LECTURE PRESENTATIONS
For CAMPBELL BIOLOGY, NINTH EDITION
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Chapter 6

A Tour of the Cell

Lectures by
Erin Barley
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Overview: The Cell Theory

- All organisms are made of cells
- The basic unit of life is the cell
- All cells come from preexisting cells

Concept 6.1: Biologists use microscopes and the tools of biochemistry to study cells

- Though usually too small to be seen by the unaided eye, cells can be complex
- 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 parts of the sample (1)

- Three important parameters of microscopy
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  - *Resolution*, the measure of the clarity of the image, or the minimum distance of two distinguishable points
  - *Contrast*, visible differences in parts of the sample

Figure 6.2

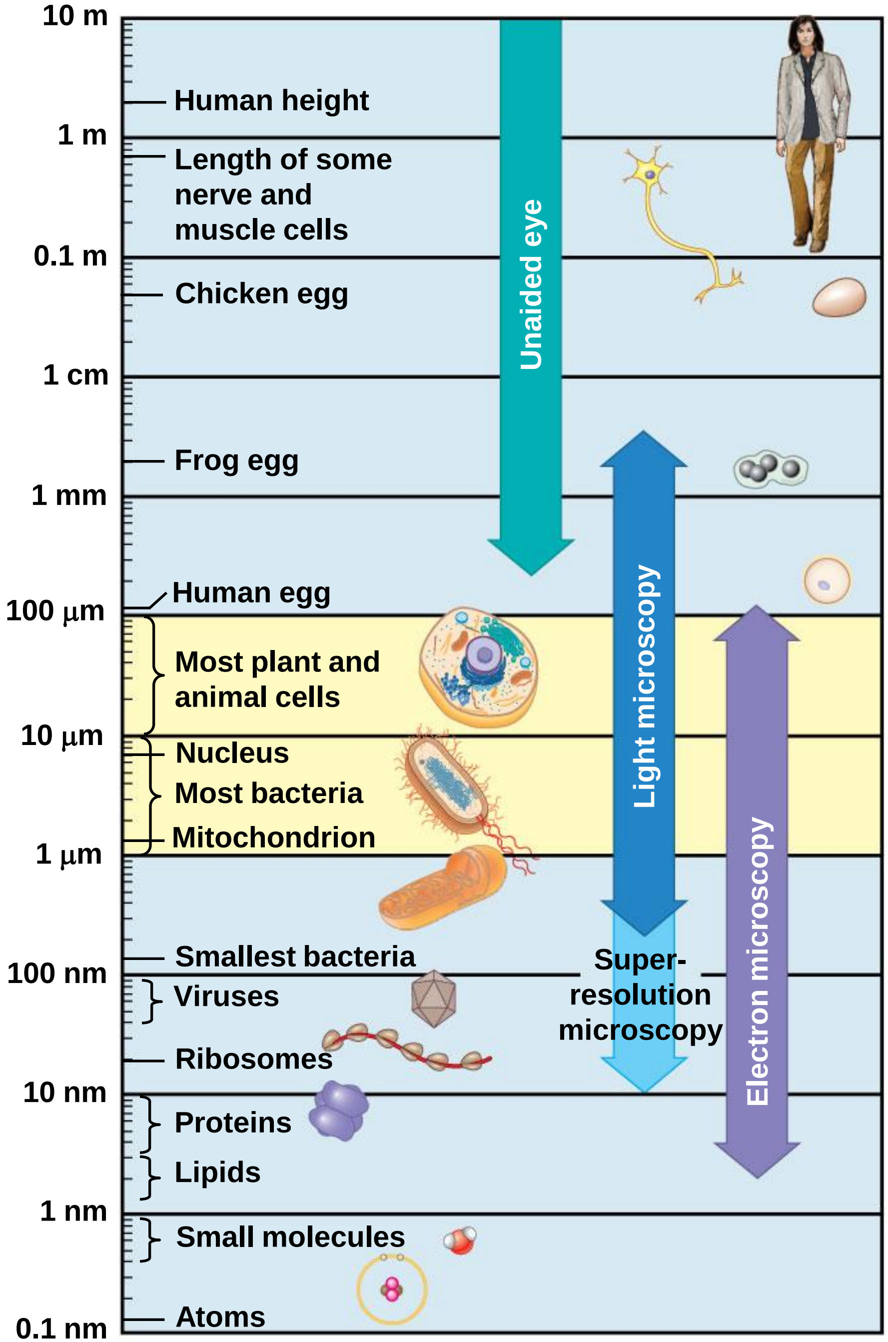

10 m
Human height
1 m
Length of some nerve and muscle cells
0.1 m
Chicken egg
1 cm
Frog egg
1 mm
Human egg
100 µm
Most plant and animal cells
10 µm
Nucleus
Most bacteria
Mitochondrion
1 µm
Smallest bacteria
100 nm
Viruses
Ribosomes
10 nm
Proteins
Lipids
1 nm
Small molecules
Atoms
0.1 nm
Unaided eye
Light microscopy
Super-resolution microscopy
Electron microscopy

Figure 6.3a

Brightfield
(unstained specimen)

Figure 6.3b

Brightfield (stained specimen)

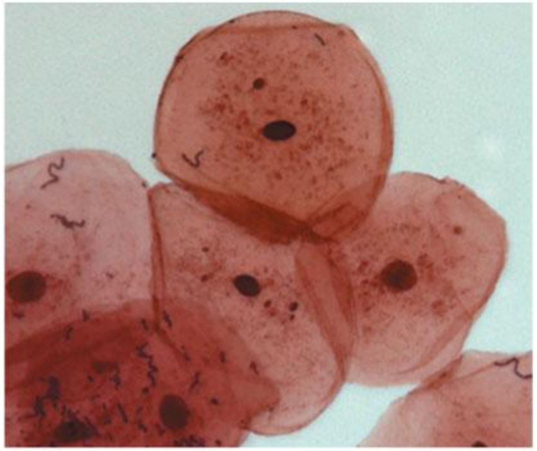
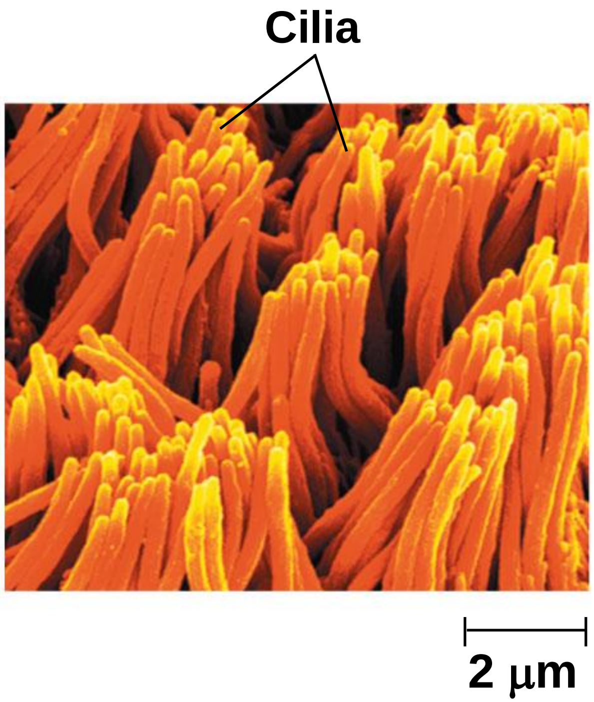
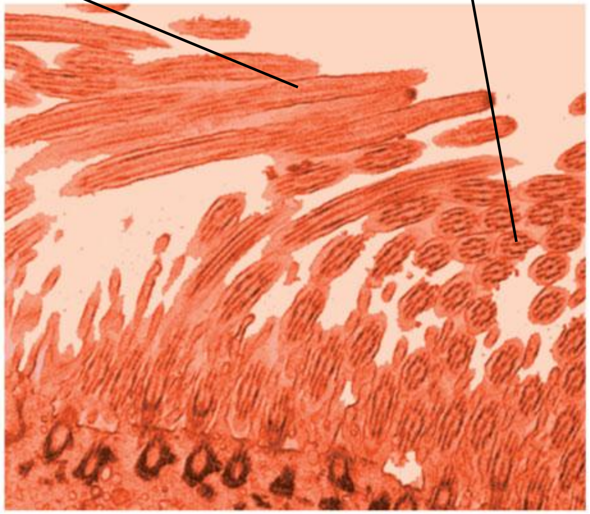


Figure 6.3i



Scanning electron microscopy (SEM) (2 & 3)

Figure 6.3j



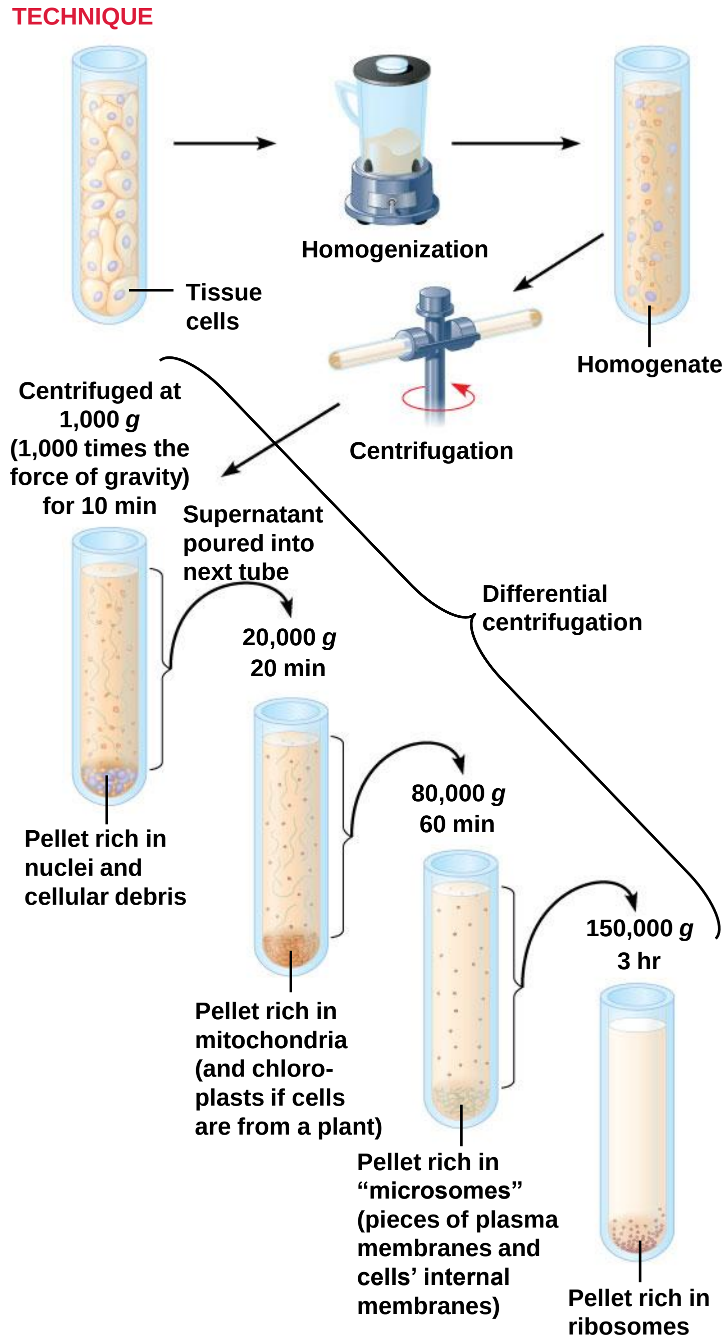
Transmission electron microscopy (TEM) (2 & 3)

Cell Fractionation

- **Cell fractionation** takes cells apart and separates the major organelles from one another
- Centrifuges fractionate cells into their component parts
- Cell fractionation enables scientists to determine the functions of organelles
- Biochemistry and cytology help correlate cell function with structure

Figure 6.4

(4)


TECHNIQUE
Homogenization
Tissue cells
Homogenate
Centrifugation
Centrifuged at 1,000 g (1,000 times the force of gravity) for 10 min
Supernatant poured into next tube
Differential centrifugation
20,000 g 20 min
80,000 g 60 min
150,000 g 3 hr
Pellet rich in nuclei and cellular debris
Pellet rich in mitochondria (and chloro-plasts if cells are from a plant)
Pellet rich in "microsomes" (pieces of plasma membranes and cells' internal membranes)
Pellet rich in ribosomes

Concept 6.2: Eukaryotic cells have internal membranes that compartmentalize their functions

- The basic structural and functional unit of every organism is one of two types of cells: prokaryotic or eukaryotic
- Only organisms of the domains Bacteria and Archaea consist of prokaryotic cells (5)
- Protists, fungi, animals, and plants all consist of eukaryotic cells

