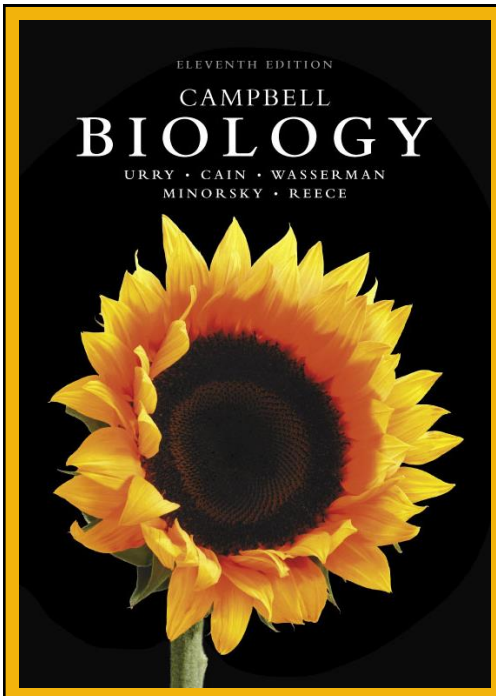


Chapter 6

A Tour of the Cell

Lecture Presentations by
Nicole Tunbridge and
Kathleen Fitzpatrick

The Fundamental Units of Life

- *All organisms* are made of cells
- The cell is the *simplest collection of matter* that can be alive
- All cells are related by their *descent from earlier cells*
- Cells can *differ* greatly from one another but *share common features*

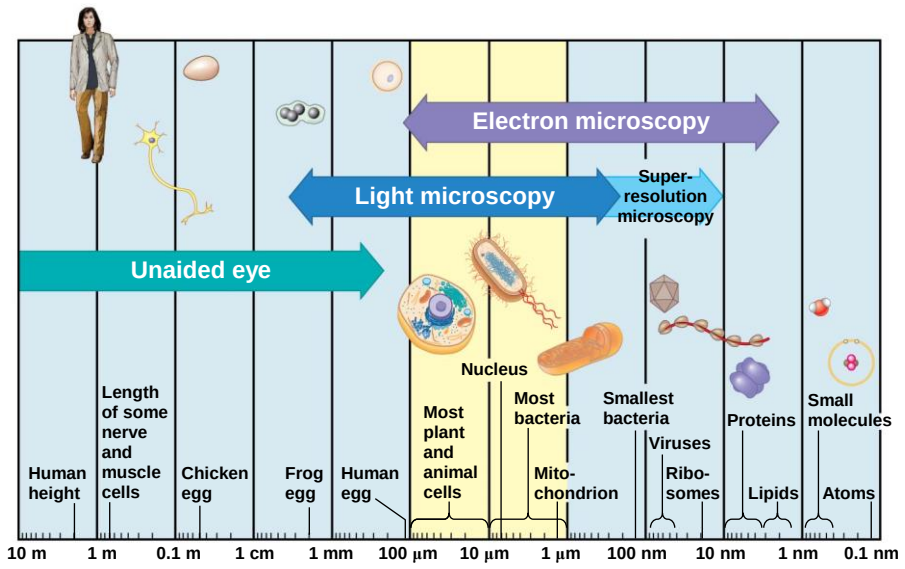
Concept 6.1: Biologists use microscopes and the tools of biochemistry to study cells

- Cells are usually too small to be seen by the naked eye
- 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**
- In an **electron microscope (EM)**, a beam of electrons is passed on or through a specimen

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

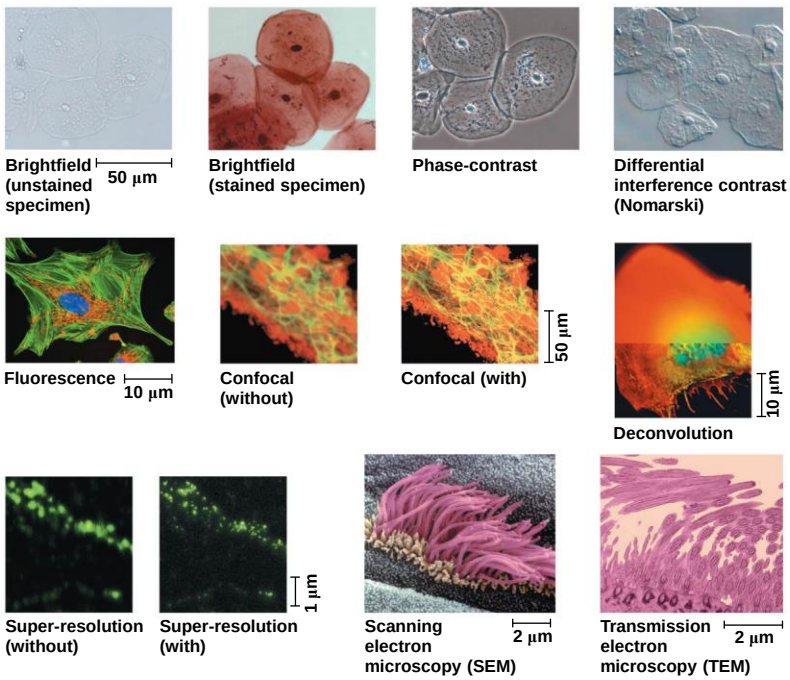
- Light microscopes can magnify effectively to about **1,000 times the size** of the actual specimen
- The resolution of standard light microscopy is too low to study **organelles**, the membrane-enclosed structures in eukaryotic cells

Figure 6.2c



- 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

Figure 6.3



LM vs. EM!

	Light microscope	Electron microscope
Illumination source	Light	Beam of electrons
Lenses	Glass	Electromagnetic or electrostatic
Live or dead specimen	Live & dead	Dead
Resolution	0.2 um or 200nm	0.002um or 2nm
Magnification	~1,000-1,400X	100,000 -300,000X
Image color	Colored	Black and white

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

Cell theory

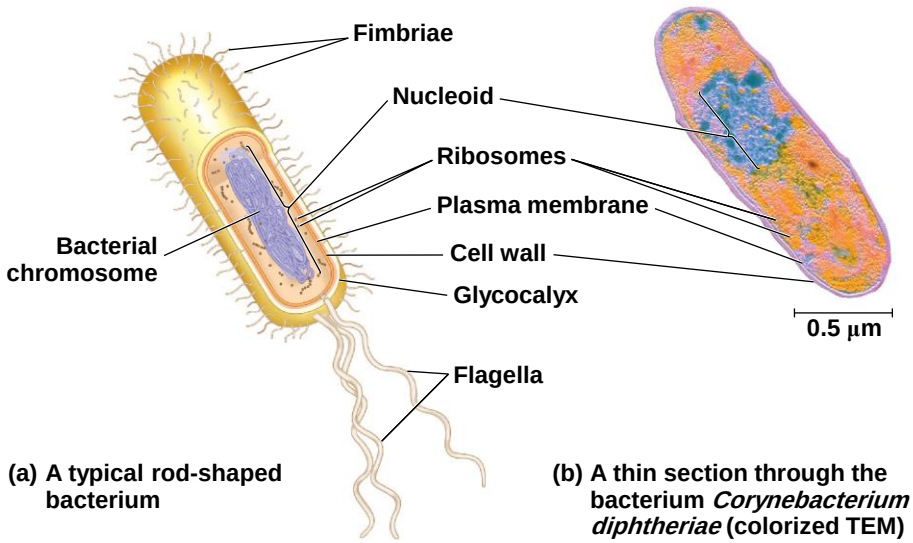
- The cell theory has three tenets (مبادئ اساسية):
  - All living organisms are composed of one or more cells
  - The cell is the basic unit of structure and organization in organisms
  - Cells arise from pre-existing cells

