DAT Biology Rapid Learning Series – Course GuideBook

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Chemistry : Biology : Physics : Math

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COURSE FEATURES

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

Core Tutorials
Self-contained tutorials…not an outline of information which would need to be supplemented by an instructor.

Concept map showing inter-connections of new concepts in this tutorial and those previously introduced.
Definition slides introduce terms as they are needed.
Visual representation of concepts.
Conceptual explanation of important properties and problem solving techniques
Animated examples of processes and cycles in human physiology.
A concise summary is given at the conclusion of the tutorial.

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

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

Chapter by Chapter Detailed Content Descriptions

01: Introduction to DAT Biology

Chapter Summary

This introductory tutorial is to warm you up on the DAT Biology course and get ready for the extensive coverage on required knowledge in the Biology section of biological survey subtest. The DAT and CBT are defined and the scope of the biology section is introduced. The test-prep and test-taking strategies are also discussed. Finally, the tips in how to solve biology problems are described.

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.

Key Concepts

DAT and CBT Test Format
The DAT Natural Sciences
The Scope of DAT Biology
Test-Prep Strategies
Test-Taking Strategies
How to Attack and Solve Biology Problems

Chapter Review

DAT - The DAT is the Dental College Admissions Test by American Dental Association (ADA). Its computer based test is a standardized exam that most US and Canadian dental schools require in order to consider a student for admission.
DAT Biology - The science section of the DAT consists of 100 items that includes questions about: General Chemistry, Organic Chemistry and Biology. Biology usually consists of about 40 items broken down as shown with the numbers representing the number of items usually tested within each focus area.
Official Required Topics (total 40 questions): Cell & Molecular Biology (13); Diversity of Life: Biological Organization (3); Systems: Structure & Function (9); Developmental biology (4); Genetics (7); Evolution, Ecology, Behavior (4)
Test -Prep Strategies: (1) Smart Time Management (2) Key Concept Mastery (3) Practice-Practice-Practice (4) Systematic Review
Test-Taking Strategies: (1) Know the Test (2) Plan Your Attack (3) Build Focus (4) Zoom In On The Answer (5) Guess The Right Way
Biology Problem Solving: (1) Think of the answer before scanning the answer choices (2) Beware of the familiar (3) Aware of the Absolute (4) Deal with the Similar and Opposites (5) Know about the elimination and answer selection (6) Make educated guesses.

02: Cellular Structure and Membranes

Chapter Summary

A cell is a building unit of an organism that can function independently. The cell maintains life by assigning each responsibility to separate specialized machines. These machines are called organelles. An organelle is a compartmentalized structure that performs a specialized function within a cell. An animal cell contains a nucleus, ribosomes, mitochondria, rough endoplasmic reticulum, smooth endoplasmic reticulum, plasma membrane, Golgi apparatus and lysosomes. The nucleus controls the cell function. Other organelles provide energy and building blocks for cells. Cell membrane is a selectively permeable structure that envelops the cell and protects the cell's internal environment. The cell's membrane is made of bi-layer of phospholipids and proteins, which can communicate with other cells or environment.

Tutorial Features

- Concept map showing inter-connections of concepts.
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- A concise summary is given at the conclusion of the tutorial.

Key Concepts

Introduction
- What is a cell
- Type of cells
- Requirement for life
- A cell maintain life by assigning each responsibility to organelles

Organelle
- What are organelles
- Nucleus
- Ribosomes
- Endoplasmic Reticulum
- Golgi Apparatus
- Protein synthesis and delivery
- Mitochondria
- Lysosomes
- Summary

Cell Membrane
- What is a cell membrane?
- Cell membrane composition
- Cell membrane synthesis

Cell membrane function

Chapter Review

Introduction

A cell is a smallest unit of an organism that can live independently. There are two cell types: prokaryotic and eukaryotic cells. Prokaryotic cells include bacteria and a large group of other microorganisms with no nucleus. Eukaryotic cells include plant cell and animal cells, they have distinct nucleus and cell organelles.

How the cell maintains life using organelles?

The cell maintains life by assigning each responsibility to separate specialized machines. These machines are called organelles. An organelle is a compartmentalized structure that performs a specialized function within a cell. An animal cell contains a nucleus, ribosomes, mitochondria, rough endoplasmic reticulum, smooth endoplasmic reticulum, plasma membrane, Golgi apparatus and lysosomes. The nucleus controls the cell function.

Organelle structures and functions

Ribosomes: make proteins for the cell. Each ribosome is made of two protein subunits: the large subunit and the small subunit. The units clasp around a strand of nucleic acid instructions from the nucleus. The ribosome reads the strand instructions to make proteins for the cell to use in its normal activities.
Endoplasmic reticulum: Including rough ER and smooth ER. Rough ER is found attached to the outside of the nucleus. It appears rough because of the ribosomes on its surface. It helps the attached ribosomes in finishing protein synthesis. Smooth ER is NOT attached to the nucleus and DOES NOT have attached ribosomes (thus smooth). Smooth ER synthesizes carbohydrates and lipids.
The Golgi apparatus: made up of flattened, folded sacs, ships packages around the cell.
Mitochondria: converts carbohydrates taken from food into ATP -- produce energy to power the cell.
Lysosome: highly acidic, destroy waste to clean up the cell.

