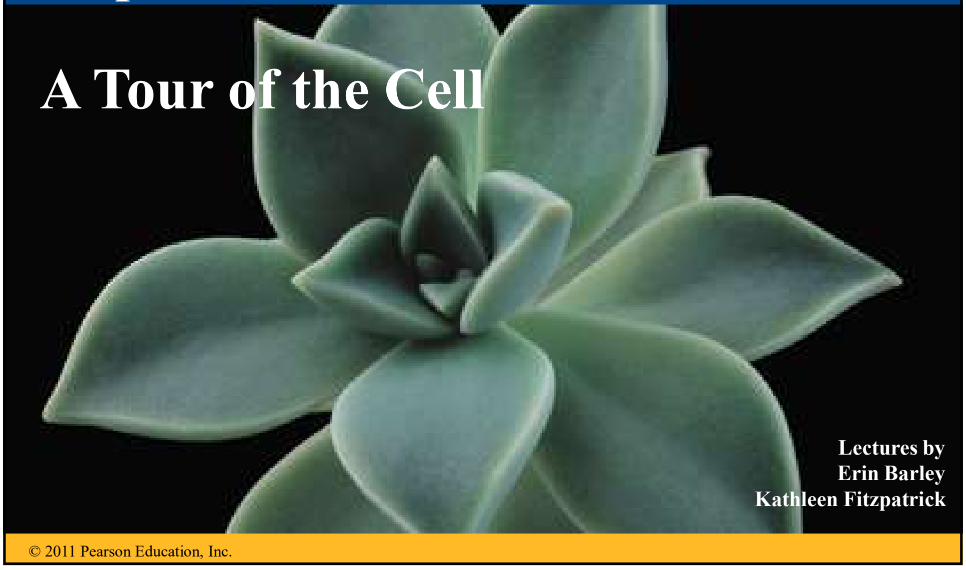
LECTURE PRESENTATIONS
For CAMPBELL BIOLOGY, NINTH EDITION
Jane B. Reece, Lisa A. Urry, Michael L. Cain, Steven A. Wasserman, Peter V. Minorsky, Robert B. Jackson

Chapter 6



A Tour of the Cell

Lectures by
Erin Barley
Kathleen Fitzpatrick

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

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

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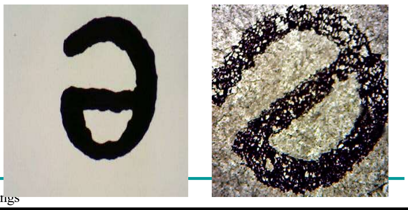
microscope

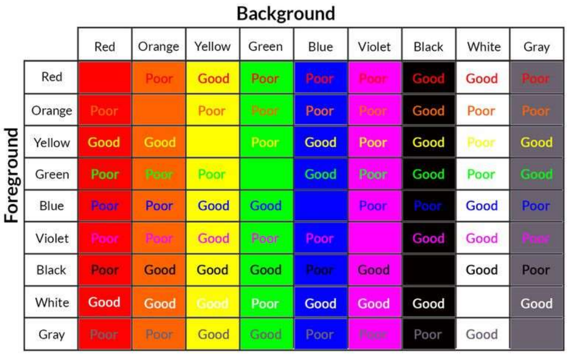
- In a light microscope (LM), visible light passes through a specimen and then through glass lenses, which magnify the image

- 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***



The quality of an image depends on

- ***Contrast***, ***visible differences in parts of the sample***



		Background								
		Red	Orange	Yellow	Green	Blue	Violet	Black	White	Gray
Foreground	Red		Poor	Good	Poor	Poor	Poor	Good	Good	Poor
	Orange	Poor		Poor	Poor	Poor	Poor	Good	Poor	Poor
	Yellow	Good	Good		Poor	Good	Poor	Good	Poor	Good
	Green	Poor	Poor	Poor		Good	Poor	Good	Poor	Good
	Blue	Poor	Poor	Good	Good		Poor	Poor	Good	Poor
	Violet	Poor	Poor	Good	Poor	Poor		Good	Good	Poor
	Black	Poor	Good	Good	Good	Poor	Good		Good	Poor
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Figure 6.2

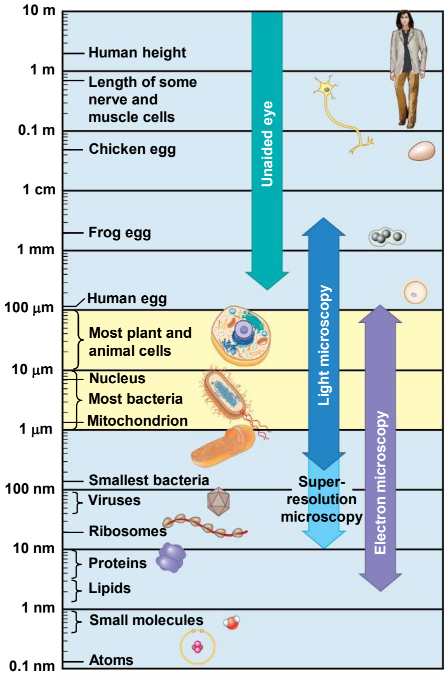
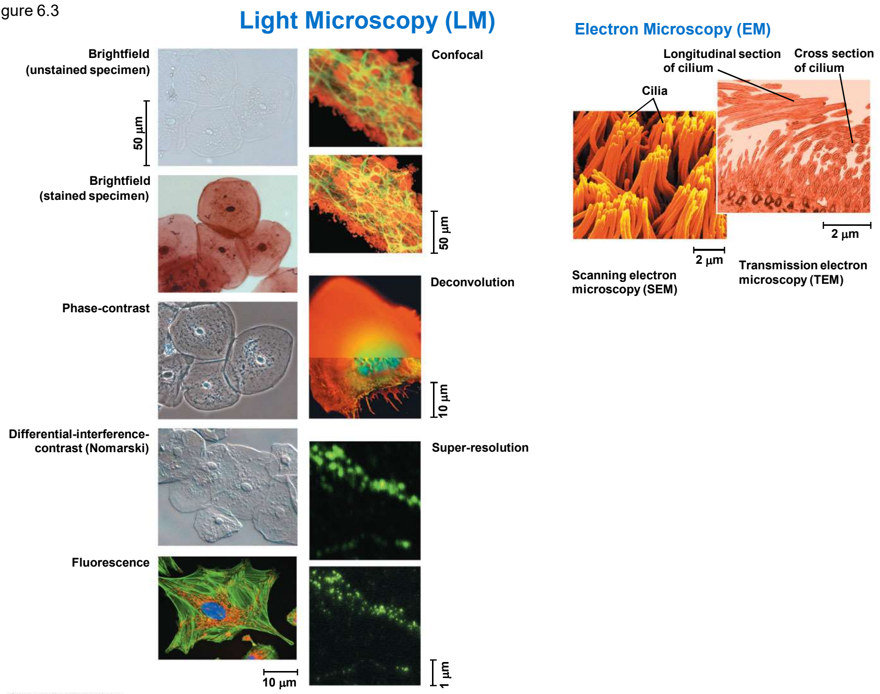


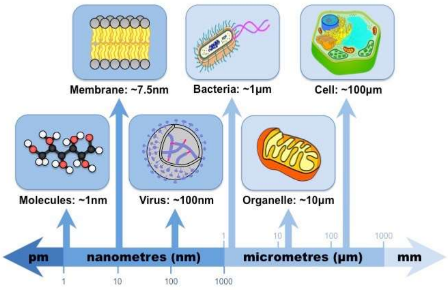
Figure 6.3



- 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**

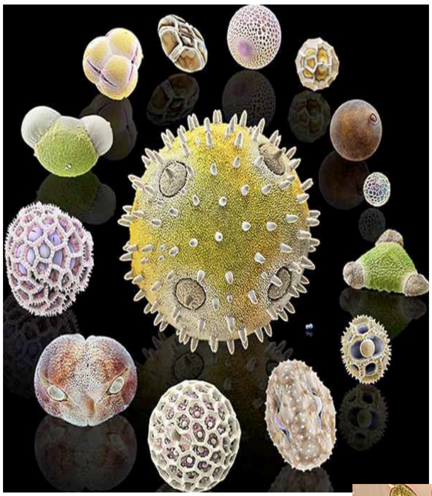
- Most subcellular structures, including **organelles** (membrane-enclosed compartments), are too small to be resolved by an LM

