



ESSENTIALS OF

HUMAN ANATOMY AND PHYSIOLOGY

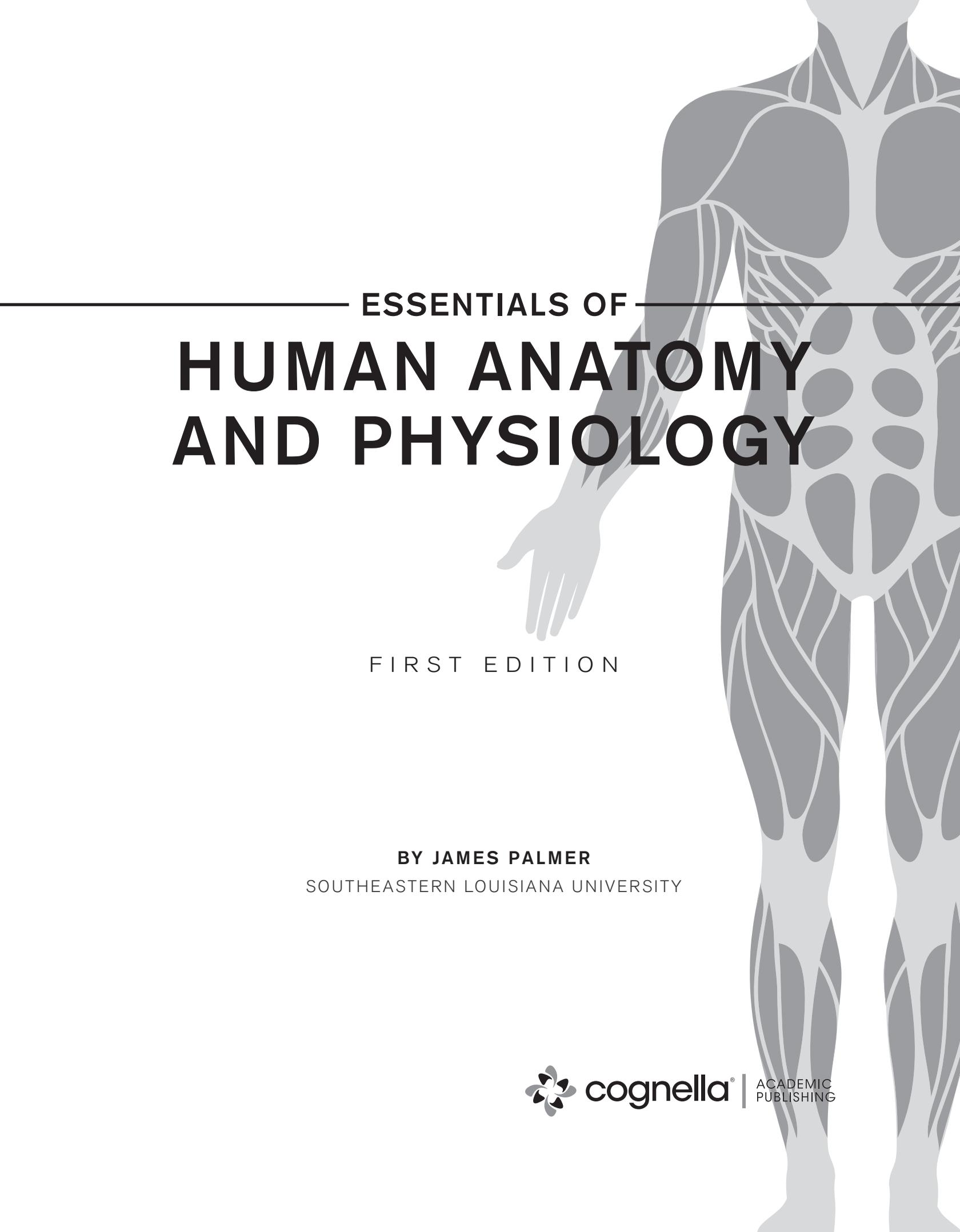
FIRST EDITION



**SNEAK
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JAMES PALMER



ESSENTIALS OF

HUMAN ANATOMY AND PHYSIOLOGY

FIRST EDITION

BY JAMES PALMER
SOUTHEASTERN LOUISIANA UNIVERSITY

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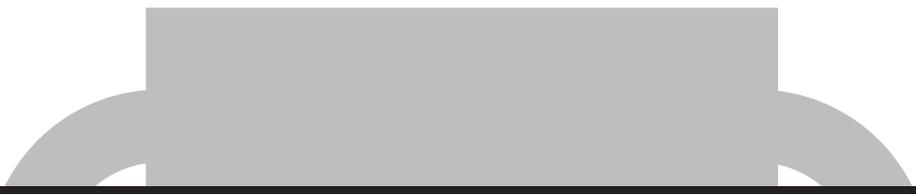
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Note for the User: Chapters 1 through 7 apply to the first half of a two-semester course which combines anatomy and physiology of each of the systems essential for the entry-level students.

GENERAL INTRODUCTION

Human anatomy and physiology is very much like learning a different language. The vocabulary is composed of many terms derived from Greek or Latin. Learning these terms and definitions will make the course easy. Good luck in your efforts and future.



