MCAT Biology Rapid Learning Series
Test-Prep Course Study Guide

Course Table of Contents

Chapter 01: Introduction to MCAT Biology

- In this core unit, you will learn about the Medical College Admissions Test and how it is formatted, scheduled and scored. The "new" exam has the expanded scope of contents and the required biology has more in-depth coverage.
- It will also introduce the Rapid Learning path to MCAT preparation.
- The tutorial explains the various options for navigating the CBT and using its various attributes to enhance your performance. Test preparation and test taking strategies are presented. The tutorial summarizes all these strategies by providing practice problem drills with complete explanations and solutions.
- The biology topics list is presented and a discussion about "Passage" based versus "Non-Passage" based questions reviewed.

Chapter 02: Chemical Basis of Life

- This chapter reviews the concepts of atoms, elements and molecules using 3D images. The molecules covered include: organic, biologically relevant macromolecules and biochemical reactions such as enzyme reactions and coupled reactions in biological systems.
- The major biological macromolecules are introduced and the important chemical groups on each type of macromolecule defined. These include: nucleotides, carbohydrates, proteins and lipids. Acids, bases and buffers are reviewed and their relevance with respect to electrolytes and biological systems presented.
- The chapter concludes with test questions that helps to focus on the concepts presented in the chapter.

Chapter 03: Enzymes and Cellular Metabolism

- Enzymes, their structure function and mechanisms as well as specificity of reactions are reviewed. The reaction kinetics, inhibition mechanisms are shown using animated models. Application of the Michaelis-Menten equation and its use in interpreting enzyme kinetics are shown. The two primary theory's of enzyme kinetics are presented. These two theories are the lock and key theory and induced fit models of enzyme catalysis.
- The second segment of the tutorial focuses on cellular metabolism, specifically: TCA cycle, glycolysis, pyruvate oxidation, and respiratory chain. Respiration and fermentation are shown. Respiration is typically the preferred mode of metabolism and involves using oxygen as the final electron acceptor in the production of ATP.
- The structure of enzymes and their substrates are described and effect of binding the enzyme at its active site is shown using animated models. Inhibition of enzyme

activity as a function of change in 3D enzyme structure is demonstrated using animated models. Cellular metabolism is dependent on the effectiveness of the enzyme reactions. Animated coupled reactions are shown

Chapter 04: DNA Structure and Function

- The structure, function and replication of DNA in eukaryotes and prokaryotes are discussed. Anatomy of the chromosome is detailed including the centromeres, telomeres and how the chromosome is associated with proteins such as histones to form nucleosomes and chromatin. The chemical composition of the DNA and RNA base pairs is describes and how these pairs align within the DNA molecule.

- DNA in eukaryotes, is typically double stranded, anti-parallel and associated with proteins. Viral and prokaryotic DNA has unique structural characteristics. Prokaryotic DNA frequently is circular and not contained within a nucleus.

- The 5 primary types of mutations include: deletion, duplication, inversion, insertion and translocation mutations. These contain more specific mutations such as: silent, missence, nonsence, insertion, neutral, tranversion, transition and others.

- Recombinant technology is introduced including restriction enzymes that cleave DNA at specific sites and facilitate the cloning of DNA fragments into plasmids. DNA and proteins are separated using gel electrophoresis.

Chapter 05: RNA and Protein Biosynthesis

- The flow of information in the cell is from DNA to mRNA to protein. This is accomplished by using DNA as the template from which mRNA is copied. The mRNA is then edited removing introns and forming a mature mRNA molecule. Variable splicing of pre-mRNA molecules allow a single pre-mRNA to provide information for the formation of different proteins.

- The mature mRNA is then read in the ribosome. The ribosome is a complex of proteins that have rRNA (ribosomal RNA) associated with it. rRNA serves the purpose of aligning the mRNA to be copied into protein. tRNA binds a complementary region (codon) consisting of 3 nucleotides. The tRNA carries with it an amino acid. Upon binding the mRNA the amino acid is transferred to the growing chain of amino acids and a peptide bond is formed between the amino acids.

Chapter 06: Molecular Biology of Eukaryotes

- A karyotypes is a set of human chromosomes stained with specific dyes. The karyotype of a eukaryote is unique. Human chromosomes consist of DNA strands complexed with specific proteins called histons. The association of DNA with protein allows the DNA to wind and compact. Euchromatin is a lightly packed form of chromatin having many genes that are often under active transcription.

- Eukaryotic genes are transcribed in nucleus. Genes are under transcriptional control. When the DNA is transcribed into pre-mRNA it undergoes RNA processing followed by mRNA export into the cytoplasm. mRNA is translated into protein at this point it is under translational control. The new protein can be modified under what is known as post translational control.

- The gene in eukaryotes have a generalized structure. Eukaryotic genes include: promoter is a regulatory region of DNA that is located upstream toward the 5' region (usually) of a gene. It provides a control point for regulated gene transcription. Protein-coding sequences of the gene are exons.

- Non-protein-coding sequences of the gene are called the introns. Enhancers are sequences that serve to enhance transcription of genes. Silencers are similar to enhancers, but they have the opposite effect on transcription (i.e., they repress transcription).

Chapter 07: Genetic and Mendelian Concepts

- This chapter describes the laws of genetics otherwise known as Mendelian inheritance. These underlie much of modern genetics. Mendel's first law is known as the Law of Segregation. In the Law of segregation Mendel states that there are alternative versions of genes called alleles.

- For each characteristic an organism inherits two alleles one from each parent. So that somatic cells have two alleles the alleles may be the same and are called true breeding or homozygous or they may be different called heterozygous. If the two alleles differ one is dominant and the other recessive. The dominant trait will show regardless of what the recessive trait is. The recessive trait will only show if it is homozygous. There are instances of codominance which is seen in the human ABO blood type.

- Mendel's second law is the Law of Independent Assortment. This states that the inheritance pattern of one trait will not affect the inheritance pattern of another. Independent assortment happens in meiosis I in eukaryotic organisms and makes a gamete with a mixture of organisms' maternal and paternal chromosomes. Chromosomal crossover provides genetic diversity by producing new genetic combinations.

Chapter 08: Meiosis and Genetic Variability

- This chapter details the process of meiosis and mitosis. Meiosis proceeds in two steps called Meiosis I and Meiosis II.

- Meiosis I: Prophase I, Metaphase I, Anaphase I, Telophase I.

- Meiosis II: Prophase II, Metaphase II, Anaphase II, Telophase II. Sex linked genetics, the pedigrees of sex linked traits and the various methods of determination of gender are shown.

- The Hardy-Weinberg Law is described and how it is used to predict the distributions of and frequency of alleles shown. At equilibration the equation $p^2 + 2pq + q^2 = 1$ describes the allelic frequency.

Chapter 09: Prokaryotes and Fungi

- This chapter details the primary structural components of prokaryotes and fungi. Gram negative and gram positive prokaryotes are compared and contrasted. Additionally the reproductive methods, such as binary fission and sporulation are discussed. In Fungi the unique structural components of fungi including the function of a hyphae.

- Prokaryotes are classified based on a number of parameters: Oxygen Requirements, Nutrition, Photosynthetic Capacity, Chemosynthetic Capacity, Feeding of Organic Matter, Staining and Shape. Major types of prokaryotes are presented.

Chapter 10: Viruses

- The virus is introduced and defined. Viral Classification which is based on the genomic structure: I: dsDNA, II: ssDNA, III: dsRNA, IV: (+)ssRNA, V: (-)ssRNA, VI: ssRNA-RT, VII: dsDNA-RT is described and integrated with the International Committee on Taxonomy of Viruses on naming conventions and additional guidelines.

- ICTV classification uses a numerical code to represent: order, family, subfamily, genus, species, subspecies, serotype (or subtype) and strain (or isolate).

- A detailed description of the HIV life cycle is described and shown in animation.

Chapter 11: Eukaryotic Cell Biology

- Eukaryotes are defined as animal, plants, fungi and protists. Their general structure is detailed including the cell's membrane and various organelles.

- The primary function of the eukaryotic cell's organelles is described in detail. Animal, plant cell schematics are shown and compared. The cells endomembrane structure is outlined. The cells requirement for life and replication are shown in animated schematics.

Chapter 12: Specialized Eukaryotic Cells and Tissues

- Nervous system is divided into central nervous system and peripheral nervous system. The central nervous system includes brain and spinal cord. The peripheral nervous system contains all neurons and nerves that are not in the central nervous system.

- The function of nervous system is to Coordinates the activity of the muscles, to monitors the organs constructs and to processes input from the senses, and initiates actions. Neurotransmitter binds to receptor on the receiving neuron. The binding opens ion channels in the receiving neuron and generates a new action potential. The potential arrives at the synaptic cleft and releases neuro-transmitter. Neurons communicate at the synapse.

- An action potential can regenerate itself along the neuron. Action potential is a spike or electrical discharge that moves along the membrane of the neuron. An action potential happens when a neuron sends information down an axon away from the cell body. The action potential of a neuron is driven by an electrochemical gradient.

- Muscle cells, skin cells and integument cells including their structure and mechanism of functioning are outlined in with detailed animations.

Chapter 13: Nervous System

- Brain and Spinal Cord form the Central Nervous System. *Brain: Three parts:* The Brainstem is the connection between the rest of the brain and the rest of the central nervous system. It is the most primitive in the evolutionary chain, for life support and basic functions such as movement.

- The Cerebellum Consists of two hemispheres it is primarily concerned with movement and works in partnership with the brainstem area of the brain and focuses on the well being and functionality of muscles. The Forebrain lies above the brainstem and cerebellum and is the most advanced in evolutionary terms. It is involved in learning ability and creativity.

- The 3 types of neurons, sensory, interneurons and motor neurons are described with their function outlined. There are specialized cells for different organ system in order for these systems to function. This includes neural cells like rods and cones in the eye.

Chapter 14: The Endocrine System

- The endocrine system and the nervous system are structurally, chemically and functionally related. Many endocrine organs and tissues have specialized nerve cells called neurosecretory cells that secrete hormones.

- Regulation of several physiological process involves overlap between the endocrine and nervous system. The Endocrine System is an organ system which releases products into the blood that can effect the entire body. These signals can last for a long time. The purpose is to maintain homeostasis as well as to allow the body to have a customized response to physiological changes.

- The nervous system only sends commands to specific cells that last for a brief period of time. Endocrine system uses the blood vessels to deliver the hormones to a target that is distant from the gland that synthesized it. The Paracrine signaling is targeting cells that are close by, perhaps even touching the cell that synthesized it. Autocrine signaling is signaling the same cell that synthesized it.

- The reproductive systems contain elements of the endocrine system. These components of the reproductive system facilitate the development of mature sex organs which are used to produce gametes for reproduction.

Chapter 15: The Circulatory System

- Blood is carried through the body in a network of blood vessels. Arteries carry blood away from the heart while veins carry blood to the heart. Capillaries are the smallest blood vessels, where exchange takes place.

- Passive diffusion lets oxygen/nutrients out of the blood into the tissue and carbon dioxide/waste out of the tissue into the blood. Note: arteries are not always red and veins are not always blue. (Arteries to the lungs are deoxygenated, and veins from the lungs to the heart are oxygenated.)

- The heart structure and coronary circulation is important for keeping oxygen flowing to the heart muscle. The importance of thermoregulation and how the circulatory system helps to regulate the bodies temperature is described.

Chapter 16: Lymphatic and Immune System

- The Lymphatic system is responsible for returning lymph fluid to the body which is involved in the immune response. Organs of the lymphatic system include: Primary organs: Bone marrow and thymus. Secondary organs: Spleen, lymph nodes, Peyer's patches and tonsils.

- Cells of the immune system include B-lymphocytes and T-lymphocytes. B-lymphocytes develop in the bone marrow and become antibody-producing plasma cells. T-lymphocytes develop in the thymus, differentiate into T-helper cells or T-cytotoxic cells. T-helper cells induce B-Cell differentiation, antibody production and inflammation.

- Resistance to pathogens arises from two interactive immune responses: The humoral immune response: antibodies in blood system, it Involves B cells and antibodies, which recognize antigens; Some antibodies are soluble proteins that travel free in blood and lymph, others are integral membrane proteins on B cells.

- When a pathogen invades the body, it may be detected by and bind to an antibody on B cell. This binding, along other system components, activates the B cell, which makes multiple soluble copies of an antibody with the same specificity. The antibodies then attach the invaders and kill them.

- The cellular immune response: detect antigens that reside within or on cells. Main component is T cells. Destroys virus-infected or mutated cells. T cell receptors recognize and bind specific antigens on cell surface and lyse the infected cells.

Chapter 17: Respiratory System

- The lung has specialized cells and structures to facilitate breathing and the exchange of gases between it and hemoglobin carried in red blood cells. The exchange of involves both the inflow of oxygen and the release of CO_2 waste that has been carried from peripheral tissues.

- The mechanics of respiration is complex and involves the diaphragm muscle. When expiration ends and just before the beginning of inspiration, the pressure inside the lung is the same as the atmospheric pressure outside the body. The diaphragm contracts and the internal lung volume increases and the pressure inside the lung decreases. The change in internal pressure causes air to rush into the lungs and down its pressure gradient.

- At the end of inspiration, the diaphragm relaxes. The lung volume decreases and this causes the internal pressure inside the lungs to increase to a level higher than atmospheric pressure outside the body. The air then leaves the lung due to the differential pressure gradient.

Chapter 18: Muscular System

- Muscles are important in body support. They have an origin, usually attached to a stationary bone. The thick portion of the muscle between the insertion and origin is called the muscle belly or gaster. Muscles are attached to movable bones by a tendon. Muscles are arranged in groups throughout the body which moves and supports the body, bones and organs.

- Voluntary Muscles include skeletal muscles, which are under voluntary control. Meaning we can contract the muscles at will. Involuntary muscles are rhythmic, automatically controlled muscles. These muscles include: breathing (under both voluntary and involuntary control), Cardiac (heart) muscle is under involuntary control. The sinoatrial node sets the rate and the autonomic nervous system can modulate that rate. Smooth muscles in the walls of organs and blood vessels are primarily under involuntary control.

- The autonomic nervous system regulates the activities of smooth muscle, cardiac muscle and certain glands. The autonomic nervous system is divided into two components the parasympathetic branch and the sympathetic branch. Parasympathetic branch of the autonomic nervous system has been called "rest and digest", because it slows down the body and increases digestive activity.

Chapter 19: Skeletal and Skin System

- Bones are the rigid frame for the human body. Muscles are attached to bones and use them as an anchor from which to exert forces that result in limb movement.

- Calcium is stored primarily in bones, and is released into the blood in response to hormones. Calcium is released from the bone in response to parathyroid hormone (PTH). When blood Ca^{2+} is low more PTH is released from the parathyroid glands. This causes increased Ca^{2+} absorption from the gastrointestinal tract increased osteoclast (bone resorptive cells) activity, both of which increase blood Ca^{2+} levels.

- Thermoregulation includes hair, subcutaneous fat tissue and the capillary beds. The skin plays an important role in physical protection. Fingernails which are made of keratin provide the strength of the nail. Calluses are an area of skin that has become relatively thick and hard. Calluses protect the underlying skin from damage due to repeated contact with hard or rough surfaces.

Chapter 20: The Digestive System

- The digestive system includes various organs including the: stomach, liver, gallbladder, pancrease, small intestine and large intestine. The digestive system is responsible for the absorbance of food and water molecules and provides mucosal immunity finally it stores and eliminates waste products. Saliva in the mouth contains salivary amylase, which is an enzyme that digests starch. The fundus is a storage are of the stomach, food can remain in this region for up to an hour prior to mixing with gastric juices. Food mixes with gastric juices in to produce chyme. Rugae line the stomach, these folds of mucosa allow the stomach to expand when filled. Pepsin is an enzyme made by chief cells in the stomach; it is released into the stomach as a precursor called pepsinogen. Pepsin is converted to pepsin when it comes into contact with the hydrochloric acid secreted by the parietal cells.

- The liver is supplied by two main blood vessels on its right lobe: (a) hepatic artery- which distributes blood to the liver, gallbladder and pancreas and (b) portal vein- brings venous blood from the spleen, pancreas and small intestines for processing by the liver. The liver filters all blood coming through the portal vein carrying the products of digestion and absorption. The gallbladder is underneath the liver and stores and concentrates bile. Bile is an alkaline fluid produced by hepatocytes in the liver, and helps to emulsify fats during digestion and absorption in the small intestine. The large intestine is the primary location for the absorption of liquids, primarily water, and salt ions. The small intestine is the site where most of the nutrients from food are absorbed.

Chapter 21: Urinary System

- The urinary system is involved in maintaining the bodies homeostasis. That is how much water is retained, released and reabsorbed. The organs involved in the urinary system include the: kidney, ureters, bladder and urethra. The kidney has highly specialized cells and structures that help it to function.

- The three regions of the kidney are the outer cortex, central medulla and the inner pelvis. The fundamental unit of the kidney is the nephron, which filters the blood reabsorbing what is needed by the body and excreting the rest as urine.

Chapter 22: Reproductive System

- The reproductive system includes a system of organs that are coordinated for the purpose of reproduction. Human reproductive systems include external genitalia (penis and vulva) and internal organs for the production of gonads such as testicles and ovaries. Human reproduction involved internal fertilization. The sperm typically fertilize an ovum in either the fallopian tubes or uterus.

- Components of the male reproductive system include: testicles, epididymis, corpus cavernosa, foreskin, frenulum, urethral opening, glans penis, corpus spongiosum, penis and scrotum. Female reproductive system is a series of organs most of which are located internally. Female reproductive organs include: vulva, vagina, ovaries, labia, clitoris, uretra, cervix, fallopian tubes and uterus.

Chapter 23: Embryogenesis, Developmental Mechanics, and Comparative Anatomy

- An embryo begins as a newly fertilized single cell. The main events leading to increased complexity are cleavage, which forms the blastula; gastrulation, where the three germ layers of endoderm, mesoderm, and ectoderm are formed; and neurulation, which generates the future nervous system.

- This section will cover each of these steps in more detail. Fertilization occurs between two gametes - the sperm and the egg. During cleavage, the cells divide but do not grow in size.

- The ultimate consequence of numerous rounds of cell division during cleavage is formation of the blastocyst. Gastrulation is an embryonic stage following cleavage and results in ectoderm, mesoderm, and endoderm. Neurulation results in formation of the neural tube, which will become components of the central nervous system such as the brain and spinal cord. Cell commitment involves three cell types: unspecified cells, specified cells, and determined cells. During differentiation cells go from unspecified to determined or committed to a specific cell fate.

Chapter 24: Evolution

- Evolution is a process where certain genes or genotypes are selected for or against. This gives rise to the concept of Descent with modification.

- Natural selection is the process in which heritable traits that are helpful to survival and reproduction become more common.

- Evolution works on populations, not individuals. When a certain favorable phenotype is selected for and that phenotype is genetic in origin the genes coding for the pheonotype will become more prevalent in the population.

- A mode of evolution also involves the genetic isolation of a species. The isolation may be due to physical barriers or non-physical barriers.

- Physical barriers such as mountains or water can separate a population however changes in behavior patters may also affect the degree to which a population may freely mate.

Chapter by Chapter Content Guide:

Chapter 01: Introduction to MCAT Biology

Chapter Summary:

This module introduces the Medical College Admissions Test and how it is formatted. The "new" exam is longer and broader. The biology is covered in three test sections. In-depth study of this subject is highly recommended.

The tutorial provides various attributes to enhance your performance. Test preparation and test taking strategies are presented. The tutorial summarizes all these strategies by providing practice problem drills with complete explanations and solutions.

The key details of the MCAT biology related contents are discussed in this chapter. The understanding of biological science should focus at three different organization levels – molecular, cellular and systemic. There are two question formats: passage-based questions which are based on information in a passage and require outside knowledge, and stand-alone questions which require only outside knowledge.

Tutorial 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.
- Practice test passages and questions are provided along with a detailed step by analysis of selecting the correct answer.

Key Concepts:

- MCAT: The Medical College Admissions Test is a standardized exam required to gain admission to medical school.
- MCAT Courses: The new four-sections MCAT requires seven college courses – general chemistry, organic chemistry, biochemistry, biology, physics, psychology and sociology.
- Passage-Based Question: A question relating to information in an accompanying passage. The answer may or may not be in the passage.
- Discrete Question: A question that has a topic independent of a passage or other questions with four possible answer options.
- Test Sections: (1) Chemical and physical foundations (2) Critical Analysis and Reasoning Skills (3) Biological and Biochemical Foundations (4) Psychological, Social and Biological foundations.
- Organic Chemistry: MCAT requires students to take two semesters of college-level organic chemistry for pre-med.
- Computer-based Test: MCAT is 100% to be taken on computer with on-screen timer and but no calculator provided.

Chapter Review:

Biology Topics Tested:

- Enzyme Structure & Function
- Control of Enzyme Activity
- Basic Metabolism
- Molecular Biology: DNA and Protein Synthesis
- DNA structure & Function
- DNA replication, repair and recombination
- Protein Synthesis

- Genetic code, transcription & translation
- Molecular Biology: Eukaryotes
- Chromosome organization, control and gene expression.
- Genetics
- Mendelian concepts
- Meiosis, genetic variability, mutation
- Sex linked characteristics
- Analytic Methods
- Microbiology
- Fungi, Virus Structure and life cycle
- Prokaryotic structure, growth, physiology and genetics.
- Eukaryotic Cells: structure, function, regulation and specialization.
- Nervous and Endocrine system
- Circulatory, lymphatic and immune systems
- Respiratory system
- Skin system
- Digestive and Excretory Systems
- Muscle and Skeletal Systems
- Reproductive System and Development
- Evolution

Registration

- The MCAT is offered multiple times a year.
- Register here: http://www.aamc.org/mcat/
- Plan ahead six months before taking the exam.

Scoring

Four sectional scores and one total score with midpoint

- Chem/Phys Section: 118-132 (midpoint = 125)
- Critical/Reasoning: 118-132 (midpoint = 125)
- Bio/Biochem – 118-132 (midpoint = 125)
- Psy/Social - 118-132 (midpoint = 125)
- Composite Score: 472-528 (midpoint = 500)

Test Day Schedule (4 sections 10-min break each)

- Chem/Phys: 95 minutes, 59 questions.
- Critical/Reasoning: 90 minutes, 53 questions.
- Bio/Biochem: 95 minutes, 59 questions.
- Psy/Social: 95 minutes, 59 questions.