Comparing Prokaryotic and Eukaryotic Cells

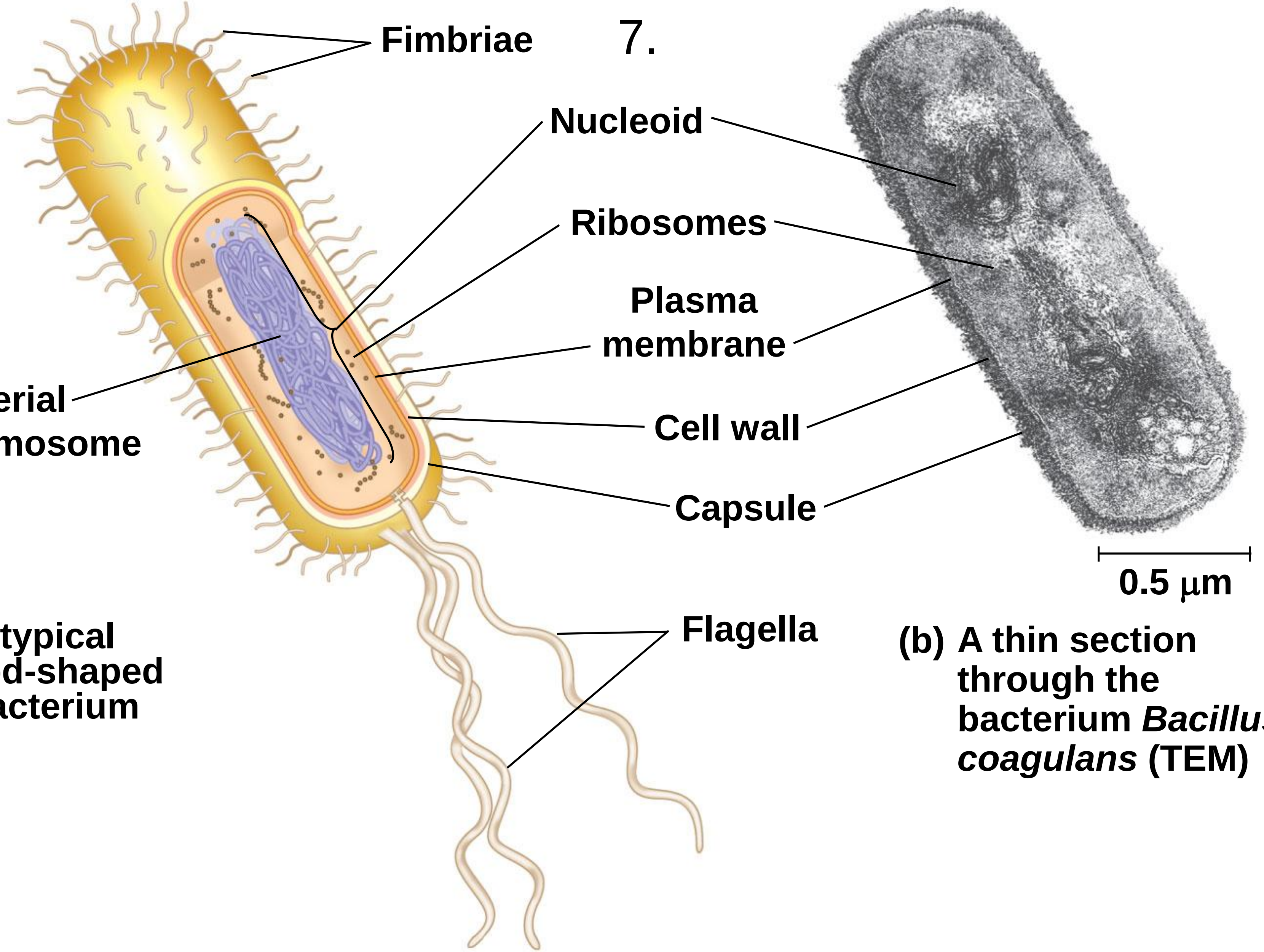
- Basic features of all cells
  - Plasma membrane
  - Semifluid substance called **cytosol**
  - Chromosomes (carry genes)
  - Ribosomes (make proteins)

- **Eukaryotic cells** are characterized by having
  - DNA in a nucleus that is bounded by a membranous nuclear envelope
  - Membrane-bound organelles
  - Cytoplasm in the region between the plasma membrane and nucleus
- Eukaryotic cells are generally much larger than prokaryotic cells

- **Prokaryotic cells** are characterized by having
  - No nucleus
  - DNA in an unbound region called the **nucleoid (unlike eukaryotes; in nucleus) (6)**
  - No membrane-bound organelles
  - **Cytoplasm** bound by the plasma membrane

Figure 6.5

7.



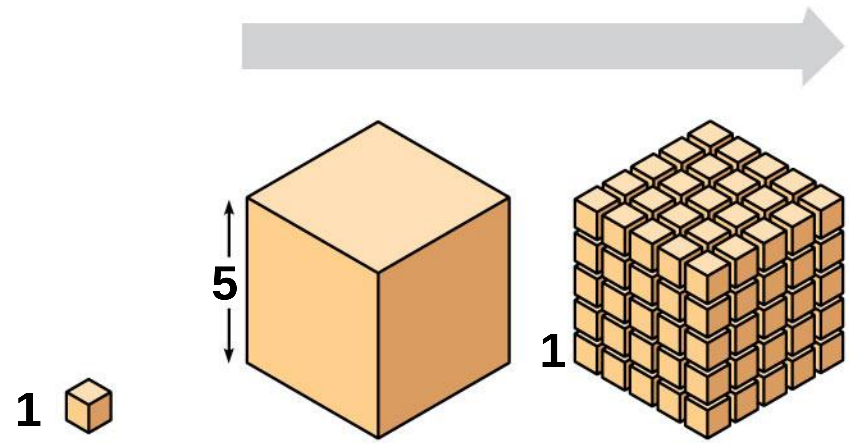
(a) A typical rod-shaped bacterium

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

- Metabolic requirements set upper limits on the size of cells
- The surface area to volume ratio of a cell is critical
- As the surface area increases by a factor of n^2, the volume increases by a factor of n^3
- Small cells have a greater surface area relative to volume
- (8)

Figure 6.7

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

A Panoramic View of the Eukaryotic Cell

- A eukaryotic cell has internal membranes that partition the cell into organelles
- Plant and animal cells have most of the same organelles

PLAY BioFlix: Tour of an Animal Cell

PLAY BioFlix: Tour of a Plant Cell

Figure 6.8a

9.

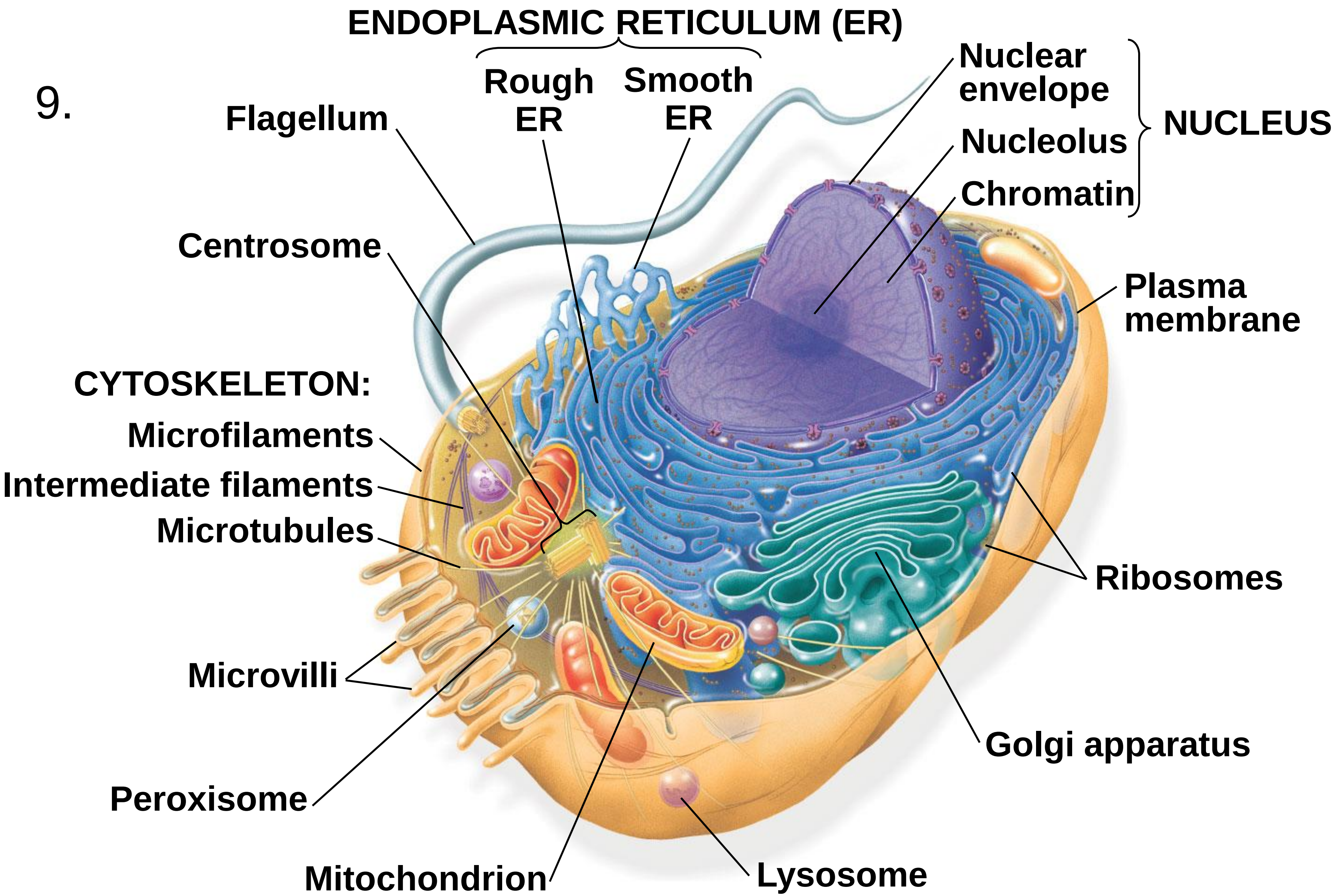
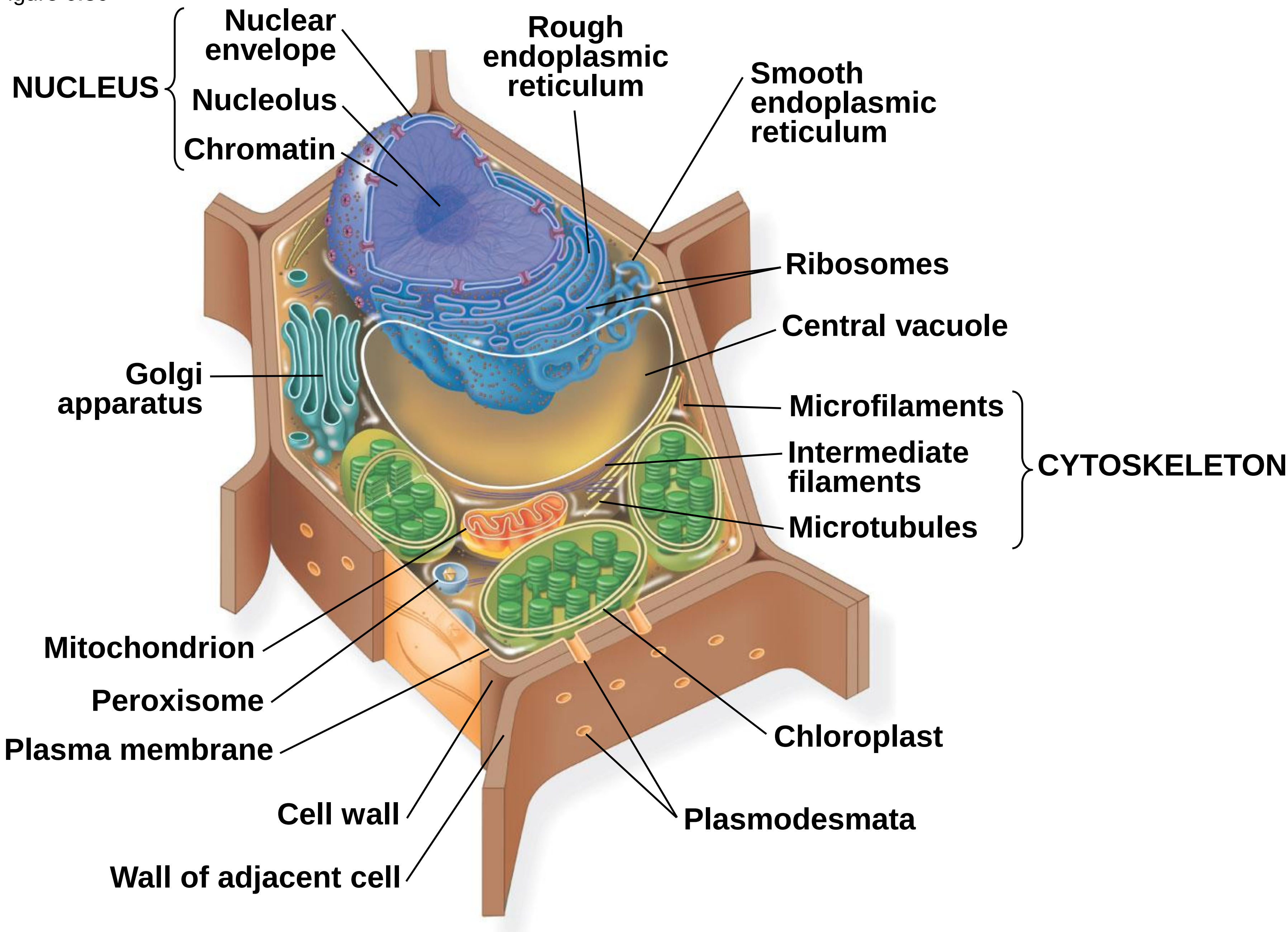

