Human Physiology Rapid Learning Series – Master Contents

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Tutorial Series Summary

Core Unit #1 – Basic Cellular Physiology

In this core unit, you will acquire the basic concepts of cellular physiology. With an understanding of cells, cellular interaction and energy production, you will form a strong foundation for the physiology of organized tissues and organ systems.

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Core Unit #2 – Body Control Mechanisms

In this core unit, you will review body control mechanisms. Hormone signaling and hormone targets will be reviewed. Also, you will also learn about the control of the human body from both the central and peripheral system.

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The Brain regions involved in memory
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What the divisions of the Autonomic Nervous System are
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What the Neural Signals used by the Autonomic Nervous System are
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Core Unit #3 – Integration of Body Systems: Movement and Maintenance

In this core unit, you will learn about muscle physiology, the mechanism of skeletal muscle contraction, cardiovascular physiology, the control of blood flow and pressure, and respiratory physiology.

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The Sarcomere
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The Structure and Characteristics of a Skeletal Muscle Fiber
The Mechanics of Body Movement
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The Basic Functions of the Respiratory System
The Mechanics of Breathing
The Principles of Gas Exchange
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How the Respiratory System is Regulated
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Core Unit #4 – Integration of Body Systems: Metabolism

In this core unit, you will learn about the role of the kidneys in acid-base balance and fluid management. Also the digestive tract and metabolism will be covered.

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The Regulation of Urine Concentration and Volume
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Body Fluid Compartments
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Electrolyte Concentration
Glomerulus: Blood Filtration
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Tutorial 19: Digestive Physiology and Nutrition
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The Basic Functions of the Digestive System
The Anatomy, Secretions, Absorption, and Motility of the Digestive Organs
The Anatomy, Function, and Secretions of Accessory organs
How Nutrients are absorbed
The role of Nutrition in Health
The Nutritional Value and sources of the Major Macromolecules
The role of Vitamins and Minerals in Health

Tutorial 20: Energy Balance and Metabolism
Energy Balance and how it occurs in the Body
The Role of Nutrients in Energy Balance
The Determinants of Metabolic Rate
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How Hormones maintain Energy Balance

Core Unit #5 – Integration of Body Systems: Protection and Perpetuation
In this core unit, you will learn about the immune system and reproduction and development.

Tutorial 21: Body's Defenses: The Immune System
Non-specific Immunity: B-Cells
Human Antibodies
Specific Immunity: T-Cells
Immune Responses to Viruses and Bacteria
Allergies and Autoimmune Disease

Tutorial 22: Reproduction and Development
Reproduction and Development
Sex Hormones
Testes and Spermatogenesis
Ovulation and the Corpus Luteum
Pregnancy and Labor

Core Unit #6 – Applications
In this core unit, you will learn about the exercise and medical physiology.

Tutorial 23: Exercise Physiology
Basic training principles
How the muscular and neural systems adapt to exercise
How the cardiovascular system adapts to exercise
How the respiratory system responds to exercise
Metabolism and exercise
Body composition and nutrition in relation to exercise

Tutorial 24: Medical Physiology
Diseases of the cardiovascular system
Diseases of the respiratory system
Diseases of the digestive system
Diseases of the renal system
Diseases of the reproductive system

Diseases of the muscular and skeletal systems
Diseases of the neural and endocrine systems

Tutorial Series Features

This tutorial series is a carefully selected collection of core concept topics in human physiology that cover the essential concepts. It consists of three parts:
Human Physiology Concept Tutorials – 24 essential topics
Problem-Solving Drills – 24 practice sets
Super Condense Cheat Sheets – 24 super review sheets

Tutorials

- Self-contained tutorials…not an outline of information which would need to be supplemented by an instructor.
- Concept map showing inter-connections of new concepts in this tutorial and those previously introduced.
- Definition slides introduce terms as they are needed.
- Visual representation of concepts.
- Conceptual explanation of important properties and problem solving techniques
- Animated examples of processes and cycles in human physiology.
- A concise summary is given at the conclusion of the tutorial.

Problem Solving Drills

Each tutorial has an accompanying Problem Set with 10 problems covering the material presented in the tutorial. The problem set affords the opportunity to practice what has been learned.

Condensed Cheat Sheet

Each tutorial has a one-page cheat sheet that summarizes the key concepts and vocabularies and structures presented in the tutorial. Use the cheat sheet as a study guide after completing the tutorial to re-enforce concepts and again before an exam.

Chapter by Chapter Detailed Content Descriptions

01: Introduction to Human Physiology

Chapter Summary:

The history, scope and methodology of human physiology are introduced. Human Physiology is the study of body function. Physiology and anatomy are interconnected; anatomy describes the location and structure of a particular body part, and physiology describes how and what it does.

Tutorial Features:

Specific Tutorial Features:

- Define the discipline of Physiology.
- Elucidate the connection between anatomy and physiology.
- Review the history and the importance of the major milestones of physiology.
- Demonstrate the relationship between physiology and other disciplines of biology.
- Describe the organization of the human body systems.

Series Features:

- Concept map showing inter-connections of concepts.
- Definition slides introduce terms as they are needed.
- Examples given throughout to illustrate how the concepts apply.
- A concise summary is given at the conclusion of the tutorial.

Key Concepts:

Physiology is the study of body function.
Physiology encompasses organic chemistry, biochemistry and anatomy.
Physiology at the cellular level impacts body organs and body systems.
The history of physiology is described and important milestones detailed.

Chapter Review:

- Physiology is the study of body function. It is the study of the biochemical, physical and mechanical functions of living organisms.
- Physiology is represented in many disciplines, such as Medicine. Physicians are trained in the location and normal function of organs and body systems.
- A related discipline physiology is related to is Biochemistry, the study of cellular interactions and metabolism, etc.
- Human Physiology dates back to at least 420 B.C., during the time of Hippocrates. Industry applications of microbiology: waste management, food industry, mining, medicine, research and biotechnology.
- **Between 380-322 B.C,** Aristotle began thinking critically about the relationship between structure and function, which marks the beginning of the discipline of physiology.
- **Claudius Galenus (126 – 199 A.D.)** was the first investigator of physiology. As an experimentalist, he studied experimental physiology and his theories dominated for over 1000 years.
- **In the 19th century,** the accumulation of physiologic knowledge was rapid. Notable figures include: Matthias and Schwann for the Cell Theory.
- **In 2008,** the Nobel Prize was awarded to 3 investigators for their discovery of the Human Papilloma virus and the Human Immunodeficiency Virus (HIV).
- The human body is made up of 11 body systems. These systems function together to provide the overall normal functioning of the organism.

- The skin is the largest organ of the body, covering the entire surface of the body. The skin provides a protective barrier for the human body, as well as playing a key role in body temperature regulation as part of homeostasis. The skin is divided into 2 layers: the epidermis and the dermis.
- The skeletal system provides the rigid, yet mobile, structure for the human body. It protects the underlying organs and prevents injury to them.
- The muscular system, along with the nerves that supply them, generate motion in arms and limbs.
- The nervous system controls movement and function through nerve impulses sent to and from the brain. The nervous system is divided into the Central Nervous system and the Peripheral Nervous system.
- The Endocrine system is a series of organs or glands spread throughout the body whose effects include the production and release of circulating hormones.
- The cardiovascular system, or circulatory system, is responsible for moving oxygen and carbon dioxide, as well as nutrients and waste products in and out of cells in the body.
- The Lymphatic system is a network through which lymph fluid circulates, providing a filter system for the body.
- The Respiratory system's function is gas exchange, including oxygen uptake and carbon dioxide release in the lungs.
- The Digestive System is responsible for breaking down, digesting and absorbing the food we eat and what we drink.
- The urinary system filters the blood and removes waste and excess water from the bloodstream which, in turn, removes waste and excess fluid from the tissues.
- The Reproductive system, in both males and females, is responsible for reproduction of humans.

Recommendations for Success in Physiology

- Memorize basic information to save time later ,e.g., commonly used terms and concepts, the four tissues, eleven body systems, etc.,
- Learn vocabulary quickly for understanding when it's used later. Make cheat-sheet or flashcards if needed.
- Brush up on your basic biology; don't try to remember every variation of each process.
- Look for the commonalities between processes and functions; don't treat each one as different.
- Typically in science, keyword mnemonics are a great way to memorize what is needed for class.
- Read and master learning objectives laid out in the text book.
- Master definitions presented in the course.

02: Chemical Composition of the Body

Chapter Summary:

In this tutorial the atom and atomic mass are presented, along with the bonds that hold chemical compounds together. Blood pH buffering and acid-base balance is reviewed.

The human body is made up of organs and tissue that include carbohydrates, proteins and lipids. At the smallest level, the body includes atoms and molecules held together by bonds to form larger macromolecules.

Tutorial Features:

Specific Tutorial Features:

- Atoms and Molecules
- Ionic, Hydrogen and Covalent Bonds
- Hydrophobic and Hydrophilic Compounds
- Blood pH Buffering
- Carbohydrates and Lipids
- Proteins and Peptide Bonds
- Structure of DNA and RNA

Series Features:

- Concept map showing inter-connections of concepts.
- Definition slides introduce terms as they are needed.
- Examples given throughout to illustrate how the concepts apply.
- A concise summary is given at the conclusion of the tutorial.

Key Concepts:

Atoms and Molecules
Bonds in Chemical Compounds
   Covalent Bonds
   Ionic Bonds
   Hydrogen Bonds
Blood pH Buffering
   Acidosis
   Alkalosis
Formation of complex Carbohydrates
Categories of Lipids
Proteins and Peptide Bonds
Nucleic Acids

Chapter Review:

Atoms and Molecules

- Atomic nuclei contain protons and neutrons. Each type of atom, or element, has a different number of protons.

- **Atomic Mass** is defined as the total mass of protons, neutrons and electrons. Atomic mass is measured using a technique known as Mass Spectrometry and the following equation: mass contribution = (%abundance) (mass).
- **Atomic Number**: as previously mentioned, the atomic number of an atom is equal to the number of protons.
- **Covalent bonds** are formed when atoms share electrons. They are very strong bonds and are the major type in organic chemicals. When the sharing of the electron is unequal (when electrons spend more time around a particular atom), this is known as a polar covalent bond.
- **Hydrogen bonds** are weak intra- or inter-molecular attractions between molecules with a net dipole.

Blood pH Buffering

- Substances that release ions in water are called electrolytes. Acids release H+ in water and bases release OH– in water that can combine with H+ to form H_20. Strong acids and bases completely dissociate in H_20.
- Carbonic Anhydrase (CA) is an enzyme that catalyzes the conversion of carbon dioxide to bicarbonate and protons. Most body processes produce more acid than base and, therefore, tend to acidify the blood.
- **Acidosis** is an increased in acidity in the blood, defined by a pH below 7.35. There are two form of acidosis: Respiratory acidosis, and Metabolic acidosis.
- **Alkalosis** is an increase in alkalinity of the blood, defined by a pH above 7.45. There are two form of alkalosis: Respiratory alkalosis, and Metabolic alkalosis.

Macromolecules

- Carbohydrates: Carbohydrates are categorized into 3 main forms: monosaccharides, disaccharides and polysaccharides. The functions of carbohydrates include energy usage, energy storage, and building material (e.g., cellulose in plant cell walls); they can also modify other macromolecules (e.g., glycolipids, glycoproteins).
- Lipids are group of fat soluble molecules, such as free fatty acids and cholesterol. Lipid functions include: energy storage, cell membrane components, and steroid hormones. Categories of lipids include: free fatty acids, cholesterol, triglycerides, and phospholipids.
- Proteins are formed by amino acids being linked together and assuming their final conformation. The amino acids are linked together through peptide bonds. Proteins levels of structure are: primary, secondary, tertiary and quaternary.
- **Deoxyribonucleic acid** (DNA) is the blueprint of life, it is present in almost every cell in the body. A copy from a male donor and a copy from a female donor, through fertilization, can create a human being.
- **Ribonucleic acid** (RNA) is usually single-stranded. It is made from a DNA blueprint. RNA translates the message from the DNA to produce the correct protein. The different types of RNA are: (1) Messenger RNA (mRNA), (2) Transfer RNA (tRNA), and (3) Ribosomal RNA (rRNA).

03: Cell Structure and Function

Chapter Summary:

This tutorial reviews the cell structure including the plasma membrane and cell processes. DNA replication and the cell cycle are presented along with RNA transcription and proteins translation.

The cell is surrounded by a protective, functional plasma membrane. The plasma membrane protects the cell, separates it from the interstitial fluid and is involved in cell signaling. Cells must copy their DNA in order to replicate and divide into daughter cells.

Tutorial Features:

Specific Tutorial Features:

- Plasma Membrane, Structure and Function
- Cilia and Flagella
- Phagocytosis, Pinocytosis and Exocytosis
- Transcription: RNA Synthesis
- Protein Translation
- Cell Cycle
- Meiotic Division

Series Features:

- Concept map showing inter-connections of concepts.
- Definition slides introduce terms as they are needed.
- Examples given throughout to illustrate how the concepts apply.
- A concise summary is given at the conclusion of the tutorial.

Key Concepts:

Plasma Membrane and the Phospholipid Bilayer
Amooeboid Movement
Cellular Processes
    Cilia
    Flagella
Phagocytosis
RNA Transcription
Types of RNA
Protein Translation
Cell Cycle Divisions

Chapter Review:

Plasma Membrane

- **Phospholipids** are a type of lipid that make up the majority of mammalian cell membranes. The phospholipids are amphipathic because they have a hydrophobic tail and hydrophilic head group.
- **The plasma membrane** of mammalian cells is also known as the phospholipid bilayer. It is semi-permeable barrier around the outside of the cell and, within its interior, is the cytosol, organelles and nucleus of the cell.
- The plasma membrane's major functions include: Semi-permeable barrier, Anchor for the Cytoskeleton, and Signaling.