CHAPTER ONE

INTRODUCTION TO TERMS AND CONCEPTS IN ANATOMY AND PHYSIOLOGY



General Terms

The first terms you must understand are anatomy and physiology. *Anatomy* is the study of the structure and shape of the body and its parts, usually with the emphasis on how structure influences function. *Physiology* is the study of the functions of the body and the role of various structures on the function. Another term that is very important to understand is *homeostasis*, which is the balance or equilibrium of various functions of the body, such as temperature, pH, blood pressure, and nutrition, as it maintains the internal environment.

Levels of Organization of Living Organisms

A living organisms' survival depends on maintaining an organized series of structures. It begins at the *chemical level* of organization, where various atoms or elements are organized into molecules, forming structural and functional components required to support the next higher level. The *cellular level* of organization is where the molecules are used to provide the structure and function required for life. Groups of cells having similar structure and function are organized into the *tissue level* of organization, where these tissues perform specific functions required to support life. Groups of tissues organized into structure with a defined shape and function make up the *organ level* of organization, with examples such as the liver, heart, lungs, stomach, and others. Groups of tissue coupled with one or more organs are organized into a *systems level*, which performs a series of various functions supporting the organism; for example, the urinary, cardiovascular, and the nervous systems. The final level of organization to consider is the *organism level*, which is all of the systems working together to make the living organism function in the environment.

Life Processes

In order for life to exist, a series of events and processes must occur. The ability of an organism to control energy is called *metabolism*, which is the sum of all chemical activities within the body. It is divided into those activities which harvest energy, catabolic processes, and those which transform and store energy, anabolic processes. The organism requires the ability to detect changes in its internal and external environments, and respond to those changes; this is *responsiveness*. If the organism's materials must be relocated to meet needs both in the organism and within the cells, this is *movement*, which is vital for the removal of wastes and nutrients and the removal of the organism from threats. A living organism's increase in size or number of cells defines *growth*, which is critical for the development of the organism through life. Since organisms develop from a single unspecialized cell, which provides the basis of all the specialized cells, the process of *differentiation* occurs, where the single zygote gives rise to muscle, bone, and blood. The final life process that is essential for the survival of organisms is *reproduction*, which is required for repair and replacement of damaged cells and tissues as well as the production of a new individual.

Homeostasis

Homeostasis is the outcome of the processes that maintain an internal balance or equilibrium in the body. It is controlled by the actions of specific control centers in the brain and the actions of hormones produced by the endocrine system. Changes are made in various systems in response to stresses placed on the organism, either external or internal. When the balance is disrupted, the body will use mechanisms to attempt to reduce the effect of the stress, which is negative feedback, or enhance the response of the body to the stress, which is positive feedback. An example of negative feedback would be as follows: after a meal your blood sugar increases as you digest the food; in response, your pancreas releases insulin, which promotes the cells to absorb the glucose and the liver and muscle cells to convert it to glycogen. An example of positive feedback would be as follows: a person who is allergic is exposed to a sting, and the person's immune response magnifies the level of histamines released, causing a risk of death. Another positive feedback example would be a woman in labor, where the endocrine system releases oxytocin, which increases the strength of the contraction of muscles to aid in expelling the fetus.

Directional Terms

When we discuss various structures on the body or the relationship of structures, establishing a reference position is necessary. This is called the *anatomical position*, which is defined as either standing erect, facing forward with the palms of the hands forward, or supine (laying on the back facing upward) with the palms facing upward. This puts various body structures in a predictable relationship. We frequently use a variety of terms to describe how structures relate. If a structure is above a defined reference point, we would describe it as *superior* to that structure. If it is below the reference point, it would be *inferior*. Structures defined as being toward the front of the body would be *anterior* or *ventral*; toward the back would be *posterior* or *dorsal*. The midline of the body or structure along the long being the reference point a structure or feature would be either closer to the midline would be *medial* and further away from the midline would be *lateral*. The term *intermediate* may occasionally be used when discussing three structures. When working with the appendages, a structure closer to the central body would be *proximal* and a structure further away would be *distal*. A structure located on or near the surface would be *superficial*, and one closer to the skeleton would be *deep*.

Planes and Cavities

Planes allow the division of the body into defined areas for ease of placement of various structures. The *sagittal plane* divides the body along the long axis into right and left, with various structures located either right or left of the midline. The *frontal (coronal) plane* divides the body into an anterior or posterior relationship. The *horizontal (transverse) plane* divides the structures into superior and inferior relationships.

Cavities of the body were originally used with four-legged animals, but the human rotated into an upright position rearranges those cavities. The *dorsal cavity*, also referred to as the posterior

cavity, is composed of various body structures protecting vital structures. It is subdivided into a *cranial component*, which surrounds and encapsulates the brain in bone, and the *spinal component*, which surrounds the spinal cord in bone and muscle. The *ventral cavity* is located in the central body area and is composed of the *thoracic portion*, composed of bone and muscle, separated from the *abdominopelvic portion* by the diaphragm. The thoracic portion is divided into three cavities: two housing the lungs, which are the *pleural cavities*, and the mediastinal region, which contains the *pericardial cavity*, housing the heart. The abdominopelvic portion is divided into an abdominal region, located above the top of the pelvis, and the pelvis proper.

