MCAT Biological Sciences Topics

BIOLOGY

This portion of the test will concentrate primarily on two major groups of living organisms: the vertebrates and the microbes. Within these two general groups, your study should focus on concepts and information common to the life processes of organisms. These concepts include basic principles of molecular biology, cellular structure and function, and genetics and evolution. Additionally, vertebrate systems will be approached from the organism or body-system level of organization. In this context, topics may focus on some aspect of the structure or function of a given body system, on the interaction of two or more body systems, or on the effects of an external factor (for example, a disease or an environmental influence) on the total physiology of an organism. Major topics are indicated by Roman numerals (I, II, III, etc.); alphabetic topic subdivisions (A, B, C, etc.) describe the topic content in more detail.

I. MOLECULAR BIOLOGY

Molecular biology is concerned with the biochemical reactions that occur within living cells and the molecules that make these reactions possible. Specifically, molecular biology covers cellular metabolism and its regulation by enzymes and the functions of DNA in transmitting genetic information and directing protein synthesis. Questions require an understanding of processes at the cell and molecular levels.

A. Enzymes and cellular metabolism
   1. Enzyme structure and function
   2. Control of enzyme activity
   3. Feedback inhibition
   4. Glycolysis
      a. Anaerobic
      b. Aerobic
   5. Krebs (citric acid) cycle
   6. Electron transport chain, oxidative phosphorylation

B. DNA and protein synthesis
   1. DNA structure and function
      a. Structure and composition
         i. Watson-Crick model
         ii. Double helix
         iii. Base-pair specificity
      b. DNA as transmitter of genetic information (the genetic code)
      c. DNA replication
   2. Protein synthesis
      a. Transcription
         i. Mechanism
         ii. Regulation
      b. Translation
         i. Codons and anticodons
         ii. Roles of mRNA, tRNA, rRNA
         iii. Structure and function of ribosomes

II. MICROBIOLOGY

Viruses, bacteria, and fungi represent a vast and integral part of life on earth. They are essential to the earth's ecology and to the lives of individual organisms yet are often sources of disease and death. Your study should focus on the general structures and life histories of these groups of microbes.

A. Viral structure and life history
   1. Nucleic acid (DNA and RNA) and protein components
   2. Typical bacteriophage structure and function
   3. Size relative to bacteria and eukaryotic cells
   4. Generalized phage and animal virus life cycles
B. Prokaryotic cells
   1. Cell structure and physiology
   2. Bacterial life history
C. Fungi
   1. Major structural types
   2. General life history and physiology

III. GENERALIZED EUKARYOTIC CELL

Since the typical eukaryotic cell is the site of the life processes covered in molecular biology and is the basic unit of which all complex organisms are formed, you should have a thorough understanding of its major structures and functions. Questions will require knowledge of the major cell organelles—particularly the nucleus and the membrane structures—and of the processes carried out by all living cells, such as movement of materials across membranes and cell replication by mitosis.

A. Nucleus: structure and functions
   1. Nucleolus
   2. Nuclear envelope and nuclear pores
B. Membrane-bound organelles: structures and functions
   1. Mitochondria
   2. Lysosomes
   3. Endoplasmic reticulum
   4. Golgi apparatus
C. Plasma membrane: structure and functions
   1. Protein and lipid components
   2. Fluid mosaic model, membrane traffic
   3. Movement across membranes
      a. Osmosis
      b. Passive and active transport
      c. Endocytosis and exocytosis
   4. Membrane channels, sodium/potassium pump, membrane potential
   5. Membrane receptors
   6. Cellular adhesion

D. Cytoskeleton: structure and functions
   1. Microfilaments, microtubules, intermediate filaments
   2. Cilia and flagella
   3. Centrioles
E. Mitosis
   1. Mitotic process, phases of the cell cycle
   2. Mitotic structures
      a. Centrioles, asters, spindles
      b. Chromatids, centromeres, telomeres, kinetochores
   3. Nuclear membrane breakdown and reorganization
   4. Mechanisms of chromosome movement

IV. SPECIALIZED EUKARYOTIC CELLS AND TISSUES

The plan of the generalized cell undergoes many specializations that provide the basis for our complex organ systems. Questions will require you to understand the structure and function of these organ systems and to interpret the specialized characteristics of the cells and tissues of nerves, muscles, skin, and connective tissue.