- **Amoboid movement** is a complex process, also called cell motility, can be divided into 4 phases: Phase 1: The leading edge of the cell expands, known as a lamellipod, Phase 2: formation of attachment points, or focal complexesare, Phase 3: Actin-myosin contractile forces provide the power for cell motility, and Phase 4: the integrin attachment points at the rear of the cell must be detached.
- **Hydrogen bonds** are weak intra- or inter-molecular attractions between molecules with a net dipole.

Cell Processes

- **Cilia** are tail-like projections, which extend approximately 5-10 microns from the cell body. Motile cilia are usually found in large numbers, beating together in waves.
- **Flagella** are tail-like structures that project from the cell body of certain cells, such as a sperm cell. The flagella itself is made up of a series of paired microtubules.
- Phagocytosis is a form of endocytosis where portions of the cell or an entire cell, such as a bacterium, are engulfed. Phagocytes, such as macrophages and neutrophils, perform this function regularly as part of an immune response.
- Exocytosis is a process used by cells to deliver materials to the extracellular fluid, as well as membrane proteins, to be incorporated into the plasma membrane.

Transcription and Translation

- The cell nucleus is usually near the center of the cell; it contains the majority of the genetic material in cells. Within the nucleus, the DNA is compacted and organized into chromosomes.
- Genes drive protein synthesis in the following manner: DNA is transcribed into RNA, and then RNA is translated into proteins. RNA is produced by an enzyme known as RNA Polymerase.
- There are three types of RNA: (1) Ribosomal RNA (rRNA), Transfer RNA (tRNA), and Messenger RNA (mRNA).
- **Protein translation** is the process by where amino acids are assembled into a polypeptide chain or protein, based on the DNA code.

Cell Cycle Division

- DNA replication must take place in order for a cell to divide during mitosis. During DNA replication, the parental DNA is separated and each parent strand acts as a template for the formation of a new complementary strand.
- The cell cycle is a series of events that takes place before the cell divides, during mitosis (M phase). There are regulatory molecules, such as cyclins and cyclin-dependent kinases, which determine a cell’s progression through the cell cycle. The cell cycle is divided into 4 phases: G_1, S, G_2 and M.
- Meiotic cell division and Mitotic cell division have a lot in common, although there are some key differences between these two processes. One way that these two processes are different is in the amount of DNA in the offspring cells. At the end of mitosis, each daughter cell has a total of 46 chromosomes whereas, at the end of meiotic cell division, each gamete has a total of 23 chromosomes.

04: Enzymes and Energy

Chapter Summary:

This tutorial reviews biochemical reactions including enzymatic action. Factors that effect enzyme function and the role of enzymes in metabolism are covered.

Enzymes perform unfavorable reactions by lowering the energy of activation. This unique class of proteins, convert reactants into products at a very fast rate over long periods of time. Enzymes play a major role in converted the food we eat into usable energy for cells of the body.

Tutorial Features:

Specific Tutorial Features:

- Enzymes as Catalysts
- The energy of activation
- The effects of pH and Temperature on Enzymes
- Metabolic Pathways: Cooperative Enzyme Function
- ATP Production
- Oxidation and Reduction
- The Role of NAD and FAD

Series Features:

- Concept map showing inter-connections of concepts.
- Definition slides introduce terms as they are needed.
- Examples given throughout to illustrate how the concepts apply.
- A concise summary is given at the conclusion of the tutorial.

Key Concepts:

Principles of Catalysis
Effects of Temperature and pH on Enzymes
Law of Mass Action
Metabolic Pathways
    Enzyme Cooperation
    End-product Inhibition
    Endergonic and Exergonic reactions
Role of NAD and FAD in ATP Production

Chapter Review:

Enzymes and Catalysis

- **Catalysts** are molecules or substances that effect the conversion of reactants to reaction products. By interacting with one or more of the reactants, catalysts provide an alternative reaction pathway. Catalysts themselves are not altered or consumed during the reaction.
- Most biochemical reactions are catalyzed by enzymes. For reactants to form products, a certain input of energy is necessary to get things going. This energy is called the energy of activation. Enzymes function as catalysts by lowering the Energy of activation (Ea), but they do not change the Gibbs free energy (ΔG).
- The International Union of Biochemistry and Molecular Biology has developed a nomenclature for enzymes and categorized them into 6 broad classes.

- Enzymes can perform many reactions in a short amount of time, up to millions per second. The optimal pH for most enzymes in human cells is around 7. The point at where enzyme activity begins to decrease is the optimal temperature.
- **Cofactors** are usually non-protein chemicals that are used by an enzyme during the reaction.
- **The Law of Mass Action** states that the rate of a given chemical reaction is proportional to the product of the concentration of the reactants. The Michaelis-Menten equation, which allows one to calculate the maximal enzyme rate for a given reaction, is based on this law.

Metabolic Pathways

- A metabolic pathway is a series of chemical reactions that convert an initial molecule into a final product. At each step in the pathway, an enzyme uses the product from the previous reaction, as its substrate.
- The regulation of metabolic pathways includes **end-product inhibition**. This involves a product of a metabolic pathway or cycle, inhibiting an upstream enzyme.
- Inborn errors of metabolism are a group of genetic inherited diseases, in which a defective gene produces an enzyme that doesn't perform its intended chemical reaction.
- **Exergonic reaction** is characterized by a ΔG less than 0 - in other words, a favourable, spontaneous reaction.
- **Endergonic reaction** is characterized by a ΔG greater than 0; the reaction is unfavourable and it takes more energy to start the reaction than it yields.
- **Reaction at Equilibrium** when ΔG is equal to 0, the reaction is at equilibrium.

Role of NAD and FAD in Energy Production

- **Adenosine-5'-triphosphate (ATP)** is the form in which energy is stored inside cells; it is the "energy currency". ATP is produced during metabolic reactions, as well as through the electron transport chain.
- While there is some ATP production during glycolysis, the majority of the cell's ATP is produced through oxidative phosphorylation and the electron transport chain.
- **Nicotinamide Adenine Dinucleotide (NAD)** is a coenzyme found in cells that is active in metabolism and ATP production. It is produced by cells to function in enzymatic reactions. Specifically, NAD is utilized as part of the Krebs cycle and during ATP production via the electron transport chain.
- **Flavin Adenine Dinucleotide (FAD)** is a redox cofactor that is involved in metabolic reactions. This molecule is derived from vitamin B12 (riboflavin). FAD, similar to NAD, can exist in two states, oxidized and reduced. The $FADH_2$ form is an energy carrying one and, therefore, can be utilized during oxidative phosphorylation.

05: Cellular Respiration and Metabolism

Chapter Summary:

Glycolysis and the other metabolic pathways and cycles are presented in this tutorial. The formation of ATP to meet the energy needs of the cell is reviewed, along with storage of excess nutrients as glycogen.

Cells take up micronutrients from the interstitial fluid and utilize them for function and cell viability. Within cells there is a vast network of enzymes functioning together to facilitate the conversion of these micronutrients into ATP for cellular energy usage.

Tutorial Features:

Specific Tutorial Features:
- Metabolism: Glycolysis
- Gluconeogenesis and the Cori Cycle
- Aerobic Respiration and the Krebs Cycle
- Aerobic and Anaerobic ATP Production
- Glycogenolysis, Lipolysis and β-Oxidation
- Oxidative Deamination and Transamination

Series Features:
- Concept map showing inter-connections of concepts.
- Definition slides introduce terms as they are needed.
- Examples given throughout to illustrate how the concepts apply.
- A concise summary is given at the conclusion of the tutorial.

Key Concepts:

Metabolism and Glycolysis
The Krebs Cycle
ATP Production
   Aerobic Conditions
   Anaerobic Conditions
Metabolism of Glycogen and Fat
Oxidative Deamination and Transamination
Organ Energy Preferences

Chapter Review:

Metabolism and Glycolysis

- Metabolism is the catalytic breakdown of the products of digestion to provide nutrients for the cells of the body.
- **Glycolysis** is a series of 10 steps with reactions that convert glucose into pyruvate. During the process of these reactions, ATP is produced and the coenzyme NADH is produced. The end-product, pyruvate, is used as a substrate to begin the Krebs cycle.
- After glycolysis is complete, from a single glucose, there is a net gain of 2 molecules of ATP and 2 molecules of NADH.
- The human body can benefit from the lactic acid that is produced during strenuous exercise in the following ways: (1) Cori cycle and (2) during the conversion of pyruvate into lactate, NAD+

is generated. This coenzyme can participate in redox reactions during glycolysis to contribute to the production of ATP.

- Gluconeogenesis is the process used primarily by the liver to convert pyruvate from the Cori cycle into glucose. This occurs during states of low blood sugar, such as fasting or intense exercise.

The Krebs Cycle

- The **Krebs cycle** is also known as the Citric Acid Cycle and the Tricarboxylic Acid Cycle. This cycle converts Acetyl CoA into a reaction net of: 2 GTP, 6 NADH, 2 FADH2 and 4 CO2 (from 2 turns, 2 Acetyl CoA from each glucose).
- The Krebs cycle has major metabolic pathways that converge on it: protein catabolism and fat metabolism.
- The Krebs Cycle contributes the coenzymes NADH and FADH2 for redox reactions during electron transport chain function. These molecules also participate in the pumping of H+ out of the mitochondria matrix and into the intermembrane space.

ATP Production

- While there is some ATP production during glycolysis, the majority of the cell's ATP is produced through oxidative phosphorylation and the electron transport chain.
- The potential energy is used by an enzyme, known as ATP Synthase, to generate ATP from the phosphorylation of ADP.
- The amounts of ATP, coenzymes, and the energy produced/consumed are different, depending on whether the cell is under aerobic or anaerobic conditions. Initially, a cell may be performing aerobic respiration but, as oxygen levels decrease, it will switch to anaerobic respiration.

Metabolism of Glycogen and Fat

- **Glycogen** is a polysaccharide of glucose used as a energy storage from by the liver and skeletal muscles. This is a short energy reserve that can be mobilized quickly. When muscle or liver cells need quick energy, they can breakdown their glycogen storage into glucose, a process called glycogenolysis.
- **Lipolysis** is the breakdown of fat into glycerol and free fatty acids, which eventually are converted into Acetyl-CoA (β-oxidation). **β-Oxidation** is the process of converting the Acyl-CoA from fatty acid metabolism into Acetyl-CoA, a Krebs cycle substrate.
- Amino acids can be degraded and used as intermediates in energy production. This is accomplished by the **deamination and transamination** of certain amino acids into glutamate and α–ketoglutarate.
- Different organs in the body have different preferred energy sources, for example the brain is an obligate glucose consumer; it utilizes 25-50% of the glucose circulating in the blood.

06: Tissues and Organ Systems

Chapter Summary:

This tutorial reviews the cell structure including primary tissue types. The 11 body organ systems and their function as covered.

Cells in the human body are organized into tissues and organ systems. The organ systems perform all the major functions of the body and each organ system has independent functions that also impact the body as a whole.

Tutorial Features:

Specific Tutorial Features:
- The Four Primary Tissues
- Different forms of Epithelial, Connective, Muscle and Nervous Tissue
- Extracellular and Intracellular Compartments
- Fluid Exchange between Compartments
- Organ Systems of the Human Body

Series Features:
- Concept map showing inter-connections of concepts.
- Definition slides introduce terms as they are needed.
- Examples given throughout to illustrate how the concepts apply.
- A concise summary is given at the conclusion of the tutorial.

Key Concepts:

Four Primary Tissues
Body Fluid Compartments
  Intracellular
  Extracellular
Organ Systems of the Human Body

Chapter Review:

Four Primary Tissues
- Cells are organized into tissues within the human body and, together, tissues make up body organs. Histology is the study of tissue, and histopathology is the study of diseases in certain tissues.
- **Epithelial tissue** is made of different cell types organized into a sheet with one or more layers. An epithelium consists mostly of cells with little extracellular material between adjacent plasma membranes. Epithelium, as a primary tissue comes in 3 main forms – simple, glandular, and stratified.
- **Connective tissue** is the most abundant body tissue. It consists of cells and a matrix of ground substance and fibers. Connective tissue has abundant matrix with relatively few cells. Connective tissue is divided into 3 main categories – connective tissue proper, embryonic connective tissue and specialized connective tissue.
- **Muscle tissue** generates the force used by the axial skeleton for movement. Through the attachment on bones and lever action, muscle provides for movements of limbs and the head

and neck. Muscles also make up the walls of organs, which allow those organs to contract and perform their function. Muscle tissue exists on 3 forms: skeletal, smooth, and cardiac.
- **The nervous system** is composed of neurons (nerve cells) and neuroglia (protective and supporting cells). Neuroglia are found in the central and peripheral nervous system.

Body Fluid Compartments
- The human body contains a very large volume of fluid. Body fluids are dilute watery solutions found in and around cells. These are divided into intracellular and extracellular fluids.
- **Intracellular fluid** is of the utmost importance to the cell; in it are the nutrients, electrolytes and components necessary for cell division and viability.
- **The extracellular fluid** compartment includes the interstitial fluid (which is between the cells themselves) and the blood plasma.
- Water moves freely between the intracellular fluid (ICF) and extracellular fluid (ECF) compartments; this movement is governed by hydrostatic pressure and osmotic pressure.