The abdominal area is divided into areas for the purpose of locating various structures, or to suggest which structures might be involved in a patient's complaint. In medicine, the quadrant system is used to divide the abdomen into right and left upper quadrants, and right and left lower quadrants. Anatomists divide the abdomen into nine regions, with the central region being the umbilical (navel) and on either side being the right or left lumbar; above the umbilical in the center would be the epigastric and either the right or left hypochondriac; below the umbilical in the center would be the hypogastric (pubic) and left or right iliac (inguinal) regions.

Systems

The human body can easily be divided into systems, and most agree that there are eleven or twelve systems. The typical coverage of the systems begins with the *integument system* (skin), which covers the exterior of the body, providing protection and sensory input, and acting as a blood reservoir and a site of the synthesis of vitamin D precursor. The next system is typically the *skeleton system*, composed of bone, cartilage, and other connective tissues providing protection, support, movement, mineral storage, and energy storage. The *muscle system* is described by most texts with a focus on the skeletal muscle, describing the anatomy, organization, and physiology in detail, with limited mention of cardiac and smooth muscle tissue. The *nervous system* is usually the next system covered, with the anatomy and physiology of both the neurons and neuroglia in the central and peripheral systems, coupled with the primary sensory structures. These are normally covered in the first semester of a two-semester course.

The second semester begins with the *circulatory* or *cardiovascular systems*, which cover the blood, the heart, and the vascular systems. The next system covered is usually the *respiratory system*, due to its interactions with the blood and heart to supply oxygen and remove waste carbon dioxide to maintain the pH of the body. The *digestive system* frequently follows, with description of the anatomy and physiology of the components of the system and nutrition. This is followed by the *urinary system*, with the anatomy and physiology contributions to the fluid and electrolyte values in the body. The anatomy and physiology of the male and female *reproductive systems* describes the influence of the hormones on each, as well as the development of a new individual. The *lymphatic* and *immune systems* follow, with the comparison of the vessels to those previously covered and the anatomy and physiology of the system. The immune system covers the various mechanisms and actions conducted by the body to protect and prevent disorders and diseases. The last covered is the *endocrine system*, with description of the anatomy and physiology of its components and the impact on the organism.

CHAPTER TWO

REVIEW



Chemistry

The following information is a summary of essential concepts in chemistry that are critical in understanding fundamental life processes.

Elements (Atoms)

Matter is defined as anything that has mass and occupies space, which is also what defines an atom (element). Elements are the simplest substances which cannot be broken down by chemical means and have distinct physical and chemical properties. The majority of the human body is composed of only four elements (carbon, hydrogen, oxygen, and nitrogen), which represent ninety-six percent of our total body mass; when we include calcium and phosphorous, it increases to ninety-nine percent of the body's mass. Atoms consist of a nucleus containing protons and neutrons, with a cloud of electrons in orbits around the nucleus. Protons are positively charged, neutrons have no measurable charge, and electrons are negatively charged. Each element is assigned an atomic number that reflects the number of protons found in the nucleus and the number of electrons in the orbits. The protons and neutrons have a mass of approximately one dalton, which is reflected in the atomic mass of the element, with the difference from the atomic number being the number of neutrons found in the most common isotope of the element. When atoms interact in chemical reactions they form molecules, which result from the interactions with the outermost electrons, which are called the valence electrons.

Molecules

A molecule results from the chemical interaction that joins two or more atoms by chemical bonds. Compound is a term which may also be used to describe a molecule, but is defined by the atoms being of more than one type. In inorganic molecules the bond is the *ionic bond*, where the outermost electrons on one atom are attracted to the reacting atom, or the electron is lost to the reacting atom, to fulfill its outermost orbit with electrons. In many molecules the electrons are shared by the reacting atoms, this is common in organic molecules. These are *covalent bonds*, which frequently are stronger than ionic bonds. In biological systems, molecules interact due to the shape of the molecules having a positive or negative pole, so that weak bonds tend to tie the molecules to one another, which is common in proteins and nucleic acids.

Reactions

Chemical reactions involve the processes of bond breaking and rearrangement to form new molecules. When bonds are broken, energy is liberated and forms new bonds, which capture some of that energy in new molecules; some energy is lost as heat. There are two types of reactions: *synthesis reactions*, which form new molecules with a higher energy state, and *decomposition reactions*, where the new molecules formed have a lower energy state than the original molecules.

