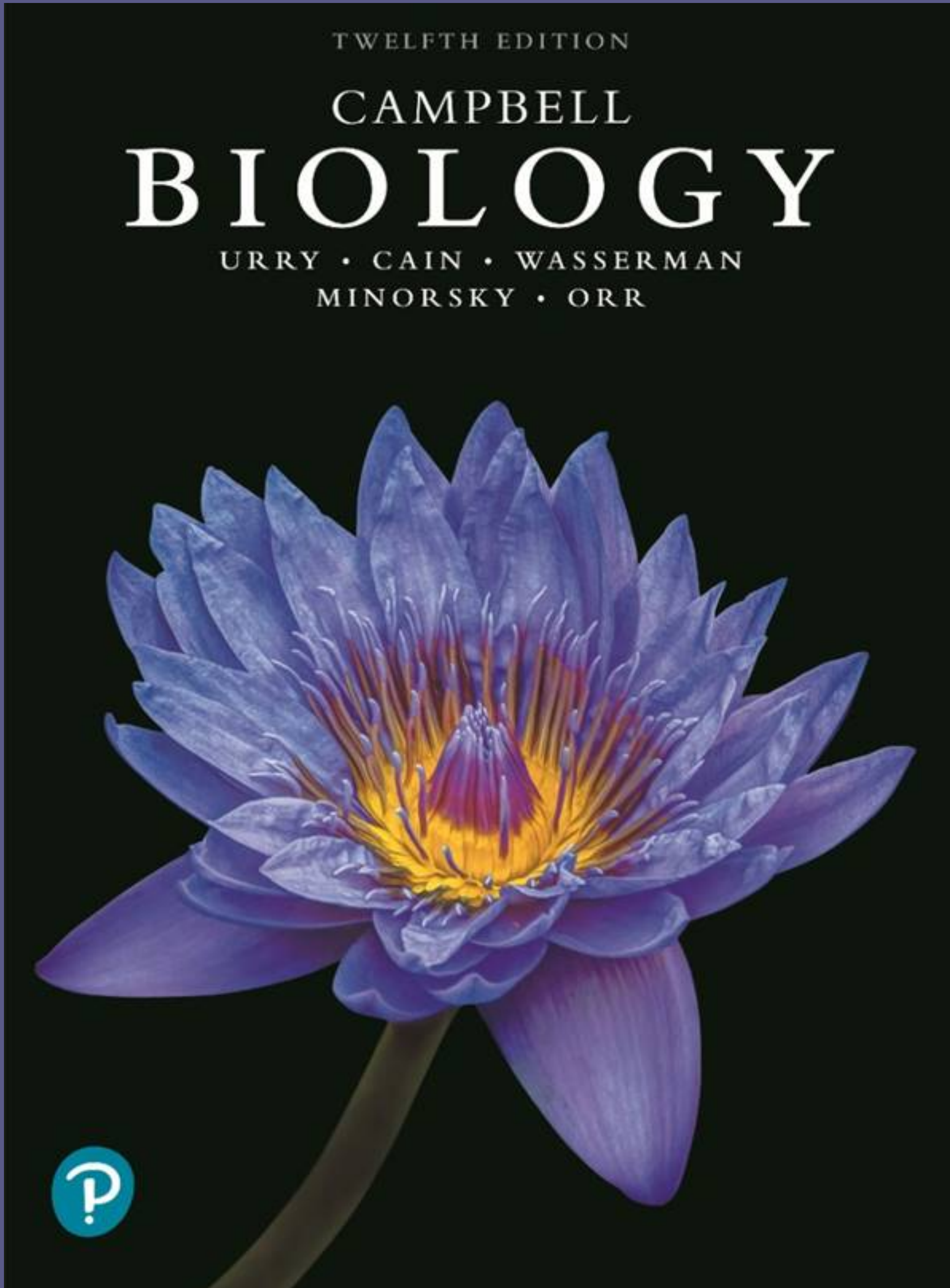


Chapter 06

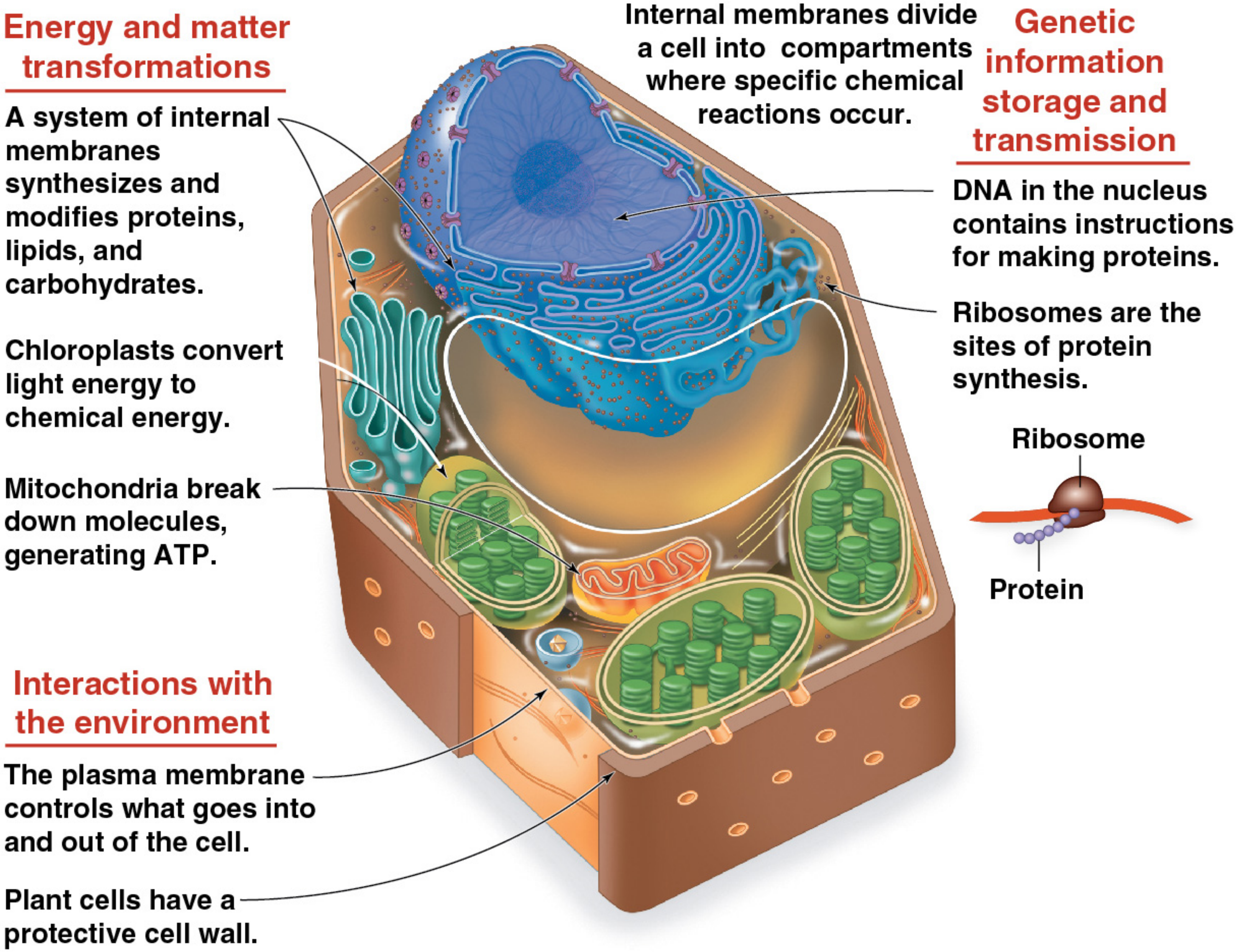
A Tour of the Cell

Lecture Presentations by
Nicole Tunbridge and
Kathleen Fitzpatrick

Figure 6.1a

Figure 6.1b

How does the internal organization of eukaryotic cells allow them to perform the functions of life?



Concept 6.1: Biologists use microscopes and biochemistry to study cells

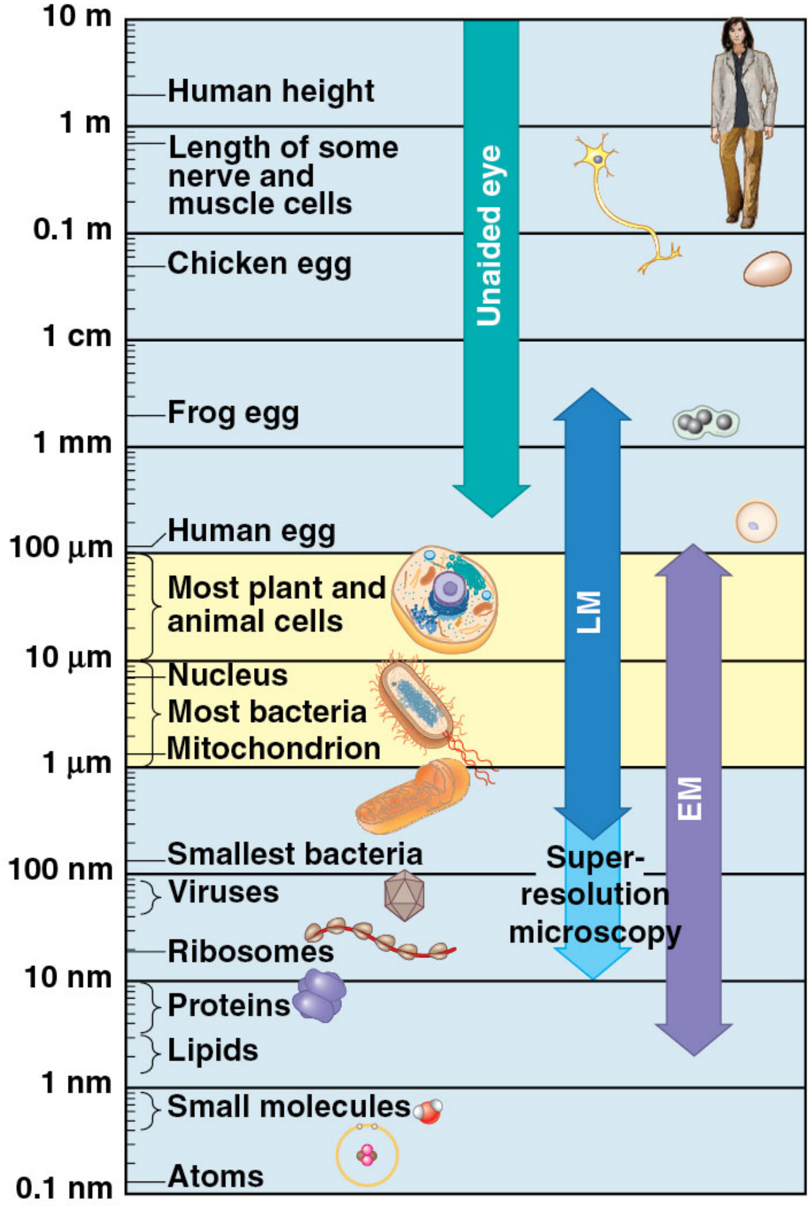
- Cells are usually too small to be seen by the naked eye
- It is helpful to understand how cells are studied

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

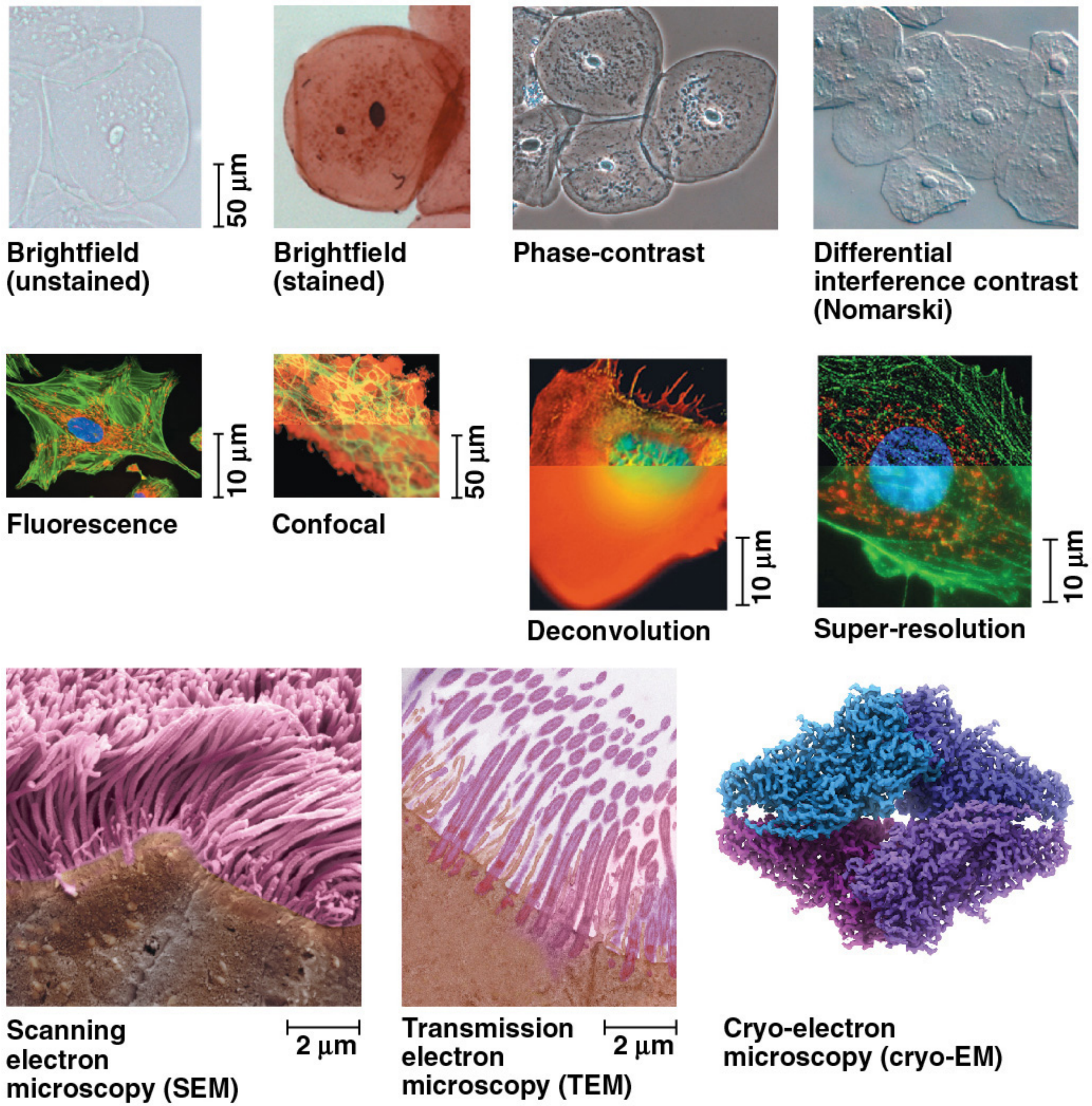
- Three important parameters of microscopy:
  - *Magnification*, the ratio of an object's image size to its real size
  - *Resolution*, the measure of the clarity of the image, or the minimum distance of two distinguishable points
  - *Contrast*, visible differences in brightness between parts of the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

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
LM
EM
Super-resolution microscopy

- 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

Figure 6.3


50 µm
Brightfield (unstained)
Brightfield (stained)
Phase-contrast
Differential interference contrast (Nomarski)
10 µm
Fluorescence
50 µm
Confocal
10 µm
Deconvolution
10 µm
Super-resolution
2 µm
Scanning electron microscopy (SEM)
2 µm
Transmission electron microscopy (TEM)
Cryo-electron microscopy (cryo-EM)

- 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

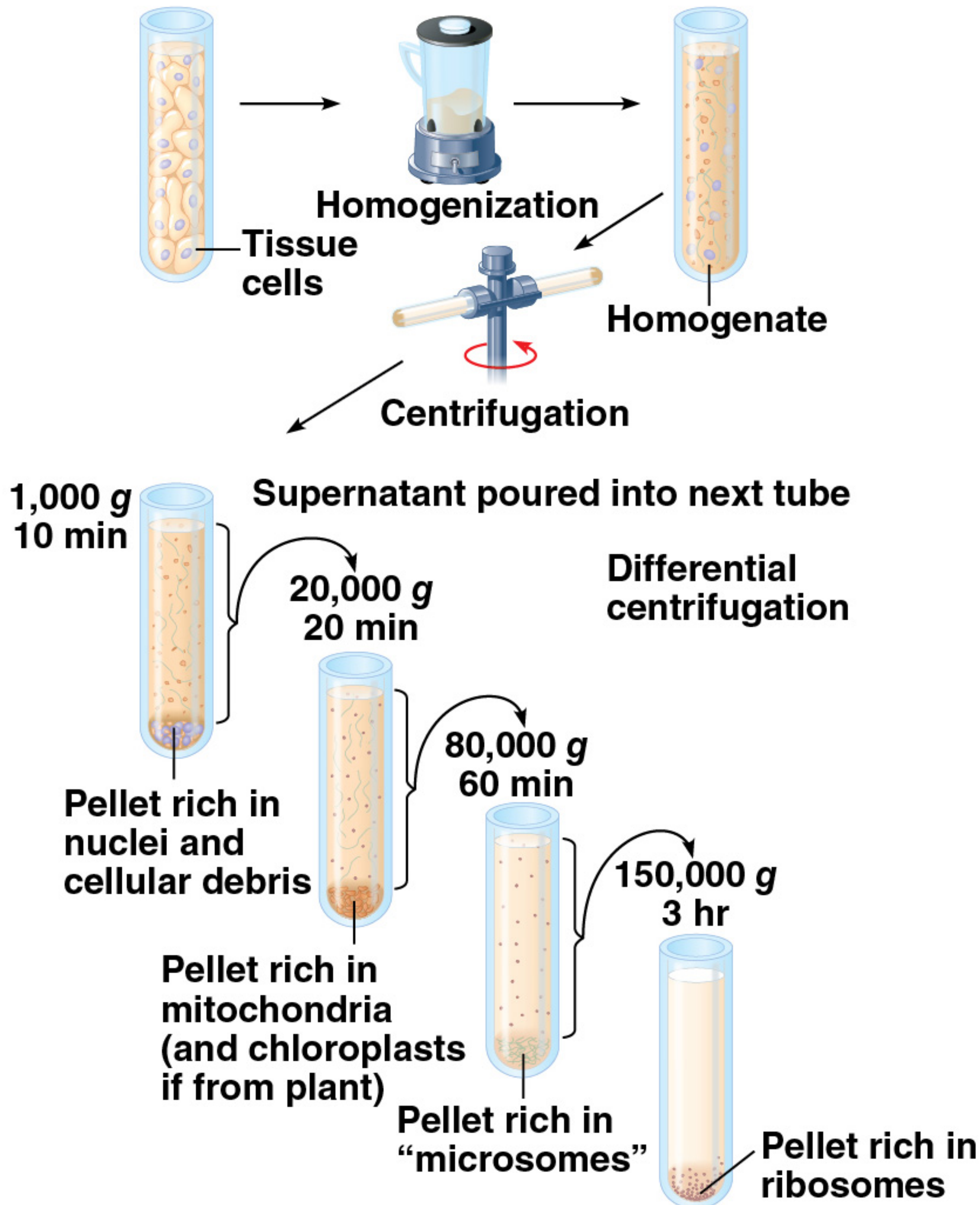
- Recent advances in light microscopy:
  - Labeling individual cells with fluorescent markers improves the level of detail that can be seen
  - Confocal microscopy and deconvolution microscopy provide sharper images of three-dimensional tissues and cells

- Cryo-electron microscopy (cryo-EM) allows preservation of specimens at very low temperatures
- This allows visualization of structures in their cellular environment, with no need for preservatives
- This method is used to complement X-ray crystallography in revealing protein complexes and subcellular structures
- Microscopes are important tools of cytology, the study of cell structure

Cell Fractionation

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

Figure 6.4



Homogenization
Tissue cells
Homogenate
Centrifugation
1,000 g
10 min
Supernatant poured into next tube
20,000 g
20 min
Differential centrifugation
80,000 g
60 min
150,000 g
3 hr
Pellet rich in nuclei and cellular debris
Pellet rich in mitochondria (and chloroplasts if from plant)
Pellet rich in "microsomes"
Pellet rich in ribosomes

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

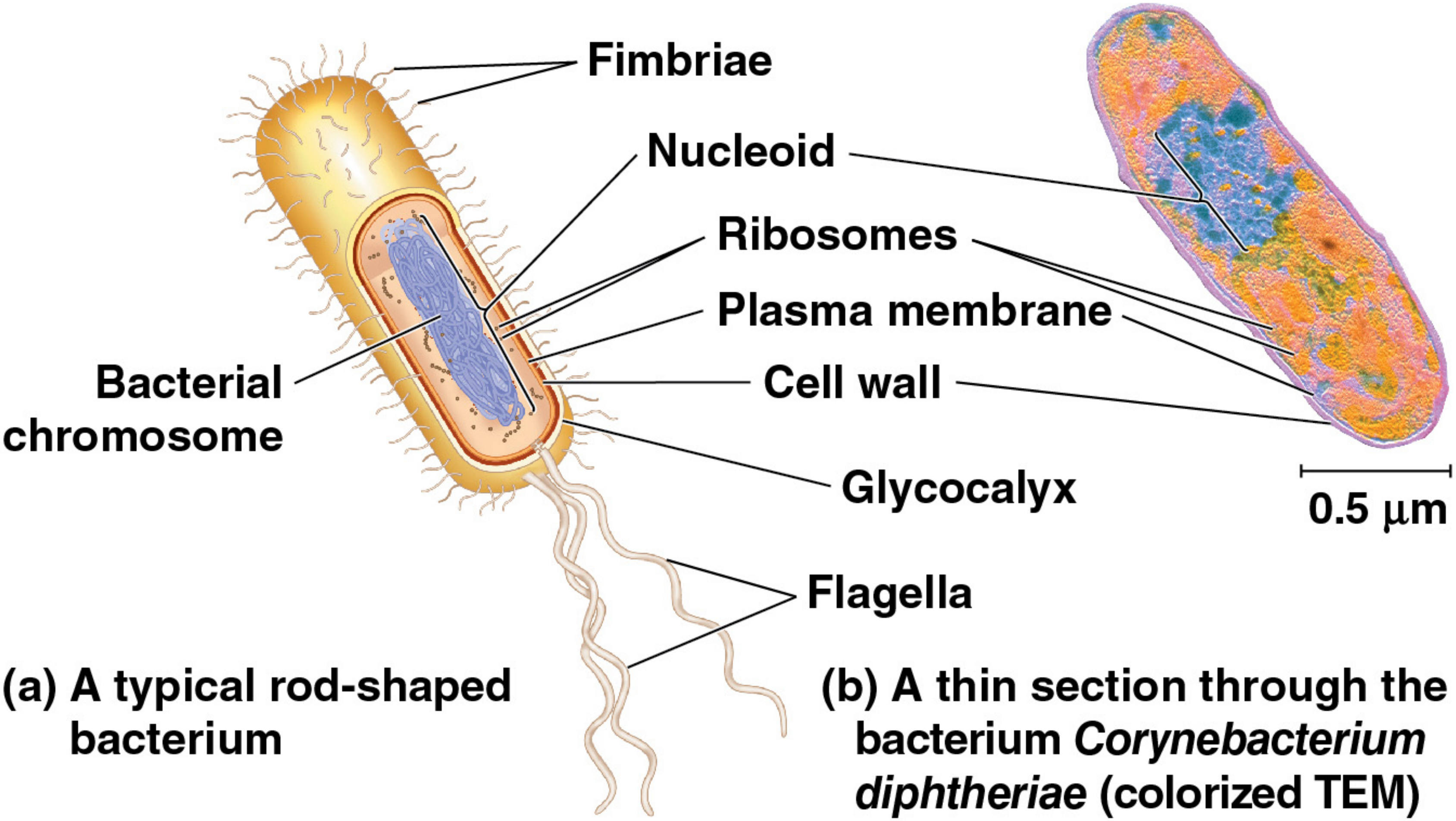
- The basic structural and functional unit of every organism is one of two types of cells: prokaryotic or eukaryotic
- Only organisms of the domains Bacteria and Archaea consist of prokaryotic cells
- Protists, fungi, animals, and plants all consist of eukaryotic cells

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



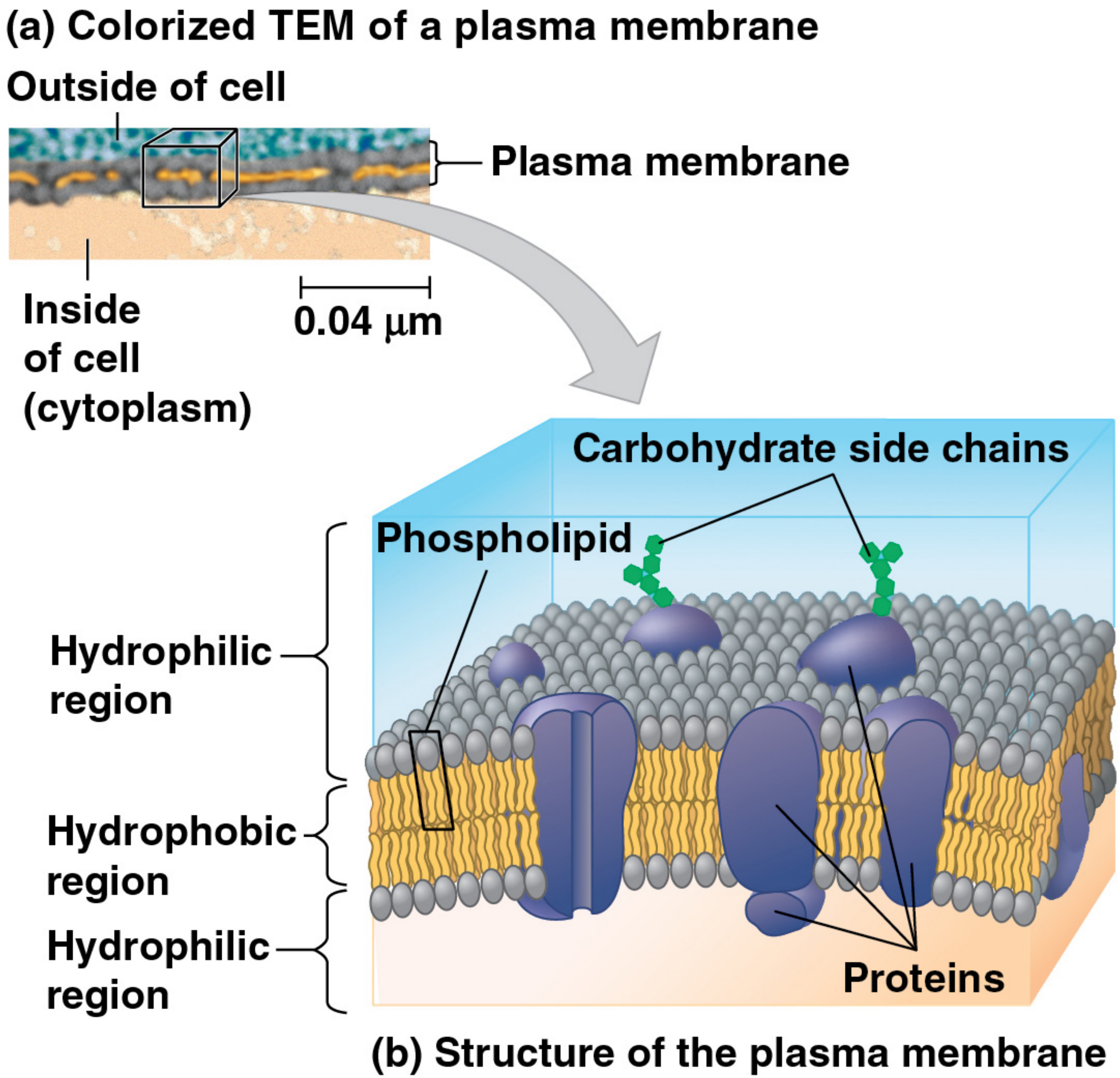
(a) A typical rod-shaped bacterium

(b) A thin section through the bacterium *Corynebacterium diphtheriae* (colorized TEM)