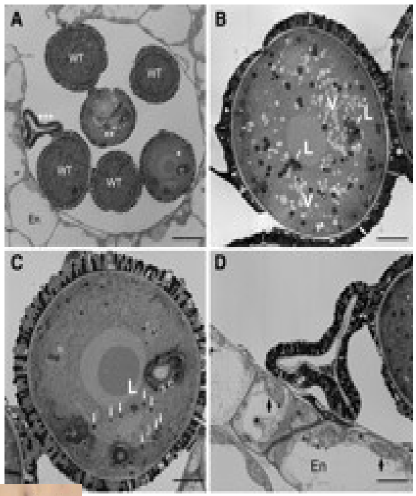


Electron microscopes

- 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

TEM

- LM

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**

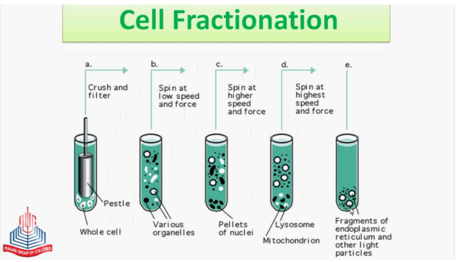
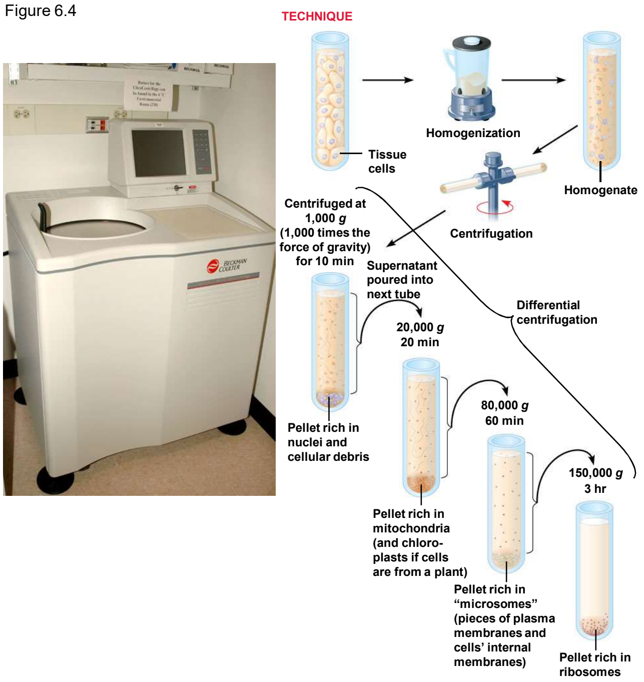
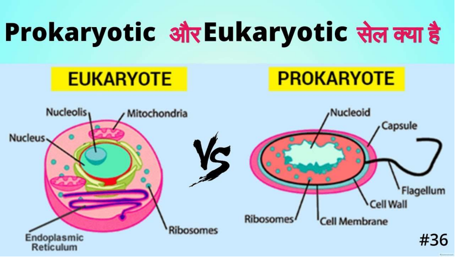


Figure 6.4



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

Prokaryotic vs. Eukaryotic Cells

- **Basic features of all cells:**

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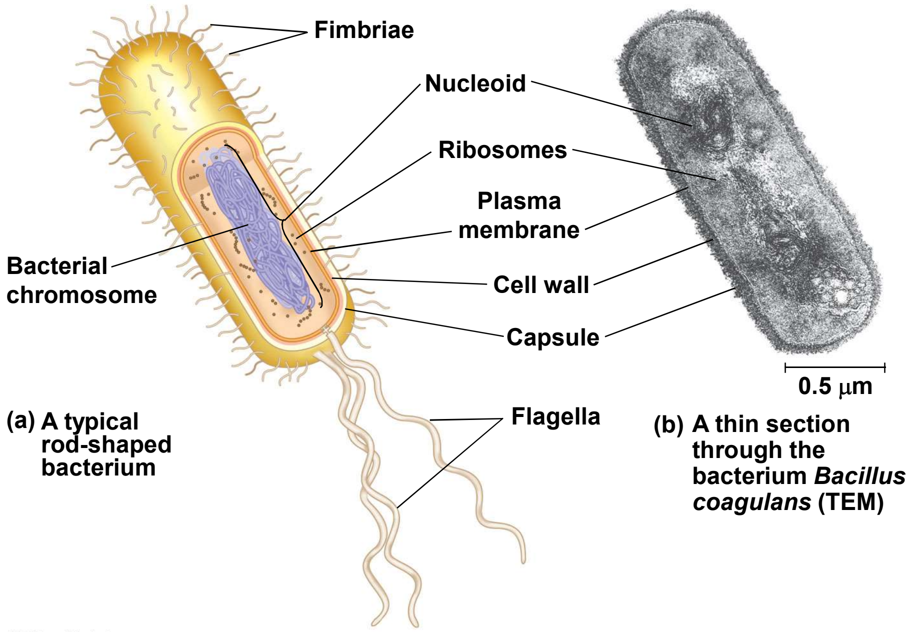
  - Plasma membrane
  - Semifluid substance called cytosol
  - Chromosomes (carry genes)
  - Ribosomes (make proteins)

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

Figure 6.5

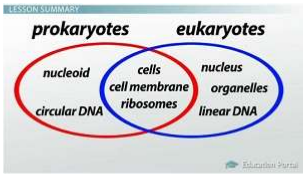


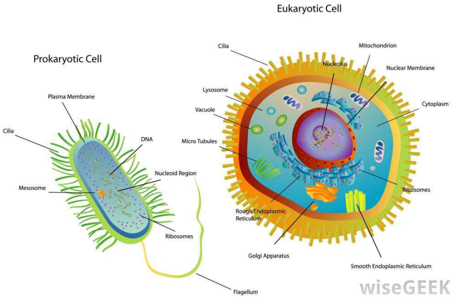
(a) A typical rod-shaped bacterium

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

- 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 <u>much larger</u> than prokaryotic cells***

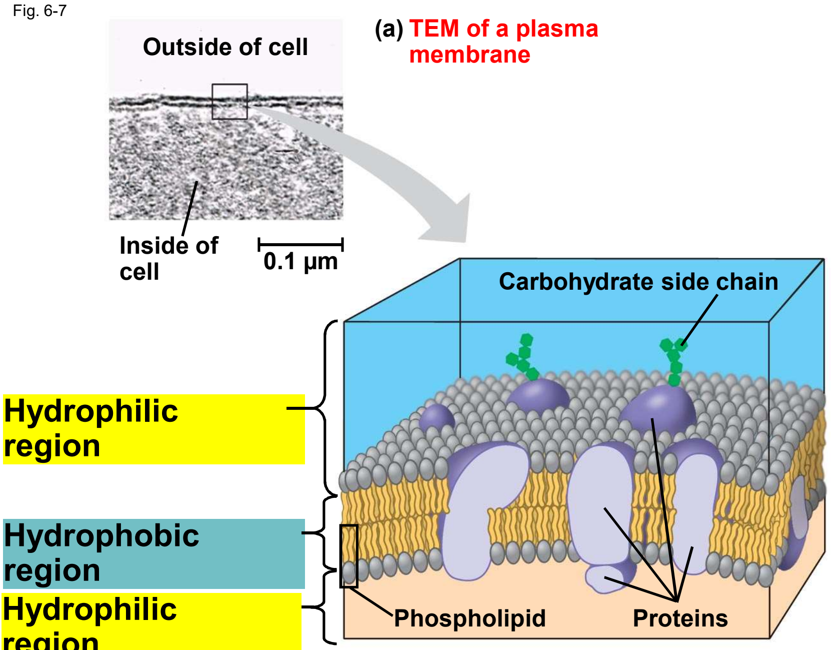




- **The plasma membrane is a *<u>selective</u> barrier that <u>allows sufficient passage of oxygen, nutrients, and waste to service the volume of every cell</u>***

- **The general structure of a biological membrane is a <u>double layer of phospholipids</u>**

