LECTURE PRESENTATIONS
For CAMPBELL BIOLOGY, NINTH EDITION
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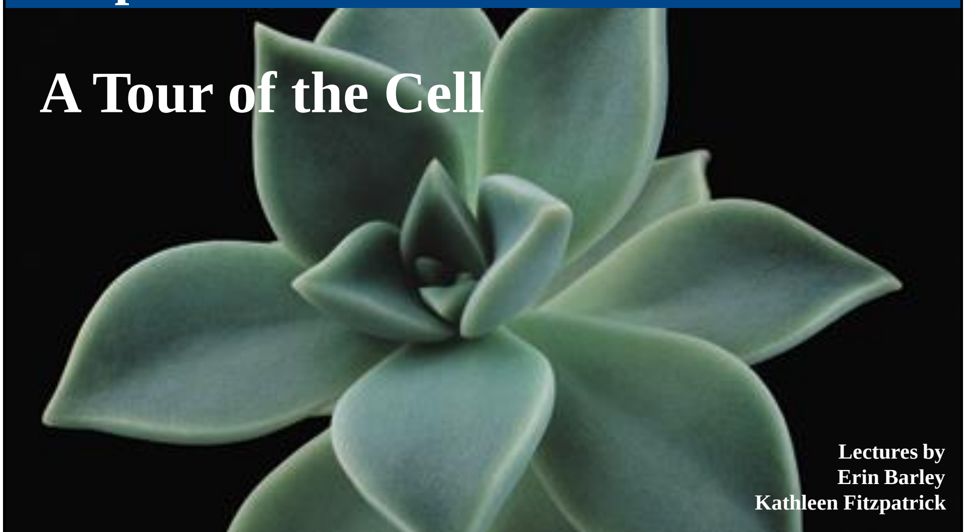
Chapter 6

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 live
- Cell **structure** is correlated to cellular **function**
- All cells are related by their descent from earlier cells

Concept 6.1: To study cells, biologists use microscopes and the tools of biochemistry

- 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 passes through a specimen and then through glass lenses, which magnify the image

- The **quality of an image** depends on
  - ***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

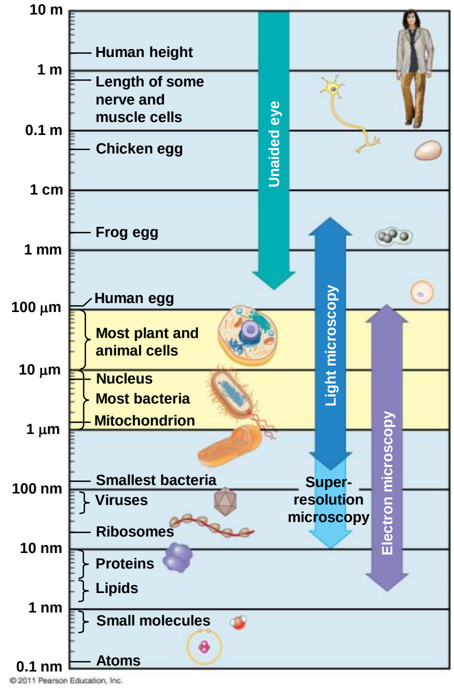
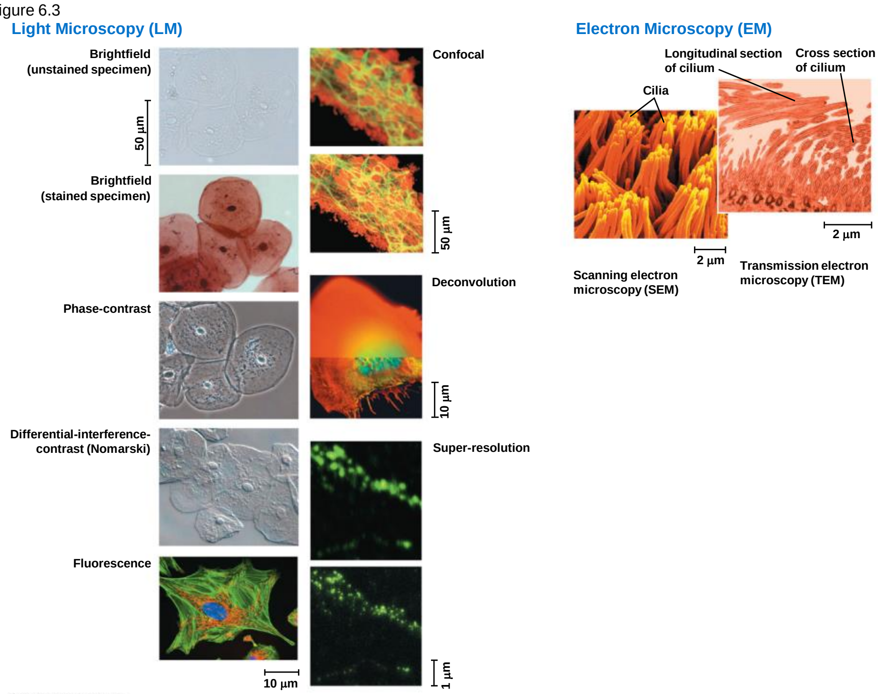


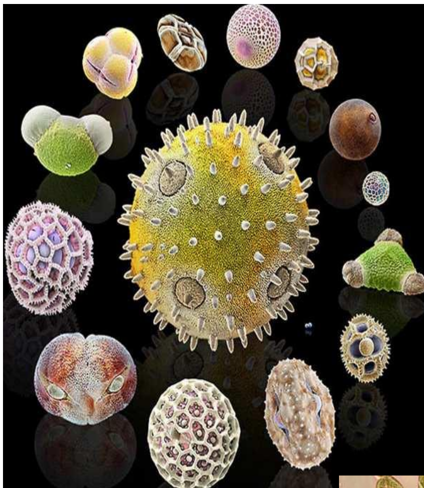
Figure 6.3

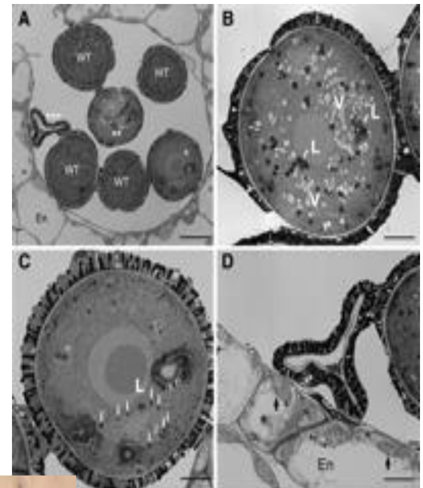


- **LMs can magnify** effectively to about **1,000 times** the size of the actual specimen
- Various techniques enhance contrast and enable cell components to be stained or labeled
- Most subcellular structures, including **organelles** (membrane-enclosed compartments), are **too small to be resolved by an LM**

