Cell Structure and Function

Chapter 4 Part 1
A strain of *E. coli* bacteria that causes severe illness or death occasionally contaminates foods such as ground beef and fresh vegetables.
The cell theory, a foundation of modern biology, states that cells are the fundamental units of life.
Measuring Cells

- One micrometer (μm) is one-thousandth of a millimeter
Van Leeuwenhoek was the first to describe small organisms seen through a microscope, which he called animalcules and beasties.

Hooke was the first to sketch and name cells.
Development of the Microscope
In 1839, Schleiden and Schwann proposed the basic concepts of the modern cell theory:

- All organisms consist of one or more cells.
- A cell is the smallest unit with the properties of life.
- Each new cell arises from division of another, preexisting cell.
- Each cell passes its hereditary material to its offspring.
4.2 What Is a Cell?

- **Cell**
  - The smallest unit that shows the properties of life

- All cells have a plasma membrane and cytoplasm, and all start out life with DNA
The Basics of Cell Structure

- **Eukaryotic cell**
  - Cell interior is divided into functional compartments, including a nucleus

- **Prokaryotic cell**
  - Small, simple cells without a nucleus
All Cells Have Three Things In Common

- **Plasma membrane**
  - Controls substances passing in and out of the cell

- DNA containing region
  - *Nucleus* in eukaryotic cells
  - *Nucleoid* region in prokaryotic cells

- **Cytoplasm**
  - A semifluid mixture containing cell components
Prokaryotic and Eukaryotic Cells

a. Bacterial cell (prokaryotic)
   - plasma membrane
   - DNA
   - cytoplasm

b. Plant cell (eukaryotic)
   - cytoplasm
   - DNA in nucleus
   - plasma membrane

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Fig. 4-4a, p. 56

a Bacterial cell (prokaryotic)

- plasma membrane
- DNA
- cytoplasm
b Plant cell (eukaryotic)

c Animal cell (eukaryotic)

cytoplasm

DNA in nucleus

plasma membrane

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b  Plant cell (eukaryotic)
c Animal cell (eukaryotic)
Cell Size

- **Surface-to-volume ratio** restricts cell size by limiting transport of nutrients and wastes

<table>
<thead>
<tr>
<th>Diameter (cm)</th>
<th>2</th>
<th>3</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface area (cm²)</td>
<td>12.6</td>
<td>28.2</td>
<td>113</td>
</tr>
<tr>
<td>Volume (cm³)</td>
<td>4.2</td>
<td>14.1</td>
<td>113</td>
</tr>
<tr>
<td>Surface-to-volume ratio</td>
<td>3:1</td>
<td>2:1</td>
<td>1:1</td>
</tr>
</tbody>
</table>
Animation: Surface-to-volume ratio

- Cell diameter: \( \mu \text{m} \)
- Cell surface area: \( \mu \text{m}^2 \)
- Cell volume: \( \mu \text{m}^3 \)

\[ \mu \text{m}^2 \text{ of surface area per } \mu \text{m}^3 \text{ of volume} \]
Lipid bilayer

- A double layer of phospholipids organized with their hydrophilic heads outwards and their hydrophobic tails inwards
- Many types of proteins embedded or attached to the bilayer carry out membrane functions
B A lipid bilayer has two layers of lipids, the tails of which are sandwiched between the heads. Proteins (not shown) typically intermingle among the lipids.

A A phospholipid, the main type of lipid in cell membranes.

C The hydrophilic heads of the phospholipids bathe in the watery fluid on both sides of the bilayer.
A phospholipid, the main type of lipid in cell membranes.
A lipid bilayer has two layers of lipids, the tails of which are sandwiched between the heads. Proteins (not shown) typically intermingle among the lipids.
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The hydrophilic heads of the phospholipids bathe in the watery fluid on both sides of the bilayer.
The hydrophilic heads of the phospholipids bathe in the watery fluid on both sides of the bilayer.
Animation: Lipid bilayer organization
4.1-4.2 Key Concepts:
What All Cells Have In Common

- Each cell has a plasma membrane, a boundary between its interior and the outside environment.
- The interior consist of cytoplasm and an innermost region of DNA.
We use different types of microscopes to study different aspects of organisms, from the smallest to the largest.
Modern Microscopes

- Light microscopes
  - Phase-contrast microscopes
  - Reflected light microscopes
  - Fluorescence microscopes

- Electron microscopes
  - Transmission electron microscopes
  - Scanning electron microscopes
Light and Electron Microscopes

A. A compound light microscope has more than one glass lens.

B. Transmission electron microscope (TEM). Electrons passing through a thin slice of a specimen illuminate a fluorescent screen. Internal details of the specimen cast visible shadows, as in Figure 4.8d.
A compound light microscope has more than one glass lens.
A compound light microscope has more than one glass lens.
**B** Transmission electron microscope (TEM). Electrons passing through a thin slice of a specimen illuminate a fluorescent screen. Internal details of the specimen cast visible shadows, as in Figure 4.8d.
B Transmission electron microscope (TEM). Electrons passing through a thin slice of a specimen illuminate a fluorescent screen. Internal details of the specimen cast visible shadows, as in Figure 4.8d.
Animation: How a light microscope works
Animation: How an electron microscope works
Different Microscopes, Different Characteristics

