Anatomy and Physiology: Histology

AI-Generated Study Guide

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

I. Introduction to Cells

This unit provides foundational knowledge about cells and tissues, which are the basic building blocks of the human body. Understanding these concepts is crucial before delving into specific organ systems.

A. Cell Types: Prokaryotic vs. Eukaryotic

1. **Prokaryotic Cells:**
- Lack a "true nucleus."
- Do not possess any other membrane-bounded organelles.
- Have a plasma membrane, which defines the cell boundary.
- Are a single compartment.
- Examples: Bacteria, Archaea (not discussed in detail in this material).
1. **Eukaryotic Cells:**
- Possess a "true nucleus."
- Contain various membrane-bounded organelles, creating multiple internal compartments.
- Have a plasma membrane.
- All animal cells, including human cells, are eukaryotic.

B. Cellular Structures and Organelles (Eukaryotic Cells)

1. **Plasma Membrane:**
- The outermost boundary of an animal cell.
- Composed primarily of a **phospholipid bilayer**.
- **Phospholipids:** Similar to fats, but with two non-polar hydrocarbon tails and a polar phosphate head.
- **Self-assembly:** Phospholipids spontaneously form a bilayer in water, with polar heads facing the water and non-polar tails facing each other (hydrophobic interactions).
- **Membrane-bound proteins:** Embedded within the phospholipid bilayer.

- Not enclosed by their own membranes.
- Perform various functions, including facilitating transport of substances across the membrane.
- **Permeability:**Small, non-polar particles can diffuse directly through the phospholipid bilayer.
- Large, polar, or charged particles require membrane-bound proteins for transport.

1. **Nucleus:**

- A prominent, often double-membrane-bounded organelle.
- **Nuclear envelope:** The double membrane surrounding the nucleus.
- **Nuclear pores:** Holes in the nuclear envelope that allow substances to enter and exit the nucleus.
- **Function:** Contains the cell's DNA.

1. **Endoplasmic Reticulum (ER):**

- A network of membranes continuous with the outer membrane of the nuclear envelope.
- **Rough Endoplasmic Reticulum (RER):**Studded with **ribosomes** (small, non-membrane-bounded organelles).
- **Function:** Modifies newly synthesized proteins (e.g., adding or cutting off parts). Ribosomes synthesize proteins, which are then modified within the RER.
- **Smooth Endoplasmic Reticulum (SER):**Lacks ribosomes; appears "smooth."
- **Function:** Produces lipids; stores calcium ions (important for muscle contraction).

1. **Ribosomes:**

- Tiny molecular machines responsible for assembling proteins from amino acids.
- Not membrane-bounded, thus found in both prokaryotic and eukaryotic cells.
- Can be free in the cytoplasm or attached to the RER.

1. **Golgi Complex (Golgi Apparatus/Golgi):**

- Structurally similar to the ER (flattened sacs) but separate.
- **Function:** Receives modified proteins from the RER (packaged in vesicles), sorts them, and repackages them into new vesicles for transport to their final destinations (secretion out of the cell, insertion into the plasma membrane, or delivery to other organelles). Functions as a "receiving and shipping center."

1. **Mitochondria:**

- Often called the "powerhouse of the cell."
- Double-membrane-bounded organelles.
- **Function:** Site of **cellular respiration**, where food molecules are completely dismantled to extract energy and produce ATP. Carbon dioxide is a byproduct.

1. **Lysosomes:**

- Membrane-bounded vesicles.
- **Function:** Contain powerful digestive enzymes that break down molecules. These enzymes are sequestered to prevent damage to the cell itself.

1. **Peroxisomes:**

- Membrane-bounded vesicles.
- **Function:** Detoxify harmful peroxides that are natural byproducts of cellular activities, converting them into safer substances.

1. **Cytoskeleton:**

- A complex network of protein fibers providing structural support and maintaining cell shape.
- Not a hard, bony skeleton.
- Composed of three main types of fibrous proteins:
- **Microfilaments:** Narrowest diameter.
- **Intermediate filaments:** Intermediate diameter.
- **Microtubules:** Widest diameter.

