Preface

We created this Test Bank to provide a variety of exam questions for instructors using the Fourth Edition of *Principles of Human Physiology*, by Cindy L. Stanfield. For each chapter, we developed five styles of questions, which are rated for difficulty on a scale of 2 through 9. The question styles are:

- Multiple Choice
- True/False
- Matching
- Essay
- Short Answer

The Test Bank provides instructors with a variety of questions for each chapter in the textbook. The range of difficulty is based, for the most part, on the extent of integration required of the student to answer the questions.

The Test Bank is available in electronic format through the TestGen software, which provides instructors with an intuitive, user-friendly interface with maximum flexibility in the development of exams. The software provided to instructors is the same as that used to generate the Test Bank. Therefore, instructors have several options for developing their exams: they can use the questions provided in the Test Bank, edit the questions from the Test Bank, or generate new questions that can be added to the Test Bank. An interactive Macintosh and Windows CD-ROM version of the Test Bank is available, which will allow you to easily alter the questions provided or add new questions to fit. Visit the Addison Wesley/Benjamin Cummings catalog page to download the electronic version of this printed Test Bank and other available instructor supplements at www.aw-bc.com.

I appreciate any feedback from instructors using the Test Bank. In particular, I am interested in feedback on potential revisions to Test Bank questions and difficulty ratings, as well as any new questions instructors might suggest. Please send these to me in care of the publisher.

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Multiple Choice Questions

1) The smallest living units capable of carrying out their own basic life functions are called _______.
   A) organs
   B) organ systems
   C) tissues
   D) cells
   E) organelles
   Answer: D
   Diff: 2   Page Ref: 3

2) _______ carry/carries oxygen to the cells of the body, while the synthesis of these cells is regulated by the hormone ________.
   A) Erythrocytes : bone marrow
   B) Bone marrow : erythrocyte
   C) Erythrocytes : erythropoietin
   D) Erythropoietin : erythrocyte
   E) Bone marrow : erythropoietin
   Answer: C
   Diff: 4   Page Ref: 2

3) Which of the following is NOT one of the major cell types found in the human body?
   A) epithelial cells
   B) muscle cells
   C) endocrine cells
   D) nervous cells
   E) connective tissue cells
   Answer: C
   Diff: 3   Page Ref: 3

4) Which of the following is NOT a primary type of tissue?
   A) muscle
   B) skeletal
   C) nerve
   D) epithelial
   E) connective
   Answer: B
   Diff: 3   Page Ref: 3
5) The tissue type that generates mechanical force and movement, and whose activity is controlled both on a voluntary and involuntary level, is ________.
   A) muscle tissue  
   B) epithelial tissue  
   C) connective tissue  
   D) nervous tissue  
   E) skeletal tissue  
   Answer: A  
   Diff: 4   Page Ref: 5

6) What tissue type functions in the transport of specific molecules from one body compartment to another?
   A) muscle tissue  
   B) epithelial tissue  
   C) connective tissue  
   D) nervous tissue  
   E) reticular tissue  
   Answer: B  
   Diff: 4   Page Ref: 5

7) What tissue type lines internal hollow organs and external surfaces of the body, providing a barrier between the internal and external environment?
   A) epithelial tissue  
   B) muscle tissue  
   C) nervous tissue  
   D) connective tissue  
   E) reticular tissue  
   Answer: A  
   Diff: 4   Page Ref: 5

8) Glands are derived from what type of tissue?
   A) muscle  
   B) connective  
   C) epithelial  
   D) nerve  
   E) kleenex  
   Answer: C  
   Diff: 3   Page Ref: 5

9) What type of tissue lines exocrine glands?
   A) connective  
   B) epithelial  
   C) exonuclear  
   D) nerve  
   E) muscle  
   Answer: B  
   Diff: 4   Page Ref: 5
10) Endocrine glands are derived from what type of tissue?
   A) muscle  
   B) nerve  
   C) epithelial  
   D) connective  
   E) reticular  
   Answer: C  
   Diff: 3  Page Ref: 5

11) What type of gland secretes products into ducts leading to the external environment?
   A) endocrine glands  
   B) exocrine glands  
   C) both endocrine and exocrine  
   D) neither endocrine nor exocrine  
   Answer: B  
   Diff: 4  Page Ref: 5

12) Which tissue type includes cells contained in an extracellular matrix composed of collagen and elastin?
   A) muscle tissue  
   B) epithelial tissue  
   C) connective tissue  
   D) nervous tissue  
   E) endocrine tissue  
   Answer: C  
   Diff: 3  Page Ref: 5

13) Which of the following descriptions INCORRECTLY describes the tissue type?
   A) Muscle tissue is specialized for contraction and generation of force.  
   B) Epithelial tissue forms glands.  
   C) Nervous tissue is specialized for transmission of electrical impulses.  
   D) Connective tissue is specialized for exchange between the internal and external environments.  
   E) Epithelial tissue lines the lumen of internal organs.  
   Answer: D  
   Diff: 4  Page Ref: 5

14) What is a general name for the non-cellular material that holds the widely scattered cells of connective tissue together?
   A) Basement membrane  
   B) Collagen  
   C) Intracellular matrix  
   D) Extracellular matrix  
   E) Elastin  
   Answer: D  
   Diff: 4  Page Ref: 5
15) Which of the following is a protein found in the body that provides the tensile strength to resist stretching?
   A) Collagen  
   B) Elastin  
   C) Erythropoietin  
   D) Basement membrane  
   E) Vimentin  
Answer: A  
Diff: 4  Page Ref: 5

16) Which of the following is a tissue type that includes the cells found within blood and bones?
   A) muscle tissue  
   B) epithelial tissue  
   C) connective tissue  
   D) nervous tissue  
   E) endocrine tissue  
Answer: C  
Diff: 4  Page Ref: 5

17) What are the structures that attach bone to muscle called?
   A) ligaments  
   B) aponeuroses  
   C) extracellular matrix proteins  
   D) tendons  
   E) intracellular matrix proteins  
Answer: D  
Diff: 4  Page Ref: 5

18) Organs of the body are defined as _______.
   A) a collection of cells that perform similar functions  
   B) two or more tissues combined to form a structure that allows each tissue to function independently  
   C) a collection of cells that function independently of one another  
   D) a combination of two or more tissues that makes a structure which performs specific functions  
   E) a collection of tissues that function independently of one another  
Answer: D  
Diff: 3  Page Ref: 5

19) Which of the following accurately represents the order of complexity for the components of the body, from least to most complex?
   A) organ systems, cells, tissues, organs  
   B) tissues, cells, organs, organ systems  
   C) cells, tissues, organs, organ systems  
   D) cells, tissues, organ systems, organs  
   E) organ systems, organs, tissues, cells  
Answer: C  
Diff: 2  Page Ref: 5
20) Which of the following organ systems is primarily involved in the process of digestion?
   A) immune system  
   B) endocrine system  
   C) gastrointestinal system  
   D) cardiovascular system  
   E) integumentary system  
Answer: C  
Diff: 2  Page Ref: 5

21) Which of the following is NOT a component of the gastrointestinal system?
   A) salivary glands  
   B) stomach  
   C) gall bladder  
   D) liver  
   E) kidneys  
Answer: E  
Diff: 4  Page Ref: 5

22) Name the two organ systems that the kidneys belong to.
   A) urinary and digestive systems  
   B) urinary and immune systems  
   C) endocrine and urinary systems  
   D) urinary and skeletal systems  
   E) endocrine and gastrointestinal systems  
Answer: C  
Diff: 5  Page Ref: 6

23) The uptake of nutrients across the epithelial cells of the gastrointestinal tract and into the bloodstream is called _______.
   A) filtration  
   B) excretion  
   C) secretion  
   D) absorption  
   E) reabsorption  
Answer: D  
Diff: 4  Page Ref: 7

24) What organ system includes the pituitary gland, adrenal gland, and thyroid gland?
   A) nervous  
   B) endocrine  
   C) cardiovascular  
   D) integumentary  
   E) immune  
Answer: B  
Diff: 3  Page Ref: 6
25) What organ system protects the body against pathogens and abnormal cells?
   A) nervous  
   B) endocrine  
   C) respiratory  
   D) integumentary  
   E) immune  
   Answer: E  
   Diff: 3  Page Ref: 6

26) What organ system functions in communication between cells of the body?
   A) nervous only  
   B) integumentary only  
   C) endocrine only  
   D) both nervous and endocrine  
   E) nervous, integumentary, and endocrine  
   Answer: D  
   Diff: 4  Page Ref: 6

27) What type of tissue separates the internal from the external environment?
   A) connective  
   B) epithelial  
   C) plasma membrane  
   D) nerve  
   E) reticular  
   Answer: B  
   Diff: 3  Page Ref: 4

28) The lumen of which of the following systems is part of the INTERNAL environment?
   A) gastrointestinal system  
   B) respiratory system  
   C) cardiovascular system  
   D) urinary system  
   E) gastrointestinal and urinary systems  
   Answer: C  
   Diff: 4  Page Ref: 6

29) What separates the internal environment of the body from the external environment?
   A) water  
   B) walls of blood vessels  
   C) membranes of blood cells  
   D) plasma membrane of all body cells  
   E) epithelium  
   Answer: E  
   Diff: 4  Page Ref: 6
30) Which of the following is NOT a part of the internal environment?
   A) blood  
   B) brain  
   C) heart  
   D) airways to lungs  
   E) endocrine glands
   Answer: D  
   Diff: 4  Page Ref: 7

31) The process whereby fluid from the bloodstream enters the tubules of the kidneys is called _______.
   A) filtration  
   B) excretion  
   C) secretion  
   D) absorption  
   E) reabsorption
   Answer: A  
   Diff: 5  Page Ref: 8

32) The process whereby fluid in the kidneys is transported from the tubules back into the bloodstream is called _______.
   A) filtration  
   B) excretion  
   C) secretion  
   D) absorption  
   E) reabsorption
   Answer: E  
   Diff: 5  Page Ref: 8

33) Referring to a membrane as "selectively permeable" describes its ability to _______.
   A) restrict the movement of particular molecules across a membrane  
   B) restrict only the movement of sodium across a membrane  
   C) provide a barrier that restricts the movement of all molecules across a membrane  
   D) provide a minimal barrier that allows almost any molecule to move across a membrane  
   E) restrict only the movement of potassium across the membrane
   Answer: A  
   Diff: 6  Page Ref: 8

34) Extracellular fluid is composed of _______.
   A) interstitial fluid and plasma  
   B) plasma and intracellular fluid  
   C) interstitial fluid only  
   D) plasma only  
   E) intracellular fluid only
   Answer: A  
   Diff: 4  Page Ref: 9
35) Total body water is composed of _______.
   A) intracellular fluid only
   B) extracellular fluid only
   C) intracellular and interstitial fluid
   D) intracellular and extracellular fluid
   E) plasma and intracellular fluid
Answer: D

36) Where is most of our total body water?
   A) in the lumen of the kidneys
   B) in the lumen of the gastrointestinal tract
   C) in blood
   D) inside cells
   E) surrounding the cells
Answer: D

37) Which of the following compartments contains most of the water found in the human body?
   A) intracellular fluid
   B) plasma
   C) interstitial fluid
   D) extracellular fluid
   E) lumen of the intestinal tract
Answer: A

38) What are the two extracellular fluid compartments of the body?
   A) intracellular fluid and interstitial fluid
   B) intracellular fluid and plasma
   C) intracellular fluid and blood
   D) interstitial fluid and plasma
   E) interstitial fluid and blood
Answer: D

39) The portion of body water outside of cells that bathes most cells of the body is called _______.
   A) intracellular fluid
   B) intercellular fluid
   C) interstitial fluid
   D) plasma
   E) extracellular fluid
Answer: C
40) The fluid compartment with a high sodium and protein concentration is called _______.
   A) interstitial fluid  
   B) plasma  
   C) intracellular fluid  
   D) extracellular fluid  
   E) intracellular and extracellular fluids

   Answer: B  
   Diff: 7  Page Ref: 9

41) Which of the following best describes intracellular fluid?
   A) rich in sodium, potassium, and chloride  
   B) rich in sodium and chloride  
   C) rich in proteins and chloride  
   D) rich in proteins and potassium  
   E) rich in potassium and chloride

   Answer: D  
   Diff: 4  Page Ref: 9

42) The fluid compartment with a high sodium concentration that contains only trace amounts of protein is called _______.
   A) interstitial fluid  
   B) plasma  
   C) intracellular fluid  
   D) extracellular fluid  
   E) intracellular and extracellular fluids

   Answer: A  
   Diff: 5  Page Ref: 9

43) Homeostasis is a term which describes the process whereby the body _______.
   A) affects the external environment  
   B) maintains a constant external environment  
   C) maintains a constant internal environment  
   D) maintains a variable internal environment  
   E) maintains a constant internal and external environment

   Answer: C  
   Diff: 3  Page Ref: 9

44) Which of the following statements about homeostasis is FALSE?
   A) The extracellular fluid is maintained in a state compatible for life.  
   B) The primary mechanism to maintain homeostasis is negative feedback.  
   C) The organ systems work together to maintain homeostasis.  
   D) The intracellular fluid makes up the majority of the body fluids.  
   E) Intrinsic control mechanisms maintain the extracellular fluid in a constant state.

   Answer: E  
   Diff: 4  Page Ref: 10
45) The maintenance of a stable internal environment compatible for life is called what?
   A) physiology 
   B) anatomy 
   C) biochemistry 
   D) microbiology 
   E) homeostasis 
   Answer: E 
   Diff: 2 Page Ref: 9

46) What is the primary mechanism for maintaining homeostasis?
   A) positive feedback 
   B) negative feedback 
   C) intrinsic control 
   D) extrinsic control 
   E) inherent control 
   Answer: B 
   Diff: 3 Page Ref: 9

47) Which of the following statements about homeostasis is FALSE?
   A) The extracellular fluid is maintained in a state compatible for life. 
   B) The primary mechanism to maintain homeostasis is positive feedback. 
   C) The organ systems work together to maintain homeostasis. 
   D) Illness can result if homeostasis is disrupted. 
   E) Homeostasis is the maintenance of the internal environment. 
   Answer: B 
   Diff: 4 Page Ref: 9

48) Changes in the external environment alter the __________, which is detected by the __________, and that information is sent to the integrator.
   A) set point : regulated variable 
   B) regulated variable : set point 
   C) error signal : regulated variable 
   D) sensor : regulated variable 
   E) regulated variable : sensor 
   Answer: E 
   Diff: 4 Page Ref: 10

49) The ________ determines the extent of the error signal in a feedback loop, in order to initiate the appropriate response.
   A) sensor 
   B) integrator 
   C) effector 
   D) set point 
   E) regulated variable 
   Answer: B 
   Diff: 6 Page Ref: 12
50) The process of maintaining the internal environment in a state compatible for life is called ________, and it occurs primarily through ________.
   A) intrinsic control : homeostasis
   B) negative feedback : intrinsic control
   C) homeostasis : negative feedback
   D) intrinsic control : negative feedback
   E) positive feedback : intrinsic control

   Answer: C  
   Diff: 4  Page Ref: 10

51) Which of the following is an example of negative feedback?
   A) If blood pressure increases above normal, baroreceptors in major arteries detect the change and send signals to the brain. Certain areas of the brain then send signals to the nerves that control the heart and blood vessels to make the heart beat slower and the blood vessels increase in diameter, which in turn reduce the blood pressure.
   B) During a blood clot, platelets release ADP, which stimulates platelet aggregation, causing platelets to release more ADP.
   C) During an infection, the body temperature set point is increased. The hypothalamus communicates to skeletal muscles to shiver and to blood vessels to decrease blood flow to the skin, causing a rise in body temperature.
   D) At the time of birth, uterine contractions push the baby toward the cervix. Receptors in the cervix detect the pressure caused by the baby and cause the release of a hormone called oxytocin. This hormone stimulates stronger uterine contractions, which push more on the baby, causing an increase in pressure and another increase in oxytocin. The cycle continues until the baby is delivered from the mother.
   E) Consumption of caffeine increases urine output, causing dehydration.

   Answer: A  
   Diff: 5  Page Ref: 10

52) Luteinizing hormone–mediated regulation of estrogen during ovulation in women is an example of ________.
   A) a negative feedback loop
   B) a positive feedback loop
   C) a quasi-negative feedback loop
   D) a quasi-positive feedback loop
   E) both a positive and negative feedback loop

   Answer: B  
   Diff: 5  Page Ref: 12

53) The positive feedback loop involving luteinizing hormone and estrogen is terminated by ________.
   A) nothing; the cycle cannot be terminated
   B) ovulation, which decreases estrogen secretion
   C) pregnancy
   D) birth
   E) ovulation, which directly inhibits luteinizing hormone secretion

   Answer: B  
   Diff: 5  Page Ref: 12
54) Which of the following is a normal blood glucose level?
   A) 100 mg/dL
   B) 100 gm/mL
   C) 50 mg/dL
   D) 50 mmolar
   E) 200 mmolar

   Answer: A
   Diff: 4   Page Ref: 15

55) What is the difference between diabetes mellitus and diabetes insipidus?
   A) one is a deficit in insulin activity, the other a deficit in ADH activity
   B) one is a lack of insulin secretion, the other a resistance to insulin
   C) one is a lack of ADH secretion, the other a resistance to ADH
   D) one causes increased fluid loss, the other causes increased thirst
   E) one causes diarrhea the other causes diuresis

   Answer: A
   Diff: 6   Page Ref: 14

56) What cells secrete insulin?
   A) I cells of the adrenal cortex
   B) G cells of the adrenal cortex
   C) alpha cells of the pancreas
   D) beta cells of the pancreas
   E) several cells located throughout the body

   Answer: D
   Diff: 5   Page Ref: 15

57) Approximately what percentage of people living in the United States suffer from diabetes mellitus?
   A) 0.1%
   B) 0.5%
   C) 1%
   D) 8%
   E) 15%

   Answer: D
   Diff: 4   Page Ref: 13

58) Who would be more prone to develop diabetes mellitus type II?
   A) thin, malnourished African American child
   B) obese white adult
   C) thin white adult
   D) obese hispanic adult
   E) obese hispanic child

   Answer: D
   Diff: 6   Page Ref: 13
59) What percentage of adults in the United States is obese?
   A) 10%
   B) 15%
   C) 20%
   D) 25%
   E) 30%
   Answer: E
   Diff: 4 Page Ref: 13

60) Type I diabetes mellitus is also known as ________.
   A) juvenile onset diabetes mellitus
   B) adult onset diabetes mellitus
   C) ketoacidosis
   D) non-insulin dependent diabetes mellitus
   E) diabetes insipidus
   Answer: A
   Diff: 4 Page Ref: 14

True/False Questions

1) Physiologists use research tools from different fields that include biochemistry and cell biology.
   Answer: TRUE
   Diff: 2 Page Ref: 2

2) Cardiac muscle is located in the heart.
   Answer: TRUE
   Diff: 2 Page Ref: 4

3) Connective tissue forms both endocrine and exocrine glands.
   Answer: FALSE
   Diff: 2 Page Ref: 4

4) Exocrine glands secrete hormones.
   Answer: FALSE
   Diff: 3 Page Ref: 4

5) The immune system protects the body from invading microorganisms.
   Answer: TRUE
   Diff: 3 Page Ref: 6

6) Most of the cells of the body are able to directly exchange materials with the external environment.
   Answer: FALSE
   Diff: 4 Page Ref: 7

7) The internal and external environments are separated by the selectively permeable membranes of epithelial cells.
   Answer: TRUE
   Diff: 3 Page Ref: 8
8) The most abundant substance in the body is carbon.
   Answer: FALSE
   Diff: 2   Page Ref: 9

9) Intracellular and extracellular fluid are of the same ion composition.
   Answer: FALSE
   Diff: 3   Page Ref: 9

10) The homeostatic mechanisms of the body are unlimited in their ability to respond to changes
    in the external environment.
    Answer: FALSE
    Diff: 4   Page Ref: 9

11) Blood glucose is a regulated variable.
    Answer: TRUE
    Diff: 2   Page Ref: 10

12) Effectors bring about a final response in a negative feedback loop.
    Answer: TRUE
    Diff: 3   Page Ref: 10

13) Positive feedback loops are impossible to stop once they have begun.
    Answer: FALSE
    Diff: 4   Page Ref: 12

14) All forms of diabetes involve a decrease in plasma levels of insulin.
    Answer: FALSE
    Diff: 4   Page Ref: 15

15) Diabetes mellitus requires insulin injections for maintenance.
    Answer: FALSE
    Diff: 4   Page Ref: 15

16) Once a person develops gestational diabetes, she will have diabetes for life?
    Answer: FALSE
    Diff: 6   Page Ref: 14

17) People with a body mass index (BMI) less than 25 are most prone to develop type 2 diabetes
    mellitus.
    Answer: FALSE
    Diff: 5   Page Ref: 13

18) Cases of diabetes mellitus are increasing throughout the world, not just in the United States.
    Answer: TRUE
    Diff: 6   Page Ref: 13

19) Obesity predisposes a person to develop type 1 diabetes mellitus.
    Answer: FALSE
    Diff: 4   Page Ref: 13
20) Diabetes mellitus causes hyperglycemia.
   Answer: TRUE
   Diff: 3   Page Ref: 15

Matching Questions

Match the following functions to the correct tissue type.

1) Specialized for exchange of material.
   Diff: 2   Page Ref: 4
   A) nervous tissue
   B) muscle tissue
   C) epithelial tissue
   D) connective tissue

2) Conducts signals via electrical impulses.
   Diff: 2   Page Ref: 3

3) Provides structural support.
   Diff: 2   Page Ref: 4

4) Contracts to generate a force.
   Diff: 2   Page Ref: 3

Answers: 1) C  2) A  3) D  4) B

Match the following descriptions with the correct function.

5) Elimination from the body.
   Diff: 3   Page Ref: 8
   A) absorption
   B) excretion
   C) filtration

6) Movement from the lumen of the gastrointestinal tract to blood.
   Diff: 3   Page Ref: 7

7) Movement from blood into the kidney tubules.
   Diff: 3   Page Ref: 8

Answers: 5) B  6) A  7) C
Match the organ to the organ system with which it belongs.

8) Adrenal gland
   Diff: 5 Page Ref: 6
   Answers: 8) A

9) Esophagus
   Diff: 4 Page Ref: 6
   Answers: 9) D

10) Blood vessels
    Diff: 3 Page Ref: 6
    Answers: 10) E

11) Bronchi
    Diff: 4 Page Ref: 6
    Answers: 11) C

12) Brain
    Diff: 2 Page Ref: 6
    Answers: 12) B

Essay Questions

1) Describe the four general groups of cells (tissues) that are found in the body, outlining the important characteristics of each group.
   Answer: Nervous tissue – Neurons are specialized for the transmission of information in the form of electrical signals. They typically possess a number of branches that function to receive or transmit those electrical signals. Some are even capable of detecting sensory information.
   Muscle tissue – Muscle cells are involved in force development and movement. They tend to be elongated in shape and can be under either voluntary or involuntary control. Epithelial tissue – Epithelial cells are arranged as a sheet-like layer of cells connected to a thin, non-cellular basement membrane. These cells are found in many shapes, sizes, and layer thicknesses. They are closely associated with their neighbors, providing a barrier separating body fluids from the external environment. Certain epithelial cells are specialized to transport specific molecules from one compartment to another.
   Connective tissue – This tissue encompasses many cell types including blood cells, bone cells, and many others. In a narrow sense, these cells provide physical support for other structures like tendons and ligaments. In a broader sense, the term connective tissue encompasses fluids like blood and lymph that “connect” parts of the body by providing an avenue for communication.
   Diff: 3 Page Ref: 3
2) Describe the essential role of water in the body and how it is compartmentalized throughout the body.

Answer: Water is the most abundant molecule in the human body. It acts as a solvent for a variety of solutes within the body. There are three compartments that comprise total body water (TBW). Extracellular fluid (1/3 of TBW), the fluid outside of cells, is composed of two compartments: 1) the fluid component of blood (plasma), which is composed mostly of sodium and protein, and 2) the fluid that bathes cells (interstitial), which is composed primarily of sodium with little protein present. The other component of TBW is intracellular fluid (2/3 of TBW). This fluid is present inside cells (cytoplasm). Intracellular fluid is relatively high in protein and potassium, and is separated from extracellular fluid by a cell membrane that is selectively permeable, allowing only specific ions through.

Diff: 4 Page Ref: 8

3) Describe the role of insulin in negative feedback control of blood glucose levels.

Answer: Increases in blood glucose levels stimulate insulin secretion from beta cells of the pancreas. Insulin acts on cells throughout the body increasing their uptake of glucose, thereby removing glucose from the blood. This causes blood glucose levels to return toward normal.

Diff: 5 Page Ref: 15

4) Compare the different forms of diabetes.

Answer: There are several types of diabetes, including diabetes mellitus type 1, diabetes mellitus type 2, diabetes insipidus, and gestational diabetes. Diabetes mellitus types 1 and 2 are associated with insufficient actions of insulin causing hyperglycemia and a number of other symptoms. Diabetes mellitus type 1 is caused by decreased secretion of insulin. Without sufficient insulin, cells do not uptake glucose to meet their metabolic needs. Liver and muscle cells do not uptake insulin to store energy for later needs. Thus hyperglycemia and fatigue are common symptoms. In diabetes mellitus type 2, beta cells of the pancreas secrete insulin, but effector cells do not respond to the insulin. Thus symptoms are similar to that of diabetes mellitus type 1. Diabetes insipidus is a disease affecting the release of antidiuretic hormone (ADH). ADH promotes water reabsorption from the kidneys, and in its absence (or a decrease in tissue responsiveness to it), excessive water is lost in the urine causing dehydration. Gestational diabetes develops in some pregnant women. It is similar to type 2 diabetes mellitus, with hormones of pregnancy thought to induce the insulin resistance. Gestational diabetes often reverses following delivery of the baby.

Diff: 5 Page Ref: 14

Short Answer Questions

1) The smallest living units, capable of carrying out its own basic life processes are ________.

Answer: cells

Diff: 2 Page Ref: 2

2) Cells that carry oxygen in the bloodstream are called ________.

Answer: erythrocytes

Diff: 5 Page Ref: 2
3) Name the types of tissue described below.

This tissue is specialized for transport and exchange of material.
This tissue is a major component of bone, ligaments, and blood.
This tissue is specialized for generating electrical signals.
This tissue is specialized to contract.
Answer: epithelial, connective, nervous, muscle
Diff: 4  Page Ref: 3

4) Name the two types of glands and describe their secretions.
Answer: Exocrine glands secrete their product into ducts that lead to an epithelial surface.
Endocrine glands secrete their product (hormones) into the bloodstream where the hormones travel throughout the body.
Diff: 4  Page Ref: 4

5) The specific structures that attach bone to bone are called ________.
Answer: ligaments
Diff: 5  Page Ref: 5

6) The layer of epithelial cells that coats the inside (lumen) of blood vessels is called the ________.
Answer: endothelium
Diff: 5  Page Ref: 4

7) The ________ is the interior compartment of a hollow organ or vessel.
Answer: lumen
Diff: 4  Page Ref: 4

8) What organ system(s) provides communication between the cells of the body?
Answer: nervous and endocrine
Diff: 5  Page Ref: 6

9) The process whereby enzymes are moved into the gastrointestinal tract to digest nutrients is called ________.
Answer: secretion
Diff: 5  Page Ref: 7

10) The process whereby fluid and ions that have not been removed by the kidneys exit the body as urine is referred to as ________.
Answer: excretion
Diff: 4  Page Ref: 8

11) The fluid (non-cellular) portion of blood is called ________.
Answer: plasma
Diff: 4  Page Ref: 9

12) The fluid compartment with a high protein and potassium concentration is called ________.
Answer: intracellular fluid
Diff: 4  Page Ref: 9
13) Most of the water in the body is found (inside cells / in blood / bathing cells).
   
   Answer: inside cells
   
   Diff: 4   Page Ref: 9

14) Define homeostasis.
   
   Answer: Homeostasis is the process whereby the body maintains the internal environment in a state compatible for life.
   
   Diff: 4   Page Ref: 9

15) Insulin is a hormone that regulates blood glucose levels. It is released when glucose levels increase above normal. Based on the concept of negative feedback, insulin (increases / decreases) blood glucose levels.
   
   Answer: decreases
   
   Diff: 5   Page Ref: 10

16) List the essential components of a feedback loop and describe their function.
   
   Answer: Sensor – detects the regulated variable
   
   Set point – value to which the regulated variable is compared by the integrator
   
   Integrator – determines the extent of the error signal in order to provide appropriate effector response
   
   Effector - that which can alter the regulated variable

   Diff: 5   Page Ref: 10

17) What cells secrete insulin and where are they located?
   
   Answer: beta cells located in the islets of Langerhans in the pancreas
   
   Diff: 6   Page Ref: 15

18) Insulin-dependent diabetes mellitus is also called ________.
   
   Answer: type 1 diabetes mellitus or juvenile-onset diabetes mellitus
   
   Diff: 4   Page Ref: 14

19) Body mass index is a measure of weight in kilograms relative to ________.
   
   Answer: height in meters (squared)
   
   Diff: 4   Page Ref: 13

20) What percentage of people in the United States have diabetes mellitus?
   
   Answer: 8
   
   Diff: 5   Page Ref: 13
Multiple Choice Questions

Using Figure 2.1, answer the following questions:

1) Which of the following nucleotide sequences accurately reflects the mRNA that would be produced from the double-stranded DNA pictured in Figure 2.1?
   A) TGTCTCAGCTTTG
   B) ACAGAGTGACAGAAC
   C) UGUCUCACUGUCUUG
   D) ACAGAGUGACAGAAC
   E) GTTCTGTCACTCTGT

Answer: C
Diff: 5 Page Ref: 26
2) Based upon the number of nucleotides, how many amino acids will be formed from the DNA strand shown in Figure 2.1?
   A) 2
   B) 3
   C) 5
   D) 7
   E) 50
Answer: C
Diff: 3 Page Ref: 42

3) In Figure 2.1, _______ between complementary bases hold the two strands of DNA together.
   A) hydrogen bonds
   B) disulfide bridges
   C) ionic bonds
   D) covalent bonds
   E) van der Waals forces
Answer: A
Diff: 3 Page Ref: 26

4) In Figure 2.1, _______ between phosphate and carbohydrate of the nucleotides hold the backbone of the DNA strands together.
   A) hydrogen bonds
   B) disulfide bridges
   C) ionic bonds
   D) covalent bonds
   E) van der Waals forces
Answer: D
Diff: 3 Page Ref: 26

5) Which of the following is NOT a monosaccharide?
   A) glucose
   B) fructose
   C) galactose
   D) deoxyribose
   E) lactose
Answer: E
Diff: 5 Page Ref: 20
6) What type of molecule is shown in the accompanying figure?

![Diagram of a disaccharide molecule]

A) monosaccharide  
B) disaccharide  
C) fatty acid  
D) phospholipid  
E) amino acid  

Answer: B  
Diff: 5  
Page Ref: 20

7) The presence of _______ chemical groups makes carbohydrates _______.

A) hydroxyl : polar  
B) hydroxyl : nonpolar  
C) amino : polar  
D) amino : acidic  
E) carboxyl : polar and acidic  

Answer: A  
Diff: 4  
Page Ref: 20

8) Which of the following molecules is a disaccharide?

A) glucose  
B) fructose  
C) lactose  
D) galactose  
E) glycogen  

Answer: C  
Diff: 3  
Page Ref: 20

9) Glycogen _______.

A) serves as a structural component of human cells  
B) is an important storage polysaccharide found in animal tissues  
C) forms the regulatory molecules known as enzymes  
D) helps to protect vital organs from damage  
E) contains the genetic information found in cells  

Answer: B  
Diff: 3  
Page Ref: 21
10) Glycogen is an example of a _______.
   A) fatty acid
   B) steroid
   C) polysaccharide
   D) nucleotide
   E) nucleic acid
   Answer: C
   Diff: 3  Page Ref: 21

11) _______ is a polysaccharide found in animal cells, whereas _______ is a polysaccharide found in plants that can be degraded by humans.
   A) Galactose : starch
   B) Glycogen : starch
   C) Glycogen : cellulose
   D) Lactose : starch
   E) Galactose : cellulose
   Answer: B
   Diff: 5  Page Ref: 21

12) Which of the following molecules will dissolve readily in water?
   A) NaCl
   B) cholesterol
   C) C₆H₁₄
   D) triglyceride
   E) fatty acid
   Answer: A
   Diff: 5  Page Ref: 31

13) Each of the following statements concerning hydrogen bonds is true except one. Identify the exception.
   A) Hydrogen bonds are strong attractive forces between hydrogen atoms and negatively charged atoms.
   B) Hydrogen bonds can occur within a single molecule.
   C) Hydrogen bonds can form between neighboring molecules.
   D) Hydrogen bonds are important forces for tertiary structure of proteins.
   E) Hydrogen bonds are responsible for many of the unique properties of water.
   Answer: A
   Diff: 6  Page Ref: 31

14) _______ are molecules that contain primarily carbons and hydrogens linked together by nonpolar covalent bonds.
   A) Lipids
   B) Carbohydrates
   C) Proteins
   D) Nucleotides
   E) Polysaccharides
   Answer: A
   Diff: 4  Page Ref: 21
15) ______ are molecules composed of a glycerol and three fatty acids.
   A) Phospholipids
   B) Saturated fatty acids
   C) Eicosanoids
   D) Steroids
   E) Triglycerides
   Answer: E
   Diff: 3   Page Ref: 21

16) A fatty acid that contains three double bonds in its carbon chain is said to be ______.
   A) saturated
   B) monounsaturated
   C) polyunsaturated
   D) hypersaturated
   E) polysaturated
   Answer: C
   Diff: 3   Page Ref: 22

17) ______ are molecules that form the core structure of cell membranes and micelles.
   A) Phospholipids
   B) Saturated fatty acids
   C) Triglycerides
   D) Steroids
   E) Eicosanoids
   Answer: A
   Diff: 3   Page Ref: 23

18) The amphipathic property of phospholipids can be described as ______.
   A) a nonpolar region facing the outside and a polar region facing the inside of a cell
   B) a single polar region that is miscible in aqueous solution
   C) a nonpolar region that dissolves in water and a polar region that face one another
   D) a polar region that dissolves in water and a nonpolar region that faces away from water
   E) a single nonpolar region that is not miscible in aqueous solution
   Answer: D
   Diff: 4   Page Ref: 24

19) ______ are modified fatty acids that function in intercellular communication and include prostaglandins and thromboxanes.
   A) Steroids
   B) Eicosanoids
   C) Saturated fatty acids
   D) Phospholipids
   E) Triglycerides
   Answer: B
   Diff: 3   Page Ref: 23
20) _______ act(s) as the precursor to steroid molecules, many of which function as hormones.
   A) Cholesterol
   B) Saturated fatty acids
   C) Unsaturated fatty acids
   D) Eicosanoids
   E) Phospholipids

Answer: A
Diff: 4    Page Ref: 23

21) Based on the following figure, what type of molecule is this?

   A) amino acid
   B) phospholipid
   C) steroid
   D) nucleotide
   E) fatty acid

Answer: C
Diff: 3    Page Ref: 24

22) _______ are molecules whose general structure includes a carboxyl group, an amine group, a hydrogen molecule, and a residual group.
   A) Lipids
   B) Nucleotides
   C) Proteins
   D) Amino acids
   E) Carbohydrates

Answer: D
Diff: 4    Page Ref: 24

23) Alpha-helixes and β-pleated sheets are examples of _______ structure of a protein.
   A) primary
   B) secondary
   C) tertiary
   D) quaternary
   E) pentanary

Answer: B
Diff: 3    Page Ref: 25
24) Formation of peptide bonds occurs by _______ reactions between a(n) _______ and a(n) _______.

   A) condensation: fatty acid: glycerol
   B) condensation: amino acid: amino acid
   C) hydrolysis: fatty acid: glycerol
   D) hydrolysis: amino acid: amino acid
   E) oxidation: glucose: glucose

   Answer: B
   Diff: 5   Page Ref: 25

25) What type of molecule is shown below?

   A) amino acid
   B) nucleotide
   C) carbohydrate
   D) protein
   E) steroid

   Answer: A
   Diff: 4   Page Ref: 24

26) Each amino acid differs from others in the _______.

   A) number of central carbon atoms
   B) size of the amino group
   C) number of carboxyl groups
   D) characteristic of the R group
   E) number of peptide bonds in the molecule

   Answer: D
   Diff: 4   Page Ref: 24

27) Hydrogen bonding between the amino hydrogen of one amino acid and the carboxyl oxygen of another is responsible for which of the following?

   A) Holding the two strands of DNA together by the Law of Complementary Base Pairing.
   B) Twisting the DNA into a helical structure.
   C) Primary protein structure.
   D) Secondary protein structure.
   E) Tertiary protein structure.

   Answer: D
   Diff: 5   Page Ref: 25
28) Secondary protein structure is the result of ________.
   A) hydrogen bonds
   B) ionic bonds
   C) van der Waals forces
   D) covalent bonds
   E) all of the above
   Answer: A
   Diff: 4    Page Ref: 25

29) The ________ structure of a protein is created by hydrogen bonds between the hydrogen atom on the amine group and the oxygen atom on the carboxyl group.
   A) primary
   B) secondary
   C) tertiary
   D) quaternary
   E) quintary
   Answer: B
   Diff: 4    Page Ref: 25

30) The ________ structure of a protein is formed between residual groups of the amino acid backbone by a number of different chemical interactions, dependent upon the nature of the residual groups interacting.
   A) primary
   B) secondary
   C) tertiary
   D) quaternary
   E) quintary
   Answer: C
   Diff: 5    Page Ref: 25

31) Which of the following is an example of a fibrous protein?
   A) growth hormone
   B) insulin
   C) hemoglobin
   D) Na⁺/K⁺ pumps
   E) collagen
   Answer: E
   Diff: 5    Page Ref: 25

32) ________ are molecules that are composed of one or more phosphate groups, a 5-carbon sugar, and a nitrogenous base.
   A) Lipids
   B) Phospholipids
   C) Nucleotides
   D) Amino acids
   E) Glycoproteins
   Answer: C
   Diff: 3    Page Ref: 27
33) Which of the following chemical groups are necessary components of a nucleotide?
   A) phosphate, peptide, and base
   B) carbohydrate, phosphate, and peptide
   C) phosphate, carbohydrate, and base
   D) peptide, phosphate, and carbohydrate
   E) carbohydrate, base, and peptide

   Answer: C
   Diff: 4 Page Ref: 27

34) Which of the following is an INCORRECT association between a molecule and its chemical property?
   A) monosaccharide : hydrophilic
   B) DNA : polymer of nucleotides
   C) fatty acid : amphipathic
   D) ATP : nucleotide
   E) steroid : derived from cholesterol

   Answer: C
   Diff: 6 Page Ref: 27

35) Which of the following is found in DNA but not RNA?
   A) deoxyribose only
   B) adenine only
   C) thymine only
   D) both adenine and thymine
   E) both thymine and deoxyribose

   Answer: E
   Diff: 4 Page Ref: 27

36) Which of the following molecules is a polymer?
   A) protein only
   B) glycogen only
   C) nucleic acid only
   D) both protein and nucleic acid
   E) protein, nucleic acid, and glycogen

   Answer: E
   Diff: 5 Page Ref: 27

37) Which of the following molecule types is NOT a polymer?
   A) protein
   B) fatty acid
   C) glycogen
   D) DNA
   E) RNA

   Answer: B
   Diff: 5 Page Ref: 27
38) Which of the following is NOT a base in RNA?
   A) adenine
   B) thymine
   C) uracil
   D) guanine
   E) cytosine

   Answer: B  
   Diff: 3  Page Ref: 27

39) Which of the following INCORRECTLY describes a polymer?
   A) Glycogen is a polymer of glucose.
   B) Starch is a polymer of glucose.
   C) ATP is a polymer of phosphates.
   D) DNA is a polymer of nucleotides.
   E) A protein is a polymer of amino acids.

   Answer: C  
   Diff: 5  Page Ref: 27

40) Which of the following is NOT a function of nucleotides?
   A) Nucleotides store the genetic code.
   B) Nucleotides are necessary for expression of the genetic code.
   C) Nucleotides provide most of the energy for cellular processes.
   D) Nucleotides provide electrons to the electron transport chain.
   E) Nucleotides provide substrates for the citric acid cycle.

   Answer: E  
   Diff: 7  Page Ref: 27

41) Which of the following properties is true for both DNA and RNA?
   A) double-stranded
   B) follows the law of complementary base pairing
   C) contains the sugar deoxyribose
   D) contains the base thymine
   E) contains the base uracil

   Answer: B  
   Diff: 4  Page Ref: 27

42) _________ is composed of nucleotide polymers with the phosphate of one nucleotide bound to the ribose sugar of another.
   A) Ribonucleic acid
   B) Deoxyribonucleic acid
   C) Guanosine monophosphate
   D) Adenosine diphosphate
   E) Flavin adenine dinucleotide

   Answer: A  
   Diff: 5  Page Ref: 27
43) The presence of _______ in the plasma membrane can increase the fluidity of the membrane.
   A) cholesterol
   B) integral membrane proteins
   C) peripheral membrane proteins
   D) glycoproteins
   E) phospholipids

Answer: A
Diff: 5    Page Ref: 30

44) Which of the following is NOT found in plasma membranes?
   A) proteins
   B) eicosanoids
   C) cholesterol
   D) carbohydrates
   E) phospholipids

Answer: B
Diff: 5    Page Ref: 30

45) Which of the following components of the plasma membrane forms ion channels?
   A) phospholipids
   B) cholesterol
   C) carbohydrates
   D) integral membrane proteins
   E) peripheral membrane proteins

Answer: D
Diff: 5    Page Ref: 31

46) Which of the following is NOT an integral membrane protein?
   A) carrier proteins for mediated transport
   B) connexons
   C) channels for ion diffusion across membranes
   D) occludins
   E) actin

Answer: E
Diff: 8    Page Ref: 31

47) Which of the following is an amphipathic molecule?
   A) peripheral membrane protein
   B) integral membrane protein
   C) glycogen
   D) glucose
   E) triglyceride

Answer: B
Diff: 5    Page Ref: 31
48) Which of the following is NOT an amphipathic molecule?
   A) phospholipid
   B) integral membrane protein
   C) glycolipid
   D) glucose
   E) connexon

Answer: D  
Diff: 6  Page Ref: 31

49) The layer of carbohydrates on the external surface of a cell is called what?
   A) inclusion
   B) glycoalcalyx
   C) glycogen
   D) glycolipid
   E) desmosome

Answer: B  
Diff: 2  Page Ref: 32

50) The ________ is the site of ribosomal RNA production.
   A) nucleus
   B) nucleolus
   C) mitochondria
   D) cytosol
   E) lysosome

Answer: B  
Diff: 4  Page Ref: 32

51) Where is the genetic code stored?
   A) brain
   B) heart
   C) nucleus
   D) Golgi apparatus
   E) cytoplasm

Answer: C  
Diff: 2  Page Ref: 32

52) Where inside a cell is glycogen stored?
   A) mitochondria
   B) lysosomes
   C) cytosol
   D) Golgi apparatus
   E) smooth endoplasmic reticulum

Answer: C  
Diff: 3  Page Ref: 32
53) Lipophobic molecules that are to be released by cells are stored in membrane-bound structures called ________.
   A) secretory vesicles
   B) inclusions
   C) the Golgi apparatus
   D) excretory vesicles
   E) the endoplasmic reticulum
Answer: A
Diff: 4 Page Ref: 32

54) Continuous with the outer portion of the nuclear pore, this membrane-bound structure functions in the synthesis of secretory proteins, integral membrane proteins, or proteins bound for other organelles.
   A) rough endoplasmic reticulum
   B) smooth endoplasmic reticulum
   C) mitochondria
   D) lysosome
   E) nucleolus
Answer: A
Diff: 3 Page Ref: 33

55) The ________ is the site where lipids, triglycerides, and steroids are synthesized, as well as where calcium is stored within the cell.
   A) rough endoplasmic reticulum
   B) smooth endoplasmic reticulum
   C) mitochondria
   D) lysosome
   E) nucleolus
Answer: B
Diff: 3 Page Ref: 33

56) Where are triglycerides synthesized?
   A) cytosol
   B) mitochondria
   C) rough endoplasmic reticulum
   D) smooth endoplasmic reticulum
   E) Golgi apparatus
Answer: D
Diff: 3 Page Ref: 33

57) What organelle packages and directs proteins to their proper destination?
   A) ribosomes
   B) smooth endoplasmic reticulum
   C) rough endoplasmic reticulum
   D) Golgi apparatus
   E) lysosomes
Answer: D
Diff: 3 Page Ref: 34

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58) Which of the following is NOT a property of smooth endoplasmic reticulum?
   A) steroid hormone synthesis  
   B) stores calcium  
   C) in liver cells, it contains detoxifying enzymes  
   D) forms transport vesicles to move proteins to the Golgi apparatus  
   E) contains the enzyme catalase
   Answer: E  
   Diff: 4  Page Ref: 33

59) Which of the following organelles is specialized for lipid and steroid synthesis?
   A) rough endoplasmic reticulum  
   B) smooth endoplasmic reticulum  
   C) mitochondria  
   D) lysosomes  
   E) peroxisomes
   Answer: B  
   Diff: 3  Page Ref: 33

60) Which of the following is an INCORRECT description of the function of the organelle?
   A) ATP synthesis occurs in the mitochondria.  
   B) Peptide hormone synthesis occurs in the rough endoplasmic reticulum.  
   C) Breakdown of phagocytosed debris occurs in the peroxisomes.  
   D) Packaging of secretory products into vesicles occurs in the Golgi apparatus.  
   E) Calcium is stored in the smooth endoplasmic reticulum.
   Answer: C  
   Diff: 5  Page Ref: 33

61) In the liver, detoxifying enzymes are localized in what organelle?
   A) lysosomes  
   B) peroxisomes  
   C) smooth endoplasmic reticulum  
   D) Golgi apparatus  
   E) mitochondria
   Answer: C  
   Diff: 5  Page Ref: 33

62) Which of the following statements is true?
   A) The compositions of the intracellular fluid and extracellular fluid are identical due to the 
      free movement of molecules across the cell membrane.  
   B) The nuclear envelope is continuous with the membrane of the endoplasmic reticulum.  
   C) The Golgi apparatus contains the enzyme catalase to break down the hydrogen peroxide 
      it produces when degrading oxygen–derived wastes.  
   D) Proteins to be secreted from the cell are synthesized in the mitochondrial matrix.  
   E) Ribosomes are composed of protein and lipid.
   Answer: B  
   Diff: 5  Page Ref: 33
63) What organelle synthesizes most of the ATP used by cells?
   A) lysosomes
   B) peroxisomes
   C) ribosomes
   D) mitochondria
   E) Golgi apparatus

   Answer: D
   Diff: 3  Page Ref: 35

64) _______ are membrane-bound organelles containing enzymes that degrade cellular and extracellular debris.
   A) Lysosomes
   B) Mitochondria
   C) Peroxisomes
   D) Ribosomes
   E) Vaults

   Answer: A
   Diff: 4  Page Ref: 35

65) _______ are membrane-bound organelles that contain enzymes like catalase, which catalyzes the breakdown of \( \text{H}_2\text{O}_2 \) to \( \text{H}_2\text{O} \) and \( \text{O}_2 \).
   A) Lysosomes
   B) Peroxisomes
   C) Ribosomes
   D) Mitochondria
   E) Vaults

   Answer: B
   Diff: 4  Page Ref: 35

66) Which of the following statements about ribosomes is FALSE?
   A) Ribosomes contain protein.
   B) Ribosomes contain ribosomal RNA.
   C) Ribosomes are the site of protein synthesis.
   D) Ribosomes can be located free in the cytosol.
   E) Ribosomes can be located in the Golgi apparatus.

   Answer: E
   Diff: 4  Page Ref: 36

67) Which of the organelles contains its own DNA?
   A) mitochondria
   B) lysosomes
   C) rough endoplasmic reticulum
   D) smooth endoplasmic reticulum
   E) Golgi apparatus

   Answer: A
   Diff: 4  Page Ref: 34

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68) Which of the following is NOT a function of the cytoskeleton?
   A) cellular movement  
   B) contraction  
   C) mechanical support  
   D) suspension of organelles  
   E) cellular metabolism  
   Answer: E  
   Diff: 4  Page Ref: 36

69) Which cytoskeletal proteins provide the structural support for microvilli?
   A) microfilaments  
   B) intermediate filaments  
   C) microtubules  
   D) centrioles  
   E) tight junctions  
   Answer: A  
   Diff: 4  Page Ref: 36

70) Keratin is an example of which type of cytoskeletal protein?
   A) microfilaments  
   B) intermediate filaments  
   C) microtubules  
   D) centrioles  
   E) tight junctions  
   Answer: B  
   Diff: 4  Page Ref: 36

71) Which of the following filaments is found in cilia and flagella?
   A) microfilaments only  
   B) intermediate filaments only  
   C) microtubules only  
   D) microfilaments and microtubules  
   E) microfilaments and intermediate filaments  
   Answer: C  
   Diff: 4  Page Ref: 36

72) Which microtubular proteins are responsible for the distribution of chromosomes during cell division?
   A) tubulin  
   B) spindle fibers  
   C) actin  
   D) myosin  
   E) keratin  
   Answer: B  
   Diff: 5  Page Ref: 36
73) The protein _______ is responsible for generating force as microtubular proteins slide past one another.
   A) tubulin  
   B) dynein  
   C) myosin  
   D) actin  
   E) keratin  
Answer: B  
Diff: 6  Page Ref: 36

74) _______ are proteins that fuse adjacent cells together to form a nearly impermeable barrier.
   A) Connexins  
   B) Cadherins  
   C) Syneins  
   D) Occludins  
   E) Tubulins  
Answer: D  
Diff: 6  Page Ref: 37

75) _______ are proteins attached to intermediate filaments in regions where cells are exposed to mechanical stresses.
   A) Connexins  
   B) Cadherins  
   C) Dyneins  
   D) Occludins  
   E) Tubulins  
Answer: B  
Diff: 6  Page Ref: 38

76) _______ are proteins that form channels between cells, allowing ions and small molecules to diffuse directly from one cell to the other.
   A) Connexins  
   B) Cadherins  
   C) Dyneins  
   D) Occludins  
   E) Tubulins  
Answer: A  
Diff: 6  Page Ref: 38

77) In some cases, signals originating within one cell can diffuse directly to a neighboring cell through _______.
   A) desmosomes  
   B) cadherins  
   C) gap junctions  
   D) tight junctions  
   E) occludins  
Answer: C  
Diff: 4  Page Ref: 38
78) What type of junction would you expect to find most commonly in the intestinal tract, where exchange across epithelium is common?

A) tight junctions  
B) loose junctions  
C) gap junctions  
D) I junctions  
E) desmosomes

Answer: A
Diff: 5 Page Ref: 38

79) Intercellular communication can occur through the binding of a chemical released from one cell to a specific ________ on another cell.

A) receptor  
B) organelle  
C) nucleus  
D) clathrin-coated vesicle  
E) phagosome

Answer: A
Diff: 3 Page Ref: 42

80) Which of the following does NOT describe a part of post-transcriptional processing?

A) capping of the 5’ end  
B) removal of the introns from the strand  
C) addition of a poly A tail at the 3’ end  
D) formation of bonds between a phosphate group and a sugar  
E) splicing of nucleic acid fragments

Answer: D
Diff: 6 Page Ref: 43

81) The process whereby a complementary mRNA is produced from a DNA template is called ________.

A) translation  
B) post-translational modification  
C) transcytosis  
D) transcription  
E) transoperon

Answer: D
Diff: 3 Page Ref: 42

82) During translation, ________ is synthesized in the ________.

A) DNA : nucleus  
B) RNA : nucleus  
C) protein : nucleus  
D) RNA : cytoplasm  
E) protein : cytoplasm

Answer: E
Diff: 5 Page Ref: 42
83) Based upon the triplet nature of a codon and the presence of four possible bases, how many possible amino acids might be coded for by mRNA?
   A) 8  
   B) 16  
   C) 32  
   D) 64  
   E) 128  

Answer: D
Diff: 4 Page Ref: 42

84) The initiator codon is composed of the sequence _______.
   A) CCG  
   B) CCC  
   C) UUG  
   D) AUG  
   E) AAC  

Answer: D
Diff: 5 Page Ref: 42

85) The initiator codon, that originates transcription, codes for the amino acid _______.
   A) proline  
   B) methionine  
   C) arginine  
   D) leucine  
   E) tyrosine  

Answer: B
Diff: 4 Page Ref: 42

86) What strand of mRNA would be transcribed from the following strand of DNA: AATG?
   A) TTUC  
   B) TTAC  
   C) UUGT  
   D) UUAC  
   E) GGUA  

Answer: D
Diff: 4 Page Ref: 42

87) Which of the following statements about the genetic code is true?
   A) A single gene contains only those nucleotides that code for a single protein.  
   B) Termination codons do not code for amino acids.  
   C) The tRNA anticodon is complementary to the mRNA codon, and therefore is ALWAYS identical to the DNA triplet word.  
   D) The promoter sequence is found on the antisense strand of DNA.  
   E) A single codon may code for more than one amino acid.  

Answer: B
Diff: 7 Page Ref: 42
88) The strand of DNA that gets transcribed to mRNA is called the _______.
   A) intron strand
   B) exon strand
   C) ribophorin
   D) sense strand
   E) promoter sequence

Answer: D
Diff: 4 Page Ref: 43

89) RNA polymerase binds to a _______ to initiate the process of _______.
   A) leader sequence : translation
   B) leader sequence : transcription
   C) gene : translation
   D) promoter sequence : transcription
   E) triplet : translation

Answer: D
Diff: 6 Page Ref: 43

90) During transcription, _______.
   A) DNA is synthesized from DNA in the nucleus
   B) RNA is synthesized from DNA in the nucleus
   C) RNA is synthesized from DNA in the cytoplasm
   D) protein is synthesized from RNA in the nucleus
   E) protein is synthesized from RNA in the cytoplasm

Answer: B
Diff: 5 Page Ref: 42

91) What is the portion of DNA that codes for a particular protein called?
   A) nucleotide
   B) gene
   C) triplet
   D) codon
   E) promoter sequence

Answer: B
Diff: 3 Page Ref: 42

92) Which of the following protects mRNA from degradation in the cytosol?
   A) introns
   B) exons
   C) poly A tail
   D) RNA CAP
   E) ubiquitin

Answer: C
Diff: 6 Page Ref: 44
93) What causes DNA to uncoil during transcription?
   A) binding of tRNA to the initiator codon
   B) binding of RNA polymerase to the promoter sequence
   C) binding of DNA polymerase to the leader sequence
   D) binding of helicase to the DNA
   E) binding of ubiquitin to the DNA

   Answer: B
   Diff: 5    Page Ref: 43

94) A mRNA codon is complementary to the DNA ________.
   A) leader sequence
   B) promoter sequence
   C) triplet
   D) gene
   E) anticodon

   Answer: C
   Diff: 3    Page Ref: 42

95) Which of the following statements about the genetic code is FALSE?
   A) mRNA is read 3 bases at a time, which are called codons.
   B) Each codon is specific for only one amino acid.
   C) Each amino acid is coded for by only one codon.
   D) There are 3 termination codons that do not code for amino acids.
   E) There is one initiator codon that codes for an amino acid.

   Answer: C
   Diff: 6    Page Ref: 42

96) Where does RNA polymerase bind to initiate transcription?
   A) hormone response element
   B) initiation factor
   C) promoter sequence
   D) leader sequence
   E) P subunit of the ribosome

   Answer: C
   Diff: 4    Page Ref: 43

97) A codon is ________.
   A) a series of three nucleotides found in mRNA that codes for an amino acid
   B) the sequence of amino acids within a protein
   C) a monosaccharide linked to a disaccharide
   D) a phosphate group attached to a base
   E) a membrane-bound protein that binds hormones

   Answer: A
   Diff: 3    Page Ref: 42
98) The promoter sequence of the gene is recognized by _______, which initiates transcription.
   A) DNA polymerase
   B) RNA polymerase
   C) tRNA polymerase
   D) helicase
   E) methioninase

   Answer: B
   Diff: 4  Page Ref: 43

99) What is the base sequence of the tRNA molecule that recognizes the complementary mRNA molecule?
   A) anticodon
   B) codon
   C) initiator codon
   D) P site
   E) A site

   Answer: A
   Diff: 4  Page Ref: 44

100) Following is a list of steps for initiating translation. Put them in the correct order.
     1. Binding of initiator tRNA to mRNA
     2. Binding of large ribosomal subunit to mRNA
     3. Binding of small ribosomal subunit to mRNA
     4. Binding of tRNA with 2nd amino acid to the A site
     5. Formation of covalent bond between methionine and second amino acid

       A) 1, 2, 3, 4, 5
       B) 1, 3, 2, 4, 5
       C) 2, 3, 1, 4, 5
       D) 3, 2, 1, 4, 5
       E) 3, 1, 2, 4, 5

   Answer: E
   Diff: 8  Page Ref: 44

101) What is special about the P site of a ribosome?
     A) It contains the enzyme that catalyzes formation of a peptide bond.
     B) It has the binding site for mRNA.
     C) It holds the tRNA with the most recent amino acid that has been added to the polypeptide chain.
     D) It holds the tRNA with the next amino acid to be added to the polypeptide chain.
     E) It causes the ribosome to attach to the endoplasmic reticulum.

   Answer: C
   Diff: 5  Page Ref: 45
102) Post-transcriptional processing adds a(n) _______ to the 5’ end of the mRNA molecule.
   A) poly A tail
   B) exon
   C) CAP
   D) intron
   E) poly C tail
   Answer: C
   Diff: 6   Page Ref: 45

103) Post-transcriptional processing adds a(n) _______ to the 3’ end of the mRNA molecule.
   A) poly A tail
   B) exon
   C) CAP
   D) intron
   E) poly C tail
   Answer: A
   Diff: 6   Page Ref: 45

104) Which of the following is NOT a function of the initiation factors associated with translation of protein from mRNA?
   A) They bind to the CAP group at the 5’ end.
   B) They form a complex with small ribosomal subunits.
   C) They form a complex with charged tRNA.
   D) They align the first tRNA with the P site on a ribosome.
   E) They trigger binding of the small ribosomal subunit to AUG.
   Answer: D
   Diff: 7   Page Ref: 45

105) The leader sequence of a protein that has just been translated functions to _______.
   A) end translation of a protein
   B) determine the destination of the protein
   C) initiate degradation of an incomplete protein
   D) stimulate translation of a protein
   E) keep the protein in the cytosol
   Answer: B
   Diff: 4   Page Ref: 46

106) Which of the following processes is NOT a post-translational modification that occurs in the endoplasmic reticulum or Golgi apparatus to make proteins functional?
   A) the removal of the leader sequence
   B) the cleavage of excess amino acids
   C) the addition of carbohydrates
   D) the addition of more amino acids
   E) the addition of lipids
   Answer: D
   Diff: 5   Page Ref: 47
107) Protein enters the Golgi apparatus _______.
   A) directly from the smooth endoplasmic reticulum
   B) from a transport vesicle that enters the trans face of the Golgi apparatus
   C) from a transport vesicle that enters the cis face of the Golgi apparatus
   D) after leaving the rough endoplasmic reticulum
   E) through a diffusive process
   Answer: C
   Diff: 4  Page Ref: 47

108) Which of the following is NOT a possible destination for proteins synthesized on ribosomes
    free in the cytosol?
    A) remains in cytosol
    B) peroxisome
    C) mitochondrion
    D) nucleus
    E) secreted from the cell
    Answer: E
   Diff: 5  Page Ref: 47

109) When proteins are synthesized by ribosomes on the rough endoplasmic reticulum, where does
     the translation begin?
     A) cytosol
     B) rough endoplasmic reticulum
     C) smooth endoplasmic reticulum
     D) nucleus
     E) Golgi apparatus
     Answer: A
   Diff: 5  Page Ref: 47

110) What organelle packages proteins into secretory vesicles?
    A) rough endoplasmic reticulum
    B) smooth endoplasmic reticulum
    C) Golgi apparatus
    D) lysosomes
    E) peroxisomes
    Answer: C
   Diff: 3  Page Ref: 47

111) What functions as a marker to direct proteins to proteasomes that degrade proteins?
    A) Protease
    B) Polymerase
    C) AUG
    D) Ubiquitin
    E) The A site
    Answer: D
   Diff: 6  Page Ref: 49
112) Ubiquitin tags proteins for what purpose?  
   A) protect from degradation by proteasomes  
   B) mark for degradation by proteasomes  
   C) for synthesis to continue on the rough endoplasmic reticulum  
   D) for the protein to be secreted by exocytosis  
   E) for the protein to enter the nucleus and alter transcription  

   Answer: B  
   Diff: 4    Page Ref: 49

113) What enzyme catalyzes the reaction whereby nucleotides are added to the polynucleotide chain during replication?  
   A) RNA polymerase  
   B) helicase  
   C) DNA polymerase  
   D) histone  
   E) chromatin  

   Answer: C  
   Diff: 3    Page Ref: 50

114) What is/are the beadlike structure(s) of chromosomes within the nucleus between periods of cell division?  
   A) Histones  
   B) Chromatin  
   C) Chromophore  
   D) Chromatid  
   E) Promoter  

   Answer: B  
   Diff: 4    Page Ref: 50

115) During replication, which strand of the new DNA is synthesized from the 5' to 3' strand of original DNA?  
   A) beginning strand  
   B) ending strand  
   C) leading strand  
   D) lagging strand  
   E) trailing strand  

   Answer: C  
   Diff: 6    Page Ref: 50

116) What are Okazaki fragments?  
   A) sections of RNA prior to splicing  
   B) termination codons  
   C) initiation factors  
   D) sections of DNA formed during replication  
   E) proteins that target other cell proteins for degradation  

   Answer: D  
   Diff: 6    Page Ref: 50
117) During what phase of the cell cycle is the cell carrying out its normal activity and NOT involved directly in cell division?
   A) G0
   B) G1
   C) G2
   D) S
   E) mitosis
   Answer: A
   Diff: 4 Page Ref: 51

118) During what phase of the cell cycle does cellular replication of DNA occur?
   A) G0
   B) G1
   C) G2
   D) S
   E) mitosis
   Answer: D
   Diff: 4 Page Ref: 51

119) During what phase of the cell cycle does rapid protein synthesis occur as the cell grows to double its size.
   A) G0
   B) G1
   C) G2
   D) S
   E) mitosis
   Answer: C
   Diff: 4 Page Ref: 51

120) Which of the following is NOT a phase of mitosis?
   A) meiosis
   B) prophase
   C) metaphase
   D) telophase
   E) anaphase
   Answer: A
   Diff: 3 Page Ref: 51

121) During what phase of cell division do chromosomes align along the midline?
   A) prophase
   B) interphase
   C) telophase
   D) anaphase
   E) metaphase
   Answer: E
   Diff: 3 Page Ref: 51
122) During what phase of cell division do two new nuclear envelopes begin to redevelop?
   A) prophase
   B) interphase
   C) telophase
   D) anaphase
   E) metaphase
   Answer: C
   Diff: 3  Page Ref: 51

123) What links sister chromatids together?
   A) histones
   B) chromatins
   C) centromeres
   D) dyneins
   E) actins
   Answer: C
   Diff: 4  Page Ref: 51

True/False Questions

1) Sucrose is a disaccharide composed of a glucose and a lactose molecule.
   Answer: FALSE
   Diff: 4  Page Ref: 20

2) Disulfide bridges contribute to the tertiary structure of proteins by covalent bonds between the sulfhydryl groups on two cysteine amino acids.
   Answer: TRUE
   Diff: 4  Page Ref: 24

3) Cholesterol is the precursor molecule for all steroids in the body.
   Answer: TRUE
   Diff: 4  Page Ref: 23

4) Glycoproteins have a glycogen molecule covalently bound to a protein.
   Answer: FALSE
   Diff: 4  Page Ref: 30

5) Cyclic nucleotides form ring structures due to the covalent bonding between an oxygen of the phosphate group and a carbon of the carbohydrate.
   Answer: TRUE
   Diff: 7  Page Ref: 26

6) Thymine is a pyrimidine.
   Answer: TRUE
   Diff: 3  Page Ref: 26

7) Guanine and cytosine are held together by two hydrogen bonds.
   Answer: FALSE
   Diff: 4  Page Ref: 26
8) Inclusions are intracellular stores of glycogen or triglycerides.
   Answer: TRUE
   Diff: 4   Page Ref: 32

9) The innermost compartment of a mitochondrion is called the matrix.
   Answer: TRUE
   Diff: 3   Page Ref: 35

10) Vaults direct the development of the mitotic spindle during cell division.
    Answer: FALSE
    Diff: 3   Page Ref: 36

11) The cytoskeleton suspends the organelles within the cytoplasm.
    Answer: TRUE
    Diff: 3   Page Ref: 37

12) Movement between cells in an epithelium is called transepithelial transport.
    Answer: FALSE
    Diff: 5   Page Ref: 39

13) Anabolism describes the breakdown of large molecules to smaller molecules.
    Answer: FALSE
    Diff: 3   Page Ref: 40

14) Every adenine nucleotide of DNA will be transcribed into a thymine on the mRNA.
    Answer: FALSE
    Diff: 3   Page Ref: 42

15) The exon is cut from the original mRNA sequence, leaving the intron as the portion of mRNA that leaves the nucleus to be translated into a protein.
    Answer: FALSE
    Diff: 4   Page Ref: 43

16) The mRNA codon UUU codes for the amino acid phenylalanine. Therefore, no other codon can code for phenylalanine.
    Answer: FALSE
    Diff: 4   Page Ref: 42

17) Each strand of mRNA is translated by one ribosome at a time.
    Answer: FALSE
    Diff: 5   Page Ref: 46

18) The Golgi apparatus sorts and packages proteins into vesicles targeted for their final destination.
    Answer: TRUE
    Diff: 3   Page Ref: 47

19) The anticodon is complementary to the triplet coding for a particular amino acid.
    Answer: FALSE
    Diff: 5   Page Ref: 45
20) The hormone insulin is a peptide hormone consisting of two polypeptides held together by disulfide bridges.
   Answer: TRUE
   Diff: 5 Page Ref: 47

21) The semiconservative nature of the replication of DNA means that a new strand is coupled to an old strand.
   Answer: TRUE
   Diff: 3 Page Ref: 50

22) When insulin is first translated by ribosomes, the initial inactive polypeptide that is formed is called preinsulin.
   Answer: FALSE
   Diff: 3 Page Ref: 47

23) Bonding between Okazaki fragments forms the lagging strand of DNA.
   Answer: TRUE
   Diff: 4 Page Ref: 50

24) Helicase catalyzes the uncoiling of DNA during transcription.
   Answer: FALSE
   Diff: 4 Page Ref: 50

25) Proteases break peptide bonds.
   Answer: TRUE
   Diff: 4 Page Ref: 49

26) Microtubules are dynamic structures in that they may form and disassemble repeatedly in a cell.
   Answer: TRUE
   Diff: 3 Page Ref: 38

27) The mitotic spindle forms from the centrosome during cell division.
   Answer: FALSE
   Diff: 5 Page Ref: 36
Matching Questions

Match the following descriptions to the correct level of protein structure.

1) Applies to proteins containing more than one polypeptide chain.  
   Diff: 4 Page Ref: 24  
   A) quaternary  
   B) secondary  
   C) tertiary  
   D) primary

2) The sequence and number of amino acids in the polypeptide chain.  
   Diff: 4 Page Ref: 24  
   A) quaternary  
   B) secondary  
   C) tertiary  
   D) primary

3) Formed by chemical interactions between R groups within the same polypeptide chain.  
   Diff: 4 Page Ref: 24  
   A) quaternary  
   B) secondary  
   C) tertiary  
   D) primary

4) Formed by hydrogen bonds between the amino hydrogen and carboxyl oxygen of amino acids within the same polypeptide chain.  
   Diff: 4 Page Ref: 24  
   A) quaternary  
   B) secondary  
   C) tertiary  
   D) primary

Answers: 1) A 2) D 3) C 4) B

Match the following descriptions with the correct junction type.

5) Intermediate filaments penetrate the membranes between two cells at the site of protein plaques forming strong linkage between the two cells.  
   Diff: 5 Page Ref: 24  
   A) desmosomes  
   B) gap junctions  
   C) tight junctions

6) These junctions are found in epithelial tissue where they prevent paracellular movement of molecules.  
   Diff: 5 Page Ref: 23  
   A) desmosomes  
   B) gap junctions  
   C) tight junctions

7) These junctions allow the passage of small molecules and ions from the cytosol of one cell to that of a neighboring cell.  
   Diff: 4 Page Ref: 23  
   A) desmosomes  
   B) gap junctions  
   C) tight junctions
Answers: 5) A 6) C 7) B

Match the following descriptions with the correct organelle.

8) Proteins are packaged into secretory vesicles.
   Diff: 4 Page Ref: 34
   A) smooth endoplasmic reticulum
   B) peroxisomes
   C) mitochondria
   D) lysosomes
   E) Golgi apparatus

9) Proteins are packaged into transport vesicles.
   Diff: 5 Page Ref: 35

10) The enzyme catalase is located here.
    Diff: 3 Page Ref: 36

11) Endocytotic vesicles fuse with this organelle.
    Diff: 4 Page Ref: 36

12) Most ATP in cells is produced here.
    Diff: 3 Page Ref: 34

13) Lipids are synthesized here.
    Diff: 4 Page Ref: 33


Match the following junctional proteins with the correct junction type.

14) Cadherins.
    Diff: 4 Page Ref: 40
    A) tight junctions
    B) gap junctions
    C) desmosomes

15) Connexons.
    Diff: 4 Page Ref: 40

16) Occludins.
    Diff: 4 Page Ref: 39

Answers: 14) C 15) B 16) A
Essay Questions

1) Carbohydrates and lipids are important biomolecules that store energy for the body to use later. Describe the structures and properties of carbohydrates and lipids, including the different forms of these biomolecules that are present within the body.

Answer: Carbohydrates have the general structure of \( C_nH_{2n}O_n \). They are polar molecules that readily dissolve in water. They are described based on their size as mono, di, and polysaccharides. Monosaccharides are simple sugars composed of six carbons, including glucose, fructose, and galactose, or five carbons, as with ribose and deoxyribose. Disaccharides are combinations of simple sugars covalently bound together, as with sucrose (glucose and fructose) and lactose (glucose and galactose). Polysaccharides are formed by many simple sugars bound together covalently, including glycogen and starch.

Lipids are a diverse group of molecules primarily containing carbons and hydrogens bound by nonpolar covalent bonds. Some contain oxygen, while others contain phosphate groups that polarize the molecule. Triglycerides are a form of lipid typically referred to as a fat composed of one glycerol with three fatty acids bound to it. Fatty acids are long carbon chain molecules with a carboxyl group at the end. Saturated fatty acids have no double bonds between the carbons, whereas unsaturated fatty acids have at least one (monounsaturated) or more (polyunsaturated) double bonds between carbons on the fatty acid. Triglycerides and fatty acids are both nonpolar and do not readily dissolve in water. Phospholipids are similar to triglycerides except one of the fatty acids attached to glycerol is replaced with a phosphate group. Therefore, the molecule is amphipathic with a polar (phosphate) and nonpolar (fatty acids) region. Eicosanoids are fatty acid derivatives that function in cellular communication. Finally, steroids are produced from the precursor cholesterol and act as hormones to communicate between cells.

Diff: 7    Page Ref: 20

2) Define and describe the structure of proteins, including the forces that determine the three-dimensional structure of these molecules.

Answer: Proteins are chains of amino acids bound by peptide bonds formed by the condensation reaction of the amine group on one amino acid with the carboxyl group on the other amino acid. The difference between peptides and proteins is the number of amino acids; peptides are composed of less than 50 amino acids, whereas proteins have more than 50. Once formed, there are many chemical interactions involved in the creation of this three-dimensional structure that can be described at different levels. Primary structure refers to the sequence of amino acids that comprise a particular peptide or protein. Secondary structure involves the folding of that primary structure, produced by hydrogen bonds between amine groups with the oxygen on the carboxyl group of another amino acid. This forms proteins into \( \alpha \)-helices and \( \beta \)-pleated sheets. Tertiary structure is formed by the interaction between residual groups (R groups) on particular amino acids. Hydrogen bonds can form between polar R groups. Ionic bonds can form between ionized or charged R groups. Van der Waals forces are an electrical attraction between the electron of one molecule with the neutron of another, whereas covalent bonds can form disulfide bridges between sulfhydryl groups on cysteine residues. Quaternary structure exists only in proteins with more than one polypeptide chain, like hemoglobin, which contains four separate polypeptide chains.

Diff: 6    Page Ref: 24
3) Describe the structure and function of nucleotides and nucleic acids.

Answer: Nucleotides are composed of one or more phosphate groups, a five-carbon sugar (ribose or deoxyribose), and a nitrogenous base. The nitrogenous bases in nucleotides can be from one of two classes: purines (a double carbon–nitrogen ring for adenine and guanine) or pyrimidines (a single carbon–nitrogen ring for cytosine, thymine, and uracil). Nucleotides can function in the exchange of cellular energy in molecules like adenosine triphosphate (ATP), nicotinamide adenine dinucleotide (NAD+) and flavin adenine dinucleotide (FAD). Cyclic nucleotides function as intracellular second messengers, like cyclic guanosine monophosphate (cGMP) and cyclic adenine monophosphate (cAMP). Nucleotide polymers function in the storage of genetic information, like deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). The polymeric strands of DNA and RNA are identified by the 3’ and 5’ end, with the 3’ being the carboxyl end (from the carbohydrate) and the 5’ end containing the phosphate group. The Law of Complementary Base Pairing ensures that double-stranded DNA will have matching information on both strands. Cytosine is always paired with guanine, whereas adenine is always paired with thymine. In RNA, the thymine is replaced with uracil. DNA stores the genetic code whereas RNA is necessary for expression of the code.

Diff: 8  Page Ref: 26

4) The membrane of a cell is an important structure that isolates the cell’s cytosol from the external environment. The components of membranes are important determinants of their function. What are the components of a membrane and how do those components function?

Answer: Cell membranes are composed of phospholipids, cholesterol, integral proteins, peripheral proteins, and carbohydrates. Phospholipids are the major constituent of membranes. They are amphipathic molecules with polar (hydrophilic) and nonpolar (hydrophobic) regions. The phospholipids form a bilayer with the hydrophilic region exposed to the outside and inside of the cell, and the nonpolar region associated with itself within the core of the phospholipid bilayer. As a consequence, the membrane is a fluid structure with no strong bonds between its components. Cholesterol can also be present within the membrane, which acts to interfere with hydrophobic interactions within the membrane, thereby increasing membrane fluidity. Integral membrane proteins are intimately associated with the membrane and cannot be easily removed. Many are transmembrane proteins whose amino acid chain passes through the lipid bilayer multiple times. These transmembrane proteins can function as ion channels and transporters to move ions across the membrane. Other integral membrane proteins are located on the cytosolic or interstitial side of the membrane. Peripheral membrane proteins are more loosely associated with the membranes and, therefore, can be easily removed. Most are located on the cytosolic side of the membrane and can be associated with the cytoskeleton. Carbohydrates are located on the extracellular side of the membrane and can act as a protective layer (glycocalyx) or be involved in cell recognition.

Diff: 6  Page Ref: 29
5) List the membranous organelles that are present within the cell and describe their function.

Answer: The endoplasmic reticulum is composed of two structures that are smooth and rough in character. The rough portion contains ribosomes that are involved in the translation of proteins. Those proteins can be secreted from the cell (hormones), incorporated into the cell membrane (receptors and ion channels), or incorporated into lysosomes. The smooth portion of the endoplasmic reticulum is the site of lipid synthesis and the storage of calcium. The Golgi apparatus is closely associated with the endoplasmic reticulum, processing molecules that were synthesized in the endoplasmic reticulum and packaging them into vesicles for delivery to their site of action. Mitochondria are structures that contain both an inner and outer membrane. The innermost compartment contains the enzymes of the Krebs cycle. The inner membrane contains the components of the electron transport chain. The lysosome is a membrane-bound vesicle that contains lytic enzymes, which can degrade debris (intra or extracellular). Old organelles can be degraded in this manner. Peroxisomes are vesicles, usually smaller than lysosomes, which contain enzymes that degrade amino acids and fatty acids. A byproduct of this degradation is hydrogen peroxide, which is toxic to cells. However, they also contain catalase, an enzyme that degrades hydrogen peroxide.

Diff: 6  Page Ref: 32

6) All of the organelles present within a cell are not bound by membranes. Describe the non-membrane-bound organelles that are found in cells.

Answer: Ribosomes are dense granules composed of rRNA and protein, some of which are associated with the rough endoplasmic reticulum. These structures play an important role in protein synthesis. The ribosomes that are free within the cytosol synthesize proteins that remain in the cytosol, or can enter the mitochondria, the nucleus, or the peroxisome. Proteins synthesized within the rough endoplasmic reticulum will cross the membrane (be secreted) or become associated with membranes, such as a plasma membrane or an organelle. The other non-membranous structures of the cell are vaults. These recently discovered organelles are barrel-shaped and three times larger than ribosomes, but their function is not yet clearly understood. They may be involved in the transport of molecules between the nucleus and cytoplasm. They have received considerable attention of late for their role in the development of resistance to chemotherapies.

Diff: 6  Page Ref: 35

7) Describe the three types of proteins that comprise the cytoskeleton.

Answer: Microfilaments are the smallest of the cytoskeletal proteins. The functions of microfilaments, such as actin, include contraction, amoeboidlike movement of cells, and separation of the cytoplasm during cell division. Other microfilaments provide the structural support for the microvilli of cells within the small intestines and hair cells of the cochlea. Intermediate filaments tend to be stronger and more stable than microfilaments, and include proteins like keratin (located in the skin) and myosin. The largest of the cytoskeletal proteins are microtubules, which are composed of proteins called tubulin. Microtubules form the spindle fibers that are involved in the distribution of chromosomes during cell division. Microtubules are also the primary component of cilia and flagella—hair-like protrusions involved in motility. Cilia are composed of ten microtubules connected by the protein dynein that generate the force necessary to cause the microtubules to slide past one another, thereby moving the cilia. Flagella are similar in structure, except they are longer than cilia.

Diff: 7  Page Ref: 37

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8) In order for tissues to maintain their structure and function, there must be some way for cells to adhere to their neighbors. Describe the adhesion proteins that function in coupling one cell to the next.

Answer: Tight junctions are composed of integral membrane proteins called occludins that fuse neighboring cells, creating an impermeable barrier. Because of this barrier, most polar solutes must pass through the cell itself by transepithelial transport, rather than by moving between cells (paracellular transport). These tight junctions are commonly found between epithelial cells that line hollow organs in order to maintain separation between fluid compartments. The extent to which fluid compartments are separated is determined by the expression of occludin proteins. Desmosomes are strong filamentous junctions that provide the structural support for cell attachment. Proteins called cadherins are involved in creating these connections between cells. Gap junctions are protein channels formed by connexin proteins. Gap junctions allow for communication between neighboring cells. Molecules, some relatively large (cAMP), can diffuse from one cell to the next when these channels are open.

Diff: 6  Page Ref: 39

9) Describe the process of gene transcription, including how that process is regulated.

Answer: The section of DNA that contains a gene is identified by the promoter that is upstream from the gene. There is a specific promoter sequence that is recognized by an RNA polymerase causing that enzyme to bind and uncoil the DNA. Free nucleotides align with the sense strand of DNA based upon the Law of Complementary Base Pairing. The RNA polymerase will catalyze the formation of bonds between the free nucleotides, thereby forming a single-stranded mRNA. As it is being synthesized, segments of the mRNA called introns are spliced from the mRNA strand until all that is left are the exons, which are joined together. A CAP is added to the 5' end, which is necessary for the initiation of translation. At the same time, many adenine molecules (the poly A tail) are added to the other end (the 3' region) of the mRNA molecule, protecting the mRNA from degradation once it is in the cytosol. The regulation of mRNA concentration in the cytosol can occur through a number of mechanisms. The mRNA can be bound to a protein, thereby inactivating that mRNA. In addition, both stability and synthesis rates of mRNA are an important determinant of the amount of mRNA coding for a particular protein that is present. This process of transcription can be regulated by DNA binding proteins, whose binding to the promoter region of the gene can either enhance or inhibit binding of the RNA polymerase to the gene, thereby altering expression of the gene.

Diff: 8  Page Ref: 44
10) In general, describe the process whereby mRNA that has exited the nucleus is used to synthesize a functional protein.

Answer: mRNA is read in triplets, from the initiator codon (AUG), which codes for the amino acid methionine, to a termination codon. Translation is started by initiation factors that bind to the CAP group on the mRNA, while other factors form a complex with small ribosomal subunits and a charged tRNA (containing an amino acid). The tRNA with an anticodon will bind to the codon on the mRNA by the Law of Complementary Base Pairs. The large ribosomal subunit then binds, causing initiation factors to dissociate, thereby aligning the first tRNA with the P site of the ribosome. A second charged tRNA with the appropriate anticodon will attach itself to the A site on the ribosome. An enzyme within the ribosome then catalyzes the formation of a peptide bond between amino acids, and the first tRNA will be released from the amino acid. The ribosome will then move three bases down to the next codon. As the first tRNA leaves the P site, the second tRNA will move from the A to the P site. Then, a new charged tRNA will bind to the A site; the tRNA with the anticodon that matches the mRNA. This process will continue until the termination codon is reached. The leader sequence will determine whether the protein will remain in the cytosol or attach to the endoplasmic reticulum. Post-translational modification is required in order to make the protein functional, and this process can occur anywhere from the rough endoplasmic reticulum to the Golgi apparatus. The leader sequence must first be cleaved as well as any other excess amino acids that are present on the protein. Thereafter, other molecules can be added to proteins, like carbohydrates (glycoprotein), or lipids (lipoproteins), in order to make the protein functional.

Diff: 9 Page Ref: 45

Short Answer Questions

Using Figure 2.2, answer the following questions:

1) Identify the organelle referred to as A in the picture of the cell above and give the function of that organelle.

Answer: rough endoplasmic reticulum—synthesis of proteins to be packaged into vesicles

Diff: 5 Page Ref: 33
2) Identify the organelle referred to as B in the picture of the cell above and give the function of that organelle.
   Answer: nucleus—contains the cell’s DNA
   Diff: 5    Page Ref: 32

3) Identify the organelle referred to as C in the picture of the cell above and give the function of that organelle.
   Answer: nucleolus—site within the nucleus for the synthesis of rRNA
   Diff: 5    Page Ref: 32

4) Identify the organelle referred to as D in the picture of the cell above and give the function of that organelle.
   Answer: mitochondria—membrane-bound organelle that contains the enzymes of the Krebs cycle and the electron transport chain and is, therefore, involved in the production of cellular energy in the form of ATP
   Diff: 5    Page Ref: 34

5) Identify the organelle referred to as E in the picture of the cell above and give the function of that organelle.
   Answer: smooth endoplasmic reticulum—site of lipid synthesis and storage of calcium
   Diff: 5    Page Ref: 33

6) Identify the organelle referred to as F in the picture of the cell above and give the function of that organelle.
   Answer: Golgi apparatus—processes peptides produced within the rough endoplasmic reticulum, packages them in vesicles, and directs them to their ultimate location
   Diff: 5    Page Ref: 34

7) Describe the makeup of a triglyceride.
   Answer: a glycerol with 3 fatty acids attached
   Diff: 4    Page Ref: 21

8) Fatty acids are a major component of ________, which are our storage form of lipids and ________, which form the basic structure of cell membranes.
   Answer: triglycerides : phospholipids
   Diff: 4    Page Ref: 21
9) What molecule is shown in the figure below?

Answer: glycogen
Diff: 6 Page Ref: 20

10) Identify the structure below. What type of molecule makes up this structure?

Answer: Structure is a micelle. It is composed of phospholipids.
Diff: 5 Page Ref: 23

11) What two structural characteristics of proteins are formed by hydrogen bonds between the carboxyl O and the amino H of amino acids within the same protein?

Answer: α-helices : β-pleated sheets
Diff: 4 Page Ref: 25

12) What spherical structures are involved in the transport of nonpolar molecules through the aqueous environment and are composed of a phospholipid monolayer?

Answer: micelles
Diff: 5 Page Ref: 23

13) Name the three components of a nucleotide.

Answer: 5-carbon carbohydrate, phosphate, base (purine or pyrimidine)
Diff: 5 Page Ref: 26

14) Name the five bases found in nucleic acids, and state whether each is a purine or a pyrimidine.

Answer: Pyrimidines = cytosine, thymine, and uracil
Purines = adenine and guanosine
Diff: 8 Page Ref: 26
15) Name the two five-carbon sugar molecules that are found in nucleotides.
   Answer: ribose, deoxyribose
   Diff: 5  Page Ref: 26

16) What type of integral membrane protein spans the membrane repeatedly, thereby allowing portions of the protein to face the cytosol while other portions of the protein face the extracellular fluid?
   Answer: transmembrane protein
   Diff: 5  Page Ref: 32

17) What structure separates the nucleus from the cytosol?
   Answer: nuclear envelope
   Diff: 4  Page Ref: 32

18) Through what structure in the nuclear envelope can mRNA pass through to get into the cytosol?
   Answer: nuclear pore
   Diff: 4  Page Ref: 32

19) What are masses in the cytosol of cells that contain glycogen called?
   Answer: inclusions
   Diff: 5  Page Ref: 32

20) Molecules that are to be released from the cell can be stored in ________ vesicles.
   Answer: secretory
   Diff: 4  Page Ref: 32

21) The membrane of the rough endoplasmic reticulum is continuous with what other membrane(s)?
   Answer: smooth endoplasmic reticulum and nuclear envelope
   Diff: 4  Page Ref: 33

22) What is the innermost chamber of a mitochondrion called?
   Answer: mitochondrial matrix
   Diff: 4  Page Ref: 35

23) Components of the electron transport chain are found in what region of a mitochondrion?
   Answer: inner mitochondrial membrane
   Diff: 4  Page Ref: 34

24) What organelle contains catalase?
   Answer: peroxisomes
   Diff: 4  Page Ref: 35

25) What two types of molecules make up ribosomes?
   Answer: rRNA : proteins
   Diff: 5  Page Ref: 36
26) Myosin is a type of (microfilament / intermediate filament / microtubule).
   Answer: intermediate filament
   Diff: 4 Page Ref: 38

27) Certain epithelial cells have a decided polarity where the ______ membrane faces the lumen of a hollow tube, whereas the ______ membrane faces the extracellular fluid.
   Answer: apical : basolateral
   Diff: 5 Page Ref: 39

28) The CAP region of mRNA is necessary for (initiation / termination) of translation.
   Answer: initiation
   Diff: 5 Page Ref: 43

29) Name the two sites on the ribosome where tRNA will bind.
   Answer: A and P sites
   Diff: 5 Page Ref: 44

30) What structural component of mRNA functions to stabilize mRNA, thereby preventing its degradation in the cytoplasm?
   Answer: poly A tail
   Diff: 6 Page Ref: 43

31) Proteins tagged with the polypeptide ______ are targeted for degradation by a protein complex called a ______.
   Answer: ubiquitin : proteasome
   Diff: 6 Page Ref: 49

32) This enzyme is involved in producing the exact copy of DNA required for cell replication.
   Answer: DNA polymerase
   Diff: 5 Page Ref: 50

33) Within the nucleus, chromosomes are coiled around these proteins.
   Answer: histones
   Diff: 6 Page Ref: 50

34) List the five phases of mitosis.
   Answer: prophase, prometaphase, metaphase, anaphase, telophase
   Diff: 5 Page Ref: 51
Chapter 3  Cell Metabolism

Multiple Choice Questions

1) In the chemical equation $A + B \Leftrightarrow C + D$, which of the chemicals would be termed the reactant(s)?
   A) A only
   B) B only
   C) A and B
   D) C and D
   E) C only
   Answer: C
   Diff: 2   Page Ref: 57

2) In the chemical equation $A + B \Leftrightarrow C + D$, which of the chemicals would be termed the product(s)?
   A) A only
   B) B only
   C) A and B
   D) C and D
   E) C only
   Answer: D
   Diff: 2   Page Ref: 57

3) The sum of the thousands of chemical reactions that occur within the body is called ________.
   A) metabolism
   B) hydrolysis
   C) phosphorylation
   D) oxidation
   E) reduction
   Answer: A
   Diff: 2   Page Ref: 57

4) Metabolism is a term that describes ________.
   A) all work done by a living organism
   B) all chemical reactions that take place within an organism
   C) only chemical reactions that release ATP from living cells
   D) the energy released from chemical bonds in living cells
   E) the extraction of nutrients from biomolecules
   Answer: B
   Diff: 3   Page Ref: 57
5) Which of the following is a correct description of an anabolic pathway?
   A) Proteins are transcribed from DNA in the nucleus.
   B) Proteins are degraded by mRNA in the cytoplasm.
   C) Glycogen is synthesized in the cytosol from glucose.
   D) The primary site of the synthesis of triglycerides is in the liver.
   E) The primary site of the breakdown of triglycerides is in the adipose tissue.
   Answer: C
   Diff: 5  Page Ref: 57

6) The addition of a phosphate group to a substrate is called ________. The enzyme that catalyzes this reaction is referred to as a ________.
   A) proteolysis : peptidase
   B) phosphorylation : phosphatase
   C) proteolysis : kinase
   D) phosphorylation : kinase
   E) hydrolysis : hydrase
   Answer: D
   Diff: 5  Page Ref: 58

7) The addition of two hydrogens and two electrons to NAD+ is an example of what type of chemical reaction?
   A) hydrolysis
   B) oxidation
   C) condensation
   D) phosphorylation
   E) reduction
   Answer: E
   Diff: 5  Page Ref: 58

8) Chemical reactions that involve the formation of peptide bonds between amino acids that produce water as a byproduct are called ________ reactions.
   A) hydrolysis
   B) phosphorylation
   C) condensation
   D) oxidation
   E) reduction
   Answer: C
   Diff: 5  Page Ref: 58

9) Chemical reactions that involve the production of a phosphate bond are called ________ reactions.
   A) condensation
   B) phosphorylation
   C) dephosphorylation
   D) oxidation
   E) reduction
   Answer: B
   Diff: 3  Page Ref: 58
10) Chemical reactions that involve the breaking of a phosphate bond are called ______ reaction.
   A) condensation
   B) phosphorylation
   C) dephosphorylation
   D) oxidation
   E) reduction
Answer: C
.Diff: 3 Page Ref: 58

11) In a reduction reaction, which of the following is most likely added to the reactants?
   A) water
   B) neutrons
   C) oxygen
   D) electrons
   E) phosphate
Answer: D
.Diff: 5 Page Ref: 58

12) During what type of reaction are electrons removed from the reactant?
   A) oxidation
   B) reduction
   C) phosphorylation
   D) electrocution
   E) deelectronofication
Answer: A
.Diff: 5 Page Ref: 58

13) What type of reaction occurs when a saturated fatty acid becomes unsaturated?
   A) oxidation
   B) reduction
   C) lipolysis
   D) phosphorylation
   E) hydrolysis
Answer: A
.Diff: 7 Page Ref: 58

14) If the energy change of a reaction (ΔE) is positive, then ______.
   A) the reactants had more energy than the products
   B) the products had more energy than reactants
   C) energy has been released as a byproduct
   D) no energy was added to the reaction
   E) the reactants had the same energy as the products
Answer: B
.Diff: 5 Page Ref: 62
15) Which of the following is true of an endergonic reaction?
   A) The change in energy of the reaction is positive.
   B) The reaction proceeds spontaneously.
   C) The only product of the reaction is heat.
   D) The only product of the reaction is water.
   E) Endergonic reactions never occur.
   Answer: A

16) The kinetic energy of a molecule can be increased by _______.
   A) increasing its mass
   B) increasing its temperature
   C) decreasing its mass
   D) decreasing its temperature
   E) decreasing its velocity
   Answer: B

17) The energy that is stored within an object for later use is referred to as _______.
   A) kinetic energy
   B) thermal energy
   C) potential energy
   D) radiant energy
   E) kinesthetic energy
   Answer: C

18) Which of the following statements about chemical equilibrium is FALSE?
   A) At equilibrium, the rate of formation of products equals the rate of formation of reactants.
   B) At equilibrium, the concentration of products equals the concentration of reactants.
   C) Increasing the amount of reactant will increase the production of product.
   D) Decreasing the amount of product will increase the production of product.
   E) Adding an enzyme will not alter the equilibrium.
   Answer: B

19) When an enzyme-catalyzed reaction is at equilibrium, _______.
   A) there is no net change in the amount of reactants or products
   B) the reaction is proceeding at its maximum rate
   C) the reaction is prevented from occurring
   D) there are equivalent amounts of substrate and enzyme present
   E) there are equivalent amounts of substrate and product present
   Answer: A
20) Start with the following chemical reaction at equilibrium: \( A \leftrightarrow B \). If you add product \( B \) to the system from a separate pathway, then what change in the reaction occurs?

A) Because the reaction is at equilibrium, there will be no change in rates of either the forward or reverse reaction.
B) Because the reaction is at equilibrium, the rates of both the forward and reverse reactions increase.
C) The rate of the forward reaction increases.
D) The rate of the reverse reaction increases.
E) The rate of the forward and reverse reactions both decrease.

Answer: D  
Diff: 6  Page Ref: 61

21) The enzyme carbonic anhydrase catalyzes the following reaction:

\[ \text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3, \]  
then \( \text{H}_2\text{CO}_3 \) dissociates reversibly to form \( \text{H}^+ + \text{HCO}_3^- \)

When tissue becomes more active, carbon dioxide increases due to its production in _______, causing hydrogen ion concentration to _______.

A) the cytosol : increase  
B) the cytosol : decrease  
C) mitochondria : increase  
D) mitochondria : decrease  
E) both the cytosol and mitochondria : decrease

Answer: C  
Diff: 9  Page Ref: 61

22) Molecules must have sufficient potential energy to overcome the _______ and, thereby, allow the reaction to proceed.

A) transformation state  
B) mass action  
C) transitional energy barrier  
D) activation energy barrier  
E) kinetic energy

Answer: D  
Diff: 6  Page Ref: 62

23) Once a molecule is already in motion, conversion of that molecule’s kinetic energy into potential energy occurs as a consequence of _______.

A) the collision of molecules  
B) an increased temperature  
C) its transition state  
D) its transfer state  
E) mass action

Answer: A  
Diff: 4  Page Ref: 63
24) Decreasing temperatures will _______ the frequency of collisions between molecules, thereby _______ the reaction rate.
   A) increase : decreasing
   B) decrease : decreasing
   C) not alter : not changing
   D) increase : increasing
   E) not alter : increasing

Answer: B
Diff: 4 Page Ref: 64

25) As the _______ energy of a molecule increases with temperature, the molecule will _______ more frequently with other reactants, thereby increasing reaction rate.
   A) potential : oxidize
   B) kinetic : hydrolyze
   C) kinetic : collide
   D) potential : hydrolyze
   E) activation : collide

Answer: C
Diff: 5 Page Ref: 64

26) As the energy required to overcome the activation energy barrier increases, the reaction rate will _______.
   A) decrease
   B) increase
   C) occur more frequently
   D) remain unaltered
   E) depend solely upon temperature

Answer: A
Diff: 4 Page Ref: 64

27) Enzymes act as _______ to increase reaction rate.
   A) an energy source
   B) reactants
   C) products
   D) catalysts
   E) intermediates

Answer: D
Diff: 4 Page Ref: 65

28) Which of the following would NOT increase the rate of a chemical reaction?
   A) increasing the concentration of reactants
   B) increasing the temperature
   C) increasing the activation energy barrier
   D) adding a catalyst
   E) adding an enzyme

Answer: C
Diff: 4 Page Ref: 66
29) Enzymes are what class of molecule?
   A) trace metals
   B) nucleic acids
   C) proteins
   D) carbohydrates
   E) lipids
   Answer: C
   Diff: 3 Page Ref: 67

30) How do enzymes increase the rate of chemical reactions?
   A) changing the equilibrium of the reaction
   B) bringing the substrates together to undergo collision
   C) adding potential energy to the reaction
   D) adding kinetic energy to the reaction
   E) converting kinetic energy to potential energy
   Answer: B
   Diff: 6 Page Ref: 67

31) Which of the following statements about enzymes is FALSE?
   A) An enzyme shows specificity for its substrate(s).
   B) An enzyme can be used over and over again because it is not changed in the chemical reaction.
   C) Enzymes are necessary to cause certain reactions to occur in cells that cannot occur in the absence of enzymes.
   D) Some enzymes require the presence of trace metals to be active.
   E) Once a substrate binds to an enzyme, it can leave the active site unaltered.
   Answer: C
   Diff: 5 Page Ref: 66

32) In the induced-fit model for enzyme activity, the substrate alters the _______ of the _______ site on the enzyme.
   A) conformation : allosteric
   B) conformation : inactive
   C) activity : active
   D) conformation : active
   E) shape : allosteric
   Answer: D
   Diff: 5 Page Ref: 67

33) The rate at which an enzyme-catalyzed reaction occurs can be increased by _______.
   A) decreasing substrate concentration
   B) releasing the cofactor that was bound to the enzyme
   C) increasing enzyme concentration
   D) decreasing temperature
   E) changing the enzyme’s conformation, thereby reducing its affinity for the substrate
   Answer: C
   Diff: 4 Page Ref: 67
34) The measure of how many product molecules can be produced by an enzyme per unit of time is referred to as that enzyme’s ________.
   A) specificity
   B) cofactor rate
   C) affinity
   D) catalytic rate
   E) coenzyme rate

   Answer: D
   Diff: 4 Page Ref: 67

35) Which of the following is NOT a mechanism for regulating the flow of molecules through metabolic pathways?
   A) changing the amount of enzyme that a cell has available
   B) allosteric regulation of enzymes
   C) isolating enzymes within a particular organelle
   D) covalent regulation of enzymes
   E) changing the potential energy of reactants and products

   Answer: E
   Diff: 6 Page Ref: 70

36) Which of the following would decrease the rate of an enzyme-catalyzed reaction?
   A) increasing the concentration of enzyme
   B) increasing the affinity of the enzyme for its substrate
   C) increasing the concentration of substrate
   D) increasing the concentration of product
   E) increasing the kinetic energy

   Answer: D
   Diff: 4 Page Ref: 68

37) Some enzymes require trace metals to function as cofactors. What do the trace metals do?
   A) Trace metals must be present in the enzyme in order for the enzyme to bind substrate.
   B) Trace metals are necessary for the transfer of electrons between substrates.
   C) Trace metals are necessary for the transfer of uncharged chemical groups between substrates.
   D) Trace metals provide energy for the reaction.
   E) Trace metals covalently modulate the enzyme.

   Answer: A
   Diff: 5 Page Ref: 68

38) Coenzyme A is derived from which of the following vitamins?
   A) niacin
   B) vitamin A
   C) vitamin C
   D) riboflavin
   E) pantothenic acid

   Answer: E
   Diff: 4 Page Ref: 68
39) What are coenzymes?
   A) inorganic molecules derived from trace metals that function in the transfer of a chemical group
   B) organic molecules derived from vitamins that function in the transfer of a chemical group
   C) inorganic molecules derived from vitamins that function in the transfer of a chemical group
   D) organic molecules derived from trace metals that function in the transfer of a chemical group
   E) protein complexes that function as enzymes with more than one active site
   Answer: B
   Diff: 5   Page Ref: 68

40) The greater the attractive forces between substrate and enzyme, that enzyme is said to have a higher ________ for the substrate.
   A) repulsion
   B) catalytic rate
   C) coenzyme activity
   D) cofactor activity
   E) affinity
   Answer: E
   Diff: 3   Page Ref: 69

41) Which of the following describes the strength of binding between a protein and a ligand?
   A) chemical specificity
   B) affinity
   C) saturation
   D) competition
   E) lock-and-key model
   Answer: B
   Diff: 5   Page Ref: 69

42) Affinity is a measure of ________.
   A) the rate of an enzyme catalyzed reaction
   B) the rate of a metabolic pathway, from initial substrate to final product
   C) the degree of phosphorylation of a molecule
   D) the strength of interactions between a ligand and binding site
   E) the rate of electron flow down the electron transport chain
   Answer: D
   Diff: 4   Page Ref: 69

43) Which of the following statements best describes allosteric regulation?
   A) A modulator molecule loosely binds to a protein, altering its activity.
   B) Rate of protein synthesis is changed by binding of a regulator molecule to the promoter sequence.
   C) A phosphate group is attached to a protein, changing its activity.
   D) Coenzymes bind to a protein, changing its activity.
   E) A trace metal binds to an enzyme and a substrate, linking the two together.
   Answer: A
   Diff: 4   Page Ref: 71
44) If the graph of an enzyme–catalyzed reaction shows a sigmoidal relationship between substrate concentration and reaction rate, then what can be said about the reaction?
   A) It is endergonic.
   B) It is exergonic.
   C) It is allosterically regulated.
   D) It is covalently regulated.
   E) It is part of an oxidation–reduction process.
   Answer: C
   Diff: 5 Page Ref: 71

45) In allosteric regulation, the modulator molecule binds to the _______.
   A) catalytic site of the enzyme by weak, reversible interactions
   B) regulatory site of the enzyme by weak, reversible interactions
   C) catalytic site by covalent bonds
   D) regulatory site by covalent bonds
   E) cofactor by weak, reversible interactions
   Answer: B
   Diff: 5 Page Ref: 71

46) Regulation of an enzyme through reversible binding of a modulator to a regulatory site on an enzyme is specifically called ________.
   A) allosteric regulation
   B) covalent regulation
   C) the induced–fit model
   D) the lock-and-key model
   E) pH regulation
   Answer: A
   Diff: 5 Page Ref: 71

47) Regulating an enzyme through protein kinase–induced phosphorylation of that enzyme is an example of ________.
   A) allosteric regulation
   B) covalent regulation
   C) the induced–fit model
   D) feedback inhibition
   E) cofactor regulation
   Answer: B
   Diff: 5 Page Ref: 71

48) Which of the following enzymes covalently modulates another enzyme?
   A) DNA polymerase
   B) protein kinase
   C) RNA polymerase
   D) catalase
   E) phosphatase
   Answer: B
   Diff: 4 Page Ref: 71
49) A protein kinase catalyzes which of the following types of chemical reactions?
   A) phosphorylation  
   B) dephosphorylation  
   C) condensation  
   D) oxidation  
   E) hydrolysis

   Answer: A  
   Diff: 4  
   Page Ref: 71

50) Which of the following statements about end-product inhibition is FALSE?
   A) The last product of a metabolic pathway inhibits the activity of an enzyme earlier in that path.  
   B) It usually involves allosteric modulation of an enzyme.  
   C) It is an example of negative feedback.  
   D) The enzyme modulated is often the rate-limiting enzymes.  
   E) The amount of product produced is increased by this process.

   Answer: E  
   Diff: 6  
   Page Ref: 72

51) What type of enzyme catalyzes the phosphorylation of another enzyme, thereby altering that enzyme’s activity?
   A) Dehydrogenase  
   B) Phosphorylase  
   C) Protein kinase  
   D) Synthase  
   E) Cofactor

   Answer: C  
   Diff: 4  
   Page Ref: 71

52) During end–product inhibition, ________.
   A) the initial substrate of an enzyme–catalyzed reaction inhibits the rate–limiting enzyme via allosteric regulation
   B) the product of the rate–limiting step of an enzyme–catalyzed reaction inhibits the rate–limiting enzyme via covalent regulation
   C) the product of the rate–limiting step of an enzyme–catalyzed reaction inhibits the rate–limiting enzyme via allosteric regulation
   D) the final product of an enzyme–catalyzed reaction inhibits the rate–limiting enzyme via allosteric regulation
   E) the final product of an enzyme–catalyzed reaction inhibits the rate–limiting enzyme via covalent regulation

   Answer: D  
   Diff: 5  
   Page Ref: 72
53) What is the most important energy-transferring compound in cells?
   A) glucose
   B) fructose
   C) protein
   D) adenosine triphosphate
   E) deoxyribonucleic acid

   Answer: D
   Diff: 2   Page Ref: 73

54) In skeletal muscle, ATP can be synthesized by transferring a phosphate group from creatine-P to ADP to form ATP and creatine. In this example, ATP was synthesized by what process?
   A) oxidative phosphorylation
   B) substrate-level phosphorylation
   C) oxidation
   D) reduction
   E) condensation

   Answer: B
   Diff: 4   Page Ref: 73

55) The complete oxidation of glucose releases how many kcal of energy for every mole of glucose?
   A) 686
   B) 7
   C) 266
   D) 420
   E) 98

   Answer: A
   Diff: 4   Page Ref: 73

56) The reaction whereby energy is released from an ATP molecule can be described by which of the following?
   A) ATP reduction
   B) ATP oxidation
   C) ATP hydrolysis
   D) ATP synthase
   E) ATP hydrogenation

   Answer: C
   Diff: 5   Page Ref: 73

57) How much energy is required to produce 1 mole of ATP?
   A) 7 kcal
   B) 686 kcal
   C) 266 kcal
   D) 420 kcal
   E) 98 kcal

   Answer: A
   Diff: 3   Page Ref: 73

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58) Where does glycolysis occur?
   A) cytosol
   B) mitochondrial matrix
   C) mitochondrial intermembrane space
   D) mitochondrial inner membrane
   E) lysosomes

   Answer: A
   Diff: 4 Page Ref: 74

59) Which of the following associations between metabolic pathway and location in the cell is INCORRECT?
   A) glycolysis : cytosol
   B) electron transport system : inner mitochondrial membrane
   C) transcription : nucleus
   D) lipid synthesis : smooth endoplasmic reticulum
   E) Krebs cycle : mitochondrial intermembrane space

   Answer: E
   Diff: 6 Page Ref: 74

60) ATP is synthesized by substrate–level phosphorylation during which of the following?
   A) glycolysis only
   B) conversion of pyruvate to lactate only
   C) Krebs cycle only
   D) glycolysis and the Krebs cycle only
   E) glycolysis, the Krebs cycle, and during conversion of pyruvate to lactate

   Answer: D
   Diff: 6 Page Ref: 75

61) Which of the following does NOT occur in mitochondria?
   A) Krebs cycle
   B) oxidative phosphorylation
   C) consumption of oxygen
   D) production of carbon dioxide
   E) conversion of pyruvate to lactate

   Answer: E
   Diff: 5 Page Ref: 76

62) The final product of glycolysis under aerobic conditions is pyruvate. What happens to pyruvate under aerobic conditions?
   A) Pyruvate is converted into acetyl CoA in the cytosol, and the acetyl CoA then enters the mitochondrial matrix.
   B) Pyruvate enters the mitochondrial matrix where it is converted into acetyl CoA.
   C) Pyruvate is converted to lactic acid in the cytosol.
   D) Pyruvate is converted to lactic acid in the mitochondrial matrix.
   E) Pyruvate provides electrons to the electron transport chain.

   Answer: B
   Diff: 6 Page Ref: 77
63) With the 38 moles of ATP that are generated within a cell from 1 mole of glucose, what percentage of the energy released from glucose is lost as heat?
   A) 25%
   B) 33%
   C) 40%
   D) 60%
   E) 70%

   Answer: D
   Diff: 5   Page Ref: 74

64) In the presence of oxygen, the process of glycolysis produces which of the following products?
   A) 1 pyruvate
   B) 1 lactate
   C) 2 pyruvate
   D) 2 lactate
   E) 2 glycerol

   Answer: C
   Diff: 3   Page Ref: 75

65) Where are the enzymes of glycolysis located within the cell?
   A) inner mitochondrial membrane
   B) outer mitochondrial membrane
   C) lysosome
   D) cytosol
   E) nucleus

   Answer: D
   Diff: 4   Page Ref: 74

66) In the presence of a limited oxygen supply, pyruvate is converted to what?
   A) lactate
   B) acetyl CoA
   C) NADH
   D) ATP
   E) glucose

   Answer: A
   Diff: 3   Page Ref: 82

67) How many ATP are generated per acetyl coenzyme A going through the Krebs cycle followed by the electron transport system?
   A) 2
   B) 3
   C) 12
   D) 24
   E) 36~38

   Answer: C
   Diff: 4   Page Ref: 78
68) Which of the following statements about the Krebs cycle is FALSE?
   A) The initial substrate is acetyl CoA.
   B) Three NADs are reduced to NADH + H⁺.
   C) Two FADs are reduced to FADH₂.
   D) Carbon dioxide is produced.
   E) One ATP (GTP) is formed by substrate phosphorylation.

   Answer: C

69) In terms of energy production, the Krebs cycle is significant because it _______.
   A) directly produces large amounts of ATP
   B) breaks down glucose
   C) reduces the coenzymes NAD and FAD for oxidative phosphorylation
   D) produces acetylcoenzyme A for fatty acid synthesis
   E) provides acetylcoenzyme A for glucose synthesis

   Answer: C

70) Which of the following statements about oxidative phosphorylation is FALSE?
   A) More ATP can be produced when NADH provides electrons to the electron transport
      chain than when FADH₂ provides electrons.
   B) Hydrogen ion movement from the mitochondrial matrix to the intermembrane space
      activates the enzyme ATP synthase.
   C) As electrons move down the electron transport chain, released energy is used to
      transport hydrogen ions across the inner mitochondrial membrane.
   D) Oxygen is reduced to water.
   E) The components of the electron transport chain are located on the inner mitochondrial
      membrane.

   Answer: B

71) What is the final acceptor of electrons in the electron transport?
   A) pyruvate
   B) carbon dioxide
   C) water
   D) oxygen
   E) glucose

   Answer: D

72) Where is the electron transport chain?
   A) cytosol
   B) outer mitochondrial membrane
   C) inner mitochondrial membrane
   D) intermembrane space of the mitochondria
   E) mitochondrial matrix

   Answer: C
73) Chemiosmotic coupling refers to _______.
   A) chemical coupling between substrate and enzymes
   B) chemical coupling of each reaction within the mitochondria
   C) coupling of the Krebs cycle to the electron transport chain
   D) the harnessing of energy from the reactions of the electron transport chain to make ATP
   E) the transfer of a phosphate group from one molecule to another

   Answer: D
   Diff: 5  Page Ref: 80

74) Hydrogen ions activate the enzyme ATP synthase by moving from _______.
   A) cytosol to inner mitochondrial membrane
   B) inner mitochondrial membrane to cytosol
   C) cytosol to outer mitochondrial membrane
   D) mitochondrial matrix to intermembrane space
   E) intermembrane space to mitochondrial matrix

   Answer: E
   Diff: 7  Page Ref: 80

75) Each time an electron is passed between the molecules of the electron transport chain, _______.
   A) energy is gained
   B) energy is released
   C) an ATP molecule is produced
   D) oxygen accepts the electrons
   E) carbon dioxide is produced

   Answer: B
   Diff: 4  Page Ref: 80

76) What is the first component of the electron transport chain that accepts electrons from an NADH molecule?
   A) flavin mononucleotide
   B) cytochrome b
   C) cytochrome a3
   D) coenzyme Q
   E) flavin adenine dinucleotide

   Answer: A
   Diff: 5  Page Ref: 79

77) What is the first component of the electron transport chain that accepts electrons from an FADH2 molecule?
   A) flavin mononucleotide
   B) cytochrome b
   C) cytochrome a3
   D) coenzyme Q
   E) flavin adenine dinucleotide

   Answer: D
   Diff: 6  Page Ref: 80
78) ATP synthase is able to use the potential energy that originates from ______ to produce ATP.
   A) the hydrogen gradient across the inner mitochondrial membrane
   B) the phosphorylation of cytochromes
   C) the sodium gradient across the inner mitochondrial membrane
   D) complex I
   E) complex IV
Answer: A  
Diff: 6  Page Ref: 80

79) Under low oxygen conditions, ______ must unload its electrons to allow glycolysis to continue the production of ATP.
   A) FADH₂
   B) lactate
   C) NAD⁺
   D) NADH
   E) pyruvate
Answer: D  
Diff: 5  Page Ref: 82

80) What is the net energy yield for the anaerobic metabolism of one glucose molecule?
   A) two molecules of ATP and two NADH
   B) two molecules of NADH and 0 ATP
   C) two molecules of ATP and 0 NADH
   D) 36 molecules of ATP and 0 NADH
   E) two molecules of ATP and three NADH
Answer: C  
Diff: 5  Page Ref: 84

81) Under anaerobic conditions, what is pyruvate converted to and where does this occur?
   A) acetyl coenzyme A in the mitochondria
   B) acetyl coenzyme A in the cytosol
   C) lactate in the mitochondria
   D) lactate in the cytosol
   E) fatty acid in the cytosol
Answer: D  
Diff: 5  Page Ref: 83

82) Under anaerobic conditions, which of the following is a final product of glucose catabolism?
   A) pyruvic acid
   B) lactic acid
   C) carbon dioxide
   D) acetyl coenzyme A
   E) water
Answer: B  
Diff: 3  Page Ref: 84
83) How is glucose stored in muscle and liver cells?
   A) starch
   B) glycogen
   C) cellulose
   D) lipids
   E) amino acids

   Answer: B
   Diff: 3 Page Ref: 84

84) Glycogen in muscle is used to ________.
   A) contribute to the maintenance of blood glucose
   B) convert glucose to amino acids
   C) convert glucose to fats
   D) fuel the activity of that muscle exclusively
   E) both fuel muscle activity and maintain blood glucose

   Answer: D
   Diff: 6 Page Ref: 86

85) What organ contains glucose-6-phosphatase?
   A) brain
   B) heart
   C) liver
   D) skeletal muscle
   E) all organs in the body

   Answer: C
   Diff: 6 Page Ref: 86

86) What is the function of glucose-6-phosphatase?
   A) catalyze addition of one phosphate group to glucose
   B) catalyze removal of one phosphate group from glucose
   C) catalyze addition of six phosphate groups to glucose
   D) catalyze removal of six phosphate groups from glucose
   E) catalyze the removal of the phosphate group from glucose and add it to ADP to form ATP by substrate-level phosphorylation

   Answer: B
   Diff: 7 Page Ref: 86

87) Which of the following molecules is NOT converted to glucose through the process of gluconeogenesis?
   A) glycerol
   B) lactate
   C) amino acids
   D) pyruvate
   E) fatty acids

   Answer: E
   Diff: 5 Page Ref: 86
88) What is glycogenolysis?
   A) the synthesis of membrane carbohydrates
   B) the breakdown of glycoproteins
   C) the synthesis of glycogen from glucose
   D) the breakdown of glycogen to glucose
   E) a form of gluconeogenesis
   Answer: D  Diff: 3  Page Ref: 86

89) Which of the following molecules is a substrate for gluconeogenesis?
   A) amino acids only
   B) glycogen only
   C) glycerol only
   D) amino acids and glycerol only
   E) amino acids, glycogen, and glycerol
   Answer: D  Diff: 5  Page Ref: 86

90) Gluconeogenesis refers to synthesis of ________ and occurs in ________.
   A) glycogen : the liver
   B) triglycerides : adipose tissue
   C) glucose : liver
   D) fatty acids : adipose tissue
   E) glucose : all organs
   Answer: C  Diff: 4  Page Ref: 86

91) The conversion of triglycerides to glycerol and fatty acids is called ________.
   A) triglycerolysis
   B) glycolysis
   C) gluconeogenesis
   D) lipolysis
   E) liposuction
   Answer: D  Diff: 4  Page Ref: 87

92) A substantial amount of ATP is generated from the metabolism of long carbon chains called
   ________.
   A) glycogen
   B) fatty acids
   C) glycerol
   D) glucose
   E) amino acids
   Answer: B  Diff: 3  Page Ref: 87
93) Metabolism of fatty acids that results in the accumulation of acetyl CoA can lead to a buildup of ________.
   A) ketones
   B) ATP
   C) glycerol
   D) lactate
   E) amino acids
   Answer: A
   Diff: 7   Page Ref: 87

94) Beta-oxidation of a 14–chain fatty acid results in how many acetyl CoA molecules?
   A) 1
   B) 2
   C) 4
   D) 7
   E) 14
   Answer: D
   Diff: 5   Page Ref: 87

95) Where does beta-oxidation of fatty acids occur?
   A) cytosol
   B) smooth endoplasmic reticulum
   C) mitochondrial matrix
   D) mitochondrial intermembrane space
   E) peroxisome
   Answer: C
   Diff: 4   Page Ref: 87

96) Before converting amino acids into intermediates for energy metabolism, they must first undergo ________.
   A) denaturation
   B) deamination
   C) detoxification
   D) depeptidization
   E) oxidation
   Answer: B
   Diff: 7   Page Ref: 90

97) Any nutrient that is not synthesized by the body and must, therefore, be acquired through the diet is a(n) ________ nutrient.
   A) essential
   B) primary
   C) secondary
   D) non-essential
   E) consumptive
   Answer: A
   Diff: 4   Page Ref: 90
98) The amine group removed from an amino acid must be converted to ________ before being eliminated from the human body.
   A) uric acid
   B) ornithine
   C) keto acid
   D) urea
   E) ammonium

   Answer: D  
   Diff: 4  Page Ref: 88

99) Insulin levels in the blood are elevated in response to which of the following?
   A) increased blood glucose levels
   B) decreased blood fatty acids
   C) decreased blood triglycerides
   D) fasting for 12 hours
   E) sleep

   Answer: A  
   Diff: 5  Page Ref: 89

100) Which of the following is not an action of insulin on liver cells?
    A) increase glucose uptake
    B) activate glycogen synthetase
    C) activate glucokinase
    D) inhibit glucose-6-phosphatase
    E) increase gluconeogenesis

   Answer: A  
   Diff: 9  Page Ref: 89

True/False Questions

1) Chemical reactions are only able to occur in one direction.

   Answer: FALSE  
   Diff: 3  Page Ref: 57

2) Phosphorylation reactions are specific examples of a condensation reaction.

   Answer: FALSE  
   Diff: 4  Page Ref: 58

3) Sucrose is synthesized from the condensation of fructose and glucose.

   Answer: TRUE  
   Diff: 4  Page Ref: 58

4) The following reaction is an example of an oxidation: \( \text{FAD} + 2 \text{H}^+ \rightarrow \text{FADH}_2 \)

   Answer: FALSE  
   Diff: 5  Page Ref: 59

5) According to the first law of thermodynamics, energy cannot be created or destroyed.

   Answer: TRUE  
   Diff: 4  Page Ref: 59
6) Potential energy describes the energy possessed by an object in motion.
   Answer: FALSE
   Diff: 4   Page Ref: 60

7) A reaction is at equilibrium when the rate of the forward and reverse reactions are equal.
   Answer: TRUE
   Diff: 4   Page Ref: 61

8) Energy-releasing reactions occur spontaneously.
   Answer: TRUE
   Diff: 4   Page Ref: 61

9) Energy-requiring reactions will always proceed spontaneously in the forward direction.
   Answer: FALSE
   Diff: 4   Page Ref: 61

10) An increase in the concentration of a product will increase the rate of a reaction in the reverse direction.
    Answer: TRUE
    Diff: 4   Page Ref: 61

11) An increase in temperature increases the potential energy of molecules.
    Answer: FALSE
    Diff: 4   Page Ref: 64

12) Most enzymes only catalyze reactions in one direction.
    Answer: FALSE
    Diff: 5   Page Ref: 67

13) An increase in the affinity of an enzyme for its substrate will increase the reaction rate.
    Answer: TRUE
    Diff: 4   Page Ref: 69

14) According to the induced fit model for enzymes, the binding of substrate to the active site alters the structure of the enzyme.
    Answer: TRUE
    Diff: 4   Page Ref: 68

15) A single enzyme could be simultaneously affected by both allosteric regulation and covalent regulation.
    Answer: TRUE
    Diff: 4   Page Ref: 71

16) Enzymes increase the activation energy of a reaction.
    Answer: FALSE
    Diff: 4   Page Ref: 66

17) An increase in the concentration of enzyme will increase the reaction rate.
    Answer: TRUE
    Diff: 4   Page Ref: 69

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18) Binding of a modulator to a regulatory site alters the structure of the enzyme in a way that can affect catalytic rate and/or affinity.
   Answer: TRUE
   Diff: 4   Page Ref: 71

19) Addition of a phosphate group to an enzyme to change its activity is an example of covalent regulation.
   Answer: TRUE
   Diff: 4   Page Ref: 71

20) A phosphatase is an enzyme that catalyzes the addition of a phosphate group to a protein.
   Answer: FALSE
   Diff: 5   Page Ref: 71

21) All of the energy released by the oxidation of glucose is converted and stored in the form of ATP.
   Answer: FALSE
   Diff: 2   Page Ref: 74

22) Carbon dioxide can react with water to produce bicarbonate and hydrogen ions through 2 reversible reactions as follows:

   \[ \text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3 \leftrightarrow \text{H}^+ + \text{HCO}_3^- \]

   Blood flows from arteries into capillaries and then into veins. As the blood moves through the capillaries, carbon dioxide produced by the cells enters the blood. Therefore, venous blood has a higher pH than arterial blood.
   Answer: FALSE
   Diff: 9   Page Ref: 62

23) The condensation of ATP releases energy to drive cellular processes.
   Answer: FALSE
   Diff: 5   Page Ref: 74

24) The carbohydrate in adenosine is ribose.
   Answer: TRUE
   Diff: 8   Page Ref: 73

25) Complete oxidation of 1 mole glucose produces 6 moles of water and 6 moles of carbon dioxide.
   Answer: TRUE
   Diff: 4   Page Ref: 73

26) Pyruvate is converted to lactate in the cytosol under anaerobic conditions, but it is converted to acetyl CoA in the mitochondrial matrix under aerobic conditions.
   Answer: TRUE
   Diff: 6   Page Ref: 77

27) Glycogenolysis is an example of a catabolic reaction.
   Answer: TRUE
   Diff: 4   Page Ref: 85
28) Lactate dehydrogenase is an enzyme in the mitochondrial matrix.
   Answer: FALSE
   Diff: 5    Page Ref: 83

Matching Questions

Match the correct metabolic pathway to the following descriptions.

1) Acetyl CoA is the initial substrate.
   Diff: 4    Page Ref: 77

2) Pyruvate is the final product.
   Diff: 3    Page Ref: 76

3) Glucose is synthesized.
   Diff: 4    Page Ref: 85

4) It occurs within the inner mitochondrial membrane.
   Diff: 3    Page Ref: 79

5) Glucose is used to synthesize a larger molecule.
   Diff: 4    Page Ref: 85

Answers: 1) B  2) D  3) A  4) C  5) F

Match the correct location in the cell for the following metabolic pathways.

6) Glycolysis.
   Diff: 3    Page Ref: 76

7) Krebs cycle.
   Diff: 3    Page Ref: 77

8) Electron transport system.
   Diff: 3    Page Ref: 79

9) Conversion of pyruvate to lactate.
   Diff: 5    Page Ref: 84

10) Conversion of pyruvate to acetyl CoA.
    Diff: 4    Page Ref: 77

Match the following chemical reactions with its correct name.

11) Protein + H₂O → Amino acids.
   Diff: 5 Page Ref: 58

12) Monounsaturated fatty acid + 2H → Saturated fatty acid.
   Diff: 6 Page Ref: 58

13) Protein + Phosphate → Protein - Phosphate.
   Diff: 4 Page Ref: 58

14) ADP + Pi → ATP + H₂O.
   Diff: 5 Page Ref: 58

15) FAD + 2H → FADH₂.
   Diff: 4 Page Ref: 58

16) C₆H₁₂O₆ + 6 O₂ → 6 CO₂ + 6 H₂O.
   Diff: 4 Page Ref: 58


Essay Questions

1) Chemical reactions are essential to a multitude of functions within the human body. Describe the general properties of a chemical reaction.

Answer: A reaction can be written in the form A + B ⇌ C + D. A and B are considered the reactants, whereas C and D are the products of the reaction. The ⇌ is pointing out that reactions can occur in both directions (forward reaction produces C and D, whereas reverse reaction produces A and B). In metabolism, many of these reactions are linked to one another, creating a metabolic pathway of reactions. The final product of the reaction is the end product, and all of the reactants in between are considered intermediates.

Diff: 4 Page Ref: 57
2) Several types of chemical reactions are involved in the process of metabolism. Provide a general description of these reactions: hydrolysis, condensation, phosphorylation, dephosphorylation, oxidation, and reduction reactions.

Answer: Hydrolysis/condensation reactions involve either the addition or production of water. Hydrolysis reactions are driven by the cleavage of water. One example of a hydrolysis reaction is the breaking of a peptide bond between amino acids. Water is split into a hydroxyl group and a hydrogen, each of which combine with one of the amino acids. The reverse of a hydrolysis reaction is a condensation reaction, where water is a product of the reaction. Phosphorylation/dephosphorylation reactions involve the addition or removal of a phosphate group. Addition of a phosphate group involves a kinase enzyme in a process called phosphorylation. Alternatively, the loss of a phosphate group requires a phosphatase enzyme and is called dephosphorylation. These two reactions are unique examples of the first reaction, with phosphorylation requiring the splitting of water (hydrolysis) and dephosphorylation resulting in the production of water (condensation). Oxidation/reduction reactions involve the transfer of electrons. Oxidation reactions can be narrowly defined as the loss of electrons, which can involve the addition of oxygen. Reduction reactions involve the addition of electrons or hydrogen molecules.

3) Describe the role that energy (potential and kinetic) plays in mediating chemical reactions.

Answer: Energy is broadly defined as the capacity to do work. A reaction’s energy requirement can be determined by the simple equation \( \Delta E = E_{\text{products}} - E_{\text{reactants}} \). A negative \( \Delta E \) indicates a reaction where energy is released, whereas a positive \( \Delta E \) indicates that energy is consumed. At the same time, energy can be present in two forms: kinetic and/or potential. Kinetic energy is the energy of motion, which depends upon the speed and mass of the object. Molecules possess kinetic energy because they undergo thermal motion. Thus, the kinetic energy of a molecule is directly proportional to its temperature and is, therefore, referred to as thermal energy. This can be contrasted with potential energy, which is energy that is stored and eventually converted into kinetic energy. When referring to the energy change in a reaction, we are referring to potential energy. An energy-releasing reaction may occur spontaneously in the forward direction, whereas an energy-requiring reaction does not move forward spontaneously and will only move forward when more energy is applied to the system.
4) The rates of chemical reactions are important to their biological function. Describe the factors that can affect reaction rates and how these changes are mediated (do not include enzymes in this discussion).

Answer: The rate of a reaction can be expressed as a change in concentration per unit time. First, reaction rates can be determined by the concentration of reactants and products. Since reactions are bi-directional, we are really referring to the net rate of a reaction. Any increase in a reactant’s concentration will increase the reaction rate in the forward direction. In addition, any increase in product will increase the reaction rate in the reverse direction. Any increase in concentration will increase the frequency of collisions between reactants, thus increasing the likelihood that, when they collide, a reaction will occur. However, the occurrence of a reaction is dependent upon the energy of the collision and, therefore, another way to increase the rate of a reaction is to increase temperature. When temperature increases, each molecule will have more kinetic energy, thereby increasing the likelihood that a collision between reactants will result in product (i.e., the activation energy barrier can be overcome). Finally, any change in the amount of energy required to overcome the activation energy barrier (height of the activation energy barrier) will alter the rate of a reaction. An elevated activation energy barrier will make it less likely that a collision between two reactants will result in product. Conversely, as the activation energy barrier is reduced, a collision between reactants will be more likely to result in a product, thereby increasing the reaction rate.

Diff: 6  Page Ref: 64

5) Enzymes are important determinants of chemical reaction rates in the body. Describe the mechanisms by which enzymes function to stimulate a reaction.

Answer: Enzymes act as catalysts to increase the rate of a chemical reaction. Most enzymes are specific for a particular reaction through a two-step process. The enzyme must first bind to the substrate to form an enzyme–substrate complex. The substrate is then acted on by the enzyme to form a product. The initial step is referred to as the binding step, which is a reversible process. If the complex is around for long enough, the second step, or catalytic step, of the reaction will occur. Each enzyme has a specificity for a particular substrate or class of substrates. The site of substrate binding has been termed the active site, whose binding to the substrate has been modeled in two ways: lock-and-key or induced-fit models. Both of these models refer to the complementary nature of the substrate’s conformation for an enzyme. Many of these enzyme reactions require a cofactor, either a trace metal or a coenzyme. Trace metals bind to an enzyme on a site other than the active site, and maintain the enzyme in a structure that will bind to the substrate. The coenzyme is a particular type of cofactor that does not have any catalytic activity of its own but does participate directly in the reaction catalyzed by its partner enzyme by transferring a chemical group with the substrate.

Diff: 6  Page Ref: 65
6) Describe the factors that affect the rates of enzyme reactions.

Answer: The presence of an enzyme increases reaction rates by decreasing the activation energy required to initiate a reaction. The rate at which an enzyme catalyzes a reaction can be altered by several variables. First, reaction rates can be affected by the catalytic rate of an enzyme. This is a measure of how many substrate molecules an enzyme can convert to product within a given period of time, reflecting how quickly the enzyme can move through the second step of the reaction (the catalytic step). Some enzymes are inherently faster acting than others. Another way enzymes can alter reaction rates is through their affinity for the substrate (how easily the substrate binds to the enzyme). This is a reflection of how well an enzyme facilitates the first step of a reaction (the binding step). A higher affinity implies the substrate is a better fit within the active site of the enzyme. Based upon what we know about reactions, both substrate and enzyme concentrations will also affect reaction rates. The more enzyme present, the more product that can be produced. The more substrate, the more likely that substrate will collide with and be bound to the enzyme. However, as concentration increases, there is a limit to how much reaction rates will increase once all of the enzymes present are saturated (bound) by substrate. In addition, any situation that can alter the structure of an enzyme will affect reaction rates. This includes temperature, pH, allosteric regulation, and covalent regulation. Each enzyme has an optimal value of pH and temperature at which it has the highest reaction rates.

Diff: 6 Page Ref: 67

7) With the plethora of enzymes that are present within each cell, the activity of each enzyme must be carefully regulated. Describe the two ways that enzyme reactions are regulated within the body and give examples of each.