Comparing Prokaryotic and Eukaryotic Cells

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

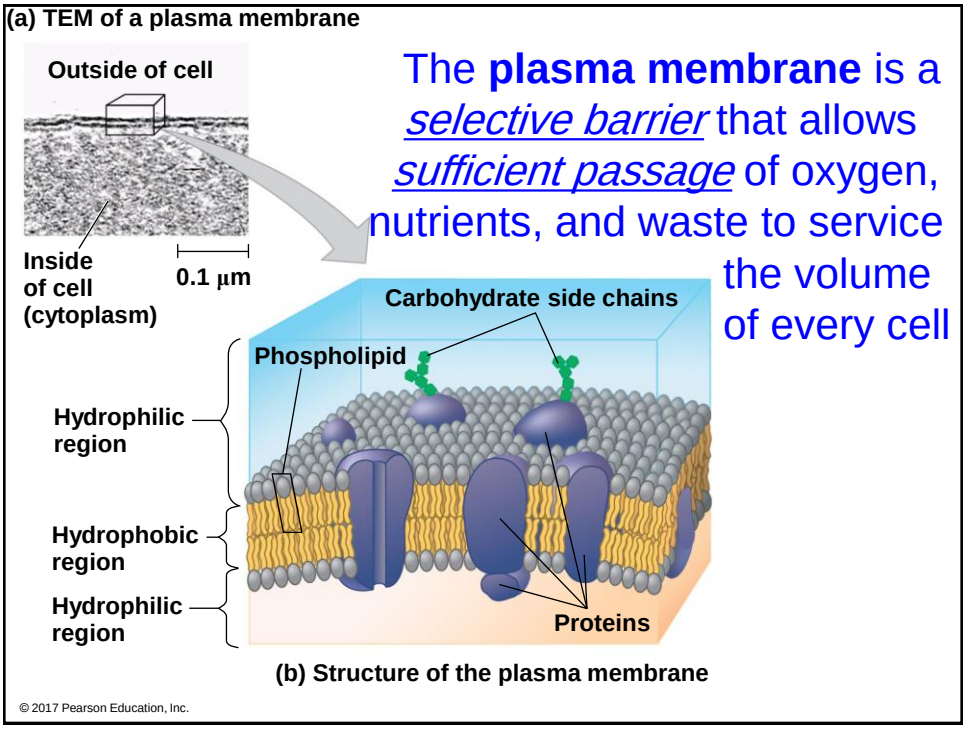
- **Prokaryotic cells** are characterized by having
  - No nucleus
  - DNA in an unbound region called the **nucleoid**
  - No membrane-bound organelles
  - **Cytoplasm** bound by the plasma membrane
- **Eukaryotic cells** are characterized by having
  - DNA in a nucleus that is bounded by a double membrane
  - Membrane-bound organelles
  - **Cytoplasm** in the region between the plasma membrane and nucleus
- Eukaryotic cells are generally much larger than prokaryotic cells

Figure 6.5



(a) A typical rod-shaped bacterium

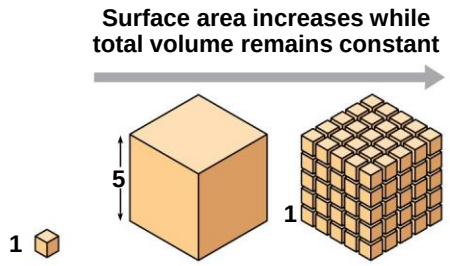
(b) A thin section through the bacterium *Corynebacterium diphtheriae* (colorized TEM)



The **plasma membrane** is a *selective barrier* that allows *sufficient passage* of oxygen, nutrients, and waste to service the volume of every cell

- Metabolic requirements set upper limits on the size of cells
- 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 6.7



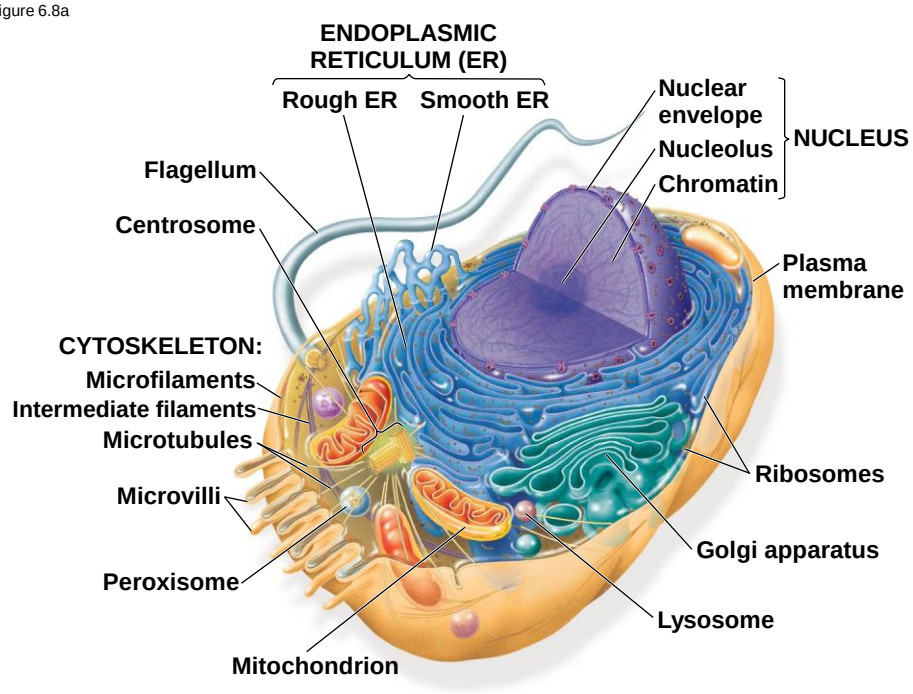
	1	125	750
Total surface area [sum of the surface areas (height × width) of all box sides × number of boxes]	6	150	750
Total volume [height × width × length × number of boxes]	1	125	125
Surface-to-volume (S-to-V) ratio [surface area ÷ volume]	6	1.2	6

A Panoramic View of the Eukaryotic Cell

- A eukaryotic cell has **internal membranes** that divide the cell into **compartments**—the **organelles**
- The basic component of biological membranes is a *double layer of phospholipids* and other lipids
- Plant and animal cells have *most* of the same organelles

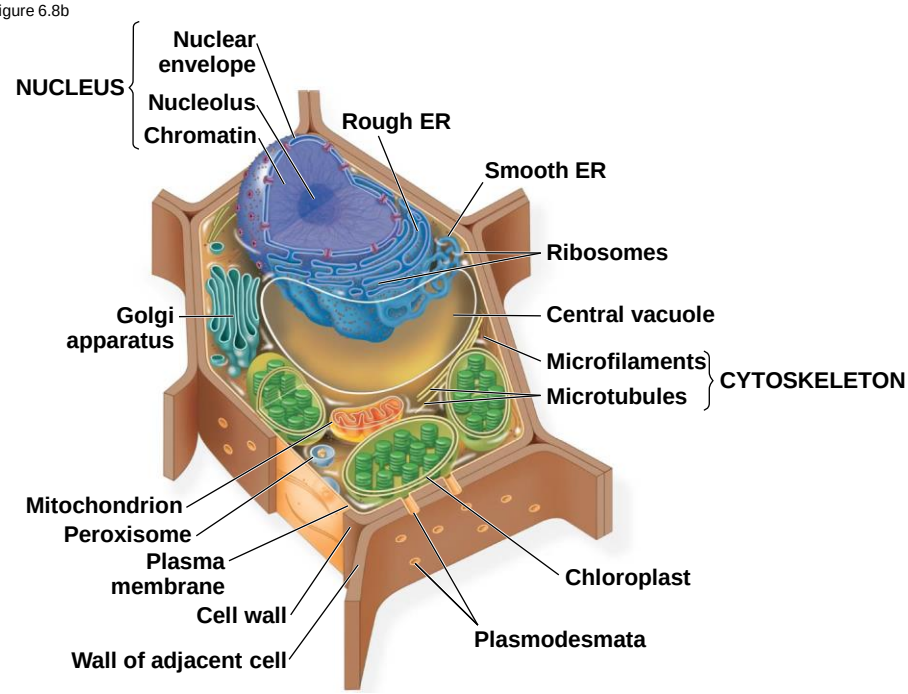
- ***HOMEWORK: What are the different organelles between animal and plant cells?***