Fig. 6-7



(a) TEM of a plasma membrane

(b) Structure of the plasma membrane

Cell size

- 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***

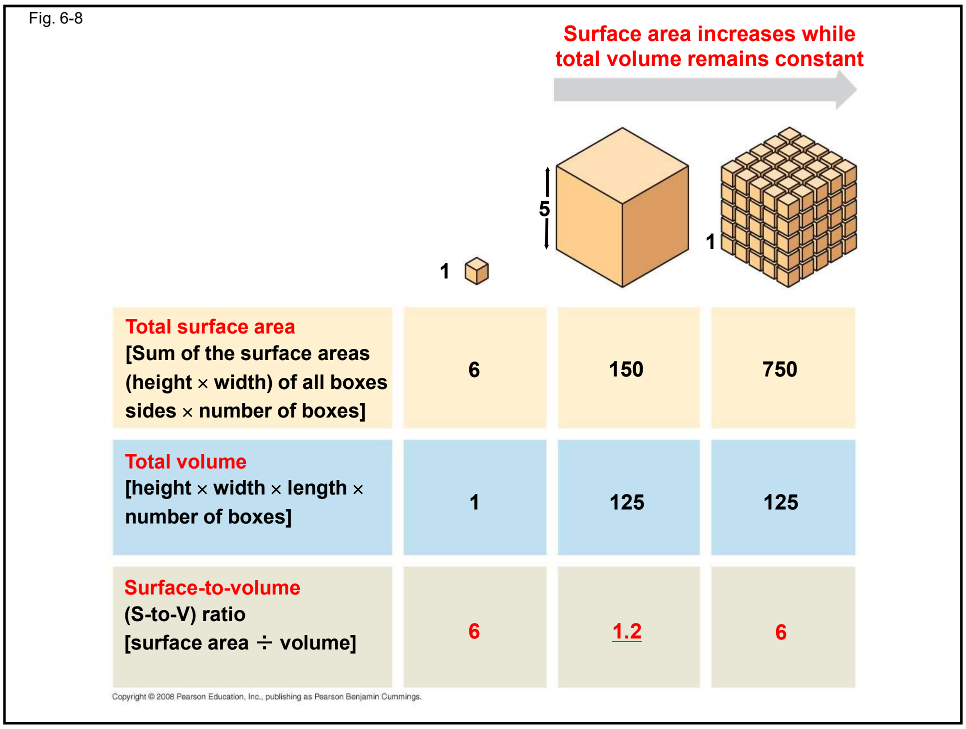


Fig. 6-8

Surface area increases while total volume remains constant

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

Fig. 6-9a

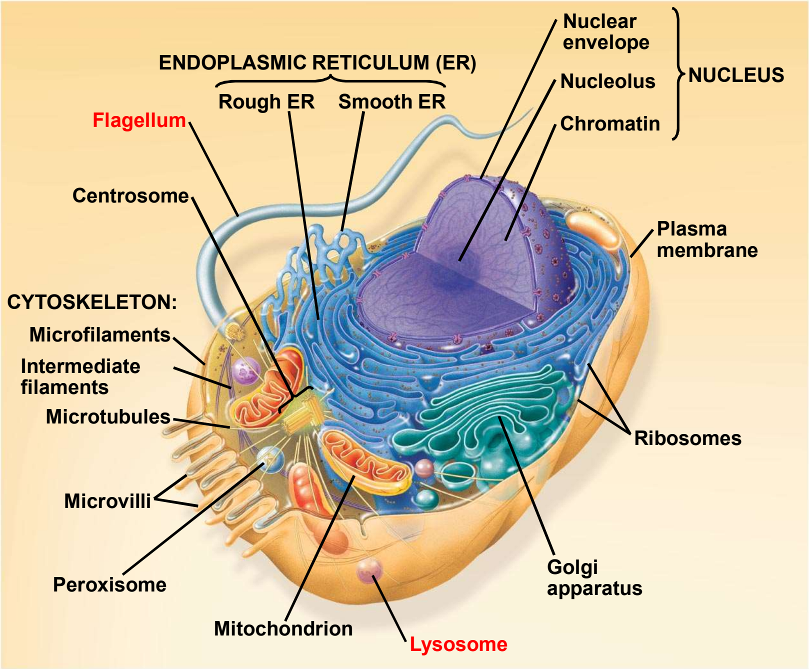
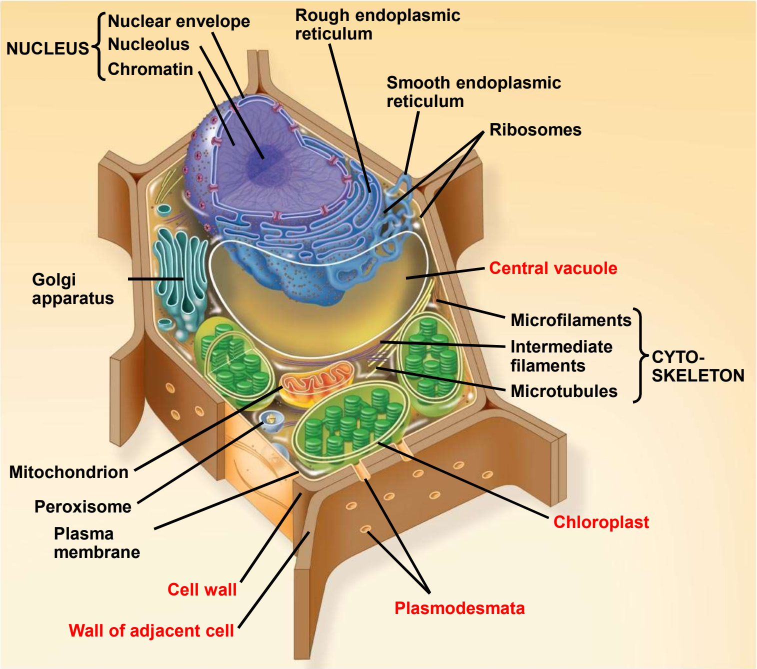


Fig. 6-9b



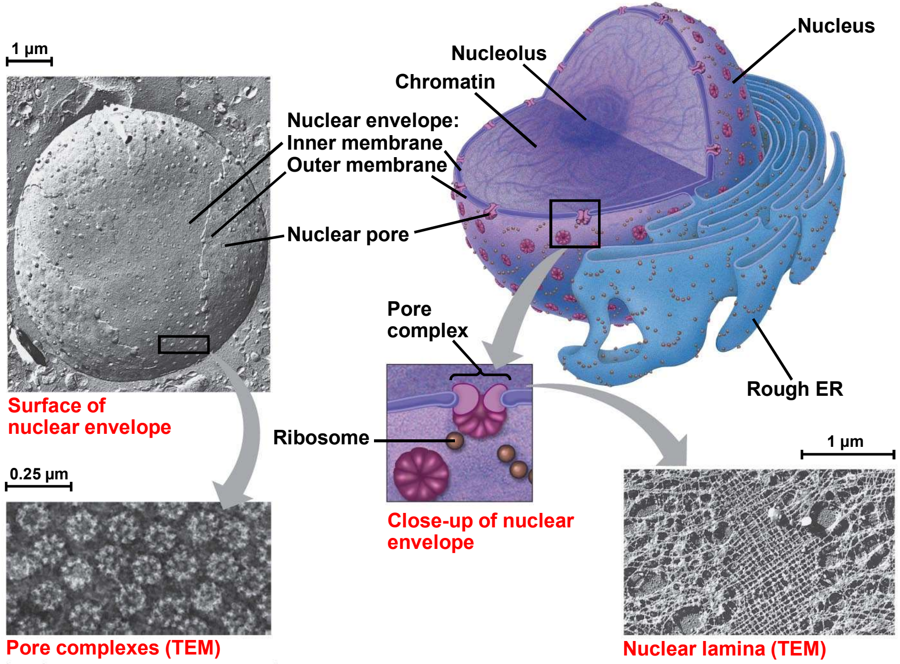
The eukaryotic cell’s genetic instructions are housed in the nucleus and carried out by the ribosomes

