Chapter 4
Inside the Cell

Cytology
• Study of cells
• Cell – basic unit of life
  ▪ Are extremely diverse
  ▪ Most microscopic
  ▪ Each cell is specialized for a particular function
• Light microscope
  ▪ Invented in 17th century – Robert Hooke
  ▪ Limited view of cell due to properties of light
• Electron microscope
  ▪ Invented in 1930s
  ▪ Overcomes limitation of light by using beam of electrons; however cells will be dead

Tools Used By Biologist
• Microscopes vary in magnification and resolving power.
  – Magnification is the ratio of an object’s image to its real size. (eyepiece X objective)
  – Resolving power is the ability to distinguish 2 points that are close together as 2 separate points.
Electron Microscopes

1. Transmission electron microscopes (TEM) are used mainly to study the internal structure of cells.
2. Scanning electron microscopes (SEM) are used to study surface structures.
   - The SEM has an image that seems 3-D

Using microscopes to see cells

Why are cells so small?

- Nucleus can only control a small area
- Surface-area-to-volume ratio
  - Need surface areas large enough for entry & exit of materials
  - Small cells have more surface area for exchange.
- Adaptations to increase surface area
  - Microvilli in the small intestine increase surface area for absorption of nutrients
Cell theory

- Cells are the basic unit of life
- All organisms composed of cells
- Cells arise from pre-existing cell

Cell Info

- Largest cells are nerve cells from the giant squid & colossal squid (46 feet long)
- Most common example of large cells is ostrich egg
- ALL cells have:
  - A plasma membrane to regulate movement of material
  - Cytoplasm where chemical reactions occur
  - Genetic material for growth and reproduction

2 Types of Cells

- **Prokaryotes** – cells without a nucleus and membrane bound organelles, smallest & most abundant cells
  - Domain Archaea & Bacteria
  - *only EX.* bacteria
- **Eukaryotes** – cells with a nucleus and membrane bound organelles
  - *EX.* All life except bacteria
Cell Differences

• A major difference between prokaryotic & eukaryotic cells is the location of chromosomes.
• In an eukaryotic cell, chromosomes are contained in a membrane-enclosed structure, the **nucleus**.
• In a prokaryotic cell, the DNA is concentrated in the **nucleoid** w/out a membrane separating it from the rest of the cell.

Cell Differences

• In eukaryote cells, the chromosomes are contained within a membranous nuclear envelope.
• The region between the nucleus and the plasma membrane is the **cytoplasm**.
• Within the cytoplasm of a eukaryotic cell is a variety of membrane-bounded organelles with a specific function.
  – absent in prokaryotes.

A prokaryotic cell
**Bacterial Structures**

- Cytoplasm surrounded by plasma membrane & cell wall
  - Sometimes a capsule - protective layer
- Cell wall maintains the shape of a cell
- DNA - single circular chromosome located in nucleoid region - (not membrane enclosed)
- Ribosomes - site of protein synthesis
- Appendages
  - Flagella - movement
  - Fimbriae - attachment to surfaces
  - Conjugation pili - DNA transfer

**Eukaryote Cell Characteristics**

- Kingdoms: Protista, Fungi, Plantae, Animalia
- All eukaryotic cells have the following
  - Plasma membranes – outer membrane for protection and support
  - Nucleus – control center
  - Cytoplasm – (cytosol) fluid of the cell
  - Organelles – little organs that have a specific function

**Eukaryotic Animal Cell**
**The nucleus**

- **Chromatin** – consist of DNA & proteins and appears as thin strands in the nucleus.
- **Chromosomes** – thick, coiled strand that appear during cell division:
  - contains the genes in a eukaryotic cell.
  - Some genes are located in mitochondria & chloroplasts.
  - **Somatic cells** have 46 chromosomes
  - **Gametes** have 23 chromosomes
  - RBC are only **anucleated** cells
- **Nucleoplasm** – fluid material in the nucleus

**The Nucleus**

- **Nuclear membrane** or **nuclear envelope** – a double membrane that separates nucleus from the cytoplasm.
- **Nuclear pores** - allows large macromolecules & particles to pass through.
- **Nucleolus** – helps in the production of ribosomes;
  - Cells may have more than 1 (nucleoli);
  - makes **rRNA** (ribosomal RNA)
Eukaryote Cell Characteristics

- The plasma membrane functions as a selective barrier that allows passage of oxygen, nutrients, and wastes for the cell.
- Consist of a double layer of phospholipids and other diverse proteins.