Electron microscopes

- 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





- SEM

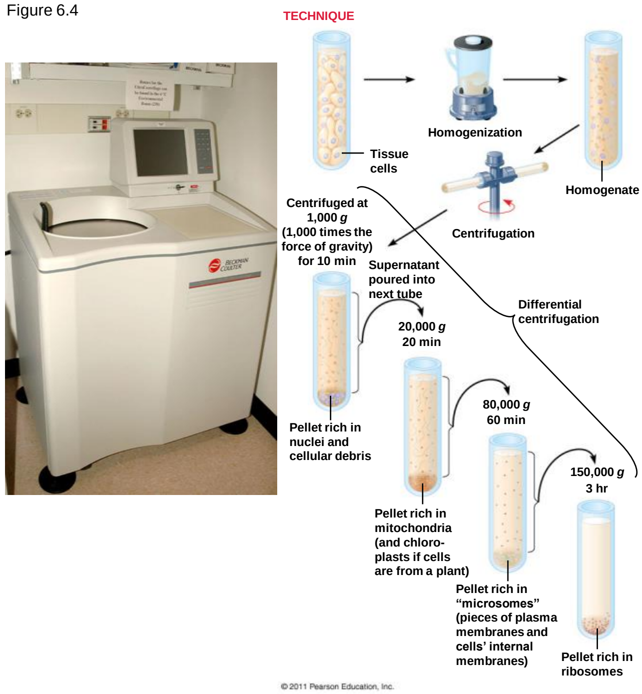
- LM

TEM

Cell Fractionation

- **Cell fractionation** takes cells apart and separates the major organelles from one another
- Ultracentrifuges 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



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

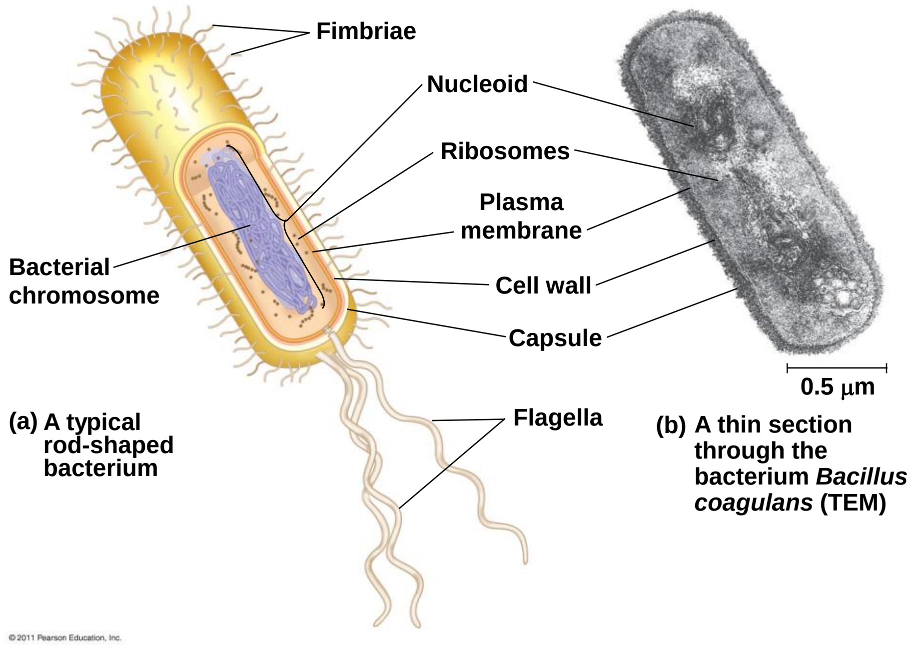
- The basic structural and functional unit of every organism is one of two types of cells: **prokaryotic** or **eukaryotic**
- Only organisms of the domains **Bacteria** and **Archaea** consist of prokaryotic cells
- Protists, fungi, animals, and plants all consist of **eukaryotic cells**

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

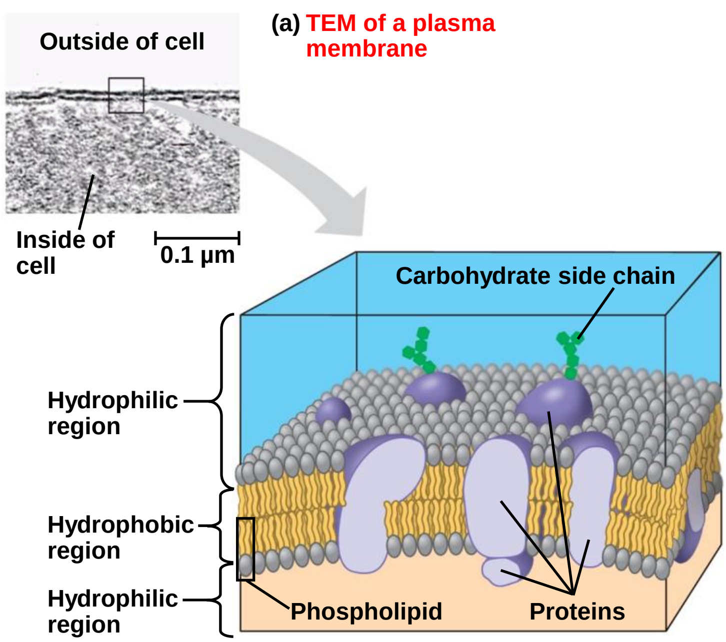
Figure 6.5



- **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

Fig. 6-7

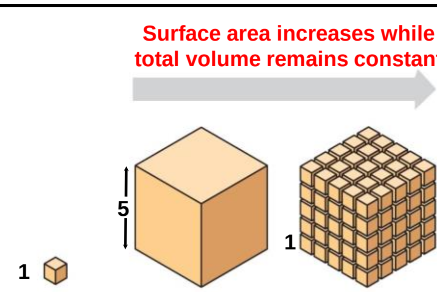


(a) TEM of a plasma membrane

(b) Structure of the plasma membrane

- **Metabolic requirements** set upper limits on the size of cells
- The surface area to volume ratio of a cell is critical
- **Small cells** *have a greater surface area relative to volume*

