INTRODUCTION TO THE CELL
Cells, the simplest collection of matter that can live, were first observed by Robert Hooke in 1665.

Antoni van Leeuwenhoek later described cells that could move.

- He viewed bacteria with his own hand-crafted microscopes.
Introduction: *Cells on the Move*

- Although cell movement attracted the early scientists, we know today that not all cells move
  - However, the cellular parts are actively moving
  - Cells are dynamic, moving, living systems
The early microscopes provided data to establish the cell theory

- That is, all living things are composed of cells and that all cells come from other cells
Human cervical carcinoma cells dividing in culture

Green: microtubules, Blue: Chromosomes, Pink: centrioles
Elodea Leaf Cells
4.1 Microscopes reveal the world of the cell

- A variety of microscopes have been developed for a clearer view of cells and cellular structure.

- The most frequently used microscope is the light microscope (LM)—like the one used in biology laboratories.
  - Light passes through a specimen then through glass lenses into the viewer’s eye.
  - Specimens can be magnified up to 1,000 times the actual size of the specimen.
Enlarges image formed by objective lens

Magnifies specimen, forming primary image

Focuses light through specimen
4.1 Microscopes reveal the world of the cell

- Microscopes have limitations
  - Both the human eye and the microscope have limits of resolution—the ability to distinguish between small structures
  - Therefore, the light microscope cannot provide the details of a small cell’s structure
4.1 Microscopes reveal the world of the cell

- Biologists often use a very powerful microscope called the **electron microscope (EM)** to view the ultrastructure of cells
  - It can resolve biological structures as small as 2 nanometers and can magnify up to 100,000 times
  - Instead of light, the EM uses a beam of electrons
<table>
<thead>
<tr>
<th>TABLE 4.1 MEASUREMENT EQUIVALENTS</th>
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<tbody>
<tr>
<td>1 meter (m) = $10^0$ m = 39.37 inches</td>
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<tr>
<td>1 millimeter (mm) = $10^{-3}$ m (1/1,000 m) = 0.04 inch</td>
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<tr>
<td>1 micrometer (µm) = $10^{-3}$ mm = $10^{-6}$ m (1/1,000,000 m)</td>
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<tr>
<td>1 nanometer (nm) = $10^{-3}$ µm = $10^{-9}$ m (1/1,000,000,000 m)</td>
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1 meter = $10^3$ mm = $10^6$ µm = $10^9$ nm
Electron Microscopy

Scanning Electron Micrograph of *Paramecium* (900X) showing surface features

Transmission Electron Micrograph of *Paramecium* (775X). Thin section showing internal details
4.2 Most cells are microscopic

- Most cells cannot be seen without a microscope
  - Bacteria are the smallest of all cells and require magnifications up to 1,000X
  - Plant and animal cells are 10 times larger than most bacteria
Human height
Length of some nerve and muscle cells
Frog egg
Chicken egg

Unaided eye

Light microscope

Electron microscope

Most plant and animal cells
Nucleus
Most bacteria
Mitochondrion
Mycoplasmas (smallest bacteria)
Viruses
Ribosome
Proteins
Lipids
Small molecules
Atoms

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4.2 Most cells are microscopic

The surface area of a cell is important for carrying out the cell’s functions, such as acquiring adequate nutrients and oxygen.

- A small cell has more surface area relative to its cell volume and is more efficient.
Surface area of one large cube = 5,400 µm²

Total surface area of 27 small cubes = 16,200 µm²
4.3 Prokaryotic cells are structurally simpler than eukaryotic cells

- Bacteria are **prokaryotic** cells

- All other forms of life are **eukaryotic** cells
  
  - Both prokaryotic and eukaryotic cells have a plasma membrane and one or more chromosomes and ribosomes
  
  - Eukaryotic cells have a membrane-bound nucleus and a number of other organelles, whereas prokaryotes have a nucleoid and no true organelles
A typical rod-shaped bacterium

Bacterial chromosome

Nucleoid

Ribosomes

Plasma membrane

Cell wall

Capsule

Flagella

Pili

Hair-like appendage on surface of bacteria used for mating, motility and attachment

A thin section through the bacterium *Bacillus coagulans* (TEM)
Cranberry Extracts Prevent and Treat Urinary Tract Infections

Fimbria are a type of Pili used for attachment of bacteria to surfaces
4.4 Eukaryotic cells are partitioned into functional compartments