Chapter 02: Chemical Basis of Life

Chapter Summary:

This chapter reviews the concepts of atoms, elements and molecules. The molecules covered include: organic, biologically relevant macromolecules and biochemical reactions such as enzyme reactions and coupled reactions in biological systems. Finally acids, bases and buffers are reviewed and how these combine to form electrolytes which are very important in biological systems. The chapter summarizes with test questions that uses the concepts presented in the chapter.

Tutorial Features:

- Diagrams of atoms, elements and molecules including their various bonding characteristics are shown.
- In addition to these pictures and 3D models their application in biological systems are presented.
- The major biological macromolecules are introduced and the important chemical groups on each type of macromolecule defined. These include: nucleotides, carbohydrates, proteins and lipids.
- 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.
- Practice test passages and questions are provided along with a detailed step by analysis of selecting the correct answer.

Key Concepts:

- Atoms, elements, and molecules
- Chemical bonds: single, double, triple, ionic, covalent, hydrogen
- Organic chemicals and macromolecules
- Acids, bases, and buffers
- Biochemical reactions
- Test applications

Chapter Review:

- Atoms and Life: All living organisms are made of organic and inorganic molecules; molecules are made of elements, elements are made of atoms, atoms are made of proton, neutron and electrons.
- A molecule is a stable neutral or charged group consisting of at least two atoms in a definite arrangement held together by strong chemical bonds.
- An atom consists of protons, neutrons, and electrons. Protons are equal to the atomic number. Neutrons are equal to the mass number – atomic number. Electrons are equal to the protons, if the atom is neutral. Whole numbers are used for protons, neutrons, and electrons. Phosphorus has 15 protons, 16 neutrons, and 15 electrons.
- Atoms form bonds by gaining, losing, or sharing electrons. Atoms become ions when gaining or losing electrons, ion bonds are weak, tend to dissociate in water e.g. NaCl.
- Covalent bonds form when atoms share electrons, very strong bonds. The major one in organic chemicals. For example, in methane, the carbon shares 8 electrons with 4 hydrogen atoms.
- Hydrogen bond, a type of weak electrical attraction between the positive end of one molecule and the negative end of another. An example is a water molecule; polarized

water molecules have two ends, positive end and negative end. The positive end can be attracted to another water molecules negative end.

- Organic compounds are a class of molecules that have carbon. There a few carbon compounds such as: carbonates, carbon oxides and cyanides that are considered inorganic. Some systems classify an organic compound based on the type of functional group the compounds carry.
- Isomers: molecules having same molecular formula but different structure formula, e.g. 1-butanol and 2-butanol.
- Structure formula shows how atoms are arranged in a molecule.
- Chemical bonds are formed when atoms share their outer shell electrons. In organic chemicals, there are several types of bonds: single bond, Atoms share one pair of electrons in the molecule, e.g., CH3-CH3; double bond: Atoms in a molecule share two pairs of electrons, e.g., R-CHO, R-CH=CH2; triple bond: Atoms in a molecule share two pairs of electrons. Chemical bonds store energy, and the energy in a double bond is greater than that in a single bond but less than that in a triple bond.
- The organic chemicals are classified by their functional groups which determine the properties of a molecule. These include: alcohol group, aldehyde group, ketone group, carboxylic acid group, amine group, phosphate group and thiol groups. All these groups are chemically reactive.
- There are many organic chemicals in living organisms. However, the most abundant and most important small molecules are: monosaccharides which contains C, H and O; amino acids, which contains C, H, N and O; fatty acids, which are mainly composed of C and H, small amount of O. Nucleotides, contains C, H, O, N and P. Nucleotides have three parts: a base, a ribose and a phosphate group.
- There are four major groups of macromolecules, polysaccharides, which are made from monosaccharides, they store energy and provide building unit for cells. Lipids are made from fatty acids and glycerol, they too store energy and are major component for cell membranes. Proteins are made from amino acids and they make up both structure protein and enzymes. The last group is nucleic acids, which are made from nucleotides. Nucleic acids are genetic materials.
- Fatty acids are one component of lipids (phospholipids are another). Fatty acids are characterized by a long hydrocarbon chain, which have all single bonds (saturated), or some multiple bonds (unsaturated), plus a carboxyl group. Unsaturated fatty acids can exist as cis or trans forms. When glycerides: such as triglyceride are formed between glycerol and fatty acids, ester bonds are between the carboxyl group of the fatty acid and an alcohol group on glycerol. Nucleotides polymerize by ester linkages to form nucleic acids, our genetic material. The consist of a base (G,T,A,C in DNA; G,U,A,C in RNA), a pentose (deoxyribose in DNA, ribose in RNA), and a phosphate (one makes a monophosphate, two make a diphosphate, and three make a triphosphate). Phosphate-ester linkages allow nucleotides to polymerize.
- An electrolyte is a material having free ions that are able to conduct an electric current. They generally are made up of ions in solution. Electrolytes are also known as ionic solutions. Electrolytes usually are solutions of acids, bases or salts. Electrolyte solutions are formed when a salt is put in a solvent and the individual components dissociate.
- The first law of thermodynamics: the total energy of the universe is always conserved. Energy can neither be created nor destroyed.
- The second law of thermodynamics: the universe tends towards maximum disorder, or, in other words, a spontaneous process will occur in the direction that increases the entropy of the system plus its surroundings.
- The measure of a system's degree of disorder is entropy (S). It increases with increasing disorder.
- Free energy (ΔG) refers to the energy available in a system for doing work. ΔG is the net change in free energy (i.e., $G_{products} - G_{reactants}$) for a chemical reaction, and it is

expressed as kcal/mol or kJ/mol. The equation $\Delta G = \Delta H - T(\Delta S)$ is important for describing the spontaneity of a reaction (ΔH=net change in enthalpy, $\Delta H > 0$ is endothermic, $\Delta H < 0$ is exothermic; T is the temperature in Kelvin; ΔS = net change in entropy). A spontaneous reaction has negative ΔG (exergonic) and a non-spontaneous reaction has a positive ΔG (endergonic). A reaction at equilibrium has a ΔG of zero.

Chapter 03: Enzymes and Cellular Metabolism

Chapter Summary:

In the first part of the tutorial enzymes, their structure function and mechanisms as well as specificity of reactions are reviewed. Enzyme reaction kinetics and inhibition mechanisms are discussed including allosteric, and non-allosteric mechanisms. Application of the Michaelis-Menten equation and its use in interpreting enzyme kinetics are shown. The lock and key theory and induced fit models of enzyme catalysis are described.

The second segment of the tutorial focuses on cellular metabolism, specifically: TCA cycle, glycolysis, pyruvate oxidation, and respiratory chain. Respiration and fermentation are shown. Respiration is typically the preferred mode of metabolism and involves using oxygen as the final electron acceptor in the production of ATP.

Tutorial Features:

- The structure of enzymes and substrates are described in detail and shown in 3D structure. The effect of binding the enzyme on its structure is shown using animated models as well as the effect that inhibitors have on the structure of the enzyme. How the optimum enzyme structure determines its efficiency of reaction is show.
- Cellular metabolism is dependent on the effectiveness of the enzyme reactions. Animated coupled reactions it is shown how enzyme use energy from one reaction to drive reactions of thermodynamically unfavorable reactions. An overview of the main cellular metabolic pathways is presented.
- 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.
- Practice test passages and questions are provided along with a detailed step by analysis of selecting the correct answer.

Key Concepts:

- Cellular Metabolism for the production of ATP: TCA cycle, glycolysis, pyruvate oxidation, and respiratory chain.
- Aerobic and Anaerobic respiration
- Enzymes: Structure, function, specificity, kinetics and regulation.
- Models of enzyme mechanisms and their inhibition.
- Michaelis-Menten reaction kinetics.

Chapter Review:

- Enzymes are proteins that accelerate the rate of a chemical reaction.
- Enzymes require metal atoms as cofactors to function.
- Enzymes are catalysts that promote the same reaction over and over without being used up. They are neither product nor reactant.
- The active site is the location on the enzyme where the catalysis of the chemical reaction takes place.
- A substrate is a molecule that a enzyme “acts on” and it binds to the enzymes active site.
- Enzymes are proteins that act as catalysts in biochemical reactions.
- Enzymes may speed up reactions by a factor of many thousands.
- Like all catalysts, enzymes are not altered or consumed by the reactions they participate in.

- Types of enzyme specificity include: stereo specificity, reaction specificity, and substrate specificity.
- Stereo specificity, the enzyme will act on only one type of isomer.
- Reaction specificity refers to the fact that while substrates can often participate in numerous different chemical reactions, enzymes catalyze one specific reaction only.
- Substrate specificity refers to the types of molecules that are accepted into an enzyme's active site.
- Group specificity refers to enzymes that act on substrates that contain particular functional groups or bonds.
- Steps of Enzyme Catalysis: Step 1 Substrate approaches the active site. Step 2 Formation of enzyme substrate complex. Step 3 Enzyme substrate complex reaches the transition state. Step 4 Formation of enzyme product complex. Step 5 Release of Product
- Lock and Key Hypothesis: Enzyme active site acts as a "lock" into which the substrate inserts "key". The enzyme positions the substrate in such a way as to facilitate the reaction. Once the substrates have "reacted" the bonds holding them in the active sites are weakened and the products are released.
- Enzyme induced-fit hypothesis, which is the most accepted theory of enzyme function, the shape of the active site is not rigid, and binding of the substrate induces a conformational change within the enzyme's active site that promotes the formation of the enzyme-product complex. Dissociation of the product from the active site allows it to resume its original shape.
- Activation Energy: the amount of energy required to convert all reacting substances from ground state to transition state. It determines the rate of the reaction. Enzymes works by lowering the activation energy, the lower the activation energy the faster the rate.
- Some enzymes require a cofactor to function at full activity. Cofactors are non-protein molecules. Cofactors can be inorganic (e.g. metal ions) or organic compounds (e.g. flavin, heme). Examples of coenzymes: NADH, NADPH and ATP
- Michaelis-Menten & Enzyme Kinetics: As substrate concentration increases the velocity increases proportionately in initial phases. Later with further increase in substrate concentration the velocity does not increase proportionately. At substrate saturation the reaction attains maximal velocity (V_{max}). At substrate saturation the velocity of reaction is independent of any further increase in substrate concentration.

$$E + S \underset{k_{-1}}{\overset{k_1}{\rightleftarrows}} ES \xrightarrow{k_2} E + P$$

$$K_m = \frac{k_{-1} + k_2}{k_1}$$

- Enzymes have optimum functional characteristics: temperature, pH and ionic strength. These tend to be around physiological ranges however there are exceptions.
- Enzymes can be inhibited by a variety of mechanisms. Allosteric activator binds to the allosteric site. Causes favorable conformational changes in the active site and increases the affinity of the enzyme towards the substrate. A competitive inhibitor competes with the substrate for the active site of an enzyme. Non-competitive inhibition the inhibitor effectively lowers the concentration of active enzyme and hence lowers the V_{max}. Uncompetitive inhibition: a type of reversible inhibition where the inhibitor binds to the enzyme-substrate complex and inhibits its dissociation into products.
- Catabolism breakdown of complex molecules into smaller less complex molecules.
- Anabolism simple molecules used to synthesize complex molecules.

- Cellular respiration can take two paths: aerobic respiration or <u>an</u>aerobic respiration. Which one a cell chooses depends on whether or not oxygen is available. If oxygen is available, the cell follows aerobic respiration. If oxygen is <u>un</u>available, the cell relies on <u>an</u>aerobic respiration.
- Glycolysis is the sequence of reactions where a glucose molecule is degraded to yield two molecules of pyruvate during which some of the free energy released is conserved in the form of ATP.
- There are four metabolic pathways involved in carbohydrate catabolism and ATP production: TCA cycle, glycolysis, pyruvate oxidation, and respiratory chain.
- TCA is involved in the conversion of carbohydrates, fats and proteins into carbon dioxide, water and energy. AKA Krebs cycle, and citric acid cycle.
- Oxidative phosphorylation (oxidative – using oxygen, phosphorylation – adding phosphate which changes ADP to ATP), creates a concentration gradient to produce 32 ATP.
- Fermentation (a process which means to break down without oxygen), the second step of anaerobic respiration, converts pyruvate into another form, and in the process regenerates intermediates for glycolysis. Fermentation breaks down pyruvate in a series of redox reactions. The product can be ethanol or lactic acid, depending on the organism. The energy-releasing breakdown of pyruvate is coupled to the production of glycolysis intermediates, “helper” molecules that are used up during glycolysis. The main role of fermentation is to allow the glycolysis reaction to run repeatedly and rapidly.

Chapter 04: DNA Structure and Function

Chapter Summary:

This chapter focuses on the structure, function and replication of DNA in eukaryotes and prokaryotes. The chemical composition of the DNA and RNA base pairs is describes and how these pairs align within the DNA molecule. DNA in eukaryotes, is typically double stranded, anti-parallel and associated with proteins. Viral and prokaryotic DNA has unique structural characteristics. Prokaryotic DNA frequently is circular and not contained within a nucleus. Viral genetic material can be RNA or DNA in a variety of confirmations, single or double stranded.

The 5 primary groups of mutations include: deletion, duplication, inversion, insertion and translocation mutations. These contain more specific mutations such as: silent, missence, nonsence, insertion, neutral, tranversion, transition and others. Recombinant technology is introduced including restriction enzymes that cleave DNA at specific sites and facilitate the cloning of DNA fragments into plasmids. DNA and proteins are separated using gel electrophoresis.

Tutorial Features:

- DNA, RNA structure, function and replication in eukaryotes and prokaryotes using animated models.
- Molecular cloning techniques: electrophoresis, restriction enzymes and plasmid construction are reviewed.
- Detailed animated models of replication mechanisms of eukaryotes, prokaryotes are shown.
- DNA mutation and repair mechanisms are shown.
- 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.
- Practice test passages and questions are provided along with a detailed step by analysis of selecting the correct answer.

Key Concepts:

- Chromosomes and DNA
- DNA structure: base, deoxyribose, and phosphates
- Base pairing: A-T, G-C
- Replication
- DNA repair
- Recombinant DNA technology

Chapter Review:

- Eukaryotic cells contain membrane-bound nuclei that contain genomic DNA. The only exceptions are the mitochondria, which have their own small genomes, and plant cells, which have some additional DNA stored in the chloroplasts.
- Prokaryotic cells, such as a single bacterium, do not have a membrane-bound nucleus. Many prokaryotes have tightly-wound circular genomic DNA that sits within the cytoplasm. An important feature of the eukaryotic life cycle is sexual reproduction in which half the genetic material in an organism comes from one parent, and half comes from the other parent.

- One DNA molecule can be very long if stretched out. Double stranded DNA can automatically form double helix structure, the double helix DNA is then wrapped around by proteins to form a more condensed form called nucleosome. Nucleosomes further coil up to form chromatin. Chromatin further folds and turns and forms chromosome, which is visible in cells during certain stages.
- Virus have various chromosomes. The viral genome can be either DNA or RNA, therefore they are divided into DNA virus or RNA virus. These DNA or RNA can be single stranded or double stranded. One viral genome can contain single molecule or multiple molecules; the DNA or RNA can be circular or linear. In total, viral genome are the most diversified in terms of composition.
- Bacterial lambda phage is one example of viral genome. It has a linear double strand DNA, the ends of the DNA is "sticky", meaning that the two ends can complement each other and fold back to form a circular molecule. The whole genome can be integrated into its host E. coli chromosome for replication.
- DNA is composed of four chemical bases including A, adenine, G, guanine, C, cytosine and T, thymine. These base are connected sequentially on a backbone made from deoxyribose and phosphate. DNA bases can pair with each other, A can only pair with T, and C can only pair with G.
- Nucleotides consist of three parts:
    - A five-carbon sugar (hence a pentose). Two kinds are found: deoxyribose, which has a hydrogen atom attached to its 2' carbon atom and ribose, which has a hydroxyl group atom at the 2' carbon.
    - A nitrogen-containing ring structure called a base. The base is attached to the 1' carbon atom of the pentose. In DNA, four different bases are found: two purines, called adenine (A) and guanine (G) two pyrimidines, called thymine (T) and cytosine (C). Purine is a heterocyclic aromatic organic compound, consisting of a pyrimidine ring fused to an imidazole ring. Pyrimidine is a heterocyclic aromatic organic compound, which is similar to benzene and pyridine and that contains two nitrogen atoms at positions 1 and 3 of the six-membered ring. It is isomeric with two other forms of diazine.
    - One, two, or three phosphate groups. These are attached to the 5' carbon atom of the pentose.
- The DNA double helix characteristics: Anti-parallel, Enormous Numbers of Hydrogen Bonds, Major/Minor Grooves
- DNA has Maximum absorbance at 260 nm. One characteristics about DNA is Melting temperature (Tm): The double strand is held together by hydrogen bonds; When heated, the structure loose and two strands separate (melting), Tm = temperature when 50% of double strand are unwound. GC pair has three hydrogen bond and AT has two, therefore high GC% leads to high Tm. Absorbance 260nm increases upon melting of the double strand.
- DNA Replication is semi-conservative.
- Initiation of DNA replication: Four steps: 1. recognition and binding of the ORIGIN by proteins 2. melting DNA at origin (strand separation) 3. stabilize single strands, 4. priming with RNA (primosome).
- Lagging strand is synthesis: first, the RNA primers are synthesized by primase, the primer anneal to the DNA template and then the DNA polymerase synthesizes new DNA fragments, when these newly synthesized fragments reach the down stream (which is the opposite direction to the fork moving direction) RNA primer, it replaces the RNA primer and the gap is filled by DNA polymerase. Then finally these pieces of DNA fragments are ligated together by DNA ligase.
- The DNA replication of the lagging strand of DNA is more complex then the replication of the leading strand. Pol II is the major DNA replication enzyme but it does not work in the 3'5' direction. On the lagging strand, primase "reads" the DNA and adds RNA to it in

short segments. Pol III lengthens these segments making what is called Okazaki fragments. Pol I then "reads" the fragments, removes the RNA and adding nucleotides. DNA ligase then joins the fragments.

- DNA Leading strand synthesis: The leading strand of DNA goes from the 5′ to 3′ direction. On the leading strand Pol II reads the DNA and adds nucleotides continuously. On the leading strand DNA polymerase III is able to synthesize DNA using free 3′OH group donated by a single RNA primer. Continuous synthesis occurs in the direction the replication fork is moving.
- DNA strand elongation: Step 3 is strand elongation. There are two facts: 1) DNA polymerase can only synthesize DNA from 5′ → 3′ direction; 2) DNA double strand is antiparallel.
- A telomerase is an enzyme that adds telomere repeat sequences to the 3″end of DNA strands. By lengthening the strand DNA polymerase is able to finish the synthesis of the incomplete ends of the opposite strand. Telomerase is usually only in germ cells, unicellular eukaryotes, some adult stem cells and cancer cells.
- A mutation is a permanent change in DNA sequence. This may be due to a number of factors including environmental damage, DNA replication and or repair errors.
- There are 5 basic "groups" of mutations include: deletion, duplication, inversion, insertion and translocation mutations.
- Missense Mutation: A mutation in which a base pair change in the DNA causes an altered amino acid in protein so that the phenotype changes.
- Transition Mutation:
- One purine-pyrimidine base pair change to another purine-pyrimidine base pair, e.g., AT to GC
- Transversion Mutation: One purine-pyrimidine base pair change to a pyrimidine-purine base pair, e.g., AT to TA
- Nonsense Mutation: A mutation that changes an amino-acid encoding codon into a stop codon
- This results in truncated protein
- Neutral mutations have no phenotypic effect. Often it is a change from one amino acid to another with similar chemical properties. Typically the function of a protein is not affected.
- A silent mutation is a DNA sequence that is changed but the amino acid it codes for does not change. This is because of the degenerative nature of codons.
- The frame-shift mutation is the addition or deletion of one or a few base pairs that leads to a change in the reading frame of an amino acid. This usually results in a non-functional protein.
- There are two classes of repair mechanisms: direct repair of DNA lesion and repair involving excision of base pairs. Direct Repair of DNA Lesions, can be DNA polymerase proofreading, Light repair or Repair of alkylation damage. Repair involving excision of base pairs includes Excision repair, Glycosylase repair, Mismatch repair and SOS response.
- Molecular DNA Techniques: Restriction endonuclease are found in bacteria, they recognize specific DNA sequences, modify and cut DNA. When cut, it generated either blunt ends or sticky ends of the DNA.
- Plasmids for cloning characteristics: An ore sequence: allows the plasmid to replicate in E. coli A dominant Selection marker allowing the transformed E. coli distinguish from untransformed cells, often antibiotic resistance genes and unique restriction enzyme sites: allow cloning of the foreign DNA into the vector.
- Transformation of bacteria: Using a recombinant plasmid, insert the DNA fragment into a vector by restriction digestion and ligation. The plasmid is placed into a host cell (E. coli) for amplification.

- Electrophoresis is the method were by macromolecules are separated based on their size or charge using an electric field and samples placed on some sort of solid matrix, like a gel or paper. DNA is a negatively charged molecule, and is moved by electric current through a matrix of agarose. The rate of migration is proportional to size ◊ smaller fragments moving more quickly. DNA is visualized by staining with ethidium bromide ◊ fluoresce under UV light.

Chapter 05: RNA and Protein Biosynthesis

Chapter Summary:

The flow of information in the cell is from DNA to mRNA to protein. This is accomplished by using DNA as the template from which mRNA is copied. The mRNA is then edited removing introns and forming a mature mRNA molecule. Variable splicing of pre-mRNA molecules allow a single pre-mRNA to provide information for the formation of different proteins. The mature mRNA is then read in the ribosome. The ribosome is a complex of proteins that have rRNA (ribosomal RNA) associated with it. rRNA serves the purpose of aligning the mRNA to be copied into protein. tRNA binds a complementary region (codon) consisting of 3 nucleotides. The tRNA carries with it an amino acid. Upon binding the mRNA the amino acid is transferred to the growing chain of amino acids and a peptide bond is formed between the amino acids.

Tutorial Features:

- Animation of mRNA synthesis and subsequent protein synthesis are presented.
- Pre-mRNA maturation and editing is detailed.
- 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.
- Practice test passages and questions are provided along with a detailed step by analysis of selecting the correct answer.