1. **Cytoplasm:**

- All the material inside the cell, but outside of other organelles.
- **Cytosol:** The liquid portion of the cytoplasm where many chemical reactions of life occur.

C. Intercellular Junctions (Connections Between Cells)

1. **Desmosomes:**

- Complexes of proteins connecting the plasma membranes of adjacent cells.
- **Function:** Act like "spot welds," holding cells together to maintain tissue integrity. Primarily for mechanical rigidity.

1. **Tight Junctions:**

- Complexes of proteins that form a continuous seal all the way around cells, like "double-sided tape."
- **Function:** Form blockades that prevent particles from passing in the spaces between cells (paracellular route). Forces substances to pass *through* cells to cross a multicellular membrane.

1. **Gap Junctions:**

- Complexes of proteins that form tiny tunnels between adjacent cells.
- **Function:** Allow small particles (e.g., ions) to pass directly from one cell's cytoplasm to another. Essential for intercellular communication and synchronized activity (e.g., heart muscle contraction).

D. Cellular Processes

1. **Protein Synthesis and Modification:**

- **Ribosomes** synthesize proteins.
- **Rough ER** modifies proteins.
- **Golgi Complex** sorts and packages proteins into vesicles.

1. **Vesicular Transport:**

- General process of moving substances into or out of a cell using vesicles.
- **Exocytosis:** Movement of substances *out* of the cell via a vesicle.
- Vesicle fuses with the plasma membrane, releasing its contents.
- Example: Secretion by glands.
- **Endocytosis:** Movement of substances *into* the cell via a vesicle.
- **Pinocytosis:** "Cell drinking" – taking in sips of extracellular fluid.

- **Phagocytosis:** "Cell eating" – taking in solid chunks of material.
- **Receptor-mediated endocytosis:** Specific uptake of substances that bind to receptors on the cell surface, triggering vesicle formation.

1. **Passive Transport:**

- Requires no additional energy input from the cell. Driven by existing energy (e.g., concentration gradients).
- **Diffusion:** Movement of particles from an area of higher concentration to an area of lower concentration (down the gradient).
- **Simple diffusion:** Direct movement of small, non-polar particles through the phospholipid bilayer.
- **Facilitated diffusion:** Movement of large, polar, or charged particles across the membrane with the help of **transport proteins**. Still moves down the concentration gradient.
- **Osmosis:** A special case of diffusion involving the movement of **water (solvent)** across a selectively permeable membrane.
- Water moves from an area of higher water concentration (less solute) to an area of lower water concentration (more solute).
- **Tonicity:** Describes the relative solute concentration of a solution compared to a cell.
- **Isotonic solution:** Same solute concentration as the cell; no net water movement; cell volume remains stable.
- **Hypertonic solution:** Higher solute concentration than the cell (less watery); water leaves the cell, causing it to shrink (**crenation**).
- **Hypotonic solution:** Lower solute concentration than the cell (more watery); water enters the cell, causing it to swell and potentially burst (**lysis**).

1. **Active Transport:**

- Requires the cell to expend energy (often ATP).
- Moves substances *against* their concentration gradient (from lower to higher concentration).
- Performed by **pumps** (specific types of transport proteins).
- **Sodium-Potassium Exchange Pump:** A crucial pump that simultaneously moves sodium ions out of the cell and potassium ions into the cell, maintaining gradients essential for nervous and muscle cell function, and consuming a significant portion of the body's energy.

E. Cell Division and Gene Expression

1. **DNA Replication:**

- The exact copying of DNA.
- Occurs before cell division to ensure each new cell receives a complete set of DNA.
- Relies on the complementary nature of DNA strands (A pairs with T, C pairs with G). Each strand serves as a template to build a new complementary strand.

1. **Cell Division:**

- The process by which one cell splits into two daughter cells. The original cell does not survive as an individual entity.