Fig. 6-8



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

A Panoramic View of the Eukaryotic Cell

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

PLAY BioFlix: Tour Of An Animal Cell

PLAY BioFlix: Tour Of A Plant Cell

Fig. 6-9a

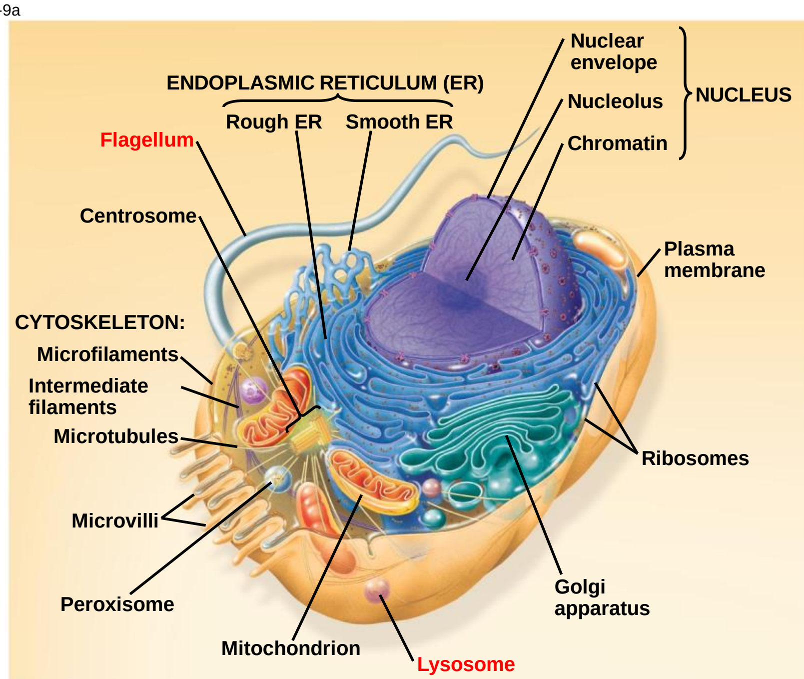
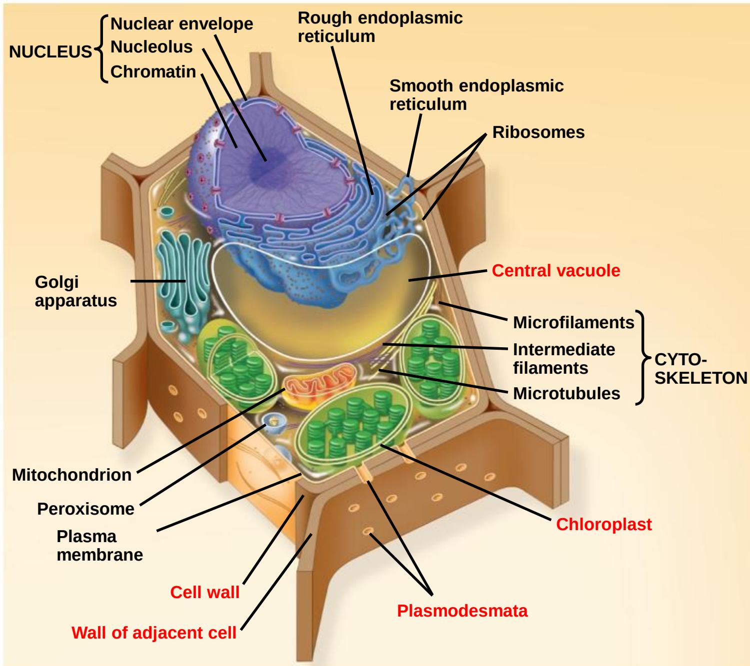


Fig. 6-9b



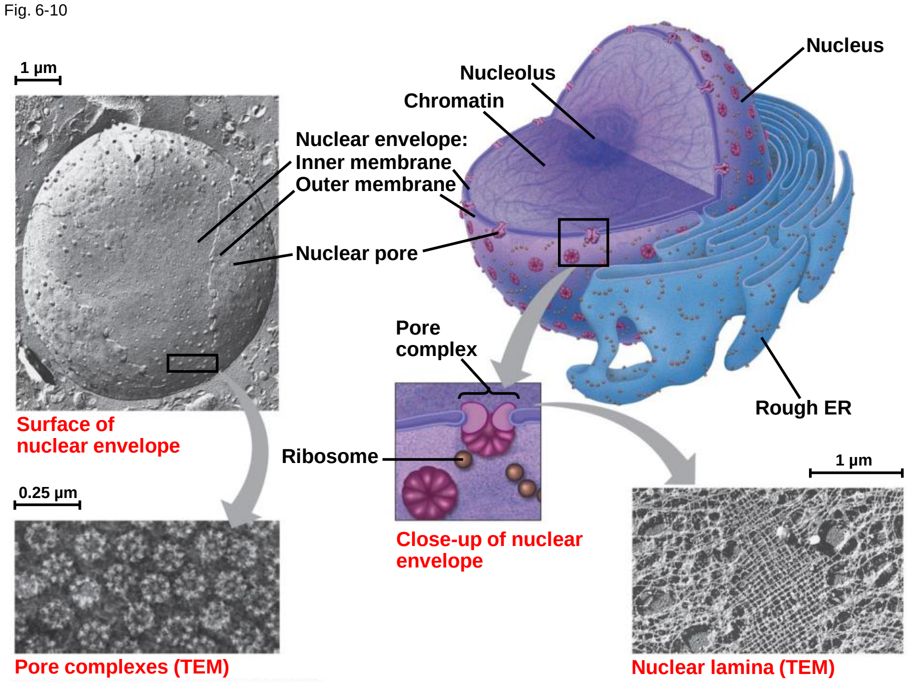
Concept 6.3: The eukaryotic cell's genetic instructions are housed in the nucleus and carried out by the ribosomes

- 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 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

Fig. 6-10



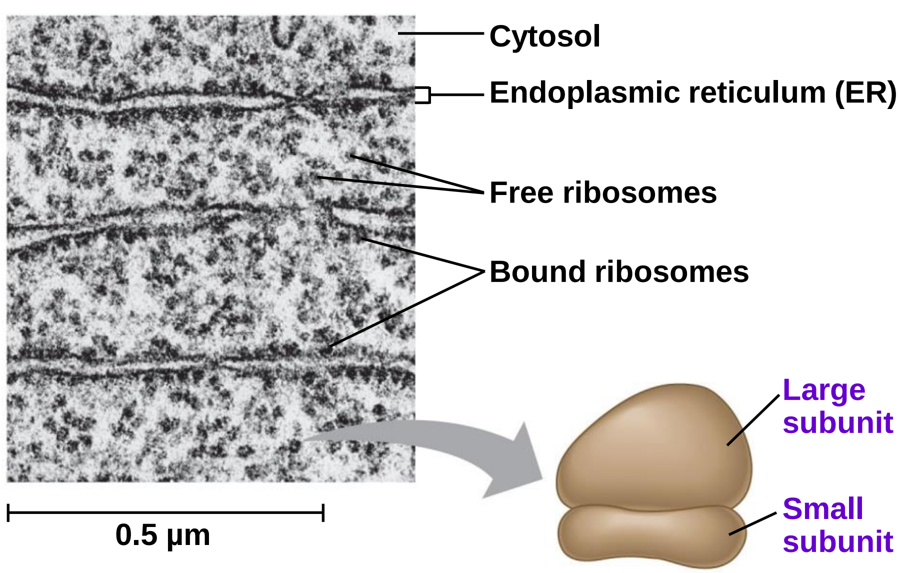
- **Pores** regulate the entry and exit of molecules from the nucleus
- The shape of the nucleus is maintained by the **nuclear lamina**, which is composed of protein

- In the nucleus, DNA is organized into discrete units called **chromosomes.**
- Each chromosome is composed of a single DNA molecule associated with proteins
- **DNA and proteins** form genetic material 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)**