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

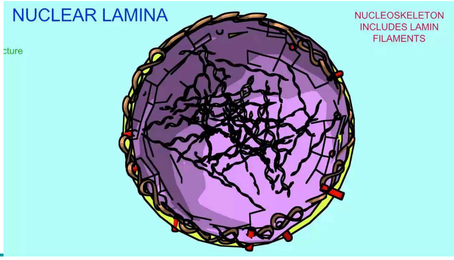
The Nucleus: Information Central

- The nucleus is usually the most conspicuous organelle
- The nuclear envelope encloses the nucleus
- 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



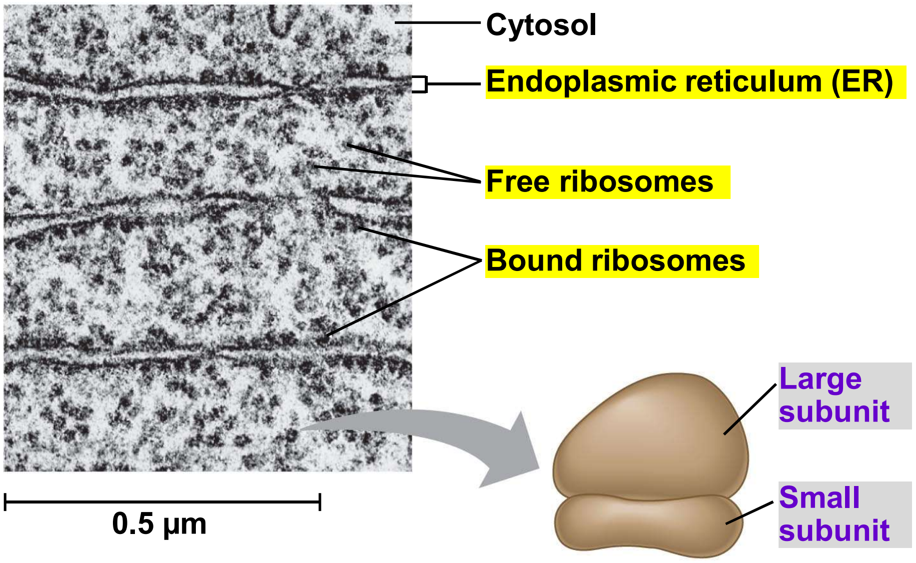
- In the nucleus, DNA is organized into discrete units called **chromosomes.**
- Each chromosome is composed of a single DNA molecule **associated** with **proteins**
- DNA and proteins form genetic material called **chromatin.**

- 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 <u>two locations</u>:
  - In the cytosol (***free ribosomes***)
  - On the outside of the endoplasmic reticulum or the nuclear envelope <u>(*bound ribosomes*)</u>

Fig. 6-11



TEM showing ER and ribosomes

Diagram of a ribosome

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

- Components of the system:
  - Nuclear envelope
  - Endoplasmic reticulum
  - Golgi apparatus
  - Lysosomes
  - Vacuoles
  - Plasma membrane

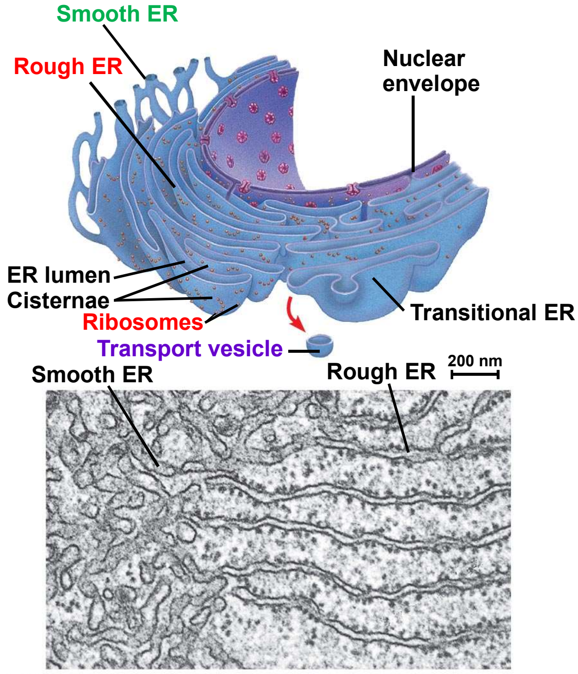
- These components are either continuous or connected via transfer by **vesicles**

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** that lacks ribosomes
  - **Rough ER** that have 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

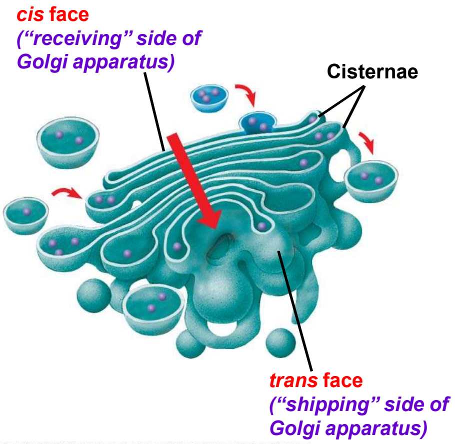
- The rough ER
  - Has bound ribosomes, which secrete **glycoproteins** (*proteins covalently bonded to carbohydrates*)
  - Distributes transport vesicles ► proteins surrounded by membranes
  - Is a membrane factory for the cell

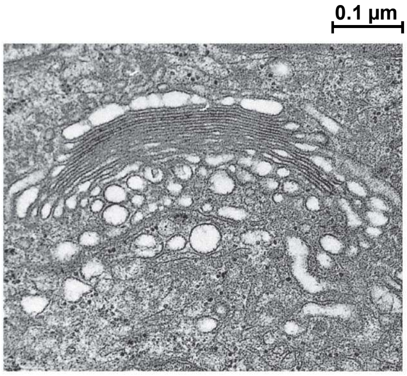
The Golgi Apparatus: *Shipping and Receiving Center*

- 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

- **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

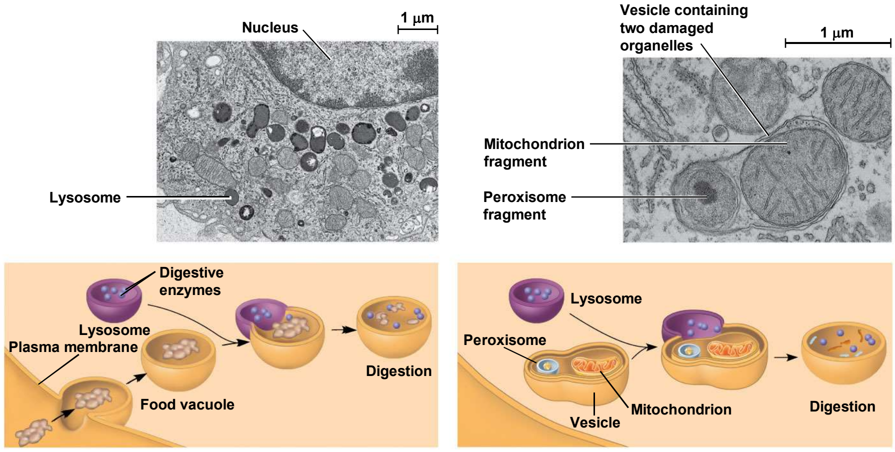
Lysosomes: Digestive Compartments

- 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

- 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

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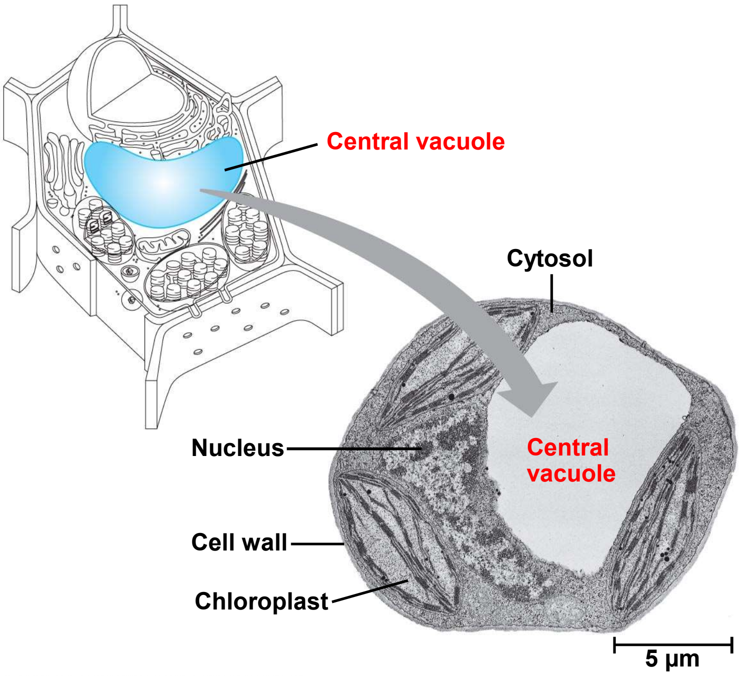
- Types of Vacuoles:

