Chapter 6

A Tour of the Cell

Overview: The Fundamental Units of Life

- All organisms are made of cells
- Cell structure is correlated to cellular function
- All cells are related by their descent from earlier cells
- Cytology = the study of cell

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

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

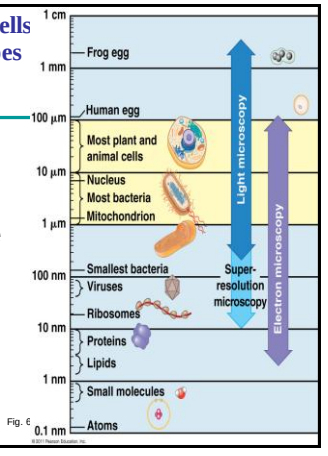
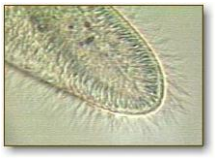


Fig. 6

Microscopy

- Light microscopes (LMs)
  - Pass visible light through a specimen
  - Magnify cellular structures with lenses
- Electron microscopes (EMs)
  - Use a beam of electrons

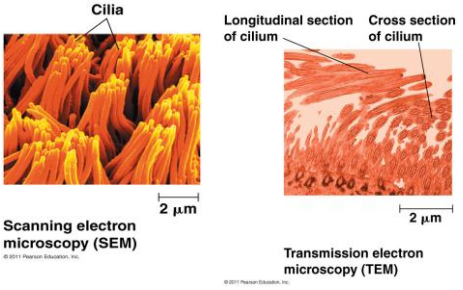
- In a **LM**, visible light passes through a specimen and then through glass lenses, which magnify the image up to 1000 x



http://www.microscope-microscope.org/applications/pond-critters/protozoans/images/Cillia.jpg

- Various techniques enhance contrast and enable cell components to be stained or labeled
- Most subcellular structures, including **organelles** are too small to be resolved by an LM

- Two basic types of **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



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

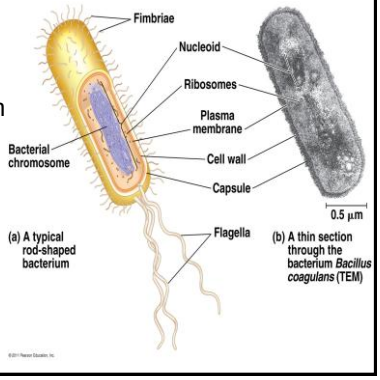
- Two types of cells:
  - Prokaryotic cells
    - Domains Bacteria and Archaea
  - Eukaryotic cells
    - Domain Eukarya: protists, fungi, animals, and plants

Comparing Prokaryotic and Eukaryotic Cells

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

Prokaryotic Cells

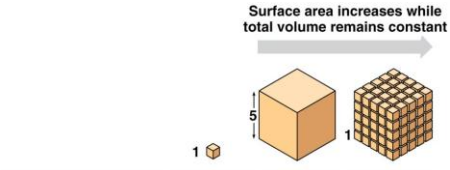
- No nucleus
- DNA in an unbound region called the **nucleoid**
- No membrane-bound organelles



- **Eukaryotic cells** are characterized by having
  - DNA in a nucleus that is bounded by a membranous nuclear envelope
  - Membrane-bound organelles in additional to non membrane-bound organelles
  - Much larger size than prokaryotic cells

Why are Cells So Small?

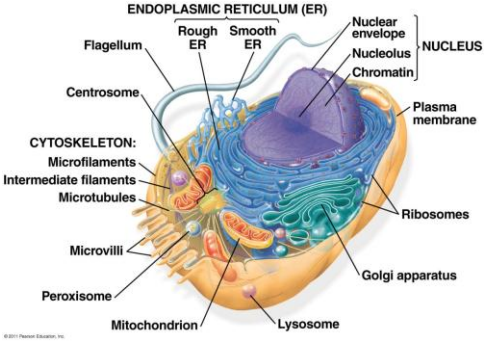
- The logistics of carrying out cellular metabolism sets limits on the size of cells
- The surface area to volume ratio of a cell is critical for the materials exchange between a cell and its environment
- A greater surface area= more access to nutrients
- A small cell
  - Has a higher surface to volume ratio, which facilitates the exchange of materials into and out of the cell

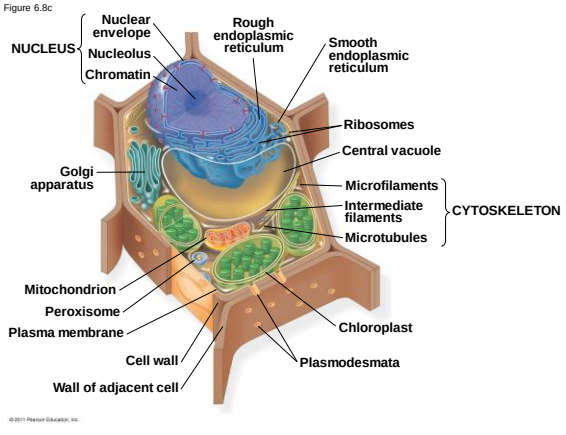


Total surface area [sum of the surface areas (height × width) of all box sides × number of boxes]	6	150	750
Total volume [height × width × length × number of boxes]	1	125	125
Surface-to-volume (S-to-V) ratio [surface area ÷ volume]	6	1.2	6