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

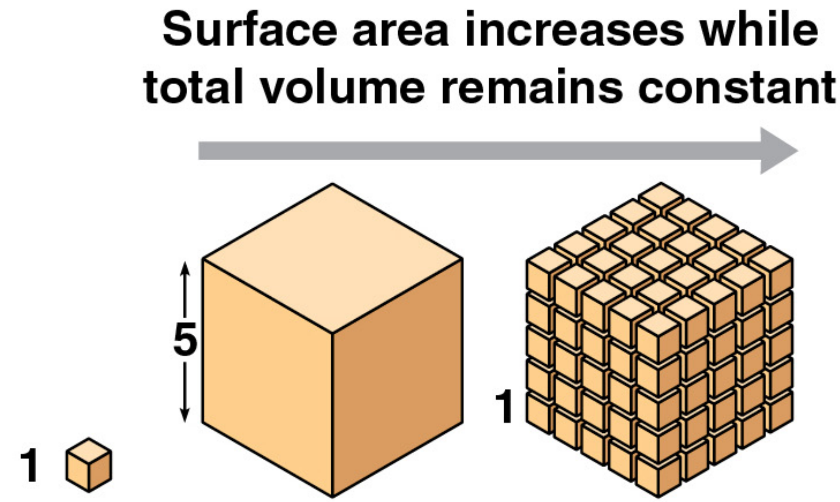
- Metabolic requirements set upper limits on the size of cells
- The **plasma membrane** is a selective barrier that allows sufficient passage of oxygen, nutrients, and waste to service the volume of every cell
- The surface area to volume ratio of a cell is critical
- As a cell increases in size, its volume grows proportionately more than its surface area

Figure 6.6



(a) Colorized TEM of a plasma membrane
Outside of cell
Plasma membrane
Inside of cell (cytoplasm)
0.04 µm
Carbohydrate side chains
Phospholipid
Hydrophilic region
Hydrophobic region
Hydrophilic region
Proteins
(b) Structure of the plasma membrane

Figure 6.7

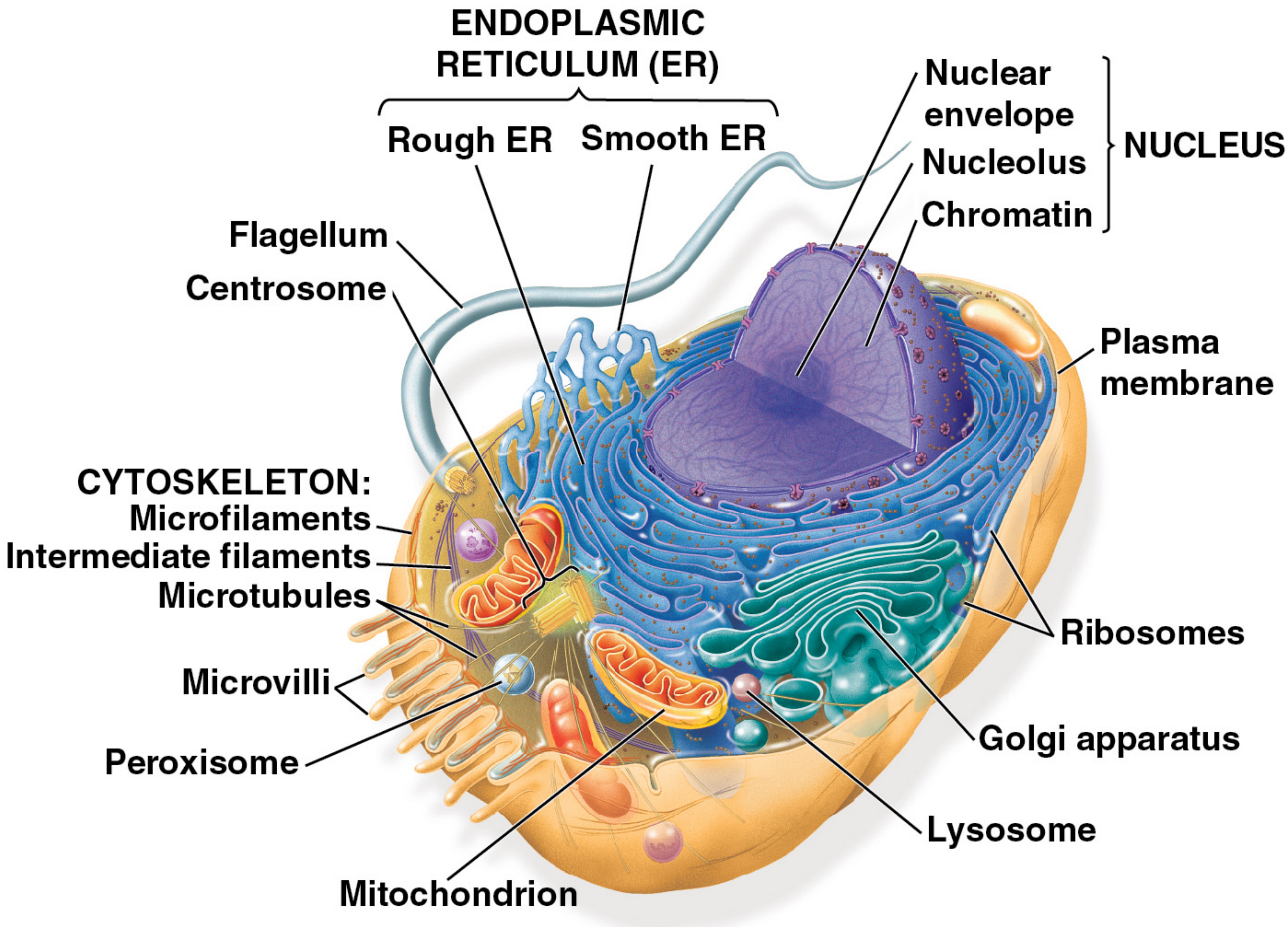


Total surface area [(height × width of 1 side) × 6 sides × number of cells]	**6 units^2**	**150 units^2**	**750 units^2**
Total volume [(height × width × length of 1 cell) × number of cells]	**1 unit^3**	**125 units^3**	**125 units^3**
Surface area-to-volume ratio [surface area ÷ volume]	**6**	**1.2**	**6**

A Panoramic View of the Eukaryotic Cell

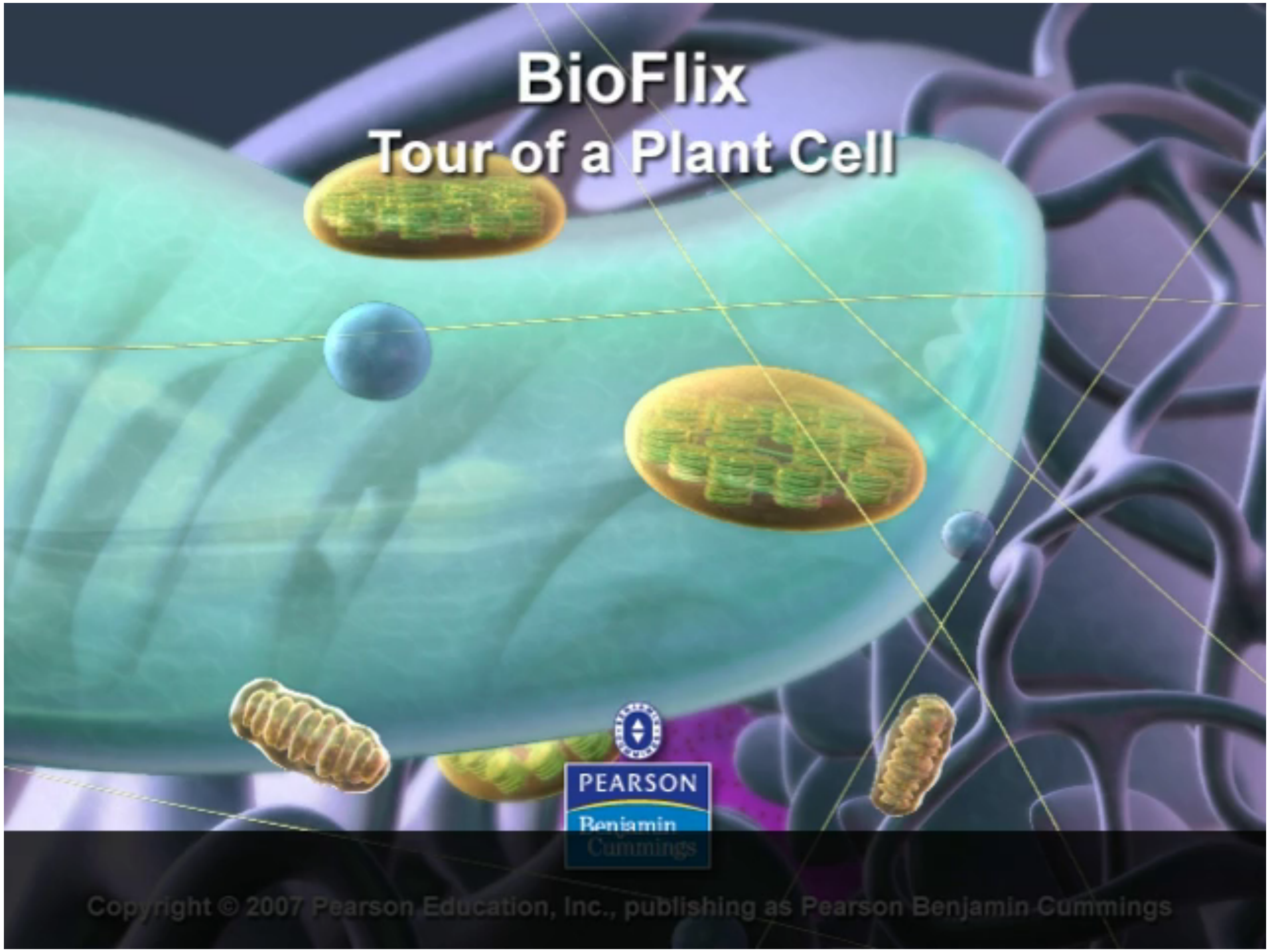
- A eukaryotic cell has internal membranes that divide the cell into compartments—the organelles
- The cell's compartments provide different local environments so that incompatible processes can occur in a single cell
- The basic fabric of biological membranes is a double layer of phospholipids and other lipids
- Plant and animal cells have most of the same organelles

Figure 6.8


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

BioFlix® Animation: Tour of an Animal Cell

BioFlix® Animation: Tour of a Plant Cell

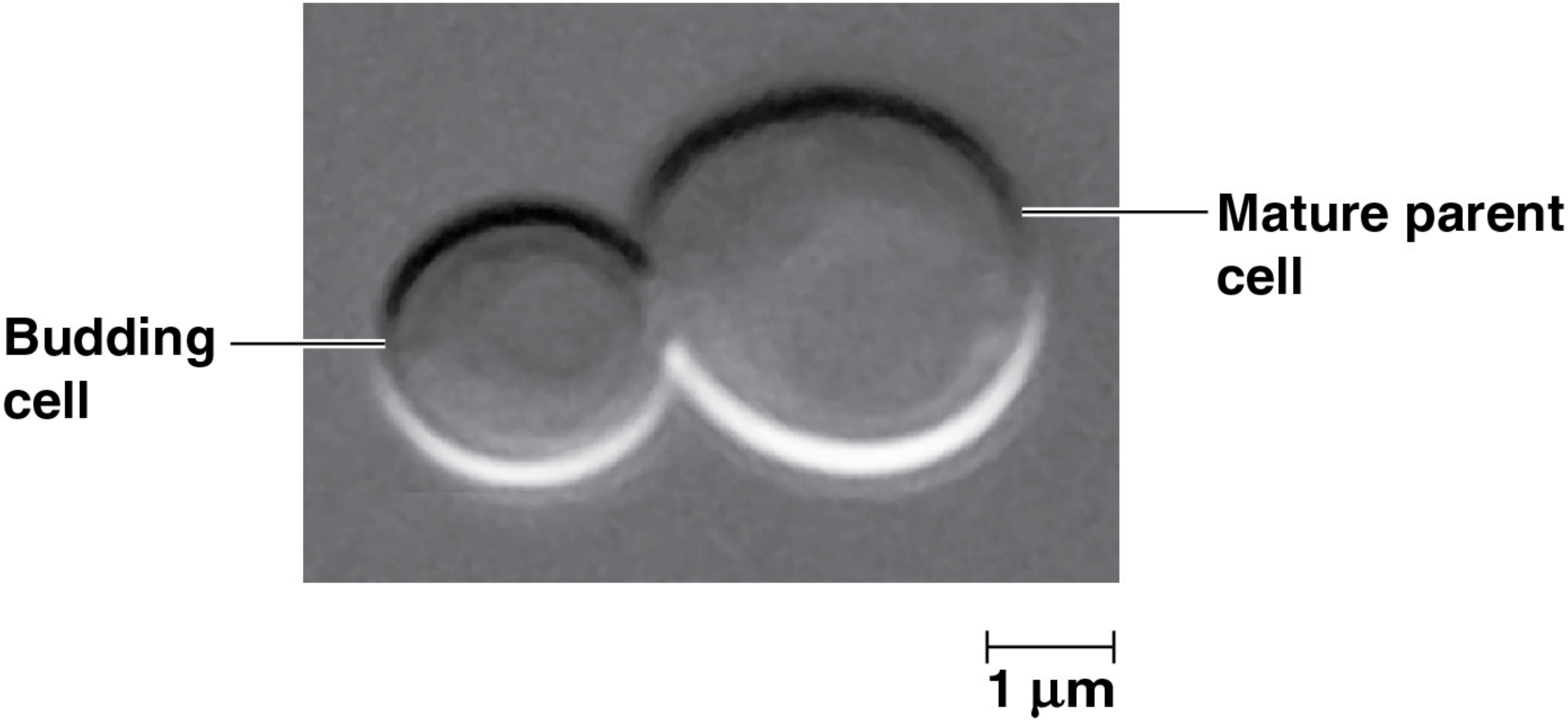


Concept 6.3: The eukaryotic cell's genetic instructions are housed in the nucleus and carried out by the ribosomes

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

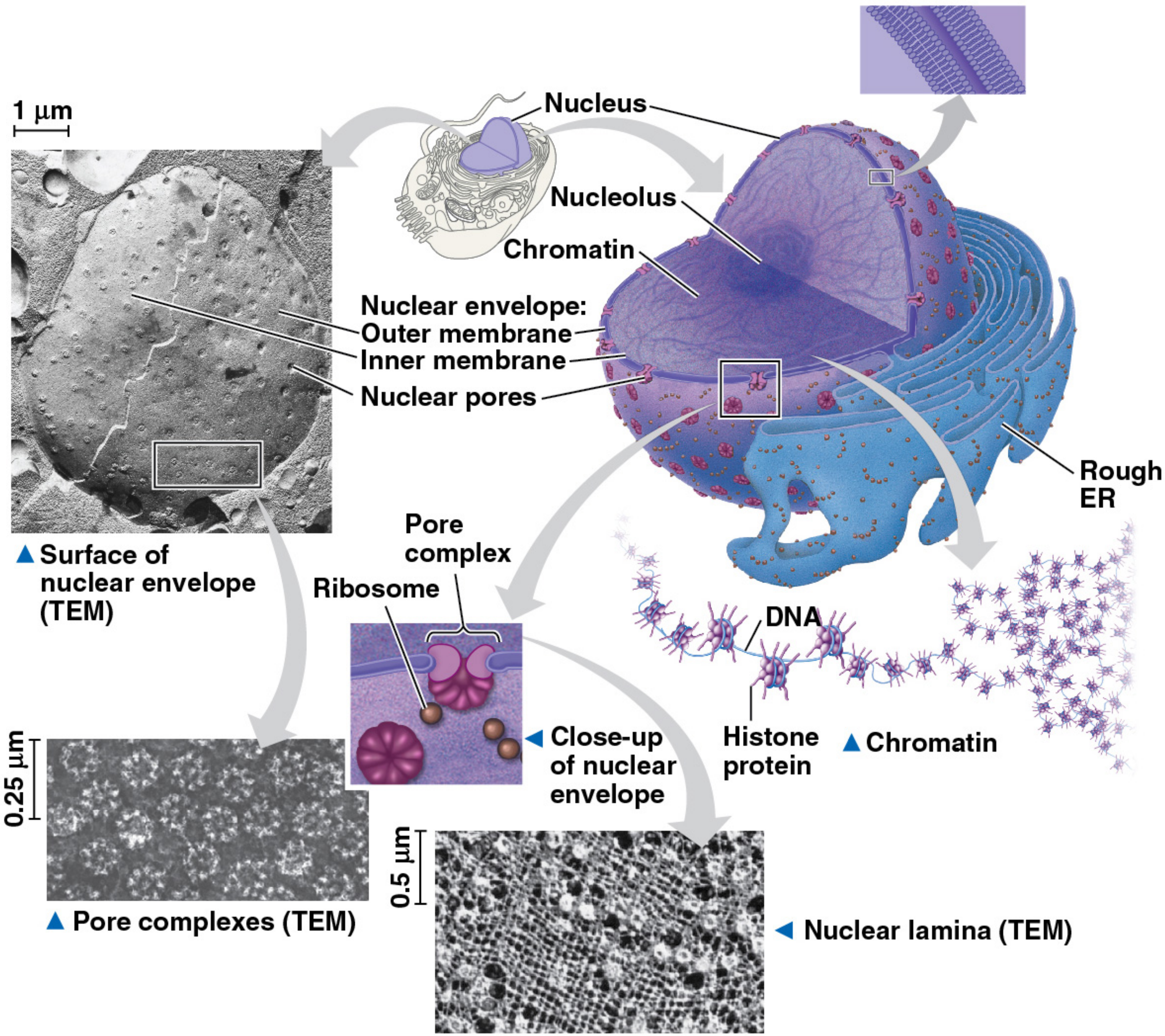
The Nucleus: Information Central

- 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 envelope is a double membrane; each membrane consists of a lipid bilayer



Micrograph from K. Tatchell, using yeast cells grown for experiments described in L. Kozubowski et al., Role of the septin ring in the asymmetric localization of proteins at the mother-bud neck in *Saccharomyces cerevisiae*, *Molecular Biology of the Cell* 16:3455–3466 (2005).

Figure 6.9


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

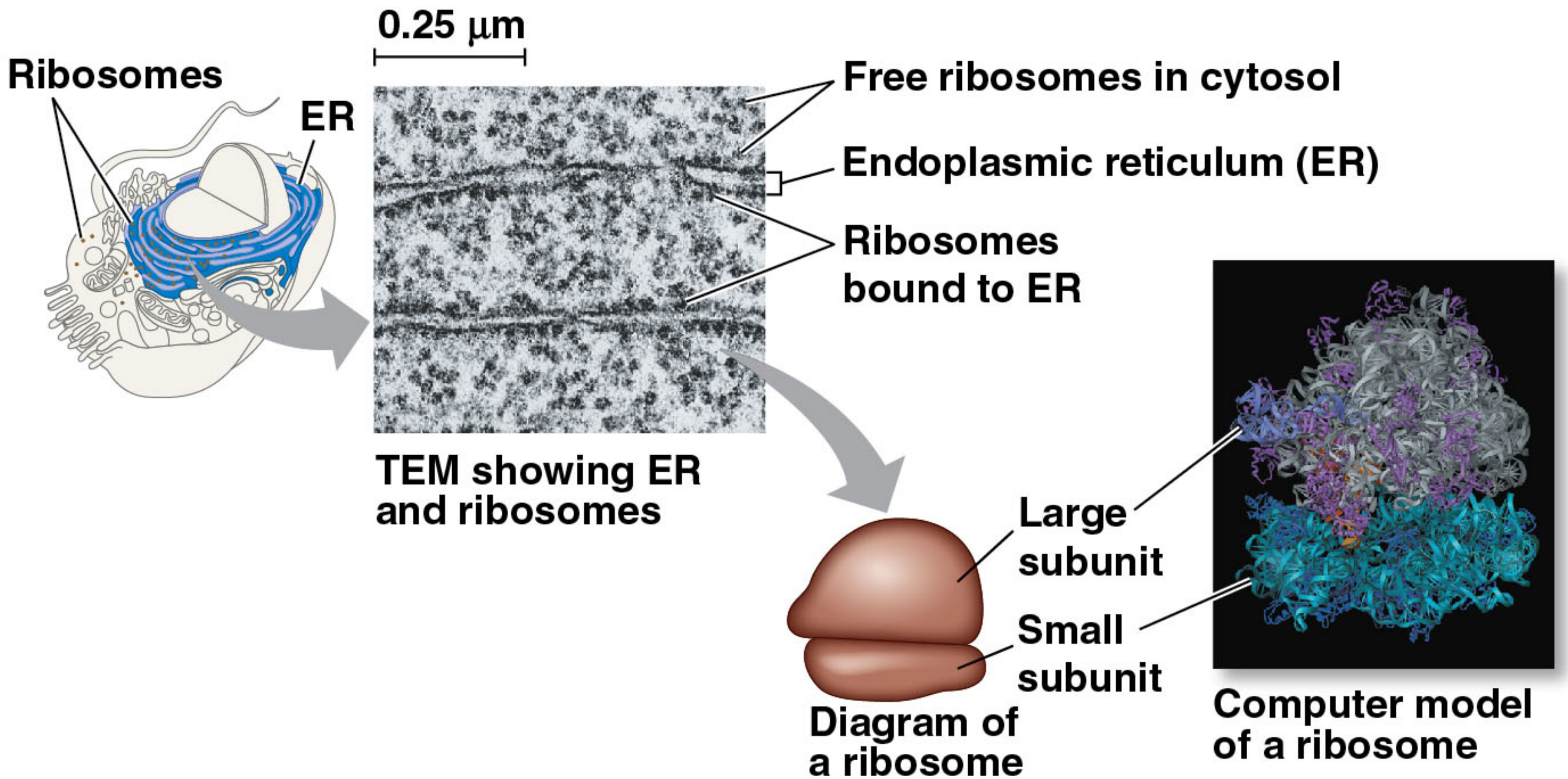
- Pores, lined with a structure called a pore complex, regulate the entry and exit of molecules from the nucleus
- The nuclear side of the envelope is lined by the **nuclear lamina**, which is composed of proteins and maintains the shape of the nucleus
- There is evidence for a nuclear matrix, a framework of protein fibers throughout the interior of the nucleus

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

Ribosomes: Protein Factories

- **Ribosomes** are complexes made of ribosomal RNA and protein
- Ribosomes build proteins in two locations:
  - In the cytosol (free ribosomes)
  - On the outside of the endoplasmic reticulum or the nuclear envelope (bound ribosomes)

Figure 6.10


Ribosomes
ER
0.25 µm
Free ribosomes in cytosol
Endoplasmic reticulum (ER)
Ribosomes bound to ER
TEM showing ER and ribosomes
Large subunit
Small subunit
Diagram of a ribosome
Computer model of a ribosome

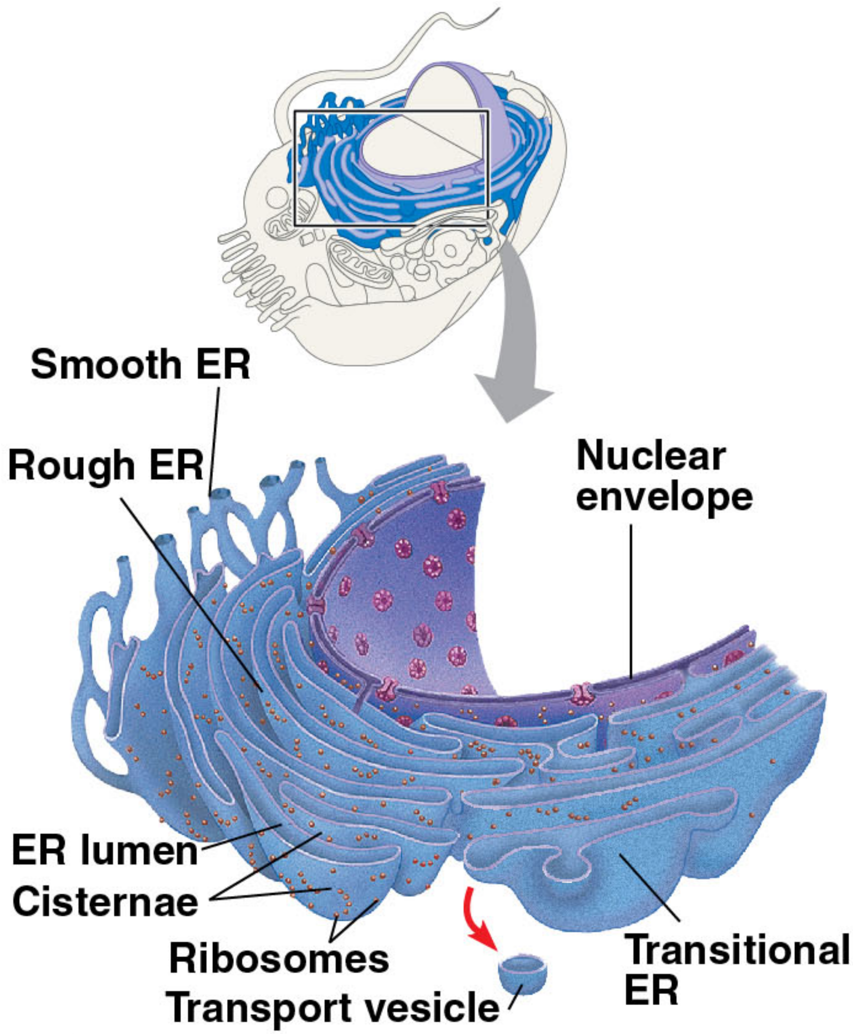
Concept 6.4: The endomembrane system regulates protein traffic and performs metabolic functions

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

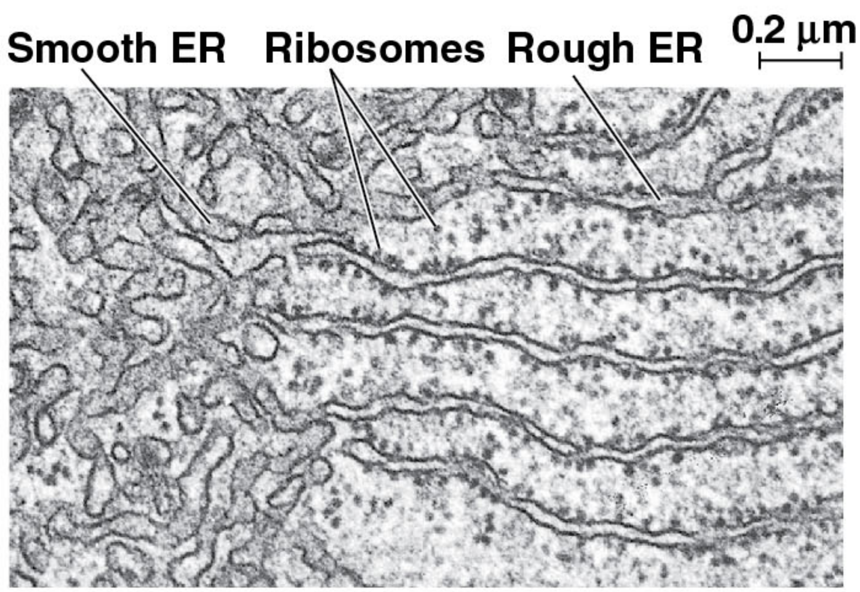
The Endoplasmic Reticulum: Biosynthetic Factory

