LECTURE PRESENTATIONS
For CAMPBELL BIOLOGY, NINTH EDITION
Jane B. Reece, Lisa A. Urry, Michael L. Cain, Steven A. Wasserman, Peter V. Minorsky, Robert B. Jackson

Chapter 6

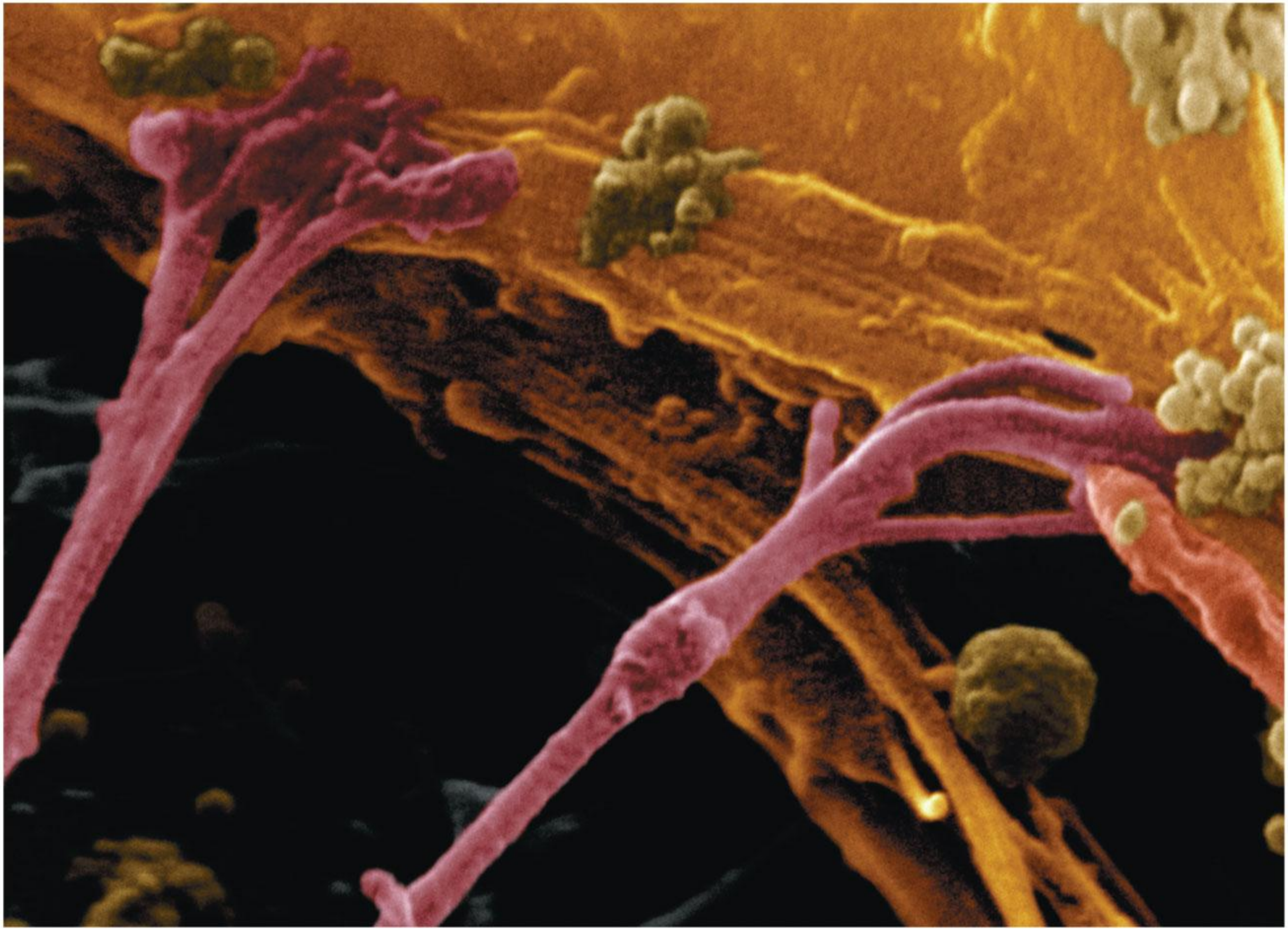
A Tour of the Cell

Lectures by
Erin Barley
Kathleen Fitzpatrick

Overview: The Fundamental Units of Life

- All organisms are made of cells
- The cell is the simplest collection of matter that can be alive
- Cell structure is correlated to cellular function
- All cells are related by their descent from earlier cells

Figure 6.1



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

Microscopy

- Scientists use microscopes to visualize cells too small to see with the naked eye
- 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 parts of the sample

Figure 6.2

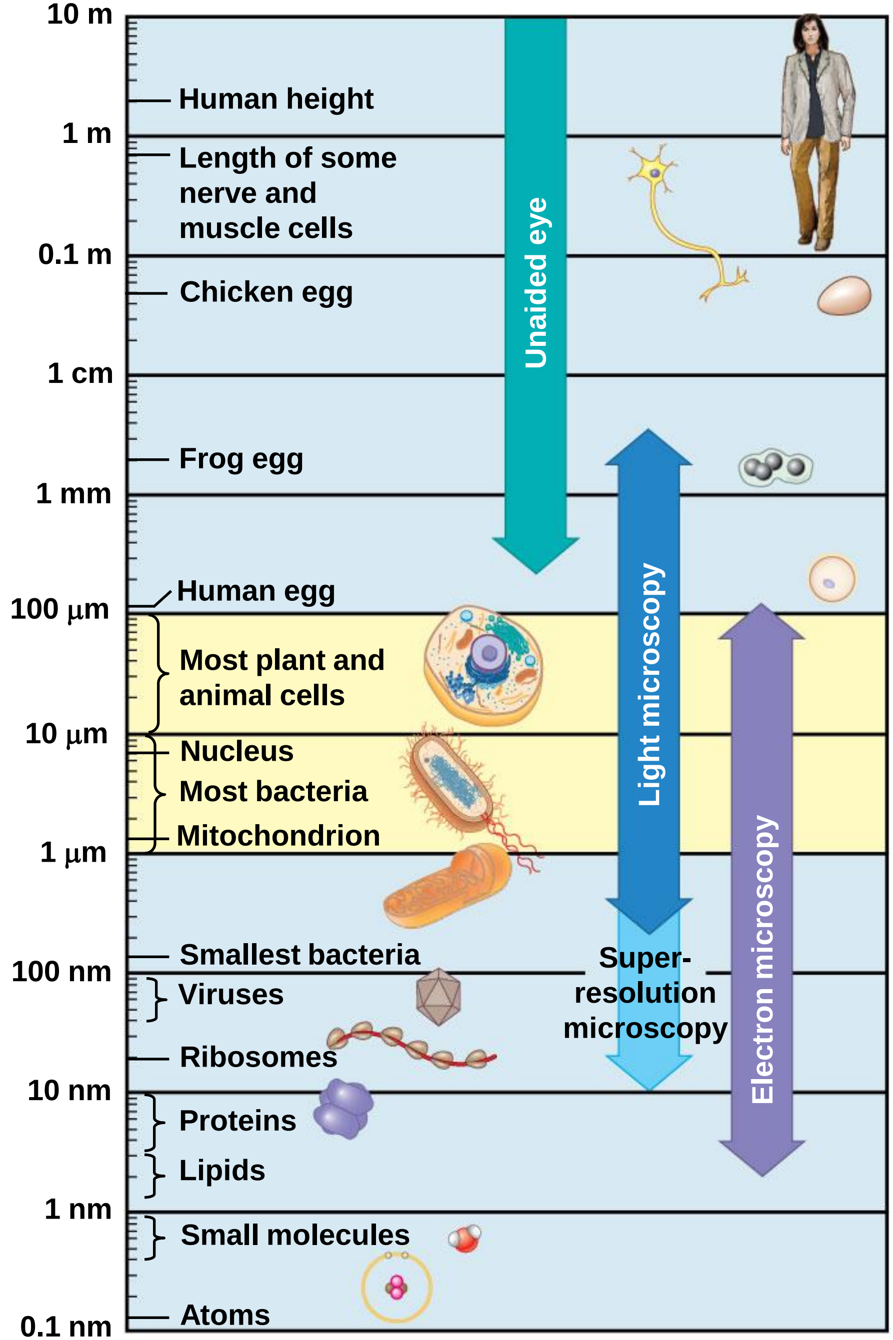

10 m
Human height
1 m
Length of some nerve and muscle cells
0.1 m
Chicken egg
1 cm
Frog egg
1 mm
Human egg
100 µm
Most plant and animal cells
10 µm
Nucleus
Most bacteria
Mitochondrion
1 µm
Smallest bacteria
100 nm
Viruses
Ribosomes
10 nm
Proteins
Lipids
1 nm
Small molecules
Atoms
0.1 nm
Unaided eye
Light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

Figure 6.2a

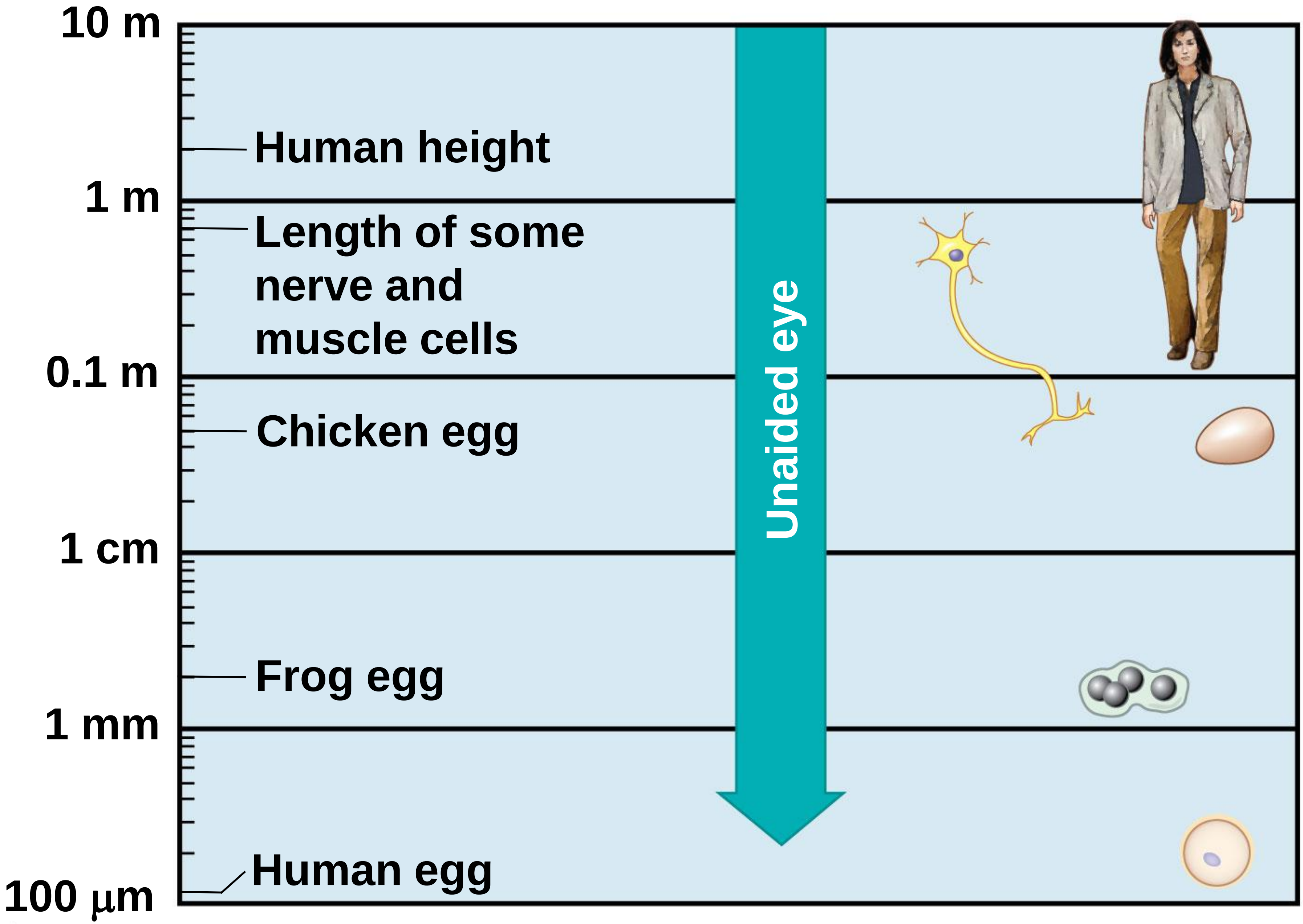

10 m
1 m
0.1 m
1 cm
1 mm
100 µm
Human height
Length of some
nerve and
muscle cells
Chicken egg
Frog egg
Human egg
Unaided eye

Figure 6.2b

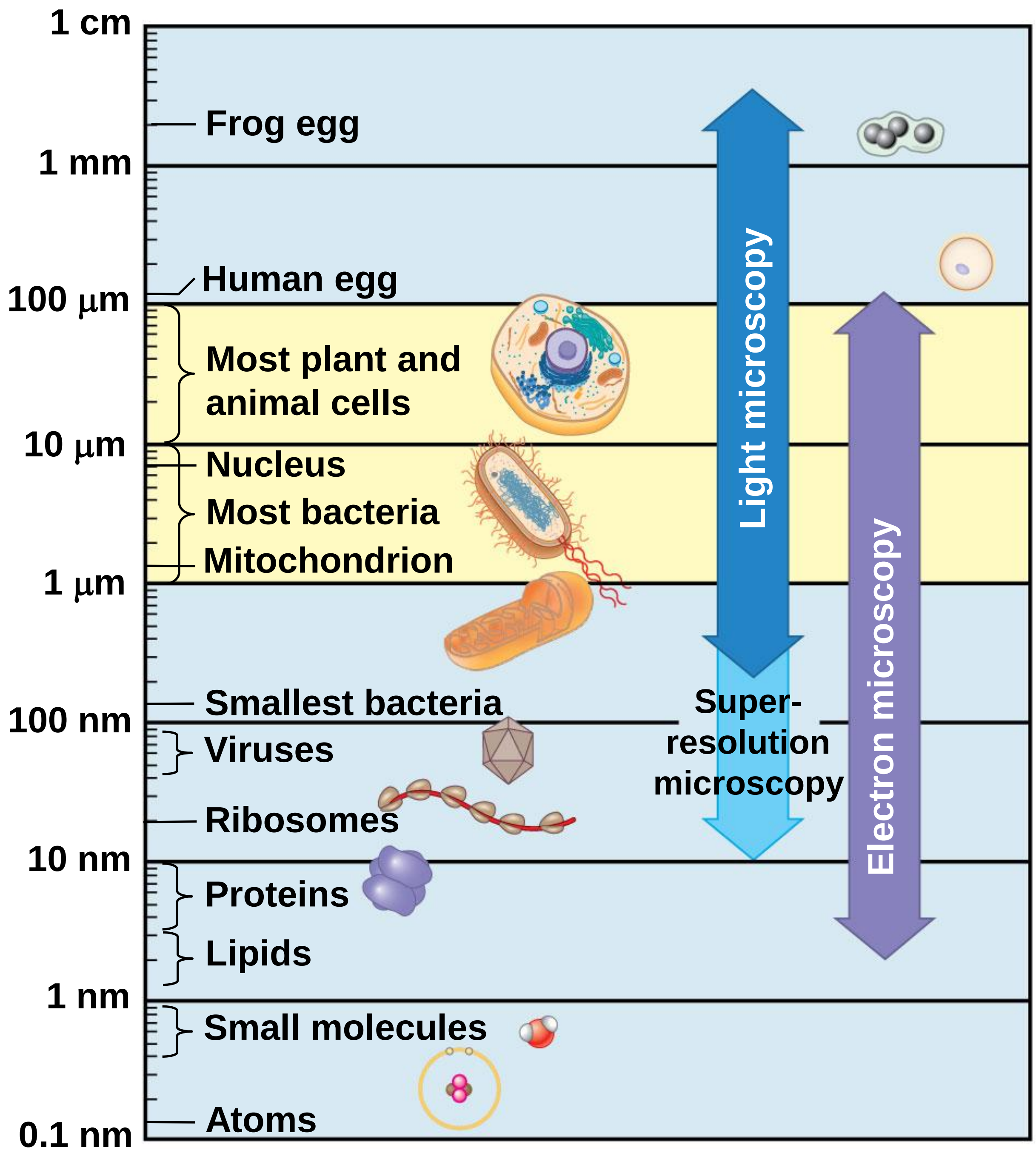
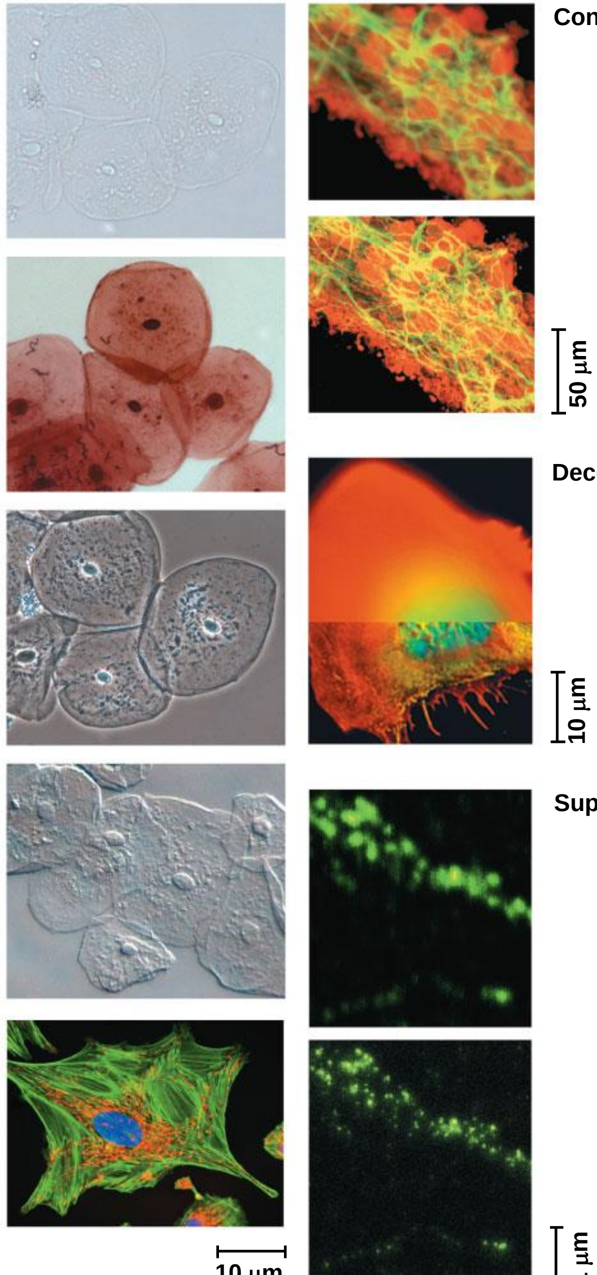

1 cm
Frog egg
1 mm
Human egg
100 µm
Most plant and animal cells
10 µm
Nucleus
Most bacteria
Mitochondrion
1 µm
Smallest bacteria
100 nm
Viruses
Ribosomes
10 nm
Proteins
Lipids
1 nm
Small molecules
Atoms
0.1 nm
Light microscopy
Super-resolution microscopy
Electron microscopy

Figure 6.3

Light Microscopy (LM)



Electron Microscopy (EM)

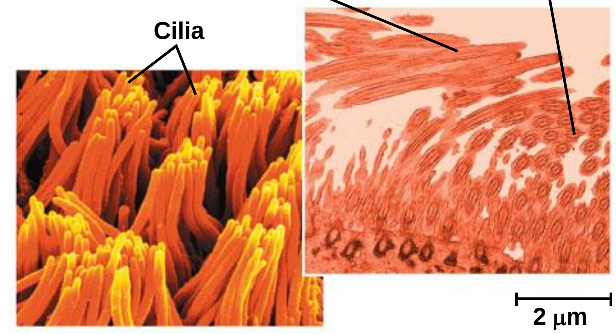


Figure 6.3a

Brightfield (unstained specimen)

50 µm

Figure 6.3b

Brightfield (stained specimen)

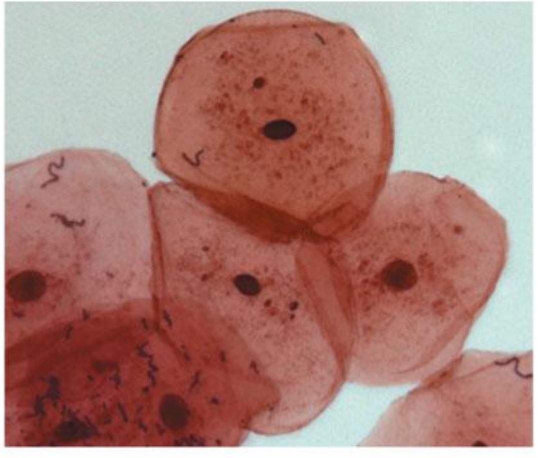


Figure 6.3c

Phase-contrast

Figure 6.3d

Differential-interference-contrast (Nomarski)

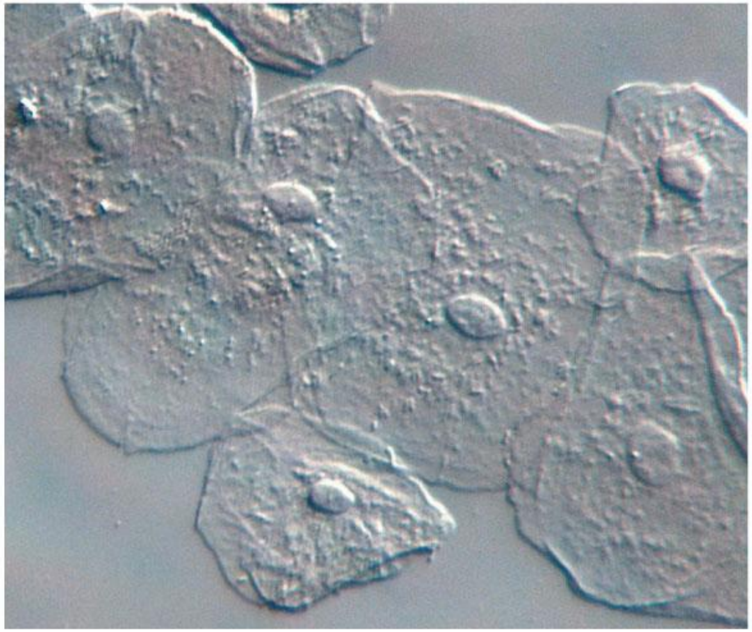


Figure 6.3e

Fluorescence

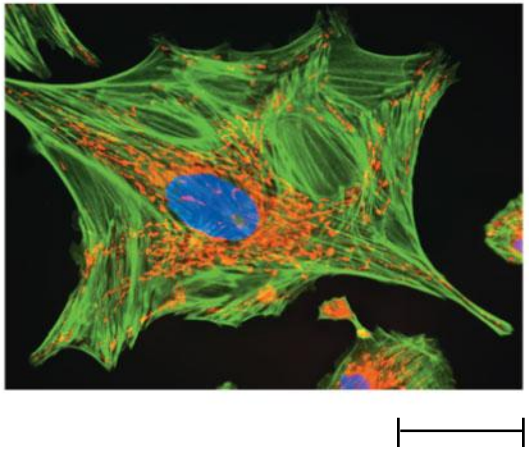


Figure 6.3f

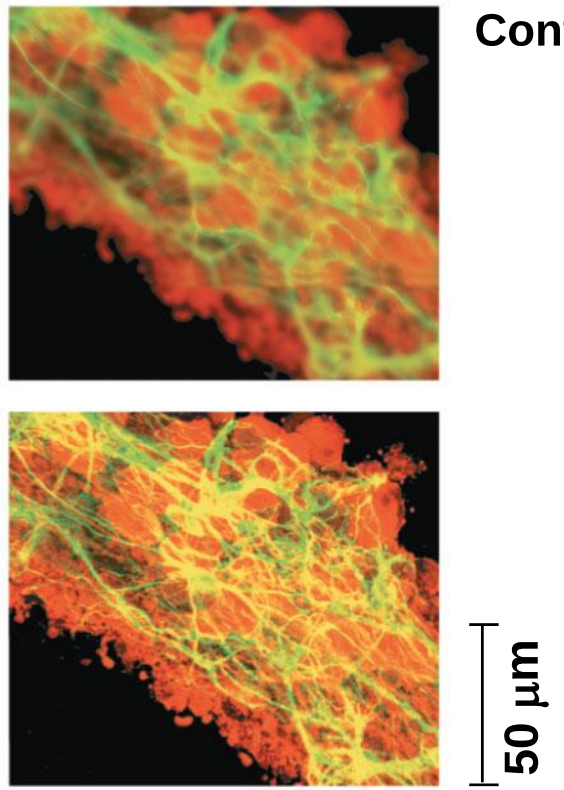


Figure 6.3fa

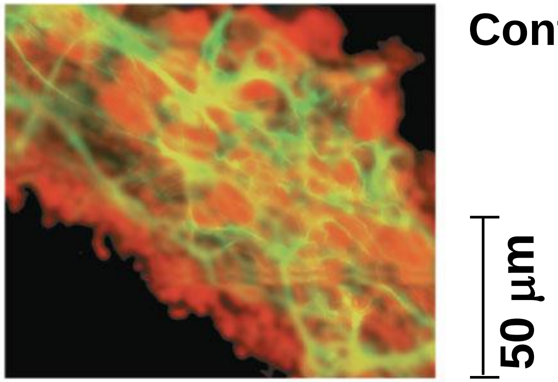
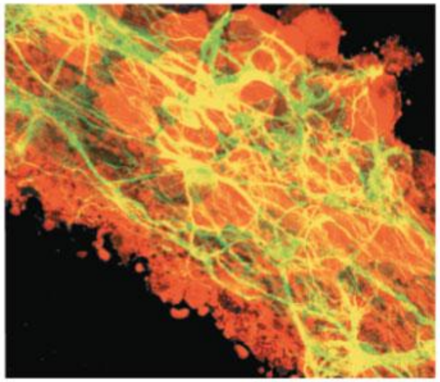


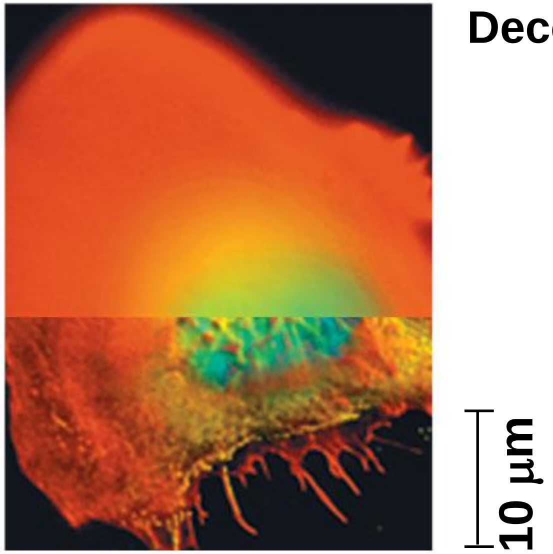
Figure 6.3fb



Confocal

50 µm

Figure 6.3g



Deconvolution

Figure 6.3h

Super-resolution

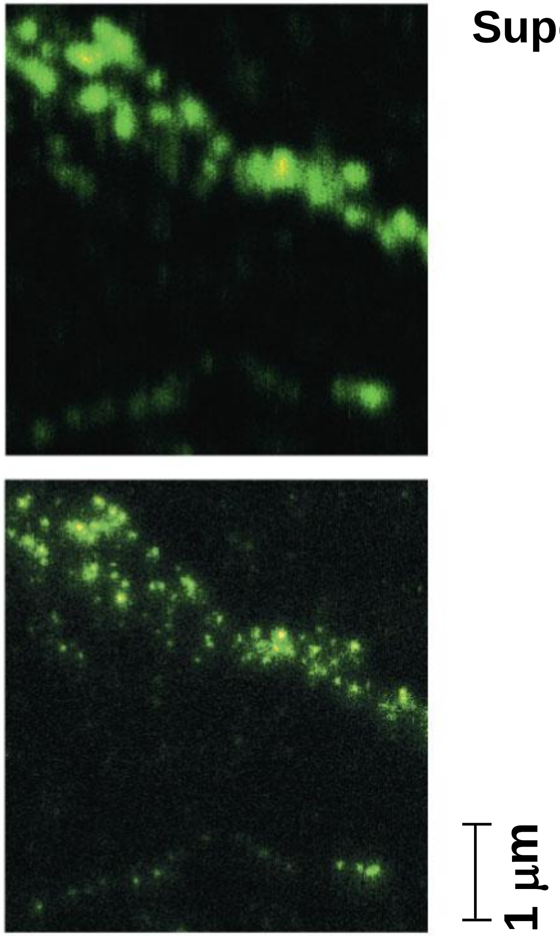
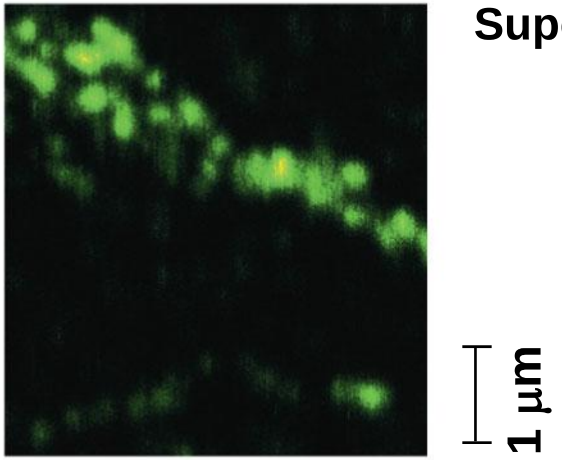
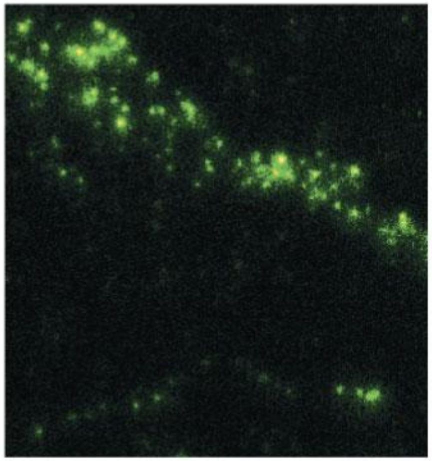


Figure 6.3ha



Super-resolution

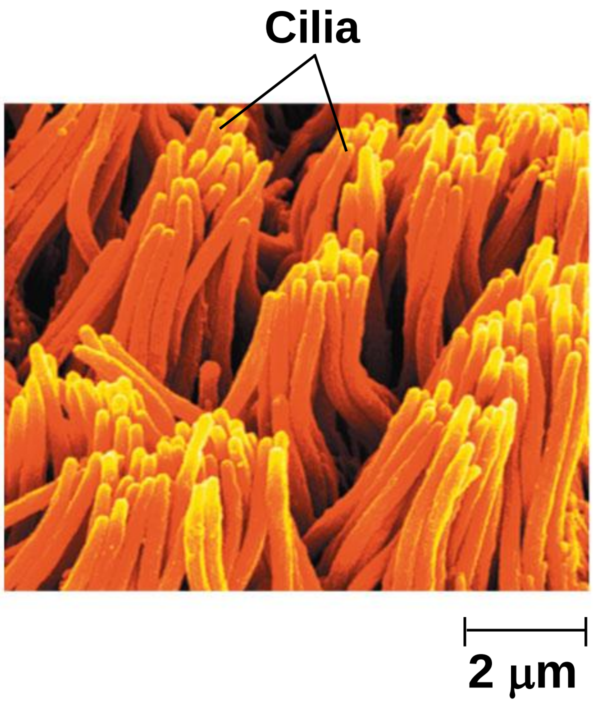
Figure 6.3hb



Super-resolution

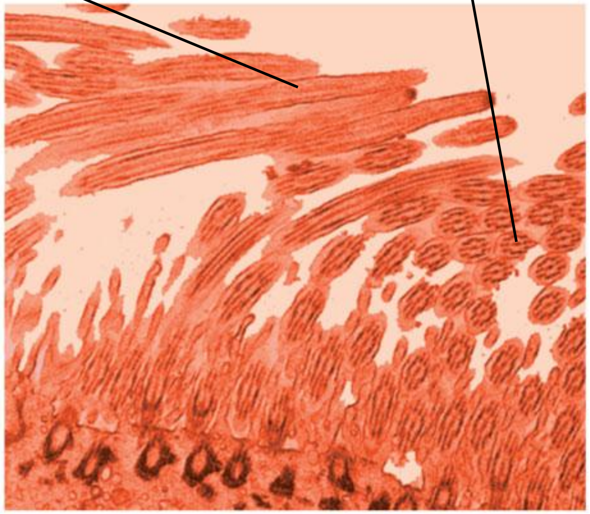
1 µm

Figure 6.3i



Scanning electron microscopy (SEM)

Figure 6.3j



Transmission electron microscopy (TEM)

- LMs 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
- Most subcellular structures, including **organelles** (membrane-enclosed compartments), are too small to be resolved by an LM

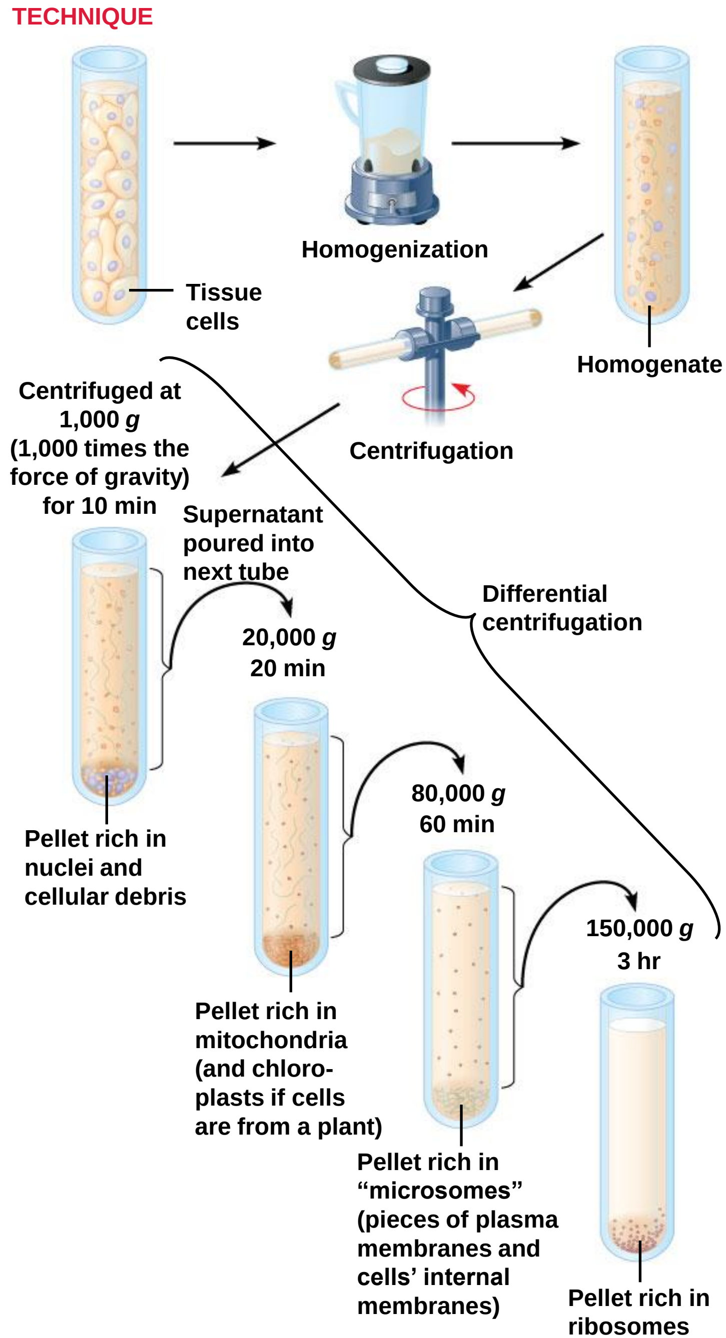
- Two basic types of **electron microscopes (EMs)** are used to study subcellular structures
- **Scanning electron microscopes (SEMs)** focus a beam of electrons onto the surface of a specimen, providing images that look 3-D
- **Transmission electron microscopes (TEMs)** focus a beam of electrons through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

- Recent advances in light microscopy
  - Confocal microscopy and deconvolution microscopy provide sharper images of three-dimensional tissues and cells
  - New techniques for labeling cells improve resolution

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



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

TECHNIQUE

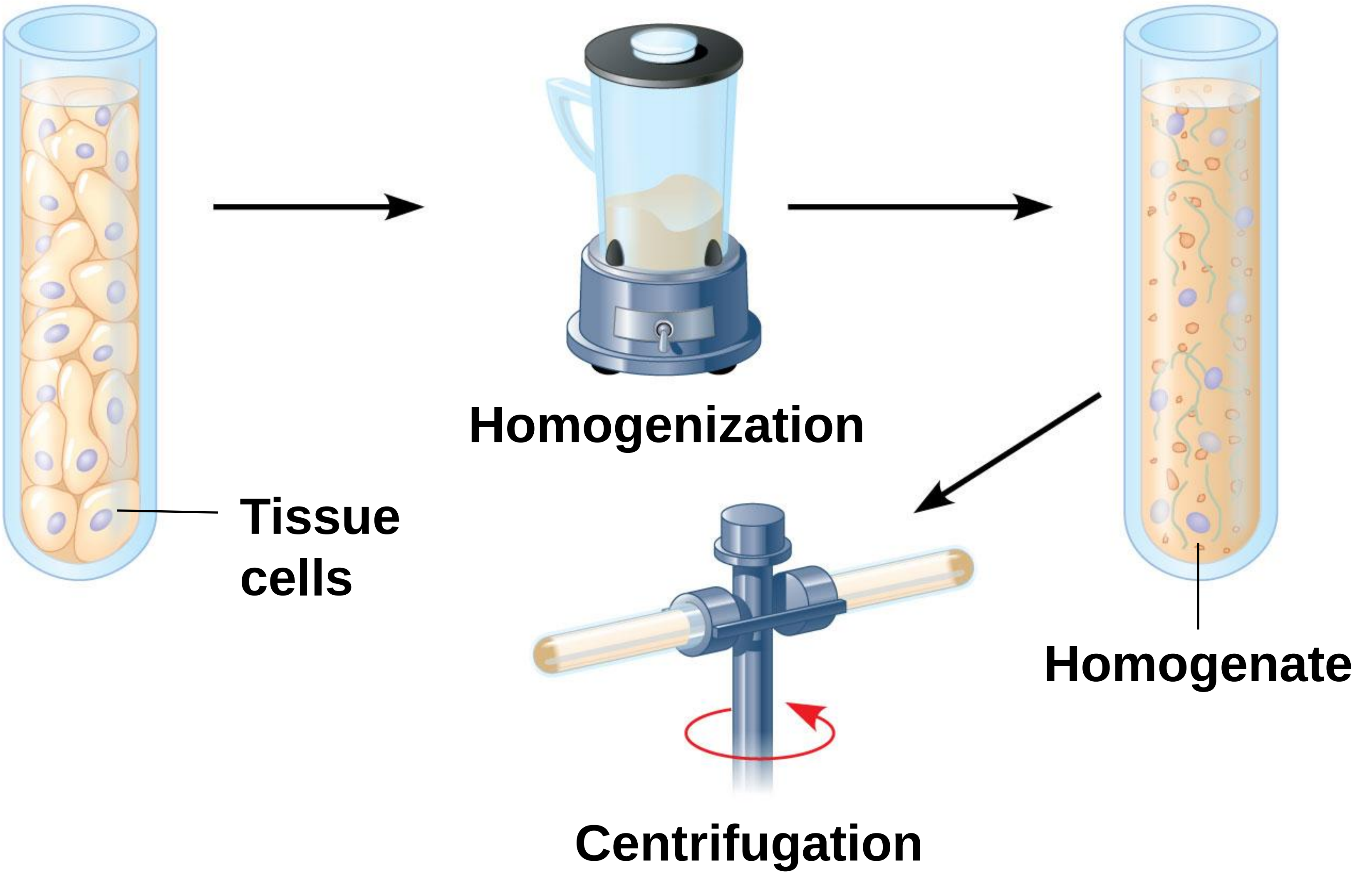
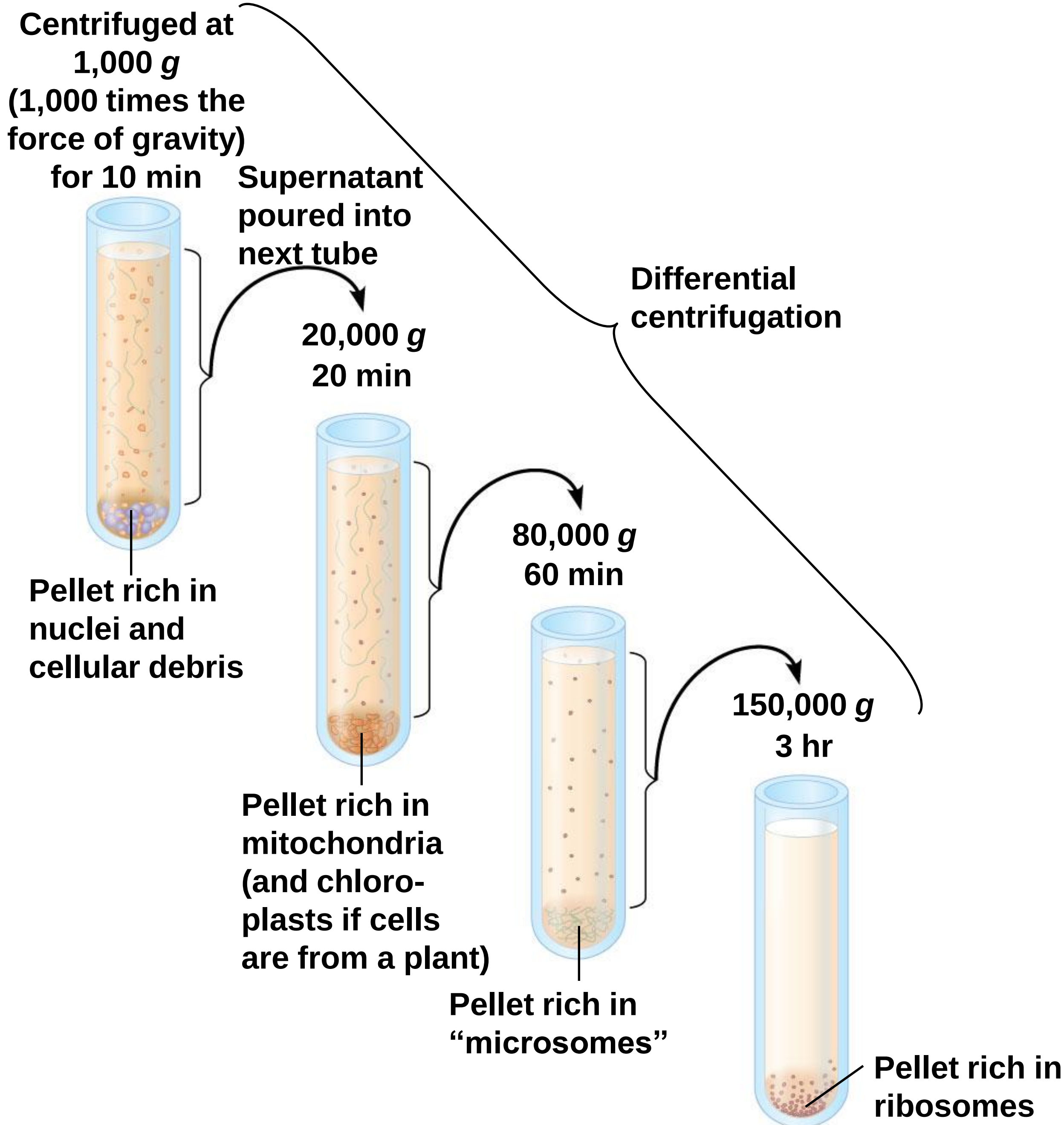


Figure 6.4b

TECHNIQUE (cont.)