- **Mitosis:** Division of the nucleus, ensuring accurate distribution of replicated DNA to daughter nuclei.
- **Cytokinesis:** Division of the rest of the cell (cytoplasm and organelles) into two separate cells.

1. **Gene Expression:**

- The process by which the information in a gene (DNA) is used to create a functional product, typically a protein.
- **Transcription:**Occurs in the nucleus.
- The DNA sequence of a gene is used as a template to synthesize an RNA molecule.
- RNA carries the genetic code out of the nucleus through nuclear pores.
- **Translation:**Occurs at **ribosomes** in the cytoplasm.
- The ribosome reads the RNA code and assembles amino acids in the correct order to build a specific protein.

F. Diverse Cell Functions in the Body

Cells specialize to perform various functions in the body:

- **Connecting body parts:** e.g., Fibroblasts, red blood cells (functionally connect).
- **Covering and lining body organs:** e.g., Epithelial cells (epidermis, internal linings).
- **Moving organs and body parts:** e.g., Muscle cells (contract to shorten).
- **Storing nutrients:** e.g., Adipocytes (fat cells) store fat efficiently for energy, padding, and insulation.
- **Fighting disease:** e.g., Leukocytes (white blood cells) are involved in immunity, producing antibodies.
- **Gathering information and controlling body functions:** e.g., Neurons (transmit electrochemical signals), Endocrine cells (secrete hormones).
- **Reproduction:** e.g., Gametes (sperm, egg) fuse to form a zygote, initiating a new life.

II. Tissues

Histology: The study of tissues.

- Tissues are collections of specialized cells that come together to perform a specific job.
- Humans have four major categories of tissues: Epithelial, Connective, Muscle, and Nervous.

A. Epithelial Tissue (Epithelia)

- **Function:** Line surfaces and organs, both externally (e.g., epidermis) and internally (e.g., digestive tract lining).
- **Polarity:** Epithelia have distinct surfaces due to their attachment.

- **Basal surface:** Attached to an underlying **basement membrane**.
- **Apical surface:** Free or unattached (e.g., surface of skin exposed to air, lumen of an organ).
- **Classification (Two Independent Criteria):**

1. **Number of Cell Layers:**

- **Simple epithelium:** A single layer of cells.
- Optimized for diffusion, absorption, or secretion (e.g., lung lining).
- **Stratified epithelium:** More than one layer of cells.
- Provides protection against abrasion (e.g., skin, throat lining).
- **Pseudostratified epithelium:** Appears stratified (falsely stratified) but is actually simple. All cells are in contact with the basement membrane, but they vary in height.

1. **Shape of Apical Layer Cells:** (Important: For stratified epithelia, only the shape of the *apical* layer cells determines the classification).

- **Squamous cells:** Flat, thin, scale-like (wider than tall). Ideal for diffusion.
- **Cuboidal cells:** Cube-shaped (roughly as tall as wide). Often involved in secretion and absorption, requiring more internal machinery.
- **Columnar cells:** Column-shaped (taller than wide). Often involved in absorption and secretion, requiring even more internal machinery.
- **Transitional epithelium:** Special type found in organs like the urinary bladder. Cells can change shape (from columnar/cuboidal to more squamous) and layers can slip past each other, allowing for significant stretching.

B. Connective Tissue

- **Function:** A "catch-all" category; includes tissues that connect, support, protect, insulate, and transport. Characterized by abundant **extracellular matrix**.
- **Components:**
- **Cellular component:** Various cell types specific to the connective tissue (e.g., osteocytes in bone, chondrocytes in cartilage, adipocytes in adipose tissue).
- **Extracellular matrix:** The non-living material outside the cells. Its composition varies greatly and determines the tissue's properties.
- **Types of Connective Tissue:**

1. **Bone:**

- **Cellular component:** Osteocytes (bone cells) living in spaces called **lacunae**.
- **Extracellular matrix:** Hard, mineralized material.
- **Structure:** Organized into structural units called **osteons** (concentric layers of matrix around a central canal).
- **Function:** Support, protection, mineral storage.

