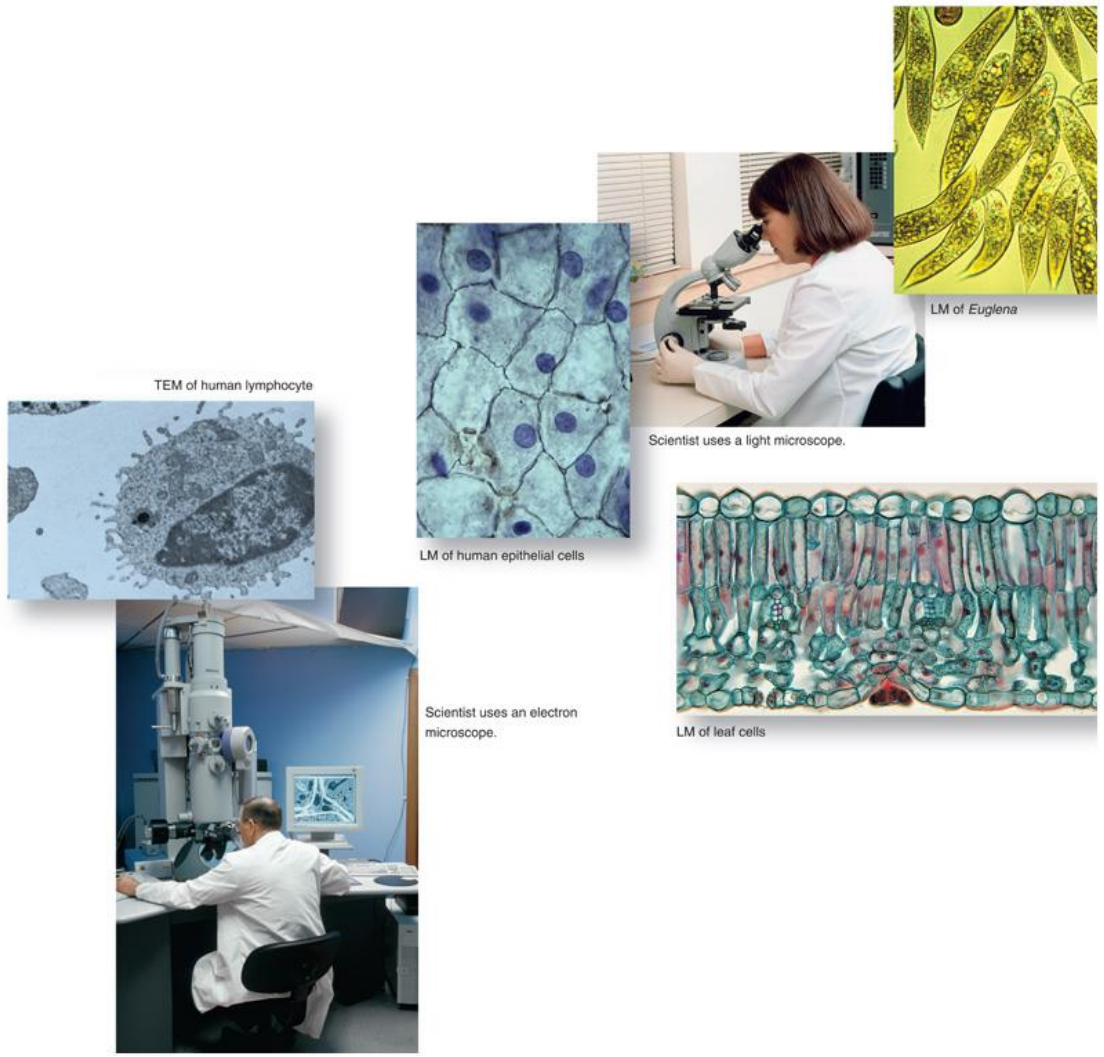
4.1 Cell Theory

- The cell theory based upon the work of Schleiden and Schwinn.
- The key points of the cell theory.
  - All organisms are composed of cells.
  - Cells are the basic units of structure and function in organisms
  - Cells come only from preexisting cells.
- All cells have an outer membrane called the plasma membrane.
- The plasma membrane encloses a semifluid substance called the cytoplasm, the cell's genetic material and ribosomes.

4.1 Cells Under the Microscope

- Our bodies are comprised of several hundred different types of cells, with billions of each cell type present.
- Each type of cell is specialized in its particular function.
- Cells are so small that a microscope is needed to see them.

4.1 Cells Under the Microscope (cont.)



4.1 Cells Under the Microscope (cont.)

- Light microscopes can be used to view cells but not in much detail.

- Electron microscopes allow the structure of cells to be viewed in greater detail.

Microscopy

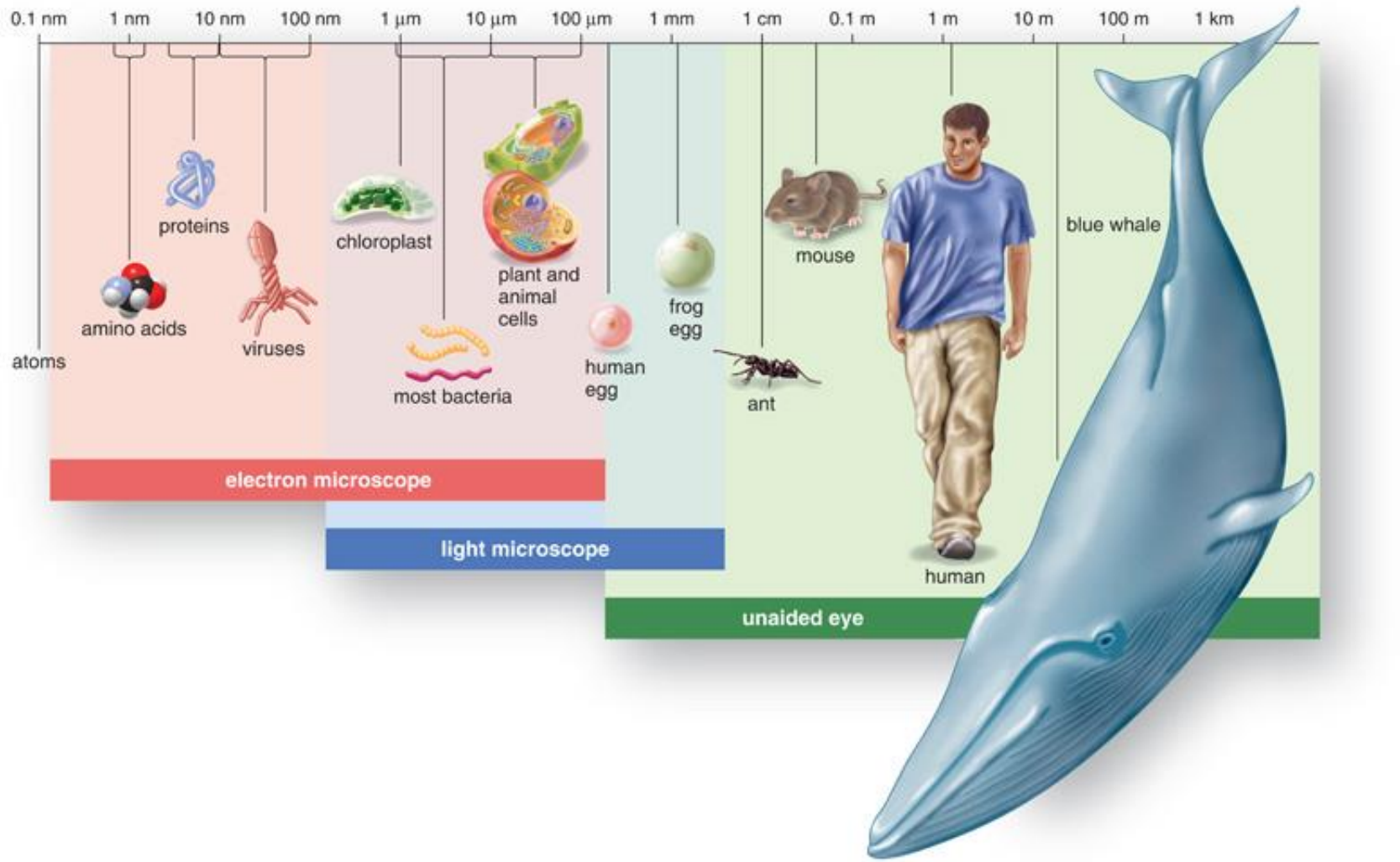
- Microscopes are used to visualize cells
- In a **light microscope (LM)**, visible light is passed through a specimen and then through glass lenses
- Lenses refract (bend) the light, so that the image is magnified

- Three important parameters of microscopy
  - *Magnification*, the ratio of an object’s image size to its real size
  - *Resolution*, the measure of the clarity of the image, or the minimum distance of two distinguishable points
  - *Contrast*, visible differences in brightness between parts of the sample

- Light microscopes can magnify effectively to about 1,000 times the size of the actual specimen
- Various techniques enhance contrast and enable cell components to be stained or labeled
- The resolution of standard light microscopy is too low to study **organelles**, the membrane-enclosed structures in eukaryotic cells

- Two basic types of **electron microscopes (EMs)** are used to study subcellular structures
- **Scanning electron microscopes (SEMs)** focus a beam of electrons onto the surface of a specimen, providing images that look 3-D
- **Transmission electron microscopes (TEMs)** focus a beam of electrons through a specimen
- TEMs are used mainly to study the internal structure of cells

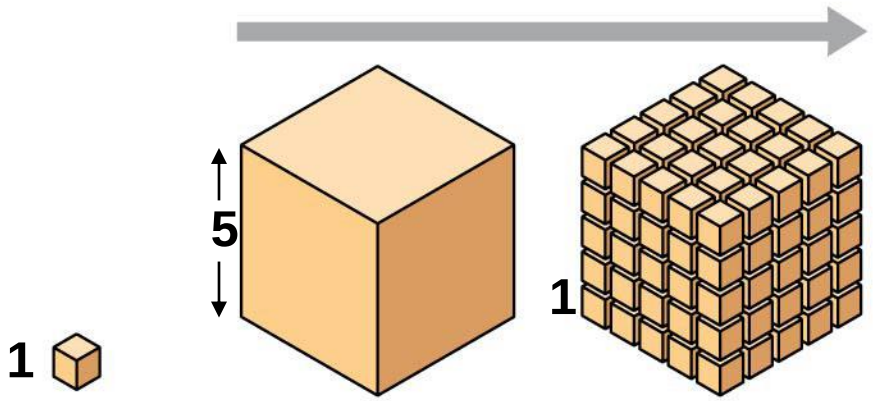
4.1 Cells Under the Microscope (cont.)



4.1 Cells Under the Microscope (cont.)

- Cells are small because they are limited by their surface-area-to-volume-ratio.
- The surface area of a cell is critical because it must be large enough to allow adequate nutrients to enter the cell.
- Cells can increase their surface area with specialized projections such as microvilli.

Surface area increases while total volume remains constant



Total surface area [sum of the surface areas (height × width) of all box sides × number of boxes]	**6**	**150**	**750**
Total volume [height × width × length × number of boxes]	**1**	**125**	**125**
Surface-to-volume (S-to-V) ratio [surface area ÷ volume]	**6**	**1.2**	**6**

4.2 The Two Main Types of Cells

- There are two components to the cell theory.
  - All organisms are composed of cells.
  - Cells come only from preexisting cells.

- All cells have an outer membrane called the plasma membrane.

- The plasma membrane encloses a semifluid substance called the cytoplasm and the cell's genetic material.