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

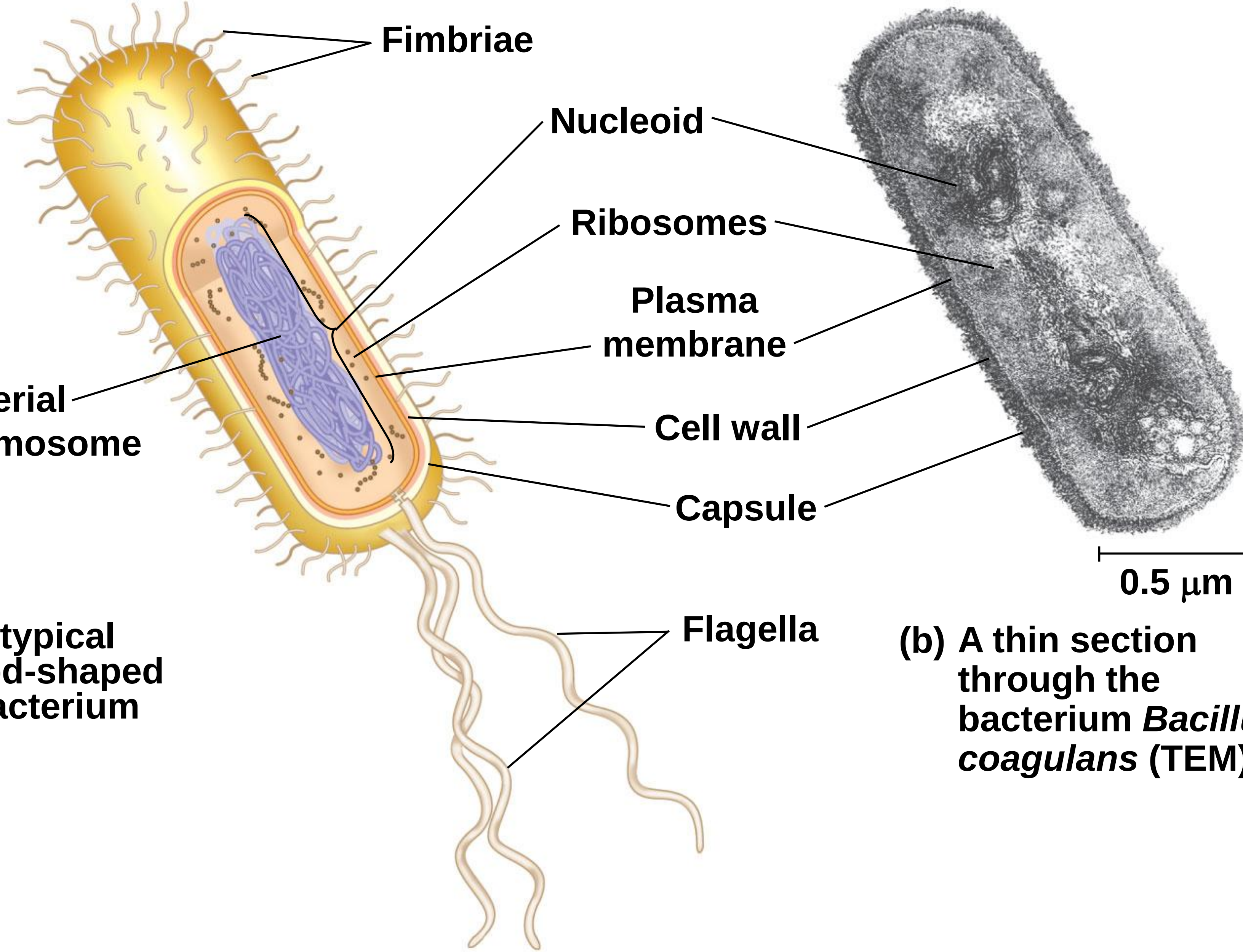
- The basic structural and functional unit of every organism is one of two types of cells: prokaryotic or eukaryotic
- Only organisms of the domains Bacteria and Archaea consist of prokaryotic cells
- Protists, fungi, animals, and plants all consist of eukaryotic cells

Comparing Prokaryotic and Eukaryotic Cells

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

- **Prokaryotic cells** are characterized by having
  - No nucleus
  - DNA in an unbound region called the **nucleoid**
  - No membrane-bound organelles
  - **Cytoplasm** bound by the plasma membrane

Figure 6.5



(a) A typical rod-shaped bacterium

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

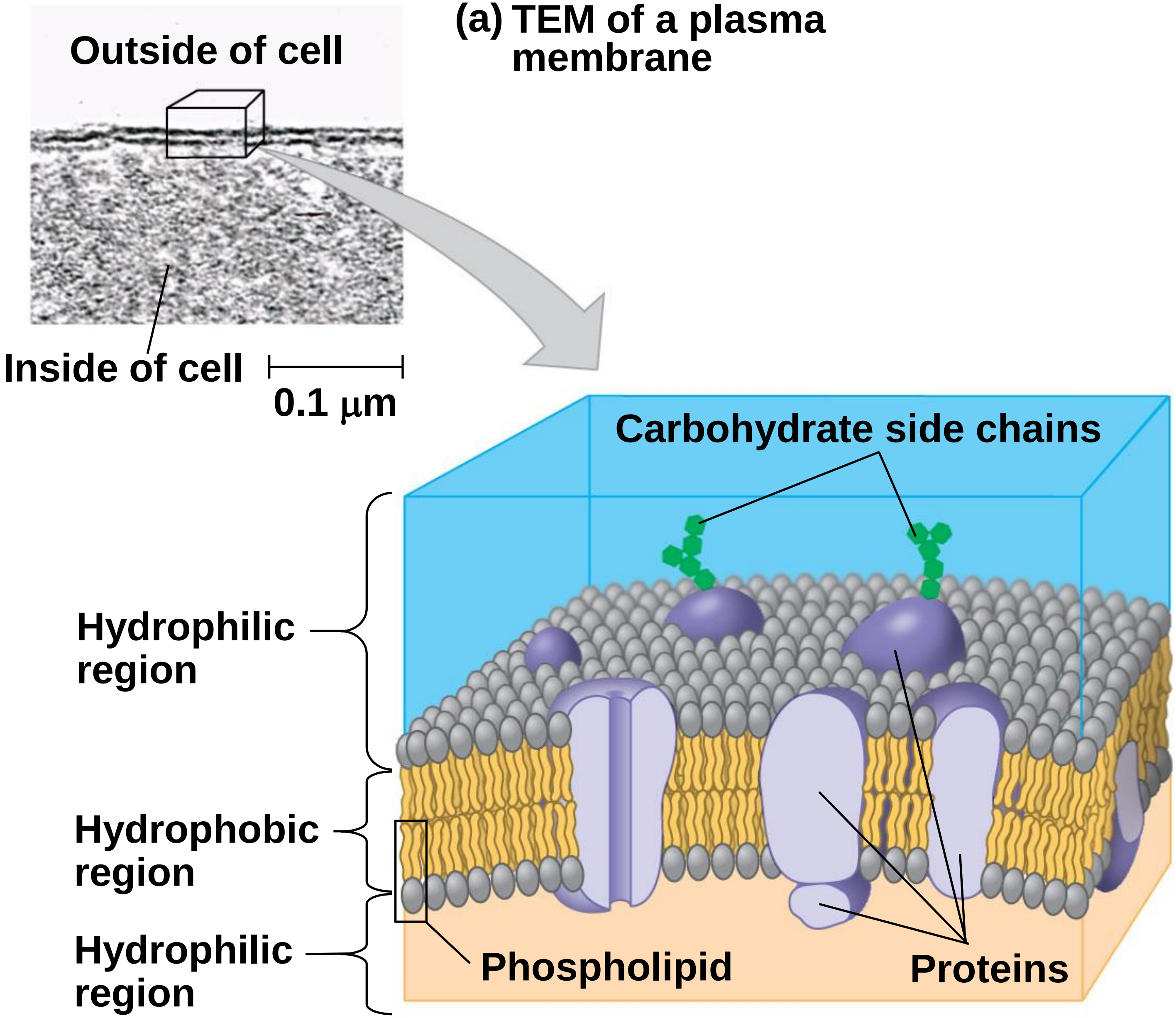
Figure 6.5a

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

- **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

- The **plasma membrane** is a selective barrier that allows sufficient passage of oxygen, nutrients, and waste to service the volume of every cell
- The general structure of a biological membrane is a double layer of phospholipids

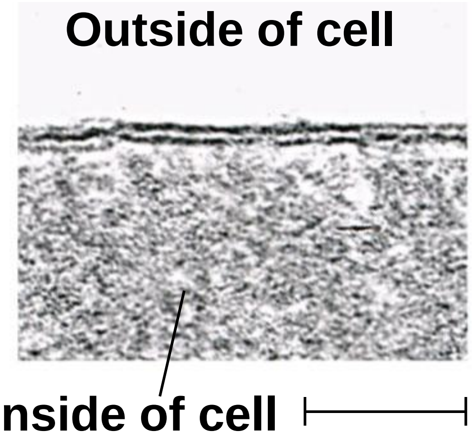
Figure 6.6



(a) TEM of a plasma membrane

(b) Structure of the plasma membrane

Figure 6.6a

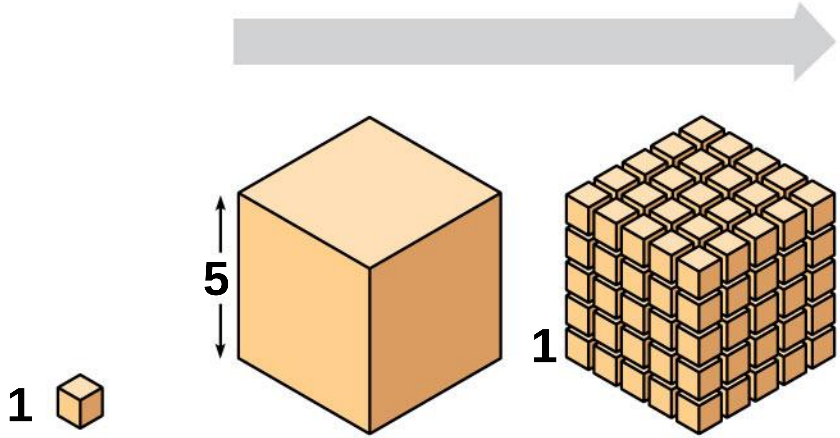


(a) TEM of a plasma membrane

- 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

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

Figure 6.8a

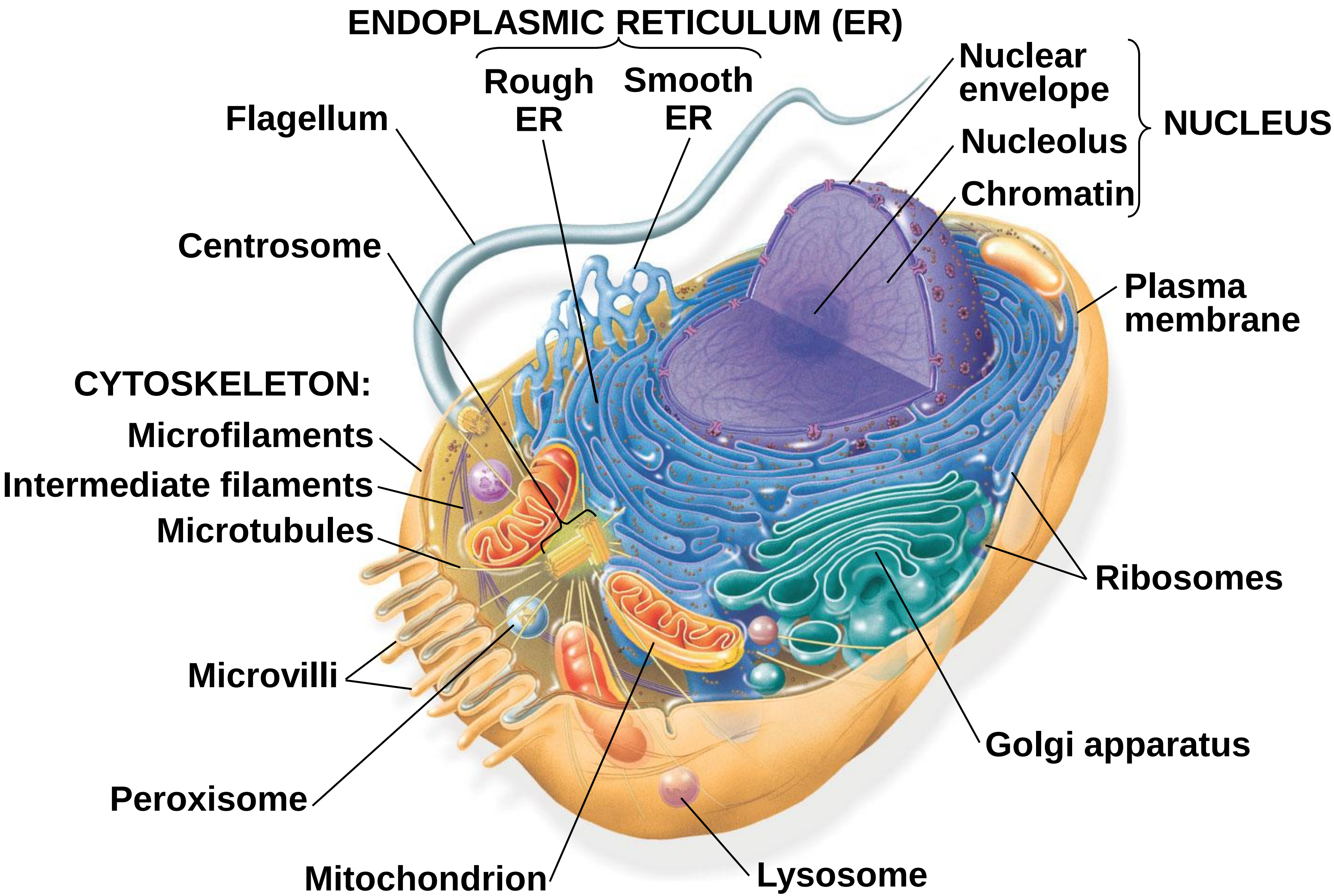
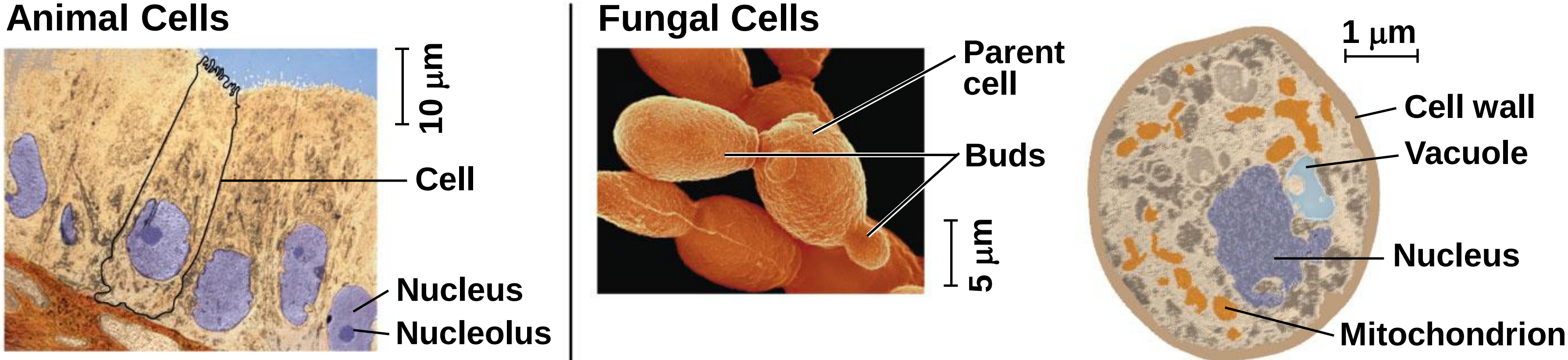

ENDOPLASMIC RETICULUM (ER)
Rough ER
Smooth ER
Flagellum
Nuclear envelope
Nucleolus
Chromatin
NUCLEUS
Centrosome
Plasma membrane
CYTOSKELETON:
Microfilaments
Intermediate filaments
Microtubules
Ribosomes
Microvilli
Golgi apparatus
Peroxisome
Mitochondrion
Lysosome

Figure 6.8b

Animal Cells

Fungal Cells



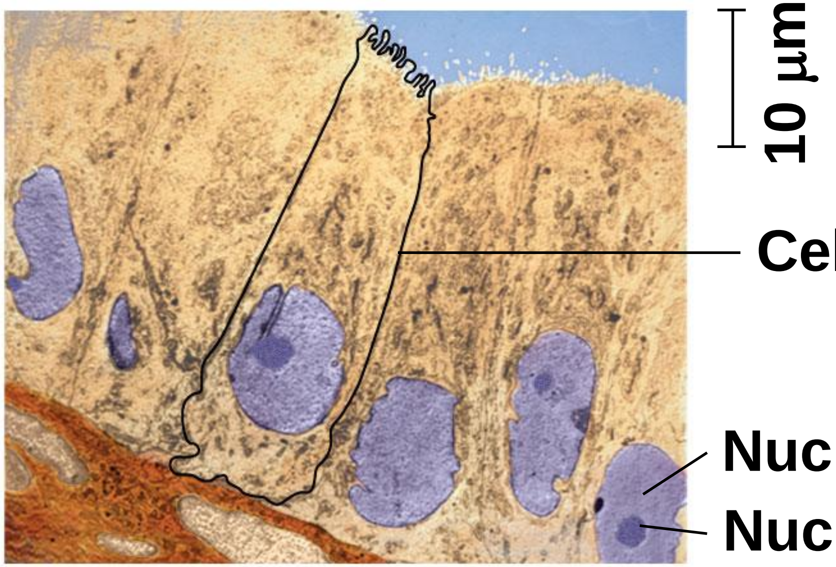
Human cells from lining of uterus (colorized TEM)

Yeast cells budding (colorized SEM)

A single yeast cell (colorized TEM)

Figure 6.8ba

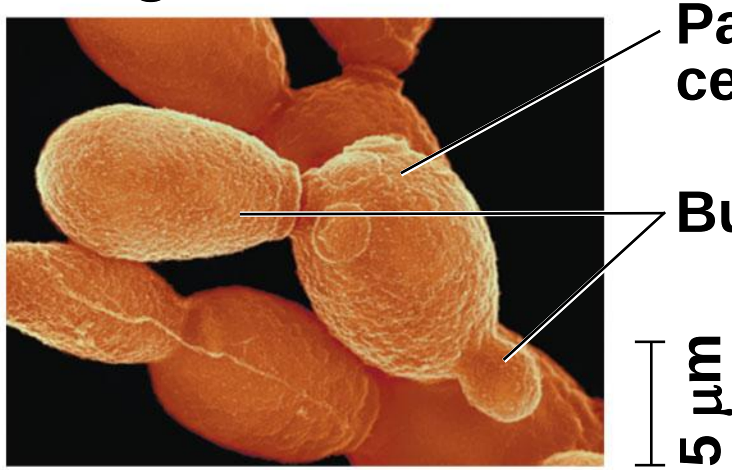
Animal Cells



Human cells from lining of uterus (colorized TEM)

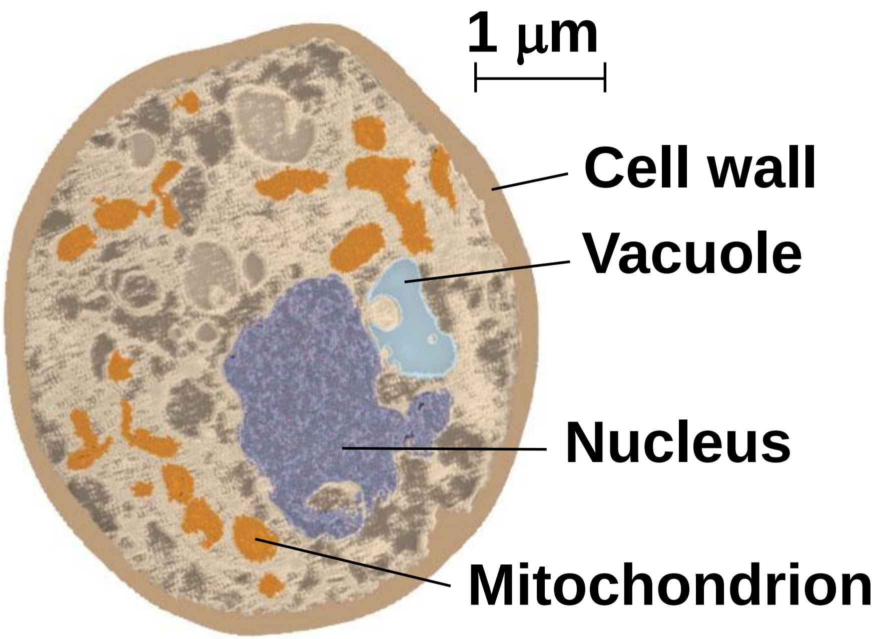
Figure 6.8bb

Fungal Cells



Yeast cells budding (colorized SEM)

Figure 6.8bc



A single yeast cell (colorized TEM)

Figure 6.8c

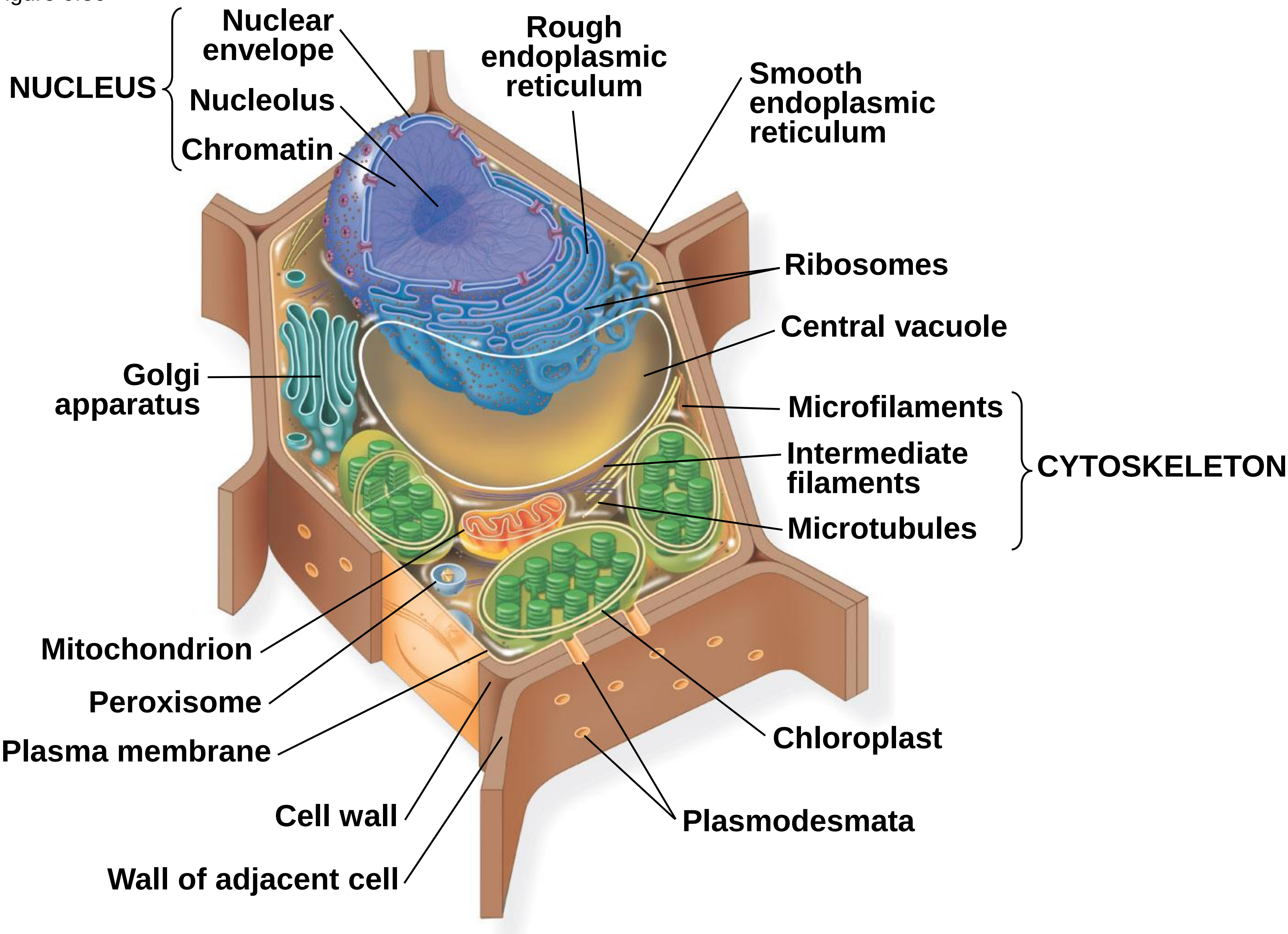
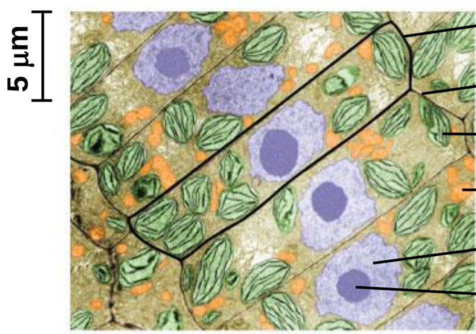

NUCLEUS
Nuclear envelope
Nucleolus
Chromatin
Rough endoplasmic reticulum
Smooth endoplasmic reticulum
Ribosomes
Central vacuole
Golgi apparatus
Microfilaments
Intermediate filaments
Microtubules
CYTOSKELETON
Mitochondrion
Peroxisome
Plasma membrane
Cell wall
Wall of adjacent cell
Chloroplast
Plasmodesmata

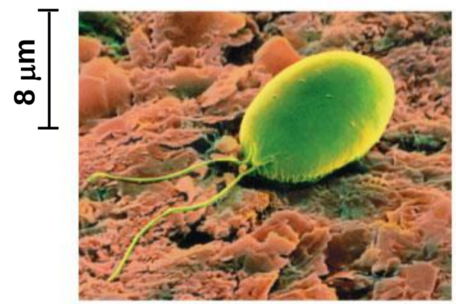
Figure 6.8d

Plant Cells

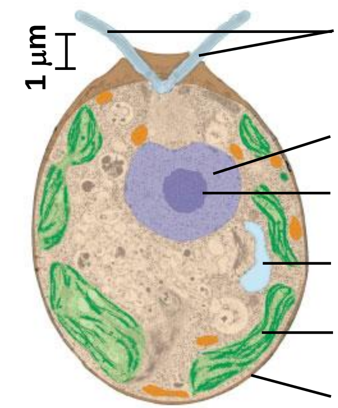


Cells from duckweed (colorized TEM)

Protistan Cells



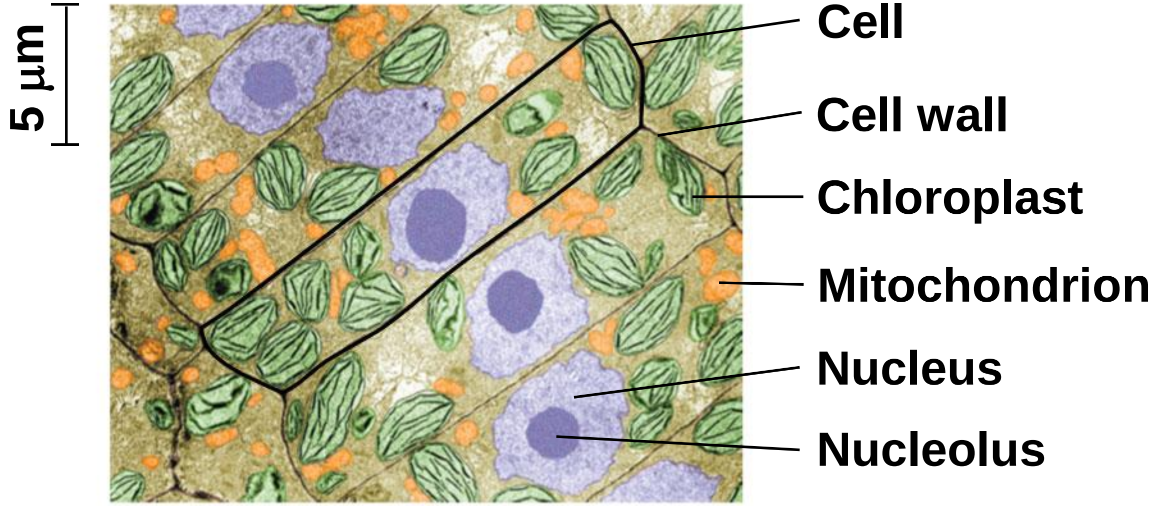
Chlamydomonas **(colorized SEM)**



Chlamydomonas **(colorized TEM)**

Figure 6.8da

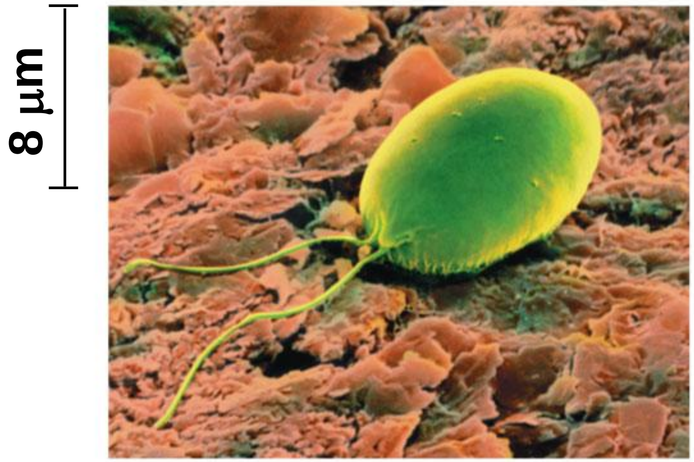
Plant Cells



Cells from duckweed (colorized TEM)

Figure 6.8db

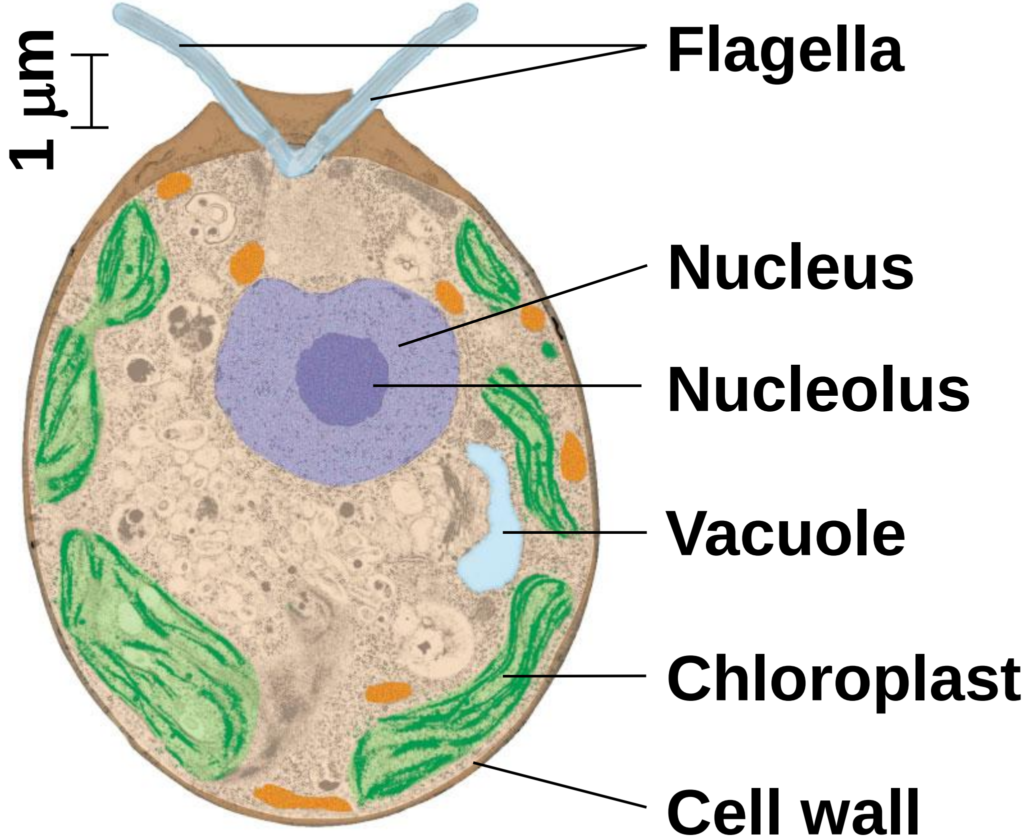
Protistan Cells



***Chlamydomonas* (colorized SEM)**

Figure 6.8dc

Protistan Cells



Chlamydomonas
(colorized TEM)

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

The Nucleus: Information Central

- The **nucleus** contains most of the cell's genes and is usually the most conspicuous organelle
- The **nuclear envelope** encloses the nucleus, separating it from the cytoplasm
- The nuclear membrane is a double membrane; each membrane consists of a lipid bilayer

Figure 6.9

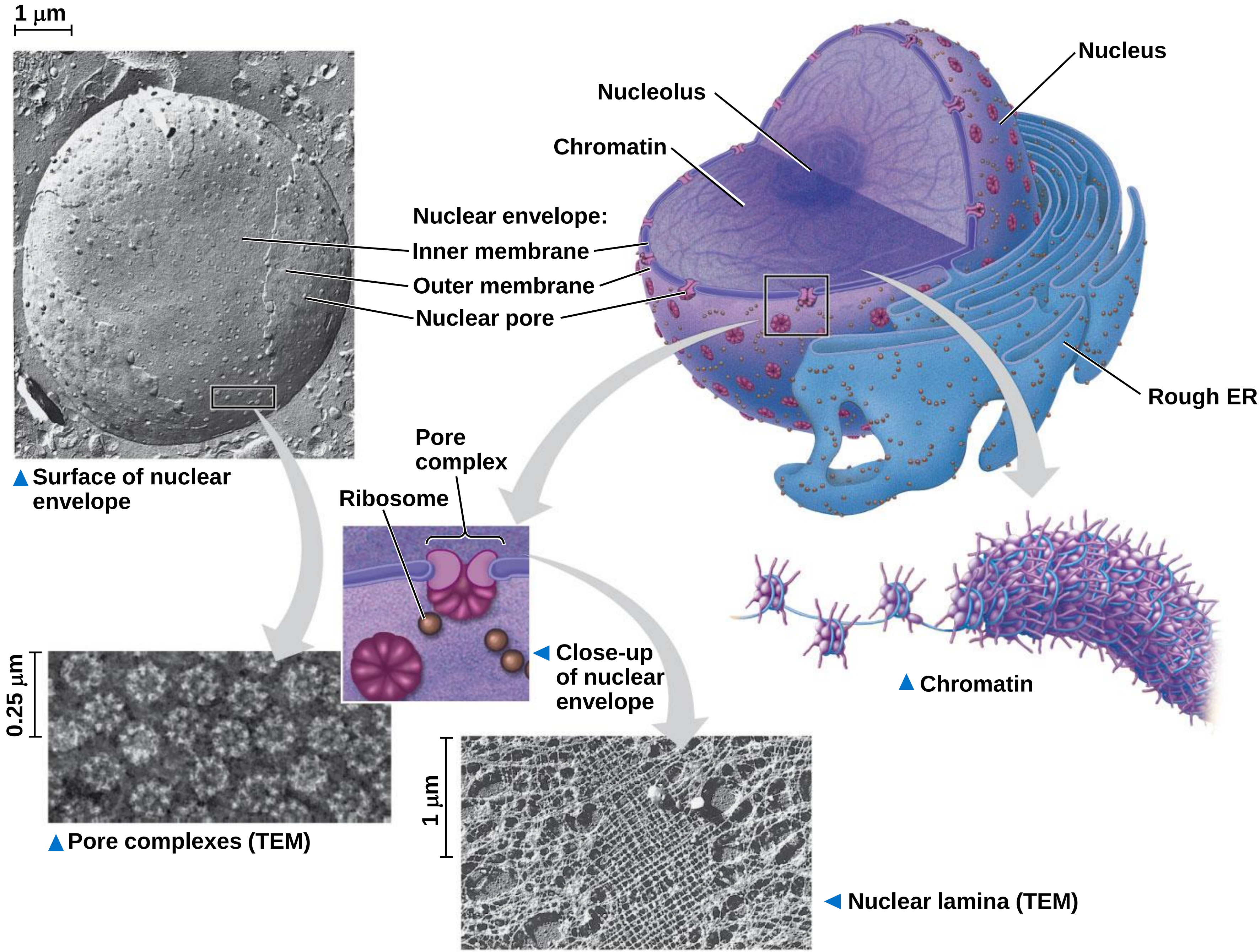
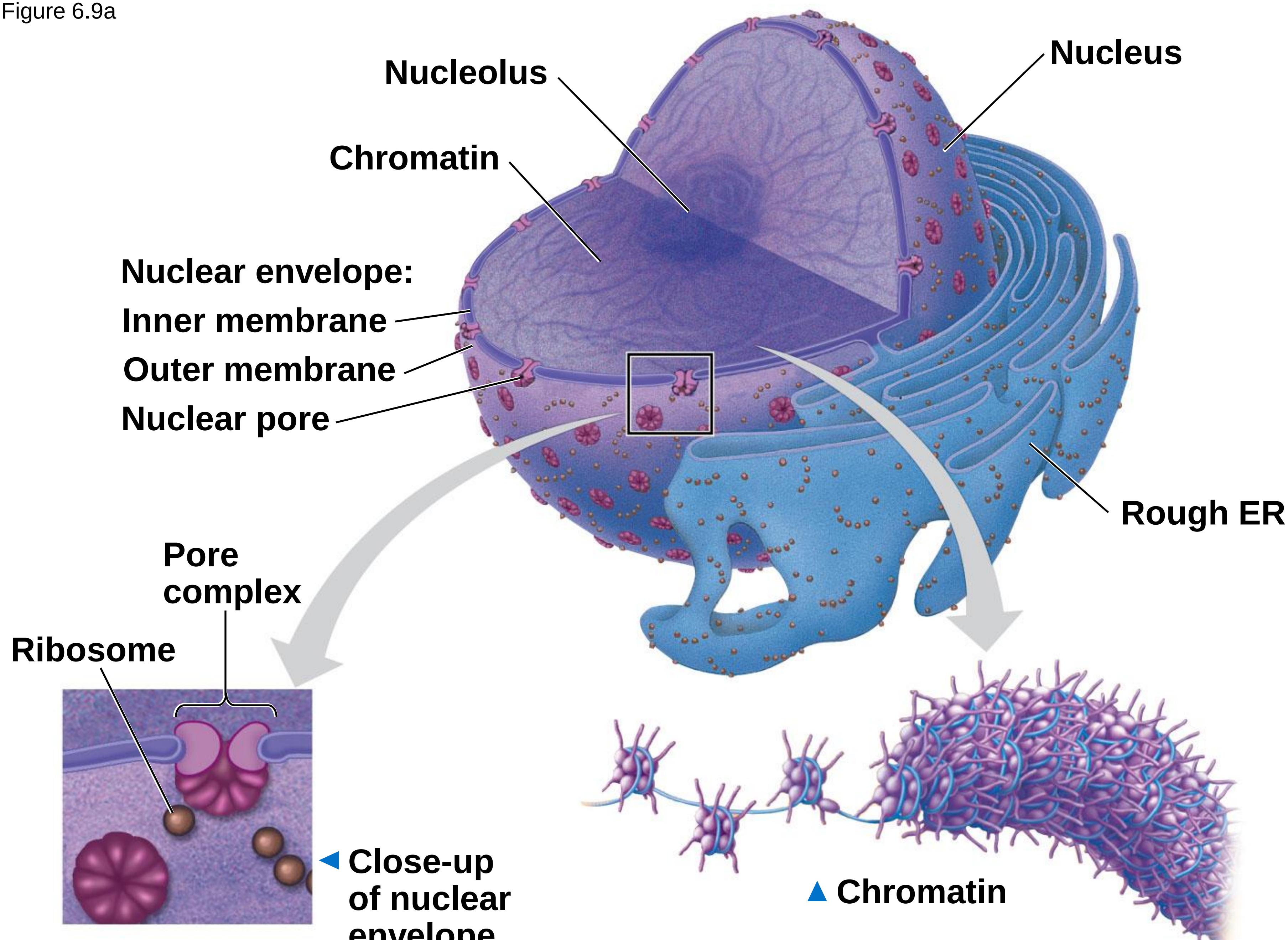