Cell Membrane: composition and function

A cell membrane is a selectively permeable structure that envelops the cell and protects the cell's internal environment. The cell's membrane is made of phospholipids, which have carbohydrate heads and lipid tails. Proteins can be embedded or anchored on cell membrane. Cell membranes provides a stable environment for cells, perform communication function among cells via the surface proteins, and selectively exchange material between a cell and its environment.

03: Metabolism, Thermodynamics and Cellular Respiration

Chapter Summary

Metabolism includes catabolism and anabolism. Anabolism is the synthesis of complex molecules from precursors, while catabolism is the breakdown of complex molecules into smaller precursors from which they are synthesized. All these pathways involve biochemical reactions. Free energy describes whether a reaction will occur spontaneously. In metabolism, reactions which are spontaneous are favorable because these run automatically and release free energy.

Every reaction has an activation energy which can be lowered down by enzymes. Enzymes do this by bringing the reactants closer together. ATP is the energy currency of all cells. Most of the reactions in the cell require ATP. A non-spontaneous reaction can be coupled to ATP hydrolysis reaction to enable the overall reaction release free energy and therefore become favorable. ATP is generated by cellular respiration, which contains fermentation (anaerobic respiration) and the Krebs cycle (aerobic fermentation).

Tutorial Features

- Concept map showing inter-connections of concepts.
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Key Concepts

Metabolism
- Building Blocks & Precursors
- Anabolism
- Catabolism
- The Role of ATP

Energetics of Biological Reactions
- Energy
- Thermodynamics
- Activation Energy & Enzymes
- Redox Reactions
- The Role of ATP in Metabolism
- Coupling

Cellular Respiration
- Definition
- Aerobic Respiration
- Anaerobic Respiration

Aerobic Respiration
- Glycolysis
- The Krebs cycle
- Oxidative phosphorylation

Anaerobic Respiration
- Glycolysis
- Fermentation

Summary on respiration

Chapter Review

What is metabolism?
All living things must have an unceasing supply of energy and matter. The transformation of this energy and matter within the body is called metabolism. Metabolism includes two different types: catabolism and anabolism. Catabolism is destructive metabolism. Typically, in catabolism, larger organic molecules are broken down into smaller constituents. This usually occurs with the release of energy. Anabolism is constructive metabolism. Typically, in anabolism, small precursor molecules are assembled into larger organic molecules. This always requires the input of energy.

Anabolism and catabolism Pathways
Anabolism is the synthesis of complex molecules from precursors. This includes synthesis of proteins, carbohydrates, nucleic acids and lipids, usually from their building block monomers. Catabolism is the breakdown of complex molecules into smaller precursors from which they are synthesized. It is a reversed process of anabolism. When cells have excess resources such as food and extra energy, anabolism occurs to store unused nutrients for later use. When cells are deficient for food or energy, catabolism occurs to break down the stored nutrients for the body to use.

Energetics of biological Reactions
Biological energy is the capacity to run biochemical reactions to enable the cells to do their work. Free energy (G) relates temperature, enthalpy and entropy. Free energy is used to determine if the reaction is spontaneous at a specific temperature.

Determining spontaneity of a process
Free energy describes whether a reaction will occur spontaneously. The First Law of Thermodynamics states that energy is conserved: energy can neither be created nor destroyed. The Second Law of Thermodynamics states that the work produced from a given energy can never be 100% efficient. In metabolism, reactions which are spontaneous are favorable because these run automatically and release free energy. Every reaction has an activation energy, which describes an energy barrier that is overcome every time the reaction occurs. Most of the reactions in the cell require enzymes. Enzymes are proteins to speed up reactions by grabbing onto reactants to bring them closer together. Reactants which are closer together can reach activation energy more easily. Thus, enzymes lower activation energy and speed up the reaction.

ATP
ATP is the energy currency of all cells. Most of the reactions in the cell require ATP.

ATP is energy rich. When the energy is used by a reaction, ATP breaks up into ADP and Pi. In order to use the energy again, ADP and Pi must be changed back into ATP. This requires energy. Non-spontaneous reactions requires energy, and this is often done by coupling this reaction with an ATP breaking down reaction, the combined free energy will be negative and therefore enables the overall reaction.