- 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**, whose surface is studded with ribosomes

Figure 6.11



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



Smooth ER
Ribosomes
Rough ER
0.2 µm

Functions of Smooth ER

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

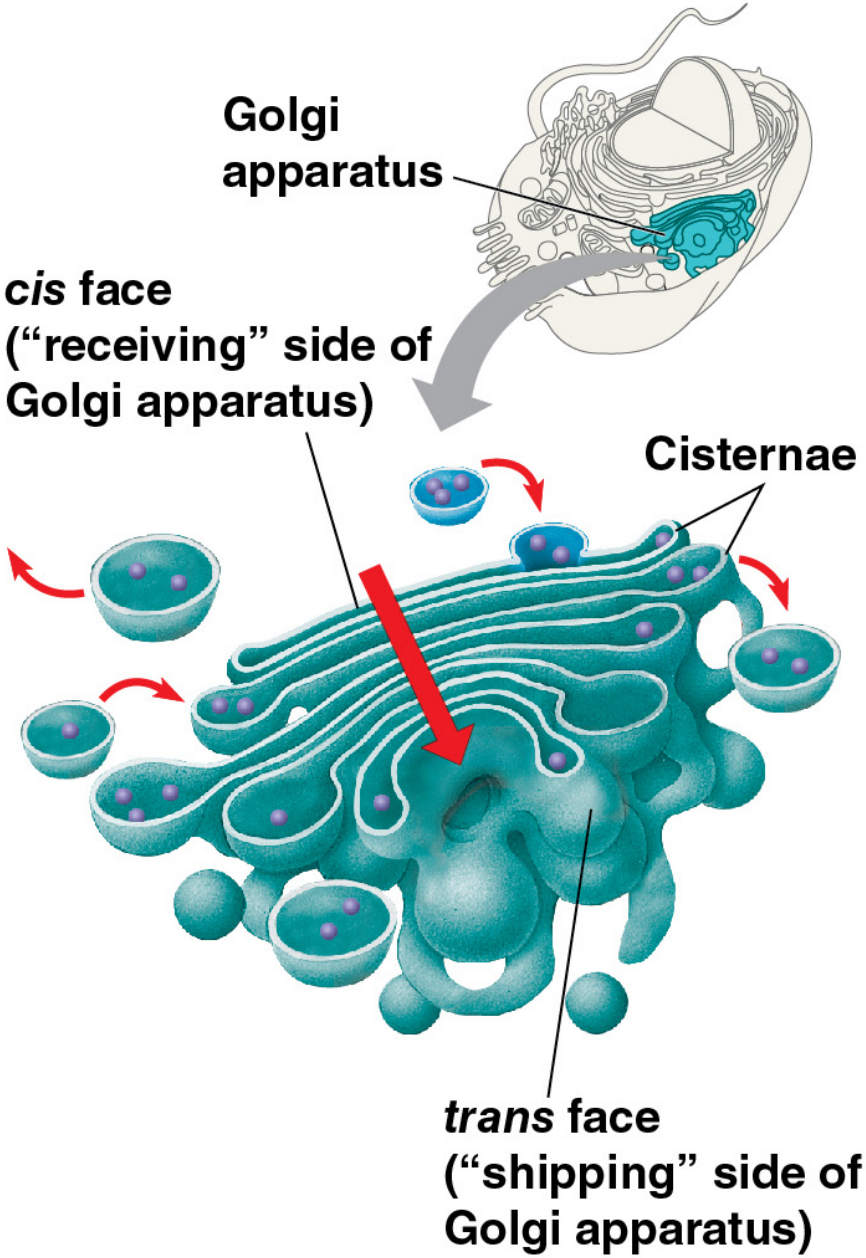
Functions of Rough ER

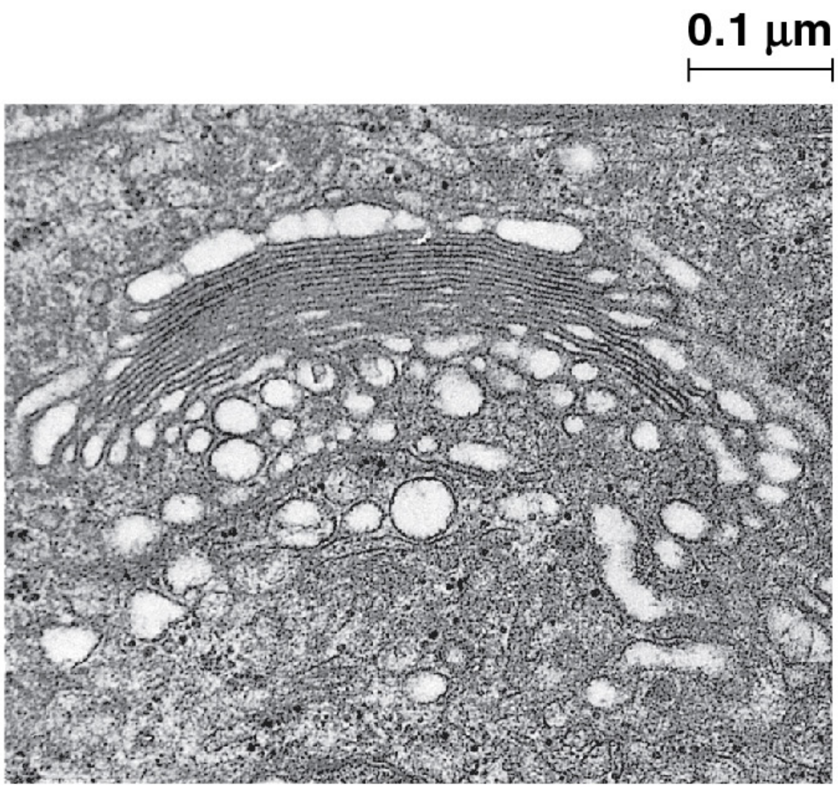
- The rough ER
  - Has bound ribosomes, which secrete **glycoproteins** (proteins covalently bonded to carbohydrates)
  - Distributes **transport vesicles**, secretory proteins surrounded by membranes
  - Is a membrane factory for the cell

The Golgi Apparatus: Shipping and Receiving Center

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

Figure 6.12





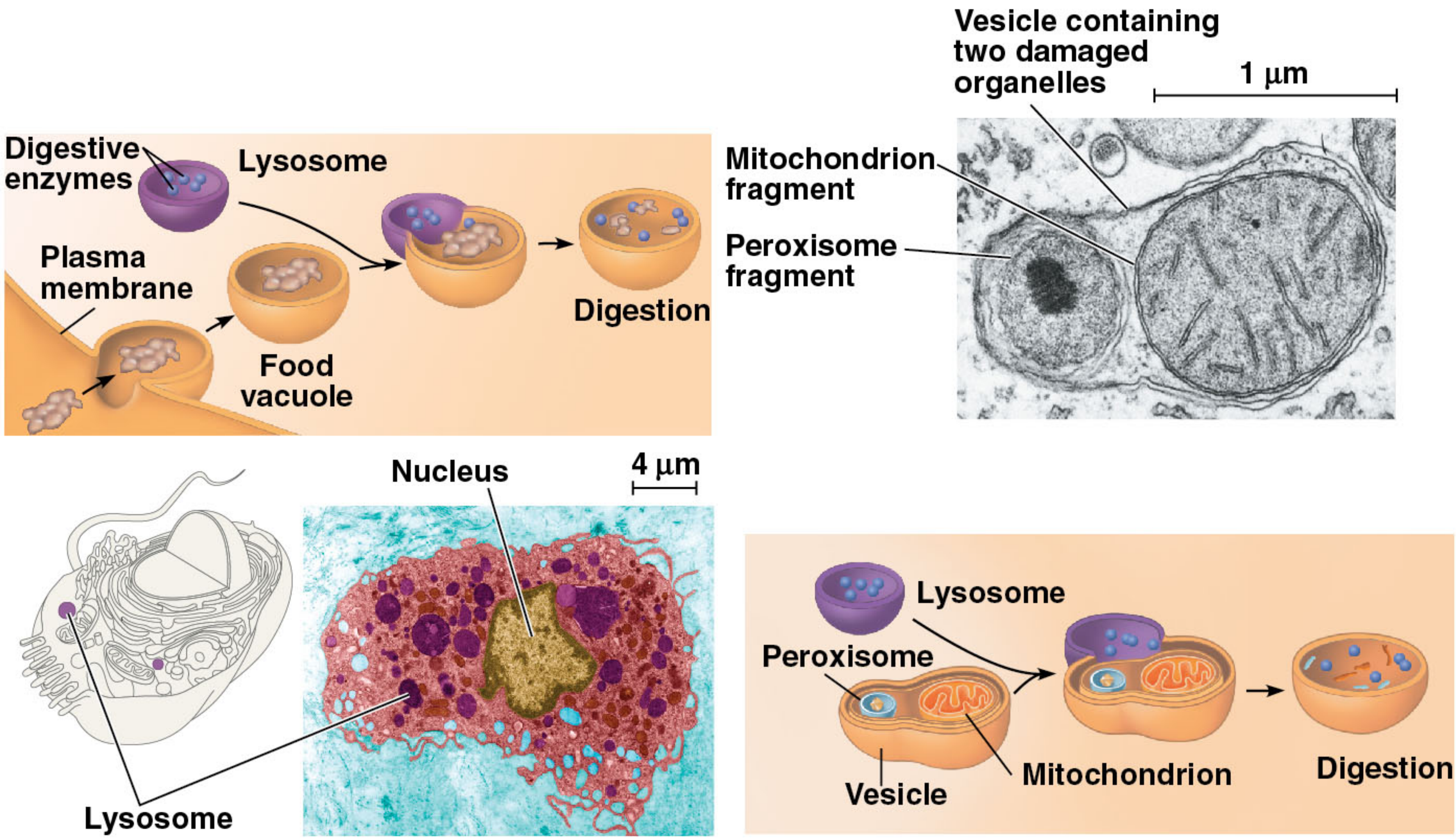
TEM of Golgi apparatus

Lysosomes: Digestive Compartments

- A **lysosome** is a membranous sac of hydrolytic enzymes that can digest macromolecules
- Lysosomal enzymes work best in the acidic environment inside the lysosome
- Hydrolytic enzymes and lysosomal membranes are made by rough ER and then transferred to the Golgi apparatus for further processing
- Some lysosomes probably arise by budding from the trans face of the Golgi apparatus

- 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 contents
- Lysosomes also use enzymes to recycle the cell’s own organelles and macromolecules, a process called *autophagy*

Figure 6.13



(a) Phagocytosis

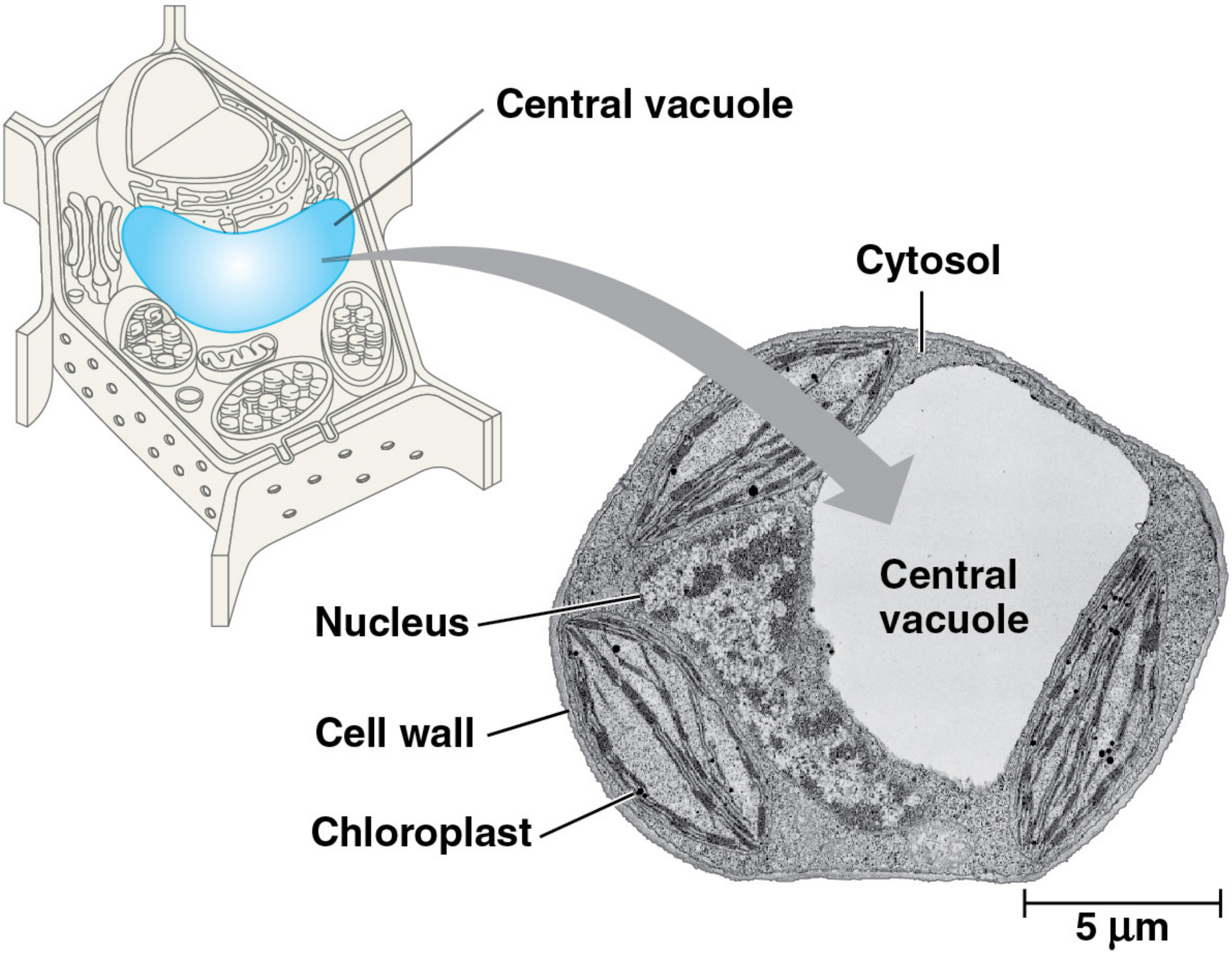
(b) Autophagy

Vacuoles: Diverse Maintenance Compartments

- **Vacuoles** are large vesicles derived from the ER and Golgi apparatus
- Vacuoles perform a variety of functions in different kinds of cells

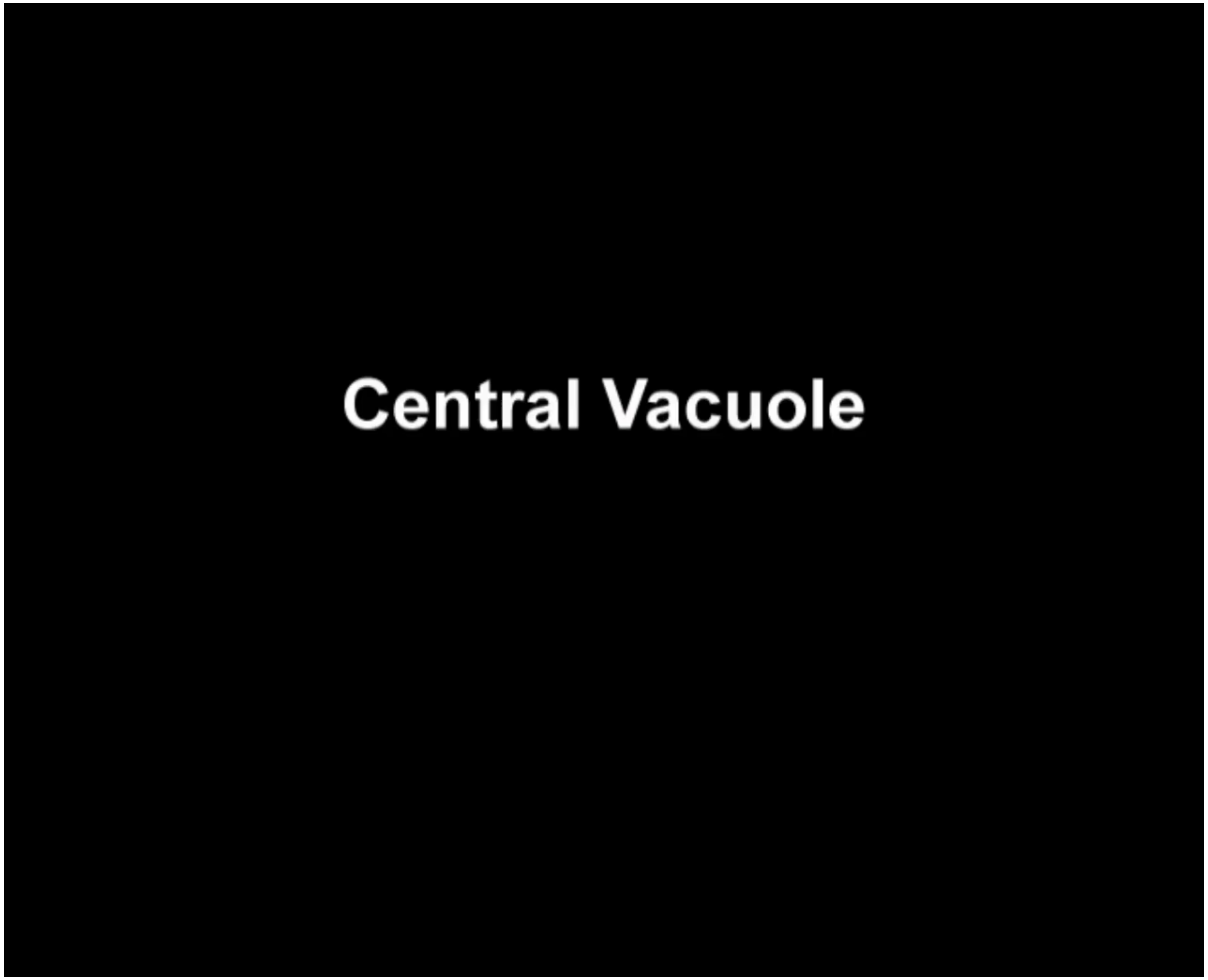
- **Food vacuoles** are formed by phagocytosis
- **Contractile vacuoles**, found in many freshwater protists, pump excess water out of cells
- **Central vacuoles**, found in many mature plant cells, contain a solution called sap
- It is the plant cell's main repository of inorganic ions, including potassium and chloride
- The central vacuole plays a major role in the growth of plant cells

Figure 6.14



Central vacuole
Cytosol
Central vacuole
Nucleus
Cell wall
Chloroplast
5 µm

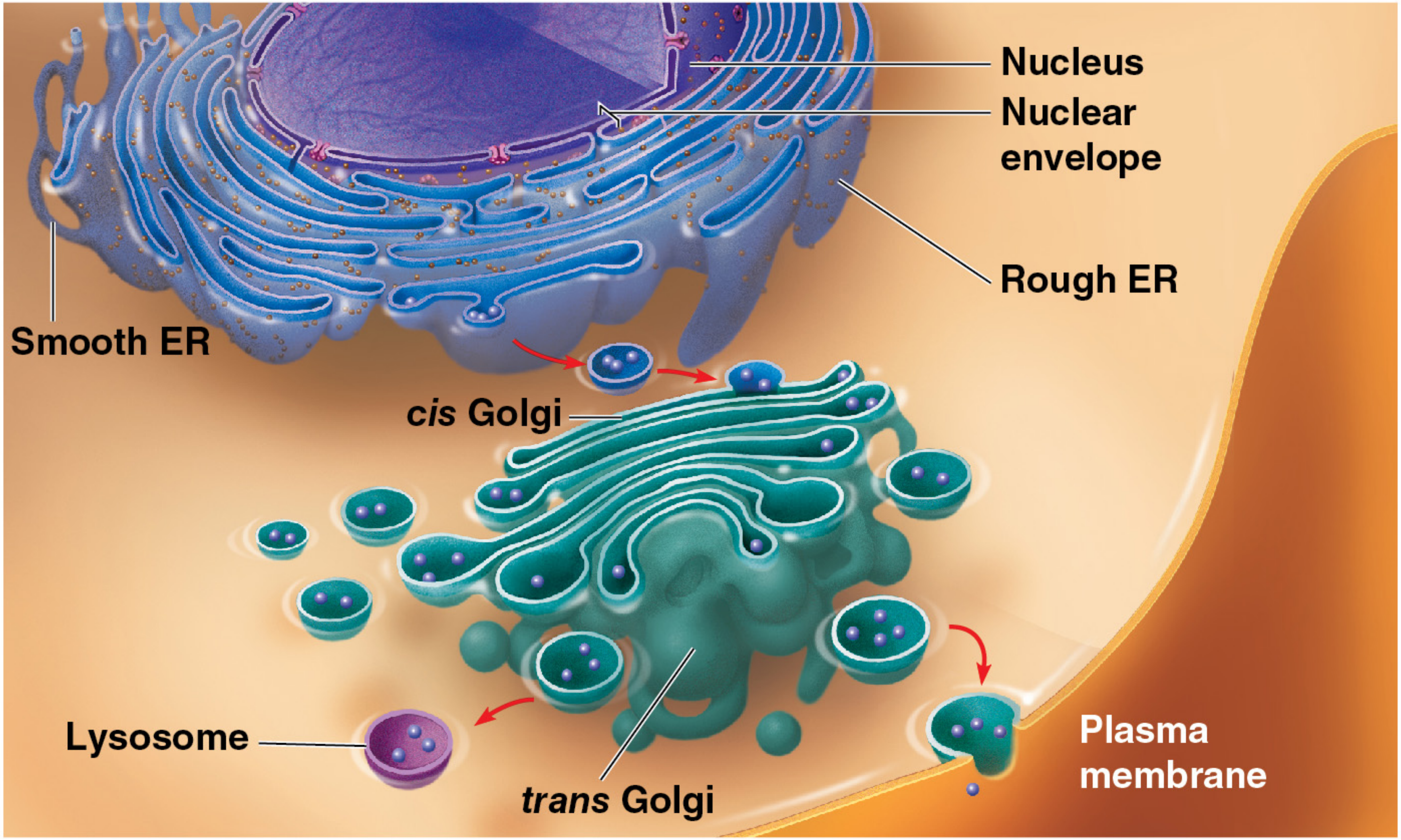
BioFlix® Animation: Tour of a Plant Cell



The Endomembrane System: *A Review*

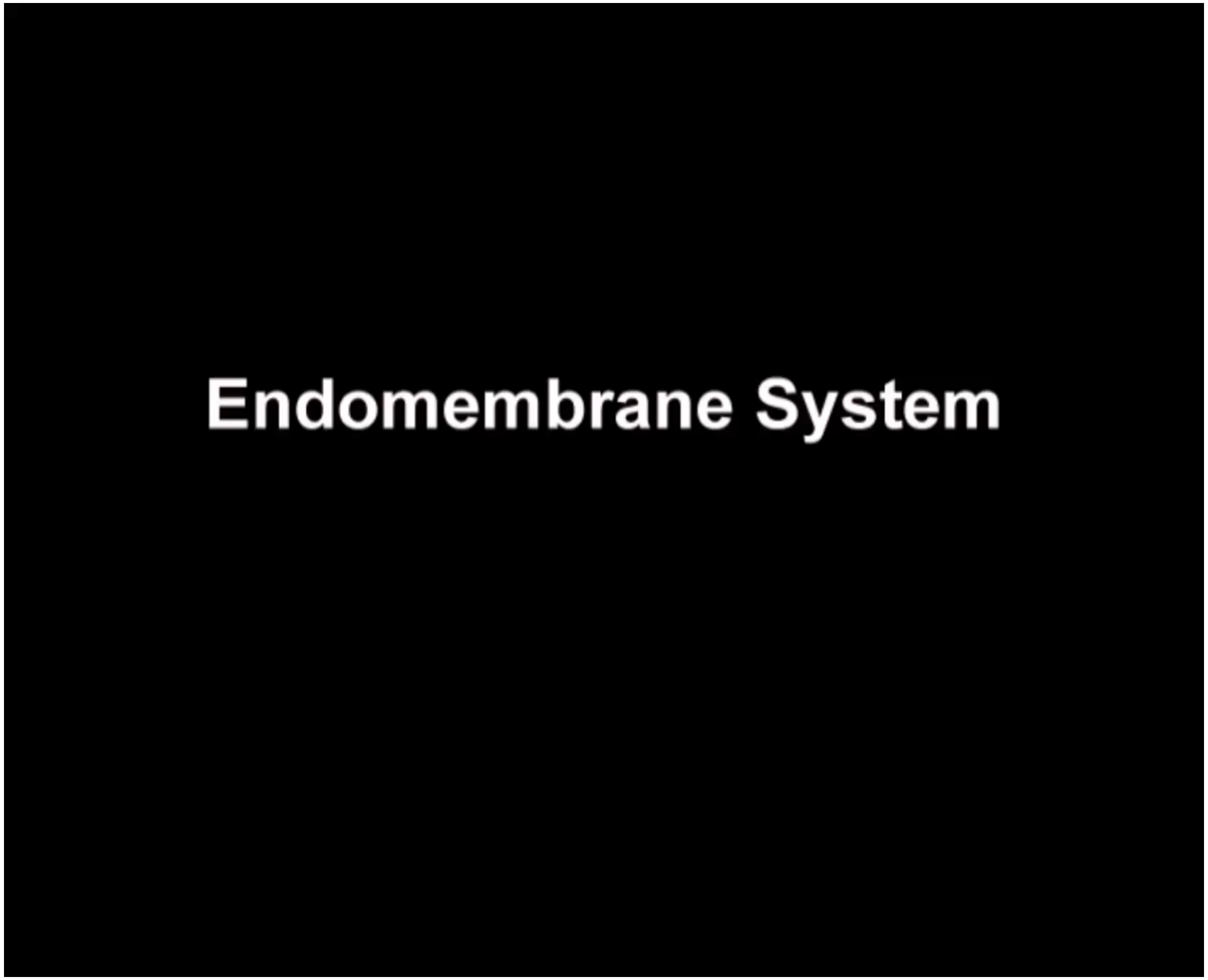
- The endomembrane system is a complex and dynamic player in the cell's compartmental organization

Figure 6.15



Nucleus
Nuclear envelope
Rough ER
Smooth ER
cis Golgi
Lysosome
trans Golgi
Plasma membrane