Answer: Reaction rates of enzymes are continuously changing within the body and can occur through alterations in enzyme concentration or enzyme activity. Concentration of an enzyme can be altered by rates of synthesis, rates of release, and stability (degradation or inactivation). Alternatively, the activity of an enzyme can be altered. Certain enzymes have another site (other than the active site) where molecules can bind and alter reaction rates. This is the regulatory site where modulators can bind and thereby alter reaction rates. This type of regulation is called allosteric regulation, since the modulator alters the structure of the enzyme in a way that affects its activity (either to increase or decrease). Binding to that allosteric site is reversible, which means that the activity of the enzyme can be altered by the concentration of the modulator. Alternatively, enzymes can be controlled via covalent regulation, where changes in enzyme activity are brought about by covalent bonding of specific chemical groups to enzymes. These covalent bonds are usually created by another enzyme. A common form of covalent regulation involves the addition or removal of a phosphate group. Addition is called phosphorylation, whereas removal is called dephosphorylation. Protein kinases are enzymes that phosphorylate enzymes while phosphatases dephosphorylate enzymes. Interestingly, enzymes can also be regulated by feedback loops involving the product of a series of reactions. This type of feedback inhibition is quite common in metabolic pathways where it has been called end-product inhibition. The product of one reaction will alter the structure of an earlier enzyme, thereby decreasing its activity. Thus, feedback inhibition is a specific form of allosteric regulation. Finally, some reactions are controlled through a feedforward activation. In a series of enzyme-mediated reactions, products from an earlier reaction will activate the enzyme for a reaction that is downstream from the product in question.

Diff: 7 Page Ref: 69

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8) Describe the process whereby energy is obtained by glucose oxidation.

Answer: The oxidation of glucose requires three steps: glycolysis, Krebs cycle, and oxidative phosphorylation. Glycolysis takes place in the cytosol and is the conversion of glucose to 2 pyruvate molecules, generating 2 ATP and 2 NADH + 2 H⁺.

The two pyruvate molecules enter the mitochondrial matrix, where they are converted to 2 acetyl CoA. In the process, 2 NAD⁺ are reduced to 2 NADH + 2 H⁺.

The 2 acetyl CoA each enter the Krebs cycle of the mitochondrial matrix. In the process, 2 ATP, 6 NADH + 6 H⁺, and 2 FADH₂ are produced.

Thus, from one glucose, the processes of glycolysis and the Krebs cycle directly produce 4 ATP by substrate-level phosphorylation. More importantly, they produced reduced coenzymes. In the cytosol, 2 NADH + 2 H⁺ are produced, and in the mitochondrial matrix, 8 NADH + 8 H⁺ and 2 FADH₂ are produced. These coenzymes provide electrons to the electron transport chain to synthesize ATP by oxidative phosphorylation.

For electrons to enter the electron transport chain, they must be located in the mitochondria. Thus, the electrons associated with the 2 NADH + 2 H⁺ produced in the cytosol must be moved into the mitochondria. NADH + H⁺ cannot permeate the membranes of the mitochondria; therefore, the electrons are shuttled across. In the process, either an NAD⁺ or an FAD can accept the electrons inside the mitochondrial matrix.

For each NADH + H⁺ that provides electrons for the electron transport chain, a maximum of 3 ATP are produced by oxidative phosphorylation. For each FADH₂ that provides the electrons, a maximum of 2 ATP can be produced by oxidative phosphorylation. Thus there are 8 NADH + 8 H⁺, 2 FADH₂, and 2 more of either NADH + H⁺ or FADH₂. Therefore, the net number of ATP produced by oxidative phosphorylation from one glucose is \((8 \times 3) + (2 \times 2) + (2 \times 3) + 2 \times 2) = 32 \text{ or } 34.

The total number of ATP by oxidation of glucose is 36 – 38.

Diff: 7  Page Ref: 72

Short Answer Questions

1) \(A-B + H_2O \rightarrow A-OH + H-B\) describes what type of reaction?

Answer: hydrolysis

Diff: 3  Page Ref: 58

2) \(A-OH + H-B \rightarrow A-B + H_2O\) describes what type of reaction?

Answer: condensation

Diff: 3  Page Ref: 58
3) \( C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O \) is an example of what type of reaction?

Answer: oxidation

Diff: 4  Page Ref: 58

4) \( HA-BH \rightarrow A=B + 2H \) is an example of what type of reaction?

Answer: oxidation

Diff: 4  Page Ref: 58

5) \( A=B + 2H \rightarrow HA-BH \) is an example of what type of reaction?

Answer: reduction

Diff: 4  Page Ref: 58

6) When a reaction occurs and that reaction is moving equally in a forward and reverse direction, that reaction is said to be at _______.

Answer: equilibrium

Diff: 5  Page Ref: 61

7) \( A + B \leftrightarrow C + D \) How will this reaction be altered if an excess of C is added to the reaction?

Answer: The reverse direction will be favored.

Diff: 5  Page Ref: 61

8) \( A + B \leftrightarrow C + D \) How will this reaction be altered if an excess of B is added to the reaction?

Answer: The forward direction will be favored.

Diff: 5  Page Ref: 61

9) In order for a reaction to proceed past the transition state, the reaction must overcome what energy barrier?

Answer: the activation energy barrier

Diff: 6  Page Ref: 62

10) According to the law of mass action, an increase in the concentration of product will cause a reaction to move in the (forward / reverse) direction.

Answer: reverse

Diff: 4  Page Ref: 61

11) In a reaction that proceeds in the forward direction spontaneously, which has more free energy, the reactant or the product?

Answer: reactant

Diff: 3  Page Ref: 61

12) Metabolism includes _______ reactions, which release energy and result in the breakdown of large biomolecules, and _______ reactions, which require a net input of energy and result in the synthesis of large biomolecules.

Answer: catabolic : anabolic

Diff: 3  Page Ref: 57

13) What is the strength of binding between an enzyme and substrate called?

Answer: affinity

Diff: 3  Page Ref: 69
14) During (allosteric / covalent) regulation, a modulator binds to a regulatory site on an enzyme by weak interactions altering the activity of the enzyme.
   
   Answer: allosteric
   
   Diff: 4 Page Ref: 71

15) An enzyme that catalyzes phosphorylation of a protein is called a(n) ________. An enzyme that catalyzes dephosphorylation of a protein is called a(n) ________.
   
   Answer: protein kinase ; phosphatase
   
   Diff: 5 Page Ref: 71

16) What chemical group is most commonly added to a protein during covalent regulation?
   
   Answer: phosphate
   
   Diff: 5 Page Ref: 71

17) During end-product inhibition, the final product in a metabolic pathway (allosterically / covalently) regulates the activity of an enzyme earlier in the pathway.
   
   Answer: allosterically
   
   Diff: 5 Page Ref: 72

18) The figure below shows the relative activity of an enzyme in two states: high affinity and low affinity. Which curve, A or B, represents the high affinity state?

   Answer: A
   
   Diff: 5 Page Ref: 69

19) What chemical group is transferred by the following coenzymes: NAD? FAD? Coenzyme A?
   
   Answer: hydrogens or electrons ; hydrogen or electrons : acetyl group
   
   Diff: 5 Page Ref: 67

20) A (coenzyme / trace metal) alters the ability of an enzyme to bind its substrate.
   
   Answer: trace metal
   
   Diff: 6 Page Ref: 67

21) Provide the correct number in each blank. For each acetyl CoA that enters the Krebs cycle, _______ NAD(s) are reduced, _______ FAD(s) are reduced, and _______ ATP are synthesized by substrate-level phosphorylation.
   
   Answer: 3 : 1 : 1
   
   Diff: 6 Page Ref: 77

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22) Which of the following is the reduced form: FAD or FADH2?
   Answer: FADH2
   Diff: 4  Page Ref: 67

23) During ________, a phosphate group is transferred from a metabolic intermediate to an ADP to synthesize ATP.
   Answer: substrate-level phosphorylation
   Diff: 4  Page Ref: 72

24) Fill in the blanks with the appropriate numbers. For each FADH2 that supplies electrons to the electron transport system, ________ ATP(s) is/are synthesized. For each NADH + H+ that supplies electrons to the electron transport system, ________ ATP(s) is/are synthesized.
   Answer: 2 : 3
   Diff: 4  Page Ref: 80

25) How many ATP are produced for each acetyl coenzyme A completely catabolized in the presence of oxygen?
   Answer: 12
   Diff: 6  Page Ref: 78

26) Glucose is stored in the form of glycogen primarily within what two organs?
   Answer: skeletal muscle and liver
   Diff: 4  Page Ref: 87

27) Most of our fat is stored in adipocytes in the form of ________. This fat can be broken down by a process called ________ to ________ and ________.
   Answer: triglycerides : lipolysis : glycerol : 3 fatty acids
   Diff: 6  Page Ref: 88

28) Proteins are broken down to amino acids by ________.
   Answer: proteolysis
   Diff: 4  Page Ref: 89

29) In the liver, ammonia is converted to ________ for eventual elimination in the urine.
   Answer: urea
   Diff: 5  Page Ref: 89

30) The synthesis of glucose from non-carbohydrate precursors is called ________ and it occurs in the ________.
   Answer: gluconeogenesis : liver
   Diff: 6  Page Ref: 87

31) What is the storage form of carbohydrates in animal cells?
   Answer: glycogen
   Diff: 3  Page Ref: 87
32) The organ that stores glucose as glycogen and then provides glucose to the blood when needed is the ________.

   Answer: liver

   Diff: 4    Page Ref: 87
Chapter 4  Cell Membrane Transport

Multiple Choice Questions

1) The chemical force for which of the following ions is directed into the cell?
   A) potassium only
   B) sodium only
   C) calcium only
   D) both potassium and sodium
   E) both sodium and calcium

   Answer: E  
   Diff: 6   Page Ref: 95

2) Which of the following is found in greater concentration inside the cell than outside?
   A) sodium
   B) calcium
   C) potassium
   D) water
   E) chloride

   Answer: C  
   Diff: 4   Page Ref: 95

3) When molecules are passively transported across a membrane, the direction of their movement is dictated by the molecule's tendency to move _______.
   A) from higher to lower energy
   B) from lower to higher energy
   C) out of a cell
   D) into a cell
   E) in both directions; there is no preference

   Answer: A  
   Diff: 3   Page Ref: 96

4) Of the gradients listed below, which is the most accurate description of the force that ultimately determines the movement of ions across the membrane?
   A) chemical gradient
   B) potential gradient
   C) electrochemical gradient
   D) concentration gradient
   E) electrical gradient

   Answer: C  
   Diff: 3   Page Ref: 99
5) Molecules tend to move spontaneously _______ their chemical gradient.
   A) down
   B) up
   C) through
   D) around
   E) over
Answer: A
Diff: 3    Page Ref: 96

6) When more than one ion species (i.e., Na\(^+\) and K\(^+\)) is present on both sides of the membrane, the chemical driving force acting on Na\(^+\) will include _______.
   A) all positively charged ions
   B) all negatively charged ions
   C) the most concentrated ion only
   D) sodium only
   E) all ions present
Answer: D
Diff: 3    Page Ref: 97

7) Which of the following is a reflection of the unequal distribution of positive and negative ions across the plasma membrane?
   A) Chemical gradient
   B) Extracellular potential
   C) Membrane potential
   D) Chemical driving force
   E) Electrochemical driving force
Answer: C
Diff: 5    Page Ref: 97

8) Comparing intracellular to extracellular fluid, the intracellular fluid has a _______ charge relative to the outside of a cell due to the presence of more _______ in that solution.
   A) positive : cations
   B) negative : anions
   C) negative : cations
   D) positive : anions
   E) neutral : cations
Answer: B
Diff: 5    Page Ref: 98

9) The unequal distribution of charge in solutions on either side of a membrane will lead to a _______ of charge across the membrane and a _______ of counter ions in a region close to the membrane.
   A) separation : clustering
   B) collection : restriction
   C) buildup : restriction
   D) separation : restriction
   E) collection : clustering
Answer: A
Diff: 6    Page Ref: 98
10) Based solely upon its electrical charge, the inside of a typical cell will tend to attract extracellular ________ to move inward.
   A) proteins  
   B) anions  
   C) cations  
   D) uncharged ions  
   E) ions whose concentration gradient allows them
Answer: C
Diff: 4 Page Ref: 98

11) Which of the following factors does NOT directly affect the direction or magnitude of the electrical driving force?
   A) the sign of the membrane potential  
   B) an ion’s charge  
   C) the amplitude of membrane potential  
   D) the molecular weight of an ion  
   E) the quantity of charge carried by an ion
Answer: D
Diff: 6 Page Ref: 99

12) Which of the following is NOT a determinant of the magnitude and direction of the equilibrium potential for an ion?
   A) lipid solubility of the ion  
   B) concentration gradient  
   C) charge of the ion  
   D) valence of the ion  
   E) chemical driving force
Answer: A
Diff: 5 Page Ref: 99

13) If a positively charged ion is more concentrated outside the cell, the forces required to balance the chemical gradient would be directed ________. Thus, the equilibrium potential for this ion would be ________ charged.
   A) outward : negatively  
   B) outward : positively  
   C) inward : positively  
   D) inward : negatively  
   E) outward : neutrally
Answer: B
Diff: 7 Page Ref: 99

14) Which of the following cells would have a greater electrical attraction for sodium ions to enter the cell?
   A) cell with membrane potential = -70 mV  
   B) cell with membrane potential = -90 mV  
   C) cell with membrane potential = -50 mV  
   D) cell with membrane potential = 0 mV  
   E) cell with membrane potential = +20 mV
Answer: B
Diff: 4 Page Ref: 98
15) If a negatively charged ion is more concentrated outside the cell, the forces required to balance the chemical gradient would be directed _______. Thus, the equilibrium potential for this ion would be _______ charged.
   A) outward : negatively
   B) outward : positively
   C) inward : positively
   D) inward : negatively
   E) outward : neutrally

   Answer: A
   Diff: 7    Page Ref: 99

16) If a negatively charged ion is more concentrated inside the cell, the forces required to balance the chemical gradient would be directed _______. Thus, the equilibrium potential for this ion would be _______ charged.
   A) outward : negatively
   B) outward : positively
   C) inward : positively
   D) inward : negatively
   E) outward : neutrally

   Answer: C
   Diff: 7    Page Ref: 99

17) If a positively charged ion is more concentrated inside the cell, the forces required to balance the chemical gradient would be directed _______. Thus, the equilibrium potential for this ion would be _______ charged.
   A) outward : negatively
   B) outward : positively
   C) inward : positively
   D) inward : negatively
   E) outward : neutrally

   Answer: D
   Diff: 7    Page Ref: 99

18) Which of the following can be used to determine an ion's equilibrium potential?
   A) Navier Stokes equation
   B) oscilloscope
   C) intracellular voltmeter
   D) Nernst equation
   E) concentration of an ion only

   Answer: D
   Diff: 5    Page Ref: 99
19) The potassium equilibrium potential is \(-94\) mV. What does this mean?
   A) at the resting membrane potential of neurons, potassium is at equilibrium  
   B) at \(-94\) mV, the chemical force for potassium movement is zero  
   C) at \(-94\) mV, the electrical force for potassium movement is zero  
   D) at \(-94\) mV, the chemical force for potassium movement is opposed exactly by the electrical force  
   E) at \(-94\) mV, potassium movement is opposed exactly by sodium movement

Answer: D  
Diff: 4  Page Ref: 99

20) An anion has an equilibrium potential of \(-40\) mV. What direction are the chemical and electrical forces acting on the anion at the resting membrane potential (\(-70\) mV)?
   A) The chemical force is directed into the cell and the electrical force is directed out of the cell.  
   B) Both the chemical and electrical forces are directed out of the cell.  
   C) The chemical force is directed out of the cell and the electrical force is directed into the cell.  
   D) Both the chemical and electrical forces are directed into the cell.  
   E) There is insufficient information to answer this question.

Answer: A  
Diff: 9  Page Ref: 100

21) Which of the following best describes the potassium equilibrium potential?
   A) \(+94\) mV  
   B) \(+60\) mV  
   C) \(-60\) mV  
   D) \(-70\) mV  
   E) \(-94\) mV

Answer: E  
Diff: 3  Page Ref: 101

22) An anion is found in greater concentration inside the cell than outside. Which of the following statements best describes forces acting on the anion at the resting membrane potential (\(-70\) mV)?
   A) The chemical force is directed into the cell and the electrical force is directed out of the cell.  
   B) Both the chemical and electrical forces are directed out of the cell.  
   C) The chemical force is directed out of the cell and the electrical force is directed into the cell.  
   D) Both the chemical and electrical forces are directed into the cell.  
   E) There is insufficient information to answer this question.

Answer: B  
Diff: 7  Page Ref: 100
23) The equilibrium potential for a cation is -20 mV. Which of the following statements is true when a cell is at the resting membrane potential (-70 mV)?
   A) The chemical force is directed into the cell and the electrical force is directed out of the cell.
   B) Both the chemical and electrical forces are directed out of the cell.
   C) The chemical force is directed out of the cell and the electrical force is directed into the cell.
   D) Both the chemical and electrical forces are directed into the cell.
   E) There is insufficient information to answer this question.

Answer: C
Diff: 9    Page Ref: 100

24) The equilibrium potential describes the membrane potential where what two forces are balanced?
   A) chemical and temperature
   B) chemical and electrical
   C) electrical and permeability
   D) temperature and density
   E) density and magnetic

Answer: B
Diff: 4    Page Ref: 99

25) Which of the following is NOT required to determine equilibrium potential of a particular ion?
   A) size of the ion
   B) valence of the ion
   C) concentration gradient for ion across the membrane
   D) temperature
   E) charge

Answer: A
Diff: 5    Page Ref: 99

26) Which of the following does NOT directly determine the rate at which an ion will move passively across a membrane?
   A) magnitude of driving force
   B) permeability of the membrane
   C) membrane surface area
   D) amount of ATP available
   E) concentration gradient

Answer: D
Diff: 4    Page Ref: 103

27) Which of the following would NOT increase the rate of simple diffusion across the phospholipid bilayer of the plasma membrane?
   A) greater available surface area
   B) greater lipid solubility
   C) greater concentration gradient
   D) greater number of protein carriers
   E) smaller size

Answer: D
Diff: 4    Page Ref: 103
28) Which of the following pairs of characteristics is more likely to make a substance diffuse through the cell membrane?
   A) large, polar molecule
   B) large, non-polar molecule
   C) small, polar molecule
   D) small, non-polar molecule
   E) large amphipathic molecule

   Answer: D
   Diff: 4   Page Ref: 103

29) Oxygen diffuses from blood into cells down its concentration gradient. As cells become more active and oxidative phosphorylation increases in the cell, which of the following occurs?
   A) The concentration gradient for oxygen decreases and oxygen movement into the cell decreases.
   B) The concentration gradient for oxygen increases and oxygen movement into the cell decreases.
   C) The concentration gradient for oxygen decreases and oxygen movement into the cell increases.
   D) The concentration gradient for oxygen increases and oxygen movement into the cell increases.
   E) The concentration gradient for oxygen and its rate of movement into the cell do not change.

   Answer: D
   Diff: 5   Page Ref: 103

30) How will increases in the concentration difference of an uncharged molecule across a membrane affect the rate of diffusion between two compartments?
   A) Diffusion rate will not be affected.
   B) Diffusion rate will increase.
   C) Diffusion rate will progressively decrease until zero.
   D) Diffusion rate will decrease.
   E) Diffusion rate will remain constant.

   Answer: B
   Diff: 5   Page Ref: 103

31) The concentration of sodium is greater in the extracellular fluid compared to the intracellular fluid. If the membrane potential was equal to the equilibrium potential for sodium, then what would be the direction of the electrochemical force acting on sodium?
   A) inward
   B) outward
   C) no force
   D) varies by cell
   E) varies based on concentration of potassium in the intracellular and extracellular fluids

   Answer: C
   Diff: 5   Page Ref: 99
32) One way that membrane surface area is increased in absorptive cells is through increasing the ________ of the apical membrane.
   A) thickness
   B) number of protein channels
   C) number of protein carriers
   D) folding
   E) receptor number

   Answer: D
   Diff: 4    Page Ref: 104

33) When a substance crossing the membrane is driven by diffusion, the net flux of that molecule can be described mathematically by ________.
   A) the Nernst equation
   B) Fick’s Law
   C) the Navier Stokes equation
   D) the Goldman Hodgkins Katz equation
   E) Einstein’s equation

   Answer: B
   Diff: 6    Page Ref: 104

34) Sodium permeability refers to a property of ________.
   A) sodium
   B) organelles
   C) molecules
   D) the cell membrane
   E) lipid soluble molecules only

   Answer: D
   Diff: 6    Page Ref: 104

35) Which of the following will NOT increase the net flux of an ion across a membrane?
   A) elevated permeability of the membrane
   B) increased concentration gradient across the membrane
   C) enhanced surface area
   D) more channels for that ion in the membrane
   E) reduced surface area

   Answer: E
   Diff: 4    Page Ref: 104

36) Molecules with a relatively high lipid solubility are capable of crossing the membrane ________.
   A) directly across the lipid bilayer
   B) only through specific protein channels
   C) only with the addition of energy
   D) indirectly by moving across a carrier protein
   E) through specific lipid channels

   Answer: A
   Diff: 5    Page Ref: 104
37) Which of the following molecules is least likely to diffuse through the phospholipid bilayer of the plasma membrane?
   A) fatty acid
   B) water
   C) disaccharide
   D) oxygen
   E) steroids
   Answer: C
   Diff: 5   Page Ref: 104

38) Which of the following is NOT true for all three of the following transport mechanisms: facilitated diffusion, primary active transport, and secondary active transport?
   A) The transport mechanism is specific for a particular solute(s).
   B) The transport mechanism requires a protein.
   C) The transport mechanism has a limit to the total number of molecules that can be transported per unit of time.
   D) The transport mechanism requires energy.
   E) Transport can be increased by increasing the number of transport molecules in the plasma membrane.
   Answer: D
   Diff: 5   Page Ref: 106

39) Which of the following transport mechanisms is passive?
   A) cotransport of glucose with sodium
   B) transport of sodium and potassium across the membrane by the Na⁺/K⁺ pump
   C) movement of sodium through ion channels
   D) countertransport of hydrogen ions with sodium
   E) movement of calcium out of the cytosol
   Answer: C
   Diff: 6   Page Ref: 108

40) A carrier is a transmembrane protein that moves molecules across the membrane through
   ________.
   A) small gaps in the fluid portion of the membrane
   B) a lipid–filled pore
   C) a water–filled pore
   D) opening its gate and allowing molecules through
   E) conformational changes in the carrier proteins
   Answer: E
   Diff: 5   Page Ref: 106

41) In general, the molecules that move through specific carrier proteins are determined by which of the following?
   A) a water–filled pore
   B) the molecule’s lipid solubility
   C) the size of a molecule
   D) the unique binding sites on the channel or carrier protein
   E) conformational changes in the pore
   Answer: D
   Diff: 5   Page Ref: 106
42) In facilitated diffusion, \_
A) a molecule is moved down its concentration gradient with the assistance of a protein carrier molecule, and no energy is required
B) a molecule is moved against its concentration gradient with the assistance of a protein carrier molecule and requires energy
C) a molecule is moved against its concentration gradient with the assistance of a protein carrier molecule, but no energy is required
D) a molecule is moved against its concentration gradient while Na is moved with its concentration gradient
E) a molecule is moved with its concentration gradient while Na is moved against its concentration gradient

Answer: A
Diff: 4 Page Ref: 106

43) Which of the following transport mechanisms requires energy?
A) primary active transport only
B) secondary active transport only
C) facilitated diffusion only
D) both primary and secondary active transport
E) both primary active transport and facilitated diffusion

Answer: D
Diff: 5 Page Ref: 108

44) In active transport, the affinity of the carrier protein for the molecule being transported is greater on which side of the membrane?
A) always the side facing the intracellular fluid
B) always the side facing the extracellular fluid
C) on the side where the molecule is in lower concentration
D) on the side where the molecule is in greater concentration
E) Neither; it is equal on both sides of the membrane.

Answer: C
Diff: 6 Page Ref: 109

45) During cotransport of glucose with sodium, sodium increases the affinity of the carrier molecule for glucose when the binding site is facing which side?
A) the extracellular fluid
B) the intracellular fluid
C) both sides are affected equally
D) cotransport does not involve changes in affinity of the carrier molecule
E) sodium decreases the affinity of the carrier for glucose--it does not increase affinity

Answer: A
Diff: 4 Page Ref: 119

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46) What is the main difference between primary and secondary active transport?
   A) the location of the binding sites
   B) the direction that molecules are being moved across the membrane
   C) One uses energy whereas the other requires no energy.
   D) the form of energy (ATP vs. electrochemical gradient) used to move molecules across the membrane
   E) The molecules that are transported access the binding sites differently.

   Answer: D  Diff: 6  Page Ref: 108

47) What are aquaporins?
   A) water-soluble molecules
   B) water channels
   C) ion channels
   D) ion transporters
   E) oxygen transporters

   Answer: B  Diff: 3  Page Ref: 108

48) Movement of water through aquaporins occurs by what process?
   A) active transport
   B) passive transport
   C) cotransport
   D) mediated transport
   E) electrical forces

   Answer: B  Diff: 3  Page Ref: 108

49) Most water molecules that cross the plasma membrane do so by _______.
   A) diffusion through the plasma membrane
   B) diffusion through ion channels
   C) diffusion through aquaporins
   D) active transport by ion channels
   E) active transport by aquaporins

   Answer: C  Diff: 4  Page Ref: 108

50) What transport process couples the movement of an ion against its electrochemical gradient to another ion that is moving down its electrochemical gradient that was established using cellular energy (ATP)?
   A) Primary active transport
   B) Secondary active transport
   C) Tertiary passive transport
   D) Primary passive transport
   E) Secondary passive transport

   Answer: B  Diff: 4  Page Ref: 110
51) Primary active transporters are unique in their ability to couple the movement of ions directly to what?
   A) another ion's electrochemical gradient
   B) ATP hydrolysis
   C) a carrier protein
   D) its electrochemical gradient
   E) a channel

   Answer: B
   Diff: 4 Page Ref: 109

52) In addition to functioning as a transporter, primary active transporters also function as _______ in order to make use of energy.
   A) channels
   B) carriers
   C) enzymes
   D) receptors
   E) structural proteins

   Answer: C
   Diff: 5 Page Ref: 109

53) The first step of the Na⁺/K⁺ pump's activity involves the binding of which of the following?
   A) 3 Na⁺ to their binding site on the outside of the cell
   B) 3 Na⁺ to their binding site on the inside of the cell
   C) 2 K⁺ to their binding site on the inside of the cell
   D) 2 K⁺ to their binding site on the outside of the cell
   E) 3 Na⁺ and 2 K⁺ to their respective binding sites

   Answer: B
   Diff: 6 Page Ref: 109

54) The hydrolysis of ATP on the Na⁺/K⁺ pump results in _______.
   A) Na⁺ adhering to its binding site
   B) a conformational change that exposes the K⁺ binding site to the outside of the cell
   C) a conformational change that exposes the Na⁺ binding site to the outside of the cell
   D) a conformational change that exposes the K⁺ binding site to the inside of the cell
   E) a conformational change that exposes the Na⁺ binding site to the inside of the cell

   Answer: C
   Diff: 6 Page Ref: 110

55) Na⁺ is released from its binding site on the Na⁺/K⁺ pump as a result of _______.
   A) the interaction of the Na⁺ and K⁺ binding sites
   B) the enzyme on the inside of the cell which cleaves the Na⁺ from its binding site
   C) the exposure of the Na⁺ binding site to the inside of the cell
   D) the conformational change decreasing the affinity of the Na⁺ binding site
   E) the binding of K⁺ to its binding site

   Answer: D
   Diff: 5 Page Ref: 110

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56) Which of the following statements about the Ca\(^{2+}\) pump is FALSE?
   A) Calcium is actively transported from an organelle into the cytosol.
   B) Calcium is actively transported from the cytosol into the extracellular fluid.
   C) It maintains low cytosolic calcium levels.
   D) It is a form of primary active transport.
   E) The pump is also an ATPase.
   Answer: A
   Diff: 4   Page Ref: 110

57) In secondary active transport with sodium, which of the following is FALSE?
   A) ATP is necessary to produce an electrochemical gradient for sodium ions across the cell membrane.
   B) Sodium binds to a carrier molecule, changing its binding properties for another molecule to be transported across the cell membrane.
   C) Sodium always moves into the cell.
   D) The molecule being transported into the cell may move in or out, depending on the carrier molecule.
   E) The molecule being transported moves down its electrochemical gradient.
   Answer: E
   Diff: 4   Page Ref: 110

58) Which of the following correctly describes cotransport of Y with sodium?
   A) Y and sodium both move into the cell.
   B) Y and sodium both move out of the cell.
   C) Y moves into the cell as sodium moves out of the cell.
   D) Y moves out of the cell as sodium moves into the cell.
   E) Not enough information is provided to answer this question.
   Answer: A
   Diff: 4   Page Ref: 118

59) Which of the following statements about glucose cotransport with sodium is true?
   A) Glucose moves into the cell while sodium moves out of the cell.
   B) Glucose moves out of the cell while sodium moves into the cell.
   C) Glucose and sodium both move into the cell.
   D) Glucose and sodium both move out of the cell.
   E) Sodium moves out of the cell, but the movement of glucose will vary based on the type of cell.
   Answer: C
   Diff: 4   Page Ref: 110

60) Which of the following statements about primary active transport is FALSE?
   A) The Na\(^+\)/K\(^+\) pump transports two potassium ions into the cell and three sodium ions out of the cell.
   B) The Ca\(^{2+}\) pump always moves calcium into the extracellular fluid.
   C) Phosphorylation of the carrier protein covalently regulates the carrier.
   D) ATP directly provides the energy for transport.
   E) Energy is used to change the affinity of the transporter for the solute being transported.
   Answer: B
   Diff: 4   Page Ref: 110

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61) The concentration of an anion inside a cell is 0.3%. The concentration of this anion outside the cell is 0.1%. How could the cell obtain more of this ion inside the cell?
   A) passive transport
   B) active transport
   C) osmosis
   D) exocytosis
   E) pinocytosis
   Answer: B
   Diff: 6   Page Ref: 108

62) What effect does diabetes mellitus have on blood osmolarity?
   A) None
   B) increases it, causing a hyperosmotic state compared to normal
   C) decreases it, causing a hyperosmotic state compared to normal
   D) increases it, causing a hypoosmotic state compared to normal
   E) decreases it, causing a hypoosmotic state compared to normal
   Answer: B
   Diff: 5   Page Ref: 116

63) Which of the following statements about the Na⁺/K⁺ pump is FALSE?
   A) Three sodium ions are moved out of the cell per ATP.
   B) Two potassium ions are moved into the cell per ATP.
   C) It is a form of primary active transport.
   D) The pump's activity is regulated through allosteric modulation.
   E) The pump is also an enzyme.
   Answer: D
   Diff: 6   Page Ref: 109

64) Sodium–linked glucose transport, where both Na⁺ and glucose are moving in the same direction, is an example of ________.
   A) countertransport
   B) symport
   C) antiport
   D) exchange
   E) primary active transport
   Answer: B
   Diff: 4   Page Ref: 110

65) The sodium–proton exchanger is an example of a(n) ________.
   A) antiporter
   B) cotransporter
   C) symporter
   D) primary active transporter
   E) passive transporter
   Answer: A
   Diff: 4   Page Ref: 110

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66) The flow of water across a membrane down its concentration gradient is called _______.
   A) leaking
   B) symporting
   C) facilitated diffusion
   D) osmosis
   E) antiporting

   Answer: D
   Diff: 3 Page Ref: 112

67) A membrane permeable to water separates a chamber into two compartments: A and B. Compartment A contains a 10 mM solution of non-permeating solute, whereas compartment B contains a 40 mM solution of non-permeating solute. Which of the following statements is true?
   A) Solute will move from side A to B, and water will move from side B to A.
   B) Solute will move from side B to A, and water will move from side A to B.
   C) Both water and solute will move from side B to A.
   D) Water will move from side A to B, but solute will not move.
   E) Water will move from side B to A, but solute will not move.

   Answer: D
   Diff: 5 Page Ref: 112

68) A cell is placed in a 200 mM NaCl solution. This solution is _______ and the cell will _______.
   A) isotonic: not change size
   B) hypotonic: shrink
   C) hypertonic: swell
   D) hypertonic: shrink
   E) hypertonic: swell

   Answer: D
   Diff: 5 Page Ref: 113

69) If a solution contains 0.1 M glucose along with 0.15 M NaCl, what is the osmolarity of this solution?
   A) 0.25 M
   B) 400 mOsm
   C) 250 mOsm
   D) 350 mOsm
   E) 0.4 M

   Answer: B
   Diff: 4 Page Ref: 113

70) If solution 1 (0.1 M glucose and 0.15 M NaCl) and solution 2 (0.4 M glucose) are separated by a membrane, then solution 1 is _______ relative to solution 2.
   A) iso-osmotic
   B) hyperosmotic
   C) hypo-osmotic
   D) hypertonic
   E) hypotonic

   Answer: A
   Diff: 5 Page Ref: 113
71) If there is a difference in osmolarity between a cell and its environment, water will move _______ its osmotic pressure gradient.
   A) across  
   B) down  
   C) up  
   D) through  
   E) between  
   Answer: C  
   Diff: 4    Page Ref: 113

72) The osmotic pressure of a solution is a(n) _______.  
   A) indication of its glucose concentration  
   B) direct measure of its solvent concentration  
   C) indirect measure of its solvent concentration  
   D) direct measure of its solute concentration  
   E) indirect measure of its solute concentration  
   Answer: E  
   Diff: 5    Page Ref: 113

73) A cell is placed into a solution that has the same osmolarity. However, one of the solutes in the solution is able to move across the membrane (the cell does not contain this solute). After a period of time, the solution into which the cell was placed would become _______.  
   A) isotonic  
   B) hypertonic  
   C) hypotonic  
   D) iso-osmotic  
   E) hyperosmotic  
   Answer: C  
   Diff: 6    Page Ref: 115

74) White blood cells are an important component of our immune system. One thing they do is consume and destroy bacteria by extending their plasma membrane around the bacterium and bringing it inside the cell in a vesicle. By what process do they engulf the bacterium?  
   A) phagocytosis  
   B) receptor-mediated endocytosis  
   C) pinocytosis  
   D) exocytosis  
   E) transcytosis  
   Answer: A  
   Diff: 4    Page Ref: 118

75) Vesicles formed during phagocytosis or endocytosis often fuse with the membrane of which of the following organelles?  
   A) rough endoplasmic reticulum  
   B) smooth endoplasmic reticulum  
   C) mitochondria  
   D) lysosome  
   E) peroxisome  
   Answer: D  
   Diff: 4    Page Ref: 118
76) Secretory vesicles are a part of what transport mechanism?
   A) phagocytosis
   B) pinocytosis
   C) receptor-mediated endocytosis
   D) exocytosis
   E) osmosis

   Answer: D
   Diff: 4  Page Ref: 118

77) Which of the following correctly describes phagocytosis?
   A) A cell synthesizes a product and packages it into vesicles. The product is released by
   phagocytosis.
   B) Cells engulf large particles, such as bacteria, by phagocytosis.
   C) A substance in the extracellular fluid binds to specific receptors for it on the cell
   membrane inducing the formation of a coated pit. The coated pit invaginates and enters
   the cell by phagocytosis.
   D) Cells non-specifically engulf extracellular fluid.
   E) Carrier proteins in the cell membrane transport a specific substance into the cell.

   Answer: B
   Diff: 4  Page Ref: 118

78) Epithelial cells are polarized with different structures on either side of the cell. The portion
   of the membrane that faces the lumen is called the ________ membrane.
   A) basolateral
   B) ablumenal
   C) basement
   D) apical
   E) transport

   Answer: D
   Diff: 3  Page Ref: 119

79) The extent of ion movement through the ________ space between epithelial cells is determined
   by the extent of ________ coupling between neighboring epithelial cells.
   A) transcellular : desmosomal
   B) transcellular : gap junctional
   C) transcellular : tight junctional
   D) paracellular : gap junctional
   E) paracellular : tight junctional

   Answer: E
   Diff: 5  Page Ref: 119
80) The movement of a number of molecules across the apical surface of the epithelial cell by secondary transporters is coupled to the _______ gradient that is maintained by the _______ on the basolateral surface of the epithelial cell.
A) Na⁺ : Na⁺/K⁺ pump
B) Na⁺ : Na⁺ channel
C) K⁺ : K⁺ channel
D) K⁺ : K⁺ pump
E) Ca²⁺ : Na⁺/K⁺ pump
Answer: A
Diff: 4 Page Ref: 121

81) When solute is actively transported across epithelium, what usually follows?
A) water movement in the same direction
B) water movement in the opposite direction
C) passive transport of the solute in the opposite direction
D) active transport of the solute in the opposite direction
E) passive transport of solute in the same direction
Answer: A
Diff: 4 Page Ref: 121

True/False Questions

1) Oxygen is able to move across the cell membrane based upon its thermal energy.
Answer: TRUE
Diff: 4 Page Ref: 96

2) The movement of a molecule is determined by its energy state, with that molecule moving from a lower to a higher energy state.
Answer: FALSE
Diff: 4 Page Ref: 96

3) In the presence of two or more ions, it is the sum of their concentration that determines the direction of movement of those ions across a membrane.
Answer: FALSE
Diff: 5 Page Ref: 99

4) Most of the time, the body is neutral with respect to its electrical charge due to the equal distribution of anions and cations within the body.
Answer: TRUE
Diff: 4 Page Ref: 97

5) If the membrane potential is equal to the equilibrium potential for an ion, individual ions will not move across the membrane in either direction.
Answer: FALSE
Diff: 6 Page Ref: 99

6) Ions move passively down their electrochemical gradient.
Answer: TRUE
Diff: 4 Page Ref: 99

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7) The rate at which molecules are actively transported across a membrane is determined by the rate of transport of individual pumps and the number of pumps in the membrane.

   Answer: TRUE  
   Diff: 4  Page Ref: 111

8) If the direction of the net flux of an ion is against its electrochemical gradient, then that transport is passive.

   Answer: FALSE  
   Diff: 4  Page Ref: 101

9) The driving force for simple diffusion is the electrochemical gradient.

   Answer: TRUE  
   Diff: 4  Page Ref: 103

10) Facilitated diffusion is a form of mediated transport.

    Answer: TRUE  
    Diff: 3  Page Ref: 106

11) In facilitated diffusion, the carrier protein has equal affinity for the molecule being transported on both sides of the membrane.

    Answer: TRUE  
    Diff: 4  Page Ref: 106

12) Ions can always move through the ion channels present in the plasma membrane as long as there is an electrochemical gradient to drive the movement.

    Answer: FALSE  
    Diff: 5  Page Ref: 108

13) Primary active transporters are similar to carriers, with the exception that they are able to use energy to move ions against their electrochemical gradient.

    Answer: TRUE  
    Diff: 5  Page Ref: 108

14) Pumps can move ions in either direction, as long as it is against that ion’s electrochemical gradient.

    Answer: FALSE  
    Diff: 6  Page Ref: 108

15) A cotransporter uses an ion’s concentration gradient to move a second ion or molecule in the same direction as the first.

    Answer: TRUE  
    Diff: 4  Page Ref: 110

16) The movement of water across a membrane is always a passive process.

    Answer: TRUE  
    Diff: 4  Page Ref: 112

17) Large differences in water concentration are required to drive water across a membrane.

    Answer: FALSE  
    Diff: 4  Page Ref: 113
18) At the resting membrane potential, a cell is at equilibrium.
   Answer: FALSE
   Diff: 4  Page Ref: 111

19) At the resting membrane potential, leakage of sodium ions into the cell and potassium ions out of the cell is balanced by the action of the Na+/K+ pump.
   Answer: TRUE
   Diff: 4  Page Ref: 111

20) Osmosis occurs through aquaporins.
   Answer: TRUE
   Diff: 4  Page Ref: 108

21) Phagosomes are formed following receptor-mediated endocytosis.
   Answer: FALSE
   Diff: 3  Page Ref: 118

22) Aquaporins are primary active transporters of water.
   Answer: FALSE
   Diff: 3  Page Ref: 108

Matching Questions

Match the following solutes with the region of highest concentration in body fluids.

1) Sodium.
   Diff: 3  Page Ref: 95

2) Potassium.
   Diff: 3  Page Ref: 95

3) Calcium.
   Diff: 4  Page Ref: 95

4) Chloride.
   Diff: 4  Page Ref: 95

5) Magnesium.
   Diff: 6  Page Ref: 95

6) Phosphate.
   Diff: 5  Page Ref: 95

7) Proteins.
   Diff: 4  Page Ref: 95

8) Glucose.
   Diff: 4  Page Ref: 95
Answers: 1) A  2) B  3) A  4) A  5) A  6) B  7) B  8) A

Match the following transport mechanisms with the correct energy requirement.

9) Primary active transport.  
   A) no energy required
   Diff: 2  Page Ref: 109
   B) requires energy

10) Secondary active transport.  
    Diff: 2  Page Ref: 110

11) Osmosis.  
    Diff: 3  Page Ref: 112

12) Simple diffusion.  
    Diff: 3  Page Ref: 102

13) Facilitated diffusion.  
    Diff: 4  Page Ref: 106

14) Movement of ion through ion channels.  
    Diff: 4  Page Ref: 108

Match the correct tonicity with solutions bathing cells.

15) The solution causes the cell to swell.
   Diff: 3  Page Ref: 115
   A) hypertonic
   B) isotonic
   C) hypotonic

16) The solution causes the cell to shrink.
   Diff: 3  Page Ref: 115

17) The cell in the solution does not change size.
   Diff: 2  Page Ref: 115

18) A solution containing 400 mOsm non-permeating solute.
   Diff: 4  Page Ref: 115

19) A solution containing 200 mM NaCl.
   Diff: 5  Page Ref: 115

20) A solution containing 200 mOsm NaCl.
   Diff: 5  Page Ref: 115

21) A solution containing 100 mM MgCl2.
   Diff: 5  Page Ref: 115

Match the following transport mechanisms with the correct description.

22) Molecules in membrane-bound vesicles are secreted from the cell.
   Diff: 3   Page Ref: 118
   A) phagocytosis
   B) pinocytosis
   C) receptor-mediated endocytosis
   D) exocytosis

23) A specific particle is brought into the cell by plasma membrane processes that extend around the particle forming a vesicle.
   Diff: 3   Page Ref: 118
   A) phagocytosis
   B) pinocytosis
   C) receptor-mediated endocytosis
   D) exocytosis

24) Mostly fluid is brought into the cell by invagination of the plasma membrane to form a vesicle.
   Diff: 3   Page Ref: 118
   A) phagocytosis
   B) pinocytosis
   C) receptor-mediated endocytosis
   D) exocytosis

25) A specific molecule is brought into the cell by interacting with membrane-bound receptors to form a coated pit.
   Diff: 3   Page Ref: 118
   A) phagocytosis
   B) pinocytosis
   C) receptor-mediated endocytosis
   D) exocytosis


Essay Questions

1) Describe the chemical and electrical driving forces that move ions across a membrane.

   Answer: The chemical driving force is created by the difference in an ion’s concentration across a membrane. This chemical gradient will cause ions to move passively via diffusion from a higher to lower concentration. However, the only chemical driving force acting on a specific ion is the concentration gradient of that ion. The concentration gradient for Na⁺ does not directly affect the diffusion of K⁺ across a membrane. However, because ions have an electrical charge, the movement of ions is also affected by electrical driving forces. These forces arise from the membrane potential, which is the difference in voltage across a membrane due to an unequal distribution of charged ions across the membrane. Ions can have either a positive (cation) or negative (anion) charge. When the positive ions balance the negative, the solution is said to be neutral. Intracellular fluids contain an excess of anions, whereas the cations are in excess outside the cell. Thus, the inside of the cell is relatively negative. Since opposite charges attract, the electrical driving force for a positive ion is inward, with the opposite being true for a negative ion (outward). There are several factors that can affect the direction and magnitude of ion movement. The direction can be affected by the polarity of the membrane potential and the ion (the idea that opposites attract). The magnitude of the electrical driving force is affected by the magnitude of the membrane potential and the quantity of charge carried by an ion. However, the direction which an ion moves is ultimately dependent upon a combination of the electrical and chemical gradients—its electrochemical gradient.

   Diff: 6   Page Ref: 99
2) In the end, it is the electrochemical gradient that determines the direction and magnitude of an ion's movement across a membrane. Describe this electrochemical gradient and how one can determine the direction of ion movement based on the electrical and chemical gradients.

Answer: The electrochemical gradient is created by the combination of the chemical and electrical gradient, as its name suggests. In order to determine which of the two forces is going to contribute the most to an ion's movement, the equilibrium potential of an ion must be determined. This requires knowledge of the concentration of the ion on either side of the membrane and the charge and valence of that ion. These values are then used to calculate equilibrium potential using the Nernst equation. If the equilibrium potential for an ion is equal to membrane potential, then there will be no net movement of that ion. That is not to say the ion cannot move across the membrane, but rather that the net flux is equal in both directions. The magnitude and polarity of an ion's equilibrium potential is dependent upon the size and direction of the ion's concentration gradient. The sign of the equilibrium potential goes in the direction opposite of the chemical gradient. In order to determine the direction in which an electrochemical gradient will move ions, a three step process must be employed: 1) determine the direction of the chemical and electrical gradients, 2) if they are in opposite directions, compare the size of the chemical gradient and electrical potential, and 3) if the equilibrium potential is larger than the membrane potential, then the chemical force is larger than the electrical force and ions will move in the direction of the chemical gradient. If the membrane potential is larger than the equilibrium potential, then the electrical forces are larger and ions will move in the direction of the electrical gradient.

Diff: 7 Page Ref: 99

3) Describe the factors that affect the rate of passive transport of molecules across a membrane.

Answer: The rate at which a molecule will passively move across a membrane is determined by three factors: magnitude of the driving force, membrane surface area, and permeability of the membrane. The chemical driving force will not only affect the direction that a molecule moves across the membrane, but also the rate at which it travels. The greater the concentration gradient, the higher the net flux of that molecule. Keep in mind that molecules can move in both directions, but we are referring to the net flux of molecules. Over time, if there was no mechanism to move that molecule in the other direction, the concentration gradient would be progressively reduced, thereby reducing the rate at which that molecule would move across the membrane. At the same time, the rate a molecule can move across a membrane is directly proportional to the membrane surface area of the cells. Our bodies have used this to their advantage; substantial infolding of the cellular membrane exists in tissues that function in molecule transport. Finally, the permeability of the membrane will also affect molecule flux. The higher the permeability of a molecule through the membrane, the greater its rate of flux. Permeability refers to the ease with which a molecule will cross the membrane. This is especially true for molecules with a relatively high lipid solubility. These molecules can diffuse directly across the membrane in proportion to their lipid solubility without the help of a protein channel. For the more hydrophilic ions, their ability to permeate a membrane depends upon the presence of proteins in the membrane that will allow them to cross the membrane. The greater the density of open channels or functioning transporters, the greater the movement of molecules across that membrane.

Diff: 6 Page Ref: 103
4) Since diffusion is defined as the random movement of molecules, how can this random movement result in the net movement of ions across a membrane?

Answer: Diffusion is a general term that describes the movement of ions in solution. Diffusion occurs as a consequence of the thermal motion of ions, which is, by definition, a random process. As temperature increases, these molecules move more quickly. Those ions are continuously running into other ions, which changes their direction of motion in a manner that is not predictable (hence, the randomness of their motion). However, if there are more ions behind a molecule than in front (as would occur if an ion were moving from a higher to lower concentration), then the ion will move further in the forward direction before hitting another molecule. This will continue to happen such that an increasing number of ions will move further in the direction with the lower concentration and, therefore, diffuse. Thus, while individual molecules move randomly, the population of molecules will always move down their concentration gradient.

Diff: 4  Page Ref: 103

5) Describe the factors that will affect the ability of a molecule to diffuse through a cell membrane.

Answer: The first factor that will affect the permeability of a membrane to simple diffusion is the lipid solubility of the molecule. The more lipid soluble a molecule is, the greater the chance that molecules will be able to diffuse directly across the lipid bilayer. At the same time, the lipid composition of the membrane will affect the permeability of lipid soluble molecules through the membrane. Second, the size and shape of a molecule will affect its permeability. As a molecule gets larger and more irregular in shape, it will move through the membrane more slowly, thereby reducing its permeability.

Temperature will also have a substantial effect on how quickly a molecule can move across the membrane. The higher the temperature, the greater that molecule’s membrane permeability. However, within the body, temperature tends to change little, which means that temperature should only have a small affect on membrane permeability. Finally, the thickness of the layer of cells that must be crossed will also affect diffusion. The further a molecule has to move, the longer it will take to get there, thereby reducing that molecule’s permeability.

Diff: 5  Page Ref: 104

6) Describe the process of facilitated diffusion and the proteins involved in that process.

Answer: Facilitated diffusion describes a process whereby molecules that cannot move through the membrane are allowed to cross the membrane through membrane proteins called carriers. Carrier proteins have binding sites for specific molecules that allow them to selectively move those molecules across the membrane. However, those molecules will always move down their electrochemical gradient. Thus, these proteins can move molecules in either direction (in or out of cell). Once the molecule has attached to its binding site, the molecule goes through a conformational change that allows that molecule to be released on the other side of the membrane. Due to the presence of these binding sites, the carriers can be saturated as the concentration gradient is increased. Thus, at a high concentration, the carriers move the molecules across the membrane at their maximal rate of flux. The saturation kinetics of individual carriers will alter the rate of flux as will the number of active carriers that are present on the membrane. Since it is the electrochemical gradient of a molecule that drives facilitated diffusion, anything that affects the electrochemical driving force will alter the rates of ion movement through these proteins.

Diff: 5  Page Ref: 106
7) Describe the processes of primary and secondary active transport, including the factors that can affect active transport.

Answer: Active transport, by definition, requires energy, which means that molecules are going to be moved up their concentration gradient. Primary active transport refers to the movement of molecules that are directly coupled to cellular energy in the form of ATP, whereas with secondary active transport, the movement of a molecule is coupled to a second molecule's electrochemical gradient that is maintained with ATP. The proteins that function as primary active transporters are called pumps. They contain an enzyme within their structure that acts as an ATPase to hydrolyze ATP for energy. Like carriers, these pumps have binding sites that can become saturated at high molecule concentrations.

Secondary active transport is mediated by two types of proteins characterized by the direction in which the molecules are moving relative to one another. Cotransporters (symport) are proteins that move molecules across a membrane against their electrochemical gradient by coupling that movement to the electrochemical gradient of a second molecule, both of which move in the same direction. Countertransporters (antiporters or exchangers) are proteins that move molecules in opposite directions (the electrochemical gradient of one molecule is used to move another molecule against its electrochemical gradient in the opposite direction to the first). Since these pumps, antiporters and symports, all have a binding site, they will all demonstrate saturation kinetics, which means they will have a maximal transport rate. At the same time, the rate of transport could be increased by having more of these proteins present.

Diff: 6  Page Ref: 109

8) Describe the process whereby the Na⁺/K⁺ pump is involved in moving those ions across a membrane.

Answer: The Na⁺ binding site on the Na⁺/K⁺ pump faces inward. Once 3 Na⁺ have attached themselves to this binding site, an ATP is hydrolyzed and the pump phosphorylated, which changes the conformation of the Na⁺/K⁺ pump. This conformational change leaves the Na⁺ binding domain that is bound to the 3 Na⁺ molecules facing the outside of the cell. Another effect of that conformational change is to decrease the affinity of the binding site for Na⁺. Thus, once the 3 Na⁺ face the outside of the cell, they are released. However, the affinity of a K⁺ binding site is also altered by the original phosphorylation and subsequent conformational change; their affinity for K⁺ is increased such that 2 K⁺ bind. At that time, the phosphorylated site is dephosphorylated. Once the dephosphorylation takes place, the Na⁺/K⁺ pump returns to its original conformation with K⁺ binding site now facing the inside of the cell. As expected, the conformational changes return the affinity of K⁺ binding site to its original state, which has a low affinity for K⁺. This causes the release of K⁺ to the inside of the cell.

Diff: 6  Page Ref: 109
9) Describe the process whereby water moves passively across a membrane.
   Answer: Water moves across a cell membrane through the process of osmosis. In osmosis, water moves down its concentration gradient. Rarely do we think about a concentration gradient for water, but as more solutes are present in a solution, the concentration of water is decreased (pure water is a 55.5 M solution). Therefore, water will always move down its concentration gradient from a solution higher in water concentration (lower solute concentration) to a solution with lower water concentration (higher solute concentration). What drives water movement is the total number of solute particles in a solution, which is referred to as osmolarity. In fact, it only takes a very small change in osmolarity to cause a substantial amount of water to move. We tend to talk about the driving force for water movement as an osmotic pressure. The osmotic pressure of a solution increases as the total solute concentration (osmolarity) increases. However, water will always move toward the solution with the greatest osmotic pressure.

Because water is polar, its ability to pass the lipid bilayer is limited. Most cell membranes have aquaporins (water channels) in them, which allow water to move across the membrane by osmosis.

Diff: 7  Page Ref: 112

10) Discuss the differences between the osmolarity and tonicity of a solution.
   Answer: Osmolarity refers to the number of solute particles within a solution, whereas tonicity refers to the effect of a solution on cell volume. Thus, a solution that is iso-osmotic is not necessarily isotonic. Whether the solution is isotonic will depend upon the solute content of the cell and the permeability of that cell’s membrane. If the extracellular solution contains an ion that is membrane permeant and that ion is not equally distributed intracellularly (lower concentration on the inside), that molecule will diffuse into the cell. As that ion diffuses into the cell, it will drive water with it to maintain osmotic balance. Thus, while the extracellular solution remains iso-osmotic relative to the intracellular solution, the cell will not be isotonic since the influx of water will cause the cell to swell or even burst. Therefore, the extracellular solution was hypotonic with respect to cell volume. The opposite could be true if there was a membrane permeant ion intracellularly that was at a lower concentration in the extracellular solution: the extracellular solution would be hypertonic and the cell would shrivel as water moved outward. Thus, while these terms have sometimes been used interchangeably, they are not synonymous.

Diff: 6  Page Ref: 115

Short Answer Questions

1) If glucose molecules outside a cell have higher energy than those inside the cell, in which direction will those molecules move?
   Answer: inward
   Diff: 6  Page Ref: 95

2) With a concentration of 10 mM glucose and 5 mM K⁺ on the outside of the membrane and 1 mM glucose and 140 mM K⁺ on the inside, in which direction will the glucose move if the membrane is permeable to glucose?
   Answer: inward
   Diff: 4  Page Ref: 96
3) If the solutions on either side of the membrane have an unequal distribution of charged ions with the inside having an excess of anions, the inside of the cell would be _______ relative to the outside.
Answer: negative  
Diff: 4  Page Ref: 98

4) Ions with a positive charge are called _______; ions with a negative charge are called _______. Ions with a positive charge attract ions with a _______ charge.
Answer: cations : anions : negative  
Diff: 3  Page Ref: 97

5) As the magnitude of charge difference across the membrane increases, how would that affect the magnitude of the electrical driving force across that membrane?
Answer: The electrical driving force will increase.  
Diff: 5  Page Ref: 99

6) If one ion carried a greater quantity of charge than another, how would that affect the electrical driving force for the ion with the greater quantity of charge?
Answer: The electrical driving force would increase.  
Diff: 5  Page Ref: 99

7) Use the information in the table below to answer the questions.

<table>
<thead>
<tr>
<th>Ion</th>
<th>ECF</th>
<th>ICF</th>
</tr>
</thead>
<tbody>
<tr>
<td>X+</td>
<td>120 mM</td>
<td>30 mM</td>
</tr>
<tr>
<td>A-</td>
<td>100 mM</td>
<td>100 mM</td>
</tr>
<tr>
<td>B-</td>
<td>140 mM</td>
<td>30 mM</td>
</tr>
</tbody>
</table>

a) Which ion(s) have a net chemical force acting to move the ion(s) into the cell?
b) Which ion(s) have a net electrical force acting to move the ion(s) into the cell?
c) Would the equilibrium potential for X+ be a positive or negative value?
Answer: a) X+ and B-; b) X+; c) positive  
Diff: 6  Page Ref: 99

8) If the concentration of sodium in the extracellular fluid increased, then the equilibrium potential would (become more positive / become less positive / remain the same)?
Answer: become more positive  
Diff: 5  Page Ref: 99

9) Assuming that for K+ (higher concentration inside cell), $E_K^+ = -90 \text{ mV}$ and $V_M = -70 \text{ mV}$, what is the direction of the electrochemical gradient?
Answer: outward  
Diff: 6  Page Ref: 100

10) Assuming that for Na+ (higher concentration outside cell), $E_{Na^+} = +60 \text{ mV}$ and $V_M = -70 \text{ mV}$, what is the direction of the electrochemical gradient?
Answer: inward  
Diff: 6  Page Ref: 100

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11) Choose the correct word in parentheses. Anion Q has an equilibrium potential of ~60 mV. Q is located in greater concentration (inside / outside) the cell. When a cell is at rest (~70 mV), the direction of the electrochemical force acting on Q is to move it (into / out of) the cell? If channels for Q suddenly opened, the membrane potential would become (more negative / less negative / or not change)?
Answer: outside, out of, less negative
Diff: 8 Page Ref: 100

12) As an ion moves passively across a membrane into the cell, the progressive increase in concentration within the cell will ______ the net flux across the membrane.
Answer: decrease
Diff: 5 Page Ref: 99

13) The process of diffusion involves ________.
Answer: the random movement of individual molecules due to thermal motion
Diff: 5 Page Ref: 103

14) As the molecular weight of a molecule increases, its membrane permeability ________.
Answer: decreases
Diff: 4 Page Ref: 105

15) As the thickness of a layer of epithelial cells decreases, the permeability of that cell layer will ________.
Answer: increase
Diff: 5 Page Ref: 105

16) Does the following graph represent simple diffusion, facilitated diffusion, or both?

![Graph of Net Flux vs. Concentration Gradient](image)
Answer: facilitated diffusion
Diff: 4 Page Ref: 107

17) Choose the correct word in parentheses. During cotransport with sodium ions, a molecule is (actively / passively) transported (into / out of) the cell.
Answer: actively : into
Diff: 5 Page Ref: 110

18) Insulin triggers the insert ion of what protein into the cell membrane of its target cell?
Answer: GLUT 4
Diff: 5 Page Ref: 107
19) Fill in the blanks with the correct number, and circle the correct response in parentheses. The Na+/K+ pump transports ______ sodium ions (into / out of) the cell and ______ potassium ions (into / out of) the cell per ATP hydrolyzed.
Answer: three : out of : two : into
Diff: 5 Page Ref: 109

20) Like carrier proteins, pumps can become ______, reaching a maximal net flux beyond which further increases in concentration will not affect net flux.
Answer: saturated
Diff: 6 Page Ref: 109

21) Primary active transporters are many times called ______ because they act as enzymes to acquire energy.
Answer: ATPases
Diff: 5 Page Ref: 109

22) The primary role for the Na+/K+ pump is ______.
Answer: the maintenance of Na+ and K+ concentrations on either side of the membrane
Diff: 5 Page Ref: 110

23) The more solutes present in a solution, the ______ the concentration of water in that solution.
Answer: lower
Diff: 4 Page Ref: 113

24) If there is 0.2 M glucose along with 0.15 M NaCl in solution, what is the osmolarity of this solution?
Answer: 500 mOsm or 0.5 Osm
Diff: 4 Page Ref: 113

25) If a 300 mOsm cell (10 mOsm of which are from the membrane permeable molecule urea) is placed into 300 mOsm solution containing no urea, what will happen to the cell?
Answer: shrink (shriveled)
Diff: 6 Page Ref: 115

26) If a 300 mOsm cell that contains no urea is placed into 300 mOsm solution (10 mOsm of which are from the membrane permeable molecule urea), what will happen to the cell?
Answer: swell
Diff: 6 Page Ref: 115

27) Given a beaker with a membrane separating two solutions, initially of equal volume. The solution on side A is 100 mM KCl while the solution on side B is 150 mM sucrose. The membrane is not permeable to ions or carbohydrates. What direction will water move?
Answer: Side B to side A
Diff: 6 Page Ref: 115
28) In epithelial tissue, the cells are linked together by ______, which prevent paracellular movement from lumen to extracellular fluid.
   
   Answer: tight junctions
   
   Diff: 4  Page Ref: 119

29) In epithelial tissue, the portion of the plasma membrane facing the lumen is called the ______. The portion of the plasma membrane facing the extracellular fluid is called the ______.
   
   Answer: apical membrane : basolateral membrane
   
   Diff: 5  Page Ref: 119

30) In epithelial transport, movement from the internal environment to the external environment is called ______, whereas movement from the external environment to the internal environment is called ______.
   
   Answer: secretion : absorption
   
   Diff: 5  Page Ref: 119
Chapter 5  Chemical Messengers

Multiple Choice Questions

1) In chemical communication between cells, a _______ cell secretes a chemical messenger that binds to _______ on the _______ cell.
   A) gap : connexons : secretory
   B) secretory : connexons : gap
   C) secretory : connexons : target
   D) target : receptors : secretory
   E) secretory : receptors : target

Answer: E  
Diff: 2  Page Ref: 128

2) Direct communication between cells in contact with one another is accomplished through _______.
   A) ligands
   B) receptors
   C) gap junctions
   D) paracrine chemical messengers
   E) endocrine hormones

Answer: C  
Diff: 3  Page Ref: 127

3) Which type of chemical messenger, when released, binds to receptors on the cell that released the chemical messenger?
   A) neurohormone
   B) autocrine
   C) hormone
   D) cytokine
   E) neurotransmitter

Answer: B  
Diff: 3  Page Ref: 129

4) Which type of chemical messenger is released into the bloodstream by an endocrine gland where it can affect target cells throughout the body?
   A) paracrine
   B) autocrine
   C) hormone
   D) cytokine
   E) neurotransmitter

Answer: C  
Diff: 3  Page Ref: 130

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5) Which type of chemical messenger is released from the axon terminal of a neuron and directly communicates with other cells?
   A) paracrine
   B) autocrine
   C) hormone
   D) cytokine
   E) neurotransmitter
   Answer: E
   Diff: 3    Page Ref: 129

6) Communication across a synapse is initiated by the release of a neurotransmitter from the _______ region of the neuron.
   A) postsynaptic
   B) axon terminal
   C) perisynaptic
   D) dendritic
   E) axon hillock
   Answer: B
   Diff: 4    Page Ref: 129

7) Vasopressin (antidiuretic hormone), which is released from the posterior pituitary, is an example of this type of chemical messenger.
   A) cytokine
   B) autocrine
   C) paracrine
   D) neurohormone
   E) neurotransmitter
   Answer: D
   Diff: 4    Page Ref: 130

8) Which of the following classes of chemical messengers moves to the target cell by diffusion?
   A) paracrine only
   B) hormone only
   C) neurotransmitter only
   D) both paracrine and neurotransmitter
   E) both hormone and neurotransmitter
   Answer: D
   Diff: 4    Page Ref: 129

9) Which of the following classes of chemical messengers travels in the bloodstream to the target cell?
   A) paracrine only
   B) hormone only
   C) neurotransmitter only
   D) both paracrine and neurotransmitter
   E) both hormone and neurotransmitter
   Answer: B
   Diff: 4    Page Ref: 129
10) Which of the following chemical messengers is lipophilic?
   A) glutamate
   B) histamine
   C) norepinephrine
   D) prostaglandin
   E) gamma-amino butyric acid

   Answer: D
   Diff: 4   Page Ref: 130

11) Which of the following chemical messengers is lipophilic and is therefore able to cross the cell membrane?
   A) amino acids
   B) amines (excluding thyroid hormone)
   C) peptides
   D) eicosanoids
   E) proteins

   Answer: D
   Diff: 4   Page Ref: 130

12) Histamine acts as a(n) _______ in its role in inflammation.
   A) paracrine
   B) autocrine
   C) hormone
   D) neurotransmitter
   E) cytokine

   Answer: A
   Diff: 5   Page Ref: 129

13) Which of the following chemical messengers is NOT derived from an amino acid?
   A) epinephrine
   B) testosterone
   C) histamine
   D) thyroid hormones
   E) serotonin

   Answer: B
   Diff: 5   Page Ref: 131

14) All the messengers function as hormones for which of the following chemical classes?
   A) amines
   B) peptides/proteins
   C) steroids
   D) eicosanoids
   E) amino acids

   Answer: C
   Diff: 4   Page Ref: 131
15) All the messengers function as neurotransmitters for which of the following chemical classes?
   A) amines
   B) peptides/proteins
   C) steroids
   D) eicosanoids
   E) amino acids
   Answer: E  Diff: 4  Page Ref: 131

16) In order to convert the amino acid glutamate to gamma–amino butyric acid, cells must produce the enzyme _______ that catalyzes this reaction.
   A) glutamic acid dehydrogenase
   B) glutamate dehydrogenase
   C) glutamic acid hydroxylase
   D) glutamate hydrolase
   E) glutamic acid decarboxylase
   Answer: E  Diff: 6  Page Ref: 131

17) The body is able to synthesize the amino acids glutamate, aspartate, and glycine from _______.
   A) essential amino acids
   B) the degradation of fatty acids
   C) the degradation of glucose in glycolysis and the Krebs cycle
   D) the glycerol in a triglyceride
   E) cholesterol
   Answer: C  Diff: 7  Page Ref: 131

18) Cells that secrete dopamine must contain which enzymes?
   A) dopamine β–hydroxylase only
   B) dopa decarboxylase only
   C) tyrosine β–hydroxylase
   D) dopamine β–hydroxylase and dopa decarboxylase only
   E) tyrosine β–hydroxylase and dopa decarboxylase
   Answer: E  Diff: 5  Page Ref: 131

19) Cells that secrete epinephrine must contain which enzymes?
   A) dopamine β–hydroxylase and dopa decarboxylase only
   B) dopamine β–hydroxylase, tyrosine β–hydroxylase, and dopa decarboxylase only
   C) tyrosine β–hydroxylase and phenylethanolamine N–methyl transferase only
   D) dopamine β–hydroxylase, tyrosine β–hydroxylase, phenylethanolamine N–methyl transferase, and dopa decarboxylase
   E) phenylethanolamine N–methyl transferase and dopa decarboxylase only
   Answer: D  Diff: 5  Page Ref: 132
20) Catecholamines are derived from what amino acid?
   A) glutamate
   B) tryptophan
   C) tyrosine
   D) histidine
   E) glycine
   Answer: C
   Diff: 4   Page Ref: 131

21) Thyroid hormones are synthesized from what amino acid?
   A) glutamate
   B) tryptophan
   C) tyrosine
   D) histidine
   E) glycine
   Answer: C
   Diff: 4   Page Ref: 131

22) Peptide/protein messengers are translated from ribosomes ________.
   A) free in the cytosol
   B) attached to the rough endoplasmic reticulum
   C) attached to the smooth endoplasmic reticulum
   D) attached to the Golgi apparatus
   E) attached to the nuclear envelope
   Answer: B
   Diff: 3   Page Ref: 132

23) While in the rough endoplasmic reticulum, what is the initial polypeptide formed during protein synthesis called?
   A) exon
   B) peptide
   C) propeptide
   D) prepropeptide
   E) prepeptide
   Answer: D
   Diff: 4   Page Ref: 132

24) Once a steroid hormone is synthesized, it is ________.
   A) immediately capable of diffusing across the membrane
   B) stored in a vesicle until released
   C) bound to albumin until released from the cell
   D) stored in a unique protein structure that maintains steroids in the cell
   E) bound to the mitochondria until released
   Answer: A
   Diff: 4   Page Ref: 132
25) What organelle packages peptide/protein messengers into secretory vesicles?
   A) nucleus  
   B) rough endoplasmic reticulum  
   C) smooth endoplasmic reticulum  
   D) Golgi apparatus  
   E) lysosomes  
   Answer: D  
   Diff: 3   Page Ref: 132

26) Name the enzyme that, when activated, will directly release arachidonic acid from a membrane phospholipid.  
   A) Phospholipase A₂  
   B) Phospholipase C  
   C) Phospholipase D  
   D) Protein kinase A  
   E) Protein kinase C  
   Answer: A  
   Diff: 5   Page Ref: 133

27) In order to synthesize eicosanoids, _______ catalyzes the release of _______ from a membrane phospholipid.  
   A) phospholipase A₂ : cholesterol  
   B) phospholipase C : arachidonic acid  
   C) phospholipase A₂ : arachidonic acid  
   D) phospholipase C : cholesterol  
   E) phospholipase C : inositol biphosphate  
   Answer: C  
   Diff: 6   Page Ref: 133

28) An equilibrium exists between a hormone that is bound to a carrier protein and a free hormone such that, as the amount of free hormone increases, _______.  
   A) the amount of bound hormone will not change  
   B) more hormone must be synthesized to directly replace the free hormones  
   C) more bound hormone will be released from its carrier proteins  
   D) more free hormone will become bound to carrier proteins  
   E) cells will be stimulated to secrete more free hormone  
   Answer: D  
   Diff: 5   Page Ref: 134

29) Lipophilic chemical messengers are poorly soluble in water. However, many of these lipophilic messengers are transported throughout the body. Their transport in blood (water) is facilitated by _______.  
   A) chylomicrons  
   B) lipoproteins  
   C) carrier proteins  
   D) red blood cells  
   E) white blood cells  
   Answer: C  
   Diff: 4   Page Ref: 134
30) What enzyme catalyzes synthesis of prostaglandins from arachidonic acid?
   A) phospholipase C  
   B) phospholipase A₂  
   C) lipoxygenase  
   D) cyclooxygenase  
   E) tyrosine β-hydroxylase  
   Answer: D  
   Diff: 5  Page Ref: 133

31) Androgens are precursor molecules for the synthesis of _______.
   A) estradiol  
   B) cortisol  
   C) progesterone  
   D) aldosterone  
   E) cholesterol  
   Answer: A  
   Diff: 7  Page Ref: 132

32) Progesterone is a precursor for the synthesis of _______.
   A) estradiol  
   B) cortisol  
   C) testosterone  
   D) dehydroepiandrosterone  
   E) androstenedione  
   Answer: B  
   Diff: 7  Page Ref: 132

33) Aspirin decreases inflammation by inhibiting the actions of what enzyme?
   A) phospholipase A₂  
   B) cyclooxygenase  
   C) lipoxygenase  
   D) protein kinase A  
   E) dopa decarboxylase  
   Answer: B  
   Diff: 5  Page Ref: 133

34) Hormones that are dissolved in blood typically exhibit a half-life on the order of _______, whereas hormones that are bound to carrier proteins can remain undegraded for _______.
   A) seconds : hours  
   B) seconds : minutes  
   C) minutes : hours  
   D) hours : minutes  
   E) minutes : seconds  
   Answer: C  
   Diff: 4  Page Ref: 135
35) The β₁ adrenergic receptor has the greatest affinity for what messenger?
   A) norepinephrine
   B) epinephrine and norepinephrine equally
   C) epinephrine
   D) dopamine
   E) serotonin

   Answer: B
   Diff: 4   Page Ref: 136

36) The α₁ adrenergic receptor has the greatest affinity for what messenger?
   A) norepinephrine
   B) epinephrine and norepinephrine equally
   C) epinephrine
   D) dopamine
   E) serotonin

   Answer: A
   Diff: 4   Page Ref: 136

37) Which of the following will NOT affect the magnitude of a cell’s response to a specific hydrophilic ligand?
   A) ligand concentration
   B) number of receptors
   C) receptor upregulation
   D) affinity of the receptor for the ligand
   E) lipid solubility of the ligand

   Answer: E
   Diff: 5   Page Ref: 136

38) Chronic exposure to a ligand (messenger) ________ the receptor population for that chemical messenger on the target cell.
   A) decreases the specificity of
   B) decreases the affinity of
   C) upregulates
   D) downregulates
   E) changes the conformation of

   Answer: D
   Diff: 5   Page Ref: 137

39) Which of the following statements best describes the release of lipophobic messengers?
   A) Lipophobic messengers are stored in vesicles and released by exocytosis in response to a stimulus.
   B) Lipophobic messengers are stored in vesicles and released by simple diffusion in response to a stimulus.
   C) Lipophobic messengers are released immediately upon synthesis by simple diffusion.
   D) Lipophobic messengers are stored in vesicles and released by exocytosis immediately after synthesis.
   E) Lipophobic messengers are stored free in the cytosol and released by simple diffusion in response to a stimulus.

   Answer: A
   Diff: 4   Page Ref: 131
40) Which of the following statements best describes the release of a lipophilic messenger?
   A) Lipophilic messengers are stored in vesicles and released by exocytosis in response to a stimulus.
   B) Lipophilic messengers are stored in vesicles and released by simple diffusion in response to a stimulus.
   C) Lipophilic messengers are released immediately upon synthesis by simple diffusion.
   D) Lipophilic messengers are stored in vesicles and released by exocytosis immediately after synthesis.
   E) Lipophilic messengers are stored free in the cytosol and released by simple diffusion in response to a stimulus.
   Answer: C

41) Lipophilic hormones are transported in blood _______ and bind to receptors located _______.
   A) dissolved in the plasma : on the plasma membrane of the target cell
   B) dissolved in the plasma : inside the target cell
   C) bound to carrier proteins : on the plasma membrane of the target cell
   D) bound to carrier proteins : inside the target cell
   E) inside red blood cells : inside the target cell
   Answer: D

42) What is a molecule that is similar in structure to a messenger and binds with that messenger’s receptor to stimulate a response from the target cell called?
   A) blocker
   B) synergist
   C) antagonist
   D) agonist
   E) protagonist
   Answer: D

43) Which of the following is a non-steroidal antiinflammatory drug?
   A) aspirin
   B) cortisone
   C) testosterone
   D) prostaglandins
   E) morphine
   Answer: A
44) What is the portion of a gene that is capable of being bound by a particular hormone–receptor complex to stimulate alterations in that gene’s expression?
   A) nuclear receptor
   B) hormone response element
   C) intron
   D) exon
   E) promoter
   Answer: B
   Diff: 4  Page Ref: 138

45) The affinity of a receptor for its ligand is a measure of _______.
   A) the strength of binding between ligand and receptor
   B) the number of binding sites available for the ligand
   C) the ability of the ligand to permeate the plasma membrane and reach its receptor
   D) the response produced in the target cell when the ligand binds to the receptor
   E) the percent of receptors on a specific target cell with bound ligand
   Answer: A
   Diff: 4  Page Ref: 137

46) Typical responses to _______ messengers require a long time to develop because they necessitate transcription of mRNA and translation of that mRNA into a functional protein.
   A) lipophobic
   B) lipophilic
   C) amino acid
   D) protein
   E) peptide
   Answer: B
   Diff: 4  Page Ref: 138

47) Which of the following describes ion channels that are coupled to membrane receptors such that their gating properties (opening and closing) are altered by messenger binding.
   A) Enzyme–linked receptors
   B) G protein–linked channels
   C) Voltage–gated channels
   D) Ligand–gated channels
   E) Potential–gated channels
   Answer: D
   Diff: 5  Page Ref: 138

48) Slow gated channels are identified as such because, once the receptor is bound by the ligand, the receptor must first activate a(n) _______ prior to the channel opening or closing.
   A) G protein
   B) ion channel
   C) enzyme
   D) RNA polymerase
   E) hormone response element
   Answer: A
   Diff: 4  Page Ref: 138
49) Differences in the rate of activity between fast and slow ligand-gated channels is caused by 

- A) ligand selectivity
- B) G protein activity gating the fast channel
- C) ligands gating both channels to the closed state
- D) G protein activity gating the slow channel
- E) ligand affinity

Answer: D

Diff: 3 Page Ref: 138

50) Which of the following ions can act as a second messenger?

- A) sodium only
- B) potassium only
- C) calcium only
- D) both sodium and potassium
- E) both sodium and calcium

Answer: C

Diff: 3 Page Ref: 139

51) Opening channels for which of the following ions can trigger exocytosis?

- A) sodium
- B) potassium
- C) calcium
- D) chloride
- E) magnesium

Answer: C

Diff: 3 Page Ref: 139

52) Which of the following ions binds to calmodulin to ultimately activate a protein kinase?

- A) sodium
- B) potassium
- C) calcium
- D) chloride
- E) magnesium

Answer: C

Diff: 4 Page Ref: 139

53) Binding of acetylcholine to a nicotinic cholinergic receptor on skeletal muscle will lead directly to what type of movement across the cell membrane?

- A) rapid influx of Na\(^+\) through its channel and no movement of K\(^+\)
- B) rapid influx of K\(^+\) through its channel and no movement of Na\(^+\)
- C) rapid influx of Na\(^+\) and slow outward flux of K\(^+\)
- D) slow influx of Na\(^+\) through its channel and rapid outward flux of K\(^+\)
- E) fast influx of Na\(^+\) and K\(^+\) through its channel

Answer: C

Diff: 5 Page Ref: 139
54) In its role as a ________, calcium binds to _______ forming a complex that activates a protein kinase.
   A) second messenger : a phosphatase
   B) first messenger : a hydrolase
   C) second messenger : calmodulin
   D) first messenger : a protein kinase
   E) third messenger : calmodulin

   Answer: C
   Diff: 5 Page Ref: 139

55) Which of the following statements best describes the function of tyrosine kinase?
   A) It catalyzes the formation of dopamine from L-dopa.
   B) It catalyzes the formation of norepinephrine from dopamine.
   C) It catalyzes the phosphorylation of a protein inside a cell.
   D) It catalyzes the phosphorylation of a protein in the extracellular fluid.
   E) It sequesters calcium in the cytosol.

   Answer: C
   Diff: 5 Page Ref: 140

56) Which of the following is NOT an integral membrane protein?
   A) tyrosine kinase
   B) calmodulin
   C) G proteins
   D) adenylate cyclase
   E) phospholipase C

   Answer: B
   Diff: 6 Page Ref: 139

57) Which of the following enzymes directly covalently modulates a protein?
   A) tyrosine kinase
   B) tyrosine β-hydroxylase
   C) adenylate cyclase
   D) phosphodiesterase
   E) phospholipase C

   Answer: A
   Diff: 4 Page Ref: 140

58) The function of a second messenger system is to ________.
   A) buffer a cells response to a ligand
   B) isolate the response to the inside of a cell
   C) keep calcium involved in these responses
   D) amplify the response of the first messenger
   E) facilitate the process of covalent modification of a protein

   Answer: D
   Diff: 4 Page Ref: 143
59) Which of the following is NOT a process whereby calcium is functionally removed from the cytosol of a cell?
   A) active pumping of calcium across the plasma membrane
   B) sequestration of calcium by proteins within the cytosol
   C) active transport of calcium into the smooth endoplasmic reticulum
   D) sequestration of calcium within the Golgi apparatus
   E) active transport of calcium into the mitochondria

Answer: D
Diff: 5   Page Ref: 139

60) In its active form, a G protein will have ________.
   A) the alpha and beta subunit separated from the gamma subunit
   B) the gamma subunit separated from the alpha and beta subunit
   C) the beta subunit separated from the alpha and gamma subunit
   D) the alpha subunit separated from the gamma and beta subunit
   E) the alpha and gamma subunit separated from the beta subunit

Answer: D
Diff: 5   Page Ref: 140

61) When the alpha subunit of the G protein is activated, it can stimulate ion channels to do what?
   A) either open or close
   B) open only
   C) close only
   D) alter the ion that travels through the channel
   E) degrade

Answer: A
Diff: 5   Page Ref: 141

62) The enzyme that catalyzes synthesis of cAMP is called ________ and is activated by ________.
   A) adenylate cyclase : a Gs protein
   B) adenylate cyclase : a Gi protein
   C) phosphodiesterase : a Gs protein
   D) phosphodiesterase : a Gi protein
   E) phosphoprotein phosphatase : a Gi protein

Answer: A
Diff: 4   Page Ref: 141

63) What enzyme is activated by cAMP?
   A) phosphodiesterase
   B) adenylate cyclase
   C) tyrosine kinase
   D) protein kinase A
   E) protein kinase C

Answer: D
Diff: 4   Page Ref: 141
64) What type of enzyme removes the phosphate group from a covalently modulated protein?
   A) protein kinase  
   B) tyrosine kinase  
   C) phosphoprotein phosphatase  
   D) phosphodiesterase  
   E) phospholipase  
   Answer: C  
   Diff: 5  Page Ref: 142

65) In order to terminate a cAMP-mediated response, the enzyme ______ can be activated to degrade cAMP.  
   A) cAMP decarboxylase  
   B) cAMP hydrolase  
   C) cAMP hydrogenase  
   D) cAMP phosphodiesterase  
   E) cAMP protein kinase  
   Answer: D  
   Diff: 5  Page Ref: 142

66) When associated with G protein, guanylate cyclase will activate what enzyme?  
   A) protein kinase C  
   B) protein kinase G  
   C) protein kinase A  
   D) phosphodiesterase  
   E) phospholipase C  
   Answer: B  
   Diff: 4  Page Ref: 142

67) Which of the following second messengers, when released by phospholipase C, will directly activate the enzyme protein kinase C?  
   A) inositol triphosphate  
   B) inositol biphosphate  
   C) diacylglycerol  
   D) phosphatidylinositol biphosphate  
   E) cGMP  
   Answer: C  
   Diff: 4  Page Ref: 143

68) What molecule, whose synthesis is catalyzed by phospholipase C, triggers the release of calcium from the endoplasmic reticulum?  
   A) Inositol triphosphate  
   B) Inositol biphosphate  
   C) Diacylglycerol  
   D) Phosphatidylinositol biphosphate  
   E) cGMP  
   Answer: A  
   Diff: 5  Page Ref: 143
69) Which of the following proteins is directly activated by a G protein?
   A) phospholipase A2
   B) adenylate cyclase
   C) tyrosine kinase
   D) calmodulin
   E) protein kinase G

   Answer: B
   Diff: 4   Page Ref: 141

70) What is phosphatidylinositol-4,5-biphosphate?
   A) a second messenger
   B) a phospholipid in plasma membranes
   C) an enzyme that catalyzes formation of a second messenger
   D) a component of a G protein
   E) an enzyme that catalyzes degradation of a second messenger

   Answer: B
   Diff: 5   Page Ref: 142

71) Which of the following describes the signal transduction mechanism for estrogen, a steroid hormone?
   A) opening of fast ligand-gated channels
   B) activation of enzyme-linked receptor
   C) activation of cAMP second messenger system
   D) opening or closing of fast ligand-gated channels
   E) altering transcription of mRNA

   Answer: E
   Diff: 5   Page Ref: 138

72) Which of the following is a second messenger?
   A) cAMP only
   B) calcium only
   C) inositol triphosphate only
   D) both cAMP and inositol triphosphate
   E) cAMP, calcium, and inositol triphosphate

   Answer: E
   Diff: 6   Page Ref: 141

73) Which of the following statements is true for the nervous system but NOT the endocrine system?
   A) A messenger communicates to target cells by binding to specific receptors.
   B) A messenger is transported in the bloodstream.
   C) There is a special anatomical arrangement between the secretory cell and the target cell.
   D) Communication occurs over long distances.
   E) Effector organs are scattered throughout the body.

   Answer: C
   Diff: 4   Page Ref: 145

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74) What part of a neuron releases neurotransmitter by exocytosis?
   A) soma
   B) dendrites
   C) axon hillock
   D) axon terminal
   E) all of the above

   Answer: D
   Diff: 4  Page Ref: 145

True/False Questions

1) Lipophobic chemical messengers communicate a message to the target cell by binding to receptors on that cell’s membrane.
   Answer: TRUE
   Diff: 3  Page Ref: 136

2) The target cell of a neurotransmitter is the postsynaptic cell.
   Answer: TRUE
   Diff: 3  Page Ref: 129

3) Endocrine glands secrete neurohormones.
   Answer: FALSE
   Diff: 3  Page Ref: 130

4) Tyrosine is one of four amino acids that function directly as chemical messengers.
   Answer: FALSE
   Diff: 5  Page Ref: 131

5) Steroid hormones are produced within cells and stored in vesicles until they are released.
   Answer: FALSE
   Diff: 4  Page Ref: 132

6) The enzyme glutamic acid decarboxylase catalyzes the synthesis of glutamate.
   Answer: FALSE
   Diff: 4  Page Ref: 131

7) All catecholamine-secreting cells synthesize dopamine.
   Answer: TRUE
   Diff: 5  Page Ref: 131

8) Eicosanoids are released immediately upon synthesis.
   Answer: TRUE
   Diff: 4  Page Ref: 133

9) Albumin is a peptide hormone.
   Answer: FALSE
   Diff: 3  Page Ref: 134
10) A single cell can have receptors for different messengers.
   Answer: TRUE  
   Diff: 3  Page Ref: 136

11) Most receptors are relatively non-specific for the ligand that will bind to them.
   Answer: FALSE  
   Diff: 3  Page Ref: 136

12) Receptors for lipophilic chemical messengers are only located on the surface of a cell's membrane.
   Answer: FALSE  
   Diff: 4  Page Ref: 136

13) Tyrosine kinases are enzymes that add a phosphate group to tyrosine residues on other proteins, changing the conformation of those proteins.
   Answer: TRUE  
   Diff: 4  Page Ref: 140

14) The higher concentration of messenger, the greater the response in the target cell.
   Answer: TRUE  
   Diff: 3  Page Ref: 136

15) Enkephalin is an opiate produced in the body. When enkephalin binds to opioid receptors it produces analgesia (a lack of pain sensation). Morphine can also bind to opioid receptors and produce analgesia. Morphine is an opiate antagonist.
   Answer: FALSE  
   Diff: 4  Page Ref: 137

16) Thyroid hormones alter the transcription of mRNA in the target cell.
   Answer: TRUE  
   Diff: 4  Page Ref: 138

17) If calcium channels open in the plasma membrane, calcium ions enter the cell.
   Answer: TRUE  
   Diff: 3  Page Ref: 139

18) An amplifier enzyme catalyzes the synthesis of a second messenger.
   Answer: TRUE  
   Diff: 3  Page Ref: 139

19) In its active form, a G protein has a GDP bound to its alpha unit.
   Answer: FALSE  
   Diff: 5  Page Ref: 139

20) Generally, the nervous system is a more rapid means of communication than the endocrine system.
   Answer: TRUE  
   Diff: 3  Page Ref: 145
21) The site of communication between two neurons is called a synapse.

Answer: TRUE

Diff: 3 Page Ref: 145

Matching Questions

Match the chemical messenger with its correct description.

1) Diffuses to neighboring cells to exert an effect.
   A) neurotransmitter
   Diff: 3 Page Ref: 129
   B) paracrine

2) Released from endocrine glands into the bloodstream.
   C) hormone
   Diff: 3 Page Ref: 130

3) Released by a presynaptic cell.
   Diff: 3 Page Ref: 129

Answers: 1) B 2) C 3) A

Match the chemical property to the messenger.

4) Catecholamines.
   A) lipophobic
   Diff: 4 Page Ref: 130
   B) lipophilic

5) Peptides/proteins.
   Diff: 4 Page Ref: 130

6) Steroids.
   Diff: 4 Page Ref: 130

7) Thyroid hormones.
   Diff: 5 Page Ref: 130

8) Eicosanoids.
   Diff: 4 Page Ref: 130

Answers: 4) A 5) A 6) B 7) B 8) B
Match the following enzymes with their functions.

9) Catalyzes phosphorylation of a protein.
   Diff: 5  Page Ref: 140
   A) tyrosine β-hydroxylase
   B) phospholipase A2

10) Catalyzes synthesis and release of arachidonic acid.
    Diff: 5  Page Ref: 133
    C) phospholipase C
    D) phenylethanolamine N-methyl transferase

11) Catalyzes synthesis of epinephrine from norepinephrine.
    Diff: 5  Page Ref: 132
    E) cyclooxygenase

12) Catalyzes synthesis of cAMP.
    Diff: 3  Page Ref: 141
    F) phosphoprotein phosphatase

13) Catalyzes synthesis of prostaglandins and thromboxanes.
    Diff: 5  Page Ref: 134
    G) adenylate cyclase

14) Catalyzes dephosphorylation of a protein.
    Diff: 5  Page Ref: 142
    H) tyrosine kinase

15) Catalyzes synthesis of diacylglycerol and inositol trisphosphate.
    Diff: 5  Page Ref: 142
    I) phosphodiesterase

J) dopamine β-hydroxylase

K) dopa decarboxylase


Match the following properties to the correct communication system.

16) Messenger is a hormone.
    Diff: 2  Page Ref: 145
    A) nervous system

17) Quick response time.
    Diff: 3  Page Ref: 145
    B) endocrine system

18) Target cells limited to neurons, muscles, and glands.
    Diff: 3  Page Ref: 145

19) Effects tend to be long-lasting.
    Diff: 3  Page Ref: 145

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Essay Questions

1) Describe the process whereby a polypeptide chain, which has been translated in the rough endoplasmic reticulum, is converted to an active protein hormone.

   Answer: Polypeptides are synthesized within the rough endoplasmic reticulum. Once completed, those polypeptide chains are called prepropeptide. Following its completion, the prepropeptide has a number of amino acid fragments removed in the lumen of the endoplasmic reticulum, thereby changing it to a propeptide. As the propeptide moves through the smooth endoplasmic reticulum, it is packaged into transport vesicles that carry the propeptide to the Golgi apparatus, where they are stored in vesicles until release is triggered. While in those storage vesicles or in the Golgi apparatus itself, more amino acids are cleaved from the propeptide, thereby producing an active peptide hormone that can be released to produce a biological effect. The peptide fragments that were cleaved from the propeptide are also released, and may have their own biological activity (although most are biologically inactive).

   Diff: 5  Page Ref: 132

2) Describe how chemical messengers are transported to their target tissues.

   Answer: The release of chemical messengers that act as paracrine or neurotransmitters occurs at minimal distance from their target tissues. Simple diffusion of those chemicals through the interstitium carries those messengers to their target tissue. These chemical messengers are quickly inactivated and/or degraded, thereby minimizing the spread of these messengers to other tissues that might be capable of responding. For those chemical messengers that are synthesized and released at a distance from their target tissues (hormones and neurohormones), these messengers must be transported through the bloodstream to their target tissues. This presents a problem for steroid hormones and other lipophilic chemical messengers that are hydrophobic. In order to move through the blood, these lipophilic hormones must be bound to carrier proteins. At the same time, the binding of these chemical messengers to carrier proteins protects them from degradation by the liver and filtration by the kidneys. Hormones dissolved in the blood have a short half-life (the time required for half of the hormone present to be degraded), on the order of minutes, relative to messengers that are bound to carrier proteins (half-life on the order of hours). Some carrier proteins are quite specific to the hormone that they carry; corticosteroid-binding globulin transports cortisol. Other carriers, like albumin, are less specific and can carry many different types of hormones. In the bloodstream, there is an equilibrium between bound (to carrier proteins) and free hormones. Typically, the free hormone is able to interact with receptors on the target tissue. As the free hormone binds to its receptors, the equilibrium of the hormone is altered such that more of the bound hormone is freed.

   Diff: 6  Page Ref: 134
3) Describe the factors that affect the magnitude of a target cell’s response. Assume that there is a receptor on the cell for the ligand.

Answer: The first factor that affects a target cell’s response to a ligand is the concentration of the ligand. The kinetics of a ligand’s binding to a receptor is shown as $M + R \leftrightarrow M*R \Rightarrow$ Response, where $M$ is the messenger (ligand), $R$ is the receptor, and $M*R$ is the messenger-receptor complex. As the concentration of ligand increases, the number of bound receptors will increase until all receptors on the target cell are bound by ligand (saturated). This relationship between ligand and receptor means that the response to a ligand will also be affected by the number of receptors available. At any concentration of ligand, the number of receptors bound depends upon the total number of receptors on the target cell. In order to change the number of receptors on the target cell, some time is required to alter the regulation of protein synthesis or degradation of that receptor. If the concentration of ligand is low for long periods of time, cells tend to upregulate (increase) the number of receptors for that ligand. In that way, the cell can be more responsive to lower concentrations of ligand. Alternatively, long periods of high ligand concentration may down regulate that ligand’s receptor population, thereby reducing the cell’s responsiveness to the ligand. Finally, a cell’s responsiveness to a ligand is determined by the affinity of the receptor for the ligand. As the receptor affinity increases, more receptors will be bound at the same ligand concentration. This is especially important when there are several classes of receptors that have different affinities for a ligand such as epinephrine. Two types of receptors are capable of binding the catecholamine epinephrine: $\alpha$ and $\beta_2$ adrenergic receptors. Both of these receptors are found on blood vessels and have the opposite effect on those vessels: $\alpha$ adrenoreceptors induce vasoconstriction, whereas $\beta_2$ adrenoreceptors induce vasodilation. However, in the presence of epinephrine, the $\beta_2$ adrenoreceptor–induced vasodilation will predominate because the $\beta_2$ adrenoreceptor has a greater affinity for epinephrine than the $\alpha$ adrenoreceptor.

Diff: 7  Page Ref: 136
4) Describe the function of the fast channel−linked receptors, including the role of calcium in their response.

Answer: Channel−linked receptors function in the gating of an ion channel into the open or closed states, in response to ligand−receptor binding. These ligand−gated channels are usually very specific for a particular ion and fall into two categories: fast and slow channels. Fast channels are those where the receptor and channel are directly coupled, whereas with slow channels, the receptor and channel are linked by confusing a G protein. The binding of a ligand to a fast channel receptor will increase the likelihood that an ion channel will open. That channel will only remain open for a short period of time, allowing the flux of a particular ion across the membrane either into or out of the cell, depending upon that ion’s electrochemical gradient. The flux of ions across a membrane can alter cellular function in two ways: by changing that cell’s membrane potential, and/or the ion can act as a second messenger inside the cell. The movement of sodium into a cell induces a rapid depolarization. Alternatively, if the channel is specific for calcium, then the influx of calcium can trigger a series of responses by binding to the cytosolic protein calmodulin or by binding to other proteins. The calcium−calmodulin complex activates a protein kinase which catalyzes phosphorylation of a protein. Calcium is well suited to this role due to its low cytosolic concentration, making the cell very responsive to changes in intracellular calcium. The cytosolic concentration of calcium is kept low by 1) the active transport of calcium out of the cell, 2) sequestration of calcium by cytosolic binding proteins, and 3) the active transport of calcium into the smooth endoplasmic reticulum and mitochondria.

Diff: 7   Page Ref: 139

5) Describe G protein−linked receptors, including a discussion of the different enzyme pathways activated by G protein.

Answer: G proteins act as a bridge between a receptor and a channel. Receptor−ligand binding activates a G protein within the cell membrane. G proteins can act through a number of second messenger pathways. cAMP is the most common pathway. A ligand binding to its receptor will activate Gs (or Gi, depending upon the receptor). The α subunit of the G protein is released to activate the enzyme adenylate cyclase. This step appears to be the most important because several other enzymes can be activated by the α subunit of the G protein. Adenylate cyclase catalyzes the conversion of ATP to cAMP. Once produced, cAMP will activate protein kinase A (cAMP−dependent protein kinase) by phosphorylating it. Protein kinase A uses ATP to phosphorylate another enzyme, thereby altering that protein’s function and causing a response within the cell. This cascade of reactions can be halted by the action of the cAMP phosphodiesterase, which degrades cAMP. At the same time, the protein activated by protein kinase A can be inactivated by a phosphatase enzyme that removes the phosphate group. As stated above, the α subunit of G protein could activate other enzymes like guanylate cyclase, which would stimulate the production of cGMP and ultimately activate protein kinase G. In addition, the α subunit of G protein could activate the enzyme phospholipase C. This enzyme is part of the phosphatidylinositol system. Activation of phospholipase C cleaves the membrane phospholipid phosphatidylinositol 4,5−biphosphate (PIP2) into diacylglycerol (DAG) and inositol triphosphate (IP3). DAG remains in the membrane and activates protein kinase C, which stimulates other enzymes to initiate a cellular response. IP3 moves into the cytosol and stimulates the release of calcium from the endoplasmic reticulum. In this case, it is calcium that stimulates the cellular response through its binding to calmodulin or another protein with a calcium binding site.

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Short Answer Questions

1) A target cell will respond to a chemical messenger once that molecule has bound to a(n) ________.
   Answer: receptor
   Diff: 2 Page Ref: 128

2) A (paracrine / hormone) is transported in the bloodstream.
   Answer: hormone
   Diff: 2 Page Ref: 129

3) Histamine is an example of a (paracrine / hormone).
   Answer: paracrine
   Diff: 4 Page Ref: 129

4) A neurohormone is (ADH / acetylcholine), which is released from the (kidney / pituitary gland).
   Answer: ADH : pituitary gland
   Diff: 4 Page Ref: 130

5) Lipid soluble molecules are not only hydrophobic, but are also ________.
   Answer: lipophilic
   Diff: 3 Page Ref: 130

6) Catecholamines, such as dopamine, norepinephrine, and epinephrine, are derived from the amino acid ________.
   Answer: tyrosine
   Diff: 4 Page Ref: 131

7) Identify the two enzymes involved in converting tyrosine into dopamine.
   Answer: tyrosine β hydroxylase and dopa decarboxylase
   Diff: 7 Page Ref: 131

8) Eicosanoids are derived from what phospholipid?
   Answer: arachidonic acid
   Diff: 5 Page Ref: 133

9) Steroid messengers are derived from what precursor molecule?
   Answer: cholesterol
   Diff: 3 Page Ref: 132

10) Catecholamines are released from the secretory cell by (diffusion / exocytosis).
    Answer: exocytosis
    Diff: 4 Page Ref: 132

11) Steroids are released from the secretory cell by (diffusion / exocytosis).
    Answer: diffusion
    Diff: 4 Page Ref: 132
12) Name a protein in the blood that is relatively non-specific with respect to its ability to bind and transport chemical messengers in the blood.
Answer: albumin  
Diff: 6  Page Ref: 134

13) As free hormones bind to their receptors and no more hormone is released from their cell of origin, the concentration of hormone bound to carrier proteins will (increase / decrease).
Answer: decrease  
Diff: 4  Page Ref: 134

14) The strength with which a ligand (chemical messenger) will bind with a receptor is referred to as its ________.
Answer: affinity  
Diff: 4  Page Ref: 136

15) Name a non-steroidal antiinflammatory drug.
Answer: aspirin  
Diff: 4  Page Ref: 134

16) As the concentration of a ligand (chemical messenger) increases, the magnitude of a cell’s response to that ligand will _______ until receptors are saturated.
Answer: increase  
Diff: 4  Page Ref: 136

17) As the concentration of receptors on the cell membrane decreases, the response of the target cell will (increase / decrease).
Answer: decrease  
Diff: 4  Page Ref: 136

18) The delay between release of a steroid hormone and an observable response from the target cell tends to be quite (long / short) compared with protein hormones that bind to receptors on the cell membrane.
Answer: long  
Diff: 5  Page Ref: 138

19) An enzyme-linked receptor called _______ catalyzes the conversion of GTP to cGMP.
Answer: guanylate cyclase  
Diff: 4  Page Ref: 142

20) What is the site of communication between two neurons called?
Answer: synapse  
Diff: 4  Page Ref: 145
Chapter 6  The Endocrine System: Endocrine Glands and Hormone Actions

Multiple Choice Questions

1) A secondary endocrine organ is ________.
   A) an organ that secretes at least two hormones
   B) an organ that receives communication from at least two hormones
   C) an organ that secretes tropic hormones
   D) an organ that is the target of tropic hormones
   E) an organ that secretes hormones, but is better known for another function

   Answer: E  
   Diff: 4     Page Ref: 150

2) Which of the following endocrine organs is located in the brain?
   A) pancreas
   B) adrenal gland
   C) hypothalamus
   D) gonads
   E) thymus

   Answer: C  
   Diff: 4     Page Ref: 150

3) What is another name for the posterior lobe of the pituitary gland?
   A) adenohypophysis
   B) neurohypophysis
   C) pineal gland
   D) melanocyte
   E) paraventricular nucleus

   Answer: B  
   Diff: 4     Page Ref: 150

4) What hormone released by the posterior pituitary functions in uterine contraction and milk letdown in the breast?
   A) Somatomedin
   B) Vasopressin
   C) Antidiuretic hormone
   D) Oxytocin
   E) Prolactin

   Answer: D  
   Diff: 5     Page Ref: 150

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5) Secretion of hormones from the anterior pituitary is stimulated by _______ released from the _______.
   A) antidiuretic hormone : hypothalamus
   B) inhibiting hormones : posterior pituitary
   C) oxytocin : hypothalamus
   D) stimulating hormones : posterior pituitary
   E) releasing hormones : hypothalamus
   Answer: E
   Diff: 4    Page Ref: 150

6) What ensure(s) that blood levels of a specific releasing hormone are locally high in order to stimulate the pituitary?
   A) degradation rates of tropic hormones
   B) affinity of the tropic hormones
   C) hepatic portal system
   D) hypothalamic-pituitary portal system
   E) pulsatility of tropic hormone release
   Answer: D
   Diff: 5    Page Ref: 152

7) Which of the following is NOT a hormone released from the anterior pituitary?
   A) prolactin inhibiting hormone
   B) luteinizing hormone
   C) follicle stimulating hormone
   D) growth hormone
   E) adrenocorticotropic hormone
   Answer: A
   Diff: 5    Page Ref: 153

8) Which tropic hormone is responsible for controlling the release of follicle stimulating hormone from the anterior pituitary?
   A) growth hormone releasing hormone
   B) corticotropin releasing hormone
   C) follicle releasing hormone
   D) gonadotropin releasing hormone
   E) follicle stimulating releasing hormone
   Answer: D
   Diff: 5    Page Ref: 153

9) Which of the following correctly describes a pathway for secretion of a hormone under the control of tropic hormones?
   A) CRH stimulates ACTH release, which stimulates somatomedin release.
   B) PRH stimulates PH release, which stimulates prolactin release.
   C) GHRH stimulates GH release, which stimulates insulin-like growth factor release.
   D) GnRH stimulates PH release, which stimulates prolactin release.
   E) TRH stimulates TSH release, which stimulates thymosin release.
   Answer: C
   Diff: 4    Page Ref: 153
10) Which of the following tropic hormones is a catecholamine?
   A) prolactin–releasing hormone
   B) prolactin–inhibiting hormone
   C) growth hormone–inhibiting hormone
   D) growth hormone
   E) luteinizing hormone

   Answer: B
   Diff: 5 Page Ref: 153

11) Which of the following is a correct example of long–loop negative feedback?
   A) TSH inhibits the release of TRH.
   B) TSH stimulates the release of TRH.
   C) Glucocorticoids inhibit the release of CRH.
   D) FSH inhibits the release of GnRH.
   E) GH stimulates the release of GHIH.

   Answer: C
   Diff: 6 Page Ref: 153

12) Which of the following is a correct example of short–loop negative feedback?
   A) Thyroid hormones inhibit the release of TRH.
   B) Thyroid hormones inhibit the release of TSH.
   C) TRH stimulates the release of thyroid hormones.
   D) TSH inhibits the release of TRH.
   E) TRH inhibits the release of TSH.

   Answer: D
   Diff: 6 Page Ref: 153

13) The release of ______ from the pineal gland is important for establishing ______.
    A) melatonin : thirst
    B) prolactin : circadian rhythm
    C) melatonin : circadian rhythm
    D) prolactin : breast milk production
    E) melanin : thirst

   Answer: C
   Diff: 6 Page Ref: 154

14) The thyroid gland secretes what hormone?
    A) thyroid hormones only
    B) thymosin only
    C) calcitonin only
    D) both thyroid hormones and thymosin
    E) both thyroid hormones and calcitonin

   Answer: E
   Diff: 4 Page Ref: 154
15) What is triiodothyronine?
   A) a catecholamine released from the adrenal cortex
   B) a catecholamine released from the adrenal medulla
   C) a thyroid hormone secreted from the thyroid gland
   D) the hormone secreted from the thymus
   E) the hormone secreted from the pineal gland

   Answer: C
   Diff: 4   Page Ref: 154

16) Which of the following hormones is NOT released from the adrenal gland?
   A) adrenocorticotropic hormone
   B) aldosterone
   C) cortisol
   D) androgens
   E) epinephrine

   Answer: A
   Diff: 3   Page Ref: 155

17) Which of the following hormones is NOT secreted by the endocrine region of the pancreas?
   A) insulin
   B) glucagon
   C) somatostatin
   D) pancreatic polypeptide
   E) glucocorticoids

   Answer: E
   Diff: 6   Page Ref: 156

18) What layer of the adrenal cortex secretes mineralocorticoids?
   A) zona reticularis only
   B) zona fasciculata only
   C) zona glomerulosa only
   D) both zonae reticularis and fasciculata
   E) both zonae reticularis and glomerulosa

   Answer: C
   Diff: 6   Page Ref: 155

19) What layer of the adrenal cortex secretes androgens?
   A) zona reticularis only
   B) zona fasciculata only
   C) zona glomerulosa only
   D) both zonae reticularis and fasciculata
   E) both zonae reticularis and glomerulosa

   Answer: D
   Diff: 6   Page Ref: 156
20) What region of the adrenal gland secretes epinephrine?
   A) zona reticularis
   B) zona fasciculata
   C) zona glomerulosa
   D) medulla
   E) zonae reticularis, fasciculata, and glomerulosa
   Answer: D
   Diff: 4 Page Ref: 156

21) What cells secrete epinephrine from the adrenal medulla?
   A) chromaffin cells
   B) A cells
   C) B cells
   D) D cells
   E) zona reticularis cells
   Answer: A
   Diff: 5 Page Ref: 156

22) Which of the following is an incorrect association between pancreatic cell type and hormone secreted?
   A) Alpha cells secrete glucagon.
   B) Beta cells secrete insulin.
   C) Delta cells secrete somatostatin.
   D) Epsilon cells secrete calcitonin.
   E) F cells secrete pancreatic polypeptide.
   Answer: D
   Diff: 5 Page Ref: 156

23) Which of the following hormones is NOT secreted by gonads?
   A) testosterone
   B) oxytocin
   C) androstenedione
   D) estradiol
   E) progesterone
   Answer: B
   Diff: 4 Page Ref: 156

24) What anterior pituitary hormone is NOT a tropic hormone?
   A) prolactin
   B) growth hormone
   C) adrenocorticotropic hormone
   D) follicle stimulating hormone
   E) luteinizing hormone
   Answer: A
   Diff: 5 Page Ref: 153
25) Which of the following hormones regulates plasma calcium levels?
   A) calcitonin only
   B) oxytocin only
   C) parathyroid hormone only
   D) both calcitonin and oxytocin
   E) both calcitonin and parathyroid hormone

   Answer: E  
   Diff: 6  Page Ref: 154

26) What hormone is secreted by the heart?
   A) erythropoietin
   B) thymosin
   C) atrial natriuretic peptide
   D) epinephrine
   E) somatostatin

   Answer: C  
   Diff: 5  Page Ref: 157

27) Where does the neural input for circadian rhythmicity of hypothalamic tropic hormones originate?
   A) suprachiasmatic nucleus
   B) paraventricular nucleus
   C) supraoptic nucleus
   D) pineal gland
   E) cerebrum

   Answer: A  
   Diff: 6  Page Ref: 159

28) Abnormal hormone secretions from an endocrine gland due to altered tropic hormone release are called _______.
   A) primary secretion disorders
   B) hypersecretions
   C) secondary secretion disorders
   D) hyposecretions
   E) tertiary secretion disorders

   Answer: C  
   Diff: 4  Page Ref: 161

29) Which of the following changes in plasma levels would be observed in a primary hyposecretion of cortisol?
   A) increased CRH, increased ACTH, and increased cortisol
   B) decreased CRH, decreased ACTH, and decreased cortisol
   C) increased CRH, increased ACTH, and decreased cortisol
   D) decreased CRH, decreased ACTH, and increased cortisol
   E) increased CRH, decreased ACTH, and decreased cortisol

   Answer: C  
   Diff: 7  Page Ref: 161
30) A person has a tumor in the hypothalamus causing an excess in TRH secretion. Which of the following correctly describes changes in plasma levels of hormones?
   A) increased TRH, increased TSH, and increased thyroid hormones
   B) decreased TRH, decreased TSH, and decreased thyroid hormones
   C) increased TRH, increased TSH, and decreased thyroid hormones
   D) decreased TRH, decreased TSH, and increased thyroid hormones
   E) increased TRH, decreased TSH, and decreased thyroid hormones

   Answer: A
   Diff: 7   Page Ref: 161

31) A person has a tumor in the anterior pituitary causing a decrease in ACTH secretion. Which of the following correctly describes changes in plasma levels of hormones?
   A) increased CRH, increased ACTH, and increased cortisol
   B) decreased CRH, decreased ACTH, and decreased cortisol
   C) increased CRH, increased ACTH, and decreased cortisol
   D) decreased CRH, decreased ACTH, and increased cortisol
   E) increased CRH, decreased ACTH, and decreased cortisol

   Answer: E
   Diff: 7   Page Ref: 161

32) Which of the following best describes the mechanism of insulin catabolism in target cells?
   A) degradation by lysosomes following receptor-mediated endocytosis
   B) degradation by insulin-degrading enzyme following receptor-mediated endocytosis
   C) degradation by proteases in the extracellular fluid
   D) degradation by mitochondrial enzymes following receptor-mediated endocytosis
   E) degradation by peroxisomal enzymes

   Answer: B
   Diff: 7   Page Ref: 161

33) When the response to two hormones is equal to the sum of their individual responses, the response is described as _______.
   A) permissive
   B) antagonized
   C) synergistic
   D) additive
   E) agonistic

   Answer: D
   Diff: 5   Page Ref: 162

34) When the response to two hormones is greater than the sum of the individual responses, the response is described as _______.
   A) permissive
   B) antagonized
   C) synergistic
   D) additive
   E) agonistic

   Answer: C
   Diff: 5   Page Ref: 162
True/False Questions

1) A releasing hormone is a type of tropic hormone.
   Answer: TRUE
   Diff: 3 Page Ref: 150

2) The hypothalamus is connected to the posterior pituitary by the hypothalamic-pituitary portal system.
   Answer: FALSE
   Diff: 4 Page Ref: 150

3) The secretion of hormones from the anterior pituitary is controlled by hypothalamic tropic hormones.
   Answer: TRUE
   Diff: 4 Page Ref: 150

4) Growth hormone functions as both a tropic hormone and as a hormone that acts on target cells throughout the body.
   Answer: TRUE
   Diff: 4 Page Ref: 153

5) The only non-peptide/protein tropic hormone is somatostatin.
   Answer: FALSE
   Diff: 7 Page Ref: 153

6) The only non-peptide/protein tropic hormone is dopamine.
   Answer: TRUE
   Diff: 7 Page Ref: 153

7) The release of LH and FSH by the anterior pituitary is under control of the same hypothalamic tropic hormone.
   Answer: TRUE
   Diff: 5 Page Ref: 153

8) In a short negative feedback loop, a tropic hormone from the anterior pituitary inhibits the release of its own releasing hormone from the hypothalamus.
   Answer: TRUE
   Diff: 5 Page Ref: 153

9) The hormone thymosin is released from the thyroid gland.
   Answer: FALSE
   Diff: 4 Page Ref: 155

10) The thyroid gland secretes parathyroid hormone.
    Answer: FALSE
        Diff: 4 Page Ref: 154

11) The parathyroid glands secrete calcitonin.
    Answer: FALSE
        Diff: 4 Page Ref: 154
12) The zona fasciculata secretes both androgens and glucocorticoids.
   Answer: TRUE
   Diff: 5  Page Ref: 155

13) All hormones of the adrenal cortex are steroid hormones.
   Answer: TRUE
   Diff: 6  Page Ref: 155

14) The skin is necessary for the activation of calcitonin.
   Answer: FALSE
   Diff: 5  Page Ref: 157

15) Insulin–like growth factors are secreted by the liver and function to promote tissue growth.
   Answer: TRUE
   Diff: 4  Page Ref: 157

16) The magnitude of response at the target cell depends on both the concentration of hormone and the concentration of receptor.
   Answer: TRUE
   Diff: 4  Page Ref: 157

17) All hormones are required to be bound to carrier proteins in order to be active.
   Answer: FALSE
   Diff: 4  Page Ref: 160

18) Hormones transported in blood bound to proteins are metabolized more slowly than those traveling dissolved in plasma.
   Answer: TRUE
   Diff: 5  Page Ref: 160

19) Regulation of insulin release by blood glucose levels is an example of humoral control of hormone secretion.
   Answer: TRUE
   Diff: 4  Page Ref: 159

20) Growth hormone has direct action on target cells throughout the body.
   Answer: TRUE
   Diff: 4  Page Ref: 153

21) Much of the insulin is removed from the blood as it passes through the liver.
   Answer: TRUE
   Diff: 4  Page Ref: 160

22) Kidney cells contain insulin–degrading enzyme.
   Answer: TRUE
   Diff: 4  Page Ref: 161
CHAPTER 6 The Endocrine System: Endocrine Glands and Hormone Actions

Matching Questions

Match the endocrine gland to the hormone.

1) Calcitonin.
   Diff: 5 Page Ref: 154
   A) adrenal cortex
   B) thyroid gland
   C) pancreas
   D) posterior pituitary
   E) adrenal medulla

2) Insulin.
   Diff: 4 Page Ref: 156

3) Vasopressin.
   Diff: 4 Page Ref: 150

4) Somatostatin.
   Diff: 4 Page Ref: 156

5) Aldosterone.
   Diff: 5 Page Ref: 155

6) Androgens.
   Diff: 5 Page Ref: 155

7) Glucagon.
   Diff: 4 Page Ref: 156

8) Cortisol.
   Diff: 4 Page Ref: 155

9) Epinephrine.
   Diff: 4 Page Ref: 156

10) Oxytocin.
    Diff: 4 Page Ref: 150

   Answers: 1) B  2) C  3) D  4) C  5) A
           6) A  7) C  8) A  9) E  10) D

Match the hypothalamic tropic hormone to the hormone whose release is ultimately affected.

11) GnRH.
    Diff: 5 Page Ref: 153
    A) glucagon
    B) thyroid hormone
    C) cortisol
    D) insulin–like growth factors
    E) sex hormones

12) CRH.
    Diff: 5 Page Ref: 153

13) GHRH.
    Diff: 5 Page Ref: 153

14) TRH.
    Diff: 4 Page Ref: 153

**Match the pancreatic cell type with the hormone it secretes.**

15) Insulin.  
   A) F cells  
   **Diff: 4  Page Ref: 156**

16) Somatostatin.  
   B) delta cells  
   **Diff: 5  Page Ref: 156**

17) Glucagon.  
   C) beta cells  
   **Diff: 4  Page Ref: 156**

18) Pancreatic polypeptide.  
   D) alpha cells  
   **Diff: 5  Page Ref: 156**

Answers:  15) C  16) B  17) D  18) A

**Essay Questions**

1) Discuss the structure and function of the pituitary gland, with special emphasis on the hormones released from the posterior pituitary.

**Answer:** The pituitary gland is attached to the brain by the infundibulum. This structure is a stalk with two important components: 1) nerves whose cell bodies are located within the hypothalamus and 2) a capillary bed that has already passed through the hypothalamus. Both of these structures are integral to the function of the pituitary gland. The pituitary gland can be divided into an anterior portion (adenohypophysis) and a posterior portion (neurohypophysis). The posterior portion contains the nerve endings that originate within the hypothalamus. The two peptide hormones released from the posterior pituitary are antidiuretic hormone (ADH or vasopressin) and oxytocin. ADH is synthesized in the paraventricular nucleus of the hypothalamus, while oxytocin is synthesized in the supraoptic nucleus of the hypothalamus. Following their synthesis, ADH and oxytocin are packaged into vesicles within the Golgi apparatus and transported along the nerves within the infundibulum to the posterior pituitary, from which they are released. Both ADH and oxytocin are considered neurohormones because they are released from nerve terminals. ADH alters water reabsorption in the kidneys, whereas oxytocin functions in uterine contraction and milk let-down in the breast. The hypothalamic–pituitary portal system describes the capillary bed that first drains the hypothalamus. The cells of the hypothalamus release tropic hormones into the bloodstream. Those tropic hormones diffuse from the second capillary bed to the cells of the anterior pituitary. The endocrine cells of the anterior pituitary are stimulated to increase or decrease their release of hormones into the bloodstream.

**Diff: 6  Page Ref: 150**
2) Discuss the hypothalamic–pituitary feedback regulation of hormone release from the anterior pituitary. Include long and short feedback loops, using thyroid hormone as an example.

Answer: The hypothalamic–pituitary portal system is important for the regulation of hormone release from the anterior pituitary by tropic hormones originating from the hypothalamus. Tropic hormones are released from nerve cells in the hypothalamus, at concentrations that will have the greatest affect on the release of hormones from the anterior pituitary. Their concentration is reduced by dilution and degradation before they reach other cells of the body. Five of the tropic hormones released by the hypothalamus are stimulatory, while two are inhibitory. Of these seven anterior pituitary hormones whose release is stimulated by hypothalamic tropic hormones, five are themselves tropic hormones that stimulate the release of another hormone (prolactin is the only hormone released from the anterior pituitary that is not tropic). Thus, the hypothalamus and pituitary provide for the multi-step regulation of hormone secretion.

The inhibition of hypothalamic hormone release by the anterior pituitary hormones is called short-loop negative feedback regulation, which prevents the buildup of excessive anterior pituitary tropic hormones. However, a hormone whose release is stimulated by pituitary tropic hormones can inhibit its own release by affecting the release of the tropic hormones from the pituitary as well as the hypothalamus. This inhibition of hypothalamic and anterior pituitary tropic hormone release by the end-product hormone is called a long-loop negative feedback. The hypothalamus secretes thyrotropin releasing hormone (TRH) that stimulates the release of thyroid stimulating hormone (TSH) from the anterior pituitary. TSH stimulates the release of thyroid hormone, which provides a long-loop negative feedback by inhibiting the release of tropic hormones from the hypothalamus and anterior pituitary. At the same time, TSH provides the short-loop negative feedback regulation by inhibiting the release of TRH from the hypothalamus.

Diff: 7  Page Ref: 153
3) Describe the structure of the adrenal glands and the hormones that originate from within those structures.

Answer: Each adrenal gland consists of a cortex (outer region), which accounts for 80% of the adrenal gland, and an inner core called the medulla. These structures are essentially separate endocrine glands composed of different cell types that secrete different hormones. The cortex secretes a number of hormones that are collectively called adrenocorticoids, referring to their origin (cortex) and their structure (steroids). Three classes of adrenocorticoids are produced from within the adrenal cortex: mineralocorticoids, glucocorticoids, and sex hormones. Mineralocorticoids, such as aldosterone, are involved in regulating sodium and potassium secretion in the kidneys. Glucocorticoids, such as cortisol, are involved in regulating the body's response to stress by controlling carbohydrate, protein, and lipid metabolism as well as the availability of blood glucose. The sex hormones secreted by the adrenal cortex appear to play a minor role in the regulation of reproductive function as a consequence of the greater secretion of those hormones from the gonads. The cortex is stratified into three layers: zona glomerulosa, zona fasciculata, and zona reticularis. The zona glomerulosa is exclusively responsible for the production of mineralocorticoids, whereas the zona fasciculata and zona reticularis both play a role in the production of glucocorticoids and sex hormones. The adrenal medulla is one of the postganglionic cells of the sympathetic nervous system, containing chromaffin cells that secrete catecholamines. The secretion of the chromaffin cells contain 80% epinephrine, 20% norepinephrine, and a very small amount of dopamine.
4) The effect a hormone will have on the target tissue is, in part, dependent upon the concentration of free hormone in the blood. How are the levels of free hormone within the blood regulated?

Answer: The first factor that will affect free hormone concentrations within the blood is the rate of production/secretion of a hormone. The rate of release for individual hormones can be quite variable, but for the most part, the secretion rate for a particular hormone occurs at a fairly steady rate. These rates of secretion are altered by either neural or humoral signals, which can either inhibit or stimulate their secretion. An example of neural signaling involves the regulation of hypothalamic hormones. Humoral signals can be quite variable and will depend upon the function of the hormone. Thus, other hormones, ions, and/or metabolites can alter the rates of hormone secretion. These humoral signals are part of the regulation of specific hormones, such as insulin, whose secretion is modified by blood glucose or aldosterone, whose secretion is altered by high levels of potassium in the blood. At the same time, the secretion of a number of hormones occurs with a circadian rhythm, meaning that the rates of secretion vary with time of day (light–dark cycle). A second factor in the concentration of free hormones in the blood is the availability of carrier proteins. These carrier proteins stabilize hormones and prevent their degradation while also allowing lipophilic hormones to remain in solution. Once a hormone binds to a receptor, it may be internalized and degraded by lysosomes within the target cell. There are a number of proteolytic enzymes within the blood that degrade hormones, however, the degradation of steroid and thyroid hormones occurs at a much lower rate due to their binding to carrier proteins in the blood. An equilibrium exists between free and bound hormones such that, as hormones are released, a proportion will become bound to a carrier protein while others remain as free hormones. At the same time, as free hormone binds to its receptor, the decrease in free hormones will cause some of the bound hormones to be released.

Diff: 8 Page Ref: 159

Short Answer Questions

1) What is the name of the stalk that connects the hypothalamus and pituitary gland?
   Answer: infundibulum
   Diff: 4 Page Ref: 150

2) What are hormones that regulate the release of other hormones called?
   Answer: tropic hormones
   Diff: 4 Page Ref: 150

3) What is the hormone whose release is stimulated by follicle stimulating hormone (FSH) in men?
   Answer: inhibin
   Diff: 6 Page Ref: 153

4) Name the two hormones released in females in response to LH.
   Answer: estrogens and progesterones
   Diff: 5 Page Ref: 153
5) Inhibition of TRH release by the thyroid hormones is an example of (long-loop / short-loop) negative feedback.
   Answer: long loop
   Diff: 5  Page Ref: 153

6) What hormone released from the thyroid gland regulates blood calcium?
   Answer: calcitonin
   Diff: 5  Page Ref: 154

7) Parathyroid hormone regulates blood levels of what ion?
   Answer: calcium
   Diff: 5  Page Ref: 155

8) Aldosterone is secreted by which layer(s) of cells within the adrenal cortex?
   Answer: zona glomerulosa
   Diff: 5  Page Ref: 155

9) What cells of the adrenal medulla secrete catecholamines?
   Answer: chromaffin cells
   Diff: 5  Page Ref: 156

10) Identify the two classes of input that can alter the secretion of hormones.
    Answer: neural signals and humoral signals
    Diff: 6  Page Ref: 159

11) An alteration within the anterior pituitary that decreases the secretion of thyroid hormone would be termed a ________ disorder.
    Answer: secondary secretion
    Diff: 4  Page Ref: 162

12) Acromegaly is caused by a(n) (increase / decrease) in growth hormone in adults.
    Answer: increase
    Diff: 5  Page Ref: 161

13) A hormone is ________ when a second hormone is required for the first hormone to have any activity.
    Answer: permissive
    Diff: 4  Page Ref: 162

14) What is the name of the enzyme that breaks down insulin in target cells?
    Answer: insulin-degrading enzyme
    Diff: 5  Page Ref: 161

15) What is the name of the enzyme that breaks down insulin in kidney cells?
    Answer: insulin-degrading enzyme
    Diff: 5  Page Ref: 161
Chapter 7  Nerve Cells and Electrical Signaling

Multiple Choice Questions

1) Which of the following correctly lists the components of the central nervous system?
   A) brain and nerves
   B) brain and spinal cord
   C) spinal cord and nerves
   D) brain, spinal cord, and nerves
   E) sympathetic and parasympathetic nervous system
Answer: B
Diff: 2  Page Ref: 167

2) Which of the following is located in the autonomic nervous system?
   A) sympathetic nervous system only
   B) parasympathetic nervous system only
   C) somatic nervous system only
   D) both sympathetic and parasympathetic nervous systems
   E) both sympathetic and somatic nervous systems
Answer: D
Diff: 3  Page Ref: 167

3) Which of the following accurately describes afferent neurons?
   A) They transmit information from the periphery to the CNS.
   B) The cell body is located in the ventral horn of the spinal cord.
   C) They are the most abundant class of neurons.
   D) They transmit information from the CNS to the periphery.
   E) They are typically multipolar neurons.
Answer: A
Diff: 4  Page Ref: 167

4) What is the functional unit of the nervous system?
   A) neurons
   B) glial cells
   C) the central nervous system
   D) axons
   E) the brain
Answer: A
Diff: 3  Page Ref: 167

5) On what portion of the neuron do action potentials propagate?
   A) soma
   B) cell body
   C) dendrite
   D) axon
   E) nucleus
Answer: D
Diff: 3  Page Ref: 168
6) Information is transmitted from cell to cell across the chemical synapse via a(n) _______.
A) neurotransmitter
B) action potential
C) graded potential
D) collateral potential
E) neurosecretory hormone
Answer: A
Diff: 2 Page Ref: 168

7) An action potential originates at the _______ and travels along the axon until it reaches the _______.
A) axon terminal : axon hillock
B) dendrite : axon terminal
C) axon hillock : dendrite
D) dendrite : axon hillock
E) axon hillock : axon terminal
Answer: E
Diff: 3 Page Ref: 168

8) What type of ion channels in the membrane of neurons allow ions to move across the membrane at rest and thereby contribute to resting membrane potential?
A) voltage-gated channels
B) resting channels
C) potential-gated channels
D) leak channels
E) ligand-gated channels
Answer: D
Diff: 4 Page Ref: 168

9) What type of ion channels in the membrane of neurons open or close in response to a neurotransmitter binding to its receptor?
A) voltage-gated channels
B) synaptic channels
C) potential-gated channels
D) leak channels
E) ligand-gated channels
Answer: E
Diff: 4 Page Ref: 168

10) In a neuron, where is the greatest concentration of voltage-gated sodium and voltage-gated potassium channels?
A) dendrites
B) soma
C) axon hillock
D) axon
E) axon terminal
Answer: C
Diff: 4 Page Ref: 169
CHAPTER 7 Nerve Cells and Electrical Signaling

11) In a neuron, where are voltage-gated calcium channels located?
   A) dendrites
   B) soma
   C) axon hillock
   D) axon
   E) axon terminal

   Answer: E
   Diff: 3   Page Ref: 169

12) What is the structural classification of a neuron composed of a single axon and a number of
dendritic projections from the nerve cell body?
   A) multipolar
   B) bipolar
   C) pseudo-unipolar
   D) unipolar
   E) polar

   Answer: A
   Diff: 4   Page Ref: 171

13) Which of the following is a functional classification of neurons that, for the most part, are
   bipolar in structure and carry information from the peripheral axon to the central axon?
   A) interneurons
   B) efferent neurons
   C) afferent neurons
   D) bipolar cells
   E) multipolar cells

   Answer: C
   Diff: 5   Page Ref: 172

14) Which of the following terms is NOT used to describe a bundle of axons in the central or
   peripheral nervous system?
   A) ganglia
   B) pathways
   C) tracts
   D) nerves
   E) commissures

   Answer: A
   Diff: 4   Page Ref: 171

15) Which of the following cells is NOT classified as a glial cell?
   A) astrocyte
   B) ependymal cell
   C) oligodendrocyte
   D) Schwann cell
   E) ventricular cell

   Answer: E
   Diff: 5   Page Ref: 172
16) What type of cell enhances the velocity of electrical transmission of an action potential along an axon in the central nervous system?
   A) oligodendrocyte
   B) Schwann cell
   C) astrocyte
   D) ependymal cell
   E) microglia

   Answer: A
   Diff: 5   Page Ref: 172

17) Which of the following best describes the function of the myelin sheath?
   A) decrease ion permeability in the nodes of Ranvier
   B) increase leakage of ions across the membrane
   C) decrease axonal conduction velocity
   D) increase a membrane’s ion permeability
   E) reduce a membrane’s ion permeability

   Answer: E
   Diff: 5   Page Ref: 172

18) Which of the following is the correct term for the movement of an electrical charge across a membrane?
   A) resistance
   B) current
   C) potential difference
   D) transistor
   E) capacitance

   Answer: B
   Diff: 5   Page Ref: 174

19) Which of the following determines the resistance to an ion’s movement across a membrane?
   A) enzymes on the surface of the cell membrane
   B) ion channels within the membrane
   C) receptors on the cell membrane
   D) the ions present on either side of the membrane
   E) the resting membrane potential

   Answer: B
   Diff: 4   Page Ref: 174

20) What is the inverse of resistance?
   A) voltage
   B) current
   C) conductance
   D) impedance
   E) flux

   Answer: C
   Diff: 5   Page Ref: 174
CHAPTER 7 Nerve Cells and Electrical Signaling

21) Which of the following is NOT a factor involved in the determination of resting membrane potential?
   A) concentration of sodium
   B) concentration of potassium
   C) presence of sodium channels
   D) presence of potassium channels
   E) concentration of sodium receptors

Answer: E
Diff: 3 PageRef: 174

22) Which of the following statements about sodium is FALSE?
   A) There is a chemical force driving sodium ions into the cell.
   B) At the resting membrane potential, there is an electrical force driving sodium ions into the cell.
   C) At the sodium equilibrium potential, there is an electrical force driving sodium ions out of the cell.
   D) At the potassium equilibrium potential, there is an electrical force driving sodium ions out of the cell.
   E) At the sodium equilibrium potential, the electrochemical force for sodium movement across the plasma membrane is zero.

Answer: D
Diff: 6 PageRef: 175

23) Which of the following best describes the electrochemical forces acting on sodium and potassium ions at the resting membrane potential?
   A) Forces on both sodium and potassium ions are to move into the cell.
   B) Forces on both sodium and potassium ions are to move out of the cell.
   C) The force on sodium ions is to move into the cell, and the force on potassium ions is to move out of the cell.
   D) The force on sodium ions is to move out of the cell, and the force on potassium ions is to move into the cell.
   E) There is no force on either ion to move.