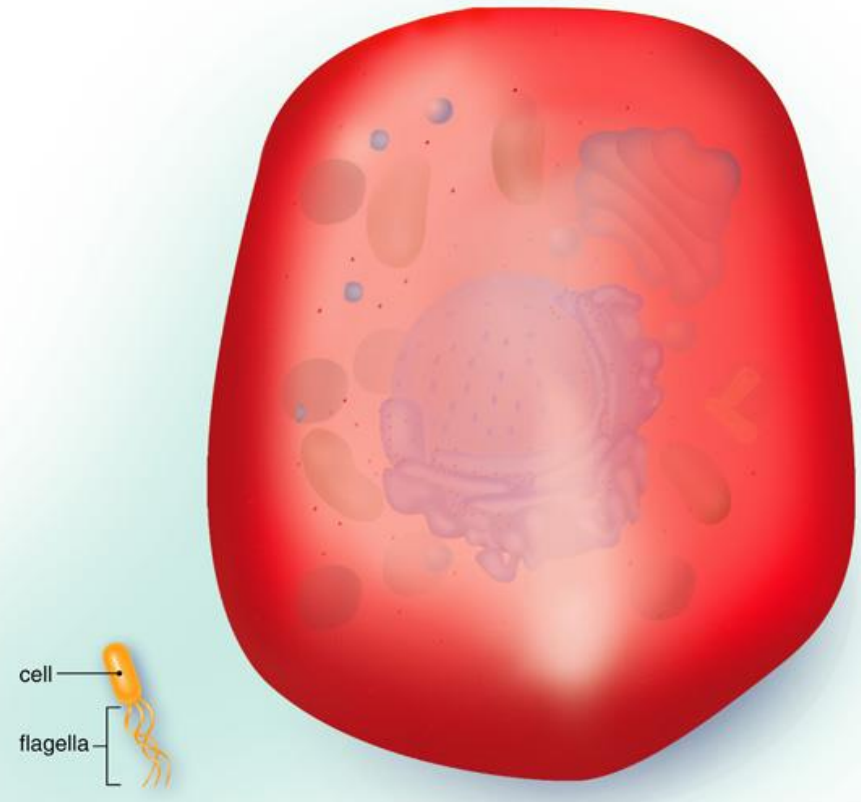
4.2 The Two Main Types of Cells (cont.)

- Cells are divided into two types according to the way their genetic material is organized.
- Prokaryotic cells, which lack a membrane-bound nucleus, have their genetic material located in a region called the nucleoid.
- Eukaryotic cells have a membrane-bound nucleus which stores the DNA.

Prokaryotic Cells

- Prokaryotic cells are simpler and much smaller than eukaryotic cells.
- Prokaryotic cells were among the first organisms on the earth.
- Prokaryotic cells live in a wide variety of environments and can be found in water, soil, and the air.
- Prokaryotes are divided into two groups:
- Bacteria and archaea.

Prokaryotic Cells (cont.)



Prokaryotic cell: simple internal structure

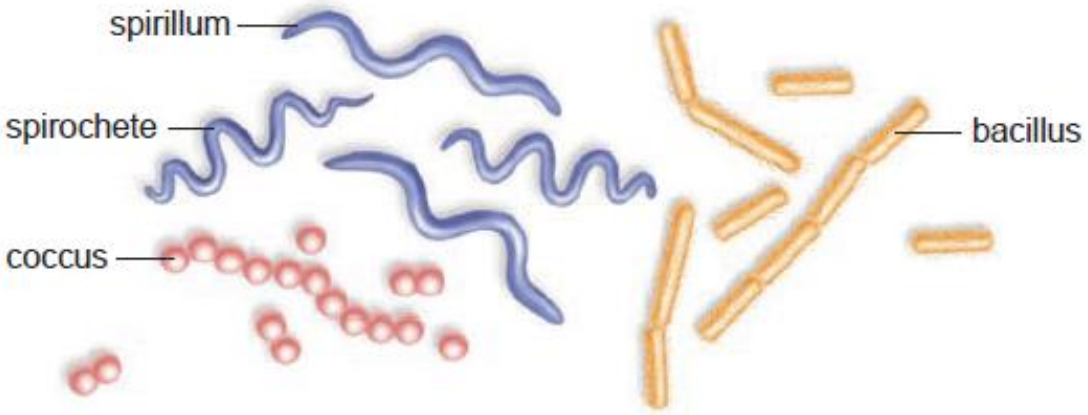
Eukaryotic cell: complex internal structure

Prokaryotic Cells (cont.)

- Bacteria are a type of a prokaryotic cell.
- Some bacteria cause harmful diseases.
- Some bacteria are beneficial.
  - Bacteria decompose dead remains.
  - Bacteria can be used to manufacture chemicals for human use (e.g., industrial chemicals, medicines).
  - Bacteria are an important component of some human foods (e.g., yogurt).

Bacterial structure

- Three basic shapes of prokaryotes are found



- - Bacillus: Rod-shaped bacteria.
- - Coccus: Spherical-shaped bacteria.
- - Spirillum: Rigid spiral-shaped bacteria.

Bacterial Structure

- Bacterial cytoplasm is surrounded by a cell envelope which is made of cell membrane, a cell wall, and a capsule.
  - The cell membrane is similar to that of eukaryotic cells.
  - The cell wall maintains the shape of the cell.
  - The capsule is a protective layer of polysaccharides around the cell wall that help bacteria resist the host immune system and protect it from drying.

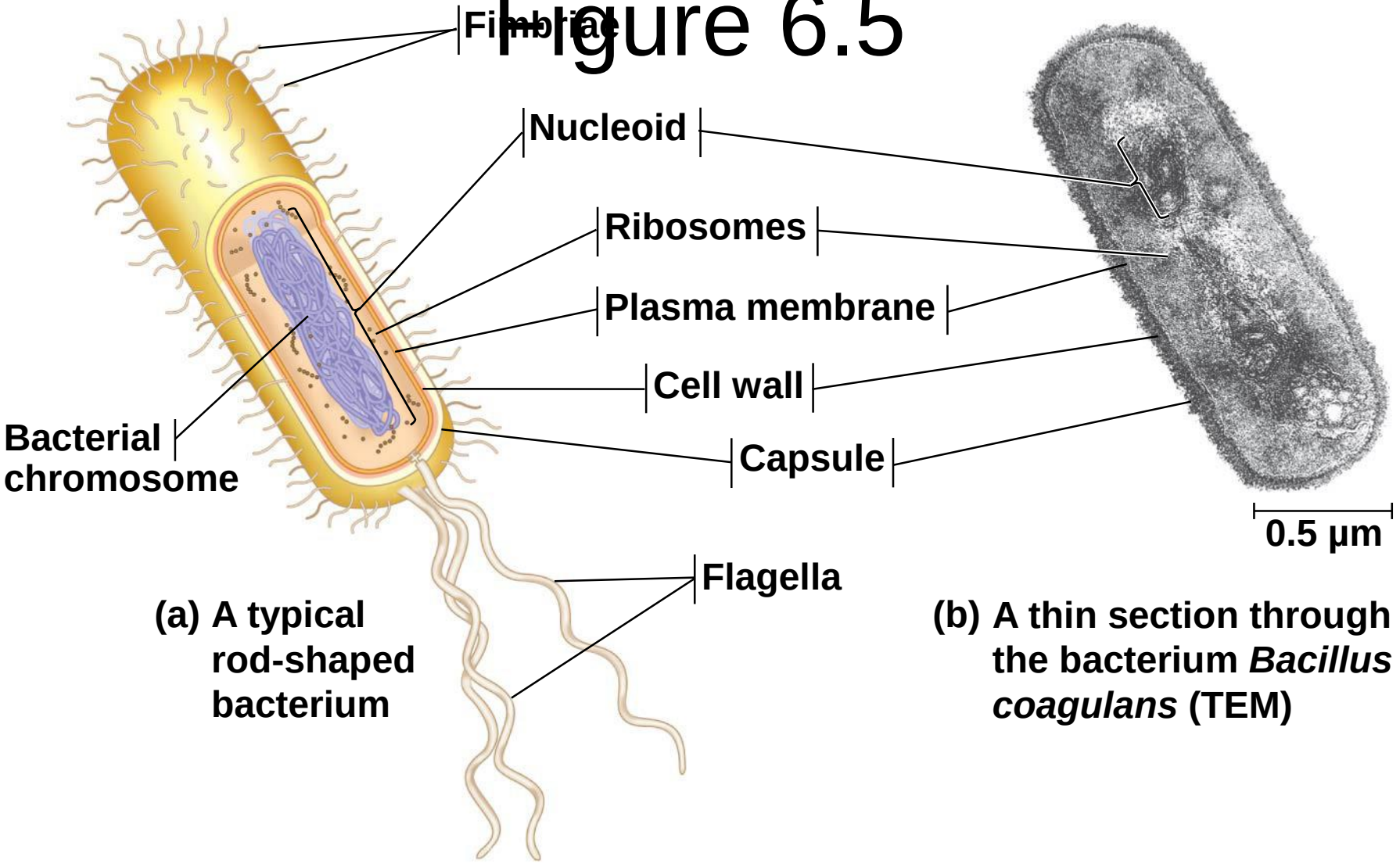
Bacterial Structure (cont.)

- The DNA of a bacterium is a single coiled chromosome that resides in the nucleoid.
- Many bacteria have part of DNA as circular called plasmid.
- The cytoplasm of a bacterium has thousands of tiny particles called ribosomes that synthesize all the proteins needed by the cell.
- Most bacteria metabolize as same as animals, but cyanobacteria (blue-green bacteria) are photosynthetic in similar way to plants because they contain thin threads called Thylakoids.

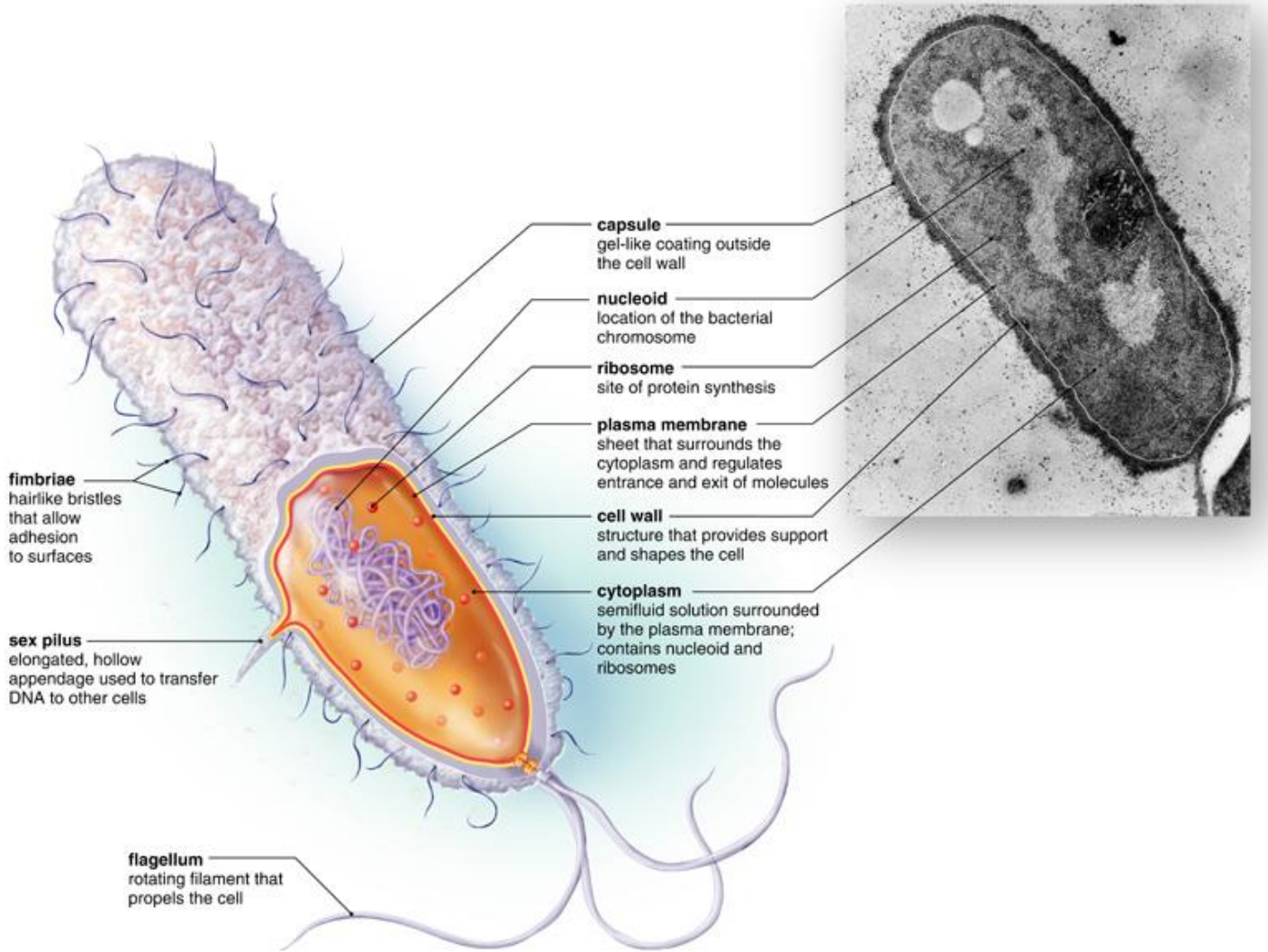
Bacterial Structure (cont.)

