**MCAT Biological Sciences Practice**

## Verbal Reasoning Writing Sample

## Biological Sciences

Passage I Autonomic nervous system drugs

Passage II Blood pH

Independent questions

Passage III Circulatory system

Passage IV Alkyl halides

Passage V Respiratory system

Independent questions

Passage VI Organic synthesis

Passage VII Digestive system

Independent questions

**Biological Sciences**

**Number of Items: 52**

**Time Allowed: 70 minutes**

**DIRECTIONS:** Most questions in the Physical Sciences test are organized into groups, each preceded by a descriptive passage. After studying the passage, select the one best answer to each question. Some questions are not based on a descriptive passage and are also independent of each other. You should also select the one best answer to these independent questions. A periodic table is provided and you may consult it whenever you wish.

**Periodic Table of the Elements**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| IA | IIA |  |  |  |  |  |  |  |  |  |  | IIIA | IVA | VA | VIA | VIIA | VIIA |
| 1**H**1.0 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 2**He**4.0 |
| 3**Li**6.9 | 4**Be**9.0 |  |  |  |  |  |  |  |  |  |  | 5**B**10.8 | 6**C**12.0 | 7**N**14.0 | 8**O**16.0 | 9**F**17.0 | 10**Ne**20.2 |
| 11**Na**23.0 | 12**Mg**24.3 |  |  |  |  |  |  |  |  |  |  | 13**Al**27.0 | 14**Si**28.1 | 15**P**31.0 | 16**S**32.1 | 17**Cl**35.5 | 18**Ar**39.9 |
| 19**K**39.1 | 20**Ca**40.1 | 21**Sc**45.0 | 22**Ti**47.9 | 23**V**50.9 | 24**Cr**52.0 | 25**Mn**54.9 | 26**Fe**55.8 | 27**Co**58.9 | 28**Ni**58.7 | 29**Cu**63.5 | 30**Zn**65.4 | 31**Ga**69.7 | 32**Ge**72.6 | 33**As**74.9 | 34**Se**79.0 | 35**Br**79.9 | 36**Kr**83.8 |
| 37**Rb**85.5 | 38**Sr**87.6 | 39**Y**88.9 | 40**Zr**91.2 | 41**Nb**92.9 | 42**Mo**95.9 | 43**Tc**(98) | 44**Ru**101.1 | 45**Rh**102.9 | 46**Pd**106.4 | 47**Ag**107.9 | 48**Cd**112.4 | 49**In**114.8 | 50**Sn**118.7 | 51**Sb**121.8 | 52**Te**127.6 | 53**I**126.9 | 54**Xe**131.3 |
| 55**Cs**132.9 | 56**Ba**137.3 | 57**La**\*138.9 | 72**Hf**178.5 | 73**Ta**180.9 | 74**W**183.9 | 75**Re**186.2 | 76**Os**190.2 | 77**Ir**192.2 | 78**Pt**195.1 | 79**Au**197.0 | 80**Hg**200.6 | 81**Tl**204.2 | 82**Pb**207.2 | 83**Bi**209.0 | 84**Po**(209) | 85**At**(210) | 86**Rn**(222) |
| 87**Fr**(223) | 88**Ra**(226) | 89**Ac**†(227) | 104**Rf**(261) | 105**Db**(262) | 106**Sg**(266) | 107**Bh**(264) | 108**Hs**(277) | 109**Mt**(268) | 110**Ds**(281) | 111**Uuu**(272) | 112**Uub**(261) |  | 114**Uuq**(289) |  | 116**Uuh**(289) |  |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| \* | 58**Ce**140 | 59**Pr**140 | 60**Nd**144 | 61**Pm**144 | 62**Sm**150 | 63**Eu**152 | 64**Gd**157 | 65**Tb**158 | 66**Dy**162 | 67**Ho**164 | 68**Er**167 | 69**Tm**168 | 70**Yb**173 | 71**Lu**175 |
| † | 90**Th**232 | 91**Pa**231 | 92**U**238 | 93**Np**237 | 94**Pu**244 | 95**Am**243 | 96**Cm**247 | 97**Bk**247 | 98**Cf**251 | 99**Es**252 | 100**Fm**257 | 101**Md**258 | 102**No**259 | 103**Lr**262 |

**Passage I**

The autonomic nervous system consists of two divisions: the sympathetic nervous system, which is mainly concerned with activating organs for “fight or flight”; and the parasympathetic nervous system, which essentially counteracts the sympathetic nervous system when there are no stressors and thus allows the body to resume a more restful and restorative state.

The functions of the autonomic nervous system are reflexly controlled. The two divisions usually act in a balanced fashion: the activity of an organ at any one time is the result of the two opposing influences. However, this is not always true, for example: most blood vessels have only sympathetic innervation. The main types of receptors in the sympathetic nervous system are adrenergic; that is, they are stimulated by norepinepherine and substances similar to norepinepherine.

Various pharmaceuticals take advantage of this fact to stimulate (adrenergic agonists) or inhibit (adrenergic antagonists) specific adrenergic receptors and thus treat certain medical conditions. The table below shows a few of the effects that stimulation of the various types of adrenergic receptors produces.

|  |  |  |
| --- | --- | --- |
| **Tissue** | **Predominant****adrenergic****receptor** | **Response** |
| bronchiolar smooth muscle | 2 | relaxation |
| myocardium | 1 | increased conduction velocity & contractility |
| sino-atrial node | 1 | increased heart rate |
| smooth muscle in cardiac & skeletal muscle arterioles | 2 | relaxation |
| smooth muscle in skin & mucosal arterioles | 1 | contraction |

95. Prazosin, an 1 antagonist, could be used to

A) treat diabetes.