Organ Systems of the Human Body
- **The Integumentary system** includes the skin, hair and nails. The skin is the largest organ of the body, covering the entire surface of the body.
- **The skeletal system** provides the rigid, yet mobile, structure for the human body. It protects the underlying organs and prevents injury to them.
- **The muscular system,** along with the nerves that supply them, generate motion in arms and limbs.
- **The nervous system** controls movement and function through nerve impulses sent to and from the brain.
- **The endocrine system** is a series of organs or glands spread throughout the body whose effects include the production and release of circulating hormones.
- **The cardiovascular system**, or circulatory system, is responsible for moving oxygen and carbon dioxide, as well as nutrients and waste products in and out of cells in the body.
- **The Lymphatic system** is a network through which lymph fluid circulates, providing a filter system for the body. **The Immune system** uses lymphocytes and antibodies to defend against invading organisms.
- **The Respiratory system's** function is gas exchange, including oxygen uptake and carbon dioxide release in the lungs.
- **The Digestive System** is responsible for breaking down, digesting and absorbing the food we eat and drink.
- **The urinary system** filters the blood and removes waste and excess water from the bloodstream which, in turn, removes waste and excess fluid from the tissues.
- **The Reproductive system,** in both males and females, is responsible for reproduction of humans.

07: Endocrine System Physiology

Chapter Summary:

The hormones of the endocrine system, the glands that produce them and their targets re presented.

Hormones exert their function by binding to or entering the target cell and inducing intracellular signaling. Signaling inside cells involves second messengers and intracellular signaling cascades.

Tutorial Features:

Specific Tutorial Features:

- Hormones: categories and mechanisms of action
- Hormone-Induced Second Messengers
- Cyclic Adenosine Monophosphate as a Second Messenger
- Calcium as a Second Messenger
- Protein Phosphorylation and Dephosphorylation
- Endocrine organs: location and function
- Autocrine and Paracrine Signaling

Series Features:

- Concept map showing inter-connections of concepts.
- Definition slides introduce terms as they are needed.
- Examples given throughout to illustrate how the concepts apply.
- A concise summary is given at the conclusion of the tutorial.

Key Concepts:

Chemical classes of Hormones
- Amine Hormones
- Peptide Hormones
- Lipid Hormones

Hormone Mechanisms
- Signal Transduction
- Second Messengers

Endocrine Organs
Hormone Feedback
Autocrine and Endocrine Signaling

Chapter Review:

Chemical Classes of Hormones

- **Hormones** are chemicals that are produced in one cell type and then travel some distance and affect their target cells. Hormones can be broken down into 3 major categories: (A) Amine, (B) Peptide hormones, and (C) Lipid hormones.
- **Amine hormones**, this class of hormones are derivatives of ammonia, with various functional groups.
- **Peptide hormones** are hormones that are synthesized from amino acids. Like most proteins, they are processed in the endoplasmic reticulum, including glycosylation.

- **Lipid hormones, m**ost lipid hormones are derivatives of cholesterol, in a process called steroidegenesis. This is a multi-step process that leads to the formation of various hormones.
- Hormones can travel free in the plasma. Examples include peptide hormones and those from the amine class. Hormones can also travel, bound to carrier proteins, such as serum albumin.

Hormone Mechanisms

- Steroid hormones enter the target cell by diffusing through the cell membrane. Once inside the cytoplasm, they bind to a hormone receptor. Next, the steroid-receptor complex translocates to the nucleus. This complex then binds to a specific region of DNA and, in turn, affects gene expression, leading to protein translation.
- Thyroid hormones enter the cell via a carrier-mediated mechanism. Thyroid hormone transporters at the cell membrane transport both thyroxine (T4) and triiodothyronine (T3) into the cytoplasm.
- Once inside the cell, most of the thyroxine undergoes conversion to triiodothyronine. The converted hormone can then move into the nucleus and affect gene expression and eventually, protein translation.
- Hormone signaling involves the transduction of the extracellular hormone signal into an intracellular signal.
- Cyclic adenosine monophosphate (cAMP) is involved in signal transduction for blood sugar regulation and lipid metabolism.
- Calcium can function as a second messenger in intracellular signaling cascades, triggered by hormones.

Endocrine Organs

- The Hypothalamus-Pituitary system is the master control center of endocrine physiology. Hormones and signals from the hypothalamus drive pituitary hormone secretion. The hypothalamus and pituitary gland directly share a local blood supply. Releasing or inhibiting hormones from the hypothalamus can enter the median eminence, which it shares with the pituitary gland.
- The thyroid gland produces thyroxine (T4) and Triiodothyronine (T3). The element Iodine is critical to the production of thyroxine.
- On the posterior surface of the thyroid gland, there are 4 or more small glands known as the parathyroid glands. The parathyroid glands produce Parathyroid Hormone (PTH).
- The Adrenal glands are located on top of the kidneys; they receive their own blood supply and are divided into 2 regions – the adrenal cortex and adrenal medulla.
- The Thymus is located in the chest just behind the sternum. The thymus is involved in immune function and the development of T-cells. The Thymus hormones include thymopoietin and thymosin.
- The Pancreas is a gland contained within the digestive system. It is physically attached and communicates with the small intestine. The pancreas is unique, in that it has both endocrine and exocrine capabilities.
- The gonads (ovaries and testes) are the endocrine glands responsible for the development of men and women, through the sex hormones Testosterone and Estradiol.
- Estrogen is produced by the granulosa cells in the ovary, and its levels in the blood have a negative feedback on the hypothalamus-pituitary system.

Hormone Signaling Methods

- In **Autocrine signaling,** the hormone is secreted, binds to receptors on and affects the same cell.
- In **Paracrine signaling,** the hormone is released from a cell and the target for that hormone is near.
- **Endocrine signaling** is when the target cell is some distance away from the hormone-producing cell.

08: Neuronal Structure and Signaling

Chapter Summary:

This tutorial reviews the structure of the nervous system, including the structure and classes of neurons.

Neurons are unique, excitable cells that transmit impulses and direct target cell function. The brain and spinal cord process and transmit impulses to the peripheral nervous system for function.

Tutorial Features:

Specific Tutorial Features:

- Neurons: Structure, components and classes of neurons.
- Function of the Soma, Axon and Dendrites
- Neurolemma and myelin sheath
- Peripheral Nerve Regeneration
- Blood-Brain Barrier
- Action potentials
- Resting Membrane Potential
- Phases of an Action Potential
- Chemical Synapses and Neurotransmitters
- Synaptic Plasticity
- Synaptic Integration

Series Features:

- Concept map showing inter-connections of concepts.
- Definition slides introduce terms as they are needed.
- Examples given throughout to illustrate how the concepts apply.
- A concise summary is given at the conclusion of the tutorial.

Key Concepts:

Structure of a Neuron
Classes of Neurons
The Neurolemma and Myelin Sheath
Action potentials
Chemical Synapses and Neurotransmitters
Synaptic plasticity
Synaptic integration
    Long-term potentiation

Chapter Review:

Neurons

- Neurons have a unique anatomy that facilitates their function within the nervous system. The soma or nerve cell body is the center of the neuron and it contains a nucleus and other organelles.
- **Dendrites** exist in many branches and make up a dendritic tree around the neuron soma. This is in the afferent region of the neuron where the majority of information flows into the neuron cell body.

- **The axon** is the cable-like projection that travels between the soma of a neuron and the dendrites of the next neuron. Axons contain microfilaments and microtubules, which are involved in vesicle traffic along the axon.
- Neurons can be classified based on cell polarity. There are 3 main types: (A) unipolar, (B) bipolar and (C) multipolar. Neurons can be also be classified based on function, such as the direction in which information is transmitted. Excitatory neurons activate or excite their target. Examples include spinal neurons, which synapse onto muscle cells. Inhibitory neurons inhibit or block the output of their targets. Interneurons are usually inhibitory in their action.

Neurolemma and Myelin Sheath

- The **Neurolemma** is the outermost layer of Schwann cells that surround the axon of neurons in the peripheral nervous system.
- The presence of the neurolemma or Schwann cell layer around axons permits neuronal repair within the peripheral nervous system.
- The passage of ions, nutrients and pharmaceutics into the brain and spinal cord (CNS) is severely restricted by the **Blood-Brain barrier.**

Action potentials

- The -60 to -90mV potential difference across the membrane of excitable cells is the resting membrane potential.
- An **action potential** is defined as a change in the membrane potential of an excitable cell, followed by a return to its resting membrane potential.
- The phases of an action potential include: (1) Resting state, (2) Depolarizing phase: If the there is a large enough depolarization of the resting membrane, sodium and potassium channels open, (3) Repolarizing phase: After the peak of the depolarization, the voltage-gated Na+ ion channels begin to close and, therefore, less Na+ ions enter the cell, (4) Undershoot phase: The undershoot or hyperpolarization, and (1) Return to resting state.

Chemical Synapses and Neurotransmitters

- The majority of synapses are made up of axons and dendrites, but there are other types including: axon-cell body, dendrite-dendrite. Initially, the action potential reaches the synapse. This leads to the opening of voltage-gated calcium channels.
- After the neurotransmitter binds to the receptor and is released, it can be taken up again by the presynaptic cell, bind more receptors or undergo enzymatic degradation.
- There are 3 major types of neurotransmitters: (A) amino acids, (B) monoamines and (C) peptides. Neurotransmitters can be excitatory or inhibitory, and this depends on the type or receptor that binds them.
- **Acetylcholine** is a unique neurotransmitter that is used in both the peripheral and central nervous system. Acetylcholine exerts its stimulation effects, in part, by blocking the passage of K+ ions.
- **Excitatory postsynaptic potentials (EPSP)** represent a temporary membrane depolarization of a post-synaptic cell.
- An **inhibitory post-synaptic potential (IPSP)** occurs due to the activation of inhibitory neurotransmitter receptors.

Synaptic Plasticity and Integration

- **Synaptic plasticity** is defined as the potential a synapse between 2 cells has, to change in the strength of the interaction.
- In spatial summation, two separate inputs arrive simultaneously and are added together.
- In temporal summation, multiple inputs arrive simultaneously, either from the same cell or separate cells. These inputs are also added together.
- Long-term potentiation is defined as the persistent enhancement of the post-synaptic potential response. It was first discovered in the hippocampus region of the brain and is believed to be involved in learning and long-term memory.

09: The Central Nervous System

Chapter Summary:

The anatomy and organization of the human brain is presented in this tutorial. The discussion of the central nervous system is completed with the spinal cord and tracts.

The brain is the master control center of the human body. Along with the spinal cord, control of body functions, actions and movements take place.

Tutorial Features:

Specific Tutorial Features:

- The Brain: regions and organization
- The Sensory Cortex
- The Motor Cortex
- The Right and Left Hemispheres
- Lateralization of Speech
- The Limbic System
- The Brain regions involved in memory
- Sensory Memory, Short-Term Memory, and Long-Term Memory
- Midbrain, Hindbrain and Medulla Oblongata
- The Spinal cord: motor tracts, the reflex arc

Series Features:

- Concept map showing inter-connections of concepts.
- Definition slides introduce terms as they are needed.
- Examples given throughout to illustrate how the concepts apply.
- A concise summary is given at the conclusion of the tutorial.

Key Concepts:

Brain regions and Organization
  Lobes of the Brain
  Motor Cortex
  Sensory Cortex
Brain Laterilzation
Memory
  Sensory
  Short-term
  Long-term
The Spinal Cord

Chapter Review:

Brain Regions and Organization

- The human brain is organized into 2 hemispheres and each hemisphere if further divided into a number of lobes: (A) Frontal, (B) Temporal lobe, (C) Parietal lobe and (D) Occipital lobe.
- **The cerebellum** is part of the hindbrain (little brain); it is located underneath the occipital lobes. The cerebellum is a signal integration center.
- **The sensory cortex** is a term used to describe all the sensory areas in the brain. The areas include: somatosensory cortex, visual cortex, auditory cortex, olfactory cortex (smell) located in the temporal lobe, and the gustatory cortex (taste) in the parietal lobe.

- **The motor cortex** includes: primary motor cortex, posterior parietal cortex, premotor cortex, and the supplementary motor cortex. The primary motor cortex is responsible for the signals to execute movement.
- The left and right hemispheres of the brain are separated by a longitudinal fissure. There is a lateralization or dominance of function in the human brain. Certain functions, such as which hand we write with, are driven predominantly from one hemisphere of our brain.
- It has been estimated that approximately 70% of individuals have speech lateralized to the left hemisphere.
- The limbic system involves a number of structures and functions to produce emotion, behavior, memory and olfaction (smell).
- Aphasia results from brain damage to key areas involved in speech and language.

Memory

- Studies on human memory have revealed certain brain regions that are involved in learning and storing memories. These brain regions include: the hippocampus, the amygdala, the striatum, and the mammillary bodies.
- **Sensory memory** is defined as a "sense" or perception of something that was just presented.
- **Short-term memory** allows the recall of information for a few minutes or up to an hour or more. There is evidence to suggest that short-term memory involved changes in electrochemical events, as opposed to structural changes in the brain.
- **Long-term memory** provides recall of information for years. The hippocampus region of the brain is required for both learning and the conversion of information from short-term memory to long-term memory.

The Spinal Cord

- **Midbrain –** this brain region includes the following key structures: cerebral peduncles, colliculus, substantia nigra and the red nucleus.
- **Hindbrain –** is made up of the pons and the medulla oblongata. These two brain structures contain cranial nerves and make up the fourth ventricle.
- The spinal cord is a long, thin (1inch) collection of nerves from the brain that extends to approximately the 2nd lumbar vertebra. The spinal cord is made up of grey matter, which contains nerve cell bodies and blood supply, and the white matter. The white matter contains bundles of nerve fibers that travel within the spinal cord, known as ascending and descending tracts.
- The descending tracts convey impulses from the brain into the spinal cord grey matter and then out to the periphery.
- **The Pyramidal (Corticospinal) Motor tracts c**onduct motor impulses from the motor areas of the brain to the efferent neurons which, in turn, lead to voluntary movement.
- **The reflex arc** is a multi-neuron conduction pathway, including a receptor, sensory neuron, interneuron or center, efferent or motor neuron and the effector, such as a muscle.

