

Lecture Outline: Cells and Organelles

I. Introduction to Cells and Microscopy

A. Cell Size and Scale

1. Typical eukaryotic cell is about 1,000 times as big as a typical prokaryotic cell in volume, being 10 times as big in all three dimensions (length, width, height)
2. Cells exist within a pretty small range overall, but the size scale is logarithmic, where each step is 10 times bigger than the step below
3. Cells lie in a range that is **invisible to the unaided human eye**, requiring a microscope

B. Types of Microscopes

1. **Light Microscopes**: Operate by light shining through the specimen to be magnified, used in labs
2. **Electron Microscopes**
 - a. Operate by sending a beam of electrons through the specimen or bombarding it with electrons, forming an image on a computer screen
 - b. **Big advantage**: Have much more resolving power, can see much tinier objects down to the molecular level, almost individual atoms

II. Prokaryotic Cells

A. Defining Characteristics

1. Named “before the nucleus” (prokaryotic) because they existed longer than nuclei have
2. Characterized by the **absence of a true nucleus**
3. Do **not have any membrane-bounded organelles**
4. Have only one membrane: the plasma membrane
5. Possess only one compartment inside, called the cytoplasm

B. Components

1. **Cytoplasm:** Collectively all the stuff inside the cell
2. **DNA:** Present, but is part of the cytoplasm, condensed in a region called the **nucleoid** (not a true nucleus as it lacks a membrane)
3. **Ribosomes:** Found in both prokaryotic and eukaryotic cells, do the same job (translation to make proteins); are organelles but **not membrane-bounded**

C. Cell Wall

1. Typical prokaryotic cells have a much **thicker and tougher cell wall exterior** to the plasma membrane
2. Made of different material compared to plant cell walls but serves the **same purpose: to hold in pressure and keep the cell from exploding**
3. Crucial for unicellular organisms, as losing the single cell means death

D. **Examples:** Bacteria and Archaea collectively make up the prokaryotes

III. Eukaryotic Cells (General & Animal Focus)

A. Cell Size Constraints: Surface Area to Volume Ratio

1. As a cell grows, its surface area to volume ratio gets smaller because volume outgrows area (volume grows more quickly than area does as dimensions increase)
2. This ratio puts a **limit on how big cells can get** because they need sufficient surface area (plasma membrane) to exchange materials (needed substances in, wastes out) to remain alive
3. When organisms get big (e.g., from zygote to adult human), they do so by **adding a bunch of smaller cells**, not by growing a single, enormous cell; each individual cell maintains a high surface area to volume ratio

B. Plasma Membrane

1. **Definition:** The boundary between the cell and everything else, making the cell a "tiny test tube" for life's chemistry in isolation
2. **Composition:** Mainly a **phospholipid bilayer**, but also contains **membrane-bound proteins**
3. **Transport Proteins:** Allow necessary substances to get into or out of

the cell if they cannot pass directly through the phospholipid bilayer

4. **Continuous Adjustment:** Plasma membrane is always changing, receiving new membrane from vesicles (exocytosis) and giving up membrane (endocytosis)

C. Nucleus

1. **Defining Feature of Eukaryotes:** Named “having a true nucleus” (eukaryotic)
2. **Structure:**
 - a. An example of a **multiply membrane-bounded organelle**, surrounded by a **nuclear envelope** consisting of two bilayers (two membranes)
 - b. Studded with **nuclear pores** (protein complexes forming tunnels)
3. **Contents:**
 - a. **DNA:** Located in the nucleus
 - b. **Nucleoplasm:** The stuff inside the nucleus
 - c. **Nucleolus:** A region within the nucleoplasm where genes coding for RNAs other than messenger RNA are located and produced
4. **Functions:**
 - a. **Transcription:** Occurs in the nucleus where DNA is located, making mRNA molecules
 - b. **mRNA Exit:** Messenger RNA exits the nucleus through nuclear pores to reach ribosomes in the cytoplasm for translation

D. Endoplasmic Reticulum (ER)

1. A membrane-bounded organelle that is **continuous with the outer membrane of the nuclear envelope**
2. Consists of two major components: Rough ER and Smooth ER
3. **Rough Endoplasmic Reticulum (Rough ER)**
 - a. **Appearance:** Looks rough due to being studded with ribosomes on its surface
 - b. **Function:** Takes in newly formed polypeptides (proteins) right off the assembly line, modifies them, and packages them into vesicles

4. **Smooth Endoplasmic Reticulum (Smooth ER)**

- a. **Appearance:** Looks smooth because it lacks associated ribosomes
- b. **Functions:** Major job is to **make lipids**; can also be a storage place for substances like calcium ions (especially in muscles)

E. **Golgi Apparatus (Golgi Complex or Golgi)**

- 1. Located next door to the Rough ER
- 2. **Structure:** Made up of membranes folded back and forth into sack-like flatness, similar in appearance to Rough ER but with a different job
- 3. **Function:** Acts like a **receiving and shipping center** for proteins
- 4. **Polarity:** Has two different ends, or faces
 - a. **Cis face:** The receiving end, facing the Rough ER, where vesicles carrying modified proteins fuse with the Golgi membrane and spill their contents
 - b. **Trans face:** The shipping end, where the Golgi packages proteins into new vesicles (made from its own membrane) and sends them to their appropriate destinations (other organelles, plasma membrane, or out of the cell)

F. **Lysosomes**

- 1. **Structure:** Small, membrane-bounded organelle, a specialized vesicle
- 2. **Contents:** Contain **hydrolytic enzymes** that break apart larger molecules into smaller ones
- 3. **Function:** Hydrolysis occurs safely inside lysosomes, preventing dangerous enzymes from damaging other cell components