Plasma Membrane

- Marks outer boundary
- Regulates passage in & out of a cell
- Phospholipid bilayer with embedded proteins
  - Polar heads (hydrophilic) phospholipids face into watery medium
  - Nonpolar tails (hydrophobic) face each other
- Fluid-mosaic model—the structure of the plasma membrane
Model of the plasma membrane

- Model of the plasma membrane showing the bilayer structure with hydrophilic and hydrophobic regions.

Functions of Membrane Proteins

- Channel Proteins
- Transport Proteins
- Cell Recognition Proteins
- Receptor Proteins
- Enzymatic Proteins
- Junction Proteins

Channel Proteins

- Form tunnel for specific molecules

a. Channel protein
b. Transport protein

- Passage of molecules through the membrane, sometimes requiring input of energy

- Cell recognition proteins
  - Enables our body to distinguish between our own cells and cells of other organisms

- Receptor proteins
  - Allow signal molecules to bind, causing a cellular response
Enzymatic proteins
- Directly participate in metabolic reactions

Junction proteins
- Form junctions between cells
- Cell-to-cell adhesion and communication

Introduction to Organelles
- Many of the organelles in a eukaryotic cell are part of the endomembrane system.
- These membranes are either in direct contact or connected via transfer of vesicles, (sacs).
- The endomembrane system includes the nuclear envelope, endoplasmic reticulum, Golgi apparatus, lysosomes, vacuoles, & the plasma membrane.
Organelles

- **Ribosome** is composed of two subunits that combine to carry out protein synthesis.
- Can be attached to the ER or free in the cytoplasm.

- **Endoplasmic reticulum (ER)** accounts for half the membranes in a eukaryotic cell.
- Includes membranous tubes for the transport of material
  - **Smooth ER** lacks ribosomes.
    - Synthesize lipids, (oils, phospholipids, & steroids)
    - Rich in enzymes; plays a role in a variety of metabolic processes
  - **Rough ER** ribosomes are attached to the outside. Transports materials

- **Golgi apparatus** - modifies, stores, sorts, and ships materials made by the cell.
- Consists of flattened, curved membranous sacs.
- Materials are released in membrane bound packages called **vesicles**.
- Many vesicles from the ER travel to the **Golgi apparatus** for modification of their contents.
Organelles

- **Lysosome** is a sac of hydrolytic enzymes that digests macromolecules.
- Massive leakage from lysosomes can destroy a cell by auto-digestion
- Some diseases affect lysosomal metabolism.
  - Individuals lack a functioning hydrolytic enzyme.
  - Pompe's disease in the liver (can't break down glycogen)
  - Tay-Sachs disease in the brain (can't break down lipids).

(a) Lysosomes in a white blood cell
Peroxisomes contain enzymes that break down toxins by transferring H from various substrates to O. Creates hydrogen peroxide (H\textsubscript{2}O\textsubscript{2}).
- The peroxisome has another enzyme that converts H\textsubscript{2}O\textsubscript{2} to water.
- Detoxify alcohol and other harmful compounds.

Vacuoles are membrane-bound sacs with varied functions such as storing water, food or waste. Larger than vesicles
- Food vacuoles - fuse with lysosomes to digest food.
- Contractile vacuoles - pump excess water out of the cell.
- Central vacuoles - largest structure in plant cell. Stores water & other metabolic byproducts
Inside the chloroplast is a fluid-filled space, the **stroma**, in which float sacs containing chlorophyll, the **thylakoids**.
- The stroma contains DNA, ribosomes, and enzymes for photosynthesis.
- The thylakoids are stacked into **grana** and are critical for converting light to chemical energy.