Figure 6.8a

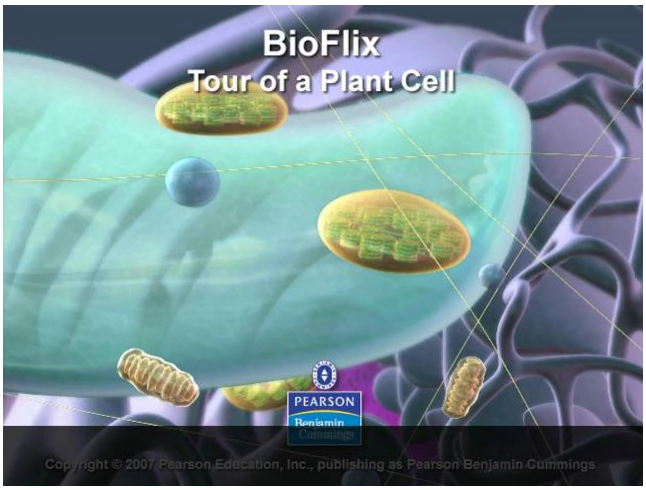


BioFlix: Tour of an Animal Cell

Figure 6.8b



BioFlix: Tour of a Plant Cell



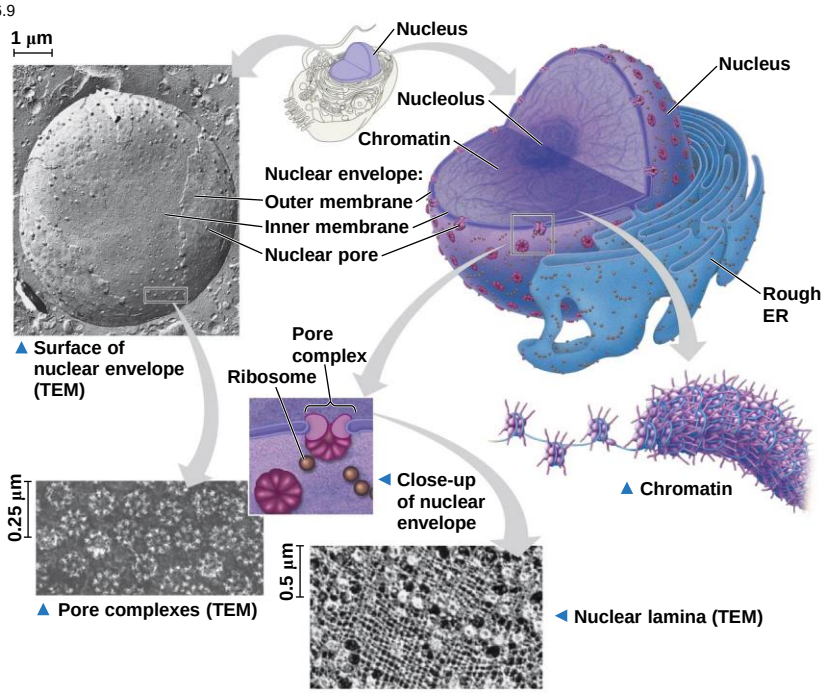
Concept 6.3: The eukaryotic cell's genetic instructions are housed in the nucleus and carried out by the ribosomes

- 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 visible 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*

Figure 6.9



- In the nucleus, DNA is packaged with proteins, called **histones** forming **chromatin**
- When the cell prepares to divide, chromatin *condenses* to form discrete **chromosomes**
- The **nucleolus** is located within the nucleus and is the place where ribosomal RNA (rRNA) are produced

Questions!

- Which of the following structures is shared by ALL living cells?
  a. Plasma membrane
  b. DNA
  c. Cytoplasm
  d. RNA
  e. All of the above

Questions!

- Which of the following best describe the nuclear envelop?
  a. Made of phospholipid bilayer
  b. A double membrane and each is a phospholipid bilayer
  c. Contains pores that allow communication with cytoplasm
  d. It is continuous with endoplasmic reticulum
  e. All of the above

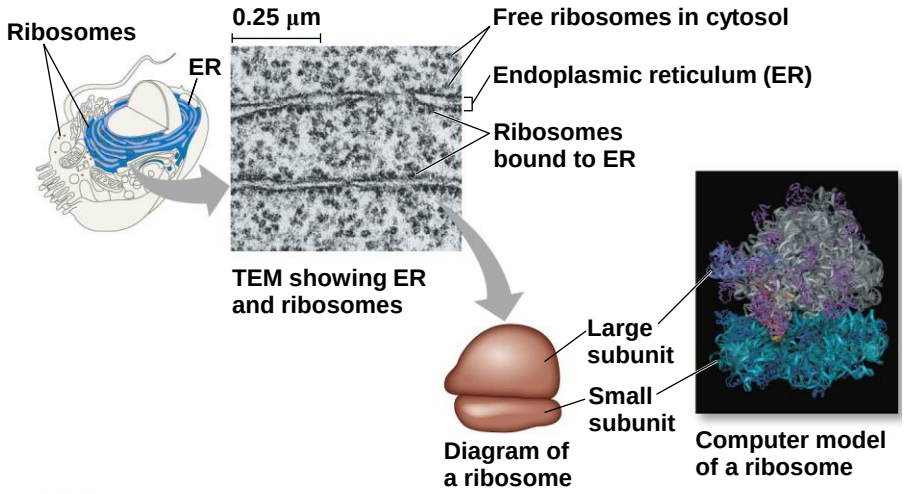
Class activity!

- As a cell begins the process of dividing, its chromosomes becomes shorter, thicker and individually visible in an LM.
- Explain what is happening at the molecular level?
- Why?

Ribosomes: Protein Factories

- **Ribosomes** are complexes made of *ribosomal RNA* and *proteins*
- 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



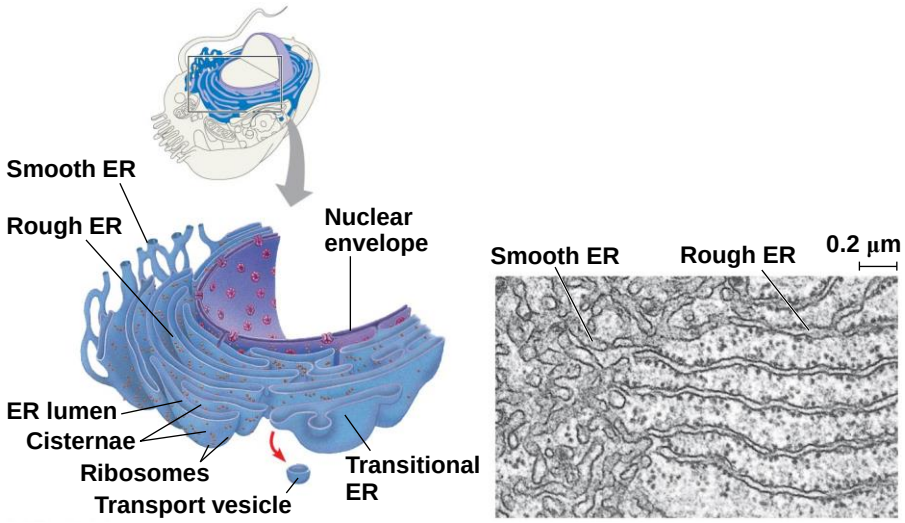
Concept 6.4: The endomembrane system regulates protein traffic and performs metabolic functions in the cell