1. **Cartilage:** (Tough but not as hard as bone)

- **Cellular component:** Chondrocytes (cartilage cells) living in lacunae.
- **Hyaline Cartilage:** "Glassy" appearance. Found in places like the ends of bones in joints, connecting ribs to sternum.
- **Fibrocartilage:** Contains abundant protein fibers (e.g., collagen) in its matrix, making it very strong. Found in intervertebral discs.

1. **Dense Fibrous Connective Tissue:**
- **Extracellular matrix:** Densely packed protein fibers (primarily collagen).
- **Dense Regular:** Fibers oriented in parallel (e.g., **tendons**, which connect muscle to bone; strong in one direction of pull).
- **Dense Irregular:** Fibers oriented in various directions (provides strength in multiple directions).
1. **Areolar Tissue (Loose Connective Tissue):**
- **Extracellular matrix:** Fibers are loosely packed with a lot of space between them.
- **Function:** Acts as packing material, allowing for free movement (e.g., found in the hypodermis, beneath the skin). Not particularly tough.
1. **Adipose Tissue:**
- **Cellular component:** Adipocytes (fat cells), specialized for storing large lipid droplets (which appear "empty" in stained slides because fat is dissolved).
- **Function:** Energy storage, insulation, organ padding.
1. **Reticular Tissue:**
- **Extracellular matrix:** Weblike network of reticular fibers.
- **Function:** Forms a supportive framework (stroma) for organs like lymph nodes and the spleen (which filters out old red blood cells).
1. **Blood:**
- **Function:** Mobile tissue involved in transport (oxygen, carbon dioxide, nutrients, hormones, waste), immunity.
- **Cellular component:** Red blood cells (erythrocytes), white blood cells (leukocytes – five types involved in immunity).
- **Extracellular matrix: Plasma** (the liquid component of blood).

C. Muscle Tissue

- **Characteristics:** Excitable (can generate and transmit electrochemical signals) and contractile (can shorten).
- **Types:**
1. **Skeletal Muscle:**
- **Location:** Forms the muscles attached to bones (e.g., biceps).
- **Structure:** Long, cylindrical, unbranched cells (myofibers) that run the entire length of the muscle.
- **Striations:** Highly regular banding patterns visible under a microscope.
- **Control:** Voluntary (requires conscious thought and nervous system signals).
- **Function:** Movement of body parts.
1. **Cardiac Muscle:**
- **Location:** Walls of the heart.
- **Structure:** Branched cells.
- **Striations:** Present, but less regular due to branching.
- **Control:** Involuntary; **autorhythmic** (contracts on its own, without direct nervous system input).
- **Function:** Pumping blood.

1. **Smooth Muscle:**
- **Location:** Walls of hollow organs (e.g., intestines, blood vessels, urinary bladder).
- **Structure:** Spindle-shaped cells (thicker in the middle, tapering at ends).
- **Striations: Absent**.
- **Control:** Involuntary; often autorhythmic.
- **Function:** Propels substances through organs, regulates organ diameter (e.g., blood pressure).

D. Nervous Tissue

- **Location:** Brain, spinal cord, nerves.
- **Components:**
1. **Neurons:**
- **Characteristics:** Excitable cells that generate and transmit electrochemical signals (action potentials).
- **Structure:** Large cell body (contains nucleus), dendrites (inputs), and a long axon (output).
- **Function:** Communication and control of body functions (e.g., thought, movement, sensation).
1. **Neuroglia (Glial Cells):**
- **Characteristics:** Non-excitable cells.
- **Function:** Support, protect, and insulate neurons, enabling them to live and perform their functions. (Not involved in transmitting signals themselves).

III. Hierarchy of Biological Organization

- **Cells** are the basic unit of life.
- Collections of specialized cells form **Tissues**.
- Collections of different tissues form **Organs**.
- Collections of organs working together form **Organ Systems**.

Quiz: Cells and Tissues

Instructions: Answer each question in 2-3 sentences.

