Cell Biology: Cells and Organelles

AI-Generated Study Guide

(Based on lectures delivered by Dr. Ty C.M. Hoffman)

Quiz

Instructions: Answer each question in 2-3 sentences.

1. Compare and contrast the size difference between a typical eukaryotic cell and a prokaryotic cell. What is the approximate volumetric difference, and why is this scale described as logarithmic?
2. Explain the primary difference between light microscopes and electron microscopes in terms of their operational principles and resolving power. What advantage does one offer over the other?
3. Describe the defining characteristic that differentiates prokaryotic and eukaryotic cells, as reflected in their names. Provide an example of a structure that exemplifies this difference.
4. What is the cytoplasm in a prokaryotic cell, and how does it differ from the cytoplasm in a eukaryotic cell? What accounts for this difference?
5. Why are ribosomes considered organelles even though they are not membrane-bounded? What is their essential function in both prokaryotic and eukaryotic cells?
6. Explain the importance of the cell wall in a typical prokaryotic cell. How does its composition differ from the cell wall in plants, and what shared purpose do they serve?
7. Define the surface area to volume ratio and explain why it is a critical constraint on cell size. How do multicellular organisms overcome this limitation?
8. Describe the structure and primary function of the nuclear envelope. Why are nuclear pores essential for the nucleus's operation?
9. Differentiate between the rough endoplasmic reticulum (ER) and the smooth ER in terms of their anatomical appearance and primary functions. Why is one "rough" and the other "smooth"?
10. Explain the "receiving and shipping center" analogy for the Golgi apparatus. Describe the role of vesicles in its function and the concept of its "polarization."

Answer Key

1. A typical eukaryotic cell is approximately 1,000 times larger in volume than a typical prokaryotic cell, being 10 times bigger in all three dimensions (length, width, height). The size scale is logarithmic, meaning each step represents a tenfold increase in size, allowing for a vast range of cellular and atomic dimensions to be represented.
2. Light microscopes operate by shining light through a specimen, while electron microscopes use a beam of electrons or bombard the specimen with electrons, forming an image on a computer screen. Electron microscopes have significantly greater resolving power, allowing visualization of much tinier objects, almost down to the molecular or atomic level, which light microscopes cannot achieve.
3. The primary difference between prokaryotic and eukaryotic cells lies in the absence or presence of a true nucleus. Prokaryotic means "before the nucleus," indicating they existed before nuclei, while eukaryotic means "having a true nucleus." The nucleus, a membrane-bounded organelle, is a prime example of this distinguishing characteristic.
4. In a prokaryotic cell, the cytoplasm refers to all the cellular material enclosed by the single plasma membrane, as there are no internal membrane-bounded organelles. In a eukaryotic cell, the cytoplasm is everything inside the cell but *outside* of all the membrane-bounded organelles, as these organelles create distinct compartments.
5. Ribosomes are considered organelles because they are "little organ-like things" within a cell, performing a specific function. However, they are not membrane-bounded organelles, meaning they lack their own enclosing membrane. Their essential job in both cell types is translation, the process of assembling polypeptides (proteins) from messenger RNA instructions.
6. The cell wall in a typical prokaryotic cell provides structural support and protects the cell from exploding due to internal pressure, especially crucial for unicellular organisms. While prokaryotic cell walls are made of different materials than plant cell walls, they serve the same protective and supportive purpose.
7. The surface area to volume ratio is the mathematical relationship between a cell's outer surface area and its internal volume. As a cell grows, its volume increases faster than its surface area, leading to a decreased ratio. This is a limit because the cell's membrane (surface area) must be large enough to facilitate sufficient exchange of materials to support its internal volume, and if the ratio becomes too low, the cell cannot sustain itself. Multicellular organisms overcome this by being composed of many small cells rather than one giant cell, ensuring each individual cell maintains a high surface area to volume ratio.
8. The nuclear envelope is a double membrane (two bilayers) that surrounds the nucleus, forming its boundary. It is studded with nuclear pores, which are essential for selective permeability, allowing specific molecules, such as messenger RNA (mRNA), to exit the nucleus to reach ribosomes in the cytoplasm for translation, while keeping DNA safely contained.
9. The rough ER is studded with ribosomes, giving it a "rough" appearance, and its primary function is to modify newly synthesized proteins that are destined for secretion or incorporation into membranes. The smooth ER lacks ribosomes, giving it a "smooth" appearance, and its main jobs include lipid synthesis and the storage of substances like calcium ions.

10. The Golgi apparatus functions like a "receiving and shipping center" because it receives vesicles containing modified proteins from the rough ER at its "cis face" (receiving end). It then further processes, sorts, and repackages these proteins into new vesicles at its "trans face" (shipping end), sending them to their final destinations either within the cell, embedded in the plasma membrane, or secreted outside the cell. This directional flow defines its polarization.