Answer: C
Diff: 4 PageRef: 177

24) Given a cation with an equilibrium potential of \(-55\) mV, if the plasma membrane of the cell is permeable only to this ion, then which of the following best describes the resting membrane potential?
   A) \(-55\) mV
   B) \(+55\) mV
   C) \(-70\) mV
   D) More negative than \(-55\) mV
   E) More positive than \(-55\) mV

Answer: A
Diff: 6 PageRef: 175
25) At the resting membrane potential, the membrane is most permeable to ________, which moves ________ the cell due to its electrochemical gradient.
   A) sodium : into
   B) potassium : into
   C) potassium : out of
   D) sodium : out of
   E) chloride : into

   Answer: C
   Diff: 5   Page Ref: 176

26) At the resting membrane potential, the electrochemical gradient for sodium across the membrane is such that the net flux for sodium movement is directed ________, thereby causing the cell’s membrane potential to become more ________.
   A) inward : positive
   B) inward : negative
   C) outward : positive
   D) outward : negative
   E) at equilibrium : positive

   Answer: A
   Diff: 5   Page Ref: 176

27) The membrane potential at which there is no net flux of an ion across the membrane is called that ion’s ________.
   A) potential difference
   B) action potential
   C) resting membrane potential
   D) equilibrium potential
   E) graded potential

   Answer: D
   Diff: 3   Page Ref: 175

28) The presence of the ________ prevents the dissipation of the concentration gradient for Na⁺.
   A) Na⁺/K⁺ pump
   B) action potential
   C) equilibrium potential
   D) Na⁺/Ca²⁺ exchanger
   E) Na⁺/H⁺ antiporter

   Answer: A
   Diff: 4   Page Ref: 177

29) The Na⁺/K⁺ pump is called an electrogenic pump because the imbalance between ________.
   A) Na⁺ in to K⁺ out leaves the inside of the cell with a net negative charge
   B) Na⁺ out to K⁺ in leaves the inside of the cell with a net positive charge
   C) Na⁺ in to K⁺ out leaves the inside of the cell with a net positive charge
   D) Na⁺ out to K⁺ in leaves the inside of the cell with a net negative charge
   E) ATP utilization inside the cell relative to the outside

   Answer: D
   Diff: 4   Page Ref: 177
30) Why is the electrical potential of a membrane at rest closest to potassium’s equilibrium potential than to sodium’s equilibrium potential?
   A) more sodium channels are open, allowing more sodium to move into the cell
   B) more sodium channels are open, allowing more sodium to move out of the cell
   C) more potassium channels are open, allowing more potassium to move out of the cell
   D) more potassium channels are open, allowing more potassium to move into the cell
   E) all potassium channels are open
   Answer: C
   Diff: 4 Page Ref: 178

31) If, under resting conditions, the membrane is much more permeable to sodium than potassium, what would happen to the resting membrane potential?
   A) be altered very little
   B) become more negative
   C) approach potassium’s equilibrium potential
   D) approach sodium’s equilibrium potential
   E) approach chloride’s equilibrium potential
   Answer: D
   Diff: 4 Page Ref: 178

32) As a membrane’s permeability to a particular ion increases, membrane potential will move _______ that ion’s _______.
   A) away from: electrical gradient
   B) away from: electrochemical gradient
   C) away from: equilibrium potential
   D) closer to: electrochemical gradient
   E) closer to: equilibrium potential
   Answer: E
   Diff: 5 Page Ref: 178

33) What equation is used to calculate the membrane potential based on ion concentration gradients and permeabilities?
   A) GHK equation
   B) NAD equation
   C) Nernst equation
   D) Ficks equation
   E) Lotts equation
   Answer: A
   Diff: 4 Page Ref: 178

34) Membrane permeability is altered in the short term (milliseconds to seconds) by changes in the _______ of ion channels.
   A) gating
   B) cleavage
   C) production
   D) formation
   E) degradation
   Answer: A
   Diff: 4 Page Ref: 179
35) The opening of an ion channel increases a cell membrane’s ________, whereas ________ will decrease.
   A) resistance : permeability
   B) permeability : conductance
   C) permeability : electrical current
   D) resistance : conductance
   E) conductance : resistance
   Answer: E  
   Diff: 6  Page Ref: 179

36) The fact that a cell has an electrical potential difference across its membrane makes that cell ________.
   A) depolarized
   B) hyperpolarized
   C) repolarized
   D) polarized
   E) polar
   Answer: D  
   Diff: 4  Page Ref: 179

37) A change in a cell’s membrane potential, such that it becomes more positive, is referred to as a ________.
   A) depolarization
   B) hyperpolarization
   C) hypopolarization
   D) polarization
   E) repolarization
   Answer: A  
   Diff: 2  Page Ref: 179

38) A change in a cell’s membrane potential, such that it becomes more negative, is referred to as a ________.
   A) depolarization
   B) hyperpolarization
   C) hypopolarization
   D) polarization
   E) repolarization
   Answer: B  
   Diff: 2  Page Ref: 179

39) A ________ is a subthreshold change in membrane potential within the cell body that decays as it travels away from its point of origin.
   A) polarization
   B) hyperpolarization
   C) depolarization
   D) action potential
   E) graded potential
   Answer: E  
   Diff: 4  Page Ref: 180
40) The direction of change in membrane potential, in response to a stimulus that initiates a graded potential, is dependent upon _______.
   A) that membrane’s threshold potential
   B) the gating of potassium channels only
   C) the gating of sodium channels only
   D) the changes in ion concentration across the membrane
   E) the ion channels that are opened or closed

   Answer: E
   Diff: 5   Page Ref: 180

41) Which of the following does NOT produce graded potentials?
   A) the release of a neurotransmitter onto a cell body
   B) the release of a neurotransmitter onto a dendrite
   C) arrival of a suprathreshold stimulus at the axon hillock
   D) light impinging on a photoreceptor
   E) touching a sensory receptor

   Answer: C
   Diff: 4   Page Ref: 180

42) Which of the following statements is FALSE?
   A) Graded potentials can sum over time but action potentials cannot.
   B) Graded potentials do not have refractory periods, but action potentials do.
   C) Graded potentials and action potentials are all-or-none.
   D) Graded potentials and action potentials are caused by ions moving through channels.
   E) Graded potentials and action potentials can change the membrane potential of adjacent areas of the membrane through electrotonic conduction.

   Answer: C
   Diff: 5   Page Ref: 181

43) The _______ in graded potential that occurs as current spreads along the membrane happens as a consequence of the _______ of current across the membrane.
   A) elevation : leakage
   B) decrement : leakage
   C) decrement : blockade
   D) elevation : blockade
   E) elevation : generation

   Answer: B
   Diff: 4   Page Ref: 181

44) Which of the following is an example of spatial summation?
   A) Two stimuli from two sources produce graded potentials on the same neuron at the same time such that the two potentials sum.
   B) Two rapid stimuli from the same source produce graded potentials on the neuron that sum.
   C) An action potential occurs at the same time as a graded potential, and they sum.
   D) A neuron sends out information through collaterals to several target cells.
   E) Two action potentials occur at the same time and sum.

   Answer: A
   Diff: 4   Page Ref: 181
45) Which of the following changes in membrane potential is considered excitatory?
   A) hyperpolarization only  
   B) depolarization only  
   C) repolarization only  
   D) both hyperpolarization and depolarization  
   E) both hyperpolarization and repolarization  
   Answer: B  
   Diff: 3  Page Ref: 180

46) The spread of voltage by passive charge movement is called ______.  
   A) diffusion  
   B) integration  
   C) propagation  
   D) electrotonic conduction  
   E) saltatory conduction  
   Answer: D  
   Diff: 5  Page Ref: 181

47) If the graded potential remains above threshold once it reaches the ________, an action potential will be generated.  
   A) cell body  
   B) dendrite  
   C) axon  
   D) axon hillock  
   E) nucleus  
   Answer: D  
   Diff: 4  Page Ref: 183

48) Which of the following characteristics does NOT describe an action potential?  
   A) rapid increase in potassium permeability  
   B) rapid reversal of membrane potential  
   C) it does not decay over long distances  
   D) large depolarization  
   E) rapid increase in sodium permeability  
   Answer: A  
   Diff: 5  Page Ref: 183

49) The opening of sodium channels causes a rapid ______ of sodium that ______ the neuron's membrane.  
   A) efflux : hyperpolarizes  
   B) influx : hyperpolarizes  
   C) efflux : depolarizes  
   D) influx : depolarizes  
   E) influx : repolarizes  
   Answer: D  
   Diff: 4  Page Ref: 183
50) The depolarization phase of the action potential is generated by a rapid _______.
   A) opening of sodium channels  
   B) closure of potassium channels  
   C) closure of sodium channels  
   D) opening of potassium channels  
   E) opening of chloride channels  
   Answer: A  
   Diff: 4  Page Ref: 183

51) The repolarization phase of the action potential in a neuron is driven by the _______.
   A) closure of potassium channels  
   B) opening of calcium channels  
   C) opening of sodium channels  
   D) opening of sodium channels and closure of potassium channels  
   E) closure of sodium channels and opening of potassium channels  
   Answer: E  
   Diff: 4  Page Ref: 183

52) The patterns of change in ion channel permeability that occur during an action potential are
due to _______ gating of voltage-sensitive potassium and sodium channels.
   A) mechanically-induced  
   B) ligand-driven  
   C) time-dependent  
   D) temperature-induced  
   E) light-sensitive  
   Answer: C  
   Diff: 7  Page Ref: 184

53) For the sodium channel to open and allow sodium into the cell, _______.
   A) the activation and inactivation gates must both be open  
   B) only the activation gate must be open  
   C) only the inactivation gate must be open  
   D) the inactivation gate must open shortly before the activation gate opens  
   E) the activation and inactivation gates must both be closed  
   Answer: A  
   Diff: 4  Page Ref: 184

54) Which of the structures below lacks voltage-gated ion channels responsible for the production
of action potentials?
   A) axon hillock  
   B) axon  
   C) nodes of Ranvier  
   D) muscle cell membrane  
   E) epithelial cell membrane  
   Answer: E  
   Diff: 5  Page Ref: 183
55) Which of the following events is fastest?
   A) opening sodium activation gates
   B) closing sodium inactivation gates
   C) opening voltage-gated potassium channels
   D) closing voltage-gated potassium channels
   E) closing sodium activation gates

   Answer: A
   Diff: 5   Page Ref: 184

56) Stimuli A and B are both suprathreshold stimuli that last for one second, but stimulus A is stronger. Which of the following statements is TRUE?
   A) Only stimulus A can produce an action potential.
   B) The action potential produced by stimulus A will be larger than that produced by stimulus B.
   C) The action potential produced by stimulus A will be of longer duration than that produced by stimulus B.
   D) Stimulus A will cause a higher frequency of action potentials.
   E) A single action potential will be produced by both stimulus A and stimulus B. The action potentials produced from each stimulus will be identical in size and duration.

   Answer: D
   Diff: 5   Page Ref: 188

57) The repolarization phase of action potentials in neurons is due primarily to ________.
   A) increased activity of the Na⁺/K⁺ pump
   B) sodium flow out of the cell
   C) sodium flow into the cell
   D) potassium flow into the cell
   E) potassium flow out of the cell

   Answer: E
   Diff: 4   Page Ref: 183

58) During which of the following states are the majority of voltage-gated sodium channels closed and incapable of opening?
   A) at the resting membrane potential
   B) during depolarization
   C) during the absolute refractory period
   D) during the relative refractory period
   E) during the after-hyperpolarization

   Answer: C
   Diff: 5   Page Ref: 187

59) The regenerative nature of a sodium channel’s activation gate refers to the situation where an activation gate opens causing a depolarization that triggers which of the following?
   A) closure of other sodium channels’ activation gates
   B) opening of the inactivation gate of the same sodium channel
   C) opening of other sodium channels’ activation gates
   D) closing of other sodium channels’ inactivation gate
   E) opening of a potassium channels

   Answer: C
   Diff: 6   Page Ref: 185
60) The stimulation of an inadequate number of sodium channels for the generation of a positive sodium channel feedback loop is considered a ______ stimulus.
   A) threshold
   B) degenerative
   C) suprathreshold
   D) subthreshold
   E) regenerative

   Answer: D
   Diff: 5     Page Ref: 185

61) In order to generate an action potential, the magnitude of the inward sodium current must be large enough to overcome which of the following?
   A) outward potassium current
   B) inward potassium current
   C) outward sodium current
   D) inward chloride current
   E) outward calcium current

   Answer: A
   Diff: 6     Page Ref: 185

62) What terminates the positive feedback loop that is involved in the generation of an action potential?
   A) opening of activation gates on sodium channels
   B) closure of activation gates on sodium channels
   C) opening of inactivation gates on sodium channels
   D) closure of inactivation gates on sodium channels
   E) closure of potassium channels

   Answer: D
   Diff: 5     Page Ref: 185

63) Why will the magnitude of an action potential never reach sodium's equilibrium potential?
   A) the inactivation gate closes the sodium channel so rapidly
   B) the potassium channel opens slowly
   C) the sodium channel only opens for a short time
   D) the inward movement of sodium is countered by the outward movement of potassium
   E) the outward movement of sodium is countered by the inward movement of potassium

   Answer: D
   Diff: 6     Page Ref: 185

64) The all-or-none principle, associated with the action potential, states that ______.
   A) the positive feedback loop for the sodium channel is terminated by the inactivation gate
   B) there is a positive feedback loop for sodium channels that results in a rapid membrane depolarization
   C) all of the action potentials will be generated from the axon hillock
   D) once membrane potential reaches threshold, an action potential will be generated and that action potential will always be the same magnitude
   E) following an action potential, the membrane will be repolarized by the opening of a potassium channel

   Answer: D
   Diff: 5     Page Ref: 185
65) In order for a neuron to move from the absolute to the relative refractory period, a majority of that neuron’s sodium channels must have their _______.
   A) inactivation gates open
   B) activation gates closed
   C) inactivation gates closed
   D) activation gates opened and inactivation gates closed
   E) inactivation gates closed and activation gates closed

   Answer: A
   Diff: 6 Page Ref: 187

66) Toward the end of the relative refractory period, the continued decrease in stimulus intensity required to initiate an action potential is caused by _______.
   A) decreased sodium permeability
   B) increased potassium permeability
   C) closure of the sodium activation gate
   D) decreased potassium permeability
   E) the number of sodium channels whose inactivation gate has not opened

   Answer: D
   Diff: 6 Page Ref: 187

67) The stimulus intensity required to initiate an action potential is _______ through the course of the relative refractory period.
   A) stable
   B) increased
   C) unaltered
   D) progressively reduced
   E) progressively increased

   Answer: D
   Diff: 5 Page Ref: 187

68) Which of the following characteristics of an action potential does NOT result directly from the refractory period?
   A) the lack of summation of action potentials
   B) the all-or-none principle of action potentials
   C) the peak level of depolarization reached
   D) the frequency of action potentials
   E) the unidirectional propagation of action potentials

   Answer: C
   Diff: 6 Page Ref: 188

69) The time between action potentials is directly determined by the _______ the graded potential at the axon hillock.
   A) distance traveled by
   B) duration of
   C) frequency of
   D) amplitude of
   E) source of

   Answer: D
   Diff: 5 Page Ref: 188
70) For an unmyelinated axon, conduction velocity is primarily determined by the _______.
   A) type of potassium channel activated
   B) type of sodium channel activated
   C) diameter of the axon
   D) permeability of the axonal membrane
   E) number of ion channels present on the membrane

   Answer: C
   Diff: 4     Page Ref: 190

71) As an action potential is propagated away from the axon hillock, why does propagation continue in one direction?
   A) the region just behind the action potential is in the absolute refractory period
   B) the region just in front of the action potential is in the absolute refractory period
   C) the region just behind the action potential is in the relative refractory period
   D) the region just in front of the action potential is in the relative refractory period
   E) they will travel the path of least resistance

   Answer: A
   Diff: 4     Page Ref: 190

72) In myelinated nerve fibers, where do action potentials occur?
   A) cell body
   B) nodes of Ranvier
   C) Schwann cell
   D) underlying myelin sheath
   E) oligodendrocyte

   Answer: B
   Diff: 3     Page Ref: 190

73) The jumping of an action potential from node-to-node is called _______.
   A) nodal conduction
   B) propagation
   C) electrotonic conduction
   D) saltatory conduction
   E) nodal propagation

   Answer: D
   Diff: 4     Page Ref: 190

74) Which of the following axons would have the fastest conduction velocity?
   A) diameter = 5 microns, myelinated
   B) diameter = 5 microns, unmyelinated
   C) diameter = 20 microns, myelinated
   D) diameter = 20 microns, unmyelinated
   E) diameter = 1 micron, myelinated

   Answer: C
   Diff: 5     Page Ref: 190
75) What percentage of people with diabetes develop peripheral neuropathy?
   A) 5
   B) 10
   C) 20
   D) 30
   E) 50
   Answer: D  
   Diff: 5  Page Ref: 192

76) What percentage of people with neuropathy have it secondary to diabetes?
   A) 5
   B) 10
   C) 20
   D) 30
   E) 50
   Answer: D  
   Diff: 6  Page Ref: 192

77) Why do the distributions of sodium and potassium ions across the plasma membrane of neurons not change appreciably, even following hundreds of action potentials?
   A) The movement of sodium and potassium ions that occurs during an action potential is countered by the passive leak of these ions when a neuron is at rest.
   B) The movement of sodium and potassium ions that occurs during an action potential is countered by the active transport of these ions by the Na⁺/K⁺ pump.
   C) The movement of sodium and potassium ions that occurs during an action potential is countered by the passive movement of these ions during the repolarization phase.
   D) The movement of sodium and potassium ions that occurs during an action potential is countered by the passive movement of these ions during the after-hyperpolarization.
   E) The movement of sodium and potassium ions that occurs during an action potential is countered by counter-transport of potassium with sodium during rest.
   Answer: B  
   Diff: 5  Page Ref: 192

True/False Questions

1) Effector organs act as receptors that detect information about the external environment and transmit that information to the central nervous system.
   Answer: FALSE  
   Diff: 3  Page Ref: 167

2) Excitable cells are capable of producing action potentials.
   Answer: TRUE  
   Diff: 3  Page Ref: 167

3) Axons can branch.
   Answer: TRUE  
   Diff: 3  Page Ref: 168
4) Leak channels are most concentrated in the soma of neurons.
   Answer: FALSE
   Diff: 3  Page Ref: 168

5) Afferent neurons are generally bipolar neurons.
   Answer: TRUE
   Diff: 4  Page Ref: 169

6) Oligodendrocytes are located in the peripheral nervous system, providing the myelin sheath that forms the nodes of Ranvier.
   Answer: FALSE
   Diff: 5  Page Ref: 172

7) Schwann cells are the only glial cells in the peripheral nervous system.
   Answer: TRUE
   Diff: 4  Page Ref: 172

8) The number of ions whose movement across the membrane creates the resting membrane potential are so few that their movement does not affect that ion's concentration gradient.
   Answer: TRUE
   Diff: 4  Page Ref: 177

9) The membrane potential of a cell is determined exclusively by that cell's sodium and potassium permeability.
   Answer: FALSE
   Diff: 5  Page Ref: 176

10) At the resting membrane potential, a cell is at equilibrium.
    Answer: FALSE
    Diff: 4  Page Ref: 177

11) The Na⁺/K⁺ pump is electrogenic.
    Answer: TRUE
    Diff: 4  Page Ref: 177

12) An ion's net electrochemical force will tend to move that ion across the membrane in a direction that will cause membrane potential to move toward that ion's equilibrium potential.
    Answer: TRUE
    Diff: 4  Page Ref: 178

13) The Nernst equation is used to calculate the resting membrane potential.
    Answer: FALSE
    Diff: 4  Page Ref: 178

14) The GHK equation is used to calculate the equilibrium potential for a specific ion.
    Answer: FALSE
    Diff: 4  Page Ref: 178
15) In temporal summation, stimuli from different sources are applied at the same time such that they overlap and sum.

Answer: FALSE
Diff: 4 Page Ref: 181

16) Excitatory graded potentials are those where the stimulus initiates a hyperpolarization of the cell.

Answer: FALSE
Diff: 3 Page Ref: 180

17) Under resting conditions, the sodium channel responsible for generating an action potential is closed and incapable of opening.

Answer: FALSE
Diff: 4 Page Ref: 184

18) Both activation and inactivation gates of a sodium channel are stimulated at the same time by a depolarization with the inactivation gate acting more slowly than the activation gate, thereby allowing sodium to enter the cell.

Answer: TRUE
Diff: 5 Page Ref: 184

19) The magnitude of the action potential is dependent upon the extent to which the change in membrane potential is above threshold.

Answer: FALSE
Diff: 4 Page Ref: 185

20) During the relative refractory period, the stimulus intensity required to initiate an action potential is elevated.

Answer: TRUE
Diff: 4 Page Ref: 187

21) Once an action potential is generated, it will always depolarize the neighboring membrane above threshold, ensuring the action potential will travel along the axon without interruption.

Answer: TRUE
Diff: 4 Page Ref: 189

22) Tingling can be a sign of diabetic neuropathy.

Answer: TRUE
Diff: 4 Page Ref: 192

23) Diabetic neuropathy can affect nerves of the autonomic nervous system.

Answer: TRUE
Diff: 4 Page Ref: 192
Matching Questions

Match the following branches of the nervous system with its correct description. Choose the BEST single answer.

1) The portion of the peripheral nervous system that communicates to effector organs.
   - Diff: 5   Page Ref: 167

   A) autonomic nervous system
   B) efferent nervous system
   C) somatic nervous system
   D) afferent nervous system
   E) central nervous system
   F) peripheral nervous system
   G) enteric nervous system

2) The portion of the peripheral nervous system that transmits information from sensory receptors to the central nervous system.
   - Diff: 5   Page Ref: 167

3) The portion of the efferent branch of the nervous system that communicates to glands and cardiac muscle.
   - Diff: 4   Page Ref: 167

4) The brain and spinal cord.
   - Diff: 3   Page Ref: 167

5) Portion of the efferent nervous system that communicates with skeletal muscle.
   - Diff: 4   Page Ref: 167

6) Provides communication between peripheral organs and the brain and spinal cord.
   - Diff: 3   Page Ref: 167

7) Nervous system of the intestinal tract.
   - Diff: 5   Page Ref: 167

For each of the following, indicate whether the property corresponds to graded potentials, action potentials, both, or neither.

8) Can sum.  
A) neither graded potentials nor action potentials

9) Are affected by refractory periods.  
B) action potentials

10) Are a result of opening or closing of ion channels.  
C) graded potentials

11) Dissipate in size as the potential moves away from the site of initiation.  
D) both graded potentials and action potentials


Essay Questions

1) Describe the organization of the nervous system, including a description of the different branches.

Answer: The entire nervous system is organized into two main divisions: the central nervous system and the peripheral nervous system. The central nervous system (the brain and spinal cord) receives sensory input from the body, which it integrates to determine whether a response is warranted. Within the central nervous system, learning, memory, emotion, and other complex functions occur. The peripheral nervous system is divided into two main divisions: the afferent and efferent limbs. The afferent limb detects sensory (external) and visceral (internal) information and sends it to the central nervous system. The efferent limb sends information to the effector organ from the central nervous system to initiate a response. The efferent limb can be divided into two branches: the autonomic nervous system and the somatic nervous system. The somatic nervous system transmits information to skeletal muscle, whereas the autonomic nervous system sends information either through the sympathetic or parasympathetic nervous systems, which tend to be counterregulatory (produce the opposite effects). The autonomic nervous system is not under voluntary control. Finally, there is the enteric nervous system in the gastrointestinal tract, involved in digestion, that acts independently of the central and peripheral nervous systems.

Diff: 5  Page Ref: 167
2) Describe the structure of a neuron and the important consequences of that arrangement.

Answer: Neurons are composed of a cell body (or soma), where a majority of their organelles are located, and several projections from the cell body that are classified as dendrites and axons based upon their function. The cell body itself is incapable of generating an action potential. This inability derives from the absence of voltage-gated sodium channels in the membrane of the cell body that are required for an action potential to be generated. Projecting from the cell body are a number of dendrites that receive synaptic input from axon terminals of other neurons. Another projection from the cell body is a single axon that transmits information from axon hillock to axon terminal in the form of action potentials. Thus, dendrites receive information from other cells while axons transmit that information. At axodendritic synapses, neurotransmitters are released from the axon terminals onto the dendrites to generate a change in membrane potential. The graded change in membrane potential at the dendrite decays as it travels across the cell body from its source. This allows for the integration of numerous synaptic inputs onto one cell body. The final integration occurs at the axon hillock. Within this structure, the voltage-gated sodium channels required for an action potential are present in their greatest concentration. Thus when the axon hillock is depolarized above threshold, an action potential will be generated. Once initiated, the action potential will move along the axon in one direction. That action potential will travel along the axon until it reaches the axon terminal, where a synapse is formed for the transfer of the information on to the next neuron or effector organ.

Diff: 5  Page Ref: 168

3) Every cell within the body has a potential difference across its membrane. Discuss the role of potassium ions in creating that potential difference across the cell membrane at rest. Include in your discussion a description of equilibrium potential.

Answer: The source of membrane potential is the difference in ion concentration across a membrane and ion permeability. The separation of charge means that when charged ions move through open ion channels across the membrane, an electrical current is created that is resisted by the closure of those ion channels. Thus, the movement of ions across the membrane can be described by Ohm’s law (I = E/R). With respect to the potassium concentration difference across the cell membrane, there are more potassium ions inside the cell. Thus, the concentration gradient would tend to move potassium out of the cell. At rest, the membrane is most permeable to potassium (more potassium leak channels are open at rest). This means that potassium ions are moving out of the cell, leaving the inside of the cell relatively negative and thereby creating a negative membrane potential. After the development of that negative membrane potential, the electrochemical gradient acting on potassium is such that the chemical forces are still pushing potassium outward, but the negative membrane potential created by their outward movement is pulling the potassium back into the cell. As more potassium leaves, the increasing negative electrical potential becomes a stronger force, pulling potassium back into the cell. When these two forces are balanced (chemical and electrical gradients), such that there is no net movement of ions across the membrane (they are moving equally in both directions), the membrane potential has reached the equilibrium potential for potassium. However, it is important to remember that the number of ions required to create this electrical difference is relatively small.

Diff: 8  Page Ref: 174
4) Several ions are responsible for the resting membrane potential. Describe the forces that determine resting membrane potential.

Answer: The first determinant of the resting membrane potential is the distribution of ions across the membrane: there is a higher concentration of sodium outside the cell, whereas potassium is greater inside the cell. This means that potassium will diffuse out of the cell as sodium diffuses into the cell. This ability of an ion to diffuse across the membrane is determined by the ion channels present on the cell membrane: the more ion channels open, the more a particular ion will be able to move across the membrane. The more an ion moves across the membrane, the greater its effect on membrane potential. Thus, along with the concentration difference, membrane potential is determined by the population of ion channels that remain open under resting conditions. Under resting conditions, most cells have more potassium leak channels open than sodium leak channels. This means that more potassium ions are moving out of the cell than sodium ions are moving in. Thus, the negative charge created by potassium moving out will outweigh the positive charge created by sodium moving in, leaving membrane potential relatively negative. If a channel for a specific ion is open, then membrane potential will tend to move toward the equilibrium potential for that ion (i.e., as those ions are able to move across the membrane, they create an electrical force that tends to pull them in the opposite direction, approaching equilibrium). The channel that is primarily open at rest, potassium, ensures that resting membrane potential is closer to the equilibrium potential for potassium than sodium. However, neither ion ever comes to complete equilibrium. There are several other ions (chloride and calcium) that can play an important role in the resting membrane potential. Their role will vary by cell type.

Diff: 7  Page Ref: 176
5) Graded potentials develop in the cell body of neurons as well as in sensory receptor cells. In order for sensory information to reach the central nervous system, that graded potential must be converted into an action potential. How are graded potentials created, and how are they different from action potentials?

Answer: The negative nature of the resting membrane potential is determined by the greater permeability of the membrane to potassium. Any change in membrane potential involves a change in the number of ion channels that are open or closed. For a graded potential to be excitatory, the membrane must depolarize (become more positive), which could occur by more potassium channels closing or more sodium channels opening. For a graded potential to be inhibitory, the membrane must hyperpolarize or be stabilized at a sub-threshold potential. The could occur by more potassium channels opening, chloride channels opening, or more sodium channels closing. These channel gating events (openings and closings) are created by neurotransmitters binding to receptors at the synapse or by direct activation of an ion channel on a receptor cell. Once created, the graded potential will degrade as it moves along the membrane, further away from the site that was stimulated. The magnitude of the graded potential can be quite variable, depending upon the number and type of channels affected. The magnitude of the graded potential will determine the frequency of action potentials generated. Different ion channels are responsible for an action potential. Voltage-gated sodium channels open and the membrane potential rapidly depolarizes. These channels close and voltage-gated potassium channels open, causing the membrane to repolarize and then hyperpolarize before returning to the resting membrane potential. Action potentials are all-or-none, and once threshold is reached, an action potential will be generated. They are also subject to refractory periods.

Diff: 6 Page Ref: 180
6) Describe the voltage gating of ion channels and how this plays a role in an action potential.

Answer: The action potential is generated by the activity of a specific type of sodium channel that has very unique gating properties. There are two gates on these sodium channels; one is the activation gate and the other is the inactivation gate. At the resting membrane potential, the activation gates are closed and the inactivation gates are open. On depolarization of the membrane to threshold, the activation gates open rapidly creating an open channels. In approximately one millisecond, the inactivation gates close thereby closing the channels. This short duration of time in which the sodium channel remains open is long enough to cause a large change in membrane potential due to the strong electrochemical driving force for sodium to move into the cell. This creates a positive feedback loop where the activation of one sodium channel causes the membrane to depolarize further, thereby opening other sodium channels. This regenerative process in the sodium channel is activated to produce an action potential only if the change in membrane potential is above threshold. At the same time that depolarization activates the sodium channels, there are potassium channels that are sensitive to depolarization and are stimulated to open. These channels are slow–acting as well, with respect to the activation gate of the sodium channel, meaning that the potassium channels open after a short delay. Thus, the action potential is generated by the opening of enough sodium channels, which rapidly depolarizes the membrane. That depolarization is reversed by the closure of the sodium channel’s inactivation gate. The potassium channel opens more slowly and remain open for a longer period of time. The delayed opening of the potassium channels increase the rate of repolarization of the membrane following the upstroke of the action potential, and the slow closure results in the after-hyperpolarization of the membrane below resting membrane potential.
7) Once an action potential is generated, there is a delay before another action potential can be generated. Name and describe the basis for the two refractory periods.

Answer: The refractory period is broken into two components: the absolute and relative refractory periods. The absolute refractory period is, as the name suggests, a duration of time following the initiation of an action potential in which a second action potential can not be generated. The absolute refractory period spans all of the depolarization phase of the action potential, as well as most of the repolarization phase (1-2 msec). During this period, a second action potential cannot be generated irrespective of stimulus activity. The cause is two-fold: 1) once rapid depolarization is initiated, it must continue to its conclusion, and 2) at the beginning of the repolarization phase, the inactivation gates of the sodium channel are closed and cannot be opened by a second stimulus. Those channels can be found in three different states: 1) closed but capable of opening, 2) open, and 3) closed yet incapable of opening. After the activation gate has opened (the inactivation gate is already open under resting conditions), the inactivation gate closes. The channel cannot be opened again until the inactivation gate has opened. The remainder of the repolarization and after-hyperpolarization phases is part of the relative refractory period. A second stimulus can initiate an action potential, but that stimulus must be suprathreshold. The relative refractory period is reflective of two changes: 1) increased potassium permeability of the membrane, and 2) opening of the inactivation gate in a portion of the sodium channels. From the beginning to the end of the relative refractory period, the amplitude of the suprathreshold stimulus required to initiate an action potential is reduced as potassium permeability declines and more inactivation gates open. Early in the relative refractory period, all of the sodium channels have not returned to the resting state. At the same time, the cell must overcome a greater potassium current created by the number of open potassium channels that are repolarizing the cell. Thus, a greater depolarization is required.
8) Describe how an action potential, originating at the axon hillock, is propagated along the axon. Include those factors that can alter conduction velocity.

Answer: As an action potential is generated at the axon hillock, the change in membrane potential moves (via electrotonic conduction) along the axon. That electrotonic movement of current along the membrane causes the axonal membrane to depolarize. The extent of depolarization of the axonal membrane downstream from an action potential is always enough to trigger another action potential. This process is repeated multiple times as the action potential moves along the axon. This is the reason for the lack of decay in the action potential as well as the all-or-none property of an action potential, along with the fact that the magnitude of an action potential does not vary from one to the next. In unmyelinated axons, this process continues along the entire axon. The speed with which that action potential can move along the axon is dependent upon the electrical resistance of that axon. The electrical resistance of the axon is determined by the diameter of the axon, with the larger diameter axon having a lower resistance (conduction velocity will be greater) than a smaller diameter axon. In axons that are myelinated, action potentials will occur at discrete points along the axon, known as the nodes of Ranvier. Thus, the action potential jumps from node to node in what has been called saltatory conduction. The resistance of the membrane under the myelin sheath (acting as an insulator) is great enough that there is only a small amount of current lost as it moves between nodes. Because the action potential is jumping from node to node, the speed with which that action potential moves along the axon is greatly increased.

Diff: 7  Page Ref: 189

9) Describe the types of ion channels that are found in a neuron and how those channels are gated.

Answer: There are many types of ion channels that can be characterized by their specificity for an ion as well as their mechanism of gating. This gating refers to the opening and closing of ion channels, either allowing ions through or restricting their access, respectively. There is a population of ion channels that are specific for particular ions like sodium, potassium, calcium, and chloride. In addition, other ion channels are less specific, allowing a number of different ions to traverse the channel. With respect to gating, channels can be leak channels that are open under resting conditions and, on neurons, these channels are most permeable to potassium. Ion channels can also be gated by ligands. These ligand–gated channels act as receptors such that when a ligand (including neurotransmitters) binds to that receptor, ion channels are stimulated to open or close with a greater frequency. These channels tend to be located within the dendrites and cell body of a neuron. Another type of ion channel is the voltage–gated channel, whose gating is determined by membrane potential. There are voltage–gated sodium and potassium channels on the axon that are responsible for the initiation, propagation, and repolarization of an action potential. A voltage–gated calcium channel is present within the axon terminal and is responsible for regulating the release of neurotransmitter.

Diff: 6  Page Ref: 168
Short Answer Questions

Using Figure 7.1, answer the following questions:

1) Describe the event C indicated in the figure above and how that event is initiated.
   Answer: graded potential (depolarization) that could have resulted from the opening of sodium channels, closure of potassium channels, or opening of ion channels for sodium and potassium
   Diff: 5  Page Ref: 181

2) What ion channel(s) is/are responsible for event A in the figure above?
   Answer: opening of sodium channels
   Diff: 5  Page Ref: 184

3) What ion channel(s) is/are responsible for event B in the figure above?
   Answer: closure of the sodium channels and opening of the potassium channels
   Diff: 5  Page Ref: 185

4) Identify the type of summation that is occurring in the figure above, where S refers to a stimulus from one source measured in the postsynaptic membrane.
   Answer: temporal
   Diff: 5  Page Ref: 181

5) In the figure above, if the direction of event C was reversed (hyperpolarization), how would this affect the ability of the postsynaptic membrane to generate an action potential?
   Answer: Hyperpolarization will reduce the likelihood that an action potential will be generated.
   Diff: 4  Page Ref: 180

6) In the figure above, if S₂ indicated a stimulus from a different source, and S₁ occurred coincident with S₂, what type of summation has been generated?
   Answer: spatial
   Diff: 4  Page Ref: 181

7) Movement of what ion is responsible for event D in the figure above?
   Answer: potassium moving out of the cell
   Diff: 5  Page Ref: 185
8) Information gathered about our internal environment (i.e., fullness of the stomach, blood pressure, etc.) is called ________ information.
   Answer: visceral
   Diff: 3   Page Ref: 167

9) What is the most common neuronal cell type?
   Answer: interneuron
   Diff: 4   Page Ref: 172

10) What is the only glial cell found outside of the central nervous system?
    Answer: Schwann cell
    Diff: 4   Page Ref: 172

11) Each ________ provides the myelin sheath for many axons in the central nervous system.
    Answer: oligodendrocyte
    Diff: 5   Page Ref: 172

12) Once a membrane potential has been developed, the force that drives a particular ion across the membrane is its ________.
    Answer: electrochemical gradient
    Diff: 5   Page Ref: 174

13) When they are not at equilibrium, an ion will move across the membrane in a direction that moves membrane potential toward that ion’s ________.
    Answer: equilibrium potential
    Diff: 5   Page Ref: 178

14) What is the passive spread of current along a membrane called?
    Answer: electrotonic conduction
    Diff: 5   Page Ref: 181

15) Following the opening of the activation gate of the sodium channel, the ________ gate closes shortly thereafter.
    Answer: inactivation
    Diff: 4   Page Ref: 184

16) The inactivation gate is opened by ________.
    Answer: repolarization of the membrane to resting membrane potential
    Diff: 5   Page Ref: 184

17) The fact that the opening of some sodium channels can induce several other sodium channels to open describes the ________ property of these channels.
    Answer: regenerative
    Diff: 5   Page Ref: 185

18) What is the level of membrane depolarization required to induce the sodium channel’s positive feedback loop called?
    Answer: threshold
    Diff: 6   Page Ref: 185
19) The type of ion channels located along the axon is (ligand-gated channels / voltage-gated channels).
   Answer: voltage-gated channels
   Diff: 4 Page Ref: 169

20) In the peripheral nervous system, myelin is formed by _______. In the central nervous system, myelin is formed by _______. Gaps in the myelin are called _______. Propagation of action potentials in myelinated axons is called _______.
   Answer: Schwann cells : oligodendrocytes : nodes of Ranvier : saltatory conduction
   Diff: 5 Page Ref: 172

21) At rest, the plasma membrane is more permeable to (sodium / potassium).
   Answer: potassium
   Diff: 3 Page Ref: 176

22) The resting membrane potential is close to the (sodium / potassium) equilibrium potential.
   Answer: potassium
   Diff: 4 Page Ref: 176

23) Which is larger, an action potential or a graded potential? Which lasts longer, an action potential or a graded potential?
   Answer: action potential : graded potential
   Diff: 4 Page Ref: 183

24) During the rapid depolarization phase of an action potential, the plasma membrane is more permeable to (sodium / potassium).
   Answer: sodium
   Diff: 3 Page Ref: 183

25) The sodium inactivation gate (opens / closes) with depolarization.
   Answer: closes
   Diff: 5 Page Ref: 184

26) Increased permeability to what ion is responsible for the relative refractory period?
   Answer: potassium
   Diff: 4 Page Ref: 187

27) As the membrane potential moves further away from the equilibrium potential for a certain ion, the electrochemical force acting on that ion (increases / decreases).
   Answer: increases
   Diff: 5 Page Ref: 178

28) At the peak of an action potential, the electrochemical force is greater for (sodium / potassium).
   Answer: potassium
   Diff: 6 Page Ref: 183

29) The current produced by a specific ion moving across the plasma membrane increases as conductance (increases / decreases).
   Answer: increases
   Diff: 5 Page Ref: 178
Multiple Choice Questions

1) For cells that communicate by electrical synapses, the message travels between cells via _______.
   A) ions moving across the synaptic cleft
   B) the diffusion of neurotransmitters
   C) gap junctions
   D) active transport across the synaptic cleft
   E) passive transport across the synaptic cleft

   Answer: C
   Diff: 3 Page Ref: 197

2) Which of the following statements about synapses is FALSE?
   A) Communication across electrical synapses is bi-directional.
   B) Neurotransmitters can move from one cell to another through gap junctions at an electrical synapse.
   C) Communication at chemical synapses is slower than at electrical synapses.
   D) Electrical synapses can be gated.
   E) Most synapses in the nervous system are chemical synapses.

   Answer: B
   Diff: 4 Page Ref: 197

3) Which of the following statements about electrical synapses is FALSE?
   A) Gap junctions are formed from proteins called connexins.
   B) Electrical synapses connect hypothalamic neurons that release tropic hormones.
   C) Electrical synapses are found in the retina.
   D) Electrical synapses are found in the brainstem.
   E) All electrical synapses provide for bi-directional communication.

   Answer: E
   Diff: 4 Page Ref: 197

4) The chemical synapse is bounded by the _______ neuron, from which neurotransmitters are released across the synaptic cleft, to the _______ neuron, where the receptors for that neurotransmitter are located.
   A) presynaptic : postsynaptic
   B) postsynaptic : presynaptic
   C) parasympathetic : postsynaptic
   D) presynaptic : parasympathetic
   E) terminal : presynaptic

   Answer: A
   Diff: 2 Page Ref: 197
5) What type of synapse occurs between an axon terminal of one neuron and the axon from another neuron?
   A) axodendritic synapse
   B) axoaxonic synapse
   C) axosomatic synapse
   D) dendroaxonic synapse
   E) somatoaxonic synapse
   Answer: B
   Diff: 2   Page Ref: 198

6) What type of synapse occurs between an axon terminal of one neuron and the cell body of another neuron?
   A) axodendritic synapse
   B) axoaxonic synapse
   C) axosomatic synapse
   D) dendroaxonic synapse
   E) somatoaxonic synapse
   Answer: C
   Diff: 2   Page Ref: 198

7) The neurotransmitter that is released from the presynaptic neuron must diffuse across the _______ to reach the postsynaptic neuron.
   A) axon hillock
   B) dendrite
   C) cell body
   D) axon
   E) synaptic cleft
   Answer: E
   Diff: 3   Page Ref: 197

8) What type of ion channels are necessary for the function of the axon and the axon terminal?
   A) receptor-gated
   B) mechanically-gated
   C) ligand-gated
   D) voltage-gated
   E) chemically-gated
   Answer: D
   Diff: 5   Page Ref: 199

9) Synaptic vesicles store _______.
   A) calcium
   B) sodium
   C) potassium
   D) neurotransmitter
   E) enzymes that degrade neurotransmitter
   Answer: D
   Diff: 3   Page Ref: 198
10) Most neurotransmitters are synthesized in what region of a neuron?
   A) cytosol
   B) synaptic vesicles
   C) Golgi apparatus
   D) rough endoplasmic reticulum
   E) axon hillock
   Answer: A
   Diff: 5 Page Ref: 198

11) Neurotransmitter release occurs by what mechanism?
   A) diffusion
   B) primary active transport
   C) secondary active transport
   D) endocytosis
   E) exocytosis
   Answer: E
   Diff: 3 Page Ref: 198

12) Voltage-gated calcium channels in the axon terminal open in response to which of the following?
   A) initiation of an action potential in the axon hillock
   B) arrival of an action potential at the axon terminal
   C) neurotransmitter binding to receptor
   D) summation of graded potentials at the axon hillock
   E) paracrines released from the post-synaptic cell
   Answer: B
   Diff: 4 Page Ref: 198

13) The influx of calcium into the axon terminal of a chemical synapse is responsible for which of the following?
   A) initiation of an action potential
   B) termination of an action potential
   C) fusion of vesicles to the membrane and of exocytosis neurotransmitter
   D) diffusion of the neurotransmitter across the membrane and into the cleft
   E) movement of calcium through gap junctions
   Answer: C
   Diff: 4 Page Ref: 198

14) Which of the following is NOT a mechanism whereby neurotransmitters are rapidly removed from the synaptic cleft?
   A) diffusion out of the cleft
   B) degradation by enzymes
   C) active reuptake across the presynaptic membrane
   D) binding to the receptor
   E) transport back up the axon to be immediately repackaged
   Answer: E
   Diff: 5 Page Ref: 198

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15) Neurotransmitters can be reused through the process of ________, where neurotransmitters are transported across the presynaptic membrane.
   A) reuptake  
   B) regeneration  
   C) recycling  
   D) resynthesis  
   E) receptor binding
   Answer: A  
   Diff: 4  Page Ref: 199

16) The extent of neurotransmitter binding to receptors on the postsynaptic membrane is determined primarily by which of the following?
   A) sodium  
   B) calcium  
   C) the distance of the cleft  
   D) the concentration of neurotransmitter  
   E) neurotransmitter vesicles
   Answer: D  
   Diff: 4  Page Ref: 198

17) The synaptic delay is caused by the time required for which step of neurotransmitter release?
   A) an action potential to move from axon hillock to axon terminal  
   B) the synthesis of neurotransmitter  
   C) packaging of neurotransmitter into synaptic vesicles  
   D) calcium entry to trigger exocytosis  
   E) the neurotransmitter to diffuse across the synaptic cleft
   Answer: D  
   Diff: 5  Page Ref: 199

18) What type of receptor is responsible for the rapid opening of ion channels in response to the interaction between the ligand and receptor?
   A) mechanotropic receptor  
   B) metabotropic receptor  
   C) ionotropic receptor  
   D) potentiotropic receptor  
   E) chemotropic receptor
   Answer: C  
   Diff: 5  Page Ref: 199

19) The opening of ion channels that is stimulated by the binding of a neurotransmitter to its receptor on a neighboring neuron, and the subsequent movement of ions across that membrane, describes the development of which of the following?
   A) action potential  
   B) presynaptic potential  
   C) neurogenic potential  
   D) postsynaptic potential  
   E) cleft potential
   Answer: D  
   Diff: 4  Page Ref: 200
20) The rapid change in membrane potential that occurs when a ligand binds to an ionotropic receptor is caused by which of the following?
   A) the rapid gating of the ion channel by G protein
   B) the rapid G protein response that indirectly links receptor to channel
   C) the G protein amplification that causes the rapid channel response
   D) the presence of one protein that functions as both an ionotropic receptor and an ion channel
   E) the large ion gradient across the membrane

   Answer: D  
   Diff: 5  Page Ref: 199

21) Synaptic potentials are produced at what type of synapse?
   A) axo–axonic, axo–dendritic, and axo–somatic synapses
   B) axo–axonic and axo–dendritic synapses only
   C) axo–axonic and axo–somatic synapses only
   D) axo–dendritic and axo–somatic synapses only
   E) axo–dendritic synapses only

   Answer: D  
   Diff: 5  Page Ref: 198

22) At ionotropic receptors, a(n) ________.
   A) neurotransmitter binding to a receptor opens channels that are a part of the same protein as the receptor
   B) neurotransmitter binding to a receptor opens channels that are a separate protein from the receptor
   C) neurotransmitter binding to a receptor opens or closes channels that are part of the same protein as the receptor
   D) neurotransmitter binding to a receptor opens or closes channels that are a separate protein from the receptor
   E) ion binding to a receptor opens channels in the plasma membrane

   Answer: A  
   Diff: 6  Page Ref: 199

23) Presynaptic modulation occurs at what type of synapse?
   A) axo–dendritic
   B) axo–axonic
   C) axo–somatic
   D) dendro–dendritic
   E) dendro–somatic

   Answer: B  
   Diff: 4  Page Ref: 205
24) Metabotropic receptor-induced gating of ion channels requires more time to occur because of which of the following? 
   A) their gating is linked to a G protein  
   B) the channels are slower to open  
   C) intracellular calcium must increase before those channels will open  
   D) ion channels linked to metabotropic receptors must move to the membrane before gating  
   E) metabolic byproducts are required to open those channels  
   Answer: A  
   Diff: 5  Page Ref: 200

25) What is a change in the postsynaptic potential that brings membrane potential closer to threshold called?  
   A) excitatory postsynaptic potential  
   B) inhibitory postsynaptic potential  
   C) suprathreshold postsynaptic potential  
   D) hyperpolarizing postsynaptic potential  
   E) inhibitory presynaptic potential  
   Answer: A  
   Diff: 4  Page Ref: 200

26) The most common mechanism for producing a fast EPSP involves which of the following?  
   A) opening of sodium-selective channels  
   B) opening of potassium-selective channels  
   C) closing of sodium-selective channels  
   D) closing of potassium-selective channels  
   E) opening of channels that permit both sodium and potassium to flow through  
   Answer: E  
   Diff: 6  Page Ref: 201

27) What ion directly triggers neurotransmitter release from the presynaptic neuron?  
   A) sodium  
   B) potassium  
   C) chloride  
   D) calcium  
   E) magnesium  
   Answer: D  
   Diff: 3  Page Ref: 198

28) An example of a slow excitatory postsynaptic potential that involves closure of potassium channels relies on cAMP produced by what enzyme?  
   A) phosphodiesterase  
   B) protein kinase A  
   C) G protein  
   D) adenylate cyclase  
   E) protein kinase C  
   Answer: D  
   Diff: 4  Page Ref: 201
29) The duration of a slow, excitatory postsynaptic potential mediated by cAMP is driven by the extent of time that cAMP remains active before being degraded by what protein?
   A) phosphodiesterase  
   B) protein kinase A  
   C) G protein  
   D) adenylate cyclase  
   E) protein kinase C  
   Answer: A  
   Diff: 4  Page Ref: 201

30) Fast excitatory responses not only occur quickly, but _______.
   A) they also have a slow component  
   B) they remain active for a long period of time  
   C) they end quickly  
   D) they always create a substantial depolarization  
   E) they are maintained for minutes to hours  
   Answer: C  
   Diff: 4  Page Ref: 201

31) The binding of a neurotransmitter to its receptor at an inhibitory synapse can lead to the _______ of _______ channels.
   A) opening : chloride  
   B) closure : potassium  
   C) opening : sodium  
   D) closure : chloride  
   E) opening : calcium  
   Answer: A  
   Diff: 5  Page Ref: 202

32) The binding of a neurotransmitter to its receptor at an inhibitory synapse can lead to the _______ of _______ channels.
   A) opening : potassium  
   B) closure : potassium  
   C) opening : sodium  
   D) closing : chloride  
   E) opening : calcium  
   Answer: A  
   Diff: 5  Page Ref: 202

33) In the absence of active chloride ion transport, opening of chloride channels in a cell that has hyperpolarized will result in which of the following?
   A) net movement of chloride out of the cell  
   B) net movement of chloride into the cell  
   C) movement of chloride equally in both directions  
   D) absence of any chloride movement  
   E) depolarization of the cell  
   Answer: A  
   Diff: 7  Page Ref: 202
34) In the presence of active chloride ion transport within a neuron, the opening of chloride channels will result in which of the following?
   A) net movement of chloride out of the cell
   B) net movement of chloride into the cell
   C) movement of chloride equally in both directions
   D) absence of any chloride movement
   E) depolarization of the cell

   Answer: B
   Diff: 6 Page Ref: 202

35) If the resting membrane potential is equal to chloride’s equilibrium potential, in which direction will chloride ions move if chloride channels open while the cell remains at resting membrane potential?
   A) inward
   B) outward
   C) No ions will move through the channel.
   D) Ions will move equally in both directions.
   E) Three chloride ions will move out for every two chloride ions that move in.

   Answer: D
   Diff: 6 Page Ref: 202

36) In the absence of an active chloride transporter in the plasma membrane, chloride acts to _______ membrane potential by resisting any change in membrane potential.
   A) hyperpolarize
   B) depolarize
   C) stabilize
   D) modify
   E) alter

   Answer: C
   Diff: 5 Page Ref: 202

37) The opening of a chloride channel acts to _______ the development of an action potential at the axon hillock.
   A) stimulate
   B) inhibit
   C) facilitate
   D) further
   E) enhance

   Answer: B
   Diff: 4 Page Ref: 202

38) Convergence in neurophysiology refers to which of the following?
   A) the presence of EPSPs and IPSPs on a neuron at the same time
   B) the communication of several neurons to one postsynaptic cell
   C) the summation of graded potentials to determine whether or not an action potential will be generated
   D) the level of depolarization required to generate an action potential
   E) the arrival of an action potential at the axon terminal

   Answer: B
   Diff: 4 Page Ref: 203
39) The final integration of postsynaptic potentials that determines whether an action potential is generated occurs within what region of a neuron?
   A) dendrites  
   B) cell body  
   C) axon  
   D) axon hillock  
   E) rough endoplasmic reticulum  
   Answer: D  
   Diff: 3  Page Ref: 203

40) The degree of summation that can occur for inhibitory postsynaptic potentials is limited by what?
   A) the equilibrium potential for sodium  
   B) the extent of depolarization that is occurring at the same time  
   C) the equilibrium potential for potassium  
   D) the equilibrium potential for the ion creating the hyperpolarization  
   E) the equilibrium potential for chloride  
   Answer: D  
   Diff: 5  Page Ref: 204

41) For ionotropic receptors, their _______ response _______ the likelihood that two pulses from the same neuron will summate.
   A) rapid : decreases  
   B) rapid : increases  
   C) rapid : does not affect  
   D) slow : decrease  
   E) slow : increase  
   Answer: A  
   Diff: 7  Page Ref: 204

42) Which of the following would increase the likelihood of an action potential being generated in a postsynaptic cell?
   A) presynaptic inhibition at an excitatory synapse  
   B) presynaptic excitation at an excitatory synapse  
   C) opening of potassium channels on the postsynaptic cell  
   D) opening of chloride channels on a postsynaptic cell with no active transport of chloride ions  
   E) opening of chloride channels on a postsynaptic cell that actively transports chloride ions out of the cell  
   Answer: B  
   Diff: 5  Page Ref: 206
43) Which of the following statements about inhibitory synapses is FALSE?
   A) Opening of potassium channels can generate an IPSP.
   B) Opening of chloride channels can generate an IPSP.
   C) In presynaptic inhibition, opening of chloride channels can stabilize the membrane, opposing a depolarizing force.
   D) The membrane potential of the postsynaptic cell can be hyperpolarized.
   E) The postsynaptic cell is less likely to generate an action potential.

Answer: C
Diff: 5   Page Ref: 202

44) For the slow receptors, the likelihood of summation is ______ by the ______ of time required for those responses to decay.
   A) decreased: short period
   B) increased: short period
   C) decreased: long period
   D) increased: long period
   E) unaffected: long period

Answer: D
Diff: 5   Page Ref: 204

45) As the amplitude of the excitatory postsynaptic potential increases above threshold, the time between each action potential will ______, thereby increasing the ______ of the action potentials.
   A) decrease: frequency
   B) decrease: amplitude
   C) increase: frequency
   D) increase: amplitude
   E) not be altered: amplitude

Answer: A
Diff: 5   Page Ref: 206

46) Suprathreshold graded potentials within a neuron can generate ______ action potential(s) at the axon hillock, which allows for the ______ of the magnitude of the stimulus.
   A) multiple: amplitude coding
   B) multiple: frequency coding
   C) a single: frequency coding
   D) a single: amplitude coding
   E) several: amplitude coding

Answer: B
Diff: 6   Page Ref: 206

47) Axoaxonic synapses are responsible for ______ the extent of neurotransmitter released at the synapse.
   A) inhibiting
   B) decreasing
   C) increasing
   D) modulating
   E) enhancing

Answer: D
Diff: 5   Page Ref: 206
48) Presynaptic modulation of neurotransmitter release involves modifying _______ at the axon terminal.
   A) membrane potential
   B) calcium influx
   C) the vesicles selected for release
   D) sodium channels
   E) potassium channels

Answer: B
Diff: 6 Page Ref: 206

49) During presynaptic inhibition, the release of a neurotransmitter from the modulating neuron causes which of the following?
   A) a decrease in neurotransmitter release from the neuron it is modulating
   B) a hyperpolarization of the neuron it is modulating
   C) an IPSP on the postsynaptic cell
   D) an EPSP on the postsynaptic cell
   E) an increase in calcium entry into the axon terminal of the neuron it is modulating

Answer: A
Diff: 5 Page Ref: 206

50) Which of the following best describes presynaptic facilitation?
   A) The modulating neuron causes an EPSP on the postsynaptic cell.
   B) The modulating neuron enhances neurotransmitter release from the postsynaptic cell.
   C) The modulating neuron triggers an action potential in the postsynaptic cell.
   D) The modulating neuron stabilizes the membrane potential of the postsynaptic cell.
   E) The modulating neuron decreases the effective communication between the cell it is
       modulating and its postsynaptic cell.

Answer: B
Diff: 5 Page Ref: 206

51) The synthesis of acetylcholine involves an enzyme called _______, which is present within the cytosol and is responsible for converting _______ into acetylcholine.
   A) choline acetyl transferase : choline + acetate
   B) acetylcholinesterase : acetyl CoA + choline
   C) choline acetyl transferase : acetyl CoA + choline
   D) acetylcholinesterase : choline
   E) choline acetyl transferase : acetyl CoA

Answer: C
Diff: 4 Page Ref: 207

52) Neurons that synthesize and release acetylcholine are called _______.
   A) cholinergic neurons
   B) adrenergic neurons
   C) dopaminergic neurons
   D) nitridergic neurons
   E) acetylergic neurons

Answer: A
Diff: 2 Page Ref: 207

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53) Once released, acetylcholine is degraded by extracellular enzymes into what product(s)?
   A) acetate + choline
   B) acetyl CoA + choline
   C) methylcholine + acetate
   D) choline only
   E) acetate only
   Answer: A
   Diff: 4   Page Ref: 208

54) What is transported back into the axon terminal of cholinergic neurons to be resynthesized into active neurotransmitter?
   A) Acetylcholine
   B) Acetyl CoA
   C) Acetate
   D) Choline
   E) Epinephrine
   Answer: D
   Diff: 4   Page Ref: 208

55) What type of receptor is both ionotropic and cholinergic?
   A) muscarinic receptors
   B) dopaminergic receptors
   C) nitridergic receptors
   D) adrenergic receptors
   E) nicotinic receptors
   Answer: E
   Diff: 4   Page Ref: 208

56) What type of receptor is both metabotropic and cholinergic?
   A) muscarinic receptors
   B) dopaminergic receptors
   C) nitridergic receptors
   D) adrenergic receptors
   E) nicotinic receptors
   Answer: A
   Diff: 4   Page Ref: 208

57) Which of the following is a neurotransmitter that contains a six-carbon ring with two hydroxyl groups and an amine group?
   A) acetylcholine
   B) norepinephrine
   C) amino acids
   D) neuroactive peptides
   E) nitric oxide
   Answer: B
   Diff: 7   Page Ref: 209
58) Which of the following couplings between neurotransmitter and neurotransmitter class is INCORRECT?
   A) adenosine : amino acid
   B) norepinephrine : catecholamine
   C) histamine : biogenic amine
   D) enkephalin : neuropeptide
   E) nitric oxide : gas

   Answer: A  
   Diff: 5  Page Ref: 207

59) Which of the following is an ionotropic purinergic receptor that binds ATP?
   A) P2X
   B) P2Y
   C) A1
   D) A2
   E) A3

   Answer: A  
   Diff: 6  Page Ref: 210

60) Biogenic amines are synthesized in what region of a neuron?
   A) cytosol of the cell body
   B) axon hillock
   C) rough endoplasmic reticulum
   D) extracellular space
   E) cytosol of the axon terminal

   Answer: E  
   Diff: 4  Page Ref: 209

61) The action of adrenergic receptors identifies them as _______ receptors.
   A) metabotropic
   B) chemotropic
   C) ionotropic
   D) voltage-gated
   E) mechanically-gated

   Answer: A  
   Diff: 4  Page Ref: 209

62) Which of the following is a biogenic amine that is NOT classified as a catecholamine?
   A) norepinephrine
   B) epinephrine
   C) adrenaline
   D) serotonin
   E) dopamine

   Answer: D  
   Diff: 4  Page Ref: 209
63) What two enzymes catalyze the breakdown of catecholamines?
   A) catechol-O-methyltransferase and acetylcholinesterase
   B) acetylcholinesterase and dopa decarboxylase
   C) monoamine oxidase and phenylethanolamine N methyltransferase
   D) dopa decarboxylase and phenylethanolamine N methyltransferase
   E) monoamine oxidase and catechol-O-methyltransferase

   Answer: E
   Diff: 5       Page Ref: 210

64) Epinephrine binds best to which of the following receptor types?
   A) nicotinic cholinergic receptors
   B) muscarinic cholinergic receptors
   C) alpha adrenergic receptors
   D) beta1 adrenergic receptors
   E) beta2 adrenergic receptors

   Answer: E
   Diff: 5       Page Ref: 209

65) Fast EPSPs are produced at which of the following types of receptor?
   A) nicotinic cholinergic only
   B) alpha-adrenergic only
   C) AMPA receptors only
   D) both nicotinic cholinergic and AMPA receptors
   E) both nicotinic cholinergic and alpha-adrenergic receptors

   Answer: D
   Diff: 6       Page Ref: 211

66) In which region of the brain does histamine function as a neurotransmitter?
   A) hypothalamus
   B) medulla
   C) pons
   D) cerebrum
   E) cerebellum

   Answer: A
   Diff: 4       Page Ref: 210

67) ______ is an amino acid neurotransmitter at excitatory synapses whereas ______ is an
    amino acid neurotransmitter at inhibitory synapses.
   A) Gamma-aminobutyric acid : glutamate
   B) Gamma-aminobutyric acid : glycine
   C) Glycine : aspartate
   D) Aspartate : glycine
   E) Glutamate : aspartate

   Answer: D
   Diff: 4       Page Ref: 210
68) Which of the following GABA receptor types is coupled to chloride channels?
   A) GABA_A only
   B) GABA_B only
   C) GABA_C only
   D) both GABA_A and GABA_B
   E) both GABA_A and GABA_C

   Answer: A  
   Diff: 6   Page Ref: 211

69) IPSPs are produced when GABA binds to what class of receptor?
   A) GABA_A only
   B) GABA_B only
   C) GABA_C only
   D) both GABA_A and GABA_B
   E) both GABA_A and GABA_C

   Answer: A  
   Diff: 6   Page Ref: 211

70) What is the most common inhibitory neurotransmitter in the central nervous system?
   A) glycine
   B) GABA
   C) glutamate
   D) acetylcholine
   E) aspartate

   Answer: B  
   Diff: 5   Page Ref: 211

71) Neuropeptides are synthesized in what region of a neuron?
   A) within the axon terminal
   B) in the rough endoplasmic reticulum
   C) along the axon
   D) within the vesicles
   E) at the dendrite

   Answer: B  
   Diff: 3   Page Ref: 211

72) Which of the following compounds is NOT a neuropeptide?
   A) substance P
   B) vasopressin
   C) oxytocin
   D) endorphin
   E) epinephrine

   Answer: E  
   Diff: 3   Page Ref: 211
73) Which of the following is a hypothalamic neuropeptide that regulates the sleep–wake cycle?
   A) orexin
   B) vasopressin
   C) oxytocin
   D) melatonin
   E) substance P

   Answer: A  
   Diff: 5  Page Ref: 212

74) Nitric oxide is a _______ that functions as a neurotransmitter.
   A) catecholamine
   B) gas
   C) neuroactive peptide
   D) biogenic amine
   E) amino acid

   Answer: B  
   Diff: 4  Page Ref: 211

75) Which of the following chemicals is NOT a known neurotransmitter?
   A) acetylcholine
   B) nitric oxide
   C) ATP
   D) substance P
   E) carbon dioxide

   Answer: E  
   Diff: 3  Page Ref: 208

76) What chemical targets CB1 receptors?
   A) tetrahydrocannabinol
   B) enkephalin
   C) carbonic acid
   D) carbon dioxide
   E) glutamate

   Answer: A  
   Diff: 4  Page Ref: 212

True/False Questions

1) When voltage-dependent calcium channels open, calcium moves out of the cell.

   Answer: FALSE  
   Diff: 4  Page Ref: 198

2) Every time an action potential reaches the axon terminal, a quick burst of neurotransmitter is released into the synaptic cleft.

   Answer: TRUE  
   Diff: 4  Page Ref: 198

3) Excitatory postsynaptic potentials can occur as either fast or slow responses.

   Answer: TRUE  
   Diff: 4  Page Ref: 201
4) In the absence of active transport of chloride, membrane potential will determine the concentration of chloride ions across a neuron’s plasma membrane.
   Answer: TRUE
   Diff: 5 Page Ref: 202

5) Once initiated, excitatory postsynaptic potentials last for hours, especially if a fast receptor is activated.
   Answer: FALSE
   Diff: 5 Page Ref: 201

6) An action potential is triggered if the membrane potential at the axon hillock is depolarized to threshold.
   Answer: TRUE
   Diff: 3 Page Ref: 203

7) IPSPs can only summate with IPSPs, and EPSPs can only summate with EPSPs.
   Answer: FALSE
   Diff: 3 Page Ref: 205

8) Two or more graded potentials originating from a different synapse on the same neuron at approximately the same time will cause spatial summation.
   Answer: TRUE
   Diff: 4 Page Ref: 204

9) Information on the amplitude of a particular response is coded for by the amplitude of the action potential generated.
   Answer: FALSE
   Diff: 3 Page Ref: 206

10) Presynaptic modulation involves a neurotransmitter from the axon terminal of one neuron affecting the membrane potential of an axon terminal from another neuron on which the first has synapsed (axoaxonic synapse).
    Answer: FALSE
    Diff: 5 Page Ref: 206

11) An axoaxonic synapse is unique in its ability to affect only one synapse.
    Answer: TRUE
    Diff: 4 Page Ref: 206

12) The similarity in structure between glutamate and GABA are indicative of the similarity in their function.
    Answer: FALSE
    Diff: 5 Page Ref: 210

13) Connexons are a necessary component of electrical synapses.
    Answer: TRUE
    Diff: 5 Page Ref: 197
14) Most neurotransmitters are synthesized in the cytosol and actively transported into synaptic vesicles.
   Answer: TRUE
   Diff: 4    Page Ref: 198

15) Slow postsynaptic potentials can be caused by the opening or closing of ion channels, whereas fast postsynaptic potentials only involve the opening of ion channels.
   Answer: TRUE
   Diff: 4    Page Ref: 200

16) Closing of potassium channels causes a hyperpolarization.
   Answer: FALSE
   Diff: 4    Page Ref: 202

17) If the equilibrium potential of a cation is ~40 mV, then opening of channels for this cation will result in excitation of the neuron.
   Answer: TRUE
   Diff: 7    Page Ref: 200

18) Neural integration occurs at a neuron’s cell body.
   Answer: FALSE
   Diff: 4    Page Ref: 203

19) Presynaptic modulation occurs at axo-somatic synapses.
   Answer: FALSE
   Diff: 4    Page Ref: 206

20) Adenosine is degraded by nucleotidases.
   Answer: FALSE
   Diff: 6    Page Ref: 211

21) GABA is a biogenic amine.
   Answer: FALSE
   Diff: 3    Page Ref: 210

22) When one neuron has several axon collaterals that communicate with several other neurons, it is called divergence.
   Answer: TRUE
   Diff: 3    Page Ref: 203

23) GABA acts as an autocrine at GABA_A receptors.
   Answer: FALSE
   Diff: 4    Page Ref: 211

24) Most EPSPs are at least 10 mV in magnitude at the point of synaptic communication.
   Answer: FALSE
   Diff: 5    Page Ref: 204
25) Most communication between neurons in the central nervous system is one-to-one, that is, one presynaptic neuron communicates to just one postsynaptic neuron.

Answer: FALSE

Diff: 3 Page Ref: 203

Matching Questions

Match the following neurotransmitters with the appropriate description.

1) A neuropeptide.

Diff: 3 Page Ref: 211

2) Amino acid neurotransmitter released at excitatory synapses.

Diff: 3 Page Ref: 210

3) Catecholamine.

Diff: 3 Page Ref: 209

4) Biogenic amine, but not a catecholamine.

Diff: 3 Page Ref: 209

5) Amino acid neurotransmitter released at inhibitory synapses.

Diff: 3 Page Ref: 210

6) Most common neurotransmitter in the peripheral nervous system.

Diff: 3 Page Ref: 207

Answers: 1) A 2) C 3) F 4) B 5) E 6) D
Match the change in membrane potential that occurs due to the described change in ion channel. In all cases, assume the resting membrane potential to be −70 mV.

7) Sodium channels open.
   Diff: 3  Page Ref: 201
   A) membrane stabilization
   B) hyperpolarization
   C) depolarization

8) Sodium channels close.
   Diff: 3  Page Ref: 202

9) Potassium channels open.
   Diff: 3  Page Ref: 202

10) Potassium channels close.
    Diff: 3  Page Ref: 201

11) Channels for an anion with an equilibrium potential of −80 mV open.
    Diff: 6  Page Ref: 201

12) Channels for a cation with an equilibrium potential of −80 mV open.
    Diff: 6  Page Ref: 201

13) Channels for a cation with an equilibrium potential of −30 mV open.
    Diff: 6  Page Ref: 201

14) Channels that permit both sodium and potassium to move through open.
    Diff: 4  Page Ref: 201

Match the following enzymes with their functions.

15) Catalyzes synthesis of cAMP.
   Diff: 3 Page Ref: 201
   A) choline acetyl transferase
   B) acetylcholinesterase
   C) adenylate cyclase
   D) monoamine oxidase
   E) catechol-O-methyltransferase

16) Catalyzes synthesis of acetylcholine.
   Diff: 4 Page Ref: 207
   A) choline acetyl transferase

17) Catalyzes breakdown of catecholamines in the synaptic cleft and in the axon terminal of the presynaptic cell.
   Diff: 5 Page Ref: 210
   A) choline acetyl transferase
   B) acetylcholinesterase
   C) adenylate cyclase
   D) monoamine oxidase
   E) catechol-O-methyltransferase

18) Catalyzes breakdown of catecholamines in the synaptic cleft only.
   Diff: 5 Page Ref: 210
   A) choline acetyl transferase
   B) acetylcholinesterase
   C) adenylate cyclase
   D) monoamine oxidase
   E) catechol-O-methyltransferase

19) Catalyzes breakdown of acetylcholine.
   Diff: 4 Page Ref: 208
   A) choline acetyl transferase


Match the receptor type to the correct class.

20) Nicotinic cholinergic.
   Diff: 3 Page Ref: 208
   A) ionotropic receptor
   B) metabotropic receptor

21) Muscarinic cholinergic.
   Diff: 3 Page Ref: 208
   A) ionotropic receptor
   B) metabotropic receptor

22) Alpha adrenergic.
   Diff: 3 Page Ref: 209
   A) ionotropic receptor
   B) metabotropic receptor

23) Beta1 adrenergic.
   Diff: 3 Page Ref: 209
   A) ionotropic receptor
   B) metabotropic receptor

24) AMPA.
   Diff: 5 Page Ref: 211
   A) ionotropic receptor

25) NMDA.
   Diff: 5 Page Ref: 211
   A) ionotropic receptor


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Essay Questions

1) Information travels through the nervous system along the axons as action potentials. These action potentials must be transmitted across the synaptic cleft. Describe the process whereby an action potential that has entered the axon terminal is able to induce a change in membrane potential in the postsynaptic membrane, following neurotransmitter binding to a metabotropic receptor.

Answer: An action potential travels rapidly along the axon as a wave of depolarization. As that depolarization reaches the axon terminal, the action potential is terminated by an absence of the voltage-gated sodium channels in the axon terminal. However, the voltage-gated calcium channels in the axon terminal are opened by the depolarization. The subsequent increase in cytoplasmic calcium in the axon terminal causes the vesicles containing neurotransmitter to fuse with the presynaptic membrane and release their contents through exocytosis. Thereafter, cytoplasmic calcium concentrations are rapidly returned to resting values by the short duration that the calcium channel remains open (milliseconds) and pumps in the presynaptic membrane moving calcium out of the cell. This rapid return of cytoplasmic calcium to resting values allows subsequent action potentials to repeat the process described above and release more neurotransmitter. A reduction in cytoplasmic calcium will decrease the release of neurotransmitter. Once that neurotransmitter is released, it has several possible fates: it could be 1) bound to a receptor on the postsynaptic membrane, 2) degraded by enzymes around the synaptic cleft, or 3) actively transported back into the presynaptic terminal. For those neurotransmitters that have bound to metabotropic receptors on the cell membrane, the binding of a ligand to its receptor will set into motion a chain of reactions that will result in the opening or closure of an ion channel. Thus, depending upon the ion selectivity of the channel that is affected, the postsynaptic membrane can either depolarize or hyperpolarize (sodium opening will depolarize as will potassium channel closure, and vice versa). Some metabotropic receptors are coupled to G proteins, which accounts for their being described as slow channels. Activation of G protein by receptor–ligand interactions can act in two ways: 1) directly on an ion channel, or 2) indirectly through the activation of a second messenger cascade. Not only are these responses slow in comparison to ionotrophic receptors, but they can require longer periods of time to decay (i.e., the change in membrane potential is maintained for minutes to hours).

Diff: 7 Page Ref: 198
2) Postsynaptic potentials generated by neurotransmitter binding to receptors on the postsynaptic membrane can be excitatory or inhibitory. Describe excitatory postsynaptic potentials and their temporal characteristics.

Answer: Excitatory postsynaptic potentials (EPSPs) describe a graded depolarization of the postsynaptic membrane that is generated by neurotransmitter binding to a receptor on the postsynaptic membrane of the dendrites or cell body. EPSPs are called excitatory because they bring membrane potential closer to the threshold for an action potential. That depolarization can occur by opening sodium channels or by closing potassium channels. In addition, opening non-selective cation channels that are equally permeated by potassium and sodium would also lead to a depolarization due to the stronger electrochemical gradient for sodium at resting membrane potential. The stronger sodium gradient would result in a greater influx of sodium compared with the efflux of potassium, which would result in a depolarization of the membrane. Fast EPSPs are very short-lived (i.e., milliseconds). Because responses generated by ionotropic receptors degrade so quickly, the potential for summation is reduced. Alternatively, EPSPs generated by metabotropic receptors are slow to develop and persist for longer periods of time, thereby increasing the possibility that they will summate. Those slow EPSPs generated via metabotropic receptors often involve the cAMP-dependent closure of potassium channels. The metabotropic receptor is coupled to G protein which, once activated, will activate the enzyme adenylate cyclase, which converts ATP to cAMP. An increase in cAMP will activate protein kinase A, which phosphorylates the potassium channel, causing it to close. This depolarization is maintained until cAMP is degraded by phosphodiesterase.

Diff: 7    Page Ref: 200

3) Postsynaptic potentials, generated by neurotransmitter binding to receptors on the postsynaptic membrane can be excitatory or inhibitory. Describe inhibitory postsynaptic potentials and how chloride channels can be inhibitory without producing an IPSP.

Answer: Inhibitory postsynaptic potentials (IPSPs) describe a graded hyperpolarization of the postsynaptic membrane, which is generated by ligand binding to a receptor on the postsynaptic membrane of the dendrites or the nerve cell body itself. IPSPs are called inhibitory because they take membrane potential further away from the threshold for an action potential. That hyperpolarization can occur by closing sodium channels, by opening potassium channels, or by opening chloride channels. With respect to chloride channels, the electrical gradient drives chloride out of the cell while the chemical gradient drives chloride into the cell. The net movement of chloride will depend upon the neuron involved: 1) neurons with active transporters that move chloride out of the cell set up an inward chloride gradient, while 2) in the absence of an active chloride transporter, chloride is at equilibrium. In neurons with active chloride transporters, opening a chloride channel will initiate the influx of chloride into the cell, thereby causing a hyperpolarization. However, when chloride is at equilibrium, opening a chloride channel will not alter membrane potential and thus, does not produce an IPSP. However, this synapse is considered inhibitory because once an EPSP is initiated, that depolarization will create an electrical gradient that will move chloride into the cell, thereby decreasing the extent of depolarization from any EPSP. Thus, while opening a chloride channel in a neuron lacking an active chloride transporter will not alter membrane potential, the mere presence of open chloride channels will counter any EPSP that might be initiated.

Diff: 9    Page Ref: 202
4) Once an action potential reaches the axon terminal, that depolarization stimulates the release of neurotransmitters that can be modulated by other neurons that synapse with the axon terminal. Describe how neurotransmitters are released from the axon terminal and how that response is altered by axoaxonic synapses.

Answer: Axoaxonic synapses describe a structure where the axon terminal from one neuron synapses with another axon terminal. These axoaxonic synapses are quite specific for a particular axon terminal. The release of neurotransmitter from the postsynaptic neuron is determined by the extent of calcium released within the axon terminal. There are two types of neuromodulation that can occur: presynaptic facilitation and presynaptic inhibition. In presynaptic facilitation, calcium release in the axon terminal is enhanced, which increases the release of neurotransmitter. For presynaptic inhibition, calcium release in the axon terminal is decreased, thereby decreasing the amount of neurotransmitter released from the axon terminal.

Diff: 6 Page Ref: 206

5) The neurotransmitter for skeletal muscle is acetylcholine which binds to nicotinic receptors on skeletal muscle. Describe the process whereby acetylcholine is synthesized, released, and degraded within the synapse.

Answer: Acetylcholine is a neurotransmitter that is synthesized within the axon terminal. Choline acetyl transferase is the enzyme within the axon terminal that converts acetyl CoA and choline into acetylcholine. The acetylcholine is packaged within the vesicles for release into the synapse. Once released, acetylcholine diffuses across the synaptic cleft and binds with a cholinergic receptor. There are two types of cholinergic receptors that are present: muscarinic and nicotinic. The distribution of these receptors varies by tissue, as does the response originated from these receptors. Nicotinic receptors are ionotropic and thereby trigger an ion channel opening. Muscarinic receptors are metabotropic receptors whose activity is triggered via a G protein. In response to activation by acetylcholine, muscarinic receptors can either open or close ion channels or activate enzymes. The remainder of the acetylcholine must be removed from the synapse. This is done by the presence of acetylcholinesterase. Acetylcholine is degraded to choline and acetate. The choline can be actively transported back into the axon terminal and recycled into acetylcholine.

Diff: 6 Page Ref: 207
6) Catecholamines are an important class of neurotransmitter. Describe the receptors involved in responding to catecholamines and how they are degraded.

Answer: Catecholamines are synthesized within the axon terminal from the amino acid tyrosine. The catecholamines include dopamine, norepinephrine, and epinephrine. Once released, dopamine will bind to dopaminergic receptors, whereas norepinephrine and epinephrine both bind to adrenergic receptors. There are two main classes of adrenergic receptor: alpha and beta. Each is divided into multiple subclasses (α 1-2 and β 1-3). Adrenergic receptors are found in the central nervous system and on effector organs for the sympathetic nervous system. Adrenergic receptors are coupled to G protein, making adrenergic receptors metabotropic receptors. At the same time, adrenergic receptors are autoreceptors, meaning that they are present on the presynaptic membrane to modify the release of catecholamines. Thus, catecholamines released from an axon terminal will bind to adrenergic receptors on both the presynaptic and postsynaptic membrane. Following their release, catecholamines are degraded by monoamine oxidase (MAO) and catechol-O-methyltransferase (COMT). MAO and COMT are located within the synaptic cleft, while MAO is also found in the axon terminal and some glial cells.

Diff: 7 Page Ref: 209

7) Describe the process of neural integration in neurons, with particular emphasis on summation and how action potentials are generated within neurons.

Answer: In order for an action potential to be triggered from a neuron, membrane potential must be above threshold at the axon hillock. Thus, both axodendritic and axosomatic synapses are involved. The responses that originate from these synapses are dependent upon the neurotransmitter released and the receptor to which those neurotransmitters bind. Membrane potential changes originate from ionotropic and metabotropic receptors. The ionotropic receptors are both a receptor and an ion channel such that neurotransmitter binding to the receptor induces the ion channel to open, but only for a short duration (milliseconds). However, metabotropic receptors are coupled to ion channels via G proteins. When activated, they act slowly to open or close ion channels. These changes in the gating of ion channels are rather long-lived (seconds to hours). Summation occurs when multiple postsynaptic potentials are generated in rapid succession at the same synapse. If a postsynaptic potential is generated by repeated bursts of action potentials from the same synapse that occurred before the original postsynaptic response can completely decay, then a temporal summation has occurred. If the multiple action potentials that enhance the magnitude of the postsynaptic potential originate from several synapses, then a spatial summation has occurred. Each of these types of summation can either increase or decrease the likelihood of an action potential being generated. If two synapses are active but one generates excitatory postsynaptic potentials (EPSPs) and the other generates inhibitory postsynaptic potentials (IPSPs) of equal magnitude, then the two will cancel one another. However, if several EPSPs are generated, then it becomes more likely that an action potential will be generated. In the end, each of the EPSPs and IPSPs are graded potentials that decay as they move from the dendrite to the cell body and eventually to the axon hillock. Thus, whether an action potential is generated will depend upon the membrane potential at the axon hillock.

Diff: 8 Page Ref: 203
8) A number of modified epithelial cells, acting as sensory receptors, innervate a single neuron. Some of these cells release excitatory neurotransmitters, while others release inhibitory neurotransmitters. How are these responses integrated by the neuron to determine whether an action potential will be generated or not?

Answer: These modified epithelial cells will synapse with the dendrites on the body of a neuron. As neurotransmitters are released onto those dendrites, a graded potential is produced at the postsynaptic membrane that will either depolarize (excitatory postsynaptic potential) or hyperpolarize (inhibitory postsynaptic potential) the membrane. From the synapse, the graded potential will decay as it moves along the membrane of the cell body. In contrast, action potentials do not decay as they move along an axon. Whether or not an action potential is generated is determined by the magnitude of the membrane potential once it reaches the axon hillock. The axon hillock contains the ion channels that are necessary for the generation of an action potential. Thus, if the graded potential that originates at the dendritic synapse and travels along the cell body is still above threshold once it reaches the axon hillock, an action potential will be generated. Two types of integration, referred to as summation, are spatial and temporal. Spatial summation refers to a situation where two synapses are activated at the same time such that the graded potential generated is the sum of the two inputs. Temporal summation refers to two impulses from the same neuron where the second reaches the synapse before the first has decayed completely. However, the process of summation does not necessarily lead to the generation of an action potential. The generation of an action potential is dependent upon the nature of the impulses that are being summed (excitatory or inhibitory) and the magnitude of those impulses.

Diff: 7  Page Ref: 203
Short Answer Questions

Using Figure 8.1, answer the following questions:

1) What is occurring in Step 2 of the figure above, and how is that process originated?
   Answer: influx of calcium: depolarization causes voltage–gated calcium channels to open
   Diff: 4    Page Ref: 198

2) Identify the structures on the postsynaptic membrane that bind with the neurotransmitter in Steps 4 and 6 of the figure above, and indicate their function.
   Answer: Step 4 is a receptor that can stimulate a cellular response by gating its ion channel or stimulating a G protein to gate an ion channel.
   Step 6 shows an enzyme that is degrading the neurotransmitter.
   Diff: 5    Page Ref: 198

3) In the figure above, the overall function of Steps 6–8, which occur simultaneously, is to _______.
   Answer: remove neurotransmitter from the synaptic cleft
   Diff: 4    Page Ref: 198

4) Based on the figure, describe the two possible mechanisms whereby Step 5 can occur on the postsynaptic membrane.
   Answer: 1) A fast receptor opens an ion channel that is part of the receptor.
            2) A slow receptor can open or close an ion channel by G protein coupling between receptor and ion channel.
   Diff: 6    Page Ref: 198
5) Based on the figure, identify the structure in Step 6, if this presynaptic neuron is cholinergic. What if the neuron is adrenergic?
   Answer: acetylcholinesterase : monoamine oxidase or catechol-O-methyltransferase
   Diff: 5 Page Ref: 208

6) In the figure, what is the event in Step 1 that is required to start the process that leads to the release of neurotransmitter from an axon terminal?
   Answer: action potential
   Diff: 3 Page Ref: 198

7) Describe what is going on in Steps 3 and 4 of the figure above.
   Answer: Step 3 is the migration of the vesicle containing neurotransmitter to the cell membrane and its release by exocytosis.
   Step 4 indicates that the neurotransmitter must diffuse across the synaptic cleft in order to bind to the receptor on the postsynaptic membrane.
   Diff: 5 Page Ref: 198

8) What channels are the most abundant type of voltage–gated channel within the axon terminal and are responsible for the release of neurotransmitter?
   Answer: Voltage–gated calcium channels
   Diff: 5 Page Ref: 198

9) The opening of a calcium channel in the axon terminal results in the movement of calcium (into / out of) the cell.
   Answer: into
   Diff: 3 Page Ref: 198

10) The synaptic delay required for responses to be generated within the postsynaptic neuron are primarily caused by __________.
    Answer: the time required for calcium to induce exocytosis
    Diff: 6 Page Ref: 199

11) (Opening / Closing) of a potassium channel results in an excitatory postsynaptic potential.
    Answer: Closing
    Diff: 5 Page Ref: 201

12) If the membrane is depolarized to +10 mV, which cation will move more frequently through a small cation channel?
    Answer: potassium
    Diff: 7 Page Ref: 201

13) If the resting membrane potential is −70 mV, which cation will move more frequently through a small cation channel?
    Answer: sodium
    Diff: 5 Page Ref: 201
14) A neuron actively transports chloride ions out of the cell. Opening of chloride channels in response to a neurotransmitter binding to receptors on this neuron will produce (an IPSP / membrane stabilization) thereby (exciting / inhibiting) the neuron.
   Answer: IPSP : inhibiting
   Diff: 5 Page Ref: 202

15) A neuron has no active transport systems for chloride ions. Opening of chloride channels in response to a neurotransmitter binding to receptors on this neuron will produce (an IPSP / membrane stabilization) thereby (exciting / inhibiting) the neuron.
   Answer: membrane stabilization : inhibiting
   Diff: 7 Page Ref: 202

16) Once the neurotransmitter that has activated a slow receptor has been cleared from the synapse, the change in membrane potential (will immediately dissipate / can last a while before dissipating).
   Answer: can last a while before dissipating
   Diff: 5 Page Ref: 200

17) Temporal summation is less likely to occur when the receptor that has been activated is a (fast / slow) receptor.
   Answer: fast
   Diff: 4 Page Ref: 204

18) How will two bursts of action potentials that are traveling along the same neuron induce a temporal summation?
   Answer: If the second burst reaches the axon terminal to induce the release of neurotransmitter before the first has decayed, the postsynaptic membrane will not have completely returned to resting membrane potential, thereby increasing the magnitude of the change in membrane potential relative to a single burst.
   Diff: 5 Page Ref: 204

19) The higher the frequency of action potentials generated, the (more / less) neurotransmitter released at a synapse.
   Answer: more
   Diff: 3 Page Ref: 204

20) _______ must be actively taken up by cholinergic neurons in order to synthesize neurotransmitter.
   Answer: Choline
   Diff: 4 Page Ref: 208

21) Which adrenergic receptor(s) has the greatest affinity for norepinephrine?
   Answer: alpha and beta₁
   Diff: 5 Page Ref: 209

22) Name the type of receptor that is present on the axon terminal and that responds to the release of neurotransmitter from that axon terminal.
   Answer: autoreceptors
   Diff: 4 Page Ref: 209
23) What two enzymes degrade catecholamines?
   Answer: monoamine oxidase and catechol-O-methyltransferase
   Diff: 5  Page Ref: 210

24) What is the active ingredient of cannabis?
   Answer: tetrahydrocannabinol
   Diff: 5  Page Ref: 212
Chapter 9  The Nervous System: Central Nervous System

Multiple Choice Questions

1) Which of the following numbers is closest to the number of neurons in the human brain?
   A) $1 \times 10^6$
   B) $1 \times 10^9$
   C) $1 \times 10^{11}$
   D) $1 \times 10^{14}$
   E) $1 \times 10^{18}$
   Answer: C
   Diff: 3   Page Ref: 216

2) What type of glial cell is necessary for normal development of the blood–brain barrier?
   A) astrocytes
   B) oligodendrocytes
   C) ependymal cells
   D) microglia
   E) Schwann cells
   Answer: A
   Diff: 4   Page Ref: 221

3) What type of glial cell acts locally to maintain normal electrolyte composition of the cerebrospinal fluid?
   A) astrocytes
   B) oligodendrocytes
   C) ependymal cells
   D) microglia
   E) Schwann cells
   Answer: A
   Diff: 5   Page Ref: 216

4) What type of glial cell is a phagocyte?
   A) astrocytes
   B) oligodendrocytes
   C) ependymal cells
   D) microglia
   E) Schwann cells
   Answer: D
   Diff: 5   Page Ref: 217
5) What type of glial cell contributes to neurodegenerative diseases, such as Alzheimer’s disease?
   A) astrocytes only
   B) ependymal cells only
   C) microglia only
   D) both astrocytes and microglia
   E) both ependymal cells and microglia
   Answer: D
   Diff: 7    Page Ref: 217

6) What type of glial cell is located in both the central nervous system and the peripheral nervous system?
   A) astrocytes
   B) oligodendrocytes
   C) Schwann cells
   D) none
   E) microglia
   Answer: D
   Diff: 4    Page Ref: 216

7) Which of the following is the correct order of the meninges, from neural tissue to bone?
   A) Arachnoid mater : dura mater : pia mater
   B) Pia mater : arachnoid mater : dura mater
   C) Arachnoid mater : pia mater : dura mater
   D) Pia mater : dura mater : arachnoid mater
   E) Dura mater : arachnoid mater : pia mater
   Answer: B
   Diff: 3    Page Ref: 217

8) Where is cerebrospinal fluid synthesized?
   A) cerebral ventricles
   B) central canal
   C) subarachnoid space
   D) arachnoid villi
   E) sinusoids
   Answer: A
   Diff: 5    Page Ref: 219

9) Cerebrospinal fluid is produced within the ________ and is reabsorbed into the venous circulation by special structures called the ________.
   A) choroid plexus : subarachnoid space
   B) central canal : arachnoid villi
   C) central canal : subarachnoid space
   D) choroid plexus : arachnoid villi
   E) central canal : ependymal villi
   Answer: D
   Diff: 5    Page Ref: 219
10) What are hollow cavities within the brain that are bathed by cerebrospinal fluid?
   A) central canals  
   B) ventricles  
   C) choroid plexi  
   D) arachnoid villi  
   E) arachnoid spaces  
   Answer: B  
   Diff: 2   Page Ref: 219

11) Which of the following is NOT an accurate explanation for the reliance of the central nervous system on blood flow?
   A) its inability to store glucose  
   B) its inability to metabolize fatty acids  
   C) its inability to obtain energy from anaerobic metabolism  
   D) its inability to metabolize ketones  
   E) 50% of the glucose metabolized by the body fuels the central nervous system.  
   Answer: D  
   Diff: 7   Page Ref: 220

12) Tight junctions between capillary endothelial cells in the central nervous system create the blood–brain barrier, thereby restricting what type of movement of molecules into the brain?
   A) active transport of  
   B) transcytosis of  
   C) facilitated diffusion of hydrophobic  
   D) diffusion of lipophilic  
   E) diffusion of hydrophilic  
   Answer: E  
   Diff: 6   Page Ref: 221

13) In order for ions to move across the capillary endothelial cells of the blood–brain barrier, they must _______.  
   A) move through the endothelial cell layer by transcytosis  
   B) be lipophobic  
   C) be hydrophilic  
   D) be transported across endothelial cells  
   E) move through pores between endothelial cells  
   Answer: D  
   Diff: 4   Page Ref: 221

14) Which of the following substances requires mediated transport to cross the blood–brain barrier?
   A) glucose  
   B) hydrogen ions  
   C) oxygen  
   D) carbon dioxide  
   E) ethanol  
   Answer: A  
   Diff: 4   Page Ref: 221
15) What type of glucose transporter is located in the endothelial cells of the blood-brain barrier?
   A) co-transporter with sodium
   B) counter-transporter with sodium
   C) GLUT-1
   D) GLUT-2
   E) GLUT-4

   Answer: C
   Diff: 4    Page Ref: 221

16) Which of the following structures is found primarily in white matter?
   A) myelinated axons
   B) neuron cell bodies
   C) dendrites
   D) axon terminals
   E) synapses

   Answer: A
   Diff: 4    Page Ref: 223

17) The outermost layer of the brain is called the _______.
   A) corpus callosum
   B) cerebral cortex
   C) coccyx
   D) commissure
   E) choroid plexus

   Answer: B
   Diff: 2    Page Ref: 223

18) What are the fibers that connect the cortical regions on one side of the brain with the corresponding cortical region on the other side of the brain?
   A) Commissural fibers
   B) Projection fibers
   C) Association fibers
   D) Spinothalamic tracts
   E) Arcuate fasciculi

   Answer: A
   Diff: 5    Page Ref: 223

19) The face is innervated by what type of nerves?
   A) thoracic
   B) cervical
   C) cranial
   D) sacral
   E) lumbar

   Answer: C
   Diff: 4    Page Ref: 226
20) Where is the cauda equina?
   A) surrounding the central canal
   B) surrounding the ventricles
   C) within the ventricles
   D) within the cranium
   E) within the vertebral column

   Answer: E  
   Diff: 4  Page Ref: 225

21) Which spinal nerves originate in the neck region?
   A) lumbar nerves
   B) sacral nerves
   C) cervical nerves
   D) thoracic nerves
   E) coccygeal nerve

   Answer: C  
   Diff: 3  Page Ref: 224

22) Which nerves innervate the thigh?
   A) cranial nerves
   B) cervical nerves
   C) sacral nerves
   D) thoracic nerves
   E) lumbar nerves

   Answer: E  
   Diff: 5  Page Ref: 225

23) Which of the following would NOT be found within the gray matter of the spinal cord?
   A) interneurons
   B) afferent neuron cell bodies
   C) efferent neuron cell bodies
   D) efferent neuron dendrites
   E) axon terminals from afferent neurons

   Answer: B  
   Diff: 6  Page Ref: 226

24) Where are the cell bodies of afferent neurons located?
   A) ventral horn
   B) dorsal horn
   C) dorsal root ganglia
   D) ventral root ganglia
   E) lateral horn

   Answer: C  
   Diff: 4  Page Ref: 226
25) Where are the cell bodies of efferent neurons located?
   A) ventral horn
   B) dorsal horn
   C) dorsal root ganglia
   D) ventral root ganglia
   E) dorsal root
   Answer: A
   Diff: 4 Page Ref: 226

26) Which of the following is a descending tract?
   A) anterior pyramidal tract
   B) dorsal columns
   C) anterior spinothalamic tract
   D) spinotectal tract
   E) lateral spinothalamic tract
   Answer: A
   Diff: 7 Page Ref: 227

27) An ascending or descending pathway that is located on the same side of the central nervous system integration center is called ________.
   A) longitudinal
   B) lateralized
   C) sideways
   D) ipsilateral
   E) commissural
   Answer: D
   Diff: 4 Page Ref: 227

28) What two structures make up the forebrain?
   A) thalamus and hypothalamus
   B) cerebrum and diencephalon
   C) brainstem and cerebellum
   D) brainstem and spinal cord
   E) cerebrum and cerebellum
   Answer: B
   Diff: 4 Page Ref: 227

29) Which of the following is NOT a component of the brainstem?
   A) midbrain
   B) pons
   C) medulla oblongata
   D) cerebellum
   E) reticular formation
   Answer: D
   Diff: 3 Page Ref: 227
30) Where do most cranial nerves originate?
   A) spinal cord
   B) cerebellum
   C) diencephalon
   D) brainstem
   E) cerebral cortex

   Answer: D
   Diff: 4  Page Ref: 229

31) Which of the following cranial nerves does NOT transmit information associated with a special sense?
   A) olfactory
   B) optic
   C) oculomotor
   D) vestibulocochlear
   E) facial

   Answer: C
   Diff: 8  Page Ref: 231

32) Which cranial nerve controls the muscles for chewing?
   A) oculomotor
   B) trochlear
   C) trigeminal
   D) abducens
   E) glossopharyngeal

   Answer: C
   Diff: 8  Page Ref: 231

33) The central sulcus separates the ________.
   A) cerebellum from the forebrain
   B) brainstem from the spinal cord
   C) thalamus from the hypothalamus
   D) frontal lobe from the parietal lobe
   E) temporal lobe from the parietal lobe

   Answer: D
   Diff: 5  Page Ref: 230

34) Which cerebral lobe contains the visual cortex?
   A) occipital lobe
   B) temporal lobe
   C) parietal lobe
   D) frontal lobe
   E) medial lobe

   Answer: A
   Diff: 3  Page Ref: 231
35) Which cerebral lobe contains the auditory cortex?
   A) occipital lobe
   B) temporal lobe
   C) parietal lobe
   D) frontal lobe
   E) medial lobe
   Answer: B
   Diff: 3   Page Ref: 231

36) Which cerebral lobe contains the primary motor cortex?
   A) occipital lobe
   B) temporal lobe
   C) parietal lobe
   D) frontal lobe
   E) medial lobe
   Answer: D
   Diff: 4   Page Ref: 231

37) Which of the following characteristics is NOT a specialization of the right side of the cerebrum in most individuals?
   A) creativity
   B) artistic qualities
   C) musical
   D) spatial perception
   E) logic
   Answer: E
   Diff: 4   Page Ref: 233

38) Which of the following characteristics is NOT a specialization of the left side of the cerebrum in most individuals?
   A) expression of language
   B) comprehension of language
   C) analytical reasoning
   D) spatial perception
   E) logical reasoning
   Answer: D
   Diff: 4   Page Ref: 233

39) What region of the diencephalon filters and refines sensory information, allowing us to direct our attention to specific external stimuli?
   A) hypothalamus
   B) thalamus
   C) basal nuclei
   D) limbic system
   E) putamen
   Answer: B
   Diff: 6   Page Ref: 233
40) What region of the diencephalon provides an important link between the endocrine and nervous system?
   A) hypothalamus  
   B) thalamus  
   C) basal nuclei  
   D) limbic system  
   E) putamen  
   Answer: A  
   Diff: 4  Page Ref: 235

41) The _______ plays a principle role in establishing the circadian rhythm of the body.
   A) caudate nucleus  
   B) globus pallidus  
   C) putamen  
   D) suprachiasmatic nucleus  
   E) cingulate gyrus  
   Answer: D  
   Diff: 4  Page Ref: 235

42) Which of the following is NOT a function of the hypothalamus?
   A) communication between the nervous and endocrine system  
   B) controls hunger and thirst  
   C) affects emotions and behaviors in response to emotions  
   D) controls thermoregulation  
   E) contains the cardiovascular control centers  
   Answer: E  
   Diff: 5  Page Ref: 235

43) Where is the thermoregulatory center?
   A) hypothalamus  
   B) medulla oblongata  
   C) pons  
   D) amygdala  
   E) hippocampus  
   Answer: A  
   Diff: 4  Page Ref: 233

44) Which region of the limbic system is primarily involved in the emotion fear?
   A) hippocampus  
   B) fornix  
   C) amygdala  
   D) cingulate gyrus  
   E) thalamus  
   Answer: C  
   Diff: 5  Page Ref: 234

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45) Which of the following is NOT part of the limbic system?
   A) amygdala
   B) putamen
   C) fornix
   D) hippocampus
   E) cingulated gyrus

   Answer: B
   Diff: 6   Page Ref: 234

46) How is a reflex that requires communication with the brain classified?
   A) visceral
   B) spinal
   C) cranial
   D) somatic
   E) innate

   Answer: C
   Diff: 2   Page Ref: 236

47) How is a reflex that involves signals sent along autonomic sensory nerves classified?
   A) visceral
   B) spinal
   C) cranial
   D) somatic
   E) innate

   Answer: A
   Diff: 3   Page Ref: 236

48) How is a reflex that we are born with classified?
   A) visceral
   B) spinal
   C) cranial
   D) somatic
   E) innate

   Answer: E
   Diff: 3   Page Ref: 236

49) How is a reflex that requires only a single synapse between two neurons classified?
   A) bineuronal
   B) bisynaptic
   C) polysynaptic
   D) monosynaptic
   E) polyneuronal

   Answer: D
   Diff: 3   Page Ref: 236
50) Which of the following does NOT describe a type of reflex that occurred when Pavlov’s dogs salivated in response to the ringing of a bell?
   A) conditioned
   B) cranial
   C) visceral
   D) polysynaptic
   E) spinal

Answer: E  
Diff: 5  Page Ref: 236

51) Which of the following reflexes is a monosynaptic reflex found in the human body?
   A) crossed-flexor reflex
   B) pupillary light reflex
   C) crossed-extensor reflex
   D) muscle spindle stretch reflex
   E) withdrawal reflex

Answer: D  
Diff: 4  Page Ref: 237

52) The withdrawal reflex is initiated by activation of what type of receptor?
   A) muscle spindle stretch receptor
   B) nociceptor
   C) photoreceptor
   D) taste receptor
   E) warm receptor

Answer: B  
Diff: 5  Page Ref: 238

53) The crossed-extensor reflex is initiated by activation of what type of receptor?
   A) muscle spindle stretch receptor
   B) nociceptor
   C) photoreceptor
   D) taste receptor
   E) warm receptor

Answer: B  
Diff: 5  Page Ref: 238

54) Where is the integration center for the pupillary light reflex located?
   A) hypothalamus
   B) cerebellum
   C) occipital lobe
   D) brainstem
   E) spinal cord

Answer: D  
Diff: 5  Page Ref: 239
55) The execution of a voluntary motor task involves a series of steps. Which of the following present those steps in the correct order?
   A) program, intent, feedback, execute
   B) program, intent, execute, feedback
   C) intent, program, execute, feedback
   D) feedback, intent, program, execute
   E) intent, feedback, program, execute
   Answer: C
   Diff: 3 Page Ref: 239

56) Which of the following regions of the cortex is NOT involved in formulating the intention to move?
   A) supplementary motor area
   B) association area
   C) limbic system
   D) frontal lobe
   E) primary motor cortex
   Answer: E
   Diff: 6 Page Ref: 239

57) Which of the following cortical regions is NOT involved in the development of a motor program?
   A) limbic system
   B) premotor area
   C) supplementary motor area
   D) primary motor cortex
   E) somatosensory area
   Answer: A
   Diff: 7 Page Ref: 240

58) Which of these brain structures, outside of the cortex, is NOT involved in assisting with motor programming and providing feedback on the execution of a motor program?
   A) cerebellum
   B) thalamus
   C) basal nuclei
   D) hypothalamus
   E) brainstem nuclei
   Answer: D
   Diff: 8 Page Ref: 240

59) The efferent neurons that innervate skeletal muscle, and induce them to contract, originate from the ________.
   A) ventral horn of the spinal cord
   B) dorsal horn of the spinal cord
   C) motor cortex
   D) basal nuclei
   E) pyramidal tract
   Answer: A
   Diff: 4 Page Ref: 240
60) What neural pathway provides for the control of fine, discrete movements of the extremities?
   A) extrapyramidal tract  
   B) pyramidal tract  
   C) thalamocorical tract  
   D) spinothalamic tract  
   E) intrapyramidal tract  
   Answer: B  
   Diff: 4    Page Ref: 240

61) What neural pathway provides for the control of large muscle groups that function in posture and balance?
   A) extrapyramidal tract  
   B) pyramidal tract  
   C) thalamocortical tract  
   D) spinothalamic tract  
   E) intrapyramidal tract  
   Answer: A  
   Diff: 4    Page Ref: 240

62) Where do lower motor neurons originate?
   A) primary motor cortex  
   B) primary somatosensory cortex  
   C) brainstem  
   D) cerebellum  
   E) ventral horn of the spinal cord  
   Answer: E  
   Diff: 4    Page Ref: 240

63) Most pyramidal tract neurons cross to the opposite side of the body in what region?
   A) primary motor cortex  
   B) thalamus  
   C) corpus callosum  
   D) brainstem  
   E) spinal cord  
   Answer: D  
   Diff: 5    Page Ref: 240

64) Which of the following areas of the brain is involved in control of posture?
   A) cortex  
   B) cerebellum  
   C) brainstem nuclei  
   D) thalamus  
   E) pineal gland  
   Answer: C  
   Diff: 4    Page Ref: 240
65) What region of the brain provides feedback control of voluntary movement to the motor program that was generated?
   A) cortex
   B) cerebellum
   C) brainstem nuclei
   D) thalamus
   E) pineal gland

   Answer: B  
   Diff: 4  Page Ref: 241

66) Damage to the cerebellum will lead to which of the following symptoms?
   A) a complete inability to move (lack of execution)
   B) an inability to accurately plan a movement
   C) the generation of slow, fine movements only
   D) the generation of clumsy, poorly directed movements
   E) the generation of movement of large muscle groups only

   Answer: D  
   Diff: 6  Page Ref: 242

67) Which of the following structures does NOT have direct neural connections to the cerebellum?
   A) cortex
   B) thalamus
   C) basal nuclei
   D) brainstem
   E) spinal cord

   Answer: B  
   Diff: 6  Page Ref: 242

68) Parkinson's disease appears to target _______ cells within the _______.
   A) cholinergic : substantia nigra
   B) adrenergic : substantia nigra
   C) dopaminergic : substantia nigra
   D) adrenergic : red nuclei
   E) cholinergic : red nuclei

   Answer: C  
   Diff: 5  Page Ref: 242

69) What is dementia?
   A) loss of mental function
   B) loss of language comprehension
   C) loss of language expression
   D) excess muscle movement due to loss of inhibition
   E) loss of memory

   Answer: A  
   Diff: 7  Page Ref: 242
70) What area of the brain controls language comprehension?
   A) Broca’s area
   B) Wernicke’s area
   C) amygdala
   D) limbic system
   E) hypothalamus

   Answer: B  
   Diff: 4  Page Ref: 243

71) A person with aphasia would have which of the following symptoms?
   A) deafness
   B) difficulty in communicating
   C) intention tremors
   D) inability to sleep
   E) night sweats

   Answer: B  
   Diff: 4  Page Ref: 243

72) A person with Broca’s aphasia has what type of symptom?
   A) difficulty speaking words clearly
   B) intention tremors
   C) dementia
   D) inability to comprehend spoken or written language
   E) insomnia

   Answer: A  
   Diff: 4  Page Ref: 243

73) Which of the following has NOT been proposed as a function of sleep?
   A) to conserve energy
   B) mental practicing while dreaming
   C) to clear short-term memory
   D) to enhance immune function
   E) to facilitate long-term memory

   Answer: C  
   Diff: 6  Page Ref: 243

74) Which of the following is NOT characteristic of slow-wave sleep?
   A) decreased muscle tone
   B) elaborate and intense dreams
   C) snoring
   D) decreased brain activity
   E) increased parasympathetic activity

   Answer: B  
   Diff: 5  Page Ref: 243
75) Which of the following is NOT characteristic of rapid eye movement (REM) sleep?
   A) postural muscles lose tone
   B) thoughts are illogical and bizarre
   C) increased parasympathetic activity
   D) increased brain activity
   E) decreased limbic system activity

   Answer: C
   Diff: 5 Page Ref: 243

76) What is the principle region of the brain involved in the maintenance of an alert, awake state?
   A) limbic system
   B) pons
   C) forebrain
   D) reticular formation
   E) cerebellum

   Answer: D
   Diff: 5 Page Ref: 244

77) What is the principle region of the brain involved in the initiation of rapid eye movement (REM) sleep?
   A) limbic system
   B) pons
   C) forebrain
   D) reticular formation
   E) cerebellum

   Answer: B
   Diff: 5 Page Ref: 245

78) What is the principle region of the brain involved in the induction of slow-wave sleep?
   A) limbic system
   B) pons
   C) forebrain
   D) reticular formation
   E) cerebellum

   Answer: C
   Diff: 5 Page Ref: 245

79) What neurotransmitter appears to be involved in initiating slow-wave sleep?
   A) adenosine
   B) acetylcholine
   C) dopamine
   D) serotonin
   E) epinephrine

   Answer: A
   Diff: 4 Page Ref: 245
80) When awake and alert, the brain is generating ______ waves that are detectable with an electroencephalogram.
   A) gamma
   B) alpha
   C) delta
   D) beta
   E) epsilon
Answer: D
Diff: 4 Page Ref: 245

81) When awake but resting, the brain is generating ______ waves that are detectable with an electroencephalogram.
   A) gamma
   B) alpha
   C) delta
   D) beta
   E) epsilon
Answer: B
Diff: 4 Page Ref: 245

82) During slow-wave sleep, there is a progressive ______ in the strength of stimulus required to awaken a person and a(n) ______ frequency of electroencephalogram (EEG) activity, indicative of a synchronization of EEG activity.
   A) decrease : enhanced
   B) increase : reduced
   C) increase : enhanced
   D) decrease : reduced
   E) increase : stable
Answer: B
Diff: 6 Page Ref: 246

83) During rapid eye movement sleep, there is a(n) ______ in frequency of the electroencephalogram and a(n) ______ in arousal threshold.
   A) decrease : increase
   B) decrease : decrease
   C) increase : decrease
   D) increase : increase
   E) stabilization : decrease
Answer: D
Diff: 5 Page Ref: 246
84) Rapid eye movement (REM) is called paradoxical sleep because _______.
   A) electroencephalogram activity reverts toward that observed in an awake, alert person
   B) electroencephalogram activity can change quite extensively during REM sleep
   C) electroencephalogram activity is quite different from slow-wave sleep
   D) people are less likely to awaken spontaneously during REM sleep when arousal threshold is lowest
   E) people are more likely to awaken spontaneously during REM sleep when arousal threshold is highest

   Answer: E
   Diff: 6   Page Ref: 246

85) The euphoria that is perceived when one ingests drugs such as opioids or amphetamines results from the activation of the _______ system.
   A) cholinergic
   B) dopaminergic
   C) adrenergic
   D) nitridergic
   E) sympathetic

   Answer: B
   Diff: 4   Page Ref: 246

86) Which of the following brain regions is NOT involved in emotion?
   A) cerebral cortex
   B) limbic system
   C) hypothalamus
   D) thalamus
   E) brainstem

   Answer: E
   Diff: 4   Page Ref: 246

87) What emotion drives addiction?
   A) depression
   B) anger
   C) fear
   D) pleasure
   E) aggression

   Answer: D
   Diff: 4   Page Ref: 246

88) The transitioning of a memory from short to long term is called _______.
   A) remembering
   B) declaration
   C) plasticity
   D) consolidation
   E) memorizing

   Answer: D
   Diff: 4   Page Ref: 248
89) The ability of the nervous system to alter its anatomy and function in response to changes in its activity pattern is called _______.
   A) remembering
   B) declaration
   C) plasticity
   D) consolidation
   E) memorizing

Answer: C
Diff: 4 Page Ref: 248

90) In long-term potentiation, the enhanced possibility that an activated postsynaptic membrane will generate an action potential is associated with a(n) _______.
   A) decrease in its threshold
   B) increase in its threshold
   C) increased number of EPSPs
   D) increased strength of the EPSPs
   E) reduction in the number of IPSPs

Answer: D
Diff: 7 Page Ref: 248

91) The increased influx of calcium at a postsynaptic terminal with glutamate receptors _______.
   A) causes a greater release of neurotransmitter from the postsynaptic cell
   B) activates the NMDA receptor to increase calcium influx
   C) activates a protein kinase that phosphorylates the AMPA receptor, making it more sensitive to glutamate
   D) activates a protein kinase that phosphorylates the NMDA receptor, making it more sensitive to glutamate
   E) activates the AMPA receptor to increase sodium influx

Answer: C
Diff: 6 Page Ref: 248

92) In addition to an increase in sensitivity to glutamate, the binding of large amounts of glutamate to its receptors on the postsynaptic membrane also _______.
   A) directly causes more NMDA channels to open
   B) stimulates the release of a paracrine messenger that further increases glutamate release
   C) affects other synapses that are close to the first
   D) stimulates presynaptic autoreceptors and enhances its release
   E) can overwhelm the synapse

Answer: B
Diff: 5 Page Ref: 248

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93) Which of the following best describes events happening during long-term potentiation?
   A) The presynaptic cell releases more glutamate compared to nonpotentiated conditions, but the postsynaptic cell is less sensitive to the glutamate.
   B) The presynaptic cell releases more GABA compared to nonpotentiated conditions, but the postsynaptic cell is less sensitive to the GABA.
   C) The presynaptic cell releases more glutamate compared to nonpotentiated conditions, and the postsynaptic cell is more sensitive to the glutamate.
   D) The presynaptic cell releases less GABA compared to nonpotentiated conditions, but the postsynaptic cell is more sensitive to GABA, thereby enhancing the overall communication.
   E) The presynaptic cell releases acetylcholine at the same levels as under nonpotentiated conditions, but the postsynaptic cell has upregulated cholinergic receptors, thereby making the postsynaptic cell more sensitive to the acetylcholine.

   Answer: C
   Diff: 6   Page Ref: 248

94) Which of the following would consist of white matter?
   A) dorsal columns of the spinal cord
   B) basal nuclei
   C) cerebral cortex
   D) dorsal horn of the spinal cord
   E) ventral horn of the spinal cord

   Answer: A
   Diff: 5   Page Ref: 223

95) In response to stepping on a nail, the crossed-extensor reflex causes ________.
   A) flexion of the leg on the side of receptor activation
   B) extension of the leg on the side of receptor activation
   C) extension of the leg opposite the side of receptor activation
   D) flexion of the leg opposite the side of receptor activation
   E) extension of the arm on the side of receptor activation

   Answer: C
   Diff: 5   Page Ref: 238

96) A stroke occurring in the basal nuclei could produce which of the following symptoms?
   A) loss of language comprehension
   B) muscle rigidity
   C) blindness or blurred vision
   D) deafness
   E) altered sleep-wake patterns

   Answer: B
   Diff: 7   Page Ref: 242

True/False Questions

1) The composition of cerebrospinal fluid is identical to plasma.

   Answer: FALSE
   Diff: 2   Page Ref: 219
2) The central nervous system is very sensitive to interruptions in blood flow.
   Answer: TRUE  
   Diff: 1  Page Ref: 220

3) Tight junctions between astrocytes form the blood–brain barrier.
   Answer: FALSE  
   Diff: 4  Page Ref: 223

4) The facilitated diffusion of molecules across the blood–brain barrier relies on protein carriers that are specific for the movement of particular molecules.
   Answer: TRUE  
   Diff: 4  Page Ref: 223

5) Cerebrospinal fluid is completely recycled every three days.
   Answer: FALSE  
   Diff: 5  Page Ref: 219

6) The central nervous system can only use ketones for energy.
   Answer: FALSE  
   Diff: 2  Page Ref: 220

7) Hydrogen ions cannot permeate the blood–brain barrier.
   Answer: TRUE  
   Diff: 3  Page Ref: 223

8) There are no nerves in the central nervous system.
   Answer: TRUE  
   Diff: 5  Page Ref: 223

9) The spinal cord travels the entire length of the vertebral column.
   Answer: FALSE  
   Diff: 3  Page Ref: 224

10) All spinal nerves are mixed nerves containing both sensory and motor fibers.
    Answer: TRUE  
    Diff: 3  Page Ref: 226

11) A region of the sensory innervation of the body by a certain spinal nerve is called a somatotopic region.
    Answer: FALSE  
    Diff: 4  Page Ref: 225

12) The brainstem is composed of the midbrain, pons, and medulla oblongata.
    Answer: TRUE  
    Diff: 3  Page Ref: 229

13) The cerebral cortex carries out the highest level of neural processing.
    Answer: TRUE  
    Diff: 3  Page Ref: 230

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14) In the cerebral cortex, grooves are called sulci whereas ridges are called gyri.
   Answer: TRUE
   Diff: 3   Page Ref: 230

15) Thoughts are generated in the frontal lobe.
   Answer: TRUE
   Diff: 4   Page Ref: 231

16) In the somatosensory cortex, the hands have a greater area of representation than the feet.
   Answer: TRUE
   Diff: 3   Page Ref: 231

17) Movement of the right side of the body is controlled by the right side of the cerebral cortex.
   Answer: FALSE
   Diff: 3   Page Ref: 233

18) Somatic reflexes involve somatic neurons transmitting information to smooth and cardiac muscle cells.
   Answer: FALSE
   Diff: 4   Page Ref: 236

19) Initiation of a withdrawal reflex also activates the crossed–extensor reflex.
   Answer: TRUE
   Diff: 4   Page Ref: 238

20) Motor neurons are exclusively excitatory, which means that activity of those motor neurons cannot be modulated.
   Answer: FALSE
   Diff: 4   Page Ref: 240

21) Normally, the vestibular nuclei and the red nuclei of the brainstem are incapable of originating voluntary movements.
   Answer: TRUE
   Diff: 4   Page Ref: 240

22) Although extrapyramidal tracts predominate in the control of large muscle groups, the pyramidal tract also controls those muscles to some degree.
   Answer: TRUE
   Diff: 5   Page Ref: 240

23) As the night progresses, we spend more time in rapid eye movement sleep.
   Answer: TRUE
   Diff: 3   Page Ref: 246

24) Adults need less sleep as they get older.
   Answer: TRUE
   Diff: 3   Page Ref: 243
25) All that we learn is put into memory.
   Answer: FALSE
   Diff: 5 Page Ref: 247

Matching Questions

*Match the following glial cells to their correct description.*

1) Phagocytic cell that protects central nervous system from pathogens.
   A) microglia
   Diff: 4 Page Ref: 217

2) Form myelin in the central nervous system.
   B) oligodendrocyte
   C) Schwann cell
   Diff: 3 Page Ref: 216

3) Only glial cell located in the peripheral nervous system.
   D) astrocyte
   E) ependymal cell
   Diff: 3 Page Ref: 216

4) Provides support for development of the blood–brain barrier.
   Diff: 3 Page Ref: 223

5) Degrades certain neurotransmitters.
   Diff: 4 Page Ref: 216

6) Forms the choroid plexus.
   Diff: 3 Page Ref: 219

7) Lines cerebral ventricles.
   Diff: 3 Page Ref: 219

8) Enhances the conduction velocity of neurons in the central nervous system.
   Diff: 4 Page Ref: 216

Match the portions of a neuron with its primary location in the central nervous system.

9) Axons.  
   Diff: 4  Page Ref: 223  
   A) white matter  
   B) gray matter

10) Dendrites.  
   Diff: 4  Page Ref: 223

11) Cell body.  
   Diff: 4  Page Ref: 223

12) Axon terminals.  
   Diff: 4  Page Ref: 223


Match the areas of the nervous system with the type of information transmitted.

13) Dorsal horn.  
   Diff: 3  Page Ref: 226  
   A) afferent  
   B) both afferent and efferent  
   C) efferent  
   D) neither afferent nor efferent

14) Ventral horn.  
   Diff: 3  Page Ref: 226

15) Lateral horn.  
   Diff: 5  Page Ref: 226

16) Dorsal roots.  
   Diff: 3  Page Ref: 226

17) Ventral roots.  
   Diff: 3  Page Ref: 226

18) Spinal nerves.  
   Diff: 4  Page Ref: 226


Match the brain regions to the appropriate functions.

19) Perception of touch sensations begins here.  
   Diff: 4  Page Ref: 231  
   A) Broca’s area  
   B) primary somatosensory cortex  
   C) thalamus  
   D) primary motor cortex  
   E) Wernicke’s area  
   F) hypothalamus

20) Perception of vision begins here.  
   Diff: 3  Page Ref: 231

21) Relays sensory information to the cerebral cortex.  
   Diff: 4  Page Ref: 233

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22) Integration center for neural and endocrine controls.
   Diff: 4 Page Ref: 234

23) Hunger and satiety centers located here.
    Diff: 4 Page Ref: 234

24) Thermoregulatory centers located here.
    Diff: 4 Page Ref: 234

25) Regulates autonomic functions including cardiovascular and digestive functions.
    Diff: 4 Page Ref: 234

26) Contains the ascending reticular activating system.
    Diff: 4 Page Ref: 244

27) Origin of the pyramidal tract.
    Diff: 4 Page Ref: 240

28) Perception of sound begins here.
    Diff: 4 Page Ref: 231

29) Important for learning and memory.
    Diff: 5 Page Ref: 247

30) Damage to this area can result in Huntington’s chorea or Parkinson’s disease.
    Diff: 4 Page Ref: 242

31) Provides feedback control of voluntary movement by comparing accomplished movement to planned movement.
    Diff: 4 Page Ref: 241

32) Necessary for language comprehension.
    Diff: 4 Page Ref: 243

G) hippocampus
H) basal nuclei
I) limbic system
J) primary auditory cortex
K) cerebellum
L) brainstem
M) primary visual cortex

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33) Necessary for language expression.

Diff: 4  Page Ref: 243

Answers:  19) B  20) M  21) C  22) F  23) F
  29) G  30) H  31) K  32) E  33) A

Match the stage of sleep to the appropriate descriptions.

34) Fast, low amplitude EEG.

Diff: 4  Page Ref: 245
   A) REM sleep

35) Decreased heart rate and respiration rate.

Diff: 5  Page Ref: 243
   B) both slow wave and REM sleep
   C) slow wave sleep

36) Snoring.

Diff: 4  Page Ref: 243

37) Increased parasympathetic activity.

Diff: 5  Page Ref: 243

38) Elevated arousal threshold.

Diff: 4  Page Ref: 243

39) More likely to awake spontaneously from this phase.

Diff: 4  Page Ref: 243

40) Duration increases as the duration of sleep increases.

Diff: 4  Page Ref: 246

Answers:  34) A  35) C  36) C  37) C  38) A
  39) A  40) A

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Match the lobe of the cerebral cortex to the correct brain functions.

41) Voluntary control of fine discrete movement.
   Diff: 3   Page Ref: 231
   A) temporal lobe
   B) parietal lobe

42) Visual perception.
   Diff: 3   Page Ref: 231
   C) occipital lobe
   D) frontal lobe

43) Auditory perception.
   Diff: 3   Page Ref: 231

44) Thoughts.
   Diff: 4   Page Ref: 231

45) Personality traits.
   Diff: 4   Page Ref: 231

46) Awareness of limb positions and muscle tension.
   Diff: 5   Page Ref: 231

47) Perception of odors.
   Diff: 4   Page Ref: 231

48) Expression of language.
   Diff: 5   Page Ref: 231

Essay Questions

1) The maintenance of an uninterrupted delivery of oxygen and glucose to the brain is essential to its function. What is it about the brain and nervous tissue in general that makes them so sensitive to changes in blood flow?

Answer: At rest, the central nervous system receives 15% of the blood pumped from the heart, while only accounting for 2% of body weight. This high proportion of blood flowing to the brain is necessary to meet the demands of this metabolically active tissue. At rest, the brain accounts for 20% of the oxygen and 50% of the glucose consumed by the body. Thus, high blood flow is required to ensure continuous delivery of oxygen and glucose to the brain. When those demands are not met, even for short periods of time, as would occur during cardiac arrest or during focal blood flow interruptions (strokes), the brain can be irreversibly damaged. This maintenance of blood flow is essential because the brain is not able to store glucose in the form of glycogen. At the same time, the brain is reliant on glucose as its primary energy source because neurons are incapable of metabolizing fatty acids. Thus, all of the brain’s primary energy substrate, glucose, must be continuously extracted from the blood. The brain’s reliance on oxygen derives from its inability to undergo anaerobic metabolism. There is an alternative fuel source, ketones, that can be used by the brain when glucose availability to the cell is reduced (during starvation or diabetes). Ketones in the blood are a byproduct of fatty acid metabolism in the liver. Up to 2/3 of the brain’s energy substrate can be supplied by ketones, but the other third must still be derived from glucose. Thus, the brain relies on a continuous supply of glucose and oxygen through the vasculature in order to function.

Diff: 6  Page Ref: 220
2) Describe the structure of the spinal cord and how the spinal cord is organized.

Answer: The spinal cord is a cylinder of nervous tissue, continuous with the lower portion of the brain. The spinal cord is surrounded by the vertebral column. At each intersection of the vertebral column, a pair of spinal nerves exit the spinal cord for a total of 31 pairs of spinal nerves. The spinal nerves are classified by the vertebral column from which they emerge (8 cervical, 12 thoracic, 5 lumbar, 5 sacral, and the coccygeal nerve). However, the spinal cord does not travel the entire length of the vertebral column. The spinal cord only travels 2/3 of the length of the vertebral column with the remainder containing spinal nerves. This bundle of spinal nerve is called the cauda equina. The nerve fibers that leave the spinal cord within the spinal nerves travel to adjacent tissues, making it possible to map the body into sensory regions called dermatomes, which are associated with specific spinal nerves. The spinal cord is composed of both gray and white matter, with the gray matter assuming a butterfly-like arrangement when viewed in cross section. The gray matter contains interneurons, efferent neurons (dendrites and cell bodies), and axon terminals of afferent neurons. The gray matter is organized into the dorsal and ventral horn, with the dorsal horn containing the terminal axon of afferent neurons (the cell bodies of those neurons are located within the dorsal root ganglia). The ventral horn contains the cell bodies of the efferent neurons that travel to the periphery and synapse with skeletal muscle. In the thoracic and upper lumbar regions of the spinal cord, there is also a lateral horn (intermediolateral cell column) from which the efferent neurons of the autonomic nervous system originate. Both afferent and efferent neurons travel in spinal nerve bundles, but they separate before entering the spinal cord. Afferent fibers enter through the dorsal root, whereas efferent fibers exit through the ventral root. The white matter of the spinal cord provides tracts that communicate with other levels of the spinal cord or with the brain. Ascending tracts carry information to the brain, whereas descending tracts carry information from the brain to the spinal cord.

Diff: 7 Page Ref: 223
3) The development of the cerebral cortex is what appears to set humans apart from other species. Identify the structures and general functions of the cortex.

Answer: The cerebral cortex is the outer layer of the cerebrum that is composed of highly convoluted layers of gray matter. These convolutions consist of grooves (sulci) and ridges (gyri) that allow for a greater surface area of the cortex. This thin outer layer is comprised of six functionally distinct layers. The cerebral cortex carries out the higher neural functions, including perception, formulating ideas, experiencing emotion, recalling past events, and coordinating body movements. Each of the cerebral hemispheres can be divided into four distinct lobes: the frontal, parietal, occipital, and temporal lobes. The frontal lobe is the foremost portion of the cerebrum and is separated from the parietal lobe by the central sulcus. Behind the parietal lobe is the occipital lobe, while the temporal lobe is located beneath the frontal and parietal lobes on the side of the brain and is separated from the frontal lobe by the lateral sulcus (sylvian fissure). The occipital lobe contains the visual cortex, which is involved in the processing of visual information. The auditory cortex is located within the superior temporal lobe. The primary somatosensory cortex is located within the parietal lobe and is involved in processing somatic sensory information from the surface of the skin (somesthetic) as well as an awareness of muscle tension and joint and limb position (proprioception). The frontal lobe contains the primary motor cortex that initiates voluntary movement, and is also important in language, planning, and personality development. Several regions of the cortex are topographically organized, the best examples of which are the primary motor cortex and the primary somatosensory cortex. Their somatotopic organization can be mapped into motor and sensory homunculi that indicate which regions of the cortex are devoted to a particular region of the body. Both the primary visual cortex and primary auditory cortex are mapped similarly. This is not to say that the regions of the cortex are isolated from one another. There are association areas within the cortex that provide for integration of information between the lobes of the cortex.

There are two cerebral hemispheres whose divisions appear to be both anatomical and functional. There appears to be specialization of the right and left sides of the brain. The right side of the brain receives sensory information from the left side of the body and controls the motor system on this side of the body. The right hemisphere appears to be involved in creative and artistic endeavors, whereas the left hemisphere appears to be involved in the performance of logical, analytical tasks.

Diff: 8  Page Ref: 230
4) The cortex is not the only functional portion of the cerebrum; subcortical structures are important to a number of systems. Describe the subcortical structures of the cerebrum and their various functions.

Answer: Subcortical structures are nuclei (clusters of neuron cell bodies) located deep within the cerebrum that include the basal nuclei, thalamus, hypothalamus, and the limbic system. The basal nuclei include the caudate nucleus, the globus pallidus, and the putamen. These structures are involved in modifying movement. The thalamus is a cluster of nuclei located within the diencephalon. All sensory information has a direct relay through the thalamus (with the exception of smell). Thus, the thalamus is involved in filtering and refining sensory information, directing attention to specific sensory information, and in the control of movement. The hypothalamus, located below the thalamus, is primarily involved in the maintenance of body homeostasis. The hypothalamus is an important link between the endocrine and nervous system via its release of tropic hormones (which are neurohormones). These tropic hormones stimulate the release of hormones from the anterior pituitary as well as stimulate the release of hormones from the posterior pituitary (antidiuretic hormone and oxytocin). The hypothalamus is also involved in the regulation of behaviors through centers like the satiety and hunger center (eating behavior) as well as the thirst center (drinking). Many of the responses produced by the hypothalamus are ultimately regulated by the autonomic nervous system, including emotions that can affect digestive, cardiovascular, and respiratory function through inputs to the brainstem and body temperature. Finally, the hypothalamus is responsible for the generation of circadian rhythms originating from the suprachiasmatic nucleus. The limbic system is a collection of closely associated cortical, subcortical, and forebrain regions that function in learning and emotion. This system includes the amygdala, hippocampus, fornix, and cingulate gyrus of the cerebral cortex as well as portions of the thalamus and hypothalamus. The limbic system is the primitive region of the brain involved in basic drives. The hippocampus is a major component in the regulation of learning and memory.
5) Characterize the four types of reflexes, including the essential components of a reflex arc, and describe the details of the withdrawal reflex.

Answer: Reflexes describe automatic, patterned responses to a sensory stimulus. As such, reflexes can be distributed into four categories: spinal vs. cranial (depending upon the region of the nervous system where responses are integrated), somatic vs. autonomic (depending upon the efferent pathway that is activated), conditioned vs. innate (depending upon whether they are learned or not), and monosynaptic vs. polysynaptic (the number of synapses in the pathway). A reflex arc is composed of a sensory receptor, an afferent neuron, an integration center, an efferent neuron, and an effector organ. The reflex arc is initiated by a sensory receptor that detects a stimulus, which is then communicated to the integration center via an action potential, thereby resulting in an efferent response. For the withdrawal reflex, the sensory receptor originating the response is a nociceptor, which detects an intense stimulus that is potentially damaging. The action potential generated by the afferent neuron travels to the spinal cord and synapses with a number of interneurons. One of the interneurons excites the efferent neurons that innervate the flexor muscle of the limb affected (the flexor muscles of the leg is the hamstring), causing that limb to withdraw. In order for this to work effectively, the antagonistic muscles (the extensor muscles of the leg are the quadriceps) must be simultaneously relaxed. Thus, at the same time the excitatory interneuron is activated, an inhibitory interneuron is activated that reduces frequency of action potentials along the efferent neuron, causing the quadriceps muscle to relax. If we were standing at the time, the movement of one leg only would result in a loss of balance. So, the withdrawal reflex also activates the crossed-extensor reflex. This reflex is mediated by other interneurons within the spinal cord that synapse with the nociceptor that originated the reflex. Those interneurons synapse with efferent neurons that innervate the flexor and extensor muscle of the opposite leg. In the opposite leg, the response initiated is the opposite of what occurs in the leg where the reflex was originated: the extensor contracts while the flexor relaxes. This crossed-extensor reflex allows us to rapidly withdraw from a painful stimulus (like stepping on a tack) without losing our balance.

Diff: 7  Page Ref: 236
6) Describe the steps required for a voluntary movement to be generated, including the structures involved in each step of the process along with a description of the pyramidal and extrapyramidal tracts.