1 µm
Nucleus
Nucleolus
Chromatin
Nuclear envelope:
Inner membrane
Outer membrane
Nuclear pore
Rough ER
Surface of nuclear envelope
Pore complex
Ribosome
Close-up of nuclear envelope
Chromatin
0.25 µm
Pore complexes (TEM)
1 µm
Nuclear lamina (TEM)

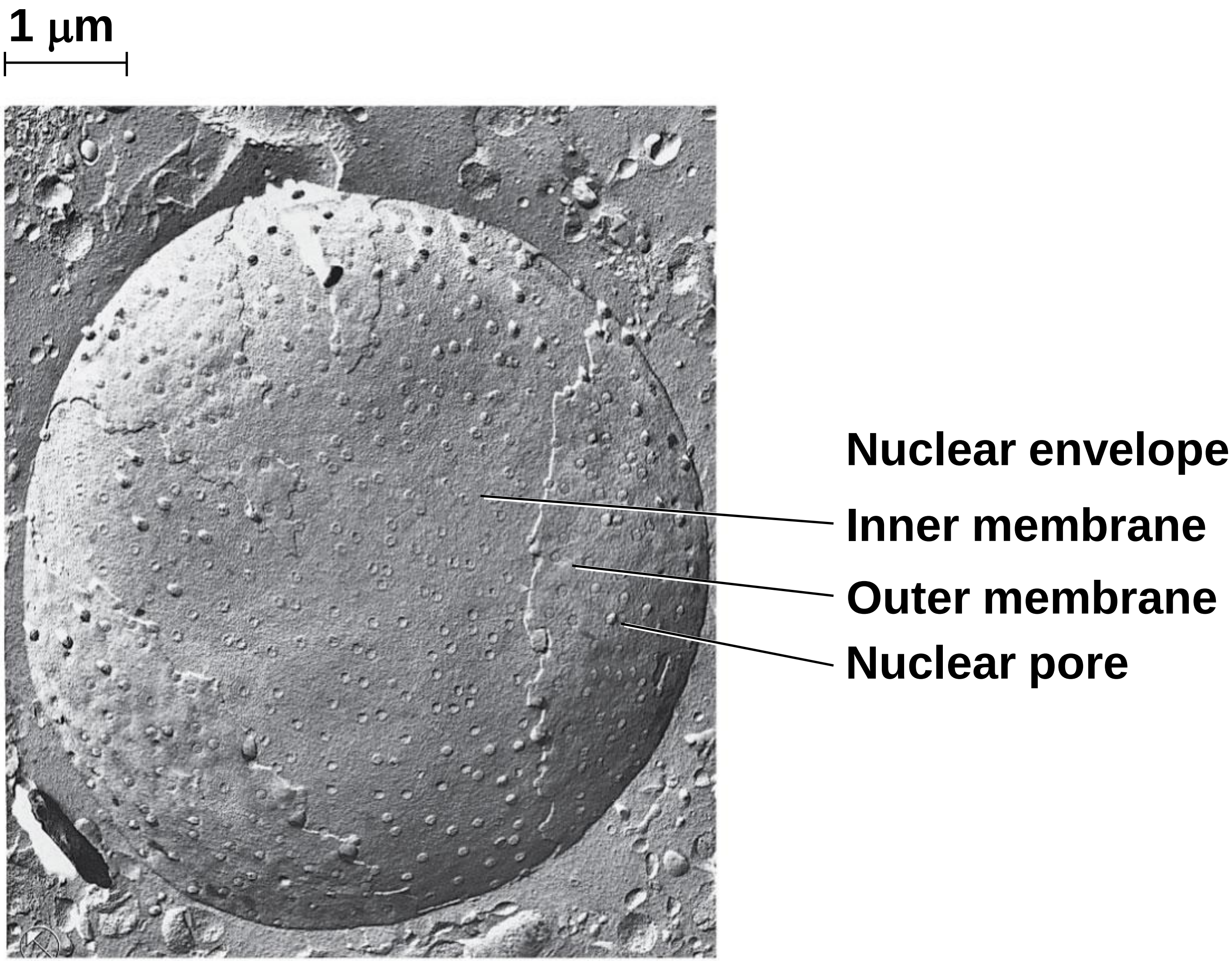
Figure 6.9a



◄ Close-up of nuclear envelope

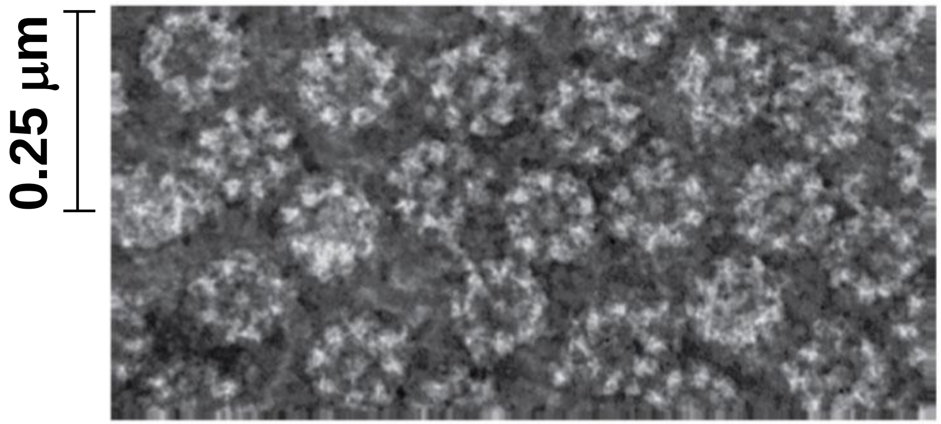
▲ Chromatin

Figure 6.9b



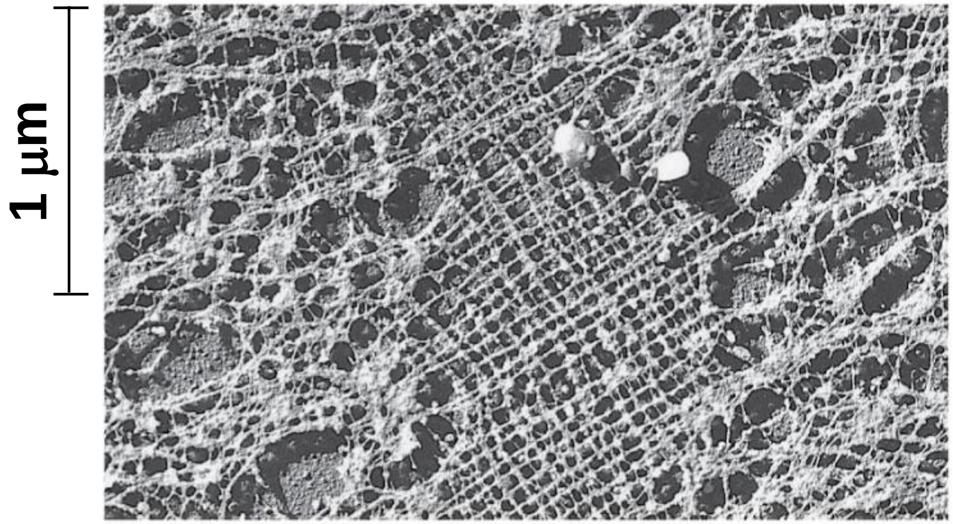
▲ **Surface of nuclear envelope**

Figure 6.9c



▲ **Pore complexes (TEM)**

Figure 6.9d



Nuclear lamina (TEM)

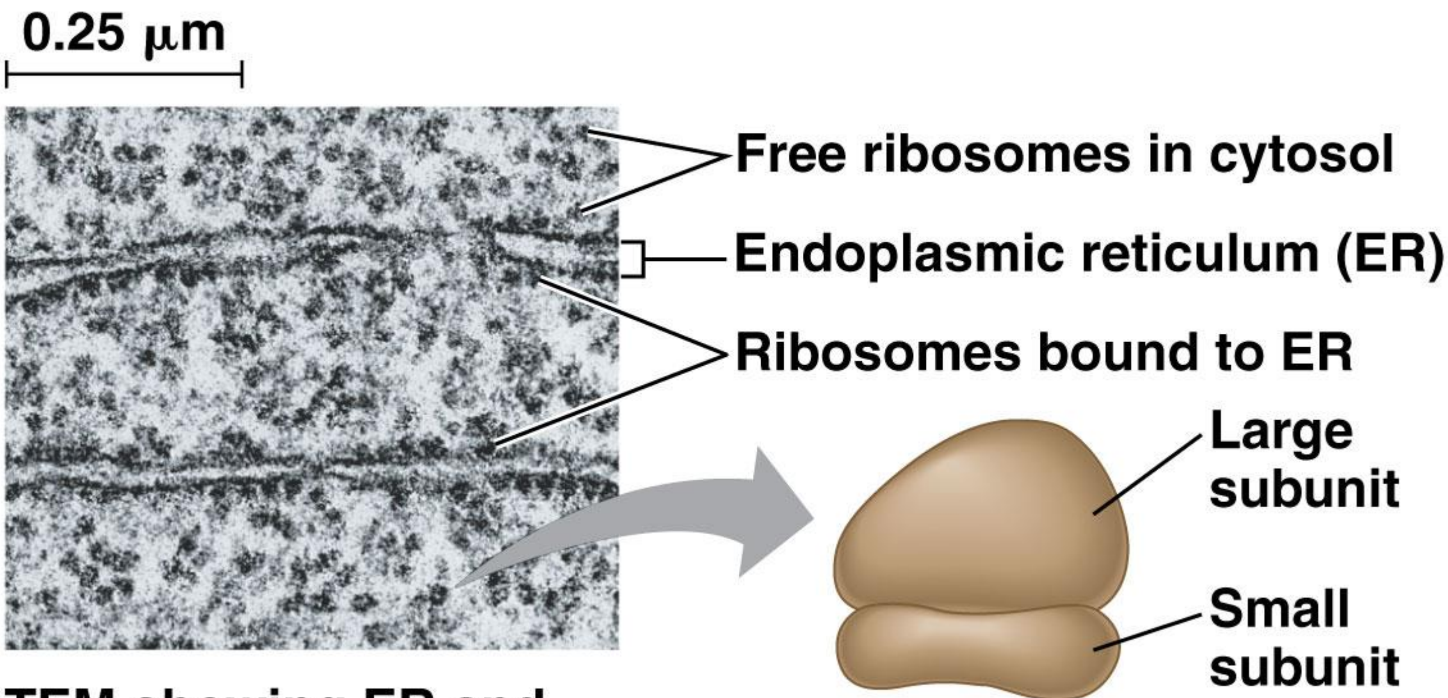
- Pores regulate the entry and exit of molecules from the nucleus
- The shape of the nucleus is maintained by the **nuclear lamina**, which is composed of protein

- 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

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)
  - On the outside of the endoplasmic reticulum or the nuclear envelope (bound ribosomes)

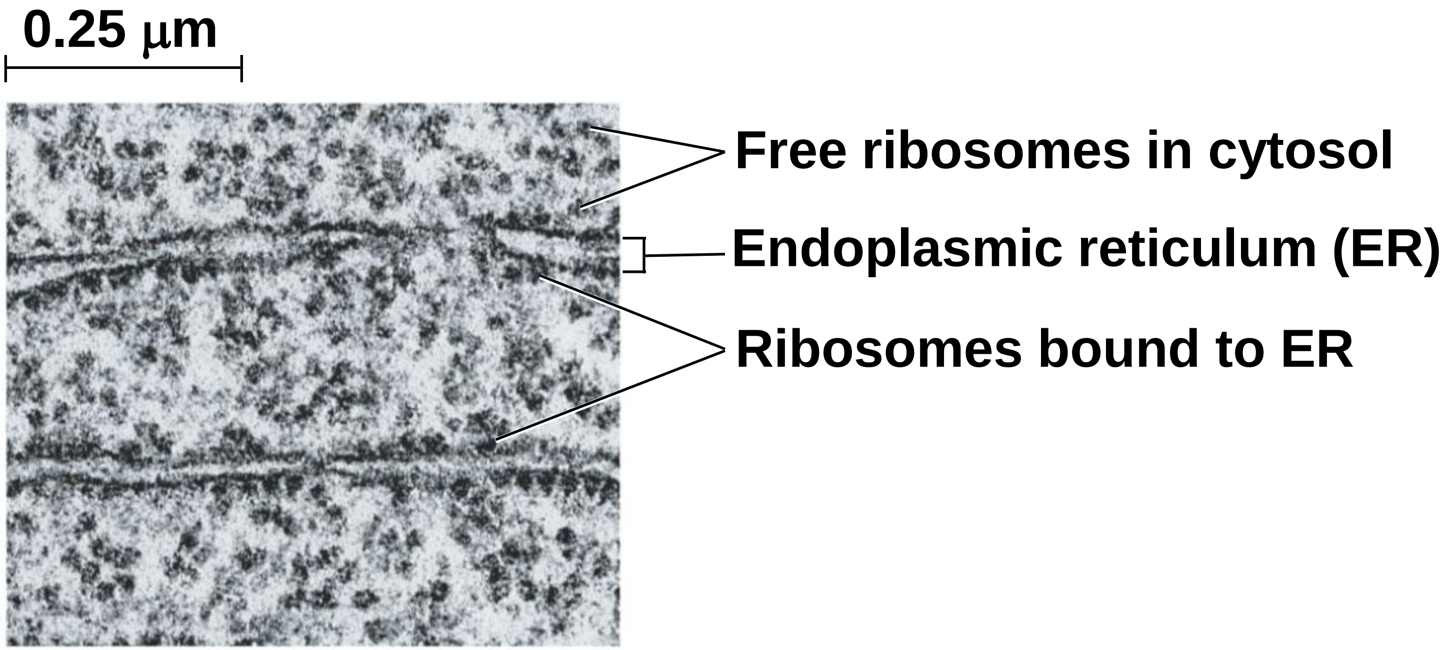
Figure 6.10



TEM showing ER and ribosomes

Diagram of a ribosome

Figure 6.10a



TEM showing ER and ribosomes

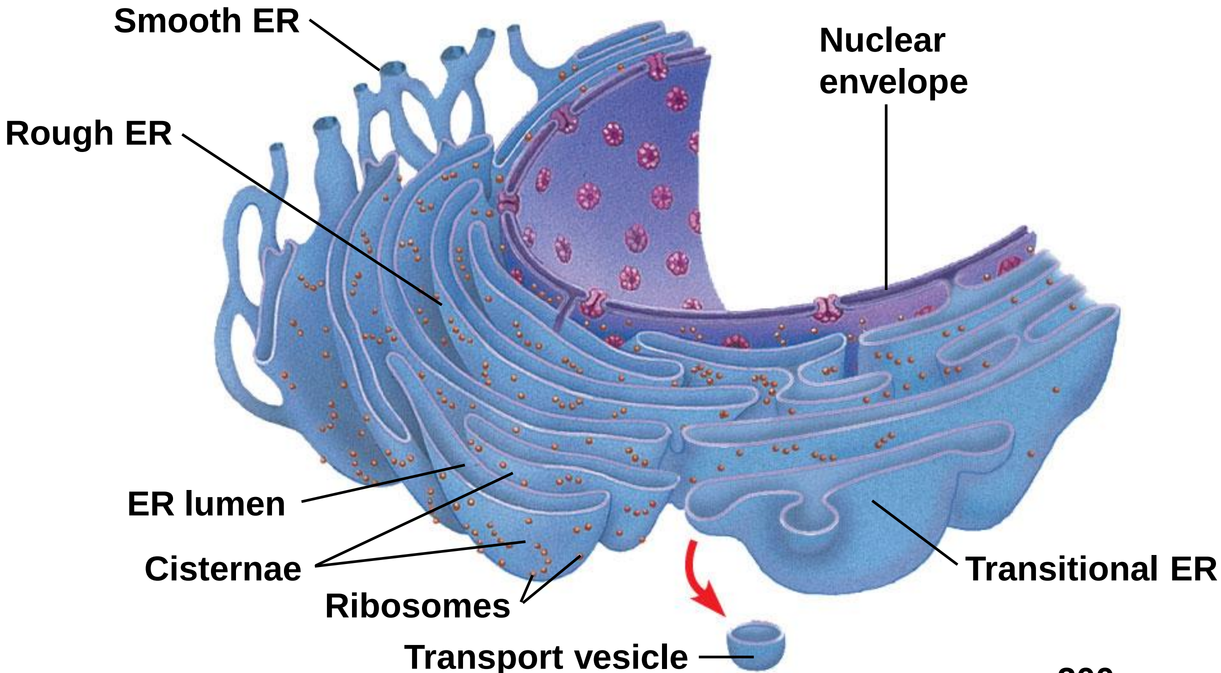
Concept 6.4: The endomembrane system regulates protein traffic and performs metabolic functions in the cell

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

The Endoplasmic Reticulum: Biosynthetic Factory

- The **endoplasmic reticulum (ER)** accounts for more than half of the total membrane in many eukaryotic cells
- The ER membrane is continuous with the nuclear envelope
- There are two distinct regions of ER
  - **Smooth ER**, which lacks ribosomes
  - **Rough ER**, surface is studded with ribosomes

Figure 6.11


Smooth ER
Rough ER
Nuclear envelope
ER lumen
Cisternae
Ribosomes
Transport vesicle
Transitional ER

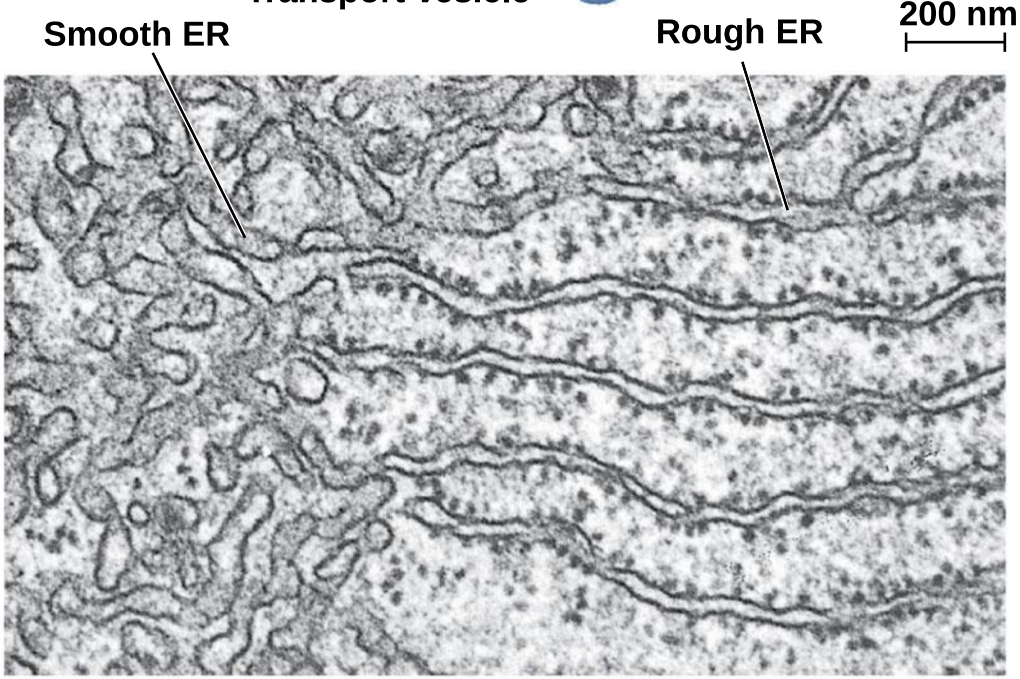

Smooth ER
Rough ER
200 nm

Figure 6.11a

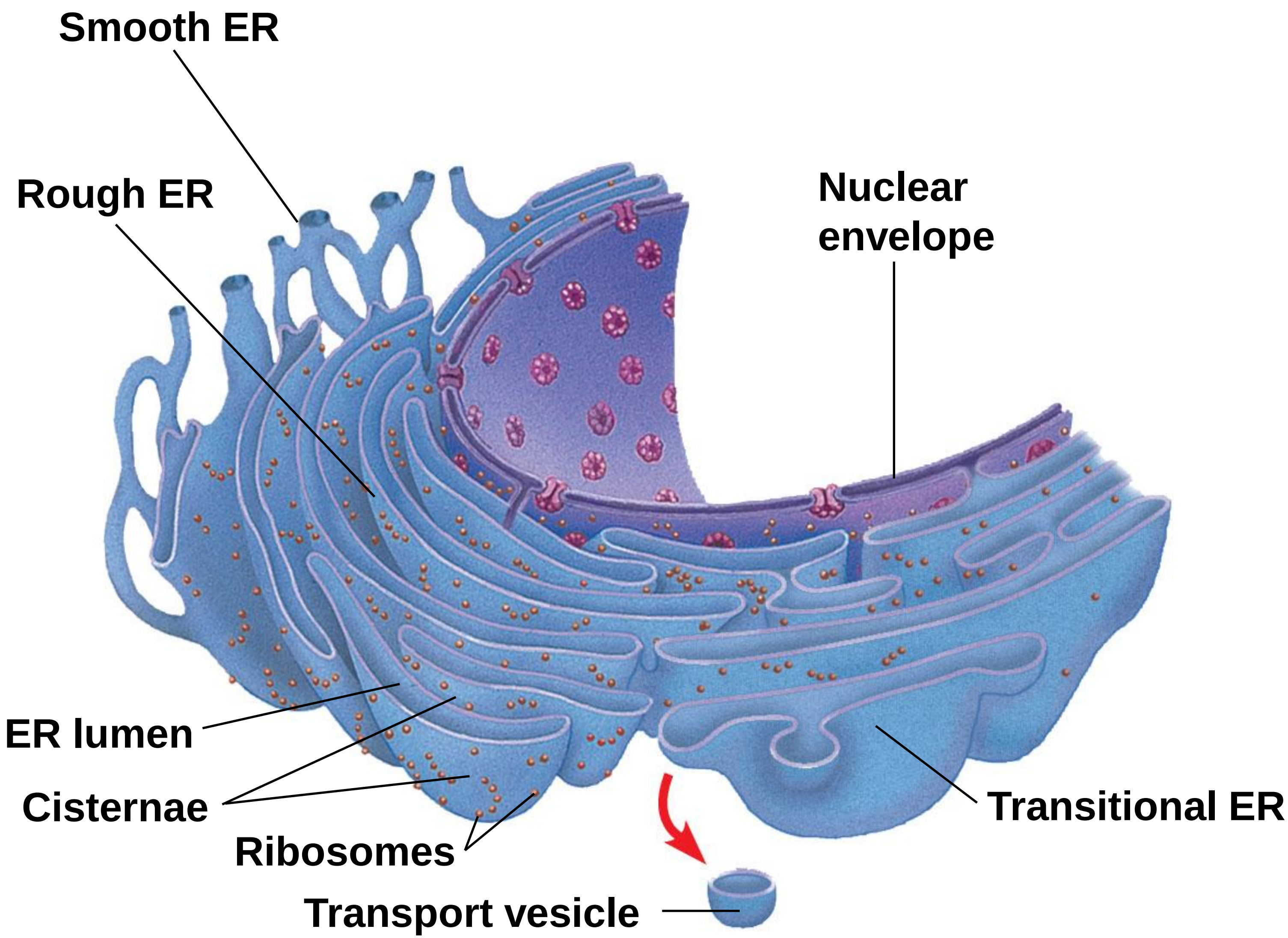
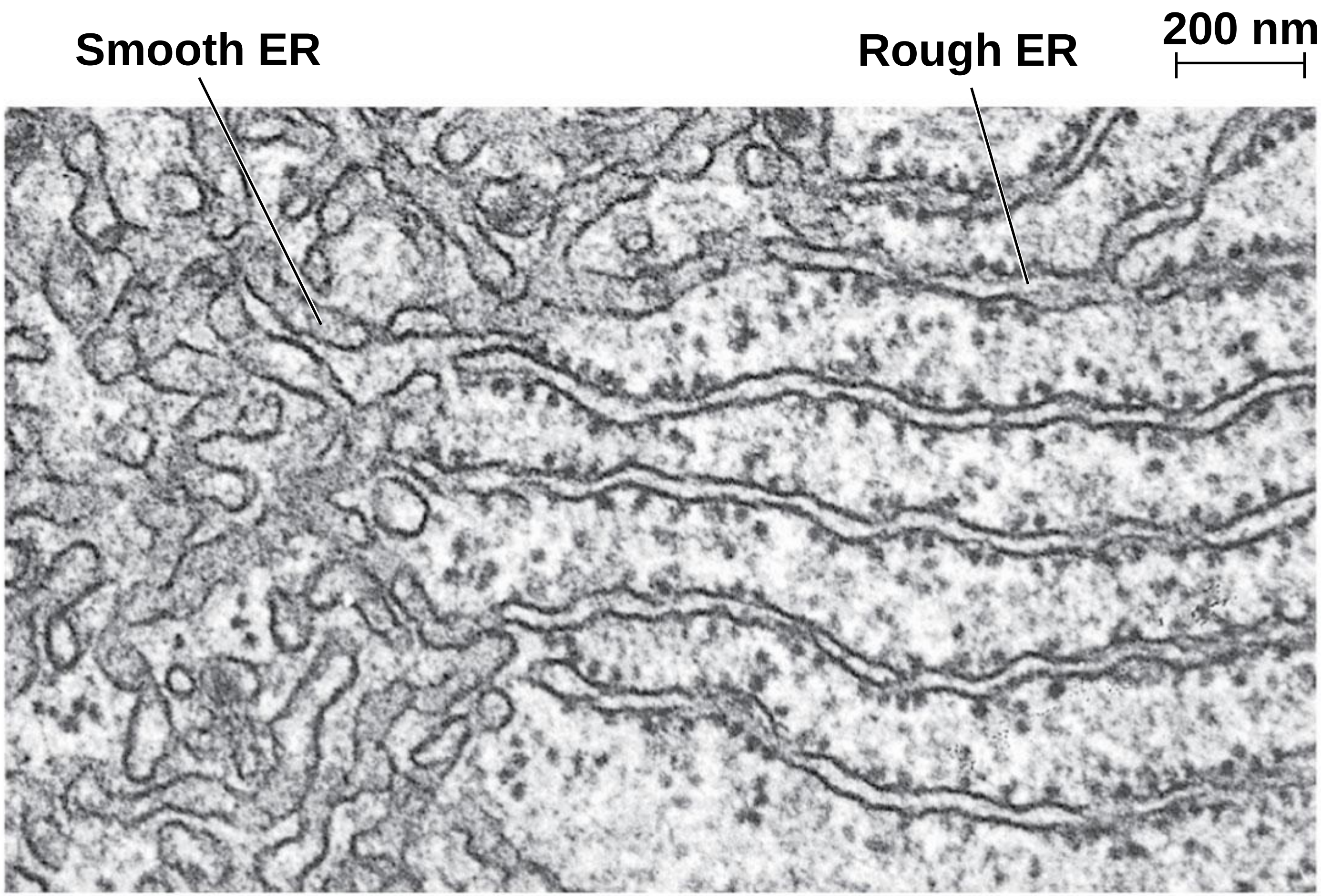

Smooth ER
Rough ER
Nuclear envelope
ER lumen
Cisternae
Ribosomes
Transport vesicle
Transitional ER

Figure 6.11b



Functions of Smooth ER

- The smooth ER
  - Synthesizes lipids
  - Metabolizes carbohydrates
  - Detoxifies drugs and poisons
  - Stores calcium ions

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

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

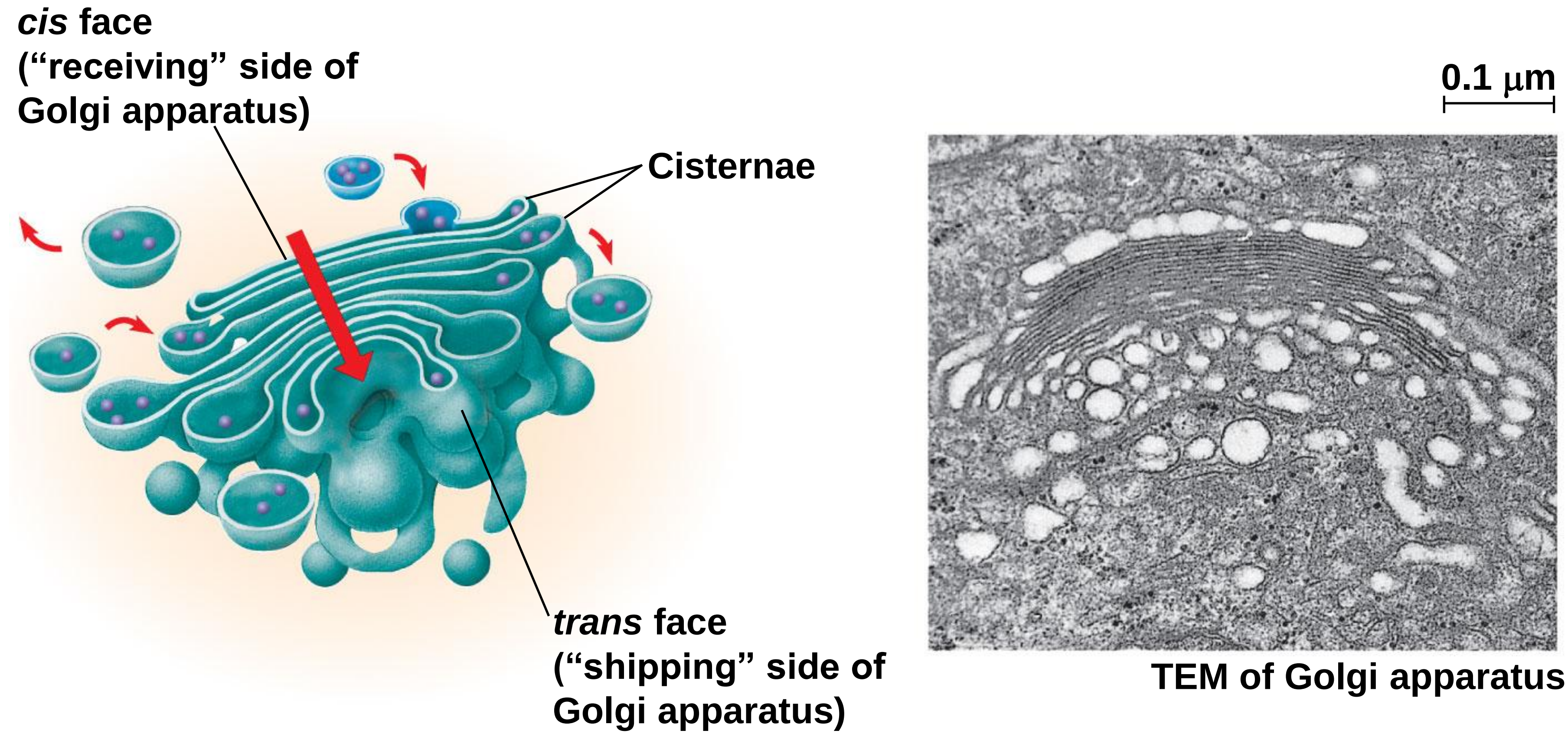
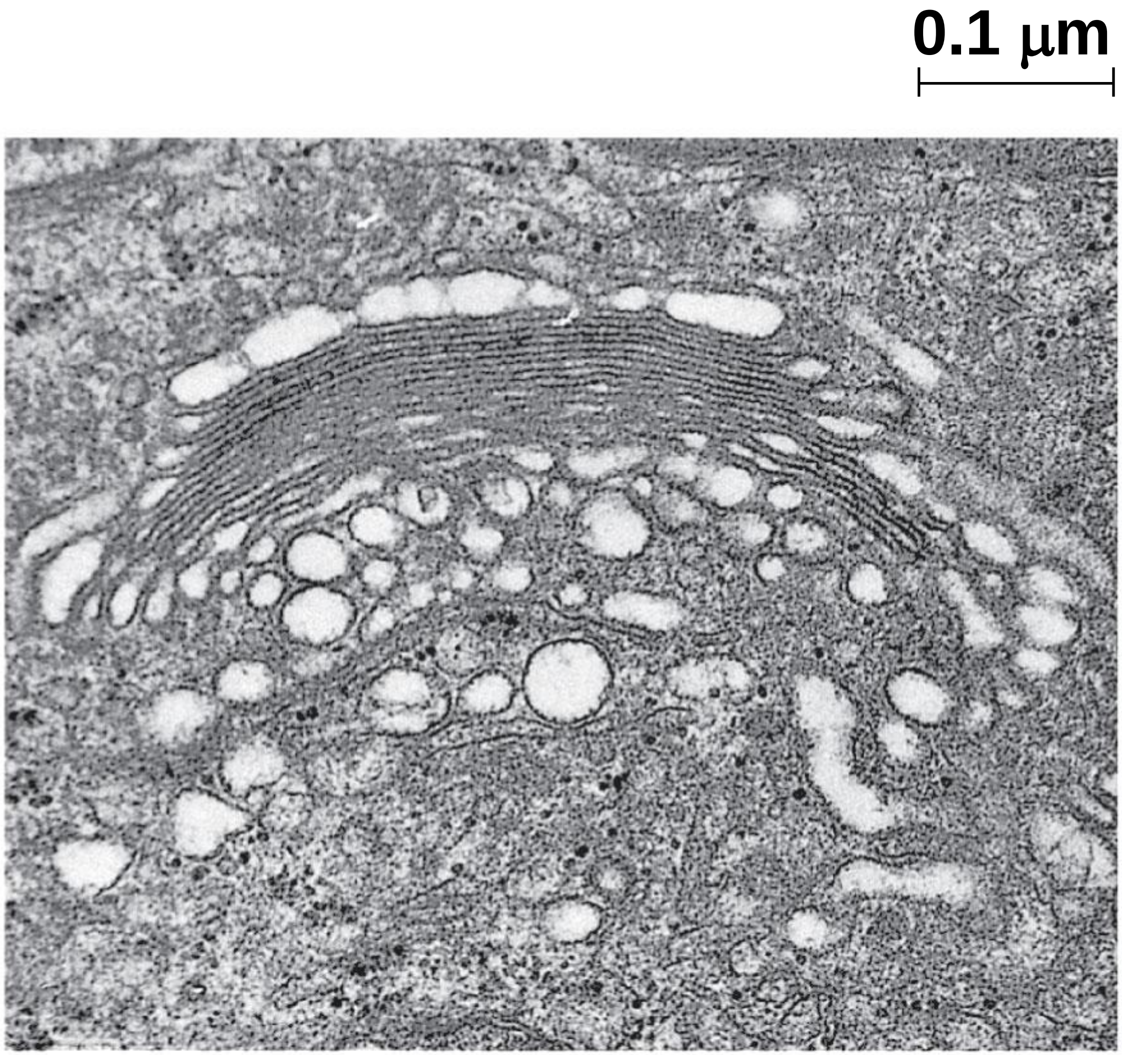

cis face
(“receiving” side of
Golgi apparatus)
Cisternae
trans face
(“shipping” side of
Golgi apparatus)
0.1 µm
TEM of Golgi apparatus