Fig. 6-11



TEM showing ER and ribosomes

Diagram of a ribosome

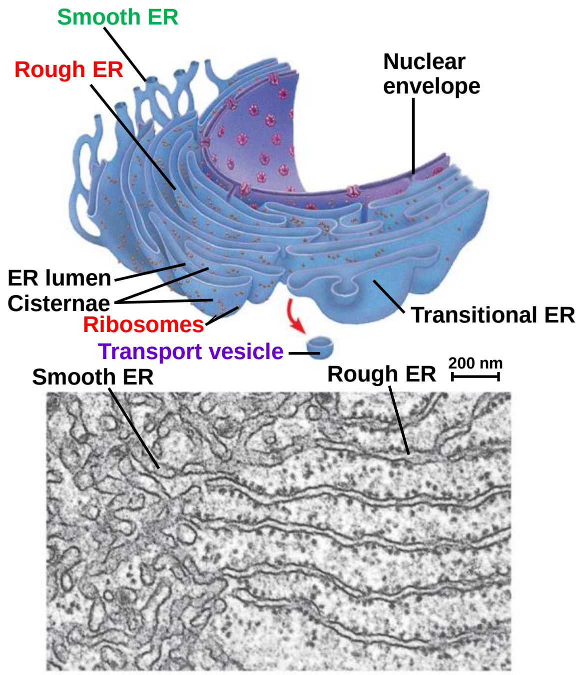
Concept 6.4: The endomembrane system regulates protein traffic and performs metabolic functions in the cell

- 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**, with ribosomes studding its surface

Fig. 6-12



Functions of Smooth ER

- The smooth ER
  - **Synthesizes lipids**
  - **Metabolizes carbohydrates**
  - **Detoxifies poison**
  - **Stores calcium**

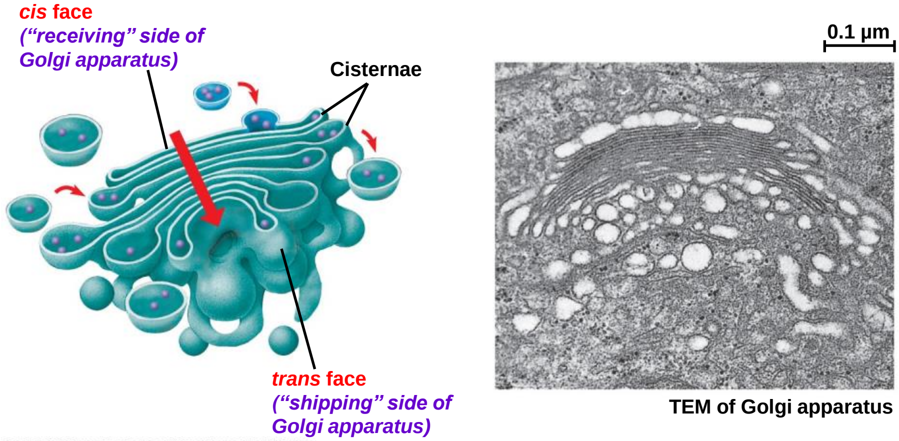
Functions of Rough ER

- 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

Fig. 6-13



TEM of Golgi apparatus

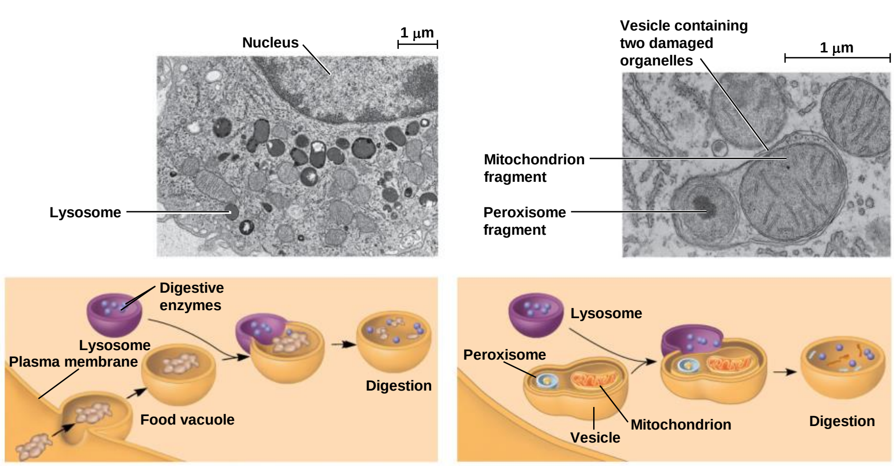
Lysosomes: Digestive Compartments

- 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

PLAY Animation: Lysosome Formation

- 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

Vacuoles: Diverse Maintenance Compartments

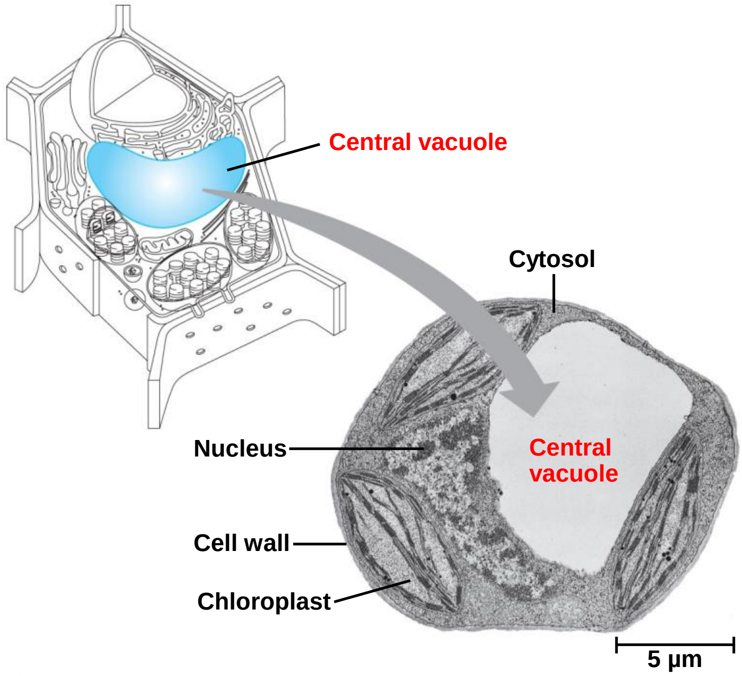
- A plant cell or fungal cell may have **one or several vacuoles** derived from endoplasmic reticulum and Golgi apparatus