- 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 (SER)**, which doesn't have ribosomes
  - **Rough ER (RER)**, whose surface is filled with ribosomes

Figure 6.11



Functions of Smooth ER

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

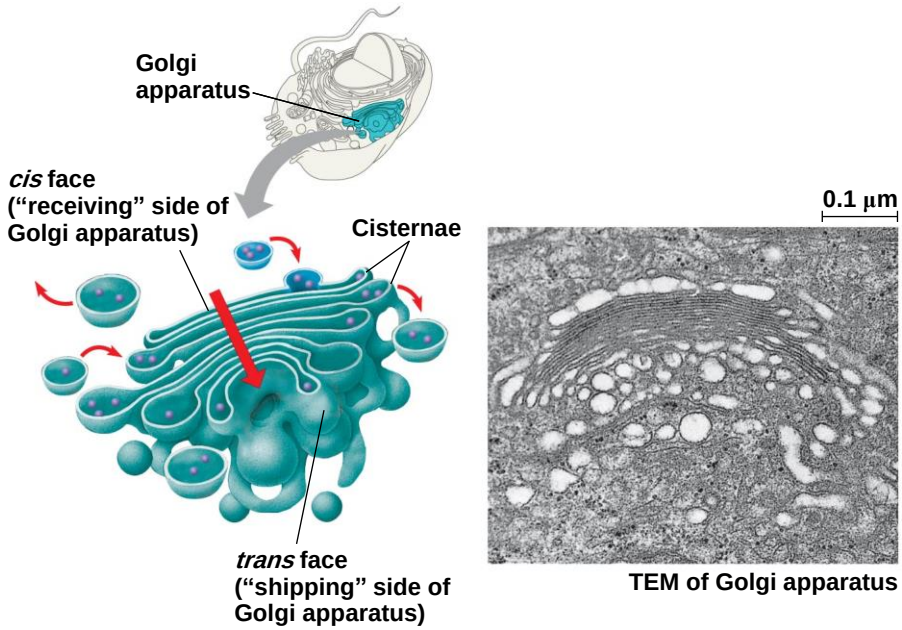
Functions of Rough ER

- 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



Class activity!

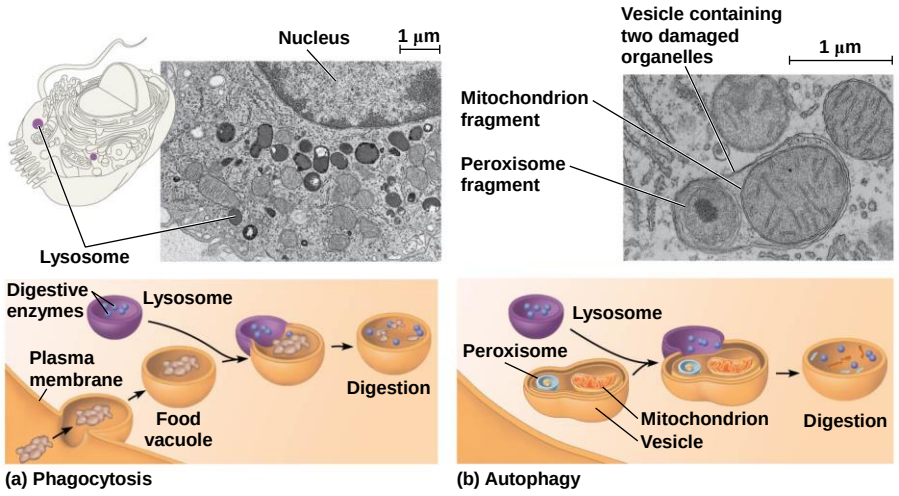
- Imagine a protein that functions in the ER but requires modifications in the Golgi complex before it can achieve this function. Describe the protein's path through the cell, starting with the mRNA molecule that specifies that protein .

Lysosomes: Digestive Compartments

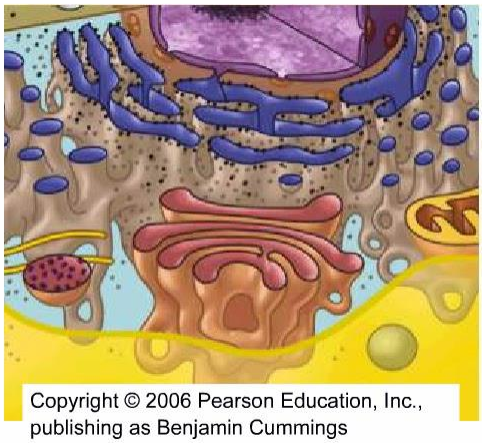
- A **lysosome** is a membranous sac containing *hydrolytic enzymes* that can digest macromolecules
- Lysosomal enzymes work best in the acidic environment inside the lysosome
- Hydrolytic enzymes and lysosomal membranes are made by rough ER and then transferred to the Golgi apparatus for further processing

- Some types of cells can *engulf* other cells 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



Animation: Lysosome Formation

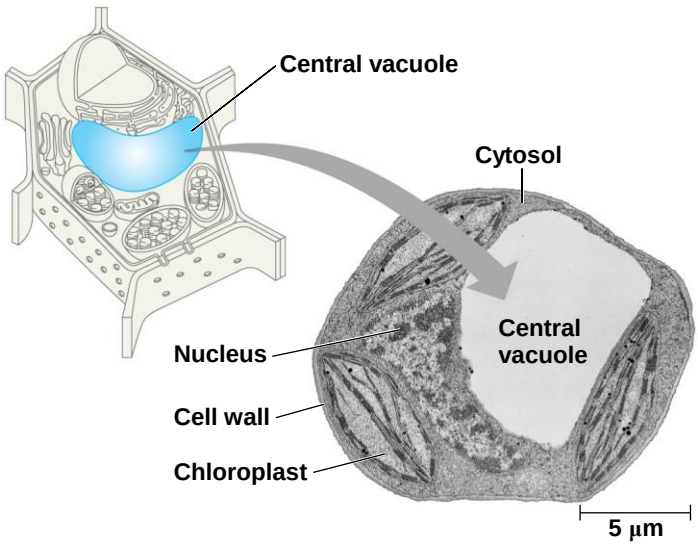


Video: Phagocytosis in Action

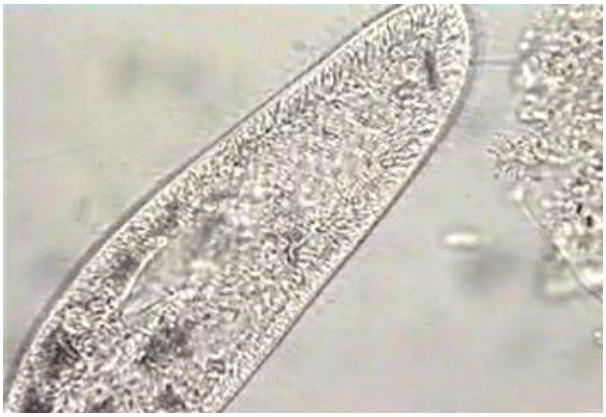
Vacuoles: Diverse Maintenance Compartments

- **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, hold organic compounds and water