B) treat an asthmatic attack.

C) lower high blood pressure.

D) treat peptic ulcer disease.

96. Propranolol, a 1 and 2 antagonist, should not be used by individuals who

I. have arthritis

II. have peripheral vascular disease (poor circulation in the extremities)

III. have asthma (episodic narrowing of the bronchioles)

IV. have heart failure

A) I, II, and III are correct

B) I, II, and IV are correct

C) II, III, and IV are correct

D) I, III, and IV are correct

97. Salbutamol, a 2 agonist, is best used to

A) treat wound infections.

B) treat asthmatic attacks.

C) lower high blood pressure.

D) treat peptic ulcer disease.

98. Anaphylaxis (an allergic reaction in which there is severe bronchoconstriction and generalized vasodilation causing hypotension) is best treated with

A) norepinephrine, which is an 1 and 1 agonist.

B) isoproterenol, which is a 1 and 2 agonist.

C) phenylephrine, which is an 1 agonist.

D) epinephrine, which is an 1, 1, and 2 agonist.

99. The most specific treatment of nasal congestion due to dilated blood vessels due to a viral upper respiratory tract infection would be administration of

A) norepinephrine, which is an 1 and 1 agonist.

B) isoproterenol, which is a 1 and 2 agonist.

C) phenylephrine, which is an 1 agonist.

D) epinephrine, which is an 1, 1, and 2 agonist.

**Passage II**

The maintenance of a narrow range of blood pH is essential to normal functioning. The body maintains normal pH by means of chemical buffer systems, the kidneys, and the lungs.

100. The major buffer system in the body is the carbonic acid/bicarbonate buffer system. Other buffer systems include

I. H2PO4-/HPO42-

II. intracellular and plasma proteins

III. hemoglobin

IV. phosholipids

A) I and II

B) I, II, and III

C) II, III, and IV

D) All of the above

101. Given that the pKa of H2CO3 is 6.1 and [H2CO3] in mmol/L is 0.03 x PaCO2 in mmHg (where PaCO2 is the partial pressure of arterial CO2), which of the following expresses arterial [H+] in terms of [HCO3 -] and PaCO2?

A) [H+] in nmol/L = 800 x PaCO2 in mmHg / [HCO3-] in mmol/L

B) [H+] in mmol/L = 24 x PaCO2 in mmHg / [HCO3-] in mmol/L

C) [H+] in mmol/L = 24 x PaCO2 in mmHg / [HCO3-] in mmol/L

D) [H+] in nmol/L = 24 x PaCO2 in mmHg / [HCO3-] in mmol/L

102. Aerobic metabolism produces 13 to 24 moles of CO2 per day. This represents how much potential H+ production per day?

A) 13 to 24 moles

B) 26 to 48 moles

C) 6.5 to 12 moles

D) 104 to 255 moles

103. What happens to the acid load referred to in the previous question?

A) At the tissue capillaries, CO2 enters red blood cells where carbonic anhydrase catalyses the production of H+. H+ combines with hemoglobin and is transported to the lungs where the reverse process occurs and CO2 is exhaled.

B) At the tissue capillaries, CO2 combines with water to form carbonic acid, which is transported to the lungs where the reverse process occurs and CO2 is exhaled.

C) At the tissue capillaries, CO2 combines with water to form carbonic acid, which is transported to the kidneys where H+ is actively transported into the lumen of the proximal tubule.

D) At the tissue capillaries, CO2 combines with water to form carbonic acid, which is transported to the kidneys where H+ is actively transported into the lumen of the distal tubule.

104. H+ excretion in the kidneys is enhanced by all of the following except

A) increased levels of aldosterone

B) increased concentration of ammonia and HPO42- in the tubular lumen

C) acidosis

D) increased concentration of potassium in the blood

105. During metabolism more H+ ions are produced than are consumed. All of the following are sources of H+ ions except

A) anaerobic respiration during intense exercise

B) metabolism of dietary protein (especially from meat)

C) aerobic respiration

D) lipogenesis

**Questions 106 to 109 are independent of any passage and of each other.**

106. The base sequence of one strand of a piece of double-stranded DNA is found to be 5’-TGTCA-3’. The sequence of the other strand is

A) 5’-TGACA-3’

B) 5’-ACTGT-3’

C) 5’-TGTCA-3’

D) 5’-GTCAC-3’

107. The correct order of increasing basicity for the following amines is



A) II, I, III

B) I, II, III

C) III, I, II

D) III, II, I

108. The primary spermatocyte gives rise to four spermatozoa. The primary oocyte gives rise to

A) 8 ova.

B) 4 ova.

C) 2 ova.

D) 1 ovum.

109. Fruit flies that are heterozygous for a dominant eye color can be distinguished from those that are homozygous dominant by

A) crossing them with homozygous dominant flies.

B) crossing them with other offspring from the same parents.

C) crossing them with homozygous recessive flies.

D) crossing them with heterozygous flies.

**Passage III**

The main purpose of the circulatory system is to deliver food and oxygen to tissues and remove wastes from tissues. These processes occur in capillaries, which are the smallest blood vessels in the body and the only ones that are semipermeable. The flow of blood to a particular organ is regulated by the caliber of the arterioles in the organ as well as by the caliber of the precapillary sphincters. Generally, the percentage of cardiac output flowing to a particular organ is related to the metabolic activity of that organ in comparison with the other organs in the body.

110. Which of the following is not a determinant of blood flow?

A) colloid osmotic pressure

B) pressure gradient

C) blood vessel diameter

D) blood viscosity

111. An organ in which the percentage of cardiac output flowing to it is not related to its metabolic activity in comparison with the other organs in the body is

A) the heart.