10: The Autonomic Nervous System

Chapter Summary:

This tutorial reviews the autonomic nervous system, including its location and function in the body.

The autonomic nervous system is in control of unconscious processes such as heart rate and breathing. The automatic processes controlled by this branch of the nervous system integrate sensory information into its functions.

Tutorial Features:

Specific Tutorial Features:

- The role of the Autonomic Nervous System
- How the Autonomic Nervous System relates to the entire Nervous System
- What organs and tissues the Autonomic Nervous System controls
- What the divisions of the Autonomic Nervous System are
- Comparison of the Sympathetic and Parasympathetic Divisions
- Where the Autonomic Nervous System is located
- Two-Neuron Pathways
- What the Neural Signals used by the Autonomic Nervous System are
- Dual Innervation

Series Features:

- Concept map showing inter-connections of concepts.
- Definition slides introduce terms as they are needed.
- Examples given throughout to illustrate how the concepts apply.
- A concise summary is given at the conclusion of the tutorial.

Key Concepts:

Autonomic Nervous System
   Sympathetic Divisions
   Parasympathetic Division
The Efferent system
    Neuronal Signals
Two-Neuron Pathways
Autonomic Nervous System Neurotransmitters

Chapter Review:

Autonomic Nervous System

- The **autonomic nervous system** regulates homeostasis throughout the body, including oxygen levels, blood pressure, and heart rate.
- Sensory information enters the central nervous system for organs under the regulation of the autonomic nervous system.
- **The sympathetic** branch is known as the "Fight or Flight" response and becomes more active during stress. When activated, the sympathetic nervous system acts primarily on the cardiovascular system through epinephrine and norepinephrine.
- **The parasympathetic** branch nervous system is known as the "Wine and Dine" or "Rest and Digest" system. It functions by decreasing the heart rate, increasing glandular activity, and increasing intestinal activity for digestion and absorption.

- **The enteric division** of the autonomic nervous system is located completely within the gastrointestinal tract, although it does receive signals from the brain. It has both sensory and motor components whose activities it can coordinate with minimal input from the central nervous system.
- The sympathetic division is primarily located in the Thoracolumbar region of the spinal cord. The parasympathetic division is primarily located in the Craniosacral region of the spinal cord.

The Efferent system of the Autonomic Nervous System

- Unlike the somatic nervous system, in which one long neuron reaches the target tissue from the spinal cord, two neurons are required for the autonomic nervous system.
- The first neuron is known as the Pre-ganglion Neuron. This neuron will release a signal, a neurotransmitter which activates the second neuron, known as the Post-Ganglion neuron. The post-ganglion neuron then releases a neurotransmitter which affects the effector organ.
- Neuronal signals in the Sympathetic Branch. Pre-ganglion neurons in the Sympathetic Branch are short. In fact, they synapse with the post-ganglion neurons in a region very close to the spine, known as the sympathetic chain.
- The parasympathetic branch arises in the craniosacral region of the spinal cord and has long pre-ganglionic neurons.

Autonomic Nervous System Neurotransmitters

- The sympathetic division uses the neurotransmitter norepinephrine. The signal that causes activation of most organs leads to the adrenal gland release of norephinephrine and epinephrine.
- The parasympathetic division uses the neurotransmitter acetylcholine. Its function includes, most frequently, opposing effects of norepinephrine.
- Most of the major organs of the body receive projections from the sympathetic and parasympathetic divisions, known as dual innervation. Each system is "on" or active when needed and, at the same time, will inhibit or shut down the opposing system.

11: Sensory Physiology

Chapter Summary:

This tutorial reviews the major senses, and presents the mechanisms from the sensory receptor to the brain for decision making and interpretation.

Each of our senses has a wide variety of stimuli to trigger a response, which affords us a tremendous variety to our sense of sight, smell and taste.

Tutorial Features:

Specific Tutorial Features:

- Sensory Physiology: Sensory Receptors
- Functional Categories of Sensory Receptors
- Law of Specific Nerve Energies
- Receptive Fields
- Gustatory and Olfactory Cells
- Taste Neural Pathway
- Smell Receptor Pathway
- Inner Ear and Hearing
- Inner Ear Ossicles
- The Eye and Neural Pathways of Vision
- The Retina
- Disorders of the Visual System
- Rod and Cone Cells

Series Features:

- Concept map showing inter-connections of concepts.
- Definition slides introduce terms as they are needed.
- Examples given throughout to illustrate how the concepts apply.
- A concise summary is given at the conclusion of the tutorial.

Key Concepts:

Sensory Receptors
  Tonic and Phasic Adaptation
  Receptive Fields
Cutaneous Receptors
Gustatory Cells
Olfactory Cells
Inner Ear and Hearing
The Eye and Vision

Chapter Review:

Sensory Receptors

- Sensory receptors are the initial component of our sensory systems, such as touch and vision. They respond to a stimulus and perform sensory transduction.
- Sensory receptors have been categorized based on their function. Each functional category has a unique location and role in sensory physiology. Functional categories include: (1) Photoreceptors, (2) Baroreceptors, (3) Thermoreceptors, and (4) Osmoreceptors.

- **Tonic Receptors** adapt slowly to the stimulus and, therefore, produce and transmit action potentials over a period of time.
- **Phasic Receptors** react and adapt quickly to the stimulus and do not produce action potentials over time after a single stimulus.
- **The law of specific nerve energies** states that the pathway over which nerve energy flows is more important than the origin, with respect to the nature of perception.
- **The receptor generator potential** is defined as: the response a sensory nerve cell has to stimulation at the receptor, whose change in membrane potential is proportional to the strength of the stimulus.
- The receptive field of a sensory neuron is the physical region of space where a stimulus must occur to trigger that neuron to fire.
- **In lateral inhibition**, an excited neuron inhibits a neighboring neuron. This process allows, for example, our eyes to provide sharp visual responses.

The Senses

- The skin contains more than 4 types of sensory receptors, they each function slightly different. These receptors allow human hands to be very dextrous and highly functional. The types are: Meissner's corpuscles, Merkel's Disc, Pacinian Corpuscles, and Ruffini's Endings.
- The human taste, or gustatory system, is a system based on chemoreception. This system detects the flavors of food and drinks. Taste buds, spread along the tongue, allow us to taste: (A) Sweet – near the tip of the tongue, (B) Salty – directly behind the sweet stating region, (C) Sour – at the sides of the mouth and (D) Bitter – across the back of the tongue.
- The human sense of Olfaction (smell) is based on olfactory receptors detecting odorants, which are dissolved in the overlying mucous membrane. Odorants are introduced to the olfactory system through normal breathing, eating and sniffing.
- The vestibular apparatus functions with the inner ear components of hearing. The vestibular apparatus detects angular and linear accelerations of the head.
- The outer ear includes the pinna, external auditory meatus, and the auditory canal. The middle ear is separated from the outer ear and the outside world by the tympanic membrane (eardrum). The inner ear ossicles are the malleus, incus and stapes. These 3 small bones transmit vibrations from the eardrum to the cochlea.
- The human eye detects light and transmits nerve impulses along the optic nerve to the visual area of the brain in the occipital lobe. The trichromatic theory of Color Vision was first proposed by Thomas Young. The theory states that color vision in humans is possible because of three different groups of photorecpetors in the retina. There are 3 types of cones whose pigments have increased absorption for blue, green or red light. This theory is based on the premise that any color is a mixture of blue, green and red.

Disorders of Vision

- **Myopia or (nearsightedness)**: In this disorder, the image focus is in front of the retina, either due to an eyeball that is too long or a cornea that is too steep. This is corrected by wearing a concave corrective lens in front of the affected eye; this helps to move the focal plane on the retina.
- **Hyperopia or (farsightedness):** is caused by an eye ball that is too short or when the lens of the eye can't round up enough. This is corrected by wearing a convex corrective lens in front of the affected eye; this helps to move the focal plane on the retina.
- **Astigmatism** is a disorder that occurs when there is an irregularity in the surface of the cornea or lens. This can also be corrected with glasses or corrective eye surgery.

12: Muscle Physiology

Chapter Summary:

The major types of muscle and their functions are presented in this tutorial. Also, a detailed discussion of skeletal muscle fibers and filaments is included.

Muscle tissue performs work using bones as levers. Muscle performs key functions such as mobility, pumping of blood and vascular resistance.

Tutorial Features:

Specific Tutorial Features:

- The basic structure of Skeletal Muscle
- The Sarcomere
- Muscle Twitch and Tension
- The Classification of Skeletal Muscle
- The Structure and Characteristics of a Skeletal Muscle Fiber
- The Mechanics of Body Movement
- Isometric and Isotonic contractions
- Concentric and Eccentric Actions
- The Basis of Levers
- Skeletal Muscle Disorders
- Structure of Smooth Muscles
- Preview of Cardiac Muscle
- Comparison of Muscle Types

Series Features:

- Concept map showing inter-connections of concepts.
- Definition slides introduce terms as they are needed.
- Examples given throughout to illustrate how the concepts apply.
- A concise summary is given at the conclusion of the tutorial.

Key Concepts:

Muscle Types
The Structure of skeletal muscle
  Myofibril
  Sarcomere
  Muscle Twitch
Body Movements
Smooth and Cardiac Muscle

Chapter Review:

Muscle Types

- There are three types of muscles: (1) Skeletal muscles, (2) Smooth muscles and (3) Cardiac muscle which is found only in the heart.
- **Skeletal muscle** is multinucleated, striated, and arranged in long fibers. The skeletal muscles use bones and ligaments as levers to generate the power stroke of movement.

- **Smooth muscle** has a single nucleus, is non-striated, and is arranged into spindle-shaped cells. Smooth muscles are under involuntary control from the nervous system. They provide key system functions, such as the regulation of blood pressure.
- **Cardiac muscle** is striated and made up of branched cells connected through Intercalated discs. Cardiac muscle is unique to the heart and provides the pumping action of the heart to move the blood through the circulatory system.

The Structure of Skeletal Muscle

- Skeletal muscle makes up the bulk of the muscles in the body. They are responsible for the positioning and movement of the skeleton.
- **Fascicles** are composed of the bundles of muscle fibers. The cell membrane of a muscle fiber is called the sarcolemma and the cytoplasm is called the sarcoplasm. These fibers contain an extensive sarcoplasmic reticulum that surrounds each fiber like a lace pattern. Within the fibers are branches of network called the Transverse tubules (T- tubules). Within the sarcoplasm is the myofibril. There are a thousand or more myofibrils within a muscle fiber.
- The **sarcomere** is made of the following: The thin filaments are made of actin and the thick filaments are made of myosin. The A band is the darkest of the bands and it encompasses the thick filament. Within the A band is the lighter region known as the H zone. Within the H zone, there is a dark line known as the M line which is the attachment site for the thick filaments. The other band is called the I band. This is the region occupied by the thin filaments. Within the I band is the Z disc which is the attachment site for thin filaments. A sarcomere is from Z disc to Z disc.
- A single contraction-relaxation cycle is called a twitch, and a single action potential invokes a twitch.

Body movements

- An **isotonic contraction** is any contraction that creates force and moves a load. It is characterized by a steady tension, while the muscle's length changes.
- **Isometric contractions** create force without movement. An example would be picking up a weight and holding it stationary in front of you.

Smooth and Cardiac Muscle

- Smooth muscle is made up of: spindle-shaped cells and is non-striated. Actin and myosin are arranged in long bundles that form a lattice around the central nucleus.
- Cardiac muscle is found only in the heart and is very similar in structure to skeletal muscle. The contractile proteins are arranged in sarcomeres, and the fibers appear branched with a single nucleus.

13: Muscle: Mechanisms of Contraction

Chapter Summary:

This tutorial reviews the sliding filament theory of muscle contraction, including the role of actin and myosin. Nervous reflexes are presented, and the neural pathways included.

Muscle contraction involves ATP, regulatory proteins and fiber movement. Both skeletal muscles and smooth muscles are working almost constantly.

Tutorial Features:

Specific Tutorial Features:
- The Mechanism of Skeletal Muscle Contraction
- Sliding Filament Theory
- Role of Regulatory Proteins
- Factors that control Skeletal Muscle Contraction
- The mechanism of Smooth Muscle Contraction
- Factors that control Smooth Muscle Contraction
- Effects of Neural Control
- Different types of Reflexes

Series Features:
- Concept map showing inter-connections of concepts.
- Definition slides introduce terms as they are needed.
- Examples given throughout to illustrate how the concepts apply.
- A concise summary is given at the conclusion of the tutorial.

Key Concepts:

Skeletal Muscle Contraction
Sliding Filament Theory
Smooth Muscle Contraction
Factors that control Smooth Muscle Contraction
Types of Reflexes

Chapter Review:

Skeletal Muscle Contractions

- The sliding filament theory of contraction involves movement of muscle fibers leading to muscular contraction. The molecular motor, mysoin, and the energy from ATP facilitate this process.
- Actin and myosin are linked together by myosin crossbridges. Myosin is a motor protein that converts ATP into energy of motion. Each myosin has a ATPase that will bind ATP and hydrolyze it. The force that pushes the actin filaments is the movement of myosin crossbridges that link actin and myosin. The power stroke occurs when myosin pushes actin filaments toward the sarcomere. The myosin head releases actin at the end of power stroke. This process is repeated as long as the muscle fiber contracts.
- **Acetylcholine** is the neurotransmitter that initiates muscle contraction. It is released from the neuron and binds to the ACh receptors/channels on the motor end plate. After depolarization, this action potential is propagated across the muscle fiber and into the T-tubules.