ENDOPLASMIC RETICULUM (ER)
Rough ER
Smooth ER
Flagellum
Nuclear envelope
Nucleolus
Chromatin
NUCLEUS
Centrosome
Plasma membrane
CYTOSKELETON:
Microfilaments
Intermediate filaments
Microtubules
Ribosomes
Microvilli
Golgi apparatus
Peroxisome
Mitochondrion
Lysosome

Figure 6.8c

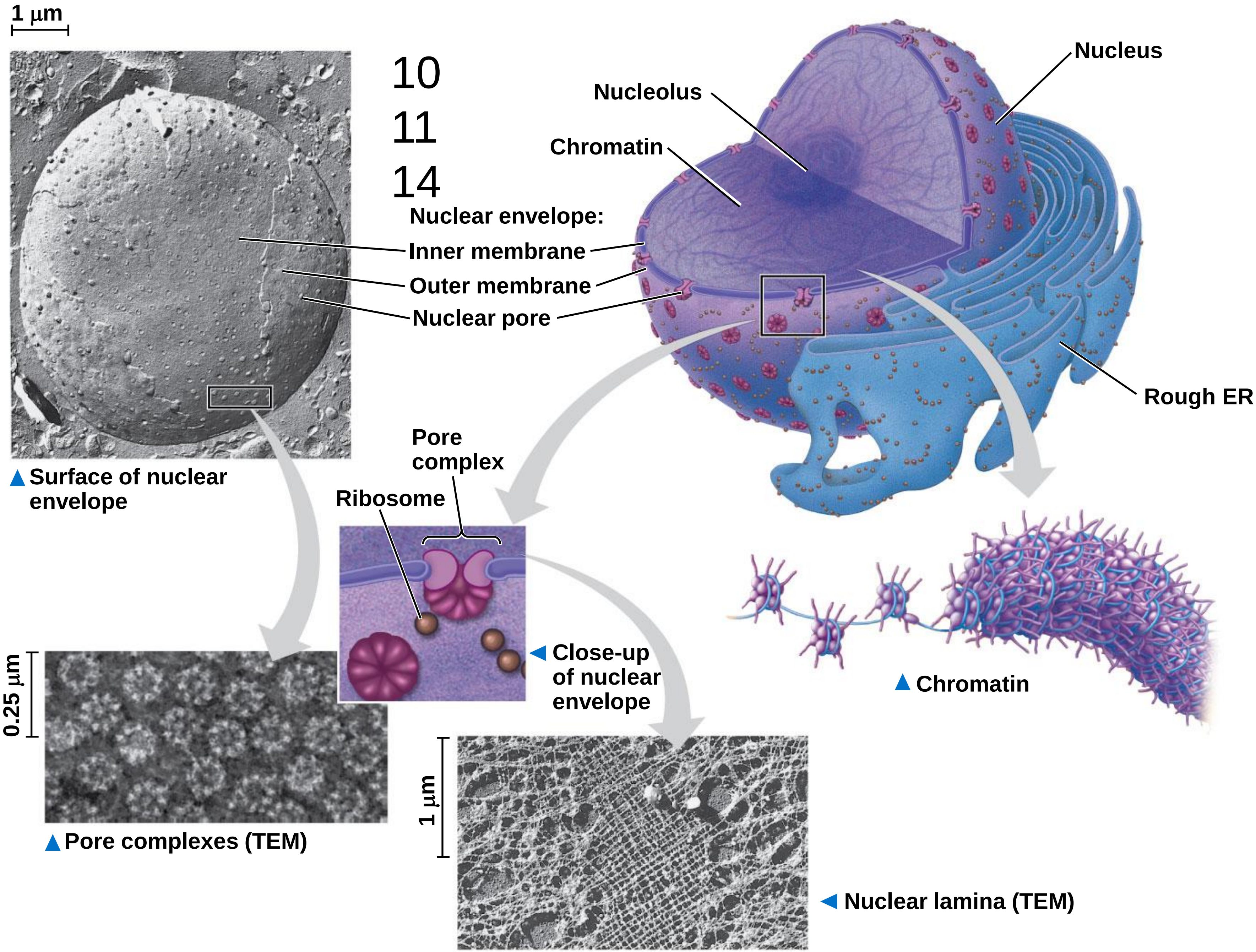


NUCLEUS
Nuclear envelope
Nucleolus
Chromatin
Rough endoplasmic reticulum
Smooth endoplasmic reticulum
Ribosomes
Central vacuole
Microfilaments
Intermediate filaments
Microtubules
CYTOSKELETON
Golgi apparatus
Mitochondrion
Peroxisome
Plasma membrane
Cell wall
Wall of adjacent cell
Chloroplast
Plasmodesmata

Concept 6.3: The eukaryotic cell's genetic instructions are housed in the nucleus and carried out by the ribosomes

- The nucleus contains most of the DNA in a eukaryotic cell
- Ribosomes use the information from the DNA to make proteins

Figure 6.9


1 µm
10
11
14
Nuclear envelope:
Inner membrane
Outer membrane
Nuclear pore
Nucleolus
Chromatin
Nucleus
Rough ER
Surface of nuclear envelope
Pore complex
Ribosome
Close-up of nuclear envelope
Chromatin
0.25 µm
Pore complexes (TEM)
1 µm
Nuclear lamina (TEM)

- Pores regulate the entry and exit of molecules from the nucleus
- The shape of the nucleus is maintained by the **nuclear lamina**, which is composed of protein
- the **nuclear matrix** is the network of fibers found throughout the inside of a cell nucleus and is somewhat analogous to the cell cytoskeleton
- (12)

- In the nucleus, DNA is organized into discrete units called **chromosomes**
- Each chromosome is composed of a single DNA molecule associated with proteins
- The DNA and proteins of chromosomes are together called **chromatin**
- Chromatin condenses to form discrete **chromosomes** as a cell prepares to divide
- The **nucleolus** is located within the nucleus and is the site of ribosomal RNA (rRNA) synthesis (13)

Ribosomes: Protein Factories

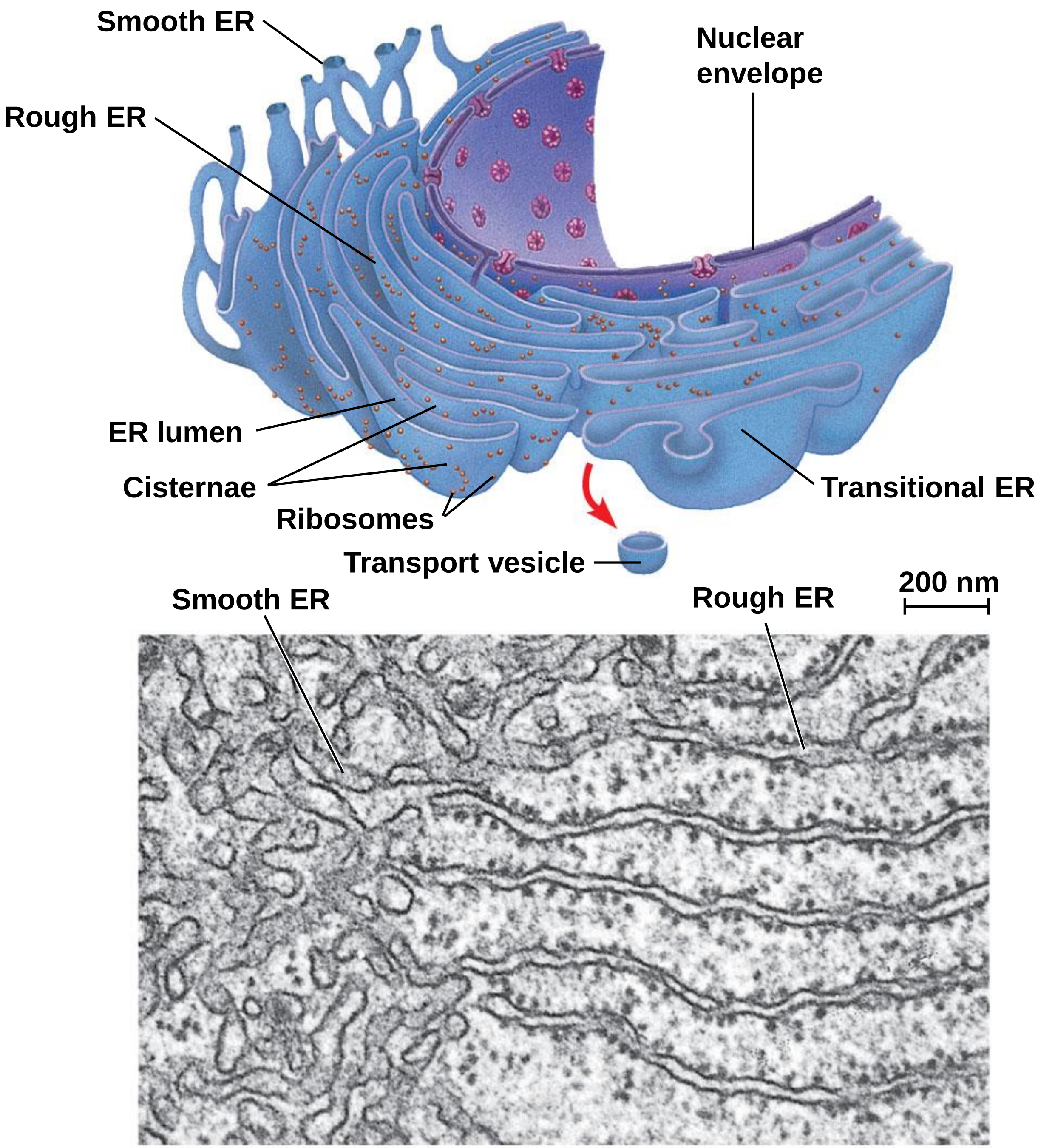
- **Ribosomes** are particles made of ribosomal RNA and protein
- Ribosomes carry out protein synthesis in two locations
  - In the cytosol (free ribosomes)-”in house” proteins
  - On the outside of the endoplasmic reticulum or the nuclear envelope (bound ribosomes)-secreted proteins
  - (15 & 16)

Concept 6.4: The endomembrane system regulates protein traffic and performs metabolic functions in the cell

- Components of the **endomembrane system (17)**
  - Nuclear envelope
  - Endoplasmic reticulum
  - Golgi apparatus
  - Lysosomes
  - Vacuoles
  - Plasma membrane
- These components are either continuous or connected via transfer by **vesicles**

Figure 6.11

18



Functions of Smooth ER

- The smooth ER
  - Synthesizes lipids
  - Metabolizes carbohydrates
  - Detoxifies drugs and poisons
  - Stores calcium ions
  - (19 & 20)

Functions of Rough ER

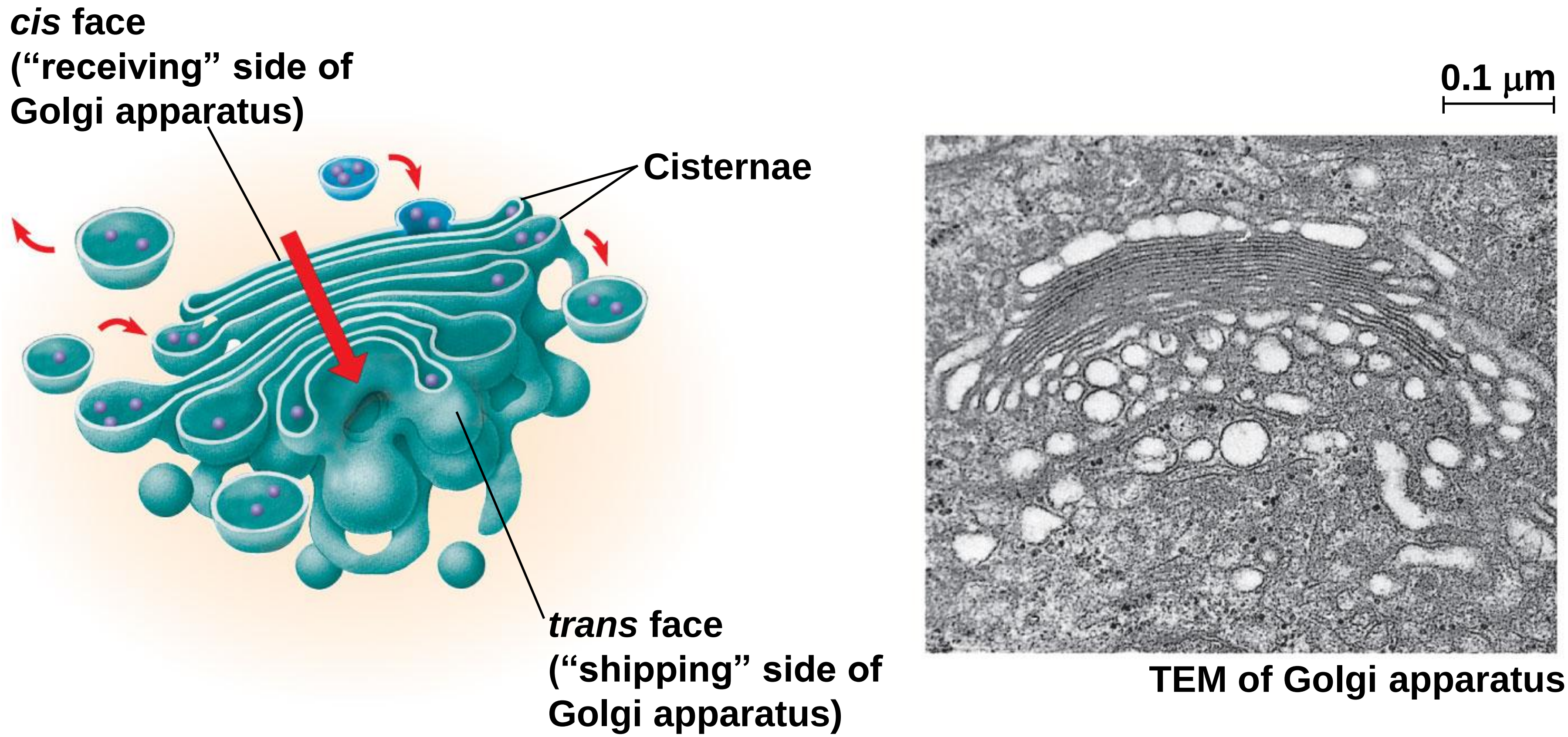
- The rough ER
  - Has bound ribosomes, which secrete **glycoproteins** (proteins covalently bonded to carbohydrates)
  - Distributes **transport vesicles,** proteins surrounded by membranes
  - Is a membrane factory for the cell
  - (21 & 22)