Cellular Respiration

Cellular respiration is a series of metabolic processes which all living cells use to produce energy in the form of ATP. In cellular respiration, the cell breaks down glucose to produce large amounts of energy in the form of ATP. Cellular respiration can take two paths: aerobic respiration or anaerobic respiration. Aerobic respiration occurs when oxygen is available, whereas anaerobic respiration occurs when oxygen is not available. The two paths of cellular respiration share the glycolysis step. Aerobic respiration has three steps: glycolysis, Krebs cycle, and oxidative phosphorylation. During glycolysis, glucose is broken down into pyruvate and produces 2 ATP. The Krebs cycle is also known as TCA cycle which contains a series of Redox reactions to convert pyruvate into CO_2 and produce NADH and FADH2. During oxidative phosphorylation, NADH and FADH2 are used as substrate to generate a pH gradient on mitochondria membrane which is used to generate ATP via ATP synthase. Anaerobic respiration contains two steps: glycolysis and fermentation. Fermentation regenerates the reactants needed for glycolysis to run again. Fermentation converts pyruvate into ethanol or lactic acid, and in the process regenerates intermediates for glycolysis.

04: Photosynthesis

Chapter Summary

Photosynthesis is a process where by energy from light is harvested and used to drive synthesis of organic carbohydrates from carbon dioxide and water. Photosynthesis takes place in chloroplasts and can be divided into two steps: light reactions which require light and dark reactions which do not require light. During light reaction, light energy is captured by photosystems and electrons are transferred among the electron receptors. ATP and NADPH are generated. During dark reactions, CO_2 is fixed using ATP and NADPH generated by the light reactions and organic carbohydrates are synthesized via the Calvin Cycle. When the CO_2 is first fixed into a 3 carbon compound 3PGA, it is called C3 pathways and these plants are called C3 plants. The disadvantage of C3 plants is that they undergo photorespiration and thus waste some energy gained in light reactions. C4 cycle is the pathway adopted by C4 plants to bypass photorespiration.

Tutorial Features

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Key Concepts

Importance of photosynthesis
- Definition
- Importance

Absorption of light
- Pigments
- Light absorption
- Photosystems

Light reactions
- Cyclic electron transfer
- Non-cyclic electron transfer
- Energy production

Dark reactions
- Important molecules
- The Calvin cycle

Photorespiration and C4 pathway
- C3 plants and C3 pathway
- Mechanism of photorespiration
- C4 pathway

Chapter Review:

What is photosynthesis and why it is important
Photosynthesis is a process during which energy from light is harvested and used to drive synthesis of organic carbohydrates from carbon dioxide and water, generating oxygen. Photosynthesis is the only way that radiant energy from the sun can be converted into organic molecules for plants and animals to consume.

Structure of Chloroplasts
Chloroplasts are specialized organelles in plant cells for the purpose of photosynthesis. Each cell may contain 1-1000 copies of chloroplasts. Chloroplasts are double membrane structure with stacked disc-like membrane structure (called thylakoids) inside the stroma. Light reactions of photosynthesis occur in thylakoids, and dark reactions occur in stroma.

Physics of light
Quantum is the elemental unit of energy. Photon is a quantum of electromagnetic energy and it is particle of light.

Light reaction and photophosphorylation
Pigments embedded on thylakoid membranes form photosystems. There are of two types: PS I P700, PS II P680. Components of photosystem I and II transfer the electrons from water to NADP via cyclic electron transfer or non-cyclic electron transfer. During electron transfer, the light energy captured by the photosynthetic organisms is transformed into the phosphate bond energy of ATP. This is called photophosphorylation. NADPH is generated during non-cyclic electron transfer.

Dark reaction – Calvin cycle
Second step of photosynthesis is called Calvin's cycle. Because it does not require light, so it is called dark reaction. During dark reaction, the ATP and NADPH generated by light reaction are consumed to fix carbon dioxide into organic carbohydrates. The first fixed carbohydrate is a three carbon compound 3-phosphoglycerate (3PGA). The final product is a high-energy 3 carbon compound glyceraldehyde-3-phosphate (G3P) which can be used to synthesize a broad range of organic molecules. An important intermediate molecule for carbon dioxide fixation is ribulose bisphosphate (RuBP), and the enzyme catalyzing the CO2 fixation is Rubisco.

Photorespiration
Under high oxygen and low carbon dioxide conditions, Rubisco favors binding to oxygen instead of carbon dioxide, therefore the energy produced in light reactions are consumed for no productivity of organic carbohydrates. The final result is that oxygen is consumed and CO2 is produced, which mimics respiration, and therefore named photorespiration.

C4 pathway
C4 cycle is the pathway adopted by C4 plants to conserve the carbon dioxide released via photorespiration. It adopts a new enzyme (PEPC, Phosphoenol pyruvate carboxylase) which does not react with oxygen; it also adopted a separated compartment for CO2 up taking and fixation.
CO2 is taken in mesophyll cells and further fixation occurs in bundle sheath cells. Carbon dioxide is incorporated to form 4-carbon oxaloacetate.