Inorganic Molecules

Most inorganic molecules are composed of ionic bonds and lack carbon. They tend to risk decomposition and are usually soluble in water to some extent. Oxygen, water, carbon dioxide, and ammonia are inorganic molecules that are covalently bonded; they are the exception to the ionic bonding characteristic. *Water* is the most common and abundant inorganic molecule, composed of hydrogen and oxygen covalently bonded. This polar molecule makes an excellent solvent, it traps and releases heat slowly, lubricates movable components of the body, and is involved in chemical reactions. Typical inorganic molecules are *salts*, which are the product of reactions between acids and bases. Salts dissociate in water, creating charged ions. If excess hydrogen ions are released then the solution will be acidic, and if excess of hydroxyl ions are released then the solution created is basic. Usually a solution is described by its *pH*, which expresses the concentration of hydrogen ions present in a scale from 0 to 14, which are the negative exponent of the base 10. Water in its pure state has a pH of 7.0 momentarily. A solution below 7 (0 to 6.99) would be an acidic solution whose strength is reduced the closer it gets to 7 and above (7.1 B 14); the strength of the basic solution increases the further it is from 7. Each whole unit difference is a ten-fold increase or decrease from the previous number. In biological systems extremes of pH are not tolerated, so there are a series of *buffers*, which trap and release hydrogen ions to maintain the hydrogen ion concentration within narrow limits so that successful activities can take place. In humans buffer systems exist in the blood, composed of carbonic acid in the plasma and hemoglobin in the red cells. In the cells, buffer systems involve phosphates and proteins all working together to maintain the slightly basic condition within the body.

Organic Molecules

All organic molecules are composed of carbon and hydrogen bonded by covalent bonds, creating molecules which are either polar molecules that are soluble in water or non-polar molecules, which are insoluble in water. Organic molecules with oxygen added to the carbon and hydrogen skeleton form carbohydrates and lipids.

Carbohydrates have a ratio of 1 carbon, 2 hydrogen, 1 oxygen (1:2:1) ratio. Sugars, starches, cellulose, and chitin are forms of carbohydrates and are polymers made up of various monomers by a dehydration synthesis. They can be broken into simple sugars by hydrolysis reactions, which is the removal or addition of water to the molecules. These reactions are driven by specific enzymes. Carbohydrates are the primary energy source, but can also form storage and structural components in the cells.

Lipids are another organic molecule to which oxygen is added to the carbon hydrogen skeleton, but lacks a fixed ratio. Lipids are non-polar covalently bonded and tend to be non-soluble in water. They consist of fats, steroids, phospholipids, vitamins, and prostaglandins, which insulate, protect, and store energy.

Proteins are polymers formed by the combining of various amino acids to create a molecule. They function in the protection, contraction, and regulation of structural components and enzymes. The amino acid is composed of a carbon skeleton that has two functional groups attached; one is an amino group containing nitrogen and hydrogen, and the other a carboxyl group

containing a carbon with a double-bond oxygen and a hydroxyl group. Proteins are formed by ribosomes, in which a hydrogen is removed from the amino group, and a hydroxyl group from the carboxyl group, dehydrating the chain by creating the peptide bonds.

The last group of organic molecules is the *nucleic acids*, which are composed of a pentose sugar, nitrogenous group, and phosphate group. They function in the storage of information and the capture and transport of energy, and are involved in protein formation. DNA (deoxyribonucleic acid) is a double helix that stores the genetic information for the body. It is located in the nucleus of the cells. RNA (ribonucleic acid) transcribes the information from the DNA and translates it into proteins in the cytoplasm. Capture and transport of energy involves ATP (adenosine tri-phosphate), NADP (nicotinamide adenine dinucleotide phosphate), and FAD (flavin adenine dinucleotide) in various places to support life processes. Some trap and transport electrons and hydrogen, while others develop high-energy bonds to transport the energy.

Cell

The following is a summary of the essential cellular components and their function. Just as the atom is the smallest unit of matter, the cell is the smallest unit capable of carrying out the life processes. A *cytologist* is an individual who studies cells. Those at the technician level screen for atypical cells from various tissue samples. Cells are divided into those which have an organized nucleus surrounded by a nuclear membrane, and those which do not have an organized nucleus. *Prokaryotes* are those without an organized nucleus, and frequently lack membrane organelles. *Eukaryotes* have internal organized organelles in addition to the nucleus. All cells, whether prokaryotes or eukaryotes, have a membrane that surrounds the cellular contents called the *plasma membrane*.

Plasma Membrane

The plasma membrane is composed of a bi-layer of phospholipids, with the hydrophilic ends facing the interior of the cell or the environment. There are integral proteins embedded in the membrane, and the membrane is frequently stabilized by cholesterol. The configuration of the membrane makes it highly selective, permitting lipid-soluble materials to pass into the cell, controlling those molecules which are water soluble and polar passage into the cell. Most of the polar molecules that are transported into the cell are bound to carrier proteins or small enough to pass through pores in the membrane.

Movement across the Membrane

Movement of molecules across the plasma membrane is either active, where energy (ATP) is expended, or passive, where the cell expends no energy. *Passive transport* involves the kinetic energy of molecules or molecular size moving from higher to lower concentrations.

Diffusion is one form of passive transport that involves the kinetic movement of molecules from a higher to lower concentration location; this does not involve a membrane.

Osmosis is the movement of water from higher to lower concentrations through a selective membrane until equilibrium is established. A state where the solute concentration is lower inside the cell would indicate a hypotonic *condition* in the cell, with water moving out of the cell, attempting to reach equilibrium. If the concentration of the solute is equal on either side of the membrane, an *isotonic condition* exists in the cell, where water will move into and out of the cell equally. If the solute concentration is greater inside the cell than that surrounding the cell, water will move into the cell attempting to establish equilibrium. This is a *hypertonic condition*.