1. Differentiate between prokaryotic and eukaryotic cells based on their internal structure.
2. Explain the primary function of the plasma membrane and describe its key structural components.
3. What is the main role of the rough endoplasmic reticulum (RER) and how do ribosomes contribute to this function?
4. Describe the function of the Golgi complex and explain how it relates to the rough ER.

5. What is the "powerhouse of the cell" and what vital process occurs there? What is a significant byproduct of this process?
6. Compare and contrast desmosomes and tight junctions in terms of their primary functions.
7. Explain the concept of osmosis and how a red blood cell behaves in a hypotonic solution.
8. Distinguish between simple diffusion and facilitated diffusion. What fundamental characteristic do they share that classifies them as "passive" processes?
9. Name the four major tissue types found in humans and briefly state a general function for each.
10. Describe the key characteristics of skeletal muscle tissue that differentiate it from cardiac and smooth muscle, particularly regarding striations and control.

Quiz Answer Key

1. Prokaryotic cells lack a true nucleus and other membrane-bounded organelles, making them a single compartment. Eukaryotic cells, in contrast, possess a true nucleus and multiple membrane-bounded organelles, creating internal subcompartments.
2. The plasma membrane defines the cell boundary and controls substance movement. It is primarily composed of a phospholipid bilayer, with embedded membrane-bound proteins that facilitate specific transport and other functions.
3. The rough endoplasmic reticulum (RER) modifies newly synthesized proteins. Ribosomes, attached to the RER membrane, are responsible for assembling these proteins, which are then processed and folded within the RER's interior.
4. The Golgi complex acts as a cellular receiving and shipping center. It receives modified proteins from the rough ER via vesicles, sorts them, and then repackages them into new vesicles to be sent to their correct destinations within or outside the cell.
5. Mitochondria are known as the "powerhouse of the cell," where cellular respiration occurs to extract energy from food molecules and produce ATP. A significant byproduct of this complete dismantling process is carbon dioxide.
6. Desmosomes primarily function as "spot welds" to mechanically hold adjacent cells together, maintaining tissue integrity. Tight junctions, conversely, form blockades between cells to prevent substances from passing through the intercellular spaces, forcing them to enter cells directly.
7. Osmosis is the passive diffusion of water across a selectively permeable membrane. In a hypotonic solution, which is more watery than the cell's interior, water will move into the red blood cell, causing it to swell and potentially undergo lysis (bursting).
8. Simple diffusion involves small, non-polar particles moving directly through the phospholipid bilayer, while facilitated diffusion requires transport proteins for movement across the membrane. Both are passive processes because they move substances down their concentration gradient without the cell expending additional energy.

9. The four major tissue types are: Epithelial (lining and covering surfaces), Connective (support, protection, binding, transport), Muscle (movement through contraction), and Nervous (communication and control via electrochemical signals).
10. Skeletal muscle tissue consists of long, cylindrical, unbranched myofibers that display highly regular striations. Unlike cardiac and smooth muscle, skeletal muscle contraction is voluntary, meaning it requires conscious thought and signals from the nervous system.

Essay Format Questions

1. Discuss the evolutionary significance of the phospholipid bilayer in the formation of early cells. Explain how the addition of membrane-bound proteins enhanced the functionality and survival of these early cellular structures.
2. Compare and contrast the structure and function of the rough endoplasmic reticulum, smooth endoplasmic reticulum, and Golgi complex, highlighting their interconnected roles in the synthesis, modification, and transport of cellular products.
3. Explain the different mechanisms of transport across the plasma membrane, including passive (simple diffusion, facilitated diffusion, osmosis) and active transport. Provide specific examples of substances transported by each mechanism and discuss the cellular energy requirements.
4. Describe the three major types of intercellular junctions (desmosomes, tight junctions, and gap junctions). For each type, explain its structural features, primary function, and provide an example of where it might be found in the body to illustrate its importance.
5. Categorize and describe the four major tissue types in the human body (epithelial, connective, muscle, nervous). For each category, discuss its general characteristics, main functions, and provide two distinct examples, explaining how their specific structure enables their function.