Key Concepts:

- RNA
- Transcription: DNA to RNA
- RNA structure: base, ribose, and phosphate
- RNA types: mRNA, tRNA, rRNA
- Protein biosynthesis
- Translation: mRNA to protein
- Codons and amino acids

Chapter Review:

- mRNA, Messenger RNA, encodes the amino acid sequence of a polypeptide.
- tRNA: Transfer RNA, transports amino acids to ribosomes during translation.
- rRNA: Ribosomal RNA, forms complexes called ribosomes with protein, the structure on which mRNA is translated.
- RNA structure: RNA is a polymer having a ribose and phosphate backbone. RNA has four different bases: adenine, guanine, cytosine and uracil. Adenine, guanine and cytosine are found in DNA uracil replaces thymine in RNA. There are many modified bases and sugars in RNA. Ψ pseudouridine the linkage between uracil and ribose is changed from a C–N bond to a C–C bond. Inosine is a deaminated guanine base. Single stranded RNA has a right handed stacking pattern.
- RNA (Ribonucleic Acid) is a nucleic acid found in the nucleus and cytoplasm. RNA contains 2 purine bases (adenine and guanine) and 2 pyrimidine bases (uracil and cytosine). Like DNA, the bases in RNA have complementary pairings that involve H bonds. Adenine and uracil form 2 H bonds with each other, while guanine and cytosine form 3 H bonds with each other. RNA molecules are generally single-stranded, but they may also be double-stranded helices or contain loops (i.e., areas where the RNA doubles back on itself via a hairpin turn).

- DNA and RNA are both nucleic acids (i.e., linear, unbranched polymers of nucleotides), but they differ in three basic respects:
  - The five-carbon sugar in DNA is deoxyribose (H atom attached to the 2′ carbon atom) while in RNA the sugar in ribose (OH group attached to the 2′ carbon atom).
  - The nitrogen-containing ring structures called bases, which attach to the 1' carbon atom of the sugar, are slightly different. RNA, includes two purines, adenine (A) and guanine (G), and two pyrimidines, Uracil (U) and cytosine (C). DNA does not contain Uracil. Instead, it has a pyrimidine base called Thymine.
  - The 3-D structure of RNA is more variable than DNA. DNA exists as a double helix, while RNA is usually a single-stranded molecule that can adopt a variety of structural conformations, depending on the type of RNA.
- tRNA: The genetic code is translated by means of two adaptors that act one after another. The first adaptor is the aminoacyl-tRNA synthetase, which couples a particular amino acid to its corresponding tRNA; the second adaptor is the tRNA molecule itself, whose *anticodon* forms base pairs with the appropriate *codon* on the mRNA. An error in either step would cause the wrong amino acid to be incorporated into a protein chain. In the sequence of events shown, the amino acid tryptophan (Trp) is selected by the codon UGG on the mRNA.
- rRNA is a major structural component of ribosomes (site of protein synthesis), and is probably involved in binding the mRNA to the ribosome to enable it to be translated. It is the construction site where the protein is made.
- RNA Synthesis includes the following steps:
- Regulated by gene regulatory elements (promoters) within each gene.
- RNA polymerase unwinds DNA next to a gene.
- RNA is transcribed 5′ to 3′ from the template (3′ to 5′).
- Transcription from DNA to RNA uses NTPs instead, no primer is needed, no proofreading function, adds Uracil (U) instead of thymine (T) and RNA polymerase is involved. Genomic DNA is kept in the nucleus of the cell and must be protected from mutation. In order to create the many proteins that build cells and allow them to carry out their metabolic reactions, then, a transient copy of the information in DNA, called mRNA, is created. There are three basic steps in RNA synthesis: Initiation, Elongation, and Termination.
- In **initiation**, the DNA double helix is unwound only in the region where transcription will occur. This spot is specified by the promoter of the gene to be copied. RNA Polymerase recognizes the promoter sequence, binds the double helix, and forces open the strands.
- In **elongation**, RNA polymerase incorporates ribonucleosides into the growing RNA strand. To make the RNA copy of DNA, base pairing rules are followed, such that if a G is present in the DNA template, a C is incorporated into the RNA strand; however, wherever there is an A in the DNA molecule a U will be incorporated into the RNA strand, instead of a T (RNA contains Uracil, not Thymine). As in replication, RNA synthesis occurs in the 5′ to 3′ direction.
- **Termination** occurs when RNA Polymerase reads a stop signal in the DNA. The double helix reanneals, and after a processing step the RNA is ready to leave the nucleus. If the RNA created is an mRNA molecule, it will be subsequently translated into protein.
- There are 61 amino acid coding codons and about 40 tRNA molecules for 20 amino acids.
- Codons that encode the same amino acid often differ only by their third base.
- The binding of the third base is less stringent than the other two.
- Because of this <u>wobble</u> one tRNA can pair with multiple mRNA codons.
- RNA splicing: introns sequences are removed from RNA transcripts in the nucleus during DNA transcription.
- Ribosome is a protein which along with rRNA catalyzes the synthesis of proteins.

Chapter 06: Molecular Biology of Eukaryotes

Chapter Summary:

A karyotypes is a set of human chromosomes stained with specific dyes. The karyotype of a eukaryote is unique. Human chromosomes consist of DNA strands complexed with specific proteins called histons. The association of DNA with protein allows the DNA to wind and compact. Euchromatin is a lightly packed form of chromatin having many genes that are often under active transcription.

Eukaryotic genes are transcribed in nucleus. Genes are under transcriptional control. When the DNA is transcribed into pre-mRNA it undergoes RNA processing followed by mRNA export into the cytoplasm. mRNA is translated into protein at this point it is under translational control. The new protein can be modified under what is known as post translational control. The gene in eukaryotes has a generalized structure. Eukaryotic genes include: promoter is a regulatory region of DNA that is located upstream toward the 5′ region (usually) of a gene. It provides a control point for regulated gene transcription. Protein-coding sequences of the gene are exons. Non-protein-coding sequences of the gene are called the introns. Enhancers are sequences that serve to enhance transcription of genes. Silencers are similar to enhancers, but they have the opposite effect on transcription (i.e., they repress transcription).

Tutorial Features:

- Detailed description of eukaryotic chromosome.
- Outline of generalized eukaryotic gene with its regulatory regions.
- Methods of regulation of both gene transcription and mRNA translation are demonstrated with animated diagrams.
- The mechanisms of carcinogenesis. Proto Oncogenes, viral Oncogenes and tumor suppressor genes are detailed.
- 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.
- Practice test passages and questions are provided along with a detailed step by analysis of selecting the correct answer.

Key Concepts:

- Eukaryotic chromosome composition, DNA and proteins associated to form chromosomes.
- Structure of Eukaryotic chromosomes: telomeres and centromeres.
- Eukaryotic gene expression is outlined.
- Regulation of transcription is described.
- Transcription factors and their roles are detailed.
- The post-transcriptional modifications of RNA are shown.
- Carcinogenesis causes and mechanisms shown.

Chapter Review:

- The karyotype is the complete set of metaphase chromosomes in a cell.
- Chromosomes can be “stained” using different chemicals and conditions resulting in a characteristic “banding pattern”.
- Chromatin is made up of DNA and proteins, RNAs and even lipid molecules.
- Heterochromatin is tightly packed and transcription is limited.

- Euchromatin is a lightly packed form of chromatin having many genes that are often under active transcription.
- The repeat element of chromatin is a nucleosome. The repeats are connected by sections of DNA known as linker DNA which is fairly short in length. There is the main or core histones and linker histones called H1 which contacts the exit and entry of the DNA strand on the nucleosome.
- Unlike prokaryotic cells, eukaryotic cells contain membrane-bound nuclei that house their genomic DNA. Some additional DNA is stored in mitochondria and plant chloroplasts.
- Eukaryotic cells include the gametes (reproductive cells) and somatic (all other) cells.
- The basic set of human chromosomes includes 22 paired autosomes and 1 pair of sex chromosomes.
- Somatic cells are diploid (46 chromosomes) while gametes are haploid (23 chromosomes).
- Telomere Structure and Function
  - The sequence at the ends of the eukaryotic chromosome.
  - The telomere consists of simple repeated sequences of DNA.
  - They are important in replication of the ends of linear DNA molecules.
- Centromere Structure and Function
  - Consist of specific DNA sequences.
  - Ensure precise segregation of the duplicated chromatids.
- Genes are segments of the chromosome that contain the code or information of a proteins amino acid sequence. A gene has introns, exons and regulatory regions. The regulatory regions help determine what is transcribed. Exons contain the information for the protein sequence. The introns are non coding regions that are removed during the process of making a mature mRNA molecule.
- Regulation may occur at: transcription initiation, transcriptional antitermination, post-transcriptional, regulation of translation and post translational regulation.
- Gene Expression: A eukaryotic gene is transcribed in nucleus, which is under the transcriptional control. Then the pre-mRNA undergoes RNA processing and mRNA export, which belongs to post-transcriptional control. When mRNA is translated into protein, it is under the translational control. The newly synthesized protein is modified and sorted into different compartment of the cell for proper function, which is under the post-translational control.
- Gene Expression & Regulation: Eukaryotic genes have several characteristic features that are important in regulating their expression.
- Promoters are transcription permission sequences. They may be upstream or downstream of the transcription start site.
- Protein-coding sequences of the gene are called the exons.
- Non-protein-coding sequences of the gene are called the introns.
- Enhancers are sequences that serve to enhance transcription of genes. They may be far upstream or downstream of the transcription start site, or even on separate chromosomes.
- Silencers are similar to enhancers, but they have the opposite effect on transcription (i.e., they repress transcription).
- Enhancers and eukaryotic genes: Eukaryotic genes contains: Enhancers: a short region of DNA that can be bound with proteins to promote expression of a distal or proximal gene. Promoter: Proximal DNA sequence that binds to RNA polymerase for regulating gene expression. TATA Box: Binds to transcription factor for regulating gene expression, usually within 30bp of the transcription start site.
- The control at mRNA level includes transcriptional control and post-transcriptional control. Transcriptional control is coordinated by promoter, enhancer, and transcription

factors, normally involve the initiation; polyadenylation and capping; mRNA sequestration and mRNA export; mRNA stability and availability for translation.

- Transcription Initiation is the key step to control transcription. It is regulated by multiple transcription elements such as promoters, Enhancers; RNA polymerase complex; Transcription factors which has a large number and divided into two groups: Basal Transcription factors which are Required for all transcription, assist RNA polymerase to bind to promoter sequences, and Unwinding the DNA double helix.
- Transcription factors are a type of proteins that bind to promoter sequences to either promote or repress their transcription. Transcription factors recognize and bind promoters before RNA Polymerase. In fact, several transcription factors may bind a promoter via protein-DNA and protein-protein interactions, and this series of interactions recruits RNA Polymerase to the promoter to actually begin synthesis.
- Alternative splicing: Alternative splicing an important mechanism in gene regulation.
- Introns are spliced out at different positions.
- Results in many isoforms of the same protein.
- Improper splicing may cause severe disease.
- 5′ mRNA capping: Another important post-transcriptional control is 5′ capping. All mRNA is capped at 5′ end. This protects mRNA from nuclease and increases its stability. 5′ caps also allow ribosome to bind to mRNA and initiate translation.
- uORF stands for upstream open reading frame. They are short open reading frame upstream of main ORF AUG.
- They inhibit main ORF by its own AUG –which is upstream of the main ORF AUG, has the priority to attract the scanning initiation complex. The uORF peptide can also inhibit translation of main ORF by occupying ribosomes. The main ORF can be initiated by two mechanisms: re-initiation and leaky scanning.
- Post-translational control includes: Attachment of a specific group to the protein; Sort the protein to the proper cellular location; and Protein folding and complex formation.
- Three classes of genes frequently are mutated in cancer: Proto-oncogenes and oncogenes; Tumor suppressor genes
- and DNA repair genes. Proto-oncogene stimulates cell growth and proliferation for normal cell division. When proto-oncogene is mutated, it becomes oncogene, which increase cell proliferation and leads to malignant transformation.
- Oncogenes arise from proto-oncogenes that have been activated or mutated.
- Some tumor viruses possess oncogenes, these are called viral oncogenes. There are Two Types of virus that caused tumors: RNA tumor viruses and DNA tumor virus. RNA tumor virus possess viral oncogenes derived from cellular proto-oncogenes and capable of transforming cells to a cancerous state. DNA tumor viruses do not carry oncogenes, they induce cancer by activity of viral gene products, mainly act through inactivating tumor suppressors.
- Tumor suppressors are genes that reduce the probability of tumorigenesis. A mutation or deletion of such a gene will increase the probability of the formation of tumor. They function in inhibiting cell division and promoting cell death. Tumor suppressor function in malignant transformation is outlined in this slide; mainly rendering cells lose control of cell growth and proliferation.
- DNA repair genes are a group of genes that function in repair damaged DNA and reduce mutations, therefore maintain genome integrity. During normal DNA replication or exposure to chemical/physical agents, DNA damage may occur. These damages are repaired by DNA repair genes and cells can back to normal cycle again. When DNA repair genes are mutated, more mutations will accumulate and lead to malignant transformation.

Chapter 07: Genetics and Mendelian Concepts

Chapter Summary:

This chapter describes the laws of genetics otherwise known as Mendelian inheritance. These underlie much of modern genetics. Mendel's first law is known as the Law of Segregation. In the Law of segregation Mendel states that there are alternative versions of genes called alleles. For each characteristic an organism inherits two alleles one from each parent. So that somatic cells have two alleles the alleles may be the same and are called true breeding or homozygous or they may be different called heterozygous. If the two alleles differ one is dominant and the other recessive. The dominant trait will show regardless of what the recessive trait is. The recessive trait will only show if it is homozygous. There are instances of codominance which is seen in the human ABO blood type.

Mendel's second law is the Law of Independent Assortment. This states that the inheritance pattern of one trait will not affect the inheritance pattern of another. Independent assortment happens in meiosis I in eukaryotic organisms and makes a gamete with a mixture of organisms' maternal and paternal chromosomes. Chromosomal crossover provides genetic diversity by producing new genetic combinations.

Tutorial Features:

- Description Mendel's law of Segregation
- Description of Mendel's Law of Independent Assortment.
- Demonstration of supporting experiments of Mendel's Laws.
- Example of relevant pedigrees which reflect many of the genetic principles of Mendel.
- Recombination and how it is used to show distance between linked genes.
- Exceptions to Mendel's law such as maternal inheritance and linked genes are shown.
- 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.
- SURE method for passage questions is described.

Key Concepts:

- Basic concepts about Mendelian Genetics.
- Mendel's Principle of Segregation.
- Mendel's Principle of Independent Assortment.
- Extensions to Mendelian Genetics.
- Statistical Analysis of Genetic Data.
- Mendelian Genetics in Human.

Chapter Review:

- Homologs are a pair of nearly identical chromosomes, one from the father and the other from the mother.
- Allele: each homologous chromosome has one copy of a gene (one allele). A 2N cell, having a pair of homologous chromosomes, carry two alleles one for each gene. These alleles can be identical or different: AA, aa or Aa.
- *Homozygous* means that the two alleles are identical e.g. AA or aa.
- *Heterozygous* means that the two alleles are different one is dominant and the other recessive e.g. Aa.

- Dominant allele is one that expresses its trait regardless of the other allele present. It is usually designated by a upper case letter.
- Recessive allele is one that cannot express its phenotype when a dominant allele is present; it is usually designated by lower case letters.
- A gamete is a mature reproductive haploid cell, like egg or sperm.
- A haploid cell has only one set of chromosomes. All gametes from diploid organisms are haploid (1N).
- Diploid cells have two sets of chromosomes. Most somatic cells are diploid (2N).
- Genotype is the composition of two alleles of a gene or multiple genes, e.g. genotype: RR, Rr or rr or RrYy, RRyy etc.
- Phenotype is the expression of the genotype the observed trait of the gene, e.g. green color and round shape of a pea seed. The phenotype is controlled by genotype.
- Mendel developed two laws of genetics: First Law: Principal of Segregation, two members of a gene pair (alleles) separate (segregate) from one another in forming the gametes. Each gamete carries one allele. Second Law: Principle of Independent Assortment: Genes for different traits assort independently of one another in the formation of gametes.
- During the formation of gametes genes from different chromosomes assort independently and combine randomly. What this means is that genes are not influenced by how other genes assort i.e. just because the yellow allele goes to one cell has no influence on the migration of the allele for round or wrinkled. The law of independent assortment may be disobeyed if two alleles are linked. The closer two alleles are on a chromosome the greater the probability is that they will migrate together.
- Linked genes can cross-over, called recombination and sometimes "sister chromatid exchange".
- Maternal inheritance: The mitochondria and chloroplasts are in the cytoplasm and are transmitted only by the mother. So all the mitochondria in an offspring comes from the mom.
- In some cases, both allele can be expressed when they are present, i.e., the phenotype of each allele is not masked by the presence of the other alleles. This is called co-dominance. For example, sickle cell anemia allele HbS can be co-dominant with normal hemoglobin allele Hbb. In a heterozygous patient, both alleles are expressed and about half of the red blood cells will exhibit the sickle cell phenotype, half of the blood cells will be normal.
- Epistasis is when one gene's function is modified by one or more other genes.
- The human ABO blood type is an example of multiple alleles that are co-dominant.
- Recessive Characteristics:
  - Most individuals have two normal parents (Aa X Aa).
  - They may skip a generation.
  - Mating of two normal parents produce about 3:1 normal to recessive traits.
  - If both parents are affected all children will be affected (aa X aa).
- Dominant Characteristics:
  - Every affected individual must have at least one affected parent.
  - Will not skip a generation.
  - Half of the children from the affected individual will have the phenotype (Aa X aa, Aa X Aa).

Chapter 08: Meiosis and Genetic Variability

Chapter Summary:

This chapter details the process of meiosis and mitosis. Meiosis proceeds in two steps called Meiosis I and Meiosis II. Meiosis I: Prophase I, Metaphase I, Anaphase I, Telophase I. Meiosis II: Prophase II, Metaphase II, Anaphase II, Telophase II.

Mitosis is a process of cell division which results in the production of two daughter cells from a single parent cell. The daughter cells are identical to one another and to the original parent cell. Mitosis: Interphase (parental cell): coiled chromatin, DNA already replicated, Prophase: nuclear envelop broken down, chromosome condensed and visible, Metaphase: chromosomes line up at the equatorial plate, Centromeres are attached to spindles, Anaphase: Sister chromatids are pulled to the two poles, Telophase: chromatids expand to chromatin form, cytoplasm separate, nuclear membrane reappear, cytokinesis occur.

The Hardy-Weinberg Law is described and its effect on the genotype frequencies of a large, randomly mating population remains constant provided immigration, mutation, and selection do not take place. The equation of the Hardy-Weinberg Law has certain assumptions including: that the population is infinitely large, mating is random, no natural selection, no mutation and no migration. If these assumptions are met the allele frequencies will not change over generations. At equilibration the equation $p^2 + 2pq + q^2 = 1$ describes the allelic frequency.

- p^2 = frequency of AA
- $2pq$ = frequency of Aa
- q^2 = frequency of aa
- p = allelic frequency of A
- q = allelic frequency of a

Tutorial Features:

- Pedigrees of sex linked traits are portrayed and analyzed.
- Meiosis is detailed.
- Mitosis is described and detailed.
- The importance of linkage and recombination are shown
- Hardy Weinberg equation and its assumptions are demonstrated.
- 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.
- SURE Method: Practice test passages and questions are provided along with a detailed step by analysis of selecting the correct answer.

Key Concepts:

- Meiosis and its significance.
- Mitosis and how it differs from meiosis.
- Types of DNA mutation.
- Hardy-Weinberg theory and its implications for evolution.

Chapter Review:

- Human somatic cells contain 2N chromosomes, total 46 chromosomes consisting of 23 pairs of nearly identical ones. Each pair contains one chromosome from father and one from mother termed homologous chromosomes. Human germ cells contain only half number of chromosomes compared to somatic cells, i.e., 1N.

- Mitosis is DNA replication and forms two cells that are exactly like the cell it started from.
- Meiosis is "reduction – division". Occurs in the germ cells and forms gametes that are haploid 1N.
- Meiosis proceeds in two steps called Meiosis I and Meiosis II.
- Meiosis I: Prophase I, Metaphase I, Anaphase I, Telophase I
- Meiosis II: Prophase II, Metaphase II, Anaphase II, Telophase II
- Mitosis is a process of cell division which results in the production of two daughter cells from a single parent cell. The daughter cells are identical to one another and to the original parent cell
- Mitosis:
- Interphase (parental cell): coiled chromatin, DNA already replicated
- Prophase: nuclear envelop broken down, chromosome condensed and visible
- Metaphase: chromosomes line up at the equatorial plate, Centromeres are attached to spindles
- Anaphase: Sister chromatids are pulled to the two poles
- Telophase: chromatids expand to chromatin form, cytoplasm separate, nuclear membrane reappear, cytokinesis occur
- Genetic markers include phenotypes such as color and size at early stages, now they also include molecular markers which can be known DNA sequences located in a known position on the chromosomes. Linkage of markers is referred to two markers segregate together during gamete formation.
- Recombination: linked genes can cross over during meiosis to produce new gamete types .
- Genetic distance can be measured by recombination frequency. The more distant a set of genes the more likely crossover will occur.
- The genetic distance is measured by map unit (m.u.), one map unit equals to one percent recombinant frequency; One m.u. also is called 1 centiMorgan (in honor of Morgan's work).
- Sex Linked Genetics
- The X and Y chromosomes determine human sex. Females have two X chromosomes (XX) and males have one X and one Y chromosome (XY). Females have 44 autosomal + XX chromosomes. Males have 44 autosomal + XY chromosomes.
- Summary X linked Traits:
- Females have two XX chromosomes.
- X linked means the gene of a particular trait resides on the X chromosome.
- A gene on the X chromosome can be recessive or dominant.
- Genes on the X chromosome are expressed differently in females then in males.
- An X linked recessive gene in females is expressed on if both XX chromosomes carry the recessive gene.
- A X linked recessive gene can be expressed in males because they carry a Y chromosome.
- During fertilization females only contribute an X chromosome.
- Summary Y linked Traits:
- Y linked traits appear only in males and are passed from father to son. Y linked genes reside only on the Y chromosome. There are very few Y linked traits. Y linked traits do not skip generations. Males contribute either an X or Y chromosome. If an X chromosome is contributed the genotype will be XX female, and if a Y is contributed the genotype will be XY and the offspring male.
- Gender Determination: in humans it is determined by the presence of XX or XY however not all species do it this same way.