- Bacteria can have appendages with specific functions.
  - Flagella can be used to help bacteria move in water.
  - Fimbriae are small bristlelike fibers that allow bacteria to attach themselves to surfaces.
  - Conjugation pili are used to transfer DNA from one bacteria to another.

Figure 6.5


Fimbriae
Nucleoid
Ribosomes
Plasma membrane
Cell wall
Capsule
Bacterial chromosome
Flagella
0.5 µm
(a) A typical rod-shaped bacterium
(b) A thin section through the bacterium *Bacillus coagulans* (TEM)

Bacterial Structure (cont.)



4.4 Eukaryotic Cells

- Eukaryotic cells have a membrane bound nucleus that houses their DNA.
- Eukaryotic cells are larger than prokaryotic cells with a lower surface area to volume ratio.
- Eukaryotic cells have a number of membrane-bound inner compartments called organelles.

4.4 Eukaryotic Cells (cont.)

- The organelles can be divided into four categories.
  - The nucleus and ribosomes.
  - Organelles of the endomembrane system.
  - The energy-related organelles.
  - The cytoskeleton.

4.4 Eukaryotic Cells (cont.)

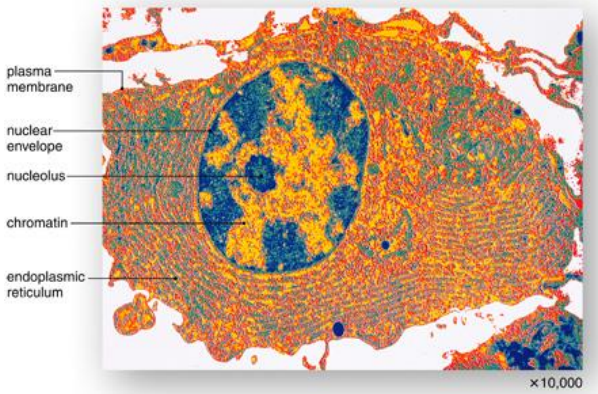
- The nucleus communicates with the ribosomes to control protein synthesis.
- Each organelle of the endomembrane system has its own enzymes and produces specific products.
- The products of the endomembrane system are shuttled in the cells as transport vesicles.

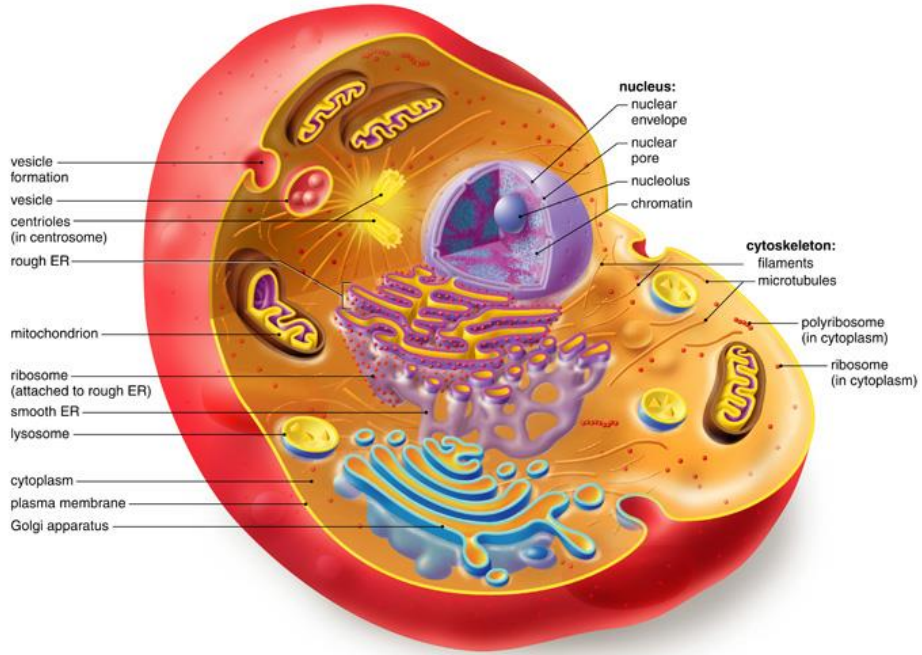
4.4 Eukaryotic Cells (cont.)

- The two types of energy-related organelles have their own genetic material and ribosomes.
  - Mitochondria are found in all eukaryotic cells.
  - Chloroplasts are found in the cells of photosynthetic eukaryotes.

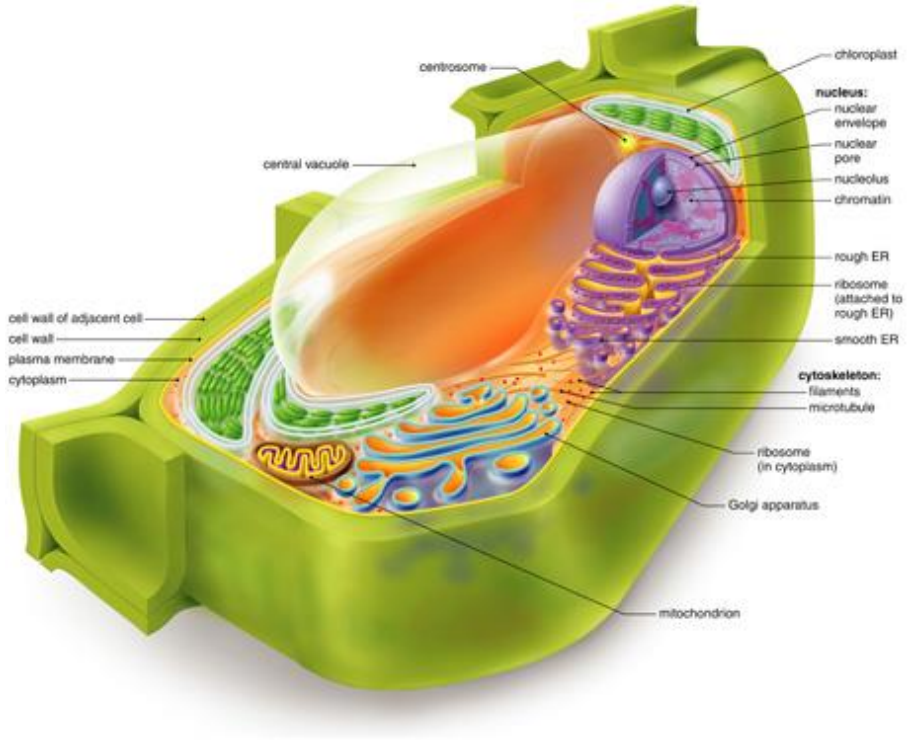
- The cytoskeleton is a protein lattice that maintains cell shape and assists in the movement of organelles.

4.4 Eukaryotic Cells (cont.)





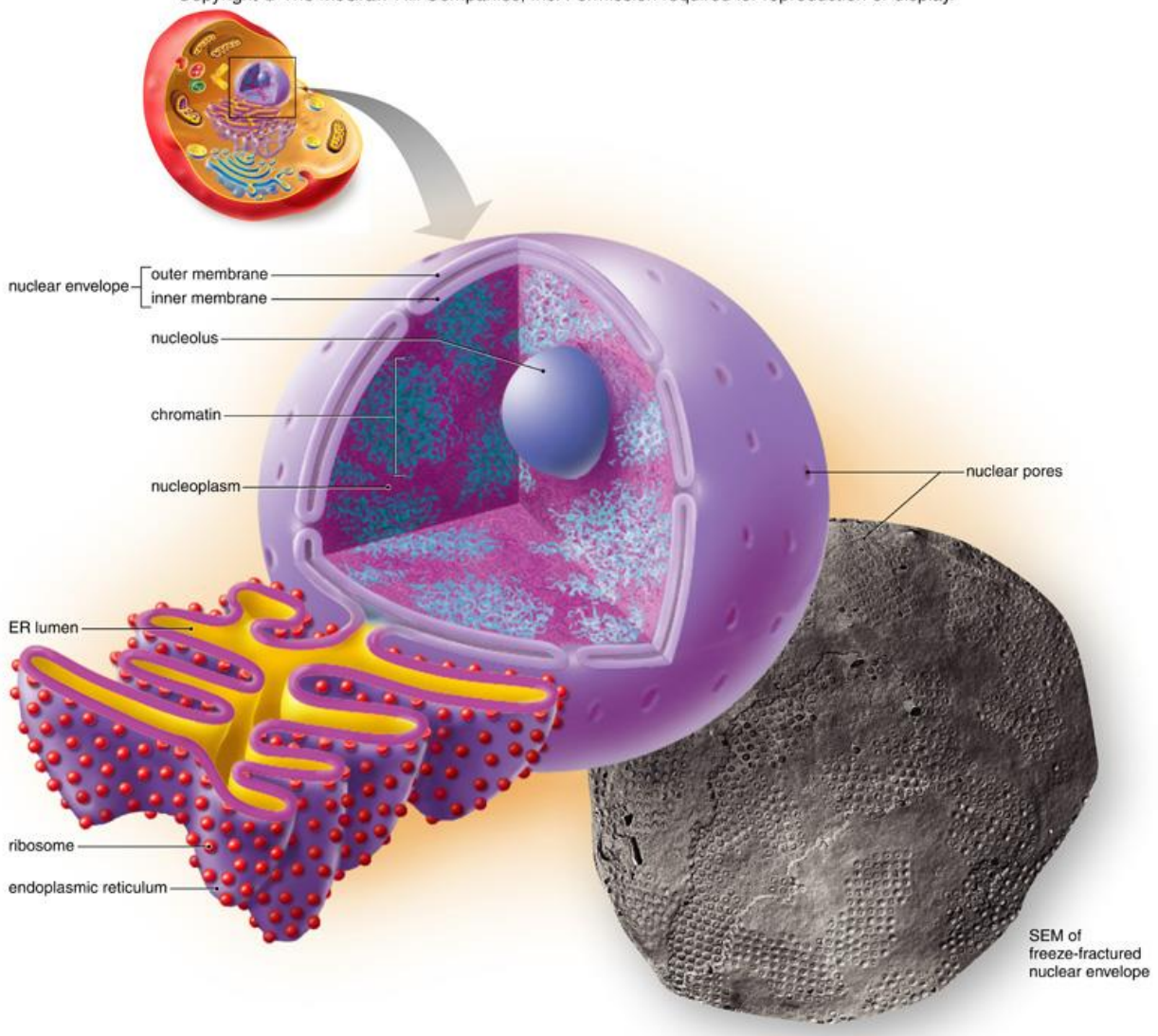
4.4 Eukaryotic Cells (cont.)



Nucleus and Ribosomes

- The nucleus is an oval structure located near the center of most eukaryotic cells.
- The nucleus of the eukaryotic cell contains chromatin within a semifluid nucleoplasm.
- Chromatin, which is composed of DNA, protein, and some RNA, is usually a network of fine strands.
- The strands condense during cell division to form visible chromosomes.

Nucleus and Ribosomes (cont.)



Nucleus and Ribosomes (cont.)