B) the intestine.

C) the kidney.

D) the brain.

112. During exercise, blood flow in skeletal muscle increases. Circulatory system adjustments responsible for this change include

I. Increased cardiac output.

II. Vasodilation in skeletal muscle.

III. Increased alveolar ventilation rate.

A) I is correct

B) I and II are correct

C) I and III are correct

D) II and III are correct

113. In which of the following organs will blood flow change the least during exercise?

A) intestine

B) skin

C) heart

D) brain

114. Net movement of fluid from the intravascular space to the interstitial space occurs with all of the following except

A) decreased plasma protein concentration

B) lymphatic obstruction

C) constriction of precapillary arterioles

D) constriction of postcapillary venules

115. Lymph flow is increased by all of the following except

A) bradykinin

B) elevated plasma protein concentration

C) elevated capillary pressure

D) elevated interstitial fluid protein concentration

**Passage IV**

A characteristic of alkyl halides is their ability to undergo nucleophilic substitution reactions with nucleophiles and elimination reactions with bases, although reactants are often both nucleophiles and bases. Depending on factors such as the relative strength of nucleophile versus base, steric effects, temperature, and carbocation stability, the reaction mechanism and most abundant products of certain reactions involving alkyl halides can be predicted.

116. What is the major product of the reaction below, and what is the mechanism by which it is produced?

CH3CH2Br + CH3O- 

temperature: 500oC

solvent: CH3OH

A) ethene; E1

B) ethene; E2

C) ethyl methyl ether; SN2

D) ethyl methyl ether; SN1

117. What is the major product of the reaction below, and what is the mechanism by which it is produced?

(CH3CH2)3CBr + OH- 

temperature: 500oC

solvent: CH3OH

A) (CH3CH2)3COH; SN1

B) (CH3CH2)3COH; SN2

C) CH3CH=C(CH2CH3)2; E2

D) CH3CH=C(CH2CH3)2; E1

118. What is the major product of the reaction below, and what is the mechanism by which it is produced?

(CH3CH2)3CBr + CH3OH 

temperature: 250oC

solvent: CH3OH

A) (CH3CH2)3COCH3; SN1

B) (CH3CH2)3COCH3; SN2

C) CH3CH=C(CH2CH3)2; E2

D) CH3CH=C(CH2CH3)2; E1

119. What is the major product of the reaction below, and what is the mechanism by which it is produced?

CH3CH2Br + (CH3)3CO- 

temperature: 500oC

solvent: (CH3)3COH

A) (CH3)3COCH2CH3; SN1

B) (CH3)3COCH2CH3; SN2

C) CH2=CH2; E1

D) CH2=CH2; E2

120. What is the major product of the reaction below, and what is the mechanism by which it is produced?

 

temperature: 500oC

solvent: CH3OH

A) (R)-2-butanethiol; SN2

B) (S)-2-butanethiol; SN2

C) (±)-2-butanethiol; SN1

D) (S)-2-butanethiol; SN1

121. What is the major product of the reaction below, and what is the mechanism by which it is produced?

CH2=CHBr + CH3O- 

temperature: 500oC

solvent: CH3OH

A) no reaction occurs

B) ethyne; E2

C) methoxyethene; SN2

D) methoxyethene; SN1

**Passage V**

A test subject at rest is connected to a spirometer and asked to breathe normally for a few seconds then to inspire maximally and expire maximally. The spirometer and the subject form a closed system so that air cannot leak in or out. Air moving into the subject causes an upward deflection of the spirometer needle, while expiration causes the reverse. The following graph of volume of air breathed in and out versus time is produced. (As shown, the subject is connected to the spirometer midway through expiration.)

 

122. What is the respiratory minute volume at rest?

A) 5000 ml/min

B) 2500 ml/min

C) 7500 ml/min

D) 2000 ml/min

123. What is the inspiratory capacity?

A) 4500 ml

B) 3000 ml

C) 3500 ml

D) 3250 ml

124. The spirometer initially contains 12 L of air with 10% helium. After several minutes of breathing, the concentration of helium falls to 8%. Ignoring any helium absorption into the blood, what is the residual volume?

A) 1.0 L

B) 1.5 L

C) 2.0 L

D) 3.0 L

125. If the patient’s anatomical dead space is 200 ml, what is his alveolar ventilation rate at rest?

A) 4000 ml/min

B) 4200 ml/min

C) 4500 ml/min

D) 7500 ml/min

126. Which maneuver will increase a person’s alveolar ventilation rate the most?

A) Doubling tidal volume and decreasing respiratory rate by half

B) Doubling respiratory rate and decreasing tidal volume by half

C) Breathing 100% oxygen while maintaining the initial tidal volume and respiratory rate

D) Breathing 100% oxygen and using positive end-expiratory pressure while maintaining the initial tidal volume and respiratory rate

127. The concentration of carbon dioxide is lowest in

A) the alveoli at the end of inspiration

B) the alveoli at the end of expiration

C) the trachea at the end of inspiration

D) the trachea at the end of expiration

**Questions 128 to 131 are independent of any passage and of each other.**

128. Which of the following structures is(are) not prominent during mitosis?

A) nucleolus

B) spindles

C) chromatids

D) centrioles

129. One percent of a population exhibits the trait for a recessive allele. What is the probability that an individual selected at random from this population carries at least one copy of the allele?

A) 1%

B) 10%

C) 18%

D) 19%

130. Which is the predominant product when 1,4-dimethylcyclohexane is reacted with the same number of moles of chlorine gas under photochemical conditions?