Answer: There are four main steps involved in the successful execution of a voluntary motor task. First, the intention to move must be formulated. Then, a program of motor commands must be generated to ultimately direct the appropriate muscles to contract in the correct order to bring about the intended task. Third, the program must be executed by sending those commands to the appropriate muscles. Finally, as the motion is being generated, feedback must be continuously provided to the central nervous system to ensure that the original program is being followed, or, to change that program as needed to ensure a smooth, reliable completion of the task.

The highest level of control is within the cerebral cortex, which formulates the intention to move and translates that into a plan for movement. There are several regions of the cortex involved in these processes, including the supplementary motor cortex, the association area, and the limbic system. The development of a motor program also involves the primary motor cortex, the somatosensory cortex, the premotor area, and the supplementary motor areas. The programming and feedback are supported by the cerebellum, thalamus, basal nuclei, certain brainstem nuclei, and various cortical association areas.

The execution of the motor program requires involvement of the efferent neurons that innervate skeletal muscle. The efferent neurons are called the lower motor neurons. Inputs to the motor neurons can originate from many different levels of the nervous system. The motor neurons can be modified by spinal inputs as well as inputs that descend from the brain. There are two important descending pathways of neurons for the motor system: the pyramidal and extrapyramidal tracts. The pyramidal tract is a direct pathway from the motor cortex to the spinal cord. The axons terminate in the ventral horn and are called the upper motor neurons. Some synapse directly on the motor neurons, while others synapse with interneurons. Most of the axons in the pyramidal tract cross over in the medulla. The pyramidal tract controls fine, discrete movements of the distal extremities. The extrapyramidal tract includes all pathways outside of the pyramidal tract. These tracts are comprised of indirect connections between the brain and spinal cord (the extrapyramidal tract does not directly synapse with motor neurons). The extrapyramidal tract is primarily involved in the control of large muscle groups and the maintenance of posture and balance.

Although the pyramidal and extrapyramidal tracts are physically separate, a portion of each motor response can occur in both tracts. This parallel processing is not to say that every response is exactly duplicated along both pathways. Rather, if the pyramidal tract is damaged, a certain amount of the function of the pyramidal tracts can be assumed by the extrapyramidal tract, and vice versa.

Diff: 9  Page Ref: 239
7) Describe the role of the brainstem, cerebellum, and basal nuclei in the control of movement.

Answer: The brainstem contains a number of nuclei that project to the extrapyramidal tract, including the reticular formation, vestibular nuclei, and the red nuclei. In general, the brainstem appears to be involved with involuntary control of posture. The nuclei listed above are incapable of originating a voluntary movement. Our muscles are always adjusting to changes in posture. The brainstem uses sensory inputs from the skin, proprioceptors, and vestibular receptors to inform the brainstem about the body’s position and the forces acting upon it. The brainstem also receives inputs from the auditory and visual system.

The cerebellum acts as a guidance system by comparing the actual movements with the plan of movement that was generated, making corrections in force and direction of movement. In addition, the cerebellum appears to play a role in the maintenance of muscle tone (constant level of tension). The cerebellum may store memories of previous movements so that the movement can be further refined. The cerebellum receives information from the cortex, spinal cord, brainstem, basal nuclei, and sensory information from all areas of the body. It then sends signals back to the cortex (via the thalamus) so that the movement can be adjusted. People who have damaged their cerebellum can carry out voluntary movements but the movements are clumsy, misdirected, and are often made with inappropriate force. A characteristic sign of cerebellar damage is intention tremors that are a sometimes violent shaking that occurs when a person makes a voluntary movement.

The basal nuclei are thought to provide feedback to the cortex for the development of motor strategies and to smooth out movements. There is evidence that the basal nuclei are necessary for automatic performance of learned repetitive motions. The basal nuclei receive input from the cortex and output goes back to the cortex via the thalamus. There are two disease processes that have expanded our knowledge of the basal nuclei: Huntington’s chorea and Parkinson’s disease. Both are neurodegenerative diseases that appear to exert their primary action on the basal nuclei. Huntington’s chorea appears to originate from damage that disrupts the transmission of information from the basal nuclei to the thalamus. This causes several motor pathways to become overactive, thereby exerting an inhibitory influence over motor control. Parkinson’s appears to originate as a disruption of communication from the dopaminergic cells of the substantia nigra. Parkinson’s is characterized by involuntary tremors, a stooped shuffling gait, and movements that are generally slow and stiff. There also appears to be difficulty in originating movement.

Diff: 9 Page Ref: 241
8) Define sleep, listing the theories that have been developed to explain our need for sleep. Include in this discussion the two types of sleep and the characteristics of each type of sleep.

Answer: Sleep is an active process that requires energy and is defined as a state of depressed motor activity and perception that occurs on a cyclical basis. Note that activity is decreased but is not completely absent during sleep. Several theories have been developed to explain our need for sleep: Sleep may 1) play a restorative role, allowing us to recover from our daily activity, 2) provide us an opportunity to conserve energy, 3) allow us to dream, providing time for mental practicing, 4) facilitate long-term memory storage, and 5) provide a time for the immune system to function optimally.

From measurement of brain waves via electroencephalogram (EEG), sleep has been divided into two types: 1) slow-wave sleep (SWS), characterized by multiple stages of low-frequency EEG waves, and 2) rapid eye movement sleep (REM), characterized by high-frequency brain waves and periodic rapid eye movement. In SWS, muscle tone is decreased, but occasional bursts of involuntary activity occur every 10–20 minutes. In the brain, activity decreases in most regions except the parasympathetic nervous system, where activity is increased. During SWS, a person may dream but the dreams are less detailed than during REM sleep, and are more logical and less emotional. In REM sleep, postural muscles lose their tone and become paralyzed and the jaw muscles relaxed (causing the mouth to open). Snoring usually occurs within SWS sleep. In REM sleep, the muscles controlling face, eyes, and distal limbs frequently twitch. REM sleep demonstrates an overall increase in brain activity compared to SWS sleep, except for the limbic system, where activity decreases during REM sleep. Periodically, breathing is stimulated and sympathetic activity is increased. Heart rate and blood pressure may rise while body temperature control is lost. During REM sleep, dreams are more elaborate and intense and are usually more narrative. In SWS, dreams are more like feelings or apparitions, whereas in REM sleep, thoughts are more illogical and bizarre.

Diff: 7 Page Ref: 243

9) Describe memory and learning, including the different types of learning and memory.

Answer: Learning is described as the acquisition of new information or skills. Memory is the retention of information, skills, or thoughts. There are two major types of learning that take place: associative and nonassociative. Associative learning requires making connections between two or more stimuli. We learn to associate one thing with another (Pavlov’s dog is an example where ringing of a bell was associated with the arrival of food). Nonassociative learning occurs in response to repetition of the same stimulus and includes the process of habituation and sensitization. Habituation is a decrease in the response to a repeated stimulus. Sensitization is an increase in response to a repetitive stimulus.

Memory can be classified as either procedural or declarative. Procedural memory is the memory of learned motor skills and behaviors. This type of memory is thought to reside in the cerebellum. Declarative memory is the memory of learned experiences such as facts or events that can be stated verbally. Memory occurs at two levels: long term and short term. Short-term memory is temporary storage that lasts only a few seconds. That memory will be lost if it is not consolidated into long-term memory. The methods by which consolidation occur are not well understood.

Diff: 6 Page Ref: 247
10) Describe the receptor-mediated events that appear to play a role in long-term potentiation and learning plasticity within the central nervous system.

Answer: Learning and memory are able to occur within the brain because of its plasticity, which can be defined as the brain’s ability to alter its anatomy and function in response to changes in its activity pattern. This plasticity derives from the fact that the function of existing synapses can be altered for short or long periods of time. Long-term potentiation is one form of plasticity. Repetitive stimulation of a particular synapse eventually leads to an increase in the strength of the synaptic connection. That is to say that the synapse is more likely to develop an action potential when stimulated. This enhanced ability to generate an action potential is mediated by an increase in the strength of the excitatory postsynaptic potential (EPSP) generated. The EPSP can be increased by: 1) increasing the sensitivity of a postsynaptic receptor to a neurotransmitter, or 2) increasing the amount of neurotransmitter released, or 3) both. Long-term potentiation is thought to be important in the consolidation of long-term memory. One type of potentiation occurs in synapses with the neurotransmitter glutamate. There are two receptors for glutamate that are present on the postsynaptic membrane: NMDA and AMPA receptors. NMDA receptors initiate the opening of calcium channels, whereas AMPA receptors cause sodium channels to open. When glutamate is released into the synapse, both receptors are activated. The amount of glutamate released is dependent upon the frequency of action potentials within the presynaptic membrane. When glutamate release is low to moderate, some AMPA receptors and NMDA receptors are activated, opening sodium and calcium channels, respectively. Even though the NMDA channels are open, the movement of calcium through these channels is blocked by magnesium. Thus, the extent of the depolarization is reduced by the blockade of NMDA receptors by magnesium when glutamate levels are low to moderate. However, if the frequency of action potentials is increased, large amounts of glutamate are released. This produces a stronger depolarization that prevents the magnesium-induced blockade of the NMDA, thereby increasing the extent of depolarization. At the same time, this increased calcium influx triggers the activation of protein kinases. These protein kinases can 1) phosphorylate AMPA receptors, making them more sensitive to glutamate (which further enhances the depolarization), and 2) stimulate the postsynaptic membrane to release a paracrine messenger that triggers presynaptic release of glutamate. All of these changes increase the likelihood that the glutamate released across the synapse will initiate an action potential in the postsynaptic membrane.

Diff: 7 \hspace{1cm} Page Ref: 248

Short Answer Questions

1) Most of the central nervous system is comprised of (neurons / glial cells).

Answer: glial cells

Diff: 3 \hspace{1cm} Page Ref: 216

2) The three meninges from neural tissue to bone are _______, _______, and _______.

Answer: pia mater, arachnoid mater, dura mater

Diff: 3 \hspace{1cm} Page Ref: 217

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3) The space between the pia mater and the arachnoid mater that contains cerebrospinal fluid is called ________.

   Answer: subarachnoid space
   Diff: 3 Page Ref: 217

4) The interstitial fluid of the central nervous system is ________.

   Answer: cerebrospinal fluid
   Diff: 3 Page Ref: 218

5) The choroid plexus consists of ________, ________, and ________ that are each involved in the production of cerebrospinal fluid.

   Answer: pia mater : capillaries : ependymal cells
   Diff: 5 Page Ref: 218

6) At rest, ________ percent of the blood pumped by the heart goes to the central nervous system as the central nervous system utilizes ________ percent of the oxygen consumed by the body.

   Answer: 15% : 20%
   Diff: 7 Page Ref: 220

7) In a ________, cerebral blood flow is interrupted due to blockage or rupturing of a cerebral blood vessel.

   Answer: stroke
   Diff: 4 Page Ref: 220

8) The blood–brain barrier is formed by what type of junction between capillary endothelial cells?

   Answer: tight junctions
   Diff: 4 Page Ref: 223

9) White matter is white due to the presence of what insulating substance?

   Answer: myelin
   Diff: 3 Page Ref: 223

10) What pathway consists of projection fibers that travel from the primary motor cortex to the spinal cord?

    Answer: pyramidal tract
    Diff: 4 Page Ref: 223

11) Most of the commissural fibers are located within what band of nervous tissue?

    Answer: corpus callosum
    Diff: 4 Page Ref: 223

12) Broca's area and Wernicke's area are regions important in language that are connected by the ________.

    Answer: arcuate fasciculus
    Diff: 6 Page Ref: 223
13) The body surface is mapped into ________, which are regions that receive sensory information from particular spinal nerves.
   Answer: dermatomes
   Diff: 4     Page Ref: 225

14) A (spinal tap / epidural) is the removal of a sample of cerebrospinal fluid.
   Answer: spinal tap
   Diff: 3     Page Ref: 225

15) Cell bodies of somatic efferent neurons are located in the spinal cord (dorsal horn / ventral horn).
   Answer: ventral horn
   Diff: 3     Page Ref: 226

16) The somatosensory cortex receives information from the (ipsilateral / contralateral) body surface.
   Answer: contralateral
   Diff: 5     Page Ref: 227

17) The forebrain consists of what two subdivisions?
   Answer: cerebrum and diencephalon
   Diff: 4     Page Ref: 227

18) The region of the brainstem important in the sleep–wake cycle, the arousal of the cerebral cortex, and in consciousness is known as the ________.
   Answer: reticular formation
   Diff: 5     Page Ref: 229

19) The temporal lobe is separated from the frontal lobe by the ________.
   Answer: lateral sulcus (or Sylvian fissure)
   Diff: 5     Page Ref: 230

20) The (hand / arm) has a greater area of motor cortex devoted to its control.
   Answer: hand
   Diff: 4     Page Ref: 231

21) The (right / left) side of the brain is more associated with logic and analytical ability.
   Answer: left
   Diff: 4     Page Ref: 233

22) What endocrine gland is attached to the hypothalamus and involved in the regulation of circadian rhythms?
   Answer: pineal gland
   Diff: 4     Page Ref: 234

23) A(n) ________ is an automatic, patterned response to a sensory stimulus.
   Answer: reflex
   Diff: 4     Page Ref: 236

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24) List the five components of a reflex arc.
   Answer: sensory receptor, afferent neuron, integration center, efferent neuron, effector organ
   Diff: 5 Page Ref: 236

25) The withdrawal reflex is originated by a sensory receptor called a ________.
   Answer: nociceptor
   Diff: 4 Page Ref: 286

26) In response to light, activation of the pupillary light reflex causes pupillary (constriction / dilation).
   Answer: constriction
   Diff: 4 Page Ref: 287

27) Name the three nuclei located within the brainstem that are involved in the control of involuntary posture.
   Answer: reticular formation, vestibular nuclei, red nuclei
   Diff: 6 Page Ref: 290

28) One of the characteristic signs of cerebellar damage is ________, a sometimes violent shaking that occurs when a person makes a voluntary movement.
   Answer: intention tremor
   Diff: 5 Page Ref: 291

29) As the night continues, the ________ periods of sleep last longer and occur closer together.
   Answer: rapid eye movement
   Diff: 5 Page Ref: 294

30) The emotions of anger and aggression appear to originate primarily from within what area of the brain?
   Answer: hypothalamus
   Diff: 4 Page Ref: 295

31) During REM sleep, the EEG recording shows ________ waves.
   Answer: beta
   Diff: 6 Page Ref: 294

32) Paradoxical sleep is another name for (REM / SWS) sleep.
   Answer: REM
   Diff: 4 Page Ref: 294

33) The process of converting short-term memory into long-term memory is called ________.
   Answer: consolidation
   Diff: 4 Page Ref: 296

34) The ability of the nervous system to adapt anatomically and functionally to changes in its activity is called ________.
   Answer: plasticity
   Diff: 5 Page Ref: 296
35) In the figure below, identify the four cerebral lobes indicated by A, B, C, and D.

Answer: A. frontal lobe, B. parietal lobe, C. occipital lobe, D. temporal lobe

Diff: 4 Page Ref: 231
Chapter 10  The Nervous System: Sensory Systems

Multiple Choice Questions

1) Which of the following is the most accurate definition of perception?
   A) the detection of stimuli in the external environment by sensory receptors
   B) the detection of stimuli in the internal environment by visceral receptors
   C) the processing of visual stimuli by the brain to give an accurate representation of the view of the world
   D) the conscious interpretation of the world around us
   E) the detection of the various energy forms in the environment by sensory receptors
Answer: D  
Diff: 3  Page Ref: 254

2) What type of receptor detects blood pressure?
   A) osmoreceptor
   B) baroreceptor
   C) thermoreceptor
   D) nociceptor
   E) proprioceptor
Answer: B  
Diff: 4  Page Ref: 254

3) According to the law of specific nerve energies, a single sensory receptor _______.
   A) responds equally to several types of stimuli
   B) responds to only one type of stimulus, regardless of the strength of stimulation
   C) responds best to a specific energy modality
   D) type detects all the somatic sensations
   E) type detects all the somesthetic sensations
Answer: C  
Diff: 4  Page Ref: 255

4) The modality to which a receptor responds best is called the _______.
   A) appropriate stimulus
   B) appropriate modality
   C) least energy stimulus
   D) adequate stimulus
   E) composite modality
Answer: D  
Diff: 3  Page Ref: 255

5) The perception of the position of one’s joints and limbs is called _______.
   A) proprioception
   B) nociception
   C) kinesthesiology
   D) nociology
   E) positionology
Answer: A  
Diff: 3  Page Ref: 254

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6) The process whereby a sensory receptor converts a stimulus modality into a change in membrane potential is called what?
   A) sensory generation  
   B) sensory production  
   C) sensory transduction  
   D) sensory conversion  
   E) modality conversion  
   Answer: C  
   Diff: 3   Page Ref: 255

7) What is another name for a receptor potential produced at sensory receptors?
   A) generator potential  
   B) sensory potential  
   C) synaptic potential  
   D) detector potential  
   E) afferent potential  
   Answer: A  
   Diff: 3   Page Ref: 255

8) A ______ refers to a single afferent neuron and all of the sensory receptors associated with that neuron.
   A) motor unit  
   B) neuronal field  
   C) sensory unit  
   D) second-order neuron  
   E) receptive unit  
   Answer: C  
   Diff: 4   Page Ref: 257

9) What is a region of skin that, when activated, will result in the change of activity within a particular afferent neuron?
   A) motor units  
   B) neuronal fields  
   C) labeled lines  
   D) second-order neurons  
   E) receptive fields  
   Answer: E  
   Diff: 4   Page Ref: 258

10) Another name for an afferent neuron is ______.
    A) multipolar neuron  
    B) receptor neuron  
    C) first-order neuron  
    D) second-order neuron  
    E) third-order neuron  
    Answer: C  
    Diff: 3   Page Ref: 258
11) What type of neuron in the thalamus communicates sensory information to the cerebral cortex?
   A) first-order neurons
   B) second-order neurons
   C) third-order neurons
   D) forth-order neurons
   E) afferent neurons
   Answer: C
   Diff: 4 Page Ref: 258

12) How is the intensity of a stimulus encoded during information transmittal to the central nervous system?
   A) The amplitude of action potentials transmitted to the central nervous system is greater for a stronger stimulus.
   B) The frequency of action potentials transmitted to the central nervous system is greater for a stronger stimulus.
   C) Different afferent neurons transmit information about stimuli of varying intensities.
   D) Different second-order neurons transmit information about stimuli of varying intensities.
   E) The neurotransmitter released from an afferent neuron differs based on the intensity of the stimulus.
   Answer: B
   Diff: 4 Page Ref: 259

13) Which of the following statements about lateral inhibition is FALSE?
   A) Lateral inhibition produces contrast within the nervous system.
   B) Lateral inhibition enhances acuity.
   C) Lateral inhibition occurs when communication is inhibited to second-order neurons receiving information from afferents associated with neighboring receptive fields.
   D) Lateral inhibition results in a stronger signal coming from second-order neurons associated with the central point of stimulation.
   E) Lateral inhibition decreases the two-point discrimination threshold.
   Answer: D
   Diff: 7 Page Ref: 260

14) Which of the following would NOT affect our ability to resolve the location of a specific stimulus?
   A) size of the receptive field
   B) density of receptors in the area
   C) extent of overlap between receptive fields
   D) location of cell body of the afferent neuron
   E) lateral inhibition between receptive fields
   Answer: D
   Diff: 4 Page Ref: 259
15) What is a decrease in the amplitude of a receptor potential in the presence of a continuing stimulus called?
   A) habituation
   B) adaptation
   C) sensitization
   D) transduction
   E) localization

Answer: B

Diff: 3 Page Ref: 256

16) Of the following areas of the body, which has the greatest tactile acuity?
   A) back
   B) upper arm
   C) forehead
   D) lips
   E) hand

Answer: D

Diff: 5 Page Ref: 261

17) The ability to detect the direction from which a sound originates is determined by ________.
   A) the time delay between that sound reaching the right and left cochlea
   B) mapping of sound location on the cerebral cortex
   C) differences in sound intensity as it reaches the right and left cochlea
   D) lateral inhibition that occurs between the right and left cochlea
   E) lateral excitation occurring between the right and left cochlea

Answer: A

Diff: 4 Page Ref: 261

18) Which of the following structures is NOT a mechanoreceptor located within the skin?
   A) Pacinian corpuscles
   B) hair follicle receptors
   C) Meissner's corpuscles
   D) Merkel's disks
   E) hair cells

Answer: E

Diff: 3 Page Ref: 262
19) Which of the following best describes the response of thermoreceptor afferents when temperature decreases from 35°C to 25°C?
   A) Afferents associated with both warm and cold receptors show a decrease in the frequency of action potentials.
   B) Afferents associated with both warm and cold receptors show an increase in the frequency of action potentials.
   C) Warm-receptor afferents show an increase in the frequency of action potentials, whereas cold-receptor afferents show a decrease in the frequency of action potentials.
   D) Warm-receptor afferents show a decrease in the frequency of action potentials, whereas cold-receptor afferents show an increase in the frequency of action potentials.
   E) Warm-receptor afferents show a decrease in the frequency of action potentials, whereas cold-receptor afferents fire at the same frequency.

Answer: D  
Diff: 6  Page Ref: 263

20) What are sensory receptors that respond to tissue-damaging stimuli or stimuli that have the potential to damage tissue called?
   A) thermoreceptors  
   B) proprioceptors  
   C) nociceptors  
   D) Merkel's disk  
   E) Meissner's corpuscle

Answer: C  
Diff: 4  Page Ref: 262

21) Which of the following is NOT a function of TRP channels?
   A) warm transduction  
   B) cold transduction  
   C) respond to painfully hot stimuli  
   D) respond to painfully hot chemicals  
   E) respond to painful mechanical stimulation

Answer: E  
Diff: 6  Page Ref: 264

22) What class of TRP channels responds to menthol?
   A) TRPV3  
   B) TRPV1  
   C) TRPM8  
   D) TRPA1  
   E) TRPV2

Answer: A  
Diff: 6  Page Ref: 264
23) What type of receptor responds to chemicals like histamine and bradykinin that are released from damaged tissue?
   A) Ruffini’s endings
   B) Hair follicle receptors
   C) Mechanical nociceptors
   D) Polymodal nociceptors
   E) Thermal nociceptors
   Answer: D
   Diff: 5 Page Ref: 264

24) What is the adequate stimulus for nociceptors?
   A) warmth
   B) cold
   C) touch
   D) pain
   E) change in muscle length
   Answer: D
   Diff: 3 Page Ref: 264

25) A person has damage to the right dorsal columns of the spinal cord at the thoracic level. This person would have impaired _______.
   A) temperature sensation of the right leg
   B) touch sensation of the right leg
   C) temperature sensation of the right arm and leg
   D) temperature sensation of the left leg
   E) touch sensation of the left leg
   Answer: B
   Diff: 8 Page Ref: 266

26) Which of the following statements about the spinothalamic tract is FALSE?
   A) Pain signals are transmitted along this pathway.
   B) Cold signals are transmitted along this pathway.
   C) Warm signals are transmitted along this pathway.
   D) The pathway crosses to the contralateral side in the brainstem.
   E) The first-order neuron synapses with the second order neuron in the spinal cord dorsal horn.
   Answer: D
   Diff: 5 Page Ref: 266

27) Fast pain originating from nociceptors is perceived as a _______ pain and is carried along _______ fibers.
   A) sharp : A δ
   B) sharp : C
   C) dull : A δ
   D) dull : C
   E) sharp : A β
   Answer: A
   Diff: 5 Page Ref: 267
28) Which of the following is a neurotransmitter responsible for the transmission of a painful stimulus between first- and second-order neurons?
   A) Acetylcholine
   B) Norepinephrine
   C) Bradykinin
   D) Histamine
   E) Substance P
Answer: E
Diff: 4 Page Ref: 267

29) How are pain signals from visceral receptors "referred" to the body surface?
   A) the convergence of visceral and somatic afferents on the same second-order neurons
   B) the convergence of visceral and somatic afferents on the same first-order neurons
   C) signals from visceral receptors that travel to skin receptors to activate them
   D) the convergence of visceral and somatic afferents on the same third-order neurons
   E) the divergence of visceral and somatic afferents onto different second-order neurons
Answer: A
Diff: 5 Page Ref: 268

30) The gate-control theory of pain modulation states that ______.
   A) pain sensation must be modified within the sensory receptors
   B) C fibers themselves can act to modify their own pain signal
   C) the signal that modifies pain sensation in the spinal cord must originate from the nucleus raphe magnus
   D) non-painful somatic signals can inhibit signals of pain
   E) painful somatic signals can inhibit signals of pain
Answer: D
Diff: 5 Page Ref: 268

31) Which of the following is NOT part of the gate-control theory of pain modulation?
   A) Inhibitory interneurons can modulate second-order pain neurons.
   B) Inhibitory interneurons are activated by collaterals of Aβ fibers that are associated with mechanical stimuli.
   C) Inhibitory interneurons are inhibited by collaterals from the nociceptor afferent.
   D) A non-painful stimulus can activate the inhibitory interneuron and thereby inhibit the painful stimulus.
   E) Signals that modify pain originate from higher centers of the brain.
Answer: E
Diff: 5 Page Ref: 268

32) Which of the following statements about sensory coding is FALSE?
   A) The type of stimulus is coded for by the specific pathway activated.
   B) The intensity of stimulus is coded for by the size of the action potential.
   C) The location of the stimulus is coded for by the receptive field activated.
   D) The ability to locate the stimulus is enhanced by lateral inhibition.
   E) Coding for a stimulus type is maintained from receptor to cortex.
Answer: B
Diff: 4 Page Ref: 259
33) Amputation in diabetics is often secondary to what other problem with diabetes?
   A) neuropathy
   B) retinopathy
   C) hyertension
   D) cardiomyopathy
   E) renal failure

   Answer: A
   Diff: 4   Page Ref: 269

34) What is the function of the retinal pigmented epithelium?
   A) Provide nutrients and oxygen to the retina.
   B) Provide nutrients and oxygen to the lens and cornea.
   C) Absorb light that enters the eye.
   D) Secrete vitreous humor.
   E) Secrete aqueous humor.

   Answer: C
   Diff: 4   Page Ref: 270

35) Which of the following best describes the location of the anterior segment?
   A) within the eye, between the cornea and lens
   B) within the eye, between the cornea and iris
   C) within the eye, between the iris and lens
   D) within the ear, between the vestibular and basilar membranes
   E) within the ear, between the basilar and tympanic membranes

   Answer: A
   Diff: 5   Page Ref: 270

36) The amount of light that impinges on the retina is primarily regulated by what structure?
   A) cornea
   B) iris
   C) optic disk
   D) fovea
   E) ciliary body

   Answer: B
   Diff: 3   Page Ref: 270

37) The cornea and lens are ______ surfaces that cause light to converge on a ______.
   A) concave : focal length
   B) convex : focal point
   C) concave : focal point
   D) convex : focal length
   E) transparent : focal length

   Answer: B
   Diff: 5   Page Ref: 272
38) What nourishes the lens and cornea?
   A) Purkinje fibers
   B) the optic disk
   C) the choroid
   D) aqueous humor
   E) vitreous humor

   Answer: D
   Diff: 4   Page Ref: 270

39) Light waves refract as they pass through what structures of the eye?
   A) cornea only
   B) lens only
   C) cornea and lens
   D) choroid only
   E) cornea, lens, and choroid

   Answer: C
   Diff: 5   Page Ref: 272

40) In order to focus light coming from a near source onto the retina, the lens adjusts its refractive power through what process?
   A) accommodation
   B) acclimation
   C) acclimatization
   D) telescoping
   E) refractometry

   Answer: A
   Diff: 4   Page Ref: 273

41) When the ciliary muscles are relaxed, the lens is relatively _______, allowing the eye to focus on objects that are _______.
   A) round : close
   B) round : distant
   C) flat : close
   D) flat : distant
   E) transparent : anywhere within the field of view

   Answer: D
   Diff: 5   Page Ref: 274

42) Ciliary muscle is innervated by what branch of the nervous system?
   A) somatic nervous system
   B) enteric nervous system
   C) sympathetic nervous system
   D) parasympathetic nervous system
   E) central nervous system

   Answer: D
   Diff: 5   Page Ref: 274
43) In the visual system, activation of the parasympathetic nervous system causes which of the following?
   A) pupillary constriction and an increase in the refractive power of the lens
   B) pupillary constriction and a decrease in the refractive power of the lens
   C) pupillary dilation and an increase in the refractive power of the lens
   D) pupillary dilation and a decrease in the refractive power of the lens
   E) pupillary dilation and no effect on the refractive power of the lens
   Answer: A
   Diff: 5   Page Ref: 274

44) Which of the following defects in vision is incorrectly matched with its cause?
   A) myopia : lens too strong
   B) astigmatism : hardening of the lens
   C) glaucoma : increased volume of aqueous humor
   D) cataract : discoloration of the lens
   E) myopia : eyeball too long
   Answer: B
   Diff: 6   Page Ref: 274

45) What is a condition where light, originating from a distance, is focused in front of the retina?
   A) presbyopia
   B) emmetropia
   C) hyperopia
   D) myopia
   E) neurotropia
   Answer: D
   Diff: 5   Page Ref: 275

46) What is a condition where light, originating from a close up source, is focused behind the retina?
   A) presbyopia
   B) emmetropia
   C) hyperopia
   D) myopia
   E) neurotropia
   Answer: C
   Diff: 5   Page Ref: 275

47) Which of the conditions below describes irregularities in the structure of the cornea or lens?
   A) cataracts
   B) presbyopia
   C) glaucoma
   D) astigmatism
   E) hyperopia
   Answer: D
   Diff: 4   Page Ref: 275
48) Angiogenesis contributes to the cause of what visual defect in diabetes?
   A) macular degeneration
   B) glaucoma
   C) myopia
   D) hyperopia
   E) cataracts
   Answer: A
   Diff: 5 Page Ref: 276

49) The radial muscles of the iris are innervated by the ______ nervous system and their 
contraction causes pupillary ______. 
   A) sympathetic : constriction
   B) sympathetic : dilation
   C) parasympathetic : constriction
   D) parasympathetic : dilation
   E) somatic : constriction
   Answer: B
   Diff: 5 Page Ref: 276

50) The circular muscles of the iris are innervated by the ______ nervous system and their 
contraction causes pupillary ______. 
   A) sympathetic : constriction
   B) sympathetic : dilation
   C) parasympathetic : constriction
   D) parasympathetic : dilation
   E) somatic : constriction
   Answer: C
   Diff: 5 Page Ref: 276

51) When the doctor shines a penlight into the patient’s eye, which of the following occurs?
   A) The parasympathetic nervous system is activated, which causes contraction of the outer 
      radial muscle of the iris and pupillary constriction.
   B) The sympathetic nervous system is activated, which causes contraction of the outer 
      radial muscle of the iris and pupillary constriction.
   C) The parasympathetic nervous system is activated, which causes contraction of the inner 
      circular muscle of the iris and pupillary constriction.
   D) The sympathetic nervous system is activated, which causes contraction of the outer 
      radial muscle of the iris and pupillary dilation.
   E) The parasympathetic nervous system is activated, which causes contraction of the outer 
      radial muscle of the iris and pupillary dilation.
   Answer: C
   Diff: 5 Page Ref: 276
52) Which of the following occurs during accommodation for near vision?
   A) Ciliary muscles contract, causing zonular fibers to become tight, flattening the lens.
   B) Ciliary muscles contract, causing zonular fibers to become slack, flattening the lens.
   C) Ciliary muscles contract, causing zonular fibers to become tight, and the lens becomes rounder.
   D) Ciliary muscles relax, causing zonular fibers to become slack, and the lens becomes rounder.
   E) Ciliary muscles contract, causing zonular fibers to become slack, and the lens becomes rounder.
   Answer: E  Diff: 6  Page Ref: 274

53) Which of the following is NOT a cell type found in the retina?
   A) photoreceptors
   B) amacrine cells
   C) horizontal cells
   D) bipolar cells
   E) macular cells
   Answer: E  Diff: 4  Page Ref: 276

54) The lateral displacement of bipolar and ganglion cells within the macula lutea allow for
   ________.  
   A) enhanced communication between bipolar and ganglion cells
   B) processing of information from the rods
   C) processing of information from the cones
   D) an unhindered pathway for light to reach the rods of the fovea
   E) an unhindered pathway for light to reach the cones of the fovea
   Answer: E  Diff: 4  Page Ref: 276

55) What are the cones called that respond to the red spectrum of light?
   A) R cones
   B) G cones
   C) Y cones
   D) L cones
   E) S cones
   Answer: D  Diff: 4  Page Ref: 277

56) Cones that respond to the shortest wavelengths of light (S cones) respond best to what color spectrum?
   A) red
   B) blue
   C) green
   D) yellow
   E) violet
   Answer: B  Diff: 4  Page Ref: 277
57) The light-absorbing portion of the photopigment is ________; its sensitivity to a particular wavelength of light is altered by ________.
   A) retinal : opsin
   B) opsin : retinal
   C) transducin : phosphodiesterase
   D) phosphodiesterase : transducin
   E) opsin : transducin

   Answer: A
   Diff: 6  Page Ref: 277

58) The presence of cGMP in the cytosol of a photoreceptor will directly stimulate the ________.
   A) opening of sodium channels
   B) opening of potassium channels
   C) closure of sodium channels
   D) closure of potassium channels
   E) opening of calcium channels

   Answer: A
   Diff: 5  Page Ref: 277

59) In the absence of light, the membrane potential of a photoreceptor is relatively ________ by the presence of open ________ channels.
   A) depolarized : potassium
   B) hyperpolarized : potassium
   C) hyperpolarized : sodium
   D) depolarized : calcium
   E) depolarized : sodium

   Answer: E
   Diff: 5  Page Ref: 278

60) The closure of sodium channels is mediated by a decrease in the cytosolic concentration of ________, which is degraded by ________.
   A) cGMP : transducin
   B) cGMP : phosphodiesterase
   C) cAMP : transducin
   D) cAMP : phosphodiesterase
   E) cAMP : ATP synthase

   Answer: B
   Diff: 5  Page Ref: 278

61) When we enter a dark room, the retinal and opsin molecules within the ________ must first ________ before low light levels can be detected.
   A) rods : bleach
   B) rods : dissociate
   C) cones : dissociate
   D) rods : associate
   E) cones : associate

   Answer: D
   Diff: 6  Page Ref: 280
62) Which of the following is TRUE of photoreceptors in the light (relative to the dark)?
   A) cGMP levels are elevated.
   B) Sodium channels are open.
   C) The photoreceptors are depolarized.
   D) The synaptic terminal is releasing more transmitter.
   E) Phosphodiesterase is more active.
   Answer: E
   Diff: 7    Page Ref: 278

63) What type of vision occurs in light levels that activate both rods and cones?
   A) scotopic
   B) photopic
   C) mesopic
   D) retinotopic
   E) all of the above
   Answer: C
   Diff: 7    Page Ref: 280

64) Disks of a photoreceptor are located in the _______ and contain _______.
   A) inner segment : transmitter
   B) outer segment : transmitter
   C) inner segment : photopigment
   D) outer segment : photopigment
   E) synaptic terminal : transmitter
   Answer: D
   Diff: 4    Page Ref: 277

65) Which of the following is the correct order of communication of visual information in the retina?
   A) photoreceptor; bipolar cell; ganglion cell
   B) photoreceptor; ganglion cell; bipolar cell
   C) bipolar cell; ganglion cell; photoreceptor
   D) bipolar cell; photoreceptor; ganglion cell
   E) ganglion cell; bipolar cell; photoreceptor
   Answer: A
   Diff: 3    Page Ref: 280

66) Photoreceptors transmit information directly to _______ cells via the release of a neurotransmitter, causing those cells to develop a(n) _______ potential proportional to the intensity of the stimulus.
   A) ganglion : graded
   B) amacrine : graded
   C) bipolar : graded
   D) amacrine : action
   E) ganglion : action
   Answer: C
   Diff: 5    Page Ref: 280

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67) The first neurons capable of generating action potentials in the transmission pathway for visual information detected by rods and cones are the _______ cells.
   A) ganglion
   B) bipolar
   C) amacrine
   D) vertical
   E) horizontal

Answer: A
Diff: 4     Page Ref: 280

68) Which of the following best describes ON-center, OFF-surround cells in the retina?
   A) They are photoreceptors that are excited by light applied in the center of their visual fields and inhibited by light in the surrounding regions of their visual fields.
   B) They are bipolar cells that are excited by light applied in the center of their visual fields and inhibited by light in the surrounding regions of their visual fields.
   C) They are ganglion cells that are excited by light applied in the center of their visual fields and inhibited by light in the surrounding regions of their visual fields.
   D) They are photoreceptors that are excited by light striking the center of the retina and inhibited by light striking the peripheral retina.
   E) They are ganglion cells that are excited by light striking the center of the retina and inhibited by light striking the peripheral retina.

Answer: C
Diff: 5     Page Ref: 281

69) Which of the following components of the visual pathway is 100% ipsilateral to the visual field?
   A) visual cortex
   B) optic nerve
   C) optic tract
   D) lateral geniculate nucleus
   E) none

Answer: E
Diff: 5     Page Ref: 281

70) In the optic chiasm, ganglion cells from the _______ portion of the retina cross over, whereas the ganglion cells from the _______ portion of the retina remain on the same side.
   A) nasal : center
   B) center : nasal
   C) temporal : nasal
   D) nasal : temporal
   E) temporal : center

Answer: D
Diff: 5     Page Ref: 283
71) The ganglion cells of the retina synapse with neurons in the _______ that ascend to the _______.
   A) hypothalamus : primary visual cortex
   B) thalamus : primary motor cortex
   C) lateral geniculate body : cerebellum
   D) thalamus : primary somatosensory cortex
   E) lateral geniculate body : primary visual cortex
   Answer: E
   Diff: 4 Page Ref: 283

72) The neural pathway from the lateral geniculate body to the visual cortex is called the _______.
   A) optic nerve
   B) optic tract
   C) optic radiations
   D) optic fasciculus
   E) optic chiasm
   Answer: C
   Diff: 4 Page Ref: 283

73) The visual system is an excellent example of parallel processing, where visual details are _______.
   A) integrated before reaching the primary visual cortex
   B) integrated by bipolar cells and sent to the primary visual cortex
   C) transmitted along separate pathways to the primary visual cortex where they are then integrated
   D) maintained within the optic chiasm where they are integrated
   E) transmitted to the lateral geniculate body where they are integrated
   Answer: C
   Diff: 5 Page Ref: 283

74) Both the auditory and vestibular systems rely upon _______ to detect movement of fluid within the ear.
   A) hair cells
   B) chemoreceptors
   C) thermoreceptors
   D) magnetoreceptors
   E) hydroreceptors
   Answer: A
   Diff: 3 Page Ref: 283

75) Sound waves traveling through the air initiate a vibration of the _______. The sound waves are then transmitted along the _______ to the cochlea.
   A) saccule : eustachian tube
   B) oval window : ossicles
   C) oval window : eustachian tube
   D) tympanic membrane : ossicles
   E) round window : saccule
   Answer: D
   Diff: 4 Page Ref: 284
76) The amplitude of a sound wave is determined by the difference in the _______.
   A) number of sound waves per second
   B) energy embedded in the air molecules
   C) pitch of the sound
   D) air molecule density in the compressed versus rarified regions of the sound wave
   E) size of the air molecules in the compressed region of the sound wave

Answer: D  
Diff: 3  Page Ref: 284

77) What structure separates the middle from the external ear?
   A) round window
   B) tympanic membrane
   C) Eustachian tube
   D) oval window
   E) basilar membrane

Answer: B  
Diff: 3  Page Ref: 283

78) What is the function of the ear ossicles?
   A) transduce sound waves to neural impulses
   B) maintain the sensitivity of hair cells for hearing
   C) amplify sound waves as they are transmitted from the middle to the inner ear
   D) provide structural support of the eardrum
   E) provide structural support of the cochlea

Answer: C  
Diff: 4  Page Ref: 284

79) Which of the following best represents the endocochlear potential?
   A) -90 mV
   B) -70 mV
   C) -20 mV
   D) +60 mV
   E) +80 mV

Answer: E  
Diff: 5  Page Ref: 286

80) Which of the following statements about hair cells in the ear is FALSE?
   A) There are three rows of outer hair cells and one row of inner hair cells.
   B) Hair cells are surrounded by endolymph.
   C) Only the inner hair cells of the cochlea function directly in sound transduction.
   D) Both the hair cells for hearing and those for equilibrium are depolarized when bent toward the kinocilium.
   E) When potassium channels in hair cells open, potassium ions move into the cell, depolarizing it.

Answer: D  
Diff: 7  Page Ref: 288
81) The organ of Corti is located on what membrane?
   A) vestibular membrane
   B) tympanic membrane
   C) tectorial membrane
   D) basilar membrane
   E) plasma membrane of hair cells

   Answer: D
   Diff: 5   Page Ref: 288

82) The ________, projecting from the end of hair cells, are attached to the ________, which causes them to bend when sound waves enter the cochlea.
   A) stereocilia : basilar membrane
   B) stereocilia : tectorial membrane
   C) nitrocilia : tectorial membrane
   D) kinocilia : basilar membrane
   E) cilia : basilar membrane

   Answer: B
   Diff: 5   Page Ref: 288

83) The hair cells are embedded within endolymph, thus, when a potassium channel opens, potassium moves ________ the cell, causing it to ________.
   A) into : depolarize
   B) out of : hyperpolarize
   C) into : hyperpolarize
   D) out of : depolarize
   E) equally into and out of : maintain its polarized state

   Answer: A
   Diff: 6   Page Ref: 288

84) Bending of the stereocilia on the hair cell can induce either a closure or an opening of a potassium channel based upon the ________.
   A) size of the stereocilia
   B) frequency of the sound
   C) intensity of the sound
   D) direction that the stereocilia move
   E) acceleration of the body

   Answer: D
   Diff: 5   Page Ref: 288

85) Frequency of sound is coded for by ________.
   A) the number of hair cells stimulated
   B) the direction that the stereocilia are stimulated
   C) the amplitude of the action potentials
   D) the frequency of action potentials
   E) the location of the hair cell stimulated

   Answer: E
   Diff: 4   Page Ref: 290
86) In comparison to low pitch sound, high pitch sound will cause vibrations of the basilar membrane ________.
   A) closer to the oval window
   B) closer to the helicotrema
   C) closer to the tympanic membrane
   D) of lesser amplitude
   E) of greater amplitude
Answer: A
Diff: 5 Page Ref: 290

87) The transduction of sound waves into neural impulses occurs in the ________.
   A) ossicles
   B) cochlea
   C) semicircular canals
   D) utricle
   E) eustachian tube
Answer: B
Diff: 3 Page Ref: 288

88) The anterior portion of the semicircular canal detects acceleration in which direction?
   A) the rotation of the head from side to side, as in moving the ear toward the shoulder
   B) rotating the head as in saying "no"
   C) moving the head up and down as in saying "yes"
   D) linear acceleration in the forward and backward directions
   E) linear acceleration in the up and down directions
Answer: C
Diff: 5 Page Ref: 291

89) The posterior portion of the semicircular canal detects acceleration in which direction?
   A) rotation of the head from side to side, as in moving the ear toward the shoulder
   B) rotating the head as in saying "no"
   C) moving the head up and down as in saying "yes"
   D) linear acceleration in the forward and backward directions
   E) linear acceleration in the up and down directions
Answer: A
Diff: 5 Page Ref: 291

90) Located within the ________ of the semicircular canal, a gelatinous structure called the ________ surrounds the stereocilia and kinocilium.
   A) lumen : otolith
   B) cupula : otolith
   C) cupula : ampulla
   D) ampulla : otolith
   E) ampulla : cupula
Answer: E
Diff: 6 Page Ref: 291
91) Whether the hair cell in the semicircular canal is depolarized or hyperpolarized is dependent upon which of the following?
   A) speed at which the head rotates
   B) direction toward which the stereocilia are bent relative to the kinocilium
   C) extent to which the stereocilia are bent
   D) direction toward which ONLY the kinocilia are bent
   E) speed at which the stereocilia are bent

Answer: B
Diff: 5 Page Ref: 291

92) The mass of the gelatinous material within the saccule and utricle is enhanced by the presence of what type of crystals?
   A) sodium carbonate
   B) sodium chloride
   C) potassium chloride
   D) calcium carbonate
   E) calcium phosphate

Answer: D
Diff: 6 Page Ref: 293

93) The saccule detects what type of motion?
   A) angular acceleration as when nodding the head yes
   B) angular acceleration as when shaking the head no
   C) angular acceleration as when tilting the head so that the ear approaches the shoulder
   D) linear acceleration forward and backward
   E) linear acceleration up or down

Answer: E
Diff: 4 Page Ref: 293

94) Depolarization of hair cells in the utricle occurs when _______.
   A) the head is tilted to the left
   B) the head is tilted to the right
   C) the head is tilted forward
   D) the hair cell bends toward the kinocilium
   E) the hair cell bends away from the kinocilium

Answer: D
Diff: 4 Page Ref: 293

95) Afferent neurons from the semicircular canal, the utricle, and the saccule enter the brainstem where most terminate within the _______.
   A) medial geniculate body
   B) lateral geniculate body
   C) lateral reticular formation
   D) vestibular nuclei
   E) nucleus raphe magnus

Answer: D
Diff: 6 Page Ref: 293
96) Which of the following is NOT one of the primary tastes?
   A) bitter
   B) sweet
   C) salty
   D) hot
   E) sour
   Answer: D
   Diff: 3 Page Ref: 295

97) The detection of sweet by taste receptors occurs via the binding of organic molecules to receptors on the cell membrane activating _______ that ultimately causes a _______.
   A) gustducin : sodium channel to close
   B) transducin : sodium channel to close
   C) transducin : potassium channel to open
   D) gustducin : potassium channel to close
   E) G_olf : potassium channel to close
   Answer: D
   Diff: 6 Page Ref: 295

98) The primary afferent neurons from taste receptor cells terminate within what structure of the central nervous system?
   A) thalamus
   B) cerebellum
   C) medulla oblongata
   D) gustatory cortex
   E) olfactory tubercle
   Answer: C
   Diff: 5 Page Ref: 295

99) What two taste qualities use a G protein during the transduction process?
   A) sweet and sour
   B) sweet and bitter
   C) salty and sweet
   D) sour and salty
   E) bitter and salty
   Answer: B
   Diff: 4 Page Ref: 295

100) Which cranial nerve transmits taste information to the central nervous system?
    A) VII only
    B) IX only
    C) X only
    D) both VII and IX
    E) VII, IX, and X
    Answer: E
    Diff: 7 Page Ref: 295
101) Which of the following cells is the precursor cell for the olfactory cells?
   A) support cells
   B) basal cells
   C) olfactory receptor cells
   D) mitral cells
   E) ciliary cells
   Answer: B
   Diff: 4    Page Ref: 297

102) The detection of odorants occurs via the binding of organic molecules to receptors on the cell membrane, activating _______ that ultimately causes the ________.
   A) gustducin : sodium channel to close
   B) G_{olf}: potassium channel to open
   C) transducin: potassium channel to open
   D) gustducin: potassium channel to close
   E) G_{olf}: cation channel to open
   Answer: E
   Diff: 6    Page Ref: 297

103) First-order olfactory neurons synapse with _________. These synapses occur in clusters called _________.
   A) mitral cells: glomeruli
   B) bicuspid cells: glomeruli
   C) mitral cells: criiform areas
   D) olfactory neurons: glomeruli
   E) olfactory neurons: criiform areas
   Answer: A
   Diff: 4    Page Ref: 298

104) Which of the following is an INCORRECT match between cranial nerve and special sense?
   A) cranial nerve I – olfaction
   B) cranial nerve II – vision
   C) cranial nerve III – taste
   D) cranial nerve VIII – hearing
   E) cranial nerve VIII – equilibrium
   Answer: C
   Diff: 6    Page Ref: 298

105) Which sensory system does not need to transmit information through the thalamus to get to the cortex?
   A) somatosensory systems
   B) taste
   C) olfaction
   D) vestibular/equilibrium
   E) hearing
   Answer: C
   Diff: 4    Page Ref: 299
106) Axons of the olfactory nerve travel through what special structure?
   A) glomeruli
   B) cribiform plate
   C) olfactory bulb
   D) cochlear membrane
   E) organ of Corti
   Answer: B
   Diff: 5     Page Ref: 298

True/False Questions

1) We generally do NOT perceive information transmitted by visceral afferents.
   Answer: TRUE
   Diff: 3     Page Ref: 254

2) All people have the same perception of the external environment.
   Answer: FALSE
   Diff: 2     Page Ref: 254

3) The term modality refers to the form of energy that defines a specific stimulus.
   Answer: TRUE
   Diff: 3     Page Ref: 255

4) Olfactory receptors are tonic (slowly adapting) receptors that detect odors.
   Answer: FALSE
   Diff: 4     Page Ref: 257

5) The lips are the most sensitive to the two-point discrimination threshold because their receptive fields are relatively small.
   Answer: TRUE
   Diff: 4     Page Ref: 261

6) Merkel's disks are superficial mechanoreceptors located in both glabrous and hairy skin.
   Answer: TRUE
   Diff: 6     Page Ref: 265

7) There are separate receptors for warm and cold.
   Answer: TRUE
   Diff: 5     Page Ref: 263

8) Chemical nociceptors respond to chemical substances released by damaged tissue.
   Answer: FALSE
   Diff: 4     Page Ref: 264

9) The dorsal column-medial lemniscal pathway carries mechanoreceptive and proprioceptive information to the thalamus, whereas the spinothalamic tract carries thermoreceptive and nociceptive information.
   Answer: TRUE
   Diff: 4     Page Ref: 265
10) Transcutaneous nerve stimulation describes a technique whereby current applied to the skin stimulates large diameter afferent axons (Aβ fiber) to inhibit the transmission of a painful stimulus from the C fiber to a second-order neuron.

Answer: TRUE
Diff: 3 Page Ref: 268

11) Modulation of sensory information as it is transmitted from receptors to the cerebral cortex can only occur at synapses.

Answer: TRUE
Diff: 6 Page Ref: 268

12) Cytokines released during illness can cause a person to be more sensitive to pain.

Answer: TRUE
Diff: 6 Page Ref: 270

13) Capsaicin causes a burning sensation in the mouth because it binds to TRPV1 receptors.

Answer: TRUE
Diff: 6 Page Ref: 264

14) The point on the retina with greatest visual acuity is the optic disk.

Answer: FALSE
Diff: 3 Page Ref: 271

15) The wavelength of light that we perceive is that wavelength that has been absorbed by the object being observed.

Answer: FALSE
Diff: 3 Page Ref: 271

16) Corrective lenses that are concave are used to correct myopia.

Answer: TRUE
Diff: 5 Page Ref: 275

17) Along a large portion of the retina, light must pass through two layers of cells before reaching a photoreceptor.

Answer: TRUE
Diff: 4 Page Ref: 276

18) The concentration of cGMP in a photoreceptor is relatively high in the dark, thereby maintaining rods and cones in the depolarized state.

Answer: TRUE
Diff: 5 Page Ref: 278

19) Extensive convergence exists from the cones to the bipolar cells within the fovea.

Answer: FALSE
Diff: 4 Page Ref: 280

20) Extensive convergence of rods onto bipolar cells allows for greater sensitivity to light.

Answer: TRUE
Diff: 4 Page Ref: 279
21) The photoreceptors responsible for resetting the light/dark cycle contains a photopigment called melanopsin.
   Answer: TRUE
   Diff: 6  Page Ref: 281

22) Information from the right visual field is perceived in the left visual cortex.
   Answer: TRUE
   Diff: 3  Page Ref: 283

23) Depth perception requires visual input from both eyes.
   Answer: TRUE
   Diff: 4  Page Ref: 283

24) In a neural pathway, when an excitatory synapse follows an inhibitory synapse, this is called disinhibition.
   Answer: FALSE
   Diff: 7  Page Ref: 282

25) The eighth cranial nerve carries information about hearing and equilibrium from the ear to the central nervous system.
   Answer: TRUE
   Diff: 4  Page Ref: 284

26) Auditory information is transmitted through the medial geniculate nucleus in the thalamus to the cortex.
   Answer: TRUE
   Diff: 4  Page Ref: 290

27) Each semicircular canal can only detect rotation in one direction.
   Answer: FALSE
   Diff: 6  Page Ref: 291

28) The vestibular apparatus can only detect changes in the rate of head movement.
   Answer: TRUE
   Diff: 4  Page Ref: 291

29) Taste receptor cells are located only on the tongue.
   Answer: FALSE
   Diff: 3  Page Ref: 293

30) Each taste receptor cell is specific to only one of the four primary tastes.
   Answer: FALSE
   Diff: 5  Page Ref: 295

31) Tonic receptors are best at detecting changes in the environment.
   Answer: FALSE
   Diff: 4  Page Ref: 257
32) Receptive field sizes are approximately the same over all parts of the body for a specific modality.
   Answer: FALSE  
   Diff: 5  Page Ref: 260

33) Although pain perception can vary between individuals, one person always perceives the identical painful stimulus as being the same.
   Answer: FALSE  
   Diff: 4  Page Ref: 268

34) A decrease in the amplitude of a receptor potential over time in the presence of a continued stimulus is called habituation.
   Answer: FALSE  
   Diff: 6  Page Ref: 256

35) In order to taste food, the chemicals must be dissolved in mucus.
   Answer: FALSE  
   Diff: 5  Page Ref: 295

Matching Questions

Match the following words to their correct definition.

1) Mechanism by which receptors convert stimulus energies into changes in membrane potential.  
   A) modality  
   B) perception  
   C) transduction  
   D) appropriation  
   E) adequate stimulus  
   Diff: 3  Page Ref: 255

2) The form of energy associated with a particular stimulus type.  
   Diff: 3  Page Ref: 255

3) A person's conscious interpretation of the external environment.  
   Diff: 2  Page Ref: 254

4) The stimulus type to which a receptor responds to greatest.  
   Diff: 3  Page Ref: 255

Answers:  1) C  2) A  3) B  4) E
Match the following receptor types to the correct modality.

5) Sound waves.
   Diff: 4   Page Ref: 288
   A) hair cells in utricle
   B) cold receptors

6) Stretch of specific blood vessels.
   Diff: 6   Page Ref: 254
   C) warm receptors
   D) baroreceptors

7) Photons of light.
   Diff: 2   Page Ref: 270
   E) photoreceptors

8) Linear acceleration forward or backward.
   Diff: 6   Page Ref: 291
   F) chemoreceptors
   G) hair cells in cochlea

9) Swelling of receptor cells.
   Diff: 5   Page Ref: 254
   H) mechanical nociceptors

10) Angular acceleration
    Diff: 6   Page Ref: 291
    I) osmoreceptors

11) Decreases in temperature from 35°C to 20°C.
    Diff: 2   Page Ref: 263
    J) hair cells in semicircular canals

12) Free hydrogen ion content of blood.
    Diff: 5   Page Ref: 254

13) Intense mechanical stimuli.
    Diff: 4   Page Ref: 264

14) Increases in temperature between 30°C and 43°C.
    Diff: 2   Page Ref: 263

Match the following with the correct location in the brain.

15) Where the spinothalamic tract crosses over to the opposite side.
   A) frontal lobe
   B) occipital lobe
   C) brainstem
   Diff: 5    Page Ref: 266

16) Where the dorsal column pathway crosses over to the opposite side.
   D) thalamus
   E) parietal lobe
   F) temporal lobe
   G) spinal cord
   Diff: 5    Page Ref: 266

17) Somatosensory cortex.
   Diff: 3    Page Ref: 265

18) Visual cortex.
   Diff: 2    Page Ref: 283

19) Auditory cortex.
   Diff: 2    Page Ref: 290

20) Location of vestibular nuclei.
   Diff: 6    Page Ref: 293

21) Location of gustatory nucleus.
   Diff: 6    Page Ref: 295

22) Gustatory cortex.
   Diff: 6    Page Ref: 295

23) Location of medial geniculate body.
   Diff: 4    Page Ref: 290

24) Termination of second-order neurons.
   Diff: 3    Page Ref: 257

25) Location of the dorsal columns.
   Diff: 4    Page Ref: 265

Match the following structures of the eye with the correct function/description.

26) Tough connective tissue that makes up the "white" of the eye.
   A) cornea
   B) photoreceptors
   C) ciliary muscles
   Diff: 3  Page Ref: 270

27) Strands of connective tissue that connect the lens to muscles for accommodation.
   D) lens
   E) fovea
   F) zonular fibers
   Diff: 4  Page Ref: 270

28) First refractive structure light waves must pass through as they enter the eye.
   G) iris
   H) sclera
   I) optic disk
   J) retinal pigmented epithelium
   Diff: 4  Page Ref: 270

29) Comprised of neural tissue that includes bipolar cells.
   K) retina
   L) pupil
   Diff: 4  Page Ref: 270

30) Hole through which light can enter the eye.
   Diff: 2  Page Ref: 270

31) Includes the rods and cones.
   Diff: 2  Page Ref: 270

32) Pigmented structure that absorbs light waves.
   Diff: 4  Page Ref: 270

33) Muscle under parasympathetic control to regulates the refractive power of the lens.
   Diff: 4  Page Ref: 274

34) Muscle under autonomic control that regulates the diameter of the pupil.
   Diff: 4  Page Ref: 276

35) Site of highest visual acuity.
   Diff: 5  Page Ref: 270

36) The refractive power of this structure can be altered to focus light.
   Diff: 2  Page Ref: 270

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37) The optic nerve exits the eye at this point.
   Diff: 4 Page Ref: 271

38) Light striking this region of the retina is not detected by photoreceptors.
   Diff: 5 Page Ref: 271

         36) D 37) I 38) I

For each of the following, indicate whether it describes rods, cones, or both.

39) Contains retinal.
   Diff: 4 Page Ref: 277
   A) cones
   B) rods
   C) both

40) Contains rhodopsin.
   Diff: 4 Page Ref: 277

41) Is the most abundant in the retina.
   Diff: 4 Page Ref: 277

42) Is associated with high visual acuity.
   Diff: 5 Page Ref: 279

43) Is more sensitive to light.
   Diff: 2 Page Ref: 279

Match the structures of the ear with the appropriate function.

44) This structure sits on the basilar membrane and contains the hair cells for sound.  
   Diff: 4 Page Ref: 286

45) Detects linear acceleration.  
   Diff: 4 Page Ref: 291

46) This structure includes the scala media, scala tympani, and scala vestibuli.  
   Diff: 4 Page Ref: 286

47) Transmits sound energy from the outer ear to the middle ear.  
   Diff: 4 Page Ref: 283

48) Connects the middle ear to the pharynx.  
   Diff: 5 Page Ref: 283

49) Detects rotational acceleration of the head.  
   Diff: 4 Page Ref: 291

50) Tips of stereocilia for sound are embedded in this structure.  
   Diff: 5 Page Ref: 288

51) Enlarged area at the base of the semicircular canals; contains hair cells.  
   Diff: 5 Page Ref: 291

Answers:  
49) B  50) E  51) D
Match the sensation of taste, olfaction, or both with the correct description.

52) Receptor type is a chemoreceptor.
   Diff: 2   Page Ref: 293
   A) taste
   B) both
   C) olfaction

53) Molecules must be dissolved in fluid to interact with receptor.
   Diff: 3   Page Ref: 295
   A) taste
   B) both
   C) olfaction

54) Receptor cells are modified epithelial cells.
   Diff: 5   Page Ref: 295
   A) taste
   B) both
   C) olfaction

55) Synapses with second-order neurons in glomeruli.
   Diff: 5   Page Ref: 298
   A) taste
   B) both
   C) olfaction

Answers: 52) B 53) B 54) A 55) C

Essay Questions

1) The response of every sensory receptor is governed by the law of specific nerve energies. Explain this law and its consequence for a receptor’s response to low- and high-intensity stimuli, along with the general process of sensory transduction.

Answer: The law of specific nerve energies states that a given sensory receptor is specific for a particular energy modality. Thus, different modalities of energy, including light waves, sound waves, pressure, temperature, etc., are ultimately transduced into electrical energy in the form of an action potential. The specific energy modality to which a receptor responds best (low energy state) is called the adequate stimulus. Receptors will also respond to other energy forms, but they must be at a higher energy to activate that receptor. However, our perception of a stimulus is linked to the receptor that has been activated. Thus, activating a photoreceptor on the retina by pushing on the eye (pressure) will result in our perception of a flash of light even though the stimulus was pressure. The process of converting one form of energy into another is called transduction. For sensory transduction, a graded potential is produced, which can lead to an action potential if the stimulus is strong enough and the receptor is a part of a neuron. However, not all receptors are neurons (some are modified neurons or epithelial cells that can not produce an action potential). A graded potential in these receptor cells will stimulate a proportional release of neurotransmitter that will induce an action potential in a neighboring nerve cell.

Diff: 5   Page Ref: 255
2) All receptors, by definition, must transduce the energy from a stimulus into an electrical signal before that information can be sent to the central nervous system. Once that electrical signal is generated, how does the brain decode the type, intensity, duration, and location of a stimulus?

Answer: Our perception of a stimulated receptor is based upon the sensory pathway activated and the region of the brain where those pathways terminate. Thus, activation of an auditory neuron will result in the perception of sound independent of how that neuron was activated. The specific pathway that transmits information is referred to as labeled lines, with each sensory receptor having its own unique labeled line. Stimulus intensity is coded for in two ways: 1) action potential frequency (frequency coding) and 2) the number of receptors activated (population coding). As stimulus intensity increases, the magnitude of the graded potential will increase, resulting in more frequent action potentials (increased frequency). Alternatively, a stronger stimulus could activate more receptors. The number of receptors activated depends upon the size and density of each receptor’s receptive field.

Stimulus intensity is coded for in two ways: 1) action potential frequency (frequency coding) and 2) the number of receptors activated (population coding). As stimulus intensity increases, the magnitude of the graded potential will increase, resulting in more frequent action potentials (increased frequency). Alternatively, a stronger stimulus could activate more receptors. The number of receptors activated depends upon the size and density of each receptor’s receptive field.

Slowly adapting receptors work best for coding intensity while rapidly adapting receptors are better for coding change (not magnitude of change). The location of a stimulus is coded by location of their receptive field. The precision with which we can perceive location is called acuity. Acuity for a particular stimulus will depend upon a receptive field’s size, number of receptors, the extent of overlap, and its lateral inhibition. These can vary considerably between receptive fields throughout the body. Lateral inhibition describes a situation where input from a strongly stimulated receptor will inhibit the afferent pathway transmitting information from nearby receptors.

**Diff: 7  Page Ref: 259**
3) The primary interface between the body and the external environment is the skin. Thus, a variety of receptors exist within the skin for the detection of our external environment. List the three classes of receptors found in the skin (with an example of each with its function), and the pathways that those stimuli must follow to reach the somatosensory cortex.

Answer: The three types of skin receptors are mechanoreceptors, thermoreceptors, and nociceptors.

Mechanoreceptors: Merkel’s disks – pressure; Meissner’s corpuscles – vibration; free nerve endings – light touch; Pacinian corpuscles – vibration; Ruffini’s end organs – pressure.

Thermoreceptors: cold and warm.

Nociceptors: mechanical – intense mechanical; thermal – intense thermal; polymodal – intense mechanical or thermal stimuli; or specific chemicals.

There are two main pathways by which sensory information will travel to the somatosensory cortex: the dorsal column–medial lemniscal pathway and the spinothalamic tract. The dorsal column–medial lemniscal pathway carries information from mechanoreceptors and proprioceptors. In this pathway, the first-order neurons enter the dorsal horn of the spinal cord where most of the collaterals from that neuron terminate. However, the main branch ascends the spinal cord within the dorsal column to the ipsilateral brainstem. That first–order neuron synapses in the dorsal column nuclei of the medulla with a second–order neuron. The second–order neurons cross over to the contralateral side of the medulla along the medial lemniscus and ascend to the thalamus. In the thalamus, the second–order neurons synapse with third–order neurons that transmit the information to the somatosensory cortex. The spinothalamic tract carries information from thermoreceptors and nociceptors. The first–order neurons enter the spinal cord at the dorsal horn and travel a short distance in either direction along the spinal cord within Lissauer’s tract where they will synapse with second–order neurons. The second–order neurons cross over to the contralateral side and ascend to the anterolateral quadrant of the spinal cord and through the brainstem before they enter the thalamus. In the thalamus, the second–order neuron synapses with the third–order neuron, which ascends to the somatosensory cortex.

Diff: 7  Page Ref: 262
4) Nociceptors play an important role in protecting us from damaging stimuli. Describe the two types of pain and the difference between discriminative and affective pain. Describe the gate-control theory of pain modulation.

Answer: Activation of nociceptors leads to the perception of pain. That perception of pain can lead to several possible responses that include a reflex withdrawal from the stimulus, increased autonomic response, or an emotional response. We perceive pain in two ways, which are termed as fast pain and slow pain. Fast pain is perceived as a sharp, pricking sensation that can be easily localized and is transmitted over Aδ fibers. Slow pain is detected as a poorly localized, dull ache that is transmitted over C fibers. The primary afferents from nociceptors synapse with second-order receptors in the spinal cord. The discriminative properties of pain relate directly to our perception of pain. At the same time, activation of that pathway will stimulate (coactivate) a second pathway that assesses the affective component of the painful stimulus. The affective component of a painful stimulus is the aspect of pain that is not associated with the pain itself, as in the case of an autonomic or emotional response to pain. The pathway utilized by the affective components of pain ascend through the reticular formation of the brainstem, to the hypothalamus, and to the limbic system. The gate-control theory of pain modulation maintains that a non-painful somatic stimuli can inhibit pain signals at the level of the spinal cord. There are many interneurons within the spinal cord; one type of these is inhibitory for second-order nociceptive neurons. If this interneuron is active, then the transmission of the painful message will be diminished and the perception of pain will be lessened. The inhibitory interneuron is activated by Aβ fibers (associated with mechanical stimuli) and inhibited by collaterals from C fibers (nociceptors). However, when the two neuronal tracts are activated, collaterals from the Aβ fibers will stimulate the inhibitory interneuron, thus decreasing the transmission of the painful message.
5) Describe the process involved in focusing an image onto the retina for objects near and far and how that process is controlled. Identify the two common defects in our ability to focus light on the retina and how they can be fixed.

Answer: As light moves from one transparent material to the next (cornea → aqueous humor → lens → vitreous humor), those wavelengths of light are bent (refracted). Light is refracted as it moves through the interface of two transparent materials of different densities. In the human eye, the lens is capable of actively modifying its refractive power through accommodation (the process of modifying the structure of the lens). The thickness of the lens can be altered by ciliary muscles that are attached to the lens by zonular fibers. The ciliary muscle forms a ring around the lens such that, when it contracts, the amount of tension on the lens from the zonular fibers is reduced. This reduction in radial tension on the lens causes the lens to thicken due to its inherent elasticity. As the lens thickens, light is bent to a greater extent in order to focus objects that are close to the eye onto the retina. When viewing something at a distance, the ciliary muscle relaxes, which increases the tension on the zonular fibers and thereby causes the lens to flatten. Accommodation is under the control of the parasympathetic nervous system, whose activity stimulates ciliary muscle contraction, causing the lens to thicken as it focuses on an object that is near. A distant object is brought into focus by the relaxation of the ciliary muscle induced by a decrease in parasympathetic activity. However, the lens is not always able to focus the light onto the retina. In myopia (near-sightedness), the lens and cornea refract the light such that the image is focused in front of the retina. This can be corrected by positioning a concave lens in front of the cornea, which will cause the light to diverge before reaching the eye. Hyperopia occurs because the lens cannot accommodate enough for near vision (the light is not refracted enough). Thus, the object is focused behind the retina. A convex lens in front of the cornea can correct for this by causing the light to converge before reaching the eye.
6) Photoreceptive cells are located within the retina. Describe the general structure and the cells present within the retina, and how light is converted into electrical energy within rods and cones.

Answer: There are three distinct layers of cells within the retina: 1) an outer layer of rods and cones (the photoreceptive cells), 2) a middle layer of bipolar cells, and 3) an inner layer of neurons called ganglion cells. Light must pass through the second and third layers to reach photoreceptors. The bipolar cells, along with amacrine and horizontal cells, are involved in processing visual information, while the ganglion cells are the neural cells that transmit the visual information back to the visual center of the brain. The main difference between rods and cones lies in the photopigment that detects light and the sensitivity of that pigment to particular wavelengths of light. In rods, the photopigment is rhodopsin. The light-absorbing portion of the photopigment (rhodopsin) is retinal. The other portion of that protein (opsin) determines the sensitivity of rhodopsin to particular wavelengths of light. Rhodopsin is located within membranous disks that are associated with transducin and phosphodiesterase (which degrades cGMP). In the presence of cGMP, sodium channels on the cell membrane of the photoreceptor are more likely to be in the open state. In the dark, phosphodiesterase is relatively inactive, allowing cGMP to be elevated and sodium channels to be maintained in the open state, which depolarizes the photoreceptor. This depolarization stimulates voltage-sensitive calcium channels to remain open, which causes the release of neurotransmitter onto bipolar cells. When light impinges on rhodopsin, the opsin molecule bleaches, activating transducin, which activates phosphodiesterase. This will decrease the intracellular concentration of cGMP, causing sodium channels to close and the cell to hyperpolarize. This hyperpolarization closes the voltage-sensitive calcium channel, which decreases the release of neurotransmitter onto the bipolar cells. Rods are sensitive to low intensities of light, whereas cones require a greater intensity of light in order be activated. The same mechanisms that are active in the rods are active in the cones. The color sensitivity of cones derives from the three different forms of rhodopsin found in cones. These molecules are most sensitive to red, green, and blue wavelengths of light.

Diff: 8  Page Ref: 276
7) Describe the neural pathway of vision from the photoreceptor to the primary visual cortex. How are we able to perceive the three-dimensional character of the world around us?

Answer: Throughout the retina, varying numbers of photoreceptors converge onto a bipolar cell. These cells are capable of generating graded potentials, the nature of which is determined by the photoreceptor. Two types of photoreceptors are present within the retina: those that release excitatory neurotransmitters and those that release inhibitory neurotransmitters. As neurotransmitter release is reduced when the photoreceptor is activated by light, the bipolar cells are either depolarized or hyperpolarized. Thus, some bipolar cells are activated by light while others are inhibited by light. In addition, the synapse between the photoreceptor and bipolar cells can be modulated by horizontal cells. When depolarized, the bipolar cells release their neurotransmitter onto a ganglion cell. The direction of the response from the ganglion cell will depend upon whether the neurotransmitter from the bipolar cells is excitatory or inhibitory. Ganglion cells are the first-order neurons in the pathway of vision and are therefore the first cells capable of generating an action potential. The axons of the ganglion cells form the optic nerve and exit the eye at the optic disk. The two bundles of nerves combine at the base of the brain to form the optic chiasm. In the optic chiasm, half of the axons from each eye cross over. The cells from the nasal portion of the eye cross over to combine with the temporal portion of the eye from the other side. The ganglion cells terminate in the lateral geniculate body of the thalamus, where they synapse with the neurons that ascend to the primary visual cortex. Depth perception is dependent upon the brain receiving input from both eyes. The region of the visual field that is detected by both eyes is the binocular visual field. Within this area, we are able to perceive depth. The cortex uses the difference in angle between the visual field of both eyes to perceive a three-dimensional image.
8) What are the components of sound that are detected within the ear and how does that sound reach the inner ear where it is transduced into electrical energy?

Answer: Sound waves travel and affect the gas molecules that compose the air by putting them into motion. Sound waves traveling through the air consist of regions where the air molecules are closer together (compressed) and regions where those molecules are further apart (rarified). The amplitude of sound is proportional to the differences in air molecule densities between the compressed and rarified air. Amplitude is expressed as a log scale in decibels. The pitch of the sound is determined by the frequency of the sound waves measured as the number of waves per second (hertz: Hz).

To detect sound, the properties of the sound wave must be transmitted to a solid structure. That transition occurs at the ear drum where sound waves cause the tympanic membrane to vibrate at the frequency of the sound waves. That vibration is passed along the middle ear across three bones: from the malleus (hammer), to the incus (anvil), and finally, onto the stapes (stirrup). The stapes is in contact with the cochlea at the oval window. Once the vibration reaches the stapes, it is passed to the oval window, which vibrates the fluid of the cochlea. There are two membranes within the cochlea (basilar and vestibular) that separate the cochlea into three fluid filled compartments (scala vestibuli, scala tympani, and scala media). The tympani and vestibuli are filled with perilymph while the media is filled with endolymph. Vibration is passed from the oval window to the scala vestibuli onto the scala tympani. This will cause the basilar and vestibular membranes to vibrate as well. The organ of Corti, which contains the hair cells that detect sound, is located on the top of the basilar membrane. The stereocilia of the hair cells are embedded within the tectorial membrane. When the basilar membrane vibrates, the stereocilia that are attached to the tectorial membrane are sheared. This movement bends the stereocilia, causing a change in membrane potential within the hair cell.
9) Within the inner ear are several structures that are involved in equilibrium and balance. Describe these structures and how they are able to detect changes in velocity and direction.

Answer: The vestibular organs in the inner ear are composed of the semicircular canals (of which there are three) and two otolithic organs (utricle and saccule). They are able to detect a change in linear and rotational velocity (acceleration or deceleration). The vestibular apparatus is located within the temporal bone and consists of a membranous labyrinth that is filled with endolymph and is surrounded by perilymph. The three semicircular canals are located perpendicular to one another, allowing them to detect rotational movement of the head in three planes. The anterior canal detects rotation in the up and down direction, as when nodding “yes.” The posterior canal detects motion of the head from side to side, as when the ear moves toward the shoulder. The lateral canal detects rotation of the head from side to side, as when shaking the head to say “no.” These canals contain an enlarged region called the ampulla where the sensory cells are located. Within the ampulla is the cupula, a gelatinous mass in contact with the stereocilia that project from the hair cells. Bending of the stereocilia causes a change in membrane potential of the hair cell. The stereocilia are bent by endolymph pushing against the cupula. As the head is put into motion (accelerates), the endolymph lags behind, causing it to move within the canal, which pushes on the cupula. This movement of the cupula bends the stereocilia, thereby altering the membrane potential of the hair cell. If that acceleration of the head reaches a constant velocity (acceleration is an increase in velocity whereas deceleration is a decrease in velocity), the endolymph will stop moving within the canal as the head comes to a constant velocity and the stereocilia will no longer be stimulated. Any change in velocity (acceleration or deceleration) would cause the endolymph to move again within the canal and thereby stimulate the stereocilia.

Otoliths are the small calcium carbonate crystals that are embedded within the gelatinous mass in contact with the stereocilia of the hair cells. The hair cells of the utricle are oriented horizontally with the stereocilia extending vertically, while the hair cells of the saccule are oriented vertically with the stereocilia extending horizontally. Thus, the utricle can detect forward and backward acceleration while the saccule detects upward and downward acceleration. Again, the otolith lags behind the movement of the body, causing the bending of the stereocilia of the hair cell that alters membrane potential of the hair cell.

Diff: 8  Page Ref: 286
10) Taste involves a complex mixture of different receptors for particular classes of compounds that can be present in food. Describe how taste receptors are able to detect the four primary tastes.

Answer: The sensation of taste derives from chemoreceptors within the mouth. Those chemoreceptors are located within structures called taste buds on the tongue and roof of the mouth. Taste sensitive cells are modified epithelial cells with taste receptors that bind selectively to chemicals (tastants) in the food that we ingest. In order to bind, the chemical must be dissolved in saliva. There are four primary tastes: salt, sour, sweet, and bitter. Sour derives from the presence of hydrogen ions that block potassium channels, which causes the cells to depolarize. Salty foods are sensed by the increased electrochemical driving force for movement of sodium into the cell, which would cause the cell to depolarize. Sweet is mediated by the receptor linked to a G protein called gustducin, which binds to organic molecules such as sucrose to stimulate the production of cAMP. This phosphorylation causes more potassium channels to remain in the closed state, thereby depolarizing the cell. Bitter is associated with detection of nitrogenous compounds. Bitter substances can be sensed by several different mechanisms: the direct binding to a receptor, which causes the closure of potassium channels, and the binding to a receptor that activates a G protein, called transducin. In that case, transducin activates the enzyme phospholipase C, which leads to the production of IP₃. An increase in IP₃ stimulates the release of calcium from the sarcoplasmic reticulum.

Diff: 6  Page Ref: 295
Short Answer Questions

1) In the figure below, identify the structures labeled A, B, C, D, and E.

![Eye Diagram](image)

A) ____________________________
B) ____________________________
C) ____________________________
D) ____________________________
E) ____________________________

Answer: A) ciliary body
        B) iris
        C) fovea
        D) retina
        E) sclera

Diff: 5  Page Ref: 271
2) In the figure below, identify the structures labeled A, B, C, D, and E.

A. ________________________________________
B. ________________________________________
C. ________________________________________
D. ________________________________________
E. ________________________________________

Answer: A. malleus
B. tympanic membrane
C. round window
D. cochlea
E. Eustachian tube

Diff: 5 Page Ref: 284

3) In the presence of a stimulus of constant intensity, a decrease in the magnitude of a graded potential within a sensory receptor over time is called _______.

Answer: adaptation

Diff: 4 Page Ref: 256

4) Proprioceptors provide the body with continuous information that changes little as a particular joint angle is maintained, and are therefore an example of _______ receptors.

Answer: tonic or slowly adapting

Diff: 4 Page Ref: 257

5) _______ receptors are better able to provide information on whether a stimulus has changed, whereas _______ receptors are better adapted to provide information on the extent of that change.

Answer: Phasic : tonic

Diff: 4 Page Ref: 257

6) Which of the sensory receptors located within the skin are located deep within the dermis?

Answer: Pacinian corpuscles and Ruffini’s endings

Diff: 6 Page Ref: 263
7) Which type of nociceptor is associated with C fibers?
   Answer: polymodal nociceptors
   Diff: 6    Page Ref: 265

8) Thermoreceptors have relatively (large / small) receptive fields.
   Answer: small
   Diff: 7    Page Ref: 265

9) Somatosensory receptors that lack identifiable specialized structures are called _______.
   Answer: free nerve endings
   Diff: 4    Page Ref: 262

10) (Nociceptors / warm receptors) respond best to temperatures greater than 44°C.
    Answer: nociceptors
    Diff: 5    Page Ref: 264

11) Slow pain is mediated by what type of nociceptor?
    Answer: polymodal nociceptors
    Diff: 9    Page Ref: 267

12) The absence of pain, but not other somatosensations, is called (anesthesia/analgesia)
    Answer: analgesia
    Diff: 7    Page Ref: 268

13) A (concave/convex) lens causes light waves to converge onto a focal point.
    Answer: convex
    Diff: 4    Page Ref: 272

14) During near vision, the ciliary muscle (contracts/relaxes) due to activation of the
    (sympathetic/parasympathetic) nervous system. As a result, the zonular fibers to go
    (taut/slack), which causes the refractive power of the lens to (increase/decrease) and the lens
    become (flatter/rounder).
    Answer: contracts : parasympathetic : slack : increase : rounder
    Diff: 7    Page Ref: 274

15) An increase in pressure within the eye due to expansion of the aqueous humor that can
    eventually compromise blood flow to the eye is called _______.
    Answer: Glaucoma
    Diff: 5    Page Ref: 275

16) Activation of the sympathetic nervous system causes (contraction/relaxation) of the
    (circular/radial) muscle, which causes pupillary (constriction/dilation).
    Answer: contraction : radial : dilation
    Diff: 6    Page Ref: 276

17) The ______ is an indentation in the retina that contains the fovea.
    Answer: macula lutea
    Diff: 5    Page Ref: 276
18) Cones are most concentrated in the (fovea / optic disk)
   Answer: fovea
   Diff: 4   Page Ref: 276

19) (Rods/cones) are more sensitive to light.
   Answer: rods
   Diff: 3   Page Ref: 279

20) (Rods/cones) have a greater degree of convergence with bipolar cells.
   Answer: rods
   Diff: 4   Page Ref: 280

21) Arrange the following components of the neural pathway for vision in the correct order
    starting with the photoreceptor and ending with the visual cortex: photoreceptor, optic
    radiations, optic tract, ganglion cell, bipolar cell, optic nerve, optic chiasm, lateral geniculate
    body, visual cortex.
   Answer: photoreceptor, bipolar cell, ganglion cell, optic nerve, optic chiasm, optic tract, lateral
    geniculate body, optic radiations, visual cortex
   Diff: 6   Page Ref: 281

22) Name the three ossicles in the middle ear.
    Answer: malleus, incus, stapes
    Diff: 4   Page Ref: 283

23) What chamber(s) of the cochlea contains endolymph?
    Answer: scala media
    Diff: 6   Page Ref: 286

24) Describe the pathway whereby vibration, initiated by sound waves, reaches the cochlea.
    Answer: The tympanic membrane is vibrated by sound waves that pass that vibration from the
    malleus to the incus and finally onto the stapes, which vibrates the round window of
    the cochlea.
    Diff: 5   Page Ref: 284

25) Sensory information about (vision / sound) is relayed through the medial geniculate body of
    the thalamus.
    Answer: sound
    Diff: 5   Page Ref: 290

26) The fluid inside the semicircular canals is (endolymph / perilymph).
    Answer: endolymph
    Diff: 5   Page Ref: 291

27) Bending of stereocilia of a hair cell toward the kinocilium causes
    (depolarization/hyperpolarization) of the hair cell.
    Answer: depolarization
    Diff: 4   Page Ref: 291
28) The stereocilia and kinocilium on the hair cells of the ampulla project into what structure?
   Answer: cupula
   Diff: 4 Page Ref: 291

29) What molecules within the mucus of the olfactory epithelium carry odorants to the receptor on the cilia?
   Answer: olfactory binding proteins
   Diff: 4 Page Ref: 297

30) What type of cells in the olfactory mucosa maintain the extracellular environment surrounding the receptor cells?
   Answer: sustentacular cells
   Diff: 4 Page Ref: 298

31) The bone overlying the olfactory epithelium is called the ________.
   Answer: cribriform plate
   Diff: 6 Page Ref: 297

32) The second-order neurons in the olfactory pathway are called ________.
   Answer: mitral cells
   Diff: 5 Page Ref: 298
Chapter 11  The Nervous System: Autonomic and Motor Systems

Multiple Choice Questions

1) The autonomic nervous system innervates all the following effector organs and tissues except _______.
   A) skeletal muscles
   B) cardiac muscles
   C) endocrine glands
   D) adipose tissues
   E) exocrine glands

Answer: A
Diff: 3  Page Ref: 303

2) Dual innervation of organs by the autonomic nervous system refers to the observation that _______.
   A) two postganglionic sympathetic neurons innervate each target organ
   B) both sympathetic and parasympathetic neurons innervate most organs
   C) autonomic innervation involves preganglionic and postganglionic neurons
   D) autonomic and somatic neurons innervate all organs
   E) autonomic neurons that innervate each target organ originate from two ganglia

Answer: B
Diff: 3  Page Ref: 303

3) Which of the following physiological responses are associated with elevated sympathetic nervous system activity?
   A) enhanced digestion
   B) enhanced absorption of nutrients
   C) decreased heart rate
   D) increased contractile force of the heart
   E) inhibition of cardiovascular function

Answer: D
Diff: 4  Page Ref: 303

4) Which of the following physiological responses are associated with an elevation in parasympathetic nervous system activity?
   A) shifting blood flow away from the gastrointestinal tract
   B) enhanced absorption of nutrients
   C) increased heart rate
   D) increased contractile force of the heart
   E) enhanced mobilization of energy stores

Answer: B
Diff: 4  Page Ref: 303
5) At rest, what is the relative contribution of the sympathetic and parasympathetic nervous systems to the regulation of homeostasis?
   A) Only the sympathetic system is active.
   B) Both systems are active but the parasympathetic predominates.
   C) Only the parasympathetic system is active.
   D) Both systems are active but the sympathetic predominates.
   E) Neither system is active.
Answer: B  Diff: 4  Page Ref: 303

6) When the body is stressed, what is the relative contribution of the sympathetic and parasympathetic nervous systems to the regulation of homeostasis?
   A) Only the sympathetic system is active.
   B) Both systems are active but the parasympathetic predominates.
   C) Only the parasympathetic system is active.
   D) Both systems are active but the sympathetic predominates.
   E) Neither system is active.
Answer: D  Diff: 3  Page Ref: 303

7) Which of the following best describes the general arrangement of the efferent limb of the autonomic nervous system?
   A) one neuron
   B) two neurons in parallel
   C) two neurons in series
   D) three neurons in series
   E) three neurons in parallel
Answer: C  Diff: 3  Page Ref: 303

8) Within the autonomic ganglia, what are the cells that modulate the flow of information to the target organ called?
   A) intraganglionic neurons
   B) ganglionic neurons
   C) preganglionic neurons
   D) postganglionic neurons
   E) intrinsic neurons
Answer: E  Diff: 5  Page Ref: 304

9) Which of the following structures of an autonomic neuron is NOT located within the ganglion?
   A) the cell body of preganglionic neurons
   B) the terminal axon of preganglionic neurons
   C) the intrinsic neurons
   D) the cell body of postganglionic neurons
   E) the dendrites of postganglionic neurons
Answer: A  Diff: 4  Page Ref: 304
10) Where do the preganglionic neurons of the sympathetic nervous system emerge from the spinal cord?
   A) thoracic region only
   B) sacral region only
   C) lumbar region only
   D) thoracic and lumbar regions
   E) lumbar and sacral regions
Answer: D  Diff: 4  Page Ref: 305

11) Sympathetic preganglionic neurons exit the spinal nerve via the _______ before they enter the _______.
   A) white ramus : effector organ
   B) gray ramus : effector organ
   C) gray ramus : ganglion of the sympathetic trunk
   D) ventral root : ganglion of the sympathetic trunk
   E) white ramus : ganglion of the sympathetic trunk
Answer: E  Diff: 5  Page Ref: 305

12) Which of the following contributes to the ability of the sympathetic nervous system to produce widespread responses within the body?
   A) multiple preganglionic neurons innervate each ganglion, sending out individual postganglionic neurons
   B) one postganglionic neuron branches into many collaterals that affect multiple organs
   C) one preganglionic neuron sends collaterals to multiple ganglia, affecting multiple postganglionic neurons
   D) one preganglionic neuron can activate only one postganglionic neuron
   E) several preganglionic neurons activate a single postganglionic neuron
Answer: C  Diff: 4  Page Ref: 305

13) Which of the following endocrine glands is innervated by sympathetic preganglionic neurons?
   A) adrenal cortex
   B) adrenal medulla
   C) thyroid gland
   D) anterior pituitary
   E) pancreas
Answer: B  Diff: 3  Page Ref: 305

14) What cells of the adrenal medulla release epinephrine?
   A) alpha cells
   B) beta cells
   C) delta cells
   D) adrenergic cells
   E) chromaffin cells
Answer: E  Diff: 4  Page Ref: 305
15) Which of the following are indicative of the relative release of catecholamines from the adrenal medulla?
   A) 80% epinephrine : 20% dopamine
   B) 80% norepinephrine : 20% dopamine
   C) 80% norepinephrine : 20% epinephrine
   D) 80% epinephrine : 20% norepinephrine
   E) 100% acetylcholine

Answer: D
Diff: 3 Page Ref: 305

16) Which of the following descriptions of collateral ganglia is true?
   A) Collateral ganglia are part of the somatic nervous system, located where the motor neuron leaves the ventral horn.
   B) Collateral ganglia are part of the somatosensory system, located off of the afferent neuron just prior to entering the spinal cord dorsal horn.
   C) Collateral ganglia are located within the effector organs and are the sites of communication between parasympathetic preganglionic neurons and postganglionic neurons.
   D) Collateral ganglia are located within a chain just outside the spinal cord and are the sites of communication between sympathetic preganglionic neurons and postganglionic neurons.
   E) Collateral ganglia are in the sympathetic nervous system but distinct from the sympathetic chain, and they function as a site of communication between sympathetic preganglionic neurons and postganglionic neurons.

Answer: E
Diff: 5 Page Ref: 305

17) The gray ramus is comprised of what fiber type?
   A) A alpha
   B) A beta
   C) A delta
   D) B
   E) C

Answer: E
Diff: 5 Page Ref: 306

18) Where in the central nervous system do the preganglionic neurons of the parasympathetic nervous system originate?
   A) thoracic region of the spinal cord only
   B) sacral region of the spinal cord only
   C) lumbar region of the spinal cord only
   D) thoracic and lumbar regions of the spinal cord
   E) brainstem and sacral region of the spinal cord

Answer: E
Diff: 4 Page Ref: 307
19) Parasympathetic preganglionic neurons travel in what nerves?
   A) cranial nerves only
   B) spinal nerves only
   C) pelvic nerves only
   D) cranial and spinal nerves
   E) cranial and pelvic nerves

   Answer: E
   Diff: 5  Page Ref: 307

20) Parasympathetic neurons from which cranial nerve innervate most of the viscera in the thoracic and abdominal cavities?
   A) I
   B) III
   C) VII
   D) IX
   E) X

   Answer: E
   Diff: 7  Page Ref: 307

21) Which of the following cranial nerves does NOT include parasympathetic nerves?
   A) III – oculomotor nerve
   B) V – trigeminal nerve
   C) VII – facial nerve
   D) IX – glossopharyngeal nerve
   E) X – vagus nerve

   Answer: B
   Diff: 8  Page Ref: 307

22) Parasympathetic preganglionic neurons release the neurotransmitter _______; sympathetic preganglionic neurons release the neurotransmitter _______.
   A) epinephrine : norepinephrine
   B) acetylcholine : norepinephrine
   C) norepinephrine : acetylcholine
   D) acetylcholine : acetylcholine
   E) norepinephrine : norepinephrine

   Answer: D
   Diff: 3  Page Ref: 307

23) Parasympathetic postganglionic neurons release the neurotransmitter _______; sympathetic postganglionic neurons release the neurotransmitter_______.
   A) epinephrine : norepinephrine
   B) acetylcholine : norepinephrine
   C) norepinephrine : acetylcholine
   D) acetylcholine : acetylcholine
   E) norepinephrine : norepinephrine

   Answer: B
   Diff: 3  Page Ref: 208
24) Which of the following neurons of the efferent branch of the peripheral nervous system does NOT release acetylcholine?
   A) sympathetic preganglionic neuron
   B) parasympathetic preganglionic neuron
   C) sympathetic postganglionic neuron
   D) parasympathetic postganglionic neuron
   E) motor neuron
   Answer: C
   Diff: 4 Page Ref: 208

25) Binding of acetylcholine to _______ receptors causes a _______ by opening channels that permit both sodium and potassium to permeate the membrane.
   A) muscarinic : depolarization
   B) muscarinic : hyperpolarization
   C) nicotinic : depolarization
   D) nicotinic : hyperpolarization
   E) nicotinic : no change in membrane potential
   Answer: C
   Diff: 5 Page Ref: 309

26) What cholinergic receptors are coupled to G proteins?
   A) alpha1
   B) alpha2
   C) beta2
   D) nicotinic
   E) muscarinic
   Answer: E
   Diff: 4 Page Ref: 309

27) Binding of norepinephrine to what type of receptor will trigger the activation of phospholipase C?
   A) α1
   B) α2
   C) β1
   D) β2
   E) muscarinic
   Answer: A
   Diff: 5 Page Ref: 309

28) Compared to norepinephrine, epinephrine has a greater affinity for what type of receptor?
   A) nicotinic
   B) muscarinic
   C) alpha1
   D) beta1
   E) beta2
   Answer: E
   Diff: 4 Page Ref: 310
29) Activation of which class of adrenergic receptor will result in calcium release from intracellular stores?
   A) alpha1 only
   B) alpha2 only
   C) beta1 only
   D) beta2 only
   E) alpha1, alpha2, and beta1

   Answer: A
   Diff: 6 Page Ref: 309

30) Activation of which class of adrenergic receptor decreases the cytosolic levels of cAMP?
   A) alpha1 only
   B) alpha2 only
   C) beta1 only
   D) beta2 only
   E) both beta1 and beta2

   Answer: B
   Diff: 6 Page Ref: 310

31) What class of adrenergic receptor activates the enzyme adenylate cyclase?
   A) alpha1 only
   B) alpha1 and alpha2
   C) beta2 only
   D) beta1 and beta2
   E) beta1, beta2, and beta3

   Answer: E
   Diff: 7 Page Ref: 310

32) Actions at which class of adrenergic receptor generally have excitatory effects?
   A) alpha1 and alpha2
   B) beta1 and beta3
   C) beta1, beta2, and beta3
   D) alpha1 and beta1
   E) alpha1, alpha2, beta1, and beta3

   Answer: E
   Diff: 7 Page Ref: 310

33) Which of the following does NOT have nicotinic cholinergic receptors?
   A) skeletal muscle cells
   B) parasympathetic postganglionic neuron cell bodies
   C) sympathetic postganglionic neuron cell bodies
   D) effector organs for the parasympathetic nervous system
   E) chromaffin cells

   Answer: D
   Diff: 5 Page Ref: 308

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34) What type of receptor agonists are used to treat people suffering from asthma or nasal congestion?
   A) muscarinic
   B) nicotinic
   C) α2
   D) β3
   E) β2
   Answer: E
   Diff: 5   Page Ref: 310

35) What are swellings of postganglionic autonomic axons from which neurotransmitters are released called?
   A) Varicosities
   B) Neuromuscular junctions
   C) Sympathetic trunks
   D) Parasympathetic chains
   E) Ganglia
   Answer: A
   Diff: 3   Page Ref: 310

36) The presence of ______ within varicosities mediate the release of neurotransmitter.
   A) mechanically-gated Na+ channels
   B) mechanically-gated Ca2+ channels
   C) voltage-gated Na+ channels
   D) voltage-gated Ca2+ channels
   E) voltage-gated K+ channels
   Answer: D
   Diff: 4   Page Ref: 310

37) What type of channels that are present within the varicosities of autonomic neurons are absent from the axon terminal of other neurons?
   A) Voltage-gated Na+ and K+ channels
   B) Voltage-gated Ca2+ and Na+ channels
   C) Voltage-gated Na+ channels, exclusively
   D) Voltage-gated Ca2+ channels, exclusively
   E) Voltage-gated K+ channels, exclusively
   Answer: A
   Diff: 5   Page Ref: 310

38) What enzyme degrades the neurotransmitter released from varicosities of parasympathetic postganglionic neurons?
   A) catechol-O-methyltransferase only
   B) acetylcholinesterase
   C) monoamine oxidase only
   D) choline acetyl transferase
   E) catechol-O-methyltransferase and monoamine oxidase
   Answer: B
   Diff: 4   Page Ref: 310
39) In what class of neuron and within what organelle is the enzyme monoamine oxidase located?
   A) synaptic vesicles of sympathetic postganglionic neurons
   B) mitochondria of sympathetic postganglionic neurons
   C) lysosomes of sympathetic preganglionic neurons
   D) smooth ER of parasympathetic postganglionic neurons
   E) Golgi apparatus of parasympathetic postganglionic neurons

   Answer: B
   Diff: 4 Page Ref: 310

40) The balance between sympathetic and parasympathetic activity is modified primarily by ________.
   A) voluntary mechanisms
   B) hunger
   C) time of day
   D) body temperature
   E) the activity of the body

   Answer: E
   Diff: 4 Page Ref: 310

41) Which of the regions of the brain listed below is NOT involved in the control of the autonomic nervous system?
   A) hypothalamus
   B) pons
   C) medulla oblongata
   D) cerebellum
   E) limbic system

   Answer: D
   Diff: 5 Page Ref: 312

42) What area of the brain initiates the fight-or-flight response by producing widespread activation of the sympathetic nervous system?
   A) brainstem
   B) cerebellum
   C) amygdala
   D) limbic system
   E) hypothalamus

   Answer: E
   Diff: 5 Page Ref: 312

43) Which of the following is NOT a visceral reflex?
   A) pupillary light reflex
   B) withdrawal reflex
   C) vomiting
   D) urination
   E) swallowing

   Answer: B
   Diff: 4 Page Ref: 312
44) Where are most of the autonomic nervous system control centers located?
   A) brainstem
   B) frontal lobe
   C) thalamus
   D) limbic system
   E) spinal cord
   Answer: A
   Diff: 5   Page Ref: 312

45) Which of the following descriptions is TRUE for the parasympathetic nervous system, but NOT the sympathetic nervous system?
   A) Some preganglionic neurons originate in the spinal cord.
   B) Some ganglia are connected together in a chain.
   C) Preganglionic fibers release acetylcholine.
   D) Postganglionic fibers release acetylcholine.
   E) Receptors on effector organs are nicotinic cholinergic.
   Answer: D
   Diff: 6   Page Ref: 307

46) Which class of autonomic nervous system receptors is ionotropic?
   A) all alpha adrenergic
   B) all beta adrenergic
   C) some beta adrenergic but no alpha adrenergic
   D) muscarinic cholinergic
   E) nicotinic cholinergic
   Answer: E
   Diff: 5   Page Ref: 308

47) Mismatches between vestibular, visual, and proprioceptive sensory inputs activate the autonomic nervous system, leading to symptoms that are characteristic of ________.
   A) the accommodation reflex
   B) the vomiting reflex
   C) fainting
   D) motion sickness
   E) the pupillary light reflex
   Answer: D
   Diff: 3   Page Ref: 313

48) The somatic nervous system regulates the activity of ________.
   A) endocrine organs
   B) many organs
   C) skeletal muscle
   D) the kidneys
   E) the cardiovascular system
   Answer: C
   Diff: 2   Page Ref: 314
49) With respect to their innervation, individual skeletal muscle fibers (cells) are innervated by ________.
   A) a single motor neuron  
   B) multiple motor neurons  
   C) a single motor neuron and autonomic neuron  
   D) multiple motor neurons and autonomic neurons  
   E) a single motor neuron and multiple autonomic neurons  
   Answer: A  
   Diff: 4  Page Ref: 314

50) What is the neurotransmitter released from motor neurons?
   A) Epinephrine  
   B) Norepinephrine  
   C) Acetylcholine  
   D) Dopamine  
   E) GABA  
   Answer: C  
   Diff: 3  Page Ref: 316

51) Where on skeletal muscle is the highest density of nicotinic receptors?
   A) terminal bouton  
   B) motor end plate  
   C) motor unit  
   D) dendrites  
   E) axon hillock  
   Answer: B  
   Diff: 3  Page Ref: 316

52) Which of the following is located between the invaginations of the motor end plate of a neuromuscular junction?
   A) β2 receptors  
   B) β3 receptors  
   C) Acetylcholinesterase  
   D) Muscarinic receptors  
   E) Nicotinic receptors  
   Answer: C  
   Diff: 5  Page Ref: 316

53) What is the graded change in membrane potential that occurs at the motor end plate of skeletal muscle called?
   A) Inhibitory postsynaptic potential  
   B) End-plate potential  
   C) Muscarinic potential  
   D) Adrenergic potential  
   E) Action potential  
   Answer: B  
   Diff: 4  Page Ref: 316
54) The opening of a cation channel that allows both Na\(^+\) and K\(^+\) to move through will cause the membrane to _______ because of the _______.
   A) hyperpolarize: greater K\(^+\) electrochemical gradient as compared with Na\(^+\)
   B) hyperpolarize: greater Na\(^+\) electrochemical gradient as compared with K\(^+\)
   C) depolarize: greater K\(^+\) electrochemical gradient as compared with Na\(^+\)
   D) depolarize: greater Na\(^+\) electrochemical gradient as compared with K\(^+\)
   E) not change: same electrochemical gradient for K\(^+\) and Na\(^+\)

Answer: D

55) Which of the following statements is TRUE of communication across the neuromuscular junction?
   A) Acetylcholine released from a motor neuron binds to muscarinic cholinergic receptors.
   B) The end-plate potential is always of sufficient magnitude to depolarize the muscle cell to threshold to initiate an action potential.
   C) Acetylcholinesterase located in the cytosol of the motor neuron degrades acetylcholine to acetate and choline.
   D) Acetylcholinesterase located in mitochondria of the motor neuron degrades acetylcholine to acetate and choline.
   E) Synaptic communication to the muscle cell can be excitatory or inhibitory.

Answer: B

56) How does latrozin, the venom of the black widow spider, cause muscle spasms and rigidity.
   A) It stimulates acetylcholine release from motor neurons.
   B) It stimulates acetylcholine release from autonomic preganglionic neurons.
   C) It inhibits acetylcholine release from motor neurons.
   D) It inhibits the degradation of acetylcholine at all synapses.
   E) It blocks nicotinic cholinergic receptors.

Answer: A

57) The steps of synaptic transmission at the motor end plate are listed below, out of order. Choose the correct order.
   1. Acetylcholine binds to postsynaptic receptors.
   2. Acetylcholine is released by exocytosis.
   3. A graded depolarization is produced.
   4. An action potential is produced on the muscle cell membrane.
   5. Channels for both sodium and potassium are opened.
   7. An action potential arrives at the axon terminal.

A) 7521346
B) 7621534
C) 5231746
D) 2153674
E) 4357261

Answer: B
True/False Questions

1) The autonomic nervous system is also known as the involuntary nervous system.
   
   Answer: TRUE
   
   Diff: 2    Page Ref: 303

2) Physiological stressors will cause parasympathetic nervous system activity to increase.
   
   Answer: FALSE
   
   Diff: 3    Page Ref: 303

3) The autonomic nervous system consists of efferent pathways with two peripheral neurons that travel in series from the central nervous system to the effector organ.
   
   Answer: TRUE
   
   Diff: 3    Page Ref: 303

4) Sympathetic preganglionic neurons traveling to collateral ganglia travel through ganglia of the sympathetic trunk without making synaptic communication.
   
   Answer: TRUE
   
   Diff: 5    Page Ref: 305

5) The preganglionic neurons of the sympathetic nervous system originate in the spinal cord from a region of gray matter called the intermediolateral cell column.
   
   Answer: TRUE
   
   Diff: 4    Page Ref: 305

6) The primary hormone released from the adrenal medulla is norepinephrine.
   
   Answer: FALSE
   
   Diff: 4    Page Ref: 305

7) The parasympathetic nervous system exerts more discrete effects on effector organs than the sympathetic nervous system due to the independence of parasympathetic ganglia.
   
   Answer: TRUE
   
   Diff: 4    Page Ref: 307

8) All autonomic nerves contain only efferent fibers.
   
   Answer: FALSE
   
   Diff: 4    Page Ref: 307

9) The most abundant neurotransmitter in the peripheral nervous system is acetylcholine.
   
   Answer: TRUE
   
   Diff: 3    Page Ref: 307

10) Acetylcholine binding to nicotinic cholinergic receptors always excites the postsynaptic cell.
    
    Answer: TRUE
    
    Diff: 4    Page Ref: 309

11) Alpha adrenergic receptors have a greater affinity for norepinephrine than for epinephrine.
    
    Answer: TRUE
    
    Diff: 4    Page Ref: 310

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12) Binding of a ligand to the $\alpha_1$ adrenergic receptor activates $G_i$, thereby inhibiting the synthesis of cAMP.
   Answer: FALSE
   Diff: 4   Page Ref: 309

13) Atropine, first derived from the *Atropa belladonna* plant, is a nicotinic receptor antagonist.
   Answer: FALSE
   Diff: 5   Page Ref: 310

14) The somatic nervous system provides both excitatory and inhibitory signals to skeletal muscle.
   Answer: FALSE
   Diff: 4   Page Ref: 316

15) A motor unit consists of a skeletal muscle fiber (cell) and all of the motor neurons that innervate that skeletal muscle fiber.
   Answer: FALSE
   Diff: 4   Page Ref: 314

16) Some visceral reflexes are spinal reflexes.
   Answer: TRUE
   Diff: 4   Page Ref: 312

17) According to the theory of dual innervation, the two branches of the autonomic nervous system innervate the same effector organs, but tend to have opposite effects on those organs.
   Answer: TRUE
   Diff: 3   Page Ref: 303
Matching Questions

*Match the sympathetic nervous system, parasympathetic nervous system, both, or neither to the correct description.*

1) Preganglionic axons are short, traveling from central nervous system to a chain of ganglia.
   - Diff: 3   Page Ref: 305
   - A) sympathetic nervous system
   - B) both sympathetic and parasympathetic nervous systems.
   - C) parasympathetic nervous system
   - D) neither sympathetic nor parasympathetic nervous system
   - E) both sympathetic and parasympathetic nervous systems

2) Active at rest.
   - Diff: 3   Page Ref: 304

3) Releases norepinephrine.
   - Diff: 3   Page Ref: 308

4) Releases acetylcholine from its preganglionic fibers.
   - Diff: 3   Page Ref: 308

5) Releases acetylcholine from its postganglionic fibers.
   - Diff: 4   Page Ref: 308

6) Ganglia are located in or near the effector organ.
   - Diff: 3   Page Ref: 307

7) Preganglionic fibers originate in the brainstem.
   - Diff: 4   Page Ref: 307

Answers:  
1) A  
2) E  
3) A  
4) B  
5) C  
6) C  
7) C
Match the following neurotransmitters to the correct description.

8) Released from sympathetic preganglionics.
   A) acetylcholine
   Diff: 3   Page Ref: 308
   B) norepinephrine

9) Released from motor neurons.
   Diff: 3   Page Ref: 315

10) Released from varicosities in the parasympathetic nervous system.
    Diff: 4   Page Ref: 310

11) Released from varicosities in the sympathetic nervous system.
    Diff: 4   Page Ref: 310

Answers:  
8) A  
9) A  
10) A  
11) B
Essay Questions

1) The nature of a response from the sympathetic nervous system is determined by the anatomy of this system. Describe the general structure of the sympathetic nervous system, including the three anatomical configurations and how they contribute to the overall sympathetic response.

Answer: The efferent pathway of the sympathetic nervous system is composed of two neurons, connected in series, that provide for communication between the central nervous system and the effector organ. Those neurons communicate with one another by synapsing within autonomic ganglia. The neurons that travel from the central nervous system to the sympathetic ganglia are the preganglionic neurons, while those that travel from the ganglia to the effector organ are the postganglionic neurons. The preganglionic neurons of the sympathetic nervous system emerge from the lateral horn of the spinal cord within the thoracic and lumbar (thoracolumbar) regions, and exit from the ventral root. The dorsal and ventral roots combine to form the spinal nerve. Thereafter, the organization of the sympathetic nervous system can be described in three ways, based upon anatomical differences. First, the most common arrangement involves a short preganglionic neuron (compared to the postganglionic neuron) that leaves the spinal nerve via a branch called the white ramus and enters one of several sympathetic ganglia. These ganglia are linked together to form a structure that parallels the spinal cord within the sympathetic chain. After entering the sympathetic chain, a preganglionic neuron may branch into several collateral axons that travel up and down the sympathetic trunk to synapse with other postganglionic neurons. Each of these postganglionic neurons travels to a particular effector organ. Thus, activation of the sympathetic nervous system typically produces a response that is widespread, affecting multiple organs simultaneously. The second anatomical arrangement of the sympathetic nervous system contains a long preganglionic fiber that innervates the adrenal medulla. In this case, the chromaffin cells of the adrenal medulla act as the postganglionic neuron. When stimulated, chromaffin cells release catecholamines into the blood (80% epinephrine, 20% norepinephrine, and trace amount of dopamine). This architecture reinforces the widespread effect of the sympathetic nervous system on the body. The final anatomical arrangement contains preganglionic neurons that synapse with postganglionic fibers in collateral ganglia located outside of the sympathetic trunk. One example is a ganglion within the digestive system called the celiac ganglion, which is innervated by a long preganglionic neuron and is located outside of the sympathetic trunk. This arrangement provides for some very specific activity particular to organs, although this type of arrangement is uncommon.

Diff: 8 Page Ref: 305
2) The nature of a response from the parasympathetic nervous system is determined by the anatomy of this system. Describe the anatomy of the parasympathetic nervous system and how that differs from the sympathetic nervous system.

Answer: Preganglionic neurons from the parasympathetic nervous system originate from the brainstem and the sacral region of the spinal cord (craniosacral region). The parasympathetic nerves that leave the spinal cord do not join with the spinal nerve as occurs in the sympathetic nervous system. Instead, they join with other parasympathetic preganglionic fibers to form pelvic nerves. Generally speaking, preganglionic parasympathetic nerves are long (compared with the postganglionic nerves), traveling to a ganglion that is located near the effector organ. This arrangement is quite different from the sympathetic nervous system, where most preganglionic nerves are short and enter ganglia within the sympathetic trunk. Thus, the parasympathetic nervous system is able to exert more discrete effects than the sympathetic nervous system due to the lack of interconnection between ganglia. Four parasympathetic preganglionic neurons originate from cranial nerve nuclei located within the brainstem, which explains why some preganglionic parasympathetic nerves travel within cranial nerves. The vagus nerve (X) is one of the more important parasympathetic nerves, innervating the lungs, heart, stomach, etc. The other cranial nerves that contain preganglionic parasympathetic axons are the oculomotor (III), facial (VII), and glossopharyngeal nerves (IX).

Diff: 5  Page Ref: 307

3) Acetylcholine is one of the most common neurotransmitters in the peripheral nervous system. Identify the branches of the peripheral nervous system for which acetylcholine is the neurotransmitter and describe the receptors responsible for responding to acetylcholine. Include the mechanisms whereby these receptors transduce the response to acetylcholine.

Answer: Peripheral neurons that release the neurotransmitter acetylcholine are classified as cholinergic. Acetylcholine is released by all autonomic preganglionic fibers, postganglionic fibers of the parasympathetic nervous system, and the somatic branch of the efferent nervous system. One exception is that acetylcholine is a postganglionic sympathetic neurotransmitter for sweat glands. The two classes of cholinergic receptors are termed nicotinic (based upon the binding of this receptor to nicotine) and muscarinic (based upon the binding of this receptor to a toxic chemical in mushrooms). Nicotinic receptors are ionotropic receptors (receptor and ion channel are within the same protein) that are always excitatory. Thus, the binding of acetylcholine increases the number of open non-selective cation channels that are permeable to both sodium and potassium. The greater electrochemical gradient for sodium means that activating a nicotinic receptor will result in a depolarization of the membrane (i.e., more sodium moves in than potassium moves out). Nicotinic receptors are found on all autonomic postganglionic fibers and the end organ of the somatic nervous system (skeletal muscle). Muscarinic receptors are coupled to G proteins. Thus, these metabotropic receptors can be either inhibitory or excitatory, depending upon the target cell and the signal transduction pathway. Muscarinic receptors are found on the effector organs of the parasympathetic nervous system.

Diff: 6  Page Ref: 307
4) Norepinephrine is one of the more important neurotransmitters of the peripheral nervous system. Identify the branches of the peripheral nervous system for which norepinephrine is the neurotransmitter and describe the receptors responsible for responding to norepinephrine. Include the mechanisms whereby these receptors transduce the response to norepinephrine.

Answer: Neurons that release norepinephrine are referred to as adrenergic neurons. Norepinephrine is the neurotransmitter for most postganglionic sympathetic neurons (except sympathetic neurons that innervate sweat glands). The end organ receptors for norepinephrine are classified into two majors groups: α and β receptors. Within each of these classes are several subclasses of receptors with different sensitivities to catecholmines (norepinephrine and epinephrine) and different links to second messenger cascades. Each of the adrenergic receptors are metabotropic and are coupled to a G protein, but the particular G protein can be different (Gs vs Gi). The α1 adrenergic receptor subtype is coupled to activation of phospholipase C for the synthesis of inositol triphosphate, while the α2 adrenergic receptor subtype acts through Gi to suppress the synthesis of cAMP. All three of the β receptors are stimulatory, linked through Gs, and are involved in the activation of cAMP.

Diff: 6    Page Ref: 309

5) Describe the anatomical arrangement of the somatic nervous system, including the concept of motor units.

Answer: In the somatic nervous system, a single efferent neuron runs from the central nervous system to the skeletal muscle. These motor neurons originate in the ventral horn of the spinal cord and receive input from multiple sources, including afferent neurons. A single motor neuron innervates multiple muscle fibers but each muscle is innervated by a single neuron. A motor unit describes a single motor neuron and all of the skeletal muscle fibers innervated by that neuron. Thus, when a motor neuron is activated, all of the muscle fibers innervated by that motor neuron are stimulated to contract simultaneously.

Diff: 4    Page Ref: 314
6) Describe the synaptic junctions between the neurons of the autonomic and somatic nervous systems and their effector organs.

Answer: The neuroeffector junction describes the synapse between neurons of the autonomic nervous system and their effector organs. The anatomy of these structures is quite different from the typical neuron–neuron synapse. The postganglionic neuron does not have a discrete, well-defined axon terminal. Rather, those neurons contain numerous swellings along their length (varicosities). Within those varicosities, neurotransmitters (norepinephrine and acetylcholine) are synthesized and stored in vesicles, as occurs at axon terminals. However, while the swellings contain the voltage-gated calcium channels that are required for the release of neurotransmitter, they also contain the voltage-gated sodium and potassium channels that are required for the propagation of an action potential along the length of the axon. At the same time, the distance between a varicosity and the postsynaptic membrane is greater than what is observed in the synaptic cleft of other synapses.

In the somatic nervous system, the synapse (neuromuscular junction) couples the motor neuron to skeletal muscle fibers. The terminal bouton of the motor neuron contains acetylcholine stored in vesicles. The motor end plate is a specialized region of the skeletal muscle that contains an invagination where nicotinic receptors are located. Surrounding this invagination are local regions of high acetylcholinesterase concentration.

Short Answer Questions

1) The sympathetic nervous system mediates the ______ response as a consequence of its ability to prepare the body to cope with threatening situations.

Answer: "fight-or-flight"

2) Sympathetic preganglionic neurons exit the spinal cord via the (dorsal / ventral) root, and then join the spinal nerve. They leave the spinal nerve and enter the ganglion via the (gray / white) ramus. Most of the postganglionic fibers return to the spinal nerve via the (gray / white) ramus.

Answer: ventral : white : gray

3) Cells of the adrenal (medulla / cortex) that release epinephrine are called _______.

Answer: medulla : chromaffin cells

4) The cranial nerve that innervates most of the viscera in the thoracic and abdominal cavities is the _______.

Answer: cranial nerve X or vagus nerve

5) The sympathetic nervous system is also called the _______ division of the autonomic nervous system.

Answer: thoracolumbar
6) Name the sympathetic collateral ganglia.
   Answer: celiac, superior mesenteric, and inferior mesenteric
   Diff: 4   Page Ref: 308

7) The parasympathetic nervous system is also called the _______ division of the autonomic nervous system.
   Answer: craniosacral
   Diff: 4   Page Ref: 307

8) What branch of the nervous system is considered the involuntary nervous system?
   Answer: autonomic nervous system
   Diff: 3   Page Ref: 304

9) Adrenergic receptors with the greatest affinity for epinephrine are _______ receptors.
   Answer: beta2
   Diff: 5   Page Ref: 310

10) Binding of acetylcholine to _______ receptors will activate a G protein.
    Answer: muscarinic
    Diff: 5   Page Ref: 309

11) Adrenergic neurotransmitters bind to both α (1 & 2) and β (1, 2 & 3) receptors with different affinities. Outline the affinities of these receptors for adrenergic neurotransmitters and characterize their activity as excitatory or inhibitory.
    Answer: greater affinity for norepinephrine – α1 & α2 (excitatory)
    greater affinity for epinephrine – β2 (inhibitory)
    equal affinity for norepinephrine and epinephrine – β1 & β3 (excitatory)
    Diff: 8   Page Ref: 310

12) Postganglionic neurons of the autonomic nervous system release neurotransmitter from _______.
    Answer: varicosities
    Diff: 4   Page Ref: 310

13) Autonomic reflexes are also called _______ reflexes.
    Answer: visceral
    Diff: 4   Page Ref: 312

14) The region of skeletal muscle underlying the terminal bouton of a motor neuron is called the _______.
    Answer: motor end plate
    Diff: 4   Page Ref: 316

15) The change in membrane potential that occurs in skeletal muscle cells in response to acetylcholine binding to its receptors is called a(n) _______.
    Answer: end-plate potential
    Diff: 4   Page Ref: 316
Multiple Choice Questions

1) A skeletal muscle is composed of a number of ________, each composed of many muscle fibers bundled by connective tissue.
   A) fascicles
   B) myofibrils
   C) muscle cells
   D) myofilaments
   E) sarcomeres

Answer: A  
Diff: 5  Page Ref: 323

2) What structure composed of connective tissue transmits force from contracting skeletal muscle to bone?
   A) myofibril
   B) fascicle
   C) tendon
   D) ligament
   E) aponeurosis

Answer: C  
Diff: 3  Page Ref: 323

3) What is the saclike membranous network that surrounds each myofibril called?
   A) sarcolemma
   B) sarcoplasmic reticulum
   C) transverse tubule
   D) nucleus
   E) mitochondrion

Answer: B  
Diff: 4  Page Ref: 323

4) The fundamental repeating unit of the myofibril called a ________ gives skeletal muscle its striated appearance, and is bordered by ________.  
   A) crossbridge : Z lines
   B) sarcomere : M lines
   C) sarcomere : I bands
   D) sarcomere : Z lines
   E) crossbridge : A bands

Answer: D  
Diff: 5  Page Ref: 325
5) What is the region of the striated muscle's banding patterns that contains only the connections between the tails of myosin molecules?
   A) A band
   B) I band
   C) H zone
   D) Z line
   E) M line
   Answer: E  
   Diff: 3  Page Ref: 325

6) The contractile portion of the thin filament is composed of what protein?
   A) myosin
   B) tropomyosin
   C) troponin
   D) actin
   E) titin
   Answer: D  
   Diff: 4  Page Ref: 325

7) What is the protein component of the thin filament that binds to calcium thereby initiating skeletal muscle contraction?
   A) myosin
   B) tropomyosin
   C) troponin
   D) actin
   E) titin
   Answer: C  
   Diff: 4  Page Ref: 325

8) Which of the following is a structural protein that extends along each thick filament from M line to Z line.
   A) Titin
   B) Actin
   C) Myosin
   D) Tropomyosin
   E) Troponin
   Answer: A  
   Diff: 5  Page Ref: 326

9) The shortening of a skeletal muscle fiber during contraction involves which of the following?
   A) the thick filaments shortening
   B) the thin filaments shortening
   C) the sarcomeres shortening
   D) the A bands shortening
   E) the Z lines not changing their position
   Answer: C  
   Diff: 4  Page Ref: 327
10) During skeletal muscle contraction, as the muscle shortens, the thick and thin filaments ________.
   A) shorten
   B) slide past one another
   C) do not interact
   D) condense
   E) lengthen
   Answer: B
   Diff: 3  Page Ref: 327

11) When a skeletal muscle is passively stretched, that cell has a tendency to spring back once the force that was stretching the muscle is removed due to ________.
   A) the passive interaction between actin and myosin (no energy required)
   B) the active interaction between actin and myosin (energy required)
   C) titin acting as a spring using the energy stored by the stretching
   D) actin and myosin acting as a spring using the energy stored by the stretching
   E) the elastic connective tissue that surrounds the muscle cells and fascicles
   Answer: C
   Diff: 6  Page Ref: 326

12) The repeated, oscillating interaction between actin and myosin that results in the generation of force by a skeletal muscle cell is called what?
   A) crossbridge cycling
   B) the sliding-filament model
   C) Z line interaction
   D) sarcomeric facilitation
   E) titin cycling
   Answer: A
   Diff: 2  Page Ref: 327

13) What converts the myosin head into the high-energy state?
   A) binding to ATP only
   B) binding to actin
   C) the condensation of ATP
   D) the hydrolysis of ATP
   E) binding to titin
   Answer: D
   Diff: 5  Page Ref: 327

14) The release of an inorganic phosphate from the myosin molecule directly results in which of the following?
   A) development of rigor
   B) power stroke
   C) cocking of the myosin head
   D) binding of actin to myosin
   E) breaking of the actin myosin complex
   Answer: B
   Diff: 5  Page Ref: 328
15) In order for crossbridge cycling to occur, the actin-myosin complex must be broken by which of the following?
   A) binding of tropomyosin to myosin
   B) binding of ATP to actin
   C) binding of the tropinin complex to actin
   D) conformational change that occurs as the myosin head changes from the high to low energy state
   E) binding of ATP to myosin

   Answer: E  
   Diff: 5  Page Ref: 328

16) The sequence of events that links the action potential to changes in skeletal muscle force development is called what?
   A) the sliding-filament model  
   B) crossbridge cycling  
   C) myoaction coupling  
   D) excitation-contraction coupling  
   E) oxidative phosphorylation

   Answer: D  
   Diff: 3  Page Ref: 329

17) During skeletal muscle contraction, multiple crossbridge cycles are occurring between the same thick and thin filament. Which of the following best describes this process?
   A) Crossbridge cycling is highly synchronized between a certain thick and thin filament.  
   B) Crossbridge cycling is asynchronous between a certain thick and thin filament.  
   C) No more than one myosin head links to the thin filament at the same time.  
   D) No more than one myosin head detaches from the thin filament at the same time.  
   E) Tropomyosin only exposes one binding site on actin at a time allowing only one crossbridge to form with actin at a given time.

   Answer: B  
   Diff: 5  Page Ref: 329

18) Contraction of skeletal muscle fibers is stimulated by what type of neuron?
   A) autonomic neurons  
   B) sympathetic neurons  
   C) motor neurons  
   D) parasympathetic neurons  
   E) afferent neurons

   Answer: C  
   Diff: 2  Page Ref: 329

19) Which of the following is NOT a specialization observed at the neuromuscular junction?
   A) the high density of acetylcholine receptors in the motor end plate  
   B) Every action potential that reaches the axon terminal of the motor neuron will generate an action potential in the muscle fiber.  
   C) The motor end plate is relatively large compared with other synapses.  
   D) The terminal bouton fans out over a wide area of the sarcolemma.  
   E) Each muscle fiber is innervated by multiple motor neurons.

   Answer: E  
   Diff: 5  Page Ref: 329
20) Increases in the amount of cytoplasmic calcium required to initiate a muscle contraction are mediated by the coupling between a ______ on the T tubule and a ______ on the membrane of the sarcoplasmic reticulum.
   A) dihydropyridine receptor : calcium pump
   B) dihydropyridine receptor : ryanodine receptor
   C) ryanodine receptor : calcium pump
   D) calcium pump : ryanodine receptor
   E) calcium-induced calcium release channel : dihydropyridine receptor

Answer: B  
Diff: 5  Page Ref: 331

21) Which of the following is the voltage sensor that initiates an increase in cytoplasmic calcium in response to an action potential?
   A) dihydropyridine receptor
   B) ryanodine receptor
   C) calcium pump
   D) calcium-induced calcium release channel
   E) sodium channel

Answer: A  
Diff: 4  Page Ref: 331

22) The binding of calcium to troponin will directly cause which of the following?
   A) the binding of ATP to myosin
   B) the further release of calcium into the cytoplasm
   C) the movement of tropomyosin, thereby exposing the myosin-binding site on the actin molecule
   D) the movement of tropomyosin, thereby exposing the actin-binding site on the myosin molecule
   E) the hydrolysis of ATP

Answer: C  
Diff: 4  Page Ref: 331

23) What portion of a sarcomere shows up as light striations when viewed under a microscope?
   A) A band
   B) I band
   C) H zone
   D) M line
   E) Z line

Answer: B  
Diff: 3  Page Ref: 325
24) Which of the following best describes the function of transverse (t) tubules and the sarcoplasmic reticulum in skeletal muscle contraction?
   A) Action potentials in T tubules trigger the release of acetylcholine, which binds to receptors on the sarcoplasmic reticulum and triggers calcium release.
   B) Action potentials in T tubules trigger the release of norepinephrine, which binds to receptors on the sarcoplasmic reticulum and triggers calcium release.
   C) Action potentials in T tubules are detected by DHP receptors, which are coupled to ryanodine receptors in the sarcoplasmic reticulum and open channels for calcium.
   D) Action potentials in T tubules are detected by ryanodine receptors, which are coupled to DHP receptors in the sarcoplasmic reticulum and open channels for calcium.
   E) Action potentials in T tubules cause a depolarization of the sarcoplasmic reticulum membrane, thereby opening calcium channels to trigger calcium release.

Answer: C
Diff: 5 Page Ref: 331

25) During the cross-bridge cycle, ATP binding to myosin causes which of the following?
   A) the myosin head to attach to actin
   B) the myosin head to detach from actin
   C) the myosin head to swing forward pulling actin toward the M line
   D) the myosin head to interact with calcium channels, triggering calcium release from the sarcoplasmic reticulum
   E) the myosin head to be in its high-energy form

Answer: B
Diff: 5 Page Ref: 330

26) What is the function of T tubules?
   A) They store calcium.
   B) Actin and myosin are synthesized here.
   C) They conduct action potentials from the sarcolemma to the interior of the muscle cell.
   D) They provide elasticity to the muscle.
   E) They hold the thick filaments to the Z line.

Answer: C
Diff: 3 Page Ref: 331

27) What is a motor unit?
   A) all the muscle fibers in a fascicle
   B) all the myofibrils in a muscle fiber
   C) a muscle fiber and all the motor neurons that innervate it
   D) a motor neuron and all the muscle fibers it innervates
   E) a spinal nerve and all the muscle fibers it innervates

Answer: D
Diff: 4 Page Ref: 329
28) In order to allow discrete contractile events to occur, calcium is rapidly removed from the cytoplasm via ________.
   A) calcium pumps (active transport of calcium)
   B) dihydropyridine receptors
   C) ryanodine channels
   D) calcium–sequestering proteins in the cytoplasm
   E) calcium–binding proteins on the sarcoplasmic reticulum
   Answer: A
   Diff: 4 Page Ref: 331

29) Which of the following is NOT part of the process whereby skeletal muscles relax?
   A) Sarcolemmal calcium channels open to allow the efflux of calcium.
   B) The binding of calcium to a low–affinity site closes sarcoplasmic reticulum calcium channels.
   C) A calcium pump actively removes calcium.
   D) Amount of calcium bound to troponin decreases.
   E) A myosin-binding site on the actin molecule is blocked by tropomyosin.
   Answer: A
   Diff: 4 Page Ref: 331

30) What enzyme catalyzes the reaction that creates creatine phosphate?
   A) creatine phosphatase
   B) creatine hydrolase
   C) creatine hydrogenase
   D) creatine kinase
   E) ATP hydrolase
   Answer: D
   Diff: 4 Page Ref: 332

31) Since the creatine phosphorylation reaction is substrate driven, an increase in the concentration of creatine within a skeletal muscle fiber will directly have what effect?
   A) increase creatine phosphate concentration
   B) decrease creatine phosphate concentration
   C) increase ATP generation
   D) decrease creatine kinase activity
   E) increase glucose metabolism
   Answer: A
   Diff: 4 Page Ref: 332

32) During intense (heavy) exercise, the ability of oxidative phosphorylation to provide enough ATP for force generation by the skeletal muscle is ________, thereby causing the muscle fiber to derive energy from ________.
   A) enhanced : substrate–level phosphorylation
   B) diminished : substrate–level phosphorylation
   C) enhanced : fatty acids
   D) enhanced : glucose
   E) diminished : fatty acids
   Answer: B
   Diff: 4 Page Ref: 333
33) As the intensity of exercise increases, the muscles switch from oxidative to substrate-level phosphorylation, resulting in the increased generation of which of the following?
   A) lactic acid
   B) water from the electron transport chain
   C) glucose
   D) fatty acid
   E) ATP
   Answer: A
   Diff: 5  Page Ref: 333

34) When an action potential is generated within a motor neuron, _____.
   A) the muscle cells of the motor unit will occasionally contract
   B) only select muscle cells within the motor unit are stimulated to contract
   C) every muscle cell of the motor unit is stimulated to contract
   D) the muscle cells from a neighboring motor unit will contract
   E) all of the muscle cells within the motor unit are stimulated to relax
   Answer: C
   Diff: 4  Page Ref: 334

35) Which is the longest phase of a twitch?
   A) latent
   B) contraction
   C) plateau
   D) relaxation
   E) initial
   Answer: D
   Diff: 4  Page Ref: 334

36) Which of the following is NOT part of the explanation for the all-or-nothing property of an isometric twitch contraction of skeletal muscle?
   A) equivalent calcium reuptake by the sarcoplasmic reticulum
   B) equivalent calcium released by each action potential
   C) equivalent activation of calmodulin stimulating myosin light-chain kinase activity
   D) equal numbers of crossbridges activated by the calcium released
   E) all-or-nothing property of the action potential generated by a skeletal muscle
   Answer: C
   Diff: 5  Page Ref: 334

37) Which of the following is a property of isometric skeletal muscle contraction?
   A) rapid shortening of the muscle
   B) rapid lengthening of the muscle
   C) load is greater than the force generated by the muscle
   D) load is equal to the force generated by the muscle
   E) load is less than the force generated by the muscle
   Answer: C
   Diff: 4  Page Ref: 335
38) Which of the following is a property of isotonic skeletal muscle contraction?
A) slow increase in force with no change in muscle length
B) rapid increase in force with no change in muscle length
C) muscle length will be increased by contraction
D) load is greater than the force generated by the muscle
E) load is less than the force generated by the muscle
Answer: E
Diff: 4 Page Ref: 336

39) Which of the following statements about excitation-contraction coupling in skeletal muscle is FALSE?
A) An action potential in the sarcolemma stimulates the opening of voltage-gated calcium channels in the plasma membrane and the sarcoplasmic reticulum.
B) Calcium binds to troponin, causing a shift in tropomyosin thereby exposing the binding sites on actin for myosin.
C) DHP receptors on the T tubules detect changes in voltage and communicate to ryanodine receptors on the sarcoplasmic reticulum to open calcium channels.
D) An end-plate potential triggers an action potential on the sarcolemma.
E) Calcium ATPases in the sarcoplasmic reticulum are necessary for relaxation of the muscle.
Answer: A
Diff: 6 Page Ref: 329

40) Which of the following statements about end-plate potentials is FALSE?
A) They are graded potentials.
B) They are always depolarizations.
C) They are always of sufficient magnitude to generate an action potential in the sarcolemma.
D) They are a result of acetylcholine binding to muscarinic cholinergic receptors.
E) They are terminated by removal of acetylcholine from the synaptic cleft.
Answer: D
Diff: 5 Page Ref: 329

41) Which of the following best describes an isotonic contraction?
A) When the contractile elements shorten, they lengthen the elastic elements but do not move the load.
B) When the contractile elements shorten, they create enough force to move the load.
C) When the contractile elements lengthen, they shorten the elastic elements and move the load.
D) When the contractile elements lengthen, they lengthen the elastic elements but do not move the load.
E) The contractile elements stay the same length as the elastic elements shorten and move the load.
Answer: B
Diff: 5 Page Ref: 336
42) The speed with which the skeletal muscle generates force is determined primarily by ________.
   A) the amount of energy available
   B) the type of myosin present
   C) actin
   D) troponin
   E) tropomyosin
Answer: B
Diff: 5 Page Ref: 344

43) Which of the following is the property of skeletal muscle whereby an increase in the frequency of action potentials enhances the force developed by the muscle cell?
   A) Length-tension relationship
   B) Summation
   C) Force-velocity relationship
   D) External tension
   E) Internal tension
Answer: B
Diff: 5 Page Ref: 337

44) The tension produced during skeletal muscle contraction can be increased by all of the following except one. Which one is it?
   A) recruiting motor units
   B) increasing the frequency of action potentials in the motor neuron innervating the muscle
   C) increasing the frequency of action potentials in the muscle fiber
   D) initiating the contraction when the muscle is at its optimum length
   E) increasing the load on the muscle
Answer: E
Diff: 5 Page Ref: 337

45) Which of the following statements about summation and tetanus is FALSE?
   A) Summation and tetanus occur at high frequencies of skeletal muscle stimulation.
   B) Summation and tetanus do NOT occur in cardiac muscle.
   C) Summation and tetanus result from increases in cytosolic calcium levels.
   D) Summation and tetanus result in greater tension in the muscle.
   E) The maximum tension developed during summation and tetanus is treppe.
Answer: E
Diff: 5 Page Ref: 338

46) Once a skeletal muscle cell begins to shorten during an isotonic twitch contraction, ________.
   A) the amount of force generated by the muscle will continue to increase
   B) the amount of force generated by the muscle will start to decrease
   C) the amount of force generated by the muscle will remain constant
   D) the muscle will continue to shorten until the force generated by the muscle stops increasing
   E) the muscle will stop shortening once the force is greater than the load
Answer: C
Diff: 5 Page Ref: 336
47) Which of the following conditions will result in a skeletal muscle that produces a greater amount of force?
   A) more sarcomeres in series
   B) more sarcomeres in parallel
   C) fewer myofibrils per muscle cell
   D) fewer sarcomeres in parallel
   E) fewer sarcomeres in series

Answer: B
Diff: 5 Page Ref: 340

48) Which of the following is NOT an accurate description of specific muscle fiber types?
   A) Fast glycolytic fibers are the largest diameter fibers.
   B) Slow oxidative fibers are the smallest diameter fibers.
   C) Slow oxidative fibers are quick to fatigue.
   D) Fast glycolytic fibers produce their ATP by glycolysis.
   E) Fast oxidative fibers have a high mitochondrial density.