- RNA, a nucleic acid, is produced in the nucleus.
  - Messenger RNA (mRNA) acts as an intermediary to DNA and carries the information for the amino acid sequence of a protein.
  - Ribosomal RNA (rRNA) combines with specific proteins to form the subunits of ribosomes.
  - Transfer RNA (tRNA) participate in assembly of amino acids during protein synthesis.

Nucleus and Ribosomes (cont.)

- The contents of the nucleus are separated from the cytoplasm by the nuclear membrane.
- The nuclear membrane has nuclear pores that permit the passage of ribosomal subunits and mRNA out of the nucleus and proteins into the nucleus.
- Ribosome subunits, one large and one small, are assembled in the cytoplasm and used to make proteins.

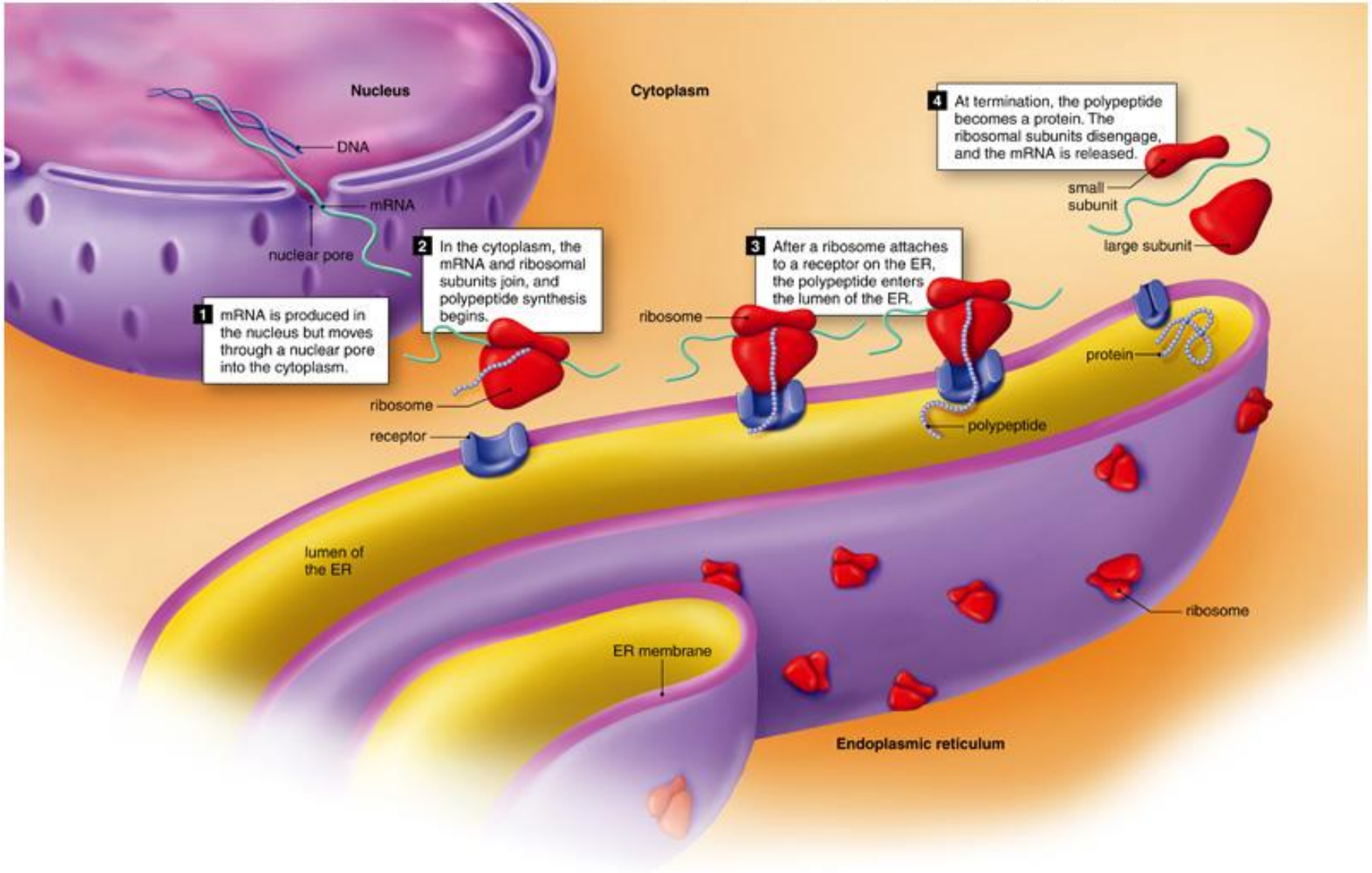
Ribosomes

- Ribosomes are found in both prokaryotes and eukaryotes, but in different sizes.
- Ribosomes are made of two subunits: the small subunit and large subunit.
- In eukaryotic cells, ribosomes can be found in different locations and forms.
  - Free Single ribosomes in the cytoplasm
  - Groups in cytoplasm called polyribosomes
  - Attached to the endoplasmic reticulum (ER)

Ribosomes (cont.)

- The proteins made by these different ribosomes are used in different parts of the cell.
- Proteins from free ribosomes are used in the cytoplasm.
- Proteins from ribosomes attached to the ER are deposited in the ER.

Ribosomes (cont.)



Endomembrane System

- The endomembrane system has four components.
  - The nuclear membrane
  - The endoplasmic reticulum (ER)
  - The Golgi apparatus
  - Membranous sacs called vesicles

- This system compartmentalizes the cell and carries molecules between components of the system.

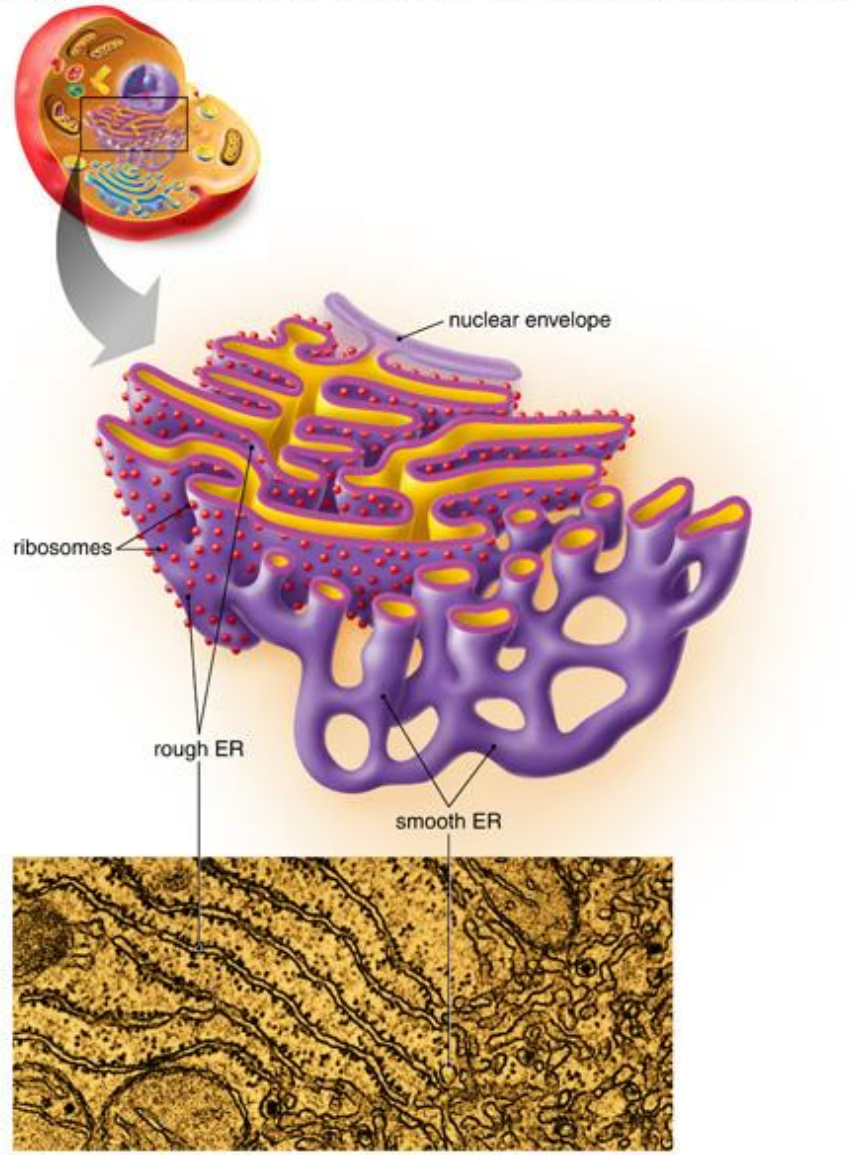
Endoplasmic Reticulum

- The ER is a complicated system of membranous channels and flattened vesicles (saccules).

- The rough ER is studded with ribosomes.
  - The rough ER synthesizes proteins.
  - These proteins are packaged in transport vesicles.

- The smooth ER synthesizes lipids that are also packaged in transport vesicles, Smooth ER doesn`t have attached ribosomes. It also function in detoxification of drugs especially in liver.

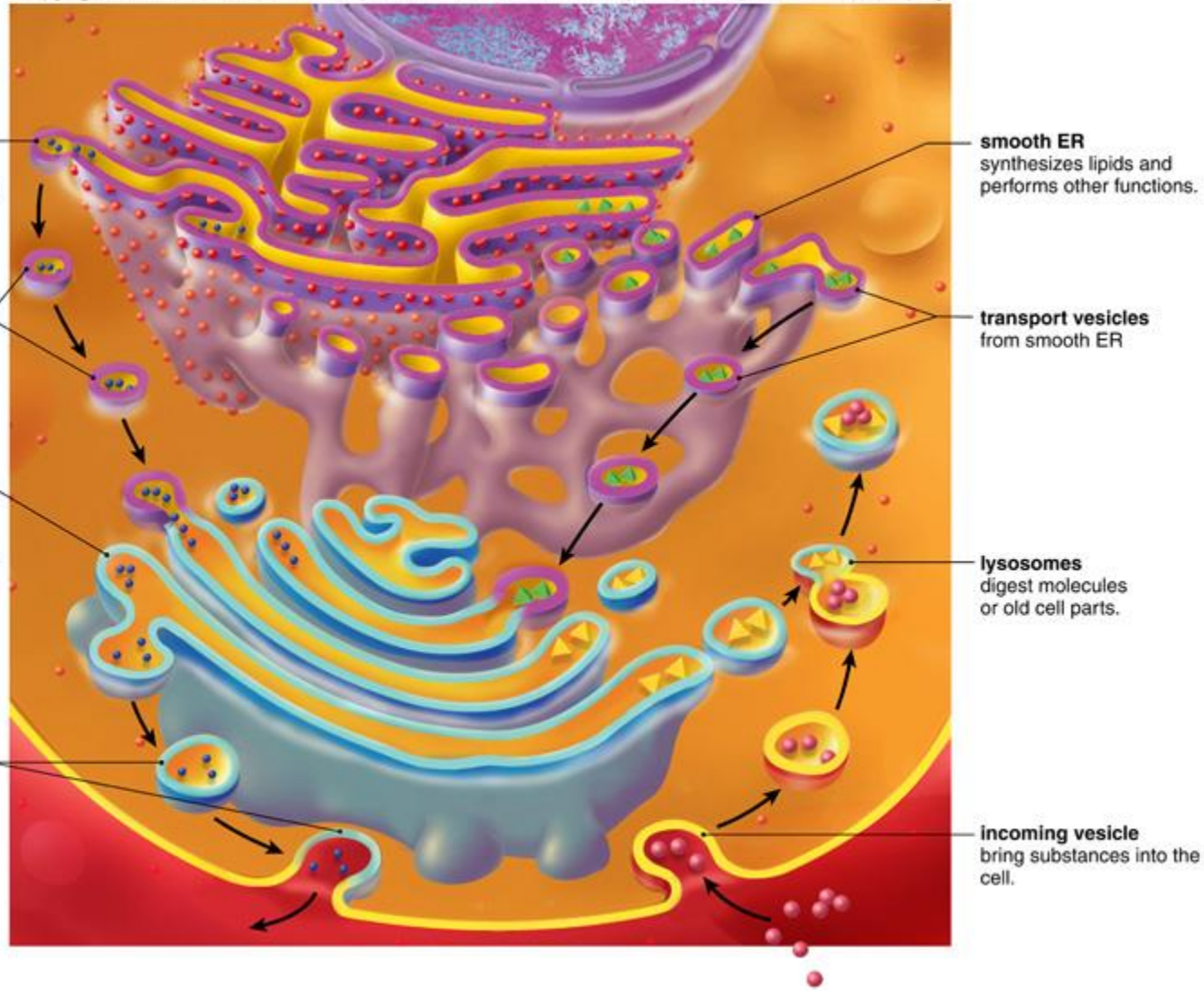
Endoplasmic Reticulum (cont.)