Figure 6.14



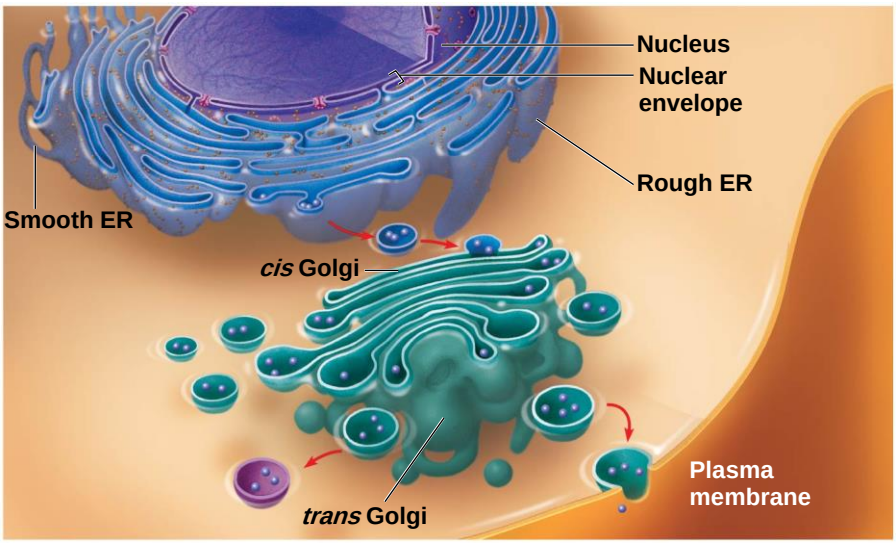
Video: *Paramecium* Vacuole



The Endomembrane System: *A Review*

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

Figure 6.15



Video: ER to Golgi Traffic

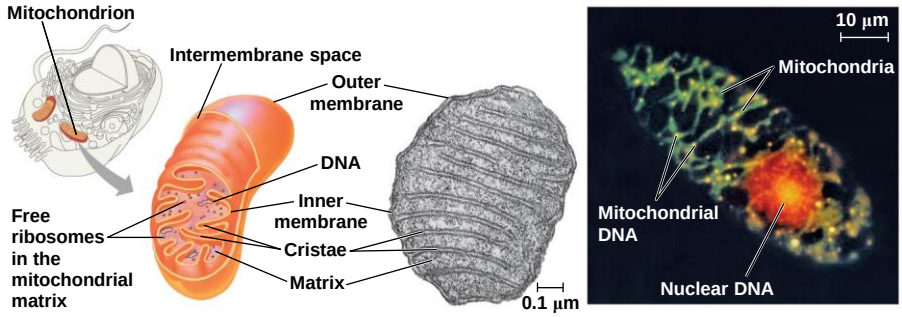
Concept 6.5: Mitochondria and chloroplasts change energy from one form to another

- **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

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

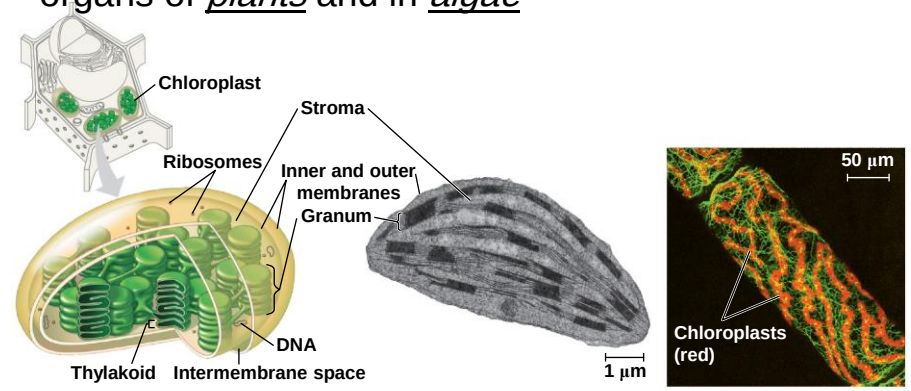


(a) Diagram and TEM of mitochondrion

(b) Network of mitochondria in *Euglena* (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*



(a) Diagram and TEM of chloroplast

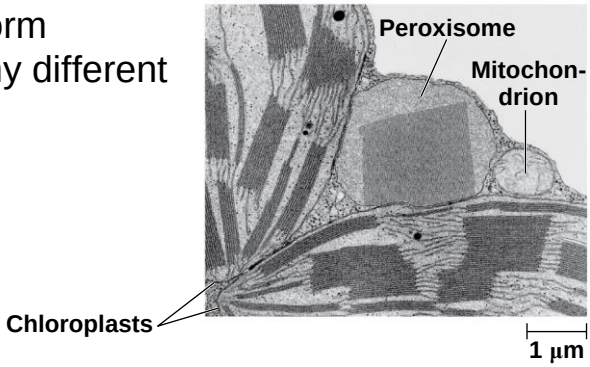
(b) Chloroplasts in an algal cell

Class activity!

- Do plant cells have mitochondria? Explain.
- Do you think that the chloroplasts and mitochondria should be classified in the endomembrane system? Explain.

Peroxisomes: Oxidation

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



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* - thickest of the three components
  - *Microfilaments* - *actin filaments*, are the thinnest components
  - *Intermediate filaments* - are fibers with diameters in a middle range

Figure 6.T01

Table 6.1 The Structure and Function of the Cytoskeleton

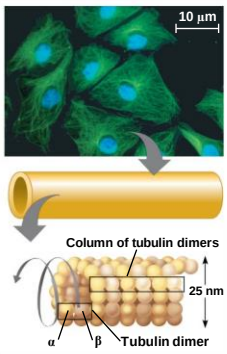
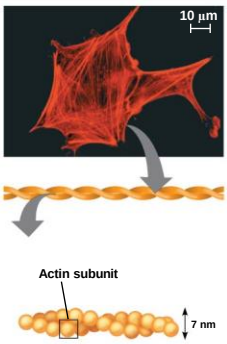
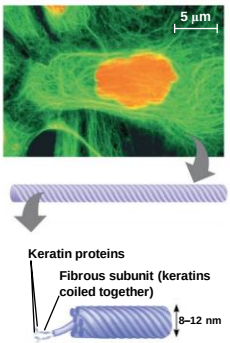
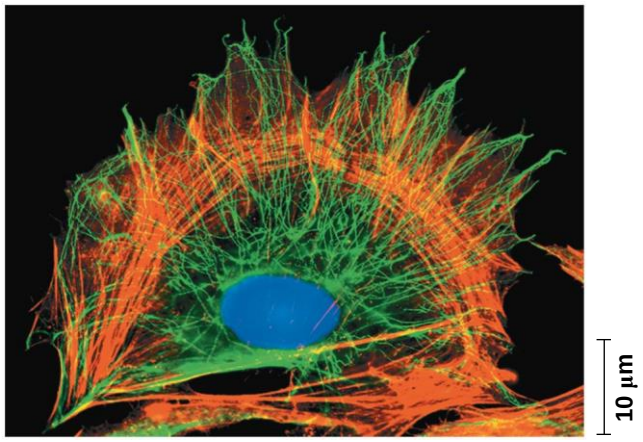
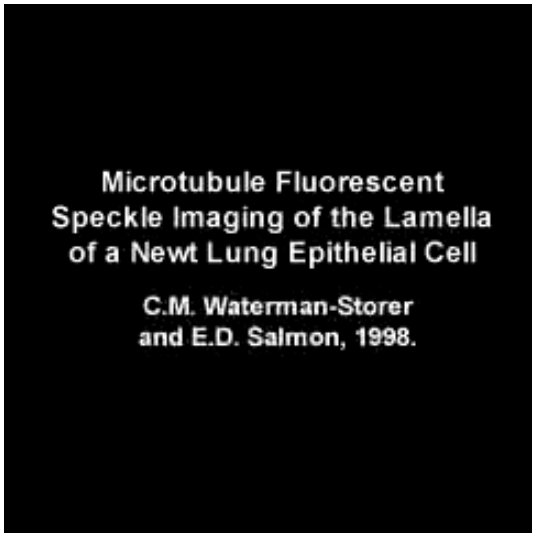
Property	Microtubules (Tubulin Polymers)	Microfilaments (Actin Filaments)	Intermediate Filaments
Structure	Hollow tubes	Two intertwined strands of actin	Fibrous proteins coiled into cables
Diameter	25 nm with 15-nm lumen	7 nm	8–12 nm
Protein subunits	Tubulin, a dimer consisting of α-tubulin and β-tubulin	Actin	One of several different proteins (such as keratins)
Main functions	Maintenance of cell shape (compression-resisting "girder"); 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 in plant cells; cell motility (as in amoeboid movement); division of animal cells	Maintenance of cell shape (tension-bearing elements); anchorage of nucleus and certain other organelles; formation of nuclear lamina
Fluorescence micrographs of fibroblasts. Fibroblasts are a favorite cell type for cell biology studies because they spread out flat and their internal structures are easy to see. In each, the structure of interest has been tagged with fluorescent molecules. The DNA in the nucleus has also been tagged in the first micrograph (blue) and third micrograph (orange).			