When a polar molecule such as glucose combines with an integral protein in the membrane, as the combination rotates with the fluid movement of the membrane the glucose is moved into the cell. This is *facilitated diffusion*, in which the molecular shape of the protein changes slightly, encouraging movement into the cell.

The last type of passive transport is triggered by the pressure exerted by water on the membrane. The pressure exerted by the water is the hydrostatic pressure and the process is *filtration*, where water is forced through membrane pores, removing other components in the process.

In *active transport* the cell expends energy (ATP) to move the molecules or components into the cell at time against a concentration gradient, an example would be ion pumps. In some cases, the energy is used to reconstruct the plasma membrane, such as in *endocytosis*, where the entrapment of extracellular materials occurs by surrounding them with extensions of the plasma membrane. There are two forms of endocytosis: *phagocytosis* is the ingestion of solid particles, which is used by white blood cells to ingest foreign bodies; *pinocytosis* is the ingestion of liquid materials. Receptor-mediated endocytosis is a form where large molecules are selectively ingested; an example would be the ingestion of antibody-labeled foreign antigen. The last of the active transports is the *ion-pump*. This is where integral proteins utilize the energy from ATP to move ions against a concentration gradient. Examples include the movement of sodium and potassium in muscle cells, and calcium and magnesium in the sarcoplasmic reticulum of skeletal muscle.

Cytosol

The cytosol is the cell contents between the plasma membrane and the nuclear membrane. This includes organelles, inclusions, and the cytoplasm (the fluid portion). It is composed mostly of water, which contains proteins, carbohydrates, and lipids as well as a variety of inorganic molecules. This is the location where many chemical reactions occur.

Organelles

In most cells, the *nucleus* is the largest visible organelle. It is a complex structure encapsulated by the nuclear membrane, which regulates the cell's activities and stores the genetic code the cell uses to form proteins and other cellular components. The nucleoplasm contains the chromosomes where the code is transcribed and a nucleolus where the ribosomes are formed, consisting of RNA and protein enzymes. Some tissues have multiple nuclei, because of the merging of cells during development such as that found in skeletal muscles, or lack a nucleus, in the case of red blood cells where the nucleus and mitochondria are lost as the cells mature.

Ribosomes are granular structures formed of ribosomal RNA and proteins transferred from the nucleolus to the cytoplasm, where they construct proteins from amino acids. Some are bound to the endoplasmic reticulum, creating a rough condition, and the majority of the ribosomes are free in the cytoplasm.

Endoplasmic reticulum is a network of parallel bi-layer membranes located in the cytoplasm that connects the plasma and nuclear membranes. It provides mechanical support and a site where materials are exchanged with the cytoplasm. Materials are transported throughout the cell in the endoplasmic reticulum. There are two distinct segments of the endoplasmic reticulum: one is the *smooth endoplasmic reticulum*, where many of the steroids are produced, and the second is the *rough endoplasmic reticulum*, where proteins are stored and lipoproteins are formed.

Adjacent to the endoplasmic reticulum is the *Golgi complex*, which is composed of eight stacked and flattened membrane sacs called cisternae. Many materials and molecules are processed and packaged in the Golgi complex for transport or storage within the cell. Some of these packages are the *lysosomes*, which are spherical vacuoles containing digestive enzymes. The lysosomes are involved in the digestion of phagocytized materials ingested by macrophages, and are responsible for cell destruction of worn out cells in a process called autophagy, where the cells undergo autolysis. Many lysosomes are secreted to extracellular sites to aid in digestion.

Mitochondria are the site where the majority of the ATP is produced in the cell by the citric acid cycle, which yields ATP, electrons, and hydrogen ions, which are transported to the electron transport chain and produce ATP by oxidative phosphorylation. The structure possesses a smooth outer membrane with folded cristae internally surrounding a matrix. The mitochondria has distinct ribosomes and genetic code separate from the rest of the cell.

The cytoskeleton of the cell is composed of various proteins that provide support, movement, and structural reinforcement of the cell. There are microfilaments, which consist of the proteins actin and myosin, which are involved in contraction, providing movement and support. Microtubules are slender tubes composed of the protein tubulin, which provides support and structure for the cilia, flagella, and centrioles, which form the mitotic spindle during mitosis. Intermediate filaments are composed of various proteins reinforcing the structure of the cell. In the resting cell the *centrioles* are paired cylinders arranged at right angles to each other in the dense *centrosome*. Extensions from the plasma membrane composed of tubulin are the flagella and cilia, which are used to promote motion. Cilia are commonly found in the trachea, reproductive ducts, and other locations, while the flagella are only found in human sperm.

Inclusions

Inclusions are any chemicals produced by the cell that are stored in the cytoplasm. Inclusions are usually organic and easily recognizable. Melanin is one type of inclusion, typically found in the epidermal cells as a brownish-black pigment that gives skin its color. Its production is accelerated with exposure to sunlight. Glycogen is another inclusion, which is animal starch used to store energy in the liver and skeletal muscles. The most obvious inclusion is the oil (lipids) stored in the specialized vacuoles in the fat cells.