The Golgi Apparatus: Shipping and Receiving Center

- The **Golgi apparatus** consists of flattened membranous sacs called cisternae
- Functions of the Golgi apparatus
  - Modifies products of the ER
  - Manufactures certain macromolecules
  - Sorts and packages materials into transport vesicles

Figure 6.12

23



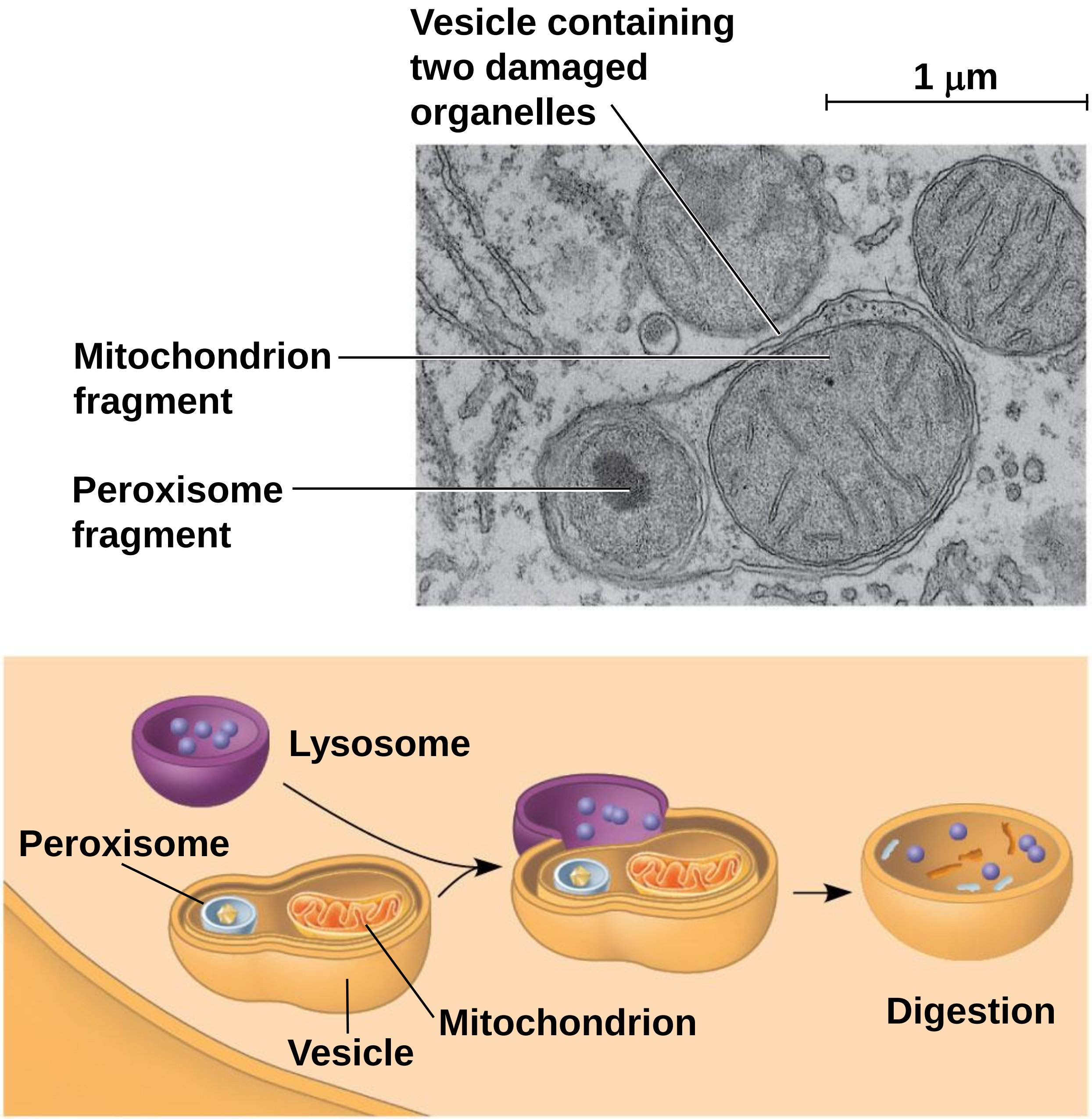
Lysosomes: Digestive Compartments

- A **lysosome** is a membranous sac of hydrolytic enzymes that can digest macromolecules
- Lysosomal enzymes can hydrolyze proteins, fats, polysaccharides, and nucleic acids
- Lysosomal enzymes work best in the acidic environment inside the lysosome
- (24)

PLAY Animation: Lysosome Formation

- Some types of cell can engulf another cell by **phagocytosis**; this forms a food vacuole
- Ex. Macrophages (25)
- A lysosome fuses with the food vacuole and digests the molecules
- Lysosomes also use enzymes to recycle the cell's own organelles and macromolecules, a process called autophagy (26)
- Tay Sach's is a lysosomal disorder that results in the buildup of a lipid in nerve cells impairing their function.(27)

Figure 6.13b



(b) Autophagy

Vacuoles: Diverse Maintenance Compartments

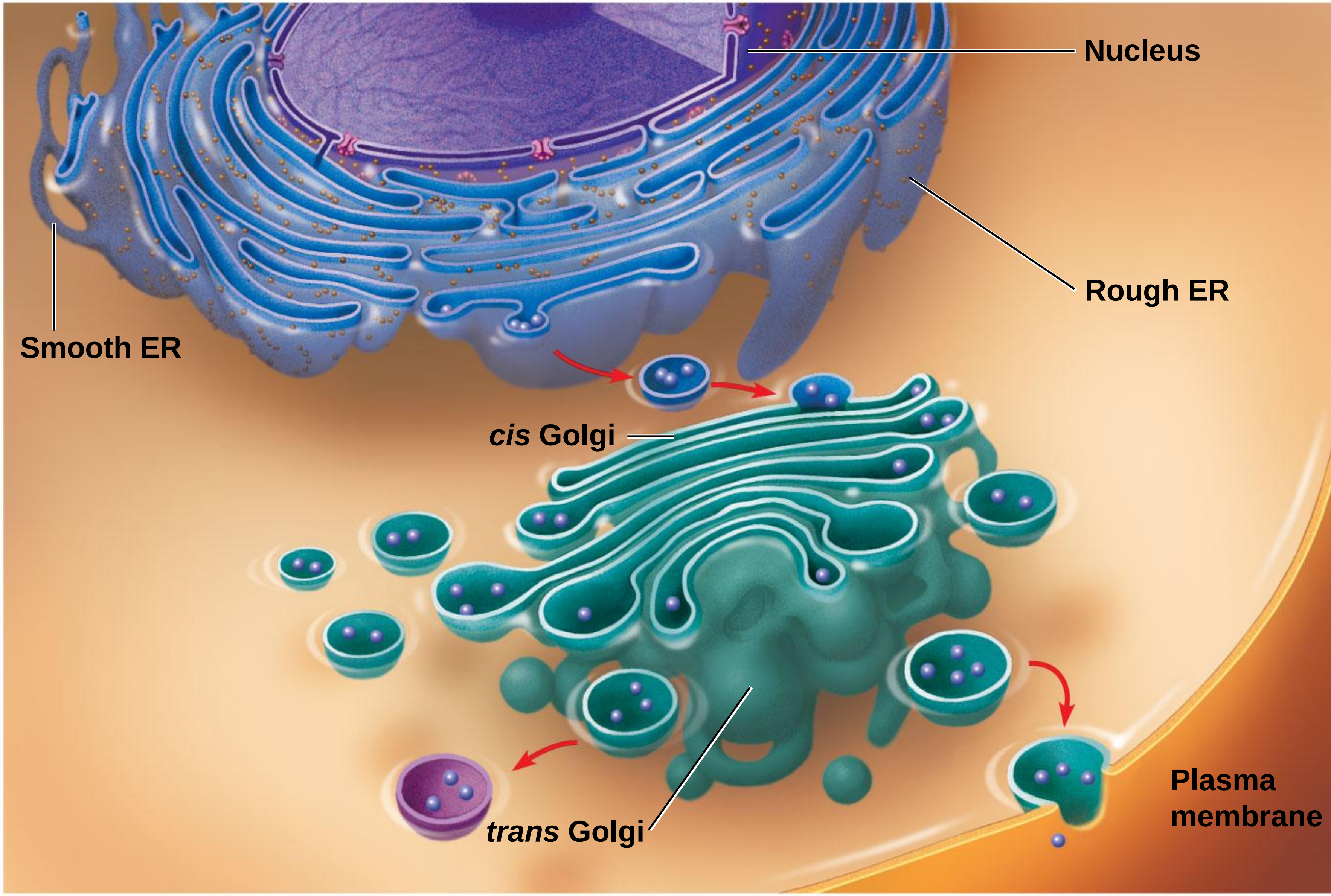
- A plant cell or fungal cell may have one or several **vacuoles**, derived from endoplasmic reticulum and Golgi apparatus
- **Food vacuoles** are formed by phagocytosis
- **Contractile vacuoles**, found in many freshwater protists, pump excess water out of cells
- **Central vacuoles**, found in many mature plant cells, hold organic compounds and water

PLAY Video: Paramecium Vacuole

The Endomembrane System: *A Review*

- The endomembrane system is a complex and dynamic player in the cell's compartmental organization
- Next slide (29)

Figure 6.15-3



Nucleus
Rough ER
Smooth ER
cis Golgi
trans Golgi
Plasma membrane

Concept 6.5: Mitochondria and chloroplasts change energy from one form to another

- **Mitochondria** are the sites of cellular respiration, a metabolic process that uses oxygen to generate ATP
- **Chloroplasts**, found in plants and algae, are the sites of photosynthesis
- Peroxisomes are oxidative organelles

- The **Endosymbiont theory**
- endosymbiont-“internal symbiont”
  - An early ancestor of eukaryotic cells engulfed a nonphotosynthetic prokaryotic cell, which formed an endosymbiont relationship with its host
  - The host cell and endosymbiont merged into a single organism, a eukaryotic cell with a mitochondrion
  - At least one of these cells may have taken up a photosynthetic prokaryote, becoming the ancestor of cells that contain chloroplasts
  - (30 & 31)

