Chapter 4
Cell Structure
4.2 What Is a Cell?

• Cells
  – First observed in the microscope of Antoni van Leeuwenhoek
  – First called ‘cells’ by Robert Cooke
  – Smallest unit of life

• Cell theory is a foundation of modern biology
# The Cell Theory

## Table 4.1 The Cell Theory

1. Every living organism consists of one or more cells.
2. The cell is the structural and functional unit of all organisms. A cell is the smallest unit of life, individually alive even as part of a multicelled organism.
3. All living cells arise by division of preexisting cells.
4. Cells contain hereditary material, which they pass to their offspring when they divide.
Components of All Cells

• All cells have three common features
  – Plasma membrane
    • Separates cell contents from the external environment
    • Controls exchanges between cell and environment
  – Cytoplasm
    • Jellylike mixture of water, sugars, ions, and proteins with all cellular components inside cell
  – DNA
    • The hereditary material of cells

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The General Organization of a Cell

- **A bacterial cell**
  - DNA
  - Cytoplasm
  - Plasma membrane

- **A plant cell**
  - Cytoplasm
  - DNA in nucleus
  - Plasma membrane

- **An animal cell**
  - Cytoplasm
  - DNA in nucleus
  - Plasma membrane
Constraints on Cell Size

- Surface-to-volume ratio restricts cell size by limiting transport of nutrients and wastes.
4.3 How Do We See Cells?

• Most cells are 10-20 micrometers in diameter, much too small to see with the unaided human eye

• One micrometer (μm) is one-thousandth of a millimeter, which is one-thousandth of a meter
Microscopes

• Used to visualize cells
  – Light microscopes use visible light to illuminate samples
  – Electron microscopes use electrons to image samples
    • Scanning electron microscopes image surface of sample by bouncing electrons off sample
    • Transmission electron microscopes image internal details by passing electrons through sample
Cell Sizes

- **Electron Microscopes**
  - Small molecules
    - Lipids
    - Carbohydrates
    - Proteins
    - DNA
  - Viruses
  - Mitochondria
  - Chloroplasts

- **Light Microscopes**
  - Most bacteria
  - Most eukaryotic cells

**Human Eye (No Microscope)**

- Frog eggs
- Small animals (human, ant, frog)
- Largest organisms (human, giraffe, fish, tree)
4.4 Introducing Prokaryotes

• Prokaryotic cells
  – No nucleus
  – Bacteria and archaea
  – Single-celled organisms
  – Smallest and most metabolically diverse life forms we know
  – Share basic structures
Generalized Prokaryote

1. cytoplasm, with ribosomes
2. DNA in nucleoid
3. plasma membrane
4. cell wall
5. capsule
6. pilus
7. flagellum
General Prokaryote Body Plan

- **Cell wall**
  - Surrounds the plasma membrane
  - Made of peptidoglycan (in bacteria) or proteins (in archaea)
  - Coated with a sticky capsule
- **Flagellum**
  - For motion
- **Pili**
  - Help cells move across surfaces
  - “Sex” pilus aids in sexual reproduction
General Prokaryote Body Plan (cont’d.)

- **Ribosomes**
  - Organelles upon which polypeptides are assembled

- **Nucleoid**
  - Irregularly shaped region of cytoplasm containing single large circular DNA molecule

- **Plasmids**
  - Small circles of DNA carrying only a few genes
Biofilms

• 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/or archaea
Dental Plaque: A Biofilm
4.5 Introducing Eukaryotic Cells

• Eukaryotic cells
  – DNA contained inside nucleus
  – Contain many other membrane-enclosed organelles

• Membranes allow organelles to:
  – Regulate substances entering and exiting
  – Specialized environment allows organelle to have particular function
### Some Organelles

<table>
<thead>
<tr>
<th>Organelles with membranes</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nucleus</td>
<td>Protects, controls access to DNA</td>
</tr>
<tr>
<td>Endoplasmic reticulum (ER)</td>
<td>Makes, modifies polypeptides and lipids; other tasks</td>
</tr>
<tr>
<td>Golgi body</td>
<td>Modifies and sorts polypeptides and lipids</td>
</tr>
<tr>
<td>Vesicle</td>
<td>Transports, stores, or breaks down substances</td>
</tr>
<tr>
<td>Mitochondrion</td>
<td>Makes ATP by glucose breakdown</td>
</tr>
<tr>
<td>Chloroplast</td>
<td>Makes sugars (in plants, some protists)</td>
</tr>
<tr>
<td>Lysosome</td>
<td>Intracellular digestion</td>
</tr>
<tr>
<td>Peroxisome</td>
<td>Breaks down fatty acids, amino acids, toxins</td>
</tr>
<tr>
<td>Vacuole</td>
<td>Storage, breaks down food or waste</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Organelles without membranes</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ribosomes</td>
<td>Assembles polypeptides</td>
</tr>
<tr>
<td>Centriole</td>
<td>Anchors cytoskeleton</td>
</tr>
</tbody>
</table>