Protein Production in the Cells

The code for the proteins is contained in the sequence of DNA, which first have to be transcribed. This occurs by the production of an RNA strand from the DNA. There are three forms of RNA produced. The first form is rRNA (ribosomal RNA), which is transported to the nucleolus to produce a ribosome. The second is mRNA (messenger RNA), which goes to the ribosome, initiates its activity, and defines the sequence of amino acids required to produce its protein. The last is tRNA (transfer RNA), which selects the appropriate amino acids and transports them to the ribosome to produce the protein.

Reproduction

Cells within the body are constantly reproducing; as some die, they are replaced by new cells. This process is by *mitosis*, which is the division of the nucleus through a series of steps developing replacement cells that are genetically and functionally identical. The cells then mature and produce additional DNA to form chromosomes during a period called *interphase* or *S phase*. The chromosomes are organized into duplicates during the *G2 phase* part of the interphase if the cell is stimulated to divide. The cells that are going to divide chromosomes condense, becoming visible while the nuclear membrane and nucleoli disappear and the centrioles migrate, forming poles during *prophase*. A series of spindles develop from the centrioles, with the chromosomes migrating and attaching to the spindles during *metaphase*. The chromosomes divide along a midline of the spindle and begin to be pulled toward the poles formed by part of the centriole during *anaphase*. As the chromosomes reach the poles, they tend to unwind and stretch out, becoming less apparent as a nuclear membrane begins to re-form around each pole, with the nucleoli reappearing during *telophase*. These are the stages of mitosis, which only defines the nuclear portion of cell division. The cell divides into daughter cells by a process called *cytokinesis*, which begins during the later stage of anaphase of the nuclear division and proceeds with the development of a plasma membrane along the midline of the dividing cell, until the cells separate into genetically identical daughter cells.

To produce a new organism, the chromosome number must be reduced to maintain organism characteristic functions. This is *meiosis*. Meiosis occurs as a two-stage division of the chromosomes, producing four genetically unique cells called *gametes*, which are incapable of survival unless fused with another gamete to obtain a complete genetic profile. The male gametes are *sperm* and the female gametes are *ova*, neither of which are capable of long-term existence unless preserved.

In some cases, cell division fails to be controlled; cell inhibition may be lost or the cell may divide rapidly, resulting in cancer cells, which can be called *neoplasms*. The loss of control can be correlated with a variety of viral and environmental factors that cause a modification in the genetic mechanisms that control growth and division of the cells

CHAPTER THREE

HISTOLOGY

TISSUES IN HUMAN ANATOMY



Tissues are formed by groups of cells that are genetically alike, functioning to provide support of the body by the unique properties of the cell. The functional capacity of the tissue is greater than which would be expected by the performance of each individual cell. The study of the anatomy of tissues is *histology* and the study of the function would be *histophysiology*.

Tissues are groups of similar cells assembled together and bound by extracellular substances in the intracellular spaces to provide specialized activities required to support the life of the organism. Tissues are described and characterized by the cells and the associated quantity of the extracellular materials in the intracellular spaces. The combination of the cells and extracellular materials influence the function of the tissue and the locations where they are found.

The extracellular materials are referred to by a variety of names, such as interstitial fluid, plasma, and mucus. The most abundant extracellular materials are found in connective tissue and are frequently referred as matrix or ground substance. The matrix molecules support, strengthen, and bind embedded cells together and contribute unique properties to the tissues in which they are encountered. Examples of common extracellular materials include the following: 1) *hyaluronic acid*, which lubricates movable joints of the skeleton and aids in maintaining the shape of the eyeball; 2) *chondroitin sulfate*, which provides support and adhesion of cells in cartilage, bone, heart valves, umbilical cord, and the cornea of the eye; 3) *collagen fibers*, which are found throughout cartilage, bone, and skin in varying concentrations and make up the majority of tendons and ligaments, being inelastic and providing strength and support; 4) *reticular fibers*, composed of small strands of collagen wrapped with glycoproteins providing the support network around fat and nerve cells, wrapping around muscle cells, and elasticity to blood vessels and the skin; and 5) *elastic fibers*, composed of the protein *elastin*, which provide flexibility and support to the skin and blood vessels.

Epithelial Tissue

Epithelial tissues are defined as the tissues that cover or line spaces. This includes the skin and various membranes lining spaces around the heart or abdomen where it lines the space and covers the internal organ such as the pleural membrane. The cells of the epithelial tissue on the outermost location have a surface that does not contact any other cell; this is called a free surface. Cells in epithelial tissue are supported by a *basement membrane*, formed by the underlying connective tissue interacting with the cells of the epithelial layer. When you name epithelial tissue, the first characteristic is the shape of the cells: those which are flattened are identified as *squamous*; those which resemble a square box are identified as *cuboidal*; those which are elongated are identified as *columnar*; and those which change shape under tension are *transitional*. The second characteristic used to name epithelial tissue is the arrangement of the cells in layers: if the cells are all in a single layer, the tissue is named *simple*; if the cells are in two or more layers, the tissue is named *stratified*; and if mature and immature cells are grouped together, appearing as though a layer exists, the tissue is named *pseudostratified*. Little extracellular material is present in epithelial cells, which are attached tightly together, providing the tissues with unique abilities. Epithelial tissues do not have a direct blood supply, which makes them *avascular*. Additional names associated with epithelial tissue are *mesothelial*, which are tissues forming some middle layer (usually membranes) in closed body cavities, and *endothelial*, which line internal structures like the blood vessels or the heart.