Essay Format Questions

1. Discuss the evolutionary implications of the differences in cellular complexity between prokaryotic and eukaryotic cells, particularly regarding compartmentalization and its advantages.
2. Analyze the role of various membrane-bounded organelles (nucleus, ER, Golgi, lysosomes, mitochondria, chloroplasts) in the overall functioning of a eukaryotic cell. How do these organelles interact to maintain cellular homeostasis and perform specialized tasks?
3. Explain the concept of the surface area to volume ratio as a fundamental constraint on cell size. Provide specific examples of how cells and multicellular organisms have adapted to overcome this limitation, referencing structures like microvilli and the multicellular body plan.
4. Compare and contrast the structure and function of the cytoskeleton components (microfilaments, intermediate filaments, and microtubules). How do these components contribute to cell shape, internal transport, and cellular movement?
5. Describe the different types of intercellular junctions found in animal and plant cells (desmosomes, gap junctions, tight junctions, plasmodesmata). For each type, explain its structural characteristics, primary function, and the physiological importance of that function to the organism.

Glossary of Key Terms

- **181.06.1.mp4 & 181.06.2.mp4:** Source audio/video files for the lecture material on cell biology.
- **Actin Microfilaments:** Proteins that form the thinnest type of cytoskeletal filaments; involved in cell shape, muscle contraction, and cell movement.
- **ATP (Adenosine Triphosphate):** The primary energy currency of the cell, used to power various cellular processes, including motor protein movement.
- **Autophagy:** A cellular process meaning "self-eating," where a cell breaks down and recycles its own damaged or unnecessary components, often using lysosomes.
- **Bound Ribosomes:** Ribosomes that are attached to the membrane of the rough endoplasmic reticulum, typically synthesizing proteins destined for secretion or insertion into membranes.
- **Carbon Fixation:** The process by which inorganic carbon (e.g., carbon dioxide) is incorporated into organic compounds, primarily performed by photosynthetic organisms.

- **Cell Wall:** A rigid outer layer found in plant, fungal, and prokaryotic cells, providing structural support, protection, and maintaining cell shape; distinct in composition across different kingdoms.
- **Cellular Respiration:** A complex set of biochemical reactions occurring primarily in the mitochondria, which drastically increases the efficiency of energy extraction from fuel molecules to produce ATP.
- **Centrioles:** Two complexes of proteins found within the centrosome of animal cells (and some other eukaryotes), arranged in a T-shape; their exact function is not fully understood, but they are associated with cell division.
- **Centrosome:** A microtubule-organizing center (MTOC) in eukaryotic cells, important for cell division (mitosis) and the organization of the cytoskeleton.
- **Chloroplast:** A multiply membrane-bounded organelle found in plant and algal cells, responsible for photosynthesis and carbon fixation.
- **Christa (plural: Christi):** The folds of the inner mitochondrial membrane, which increase the surface area for cellular respiration reactions.
- **Cilia (singular: Cilium):** Short, hair-like appendages that project from the surface of some eukaryotic cells; involved in movement of the cell or movement of fluid/substances past the cell.
- **Cis Face:** The "receiving" side of the Golgi apparatus, where vesicles from the ER fuse and deliver their contents.
- **Cytoplasm:** In prokaryotes, all the cellular material enclosed by the plasma membrane. In eukaryotes, everything within the plasma membrane *excluding* the contents of the membrane-bounded organelles.
- **Cytoplasmic Streaming:** The directed flow of cytoplasm within a cell, often driven by microfilaments, used to move organelles or distribute materials.
- **Cytoskeleton:** A complex network of fibrous proteins (microfilaments, intermediate filaments, microtubules) within the cytoplasm of eukaryotic cells, providing structural support, maintaining cell shape, and facilitating cell movement and transport.
- **Desmosome:** A type of animal intercellular junction that acts like a "spot weld," mechanically attaching adjacent cells together for structural integrity.
- **DNA (Deoxyribonucleic Acid):** The genetic material of the cell, containing the instructions for building and maintaining an organism.
- **Electron Microscope:** A type of microscope that uses a beam of electrons to create an image, offering much higher resolution and magnification than light microscopes.
- **Endocytosis:** A form of vesicular transport where a cell takes in substances by engulfing them in a vesicle that pinches off from the plasma membrane (e.g., phagocytosis, pinocytosis).
- **Endoplasmic Reticulum (ER):** A network of membranes continuous with the outer nuclear envelope, consisting of rough ER and smooth ER, involved in protein modification, lipid synthesis, and detoxification.
- **Eukaryotic Cell:** A cell characterized by the presence of a true nucleus and other membrane-bounded organelles; typically much larger than prokaryotic cells.
- **Exocytosis:** A form of vesicular transport where a cell releases substances to the outside by fusing a vesicle with the plasma membrane, spilling its contents.