- Food vacuoles ▶ formed by phagocytosis
- Contractile vacuoles ▶ in many freshwater protists ▶ pump excess water out of cells
- Central vacuoles ▶ in plant cells ▶ hold organic compounds and water

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

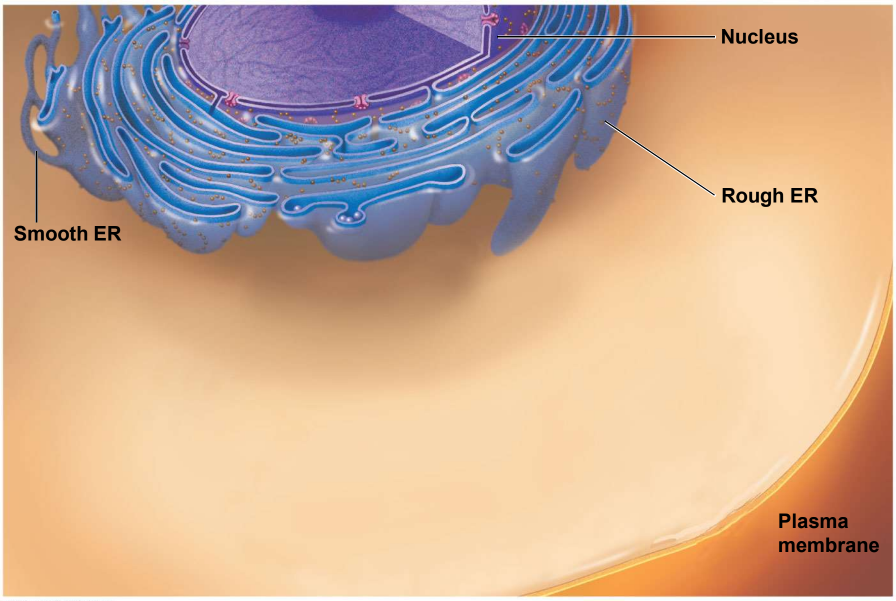


Figure 6.15-2

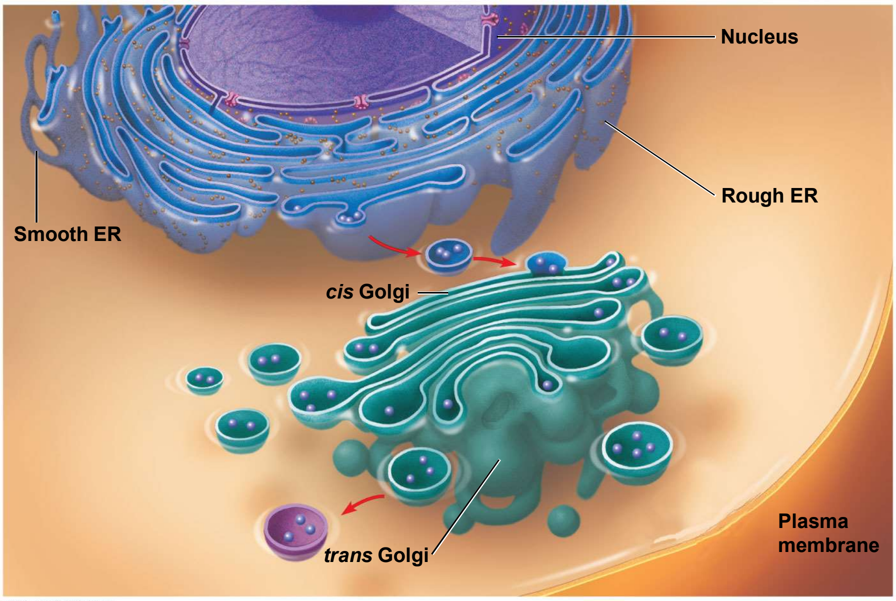
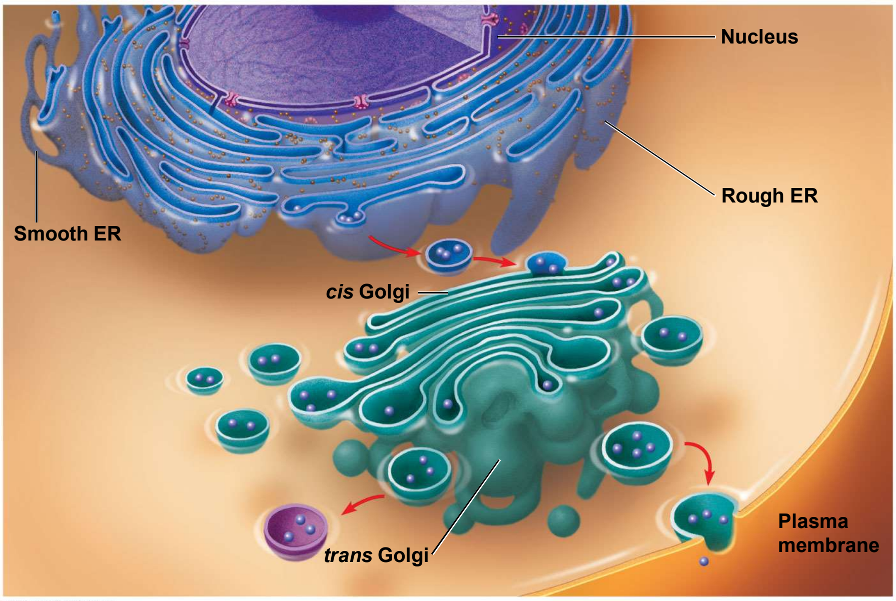


Figure 6.15-3



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

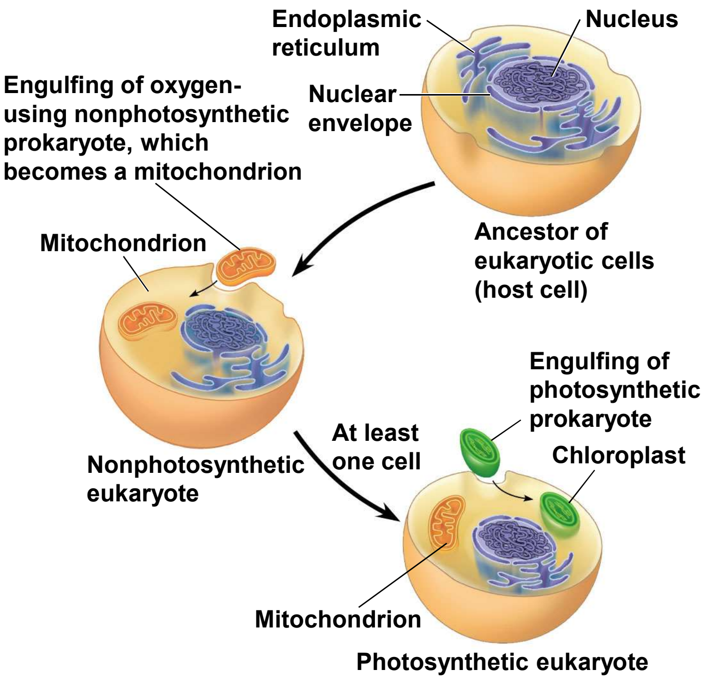
The Evolutionary Origins of Mitochondria and Chloroplasts

- 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**

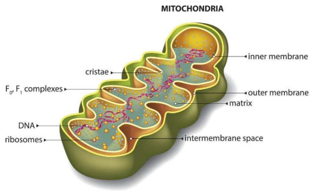
At least one of these cells may have taken up a **photosynthetic prokaryote**, becoming the ancestor of cells that contain **chloroplasts**