The epithelial tissues which line or cover the body have unique properties dependent upon the character of the tissue. *Simple squamous epithelial tissue* is found in the alveoli of the lungs, lining the blood vessels and forming the capillaries, where they function to diffuse gases and move fluids and dissolved substances by osmosis at a variety of locations in the body. *Simple cuboidal epithelial tissues* are found in the salivary glands and tear ducts, where they are involved in secretion, and lining the tubules in the kidney, where they are involved in the absorption of water from the filtrate. *Simple columnar epithelial tissues* are abundant in the digestive tract, where they are involved in the absorption of nutrients and have the free surface area of the cell convoluted into microvilli to increase surface area. *Stratified squamous epithelial tissues* are found in the skin and openings to the exterior, where they provide protection against microbes; some are filled with a waxy protein called keratin and others are very moist. *Stratified cuboidal epithelial tissues* are found in the conjunctiva of the eye, the urethra of the male, and sweat glands. They function in the protection of the structures where they are located. *Stratified columnar epithelial tissues* are found in the male urethra, where they provide protection and secretion. *Pseudo-stratified columnar epithelial tissues* are found in large excretory ducts and in the respiratory tract, where they provide protection and movement of material along a tract. *Transitional epithelial tissues* are found in various bladders, where they retain fluids and distend.

Connective Tissues

Connective tissue is the most diverse and abundant type of tissue found in the body. It is composed of cells surrounded with an abundance of extracellular materials. Most connective tissue is vascular, with the exception of cartilage. It is involved in protecting, supporting, and binding elements of the body together, and in storing energy. Embryonic connective tissues are the mesenchyme and mucous connective tissue, which are found in the embryo and later in the umbilical cord. Adult connective tissues are diverse, having various cells contained in a matrix of differing characteristics.

The first connective tissues to be considered are those grouped as loose, where the cells are not in a fixed position. These are *areolar tissue*, located in organs, abundant in the dermis and underlying layers; it consists of fibroblast, macrophages, and plasma cells contained in a matrix containing collagen, elastic, and reticular fibers in a jelly-like mass. *Adipose tissue* is another type of loose connective tissue, located throughout the body in the dermis, around the heart and kidneys, and in the yellow bone marrow and surrounding joints, where it is composed of storage cells in a fibrous matrix of reticular fibers, providing energy storage, support, and protection of vital structures.

Another grouping of connective tissue is *collagenous connective tissues (dense)*, which are composed of fibroblasts that produce an abundance of extracellular collagen, which dominates the tissues; these are found in tendons (regular type) and ligaments (irregular), providing the heart, liver, kidneys, and lymph nodes structural support and protection throughout. Another *collagenous connective tissue (elastic)* is found in the vocal cords, lungs, and trachea. The amount of collagen is reduced and replaced by elastic fibers, providing flexibility and stretching. A third type of *collagenous connective tissue (reticular)* is found in the structure (stroma) of the liver, spleen, lymph nodes, and the basal lamina.

The next group of connective tissue is cartilaginous connective tissues, which have a large amount of chondroitin sulfate and glucosamine in the extracellular matrix surrounding scattered cells (*chondrocytes*), located in *lacuna* or spaces. These tissues lack a blood supply. The first type is *hyaline cartilage*, which is found covering the ends of long bones, attaching the ribs to the sternum, providing support to the trachea and bronchi, and forming the structure of the larynx, as well as forming the embryonic skeleton; it provides flexibility, support, and movement. The second type is *fibro-cartilage*, which is found in the knee as the menisci, in the vertebral column as intervertebral discs, and as the attachment at the pubic symphysis; the matrix is filled with an abundance of collagen fibers that function to absorb energy, provide support, and fuse bone components together. The third type is *elastic cartilage*, which is found in the epiglottis, Eustachian tubes, and the external ear; collagen fibers are replaced in the matrix by elastic fibers, providing flexibility.

The next type of connective tissue is composed of a dense, mineral-rich matrix surrounded by a thin fibrous covering; this is the *osseous connective tissue (bone)*. The cells (*osteocytes*) are located in organized structures in the mineral matrix or in the *periosteum* covering the bone. The mineral salts making up the matrix are primarily calcium and phosphorous, supported by collagen fibers. The mineral salts provide hardness, while the collagen provides elasticity and strength. The bone provides protection to vital structures, supports various structures, stores minerals, provides movement, and houses blood-forming tissues.

The last type of connective tissue has a fluid matrix in which diversified cells and components are located; this is *vascular connective tissue (blood)*. Blood is composed of a liquid matrix (*plasma*) composed mainly of water, and contains salts and nutrients as well as cellular components (*platelets*) and either red blood cells or white blood cells. The various components of the blood are involved in transport, removal of pathogens or cellular debris, immune reactions, and prevention of blood loss (clotting).