### Other components

<table>
<thead>
<tr>
<th>Cytoskeleton</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Contributes to cell shape, internal organization, movement</td>
</tr>
</tbody>
</table>
Rough ER
- Modifies proteins made by ribosomes attached to it

Smooth ER
- Makes lipids, breaks down carbohydrates and fats, inactivates toxins

Golgi Body
- Finishes, sorts, ships lipids, enzymes, and proteins

Lysosome
- Digests, recycles materials
Typical Animal Cell

- Rough ER
- Smooth ER
- Golgi Body
- Lysosome
4.6 The Nucleus

- Eukaryotic nucleus contains the cell’s DNA, separating it from potential damage in the cytoplasm

<table>
<thead>
<tr>
<th>Table 4.4</th>
<th>Components of the Nucleus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromatin</td>
<td>DNA and associated proteins in a cell nucleus</td>
</tr>
<tr>
<td>Nucleoplasm</td>
<td>Semifluid interior portion of the nucleus</td>
</tr>
<tr>
<td>Nuclear envelope</td>
<td>Double membrane with nuclear pores that control which substances enter and exit the nucleus</td>
</tr>
<tr>
<td>Nucleolus</td>
<td>Dense region of proteins and nucleic acid where ribosomal subunits are being produced</td>
</tr>
</tbody>
</table>
Components of the Nucleus

- nuclear envelope
- nucleoplasm
- chromatin
- nucleolus
- nuclear pore

1 µm
4.7 The Endomembrane System

• Series of interacting organelles between nucleus and plasma membrane
• Makes, modifies, and transports proteins and lipids for secretion or insertion into cell membranes
• Destroys toxins, recycles wastes, and has other specialized functions
The Endomembrane System

- central vacuole
- rough ER
- smooth ER
- Golgi body
- vesicle
The Endoplasmic Reticulum

• Endoplasmic reticulum (ER)
  – An extension of the nuclear envelope that forms a continuous, folded compartment

• Two kinds of endoplasmic reticulum
  – Rough ER (with ribosomes) folds polypeptides into their tertiary form
  – Smooth ER (no ribosomes) makes lipids, breaks down carbohydrates and lipids, and detoxifies poisons
Vesicles

- Small, membrane-enclosed saclike organelles that store or transport substances

- Peroxisomes
  - Vesicles containing enzymes that break down hydrogen peroxide, alcohol, and other toxins

- Lysosomes
  - Vesicles containing enzymes that fuse with vacuoles and digest waste materials
Vacuoles

- Vesicles with various functions depending on cell type
  - Many isolate or dispose of waste, debris, and toxins

- Central vacuole
  - Occupies 50 to 90 percent of a cell’s interior
  - Stores amino acids, sugars, ions, wastes, toxins
  - Fluid pressure keeps plant cells firm
Golgi Bodies

• A folded membrane containing enzymes that finish polypeptides and lipids delivered by the ER
  – Packages finished products in vesicles that carry them to the plasma membrane or to lysosomes
Interactions in the Endomembrane System

1 Vesicles

Vesicles are membrane-enclosed sacs that often form by budding from other components of the endomembrane system. Many transport substances among organelles of the ER, and to and from the plasma membrane. Other vesicles store or break down substances.

2 Rough ER

Ribosomes attached to the rough ER use RNA in the cytoplasm to make polypeptides. The newly synthesized polypeptide chains enter rough ER, where they take on tertiary structure and assemble with other polypeptide chains.

3 Smooth ER

Proteins migrate through the interior of the rough ER, and end up in the smooth ER. Some stay in smooth ER, as enzymes that assemble lipids and break down carbohydrates, wastes, and toxins. Other proteins are packaged in vesicles for transport to Golgi bodies.