- Grasshoppers: Females have XX – Males have XO – one X chromosome, not paired. O means missing one chromosome.
- Chickens ZZ-ZW Determination, Females have ZW –one Z chromosome and one W chromosome and Males have ZZ –a pair of Z chromosomes. Some birds such as chicken belong to this group. When a male is crossed with a female, the sperms carry a Z chromosome, the egg carries either a Z chromosome or a W chromosome, when the fertilization occur, the offsprings have ZW:ZZ= 1:1.
- In some species gender is determined by chromosome number. In bees a 2N individual will be female and a 1N individual will be a male.
- The Hardy-Weinberg Law: The genotype frequencies of a large, randomly mating population remains constant provided immigration, mutation, and selection do not take place.
- Hardy-Weinberg Law Assumptions: Population is infinitely large, Mating is random, No natural selection, No mutation and No migration. Expectations if the assumptions are met: Allele frequencies do not change over generations.
- At equilibration equation: $p^2 + 2pq + q^2 = 1$

  p^2 = frequency of AA

  $2pq$ = frequency of Aa

  q^2 = frequency of aa

  p = allelic frequency of A

  q = allelic frequency of a

- Females have two X-chromosomes, and males have one X and one Y chromosome. A woman carrying a recessive defect on one of her X-chromosomes may not be affected because she has a second "normal" X chromosome (normal allele). Males on the other hand do not have a allele that match up to all the genes on the X chromosome, in that situation all male children inheriting the X chromosome with the defect will have and show the defective trait. Girl carriers will be able to pass the gene on to their offspring but will not show the trait the girl children may also be normal if they inherited the normal X from their mom (which they have a 50% chance of doing) and the normal X from their Dad. This is the situation with the disease known as hemophilia. This is a clotting disorder where one of the proteins need to make the blood clot is defective so a person has difficulty clotting their own blood.

Chapter 09: Prokaryotes and Fungi

Chapter Summary:

This chapter details the primary structural components of prokaryotes and fungi. Gram negative and gram positive prokaryotes are compared and contrasted. Additionally the reproductive methods, such as binary fission and sporulation are discussed.

Prokaryotes are classified based on a number of parameters: Oxygen Requirements, Nutrition, Photosynthetic Capacity, Chemosynthetic Capacity, Feeding of Organic Matter, Staining and Shape. Major types of prokaryotes are presented.

Tutorial Features:

- Animated presentation of gram negative and gram positive bacteria cells.
- Detailed comparison between prokaryote and eukaryote cell.
- Introduction to fungi and their unique structures.
- Description of bacteria classification methods.
- 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.
- SURE Method: Practice test passages and questions are provided along with a detailed step by analysis of selecting the correct answer.

Key Concepts:

- Structure of Prokaryotic Cells
- Classification of Bacteria
- Prokaryotic Mobility
- Bacterial Cell Wall
- Reproduction in Bacteria
- Bacterial Growth & Physiology
- Bacterial Genetics
- Characteristics & Life Cycle of Fungus

Chapter Review:

- **Prokaryotes**: No Membrane Bound Nucleus, One Continuous DNA Strand, Have a Cell Wall, Ribosomes Only, No Centrioles for Mitosis, Simple Flagella.
- **Eukaryotes**: Membrane Bound Nucleus, Multiple Separate Chromosomes, Cell Wall in Plant Cells Only, Many Organelles, Extensive Mitotic Organization, Complex Flagella
- The cell envelope is the cell membrane, the cell wall plus an outer membrane if present. Bacterial cell envelopes are two major kinds, Gram positive and Gram negative.
- Cell capsule is an organelle in some bacteria that is on the outside of the cell wall. The capsule is composed of polysaccharides and protects the bacteria against phagocytosis. Because of this it is considered a virulence factor. The capsule also protects bacteria from desiccation, viruses and detergents. It is most common in Gram Negative bacteria like E.coli. But can be in gram positive cells. It is sometimes called the "outer membrane".
- The cell membrane is a semi permeable phospholipid bilayer it has a variety of biological molecules like proteins and lipids. It also serves as the attachment for the intracellular cytoskeleton and if present the cell wall.
- The cell wall is a rigid layer surrounding the it is external to the cell membrane. The cell wall is import for structural support and prevents over-expansion when water enters the

cell. Cell walls are found in plants, bacteria, archaea, fungi and algae. Animals and most protists do not have cell calls. The cell wall is composed of different materials depending on the species. In bacteria peptidoglycan forms the cell wall. In Archaea it is mostly composed of glycoprotein, pseudopeptidoglyan or polysaccharides.

- Gram Positive Bacteria Characteristics: cytoplasmic membrane, thick peptidoglycan layer, teichoic acids and lipteichoic acids are present, capsule polysaccharides. It is has a flagellum it has two rings for support.
- Gram Negative Bacteria Characteristics: Cytoplasmic membrane, thin peptidoglycan layer, outer membrane has lipopolysaccharide (LPS have lipidA, and O antigens) outside the peptidoglycan layer, porins are in the outer membrane, space between the layers of peptidoglycan and the secondary cell membrane called the periplasmic space, The S-layer is directly attached to the outer membrane. If a flagella is present it has four supporting rings. No teichoic acids or lipoteichoic acids are present. Lipoproteins are attached to the polysaccharide backbone (Gram-positive bacteria no lipoproteins are present). Most do not sporulate (*Coxiella burnetti*, which produces spore-like structures is an exception).
- Bacterial growth: Initially the growth of bacteria is slow, and this phase is called the lag phase. As the bacterial population starts to rise, each round a doubling of the population occurs- this is the exponential or log phase of growth. Once bacterial numbers are high enough to strain the nutrients in the environment, growth slows and this is called the stationary phase. Lastly, as the nutrients become more depleted bacterial cells die.
- Prokaryotes contain a single circular chromosome which is many times the entire length of the cell. The chromosome is attached to the inside of the plasma membrane. No other proteins are found on the chromosome, except for DNA. Prokaryotes do not reproduce sexually. Prokaryotes reproduce by Binary fission In binary fission, spindle formation does not occur in mitosis.
- Conjugation:
  - Pilus comes from donor cell.
  - Pilus attaches to new cell.
  - A linearized plasmid is transferred to the new recipient cell.
  - Both cells recircularize their plasmids and synthesize second strands.
  - Both cells an now donate plasmids.
- Transformation is the event when a bacteria picks up DNA that has been left from dead or living bacteria. These DNA can then be used to acquire new abilities.
- An endospore is a dormant, tough and non-reproductive structure. It is made by a small number of bacteria. The main purpose of endospores is to enable the cell to survive during periods of environmental stress.
- Prokaryotic Classification Parameters
  - Oxygen Requirements
  - Nutrition
  - Photosynthetic Capacity
  - Chemosynthetic Capacity
  - Feeding of Organic Matter
  - Staining
  - Shape
- Photoheterotrophs are heterotrophs that use light for energy, but cannot use carbon dioxide as their sole carbon source. Therefore they use organic compounds from the environment for their carbon needs. Examples include: purple non-sulfur bacteria and heliobacteria.
- Photoautotrophs are organisms which can photosynthesize and use energy from sunlight, carbon dioxide and water which are converted into organic molecules for use in cellular functions.

- Chemotrophs are organisms that get energy by oxidation of electron donating molecules. These molecules can be organic or inorganic. The chemotroph is in contrast to phototrophs. Chemotrophs can be either autotrophic or heterotrophic.
- Chemoheterotrophs have to take in organic building blocks that they cannot create. Most chemoheterotrophs get energy from organic molecules like glucose.
- Chemoautotrophs in addition to getting energy from chemical reactions also synthesize all necessary organic compounds from carbon dioxide.
- Chemosynthetic Prokaryotes use inorganic chemicals to make energy, Acquire energy to make organic food by oxidizing high energy inorganic compounds: such as hydrogen gas, ammonia, nitrites, sulfides and Majority of these organisms are anaerobic and found in deep water lakes and rivers.
- Heterotrophic prokaryotes are the Organisms which acquire energy by feeding on organic matter, they have enzymes for absorption and digestion of the organic matter and the majority of these organisms are aerobic.
- 3 basic types of heterotrophic prokaryotes: Saprophytes, mutualists and parasites. Saprophytes decompose organic matter, release nutrients and chemicals by feeding on other dead organisms and they make up the largest number of heterotrophs. Mutualists live in close proximity to another species and both organisms benefit as a result of this association. Parasites live in close association with another organism but only one species benefits from this relationship
- Eubacteria: Aerobic & Anaerobic, Ester linkages on membrane, Have Murein peptidoglycan, Need physiologic environment, Human pathogens
- Archaea: Exclusively Anaerobic, Ether linkages on membrane, Lack a peptidoglycan wall, Tolerate extreme heat & pH, Do not infect humans
- Cytoplasm of prokaryotes contains chromosome and ribosome. Enzymes for cellular respiration are attached to plasma membrane. Organelles are often found in cytoplasm of prokaryotes as distinct granules. These granules store fat or glycogen or contain enzymes. Ribosomes are the only cytoplasmic organelles in prokaryotes. They are much smaller in size compared to ribosomes seen in eukaryotes.
- Characteristics of Fungi: Fungi are eukaryotic, non-vascular organisms. Primarily coenocytic, having many nuclei in a single cytoplasm. Cell walls have chitin. Primarily non-motile, no flagella. Undergo sexual and asexual reproduction. Heterotrophes, must get nutrition from outside sources: absorb nutrition after it has been broken down outside the cell.
- Characteristic structures of fungi: Hypha (hyphae plural): long branching filaments. Main mode of vegetative growth. A collection of hyphae are called mycelium. Hypha consist of one or more cells surrounded by a cell wall. Divisions are called septa. Hyphae grow at their ends.
- Asexual reproduction in fungi:
  - 1. Spores are released from mature fungi.
  - 2. Spores germinate and begin to lengthen.
  - 3. Spores elongate and are then called hyphae.
  - 4. Hyphae continue to elongate and cluster together and are called mycelium.
  - 5. Mature mycelium release spores.

Chapter 10: Viruses

Chapter Summary:

The virus is introduced and defined. Viral Classification which is based on the genomic structure: I: dsDNA, II: ssDNA, III: dsRNA, IV: (+)ssRNA, V: (-)ssRNA, VI: ssRNA-RT, VII: dsDNA-RT is described and integrated with the International Committee on Taxonomy of Viruses on naming conventions and additional guidelines. ICTV classification uses a numerical code to represent: order, family, subfamily, genus, species, subspecies, serotype (or subtype) and strain (or isolate).

A detailed description of the HIV life cycle is described and shown in animation.

Tutorial Features:

- Detailed animation of HIV infection and pathogenesis.
- Animated lambda phage lysogenic and lytic life cycles.
- The methods of viral classification are described.
- 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.
- Practice test passages and questions are provided along with a detailed step by analysis of selecting the correct answer.
- SURE Method: Practice test passages and questions are provided along with a detailed step by analysis of selecting the correct answer.

Key Concepts:

- Structure & Characteristics of Viruses
- Structure & Characteristics of Bacteriophages
- Classification of Viruses
- Viral Genetics
- Viral Pathogenesis
- Viral Transduction
- Life Cycle of Viruses

Chapter Review:

- Virus – an "organism" who's genetic material may be either DNA or RNA surrounded by a protein coat. Viruses have to take over other cells in order to reproduce. Non-living self-replicating biological units that must utilize a host cell to reproduce. Have no nucleus or organelles. Infects all life forms from bacteria to mammals. Viruses are small intracellular particles. A fraction of the size of the typical bacterial cell.
- Viruses infect all life forms: bacteria, fungi, insects, birds, mammals including humans. Viruses can cause serious diseases such as HIV/AIDS and milder diseases like the common "cold". The mode of pathogenesis of a virus makes it difficult to cure. Hosts can be "exchanged". That means they can jump from one host to another for instance some bird viruses can infect humans. Antibiotics do not work against viruses. There are a few antiviral medications that can shorten the duration of infection of some viruses.
- Viral Classification
    - There are seven groups of viruses. These groups are based on the structure of the viral nucleic acid.
- Viral Groups :

- I: dsDNA,
- II: ssDNA
- III: dsRNA
- IV: (+)ssRNA
- V: (-)ssRNA
- VI: ssRNA-RT
- VII: dsDNA-RT

- Virion is a viral particle. The genetic material is either DNA or RNA. Nucleocapsid is the capsid + nucleic acid. Capsid protective protein coat. The shape varies from helical and icosahedra to complex structures with tails or an envelope. The viral envelope covers the protein capsid. The envelope is derived from portions of the host cell membranes (phospholipids and proteins) and may include some viral glycoproteins.
- Bacteriophage are viruses that only infect bacteria.
- Virus classification is a combination of two systems: Phenotypic characteristics, mode of replication and host organisms as well as type of disease they cause. Guidelines set out by the International Committee on Taxonomy of Viruses on naming conventions and additional guidelines. ICTV classification uses a numerical code to represent: order, family, subfamily, genus, species, subspecies, serotype (or subtype) and strain (or isolate).
- In Genome based classification the type of nucleic acid and weather it is + or – indicate negative or positive sense nucleic acids. ss = single stranded, and ds double stranded.
- Viruses do not grow via cell division because they are acellular. Viruses use the hosts replication machinery and metabolism to copy themselves.
- Viruses can compromise the integrity of a cell without killing it causing its death this is called cytopathic effects.
- Viral Life Cycle
  - Attachment: specific binding between viral capsid proteins and specific receptors on the host cellular surface. Attachment to the receptor can induce the viral-envelope to fuse with the cellular membranes.
  - Penetration: after attachment, viruses enter the host cell via receptor mediated endocytosis or membrane fusion.
  - Uncoating: viral capsid degraded releasing the viral genomic nucleic acid.
  - Replication: involves synthesis of viral mRNA (except for positive sense RNA viruses), viral protein synthesis of viral proteins and viral genome replication.
  - Assembled viral virus particles undergo post-translational modification (some not all molecules are modified this way).
- Viruses are released from the host cell by lysis. Enveloped viruses like HIV are released by budding in the process acquiring its phospholipid envelope.
- For a virus to replicate its genome, there are two general guidelines: 1) virus contains no transcriptional or translational machinery, therefore they are dependent on host cell machinery to reproduce themselves; 2) virus genome can be double or single DNA or RNA, each of them uses a different strategy for replication.
- For dsDNA virus such as adenovirus, the genome is replicated directly using the virus DNA as template. mRNA was synthesized from virus DNA for further viral infection and for viral structural protein. The viral protein and replicated DNA assembly into progeny virus.
- For ssDNA virus, the viral DNA is converted into dsDNA first, which then serve as template to produce progeny viral DNA. The dsDNA also serves as template to synthesize mRNA for viral protein, which is required for progeny virus assembly.
- For dsRNA virus, the virus contains a RNA-directed RNA polymerase which convert the viral RNA into mRNA. The mRNA serves as template to synthesize the other strand of the RNA and anneal to form the progeny viral RNA. The mRNA also serves as template to synthesize viral protein.

- For ss(+)RNA virus, there are two pathways. In path 1, the viral RNA can serve as template directly for viral protein synthesis. It also serves as template to make the minus strand RNA which in turn serves as template to make the progeny viral (+)RNA. The viral RNA can direct the synthesis of a polypeptide which is then cleaved to produce viral structural proteins. In path 2, the genome replication is the same as in Path 1, the strategy for protein synthesis is different.
- For ssRNA(-) virus, viral genome RNA replication requires the (+)RNA synthesis which serves as both mRNA and template for minus strand progeny RNA synthesis. The mRNA directs the synthesis of viral protein.
- Retrovirus is RNA virus but the genome replication require DNA intermediates. Usually these virus reverse-transcribe their viral RNA into double stranded DNA which is integrated into host genome. The dsDNA then serves as template for mRNA and viral genome synthesis.
- HIV is a retrovirus. That means its genetic information is in the form of RNA (not DNA). The outside of the virus has proteins that are sometime called "spikes" because of their shape. These proteins bind to cells, specifically T helper cells that have a complementary protein on its surface called CD4. In order for the HIV virus to gain entry into the cell it must bind the CD4 receptor. However CD4 alone is not sufficient for HIV to gain entry into the immune cell. A second protein on the immune cell called a "co-receptor" called a "Fusin" or CXCR4 is required for the HIV virus to get into the immune cell and is characteristic of HIV in the later stages. Other HIV co-receptors such as CCR-5 is characteristic of "early disease" strains. HIV attachment is done via the gp120 protein on the HIV molecule. This binds to the host cells receptor called CD4. Binding and entry is enhanced by co-receptors found on the host membranes. There are four primary cell targets for HIV (although there are some other tissues attacked it is more rare). HIV (covered by complement protein) will also be bound by B lymphocytes. The lymphocytes will take the HIV to T cells in the lymph nodes. This inadvertently protects the HIV from the immune mechanisms clearing and killing it in the blood. Macrophages also will attract T cells when it has captured HIV. The T cells will then become infected when the macrophages transfers the viruses to them. Human Immunodeficiency Virus causes AIDS. There are two major types of HIV. HIV-1 is more prevalent in the USA and Europe. HIV-2 is more prevalent in West Africa. HIV-2 has about a 50% homology in the nucleic acid sequence with HIV-1. HIV-2 reproduces more slowly than HIV-1.
- HIV is a retrovirus which means that makes DNA from RNA using a reverse transcriptase. HIV envelope is made up of (predominantly) two glycoproteins: gp120 and gp41. The gp120 is the primary attachment molecule and gp41 promotes fusion of the viral envelope with the target cell.
- HIV attaches to the target host cell via its gp120 protein receptor. It binds with the CD4 host cell receptor. The gp120-CD4 complex binds to anther receptor called a chemokine receptor which removes the gp120 from the virion. Different chemokine receptors exist on different types of cells. CXCR4 is found on most T cells and CCR5 is found on macrophages and smooth muscle cells. Dendritic cells are entered by HIV in one step. GP120 attached to DC-SIGN which is a receptor on a dendritic cell's cytoplasmic membrane. HIV envelope fuses with the cell and the capsid enters the cytoplasm. Infected dendritic cells deliver HIV to T cells via antigen presentation.
- Step 2: The entry into the target cell. Once the virion binds to the cells its envelope comes intact and via the gp41 leading to its fusion with the host cell membrane. The fusion of the membranes results in the HIV capsid being introduced into the host cell cytoplasm. HIV envelope stays as part of the cell's cytoplasmic membrane. Glycoprotein 41 remaining on the cytoplasmic membrane causes the cell to fuse to as many as 500 neighboring cells forming a syncytium which is a giant multinucleate cell. The capsid enters with the RNA and reverse transcriptase into the cells cytoplasm.

- Step 3: Synthesis of DNA from HIV RNA. The reverse transcriptase synthesizes double-stranded DNA (dsDNA) copies of HIV's two +ssRNA molecules. The reverse transcriptase is an enzyme that copies RNA to DNA which is the reverse of how we typically think of genome replication going. Remember in most cells the process is DNA to RNA. In this instance reverse transcriptase copies RNA from the HIV into DNA. First the enzyme synthesizes a –ssDNA copy of each +ssRNA molecule. This results in two hybrid molecules consisting of ssDNA and ssRNA. The ssRNA is then degraded and leaves only –ssDNA. The final step is completes by synthesizing a complementary strand of DNA forming dsDNA. Reverse transcriptase makes many mistakes in coping the RNA molecule and is said to be an "error prone" enzyme. The error prone nature of the enzyme results in millions of antigenic variation of HIV. A patient may have millions of variants develop over the course of HIV infection. This ultimately results in the immune systems inability to develop a single specific immune response to rid the body of the infection.
- HIV is a *latent* virus. The dsDNA of HIV is called the *provirus*. The provirus enters the nucleus and gets inserted into a human chromosome by the enzyme *integrase*. This enzyme (*integrase*) is carried into the cell by the HIV virion. The integration of HIV dsDNA happens within about 72 hours of infection. Once the *provirus* is integrated it stays a part of the cellular DNA for the life of the cell.
- In step number five the host cell having the integrated provirus replicates its DNA. In the course of the host cell replication the integrated HIV genes are transcribed to produce genomic RNA and mRNA. The mRNA is subsequently translated by ribosomes to make viral polypeptides such as the capsomeres, gp120, gp41 and reverse transcriptase and integrase. Attachment, Entry, Synthesis of DNA from HIV RNA, Integration of the DNA synthesized from the HIV RNA into the host cell's genome. Host cell (and integrated HIV segment) is replicated and RNA and polypeptides are synthesized. Release of mRNA (this is used as a template to synthesize the viral proteins such as the capsid) and the genome RNA (this is the RNA that eventually gets packaged within the virus proteins). Assembly: the final step in HIV development is completed outside the host cell by the action of protease.
- The "6th" step in HIV development involves release or budding of HIV. Two molecules of genomic RNA with viral enzymes and two molecules of tRNA (which is coded for by the host's genome) bud from the cytoplasmic membrane. An infected cell can produce 3000 to 4000 virions at any one time.
- Reverse transcriptase makes a lot of mistakes (it is an error prone polymerase) about 5 error per genome resulting in large antigenic variation of HIV molecules. There can be many millions of HIV variants in a single patient over the course of HIV infection.
- HIV viral pathogenesis: Attachment, Entry, Synthesis of DNA from HIV RNA, Integration of the DNA synthesized from the HIV RNA into the host cell's genome. Host cell (and integrated HIV segment) is replicated and RNA and polypeptides are synthesized.
- Releases involve the two molecules of genomic RNA along with viral enzyme and two molecules of tRNA budding from the cytoplasmic membrane. The infected cell can produces 3000 to 4000 virions at any one time.
- Assembly: the final step in HIV development is completed outside the host cell by the action of protease. When the virions bud from the cell they are in a nonvirulent form because capsids are not yet assembled and the reverse transcriptase is inactive. The protease packed in virion activates the reverse transcriptase and capsomeres.
- Viruses can follow two life "paths". These two alternative paths are called "lytic cycle" or "lysogenic cycle". In lytic cycle the virus infects the host and replicates. Upon completion of replication and new virion formation the host cell is ruptured (lysed) and viron released. In the lysogenic cycle the viral DNA incorporates into the hosts DNA and is copied along with the host DNA replication.