- There are four life processes in eukaryotic cells that depend upon structures and organelles
  - Manufacturing
  - Breakdown of molecules
  - Energy processing
  - Structural support, movement, and communication
4.4 Eukaryotic cells are partitioned into functional compartments

- Manufacturing involves the nucleus, ribosomes, endoplasmic reticulum, and Golgi apparatus
  - Manufacture of a protein, perhaps an enzyme, involves all of these
4.4 Eukaryotic cells are partitioned into functional compartments

- Breakdown of molecules involves lysosomes, vacuoles, and peroxisomes
  - Breakdown of an internalized bacterium by a phagocytic cell would involve all of these
4.4 Eukaryotic cells are partitioned into functional compartments

- Energy processing involves mitochondria in animal cells and chloroplasts in plant cells
  - Generation of energy-containing molecules, such as adenosine triphosphate, occurs in mitochondria and chloroplasts
4.4 Eukaryotic cells are partitioned into functional compartments

- Structural support, movement, and communication involve the cytoskeleton, plasma membrane, and cell wall
  - An example of the importance of these is the response and movement of phagocytic cells to an infected area
Membranes within a eukaryotic cell partition the cell into compartments, areas where cellular metabolism occurs.

- Each compartment is fluid-filled and maintains conditions that favor particular metabolic processes and activities.
4.4 Eukaryotic cells are partitioned into functional compartments

- Although there are many similarities between animal and plant cells, differences exist
  - Lysosomes and centrioles are not found in plant cells
  - Plant cells have a rigid cell wall, chloroplasts, and a central vacuole not found in animal cells
NUCLEUS:
- Nuclear envelope
- Chromosomes
- Nucleolus

CYTOSKELETON:
- Microtubule
- Intermediate filament
- Microfilament

Other structures:
- Rough endoplasmic reticulum
- Smooth endoplasmic reticulum
- Lysosome
- Centriole
- Peroxisome
- Ribosomes
- Golgi apparatus
- Plasma membrane
- Mitochondrion

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4.5 The structure of membranes correlates with their functions

- The plasma membrane controls the movement of molecules into and out of the cell, a trait called selective permeability
  - The structure of the membrane with its component molecules is responsible for this characteristic
  - Membranes are made of lipids, proteins, and some carbohydrate, but the most abundant lipids are phospholipids
Hydrophilic head

Phosphate group

Symbol

Hydrophobic tails
4.5 The structure of membranes correlates with their functions

- Phospholipids form a two-layer sheet called a phospholipid bilayer
  - Hydrophilic heads face outward, and hydrophobic tails point inward
  - Thus, hydrophilic heads are exposed to water, while hydrophobic tails are shielded from water

- Proteins are attached to the surface, and some are embedded into the phospholipid bilayer
Hydrophilic heads

Hydrophobic tails

Hydrophilic region of protein

Hydrophobic region of protein

Inside cell

Outside cell

Proteins
CELL STRUCTURES INVOLVED IN MANUFACTURING AND BREAKDOWN
4.6 The nucleus is the cell’s genetic control center

- The **nucleus** controls the cell’s activities and is responsible for inheritance
  - Inside is a complex of proteins and DNA called **chromatin**, which makes up the cell’s chromosomes
  - DNA is copied within the nucleus prior to cell division
4.6 The nucleus is the cell’s genetic control center

- The **nuclear envelope** is a double membrane with pores that allow material to flow in and out of the nucleus
  - It is attached to a network of cellular membranes called the endoplasmic reticulum
4.7 Ribosomes make proteins for use in the cell and export

- **Ribosomes** are involved in the cell’s protein synthesis
  - Ribosomes are synthesized in the nucleolus, which is found in the nucleus
  - Cells that must synthesize large amounts of protein have a large number of ribosomes
4.7 Ribosomes make proteins for use in the cell and export

- Some ribosomes are free ribosomes; others are bound
  - Free ribosomes are suspended in the cytoplasm
  - Bound ribosomes are attached to the endoplasmic reticulum (ER) associated with the nuclear envelope
4.8 Overview: Many cell organelles are connected through the endomembrane system

- The membranes within a eukaryotic cell are physically connected and compose the endomembrane system
  - The endomembrane system includes the nuclear envelope, endoplasmic reticulum (ER), Golgi apparatus, lysosomes, vacuoles, and the plasma membrane
4.8 Overview: Many cell organelles are connected through the endomembrane system

- Some components of the endomembrane system are able to communicate with others with formation and transfer of small membrane segments called **vesicles**
  - One important result of communication is the synthesis, storage, and export of molecules
4.9 The endoplasmic reticulum is a biosynthetic factory