131. Of five genes (A, B, C, D, E) on a chromosome, genes D and E have a higher rate of recombination than for any other pair. A probable gene order would be

A) EDCBA

B) DCAEB

C) DBCAE

D) BEDAC

**Passage VI**

Synthesis I



Synthesis II

 

132. In Synthesis I, compound A is

A) ethene.

B) ethane.

C) 1,3-butadiene.

D) acetylide ion.

133. In Synthesis I, compound B is

A) 1-pentyne.

B) 2-pentyne.

C) 1-pentene.

D) 2-pentene.

134. In Synthesis I, compound C is

A) pentane.

B) 2-bromo-1-pentene.

C) 1-pentene.

D) 2-pentene.

135. In Synthesis II, compound D is

A) 1,2-dibromobenzene.

B) bromobenzene.

C) bromocyclohexane.

D) 1,4-dibromobenzene.

136. In Synthesis II, compound E is

A) p-bromomethylbenzene.

B) m-bromomethylbenzene.

C) p-bromophenol.

D) p-bromobenzaldehyde.

**Passage VII**

The digestive system breaks down complex food molecules into simpler molecules. These are then absorbed and distributed throughout the body by means of the circulatory system.

137. Which of the following supports the idea that monosaccharides are absorbed in the gut by means of active transport?

I. There is a maximum rate of transport.

II. Transport is selective for different sugars

III. Transport can be blocked by certain chemicals

IV. Transport is not coupled with an exergonic chemical reaction

A) II and III are correct

B) I, II, and III are correct

C) II, III, and IV are correct

D) I, III, and IV are correct

138. All of the following statements concerning pancreatic juice are correct except

A) It has a high hydrogen carbonate concentration.

B) It is alkaline with a pH of approximately 8.0.

C) Its secretion is stimulated by gastrin, secretin, cholecystokinin/pancreozymin, and impulses from the vagus nerve.

D) Its secretion is primarily under neural control.

139. After trypsinogen is secreted into the duodenum, it is converted to trypsin by

A) enteropeptidase.

B) chymotrypsin.

C) a high pH environment.

D) procarboxypeptidase.

140. Bile salts facilitate the absorption of fats because of all of the following except

A) They form water-soluble complexes with fat molecules called micelles.

B) They increase the transit time of fats.

C) They reduce the surface tension of fats.

D) They emulsify fats.

141. Fat, after being absorbed by mucosal cells, enters the lymphatic system as

A) fatty acids and glycerol.

B) monoglycerides.

C) triglycerides.

D) chylomicrons.

**Questions 142 to 146 are independent of any passage and of each other.**

142. Which of the following distinguishes bacterial reproduction from viral reproduction?

A) semi-conservative DNA replcation

B) DNA polymerase

C) cross-overs

D) spindle formation

143. Which of the following is not involved in protein synthesis?

A) acetyl CoA

B) RNA polymerase

C) tRNA

D) anticodons

144. Ketones result from the oxidation of

A) primary alcohols.

B) secondary alcohols.

C) tertiary alcohols.

D) ethers.

145. What is the percentage by weight of carbon in methanal?

A) 28%

B) 34%

C) 40%

D) 47%

146. On the western side of the Grand Canyon, the species of squirrel have white tails; whereas, on the eastern side, the species of squirrel have gray tails. This is an example of

A) competition.

B) adaptive radiation.

C) reproductive isolation.

D) mutualistic symbiosis.

**STOP.** IF YOU FINISH BEFORE TIME IS CALLED, CHECK YOUR WORK. YOU MAY GO BACK TO ANY QUESTION IN THE BIOLOGICAL SCIENCES TEST BOOKLET.

**Content Outline for Biological Science Section of the MCAT**

**BIOLOGY**

**MOLECULAR BIOLOGY: ENZYMES AND METABOLISM**

1. **Enzyme Structure and Function**
	1. Function of enzymes in catalyzing biological reactions
	2. Reduction of activation energy
	3. Substrates and enzyme specificity
2. **Control of Enzyme Activity**
	1. Feedback inhibition
	2. Competitive inhibition
	3. Noncompetitive inhibition
3. **Basic Metabolism**
	1. Glycolysis (anaerobic and aerobic, substrates and products)
	2. Krebs cycle (substrates and products, general features of the pathway)
	3. Electron transport chain and oxidative phosphorylation (substrates and products, general features of the pathway)
	4. Metabolism of fats and proteins

**MOLECULAR BIOLOGY: DNA AND PROTEIN SYNTHESIS**

***DNA Structure and Function***

1. **DNA Structure and Function**
	1. Double-helix structure
	2. DNA composition (purine and pyrimidine bases, deoxyribose, phosphate)
	3. Base-pairing specificity, concept of complementarity
	4. Function in transmission of genetic information
2. **DNA Replication**
	1. Mechanism of replication (separation of strands, specific coupling of free nucleic acids, DNA polymerase, primer required)
	2. Semiconservative nature of replication
3. **Repair of DNA**
	1. Repair during replication
	2. Repair of mutations
4. **Recombinant DNA Techniques**
	1. Restriction enzymes
	2. Hybridization
5. Gene cloning
6. PCR

***Protein Synthesis***

1. **Genetic Code**
	1. Typical information flow (DNA **→** RNA **→** protein)
	2. Codon–anticodon relationship, degenerate code
	3. Missense and nonsense codons
	4. Initiation and termination codons (function, codon sequences)
2. **Transcription**
	1. mRNA composition and structure (RNA nucleotides, 5′ cap, poly-A tail)
	2. tRNA and rRNA composition and structure (e.g., RNA nucleotides)
	3. Mechanism of transcription (RNA polymerase, promoters, primer not required)
3. **Translation**
	1. Roles of mRNA, tRNA, and rRNA; RNA base-pairing specificity
	2. Role and structure of ribosomes