- Bacteriophages are viruses that infect bacteria. Here is a typical bacteriophage. A virus is made up of genetic material, the DNA or RNA that is the blueprint to make more viruses. It also includes a capsid, the protein coat which acts like a membrane and allows viruses to attach to host cells. There are also tail fibers to "land" on host cells.
- The lytic cycle kills the host cell to release more viruses. The first step is adsorption: attachment to the host cell. The next step is injection, when the virus enters the host. Then comes transcription, where the viral DNA produces all the machines it needs, and replication, when it uses those machines to make more viral DNA. Then comes assembly, when more complete viruses are made, packaged with capsids. Lastly comes release, when the virus lyses (kills by bursting) the cell to release the viruses to infect other host cells.
- Lambda Lysogenic Replication:
    - Viral DNA enters the cells.
    - The DNA of the prophage integrates into the host cell's chromosome.
    - The prophage makes the bacterium resistant to additional infection by other viruses of the same type.
    - All daughter cells of a lysogenic cell are infected with the quiescent virus.
- Induction: the prophage is induced to come out of the quiescent phase and host chromosome and begin lytic replication.
- The phage begins synthesis, assembly and release from the bacteria.
- The cell is filled with virions and busts open.
- Induction agents can be UV light, X-rays carcinogens, chemicals heat etc.
- Transformation: The modification of the genotype of a cell by introduction of DNA from another source.
- Transduction: The viral DNA becomes part of the host genome.
- Cell Transformation: Cell transformation means a normal cell becomes cancerous
- Viral Pathogenesis (Direct):
    - Diversion of the cell's energy.
    - Shutoff of cell macromolecular synthesis
    - Competition of viral mRNA for cellular ribosomes.
    - Competition of cellular RNA polymerases
    - Inhibition of the cell defense mechanisms.
- Indirect Viral Cell Damage
    - Integration of the viral genome: induction of mutations in the host genome.
    - Inflammation.
    - Weakening of the host immune response.

Chapter 11: Eukaryotic Cell Biology

Chapter Summary:

Eukaryotes are defined as animal, plants, fungi and protists. Their general structure is detailed including the cell's membrane and various organelles. The primary function of the eukaryotic cell's organelles is described in detail. Animal, plant cell schematics are shown and compared. The cells endomembrane structure is outlined. The cells requirement for life and replication are shown in animated schematics.

Tutorial Features:

- Detailed schematics of animal and plant cells are shown.
- Detailed descriptions and animations of eukaryotic organelles
- Homeostasis and the cell's requirement to maintain balance.
- 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.
- SURE Method: Practice test passages and questions are provided along with a detailed step by analysis of selecting the correct answer.

Key Concepts:

- The meaning of the term "cell".
- The significance of organelles.
- Organelle structures and functions.
- The plasma membrane, its structure and function.
- Cell membrane structure composition and function.

Chapter Review:

- Animals, plants, fungi and protists are eukaryotes.
- Eukaryotes make up on of the three domains of life (bacteria and archaea being the other two).
- Eukaryotic cells have internal membranes and a cytoskeleton.
- Eukaryotic cells have a membrane bound nucleus and other membrane bound organelles.
- Cell division involves separating the duplicated chromosome via movement of microtubules.
- In mitosis one cell divides making two genetically identical cells.
- Meiosis: required for sexual reproduction a diploid cell results in four haploid cells (gametes).
- Plant Cells: Plant cells have a large membrane enclosed vacuole. Cell wall is made up of cellulose, protein and often lignin. Plasmodesmata link pores in the cell wall that with other plant cells in order to communicate with neighboring cells. Plastids, especially chloroplasts contain chlorophyll which allows them to conduct photosynthesis. Plant groups without flagella do not have centrioles.
- Animal Cells: An animal cell is a type of eukaryotic cell. Animal cells are different than plant cells in that they do not have a cell wall or chloroplast and they have smaller vacuoles. Because they do not have a rigid cell wall they have a variety of shapes. A phagocytic cell can engulf other cells or structures. There are many different types of animals cells. Adult humans have about 210 different cell types.
- Fungi Structure: Fungal cell wall is made up of chitin. In fungi there is less definition between cells. Hyphae of higher fungi have porous partitions called septa. Septa allow

the movement through of cytoplasm, organelles, and, sometimes, nuclei. Primitive fungi have few or no septa. In this case each organism is y a giant multinucleate supercell. Coenocytic a multinucleate cell resulting from multiple nuclear divisions without any cell division. This can also happen by cellular aggregation and dissolution of the cell membranes inside the mass. Coenocytes are found in fungi and some protists like algae and slime mold. Some primitive fungi have flagella.

- Endomembrane Structure: Cell membrane is a phospholipid bilayer membrane, separates the cell from the environment, regulates transport of molecules in and out. Nuclear envelope, membrane around the nucleus. Nucleus is not part of the endomembrane system. Endoplasmic reticulum involved in synthesis and transport and is an extension of the nuclear envelope. Golgi apparatus is involved in the packaging and delivery of molecules. Lysosomes use enzymes to break down macromolecules and acts as a waste disposal system. Vacuoles act as storage in some cells. Vesicles, small membrane enclosed, transports units that can move molecules between different compartments.
- Cell requirements for life: All living organisms have the same requirements to live. Thus, cells need these to live as well. They must have a way of controlling their resources, a way of making building blocks for the rest of the cell, energy to power the organism, a way to recycle waste, and a way to protect itself to keep a stable internal environment.
- Cell organelles: The cell's main organelles are pictured here. The nucleus is a spherical compartment in the middle of the cell. The ribosomes are the numerous tiny (shown as tiny dots) spheres which are on top of the rough endoplasmic reticulum. The rough endoplasmic reticulum is a folded stack connected to the outside of the nucleus. The smooth endoplasmic reticulum is not connected to any structure, and has no ribosomes on its surface. The golgi apparatus is also a folded stack, although not attached to the nucleus like the rough endoplasmic reticulum. The mitochondria are often numerous in the cell. Lysosomes float freely around the inside of the cell. The plasma membrane, or cell membrane, envelops the entire cell (a sort of skin).
- The nucleus is the control center of the cell. Inside the nucleus is a watery mix of DNA. DNA is the cell's blueprint, and holds all of the cell's genetic information. Receiving inputs from the cell, the nucleus makes a decision regarding what the cell needs. To meet that need, the nucleus then prints out DNA instructions for the rest of the cell to follow. The nuclear pore allows molecules of selective size to pass through via diffusion. Some molecule require active transport to enter (or exit) the nucleus. This is because of the selective permeability of the nuclear envelope. The nucleolus is the dense structure where ribosomal RNA is made and where the ribosome is assembled.
- The endoplasmic reticulum or ER is an organelle present in all eukaryotic cells. It is an interconnected network made up of tubules, vesicles and cisternae. The ER has several specialized functions. Protein translation, folding and protein transport for use in the cell membrane. It is also useful in the transport of proteins that are secreted or exocytoses from the cells. The membrane structure of the ER is similar to that of the plasma membrane it is an endomembrane system. The structure of the endoplasmic reticulum membrane network is composed of cisternae (which are sac-like structures) held together by the cytoskeleton. A phospholipid membrane encloses a space, the cisternal space (also called the lumen), from the cytosol. The functions of the endoplasmic reticulum vary depending on the type of endoplasmic reticulum and the type of cell in which it is. The three varieties are called *rough endoplasmic reticulum*, *smooth endoplasmic reticulum*, and *sarcoplasmic reticulum*.
- Functions of the smooth ER include: synthesis of lipids, metabolism of carbohydrates and calcium concentration, drug detoxification, and attachment of receptors on cell membrane proteins. The smooth ER is connected to the nuclear envelope. Smooth endoplasmic reticulum is found in many different cell types including animal and plant

cells has different functions in each. The Smooth ER also contains the enzyme glucose-6-phosphatase which is used to convert to glucose-6-phosphate to glucose in gluconeogenesis. The Smooth ER is a series of tubules and vesicles that branch forming a network. The network of smooth endoplasmic reticulum results in an increased surface area for the action or storage of key enzymes and the products of these enzymes. The smooth endoplasmic reticulum is important in the storage of calcium ions in muscle cells.

- The sarcoplasmic reticulum has huge stores of calcium. Its main function is to store and pump calcium ions. This helps in the triggering of muscle contraction. The sarcoplasmic reticulum is a special kind of smooth ER present in the smooth and striated muscle. The difference between the smooth ER and sarcoplasmic reticulum is also the types of protein that are bound to their membranes and those within their lumens.
- The Golgi apparatus modifies and packages proteins for cell secretion a process known as exocytosis or for use inside the cell. Enzymes in the cisternae modify proteins by adding sugars a process known as glycosylation or by the addition of phosphates a process known as phosphorylation. Golgi transports substances like nucleotide sugars into the organelle from the cytosol to use in the process of glycosylation. Proteins are also labeled with what is known as a signal sequence. This sequence determines where the molecule or protein will be shipped. For example, the Golgi can add mannos-6-phosphate to proteins which are destined for lysosomes.
- The mitochondria is the powerhouse of the cell which produces energy from food. The mitochondria is unique because it has two protective shells and the inner shell is folded. The mitochondria converts carbohydrates from food into ATP. The mitochondria produce energy to power the cell. The mitochondria converts pyruvate (taken from glycolysis in the cytosol) and lipids (taken from food) into ATP. The inner membrane space is where protons are deposited by the electron transport chain. Since the outer shell is permeable to small ions it has the same pH as the cytosol. pH = ~7.
- Lysosomes are organelles that have digestive enzymes e.g. pepsin, gelatinase, gastric amylase and gastric lipase to name a few. These are some that are secreted in the stomach and are collectively called gastric enzymes. They digest worn out organelles and breakdown food particles and viruses or bacteria that have been engulfed by the cell. The membrane that surrounds the lysosome keeps the digestive enzymes inside from destroying the cell. Lysosomes fuse with vacuoles and discharge their contents. In this way they release their enzymes in order to digest the particles. Lysosomes are made in the Golgi.
- Homeostasis allows the organism to live and function in a broad range of environmental conditions. For instance temperature stability requires automatic regulation which necessitates additional energy. Snakes may eat only once a week because they do not require as much energy because they do not expend the energy to maintain their temperature.
- Homeostatic control mechanisms have three interdependent parts for the variable that is regulated:
    - A receptor senses a change in the environment.
    - The receptor that has detected a change or stimulus then sends information to a control center that is responsible for setting the range at which the variable is maintained. The control center decides on what the response should be based on the stimulation received.
    - The third component the effector is the control centers response to the stimulus. The effect of the effort (i.e. the organisms respond to the release of the effector) is fed back to the receptor. This results in either a positive or negative feed back and the control center then responds to the new information.
- A cell membrane is a selectively permeable structure that envelops the cell and protects the cell’s internal environment. NOTE: All cells, both prokaryotic and eukaryotic, have

cell membranes. Plants have two protective structures: the cell membrane and the cell wall. The wall surrounds the membrane. The cell membrane's protective layer is made up of a type of lipid called phospholipids, which have carbohydrate heads and lipid tails. Embedded into this protective layer of lipids are proteins, which are anchored to the cell membrane like satellites. A close-up of the lipid membrane shows that the phospholipids lie tail to tail. The phospholipids' carbohydrate heads face the water on both the inside and outside of the cell. The phospholipids' lipid tails make up the interior of the cell membrane. The tails block off all passage because water and other molecules which are polar (charged), cannot pass through the nonpolar (uncharged) area.

- Simple Diffusion is the movement of molecules across the plasma membrane towards an area of lower concentration. This method can only be employed by molecules that are permeable across the plasma membrane. Osmosis is the simple diffusion of water from an area of low solute concentration to an area of high solute concentration. Since most solutes cannot pass through the plasma membrane, protein transporters create a gateway for passage across this boundary. There is passive transport and active transport.
- The cytoskeleton is the infrastructure of the cell. It provides roadways for transport of materials. Gives cues and physical support for cell shape and polarity. And provides the physical force and navigation during cell migration.

Chapter 12: Specialized Eukaryotic Cells and Tissues

Chapter Summary:

Nervous system is divided into central nervous system and peripheral nervous system. The central nervous system includes brain and spinal cord. The peripheral nervous system contains all neurons and nerves that are not in the central nervous system. The function of nervous system is to Coordinates the activity of the muscles, to monitors the organs constructs and to processes input from the senses, and initiates actions. Neurotransmitter binds to receptor on the receiving neuron. The binding opens ion channels in the receiving neuron and generates a new action potential. The potential arrives at the synaptic cleft and releases neuro-transmitter. Neurons communicate at the synapse. An action potential can regenerate itself along the neuron. Action potential is a spike or electrical discharge that moves along the membrane of the neuron. An action potential happens when a neuron sends information down an axon away from the cell body. The action potential of a neuron is driven by an electrochemical gradient.

Tutorial Features:

- Detailed animations of muscle structure and function.
- Animations of neuron activity and propagation of signal.
- The epithelial and connective tissue cells are introduced.
- 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.
- SURE Method: Practice test passages and questions are provided along with a detailed step by analysis of selecting the correct answer.

Key Concepts:

- Characteristics of cells
- Organization of Cells, Tissues and Organs
- The Nerve Cell
- The Muscle Cell
- Epithelial Cells
- Connective Tissue Cells

Chapter Review:

- Four Major Types of Tissues
    - Epithelial Tissue: Closely packed in either single or multiple layers, and cover both internal and external surfaces of the animal body.
    - Connective Tissue: Tissue with an extensive extracellular matrix and often serves to support, bind together, and protect organs.
    - Muscle Tissue: Formed by muscle cells for movement of and/or within the animal
    - Nervous Tissue: Bundles of neuronal processes enclosed in connective tissue that carry signals to and from muscles
- 11 Major Organs Systems: Organs are grouped together according to their functions. There are 11 major organ systems: Muscular System, Skeletal System, Skin or Integument system, Respiratory System, Digestive System, Circulatory System, Excretory System, Nervous System, Endocrine System, and Reproductive System.

- Neurotransmitter binds to receptor on the receiving neuron. The binding opens ion channels in the receiving neuron and generates a new action potential. The potential arrives at the synaptic cleft and releases neuro-transmitter. Neurons communicate at the synapse. An action potential can regenerate itself along the neuron.
- The nervous system is made up of neuron cells, which conduct signals. Neurons communicate by chemical and electrical synapses.
- The neuron is specialized for receiving (dendrites, cell body), transmitting (axon), and sending (branches) signals. The cell body has the usual structures (nucleus, mitochondria, etc.) that a cell needs for life.
- Nodes of Ranvier: the electrical signal jumps from one of these gaps in myelin to the next.
- Axon: the axon is a long tube structure of the cell that transmits the signal down the cell, shooting it from the receiving end to the sending end of the neuron.
- Myelin Sheath: the axon is wrapped in fat called myelin to speed up electrical conductivity.
- Terminal Branches: at the end of the neuron, they pass the signal on to the next neuron(s).
- Neurotransmitter: when the impulse arrives from the axon, the branches release these particles into the synapse to pass the data on to the next neuron's dendrites.
- Synapse: the empty space between one neuron and the next.
- Action potential is a spike or electrical discharge that moves along the membrane of the neuron. An action potential happens when a neuron sends information down an axon away from the cell body.
- Neuron Function
  - Neurons communicate at the synapse.
  - An action potential regenerates along the neuron.
  - When the potential arrives at the synaptic cleft it causes the release of neurotransmitter.
  - The released chemical neurotransmitter binds to a receptor on the next neuron.
  - The binding opens ion channels and causes a new action potential.
- Muscle tissue: there are also three types of muscle fibers: Skeletal muscle: consists of filaments of myosin and actin, has alternating banding, its function is to power voluntary movement. Smooth muscle: Lack the banding, also consists of actin and myosin; it powers involuntary movements of the viscera. Cardiac muscle: striated muscle found only in the heart. The heart cells are usually connected to each other by intercalated disks. It powers the heartbeat.
- Neuromuscular junctions are the point where a motor neuron attaches to a muscle. The NMJ is the region responsible for starting an action potential across the muscle's surface, resulting in contraction. This is a schematic of a neuromuscular junction.
- The tendon is a bond of tough, inelastic tissue that connects a muscle to its bone.
- Muscles are made of many tiny units called sarcomeres. Sarcomeres are made of thin filaments and thick filaments. Thin filaments are made of actin proteins, and thick filaments are made of myosin proteins.
- Muscles contract when the thin filaments slide over the thick filaments, decreasing the length of the muscle fiber. On a smaller scale, the myosin grabs on to the actin and yanks the thin filaments closer together. Note; this process refers specifically to skeletal muscle contraction, but smooth and cardiac muscle contract similarly.
- The skin system is made of skin, hair, nail and skin glands and their products. The skin is divided into two layers, epidermis which includes Keratinocytes, basal cells and melanocytes; and Dermis which contains elastic and collagen fibers, capillary networks, and nerve endings. The function of skin system is to for protection, exchange and secretion.

- Epidermis is the outermost layer of skin and waterproof. It consists of sqamous epithelium and underneath basal lamina. Epidermis has 5 sublayers or stratums: corneum, lucidum, granulosum, spinosum and germinativum.
- Specialized simple squamous epithelium that line the inner core of blood vessels are called endothelial cells. They are important for vasoregulation by secreting vasodialators such as nitric oxide (look up Viagra) or vasoconstricters such as endothelin or angiothensin-converting enzyme (look up ACE inhibitors). They prevent adhesion of many blood products such as platelets. Promote the adhesion and migration of leukocytes to facilitate the immunological response.
- Connective Tissue typically contains at least three types of free migrating cells: fibroblasts, macrophage and mast cells. It has four main types of extracellular matrix: Collagen Fiber, Elastin Fiber, Proteoglycans and adhesion proteins. Loose Connective Tissue serves as a cushioning layer. Dense Connective Tissue serves structural and physical roles such as tendons.

Chapter 13: Nervous System

Chapter Summary:

Brain and Spinal Cord form the Central Nervous System. *Brain: Three parts:* The Brainstem is the connection between the rest of the brain and the rest of the central nervous system. It is the most primitive in the evolutionary chain, for life support and basic functions such as movement. The Cerebellum Consists of two hemispheres it is primarily concerned with movement and works in partnership with the brainstem area of the brain and focuses on the well being and functionality of muscles. The Forebrain lies above the brainstem and cerebellum and is the most advanced in evolutionary terms. It is involved in learning ability and creativity. The 3 types of neurons, sensory, interneurons and motor neurons are described with their function outlined. There are specialized cells for different organ system in order for these systems to function. This includes neural cells like rods and cones in the eye.

Tutorial Features:

- Animations of method of signal propagation.
- Focus on organ systems and nervous system integration
- Specialized neural tissue depending on function of organ
- Nervous system structure and function
- Detailed description of specialized nervous system tissues
- Nervous system organization
- Central nervous system
- Peripheral nervous system
- 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.
- SURE Method: Practice test passages and questions are provided along with a detailed step by analysis of selecting the correct answer.

Key Concepts:

- Characteristics of animal nervous system.
- Organs of the nervous system.
- Neurons
- The Central Nervous System
- The Peripheral Nervous System

Chapter Review:

- In animals there are four major tissue types: Epithelial Tissue: Closely packed in either single or multiple layers, and cover both internal or external surfaces of the animal body. Connective Tissue: Tissue with an extensive extracellular matrix and often serves to support, bind together, and protect organs. Muscle Tissue: Formed by muscle cells for movement of and/or within the animal. Nervous Tissue: Bundles of neuronal processes enclosed in connective tissue that carry signals to and from muscles.
- Nervous system is divided into central nervous system and peripheral nervous system. The central nervous system includes brain and spinal cord. The peripheral nervous system contains all neurons and nerves that are not in the central nervous system. The function of nervous system is to Coordinates the activity of the muscles, to monitors, the organs constructs and to Processes input from the senses, and initiates actions.

- Neurons communicate at synapse. Action potential can regenerate itself along the neuron by pumping K^+ out and Na^+ in. The potential arrives at the synaptic cleft and release neurotransmitter; Neurotransmitter then binds to receptor on the receiving neuron. The binding opens ion channel in the receive neuron and generates new action potential.
- Brain and Spinal Cord form the Central Nervous System. *Brain: Three parts:* The Brainstem is the connection between the rest of the brain and the rest of the central nervous system. It is the most primitive in the evolutionary chain, for life support and basic functions such as movement. The Cerebellum Consists of two hemispheres it is primarily concerned with movement and works in partnership with the brainstem area of the brain and focuses on the well being and functionality of muscles. The Forebrain lies above the brainstem and cerebellum and is the most advanced in evolutionary terms. It is involved in learning ability and creativity.
- 3 Types of Neurons: Sensory neurons send impulses toward the CNS away from the peripheral system. Interneurons the neurons lie entirely within the CNS. Motor neurons: these nerve cells carry signals from the CNS to the cells in the peripheral system.
- Sensory receptors are classified by the type of signal they receive: Mechanical and Chemical receptors detecting Temperature and Pressure, Sensing Muscle Contraction and Blood Pressure, Sensing Taste, Smell, and Body Position. Auditory Receptors detect pressure waves in the air. Optic Receptors detect light over a broad range of wavelengths.
- Inactive neurons have a resting potential. The Inside of the neuron cell is negative and the outside is positive. This is maintained by positively and negatively charged atoms, called ions. A separation of charges across the cell membrane creates electrical potential, the ability to transmit electricity. Inactive neurons stay at a resting potential.
- Synapse function: neurons communicate at the synapse where the action potential regenerates along the neuron. A potential arriving at the synaptic cleft causes the release of neurotransmitter. The released chemical neurotransmitter binds to a receptor on the next neuron. The binding opens ion channels and causes a new action potential.
- Brain Structure: The brain sends commands to the body. Hypothalamus: links the nervous system to the endocrine system via the pituitary gland. Cerebellum: coordination of body movement and muscles. Brainstem: life support systems, e.g. breathing and swallowing. The cerebrum: learning ability and creativity.
- The peripheral nervous system includes the nerves, which receive input and directly control the body. The two divisions of the PNS are the motor and sensory nervous systems.
- Sensory nervous system: Each sense organ has receptors specific for the type of stimulus it receives. The sensory nervous system receives information from the sense organs and sends it to the CNS. Touch: skin has receptors for temperature, touch and pain. Eyes have receptors for light while the tongue has taste receptors, nose: aroma smell receptors and ears have hearing wave receptors.
- Proprioceptors are sensors that monitor where in space the body is. It allows us to keep track of where we are physically. These receptors register pressure and tension in our joints and muscles and feed the brain with information about what our individual body parts are doing.
- The somatic system directly controls voluntary movement. When you want to kick a ball, your CNS sends the command to your PNS, which goes through the somatic nervous system to execute the movement of your leg muscles.
- The autonomic system directly controls automatic body functions (involuntary movements). Do you have to tell your heart to beat? Do you have to tell yourself to sweat? No, because your autonomic nervous system controls the necessary body parts for you. The autonomic system has two opposing parts: the sympathetic and

parasympathetic nervous systems. The sympathetic system increases effects and the parasympathetic system decreases effects (e.g. increase heart beat/decrease heart beat).