05: Enzymology and Cell Metabolism

Chapter Summary

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.

Tutorial Features

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Key Concepts

Metabolism and Glycolysis
The Krebs Cycle 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 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 (Vmax). At substrate saturation the velocity of reaction is independent of any further increase in substrate concentration.

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

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

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 Vmax. Uncompetitive inhibition: a type of reversible inhibition where the inhibitor binds to the enzyme-substrate complex and inhibits its dissociation into products.

Metabolism
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.

06: Mitosis and Meiosis

Chapter Summary

Mitosis is the process that a somatic cell divides into two daughter cells. It is an important process in normal organism development. Meiosis is the type of cell division by which germ cells (eggs and sperm) are produced. Meiosis involves a reduction in the amount of genetic material. Both types of cell division have similar phases: prophase, prometaphase, metaphase, anaphase and telophase. Chromosomes in these phases behave similarly but not identically.

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.

Key Concepts

Specialized cell structure
- Cell skeleton
- Centrosome and centriole
- Mitotic spindle
- Centromere
- Kinetichore

Mitosis
- Interphase
- Overview
- Prophase
- Prometaphase
- Metaphase
- Anaphase
- Telophase
- Cytokinesis
- Cell cycle

Meiosis
- Importance of meiosis
- Overview
- Meiosis I
- Meiosis II
- Meiosis and gamete formation

Mitosis vs meiosis
Cell level
Developmental stage

Chapter Review:

Importance of mitosis
Mitosis is the process that a somatic cell divides into two daughter cells. It is an important process in normal organism development. When mitosis is out of control, diseases such as cancer may occur.

Cell structures for mitosis
Mitosis requires a set of specialized cell structures. Chromosomes are the most important part for mitosis because they are duplicated and then separated evenly into two daughter cells. On a chromosome there is a special structure called centromere, where the spindle, a structure pulling the chromosomes to two poles, attach. The spindle is formed around a cytosolic structure called centrosome, which is main driving force for chromosome separation.

Mitosis
Mitosis is composed of prophase, prometaphase, metaphase, anaphase and telophase. The cell cycle phase between two mitoses is called interphase, where chromosomes are loose and stretched. During prophase and prometaphase, chromosome start to condense, in the metaphase, they are visible under microscope. Chromosomes are also lined up in the middle of cell and ready to be pulled to the two poles by spindle. This is done in anaphase and telophase, upon which nuclear separation is finished. Cytokinesis follow and two cells are generated.

Meiosis
Meiosis is the type of cell division by which germ cells (eggs and sperm) are produced. Meiosis involves a reduction in the amount of genetic material. It is divided into two steps: meiosis I and meiosis II. Meiosis I includes Prophase I, Metaphase I, Anaphase I and Telophase I. Meiosis II (Second division) includes Prophase II, Metaphase II, anaphase II and telophase II. Each of these phases are similar but not identical to the corresponding mitosis phases.

Difference between mitosis and meiosis
Meiosis is different than mitosis in terms of the cell division number. During mitosis, chromosomes are duplicated once, and cell divides once, therefore each daughter cell has equal chromosome number which is also equal to the mother cell's. During meiosis, chromosomes are also duplicated, cell division occurs twice consecutively, leading the half of the chromosome number in 4 daughter cells. This process is used for generating germ line cells, the gametes. When gametes from male and female parents meet, they form normal diploid chromosome number again.

07: Biological Organization and Five Kingdom System

Chapter Summary

This tutorial will introduce the biological organization in terms of taxonomy, modern classification and five kingdom system. Each of these three topics are introduced visually with illustrations.

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.

Key Concepts

Taxonomy Defined
Taxonomy of Humans
Evolutionary Relationships and Classification Techniques
The Three-Domain System
The Five-Kingdom System
Viruses

Chapter Review

Animalia: A kingdom which includes heterotrophic consumers such as herbivores, carnivores, omnivores, and detritivores.
Binomial Nomenclature: A standard way to refer to the scientific name of an organism by using the genus and species.
Derived Trait/Characteristic: A new evolved trait. Derived traits are used to distinguish between the evolutionary relationships of organisms. Newer organisms have more derived traits.
Domain: A new and most inclusive level of taxonomy, above kingdom. Life is divided into three domains.
Fungi: A kingdom which includes heterotrophic decomposers which breakdown decaying matter.
Phylogeny: The process of classifying and organizing organisms based on evolutionary relationships.
Plantae: A kingdom which includes autotrophic producers which obtain energy using photosynthesis.
Protista: A kingdom which includes single (or multi)-celled eukaryotes. The first eukaryotes.
Taxonomy: The discipline of studying and classifying organisms.
Nucleic Acid Comparisons: Compare DNA to determine evolutionary relationships.
DNA Mutations: Compare number of mutations to determine relatedness.