**MOLECULAR BIOLOGY: EUKARYOTES**

1. **Eukaryotic Chromosome Organization**
	1. Chromosomal proteins
	2. Telomeres, centromeres
2. **Control of Gene Expression in Eukaryotes**
	1. Transcription regulation
	2. DNA binding proteins, transcription factors
	3. Cancer as a failure of normal cellular controls, oncogenes, tumor suppressor genes
	4. Posttranscriptional control, basic concept of splicing (introns, exons)

**MICROBIOLOGY**

1. **Fungi**
	1. General characteristics
	2. General aspects of life cycle
2. **Virus Structure**
	1. General structural characteristics (nucleic acid and protein, enveloped and nonenveloped)
	2. Lack of organelles and nucleus
	3. Structural aspects of typical bacteriophage
	4. Genomic content (RNA or DNA)
	5. Size relative to bacteria and eukaryotic cells
3. **Viral Life Cycle**
	1. Self-replicating biological units that must reproduce within specific host cell
	2. Generalized phage and animal virus life cycles
		1. attachment to host cell, penetration of cell membrane or cell wall, entry of viral material
		2. use of host synthetic mechanisms to replicate viral components
		3. self-assembly and release of new viral particles
	3. Retrovirus life cycle, integration into host DNA, reverse transcriptase
	4. Transduction, transfer of genetic material by viruses
4. **Prokaryotic Cell: Bacteria Structure**
	1. Lack of nuclear membrane and mitotic apparatus
	2. Lack of typical eukaryotic organelles
	3. Major classifications: bacilli (rod-shaped), spirilli (spiral-shaped), cocci (spherical); eubacteria, archaebacteria
	4. Presence of cell wall
	5. Flagellar propulsion
5. **Prokaryotic Cell: Growth and Physiology**
	1. Reproduction by fission
	2. High degree of genetic adaptability, acquisition of antibiotic resistance
	3. Exponential growth
	4. Existence of anaerobic and aerobic variants
6. **Prokaryotic Cell: Genetics**
	1. Existence of plasmids, extragenomic DNA, transfer by conjugation
	2. Transformation (incorporation into bacterial genome of DNA fragments from external medium)
	3. Regulation of gene expression, coupling of transcription and translation

**GENERALIZED EUKARYOTIC CELL**

1. **Nucleus and Other Defining Characteristics**
	1. Defining characteristics (membrane-bound nucleus, presence of organelles, mitotic division)
	2. Nucleus (compartmentalization, storage of genetic information)
	3. Nucleolus (location, function)
	4. Nuclear envelope, nuclear pores
2. **Membrane-bound Organelles**
	1. Mitochondria
		1. site of ATP production
		2. self-replication; have own DNA and ribosomes
		3. inner and outer membrane
	2. Lysosomes (vesicles containing hydrolytic enzymes)
	3. Endoplasmic reticulum
		1. rough (RER) and smooth (SER)
		2. RER (site of ribosomes)
		3. role in membrane biosynthesis: SER (lipids), RER (transmembrane proteins)
		4. RER (role in biosynthesis of transmembrane and secreted proteins that cotranslationally targeted to RER by signal sequence)
	4. Golgi apparatus (general structure; role in packaging, secretion, and modification of glycoprotein carbohydrates)
3. **Plasma Membrane**
	1. General function in cell containment
	2. Protein and lipid components, fluid mosaic model
	3. Osmosis
	4. Passive and active transport
	5. Membrane channels
	6. Sodium–potassium pump
	7. Membrane receptors, cell signaling pathways, second messengers
	8. Membrane potential
	9. Exocytosis and endocytosis
	10. Cell–cell communication (general concepts of cellular adhesion)
		1. gap junctions
		2. tight junctions
		3. desmosomes
4. **Cytoskeleton**
	1. General function in cell support and movement
	2. Microfilaments (composition; role in cleavage and contractility)
	3. Microtubules (composition; role in support and transport)
	4. Intermediate filaments (role in support)
	5. Composition and function of eukaryotic cilia and flagella
	6. Centrioles, microtubule organizing centers
5. **Cell Cycle and Mitosis**
	1. Interphase and mitosis (prophase, metaphase, anaphase, telophase)
	2. Mitotic structures and processes
		1. centrioles, asters, spindles
		2. chromatids, centromeres, kinetochores
		3. nuclear membrane breakdown and reorganization
		4. mechanisms of chromosome movement
	3. Phases of cell cycle (G0, G1, S, G2,M)
	4. Growth arrest
6. **Apoptosis (Programmed Cell Death)**

**SPECIALIZED EUKARYOTIC CELLS AND TISSUES**

1. **Nerve Cell/Neural**
	1. Cell body (site of nucleus and organelles)
	2. Axon (structure, function)
	3. Dendrites (structure, function)
	4. Myelin sheath, Schwann cells, oligodendrocytes, insulation of axon
	5. Nodes of Ranvier (role in propagation of nerve impulse along axon)
	6. Synapse (site of impulse propagation between cells)
	7. Synaptic activity
		1. transmitter molecules
		2. synaptic knobs
		3. fatigue
		4. propagation between cells without resistance loss
	8. Resting potential (electrochemical gradient)
	9. Action potential
		1. threshold, all-or-none
		2. sodium–potassium pump
	10. Excitatory and inhibitory nerve fibers (summation, frequency of firing)
2. **Muscle Cell/Contractile**
	1. Abundant mitochondria in red muscle cells (ATP source)
	2. Organization of contractile elements (actin and myosin filaments, cross bridges, sliding filament model)
	3. Calcium regulation of contraction, sarcoplasmic reticulum
	4. Sarcomeres (―I‖ and ―A‖ bands, ―M‖ and ―Z‖ lines, ―H‖ zone—general structure only)
	5. Presence of troponin and tropomyosin
3. **Other Specialized Cell Types**
	1. Epithelial cells (cell types, simple epithelium, stratified epithelium)
	2. Endothelial cells
	3. Connective tissue cells (major tissues and cell types, fiber types, loose versus dense, extracellular matrix)