Figure 6.20



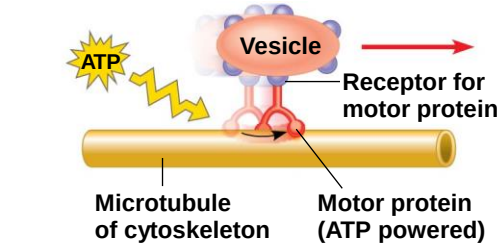
Video: Microtubule Dynamics



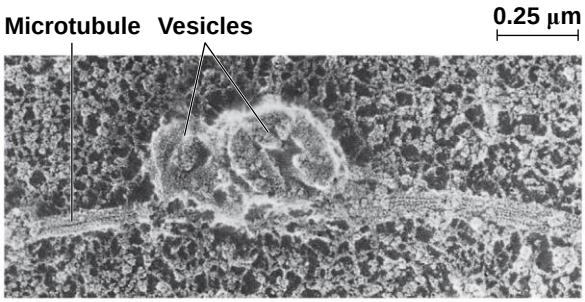
Roles of the Cytoskeleton: Support and Motility

- The cytoskeleton helps to *support the cell* and *keep its shape*
- It interacts with **motor proteins** to produce cell motility
- Inside the cell, *vesicles can travel along cytoskeleton tracks*

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).

Video: Movement of Organelles *In Vivo*

Video: Transport Along Microtubules

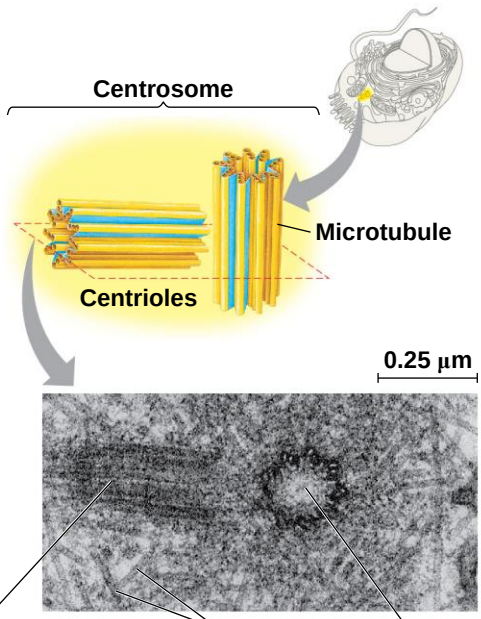
Microtubules

- **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*

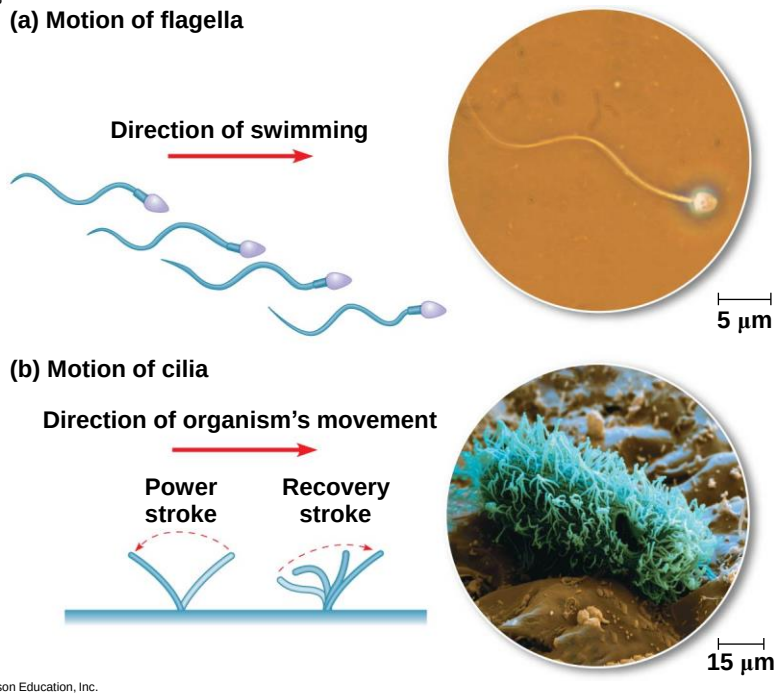
Figure 6.22



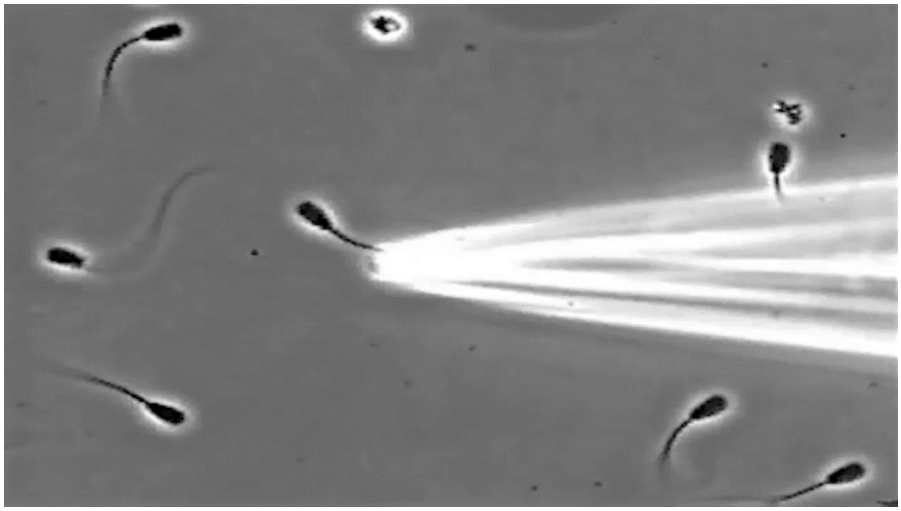
Cilia and Flagella

- Microtubules control the beating of **flagella** and **cilia**, microtubule-containing extensions that project from some cells
- Many unicellular eukaryotes move through water by cilia or flagella
- Cilia and flagella differ in their beating patterns