Figure 6.16



Mitochondria: Chemical Energy Conversion

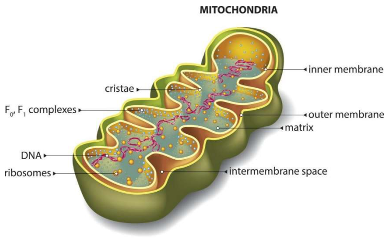
- **Mitochondria are in *nearly all eukaryotic cells***
- **They have a smooth outer membrane and an inner membrane folded into cristae**



The inner membrane creates

two compartments:

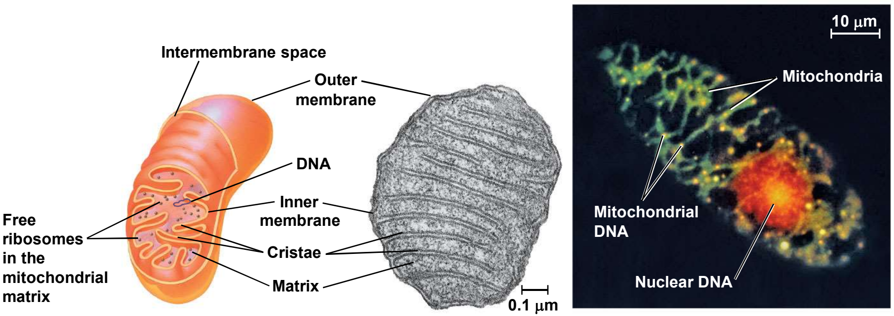
- **intermembrane space** **and**
- **mitochondrial matrix**



- 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

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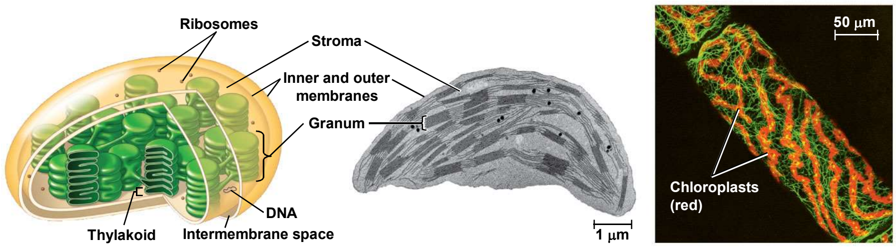
- Chloroplast structure includes
  - Thylakoids, membranous sacs, stacked to form a granum
  - Stroma, the internal fluid
- The chloroplast is one of a group of plant organelles, called plastids

Figure 6.18



(a) Diagram and TEM of chloroplast

(b) Chloroplasts in an algal cell

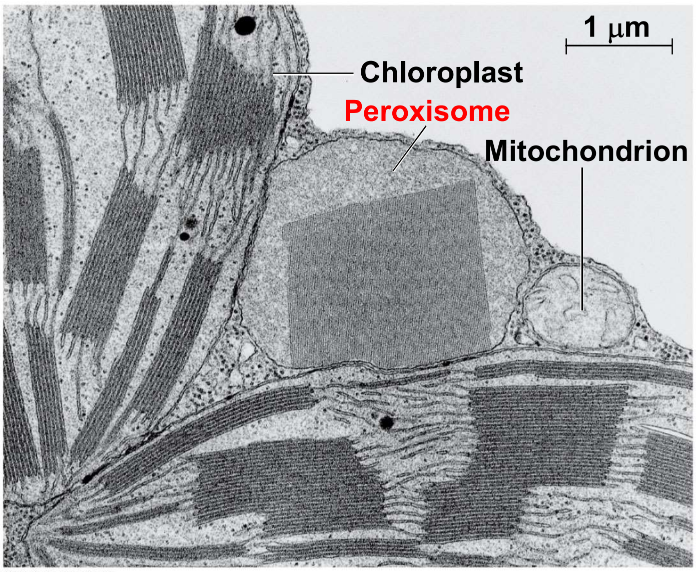
Peroxisomes: Oxidation

- **Peroxisomes** are specialized metabolic compartments bounded by a **single membrane**
- **Peroxisomes** produce **hydrogen peroxide** and convert it to water

Peroxisomes

- Peroxisomes perform reactions with many different functions
- How peroxisomes are related to other organelles is still unknown

Figure 6.19



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

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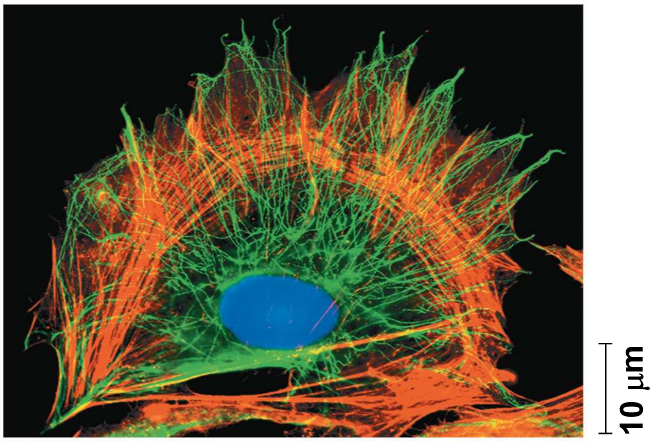
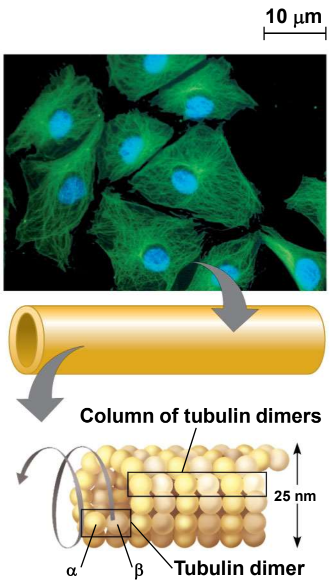
It is composed of three types of molecular structures.



- **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



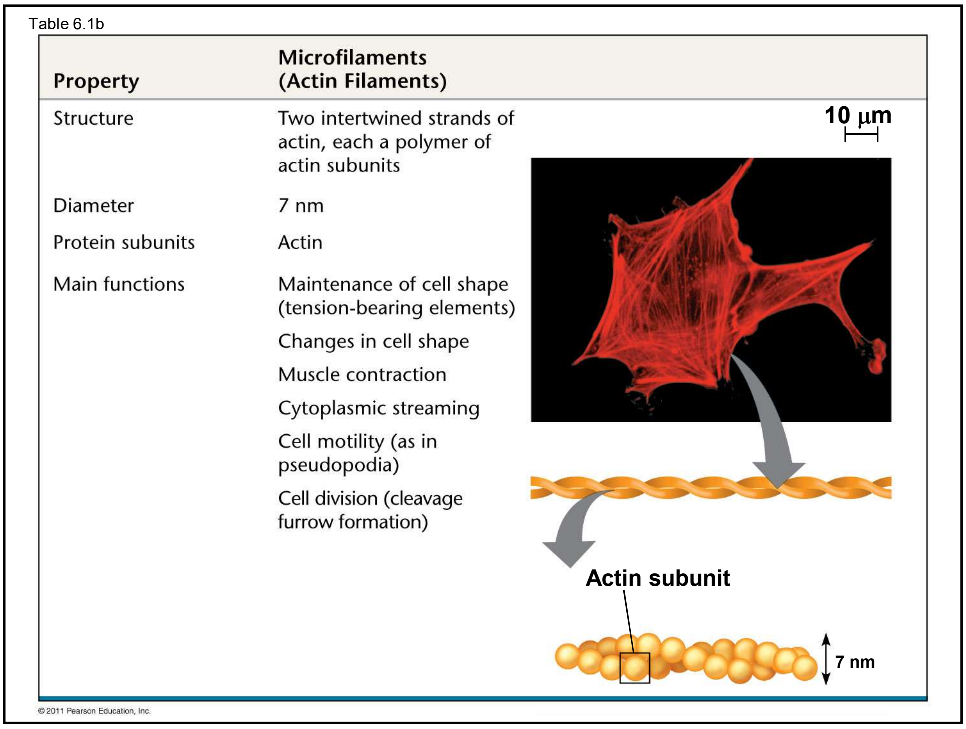


Table 6.1b

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)