- **Extracellular Matrix (ECM):** A complex network of macromolecules (proteins, carbohydrates) secreted by cells into the space between them in multicellular organisms, providing structural support and facilitating cell communication.
- **Fagocytosis:** A specific type of endocytosis where the cell engulfs large solid particles or whole cells, literally meaning "cell eating."
- **Flagellum (plural: Flagella):** A long, whip-like appendage that extends from the surface of some cells, used for locomotion (propelling the cell through fluid).
- **Free Ribosomes:** Ribosomes that are suspended freely in the cytoplasm, typically synthesizing proteins that will remain in the cytoplasm.
- **Gametes:** Reproductive cells (sperm and egg) that fuse during fertilization to form a zygote.
- **Gap Junction:** A type of animal intercellular junction that forms a small tunnel between adjacent cells, allowing for direct communication and the passage of small molecules and ions.
- **Golgi Apparatus (Golgi Complex, Golgi):** A membrane-bounded organelle consisting of flattened sacs, responsible for modifying, sorting, and packaging proteins and lipids received from the ER for secretion or delivery to other organelles.
- **Granum (plural: Grana):** A stack of thylakoids within a chloroplast.
- **Hydrolysis:** A chemical reaction in which a molecule is broken down by the addition of water.
- **Intermediate Filaments:** Cytoskeletal fibers that are intermediate in diameter between microfilaments and microtubules; provide tensile strength and anchor organelles.
- **Intermembrane Space:** The fluid-filled compartment between the outer and inner membranes of both mitochondria and chloroplasts.
- **Light Microscope:** A type of microscope that uses visible light and a system of lenses to magnify specimens.
- **Lumen:** The hollow interior space of a tube-like or sac-like structure (e.g., the lumen of the ER or Golgi).
- **Lysosome:** A small, membrane-bounded organelle containing hydrolytic enzymes, responsible for breaking down waste materials and cellular debris, as well as foreign substances.
- **Membrane-Bound Proteins:** Proteins that are embedded within or associated with the plasma membrane or other cellular membranes, performing various functions like transport, signaling, and anchoring.
- **Membrane Bounded Organelle:** A subcellular structure enclosed by its own membrane, examples include the nucleus, ER, Golgi, lysosomes, mitochondria, and chloroplasts.
- **Messenger RNA (mRNA):** A type of RNA molecule that carries genetic information from DNA in the nucleus to ribosomes in the cytoplasm, where it serves as a template for protein synthesis.
- **Microfilaments:** The thinnest type of cytoskeletal filaments, composed of actin; involved in cell shape, muscle contraction, and cell movement.
- **Microtubule Organizing Center (MTOC):** A region in the cell where microtubules are nucleated and organized (e.g., the centrosome).

- **Microtubules:** The largest type of cytoskeletal filaments, hollow tubes made of tubulin protein; involved in maintaining cell shape, intracellular transport (as "roadways" for motor proteins), and cell division (forming the spindle fibers).
- **Microvilli (singular: Microvillus):** Finger-like extensions of the plasma membrane that increase the cell's surface area without significantly increasing its volume, often found in absorptive cells (e.g., in the small intestine).
- **Mitochondrial Matrix:** The fluid-filled compartment enclosed by the inner membrane of the mitochondrion, where many steps of cellular respiration occur.
- **Mitochondrion (plural: Mitochondria):** A multiply membrane-bounded organelle, often bean-shaped, responsible for cellular respiration and ATP production; sometimes called the "powerhouse of the cell."
- **Mitosis:** A type of cell division in eukaryotic cells that results in two daughter cells each having the same number and kind of chromosomes as the parent nucleus; involved in growth and tissue repair.
- **Motor Proteins:** Proteins that "walk" along microtubules or microfilaments, powered by ATP, to transport vesicles and other cellular components or cause cellular movement.
- **Mucus:** A thick, slippery secretion produced by certain cells, often serving protective or lubricating functions (e.g., in the respiratory or digestive tracts).
- **Multicellular Organism:** An organism composed of more than one cell, where cells are specialized and cooperate.
- **Multiply Membrane Bounded Organelle:** An organelle enclosed by two or more membranes (e.g., nucleus, mitochondrion, chloroplast).
- **Natural Selection:** The process by which organisms better adapted to their environment tend to survive and produce more offspring.
- **Nuclear Envelope:** The double membrane surrounding the nucleus in eukaryotic cells.
- **Nuclear Pores:** Protein complexes embedded in the nuclear envelope that regulate the passage of molecules between the nucleus and cytoplasm.
- **Nucleoid:** The region in a prokaryotic cell where the genetic material (DNA) is concentrated; it is not enclosed by a membrane.
- **Nucleolus:** A dense region within the nucleus of eukaryotic cells where ribosomal RNA (rRNA) is synthesized and assembled with proteins to form ribosomal subunits.
- **Nucleoplasm:** The jelly-like substance found within the nucleus, analogous to the cytoplasm.
- **Organelle:** A specialized subunit within a cell that has a specific function, usually enclosed by its own membrane (though some, like ribosomes, are not).
- **Peroxisome:** A small, membrane-bounded organelle containing enzymes that deal with reactive oxygen species (like peroxides), converting them into less harmful substances.
- **Phagocytosis:** See Fagocytosis.
- **Photosynthesis:** The process carried out by plants, algae, and some bacteria, where light energy is converted into chemical energy in the form of organic molecules, using carbon dioxide and water.
- **Pinocytosis:** A specific type of endocytosis where the cell takes in extracellular fluid and dissolved solutes, literally meaning "cell drinking."