Membranes

Membranes are classified as epithelial membranes because they are composed of an epithelial layer, which is the functional area and is supported by an underlying connective layer. There four distinct membranes found in the body:

1. The *mucus (mucous) membrane*, which is moist, lines openings to the exterior of all body cavities; they provide a barrier to pathogens and flush pathogens from the surface, preventing adherence while trapping foreign particles in the *mucus* secreted, with the layer between the epithelial and connective layers forming the *lamina propria*.
2. The *serous membrane (serosa)* is the membrane found in closed body cavities. It is divided into a portion that covers the internal organs, named the *visceral* portion, and the lining of the surrounding cavity, named the *parietal* portion, with a liquid being secreted between the portions named the *serous fluid*, which lubricates the movement of the internal structures. Examples of serous membranes are the pleural and pericardial membranes in the thoracic cavity and the peritoneal membrane found in the abdomen.

3. The *cutaneous membrane* (skin, integument) is the largest of the epithelial membranes, composed of keratinized epithelial cells and diverse connective support tissues separated by a basement membrane.
4. The *synovial membrane* is unique in the epithelial membranes in that it is dominated by the connective tissue, with small islands of epithelial tissue that secrete *synovial fluid* to lubricate the articulations of the skeleton. The synovial membrane is found in tendon sheaths, joint cavities and in *bursae*, aiding in the movement and flexibility of the skeletal components.

Muscle Tissue

Muscle tissue consists of cells that contain organized strands of cytoskeletal proteins (*actin* and *myosin*) that have the ability to contract when stimulated. When these proteins contract they exert tension, which transfers as force to some point. Muscles provide motion in the body, maintain posture, and generate the majority of the heat the body requires for homeostasis. There are three distinct types of muscle tissue.

The *skeletal muscle tissue* is the most abundant and extensive, with all being attached directly or indirectly to the skeleton. The original cells merge during embryonic life, creating muscle fibers that are multi-nucleated, with the nuclei forced to the sides of the fiber; the fibers are elongated and have cross bands called striations that reflect the *sarcomere* structure of the actin and myosin. These muscle fibers are capable of generating high force levels under control (quickly or slowly) as required by conscious control of the contraction of the muscle. They are capable meeting energy needs aerobically and anaerobically, but the endurance is limited, as they easily fatigue. Some skeletal muscles contain stored oxygen in *myoglobin* and all fibers store *glycogen*.

Cardiac muscle (myocardium), which is only found in the heart, possesses characteristics similar to skeletal muscle and smooth muscle. Like skeletal muscle, it appears striated, with the contracting elements being organized into sarcomeres. Like smooth muscle, cardiac muscle has a single centrally located nucleus. Unique characteristics of the cardiac muscle are that it is highly branched, being in contact with other cardiac muscle cells with a tight gap junction; the *intercalated disc*, which aids in the spread of the stimulation-triggering contractions; in an involuntary rhythmic fashion (wave-like). The contracting stimulus is generated internal to the heart. This muscle has numerous mitochondria and stores oxygen in myoglobin to produce the energy aerobically for contraction.

Smooth (visceral) muscle is the muscle tissue found in internal structures used to provide motion, change lumens, control bladders, and modify blood pressure. The cells have a central nucleus, lack striations, and contract slowly, so they tend not to become fatigued. The tissue is organized into layers, with all the muscles cells in the layer oriented in the same direction. They are involuntary with the cells responding to local, generalized, specific, and chemical stimulations.

Nervous Tissue

Nervous tissues are composed of two types of cells that are functionally and anatomically different from each other. The *neuron* cells are electrically excitable, having the ability to respond

to a stimulus and generate an action potential to transmit the information to another location. Neurons are composed of a *cell body* (*soma*, *perikaryon*) containing the nucleus and two processes extending from the cell body: *dendrites*, which bring action potentials toward the cell body, and *axons*, which carry action potentials to other locations. Structurally, there are three types of neurons—multipolar, bipolar, and unipolar—while functionally there are those which are sensory, motor, or interneurons. Neurons are incapable of regeneration. The supporting cells in the nervous system are the *neuroglia* (*glial cells*), which perform the function of connective tissues. Glia are capable of regeneration. There are four types found in the brain and spinal cord, and two types found in the rest of the body.

Tissue Repair

Any organ or tissue can be damaged, requiring repair or replacement to restore the body function called healing. In organs, the tissue that carries out the function of the organ is named the *parenchyma*, composed usually of epithelial tissue, most of which is capable of regeneration. The *stroma* is the portion of the organ that provides support and shape, and is usually composed of connective tissue capable of regeneration. To restore the organ's function, the parenchyma tissue must regenerate; if the parenchyma is unable to regenerate, the tissues of the stroma will replace the functional tissue, restoring the organ's shape. This is frequently done by fibroblasts creating collagen and granulations (scars) or adipose tissue. When multiple layers of tissue are damaged, such as in surgery, healing and the development of scarring can tie together layers that usually are free of each other, creating *adhesions*. Healing of damaged tissue requires good nutrition with adequate protein and vitamins, and abundant local blood supply, along with growth hormones. Age slows the healing process, due to available growth hormones to stimulate the regeneration of the tissues