- **Types of Vacuoles:**

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

PLAY Video: Paramecium Vacuole

Fig. 6-15



The Endomembrane System: *A Review*

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

Figure 6.15-1

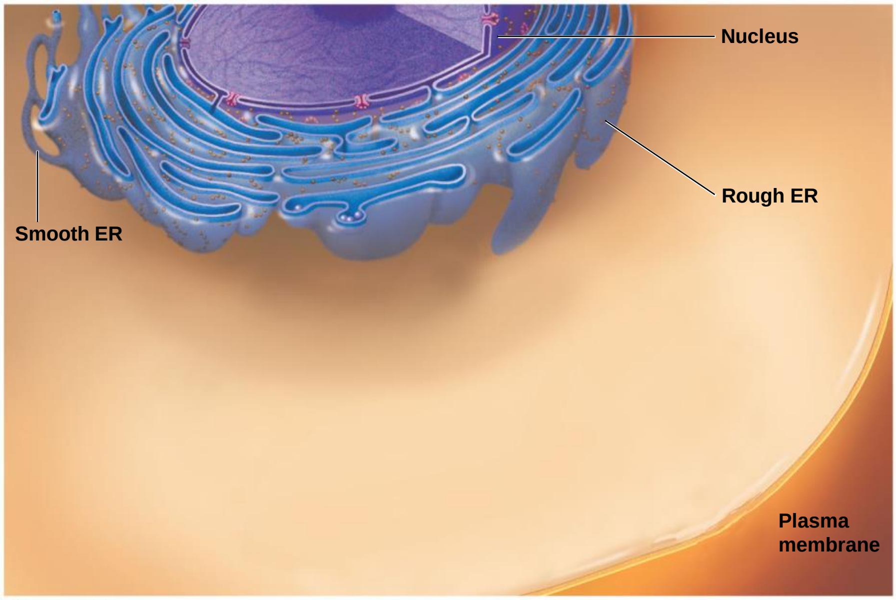


Figure 6.15-2

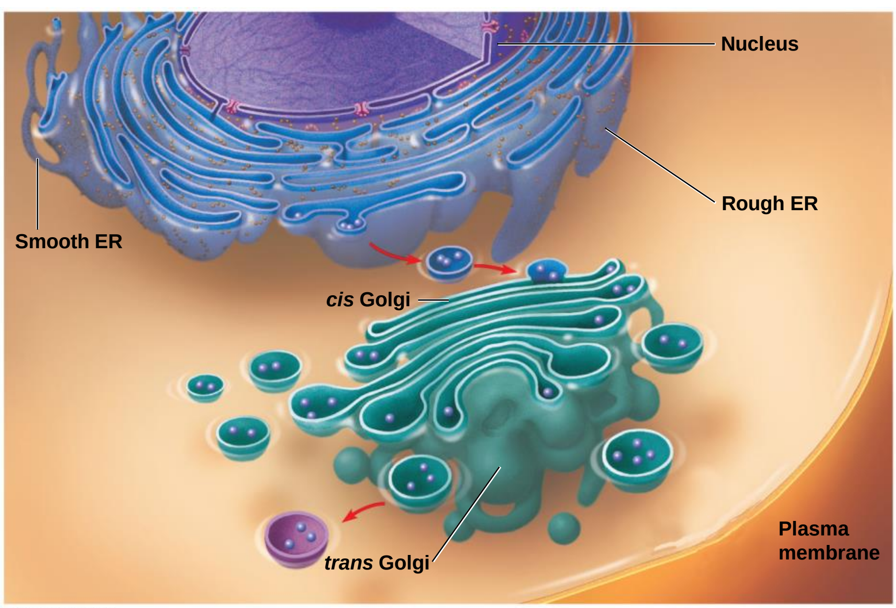
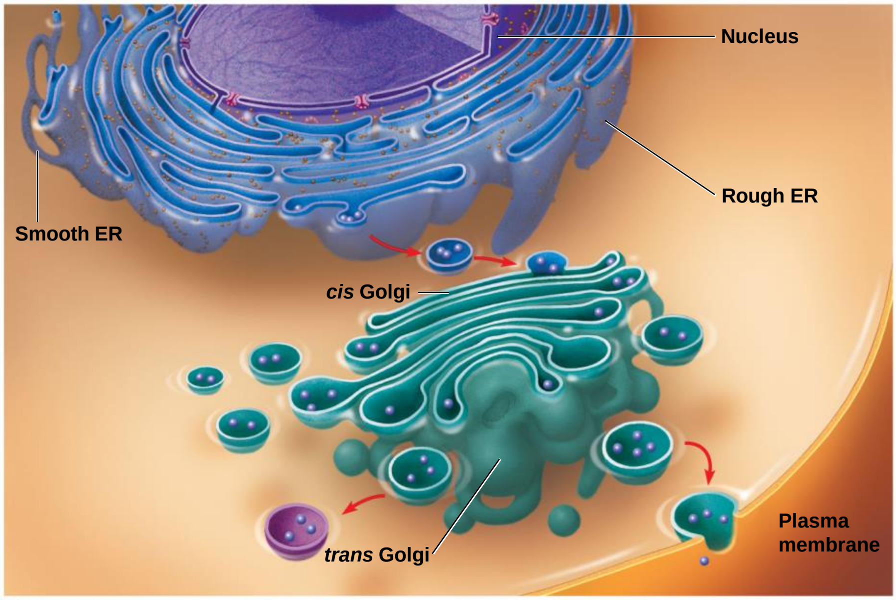


Figure 6.15-3



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

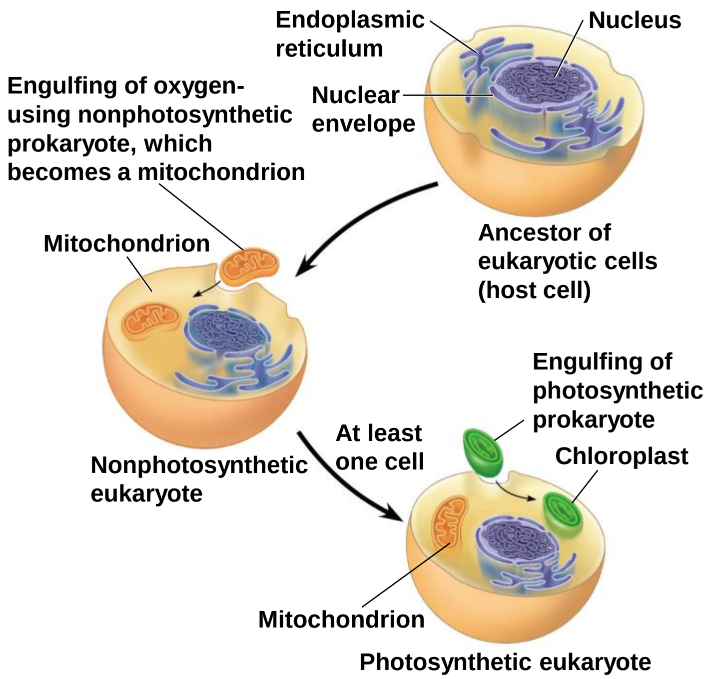
- **Mitochondria** are the sites of cellular respiration, a metabolic process that generates ATP
- **Chloroplasts**, found in plants and algae, are the sites of photosynthesis