**NERVOUS AND ENDOCRINE SYSTEMS**

1. **Endocrine System: Hormones**
	1. Function of endocrine system (specific chemical control at cell, tissue, and organ levels)
	2. Definitions of endocrine gland, hormone
	3. Major endocrine glands (names, locations, products)
	4. Major types of hormones
2. **Endocrine System: Mechanisms of Hormone Action**
	1. Cellular mechanisms of hormone action
	2. Transport of hormones (bloodstream)
	3. Specificity of hormones (target tissue)
	4. Integration with nervous system (feedback control)
3. **Nervous System: Structure and Function**
	1. Major functions
		1. high-level control and integration of body systems
		2. response to external influences
		3. sensory input
		4. integrative and cognitive abilities
	2. Organization of vertebrate nervous system
	3. Sensor and effector neurons
	4. Sympathetic and parasympathetic nervous systems (functions, antagonistic control)
	5. Reflexes
		1. feedback loop, reflex arc, effects on flexor and extensor muscles
		2. roles of spinal cord, brain
		3. efferent control
4. **Nervous System: Sensory Reception and Processing**
	1. Skin, proprioceptive and somatic sensors
	2. Olfaction, taste
	3. Hearing
		1. ear structure
		2. mechanism of hearing
	4. Vision
		1. light receptors
		2. eye structure
		3. visual image processing

**CIRCULATORY, LYMPHATIC, AND IMMUNE SYSTEMS**

1. **Circulatory System**
	1. Functions (circulation of oxygen, nutrients, hormones, ions, and fluids; removal of metabolic waste)
	2. Role in thermoregulation
	3. Four-chambered heart (structure, function)
	4. Systolic and diastolic pressure
	5. Pulmonary and systemic circulation
	6. Arterial and venous systems (arteries, arterioles, venules, veins)
		1. structural and functional differences
		2. pressure and flow characteristics
	7. Capillary beds
		1. mechanisms of gas and solute exchange
		2. mechanism of heat exchange
	8. Composition of blood
		1. plasma, chemicals, blood cells
		2. erythrocyte production and destruction (spleen, bone marrow)
		3. regulation of plasma volume
		4. coagulation, clotting mechanisms, role of liver in production of clotting factors
	9. Oxygen and carbon dioxide transport by blood
		1. hemoglobin, hematocrit
		2. oxygen content
		3. oxygen affinity
	10. Details of oxygen transport: biochemical characteristics of hemoglobin
		1. modification of oxygen affinity
2. **Lymphatic System**
	1. Major functions
		1. equalization of fluid distribution
		2. transport of proteins and large glycerides
		3. return of materials to the blood
	2. Composition of lymph (similarity to blood plasma; substances transported)
	3. Source of lymph (diffusion from capillaries by differential pressure)
	4. Lymph nodes (activation of lymphocytes)
3. **Immune System: Innate and Adaptive Systems**
	1. Cells and their basic functions
		1. macrophages, neutrophils, mast cells, natural killer cells, dendritic cells
		2. T lymphocytes
		3. B lymphocytes, plasma cells
	2. Tissues
		1. bone marrow
		2. spleen
		3. thymus
		4. lymph nodes
	3. Basic aspects of innate immunity and inflammatory response
	4. Concepts of antigen and antibody
	5. Structure of antibody molecule
	6. Mechanism of stimulation by antigen; antigen presentation

**DIGESTIVE AND EXCRETORY SYSTEMS**

1. **Digestive System**
	1. Ingestion
		1. saliva as lubrication and source of enzymes
		2. epiglottal action
		3. pharynx (function in swallowing)
		4. esophagus (transport function)
	2. Stomach
		1. storage and churning of food
		2. low pH, gastric juice, protection by mucus against self-destruction
		3. production of digestive enzymes, site of digestion
		4. structure (gross)
	3. Liver
		1. production of bile
		2. roles in nutrient metabolism, vitamin storage
		3. roles in blood glucose regulation, detoxification
		4. structure (gross)
	4. Bile
		1. storage in gallbladder
		2. function
	5. Pancreas
		1. production of enzymes, bicarbonate
		2. transport of enzymes to small intestine
		3. structure (gross)
	6. Small intestine
		1. absorption of food molecules and water
		2. function and structure of villi
		3. production of enzymes, site of digestion
		4. neutralization of stomach acid
		5. structure (anatomic subdivisions)
	7. Large intestine
		1. absorption of water
		2. bacterial flora
		3. structure (gross)
	8. Rectum (storage and elimination of waste, feces)
	9. Muscular control
		1. sphincter muscle
		2. peristalsis
2. **Excretory System**
	1. Roles in homeostasis
		1. blood pressure
		2. osmoregulation
		3. acid–base balance
		4. removal of soluble nitrogenous waste
	2. Kidney structure
		1. cortex
		2. medulla
	3. Nephron structure
		1. glomerulus
		2. Bowman’s capsule
		3. proximal tubule
		4. loop of Henle
		5. distal tubule
		6. collecting duct
	4. Formation of urine
		1. glomerular filtration
		2. secretion and reabsorption of solutes
	5. concentration of urine
	6. countercurrent multiplier mechanism (basic function)
3. Storage and elimination (ureter, bladder, urethra)