Ribosomes as chronometers: DNA coding for the ribosome is sequenced. Ribosomes change at an established rate. By determining the changes and comparing them between organisms it is possible to determine when the change occurred and how close the organisms are evolutionarily.

08: Nervous System

Chapter Summary

Brain and Spinal Cord form the Central Nervous System. Brain has 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

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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).

09: 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

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

Key Concepts

The 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.

10: 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

- Concept map showing inter-connections of concepts.
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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.
21. Arteries carry blood away from the heart.
22. Veins carry blood to the heart. Capillaries are the smallest blood vessels, where exchange takes place.
23. Passive diffusion lets oxygen/nutrients out of the blood into the tissue and carbon dioxide/waste out of the tissue into the blood.
24. Arteries to the lungs are deoxygenated, and veins from the lungs to the heart are oxygenated.
25. 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.
7. 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.
8. 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.

11: Lymphatic System 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. This 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. Destroys virus-infected or mutated cells. T cell receptors recognize and bind specific antigens on cell surface and lyse the infected cells.

Tutorial Features

- Concept map showing inter-connections of concepts.
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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.

12: 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

- Concept map showing inter-connections of concepts.
- Definition slides introduce terms as they are needed.
- Examples given throughout to illustrate how the concepts apply.
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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.

13: 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 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

- Concept map showing inter-connections of concepts.
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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 and (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:
    - (a) Muscles of the head and neck: such as the rectus muscles (control eye movement) the frontalis (forehead), buccinator (cheek).
    - (b) Muscles of the Shoulder and arm: deltoid (shoulder), bicep (arm) and extensor digitorum (extends fingers).
    - (c) 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:
- (a) Increases the heart rate and dilates coronary blood vessels.
- (b) Decreases intestinal activity and blood flow.
- (c) Uses acetylcholine to cause the release of adrenalin (epinephrine), opposes the parasympathetic nervous system.

14: 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 include 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.

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.

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 Ca2+ is low more PTH is released from the parathyroid glands. This causes increased Ca2+ 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 are 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.

15: 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 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.

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.

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.

- o 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.
- o The products of digestion go to the large intestine where water is absorbed.
- o 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 and (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 break down 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.

16: 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 filter the blood reabsorbing what is needed by the body and excreting the rest as urine.

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.

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.

17: The 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

- Concept map showing inter-connections of concepts.
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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.

18: Embryogenesis, Development 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

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

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 makes 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-β, JAK/STAT, Wnt, Hedgehog IHh), Notch

Apoptosis: programmed cell death

Activation or repression of gene transcription requires recruitment of transcriptional activators and repressors.

combinations of transcription factors regulate the expression of different genes

- **Drosophila Fly Development**
  - 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 are the gap genes, which are induced by varying concentrations of different maternal effect proteins.
  - The third class of genes are 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. The 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.

19: Molecular Genetics and Human Genetics

Chapter Summary

This tutorial will discuss the foundation of genetics, the structure and function of DNA. The molecular genetics and human genetics are then introduced.

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.

Key Concepts

Molecular Basis of Genetics:
- Structure and Function of DNA
- Structure of RNA
- Protein Synthesis

Molecular Genetics:
- Northern Blot
- Southern Blot
- and DNA Cloning

Human Genetics
- Karyotype
- Population Genetics
- Genetic Counseling

Chapter Review

- **Molecular Genetics**: is a division of biology that is involved in the study of gene structure and function.
- **DNA**: is the blueprint of life; it is present in almost every cell in the body. A copy from a male donor and a copy from a female donor, through fertilization, can create a human being.
- **Genetic Code**: dictates nucleic acid structure and function. The formation of the end-product amino acids and proteins is controlled by the genetic code set of rules. Within the code are codons, which are a nucleic acid sequence that specifies the formation of an amino acid.
- **RNA**: is usually single-stranded. It is made from a DNA blueprint. RNA translates the message from the DNA to produce the correct protein.
- **Northern Blot**: RNA can be separated using gel electrophoresis. Gel electrophoresis involves applying a current to a gel matrix containing the RNA sample. RNA samples move through the gel and separate into bands based on their charge to mass ratio.

After separation, they can be transferred to a blot membrane and probed for the RNA of interest using a specifically labeled probe.

- **Gene Cloning**: can be used to create many copies of a defined DNA sequence. The sequence of DNA or gene can then be used to test the effect of over-expression or deletion of that gene from the genetic material of cells.
- **Karyotype**: is a visual pattern of the chromosomes within cells. By using stains and probes, whole chromosomes, short and long arms, and even small regions on chromosomes can be visualized.
- **Y-linked Traits:** Y-linked traits appear only in males, and it is passed from father to son. It does not skip generation. The pedigree shown here is a typical Y-linked trait.
- **Population Genetics:** This type of study addresses changes in populations, such as adaptation and speciation. The frame work of population genetics, involving the mapping of a set of genotypes to a set of phenotypes, is called a genotype-phenotype map.