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

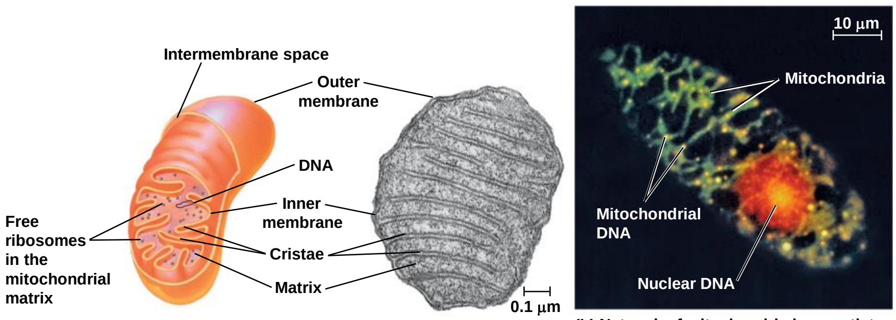
Figure 6.16



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

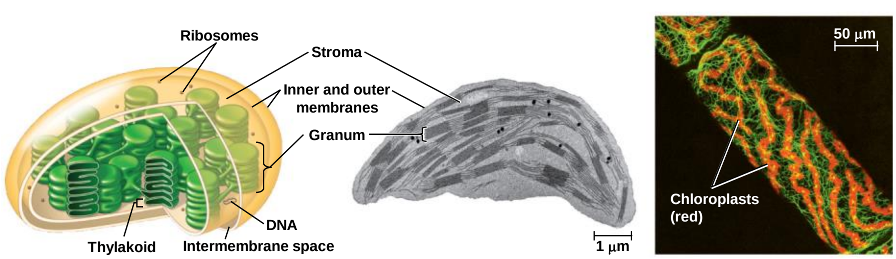
(b) Network of mitochondria in a protist cell (LM)

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



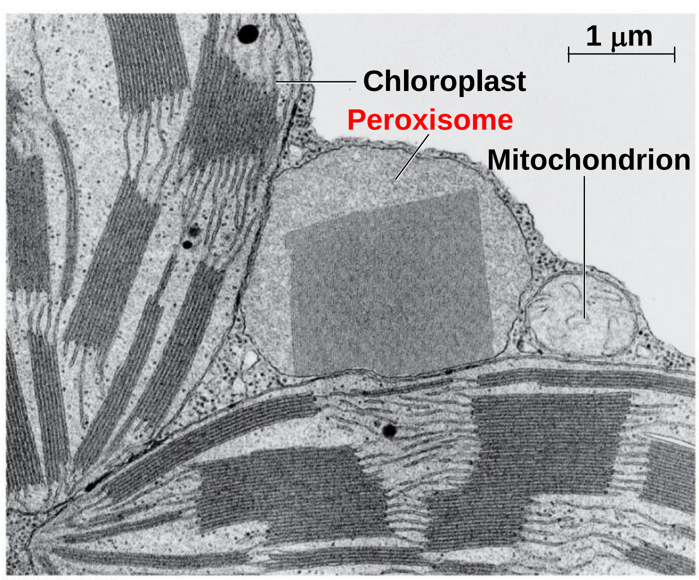
(a) Diagram and TEM of chloroplast

(b) Chloroplasts in an algal cell

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

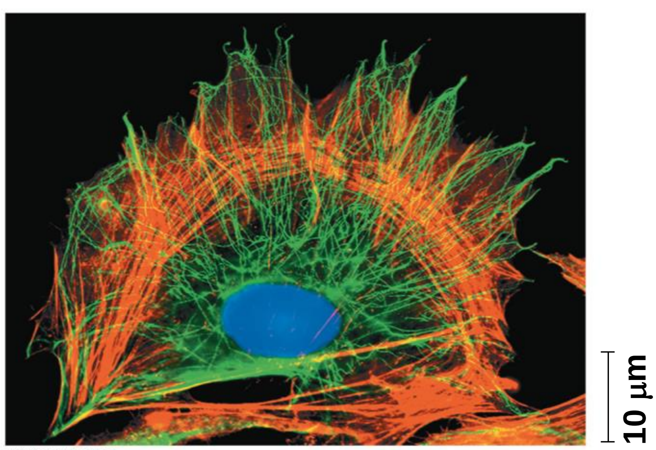
Figure 6.19



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.**

Figure 6.20



- **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 6.1a

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

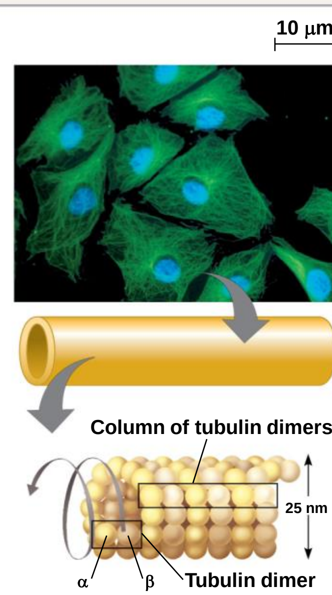


Table 6.1b

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)

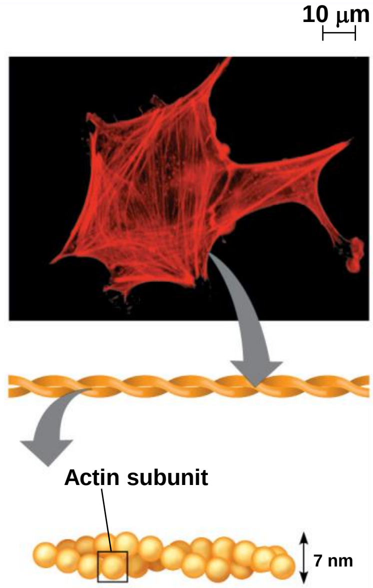
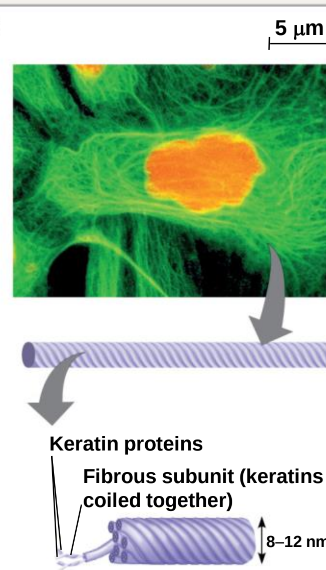