**MUSCLE AND SKELETAL SYSTEMS**

1. **Muscle System**
	1. Functions
		1. support, mobility
		2. peripheral circulatory assistance
		3. thermoregulation (shivering reflex)
	2. Structural characteristics of skeletal, smooth, and cardiac muscle; striated versus nonstriated
	3. Nervous control
		1. motor neurons
		2. neuromuscular junctions, motor end plates
		3. voluntary and involuntary muscles
		4. sympathetic and parasympathetic innervation
2. **Skeletal System**
	1. Functions
		1. structural rigidity and support
		2. calcium storage
		3. physical protection
	2. Skeletal structure
		1. specialization of bone types; structures
		2. joint structures
		3. endoskeleton versus exoskeleton
	3. Cartilage (structure, function)
	4. Ligaments, tendons
	5. Bone structure
		1. calcium–protein matrix
		2. bone growth (osteoblasts, osteoclasts)

**RESPIRATORY SYSTEM**

1. **Respiratory System**
	1. General structure and function
		1. gas exchange, thermoregulation
		2. protection against disease, particulate matter
	2. Breathing mechanisms
		1. diaphragm, rib cage, differential pressure
		2. resiliency and surface tension effects

**SKIN SYSTEM**

1. **Skin System**
	1. Functions in homeostasis and osmoregulation
	2. Functions in thermoregulation
		1. hair, erectile musculature
		2. fat layer for insulation
		3. sweat glands, location in dermis
		4. vasoconstriction and vasodilation in surface capillaries
	3. Physical protection
		1. nails, calluses, hair
		2. protection against abrasion, disease organisms
	4. Structure
		1. layer differentiation, cell types, tissue types (epithelial, connective)
		2. relative impermeability to water

**REPRODUCTIVE SYSTEM AND DEVELOPMENT**

1. **Reproductive System**
	1. Male and female reproductive structures and their functions
		1. gonads
		2. genitalia
		3. differences between male and female structures
	2. Gametogenesis by meiosis
	3. Ovum and sperm
		1. differences in formation
		2. differences in morphology
		3. relative contribution to next generation
	4. Reproductive sequence (fertilization, implantation, development, birth)
2. **Embryogenesis**
	1. Stages of early development (order and general features of each)
		1. fertilization
		2. cleavage
		3. blastula formation
		4. gastrulation
			1. first cell movements
			2. formation of primary germ layers (endoderm, mesoderm, ectoderm)
		5. neurulation
	2. Major structures arising out of primary germ layers
3. **Developmental Mechanisms**
	1. Cell specialization
		1. determination
		2. differentiation
		3. tissue types
4. Cell communication in development
5. Gene regulation in development
6. Programmed cell death

**GENETICS**

1. **Mendelian Concepts**
	1. Phenotype and genotype (definitions, probability calculations, pedigree analysis)
	2. Gene
	3. Locus
	4. Allele (single, multiple)
	5. Homozygosity and heterozygosity
	6. Wild type
	7. Recessiveness
	8. Complete dominance
	9. Codominance
	10. Incomplete dominance, leakage, penetrance, expressivity
	11. Gene pool
2. **Meiosis and Genetic Variability**
	1. Significance of meiosis
	2. Important differences between meiosis and mitosis
	3. Segregation of genes
		1. independent assortment
		2. linkage
		3. recombination
		4. single crossovers
		5. double crossovers
	4. Sex-linked characteristics
		1. very few genes on Y chromosome
		2. sex determination
		3. cytoplasmic inheritance, mitochondrial inheritance
	5. Mutation
		1. general concept of mutation
		2. types of mutations (random, translation error, transcription error, base substitution, insertion, deletion, frameshift)
		3. chromosomal rearrangements (inversion, translocation)
		4. advantageous versus deleterious mutation
		5. inborn errors of metabolism
		6. relationship of mutagens to carcinogens
3. **Analytic Methods**
	1. Hardy–Weinberg principle
	2. Testcross (backcross; concepts of parental, F1, and F2 generations)

**EVOLUTION**

1. **Evolution**
	1. Natural selection
		1. fitness concept
		2. selection by differential reproduction
		3. concepts of natural and group selection
		4. evolutionary success as increase in percent representation in the gene pool of the next generation
	2. Speciation
		1. definition of species
		2. polymorphism
		3. adaptation and specialization
		4. concepts of ecological niche, competition
		5. concept of population growth through competition
		6. inbreeding
		7. outbreeding
		8. bottlenecks, genetic drift
		9. divergent, parallel, and convergent evolution
		10. symbiotic relationships
			1. parasitism
			2. commensalism
			3. mutualism
	3. Relationship between ontogeny and phylogeny
	4. Evolutionary time as measured by gradual random changes in genome
	5. Origin of life
2. **Comparative Anatomy**
	1. Chordate features
		1. notochord
		2. pharangeal pouches, brachial arches
		3. dorsal nerve cord
	2. Vertebrate phylogeny (vertebrate classes and relations to each other)

**ORGANIC CHEMISTRY**

**THE COVALENT BOND**

1. **Sigma and Pi Bonds**
	1. Hybrid orbitals (*sp*3, *sp*2, *sp*, and their respective geometries)
	2. Valence shell electron-pair repulsion (VSEPR) theory, predictions of shapes of molecules (e.g., NH3, H2O, CO2)
	3. Structural formulas
	4. Delocalized electrons and resonance in ions and molecules
2. **Multiple Bonding**
	1. Its effect on bond length and bond energies
	2. Rigidity in molecular structure
3. **Stereochemistry of Covalently Bonded Molecules**
	1. Isomers
		1. constitutional isomers
		2. stereoisomers (e.g., diastereomers, enantiomers, cis and trans isomers)
		3. conformational isomers
	2. Polarization of light, specific rotation
	3. Absolute and relative configuration
		1. conventions for writing R and S forms
		2. conventions for writing E and Z forms
	4. Racemic mixtures, separation of enantiomers