**a** Light micrograph. A phase-contrast microscope yields high-contrast images of transparent specimens, such as cells.

**b** Light micrograph. A reflected light microscope captures light reflected from opaque specimens.

**c** Fluorescence micrograph. The chlorophyll molecules in these cells emitted red light (they fluoresced) naturally.

**d** A transmission electron micrograph reveals fantastically detailed images of internal structures.

**e** A scanning electron micrograph shows surface details of cells and structures. Often, SEMs are artificially colored to highlight certain details.
a) Light micrograph. A phase-contrast microscope yields high-contrast images of transparent specimens, such as cells.

b) Light micrograph. A reflected light microscope captures light reflected from opaque specimens.

c) Fluorescence micro-graph. The chlorophyll molecules in these cells emitted red light (they fluoresced) naturally.

d) A transmission electron micrograph reveals fantastically detailed images of internal structures.

e) A scanning electron micrograph shows surface details of cells and structures. Often, SEMs are artificially colored to highlight certain details.
Human eye, no microscope

Light microscopes

Electron microscopes

- lipids
- viruses
- mitochondria, chloroplasts
- most animal cells and plant cells
- most bacteria
- frog egg

human eye, no microscope

0.1 nm  1 nm  10 nm  100 nm  1 µm  10 µm  100 µm  1 mm  1 cm  0.1 m  1 m  10 m  100 m
4.3 Key Concepts:
Microscopes

- Microscopic analysis supports three generalizations of the cell theory:
  - Each organism consists of one or more cells and their products
  - A cell has a capacity for independent life
  - Each new cell is descended from a living cell
4.4 Introducing Prokaryotic Cells

- Bacteria and archaea are the prokaryotes (“before the nucleus”), the smallest and most metabolically diverse forms of life.

- Bacteria and archaea are similar in appearance and size, but differ in structure and metabolism.
General Prokaryote Body Plan

- **Cell wall** surrounds the plasma membrane
  - Made of peptidoglycan (in bacteria) or proteins (in archaea) and coated with a sticky **capsule**

- **Flagellum** for motion

- **Pili** help cells move across surfaces
  - Sex pilus aids in sexual reproduction
General Prokaryote
Body Plan

- flagellum
- capsule
- cell wall
- plasma membrane
- cytoplasm, with ribosomes
- DNA in nucleoid
- pilus
flagellum

- capsule
- cell wall
- plasma membrane
- cytoplasm, with ribosomes
- DNA in nucleoid
- pilus

Fig. 4-10, p. 60
Animation: Typical prokaryotic cell
Archaeans

**a.** *Pyrococcus furiosus* was discovered in ocean sediments near an active volcano. It lives best at 100°C (212°F), and it makes a rare kind of enzyme that contains tungsten atoms.

**b.** *Ferrolobus placidus* prefers superheated water spewing from the ocean floor. The unique composition of archaean lipid bilayers keeps these membranes intact at extreme heat and pH.

**c.** *Metallosphaera prunae*, discovered in a smoking pile of ore at a uranium mine, prefers high temperatures and low pH. (*White shadows are an artifact of electron microscopy.*)
Bacteria
4.5 Microbial Mobs

- Although prokaryotes are all single-celled, few live alone

- **Biofilm**
  - Single-celled organisms sharing a secreted layer of polysaccharides and glycoproteins
  - May include bacteria, algae, fungi, protists, and archaeans
A Biofilm
4.4-4.5 Key Concepts: Prokaryotic Cells

- Archaeans and bacteria are prokaryotic cells, which have few, if any, internal membrane-enclosed compartments.

- In general, they are the smallest and structurally the simplest cells.
4.6 Introducing Eukaryotic Cells

- Eukaryotic ("true nucleus") cells carry out much of their metabolism inside membrane-enclosed organelles

- **Organelle**
  - A structure that carries out a specialized function within a cell
# Organelles of Eukaryotic Cells

<table>
<thead>
<tr>
<th>Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Organelles with membranes</strong></td>
<td></td>
</tr>
<tr>
<td>Nucleus</td>
<td>Protecting, controlling access to DNA</td>
</tr>
<tr>
<td>Endoplasmic reticulum (ER)</td>
<td>Routing, modifying new polypeptide chains; synthesizing lipids; other tasks</td>
</tr>
<tr>
<td>Golgi body</td>
<td>Modifying new polypeptide chains; sorting, shipping proteins and lipids</td>
</tr>
<tr>
<td>Vesicles</td>
<td>Transporting, storing, or digesting substances in a cell; other functions</td>
</tr>
<tr>
<td>Mitochondrion</td>
<td>Making ATP by sugar breakdown</td>
</tr>
<tr>
<td>Chloroplast</td>
<td>Making sugars in plants, some protists</td>
</tr>
<tr>
<td>Lysosome</td>
<td>Intracellular digestion</td>
</tr>
<tr>
<td>Peroxisome</td>
<td>Inactivating toxins</td>
</tr>
<tr>
<td>Vacuole</td>
<td>Storage</td>
</tr>
<tr>
<td><strong>Organelles without membranes</strong></td>
<td></td>
</tr>
<tr>
<td>Ribosomes</td>
<td>Assembling polypeptide chains</td>
</tr>
<tr>
<td>Centriole</td>
<td>Anchor for cytoskeleton</td>
</tr>
</tbody>
</table>
Eukaryotes: Animal and Plant Cells

Figure 4.14  Transmission electron micrographs of eukaryotic cells. (a) Human white blood cell. (b) Photosynthetic cell from a blade of timothy grass.
(a) Human white blood cell.
(b) Photosynthetic cell from a blade of timothy grass.
Animation: Cell membranes
Animation: Cytoskeletal components
Animation: Overview of cells
Animation: Structure of a mitochondrion I