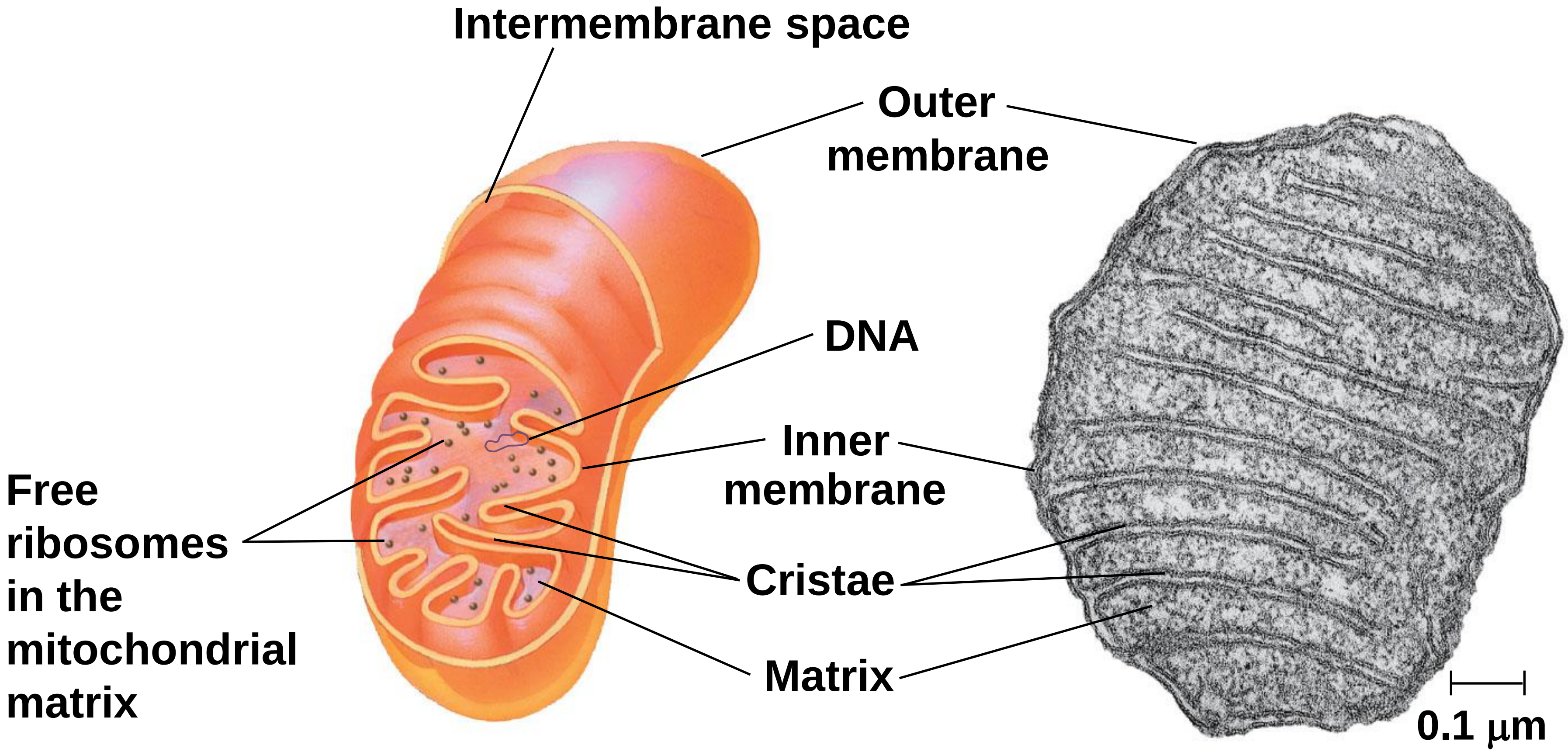
The Evolutionary Origins of Mitochondria and Chloroplasts

- Mitochondria and chloroplasts have similarities with bacteria
  - Enveloped by a double membrane
  - Contain free ribosomes and circular DNA molecules
  - Grow and reproduce somewhat independently in cells (31)

Mitochondria: Chemical Energy Conversion

- Mitochondria are in nearly all eukaryotic cells
- They have a smooth outer membrane and an inner membrane folded into **cristae**
- The inner membrane creates two compartments: intermembrane space and **mitochondrial matrix**
- Some metabolic steps of cellular respiration are catalyzed in the mitochondrial matrix
- Cristae present a large surface area for enzymes that synthesize ATP (32, 34, & 36 Next slide)

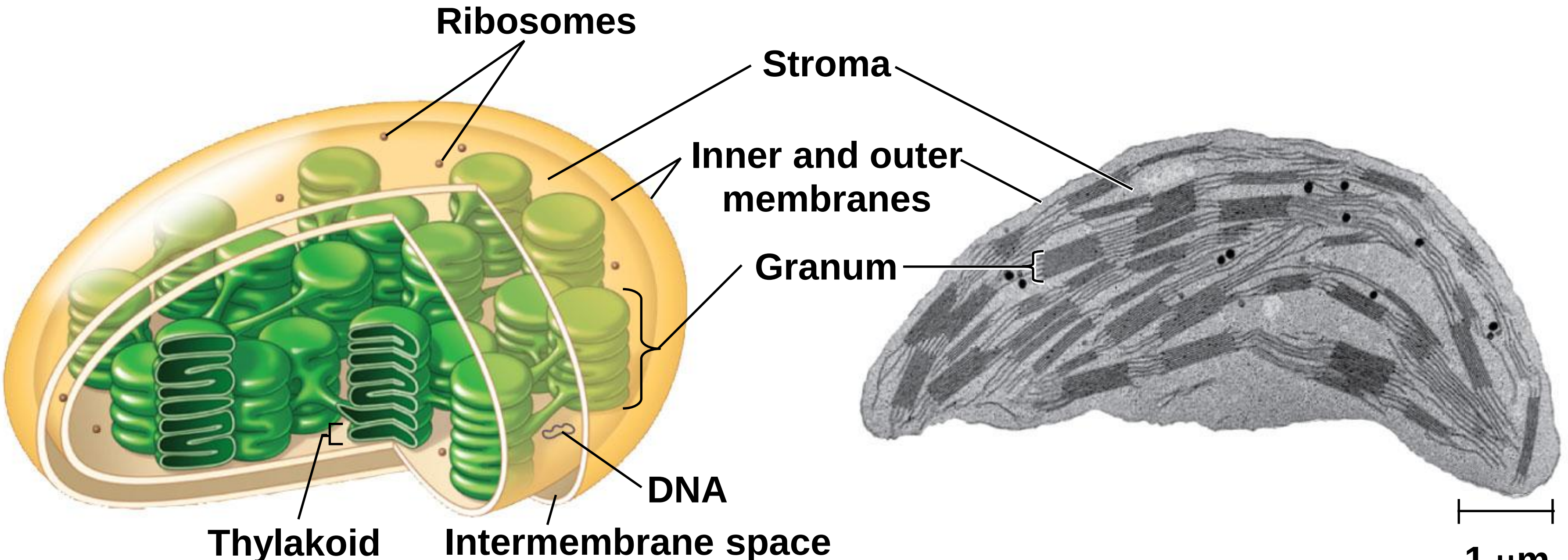
Figure 6.17a



(a) Diagram and TEM of mitochondrion

- Chloroplast structure includes
  - **Thylakoids**, membranous sacs, stacked to form a **granum**
  - **Stroma**, the internal fluid
- The chloroplast is one of a group of plant organelles, called **plastids**
- **(33 and 35 Next slide)**

Figure 6.18a



(a) Diagram and TEM of chloroplast

Peroxisomes: Oxidation

- **Peroxisomes** are specialized metabolic compartments bounded by a single membrane
- Peroxisomes produce hydrogen peroxide and convert it to water
- Peroxisomes perform reactions with many different functions

(37)

Concept 6.6: The cytoskeleton is a network of fibers that organizes structures and activities in the cell

- The **cytoskeleton** is a network of fibers extending throughout the cytoplasm
- It organizes the cell’s structures and activities, anchoring many organelles
- It is composed of three types of molecular structures
  - Microtubules
  - Microfilaments
  - Intermediate filaments (38, 39, & 40)