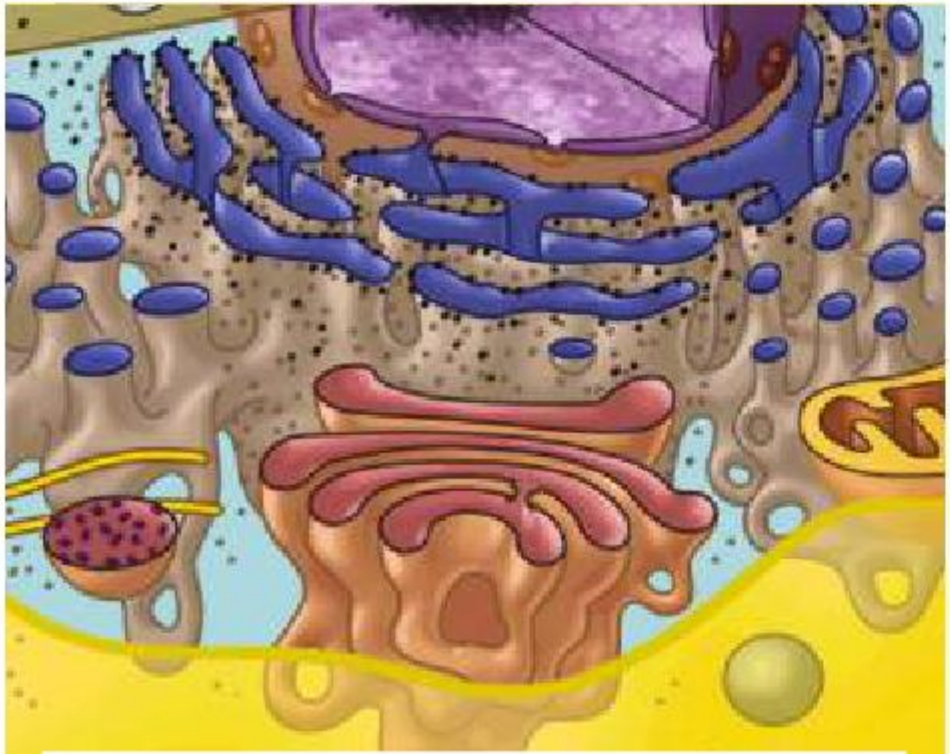
Figure 6.12a



TEM of Golgi apparatus

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

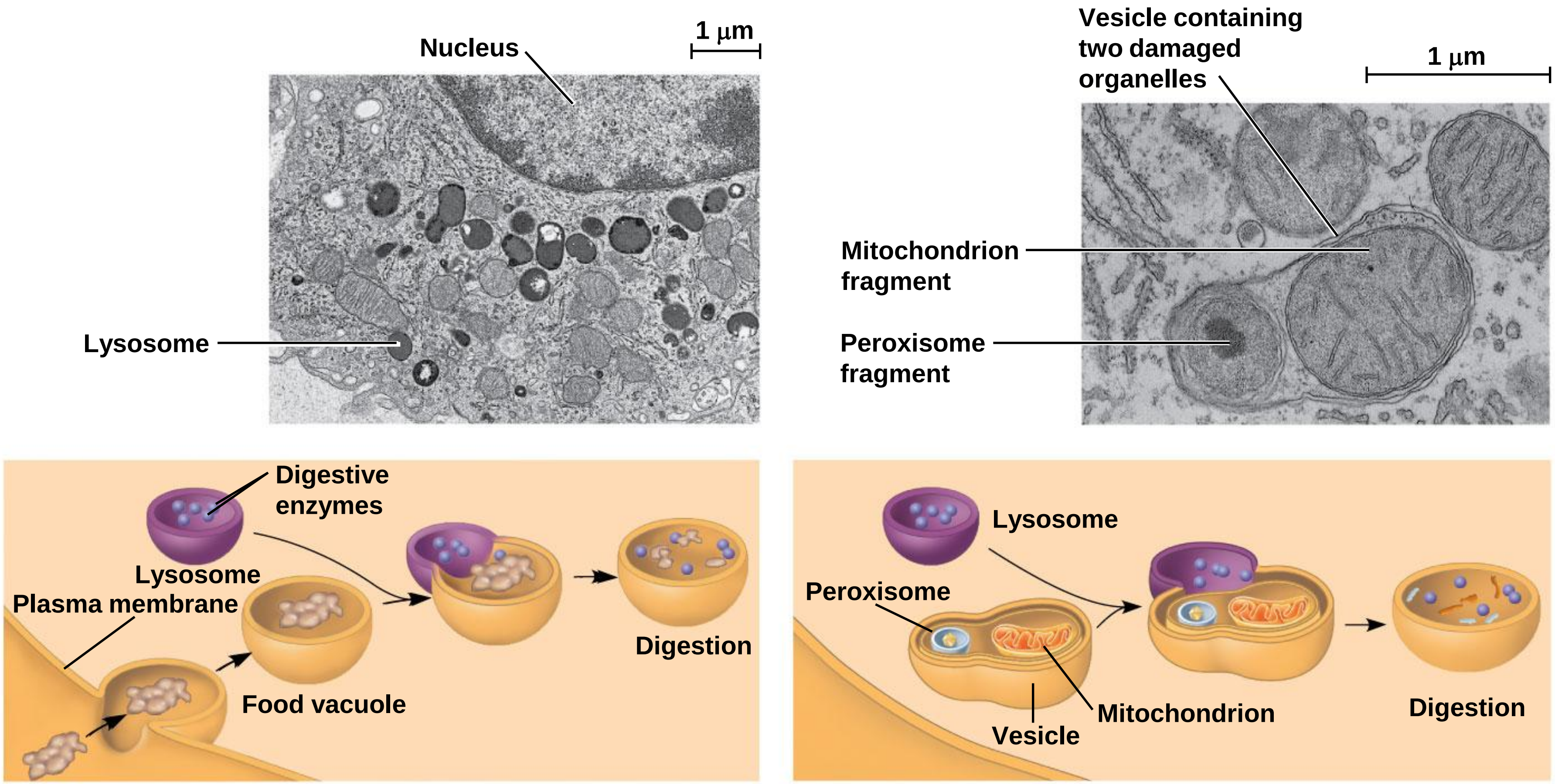


Animation: Lysosome Formation

Right-click slide / select “Play”

- Some types of cell can engulf another cell by **phagocytosis**; this forms a food vacuole
- 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

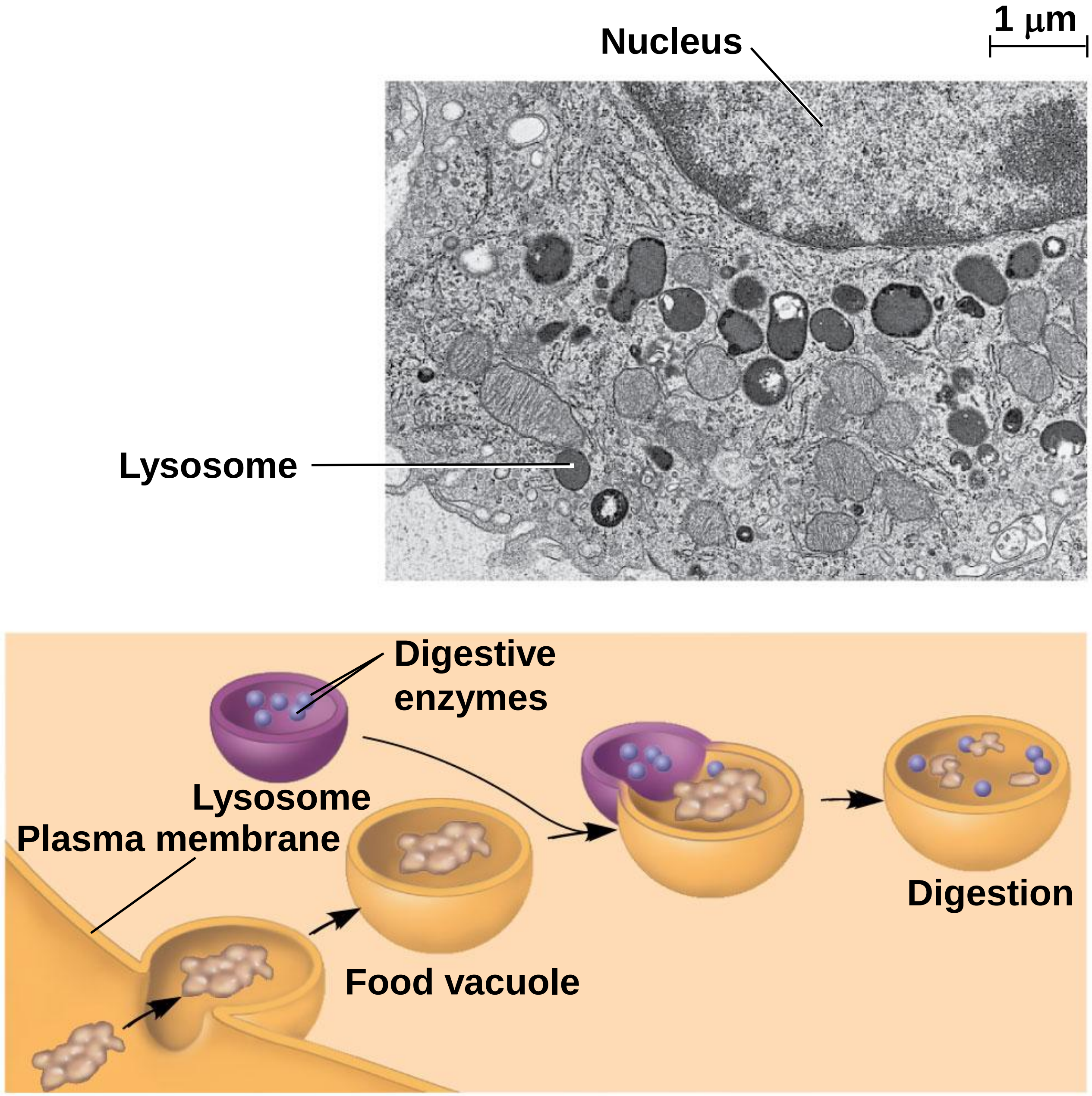
Figure 6.13



(a) Phagocytosis

(b) Autophagy

Figure 6.13a



(a) Phagocytosis

Figure 6.13aa

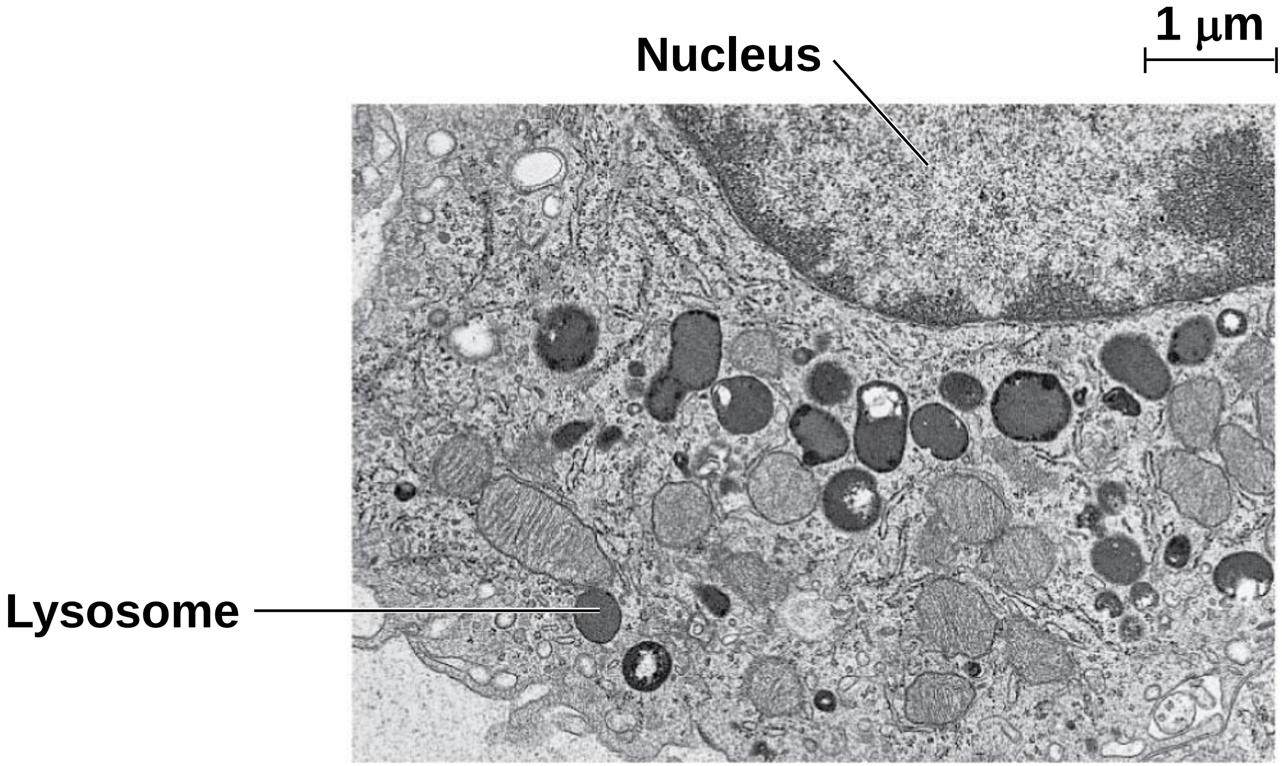
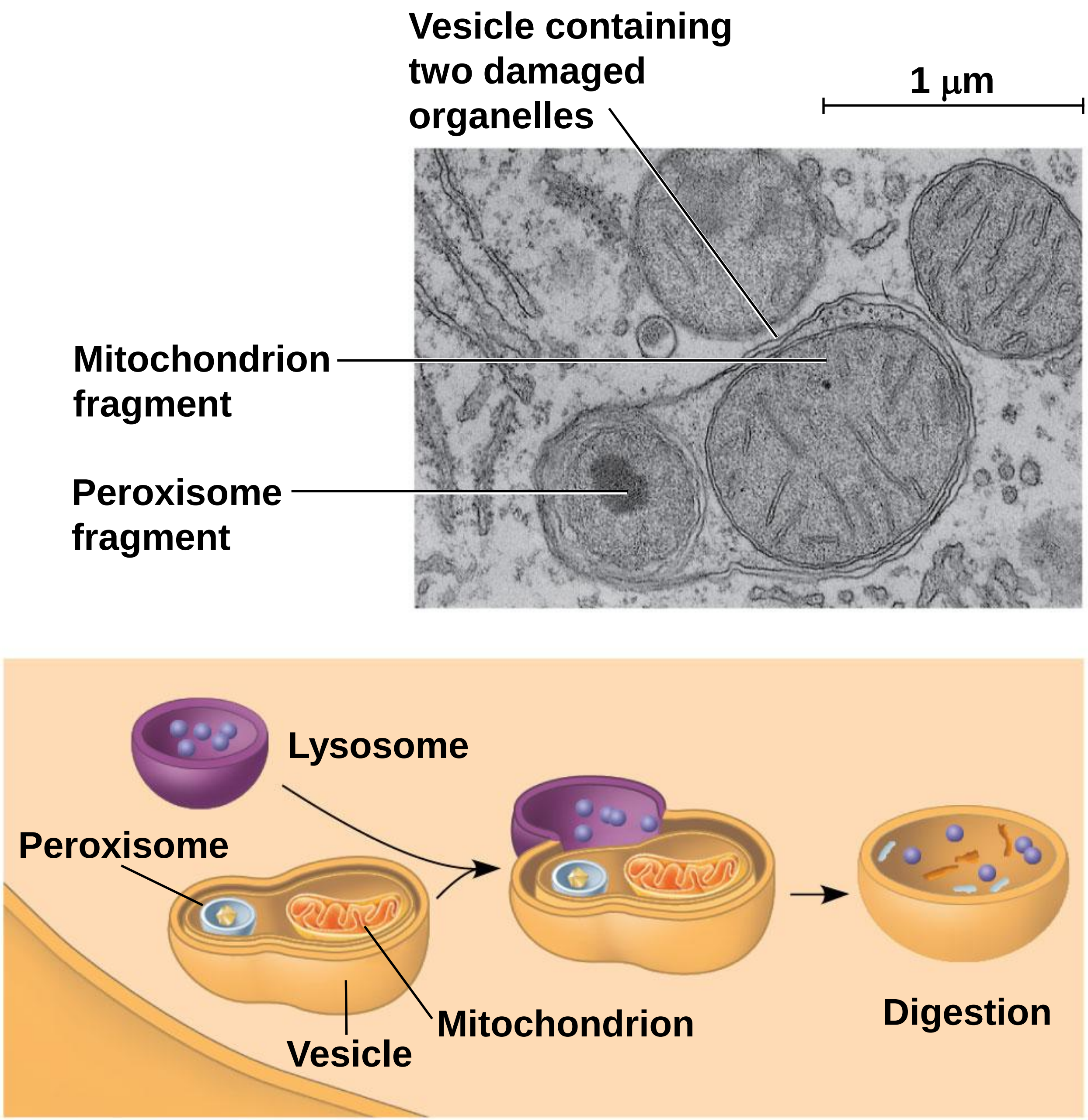
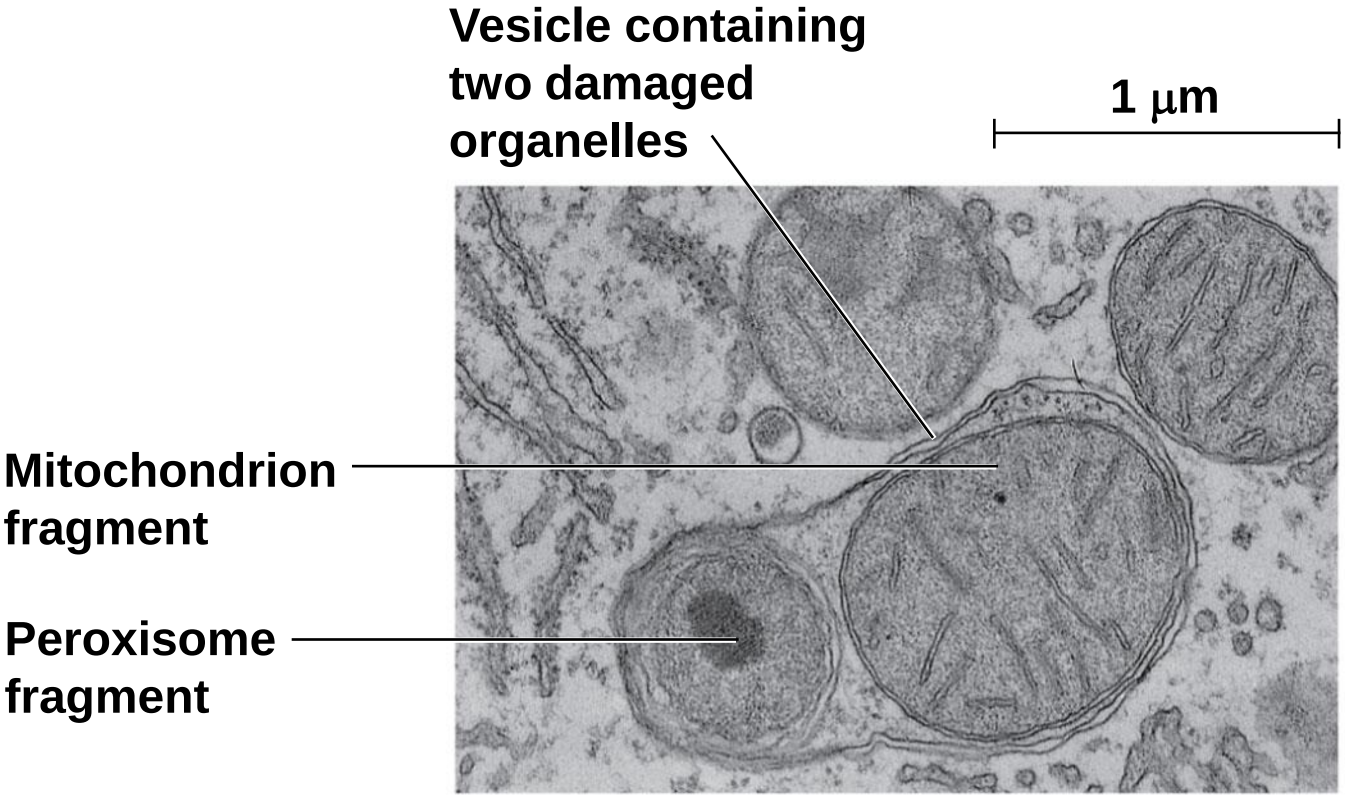


Figure 6.13b



(b) Autophagy

Figure 6.13bb

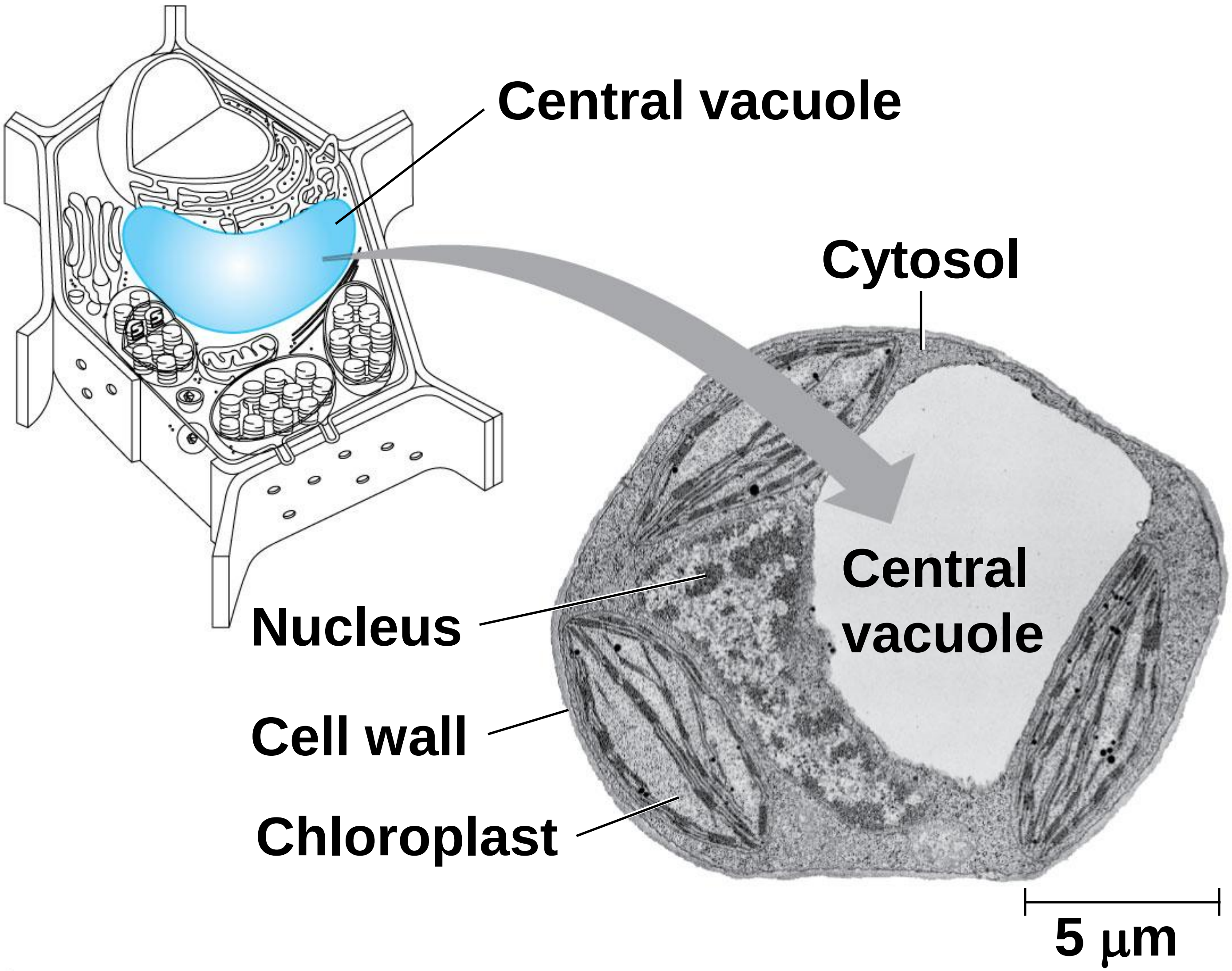


Vacuoles: Diverse Maintenance Compartments

- A plant cell or fungal cell may have one or several **vacuoles**, derived from endoplasmic reticulum and Golgi apparatus

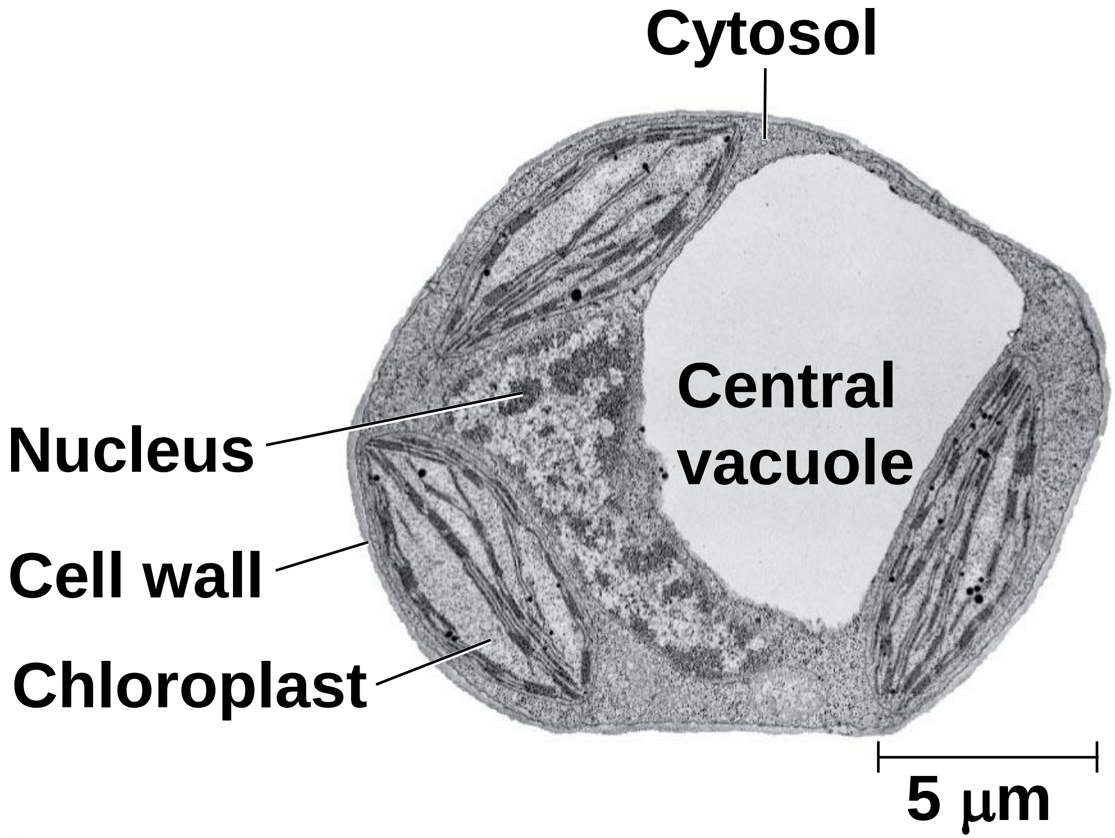
- **Food vacuoles** are formed by phagocytosis
- **Contractile vacuoles**, found in many freshwater protists, pump excess water out of cells
- **Central vacuoles**, found in many mature plant cells, hold organic compounds and water

Figure 6.14



Central vacuole
Cytosol
Central vacuole
Nucleus
Cell wall
Chloroplast
5 μm

Figure 6.14a



Cytosol
Central
vacuole
Nucleus
Cell wall
Chloroplast
5 µm

The Endomembrane System: *A Review*

- The endomembrane system is a complex and dynamic player in the cell's compartmental organization

Figure 6.15-1

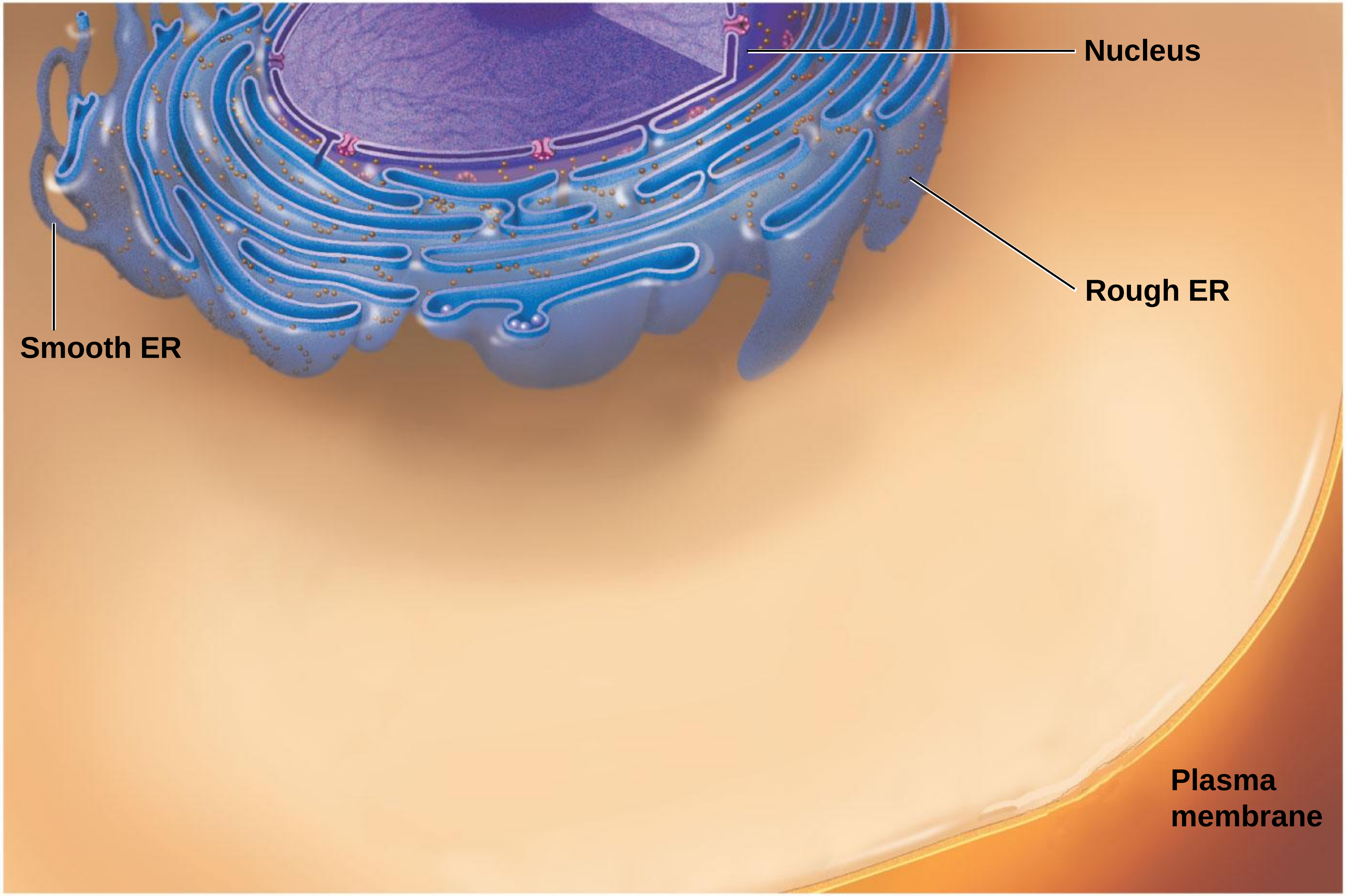
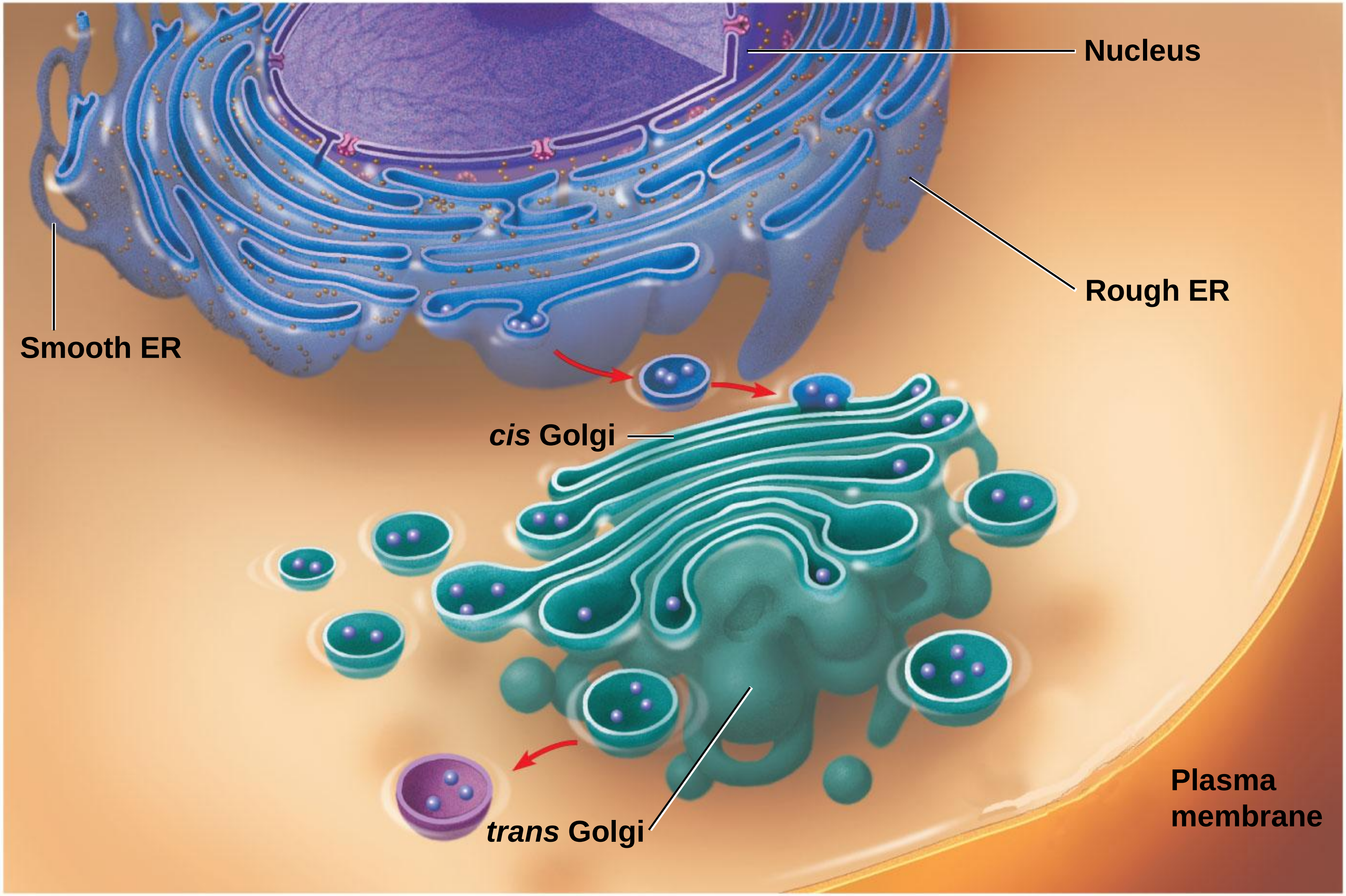
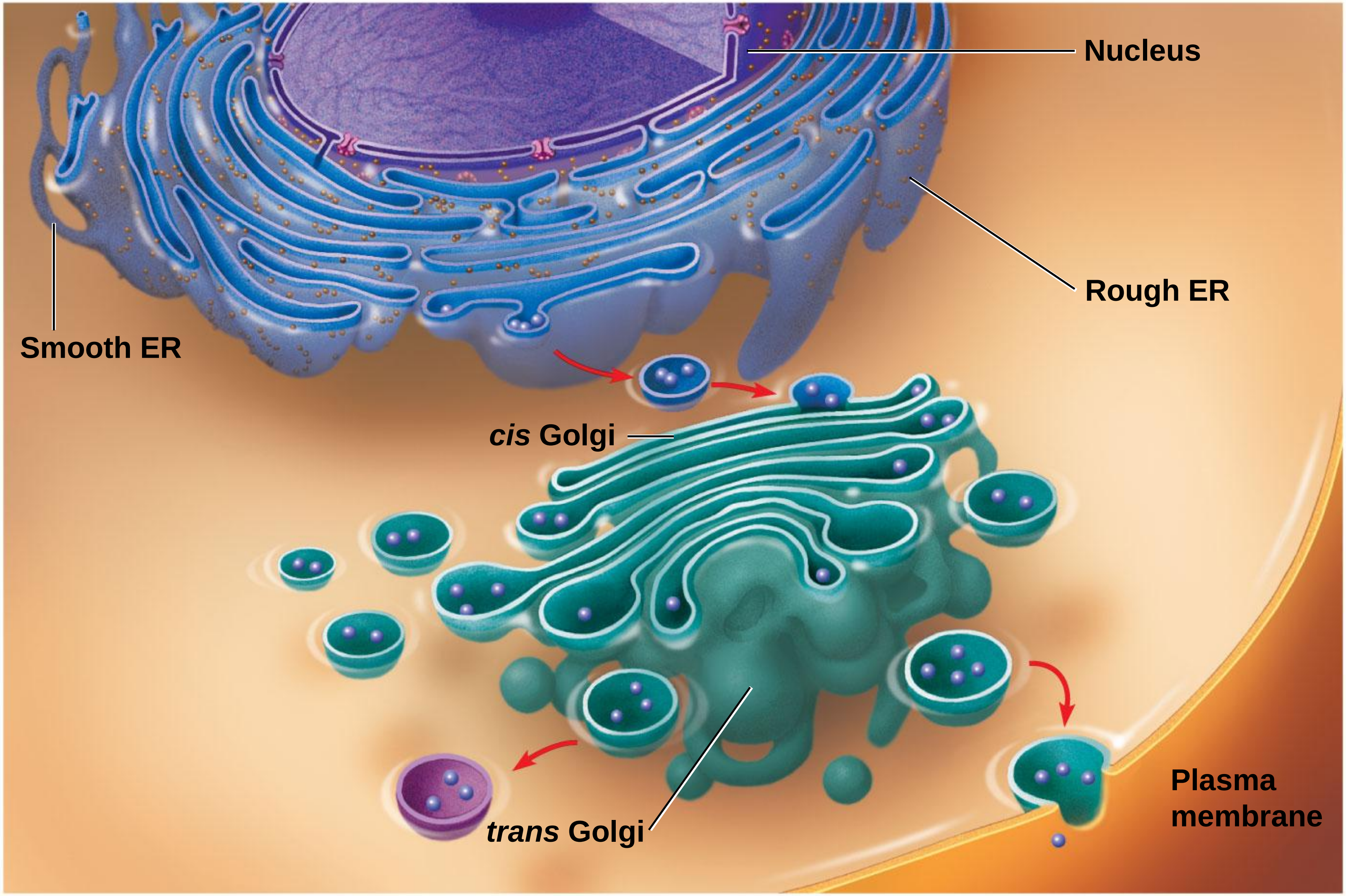


Figure 6.15-2



Nucleus
Rough ER
Smooth ER
cis Golgi
trans Golgi
Plasma membrane

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

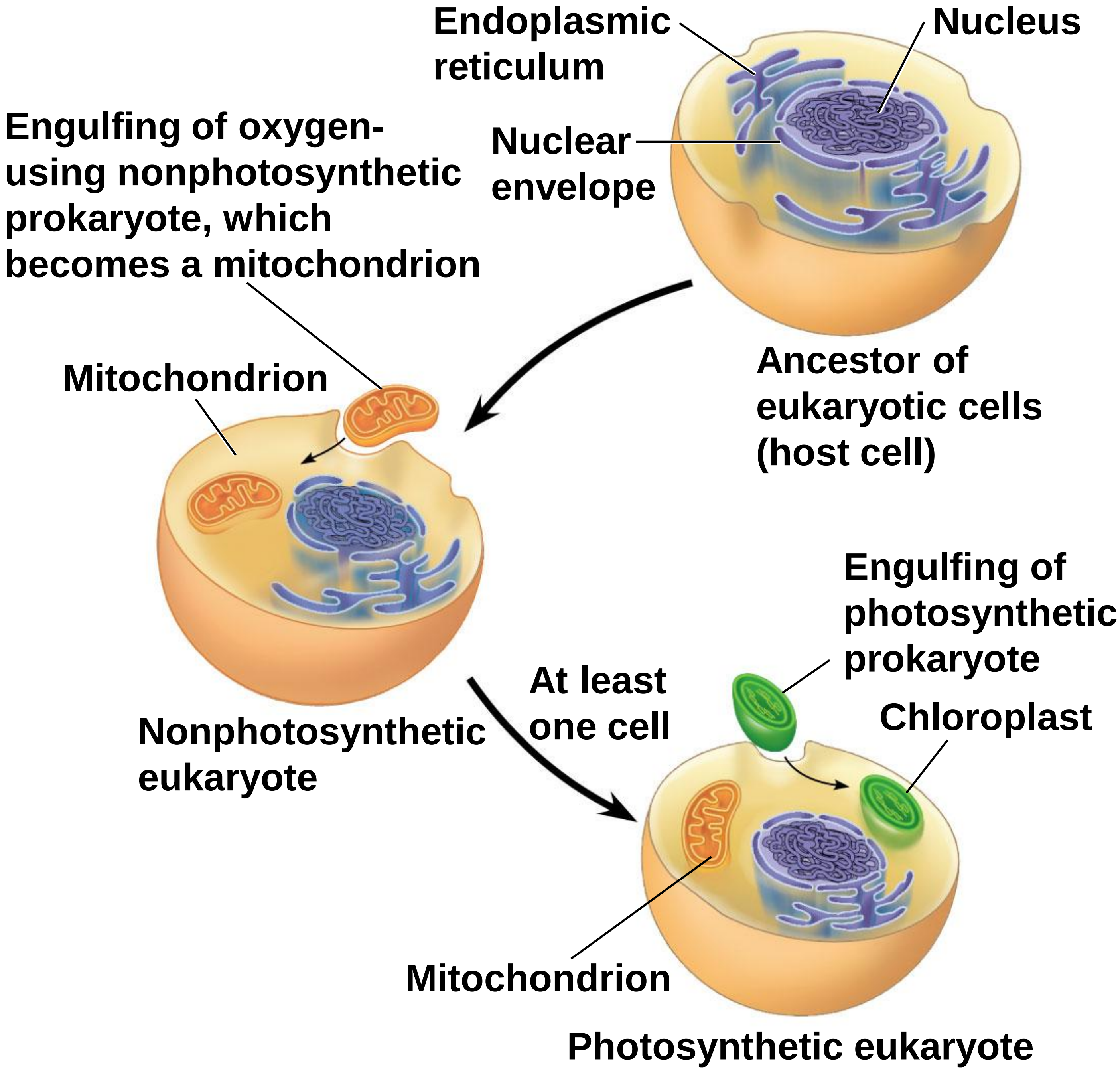
- **Mitochondria** are the sites of cellular respiration, a metabolic process that uses oxygen to generate ATP
- **Chloroplasts**, found in plants and algae, are the sites of photosynthesis
- Peroxisomes are oxidative organelles