BioFlix® Animation: Endomembrane System



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

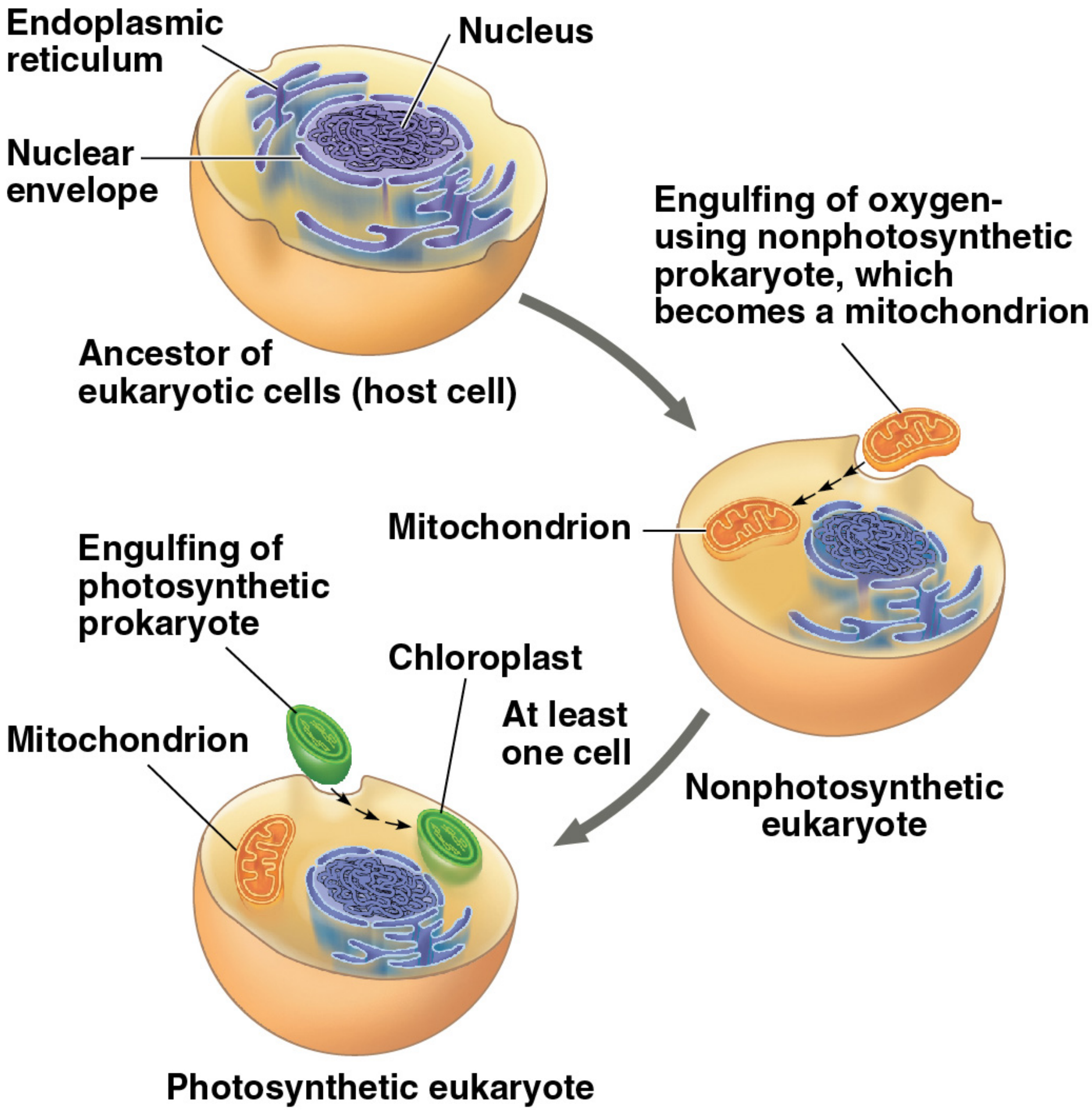
- **Mitochondria** are the sites of cellular respiration, the metabolic process that uses oxygen to generate ATP
- **Chloroplasts**, found in plants and algae, are the sites of photosynthesis
- Peroxisomes are oxidative organelles

The Evolutionary Origins of Mitochondria and Chloroplasts

- Mitochondria and chloroplasts have similarities with bacteria
- These similarities led to the **endosymbiont theory**
- It suggests that an early ancestor of eukaryotes engulfed an oxygen-using nonphotosynthetic prokaryotic cell
- The engulfed cell formed a relationship with the host cell, becoming an endosymbiont

- The endosymbionts evolved into mitochondria
- At least one of these cells may have then taken up a photosynthetic prokaryote, which evolved into a chloroplast
- Similarities between mitochondria and chloroplasts that support this theory:
  - Enveloped by a double membrane
  - Contain free ribosomes and circular DNA molecules
  - Grow and reproduce somewhat independently in cells

Figure 6.16

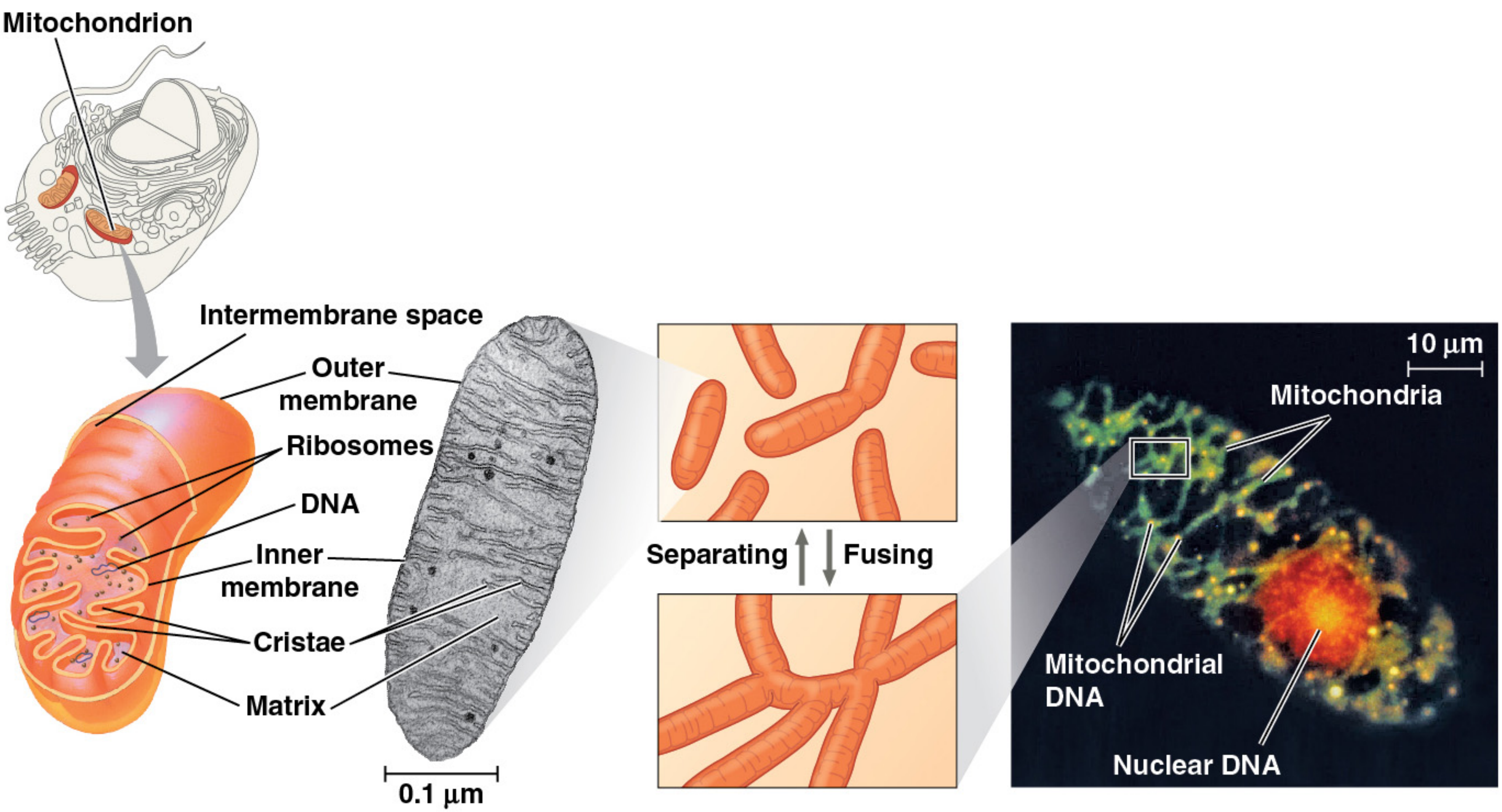


Endoplasmic reticulum
Nucleus
Nuclear envelope
Ancestor of eukaryotic cells (host cell)
Engulfing of oxygen-using nonphotosynthetic prokaryote, which becomes a mitochondrion
Mitochondrion
Nonphotosynthetic eukaryote
At least one cell
Engulfing of photosynthetic prokaryote
Chloroplast
Mitochondrion
Photosynthetic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

Mitochondria: Chemical Energy Conversion

- Mitochondria are found 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

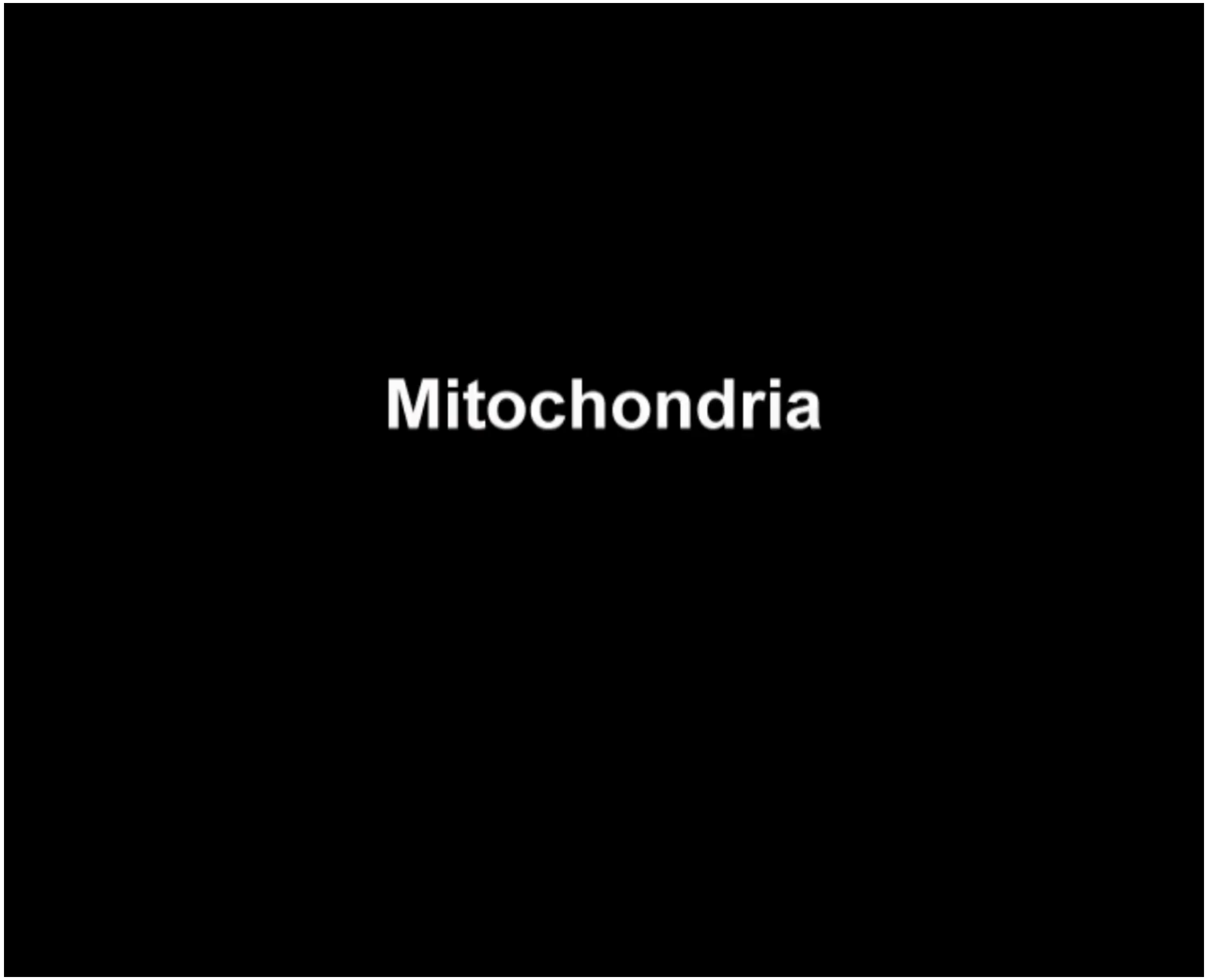


(a) Diagram and TEM of mitochondrion

(b) Dynamic nature of mitochondrial networks

(c) Network of mitochondria in *Euglena* (LM)

BioFlix® Animation: Mitochondria



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**

BioFlix® Animation: Chloroplasts and Mitochondria

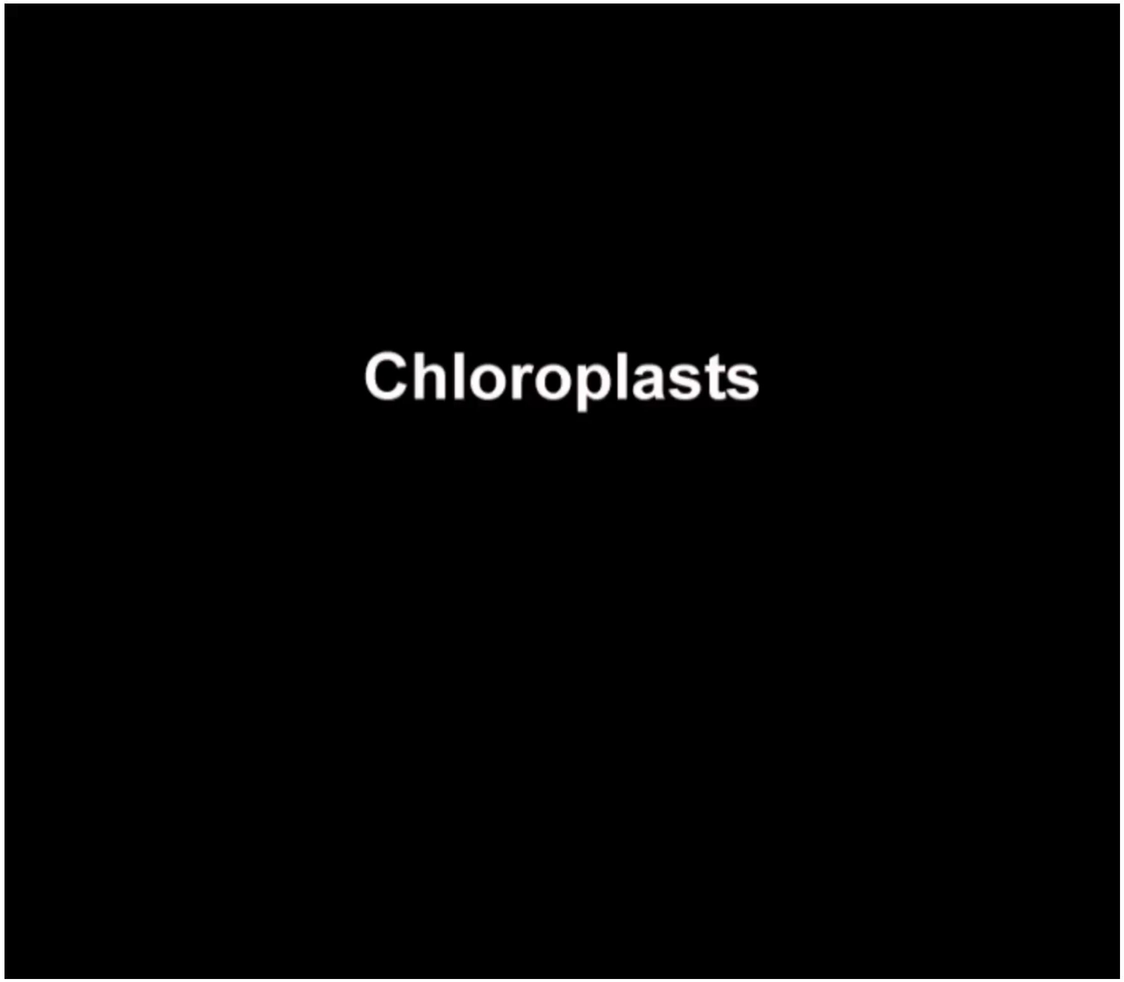
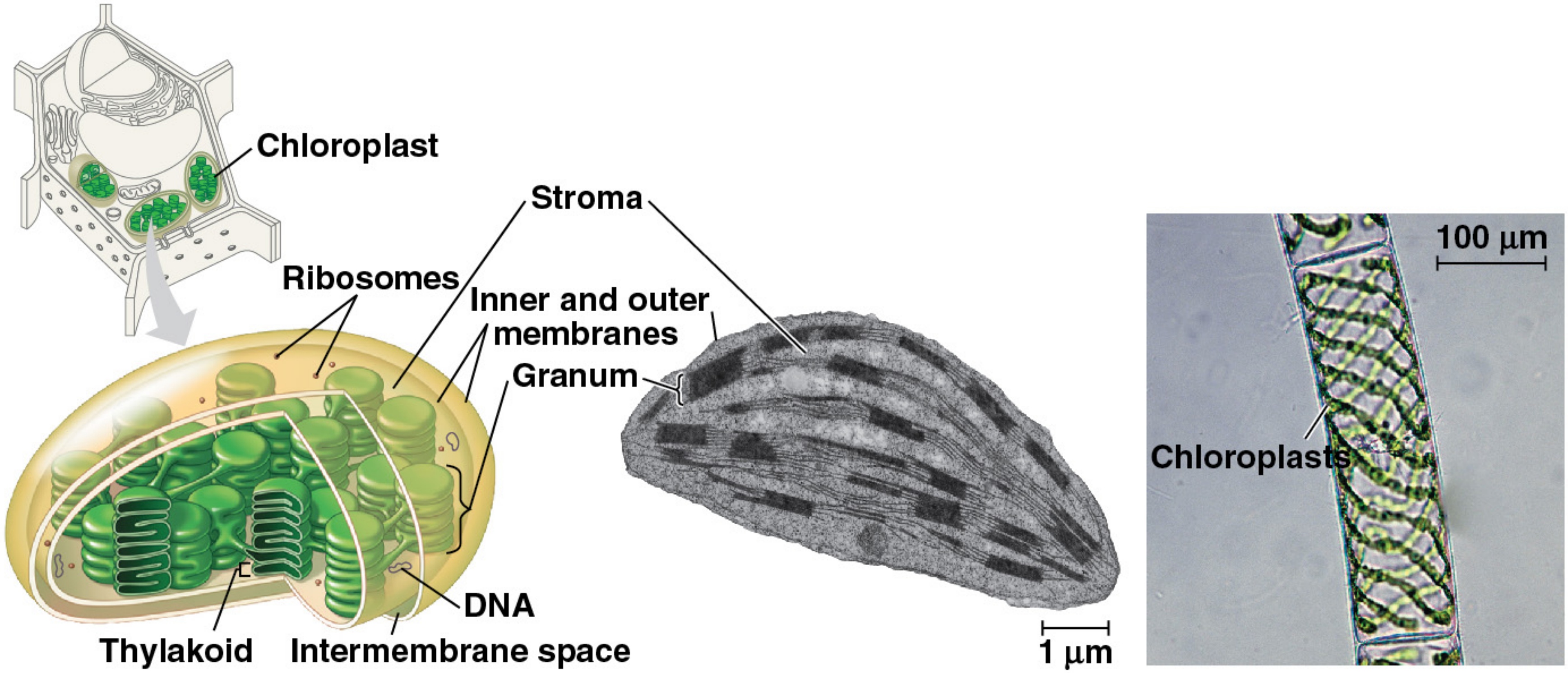


Figure 6.18



(a) Diagram and TEM of chloroplast

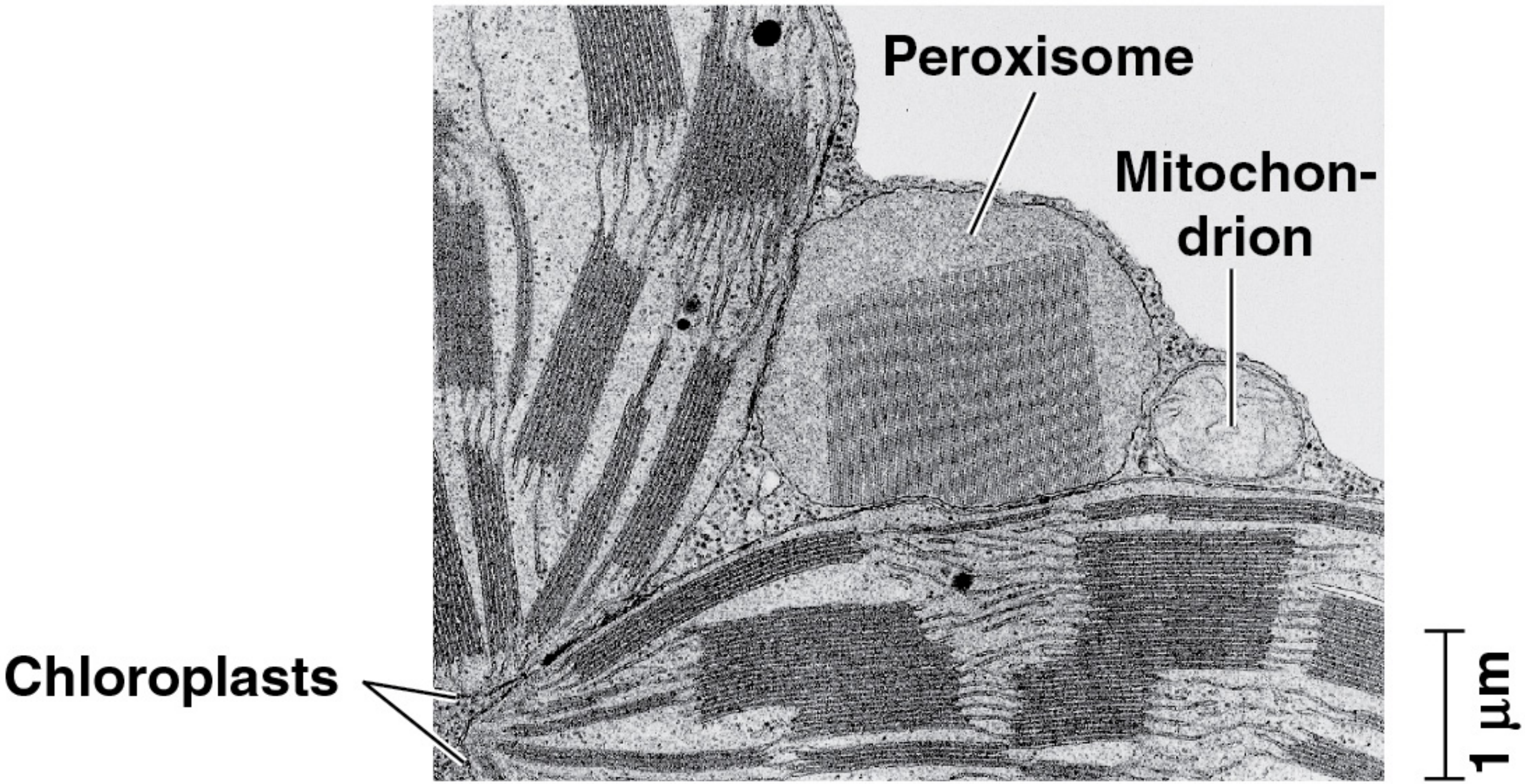
(b) Chloroplasts in an algal cell

Peroxisomes: Oxidation

- It is not known how peroxisomes are related to other organelles
- **Peroxisomes** are specialized metabolic compartments bounded by a single membrane
- They contain enzymes that remove hydrogen atoms from various substances and transfer them to oxygen
- This forms hydrogen peroxide
- These reactions have many different functions

- Functions of peroxisomes
  - Some use oxygen to break fatty acids into smaller molecules, eventually used for fuel for respiration
  - In the liver, they detoxify alcohol and other harmful compounds
  - *Glyoxysomes* in the fat-storing tissues of plant seeds, convert fatty acids to sugar to feed the emerging seedling

Figure 6.19



Peroxisomes: Oxidation

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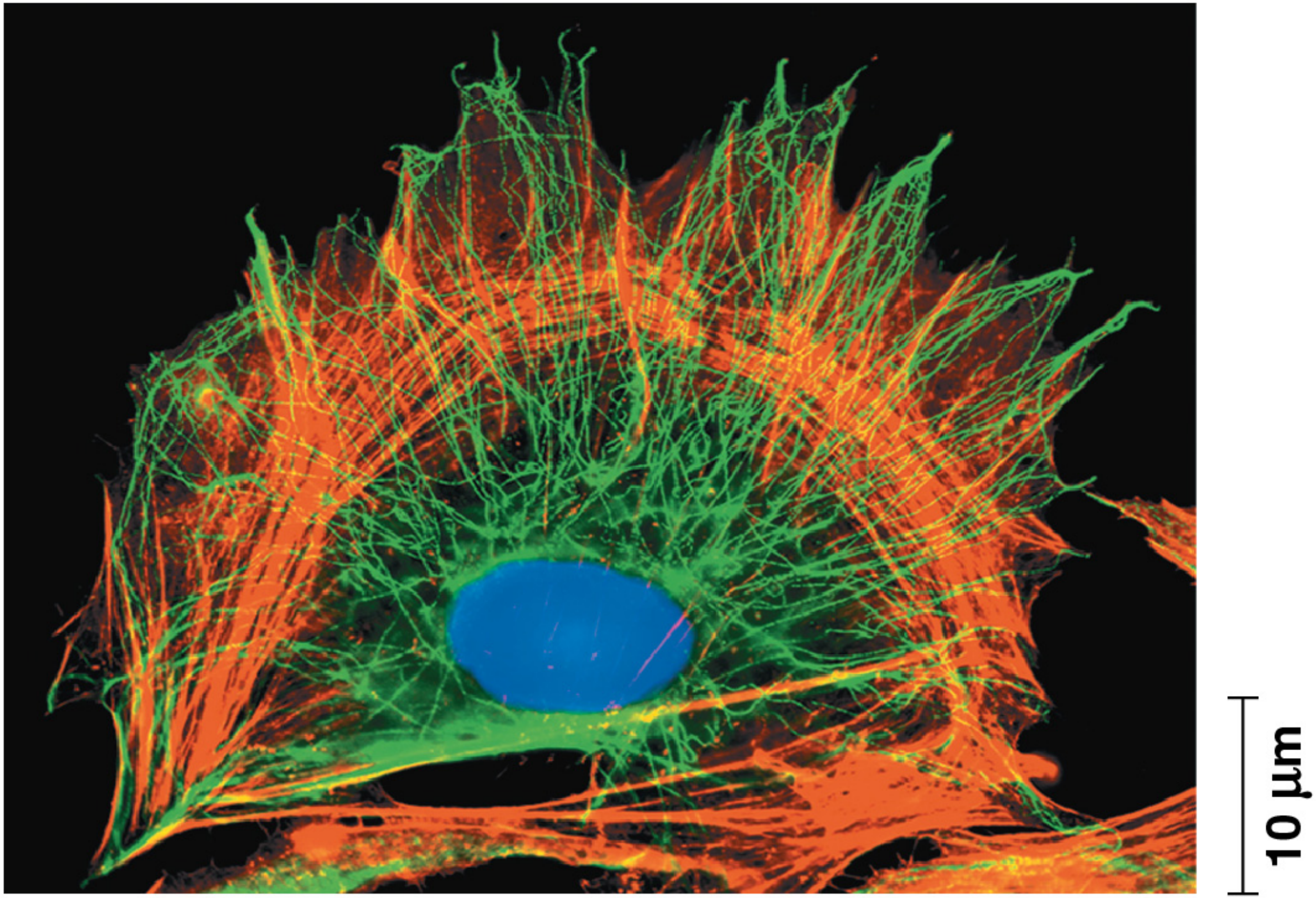
Figure 6.20