Smooth Muscle Contraction

- First, calcium enters the smooth muscle fibers from voltage and chemically gated channels. This causes increased amounts of cytosolic Ca2+ from the sarcoplasmic reticulum and from the extracellular fluid. Ca2+ binds to calmodulin which is found in the cytosol.
- Next, calcium binds to calmodulin and this complex activates an enzyme called myosin light chain kinase (MLCK). MLCK activates the myosin ATPase by phosphorylation. When myosin ATPase activity is high, this causes crossbridges to cycle. In some smooth muscle, a regulatory protein called caldesmon which is bound to actin must be phosphorylated and this allows actin and myosin to interact.
- **Myosin** is regulated by the phosphorylation of proteins. If myosin is unphosphorylated, then there is no ATPase activity. Therefore, there is no contraction. If MLCK is activated, then this will phosphorylate myosin. This in turn will lead to increase ATPase activity and muscle contraction. Phosphatase will dephosphorylate the protein leading to no contraction.
- Actin is regulated by the action of caldesmon which is bound to actin and it covers the actin binding sites for myosin. As along as caldesmon is bound to actin, myosin can not bind and there is no contraction. When protein kinase C phosphorylates caldesmon, it pulls it away from actin. Now actin can bind to myosin and initiate contraction.

Types of Regulation

- A reflex is usually a fast, involuntary response to a stimulus. They can be classified based on (1) Efferent division of nervous system, (2) CNS location of integration, (3) Reflexes can also be classified based on the time of reflex development, and (4) The number of neurons in a reflex loop can also be used to classify reflexes.
- **Monosynaptic reflexes** involve only a single sensory neuron and a single motor neuron, and when one or more interneurons are involved, along with the sensory and motor neuron, it is known as a **polysynaptic reflex**.
- A stretch reflex is a muscle contraction in response to a stretching muscle. This involves 2 neurons: 1 sensory neuron and 1 motor neuron.
- A flexor reflex, or withdrawal reflex, facilitates limb movement away from painful stimuli, for example, pain receptors in the skin that trigger a sensory impulse into the CNS.

14: Cardiovascular Physiology

Chapter Summary:

This tutorial reviews the components of the cardiovascular system including the heart, blood vessels, and the blood itself. The blood flow circuits through the systemic circulation and the pulmonary circulation are also presented.

The heart is the center of the cardiovascular system. Deoxygenated blood returns from the body to the right side of the heart, and then is pumped to the lungs for oxygenation. The left side of the heart then pumps oxygen rich blood to the tissues of the body.

Tutorial Features:

Specific Tutorial Features:

- The functions of the Cardiovascular System
- The structure and Contraction of Cardiac Muscle
- Cardiac Pacemaker Cells
- Action Potential of Cardiac Muscle
- Excitation-Contraction Coupling
- The Structure of the Heart
- Blood flow through the Heart
- Pulmonary Blood Flow Circuit
- Heart Valves
- Electrical Conduction in the Heart
- Heart Rate
- Stroke Volume
- Cardiac Output

Series Features:

- Concept map showing inter-connections of concepts.
- Definition slides introduce terms as they are needed.
- Examples given throughout to illustrate how the concepts apply.
- A concise summary is given at the conclusion of the tutorial.

Key Concepts:

The Cardiovascular System
Myocardium
  Intercalated Discs
  Pacemaker Cells
  Excitation-contraction coupling
Action Potentials in Cardiac Cells
The Heart
Blood Flow Paths
Heart Performance Measures
  Cardiac Cycle
  Stroke Volume
  Cardiac Output

Chapter Review:

The Cardiovascular System

- The cardiovascular system is made of the heart, blood and the blood vessels which transport the blood.
- The primary function of the cardiovascular system is the transport of materials throughout the body. The cardiovascular system also functions to transport materials that aid in cell-to-cell communication (such as hormones) and nutrients (such as glucose).

Myocardium

- The **myocardium** is an involuntary, striated muscle found in the walls of the heart.
- One special feature of myocardium is that it has **intercalated discs** that play an important role in functionality of heart muscle. Intercalated disks are interlocking membranes linked by cell junctions called desmosomes that connect adjacent cells. These disks allow the electrical signals to flow rapidly from cell to cell.
- **Pacemaker cells** are specialized myocardial cells that signal myocardial contraction; they make about 1% of the total myocardial cells. The pacemaker cells are located in the sinoatrial node and they directly control the heart rate, although the heart rate is influenced by the autonomic nervous system.
- Contraction is cardiac muscle uses sliding filament mechanism that occurs in skeletal muscle. The action potential does not directly release Ca 2+ instead the depolarization is what causes the release of calcium.

The Heart

- Unstable membrane potential at -60mV called pacemaker potential. The action potential in a myocardial cell is similar to what takes place in a skeletal muscle cell. The influx of Na+ controls depolarization, and the efflux of K+ controls repolarization. Stage 1 – Depolarization, Stage 2: The action potential reaches a plateau, Stage 3: Repolarization, and Stage 4: The cell membrane returns to resting potential at -90mV.
- The heart is within the thoracic cavity between the two lungs. It is composed of mainly myocardium, and is encased by a tough sac known as the pericardium.
- **Pulmonary circuit:** Deoxygenated blood is returned to the right atrium from the body and is then pumped into the right ventricle through the tricuspid valve, Next, the blood from the right ventricle is pumped through the pulmonary semilunar valve into the lung via the pulmonary arteries, and then within the lungs, the blood releases carbon dioxide, takes up oxygen, and leaves the lungs through the pulmonary veins.
- **Systemic blood flow circuit:** After leaving the lungs, the oxygenated blood enters the left atrium and is pumped into the left ventricle through the bicuspid valve, Next, the blood is pumped out of the left ventricle through the aortic valve into the aorta, and then After the oxygenated blood passes through the arch of the aorta, it is distributed to the tissues through the systemic arteries, arterioles and tissue capillary beds.

Heart Performance Measures

- The cardiac cycle is the period from the beginning of one heartbeat to the beginning of the next. Each cycle has a diastolic phase (cardiac muscle is relaxed) and systolic phase (cardiac muscle is contracted).
- **Stroke volume** is the volume of blood pumped by one ventricle in one contraction. It is measured in mL per beat. It is calculated by the following equation: SV= EDV – ESV.
- **Cardiac output** is the amount of blood pumped per ventricle per unit time. Cardiac output (Q) is used clinically as an indication of how well the heart is performing. It is calculated by multiplying the heart rate by stroke volume. Cardiac output (Q) = Heart Rate x Stroke Volume.

15: Blood Pressure and Blood Flow

Chapter Summary:

The structure, functions and regulation of blood vessels is included in this tutorial. The factors that effect blood flow such as the pressure gradient, fluid pressure and vessel resistance are presented.

Blood flows from the heart, through the vessels to the tissues of the body. Blood pressure impacts blood flow, but along with the function of the heart the diameters of the vessels themselves plays a major role in blood flow.

Tutorial Features:

Specific Tutorial Features:

- The structure and functions of the Blood Vessels
- Chemical Control of blood Vessel Contraction
- The Factors that Affect Blood Flow
- The Factors that Contribute to Blood Pressure
- Intrinsic Control Mechanisms
- The components of Whole Blood
- Various Cardiovascular Diseases

Series Features:

- Concept map showing inter-connections of concepts.
- Definition slides introduce terms as they are needed.
- Examples given throughout to illustrate how the concepts apply.
- A concise summary is given at the conclusion of the tutorial.

Key Concepts:

Blood Vessels
  Arteries
  Veins
  Capillaries
Blood Flow
  Pressure Gradients
  Resistance
Whole Blood
Cardiovascular Diseases

Chapter Review:

Blood Vessels

- There are three types of blood vessels: (1) Arteries, which carry oxygenated blood away from the heart (Pulmonary arteries are the exception), (2) Veins carry deoxygenated blood to the heart; again, pulmonary veins are the exception, and (3) Capillaries are found in the tissues.
- Blood vessels are made of layers of smooth muscles, elastic connective tissue, and fibrous connective tissues. The inner lining is known as the tunica interna. Next to the tunica interna is a layer of smooth muscle called the tunica media. Finally, the outside layer of connective tissue is the tunica externa.
- **Arteries** carry blood away from heart. They have thick layers of smooth muscle, as well as elastic and fibrous tissue. The largest artery is the aorta.

- **Veins** function by carrying blood returning to the heart from the body; the smallest veins are called venules. Venules receive blood from capillaries. Veins contain valves, which facilitate one-way blood flow; this prevents blood from pooling in the lower extremities due to the effects of gravity.
- **Capillaries** are the smallest blood vessels and they receive blood from arterioles. The capillary bed is the site of exchange between the blood and interstitial fluid. They lack smooth muscle and connective tissue and have a flat layer of endothelium supported by a basement membrane.
- **Angiogenesis** is the formation of new blood vessels from existing vessels. This process is necessary for normal development in children, and it typically only occurs during wound healing in adults.

Blood Flow

- Blood flows through the cardiovascular system and delivers oxygen and nutrients to the tissues. The three main factors that affect blood flow are: (1) Pressure gradient, (2) Resistance, and (3) Velocity.
- **The fluid pressure gradient (ΔP)** is the difference between two ends of a tube where the fluid is moving. Flow is proportional to the pressure gradient. The fluid pressure gradient can be calculated as follows: $\Delta P = P1 - P2$. Flow is dependent on the pressure gradient and not absolute pressure.
- **Resistance (R)** is the opposition of the vessels to blood flow. An increase in resistance translates to a decrease in blood flow. Resistance is influenced by three factors, and is calculated as: $R = L\eta/r^4$.
- **The mean arterial pressure** is determined by the balance of blood flow in and out of arteries. If flow in exceeds flow out, MAP rises. Blood flow into the aorta is influenced by peripheral resistance.

Whole Blood

- Whole blood is composed of: Plasma, the formed elements, Buffy coat (which includes leukocytes and platelets), and Erythrocytes.
- Plasma is the fluid part of the blood. It is composed of 92% water. There are 1% of dissolved molecules like amino acids, glucose, lipids, nitrogenous wastes, ions like sodium, potassium and dissolved gases like oxygen and carbon dioxide. The remaining 7% is made of proteins.
- The primary function of red blood cells is to transport O2 and CO2. Leukocytes are the only formed element that is a complete cell, including a nucleus. They make up less than 1% of total blood volume and are important to body defences. Platelets are small cytoplasmic fragments of large cells called megakaryocytes. Platelets play a fundamental role in the control of bleeding.

Cardiovascular Diseases

- **In Coronary Heart Disease**, the heart's blood vessels become blocked by cholesterol, calcium, and blood clots.Uncontrolled risk factors include age, gender and family history. Controlled risk factors include smoking, obesity, sedentary lifestyle, and untreated hypertension.
- **Atherosclerosis** is a condition involving hardening of the arteries. Macrophages ingest cholesterol and other lipids and deposit them under the endothelium of large arteries.
- **Congestive heart failure** is a condition in which the heart's function as a pump is inadequate to meet the body's needs. There is usually pulmonary hypertension, which leads to fluid build-up in the lungs.

16: Respiratory Physiology

Chapter Summary:

This tutorial reviews the anatomy and function of the respiratory system. The mechanics of breathing, including pressure changes during inspiration and expiration are also presented.

Gas flow into and out of the lungs is dependent on pressure gradients. When the pressure inside the lungs decreases, gas flows into the lungs from atmosphere, the reverse takes place during expiration.

Tutorial Features:

Specific Tutorial Features:

- The Basic Anatomy of the Respiratory System
- The Basic Functions of the Respiratory System
- The Mechanics of Breathing
- The Principles of Gas Exchange
- How Oxygen and Carbon Dioxide are transported in the Blood
- The Role of the Respiratory System in Acid-base Balance
- How the Respiratory System is Regulated
- How Exercise and High Altitude Affect the Respiratory System

Series Features:

- Concept map showing inter-connections of concepts.
- Definition slides introduce terms as they are needed.
- Examples given throughout to illustrate how the concepts apply.
- A concise summary is given at the conclusion of the tutorial.

Key Concepts:

Anatomy of the Lungs
  Upper Respiratory Tract
  Lower Respiratory Tract
  Thorax
Functions of the Respiratory System
Respiratory mechanics
Gas Exchange and Oxygen Transport

Chapter Review:

Anatomy of the Lungs

- The respiratory system is divided into two primary areas: (1) Upper respiratory tract, which includes the nasal cavity, pharynx, and larynx, and (2) Lower respiratory tract – from the trachea to the lungs.
- The thorax can be divided into 3 Layers: (1) The thoracic wall, which is comprised of the ribs and muscles, (2) The pleural cavity (pleura), which is the space between the ribs and lungs surrounded by pleural membranes, and (3) The lungs themselves.

The Functions of the Respiratory System

- The sense of smell (olfaction) begins in the nasal cavity. It occurs when airborne molecules enter the nasal cavity and bind to olfactory neurons. These signals are processed in the frontal lobe of the brain and provide our sense of smell.
- Voice production occurs primarily in the larynx, or voice box. Within the voice box is a set of cartilage located at the front of the throat, which contains the vocal folds. The opening and closing of the vocal folds, as air passes through, produces sounds of different quality.

- The lungs are involved in immunity and protect us from microorganisms by: (1) Cilia, (2) Mucus production, (3) Coughing reflex, and (4) Immune cell location.