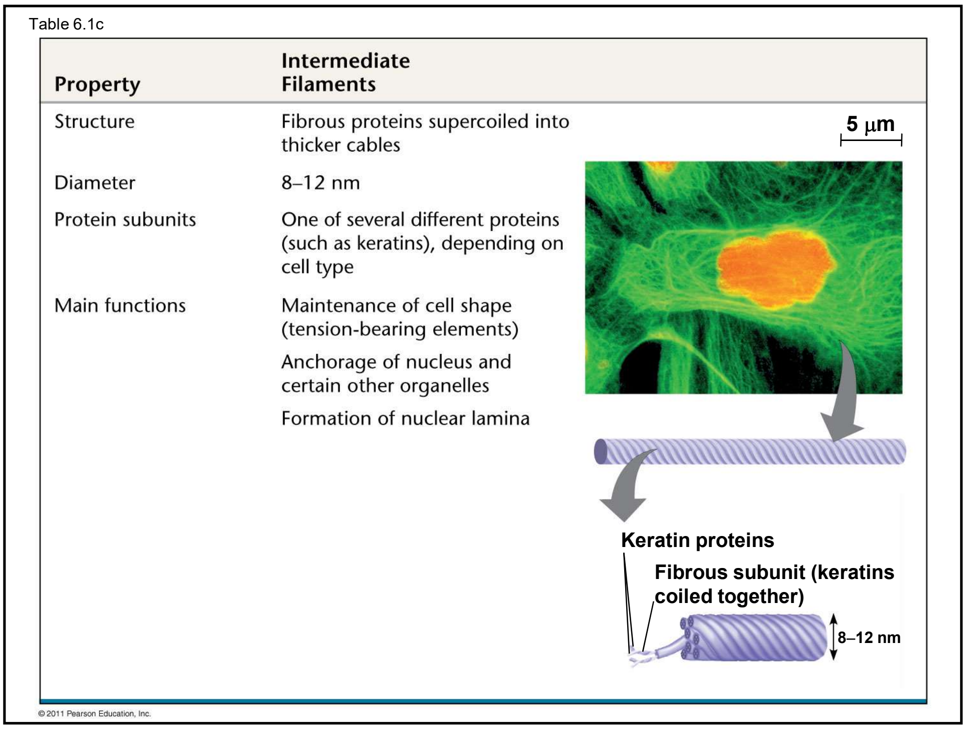


Table 6.1c

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:

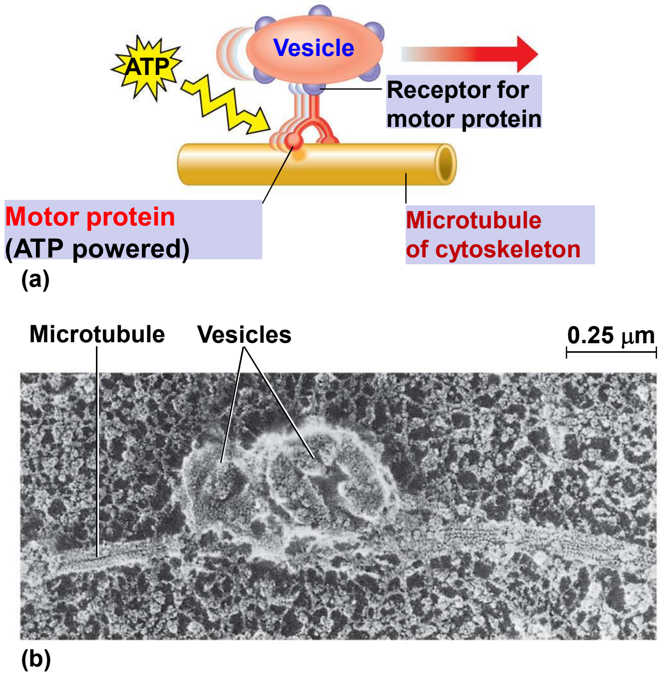
Support and Motility

- The cytoskeleton helps to support the cell and **maintain its shape**
- It interacts with motor proteins to produce **motility**

Roles of the Cytoskeleton:

- 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**"

Centrosomes and Centrioles

- **In animal cells**, the **centrosome has a pair of <u>centrioles</u>**, each with ***<u>nine</u> triplets of <u>microtubules</u> arranged in a ring***

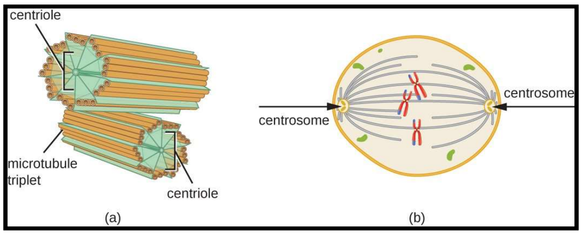
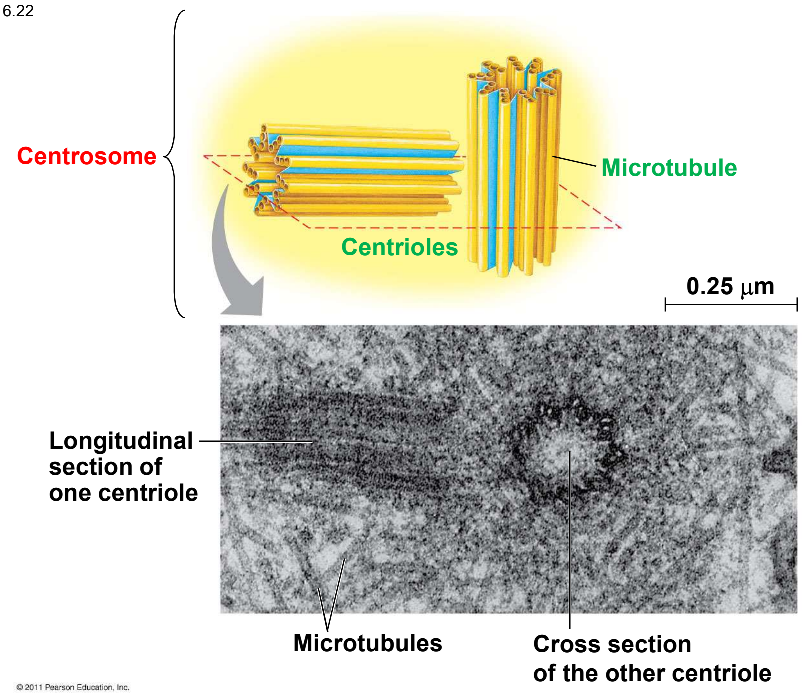