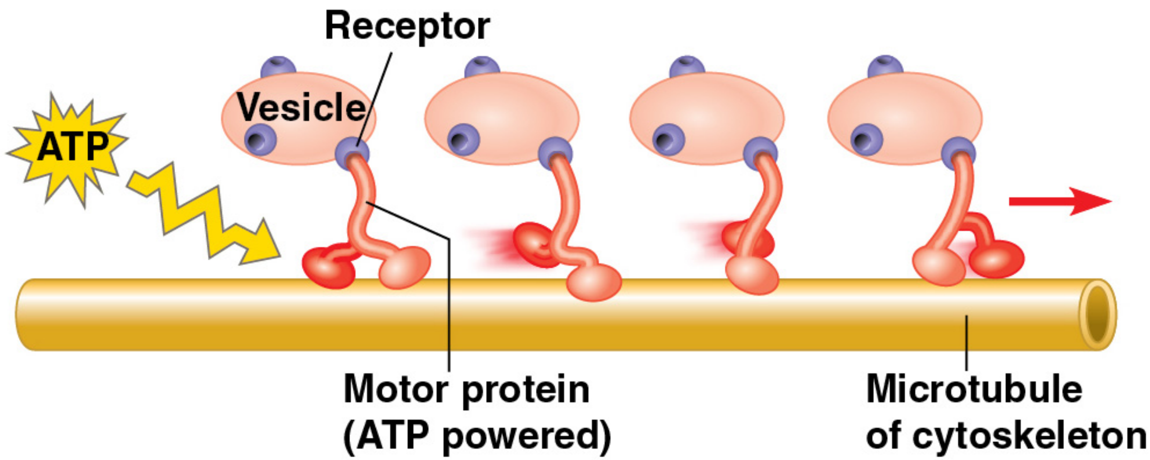


BioFlix® Animation: Cytoskeleton

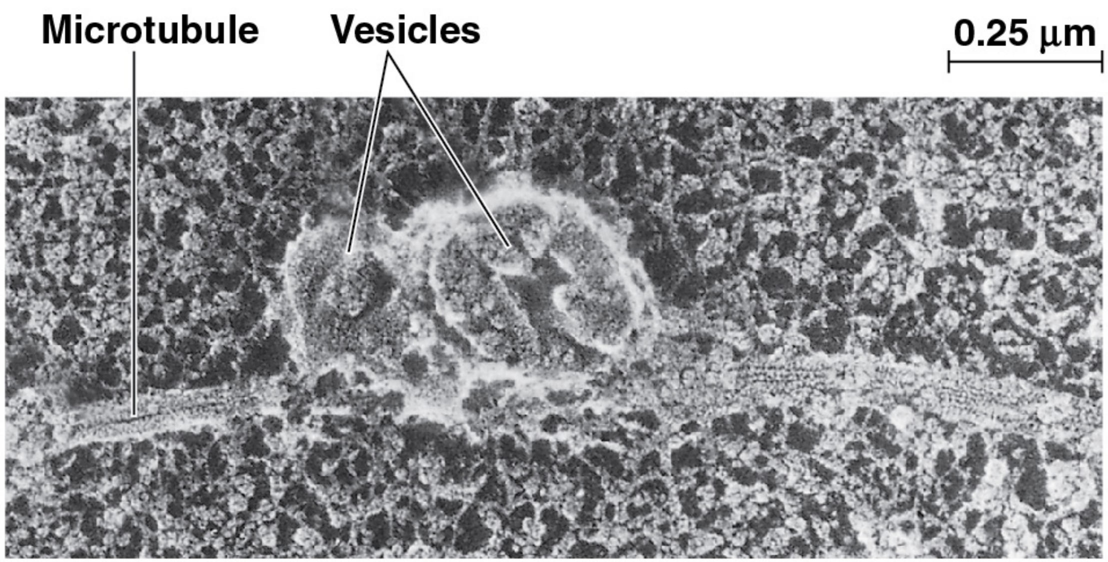
Roles of the Cytoskeleton: Support and Motility

- The cytoskeleton helps to support the cell and maintain its shape
- It interacts with **motor proteins** to produce cell motility
- Inside the cell, vesicles and other organelles can use motor protein “feet” to travel along tracks provided by the cytoskeleton

Figure 6.21



(a) Motor proteins "walk" vesicles along cytoskeletal fibers.



(b) Two vesicles move along a microtubule toward the tip of an axon (SEM)

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

Microtubules (Tubulin Polymers)	Microfilaments (Actin Filaments)	Intermediate Filaments
Hollow tubes	Two intertwined strands of actin	Fibrous proteins coiled into cables
25 nm with 15-nm lumen	7 nm	8–12 nm
Tubulin, a dimer consisting of an α-tubulin and a β-tubulin	Actin	One of several different proteins (including keratins)
Maintenance of cell shape; cell motility; chromosome movements in cell division; organelle movements	Maintenance of cell shape; changes in cell shape; muscle contraction; cytoplasmic streaming (plant cells); cell motility; cell division (animal cells)	Maintenance of cell shape; anchorage of nucleus and certain other organelles; formation of nuclear lamina

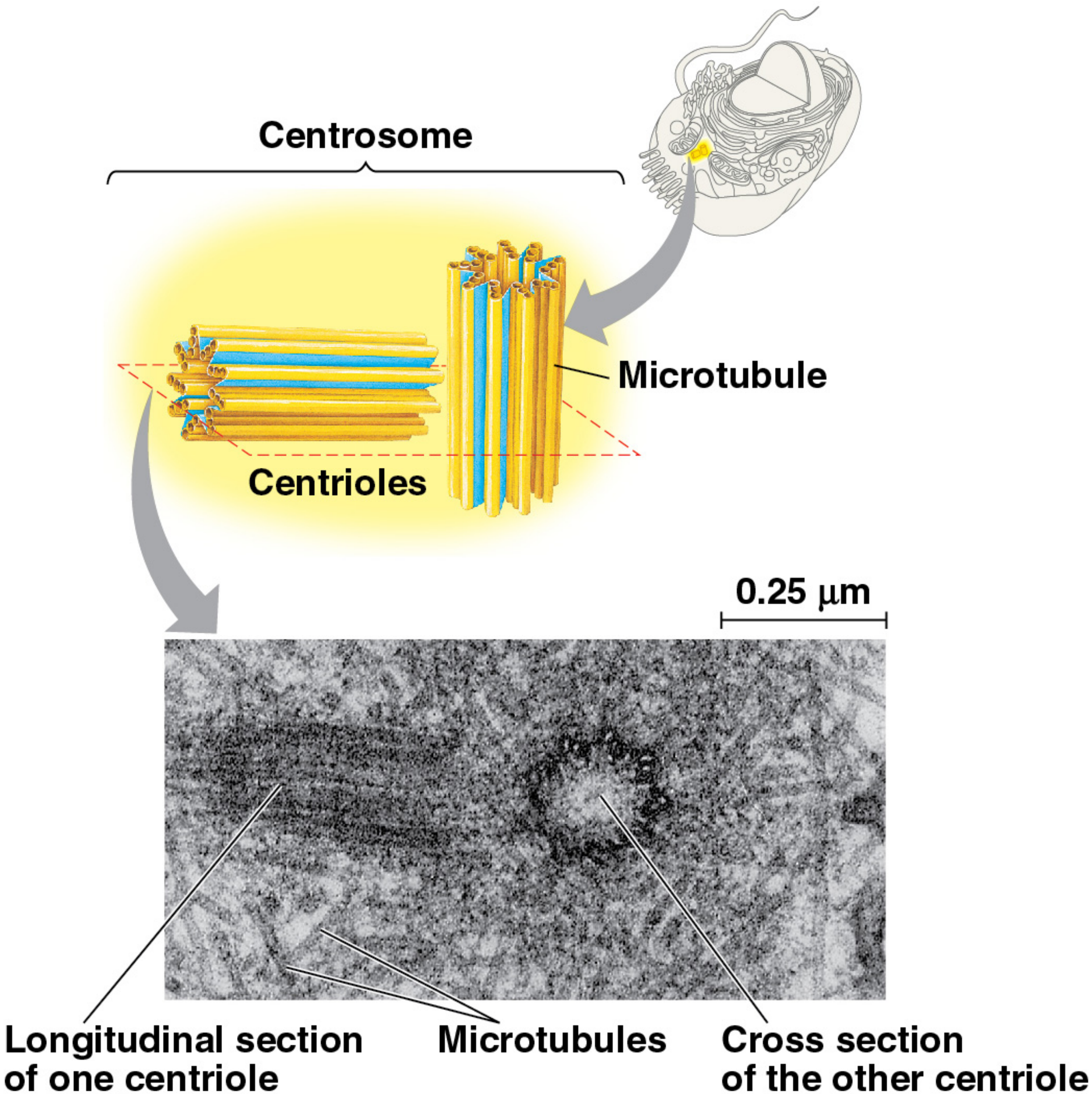
Microtubules

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

Centrosomes and Centrioles

- In animal cells, microtubules grow out from a **centrosome** near the nucleus
- In animal cells, the centrosome has a pair of **centrioles**, each with nine triplets of microtubules arranged in a ring
- Other eukaryotic cells organize microtubules in the absence of centrosomes with centrioles

Figure 6.22

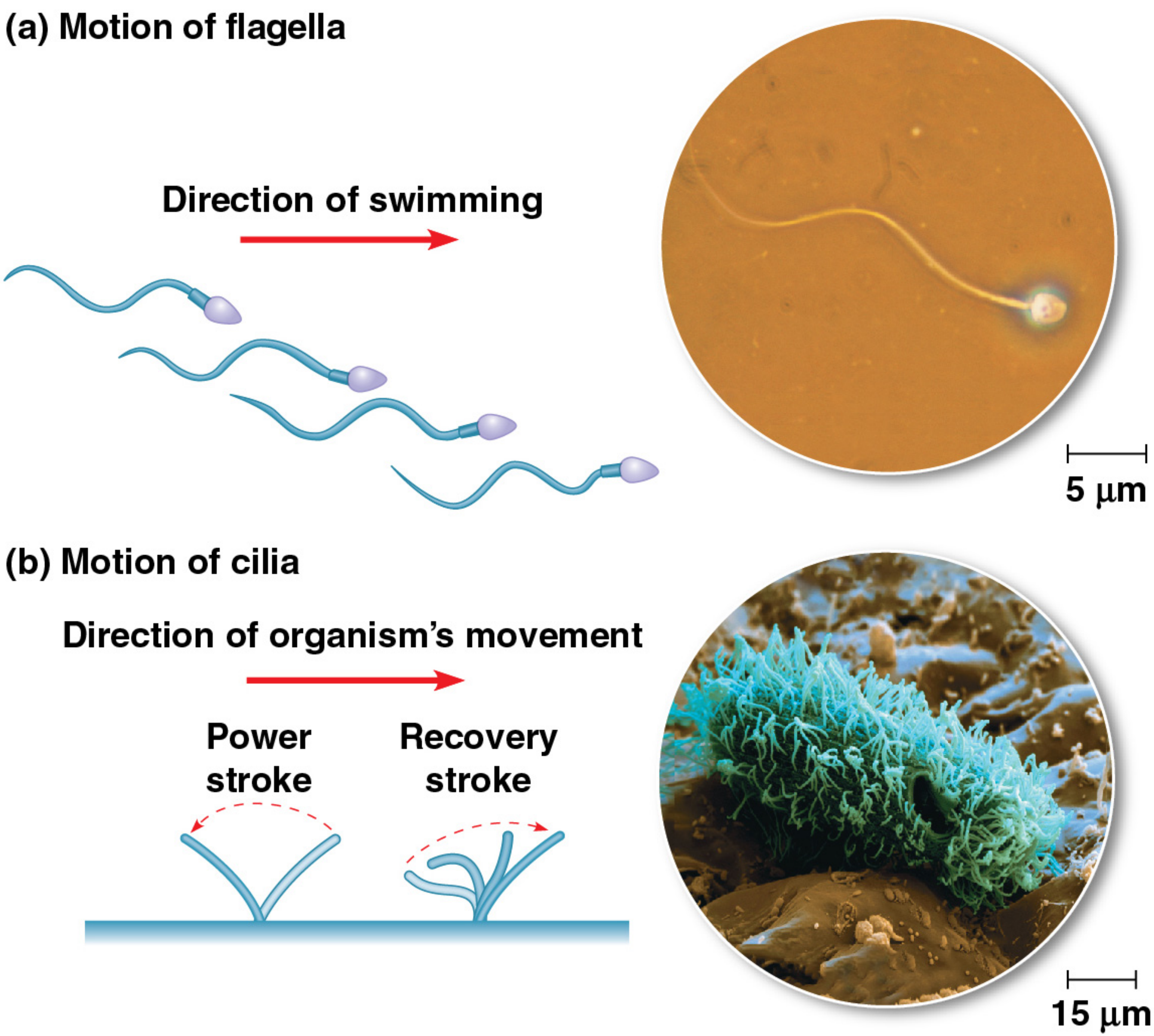


Centrosome
Microtubule
Centrioles
0.25 µm
Longitudinal section of one centriole
Microtubules
Cross section of the other centriole

Cilia and Flagella

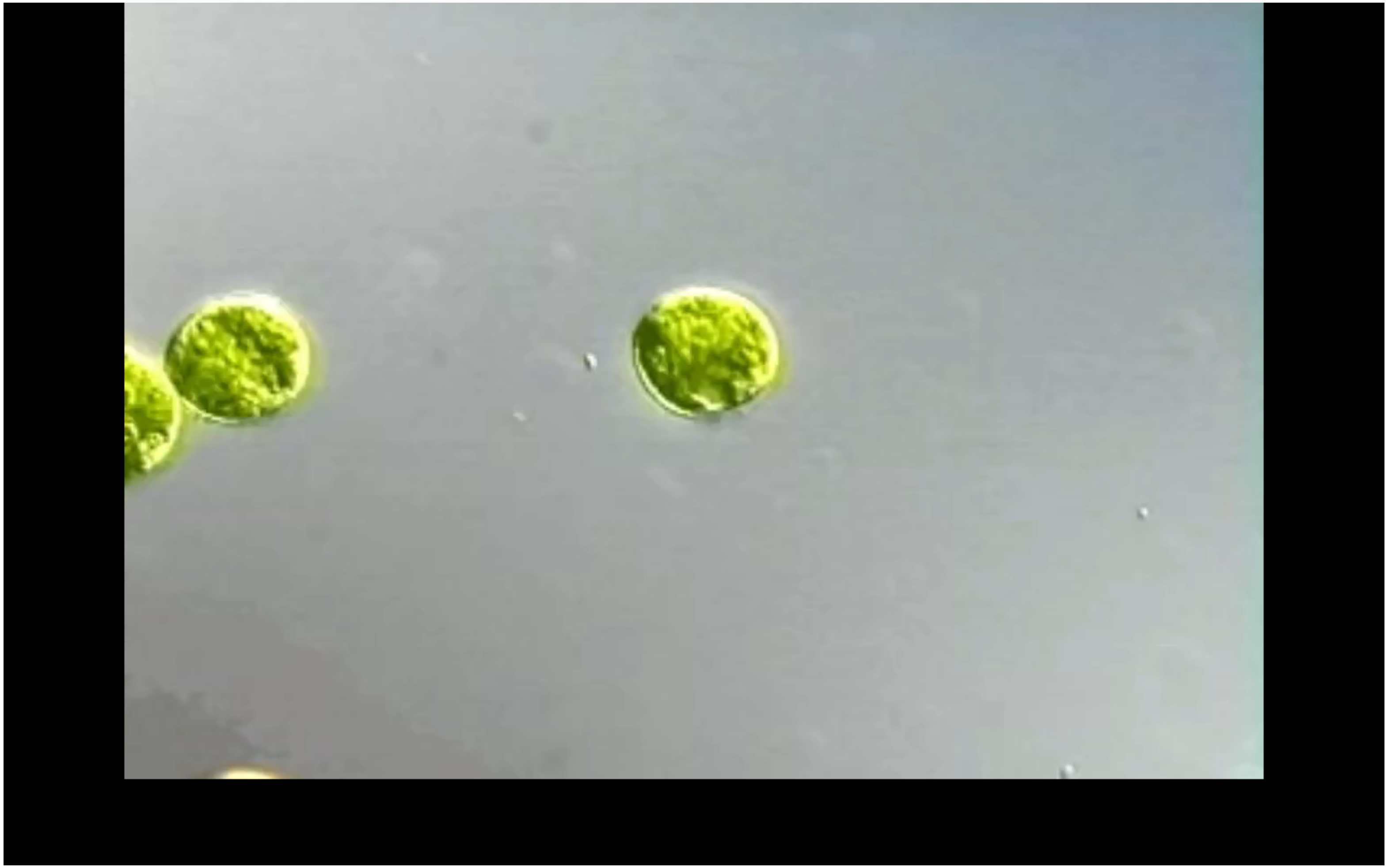
- Microtubules control the beating of **flagella** and **cilia**, microtubule-containing extensions that project from some cells
- Many unicellular protists are propelled through water by cilia or flagella
- Motile cilia are found in large numbers on a cell surface, whereas flagella are limited to one or a few per cell
- Cilia and flagella differ in their beating patterns

Figure 6.23

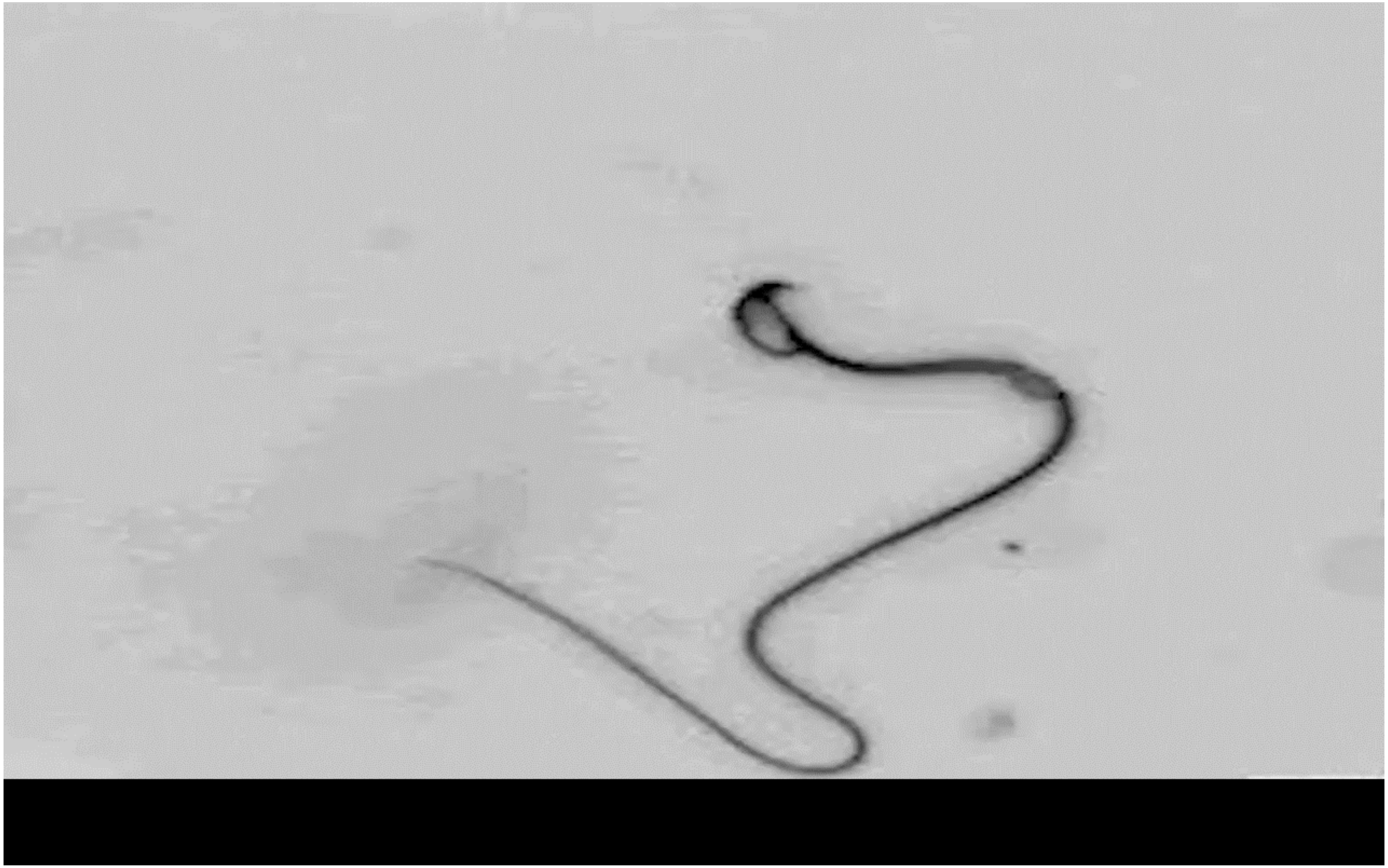


(a) Motion of flagella
Direction of swimming
5 µm
(b) Motion of cilia
Direction of organism's movement
Power stroke
Recovery stroke
15 µm

Video: *Chlamydomonas*



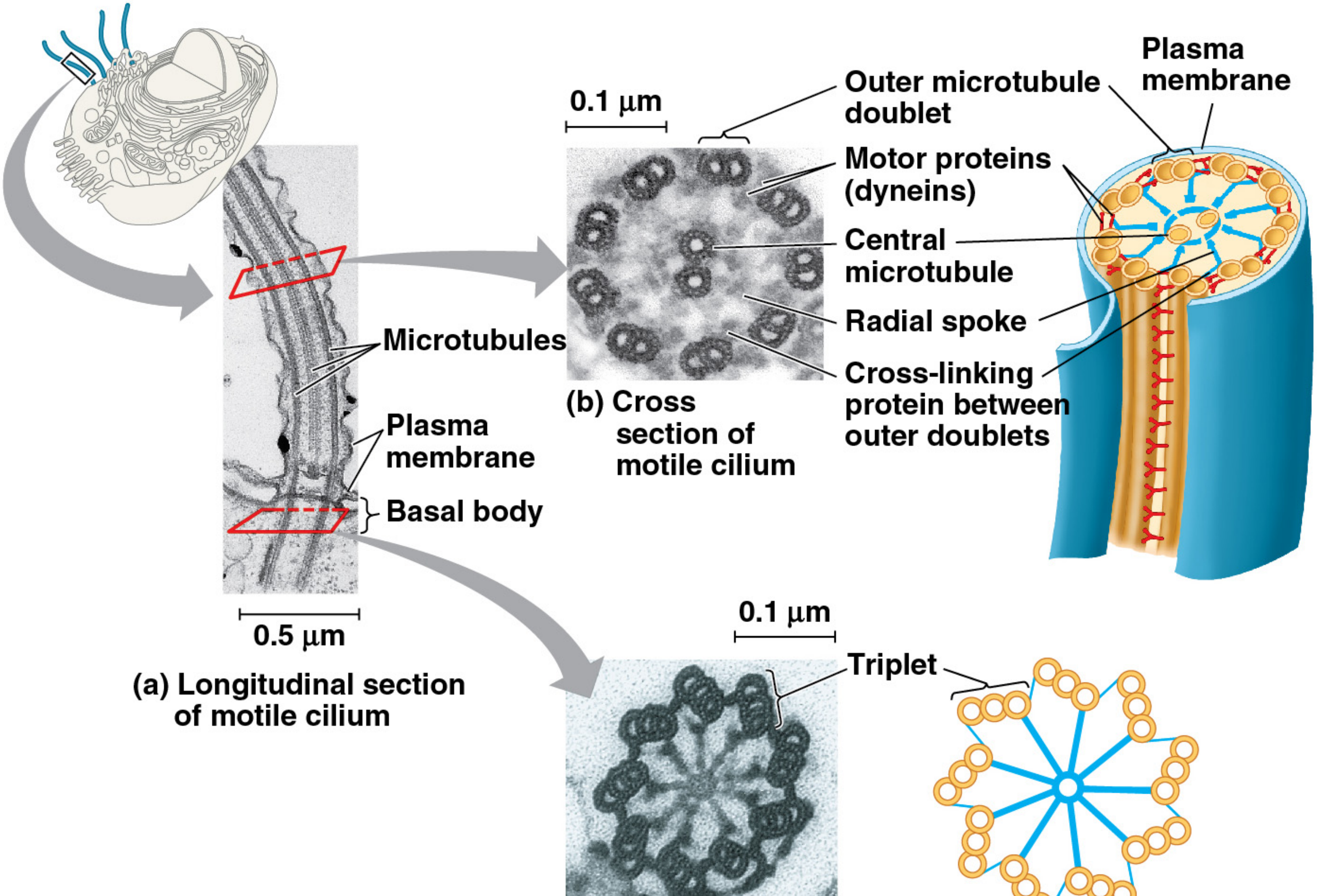
Video: Flagellum Beating with ATP



Video: Paramecium Cilia

- Cilia and flagella share a common structure
  - A group of microtubules sheathed in an extension of the plasma membrane
  - Nine doublets of microtubules are arranged in a ring with two single microtubules in the center
  - A **basal body** that anchors the cilium or flagellum
  - A motor protein called **dynein**, which drives the bending movements of a cilium or flagellum