The 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

- The **Endosymbiont theory**
  - 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

Figure 6.16

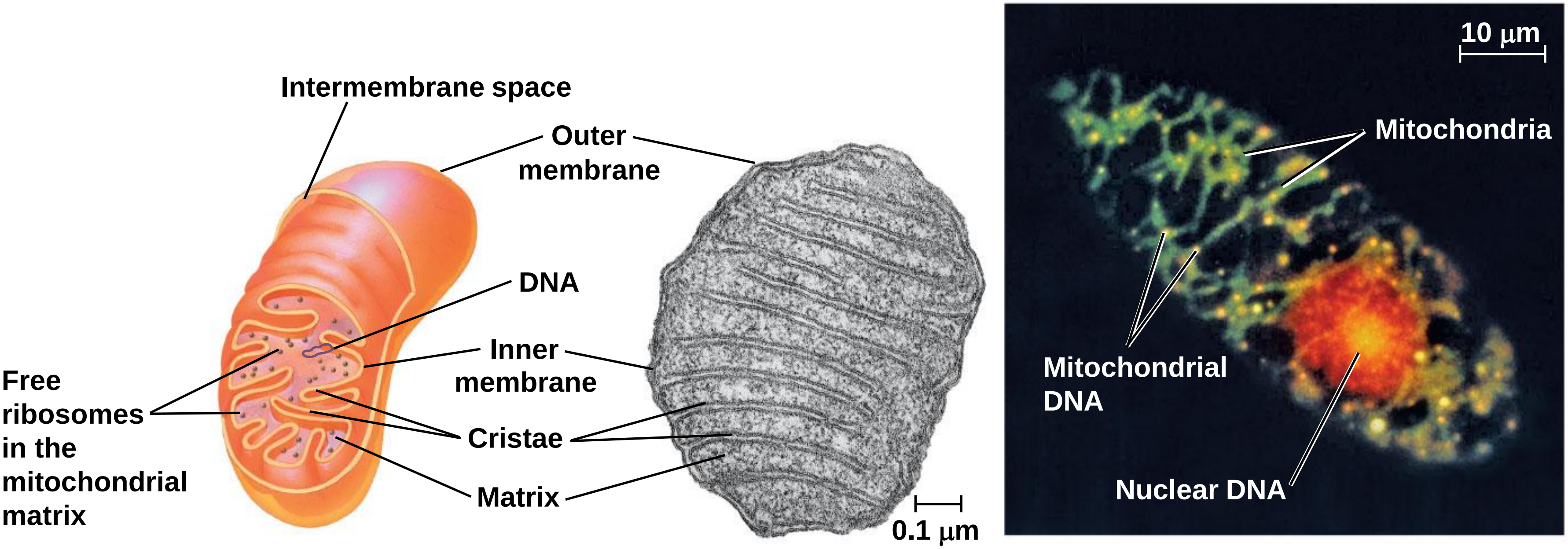


Endoplasmic reticulum
Nucleus
Engulfing of oxygen-using nonphotosynthetic prokaryote, which becomes a mitochondrion
Nuclear envelope
Ancestor of eukaryotic cells (host cell)
Mitochondrion
Nonphotosynthetic eukaryote
At least one cell
Engulfing of photosynthetic prokaryote
Chloroplast
Mitochondrion
Photosynthetic eukaryote

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

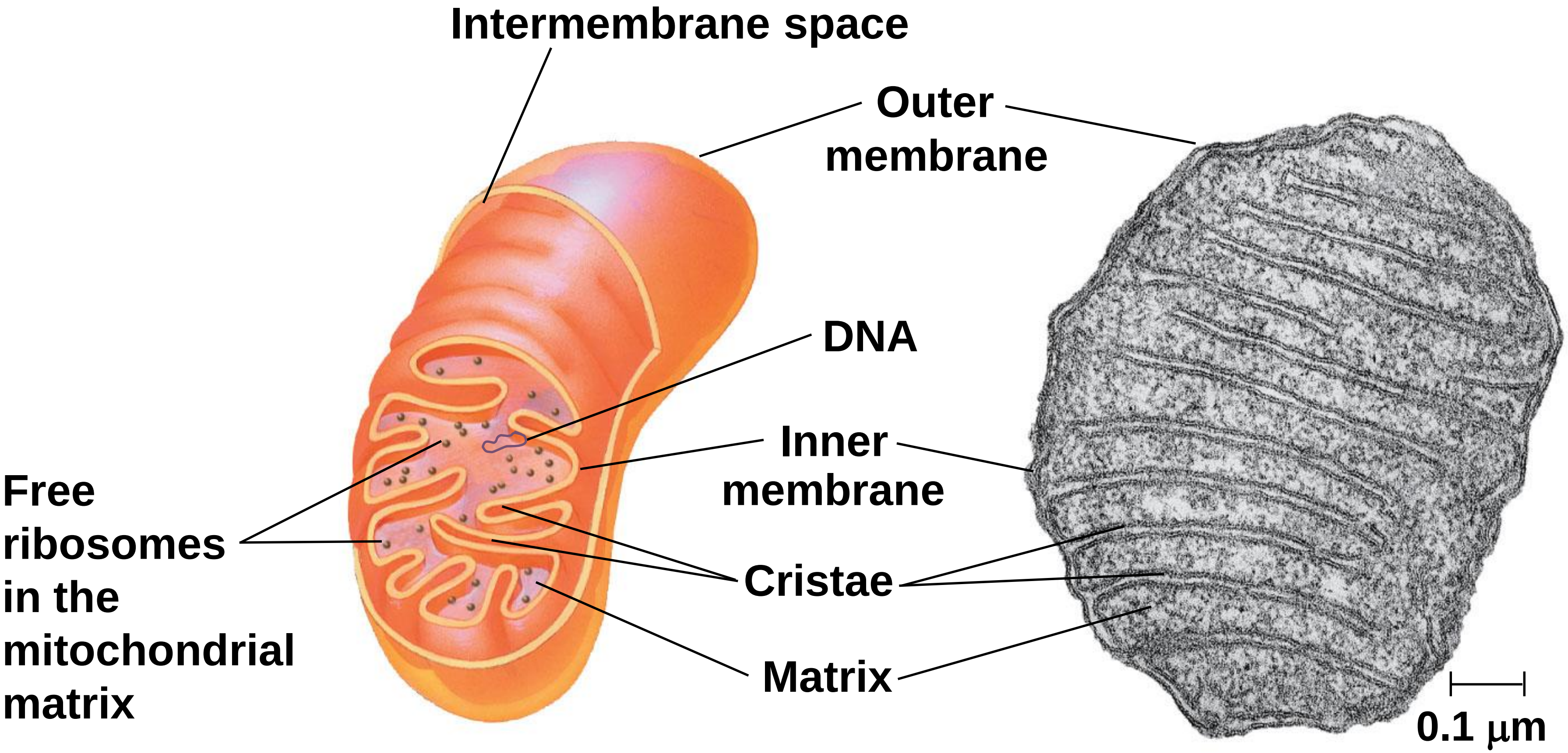
Figure 6.17



(a) Diagram and TEM of mitochondrion

(b) Network of mitochondria in a protist cell (LM)

Figure 6.17a



(a) Diagram and TEM of mitochondrion

Figure 6.17aa

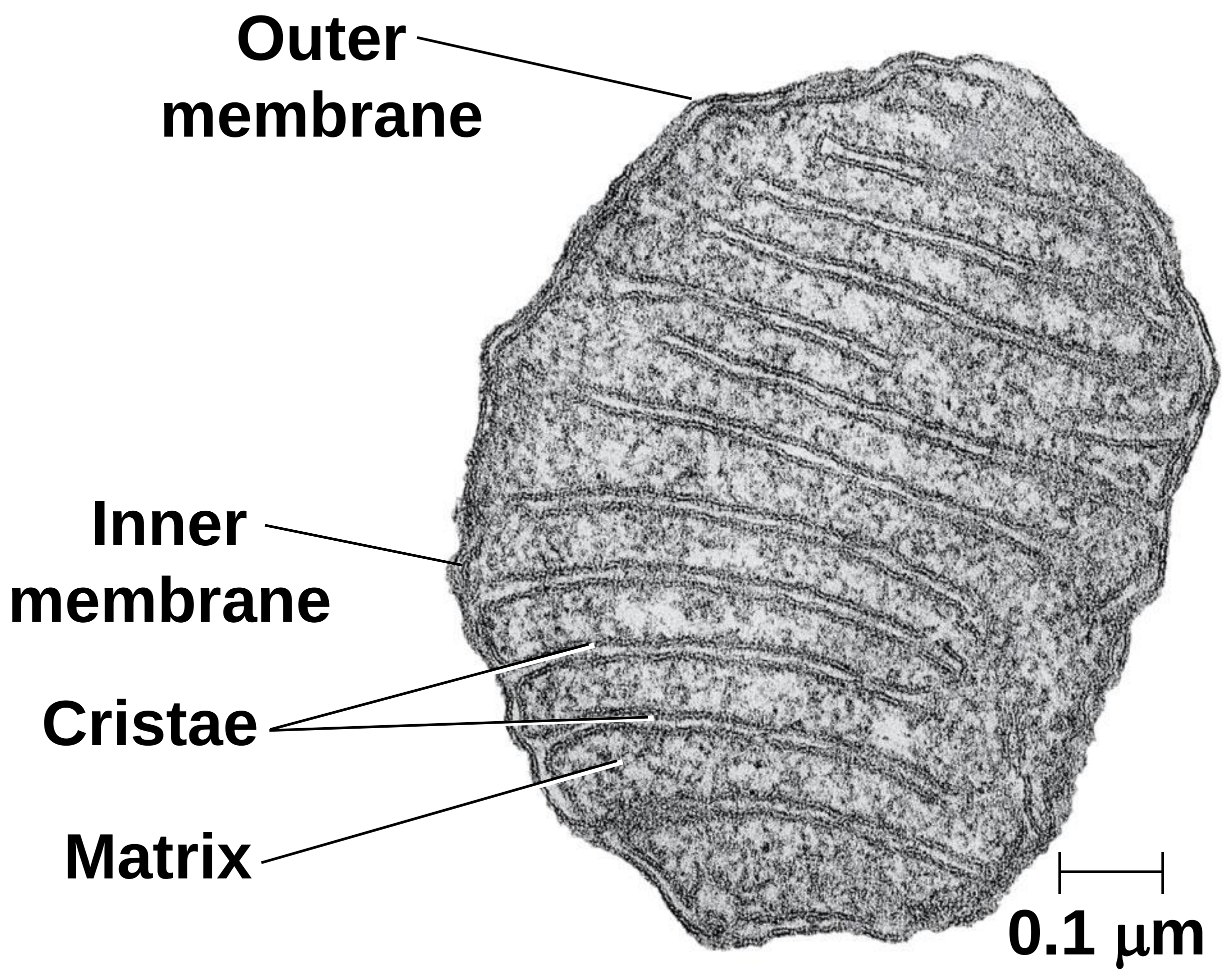
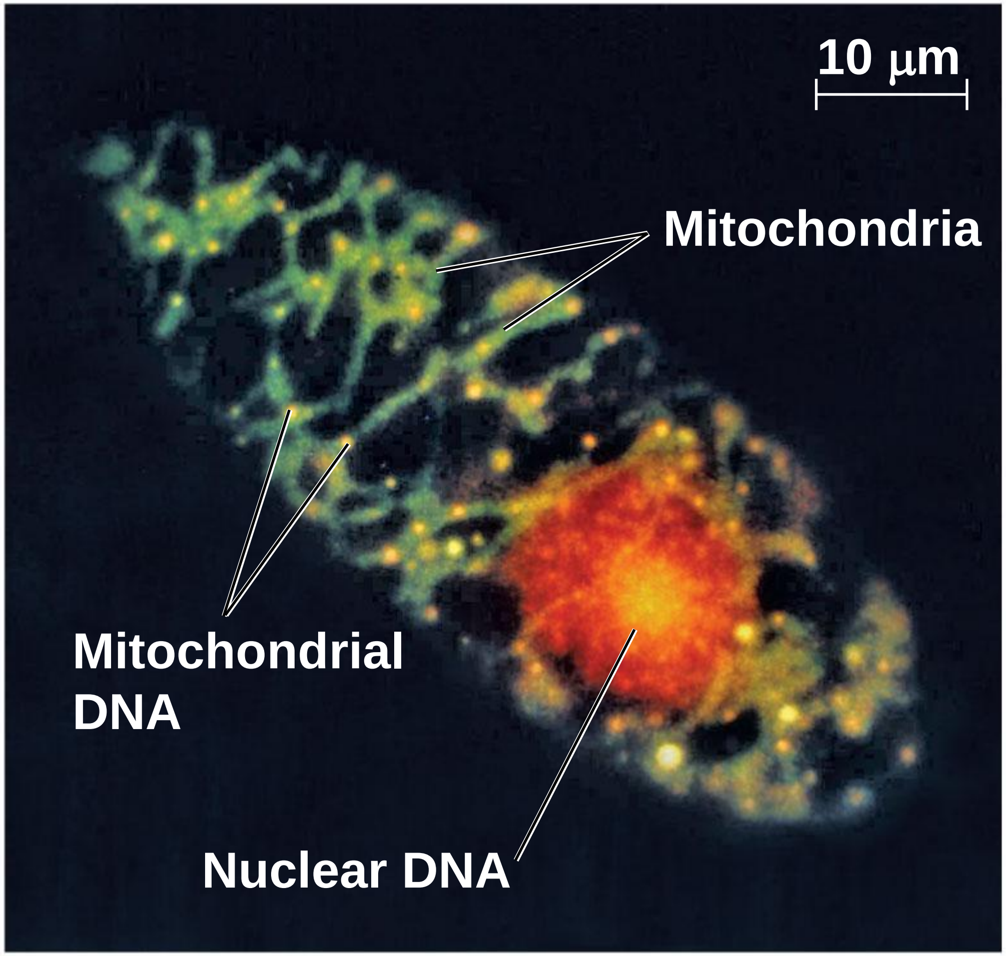


Figure 6.17b



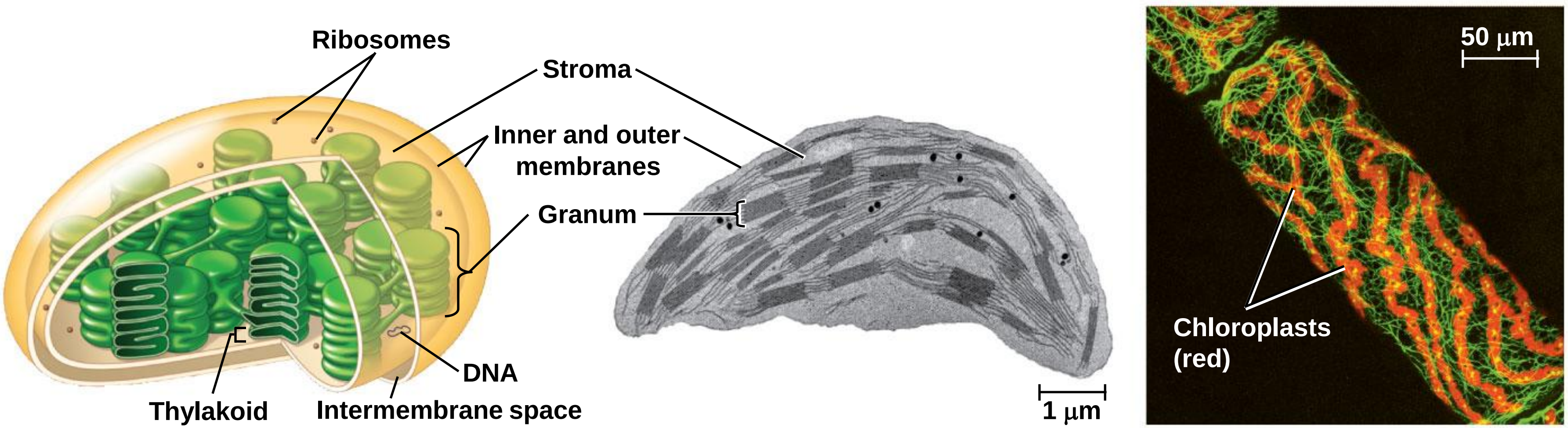
(b) Network of mitochondria in a protist cell (LM)

Chloroplasts: Capture of Light Energy

- Chloroplasts contain the green pigment chlorophyll, as well as enzymes and other molecules that function in photosynthesis
- Chloroplasts are found in leaves and other green organs of plants and in algae

- 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**

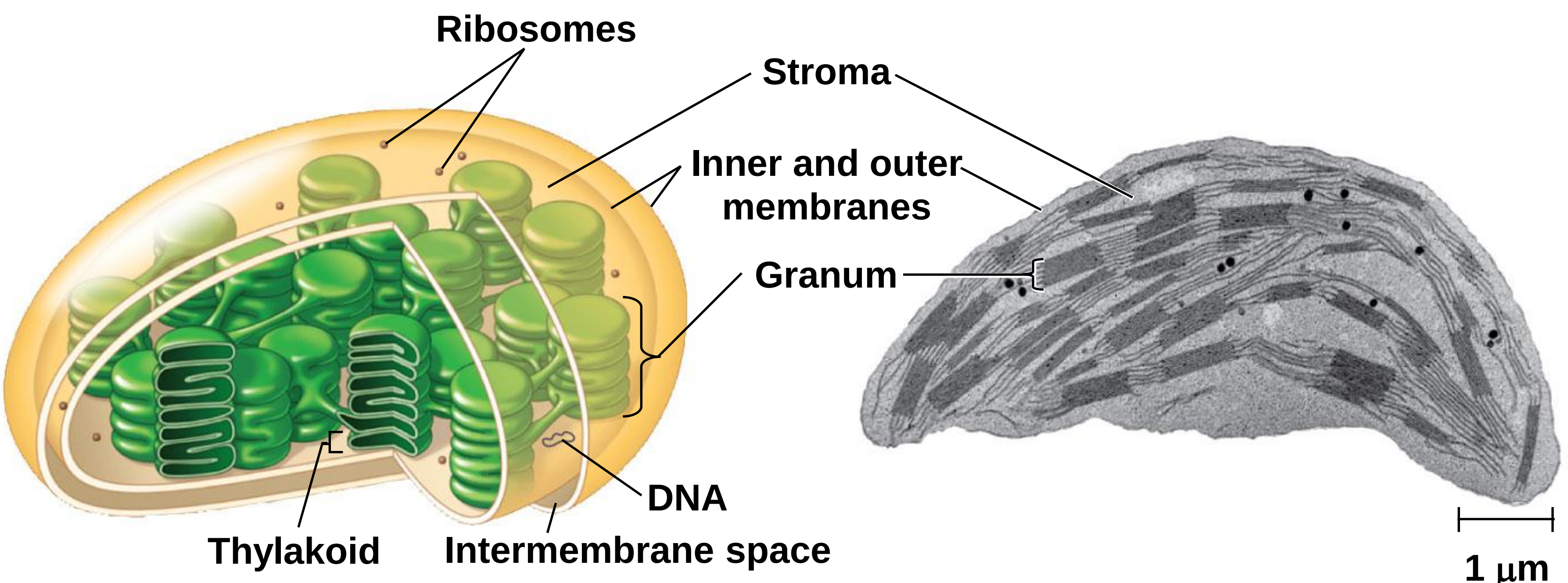
Figure 6.18



(a) Diagram and TEM of chloroplast

(b) Chloroplasts in an algal cell

Figure 6.18a



(a) Diagram and TEM of chloroplast

Figure 6.18aa

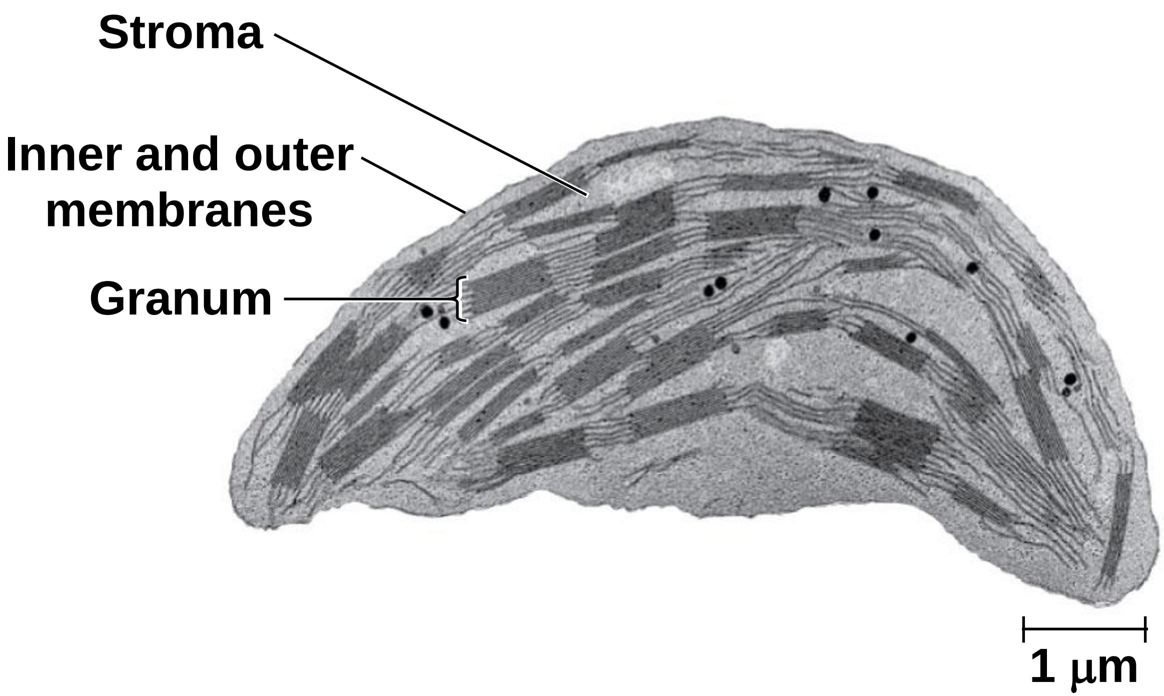
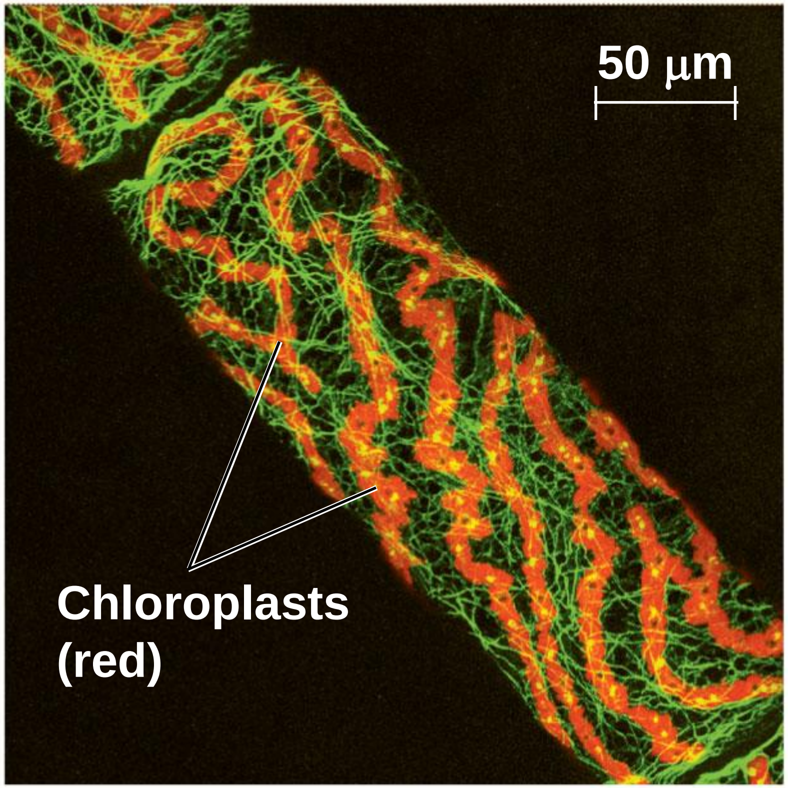


Figure 6.18b

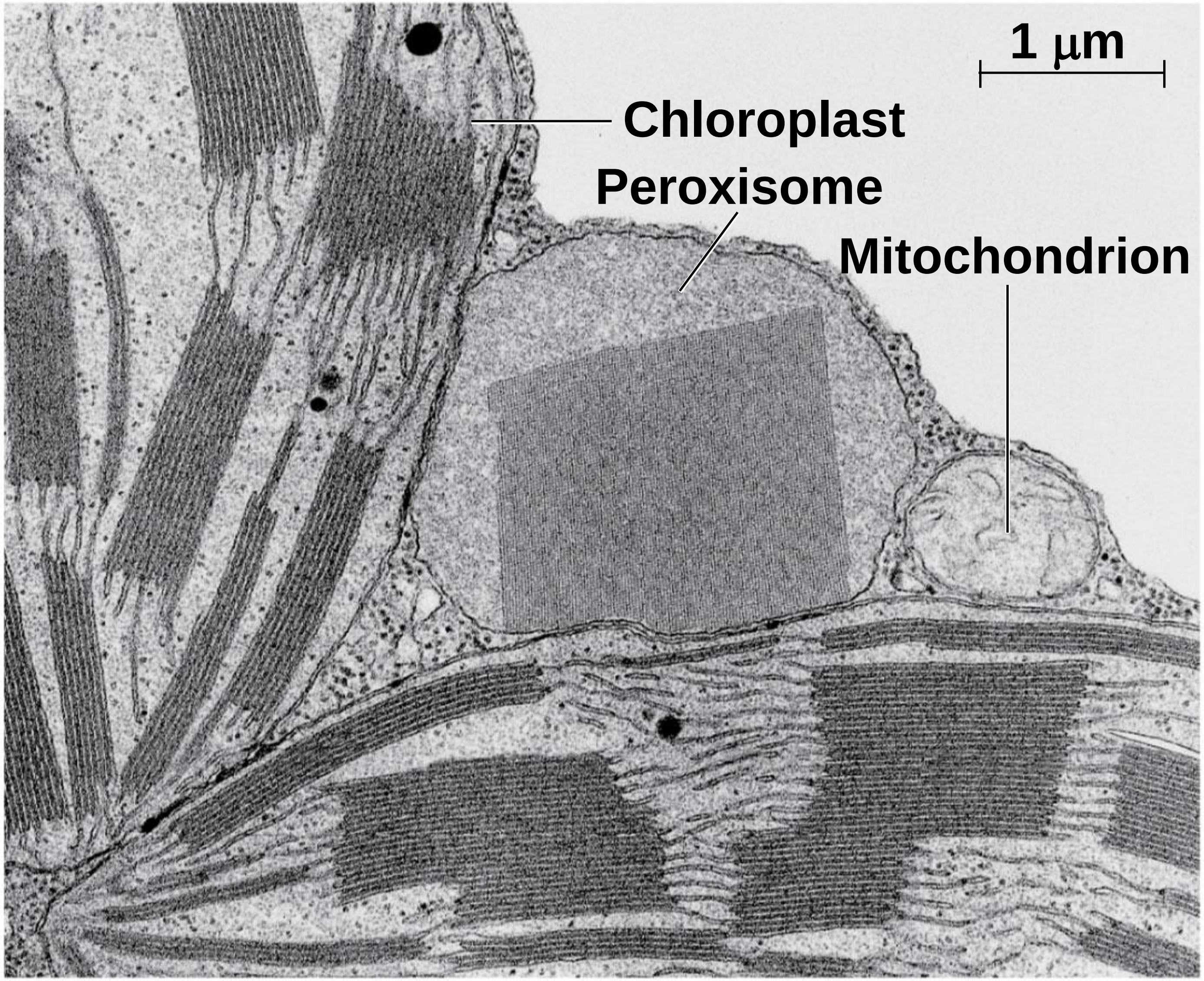


(b) Chloroplasts in an algal cell

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
- How peroxisomes are related to other organelles is still unknown

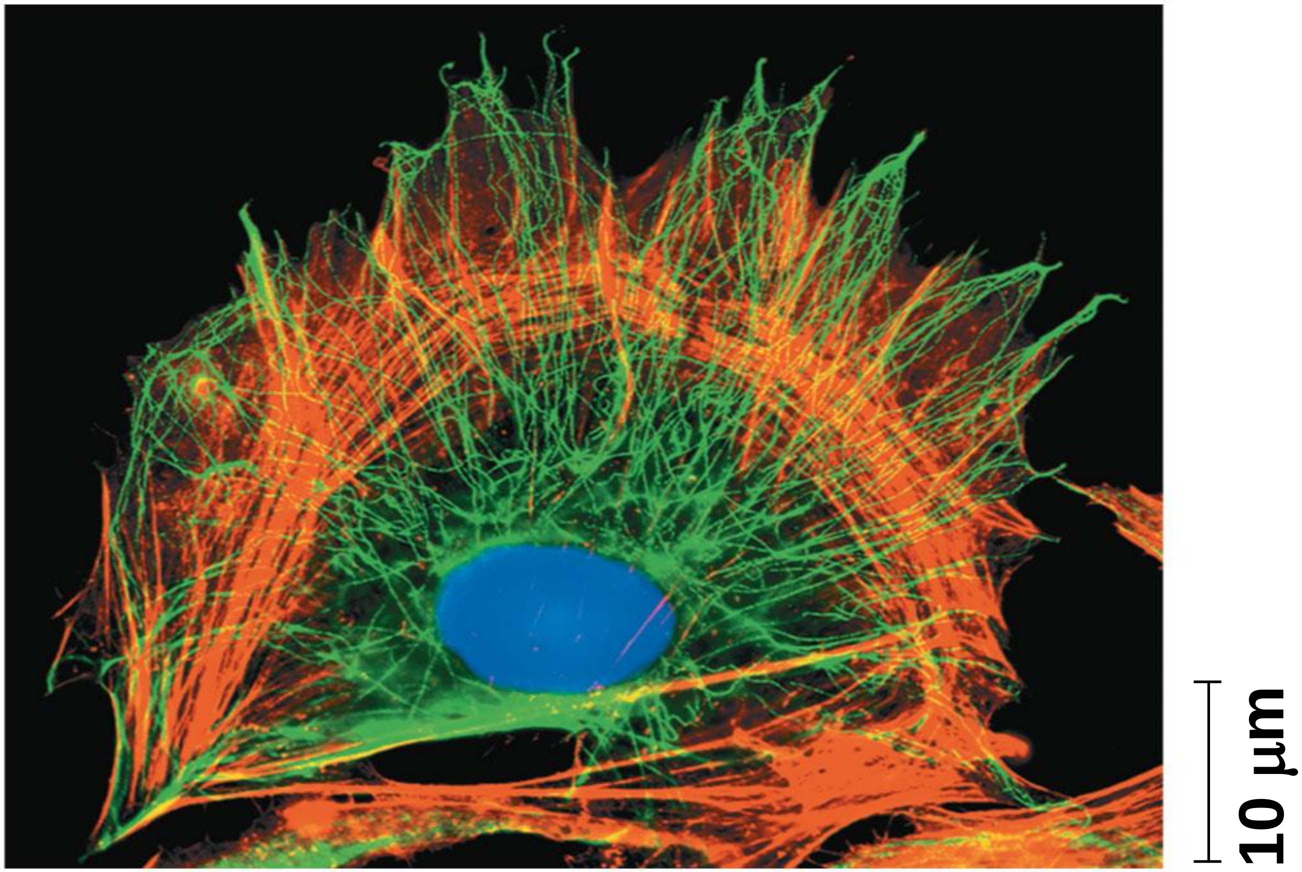
Figure 6.19



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

Figure 6.20



Roles of the Cytoskeleton: Support and Motility

- The cytoskeleton helps to support the cell and maintain its shape
- It interacts with **motor proteins** to produce motility
- Inside the cell, vesicles can travel along "monorails" provided by the cytoskeleton
- Recent evidence suggests that the cytoskeleton may help regulate biochemical activities

Figure 6.21

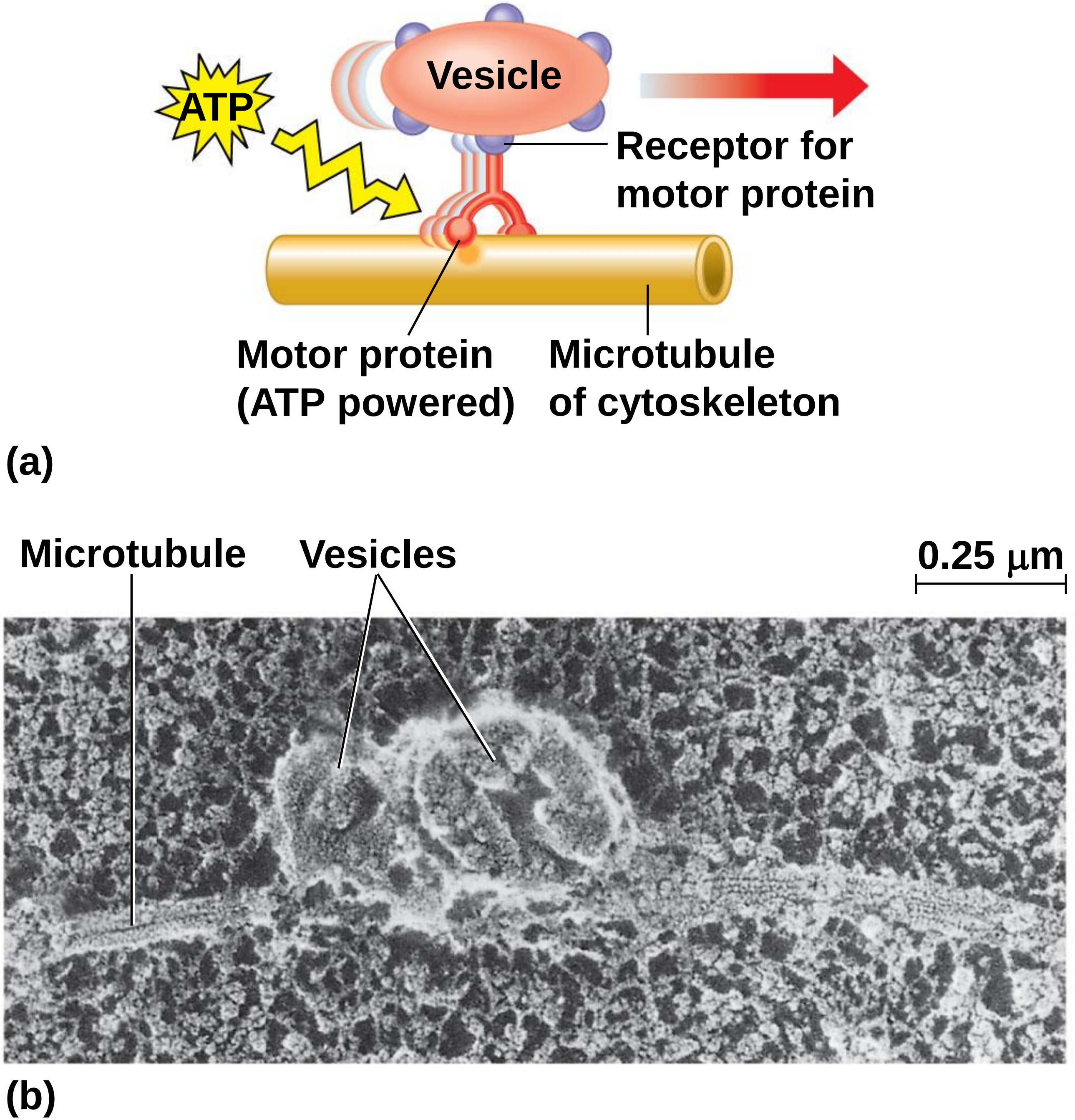
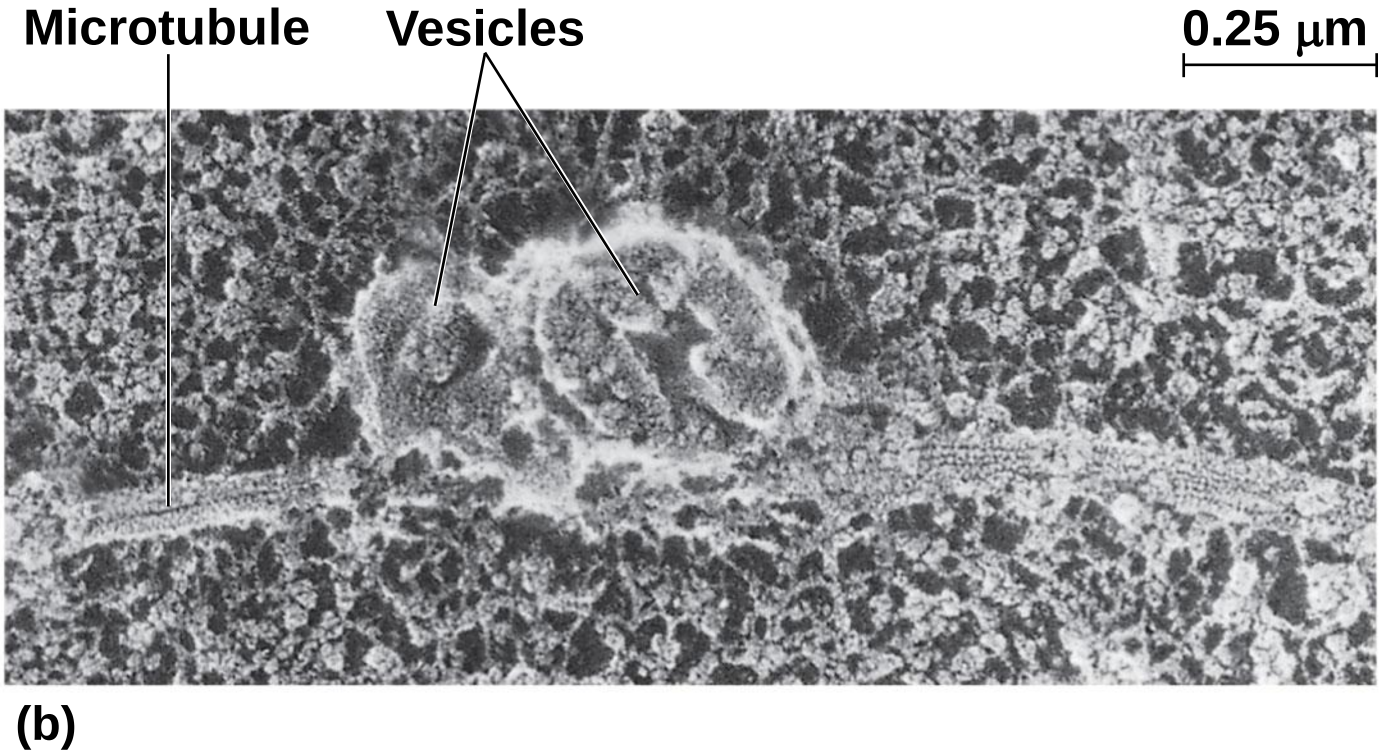

Vesicle
ATP
Receptor for motor protein
Motor protein (ATP powered)
Microtubule of cytoskeleton
(a)
Microtubule
Vesicles
0.25 µm
(b)

Figure 6.21a



Components of the Cytoskeleton

- Three main types of fibers make up the cytoskeleton
  - *Microtubules* are the thickest of the three components of the cytoskeleton
  - *Microfilaments*, also called actin filaments, are the thinnest components
  - *Intermediate filaments* are fibers with diameters in a middle range

Table 6.1

Table 6.1 The Structure and Function of the Cytoskeleton

Property	Microtubules (Tubulin Polymers)	Microfilaments (Actin Filaments)	Intermediate Filaments
Structure	Hollow tubes; wall consists of 13 columns of tubulin molecules	Two intertwined strands of actin, each a polymer of actin subunits	Fibrous proteins supercoiled into thicker cables
Diameter	25 nm with 15-nm lumen	7 nm	8–12 nm
Protein subunits	Tubulin, a dimer consisting of α-tubulin and β-tubulin	Actin	One of several different proteins (such as keratins), depending on cell type
Main functions	Maintenance of cell shape (compression-resisting "girders") Cell motility (as in cilia or flagella) Chromosome movements in cell division Organelle movements	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)	Maintenance of cell shape (tension-bearing elements) Anchorage of nucleus and certain other organelles Formation of nuclear lamina