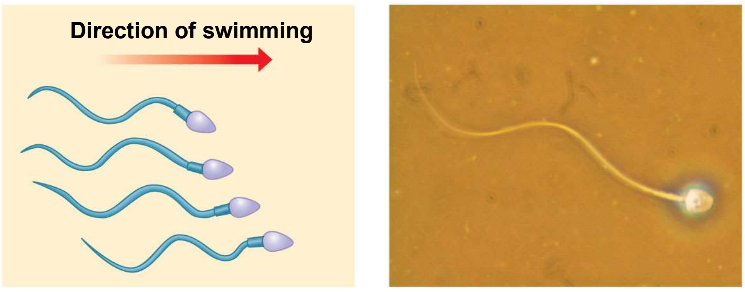
Figure 6.22



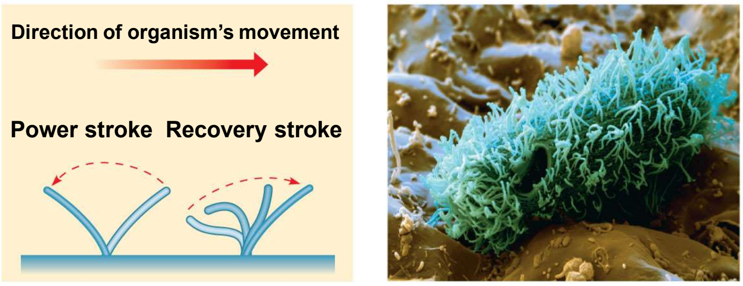
Cilia and Flagella

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

Figure 6.23

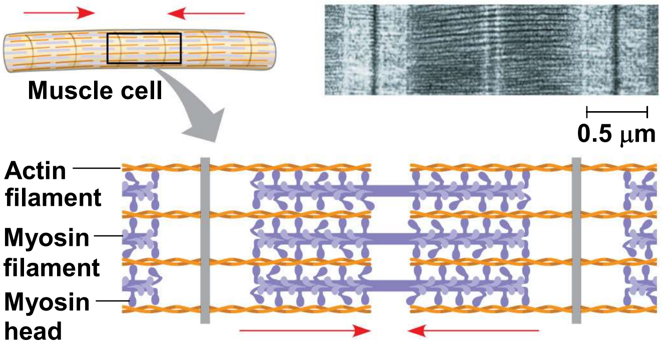


(a) Motion of flagella



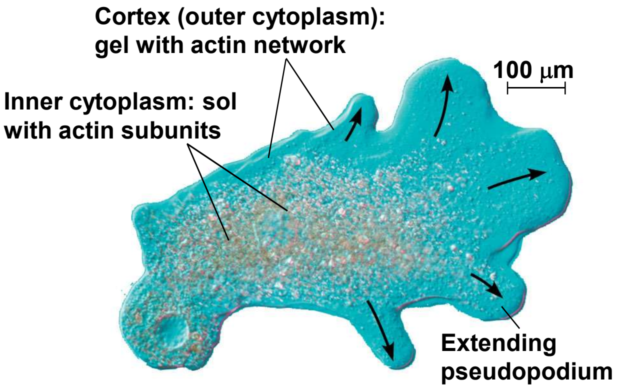
(b) Motion of cilia

Figure 6.27a



(a) Myosin motors in muscle cell contraction

Figure 6.27b



(b) Amoeboid movement

- 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

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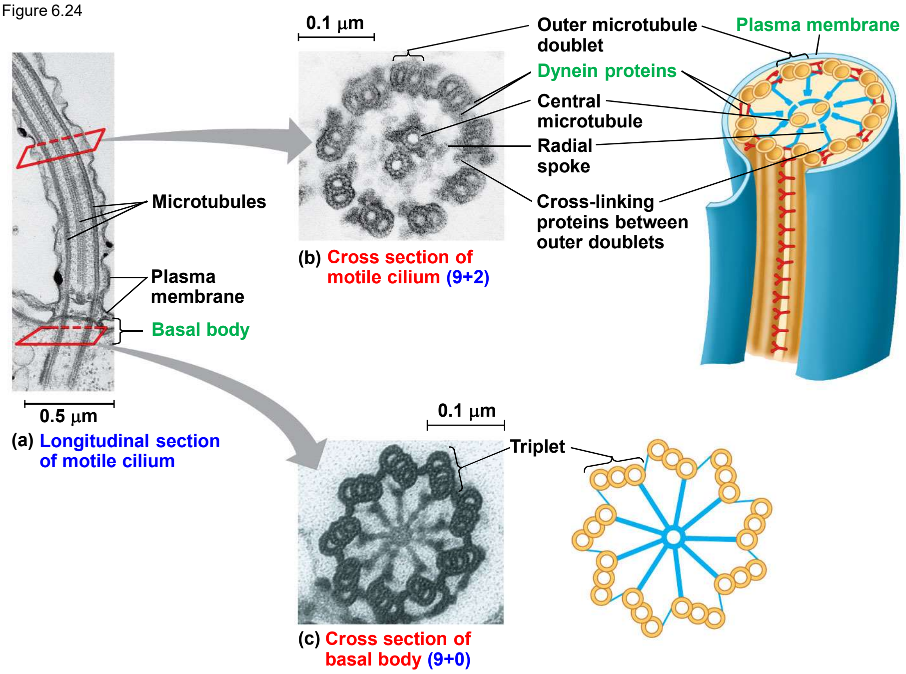
Figure 6.24



(a) Longitudinal section of motile cilium

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

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

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

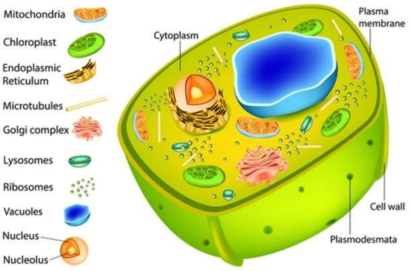
Cell Walls of Plants

- 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



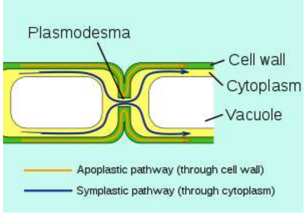
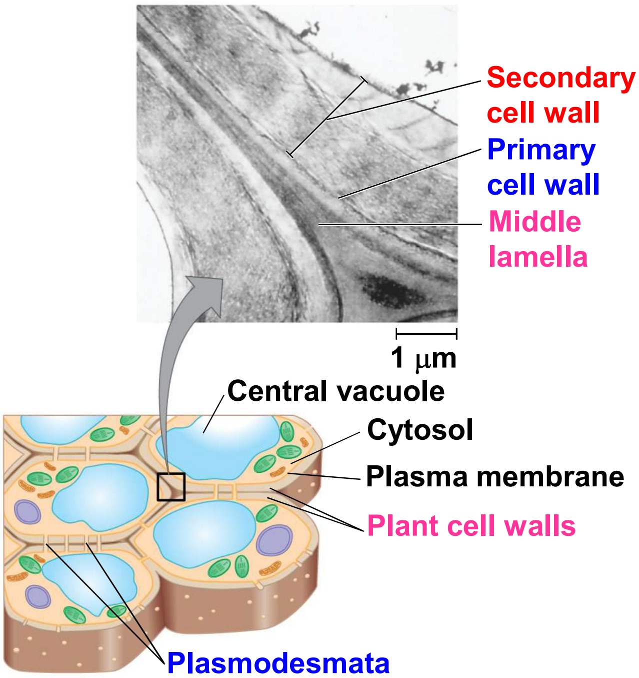


Figure 6.28



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

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The Extracellular Matrix (ECM) of Animal Cells

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

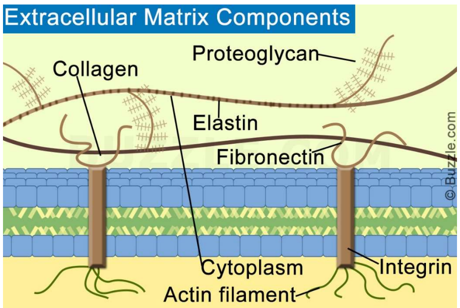
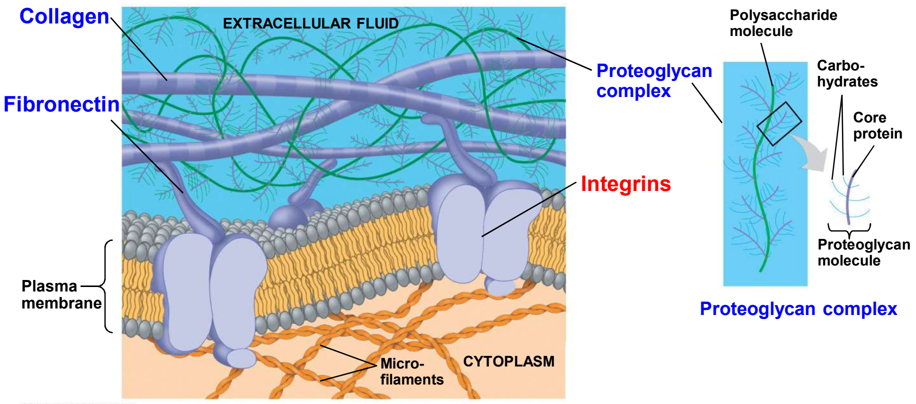


Figure 6.30



- **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**

Cell Junctions

- 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**

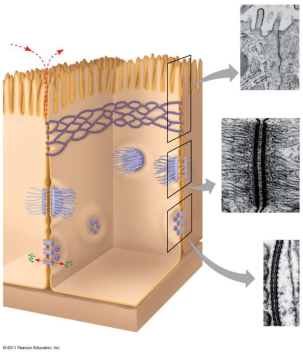
Tight Junctions, Desmosomes, and Gap Junctions in Animal Cells

- **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***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