4 Golgi Body

Proteins and lipids arriving in vesicles are modified into final form, sorted, and repackaged into new vesicles. Some of these vesicles ferry proteins to the plasma membrane for secretion or insertion into the lipid bilayer. Others become lysosomes.
4.8 Mitochondria

- Eukaryotic organelle that makes the energy molecule ATP through aerobic respiration
- Contains two membranes, forming inner and outer compartments
  - Buildup of hydrogen ions in the outer compartment drives ATP synthesis
- Has its own DNA and ribosomes
- Resembles bacteria
  - May have evolved from aerobic bacteria
The Mitochondrion

- outer membrane
- inner membrane
- outer compartment
- inner compartment

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4.9 Chloroplasts and Other Plastids

• Plastids
  – Organelles that function in photosynthesis or storage in plants and algae
  – Includes chromoplasts, amyloplasts, and chloroplasts

• Chloroplasts
  – Plastids specialized for photosynthesis
  – Resemble photosynthetic bacteria
Chloroplasts

- two outer membrane
- stroma
- inner membrane

1 µm
4.10 The Cytoskeleton

- An interconnected system of many protein filaments – some permanent, some temporary
  - Parts of the cytoskeleton reinforce, organize, and move cell structures, or even a whole cell
Cytoskeletal Elements

- **Microtubules**
  - Long, hollow cylinders made of tubulin
  - Form dynamic scaffolding for cell processes

- **Microfilaments**
  - Consist mainly of the globular protein actin
  - Make up the cell cortex

- **Intermediate filaments**
  - Maintain cell and tissue structures
Cytoskeletal Elements – Illustrated

A. Microtubule
   - tubulin subunits
   - 25 nm

B. Microfilament
   - actin subunits
   - 6–7 nm

C. Intermediate filament
   - dimer
   - tetramer
   - sheet of tetramers
   - coiled sheet
   - 8–12 nm

D. A fluorescence micrograph shows microtubules (yellow) and microfilaments (blue) in the growing end of a nerve cell. These cytoskeletal elements support and guide the cell’s lengthening in a particular direction.
Motor Proteins

- Accessory proteins that move molecules through cells on tracks of microtubules and microfilaments
  - Energized by ATP
  - Example: kinesins
Cilia and Flagella

• Formed from microtubules organized into 9 + 2 arrays
  – Cilia are usually short, hairlike structures that move in waves
  – Flagella are long whiplike structures

• Microtubules grow from a barrel-shaped centriole, which remains in the cytoplasm below as a basal body
False Feet

• Pseudopods or “false feet”
  – Temporary, irregular lobes formed by amoebas and some other eukaryotic cells
  – Bulge outward to move the cell or engulf prey
  – Elongating microfilaments force the lobe to advance in a steady direction
  – Motor proteins attached to microfilaments drag the plasma membrane along with them
4.11 Cell Surface Specializations

• Many cells secrete materials that form a covering or matrix outside their plasma membrane

• Extracellular matrix (ECM)
  – A nonliving, complex mixture of fibrous proteins and polysaccharides secreted by and surrounding cells
  – Structure and function varies with the type of tissue
  – Examples: cell walls and cuticles
Eukaryotic Cell Walls

• Animal cells do not have walls, but plant cells and many protist and fungal cells do

• Primary cell wall
  – A thin, pliable wall formed by secretion of cellulose into the coating around young plant cells

• Secondary cell wall
  – A strong wall composed of lignin, formed in some plant stems and roots after maturity
Cuticle

- Cuticle
  - A type of ECM secreted by cells at a body surface
  - Plant cuticles consist of waxes and proteins, and help plants retain water and fend off insects
  - Cuticles of crabs, spiders, and other arthropods is mainly chitin, a polysaccharide
Cell Junctions

- Cell junctions allow cells to interact with each other and the environment.
- In plants, plasmodesmata extend through cell walls to connect the cytoplasm of two cells.
- Animals have three types of cell junctions: tight junctions, adhering junctions, gap junctions.
Animal Cell Junctions

• Tight junctions
  – Fasten together plasma membranes of adjacent cells

• Adhering junctions
  – Fasten cells to one another and to basement membrane

• Gap junctions
  – Closable channels that connect the cytoplasm of adjoining animal cells
Three Types of Cell Junctions in Animal Tissues

A Three types of cell junctions in animal tissues.

B Plasmodesmata are channels that connect the cytoplasm and ER of adjacent plant cells.
4.12 The Nature of Life

- We define life by describing the set of properties that is unique to living things.
- Life is a property that emerges from cellular components, but a collection of those components in the right amounts and proportions is not necessarily alive.
- Life continues only as long as a continuous flow of energy sustains its organization.
Properties of Living Things

- Living things:
  - Make and use the organic molecules of life
  - Consist of one or more cells
  - Engage in self-sustaining biological processes such as metabolism and homeostasis
  - Change over their lifetime, for example by growing, maturing, and aging
  - Use DNA as their hereditary material
  - Have the collective capacity to adapt to the environment over successive generations