Answer: C
Diff: 4 Page Ref: 345

49) As skeletal muscle is further stretched beyond the length where optimum force is developed, ________.
   A) the amount of calcium released by the sarcoplasmic reticulum is reduced as length increases
   B) the thin filaments are pulled away from one another, thereby reducing their ability to interact with myosin
   C) the thick filaments are pulled away from one another, thereby reducing their ability to interact with actin
   D) the thick filaments overlap one another, thereby reducing their ability to interact with actin
   E) the thin filaments overlap one another, thereby reducing their ability to interact with myosin

Answer: B
Diff: 5 Page Ref: 340

50) As the sarcomere length of skeletal muscle is reduced beyond the length where optimum force is developed, ________.
   A) the amount of calcium released by the sarcoplasmic reticulum is reduced as length increases
   B) the thin filaments are pulled away from one another, thereby reducing their ability to interact with myosin
   C) the thick filaments are pulled away from one another, thereby reducing their ability to interact with actin
   D) the thick filaments overlap one another, thereby reducing their ability to interact with actin
   E) the thin filaments overlap one another, thereby reducing their ability to interact with myosin

Answer: E
Diff: 5 Page Ref: 340
51) In the body, the sarcomere length of skeletal muscle cells is usually _______.
   A) much less than optimum length
   B) near optimal
   C) much greater than optimum length
   D) quite variable from one muscle to the next
   E) 3 microns
   Answer: B
   Diff: 4  Page Ref: 341

52) Which of the following does NOT influence the force generated by an individual muscle fiber?
   A) frequency of stimulation
   B) fiber diameter
   C) length at onset of contraction
   D) recruitment
   E) summation
   Answer: D
   Diff: 4  Page Ref: 337

53) What is an increase in the number of active motor units that would increase the force developed by a skeletal muscle called?
   A) Recruitment
   B) Summation
   C) Treppe
   D) Tetanus
   E) Length–tension relationship
   Answer: A
   Diff: 3  Page Ref: 341

54) Contraction of motor units in a(n) _______ manner allows a muscle to maintain a level of force for a duration of time without fatiguing.
   A) synchronous
   B) asynchronous
   C) asymmetrical
   D) symmetrical
   E) random
   Answer: B
   Diff: 5  Page Ref: 342

55) Which of the following best describes the relationship between motor neuron size, motor unit size, and order of recruitment?
   A) large motor neurons: small motor unit: first to be recruited
   B) large motor neurons: small motor unit: last to be recruited
   C) large motor neurons: large motor unit: first to be recruited
   D) large motor neurons: large motor unit: last to be recruited
   E) There is no relationship.
   Answer: D
   Diff: 6  Page Ref: 342
56) A muscle is stimulated at a frequency that allows the muscle to relax completely between contractions. However, the amount of tension increases with each contraction. What is this called?
   A) twitch
   B) summation
   C) tetanus
   D) recruitment
   E) treppe
Answer: E
Diff: 4 Page Ref: 338

57) The mechanism responsible for the size principle involves _______.
   A) larger motor neurons that contain the greatest number of muscle cells and reach threshold easier than smaller neurons
   B) larger sympathetic neurons that contain the greatest number of muscle cells and reach threshold easier than smaller neurons
   C) smaller sympathetic neurons that contain the least number of muscle cells and reach threshold easier than larger neurons
   D) smaller motor neurons that contain the least number of muscle cells and reach threshold easier than larger neurons
   E) smaller motor neurons that contain the greatest number of muscle cells and reach threshold easier than larger neurons
Answer: D
Diff: 6 Page Ref: 342

58) Which of the following is NOT a property of glycolytic fibers as compared to oxidative fibers?
   A) high capacity for lactic acid production
   B) fewer capillaries
   C) absence of myoglobin
   D) poor ability to produce ATP in the absence of oxygen
   E) readily fatiguable
Answer: D
Diff: 4 Page Ref: 344

59) What molecule present primarily within oxidative skeletal muscle cells acts as an oxygen buffer due to its ability to bind oxygen?
   A) Hemoglobin
   B) Myoglobin
   C) Lactic acid
   D) Myosin
   E) Myosin light chain
Answer: B
Diff: 4 Page Ref: 344
60) What causes some muscle fibers to appear red?
   A) greater blood supply
   B) presence of myoglobin
   C) presence of lots of mitochondria
   D) high concentration of actin and myosin
   E) presence of troponin

   Answer: B  
   Diff: 3    Page Ref: 345

61) What is the site where a muscle attaches to a stationary bone called?
   A) origin
   B) insertion
   C) abductor
   D) adductor
   E) flexor

   Answer: A  
   Diff: 3    Page Ref: 347

62) What connects muscles to bone?
   A) ligaments
   B) tendons
   C) cartilage
   D) capillaries
   E) T tubules

   Answer: B  
   Diff: 3    Page Ref: 347

63) Relative to the triceps muscle, the biceps is its ________.
   A) origin
   B) insertion
   C) agonist
   D) antagonist
   E) abductor

   Answer: D  
   Diff: 3    Page Ref: 347

64) What type of receptor detects muscle length?
   A) DHP
   B) ryanodine
   C) muscle spindle
   D) Golgi tendon organ
   E) nociceptor

   Answer: C  
   Diff: 4    Page Ref: 349
65) What is an annulospiral ending?
   A) a structure in the cochlea that contains hair cells
   B) sensory endings in the muscle spindle that detect muscle length
   C) sensory endings in the Golgi tendon organ that detect muscle tension
   D) a structure in the semicircular canals that contains hair cells
   E) a structure in the utricle that contains hair cells

   Answer: B  
   Diff: 5  Page Ref: 349

66) What type of efferent neuron innervates intrafusal muscle fibers?
   A) type Ia
   B) type Ib
   C) type II
   D) alpha motor neurons
   E) gamma motor neurons

   Answer: E  
   Diff: 5  Page Ref: 349

67) Which of the following statements is TRUE regarding activation of alpha and gamma motor neurons?
   A) Alpha and gamma motor neurons are activated at the same time.
   B) Alpha motor neurons are activated before gamma motor neurons.
   C) Gamma motor neurons are activated before alpha motor neurons.
   D) During light activity, alpha motor neurons are activated first; during heavy activity, gamma motor neurons are activated first.
   E) During light activity, gamma motor neurons are activated first; during heavy activity, alpha motor neurons are activated first.

   Answer: A  
   Diff: 5  Page Ref: 349

68) Which of the following is the correct order of muscle fiber recruitment from first to last?
   A) slow oxidative : fast oxidative : fast glycolytic
   B) fast oxidative : fast glycolytic : slow oxidative
   C) fast glycolytic : fast oxidative : slow oxidative
   D) slow oxidative : fast glycolytic : fast oxidative
   E) fast glycolytic : slow oxidative : fast oxidative

   Answer: A  
   Diff: 4  Page Ref: 345

69) Which of the following muscle types has the slowest contraction time?
   A) fast glycolytic skeletal muscle
   B) fast oxidative skeletal muscle
   C) slow oxidative skeletal muscle
   D) smooth muscle
   E) cardiac muscle

   Answer: D  
   Diff: 6  Page Ref: 345
70) Which of the mechanisms listed below does NOT account for the decrease in force development by muscle cells during sustained force development?
   A) Compression of muscle during contraction can reduce blood flow to the muscle.
   B) Repeated action potentials along the same neuron can lead to neuromuscular fatigue.
   C) The crossbridges can become resistant to ATP.
   D) Oxidative fibers can be depleted of glycogen, their primary energy source.
   E) Glycolytic fibers produce lactic acid and inhibit enzyme activity with their hydrogen ion.
Answer: C  Diff: 4  Page Ref: 346

71) Which of the following is NOT an adaptation of skeletal muscle that would be observed in response to aerobic training?
   A) an increase in mitochondrial density
   B) an increase in capillary density
   C) an increase in the number of oxidative fibers
   D) an increase in the diameter of the skeletal muscle fibers
   E) an increase in the concentration of oxidative enzymes
Answer: D  Diff: 4  Page Ref: 345

72) Where are gap junctions commonly found?
   A) single-unit smooth muscle only
   B) multi-unit smooth muscle only
   C) cardiac muscle only
   D) both single-unit smooth muscle and cardiac muscle
   E) both single-unit and multi-unit smooth muscle
Answer: D  Diff: 4  Page Ref: 354

73) Which of the following is true of ALL muscle types?
   A) contract by using the sliding filament mechanism and cross-bridge cycling
   B) are striated
   C) contain T tubules
   D) contain calmodulin
   E) recruitment increases the strength of contraction
Answer: A  Diff: 5  Page Ref: 351

74) In smooth muscle, calcium triggers contraction by binding to what protein?
   A) troponin
   B) myosin light chain kinase
   C) myosin light chain
   D) calmodulin
   E) DHP receptors
Answer: D  Diff: 5  Page Ref: 351
75) Calcium binding to calmodulin causes phosphorylation of what protein in what type of muscle?
   A) troponin in skeletal and cardiac muscle only
   B) troponin in smooth muscle only
   C) actin in cardiac and smooth muscle
   D) actin in smooth muscle only
   E) myosin in smooth muscle only

   Answer: E
   Diff: 5   Page Ref: 351

76) Which of the following adaptations does NOT generally occur with aerobic exercise?
   A) an increase in the number of mitochondria per muscle fiber
   B) an increase in the number of myofibrils per muscle fiber
   C) a conversion of fast glycolytic fibers to fast oxidative fibers
   D) an increase in the blood supply to the muscles
   E) an increase in the aerobic capacity of muscle

   Answer: B
   Diff: 4   Page Ref: 347

77) The interaction between actin and myosin in smooth muscle requires _______.
   A) the interaction between calcium and troponin to expose the myosin binding site on the actin molecule
   B) that the calcium–calmodulin complex activates myosin light–chain kinase, which phosphorylates myosin light chain thereby allowing myosin to bind with actin
   C) the tropomyosin must be moved out of the way by troponin before myosin can bind to actin
   D) the activation of troponin, which stimulates myosin light–chain kinase to phosphorylate myosin light chain, allowing myosin to bind with actin
   E) that the calcium–calmodulin complex directly phosphorylates myosin light chain, allowing myosin to bind to actin

   Answer: B
   Diff: 5   Page Ref: 351

78) What is the source of variability in the response of smooth muscle cells from different organs to autonomic nervous activity (some relax to sympathetic nervous output while others contract)?
   A) the amount of neurotransmitter released into the synaptic cleft
   B) the duration of neurotransmitter release from the autonomic neurons
   C) the neurotransmitter released by the autonomic nervous system
   D) the type of receptor present on the effector organ
   E) the presynaptic modulation of the autonomic neurons

   Answer: D
   Diff: 4   Page Ref: 353
79) Which of the following could cause a pacemaker potential?
   A) spontaneous opening of sodium channels
   B) spontaneous opening of potassium channels
   C) spontaneous closing of calcium channels
   D) spontaneous opening of chloride channels
   E) All of the above

Answer: A
Diff: 4 Page Ref: 354

True/False Questions

1) Skeletal muscle fibers are formed by the fusion of multiple cells during embryonic development, resulting in the presence of numerous nuclei per fiber.
Answer: TRUE
Diff: 3 Page Ref: 323

2) Thick filaments have many protrusions along their middle (head of the myosin filaments) but none at their ends.
Answer: FALSE
Diff: 3 Page Ref: 326

3) Skeletal muscle and cardiac muscle are multinucleated cells, whereas smooth muscle cells each have one nucleus.
Answer: FALSE
Diff: 3 Page Ref: 353

4) As skeletal muscle shortens with contraction, the length of the I band remains constant as the length of the A band decreases.
Answer: FALSE
Diff: 4 Page Ref: 327

5) Binding of ATP to myosin increases myosin’s affinity for actin.
Answer: FALSE
Diff: 5 Page Ref: 328

6) A skeletal muscle cell produces force for only a small portion of its contractile cycle because only a small portion of the crossbridge cycle involves force generation.
Answer: FALSE
Diff: 4 Page Ref: 328

7) The proximity of the sarcoplasmic reticulum to each sarcomere permits the nearly simultaneous delivery of calcium to all sarcomeres of the muscle fiber.
Answer: TRUE
Diff: 5 Page Ref: 329

8) The primary source of calcium that drives skeletal muscle contraction is the sarcoplasmic reticulum.
Answer: TRUE
Diff: 4 Page Ref: 329
9) Ryanodine receptors are calcium channels in the sarcoplasmic reticulum.
   Answer: TRUE
   Diff: 5   Page Ref: 331

10) Creatine phosphate provides an immediate source of high energy phosphate to donate to ADP
    at the onset of muscle activity.
    Answer: TRUE
    Diff: 4   Page Ref: 332

11) The contraction phase of a twitch lasts longer than the relaxation phase.
    Answer: FALSE
    Diff: 4   Page Ref: 334

12) Skeletal muscle fibers operate at near-optimal sarcomere length in situ.
    Answer: TRUE
    Diff: 5   Page Ref: 341

13) The velocity of shortening during an isometric contraction is zero.
    Answer: TRUE
    Diff: 4   Page Ref: 343

14) The velocity of shortening of a muscle is greatest when there is no load on the muscle.
    Answer: TRUE
    Diff: 4   Page Ref: 343

15) Intrafusal muscle fibers contribute directly to the tension produced during muscle contraction.
    Answer: FALSE
    Diff: 4   Page Ref: 349

16) Alpha motor neurons innervate extrafusal muscle fibers.
    Answer: TRUE
    Diff: 4   Page Ref: 349

17) The biceps cause flexion of the arm, whereas the triceps cause extension.
    Answer: TRUE
    Diff: 4   Page Ref: 347

18) Activation of Golgi tendon organs during overstretching of a muscle protects the muscle by
    inhibiting its contraction.
    Answer: TRUE
    Diff: 5   Page Ref: 350

19) A skeletal muscle with slower ATPase activity can complete more crossbridge cycles per
    second.
    Answer: FALSE
    Diff: 4   Page Ref: 344

20) There are no slow glycolytic fibers.
    Answer: TRUE
    Diff: 4   Page Ref: 345
21) Hemoglobin in skeletal muscle acts as an oxygen buffer.
   Answer: FALSE
   Diff: 3 Page Ref: 345

22) Contraction of smooth muscle cells is driven by binding of calcium to calmodulin.
   Answer: TRUE
   Diff: 4 Page Ref: 351

23) Smooth and cardiac muscle are innervated by the autonomic nervous system, whereas skeletal muscle is innervated by the somatic nervous system.
   Answer: TRUE
   Diff: 4 Page Ref: 354

24) The speed with which smooth muscle cells contract is similar to fast glycolytic skeletal muscle cells.
   Answer: FALSE
   Diff: 4 Page Ref: 353

25) Spontaneous depolarization of smooth muscle cells is mediated by pacemaker cells.
   Answer: TRUE
   Diff: 3 Page Ref: 354

26) Slow–wave potentials are caused by cyclical fluctuations in opening and closing of potassium channels.
   Answer: FALSE
   Diff: 5 Page Ref: 354

27) Action potentials in cardiac muscle last longer than action potentials in skeletal muscle.
   Answer: TRUE
   Diff: 4 Page Ref: 355

28) Pacemaker activity occurs in certain smooth muscle cells and cardiac muscle cells.
   Answer: TRUE
   Diff: 4 Page Ref: 355

29) There is no summation of cardiac muscle.
   Answer: TRUE
   Diff: 4 Page Ref: 355

30) Oxidative phosphorylation is the primary energy source for cardiac muscle.
   Answer: TRUE
   Diff: 4 Page Ref: 323
Matching Questions

Match the following anatomical structures to their functions in skeletal muscle.

1) Stores calcium to be released for muscle contraction.
   Diff: 3   Page Ref: 323
   A) actin and myosin
   B) sarcoplasmic reticulum
   C) transverse tubules
   D) sarcomeres
   E) tendons
   F) motor end plate

2) Transmits action potentials to the interior of the muscle cell to trigger calcium release.
   Diff: 4   Page Ref: 323
   A) actin and myosin
   B) sarcoplasmic reticulum
   C) transverse tubules
   D) sarcomeres
   E) tendons
   F) motor end plate

3) Generates the mechanical force of a muscle through crossbridge cycling.
   Diff: 3   Page Ref: 325
   A) actin and myosin
   B) sarcoplasmic reticulum
   C) transverse tubules
   D) sarcomeres
   E) tendons
   F) motor end plate

4) Attaches muscle to bone.
   Diff: 4   Page Ref: 323
   A) actin and myosin
   B) sarcoplasmic reticulum
   C) transverse tubules
   D) sarcomeres
   E) tendons
   F) motor end plate

5) Functional unit of skeletal muscle.
   Diff: 5   Page Ref: 325
   A) actin and myosin
   B) sarcoplasmic reticulum
   C) transverse tubules
   D) sarcomeres
   E) tendons
   F) motor end plate

6) Contains ryanodine receptors.
   Diff: 5   Page Ref: 331
   A) actin and myosin
   B) sarcoplasmic reticulum
   C) transverse tubules
   D) sarcomeres
   E) tendons
   F) motor end plate

7) Contains DHP receptors.
   Diff: 5   Page Ref: 331
   A) actin and myosin
   B) sarcoplasmic reticulum
   C) transverse tubules
   D) sarcomeres
   E) tendons
   F) motor end plate

8) Contains nicotinic cholinergic receptors.
   Diff: 3   Page Ref: 329
   A) actin and myosin
   B) sarcoplasmic reticulum
   C) transverse tubules
   D) sarcomeres
   E) tendons
   F) motor end plate

Answers:
1) B   2) C   3) A   4) E   5) D
6) B   7) C   8) F
Match the following structures of a sarcomere with its correct description.

9) Extends the length of the thick filaments.
   Diff: 4   Page Ref: 325
   A) Z line
   B) I band

10) The region of thick filaments that has no overlap with thin filaments.
    Diff: 4   Page Ref: 325
    C) M line
    D) H zone
    E) A band

11) The region of thin filaments that has no overlap with thick filaments.
    Diff: 4   Page Ref: 325

12) Anchors thin filaments together.
    Diff: 4   Page Ref: 325

13) Anchors thick filaments together.
    Diff: 4   Page Ref: 325

14) Appears as light bands under the microscope.
    Diff: 5   Page Ref: 325

15) Appears as dark bands under the microscope.
    Diff: 5   Page Ref: 325

         14) B   15) E
Match the following proteins with their function.

16) Binds calcium in smooth muscle cells.  
   Diff: 4  Page Ref: 351
   A) tropomyosin
   B) calmodulin

17) Binds calcium in skeletal muscle cells.  
   Diff: 4  Page Ref: 325
   C) troponin
   D) titin
   E) myosin light-chain kinase

18) Binds calcium in cardiac muscle cells.  
   Diff: 6  Page Ref: 355

19) Elastic fibers that anchor thick filaments in place.  
   Diff: 5  Page Ref: 326

20) Enzyme that modulates the ability of myosin to bind actin in smooth muscle.  
   Diff: 4  Page Ref: 351


Match the following traits to the skeletal muscle fiber type.

21) High concentration of mitochondria.  
   Diff: 3  Page Ref: 344
   A) fast
   B) oxidative

22) High shortening velocities.  
   Diff: 3  Page Ref: 344
   C) glycolytic
   D) slow

23) Catalyze hydrolysis of ATP slowly.  
   Diff: 3  Page Ref: 344

24) Fatigue rapidly.  
   Diff: 4  Page Ref: 345

25) Contain myoglobin.  
   Diff: 4  Page Ref: 344

26) Most energy comes from substrate-level phosphorylation.  
   Diff: 4  Page Ref: 345

27) White muscle.  
   Diff: 4  Page Ref: 345

Match the muscle type to the correct properties.

28) Contains actin and myosin.
   Diff: 4 Page Ref: 357
   A) smooth muscle only (single-unit or multi-unit)

29) Contracts by the sliding-filament mechanism.
   Diff: 3 Page Ref: 357
   B) skeletal muscle only

30) Calcium binds to troponin.
   Diff: 5 Page Ref: 357
   C) skeletal and smooth muscle only

31) Calcium binds to calmodulin.
   Diff: 4 Page Ref: 357
   D) smooth and cardiac muscle only

32) Some cells have pacemaker activity.
   Diff: 4 Page Ref: 357
   E) cardiac muscle only

33) Innervated by autonomic nervous system.
   Diff: 4 Page Ref: 357
   F) skeletal and cardiac muscle only

34) Gap junctions present between cells.
   Diff: 5 Page Ref: 357
   G) skeletal, smooth, and cardiac muscle

35) Calcium for contraction comes entirely from the sarcoplasmic reticulum.
   Diff: 5 Page Ref: 357

36) Thick and thin filaments organized into sarcomeres.
   Diff: 5 Page Ref: 357

Essay Questions

1) Force development by muscle cells requires an interaction between actin and myosin. Describe the proteins involved in the development of force through the process of the sliding–filament theory, including crossbridge cycling.

Answer: Force development in skeletal muscle requires the interaction between the head of the myosin molecule (crossbridge) and actin. The head of the myosin molecule contains two important regions: 1) an actin–binding site, and 2) an ATPase that derives energy from ATP for force development. Actin monomers are arranged into two filaments (thin filaments) that are twisted into a double helix and are anchored to the Z–line. Myosin molecules are arranged side by side out of phase with one another. At the same time, myosin dimers are bound tail to tail such that the myosin heads on either side of the thick filament pull toward one another. The muscle is able to generate force by the cycling of crossbridges that bind to actin. The cycling starts with an ATP molecule binding to the ATPase portion of the myosin head that is still bound to actin and is in the low–energy form. This ATP binding initiates a conformational change that removes actin. The ATP molecule is then split into ADP and P_i, changing the myosin head into a high–energy form (cocked). Once this energized myosin head comes in contact with an actin molecule whose binding site is exposed, the myosin will bind to the actin molecule. The release of P_i allows the myosin head to return to the low–energy form, and in the process, the myosin head pivots, pulling the Z lines of the sarcomere toward one another. The bond between actin and myosin is maintained until ATP is able to bind to the myosin head. In the absence of ATP, the muscle is maintained in the state of rigor. The cycling of crossbridges causes the two thin filaments of the sarcomere to be pulled toward one another by the thick filament, thereby pulling the Z–lines closer together.

Diff: 7   Page Ref: 327
2) In order for skeletal muscle to develop force, a muscle cell must be able to convert the action potential generated at a neuromuscular junction into crossbridge cycling. Describe the process of excitation–contraction coupling in skeletal muscle, including all of the important ion channels and the structures involved in this process.

Answer: An action potential is generated at the motor end plate by the binding of acetylcholine to the nicotinic receptor. That action potential travels along the sarcolemma and down the transverse tubules. Located within the membrane of the transverse tubules are dihydropyridine receptors that are voltage sensitive. These receptors are usually activated by depolarization. The membrane of the transverse tubule comes into contact with the sarcoplasmic reticulum, allowing the dihydropyridine receptor to directly interact with the ryanodine receptor on the sarcoplasmic reticulum. When the dihydropyridine receptor is activated by membrane depolarization from the action potential, the ryanodine receptor is stimulated to release calcium from the sarcoplasmic reticulum. As intracellular calcium increases, the release of calcium is enhanced by the binding of calcium to another calcium channel on the sarcoplasmic reticulum. In addition to their proximity to the transverse tubule, the sarcoplasmic reticulum is positioned near contractile proteins of the sarcomere to facilitate the delivery of calcium to those contractile proteins. As calcium increases within the cell, it binds to a subunit of the troponin molecule. This binding causes a conformational change in the other two troponin subunits that move the filamentous tropomyosin. At rest, tropomyosin blocks the myosin binding site on the actin molecules. Thus, the movement of tropomyosin exposes the binding site that would allow the energized myosin to interact with actin.

Diff: 7  Page Ref: 329

3) Energy in the form of ATP is essential to the contractile process. Describe the cellular sources of energy for skeletal muscle fibers and how those energy sources play a role maintaining muscle activity at low- and high-intensities of activity.

Answer: Energy in the form of ATP is required for the release of the actin–myosin complex, in addition to energizing the myosin head. Thus, in order for skeletal muscle to contract, there must be an adequate supply of energy. At rest, the concentration of ATP is relatively low. In order to prevent this ATP supply from being depleted during the first few seconds of muscle contraction, creatine phosphate is present to act as an energy buffer by providing the P1 necessary to re-energize the ATP and allows crossbridge cycling to continue to break the actin–myosin complexes. Creatine phosphate is in equilibrium with creatine, whose concentration is also limited within skeletal muscle. The muscle must then switch to metabolizing glucose from its storage as glycogen in the muscle or liver (glucose must travel through the blood in order to enter the muscle). If the intensity of exercise is maintained at moderate levels or below, the aerobic metabolism of fatty acids through oxidative metabolism will take over as the primary source of energy. The fatty acids provide substrate (acetyl CoA) for the Krebs cycle and the electron transport chain as long as enough oxygen is present to act as the final acceptor of electrons. However, if exercise intensity increases further, the ability of aerobic metabolism to supply energy can be compromised by the limitations on blood flow (oxygen delivery) to the active muscle. In that case, oxygen delivery would be compromised and substrate–level metabolism would have to take over the production of ATP. The byproduct of this substrate–level metabolism is lactic acid, whose dissociated hydrogen ion can limit the ability of the muscle to generate force through a number of mechanisms.

Diff: 6  Page Ref: 332
4) While muscle cells respond in an all-or-nothing manner to a single action potential, the extent of force that they generate can be modified by a number of factors. Describe the mechanisms whereby individual skeletal muscle cells can modify force development.

Answer: There are a number of mechanisms that contribute to alterations in force generation by individual skeletal muscle cells. The first is the frequency of stimulation. A muscle response to frequency contains two components: the treppe phenomena and the summation of contraction. Treppé describes the phenomena where an increase in frequency of stimulation (with complete relaxation between pulses) will progressively increase the force developed by the muscle until force ultimately stabilizes. The explanation for this phenomena involves an increasing concentration of intracellular calcium, due to incomplete removal of calcium during relaxation, which elevates the force developed by the muscle cell. Summation of contraction is observed as the frequency of stimulation increases further, such that the muscle cell does not completely relax between twitches. As the frequency of twitches increases, the first twitch will not completely relax before the second twitch arrives, and so on. Thus, as frequency increases, the force generated by the muscle would continue to increase until a maximum is reached. As the frequency of stimulation increases, the muscle will eventually be able to maintain force with some oscillation around a constant value. This oscillation in force is termed tetanus. As frequency is increased further, force will eventually plateau (the trace flattens and there is no relaxation between twitches) into what is called fused (complete) tetanus or maximal tetanic tension. Prior to this force plateau (fusion), force fluctuates as the muscle cell partially relaxes between twitches, which is called unfused (incomplete) tetanus. Second, the force developed by a muscle fiber is dependent upon the diameter of that muscle fiber. As the diameter of a muscle fiber increases (number of parallel sarcomeres increases), the force generated by that muscle will increase. Finally, skeletal muscle length will affect the extent of tension development by the muscle cell. Typically, the muscle rests at near optimal length for force development. As the muscle is lengthened, the potential for interaction between actin and myosin is reduced as they slide past one another, thereby causing the force generated by the muscle to decrease. As the muscle is shortened, the extent of interaction will also be reduced by the thin filament blocking the binding of myosin and actin. In this case, force is also decreased as the muscle is shortened.

Diff: 8  Page Ref: 337
5) Irrespective of an individual muscle cell's ability to regulate the amount of force developed by that cell, the force generated by a skeletal muscle is also controlled at the whole muscle level. Describe the mechanism whereby force of a whole muscle can be modified, including a discussion on motor units.

Answer: In addition to the ability of individual muscle cells to modify their force development, the force of the entire muscle can be modulated. Every muscle cell is not contracted at the same time within a muscle. Since the functional unit of the muscle is the motor unit, the extent of force development will be determined by the number of muscle fibers associated with that motor unit and the way in which those motor units are recruited. As more motor units are simultaneously recruited, the force developed by the muscle will be increased. The extent of force developed depends upon the number of muscle cells present within a given motor unit, which can vary from several hundreds to thousands. Muscles that are involved in fine movement will have fewer muscle cells per motor unit than muscles involved in more gross movement. The specific motor units activated are determined by the size principle. This principle states that there is a correspondence between the size of motor units activated and their order of recruitment. The physiological determinant of which motor units are activated is the sensitivity of the motor neurons to action potential frequency; smaller motor neurons are stimulated to generate an action potential at a lower frequency of action potentials than larger diameter motor neurons. The smaller motor units are innervated by smaller diameter motor neurons. Thus, the size of the motor units corresponds with the diameter of the motor neuron. The larger motor units are resistant to depolarization. Thus, a higher frequency of action potentials is required to activate the larger motor units. At a lower frequency, the smaller motor units will be activated. As the force required to move an object is increased, the frequency of the action potentials from the motor center is increased, thereby recruiting more of the larger fibers that are capable of generating greater force.
6) In human skeletal muscle, a number of different fiber types exist. Describe the properties of the fibers that make them unique and how that is linked to motor units.

Answer: There are three major types of muscle fiber in human skeletal muscle, which are characterized by their metabolic profile and speed of contraction. With respect to their metabolic profile, the enzymes expressed in these cells can favor either a glycolytic (substrate-level phosphorylation) or oxidative metabolism. These alterations in enzyme profiles are supported by a number of structural differences within the muscle fibers. Muscle fibers with a greater oxidative enzyme profile will contain a greater density of capillaries, increased mitochondrial density, higher myoglobin concentration, and will have a smaller diameter than glycolytic fibers. In contrast, glycolytic fibers are thicker (have a greater diameter) than oxidative fibers, contain fewer capillaries, and have a greater capacity to produce ATP under anaerobic conditions. Thus, under high-intensity exercise, these muscles will actively produce an excess of pyruvate that is converted to lactic acid. An increase in lactic acid makes the fiber less resistant to fatigue. The contractile properties are related to the ATPase portion of the myosin molecule. The rate of ATPase activity will determine the speed with which a muscle cell can develop force. The fast fibers reach peak force sooner than the slow fibers. Putting these two properties together, the three major fiber types include slow oxidative, fast oxidative, and fast glycolytic.

Skeletal muscles generally contain differing proportions of all three skeletal muscle fiber types. However, the relative contribution of each fiber type can vary between muscles. Within a given motor unit, all of the muscle fibers are of the same fiber type, indicating that fiber type is determined by the motor neuron. The largest of the fibers are the fast glycolytic, while the smallest are the slow oxidative; the fast oxidative are intermediate. The same is true for the speed of contraction; the fast glycolytic are faster than fast oxidative, which are faster than slow oxidative. Motor units are also of different sizes; fast glycolytic are larger than fast oxidative or slow oxidative.

Diff: 7 Page Ref: 344

7) Training induces a number of changes within skeletal muscle that are specific to the type of training employed. Describe the changes that occur in skeletal muscle in response to training.

Answer: One reason why athletes train is to increase the capacity of their muscles to perform the work that their sport requires. Athletic training can be broken into two basic types: aerobic and anaerobic, depending upon the energy systems that are stressed by the specific training modality. In response to aerobic training, some of the fast glycolytic fibers are converted into fast oxidative fibers. This is accompanied by an increased mitochondrial density (size and number), an increase in the number of capillaries that surround each muscle fiber, and a decrease in the diameter of the muscle fiber (the last two would facilitate the delivery of oxygen to the active muscle fibers). For the slow oxidative fibers, they do not appear to be capable of converting to fast fiber types. However, the changes in the slow oxidative fibers to aerobic training would be similar to the fast oxidative fibers. In contrast, high-intensity anaerobic exercise will increase the glycolytic capacity of the muscle fibers (switch some of the fast oxidative to fast glycolytic fibers). At the same time, the density of mitochondria (size and number) will be decreased, the concentration of glycolytic enzymes will be increased, and the diameter of the muscle fibers will be increased. The increased skeletal muscle girth in an individual who regularly weight trains is related to an increase in the diameter of muscle fibers (increased myofibrils) rather than an increase in the number of muscle fibers.

Diff: 6 Page Ref: 347
8) While contractile proteins are similar in skeletal and smooth muscle cells, the structure and regulation of muscle contraction is quite different. Describe the arrangement of contractile proteins in smooth muscle cells and how contraction is mediated.

Answer: Contractile proteins (actin and myosin) are the same in smooth muscle and skeletal muscle. However, their arrangement within those muscle cells is quite different. Skeletal muscles are characterized by the repeating striated arrangement of the contractile proteins into sarcomeres. This is not the case for smooth muscle, where the contractile proteins are not arranged in a striated pattern, hence the smooth appearance. Rather, contractile proteins are arranged in a variety of patterns that are oblique to the long axis of the smooth muscle cell. These contractile proteins are attached to the dense bodies where the force generated by the contractile proteins is transmitted to the cell’s exterior. The regulation of excitation-contraction coupling is also quite different in smooth muscle cells. Calcium is still an important regulator of force development but is coupled to contraction in a different way than was observed in skeletal muscle cells. Calcium enters the cell through a voltage-sensitive calcium channel to bind with calmodulin. The calcium-calmodulin complex binds to the enzyme myosin light-chain kinase, causing it to become active. The myosin light-chain kinase phosphorylates the myosin light chain, causing it to become active and capable of binding to actin. Thereafter, the cycling of the crossbridges is the same as observed in skeletal muscle. In order to terminate crossbridge cycling, the smooth muscle cells must do more than remove calcium from the cytoplasm. The myosin light chain must be dephosphorylated by a phosphatase enzyme. These enzymes are always active within smooth muscle cells. Thus, the extent of force developed by smooth muscle cells is dependent upon the interaction between myosin light-chain kinase and phosphatase activity, each of which can be modulated.
Short Answer Questions

Figure 12.1

Using Figure 12.1, answer the following questions:

1) Identify the structure indicated by the number 1 in the image above and describe its functional significance.
   Answer: M line: where the tails of the myosin molecules are bound to one another
   Diff: 4   Page Ref: 325

2) Identify the structure indicated by the number 2 in the image above and describe its functional significance.
   Answer: Z line: anchors the thin filaments together
   Diff: 4   Page Ref: 325

3) Identify the structure indicated by the number 3 in the image above.
   Answer: H zone
   Diff: 3   Page Ref: 325

4) Identify the structure indicated by the number 4 in the image above.
   Answer: A band
   Diff: 3   Page Ref: 325

5) Identify the structure indicated by the number 5 in the image above and describe its functional significance.
   Answer: sarcomere: the functional unit of muscle contraction whose length is changed as a muscle shortens and lengthens
   Diff: 4   Page Ref: 325

6) Identify the structure indicated by the number 6 in the image above.
   Answer: I band
   Diff: 3   Page Ref: 325
7) Which structure(s) in Figure 12.1 would be altered by muscle shortening?
   Answer: 3, 5, and 6
   Diff: 5  Page Ref: 327

8) The continuation of the sarcolemma that penetrates the interior of the muscle fiber and thereby facilitates the release of calcium from the sarcoplasmic reticulum is called what?
   Answer: transverse tubule
   Diff: 4  Page Ref: 323

9) What is the protein component of the thin filament that blocks the myosin-binding site on the actin monomer?
   Answer: tropomyosin
   Diff: 3  Page Ref: 325

10) Troponin is a complex of three proteins that bind to ________, ________, and ________.
    Answer: tropomyosin, calcium, and actin
    Diff: 5  Page Ref: 325

11) Calcium is stored in what region of skeletal muscle cells?
    Answer: sarcoplasmic reticulum
    Diff: 3  Page Ref: 323

12) Another name for a muscle cell is (myofibril / muscle fiber).
    Answer: muscle fiber
    Diff: 3  Page Ref: 323

13) Name the three proteins found in thin filaments.
    Answer: actin, troponin, and tropomyosin
    Diff: 3  Page Ref: 325

14) Following death, rigor mortis occurs due to a lack of (calcium / ATP).
    Answer: ATP
    Diff: 4  Page Ref: 328

15) Receptor types at the motor end plate are (muscarinic / nicotinic) cholinergic receptors.
    Answer: nicotinic
    Diff: 3  Page Ref: 329

16) (Dihyropyridine / Ryanodine) receptors are located on the sarcoplasmic reticulum.
    Answer: ryanodine
    Diff: 5  Page Ref: 331

17) Heavy intensity exercise generates what by-product that contributes to fatigue?
    Answer: lactic acid
    Diff: 5  Page Ref: 333

18) During summation, calcium release is (greater than / less than / equal to) calcium reuptake.
    Answer: greater than
    Diff: 5  Page Ref: 338
19) The time between the occurrence of an action potential in skeletal muscle and the onset of tension is called what?
   Answer: latent period
   Diff: 5 Page Ref: 337

20) List the three mechanisms whereby force of individual skeletal muscle fibers can be altered.
   Answer: frequency of stimulation (summation), fiber diameter (sarcomeres in parallel), and fiber length
   Diff: 5 Page Ref: 337

21) The velocity at which a skeletal muscle contracts is (directly / inversely) related to load.
   Answer: inversely
   Diff: 5 Page Ref: 343

22) Name the two types of sensory endings found in muscle spindles.
   Answer: annulospiral endings, flower-spray endings
   Diff: 5 Page Ref: 349

23) What type of motor neuron innervates intrafusal muscle fibers?
   Answer: gamma
   Diff: 4 Page Ref: 349

24) Name the antagonistic muscle to the triceps.
   Answer: biceps
   Diff: 4 Page Ref: 347

25) Identify the three types of muscle fibers that are found in all skeletal muscles.
   Answer: slow oxidative, fast oxidative, and fast glycolytic
   Diff: 5 Page Ref: 345

26) Postural muscles of the legs and back tend to have a high proportion of this fiber type.
   Answer: slow oxidative
   Diff: 4 Page Ref: 345

27) In smooth muscle, calcium binds to ________, and then activates the enzyme ________.
   Answer: calmodulin: myosin light-chain kinase
   Diff: 5 Page Ref: 351

28) The decreased ability of a muscle to maintain a constant force of contraction during repetitive stimulation is called what?
   Answer: fatigue
   Diff: 4 Page Ref: 346

29) In smooth muscle, the structures analogous to Z lines in skeletal muscle are called ________.
   Answer: dense bodies
   Diff: 4 Page Ref: 353

30) (Single-unit / Multi-unit) smooth muscle contains pacemaker cells.
   Answer: Single-unit
   Diff: 4 Page Ref: 354
31) Cardiac muscle is (smooth / striated).
   Answer: striated  
   Diff: 3  Page Ref: 355

32) Intercalated disks contain what type of special junctions?
   Answer: gap junctions and tight junctions
   Diff: 3  Page Ref: 352
Chapter 13  The Cardiovascular System: Cardiac Function

Multiple Choice Questions

1) Keeping blood in the different chambers of the heart from mixing is a function what structure?
   A) valves  
   B) arteries  
   C) septum  
   D) apex  
   E) chordae tendinae  
   Answer: C  
   Diff: 3   Page Ref: 361

2) The primary site of exchange between blood and interstitial fluid occurs across what type of blood vessel?
   A) arteries  
   B) veins  
   C) arterioles  
   D) venules  
   E) capillaries  
   Answer: E  
   Diff: 3   Page Ref: 362

3) When blood leaves the heart, it first enters what type of blood vessel?
   A) arteries  
   B) veins  
   C) arterioles  
   D) venules  
   E) capillaries  
   Answer: A  
   Diff: 2   Page Ref: 362

4) Which of the following functions in forming blood clots?
   A) erythrocytes only  
   B) leukocytes only  
   C) platelets only  
   D) both erythrocytes and leukocytes  
   E) both leukocytes and platelets  
   Answer: C  
   Diff: 4   Page Ref: 326

5) Which of the following is NOT a component of the pulmonary circuit?
   A) right ventricle  
   B) pulmonary arteries  
   C) pulmonary veins  
   D) pulmonary capillaries  
   E) venae cava  
   Answer: E  
   Diff: 4   Page Ref: 363
6) Blood supply to the heart comes from _______.
   A) coronary arteries
   B) cerebral arteries
   C) aorta
   D) blood within the ventricles
   E) blood within the atria
Answer: A
Diff: 4 Page Ref: 364

7) What structure separates the thoracic cavity from the abdominal cavity?
   A) heart
   B) diaphragm
   C) intestines
   D) liver
   E) lungs
Answer: B
Diff: 4 Page Ref: 366

8) Which chamber of the heart has the thickest musculature?
   A) right atrium
   B) right ventricle
   C) left atrium
   D) left ventricle
   E) both ventricles have equal thickness and are thicker than the atria
Answer: D
Diff: 3 Page Ref: 366

9) Chordae tendinae are strands of connective tissue extending from _______ to _______.
   A) atria : ventricle
   B) inferior vena cava : right atrium
   C) aortic valves : ventricular myocardium
   D) semilunar valves : atrial myocardium
   E) AV valves : papillary muscle
Answer: E
Diff: 4 Page Ref: 367

10) The opening and closure of the atrioventricular and semilunar valves is driven by _______.
    A) contraction of the valve
    B) contraction of muscles attached to the valves
    C) contraction of the ventricle and atria that pull the valves into place
    D) differences in pressure across the valve
    E) contraction and relaxation of the valve
Answer: D
Diff: 4 Page Ref: 367
11) Closure of the atrioventricular valve occurs when _______.
   A) the valve contracts
   B) pressure inside the ventricle is less than pressure inside the atrium
   C) pressure inside the ventricle is greater than pressure inside the atrium
   D) the papillary muscle contracts
   E) the atrium contracts

   Answer: C  
   Diff: 4  Page Ref: 367

12) Whereas the contractile activity of skeletal muscle is called ________, that of cardiac muscle is ________ because the contraction originates within the musculature itself.
   A) somatic : autonomic
   B) voluntary : involuntary
   C) neurogenic : myogenic
   D) somatic : autorhythmic
   E) extrinsic : intrinsic

   Answer: C  
   Diff: 6  Page Ref: 368

13) What is mitral valve prolapse?
   A) inversion of the left AV valve
   B) inversion of the right AV valve
   C) inversion of the pulmonary valve
   D) inversion of the aortic valve
   E) None of the above

   Answer: A  
   Diff: 4  Page Ref: 368

14) What are the two major regions of the heart containing pacemaker cells?
   A) sinoatrial node and atrioventricular node
   B) sinoatrial node and Purkinje fibers
   C) sinoatrial node and bundle of His
   D) bundle of His and atrioventricular node
   E) bundle of His and Purkinje fibers

   Answer: A  
   Diff: 3  Page Ref: 368

15) What blood vessel carries deoxygenated blood to the lungs?
   A) inferior vena cava
   B) aorta
   C) pulmonary vein
   D) pulmonary artery
   E) superior vena cava

   Answer: D  
   Diff: 4  Page Ref: 364
16) The relative color (depth of redness) of blood is a direct indication of the amount of _______ bound to hemoglobin.
   A) sodium ions  
   B) oxygen  
   C) glucose  
   D) hydrogen ions  
   E) carbon dioxide  
   Answer: B  
   Diff: 4  Page Ref: 363

17) The term autorhythmicity refers to the heart's ability to _______.
   A) conduct action potentials along the conduction pathway  
   B) generate its own contractile cycle  
   C) originate its contraction neurogenically  
   D) act as a functional syncytium  
   E) intrinsically modify its contractility  
   Answer: B  
   Diff: 3  Page Ref: 368

18) What structure provides the pathway for the movement of electrical current between the cells of the conduction pathway and the ventricular myocytes?
   A) Desmosomes  
   B) Sodium channels  
   C) Gap junctions  
   D) Potassium channels  
   E) Funny channels  
   Answer: C  
   Diff: 3  Page Ref: 369

19) Which of the following is the correct conduction pathway through the heart?
   A) Purkinje fibers; bundle of His; bundle branches; SA node; AV node  
   B) SA node; AV node; bundle of His; bundle branches; Purkinje fibers  
   C) AV node; SA node; bundle branches; bundle of His; Purkinje fibers  
   D) Bundle of His; bundle branches; Purkinje fibers; SA node; AV node  
   E) SA node; Purkinje fibers; AV node; bundle of His; bundle branches  
   Answer: B  
   Diff: 4  Page Ref: 370

20) Conduction through which of the following is slow to allow atria to contract before the ventricles?
   A) atria  
   B) SA node  
   C) AV node  
   D) bundle of His  
   E) Purkinje fibers  
   Answer: C  
   Diff: 4  Page Ref: 371

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21) Why do AV nodal cells NOT determine the heart rate?
   A) They depolarize faster than all other conducting fibers.
   B) They depolarize slower than all other conducting fibers.
   C) They slow conduction of the wave of excitation.
   D) As depolarization initiated in the SA node reaches the AV node, it leaves the AV node in a refractory state.
   E) The AV node is connected to the SA node, but not to other conducting fibers in the heart.
   Answer: D
   Diff: 4 Page Ref: 370

22) What is an ectopic focus?
   A) a site where an abnormal depolarization in cardiac muscle initiates an extrasystole
   B) a site in the conduction fibers that functions as a pacemaker
   C) the site where coronary arteries branch off of the aorta
   D) an abnormal hole in the interventricular septum allowing blood to flow between ventricles
   E) an extra T wave in the ECG
   Answer: A
   Diff: 4 Page Ref: 371

23) Opening of which of the following channels contributes to the spontaneous depolarization of pacemaker cells?
   A) calcium channels only
   B) potassium channels only
   C) funny channels only
   D) both calcium and potassium channels
   E) both calcium channels and funny channels
   Answer: E
   Diff: 5 Page Ref: 373

24) The rapid depolarization phase of a pacemaker cell action potential is caused by which of the following types of ion movement?
   A) movement of sodium through funny channels
   B) movement of calcium through L-type channels
   C) movement of potassium through funny channels
   D) movement of calcium through T-type channels
   E) movement of sodium and calcium through funny channels
   Answer: B
   Diff: 6 Page Ref: 373

25) The transition from slow depolarization to an action potential in pacemaker cells is driven by the _______ of the _______ channel.
   A) opening : T-type calcium
   B) opening : sodium
   C) closure : L-type calcium
   D) closure : T-type calcium
   E) opening : L-type calcium
   Answer: E
   Diff: 7 Page Ref: 373
26) Which of the following is responsible for the rapid depolarization phase of an action potential within the pacemaker cells?
   A) A decrease in P_{Na}
   B) An increase in P_{Na}
   C) A decrease in P_{K}
   D) An increase in P_{K}
   E) An increase in P_{Ca}
Answer: E
Diff: 5 Page Ref: 373

27) Which of the following ion channels must open for a cardiac pacemaker cell to depolarize to threshold for an action potential?
   A) funny channels only
   B) L-type calcium channels only
   C) T-type calcium channels only
   D) both funny channels and L-type calcium channels
   E) both funny channels and T-type calcium channels
Answer: E
Diff: 6 Page Ref: 373

28) Which of the following is responsible for the repolarization of pacemaker cells?
   A) An increase in P_{Ca}
   B) An increase in P_{Na}
   C) A decrease in P_{K}
   D) An increase in P_{K}
   E) A decrease in P_{Na}
Answer: D
Diff: 5 Page Ref: 373

29) The rapid depolarization phase of a contractile cell is also known as phase _______.
   A) 0
   B) 1
   C) 2
   D) 3
   E) 4
Answer: A
Diff: 4 Page Ref: 374

30) What causes the rapid depolarization phase of a contractile cell action potential?
   A) sodium movement into the cell
   B) sodium movement out of the cell
   C) calcium movement into the cell
   D) calcium movement out of the cell
   E) potassium movement into the cell
Answer: A
Diff: 4 Page Ref: 374
31) Which of the following statements about the plateau phase of a contractile cell action potential is FALSE?
   A) Calcium permeability is high relative to the resting state.
   B) Sodium channels are inactivated.
   C) Potassium permeability is low relative to the resting state.
   D) The cardiac muscle is in the absolute refractory period.
   E) The membrane potential remains the same as the peak of the action potential for about 200 milliseconds.

   Answer: E
   Diff: 6    Page Ref: 374

32) During phase 3 of a contractile cell action potential, ________.
   A) only sodium permeability is increased
   B) only calcium permeability is increased
   C) only potassium permeability is increased
   D) sodium and calcium permeability are both increased
   E) sodium and potassium permeability are both increased

   Answer: C
   Diff: 4    Page Ref: 374

33) Which of the following ion channels does NOT participate in the contractile cell action potential?
   A) type T calcium channels
   B) type L calcium channels
   C) delayed rectifying potassium channels
   D) inward rectifying potassium channels
   E) voltage-gated sodium channels

   Answer: A
   Diff: 8    Page Ref: 374

34) Which of the following is NOT a part of the excitation–contraction coupling in cardiac muscle?
   A) An action potential travels along transverse tubules.
   B) Calcium channels in the plasma membrane open, allowing calcium ions to enter the cell.
   C) Calcium channels in the sarcoplasmic reticulum open, allowing calcium ions to enter the cytosol.
   D) Calcium binds to calmodulin in the cytosol.
   E) Calcium opens calcium channels in the sarcoplasmic reticulum.

   Answer: D
   Diff: 5    Page Ref: 375

35) What is the function of the sodium–calcium exchanger in cardiac muscle?
   A) depolarize the cell
   B) trigger the release of calcium from the sarcoplasmic reticulum
   C) remove calcium from the cytosol by transporting it to the extracellular fluid
   D) remove calcium from the cytosol by transporting it into the sarcoplasmic reticulum
   E) interact with troponin to initiate cross-bridge cycling

   Answer: C
   Diff: 4    Page Ref: 375
36) What is the role of ryanodine receptors in cardiac muscle?
   A) They release calcium from the sarcoplasmic reticulum.
   B) They transport calcium from cytosol to extracellular fluid.
   C) They transport calcium from cytosol into the sarcoplasmic reticulum.
   D) They bind hormones that affect the strength of contraction.
   E) They bind to troponin to initiate cross-bridge cycling.

   Answer: A
   Diff: 4   Page Ref: 375

37) Which of the following components of an ECG represents ventricular depolarization?
   A) P wave
   B) QRS complex
   C) T wave
   D) PQ interval
   E) TQ segment

   Answer: B
   Diff: 3   Page Ref: 377

38) Which of the following components of an ECG represents ventricular repolarization?
   A) P wave
   B) QRS complex
   C) T wave
   D) PQ interval
   E) TQ segment

   Answer: C
   Diff: 3   Page Ref: 377

39) If damage to the AV node slowed down conduction through this tissue, what would be observed on an ECG?
   A) a larger P wave
   B) a longer P wave
   C) a longer PR interval
   D) a wider QRS complex
   E) an inverted T wave

   Answer: C
   Diff: 5   Page Ref: 378

40) In an ECG recording, the RR interval is 0.5 seconds. What is the heart rate?
   A) 50 beats/min
   B) 100 beats/min
   C) 30 beats/min
   D) 60 beats/min
   E) 120 beats/min

   Answer: E
   Diff: 5   Page Ref: 378
41) Which of the following describes second degree heart block?
   A) there is a longer delay between atrial contraction and ventricular contraction
   B) not every atrial contraction is followed by a ventricular contraction
   C) not every ventricular contraction is preceded by an atrial contraction
   D) the ventricles no longer contract
   E) the atria no longer contract

   Answer: B  
   Diff: 4  Page Ref: 378

42) During isovolumetric relaxation, ________.
   A) the AV and semilunar valves are closed and ventricular pressure is increasing
   B) the AV and semilunar valves are closed and ventricular pressure is decreasing
   C) the AV and semilunar valves are open and ventricular pressure is increasing
   D) the AV and semilunar valves are open and ventricular pressure is decreasing
   E) the AV valves are open, the semilunar valves are closed, and ventricular pressure is decreasing

   Answer: B  
   Diff: 4  Page Ref: 379

43) What is occurring during ventricular ejection?
   A) the AV and semilunar valves are closed as ventricular pressure is increasing
   B) the AV valves are open and the semilunar valves are closed as ventricular pressure is increasing
   C) the AV and semilunar valves are open as blood is leaving the ventricles
   D) the AV valves are closed and the semilunar valves are open as blood is leaving the ventricles
   E) the AV valves are open and the semilunar valves are closed as blood is leaving the ventricles

   Answer: D  
   Diff: 5  Page Ref: 379

44) Which of the following is TRUE of the ventricular filling phase of the cardiac cycle?
   A) Ventricular filling occurs during systole.
   B) All valves in the heart are open.
   C) Ventricular pressure is less than aortic pressure.
   D) Ventricular pressure is greater than atrial pressure.
   E) Ventricular pressure is decreasing.

   Answer: C  
   Diff: 4  Page Ref: 379

45) What phase of the cardiac cycle is the heart in when all four valves of the heart are closed and ventricular pressure is less than atrial pressure?
   A) ventricular filling
   B) isovolumetric contraction
   C) ventricular ejection
   D) isovolumetric relaxation
   E) none

   Answer: E  
   Diff: 5  Page Ref: 379
46) What phase of the cardiac cycle is the heart in when all four valves of the heart are open and ventricular pressure is less than atrial pressure?
   A) ventricular filling
   B) isovolumetric contraction
   C) ventricular ejection
   D) isovolumetric relaxation
   E) none

   Answer: E  
   Diff: 5  
   Page Ref: 379

47) During which phase of the cardiac cycle are all four heart valves open?
   A) ventricular filling
   B) isovolumetric contraction
   C) ventricular ejection
   D) isovolumetric relaxation
   E) none

   Answer: E  
   Diff: 4  
   Page Ref: 379

48) Ejection of blood from the right ventricle will continue until ________.
   A) the pulmonary semilunar valve contracts, inducing closure
   B) pressure in the pulmonary artery is less than pressure in the right ventricle
   C) pressure in the aorta is greater than pressure in the right ventricle
   D) pressure in the pulmonary artery is greater than pressure in the right ventricle
   E) pressure in the aorta is less than pressure in the right ventricle

   Answer: D  
   Diff: 5  
   Page Ref: 379

49) The increase in ventricular volume early in diastole reflects ________.
   A) the increased stiffness of the heart
   B) the contraction of the atria moving blood into the ventricle
   C) the passive movement of blood through the atrium and into the ventricle
   D) the relaxation of the ventricle
   E) the back-flow of blood from the aorta

   Answer: C  
   Diff: 4  
   Page Ref: 379

50) The small increase in ventricular pressure observed late in diastole is caused by ________.
   A) ventricular contraction
   B) ventricular relaxation
   C) atrial contraction
   D) atrial relaxation
   E) blood moving into the atria from vena cava

   Answer: C  
   Diff: 3  
   Page Ref: 379
51) Blood is ejected from the left ventricle once pressure within _______.
   A) the ventricle is greater than pressure within the aorta
   B) the ventricle is less than pressure within the aorta
   C) the ventricle is greater than pressure within the pulmonary artery
   D) the ventricle is less than pressure within the pulmonary artery
   E) the muscles of the pulmonary semilunar valve relax

Answer: A
Diff: 5   Page Ref: 379

52) The increased aortic pressure that occurs during systole reflects a(n) _______.
   A) decreased resistance of the vasculature
   B) decreased volume of blood within the aorta
   C) increased resistance of the vasculature
   D) increased volume of blood in the aorta
   E) decreased stiffness of the aorta

Answer: D
Diff: 5   Page Ref: 381

53) With a systolic pressure of 135 mm Hg and a diastolic pressure of 75 mm Hg, mean arterial pressure would be _______.
   A) 60 mm Hg
   B) 95 mm Hg
   C) 30 mm Hg
   D) 75 mm Hg
   E) 135 mm Hg

Answer: B
Diff: 5   Page Ref: 381

54) The end-diastolic volume minus the end-systolic volume is the _______.
   A) ejection fraction
   B) stroke volume
   C) cardiac output
   D) total ventricular volume
   E) total atrial volume

Answer: B
Diff: 3   Page Ref: 382

55) The volume of blood ejected from the ventricle with each contraction can be described by the equation _______.
   A) (end-diastolic volume) - (end-systolic volume)
   B) (ejection fraction) × (end-diastolic volume)
   C) (stroke volume) - (end-diastolic volume)
   D) (end-systolic volume) - (stroke volume)
   E) (pulse pressure) - (end-diastolic volume)

Answer: A
Diff: 6   Page Ref: 382
56) What causes the sounds that one hears as the heart beats?
   A) the snapping of the valves into a closed position
   B) the turbulence created as the valves close
   C) the snapping of the valves into the open position
   D) the turbulence created as the valves open
   E) the bulk movement of blood into and out of the ventricle

   Answer: B
   Diff: 5  Page Ref: 383

57) Which of the following structures is POORLY innervated by the parasympathetic nervous system, therefore, an increase in parasympathetic activity has little effect on this structure?
   A) sinoatrial node
   B) atrioventricular node
   C) ventricles
   D) conduction pathway
   E) Purkinje fibers

   Answer: C
   Diff: 4  Page Ref: 385

58) The SA node is innervated by ________.
   A) the sympathetic nervous system only
   B) the parasympathetic nervous system only
   C) the somatic nervous system only
   D) the sympathetic and parasympathetic nervous systems
   E) the sympathetic, parasympathetic, and somatic nervous systems

   Answer: D
   Diff: 4  Page Ref: 386

59) Which of the following is an effect of parasympathetic activity to the heart?
   A) Postganglionic neurons release acetylcholine, which binds to nicotinic cholinergic receptors in the SA node.
   B) SA nodal cells are depolarized.
   C) Heart rate is increased.
   D) The rate of spontaneous depolarization in SA nodal cells decreases.
   E) cAMP is activated.

   Answer: D
   Diff: 4  Page Ref: 386

60) Which of the following is FALSE of sympathetic activity to the SA node?
   A) Norepinephrine binds to beta1 adrenergic receptors.
   B) cAMP levels in the pacemaker cells increases.
   C) Funny channel opening is enhanced.
   D) The rate of spontaneous depolarization is increased.
   E) Potassium channel closing is enhanced.

   Answer: E
   Diff: 4  Page Ref: 386

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61) Which of the following would NOT result from an increase in ventricular contractility?
   A) increased stroke volume
   B) increased ejection fraction
   C) decreased end-systolic volume
   D) increased proportion of end-diastolic volume that is ejected
   E) increased end-diastolic volume
   
   Answer: E
   Diff: 5  Page Ref: 388

62) Under resting conditions, heart rate is primarily under the control of what control system?
   A) the parasympathetic nervous system
   B) the sympathetic nervous system
   C) epinephrine
   D) the somatic nervous system
   E) intrinsic mechanisms
   
   Answer: A
   Diff: 5  Page Ref: 386

63) An increase in heart rate can be mediated through which of the following?
   A) a decrease in parasympathetic nervous activity only
   B) a decrease in sympathetic activity only
   C) an increase in sympathetic activity only
   D) an increase in parasympathetic activity and a decrease in sympathetic activity
   E) a decrease in parasympathetic activity and an increase in sympathetic activity
   
   Answer: E
   Diff: 5  Page Ref: 386

64) Which of the following variables is NOT involved in the regulation of stroke volume?
   A) ventricular contractility
   B) preload
   C) parasympathetic nervous activity
   D) sympathetic nervous activity
   E) afterload
   
   Answer: C
   Diff: 4  Page Ref: 388

65) Which of the following hormones does NOT increase cardiac contractility?
   A) epinephrine
   B) thyroid hormones
   C) glucagon
   D) insulin
   E) angiotensin II
   
   Answer: E
   Diff: 6  Page Ref: 389
66) Which of the following best describes the effect of sympathetic activity on ventricular contractile cells?
   A) the rates of contraction and relaxation both increase, whereas the force of contraction decreases
   B) the rate of contraction and the force of contraction both increase, whereas the rate of relaxation decreases
   C) the rates of contraction and relaxation and the force of contraction all increase
   D) the rates of contraction and relaxation both decrease, whereas the force of contraction increases
   E) the force of contraction increases, whereas the rates of contraction and relaxation are not affected
   Answer: C
   Diff: 5 Page Ref: 389

67) Which of the following statements is FALSE of sympathetic activity on ventricular contractile cells?
   A) Norepinephrine binds to beta1 adrenergic receptors.
   B) Phospholipase C is activated.
   C) Calcium channel opening is augmented.
   D) The rate of the Ca-ATPase activity is augmented.
   E) The rate of the myosin ATPase activity is enhanced.
   Answer: B
   Diff: 6 Page Ref: 389

68) Which of the following describes the effect of end-diastolic volume on stroke volume?
   A) An increase in end-diastolic volume stretches ventricular muscle cells to lengths greater than optimum, decreasing the strength of contraction and thereby decreasing stroke volume.
   B) An increase in end-diastolic volume stretches ventricular muscle cells to lengths closer to optimum, increasing the strength of contraction and thereby increasing stroke volume.
   C) A decrease in end-diastolic volume allows ventricular muscle cells to relax more during diastole, allowing more blood to return to the heart increasing stroke volume.
   D) A decrease in end-diastolic volume creates a vacuum drawing more blood into the ventricle increasing stroke volume.
   E) A decrease in end-diastolic volume allows cardiac muscle to relax, conserving energy for the next contraction, thereby increasing stroke volume of that next contraction.
   Answer: B
   Diff: 4 Page Ref: 389

69) Which of the following variables is NOT an intrinsic factor that alters cardiac function?
   A) preload
   B) atrial pressure
   C) end-systolic volume
   D) hormonal stimulation
   E) afterload
   Answer: D
   Diff: 4 Page Ref: 390
70) Which of the following events will NOT occur in response to norepinephrine binding to a beta adrenergic receptor on the ventricular contractile cell?
   A) an increase in cyclic AMP
   B) an increase in calcium influx through the opening of membrane calcium channels
   C) an increase in calcium release from the sarcoplasmic reticulum
   D) an increase in slow depolarization
   E) an increase in calcium bound to troponin

Answer: D  
Diff: 5  Page Ref: 389

71) The binding of a catecholamine to a beta adrenergic receptor will _______.
   A) activate guanylate cyclase
   B) activate adenylate cyclase
   C) activate phospholipase C
   D) inhibit guanylate cyclase
   E) inhibit phospholipase C

Answer: B  
Diff: 5  Page Ref: 389

72) Cardiac function curves plot _______ against _______.
   A) stroke volume : end-diastolic volume
   B) stroke volume : end-systolic volume
   C) heart rate : end-diastolic volume
   D) heart rate : end-systolic volume
   E) cardiac output : end-diastolic volume

Answer: A  
Diff: 5  Page Ref: 390

73) The preload is approximately the same as the _______.
   A) end-diastolic pressure
   B) end-systolic pressure
   C) aortic systolic pressure
   D) aortic diastolic pressure
   E) atrial pressure

Answer: A  
Diff: 5  Page Ref: 390

74) The pressure in the large systemic veins leading into the heart is called what?
   A) preload
   B) afterload
   C) central venous pressure
   D) peripheral venous pressure
   E) systemic venous pressure

Answer: C  
Diff: 4  Page Ref: 391
75) An increase in venous return would result in a(n) _______.
   A) increased end-systolic volume
   B) decreased end-systolic volume
   C) decreased end-diastolic volume
   D) increased end-diastolic volume
   E) increase mid-systolic volume

   Answer: D
   Diff: 5   Page Ref: 391

76) Which of the following variables is NOT involved in determining ventricular preload?
   A) filling time
   B) atrial pressure
   C) venous return
   D) end-systolic volume
   E) central venous pressure

   Answer: D
   Diff: 4   Page Ref: 391

77) Which of the following variables is NOT capable of directly altering venous pressure?
   A) blood volume
   B) parasympathetic nervous activity
   C) standing upright
   D) posture
   E) muscle activity

   Answer: B
   Diff: 4   Page Ref: 391

78) A decrease in afterload will lead to which of the following?
   A) increased heart rate
   B) decreased heart rate
   C) increased stroke volume
   D) decreased stroke volume
   E) decreased cardiac output

   Answer: C
   Diff: 5   Page Ref: 391

79) Which of the following decreases stroke volume?
   A) decrease in central venous pressure
   B) increase in filling time
   C) increase sympathetic activity
   D) increase parasympathetic activity
   E) increase in atrial pressure

   Answer: A
   Diff: 6   Page Ref: 391
80) Which of the following decreases heart rate?
   A) increase in venous pressure
   B) increase in filling time
   C) increase in sympathetic activity
   D) increase in parasympathetic activity
   E) increase in stroke volume

   Answer: D
   Diff: 4   Page Ref: 386

True/False Questions

1) All veins return blood to the heart.
   Answer: TRUE
   Diff: 3   Page Ref: 362

2) All veins contain deoxygenated blood.
   Answer: FALSE
   Diff: 4   Page Ref: 364

3) Deoxygenated blood is blue.
   Answer: FALSE
   Diff: 4   Page Ref: 363

4) The muscular wall of the right ventricle is thicker than that of the left ventricle because it develops a greater pressure in order to deliver blood to the organs of the body.
   Answer: FALSE
   Diff: 3   Page Ref: 366

5) Arteries are vessels that always carry oxygenated blood.
   Answer: FALSE
   Diff: 5   Page Ref: 364

6) Prolapse involves improper alignment of the atrioventricular valve such that one or more of the cusps are pushed into the atrium by the pressure developed in the ventricle.
   Answer: TRUE
   Diff: 4   Page Ref: 367

7) The contractile cycle of the heart normally originates from a pacemaker cell within the sinoatrial node.
   Answer: TRUE
   Diff: 3   Page Ref: 370

8) Action potentials travel more quickly through the ventricular contractile cells than the conduction pathway.
   Answer: FALSE
   Diff: 4   Page Ref: 368

9) Ventricular contraction begins at the top of the heart and travels downward to its apex.
   Answer: FALSE
   Diff: 4   Page Ref: 370
10) The AV node autorhythmic cells are the fastest depolarizing cells in the heart.
   Answer: FALSE
   Diff: 3   Page Ref: 370

11) Calcium movement into the cell causes the rapid depolarization of the autorhythmic cell action potential, whereas sodium movement into the cell causes the rapid depolarization of the contractile cell action potential.
   Answer: TRUE
   Diff: 5   Page Ref: 373

12) To initiate cardiac muscle contraction, calcium binds to troponin, causing a shift in tropomyosin that exposes the myosin binding sites on actin.
   Answer: TRUE
   Diff: 4   Page Ref: 375

13) An ECG detects the electrical activity occurring in a single cardiac muscle cell.
   Answer: FALSE
   Diff: 3   Page Ref: 375

14) During recording of an ECG, a depolarization that travels toward a positive lead will cause an upward deflection.
   Answer: TRUE
   Diff: 4   Page Ref: 377

15) An electrocardiogram records the waves of depolarization and repolarization as they travel along the entire heart.
   Answer: TRUE
   Diff: 3   Page Ref: 377

16) Aortic and left ventricular pressures are nearly identical throughout the entire cardiac cycle.
   Answer: FALSE
   Diff: 4   Page Ref: 381

17) Following an extrasystole, the ECG will show a skipped QRS complex.
   Answer: TRUE
   Diff: 6   Page Ref: 376

18) Contraction of the heart is triggered by the central nervous system.
   Answer: FALSE
   Diff: 3   Page Ref: 384

19) At rest, systole lasts longer than diastole.
   Answer: FALSE
   Diff: 3   Page Ref: 379

20) Calcium entering the cell during the plateau phase of the ventricular cell action potential triggers calcium release from the sarcoplasmic reticulum.
   Answer: TRUE
   Diff: 5   Page Ref: 375

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21) The first heart sound occurs during the transition from systole to diastole.
   Answer: FALSE
   Diff: 5     Page Ref: 383

22) Blood enters the aorta throughout the entire cardiac cycle.
   Answer: FALSE
   Diff: 3     Page Ref: 381

23) Blood exits the aorta throughout the entire cardiac cycle.
   Answer: TRUE
   Diff: 5     Page Ref: 382

24) The resting cardiac output for both the left and right ventricles is approximately 5.0 liters/minute.
   Answer: TRUE
   Diff: 4     Page Ref: 384

25) The heart is regulated by both intrinsic and extrinsic mechanisms.
   Answer: TRUE
   Diff: 3     Page Ref: 384

26) Parasympathetic activity enhances the closing of funny channels.
   Answer: TRUE
   Diff: 4     Page Ref: 387

27) The end diastolic volume is proportional to the length of ventricular contractile cells.
   Answer: TRUE
   Diff: 4     Page Ref: 389

28) According to Starling’s Law, as venous return increases, end-systolic volume increases.
   Answer: FALSE
   Diff: 4     Page Ref: 389

29) Given a constant pressure, the greater the radius of the vessel, the greater the tension on the vessel walls.
   Answer: TRUE
   Diff: 6     Page Ref: 390
Matching Questions

*Match the structure to the correct description.*

1) Receives deoxygenated blood from veins.
   
   **Diff: 3**  **Page Ref: 363**
   
   A) right ventricle
   B) right atrium
   
2) Receives blood from the pulmonary veins.
   
   **Diff: 3**  **Page Ref: 364**
   
   C) left ventricle
   D) left atrium
   
3) The SA node is located here.
   
   **Diff: 4**  **Page Ref: 368**
   
4) The mitral valve separates this chamber from its associated ventricle.
   
   **Diff: 4**  **Page Ref: 367**
   
5) This chamber empties into the aorta.
   
   **Diff: 2**  **Page Ref: 363**
   
6) This chamber has the thickest myocardium.
   
   **Diff: 4**  **Page Ref: 366**
   
7) During isovolumetric contraction, this chamber has the greatest pressure.
   
   **Diff: 5**  **Page Ref: 379**
   
8) This chamber is connected to the pulmonary arteries.
   
   **Diff: 3**  **Page Ref: 364**

Match the type of blood with its location.

9) Pulmonary artery.  
   Diff: 3  Page Ref: 364  
   A) deoxygenated  
   B) oxygenated

10) Systemic venules.  
    Diff: 4  Page Ref: 363

11) Right atrium.  
    Diff: 3  Page Ref: 363

12) Left ventricle.  
    Diff: 3  Page Ref: 363

13) Pulmonary arterioles.  
    Diff: 4  Page Ref: 364

14) Pulmonary veins.  
    Diff: 3  Page Ref: 364

Answers:  
9) A  
10) A  
11) A  
12) B  
13) A  
14) B
Match the channel type with the appropriate description.

15) Allows sodium movement into the cell during the early spontaneous depolarization in autorhythmic cells.
   A) voltage-gated sodium channels
   Diff: 4 Page Ref: 373

16) Allows calcium movement into the cell during the late spontaneous depolarization in autorhythmic cells.
   B) potassium channels
   Diff: 5 Page Ref: 373

17) Allows ion movement out of the cell during repolarization of the autorhythmic cells.
   C) funny channels
   Diff: 4 Page Ref: 373

18) Responsible for ion movement during the depolarization phase of the autorhythmic cell action potential.
   D) T-type calcium channels
   Diff: 5 Page Ref: 373

19) These channels open during the plateau phase of the cardiac contractile cell action potential.
   E) L-type calcium channels
   Diff: 5 Page Ref: 374

20) Opening of these channels is responsible for the depolarization phase of the cardiac contractile cell action potential.
   Diff: 4 Page Ref: 374

Match the component of the ECG with the action it represents.

21) Ventricular depolarization.  A) Q–T interval
   Diff: 3  Page Ref: 377
   B) P–R interval

22) Atrial depolarization.  C) T–Q segment
   Diff: 3  Page Ref: 377
   D) QRS complex

23) Ventricular repolarization.  E) T wave
   Diff: 3  Page Ref: 377
   F) P wave

24) Ventricular systole.
   Diff: 4  Page Ref: 377

25) Ventricular diastole.
   Diff: 4  Page Ref: 377

26) AV nodal conduction time.
   Diff: 4  Page Ref: 377

Match the phase of the cardiac cycle with its correct description.

27) All 4 valves of the heart are open.
   Diff: 4 Page Ref: 379
   A) isovolumetric contraction
   B) ventricular filling
   C) none
   D) isovolumetric relaxation
   E) ventricular ejection

28) All 4 valves are closed and pressure in the ventricle is decreasing.
   Diff: 4 Page Ref: 379

29) Ventricular pressure exceeds aortic pressure.
   Diff: 4 Page Ref: 379

30) Atrial pressure exceeds aortic pressure.
   Diff: 5 Page Ref: 379

31) AV valves are open and semilunar valves are closed.
   Diff: 5 Page Ref: 379

32) Semilunar valves are open and AV valves are closed.
   Diff: 5 Page Ref: 379

33) The first heart sound coincides with the beginning of this period.
   Diff: 6 Page Ref: 379

34) The second heart sound coincides with the beginning of this period.
   Diff: 6 Page Ref: 379

Essay Questions

1) Describe the structures of the heart that are responsible for regulating the movement of blood from one chamber to the next.

Answer: The heart is a unique structure containing two pumps that work in parallel. One of those pumps (left) drives blood to most of the tissues of the body through the systemic circulation while the other pump (right) drives blood through the lungs. These pumps are separated by a connective tissue structure called the septum that prevents the movement of blood directly from the left to the right side of the heart, or vice versa. Each pump is composed of two structures: the atrium and the ventricle. The atria are responsible for collecting the returning blood from the vena cava (left atrium) or the pulmonary vein (right atrium) until it is moved (passively at first and ending in an atrial contraction) to the ventricles. The ventricles develop the pressure that is the driving force for the movement of blood through the vasculature. The unidirectional movement of blood is ensured by the presence of atrioventricular (AV) valves located between the atrium and ventricle as well as semilunar valves between the ventricle and the vasculature. The AV valves include the bicuspid (mitral) valve on the left side of the heart and the tricuspid valve on the right side. These valves are opened and closed by changes in pressure within the chambers of the heart and vasculature. The AV valves are attached to the papillary muscle by the chordae tendinae which help to anchor the valves against the dramatic increase in pressure that occurs within the ventricles, thereby preventing the backflow of blood into the atria. The semilunar valves (pulmonary and aortic) prevent the movement of blood from the vasculature back into the ventricle.

Diff: 6  Page Ref: 367
2) Ion channels within the conduction system of the heart determine the frequency of contractile cycles generated by the heart. Describe the autorhythmic properties of the heart, with particular emphasis on the ion channels involved in the pacemaker potentials.

Answer: The pacemaker cells of the heart are involved in originating and conducting action potentials through the heart. The conduction pathway starts at the sinoatrial node, where most cardiac cycles are initiated. The heart is said to have an autorhythmicity because it is able to generate its own action potential. The pacemaker cells of the heart are responsible for this autorhythmicity, because they spontaneously generate their own action potentials. The source of that capacity resides with the ion channels that are active within pacemaker cells. After the resting membrane potential is reached, the K+ channels that were activated to return membrane potential to control will close, such that the membrane begins to slowly depolarize. At the same time, a channel that is relatively non-specific for K+ or Na+ (a funny channel, non-selective cation channel) begins to open, furthering the slow depolarization of the membrane. Before membrane potential can reach threshold, the T-type Ca2+ channels are activated. They will further the depolarization. These channels are only open for a short time span, but the depolarization that they mediate stimulates the opening of L-type Ca2+ channels that are responsible for the action potential. In the pacemaker cells, the action potential is driven by the influx of Ca2+ rather than Na+. The stimulation of L-type Ca2+ channels is regenerative, as is the stimulation of Na+ channels in neurons and skeletal muscles. The opening of one channel will induce a depolarization that stimulates others to open, further depolarizing the cell’s membrane. At some point, the permeability of that membrane to K+ is elevated. That elevation in K+ permeability is voltage dependent but occurs more slowly than the opening of L-type Ca2+ channels. The frequency with which pacemaker cells develop an action potential is affected by the rate of depolarization. The faster the cells depolarize, the sooner the cell will reach threshold and an action potential will be generated.

Diff: 8  Page Ref: 373

3) The pathway by which action potentials from the sinoatrial node travel through the heart is important for the normal function of the heart. Describe the conduction pathway of the heart and the consequences of that arrangement.

Answer: The autorhythmicity of the pacemaker cells of the sinoatrial node points to the intrinsic ability of those cells to generate action potentials. Once initiated, the action potentials travel in a wave along the atria from cell to cell, stimulating them to contract. That wave reaches the atrioventricular node, where the speed (velocity) with which the action potential travels slows dramatically. The atrioventricular node is the only pathway for the action potential to travel from atria to ventricle. This slowing of the action potential allows the ventricle more time to fill before its contractile cycle is initiated. Thus, the contraction of the atrium provides the last chance to fill the ventricles before their contraction begins. After traversing the atrioventricular node, the action potential gains speed as it travels along the bundle of His and bifurcates into the left and right bundle branches. These branches move the action potential toward the apex of the heart before the conduction pathway further branches and ultimately ends at the Purkinje fibers. It is these fibers that transmit the action potential to the ventricular myocyte. The contraction of the ventricle originates at its apex, pushing blood up and out of the ventricle.

Diff: 5  Page Ref: 370

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4) Contraction of the ventricular contractile cells originates from the Purkinje cells. Describe the electrical events responsible for the action potential of the ventricle.

Answer: Contraction of the ventricular contractile cell is originated by the action potential that has traveled along the conduction pathway and ended within the Purkinje fibers. The current responsible for the action potential in the Purkinje cells passes to the ventricular contractile cell through gap junctions. That depolarizing current causes the Na$^+$ channels to open, thereby inducing the rapid upstroke of the action potential within the contractile cell (Phase 0). Those channels are rapidly closed by their inactivation gates, as was observed in neurons. However, membrane potential does not return immediately to resting values. This reduction in the rate of repolarization (Phase 1) is driven by two events: 1) the closure of the voltage-gated inwardly rectified K$^+$ channels and 2) the opening of the voltage-gated L-type Ca$^{2+}$ channels. These two events slow the rate of repolarization of the membrane maintaining it in a relatively depolarized state for a longer period of time, which is described as the plateau (Phase 2). After a short delay (approximately 200 ms), delayed rectifier K$^+$ channels begin to open, thereby speeding the rate of repolarization (Phase 3). This repolarization causes the Ca$^{2+}$ channels to close, further repolarizing the membrane. Thereafter, the membrane maintains a stable resting membrane potential (~80 mV) through the activity of K$^+$ channels (Phase 4).

Diff: 7 Page Ref: 373

5) Describe the changes in pressure and volume that occur within the left ventricle throughout the course of the cardiac cycle, starting at the beginning of diastole.

Answer: At the beginning of diastole, intraventricular pressure is just below aortic pressure (the aortic semilunar valve has just closed). Ventricular pressure continues to decrease without any change in volume (isovolumetric relaxation), until pressure within the left ventricle is less than pressure within the left atrium. Since the movement of blood within the cardiovascular system is driven by pressure gradients, once pressure is greater in the atrium than in the ventricle, the bicuspid valve opens and blood flows into the ventricle. Thus, ventricular volume begins to increase. This continues until, toward the end of diastole, the left atrium contracts slightly, increasing ventricular pressure as the final volume of blood is moved from the left atrium to the left ventricle. This marks the end of diastole and the beginning of systole. Systole is initiated by ventricular contraction, which increases pressure within the ventricle, eventually causing the bicuspid valve to close. The contraction within the ventricle causes pressure to increase without inducing any change in volume (isovolumetric contraction). Isovolumetric contraction continues until the pressure within the ventricle is greater than within the aorta (which has been decreasing since the beginning of diastole), leading to the opening of the aortic semilunar valve. Once the valve opens, blood begins to leave the ventricle, thereby decreasing its volume. This decrease in volume continues until the heart begins to relax, at which point pressure within the ventricle decreases below aortic pressure, and the aortic semilunar valve closes and diastole begins once again.

Diff: 7 Page Ref: 379
6) Pressure within the aorta varies throughout the contractile cycle of the heart. Describe the changes in pressure that are observed in the aorta and the source of those changes.

Answer: The left ventricle develops the pressure that drives blood from the heart into the aorta. However, all of the blood that enters the aorta does not continue through to the vasculature immediately. Thus, blood accumulates within the aorta, increasing its volume and thereby stretching the structure. The aorta is an elastic structure storing energy as it stretches. Once pressure within the left ventricle drops below aortic pressure, the aortic semilunar valve closes (creating the dicrotic notch), stopping the flow of blood into the aorta. Blood continues to move into the vasculature due to the energy that was stored in the elastic aorta. Thus, blood flow through the circulation is continuous throughout the cardiac cycle even though the ventricle is actively generating force for only 1/3 of the cardiac cycle. Once the aortic semilunar valve has closed, the pressure within the aorta will slowly decrease as the blood that stretched the aorta is driven into the vasculature. That pressure will continue to decrease until pressure within the ventricle is greater than pressure in the aorta and the semilunar valve opens to allow blood to move back into the aorta, repeating the above cycle.

Diff: 6  Page Ref: 381

7) Cardiac output is in part determined by changes in heart rate. Describe the factors that are responsible for inducing changes in heart rate.

Answer: Heart rate is one of the determinants of cardiac output. The heart rate is determined by the pacemaker cells. Typically, heart beats originate from the sinoatrial node. However, other sites along the conduction pathway also contain pacemaker cells that, while they tend to have a slower rate of depolarization, can also cause contraction. The ability of these cells to generate an action potential involves the slow depolarization driven by the closure of K+ channels, the opening of non-selective cation channels (funny channels) and the ultimate opening of the Ca^{2+} channels. The autonomic nervous system is the primary modulator of heart rate. This means that activity of sympathetic and parasympathetic neurons must be able to alter the slope of the slow depolarization of the pacemaker cells. There are sympathetic and parasympathetic neurons that innervate the sinoatrial node, atrioventricular node, and other regions of the conduction pathway that can alter heart rate. Increases in sympathetic activity will increase the slope of the slow depolarization, causing heart rate to increase, whereas parasympathetic activity will decrease the slope of the slow depolarization, causing heart rate to decrease. A number of hormones like epinephrine, glucagon, thyroid hormone, and others act in a manner similar to sympathetic activity. Each of the hormones elevates heart rate by increasing the slope of the slow depolarization. Heart rate independent of the autonomic nervous system tends to be around 100 bts/min. Since normal heart rate for adults tends to be less than that, the heart is said to be under resting parasympathetic tone. However, this is not to say that the sympathetic nervous system is not active.

Diff: 6  Page Ref: 385
8) Cardiac output is in part determined by changes in stroke volume. Identify the factors involved in the determination of stroke volume.

Answer: Cardiac output is determined by the product of heart rate (the number of times the heart contracts each minute) and stroke volume (mean volume of blood ejected from the heart during each of those contractions). Stroke volume itself is determined by three important factors: 1) ventricular contractility, 2) end-diastolic volume, and 3) afterload. Contractility of the ventricle can be altered by receptors on the cell surface in response to ligand binding. Those ligands can be from the sympathetic nervous system (epinephrine and norepinephrine) or from endocrine hormones. Their binding can stimulate an increase or decrease in ventricular contractility, the nature of which depends upon the second messengers to which the receptors are coupled. The effect of end-diastolic volume on stroke volume is driven by Starling’s Law of the Heart. This law states that, as the volume of blood that fills the heart increases (increased venous return), the heart will pump out more of that blood. Thus, the ventricle matches inflow of blood with outflow. Both sympathetic activity and the heart’s response to stretch can be combined into what are called Starling’s curves. These curves plot the change in stroke volume for a given end-diastolic volume. Each curve represents Starling’s force at a given level of sympathetic activity. As sympathetic activity increases, the curve will be shifted upward such that more of the blood is ejected from the ventricle at each end-diastolic volume. The control of end-diastolic volume (sometime called preload) is in part determined by ventricular filling time and atrial pressure. As the heart slows its rate of activity, the time allowed for the ventricle to fill increases, thereby increasing the volume of blood that can be loaded into the ventricle. At the same time, blood must be driven by pressure from the atrium to the ventricle. Thus, an increase in atrial pressure that results from an increase in venous pressure will drive more blood from the atrium into the ventricle. Finally, afterload can substantially alter the volume of blood ejected from the heart. Afterload refers to aortic pressure that determines at what point during ventricular contraction blood begins to flow into the aorta. As aortic pressure increases, the heart must pump more forcefully (increased contractility) in order to maintain stroke volume.

Diff: 9  Page Ref: 387

9) While electrical events in the ventricular contractile cell initiate contraction, intracellular second messengers modify ventricular contractility. Describe the second-messenger pathway that underlies the increase in ventricular contractility.

Answer: Each of the effects on ventricular contractility are in some way related to changes in calcium or sensitivity to calcium. Hormones can alter contractility by their action on second-messenger systems. Epinephrine and norepinephrine binding to beta adrenergic receptors on the ventricular cell membrane increase the activity of the enzyme adenylate cyclase. Adenylate cyclase catalyzes the conversion of ATP to cyclic AMP (cAMP). cAMP increases the amount of calcium that enters the cell during the contractile cycle by enhancing the amount of calcium that can enter the cell through its sarcolemma calcium channels. This elevation in intracellular calcium will increase the interaction between actin and myosin by exposing more actin molecules through its binding to troponin. At the same time, calcium also triggers an increase in the release of calcium from the sarcoplasmic reticulum.

Diff: 6  Page Ref: 389
Short Answer Questions

Using Figure 13.1, answer the following questions:

1) Based upon Figure 13.1, what happens within the ventricular contractile cell to cause a shift from the initial Starling’s curve downward?
   Answer: Decreased sympathetic activity and binding of epinephrine to beta adrenergic receptors reduces cAMP, thereby decreasing intracellular calcium, which decreases the amount of troponin bound by calcium (less actin available to interact with myosin). Calcium levels are decreased by a reduction in the amount of calcium that enters the cell, which further decreases intracellular calcium by decreasing calcium release from the sarcoplasmic reticulum.
   Diff: 7 Page Ref: 390

2) Based upon Figure 13.1, identify all of the situations that would cause a leftward movement along one of the Starling’s curves.
   Answer: A decrease in central venous pressure would reduce venous return, thereby allowing less blood to fill the ventricle. At the same time, a reduction in the contraction of the atrium would also decrease the filling of the ventricle, as would a reduction in time for ventricular filling.
   Diff: 6 Page Ref: 390

3) According to Figure 13.1, any change from the initial Starling’s curve is mediated by changes in ________.
   Answer: sympathetic nervous activity
   Diff: 4 Page Ref: 390
4) Based upon Figure 13.1, if end-diastolic volume is 100 mL at rest, what would stroke volume be if sympathetic nervous activity increased?
Answer: 87 mL
Diff: 5  Page Ref: 390

5) Based upon Figure 13.1, if end-diastolic volume at rest is increased from 100 to 120 mL, what will the new stroke volume be?
Answer: 83 mL
Diff: 5  Page Ref: 390

6) Based upon Figure 13.1, if sympathetic activity is decreased from rest, and end-diastolic volume increases to 110 mL, what is the new stroke volume?
Answer: 64 mL
Diff: 5  Page Ref: 390

7) Blood returns to the left atrium via what blood vessels?
Answer: pulmonary veins
Diff: 3  Page Ref: 364

8) In pulmonary capillaries, oxygen diffuses from _______ to _______.
Answer: tissue : blood
Diff: 3  Page Ref: 364

9) Blood in pulmonary arteries is (oxygenated / deoxygenated).
Answer: deoxygenated
Diff: 4  Page Ref: 364

10) Blood flows through the different organs in (parallel / series).
Answer: parallel
Diff: 3  Page Ref: 364

11) What are the three layers of the heart, from inside to outside?
Answer: endothelium, myocardium, and epicardium
Diff: 4  Page Ref: 366

12) Blood is moved through the pulmonary vasculature by pressure generated within the ________.
Answer: right ventricle
Diff: 3  Page Ref: 364

13) What two types of cell junctions are located in intercalated disks?
Answer: gap junctions : desmosomes
Diff: 4  Page Ref: 369

14) What component of the conduction pathway transmits the action potential to the ventricular contractile cells?
Answer: Purkinje fibers
Diff: 5  Page Ref: 370

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15) What is the pacemaker of the heart?
Answer: sinoatrial (SA) node
Diff: 3 Page Ref: 370

16) The initial depolarization that occurs in pacemaker cells is caused by closing of ________
channels and opening of ________ channels.
Answer: potassium : funny
Diff: 6 Page Ref: 373

17) The depolarization of the action potential in the pacemaker cells is driven by the rapid influx
of ________ ions through ________ channels.
Answer: calcium : L-type calcium
Diff: 5 Page Ref: 373

18) An increase in the rate (slope) of slow depolarization will result in a(n) ________ in the
frequency of action potentials.
Answer: increase
Diff: 4 Page Ref: 386

19) What effect will membrane hyperpolarization have on an L-type calcium channel?
Answer: the channel will be induced to close
Diff: 6 Page Ref: 373

20) Depolarization of a cardiac contractile cell will cause the delayed rectifier potassium channel to
________, while the inward rectifier potassium channel will ________.
Answer: open : close
Diff: 6 Page Ref: 374

21) The resting membrane potential of cardiac contractile cells is (more / less / equally) negative
than that it is in neurons.
Answer: more
Diff: 5 Page Ref: 374

22) The period of ventricular contraction is called ________, whereas the period of ventricular
relaxation is called ________.
Answer: systole : diastole
Diff: 3 Page Ref: 379

23) The P wave of the electrocardiogram is created by ________.
Answer: the wave of depolarization moving along the atrium
Diff: 3 Page Ref: 377

24) The repolarization of the ventricle is reflected in the ________ of the electrocardiogram.
Answer: T wave
Diff: 5 Page Ref: 377

25) The ejection of blood from the left ventricle through the semilunar valve will begin once
pressure in the ventricle is (greater / less) than pressure in the aorta.
Answer: greater
Diff: 4 Page Ref: 379
26) The aorta acts as a (pressure/volume) reservoir, causing blood to move through the vasculature throughout the entire cardiac cycle.

   Answer: pressure
   Diff: 5 Page Ref: 382

27) The volume of blood in the ventricle during isovolumetric contraction is (end-diastolic volume / end-systolic volume).

   Answer: end-diastolic volume
   Diff: 4 Page Ref: 382

28) The volume of blood that is pumped by the heart every minute is determined by the equation ________.

   Answer: cardiac output = heart rate × stroke volume
   Diff: 5 Page Ref: 384

29) During (systole / diastole), aortic pressure reaches its highest value?

   Answer: systole
   Diff: 3 Page Ref: 381

30) As preload increases, the stroke volume (increases / decreases).

   Answer: increases
   Diff: 6 Page Ref: 390

31) As end-diastolic volume increases, stroke volume (increases / decreases).

   Answer: increases
   Diff: 4 Page Ref: 389

32) Write the equation relating stroke volume (SV), end-diastolic volume (EDV), and end-stroke volume (ESV).

   Answer: SV = EDV – ESV
   Diff: 4 Page Ref: 382
Chapter 14  The Cardiovascular System: Blood Vessels, Blood Flow, and Blood Pressure

Multiple Choice Questions

1) Which of the following equations correctly relates flow, pressure, and resistance?
   A) Flow = Pressure × Resistance
   B) Pressure = Flow × Resistance
   C) Resistance = Flow × Pressure
   D) Flow = Pressure + Resistance
   E) Flow = Pressure - Resistance

   Answer: B  
   Diff: 3  Page Ref: 396

2) What is the driving force for blood flow through the systemic circuit?
   A) capillary hydrostatic pressure
   B) central venous pressure
   C) left ventricular pressure
   D) mean arterial pressure
   E) right atrial pressure

   Answer: D  
   Diff: 4  Page Ref: 397

3) In comparison to the systemic circuit, the pulmonary circuit ________.
   A) is under greater pressure
   B) has lower blood flow
   C) has lower resistance to blood flow
   D) has an equal pressure gradient to drive blood flow
   E) transports deoxygenated blood

   Answer: C  
   Diff: 5  Page Ref: 398

4) Which of the following would increase the rate of blood flow through a blood vessel?
   A) constriction of the blood vessel
   B) increased viscosity of the blood
   C) increased pressure of the blood entering the vessel
   D) decreased radius of the vessel
   E) increased length of the vessel

   Answer: C  
   Diff: 4  Page Ref: 398
5) Which of the following equations is correct?
   A) cardiac output = stroke volume × heart rate
   B) cardiac output = mean arterial pressure × total peripheral resistance
   C) resistance = (length × radius⁴) / viscosity
   D) mean arterial pressure = cardiac output × stroke volume
   E) mean arterial pressure = resistance × viscosity

   Answer: A
   Diff: 4  Page Ref: 399

6) Which of the following is NOT a component of the microcirculation?
   A) arterioles
   B) venules
   C) capillaries
   D) metarterioles
   E) veins

   Answer: E
   Diff: 3  Page Ref: 399

7) The lumen of every blood vessel is lined by a monolayer of what cell type?
   A) endothelial cells
   B) smooth muscle cells
   C) fibroblasts
   D) erythrocytes
   E) platelets

   Answer: A
   Diff: 3  Page Ref: 400

8) What is/are the component(s) of a blood vessel’s extracellular matrix that provide(s) the tensile strength required to withstand pressure.
   A) Gap junctions
   B) Elastin
   C) Collagen
   D) Hemoglobin
   E) Albumin

   Answer: C
   Diff: 4  Page Ref: 400

9) The elastic nature of the largest blood vessel's walls allows them to act as a ________, maintaining the driving force for blood flow while the heart is relaxed during diastole.
   A) volume reservoir
   B) non-distensible structure
   C) non-compliant structure
   D) pressure reservoir
   E) resistor

   Answer: D
   Diff: 4  Page Ref: 401
10) The blood vessels of largest diameter are the _______; the blood vessels with the thickest walls are the _______.
   A) arteries : arteries
   B) veins : veins
   C) arteries : veins
   D) veins : arteries
   E) arteries : arterioles
   Answer: D
   Diff: 4   Page Ref: 401

11) What component of artery walls allows them to store energy that is later used to maintain continuous blood flow through the circulatory system?
   A) smooth muscle
   B) skeletal muscle
   C) elastin
   D) collagen
   E) endothelium
   Answer: C
   Diff: 5   Page Ref: 401

12) Arteries have _______ compliance and _______ resistance.
   A) high : high
   B) low : low
   C) high : low
   D) low : high
   E) zero : high
   Answer: B
   Diff: 6   Page Ref: 402

13) What is a measure of the change in vascular volume as pressure within the vessel is altered?
   A) Blood flow
   B) Diffusability
   C) Resistance
   D) Compliance
   E) The pressure gradient
   Answer: D
   Diff: 4   Page Ref: 402

14) A person goes to the doctor and is told his blood pressure is 90/60 and his pulse is 80. Which of the following is FALSE?
   A) Systolic pressure is 90 mm Hg.
   B) Pulse pressure is 80 mm Hg.
   C) Mean arterial pressure is 70 mm Hg.
   D) Diastolic pressure is 60.
   E) Heart rate is 80.
   Answer: B
   Diff: 4   Page Ref: 403
15) Blood pressure is usually estimated from indirect measurements of the pressure in what structure?
   A) left ventricle
   B) aorta
   C) radial artery
   D) brachial artery
   E) femoral artery
   Answer: D
   Diff: 4  Page Ref: 402

16) Resistance to blood flow is regulated primarily by what blood vessels?
   A) ventricle
   B) arteries
   C) arterioles
   D) capillaries
   E) veins
   Answer: C
   Diff: 3  Page Ref: 404

17) In the circulatory system, the largest pressure drop occurs across which blood vessels?
   A) arteries
   B) arterioles
   C) capillaries
   D) venules
   E) veins
   Answer: B
   Diff: 4  Page Ref: 405

18) The pulsatile nature of blood pressure is greatest in which blood vessels?
   A) arteries
   B) arterioles
   C) capillaries
   D) venules
   E) veins
   Answer: A
   Diff: 4  Page Ref: 405

19) The total cross-sectional area is greatest in which blood vessels?
   A) arteries
   B) arterioles
   C) capillaries
   D) venules
   E) veins
   Answer: C
   Diff: 4  Page Ref: 412
20) The contractile activity of smooth muscle cells within which type of blood vessel is primarily involved in the control of the organ blood flow and mean arterial pressure?
   A) arterioles
   B) capillaries
   C) arteries
   D) venules
   E) veins

   Answer: A
   Diff: 4   Page Ref: 405

21) Blood flow velocity is greatest in the _______ and slowest in the _______.
   A) arteries : veins
   B) arterioles : veins
   C) arteries : capillaries
   D) capillaries : arteries
   E) veins : arteries

   Answer: C
   Diff: 5   Page Ref: 412

22) Which of the following statements about smooth muscle in arterioles is FALSE?
   A) The muscle forms rings around the arteriole.
   B) Muscle contraction is under intrinsic controls.
   C) Muscle contraction is under extrinsic controls.
   D) The muscle has inherent (myogenic) tone.
   E) The muscle is multi-unit smooth muscle.

   Answer: E
   Diff: 5   Page Ref: 405

23) What is the purpose of extrinsic control of arteriolar smooth muscle contractile activity?
   A) regulate blood flow through specific capillary beds
   B) regulate mean arterial pressure
   C) regulate stroke volume
   D) regulate cardiac output
   E) regulate heart rate

   Answer: B
   Diff: 4   Page Ref: 405

24) Which of the following chemical’s concentration is NOT increased by an elevation in metabolic activity?
   A) potassium
   B) oxygen
   C) carbon dioxide
   D) hydrogen
   E) pyruvic acid

   Answer: B
   Diff: 3   Page Ref: 406
25) Chemicals released by metabolically active cells will cause which of the following?
   A) relaxation of arteriolar smooth muscle to increase blood flow
   B) relaxation of capillary smooth muscle to decrease blood flow
   C) contraction of arteriolar smooth muscle to increase blood flow
   D) contraction of arteriolar smooth muscle to decrease blood flow
   E) contraction of capillary smooth muscle to increase blood flow

   Answer: A  
   Diff: 5   Page Ref: 407

26) What is a decrease in tissue oxygen called?
   A) hypoxemia
   B) hyperemia
   C) hypoxia
   D) hyperoxia
   E) ischemia

   Answer: C  
   Diff: 4   Page Ref: 407

27) What is an increase in blood flow in response to an increase in tissue metabolic activity called?
   A) Hyperoxia
   B) Reactive hyperemia
   C) Active hyperemia
   D) Ischemia
   E) Hypoxia

   Answer: C  
   Diff: 4   Page Ref: 407

28) In response to a decrease in tissue metabolic activity, tissue oxygen concentrations ________, which causes a(n) ________.
   A) decrease : active hyperemic response
   B) decrease : increase in tissue ischemia
   C) decrease : dilation of the arterioles
   D) increase : active hyperemic response
   E) increase : constriction of the arterioles

   Answer: E  
   Diff: 5   Page Ref: 407

29) A decrease in pressure within an arteriole will initiate a(n) ________.
   A) myogenic response
   B) arterial baroreceptor reflex
   C) cardiac and venous baroreceptor reflex
   D) active hyperemia
   E) sinus arrhythmia

   Answer: A  
   Diff: 4   Page Ref: 408
30) Which of the following accurately compares active hyperemia to reactive hyperemia?
   A) One is an increase in blood flow, the other is a decrease.
   B) One is caused by an increase in metabolites, the other to a decrease in perfusion pressure.
   C) One is caused by increased metabolic activity, the other in response to release of an occlusion to blood flow.
   D) One involves vasodilation, the other vasoconstriction.
   E) One is an intrinsic response, the other an extrinsic response.

   Answer: C  
   Diff: 5  Page Ref: 408

31) An increase in the concentration of which of the following within the interstitial space surrounding an arteriole would cause that vessel to constrict?
   A) lactic acid
   B) oxygen
   C) prostacyclin
   D) bradykinin
   E) nitric oxide

   Answer: B  
   Diff: 4  Page Ref: 407

32) Which of the following substances is secreted by endothelial cells and causes vasoconstriction?
   A) oxygen
   B) nitric oxide
   C) adenosine
   D) bradykinin
   E) endothelin-1

   Answer: E  
   Diff: 5  Page Ref: 409

33) Which of the following substances is secreted by endothelial cells and causes vasodilation?
   A) oxygen
   B) nitric oxide
   C) adenosine
   D) bradykinin
   E) endothelin-1

   Answer: B  
   Diff: 5  Page Ref: 409

34) Which of the following is an important vasodilator in coronary arteries?
   A) oxygen
   B) nitric oxide
   C) adenosine
   D) bradykinin
   E) endothelin-1

   Answer: C  
   Diff: 4  Page Ref: 409

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35) During exercise, which organs receive an increase in the proportion of cardiac output delivered to it?
   A) brain and heart
   B) skeletal muscle, heart, and skin
   C) skeletal muscle, heart, and brain
   D) skeletal muscle, skin and brain
   E) gastrointestinal tract and skeletal muscle
   Answer: B
   Diff: 5 Page Ref: 410

36) Any change in the relative distribution of cardiac output to an organ is typically due to changes in which of the following?
   A) central venous pressure
   B) viscosity of the blood moving through that organ's vascular bed
   C) compliance of that organ's vascular bed
   D) mean arterial pressure
   E) resistance of that organ's vascular bed
   Answer: E
   Diff: 4 Page Ref: 406

37) During exercise, which of the following tissues receive less blood flow compared to resting conditions?
   A) gastrointestinal tract only
   B) brain only
   C) skin only
   D) heart only
   E) both gastrointestinal tract and skin
   Answer: A
   Diff: 5 Page Ref: 410

38) Which of the following would decrease mean arterial pressure?
   A) increase in heart rate
   B) increase in venous return
   C) increase in stroke volume
   D) increase in total peripheral resistance
   E) increase in arteriole diameter
   Answer: E
   Diff: 4 Page Ref: 410

39) What type of adrenergic receptor is found in the smooth muscle of most systemic arterioles?
   A) alpha only
   B) beta1 only
   C) beta2 only
   D) beta3 only
   E) both alpha and beta1
   Answer: A
   Diff: 4 Page Ref: 410
40) The effects of epinephrine on vascular resistance are dependent upon which of the following?
   A) concentration of local metabolites
   B) direction of change in mean arterial pressure
   C) specific baroreceptor activated (low or high pressure)
   D) relative distribution of alpha and beta receptors
   E) relative distribution of nicotinic and muscarinic receptors

   Answer: D
   Diff: 5   Page Ref: 411

41) In cardiac and skeletal muscle vasculature, the distribution of alpha and beta receptors are such that epinephrine will ________.
   A) induce a dilation that increases blood flow to these tissues
   B) induce a constriction that decreases blood flow to these tissues
   C) increase myocardial contractility
   D) increase skeletal muscle contractility
   E) have no affect on peripheral resistance

   Answer: A
   Diff: 5   Page Ref: 411

42) Arteriolar smooth muscle in what tissue tends to have beta2 receptors?
   A) brain
   B) skeletal muscle
   C) skin
   D) gastrointestinal tract
   E) liver

   Answer: B
   Diff: 4   Page Ref: 411

43) Drugs that block angiotensin-converting enzyme would cause which of the following?
   A) decrease mean arterial pressure
   B) stimulate reactive hyperemia
   C) increase heart rate
   D) decrease epinephrine release
   E) activate the parasympathetic nervous system

   Answer: A
   Diff: 5   Page Ref: 411

44) Fenestrated capillaries are unique in their ability to ________.
   A) allow few molecules to pass between endothelial cells
   B) allow relatively large molecules to pass between endothelial cells
   C) move molecules across endothelial cells by transcytosis
   D) restrict the passage of proteins across endothelial cells
   E) maintain a low permeability to small water-soluble molecules

   Answer: B
   Diff: 5   Page Ref: 413
45) What organ has capillaries that are the most restrictive to movement of hydrophilic solutes?
   A) liver
   B) brain
   C) bone marrow
   D) skeletal muscle
   E) kidneys
Answer: B
Diff: 4 Page Ref: 412

46) Which of the following would increase blood flow through a capillary bed?
   A) constriction of the arteriole leading into the capillary bed
   B) contraction of smooth muscle in metarterioles bypassing the capillary bed
   C) contraction of precapillary sphincters in the capillary bed
   D) decrease in blood pressure in the arteriole leading into the capillary bed
   E) increase in venous pressure
Answer: B
Diff: 6 Page Ref: 413

47) Which of the following would cause relaxation of precapillary sphincters?
   A) carbon dioxide
   B) sympathetic activity
   C) epinephrine
   D) parasympathetic activity
   E) vasopressin
Answer: A
Diff: 5 Page Ref: 413

48) Glucose moves across continuous capillary walls by what mechanism?
   A) diffusion
   B) facilitated diffusion
   C) primary active transport
   D) secondary active transport
   E) transcytosis
Answer: A
Diff: 4 Page Ref: 414

49) Which of the following is NOT a mechanism that enables molecules to move across capillary endothelial cells?
   A) transcytosis across endothelial cells
   B) movement through water–filled gaps between endothelial cells
   C) rapid diffusion of water–soluble molecules across endothelial cells
   D) diffusion of lipid–soluble molecules directly across the endothelial cell
   E) movement of exchangeable proteins across endothelial cells
Answer: C
Diff: 4 Page Ref: 414
50) ________ describes the movement of fluid out of the capillary, while ________ describes the movement of fluid into the capillary.
   A) Hydrostatic pressure : oncotic pressure
   B) Edema : venous pooling
   C) Venous pooling : edema
   D) Absorption : filtration
   E) Filtration : absorption
Answer: E
Diff: 4 Page Ref: 414

51) The portion of osmotic pressure exerted by ________ in the blood is known as colloid osmotic pressure.
   A) proteins
   B) small ions
   C) large ions
   D) lipids
   E) steroids
Answer: A
Diff: 4 Page Ref: 415

52) Under normal conditions, which Starling forces favor filtration?
   A) capillary hydrostatic pressure and interstitial fluid hydrostatic pressure
   B) capillary hydrostatic pressure and interstitial fluid osmotic pressure
   C) capillary hydrostatic pressure and plasma osmotic pressure
   D) interstitial fluid hydrostatic pressure and plasma osmotic pressure
   E) interstitial fluid hydrostatic pressure and interstitial fluid osmotic pressure
Answer: B
Diff: 5 Page Ref: 416

53) Which of the following inaccurately represents normal forces across capillary walls?
   A) Capillary hydrostatic pressure decreases from arteriole end to venous end.
   B) Interstitial fluid hydrostatic pressure increases from arteriole end to venous end.
   C) Capillary osmotic pressure is due primarily to plasma proteins.
   D) Interstitial fluid osmotic pressure is almost 0.
   E) At rest, net filtration occurs across capillary walls.
Answer: B
Diff: 5 Page Ref: 416

54) Given that the net filtration of fluid out of the capillaries averages about 3 liters per day, how is blood volume maintained in light of this apparent fluid loss?
   A) The lymphatic system returns filtered fluid to the blood.
   B) The net filtration is equally balanced by absorption.
   C) Gravity moves the fluid to the lowest point in the body, where the fluid is absorbed.
   D) While fluid moves out across the capillary, it tends to move inward across veins.
   E) The kidneys are involved in the reabsorption of the remaining fluid.
Answer: A
Diff: 5 Page Ref: 417
55) Which of the following is NOT a mechanism that alters the balance between filtration and absorption in the body?
   A) increasing capillary hydrostatic pressure within the feet as one stands
   B) increasing hydrostatic pressure gradient in cases of enhanced interstitial protein
   C) increasing the permeability of the capillaries in regions of tissue damage
   D) decreasing plasma protein synthesis in cases of liver damage
   E) increasing the elimination of plasma proteins in cases of kidney damage

Answer: B
Diff: 5 Page Ref: 416

56) Which of the following comparisons between systemic capillaries and lymphatic capillaries is true?
   A) Walls of systemic capillaries are more permeable.
   B) Net filtration occurs across systemic capillaries; net absorption occurs across lymphatic capillaries.
   C) Fluid enters systemic capillaries from systemic arterioles; fluid enters lymphatic capillaries from lymphatic veins.
   D) Pressure is higher in lymphatic capillaries.
   E) Blood cells are found in both types of capillaries.

Answer: B
Diff: 5 Page Ref: 421

57) Foreign materials are filtered out of the lymphatic fluid by what type of cell located within the lymph nodes?
   A) macrophages
   B) leukocytes
   C) platelets
   D) mast cells
   E) erythrocytes

Answer: A
Diff: 5 Page Ref: 421

58) Exchange between blood and interstitial fluid occurs across capillaries and, to a lesser extent, ________.
   A) arteries
   B) veins
   C) arterioles
   D) metarterioles
   E) venules

Answer: E
Diff: 4 Page Ref: 418

59) What region of the cardiovascular system contains valves?
   A) heart only
   B) metarterioles only
   C) veins only
   D) both the heart and veins
   E) the heart, metarterioles, and veins

Answer: D
Diff: 5 Page Ref: 418
60) Veins functions as _______ reservoirs due to their _______ compliance.
   A) pressure : high
   B) volume : high
   C) pressure : low
   D) volume : low
   E) pressure : lack of

   Answer: B
   Diff: 5 Page Ref: 418

61) Valves, which are _______, maintain the unidirectional movement of blood, thereby
   facilitating the return of blood to the heart.
   A) found in all veins
   B) found only in central veins
   C) found in all venules
   D) found only in peripheral veins
   E) found only in arteries

   Answer: D
   Diff: 5 Page Ref: 418

62) The high compliance of veins allows them to _______.
   A) act as pressure reservoirs
   B) accommodate large volumes of blood with little change in pressure
   C) rapidly change central venous pressure with small changes in blood volume
   D) hold only small volumes of blood
   E) provide the driving force for the movement of blood through the vasculature during
      diastole

   Answer: B
   Diff: 5 Page Ref: 418

63) At rest, the greatest proportion of blood volume is present within the _______.
   A) heart
   B) systemic arteries
   C) systemic capillaries
   D) systemic veins
   E) pulmonary veins

   Answer: D
   Diff: 4 Page Ref: 418

64) Which of the following would decrease central venous pressure?
   A) activity of skeletal muscles
   B) increased respiratory activity
   C) increased sympathetic activity
   D) increased blood volume
   E) standing up

   Answer: E
   Diff: 5 Page Ref: 419
65) An increase in the volume of blood ejected from the heart, with no change in total peripheral resistance, would ________.  
   A) elevate mean arterial pressure  
   B) elevate central venous pressure  
   C) reduce mean arterial pressure  
   D) elevate pulmonary venous pressure  
   E) reduce the stretch on the aorta  
   Answer: A  
   Diff: 4 Page Ref: 422

66) An increase in total peripheral resistance, in the absence of any change in cardiac output, would ________.  
   A) reduce mean arterial pressure  
   B) elevate central venous pressure  
   C) elevate mean arterial pressure  
   D) elevate pulmonary venous pressure  
   E) reduce the stretch on the aorta  
   Answer: C  
   Diff: 4 Page Ref: 422

67) The respiratory pump facilitates the return of blood to the heart by ________.  
   A) raising the pressure gradient between abdominal and thoracic veins during expiration  
   B) raising the pressure gradient between abdominal and thoracic veins during inspiration  
   C) decreasing the pressure gradient between abdominal and thoracic veins during inspiration  
   D) decreasing the pressure gradient between abdominal and thoracic veins during expiration  
   E) squeezing blood from the rhythmic contraction of the diaphragm muscle  
   Answer: B  
   Diff: 5 Page Ref: 419

68) Which of the following would NOT increase mean arterial pressure?  
   A) increased sympathetic activity to the heart  
   B) increased sympathetic activity to the veins  
   C) decreased parasympathetic activity to the heart  
   D) decreased parasympathetic activity to the arterioles  
   E) increased levels of epinephrine in the blood  
   Answer: D  
   Diff: 5 Page Ref: 425

69) The long-term regulation of arterial blood pressure involves ________.  
   A) the release of hormones over a period of minutes  
   B) the immediate change in activity of the nervous system  
   C) the control of blood volume by the kidneys  
   D) the control of peripheral resistance  
   E) the stimulation of an increase in urine flow through the kidneys  
   Answer: C  
   Diff: 5 Page Ref: 422
70) ________ are responsible for the detection of mean arterial pressure.
   A) Venous baroreceptors
   B) Arterial baroreceptors
   C) Aortic chemoreceptors
   D) Thermoreceptors
   E) Medullary chemoreceptors

   Answer: B
   Diff: 3 Page Ref: 423

71) Which of the following best classifies the baroreceptor reflex?
   A) spinal; autonomic; innate; monosynaptic
   B) spinal; autonomic; innate; polysynaptic
   C) cranial; autonomic; innate; polysynaptic
   D) cranial; somatic; conditioned; polysynaptic
   E) cranial; autonomic; conditioned; monosynaptic

   Answer: C
   Diff: 7 Page Ref: 425

72) As mean arterial pressure increases, the ________, informing the medulla oblongata that blood pressure has indeed increased.
   A) blood flow to the brain increases
   B) number of neurons stimulated within the aortic arch increases
   C) amplitude of the action potentials from the baroreceptors increases
   D) frequency of action potentials from the baroreceptors increases
   E) number of sympathetic neurons activated decreases

   Answer: D
   Diff: 5 Page Ref: 425

73) Information about mean arterial pressure is integrated within what area of the central nervous system?
   A) cervical spinal cord
   B) pons
   C) hypothalamus
   D) medulla oblongata
   E) cerebellum

   Answer: D
   Diff: 4 Page Ref: 424

74) Where is the cardiovascular control center?
   A) hypothalamus
   B) pons
   C) medulla oblongata
   D) adrenal medulla
   E) adrenal cortex

   Answer: C
   Diff: 4 Page Ref: 424
75) Which of the following is an inaccurate description of autonomic innervation of the cardiovascular system?
   A) Both sympathetic and parasympathetic neurons innervate the SA and AV nodes.
   B) Only sympathetic neurons provide significant innervation of the contractile cells of the heart.
   C) Both sympathetic and parasympathetic neurons innervate smooth muscle in arterioles.
   D) Only sympathetic neurons innervate smooth muscle in veins.
   E) Sympathetic activity increases cardiac output, whereas parasympathetic activity decreases cardiac output.

Answer: C
Diff: 5 Page Ref: 425

76) Which of the following will NOT occur in response to a decrease in the extent of stretch detected by a baroreceptor?
   A) increased urine flow
   B) increased ventricular contractility
   C) increased heart rate
   D) increased peripheral resistance
   E) increased venomotor tone

Answer: A
Diff: 4 Page Ref: 425

77) Which of the following is NOT altered within seconds to minutes of the baroreceptor reflex being activated?
   A) blood volume
   B) heart rate
   C) stroke volume
   D) total peripheral resistance
   E) venomotor tone

Answer: A
Diff: 5 Page Ref: 425

78) Which of the following does NOT occur in response to baroreceptors detecting an increase in mean arterial pressure?
   A) decreased heart rate
   B) decreased venous compliance
   C) decreased end-diastolic volume
   D) decreased frequency of sinoatrial node action potentials
   E) vasoconstriction

Answer: E
Diff: 5 Page Ref: 425
79) The chronic elevation in arterial pressure (hypertension) that occurs in many individuals results in ________.
   A) a decreased sensitivity of the baroreceptor that causes pressure to fluctuate
   B) a gradual increase in pressure that resets the baroreceptors
   C) the maintenance of a constant error signal by the baroreceptor
   D) the resetting of the baroreceptor to a lower pressure
   E) the baroreceptors becoming more sensitive to pressure

Answer: B
Diff: 5 Page Ref: 428

80) The reduction in organ blood flow that results from a decrease in mean arterial pressure would be exacerbated by the ________ that occurs as a consequence of the baroreceptor reflex.
   A) decreased compliance of the veins
   B) increased venous return
   C) increased stroke volume
   D) increased peripheral resistance
   E) increased ventricular contractility

Answer: D
Diff: 6 Page Ref: 426

81) An increase in sympathetic nervous activity to arterioles will have little effect on the vasculature of the ________.
   A) kidneys
   B) skeletal muscles
   C) gastrointestinal tract
   D) heart and kidneys
   E) brain and heart

Answer: E
Diff: 5 Page Ref: 426

82) The hormone vasopressin acts in the short term to ________ and in the long term to ________, thereby increasing mean arterial pressure.
   A) decrease urine outflow : vasoconstrict arterioles
   B) vasoconstrict arterioles : decrease urine outflow
   C) vasodilate arterioles : increase urine outflow
   D) increase urine outflow : vasodilate arterioles
   E) vasodilate arterioles : decrease urine outflow

Answer: B
Diff: 5 Page Ref: 427

83) Due to their location, baroreceptors in the large systemic veins and the heart function primarily to monitor ________.
   A) heart rate
   B) total peripheral resistance
   C) blood flow
   D) mean arterial pressure
   E) blood volume

Answer: E
Diff: 5 Page Ref: 428
84) Which of the following describes rhythmic changes in sympathetic and parasympathetic activity that affect heart rate coincident with respiration?
   A) pulmonary sinus rhythmia
   B) pulmonary sinus arrhythmia
   C) respiratory sinus rhythmia
   D) respiratory sinus arrhythmia
   E) lung sinus rhythmia

Answer: D  
Diff: 5  Page Ref: 429

85) An increase in arterial carbon dioxide levels activates _______, which causes a _______ in heart rate and a _______ in total peripheral resistance.
   A) baroreceptors : decrease : decrease
   B) baroreceptors : increase : increase
   C) baroreceptors : decrease : increase
   D) chemoreceptors: decrease : decrease
   E) chemoreceptors : decrease : increase

Answer: D  
Diff: 7  Page Ref: 430

86) Which of the following will NOT occur as a consequence of the activation of the baroreceptor reflex that would occur in response to an increased heat load within the body?
   A) an increase in heart rate
   B) an increase in stroke volume
   C) an increase in resistance within the skeletal muscle vasculature
   D) an increase in vasoconstriction
   E) an increase in resistance within the skin vasculature

Answer: E  
Diff: 6  Page Ref: 430

87) The increase in stroke volume that occurs during exercise is caused primarily by _______.
   A) a decrease in end-systolic volume
   B) an increase in end-diastolic volume
   C) an increase in venous return
   D) a decrease in peripheral resistance
   E) an increase in myocardial contractility

Answer: E  
Diff: 6  Page Ref: 431

88) The increase in blood flow to active skeletal muscle relative to other organs is largely caused by the _______.
   A) decrease in metabolic factors within the muscle
   B) decrease in parasympathetic activity
   C) increase in sympathetic activity
   D) increase in local metabolic factors within the muscle
   E) increase in parasympathetic activity

Answer: D  
Diff: 5  Page Ref: 431
89) Which of the following correctly describes sympathetic control of blood vessels in the skin during thermoregulation?
   A) Heat causes an increase in sympathetic activity, resulting in vasodilation.
   B) Heat causes a decrease in sympathetic activity, resulting in vasodilation.
   C) Heat causes an increase in sympathetic activity, resulting in vasoconstriction.
   D) Heat causes a decrease in sympathetic activity, resulting in vasoconstriction.
   E) Heat activates the parasympathetic activity and has no effect on the sympathetic nervous system.
   Answer: B
   Diff: 6 Page Ref: 430

90) Mean arterial pressure can be increased by all of the following except ________.
   A) increasing venous return
   B) decreasing end-diastolic volume
   C) increasing heart rate
   D) increasing sympathetic activity
   E) increasing blood volume
   Answer: B
   Diff: 4 Page Ref: 423

91) Which of the following can cause vasoconstriction?
   A) increase in carbon dioxide
   B) increase in osmolarity
   C) release of nitric oxide
   D) angiotensin II
   E) an increase in histamine
   Answer: D
   Diff: 4 Page Ref: 409

92) The primary mechanism for exchange of substances across the capillary wall is ________.
   A) diffusion
   B) mediated transport
   C) vesicle transport
   D) active transport
   E) bulk flow
   Answer: A
   Diff: 4 Page Ref: 414

93) Given the following information, calculate the net filtration pressure: capillary hydrostatic pressure = 30 mm Hg, interstitial fluid hydrostatic pressure = 5 mm Hg, capillary oncotic pressure = 25 mm Hg, and interstitial fluid oncotic pressure = 10 mm Hg.
   A) 40 mm Hg, favoring filtration
   B) ~40 mm Hg, favoring reabsorption
   C) 10 mm Hg, favoring filtration
   D) ~10 mm Hg, favoring reabsorption
   E) 0 mm Hg, no net force
   Answer: C
   Diff: 6 Page Ref: 416

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94) Which of the following can cause edema?
   A) increase in plasma proteins only
   B) damage to capillary walls only
   C) decreased venous pressure only
   D) both an increase in plasma proteins and a decrease in venous pressure
   E) both damage to capillary walls and decreased venous pressure
   Answer: B  
   Diff: 5  Page Ref: 416

95) Which of the following is an INCORRECT description of a blood vessel type?
   A) Arteries are elastic.
   B) The radius of arterioles can be regulated by both intrinsic and extrinsic controls.
   C) Capillary walls are comprised of only two cell layers, minimizing the distance for exchange.
   D) Veins have high compliance.
   E) Most of the blood volume at rest is in the systemic veins.
   Answer: C  
   Diff: 5  Page Ref: 411

96) During exercise, carbon dioxide produced by muscle cells causes vasodilation in skeletal muscle. This is an example of _______.
   A) active hyperemia
   B) reactive hyperemia
   C) hypoxia
   D) flow autoregulation
   E) ischemia
   Answer: A  
   Diff: 4  Page Ref: 407

97) Which of the following structures contains high pressure baroreceptors?
   A) aortic arch only
   B) carotoid sinus only
   C) right atrium only
   D) both the aortic arch and carotoid sinus
   E) aortic arch, right atrium, and carotoid sinus
   Answer: D  
   Diff: 5  Page Ref: 423

True/False Questions

1) The flow equation is: Flow = pressure gradient × resistance.
   Answer: FALSE  
   Diff: 3  Page Ref: 396

2) The pressure gradient for blood flow through the systemic circuit is the mean arterial pressure.
   Answer: TRUE  
   Diff: 3  Page Ref: 397
3) The more proteins in blood, the higher the blood viscosity.
   Answer: TRUE
   Diff: 3 Page Ref: 398

4) Flow through the pulmonary circuit is less than that through the systemic circuit due to a smaller pressure gradient.
   Answer: FALSE
   Diff: 4 Page Ref: 398

5) Resistance is lower in the pulmonary circuit than in the systemic circuit.
   Answer: TRUE
   Diff: 4 Page Ref: 398

6) The factor having the greatest influence on resistance to blood flow is the radius of the blood vessels.
   Answer: TRUE
   Diff: 4 Page Ref: 398

7) Smooth muscle is only found in arterioles.
   Answer: FALSE
   Diff: 4 Page Ref: 400

8) Blood flow through the systemic circulation is intermittent, flowing during systole and pausing during diastole.
   Answer: FALSE
   Diff: 3 Page Ref: 401

9) There is a progressive decrease in pressure throughout the vasculature as blood moves down its pressure gradient.
   Answer: TRUE
   Diff: 4 Page Ref: 404

10) Due to their diameter, capillaries have the greatest individual resistance, while the arteriole networks have the greatest total resistance.
    Answer: TRUE
    Diff: 4 Page Ref: 404

11) The distribution of cardiac output to each organ is determined by the relative resistance of that organ’s vascular bed compared with all other organs.
    Answer: TRUE
    Diff: 4 Page Ref: 405

12) An increase in blood flow to metabolically active tissue is called reactive hyperemia.
    Answer: FALSE
    Diff: 4 Page Ref: 407

13) Intrinsic regulation of arteriolar radius regulates mean arterial pressure.
    Answer: FALSE
    Diff: 4 Page Ref: 405
14) Flow autoregulation refers to an organ's ability to maintain perfusion pressure in the presence of a range of blood flows.

Answer: FALSE
Diff: 5   Page Ref: 408

15) Histamine induces vasodilation by stimulating the synthesis of nitric oxide.

Answer: TRUE
Diff: 5   Page Ref: 409

16) Intrinsic changes in arteriole radius have no effect on arterial blood pressure.

Answer: FALSE
Diff: 5   Page Ref: 410

17) Increases in angiotensin II levels in the blood will elevate total peripheral resistance.

Answer: TRUE
Diff: 4   Page Ref: 411

18) Walls of fenestrated capillaries are more permeable than the walls of continuous capillaries.

Answer: TRUE
Diff: 3   Page Ref: 412

19) Precapillary sphincters are controlled by local metabolites and the sympathetic nervous system, but not epinephrine.

Answer: FALSE
Diff: 5   Page Ref: 413

20) An increase in venous pressure can cause edema.

Answer: TRUE
Diff: 5   Page Ref: 417

21) There are no valves in the cranial veins.

Answer: TRUE
Diff: 4   Page Ref: 418

22) Veins have greater compliance than arteries.

Answer: TRUE
Diff: 4   Page Ref: 418

23) Increased respiratory activity facilitates venous return.

Answer: TRUE
Diff: 4   Page Ref: 429

24) Smooth muscle in the veins is innervated by the parasympathetic nervous system.

Answer: FALSE
Diff: 4   Page Ref: 420

25) Arterial baroreceptors are located in the left ventricle and aorta.

Answer: FALSE
Diff: 3   Page Ref: 423
26) The baroreceptor reflex responds to an increase in mean arterial pressure by increasing sympathetic nervous activity, while reducing parasympathetic nervous activity.
   Answer: FALSE
   Diff: 3  Page Ref: 425

27) The baroreceptor reflex plays a primary role in the long–term regulation of mean arterial pressure.
   Answer: FALSE
   Diff: 4  Page Ref: 422

28) Local controls of blood flow can override extrinsic controls.
   Answer: TRUE
   Diff: 4  Page Ref: 431

29) The velocity of blood flow is greatest in the arteries and slowest in the capillaries.
   Answer: TRUE
   Diff: 4  Page Ref: 412

30) The thoracic duct returns lymph to the blood by emptying into the pulmonary trunk.
   Answer: FALSE
   Diff: 4  Page Ref: 421
Matching Questions

Match the blood vessel to its description.

1) The elastic recoil of its walls during diastole causes a continuation of blood flow throughout the cardiac cycle.
   Diff: 4 Page Ref: 401
   A) artery
   B) vein
   C) capillary
   D) arteriole
   E) venule

2) Its high compliance allows it to hold a large volume of blood with little change in pressure.
   Diff: 4 Page Ref: 418

3) Regulation of its radius determines blood flow through specific organs.
   Diff: 4 Page Ref: 406

4) The smallest of blood vessels, their thin walls allow for ready exchange of material between blood and tissue.
   Diff: 2 Page Ref: 414

5) These blood vessels are slightly larger than capillaries and allow some exchange between blood and the tissue.
   Diff: 4 Page Ref: 418

Answers: 1) A 2) B 3) D 4) C 5) E
Match the following terms to the appropriate descriptions.

6) A decrease in tissue oxygen.
   Diff: 4 Page Ref: 407
   A) reactive hyperemia
   B) hypoxia

7) A decrease in blood supply to the tissue such that it does not meet the metabolic demands of the tissue.
   Diff: 4 Page Ref: 407
   C) active hyperemia
   D) myogenic response
   E) ischemia

8) An increase in blood flow to tissues in response to increased metabolic activity.
   Diff: 4 Page Ref: 407

9) A constriction of an arteriole in response to stretch of the arteriole smooth muscle.
   Diff: 4 Page Ref: 408

10) An increase in blood flow to tissues in response to a previous reduction in blood flow.
    Diff: 4 Page Ref: 408

Answers: 6) B 7) E 8) C 9) D 10) A
For each of the following, indicate whether it will cause vasoconstriction or vasodilation of the systemic arterioles, or neither.