A. Neural cells and tissues
   1. Structures
      a. Cell body
      b. Axon
      c. Dendrites
      d. Myelin sheath, Schwann cells
      e. Nodes of Ranvier
   2. Synapse
   3. Resting potential, action potential
B. Contractile cells and tissues
   1. Striated, smooth, and cardiac muscle
   2. Sarcomere
   3. Calcium regulation of contraction
C. Epithelial cells and tissues
   1. Simple epithelium
   2. Stratified epithelium
D. Connective cells and tissues
   1. Major cell and fiber types
   2. Loose vs. dense connective tissue
   3. Cartilage
   4. Extracellular matrix

V. NERVOUS AND ENDOCRINE SYSTEMS

The nervous and endocrine systems interconnect and regulate the activities of the organism as a whole by exerting precise control over processes at the cell and molecular levels. You should know the major structures and chemicals involved in these regulatory systems and the general mechanisms by which both systems work. You should also be familiar with the reception and processing of the sensory signals which activate the nervous and endocrine systems.

A. Nervous system structure and function
   1. Organization of the vertebrate nervous system
   2. Sensor and effector neurons
   3. Sympathetic and parasympathetic nervous systems
B. Sensory reception and processing
   1. Skin, proprioceptive, and somatic sensors
   2. Olfaction, taste
   3. Hearing
      a. Ear structure
      b. Mechanism of hearing
   4. Vision
      a. Eye structure
      b. Light receptors
C. Endocrine systems: hormones and their sources
   1. Function of endocrine system
   2. Major endocrine glands, their hormones, specificity, and target tissues
   3. Cellular mechanisms of hormone action
   4. Transport of hormones

VI. CIRCULATORY, LYMPHATIC, AND IMMUNE SYSTEMS

The transport of essential gases and nutrients toward and waste materials away from the tissues and the protective activities of the body's immune responses are among the vital functions performed by the circulatory, lymphatic, and immune systems. You should be familiar with the structures and functions of these systems and the general mechanisms by which they carry out their functions and help to regulate body processes.

A. Circulatory system
   1. Functions, including role in thermoregulation
   2. Four-chambered heart, pulmonary and systematic circulation
   3. Arterial and venous systems, capillary beds
   4. Systolic and diastolic pressure
   5. Composition of blood
   6. Role of hemoglobin in oxygen transport
B. Lymphatic system: structure and function
C. Immune system
   1. Cells
      a. T-lymphocytes
      b. B-lymphocytes
   2. Tissues
      a. Bone marrow
      b. Spleen
      c. Thymus
      d. Lymph nodes
   3. Antigens, antibodies, antigen-antibody reactions

VII. DIGESTIVE AND EXCRETORY SYSTEMS

The digestive system regulates the intake, processing, and absorption of nutrients. The excretory system processes and eliminates waste materials from the body. You should know the major structures of both systems, the order in which materials are processed, and the general mechanisms by which these processes occur.

A. Digestive system
   1. Ingestion: structures and their functions
   2. Stomach
   3. Digestive glands, including liver and pancreas, bile production
   4. Small intestine, large intestine
   5. Muscular control of digestion

B. Excretory system
   1. Role of the excretory system in body homeostasis
   2. Kidney: structure and function
   3. Nephron: structure and function
   4. Formation of urine
   5. Storage and elimination of wastes

VIII. MUSCLE AND SKELETAL SYSTEMS

The systems concerned with movement and support of the vertebrate body owe their structure and organization to the specialized contractile and connective cells and tissues described in section IV above. This portion of the test will require a familiarity with the various types of muscles, their control by the nervous system, and their interrelationship with the bones, ligaments, and tendons of the skeletal system.

A. Muscle system
   1. Functions
   2. Basic muscle types and locations
   3. Nervous control of muscles
      a. Motor and sensory control
      b. Voluntary and involuntary muscles

B. Skeletal system
   1. Functions
   2. Bone structure
      a. Calcium/protein matrix
   3. Skeletal structure
      a. Specialization of bone types, structures
      b. Joint structure
   4. Cartilage structure and function
      a. Ligaments
      b. Tendons

IX. RESPIRATORY AND SKIN SYSTEMS

The respiratory system functions in the intake and exchange of gases, while the skin system has a variety of functions related to protection, thermoregulation, and homeostasis. These systems, while differing in function, are similar in that each is in direct and constant contact with the organism's external environment. Questions require an understanding of the structures and functions of the two systems.

A. Respiratory system
   1. Function
      a. Gas exchange (role of alveoli)
      b. Thermoregulation
      c. Protection against disease, particulate matter
   2. Breathing structures and mechanisms
      a. Diaphragm
      b. Rib cage
      c. Differential pressure

B. Skin system
   1. Functions
      a. Homeostasis and osmoregulation
      b. Thermoregulation
      c. Physical protection
   2. Structure

X. REPRODUCTIVE SYSTEM AND DEVELOPMENT

This section covers the formation and development of vertebrate organisms. It includes the cellular and organismal structures involved in sexual reproduction and the processes of gametogenesis, reproduction, and embryogenesis. You should understand these concepts and be able to relate reproduction and development to DNA structure and function, the principles of Mendelian genetics, and the major hormones and their control.