Table 6.1c

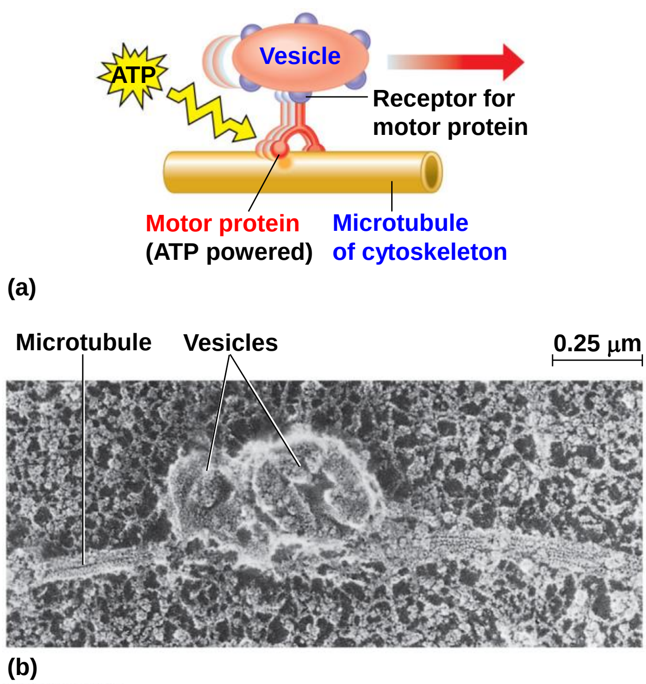
Property	Intermediate Filaments
Structure	Fibrous proteins supercoiled into thicker cables
Diameter	8–12 nm
Protein subunits	One of several different proteins (such as keratins), depending on cell type
Main functions	Maintenance of cell shape (tension-bearing elements) Anchorage of nucleus and certain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



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**

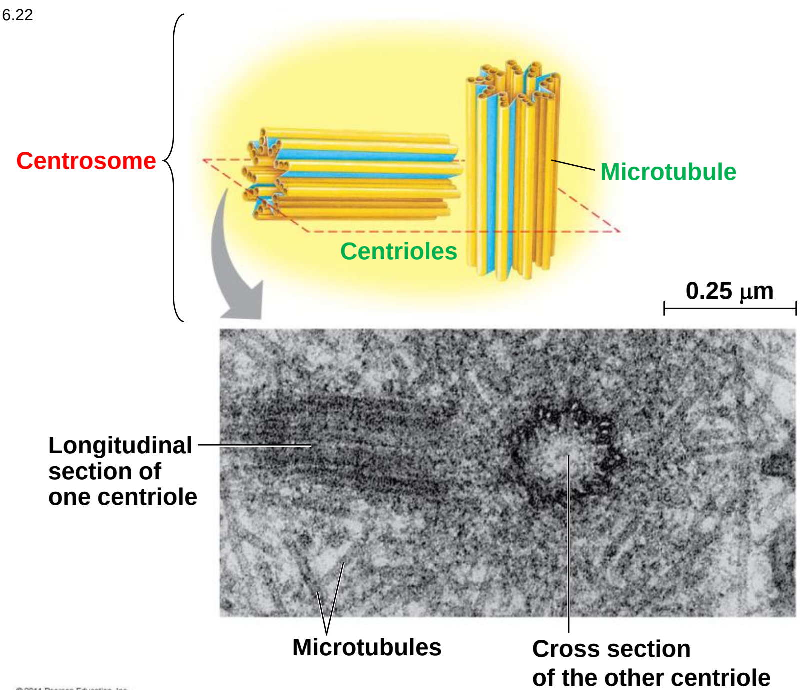
Figure 6.21



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



Cilia and Flagella

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

PLAY Video: *Chlamydomonas*

PLAY Video: *Paramecium* Cilia

Figure 6.23

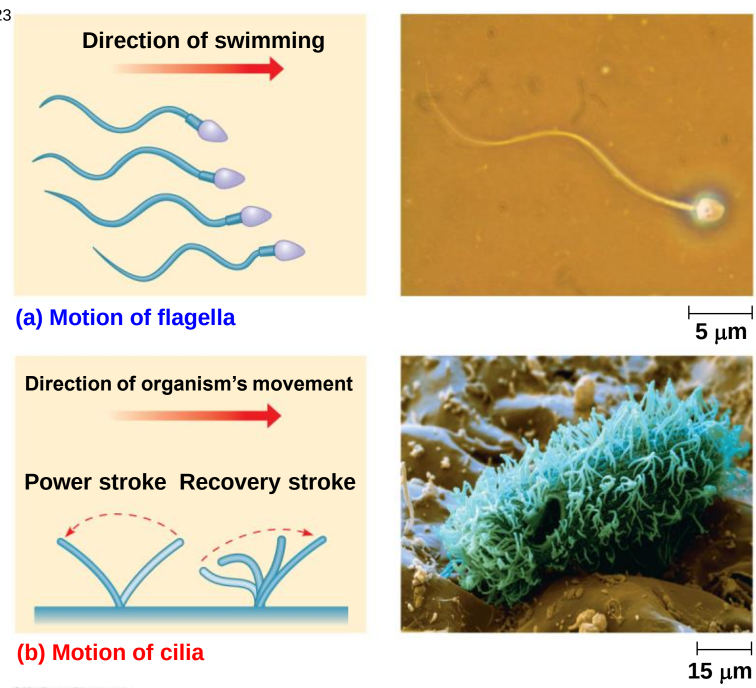
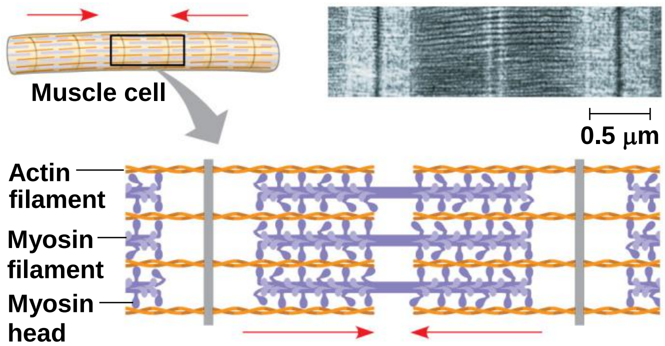
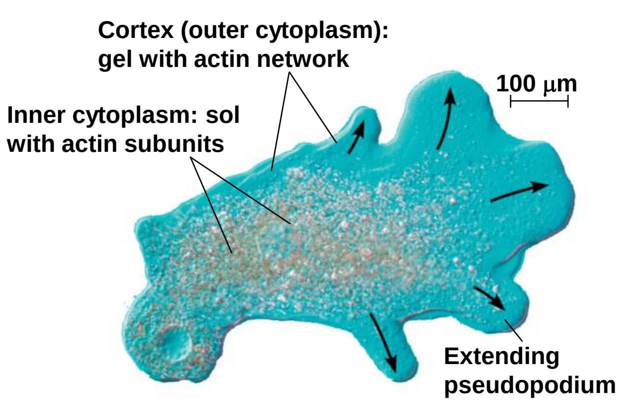


Figure 6.27a



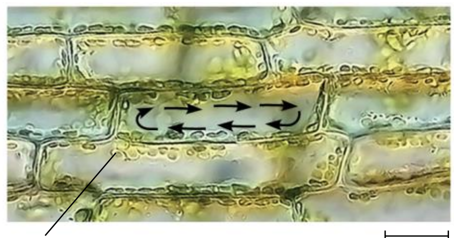
(a) Myosin motors in muscle cell contraction