Glossary of Key Terms

- **Adipocyte:** A fat cell, specialized for storing lipid droplets.
- **Adipose Tissue:** A type of connective tissue primarily composed of adipocytes, functioning in energy storage, insulation, and padding.
- **Active Transport:** Movement of substances across a cell membrane against their concentration gradient, requiring cellular energy (e.g., ATP).
- **Apical Surface:** The free, unattached surface of an epithelial tissue, often exposed to the exterior or a body cavity/lumen.
- **Areolar Tissue (Loose Connective Tissue):** A type of connective tissue with loosely packed fibers and abundant space, acting as packing material and allowing for free movement.
- **ATP (Adenosine Triphosphate):** The primary energy currency of the cell.
- **Autorhythmic:** Refers to muscle tissue (cardiac and some smooth muscle) that can contract spontaneously and rhythmically without external nervous stimulation.

- **Axon:** A long, slender extension of a neuron that transmits electrochemical signals away from the cell body.
- **Basal Surface:** The attached surface of an epithelial tissue, connected to an underlying basement membrane.
- **Basement Membrane:** A thin, non-cellular layer that anchors epithelial tissue to underlying connective tissue.
- **Blood:** A mobile connective tissue consisting of cells (red and white blood cells) suspended in an extracellular matrix called plasma.
- **Bone:** A hard, mineralized connective tissue that provides support, protection, and mineral storage.
- **Cardiac Muscle:** Striated, involuntary, and autorhythmic muscle tissue found only in the heart.
- **Cartilage:** A tough, flexible connective tissue, including hyaline and fibrocartilage, with cells (chondrocytes) within lacunae.
- **Cellular Respiration:** The metabolic process occurring mainly in mitochondria, where glucose and other molecules are broken down to produce ATP, with carbon dioxide as a byproduct.
- **Chondrocyte:** A cell found in cartilage.
- **Columnar Cell:** An epithelial cell that is taller than it is wide, shaped like a column.
- **Concentration Gradient:** A difference in the concentration of a substance across a space or membrane.
- **Connective Tissue:** One of the four major tissue types; characterized by abundant extracellular matrix and diverse functions, including support, binding, protection, and transport.
- **Crenation:** The shrinkage and shriveling of a cell due to water loss when placed in a hypertonic solution.
- **Cuboidal Cell:** An epithelial cell that is roughly as tall as it is wide, shaped like a cube.
- **Cytokinesis:** The division of the cytoplasm and organelles into two separate daughter cells during cell division.
- **Cytology:** The study of cells.
- **Cytoplasm:** All the material inside a cell, excluding the nucleus but including organelles and cytosol.
- **Cytoskeleton:** A network of protein filaments and tubules in the cytoplasm that provides structural support and helps maintain cell shape.
- **Cytosol:** The jelly-like fluid portion of the cytoplasm, excluding organelles.
- **Dendrite:** A short, branching extension of a neuron that receives electrochemical signals from other cells.
- **Dense Fibrous Connective Tissue:** Connective tissue with densely packed protein fibers; can be regular (parallel fibers, e.g., tendons) or irregular (randomly oriented fibers).
- **Desmosome:** A type of intercellular junction that acts as a "spot weld" to mechanically hold cells together, providing resistance to mechanical stress.
- **Diffusion:** The passive movement of particles from an area of higher concentration to an area of lower concentration.

