Chapter 03
Lecture Outline

See separate PowerPoint slides for all figures and tables pre-inserted into PowerPoint without notes.
Cell Structure and Function
Points to ponder

• What is a cell?
• Why are most cells small?
• What do prokaryotic and eukaryotic cells have in common?
• How are cells organized?
• How do things move across the plasma membrane?
• What is the role of an enzyme in a metabolic reaction?
• What is cellular respiration?
What does the cell theory tell us?

- A cell is the basic unit of life.
- All living things are made up of cells.
- New cells arise from pre-existing cells.
Why are most cells small?

• Consider the cell surface-area-to-volume ratio.
  – Small cells have a larger amount of surface area compared to the volume.
  – An increase in surface area allows for more nutrients to pass into the cell and wastes to exit the cell more efficiently.
  – There is a limit to how large a cell can be, and be an efficient and metabolically active cell.
Thinking about surface area-to-volume in a cell

3.1 What is a Cell?

Figure 3.2  Surface area-to-volume ratio limits cell size.

<table>
<thead>
<tr>
<th></th>
<th>One 4-cm cube</th>
<th>Eight 2-cm cubes</th>
<th>Sixty-four 1-cm cubes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total surface area</td>
<td>96 cm³</td>
<td>192 cm³</td>
<td>384 cm³</td>
</tr>
<tr>
<td>(height × width × number of sides × number of cubes)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total volume</td>
<td>64 cm³</td>
<td>64 cm³</td>
<td>64 cm³</td>
</tr>
<tr>
<td>(height × width × length × number of cubes)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface area:</td>
<td>1.5:1</td>
<td>3:1</td>
<td>6:1</td>
</tr>
<tr>
<td>Volume per cube (surface area÷volume)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
What are some common microscopes used to view cells?

**Compound light microscope**
- Lower magnification
- Uses light beams to view images
- Can view live specimens
What are some common microscopes used to view cells?

Transmission electron microscope
- 2-D image
- Uses electrons to view internal structure
- High magnification, no live specimens
3.1 What is a Cell?

What are some common microscopes used to view cells?

**Scanning electron microscope**

– 3-D image
– Uses electrons to view surface structures
– High magnification, no live specimens
3.1 What is a Cell?

Blood cells viewed with different microscopes

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Figure 3.3 Micrographs of human red blood cells.

a. Light micrograph 250×
b. Transmission electron micrograph 10,000×
c. Scanning electron micrograph

a: © Ed Reschke/Getty Images; b: © Alfred Pasieka/Science Source; c: © Science Photo Library RF/Getty RF
What are the 2 major types of cells in all living organisms?

**Prokaryotic cells**
- Thought to be the first cells to evolve
- Lack a nucleus
- Represented by bacteria and archaea

**Eukaryotic cells**
- Have a nucleus that houses DNA
- Many membrane-bound organelles
What do prokaryotic and eukaryotic cells have in common?

- A **plasma membrane** that surrounds and delineates the cell
- A **cytoplasm**: the semi-fluid substance inside the cell that contains organelles
- DNA
3.2 How Cells are Organized

What do eukaryotic cells look like?

**Figure 3.4** The structure of a typical eukaryotic cell.

- **NUCLEUS:**
  - Nuclear envelope: double membrane with nuclear pores that encloses nucleus
  - Chromatin: diffuse threads containing DNA and protein
  - Nucleolus: region that produces subunits of ribosomes

- **CYTOPLASMIC RETICULUM:**
  - Rough ER: studded with ribosomes, processes proteins
  - Smooth ER: lacks ribosomes, synthesizes lipid molecules

- **RIBOSOMES:** particles that carry out protein synthesis

- **MITOCHONDRIUM:** organelle that carries out cellular respiration, producing ATP molecules

- **POLYSOMES:** string of ribosomes simultaneously synthesizing same protein

- **GOLGI APPARATUS:** processes, packages, and secretes modified cell products

- **PLASMA MEMBRANE:** outer surface that regulates entrance and exit of molecules

- **CYTOSKELETON:** maintains cell shape and assists movement of cell parts:
  - Microtubules: cylinders of protein molecules present in cytoplasm, centrioles, cilia, and flagella
  - Intermediate filaments: protein fibers that provide support and strength
  - Actin filaments: protein fibers that play a role in movement of cell and organelles

- **CENTROSOMES:** short, cylinders of microtubules

- **CENTROLINES:** microtubule organizing center that contains a pair of centrioles

- **VESICLES:** membrane-bounded sac that stores and transports substances

- **LYSOSOMES:** vesicle that digests macromolecules and even cell parts

- **CYTOPLASM:** semifluid matrix outside nucleus that contains organelles
Where did eukaryotic cells come from?