Golgi Apparatus

- The Golgi apparatus consists of numerous flattened saccules.
- It has 2 sides: the cis face (inner) which is directed towards the ER, and the trans face (outer) which is directed towards the plasma membrane.
- The Golgi apparatus receives protein transport vesicles from the ER and packages them in new vesicles.
- The Golgi apparatus directs the new vesicles to the location intended for the protein.

Golgi Apparatus (cont.)



Lysosomes

- Lysosomes are Golgi vesicles which contain proteins that are hydrolytic enzymes. They digest molecules (materials) or nonfunctional organelles within the cell.

- Lysosomes also participate in apoptosis, or programmed cell death.

Peroxisomes

- They are membrane-bound vesicles similar to lysosomes, but their enzymes result in production of hydrogen peroxide (H_2O_2).
- Hydrogen peroxide is a toxic molecule that needs to be immediately broken into water and oxygen by another enzyme inside the Peroxisomes.

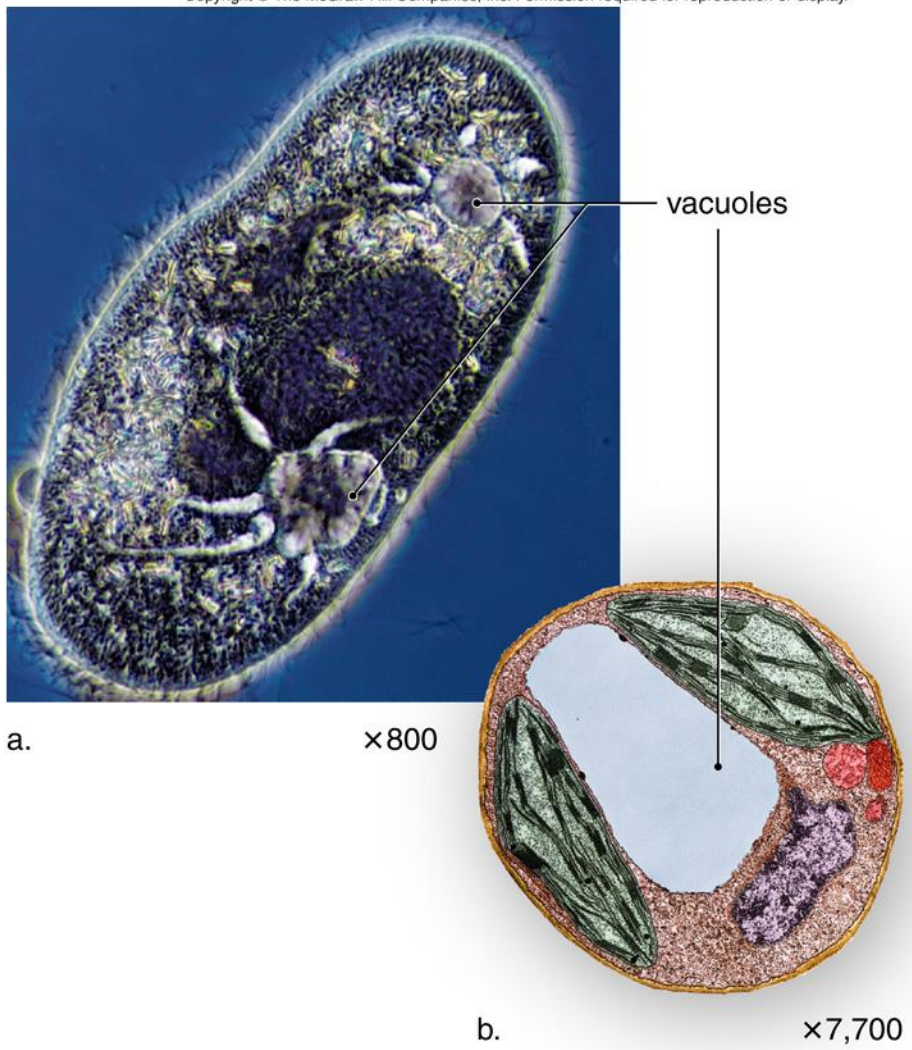
Vacuoles

- Vacuoles are membranous sacs that are larger than vesicles.
- In some organisms, like plants, vacuoles may have specialized functions.
- In most organisms, vacuoles can store nutrients, ions, or other molecules.

Vacuoles

- Types of vacuoles in plant cells:
- - Central vacuole: large vacuole that compromises up to 90% of cell size. Its filled with liquid called sap and it gives support to cell and control its size. It also stores nutrients and toxic products.
- - Other vacuoles that store pigments, water, nutrients.

Vacuoles (cont.)



Energy-Related Organelles

- Two types of membranous organelles that specialize in energy conversion are the chloroplasts and mitochondria.
- Chloroplasts use solar energy to synthesize carbohydrates via photosynthesis.
- Mitochondria break down carbohydrates to produce adenosine triphosphate (ATP).

Chloroplasts

- Chloroplasts are found in plants and other photosynthetic organisms.
- Chloroplasts are surrounded by two membranes (inner and outer).
- The large inner space contains the semifluid called the stroma.

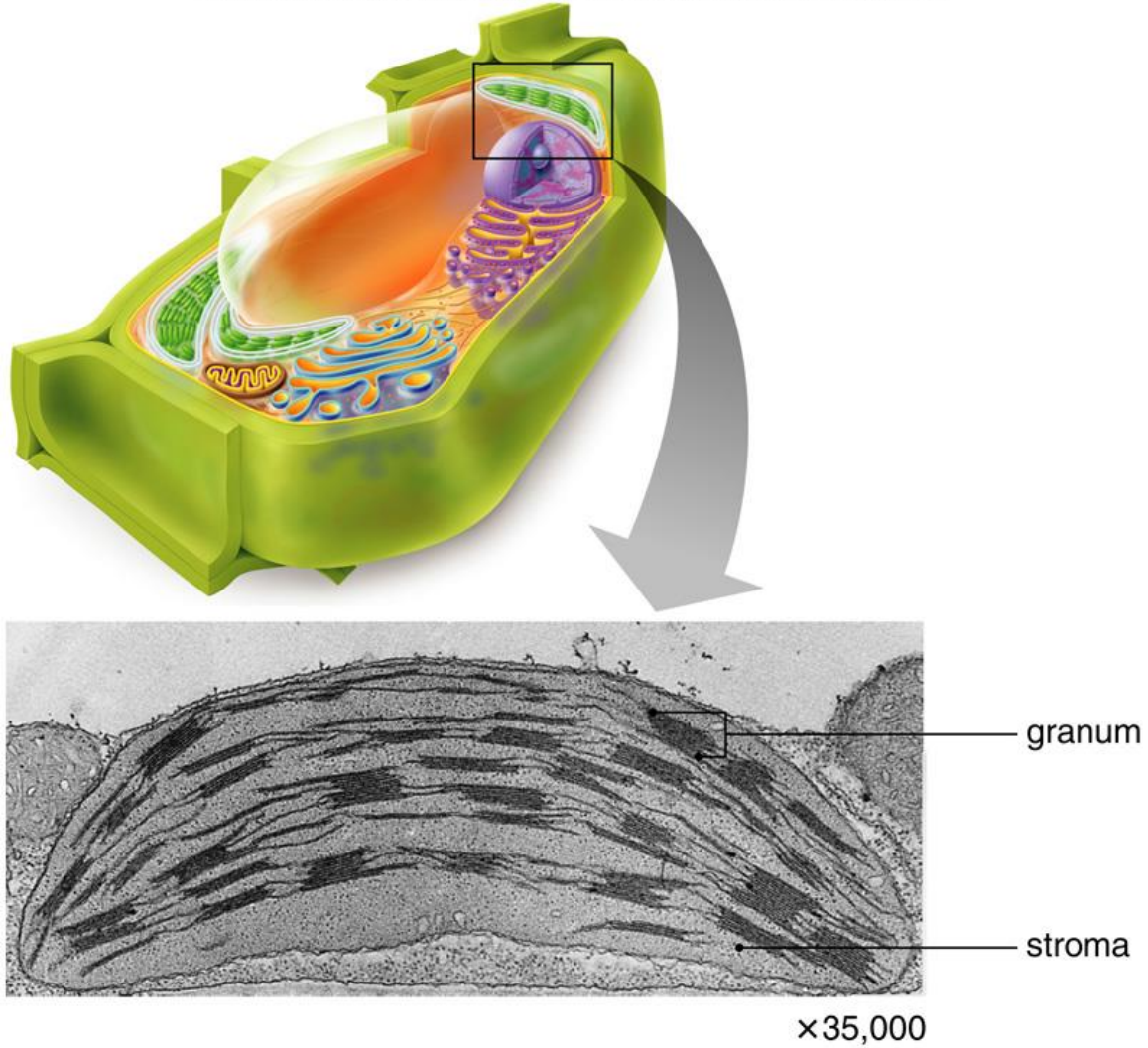
Chloroplasts (cont.)

- The stroma contains two components of the photosynthetic machinery.
  - Enzymes for photosynthesis
  - A third set of membranes, organized as a series of disk-like sacs called thylakoids.

- Thylakoids are organized into stacks, or grana.

- The pigments that capture light for photosynthesis are imbedded in the membrane of the thylakoids.

Chloroplasts (cont.)



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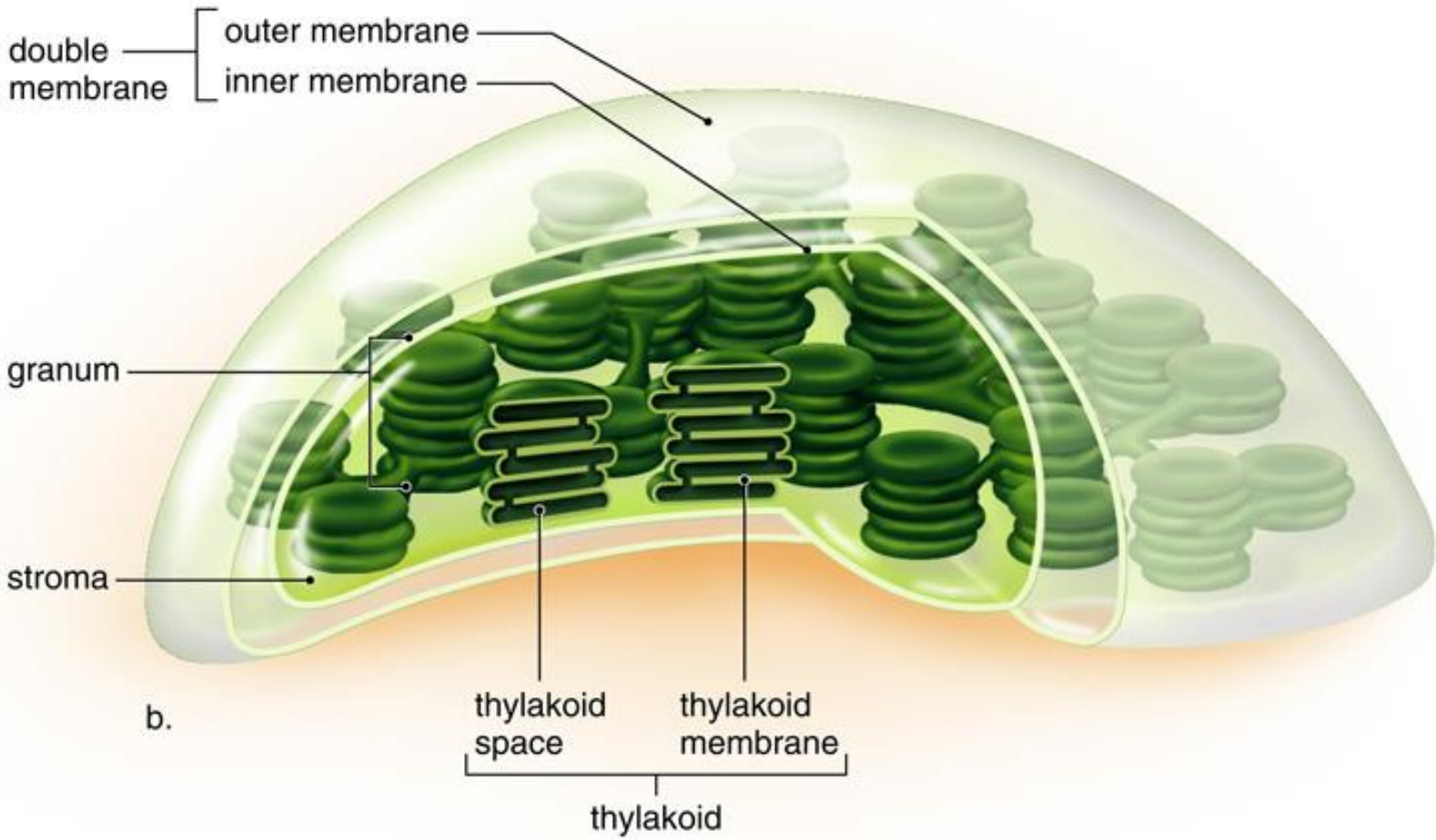
Chloroplasts (cont.)