11) Vasopressin.  
   *Diff: 3 Page Ref: 411*  
   A) vasoconstriction  
   B) vasodilation  
   C) neither

12) Oxygen.  
   *Diff: 3 Page Ref: 409*  

13) Angiotensin II.  
   *Diff: 3 Page Ref: 411*  

14) Carbon dioxide.  
   *Diff: 3 Page Ref: 409*  

15) Nitric oxide.  
   *Diff: 3 Page Ref: 409*  

16) Hydrogen ions.  
   *Diff: 3 Page Ref: 409*  

17) Sympathetic nervous system activity.  
   *Diff: 3 Page Ref: 411*  

18) Parasympathetic nervous activity.  
   *Diff: 3 Page Ref: 411*  

Essay Questions

1) Blood flowing through a vessel is subject to the same physical limitations as fluid flowing through a tube. Describe the physical properties of blood flow and blood pressure.

Answer: Blood flow = pressure gradient/resistance. This equation says that blood flow is inversely proportional to vascular resistance and proportional to the pressure gradient. Thus, a pressure gradient (the decreasing pressure that is observed through the vascular system) is the driving force for blood flow, and is hindered by the resistance of the vasculature. The greatest drop in pressure occurs in the resistance vasculature (arterioles). Blood will always move down the prevailing pressure gradient. This is true on both sides of the vasculature (in arteries and veins). Since central venous pressure (pressure within the thoracic veins) approaches zero, mean arterial pressure is a reflection of the pressure gradient that drives blood through the systemic circulation. The resistance of individual blood vessels is controlled by vessel radius, vessel length, blood viscosity, and the velocity profile of the flow stream. Of these four contributing factors, vessel radius is the most important since it can be regulated by changes in contractility of the smooth muscle cells. In addition, small changes in radius are reflected in large changes in resistance (fourth power). However, the vasculature is composed of a network of blood vessels. When the resistance of each vessel is included (resistors in parallel and series), this is called total peripheral resistance.

Diff: 7 Page Ref: 396
2) At this point, a number of equations in the text have expanded upon cardiac output = heart rate × stroke volume. These include equations for calculating blood flow, cardiac output (using variables other than those above), mean arterial pressure, and organ blood flow. Provide the equations for the above variables and briefly discuss their relevance.

Answer: Blood flow = pressure gradient/resistance. The flow of blood through vessels is driven by pressure. In particular, there must be a gradient of pressure to drive blood. However, the flow of blood through a vessel is hindered by the resistance of the vessel through which the blood is flowing. This equation can be used to describe blood flow though a specific vessel, blood flow through an organ, or the flow through the entire cardiovascular system (cardiac output). At the level of the individual vessel, resistance is determined by vessel radius, vessel length, viscosity of the fluid, and nature of the velocity profile of the fluid \((R = 8L \eta/\pi r^4)\). Blood flow through an organ is described by this equation: organ blood flow = mean arterial pressure/organ resistance. Since central venous pressure is near zero, the pressure gradient across an organ would be equal to mean arterial pressure. Thus, any change in mean arterial pressure will alter blood flow to every organ. However, the relative distribution of cardiac output is determined by the resistance of each organ’s vascular bed. If one were to look at the entire vascular bed as one resistance, cardiac output = mean arterial pressure/total peripheral resistance. Total peripheral resistance is influenced by the resistance of each vascular bed. In each of the calculations above, mean arterial pressure is the driving force for blood flow. The cardiac output equation above can be rearranged to reflect mean arterial pressure: mean arterial pressure = cardiac output × total peripheral resistance. However, since cardiac output = heart rate × stroke volume, this can replace cardiac output in that equation to produce this equation: mean arterial pressure = heart rate × stroke volume × total peripheral resistance. Thus, any change in these three variables will affect mean arterial pressure. Sympathetic nervous activity can affect all three of these variables. As flow increases with no change in resistance, pressure is elevated as blood moves into the aorta and it expands.

*Diff: 7  Page Ref: 399*
3) While the basic constituents of blood vessels are similar across all vessel types, the proportion of each constituent is quite different. Describe the structure of each class of blood vessel, including the functional significance of that structure.

Answer: The lumen of all blood vessels are lined by endothelial cells, a thin monolayer of epithelial cells in contact with blood. In arteries and veins, those endothelial cells are wrapped longitudinally by smooth muscle cells (SMC). The number and density of those SMCs is quite different between arteries and veins (arteries have a thicker SMC layer for a given diameter vessel than veins). The thickness of the SMC layer is related to that vessel’s ability to resist vascular pressure. In addition to SMCs, the strength of the blood vessel wall is determined by the amounts of elastin and collagen present. Those extracellular matrix proteins anchor SMCs. Elastin, as its name suggests, provides the elastic properties of blood vessels (compliance). Thus, more compliant vessels, such as the aorta and veins that expand as they fill with blood, have a greater elastin content. Collagen is what gives blood vessels their tensile strength. Small arteries and arterioles that are not expanded by the entry of blood are composed of more collagen than elastin. Thus, the extracellular matrix composition is reflective of the vessel’s function. Since large arteries are quite elastic, they are able to act as pressure reservoirs by expanding as they are filled with blood. When the heart ejects blood into the aorta against that arteriolar resistance, blood accumulates in the aorta, causing it to be stretched. This stretching is essential for the continuous delivery of blood to the systemic circulation. The energy stored in the stretched aorta continues to drive blood through the systemic vasculature during diastole, when the heart is not generating force. Veins act as volume reservoirs due to their high compliance. Compliance refers to a vessel’s ability to increase its volume (expand) with small changes in pressure. Nearly 60% of blood volume is located within systemic veins and venules. These vessels can act as a storage for blood against a possible loss of blood through injury or hemorrhage, allowing recruitment of that stored volume before substantial negative changes in cardiovascular function occur.

Diff: 7 Page Ref: 400

4) The smaller blood vessels, which include arterioles, capillaries, and venules, have unique functions. Identify the functions of each of the smaller blood vessels.

Answer: Arterioles are an integral part of the microcirculation (which includes capillaries and venules) that are termed the *resistance* vasculature because they provide the resistance that determines the distribution of cardiac output. Any change in contractile activity of arteriolar smooth muscle cells will alter resistance (relaxation induces a dilation that decreases resistance, whereas constriction increases resistance). Capillaries are the smallest and most numerous of the blood vessels. These vessels are composed of a thin endothelial layer with no smooth muscle cells. Thus, the high surface area in contact with blood and the thinness of the endothelial cell layer provide the perfect pathway for the exchange of substrates. There are two types of capillaries that differ in their permeabilities. *Continuous capillaries* are composed of tightly coupled endothelial cells that allow small ions to pass between cells and lipid soluble ions to move easily across them, while restricting the movement of larger ions like proteins. Some proteins are able to use energy to move directly across the endothelial cell by transcytosis. *Fenestrated capillaries* have larger gaps between endothelial cells, which allows both large and small ions to pass between the cells. Venules contain a sparse distribution of smooth muscle cells and, therefore, also function in the exchange of molecules.

Diff: 6 Page Ref: 404
5) The regulation of mean arterial pressure involves the interaction between extrinsic and intrinsic mechanisms. While the intrinsic mechanisms can affect mean arterial pressure, they also play an important role in the distribution of cardiac output to individual organs. Discuss the role of the intrinsic mechanisms in the control of organ resistance.

Answer: Intrinsic control refers to the concept that arterioles within an organ respond to the prevailing local environment in a manner that determines organ resistance (autoregulation). Smooth muscle cells of arterioles dilate and constrict in response to specific changes within an organ. The local factors that modulate arteriolar tone include metabolic activity of the organ, blood flow, perfusion pressure, and locally secreted chemical messengers. The metabolic activity of an organ can induce changes in a number of chemicals including oxygen, carbon dioxide, potassium, and hydrogen ions. Of these, oxygen is the only ion that decreases with increases in tissue metabolic activity. Ischemia (reduced tissue oxygen) results from a mismatch between the delivery and consumption of oxygen. Since oxygen causes arterioles to constrict, ischemia dilates arterioles. This dilation in response to increased metabolic activity is termed *active hyperemia*. In addition, increases in metabolic byproducts like carbon dioxide, hydrogen ions, and potassium that occur in active tissue cause arterioles to dilate. The concentration of these metabolites depends upon blood flow: greater flow removes more of the byproducts from tissues. Increases in blood flow following a reduction in blood flow is termed *reactive hyperemia*. Arterioles also respond to changes in perfusion pressure. An increase in perfusion pressure stretches the smooth muscle cells of the arteriole, causing that vessel to constrict. Once the vessel constricts, blood flow is reduced, which eventually stimulates an increase in blood flow as a consequence of an increased generation of metabolic byproduct. This interaction between flow and perfusion pressure that tends to keep blood flow within an organ constant is referred to as flow autoregulation. The endothelial cells play an important role in modifying arteriolar tone through the release of chemical messengers. Examples of these chemical messengers that induce a dilation are nitric oxide and prostacyclin, whereas endothelin induces a constriction. In addition, other chemicals that modify tone can be released.

*Diff: 8  Page Ref: 405*
6) The processes of filtration and absorption across the endothelial cells of capillaries is driven by Starling’s forces. List the components of Starling’s forces and describe how those forces determine the absorption of water across capillaries, including a discussion of how those forces are altered by standing and tissue injury.

Answer: The movement of fluid across the endothelial cell monolayer in capillaries is determined by the balance between hydrostatic and osmotic pressure gradients. The hydrostatic pressure gradient across the capillary is higher inside the capillary, meaning that the hydrostatic pressure gradient tends to move water out of the capillary. However, osmotic pressure is higher inside the capillary. Thus, the osmotic pressure gradient tends to move water back into the capillary. This osmotic pressure gradient is driven almost exclusively by differences in protein concentration across the capillary. Blood and interstitial fluid are essentially iso-osmotic with the exception of proteins, which are higher in the blood, creating a higher oncotic pressure within the blood. The presence of more osmotically active ions in the blood tends to pull water back into the capillary. In normal capillaries, the balance of these forces (net filtration pressure) is directed outward. This would lead to excess interstitial fluid if it were not for the lymphatic system. There are several conditions that can alter the balance between Starling’s forces. In the limbs, when we stand, the column of water in the veins creates a hydrostatic column that increases venous pressure. This increases hydrostatic pressure within the capillary, causing more water to move out of the capillary. In addition, when we are injured, capillaries are damaged and protein moves into the interstitial space. At the same time, histamine is released, which further increases interstitial osmotic pressure by allowing proteins to move into the interstitial space. As a consequence, less fluid is moved back into the blood and the injured region of tissue swells as a consequence of the outward movement of fluid. Alternatively, if the liver is damaged such that protein synthesis is reduced, the decrease in capillary oncotic pressure results in increased movement of fluid into the interstitial space.

Diff: 7 Page Ref: 415
7) Mean arterial pressure is regulated by a negative feedback system that involves the central nervous system. Discuss the afferent limb, the efferent limb, and the integrator of the baroreceptor reflex.

Answer: Mean arterial pressure is detected by arterial baroreceptors located within the blood vessel wall of the carotid sinus and the aortic arch. These receptors are stimulated by the extent of stretch of that wall, which is altered by changes in pressure. As mean arterial pressure increases, the vessel wall is further stretched, causing the frequency of action potentials from the baroreceptors to increase. This signal terminates within the medulla where it is integrated and a response initiated. Other afferent receptors that are not directly measuring mean arterial pressure but whose activation can affect mean arterial pressure include low-pressure baroreceptors, chemoreceptors, proprioceptors, and other internal receptors. Due to their location on the more compliant side of the vasculature (heart, large systemic veins, and pulmonary vessels), low-pressure baroreceptors respond to changes in central venous pressure (venous volume). Chemoreceptors located within the carotid arteries and aorta are involved in detecting changes in blood gases that include oxygen, carbon dioxide, or hydrogen ions. Proprioceptors provide information on the activity of skeletal muscles and joints to the central nervous system. Internal receptors, which include chemoreceptors, are located within muscles and respond to the increase in metabolites that occurs during exercise. At the same time that the medulla receives information from these receptors, it also receives inputs from other brain centers. These centers include the hypothalamus (the fight-or-flight response) and the cerebral cortex (in response to pain and emotions). The efferent portion of the baroreceptor reflex involves the autonomic nervous system. Parasympathetic nervous activity stimulates the sinoatrial node to decrease heart rate. Sympathetic nervous activity can affect mean arterial pressure through several pathways that include the sinoatrial node (increase heart rate), ventricles (increase ventricular contractility), arterioles (increase total peripheral resistance), and veins (decrease venous compliance).
8) The baroreceptors are responsible for detecting and responding to changes in mean arterial pressure. Follow the short-term and long-term responses of the baroreceptor reflex to an acute and chronic increase in mean arterial pressure.

Answer: An acute increase in mean arterial pressure would cause an increase in the stretch of the baroreceptor, causing an increase in the frequency of action potentials sent to the medulla. The medulla responds to that stimulus in the short term in a manner that rapidly decreases mean arterial pressure. That response includes both limbs of the autonomic nervous system: parasympathetic activity increases as sympathetic activity decreases. This causes a decrease in heart rate. At the same time, the reduction in sympathetic activity decreases stroke volume (ventricular contractility decreases), reduces venomotor tone (as veins relax as they become more compliant), and decreases total peripheral resistance (arterioles dilate). Arteriole dilation will also result from a decrease in angiotensin II and vasopressin levels within the blood. The reduction in angiotensin II occurs as a consequence of a decrease in the release of renin from the kidneys, which is required for the eventual conversion of angiotensinogen to angiotensin I and thereafter angiotensin II. Any changes in the release of vasopressin usually results from changes in the stimulation of the hypothalamus, which determines the release of vasopressin from the posterior pituitary. However, any changes in angiotensin II and vasopressin also have more long-term consequences. Angiotensin II stimulates the release of aldosterone from the adrenal cortex. Aldosterone and vasopressin stimulate the expansion of blood volume by decreasing urine output. Thus, a decrease in these hormones will decrease blood volume by increasing urine output (diuresis).

Diff: 7 Page Ref: 424

9) As mean arterial pressure changes, both short- and long-term changes are initiated that can interact with one another. Describe how a chronic hypotensive state could become life threatening.

Answer: Hypotension, a decrease in mean arterial pressure, stimulates the sympathetic nervous system to increase heart rate, stroke volume (ventricular contractility), venous tone (decreasing compliance), and total peripheral resistance (arteriole constriction). At the same time, increases in renin elevate aldosterone concentration and, thereby, blood volume in an attempt to provide a long-term solution to the hypotension. However, the increase in total peripheral resistance does not affect every vascular bed equally. While an increase in total peripheral resistance decreases blood flow to most organs, this is not the case for the heart and the brain. Each of these vascular beds are poorly influenced by sympathetic activity and, thus, resistance in these organs remains unaffected by sympathetic activity. This maintenance of blood flow to the brain and heart are indicative of the importance of oxygen delivery to these tissues for survival. If hypotension is maintained for more than an hour or two due to an inadequate expansion of blood volume (or continued hemorrhaging), the reduction in blood flow to the remainder of the organs of the body begins to reverse; the reduced blood flow causes the tissue to become ischemic, thereby inducing a local reflex vasodilation of the arterioles within those tissues and increasing blood flow. This further decreases total peripheral resistance and mean arterial pressure until the vasculature collapses (a dilated state). This is known as circulatory shock.

Diff: 6 Page Ref: 427
10) Both short- and long-term regulation of mean arterial pressure is mediated through the release of hormones. Describe the hormones discussed in Chapter 15 that are involved in the regulation of mean arterial pressure and how they are able to stimulate an increase in mean arterial pressure.

Answer: There are three hormones that play an important role in the regulation of mean arterial pressure: epinephrine, angiotensin II, and vasopressin (antidiuretic hormone). In the short term, each of these hormones will affect arteriolar diameter. Angiotensin II and vasopressin increase arteriolar resistance by inducing arteriolar vasoconstriction. Responses to epinephrine are more complex, and are determined by the distribution of adrenergic receptors on the smooth muscle cells: binding to beta receptors stimulates a vasodilation while binding to alpha receptors stimulates a vasoconstriction. The distribution of these receptors varies by vascular bed with cardiac and skeletal muscle having a predominance of beta receptors that causes their arterioles to dilate in response to epinephrine. Changes in vasopressin and angiotensin II concentrations also have long-term effects that include increasing blood volume through decreases in urine output. Angiotensin II alters urine output by stimulating the release of aldosterone from the adrenal cortex while vasopressin directly affects urine output. Increases in blood volume enhance central venous pressure and cause an increase in end-diastolic volume. Any increase in end-diastolic volume enhances the contractility of the heart and stimulates an increase in stroke volume, thereby increasing mean arterial pressure. Vasopressin is stimulated by the low-pressure baroreceptors whereas renin release, which ultimately increases angiotensin II, is stimulated by arterial baroreceptors and the direct effect of arterial pressure on the kidneys.

Diff: 6  Page Ref: 427

Short Answer Questions

1) Write the equation relating flow to resistance and a pressure gradient.

Answer: flow = pressure gradient / resistance

Diff: 4  Page Ref: 396

2) The driving force for blood flow through the systemic circuit is _______.

Answer: mean arterial pressure

Diff: 4  Page Ref: 397

3) Contraction of smooth muscle cells in arterioles causes (vasoconstriction / vasodilation).

Answer: vasoconstriction

Diff: 3  Page Ref: 405

4) Arteries are (elastic / compliant).

Answer: elastic

Diff: 3  Page Ref: 401

5) Arteries function as a (pressure / volume) reservoir.

Answer: pressure

Diff: 4  Page Ref: 401

6) Arteriolar tone is due to the presence of _______ in the smooth muscle.

Answer: pacemaker cells and gap junctions

Diff: 4  Page Ref: 405

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7) A decrease in blood flow to less than what is necessary to keep up with metabolic demands is called _______.
   Answer: ischemia
   Diff: 4   Page Ref: 407

8) Local controls that tend to keep blood flow constant is called _______.
   Answer: flow autoregulation
   Diff: 5   Page Ref: 408

9) Bradykinin causes vasodilation by stimulating the release of _______ from endothelial cells.
   Answer: nitric oxide
   Diff: 6   Page Ref: 409

10) Epinephrine triggers vasodilation by binding to _______ receptors and vasoconstriction by binding to _______ receptors.
    Answer: beta2 : alpha
    Diff: 5   Page Ref: 411

11) To produce angiotensin II, _______ must be secreted from the kidney to convert angiotensinogen to angiotensin I, which is then converted to angiotensin II by _______.
    Answer: renin : angiotensin converting enzyme
    Diff: 6   Page Ref: 411

12) Fenestrations in capillaries of the (kidney / liver) are necessary to allow newly synthesized proteins to enter the plasma?
    Answer: liver
    Diff: 5   Page Ref: 413

13) Blood vessels that bypass capillary beds are called _______.
    Answer: metarterioles
    Diff: 4   Page Ref: 413

14) Bulk flow of fluid from inside a capillary into interstitial fluid is called _______.
    Answer: filtration
    Diff: 3   Page Ref: 414

15) The fluid within the lymphatic vessels is called _______.
    Answer: lymph
    Diff: 2   Page Ref: 421

16) The lymphatic system empties into the (right atrium / left atrium).
    Answer: right atrium
    Diff: 3   Page Ref: 421

17) A drop in mean arterial pressure that results from standing up is called _______.
    Answer: orthostatic hypotension
    Diff: 4   Page Ref: 420

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18) Smooth muscle in the veins has what type of adrenergic receptor?
   Answer: alpha
   Diff: 4 Page Ref: 420

19) Write the equation relating cardiac output, mean arterial pressure, and total peripheral resistance.
   Answer: MAP = CO × TPR
   Diff: 4 Page Ref: 421

20) Where are the arterial baroreceptors located?
   Answer: aortic arch and carotid sinuses (carotid arteries)
   Diff: 4 Page Ref: 423

21) What are the two functions of increasing blood flow to the skin during exercise?
   Answer: facilitate dissipation of heat; provide energy for sweat production
   Diff: 5 Page Ref: 431

22) Increases in capillary hydrostatic pressure will lead to a(n) (increase / decrease) in the amount of fluid filtered by the capillaries.
   Answer: increase
   Diff: 4 Page Ref: 416

23) Increases in capillary osmotic pressure will lead to a(n) (increase / decrease) in the amount of fluid filtered by the capillaries.
   Answer: decrease
   Diff: 4 Page Ref: 416

24) In response to a decrease in the stretch of a baroreceptor, sympathetic nervous activity will _______ while parasympathetic nervous activity will _______.
   Answer: increase : decrease
   Diff: 5 Page Ref: 425

25) An increase in the stretch of a baroreceptor will cause venomotor tone to _______ while ventricular contractility will _______.
   Answer: decrease : decrease
   Diff: 5 Page Ref: 425

26) What structures of the cardiovascular system are innervated by the sympathetic nervous system, but not by the parasympathetic nervous system?
   Answer: ventricular myocardium, arteriole smooth muscle, venous smooth muscle
   Diff: 4 Page Ref: 425

27) Calculate the net filtration pressure given the following information: capillary blood pressure = 40 mm Hg, interstitial fluid hydrostatic pressure = 2 mm Hg, plasma osmotic pressure = 20 mm Hg, and interstitial fluid osmotic pressure = 5 mm Hg. Does filtration or absorption occur across this capillary wall?
   Answer: 23 mm Hg; filtration
   Diff: 7 Page Ref: 416
Chapter 15  The Cardiovascular System: Blood

Multiple Choice Questions

1) What is a hematocrit measuring?
   A) the amount of hemoglobin in blood
   B) the percentage of blood that is comprised of red blood cells
   C) the percentage of blood that is comprised of red and white blood cells
   D) the percentage of blood that is comprised of plasma
   E) the amount of oxygen that can be transported by blood

   Answer: B
   Diff: 3  Page Ref: 436

2) A normal hematocrit is approximately what value?
   A) 10
   B) 25
   C) 45
   D) 75
   E) 90

   Answer: C
   Diff: 3  Page Ref: 437

3) Which of the following is NOT a protein found in plasma?
   A) albumin
   B) hormones
   C) carbonic anhydrase
   D) fibrinogen
   E) globulins

   Answer: C
   Diff: 4  Page Ref: 437

4) What is the most abundant plasma protein?
   A) albumin
   B) hemoglobin
   C) fibrinogen
   D) globulins
   E) carbonic anhydrase

   Answer: A
   Diff: 4  Page Ref: 437

5) A majority of the protein present within blood is synthesized within what organ?
   A) skeletal muscles
   B) liver
   C) central nervous system
   D) kidneys
   E) lungs

   Answer: B
   Diff: 4  Page Ref: 437
6) Which of the following statements is NOT accurate with respect to erythrocytes?
A) They lack nuclei.
B) They lack mitochondria.
C) They contain large amounts of hemoglobin.
D) They migrate into infected regions of tissue.
E) They transport oxygen and carbon dioxide.
Answer: D
Diff: 4  Page Ref: 438

7) Which of the following proteins is located inside erythrocytes?
A) hemoglobin only
B) spectrin only
C) carbonic anhydrase only
D) both hemoglobin and spectrin
E) hemoglobin, spectrin, and carbonic anhydrase
Answer: E
Diff: 5  Page Ref: 438

8) The iron-containing ring in hemoglobin is called _______ and it binds _______.
A) heme : carbon dioxide
B) spectrin : carbon dioxide
C) heme : oxygen
D) globin : oxygen
E) heme : carbon dioxide or oxygen
Answer: C
Diff: 4  Page Ref: 438

9) What enzyme catalyzes the conversion of carbon dioxide and water to carbonic acid, and where is this enzyme located?
A) carbonic anhydrase : plasma
B) carbonic dehydrogenase : plasma
C) carbonic anhydrase : hemoglobin
D) carbonic dehydrogenase : hemoglobin
E) carbonic anhydrase : erythrocytes
Answer: E
Diff: 4  Page Ref: 438

10) Carbonic acid reversibly dissociates to form what two products, without the need of an enzyme?
A) water and carbon dioxide
B) water and bicarbonate
C) carbon dioxide and bicarbonate
D) bicarbonate and hydrogen ion
E) water and hydrogen ion
Answer: D
Diff: 5  Page Ref: 438
11) Erythrocytes are synthesized in what organ and under the control of what chemical?
   A) liver : bilirubin
   B) bone marrow : erythropoietin
   C) kidney : transferrin
   D) liver : erythropoietin
   E) bone marrow : bilirubin
   Answer: B  
   Diff: 4  Page Ref: 441

12) What hematopoietic growth factor controls red blood cell synthesis, and what organ releases it?
   A) oxytocin : posterior pituitary
   B) calcitonin : kidney
   C) parathyroid hormone : parathyroid glands
   D) erythropoietin : kidney
   E) transferrin : bone marrow
   Answer: D  
   Diff: 3  Page Ref: 441

13) What triggers erythropoietin release?
   A) increased blood carbon dioxide levels
   B) decreased blood oxygen levels
   C) infection in the tissues
   D) infection in the blood
   E) damage to a blood vessel wall and subsequent exposure of collagen
   Answer: B  
   Diff: 4  Page Ref: 441

14) Pernicious anemia is associated with which of the following?
   A) abnormal hemoglobin
   B) inadequate bilirubin levels
   C) bleeding
   D) damage to the bone marrow
   E) insufficient vitamin B12
   Answer: E  
   Diff: 5  Page Ref: 441

15) Old red blood cells are removed from the blood by macrophages in what organ?
   A) bone marrow
   B) spleen
   C) kidney
   D) thymus
   E) pancreas
   Answer: B  
   Diff: 4  Page Ref: 441
16) During hemoglobin metabolism, what is the yellow pigmented substance produced by the removal of the iron group called?
   A) ferritin
   B) transferrin
   C) bile
   D) bilirubin
   E) myoglobin

   Answer: D
   Diff: 4   Page Ref: 442

17) Iron is transported in blood bound to what molecule?
   A) transferrin
   B) ferritin
   C) bilirubin
   D) hemoglobin
   E) heme transporters

   Answer: A
   Diff: 7   Page Ref: 442

18) What organ can store iron as transferrin?
   A) liver, only
   B) bone marrow, only
   C) intestinal tract, only
   D) liver and bone marrow
   E) none

   Answer: E
   Diff: 5   Page Ref: 442

19) What is the most abundant class of white blood cells?
   A) neutrophils
   B) basophils
   C) eosinophils
   D) monocytes
   E) lymphocytes

   Answer: A
   Diff: 3   Page Ref: 443

20) Which of the following leukocytes has cytoplasmic granules?
   A) neutrophils only
   B) basophils only
   C) eosinophils only
   D) both basophils and eosinophils
   E) basophils, eosinophils, and neutrophils

   Answer: E
   Diff: 4   Page Ref: 443
21) Which of the following leukocytes is a phagocyte?
   A) neutrophils only
   B) basophils only
   C) monocytes only
   D) both neutrophils and basophils
   E) both neutrophils and monocytes
   Answer: E
   Diff: 5   Page Ref: 443

22) Which type of leukocyte defends against parasitic infections?
   A) neutrophils
   B) eosinophils
   C) basophils
   D) monocytes
   E) erythrocytes
   Answer: B
   Diff: 4   Page Ref: 443

23) What type of leukocyte secretes heparin?
   A) neutrophils
   B) eosinophils
   C) basophils
   D) monocytes
   E) lymphocytes
   Answer: C
   Diff: 4   Page Ref: 444

24) B cells and T cells fall under what category of leukocytes?
   A) neutrophils
   B) eosinophils
   C) basophils
   D) monocytes
   E) lymphocytes
   Answer: E
   Diff: 4   Page Ref: 444

25) What type of leukocyte differentiates into macrophages in the tissues?
   A) neutrophils
   B) eosinophils
   C) basophils
   D) monocytes
   E) lymphocytes
   Answer: D
   Diff: 4   Page Ref: 444
26) What type of cell is the precursor for platelets?
   A) neutrophils
   B) erythrocytes
   C) megakaryocytes
   D) null cells
   E) macrophages

   Answer: C
   Diff: 4   Page Ref: 444

27) What is the stoppage of bleeding called?
   A) hemostasis
   B) homeostasis
   C) erythrostasis
   D) fibrinostasis
   E) vasculostasis

   Answer: A
   Diff: 3   Page Ref: 445

28) Which of the following is the first step of hemostasis?
   A) formation of a platelet plug
   B) formation of a blood clot
   C) formation of a fibrin clot
   D) vascular spasm
   E) secretion of histamine

   Answer: D
   Diff: 4   Page Ref: 445

29) Formation of a platelet plug is initiated by ______ binding to ______.
   A) thrombin : platelets
   B) arachidonic acid : collagen
   C) fibrin : erythrocytes
   D) ADP : platelets
   E) von Willebrand factor : collagen

   Answer: E
   Diff: 5   Page Ref: 445

30) Platelets become sticky when exposed to which of the following?
   A) von Willebrand factor
   B) prostacyclin
   C) fibrin
   D) thrombin
   E) serotonin

   Answer: A
   Diff: 5   Page Ref: 445
31) Which of the following chemicals involved in the development of a platelet plug is secreted by activated platelets in response to ADP?
   A) arachidonic acid
   B) serotonin
   C) epinephrine
   D) prostacyclin
   E) thromboxane A2

   Answer: E
   Diff: 4   Page Ref: 445

32) In healthy endothelial cells, arachidonic acid is converted to ________, which ________ formation of blood clots.
   A) thromboxane A2 : inhibits
   B) thromboxane A2 : stimulates
   C) prostacyclin : inhibits
   D) prostacyclin : stimulates
   E) nitric oxide : inhibits

   Answer: C
   Diff: 4   Page Ref: 446

33) In activated platelets, arachidonic acid is converted to ________, which ________ formation of blood clots.
   A) thromboxane A2 : inhibits
   B) thromboxane A2 : stimulates
   C) prostacyclin : inhibits
   D) prostacyclin : stimulates
   E) nitric oxide : inhibits

   Answer: B
   Diff: 4   Page Ref: 446

34) What converts fibrinogen to fibrin?
   A) prostacyclin
   B) thrombin
   C) von Willebrand factor
   D) arachidonic acid
   E) plasmin

   Answer: B
   Diff: 4   Page Ref: 446

35) Which of the following is NOT a function of thrombin?
   A) converting fibrinogen to fibrin
   B) activating factor X
   C) activating factor XIII
   D) providing a positive feedback for its own release
   E) platelet aggregation

   Answer: B
   Diff: 5   Page Ref: 446
36) The activation of thrombin by the intrinsic pathway is initiated by the ________.
   A) release of factor III from damaged tissue to activate factor VII
   B) subendothelial activation of factor XII
   C) subendothelial activation of factor X
   D) activation of factor XIII
   E) release of tissue factor from damaged tissue to directly activate factor X
   Answer: B
   Diff: 6 Page Ref: 447

37) The activation of thrombin by the extrinsic pathway is initiated by the ________.
   A) release of factor III from damaged tissue to complex with factor VII
   B) subendothelial activation of factor XII
   C) subendothelial activation of factor X
   D) activation of factor XIII
   E) release of tissue factor from damaged tissue to directly activate factor X
   Answer: A
   Diff: 6 Page Ref: 447

38) ________ activates protein C when it is bound to ________.
   A) Fibrin : plasmin
   B) Thrombin : fibrin
   C) Plasmin : fibrin
   D) Thrombin : thrombomodulin
   E) Fibrin : fibrinomodulin
   Answer: D
   Diff: 6 Page Ref: 448

39) What chemical dissolves blood clots?
   A) plasmin
   B) heparin
   C) fibrin
   D) protein C
   E) thromboxane A2
   Answer: A
   Diff: 4 Page Ref: 448

40) Hemophilia is a genetic clotting disorder usually characterized by the absence of what clotting factor?
   A) von Willebrand factor
   B) factor X
   C) factor XIII
   D) thrombin
   E) factor VIII
   Answer: E
   Diff: 5 Page Ref: 448
41) Low dosages of aspirin inhibit clotting by blocking the formation of which of the following?
   A) vitamin K
   B) thromboxane A2
   C) factor X
   D) thrombin
   E) factor VIII

Answer: B
Diff: 5 Page Ref: 448

42) High doses of aspirin can stimulate clotting by inhibiting the synthesis of ________.  
   A) prostacyclin
   B) protein C
   C) thrombomodulin
   D) tissue plasminogen activator
   E) plasmin

Answer: A
Diff: 5 Page Ref: 448

43) Most coagulation factors are synthesized by what organ?
   A) bone marrow
   B) kidney
   C) liver
   D) thymus
   E) heart

Answer: C
Diff: 4 Page Ref: 448

True/False Questions

1) Following centrifuging of blood, the middle layer contains platelets and leukocytes, and is  
   called the buffy coat.

Answer: TRUE
Diff: 3 Page Ref: 436

2) Most of the blood volume consists of erythrocytes.

Answer: FALSE
Diff: 3 Page Ref: 437

3) Glucose is transported in blood dissolved in plasma.

Answer: TRUE
Diff: 4 Page Ref: 437

4) Polycythemia is a decrease in the oxygen-carrying capacity of blood.

Answer: FALSE
Diff: 4 Page Ref: 437

5) Hemoglobin transports both oxygen and carbon dioxide.

Answer: TRUE
Diff: 4 Page Ref: 438
6) Carbonic anhydrase is an enzyme in erythrocytes essential for the transport of carbon dioxide as bicarbonate ions.
   Answer: TRUE
   Diff: 4   Page Ref: 438

7) Iron can be stored in the liver and spleen bound to ferritin.
   Answer: TRUE
   Diff: 5   Page Ref: 442

8) Jaundice is caused by an excess of iron in the blood.
   Answer: FALSE
   Diff: 5   Page Ref: 442

9) B lymphocytes directly kill infected cells or tumor cells.
   Answer: FALSE
   Diff: 6   Page Ref: 444

10) Platelets contain contractile proteins.
    Answer: TRUE
    Diff: 4   Page Ref: 446

11) Release of ADP by platelets is part of a positive feedback loop for platelet aggregation.
    Answer: TRUE
    Diff: 4   Page Ref: 445

12) In healthy endothelial cells, arachidonic acid is converted to thromboxane A2.
    Answer: FALSE
    Diff: 5   Page Ref: 446

13) Thrombin is activated by factor X.
    Answer: TRUE
    Diff: 5   Page Ref: 446

14) Collagen activates factor X.
    Answer: FALSE
    Diff: 5   Page Ref: 442

15) A fibrin clot can occur in the absence of platelet aggregation.
    Answer: FALSE
    Diff: 4   Page Ref: 446

16) Coagulation factors continuously circulate in the blood in their inactive form.
    Answer: TRUE
    Diff: 4   Page Ref: 446

17) Calcium is required for formation of a blood clot.
    Answer: TRUE
    Diff: 5   Page Ref: 447
18) Vitamin K is necessary for blood clot formation because it activates the extrinsic pathway.
   Answer: FALSE
   Diff: 4   Page Ref: 448

19) Protein C inhibits both the intrinsic and extrinsic clotting pathways.
   Answer: TRUE
   Diff: 5   Page Ref: 448

Matching Questions

Match the white blood cell to its description.

1) A phagocyte that also releases toxins from its cytoplasmic granules.
   Diff: 4   Page Ref: 443
   A) basophil
   B) monocyte
   C) neutrophil

2) The most abundant phagocyte in blood.
   Diff: 4   Page Ref: 443
   D) lymphocyte
   E) eosinophil

3) Non-phagocytic granulocytes.
   Diff: 5   Page Ref: 444

4) Differentiate into macrophages in the tissue.
   Diff: 3   Page Ref: 444

5) Include B cells and T cells.
   Diff: 3   Page Ref: 444

Answers: 1) E  2) C  3) A  4) B  5) D
Match the chemical to its function.

6) Forms the meshwork of the blood clot.
   Diff: 3   Page Ref: 446

   A) thrombin
   B) von Willebrand factor

7) Formed from arachidonic acid, this chemical facilitates platelet plug formation.
   Diff: 4   Page Ref: 446

   C) fibrin
   D) protein C
   E) plasmin

8) Converts fibrinogen to fibrin.
   Diff: 4   Page Ref: 446

   F) arachidonic acid
   G) thromboxane A2
   H) ADP
   I) prostacyclin

9) Formed from arachidonic acid, this chemical inhibits platelet plug formation.
   Diff: 5   Page Ref: 446

10) This substance binds to collagen and activates platelets.
    Diff: 4   Page Ref: 445

11) This substance inhibits both the intrinsic and extrinsic clotting pathways.
    Diff: 5   Page Ref: 448

12) This chemical is released from aggregated platelets and stimulates the platelets to produce thromboxane A2.
    Diff: 4   Page Ref: 445

13) This is a precursor for prostacyclin.
    Diff: 4   Page Ref: 446

14) This substance dissolves a blood clot.
    Diff: 4   Page Ref: 448


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Essay Questions

1) Blood is composed of fluid components and formed elements (cells). Describe the properties of the fluid and cellular components of blood.

Answer: Blood is composed of both fluid and cellular constituents that can be separated by centrifugation. The fluid portion of blood is termed plasma. Plasma is an aqueous solution that contains proteins, small nutrients, metabolic waste products, gases, and electrolytes. With respect to the small solutes (other than proteins), plasma is similar to interstitial fluid in its composition; it is the amount of protein that separates plasma from interstitial fluid. Those plasma proteins can be organized into three groups: albumin, globulins and fibrinogen. Albumin is synthesized by the liver and constitutes 60% of the total protein content of the blood. Globulins are a class of protein that comprise 36% of plasma proteins (they function in lipid transport, as steroid hormones, and in blood clotting). Fibrinogen is another protein synthesized in the liver, and is essential to formation of blood clots.

With respect to its cellular constituents, the proportion of blood volume that is composed of erythrocytes is termed the hematocrit. The cellular constituents of the blood are produced within bone marrow. The most abundant cell type are the erythrocytes (45% of blood volume). These red blood cells contain large quantities of hemoglobin. Hemoglobin is essential for transport of oxygen and carbon dioxide in the blood. These cells no longer function like other cells since they lack nuclei, mitochondria, and ribosomes. They have a relatively short lifespan (120 days) and are stimulated to proliferate by erythropoietin. The remainder of the cellular components of blood include leukocytes and platelets. Leukocytes function to defend the body against microorganisms and other foreign materials. Unlike red blood cells, these cells are not restricted to the circulation and can be found in most tissues. Platelets are important in blood clots. They are derived as cellular fragments from megakaryocytes.

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2) Oxygen and carbon dioxide are poorly soluble in plasma so they require erythrocytes for their transport in blood. Describe how erythrocytes transport these gases.

Answer: Erythrocytes contain two proteins necessary for the transport of oxygen and carbon dioxide: hemoglobin and carbonic anhydrase. Hemoglobin is a protein that contains four subunits, each of which has a heme group that can bind oxygen reversibly. Thus, hemoglobin can transport up to four oxygen molecules. Hemoglobin can also transport carbon dioxide, but the carbon dioxide binds reversibly to amino acids within the polypeptide chains, not to the heme group. Carbonic anhydrase is an enzyme that catalyzes the reversible reaction converting carbon dioxide and water to carbonic acid. The carbonic acid can then dissociate into a hydrogen ion and bicarbonate ion. Most of the carbon dioxide transported in blood is transported as bicarbonate ion.

Diff: 6  Page Ref: 438
3) Erythrocytes have no nucleus or organelles. Therefore, the lifespan is short. Describe the lifecycle of erythrocytes.

**Answer:** Erythrocytes are produced by the bone marrow at a rate of approximately 200 billion per day. The synthesis of erythrocytes is under control of erythropoietin, a hematopoietic growth factor released from the kidney in response to low oxygen levels. Erythrocytes differentiate from hematopoietic stem cells. Their synthesis requires iron, which is provided from dietary intake or limited iron stores in the liver, gastrointestinal tract, or spleen. Iron is stored in these organs bound to a protein called ferritin. For erythrocyte synthesis, iron is transported in the blood bound to another protein called transferrin. The transferrin releases the iron to cells in the bone marrow. In addition to iron, erythrocyte production requires folic acid and vitamin B12. As erythrocytes age, they lose their structural integrity. Old erythrocytes are phagocytosed by macrophages in the spleen, and to a lesser extent in the liver. As the erythrocytes are broken down, hemoglobin is released and metabolized to bilirubin. The bilirubin enters the bloodstream and travels to the liver, where it is further metabolized and the by-products are secreted in bile to the small intestine to be eliminated in the feces.

**Diff:** 7  **Page Ref:** 439

4) Leukocytes are necessary to protect the body against foreign substances, including bacteria and viruses. Describe the different classes of leukocytes and their major functions.

**Answer:** There are five types of leukocytes: neutrophils, eosinophils, basophils, monocytes, and lymphocytes. Neutrophils are the most abundant of the leukocytes and defend the body against bacteria and foreign particles by phagocytosis. Eosinophils are also phagocytes, but they tend to function more in defense against parasites. Eosinophils release toxins that attack parasites. Basophils may also defend against parasites by releasing toxic molecules. Basophils also release histamine, which contributes to allergic reactions, and heparin, an anticoagulant. Monocytes are phagocytes that differentiate into macrophages in the tissues. The macrophages then phagocytose microorganisms and foreign substances in the tissues. Lymphocytes are the primary cell type found in interstitial fluid. Lymphocytes include B lymphocytes (B cells), T lymphocytes (T cells), and null cells.

**Diff:** 6  **Page Ref:** 443
5) The ability to prevent blood loss from vessels that have been damaged is an important hemostatic function. Describe in detail the three steps in the process of hemostasis including the compounds involved in those processes.

Answer: Damage of the subendothelium initiates an intrinsic mechanism within the blood vessel that causes vasoconstriction (vascular spasm). This intrinsic vasoconstriction, coupled with activation of the sympathetic nervous system, reduces blood flow to the region of damage to immediately decrease blood loss. The next step is the formation of the platelet plug. Platelets are fragments of megakaryocytes that circulate within the blood. When tissues are damaged, von Willebrand factor binds to the exposed subendothelium, which stimulates platelet adhesion to the vessel wall. When platelets contact von Willebrand factor, they are activated, which makes them more sticky. Once activated, platelets release several compounds that include serotonin, epinephrine, ADP, and thromboxane A\(_2\). Serotonin and epinephrine stimulate further vasoconstriction of the vessels. ADP causes platelets to aggregate. This aggregation stimulates further release of ADP from the platelets and the release of thromboxane A\(_2\) which plays multiple roles. Thromboxane A\(_2\) stimulates platelet aggregation, ADP secretion, and vasoconstriction. The development of this platelet plug stimulates the formation of a clot. Clot formation requires the interaction between coagulation factors that are present within the blood. The most important coagulation factor is thrombin. Thrombin stimulates the conversion of fibrinogen to fibrin, which forms a meshwork that is stabilized by factor XIII. Prothrombin is converted into thrombin by factor X, which is activated by two independent pathways: intrinsic and extrinsic. The intrinsic pathway involves activating a circulating factor XII by exposure to the subendothelium, which ultimately activates factor X. At the same time, the extrinsic pathway is initiated by damaged tissue release of tissue factor (factor III). This factor complexes with factor VII to activate factor X.
6) The formation of platelet plugs and blood clots is an important hemostatic (defined by the elimination of bleeding) function of the blood. However, there are mechanisms within vessel walls that inhibit clot formation and dissolves those clots that have formed. Describe the mechanisms that inhibit clot formation and dissolve clots, including the relevant compounds.

Answer: The formation of the platelet plug involves ADP–stimulated synthesis of thromboxane A₂ from platelets. Arachidonic acid is the precursor for thromboxane A₂. In healthy endothelial cells, the same precursor is activated, but prostacyclin is produced rather than thromboxane A₂. In contrast to thromboxane A₂, prostacyclin inhibits platelet aggregation. At the same time, the nitric oxide synthetic pathway is also stimulated, which further inhibits platelet aggregation. With respect to the inhibition of clot formation, the initial phase of clotting causes a tissue factor pathway inhibitor to be secreted from healthy endothelial cells. This inhibits the extrinsic pathway of thrombin activation. At the same time, thrombomodulin is released from healthy endothelial cells, which complexes within thrombin and, rather than acting on fibrinogen, activates protein C. Protein C inhibits both the intrinsic and extrinsic pathways of thrombin activation. Once formed, clots are dissolved by plasmin (which enzymatically degrades fibrin), a protein derived from a plasminogen precursor. Plasminogen activators are secreted by a number of cells to activate plasmin and initiated clot dissolution. One of these compounds is tissue plasminogen activator (TPA) that is released from endothelial cells by the presence of fibrin. Clinically, aspirin acts as an anticoagulant at low doses by inhibiting the synthesis of thromboxane A₂.

Diff: 7   Page Ref: 447

Short Answer Questions

1) What is plasma from which clotting factors has been removed called?
   Answer: serum
   Diff: 3   Page Ref: 437

2) What is the most abundant plasma protein?
   Answer: albumin
   Diff: 4   Page Ref: 437

3) What cytosolic protein gives the membrane of erythrocytes its flexibility?
   Answer: spectrin
   Diff: 4   Page Ref: 438

4) _______ is located in _______ and functions in the transport of oxygen.
   Answer: Hemoglobin : erythrocytes
   Diff: 4   Page Ref: 438

5) The enzyme _______ catalyzes the reversible reaction whereby carbon dioxide and water are converted to _______.
   Answer: carbonic anhydrase : carbonic acid
   Diff: 5   Page Ref: 438

6) Synthesis of red blood cells is called _______ and occurs in the _______.
   Answer: erythropoiesis : bone marrow
   Diff: 5   Page Ref: 439
7) What is a premature erythrocyte that still contains some ribosomes called?
   Answer: reticulocyte
   Diff: 5   Page Ref: 1

8) What is defined as a decrease in the oxygen-carrying capacity of blood?
   Answer: anemia
   Diff: 3   Page Ref: 1

9) An increase in plasma levels of ______ causes a yellowish appearance of the skin and the whites of the eyes. This condition is called ______.
   Answer: bilirubin : jaundice
   Diff: 5   Page Ref: 442

10) Name the granulocytes.
    Answer: neutrophils, eosinophils, and basophils
    Diff: 4   Page Ref: 443

11) Which leukocytes are phagocytes?
    Answer: neutrophils, eosinophils, and monocytes
    Diff: 5   Page Ref: 443

12) In the tissues, monocytes differentiate into what type of cell?
    Answer: macrophages
    Diff: 4   Page Ref: 444

13) Kupffer cells are an example of (fixed / wandering) macrophages.
    Answer: fixed
    Diff: 6   Page Ref: 444

14) What three changes occur in platelets when they are activated by von Willebrand factor?
    Answer: they become sticky, their metabolism changes, they secrete products
    Diff: 7   Page Ref: 445

15) Activated platelets secrete what two chemicals that cause vasoconstriction?
    Answer: serotonin : epinephrine
    Diff: 4   Page Ref: 445

16) What is the sequence of reactions resulting in the formation of a blood clot around a platelet plug called?
    Answer: coagulation cascade
    Diff: 4   Page Ref: 446

17) Both the intrinsic and extrinsic pathways converge on activation of what factor that then activates prothrombin?
    Answer: factor X
    Diff: 4   Page Ref: 446

18) What is located on the surface of the platelet and is involved in the activation of thrombin?
    Answer: Platelet factor 3
    Diff: 6   Page Ref: 447
19) The stability of the fibrin meshwork results from the formation of covalent linkages that are catalyzed by what activated blood factor?

   Answer: factor XIII
   Diff: 5       Page Ref: 446

20) Thrombin can inhibit the formation of fibrin clots by binding with thrombomodulin, and the complex then activates what molecule?

   Answer: protein C
   Diff: 6       Page Ref: 448
Chapter 16  The Respiratory System:  
Pulmonary Ventilation

Multiple Choice Questions

1) Which of the following processes is NOT a part of external respiration?
   A) the movement of air into and out of the lungs by bulk flow
   B) the exchange of oxygen and carbon dioxide between the lungs and blood by diffusion
   C) the transportation of oxygen and carbon dioxide between the lungs and body tissues by the blood
   D) the exchange of oxygen and carbon dioxide between the blood and tissues by diffusion
   E) the use of oxygen and generation of carbon dioxide by the mitochondria during energy metabolism

Answer: E
Diff: 3  Page Ref: 452

2) Which of the following specifically describes the movement of air into and out of the lungs?
   A) Secondary ventilation
   B) Pulmonary ventilation
   C) Internal respiration
   D) Respiration
   E)Expiration

Answer: B
Diff: 2  Page Ref: 452

3) Which of the following is NOT a function of the respiratory system?
   A) vocalization
   B) electrolyte balance of blood
   C) acid-base balance of blood
   D) enhancing venous return
   E) heat loss

Answer: B
Diff: 4  Page Ref: 452

4) Which of the following statements about respiratory system anatomy is FALSE?
   A) Each lung has three lobes.
   B) The nasal cavity and oral cavity are parts of the upper airways.
   C) Both air and food travel in the pharynx.
   D) The trachea remains open at all times.
   E) The trachea branches into two bronchi, one of which travels to each lung.

Answer: A
Diff: 5  Page Ref: 452

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5) Food is prevented from entering the respiratory tract by the _______, which is/are located in the ________, the entry to the larynx.
   A) glottis : pharynx
   B) glottis : epiglottis
   C) vocal cords : glottis
   D) epiglottis : glottis
   E) bronchioles : bronchi

Answer: D
Diff: 4 Page Ref: 453

6) What structure bifurcates into the bronchi that enter the right and left lungs?
   A) trachea
   B) larynx
   C) glottis
   D) pharynx
   E) bronchioles

Answer: A
Diff: 3 Page Ref: 454

7) What are the smallest (and most distal) structures that remain a component of the conducting zone in the respiratory tract?
   A) bronchi
   B) secondary bronchi
   C) tertiary bronchioles
   D) terminal bronchioles
   E) respiratory bronchioles

Answer: D
Diff: 4 Page Ref: 455

8) What is the function of ciliated cells in the conducting zone?
   A) provide the rigid support that keeps the conducting zone open
   B) produce a viscous solution called mucus
   C) engulf foreign material that has been trapped within the mucus
   D) propel mucus containing trapped particles toward the glottis
   E) move macrophages down the conducting zone toward the respiratory zone

Answer: D
Diff: 4 Page Ref: 456

9) Which of the following becomes more abundant deeper into the conducting zone (from bronchi to bronchioles)?
   A) Cartilage
   B) Type I alveolar cells
   C) Cilia
   D) Goblet cells
   E) Smooth muscle

Answer: E
Diff: 5 Page Ref: 456
10) Which of the following is most abundant in the trachea and bronchi, becoming much less dense (and eventually absent) in the bronchioles.
   A) smooth muscle cells
   B) cartilage
   C) goblet cells
   D) macrophages
   E) type II alveolar cells

Answer: B  
**Diff: 4  Page Ref: 456**

11) The transition from the conducting to the respiratory zone in the lungs occurs at the _______.
   A) alveoli
   B) alveolar ducts
   C) tertiary bronchi
   D) terminal bronchioles
   E) respiratory bronchioles

Answer: E  
**Diff: 3  Page Ref: 457**

12) What structure is the region of the lungs where the majority of gas exchange occurs?
   A) respiratory bronchiole
   B) alveolar duct
   C) alveolus
   D) terminal bronchiole
   E) bronchus

Answer: C  
**Diff: 4  Page Ref: 457**

13) What are the most common cells that line the surface of the alveoli and are therefore associated with the exchange of gases within the lungs?
   A) Macrophages
   B) Goblet cells
   C) Type I alveolar cells
   D) Type II alveolar cells
   E) Type III alveolar cells

Answer: C  
**Diff: 3  Page Ref: 457**

14) What is the thin barrier (0.2 μm) that allows for the efficient exchange of gases between the lungs and the blood called?
   A) endothelial cell
   B) type I alveolar cell
   C) type II alveolar cell
   D) alveolar macrophage
   E) respiratory membrane

Answer: E  
**Diff: 4  Page Ref: 457**
15) What type of cells secrete mucus in the respiratory tract?
   A) type I alveolar cells
   B) type II alveolar cells
   C) goblet cells
   D) macrophages
   E) ciliated cells

   Answer: C  
   Diff: 4  Page Ref: 456

16) Which of the following decreases when traveling from upper airways to the conducting zone to the respiratory zone?
   A) cilia only
   B) smooth muscle only
   C) goblet cells only
   D) both cilia and goblet cells
   E) cilia, goblet cells, and smooth muscle

   Answer: D  
   Diff: 5  Page Ref: 456

17) What type of cell in the respiratory tract functions in phagocytosis of inhaled pathogens and foreign particles?
   A) type I alveolar cells
   B) type II alveolar cells
   C) goblet cells
   D) macrophages
   E) ciliated cells

   Answer: D  
   Diff: 4  Page Ref: 457

18) Which of the following is NOT a muscle involved in breathing?
   A) the pleural muscle
   B) the internal intercostal muscle
   C) the external intercostal muscle
   D) the diaphragm
   E) the abdominal muscle

   Answer: A  
   Diff: 6  Page Ref: 457

19) The ______ is bounded by the interior surface of the chest wall and the exterior surface of the lung.
   A) interpleural space
   B) alveolar space
   C) bronchiolar space
   D) intraparietal cavity
   E) thoracic cavity

   Answer: A  
   Diff: 4  Page Ref: 457

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20) What is the connective tissue surround each lung called?
   A) pleural sac
   B) visceral sac
   C) parietal sac
   D) peripulmonary sac
   E) alveolar sac

   Answer: A
   Diff: 4   Page Ref: 457

21) What is the dome-shaped muscle that separates the thoracic and abdominal cavities and plays an important role in breathing?
   A) internal intercostals
   B) sternocleidomastoid
   C) external intercostals
   D) diaphragm
   E) scalene

   Answer: D
   Diff: 2   Page Ref: 457

22) When air is no longer moving through the respiratory tract and the airway is open to the environment, the pressure within the lung is equal to _______.
   A) systolic blood pressure
   B) transpulmonary pressure
   C) intrapleural pressure
   D) atmospheric pressure
   E) end-diastolic pressure

   Answer: D
   Diff: 5   Page Ref: 460

23) The difference between what two pressures drives air into and out of the lungs?
   A) pulmonary venous : atmospheric
   B) central venous : intracoronary
   C) intrapleural : intra-alveolar
   D) atmospheric : intra-alveolar
   E) atmospheric : intrapleural

   Answer: D
   Diff: 3   Page Ref: 460

24) Which of the following occurs when intra-alveolar pressure exceeds atmospheric pressure?
   A) air moves into the lung
   B) air moves out of the lung
   C) the lung collapses
   D) the lung must be expanding
   E) intrapleural pressure is greater than intra-alveolar pressure

   Answer: B
   Diff: 4   Page Ref: 461
25) Which of the following pressure(s) vary rhythmically with respiration?
   A) atmospheric pressure only
   B) intrapleural pressure only
   C) intra-alveolar pressure only
   D) both intrapleural pressure and intra-alveolar pressure
   E) both atmospheric pressure and intrapleural pressure

   Answer: D
   Diff: 5 Page Ref: 461

26) The difference between intrapleural pressure and intra-alveolar pressure is ________.
   A) the driving force for air flow into and out of the lungs
   B) atmospheric pressure
   C) transpulmonary pressure
   D) approximately 100 mm Hg
   E) zero

   Answer: C
   Diff: 4 Page Ref: 461

27) Which of the following is a measure of the distending force across the lungs?
   A) intrapleural pressure
   B) intra-alveolar pressure
   C) transpulmonary pressure
   D) atmospheric pressure
   E) difference between intra-alveolar pressure and atmospheric pressure

   Answer: C
   Diff: 5 Page Ref: 461

28) Equilibration of pressure between the intrapleural space and the alveoli will lead to which of the following?
   A) air moving out of the lungs
   B) air moving into the lungs
   C) a pneumothorax (the lung will collapse)
   D) chronic obstructive pulmonary disease
   E) restrictive pulmonary disease

   Answer: C
   Diff: 5 Page Ref: 461

29) What is the volume of air present in the lungs when the lungs are at rest (in between breaths)?
   A) zero
   B) functional residual capacity
   C) residual volume
   D) total lung capacity
   E) tidal volume

   Answer: B
   Diff: 4 Page Ref: 460
30) Which of the following is true when the lung volume is equal to the functional residual capacity?
   A) the elastic recoil of the lungs is balanced by the elastic recoil of the chest wall
   B) intra-alveolar pressure is greater than atmospheric pressure
   C) intra-alveolar pressure is less than atmospheric pressure
   D) intra-alveolar pressure is less than intrapleural pressure
   E) intrapleural pressure is zero

   Answer: A

   Diff: 4 Page Ref: 460

31) As the lungs expand, intra-alveolar pressure _______ and air moves _______ the lungs.
   A) increases : out of
   B) increases : into
   C) decreases : out of
   D) decreases : into
   E) does not change : neither into nor out of

   Answer: D

   Diff: 3 Page Ref: 462

32) As the volume of the lung increases, atmospheric pressure _______.
   A) will not change
   B) increases
   C) decreases
   D) will follow Starling’s Law
   E) will follow the Ideal Gas Law

   Answer: A

   Diff: 2 Page Ref: 462

33) What does contraction of the diaphragm cause?
   A) decrease in the volume of the thoracic cavity and therefore a decrease in atmospheric pressure
   B) decrease in the volume of the thoracic cavity and therefore a decrease in intra-alveolar pressure
   C) increase in the volume of the thoracic cavity and therefore a decrease in intra-alveolar pressure
   D) decrease in the volume of the thoracic cavity and therefore an increase in intra-alveolar pressure
   E) increase in the volume of the thoracic cavity and therefore an increase in intra-alveolar pressure

   Answer: C

   Diff: 4 Page Ref: 463

34) What are the primary inspiratory muscles?
   A) external and internal intercostals
   B) diaphragm and external intercostals
   C) diaphragm and internal intercostals
   D) diaphragm and the external and internal intercostals
   E) diaphragm and abdominal muscles

   Answer: B

   Diff: 4 Page Ref: 463
35) The muscles of respiration are _______.
   A) skeletal muscle innervated by the somatic nervous system
   B) skeletal muscle innervated by the autonomic nervous system
   C) smooth muscle innervated by the somatic nervous system
   D) smooth muscle innervated by the autonomic nervous system
   E) smooth muscle without innervation

   Answer: A
   Diff: 4   Page Ref: 463

36) As the volume of the chest wall increases, the concomitant expansion of the lungs is due to
   a(n) _______.
   A) increase in atmospheric pressure
   B) decrease in intra-alveolar pressure
   C) increase in intrapleural pressure
   D) decrease in transpulmonary pressure
   E) increase in transpulmonary pressure

   Answer: E
   Diff: 6   Page Ref: 463

37) At rest, expiration is a(n) _______ process that involves _______.
   A) active : contraction of the diaphragm
   B) passive : relaxation of the diaphragm and external intercostals
   C) active : contraction of the internal intercostals
   D) passive : relaxation of the internal intercostals
   E) active : relaxation of the diaphragm

   Answer: B
   Diff: 5   Page Ref: 464

38) Which of the following pressures is lower during inspiration than during expiration?
   A) intra-alveolar pressure only
   B) transpulmonary pressure only
   C) intrapleural pressure only
   D) both intra-alveolar and transpulmonary pressures
   E) both intra-alveolar and intrapleural pressures

   Answer: E
   Diff: 6   Page Ref: 463

39) The compliance of the lungs can be determined by measuring the change in _______ for a
   given change in _______.
   A) lung volume : intra-alveolar pressure
   B) lung volume : transpulmonary pressure
   C) intra-alveolar pressure : lung volume
   D) airway resistance : lung volume
   E) lung volume : airway resistance

   Answer: B
   Diff: 6   Page Ref: 466
40) The compliance of the lung is determined by the elasticity of the lung and _______.
   A) volume  
   B) transpulmonary pressure  
   C) airway resistance  
   D) surface tension  
   E) intra-alveolar pressure  
   Answer: D  
   Diff: 5  Page Ref: 466

41) The surface tension of the alveolus is reduced by surfactants produced by what type of cells?
   A) ciliated  
   B) goblet  
   C) type I alveolar  
   D) type II alveolar  
   E) type III alveolar  
   Answer: D  
   Diff: 4  Page Ref: 466

42) Which of the following is NOT involved in altering the resistance of the airway to air movement?
   A) transpulmonary pressure  
   B) contractile activity of bronchiolar smooth muscle cells  
   C) secretion of mucus into the airway  
   D) pulmonary surfactant concentration  
   E) tractive forces exerted on the airway by surrounding tissue  
   Answer: D  
   Diff: 5  Page Ref: 468

43) How do tractive forces affect the airways during inspiration.
   A) increase in compliance  
   B) decrease in compliance  
   C) increase in airway resistance  
   D) decrease in airway resistance  
   E) bronchodilation  
   Answer: D  
   Diff: 4  Page Ref: 468

44) Which of the following is responsible for changes in airway resistance that occur in a single breath?
   A) surrounding atmospheric pressure  
   B) autonomic nervous system  
   C) passive forces exerted on the airways  
   D) contractility of smooth muscle cells  
   E) sensitivity of smooth muscle cells to allergens  
   Answer: C  
   Diff: 6  Page Ref: 468
45) Which of the following chemicals will NOT result in a decrease in airway resistance?
   A) norepinephrine
   B) epinephrine
   C) carbon dioxide
   D) bronchodilators
   E) histamine

   Answer: E
   Diff: 4   Page Ref: 469

46) Which of the following is NOT part of the response of an airway to specific allergens that initiate an asthmatic response?
   A) increased airway resistance
   B) increased inflammatory response
   C) increased histamine release
   D) increased secretion of mucus
   E) increased release of corticosteroids

   Answer: E
   Diff: 5   Page Ref: 469

47) What benefit are corticosteroids in the treatment of asthma?
   A) They induce bronchodilation.
   B) They induce bronchoconstriction.
   C) They reduce inflammation of the airways.
   D) They increase blood flow to the airways.
   E) They decrease mucus secretion into the airways.

   Answer: C
   Diff: 5   Page Ref: 469

48) A(n) ________ is used clinically to measure lung volumes and rates of air flow.
   A) spirometer
   B) electrocardiograph
   C) ratiometer
   D) electroencephalogram
   E) X-ray

   Answer: A
   Diff: 3   Page Ref: 469

49) What is the volume of air moved into and out of the lungs in a single breath during unforced breathing called?
   A) Total lung capacity
   B) Functional residual capacity
   C) Tidal volume
   D) Vital capacity
   E) Minute ventilation

   Answer: C
   Diff: 4   Page Ref: 469
50) The presence of a negative intrapleural pressure at maximum expiration is responsible for which of the following?
   A) residual volume
   B) functional residual volume
   C) tidal volume
   D) vital capacity
   E) functional residual capacity

Answer: A
Diff: 5  Page Ref: 470

51) The tidal volume and inspiratory reserve volume together make up which of the following?.
   A) Residual volume
   B) Functional residual capacity
   C) Total lung capacity
   D) Inspiratory capacity
   E) Vital capacity

Answer: D
Diff: 4  Page Ref: 470

52) Functional residual capacity is comprised of which of the following?
   A) vital capacity and expiratory reserve volume
   B) tidal volume and inspiratory reserve volume
   C) tidal volume and expiratory reserve volume
   D) tidal volume, inspiratory reserve volume, and expiratory reserve volume
   E) residual volume and expiratory reserve volume

Answer: E
Diff: 4  Page Ref: 470

53) Which of the following measurements cannot be determined by a spirometer?
   A) vital capacity
   B) tidal volume
   C) residual volume
   D) inspiratory capacity
   E) inspiratory reserve volume

Answer: C
Diff: 4  Page Ref: 470

54) A normal tidal volume at rest is approximately ______ mL.
   A) 100
   B) 500
   C) 1,000
   D) 5,000
   E) 10,000

Answer: B
Diff: 4  Page Ref: 470
55) A normal vital capacity is approximately ______ mL.
   A) 100
   B) 500
   C) 1,000
   D) 4,500
   E) 9,000
   Answer: D
   Diff: 4   Page Ref: 470

56) A healthy person can normally exhale what percentage of his/her vital capacity in one second?
   A) 10
   B) 20
   C) 50
   D) 80
   E) 100
   Answer: D
   Diff: 4   Page Ref: 471

57) In an obstructive disease, the lungs can become overinflated because the difficulty in ______
tends to ______.
   A) expiration: increase vital capacity
   B) expiration: decrease total lung capacity and vital capacity
   C) expiration: increase residual volume and total lung capacity
   D) inspiration: decrease total lung capacity and vital capacity
   E) inspiration: increase total lung capacity and vital capacity
   Answer: C
   Diff: 7   Page Ref: 471

58) A decrease in ______ is indicative of a restrictive pulmonary disease.
   A) minute ventilation
   B) tidal volume
   C) forced expiratory volume
   D) residual volume
   E) vital capacity
   Answer: E
   Diff: 6   Page Ref: 471

59) A decrease in ______ is indicative of an obstructive pulmonary disease.
   A) minute ventilation
   B) tidal volume
   C) forced expiratory volume
   D) residual volume
   E) forced vital capacity
   Answer: C
   Diff: 6   Page Ref: 473
60) What is the term for the volume of air moved into the lungs every minute?
   A) alveolar ventilation
   B) tidal volume
   C) total lung capacity
   D) minute ventilation
   E) pulmonary ventilation
   Answer: D
   Diff: 3   Page Ref: 471

61) What is the term for the volume of air that reaches the respiratory zone each minute?
   A) alveolar ventilation
   B) tidal volume
   C) total lung capacity
   D) minute ventilation
   E) pulmonary ventilation
   Answer: A
   Diff: 5   Page Ref: 471

62) What is the volume of the respiratory pathway that is not able to exchange gases (conducting pathway) called?
   A) dead volume
   B) functional dead space
   C) anatomical dead space
   D) residual volume
   E) functional residual volume
   Answer: C
   Diff: 4   Page Ref: 471

True/False Questions

1) Internal respiration refers to the use of oxygen and production of carbon dioxide by cells.
   Answer: TRUE
   Diff: 3   Page Ref: 452

2) The upper airway refers to the passageway for air that is located within the head and neck.
   Answer: TRUE
   Diff: 3   Page Ref: 453

3) The bronchus diverges into two lobes, the left and right lungs.
   Answer: FALSE
   Diff: 3   Page Ref: 454

4) The trachea rhythmically collapses and expands during the respiratory cycle.
   Answer: FALSE
   Diff: 4   Page Ref: 453

5) The conducting zone adjusts the temperature and humidity of the air entering the respiratory tract.
   Answer: TRUE
   Diff: 4   Page Ref: 455
6) The mucus escalator involves cilia causing movement of mucus with its trapped particles toward the alveoli where the particles can be engulfed by alveolar macrophages.
Answer: FALSE
Diff: 4 Page Ref: 456

7) Air flows between alveoli through pores.
Answer: TRUE
Diff: 4 Page Ref: 457

8) Alveolar macrophages function to engulf pathogens and foreign particles that have been inhaled into the lungs.
Answer: TRUE
Diff: 3 Page Ref: 457

9) Intrapleural fluid is incompressible, which means that its volume does not change even as the chest wall expands and contracts as we breathe.
Answer: TRUE
Diff: 4 Page Ref: 461

10) The elasticity of the lungs facilitates expansion during inspiration.
Answer: FALSE
Diff: 5 Page Ref: 461

11) The force that moves air into and out of the lungs is the difference in pressure between the atmosphere and alveolus.
Answer: TRUE
Diff: 3 Page Ref: 462

12) The distending pressure across the lungs is the intrapleural pressure.
Answer: FALSE
Diff: 5 Page Ref: 463

13) During expiration, the intra-alveolar pressure decreases, causing air to move out of the lungs.
Answer: FALSE
Diff: 3 Page Ref: 464

14) Transpulmonary pressure is the difference between intra-alveolar pressure and intrapleural pressure.
Answer: TRUE
Diff: 3 Page Ref: 461

15) The lung is expanded during inspiration by the transpulmonary pressure that pulls on the lung as the chest wall expands.
Answer: TRUE
Diff: 4 Page Ref: 463

16) The decrease in transpulmonary pressure during expiration reduces the distending forces on the airways.
Answer: TRUE
Diff: 5 Page Ref: 468
17) Residual volume can be measured because the lungs are able to collapse under experimental conditions.
   Answer: FALSE
   Diff: 3    Page Ref: 470

18) Obstructive pulmonary disorders are characterized by an interference with the expansion of the lungs.
   Answer: FALSE
   Diff: 4    Page Ref: 471

19) Activation of the sympathetic nervous system causes bronchodilation.
   Answer: TRUE
   Diff: 4    Page Ref: 468

20) It is more efficient to increase alveolar ventilation by increasing tidal volume than by increasing respiration rate.
   Answer: TRUE
   Diff: 4    Page Ref: 472

Matching Questions
For each of the following, indicate whether they are increasing, decreasing, or not changing in the walls of the respiratory tract as they move down the respiratory tract from the upper conducting zone to the lower respiratory zone.

1) Inner diameter.
   Diff: 3    Page Ref: 455
   A) decreasing

2) Amount of cartilage.
   Diff: 3    Page Ref: 455
   B) increasing

3) Amount of cilia.
   Diff: 4    Page Ref: 455
   C) not changing

4) Number of goblet cells.
   Diff: 4    Page Ref: 455

5) Amount of smooth muscle.
   Diff: 4    Page Ref: 455

Answers: 1) A  2) A  3) A  4) A  5) B
Match the following cells to their functions.

6) Secrete surfactant.
   Diff: 3       Page Ref: 466
   A) type I alveolar cells

7) Secrete mucus.
   Diff: 3       Page Ref: 456
   B) ciliated cells

8) Form the mucus escalator.
   Diff: 3       Page Ref: 456
   C) goblet cells

9) Engulf foreign particles that reach the lungs.
   Diff: 3       Page Ref: 457
   D) type II alveolar cells

10) Form the lung component of the respiratory membrane.
    Diff: 3       Page Ref: 457
   E) alveolar macrophages

Answers: 6) D       7) C       8) B       9) E       10) A
Match the following pressures with the correct description.

11) This pressure is created by the elastic recoil of the lungs and chest wall.  
   A) intra-alveolar pressure  
   B) atmospheric pressure  
   C) transpulmonary pressure  
   D) intrapleural pressure  
   Diff: 4   Page Ref: 461

12) This pressure is constant during the respiratory cycle.  
   D) intrapleural pressure

13) This pressure is the distending force on the lungs.  
   Diff: 4   Page Ref: 461

14) The difference between this pressure and atmospheric pressure drives air into and out of the lungs.  
   Diff: 3   Page Ref: 460

15) This pressure changes with the phases of respiration but is always negative.  
   Diff: 5   Page Ref: 461

16) This pressure equals atmospheric pressure during a pneumothorax, causing the lungs to collapse.  
   Diff: 5   Page Ref: 461

17) This pressure changes with the phases of respiration from a negative value during inspiration and a positive value during expiration.  
   Diff: 4   Page Ref: 460

Answers:  
Match the following lung volumes or capacities to the appropriate description.

18) The volume of air remaining in the lungs following a maximum expiration.
   Diff: 3    Page Ref: 470
   A) vital capacity
   B) residual volume
   C) expiratory reserve volume
   D) functional residual capacity
   E) total lung capacity
   F) inspiratory capacity
   G) inspiratory reserve volume
   H) tidal volume

19) The volume of air exchanged with the environment during an unforced breath.
   Diff: 3    Page Ref: 469

20) The maximum volume of air that can be inspired following a resting inspiration.
    Diff: 4    Page Ref: 469

21) The maximum volume of air that can be inspired following a resting expiration.
    Diff: 4    Page Ref: 470

22) The maximum volume of air that can be expired following a maximum inspiration.
    Diff: 4    Page Ref: 470

23) The maximum volume of air that can be expired following a resting expiration.
    Diff: 4    Page Ref: 470

24) The volume of air in the lungs following a maximum inspiration.
    Diff: 4    Page Ref: 470

25) The volume of air in the lungs at rest, between breaths.
    Diff: 4    Page Ref: 470

26) Tidal volume + inspiratory reserve volume.
    Diff: 4    Page Ref: 470

27) Residual volume + expiratory reserve volume.
    Diff: 4    Page Ref: 470
28) Tidal volume + inspiratory reserve volume + expiratory reserve volume.

Diff: 4  Page Ref: 470

29) Tidal volume + inspiratory reserve volume + expiratory reserve volume + residual volume.

Diff: 4  Page Ref: 470


Essay Questions

1) One of the basic tenets of physiology is that function of a system follows its structure. Describe the anatomy of the conducting zone of the respiratory tract, including how those structures contribute to the function of the lungs.

Answer: The conducting pathway begins with the larynx, followed by the trachea. The trachea is composed of cartilaginous rings that provide a rigid structure that prevents it from collapsing when pressure decreases within the lung as we inspire. The trachea bifurcates into bronchi that lead to the right and left lungs. The bronchi further divide into secondary bronchi, with three on the right side and two on the left side, that enter the lobes of the lungs. The amount of cartilage within these structures decreases from the trachea to bronchi to secondary bronchi. Thereafter, each secondary bronchus further divides into tertiary bronchi (as these bronchi divide, they have successively smaller radii). Once these tubes reach ~1 mm in radius, they are called bronchioles. The bronchioles no longer contain cartilage but are still resistant to collapse due to their elastic fiber composition. These bronchioles divide further into terminal bronchioles, which are the smallest component of the conducting zone. The conducting zone functions primarily as a passageway for the movement of air to the respiratory zone where gases can be exchanged. No gas exchange occurs within the conducting zone. The rigid structure of the trachea, and ultimately the thickness of the bronchioles, prevents gas transfer. Air is heated and humidified as it moves through the conducting zone. This zone is lined by epithelial cells that include the goblet cells and the ciliated cells. The goblet cells produce the mucus that is moved up and out of the lungs by cilia on the ciliated cells. This mucus escalator moves foreign particles trapped in the mucus toward the glottis where it enters the esophagus. At the same time, the smooth muscle cells, which are absent from the trachea, progressively increase in density further into the conducting zone. The smooth muscle cells provide the airway with the ability to change radius and thereby resistance.

Diff: 7  Page Ref: 453
2) One of the basic tenets of physiology is that function of a system follows its structure. Describe the anatomy of the respiratory zone of the respiratory tract, including how that structure contributes to function.

Answer: The respiratory tract transitions from conducting zone to respiratory zone at the interface between the terminal bronchioles and the respiratory bronchioles. The primary difference between these two structures is the thickness of their membranes. The respiratory zone is defined by its ability to facilitate the exchange of gases. Thus, the wall of these structures must be quite thin to allow gases to diffuse to and from the blood of the pulmonary capillaries. The respiratory bronchioles terminate in alveolar ducts, which lead to the alveoli, the primary structures for gas exchange. Most alveoli occur in clusters that look like grapes, but some branch off from the respiratory bronchioles. An alveolus is lined by several types of epithelial cells that include type I and type II alveolar cells. Each of these cells are thin and therefore function in the exchange of gases. However, the majority of gases will cross the type I alveolar cells to move into the pulmonary capillaries because they are the most numerous cell type within the alveolus. The entire distance that gases must cross to enter the blood is termed the respiratory membrane, which includes the alveolar cells and capillary endothelial cells that are 0.2 μm in thickness. The type II alveolar cells synthesize the surfactants that are involved in reducing the surface tension within the lung. The diffusion of gases is facilitated by the surface area of the lung. At the same time, other cells called the alveolar macrophages remove foreign particles and pathogens that might have entered the lungs. These cells get caught by the mucus of the conducting zone and are ultimately moved by the mucus escalator into the digestive tract for degradation.

Diff: 7 Page Ref: 457

3) Pressure is the driving force for the movement of air into and out of the lungs. Describe the structure of the thoracic cavity and how that structure is involved in creating the pressures that are important for the movement of air into the lungs.

Answer: The thoracic cavity is composed of a number of structures that protect the lungs, including the rib cage, the sternum, the thoracic vertebrae, and a series of muscles. The most important of these muscles are the diaphragm, which separates the thoracic cavity from the abdominal cavity, and the intercostals (internal and external). Other muscles that can be involved in ventilation include the sternocleidomastoids, the scalenes, and the pectoralis minor. The inside of the chest wall and the outside of the lung are lined by an epithelial membrane called the pleura. The visceral (lung) and parietal pleura (chest wall) are in contact with one another, with a small gap between called the intrapleural space in which the intrapleural fluid is located. These two membranes are held close to one another as a consequence of surface tension. Thus, the pressure within the intrapleural space (intrapleural pressure) is always negative (because the two membranes are pulling away from one another due especially to the elasticity of the lung). The other important pressures include atmospheric pressure, intra-alveolar pressure, and transpulmonary pressure. It is the difference between atmospheric pressure and intra-alveolar pressure that moves air into and out of the lungs. As lung volume increases, transpulmonary pressure increases (due to the decrease in intrapleural pressure as the chest wall pulls outward from the lung). This increase in transpulmonary pressure will cause the lung to expand and intra-alveolar pressure to decrease. It is the decrease in intra-alveolar pressure that moves air into the lungs.

Diff: 7 Page Ref: 457
4) The generation of the pressure responsible for the movement of air follows Boyle's Law. Describe how Boyle's Law relates to pressure development in the lungs, and how that determines inspiration and expiration.

Answer: Boyle’s Law states that, for a given quantity of a gas in a container, the pressure is inversely related to the volume of the container. This means that as a container’s volume increases, the pressure within the container decreases and, if the container is open to the atmosphere, molecules of air will move into the container, causing pressure to progressively increase until it equilibrates again with atmospheric pressure. In the case of the lung, the container is the thoracic cavity. During inspiration, the volume of the thoracic cavity increases, causing intrapleural pressure to decrease. This decrease in intrapleural pressure causes transpulmonary pressure to increase since transpulmonary pressure = intra-alveolar pressure – intrapleural pressure. This causes the lung itself to expand and intra-alveolar pressure to decrease. It is this decrease in intra-alveolar pressure that causes air to move into the lungs. During expiration, the volume of the thoracic cavity decreases, causing intrapleural pressure to increase. This increase in intrapleural pressure causes transpulmonary pressure to decrease (intra-alveolar pressure – intrapleural pressure), which causes the lung itself to retract and decrease volume due to its elastic nature, thereby increasing intra-alveolar pressure. It is this increase in intra-alveolar pressure that causes air to move out of the lungs.

Diff: 6   Page Ref: 461

5) Pressure is the driving force for the movement of air into and out of the lungs. However, the development of pressure and the movement of air is modified by the compliance of the lungs. Describe how lung compliance can alter the movement of air into the lungs.

Answer: The concept of lung compliance is the same as the concept of compliance in the vascular system. Lung compliance is a measure of the extent of change in lung volume per change in transpulmonary pressure. The greater the compliance of the lung, the lower the change in transpulmonary pressure required to move air into the lung (i.e., less work). The compliance of a lung is dependent upon two variables: the elasticity of the lung itself and its surface tension. Elasticity of the lung is related to the elastic fibers that are part of the connective tissue that constitute the lung. As they are stretched, the fibers tend to recoil. The surface tension of a liquid is a measure of the work required to increase its surface area. The greater the surface tension of the water between the sheets of alveolar cells within the lung, the greater the force required to spread that fluid out as well as the lung itself. Thus, surface tension acts to decrease lung compliance. As the lung expands, work is required not only to stretch the elastic tissue but also to increase the surface area of the water. The surface tension of the lung would be much higher if it were only water that contributed to its surface tension. However, the type II alveolar cells secrete a surfactant that reduces the surface tension of water. This surfactant is not found within the intrapleural space, which is why the surface tension remains high within the intrapleural space.

Diff: 6   Page Ref: 466
6) Pressure is the driving force for the movement of air into and out of the lungs. However, the development of pressure and the movement of air is modified by the resistance of the airways. Describe how airway resistance can alter the movement of air into the lungs, including asthma in the discussion.

Answer: In the respiratory system, as with the vascular system, the pressure generated by the heart (and the change in volume of the lung) must work against the resistance of the tubes (vessels or airways) in order to move air. The radius of an airway determines its resistance. The smooth muscle cells that are found in the smaller bronchioles allow their resistance to be altered. The radii of these tubes is relatively large, meaning that their airway provides little resistance to the movement of air through the lungs. The resistance of the conducting zone is quite low due to the airway’s large radii and rapid branching. The difference between atmospheric and intra-alveolar pressure need only be 2 mm Hg to move air into the lungs. However, this resistance is altered by a number of variables that include passive forces exerted on the airways, contractile activity of the smooth muscle cells, and the secretion of mucus into the airways. The passive forces are termed the tractive forces, which are exerted on the airways by the surrounding tissue pulling on them. Thus, as we inspire, the tractive forces increase, thereby increasing the radius of the airways and decreasing their resistances. Expiration has the opposite effect, whereby a decrease in pulling on the airways causes them to retract and decrease their radii, thereby increasing resistance. In the bronchioles, the smooth muscle cell layer is such that it can alter the radius of the airway. These airways respond to extrinsic (neural and hormonal) and intrinsic (local chemical) control. The autonomic nervous system has quite a different effect on airways than blood vessels: sympathetic nervous activity induces a bronchodilation and parasympathetic nervous activity induces a bronchoconstriction. Histamine, epinephrine, and low carbon dioxide concentration all induce constriction. At the same time, histamine increases the secretion of mucus, which can build up in the airway and increase resistance (through blockage). This is the case with asthma, where airway resistance increases because of three factors: contraction of smooth muscle cells, increased mucus secretion, and inflammation of the bronchioles. It appears that a hypersensitivity of airway smooth muscle cells to allergens initiates the response.

Diff: 8  Page Ref: 466
Short Answer Questions

Using Figure 16.1, answer the following questions:

1) In Figure 16.1, tidal volume is ______ mL.
   Answer: 600
   Diff: 5    Page Ref: 470

2) In Figure 16.1, inspiratory reserve volume is ______ mL.
   Answer: 2200
   Diff: 5    Page Ref: 470

3) In Figure 16.1, expiratory reserve volume is ______ mL.
   Answer: 1300
   Diff: 5    Page Ref: 470

4) In Figure 16.1, residual volume is ______ mL.
   Answer: 1700
   Diff: 5    Page Ref: 470

5) In Figure 16.1, inspiratory capacity is ______ mL.
   Answer: 2800
   Diff: 5    Page Ref: 470
6) In Figure 16.1, vital capacity is _______ mL.
   Answer: 4100  
   Diff: 5  
   Page Ref: 470

7) In Figure 16.1, functional residual capacity is _______ mL.
   Answer: 3000  
   Diff: 5  
   Page Ref: 470

8) In Figure 16.1, total lung capacity is _______ mL.
   Answer: 5800  
   Diff: 5  
   Page Ref: 470

9) The _______ is a flap of tissue that prevents food from entering the larynx.
   Answer: epiglottis  
   Diff: 3  
   Page Ref: 453

10) The cartilage around the trachea are arranged in (rings / C shapes), whereas that around the primary bronchi are arranged in (rings / C shapes).
    Answer: C shapes : rings  
    Diff: 4  
    Page Ref: 456

11) (Ciliated cells / Goblet cells) are inhibited by smoking, which leads to the familiar "smoker's cough".
    Answer: Ciliated cells  
    Diff: 4  
    Page Ref: 457

12) Name the structures of the respiratory membrane.
    Answer: capillary wall (endothelial cell), alveolar wall (type I alveolar cell), and their basement membranes  
    Diff: 4  
    Page Ref: 457

13) The pleural sac is bounded by the _______ pleura next to the lung and the _______ pleura next to the chest wall.
    Answer: visceral : parietal  
    Diff: 4  
    Page Ref: 457

14) The volume of air within the lungs when all of the breathing muscles have relaxed is called _______.
    Answer: functional residual capacity  
    Diff: 4  
    Page Ref: 461

15) Intra-alveolar pressure is determined by what two factors?
    Answer: the quantity of air in the alveolus : the volume of the alveoli  
    Diff: 5  
    Page Ref: 462

16) As the volume of the lungs increases, intra-alveolar pressure (increases / decreases).
    Answer: decreases  
    Diff: 5  
    Page Ref: 462
17) Identify the muscles involved in resting and forced inspiration.
   Answer: Resting – diaphragm, external intercostals: Forced – scalenes, sternocleidomastoids, pectoralis minor
   Diff: 6  Page Ref: 463

18) Under normal conditions, expiration is a(n) (active / passive) process.
   Answer: passive
   Diff: 3  Page Ref: 464

19) Name two factors that determine lung compliance.
   Answer: lung elasticity : surface tension
   Diff: 4  Page Ref: 466

20) A decrease in the compliance of the lungs will cause the muscles of the lungs to work (harder / less) to expand the lungs to the same volume.
   Answer: harder
   Diff: 5  Page Ref: 466

21) What is the primary determinant of airway resistance?
   Answer: airway radius
   Diff: 4  Page Ref: 466

22) An increase in sympathetic nervous activity to the smooth muscle cells of the bronchioles will result in a (bronchoconstriction / bronchodilation).
   Answer: bronchodilation
   Diff: 4  Page Ref: 468

23) Given tidal volume = 700 mL, respiration rate = 10 breaths/minute, and dead-space volume = 200 mL, what is the minute ventilation?
   Answer: 7000 mL/min
   Diff: 4  Page Ref: 471

24) Given tidal volume = 700 mL, respiration rate = 10 breaths/minute, and dead-space volume = 200 mL, what is the minute alveolar ventilation?
   Answer: 5000 mL/min
   Diff: 4  Page Ref: 471
Multiple Choice Questions

1) The respiratory quotient is calculated as the _______.
   A) ratio of the volume of oxygen consumed per volume of carbon dioxide produced
   B) ratio of the volume of carbon dioxide produced per volume of oxygen consumed
   C) product of the volume of carbon dioxide consumed and the volume of oxygen produced
   D) product of the volume of oxygen consumed and the volume of carbon dioxide produced
   E) sum of the volume of oxygen consumed and the volume of carbon dioxide produced
   Answer: B
   Diff: 4   Page Ref: 476

2) If oxygen is consumed by the body cells at a rate of 300 mL per minute, then how much oxygen diffuses from the alveoli into the blood in the pulmonary capillaries?
   A) 300 mL per minute
   B) more than 300 mL per minute
   C) less than 300 mL per minute
   D) depends on where the oxygen is being utilized
   E) depends on whether or not carbon dioxide is being produced at the same rate
   Answer: A
   Diff: 3   Page Ref: 476

3) Oxygenated blood is found in which of the following?
   A) right atrium only
   B) pulmonary artery only
   C) pulmonary vein only
   D) both the right atrium and pulmonary artery
   E) both the right atrium and pulmonary vein
   Answer: C
   Diff: 3   Page Ref: 476

4) Movement of oxygen and carbon dioxide between alveoli and blood occurs by what process?
   A) simple diffusion
   B) facilitated diffusion
   C) osmosis
   D) primary active transport
   E) secondary active transport
   Answer: A
   Diff: 2   Page Ref: 477
5) Which of the following is NOT part of the pathway that must be crossed by oxygen on its way to binding with hemoglobin?
   A) alveolar epithelial cell
   B) basement membrane
   C) alveolar mucosal barrier
   D) endothelial cell
   E) red blood cell membrane

   Answer: C
   Diff: 4    Page Ref: 477

6) Which of the following does NOT contribute to the rapid movement of gases into and out of the blood within the lungs?
   A) rapid blood flow
   B) thin membrane
   C) large surface area
   D) concentration gradient
   E) permeability of the membrane

   Answer: A
   Diff: 3    Page Ref: 477

7) In a mixture of gases, the driving force for the movement of an individual gas within that mixture is ultimately the ________.
   A) solubility of the gas
   B) total pressure of the gases
   C) fractional concentration of that gas
   D) partial pressure of that gas
   E) volume of the gas

   Answer: D
   Diff: 3    Page Ref: 481

8) What is the most abundant gas in the air that we breathe?
   A) oxygen
   B) carbon dioxide
   C) water vapor
   D) argon
   E) nitrogen

   Answer: E
   Diff: 3    Page Ref: 478

9) What percentage of air is oxygen?
   A) < 1%
   B) 6%
   C) 12%
   D) 21%
   E) 79%

   Answer: D
   Diff: 3    Page Ref: 478
10) What percentage of air is carbon dioxide?
   A) < 1%
   B) 6%
   C) 12%
   D) 21%
   E) 79%
   Answer: A
   Diff: 3   Page Ref: 479

11) What is the partial pressure of oxygen in a gas mixture that is 40% oxygen, 40% argon, and
    20% helium, when the total pressure of the gas is 1,000 mm Hg?
   A) 100 mm Hg
   B) 200 mm Hg
   C) 333 mm Hg
   D) 400 mm Hg
   E) 600 mm Hg
   Answer: D
   Diff: 4   Page Ref: 478

12) What is the partial pressure of oxygen in air at sea level?
   A) 60 mm Hg
   B) 160 mm Hg
   C) 210 mm Hg
   D) 400 mm Hg
   E) 600 mm Hg
   Answer: B
   Diff: 4   Page Ref: 478

13) As humidity increases, the partial pressure of oxygen in air ________.
   A) increases as the total pressure of air remains the same
   B) increases as the total pressure of air increases
   C) decreases as the total pressure of air remains the same
   D) decreases as the total pressure of air increases
   E) does not change
   Answer: C
   Diff: 5   Page Ref: 479

14) As the air is saturated with water vapor (humidified) upon entry into the conducting pathway,
    there will be ________.
   A) a selective increase in the partial pressure of nitrogen
   B) a selective decrease in the partial pressure of nitrogen
   C) no change in the partial pressure of the remaining gases
   D) a decrease in the partial pressure of the remaining gases
   E) an increase in the partial pressure of the remaining gases
   Answer: D
   Diff: 4   Page Ref: 479
15) At equilibrium, the gas molecules that dissolve in solution and those that remain in the gaseous phase are, by definition, at the same _______.
   A) temperature  
   B) concentration  
   C) partial pressure  
   D) volume  
   E) humidity  
Answer: C  
Diff: 3  Page Ref: 479

16) The relationship between the concentration of a gas in solution and the partial pressure of that gas can be described by _______.
   A) Boyle's Law  
   B) Fick's Law  
   C) Dalton's Law  
   D) Henry's Law  
   E) Poiseuille's Law  
Answer: D  
Diff: 5  Page Ref: 479

17) Which of the following can increase the concentration of a particular gas in a solution?
   A) increase the partial pressure of that gas exposed to the solution  
   B) increase the volume of the container containing the gas and solution  
   C) increase the volume of the gas only  
   D) increase the volume of the solution only  
   E) decrease the concentration of other gases in the solution  
Answer: A  
Diff: 5  Page Ref: 479

18) At equilibrium, which of the following statements is true when helium and nitrogen are present in a gas at equal partial pressures over water?
   A) The concentrations of helium and nitrogen in the gas are equal.  
   B) The partial pressures of helium and nitrogen in the water are equal.  
   C) The concentrations of helium and nitrogen in the water are equal.  
   D) The concentrations of helium and nitrogen in BOTH the water and gas are equal.  
   E) The partial pressure of nitrogen is greater than the partial pressure of helium.  
Answer: B  
Diff: 5  Page Ref: 480

19) The mixing of atmospheric air within the dead space of the conducting zone of the lung upon inspiration results in a partial pressure of _______.
   A) water vapor in the alveoli that is lower than atmospheric  
   B) nitrogen in the alveoli that is higher than atmospheric  
   C) oxygen in the alveoli that is lower than atmospheric  
   D) carbon dioxide in the alveoli that is lower than atmospheric  
   E) oxygen in the alveoli that is higher than atmospheric  
Answer: C  
Diff: 5  Page Ref: 481
20) Which of the following causes a decrease in the $PO_2$ of air as it enters the conducting zone of the lungs?
   A) humidifying the air
   B) warming of the air
   C) the increasing $PCO_2$
   D) the consumption of oxygen
   E) decreasing alveolar $PO_2$

Answer: A  
Diff: 6  Page Ref: 481

21) Pulmonary edema describes a condition where the uptake of oxygen and unloading of carbon dioxide is reduced as a consequence of a(n)________.
   A) thickening of the diffusion barrier by fluid accumulation in the pulmonary blood
   B) thickening of the diffusion barrier by fluid accumulation in the alveoli
   C) decrease in the partial pressure of oxygen in the alveolus
   D) decrease in the partial pressure of carbon dioxide in the alveolus
   E) increase in the partial pressure of oxygen in the blood

Answer: B  
Diff: 5  Page Ref: 483

22) At sea level, what is the normal partial pressure of oxygen in alveolar air?
   A) 21 mm Hg
   B) 40 mm Hg
   C) 46 mm Hg
   D) 100 mm Hg
   E) 160 mm Hg

Answer: D  
Diff: 4  Page Ref: 481

23) At sea level, what is the normal partial pressure of carbon dioxide in alveolar air?
   A) 21 mm Hg
   B) 40 mm Hg
   C) 46 mm Hg
   D) 100 mm Hg
   E) 160 mm Hg

Answer: B  
Diff: 4  Page Ref: 481

24) At sea level, what is the normal partial pressure of oxygen in the pulmonary veins?
   A) 21 mm Hg
   B) 40 mm Hg
   C) 46 mm Hg
   D) 100 mm Hg
   E) 160 mm Hg

Answer: D  
Diff: 4  Page Ref: 481
25) At sea level, what is the normal partial pressure of carbon dioxide in pulmonary arteries?
   A) 21 mm Hg  
   B) 40 mm Hg  
   C) 46 mm Hg  
   D) 100 mm Hg  
   E) 160 mm Hg  
   Answer: C  
   Diff: 4  Page Ref: 481

26) At sea level, what is the normal partial pressure of oxygen in the systemic veins?
   A) 21 mm Hg  
   B) 40 mm Hg  
   C) 46 mm Hg  
   D) 100 mm Hg  
   E) 160 mm Hg  
   Answer: B  
   Diff: 4  Page Ref: 481

27) At sea level, what is the normal partial pressure of carbon dioxide in systemic veins?
   A) 21 mm Hg  
   B) 40 mm Hg  
   C) 46 mm Hg  
   D) 100 mm Hg  
   E) 160 mm Hg  
   Answer: C  
   Diff: 4  Page Ref: 481

28) During intense exercise, the metabolic activity of muscle causes a ______ in the partial pressure of oxygen in the tissue, ______ the movement of oxygen into the tissue.
   A) decrease : reducing  
   B) decrease : facilitating  
   C) increase : reducing  
   D) increase : facilitating  
   E) does not change : facilitating  
   Answer: B  
   Diff: 5  Page Ref: 483

29) A typical value for blood $P_{O_2}$ in the pulmonary vein is ______, whereas $P_{CO_2}$ is ______.
   A) 150 mm Hg : 0.3 mm Hg  
   B) 46 mm Hg : 100 mm Hg  
   C) 40 mm Hg : 46 mm Hg  
   D) 40 mm Hg : 100 mm Hg  
   E) 100 mm Hg : 40 mm Hg  
   Answer: E  
   Diff: 5  Page Ref: 481

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30) Under resting conditions, equilibration between alveolar P\textsubscript{O\textsubscript{2}} and P\textsubscript{CO\textsubscript{2}} with blood P\textsubscript{O\textsubscript{2}} and P\textsubscript{CO\textsubscript{2}} in the pulmonary capillaries occurs in approximately how many seconds?
   A) 3
   B) 2
   C) 1
   D) 0.5
   E) 0.25
   Answer: E
   Diff: 6   Page Ref: 481

31) Under resting conditions, equilibration between alveolar P\textsubscript{O\textsubscript{2}} and P\textsubscript{CO\textsubscript{2}} with blood P\textsubscript{O\textsubscript{2}} and P\textsubscript{CO\textsubscript{2}} in the pulmonary capillaries is completed by the time the blood has traveled what portion of the distance of the pulmonary capillaries?
   A) 1/10
   B) 1/8
   C) 1/4
   D) 1/3
   E) 1/2
   Answer: D
   Diff: 6   Page Ref: 481

32) Mixed venous blood samples can be taken from which of the following blood vessels?
   A) pulmonary vein
   B) pulmonary artery
   C) inferior vena cava
   D) aorta
   E) superior vena cava
   Answer: B
   Diff: 5   Page Ref: 483

33) The venous blood in the right ventricle is referred to as "mixed" because the blood that enters the heart ________.
   A) has a low P\textsubscript{O\textsubscript{2}}
   B) contains a mixture of oxygen and carbon dioxide
   C) comes from tissue with differing metabolic activities
   D) has a high P\textsubscript{CO\textsubscript{2}}
   E) is drained from the body
   Answer: C
   Diff: 4   Page Ref: 483
34) What is an increase in alveolar ventilation to match the demands of increased metabolic activity in the cells called?
   A) hyperventilation
   B) hypoventilation
   C) hyperpnea
   D) hypopnea
   E) dyspnea
Answer: C
Diff: 4 Page Ref: 484

35) Hyperventilation would lead to a(n) _______ within the systemic arteries.
   A) selective decrease in P\textsubscript{O2}
   B) selective increase in P\textsubscript{O2}
   C) selective decrease in P\textsubscript{CO2}
   D) increase in P\textsubscript{O2} and decrease in P\textsubscript{CO2}
   E) decrease in P\textsubscript{O2} and increase in P\textsubscript{CO2}
Answer: D
Diff: 4 Page Ref: 484

36) What is a decrease in carbon dioxide within the blood called?
   A) hypoxia
   B) hypoxemia
   C) hypocapnia
   D) hypercapnia
   E) hyperpnea
Answer: C
Diff: 4 Page Ref: 484

37) The majority of oxygen present within the blood is _______.
   A) bound to hemoglobin within the plasma
   B) bound to hemoglobin in red blood cells
   C) dissolved within the plasma
   D) in the plasma as HCO\textsubscript{3}⁻
   E) bound to plasma proteins
Answer: B
Diff: 4 Page Ref: 485

38) Each _______ on the hemoglobin subunit is capable of binding an oxygen molecule, thereby allowing _______ oxygen to bind with one hemoglobin molecule.
   A) heme : four
   B) heme : three
   C) globin : four
   D) globin : three
   E) free iron : one
Answer: A
Diff: 4 Page Ref: 485
39) What is the primary driving force for the binding of oxygen to hemoglobin?
   A) $\text{PCO}_2$
   B) $\text{PO}_2$
   C) pH
   D) temperature
   E) $2,3\text{-bisphosphoglycerate (2,3-BPG)}$

   Answer: B
   Diff: 3 Page Ref: 485

40) If hemoglobin is saturated (1.3 mL of oxygen per gram) and there are 150 grams of hemoglobin per liter of blood, how much oxygen can be delivered to the tissue if cardiac output is 15 liters per minute?
   A) 650 g O$_2$/min
   B) 1300 mL O$_2$/min
   C) 1300 g O$_2$/min
   D) 2925 mL O$_2$/min
   E) 2925 g O$_2$/min

   Answer: D
   Diff: 5 Page Ref: 485

41) What is the definition of anemia?
   A) a decrease in $\text{PO}_2$
   B) a increase in $\text{PCO}_2$
   C) a decrease in hemoglobin
   D) a decrease in the oxygen carrying capacity of the blood
   E) a decrease in the affinity of hemoglobin for oxygen

   Answer: D
   Diff: 4 Page Ref: 485

42) What is labored or difficult breathing called?
   A) hyperpnea
   B) dyspnea
   C) hypopnea
   D) eupnea
   E) apnea

   Answer: B
   Diff: 5 Page Ref: 484

43) What is a deficiency of oxygen in the tissues called?
   A) apnea
   B) hypoxia
   C) hypoxemia
   D) hypocapnia
   E) hypercapnia

   Answer: B
   Diff: 5 Page Ref: 484
44) What is rapid shallow breathing called?
   A) tachypnea
   B) apnea
   C) dyspnea
   D) hyperpnea
   E) eupnea

   Answer: A

   Diff: 5 Page Ref: 484

45) What is a decrease in oxygen in the blood called?
   A) hypoxia
   B) hypoxemia
   C) anemia
   D) hypocapnia
   E) dysnemia

   Answer: B

   Diff: 5 Page Ref: 484

46) As oxygen binds to hemoglobin, the ______ of the hemoglobin molecule will change through a process of ______ such that the binding of oxygen is enhanced.

   A) amino acid sequence : phosphorylation
   B) cooperativity : negativity
   C) cooperativity : positivity
   D) affinity : negative cooperativity
   E) affinity : positive cooperativity

   Answer: E

   Diff: 5 Page Ref: 486

47) Which of the following statements is FALSE of a leftward shift in the hemoglobin–oxygen dissociation curve?

   A) Affinity for oxygen is increased.
   B) Oxygen loading onto the hemoglobin is increased.
   C) Hemoglobin is more saturated at a given PO2.
   D) It can be caused by an increase in blood pH.
   E) It can be caused by an increase in PCO2.

   Answer: E

   Diff: 6 Page Ref: 487

48) Which of the following statements is FALSE of a rightward shift in the hemoglobin–oxygen dissociation curve?

   A) Affinity for oxygen is decreased.
   B) A rightward shift usually occurs in active tissue.
   C) Hemoglobin unloading of oxygen is increased.
   D) Oxygen loading onto hemoglobin is decreased.
   E) It can be caused by a decrease in 2, 3–BPG.

   Answer: E

   Diff: 6 Page Ref: 487
49) Which of the following will cause a shift in the hemoglobin–oxygen dissociation curve to the right?
   A) increase in temperature only
   B) increase in plasma pH only
   C) increase in 2,3-BPG (2,3-bisphosphoglycerate) only
   D) both an increase in temperature and an increase in 2,3-BPG
   E) both an increase in temperature and an increase in plasma pH

   Answer: D  
   Diff: 5  Page Ref: 489

50) As it leaves the lung in the pulmonary vein, blood is _______ saturated with oxygen.
   A) 75%
   B) 90%
   C) 98%
   D) completely (100%)
   E) supersaturated (108%)

   Answer: C  
   Diff: 4  Page Ref: 487

51) Which of the following increases oxygen unloading from hemoglobin?
   A) increased carbon dioxide in the tissue
   B) increased oxygen levels in the tissue
   C) increased blood pH
   D) decreased metabolism
   E) decreased temperature

   Answer: A  
   Diff: 4  Page Ref: 488

52) Which of the following will increase the unloading of oxygen within the tissue?
   A) increased hydrogen ion concentration only
   B) increased P_CO2 only
   C) increased body temperature only
   D) both increased hydrogen ion concentration and increased body temperature
   E) increased hydrogen ion concentration, increased body temperature, and increased P_CO2

   Answer: E  
   Diff: 5  Page Ref: 488

53) Which of the following will increase the loading of oxygen onto the hemoglobin molecule within the lungs?
   A) decreased hydrogen ion concentration
   B) increased P_CO2
   C) decreased pH
   D) increased 2,3-bisphosphoglycerate (2,3-BPG)
   E) increased body temperature

   Answer: A  
   Diff: 5  Page Ref: 488
54) In the systemic arteries, the partial pressure of oxygen is approximately _______, and hemoglobin is approximately _______ saturated with oxygen.
   A) 40 mm Hg: 75%
   B) 60 mm Hg: 50%
   C) 100 mm Hg: 75%
   D) 40 mm Hg: 50%
   E) 100 mm Hg: 98%
Answer: E
Diff: 4 Page Ref: 487

55) In the pulmonary arteries, the partial pressure of oxygen is approximately _______, and hemoglobin is approximately _______ saturated with oxygen.
   A) 25 mm Hg: 50%
   B) 40 mm Hg: 75%
   C) 60 mm Hg: 80%
   D) 80 mm Hg: 90%
   E) 100 mm Hg: 98%
Answer: B
Diff: 6 Page Ref: 487

56) The carbamino effect describes a change in the conformation of hemoglobin that is induced by _______.
   A) an increase in pH
   B) a decrease in temperature
   C) an increase in temperature
   D) an increase in CO₂
   E) a decrease in pH
Answer: D
Diff: 4 Page Ref: 488

57) Which of the following statements about 2,3-BPG is FALSE?
   A) 2,3-BPG is an intermediate of glycolysis.
   B) 2,3-BPG produces a rightward shift in the hemoglobin-oxygen dissociation curve.
   C) 2,3-BPG synthesis is inhibited by high levels of oxyhemoglobin.
   D) 2,3-BPG increases the affinity of hemoglobin for oxygen.
   E) 2,3-BPG is produced by red blood cells.
Answer: D
Diff: 6 Page Ref: 488

58) Where in blood does the conversion of CO₂ to bicarbonate occur?
   A) erythrocytes
   B) platelets
   C) capillary endothelial cells
   D) leukocytes
   E) plasma
Answer: A
Diff: 4 Page Ref: 489
59) What is the primary mechanism of carbon dioxide transport in blood?
   A) dissolved in the plasma
   B) dissolved in the red blood cells
   C) bound to hemoglobin
   D) as bicarbonate dissolved in the plasma
   E) as bicarbonate dissolved in the red blood cells

   Answer: D  
   Diff: 5  Page Ref: 489

60) The presence of bicarbonate ions in the blood has an important direct effect, aside from the transport of CO₂, that involves _______.
   A) stimulating the proliferation of alveolar epithelial cells
   B) altering the activity of several receptors
   C) altering the affinity of hemoglobin for oxygen
   D) maintaining acid–base balance
   E) altering the activity of carbonic anhydrase

   Answer: D  
   Diff: 4  Page Ref: 490

61) Within an erythrocyte, the conversion of CO₂ to bicarbonate is prevented from reaching equilibrium by the _______.
   A) absence of a nucleus
   B) presence of oxygen
   C) temperature of the body
   D) presence of hydrogen ions
   E) efflux of bicarbonate from the erythrocyte via the chloride shift

   Answer: E  
   Diff: 5  Page Ref: 493

62) The hydrogen ions released by the dissociation of carbonic acid are buffered by their _______.
   A) transport out of the erythrocyte as a sodium ion moves in
   B) binding to DNA within the nucleus
   C) transport into the erythrocyte as sodium ions move out
   D) binding to hemoglobin
   E) active transport out of the erythrocyte

   Answer: D  
   Diff: 5  Page Ref: 492

63) The Haldane effect describes the increase in the affinity of hemoglobin for CO₂ in the presence of a lowered _______.
   A) PCO₂
   B) concentration of bicarbonate (HCO₃⁻)
   C) PO₂
   D) pH
   E) temperature

   Answer: C  
   Diff: 5  Page Ref: 491

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64) During quiet breathing, a person's breathing cycle consists of _______.
   A) contraction of inspiratory muscles
   B) contraction and relaxation of inspiratory muscles
   C) contraction and relaxation of inspiratory and expiratory muscles
   D) contraction of expiratory muscles
   E) contraction of inspiratory muscles and relaxation of expiratory muscles

   Answer: B  Diff: 4  Page Ref: 492

65) Which of the following nerves have activity during quiet inspiration?
   A) phrenic nerve only
   B) internal intercostal nerve only
   C) external intercostal nerve only
   D) both the phrenic nerve and internal intercostal nerves
   E) both the phrenic nerve and external intercostal nerves

   Answer: E  Diff: 5  Page Ref: 492

66) During active breathing, bursts of action potentials are observed to occur _______.
   A) exclusively in the inspiratory motor neurons
   B) simultaneously in the inspiratory and expiratory motor neurons
   C) exclusively in the expiratory motor neurons
   D) asynchronously in the inspiratory and expiratory motor neurons
   E) synchronously in the inspiratory and expiratory motor neurons

   Answer: D  Diff: 5  Page Ref: 492

67) The _______ is the respiratory center that appears to facilitate the transition between
    inspiration and expiration.
   A) medullary respiratory group
   B) pontine respiratory group
   C) dorsal respiratory group
   D) ventral respiratory group
   E) central pattern generator

   Answer: B  Diff: 5  Page Ref: 493

68) Inspiratory neurons are located in the _______.
   A) dorsal respiratory group only
   B) ventral respiratory group only
   C) pontine respiratory group only
   D) both dorsal and ventral respiratory groups
   E) dorsal, ventral, and pontine respiratory groups

   Answer: E  Diff: 6  Page Ref: 493
69) In the model of quiet breathing, the breathing rhythm originated by the central pattern generator activates the _______.
   A) inspiratory neurons in the dorsal respiratory center
   B) expiratory neurons in the dorsal respiratory center
   C) inspiratory neurons in the ventral respiratory center
   D) both expiratory neurons in the ventral respiratory center
   E) both inspiratory neurons in the dorsal and ventral respiratory center
   Answer: E  Diff: 6  Page Ref: 494

70) In the model for quiet breathing, expiration is induced by_______.
   A) abrupt termination of inspiration
   B) activation of expiratory neurons in the dorsal respiratory center
   C) activation of inspiratory neurons in the ventral respiratory center
   D) activation of expiratory neurons in the ventral respiratory center
   E) activation of inspiratory neurons in the dorsal respiratory center
   Answer: A  Diff: 5  Page Ref: 494

71) Which of the following is NOT one of the sensory receptors that alter the output from the central pattern generator?
   A) peripheral chemoreceptor
   B) central chemoreceptor
   C) pulmonary stretch receptor
   D) pulmonary baroreceptors
   E) irritant receptors
   Answer: D  Diff: 4  Page Ref: 494

72) Coughing is initiated by______ located in the______.
   A) chemoreceptors : trachea
   B) irritant receptors : nose and pharynx
   C) irritant receptors : trachea
   D) chemoreceptors : nose and pharynx
   E) stretch receptor : trachea
   Answer: C  Diff: 4  Page Ref: 494

73) Peripheral chemoreceptors are specialized cells in contact with arterial blood that respond directly to changes in blood_______.
   A) pH
   B) PO2
   C) PCO2
   D) PCO2 and PO2
   E) PO2, pH, and PCO2
   Answer: E  Diff: 5  Page Ref: 496
74) Central chemoreceptors are neurons in the medulla that respond directly to changes in _______.
   A) cerebrospinal fluid pH
   B) blood pH
   C) cerebrospinal fluid PO\textsubscript{2} and pH
   D) blood pH and PO\textsubscript{2}
   E) cerebrospinal fluid PO\textsubscript{2}

Answer: A  
Diff: 5  Page Ref: 497

75) Chemoreceptors respond primarily to changes in P\textsubscript{CO\textsubscript{2}} indirectly by its effect on _______.
   A) 2,3-diphosphoglycerate (2,3-DPG) concentration
   B) PO\textsubscript{2}
   C) lactic acid concentration
   D) hydrogen ion concentration
   E) hemoglobin concentration

Answer: D  
Diff: 4  Page Ref: 496

76) Hyperventilation will cause changes in P\textsubscript{CO\textsubscript{2}} that are detected by the chemoreceptors which causes a(n) _______.
   A) decrease in breathing rate only
   B) increase in depth of breathing only
   C) increase in breathing rate only
   D) increase in breathing rate and depth of breathing
   E) decrease in breathing rate and depth of breathing

Answer: E  
Diff: 5  Page Ref: 498

77) Where are the peripheral chemoreceptors in humans?
   A) aortic bodies only
   B) carotid bodies only
   C) medulla oblongata only
   D) both aortic and carotid bodies
   E) both carotid bodies and medulla oblongata

Answer: B  
Diff: 4  Page Ref: 496

78) Which of the following BEST describes a chemoreceptor response to P\textsubscript{O\textsubscript{2}}?
   A) Peripheral chemoreceptors respond to small changes in P\textsubscript{O\textsubscript{2}}.
   B) Central chemoreceptors respond to only large decreases in P\textsubscript{O\textsubscript{2}}.
   C) Peripheral chemoreceptors respond only indirectly to P\textsubscript{O\textsubscript{2}}.
   D) Central chemoreceptors do not respond to changes in P\textsubscript{O\textsubscript{2}}.
   E) Peripheral chemoreceptors respond to oxyhemoglobin.

Answer: D  
Diff: 5  Page Ref: 497
79) A decrease in $\text{PCO}_2$ within the lung will result in a _______ in the pulmonary vasculature and a _______ in the bronchioles.
   A) vasoconstriction : lack of change
   B) weak vasoconstriction : bronchodilation
   C) vasodilation : weak bronchodilation
   D) weak vasodilation : bronchoconstriction
   E) lack of change : weak bronchoconstriction

   Answer: D
   Diff: 5   Page Ref: 499

80) A local bronchodilation within the alveolus will result in a(n) _______ in the ventilation-perfusion ratio in that region, whereas a vasoconstriction will result in a(n) _______ in the ventilation-perfusion ratio.
   A) increase : increase
   B) increase : decrease
   C) decrease : increase
   D) decrease : decrease
   E) lack of change : increase

   Answer: A
   Diff: 5   Page Ref: 498

81) The primary effect of increased $\text{PO}_2$ in the lungs is to cause _______ which _______ the ventilation-perfusion ratio.
   A) bronchoconstriction : decreases
   B) bronchodilation : increases
   C) vasoconstriction : decreases
   D) vasodilation : decreases
   E) vasoconstriction : increases

   Answer: D
   Diff: 7   Page Ref: 499

82) The primary effect of increased $\text{PCO}_2$ in the lungs is to cause _______ which _______ the ventilation-perfusion ratio.
   A) bronchoconstriction : decreases
   B) bronchodilation : increases
   C) vasoconstriction : decreases
   D) vasodilation : decreases
   E) vasoconstriction : increases

   Answer: B
   Diff: 7   Page Ref: 499
83) When the blood becomes ________, it can lead to a depression in the activity of the central nervous system.
   A) hypoxic
   B) hypocapnic
   C) pH 7.4
   D) acidic
   E) alkaline

   Answer: D
   Diff: 5 Page Ref: 501

84) The buffering capacity of hemoglobin is directly related to its ability to bind with ________.
   A) oxygen
   B) carbon dioxide
   C) carbon monoxide
   D) hydrogen ions
   E) nitrogen

   Answer: D
   Diff: 3 Page Ref: 501

85) Bicarbonate is an important buffer in blood, whose concentration is regulated by the ________.
   A) kidneys
   B) lungs
   C) heart
   D) liver
   E) pancreas

   Answer: A
   Diff: 4 Page Ref: 501

86) A change in the ratio of bicarbonate to carbon dioxide concentration in the blood will ________.
   A) change blood potassium concentration
   B) change blood chloride concentration
   C) cause a bronchodilation
   D) cause a vasodilation of systemic arterioles
   E) change blood pH

   Answer: E
   Diff: 3 Page Ref: 501

87) Respiratory acidosis will result from a(n) ________.
   A) increase in blood CO₂ concentration
   B) decrease in blood CO₂ concentration
   C) increase in blood bicarbonate
   D) decrease in blood bicarbonate
   E) increase in carbon monoxide

   Answer: A
   Diff: 5 Page Ref: 501
True/False Questions

1) Over a period of time and under resting conditions, the amount of carbon dioxide generated by the body is greater than the amount of oxygen the body consumes.
   Answer: FALSE  
   Diff: 3  Page Ref: 476

2) The average respiratory quotient at rest and on a mixed diet is 0.5.
   Answer: FALSE  
   Diff: 3  Page Ref: 476

3) The partial pressure of an individual gas within a mixture of gases is determined by the total pressure of those gases and the fractional concentration of that gas in the mixture.
   Answer: TRUE  
   Diff: 3  Page Ref: 478

4) The most abundant gas in air is oxygen.
   Answer: FALSE  
   Diff: 3  Page Ref: 478

5) The percentage of air that is oxygen decreases as altitude increases.
   Answer: FALSE  
   Diff: 5  Page Ref: 478

6) At the same partial pressure, all gases in a solution will be at equal concentration.
   Answer: FALSE  
   Diff: 4  Page Ref: 479

7) Dalton's law describes the solubility of a gas in a liquid.
   Answer: FALSE  
   Diff: 3  Page Ref: 479

8) Oxygen is much more soluble in aqueous solution than carbon dioxide.
   Answer: FALSE  
   Diff: 4  Page Ref: 480

9) There is a substantial safety margin for the uptake of gases in the alveolus because at rest, blood is completely oxygenated after traveling only 1/3 the length of the pulmonary capillary bed.
   Answer: TRUE  
   Diff: 3  Page Ref: 481

10) In active skeletal muscle, the gradient for oxygen movement into the muscle is increased by a decreased P_{O_2} within the muscle cell.
    Answer: TRUE  
    Diff: 3  Page Ref: 483

11) The blood in the pulmonary vein is called mixed venous blood.
    Answer: FALSE  
    Diff: 4  Page Ref: 483

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12) Hyperpnea describes the increase in ventilation that occurs to meet an increase in metabolic demands of the tissues.
   Answer: TRUE
   Diff: 3    Page Ref: 484

13) A decrease in oxygen-carrying capacity can result from alterations in hemoglobin structure or concentration.
   Answer: TRUE
   Diff: 3    Page Ref: 485

14) Hyperventilation decreases blood pH.
   Answer: FALSE
   Diff: 5    Page Ref: 498

15) The compound 2,3-bisphosphoglycerate is a metabolic intermediate of glycolysis within the erythrocyte that can affect the binding of oxygen to hemoglobin.
   Answer: TRUE
   Diff: 4    Page Ref: 488

16) Hemoglobin has a greater affinity for oxygen in the lungs than it does in respiring tissue.
   Answer: TRUE
   Diff: 5    Page Ref: 488

17) Carbaminohemoglobin is hemoglobin with carbon dioxide bound to it.
   Answer: TRUE
   Diff: 3    Page Ref: 488

18) The reaction catalyzed by carbonic anhydrase is an irreversible reaction.
   Answer: FALSE
   Diff: 3    Page Ref: 489

19) As blood flows through systemic capillaries, carbonic acid dissociates into a bicarbonate ion and a hydrogen ion within the erythrocyte; the bicarbonate is moved out by the chloride shift while the hydrogen ion binds with hemoglobin.
   Answer: TRUE
   Diff: 4    Page Ref: 490

20) The Haldane effect refers to the decrease in affinity of oxyhemoglobin for carbon dioxide.
   Answer: TRUE
   Diff: 4    Page Ref: 491

21) The Bohr effect describes the effects of pH on the affinity of hemoglobin for oxygen.
   Answer: TRUE
   Diff: 4    Page Ref: 488

22) The inspiratory neurons of the ventral and dorsal respiratory groups stimulate motor neurons in the phrenic nerve, which stimulates contraction of the diaphragm.
   Answer: TRUE
   Diff: 4    Page Ref: 494
23) The central chemoreceptor responds to hydrogen ions generated from the dissociation of hydrogen from carbonic acid and lactic acid produced by active skeletal muscle.
   Answer: FALSE
   Diff: 4   Page Ref: 497

24) The chemoreceptor reflex regulates ventilation primarily through sensing changes in blood $PO_2$.
   Answer: FALSE
   Diff: 4   Page Ref: 497

25) The resistance of the airways is controlled by bronchioles that are sensitive to changes in $PCO_2$.
   Answer: TRUE
   Diff: 4   Page Ref: 499

26) A respiratory acidosis is cause by increased carbon dioxide within the blood.
   Answer: TRUE
   Diff: 3   Page Ref: 501

27) Hemoglobin can bind $O_2$, $CO_2$ and $H^+$ all at the same time.
   Answer: FALSE
   Diff: 5   Page Ref: 488
Matching Questions

Match the following pressures to the correct location, assuming resting conditions.

1) Partial pressure of oxygen in air.  
   \textit{Diff: 4}  \textit{Page Ref: 481}  
   \begin{align*}
   &A) \ 46 \text{ mm Hg} \\
   &B) \ 80 \text{ mm Hg} \\
   &C) \ 100 \text{ mm Hg} \\
   &D) \ 160 \text{ mm Hg} \\
   &E) \ 40 \text{ mm Hg}
   \end{align*}

2) Partial pressure of oxygen in alveoli.  
   \textit{Diff: 4}  \textit{Page Ref: 481}  
   \begin{align*}
   &A) \ 46 \text{ mm Hg} \\
   &B) \ 80 \text{ mm Hg} \\
   &C) \ 100 \text{ mm Hg} \\
   &D) \ 160 \text{ mm Hg} \\
   &E) \ 40 \text{ mm Hg}
   \end{align*}

3) Partial pressure of carbon dioxide in alveoli.  
   \textit{Diff: 4}  \textit{Page Ref: 481}  
   \begin{align*}
   &A) \ 46 \text{ mm Hg} \\
   &B) \ 80 \text{ mm Hg} \\
   &C) \ 100 \text{ mm Hg} \\
   &D) \ 160 \text{ mm Hg} \\
   &E) \ 40 \text{ mm Hg}
   \end{align*}

4) Partial pressure of oxygen in pulmonary veins.  
   \textit{Diff: 4}  \textit{Page Ref: 481}  
   \begin{align*}
   &A) \ 46 \text{ mm Hg} \\
   &B) \ 80 \text{ mm Hg} \\
   &C) \ 100 \text{ mm Hg} \\
   &D) \ 160 \text{ mm Hg} \\
   &E) \ 40 \text{ mm Hg}
   \end{align*}

5) Partial pressure of carbon dioxide in pulmonary veins.  
   \textit{Diff: 4}  \textit{Page Ref: 481}  
   \begin{align*}
   &A) \ 46 \text{ mm Hg} \\
   &B) \ 80 \text{ mm Hg} \\
   &C) \ 100 \text{ mm Hg} \\
   &D) \ 160 \text{ mm Hg} \\
   &E) \ 40 \text{ mm Hg}
   \end{align*}

6) Partial pressure of oxygen in systemic arteries.  
   \textit{Diff: 4}  \textit{Page Ref: 481}  
   \begin{align*}
   &A) \ 46 \text{ mm Hg} \\
   &B) \ 80 \text{ mm Hg} \\
   &C) \ 100 \text{ mm Hg} \\
   &D) \ 160 \text{ mm Hg} \\
   &E) \ 40 \text{ mm Hg}
   \end{align*}

7) Partial pressure of carbon dioxide in systemic arteries.  
   \textit{Diff: 4}  \textit{Page Ref: 481}  
   \begin{align*}
   &A) \ 46 \text{ mm Hg} \\
   &B) \ 80 \text{ mm Hg} \\
   &C) \ 100 \text{ mm Hg} \\
   &D) \ 160 \text{ mm Hg} \\
   &E) \ 40 \text{ mm Hg}
   \end{align*}

8) Partial pressure of oxygen in systemic veins.  
   \textit{Diff: 4}  \textit{Page Ref: 481}  
   \begin{align*}
   &A) \ 46 \text{ mm Hg} \\
   &B) \ 80 \text{ mm Hg} \\
   &C) \ 100 \text{ mm Hg} \\
   &D) \ 160 \text{ mm Hg} \\
   &E) \ 40 \text{ mm Hg}
   \end{align*}

9) Partial pressure of carbon dioxide in systemic veins.  
   \textit{Diff: 4}  \textit{Page Ref: 481}  
   \begin{align*}
   &A) \ 46 \text{ mm Hg} \\
   &B) \ 80 \text{ mm Hg} \\
   &C) \ 100 \text{ mm Hg} \\
   &D) \ 160 \text{ mm Hg} \\
   &E) \ 40 \text{ mm Hg}
   \end{align*}

10) Partial pressure of oxygen in pulmonary arteries.  
    \textit{Diff: 4}  \textit{Page Ref: 481}  
    \begin{align*}
    &A) \ 46 \text{ mm Hg} \\
    &B) \ 80 \text{ mm Hg} \\
    &C) \ 100 \text{ mm Hg} \\
    &D) \ 160 \text{ mm Hg} \\
    &E) \ 40 \text{ mm Hg}
    \end{align*}

Answers:  
1) D  2) C  3) E  4) C  5) E  
Match the following terms to their definitions.

11) Increase in ventilation that exceeds metabolic needs of the tissue.  
   A) hypercapnia  
   B) hypoventilation  
   C) hyperventilation

12) Excess of carbon dioxide in the blood.  
   D) tachypnea  
   E) hyperpnea

13) Deficiency of oxygen in the blood.  
   F) hypoxia  
   G) hypocapnia

14) Decrease in ventilation to less than that needed by the tissues.  
   H) hypoxemia  
   I) apnea  
   J) dyspnea

16) Rapid, shallow breathing.  

17) Increase in ventilation that matches the metabolic needs of the tissues.  

18) Cessation of breathing.

19) Deficiency of oxygen in the tissues.

20) Deficiency of carbon dioxide in the blood.

Match the following factors that affect oxygen binding to hemoglobin with the correct description.

21) Decrease in the affinity of hemoglobin for oxygen caused by the binding of carbon dioxide to hemoglobin.
   A) carbamino effect
   B) Haldane effect
   C) Bohr effect
   Diff: 5   Page Ref: 488

22) Decrease in the affinity of hemoglobin for oxygen caused by the binding of a hydrogen ion to hemoglobin.
   Diff: 5   Page Ref: 488

23) Decrease in the affinity of hemoglobin for carbon dioxide caused by the binding of oxygen to hemoglobin.
   Diff: 5   Page Ref: 491

Answers: 21) A  22) C  23) B
Essay Questions

1) The air that we breathe is composed of three essential gases that include nitrogen, oxygen, and water vapor. Describe the physical properties that govern the diffusion of gases, including partial pressure and gas solubility.

**Answer:** The diffusion of a molecule is driven by its concentration gradient, which, for a gas is expressed as pressure. However, atmospheric air contains multiple gases. The pressure of an individual gas within that mixture is determined by Dalton’s Law, which states that $P_{\text{total}} = P_{\text{N}_2} + P_{\text{O}_2} + P_{\text{H}_2\text{O}}$. Thus, the total pressure of a gas mixture is the sum of the partial pressures of each component gas, which, in the case of air, includes nitrogen, oxygen, and water vapor. Functionally, the partial pressure of a gas is determined by the product of a gas’s fractional concentration and the total pressure. Oxygen composes 21% of air. At sea level (760 mm Hg), the partial pressure of oxygen is 160 mm Hg (760 mm Hg × 0.21). Since nitrogen is 79% of air, the partial pressure of nitrogen is 600 mm Hg (760 mm Hg × 0.79). The water vapor in air is quite variable and dependent upon the temperature and relative humidity of air. In the conducting zone of the lungs, air is 100% humidified, which, at 37°C, is 47 mm Hg, which decreases the partial pressure of the other gases (760 – 47 = 713 mm Hg total pressure). The amount of carbon dioxide in air is quite small, making up only 0.03% of air, which correlates to a $P_{\text{CO}_2}$ of less than 1 mm Hg at sea level. While partial pressure is the driving force for the diffusion of a gas, the movement of a gas from air to water is affected by the solubility of that gas. Carbon dioxide is more soluble in water than oxygen. At the alveolus, the interface between air and water, the $P_{\text{O}_2}$ and $P_{\text{CO}_2}$ of alveolar air and blood have equilibrated such that the blood leaving the lungs has the same partial pressure as alveolar air. However, the difference in gas solubility means that a greater partial pressure gradient is required for oxygen to diffuse into the blood than carbon dioxide. At the same time, this means that, at equal partial pressures, there is 20 times more carbon dioxide in water than oxygen. The solubility of a gas is described by Henry’s Law, which states that $c = k \times P$, where $c$ is molar concentration and $k$ is a constant, which varies by temperature and the solubility of the gas. The greater the solubility of the gas, the greater the concentration of that gas in solution.

*Diff: 7  Page Ref: 478*
2) The exchange of gases occurs primarily within the lungs and tissues. Describe the nature of the movement of gases in the lungs (including how the partial pressure of alveolar gases are determined) and tissues.

Answer: In the lungs, gases move across the respiratory membrane, including the alveolar epithelial cells, basement membrane, endothelial cells, and erythrocyte membranes. At rest, alveolar $P_{O_2}$ is 100 mm Hg while pulmonary capillary $P_{O_2}$ is 40 mm Hg, resulting in the net diffusion of oxygen into the capillaries. Alveolar $P_{CO_2}$ is 40 mm Hg whereas pulmonary capillary $P_{CO_2}$ is 46 mm Hg, resulting in the net diffusion of carbon dioxide from the blood to the alveolus. This diffusion occurs quickly. At rest, an erythrocyte remains in pulmonary capillaries for ~0.75 sec. However, $P_{O_2}$ and $P_{CO_2}$ have equilibrated before the erythrocyte travels one third of the length of the capillary. This is due to the thinness of the respiratory membrane. The direction of gas movement is reversed in tissues. Blood in systemic capillaries has a $P_{O_2}$ of 100 mm Hg and a $P_{CO_2}$ of 40 mm Hg. Since interstitial $P_{O_2}$ is less than capillary $P_{O_2}$ oxygen will move out of the capillaries. At the same time, interstitial $P_{CO_2}$ is greater than capillary $P_{CO_2}$, resulting in the net diffusion of carbon dioxide into the capillaries. However, the metabolic activity of many tissues is quite variable, which is reflected in a variable tissue venous $P_{O_2}$ and $P_{CO_2}$, which means that, once blood reaches the right ventricle, it is referred to as mixed venous blood, with a $P_{O_2}$ of 40 mm Hg and a $P_{CO_2}$ of 46 mm Hg. When physical activity increases, $P_{O_2}$ decreases as $P_{CO_2}$ increases. The partial pressures of alveolar gases are determined by the partial pressures of gases in the inspired air (determined primarily by altitude), minute ventilation, and the rate of tissue metabolic activity. Thus, the crucial factor in determining alveolar partial pressure is the alveolar ventilation relative to metabolic activity (oxygen consumption and carbon dioxide production). When alveolar ventilation increases relative to metabolic activity, alveolar $P_{O_2}$ increases and $P_{CO_2}$ decreases. In contrast, an increase in metabolic activity relative to alveolar ventilation will decrease $P_{O_2}$ and increase $P_{CO_2}$. 

Diff: 5  Page Ref: 481
3) The solubility of oxygen in solution is relatively low, necessitating the presence of hemoglobin to carry oxygen to active tissues. Hemoglobin exhibits several unique characteristics that make it well suited for the transport of oxygen. Describe the structure of hemoglobin and the mechanisms that can alter the affinity of hemoglobin for oxygen.