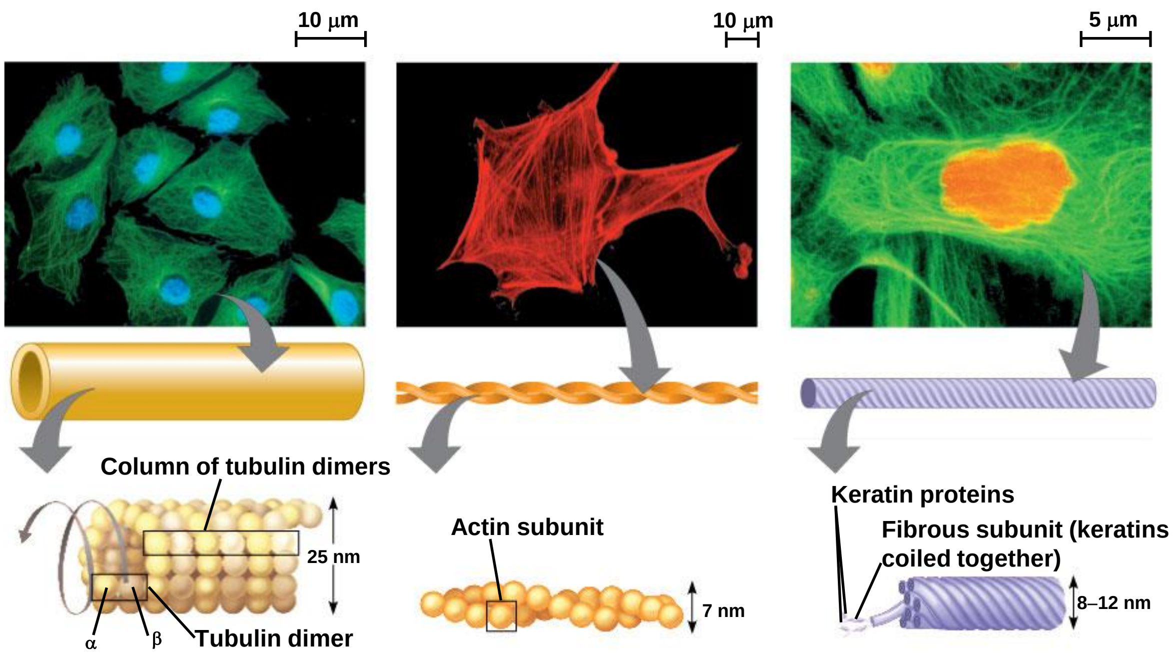


Table 6.1a

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

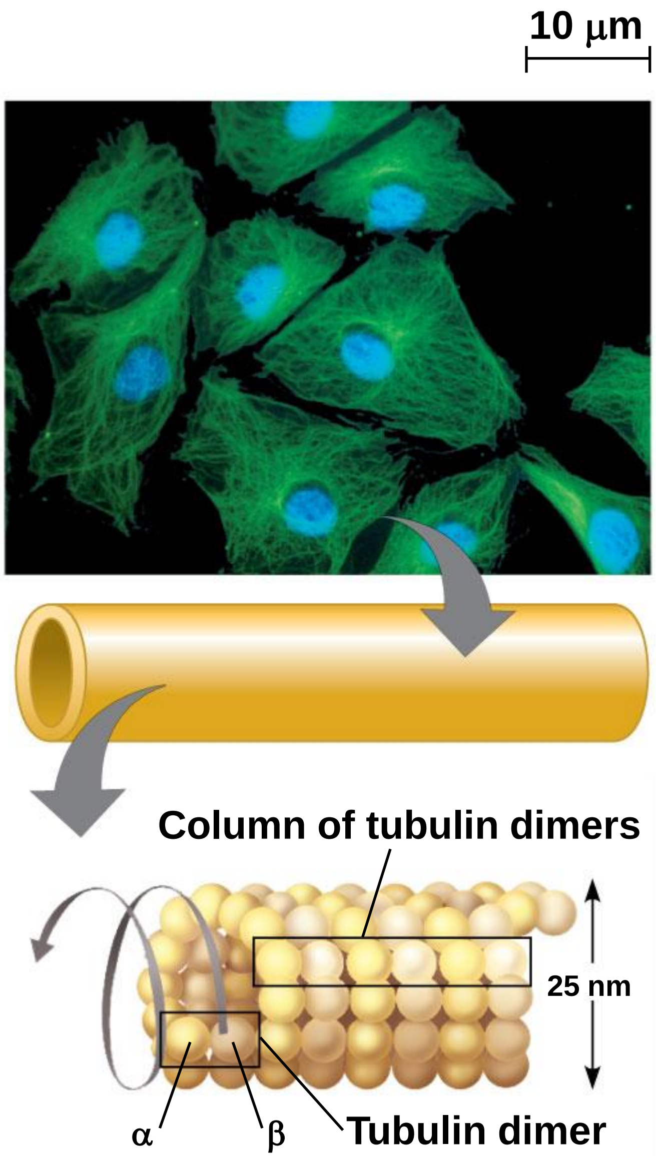


Table 6.1aa

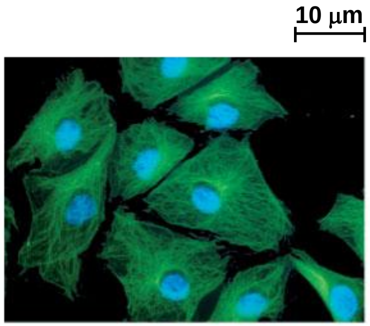


Table 6.1b

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)

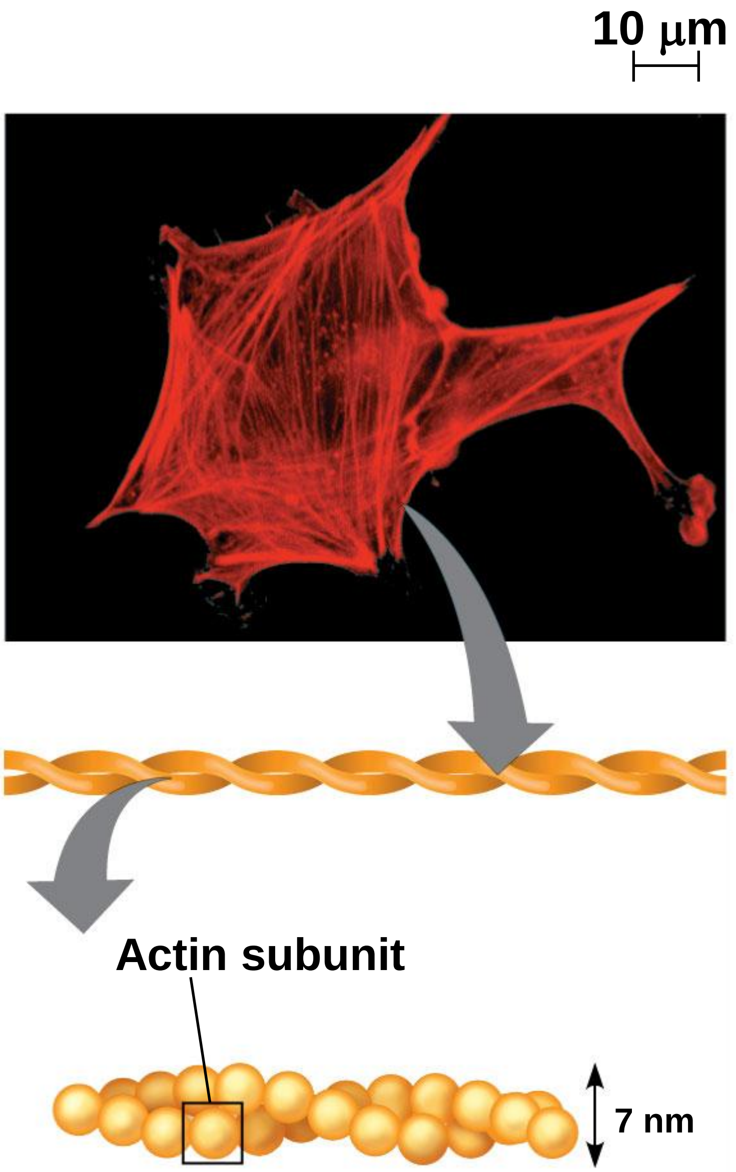


Table 6.1bb

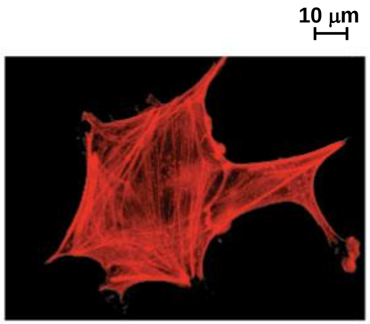


Table 6.1c

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

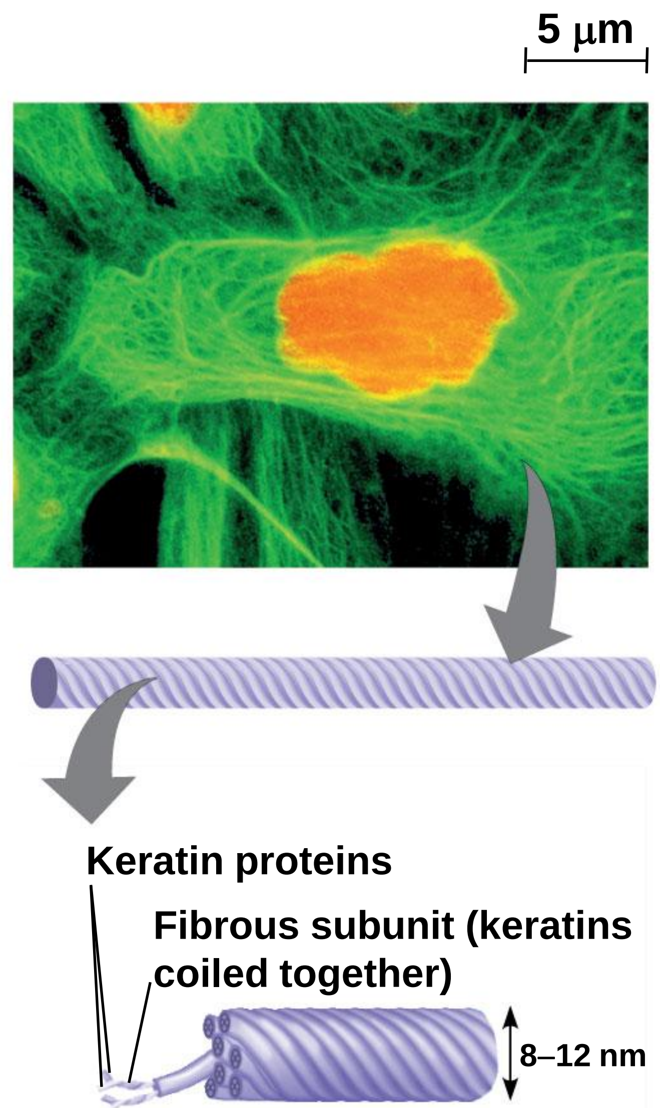
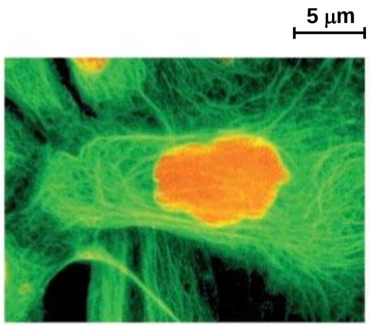


Table 6.1cc



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

Figure 6.22

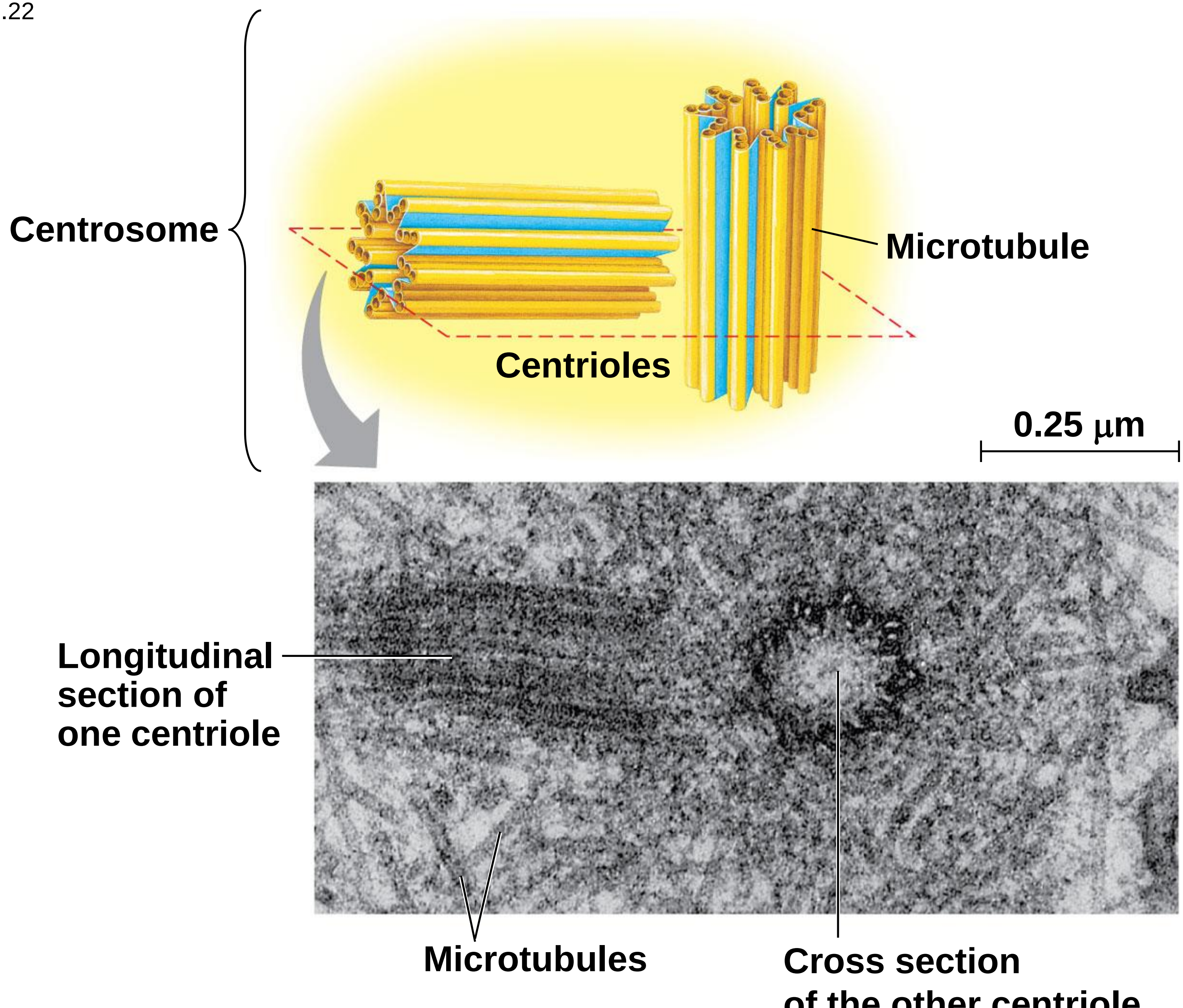
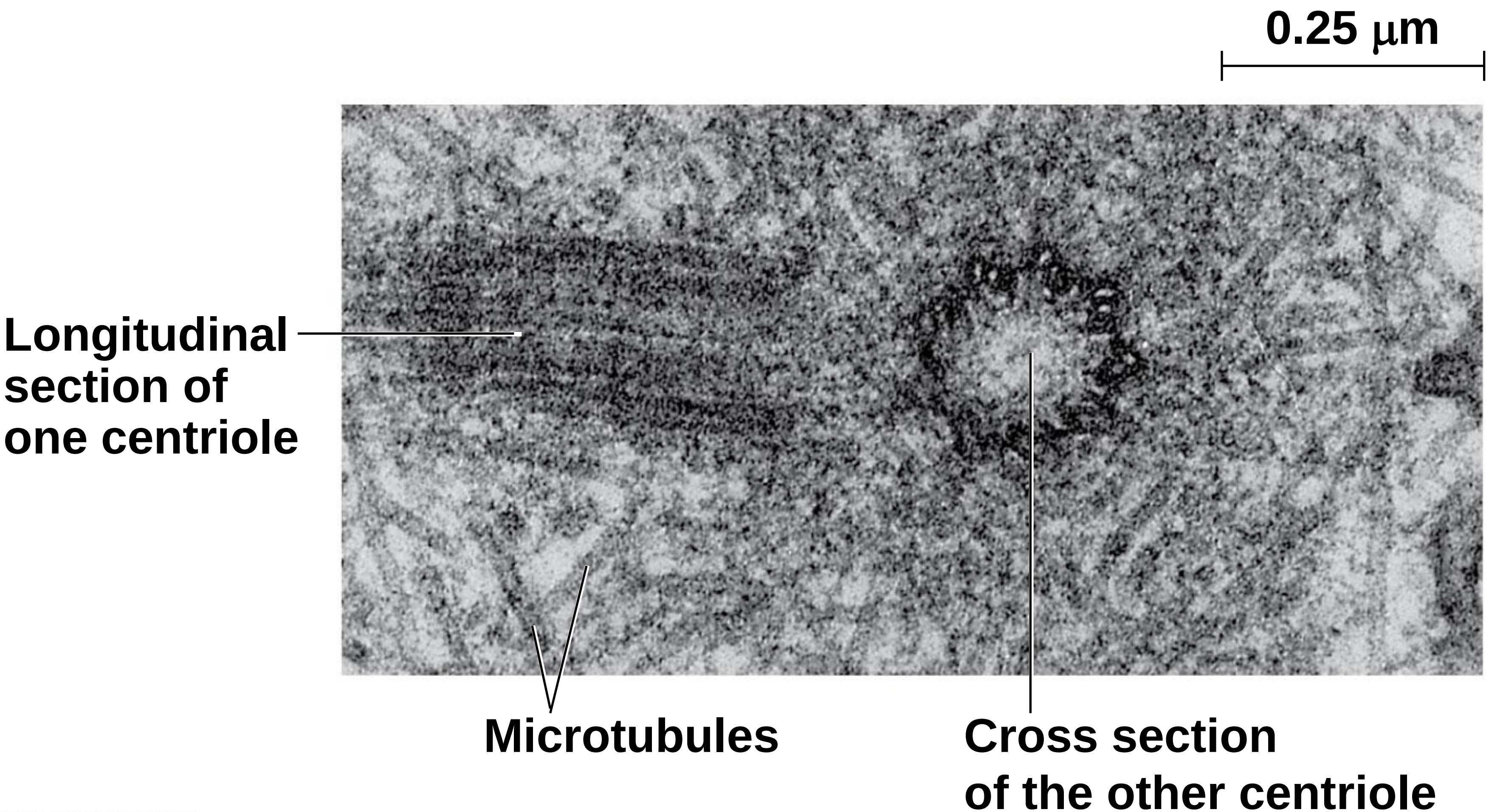

Centrosome
Microtubule
Centrioles
0.25 μm
Longitudinal section of one centriole
Microtubules
Cross section of the other centriole

Figure 6.22a

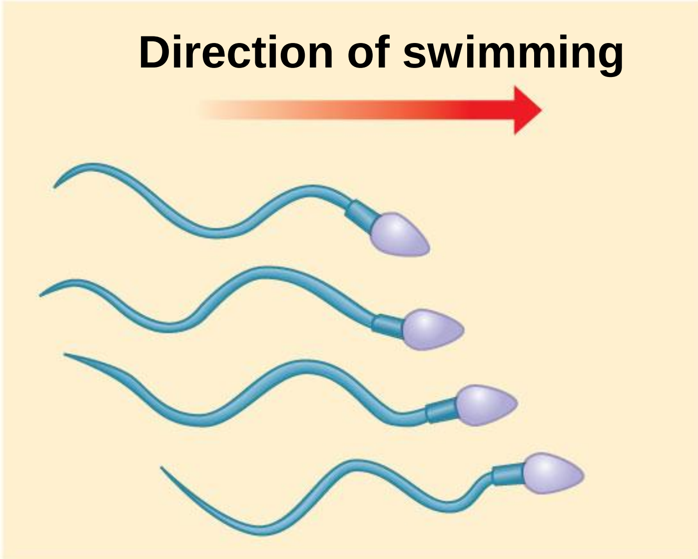


0.25 µm
Longitudinal section of one centriole
Microtubules
Cross section of the other centriole

Cilia and Flagella

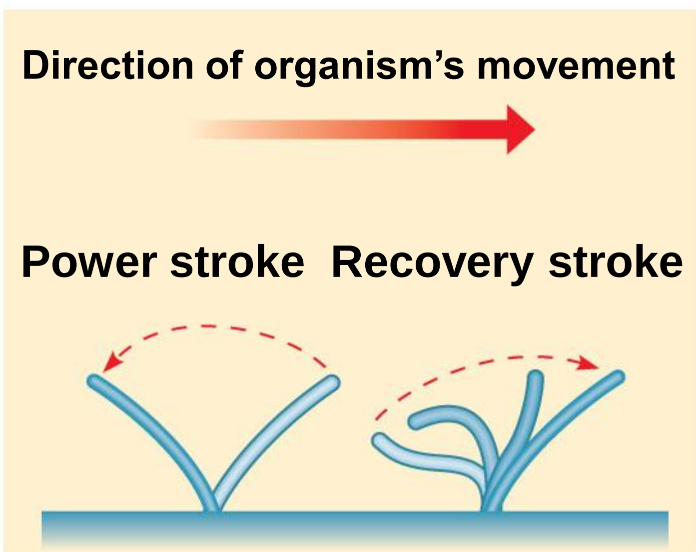
- Microtubules control the beating of **cilia** and **flagella**, locomotor appendages of some cells
- Cilia and flagella differ in their beating patterns

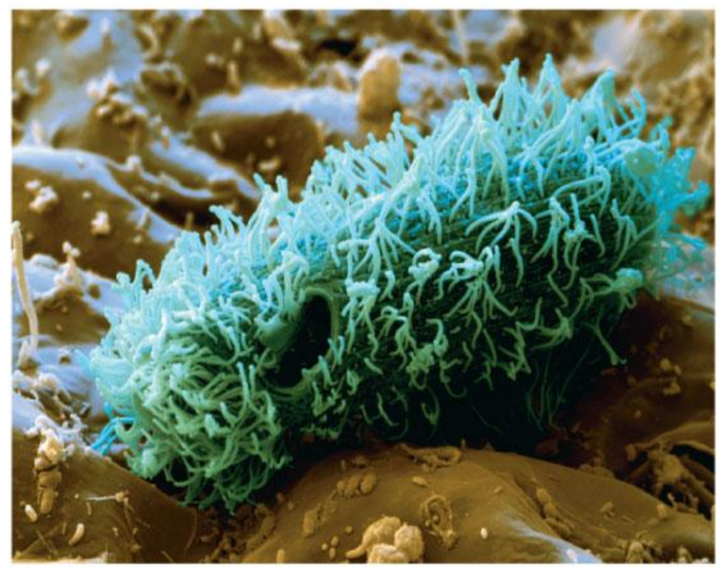
Figure 6.23



5 µm

(a) Motion of flagella



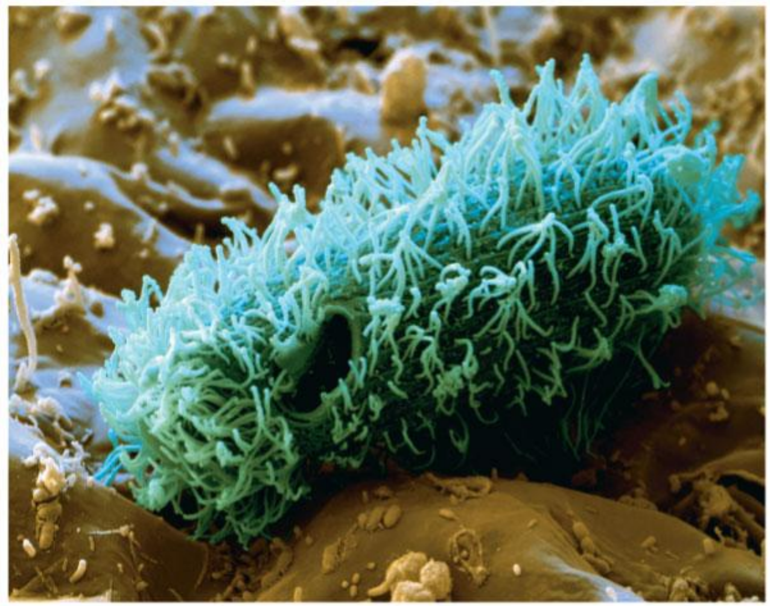


15 µm

(b) Motion of cilia

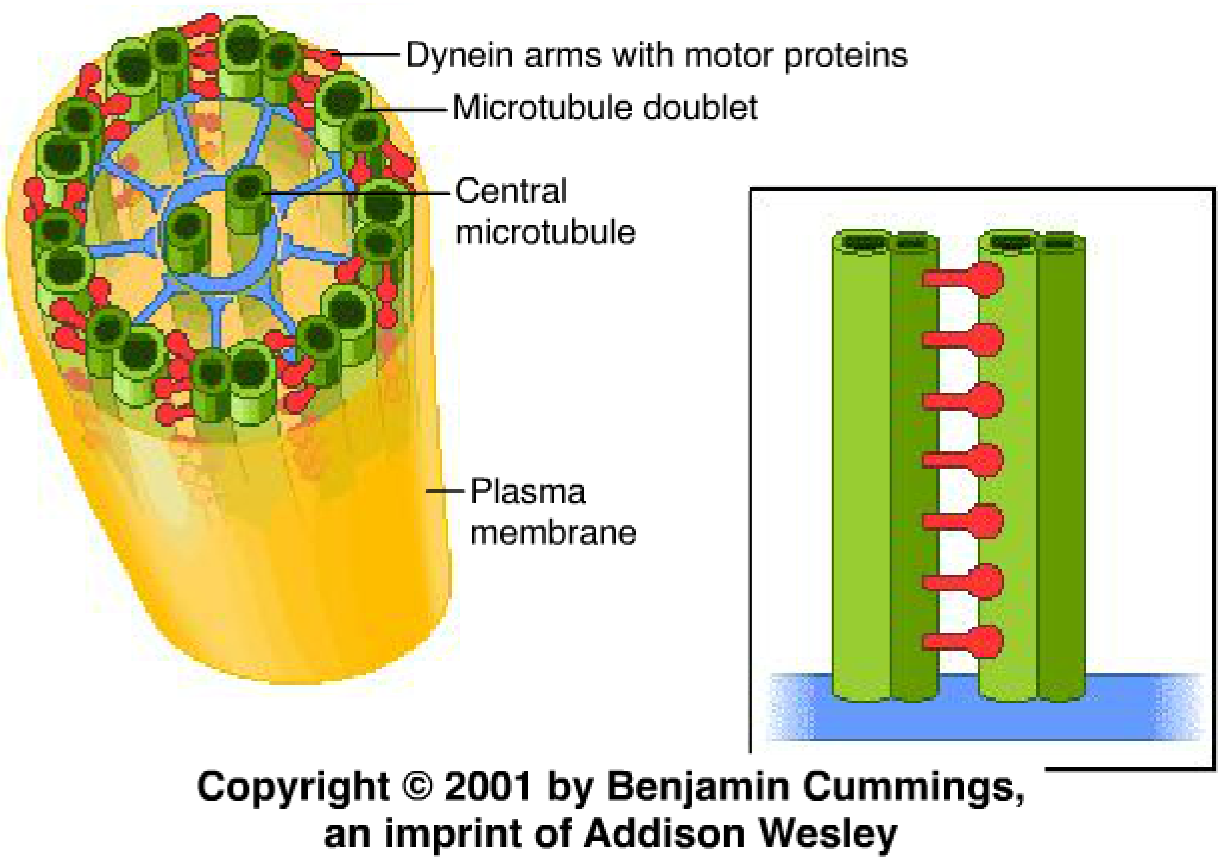
Figure 6.23a

Figure 6.23b



15 μm

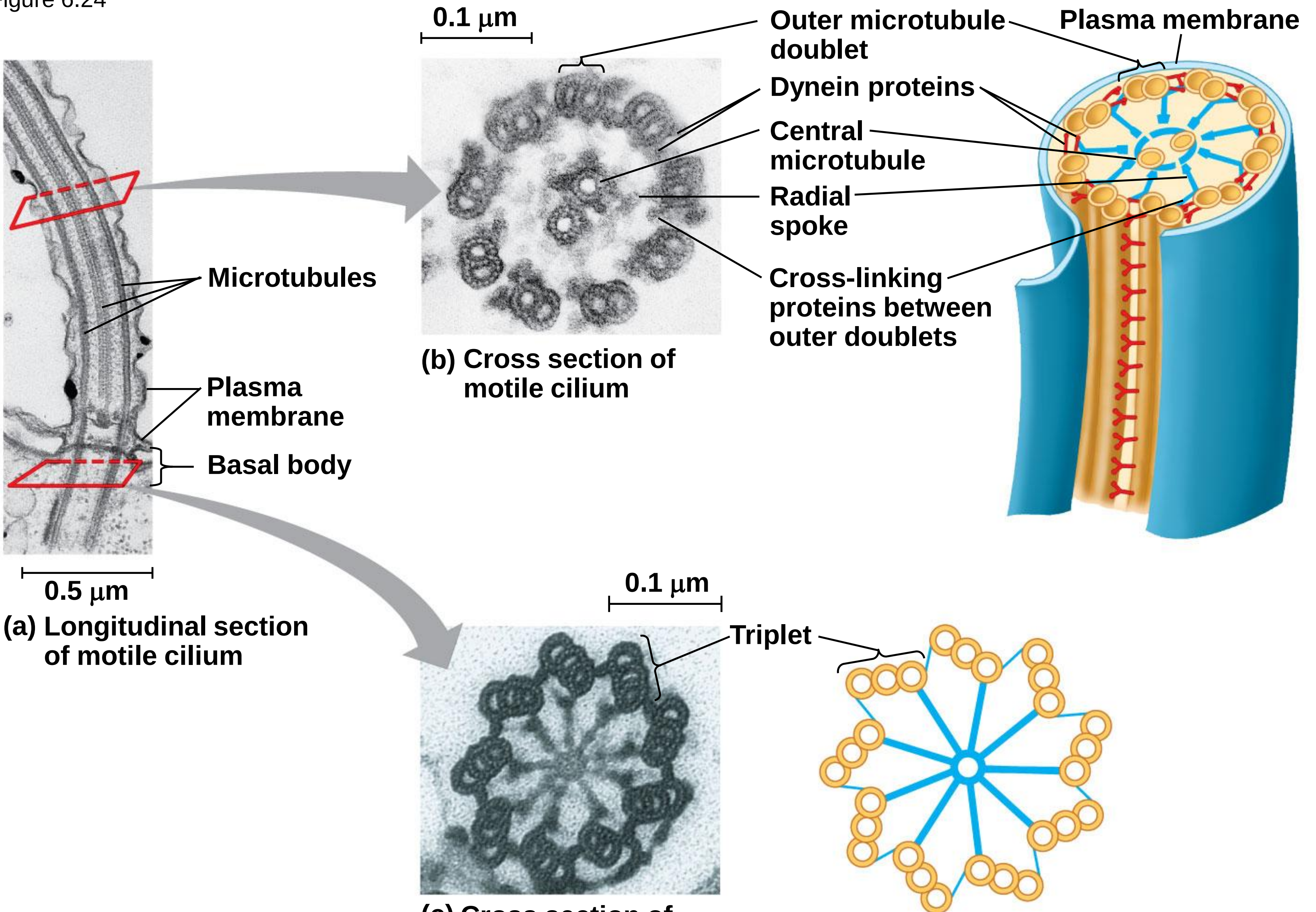
- Cilia and flagella share a common structure
  – A core of microtubules sheathed by the plasma membrane
  – A **basal body** that anchors the cilium or flagellum
  – A motor protein called **dynein**, which drives the bending movements of a cilium or flagellum



Animation: Cilia and Flagella

Right-click slide / select “Play”

Figure 6.24

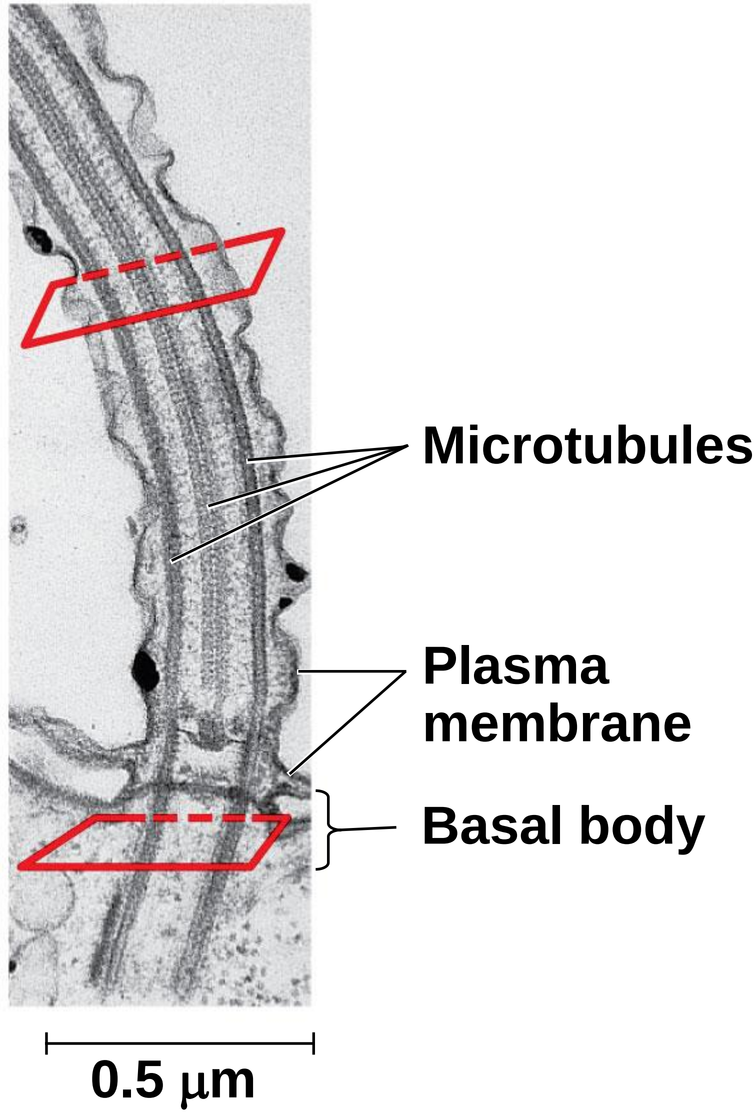


(a) Longitudinal section of motile cilium

(b) Cross section of motile cilium

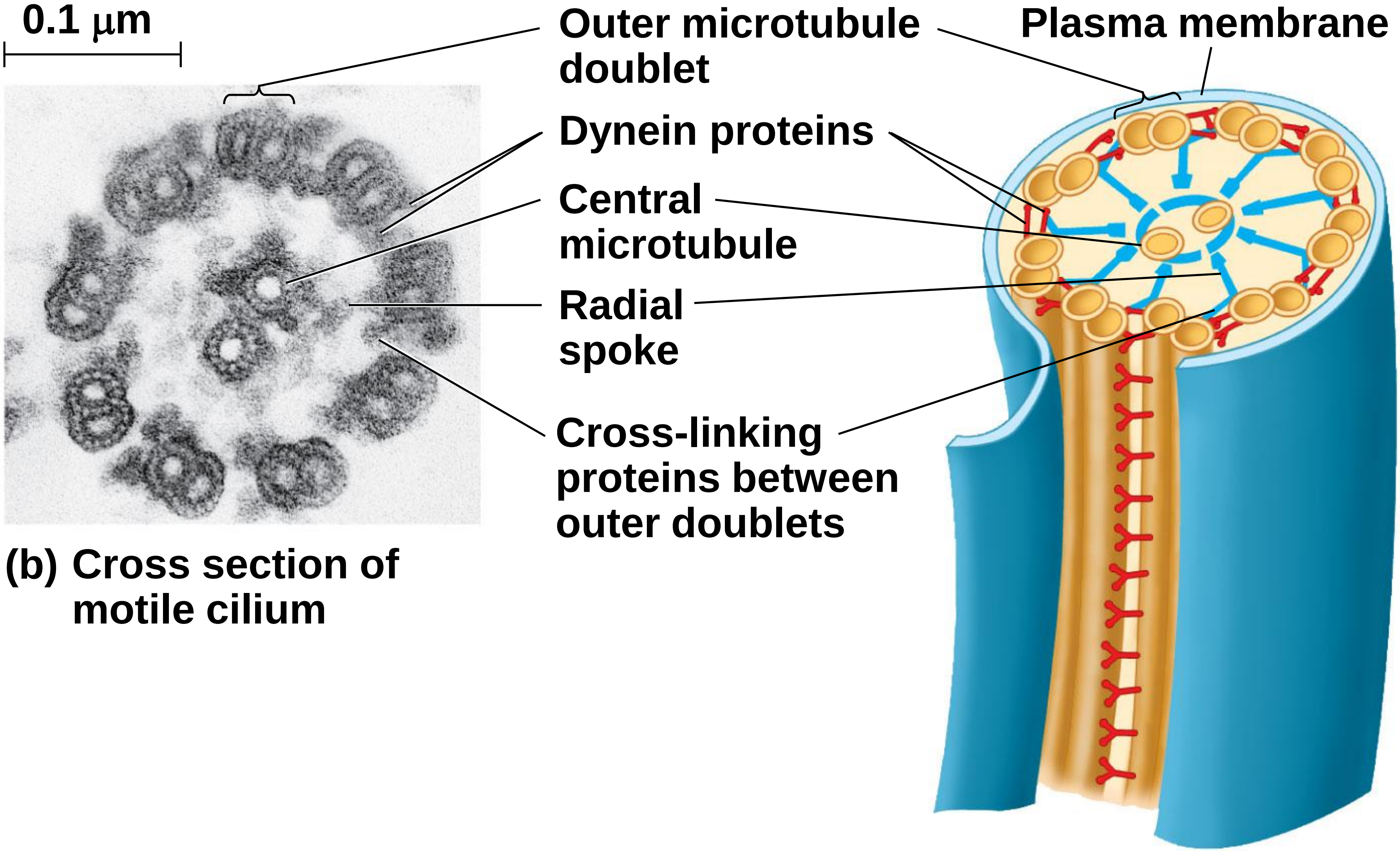
(c) Cross section of basal body

Figure 6.24a



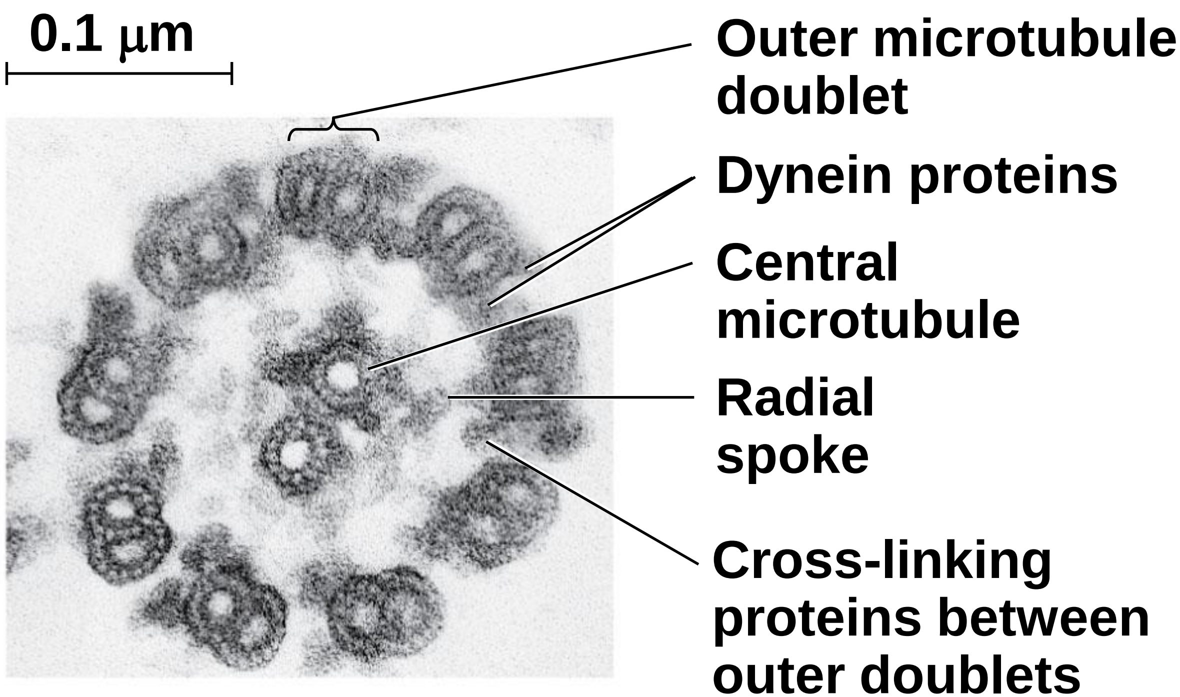
(a) Longitudinal section of motile cilium