- **DNA (Deoxyribonucleic Acid):** The genetic material of the cell, found in the nucleus, containing instructions for protein synthesis and heredity.
- **DNA Replication:** The process of making an exact copy of a DNA molecule, occurring before cell division.
- **Endocytosis:** The process by which a cell takes in substances from its exterior by engulfing them in a vesicle.
- **Endoplasmic Reticulum (ER):** A network of membranes in the cytoplasm, continuous with the nuclear envelope, involved in protein and lipid synthesis and modification.
- **Epithelial Tissue (Epithelium/Epithelia):** One of the four major tissue types; forms linings and coverings for body surfaces and organs, characterized by polarity and close cell packing.
- **Eukaryotic Cell:** A cell that possesses a true nucleus and other membrane-bounded organelles (e.g., animal, plant, fungal cells).
- **Exocytosis:** The process by which a cell releases substances to its exterior by fusing a vesicle with the plasma membrane.
- **Extracellular Matrix:** The non-living material found outside of cells in connective tissues, composed of ground substance and protein fibers.
- **Facilitated Diffusion:** Passive transport of substances across a membrane with the aid of transport proteins, still moving down the concentration gradient.
- **Fibrocartilage:** A type of cartilage with a high concentration of collagen fibers in its matrix, providing great strength (e.g., intervertebral discs).
- **Gamete:** A sex cell (sperm or egg), containing half the number of chromosomes of a somatic cell.
- **Gap Junction:** A type of intercellular junction that forms small tunnels between adjacent cells, allowing for direct communication and passage of small molecules.
- **Gene:** A segment of DNA that contains the instructions for making a specific protein or RNA molecule.
- **Gene Expression:** The process by which information from a gene is used in the synthesis of a functional gene product, such as a protein.
- **Golgi Complex (Golgi Apparatus):** An organelle involved in modifying, sorting, and packaging proteins and lipids for secretion or delivery to other organelles.
- **Histology:** The study of tissues.
- **Hyaline Cartilage:** A type of cartilage with a glassy appearance, found in the nose, trachea, and at the ends of long bones.
- **Hypertonic Solution:** A solution with a higher solute concentration (and thus lower water concentration) than the cell, causing water to leave the cell.
- **Hypotonic Solution:** A solution with a lower solute concentration (and thus higher water concentration) than the cell, causing water to enter the cell.
- **Intercellular Junctions:** Structures that connect cells to each other, allowing for communication or mechanical attachment.
- **Isotonic Solution:** A solution with the same solute concentration (and thus water concentration) as the cell, resulting in no net water movement and stable cell volume.
- **Lacuna (plural: Lacunae):** A small, hollow space or cavity within bone or cartilage where a cell (osteocyte or chondrocyte) resides.

- **Leukocyte:** A white blood cell, involved in the immune response.
- **Lysis:** The bursting or rupture of a cell, typically due to excessive water intake in a hypotonic solution.
- **Lysosome:** A membrane-bounded organelle containing digestive enzymes that break down waste materials and cellular debris.
- **Membrane-Bound Protein:** A protein embedded within or associated with a cell membrane.
- **Microfilaments:** The thinnest type of protein fiber in the cytoskeleton, involved in cell movement and shape.
- **Microtubules:** The widest type of protein fiber in the cytoskeleton, involved in cell shape, organelle movement, and cell division.
- **Mitochondrion (plural: Mitochondria):** A double-membrane-bounded organelle responsible for cellular respiration and ATP production.
- **Mitosis:** The process of nuclear division, ensuring that each daughter cell receives a complete and identical set of chromosomes.
- **Muscle Tissue:** One of the four major tissue types; specialized for contraction and generating force for movement.
- **Myofiber (Muscle Fiber):** An individual muscle cell, particularly referring to skeletal muscle cells.
- **Nervous Tissue:** One of the four major tissue types; specialized for transmitting electrochemical signals and controlling body functions.
- **Neuroglia (Glial Cells):** Non-excitable supporting cells of the nervous tissue that protect and assist neurons.
- **Neuron:** An excitable cell in nervous tissue that transmits electrochemical signals.
- **Nuclear Envelope:** The double membrane surrounding the nucleus in eukaryotic cells.
- **Nuclear Pore:** A channel through the nuclear envelope that regulates the passage of molecules between the nucleus and cytoplasm.
- **Nucleus:** A membrane-bounded organelle in eukaryotic cells that contains the cell's genetic material (DNA).
- **Osteon:** The structural unit of compact bone, consisting of concentric layers of bone matrix around a central canal.
- **Osteocyte:** A bone cell, typically residing in a lacuna within the bone matrix.
- **Osmosis:** The diffusion of water across a selectively permeable membrane.
- **Passive Transport:** Movement of substances across a cell membrane without the expenditure of cellular energy, driven by concentration or pressure gradients.
- **Peroxisome:** A membrane-bounded organelle that contains enzymes involved in various metabolic reactions, including the detoxification of peroxides.
- **Phagocytosis:** A type of endocytosis where the cell engulfs large solid particles ("cell eating").
- **Phospholipid:** A type of lipid that is a primary component of cell membranes, characterized by a polar head and two non-polar tails.
- **Phospholipid Bilayer:** The fundamental structure of cell membranes, consisting of two layers of phospholipids with their tails facing inward and heads facing outward.