**Figure 3.5** The evolution of eukaryotic cells.

1. **Cell gains a nucleus by the plasma membrane invaginating and surrounding the DNA with a double membrane.**
   - Nucleus allows specific functions to be assigned, freeing up cellular resources for other work.

2. **Cell gains an endomembrane system by proliferation of membrane.**
   - Increased surface area allows higher rate of transport of materials within a cell.

3. **Cell gains mitochondria.**
   - Ability to metabolize sugars in the presence of oxygen enables greater function and success.

4. **Cell gains chloroplasts.**
   - Ability to produce sugars from sunlight enables greater function and success.
What are some characteristics of the plasma membrane?

- It is a phospholipid bilayer.
- It is embedded with proteins that move in space.
- It contains cholesterol for support.
- It contains carbohydrates on proteins and lipids.
- It is **selectively permeable**.
Figure 3.6 Organization of the plasma membrane.
What does selectively permeable mean?

- The membrane allows some things in while keeping other substances out.

Figure 3.7 Selective permeability of the plasma membrane.
How do things move across the plasma membrane?

1. Diffusion
2. Osmosis
3. Facilitated transport
4. Active transport
5. Endocytosis and exocytosis
What are diffusion and osmosis?

1. **Diffusion** is the random movement of molecules from a higher concentration to a lower concentration.

2. **Osmosis** is the diffusion of water molecules.
What are diffusion and osmosis?

**Figure 3.8** Diffusion across the plasma membrane.
How does tonicity change a cell?

- **Isotonic** solutions have equal amounts of solute inside and outside the cell and thus do not affect the cell.

**Figure 3.9a** Effects of changes in tonicity on red blood cells.
How does tonicity change a cell?

- **Hypotonic** solutions have less solute than the inside of the cell and lead to lysis (bursting).

**Figure 3.9b** Effects of changes in tonicity on red blood cells.

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How does tonicity change a cell?

- **Hypertonic** solutions have more solute than the inside of the cell and lead to crenation (shriveling).

**Figure 3.9c** Effects of changes in tonicity on red blood cells.
3. **Facilitated transport**
is the transport of molecules across the plasma membrane from higher concentration to lower concentration via a protein carrier.

*Figure 3.10* Facilitated transport across a cell membrane.
4. **Active transport** is the movement of molecules from a lower to higher concentration using ATP as energy; it requires a protein carrier.

*Figure 3.11* Active transport and the sodium–potassium pump.
What are endocytosis and exocytosis?

5. **Endocytosis** transports molecules or cells into the cell via invagination of the plasma membrane to form a vesicle.

6. **Exocytosis** transports molecules outside the cell via the fusion of a vesicle with the plasma membrane.

**Figure 3.12** Movement of large molecules across the membrane.
What structures are involved in protein production?

- Nucleus
- Ribosomes
- Endomembrane system
What is the structure and function of the nucleus?

- Bound by a porous **nuclear envelope**
- Houses **chromatin**: DNA with associated proteins
- **Nucleolus** contains ribosomal RNA (rRNA)
What is the structure and function of ribosomes?

• Organelles made of rRNA and protein

• Found bound to the endoplasmic reticulum and free floating in the cytoplasm

• Sites of protein synthesis
3.4 The Nucleus and Endomembrane System

Figure 3.13 The nucleus and endoplasmic reticulum.
What is the endomembrane system?

• It is a series of membranes in which molecules are transported in the cell.

• It consists of the nuclear envelope, endoplasmic reticulum, Golgi apparatus, lysosomes, and vesicles.
3.4 The Nucleus and Endomembrane System

How does the endomembrane system function?