Chapter 14: The Endocrine System

Chapter Summary:

The endocrine system and the nervous system are structurally, chemically and functionally related. Many endocrine organs and tissues have specialized nerve cells called neurosecretory cells that secrete hormones. Regulation of several physiological process involves overlap between the endocrine and nervous system. The Endocrine System is an organ system which releases products into the blood that can affect the entire body. These signals can last for a long time. The purpose is to maintain homeostasis as well as to allow the body to have a customized response to physiological changes. The nervous system only sends commands to specific cells that last for a brief period. Endocrine system uses the blood vessels to deliver the hormones to a target that is distant from the gland that synthesized it. The Paracrine signaling is targeting cells that are close by, perhaps even touching the cell that synthesized it. Autocrine signaling is signaling the same cell that synthesized it.

The reproductive systems contain elements of the endocrine system. These components of the reproductive system facilitate the development of mature sex organs which are used to produce gametes for reproduction.

Tutorial Features:

- Endocrine Glands
- Reproductive systems
- Homeostasis and the endocrine system
- Endocrine system and nervous system inter-relationship
- 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.
- SURE Method: Practice test passages and questions are provided along with a detailed step by analysis of selecting the correct answer.

Key Concepts:

- The Endocrine System
- Hormones & Glands
- The Reproductive System
- Gametes & Fertilization
- Homeostasis

Chapter Review:

- The endocrine system and the nervous system are structurally, chemically and functionally related. Many endocrine organs and tissues have specialized nerve cells called neurosecretory cells that secrete hormones. Regulation of several physiological process involves overlap between the endocrine and nervous system.
- The nervous system can only send commands to specific cells that last for a brief period.
- Endocrine system uses the blood vessels to deliver the hormones to a target that is distant from the gland that synthesized it.
- Paracrine signaling is targeting cells that are close by, perhaps even touching the cell that synthesized it.
- Autocrine signaling is signaling the same cell that synthesized it.

- A hormone is either a steroid or nonsteroid. A steroid is made of lipid and passes through its target cell membrane freely. Once inside the cell, it binds to another protein so that it can enter the nucleus. In the nucleus, the steroid activates transcription of DNA to make new proteins, which will carry out the effects of the hormone. The other type of hormone, the nonsteroid hormones, is made of amino acids (protein). They do not enter the cell, but bind to the surface of the membrane at a receptor. This binding activates a protein on the inside of the membrane, which activates messengers that will start a chain reaction, activating more and more proteins to cause the hormone's effects.
- A signal molecule has a shape that is recognized by a receptor on the target cell. The binding of a signal molecule to a receptor protein on the target cell trigger a series of responses called *signal transduction* that leads to a response in the cell's behavior. A chemical signal can bind to the target cell on its surface on inside.
- Tropic hormones have other endocrine glands as their targets. Sex hormones are example of tropic hormone they promote male and female characteristics and affect most of the tissues of the body.
- The hypothalamus controls the pituitary gland, which activates many other glands to release hormones. The pituitary's own product is growth hormone, which controls body growth.
- Thyroid gland controls metabolism. The thyroid gland releases the hormone thyroxine.
- parathyroid glands control calcium in the blood. The parathyroid glands release parathyroid hormone (PTH).
- adrenal glands sit on top of the kidneys. These glands control stress reaction. They release many steroid hormones. The "flight or fight" response to danger, is controlled by the hormones epinephrine and norepinephrine.
- The pancreas, located between the kidneys, releases the hormones insulin and glucagon to control glucose levels.
- gonads release sex hormones. The male gonads are the testes and they produce the hormone testosterone, which develops male physical characteristics such as facial hair, deep voice, body mass. The female gonads are the ovaries and they produce the hormone estrogen and progesterone
- The Reproductive System is an organ system which produces, stores, and releases sex cells.
- The male reproductive system produces and delivers sperm. The testis is where the sex cells (sperm) are produced. The scrotum is a skin sac which protects the testes. When the sperm have matured, they travel through the vas deferens and merge with the urethra, a tube for exiting fluids. The penis is the sperm delivery organ which the sperm exits.
- The female reproductive system produces eggs. The eggs are produced in the ovaries. When an egg has matured, it is released into the fallopian tube, which is the travel route to stop in the uterus, the resting site. During the travel route, the egg can be fertilized. The cervix is the opening tube to the vagina, the female sex organ for sperm entry.
- Homeostasis is defined as Living organisms regulate its internal environment to maintain a stable, constant condition, by means of multiple dynamic equilibrium adjustments, controlled by interrelated regulation mechanisms.
- The mechanism of homeostasis is through a negative feedback response. Normally a threshold is set for triggering certain response. The sensor senses the change and transmits the change via a signal transduction pathway, reaching effectors to bring back the balance.
- homeostasis challenge could be extrinsic and intrinsic. The extrinsic homeostatic system is controlled by two systems: the nervous system (the sensor) and the endocrine system (the signal transmission system). The intrinsic homeostatic system often involves only one or two organs, e.g., blood vessel regulation by oxygen and carbon dioxide.

- Endocrine: sensory system homeostasis. Upon receiving signals from nervous system, endocrine system secretes hormones into blood Hormones are broken down rapidly, but they set in motion effects that may persist after the hormones are gone: stimulate metabolism, turn on genes, etc.
- The extrinsic homeostatic system is controlled by two systems: the nervous system (the sensor) and the endocrine system (the signal transmission system).
- The intrinsic homeostatic system often involves only one or two organs, e.g., blood vessel regulation by oxygen and carbon dioxide. Majority of homeostasis belong to extrinsic.

Chapter 15: The Circulatory System

Chapter Summary:

Blood is carried through the body in a network of blood vessels. Arteries carry blood away from the heart while veins carry blood to the heart. Capillaries are the smallest blood vessels, where exchange takes place. Passive diffusion lets oxygen/nutrients out of the blood into the tissue and carbon dioxide/waste out of the tissue into the blood. Note: arteries are not always red and veins are not always blue. (Arteries to the lungs are deoxygenated, and veins from the lungs to the heart are oxygenated.)
The heart structure and coronary circulation is important for keeping oxygen flowing to the heart muscle. The importance of thermoregulation and how the circulatory system helps to regulate the body's temperature is described.

Tutorial Features:

- Overview of circulatory system
- Blood and Blood Vessels
- Blood Clotting
- Capillaries
- The Heart
- Thermoregulation
- 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.
- SURE Method: Practice test passages and questions are provided along with a detailed step by analysis of selecting the correct answer.

Key Concepts:

- The circulatory system
- Blood & blood vessels
- The heart
- The lymphatic system
- The circulatory system
- The capillary bed

Chapter Review:

- The circulatory system is also known was the cardiovascular system and is the organ system or group that moves nutrients, gases and wastes to and from the bodies cells.
- This helps to maintain the body temperature and pH this is called homeostasis.

Overview Circulatory System

1. De-oxygenated blood enters the right atrium of the heart and goes to the right ventricle where it is pumped via the pulmonary arteries to the lungs.
2. Pulmonary veins return the now oxygenated blood to the heart, entering at the left atrium and then flowing into the left ventricle.
3. From the left ventricle, the oxygenated blood is pumped out via the aorta, and to the rest of the body.
4. The blood circulates through the body; oxygen diffuses from the blood into cells surrounding the capillaries.
5. Carbon dioxide diffuses into the blood from the capillary cells.

6. The deoxygenated blood collects in the venous system into two major veins: the superior vena cave and inferior vena cava.
7. The superior and inferior vena cava empty into the right atrium of the heart.
8. The coronary sinus empties the heart's veins themselves into the right atrium.
9. The blood is then pumped through the tricuspid valve, or right atrioventricular valve, into the right ventricle.
10. From the right ventricle, blood is pumped through the pulmonary semi-lunar valve into the pulmonary artery.
11. This blood goes to the pulmonary arteries (two of them one for each lung). And goes through the lungs.
12. It is oxygenated and then flows into the pulmonary veins.
13. The oxygenated blood then enters the left atrium which pumps it through the bicuspid valve, also called the mitral or left atrioventricular valve, into the left ventricle.
14. From the left ventricle, the blood is pumped through the aortic semi-lunar valve into the aorta artery.
15. The aorta branches to the upper body before going through the diaphragm supply oxygenated blood to the lower parts of the body.
16. When the blood is in the peripheral tissues oxygen and nutrients are removed and carbon dioxide and wastes added.
17. The blood is then again collected in the veins and the process is repeated.
18. Peripheral tissues do not fully deoxygenate the blood, so venous blood does have oxygen, but in a lower concentration than in arterial blood.
19. The left ventricle is thicker and more muscular than the right ventricle because it pumps blood at a higher pressure.
20. The left ventricle pumps blood to the entire body the right ventricle pumps all of its blood directly to the lungs.

- Arteries carry blood away from the heart.
- Veins carry blood to the heart. Capillaries are the smallest blood vessels, where exchange takes place.
- Passive diffusion lets oxygen/nutrients out of the blood into the tissue and carbon dioxide/waste out of the tissue into the blood.
- Arteries to the lungs are deoxygenated, and veins from the lungs to the heart are oxygenated.
- Blood Circulation is divided into two parts: pulmonary circuit and system circuit. In pulmonary circuit, Heart pumps CO_2-rich blood to lung, then the blood releases CO_2 and uptakes O_2 in the lung, the O_2-rich blood returned back to heart eventually. In *Systemic Circuit*, Heart pumps O_2-rich blood to tissues; the blood releases O_2 for tissue to use and uptakes CO_2 generated by the tissue and send the CO_2-rich blood returns back to heart.

Coronary Circulation

1. Coronary circulation is the circulation that supplies blood to and from the heat muscle.
2. Heart muscle tissue, myocardium, requires coronary blood vessels to deliver blood throughout the muscle.
3. Coronary arteries bring oxygenated blood to the myocardium.
4. Cardiac veins take deoxygenated blood from the heart muscle.
5. Surface coronary arteries are on called epicardial coronary arteries. These are narrow vessels and affected by atherosclerosis. When blocked causing angina or heart attack.
6. Subendocardial are coronary arteries deep within the myocardium.

- Capillary Function: The volume of blood in the capillary creates blood hydrostatic pressure, which tends to move fluid out of the capillary. The non-diffusible plasma proteins in the blood tend to draw fluid into the capillary (blood osmotic pressure). Fluid moves out of the capillary when the blood hydrostatic pressure is greater than the blood osmotic pressure. This occurs at the arterial end of the capillary where there is a net outward force. Fluid moves into the capillary when the blood osmotic pressure is greater than the blood hydrostatic pressure. This occurs at the venous end of the capillary where there is a net inward force.

- Capillary bed: Smooth muscle around arterioles modulates blood pressure by changing peripheral resistance. If systemic blood pressure is decreased, neuromodulation of the arterioles causes vasoconstriction which, in turn, causes an increase in blood pressure.

Heart Structure and Function

1. The right side of the heart collects de-oxygenated blood in the right atrium.
2. It is pumped into the lungs (pulmonary circulation) and CO_2 given off.
3. By gas exchange, O_2 is picked up.
4. The left side of the heart (left atrium) collects oxygenated blood from the lungs.
5. From the left atrium the blood moves to the left ventricle which pumps it out to the body.

- Superior Vena Cava: collects deoxygenated blood from the head and neck
- Inferior Vena Cava: collects deoxygenated blood from trunk and limbs.
- Pulmonary Artery: transports deoxygenated blood from the right ventricle to the lungs.
- Aorta: largest artery in the body. It transports oxygenated blood from the left ventricle to the body.
- Pulmonary Veins: transports oxygen -rich blood from the lungs to the left atrium.
- Right Atrium: reservoir of deoxygenated blood returning from the body.
- Right Ventricle: pumps blood under low pressure through the pulmonary artery to the lungs for gas exchange.
- Left Atrium: reservoir of oxygenated blood from the lungs.
- Left Ventricle: pumps oxygenated blood, under high pressure, to the body. Creates systemic arterial pressure. Walls are 3-6 times thicker than those of the right ventricle.

Chapter 16: Lymphatic and Immune System

Chapter Summary:

The Lymphatic system is responsible for returning lymph fluid to the body which is involved in the immune response. Organs of the lymphatic system include: Primary organs: Bone marrow and thymus. Secondary organs: Spleen, lymph nodes, Peyer's patches and tonsils. Cells of the immune system include B-lymphocytes and T-lymphocytes. B-lymphocytes develop in the bone marrow and become antibody-producing plasma cells. T-lymphocytes develop in the thymus; differentiate into T-helper cells or T-cytotoxic cells. T-helper cells induce B-Cell differentiation, antibody production and induce inflammation.

Resistance to specific invaders is called a immune response, which contains two interactive immune responses: The humoral immune response: antibodies in blood system, it Involves B cells and antibodies, which recognize antigens; Some antibodies are soluble proteins that travel free in blood and lymph; others are integral membrane proteins on B cells. When a pathogen invades the body, it may be detected by and bind to an antibody on B cell. The binding and other system components activate the B cell, which makes multiple soluble copies of an antibody with the same specificity. The antibody then attaches to the invaders and kill them. The cellular immune response: detect antigens that reside within or on cells. Main component is T cells. It destroys virus-infected or mutated cells. T cell receptors recognize and bind specific antigens on cell surface and lyse the infected cells.

Tutorial Features:

- Cells of the immune system
- Antibodies
- Antibody stimulation by antigens
- Lymphatic system
- Organs of the immune and lymphatic systems
- Pathogens of the immune system
- 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.
- SURE Method: Practice test passages and questions are provided along with a detailed step by analysis of selecting the correct answer.

Key Concepts:

- The lymphatic system
- Innate immunity
- Acquired immunity
- Pathogens of the immune system

Chapter Review:

- The Lymphatic system returns fluid to the body and is involved in defending the body against pathogens. Lymph Node Lymphatics: Lymph vessels collect lymphatic fluid (along with escaped red blood cells) from the interstitial space. Afferent lymphatics deliver lymphatic fluid to the lymph node. The lymph node produces specific antibodies or sensitized cells. Efferent lymphatics deliver antibodies and sensitized cells to the thoracic duct and, eventually, the systemic circulation.
- Organs: Primary: Bone marrow and thymus. Secondary: Spleen, lymph nodes, Peyer's patches and tonsils. Function: (1) Equalizes fluid distribution. (2) Returns materials to the blood. (3) Production of specific antibodies and sensitized lymphocytes.

- Lymph fluid is made up of: (1) Fluid from the intestines containing proteins and fats (2) A few red blood cells (3) Many lymphocytes
- Lymph (originally tissue fluid) is collected in the lymphatic vessels and ultimately transported back into the systemic circulation by the pressure in the tissue, skeletal muscle activity and a series of one-way valves.
- Lymph Node Lymphatics: Lymph vessels collect lymphatic fluid (along with escaped red blood cells) from the interstitial space. Afferent lymphatics deliver lymphatic fluid to the lymph node. The lymph node produces specific antibodies or sensitized cells. Efferent lymphatics deliver antibodies and sensitized cells to the thoracic duct and, eventually, the systemic circulation.
- Cells of the immune system include B-lymphocytes and T-lymphocytes.
- B-lymphocytes: Develop in the bone marrow and become antibody-producing plasma cells. Bind antigens to surface-bound antibody. Involved in antigen presentation to T-Cells, leading to activated immune response.
- T-lymphocytes develop in the thymus; differentiate into T-helper cells or T-cytotoxic cells. T-helper cells induce B-Cell differentiation, antibody production and induce inflammation. T-cytotoxic cells: sensitized against a specific antigen, kill target cells by granule exocytosis or Fas cell death system.
- Antibodies:
    - There are 5 types (isotypes) of antibodies: IgA- protects mucosal surfaces, IgD- B-Cell antigen receptor, Ig - involved in allergy, IgG - majority of antibody-based immunity, and IgM - key to B-Cell immunity.
    - Antigen-antibody complex leads to phagocytosis of antigen-antibody products, blocking of viral receptors, destruction of bacteria and also auto-immunity (Type 1 Diabetes, Rheumatoid arthritis).
- B-Cells and T-Cells interact: by binding specific antigen to the MHC molecule causing the activation of both T-Cells and B-Cells.
- Humoral Immunity:
    - B cells use antibodies to kill pathogens circulating in the body's fluid. There are many B cells which carry different antibodies for different antigens. When an antigen is recognized, the associated B cell is produced in mass quantities to release many antibodies. Antibodies kill pathogens by binding to them and grouping them together so that the pathogens cannot act.
    - The body usually has a primary immune response when the lymphocytes are first exposed to antigen and form a clone of plasma cells which produce antibodies. If the lymphocytes are exposed to the same antigens, it will trigger a stronger immune response which is called secondary response. Antigen first binds to its specific B cell and trigger mitosis of these cells. The proliferated B cells further differentiate into plasma cells which produce many copies of antibodies. Meanwhile, a small portion of B cells become memory B cells. When these cells are exposed to the antigen again, it would be stimulated to produce more plasma cells and therefore more antibodies this is the Secondary Response.
- Cell Mediated Immunity: detect antigens that reside within or on cells. Main component is T cells. Destroys virus-infected or mutated cells. T cell receptors recognize and bind specific antigens on cell surface and lyse the infected cells.
- Organs of the immune system
    - B-Cells and T-Cells are produced in the bone marrow and then circulate to other lymphoid organs to be stimulated by antigens.
    - The spleen is made up of masses of lymphoid tissue which are located around terminal branches of the circulation. The spleen contains 2 functional areas: (1) Red Pulp: made up of blood- filled sinuses and is responsible for removing worn-out or damaged red blood cells from the circulation. (2) White Pulp: made up of follicles rich in B-Cells and periarteriolar lymphoid sheaths (PALS), which are rich in T-Cells. Lymphocytes in the white pulp help fight infection.

- The thymus is made up of 2 lateral lobes, which are enclosed in a capsule. Each lateral lobe is made up of many smaller lobules. Inside the thymus, lymphocyte precursors mature into T-Cells. To be released into the circulation, the T-Cells must undergo both positive and negative selection. Positive selection involves testing the reactivity and specificity of the T-Cell. Negative selection involves the elimination of T-Cells that are autoreactive.
- Lymph nodes are located throughout the body and serve as filters for tissue fluid. When antigen enters a lymph node: (1) B-Cells and T-Cells are activated, causing the formation of germinal centers. Plasma cells differentiate and secrete specific antibodies. (2) Sensitized T-Cells also develop in the paracortical area of the lymph node and are disseminated throughout the body.

Chapter 17: Respiratory System

Chapter Summary:

The lung has specialized cells and structures to facilitate breathing and the exchange of gases between it and hemoglobin carried in red blood cells. The exchange of involves both the inflow of oxygen and the release of CO2 waste that has been carried from peripheral tissues. The mechanics of respiration is complex and involves the diaphragm muscle. When expiration ends and just before the beginning of inspiration, the pressure inside the lung is the same as the atmospheric pressure outside the body. The diaphragm contracts and the internal lung volume increases and the pressure inside the lung decreases. The change in internal pressure causes air to rush into the lungs and down its pressure gradient. At the end of inspiration, the diaphragm relaxes. The lung volume decreases and this causes the internal pressure inside the lungs to increase to a level higher than atmospheric pressure outside the body. The air then leaves the lung due to the differential pressure gradient.

Tutorial Features:

- Gas exchange
- Protective function of the respiratory system
- Respiratory system role in thermoregulation
- Respiratory mechanics
- Lung elasticity
- 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.
- SURE Method: Practice test passages and questions are provided along with a detailed step by analysis of selecting the correct answer.

Key Concepts:

- The respiratory system
- General function:
    - Gas exchange
    - Protection against disease
- Respiratory mechanics:
    - Differential pressures
    - Lung elasticity and surface tension effects

Chapter Review:

- Breathing is an automatic, rhythmic mechanical process which delivers O2 to the tissues and removes CO2 from the tissues. The circulatory system delivers the gases exchanged in the lungs during respiration.
- Lung:
    - The exchange of gases between the external environment and cells of the body takes place in the individual alveolus. Oxygen and carbon dioxide exchange passively between the pulmonary capillaries and the alveoli. These gases move along their partial pressure gradients, i.e.- from high to low. The partial pressure of oxygen is higher in the lungs. Therefore, oxygen moves along its pressure gradient from the lung into the blood. The partial pressure of carbon dioxide is higher in the blood. Therefore, carbon dioxide moves along its pressure gradient from blood into the lungs.

- During inspiration, room temperature air is brought into the respiratory system and heated to internal body temperature (37ºC, 100% humidity). Air in the lungs, below the trachea, is ~37ºC and 100% humidified. During expiration, expired gas is 100% humidified and about 30ºC. Therefore, if you are breathing in a room where the external environment is 20ºC and you are exhaling air from the lungs at about 30ºC, there is a net heat loss to the environment.

- Lung Elasticity: the ability of the lungs' elastic tissue to recoil during expiration. Elastins are elastic fibers present in the walls of the alveoli, which allow the lungs to return to their resting volume after expiration.
- Lung Compliance: the volume change per unit of pressure across the lungs. In other words, it is the dispensability of the elastic lungs and corresponds to the ability of the lungs to expand during inspiration.
- Lung Elasticity: the ability of the lungs' elastic tissue to recoil during expiration. Elastins are elastic fibers present in the walls of the alveoli, which allow the lungs to return to their resting volume after expiration.
- Lung Compliance: the volume change per unit of pressure across the lungs. In other words, it is the dispensability of the elastic lungs and corresponds to the ability of the lungs to expand during inspiration.
- In order for the incoming air to expand the alveoli, the elastic properties of the walls of the alveoli must be overcome. As the volume in the alveoli increases, lung compliance decreases, making it more difficult to inflate near the end of inspiration. The reverse is true for expiration.
- Surface Tension: Surface tension is the attraction of liquid molecules in the surface layer of a liquid inward towards each other. This causes that layer to behave like an elastic sheet.
- Pulmonary surfactant is a phospholipid, similar to those found in a lipid bilayer surrounding human cells. It is made by pneumocytes in the lungs. Pulmonary surfactant has two components: (A) A polar (water loving) head. (B) A nonpolar (water fearing) tail.
- If the alveoli in the lung are compared to an air bubble in water then (a) both are wet and surround a pocket of air and (b) surface tension acts at the air water interface to make the bubble smaller or, in the case of the lung, the alveoli to shrink. The surfactant polar head adsorbs into the liquid/ water covering of the alveoli. The surfactant nonpolar tail faces towards the air inside the alveoli. Surfactant adsorbed into the liquid layer on the alveoli decreases surface tension. This increases lung compliance and makes the lungs easier to inflate, as well as preventing the lungs from collapsing at the end of expiration.
- Cilia are special hair like projections on respiratory epithelial cells. Cilia, both in the upper airways and trachea, beat and move mucous continually towards the mouth. Along with the mucous, trapped particulate matter and pathogens are transported to the mouth. These are then swallowed and destroyed/removed by the gastrointestinal tract.
- Alveolar macrophages phagocytose inhaled particulate matter and pathogens. The macrophages can then leave the lung in the ascending layer of mucous or via the alveolar lymphatics. Immune cells are also recruited to the lungs, which can lead to inflammation.
- The Mechanics of Respiration
    - During quiet breathing, the diaphragm is the major muscle involved in the breathing cycle.
    - At the end of expiration, just before the beginning of inspiration, the pressure inside the lung is the same as the atmospheric pressure outside the body.
    - When the diaphragm actively contracts, the internal lung volume increases and the pressure inside the lung decreases. The change in internal pressure causes air to rush into the lungs and down its pressure gradient.