Respiratory Mechanics

- During breathing, air flows in and out of the lungs due to a pressure difference between the atmospheric pressure (or air pressure) and the alveolar pressure.
- The pressure of a gas is inversely related to its volume. The volume of the chest cavity (and subsequently pressure) is changed by contraction of the diaphragm.
- During **inspiration**, the volume of the chest cavity is increased; this is caused by the diaphragm contracting. During deep or laboured inspiration, the external intercostal muscles are involved along with the diaphragm. During inspiration, the pressure within the alveoli is reduced below atmospheric pressure, and this change in pressure causes air to flow into the lungs.
- During **expiration**, the diaphragm relaxes (and becomes dome-shaped). During deeper breathing, the internal intercostal muscles contract. These changes lead to a decrease in the lung volume and an increase in the pressure within the alveoli, relative to atmospheric pressure. This causes air to flow from the alveoli into the atmosphere.
- Spirometry is a means of testing lung function, and it is known as a pulmonary function test.

Gas Exchange and Oxygen Transport

- Gas diffusion depends on partial pressures of the gases. Partial pressure (P), in a mixture of gases, equals total gas pressure times the % of the gas.
- In the lungs, oxygen partial pressure is greater in the alveoli than in the capillaries. This causes oxygen to diffuse from the alveoli to the capillaries to be transported to the tissues.
- In the tissues, we see the opposite situation as the lungs. The oxygen partial pressure is greater in the capillaries than in the tissues, and this leads to the diffusion of oxygen from the capillaries to the tissues.
- Oxygen is transported in the bloodstream in 2 forms: (1) The major form is bound to Hemoglobin 98%, (2) a small amount is dissolved in the plasma.
- **Oxygen** binding to hemoglobin is highly dependent on the partial pressure of oxygen (PO2). In the lungs, PO2 = 100 mm Hg, and hemoglobin is almost 100% saturated with oxygen. At the level of the tissues, PO2 = 40 mm Hg, and hemoglobin is 70% saturated.

17: Kidney and Nephronal Physiology

Chapter Summary:

The function of the kidney and the many nephrons within it are presented, the role of the kidneys in blood volume and urine volume output is reviewed.

The kidneys filter the blood in the circulation constantly. This produces filtrate, of which the majority is reabsorbed.

Tutorial Features:

Specific Tutorial Features:

- The Anatomical and Functional overview of the Renal System
- The structure of Nephrons
- Functional Processes of the Nephron and Kidneys
- The Regulation of Urine Concentration and Volume
- The Normal Content of Urine
- How Urine is excreted
- Kidney Function Tests and Dialysis

Series Features:

- Concept map showing inter-connections of concepts.
- Definition slides introduce terms as they are needed.
- Examples given throughout to illustrate how the concepts apply.
- A concise summary is given at the conclusion of the tutorial.

Key Concepts:

The Kidney and the Nephron
The function of the Nephron
Filtration, Reabsorption, Secretion and Excretion
The regulation of Urine Volume
Urine Elimination

Chapter Review:

The Kidney and the Nehpron

- The renal system is comprised of the kidneys, ureters, bladder, and urethra. The kidneys are located retroperotineal – or behind the abdominal cavity, near the lower ribs in the back.
- The kidneys are covered by a protective fibrous tissue layer, overlying a fat layer. Situated on top of each kidney are the adrenal glands.
- The internal anatomy of the kidney is quite complex. The **cortex** is the outer area of the kidney, whereas the medulla is the inner compartment. The **medulla** contains the renal pyramids which contain nephrons. The nephrons drain into the minor calyx, then the major calyx, the renal pelvis, and finally the ureter.
- Ureters are hollow, muscular tubes that lead from each kidney to the bladder. Fluid drains from the kidneys to the bladder. The bladder serves as collection and storage area of urine. The urethra is a hollow tube leading from the bladder to the body surface. This is external opening for the elimination of urine.

The Function of the Nephron

- The **nephrons** are tubular structures, which are the functional unit of the kidneys. There are over 1 million in each kidney. All the nephrons drain towards the center of the kidney into the collecting duct system. The nephron perfoms almost all of the kidneys functions, including reabsorption and secretion of certain solutes and ions. Nephrons are classified into two groups:(1) The Juxtamedullary apparatus extends into the medulla, and (2) Cortical, which do not extend into medulla.
- The **renal corpuscle** is made up of Bowman's capsule and the glomerulus. The renal corpuscle connects the nephron to the glomerulus, which is a specialized capillary.

Filtration, Reabsorption, Secretion and Excretion

- **Filtration** in the kidney refers to the movement of substances from the glomerular capillary into the nephron. This is due to the pressure exerted by the blood entering Bowman's Capsule, which forces water and dissolved components through the glomerulus to form filtrate.
- **Reabsorption** is the process whereby the filtrate produced in the glomerulus is reabsorbed through the renal tubule. Approximately 99% of all the filtrate is reabsorbed and this includes: water, sodium, glucose, magnesium, etc. The reabsorption process is specific to the changing needs of the body.
- **Tubular secretion** performs the opposite function of reabsorption. Specifically, it adds materials to the filtrate from the bloodstream. These materials are usually unwanted substances, such as $H+$ and toxins, as well as urea.
- **Excretion** is the elimination of urine from the body. Urine formation actually begins with filtrate formation in the glomerulus; a total of 180 L/day is filtered. Next, approximately 99% of the filtrate is reabsorbed.

The regulation of Urine Volume

- When there are no hormones released for reabsorption, a large volume of dilute urine is produced. This occurs by the nephron containing dilute fluid, after the ascending limb, which then proceeds out of the kidney for excretion.
- During times of low water intake, the kidneys can conserve water by increasing the volume of reabsorbed fluid. This is accomplished by the **Countercurrent Mechanism**. The countercurrent mechanism establishes an osmolarity gradient in which the osmolarity increases from the cortex towards the medulla.
- **Antidiuretic hormone**, or vasopressin, is a hormone released from the posterior pituitary gland to act on the kidneys. When water must be conserved, ADH is released and causes water channels to be inserted.
- **Aldosterone** is released from the adrenal glands (which are attached to the kidneys), specifically from the adrenal cortex. Aldosterone causes the kidneys to increase sodium and water reabsorption, which leads to an increase in blood volume and blood pressure.
- The **Atrial natriuretic hormone** serves as a signal from the heart to the kidneys. It is released from the atria when blood pressure is high, and it reduces water reabsorption in the kidneys.

18: Fluid, Electrolyte and Acid-Base Balance

Chapter Summary:

This tutorial reviews the body fluid compartments, fluid composition, and fluid exchange between compartments.

Fluid enters through the digestive tract and then distributes between the tree major fluid compartments in the body. Along with the fluid composition the acid-base balance of the body is also highly regulated.

Tutorial Features:

Specific Tutorial Features:

- Body Fluid Compartments
- Osmolality
- Hydrostatic and Osmotic Pressure
- Electrolyte Concentration
- Glomerulus: Blood Filtration
- Hormonal Regulation of Water Reabsorption
- Acid-Base Compensation

Series Features:

- Concept map showing inter-connections of concepts.
- Definition slides introduce terms as they are needed.
- Examples given throughout to illustrate how the concepts apply.
- A concise summary is given at the conclusion of the tutorial.

Key Concepts:

Body Fluid Compartments
Osmolality
Hydrostatic and Osmotic Pressure
Electrolyte Concentration
Glomerulus: Blood Filtration
Hormonal Regulation of Water Reabsorption
Acid-Base Compensation

Chapter Review:

Body Fluid Compartments

- Water accounts for 60% of the total body weight in adults and is divided into three compartments. For a 70kg individual - Total Body Water (TBW) = 60% x Body Weight 42 Liters. Extracellular Fluid (ECF) = 1/3 of TBW 14 Liters. Intracellular Fluid (ICF) = 2/3 of TBW 28 Liters. Interstitial Fluid = 3/4 of ECF 10.5 Liters. Plasma = 1/4 ECF 3.5 Liters.
- **Osmolality:** is a measure of the osmoles of solute per kilogram of solvent. An osmole is the unit of measure that defines the number of moles of a molecule that contributes to a solution's osmotic pressure.
- Water moves freely throughout the various body fluid compartments; this movement is in response to two forces: hydrostatic pressure and osmotic pressure. While both forces

contribute to fluid movement across a capillary membrane, osmotic pressure is the major force that drives fluid across the plasma membrane of cells.

- Hydrostatic pressure is caused by the blood pressure generated by the heart beating. Osmotic pressure is caused by Na+ and other electrolytes.

Electrolyte Composition

- Electrolytes exist in different concentrations inside and outside of the cell. Concentration gradients are produced by active processes such as the Na+-K+ ATPase (pump).
- There is a concentration gradient which drives Na+ into the cell. There is a concentration gradient which drives K+ out of the cell.
- The **nephron** is the functional unit of the kidneys; nephrons are contained within the renal medulla. Nephrons are connected via the collecting duct system. Fluid flows collectively from the nephrons into the collecting duct system and, ultimately, is excreted as urine.
- The formation of urine involves: (a) the filtration of plasma by the glomerulus, (b) reabsorption of water and solutes and (c) the secretion of certain solutes into the tubular fluid which ultimately becomes urine.

Acid-Base Compensation

- The acid-base balance of the human body is tightly controlled and is fundamental to normal body functioning. Even a small deviation towards a more acid or alkaline environment can severely effect organ function.
- **Carbonic Anhydrase** is a metalloenzyme that rapidly and reversibly converts carbon dioxide and water into carbonic acid. The main function of this enzyme is to interconvert carbon dioxide and bicarbonate to maintain the acid-base balance in the blood and tissues.
- **The Davenport diagram** is a graphical representation of the relationship between the plasma bicarbonate concentration and the pH of the blood. Disturbance in the normal values of bicarbonate and pH lead to acidosis and alkalosis.
- The human body has 3 main mechanisms to control a change in the acid-base balance of body fluids: (A) Extracellular and intracellular buffering, (B) changing the respiration rate of the lungs and (C) adjustments to renal acid secretion.
- The human body responds to changes in acid-base balance in the following ways: Acidosis pH < 7.35 - Compensated by stimulating the respiratory center and causing an increase in respiratory frequency. This causes decrease In Pco2 and a resultant increase in pH. The human body compensates for changes in respiratory function by modulating kidney function and vice versa.

19: Digestive Physiology and Nutrition

Chapter Summary:

The organs of the digestive system and their function are presented. The fundamentals of nutrition and nutrient utilization are also included.

The digestive tract is responsible for processing, digesting and absorbing the nutrients we eat and drink.

Tutorial Features:

Specific Tutorial Features:
- The Basic Anatomy of the Digestive System
- The Basic Functions of the Digestive System
- The Anatomy, Secretions, Absorption, and Motility of the Digestive Organs
- The Anatomy, Function, and Secretions of Accessory organs
- How Nutrients are absorbed
- The role of Nutrition in Health
- The Nutritional Value and sources of the Major Macromolecules
- The role of Vitamins and Minerals in Health

Series Features:
- Concept map showing inter-connections of concepts.
- Definition slides introduce terms as they are needed.
- Examples given throughout to illustrate how the concepts apply.
- A concise summary is given at the conclusion of the tutorial.

Key Concepts:

Anatomy of the Digestive Organs
Anatomy and function of the Accessory Organs
Nutrient Absorption
Nutrition and Health
  Vitamins
  Minerals
  Health Authority Recommendations

Chapter Review:

Anatomy of the Digestive Organs

- The digestive system is made up of a large continuous tube beginning with the mouth, expanding to the stomach, and ending with the anus. This system utilizes accessory organs, which assist with digestion and are physically located along the digestive tract.
- The digestive tract includes the following organs: mouth, pharynx, esophagus, stomach, small intestine, large intestine (colon), rectum and anus. The entire gastrointestinal tract can be as long as 20 feet.
- The walls of digestive organs are comprised of four layers. The innermost layer is the mucosa, which is composed primarily of epithelial cells. This layer is in direct contact with ingested food. The next layer is the submucosa, which is external to the mucosa. The submucosa contains glands, vessels, and nerves. Moving further outward, the muscle layer or muscularis is next. This layer is composed of circular and longitudinal smooth muscle that enables contraction. The final out layer is the serosa, which is a tough layer of connective tissue.

- The stomach anatomy includes: (1) the esophageal sphincter, (2) pyloric sphincter(3) oblique muscle, (4) rugae, and (5) gastric pits.
- The small intestine is approximately 6 meters in length. It is made up of three main components: (1) the duodenum, which is closest to the stomach, (2) the jejunum, which is the main portion, and finally (3) the ileum, which is closest to the large intestine.
- The anatomy of the large intestine includes the following segments: Cecum, Appendix, Ascending colon, Transverse colon, Descending colon, Sigmoid colon- S-shaped curve; Rectum – straight tube, which leads to the Anus.

Accessory organs

- The **liver** is divided into 4 lobes: right, left, caudate, and quadrate. It is further divided into lobules, containing sinusoids, which are enlarged spaces for the processing of blood. The Hepatic Portal System is a unique blood supply made up of the hepatic portal vein. The functions of the liver are to: (1) receive venous drainage from intestines (hepatic portal system); (2) process nutrients, (3) produce cholesterol; (4) store energy as glycogen; (5) detoxify molecules; (6) produce plasma proteins; and (7) produce bile, which is stored in the gallbladder.
- The **gallbladder** is a small sac on the inferior side of the liver. It stores and concentrates bile and, when needed, the bile travels down the common bile duct into the duodenum. The role of bile is to emulsify fat (separate fat into smaller portions for easier digestion).
- The **pancreas** is located posterior to the stomach and is organized into lobules. In the lobule are the acinar cells, which are responsible for secreting the digestive enzymes, such as trypsin and chymotrypsin. The digestive enzymes travel through the pancreatic duct into the duodenum and are essential for proper digestion of nutrients.
- **Acidosis** is an increased in acidity in the blood, defined by a pH below 7.35. There are two form of acidosis: Respiratory acidosis, and Metabolic acidosis.
- **Alkalosis** is an increase in alkalinity of the blood, defined by a pH above 7.45. There are two form of alkalosis: Respiratory alkalosis, and Metabolic alkalosis.