Figure 6.24

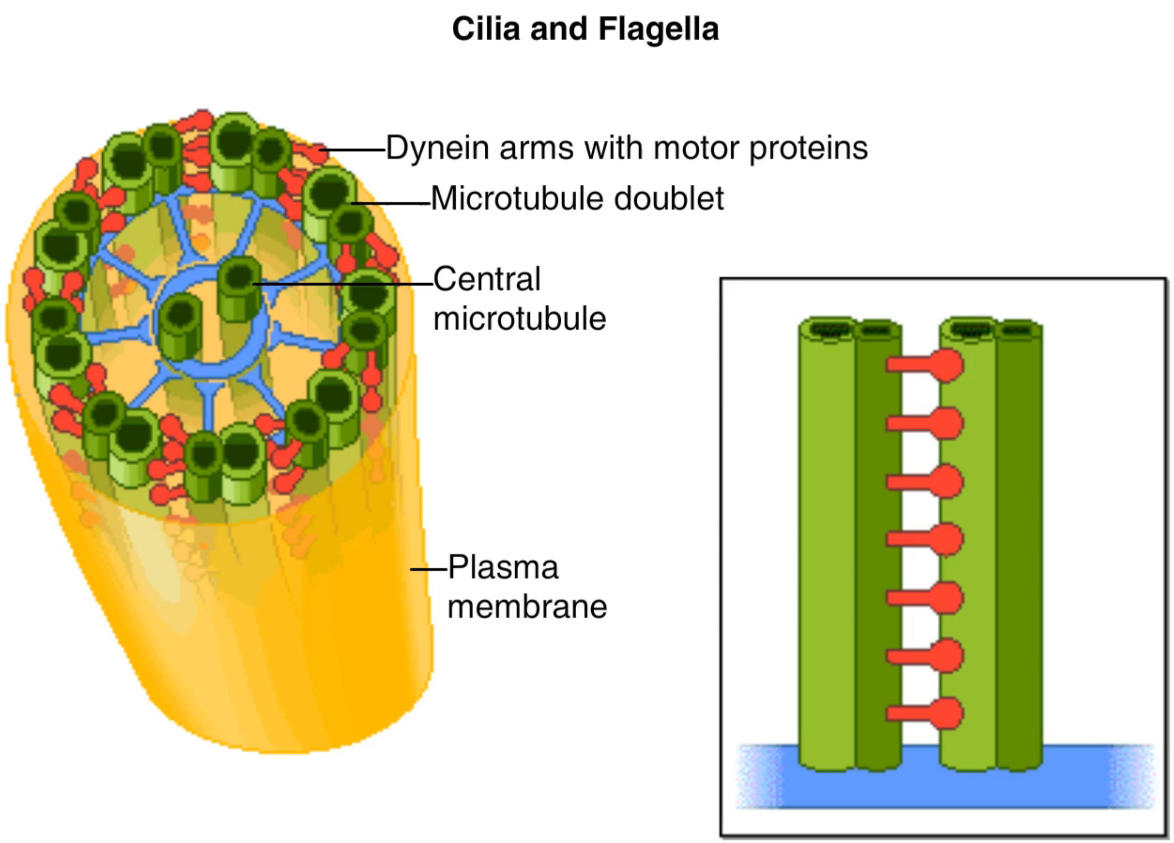


(a) Longitudinal section of motile cilium

(b) Cross section of motile cilium

(c) Cross section of basal body

Animation: Cilia and Flagella

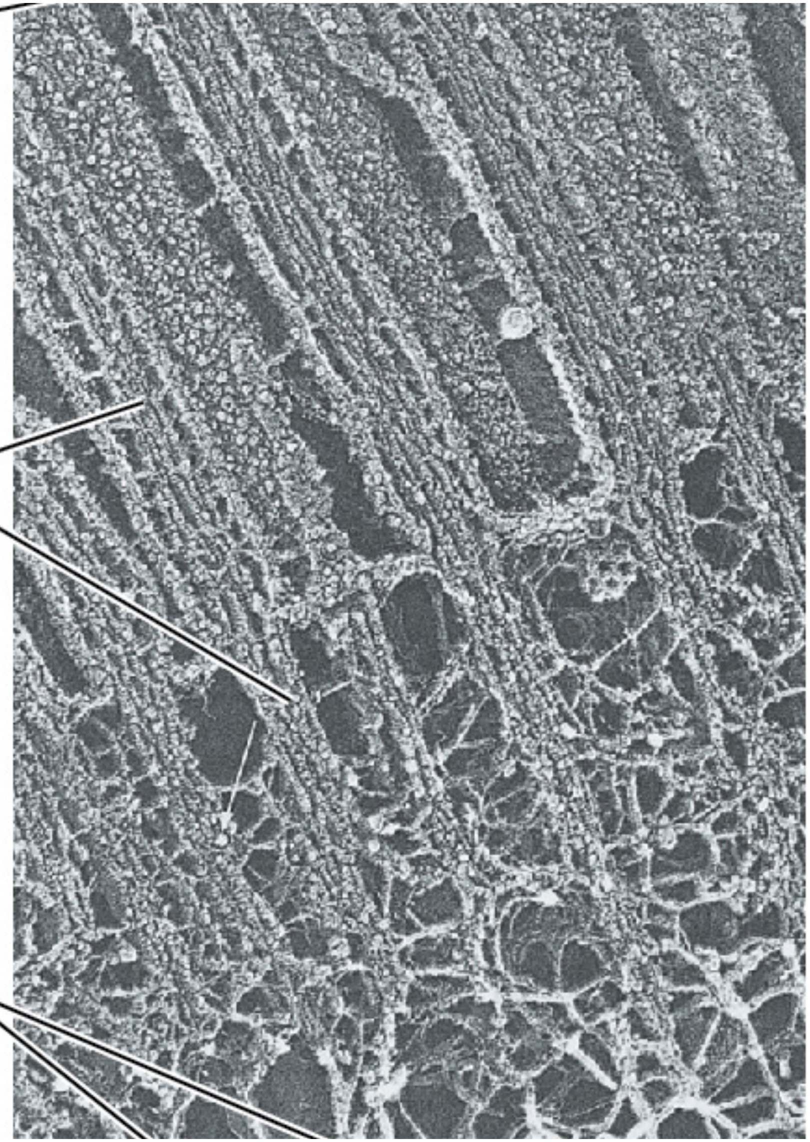


- Dynein has two “feet” that “walk” along microtubules
- One foot maintains contact, while the other releases and reattaches one step farther along
- Movements of the feet cause the microtubules to bend, rather than slide, because the microtubules are held in place

Microfilaments (Actin Filaments)

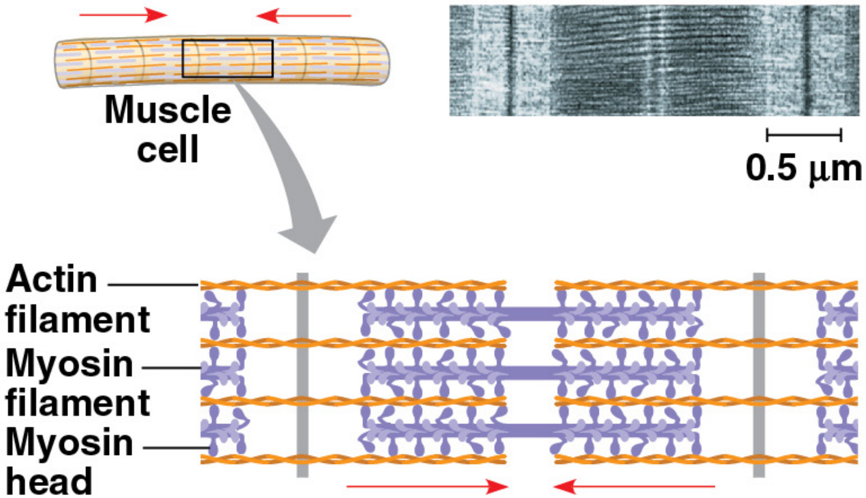
- **Microfilaments** are solid rods about 7 nm in diameter, built as a twisted double chain of **actin** subunits
- A network of microfilaments helps support the cell’s shape
- They form a **cortex** just inside the plasma membrane to help support the cell’s shape
- Bundles of microfilaments make up the core of microvilli of intestinal cells

Figure 6.25

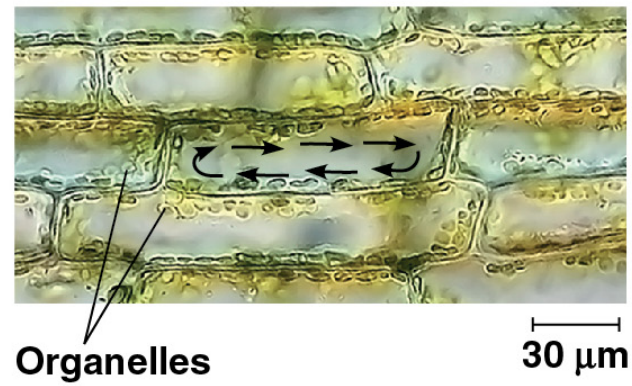

Plasma membrane
Microfilaments (actin filaments)
Intermediate filaments

- Microfilaments that function in cellular motility contain the protein **myosin** in addition to actin
- Cells crawl along a surface by extending **pseudopodia** (cellular extensions) and moving toward them
- **Cytoplasmic streaming**, in plant cells, is a circular flow of cytoplasm within cells, driven by actin-protein interactions

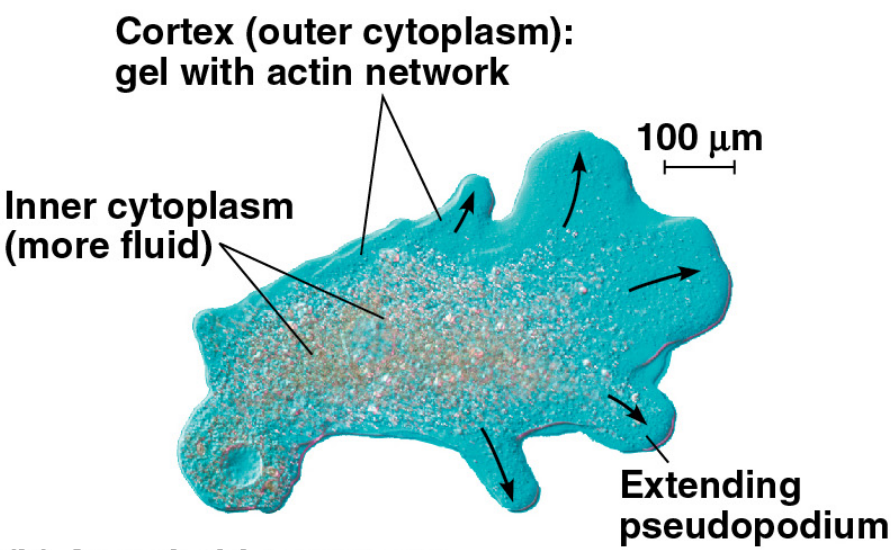
Figure 6.26



(a) Myosin motors in muscle cell contraction

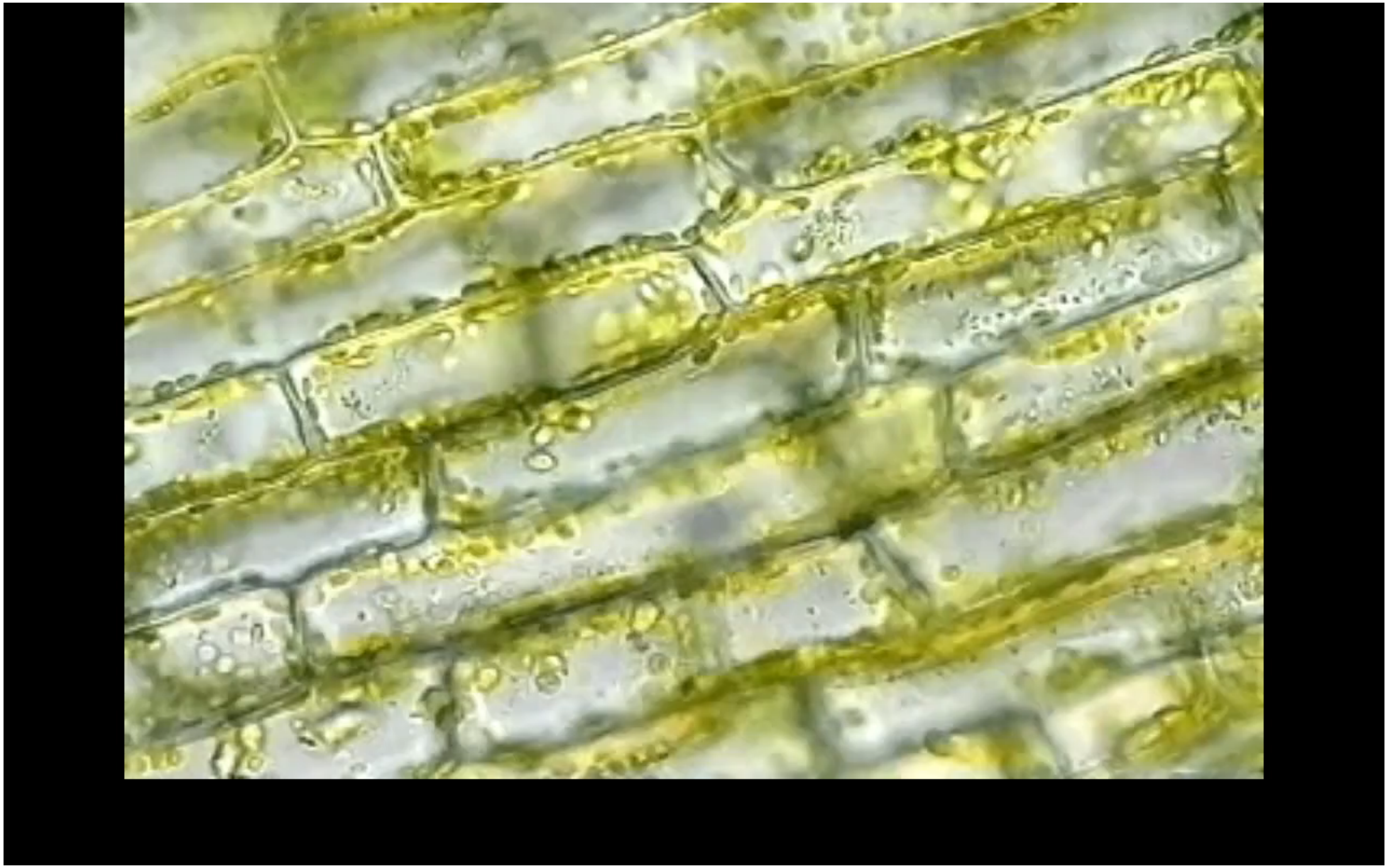


(c) Cytoplasmic streaming in plant cells



(b) Amoeboid movement

Video: Cytoplasmic Streaming



Intermediate Filaments

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

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

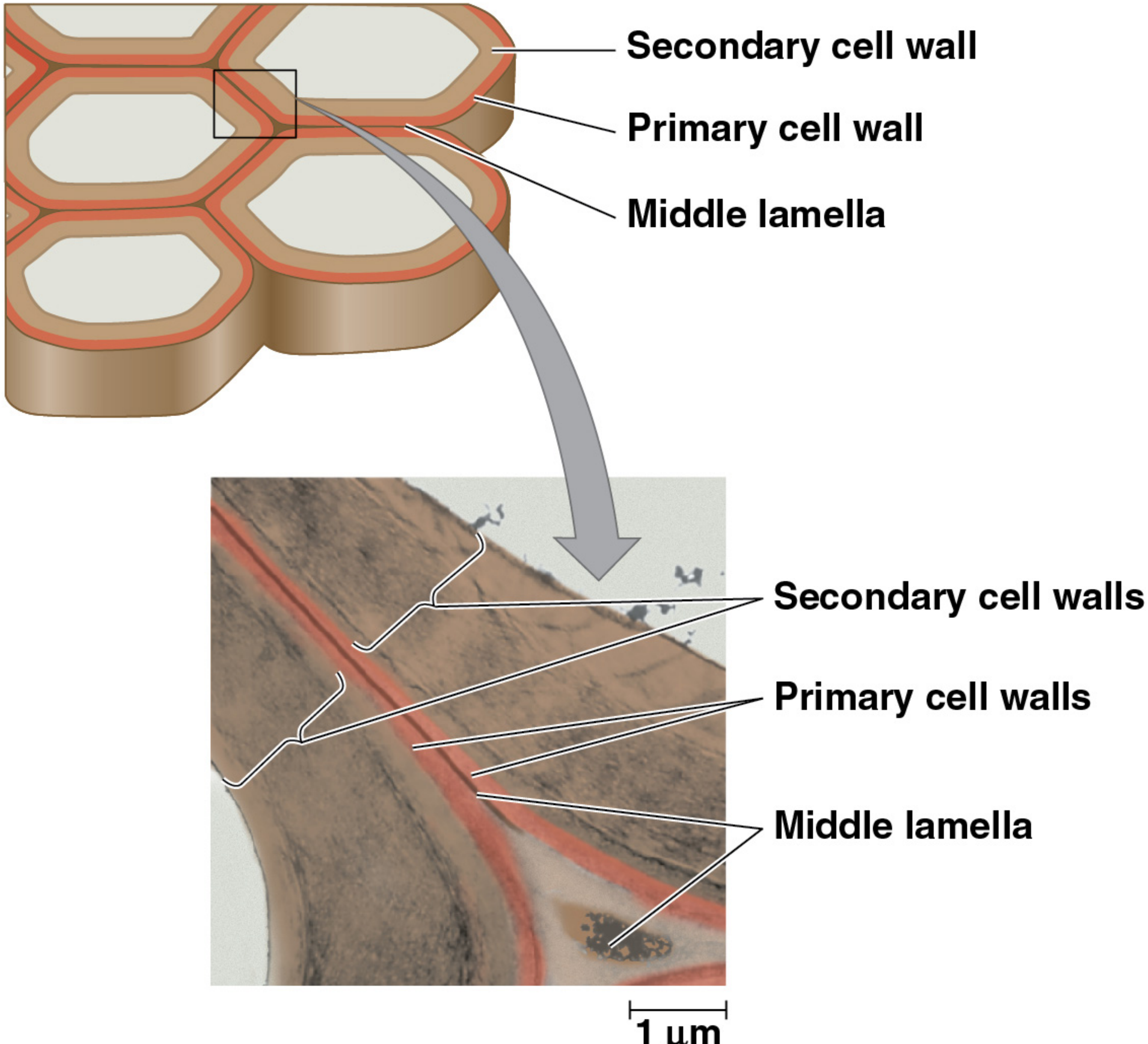
- Most cells synthesize and secrete materials to the outside of the cell
- These extracellular materials and structures are involved in many essential cellular functions

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, secreted first
  - **Middle lamella**: Thin layer between primary walls, containing polysaccharides called pectins
  - **Secondary cell wall** (in some cells): Added between the plasma membrane and the primary cell wall

Figure 6.27

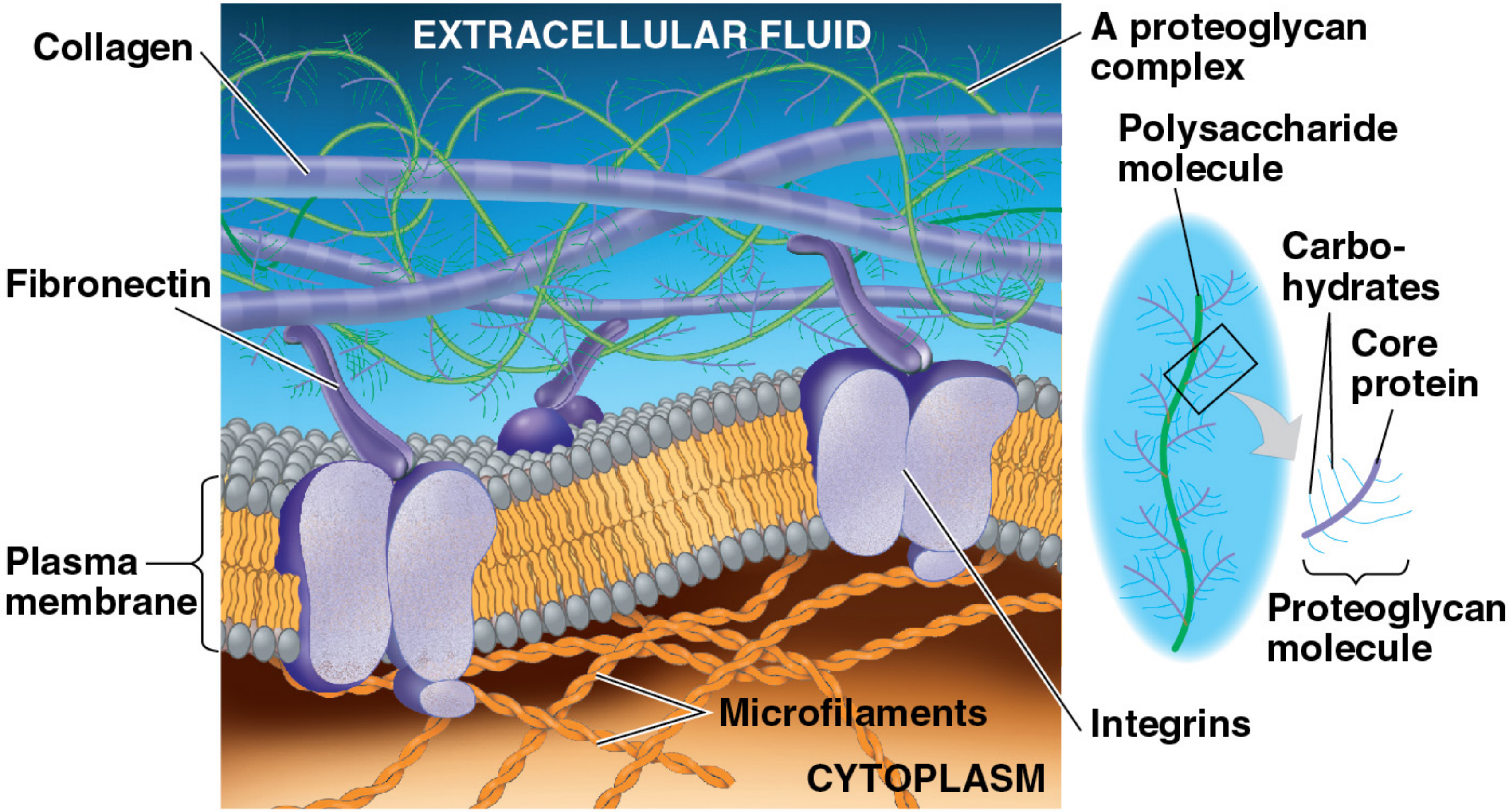


Secondary cell wall
Primary cell wall
Middle lamella
Secondary cell walls
Primary cell walls
Middle lamella
1 µm

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**
- Fibronectin and other ECM proteins bind to receptor proteins in the plasma membrane called **integrins**

Figure 6.28



Collagen
EXTRACELLULAR FLUID
A proteoglycan complex
Polysaccharide molecule
Carbo-hydrates
Core protein
Fibronectin
Plasma membrane
Proteoglycan molecule
Microfilaments
Integrins
CYTOPLASM

- The ECM has an influential role in the lives of cells
- ECM can regulate a cell’s behavior by communicating with a cell through integrins
- The ECM around a cell can influence the activity of genes in the nucleus
- Mechanical signaling may occur through cytoskeletal changes that trigger chemical signals in the cell

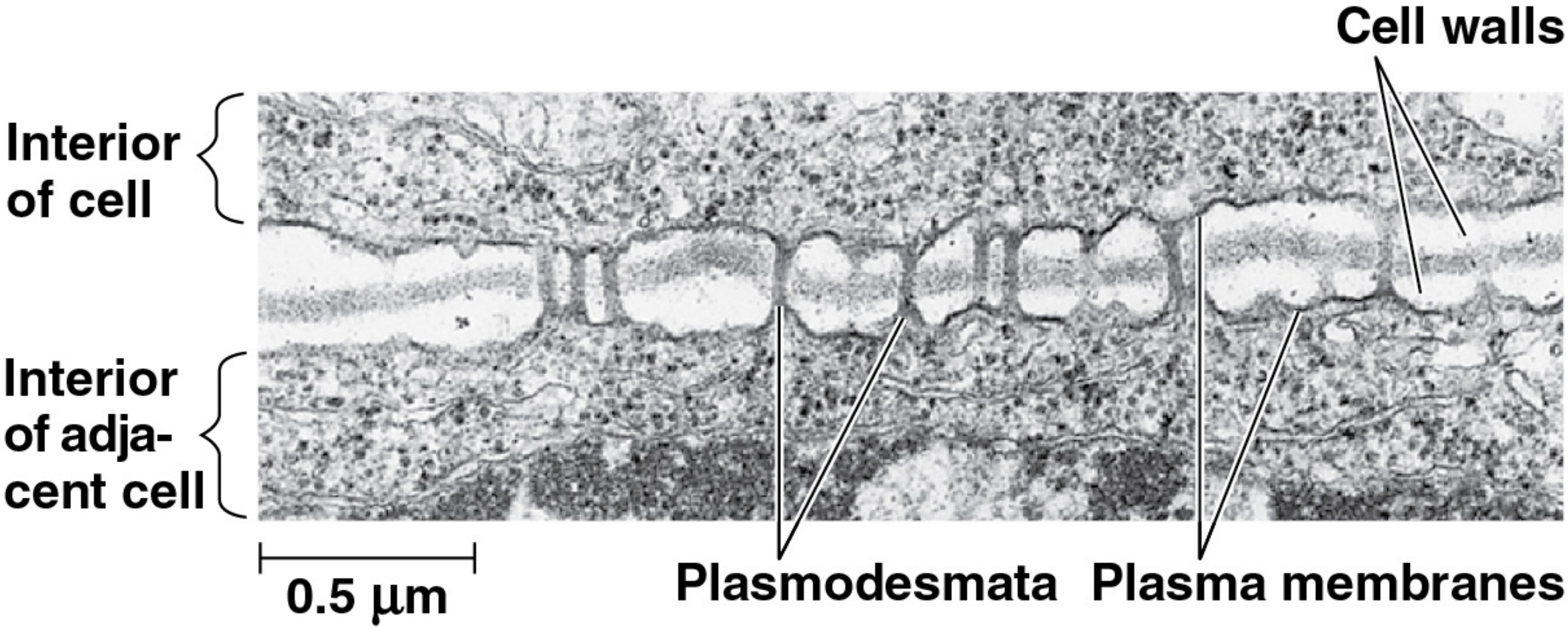
Cell Junctions

- Neighboring cells in tissues, organs, or organ systems often adhere, interact, and communicate through direct physical contact

Plasmodesmata in Plant Cells

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

Figure 6.29

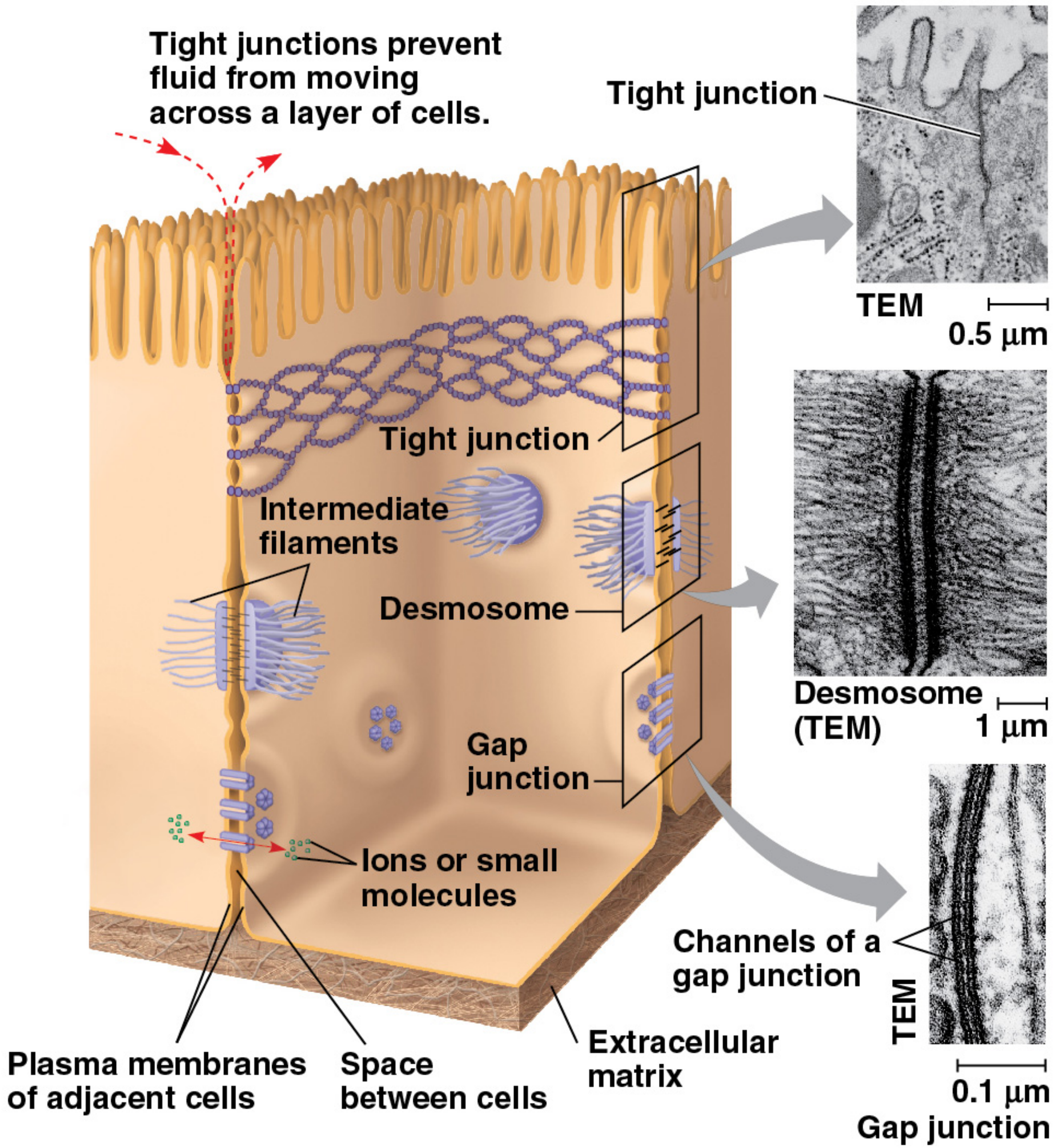


Cell walls
Interior of cell
Interior of adja-cent cell
0.5 µm
Plasmodesmata
Plasma membranes