- There are two kinds of endoplasmic reticulum—smooth and rough

- Smooth ER lacks attached ribosomes

- Rough ER lines the outer surface of membranes
  - They differ in structure and function
  - However, they are connected
Smooth ER
Nuclear envelope
Ribosomes
Rough ER
4.9 The endoplasmic reticulum is a biosynthetic factory

- Smooth ER is involved in a variety of diverse metabolic processes
  - For example, enzymes produced by the smooth ER are involved in the synthesis of lipids, oils, phospholipids, and steroids
4.9 The endoplasmic reticulum is a biosynthetic factory

- Rough ER makes additional membrane for itself and proteins destined for secretion
  - Once proteins are synthesized, they are transported in vesicles to other parts of the endomembrane system
Transport vesicle buds off

Ribosome

Glycoprotein

Polypeptide

Secretory protein inside transport vesicle

Sugar chain

Rough ER
4.10 The Golgi apparatus finishes, sorts, and ships cell products

- The Golgi apparatus functions in conjunction with the ER by modifying products of the ER
  - Products travel in transport vesicles from the ER to the Golgi apparatus
  - One side of the Golgi apparatus functions as a receiving dock for the product and the other as a shipping dock
    - Products are modified as they go from one side of the Golgi apparatus to the other and travel in vesicles to other sites
“Receiving” side of Golgi apparatus

Transport vesicle from ER

New vesicle forming

“Shipping” side of Golgi apparatus

Transport vesicle from the Golgi

Golgi apparatus

Golgi apparatus
4.11 Lysosomes are digestive compartments within a cell

- A lysosome is a membranous sac containing digestive enzymes
  - The enzymes and membrane are produced by the ER and transferred to the Golgi apparatus for processing
  - The membrane serves to safely isolate these potent enzymes from the rest of the cell
Lysosomes are digestive compartments within a cell

- One of the several functions of lysosomes is to remove or recycle damaged parts of a cell
  - The damaged organelle is first enclosed in a membrane vesicle
  - Then a lysosome fuses with the vesicle, dismantling its contents and breaking down the damaged organelle
Digestive enzymes

Lysosome

Plasma membrane
Digestive enzymes

Lysosome

Plasma membrane

Food vacuole

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Digestive enzymes

Lysosome

Plasma membrane

Food vacuole

Digestion
Lysosome

Vesicle containing damaged mitochondrion
Lysosome

Vesicle containing damaged mitochondrion
Lysosome

Vesicle containing damaged mitochondrion

Digestion
4.12 Vacuoles function in the general maintenance of the cell

- **Vacuoles** are membranous sacs that are found in a variety of cells and possess an assortment of functions

  - Examples are the central vacuole in plants with hydrolytic functions, pigment vacuoles in plants to provide color to flowers, and contractile vacuoles in some protists to expel water from the cell
Nucleus

Chloroplast

Central vacuole

Nucleus
Nucleus

Contractile vacuoles
4.13 A review of the structures involved in manufacturing and breakdown

- The following figure summarizes the relationships among the major organelles of the endomembrane system
4.14 Mitochondria harvest chemical energy from food

- Cellular respiration is accomplished in the **mitochondria** of eukaryotic cells
  - Cellular respiration involves conversion of chemical energy in foods to chemical energy in ATP (adenosine triphosphate)
  - Mitochondria have two internal compartments
    - The **intermembrane space**, which encloses the **mitochondrial matrix** where materials necessary for ATP generation are found
4.15 Chloroplasts convert solar energy to chemical energy

- **Chloroplasts** are the photosynthesizing organelles of plants
  - **Photosynthesis** is the conversion of light energy to chemical energy of sugar molecules

- Chloroplasts are partitioned into compartments
  - The important parts of chloroplasts are the stroma, thylakoids, and grana
4.16 EVOLUTION CONNECTION: Mitochondria and chloroplasts evolved by endosymbiosis

- When compared, you find that mitochondria and chloroplasts have (1) DNA and (2) ribosomes
  - The structure of both DNA and ribosomes is very similar to that found in prokaryotic cells, and mitochondria and chloroplasts replicate much like prokaryotes

- The hypothesis of **endosymbiosis** proposes that mitochondria and chloroplasts were formerly small prokaryotes that began living within larger cells
  - Symbiosis benefited both cell types
Engulfing of photosynthetic prokaryote

Some cells

Engulfing of aerobic prokaryote

Host cell

Mitochondrion

Chloroplast

Host cell

Mitochondrion