Nutrients

- Carbohydrate digestion begins in the mouth with salivary amylase, which breaks down starch into sugars. In the small intestine, disaccharidases from the small intestine and pancreatic amylase digest carbohydrates further.
- Protein digestion and absorption begins in the stomach with pepsin and continues in the small intestine with secreted peptidases. Pancreatic peptidases, such as trypsin and chymotrypsin, further digest proteins.
- Nutrition is the provision of nourishment to the cells of the body. Nutrient values of the food we eat are reported in calories, which are a unit of energy.
- The carbohydrates we ingest are composed of sugar molecules, such as glucose, and fructose (monosaccharides). It is recommended that carbohydrates make up 45-65% of one's total daily caloric intake.
- Proteins are composed of amino acids. There are a total of 20 amino acids; 12 are nonessential amino acids and 8 are essential amino acids. It is recommended that they make up 10-35% of one's total daily caloric intake.
- Lipids come in many forms, such as cholesterol, phospholipids, and the most common form in our diet, triglycerides. It is recommended that fats should be limited to 20-30% of one's total daily caloric intake.
- Vitamins are organic molecules that are present in foods in small amounts. What does not come from our diet can be supplemented. Essential vitamins can not be produced by the body and must be ingested.
- Minerals are a naturally occurring inorganic nutrient. Minerals come from a variety of sources: calcium – dairy products, iron – meats and potassium – fruits. Minerals play vital roles in certain reactions and processes in human physiology.

20: Energy Balance and Metabolism

Chapter Summary:

This balance between energy in and energy out is reviewed in this tutorial. Metabolism including nutrient metabolism, regulation of metabolism, hormones and their role in energy usage are reviewed.

Metabolism of the food we eat is a very complex process involving many reactions and enzymes.

Tutorial Features:

Specific Tutorial Features:

- Energy Balance and how it occurs in the Body
- The Role of Nutrients in Energy Balance
- The Determinants of Metabolic Rate
- Energy Metabolism and how it is regulated
- How Hormones maintain Energy Balance

Series Features:

- Concept map showing inter-connections of concepts.
- Definition slides introduce terms as they are needed.
- Examples given throughout to illustrate how the concepts apply.
- A concise summary is given at the conclusion of the tutorial.

Key Concepts:

Energy Balance in the Body
  Units of Energy
  Food labeling
  Energy Output
  Hydrogen Bonds
Energy Contents of Macromolecules
  Carbohydrates, proteins, and Lipids
  Metabolic rate
Regulation of Energy Metabolism
Hormones and Energy Balance

Chapter Review:

Energy Balance in the Body

- Energy in the food we eat is measured in calories. A calorie is the nutritional unit of energy; it is represented by a lower case “c”. A calorie is equal to the amount of energy required to raise the temperature of 1 g of water 1 degree Celsius.
- Nutrition or food labels are required to display the caloric content of the food. They are expressed as calories per serving. To determine energy input from the food, multiply the calories per serving times the number of servings ingested.
- **Energy output** is the use of energy to sustain life and complete the activities desired. Along with energy intake, energy output is also measured in calories.
- Body weight is dependent on the relation between energy input and energy output. If energy or caloric intake equals caloric output, body weight remains the same. If caloric intake exceeds caloric output, body weight is gained. On the other hand, if caloric intake is less than caloric output, body weight is reduced.

Energy Contents of Macromolecules

- The three main macromolecules provide energy for the body. Thus, their energy content can be expressed as Calories or kilocalories. In science, the term "kilocalories" is most commonly used. Carbohydrates contain 4 kcal/g. Proteins also contain 4 kcal/g, and Lipids contain 9 kcal/g.
- Food labels include: total calories per serving and grams of each macromolecule per serving. To determine energy (kcals) provided from each macromolecule type, multiply grams times kcal/g.
- Metabolism is the sum of all chemical reactions in the body. It involves thousands of chemical reactions daily, and the overall process is the breakdown of food and nutrients.
- Metabolic rate can be measured using the direct measurement method. Metabolism produces heat or energy, and heat output is correlated with metabolic rate. The direct method involves the measurement of heat output from a human being or other organism detected by specially designed metabolic rooms or chambers. The indirect method is based on the relation between oxygen consumption and metabolic rate.
- **Basal Metabolic Rate (BMR)** is defined as the lowest level of caloric intake necessary to sustain life. The BMR accounts for approximately 70% of energy output daily.
- Another aspect of metabolism that effects our basal metabolic rate is the work done and heat generated during the digestion of food, a process known as the **thermal effect of food.**
- Metabolism is the sum of two basic processes, catabolism and anabolism.

Regulation of Energy Metabolism

- The primary energy source for the body is glucose, derived, for the most part, from carbohydrate metabolism. The brain is an obligate user of glucose and uses approximately 50% of the amount in the circulation. Excess glucose is stored in the liver and muscle as glycogen and can be released from these stores as needed to maintain blood sugar levels. Glucose can also be converted to fatty acids and stored in adipocytes.
- Lipids are stored in the body in adipocytes and are released when energy is required. The excess ingestion of carbohydrates and proteins can be converted to lipids. If carbohydrate ingestion is restricted severely, lipids are converted to ketones, which can be used by the CNS, namely the brain.
- **The Urea Cycle** is an essential component of protein metabolism. Amino acids have nitrogen groups that can form ammonia. In the liver, the urea cycle minimizes the toxic ammonia by metabolizing amino acids into urea.
- **Insulin** is released from the pancreas in response to high blood glucose levels. Blood glucose levels elevate after eating carbohydrates, and glucose must be moved from the blood into the cells.
- **Glucagon** is also produced in the pancreas and performs the opposite action of insulin. It is released when blood glucose levels decrease, and it breaks down liver glycogen into glucose molecules.
- **Cortisol,** as well as other hormones secreted by the adrenal gland, function during stress to increase metabolic processes. Cortisol is released from the adrenal cortex; it functions by increasing fat catabolism, muscle catabolsim, and blood glucose levels.

21: Body's Defenses: The Immune System

Chapter Summary:

Immunity including specific and non-specific immune responses are presented. The role of B-cells, T-cells and antibodies during exposure to antigens is included.

The human body must protect itself from the many, daily attacks from microorganisms. By generating immunological memory, the body can respond to a second antigen exposure in a more rapid and robust manner.

Tutorial Features:

Specific Tutorial Features:
- Non-specific Immunity: B-Cells
- Human Antibodies
- Specific Immunity: T-Cells
- Immune Responses to Viruses and Bacteria
- Allergies and Autoimmune Disease

Series Features:
- Concept map showing inter-connections of concepts.
- Definition slides introduce terms as they are needed.
- Examples given throughout to illustrate how the concepts apply.
- A concise summary is given at the conclusion of the tutorial.

Key Concepts:

Non-specific Immunity: B-Cells
Human Antibodies
Specific Immunity: T-Cells
Immune Responses to Viruses and Bacteria
Allergies and Autoimmune Disease

Chapter Review:

Non-specific Immunity
- The human Immune system is made up of various primary and secondary lymphoid organs. Our immune system responds to an antigen initially. Then, a faster, more robust response can occur in the future. Both B-cells and T-cells, along with cytokines and antibodies, protect us from invading microorganisms.
- **Non-specific Immunity**, or Innate Immunity, is the basic resistance to disease that an individual possesses by virtue of his/her birth. It is the first line of defense against infection. It is a broad response to an invading organism or antigen.
- The human body contains non-specific defenses, in the form of barriers, to microbes and antigens. There are 4 main types of barriers: Anatomic, Physiologic, Phagocytic and Inflammatory.
- B-cells are lymphocytes that play a large role in the humoral immune response, as opposed to the cell-mediated immune response that is governed by T-cells. B-cells are activated by antigen, which leads to effector B-cell function.
- **Antibodies** or immunoglobulins, in general, are composed of four polypeptide chains, two identical copies each of a light chain (L) and a heavy chain (H). The variable region on both

the heavy and light chain makes up the antigen-binding site. Antibodies are synthesized into five classes: IgG, IgA, IgM, IgD & IgE.

- An **antigen** has been defined as any substance which, when introduced into the body, stimulates specific immune response. Antigenic molecules react specifically with the receptors on T-cells and/or B-cells.
- **Complement** is a group of serum proteins that are activated characteristically by antigen-antibody interaction and, subsequently, mediate a number of biologically significant consequences. The complement system is the major effector of the humoral branch of the immune system.

Specific Immunity

- **Specific immunity** refers to immune responses that are targeted toward specific antigenic challenges. Specific immunity can be of two types: active or passive. Clonal selection occurs when an antigen binds with a lymphocyte (B-cell or T-cell), which is specific for epitopes on that antigen. The epitope is the portion of the antigen that is physically recognized by the lymphocyte or antibody.
- T-cells are classified based on their function within the immune system. Memory T-cells play an important role in stimulating a heightened immune response to a previously encountered antigen. Effector T-cells include cytotoxic T-cells, which target and kill the invading microbe.
- **Lymphokines** are cytokines made by lymphocytes. Lymphokines can exert their effects on the lymphocyte that produced them or on a distant cell.
- **Major Histocompatibility Complex (MHC)**: These molecules play a very important role in the recognition of self and non-self antigens by T-cells. The major functions include: (1) the presentation of antigens to T- lymphocytes, (2) governing interactions between T-cells, B-cells and accessory cells, and (3) controlling the intrathymic development of the TCR repertoire against foreign antigens.
- **The Endogenous (MHC class I)** pathway mediates presentation of endogenous or intracellularly-produced proteins.
- **The Exogenous (MHC class II)** pathway mediates presentation of exogenous or externally-produced antigens.
- **Autoimmune disease** is defined as a break-down in the immune system's recognition apparatus. This leads to the production of T-cells and antibodies directed against its own cells and organs.
- In **Immune Complex diseases**, soluble immune complexes (aggregations of antigens and IgG and IgM antibodies) form in the blood.
- **Hypersensitivity - Type 1 reaction**: It is an allergic reaction provoked by re-exposure to a specific antigen. Exposure may be by ingestion, inhalation, injection or direct contact. The reaction is mediated by IgE antibodies, resulting in the immediate release of histamine, tryptase, arachidonate and derivatives by basophils and mast cells.

22: Reproduction and Development

Chapter Summary:

This tutorial reviews the gametes and their roles in fertilization and reproduction.

The sex chromosomes provide the genetic information for the development of male and female sex characteristics. Both of which contribute to reproduction.

Tutorial Features:

Specific Tutorial Features:
- Reproduction and Development
- Sex Hormones
- Testes and Spermatogenesis
- Ovulation and the Corpus Luteum
- Pregnancy and Labor

Series Features:
- Concept map showing inter-connections of concepts.
- Definition slides introduce terms as they are needed.
- Examples given throughout to illustrate how the concepts apply.
- A concise summary is given at the conclusion of the tutorial.

Key Concepts:

Sex Chromosomes
Male sex characteristics
Female sex characteristics
  Menstrual Cycle
Pregnancy and Labor

Chapter Review:

Sex Chromosomes

- Each human develops according to a total of 46 chromosomes, 44 autosomes and 2 sex chromosomes. In the process of reproduction, the sperm and female egg both contribute 1 sex chromosome.
- Depending on which 2 sex chromosomes are contributed from each parent, a male or female embryo is produced. For the first 5 weeks after gestation, the gonads of males and females are indistinguishable. As development continues, hormonal products from the testes and the absence of these products from the ovaries determine the gender differences – the internal and external genital tracts.
- **Sex determination** in humans takes place around 7-9 weeks of gestation. The Wolffian ducts, which develop in males, and the Mullerian ducts, which develop in females are under the control of a glycoprotein hormone known as Mullerian-inhibiting factor (MIF).

Male Sex Characteristics

- The **testis** is made up of coiled tubes called the seminiferous tubules. Within the tubules are the Leydig cells. Adjacent to these tubules are the Sertoli cells. The testis are contained within the scrotum where they can maintain a temperature that is 1-2°C lower than body temperature.

- The process of spermatogenesis involves the conversion of a spermatid into a functional sperm.
- The process of spermatogenesis is under hormonal control from the hypothalamus- pituitary axis. Functioning through Leydig cells and Sertoli cells, these regions of the brain control the maturation of spermatids into mobile spermatozoa.
- During sexual arousal in males, there is increased blood flow to the penis and this usually results in an erection. The corpus cavernosa is a pair of tubular structures that run the length of the penis. As venous blood engorges these tubular structures and the penis becomes hard and erect.

Female Sex Characteristics

- **Oogenesis** is the formation of an ovum (egg), which takes place in the ovarian follicle. This process begins with a primary follicle and eventually leads to the release of an ovum during ovulation.
- **Ovulation** begins as very high levels of estradiol stimulate a surge in LH. The surge of LH matures the egg and weakens the outer wall of the follicle. This leads to the release and maturation into an ovum.
- The secretion of FSH and LH are controlled through feedback mechanisms during the menstrual cycle. Increasing levels of estradiol during the follicular phase lead to a decrease in both FSH and LH levels. This negative feedback diminishes towards ovulation.