Other types of plastids

- Plants have several types of plastids:
- Chromoplasts: contain colored pigments.
- Chloroplasts: contain chlorophyll.
- Leucoplasts: synthesize and store starch and oil.

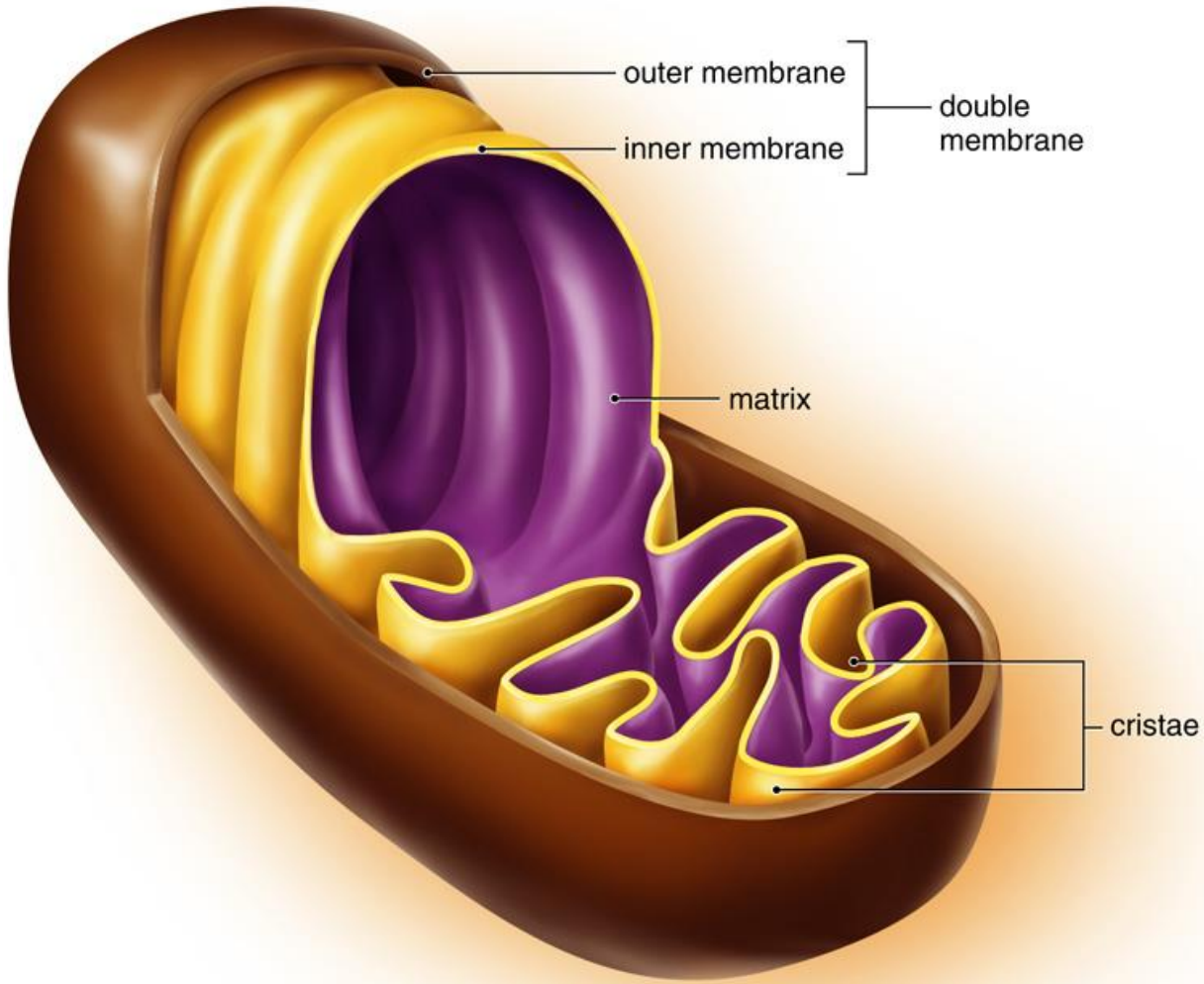
Mitochondria

- Mitochondria are surrounded by a double membrane.
- The convolutions of the inner membrane form cristae, which increase surface area.
- The inner membrane encloses the matrix.

Mitochondria (cont.)

- The matrix contains enzymes which break down carbohydrates and other nutrients for energy.
- Mitochondria are often called the cell “power-house” because they produce most of the ATP.
- The breakdown of these molecules in the presence of oxygen to produce ATP is called cellular respiration.

Mitochondria (cont.)



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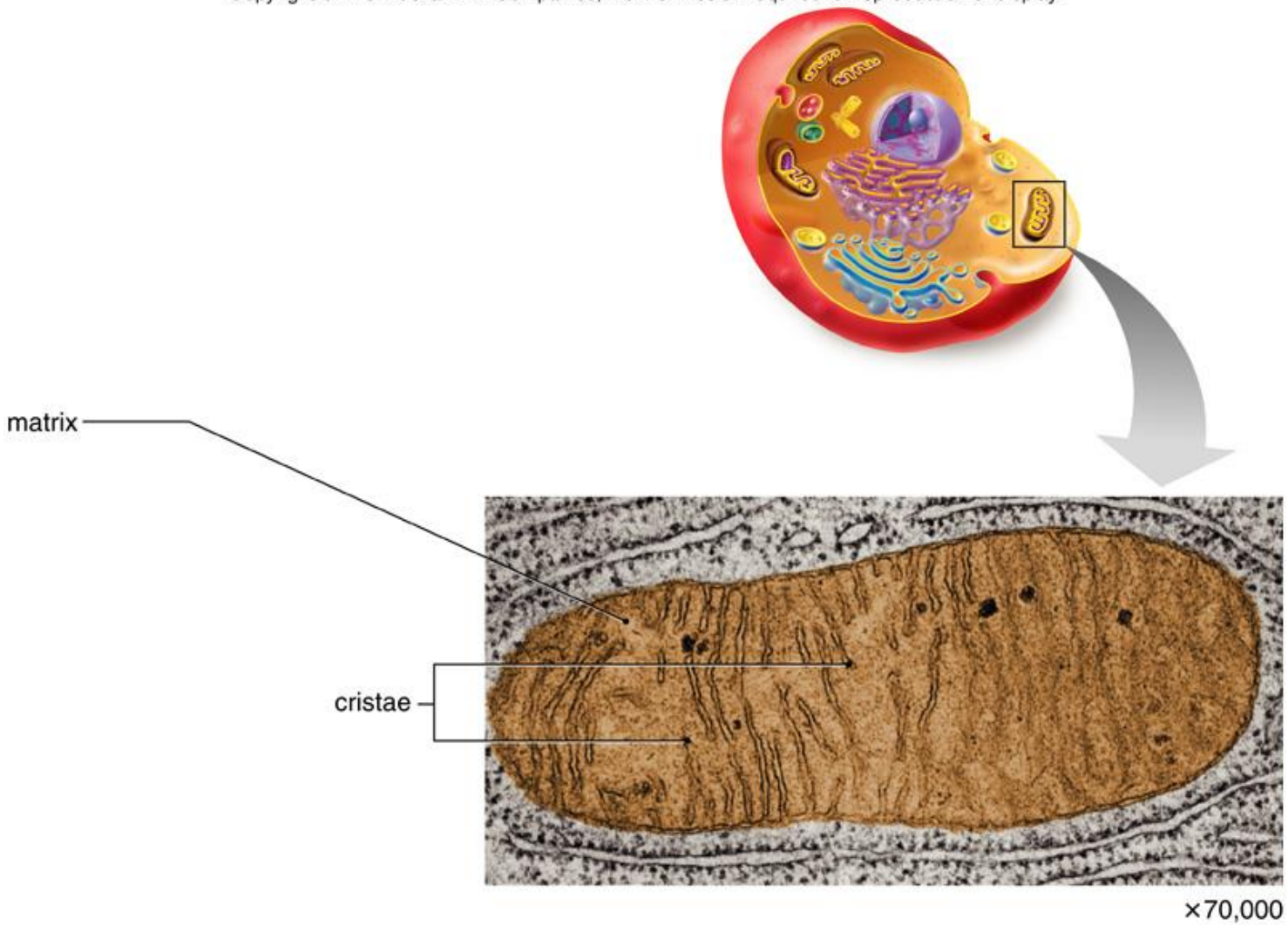
Mitochondria (cont.)



The Cytoskeleton

- The cytoskeleton is a network of protein filaments and tubules that extends from the nucleus to the plasma membrane.

- The cytoskeleton maintains cell shape.