- **Incoming vesicle**: Takes substances entering by vesicles.
- **Lysosome**: Contains digestive enzymes that break down cell parts or substances entering by vesicles.
- **Enzyme**: Digestive enzymes.
- **Transport vesicle**: Takes lipids to Golgi apparatus.
- **Golgi apparatus**: Modifies lipids and proteins from the ER; sorts and packages them in vesicles.
- **Secretory vesicle**: Takes proteins to the plasma membrane for secretion.
- **Smooth endoplasmic reticulum**: Synthesizes lipids and has various other functions.
- **Rough endoplasmic reticulum**: Synthesizes proteins and packages them in vesicles.
- **Ribosome**: Components for protein synthesis.
- **Nucleus**: Central control of the cell.

**Figure 3.14** The endomembrane system.
How can we summarize the parts of the endomembrane system?

**Rough endoplasmic reticulum** – studded with ribosomes used to make proteins

**Smooth endoplasmic reticulum** – lacks ribosomes but aids in making carbohydrates and lipids

**Golgi apparatus** – flattened stacks that process, package, and deliver proteins and lipids from the ER
How can we summarize the parts of the endomembrane system?

Lysosomes – membranous vesicles made by the Golgi that contain digestive enzymes

Vesicles – small membranous sacs used for transport
What is the cytoskeleton?

- A series of proteins that maintain cell shape, as well as anchors and/or moves organelles in the cell

- Made of 3 types of fibers: large microtubules, thin actin filaments, and medium-sized intermediate filaments
What are cilia and flagella?

- Both are made of microtubules.
- Both are used in movement.

- Cilia are about 20× shorter than flagella.

**Figure 3.15** Structure and function of the flagellum and cilia.
What are cell junctions?

- Junctions between the cells of human tissue that allow them to function in a coordinated manner.
- 3 main types:
  - Adhesion junctions mechanically attach adjacent cells (common in skin cells).

Figure 3.16a Junctions between cells.
What are cell junctions?

- **Tight junctions** are connections between the plasma membrane proteins of neighboring cells that produce a zipper-like barrier (common in digestive system and kidney where fluids must be contained to a specific area).

![Junctions between cells](Image)
What are cell junctions?

- Gap junctions are communication portals between cells; they channel proteins of the plasma membrane fuse, allowing easy movement between adjacent cells.
3.6 Metabolism and the Energy Reactions

Metabolic Pathways

- **Metabolism** includes all chemical reactions that occur in a cell.
  - Products
  - Reactants
Enzymes are important for cellular respiration and many activities in the cell.

- Most enzymes are proteins.
- Enzymes are often named for the molecules that they work on, called *substrates*.
- Enzymes are specific to what substrate they work on.
- Enzymes have *active sites* where a substrate binds.
- Enzymes are not used up in a reaction but instead are recycled.
- Enzymes lower the amount of *energy of activation* needed.
- Some enzymes are aided by nonprotein molecules called *coenzymes*.
How do enzymes work?

Degradation
A substrate is broken down to smaller products.

Synthesis
Substrates are combined to produce a larger product.

Figure 3.18 Action of an enzyme.

3.6 Metabolism and the Energy Reactions
3.6 Metabolism and the Energy Reactions

Energy of Activation
What do mitochondria do and what do they look like?

- Highly folded organelles in eukaryotic cells
- Produce energy in the form of ATP
- Thought to be derived from an engulfed prokaryotic cell

Figure 3.17 The structure of a mitochondrion.
What is cellular respiration?

• Production of ATP in a cell

• Includes
  1. Glycolysis
  2. Citric acid cycle (Krebs cycle)
  3. Electron transport chain
3.6 Metabolism and the Energy Reactions

Figure 3.19 Production of ATP.
Glycolysis

– Occurs in the cytoplasm
– Breaks glucose into 2 pyruvate
– NADH and 2 ATP molecules are made
– Does not require oxygen
Citric acid cycle (Krebs cycle)

- A cyclical pathway that occurs in the mitochondria
- Produces NADH and 2 ATP
- Releases carbon dioxide
Electron transport chain

Series of molecules embedded in the mitochondrial membrane

– NADH made in steps 1 and 2 carry electrons here
– 32-34 ATP are made depending on the cell
– Requires oxygen as the final electron acceptor in the chain
What other molecules besides glucose can be used in cellular respiration?

- Other carbohydrates
- Proteins
- Lipids
How can a cell make ATP without oxygen?

Fermentation

– Occurs in the cytoplasm
– Does not require oxygen
– Involves glycolysis
– Makes 2 ATP and lactate in human cells
– Can give humans a burst of energy for a short time