Figure 6.20

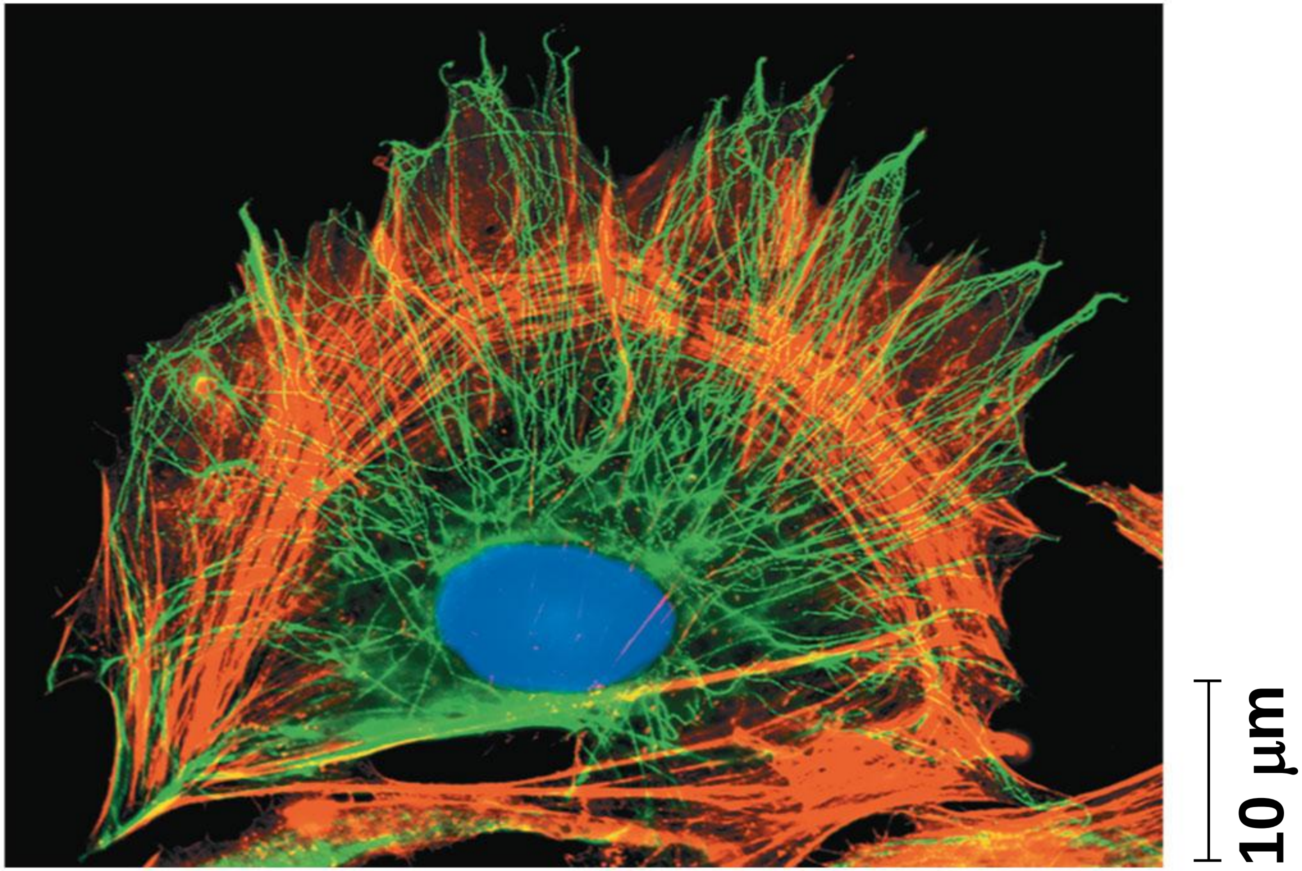


Figure 6.21

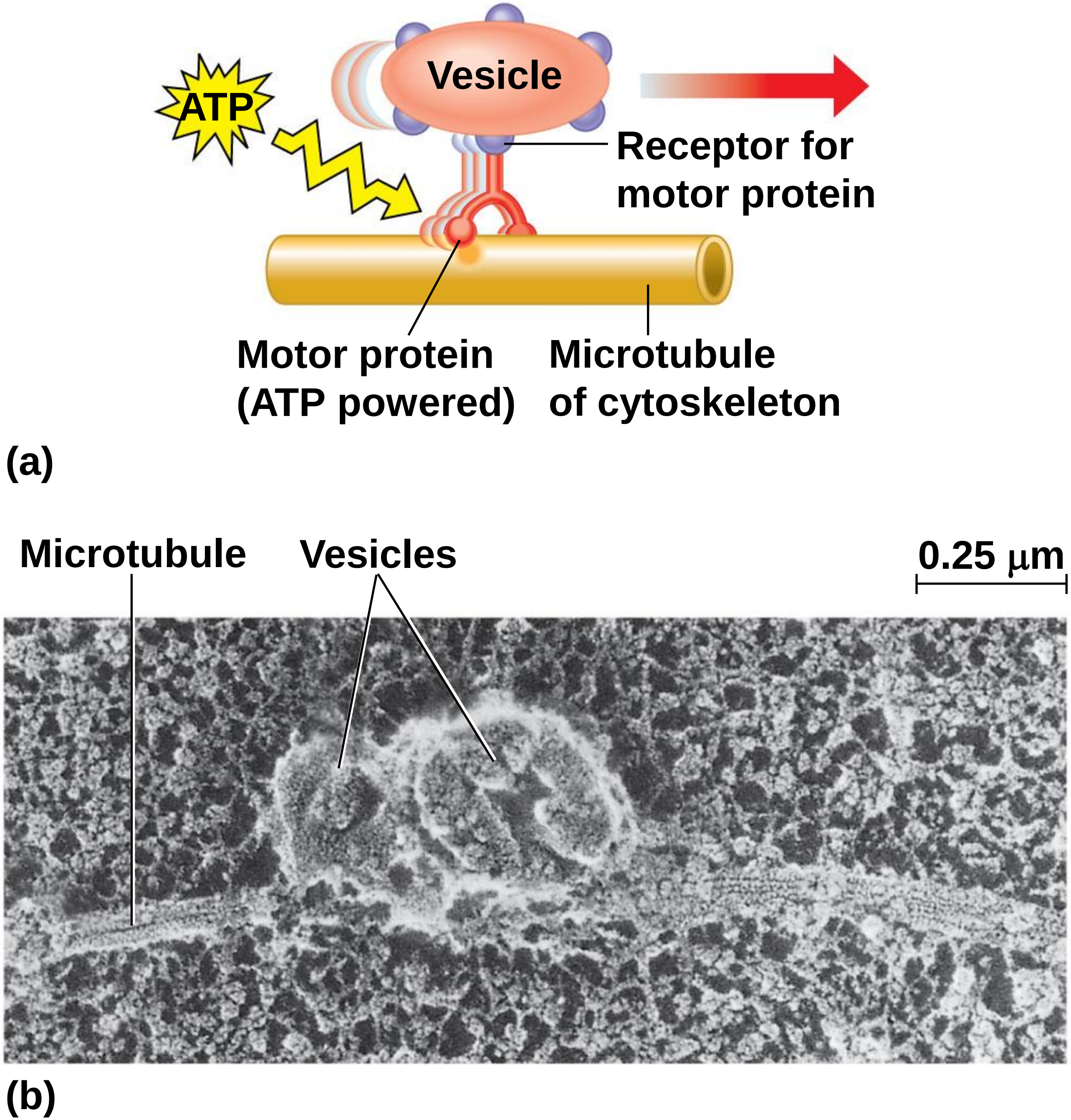
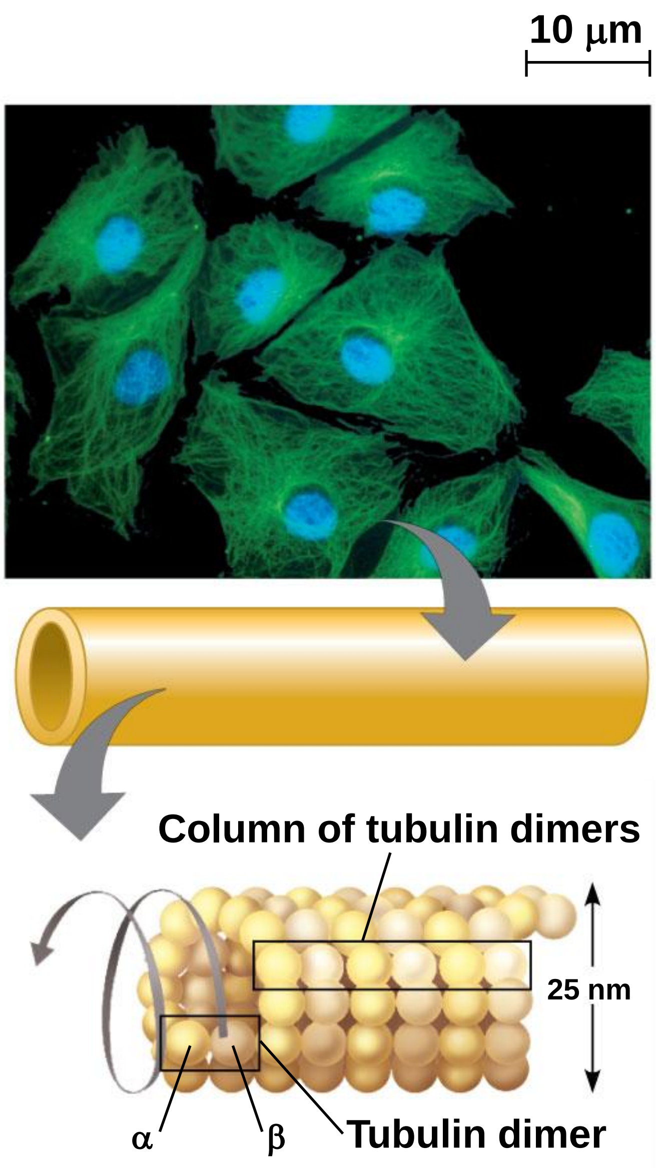

Vesicle
ATP
Receptor for motor protein
Motor protein (ATP powered)
Microtubule of cytoskeleton
(a)
Microtubule
Vesicles
0.25 µm
(b)

Table 6.1a

Property	Microtubules (Tubulin Polymers)
Structure	Hollow tubes; wall consists of 13 columns of tubulin molecules
Diameter	25 nm with 15-nm lumen
Protein subunits	Tubulin, a dimer consisting of α-tubulin and β-tubulin
Main functions	Maintenance of cell shape (compression-resisting "girders") Cell motility (as in cilia or flagella) Chromosome movements in cell division Organelle movements



41

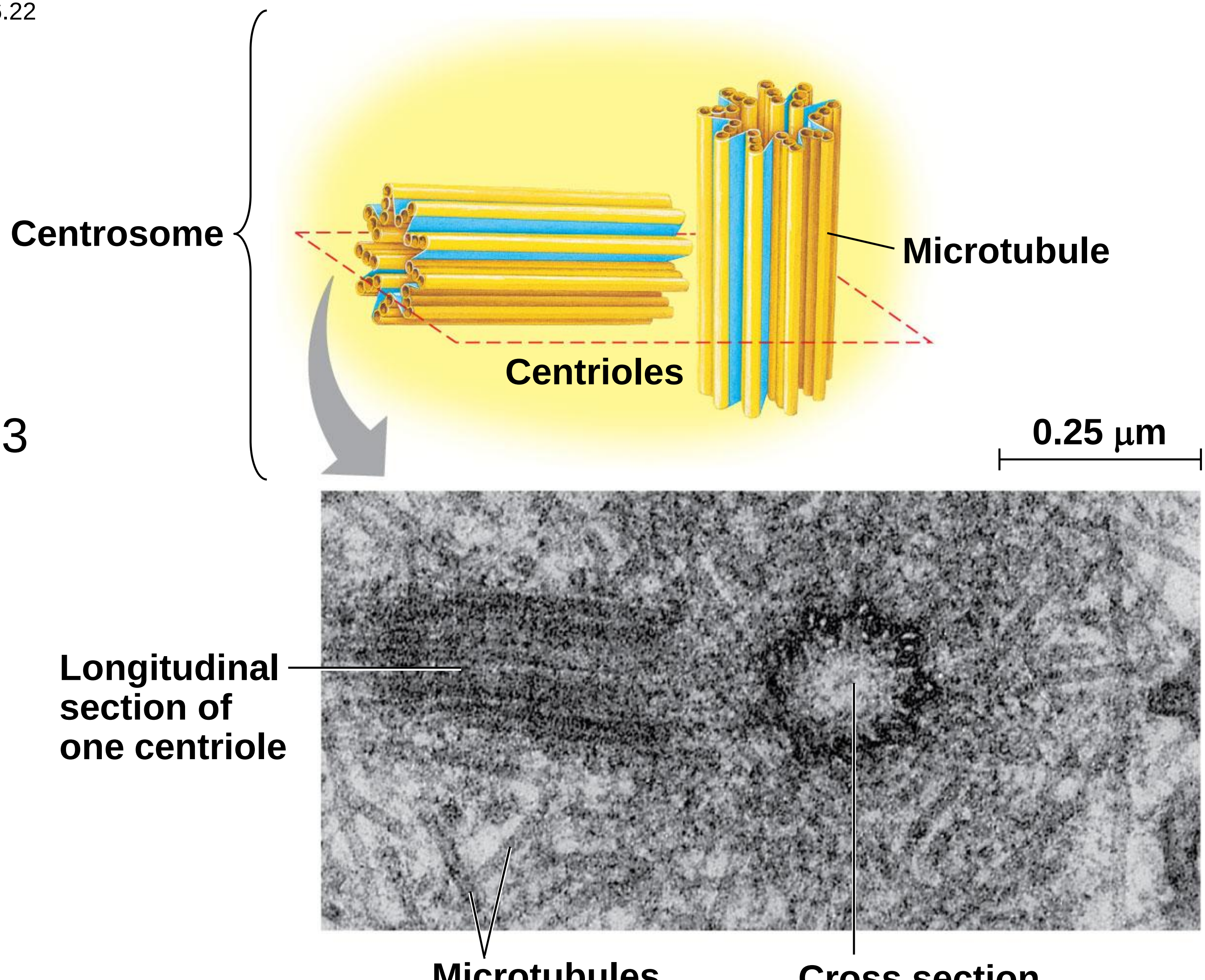
Microtubules

- **Microtubules** are hollow rods about 25 nm in diameter and about 200 nm to 25 microns long
- Functions of microtubules
  - Shaping the cell
  - Guiding movement of organelles
  - Separating chromosomes during cell division

Centrosomes and Centrioles

- In many cells, microtubules grow out from a **centrosome** near the nucleus
- The centrosome is a “microtubule-organizing center”
- In animal cells, the centrosome has a pair of **centrioles**, each with nine triplets of microtubules arranged in a ring that are “thought” to be involved with cell division
- (41)

Figure 6.22



43

Cilia and Flagella

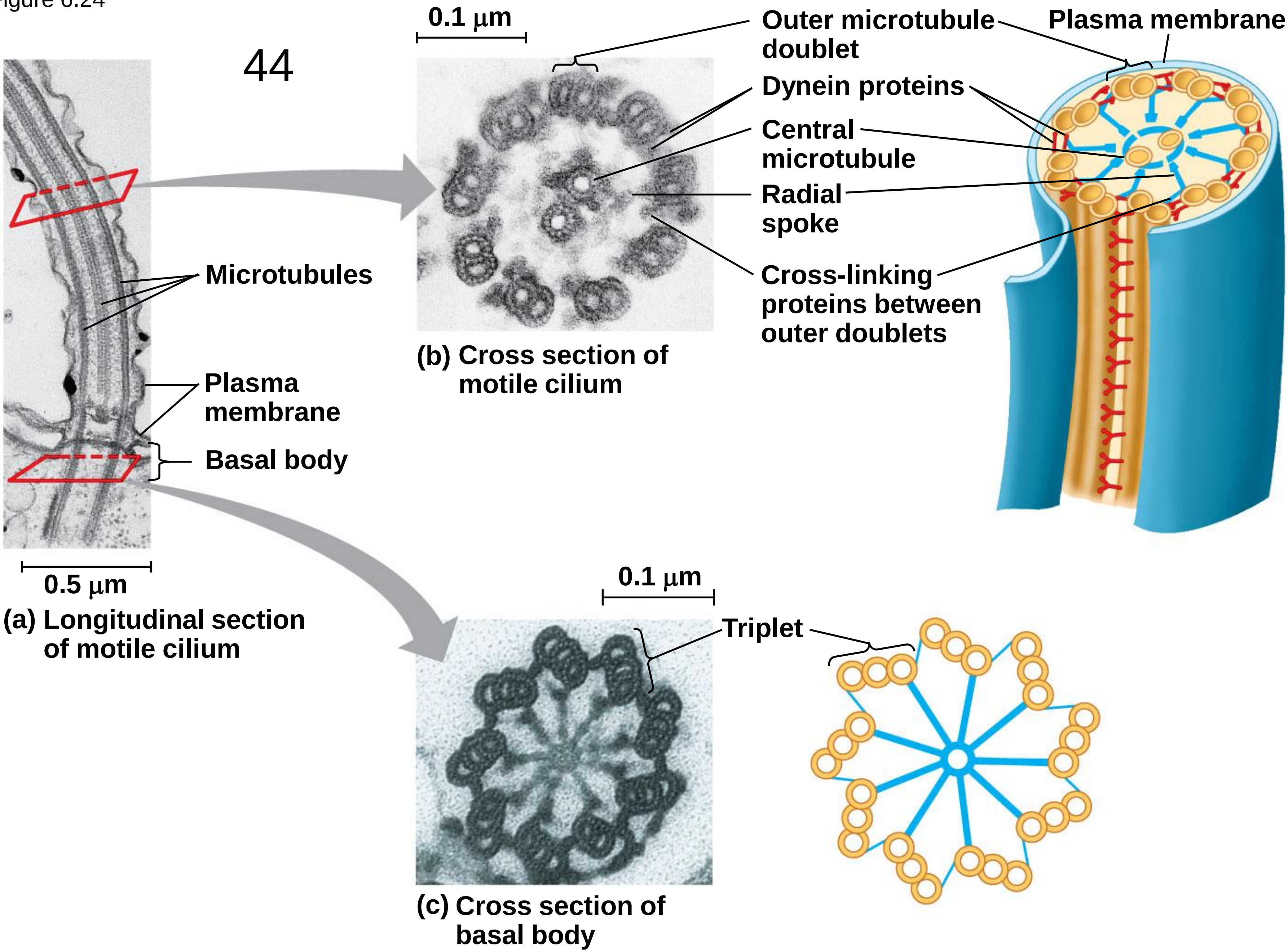
- Microtubules control the beating of **cilia** and **flagella**, locomotor appendages of some cells
- Cilia and flagella differ in their beating patterns