A Panoramic View of the Eukaryotic Cell

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





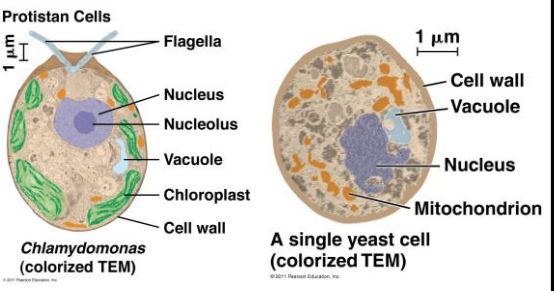
Differences between Plant and Animal Cells

•In animal cells but not plant cells:

- Lysosomes
- Centrioles
- Flagella (in some plant sperm)
- Gap Junctions

•In plant cells but not animal cells:

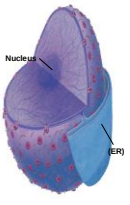
- Chloroplasts
- Central vacuole and tonoplast
- Cell wall
- Plasmodesmata



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**

Figure 6.UN01a

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

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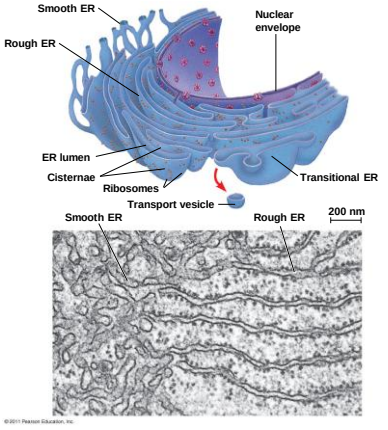
The Endoplasmic Reticulum: Biosynthetic Factory

- 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

Figure 6.11



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Functions of Rough ER

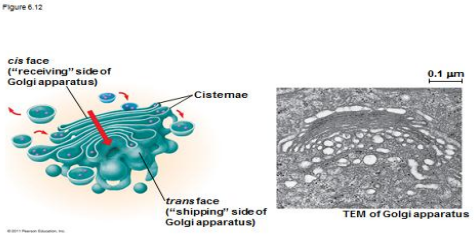
- The rough ER
  - Has bound ribosomes, which secrete **glycoproteins** (proteins covalently bonded to carbohydrates)
  - Distributes **transport vesicles,** proteins surrounded by membranes
  - Is a membrane factory for the cell

Functions of Smooth ER

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

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

Lysosomes: Digestive Compartments

- A **lysosome**
  - Is a membranous sac of hydrolytic enzymes that can digest macromolecules
  - Phagocytosis
    - Digest ingested food
  - Autophagy
    - Break down damaged organelles and own macromolecules

PLAY

Vacuoles: Diverse Maintenance Compartments

- A plant cell or fungal cell may have one or several vacuoles
- **Food vacuoles** are formed by phagocytosis
- **Contractile vacuoles**, found in many freshwater protists, pump excess water out of cells

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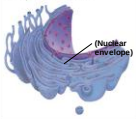
- **Central vacuoles**, found in many mature plant cells, hold organic compounds and water

Figure 6.UN01b

CONCEPT 6.4

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

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

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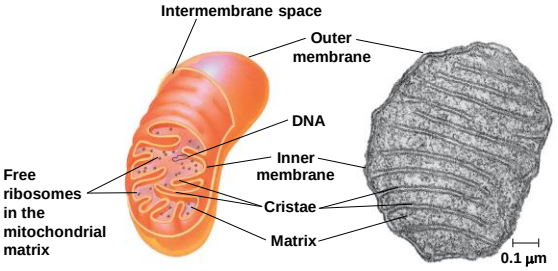
Concept 6.5: Mitochondria and chloroplasts change energy from one form to another

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

Figure 6.17a



(a) Diagram and TEM of mitochondrion

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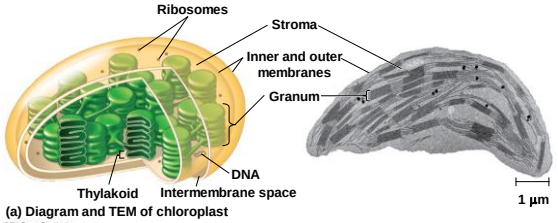
- Mitochondria and chloroplasts
  - Are not part of the endomembrane system
  - Have a double membrane
  - Have proteins made by free ribosomes
  - Contain their own DNA