20: Classical Genetics, Chromosomes and Genetic Technology

Chapter Summary

In this visual tutorial, you will learn about the Mendel's Laws of Segregation, Meiosis and recombination and Hardy Weinberg Principle. The genetic technology is also discussed.

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.

Key Concepts

Chromosome Laws of Segregation
Meiosis and Recombination
Hardy Weinberg Principle
PCR Amplification and Genetic Fingerprinting
Gene Splicing

Chapter Review

- **Gregor Mendel**: was a scientist and a priest who studied the inheritance of traits in pea plants. Later in the 20th century, his results were part of the foundation of the discipline of genetics.
- **Mendel's First Law**: Law of Segregation - two members of a gene pair (alleles) separate (segregate) from one another when forming the gametes. Each gamete carries one allele.
- **Mendel's Second Law**: Law of Independent Assortment - Genes for different traits sort independently of one another in the formation of gametes.
- **Codominance**: When two alleles are co-dominant, the phenotype of each allele is not masked by the presence of the other alleles.
- **Meiosis**: Meiosis is similar to mitosis on the basis of how chromosomes are pulled to the two poles of a cell. Before meiosis, the chromosomes also have to be duplicated. The first division involves a prophase, a metaphase, an anaphase and a telophase which are very similar to mitosis. Cells continue to a second division immediately after first division, and the two sister chromatids are separated, generating four 1N gametes.
- **Hardy-Weinberg Law**: The genotype frequencies of a large, randomly mating population remains constant if immigration, mutation, and selection do not take place.
- **Hardy Weinberg and Evolution**: Evolution is a change in the genetic composition of a population from generation to generation. Evolution happens in populations, not individuals.
- **Genetic Fingerprinting:** or DNA profiling, allows an investigator or police authority the opportunity to identify an individual based on the comparison of their DNA and a

reference sample. The process involves collecting an individual DNA sample and then fragmenting it using restriction enzymes.

21: Evolution: Origin of Life, Natural Selection, Speciation and Cladigenesis

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

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

Key Concepts

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) 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 happen 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.

22: Population Ecology

Chapter Summary

Population ecology is the study of population fluctuations as well as of the factors that regulate population size. Population density is the number of individuals per unit area or volume. It is impractical to count all individuals in a population. Population size and density reflect the relative rates of processes that add individuals to the population and processes that eliminate individuals from the population. Mortality and natality are essential factors in population dynamics. Population size is regulated through density-dependent and density-independent factors. Some populations of birds, mammals and insects fluctuate in density with remarkable regularity which is called population cycles.

Demography is the study of the vital statistics that affect population growth. It is concerned with births and deaths: Events that most directly determine population density. Different countries have different rates of growth for various reasons. Environmental, cultural and historical reasons are some of them. Although technology has increased our carrying capacity, the human population can not grow indefinitely. R-selected population refers to a type of population which produces large quantities of offspring with a relatively low probability of individual success. K-selected population refers to those whose life history is centered on producing relatively few offspring that have a good chance of survival.

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.

Key Concepts

Density and Dispersion
- Introduction
- Measurement of Density
- Patterns of Dispersion

Models of Population Growth
- Introduction
- Exponential Growth
- Logistic Growth

Regulation of Populations
- Density-Dependent Factors
- Density-Independent Factors
- Applications
- Population Cycles

Demographic Statistics
- Introduction
- Age Structure
- Life Tables
- Survivorship Curves
- Net Reproductive Rate

Human Population Growth
- Introduction
- Baby Boom

Evolution of Life Histories
- Life History Characteristics
- R-Selection
- K-Selection

Chapter Review

Density and Dispersion
Population ecology is the study of population fluctuations as well as of the factors that regulate population size. Population density is the number of individuals per unit area or volume. It is impractical to count all individuals in a population, a variety of sampling techniques are used to estimate densities and total population sizes. Dispersion is a pattern of spacing for individuals within the boundaries of the population.

Models of Population Growth
Population size and density reflect the relative rates of processes that add individuals to the population and processes that eliminate individuals from the population. Mortality and natality are essential factors in population dynamics. Generation time is the average age when females of a population begin reproducing which greatly impacts on the intrinsic rate of increase. Carrying capacity is the maximum population size that can be supported by the available resources, symbolized as K. No population can grow indefinitely.

Regulation of Populations
Population size is regulated through density-dependent and density-independent factors. Any factor influencing population regulation that has a greater impact as population density increases is a density-dependent factor. Any population influencing population regulation that acts to reduce population size by the same fraction whether the population is large or small is called density-independent factor. Population density may change with temperature. Some populations of birds, mammals and insects fluctuate in density with remarkable regularity which is called population cycles. Stress resulting from high population density may alter hormonal balance and reduce fertility.