G. **Mitochondria (plural, Mitochondrion singular)**

- 1. **Structure:** A **multiply membrane-bounded organelle** with an **outer membrane** and a highly folded **inner membrane** (folds called **cristae**)
- 2. Contains two compartments: the **intermembrane space** (between the two membranes) and the **mitochondrial matrix** (fully inside the inner membrane)
- 3. **Function:** Site of **cellular respiration**, a complex set of biochemical reactions that drastically increases the efficiency of fuel consumption and produces ATP for cell use

H. Peroxisomes

1. **Structure:** Shaped similar to lysosomes (vesicle-like)
2. **Function:** Contain enzymes that deal with **reactive oxygen species** (e.g., peroxides), converting them into less reactive substances to prevent cell damage

I. Microvilli

1. **Structure:** Finger-like extensions of the plasma membrane, not true organelles
2. **Function:** Drastically **increase the surface area** of the cell without significantly increasing its volume
3. **Example:** Epithelial cells lining the small intestine have microvilli to increase absorption efficiency of nutrients

J. Cytoskeleton

1. **Definition:** A large collection of fibrous proteins interconnected throughout the cell, acting as the "skeleton of the cell"
2. **Components:** Three major categories
 - a. **Microfilaments:** Narrowest diameter, important for structural support (like ropes) and cell movement/distortion (e.g., muscle contraction, cytoplasmic streaming)
 - b. **Intermediate Filaments:** Intermediate in diameter, more like ropes, hold things in place, high tensile strength (resist stretching)
 - c. **Microtubules:** Widest diameter, hollow tube-like structures, serve as **roadways** for transporting vesicles and other materials within the cell via motor proteins
3. **Functions:** Provides supportive framework for organelles (holds things in place), involved in cell dynamics and movement

K. Centrosome

1. **Structure:** A yellow-haloed region in the cytoplasm, a **microtubule organizing center**
2. **Function:** Important for mitosis (a part of cell division)
3. Found in both animal and plant cells

4. Centrioles:

- a. T-shaped protein complexes found **within** the centrosome of **animal cells only**
- b. Their specific function in animal cells is currently unknown, as mitosis can occur successfully without them

L. Flagella (plural, Flagellum singular)

1. **Structure:** Long, whip-like structures
2. **Function:** Used for **locomotion**, pushing on the surrounding fluid to propel the cell through the medium (like a boat propeller)
3. **Example:** Sperm cells

M. Cilia (plural, Cilium singular)

1. **Structure:** Short, hair-like appendages; much shorter than flagella and typically cover a large surface of the cell
2. **Function:**
 - a. Can be involved in cell locomotion for free-living cells (beating in synchrony to make the cell tumble)
 - b. In multicellular organisms, they move the **surrounding medium past the cell** (e.g., in the trachea, cilia move mucus and trapped debris upwards)
3. **Molecular Mechanism:** Composed of microtubules and motor proteins (like dynein) that "walk" along other microtubules; anchored proteins cause the cilium to bend rather than just slide, allowing the beating motion

IV. Plant Cell Specifics

A. Cell Wall

1. Present in plant cells, exterior to the plasma membrane
2. Thicker and tougher than the plasma membrane, providing structural support and protection

B. Chloroplasts

1. Green organelles not found in animal cells
2. **Structure:** A **multiply membrane-bounded organelle** with an outer

membrane, an inner membrane, and an elaborated **thylakoid membrane** (forming coin-shaped **thylakoids**, stacked into **grana**)

3. Contains three fluid compartments: intermembrane space, **stroma** (fluid outside thylakoids but inside inner membrane), and **thylakoid space** (fluid inside thylakoids)
4. **Function**: Site of **photosynthesis**, allowing plants to perform **carbon fixation** (incorporating inorganic carbon, like CO₂, into organic compounds)

C. **Plasmodesmata (plural, Plasmodesma singular)**

1. **Structure**: Complexes of proteins forming **tunnels through the cell wall** between adjacent plant cells (the plasma membrane wraps through these tunnels)
2. **Function**: Act as **intercellular junctions** that allow for communication and transfer of materials between cells
3. Results in the cytoplasm of one plant cell being continuous with the cytoplasm of all other cells in the plant

D. **Central Vacuole**

1. **Structure**: A large, membrane-bounded organelle in the center of plant cells, mostly filled with water
2. **Function**:
 - a. Used as a "dump" to store and isolate various substances from the rest of the cytoplasm
 - b. Contributes significantly to the cell's volume, allowing plants to grow quickly by absorbing water via osmosis, making new cells "cheaper" to manufacture compared to animal cells
 - c. Influences cell size and turgor based on water content (can swell or shrink, but cell wall prevents explosion)

V. **Animal Intercellular Junctions**

A. **Desmosomes**

1. Complexes of proteins acting like "spot welds" that mechanically hold adjacent animal cells together, providing **structural and mechanical integrity**

B. Gap Junctions

1. Complexes of proteins that form **little tunnels or roads between adjacent animal cells**
2. **Function:** Allow for **communication and transfer of materials** (e.g., electrical signals/ions) directly from one cell to another
3. They are the **animal versions of plasmodesmata** found in plants
4. **Example:** In the heart, gap junctions allow electrical signals to flow, ensuring synchronized contraction of cells

C. Tight Junctions

1. More complex in structure, like a band of "double-sided tape" sealing cells together all the way around
2. **Function: Prevent substances from slipping through the spaces between cells** (blocking the "paracellular route")
3. Ensures that only substances the cell actively allows (via the "cellular route") can pass through a multicellular membrane
4. **Example:** The skin has tight junctions around its cells, making it an effective barrier