- **Plasma Membrane:** The selective barrier that surrounds the cytoplasm of a cell, separating its internal environment from the external environment; composed primarily of a phospholipid bilayer and embedded proteins.
- **Plasmodesma (plural: Plasmodesmata):** A microscopic channel that passes through the cell walls of adjacent plant cells, allowing for direct communication and transport of molecules between cells; acts as a plant intercellular junction.
- **Polarized:** Refers to an organelle or cell that has distinct ends or regions with different structures and/or functions (e.g., the cis and trans faces of the Golgi).
- **Polypeptide:** A chain of amino acids linked by peptide bonds; a protein is typically composed of one or more polypeptides.
- **Prokaryotic Cell:** A cell that lacks a true nucleus and other membrane-bounded organelles; includes bacteria and archaea.
- **Protein:** Complex macromolecules essential for virtually all cellular processes, formed by amino acid chains; perform a vast array of functions.
- **Reactive Oxygen Species (ROS):** Highly reactive molecules containing oxygen, such as peroxides, which can cause damage to cellular components.
- **Resolving Power:** The ability of a microscope to distinguish between two closely spaced objects as separate entities.
- **Ribosome:** A molecular machine, composed of ribosomal RNA and protein, found in both prokaryotic and eukaryotic cells, responsible for protein synthesis (translation). Not membrane-bounded.
- **Rough Endoplasmic Reticulum (Rough ER):** A portion of the ER studded with ribosomes, involved in the synthesis, folding, modification, and transport of proteins that are destined for secretion, insertion into membranes, or delivery to other organelles.
- **Smooth Endoplasmic Reticulum (Smooth ER):** A portion of the ER without ribosomes, involved in lipid synthesis, detoxification of drugs and poisons, and storage of calcium ions.
- **Stroma:** The fluid-filled space within the inner membrane of a chloroplast, surrounding the thylakoids, where the light-independent reactions (Calvin cycle) of photosynthesis occur.
- **Surface Area to Volume Ratio:** The ratio of a cell's surface area to its volume, which is critical for the efficient exchange of materials between the cell and its environment. As a cell grows, this ratio decreases.
- **Thylakoid:** A flattened sac or disc-like membrane structure within the chloroplast, often stacked to form grana; contains chlorophyll and is the site of the light-dependent reactions of photosynthesis.
- **Thylakoid Membrane:** The membrane that forms the thylakoid sacs within the chloroplast.
- **Thylakoid Space:** The fluid-filled compartment inside the thylakoid sacs.
- **Tight Junction:** A type of animal intercellular junction that forms a continuous band around cells, sealing the spaces between them to prevent the leakage of extracellular fluid and regulate paracellular transport.
- **Transcription:** The process of synthesizing messenger RNA (mRNA) from a DNA template.

- **Translation:** The process of synthesizing a polypeptide (protein) from the information encoded in messenger RNA (mRNA) by ribosomes.
- **Trans Face:** The "shipping" side of the Golgi apparatus, where modified proteins and lipids are packaged into new vesicles for transport to their final destinations.
- **Vacuole:** A membrane-bounded sac within a cell that serves various functions. In plant cells, the **central vacuole** is a large, prominent organelle that stores water, nutrients, and waste products, and helps maintain turgor pressure.
- **Vesicle:** A small, membrane-bounded sac within the cytoplasm of eukaryotic cells, involved in storing or transporting substances.
- **Vesicular Transport:** The process by which substances are moved into or out of cells, or between organelles, using vesicles (e.g., endocytosis, exocytosis).
- **Zygote:** A single diploid cell formed by the fusion of two gametes (sperm and egg) during fertilization; the beginning of a new multicellular organism.