- **Pinocytosis:** A type of endocytosis where the cell takes in small sips of extracellular fluid ("cell drinking").
- **Plasma:** The liquid extracellular matrix of blood.
- **Plasma Membrane:** The selective barrier forming the outer boundary of an animal cell.
- **Prokaryotic Cell:** A cell that lacks a true nucleus and other membrane-bounded organelles (e.g., bacteria).
- **Pump:** A type of transport protein that actively moves substances against their concentration gradient, requiring energy.
- **Receptor-Mediated Endocytosis:** A highly specific type of endocytosis where external substances bind to cell surface receptors, triggering vesicle formation and uptake.
- **Red Blood Cell (Erythrocyte):** A cell in blood specialized for oxygen and carbon dioxide transport.
- **Reticular Tissue:** A type of connective tissue characterized by a network of reticular fibers, forming a supportive framework in organs like the spleen and lymph nodes.
- **Ribosome:** A non-membrane-bounded organelle responsible for protein synthesis (translation).
- **Rough Endoplasmic Reticulum (RER):** Part of the ER studded with ribosomes, involved in the modification of newly synthesized proteins.
- **Simple Diffusion:** Passive movement of small, non-polar substances directly through the phospholipid bilayer.
- **Skeletal Muscle:** Striated, voluntary muscle tissue that attaches to bones and is responsible for body movement.
- **Smooth Endoplasmic Reticulum (SER):** Part of the ER lacking ribosomes, involved in lipid synthesis, detoxification, and calcium storage.
- **Smooth Muscle:** Non-striated, involuntary muscle tissue found in the walls of hollow organs, involved in regulating internal processes.
- **Sodium-Potassium Exchange Pump:** A vital active transport pump that maintains ion gradients across cell membranes, critical for nerve and muscle function.
- **Squamous Cell:** A flat, thin, scale-like epithelial cell.
- **Stratified Epithelium:** Epithelial tissue composed of more than one layer of cells, providing protection.
- **Striations:** The characteristic banding pattern observed in skeletal and cardiac muscle tissue due to the organized arrangement of contractile proteins.
- **Tendon:** A tough band of dense regular fibrous connective tissue that connects muscle to bone.
- **Tight Junction:** A type of intercellular junction that forms a tight seal between adjacent cells, preventing the passage of substances through the intercellular space.
- **Tonicity:** A measure of the effective osmotic pressure gradient between two solutions, indicating the tendency of water to move in or out of a cell.
- **Transcription:** The process where the DNA sequence of a gene is copied into an RNA molecule.
- **Transitional Epithelium:** A specialized type of stratified epithelium that can change shape and stretch, found in organs like the urinary bladder.

- **Translation:** The process where the genetic code in an mRNA molecule is used to synthesize a protein at a ribosome.
- **Vesicle:** A small, membrane-bound sac within the cytoplasm involved in storing or transporting substances.
- **Vesicular Transport:** The general process of moving substances into or out of a cell using vesicles.
- **White Blood Cell (Leukocyte):** A cell in blood involved in the immune response.
- **Zygote:** The single cell formed by the fusion of two gametes (sperm and egg), representing the beginning of a new organism.