Tight Junctions, Desmosomes, and Gap Junctions in Animal Cells

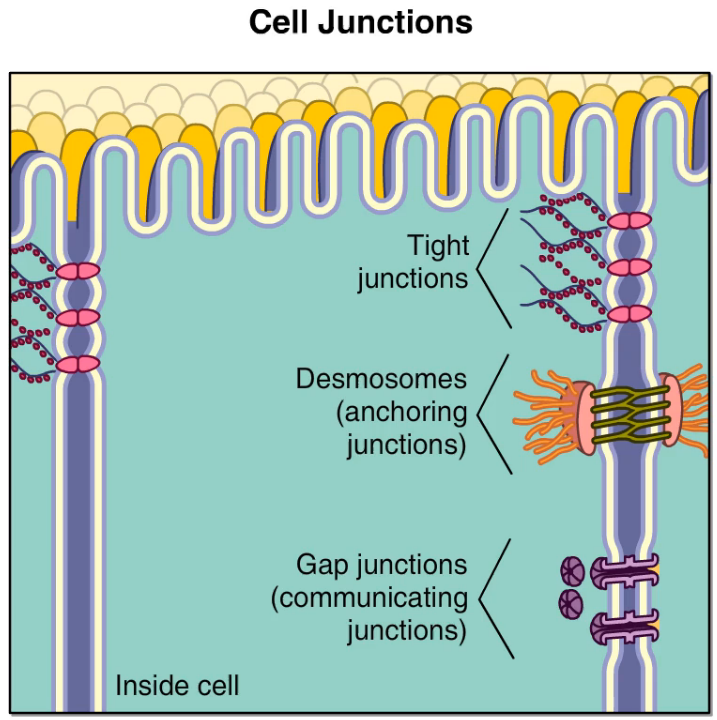
- Three types of cell junctions are common in epithelial tissues
  - At tight junctions, membranes of neighboring cells are pressed together, preventing leakage of extracellular fluid
  - Desmosomes (anchoring junctions) fasten cells together into strong sheets
  - Gap junctions (communicating junctions) provide cytoplasmic channels between adjacent cells

Figure 6.30



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

Animation: Cell Junctions



[redacted]

Concept 6.8: A cell is greater than the sum of its parts

- None of the cell's components work alone
- For example, a macrophage's ability to destroy bacteria involves the whole cell, coordinating components such as the cytoskeleton, lysosomes, and plasma membrane

Figure 6.31

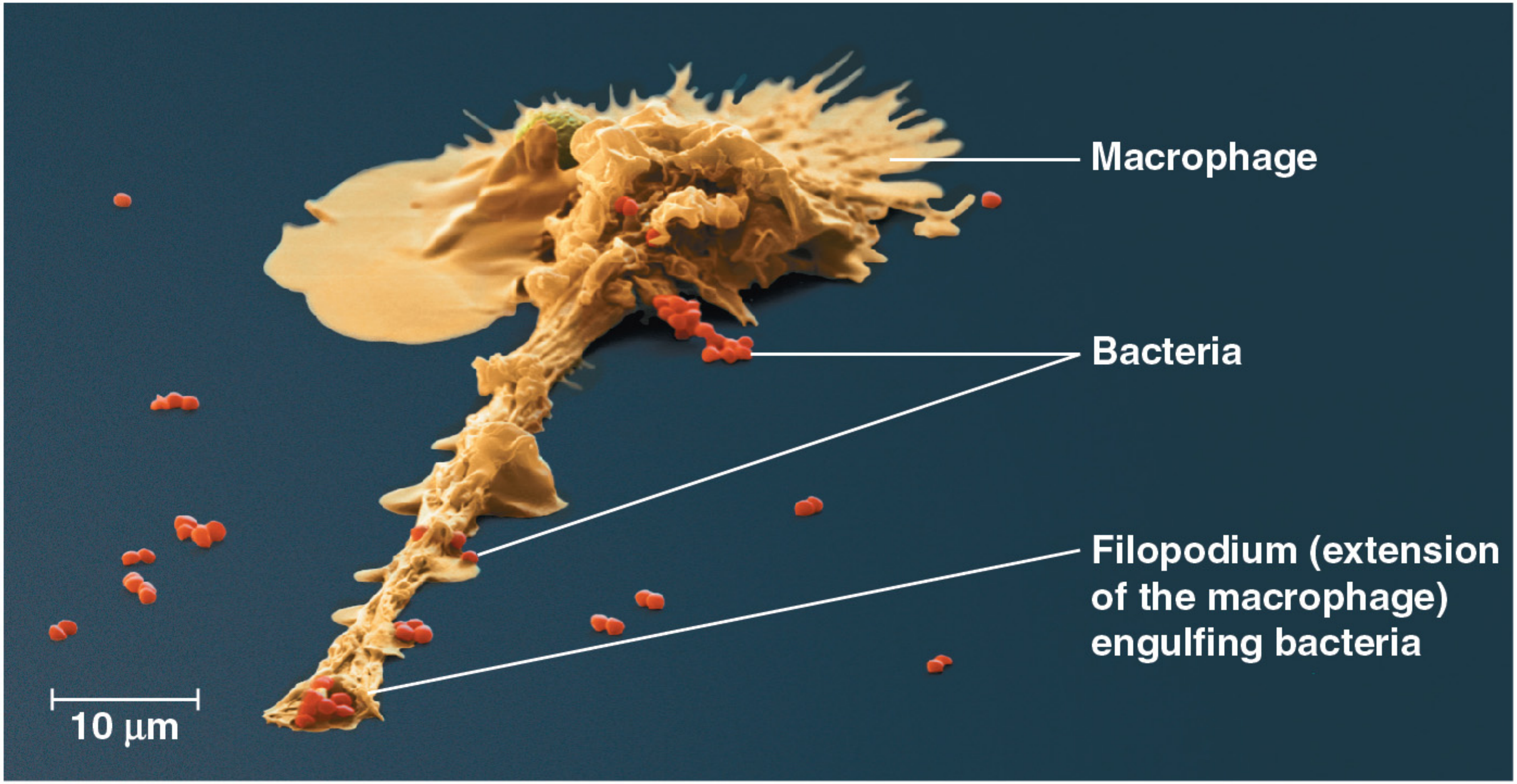

Macrophage
Bacteria
Filopodium (extension of the macrophage) engulfing bacteria
10 µm

Figure 6.32a

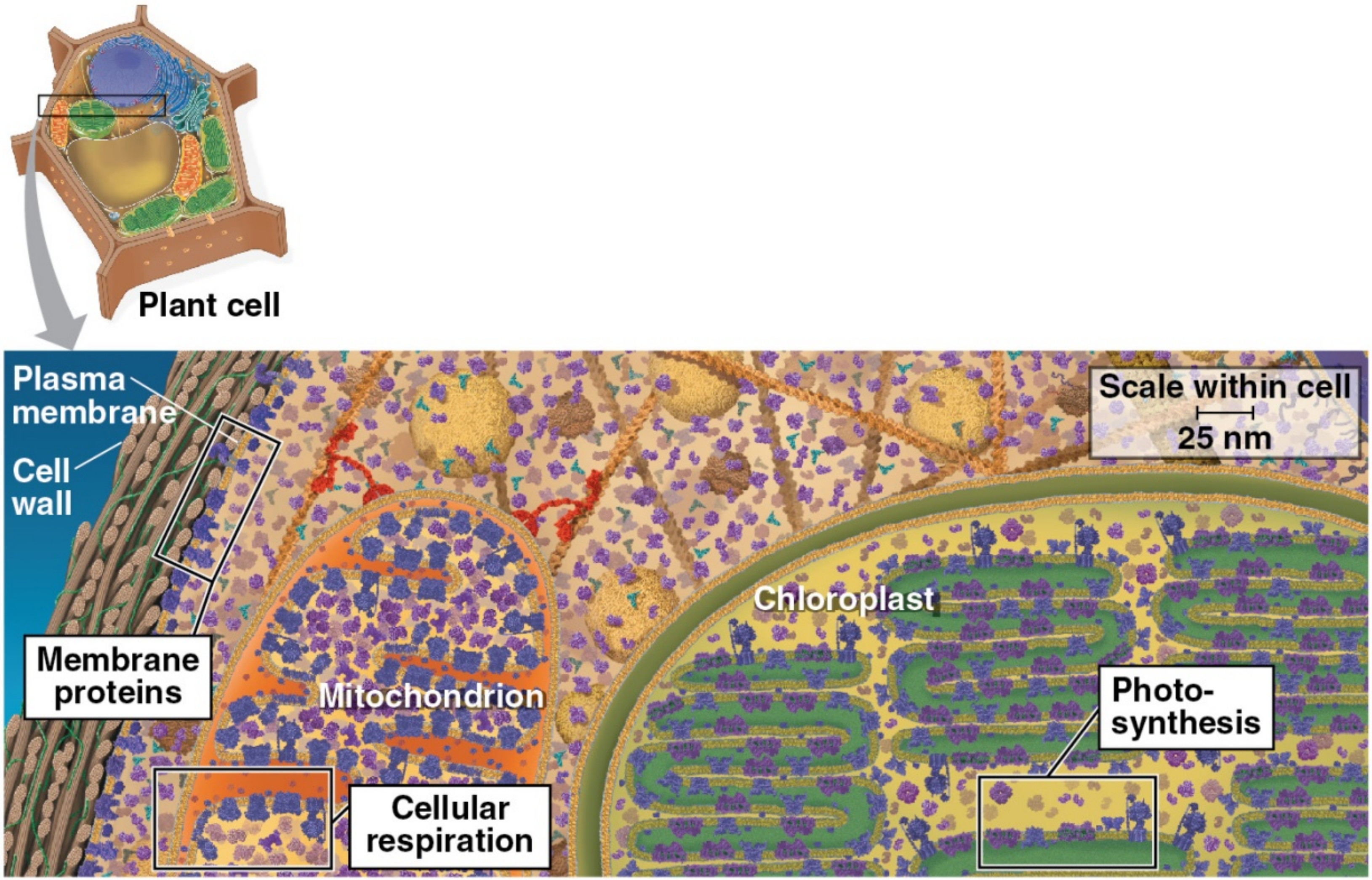
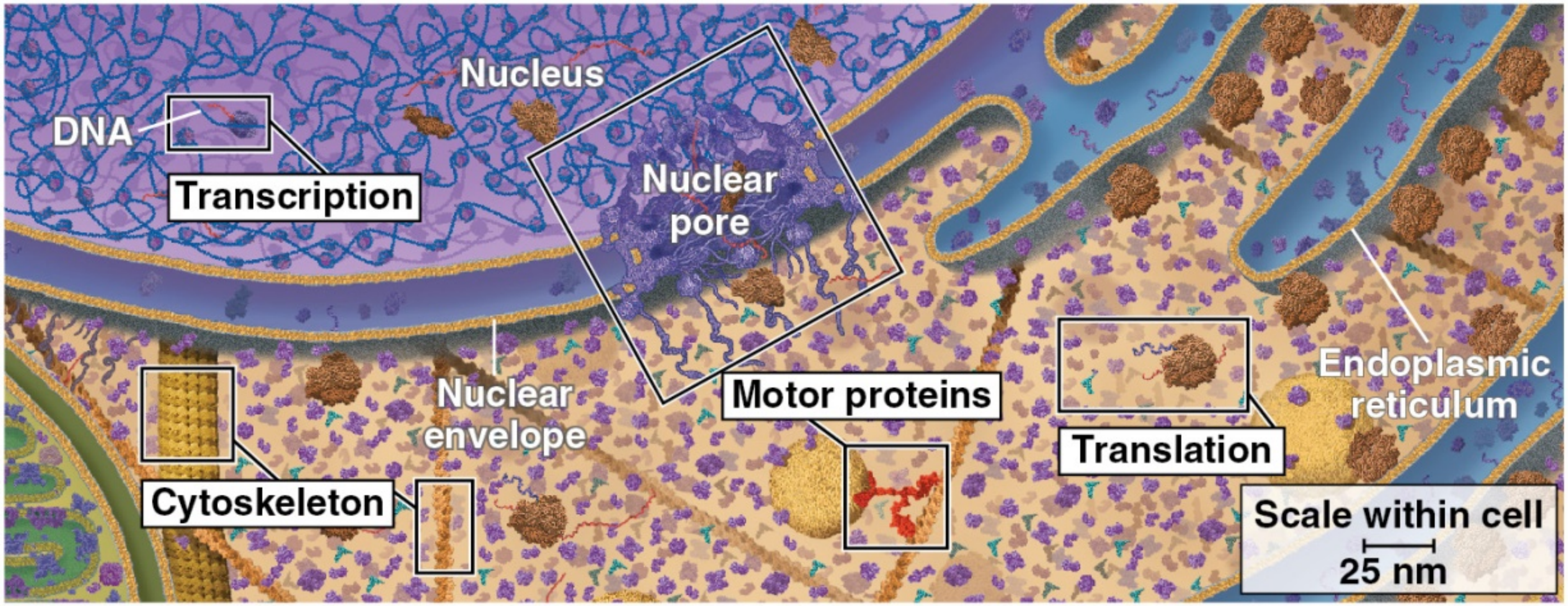
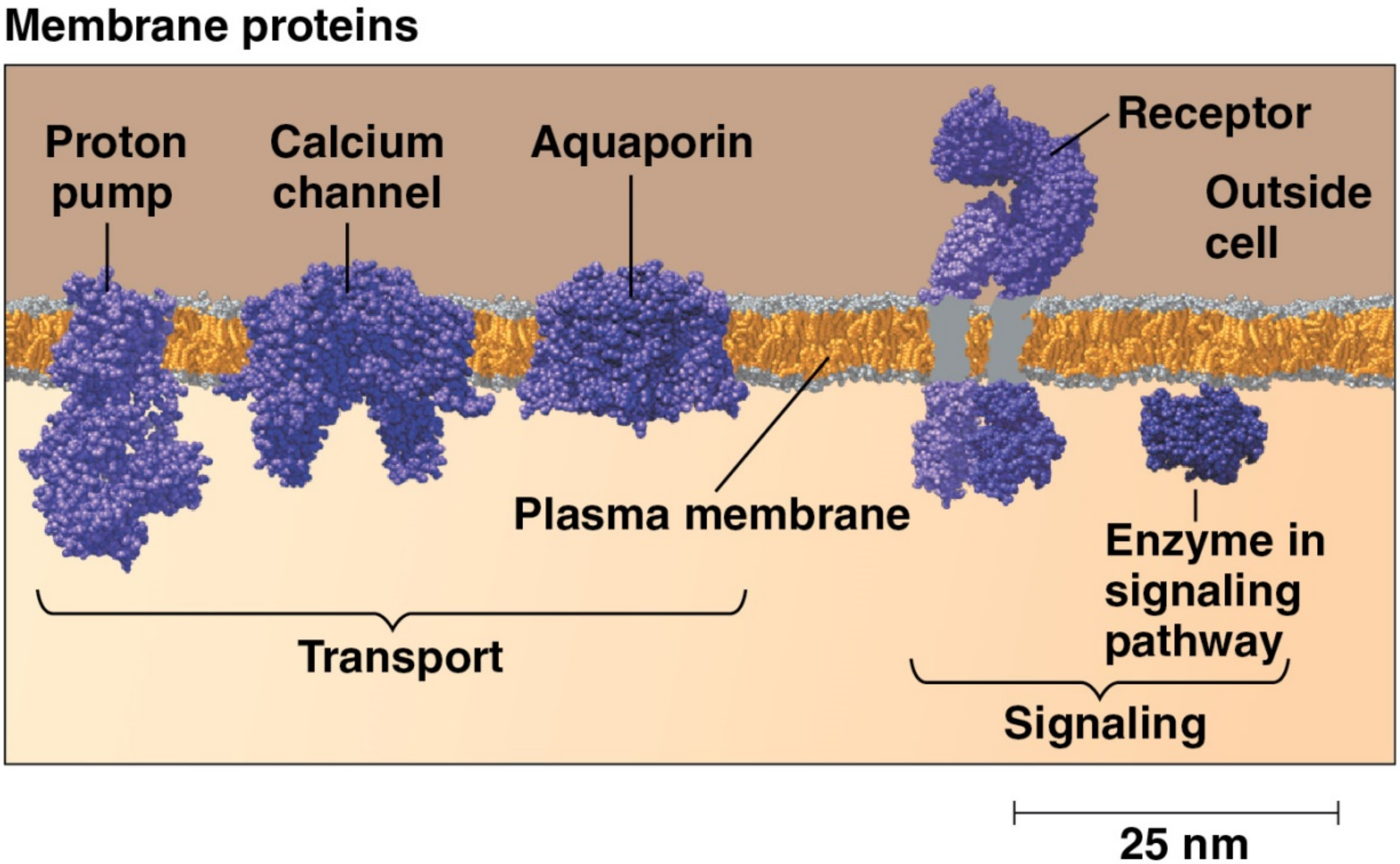

Plant cell
Plasma membrane
Cell wall
Membrane proteins
Mitochondrion
Chloroplast
Scale within cell
25 nm
Cellular respiration
Photo-
synthesis

Figure 6.32b



Nucleus
DNA
Transcription
Nuclear
pore
Nuclear
envelope
Motor proteins
Translation
Endoplasmic
reticulum
Cytoskeleton
Scale within cell
25 nm

Figure 6.32c



Membrane proteins
Proton pump
Calcium channel
Aquaporin
Receptor
Outside cell
Plasma membrane
Enzyme in signaling pathway
Transport
Signaling
25 nm

Figure 6.32d

Cellular respiration

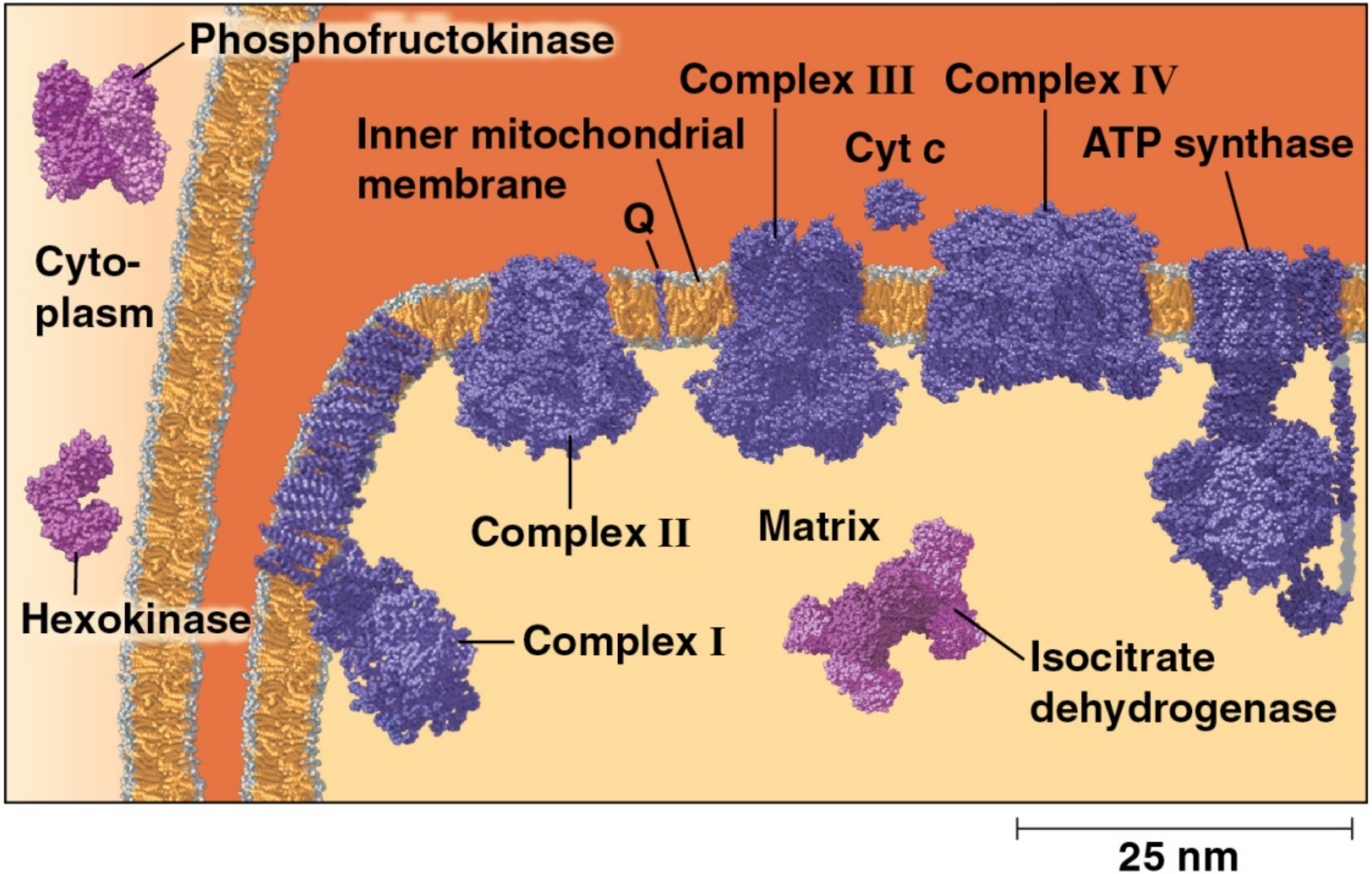
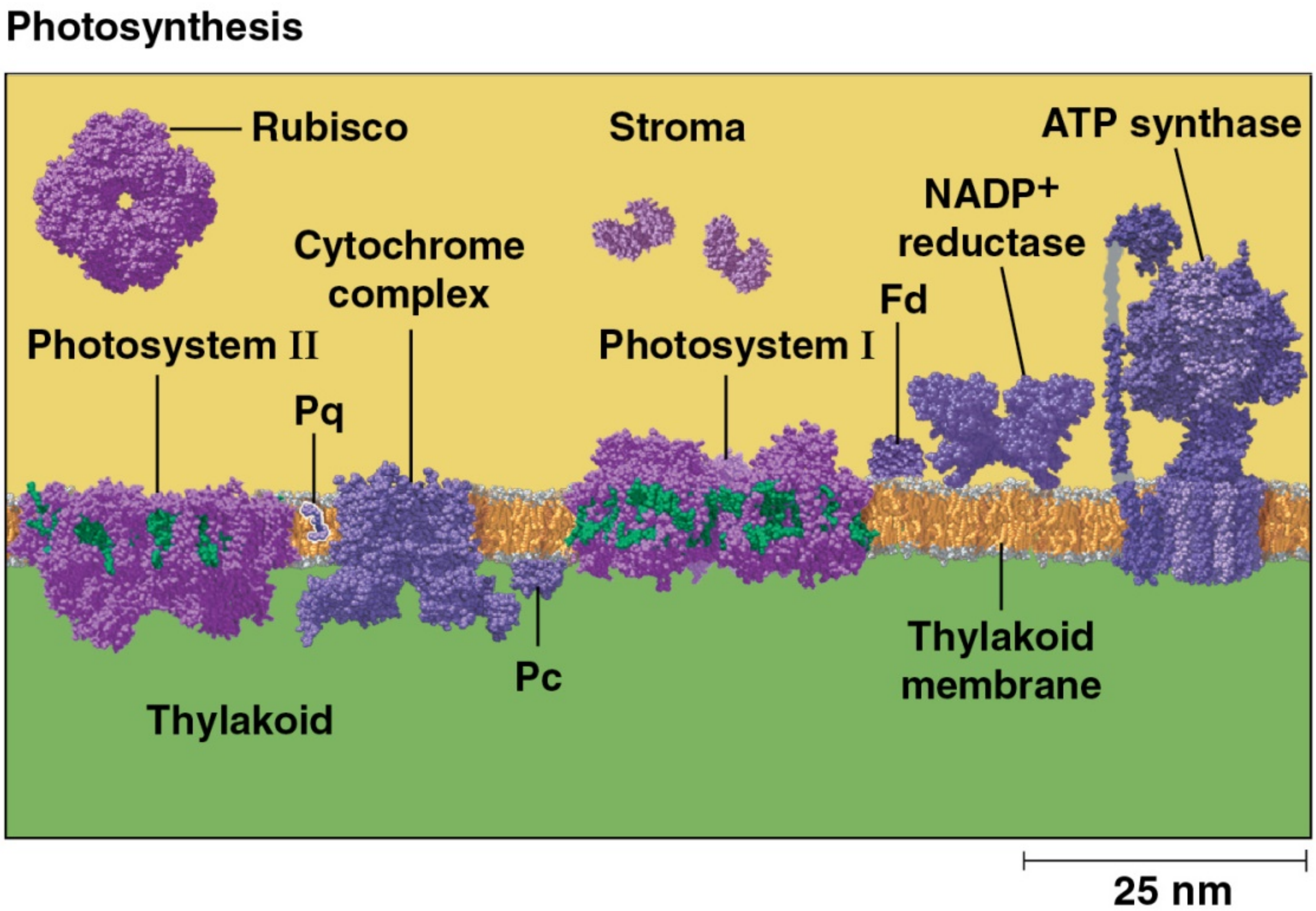


Figure 6.32e



Photosynthesis
Rubisco
Stroma
ATP synthase
NADP+ reductase
Cytochrome complex
Fd
Photosystem II
Photosystem I
Pq
Pc
Thylakoid
Thylakoid membrane
25 nm