PLAY Video: *Chlamydomonas*

PLAY Video: *Paramecium* Cilia

Figure 6.24

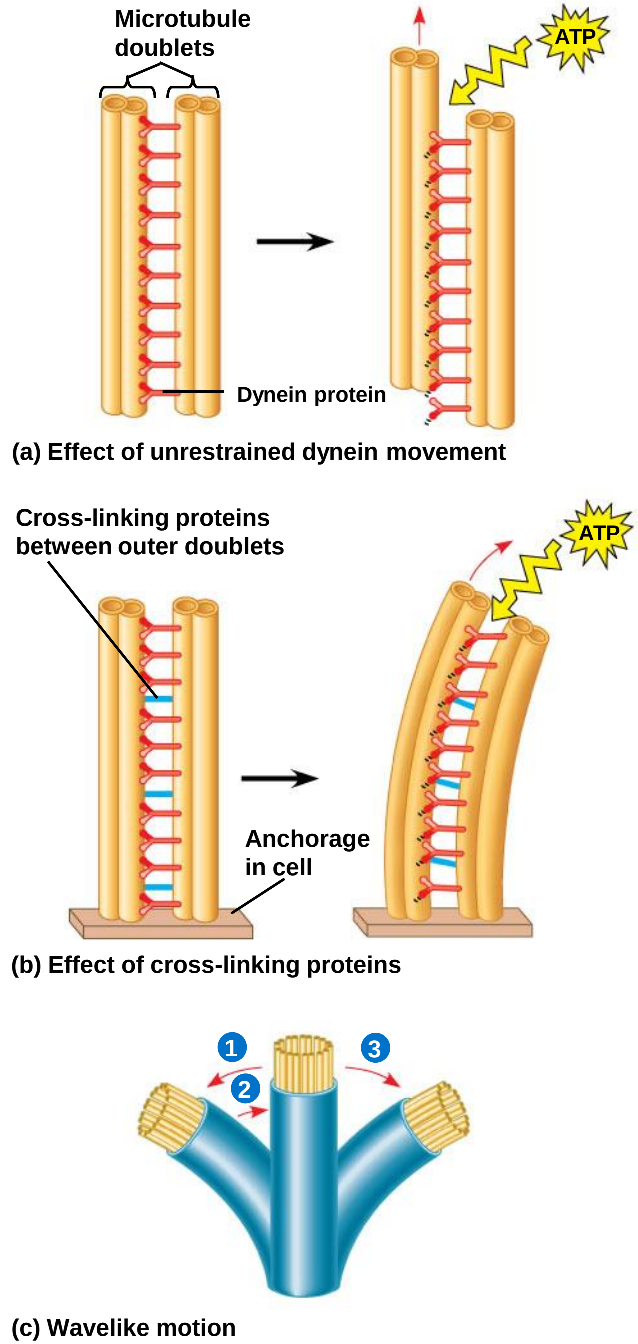
44



- Cilia and flagella share a common structure
  - A core of microtubules sheathed by the plasma membrane
  - A **basal body** that anchors the cilium or flagellum
  - A motor protein called **dynein**, which drives the bending movements of a cilium or flagellum
  - Their actual motions are different (sperm/intestines move)
  - (45)

PLAY Animation: Cilia and Flagella

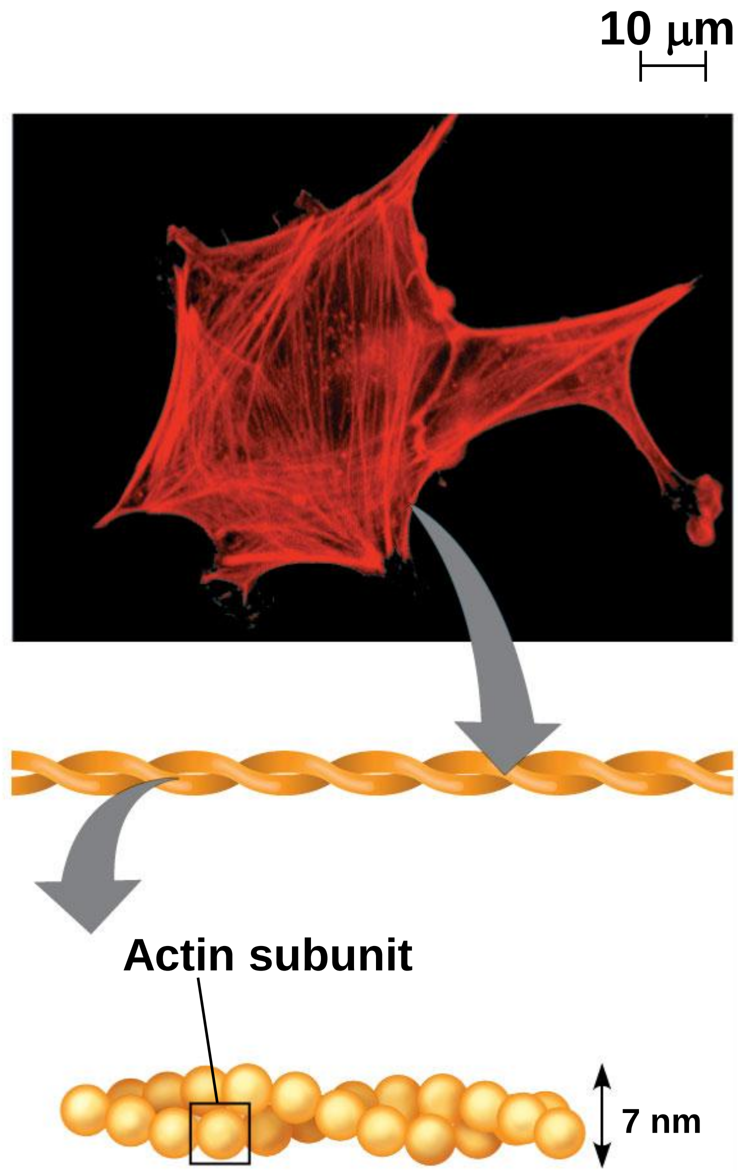
Figure 6.25



- How dynein "walking" moves flagella and cilia
  - Dynein arms alternately grab, move, and release the outer microtubules
  - Protein cross-links limit sliding
  - Forces exerted by dynein arms cause doublets to curve, bending the cilium or flagellum (46)

Table 6.1b

Property	Microfilaments (Actin Filaments)
Structure	Two intertwined strands of actin, each a polymer of actin subunits
Diameter	7 nm
Protein subunits	Actin
Main functions	Maintenance of cell shape (tension-bearing elements) Changes in cell shape Muscle contraction Cytoplasmic streaming Cell motility (as in pseudopodia) Cell division (cleavage furrow formation)



- Microfilaments that function in cellular motility contain the protein **myosin** in addition to actin
- In muscle cells, thousands of actin filaments are arranged parallel to one another
- Thicker filaments composed of myosin interdigitate with the thinner actin fibers
- (48)

Figure 6.27

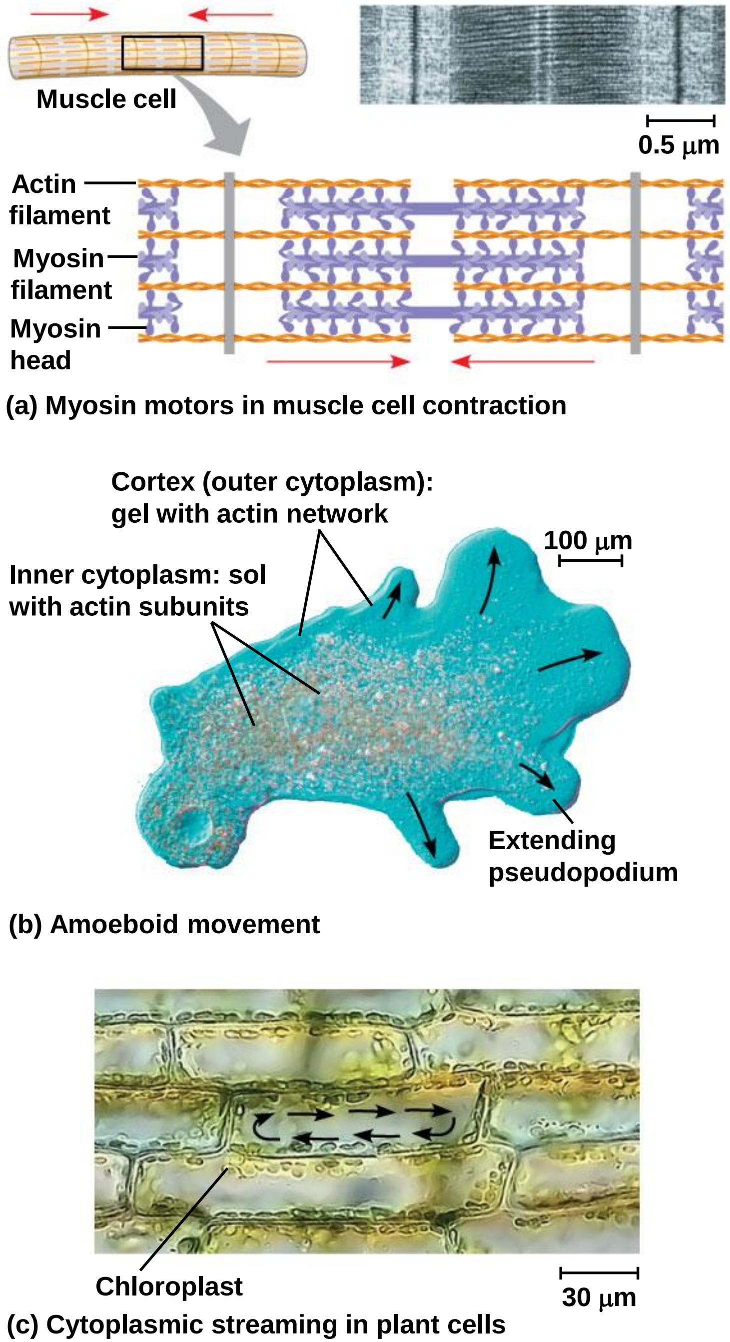
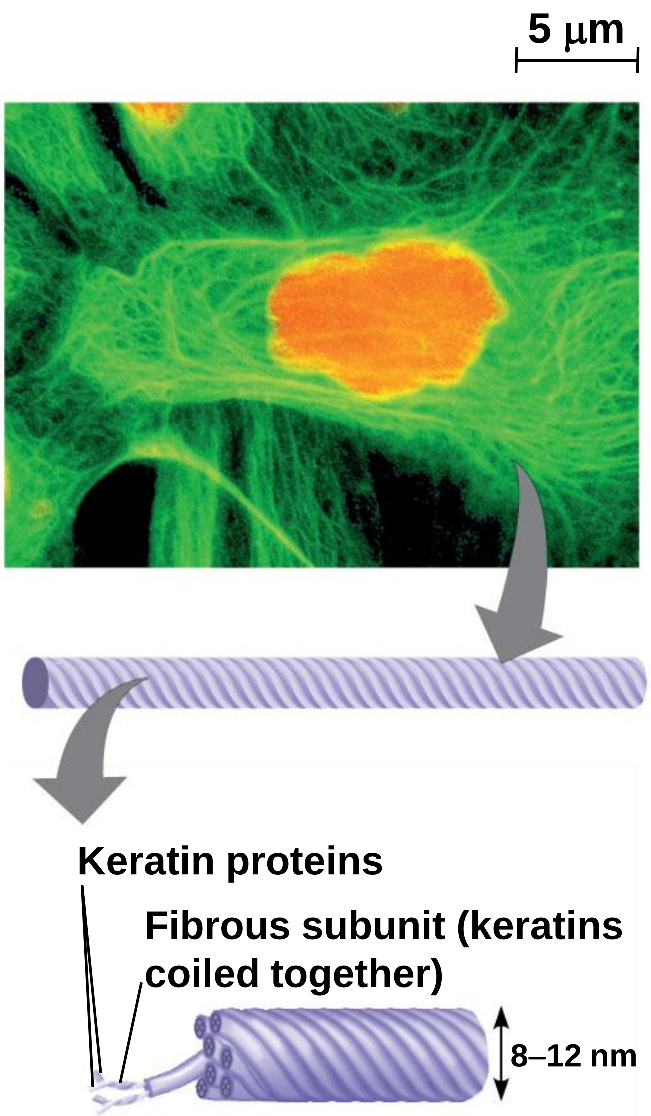

Muscle cell
0.5 µm
Actin filament
Myosin filament
Myosin head
(a) Myosin motors in muscle cell contraction
Cortex (outer cytoplasm): gel with actin network
100 µm
Inner cytoplasm: sol with actin subunits
Extending pseudopodium
(b) Amoeboid movement
Chloroplast
30 µm
(c) Cytoplasmic streaming in plant cells

Table 6.1c

Property	Intermediate Filaments
Structure	Fibrous proteins supercoiled into thicker cables
Diameter	8–12 nm
Protein subunits	One of several different proteins (such as keratins), depending on cell type
Main functions	Maintenance of cell shape (tension-bearing elements) Anchorage of nucleus and certain other organelles Formation of nuclear lamina