Figure 6.27b



(b) Amoeboid movement

Figure 6.27c

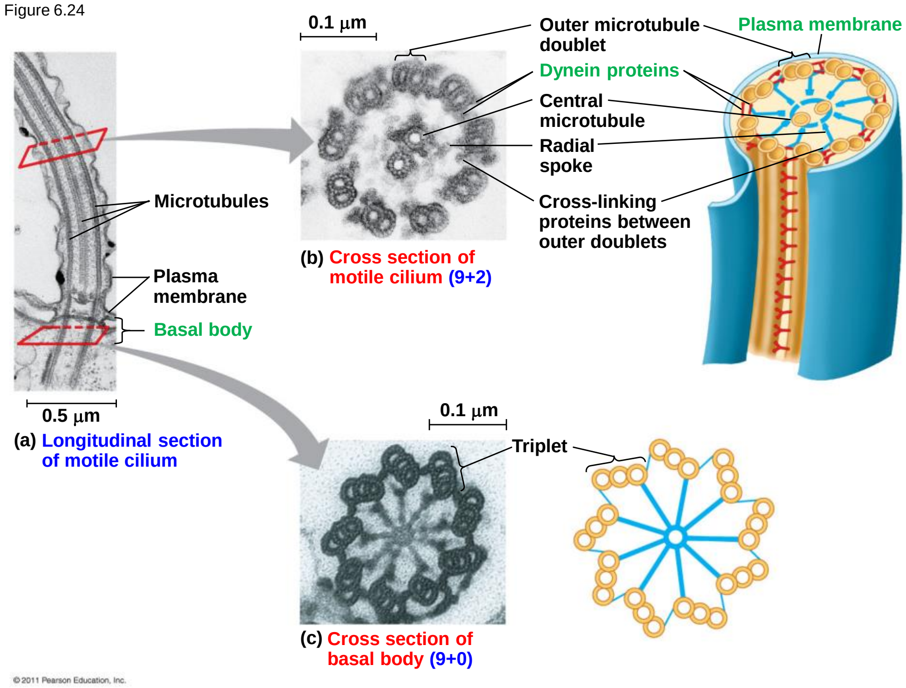


(c) Cytoplasmic streaming in plant cells

- **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

PLAY Animation: Cilia and Flagella

Figure 6.24



(a) Longitudinal section of motile cilium

(b) Cross section of motile cilium (9+2)

(c) Cross section of basal body (9+0)

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

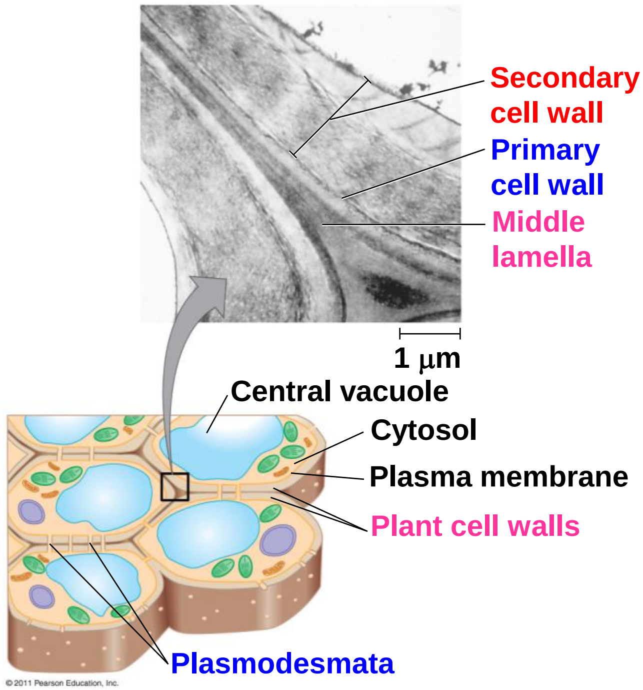
- Most cells synthesize and secrete materials that **are external to the plasma membrane**
- These extracellular structures include
  - **Cell walls of plants**
  - **The extracellular matrix (ECM) of animal cells**
  - **Intercellular junctions**

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

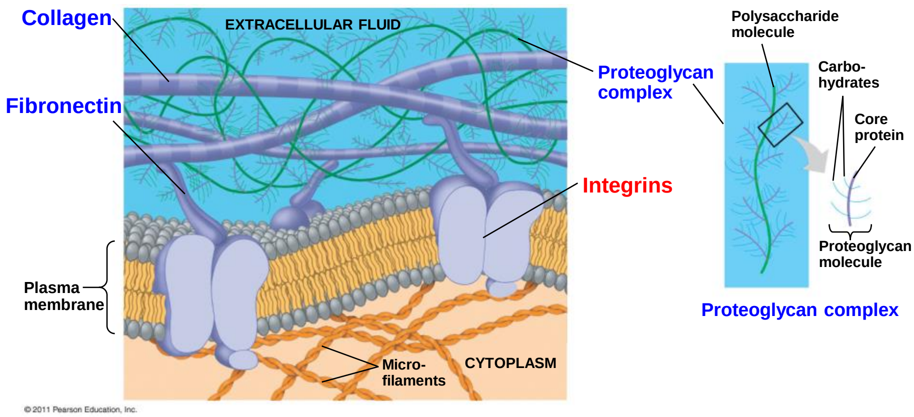
Figure 6.28



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



- **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

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*

Figure 6.32

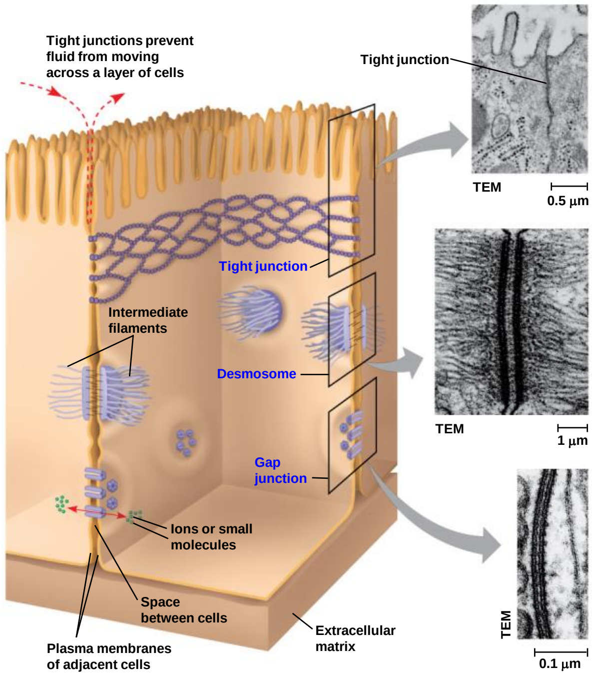


Figure 6.UN01

	Cell Component	Structure	Function
CONCEPT 6.3 The eukaryotic cell's genetic instructions are housed in the nucleus and carried out by the ribosomes	Nucleus (ER)	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 (Nuclear envelope)	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 6.33