A. Reproduction
   1. Male and female gonads and genitalia
   2. Gametogenesis by meiosis
      a. Ovum and sperm
   3. Reproductive sequence
   4. Structure and function of placenta

B. Embryogenesis
   1. Fertilization
   2. Cleavage
   3. Blastulation
   4. Gastrulation
   5. Neurulation
   6. Major structures arising out of primary germ layers

C. Developmental mechanisms
   1. Cell specialization
      a. Determination
      b. Differentiation
   2. Induction

XI. GENETICS AND EVOLUTION

Mendelian genetics forms the basis for our modern understanding of heredity. Related to Mendelian genetics are the concepts of speciation and evolution by natural selection. You should understand Mendelian concepts and be able to relate them to the more modern concepts of molecular genetics.

A. Genetics
   1. Mendelian concepts and their application
   2. Hardy-Weinberg principle and population genetics
   3. Meiosis and genetic variability
   4. Sex-linked characteristics
   5. Mutations
B. Evolution
   1. Natural selection
      a. Fitness
      b. Differential reproduction
      c. Group selection
   2. Species concept and speciation
   3. Origin of life
   4. Comparative anatomy
      a. Chordate features
      b. Vertebrate body plan

ORGANIC CHEMISTRY

Organic chemistry plays an important role in the understanding of many biological reactions. You will be expected to call upon your knowledge of organic compounds and reactions and to explain results, arguments, and experimental procedures in terms of reactions or principles of organic compounds. Because nomenclature, classifications of functional groups, and reaction mechanisms are important to the understanding of organic reactions, these areas will also be tested within the scope of the categories outlined below. Roman numerals indicate major topic areas; alphabetic subdivisions describe each topic in greater detail.

XII. BIOLOGICAL MOLECULES

You should be familiar with the general types of molecules that are biologically active and the respective reactions of these molecules. Emphasis will be placed on the descriptions and reactions of the molecules described below.

Biochem

A. Amino acids and proteins
   1. Description
      a. Absolute configuration at the α-position
      b. Amino acids as dipolar ions

c. Classification
   i. Acidic or basic
   ii. Hydrophobic or hydrophilic
2. Reactions
   a. Sulfur linkage for cysteine and cystine
   b. Peptide linkage
   c. Hydrolysis
3. General principles
   a. 1° structure of proteins
   b. 2° structure of proteins
   c. 3° structure of proteins
      i. Role of proline, cystine
      ii. Hydrophobic bonding
   d. Isoelectric point

B. Carbohydrates
   1. Description
      a. Nomenclature and classification, common names
      b. Absolute configuration
      c. Cyclic structure and conformations of hexoses
      d. Epimers and anomers
   2. Oxidation of monosaccharides
   3. Hydrolysis of the glycoside linkage

C. Lipids
   1. Description, structure
      a. Free fatty acids
      b. Triacyl glycerols
      c. Steroids

D. Phosphorus compounds
   1. Phosphoric acid-chemistry and structure of anhydrides and esters

XIII. OXYGEN-CONTAINING COMPOUNDS

The principal reactions of oxygen-containing compounds are critical to the interpretation of many reactions in organic compounds. The fundamental principles and mechanisms of these reactions offer a good guide to the understanding of organic reactions. The concepts of nucleophiles, electrophiles, organic acids and bases, acidic protons, oxidations, reductions, and physical properties of various oxygen containing compounds are outlined below. In addition, the major reactions involving condensations, rearrangements, steric and electronic effects of substituents, and dimerizations will be covered.

A. Alcohols
   1. Important reactions
      a. Dehydrations (formation of carbocations)
      b. Substitution reactions (S_N 1 or S_N2 depending on alcohol and derived product)
   2. General principles
      a. Hydrogen bonding
      b. Effect of chain branching on physical properties

B. Aldehydes and ketones
   1. Important reactions
   a. Nucleophilic addition reactions at C = O bond
      i. Acetal, ketal, hemiacetal, hemiketal
      ii. Imine, enamine
   b. Reactions at adjacent positions
      i. Aldol condensation
      ii. Keto-enol tautomerism
   2. General principles
      a. Effect of substituents on reactivity of C = O
      b. Steric hindrance
      c. Acidity of α-H
      d. Carbanions
      e. α, β, unsaturated carbonyls