- At the end of inspiration, the diaphragm relaxes passively. The lung volume decreases and this causes the internal pressure inside the lungs to increase to a level higher than atmospheric pressure outside the body. This causes air to exit the lung, down its pressure gradient.

Chapter 18: Muscular System

Chapter Summary:

Muscles are important in body support. They have an origin, usually attached to a stationary bone. The thick portion of the muscle between the insertion and origin is called the muscle belly or gaster. Muscles are attached to movable bones by a tendon. Muscles are arranged in groups throughout the body which moves and supports the body, bones and organs.
Voluntary Muscles include skeletal muscles that are under voluntary control. Meaning we can contract the muscles at will. Involuntary muscles are rhythmic, automatically controlled muscles. These muscles include: breathing (under both voluntary and involuntary control), cardiac (heart) muscle is under involuntary control. The sinoatrial node sets the rate and the autonomic nervous system can modulate that rate. Smooth muscles in the walls of organs and blood vessels are primarily under involuntary control.
The autonomic nervous system regulates the activities of smooth muscle, cardiac muscle and certain glands. The autonomic nervous system is divided into two components the parasympathetic branch and the sympathetic branch. Parasympathetic branch of the autonomic nervous system has been called "rest and digest", because it slows down the body and increases digestive activity.

Tutorial Features:

- The muscular system its structure and function is described.
- Muscle support
- Human mobility and the role of muscles.
- Muscle involvement in thermoregulation is described
- Structure of the three basic muscle types
- Nervous system control of muscles.
- Autonomic nervous system
- 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.
- SURE Method: Practice test passages and questions are provided along with a detailed step by analysis of selecting the correct answer.

Key Concepts:

- The Muscular system
- General function:
    - Support, mobility
    - Peripheral resistance, thermoregulation
- The structure of three basic types of muscles
- Nervous control

Chapter Review:

- Muscles and body support: Muscles have an origin, usually attached to a stationary bone. The thick portion of the muscle between the insertion and origin is called the muscle belly or gaster. Muscles are attached to movable bones by a tendon, such as the Achilles tendon. Muscles are arranged in groups throughout the body. Each group moves/supports the bones and organs in that region, i.e. muscles of the lower extremity move and supports the leg.

- Muscle groups are usually arranged into antagonistic pairs, each one performing the opposite function either: (a) flexors or extensors, (b) abductors or adductors. Rectus femoris (part of the quadriceps): involved in extending the leg. Biceps femoris (part of the hamstrings): flexes the leg. Tibialis anterior: dorsiflexes the foot. Gastrocnemius (part of the calf muscle):plantar flexes the foot.
- Skeletal muscles produce movement by contracting and exerting force on tendons, which in turn pull on bones. When producing a body movement, the bones act as levers and the joints act as fulcrums. A lever is acted on by two different forces the resistance to movement (force to overcome); and the effort to move the load. The origin and insertion of the muscle affords mechanical advantage. As the insertion point of the muscle is far away from the load to be moved, this allows powerful movement.
- Smooth muscle in the walls of precapillary arterioles contract and cause the peripheral vascular resistance to be increased, thereby increasing systemic blood pressure. The pressure in veins is low and the contractions of nearby muscles aid in the movement of blood through the venous system.
- Muscle contraction accounts for most of the heat generated and required in the human body. The chemical reactions occurring in muscle during contraction generate heat. Specifically, glucose is converted to ATP which powers the movement of actin against myosin to create muscle contraction.
- If the normal body temperature drops even 1-2 °C, this can result in shivering. Shivering is an involuntary, rapid contraction of the muscles, which will generate more heat quickly to counter the drop in body temperature.
- Skeletal muscle is striated, and attached to bones. Skeletal muscle facilitates movement by applying forces to bones and joints through its contraction. They are generally under voluntary control.
- Skeletal muscle has striations due to many sarcomeres (basic unit of contraction). Individual muscle myofibrils make up a muscle fiber. There are 2 types of muscle fibers:
  - (a) red (slow-twitch) have more mitochondria and are associated with endurance.
  - (b) white (fast-twitch) have fewer mitochondria and are explosive.
- Sarcomeres are the basic unit of muscle, made up of actin and myosin. Skeletal muscles contract according the sliding filament model. Sliding filament model: after the signal to contract comes from the central nervous system, an action potential spreads over the muscle fiber. Calcium is released and binds to tropomyosin; which unblocks actin binding sites. Myosin (bound with ATP) binds to actin hydrolyzes ATP and the released energy delivers a power stroke. This hydrolysis also causes the myosin head to turn and ratchet the Z lines closer together.
- Cardiac muscle is an involuntary striated muscle found exclusively in the heart. Cardiac muscle has unique properties:
  - (a) Stimulates its own contraction without the required electrical impulse from the central nervous system (CNS).
  - (b) Special pacemaker cells in the sinoatrial node (located in the right atrium), spontaneously contract and send electrical impulses throughout the heart.
  - (c) Normally the resting heart rate is between 70 – 80 bpm, determined by the pacemaker cells. The CNS does not directly create the impulse to contract, but modulates it through the autonomic nervous system.
- Smooth muscle is an involuntary non-striated muscle found in the walls of hollow organs such as the bladder, and in blood vessels. Smooth muscle can be directly stimulated by the CNS or can react to hormones secreted locally, such as vasodilators and vasoconstrictors. Smooth muscle is spindle shaped and contains actin and myosin, although there are not arranged in a sarcomere. Smooth muscle hydrolyzes ATP and contracts by myosin and actin fibers sliding over each other. Smooth muscle fibers are arranged in sheets within the walls of organs.
- The CNS (brain and spinal cord), is connected to muscles by peripheral nerves. These nerves transmit both sensory and motor impulses. Sensory (afferent) information travels

to the CNS, providing information about temperature, pressure and pain. Motor (efferent) impulses travel from the CNS along the peripheral nerves to the target, i.e. – foot; and initiate movement.

- The motor neuron and the muscle fibers it innervates are called the motor unit. Groups of motor units work together to contract a muscle. Motor neurons originate in the spinal cord and transmit motor (effector) impulses to the target muscle. Motor neurons are divided into 2 branches:
  - (a) upper motor neurons- connect the brain and spinal cord.
  - (b) lower motor neurons connect the spinal cord to the muscles.
- Motor neurons axons, connect with muscle fibers via a neuromuscular junction. The axon ends at the neuromuscular junction and is separated from the muscle fiber itself by a synaptic cleft. Neurotransmitters such as acetylcholine, cross the synaptic cleft and transmit the chemically converted electrical impulse to the muscle causing it to contract. Motor end plates are the region of sarcolemma (muscle) adjacent to the axon terminal. The terminal end of the axon and the motor end plate are known as the neuromuscular junction.
- Voluntary Muscles
  - Voluntary muscles: broadly only skeletal muscles are under voluntary control. Meaning we can contract the muscles at will.
- Specific Groups include:
  - Muscles of the head and neck: such as the rectus muscles (control eye movement) the frontalis (forehead), buccinator (cheek).
  - Muscles of the Shoulder and arm: deltoid (shoulder), bicep (arm) and extensor digitorum (extends fingers).
  - Muscles of the thorax and leg: Latissimus (back muscle), quadriceps (group of muscles on the front of the leg) and gastrocneius (calf muscle).
- Involuntary Muscles
  - Involuntary muscles are rhythmic, automatically controlled muscles. The muscles of breathing are under both voluntary and involuntary control. Cardiac (heart) muscle is under involuntary control. The pacemaker cells in the sinoatrial node set the rate and the autonomic nervous system can modulate that rate. Smooth muscles in the walls of organs and blood vessels are primarily under involuntary control. The smooth muscle in arterioles can be contracted to increase systemic blood pressure.
- The autonomic nervous system regulates the activities of smooth muscle, cardiac muscle and certain glands. The autonomic nervous system is divided into two components the parasympathetic branch and the sympathetic branch.
- The parasympathetic branch of the autonomic nervous system has been called "rest and digest", because it slows down the body and increases digestive activity.
- Parasympathetic nervous system: (a) Slows the heart rate, which conserves energy. (b) Increases intestinal blood flow and activity for digestion and absorption. (c) Uses acetylcholine as a neurotransmitter. Opposes (antagonizes) the sympathetic nervous system.
- Sympathetic Branch of autonomic nervous system "fight or flight": The sympathetic branch of the autonomic nervous system has been called "fight of flight".
  - Sympathetic nervous system:
  - Increases the heart rate and dilates coronary blood vessels.
  - Decreases intestinal activity and blood flow.
  - Uses acetylcholine to cause the release of adrenalin (epinephrine), opposes the parasympathetic nervous system.

Chapter 19: Skeletal System and the Skin

Chapter Summary:

Bones are the rigid frame for the human body. Muscles are attached to bones and use them as an anchor from which to exert forces that result in limb movement. Calcium is stored primarily in bones, and is released into the blood in response to hormones. Calcium is released from the bone in response to parathyroid hormone (PTH). When blood Ca^{2+} is low more PTH is released from the parathyroid glands. This causes increased Ca^{2+} absorption from the gastrointestinal tract increased osteoclast (bone resorptive cells) activity, both of which increase blood Ca^{2+} levels.

Thermoregulation includes hair, subcutaneous fat tissue and the capillary beds. The skin plays an important role in physical protection. Fingernails which are made of keratin provides the strength of the nail. Calluses are an area of skin that has become relatively thick and hard. Calluses protect the underlying skin from damage due to repeated contact with hard or rough surfaces.

Tutorial Features:

- Bones structure and function
- Types of bones
- Joint structure and cartilage
- Ligaments and tendons
- Skin system
- The role of the skin in thermoregulation
- Role of the skin in protecting the body
- 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.
- SURE Method: Practice test passages and questions are provided along with a detailed step by analysis of selecting the correct answer.

Key Concepts:

- The Skeletal system: Structural rigidity, support and calcium storage
- Skeletal structure:
  - Bone types and structures
  - Joint structures – cartilage structure and function
  - Ligaments and tendons
- The Skin:
  - Function in homeostasis, osmoregulation and thermoregulation
  - Structure – layer differentiation.

Chapter Review:

- Bones provide a framework for the human body. Bones also provide for functional structure in the respiratory system such as: (a) bones in the face providing a nasal cavity passageway and (b) bone of the thorax are shaped to allow expansion of the chest cavity during inspiration. Muscles are attached to bones and use them as an anchor from which to exert forces that result in limb movement.
- Calcium is stored primarily in bones, and is released into the blood in response to hormones. Calcium is needed for bone development, blood clotting, normal muscle and nerve activity. Calcium is stored in bone as a mineral salt with phosphate. Calcium is

released from the bone in response to parathyroid hormone (PTH). When blood Ca^{2+} is low more PTH is released from the parathyroid glands. This causes increased Ca^{2+} absorption from the gastrointestinal tract increased osteoclast (bone resorptive cells) activity, both of which increase blood Ca^{2+} levels.

- Calcium is stored in the bone as a mineral salt, along with phosphate, in response to decreased PTH levels and increased calcitonin (CT) release from the thyroid gland. When blood Ca^{2+} is high, less PTH is released and more CT is released. This causes decreased breakdown of bone by osteoclasts, and increased Ca^{2+} and phosphate uptake by bones. Together, these actions lead to a decrease in blood Ca^{2+} levels.
- Two types of skeleton: Endoskeleton: is an internal structure that provides support and protection. Exoskeleton: is an external protection offered by such things as a shell.
- Bones of the human body fall into four general categories: long bones, short bones, flat bones, and irregular bones. Long bones: longer than they are wide, act as levers. Examples in the upper extremity include the humerus, radius and ulna. Short bones: short cubed-shaped bones, found in the wrist and ankle. In the wrist there are 8 total in two rows. Articulate with each other as well as provide attachment points for ligaments.
- Flat bones: have broad surfaces for the protection of organs and attachment of muscles. In the skull, there are 8 bones that protect the brain and brain-stem. Irregular bones: have a unique shape and provide both protection and multiple attachment points for muscles. Examples include, the vertebra which protect the spinal cord.
- Bone is relatively hard and lightweight and is primarily made of calcium phosphate. Bone can either be: (a) spongy – which has an open meshwork which contains bone marrow or (b) compact – which is dense and it form the surface of bones, makes up approximately 80% of the bone mass. The epiphysis is the end of a long bone, and is separated from the diaphysis, by a growth plate called the epiphyseal plate. This cartilage plate, is where growth occurs. When a human reaches skeletal maturity (18 – 25 yrs) the cartilage is replaced with bone and the fusing the diaphysis and both epiphyses together.
- Bone matrix is made up of Osteons which are long narrow cylinders containing both Haversian and Volkmann canals. Within the osteon, are numerous lacunae. Inside the lacunae are a single osteocyte (bone forming cell) surrounded by the lacuna which they produced. Osteocytes communicate with each other through passages called canaliculi. Haversian canals surround blood vessels and nerves inside the bone. Volkmann's canals connect the individual osteons to each other and to the periosteum. The periosteum provides the blood supply and houses the osteoclasts, for bone resorption.
- Joints are separated into two categories: (a) fibrous – no synovial cavity containing synovial fluid, i.e.- sutures between bones of the skull and (b) synovial – in which there is a space between the articulating bones and the space is filled with synovial fluid which lubricates the joint, i.e.- knee joint. Knee joint: the ends of the femur and tibia are covered in articular cartilage. The synovial membrane covers this cartilage and encloses a space filled with synovial fluid. Synovial fluid is a thick, sticky fluid which reduces the friction between the articular cartilage, and provides nutrients.
- Cartilage is a type of dense connective tissue composed of cells called chondrocytes, which produce and maintain the cartilage. Cartilage contains no blood vessels, nutrients diffuse through the cartilage matrix. Cartilage is found between bones, in the nose, throat and in the spinal column. Hyaline cartilage: such as articular cartilage, lines bones in joints and also provides a site for bone growth (growth plate).Elastic cartilage: such as in the walls of the larynx (voice box) keeps tubes permanently open. It is made with elastin bundles to provide elasticity and yet be stiff. Fibrocartilage: such as between intervertebral disks is located in sites that require great tensile strength. It is also found at sites connecting tendons and ligaments to bone.
- Ligaments are short bands of tough fibrous tissue, composed mainly of collagen fibers. Ligaments connect bones to other bones to form a joint, i.e.- ilio-femoral ligament of the hip joint. Ilio-femoral ligament: is a Y-shaped ligament which connects the femur with

the pelvis. Its role in the body is to limit extension at the hip joint. This ligament is frequently torn when the hip is dislocated, such as in a sports injury.

- Tendons are a tough band of fibrous tissue that connect muscle to bone or muscle to muscle, i.e. – Achilles tendon. Tendons are designed to withstand tension and stretch. The origin of a tendon is where it joins to a muscle and collagen fibers from the muscle itself extend directly into the tendon. Achilles tendon: attaches the gastrocnemius (calf) muscle and soleus muscle to the heel bone. It is the thickest and strongest tendon in the body. The achilles tendon is frequently the site of inflammation and rupture.
- The skin is divided into two main layers: the epidermis and the dermis. The epidermis is the upper most layer of the skin, it provides waterproofing and a barrier to infection. The dermis which is below the epidermis serves as a location for: hair follicle, sebaceous gland, and the arrector pili muscles.
- The epidermis is divided into four layers: (a) stratum corneum (b) stratum granulosum (c) stratum spinosum and (d) stratum basale.
- Cells of the epidermis: Keratinocytes: are formed in the basal layer, these cells migrate up through all the layers of the epidermis. They are the most abundant cells in the skin and they produce keratin which provide strength and barrier function. Melanocytes: are located in the basal layer and secrete melanin, which pigments the skin and provides protection against harmful ultraviolet rays from the sun. Langerhans' cells: are immune cells that are activated during skin infections and present antigens to T-Cells in the lymph nodes. Merkel cells: are associated with the sense of touch along with nerves in the skin.
- The dermis is a thick layer of connective tissue, containing both collagen and elastin. The dermis The dermis houses blood vessels, nerves, sweat glands, and hair follicles.
- Osmoregulation: is the active regulation of the osmotic pressure of bodily fluids, in order to maintain the homeostasis of the body's water content. In other words, it keeps the body's water contents from becoming to concentrated or dilute.
- The skin provides humans with protection from the external environment, pathogens, insulation and temperature regulation. The skin contributes to osmoregulation by producing sweat for evaporation on the surface of the skin. Sweat is made in eccrine sweat gland which is distributed throughout the entire body surface.
- Thermoregulation includes hair, subcutaneous fat tissue and the capillary beds.
- The skin plays an important role in physical protection. Fingernails which are made of keratin provides the strength of the nail. Calluses are an area of skin that has become relatively thick and hard. Calluses protect the underlying skin from damage due to repeated contact with hard or rough surfaces.

Chapter 20: The Digestive System

Chapter Summary:

The digestive system includes various organs including the: stomach, liver, gallbladder, pancrease, small intestine and large intestine. The digestive system is responsible for the absorbance of food and water molecules and provides mucosal immunity finally it stores and eliminates waste products. Saliva in the mouth contains salivary amylase, which is an enzyme that digests starch. The fundus is storage of the stomach; food can remain in this region for up to an hour prior to mixing with gastric juices. Food mixes with gastric juices in to produce chyme. Rugae line the stomach; these folds of mucosa allow the stomach to expand when filled. Pepsin is an enzyme made by chief cells in the stomach; it is released into the stomach as a precursor called pepsinogen. Pepsin is converted to pepsin when it comes into contact with the hydrochloric acid secreted by the parietal cells.
The liver is supplied by two main blood vessels on its right lobe: (a) hepatic artery- which distributes blood to the liver, gallbladder and pancreas and (b) portal vein- brings venous blood from the spleen, pancreas and small intestines for processing by the liver. The liver filters all blood coming through the portal vein carrying the products of digestion and absorption. The gallbladder is underneath the liver and stores and concentrates bile. Bile is an alkaline fluid produced by hepatocytes in the liver, and helps to emulsify fats during digestion and absorption in the small intestine. The large intestine is the primary location for the absorption of liquids, primarily water, and salt ions. The small intestine is the site where most of the nutrients from food are absorbed.

Tutorial Features:

- Ingestion
- Stomach
- Liver
- Pancrease
- Large Intestine
- Small Intestine
- Muscular control
- 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.
- SURE Method: Practice test passages and questions are provided along with a detailed step by analysis of selecting the correct answer.

Key Concepts:

- The digestive system: ingestion
- Structure of the digestive organs
- Absorption of food and water molecules
- Muscular control

Chapter Review:

- Components of the Digestive system
    - Organs of the digestive system: stomach, liver, gallbladder, pancrease, small intestine and large intestine.
    - The digestive system: (a) absorbs food molecules and water. (b) provides mucosal immunity and (c) stores and eliminates waste.

- When food and liquids are ingested the food is digested in the stomach. The products of digestion move into the small intestine where digestion continues and food molecules are absorbed.
- The products of digestion go to the large intestine where water is absorbed.
- Finally, the waste of digestion and absorption is eliminated.

- The mouth, pharynx and esophagus are all involved in processing the food bolus and delivering it to the stomach for digestion. The soft palate is elevated during swallowing which seals the nasopharynx. The tongue delivers the food bolus to the pharynx during swallowing.
- Saliva in the mouth contains salivary amylase, which is an enzyme that digests starch. Saliva also moistens food while chewing, making it easier to swallow. During the act of swallowing, food and liquids are transported down through the esophagus into the stomach.
- Swallowing is a complex event that is coordinated by the swallowing center in the lower portion of the brainstem. During this process, food passes from the mouth to the pharynx and into the esophagus, this occurs in three phases:
  - (a) oral phase
  - (b) pharyngeal phase
  - (c) esophageal phase
- During the pharyngeal phase the larynx is pulled forward and upward under the tongue by muscular contraction. As the larynx rises the epiglottis moves backwards and downwards to seal off the glottis to prevent choking.
- Esophageal Phase: During the esophageal phase the food bolus is pushed through the esophagus by involuntary muscle contractions called peristalsis. The muscle fibers just above the bolus contract, this constricts the esophageal wall and pushes the bolus downward.
- The stomach is a J-shaped organ directly under the diaphragm. The superior portion is a continuation of the esophagus. The inferior portion (pylorus) empties the stomach contents into the first segment of the small intestine.
- The fundus is a storage of the stomach; food can remain in this region for up to an hour prior to mixing with gastric juices. Food mixes with gastric juices in the pyloric region. The pyloric region of the stomach can be completely shut off from the rest of the stomach during digestion, by peristaltic waves. This facilitates the mixing of food with the gastric juices to produce chyme. Chyme passes into the small intestine to continue the digestive process. The stomach is lined with rugae, these folds of mucosa allow the stomach to expand when filled. Pepsin is an enzyme made by chief cells in the stomach, it is released into the stomach as a precursor called pepsinogen. Pepsin is converted to pepsin when it comes into contact with the hydrochloric acid secreted by the parietal cells. Pepsin begins the digestion of proteins in the stomach and it contributes to the digestion of food.
- Gastric acid is hydrochloric acid produced by the parietal cells, and it makes the lumen of the stomach very acidic, pH 2-3.
- Liver: located just below the diaphragm on the right side of the upper abdomen. The liver is supplied by two main blood vessels on its right lobe: (a) hepatic artery- which distributes blood to the liver, gallbladder and pancreas and (b) portal vein- brings venous blood from the spleen, pancreas and small intestines for processing by the liver. The liver filters all blood coming through the portal vein carrying the products of digestion and absorption.
- The gallbladder is underneath the liver and stores and concentrates bile. Bile is an alkaline fluid produced by hepatocytes in the liver, and helps to emulsify fats during digestion and absorption in the small intestine. Bile contains taurocholic and deoxycholic salts, these salts combine with fat globules and break them down into small droplets fro absorption in the small intestine. Bile also serves to excrete bilirubin, which is a product of processing old or damaged red blood cells.