- The cytoskeleton has three components.
  - Actin filaments
  - Microtubules
  - Intermediate filaments

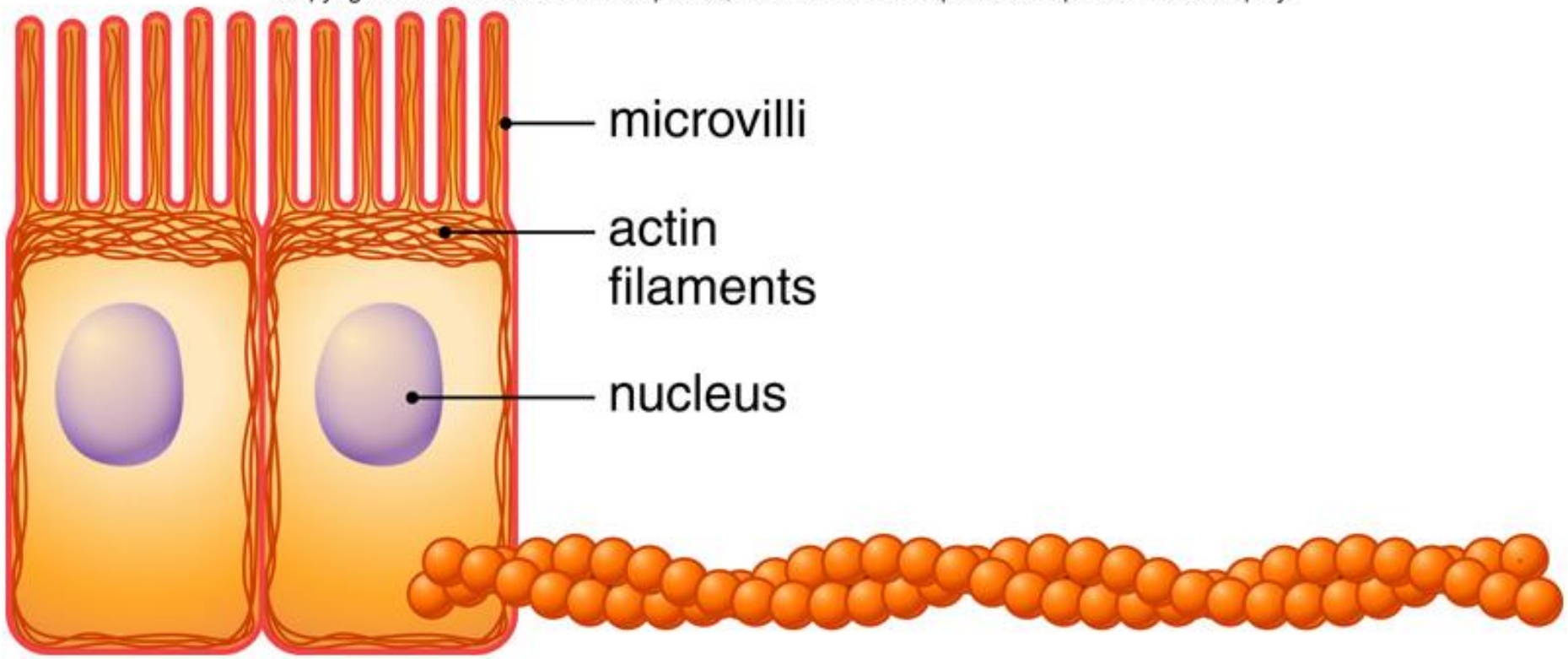
Actin Filaments

- They are also called microfilaments. They are long and extremely thin fibers.
- Actin filaments consist of two chains of globular actin monomers intertwined in a helix.
- Actin filaments support the cell and any projection, such as microvilli.
- Actin, and another molecule called myosin, are also involved in muscle contraction and cell division in process needs ATP.

Actin Filaments

- • In plants, actin filaments form a track along which chloroplasts circulate in “cytoplasmic streaming”
- Actin filaments are responsible for the formation of pseudopods that help in the amoeboid movement.
- Actin filaments play important role in cell division, by pinching off the two new cells.

Actin Filaments (cont.)



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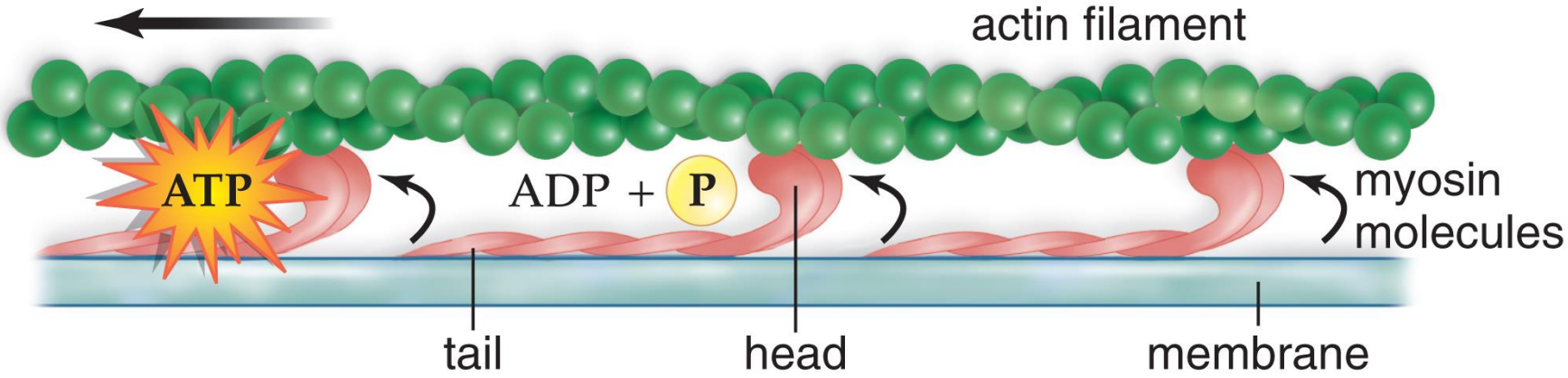


Intermediate Filaments

- Intermediate filaments are intermediate in size between actin filaments and microtubules.

- These fibrous, ropelike polypeptides support the nucleus and plasma membrane. And play role in formation of cell-to-cell junction.

Microtubules

- Microtubules are proteins arranged to form hollow cylinders.
- They are the largest among cytoskeleton components.
- Microtubules are assembled by the centrosome.

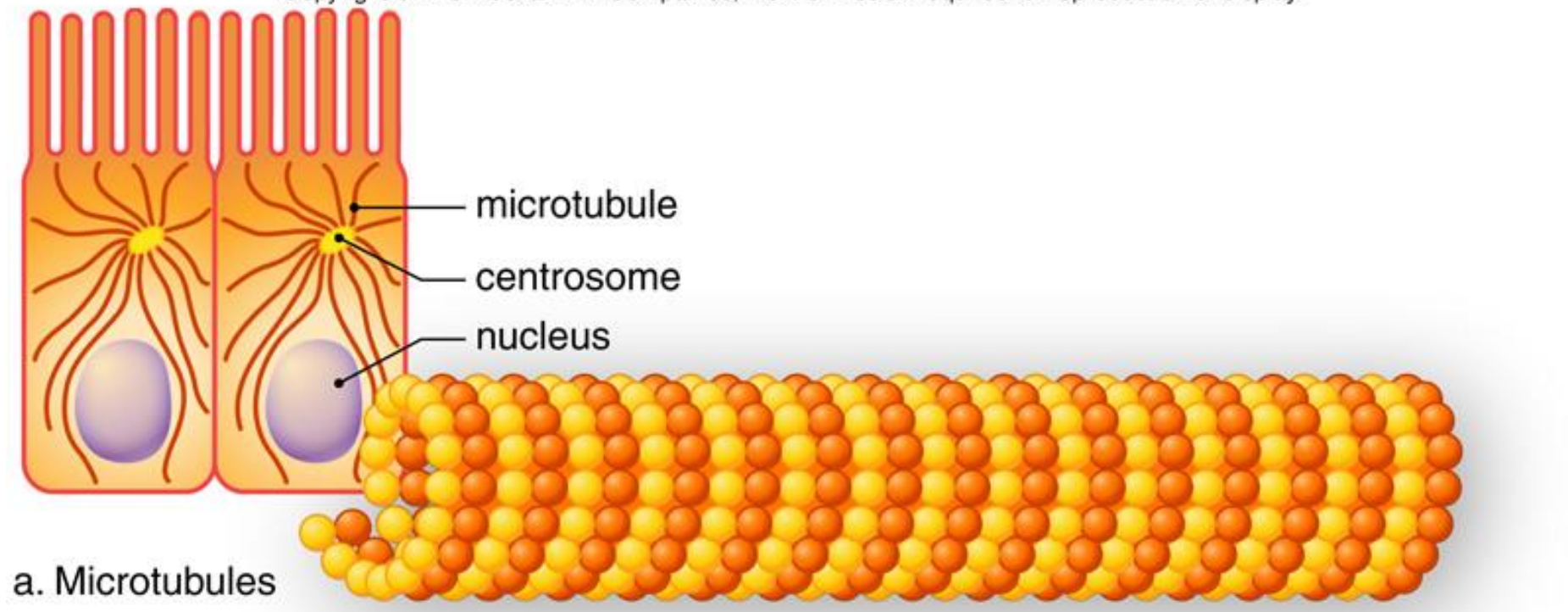
- Microtubules can be associated with motor molecules such as kinesin and dynein.

Microtubules

- Microtubules help maintain the shape of the cell and acting as tracks along which organelles can move.

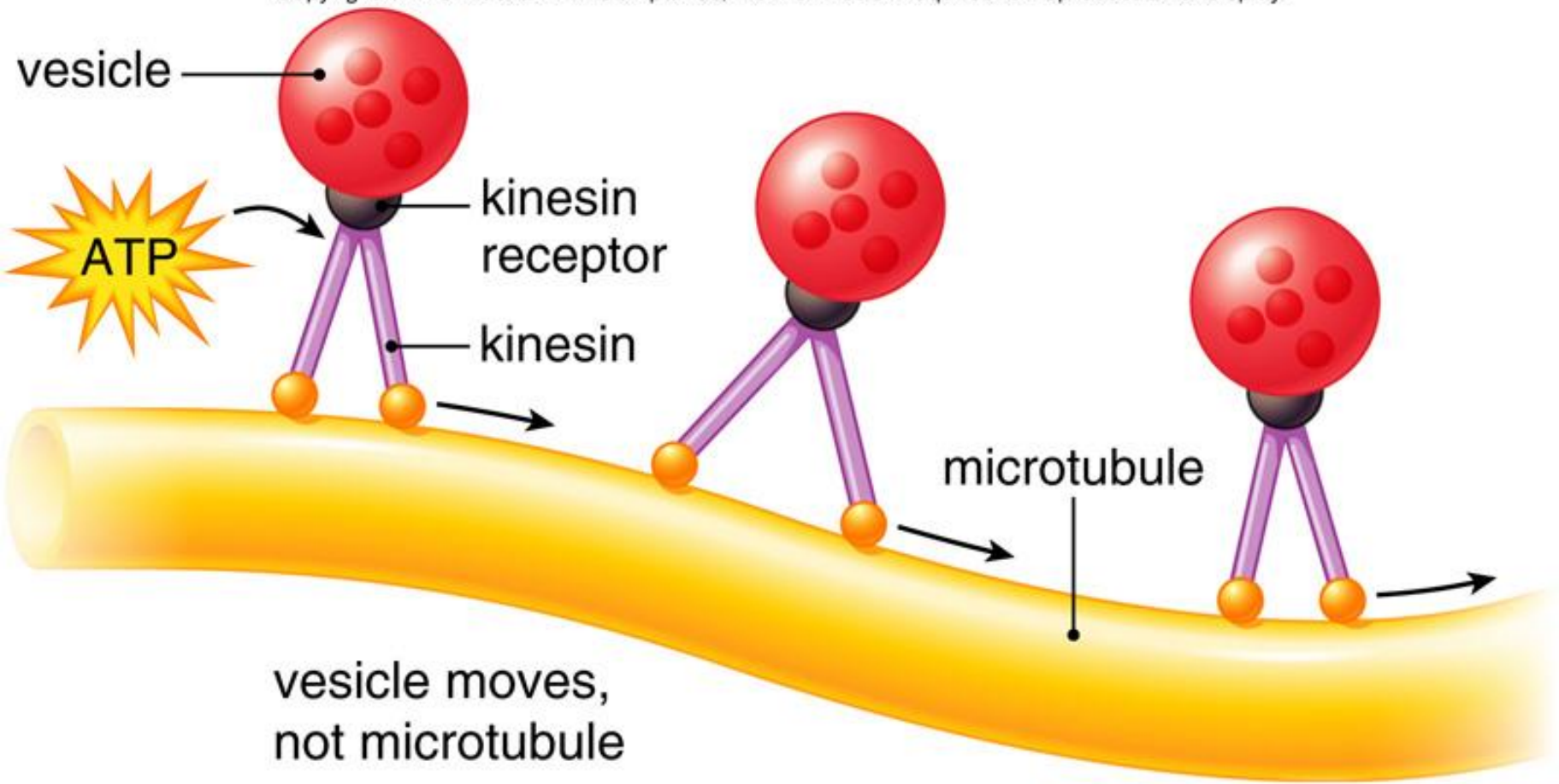
- They play important role in cell division as they form the mitotic spindle that distributes chromosomes between the resulting cells.

Microtubules (cont.)



a. Microtubules

Microtubules (cont.)