Figure 6.24b



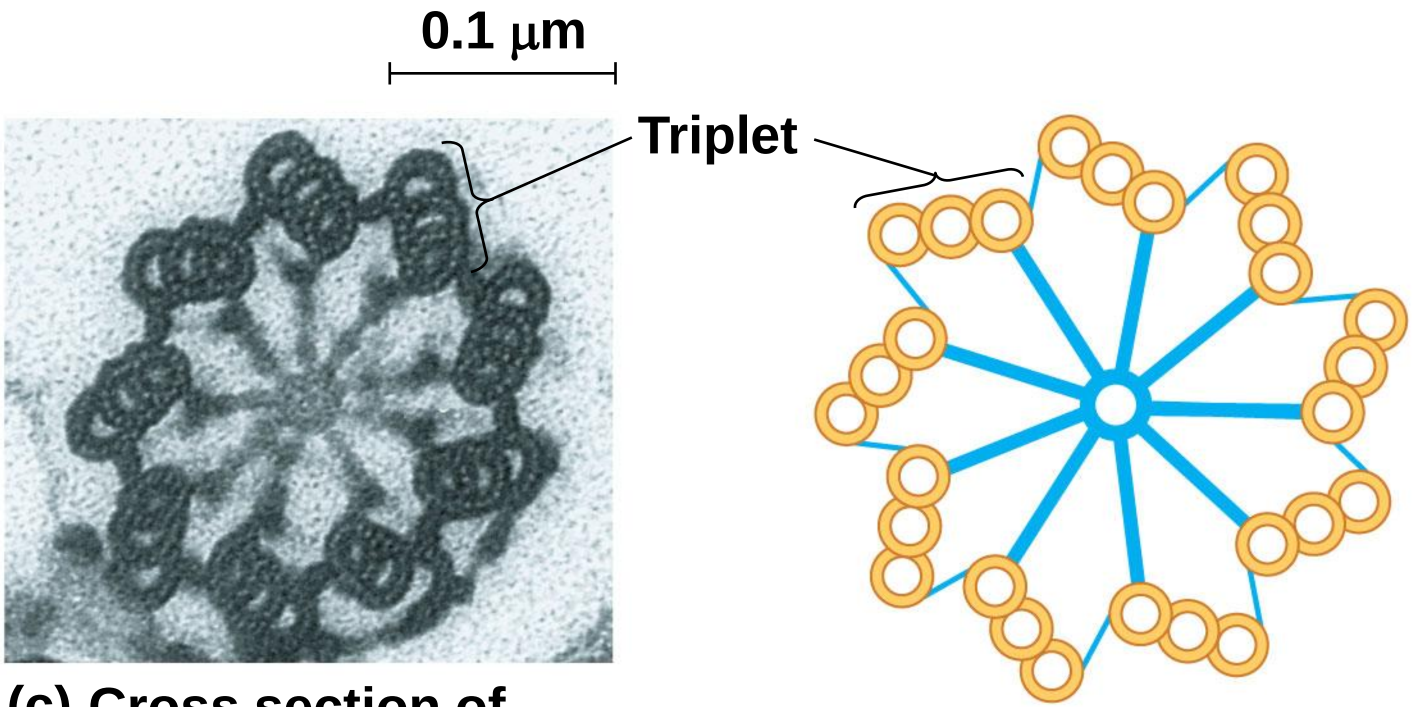
(b) Cross section of motile cilium

Figure 6.24ba



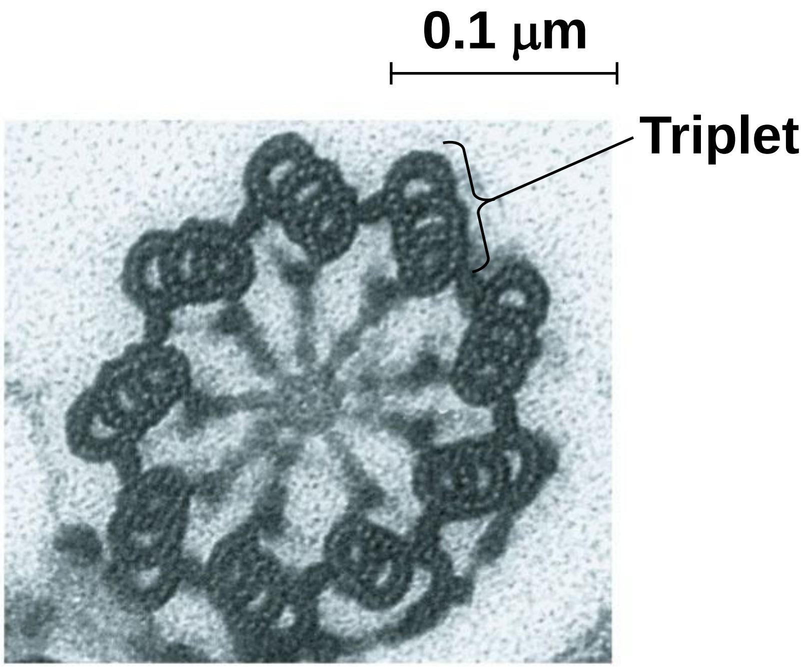
(b) Cross section of motile cilium

Figure 6.24c



(c) Cross section of basal body

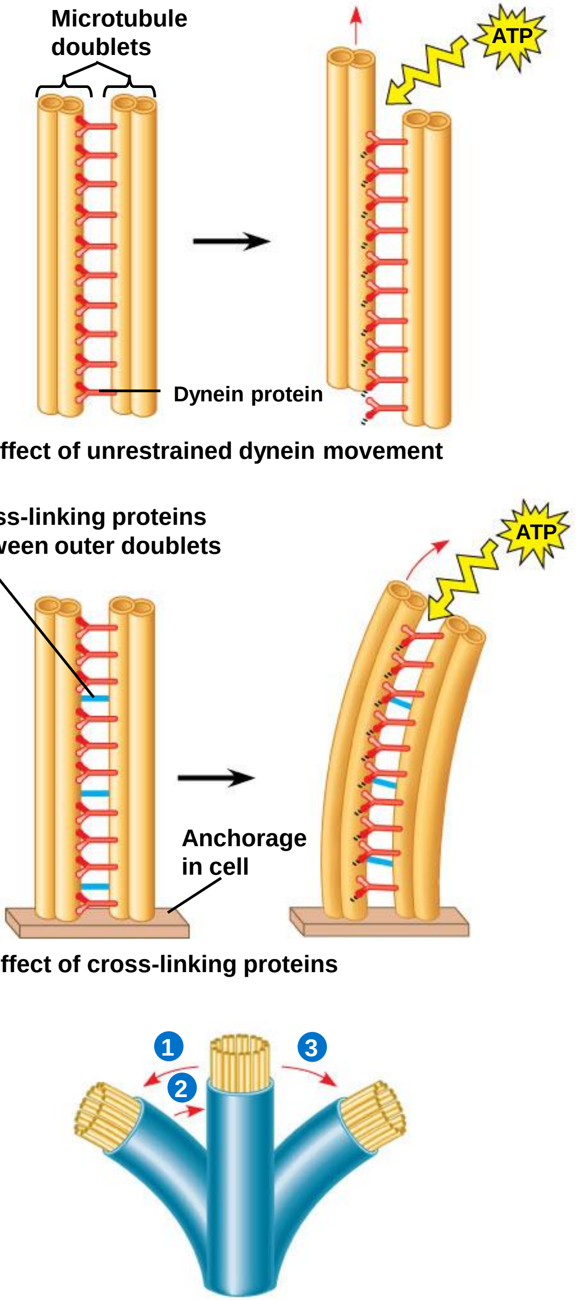
Figure 6.24ca



(c) Cross section of basal body

- 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

Figure 6.25

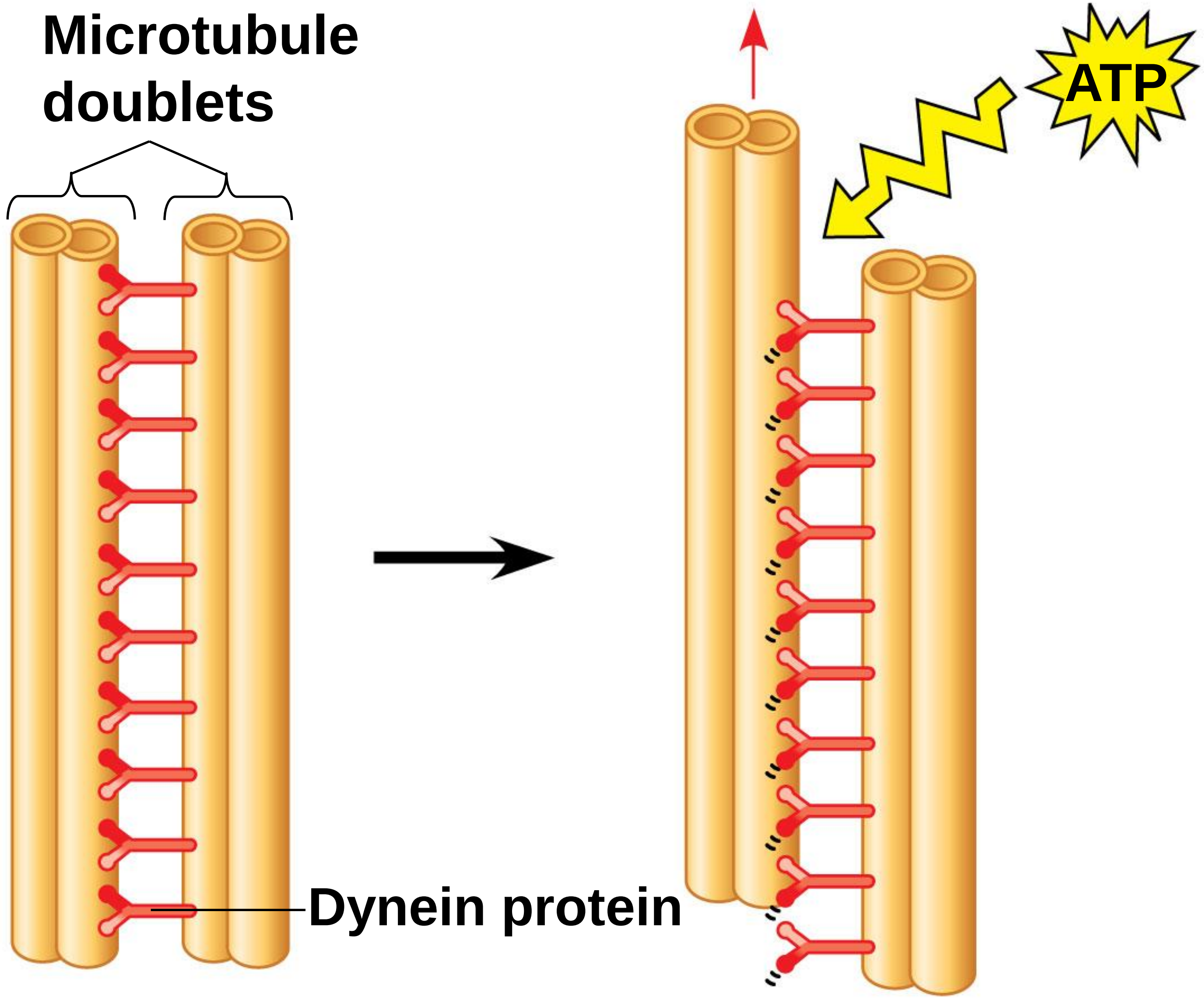


(a) Effect of unrestrained dynein movement

(b) Effect of cross-linking proteins

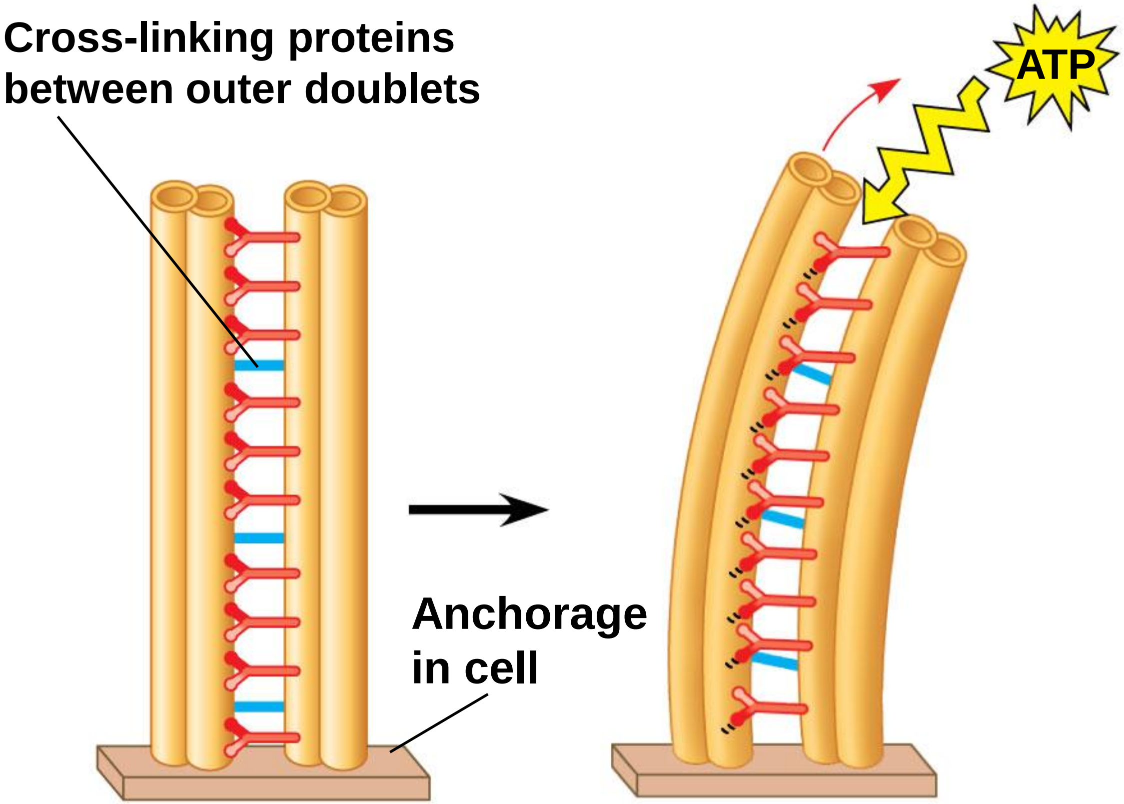
(c) Wavelike motion

Figure 6.25a

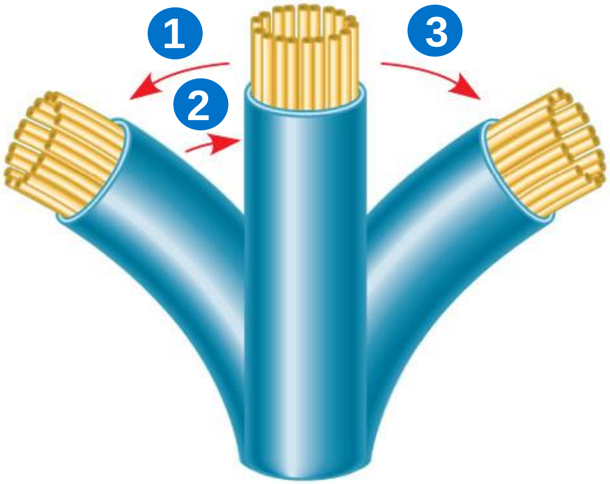


(a) Effect of unrestrained dynein movement

Figure 6.25b



(b) Effect of cross-linking proteins

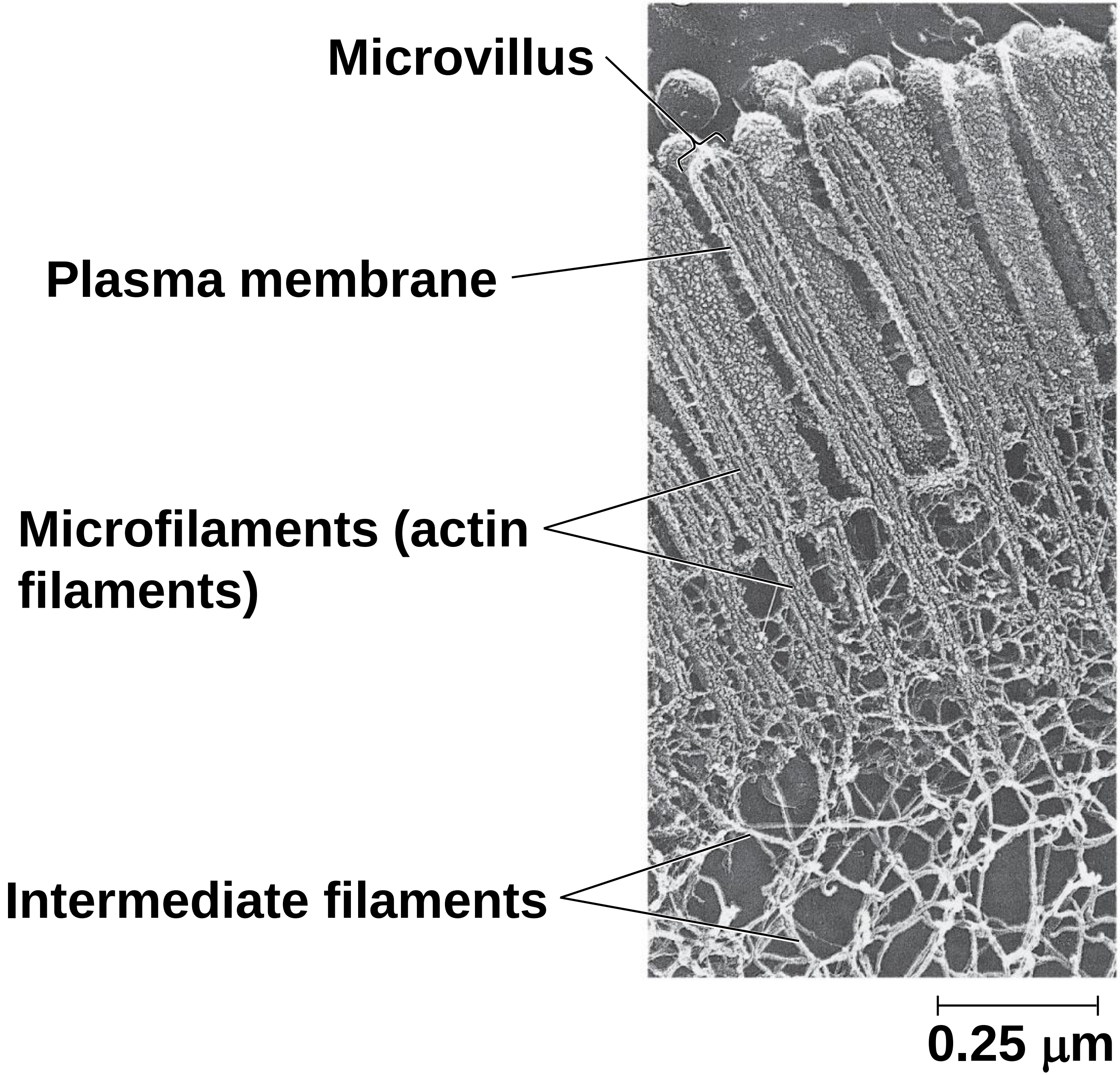


(c) Wavelike motion

Microfilaments (Actin Filaments)

- **Microfilaments** are solid rods about 7 nm in diameter, built as a twisted double chain of **actin** subunits
- The structural role of microfilaments is to bear tension, resisting pulling forces within the cell
- They form a 3-D network called the **cortex** just inside the plasma membrane to help support the cell’s shape
- Bundles of microfilaments make up the core of microvilli of intestinal cells

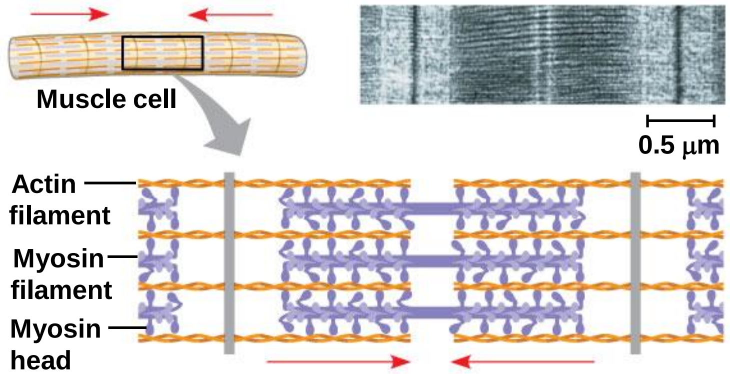
Figure 6.26



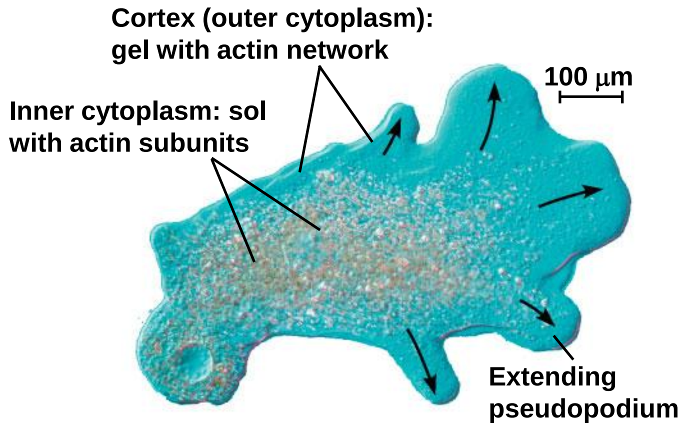
Microvillus
Plasma membrane
Microfilaments (actin filaments)
Intermediate filaments
0.25 µm

- 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

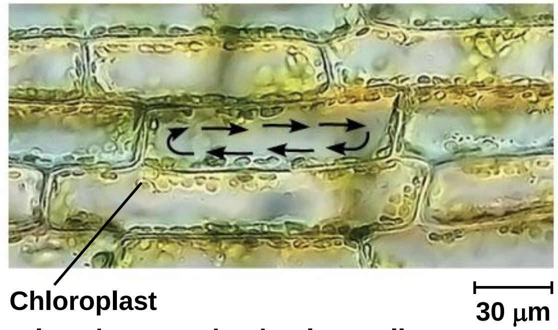
Figure 6.27



(a) Myosin motors in muscle cell contraction

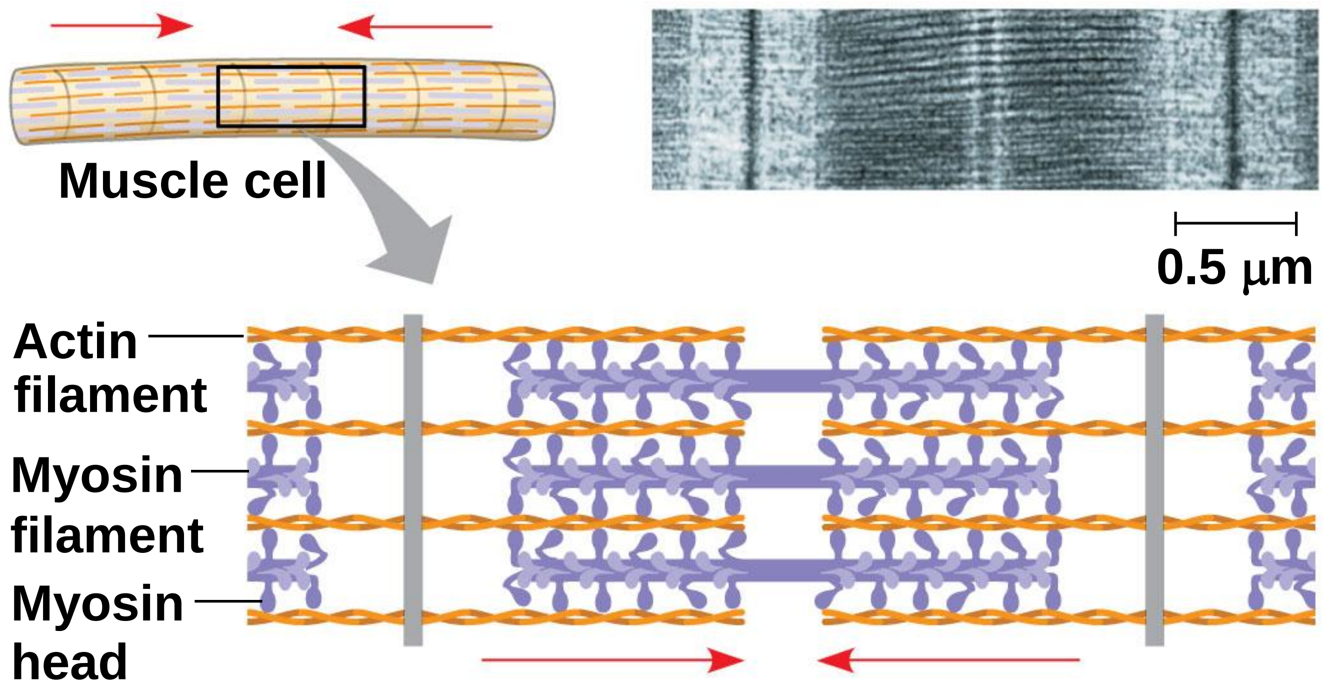


(b) Amoeboid movement



(c) Cytoplasmic streaming in plant cells

Figure 6.27a



(a) Myosin motors in muscle cell contraction

Figure 6.27aa

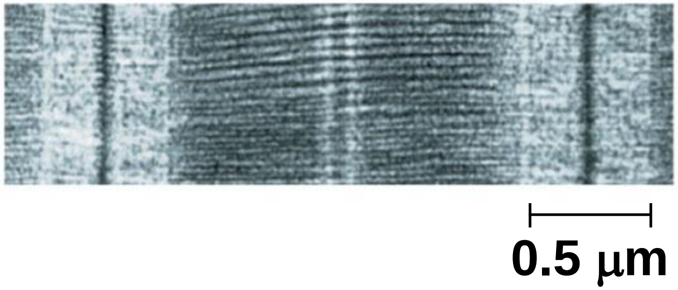
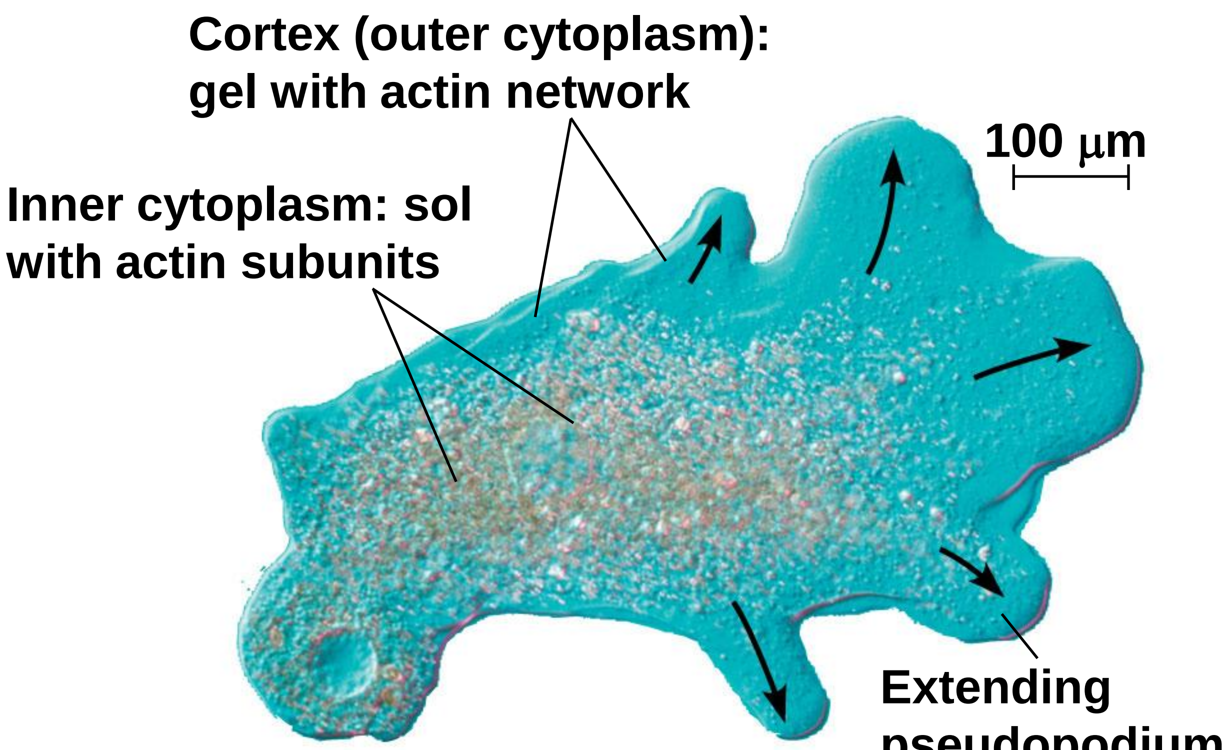
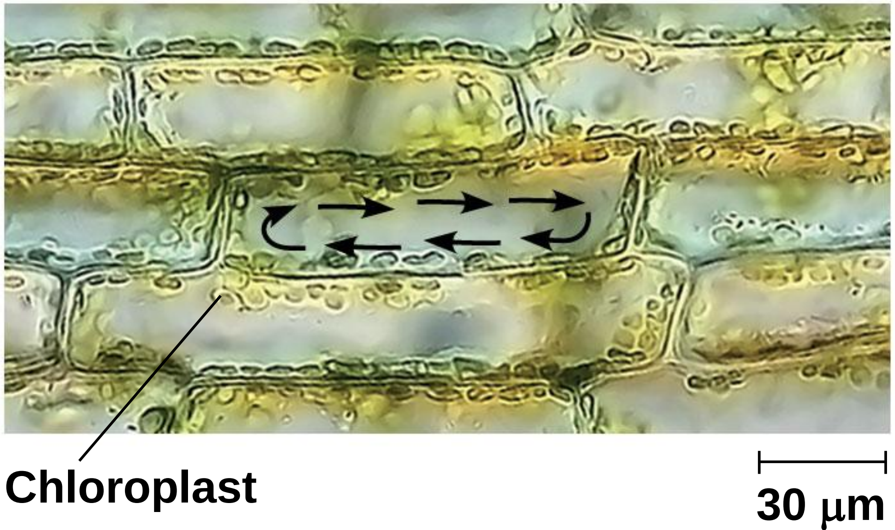


Figure 6.27b



(b) Amoeboid movement

Figure 6.27c



(c) Cytoplasmic streaming in plant cells

- Localized contraction brought about by actin and myosin also drives amoeboid movement
- **Pseudopodia** (cellular extensions) extend and contract through the reversible assembly and contraction of actin subunits into microfilaments

- **Cytoplasmic streaming** is a circular flow of cytoplasm within cells
- This streaming speeds distribution of materials within the cell
- In plant cells, actin-myosin interactions and sol-gel transformations drive cytoplasmic streaming

Intermediate Filaments

- **Intermediate filaments** range in diameter from 8–12 nanometers, larger than microfilaments but smaller than microtubules
- They support cell shape and fix organelles in place
- Intermediate filaments are more permanent cytoskeleton fixtures than the other two classes

Concept 6.7: Extracellular components and connections between cells help coordinate cellular activities

- Most cells synthesize and secrete materials that are external to the plasma membrane
- These extracellular structures include
  - Cell walls of plants
  - The extracellular matrix (ECM) of animal cells
  - Intercellular junctions

Cell Walls of Plants

- 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 fibers embedded in other polysaccharides and protein

- 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

Figure 6.28

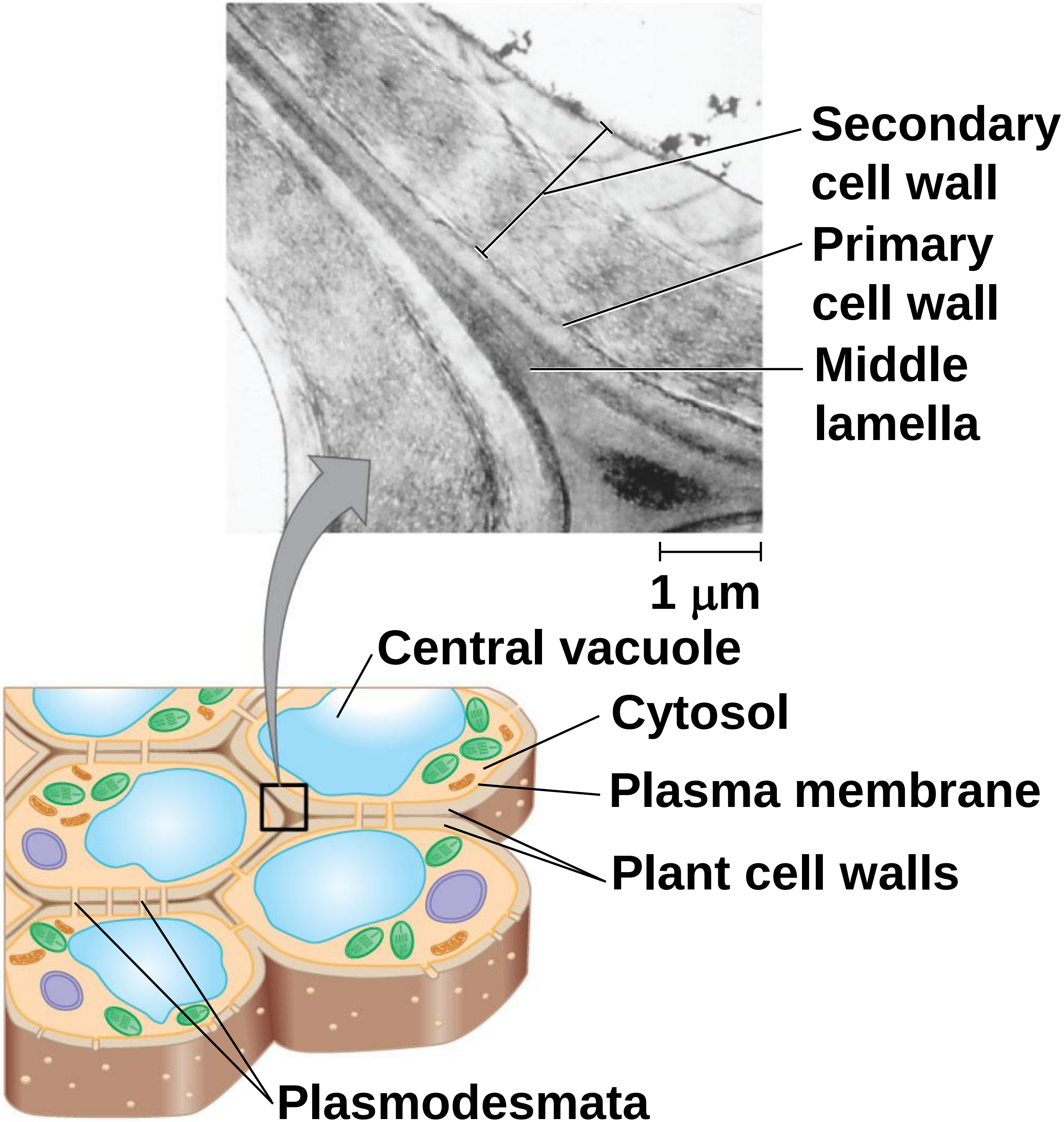

Secondary cell wall
Primary cell wall
Middle lamella
1 μm
Central vacuole
Cytosol
Plasma membrane
Plant cell walls
Plasmodesmata

Figure 6.28a

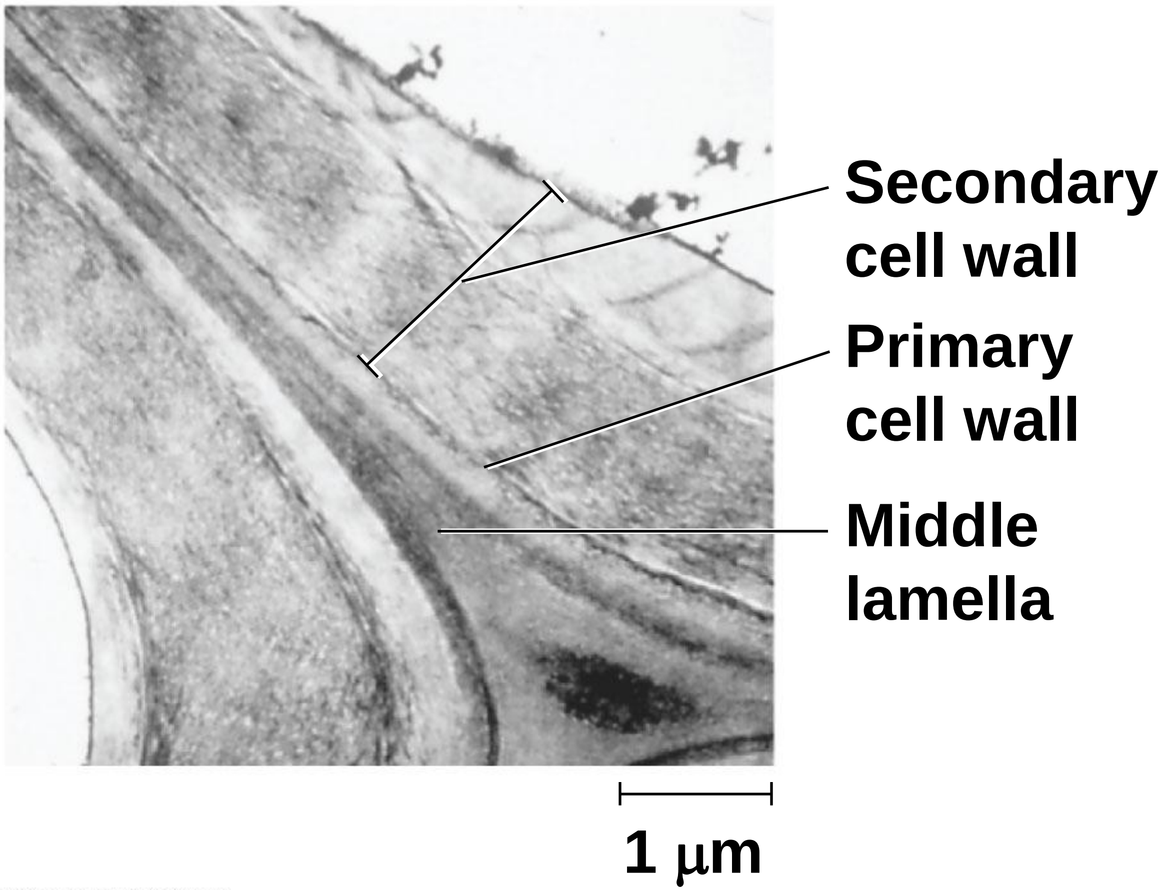
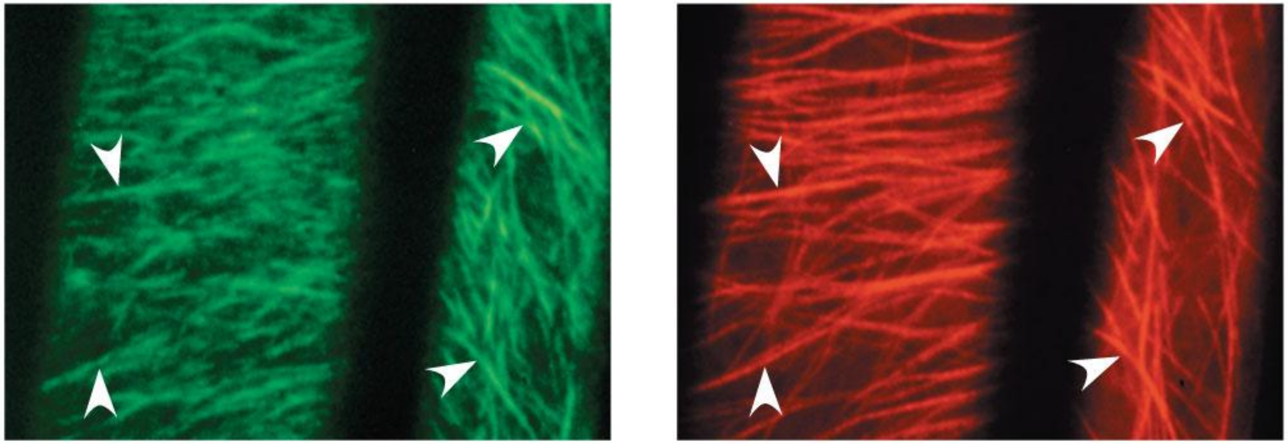