Demographic Statistics
Demography is the study of the vital statistics that affect population growth. It is concerned with births and deaths: Events that most directly determine population density. Age structure is a relative number of individuals of each age in a population. Mortality is one of the factors that determine population density. Life tables can be constructed by following the fate of a group of new born organisms throughout their lives until all are

dead. Survivorship curve is the plot of the number of the number of members of a cohort those are still alive at each age which is one way to represent age specific mortality. Birth rates also vary with age. Net reproductive rate is the expected number of female offspring that will be produced during the average lifetime of a female member of a population.

Human Population Growth
Different countries have different rates of growth for various reasons. Environmental, cultural and historical reasons are some of them. Although technology has increased our carrying capacity, the human population can not grow indefinitely.

Evolution of Life Histories
Life history contains birth, reproduction and death – the personal episodes of organisms. Three life history characteristics influence birth rates and death rates: Clutch size, age at first reproduction and number of reproductive episodes per life time. R-selected population refers to a type of population which produces large quantities of offspring with a relatively low probability of individual success. K-selection population refers to those whose life history is centered on producing relatively few offspring that have a good chance of survival.

23: Community Ecology and Ecosystem

Chapter Summary

Community is an assemblage of species living close enough together for potential interaction. Species diversity or richness is the number of species that make up a community which include relative abundance. Some species are quite rare in a community where as other species are plentiful. Coevolution is an interspecific phenomenon which is of great importance in community ecology. Interspecific competition for limited resources determines species diversity in some communities. Closely related species can coexist if there are one or more significant differences in their niches. Succession involves changes in species composition of a community over ecological time.

Biogeography is the study of the past and the present distribution of species, deals with species diversity and composition in realms that have boundaries, ultimately associated with the patterns of continental drift. Ecosystem is the level of ecological study that includes all the organisms in a given area along with the abiotic factors with which they interact. . Biogeochemical cycles are the various nutrient circuits which involve both biotic and abiotic components of ecosystems. Three important chemical cycles are carbon, nitrogen and phosphorus cycles.

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.

Key Concepts

Views of Communities
- ❖ Introduction
- ❖ Two Views

Properties of Communities & Coevolution
- ❖ Species Diversity
- ❖ Relative Abundance and Dominance
- ❖ Prevalent Form of Vegetation
- ❖ Trophic Structure
- ❖ Stability
- ❖ Coevolution

Community Interactions
- ❖ Competition between Species
- ❖ Predation
- ❖ Symbiosis
- ❖ Complex effects of community interactions on species diversity

Succession
- Introduction
- Causes
- Disturbance
- Equilibrium

Geographic Aspects of Diversity
- Limits of Species
- Island Biogeography

Ecosystem
- Trophic Levels and Food Webs
- Energy Flow
- Chemical Cycling
- Human Intrusions in Ecosystem Dynamics
- Superorganism

Chapter Review

Views of Communities

Community is an assemblage of species living close enough together for potential interaction. Community structure emerges from an interaction of many environmental variables that permits species to exist in certain places. There are two views to discuss why certain species are found together in communities.

Properties of Communities & Coevolution

Species diversity or richness is the number of species that make up a community which include relative abundance. Some species are quite rare in a community where as other species are plentiful. Dominant species are those which are abundant and have major impact on the community as a whole. Grouping of communities according to similarities in overall form without regard to the actual species is the basis for the biomes. Various feeding relationships of a community determine the flow of energy and cycling of nutrients from plants to herbivores and then to carnivores. Community stability is the ability of the community to bounce back to its original composition in the wake of some disturbance such as a fire or a disease that kills most individuals of a dominant species. Coevolution is an interspecific phenomenon which is of great importance in community ecology.

Community Interactions

Interspecific competition for limited resources determines species diversity in some communities. Closely related species can coexist if there are one or more significant differences in their niches. Predation has important roles in the evolution of defensive adaptations in the prey species. Symbiosis has different impacts on a community. Parasitism resembles the predator-prey relationship but does not kill the host. It shows coevolution. Dynamic multiple interactions of organisms with both biotic and abiotic aspects of their environment results in a complex community property, the composition of species.

Succession

Succession involves changes in species composition of a community over ecological time. Primary succession occurs where no organisms previously existed whereas secondary succession occurs after disturbance of an existing community. Facilitation, inhibition and tolerance are the causes of succession.

Geographic Aspects of Diversity

Biogeography is the study of the past and the present distribution of species, deals with species diversity and composition in realms that have boundaries, ultimately associated with the patterns of continental drift. Islands are instructive in studying the role of dispersal in determining the species composition of communities.