Answer: Hemoglobin is composed of four subunits, each containing a heme portion and a globular portion. Each of the four heme groups can bind one oxygen molecule, which means that a hemoglobin molecule can bind four oxygen molecules. The binding of oxygen to the heme groups is reversible and driven by the partial pressure of oxygen. As the first oxygen molecule binds to the hemoglobin at a $P_O^2$ of $\sim 15$ mm Hg, the affinity of the hemoglobin is altered such that the next oxygen molecule is more likely to bind to the hemoglobin. This positive cooperativity is reflected in the sigmoidal shape of the hemoglobin–oxygen dissociation curve. The curve shows that, as the partial pressure of oxygen increases, more oxygen molecules are bound to the hemoglobin. In the lungs, oxygen is loaded onto the hemoglobin while in the tissue, oxygen is unloaded. The loading and unloading of oxygen can be altered by a number of factors in the body. These factors include temperature, pH, $P_O^2$, and 2,3-bisphosphoglycerate (BPG). The first three factors act to promote the loading of oxygen at the lungs and the unloading of oxygen in the tissues. BPG is a product of anaerobic metabolism of erythrocytes that is elevated by an increase in deoxyhemoglobin. Thus, BPG facilitates the unloading of oxygen, which occurs in tissues. With respect to the hemoglobin–oxygen dissociation curve, an increase in the unloading of oxygen from the hemoglobin molecule is reflected in a rightward shift of the curve, whereas an increased loading is reflected in a leftward shift of the curve.

Diff: 7  Page Ref: 485
4) The affinity of hemoglobin for oxygen can be altered to enhance the loading or unloading of oxygen. Describe the changes in active muscle that facilitate the unloading of oxygen from hemoglobin (and the mechanisms by which oxygen binding to hemoglobin is altered by these changes).

Answer: In active muscle, the hemoglobin-oxygen dissociation curve is shifted to the right which enhances the unloading of oxygen. This rightward shift occurs due to the presence of a number of metabolic byproducts that can affect the affinity of hemoglobin for oxygen. This includes an increase in temperature, decrease in pH, increase in PCO₂, and an increase in 2,3-bisphosphoglycerate (2,3-BPG). As metabolic activity increases, temperature increases, which alters the structure of hemoglobin in a way that decreases its affinity for oxygen. This decreased affinity allows the hemoglobin to unload more oxygen at the same partial pressure (this is reflected in the rightward shift of the hemoglobin-oxygen dissociation curve). At the same time, increased metabolic activity enhances the production of hydrogen ions (decreasing pH). Hydrogen ions bind to hemoglobin, which release oxygen from the hemoglobin molecule. Thus, as hydrogen ion concentration increases, oxygen is driven off the hemoglobin molecule. This pH-induced alteration in oxygen binding has been termed the Bohr effect. At the same time, oxygen's binding to hemoglobin decreases in the presence of carbon dioxide. Carbon dioxide binds to hemoglobin, forming carbaminohemoglobin, which decreases the affinity of the hemoglobin for oxygen. Since metabolically active tissue produces more carbon dioxide (increasing PCO₂), this would tend to increase the unloading of oxygen in active tissue. 2,3-BPG is a metabolic intermediate of glycolysis that is released from erythrocytes (erythrocytes have no aerobic metabolism and therefore rely on anaerobic glycolysis for energy). The presence of oxyhemoglobin inhibits the activity of the enzymes that produce 2,3-BPG. When oxyhemoglobin levels are reduced, as occurs in active tissue, 2,3-BPG is synthesized. The binding of 2,3-BPG to hemoglobin reduces hemoglobin’s affinity for oxygen. Both anemia and high altitude enhance the production of 2,3-BPG.
5) The affinity of hemoglobin for oxygen can be altered to enhance the loading or unloading of oxygen. Describe the changes within the lungs that facilitate the loading of oxygen onto the hemoglobin (and the mechanisms by which oxygen binding to hemoglobin is altered by these changes).

Answer: In the lung, the hemoglobin-oxygen dissociation curve is shifted to the left to enhance the loading of oxygen. This leftward shift occurs due to the reductions in the presence of a number of factors, relative to active muscle, that can affect affinity of hemoglobin for oxygen. This includes a decrease in temperature, increase in pH, decrease in $P_{CO_2}$, and the presence of 2,3-bisphosphoglycerate (2,3-BPG). In active muscle, temperature is much higher than in the lungs. This increases the affinity of hemoglobin for oxygen, which causes more oxygen to be loaded onto the hemoglobin molecule at the same partial pressure (this is reflected in the leftward shift of the hemoglobin-oxygen dissociation curve). At the same time, local increases in hydrogen ion concentration are buffered in the blood (increasing pH). The removal of hydrogen ions from the hemoglobin molecule increases hemoglobin's affinity for oxygen. Thus, as hydrogen ion concentrations decrease, oxygen is driven onto the hemoglobin molecule. This pH-induced alteration in oxygen binding has been termed the *Bohr effect*. At the same time, oxygen's binding to hemoglobin increases as $P_{CO_2}$ decreases due to a reduction in concentration of carbon dioxide that is bound to hemoglobin (decreasing carbaminohemoglobin). 2,3-BPG is a metabolic intermediate of glycolysis that is released from erythrocytes (erythrocytes have no aerobic metabolism and therefore rely on anaerobic glycolysis for energy). The presence of oxyhemoglobin inhibits the activity of the enzymes that produces 2,3-BPG. The relatively high oxyhemoglobin levels in the lung would limit the synthesis of 2,3-BPG.

*Diff: 7 Page Ref: 488*
6) While carbon dioxide is more soluble in solution than oxygen, the amount of carbon dioxide produced by active cells is much greater than can dissolve in solution. Describe the mechanisms by which carbon dioxide is transported to the lungs with particular emphasis on carbon dioxide’s binding to hemoglobin and its conversion to bicarbonate.

Answer: In the blood, carbon dioxide is stored in three forms: 5–6% is dissolved in solution, 5–8% is bound to hemoglobin, and 86–90% is dissolved in blood as bicarbonate (HCO₃⁻). Bicarbonate is formed in erythrocytes by conversion of carbon dioxide to carbonic acid (H₂CO₃) with the enzyme carbonic anhydrase.

\[ \text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_₃ \leftrightarrow \text{HCO}_₃⁻ + \text{H}⁺ \]. This reaction is reversible, as indicated by the ↔. This reaction occurs within erythrocytes that perfuse active tissue (high P\text{CO}_₂).

However, the bicarbonate is not stored within the erythrocytes, where it could inhibit the further reaction of carbon dioxide due to an excess of product. The bicarbonate is transported out of each erythrocyte as a chloride ion and is transported into the cell (electroneutrality) by the chloride shift. At the same time, the hydrogen ion that is released by carbonic acid will bind to hemoglobin. This reaction is reversed within the lung, where the decrease in P\text{CO}_₂ drives this reaction in the opposite direction (bicarbonate is converted back to carbon dioxide). Within the lungs, bicarbonate moves into the erythrocyte and associates with hydrogen where it is converted back to carbon dioxide. At the same time, a portion of the carbon dioxide in the blood (5–8%) is bound to hemoglobin. The binding of carbon dioxide to hemoglobin is altered by the prevailing P\text{O}_₂. As P\text{O}_₂ decreases, more carbon dioxide is bound to hemoglobin. This is called the Haldane effect.

Diff: 7 Page Ref: 489

7) A majority of the control of ventilation resides within the central nervous system. Identify the regions of the brain that are important in the regulation of ventilation and how each of them function in the control of ventilation.

Answer: The breathing rhythm appears to involve the medulla and the pons. There are two general classes of neurons located in these regions: inspiratory neurons and expiratory neurons. There are two centers within the medulla that play a role in the control of breathing: ventral and dorsal respiratory groups. The ventral respiratory group (VRG) includes two regions of inspiratory neurons and one region of expiratory neurons. The action potential frequency from these inspiratory neurons increases as the peak of inspiration is approached, where it is abruptly terminated. The dorsal respiratory group (DRG) contains primarily inspiratory neurons, although there are some expiratory neurons. The inspiratory neurons from the DRG have a more complex firing pattern that is dependent upon the degree of stretch of the lungs. Thus, VRG and DRG inspiratory neurons activate the phrenic and external intercostal nerves to stimulate the contraction of the diaphragm and external intercostal muscles, respectively. Some inspiratory neurons from the VRG stimulate the accessory muscles while some of its expiratory neurons stimulate the expiratory muscles. The pontine respiratory group PRG appears to be involved in the transition from inspiration to expiration. Overall control of these respiratory groups lies within a network of neurons called the central pattern generator (CPG), whose location is yet to be determined. The CPG provides a repeated pattern of neural activity. The rhythmic activity of the CPG has been proposed to work through two possible mechanisms: 1) neurons spontaneously depolarize, as is observed in the pacemaker cells, or 2) there is a complex interaction between neurons.

Diff: 8 Page Ref: 493
8) Breathing involves the interaction between a number of the control centers of ventilation. Describe the model that has been developed to describe the process of quiet breathing, including how volume of the lung is altered by this process.

Answer: The model for quiet breathing involves the generation of a breathing rhythm from the central pattern generator (CPG). This rhythm is communicated to the inspiratory neurons of the dorsal respiratory group (DRG) and ventral respiratory group (VRG). This causes a ramp increase in the frequency of action potentials in these cells, which is communicated to the motor neurons of the phrenic and external intercostal nerves. Early in inspiration, only a few motor neurons are activated and contraction of the muscles (diaphragm and external intercostals) is weak. As the frequency of action potentials increases, more motor neurons are activated, causing a greater force to be generated by the respiratory muscles. The stronger force of contraction increases the volume of the lung. After a couple of seconds, the activity of the inspiratory neurons abruptly terminates. Quiet breathing means expiration involves the passive relaxation of the diaphragm and external intercostal, with no active contraction decreasing the size of the lungs. After a brief rest period, the CPG initiates the next breathing cycle. In this model, the respiratory centers of the medulla are primarily responsible for controlling breathing. However, breathing is affected by other brain areas as well, including the pons, cerebral cortex, cerebellum, limbic system, hypothalamus, and the medullary cardiovascular centers.

9) The central pattern generator is the rhythm generator that sets the background rhythm for ventilation. However, the respiratory system must be able to respond to changes that require either increases or decreases in ventilation. Describe the receptors that are involved in modulating ventilation and how they function.

Answer: There are a number of receptors involved in the modulation of ventilation, including chemoreceptors, pulmonary stretch receptors, proprioceptors (muscles and joints), arterial baroreceptors, nociceptors, thermoreceptors, and irritant receptors. The pulmonary stretch receptors do not appear to play an important role in the regulation of breathing in humans. Irritant receptors are stimulated by inhaled particulates. These receptors are located in the trachea (where they initiate a cough) and in the pharynx and nose (where they initiate a sneeze). The chemoreceptors are located peripherally and centrally. The activity of these receptors varies by location. The peripheral receptors are located within the carotid bodies. These receptors are specialized cells in direct contact with the blood that respond to changes in blood $P_{O_2}$, $P_{CO_2}$, and hydrogen ion concentration (pH). Peripheral chemoreceptors are poorly responsive to $P_{O_2}$, requiring a $P_{O_2}$ less than 60 mm Hg to initiate a response. At the same time, these receptors respond to changes in $P_{CO_2}$ and hydrogen ion concentration. An increase in blood $P_{CO_2}$ will decrease pH (increases hydrogen ion concentration), however, changes in systemic pH can also affect these receptors. In addition, low $P_{O_2}$ increases the sensitivity of peripheral chemoreceptors to pH. The central chemoreceptors are located within the medulla and respond directly to changes in hydrogen ion concentration. However, hydrogen ions are not able to move across the blood-brain barrier. Thus, any change in hydrogen ion concentration in the medulla reflects primarily a change in blood $P_{CO_2}$. Once the carbon dioxide crosses the barrier, it is converted to bicarbonate and hydrogen ions by carbonic anhydrase in the cerebrospinal fluid.
10) In the lung, the uptake of oxygen is in part determined by the ventilation-perfusion ratio, which varies throughout the lung. Describe how ventilation-perfusion is regulated within the lung itself. How would ventilation-perfusion ratio be affected by hyperventilation?

Answer: The ratio of ventilation to perfusion is an important determinant of oxygen saturation. If ventilation is restricted by an obstruction, then alveolar PO2 and PCO2 will no longer be maintained at 100 mm Hg and 40 mm Hg respectively, thereby decreasing the gradient for the movement of gases to and from the blood. There are inequalities in ventilation-perfusion ratios throughout the lung. This is especially true in the lower lung where the hydrostatic pressure of gravity increases blood flow compared to the upper regions. Thus, the ventilation-perfusion ratio is lower in the bottom of the lung than in upper portions. In addition, ventilation-perfusion is controlled locally by gases. Carbon dioxide controls the extent of bronchiole constriction. An increase in PCO2 will cause bronchioles to dilate, which affects ventilation. At the same time, an increase in PO2 will cause arterioles to constrict. Hyperventilation results in an increase in PO2 and a decrease in PCO2. Thus, both bronchioles and arterioles will constrict and thereby reduce both ventilation and perfusion. The ratio of ventilation-perfusion will be determined by the magnitude of the changes in ventilation relative to the changes in blood flow.

Diff: 6 Page Ref: 499

11) In the discussion of respiration, hydrogen ions were shown to be important in many aspects of ventilation. Thus, the respiratory system plays an important role in the regulation of acid-base balance. Describe the role of the respiratory system in the maintenance of acid-base balance.

Answer: Typically, blood pH is somewhere around 7.4. A decrease in pH (acidosis) tends to depress central nervous system activity, while an increase in pH (alkalosis) will cause a hyperexcited state that can lead to seizures or convulsions. The respiratory system provides two important buffers for the acid-base balance: hemoglobin and bicarbonate. Hemoglobin buffers pH by its ability to bind with hydrogen ions, which affects the binding of oxygen via the Bohr effect. In addition to hemoglobin, bicarbonate acts as a buffer. Bicarbonate affects pH through the interaction between PCO2 and bicarbonate concentration. Bicarbonate is regulated by the kidneys, whereas the lungs regulate PCO2. Thus, as PCO2 increases, the blood will become more acidic (pH = 6.1 + log ([HCO3]/[CO2])), creating what is called respiratory acidosis. On the other side, a decrease in PCO2 will cause a respiratory alkalosis.

Diff: 6 Page Ref: 501

Short Answer Questions

1) At an altitude where atmospheric pressure is 500 mm Hg, what is the partial pressure of oxygen?

Answer: 105 mm Hg

Diff: 5 Page Ref: 478

2) As total atmospheric pressure increases, the partial pressure of a gas in solution will (increase / decrease).

Answer: increase

Diff: 4 Page Ref: 480
3) Once equilibrated, the concentration of oxygen in water will be (greater than / less than) air.
   Answer: less than
   Diff: 5   Page Ref: 481

4) The pressure gradient that drives the movement of carbon dioxide from the blood to the alveolus measures _______, whereas the gradient for oxygen measures _______. (Be sure to include units.)
   Answer: 6 mm Hg : 60 mm Hg
   Diff: 5   Page Ref: 481

5) Give the partial pressure of oxygen and carbon dioxide in each of the following regions.
   atmosphere
   alveolar air
   pulmonary veins
   pulmonary arteries
   systemic veins
   systemic arteries
   Answer: For oxygen: 160 mm Hg, 100 mm Hg, 100 mm Hg, 40 mm Hg, 40 mm Hg, 100 mm Hg
           For carbon dioxide: 0.3 mm Hg, 40 mm Hg, 40 mm Hg, 46 mm Hg, 46 mm Hg, 40 mm Hg
   Diff: 8   Page Ref: 481

6) As the thickness of the respiratory membrane increases, the rate of oxygen uptake across that membrane (increases / decreases).
   Answer: decreases
   Diff: 3   Page Ref: 483

7) The $\text{PCO}_2$ of veins that exit active skeletal muscle is (greater than / less than) that observed in the right atrium.
   Answer: greater than
   Diff: 5   Page Ref: 483

8) Hyperventilation results in a(n) (increase / decrease) in $\text{PO}_2$ and a(n) (increase / decrease) in $\text{PCO}_2$.
   Answer: increase : decrease
   Diff: 4   Page Ref: 484

9) A decrease in the affinity of oxygen for hemoglobin is reflected as a (rightward / leftward) shift in the hemoglobin–oxygen dissociation curve, which would facilitate the (loading / unloading) of oxygen.
   Answer: rightward : unloading
   Diff: 5   Page Ref: 487

10) The enzyme ________, which is responsible for the conversion of $\text{CO}_2$ to $\text{H}_2\text{CO}_3$, can be found within ________.
    Answer: carbonic anhydrase : erythrocytes or cerebrospinal fluid
    Diff: 6   Page Ref: 489
11) Although much of the conversion of CO₂ occurs within the erythrocyte, this reaction never reaches equilibrium because the buildup of product is prevented by ________.
   Answer: the transport of bicarbonate out of the erythrocyte via the chloride shift and the binding of hydrogen to hemoglobin
   Diff: 5    Page Ref: 490

12) The (peripheral / central) chemoreceptors are responsive to increases in the hydrogen ion concentration of the blood.
   Answer: peripheral
   Diff: 4    Page Ref: 496

13) The ventilation-perfusion ratio is controlled locally within the lungs by (O₂ / CO₂) acting primarily on perfusion, while (O₂ / CO₂) acts primarily on ventilation.
   Answer: oxygen : carbon dioxide
   Diff: 5    Page Ref: 499

14) Given a gas at 1000 mm Hg that is 10% helium, 20% nitrogen, 30% neon, and 40% argon, what are the partial pressures of each gas in the mixture?
   Answer: helium 100 mm Hg, nitrogen 200 mm Hg, neon 300 mm Hg, and argon 400 mm Hg
   Diff: 4    Page Ref: 478

15) Mixed venous blood is measured in what blood vessel?
   Answer: pulmonary artery
   Diff: 4    Page Ref: 483

16) In systemic arterial blood, hemoglobin is ________% saturated, whereas in mixed venous blood, hemoglobin is ________% saturated.
   Answer: 98 : 75
   Diff: 5    Page Ref: 485

17) An increase in temperature (increases / decreases) oxygen unloading.
   Answer: increases
   Diff: 4    Page Ref: 488

18) When carbon dioxide binds to hemoglobin, the resulting molecule is called ________, and it has a (greater / lesser) affinity for oxygen.
   Answer: carbaminohemoglobin : lesser
   Diff: 4    Page Ref: 492

19) What nerve innervates the diaphragm?
   Answer: phrenic nerve
   Diff: 4    Page Ref: 493

20) Inspiratory neurons have a greater frequency of action potentials near the (beginning / end) of inspiration.
   Answer: end
   Diff: 5    Page Ref: 496

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21) Hydrogen ions produced by metabolism can only activate (peripheral / central)
chemoreceptors.
   Answer: peripheral
   Diff: 5  Page Ref: 497

22) (Carbon dioxide / Hydrogen ions) can cross the blood-brain barrier.
   Answer: carbon dioxide
   Diff: 4  Page Ref: 498

23) If air flow to an alveolus is decreased, then blood flow to the alveolus will (increase / decrease).
   Answer: decrease
   Diff: 5  Page Ref: 501

24) To maintain normal acid-base balance, the ratio of bicarbonate to carbon dioxide must be
   ________.
   Answer: 20 : 1
   Diff: 5  Page Ref: 504

25) A respiratory acidosis can occur during (hyperventilation / hypoventilation).
   Answer: hypoventilation
   Diff: 5  Page Ref: 501
Chapter 18  The Urinary System: Renal Function

Multiple Choice Questions

1) Which of the following is NOT a function of the kidneys?
   A) regulation of plasma ionic concentration
   B) regulation of plasma osmolarity
   C) regulation of plasma temperature
   D) regulation of plasma volume
   E) regulation of plasma hydrogen concentration

   Answer: C
   Diff: 3   Page Ref: 508

2) The primary function of the kidneys involves regulating the _______ and the _______ of plasma and interstitial fluid.
   A) volume : temperature
   B) volume : composition
   C) temperature : composition
   D) pressure : volume
   E) composition : osmolarity

   Answer: B
   Diff: 4   Page Ref: 508

3) Once produced, urine travels through the _______ until it reaches the bladder, from which it is released into the external environment through the _______.
   A) ureter : urethra
   B) urethra : ureter
   C) collecting duct : ureter
   D) collecting duct : urethra
   E) renal hilus : ureter

   Answer: A
   Diff: 4   Page Ref: 509

4) Which of the following is NOT part of the urinary system?
   A) kidneys
   B) liver
   C) ureters
   D) urethra
   E) bladder

   Answer: B
   Diff: 3   Page Ref: 509
5) Despite being less than 1% of body weight, the kidneys receive what percent of resting cardiac output?
   A) 1%
   B) 5%
   C) 15%
   D) 20%
   E) 35%
   Answer: D
   Diff: 4    Page Ref: 509

6) What are the conical sections of the renal medulla called?
   A) renal cortex
   B) renal pelvis
   C) renal pyramids
   D) minor calyces
   E) major calyces
   Answer: C
   Diff: 4    Page Ref: 510

7) Where do the collecting ducts of the renal tubules drain?
   A) ureters
   B) minor calyces
   C) major calyces
   D) renal pelvis
   E) glomerulus
   Answer: B
   Diff: 3    Page Ref: 510

8) What is the functional unit of the kidney?
   A) loop of Henle
   B) proximal tubule
   C) collecting ducts
   D) nephron
   E) glomerulus
   Answer: D
   Diff: 4    Page Ref: 510

9) What two structures make up the renal corpuscle?
   A) afferent and efferent arterioles
   B) major and minor calyces
   C) nephron and collecting duct
   D) Bowman's capsule and glomerulus
   E) proximal straight and proximal convoluted tubules
   Answer: D
   Diff: 4    Page Ref: 510
10) Blood leaves the _______ and enters the glomerulus.
   A) afferent arteriole  
   B) efferent arteriole  
   C) peritubular capillary  
   D) vasa recta  
   E) Bowman’s capsule

Answer: A
Diff: 3    Page Ref: 510

11) Where does blood leaving the glomerulus go to next?
   A) afferent arteriole  
   B) efferent arteriole  
   C) peritubular capillary  
   D) vasa recta  
   E) Bowman’s capsule

Answer: B
Diff: 3    Page Ref: 511

12) After fluid passes through the entire proximal tubule, the fluid will enter the _______.
   A) loop of Henle  
   B) distal tubule  
   C) connecting tubule  
   D) collecting duct  
   E) Bowman’s capsule

Answer: A
Diff: 4    Page Ref: 511

13) What type of nephrons are located within the outer region of the kidney and comprise nearly 80% of the nephrons?
   A) peritubular  
   B) medullary  
   C) juxtaglomerular  
   D) juxtamedullary  
   E) cortical

Answer: E
Diff: 5    Page Ref: 512

14) The juxtaglomerular apparatus describes the unique region of the nephron where _______.
   A) the efferent arteriole is in contact with the distal tubule  
   B) the afferent arteriole is in contact with the distal tubule  
   C) the afferent and efferent arterioles are in contact with the distal tubule  
   D) the afferent arteriole is in contact with the proximal tubule  
   E) the afferent and efferent arterioles are in contact with the proximal tubule

Answer: C
Diff: 4    Page Ref: 512
15) What capillaries come off of the efferent arterioles associated with cortical nephrons?
   A) glomerulus  
   B) peritubular  
   C) vasa recta  
   D) arcuate  
   E) lobular  
   Answer: B  
   Diff: 4  Page Ref: 512

16) What capillaries come off of the efferent arterioles associated with juxtamedullary nephrons?
   A) glomerulus  
   B) peritubular  
   C) vasa recta  
   D) arcuate  
   E) lobular  
   Answer: C  
   Diff: 4  Page Ref: 512

17) Which of the following is the correct order of blood supply to the kidneys?
   A) renal artery — interlobar arteries — arcuate arteries — segmental arteries — interlobular arteries — efferent arteriole — glomerulus — afferent arteriole  
   B) renal artery — segmental arteries — interlobar arteries — arcuate arteries — interlobular arteries — afferent arteriole — glomerulus — efferent arteriole  
   C) renal artery — arcuate arteries — interlobular arteries — segmental arteries — afferent arteriole — glomerulus — efferent arteriole — interlobar arteries  
   D) renal artery — segmental arteries — interlobar arteries — arcuate arteries — interlobar arteries — efferent arteriole — glomerulus — afferent arteriole  
   E) renal artery — interlobar arteries — interlobar arteries — arcuate arteries — segmental arteries — afferent arteriole — glomerulus — efferent arteriole  
   Answer: B  
   Diff: 6  Page Ref: 512

18) During what renal process are molecules selectively removed from the tubule lumen, moved into the interstitial space, and removed from the kidneys by the peritubular capillaries and the vasa recta?
   A) filtration  
   B) secretion  
   C) excretion  
   D) reabsorption  
   E) absorption  
   Answer: D  
   Diff: 4  Page Ref: 514
19) The peritubular capillaries and vasa recta drain into hat veins?
   A) interlobular
   B) interlobar
   C) arcuate
   D) efferent
   E) segmental
   Answer: A
   Diff: 5  Page Ref: 512

20) As fluid moves out of the glomerular capillaries, it passes through gaps in the podocytes called slit pores, whose size is regulated by what?
   A) fenestrations
   B) slit diaphragm
   C) slit muscle
   D) corpuscle
   E) glomerular capillary
   Answer: B
   Diff: 5  Page Ref: 515

21) What is the process whereby molecules are selectively transported from the peritubular fluid to the lumen of the renal tubules?
   A) glomerular filtration
   B) reabsorption
   C) absorption
   D) secretion
   E) excretion
   Answer: D
   Diff: 3  Page Ref: 515

22) What is the process whereby protein-free plasma moves by bulk flow from the glomerulus into Bowman’s capsules?
   A) glomerular filtration
   B) reabsorption
   C) absorption
   D) secretion
   E) excretion
   Answer: A
   Diff: 4  Page Ref: 514

23) Which of the following forms the filtration barrier?
   A) capillary endothelial cells only
   B) podocytes only
   C) basement membrane only
   D) both capillary endothelial cells and basement membrane
   E) capillary endothelial cells, basement membrane, and podocytes
   Answer: E
   Diff: 5  Page Ref: 515
24) What is the sum of Starling’s forces within the renal corpuscle called?
   A) glomerular filtration pressure
   B) glomerular filtration rate
   C) glomerular filtration volume
   D) glomerular oncotic pressure
   E) glomerular capillary hydrostatic pressure
   Answer: A
   Diff: 4   Page Ref: 515

25) What Starling force, which drives fluid out of the glomerulus, is relatively high (~60 mm Hg) due to the resistance of the efferent arterioles.
   A) Bowman’s capsule oncotic
   B) Glomerular capillary hydrostatic
   C) Bowman’s capsule hydrostatic
   D) Glomerular oncotic
   E) Glomerular filtration
   Answer: B
   Diff: 5   Page Ref: 515

26) Which of the following pressures across the glomerular capillaries approaches zero?
   A) glomerular filtration pressure
   B) glomerular oncotic pressure
   C) glomerular capillary hydrostatic pressure
   D) Bowman’s capsule oncotic pressure
   E) Bowman’s capsule hydrostatic pressure
   Answer: D
   Diff: 4   Page Ref: 516

27) Which of the forces across the glomerular capillaries tends to increase from the afferent to the efferent arteriole ends?
   A) glomerular filtration pressure
   B) Bowman’s capsule hydrostatic pressure
   C) Bowman’s capsule oncotic pressure
   D) glomerular capillary hydrostatic pressure
   E) glomerular oncotic pressure
   Answer: E
   Diff: 5   Page Ref: 516

28) Which of the equations below describes the calculation of glomerular filtration pressure (BC = Bowman’s capsule and GC = glomerular capillary)?
   A) \( (P_{GC} + \pi_{BC}) - (P_{BC} + \pi_{GC}) \)
   B) \( (P_{BC} + \pi_{BC}) - (P_{GC} + \pi_{GC}) \)
   C) \( (P_{GC} + \pi_{GC}) - (P_{BC} + \pi_{BC}) \)
   D) \( (P_{GC} + P_{BC}) - (\pi_{GC} + \pi_{BC}) \)
   E) \( (P_{BC} + \pi_{GC}) - (P_{GC} + \pi_{BC}) \)
   Answer: A
   Diff: 5   Page Ref: 516
29) Which of the following conditions would increase glomerular filtration pressure?
   A) decreased resistance of the efferent arterioles
   B) increased protein in Bowman’s space
   C) increased resistance of the afferent arteriole
   D) increased protein content in the blood
   E) increased Bowman’s capsule pressure

   Answer: B  
   Diff: 6  Page Ref: 516

30) Which of the following equations is correct for calculating the filtered load?
   A) glomerular filtration pressure × plasma concentration of solvent
   B) glomerular filtration pressure / renal plasma flow
   C) glomerular filtration rate / renal plasma flow
   D) glomerular filtration pressure × plasma concentration of solute
   E) glomerular filtration rate × plasma concentration of solute

   Answer: E  
   Diff: 5  Page Ref: 517

31) Changes in mean arterial pressure have the potential to alter glomerular filtration rate by 
    directly altering which of the following?
   A) glomerular oncotic pressure
   B) glomerular capillary hydrostatic pressure
   C) Bowman’s capsule oncotic pressure
   D) Bowman’s capsule hydrostatic pressure
   E) efferent arteriole resistance

   Answer: B  
   Diff: 5  Page Ref: 517

32) What is the normal glomerular filtration rate?
   A) 125 mL/min
   B) 625 mL/min
   C) 3 L/day
   D) 30 L/day
   E) 1 gallon/day

   Answer: A  
   Diff: 4  Page Ref: 516

33) If the glomerular filtration rate is 150 mL/min, renal blood flow is 750 mL/min, and the plasma 
    concentration of solute X is 10 ng/mL, then what is the filtration fraction?
   A) 10%
   B) 20%
   C) 50 ng/min
   D) 1500 ng/min
   E) 75 ng/min

   Answer: B  
   Diff: 6  Page Ref: 517
34) If the glomerular filtration rate is 150 mL/min, renal blood flow is 750 mL/min, and the plasma concentration of solute X is 10 ng/mL, then what is the filtered load of X?
   A) 10%
   B) 20%
   C) 50 ng/min
   D) 1500 ng/min
   E) 7500 ng/min

   Answer: D  
   Diff: 6  Page Ref: 517

35) Which of the following can increase the filtered load of a particular solute?
   A) increasing the glomerular filtration rate
   B) increasing the rate of reabsorption
   C) decreasing the plasma concentration of the solute
   D) increasing the rate of secretion
   E) decreasing the rate of excretion

   Answer: D  
   Diff: 5  Page Ref: 517

36) Over what range of mean arterial pressure does glomerular filtration rate remain stable due to intrinsic regulation?
   A) 50–150 mm Hg
   B) 80–180 mm Hg
   C) 70–110 mm Hg
   D) 80–100 mm Hg
   E) 80–120 mm Hg

   Answer: B  
   Diff: 5  Page Ref: 517

37) During myogenic regulation of glomerular filtration rate, an increase in mean arterial pressure will ________.
   A) cause the efferent arterioles to constrict and thereby maintain a relatively constant glomerular filtration pressure
   B) cause the afferent arterioles to constrict and thereby maintain a relatively constant glomerular filtration pressure
   C) cause the efferent arterioles to dilate and thereby maintain a relatively constant glomerular filtration pressure
   D) cause the afferent arterioles to dilate and thereby maintain a relatively constant glomerular filtration pressure
   E) cause the afferent arterioles to dilate and thereby allow glomerular filtration pressure to increase

   Answer: B  
   Diff: 5  Page Ref: 518
38) In tubuloglomerular feedback, an increase in glomerular filtration rate would increase the ________, thereby stimulating the release of a paracrine factor from the macula densa that would ________.
   A) afferent arteriolar pressure : constrict the afferent arteriole
   B) afferent arteriolar pressure : increase filtrate flow
   C) flow of tubular fluid : dilate the afferent arteriole
   D) flow of tubular fluid : constrict the efferent arteriole
   E) flow of tubular fluid : constrict the afferent arteriole

Answer: E  
*Diff: 6  Page Ref: 518*

39) Contraction of mesangial cells results in a ________, which decreases glomerular filtration.
   A) decrease in surface area of capillaries available for filtration
   B) increase in surface area of capillaries available for filtration
   C) constriction of the afferent arterioles
   D) dilation of the afferent arterioles
   E) dilation of the efferent arterioles

Answer: A  
*Diff: 5  Page Ref: 519*

40) Which of the following is NOT a mechanism whereby glomerular filtration rate is regulated?
   A) tubuloglomerular feedback
   B) myogenic regulation
   C) mesangial cell contraction
   D) granular cell contraction
   E) sympathetic nervous system

Answer: D  
*Diff: 5  Page Ref: 519*

41) A hemorrhage–induced decrease in mean arterial pressure will decrease glomerular filtration rate by intrinsic and extrinsic mechanisms; the extrinsic mechanisms act through ________.
   A) tubuloglomerular feedback
   B) the parasympathetic nervous system
   C) the sympathetic nervous system
   D) myogenic responses
   E) mesangial cells

Answer: C  
*Diff: 5  Page Ref: 519*

42) How does the sympathetic nervous system decrease glomerular filtration rate?
   A) stimulates constriction of the afferent arteriole only
   B) stimulates constriction of the efferent arteriole only
   C) stimulates constriction of both the afferent and efferent arterioles
   D) stimulates relaxation of the mesangial cells
   E) stimulates contraction of mesangial cells

Answer: C  
*Diff: 5  Page Ref: 519*
43) What is the primary barrier to reabsorption in the renal tubules?
   A) capillary endothelial cell
   B) tubule epithelial cell
   C) capillary basement membrane
   D) tubule basement membrane
   E) peritubular space

   Answer: B
   Diff: 4  Page Ref: 520

44) What condition(s) must exist for a solute to be passively reabsorbed from the renal tubules?
   A) The solute must be able to permeate the membrane of the tubule epithelial cells, and the solute must be in greater concentration in the plasma than tubule fluid.
   B) The solute must be able to permeate the membrane of the capillary endothelial cells, and the solute must be in greater concentration in the plasma than tubule fluid.
   C) The solute must be able to permeate the membrane of the capillary endothelial cells, and the solute must be in greater concentration in the tubule fluid than plasma.
   D) The solute must be able to permeate the membrane of the tubule epithelial cells, and the solute must be in greater concentration in the tubule fluid than plasma.
   E) The solute must be able to permeate the membrane of the tubule epithelial cells and capillary endothelial cells. Its concentration is irrelevant.

   Answer: D
   Diff: 5  Page Ref: 521

45) Within the kidneys, what membrane has microvillii?
   A) apical membrane of renal tubule epithelial cells
   B) basolateral membrane of renal tubule epithelial cells
   C) basolateral membrane of peritubular capillary endothelial cells
   D) apical membrane of vasa recta endothelial cells
   E) glomerulus

   Answer: A
   Diff: 5  Page Ref: 521

46) The apical membranes of the tubular epithelial cells contain _______ that increase the surface area for reabsorption.
   A) mitochondria
   B) loose junctions
   C) a basement membrane
   D) microvilli
   E) tight junctions

   Answer: D
   Diff: 4  Page Ref: 521
47) The diffusion of water across a tubule is driven by differences in _______ across the membrane.
   A) osmolarity  
   B) partial pressure  
   C) active transport  
   D) volume  
   E) potassium concentration
   Answer: A
   Diff: 3  Page Ref: 521

48) When the solute concentration is high enough in the lumen of the renal tubules such that all of the carrier proteins or pumps for that solute are occupied, the system is operating at _______.
   A) diffusional saturation  
   B) tubular threshold  
   C) renal threshold  
   D) transport maximum  
   E) tubular maximum
   Answer: D
   Diff: 4  Page Ref: 522

49) The concentration of glucose in tubular epithelial cells is maintained in an elevated state by what type of transporter on the apical membrane?
   A) ion channel  
   B) carrier protein  
   C) glucose–linked secondary active transporter  
   D) potassium–linked secondary active transporter  
   E) sodium–linked secondary active transporter
   Answer: E
   Diff: 5  Page Ref: 522

50) Which of the following is FALSE concerning glucose transport across the proximal tubule?
   A) Glucose is normally 100% reabsorbed.  
   B) Glucose is actively transported across the apical membrane by cotransport with sodium.  
   C) Glucose is passively transported across the basolateral membrane by facilitated diffusion.  
   D) Glucose transport requires energy.  
   E) Glucose moves by paracellular transport.
   Answer: E
   Diff: 5  Page Ref: 522

51) Which of the following is FALSE concerning renal handling of glucose?
   A) The maximum rate of glucose reabsorption is 375 mg/min.  
   B) The maximum rate of glucose filtration is 375 mg/min.  
   C) Once glucose concentration in the plasma exceeds the renal threshold, glucose will be excreted in the urine.  
   D) Glucose is completely reabsorbed when its plasma concentration is 100 mg/dL.  
   E) Glucose is actively reabsorbed in the proximal tubule.
   Answer: B
   Diff: 6  Page Ref: 522

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52) Which of the following substances is NOT secreted at any point into the renal tubules?
   A) choline
   B) creatinine
   C) potassium
   D) hydrogen
   E) sodium
   Answer: E
   Diff: 5 Page Ref: 524

53) By the time filtrate reaches the loop of Henle, what percentage of the sodium and water has been reabsorbed?
   A) 1%
   B) 50%
   C) 70%
   D) 90%
   E) 100%
   Answer: C
   Diff: 4 Page Ref: 524

54) By the time the filtrate reaches the loop of Henle, the reabsorption of water and ions has __________.
   A) left the filtrate iso-osmotic
   B) left the filtrate hyperosmotic
   C) left the filtrate hypoosmotic
   D) removed all of the potassium from the filtrate
   E) removed all of the sodium from the filtrate
   Answer: A
   Diff: 6 Page Ref: 524

55) Which of the following is NOT an accurate description of differences between epithelial cells of the proximal and distal tubules?
   A) less prominent microvilli in the epithelial cells of the distal tubule
   B) greater paracellular transport in the epithelial cells of the distal tubule
   C) fewer mitochondria in the epithelial cells of the distal tubule
   D) receptors for hormones on the epithelial cells of the distal tubule
   E) less permeable tight junctions between the epithelial cells of the distal tubule
   Answer: B
   Diff: 5 Page Ref: 524

56) In diabetes mellitus, why does polyuria occur?
   A) a lack of ADH decreases water reabsorption
   B) a lack of insulin decreases water reabsorption
   C) hyperglycemia causes increased permeability of the renal tubules to water
   D) hyperglycemia causes some glucose to remain in the renal tubules which pulls water with it by osmosis
   E) hypoglycemia causes the excretion of a dilute urine
   Answer: D
   Diff: 5 Page Ref: 523
57) What is the brush border?
   A) the epithelial cells of the renal corpuscle
   B) microvilli on the apical membrane of Bowman’s capsule
   C) tight junctions between epithelial cells of the loops of Henle
   D) microvilli on the apical membrane of the proximal tubule
   E) tight junctions between epithelial cells of the distal tubule

Answer: D

58) Most reabsorption occurs in the _______ and is _______.
   A) proximal tubule : regulated
   B) proximal tubule : not regulated
   C) distal tubule and collecting duct : regulated
   D) distal tubule and collecting duct : not regulated
   E) loop of Henle : regulated

Answer: B

59) Tubular epithelial cells of the collecting duct and distal tubule contain receptors for what hormone that stimulates sodium reabsorption?
   A) antidiuretic hormone
   B) renin
   C) aldosterone
   D) atrial natriuretic peptide
   E) erythropoietin

Answer: C

60) Tubular epithelial cells of the collecting duct and distal tubule contain receptors for what hormone that stimulates water reabsorption.
   A) antidiuretic hormone
   B) renin
   C) aldosterone
   D) atrial natriuretic peptide
   E) erythropoietin

Answer: A

61) What creates the osmotic gradient in the renal medulla?
   A) active transport of solute out of the proximal tubule
   B) special transport systems of the loops of Henle of juxtamedullary nephrons
   C) special transport systems of the loops of Henle of cortical nephrons
   D) active transport of solute out of the distal tubules and collecting ducts
   E) passive transport of solute out of the distal tubules and collecting ducts

Answer: B
62) Substances can enter the renal tubules by what renal processes?
   A) filtration only
   B) reabsorption only
   C) secretion only
   D) both filtration and secretion
   E) both reabsorption and secretion
   Answer: D
   Diff: 4 Page Ref: 525

63) The amount of a substance excreted from the kidneys is calculated by which of the following equations?
   A) filtration + secretion + reabsorption
   B) filtration − secretion − reabsorption
   C) filtration + secretion − reabsorption
   D) filtration + (secretion × reabsorption)
   E) filtration − (secretion × reabsorption)
   Answer: C
   Diff: 3 Page Ref: 525

64) Solute s that enter the lumen of the renal tubules are excreted unless they are ________.
   A) secreted
   B) reabsorbed
   C) filtered
   D) degraded
   E) bound to receptors
   Answer: B
   Diff: 3 Page Ref: 525

65) If the amount of solute excreted per minute is greater than the filtered load, then the NET effect on the solute is ________.
   A) a combination of reabsorption and secretion in the renal tubules
   B) an absence of secretion in the renal tubules
   C) an absence of reabsorption in the renal tubules
   D) secretion into the renal tubules
   E) reabsorption from the renal tubules
   Answer: D
   Diff: 5 Page Ref: 525

66) Which of the following equations for determining clearance is correct?
   A) Clearance = filtered load/glomerular filtration rate
   B) Clearance = filtered load × glomerular filtration rate
   C) Clearance = excretion rate/plasma concentration
   D) Clearance = excretion rate × plasma concentration
   E) Clearance = excretion rate/glomerular filtration rate
   Answer: C
   Diff: 4 Page Ref: 526
67) Which of the following equations for determining clearance is correct?

A) Clearance = \( \frac{\text{plasma concentration} \times \text{urine flow rate}}{\text{urine concentration}} \)

B) Clearance = \( \frac{\text{urine concentration} \times \text{urine flow rate}}{\text{plasma concentration}} \)

C) Clearance = \( \frac{\text{plasma concentration}}{\text{urine concentration} \times \text{urine flow rate}} \)

D) Clearance = \( \frac{\text{urine concentration}}{\text{plasma concentration} \times \text{urine flow rate}} \)

E) Clearance = \( \text{GRF} \times \text{urine concentration} \)

Answer: B

Diff: 4  Page Ref: 527

68) Calculate renal clearance of X given the following information: GFR = 100 mL/min, urine flow rate = 5 mL/min, plasma concentration of X = 10 mg/mL, urine concentration of X = 50 mg/mL.

A) 50 mg/min
B) 25 mg/min
C) 4 mg/min
D) 50 mL/min
E) 25 mL/min

Answer: E

Diff: 7  Page Ref: 527

69) Given that GFR is 125 mL/min and the clearance of substance Y is 200 mL/min, which of the following MUST be true of the renal handling of substance Y.

A) Y is freely filterable.
B) Y is reabsorbed.
C) Y is secreted.
D) Y is neither reabsorbed nor secreted.
E) Y is not freely filtered.

Answer: B

Diff: 4  Page Ref: 528

70) The clearance of what substance provides the best estimate of glomerular filtration rate?

A) sodium
B) glucose
C) inulin
D) creatine
E) PAH

Answer: C

Diff: 4  Page Ref: 527
71) The clearance of what substance provides the best estimate of renal blood flow rate?
   A) sodium
   B) glucose
   C) inulin
   D) creatine
   E) PAH
   Answer: E  
   Diff: 4  Page Ref: 528

72) The clearance of which of the following substances is normally zero?
   A) sodium
   B) glucose
   C) inulin
   D) creatine
   E) PAH
   Answer: B  
   Diff: 4  Page Ref: 528

73) If a substance is neither reabsorbed nor secreted, then its excretion rate is equal to the 
    _______.
   A) glomerular filtration rate
   B) filtered load
   C) glomerular filtration rate
   D) plasma concentration of the substance
   E) renal threshold
   Answer: B  
   Diff: 5  Page Ref: 528

74) What structure is formed by the thickening of the smooth muscle cell wall surrounding the 
    bladder that regulates the flow of urine from the bladder.
   A) bladder sphincter
   B) urethral muscle
   C) detrusor muscle
   D) internal urethral sphincter
   E) external urethral sphincter
   Answer: D  
   Diff: 4  Page Ref: 530

75) How is urine moved through the ureter?
   A) pressure created within the renal pelvis
   B) contraction of the internal urethral sphincter
   C) wavelike contractions of the ureter
   D) contraction of the detrusor muscle
   E) contraction of the external urethral sphincter
   Answer: C  
   Diff: 5  Page Ref: 530
76) Which muscle(s) that regulates micturition is under involuntary control?
   A) detrusor
   B) internal urethral sphincter
   C) external urethral sphincter
   D) detrusor and the internal urethral sphincter
   E) detrusor and the external urethral sphincter
   
   Answer: D
   Diff: 4 Page Ref: 530

77) Which of the following occurs during micturition?
   A) The detrusor muscles relax, muscles of the internal urethral sphincter relax, and muscles
      of the external urethral sphincter relax.
   B) The detrusor muscles contract, muscles of the internal urethral sphincter contract, and
      muscles of the external urethral sphincter contract.
   C) The detrusor muscles relax, muscles of the internal urethral sphincter contract, and
      muscles of the external urethral sphincter contract.
   D) The detrusor muscles relax, muscles of the internal urethral sphincter contract, and
      muscles of the external urethral sphincter relax.
   E) The detrusor muscles contract, muscles of the internal urethral sphincter relax, and
      muscles of the external urethral sphincter relax.
   
   Answer: E
   Diff: 5 Page Ref: 531

78) Stretching of the bladder reflexively causes all of the following EXCEPT _______.
   A) excitation of parasympathetic neurons, causing the detrusor muscles to contract
   B) excitation of sympathetic neurons, causing the internal urethral sphincter to relax
   C) inhibition of somatic neurons to the external urethral sphincter, causing the sphincter to
      open
   D) micturition
   E) opening of the urethral sphincters
   
   Answer: B
   Diff: 5 Page Ref: 531

79) What effect does the sympathetic nervous system have on micturition?
   A) Sympathetic activity excites muscles of the internal urethral sphincter inhibiting
      micturition.
   B) Sympathetic activity inhibits muscles of the internal urethral sphincter inhibiting
      micturition.
   C) Sympathetic activity excites muscles of the external urethral sphincter allowing
      micturition.
   D) Sympathetic activity inhibits muscles of the external urethral sphincter inhibiting
      micturition.
   E) Sympathetic activity excites muscles of the internal urethral sphincter allowing
      micturition.
   
   Answer: A
   Diff: 6 Page Ref: 531
80) Which of the following is smooth muscle?
   A) internal urethral sphincter only
   B) external urethral sphincter only
   C) detrusor muscle only
   D) both the internal urethral sphincter and detrusor muscle
   E) both internal and external urethral sphincters

   Answer: D
   Diff: 5 Page Ref: 530

81) To voluntarily control urination, the ______ nervous system innervates the _______.
   A) somatic : internal urethral sphincter
   B) somatic : external urethral sphincter
   C) somatic : detrusor muscle
   D) autonomic : internal urethral sphincter
   E) autonomic : external urethral sphincter

   Answer: B
   Diff: 4 Page Ref: 531

82) During micturition, neural activity to sphincters or detrusor muscles from which of the following is increased?
   A) parasympathetic nervous system only
   B) sympathetic nervous system only
   C) somatic nervous system only
   D) both parasympathetic and somatic nervous systems
   E) both sympathetic and somatic nervous systems

   Answer: A
   Diff: 5 Page Ref: 531

83) In older children and adults, the cerebral cortex is able to block micturition by inhibiting nerve activity to the _______.
   A) detrusor muscle only
   B) internal urethral sphincter only
   C) external urethral sphincter only
   D) detrusor muscle and external urethral sphincter
   E) internal and external urethral sphincters

   Answer: D
   Diff: 4 Page Ref: 531

84) Substance X is freely filtered at the glomerulus. 3 mmole X is filtered, 2 mmole X is reabsorbed, and 2 mmole X is secreted per minute. How much X is excreted per minute?
   A) 1 mmole
   B) 2 mmole
   C) 3 mmole
   D) 4 mmole
   E) 5 mmole

   Answer: C
   Diff: 4 Page Ref: 525
85) During tubuloglomerular feedback of glomerular filtration rate, paracrines secreted from what structure cause constriction of the afferent arteriole?
   A) glomerulus
   B) macula densa
   C) mesangial cells
   D) proximal tubule
   E) juxtaglomerular cells
   Answer: B
   Diff: 4   Page Ref: 518

86) In comparison to the distal tubule, the proximal tubule has a ________.
   A) leakier epithelium and a larger apical surface area
   B) leakier epithelium and is more responsive to hormones
   C) tighter epithelium and a larger apical surface area
   D) tighter epithelium and is more responsive to hormones
   E) small apical surface area and is more responsive to hormones
   Answer: A
   Diff: 5   Page Ref: 524

True/False Questions

1) The excretion of water and solutes in urine has a significant impact on the volume and composition of fluids in the body.
   Answer: TRUE
   Diff: 2   Page Ref: 508

2) The kidneys receive only a small proportion (1%) of cardiac output at rest.
   Answer: FALSE
   Diff: 3   Page Ref: 509

3) Bowman’s capsule consists of the renal corpuscle and glomerulus.
   Answer: FALSE
   Diff: 3   Page Ref: 510

4) The proximal tubule is connected to the thick ascending limb of the loop of Henle.
   Answer: FALSE
   Diff: 3   Page Ref: 511

5) The connecting tubules join the distal tubule with the collecting ducts.
   Answer: TRUE
   Diff: 4   Page Ref: 511

6) The macula densa consists of specialized cells of the distal tubule epithelium.
   Answer: TRUE
   Diff: 4   Page Ref: 512

7) Juxtaglomerular cells are located in the walls of the distal tubule.
   Answer: FALSE
   Diff: 4   Page Ref: 512

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8) The vasa recta are in series with the glomerulus.
   Answer: TRUE
   Diff: 5   Page Ref: 512

9) Glomerular filtration involves the bulk flow of plasma (with all of its solutes) into Bowman’s space.
   Answer: FALSE
   Diff: 4   Page Ref: 514

10) The glomerular capillaries are composed of a fenestrated surface that allows protein–free plasma to exit the vasculature.
    Answer: TRUE
    Diff: 3   Page Ref: 515

11) Glomerular capillary hydrostatic pressure is greater than systemic capillary hydrostatic pressure.
    Answer: TRUE
    Diff: 4   Page Ref: 515

12) Bowman’s capsule hydrostatic pressure is greater than systemic interstitial fluid hydrostatic pressure.
    Answer: TRUE
    Diff: 4   Page Ref: 516

13) Glomerular filtration is approximately 3 L/day.
    Answer: FALSE
    Diff: 3   Page Ref: 516

14) Filtration fraction is calculated as glomerular filtration rate \( \times \) plasma concentration of a solute.
    Answer: FALSE
    Diff: 4   Page Ref: 517

15) The intrinsic and extrinsic controls of glomerular filtration rate ultimately involve changes in resistance at the afferent arteriole.
    Answer: TRUE
    Diff: 4   Page Ref: 517

16) A decrease in mean arterial pressure will act exclusively in an extrinsic manner to affect glomerular filtration rate.
    Answer: FALSE
    Diff: 4   Page Ref: 517

17) An increase in sympathetic activity will increase glomerular filtration rate.
    Answer: FALSE
    Diff: 4   Page Ref: 519

18) A decrease in glomerular filtration rate tends to decrease urine output.
    Answer: TRUE
    Diff: 3   Page Ref: 519
19) Urea reabsorption follows water reabsorption.
   Answer: TRUE  
   Diff: 4   Page Ref: 521

20) Water reabsorption follows active reabsorption of solute.
   Answer: TRUE  
   Diff: 4   Page Ref: 521

21) The reabsorption of sodium and water occurs in a relatively unregulated manner in the proximal tubules.
   Answer: TRUE  
   Diff: 3   Page Ref: 524

22) The distal tubule functions as a mass absorber.
   Answer: FALSE  
   Diff: 4   Page Ref: 524

23) Material that enters the lumen of the renal tubules is excreted unless it is reabsorbed.
   Answer: TRUE  
   Diff: 3   Page Ref: 525

24) If the amount of solute excreted per minute is less than the filtered load, then the solute was reabsorbed in the renal tubules.
   Answer: TRUE  
   Diff: 4   Page Ref: 525

25) Renal blood flow is determined by using clearance of para-aminohippuric acid (PAH) and the hematocrit of the blood.
   Answer: TRUE  
   Diff: 4   Page Ref: 528

26) The external urethral sphincter is controlled in an involuntary manner by the sympathetic nervous system.
   Answer: FALSE  
   Diff: 3   Page Ref: 531

27) The micturition reflex is a spinal reflex that can be overridden by voluntary controls.
   Answer: TRUE  
   Diff: 4   Page Ref: 530

28) Diabetic nephropathy is caused by hyperglycemia.
   Answer: TRUE  
   Diff: 4   Page Ref: 523

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Matching Questions

*Match the region of the renal tubule to its description.*

1) Site where filtrate enters renal tubules.
   Diff: 3  Page Ref: 510
   A) distal tubule
   B) proximal tubule
   C) collecting duct
   D) loop of Henle
   E) Bowman’s capsule

2) Most filtered solutes and water are reabsorbed in this region.
   Diff: 3  Page Ref: 524

3) Filtrate moves from this structure to the loop of Henle.
   Diff: 3  Page Ref: 510

4) Located entirely within the cortex, reabsorption of water and certain solutes from this region is under hormonal control.
   Diff: 4  Page Ref: 525

5) In juxtamedullary nephrons, this region sets up the medullary osmotic gradient.
   Diff: 4  Page Ref: 525

6) This tubule drains into the minor calyces.
   Diff: 3  Page Ref: 511

Answers: 1) E  3) B  4) A  5) D  6) C
Match the following structures to their functions.
7) Filters the blood to regulate its composition.
   Diff: 3   Page Ref: 509
   A) urethra
   B) ureter
   C) bladder
   D) kidneys

8) Stores urine prior to micturition.
   Diff: 3   Page Ref: 509
   A) urethra
   B) ureter
   C) bladder
   D) kidneys

9) Transports urine from kidneys to bladder.
   Diff: 3   Page Ref: 509
   A) urethra
   B) ureter
   C) bladder
   D) kidneys

10) Transports urine from bladder to outside body.
    Diff: 3   Page Ref: 509
    A) urethra
    B) ureter
    C) bladder
    D) kidneys

Answers: 7) D 8) C 9) B 10) A

Match the following renal processes to their correct descriptions.
11) Movement from glomerular capillaries into Bowman’s capsule.
    Diff: 3   Page Ref: 514
    A) excretion
    B) filtration
    C) reabsorption
    D) secretion

12) Movement from renal tubules into the peritubular capillaries.
    Diff: 3   Page Ref: 514
    A) excretion
    B) filtration
    C) reabsorption
    D) secretion

13) Movement from peritubular capillaries into the renal tubules.
    Diff: 3   Page Ref: 515
    A) excretion
    B) filtration
    C) reabsorption
    D) secretion

14) Elimination of urine from the body.
    Diff: 3   Page Ref: 515
    A) excretion
    B) filtration
    C) reabsorption
    D) secretion

Answers: 11) B 12) C 13) D 14) A
Match the following renal blood vessels with their correct description.

15) Constriction of this vessel by intrinsic or extrinsic mechanisms decreases glomerular filtration rate.
   Diff: 5    Page Ref: 512

A) vasa recta

B) glomerulus

C) afferent arteriole

D) peritubular capillary

E) efferent arteriole

16) Substances that are reabsorbed from the proximal tubule enter this blood vessel.
   Diff: 4    Page Ref: 512

17) Filtration occurs across this capillary bed.
   Diff: 3    Page Ref: 512

18) After blood is filtered in the renal corpuscle, the blood continues moving through this blood vessel to another capillary bed.
   Diff: 3    Page Ref: 512

19) This capillary bed dips down into the renal medulla with the loop of Henle.
   Diff: 3    Page Ref: 512

Match the cell type to its location or function.

20) These are modified smooth muscle cells around the glomerulus that contract to decrease the surface area of the glomerulus available for filtration.
   Diff: 4  Page Ref: 519
   A) podocytes
   B) granular cells
   C) macula densa cells
   D) mesangial cells

21) These are epithelial cells of Bowman's capsule that form part of the filtration barrier.
   Diff: 4  Page Ref: 515
   A) podocytes

22) These cells of the afferent arteriole secrete renin.
   Diff: 4  Page Ref: 512
   A) podocytes
   B) granular cells
   C) macula densa cells
   D) mesangial cells

23) These cells of the distal tubule secrete a paracrine in response to changes in the filtrate flow rate.
   Diff: 4  Page Ref: 512
   A) podocytes
   B) granular cells
   C) macula densa cells
   D) mesangial cells


Match each of the following with the correct equation.

24) GFR/renal plasma flow
   Diff: 5  Page Ref: 517
   A) filtered load
   B) clearance

25) GFR × plasma concentration
   Diff: 4  Page Ref: 517
   C) filtration fraction
   D) excretion rate
   E) renal blood flow

26) Excretion rate/plasma concentration
   Diff: 5  Page Ref: 526

27) Urine concentration × urine flow rate
   Diff: 5  Page Ref: 527

28) (Urine concentration × urine flow rate)/plasma concentration
   Diff: 5  Page Ref: 527

29) (Clearance of PAH)/(1 - hematocrit)
   Diff: 5  Page Ref: 528

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Essay Questions

1) The vasculature of the kidneys is quite unique in its organization. This organization has consequences for the control of the renal vasculature. Describe the vasculature of the kidneys, including the consequences of the high resistance of the efferent arteriole.

Answer: The vessel that enters the kidneys is the renal artery, which branches into the segmental arteries. These arteries branch into the interlobar arteries that feed into the arcuate arteries. From the arcuate arteries, blood is carried to the individual nephrons. The blood enters the nephron through the afferent arteriole and branches into the glomerular capillaries. Pressure within these capillaries is relatively high (60 mm Hg) due, in part, to their convergence on efferent arterioles, which have relatively high resistances. The high resistance of a downstream vessel tends to increase pressure just upstream from that vessel. This elevation in capillary pressure ensures a net efflux of fluid from the glomerular capillaries. This result reflects the primary function of the glomerular capillaries, which is not exchange of substrate (as in other capillary beds), but rather, the filtration of plasma from the blood while maintaining protein and erythrocyte concentrations within the vascular space. Because the glomerulus is surrounded (fed and drained) by arterioles, changes in resistance within either arteriole can dramatically alter pressure within the glomerular capillaries, thereby affecting glomerular filtration rate. The efferent arteriole gives rise to two types of vessels: the peritubular capillaries in the cortical nephrons and the vasa recta in the juxtamedullary nephrons. The peritubular capillaries feed the renal tubules while the vasa recta feeds the loop of Henle and the collecting ducts. These two classes of post efferent arteriole vessels both drain into the interlobular veins, which take blood to the arcuate veins and onto the interlobar veins, eventually draining into the renal vein.

Diff: 7  Page Ref: 512
2) In order for a nephron to act as a filter, the plasma must be able to exit the vasculature. Describe the balance of Starling’s forces across the glomerular capillaries that drives the movement of plasma and the pathway that plasma takes as it becomes filtrate.

Answer: Blood enters the glomerular capillaries through the afferent arteriole. Due to the resistance of the efferent arterioles, the pressure within the glomerular capillaries is relatively high (60 mm Hg). That glomerular capillary hydrostatic pressure is working against Bowman’s capsule hydrostatic pressure. Hydrostatic pressure within Bowman’s space is also much higher than other vascular beds, approaching 15 mm Hg, which results from the small, rigid, enclosed structure of Bowman’s capsule. This higher pressure creates a net hydrostatic pressure that moves fluid out of the glomerular capillaries. At the same time, oncotic pressure on either side of the capillary endothelial cell will affect fluid movement across the capillary endothelial cells. Oncotic pressure is created by differences in osmolarity across a membrane that are, for the most part, dependent upon protein concentrations. Since proteins do not leave the glomerular capillaries, oncotic pressure is higher in the glomerular capillaries (29 mm Hg) than in Bowman’s capsule (near zero). The net effect of oncotic pressure alone is to pull fluid back into the glomerular capillaries. However, the net filtration pressure (glomerular filtration pressure) substantially favors the movement of protein-free plasma into Bowman’s space. The pathway that the fluid must follow to enter the Bowman’s space restricts the movement of protein out of the capillaries (as well as preventing cells from exiting). That fluid is being pushed out of the fenestrated glomerular capillaries and must only cross a thin filtration barrier before entering the Bowman’s space. This filtration barrier includes the fenestrated capillary endothelial cells, a basement membrane that restricts the movement of proteins out of the capillaries, and the slit pores through the podocytes. A slit diaphragm controls the size of the slit pores, which limits the surface area of the glomerular capillaries over which filtration can occur.

Diff: 7 Page Ref: 515
3) In spite of the large volume of fluid that enters the kidneys every day, glomerular filtration rate (GFR) is highly regulated to minimize changes that might alter urine output. Describe the intrinsic mechanisms involved in the maintenance of GFR in the presence of a stimulus that would elevate GFR.

**Answer:** Glomerular filtration rate is controlled in part by three mechanisms intrinsic to the kidneys. Of the three intrinsic mechanisms, two act by altering afferent arteriole resistance (diameter). When the afferent arteriole constricts, the pressure within the glomerular capillaries decreases. The first of the arteriole-related intrinsic mechanisms is myogenic regulation. This is the same as myogenic responses in systemic arterioles, where changes in hydrostatic pressure within the arteriole alter the stretch of the smooth muscle cells. An increase in stretch, as observed if pressure increases, results in an arteriole constriction. That constriction tends to limit the change in pressure within the glomerular capillaries, thereby maintaining GFR. The second arteriole-related intrinsic mechanisms, called tubuloglomerular feedback, involves the juxtaglomerular apparatus, where the afferent and efferent arterioles come in contact with the distal tubule. Any increase in GFR results in an increased flow of filtrate through the distal tubule. The macula densa, a region of the distal tubule wall in contact with the arterioles, responds to increased flow by releasing a paracrine factor that constricts the afferent arteriole. Again, this would decrease pressure within the glomerular capillaries and reduce GFR. In this case, the flow of fluid (GFR) through the distal tubule is held relatively constant. The final intrinsic mechanism does not involve the afferent arteriole, although it does involve contraction. This mechanism involves mesangial cells that surround the glomerular capillaries. Any increase in pressure within the glomerular capillaries that causes them to stretch will also stretch the mesangial cells. Once stretched, the mesangial cells act like smooth muscle cells and constrict in response. However, this constriction does not affect vascular resistance. Instead, mesangial cell constriction reduces the surface area over which filtration can occur.

**Diff:**  8  **Page Ref:** 517

4) Glomerular filtration rate is controlled by both intrinsic and extrinsic mechanisms. Describe the extrinsic mechanism with particular emphasis on how it would respond to a hemorrhage.

**Answer:** The extrinsic mechanism that controls glomerular filtration rate involves the sympathetic nervous system. In response to a hemorrhage, mean arterial pressure decreases, which is detected by both the arterial and venous baroreceptors, and results in elevated sympathetic nervous activity. This increase in sympathetic activity to the afferent and efferent arterioles induces a constriction. While this results in a substantial increase in total peripheral resistance because renal blood flow is relatively high at rest, it also decreases the GFR. The decrease in GFR reduces urine flow and thereby helps to maintain blood volume. At the same time, the decrease in mean arterial pressure directly affects GFR, causing it to decrease as well.

**Diff:**  6  **Page Ref:** 519
5) Glucose is an important component of the blood that is usually completely reabsorbed (there is no glucose in the urine). Outline the process whereby glucose is transported across the tubular epithelial cells, including the concepts of transport maximum and renal threshold.

Answer: The transport of glucose by the proximal tubules is a perfect example of transport maximum. This is the point at which all of the transporters of a substrate are occupied (100% saturated) and thus, further increases in substrate concentration do not affect their rate of transport. The reabsorption of glucose involves its transport across the apical membranes of the proximal tubule epithelial cells by sodium–linked cotransporters. As sodium moves into the cell, glucose follows. This causes an increase in intracellular glucose concentration, which drives glucose into the peritubular space across the epithelial cell’s basolateral membrane through a carrier protein by facilitated diffusion. As the concentration of glucose in the blood increases, as occurs in a diabetic, all of the transporters are saturated and glucose begins to remain in the filtrate. The plasma concentration at which substrate is observed in the urine is termed the renal threshold. In most individuals, little glucose ever reaches the urine. However, diabetics are characterized by the overflow of glucose into the urine, which leads to the sweet smell of the urine. Interestingly, the renal threshold occurs before the transport maximum is reached. This occurs because, even though all of the transporters are not occupied, some of the glucose molecules make it through the proximal tubule without coming into contact with an unoccupied transporter.

Diff: 7 Page Ref: 522

6) Although some of the mechanisms are the same, the functions of the proximal and distal tubules are quite different. Compare and contrast the structural differences between epithelial cells in the proximal and distal tubes.

Answer: Overall, the structural differences between epithelial cells appear to allow for more regulated transport of ions in the distal tubules than the proximal tubule. First, the brush border of the distal tubules is less prominent than in the proximal tubules, which decreases the surface area for exchange. Epithelial cells of the distal tubules also have fewer mitochondria, which provide the energy for active transporters. The tight junctions between epithelial cells are more tightly coupled in the distal tubules, allowing fewer solutes to leak into the peritubular space by paracellular transport. Finally, the epithelial cells of the distal tubules contain receptors for hormones that can modify reabsorption or secretion of substances including water. These include receptors for aldosterone, antidiuretic hormone, and atrial natriuretic peptide.

Diff: 6 Page Ref: 524
7) Ultimately, our ability to assess the function of the kidneys involves measuring what is excreted in urine. Describe the methods used to assess the function of the kidneys (glomerular filtration rate [GFR]), including the calculations and ions involved in that assessment.

Answer: In its simplest form, excretion rate can be measured as an ion’s filtration rate + secretion rate – reabsorption rate. Filtration rate can be determined as filtered load (GFR × plasma concentration of an ion). Excretion gives an indication of the net direction of movement of an ion. If the amount of a solute excreted per minute is less than its filtered load, then the solute was reabsorbed. If the amount of a solute excreted is greater than filtered load, then the solute was secreted. However, this measurement reflects which force (reabsorption or secretion) is dominating for a particular solute, which means that both are usually occurring at the same time. The rate at which a solute is excreted can be described in terms of clearance: a measure of the volume of plasma from which a solute is completely removed. Clearance is calculated as excretion rate/plasma concentration. Clearance gives an indication of how the kidneys are handling one solute relative to another. Clinically, clearance is determined by three variables: (urine concentration of a solute × urine flow rate)/plasma concentration of a solute. These are easily measured clinically. Clearance also provides a way to measure GFR. If a substance is freely filtered and is neither reabsorbed nor secreted, then the amount of that substance in the urine must be equal to the amount filtered (filtered load). In this case, the clearance of this substance is equal to GFR. Inulin is a polysaccharide that is neither secreted nor reabsorbed. In this case, GFR = (urine concentration of inulin × urine flow rate)/plasma concentration of inulin. Another less invasive method for measuring GFR involves measuring creatinine, a byproduct of muscle metabolism. Only a small amount of creatinine is secreted and none is reabsorbed.

Diff: 9   Page Ref: 526

8) Explain how diabetes mellitus causes polyuria.

Answer: Diabetes mellitus causes hyperglycemia such that blood glucose levels exceed the renal threshold for glucose. Thus some glucose is eliminated in the urine. Because all solutes exert an osmotic force for water movement, the presence of glucose in the filtrate of a person with diabetes causes more water to be in the filtrate and eliminated in the urine.

Diff: 9   Page Ref: 523
9) In order for urine to be eliminated, the process of micturition must be initiated. Describe the process whereby urine generated by the kidneys reaches the bladder and how that urine is voided from the bladder.

Answer: Once the urine reaches the renal pelvis, it is moved into the bladder by wavelike contractions of the smooth muscle cells of the ureter. The bladder is wrapped by smooth muscle cells (detrusor muscle) that converge on the neck of the bladder and form a thickening of the wall that is referred to as the internal urethral sphincter. This sphincter acts as a valve to regulate the flow of urine into the urethra. The urethra passes through the pelvic wall where it is surrounded by a skeletal muscle called the external urethral sphincter. The process of micturition is controlled by the micturition reflex. That reflex is activated by stretching of the bladder as it fills with urine. This spinal reflex stimulates the parasympathetic nervous system, which stimulates contraction of the detrusor muscle. This contraction increases the pressure within the bladder, which will eventually cause the internal urethral sphincter to open. At the same time, the stretch reflex inhibits sympathetic nerve activity, which relaxes the internal urethral sphincter, and somatic nerve activity, which relaxes the external urethral sphincter. The micturition reflex can be inhibited. Signals from the cerebral cortex inhibit 1) the increase in parasympathetic activity to the detrusor muscle and 2) the inhibition of somatic nerve activity to the external urethral sphincter. In addition, one can initiate micturition through voluntary inhibition of the external urethral sphincter. This occurs in concert with the lowering of the pelvic wall. As the pelvic wall is lowered, it causes the internal urethral sphincter to open and stretches the bladder. This, in concert with contraction of the diaphragm and abdominal muscles, can increase the volume of urine voided by an individual.

Diff: 7  Page Ref: 530

Short Answer Questions

1) What hormone is secreted by the kidneys to increase red blood cell synthesis?
   Answer: erythropoietin
   Diff: 4  Page Ref: 509

2) What is the region of the kidney called where the renal artery and vein enter?
   Answer: renal hilus
   Diff: 4  Page Ref: 509

3) What two structures make up the renal corpuscle?
   Answer: Bowman’s capsule and the glomerulus
   Diff: 4  Page Ref: 510

4) What are the three components of the loop of Henle?
   Answer: descending limb, thin ascending limb, and thick ascending limb
   Diff: 4  Page Ref: 511

5) The _______ are a small percentage of the nephrons in the kidneys that function in the maintenance of the osmotic gradient in the medullary region of the kidney.
   Answer: juxtamedullary nephrons
   Diff: 5  Page Ref: 512
6) The _______ capillaries branch from efferent arterioles of cortical nephrons, whereas the _______ capillaries branch from efferent arterioles of juxtamedullary nephrons.
   Answer: peritubular : vasa recta
   Diff: 5  Page Ref: 512

7) The juxtaglomerular apparatus consists of specialized cells of the distal tubule called _______ and specialized cells of the afferent arteriole called _______.
   Answer: macula densa : granular cells (or juxtaglomerular cells)
   Diff: 5  Page Ref: 512

8) The _______ is the layer of the filtration barrier in Bowman’s capsule that is the primary barrier to the movement of protein from the capillary.
   Answer: basement membrane
   Diff: 5  Page Ref: 512

9) Under normal conditions, the osmotic pressure gradient across the glomerular capillaries tends to move water _______.
   Answer: back into the capillaries
   Diff: 4  Page Ref: 516

10) What are the four Starling forces for glomerular filtration, and which direction does each force act (for filtration or absorption)?
    Answer: Glomerular capillary hydrostatic pressure — filtration
             Bowman’s capsule hydrostatic pressure — absorption
             Glomerular capillary oncotic pressure — absorption
             Bowman’s capsule oncotic pressure — filtration
    Diff: 5  Page Ref: 516

11) Given a GFR of 100 mL/min and a plasma concentration of solute of 10 mg/mL, what is the filtered load of this solute?
    Answer: 1,000 mg/min
    Diff: 4  Page Ref: 517

12) In response to an increase in blood pressure, the smooth muscle in the afferent arteriole (contracts / relaxes) causing a(n) (decrease / increase) in glomerular filtration rate.
    Answer: contracts : decrease
    Diff: 5  Page Ref: 518

13) In tubuloglomerular feedback regulation of glomerular filtration rate, the (macula densa / granular cells) secrete a paracrine that causes constriction of the afferent arteriole.
    Answer: macula densa
    Diff: 4  Page Ref: 518

14) In response to a loss of blood, the sympathetically-induced (increase / decrease) in renal vascular resistance will cause glomerular filtration rate to (increase / decrease).
    Answer: increase : decrease
    Diff: 5  Page Ref: 519
15) The (tubular epithelial cell / peritubular capillary endothelial cell) forms the primary barrier for reabsorption of most solutes.
Answer: tubular epithelial cell
Diff: 4 Page Ref: 520

16) When carrier proteins are saturated, they are working at the ________.
Answer: transport maximum
Diff: 4 Page Ref: 522

17) If solute A is actively transported across the basolateral membrane into the epithelial cell and then passively crosses the apical membrane, then is A (reabsorbed / secreted) across this epithelium?
Answer: secreted
Diff: 5 Page Ref: 523

18) If solute B moves passively across the basolateral membrane and is actively transported out of the epithelial cell across the apical membrane, then B is (reabsorbed / secreted) across this epithelium.
Answer: secreted
Diff: 5 Page Ref: 523

19) If solute C moves passively across the basolateral membrane and is actively transported into the epithelial cell across the apical membrane, then C is (reabsorbed / secreted) across this epithelium.
Answer: reabsorbed
Diff: 5 Page Ref: 521

20) Compared to the distal tubule, the proximal tubule utilizes (more / less) ATP?
Answer: more
Diff: 5 Page Ref: 524

21) Compared to the distal tubule, the proximal tubule has (tighter / leakier) tight junctions.
Answer: leakier
Diff: 5 Page Ref: 524

22) If the amount of a solute excreted in the urine per minute is less than the filtered load, then that solute had to have been (reabsorbed / secreted) in the renal tubules.
Answer: reabsorbed
Diff: 3 Page Ref: 525

23) ________ is a measure of the volume of plasma from which a substance is completely removed by the kidneys.
Answer: Clearance
Diff: 4 Page Ref: 526

24) If the clearance of a substance is greater than glomerular filtration rate, then that substance was (reabsorbed / secreted) in the tubules.
Answer: secreted
Diff: 4 Page Ref: 528
25) The clearance of _______ provides a measure of renal plasma flow rate.
   
   Answer: PAH
   Diff: 4   Page Ref: 528

26) The clearance of _______, which is not produced in the body but must be injected, provides a measure of glomerular filtration rate.
   
   Answer: inulin
   Diff: 4   Page Ref: 527

27) The clearance of _______, a natural by-product of muscle metabolism, provides a non-invasive estimate of glomerular filtration rate.
   
   Answer: creatinine
   Diff: 5   Page Ref: 528

28) The smooth muscle of the bladder is (single-unit / multi-unit) smooth muscle.
   
   Answer: single-unit
   Diff: 4   Page Ref: 530

29) In terms of controlling micturition, the somatic nervous system innervates the _______, the parasympathetic nervous system innervates the _______, and the sympathetic nervous system innervates the _______.
   
   Answer: external urethral sphincter : detrusor muscle : internal urethral sphincter
   Diff: 6   Page Ref: 531

30) The micturition reflex is activated by ________.
   
   Answer: a stretch of the bladder, which activates stretch receptors
   Diff: 4   Page Ref: 531
Multiple Choice Questions

1) Plasma can gain solutes and/or water from which of the following?
   A) gastrointestinal tract only
   B) renal tubules only
   C) bone only
   D) both the gastrointestinal tract and bone
   E) both the gastrointestinal tract and renal tubules

   Answer: D  
   Diff: 5  Page Ref: 535

2) Movement across which of the following generally results in a net loss of solutes and/or water?
   A) gastrointestinal tract only
   B) skin only
   C) renal tubules only
   D) both the gastrointestinal tract and renal tubules
   E) both skin and renal tubules

   Answer: E  
   Diff: 5  Page Ref: 535

3) A substance is in negative balance when _______.
   A) it enters plasma at the same rate it exits plasma
   B) it enters plasma at a greater rate than it exits plasma
   C) it exits plasma at a greater rate than it enters plasma
   D) its usage by cells is decreased
   E) its production by cells is increased

   Answer: C  
   Diff: 3  Page Ref: 536

4) The regulation of water and ion excretion occurs primarily within the ________.
   A) proximal tubules only
   B) late distal tubules only
   C) collecting ducts only
   D) both proximal tubules and late distal tubules
   E) both collecting ducts and late distal tubules

   Answer: E  
   Diff: 4  Page Ref: 537
5) The regulation of sodium and water balance in the kidneys occurs primarily through the unique action of which cells in the distal tubules and collecting ducts?
   A) intercalated cells
   B) principal cells
   C) mesangial cells
   D) granular cells
   E) podocytes
   Answer: B
   Diff: 4 Page Ref: 537

6) The regulation of acid-base balance in the kidneys occurs primarily through the unique action of which cells in the distal tubules and collecting ducts?
   A) intercalated cells
   B) principal cells
   C) mesangial cells
   D) granular cells
   E) podocytes
   Answer: A
   Diff: 4 Page Ref: 537

7) Which of the following is a source of water input?
   A) gastrointestinal tract only
   B) renal tubules only
   C) metabolism only
   D) both gastrointestinal tract and metabolism
   E) both the gastrointestinal tract and renal tubules
   Answer: D
   Diff: 5 Page Ref: 537

8) What is the force that moves water out of the distal tubules and collecting ducts?
   A) the passive regulated movement through Na+/H2O transporter
   B) the passive unregulated movement along the paracellular pathway
   C) the active transport of water
   D) an osmotic gradient
   E) an alteration in temperature
   Answer: D
   Diff: 5 Page Ref: 537

9) If a person is normovolemic and consumes a large quantity of a hyperosmotic solution, it will
   ________.
   A) have no effect on cell osmolarity and thereby cell size
   B) cause cells to shrink due to an increase in the osmolarity of extracellular fluid
   C) cause cells to swell due to an increase in the osmolarity of extracellular fluid
   D) cause cells to swell due to a decrease in the osmolarity of extracellular fluid
   E) cause cells to shrink due to a decrease in the osmolarity of extracellular fluid
   Answer: B
   Diff: 4 Page Ref: 538
10) Which of the conditions listed below is NOT indicative of a decrease in plasma osmolarity?
   A) headache
   B) nausea
   C) confusion
   D) neural hyperexcitability
   E) seizure

   Answer: D
   Diff: 6   Page Ref: 538

11) Kidneys compensate for changes in plasma volume and osmolarity by adjusting the rate of water ________.
   A) reabsorption only
   B) secretion only
   C) resorption only
   D) reabsorption and secretion
   E) secretion and resorption

   Answer: A
   Diff: 4   Page Ref: 539

12) Which of the following mechanisms is NOT important in the maintenance of the osmotic gradient within the proximal tubule that drives water movement?
   A) cotransport of chloride
   B) cotransport of amino acids
   C) cotransport of glucose
   D) active reabsorption of sodium
   E) diffusion of urea

   Answer: E
   Diff: 5   Page Ref: 539

13) Which of the following accurately describes the thick ascending limb of the loop of Henle?
   A) permeable to water in the presence of specific hormones
   B) permeable to water and does NOT contain Na⁺/K⁺/Cl⁻ cotransporters
   C) impermeable to water and does NOT contain Na⁺/K⁺/Cl⁻ cotransporters
   D) impermeable to water and contains Na⁺/K⁺/Cl⁻ cotransporters
   E) permeable to water and contains Na⁺/K⁺/Cl⁻ cotransporters

   Answer: D
   Diff: 5   Page Ref: 540

14) In the ascending limb of the loop of Henle, the filtrate will always be ________.
   A) in equilibrium with the the medullary interstitial fluid
   B) of a lower osmolarity than the medullary interstitial fluid
   C) a higher osmolarity than the medullary interstitial fluid
   D) the same osmolarity as the filtrate in the descending limb of the loop of Henle
   E) a higher osmolarity than the filtrate in the descending limb of the loop of Henle

   Answer: B
   Diff: 6   Page Ref: 541
15) The osmotic gradient in the medullary region of the kidneys is established and maintained by which of the following?
   A) Na⁺/K⁺/Cl⁻ cotransporters in the ascending limb of the loop of Henle
   B) Na⁺/K⁺/Cl⁻ cotransporters in the descending limb of the loop of Henle
   C) efflux of water from the ascending limb of the loop of Henle
   D) efflux of water from the descending limb of the loop of Henle
   E) efflux of Na⁺ from the descending limb of the loop of Henle

Answer: A

Diff: 5    Page Ref: 540

16) Which of the following comparisons of osmolarity within the kidneys is INCORRECT?
   A) The fluid in the proximal tubule is iso-osmotic with cortical interstitial fluid.
   B) Osmolarity of the ascending limb of the loop of Henle is greater than that of the descending limb.
   C) Osmolarity of the descending limb of the loop of Henle is iso-osmotic with the medullary interstitial fluid.
   D) The osmolarity of plasma in the vasa recta varies with its location in the renal medulla.
   E) Osmolarity of fluid in the proximal tubule is greater than the osmolarity of fluid in the end of the loop of Henle as it enters the distal tubule.

Answer: B

Diff: 7    Page Ref: 543

17) A long loop of Henle would result in which of the following?
   A) a higher osmolarity in the deeper regions of the renal medulla and the ability to produce a more concentrated urine
   B) a lower osmolarity in the deeper regions of the renal medulla and the ability to produce a more concentrated urine
   C) a higher osmolarity in the deeper regions of the renal medulla and the ability to produce a more dilute urine
   D) a lower osmolarity in the deeper regions of the renal medulla and the ability to produce a more dilute urine
   E) a higher osmolarity in the renal cortex and the ability to produce a more dilute urine

Answer: A

Diff: 5    Page Ref: 543

18) The hormone-induced increases in water permeability of the distal tubule and collecting ducts is mediated by a(n) ________.
   A) increase in aquaporin-2 activity
   B) increase in aquaporin-3 activity
   C) increase in paracellular permeability
   D) decrease in "tightness" of tight junctions
   E) decrease in paracellular permeability

Answer: A

Diff: 4    Page Ref: 544
19) What keeps the capillaries of the vasa recta from dissipating the medullary osmotic gradient?
   A) the smooth muscle cells contain Na⁺/K⁺/Cl⁻ cotransporters
   B) the smooth muscle cells are impermeable to water and ions
   C) the vascular endothelial cells are impermeable to water and ions
   D) capillary blood enters and exits the medulla at a similar osmolarity
   E) the vascular endothelial cells contain Na⁺/K⁺/Cl⁻ cotransporters

   Answer: D  
   Diff: 5  Page Ref: 542

20) If nothing else is removed from the filtrate once it reaches the late distal tubules, the urine excreted would have which of the following properties?
   A) devoid of ions and large volume
   B) high osmolarity and low volume
   C) low osmolarity and low volume
   D) low osmolarity and large volume
   E) high osmolarity and large volume

   Answer: D  
   Diff: 6  Page Ref: 542

21) What solute maintains the medullary interstitial fluid osmotic gradient?
   A) urea
   B) sodium ions
   C) potassium ions
   D) water
   E) glucose

   Answer: A  
   Diff: 6  Page Ref: 541

22) Which of the following correctly describes water movement across the epithelial cells lining the collecting duct?
   A) Water can permeate the lipid bilayer at all times.
   B) Water can permeate the phospholipid bilayer only in the presence of ADH.
   C) Water can permeate the phospholipid bilayer only in the presence of aldosterone.
   D) Water can permeate the apical membrane through aquaporin-2 and the basolateral membrane through aquaporin-3, but aquaporin-2 is only present in the presence of ADH.
   E) Water can permeate the basolateral membrane through aquaporin-2 and the apical membrane through aquaporin-3, but aquaporin-2 is only present in the presence of aldosterone.

   Answer: D  
   Diff: 5  Page Ref: 542

23) A person must void what volume of urine per day?
   A) 0 mL
   B) 15 mL
   C) 120 mL
   D) 440 mL
   E) 1200 mL

   Answer: D  
   Diff: 4  Page Ref: 543
24) Which of the following limits the volume of the obligatory water loss?
   A) diameter of the loop of Henle
   B) the osmolarity at the early portion of the distal tubule
   C) the maximal osmolarity of the medullary osmotic gradient
   D) the water permeability of the the collecting ducts
   E) the water permeability of the distal tubule

   Answer: C
   Diff: 5   Page Ref: 543

25) In the early portion of the collecting duct (in cortical interstitial fluid), an increase in water permeability will result in a(n) _______.
   A) increase in filtrate volume
   B) decrease in filtrate volume
   C) movement of water into the duct
   D) transport of sodium out of the tubule
   E) efflux of urea from the tubule

   Answer: B
   Diff: 4   Page Ref: 542

26) Where is ADH released from?
   A) distal tubule
   B) collecting duct
   C) pancreas
   D) posterior pituitary
   E) anterior pituitary

   Answer: D
   Diff: 3   Page Ref: 544

27) Antidiuretic hormone binds to receptors on _______ cells in the collecting ducts and distal tubules where it _______.
   A) granular : causes vesicles with aquaporin-2 to insert into the apical membrane
   B) intercalated : causes vesicles with aquaporin-3 to insert into the apical membrane
   C) intercalated : causes vesicles with aquaporin-2 to insert into the basolateral membrane
   D) principal : causes insertion of aquaporin-2 into the apical membrane
   E) principal : causes vesicle with aquaporin-3 to insert into the apical membrane

   Answer: D
   Diff: 4   Page Ref: 544

28) The intracellular event that stimulates the insertion of aquaporin-2 into the apical membranes of principal cells is driven by _______.
   A) sodium
   B) guanylate cyclase
   C) cGMP
   D) protein kinase C
   E) protein kinase A

   Answer: E
   Diff: 6   Page Ref: 544
29) At high concentrations of antidiuretic hormone, the extent of water reabsorption in the collecting ducts is ________, causing urine output to ________.
   A) high : decrease
   B) low : decrease
   C) high : increase
   D) low : increase
   E) unaffected : remain unchanged
   Answer: A
   Diff: 4 Page Ref: 544

30) What is the strongest stimulus for the release of antidiuretic hormone from the posterior pituitary?
   A) decrease in plasma osmolarity
   B) decrease in blood pressure
   C) increase in plasma osmolarity
   D) increase in blood pressure
   E) decrease in sodium content of the blood
   Answer: C
   Diff: 4 Page Ref: 544

31) Which of the following is NOT one of the stimuli that will result in the release of antidiuretic hormone?
   A) decreased blood pressure
   B) decreased plasma volume
   C) increased osmolarity
   D) decreased plasma potassium
   E) angiotensin II
   Answer: D
   Diff: 5 Page Ref: 545

32) In diabetes insipidus, blood levels of ________ are decreased causing an increase in ________.
   A) insulin : glucose in the urine
   B) aldosterone : sodium in the urine
   C) aldosterone : potassium in the urine
   D) ADH : urine volume
   E) ADH : plasma volume
   Answer: D
   Diff: 5 Page Ref: 546

33) Which of the following diseases is associated with decreased responsiveness of the renal tubules to ADH?
   A) diabetes mellitus type 1
   B) diabetes mellitus type 2
   C) central diabetes insipidus
   D) nephrogenic diabetes insipidus
   E) diabetic nephropathy
   Answer: D
   Diff: 5 Page Ref: 546
34) Which of the following is a synonym for polyuria?
   A) polydipsia  
   B) antidipsia  
   C) diuresis  
   D) antidiuresis  
   E) hyperemia  
   Answer: C  
   Diff: 4  Page Ref: 546

35) In diabetes insipidus, why does polyuria occur?
   A) a lack of ADH decreases water reabsorption  
   B) an increase in aldosterone increases water reabsorption  
   C) glucose transporters in the renal tubules become saturated  
   D) a lack of angiotensin II decreases thirst  
   E) a lack of insulin decreases water permeability of the renal tubules  
   Answer: A  
   Diff: 5  Page Ref: 546

36) Which of the following conditions would be associated with hypernatremia?
   A) increased plasma sodium  
   B) decreased plasma osmolarity  
   C) increased plasma potassium  
   D) decreased plasma volume  
   E) hypotension  
   Answer: A  
   Diff: 4  Page Ref: 547

37) Which of the following statements on sodium movement in the renal tubules is true?
   A) Sodium is actively transported across the basolateral membrane of both the proximal and distal tubule.  
   B) Sodium is actively secreted from the collecting duct.  
   C) Sodium is actively secreted from the proximal tubule.  
   D) Sodium reabsorption follows water reabsorption in all segments of the renal tubules.  
   E) Sodium channels are located on the basolateral membrane of principal cells.  
   Answer: A  
   Diff: 4  Page Ref: 547

38) In the renal tubules, where is the Na+/K+ pump located?
   A) in the basolateral membrane of the proximal tubules  
   B) in the apical membrane of the descending limb of the loop of Henle  
   C) in the apical membrane of the collecting ducts  
   D) in both the apical and basolateral membranes of principal cells  
   E) in both the apical and basolateral membranes of intercalated cells  
   Answer: A  
   Diff: 4  Page Ref: 547
39) Which of the following best describes sodium movement in the proximal tubule?
A) Sodium is transported across the basolateral membrane by the Na+/K+ pump and across the apical membrane by diffusion through sodium channels.
B) Sodium is transported across the apical membrane by the Na+/K+ pump and across the basolateral membrane by diffusion through sodium channels.
C) Sodium is transported across the basolateral membrane by the Na+/K+ pump and across the apical membrane by secondary active transport.
D) Sodium is transported across the apical membrane by the Na+/K+ pump and across the basolateral membrane by secondary active transport.
E) Sodium is transported across the apical membrane by the Na+/K+ pump and across the basolateral membrane by facilitated diffusion.

Answer: C

Diff: 5  Page Ref: 547

40) Which of the following best describes sodium movement in the distal tubule?
A) Sodium is transported across the basolateral membrane by the Na+/K+ pump and across the apical membrane by diffusion through sodium channels.
B) Sodium is transported across the apical membrane by the Na+/K+ pump and across the basolateral membrane by diffusion through sodium channels.
C) Sodium is transported across the basolateral membrane by the Na+/K+ pump and across the apical membrane by facilitated diffusion.
D) Sodium is transported across the apical membrane by the Na+/K+ pump and across the basolateral membrane by secondary active transport.
E) Sodium is transported across the apical membrane by the Na+/K+ pump and across the basolateral membrane by secondary active transport.

Answer: A

Diff: 5  Page Ref: 547

41) Aldosterone is released from the ________ in response to ________.
A) adrenal medulla : decreases in plasma sodium
B) adrenal cortex : increases in plasma potassium
C) posterior pituitary : increases in plasma osmolarity
D) pancreas : increases in plasma glucose
E) macula densa : increased flow of tubular fluid in the distal tubule

Answer: B

Diff: 4  Page Ref: 551

42) Which of the following is an effect of aldosterone on principal cells?
A) decreased number of open Na+ and K+ channels in the basolateral membrane
B) decreased number of Na+/K+ pumps in the basolateral membrane
C) increased number of open Na+ and K+ channels in the basolateral membrane
D) increased number of open Na+ and K+ channels in the apical membrane
E) increased number of Na+/K+ pumps in the apical membrane

Answer: D

Diff: 5  Page Ref: 548
43) Which of the following is associated with actions of aldosterone on principal cells?
   A) increased sodium secretion
   B) increased potassium secretion
   C) decreased blood pressure
   D) decreased plasma osmolarity
   E) increased calcium reabsorption

   Answer: B
   Diff: 4   Page Ref: 548

44) Renin is released by _______ cells of the ________.
   A) principal : afferent arteriole
   B) granular : afferent arteriole
   C) principal : distal tubule
   D) granular : distal tubule
   E) intercalated : afferent arteriole

   Answer: B
   Diff: 5   Page Ref: 548

45) What enzyme converts angiotensinogen into angiotensin I.
   A) Carbonic anhydrase
   B) Atrial natriuretic peptide
   C) Angiotensin converting enzyme (ACE)
   D) Renin
   E) Mucin

   Answer: D
   Diff: 4   Page Ref: 548

46) What enzyme converts angiotensin I into angiotensin II.
   A) Carbonic anhydrase
   B) Atrial natriuretic peptide
   C) Angiotensin converting enzyme (ACE)
   D) Renin
   E) Mucin

   Answer: C
   Diff: 4   Page Ref: 548

47) Which of the following is NOT one of the functions of angiotensin II?
   A) vasoconstriction
   B) stimulate aldosterone secretion
   C) stimulate antidiuretic hormone (ADH) secretion
   D) increased thirst
   E) stimulate renin secretion

   Answer: E
   Diff: 4   Page Ref: 548
48) Angiotensin II acts directly in the hypothalamus to stimulate what?
   A) an increase in thirst
   B) the release of oxytocin
   C) an increase in body temperature
   D) the release of aldosterone
   E) a systemic increase in blood pressure

   Answer: A
   Diff: 5   Page Ref: 550

49) Which of the following conditions is NOT responsible for stimulating the release of renin?
   A) decreased pressure within the afferent arteriole
   B) increase in sympathetic nerve activity
   C) decrease in sodium and chloride in the distal tubule
   D) increased glomerular filtration rate
   E) decreased mean arterial pressure

   Answer: D
   Diff: 5   Page Ref: 548

50) Angiotensinogen is synthesized by what organ?
   A) kidney
   B) bone marrow
   C) liver
   D) adrenal gland
   E) pituitary gland

   Answer: C
   Diff: 3   Page Ref: 548

51) What role do the macula densa cells have in controlling renin release?
   A) They release renin in response to an increase in mean arterial pressure.
   B) They release renin in response to a decrease in mean arterial pressure.
   C) They detect changes in the pressure of afferent arterioles, and communicate these changes to juxtaglomerular cells, which secrete renin.
   D) They detect changes in the pressure of efferent arterioles, and communicate these changes to juxtaglomerular cells, which secrete renin.
   E) They detect changes in the amount of sodium and chloride in the distal tubules, and communicate these changes to juxtaglomerular cells, which secrete renin.

   Answer: E
   Diff: 5   Page Ref: 548

52) What stimulates atrial natriuretic peptide release?
   A) distension of the atrial wall due to an increase in blood pressure
   B) distension of the atrial wall due to an increase in plasma volume
   C) changes in the concentration of sodium in the blood of the atrium
   D) changes in the concentration of potassium in the blood of the atrium
   E) renin

   Answer: B
   Diff: 4   Page Ref: 550
53) Which of the following conditions will NOT be stimulated by atrial natriuretic peptide?
   A) increased sodium excretion
   B) efferent arteriole constriction
   C) afferent arteriole constriction
   D) increased glomerular filtration rate
   E) increased glomerular capillary pressure

   Answer: C
   Diff: 5    Page Ref: 550

54) Atrial natriuretic peptide causes which of the following effects in principal cells?
   A) decreased activity of the Na⁺/K⁺ pump in the basolateral membrane
   B) efferent arteriole dilation
   C) afferent arteriole constriction
   D) decreased number of open sodium channels in the apical membrane
   E) increase in glomerular filtration rate

   Answer: D
   Diff: 5    Page Ref: 550

55) The extent of potassium excretion is regulated primarily by the ________.
   A) amount filtered by the basement membrane of the glomerular capillaries
   B) amount reabsorbed into the proximal tubule
   C) amount secreted into the proximal tubule
   D) amount reabsorbed in the distal tubule
   E) amount secreted into the distal tubule

   Answer: E
   Diff: 6    Page Ref: 550

56) Hyperkalemia refers to an excess of what?
   A) water
   B) sodium
   C) potassium
   D) calcium
   E) chloride

   Answer: C
   Diff: 3    Page Ref: 550

57) Which of the following is NOT a symptom of hyperkalemia?
   A) diarrhea
   B) hypotension
   C) cardiac arrhythmias
   D) muscle cramps
   E) nausea

   Answer: B
   Diff: 6    Page Ref: 550
58) Which of the following is FALSE of the renal handling of potassium?
   A) Potassium is freely filtered at the glomerulus.
   B) Potassium is only reabsorbed in the proximal tubule.
   C) Potassium is reabsorbed and secreted in the distal tubule.
   D) Potassium is only secreted in the collecting duct.
   E) Potassium secretion is regulated by aldosterone.

   Answer: C
   Diff: 5   Page Ref: 551

59) The reabsorption of potassium in the proximal tubule requires which of the following?
   A) potassium channel activity in the apical membrane
   B) potassium channel activity in the basolateral membrane
   C) Na⁺/K⁺ pump activity in the apical membrane
   D) stimulation by aldosterone
   E) stimulation by angiotensin II

   Answer: B
   Diff: 5   Page Ref: 551

60) Potassium enters the epithelial cells of the proximal tubule by which of the following mechanisms?
   A) Na⁺/K⁺ pumps in the basolateral membrane
   B) Na⁺/K⁺ pumps in the apical membrane
   C) potassium channels in the basolateral membrane
   D) Na⁺/K⁺ cotransport in the apical membrane
   E) K⁺/HCO₃⁻ countertransport in the apical membrane

   Answer: A
   Diff: 4   Page Ref: 551

61) The secretion of potassium in the distal tubule requires which of the following?
   A) Na⁺/K⁺ pump activity in the apical membrane
   B) potassium channel activity in the basolateral membrane
   C) potassium channel activity in the apical membrane
   D) stimulation by ADH
   E) stimulation by angiotensin II

   Answer: C
   Diff: 5   Page Ref: 551
62) Which of the following best describes the effect of aldosterone on renal handling of potassium?
A) Aldosterone enhances potassium reabsorption in the proximal tubule by increasing the number of Na+/K+ pumps in the basolateral membrane and increasing the number of potassium channels in the apical membrane.
B) Aldosterone enhances potassium reabsorption in the distal tubule by increasing the number of Na+/K+ pumps in the apical membrane and increasing the number of potassium channels in the basolateral membrane.
C) Aldosterone enhances potassium secretion in the proximal tubule by increasing the number of Na+/K+ pumps in the apical membrane and increasing the number of potassium channels in the basolateral membrane.
D) Aldosterone enhances potassium secretion in the distal tubule by increasing the number of Na+/K+ pumps in the apical membrane and increasing the number of potassium channels in the basolateral membrane.
E) Aldosterone enhances potassium secretion in the distal tubule by increasing the number of Na+/K+ pumps in the basolateral membrane and increasing the number of potassium channels in the apical membrane.
Answer: E
Diff: 5 Page Ref: 551

63) Which of the following structures is NOT involved in the regulation of plasma calcium?
A) skin
B) skeletal muscle
C) kidneys
D) bone
E) gastrointestinal tract
Answer: B
Diff: 4 Page Ref: 552

64) The bone can supply calcium to the plasma by what process?
A) filtration
B) reabsorption
C) calcification
D) resorption
E) ossification
Answer: D
Diff: 4 Page Ref: 552

65) Which of the following statements about renal handling of calcium is FALSE?
A) Calcium that is bound to plasma proteins is NOT filtered.
B) Most calcium is reabsorbed in the proximal tubule.
C) Calcium is reabsorbed in the thick ascending limbs of the loop of Henle.
D) Calcium is reabsorbed in the distal tubule.
E) Calcium secretion is regulated by parathyroid hormone.
Answer: E
Diff: 4 Page Ref: 553
66) Which of the following is NOT one of the responses that occur following an increase in parathyroid hormone?
   A) increased reabsorption of calcium in the ascending limb of the loop of Henle
   B) increased reabsorption of calcium in the distal tubules
   C) activation of 1, 25–dihydroxy vitamin D3 increases calcium absorption in the gastrointestinal tract
   D) increased reabsorption of calcium in the proximal tubules
   E) resorption of bone calcium

   Answer: D
   Diff: 4   Page Ref: 553

67) A decrease in plasma calcium will initiate an increase in the release of which of the following?
   A) parathyroid hormone only
   B) calcitonin only
   C) 1, 25–dihydroxy vitamin D3 only
   D) both parathyroid hormone and calcitonin
   E) both parathyroid hormone and 1, 25–dihydroxy vitamin D3

   Answer: E
   Diff: 5   Page Ref: 553

68) Which of the following hormones are lipophilic?
   A) 1, 25–dihydroxy vitamin D3 only
   B) parathyroid hormone only
   C) calcitonin only
   D) both parathyroid hormone and 1, 25–dihydroxy vitamin D3
   E) both parathyroid hormone and calcitonin

   Answer: A
   Diff: 6   Page Ref: 553

69) Which of the following hormones is a steroid?
   A) angiotensin II
   B) antidiuretic hormone
   C) aldosterone
   D) parathyroid hormone
   E) calcitonin

   Answer: C
   Diff: 4   Page Ref: 548

70) Exposure of the skin to sunlight converts _______ to vitamin D3.
   A) calcium
   B) calcitriol
   C) 25–OH D3
   D) cholesterol
   E) 7–dehydrocholesterol

   Answer: E
   Diff: 6   Page Ref: 554
71) The last step to synthesis of 1, 25–dihydroxy vitamin D₃ occurs in what organ?
A) kidney
B) liver
C) skin
D) gastrointestinal tract
E) brain
Answer: A  Diff: 6  Page Ref: 554

72) What hormone decreases plasma calcium levels?
A) calcitonin only
B) 1, 25–dihydroxy vitamin D₃ only
C) parathyroid hormone only
D) both calcitonin and 1, 25–dihydroxy vitamin D₃
E) both calcitonin and parathyroid hormone
Answer: A  Diff: 5  Page Ref: 554

73) The effects of antidiuretic hormone (ADH) are not restricted to regulating water movement; it also affects sodium reabsorption by ________.
A) increasing the synthesis of sodium channels in principal cells
B) increasing the synthesis of sodium channels in intercalated cells
C) decreasing the synthesis of sodium channels in intercalated cells
D) decreasing the synthesis of sodium channels in principal cells
E) increasing the synthesis of Na⁺/K⁺ pumps in principal cells
Answer: A  Diff: 7  Page Ref: 555

74) Angiotensin II and atrial natriuretic peptide are able to alter the reabsorption of water through a similar pathway that involves altered ________.
A) integration of aquaporin-3 into the membrane
B) release of antidiuretic hormone (ADH)
C) Na⁺/K⁺ pump activity in the intercalated cells
D) Na⁺/K⁺ pump activity in the principal cells
E) sodium channel expression on the apical membrane
Answer: B  Diff: 7  Page Ref: 555

75) Which of the following is NOT a response to hemorrhage?
A) decreased renin secretion
B) increased sympathetic activity
C) increased angiotensin II production
D) increased ADH release
E) increased epinephrine secretion
Answer: A  Diff: 6  Page Ref: 555
76) Which of the following does NOT occur as a consequence of the increased release of renin and its effects on other hormones?  
   A) vasoconstriction  
   B) thirst  
   C) sodium reabsorption  
   D) increased heart rate  
   E) water reabsorption  
   Answer: D  
   Diff: 5  Page Ref: 555

77) The hemorrhage-induced decrease in blood flow to the kidneys will _______.  
   A) decrease the release of renin  
   B) increase glomerular filtration rate  
   C) increase the production of erythrocytes  
   D) increase the release of atrial natriuretic peptide  
   E) increase the production of leukocytes  
   Answer: C  
   Diff: 6  Page Ref: 555

78) Which of the following is NOT one of the effects of changes in pH on the body?  
   A) alterations in protein function  
   B) alterations in central nervous system activity  
   C) alterations in potassium homeostasis  
   D) alteration in water balance  
   E) alterations in cardiac rhythm  
   Answer: D  
   Diff: 6  Page Ref: 556

79) The activity of the respiratory system can increase pH by _______.  
   A) a hyperventilation-induced increase in PCO₂  
   B) a hypoventilation-induced increase in PCO₂  
   C) a hyperventilation-induced decrease in PCO₂  
   D) a hypoventilation-induced decrease in PCO₂  
   E) increasing amount of carbonic acid in the blood  
   Answer: C  
   Diff: 5  Page Ref: 556

80) What is the normal range of blood pH?  
   A) 6.80–7.20  
   B) 6.90–7.10  
   C) 6.75–6.95  
   D) 7.20–7.60  
   E) 7.35–7.45  
   Answer: E  
   Diff: 5  Page Ref: 556
81) During hyperventilation, why do some people detect a tingling sensation in their hands and feet?
   A) due to hyperexcitability of afferent neurons
   B) due to a decrease in blood flow to the distal extremities
   C) due to a decrease in carbon dioxide in blood
   D) due to an increase in carbon dioxide in blood
   E) due to widespread release of catecholamines
   Answer: A
   Diff: 5  Page Ref: 556

82) Which of the following is NOT a metabolic disturbance that can result in a metabolic acidosis?
   A) high protein diet
   B) high fat diet
   C) heavy exercise
   D) excessive vomiting
   E) severe diarrhea
   Answer: D
   Diff: 4  Page Ref: 557

83) What is the most rapid defense against changes in blood pH?
   A) respiratory compensation
   B) buffering of hydrogen ions
   C) renal compensation
   D) cardiac compensation
   E) hepatic compensation
   Answer: B
   Diff: 4  Page Ref: 557

84) How does severe diarrhea cause a metabolic acidosis?
   A) production of bicarbonate
   B) production of hydrogen ions
   C) loss of hydrogen ions
   D) loss of phosphate
   E) loss of bicarbonate
   Answer: E
   Diff: 4  Page Ref: 557

85) How does severe vomiting cause a metabolic alkalosis?
   A) production of bicarbonate
   B) production of hydrogen ions
   C) loss of hydrogen ions
   D) loss of phosphate
   E) loss of bicarbonate
   Answer: C
   Diff: 4  Page Ref: 557
86) Which of the following ions acts as a buffer to minimize changes in intracellular pH?
A) phosphate
B) bicarbonate
C) chloride
D) potassium
E) sodium

Answer: A
Diff: 4 Page Ref: 557

87) The role of a buffer is to ________.
A) reduce the reabsorption of hydrogen ions in the kidneys
B) limit the change in pH with changing hydrogen ion concentrations
C) reduce the secretion of hydrogen ions in the kidneys
D) reduce the secretion of bicarbonate ions in the kidneys
E) enhance the ability of an increase in hydrogen ions to increase pH

Answer: B
Diff: 4 Page Ref: 557

88) What is the secondary defense against changes in pH that requires minutes to be activated?
A) respiratory compensation
B) buffering of hydrogen ions
C) renal compensation
D) cardiac compensation
E) hepatic compensation

Answer: A
Diff: 4 Page Ref: 559

89) Respiratory compensation for changes in pH are originated by ________.
A) proprioceptors
B) baroreceptors
C) central chemoreceptors
D) peripheral chemoreceptors
E) directly affecting the activity of the diaphragm

Answer: D
Diff: 5 Page Ref: 559

90) When an increase in hydrogen ions remains after one hour, this will lead to a(n) ________.
A) decrease in bicarbonate reabsorption in the kidneys
B) increased hydrogen reabsorption in the kidneys
C) increase in bicarbonate secretion in the kidneys
D) increase in hydrogen ion secretion from the kidneys
E) failure of the kidneys to filter any more hydrogen ions

Answer: D
Diff: 6 Page Ref: 559
91) Which of the following is an effect of the transporters in the proximal tubules?
   A) secretion of urea
   B) secretion of potassium
   C) reabsorption of hydrogen
   D) secretion of sodium
   E) reabsorption of bicarbonate

   Answer: E
   Diff: 5   Page Ref: 559

92) In the basolateral membrane of proximal tubular cells, bicarbonate is moved out of the cells by ________.
   A) \( K^+ / HCO_3^- \) countertransporters only
   B) \( HCO_3^- / Cl^- \) countertransporters only
   C) \( Na^+ / HCO_3^- \) cotransporters only
   D) both \( K^+ \) \( HCO_3^- \) and \( HCO_3^- / Cl^- \) countertransporters
   E) both \( HCO_3^- / Cl^- \) countertransporters and \( Na^+ / HCO_3^- \) cotransporters

   Answer: E
   Diff: 6   Page Ref: 559

93) In the proximal tubule, hydrogen ions are transported into the filtrate by ________.
   A) \( Na^+ / H^+ \) countertransporters only
   B) \( H^+ \) primary active transporters only
   C) \( H^+ / Cl^- \) cotransporters only
   D) both \( Na^+ / H^+ \) countertransporters and \( H^+ \) primary active transporters
   E) both \( Na^+ / H^+ \) countertransporters and \( H^+ / Cl^- \) cotransporters

   Answer: D
   Diff: 6   Page Ref: 560

94) Bicarbonate crosses the apical membrane of the proximal tubule by ________.
   A) \( HCO_3^- / Cl^- \) countertransporters
   B) \( Na^+ / HCO_3^- \) cotransporters
   C) conversion to carbon dioxide
   D) \( HCO_3^- \) active transporters
   E) \( Na^+ / HCO_3^- \) countertransporters

   Answer: C
   Diff: 6   Page Ref: 560
95) Which of the following transporters is NOT found embedded in the membrane of the intercalated cells of the late distal tubule and collecting ducts?
   A) HCO₃⁻/Cl⁻ countertransporters in the basolateral membrane
   B) Na⁺/HCO₃⁻ cotransporters in the basolateral membrane
   C) chloride channels in the basolateral membrane
   D) H⁺ pumps in the apical membrane
   E) K⁺/H⁺ countertransporters in the apical membrane

   Answer: B  
   Diff: 6  Page Ref: 560

96) What is the normal source of the new bicarbonate in the late distal tubule and collecting ducts?
   A) carbon monoxide produced in the distal tubule
   B) catabolism of lysine
   C) catabolism of glutamine
   D) carbon dioxide from the system circulation
   E) carbon dioxide produced by the tubule cells

   Answer: E  
   Diff: 5  Page Ref: 561

97) Under severe acidic conditions, the proximal tubules can convert _______ into bicarbonate.
   A) glutamate
   B) carbon monoxide
   C) lysine
   D) glutamine
   E) glycine

   Answer: D  
   Diff: 5  Page Ref: 561

98) Hydrogen ions in the filtrate within the collecting ducts are buffered by the presence of _______.
   A) phosphate
   B) bicarbonate
   C) carbon dioxide
   D) glutamine
   E) proteins

   Answer: A  
   Diff: 6  Page Ref: 561

99) In order to compensate for a hyperventilation, the _______.
   A) kidneys decrease the reabsorption of bicarbonate
   B) kidneys increase the conversion of glutamine to bicarbonate
   C) kidneys increase the secretion of hydrogen ions
   D) lungs increase ventilation rate
   E) kidneys increase the reabsorption of hydrogen ions

   Answer: A  
   Diff: 5  Page Ref: 562
100) Which of the following is NOT a compensation that would occur in response to a metabolic acidosis?
   A) increased excretion of hydrogen ions
   B) increased ventilation
   C) decreased tidal volume
   D) increased bicarbonate production
   E) increased conversion of glutamine to bicarbonate

Answer: C

Diff: 4    Page Ref: 562

101) A patient is exhibiting several signs of acid–base imbalance. Blood tests reveal that blood pH is 7.3, and bicarbonate and carbon dioxide levels in blood are both low. What is the state of this patient?
   A) metabolic acidosis with respiratory compensation
   B) respiratory acidosis with renal compensation
   C) metabolic alkalosis with respiratory compensation
   D) respiratory alkalosis with renal compensation
   E) blood pH is normal

Answer: A

Diff: 7    Page Ref: 562

102) A patient is exhibiting several signs of acid–base imbalance. Blood tests reveal that blood pH is 7.5, and bicarbonate and carbon dioxide levels in blood are both low. What is the state of this patient?
   A) metabolic acidosis with respiratory compensation
   B) respiratory acidosis with renal compensation
   C) metabolic alkalosis with respiratory compensation
   D) respiratory alkalosis with renal compensation
   E) blood pH is normal

Answer: D

Diff: 7    Page Ref: 563

True/False Questions

1) The transport of material across the gastrointestinal tract normally leads to a net gain of solutes and water by the body.

Answer: TRUE

Diff: 3    Page Ref: 536

2) In a state of negative balance, the quantity of a substance in the plasma tends to increase.

Answer: FALSE

Diff: 3    Page Ref: 536

3) The balance of a solute depends solely on its intake to and output from the body.

Answer: FALSE

Diff: 4    Page Ref: 536
4) Consumption of salty foods without drinking water will increase plasma osmolarity and cause cells to shrink.
   Answer: TRUE
   Diff: 3    Page Ref: 537

5) There is no secretion of water within the renal tubules.
   Answer: TRUE
   Diff: 3    Page Ref: 539

6) In the proximal tubule, urea is the primary solute increasing the osmolarity for water reabsorption.
   Answer: FALSE
   Diff: 4    Page Ref: 547

7) In both the proximal and distal tubules, the reabsorption of sodium involves the active transport of sodium across the basolateral membrane.
   Answer: TRUE
   Diff: 4    Page Ref: 539

8) Near the renal pelvis, the osmolarity of the medullary interstitial fluid is 300 mOsm.
   Answer: FALSE
   Diff: 4    Page Ref: 539

9) In comparison with the renal cortex, fluid in the proximal tubule is hyperosmotic.
   Answer: FALSE
   Diff: 4    Page Ref: 539

10) Urea diffuses from the collecting duct into the medullary interstitial fluid maintaining to the medullary interstitial fluid osmotic gradient.
    Answer: TRUE
    Diff: 4    Page Ref: 541

11) The thick ascending limb of the loop of Henle is impermeable to water.
    Answer: TRUE
    Diff: 4    Page Ref: 540

12) Osmolarity of the fluid in the descending limb of the loop of Henle is greater than the osmolarity of the fluid in the ascending limb of the loop of Henle at any given level in the renal medulla.
    Answer: TRUE
    Diff: 5    Page Ref: 541

13) The maximum osmolarity of urine is 1200 mOsm to 1400 mOsm.
    Answer: TRUE
    Diff: 3    Page Ref: 543

14) The minimum osmolarity of urine is 300 mOsm.
    Answer: FALSE
    Diff: 4    Page Ref: 543

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15) The obligatory water loss refers to the lowest volume of urine that must be produced to eliminate solutes.
   Answer: TRUE
   Diff: 4     Page Ref: 543

16) Antidiuretic hormone increases water reabsorption by increasing the permeability of the distal tubule and collecting duct to water.
   Answer: TRUE
   Diff: 3     Page Ref: 544

17) If plasma volume is below normal, the changes originated by the kidneys will be able to return the plasma osmolarity back to normal.
   Answer: FALSE
   Diff: 3     Page Ref: 545

18) If glomerular filtration decreases, water excretion tends to decrease as well.
   Answer: TRUE
   Diff: 4     Page Ref: 545

19) In the proximal tubule, sodium moves from the lumen into the tubule epithelial cell by diffusion through sodium channels.
   Answer: FALSE
   Diff: 4     Page Ref: 547

20) Aldosterone stimulates an increase in sodium reabsorption at the same time it stimulates an increase in potassium secretion.
   Answer: TRUE
   Diff: 4     Page Ref: 548

21) In the proximal tubules, the reabsorption of potassium involves a potassium channel on the apical membrane.
   Answer: FALSE
   Diff: 4     Page Ref: 551

22) Calcium is permanently embedded in the rigid structure of bone.
   Answer: FALSE
   Diff: 3     Page Ref: 552

23) 1, 25–dihydroxy vitamin D₃ acts to increase the absorption of calcium in the digestive tract and increase reabsorption of calcium in the distal tubules of the kidney.
   Answer: TRUE
   Diff: 4     Page Ref: 553

24) The release of antidiuretic hormone (ADH) is enhanced by an increase in the activity of the cardiac baroreceptors.
   Answer: FALSE
   Diff: 4     Page Ref: 545
25) Alterations in acid–base balance that originate from the respiratory system involve alterations in CO₂ content within the blood.
   Answer: TRUE
   Diff: 3 Page Ref: 556

26) Renal and respiratory compensation refers to the kidneys’ and lungs’ (respectively) ability to restore pH without affecting the cause of the acid–base disturbance.
   Answer: TRUE
   Diff: 3 Page Ref: 557

27) Carbonic anhydrase is located inside intercalated cells of the distal tubule and collecting duct.
   Answer: TRUE
   Diff: 4 Page Ref: 560

28) Bicarbonate is reabsorbed in the proximal tubule and newly synthesized in the distal tubule and collecting duct.
   Answer: TRUE
   Diff: 4 Page Ref: 560

29) The minimal pH of tubular fluid is 4.5 due to the pH–induced inhibition of hydrogen ion secretion.
   Answer: TRUE
   Diff: 4 Page Ref: 561

30) A metabolic alkalosis will cause a decrease in ventilation and an increased excretion of bicarbonate.
   Answer: TRUE
   Diff: 3 Page Ref: 562

31) Urea is actively transported out of the collecting duct.
   Answer: FALSE
   Diff: 5 Page Ref: 541

32) Reabsorption of glucose is an active process.
   Answer: TRUE
   Diff: 4 Page Ref: 547
Matching Questions

Match the hormone to its function.

1) Activates the cAMP second messenger system in principal cells of the distal tubules and collecting ducts.
   Diff: 4   Page Ref: 544

   A) aldosterone
   B) parathyroid hormone
   C) none
   D) 1, 25-dihydroxycholecalciferol
   E) atrial natriuretic peptide
   F) angiotensin II
   G) ADH
   H) calcitonin

2) Increases water reabsorption by inserting aquaporin-2 proteins into the apical membrane of principal cells.
   Diff: 4   Page Ref: 544

3) Increases reabsorption of both sodium and potassium.
   Diff: 4   Page Ref: 548

4) Stimulates aldosterone release.
   Diff: 3   Page Ref: 548

5) Acts on the hypothalamus to induce thirst.
   Diff: 4   Page Ref: 551

6) Release is stimulated by high levels of potassium.
   Diff: 4   Page Ref: 553

7) Decreases calcium levels in blood.
   Diff: 4   Page Ref: 554

8) Final activation step occurs in the kidneys.
   Diff: 4   Page Ref: 554

9) Increases calcium resorption from bone.
   Diff: 4   Page Ref: 553

10) Stimulates activation of 1, 25-dihydroxycholecalciferol.
    Diff: 4   Page Ref: 553
11) Activated from a precursor in the blood by two proteolytic cleavages.  
Diff: 4  Page Ref: 548

12) Increases excretion of sodium.  
Diff: 4  Page Ref: 550

13) Increases secretion of sodium and reabsorption of potassium.  
Diff: 5  Page Ref: 548

14) Released from the posterior pituitary.  
Diff: 3  Page Ref: 544

15) Released from the adrenal cortex.  
Diff: 3  Page Ref: 548

Answers:  1) G  2) G  3) C  4) F  5) F  
6) A  7) H  8) D  9) B  10) B  
11) F  12) E  13) C  14) G  15) A

Match the following locations with the proper occurrence.

16) Most sodium reabsorption is driven by the Na\(^+\)/K\(^+\) pump located in this region.  
Diff: 5  Page Ref: 547

A) none
B) principal cells basolateral membrane
C) intercalated cells apical membrane
D) proximal tubule apical membrane
E) proximal tubule basolateral membrane
F) intercalated cells basolateral membrane
G) principal cells apical membrane

17) Aquaporin–3 is located on this membrane in the absence of ADH.  
Diff: 6  Page Ref: 542

18) Receptors for aldosterone are located here.  
Diff: 5  Page Ref: 548

19) Receptors for ADH are located here.  
Diff: 5  Page Ref: 544

20) Potassium channels located here are necessary for its reabsorption.  
Diff: 6  Page Ref: 551
21) Potassium channels located here are necessary for its secretion.
   *Diff: 6  Page Ref: 551*

22) Carbonic anhydrase is located here.
   *Diff: 6  Page Ref: 559*

23) Potassium is exchanged for hydrogen across this membrane.
   *Diff: 6  Page Ref: 560*

24) Sodium–glucose cotransporters are located here.
   *Diff: 4  Page Ref: 547*

25) ADH increases the insertion of aquaporin–2 here.
   *Diff: 5  Page Ref: 544*

26) Aldosterone increases the number of potassium channels here.
   *Diff: 5  Page Ref: 548*


*Match the term with its description.*

27) Increase in plasma levels of calcium.
   *Diff: 3  Page Ref: 552*  
   A) hyperbola

28) Increase in plasma levels of sodium.
   *Diff: 3  Page Ref: 547*  
   B) hypercalcemia

29) Increase in plasma volume.
   *Diff: 3  Page Ref: 537*  
   C) hyperkalemia

30) Increase in plasma levels of potassium.
   *Diff: 3  Page Ref: 550*  
   D) hypervolemia

   E) hypernatremia

Match the acid–base disturbance to the correct blood values.

31) Blood pH = 7.3, [HCO₃⁻] is low, PCO₂ is low.

   A) respiratory alkalosis with renal compensation

   Diff: 5  Page Ref: 563

32) Blood pH = 7.3, [HCO₃⁻] is high, PCO₂ is high.

   B) metabolic acidosis with respiratory compensation

   Diff: 5  Page Ref: 563

33) Blood pH = 7.5, [HCO₃⁻] is high, PCO₂ is high.

   C) respiratory acidosis with renal compensation

   Diff: 5  Page Ref: 563

34) Blood pH = 7.5, [HCO₃⁻] is low, PCO₂ is low.

   D) metabolic alkalosis with respiratory compensation

   Diff: 5  Page Ref: 563

Answers:  31) B  32) C  33) D  34) A
Essay Questions

1) The recovery of water from the filtrate that enters Bowman’s capsule is an important function of the kidneys. Describe the mechanisms whereby water is reabsorbed in each segment of the renal tubules. Include the cellular mechanisms that allow antidiuretic hormone (ADH) to modulate reabsorption and that regulate the release of ADH.

Answer: Once filtered from the glomerular capillaries, filtrate enters the proximal tubules. Within these tubules, water moves passively into the peritubular space. The active transport of sodium creates the osmotic gradient for the outward movement of water. Thus, the osmolarity of filtrate is the same at the beginning and end of the proximal tubules, while the total volume decreases dramatically. Once the filtrate enters the descending limb of the loop of Henle, water continues to be passively pulled out of the tubule. The driving force for this outward movement of water from the tubule is a progressive increase in the osmolarity of the peritubular space, from iso-osmotic at the cortical-medullary border to a maximum at the innermost region of the medulla near the renal pelvis. Thus, the osmolarity of the filtrate will continue to increase within the descending limb of the loop of Henle until it reaches a peak at the tip of the loop of Henle. The ascending limb of the loop of Henle is not permeable to water. Thus, while no water exits this tubule, sodium is moved out such that the osmolarity of the filtrate decreases as it ascends. This active transport of sodium maintains the osmotic gradient in the medulla. The osmolarity of the filtrate in the distal tubule is less than the proximal tubule. In the distal tubule and the collecting ducts, the movement of water is regulated by aquaporins (2 & 3) located within the principal cells. ADH enhances the synthesis and insertion of aquaporin-2 into the membrane of the epithelial cells of the distal tubule and collecting ducts, resulting in an increased water reabsorption (passively) from the filtrate as it enters the medullary region of the kidney. Once ADH binds to its G protein receptor on tubular epithelial cells, adenylate cyclase is activated within those cells, resulting in the production of cAMP, which activates protein kinase A. The elevated protein kinase A stimulates the insertion of aquaporin-2 into the apical membrane, where it becomes active. The release of ADH from the posterior pituitary is stimulated by an increase in osmolarity within the hypothalamus. At the same time, a decrease in blood pressure is detected by cardiac baroreceptor, which increases the release of ADH. Finally, the extent of ADH release is modified by angiotensin II and atrial natriuretic peptide. There is a limit to the kidneys’ ability to concentrate filtrate. This creates the obligatory water loss that is based on the peak osmolarity of the innermost region of the kidneys’ medulla. Once the filtrate in the collecting ducts reaches the innermost region of the medulla, the passive movement of water outward will stop once the osmotic gradient between filtrate and peritubular space is lost (the two are iso-osmotic).
2) The recovery of sodium from the filtrate that enters Bowman's capsule is an important function of the kidneys. Describe the mechanisms for sodium reabsorption in the distal tubules and collecting ducts and the hormonal mechanisms involved in its regulation.

Answer: Sodium is an ion that is reabsorbed within the tubules. The gradient for the movement of sodium out of the filtrate is driven by the active transport of sodium out of the cell and into the peritubular space via basolateral Na+/K+ pumps, which maintains the gradient for the movement of sodium from the filtrate into the tubular epithelial cells. This sodium gradient provides for the movement of ions, like bicarbonate and water, into the cell. The principal cells of the distal tubules and collecting ducts contain cytosolic receptors for the steroid hormone aldosterone, secreted by the adrenal cortex. The release of aldosterone is stimulated by angiotensin II. The pathway for the synthesis of angiotensin II originates within the kidneys. The granular cells within the afferent arterioles respond to a decrease in pressure and a decrease in sodium or chloride within the distal tubules (through the macula densa) by increasing the secretion of renin. Renin is an enzyme that converts angiotensinogen (secreted by the liver) into angiotensin I. Angiotensin I is converted into angiotensin II by angiotensin converting enzyme (present in the capillaries). Aldosterone binds to its receptor, which causes an increase in the open state of the sodium channels in the apical membrane as well as an increase in their synthesis. In addition, there is an increase in the synthesis of the Na+/K+ pumps, which are integrated into the basolateral membrane. An increase in the number of active Na+/K+ pumps and sodium channels in the basolateral and apical membranes, respectively, will increase the movement of sodium out of the filtrate. The reabsorption of sodium is also facilitated by the vasoconstriction of afferent arterioles that is initiated by angiotensin II. That decreases the glomerular filtration rate and allows more time for sodium reabsorption. The reabsorption of sodium is so important that it is regulated by a second hormone: atrial natriuretic peptide (ANP). ANP has the opposite effect of aldosterone, inducing a decrease in sodium reabsorption. An increase in the stretch of the atria (due to an increase in atrial pressure) causes an elevation in the secretion of ANP. An increase in ANP induces an increase in glomerular filtration rate by decreasing efferent arteriole resistance through dilation and decreasing the number of open sodium channels in the apical membrane of the principal cell. ANP also decreases the secretion of renin and aldosterone.

Diff: 8 Page Ref: 547
3) The recovery of potassium from the filtrate that enters Bowman’s capsule is an important
function of the kidneys. Describe the mechanisms whereby potassium is secreted and/or
reabsorbed in each segment of the kidney tubules.

Answer: Potassium is both reabsorbed and secreted within the kidneys. Unlike water and
sodium, whose plasma concentrations are regulated by varying the extent of their
reabsorption, potassium is regulated by varying the extent of its secretion. In the
proximal tubules, potassium is reabsorbed by moving it into tubular epithelial cells via
basolateral Na+/K+ pumps (moves potassium into the cell) and by an as yet
unidentified pathway that removes potassium from the filtrate. These mechanisms both
increase intracellular potassium concentration, causing potassium to move through the
basolateral potassium channels into the peritubular fluid. Thus, while some potassium
is moved into the cell from the peritubular fluid (via the Na+/K+ pumps), the net
movement of potassium is outward into the peritubular fluid. In the principal cells of
the late distal tubule and collecting ducts, the direction of potassium movement is
reversed. The Na+/K+ pumps on the basolateral membrane of each cell move potassium
into the cell, which creates a gradient for the outward movement of potassium across
the apical membrane and into the filtrate through potassium channels. Because the
expression of Na+/K+ pumps is regulated by aldosterone and the Na+/K+ pumps
increase the concentration of potassium within the cell, increases in aldosterone will
increase the secretion of potassium into the filtrate. Decreases in pressure within the
afferent arteriole and cardiac baroreceptor will increase the secretion of renin, which
will ultimately elevate aldosterone and thereby increase potassium secretion. However,
potassium can also have a direct effect on aldosterone: high blood potassium
concentrations can stimulate the release of aldosterone from the adrenal cortex.

Diff: 7   Page Ref: 550

4) The maintenance of plasma calcium has important implications. Describe the mechanisms
whereby plasma calcium concentrations are regulated by hormones.

Answer: Calcium is tightly controlled within the body through the interaction of bone, kidneys,
and digestive tract. Much of the calcium in plasma is bound to carrier proteins. In the
kidneys, most of the calcium (70%) is reabsorbed within proximal tubules, while the
remaining calcium is reabsorbed within the ascending limb of the loop of Henle and the
distal tubules. Calcium reabsorption in the ascending limb of the loop of Henle and the
distal tubule is regulated by hormones. In response to a decrease in plasma calcium, two
hormones are released: parathyroid hormone (PTH) and calcitriol. PTH is a peptide
hormone released from the parathyroid gland and acts to increase plasma calcium by
three general mechanisms: 1) PTH stimulates calcium reabsorption in the ascending
limb of the loop of Henle and the distal tubules, which decreases the excretion of
calcium, 2) PTH stimulates the activation of 1, 25–dihydroxy vitamin D3 within the
kidneys, which enhances calcium reabsorption in the digestive tract (PTH has a small
but direct effect on calcium reabsorption in the digestive tract) and kidneys, and 3) PTH
stimulates the resorption of bone. 1, 25–dihydroxy vitamin D3 is a steroid hormone that
is synthesized from vitamin D3. PTH regulates the conversion of 25 hydroxyvitamin D3
to 1, 25–dihydroxy vitamin D3. 1, 25–dihydroxy vitamin D3 increases the reabsorption
of calcium from the digestive tract and kidneys. On the other hand, an increase in
plasma calcium will enhance the release of calcitonin from the C cells of the thyroid
gland. The primary effect of calcitonin is to increase the deposition of calcium in bone. It
also decreases the reabsorption of calcium by the kidneys.

Diff: 7   Page Ref: 552
5) Hormonal regulation plays an important role in the long-term control of blood pressure. Identify the hormones outlined in this chapter that play a role in the long-term regulation of blood pressure, how those hormones are regulated, and the mechanisms they use to affect blood pressure.

Answer: The hormones responsible for long-term regulation of blood pressure include angiotensin II, aldosterone, atrial natriuretic peptide (ANP), antidiuretic hormone (ADH), and erythropoietin. The regulation of angiotensin II and aldosterone are interrelated. The pathway to aldosterone release starts with renin. This enzyme is released from granular cells of the macula densa in response to 1) a decrease in afferent arteriole pressure, 2) a decrease in filtrate sodium and chloride in the distal tubule, and 3) an increase in renal sympathetic activity originated by activation of the baroreflex. Renin converts angiotensinogen into angiotensin I. Thereafter, angiotensin converting enzyme (located on pulmonary capillary endothelial cells) converts angiotensin I into angiotensin II, which stimulates the release of aldosterone. Aldosterone affects principal cells of the late distal tubule and collecting ducts by increasing the number and open sodium channels in the apical membrane and increasing the number of Na⁺/K⁺ pumps in the basolateral membrane. This results in an increased reabsorption of sodium. In addition, angiotensin II affects blood pressure by 1) its vasoconstrictive properties, 2) altering thirst at the hypothalamus, and 3) stimulating ADH release. ANP is counterregulatory to aldosterone and is released in response to stretch of the atria (increased blood pressure). Once released, ANP decreases glomerular filtration rate by decreasing glomerular capillary pressure through concomitant dilation of the afferent arteriole and constriction of the efferent arteriole. In addition, ANP decreases the number of open sodium channels in the apical membrane and decreases the release of ADH. The primary stimulation for the release of ADH is an increase in osmolarity within the hypothalamus. Secondarily, the release of ADH is modified by angiotensin II (increased) and ANP (decreased). ADH increases blood pressure by altering the reabsorption of water. This occurs through the insertion of aquaporin-2 into the membrane of cells within the collecting ducts. ADH also increases the number of sodium channels in the apical membrane of principal cells. Finally, erythropoietin is stimulated by a decrease in blood flow to the kidneys, which induces a hypoxia within the kidneys. Since erythrocytes make up about 45% of the volume of blood, any changes in their production will affect blood volume.