- The pancreas has both an endocrine and exocrine function. The endocrine function includes the formation and release of insulin and glucagon. The exocrine function includes the production and release of enzymes for digestion.
- Pancreas produces a number of enzymes used in the process of digestion: (a) trypsinogen and chymotrypsinogen for the digestion of proteins into amino acid for absorption (b) pancreatic lipase which works along with bile salts to break down fat globules so they can be absorbed and (c) amylase which is responsible for the breakdown of starch into sugars for absorption. The pancreas also produces bicarbonate ions which neutralize the acid chyme as it enters the duodenum.
- The duodenum is the first portion of the small intestine; it is attached to the stomach. It is mainly involved with the breakdown of food particles. The jejunum is primarily involved with the absorption of nutrient food particles from the digestion process. The ileum is the final section of the small intestine and its primary role is the absorption of primarily vitamin B12 and bile salts.
- The small intestine is lined with villi, which increase the surface for absorption. On the surface of the villi there are brush border enzymes which facilitate the final process in digestion, reducing proteins and carbohydrates to amino acids and sugars (the form absorbed by the intestine).
- The large intestine is divided into three major areas, the ascending, transverse, descending and sigmoid colon. The large and small intestines are connected through the cecum. The cecum is a small pouch from which the appendix extends.
- The large intestine is the primary location for the absorption of liquids, primarily water, and salt ions.
- The digestive system is innervated and controlled by the enteric nervous system. While the central nervous system inputs control on the enteric nervous system, the enteric nervous system can operate independently. The enteric nervous system is composed of two layers:
    - (1) Myenteric plexus which lies between the circular and longitudinal muscle layers.
    - (2) submucosal plexus which lies between the layer of circular muscle and the submucosa.

Chapter 21: The Urinary System

Chapter Summary:

The urinary system is involved in maintaining the body's homeostasis. That is how much water is retained, released and reabsorbed. The organs involved in the urinary system include the: kidney, ureters, bladder and urethra. The kidney has highly specialized cells and structures that help it to function.

The three regions of the kidney are the outer cortex, central medulla and the inner pelvis. The fundamental unit of the kidney is the nephron which filters the blood reabsorbing what is needed by the body and excreting the rest as urine.

Tutorial Features:

- Homeostasis: maintenance and organs involved.
- Urinary system structure: Organ systems and specialized tissues
- Urine formation: critical aspects of urine formation and elimination
- 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.
- SURE Method: Practice test passages and questions are provided along with a detailed step by analysis of selecting the correct answer.

Key Concepts:

Homeostasis:

- Osmoregulation and acid-base equilibrium
- Waste excretion and blood pressure regulation
- The Urinary System:
    - Kidneys, ureters, bladder, urethra
- Kidney Structure and Function:
    - Nephrons
    - Urine formation

Chapter Review:

The urinary system is involved in maintaining the equilibrium of several body processes, such as osmoregulation (the regulation of solutes and water) and blood pressure regulation. The kidneys are directly involved in maintaining the acid/base balance within the body by controlling the excretion or retention of electrolytes. The production of urine by the kidneys allows the excretion of waste products such as urea and uric acid, byproducts of protein catabolism.

- Parts of the Urinary System
    - The kidneys produce urine, which allows the removal of wastes from the body and controls the retention of salt and water.
    - The ureters transport the urine from the kidneys to the bladder for storage.
    - The bladder stores urine until the moment of elimination.
    - Urine is eliminated from the body through the urethra.
- Kidney structure:
    - The kidney has three regions: the outer cortex, the central medulla, and the inner pelvis.
    - The point of entry into the kidney is called the hilum.
    - Blood enters the kidney at the renal artery and leaves via the renal vein.

- Urine
- Urine Formation
- Nephrons filter the blood, reabsorbing what is needed by the body and excreting the rest as urine.
- Bowman's capsule is the site of blood filtration.
- The long tubule attached to Bowman's capsule allows for reabsorption of the water and small solutes that have passed through the filtration apparatus.
- Each nephron tubule empties into a collecting duct that helps transport the urine to the ureter.
- Blood is continually filtered within Bowman's capsule. Wastes and other solutes are passed into the tubule for inclusion in the urine, while large items like cells or large proteins are retained in the blood.
- The renal tubule is the second portion of the nephron, and it is specialized for absorption. It descends from the Bowman's capsule.
- The surface of the nephron is selectively permeable to different ions and water, and this permeability changes along the length of the renal tubule.
- Every nephron in the kidney is arranged with the Bowman's capsule facing towards the cortex, and the loop of Henle dropping inward towards the pelvis.
- To keep the body in balance, the kidneys must reabsorb a significant portion of the glomerular filtrate. The proximal tubule reabsorbs 75% of the fluid that leaves the Bowman's capsule (i.e., the glomerular filtrate). The fluid travels down the loop of Henle. Here, the glomerular filtrate is less concentrated than the surrounding interstitial fluid, and water leaves the renal tubule. As fluid flows up the loop of Henle, the situation is reversed, and the fluid within the tubule is more concentrated than the interstitial fluid. Efflux of sodium from the renal tubule (by both passive and active means) fixes the imbalance. Ultimately, the function of the loop of Henle is to reduce the overall filtrate volume. The mechanism that allows the reduction of the filtrate volume is known as a counter-current multiplier.
- At the distal end of the renal tubule further reabsorption of water occurs. The distal tubule adjusts its water permeability in response to hormonal signals, such as anti-diuretic hormone, which increases the permeability of the distal tubule to water and results in a more concentrated urine. As the urine passes into the collecting duct for delivery to the ureters, it is less concentrated than the surrounding interstitial fluid and further water is lost from the urine to fix the imbalance.
- Once the urine has been formed by the kidneys, it is passed to the bladder for storage via the ureters. The bladder is able to expand to store the urine as it is produced, and circular bands of muscle called sphincters help hold the urine in. Elimination of the urine occurs via the urethra.

Chapter 22: Reproductive System

Chapter Summary:

The reproductive system includes a system of organs that are coordinated for the purpose of reproduction. Human reproductive systems include external genitalia (penis and vulva) and internal organs for the production of gonads such as testicles and ovaries. Human reproduction involved internal fertilization. The sperm typically fertilize an ovum in either the fallopian tubes or uterus. Components of the male reproductive system include: testicles, epididymis, corpus cavernosa, foreskin, frenulum, urethral opening, glans penis, corpus spongiosum, penis and scrotum. Female reproductive system is a series of organs most of which are located internally. Female reproductive organs include: vulva, vagina, ovaries, labia, clitoris, uretra, cervix, fallopian tubes and uterus.

Tutorial Features:

- Reproductive anatomy: Female and Male genetalia, Hormones and gonads
- Gametogenesis: Spermatogenesis, Oogenesis,
- Sexual Reproduction: Ovulation, Ejaculation
- 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.
- SURE Method: Practice test passages and questions are provided along with a detailed step by analysis of selecting the correct answer.

Key Concepts:

- Reproductive anatomy:
  - Male and female genitalia
- Gametogenesis:
  - Gonads and meiosis
  - Ova and spermatozoa
- Reproduction:
  - Fertilization, implantation, development, birth

Chapter Review:

- Male genitalia: The genitals are those organs or parts of the body involved in the process of reproduction. Some are external and some are internal. The male external genitals are the penis and scrotum. The internal male genitalia include two testes, two vas (ductus) deferens, one prostate gland, two seminal vesicles, two epididymides, and one urethra.
- Female genitalia: The external genitalia includes the vulva, which is comprised by the labia and clitoris. Internal genitalia include the vagina, cervix, uterus, fallopian tubes, and ovaries.
- Gonads: gonad refers to the sites of gamete production (i.e., production of the reproductive germ cells). The female gonad is the ovary, while the male gonad is the testis. The ovaries produce the female gametes, the ova (egg cells), while the testes produce the male gametes, the spermatozoa (sperm cells).
- Hormone control of gonads: The gonads receive input from the hormones of the anterior pituitary gland, specifically luteinizing hormone (LH) and follicle stimulating hormone (FSH). Release of these two hormones is in turn under control of the hypothalamus, which secretes gonadotropin-releasing hormone. The gonads themselves produce

hormones. The testes make androgens, like testosterone, while the ovaries produce estrogens, such as estradiol, and progesterone.

- Spermatogenesis occurs in the highly-coiled seminiferous tubules within the testes. Undifferentiated diploid cells called spermatogonia within the seminiferous tubules produce diploid primary spermatocytes. The primary spermatocytes undergo meiosis I to produce two haploid secondary spermatocytes. Each secondary spermatocyte then undergoes meiosis II to produce two haploid spermatids. In total, spermatogenesis produces four haploid spermatids from one diploid spermatogonium. The spermatids travel from the testes to the epididymis, a coiled structure within the scrotum. Here, the spermatids mature into spermatozoa, complete with the acrosome (head portion) that contains enzymes important in fertilization and the flagellum (tail portion) that allows the sperm cell to be motile. The mature sperm are stored within the epididymis until ejaculation.
- During the process of fertilization, sperm cells are expelled from the male by ejaculation. Roughly 200-400 sperm cells are expelled in a fluid called semen, or seminal fluid. The mature sperm leave the epididymis and travel to the vas deferens. From the vas deferens the sperm move through the ejaculatory duct, with fluid added by the seminal vesicles, the prostate gland, and the bulbourethral glands (also known as Cowper's glands). This fluid offers a basic pH to protect the sperm and sugar for the sperm to use as an energy source. The sperm exit the body through the urethra, which extends through the penis.
- Oogenesis occurs in the ovaries and produces the female gametes. It follows a similar theme as spermatogenesis, in that a diploid oogonium produces a diploid primary oocyte that then undergoes meiosis I. This process, however, occurs with unequal division of the cytoplasm to produce a large secondary oocyte and a small polar body. The haploid secondary oocyte in turn will undergo meiosis II with unequal division of the cytoplasm to create a haploid ootid and a small haploid polar body. The polar body that results from meiosis I may also divide to produce two haploid polar bodies. The ootid will ultimately mature into an ovum, while the three polar bodies degenerate.
- Ovulation is the release of a mature ovum from one of the two ovaries into the attached fallopian tube. Before release, the ovum is held within the ovary surrounded by a layers of supporting cells. The ovum plus its supporting cells is referred to as a follicle. The release of the ovum (i.e., rupturing of the follicle) occurs in response to a spike in the level of luteinizing hormone (and follicle stimulating hormone) from the anterior pituitary gland. The ovum travels from the ovary towards the uterus via the fallopian tube. The fallopian tube is the normal site of fertilization.
- Normally, fertilization occurs within the fallopian tube. It involves the fusion of the nuclei of the ovum and sperm cells. The process occurs when a sperm cell is able to penetrate the ovum. This occurs because of the activity of degradative enzymes within the acrosome of the sperm cell that are able to degrade the two outer membranes (corona radiata and zona pellucida) of the ovum. The haploid nuclei of the gametes fuse, forming the zygote. The zygote, which will divide mitoticly to produce the embryo, travels to the uterus where it implants into the endometrial tissue of the uterus. Subsequently, a placenta is formed from a mix of embryonic and maternal tissues to allow the flow of nutrients to, and waste products from, the developing fetus.

Chapter 23: Embryogenesis, Developmental Mechanics, and Comparative Anatomy

Chapter Summary:

An embryo begins as a newly fertilized single cell. The main events leading to increased complexity are cleavage, which forms the blastula; gastrulation, where the three germ layers of endoderm, mesoderm, and ectoderm are formed; and neurulation, which generates the future nervous system. This section will cover each of these steps in more detail. Fertilization occurs between two gametes - the sperm and the egg. During cleavage, the cells divide but do not grow in size. The ultimate consequence of numerous rounds of cell division during cleavage is formation of the blastocyst. Gastrulation is an embryonic stage following cleavage and results in ectoderm, mesoderm, and endoderm. Neurulation results in formation of the neural tube, which will become components of the central nervous system such as the brain and spinal cord. Cell commitment involves three cell types: unspecified cells, specified cells, and determined cells. During differentiation cells go from unspecified to determined or committed to a specific cell fate.

Tutorial Features:

- Early embryogenesis
- Cell Commitment, differentiation and morphogenesis is detailed and animated.
- Cell communication in development
- Gene regulation in development and its critical nature is shown.
- Cordates, vertebrates and comparative anatomy
- 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.
- SURE Method: Practice test passages and questions are provided along with a detailed step by analysis of selecting the correct answer.

Key Concepts:

- Stages of embryonic development
- Formation of the three primary germ layers
- Cell differentiation and organ formation
- Cell communication
- Regulation of gene expression
- The vertebrates as an example of developmental end-product

Chapter Review:

- An embryo begins as a newly fertilized single cell. The main events leading to increased complexity are cleavage, which forms the blastula; gastrulation, where the three germ layers of endoderm, mesoderm, and ectoderm are formed; and neurulation, which generates the future nervous system. This section will cover each of these steps in more detail.
- Fertilization occurs between two gametes - the sperm and the egg. Each gamete has a nucleus, where the genetic material is located. The gamete is enclosed by a plasma membrane. Sperm-specific characteristics include the acrosome, which is located at the head of the sperm, and the flagellum, a ciliated structure that propels the sperm

through the female reproductive tract. Egg-specific structures include the zona pellucida, which is a clear membrane that encases the egg.

- During cleavage, the cells divide but do not grow in size. This results in division of the cytoplasm into smaller and smaller cells.
- The ultimate consequence of numerous rounds of cell division during cleavage is formation of the blastocyst. The blastocyst is a sphere of cells with a hollow cavity in the middle. This cavity is called the blastocoel. After a few more rounds of cell division, an opening becomes apparent on the dorsal side of the embryo called the blastopore. Cells will migrate into this pore during the next stage of embryogenesis, called gastrulation.
- Gastrulation is an embryonic stage following cleavage, hallmarked by cell migrations and rearrangements that establish the 3 germ layers:
  - Ectoderm = future outer cell layer
  - Mesoderm = future middle cell layer
  - Endoderm = future inner cell layer
- Neurulation results in formation of the neural tube, which will become components of the central nervous system such as the brain and spinal cord.
- Cell Commitment
- There are three different cell types: unspecified cells, specified cells, and determined cells. By eye, all three cell types look deceivingly similar, but internally they express very different genetic programs. An unspecified cell is competent to form any type of cell in the future. A specified cell has already received signals instructing it to become a certain cell type, such as a muscle cell. However, its future fate is reversible if it receives different signals. In contrast, a determined cell can only become one specific future cell type and its fate is irreversible.
- There are three main modes of specification: autonomous, conditional, and syncytial.
- Specification causes cells to adopt a particular cell fate, but this is reversible under certain conditions. Determination is the event that makes a cell's fate irreversible.
- Differentiation is the process by which a determined cell assumes the proper physical appearance and characteristics of cells normally found in a future tissue or organ. Differentiated cells form tissues and organs by arranging themselves into a proper three-dimensional spatial organization that is required for proper function. This process of cell rearrangement is called morphogenesis.
  - Induction = a group of cells changing the behavior of adjacent cells
  - Inducers = the cells that generate the signal
  - Responders = the cells that respond to the signal
  - Competence = ability to respond to an inductive signal
- There are two main ways for a competent cell to be induced: Instructive signaling, Permissive signaling
- Signal transduction pathways are a common way to transmit a signal. Even though all pathways utilize the same general players, variations on these players make each pathway unique. All signal transduction pathways begin with a ligand, which is either a soluble or membrane-bound extracellular protein. The ligand interacts with a receptor on the surface of a responding cell, which generally introduces a conformational change in the receptor that initiates a signaling cascade. The receptor is made up of two domains. The extracellular domain is outside the cell and interacts with the ligand, while the cytoplasmic domain is located inside the cell and is generally the "business end" of the molecule. Once the receptor is activated, it triggers activation of other cytoplasmic proteins that transmit the signal through a cascade of protein-protein interactions. The end product of the cascade is activation of one or more transcription factors, which are nuclear proteins that can either promote or inhibit expression of target genes.
- Various signaling cascades are important in cell development these include:
  - RTK/Ras/ERK, TGF-b, JAK/STAT, Wnt, Hedgehog IHh), Notch
- Apoptosis: programmed cell death.

- Activation or repression of gene transcription requires recruitment of transcriptional activators and repressors.
- There are five main gene classes that help to establish the body plan of the fly. The first level of patterning is laid down by maternal effect genes.
- Maternal effect mRNAs are deposited in the ooctye by the mother. When translated, the proteins form morphogen gradients and act as transcription factors that induce expression of target genes. There are several different maternal effect genes that have different patterns of gene expression.
- The next class of genes is the gap genes, which are induced by varying concentrations of different maternal effect proteins.
- The third class of genes is the pair-rule genes. This class is induced by overlapping regions of different gap proteins. There are many pair-rule genes, and some pair-rule genes are expressed in several stripes.
- The fourth class is the segment polarity genes, which divide each stripe into anterior and posterior halves, further refining the segments into smaller and smaller divisions.
- An animal can be classified as a chordate if it has these three characteristics: the presence of a notochord early in development, a dorsal nerve cord, and branchial pouches and arches.
- The notochord develops very early in development and is characterized as a rod-shaped structure that runs the length of the body and is located in the dorsal region of the embryo.
- In addition to the notochord and dorsal nerve cord, all chordates contain branchial arches and branchial pouches, also known as pharyngeal arches and pharyngeal pouches. These structures are formed from derivatives of the developing pharynx.
- branchial pouches are located in the area between each branchial arch. These are located on the endodermal side of the arch, and also form various structures during development.
- The field of comparative anatomy looks at structural similarities and differences between organisms.
- Homologous structures are defined as similar anatomical structures that originate from a common ancestor.
- Analogous structures are similar structures but not as a result of descent from a common ancestor. Instead, the structure has evolved independently, or numerous times, in unrelated species.

Chapter 24: Evolution

Chapter Summary:

Evolution is a process where certain genes or genotypes are selected for or against. This gives rise to the concept of Descent with modification. Natural selection is the process in which heritable traits that are helpful to survival and reproduction become more common. Evolution works on populations, not individuals. When a certain favorable phenotype is selected for and that phenotype is genetic in origin the genes coding for the pheonotype will become more prevalent in the population. A mode of evolution also involves the genetic isolation of a species. The isolation may be due to physical barriers or non-physical barriers. Physical barriers such as mountains or water can separate a population however changes in behavior patters may also affect the degree to which a population may freely mate.

Tutorial Features:

- Origin of Life
- Descent with modification
- Natural selection process and impact on dominant versus recessive genotypes
- Modern evolutionary theory
- 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.
- SURE Method: Practice test passages and questions are provided along with a detailed step by analysis of selecting the correct answer.

Key Concepts:

- Natural Selection
- Miller experiment
- Genetic variation and selection
- S=1-W measure of fitness
- Selection on recessive or dominant alleles and the effect it has on population genotype.

Chapter Review:

- The Urey / Miller experiment created a model system of early earth using only inorganic molecules that led to the production of organic compounds. Stanley Miller passed high-voltage electric sparks (pseudo lightening) that were passed through a gaseous mixture of water, methane, hydrogen, and ammonia. The liquid in the reaction flask eventually became a mix of amino acids and other small organic molecules. Miller's results predicted that, over time, the early oceans would have become a filled with amino acids, nucleic acids, and sugars. These results implied it was only a matter of time before these building blocks combined to form complex polymers and ultimately a replicating cell.
- Descent with modification sums Darwin's theory of natural selection. Descent referring to arising from a prior species. Modification – changing the physical constitution of ancestral species in ways that add to the descendant's adaptability.
- Natural Selection the process in which favorable traits that are heritable become more common in subsequent generations.
- The most successful species produces the most offspring. Natural selection acts on the phenotype the observable characteristics of an organism. Individuals with favorable phenotypes are more likely to survive and reproduce than those with less favorable

phenotypes. If the phenotype is due to a genetic difference that that genotype will be selected for and its frequency in the next generation increased. Over time this will result in an "adaptation" which causes the organism to specialize for a certain niche. This can even lead to the emergence of a new species.

- Some traits are the result of a single gene; most traits are a result of interactions of many genes. Pleiotropy happens when a single gene influences many different phenotypic traits.
- Four modes of natural selection that give rise to a new species and involves geographic isolation: allopatric, peripatric, parapatric and sympatric.
- Allopatric speciation, a population is split into two geographically isolated ones. The isolated populations then undergo genotypic divergence.
- Parapatric speciation, the geographic zones of the two diverging populations are separate but do overlap. Individual of each species may come in contact or mate but the fitness of the heterozygote is reduced so selected against.
- Peripatric speciation a new species is formed in small isolated peripheral populations which are prevented from exchanging genes with the main population.
- Sympatric speciation species diverge while inhabiting the same place e.g. insects which become dependent on different host plants in the same area.
- Mechanisms of genetic evolution include: natural selection, mutation, random genetic drift and gene flow.
- S=1-W W (fitness) is usually equal to the proportion of an individual's genes in all the genes of the next generation.
- Relative fitness is the average number of surviving progeny of one genotype compared with the average number of surviving progeny of a competing genotype after a single generation.
- S ranges between 0 to 1. When S=0 the population is in Hardy-Weinberg's equilibrium. When S=1 the allele will disappear.
- Selection against recessive allele = selection for dominant allele
- Selection against the dominant allele is handled the same way as selection against the recessive allele was.
- If a heterozygote has a higher fitness than the homozyotes, both alleles are kept in the population because they are favored as the heterozygote genotype.
- There are two main causes of speciation: geographic isolation and reduction of gene flow.
- Punctuated equilibrium: There is a period of very little change, and then one or a few huge changes occur, often through mutations in the genes of a few individuals, leading to new species.
- Gradualism: Speciation events have remained relatively constant over time, and evolution progresses gradually.
- The ecosystem plays a bigger role in stimulating accumulation of new species then was previously thought.
- Gene flow: individual species breed outside their native group. Non random mating: in breeding mating is not random.
- There are two basic patterns of evolution and speciation; anagenesis and cladogenesis.
- Anagenesis is the evolution of species involving a change in gene frequency in an entire population not just a cladogenetic branching event.
- Cladogenesis is an evolutionary splitting event. A clade is a process of adaptive evolution that leads to the development of a greater variety of sister organisms.
- Gene Pool The complete set of genes of all members in a population.
- Gene Pool Isolation: Cessation of gene flow: intrinsic to the organism, part of it genetic make-up or external to the organism.
- Sympatric speciation is a set of speciation events different from allopatric speciation in the following ways: Internal barriers develop first without initial external barriers. Internal barriers cause instant reproductive and gene pool isolation.