Figure 6.23



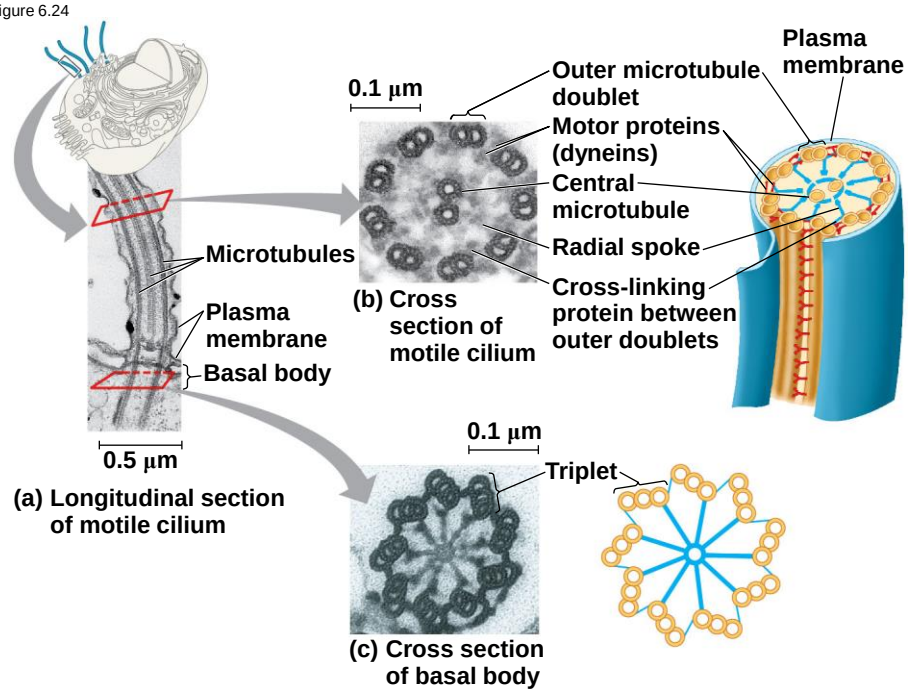
Video: Motion of Isolated Flagellum



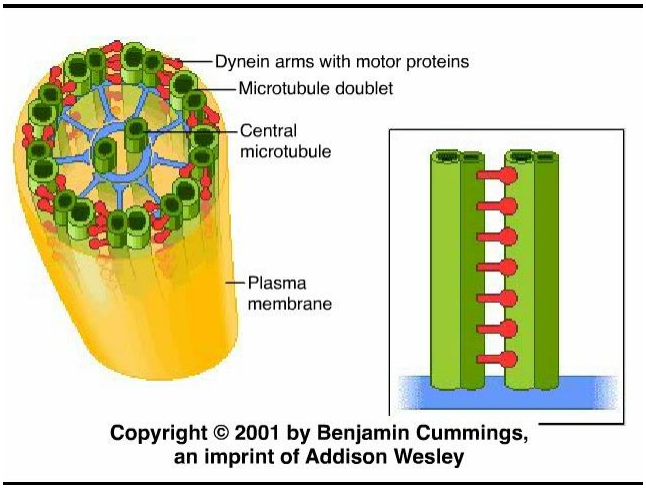
Video: *Paramecium* Cilia

- Cilia and flagella share a *common structure*
  - A group of microtubules sheathed by an extension of 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

Figure 6.24



Animation: Cilia and Flagella

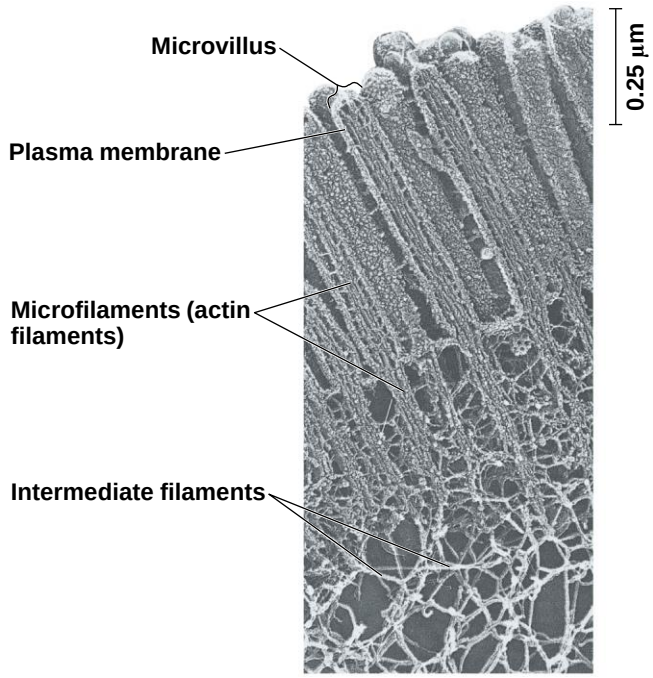


Video: Microtubule Sliding in Flagellum Movement

Microfilaments (Actin Filaments)

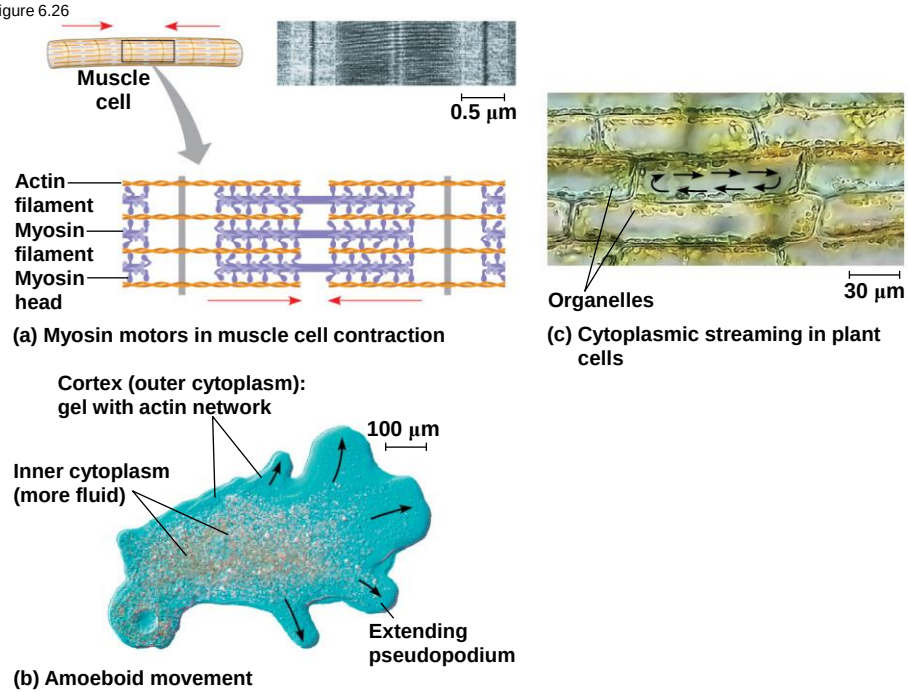
- **Microfilaments** are *solid rods* about 7 nm in diameter, built as a *twisted double chain* of **actin** subunits
- A network of microfilaments helps support the cell's shape
- They form a **cortex** just inside the plasma membrane to help support the cell's shape
- Bundles of microfilaments make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

Figure 6.25



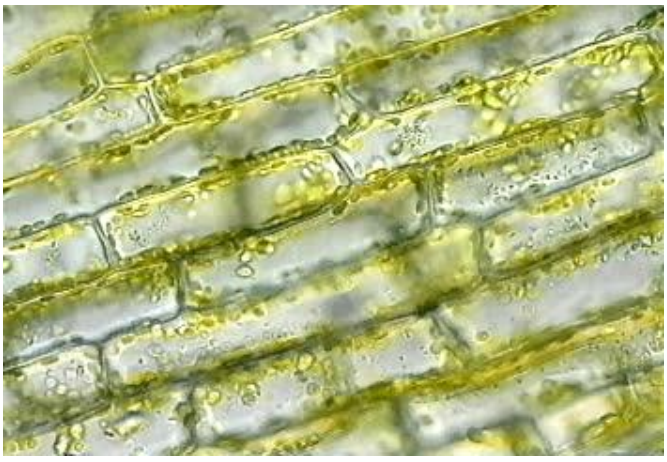
- Microfilaments that function in cellular motility contain the protein **myosin** in addition to actin
- Cells crawl along a surface by extending **pseudopodia** (cellular extensions) and moving toward them
- **Cytoplasmic streaming** is a circular flow of cytoplasm within cells, driven by actin-myosin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

Figure 6.26



Video: Actin Network in Crawling Cells

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

Class activity!