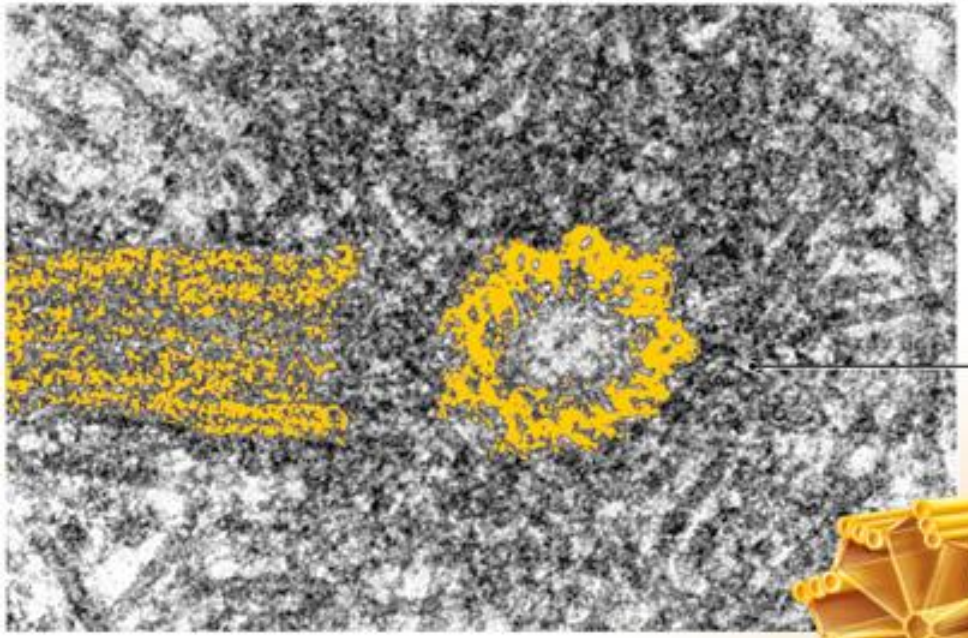
b. Microtubular tracks

Centrioles

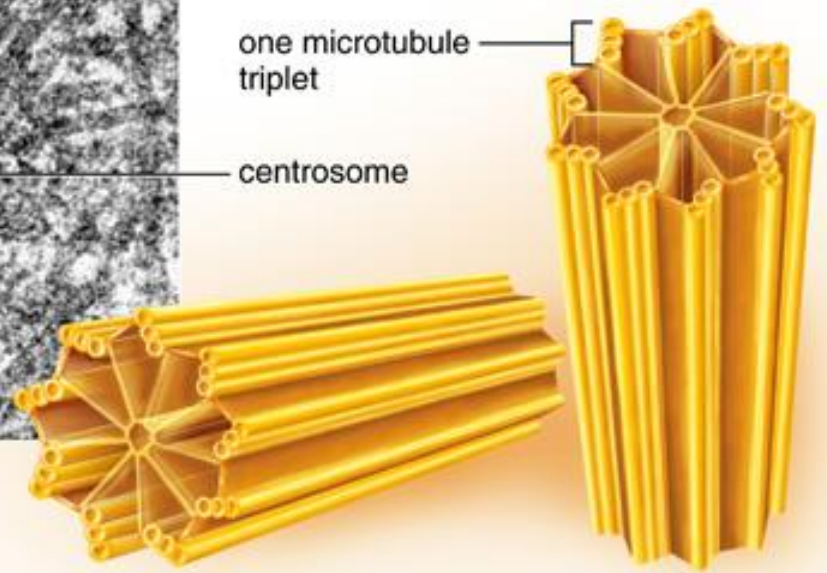
- Centrioles are short cylinders with a 9+0 pattern of microtubule triplets.
- Two centrioles are present in in cell.
- In plants and some protists, centrioles are located in the centrosome.

- Centrioles are involved in cell division.

Centrioles (cont.)



one pair of centrioles in a centrosome



Cilia and Flagella

- Cilia and flagella are hairlike projections that allow organisms to move.
- They have 9+2 pattern of microtubules doublets.
- Cilia and flagella differ in size but are similar in construction.
  - Both are membrane-bound cylinders.
  - Both have a basal body in the cytoplasm that has a structure similar to the centrioles.

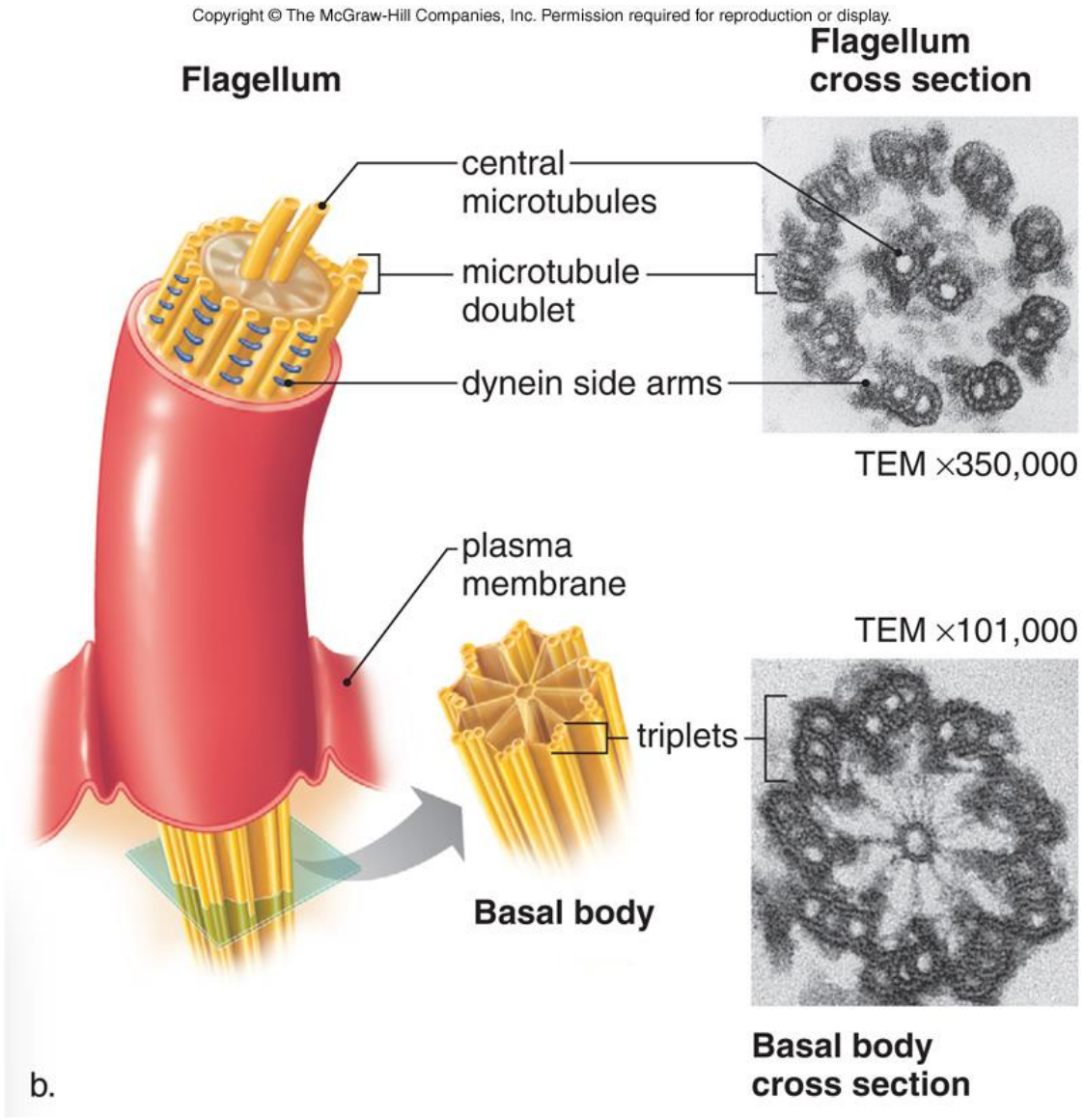
Cilia and Flagella (cont.)

cilia in bronchial wall

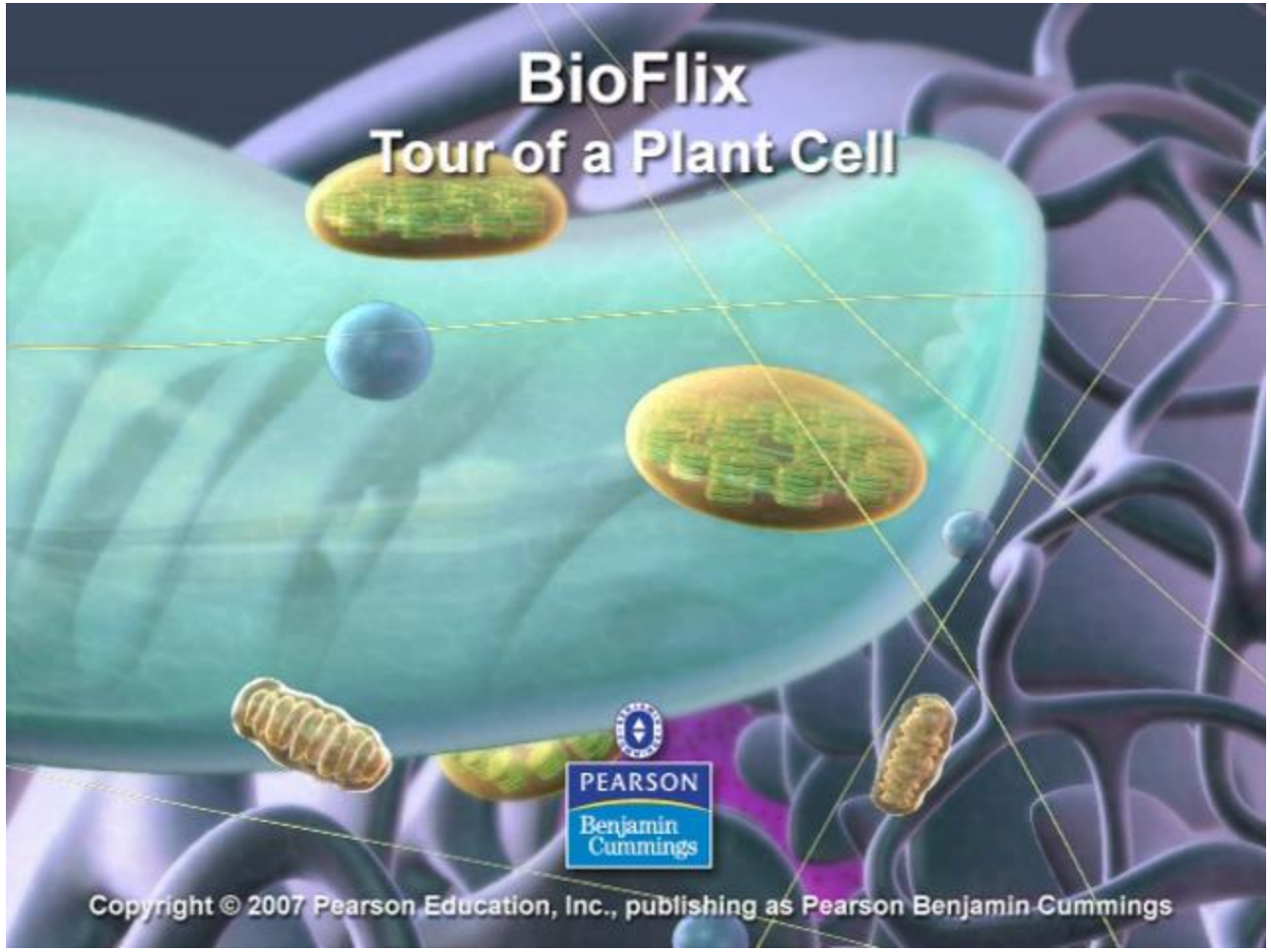
flagella of sperm

a.

Cilia and Flagella (cont.)



BioFlix: Tour of a Plant Cell



BioFlix: Tour of an Animal Cell