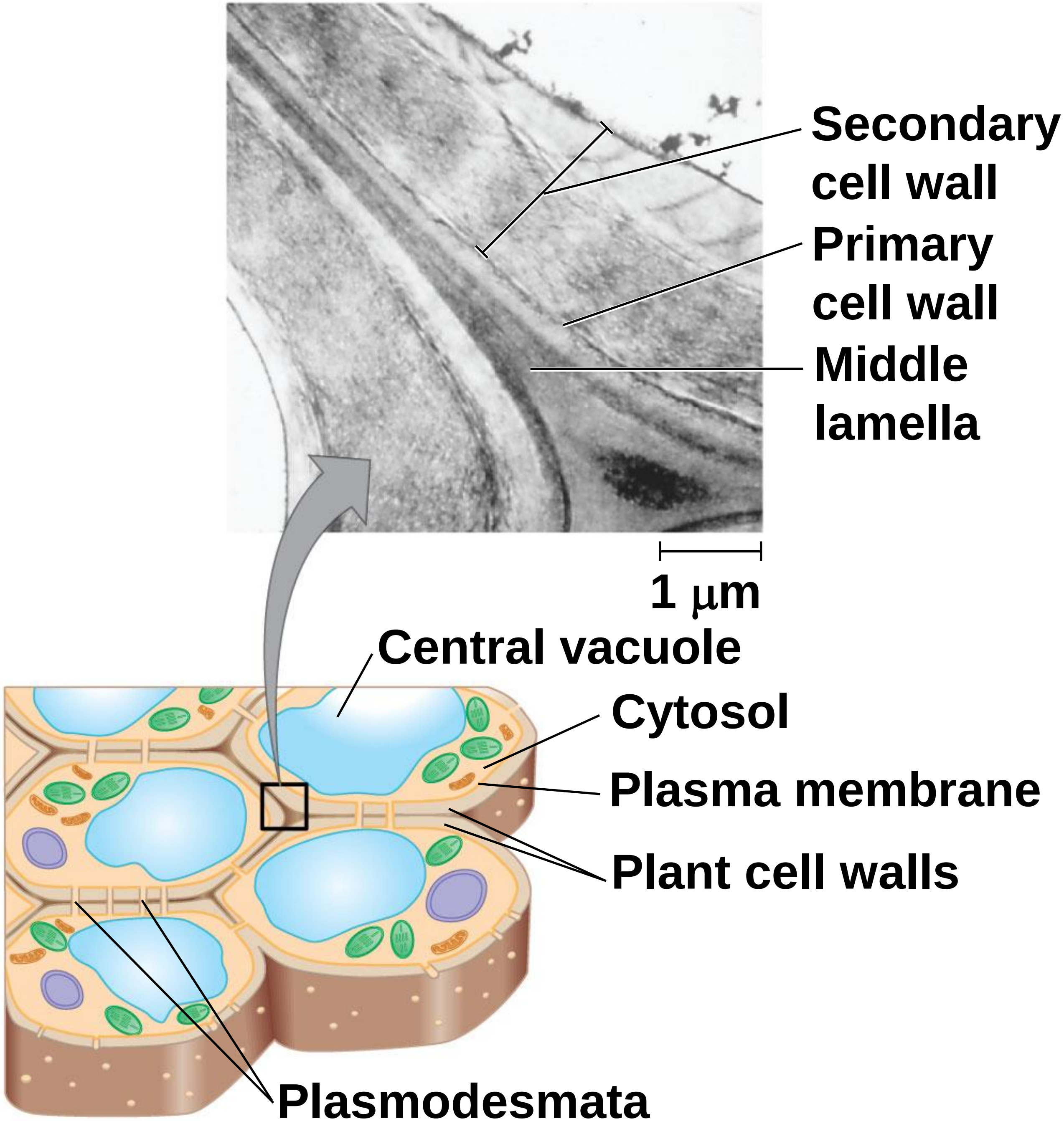
Concept 6.7: Cell Walls

- The **cell wall** is an extracellular structure that distinguishes plant cells from animal cells
- Prokaryotes, fungi, and some protists also have cell walls
- The cell wall protects the plant cell, maintains its shape, and prevents excessive uptake of water
- Plant cell walls are made of cellulose and fungi chitin.
- (50 & 51)

- Plant cell walls may have multiple layers
  - **Primary cell wall**: relatively thin and flexible
  - **Middle lamella**: thin layer between primary walls of adjacent cells
  - **Secondary cell wall** (in some cells): added between the plasma membrane and the primary cell wall
- Plasmodesmata are channels between adjacent plant cells
- (52, 53, & 54)

Figure 6.28

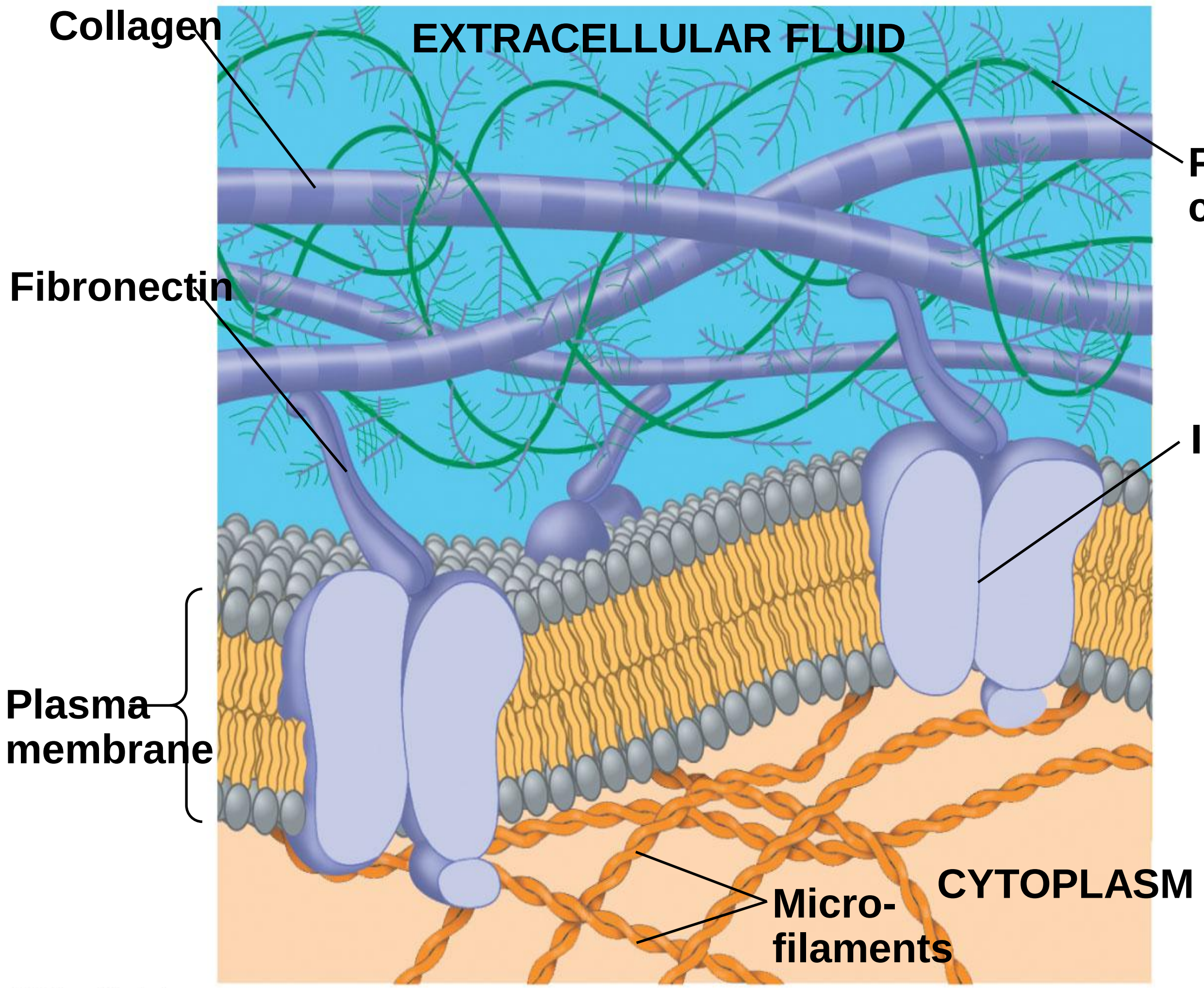
55



The Extracellular Matrix (ECM) of Animal Cells

- Animal cells lack cell walls but are covered by an elaborate **extracellular matrix (ECM)**
- The ECM is made up of glycoproteins such as **collagen**, **proteoglycans**, and **fibronectin**
- ECM proteins bind to receptor proteins in the plasma membrane called **integrins**

Figure 6.30a



- Functions of the ECM
  - Support
  - Adhesion
  - Movement
  - Regulation

Cell Junctions

- Neighboring cells in tissues, organs, or organ systems often adhere, interact, and communicate through direct physical contact
- Intercellular junctions facilitate this contact
- There are several types of intercellular junctions
  - Plasmodesmata
  - Tight junctions
  - Desmosomes
  - Gap junctions

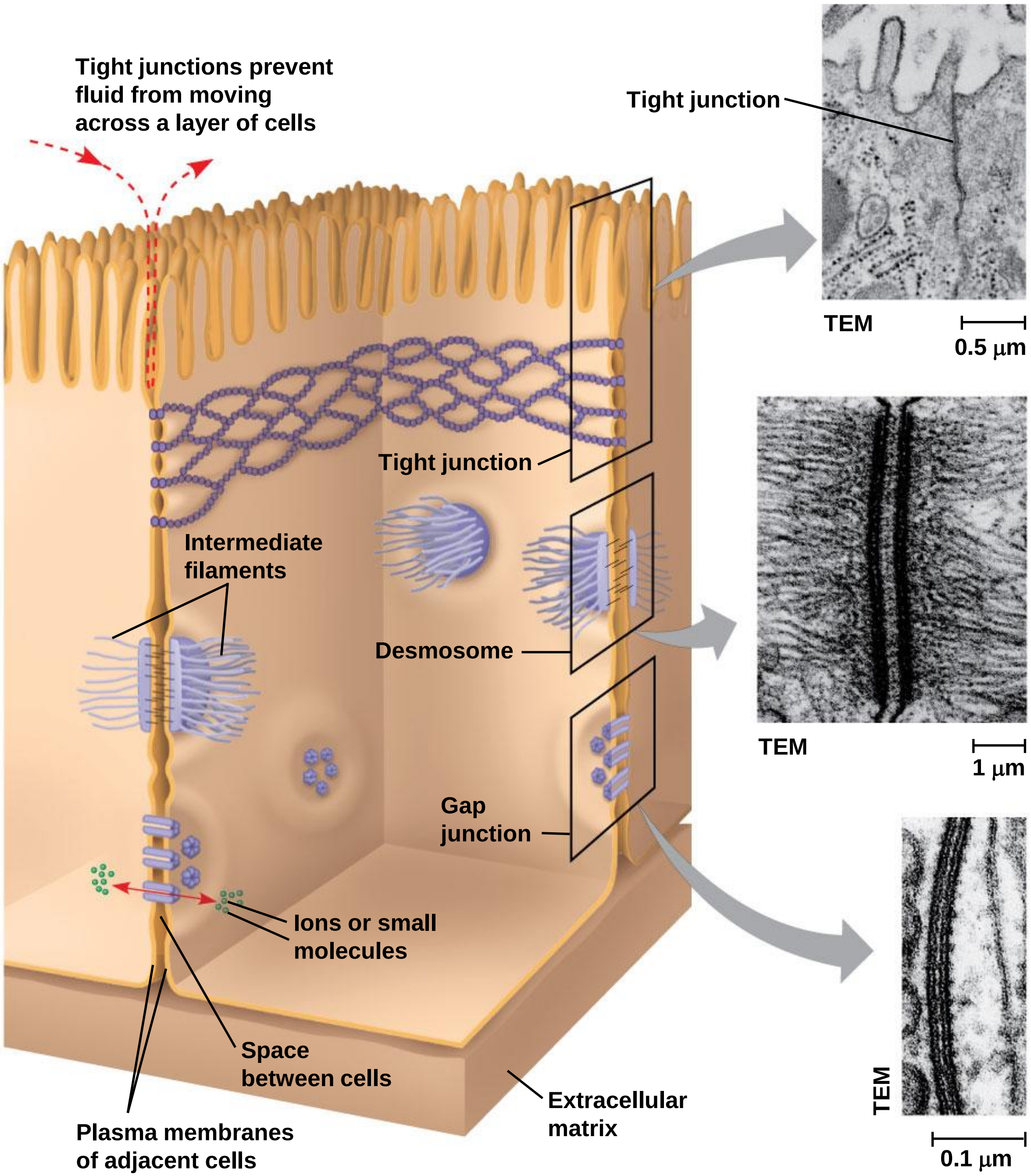
Plasmodesmata in Plant Cells

- **Plasmodesmata** are channels that perforate plant cell walls
- Through plasmodesmata, water and small solutes (and sometimes proteins and RNA) can pass from cell to cell (57)

Tight Junctions, Desmosomes, and Gap Junctions in Animal Cells

- At **tight junctions**, membranes of neighboring cells are pressed together, preventing leakage of extracellular fluid
- **Desmosomes** (anchoring junctions) fasten cells together into strong sheets
- **Gap junctions** (communicating junctions) provide cytoplasmic channels between adjacent cells
- (Next slide 58)

Figure 6.32


Tight junctions prevent fluid from moving across a layer of cells
Tight junction
TEM
0.5 µm
Tight junction
Intermediate filaments
Desmosome
TEM
1 µm
Gap junction
Ions or small molecules
Space between cells
Plasma membranes of adjacent cells
Extracellular matrix
TEM
0.1 µm