**MOLECULAR STRUCTURE AND SPECTRA**

1. **Absorption Spectroscopy**
	1. Infrared region
		1. intramolecular vibrations and rotations
		2. recognizing common characteristic group absorptions, fingerprint region
	2. Visible region
		1. absorption in visible region yielding complementary color
		2. effect of structural changes on absorption
	3. Ultraviolet region
		1. ** -electron and nonbonding electron transitions
		2. conjugated systems
2. **Mass Spectrometry**
	1. Mass-to-charge ratio (*m*/*z*)
	2. Molecular ion peak
3. **1H NMR Spectroscopy**
	1. Protons in a magnetic field, equivalent protons
	2. Spin–spin splitting

**SEPARATIONS AND PURIFICATIONS**

1. **Extraction (Distribution of Solute Between Two Immiscible Solvents)**
2. **Distillation**
3. **Chromatography (Basic Principles Involved in Separation Process)**
	1. Gas–liquid chromatography
	2. Paper chromatography
	3. Thin-layer chromatography
4. **Recrystallization (Solvent Choice from Solubility Data) HYDROCARBONS**
5. **Alkanes**
	1. Description
		1. nomenclature
		2. physical properties
	2. Important reactions
		1. combustion
		2. substitution reactions with halogens, etc.
	3. General principles
		1. stability of free radicals, chain reaction mechanism, inhibition
		2. ring strain in cyclic compounds
		3. bicyclic molecules

**OXYGEN-CONTAINING COMPOUNDS**

1. **Alcohols**
	1. Description
		1. nomenclature
		2. physical properties
	2. Important reactions
		1. substitution reactions (SN1 or SN2, depending on alcohol and derived alkyl halide)
		2. oxidation
		3. pinacol rearrangement in polyhydroxyalcohols, synthetic uses
		4. protection of alcohols
		5. reactions with SOCl2 and PBr3
		6. preparation of mesylates and tosylates
		7. esterification
		8. inorganic esters
	3. General principles
		1. hydrogen bonding
		2. acidity of alcohols compared to other classes of oxygen-containing compounds
		3. effect of chain branching on physical properties
2. **Aldehydes and Ketones**
	1. Description
		1. nomenclature
		2. physical properties
	2. Important reactions
		1. nucleophilic addition reactions at C=O bond
			1. acetal, hemiacetal
			2. imine, enamine
		2. reactions at adjacent positions
			1. haloform reactions
			2. aldol condensation
			3. oxidation
		3. 1,3-dicarbonyl compounds, internal hydrogen bonding
		4. keto–enol tautomerism
		5. organometallic reagents
		6. Wolff–Kishner reaction
		7. Grignard reagents
	3. General principles
		1. effect of substituents on reactivity of C=O; steric hindrance
		2. acidity of **α** hydrogens; carbanions
		3. α, ** −unsaturated carbonyl compounds, their resonance structures
3. **Carboxylic Acids**
	1. Description
		1. nomenclature
		2. physical properties and solubility
	2. Important reactions
		1. carboxyl group reactions
			1. nucleophilic attack
			2. reduction
			3. decarboxylation
			4. esterification
		2. reactions at α position
			1. halogenation
			2. substitution reactions
	3. General principles
		1. hydrogen bonding
		2. dimerization
		3. acidity of the carboxyl group
		4. inductive effect of substituents
		5. resonance stability of carboxylate anion
4. **Acid Derivatives (Acid Chlorides, Anhydrides, Amides, Esters)**
	1. Description
		1. nomenclature
		2. physical properties
	2. Important reactions
		1. preparation of acid derivatives
		2. nucleophilic substitution
		3. Hofmann rearrangement
		4. transesterification
		5. hydrolysis of fats and glycerides (saponification)
		6. hydrolysis of amides
	3. General principles
		1. relative reactivity of acid derivatives
		2. steric effects
		3. electronic effects
		4. Strain (e.g., ** -lactams)
5. **Keto Acids and Esters**
	1. Description
		1. nomenclature
	2. Important reactions
		1. decarboxylation
		2. acetoacetic ester synthesis
	3. General principles
		1. acidity of α hydrogens in ** −keto esters
		2. keto–enol tautomerism

**AMINES**

1. Description
	1. nomenclature
	2. stereochemistry, physical properties
2. Important reactions
	1. amide formation
	2. reaction with nitrous acid
	3. alkylation
	4. Hofmann elimination
3. General principles
	1. basicity
	2. stabilization of adjacent carbocations
	3. effect of substituents on basicity of aromatic amines

**BIOLOGICAL MOLECULES**

1. **Carbohydrates**
	1. Description
		1. nomenclature, classification, common names
		2. absolute configurations
		3. cyclic structure and conformations of hexoses
		4. epimers and anomers
	2. Hydrolysis of the glycoside linkage
	3. Reactions of monosaccharides
2. **Amino Acids and Proteins**
	1. Description
		1. a absolute configuration(s)
		2. amino acids classified as dipolar ions
		3. classification
			1. acidic or basic
			2. hydrophobic or hydrophilic
	2. Important reactions
		1. peptide linkage
		2. hydrolysis
	3. General principles
		1. 1º structure of proteins
		2. 2º structure of proteins
3. **Lipids**
	1. Description, structure
		1. steroids
		2. terpenes
		3. triacyl glycerols
		4. free fatty acids
4. **Phosphorus Compounds**
	1. Description
		1. structure of phosphoric acids (anhydrides, esters)
	2. Important reactions
		1. Wittig reaction