Ecosystem

Ecosystem is the level of ecological study that includes all the organisms in a given area along with the abiotic factors with which they interact. Most ecosystems are driven by energy from sunlight. Energy flow and chemical cycling are two inter related processes that occur by transfer of substances through the feeding levels of ecosystems. Trophic levels begin with producers, autotrophic organisms that support all other components of the community. The main producers in photosystems are photosynthetic autotrophs. Primary productivity is the rate at which light energy is converted to the chemical energy of organic compounds by autotrophs in an ecosystem. Biogeochemical cycles are the various nutrient circuits which involve both biotic and abiotic components of ecosystems. Three important chemical cycles are carbon, nitrogen and phosphorus cycles. The biosphere is a kind of superorganism with a self regulated metabolism that helps counter fluctuation in the physical environment. Processes occurring at one location can have far reaching effects and consequences.

24: Behavioral Ecology

Chapter Summary

Ethology is the study of animal behavior in their natural environment. Behavioral patterns are inherited to some extent and are subjected to environmental influence and modification by experience. Behavior can be modified by learning in various ways. Habituation is a simple kind of learning involving loss of sensitivity to unimportant stimuli. Endogenous clocks dictate various daily behaviors which in turn require exogenous cues to keep the behavior properly times with the real world. Circannual behaviors such as breeding and hibernation are directed by physiological and hormonal changes, influenced by exogenous factors like day length. Various behaviors involving orientation and navigation are important determinants of animal distribution.

The large array of animal feeding patterns has generated a varied performance of foraging behaviors. Courtship interactions are complex, species specific behaviors. Mating relationships which change widely among different species include promiscuity, monogamy and polygamy. Animals communicate with one another through their various senses. Altruistic behavior benefits animals of the same species at the expense of the helpful individual. Human behavior is probably more plastic than that of any other animal. Sociobiologists view social behavior as having a genetic basis.

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.

Key Concepts

Studying Behavior

- ❖ Introduction
- ❖ Anthropomorphism
- ❖ Ultimate and Proximate causes
- ❖ Behavioral Patterns
- ❖ Innate Components of Behavior

Learning and Behavior

- ❖ Introduction
- ❖ Imprinting
- ❖ Classical Conditioning
- ❖ Operant Conditioning
- ❖ Insight Learning

Behavior Rhythms

- ❖ Rhythmic Behavior
- ❖ Circannual Behavior

Orientation and Navigation

- ❖ Taxis
- ❖ Kinesis

Foraging Behavior and competitive Social Interaction

- ❖ Foraging Behavior
- ❖ Agonistic Behavior
- ❖ Dominance Hierarchies
- ❖ Territoriality

Mating Behavior and Communication

- ❖ Courtship
- ❖ Mating Systems
- ❖ Communication

Altruistic Behavior and Human Sociobiology

- ❖ Altruistic Behavior
- ❖ Human Sociobiology

Chapter Review

Studying Behavior

Ethology is the study of animal behavior in their natural environment. Anthropomorphism is the tendency to consider human feelings, reasoning and motivation to other animals. Behavioral patterns are inherited to some extent and are subjected to environmental influence and modification by experience. Concepts of innate releasing mechanisms and drive do not explain actual behavior mechanisms.

Learning and Behavior

Behavior can be modified by learning in various ways. Habituation is a simple kind of learning involving loss of sensitivity to unimportant stimuli. Imprinting is a type of learned behavior with a significant innate component, acquired during a limited critical period. Classical conditioning involves linking one stimulus with another. Operant conditioning is a type of associative learning exhibited by many animals. Insight learning involves the ability to reason by correctly performing a task on the first attempt in a situation in which the animal had no earlier experience.

Behavior Rhythms

Endogenous clocks dictate various daily behaviors which in turn require exogenous cues to keep the behavior properly times with the real world. Circannual behaviors such as breeding and hibernation are directed by physiological and hormonal changes, influenced by exogenous factors like day length.

Orientation and Navigation

Various behaviors involving orientation and navigation are important determinants of animal distribution. Kinesis is a random movement displaying a stimulus – specific change in activity rate.

Foraging Behavior and competitive Social Interaction

The large array of animal feeding patterns has generated a varied performance of foraging behaviors. Agonistic behavior involves a contest in which competitor gains an advantage in obtaining access to a limited resource like food or mates. Dominance hierarchies are shown by some animals with clear cut linear dominance. Territoriality is the behavior in which an animal defends a specific fixed portion of its home range against intrusion by other animals of the same species through agonistic interactions.

Mating Behavior and Communication

Courtship interactions are complex, species specific behaviors. Mating relationships which change widely among different species include promiscuity, monogamy and polygamy. Females invest much time and energy in carrying the young before birth, thus discriminate selection of a mate is important. Animals communicate with one another through their various senses. Odors are particularly effective signals in many species as shown by the evolution of pheromones.

Altruistic Behavior and Human Sociobiology

Altruistic behavior benefits animals of the same species at the expense of the helpful individual. Human behavior is probably more plastic than that of any other animal. Sociobiologists view social behavior as having a genetic basis.