C. Carboxylic acids
   1. Important carboxyl group reactions
      a. Decarboxylation
      b. Esterification
   2. General principles
      a. H bonding
      b. Inductive effect of substituents
      c. Resonance stability of carboxylate anion

D. Common acid derivatives (acid chlorides, anhydrides, amides, esters, keto acids)
   1. Important reactions
      a. Hydrolysis of fats and glycerides (saponification)
      b. Hydrolysis of amides
   2. General principles
      a. Relative reactivity of acid derivatives
      b. Steric effects

E. Ethers
   1. Cleavage by acid
   2. Weak basicity of ethers

F. Phenols
   1. General principles
      a. Effects of substituents on acidity
      b. Hydrogen bonding

XIV. AMINES

Nitrogen-containing compounds often have unique properties due to their basicity and electronic effects. The stabilization of adjacent carbocations and the solubility properties of the ammonium salts are vital to a wide area of biological and organic reactions. Major reactions of amide formation and alkylations are also important. You should understand these concepts in order to answer questions in this section.

A. Description
   1. Stereochemistry and physical properties
B. Major reactions
   1. Amide formation
   2. Alkylation
C. General principles
   1. Basicity
   2. Stabilization of adjacent carbonium ions (carbocations)
   3. Effect of substituents on basicity of aromatic amines
D. Quaternary salts
   1. Solubility properties

XV. HYDROCARBONS

The chemistry of alkanes, alkenes, and benzene derivatives is a major part of organic chemistry. Combustion, stability of free radicals and carbocations, ring strain or stabilization, and resonance stability will be included in this section, with emphasis on the properties of saturated, unsaturated, and aromatic compounds. Resonance stability and delocalization of aromatic compounds will also be included. You will need to understand these concepts in order to answer questions in this section.

A. Saturated (alkanes)
   1. Description, physical properties
   2. Important reactions
      a. Combustion
      b. Substitution reactions with halogens, etc.
   3. General principles
      a. Stability of free radicals
      b. Chain-reaction mechanism
      c. Inhibition
      d. Ring strain in cyclic compounds
B. Unsaturated (alkenes)
   1. Description
      a. Structure and isomerization
      b. Physical properties
   2. Electrophilic addition (e.g., HBr, H_2O)
C. Aromatic (benzene)
   1. Description
   2. Resonance stability, delocalization of electrons

XVI. MOLECULAR STRUCTURE OF ORGANIC COMPOUNDS

The structures, bond descriptions, and bond strengths of organic compounds are important when determining the reactions and chemistry of organic molecules. You should be familiar with common nomenclature, methods for measuring stereochemistry, hybrid orbitals, bond strengths, and resonance.

- A. σ and π bonds
  1. Hybrid orbitals (sp^3, sp^2, sp and respective geometries)
  2. Structural formulas for molecules involving H, C, N, O, F, S, P, Si, Cl
  3. Delocalized electrons and resonance in ions and molecules
- B. Multiple bonding
  1. Effect on bond-length and bond energies
  2. Rigidity in molecular structure
- C. Stereochemistry of covalently bonded molecules
  1. Isomers
     a. Structural isomers
     b. Stereoisomers (e.g., diastereomers, enantiomers, cis/trans isomers)
     c. Conformational isomers
  2. Polarization of light, specific rotation
  3. Absolute and relative configuration
     a. Conventions for writing R and S forms
  4. Racemic mixtures

XVII. SEPARATIONS AND PURIFICATIONS

While reactions and properties of organic compounds make up a major portion of organic chemistry, another important feature is the separation and purification of these compounds. You should be familiar with the methods used in these processes, as well as with the features of the different organic compounds that make the separation or purification possible.

- A. Extraction (distribution of solute between two immiscible solvents)
- B. Chromatography
  1. Gas-liquid chromatography
  2. Thin-layer chromatography
- C. Distillation
- D. Recrystallization, solvent choice from solubility data

Lab staff do!

XVIII. USE OF SPECTROSCOPY IN STRUCTURAL IDENTIFICATION

The identification of organic compounds is of prime interest when determining the products of a particular reaction. You should understand the major spectroscopic techniques employed to determine the structures of the major groups of organic compounds, as well as the features of the compounds that affect their spectroscopy. You should especially be familiar with NMR (nuclear magnetic resonance) and IR (infrared) spectroscopy and the characteristic absorptions for common functional groups.

- A. Infrared region
  1. Intramolecular vibrations and rotations
  2. Recognizing common characteristic group absorptions
- B. NMR spectroscopy
  1. Protons in a magnetic field, equivalent protons
  2. Spin-spin splitting