Chloroplasts: Capture of Light Energy

- The chloroplast is a member of a family of organelles called **plastids**
- 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

Figure 6.18a



(a) Diagram and TEM of chloroplast

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Peroxisomes: Oxidation

- Peroxisomes are specialized metabolic compartments bounded by a single membrane
- Peroxisomes produce hydrogen peroxide and convert it to water
- Oxygen is used to break down different types of molecules

Figure 6.UN01c

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

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Concept 6.6: The cytoskeleton is a network of fibers that organizes structures and activities in the cell

- The **cytoskeleton** organizes the cell's structures and activities, anchoring many organelles
- It is composed of three types of molecular structures:
  - Microtubules
  - Microfilaments
  - Intermediate filaments

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

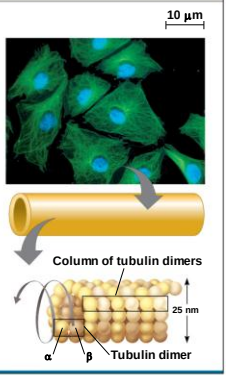

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Table 6.1b

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)

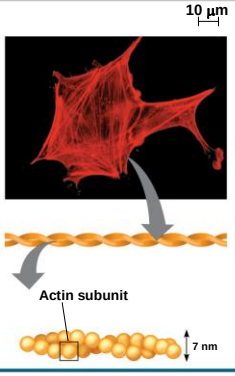

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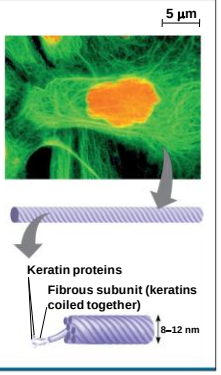
Table 6.1c

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



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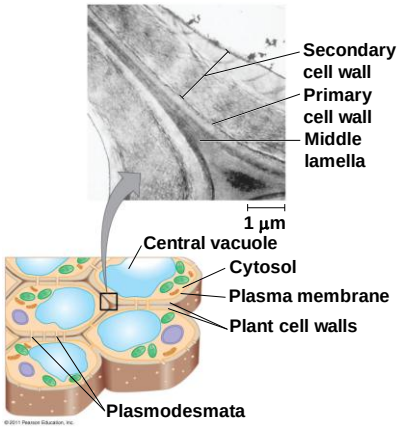
Concept 6.7: Extracellular components and connections between cells help coordinate cellular activities

- 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 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
- Prokaryotes, fungi, and some protists also have cell walls, however the cell walls are made of different molecules.

Figure 6.28



The Extracellular Matrix (ECM) of Animal Cells

- Animal cells lack cell walls but are covered by an elaborate **extracellular matrix (ECM)**

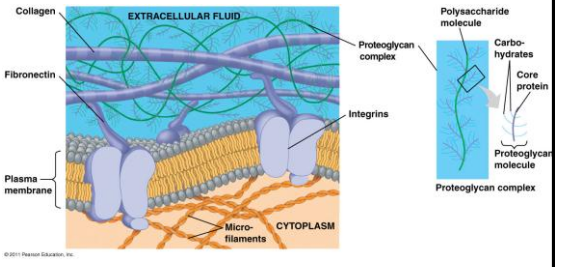


Figure 6.30

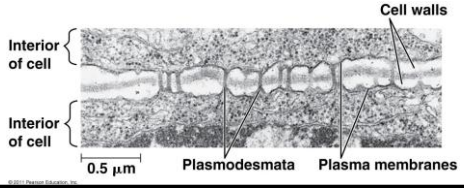
- Functions of the ECM:
  - Support
  - Adhesion
  - Movement
  - Regulation

Intercellular 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



Tight Junctions, Desmosomes, and Gap Junctions in Animal Cells

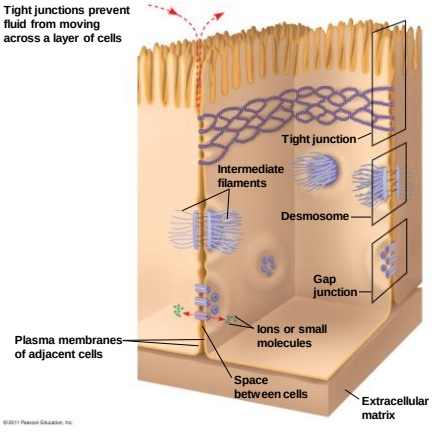
- At **tight junctions**, membranes of neighboring cells are pressed together, preventing leakage of extracellular fluid
- **Desmosomes** (anchoring junctions) fasten cells together into strong sheets
- **Gap junctions** (communicating junctions) provide cytoplasmic channels between adjacent cells

PLAY Animation: Tight Junctions

PLAY Animation: Desmosomes

PLAY Animation: Gap Junctions

Figure 6.32a Tight junctions prevent fluid from moving across a layer of cells



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

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