Figure 6.29

RESULTS

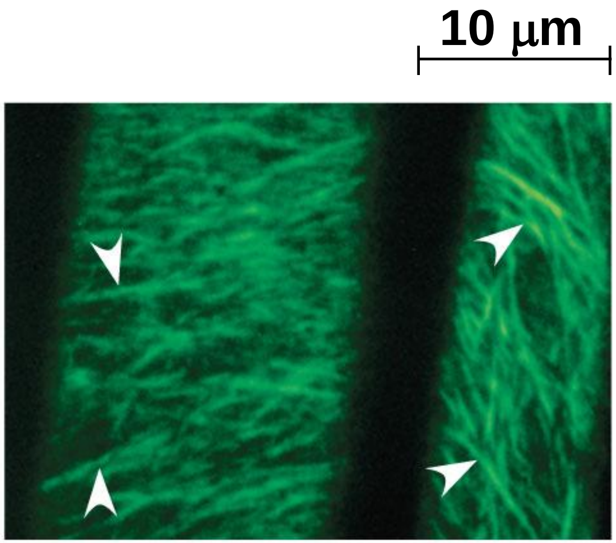
10 μm



Distribution of cellulose synthase over time

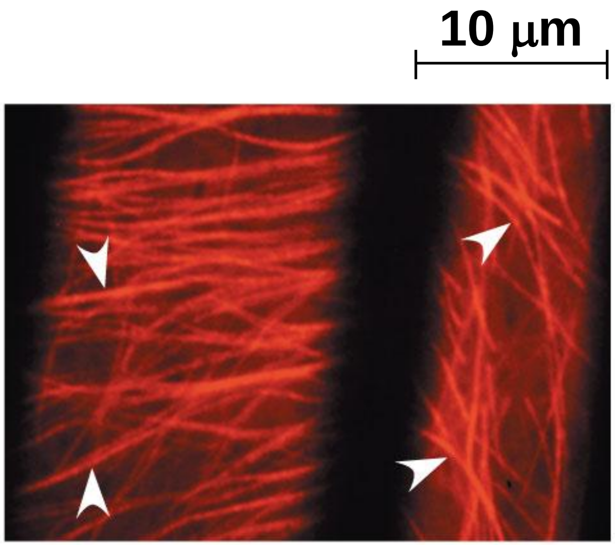
Distribution of microtubules over time

Figure 6.29a



Distribution of cellulose synthase over time

Figure 6.29b

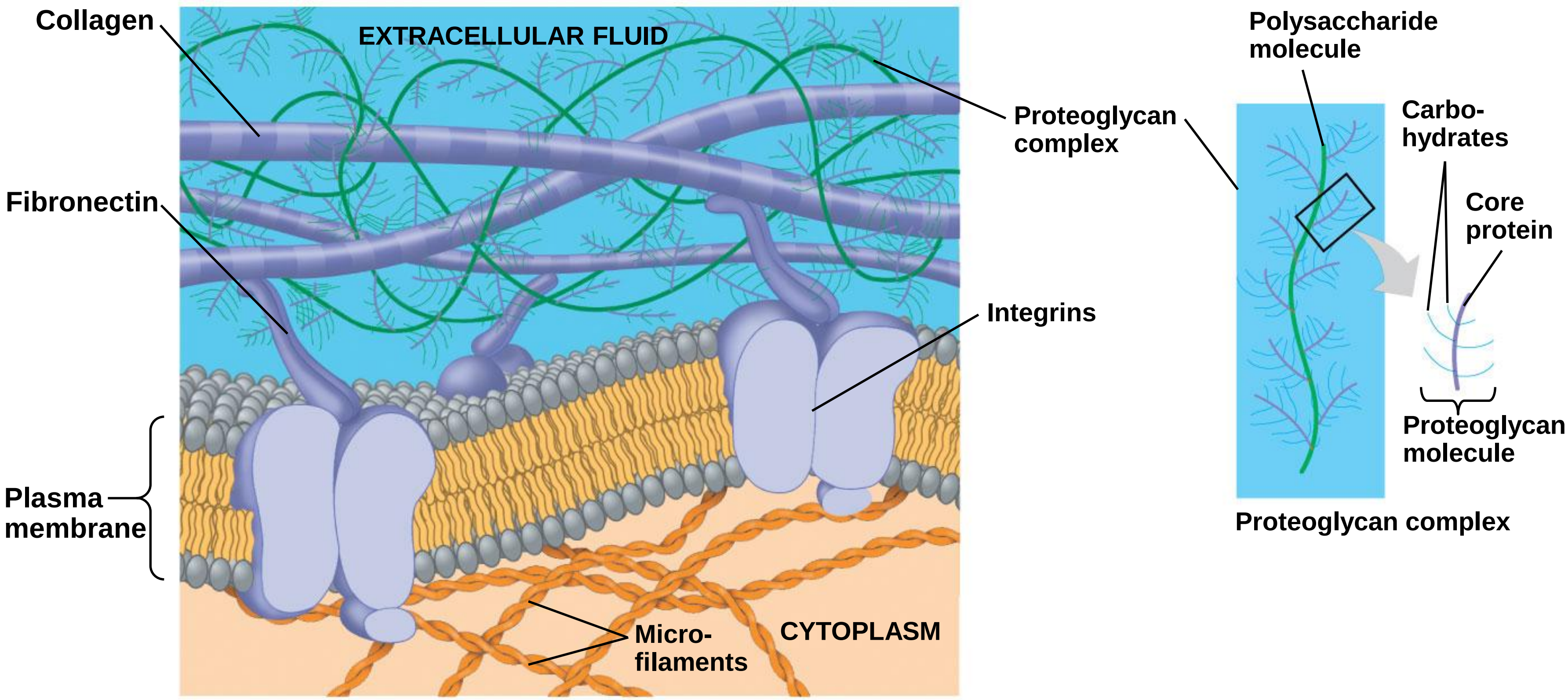


Distribution of
microtubules
over time

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 6.30



Collagen
EXTRACELLULAR FLUID
Proteoglycan complex
Fibronectin
Integrins
Plasma membrane
Micro-filaments
CYTOPLASM
Polysaccharide molecule
Carbo-hydrates
Core protein
Proteoglycan molecule
Proteoglycan complex

Figure 6.30a

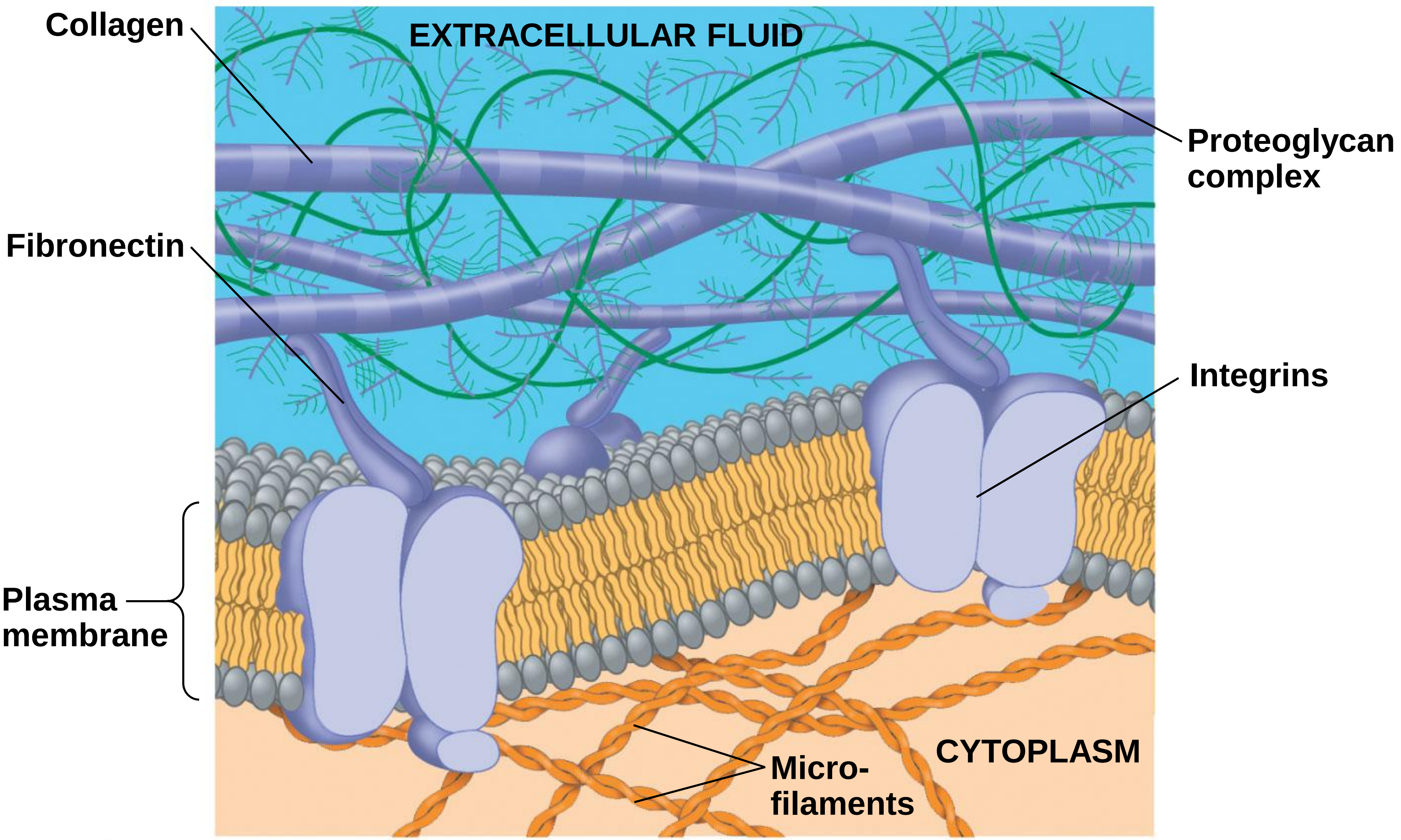
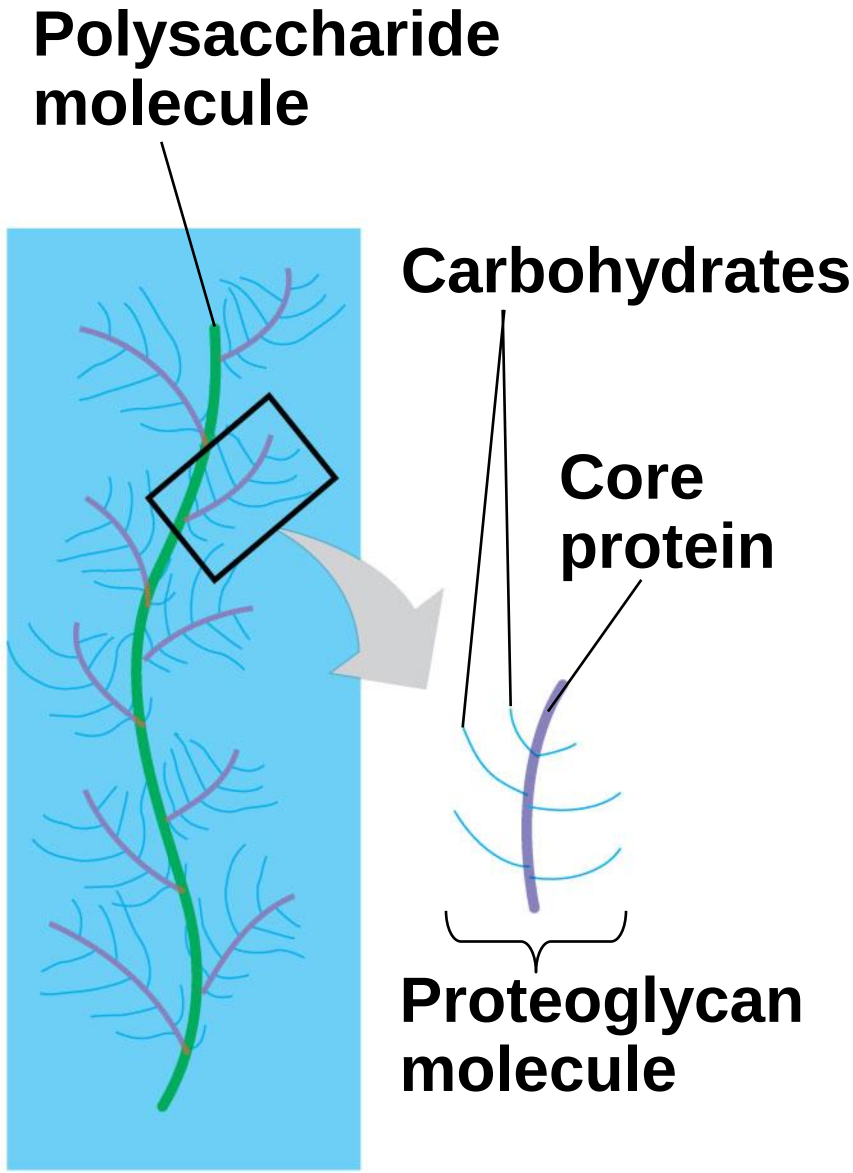

Collagen
EXTRACELLULAR FLUID
Proteoglycan complex
Fibronectin
Integrins
Plasma membrane
Micro-filaments
CYTOPLASM

Figure 6.30b



Proteoglycan complex

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

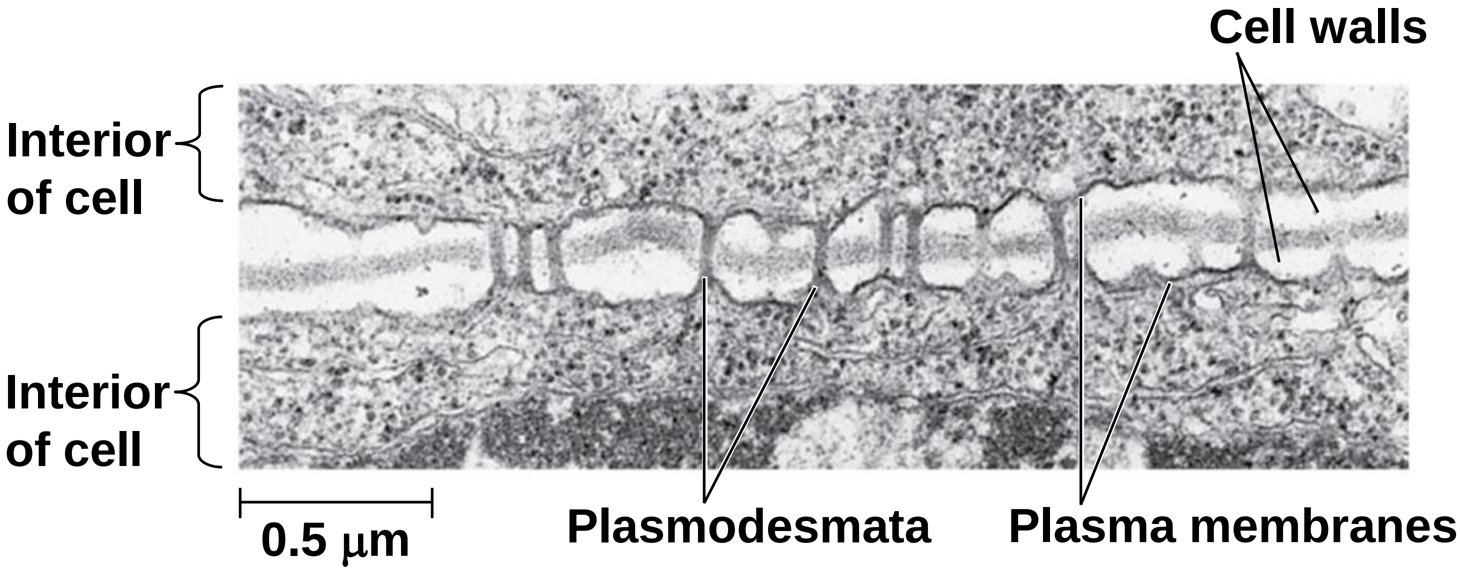
Cell Junctions

- 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

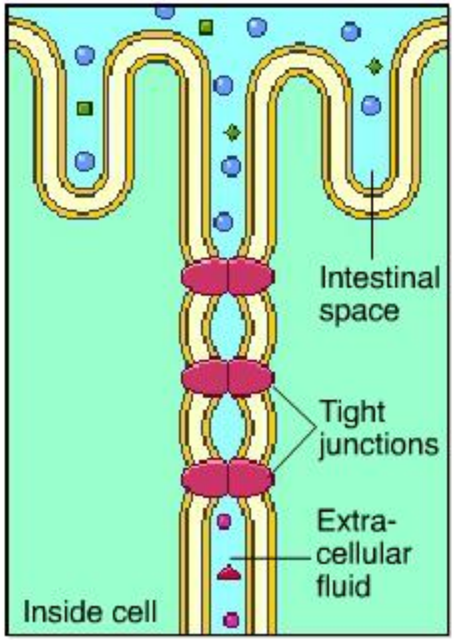
Figure 6.31



Cell walls
Interior of cell
Interior of cell
0.5 μm
Plasmodesmata
Plasma membranes

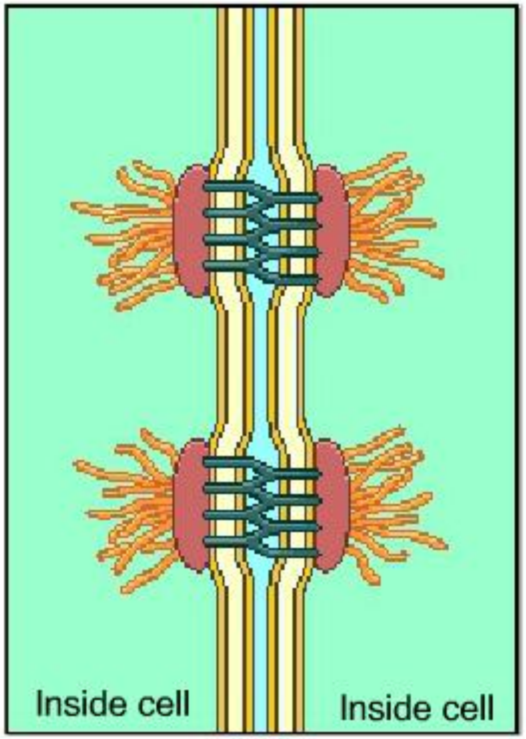
Tight Junctions, Desmosomes, and Gap Junctions in Animal Cells

- 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

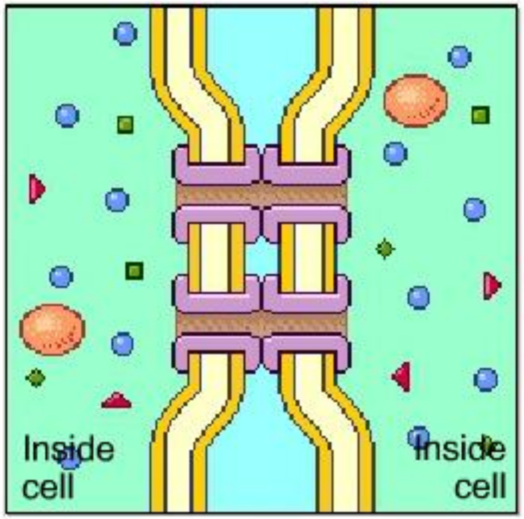


Animation: Tight Junctions

Right-click slide / select “Play”

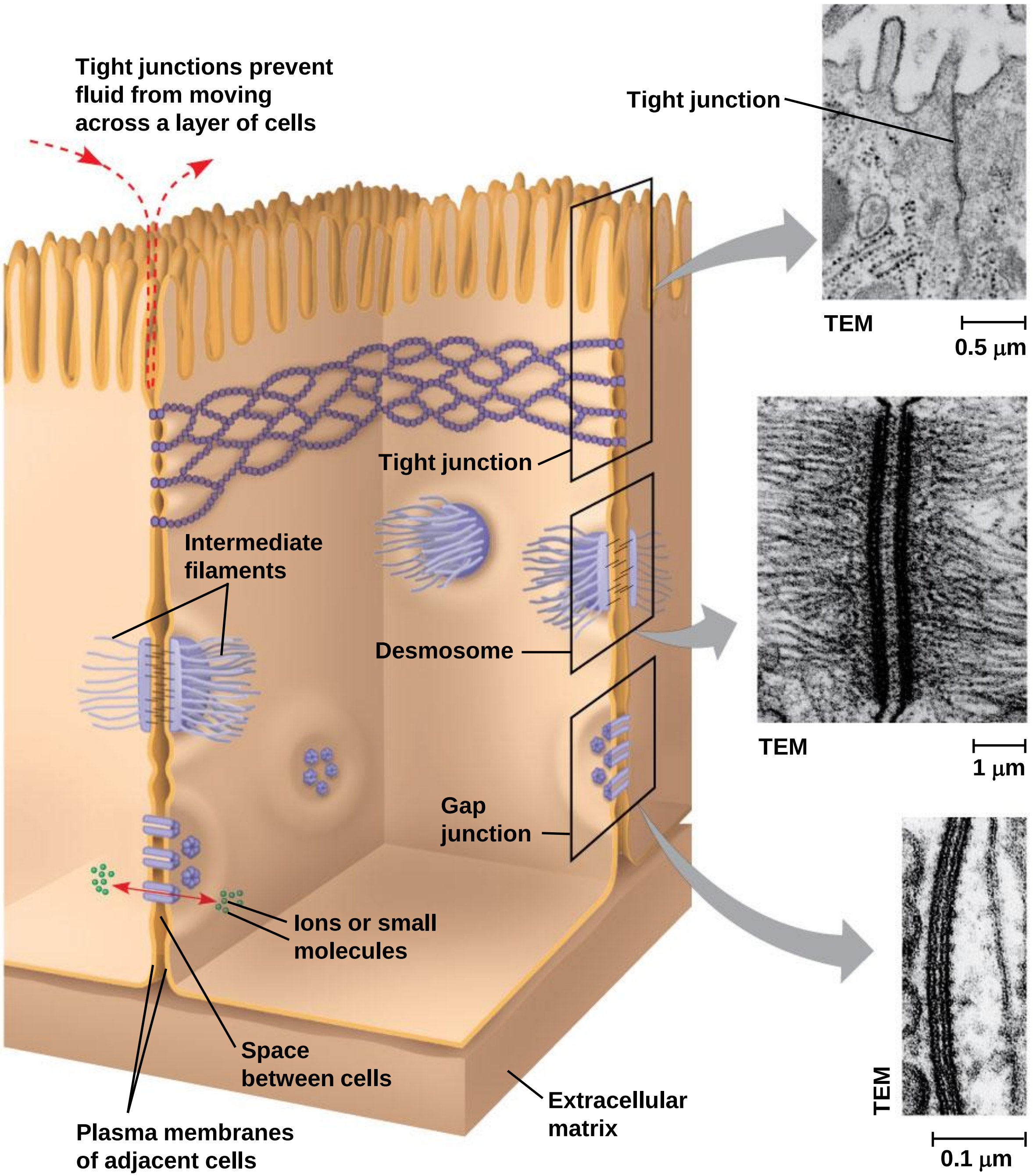


Animation: Desmosomes
Right-click slide / select “Play”



Animation: Gap Junctions
Right-click slide / select “Play”

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

Figure 6.32a

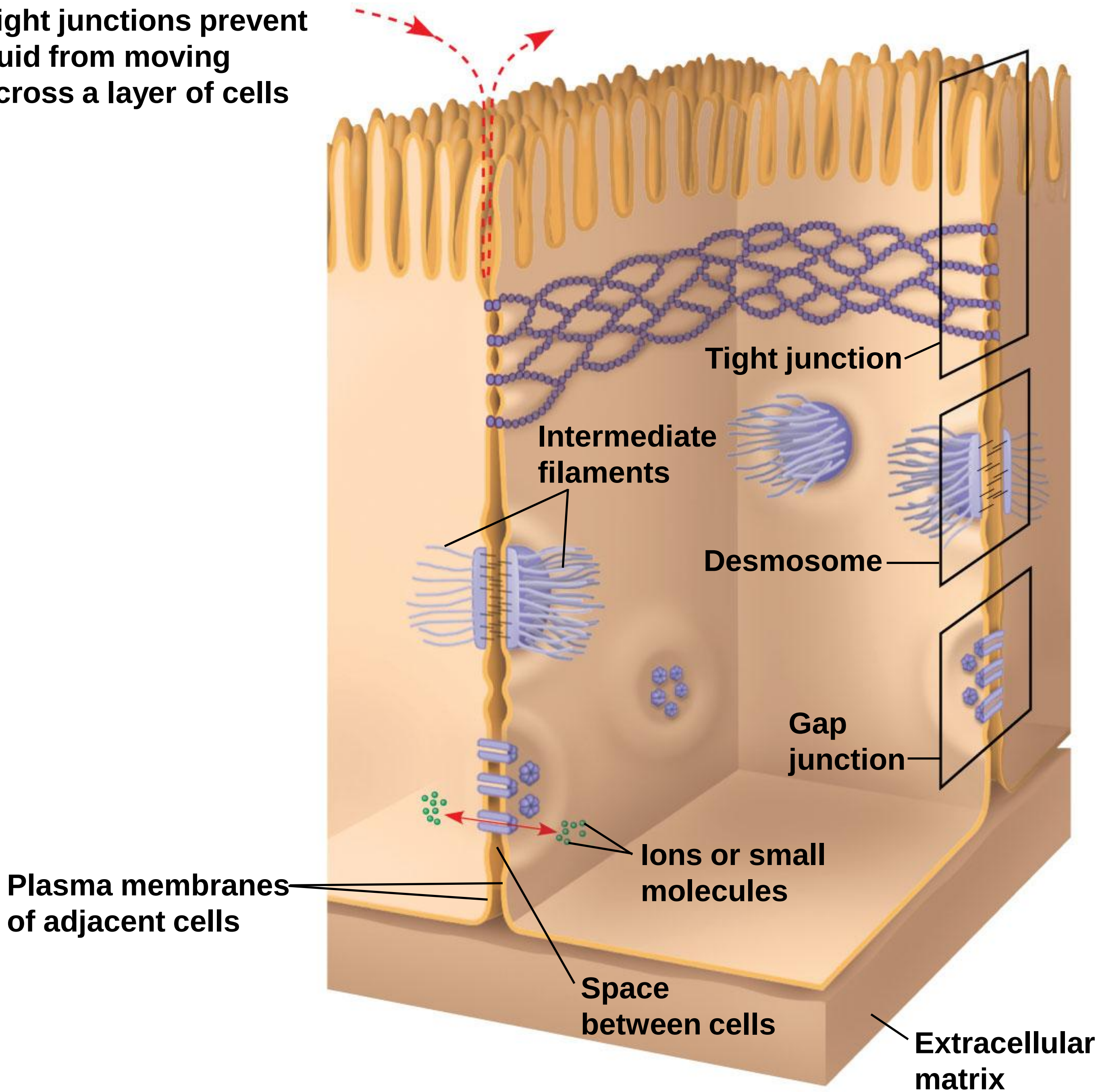

Tight junctions prevent fluid from moving across a layer of cells
Tight junction
Intermediate filaments
Desmosome
Gap junction
Ions or small molecules
Plasma membranes of adjacent cells
Space between cells
Extracellular matrix

Figure 6.32b

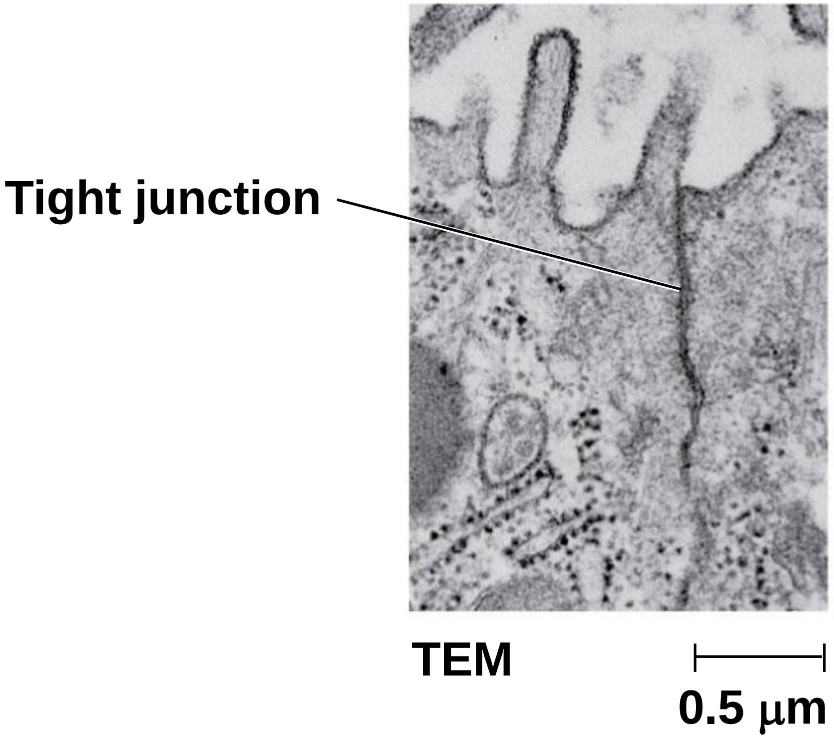


Figure 6.32c

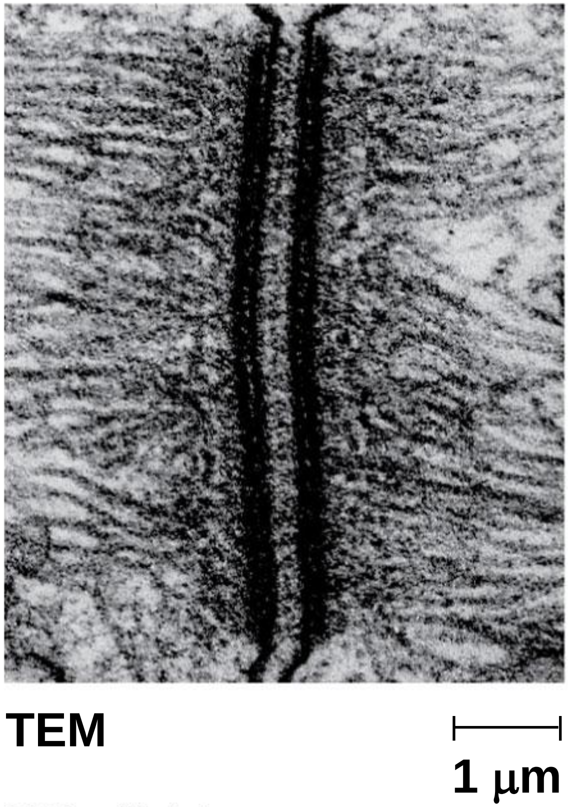


Figure 6.32d

TEM

0.1 μm

The Cell: A Living Unit Greater Than the Sum of Its Parts

- Cells rely on the integration of structures and organelles in order to function
- For example, a macrophage’s ability to destroy bacteria involves the whole cell, coordinating components such as the cytoskeleton, lysosomes, and plasma membrane

Figure 6.33

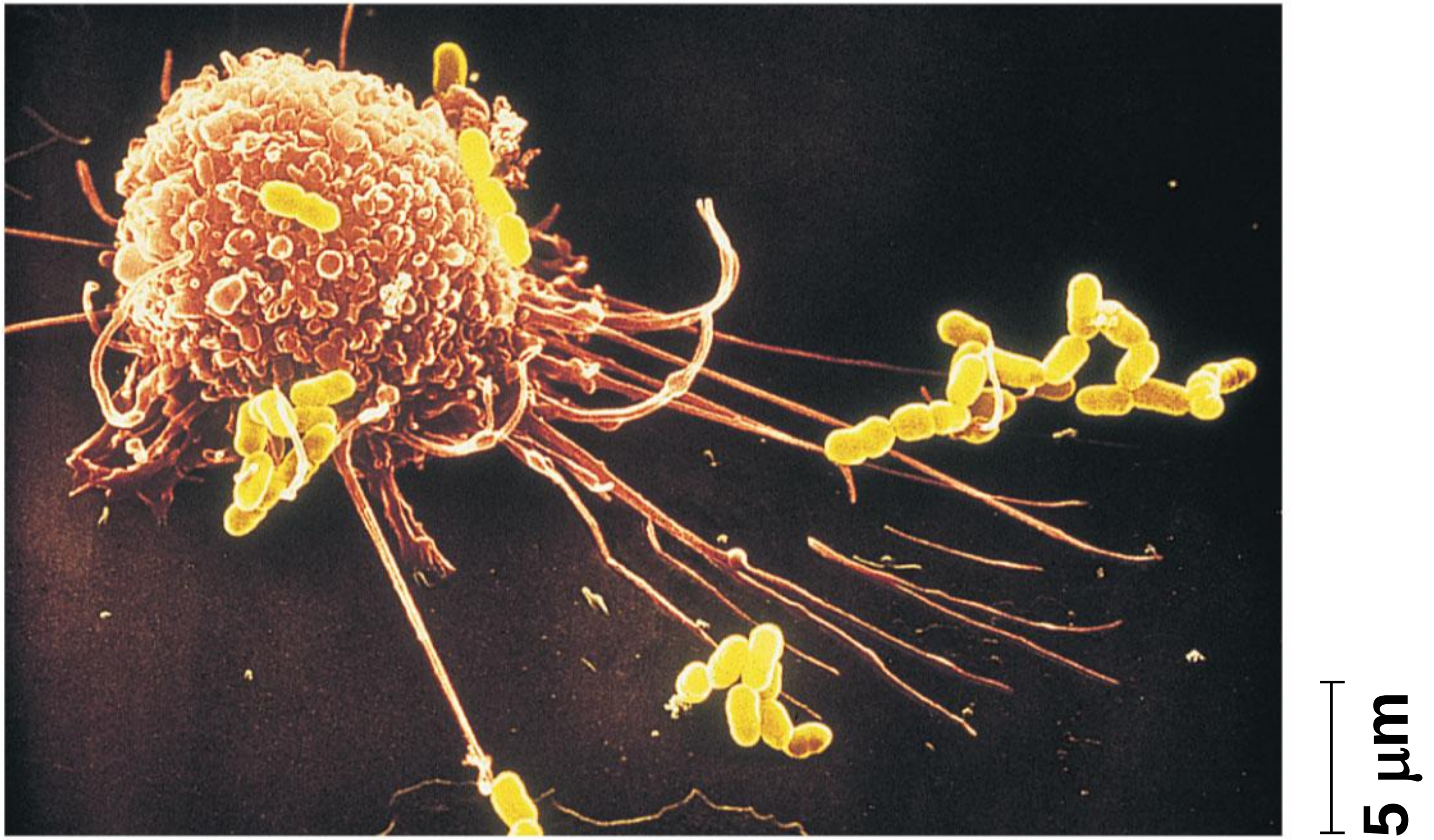


Figure 6.UN01

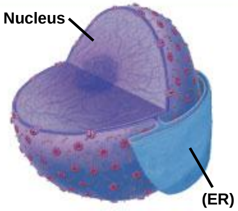
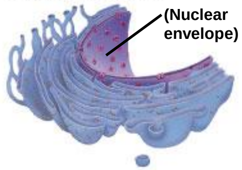
	Cell Component	Structure	Function
CONCEPT 6.3 The eukaryotic cell's genetic instructions are housed in the nucleus and carried out by the ribosomes		Surrounded by nuclear envelope (double membrane) perforated by nuclear pores; nuclear envelope continuous with endoplasmic reticulum (ER)	Houses chromosomes, which are made of chromatin (DNA and proteins); contains nucleoli, where ribosomal subunits are made; pores regulate entry and exit of materials
	Ribosome 	Two subunits made of ribosomal RNA and proteins; can be free in cytosol or bound to ER	Protein synthesis
CONCEPT 6.4 The endomembrane system regulates protein traffic and performs metabolic functions in the cell	Endoplasmic reticulum 	Extensive network of membrane-bounded tubules and sacs; membrane separates lumen from cytosol; continuous with nuclear envelope	Smooth ER: synthesis of lipids, metabolism of carbohydrates, Ca^{2+} storage, detoxification of drugs and poisons Rough ER: aids in synthesis of secretory and other proteins from bound ribosomes; adds carbohydrates to proteins to make glycoproteins; produces new membrane
	Golgi apparatus 	Stacks of flattened membranous sacs; has polarity (*cis* and *trans* faces)	Modification of proteins, carbohydrates on proteins, and phospholipids; synthesis of many polysaccharides; sorting of Golgi products, which are then released in vesicles
	Lysosome 	Membranous sac of hydrolytic enzymes (in animal cells)	Breakdown of ingested substances, cell macromolecules, and damaged organelles for recycling
	Vacuole 	Large membrane-bounded vesicle	Digestion, storage, waste disposal, water balance, cell growth, and protection
CONCEPT 6.5 Mitochondria and chloroplasts change energy from one form to another	Mitochondrion 	Bounded by double membrane; inner membrane has infoldings (cristae)	Cellular respiration
	Chloroplast 	Typically two membranes around fluid stroma, which contains thylakoids stacked into grana (in cells of photosynthetic eukaryotes, including plants)	Photosynthesis
	Peroxisome 	Specialized metabolic compartment bounded by a single membrane	Contains enzymes that transfer hydrogen atoms from substrates to oxygen, producing hydrogen peroxide (H_2O_2) as a by-product; H_2O_2 is converted to water by another enzyme

Figure 6.UN01a

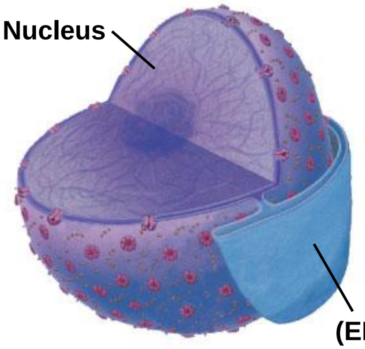
	Cell Component	Structure	Function
CONCEPT 6.3 **The eukaryotic cell's genetic instructions are housed in the nucleus and carried out by the ribosomes**		Surrounded by nuclear envelope (double membrane) perforated by nuclear pores; nuclear envelope continuous with endoplasmic reticulum (ER)	Houses chromosomes, which are made of chromatin (DNA and proteins); contains nucleoli, where ribosomal subunits are made; pores regulate entry and exit of materials
	Ribosome 	Two subunits made of ribosomal RNA and proteins; can be free in cytosol or bound to ER	Protein synthesis

Figure 6.UN01b

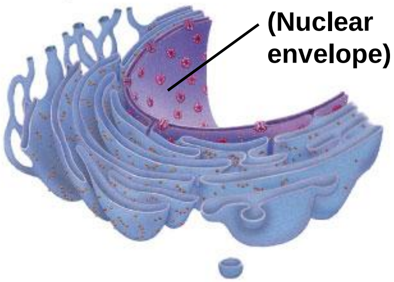
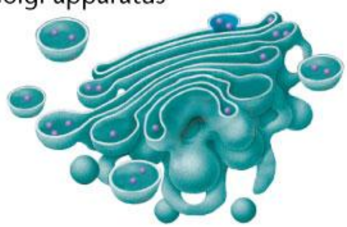
	Cell Component	Structure	Function
CONCEPT 6.4 **The endomembrane system regulates protein traffic and performs metabolic functions in the cell**	Endoplasmic reticulum 	Extensive network of membrane-bounded tubules and sacs; membrane separates lumen from cytosol; continuous with nuclear envelope	Smooth ER: synthesis of lipids, metabolism of carbohydrates, Ca^{2+} storage, detoxification of drugs and poisons Rough ER: aids in synthesis of secretory and other proteins from bound ribosomes; adds carbohydrates to proteins to make glycoproteins; produces new membrane
	Golgi apparatus 	Stacks of flattened membranous sacs; has polarity (*cis* and *trans* faces)	Modification of proteins, carbohydrates on proteins, and phospholipids; synthesis of many polysaccharides; sorting of Golgi products, which are then released in vesicles
	Lysosome 	Membranous sac of hydrolytic enzymes (in animal cells)	Breakdown of ingested substances, cell macromolecules, and damaged organelles for recycling
	Vacuole 	Large membrane-bounded vesicle	Digestion, storage, waste disposal, water balance, cell growth, and protection

Figure 6.UN01c

	Cell Component	Structure	Function
CONCEPT 6.5 **Mitochondria and chloroplasts change energy from one form to another**	Mitochondrion 	Bounded by double membrane; inner membrane has infoldings (cristae)	Cellular respiration
	Chloroplast 	Typically two membranes around fluid stroma, which contains thylakoids stacked into grana (in cells of photosynthetic eukaryotes, including plants)	Photosynthesis
	Peroxisome 	Specialized metabolic compartment bounded by a single membrane	Contains enzymes that transfer hydrogen atoms from substrates to oxygen, producing hydrogen peroxide (H_2O_2) as a by-product; H_2O_2 is converted to water by another enzyme