### Organelles

**Mitochondria** - site of cellular respiration, ATP produced from the catabolism of sugars, fats, and other fuels in the presence of **O**.
- Have small quantities of DNA
- Mitochondria have folded inner membrane, the **cristae**.
  - increases surface area for the enzymes that synthesize ATP.
Organelles

- **Plastids** – organelles found only in plants
  - **Chloroplasts** - site of photosynthesis. They convert solar energy to chemical energy and synthesize glucose from CO$_2$ and H$_2$O.
  - **Amyloplasts** or **Leucoplasts** - store starch in roots & tubers.
  - **Chromoplasts** - store accessory pigments for fruits & flowers.

Organelles

- **Chloroplast**
  - Stroma
  - Inner and outer membranes
  - Grana
  - Thylakoids

Organelles

- **Cytoskeleton** is a network of fibers extending throughout the cytoplasm.
- Provides support & maintains shape for cell.
- Plays a major role in cell motility.
- There are 3 types of fibers in the cytoskeleton: **microtubules**, **microfilaments**, & **intermediate filaments**.
Organelles - cytoskeleton

- **Microtubules**, thick, hollow tubes made of tubulin
- Give support & helps maintain cell shape
- Move chromosomes during cell division.
- In animal cells, the **centrosome** has a pair of **centrioles**, each with 9 triplets of microtubules arranged in a ring.
- Microtubules form **cilia** and **flagella**.
  - Cilia – short; large numbers on cell membrane
  - Flagella – long; few attached to cell membrane

Organelles

**Microtubules**

- Thick, hollow tubes made of tubulin
- Support and help maintain cell shape
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Organelles

**Centrioles**

- Centrosome
- Microtubules
- Cilia and flagella formation
**Organelles**

- **Microfilaments**, the thinnest, are made of **actin**.
- Microfilaments divide the cytoplasm of animals cells during cell division.
- They cause **cytoplasmic streaming** - circular flow of cytoplasm in the cell.
  - This speeds the distribution of materials within the cell.

**Organelles**

- **Intermediate filaments**, are made up of different keratins.
- They reinforce cell shape and fix organelle location.
  - Ex. Keep nucleus in the center of the cell

**Outside the Eukaryotic Cell**

- **The cell wall**, found in prokaryotes, fungi, & algae, has multiple functions.
- In plants, the cell wall protects the cell, maintains its shape, supports the plant against the force of gravity, & prevents excessive uptake of water.
- The chemical composition of cell walls differs from species to species.
  - Plants - **cellulose**
  - Fungi - **chitin**
  - Algae - **varies**
Plant Cell Wall

- **Cell wall** consists of cellulose embedded in a matrix of proteins & other polysaccharides.
- A mature cell wall consists of a **primary cell wall**, a **middle lamella** with sticky polysaccharides that holds 2 cells together, and layers of **secondary cell wall**.

Plant Cell Wall

Plant cell Walls

- Neighboring cells interact & communicate through direct physical contact.
- Plant cells are perforated with **plasmodesmata**, channels allowing cytosol & solutes to pass between cells.
Exterior Surfaces in Animal Cell

- Extracellular Matrix – network of proteins fibers & polysaccharides just outside the cell membrane
  - Collagen & elastin allow for flexibility of cell

Animal cell extracellular matrix

Exterior Surfaces in Animal Cell

- Animal have 3 types of intercellular links: 
  - tight junctions, desmosomes, & gap junctions.
- Adhesion junctions fasten cells together into strong sheets. (Rivets)
  - Prevent cells from being pulled apart
    - EX. Muscles & skin
- In tight junctions, membranes of adjacent cells are fused. (Zipper)
  - This prevents leakage of extracellular fluid.
    - EX. Intestinal cells
Gap junctions provide channels between adjacent cells. Allows cells to communicate.
- Special membrane proteins, called Connexons, surround these pores.
- Salt ions, sugar, amino acids, and other small molecules can pass.
- Ex. Embryonic cells, heart, smooth muscle

While the cell has many structures with specific functions, they must all work together.
- The enzymes of the lysosomes & proteins of the cytoskeleton are synthesized at the ribosomes.
- The information for these proteins comes from genetic messages sent by DNA in the nucleus to the ribosomes.
- All of these processes require energy in the form of ATP, most of which is supplied by the mitochondria.