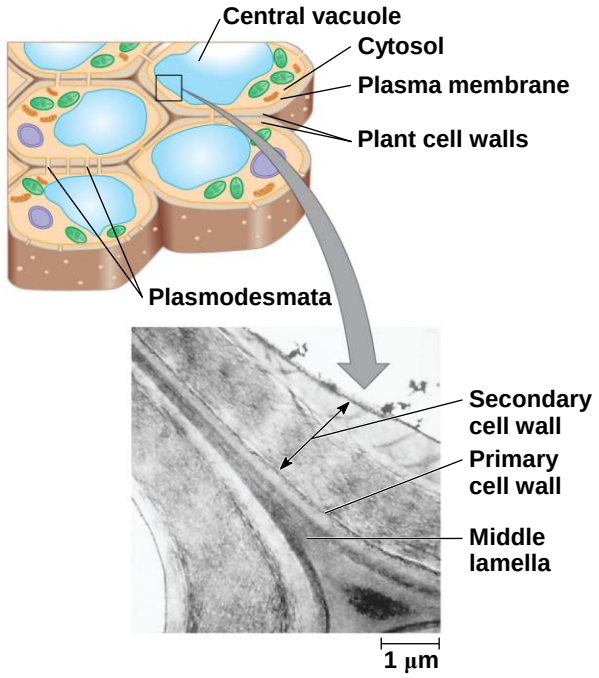
- Males afflicted with **Kartagener's** syndrome are sterile because of **immotile sperm**, and they tend to suffer from **lung infections**. This disorder has a genetic basis. Suggest what the underlying defect might be?

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

- The **cell wall** is an extracellular structure that *distinguishes plant cells from animal cells*
- *Prokaryotes, fungi, and some unicellular eukaryotes 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*

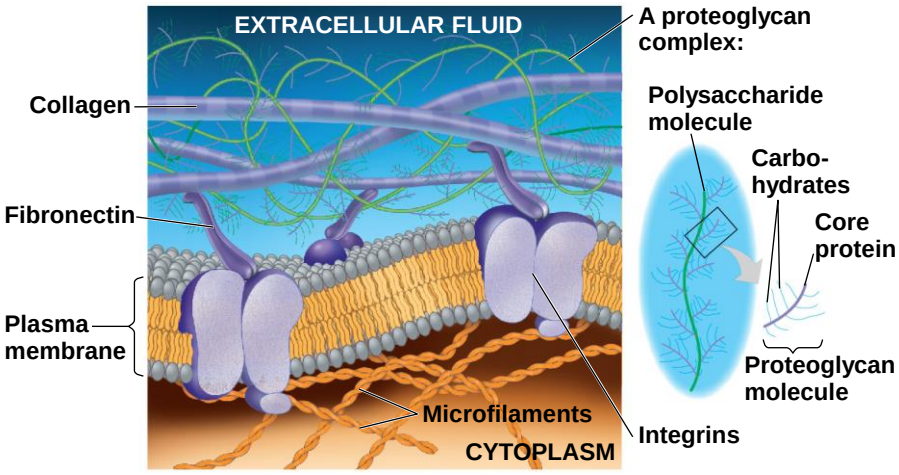
Figure 6.27



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

Figure 6.28



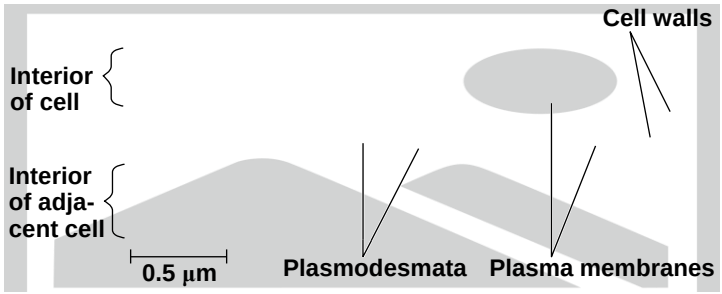
- The ECM has an influential role in the lives of cells
- *ECM can regulate a cell's behavior by communicating with a cell through integrins*
- Mechanical signaling may occur through cytoskeletal changes that trigger chemical signals in the cell

Cell Junctions

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

Plasmodesmata in Plant Cells

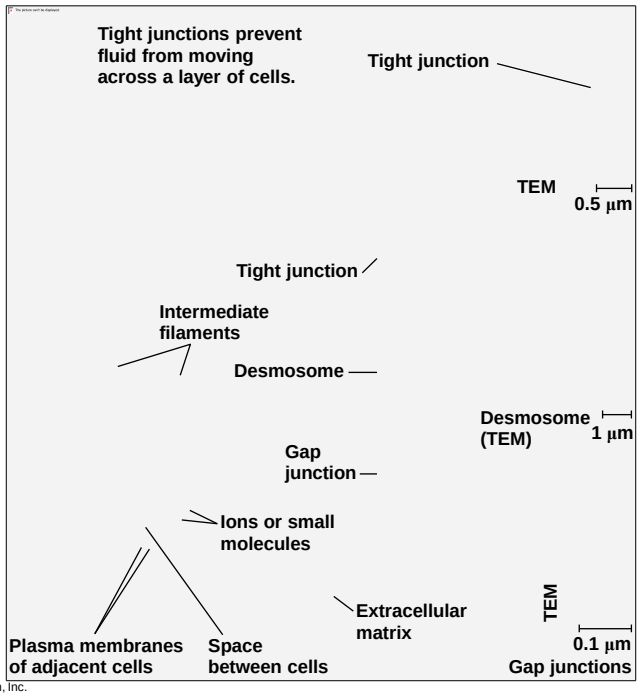
- **Plasmodesmata** are channels that perforate plant cell walls
- Through plasmodesmata, water and small solutes (and sometimes proteins and RNA) can *pass from cell to cell*



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

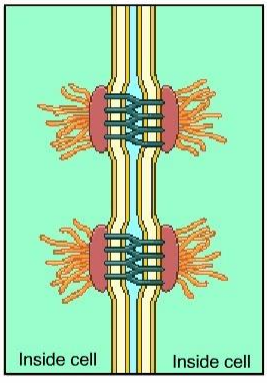
Figure 6.30



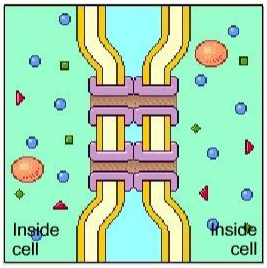
Class activity!

- In what way are the cells of plants and animals structurally different from single-celled eukaryotes?
- If a plant cell wall and animal extracellular matrix are impermeable, what effect would this have on the cell function?

Animation: Desmosomes



Animation: Gap Junctions



Animation: Tight Junctions

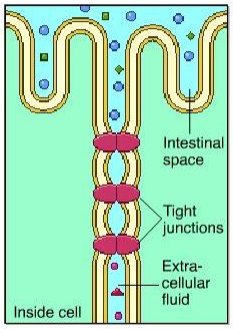


Figure 6.UN03

Summary

Cell Component	Structure	Function
Nucleus	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
(ER)		
Ribosome	Two subunits made of ribosomal RNAs and proteins; can be free in cytosol or bound to ER	Protein synthesis

Figure 6.UN04

Cell Component	Structure	Function
Endoplasmic reticulum (ER)	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 on bound ribosomes; adds carbohydrates to proteins to make glycoproteins; produces new membrane
(Nuclear envelope)		
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.UN05

Cell Component	Structure	Function
Mitochondrion	Bounded by double membrane; inner membrane has infoldings	Cellular respiration
Chloroplast	Typically two membranes around fluid stroma, which contains thylakoids stacked into grana	Photosynthesis (chloroplasts are in cells of photosynthetic eukaryotes, including plants)
Peroxisome	Specialized metabolic compartment bounded by a single membrane	Contains enzymes that transfer H atoms from substrates to oxygen, producing H_2O_2 (hydrogen peroxide), which is converted to H_2O.