Figure 6.32f

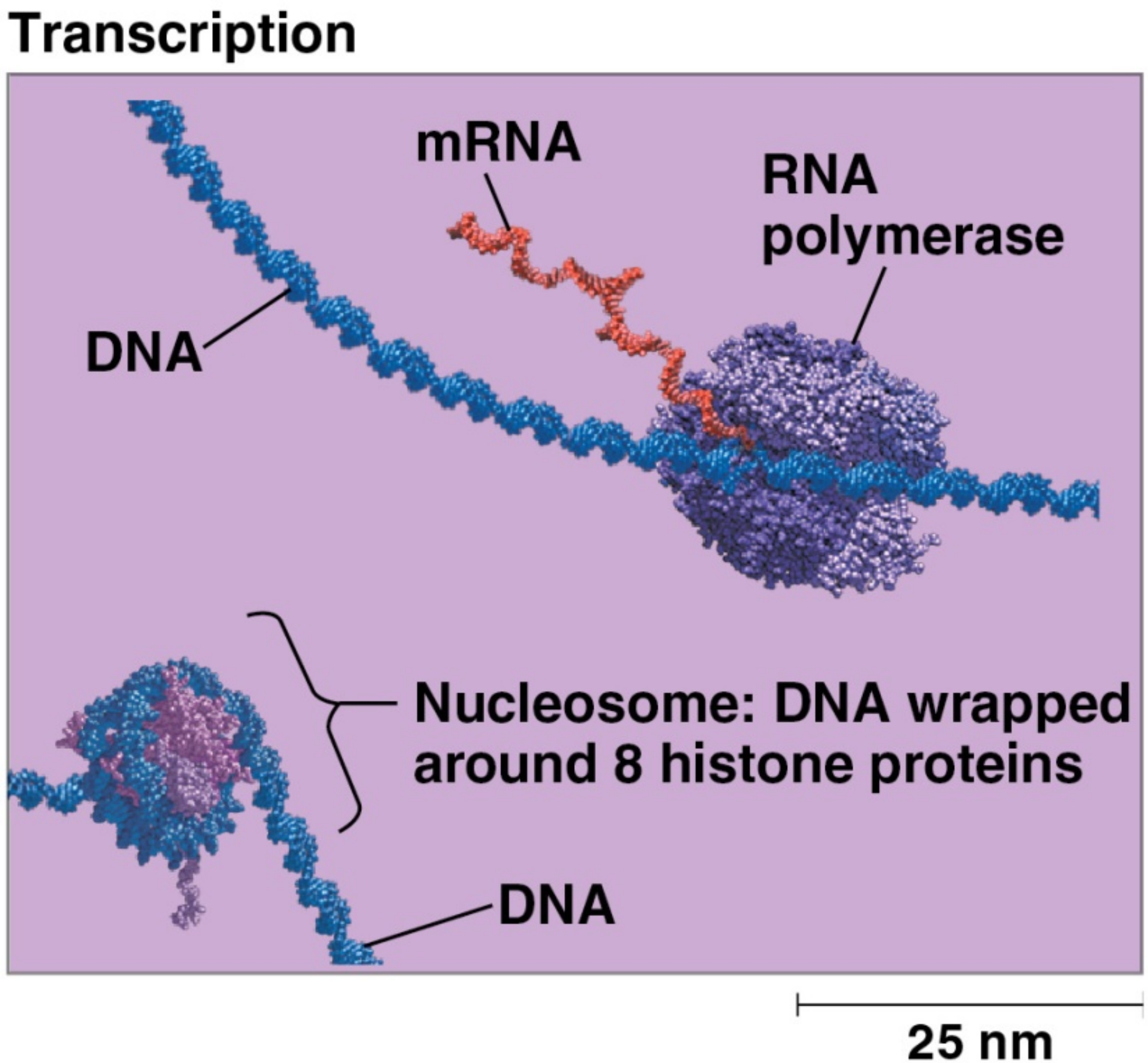
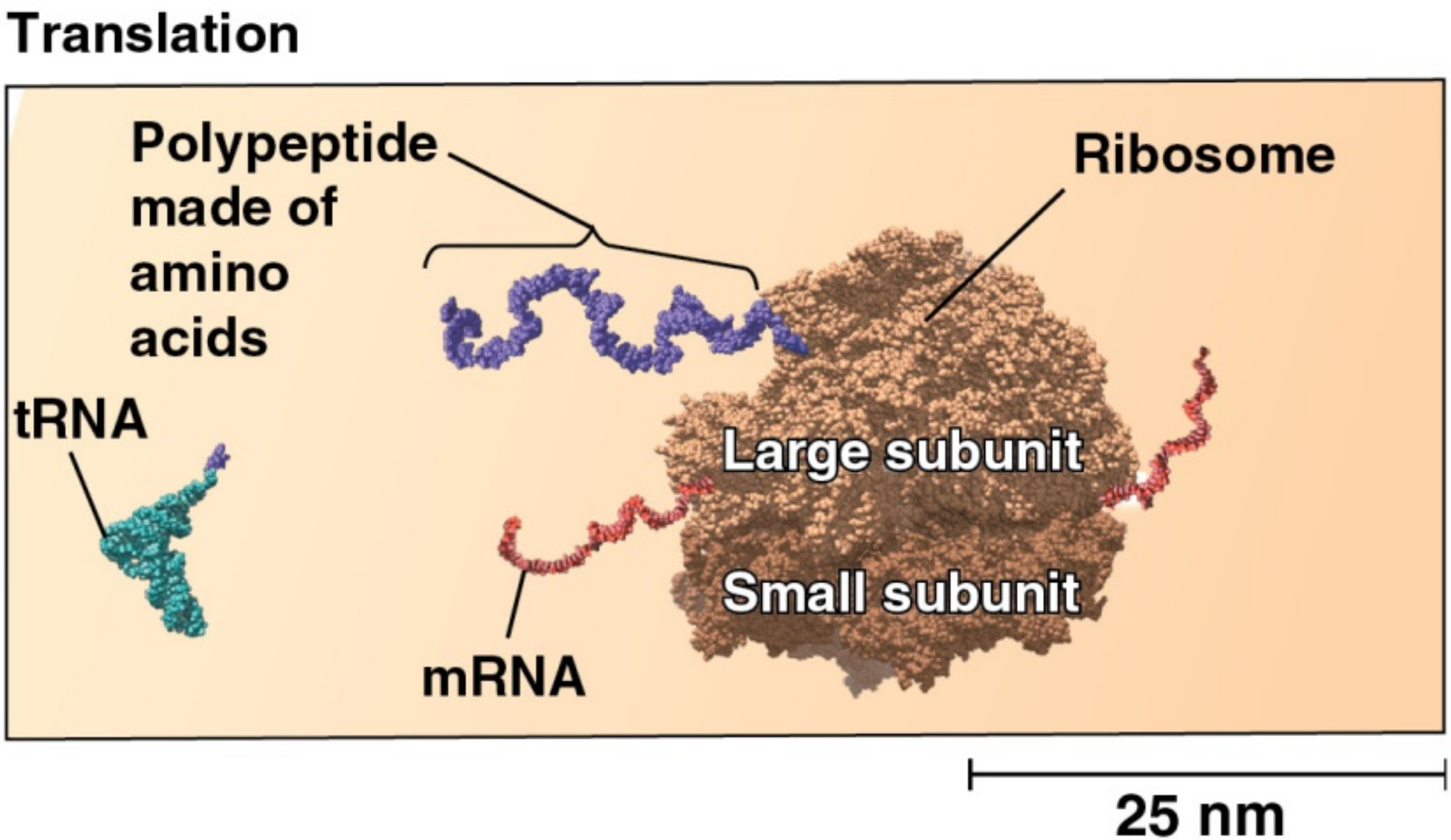

Transcription
mRNA
RNA polymerase
DNA
Nucleosome: DNA wrapped around 8 histone proteins
DNA
25 nm

Figure 6.32g



Translation
Polypeptide made of amino acids
Ribosome
tRNA
Large subunit
Small subunit
mRNA
25 nm

Figure 6.32h

Cytoskeleton

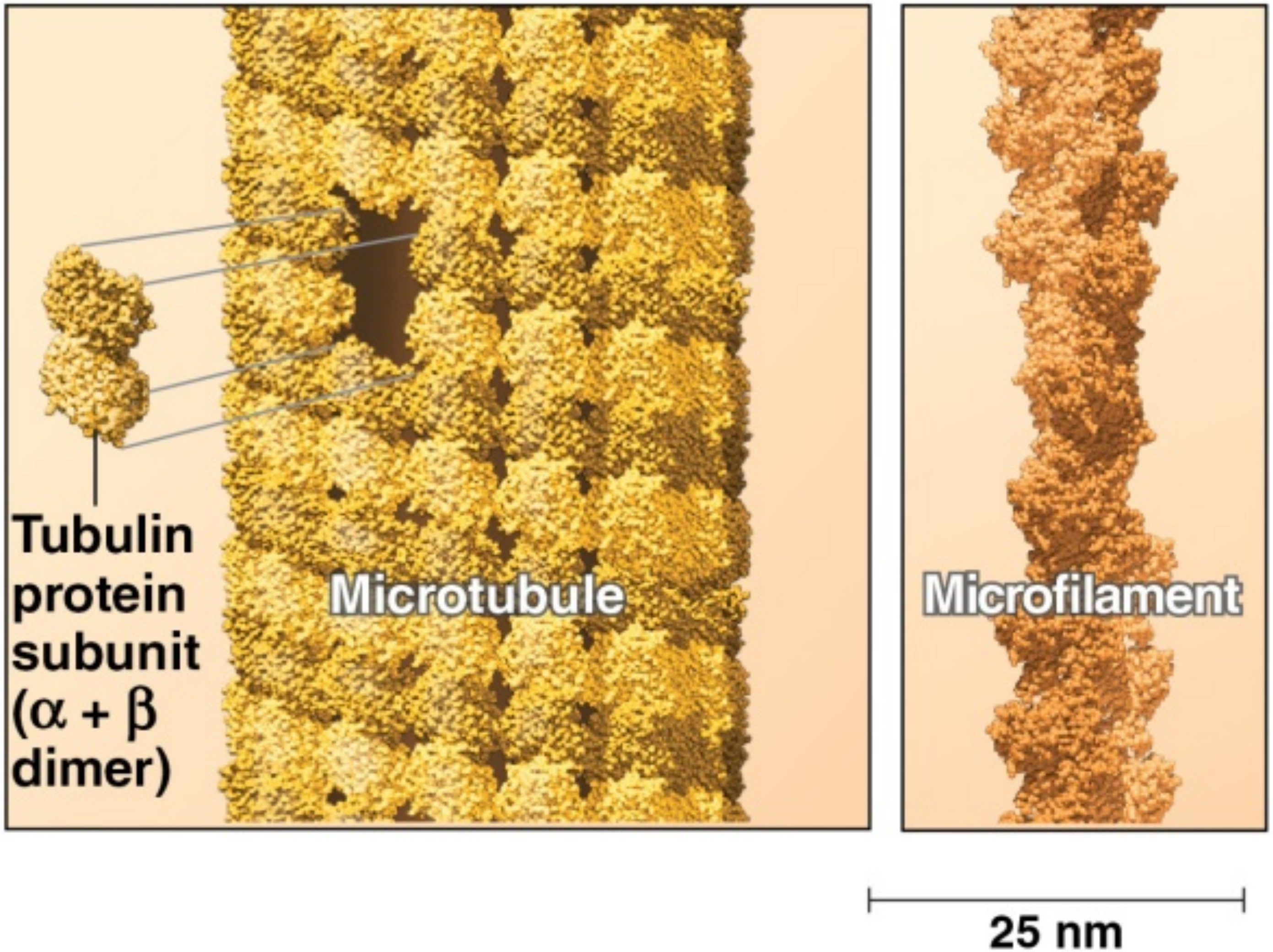


Figure 6.32i

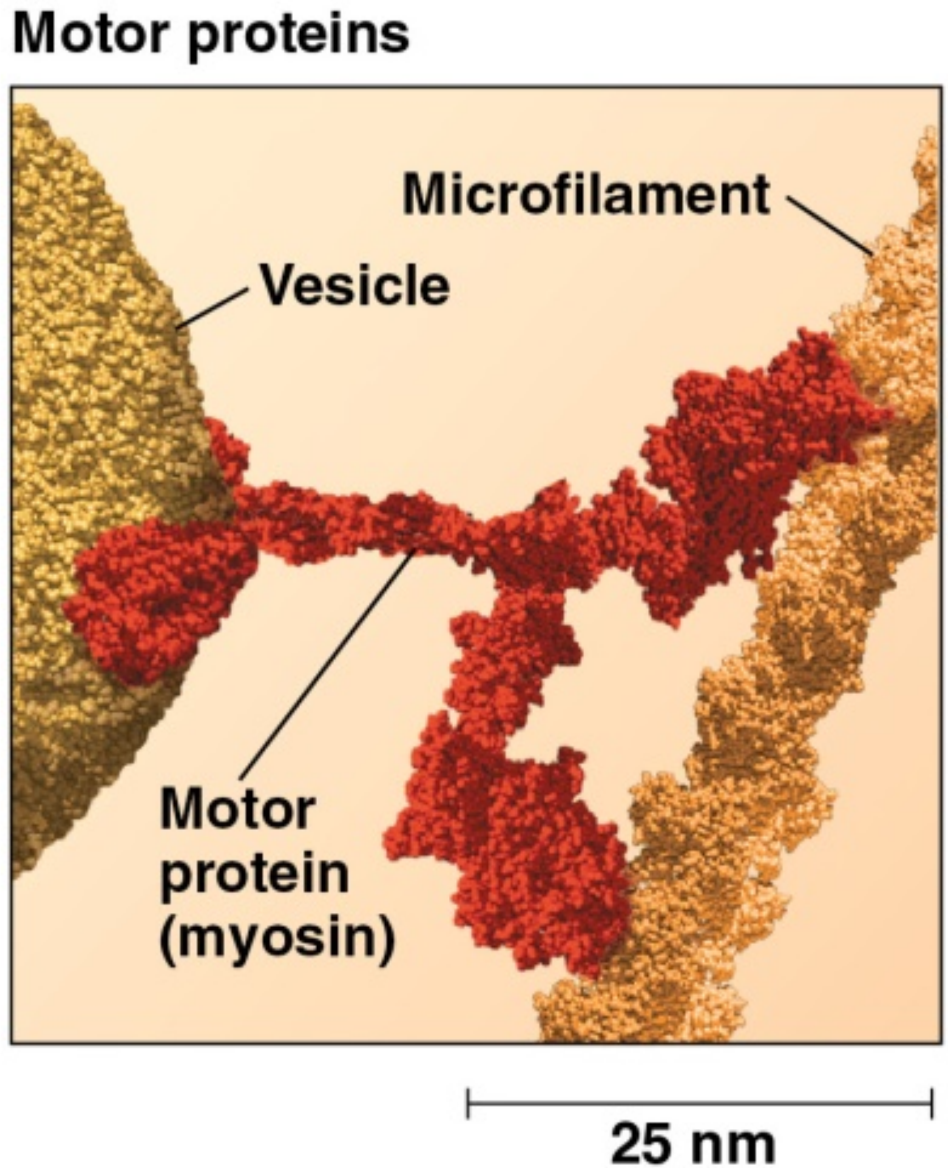

Motor proteins
Microfilament
Vesicle
Motor
protein
(myosin)
25 nm

Figure 6.UN02

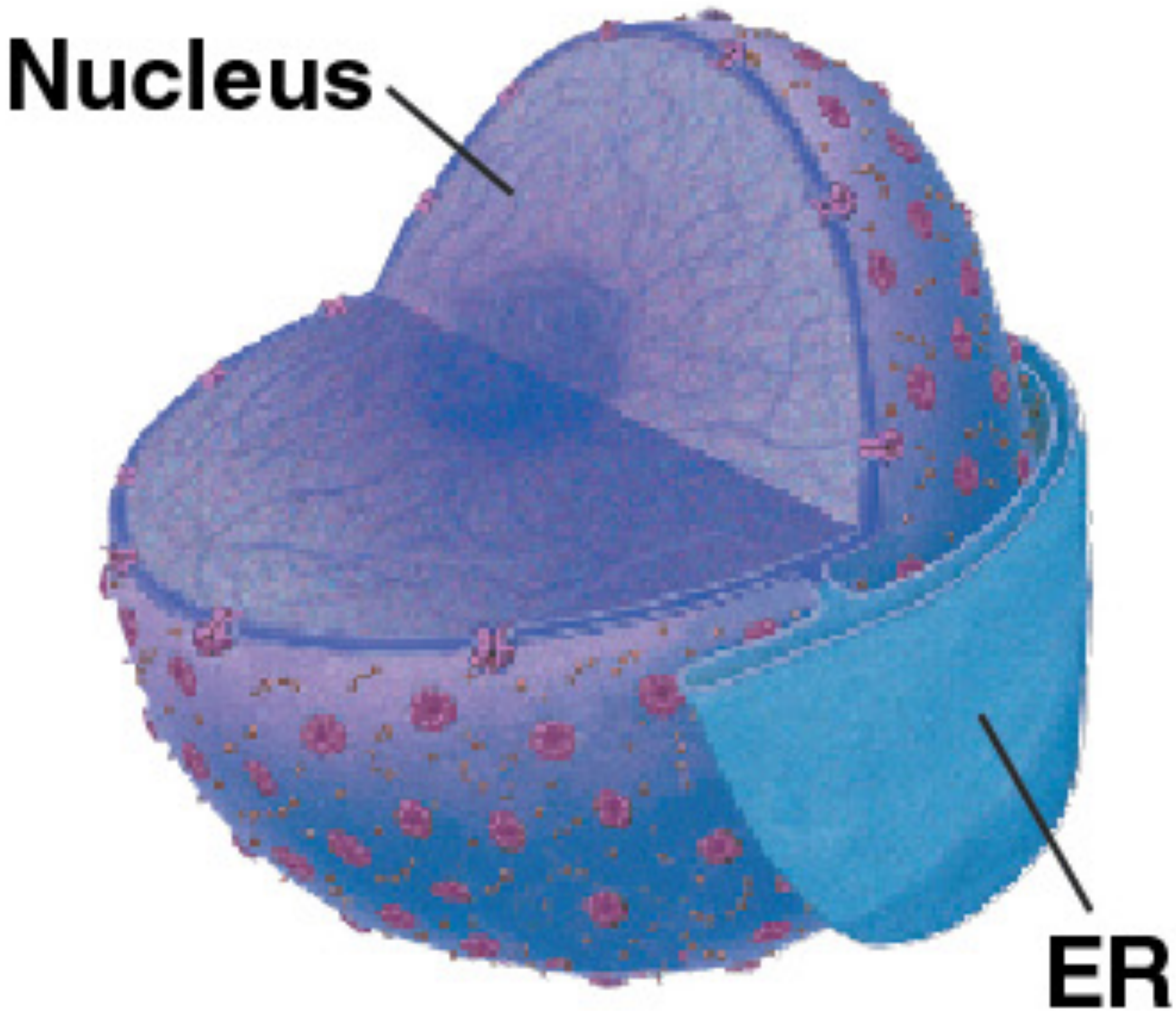
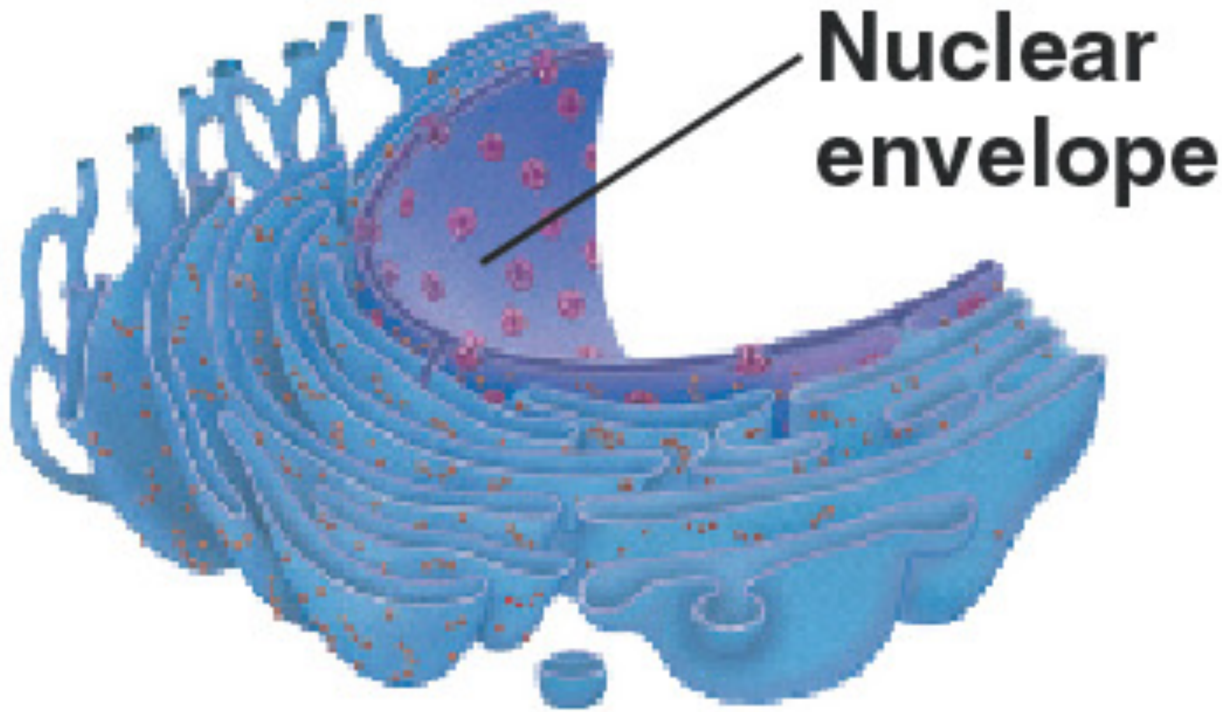


Figure 6.UN03

Ribosome

Figure 6.UN04

Endoplasmic reticulum (ER)



Golgi apparatus

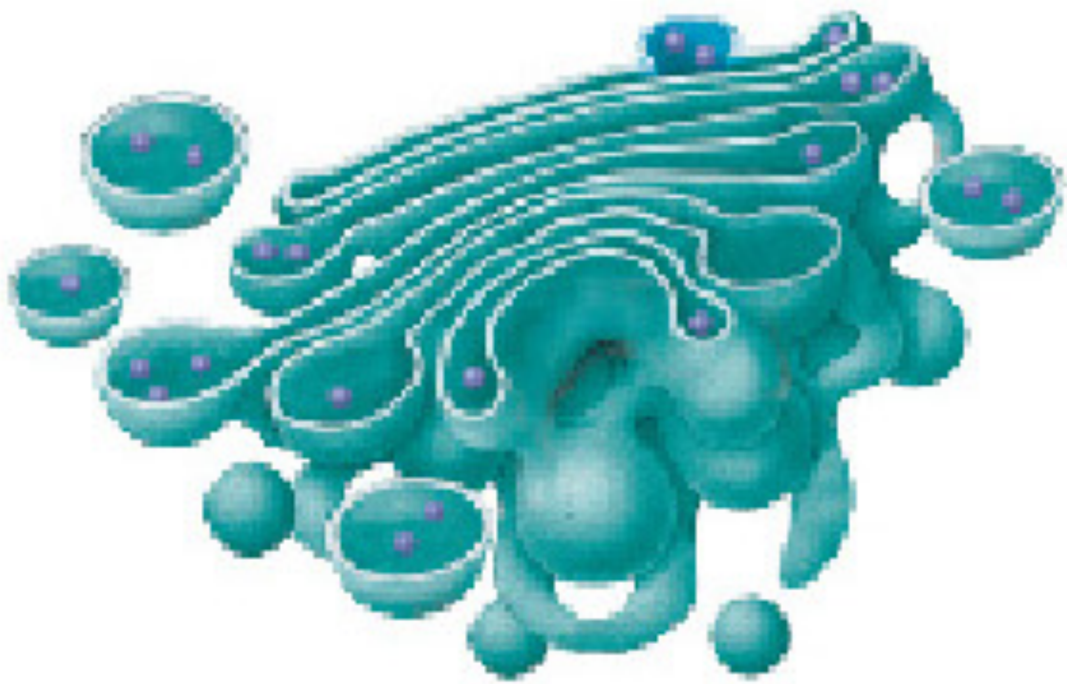
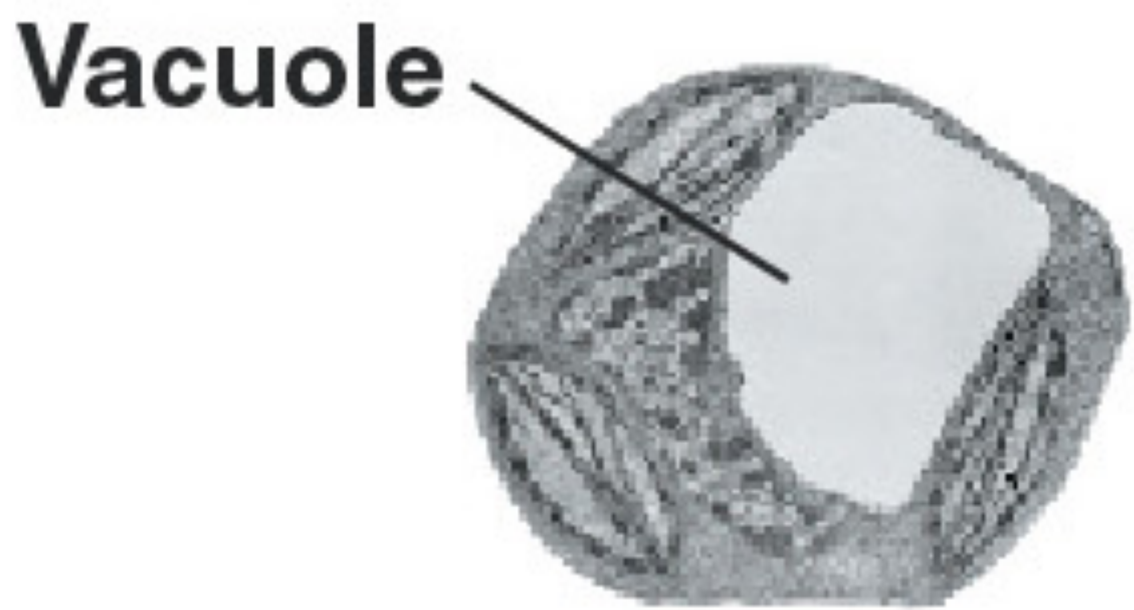


Figure 6.UN06

Lysosome

Figure 6.UN07



Chloroplast

Figure 6.UN10

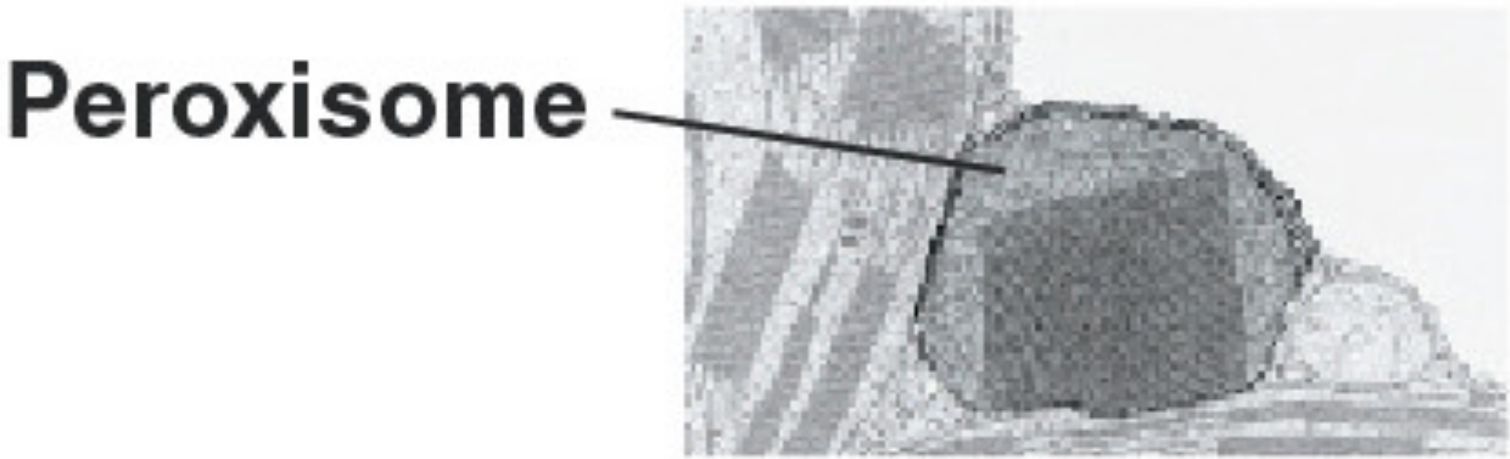


Figure 6.UN11