Pregnancy and Labor

- The goal of each spermatozoa is to find an ovum and begin the process of fertilization. Fertilization or conception is the point of fusion between two gametes.
- **Implantation** of the trophoblast must occur during a specific window. The blastocyst is made up of approximately 70-100 cells. This is surrounded by the trophoblast, which later becomes the placenta.
- The **placenta** develops from the trophoblast portion of the blastocyst. It connects to the developing baby through the umbilical cord and connects the mother's circulatory system with that of the baby's. It secretes hormones of pregnancy, including Human chorionic gonadotropin (HCG) and progesterone, both of which support the endometrium and maintain the pregnancy.
- Active labor is usually characterized by regular contractions, which begin to dilate the cervix. However, some women progress to the delivery phase quickly without going through regular, rhythmic contractions. Childbirth may be regulated initially by uterine distension from the near-term baby, stretching the uterus. Once initiated, labor is maintained through Oxytocin release from the posterior pituitary.

23: Exercise Physiology

Chapter Summary:

This tutorial discusses training principles and guidelines including exercise intensity. The responses of the respiratory and cardiovascular systems to physical exercise and training are also presented.

When we exercise there are immediate and long-term changes in your physiology. The respiratory and cardiovascular systems adapt to the increased intensity and this helps in efficiency and performance.

Tutorial Features:

Specific Tutorial Features:

- Basic training principles
- How the muscular and neural systems adapt to exercise
- How the cardiovascular system adapts to exercise
- How the respiratory system responds to exercise
- Metabolism and exercise
- Body composition and nutrition in relation to exercise

Series Features:

- Concept map showing inter-connections of concepts.
- Definition slides introduce terms as they are needed.
- Examples given throughout to illustrate how the concepts apply.
- A concise summary is given at the conclusion of the tutorial.

Key Concepts:

Training Principles
Muscle Twitch and Fiber Recruitment
Cardiovascular Response to Exercise
Respiratory Response to Exercise
Exercise and Metabolism
Exercise and Nutrition

Chapter Review:

Training Principles

- The FITT principle. Frequency – or how often one should exercise. Most recommend at least 3 days per week. Intensity is how hard you exercise. A common recommendation is that you should at least be sweating during exercise. Time refers to the duration of an exercise session, with 30 minutes being the goal. Finally, it is important to find a Type of exercise that you enjoy doing.
- The body responds in the specific manner it is trained. In other words, an individual who runs marathons needs to train specifically for running. There is a limited transference of improvement that comes from cross-training in other sports.
- To improve an individual's fitness level, the body must be overloaded in a progressive, step-wise fashion. For example, beginning with 10 pounds, then 15 pounds, then 20 pounds, etc. The **overload principle** is how this is accomplished; challenge or "overload" the body with more than it is used to.
- **Individuality,** all training principles are based on individual needs and talents. Training that may result in victory for one may be under- or overtraining for another. Most athletes and

teams also use **periodization**, which are periods of intense activity alternated with periods of less intensity and rest.

Muscle Twitch and Fiber Recruitment

- **Muscle hypertrophy** is an increase in the size of muscle cells. The most common adaptation of the muscular system to exercise is an increase in muscle size. Exercise Training Results: (1) muscle fiber size increases but muscle fiber number does not; (2) an increase in actin and myosin levels; (3) an increase in connective tissue, and (4) an increase in capillary density.
- Skeletal muscle is divided into two forms, fast twitch fibers and slow twitch fibers. Fast twitch fibers are large, explosive, and they fatigue quickly. Slow twitch fibers are smaller but do not fatigue quickly. For explosive, fast-paced activities, primarily fast twitch fibers are used. However, when going for a walk, primarily slow twitch fibers are used.
- **Muscle fiber recruitment** is the orderly process of adding more and more fibers during a contraction. The ability of the nervous system to properly activate muscle fibers and motor units is one of the strongest training adaptations.

System Response to Exercise

- **The cardiovascular system** responds to exercise in the following ways: (1) increase in cardiac output, for example from 5L/min at rest to 20-25L/min, (2) increase in systolic blood pressure; diastolic pressure doesn't normally increase, (3) increase in heart rate, and (4) increase in stroke volume. During exercise, a target heart rate for exercise can be estimated using the formula 220-age.
- The benefits of exercise on the human body are many. Specifically, an individual can reduce their personal risk for cardiovascular disease in the following ways: (1) increase HDL cholesterol (good cholesterol) and lower LDL cholesterol, (2) lower blood pressure, (3) decrease platelet aggregation, and (4) increase coronary circulation and decrease vessel plaque formation.
- **The changes in ventilation** during exercise include: (1) a rapid increase in ventilation early on, (2) an increase in the rate and depth of respiration, (3) input into ventilation rate from metabolic factors, such as carbon dioxide and lactic acid.

Exercise and Metabolism

- Glucose can be stored in skeletal muscle and the liver in the form of glycogen. Glycogen stores can be converted to glucose when needed, and the liver uses its glycogen storage for widespread glucose needs. At rest, the glycogen stores can provide glucose into the general circulation for hours.
- When glycogen and glucose levels are depleted after hours of intense exercise, it is difficult to continue. This is known as “hitting the wall” or “crashing”. Professional athletes can use carbohydrate loading (carb-loading) to ensure their glycogen stores are maximal.
- Fat can be utilized as an energy source during exercise, along with glycogen stores in muscle. Another metabolic training adaptation is that the body begins to burn fat more efficiently.

Exercise and Nutrition

- **Metabolic adaptations** that result from cardiovascular training include: liver and muscle glycogen levels are increased, enabling more fat to be oxidized; greater capillaries in the muscles to deliver more oxygen; and more red blood cells to deliver oxygen to tissues, decreasing anaerobic metabolism.
- **Ergogenic aids** are substances, other than food, that are reported to improve athletic performance. There are many of these aids on the market. Readily available ergogenic aids or fitness enhancement supplements include: megavitamins, fat burners, amino acid supplements, and creatine phosphate. Certain aids are only available through questionable or illegal means, such as anabolic steroids.

24: Medical Physiology

Chapter Summary:

This tutorial reviews the diseases of the major organ systems. Symptoms, causes and potential treatments are discussed.

Every organ and tissue in our body is subject to disease and malfunction. There is expected decline in organ function as we age, but there is also premature, permanent organ damage that can occur for a variety of reasons.

Tutorial Features:

Specific Tutorial Features:

- Diseases of the cardiovascular system
- Diseases of the respiratory system
- Diseases of the digestive system
- Diseases of the renal system
- Diseases of the reproductive system
- Diseases of the muscular and skeletal systems
- Diseases of the neural and endocrine systems

Series Features:

- Concept map showing inter-connections of concepts.
- Definition slides introduce terms as they are needed.
- Examples given throughout to illustrate how the concepts apply.
- A concise summary is given at the conclusion of the tutorial.

Key Concepts:

Diseases of the cardiovascular system
Diseases of the respiratory system
Diseases of the digestive system
Diseases of the renal system
Diseases of the reproductive system
Diseases of the muscular and skeletal systems
Diseases of the neural and endocrine systems

Chapter Review:

Diseases of the Cardiovascular System

- **Myocardial infarction**, or a heart attack, is most frequently caused by plaque formation in a coronary artery. If a heart blood vessel, such as the left or right coronary artery, is occluded or blocked, no blood reaches a portion of the heart and heart muscle damage occurs.
- **Heart arrhythmias** are due to abnormal electrical signaling in the heart. Common arrhythmias are: atrial flutter, atrial fibrillation, AV block and Bundle branch block.
- **Heart Failure** is a serious condition marked by the heart's inability to pump adequate blood. This can occur on the right side, left side, or both sides of the heart. Typically, during heart failure, the following occurs: (1) cardiac output and blood pressure fall, (2) cardiac

hypertrophy and dilation occur, (3) blood volume is increased and this causes fluid to leak from capillaries, and (4) systemic and pulmonary edema results.
- **Circulatory shock** occurs when blood return to the heart is inadequate due to hemorrhage, anaphylaxis, sepsis, etc. During shock, no matter how hard the heart pumps, blood pressure and cardiac output fall.
- **Hypertension** is defined as a chronic increase in systolic or diastolic blood pressure, for example, a blood pressure of 140/90 mm Hg or higher.

Diseases of the Respiratory System
- **Asthma** is characterized by airflow obstruction and bronchospasm due to hypersensitivity to stimuli. There are a variety of triggers that lead to an asthma attack including: dust mites, animals, pollens, air pollutants, smoke and, in some cases, exercise.
- **Emphysema** is a chronic lung condition in which there is a loss of elasticity within the lungs and a loss of alveoli integrity.
- **Chronic obstructive pulmonary disease (COPD)** is a chronic lung condition affecting 17 million people in the U.S., involving chronic bronchitis and emphysema. COPD is often present with asthma, excess mucus production, and alveolar destruction. Simple tasks can seem impossible, as so much energy is expended during the laboured breathing.
- **Pulmonary edema** is due to fluid accumulation in the lungs. Fluid accumulation is often due to cardiac problems, especially left-sided heart failure.

Diseases of the Digestive System
- **A gastric ulcer** occurs when stomach acid destroys the mucosa. The stomach is normally protected by a thick layer of mucus. Symptoms of a stomach ulcer include a burning sensation that may be relieved by antacids, pain and loss of appetite.
- **In Gastroesophageal Reflux Disease (GERD)**, the esophageal sphincter does not close completely. Acid in the stomach is then able to enter the esophagus. This produces a burning sensation or "heartburn". Treatment can include diet changes and positional changes for sleeping, along with medication to reduce acidity in the stomach or to increase lower esophageal sphincter strength.
- **Cirrhosis** is irreversible degeneration and fibrotic change of the liver. These changes occur at the cellular level, inhibiting hepatocyte function.
- **Cholecystitis** is the inflammation of the gallbladder and is normally due to gallstones. The gallbladder stores bile. Items in bile may precipitate out and form stones.

Diseases of the Renal System
- **Glomerulonephritis (GN)** is a renal disease characterized by inflammation of the glomeruli; this disease usually occurs following a streptococcal infection.
- **Renal failure**, or kidney failure, can either occur in an acute or chronic form; the chronic form represents irreversible loss of renal and nephron function due to infection or disease. Few symptoms are usually present until < 25% of glomerular function remains.
- **Renal calculi,** or kidney stones, are solid aggregates made of concentrated material or minerals in the urine. They typically form in the kidneys or bladder and form due to: calcium precipitation, increased oxalic acid, dehydration, and changes in pH.

Diseases of the Reproductive System
- **Cervical cancer** is the 3rd most common female reproductive cancer. Cervical cells, when examined during a Pap smear, can reveal suspicious pre-cancerous changes.
- Most men, age 50 and over, have some prostate enlargement, such as **Benign Prostatic Hyperplasia (BPH**). Often, this growth is benign; other times, cancerous growths may occur. Due to the prostate's location near the urethra, difficulty urinating can be a sign of prostate growth.
- **Endometriosis** is a condition in which endometrial cells are deposited outside of the uterine cavity, such as on the bowel wall.

- **Polycystic Ovarian Syndrome (PCOS)** is a complex metabolic and hormonal condition. As the name implies, ovaries become filled with cysts, and a lack of regular ovulation and menstruation can occur.

Diseases of the Muscular and Skeletal Systems

- **Muscular Dystrophy** is a genetic disorder, which involves the breakdown of muscle cells and subsequent leakage of enzymes and proteins from muscle cells. There is associated inflammation because of this. Because it is an inherited disorder, boys are more likely to be affected.
- **Myasthenia Gravis** is an autoimmune condition, which causes fluctuating muscle weakness and fatigue. The muscle weakness is caused by an immune reaction against the receptors for acetylcholine at post-synaptic neuromuscular junctions.
- **Gout** is a metabolic disorder affecting the joints, particularly the big toe, which leads to arthritis in the affected joints. It is caused by uric acid crystal deposits in the joints.
- **Osteoarthritis** is the most common form of arthritis, affecting millions of people in the US. Osteoarthritis affects the synovial joints and causes a breakdown of the joint integrity and the adjacent bone.
- **Osteoporosis** is a condition characterized by a loss of bone, which involves greater bone resorption than bone formation. As women become post-menopausal, they should be aware of their bone density and risk of osteoporosis**.**

Diseases of the Neural and Endocrine Systems

- **Cerebrovascular Accident (Stroke)** is a sudden impairment in the brain's circulation. The presentation of symptoms includes changes in brain function, such as speech, memory, etc. Symptoms will depend on the area of the brain affected. CT scans and MRIs can help determine the area of damage and, in some cases, guide intravascular treatment. Long-term treatment includes therapy to reduce the risk of reoccurrence and to regain control of lost functions if possible.
- **Paralysis** can result from a number of conditions, such as brain damage from a stroke or accident, injury to the spinal cord, severe infection, and a herniated disk in the spinal column. Paralysis of a limb or muscle group can be acute, due to a toxin, or permanent, due to central nervous system damage.
- **Thyroid** conditions include hyperthyroidism (overactive thyroid) and hypothyroidism (underactive thyroid).
- **Excess of adrenal hormones** leads to diseases, such as Cushing's disease. **Adrenal hormone insufficiency** can cause Addison 's disease. This is due to low levels of adrenal cortex hormones, caused by autoimmunity or impaired steroidogenesis.
- **Diabetes** is a syndrome of altered metabolism. It is characterized by diminished insulin production (Type I) or resistance to the effects of insulin (Type II). Both lead to increased blood glucose levels beyond normal, which cause damage to the kidneys, nerves, and vision.