Diff: 9 Page Ref: 555

6) The balance of acid and base within the blood plays an important role in a number of bodily functions. How do changes in the pH of the blood affect bodily functions?

Answer: Typically, blood remains within the pH range of 7.35 to 7.45. As the concentration of hydrogen ions moves outside of this normal range, they can affect amino acids, resulting in conformational changes of proteins that can affect their functions. At the same time, the activity of the nervous system is altered by pH. Acidosis can cause a decrease in the excitability of neurons; a severe acidosis can lead to confusion, coma, and even death. Alkalosis causes an increase in the excitability of neurons. This can lead to the generation of action potentials in sensory or motor neurons. A disturbance in acid–base balance can also lead to a potassium imbalance. Acidosis results in potassium retention, whereas alkalosis results in potassium depletion. These alterations in potassium are caused by electrochemical interactions and competition for carrier proteins. Acidosis can also lead to cardiac arrhythmias and vasodilation of blood vessels due to an impaired sympathetic activity.

Diff: 6 Page Ref: 556
7) Acid–base balance is regulated by a number of systems. Describe the sources of respiratory acidosis and alkalosis as well as metabolic acidosis and alkalosis.

Answer: Respiratory acidosis originates from changes in ventilation. A decrease in ventilation (hypoventilation) or a reduction in gas transfer across the lungs will lead to an increase in \( P_{CO_2} \). This increased \( P_{CO_2} \) will increase the carbonic acid concentration, thereby increasing the hydrogen ion concentration within the blood, leading to acidosis. On the other hand, hyperventilation will decrease \( P_{CO_2} \), thereby decreasing carbonic acid, resulting in a respiratory alkalosis. Metabolic disturbances are more complex in their origin. A metabolic acidosis can result from: 1) a high protein diet that leads to the production of phosphoric and sulfuric acids, 2) a high fat diet due to the release of free fatty acids for metabolism, 3) heavy exercise that is beyond the body’s ability to deliver oxygen for aerobic metabolism that will force a switch to a more anaerobic metabolism and lead to the production of lactic acid, 4) severe diarrhea that leads to a loss of the bicarbonate secreted into the digestive tract, and 5) any alteration in kidney function that reduces the secretion of hydrogen ions or decrease the reabsorption of bicarbonate. The causes of metabolic alkalosis are not as numerous: they include excessive vomiting, which results in a loss of hydrogen ions secreted into the stomach for digestion, and any alterations in renal function that enhance the secretion of hydrogen ions or increase the reabsorption of bicarbonate.

Diff: 7 Page Ref: 556

8) Changes in acid–base balance are continuously occurring. The body must adjust to those changes through three mechanisms that differ in their ability to affect pH and in their time courses. Describe the three mechanisms that respond to changes in blood pH and their temporal course.

Answer: The first line of defense against a change in pH involves buffering the hydrogen ions. This buffering primarily involves bicarbonate concentration of the plasma and the concentrations of phosphate and proteins within intracellular fluid. The binding of hydrogen ions to these molecules alters the relationship between pH and hydrogen ion concentration. Their binding removes the acid from solution, thereby preventing it from affecting pH. This buffering of hydrogen ions is the most rapid responder. However, this rapid response is limited in its ability to affect pH because it can only buffer changes and cannot reverse changes in pH. The second line of defense is respiratory compensation. Within minutes, any change in pH will be detected by the peripheral chemoreceptors. As pH decreases, ventilation increases to decrease arterial \( P_{CO_2} \) which leads to the removal of hydrogen ions from solution, thereby increasing pH. The situation would be reversed if pH were to increase. If respiratory compensation is unable to return pH to control, then the final mechanism, renal compensation will be activated. Renal compensation requires hours or even days to be initiated. If hydrogen ion concentrations in the blood decrease, then secretion of hydrogen would be reduced while bicarbonate reabsorption would also be reduced. At the same time, the synthesis of new bicarbonate would also be reduced. The reverse would occur if pH were to remain below normal.

Diff: 8 Page Ref: 557
9) Renal compensation is the final mechanism for the reversal of pH change within the body. Describe the mechanisms that underlie renal compensation, including the proteins involved in hydrogen and bicarbonate transport within the proximal and distal tubules. Include mechanisms for synthesis of new bicarbonate.

Answer: In the proximal tubules, bicarbonate reabsorption is coupled to hydrogen secretion. Bicarbonate is moved out of the cell by Na\(^+\)/K\(^+\) pumps, Na\(^+\)/HCO\(_3\)\(^-\) cotransporters, and HCO\(_3\)\(^-\)/Cl\(^-\) countertransporters located within the basolateral membrane, whereas hydrogen ions are secreted into the tubule filtrate by Na\(^+\)/H\(^+\) countertransporters and H\(^+\) pumps located in the apical membrane. Bicarbonate must first be converted to carbon dioxide by carbonic anhydrase in the tubule in order to move into the cell, where it is converted back to bicarbonate by the same enzyme. With the generation of bicarbonate, a hydrogen ion is produced that must be secreted by the mechanisms identified above. In the distal tubules, the secretion of hydrogen ions is coupled to the production of new bicarbonate ions. The basolateral membrane contains HCO\(_3\)\(^-\)/Cl\(^-\) countertransporters and chloride channels that move bicarbonate out of the cell, coupled to the movement of chloride in. The chloride is then able to exit the cell via chloride channels. On the apical membrane, K\(^+\)/H\(^+\) countertransporters and H\(^+\) pumps are involved in the secretion of hydrogen ions. The movement of potassium into the cell is coupled to the outward movement of hydrogen, and the active hydrogen pumps move hydrogen out against the gradient. The generation of new bicarbonate occurs as a consequence of the metabolic activity of the cells of the tubular system of the kidneys. They use ATP for the Na\(^+\)/K\(^+\) and H\(^+\) pumps. The carbon dioxide generated by metabolism is converted into HCO\(_3\)\(^-\) by carbonic anhydrase within the intercalated cells of the distal tubule. Finally, during severe acidosis, bicarbonate can be produced in the kidneys from glutamine in the cells of the proximal tubule.

\[\text{Diff: 9} \quad \text{Page Ref: 559}\]

10) Diagnosis of the source of an acid–base disturbance is important for determining the cause of the change in pH. Identify the characteristics of the acid–base disturbances and how the body would respond to those changes.

Answer: A metabolic acidosis can be characterized by a decrease in blood pH that occurs with a decrease in bicarbonate. The decrease in bicarbonate is driven by a decrease in ventilation that occurs as a consequence of the decrease in pH sensed by the peripheral chemoreceptors. For a respiratory acidosis, the decrease in pH will be coupled to an increase in P\(_{CO_2}\). The kidneys respond to the decrease in pH by increasing bicarbonate reabsorption, which increases P\(_{CO_2}\). For a metabolic alkalosis, the increase in pH will be coupled to an increase in bicarbonate. The elevation in bicarbonate is driven by the decrease in ventilation. For a respiratory alkalosis, the increase in pH will be coupled to a decrease in P\(_{CO_2}\). That decrease in P\(_{CO_2}\) is driven by a decrease in the reabsorption of bicarbonate.

\[\text{Diff: 6} \quad \text{Page Ref: 562}\]
Short Answer Questions

Using Figure 19.1, answer the following questions:

1) Identify the portion(s) of the nephron in Figure 19.1 that is/are permeable to water and are not regulated by antidiuretic hormone (ADH).
   Answer: D, E, and F
   Diff: 4   Page Ref: 544

2) Identify the structure(s) in Figure 19.1 that remove(s) all of the glucose from the filtrate in a normal individual.
   Answer: F
   Diff: 4   Page Ref: 547

3) Identify the structure(s) in Figure 19.1 that actively maintain(s) the osmotic gradient in the medullary region of the kidneys.
   Answer: B
   Diff: 4   Page Ref: 539

4) In Figure 19.1, the aquaporin-2 channels whose expression is increased by _______ are located within the structure(s) labeled _______.
   Answer: antidiuretic hormone (ADH) : A and C
   Diff: 4   Page Ref: 544

5) Name the two routes of insensible water loss.
   Answer: respiration, through the skin
   Diff: 4   Page Ref: 537
6) Water reabsorption is due to the presence of a(n) _______ established by the active reabsorption of solutes such as sodium.
   Answer: osmotic gradient
   Diff: 5       Page Ref: 539

7) What portion of the loop of Henle is impermeable to water?
   Answer: thick ascending limb
   Diff: 4       Page Ref: 540

8) What section of renal tubule contains a Na⁺/K⁺/Cl⁻ cotransporter?
   Answer: thick ascending limb of the loop of Henle
   Diff: 5       Page Ref: 540

9) The osmolarity of medullary interstitial fluid (increases / decreases) moving from cortex to pelvis.
   Answer: increases
   Diff: 3       Page Ref: 539

10) The osmolarity of the blood within the vasa recta that has returned to the cortex after descending into the medulla is (greater than / less than / the same as) when it entered the medulla.
    Answer: the same as
    Diff: 4       Page Ref: 542

11) If the collecting duct remains impermeant to water, the osmolarity of the filtrate will be (greater than / less than) when it entered Bowman’s capsule.
    Answer: less than
    Diff: 5       Page Ref: 542

12) ADH increases water permeability of (intercalated / principal) cells of the distal tubules and collecting ducts by activating the enzyme (adenylate cyclase / tyrosine kinase), ultimately inserting (aquaporin-2 / aquaporin-3) into the (apical / basolateral) membrane.
    Answer: principal : adenylate cyclase : aquaporin-2 : apical
    Diff: 6       Page Ref: 544

13) In the presence of high amounts of ADH, the urine excreted from the kidneys will have an osmolarity approaching (100 / 1200) mOsm.
    Answer: 1200
    Diff: 4       Page Ref: 544

14) What two types of visceral receptors, when activated, trigger the release of ADH?
    Answer: baroreceptors : osmoreceptors
    Diff: 5       Page Ref: 544

15) A person with polydipsia and polyuria may have the disease ________, which is caused by a deficiency of ADH.
    Answer: diabetes insipidus
    Diff: 5       Page Ref: 546
16) Central diabetes insipidus is associated with a decrease in the (release of / response of tissue to) ADH.
   Answer: release of
   Diff: 5   Page Ref: 546

17) What are the two cellular actions of aldosterone that increase sodium reabsorption and potassium secretion?
   Answer: increases the number of open sodium and potassium channels in the apical membranes of principal cells; increase the number of Na+/K+ pumps in the basolateral membrane of principal cells
   Diff: 5   Page Ref: 548

18) Receptors for aldosterone are located (on the plasma membrane / inside the cytosol) of (principal / intercalated) cells.
   Answer: inside the cytosol: principal
   Diff: 4   Page Ref: 548

19) Name three stimuli for renin release.
   Answer: decrease in sodium and chloride levels in distal tubular fluid, decrease in pressure in the afferent arteriole, and an increase in renal sympathetic nerve activity
   Diff: 5   Page Ref: 548

20) Name four effects of angiotensin II that promote an increase in mean arterial pressure.
   Answer: vasoconstriction of systemic arterioles, release of aldosterone from adrenal cortex, release of ADH from posterior pituitary, and increase in thirst
   Diff: 5   Page Ref: 548

21) Juxtaglomerular cells release the enzyme ______, which converts ______ to angiotensin I. Angiotensin I is then converted to angiotensin II by the enzyme ______.
   Answer: renin: angiotensinogen: angiotensin converting enzyme (ACE)
   Diff: 5   Page Ref: 548

22) The amount of potassium excreted is regulated primarily by regulating its (reabsorption / secretion) in the renal tubules.
   Answer: secretion
   Diff: 3   Page Ref: 550

23) Potassium is secreted by (principal / intercalated) cells.
   Answer: principal
   Diff: 3   Page Ref: 551

24) Hypercalcemia will increase the release of ______ from the ______ gland.
   Answer: calcitonin: thyroid
   Diff: 4   Page Ref: 554

25) An acidosis can lead to an increased retention of (sodium / potassium) and thereby a condition called (hypernatremia / hyperkalemia).
   Answer: potassium: hyperkalemia
   Diff: 5   Page Ref: 560

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26) Name the three mechanisms for compensating for acid–base disturbances in order of when they would occur temporally (first to last).
   Answer: buffering in blood, respiratory compensation, renal compensation
   Diff: 4  Page Ref: 557

27) In the proximal tubule, where is the enzyme carbonic anhydrase located?
   Answer: on the apical membrane and inside the cell
   Diff: 6  Page Ref: 559

28) In the intercalated cells, where is the enzyme carbonic anhydrase located?
   Answer: inside the cell
   Diff: 5  Page Ref: 561

29) New bicarbonate is synthesized in the (proximal tubule / distal tubule and collecting duct).
   Answer: distal tubule and collecting duct
   Diff: 4  Page Ref: 561

30) The most important buffer in extracellular fluids is _______.
   Answer: bicarbonate
   Diff: 3  Page Ref: 557

31) A respiratory acidosis is induced by (hyperventilation / hypoventilation), which causes a(n) (increase / decrease) in PCO₂.
   Answer: hypoventilation : increase
   Diff: 4  Page Ref: 556

32) A decrease in pH, coupled with an increase in PCO₂, indicates a(n) _______ that will be compensated for by a(n) _______.
   Answer: respiratory acidosis : increase in bicarbonate reabsorption
   Diff: 5  Page Ref: 562

33) A decrease in pH, coupled with a decrease in HCO₃⁻, indicates a(n) _______ that will be compensated for by a(n) _______.
   Answer: metabolic acidosis : increase in ventilation to decrease PCO₂
   Diff: 5  Page Ref: 562

34) An increase in pH, coupled with an increase in HCO₃⁻, indicates a(n) _______ that will be compensated for by a(n) _______.
   Answer: metabolic alkalosis : decreased ventilation will increase PCO₂
   Diff: 5  Page Ref: 562

35) An increase in pH, coupled with a decrease in PCO₂, indicates a(n) _______ that will be compensated for by a(n) _______.
   Answer: respiratory alkalosis : decreased reabsorption of HCO₃⁻
   Diff: 5  Page Ref: 562
Chapter 20  The Gastrointestinal System

Multiple Choice Questions

1) Which of the following is NOT a basic process of the gastrointestinal system?
   A) digestion
   B) filtration
   C) absorption
   D) secretion
   E) motility
   Answer: B
   Diff: 4   Page Ref: 568

2) Which of the following is the correct order of the layers of the gastrointestinal tract wall, from lumen to external surface?
   A) mucosa — submucosa — muscularis externa — serosa
   B) serosa — muscularis externa — submucosa — mucosa
   C) serosa — mucosa — submucosa — muscularis externa
   D) mucosa — submucosa — serosa — muscularis externa
   E) submucosa — mucosa — serosa — muscularis externa
   Answer: A
   Diff: 4   Page Ref: 570

3) Which of the following correctly lists the three portions of the mucosa?
   A) serosa, muscularis mucosae, muscularis externa
   B) adventitia, muscularis externa, mucous membrane
   C) muscularis mucosae, mucous membrane, submucosa
   D) mucous membrane, lamina propria, muscularis mucosae
   E) adventitia, lamina propria, muscularis externa
   Answer: D
   Diff: 4   Page Ref: 570

4) Enterocytes of the mucous membrane of the mucosal layer are classified as _______ cells if they secrete fluids and enzymes into the lumen and _______ cells if they release hormones into the bloodstream.
   A) endocrine : absorptive
   B) exocrine : endocrine
   C) endocrine : exocrine
   D) absorptive : endocrine
   E) exocrine : absorptive
   Answer: B
   Diff: 3   Page Ref: 571
5) What layer of the mucosa is connective tissue that contains blood vessels and lymphatic vessels?
   A) serosa  
   B) submucosal plexus  
   C) mucous membrane  
   D) lamina propria  
   E) muscularis mucosae  
   Answer: D  
   Diff: 4  Page Ref: 571

6) What is the thin layer of smooth muscle cells whose contraction stirs the lumenal contents and promotes contact with the mucosal membrane?
   A) muscularis mucosae  
   B) muscularis externae  
   C) muscularis internae  
   D) serosa  
   E) myenteric plexus  
   Answer: A  
   Diff: 4  Page Ref: 571

7) What layer of the gastrointestinal wall is a thick layer of connective tissue that provides the gastrointestinal tract with much of its elasticity and distensibility?
   A) peritoneum  
   B) mesentery  
   C) serosa  
   D) lamina propria  
   E) submucosa  
   Answer: E  
   Diff: 4  Page Ref: 571

8) The enteric nervous system receives its inputs from _______. 
   A) autonomic neurons only  
   B) somatic motor neurons only  
   C) sensory neurons in the wall of the gastrointestinal tract only  
   D) both autonomic neurons and sensory neurons in the wall of the gastrointestinal tract  
   E) both somatic motor neurons and sensory neurons in the wall of the gastrointestinal tract  
   Answer: D  
   Diff: 3  Page Ref: 571

9) The muscularis externa contains which of the following muscle groups?
   A) an inner circular layer capable of slow-wave potentials only  
   B) an outer longitudinal layer that requires neural input for contraction  
   C) a muscularis mucosae, which lubricates as it contracts  
   D) both an inner circular and an outer longitudinal layer  
   E) an inner circular and outer longitudinal layer, and a muscularis mucosae  
   Answer: D  
   Diff: 5  Page Ref: 571
10) Where do slow-wave potentials occur?
   A) myenteric plexus
   B) submucosal plexus
   C) muscularis mucosae
   D) inner circular muscle layer of the muscularis externa
   E) outer longitudinal muscle layer of the muscularis externa

   Answer: D
   Diff: 5   Page Ref: 571

11) The _______ is a layer of epithelial cells on the outer side of the serosa that secretes a watery lubricating fluid that makes it easier for organs to slide past one another.
   A) submucosa
   B) myenteric plexus
   C) mesentery
   D) mesothelium
   E) endothelium

   Answer: D
   Diff: 4   Page Ref: 572

12) What membrane lines the abdominal cavity?
   A) serosa
   B) peritoneum
   C) mesothelium
   D) mesenteries
   E) adventitia

   Answer: B
   Diff: 4   Page Ref: 572

13) What is the technical word for chewing?
   A) mastication
   B) micturition
   C) segmentation
   D) haustration
   E) accommodation

   Answer: A
   Diff: 3   Page Ref: 572

14) As the food is broken into smaller pieces in the mouth, it is combined with _______ that facilitates its movement down the esophagus.
   A) gastric juices
   B) amylase
   C) saliva
   D) pancreatic juices
   E) chyme

   Answer: C
   Diff: 2   Page Ref: 573
15) What is a ring of skeletal muscle that regulates the movement of a bolus into the esophagus?
   A) glottis
   B) epiglottis
   C) upper esophageal sphincter
   D) lower esophageal sphincter
   E) pyloric sphincter
   Answer: C  
   Diff: 3  Page Ref: 573

16) Gastric reflux occurs when material flows backwards through which of the following structures?
   A) glottis
   B) epiglottis
   C) upper esophageal sphincter
   D) lower esophageal sphincter
   E) pyloric sphincter
   Answer: D  
   Diff: 4  Page Ref: 573

17) What is a mixture of food particles with gastric juice called?
   A) bolus
   B) fundus
   C) chyme
   D) saliva
   E) gastric secretions
   Answer: C  
   Diff: 3  Page Ref: 573

18) The flow of chyme from the stomach to the small intestine is regulated by the _______.
   A) glottis
   B) epiglottis
   C) lower esophageal sphincter
   D) pyloric sphincter
   E) gastroileal sphincter
   Answer: D  
   Diff: 4  Page Ref: 573

19) What are rugae?
   A) folds in the small intestine that increase the surface area for absorption
   B) folds in the large intestine that increase the surface area for absorption
   C) folds in the stomach that can flatten to expand the stomach volume
   D) a motility pattern of the large intestine
   E) a motility pattern of the stomach
   Answer: C  
   Diff: 4  Page Ref: 573
20) What cells secrete pepsinogen into the lumen of the stomach?
   A) Goblet  
   B) G  
   C) Parietal  
   D) Chief  
   E) Neck  
   Answer: D  
   Diff: 3  Page Ref: 573

21) What cells function to secrete hydrogen ions into the lumen of the stomach?
   A) Goblet  
   B) Parietal  
   C) Chief  
   D) Neck  
   E) G  
   Answer: B  
   Diff: 3  Page Ref: 573

22) What do parietal cells secrete?
   A) hydrogen ions only  
   B) pepsinogen only  
   C) intrinsic factor only  
   D) both hydrogen ions and pepsinogen  
   E) both hydrogen ions and intrinsic factor  
   Answer: E  
   Diff: 5  Page Ref: 573

23) What do neck cells of gastric pits secrete?
   A) hydrogen ions  
   B) pepsinogen  
   C) intrinsic factor  
   D) gastrin  
   E) mucus  
   Answer: E  
   Diff: 3  Page Ref: 573

24) Which of the following is NOT a normal function of the high acidity of the stomach?
   A) activate pepsin  
   B) denature proteins  
   C) destroy foodborne bacteria  
   D) activate vitamin B₁₂  
   E) protect against illness  
   Answer: D  
   Diff: 6  Page Ref: 573
25) Once the chyme begins to enter the duodenum, it must first be _______ before any of the enzymes in the pancreatic juices can be activated.
   A) neutralized
   B) acidified
   C) dehydrated
   D) hydrated
   E) phosphorylated
Answer: A  
Diff: 4   Page Ref: 573

26) What protects the stomach wall from the acidic lumenal contents?
   A) a layer of parietal cells
   B) the gastric mucosal barrier
   C) the presence of rugae
   D) the gastric coat
   E) a layer of adipose tissue lining the gastric mucosa
Answer: B  
Diff: 4   Page Ref: 573

27) To increase the absorptive efficiency of the small intestine, the surface area of the mucosa is increased by the presence of folds in the wall called ________, and projections of the cell membrane called ________.
   A) microvilli : villi
   B) villi : microvilli
   C) lacteals : rugae
   D) rugae : lacteals
   E) microvilli : lacteals
Answer: B  
Diff: 4   Page Ref: 574

28) Which of the following is the correct order of the components of the small intestine, from stomach to colon?
   A) ileum — jejunum — duodenum
   B) jejunum — duodenum — ileum
   C) duodenum — ileum — jejunum
   D) jejunum — ileum — duodenum
   E) duodenum — jejunum — ileum
Answer: E  
Diff: 3   Page Ref: 573

29) A lacteal is a _______ located in ________.
   A) nerve : myenteric plexus
   B) nerve : submucosal plexus
   C) capillary : villus
   D) lymphatic vessel : villus
   E) patch of immune tissue : submucosa
Answer: D  
Diff: 3   Page Ref: 574
30) What is the brush border?
   A) microvilli from parietal cells
   B) microvilli from epithelial cells lining the small intestine
   C) villi from parietal cells
   D) villi from epithelial cells lining the small intestine
   E) villi from epithelial cells lining the stomach
   Answer: B
   Diff: 3 Page Ref: 574

31) What do the secretory cells in the crypts of Lieberkuhn’s secrete?
   A) gastric juice
   B) intestinal juice
   C) succus entericus
   D) pancreatic juice
   E) bile
   Answer: C
   Diff: 5 Page Ref: 574

32) Blood from the intestinal capillaries drains into what blood vessel before entering the hepatic portal vein?
   A) hepatic artery
   B) mesenteric vein
   C) hepatic vein
   D) coeliac vein
   E) intestinal vein
   Answer: B
   Diff: 5 Page Ref: 574

33) What region of the colon serves primarily as a storage depot for whatever material remains in the lumen after absorption has occurred?
   A) ascending
   B) transverse
   C) descending
   D) sigmoid
   E) resected
   Answer: D
   Diff: 4 Page Ref: 575

34) What is the primary function of the colon?
   A) further digest fats within the chyme
   B) reduce the volume of the chyme
   C) further digest protein within the chyme
   D) further absorb carbohydrates
   E) regulate absorption of carbohydrates and amino acids
   Answer: B
   Diff: 4 Page Ref: 575
35) Which of the following structures is NOT part of the large intestine?
   A) colon
   B) cecum
   C) rectum
   D) anus
   E) vermiform appendix

   Answer: D
   Diff: 4   Page Ref: 575

36) Which of the following sphincters is composed of skeletal muscle?
   A) pyloric sphincter only
   B) upper esophageal sphincter only
   C) external anal sphincter only
   D) both the pyloric and upper esophageal sphincters
   E) both the upper esophageal and external anal sphincters

   Answer: E
   Diff: 5   Page Ref: 575

37) Which of the following is NOT one of the components of saliva?
   A) bicarbonate ions
   B) mucus
   C) lipases
   D) amylases
   E) lysozymes

   Answer: C
   Diff: 5   Page Ref: 577

38) Which of the following is NOT one of the components of exocrine pancreatic secretions?
   A) digase
   B) lipase
   C) amylase
   D) protease
   E) nuclease

   Answer: A
   Diff: 4   Page Ref: 577

39) What enzymes secreted by the exocrine pancreas degrade fats?
   A) Proteases
   B) Digases
   C) Amylases
   D) Lipases
   E) Nuclease

   Answer: D
   Diff: 4   Page Ref: 577
40) Which of the following secretes a bicarbonate-rich fluid?
   A) salivary glands only
   B) pancreas only
   C) liver only
   D) both salivary glands and pancreas
   E) salivary glands, pancreas, and liver

   Answer: E
   Diff: 4    Page Ref: 577

41) Which of the following secretes lipase?
   A) salivary glands
   B) pancreas
   C) liver
   D) both salivary glands and pancreas
   E) pancreas and liver

   Answer: B
   Diff: 6    Page Ref: 577

42) Which of the following is NOT one of the functions of the liver?
   A) secretion of bile
   B) synthesis of albumin
   C) removal of aged erythrocytes
   D) secretion of enzymes for digestion
   E) synthesis and modification of hormones

   Answer: D
   Diff: 4    Page Ref: 577

43) What degradation by-product of hemoglobin is removed from the liver (and thereby the body) in bile?
   A) lipoproteins
   B) bilirubin
   C) iron
   D) urea
   E) uric acid

   Answer: B
   Diff: 5    Page Ref: 577

44) In order to convert amino acids to fatty acids and/or gluconeogenic precursors, an ammonium ion must be removed in the liver and converted to ________ before being excreted by the kidneys.
   A) urea
   B) uric acid
   C) bilirubin
   D) ammonia
   E) nitrogen

   Answer: A
   Diff: 4    Page Ref: 577
45) Which of the following is NOT one of the wastes that is eliminated by the liver in bile?
   A) bilirubin
   B) trace metals
   C) urea
   D) certain drugs
   E) cholesterol

   Answer: C
   Diff: 5  Page Ref: 577

46) Which of the following is NOT one of the hormone-related functions of the liver?
   A) secrete hormone binding proteins
   B) hormone degradation
   C) hormone modification
   D) hormone synthesis
   E) hormone storage

   Answer: E
   Diff: 5  Page Ref: 578

47) The flow of bile from the liver and juices from the exocrine pancreas converge at what structure?
   A) bile duct
   B) common bile duct
   C) ampulla of Vater
   D) common hepatic duct
   E) gallbladder

   Answer: C
   Diff: 5  Page Ref: 578

48) One side of a hepatocyte faces the blood while the other faces what?
   A) sinusoid
   B) bile canaliculus
   C) enterocyte
   D) acinar cells
   E) common hepatic duct

   Answer: B
   Diff: 4  Page Ref: 580

49) What is the functional unit of the liver?
   A) lobule
   B) hepatocyte
   C) bile canaliculi
   D) sinusoid
   E) lobe

   Answer: A
   Diff: 5  Page Ref: 580
50) What are liver sinusoids?
    A) the site of bile synthesis
    B) the pathway for bile to exit the liver
    C) blood-filled cavities that exchange material with the hepatocytes
    D) bile-filled cavities that exchange material with the hepatocytes
    E) air-filled cavities in the liver

Answer: C

Diff: 5  Page Ref: 580

51) What are Kupffer cells?
    A) macrophages in the liver
    B) hepatocytes
    C) cells of the stomach that secrete hydrogen ions
    D) cells lining the Crypts of Lieberkuhns
    E) cells lining the pancreatic duct

Answer: A

Diff: 4  Page Ref: 580

52) The enzyme amylase is able to cleave glycogen and starch into ________.
    A) disaccharides only
    B) monosaccharides only
    C) limit dextrins only
    D) both disaccharides and limit dextrins
    E) both monosaccharides and disaccharides

Answer: D

Diff: 4  Page Ref: 581

53) Which of the following is NOT an enzyme that acts on the products of amylase digestion of glycogen and starch?
    A) glucoamylase
    B) sucrase
    C) maltase
    D) galactase
    E) dextinase

Answer: D

Diff: 5  Page Ref: 581

54) The absorption of glucose involves ________ across the apical membrane and ________ across the basolateral membrane.
    A) facilitated diffusion: facilitated diffusion
    B) simple diffusion : facilitated diffusion
    C) secondary active transport : facilitated diffusion
    D) secondary active transport : secondary active transport
    E) secondary active transport : primary active transport

Answer: C

Diff: 5  Page Ref: 582
55) Where are enzymes that breakdown disaccharides located?
   A) in the lumen of the small intestine
   B) on the apical membrane of enterocytes
   C) inside enterocytes
   D) on the basolateral membrane of enterocytes
   E) in the lumen of the large intestine
   Answer: B
   Diff: 4 Page Ref: 581

56) The absorption of fructose across the apical membrane of the lumenal epithelial cells occurs through what process?
   A) facilitated diffusion
   B) diffusion
   C) sodium–linked secondary active transport
   D) primary active transport
   E) paracellular transport
   Answer: A
   Diff: 5 Page Ref: 582

57) The digestion of proteins begins in the _______ with the activation of the zymogen _______.
   A) small intestine : trypsinogen
   B) stomach : pepsinogen
   C) mouth : pepsinogen
   D) small intestine : chymotrypsinogen
   E) stomach : procarboxypeptidase
   Answer: B
   Diff: 4 Page Ref: 582

58) What enzyme is responsible for cleavage of the amino acid at the amine portion of the peptide fragment?
   A) carboxypeptidase
   B) trypsin
   C) chymotrypsin
   D) enterokinase
   E) aminopeptidase
   Answer: E
   Diff: 4 Page Ref: 582

59) What enzyme activates procarboxypeptidase?
   A) carboxypeptidase
   B) trypsin
   C) pepsin
   D) enterokinase
   E) aminopeptidase
   Answer: B
   Diff: 4 Page Ref: 582
60) Proteolytic enzymes secreted in pancreatic juice are stored in secretory cells of the pancreas as _______.
   A) pepsinogen
   B) limit dextrins
   C) zymogens
   D) bile salts
   E) chylomicrons
   Answer: C
   Diff: 3   Page Ref: 582

61) What enzyme cleaves trypsinogen to trypsin?
   A) chymotrypsin
   B) pepsin
   C) enterokinase
   D) procarboxypeptidase
   E) amylase
   Answer: C
   Diff: 5   Page Ref: 582

62) Many individual amino acids enter the epithelial cells that line the lumen of the digestive tract via what transport process?
   A) paracellular transport
   B) simple diffusion
   C) primary active transport
   D) sodium-linked secondary active transport
   E) facilitated diffusion
   Answer: D
   Diff: 4   Page Ref: 582

63) In order to begin the process of fat digestion, the fat globules must be _______.
   A) emulsified by lipases
   B) emulsified by trypsin
   C) emulsified by bile salts
   D) coalesced by bile salts
   E) coalesced by lipase
   Answer: C
   Diff: 4   Page Ref: 584

64) Emulsification aids in the digestion of fats by _______.
   A) increasing the surface area of the fat globule exposed to enzymes
   B) beginning the process of degrading the triglycerides within the fat globule
   C) increasing the number of fat globules
   D) the ability of bile salts to activate lipases that digest fats
   E) increasing the number of hydrophobic residues on the surface of the fat globule
   Answer: A
   Diff: 5   Page Ref: 584
65) Pancreatic lipase degrades triglycerides into _______.
   A) a monoglyceride and 1 free fatty acid
   B) a triglyceride whose free fatty acids have been shortened 2 carbons at a time
   C) a glycerol and 3 free fatty acids
   D) a diglyceride and 1 free fatty acid
   E) a monoglyceride and 2 free fatty acids

Answer: E

Diff: 4 Page Ref: 584

66) Digestion products of lipases are readily exchanged in the lumen with _______.
   A) cholesterol
   B) polysaccharides
   C) chylomicrons
   D) micelles
   E) low-density lipoproteins

Answer: D

Diff: 4 Page Ref: 584

67) Bile salts are recycled by the _______.
   A) mesenteric arteries
   B) hepatic arteries
   C) enterohepatic circulation
   D) biliary circulation
   E) common bile duct

Answer: C

Diff: 4 Page Ref: 585

68) The products of fat degradation are absorbed in the small intestines by what transport process?
   A) sodium–linked secondary active transport
   B) simple diffusion
   C) primary active transport
   D) facilitated diffusion
   E) paracellular transport

Answer: B

Diff: 5 Page Ref: 585

69) Once the degradation products of triglycerides have entered the epithelial cells that line the small intestines, they _______.
   A) cross the basolateral membrane and enter the circulation where they will be embedded into a chylomicron
   B) are reassembled into triglycerides and released into the blood where they can be incorporated into chylomicrons
   C) are reassembled into triglycerides and packaged by the Golgi apparatus into micelles
   D) are reassembled into triglycerides and packaged by the Golgi apparatus into chylomicrons
   E) are further degraded to glycerol and a free fatty acid, which are packaged by the Golgi apparatus into chylomicrons

Answer: D

Diff: 5 Page Ref: 585
70) Lipids are absorbed as _______ into _______.
   A) fatty acids and monoglycerides: mesenteric capillaries
   B) micelles: mesenteric capillaries
   C) chylomicrons: mesenteric capillaries
   D) chylomicrons: lacteals
   E) micelles: lacteals
   Answer: D
   Diff: 5 Page Ref: 585

71) Vitamin B₁₂ is absorbed in the ______ through ______.
   A) jejunum: complexing with intrinsic factor
   B) duodenum: facilitated diffusion
   C) ileum: complexing with intrinsic factor
   D) duodenum: cotransport with sodium
   E) jejunum: facilitated diffusion
   Answer: C
   Diff: 5 Page Ref: 585

72) A lack of intrinsic factor can result in _______.
   A) pernicious anemia
   B) aplastic anemia
   C) diarrhea
   D) diabetes
   E) immune suppression
   Answer: A
   Diff: 6 Page Ref: 585

73) The absorption of sodium throughout the small intestine is driven by _______ transport and is typically linked to the absorption of _______.
   A) active: chloride
   B) passive: bicarbonate
   C) active: bicarbonate
   D) active: glucose
   E) passive: glucose
   Answer: A
   Diff: 5 Page Ref: 587

74) In the jejunum, bicarbonate is ______, while in the ileum and colon, bicarbonate is ______.
   A) absorbed: absorbed
   B) absorbed: secreted
   C) secreted: secreted
   D) secreted: absorbed
   E) absorbed: not transported in either direction
   Answer: B
   Diff: 5 Page Ref: 587
75) Carbonic anhydrase is located in which of the following structures?
   A) salivary glands only
   B) parietal cells only
   C) lumen of the small intestine only
   D) both salivary glands and parietal cells
   E) both parietal cells and lumen of the small intestine

   Answer: E  
   Diff: 7  Page Ref: 587

76) Which of the following substances does NOT require the interaction with a protein in the intestinal tract to be absorbed?
   A) fat-soluble vitamins
   B) vitamin B12
   C) calcium
   D) iron
   E) sodium

   Answer: A  
   Diff: 6  Page Ref: 585

77) The central component of the long reflex pathway typically involves the _______ nervous system, which acts to promote an increase in gastrointestinal activity.
   A) parasympathetic
   B) sympathetic
   C) somatic
   D) enteric
   E) intrinsic

   Answer: A  
   Diff: 3  Page Ref: 590

78) Gastric-phase control of gastrointestinal function refers to its site of origin, which is what?
   A) the pancreas
   B) the central nervous system
   C) the stomach
   D) the intestines
   E) the colon

   Answer: C  
   Diff: 3  Page Ref: 591

79) Which of the following is NOT one of the hormones released by the gastrointestinal tract that regulates its function?
   A) gastrin
   B) cholecystokinin
   C) secretin
   D) glucose inhibitory peptide
   E) glucose-dependent insulino tropic peptide

   Answer: D  
   Diff: 4  Page Ref: 590
80) Which of the following is an enterogastrone?
   A) gastrin
   B) cholecystokinin
   C) epinephrine
   D) monoglyceride
   E) bile
   Answer: B
   Diff: 4    Page Ref: 590

81) What does the secretion of leptin cause?
   A) increased motility of the gastrointestinal tract
   B) increased pancreatic secretion into the gastrointestinal tract
   C) decreased gastric secretion into the gastrointestinal tract
   D) increased bile secretion
   E) decreased sensation of hunger
   Answer: E
   Diff: 4    Page Ref: 592

82) What causes leptin secretion to increase?
   A) increased gluconeogenesis in liver cells
   B) increased glycogenolysis in skeletal muscle cells
   C) increased storage of calories in adipose cells
   D) decreased synthesis of triglycerides in adipose cells
   E) decreased synthesis of glycogen in liver cells
   Answer: C
   Diff: 4    Page Ref: 592

83) Obesity predisposes a person for development of all of the following diseases EXCEPT
   ________.
   A) diabetes mellitus type 1
   B) atherosclerosis
   C) heart disease
   D) liver disease
   E) hypertension
   Answer: A
   Diff: 4    Page Ref: 591

84) A person is considered obese if their body fat composition is what percentage above normal?
   A) 10
   B) 20
   C) 30
   D) 40
   E) 50
   Answer: B
   Diff: 4    Page Ref: 591
85) What cell type secretes resistin?
   A) adipocytes only  
   B) hepatocytes only  
   C) G cells only  
   D) macrophages only  
   E) adipocytes and macrophages  
   Answer: E  
   Diff: 4  Page Ref: 592  

86) The increase in absorbed nutrients in blood will cause secretion of what hormone to increase, thereby decreasing the sensation of hunger?
   A) gastrin  
   B) insulin  
   C) cholecystokinin  
   D) secretin  
   E) glucagon  
   Answer: B  
   Diff: 5  Page Ref: 592  

87) The presence of food in the duodenum will cause secretion of what hormone to increase, thereby decreasing the sensation of hunger?
   A) gastrin  
   B) insulin  
   C) cholecystokinin  
   D) secretin  
   E) glucagon  
   Answer: C  
   Diff: 5  Page Ref: 592  

88) _______ ions are produced within the parietal cells and transported across the apical membrane via an active transporter while, at the same time, _______ moves across the apical membrane through ion channels.
   A) Hydrogen : sodium  
   B) Bicarbonate : chloride  
   C) Bicarbonate : hydrogen  
   D) Hydrogen : chloride  
   E) Hydrogen : bicarbonate  
   Answer: D  
   Diff: 5  Page Ref: 592  

89) Which of the following is a gastric-phase stimulus for acid secretion?
   A) distension of the stomach and the act of swallowing  
   B) chewing and the act of swallowing  
   C) distension of the stomach and the presence of protein digestion products in the lumen of the stomach  
   D) chewing, swallowing, and the presence of protein digestion products in the lumen of the stomach  
   E) the presence of fat and protein digestion products in the lumen of the stomach  
   Answer: C  
   Diff: 6  Page Ref: 594
90) Which of the following is NOT responsible for the decrease in parietal and chief cell secretion that occurs as food enters the small intestines?
   A) decreased stomach pH
   B) decreased distension of the stomach
   C) lower concentration of digestive components
   D) increased osmolarity of duodenal components
   E) decreased fats and acids in the duodenum
Answer: E
Diff: 5  Page Ref: 594

91) In response to the presence of food within the duodenum, the increased release of what hormone will primarily stimulate an increase in enzyme secretion from the exocrine pancreas?
   A) insulin
   B) gastrin
   C) cholecystokinin
   D) secretin
   E) glucose-dependent insulinotropic peptide
Answer: C
Diff: 4  Page Ref: 594

92) In response to the presence of food within the duodenum, the increased release of what hormone will primarily stimulate an increase in bicarbonate secretion from the exocrine pancreas?
   A) insulin
   B) gastrin
   C) cholecystokinin
   D) secretin
   E) glucose-dependent insulinotropic peptide
Answer: D
Diff: 4  Page Ref: 594

93) The secretion of cholecystokinin is primarily regulated by which of the following?
   A) carbohydrate digestion products
   B) protein digestion products and fat presence in the duodenum
   C) distention of the duodenum
   D) acid and amino acid content of the chyme
   E) opening of the pyloric sphincter
Answer: B
Diff: 5  Page Ref: 595

94) The secretion of secretin is primarily regulated by which of the following?
   A) carbohydrate digestion products
   B) protein digestion products and fat
   C) distention of the duodenum
   D) acid content of the duodenum
   E) opening of the pyloric sphincter
Answer: D
Diff: 5  Page Ref: 594
95) Which of the following are mechanisms by which cholecystokinin (CCK) facilitates digestion of fats?
   A) stimulation of lipase and bile secretion
   B) stimulation of gallbladder contraction and relaxation of the sphincter of Oddi
   C) stimulation of lipase secretion and gallbladder contraction
   D) stimulation of bile secretion and liver contraction
   E) stimulation of bile secretion and contraction of the sphincter of Oddi

Answer: B
Diff: 6 Page Ref: 594

96) What is the main hormone that stimulates bile secretion?
   A) cholecystokinin
   B) insulin
   C) secretin
   D) glucagon
   E) gastrin

Answer: C
Diff: 4 Page Ref: 595

97) In the intestine, smooth muscle cell contraction ________.
   A) is graded by the extent of depolarization for slow waves until an action potential is generated
   B) is graded by the extent of depolarization for slow waves whether an action potential is generated or not
   C) requires an action potential and is therefore graded by frequency of action potentials
   D) requires an action potential but is graded by slow wave height
   E) is stimulated by motor neurons

Answer: C
Diff: 5 Page Ref: 596

98) What causes peristalsis?
   A) contraction of the circular muscle layer and relaxation of the longitudinal muscle at the same segment
   B) relaxation of the circular muscle layer and contraction of the longitudinal muscle at the same segment
   C) contraction of circular muscle layer and relaxation of the longitudinal muscle in the proximal segment coupled to the contraction of longitudinal muscle and relaxation of the circular muscle in the distal segment
   D) relaxation of circular muscle layer and contraction of the longitudinal muscle in the proximal segment coupled to the relaxation of longitudinal muscle and contraction of the circular muscle in the distal segment
   E) contraction of both the circular muscle layer and longitudinal muscle in the proximal segment coupled to the relaxation of both the circular muscle layer and longitudinal muscle in the distal segment

Answer: C
Diff: 6 Page Ref: 597
99) What causes segmentation?
   A) contraction of the circular muscle at one intestinal segment coupled with its relaxation at adjoining segments
   B) contraction of longitudinal muscle at one intestinal segment coupled with its relaxation at adjoining segments
   C) contraction of the circular muscle at one intestinal segment coupled with contraction of the longitudinal muscle at adjoining segments
   D) contraction of both the circular and longitudinal layers of muscle at one segment coupled with the relaxation of both at adjoining segments
   E) relaxation of circular muscle layer and contraction of the longitudinal muscle at one segment coupled to the relaxation of longitudinal muscle and contraction of the circular muscle in the adjoining segments

   Answer: A
   Diff: 6 Page Ref: 597

100) What does propelling food to the back of the mouth with the tongue initiate?
   A) swallowing reflex
   B) chewing reflex
   C) bolus formation
   D) peristalsis
   E) receptive relaxation

   Answer: A
   Diff: 2 Page Ref: 597

101) What does entry of the bolus into the esophagus initiate by stimulating stretch receptors?
   A) the swallowing reflex
   B) the chewing reflex
   C) bolus formation
   D) peristalsis
   E) receptive relaxation

   Answer: D
   Diff: 4 Page Ref: 597

102) What is the decrease in rugae folding within the stomach in advance of the arrival of a bolus of food called?
   A) esophageal reflex relaxation
   B) gastric expansion
   C) receptive relaxation
   D) peristaltic relaxation
   E) gastric unfolding

   Answer: C
   Diff: 4 Page Ref: 598
103) The peristaltic waves of the stomach will result in _______ if the pyloric sphincter is closed.
   A) an inhibition of further waves
   B) stimulation of hormone secretion from the duodenum
   C) the formation of a bolus
   D) some of the chyme being forced into the duodenum even
   E) the mixing of the chyme

   Answer: E
   Diff: 4 Page Ref: 598

104) Which of the following describes events of the migrating motility complex in the stomach?
   A) mild fundic contractions accompanied by pyloric relaxation
   B) intense antral contractions accompanied by pyloric contraction
   C) intense antral contractions accompanied by pyloric relaxation
   D) mild antral contractions accompanied by pyloric relaxation
   E) intense fundic contractions accompanied by pyloric contraction

   Answer: C
   Diff: 4 Page Ref: 598

105) Where does peristalsis occur?
   A) esophagus only
   B) stomach only
   C) small intestine only
   D) both stomach and small intestine
   E) esophagus, stomach, and small intestine

   Answer: E
   Diff: 5 Page Ref: 597

106) Which of the following increases gastric motility?
   A) distension of the stomach
   B) cholecystokinin and secretin
   C) increased osmolarity of duodenal contents
   D) distension of the intestines
   E) increased fat content in the lumen of the duodenum

   Answer: A
   Diff: 5 Page Ref: 599

107) What is the function of segmentation in the small intestines?
   A) the opening of the pyloric valve
   B) releasing bile from the gall bladder
   C) releasing pancreatic juices
   D) propelling the chyme
   E) mixing the chyme

   Answer: E
   Diff: 4 Page Ref: 599
108) What reflex protects the small intestine by inhibiting contractions while the intestines are injured or severely distended?
   A) intestino-intestinal reflex
   B) ileogastric reflex
   C) gastroileal reflex
   D) colonocolonic reflex
   E) gastrocolic reflex
Answer: A
Diff: 4   Page Ref: 599

109) What reflex stimulates the motility of the ileum in response to the presence of chyme in the stomach?
   A) intestino-intestinal reflex
   B) ileogastric reflex
   C) gastroileal reflex
   D) colonocolonic reflex
   E) gastrocolic reflex
Answer: C
Diff: 4   Page Ref: 599

110) What stimulates the defecation reflex?
   A) increase in osmolarity of the rectum
   B) peristaltic contraction of the sigmoid colon
   C) pressure on the internal anal sphincter
   D) distention of the rectum
   E) distention of the descending colon
Answer: D
Diff: 4   Page Ref: 600

111) What is a mass movement?
   A) a segmentation-like wave in the large intestine that causes the elimination of contents as feces
   B) a peristaltic-like wave in the large intestine that causes the elimination of contents as feces
   C) a segmentation-like wave in the large intestine that mixes the contents
   D) a peristaltic-like wave in the large intestine that propels the contents toward the rectum
   E) another name for defecation
Answer: D
Diff: 4   Page Ref: 599

True/False Questions

1) Digestion refers to the process that breaks down larger molecules into smaller molecules within the lumen of the digestive tract.
   Answer: TRUE
   Diff: 3   Page Ref: 570

2) Enterocytes are located in the mucosa.
   Answer: TRUE
   Diff: 3   Page Ref: 572
3) The goblet cells secrete a sticky, viscous fluid containing the glycoprotein mucin.
   Answer: TRUE
   Diff: 3   Page Ref: 573

4) The motility of the gastrointestinal tract is controlled primarily by the muscularis mucosae.
   Answer: FALSE
   Diff: 3   Page Ref: 573

5) The enteric nervous system is located entirely in the gastrointestinal tract.
   Answer: TRUE
   Diff: 3   Page Ref: 573

6) Peyer’s patches contain neurons of the enteric nervous system.
   Answer: FALSE
   Diff: 4   Page Ref: 573

7) The muscle layers for segmentation and peristalsis are located in the muscularis mucosae.
   Answer: FALSE
   Diff: 5   Page Ref: 596

8) All the sphincters of the gastrointestinal tract consist of smooth muscle.
   Answer: FALSE
   Diff: 4   Page Ref: 575

9) The fundus plays an important role in the process of gastric emptying by forcing the chyme into the small intestine.
   Answer: FALSE
   Diff: 3   Page Ref: 575

10) In the colon, the longitudinal muscle layer is not continuous but, rather, is compressed into three narrow bands called teniae coli.
    Answer: TRUE
    Diff: 4   Page Ref: 577

11) Most absorbed molecules are transported by blood to the liver prior to entering the general circulation.
    Answer: TRUE
    Diff: 3   Page Ref: 577

12) Movement of chyme between the small and large intestine is regulated by the pyloric sphincter.
    Answer: FALSE
    Diff: 3   Page Ref: 577

13) Relative to its weight, the salivary glands secrete more protein than any other gland in the body.
    Answer: FALSE
    Diff: 4   Page Ref: 579
14) Between meals, the bile secreted by the liver is stored in the gallbladder.
   Answer: TRUE
   Diff: 3   Page Ref: 580

15) The sphincter of Oddi regulates the flow of both bile and pancreatic juice into the duodenum.
   Answer: TRUE
   Diff: 4   Page Ref: 580

16) Liver sinusoids contain bile.
   Answer: FALSE
   Diff: 4   Page Ref: 581

17) Kupffer cells produce bile.
   Answer: FALSE
   Diff: 4   Page Ref: 573

18) Chemical digestion of carbohydrates begins within the stomach.
   Answer: FALSE
   Diff: 4   Page Ref: 582

19) Pepsin degrades protein by breaking bonds between specific amino acids, which means that it is not capable of completely degrading a protein.
   Answer: TRUE
   Diff: 3   Page Ref: 584

20) Upon leaving the enterocytes as chylomicrons, fats enter capillaries in intestinal villi.
   Answer: FALSE
   Diff: 4   Page Ref: 588

21) Carbohydrates are absorbed as disaccharides.
   Answer: FALSE
   Diff: 3   Page Ref: 583

22) A genetic deficiency in the protein trypsinogen could result in decreased proteolytic activation of chymotrypsin.
   Answer: TRUE
   Diff: 4   Page Ref: 584

23) Bile salts are hydrophobic molecules, allowing them to break down lipids in a micelle.
   Answer: FALSE
   Diff: 4   Page Ref: 586

24) Colipase is required for the action of pancreatic lipase.
   Answer: TRUE
   Diff: 4   Page Ref: 586

25) Vitamin E is packaged into chylomicrons when absorbed.
   Answer: TRUE
   Diff: 5   Page Ref: 588
26) Calcium absorption is regulated by hormones.
   Answer: TRUE
   Diff: 4      Page Ref: 590

27) Iron can be stored in enterocytes as transferrin.
   Answer: FALSE
   Diff: 5      Page Ref: 590

28) Adipocytes secrete resistin.
   Answer: TRUE
   Diff: 5      Page Ref: 592

29) Obesity is the primary cause of insulin resistance.
   Answer: TRUE
   Diff: 3      Page Ref: 591

30) The extensive volume of water that is absorbed within the digestive tract is driven passively by the osmotic gradient.
   Answer: TRUE
   Diff: 3      Page Ref: 590

31) The rate of stomach acid secretion is regulated by the level of acidity within the duodenum.
   Answer: TRUE
   Diff: 4      Page Ref: 594

32) The secretion of pepsinogen and hydrogen ions are inversely related; as acid secretion increases, pepsinogen decreases.
   Answer: FALSE
   Diff: 3      Page Ref: 592

33) An increase in osmolarity of the duodenum will decrease acid secretion in the stomach.
   Answer: TRUE
   Diff: 3      Page Ref: 594

34) Acid secretion in the stomach requires the presence of carbonic anhydrase in chief cells.
   Answer: FALSE
   Diff: 5      Page Ref: 592

35) Secretin potentiates the effects of CCK, and CCK potentiates the effects of secretin.
   Answer: TRUE
   Diff: 4      Page Ref: 594

36) The rate of the basic electrical rhythm is dependent on input from the autonomic nervous system.
   Answer: FALSE
   Diff: 4      Page Ref: 596

37) Segmentation involves coordinated contractions of the circular muscle layer only.
   Answer: TRUE
   Diff: 5      Page Ref: 597
38) The swallowing reflex facilitates closure of the glottis by raising the larynx.

Answer: TRUE

Diff: 3 Page Ref: 597

Matching Questions

*Match the area of the gastrointestinal wall with its description.*

1) Innermost layer of the gastrointestinal wall.

A) serosa

Diff: 3 Page Ref: 572

B) submucosa

2) Outermost layer of the gastrointestinal wall.

C) muscularis externa

Diff: 3 Page Ref: 574

D) mucosa

3) Contains the muscularis mucosae.

E) submucosa

Diff: 4 Page Ref: 573

4) Contains enterocytes.

F) muscularis externa

Diff: 4 Page Ref: 572

5) Contains the mucous membrane.

G) serosa

Diff: 3 Page Ref: 572

6) Contains the smooth muscle layers for peristalsis and segmentation.

H) submucosal plexus

Diff: 3 Page Ref: 596

7) Contains the submucosal plexus.

I) myenteric plexus

Diff: 3 Page Ref: 573

8) Contains the myenteric plexus.

J) consists of primarily connective tissue that gives the gastrointestinal tract its distensibility and elasticity.

Diff: 4 Page Ref: 573

9) Consists of primarily connective tissue that gives the gastrointestinal tract its distensibility and elasticity.

Diff: 4 Page Ref: 572

10) Continuous with the mesenteries.

Diff: 4 Page Ref: 574
Test Bank for Principles of Human Physiology

Answers: 1) D   2) A   3) D   4) D   5) D
           6) C   7) B   8) C   9) B   10) A

Match the sphincter with its location and/or muscle type.

11) Smooth muscle between the anus and external environment.
   Diff: 3   Page Ref: 578
   A) internal anal sphincter
   B) external anal sphincter
   C) upper esophageal sphincter

12) Skeletal muscle between the anus and external environment.
   Diff: 3   Page Ref: 578
   D) lower esophageal sphincter
   E) sphincter of Oddi
   F) ileocecal sphincter
   G) pyloric sphincter

13) Smooth muscle between the small and large intestines.
   Diff: 3   Page Ref: 577

14) Smooth muscle between the ampulla of Vater and the duodenum.
   Diff: 4   Page Ref: 580

15) Smooth muscle between the stomach and duodenum.
   Diff: 3   Page Ref: 575

16) Smooth muscle between the esophagus and stomach.
   Diff: 3   Page Ref: 575

17) Skeletal muscle between the pharynx and esophagus.
   Diff: 3   Page Ref: 575

          16) D   17) C

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Match the cell type to its secretory product.

18) Acid into the stomach.
   Diff: 3  Page Ref: 575
   A) parietal cell
   B) chief cell

19) Gastrin into the bloodstream.
   Diff: 3  Page Ref: 575
   C) G cell
   D) neck cell

20) Intrinsic factor.
    Diff: 4  Page Ref: 575

21) Mucus.
   Diff: 3  Page Ref: 575

22) Pepsinogen.
    Diff: 3  Page Ref: 575


Match the organ to the corresponding structure.

23) Rugae.
    Diff: 4  Page Ref: 575
    A) stomach
    B) pancreas

24) Crypts of Lieberkuhn.
    Diff: 5  Page Ref: 577
    C) liver
    D) small intestine

25) Gastric pits.
    Diff: 3  Page Ref: 575

26) Brush border.
    Diff: 4  Page Ref: 576

27) Sinusoids.
    Diff: 4  Page Ref: 581

28) Islets of Langerhans.
    Diff: 3  Page Ref: 579

29) Acini.
    Diff: 3  Page Ref: 579

30) Bile canaliculi.
    Diff: 4  Page Ref: 581

Match the enzyme with its substrate.

31) Polysaccharides.
   Diff: 4   Page Ref: 582
   A) sucrase
   B) glucoamylase
   C) chymotrypsin
   D) amylase
   E) lipase

32) Sucrose.
   Diff: 2   Page Ref: 582

33) Straight-chain glucose polymers.
   Diff: 3   Page Ref: 582

34) Proteins.
   Diff: 4   Page Ref: 584

35) Lipids.
   Diff: 3   Page Ref: 584


Match the hormone with its function.

36) Stimulates gastric secretion and motility.
   Diff: 4   Page Ref: 593
   A) cholecystokinin
   B) glucose-dependent insulinotropic peptide
   C) gastrin
   D) secretin

37) Simulates pancreatic bicarbonate secretion (and enzyme secretion to a lesser extent).
   Diff: 4   Page Ref: 594

38) Stimulates gall bladder contraction.
   Diff: 4   Page Ref: 594

39) Inhibits gastric secretion and motility in response to distension of the duodenum.
   Diff: 5   Page Ref: 594

40) Stimulates relaxation of the sphincter of Oddi.
   Diff: 4   Page Ref: 595

Answers: 36) C 37) D 38) A 39) B 40) A
Essay Questions

1) The function of each region of the digestive tract is dependent upon its structure. Describe the general structures of the digestive tract wall, including the unique cells within the structures that provide specialized functions.

Answer: The wall of the digestive tract is composed of four distinct layers: mucosa, submucosa, muscularis externa, and serosa. The mucosa is composed of an inner mucosal layer, a middle layer called the lamina propria, and the outer muscularis mucosae. The mucosal layer is composed of epithelial cells (enterocytes) that provide exocrine, endocrine, or absorptive functions. The mucosa of the stomach contains a number of exocrine cells (chief cells secrete pepsinogen, parietal cells secrete hydrogen ions and intrinsic factor, and neck cells secrete mucin) and endocrine glands (G cells secrete gastrin). In the small intestine, the apical membranes of the mucosal epithelial cells assume a more folded arrangement (a brush border) that increases the surface area for absorption. The small intestine contains cells within the crypts of Lieberkühn that secrete bicarbonate. The lamina propria is a connective tissue layer that contains small blood vessels, lymph tissue (lacteals for uptake of chylomicrons), and Peyer’s patches that function to defend the body against the bacteria within the intestines. The muscularis mucosae is a thin layer of smooth muscle cells that are oriented longitudinally and circumferentially around the digestive tract. These muscles facilitate the mixing of chyme. The second layer of the wall of the digestive tract is the submucosa, which is a thick layer of connective tissue that provides the digestive tract with its elasticity and distensibility. There are large blood vessels and lymphatic vessels within this layer. At the same time, a portion of the enteric nervous system (submucosal [Meissner’s] plexus) is located within this layer. The muscularis externa is a thicker layer of smooth muscle cells than the muscularis mucosae that function in mixing of the chyme as well as propelling chyme through the digestive tract. The final layer of the digestive tract wall is the serosa, which consists of an inner layer of fibrous connective tissue and an outer layer of epithelial cells called the mesothelium. These epithelial cells secrete a watery fluid that lubricates the organs, allowing them to move past one another. The mesothelium is continuous with the mesenteries, a thin layer of connective tissue that connects abdominal organs and carries blood vessels and nerves.

Diff: 8  Page Ref: 570

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2) The digestive tract is much more than a hollow tube that absorbs nutrients. Accessory glands play an essential role in the process of digestion. Describe the structure of the accessory glands, their functions, and the molecules they secrete.

Answer: Exocrine glands are composed of epithelial cells arranged into acini. These acinar cells secrete fluid into ducts that travel to the digestive tract. The first accessory glands are the three pairs of salivary glands: the parotid glands, sublingual glands, and submandibular glands. Saliva from these glands is composed of bicarbonate, mucus, salivary amylase, and lysozymes. Bicarbonate neutralizes the pH in the mouth, while mucus lubricates food to facilitate its movement. Salivary amylase begins the degradation of glucose polymers, while lysozymes destroy invading bacteria. In the exocrine portion of the pancreas, the acini drain into the pancreatic duct, which enters the duodenum. Pancreatic secretions contain bicarbonate and digestive enzymes that include amylase, lipases, proteases, nucleases, and zymogens. Bicarbonate is essential for enzymatic activity since duodenal chyme is acidic and the pancreatic enzymes require a more neutral condition to be active. Pancreatic amylase continues glucose polymer degradation, while pancreatic lipases degrade triglycerides. Proteases degrade proteins, while nucleases degrade nucleic acids (DNA and RNA). Zymogens are enzymes secreted in an inactive form that include trypsinogen, chymotrypsinogen, and procarboxypeptidase. The final accessory gland, the liver, is unique in its sinusoid arrangement on one side of the hepatocyte and bile canaliculi on the other side of the hepatocyte. The bile canaliculi drains into the bile duct, which ultimately enters the duodenum. The liver provides a diversity of functions that include secretion of bile, processing of metabolic nutrients, removal of aged red blood cells, synthesis of plasma proteins, and secretion and modification of hormones. Bile is a derivative of cholesterol essential for digestion of fats, which are stored in the gallbladder until their release. The liver contains enzymes that convert metabolic substrates like glucose to glycogen, amino acids to fatty acids, fatty acids to ketones, and ammonia to urea. Additionally, the enzymes synthesize triglycerides and fatty acids, and use gluconeogenesis to produce glucose. The removal of red blood cells requires the degradation of hemoglobin and the elimination of the resulting bilirubin. Excess cholesterol, organic compounds, bilirubin, and trace metals are eliminated by adding them to bile where they can exit the body. The liver synthesizes proteins like albumin, binding proteins, clotting proteins, and angiotensinogen. Finally, the liver secretes, modifies, and degrades certain hormones.
3) The primary function of the gastrointestinal tract is digestion and absorption of nutrients. Describe the process of digestion and absorption of carbohydrates, including the enzymes and transporters involved in this process.

Answer: The carbohydrates that enter the mouth are typically complex polymers of glucose (2/3 of dietary carbohydrates) or disaccharides like sucrose (glucose and fructose), lactose (glucose and galactose), and maltose (2 glucose). These glucose polymers can be derived from plants (starch) or from animals (glycogen). The digestion of carbohydrates begins within the mouth with the secretion of salivary amylase, which begins to digest glucose polymers. Those polymers are broken into maltose or limit dextrin (short, branched polysaccharides). However, they must be broken into monosaccharides before being absorbed in the small intestines. Once the chyme reaches the small intestines, pancreatic amylase begins to work again on the glucose polymers. However, there are other enzymes attached to the brush border that include dextrinase, glucoamylase, sucrase, maltase, and lactase that will further degrade the carbohydrates into monosaccharides. Once the carbohydrates are broken down, the constituents glucose and galactose are absorbed via sodium–linked glucose transporters on the apical membrane of the epithelial cells. Fructose enters those cells through facilitated diffusion. Each of the carbohydrates exit the epithelial cells through facilitated diffusion into capillaries to be transported systemically.

Diff: 7 Page Ref: 581

4) The primary function of the gastrointestinal tract is digestion and absorption of nutrients. Describe the process of digestion and absorption of proteins, including the enzymes and transporters involved in this process.

Answer: The average dietary intake of protein is well above that required by the body. In order for proteins to be absorbed, they must be degraded into smaller molecules. This can be either individual amino acids or short peptides (dipeptide or tripeptide). Digestion of proteins begins in the stomach with the activation of pepsin. Pepsinogen is secreted from the chief cells where it is exposed to a hydrogen ion. This exposure partially activates pepsinogen which goes on to act upon other pepsinogen molecules to fully activate them into pepsin. Once activated, pepsin begins to cleave proteins between specific amino acid sequences. This means that pepsin can not completely degrade proteins. Once the chyme has moved to the intestines, proteases from the pancreas and other proteases bound to the brush border begin to act on the proteins. The enzymes from the pancreas are secreted aszymogens like trypsinogen, chymotrypsinogen, and procarboxypeptidase. Thesezymogens are activated by anenterokinase on the brush border that activates trypsin. Once activated, trypsin activates chymotrypsin and carboxypeptidase. Both trypsin and chymotrypsin are similar to pepsin in that they target specific sequences and are therefore unlikely to produce a large amount of individual amino acids. However, the enzymes carboxypeptidase and aminopeptidase (located on the brush border) cleave the amino acid at the carboxy end and the amino acid at the amino terminus, respectively. Individual amino acids can then be absorbed by a sodium–linked secondary active transport across the apical membrane of the small intestine. The dipeptides and tripeptides are actively transported into the cells where they are further degraded into individual amino acids. All of the individual amino acids are transported across the basolateral membrane by facilitated diffusion where they can diffuse into capillaries.

Diff: 7 Page Ref: 583
5) The primary function of the gastrointestinal tract is digestion and absorption of nutrients. Describe the process of digestion and absorption of fats, including the enzymes and transporters involved in this process.

Answer: Digestion of lipids does not begin until the chyme has reached the duodenum (some butter fats are digested in the stomach). The lipids are hydrophobic so they tend to coalesce into a large globule that is indigestible because the lipases that are released from the pancreas are water soluble and therefore only have access to the outer surface of the fat globule. However, bile is an amphipathic molecule with both a hydrophobic and hydrophilic region. Thus, bile is able to emulsify the fat globule, breaking it into many small droplets that increase the total surface of the fat globules, which increases their degradation by lipases. Bile salts are synthesized from cholesterol by hepatocytes and contain both polar and nonpolar groups. Once the number of smaller droplets present begins to increase, pancreatic lipase will have access to more lipids for degradation. Lipases cleave triglycerides into a monoglyceride (on the middle carbon) and two free fatty acids. Once generated, they are released into solution where they are quickly absorbed by epithelial cells of the small intestines. Other lipid byproducts remain in the chyme where they aggregate into small particles called micelles, which readily exchange lipids with the surrounding environment. Bile is reabsorbed by the ileum. The fatty acids and monoglycerides are taken into epithelial cells by simple diffusion. Inside the cell, they enter the smooth endoplasmic reticulum and are reassembled into triglycerides. The lipids are then packaged by the Golgi apparatus into chylomicrons that are released from the basolateral membrane by exocytosis. The chylomicrons enter the lacteal and travel through the lymphatic system until they reach the thoracic duct where they enter the circulation.

Diff: 8  Page Ref: 584

6) Regulation of the gastrointestinal tract involves an interaction between hormones and neural inputs. Describe the role of the four hormones that regulate digestion.

Answer: Gastrin is a hormone that is released by the G cells of the stomach. Secretion of gastrin is stimulated by proteins and protein digestion products in the stomach, distention of the stomach, and parasympathetic input to the stomach. When gastrin is released it stimulates gastric secretion and motility, ileal motility and relaxation of the ileocecal sphincter, and mass movement of the colon. The three remaining hormones are secreted by the duodenum and jejunum. The first is cholecystokinin (CCK). CCK is released in response to the presence of fat or protein digestion products in the duodenum. Once released, the actions of CCK include stimulation of pancreatic bicarbonate secretion (by potentiating the action of the hormone secretin), pancreatic enzyme secretion, bile secretion from the liver, gallbladder contraction, and relaxation of the sphincter of Oddi; at the same time CCK inhibits gastric secretion and motility. The hormone secretin is released in response to acid in the duodenum. Once released, secretin stimulates pancreatic bicarbonate secretion, pancreatic enzyme secretion (by potentiating the effect of CCK), and bile secretion by the liver, while inhibiting gastric secretion and motility. Finally, glucose-dependent insulino tropic peptide (GIP) is released from the small intestines in response to glucose, fats, or acid in the duodenum, as well as distention of the duodenum. Once released, GIP inhibits gastric secretion and motility while stimulating secretion by the pancreas.

Diff: 7  Page Ref: 590
7) Regulation of the gastrointestinal tract involves an interaction between hormones and neural inputs. Describe the role of the nervous system in the regulation of digestion, including the receptors involved. (Do not include motility in this answer.)

Answer: Neural control of digestion involves both the enteric nervous system and the central nervous system. There are several classes of receptors that initiate reflexes located within the digestive tract, including mechanoreceptors, osmoreceptors, and chemoreceptors. Once initiated, a signal can travel from the receptor to the enteric nervous system and back to the effector organ. This type of reflex is a short reflex pathway. When the signal travels to the central nervous system, they are called long reflex pathways. Some reflexes can originate within the central nervous system. These involve changes in emotional state as well as the sight, taste, or smell of food. All of the reflexes that affect the central nervous system are mediated through the autonomic nervous system (parasympathetic activity promotes digestion, whereas sympathetic activity inhibits digestion). Those that originate centrally have been termed the cephalic-phase control of digestive function. When the stimulus originates from receptors within the stomach it is called gastric-phase control, and from the small intestine it is called intestinal-phase control. When food enters the mouth, the texture of the food activates mechanoreceptors that send that information to the salivary center in the medulla to stimulate the autonomic nervous system. Input from chemoreceptors in the tongue (taste) and cerebral cortex (sight and smell) are sent to the salivary center. In addition, chewing and swallowing triggers an increase in parasympathetic activity to the stomach. At the same time, gastric-phase control involves chemoreceptors responding to proteins and protein digestion products in the stomach, and mechanoreceptors that respond to food distending the stomach. Both the cephalic-phase and gastric-phase control listed above increase parasympathetic activity that stimulates parietal cells, chief cells, and G cells. Intestinal-phase control acts to inhibit parasympathetic activity by activating duodenal osmoreceptors (stimulated by digestion products), chemoreceptors (stimulated by fats and acids), and mechanoreceptors (stimulated by distention). In addition to inhibiting the stomach, duodenal chemoreceptors also regulate intestinal function by stimulating the release of the hormones secretin (stimulating bicarbonate release to buffer pH changes) and cholecystokinin (stimulating digestive enzymes).

Diff: 8  Page Ref: 591
8) Discuss the regulation of gastrointestinal motility, including the mechanisms that control the electrical activity of the smooth muscle cell wall. (Do not include the reflexes in this answer.)

Answer: Pacemaker cells in the wall of the gastrointestinal tract generate slow, spontaneous, graded depolarizations called slow waves that travel along the smooth muscle cell layer via gap junctions. Slow wave frequency varies between regions of the digestive system due to differences in pacemaker cells. Slow waves occur at regular intervals that have been termed the basic electrical rhythm (BER). BER amplitude is affected by neural and hormonal influences. Sympathetic activity decreases slow wave amplitude which decreases contractile force; parasympathetic activity increases slow wave amplitude, which increases contractile force. The stomach generates force in a graded fashion that varies by degree of depolarization. The force of the peristaltic waves increases progressively as they move along the antrum, pushing food toward the pylorus. If the pylorus is closed, the chyme will be forced backward (mixing). Pyloric sphincter relaxation allows chyme to enter the duodenum. The rate of emptying is dependent upon the composition and volume of chyme as well as the force of gastric contraction, which can be modified by cholecystokinin (CCK), secretin, and glucose-dependent insulinoergic peptide (GIP). Gastric motility is stimulated by stomach distention and inhibited by duodenal distention and lumenal acidity, osmolality, and fat concentration. During a period of fasting, migrating motility complexes can be initiated that are characterized by a series of intense antral contractions accompanied by relaxation of the pyloric sphincter. In the intestine, no force is generated in the absence of an action potential. The force generated by the intestine is proportional to the frequency of the action potentials. Peristaltic waves move chyme through the small intestines in short distances. These waves are interspersed with longer periods of segmentation where alternating contractions and relaxations occur in neighboring segments (mixing). As in the stomach, fasting initiates the migrating motility complexes. Contractile force of the intestines is influenced by distention (increased force), enteric nervous system activity, and hormones (gastrin increases ileal motility and promotes relaxation of the ileocecal sphincter). In the proximal portion of the colon, haustrations are observed that are similar to segmentation except that segments are delineated by permanent folds in the colon wall and they are slower (2–3 per hour). About 3–4 times a day, a mass movement is initiated, causing a portion of the colon to contract and remain contracted for a longer period of time.

Diff: 8  Page Ref: 596
9) A number of reflexes play an important role in regulating motility through the digestive system. Describe each of the reflexes that are involved in gastrointestinal tract motility.

Answer: The chewing reflex is initiated by the entry of food into the mouth. This increases pressure within the mouth, which causes a relaxation of the jaw muscle, allowing it to drop. The opening of the jaw decreases pressure within the mouth, allowing the jaw to close. Once that food has been chewed and the tongue propels the bolus into the pharynx, a mechanoreceptor is activated that initiates the swallowing reflex. The glottis is closed by the bolus of food being pressed against the epiglottis and the contraction of neck muscles. At that time, inspiration is inhibited. Once the upper esophageal sphincter relaxes, the bolus enters the esophagus. This stretches the esophagus, triggering an esophageal peristalsis that propels the bolus toward the stomach. The lower esophageal sphincter must relax to allow the bolus to enter the stomach. If the first peristaltic wave does not push the bolus into the stomach, secondary waves are initiated that continue to move the bolus toward the stomach. At the same time, the stomach goes through a receptive relaxation, which increases its volume. Another reflex is the vomiting reflex. This reflex is controlled by a medullary vomiting center. Nausea, pallid appearance, and an increase in heart rate and sweating often occur before vomiting, then a series of inspirations are followed by closure of the glottis. Abdominal muscles begin to contract strongly, causing the abdominal wall to move inward as the inspiratory movements drop the diaphragm. These contractions elevate abdominal pressure, which squeezes the stomach and raises its pressure. Once the lower esophageal sphincter opens, the stomach contents enter the esophagus. Further strong contractions will push the stomach contents through the upper esophageal sphincter and eject them through the mouth. The intestino-intestinal reflex inhibits the contraction of the small intestine when it has been severely distended. The ileogastric reflex responds to a distention of the ileum by inhibiting gastric motility. The gastroileal reflex responds to the presence of chyme in the stomach by increasing motility of the ileum. The colonocolonic reflex responds to distention in one region of the colon by relaxing the other regions. The gastrocolic reflex responds to food in the stomach by increasing colonic motility and frequency of mass movement. The defecation reflex is triggered by distention of the rectum. This stimulates contraction of rectal smooth muscle cells. At the same time, peristaltic contractions are initiated in the sigmoid colon. Ultimately, the internal anal sphincter relaxes while the external sphincter contracts. This muscle can be relaxed voluntarily.

Diff: 8 Page Ref: 596

Short Answer Questions

1) Which structures of the gastrointestinal tract have a wall structure that differs from most of the tract?
Answer: mouth, pharynx, upper third of esophagus, external-most portion of anus
Diff: 5 Page Ref: 570

2) What are the three layers of the mucosa, from innermost to outermost?
Answer: mucous membrane — lamina propria — muscularis mucosae
Diff: 4 Page Ref: 572

3) Where are Peyer’s patches?
Answer: lamina propria of the mucosa
Diff: 5 Page Ref: 573
4) The _______ is the portion of the enteric nervous system located within the muscularis mucosa.
   Answer: myenteric (Auerbach's) plexus  
   Diff: 4  Page Ref: 573

5) The G cells that line the lumen of the stomach are responsible for the secretion of _______.
   Answer: gastrin  
   Diff: 4  Page Ref: 575

6) The stomach's lining is protected from the acidic contents of the lumen by a layer of mucus and bicarbonate called _______.
   Answer: gastric mucosal barrier  
   Diff: 4  Page Ref: 575

7) What are the two sources of bicarbonate secreted into the lumen of the small intestine?
   Answer: exocrine pancreas and secretory cells in the crypts of Lieberkuhn  
   Diff: 5  Page Ref: 575

8) Microvilli of epithelial cells in the small intestine make up the _______.
   Answer: brush border  
   Diff: 5  Page Ref: 576

9) What blood vessel supplies the liver with oxygenated blood?
   Answer: hepatic artery  
   Diff: 4  Page Ref: 577

10) What segments of the colon are specialized for absorbing water and ions?
    Answer: ascending colon, transverse colon, and descending colon  
    Diff: 5  Page Ref: 577

11) _______ is the process whereby fecal material is removed from the body.
    Answer: Defecation  
    Diff: 3  Page Ref: 578

12) The endocrine portion of the pancreas is composed of _______.
    Answer: islets of Langerhans  
    Diff: 4  Page Ref: 579

13) Name the three pairs of salivary glands.
    Answer: parotid, sublingual, and mandibular glands  
    Diff: 4  Page Ref: 578

14) On one side of hepatocytes, blood is contained in _______.
    Answer: sinusoids  
    Diff: 5  Page Ref: 581

15) Bile is synthesized in the (liver / gallbladder / both) and stored in the (liver / gallbladder / both).
    Answer: liver : gallbladder  
    Diff: 4  Page Ref: 580

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16) Branches of what three vessels are found at the corners of the liver lobule?
   Answer: hepatic duct, hepatic portal vein, hepatic artery
   Diff: 5  Page Ref: 580

17) What are macrophages in the liver called?
   Answer: Kupffer cells
   Diff: 4  Page Ref: 580

18) Where are the enzymes responsible for degrading disaccharides and limit dextrins located?
   Answer: the apical membrane of lumen epithelial cells (or the brush border)
   Diff: 4  Page Ref: 582

19) What is a glucose polymer found in plant products that cannot be degraded within the digestive tract of humans?
   Answer: Cellulose
   Diff: 5  Page Ref: 581

20) What is the process whereby bile salts breakdown fat globules into smaller droplets called?
    Answer: emulsification
    Diff: 4  Page Ref: 586

21) Monoglycerides and free fatty acids that are not immediately transported into lumenal enterocytes aggregate into _______ in the lumen of the small intestines.
    Answer: micelles
    Diff: 5  Page Ref: 586

22) For calcium to be absorbed, it must bind to a brush border protein called _______, the levels of which are regulated by hormones.
    Answer: calcium-binding protein
    Diff: 5  Page Ref: 590

23) Enterocytes secrete what protein into the lumen of the small intestine to facilitate the absorption of iron?
    Answer: transferrin
    Diff: 5  Page Ref: 590

24) Macrophages secrete what substance that contributes to insulin resistance?
    Answer: resistin
    Diff: 5  Page Ref: 592

25) Stimulation of chemoreceptors and mechanoreceptors by the presence of food in the lumen of the digestive tract (enhances / suppresses) hunger.
    Answer: suppresses
    Diff: 4  Page Ref: 592

26) The act of chewing and swallowing increases (parasympathetic activity / sympathetic activity), which stimulates parietal and chief cell secretion.
    Answer: parasympathetic nervous activity
    Diff: 5  Page Ref: 592
27) What are the spontaneous graded potentials that occur in smooth muscle cells of the digestive tract called?
   Answer: Slow waves
   Diff: 4   Page Ref: 596

28) In the (stomach / small intestine), smooth muscles generate force in a graded fashion that varies with the degree of depolarization of the muscle cells.
   Answer: stomach
   Diff: 5   Page Ref: 596

29) What are two functions of gastric motility?
   Answer: mix the chyme and regulate gastric emptying
   Diff: 4   Page Ref: 597

30) Name three factors that affect the rate of gastric emptying.
   Answer: composition of the chyme, volume of the chyme in the stomach, and force of gastric contraction
   Diff: 6   Page Ref: 598

31) Intense contractions of the antrum accompanied by relaxation of the pyloric sphincter that function to sweep the stomach clean of its contents are called the ________.
   Answer: migrating motility complex
   Diff: 5   Page Ref: 598

32) The defecation reflex is initiated by distention of the (sigmoid colon / rectum).
   Answer: rectum
   Diff: 4   Page Ref: 600
33) In the figure below, identify the labeled structures.

A. _____________________________________________
B. _____________________________________________
C. _____________________________________________
D. _____________________________________________
E. _____________________________________________

Answer: A. mesentery
B. mucous membrane
C. submucosa
D. circular muscle
E. longitudinal muscle

Diff: 5 Page Ref: 573
34) In the figure below, identify the labeled structures.

A. _____________________________________________
B. _____________________________________________
C. _____________________________________________
D. _____________________________________________
E. _____________________________________________
F. _____________________________________________

Answer: A. hepatic duct
        B. common hepatic duct
        C. gallbladder
        D. common bile duct
        E. ampulla of Vater
        F. pancreatic duct

Diff: 5  Page Ref: 580
Chapter 21  The Endocrine System: Regulation of Energy Metabolism and Growth

Multiple Choice Questions

1) What organ requires a steady supply of glucose, which is why blood glucose concentration must be maintained between meals.
   A) skeletal muscles
   B) brain
   C) heart
   D) liver
   E) kidneys
Answer: B
*Diff: 3  Page Ref: 604*

2) Which of the following best describes acetyl CoA?
   A) Acetyl CoA is produced from catabolism of carbohydrates, lipids, and proteins, and it directly provides electrons to the electron transport chain.
   B) Acetyl CoA is a breakdown product of lipid catabolism and a substrate for carbohydrate synthesis.
   C) Acetyl CoA provides electrons to the electron transport chain and is a substrate for fatty acid synthesis.
   D) Acetyl CoA is produced from catabolism of carbohydrates, lipids, and proteins, and it is a substrate for the Krebs cycle and for lipid synthesis.
   E) Acetyl CoA is a breakdown product of lipid catabolism and is produced in the cytosol by glycolysis.
Answer: D
*Diff: 6  Page Ref: 604*

3) Which of the following best illustrates the form in which carbohydrates, proteins, and lipids, respectively, are transported in the bloodstream?
   A) glycogen, amino acids, and triglycerides
   B) glycogen, tripeptides, and fatty acids
   C) glucose, amino acids, and lipoproteins
   D) glucose, dipeptides, and fatty acids
   E) disaccharides, amino acids, and lipoproteins
Answer: C
*Diff: 4  Page Ref: 605*

4) When amino acids are used for energy, they must be deaminated. In the process, ________ is produced, and eventually eliminated from the body in the form of ________.
   A) nitrogen : nitrous oxide and water
   B) nitrogen : bilirubin
   C) carbonic acid : carbon dioxide and water
   D) ammonia : urea
   E) ammonia : nitrous oxide
Answer: D
*Diff: 5  Page Ref: 605*
5) ________ provide an energy storage that is used primarily in times of starvation and are not metabolized by nervous tissue.
   A) Ketones
   B) Proteins
   C) Carbohydrates
   D) Fats
   E) Nucleic acid
Answer: B
Diff: 5 Page Ref: 605

6) The glycerol molecule that forms the backbone of triglyceride molecules within adipocytes is ________.
   A) derived from the monoglyceride in the blood
   B) synthesized within that cell
   C) derived from the degradation of fatty acids
   D) derived from blood triglycerides that enter the cell
   E) synthesized by capillary endothelial cells
Answer: B
Diff: 6 Page Ref: 606

7) Which of the following best describes the location and function of lipoprotein lipase?
   A) Lipoprotein lipase is found in adipose tissue, where it breaks down triglycerides to glycerol and three fatty acids.
   B) Lipoprotein lipase is found in adipose tissue, where it synthesizes triglycerides from glycerol and three fatty acids.
   C) Lipoprotein lipase is found in the liver, where it breaks down triglycerides.
   D) Lipoprotein lipase is found on capillary endothelial cells, where it degrades triglycerides on the outer surface of very low-density lipoproteins.
   E) Lipoprotein lipase is found in intestinal villi, where it synthesizes chylomicrons.
Answer: D
Diff: 5 Page Ref: 606

8) Under which of the following conditions is the basal metabolic rate measured?
   A) lying down, sleeping, and having fasted for 24 hours
   B) lying down, sleeping, and having fasted for 12 hours
   C) lying down, awake, and having fasted for 12 hours
   D) sitting, awake, and having fasted for 24 hours
   E) standing, awake, and having fasted for 12 hours
Answer: C
Diff: 4 Page Ref: 608

9) In order to maintain a positive energy balance, the body must ________.
   A) limit caloric intake
   B) expend more energy than it consumes
   C) consume more energy than it expends
   D) reduce the amount of heat produced by the body
   E) increase activity
Answer: C
Diff: 4 Page Ref: 608
10) In order to lose weight, a person must be ________.
   A) in a state of positive energy balance  
   B) in a state of negative energy balance  
   C) consume more calories than are expended  
   D) produce more heat to increase energy consumption  
   E) less active  
   Answer: B  
   Diff: 4 Page Ref: 608

11) Which of the following is true of the absorptive state?
   A) Energy input exceeds output and thus is stored in macromolecules.  
   B) Energy input is less than output and thus is stored in macromolecules.  
   C) Energy input exceeds output and thus is released from breakdown of macromolecules.  
   D) Energy input is less than output and thus is released from breakdown of macromolecules.  
   E) Energy input is equal to energy output and thus, the body is in energy balance.  
   Answer: A  
   Diff: 4 Page Ref: 608

12) What happens to glucose during the postabsorptive state?
   A) Glucose is stored as glycogen and spared for use by the nervous system.  
   B) Glucose is stored as glycogen and is the primary energy source for all body cells.  
   C) Glucose is synthesized by gluconeogenesis and glycolysis and is spared for use by the nervous system.  
   D) Glucose is synthesized by gluconeogenesis and glycolysis and is the primary energy source for all body cells.  
   E) Glucose is converted to fat for storage.  
   Answer: C  
   Diff: 5 Page Ref: 608

13) During the absorptive state, the primary energy source for most of the body cells is ________.  
   A) glucose supplied from glycogen  
   B) glucose recently absorbed into the bloodstream  
   C) fatty acids supplied from triglycerides  
   D) fatty acids recently absorbed into the bloodstream  
   E) amino acids supplied from proteins  
   Answer: B  
   Diff: 3 Page Ref: 608

14) Which cell type stores the majority of the body's glycogen?  
   A) adipocyte  
   B) nervous tissue  
   C) skeletal muscle  
   D) liver  
   E) kidney  
   Answer: C  
   Diff: 4 Page Ref: 609
15) What is the fate of any excess glucose in the liver that is not required for energy and not stored as glycogen?
   A) it is converted into fatty acids
   B) it is converted into amino acids
   C) it is immediately released back into the bloodstream
   D) it accumulates within the cell until released
   E) is is attached to very-low-density lipoprotein in its native form

Answer: A  
Diff: 5  Page Ref: 609

16) What is the fate of most of the amino acids that enter the liver?
   A) converted to glycogen
   B) synthesized into proteins
   C) converted directly into energy
   D) converted to keto acids that become fatty acids
   E) stored in very-low-density lipoproteins in their native form

Answer: D  
Diff: 5  Page Ref: 609

17) Which tissue/organ packages triglycerides into very low density lipoproteins (VLDLs)?
   A) adipose tissue
   B) liver
   C) skeletal muscle
   D) pancreas
   E) intestinal tract

Answer: B  
Diff: 4  Page Ref: 609

18) Most energy stores for the body are in the form of _______ and stored in ________.
   A) triglycerides : adipose tissue
   B) triglycerides : liver
   C) glycogen : adipose tissue
   D) glycogen : liver
   E) glycogen : skeletal muscle

Answer: A  
Diff: 4  Page Ref: 610

19) What is the most dense form of energy storage (i.e., contains the most calories per gram)?
   A) Fat
   B) Protein
   C) Glycogen
   D) Starch
   E) Cellulose

Answer: A  
Diff: 3  Page Ref: 610
20) Which of the following statements is true of the absorptive state (compared to the postabsorptive state)?
   A) Insulin levels are low, and glucagon levels are high.
   B) Most body cells use fatty acids for energy, sparing glucose for the nervous system.
   C) Glycogenolysis is increased.
   D) Gluconeogenesis is inhibited.
   E) Lipids are broken down in adipose tissue.

   Answer: C
   Diff: 4   Page Ref: 609

21) Which of the following statements about the liver is true?
   A) Gluconeogenesis occurs in the liver during the absorptive state.
   B) The liver contains most of the glycogen stores in the body.
   C) Ketones are produced in the liver during the absorptive state.
   D) The liver synthesizes triglycerides and packages them into lipoproteins during the absorptive state.
   E) The liver contains most of the triglyceride stores in the body.

   Answer: D
   Diff: 6   Page Ref: 609

22) In the postabsorptive state, what do most cells use for energy?
   A) cellulose
   B) glycogen
   C) glucose
   D) lipids
   E) amino acids

   Answer: D
   Diff: 3   Page Ref: 610

23) What is glucose sparing?
   A) an increase in gluconeogenesis to conserve glycogen stores
   B) an increase in glycogenesis to increase glycogen stores
   C) an increase in glycogenolysis to mobilize glycogen stores
   D) cells utilize fatty acids for energy instead of glucose
   E) cells utilize glucose for energy instead of fatty acids

   Answer: D
   Diff: 4   Page Ref: 610

24) The glycogen that is stored in skeletal muscle cells ________.
   A) is released into the blood to maintain blood glucose
   B) can only be used by that skeletal muscle cell
   C) is more hygroscopic than liver glycogen
   D) can be used by any skeletal muscle cell
   E) is rarely used for energy

   Answer: B
   Diff: 5   Page Ref: 610
25) Glucose molecules derived from glycogen must be ______ in order to exit a cell.
   A) converted to a fatty acid
   B) deaminated
   C) converted to a metabolic intermediate
   D) phosphorylated
   E) dephosphorylated
Answer: E  Diff: 6  Page Ref: 610

26) Breakdown of glycogen stores in what organ is required for the maintenance of blood glucose?
   A) skeletal muscle
   B) pancreas
   C) liver
   D) skin
   E) adipose tissue
Answer: C  Diff: 3  Page Ref: 611

27) The glycerol released from the adipocyte from the catabolism of a triglyceride is _______.
   A) converted into amino acids in the kidneys
   B) excreted by the kidneys
   C) used by nervous tissue for energy
   D) used by skeletal muscle for energy
   E) converted into glucose in the liver
Answer: E  Diff: 6  Page Ref: 612

28) The metabolic adjustments that occur in the body during the switch from postabsorptive to absorptive state are largely triggered by increases in what hormone?
   A) insulin
   B) glucagon
   C) thyroid hormone
   D) epinephrine
   E) cortisol
Answer: A  Diff: 4  Page Ref: 612

29) Which of the following stimuli does NOT stimulate insulin secretion?
   A) increased blood glucose
   B) increased blood amino acids
   C) increased parasympathetic nervous activity
   D) increased epinephrine
   E) increased glucose-dependent insulinotropic peptide
Answer: D  Diff: 5  Page Ref: 612
30) Insulin is secreted by the _______ cells of the pancreas and stimulates _______.
   A) alpha : anabolism
   B) beta : anabolism
   C) delta : anabolism
   D) alpha : catabolism
   E) beta : catabolism
   Answer: B
   Diff: 4 Page Ref: 612

31) Which of the following is NOT an action of insulin?
   A) synthesis of fatty acids in liver
   B) synthesis of glycogen in skeletal muscle
   C) synthesis of glycogen in the liver
   D) synthesis of proteins in most cells
   E) synthesis of fatty acids in skeletal muscle
   Answer: E
   Diff: 5 Page Ref: 613

32) Which of the following is NOT an action of insulin?
   A) inhibit the breakdown of proteins
   B) inhibit glycogenesis
   C) inhibit the breakdown of fats
   D) inhibit the breakdown of glycogen
   E) inhibit gluconeogenesis
   Answer: B
   Diff: 5 Page Ref: 613

33) How does insulin increase cellular uptake of glucose?
   A) causing GLUT-4 to be incorporated into the plasma membrane of some cells
   B) activating the Na+/K+ pump
   C) increasing the activity of the sodium–linked glucose transporter
   D) causing GLUT-1 to be incorporated into the membrane of cells
   E) causing the sodium–linked glucose transporter to be incorporated into the membrane of cells
   Answer: A
   Diff: 5 Page Ref: 613

34) The metabolic adjustments that occur in the body during the switch from absorptive to postabsorptive state are largely triggered by increases in what hormone?
   A) insulin
   B) glucagon
   C) thyroid hormone
   D) epinephrine
   E) cortisol
   Answer: B
   Diff: 4 Page Ref: 613
35) Glucagon is secreted from _______ cells of the pancreas and stimulates _______.
   A) alpha : anabolism
   B) beta : anabolism
   C) delta : anabolism
   D) alpha : catabolism
   E) beta : catabolism
   Answer: D
   Diff: 4 Page Ref: 613

36) During the postabsorptive state, what happens to the blood levels of insulin and glucagon?
   A) insulin and glucagon both increase
   B) insulin and glucagon both decrease
   C) insulin increases, whereas blood levels of glucagon decrease
   D) insulin decreases, whereas blood levels of glucagon increase
   E) glucagon increases, whereas insulin levels do not change
   Answer: D
   Diff: 4 Page Ref: 613

37) Which of the following increases the release of glucagon?
   A) increased blood glucose, increased sympathetic activity, and increased blood amino acids
   B) increased blood glucose, increased sympathetic activity, and decreased blood amino acids
   C) increased blood glucose, decreased sympathetic activity, and increased blood amino acids
   D) decreased blood glucose, increased sympathetic activity, and increased blood amino acids
   E) decreased blood glucose, decreased sympathetic activity, and decreased blood amino acids
   Answer: D
   Diff: 5 Page Ref: 613

38) Which of the following is NOT an action of the hormone glucagon?
   A) increased triglyceride synthesis
   B) increased glycochenoneogenesis
   C) increased gluconeogenesis
   D) increased ketone synthesis
   E) increased protein degradation
   Answer: A
   Diff: 5 Page Ref: 613

39) Which of the following increases blood glucose levels?
   A) increases in insulin only
   B) increases in glucagon only
   C) increases in epinephrine only
   D) increases in both insulin and epinephrine
   E) increases in both glucagon and epinephrine
   Answer: E
   Diff: 5 Page Ref: 613
40) What is the normal level of glucose in blood?
   A) 10 mg/dL
   B) 50 mg/dL
   C) 100 mg/dL
   D) 150 mg/dL
   E) 300 mg/dL

   Answer: C
   Diff: 4 Page Ref: 614

41) The release of glucagon during the absorptive state by certain amino acids in a high-protein meal would facilitate the ________.
   A) synthesis of triglycerides
   B) synthesis of proteins
   C) uptake of amino acids
   D) maintenance of blood glucose in a low-carbohydrate meal
   E) growth of muscle

   Answer: D
   Diff: 6 Page Ref: 615

42) The decrease in blood glucose activates glucose receptors in the brain, which leads directly to a(n) ________.
   A) increase in parasympathetic activity
   B) increase in sympathetic activity
   C) decrease in parasympathetic activity
   D) increase in the release of insulin
   E) decrease in the release of insulin

   Answer: B
   Diff: 5 Page Ref: 616

43) Which of the following will NOT occur as a consequence of the release of epinephrine?
   A) increased release of amino acid
   B) increased gluconeogenesis
   C) increased glycogenolysis
   D) increased lipolysis
   E) increased blood glucose

   Answer: A
   Diff: 5 Page Ref: 616

44) Prolonged exposure to a cold environment can cause ________.
   A) poikilothermia
   B) ectothermia
   C) hypothermia
   D) hyperthermia
   E) normothermia

   Answer: C
   Diff: 4 Page Ref: 617
45) What are animals whose body temperature changes with environmental temperatures called?
   A) endotherms
   B) hypotherms
   C) hypertherms
   D) poikilotherms
   E) homeotherms

   Answer: D
   Diff: 3 Page Ref: 616

46) What is the process whereby energy is transferred to and from the body through
electromagnetic waves called?
   A) radiation
   B) conduction
   C) evaporation
   D) convection
   E) sweating

   Answer: A
   Diff: 3 Page Ref: 617

47) What is the process whereby energy is transferred to and from the body through direct contact
with a solid body called?
   A) radiation
   B) conduction
   C) evaporation
   D) convection
   E) sweating

   Answer: B
   Diff: 3 Page Ref: 617

48) When a person sits on a metal chair on a cold day, they feel the cold of the metal. This is an
example of ________.
   A) conduction
   B) convection
   C) radiation
   D) evaporation
   E) cold feet

   Answer: A
   Diff: 4 Page Ref: 617

49) What are the primary components of sweat produced by eccrine glands?
   A) water and oil
   B) water and salt
   C) oil and salt
   D) water only
   E) water, oil, and salt

   Answer: B
   Diff: 4 Page Ref: 618
50) What differentiates sweat produced by apocrine glands from sweat produced by eccrine glands?
   A) they are located in different regions of the body
   B) apocrine glands empty into hair follicles, whereas eccrine glands empty on the skin surface
   C) apocrine glands do not become active until puberty; eccrine glands are active from birth
   D) sweat from apocrine glands contains proteins and fatty acids that are not found in sweat from eccrine glands
   E) All of the above

   Answer: E  
   Diff: 4  Page Ref: 619

51) What is an increase in body temperature to greater-than-normal levels called?
   A) conduction
   B) convection
   C) hypothermia
   D) hyperthermia
   E) poikilothermia

   Answer: D  
   Diff: 4  Page Ref: 617

52) What do peripheral thermoreceptors detect?
   A) core body temperature
   B) skin temperature
   C) blood temperature
   D) temperature in the heart
   E) temperature in the hypothalamus

   Answer: B  
   Diff: 5  Page Ref: 618

53) What is the thermoneutral zone?
   A) The range of temperatures at which poikilothermic animals can maintain body temperature without regulatory systems.
   B) The range of temperatures at which homeothermic animals can maintain body temperature without regulatory systems.
   C) The range of temperatures at which homeothermic animals can maintain body temperature through evaporation only.
   D) The range of temperatures at which poikilothermic animals can maintain body temperature through convection only.
   E) The range of temperatures at which homeothermic animals can maintain body temperature by regulating blood flow to the skin only.

   Answer: E  
   Diff: 4  Page Ref: 618
54) Following an increase in body temperature, which of the following responses will NOT occur?
   A) an increase in skin blood flow
   B) an increase in sweat production
   C) an increase in skin temperature
   D) an increase in shivering
   E) an increase in water on the skin

   Answer: D
   Diff: 2 Page Ref: 607

55) Following a mild decrease in body temperature, which of the following responses will NOT occur?
   A) an increase in skin blood flow
   B) a decrease in sweat production
   C) a decrease in skin temperature
   D) an increase in shivering
   E) a decrease in water on the skin

   Answer: A
   Diff: 4 Page Ref: 607

56) Which of the following structures of the body is NOT normally involved in the control of body temperature?
   A) skeletal muscle
   B) hypothalamus
   C) sweat glands
   D) skin blood vessels
   E) chemoreceptors

   Answer: E
   Diff: 5 Page Ref: 618

57) Shivering to increase body temperature is characterized by ________.
   A) slow, involuntary bursts of muscle contraction
   B) rapid, involuntary bursts of muscle contraction
   C) slow, voluntary bursts of muscle contraction
   D) rapid, voluntary bursts of muscle contraction
   E) maintained muscle contraction similar to a cramp

   Answer: B
   Diff: 3 Page Ref: 619

58) What is the ultimate cause of the increase in body temperature associated with an infection (fever)?
   A) increased rate of sweating
   B) pyrogen-induced upward movement of the set point
   C) increased error signal
   D) change in the thermoregulatory integrator from one area of the brain to another
   E) decrease in skin blood flow

   Answer: B
   Diff: 6 Page Ref: 620
59) The increase in the set point of body temperature that occurs during a fever is caused by the release of substances from ________ that affect the hypothalamic temperature set point.
   A) red blood cells
   B) erythrocytes
   C) white blood cells
   D) bacteria
   E) nerve cells
   Answer: C
   Diff: 5    Page Ref: 620

60) A substance that causes an increase in the set point for body temperature is called a ________.
   A) pyrogen
   B) poikogen
   C) homeogen
   D) thermogen
   E) hyperthermogen
   Answer: A
   Diff: 4    Page Ref: 620

61) Which of the following is NOT required for growth?
   A) growth hormone
   B) growth factors
   C) insulin–like growth factors
   D) dietary intake of proteins
   E) dietary intake of starch
   Answer: E
   Diff: 3    Page Ref: 617

62) Growth hormone, directly or through release of insulin–like growth factors, stimulates which of the following?
   A) hyperplasia, hypertrophy, and bone growth
   B) hypoplasia, hypotrophy, and bone growth
   C) hyperplasia and bone growth, but not hypertrophy
   D) hypertrophy and bone growth, but not hyperplasia
   E) hypertrophy and hyperplasia, but not bone growth
   Answer: A
   Diff: 4    Page Ref: 617

63) Insulin–like growth factors function as a ________ in promoting growth.
   A) hormone only
   B) paracrine only
   C) neurotransmitter only
   D) hormone and paracrine
   E) hormone and neurotransmitter
   Answer: D
   Diff: 6    Page Ref: 618
64) What organ secretes insulin–like growth factors into the bloodstream?
   A) pancreas  
   B) liver  
   C) all organs  
   D) adipose tissue  
   E) skeletal muscle
   Answer: B
   Diff: 4  Page Ref: 618

65) Which of the following is NOT one of the growth supporting functions of growth hormone?
   A) increased plasma glucose concentration  
   B) decreased glucose uptake by adipocytes  
   C) increased lipolysis in adipocytes  
   D) increased gluconeogenesis in the liver  
   E) increased glycogenolysis in skeletal muscle
   Answer: E
   Diff: 5  Page Ref: 618

66) The growth–promoting functions of growth hormone rely partially on the activity of ________.
   A) insulin–like growth factors  
   B) somatostatins  
   C) epidermal growth factors  
   D) nerve growth factors  
   E) epinephrine
   Answer: A
   Diff: 6  Page Ref: 618

67) The secretion of growth hormone releasing hormone is stimulated by which of the following?
   A) increase in glycogenolysis in the liver  
   B) decrease in plasma amino acid concentration  
   C) decrease in plasma glucose concentration  
   D) increase in gluconeogenesis in the kidneys  
   E) decrease in insulinlike growth factor release from the liver
   Answer: C
   Diff: 6  Page Ref: 618

68) Which of the following does NOT enhance the release of growth hormone?
   A) stress  
   B) exercise  
   C) sleep  
   D) increased plasma amino acids  
   E) increased plasma glucose
   Answer: E
   Diff: 5  Page Ref: 618

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69) During which phase of life are growth hormone levels greatest?
   A) fetal
   B) prepubertal
   C) puberty
   D) early adulthood (20s–50s)
   E) late adulthood (50s–100s)
   Answer: C  Diff: 4  Page Ref: 618

70) Crystals called _______ give bone a mineral component that is able to withstand compressive forces.
   A) sodium chloride
   B) calcium bisphosphate
   C) hydroxyapatite
   D) osteoids
   E) calcium chloride
   Answer: C  Diff: 5  Page Ref: 618

71) An organic compound called _______ gives bone its ability to withstand tensile forces.
   A) collagen
   B) elastin
   C) hydroxyapatite
   D) osteoid
   E) calcium chloride
   Answer: D  Diff: 4  Page Ref: 618

72) What cell type resorbs bone during remodeling?
   A) osteoblasts
   B) osteoclasts
   C) chondrocytes
   D) osteoids
   E) osteocytes
   Answer: B  Diff: 5  Page Ref: 618

73) What cell type deposits bone during remodeling?
   A) osteoblasts
   B) osteoclasts
   C) chondrocytes
   D) osteoids
   E) osteocytes
   Answer: A  Diff: 5  Page Ref: 618
74) Which of the following is a function of osteoblasts?
   A) production of osteoid
   B) release of enzymes that digest osteoid
   C) dissolving of calcium phosphate crystals
   D) production of cartilage
   E) release of a chemical that triggers the conversion of cartilage cells to bone cells

   Answer: A
   Diff: 4   Page Ref: 618

75) What cell type is surrounded by calcified bone and secretes matrix to support bone.
   A) osteoblast
   B) osteoclast
   C) chondrocytes
   D) osteoid
   E) osteocyte

   Answer: E
   Diff: 5   Page Ref: 618

76) What is the function of gap junctions in bone?
   A) for action potential transmission that initiates bone resorption by osteoblasts
   B) for action potential transmission that initiates bone deposition by osteoblasts
   C) for action potential transmission that initiates bone deposition by osteoclasts
   D) for action potential transmission that initiates bone resorption by osteoclasts
   E) to provide nutrients to cells embedded within the rigid bone matrix

   Answer: E
   Diff: 5   Page Ref: 619

77) Which of the following is a function of osteoclasts?
   A) secretion of osteoid
   B) calcification of bone
   C) release of enzymes that degrade the osteoid
   D) formation of cartilage
   E) breakdown of cartilage

   Answer: C
   Diff: 4   Page Ref: 619

78) In the young, the epiphyseal plate is composed of _______, which plays an important role in the _______ during growth.
   A) bone marrow : thickening of bone
   B) bone : thickening of bone
   C) cartilage : thickening of bone
   D) bone marrow : elongation of bone
   E) cartilage : elongation of bone

   Answer: E
   Diff: 4   Page Ref: 620
79) The increase in bone thickness stimulated by growth hormone involves which of the following?
   A) increased osteoblast activity on the outer surface of the bone and increased osteoclast activity on the inner surface of bone
   B) increased osteoclast activity on the outer surface of the bone and increased osteoblast activity on the inner surface of bone
   C) increased osteoblast and chondrocyte activity at the epiphyseal plate
   D) increased osteoclast and chondrocyte activity at the epiphyseal plate
   E) increased chondrocyte activity on the inner surface of bone and increased osteoclast activity on the outer surface of the bone

   Answer: A
   Diff: 5   Page Ref: 620

80) What type of cell forms cartilage?
   A) osteoblasts
   B) osteocytes
   C) osteoclasts
   D) chondrocytes
   E) chondroblasts

   Answer: D
   Diff: 5   Page Ref: 620

81) Epiphyseal plate closure is triggered by ________.
   A) osteoclasts
   B) osteoblasts
   C) osteocytes
   D) somatomedins
   E) sex hormones

   Answer: E
   Diff: 4   Page Ref: 620

82) Which of the following conditions occurring in childhood would NOT result in the condition of dwarfism?
   A) decreased stimulation of growth hormone secretion
   B) increased responsiveness of tissues to insulin-like growth factors
   C) decrease responsiveness of tissues to growth hormone
   D) insufficient production of insulin-like growth factors
   E) defective growth hormone receptors

   Answer: B
   Diff: 4   Page Ref: 620

83) The hormone insulin is ________ for the regulation of growth due to its stimulation of ________.
   A) permissive : insulinlike growth factor secretion
   B) permissive : growth hormone secretion
   C) required : bone growth
   D) required : muscle growth
   E) required : nervous system development

   Answer: A
   Diff: 5   Page Ref: 621
84) Which of the following hormones inhibits growth?
   A) growth hormone
   B) somatomedins
   C) insulin–like growth factors
   D) thyroid hormones
   E) glucocorticoids

   Answer: E
   Diff: 4   Page Ref: 621

85) What is the precursor compound located within colloid that is converted into thyroid hormone?
   A) Proiodotyrosine
   B) Preiodotyrosine
   C) Iodotyrosine
   D) Thyroglobulin
   E) Calcitonin

   Answer: D
   Diff: 4   Page Ref: 622

86) Thyroid stimulating hormone activates what signal transduction mechanism within the follicle cell that will result in the release of thyroid hormone?
   A) cGMP
   B) cAMP
   C) opening of ligand–gated calcium channels
   D) inositol triphosphate
   E) diacylglycerol

   Answer: B
   Diff: 5   Page Ref: 622

87) The iodinated tyrosine residues on the thyroglobulin molecule are cleaved to produce T₃ and T₄ in what organelle?
   A) lysosome
   B) Golgi apparatus
   C) colloid
   D) endoplasmic reticulum
   E) peroxisome

   Answer: A
   Diff: 5   Page Ref: 622

88) The release of T₃ and T₄ occurs through ______, and they can bind to ______ to be transported in the bloodstream.
   A) endocytosis : transthyrethin
   B) exocytosis : thyroxine–binding globulin
   C) diffusion : albumin
   D) exocytosis : transthyrethin
   E) endocytosis : albumin

   Answer: C
   Diff: 5   Page Ref: 622
89) The most abundant form of thyroid hormone secreted into the blood is _______; the most active form at the target cell is _______; and the form that provides long-loop negative feedback is _______.
   A) T3 : T3 : T4
   B) T4 : T4 : T3
   C) T4 : T3 : T4
   D) T3 : T4 : T3
   E) T3 : T4 : T4

Answer: C
Diff: 7    Page Ref: 622

90) What does an increase in cAMP levels in thyroid follicular cells cause?
   A) increase in secretion of thyroid hormones
   B) decrease in secretion of thyroid hormones
   C) increase in secretion of calcitonin
   D) decrease in secretion of calcitonin
   E) increase in secretion of parathyroid hormone

Answer: A
Diff: 3    Page Ref: 622

91) Where does conversion of T4 to T3 occur?
   A) colloid of thyroid follicles
   B) follicle cells
   C) lysosome
   D) plasma near the target cell
   E) inside the nucleus of the target cell

Answer: D
Diff: 5    Page Ref: 622

92) Where are receptors for thyroid hormones located?
   A) on the plasma membrane of target cells
   B) in the cytosol of target cells
   C) in the nucleus of target cells
   D) on the plasma membrane of all cells in the body
   E) in the cytosol of all cells in the body

Answer: C
Diff: 4    Page Ref: 623

93) The calorigenic action of thyroid hormone is mediated by _______.
   A) promoting lipolysis
   B) promoting glycogenolysis
   C) promoting protein synthesis
   D) promoting glycogenesis
   E) increasing Na+/K+ pump activity

Answer: E
Diff: 4    Page Ref: 623
94) Which of the following is NOT one of the actions of thyroid hormone?
   A) calorigenesis
   B) enhance sympathetic nervous activity
   C) energy mobilization
   D) promote synthesis of beta adrenergic receptors
   E) permissive to growth hormone

   Answer: B  
   Diff: 5  Page Ref: 623

95) To what class of hormones does cortisol belong?
   A) mineralocorticoids
   B) glucocorticoids
   C) growth factors
   D) androgens
   E) metabolotropins

   Answer: B  
   Diff: 3  Page Ref: 623

96) What is the primary hormone mediating the stress response (or general adaptation syndrome)?
   A) growth hormone
   B) insulin
   C) glucagon
   D) thyroid hormone
   E) cortisol

   Answer: E  
   Diff: 3  Page Ref: 624

97) Which of the following is NOT an action of glucocorticoids?
   A) mobilize energy
   B) growth hormone secretion
   C) glucose sparing
   D) increase the uptake of fatty acids
   E) maintain responsiveness of blood vessels to sympathetic nervous activity

   Answer: D  
   Diff: 4  Page Ref: 624

98) What is the hypothalamic tropic hormone that regulates cortisol secretion?
   A) oxytocin
   B) thyrotropin releasing hormone
   C) growth hormone releasing hormone
   D) adrenocorticotropic hormone
   E) corticotropin releasing hormone

   Answer: E  
   Diff: 4  Page Ref: 623
99) Which of the hormones listed below is NOT secreted in response to stress?
   A) cortisol  
   B) thyroid hormone  
   C) angiotensin II  
   D) epinephrine  
   E) antidiuretic hormone  
   Answer: B  
   Diff: 5  Page Ref: 624

100) Which of the following is NOT a characteristic of Cushing’s syndrome?
   A) deposition of fat in the abdomen  
   B) bruise easily  
   C) protein depletion (wasting)  
   D) hypoglycemia  
   E) deposition of fat in the face  
   Answer: D  
   Diff: 5  Page Ref: 624

101) Which of the following hormones increase blood glucose levels?
   A) glucagon only  
   B) epinephrine only  
   C) growth hormone only  
   D) both glucagon and epinephrine  
   E) glucagon, epinephrine, and growth hormone  
   Answer: E  
   Diff: 5  Page Ref: 625

102) Which of the following hormones decrease protein synthesis?
   A) insulin only  
   B) thyroid hormones only  
   C) growth hormone only  
   D) both insulin and growth hormone  
   E) insulin, growth hormone, and thyroid hormone  
   Answer: E  
   Diff: 7  Page Ref: 625

103) Which of the following hormones decrease lipolysis?
   A) glucagon  
   B) epinephrine  
   C) growth hormone  
   D) cortisol  
   E) insulin  
   Answer: E  
   Diff: 6  Page Ref: 625
104) Addison’s disease is associated with what endocrine malfunction?
   A) increase in growth hormone in adults
   B) decrease in growth hormone in children
   C) decrease in cortisol
   D) increase in epinephrine
   E) decrease in thyroid hormones

   Answer: C
   Diff: 5   Page Ref: 624

105) Acromegaly is associated with what endocrine malfunction?
   A) increase in growth hormone in adults
   B) decrease in growth hormone in children
   C) decrease in cortisol
   D) increase in epinephrine
   E) decrease in thyroid hormones

   Answer: A
   Diff: 5   Page Ref: 620

True/False Questions

1) Catabolism of carbohydrates, proteins, and lipids can be used to generate ATP.
   Answer: TRUE
   Diff: 2   Page Ref: 605

2) Carbohydrates and proteins can be converted to lipids.
   Answer: TRUE
   Diff: 3   Page Ref: 605

3) Most of the body’s energy is stored as glycogen.
   Answer: FALSE
   Diff: 3   Page Ref: 607

4) Energy mobilization refers to the catabolism of large molecules into smaller nutrient molecules that are released into the bloodstream to provide energy to the cells of the body.
   Answer: TRUE
   Diff: 3   Page Ref: 607

5) Energy from the hydrolysis of ATP is used for most cellular processes.
   Answer: TRUE
   Diff: 2   Page Ref: 607

6) While proteins are a form of energy storage, most proteins are unavailable metabolically due to their structural and functional roles.
   Answer: TRUE
   Diff: 3   Page Ref: 605

7) The metabolic rate while sleeping is higher than the basal metabolic rate.
   Answer: TRUE
   Diff: 3   Page Ref: 608
8) The postabsorptive state is characterized by mobilization of energy stores, which is stimulated by the hormone insulin.
   Answer: FALSE  
   Diff: 4  Page Ref: 610

9) Lipoprotein lipase is found only on the plasma membranes of adipocytes.
   Answer: FALSE  
   Diff: 4  Page Ref: 606

10) Glycogen stored in skeletal muscle cannot provide glucose to the bloodstream because skeletal muscle lacks the enzyme glucose-6-phosphatase.
   Answer: TRUE  
   Diff: 4  Page Ref: 610

11) Gluconeogenesis typically occurs in skeletal muscle, a tissue requiring substantial energy to maintain its activity.
   Answer: FALSE  
   Diff: 4  Page Ref: 611

12) During the absorptive state, the decrease in blood glucose acts to increase insulin.
   Answer: FALSE  
   Diff: 4  Page Ref: 612

13) The transport of glucose into cells of the central nervous system requires the presence of insulin.
   Answer: FALSE  
   Diff: 4  Page Ref: 613

14) The overall affect of glucagon is to mobilize energy stores and the synthesis of new energy sources.
   Answer: TRUE  
   Diff: 3  Page Ref: 613

15) An increase in the size of an organ as a consequence of an increase in cell number is referred to as hypertrophy.
   Answer: FALSE  
   Diff: 3  Page Ref: 617

16) On a regular basis, heat is produced in animals by metabolism.
   Answer: TRUE  
   Diff: 4  Page Ref: 616

17) The set point for body temperature is 41°C.
   Answer: FALSE  
   Diff: 4  Page Ref: 617

18) On a regular basis, heat is lost from the body through the process of insensible water loss.
   Answer: TRUE  
   Diff: 4  Page Ref: 618
19) Peripheral thermoreceptors detect core body temperature.
Answer: FALSE
Diff: 4  Page Ref: 618

20) In the cold, blood flow to the skin increases.
Answer: FALSE
Diff: 4  Page Ref: 618

21) The thermoregulatory center is located in the medulla oblongata.
Answer: FALSE
Diff: 4  Page Ref: 618

22) Bone is static tissue that undergoes few changes in its structure due to the low level of osteoblastic activity.
Answer: FALSE
Diff: 2  Page Ref: 618

23) Yellow bone marrow is composed of adipocytes.
Answer: TRUE
Diff: 2  Page Ref: 620

24) The release of thyrotropin releasing hormone from the anterior pituitary stimulates secretion of thyroid hormone.
Answer: FALSE
Diff: 3  Page Ref: 622

25) Bone elongates by chondrocytes producing cartilage at the epiphyseal plate, followed by osteoblasts depositing new bone to replace the cartilage.
Answer: TRUE
Diff: 4  Page Ref: 620

26) Glucocorticoids, insulin, glucagon, thyroid hormones, and epinephrine are all lipophilic.
Answer: FALSE
Diff: 4  Page Ref: 612
Matching Questions

Match the following absorptive status to the condition under which it exists.

1) Plasma insulin levels increase.
   Diff: 3 Page Ref: 612
   A) postabsorptive state

2) Plasma glucagon levels increase.
   Diff: 3 Page Ref: 613
   B) absorptive state

3) Glucose is stored as glycogen in liver and skeletal muscle.
   Diff: 4 Page Ref: 610
   C) both the absorptive and postabsorptive states

4) The liver converts amino acids into fatty acids.
   Diff: 5 Page Ref: 609
   D) neither the absorptive nor postabsorptive state

5) Most body cells use glucose for energy.
   Diff: 3 Page Ref: 609

6) Glucose is "spared" for use by the central nervous system.
   Diff: 4 Page Ref: 610

7) The liver packages lipids into very low density lipoproteins to transport lipids to adipose tissue.
   Diff: 5 Page Ref: 609

8) Glycerol is converted by the liver to glucose.
   Diff: 5 Page Ref: 611

9) The liver converts fatty acids to ketones.
   Diff: 4 Page Ref: 611

10) Glucose transport into most body cells is increased.
    Diff: 4 Page Ref: 609

11) The brain utilizes primarily glucose for energy.
    Diff: 4 Page Ref: 608
12) Carbohydrates are converted to fat.
    Diff: 3    Page Ref: 609

13) Ketones provide energy for most body cells, sparing glucose.
    Diff: 5    Page Ref: 610

Answers: 1) B  2) A  3) B  4) B  5) B
         6) A  7) B  8) A  9) A 10) B
         11) C  12) B  13) D

Match the following descriptions with the correct mechanism of heat exchange.

14) Exchange of heat by direct contact with an object.
    Diff: 4    Page Ref: 618
    A) conduction
    B) radiation

15) Exchange of heat in the form of electromagnetic waves.
    Diff: 4    Page Ref: 618
    C) convection
    D) evaporation

16) Loss of heat by conversion of a liquid to a vapor.
    Diff: 4    Page Ref: 618

17) Movement of heat by movement of a gas or liquid carrying the heat.
    Diff: 4    Page Ref: 618

Match the cell type to its function.

18) Produces cartilage.
   Diff: 4  Page Ref: 620
   A) osteoclast
   B) osteoblast
   C) chondrocyte
   D) osteocyte

19) Bone resorption.
   Diff: 4  Page Ref: 618

20) Bone deposition.
   Diff: 4  Page Ref: 618

21) Maintains osteoid of bone.
   Diff: 4  Page Ref: 618

22) Secretes enzymes and acid.
   Diff: 5  Page Ref: 618

23) Secretes osteoid.
   Diff: 5  Page Ref: 618

Answers:  18) C  19) A  20) B  21) D  22) A

Match the hormone to its description.

24) Released from the adrenal cortex, this hormone contributes to the general adaptation syndrome.
   Diff: 4  Page Ref: 624
   A) epinephrine
   B) glucocorticoids
   C) insulin
   D) glucagon
   E) growth hormone
   F) thyroid hormones
   G) insulin–like growth factors

25) Stimulates insertion of GLUT-4 transporters into cells of the body.
   Diff: 4  Page Ref: 613

26) This hormone is released in response to activation of the sympathetic nervous system and binds to adrenergic receptors on effector cells.
   Diff: 4  Page Ref: 615

27) This hormone is secreted from the liver in response to a tropic hormone from the anterior pituitary.
   Diff: 4  Page Ref: 617
28) This hormone is secreted from the anterior pituitary; it functions as both a tropic hormone and a hormone that has effects on target cells.  
*Diff: 4  Page Ref: 617*

29) This hormone is secreted from the pancreas during the postabsorptive state.  
*Diff: 3  Page Ref: 613*

30) This hormone contains at least 3 iodide residues.  
*Diff: 4  Page Ref: 622*

31) Acromegaly is caused by an excess of this hormone.  
*Diff: 5  Page Ref: 620*

32) A person with an excess of this hormone would tend to have a high metabolic rate.  
*Diff: 5  Page Ref: 623*

33) Too much of this hormone causes Cushing’s disease.  
*Diff: 5  Page Ref: 624*

34) Too little of this hormone causes Addison’s disease.  
*Diff: 5  Page Ref: 624*

35) Some diabetics lack sufficient amounts of this hormone.  
*Diff: 3  Page Ref: 614*

36) This hormone is released from the adrenal medulla.  
*Diff: 3  Page Ref: 616*

Answers:  
24) B  
25) C  
26) A  
27) G  
28) E  
29) D  
30) F  
31) E  
32) F  
33) B  
34) B  
35) C  
36) A  

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CHAPTER 21 The Endocrine System: Regulation of Energy Metabolism and Growth 653

Essay Questions

1) Describe the use and storage of energy from carbohydrates, fats, and proteins.

   Answer: Carbohydrates are transported in the blood as glucose. Once in the bloodstream, glucose moves into the cells through glucose transporters (GLUT-4 is the insulin-sensitive form). Once inside the cell, the intracellular concentration of glucose will determine whether it is consumed for energy or stored as glycogen. Proteins are transported in the blood as amino acids. Once they have entered the cell, those amino acids can be used to synthesize new proteins or are deaminated (stripped of ammonia) and used for energy. Amino acids are used for energy only during periods of starvation. Triglycerides are transported in blood within lipoproteins. The triglycerides on the outer surface of the lipoprotein are degraded into monoglycerides and free fatty acids by lipoprotein lipase on capillary endothelial cells. The fatty acids are taken up by the neighboring cells while the monoglycerides remain in the bloodstream to be acted upon by the liver. The fatty acids are oxidized upon entry into new triglycerides that are maintained as droplets within the cytosol, especially within adipocytes. The triglycerides can be broken down into fatty acids and a glycerol through the process of lipolysis and used for energy.

   Diff: 6  Page Ref: 605

2) Describe energy balance in the body.

   Answer: To maintain energy balance, the extent of energy uptake and output must be equal. There are two ways for the cells of the body to acquire energy: through the nutrients consumed, or from nutrients that are stored in the body. The energy that is input arrives in the form of absorbed nutrients. When these are oxidized, they liberate energy. The amount of energy released is related to the energy content of the molecule consumed. A person’s energy intake is the sum of the energy content of the nutrients consumed. A majority (60%) of the energy inherent in nutrient molecules is released as heat. The remaining 40% is used in the production of ATP. ATP is used in energy-requiring processes of the cell, which include mechanical work, chemical work, and transport work. Mechanical work requires the use of intracellular proteins to generate movement, such as occurs in the cilia of the respiratory tract. Chemical work is used in the formation of bonds during chemical reactions when small molecules are used to synthesize larger molecules. Transport work refers to the energy that moves molecules from one side of the membrane to the other. Metabolic rate refers to the energy that the body consumes within a period of time. Metabolic rate is affected by muscle activity, age, gender, body surface area, and environmental temperature. Basal metabolic rate is the energy expenditure by a person who is awake, lying down mentally and physically relaxed, and has fasted for 12 hours. That energy consumption is usually reported normalized to body weight. Thus, in order to maintain energy balance, the body must address the equation: Energy input = work performed + heat released. Thus, energy stored = energy input – (work performed + heat released). If we are in positive energy balance, there would tend to be an increase in body weight because some of the energy is being stored. On the other hand, maintenance of a negative energy balance involves a decrease in body weight.

   Diff: 6  Page Ref: 607
3) Describe metabolism that occurs during the absorptive state, including what occurs in the relevant cell types.

Answer: During the absorptive state, nutrient concentrations in the body are relatively high. Therefore, the body tends to be in an anabolic state where molecules are synthesized. During this time, most of the cells of the body are moving glucose, amino acids, and fatty acids across their plasma membranes. Fatty acids can be converted to acetyl CoA that can enter the Krebs cycle, whereas amino acids are converted to keto acids. Those amino acids are also used in protein synthesis. However, most proteins play structural or functional roles that preclude their use as energy storage substrates. In skeletal muscle, glucose is taken into the muscle and converted to glycogen. These cells comprise 70% of the glycogen in the body. The remainder of the body’s glycogen is stored in the liver. Along with the conversion of glucose to glycogen, the liver can also convert fatty acids into triglycerides. The liver uptakes amino acids that are synthesized into protein as well as converted into keto acids. However, most keto acids are used for fatty acid synthesis. The triglycerides produced in the liver are packaged into very-low-density lipoproteins (VLDL) to be transported to adipocytes. These cells have a high concentration of lipoprotein lipase on their plasma membrane that cleaves the triglycerides into monoglycerides and fatty acids. The fatty acids are taken into the adipocytes for synthesis into triglycerides. Adipocytes also receive their fatty acids from chylomicrons in addition to the VLDLs. Excess glucose can be converted into fatty acids within the adipocyte.

Diff: 6   Page Ref: 609

4) Describe the metabolism that occurs during the postabsorptive state, including the mechanisms responsible for regulating metabolism in adipocytes, skeletal muscle, and the liver.

Answer: Within a few hours after consuming a meal, the absorption of nutrients ceases. Thereafter, the body must rely on the energy it stored during the absorptive state. Thus, the postabsorptive state is primarily a catabolic state. The primary function of the postabsorptive state is the maintenance of blood glucose for delivery to the central nervous system. Most cells use fatty acids instead of glucose during the postabsorptive state to spare glucose. In skeletal muscle, glycogen is cleaved into glucose-6-phosphate. However, skeletal muscle lacks the glucose-6-phosphatase enzyme. Since glucose must be dephosphorylated to exit the cell across the GLUT transporter, the glucose derived from glycogen does not exit skeletal muscle cells. The liver, however, expresses the enzyme glucose-6-phosphatase and can therefore release its glucose stores into the blood. The liver is also the primary site for gluconeogenesis (in addition to the kidneys). The liver converts fatty acids into ketones, which can be used as energy sources by the central nervous system during prolonged starvation. Adipocytes supply fatty acids to the bloodstream. The triglycerides are metabolized into glycerol and three free fatty acids.

Diff: 6   Page Ref: 610
5) Describe the function of insulin, including the mechanisms regulating the release of insulin and its actions in target tissues.

Answer: Insulin is a peptide hormone released from the beta cells of the islets of Langerhans of the pancreas, whose action is primarily anabolic. The secretion of insulin is increased in the absorptive state by plasma glucose and amino acid concentrations. An increase in plasma glucose or amino acids will increase insulin secretion. At the same time, insulin secretion is also stimulated by parasympathetic nervous activity and glucose-independent insulinotropic peptide, both of which are increased by the presence of food in the digestive tract. Insulin secretion is inhibited by sympathetic nervous activity and epinephrine. Insulin promotes energy storage by stimulating the synthesis of fatty acids and triglycerides in the liver and adipocytes, glycogen in liver and skeletal muscle, and proteins in most tissues. Insulin also inhibits the breakdown of proteins, triglycerides, and glycogen, and suppresses gluconeogenesis in the liver. In addition, insulin affects the transport of nutrients in most tissues. For glucose, this involves increasing the stimulation of vesicles within cells containing GLUT-4 (glucose transport protein) to be incorporated into the plasma membrane, and increasing the synthesis of new transporters. In the liver and central nervous system, insulin has no effect on glucose uptake. Exercise will increase glucose permeability of active skeletal muscle by increasing the incorporation of glucose transporters in the membrane, independent of insulin. However, insulin still affects the uptake of glucose in resting skeletal muscle. In addition, the anabolic effects of insulin include growth promoting properties that, in concert with growth hormone, will promote protein synthesis, DNA synthesis, and cell division. Some have suggested that insulin and glucagon have paracrine effects on each other, with increases in insulin inhibiting glucagon release and vice versa.

Diff: 7  Page Ref: 612

6) In the postabsorptive state, the hormones released within the body maintain a catabolic state where the body releases energy. Describe the role of glucagon in the postabsorptive state, including the regulation of its release and its actions in target tissues. Include in this answer the role of sympathetic nervous activity on metabolism.

Answer: Glucagon is released from the alpha cells of the islet of Langerhans in the pancreas. The action of glucagon is primarily catabolic. The release of glucagon is controlled by glucose and amino acids; a decrease in blood glucose will increase glucagon release while an increase in amino acids will increase glucagon secretion. At the same time, the release of glucagon is increased by sympathetic nervous activity and epinephrine. In the liver, glucagon promotes glycogenolysis, gluconeogenesis, ketone synthesis, and the breakdown of proteins, while inhibiting glycogen and protein synthesis. In adipocytes, glucagon stimulates lipolysis and suppresses triglyceride synthesis. Some have suggested that insulin and glucagon can have paracrine effects on each other, with increases in insulin inhibiting glucagon release and vice versa. At the same time, there are direct effects of sympathetic activity on metabolism. A decrease in glucose affects glucose receptors in the central nervous system, which increases sympathetic nervous activity and results in the release of epinephrine. Epinephrine acts on the liver to increase glycogenolysis and gluconeogenesis, on skeletal muscle to increase glycogenolysis and on adipocytes to increase lipolysis. Similar actions are supported by increased sympathetic activity to the liver and adipocytes, which is mediated by norepinephrine.

Diff: 7  Page Ref: 613
7) Describe the physical mechanisms whereby heat is transferred between objects. What role does the protective layer play in that process?

Answer: Radiation refers to the transfer of energy from an object that is emitting electromagnetic waves. Thus, these waves can either be directed at the body (i.e., from the sun) or emitted from the body. Heat is always transferred from a warmer body to a colder body. You could also say that a cold environment absorbs more radiant energy.

Conduction is the transfer of energy between two solid objects that are in contact with one another. As with radiation, heat is always transferred from a warmer to a colder object.

Evaporation refers to the heat that is absorbed as water transitions from a liquid to a gaseous state. That process absorbs energy, and can either be insensible (undetectable) or sensible.

At the same time, a protective layer of air is present at the surface of the body that will decrease one’s loss of heat to the environment (convection). This barrier can also inhibit the evaporation of sweat from the skin. As that barrier is broken down by wind or water moving over the skin, the rate of temperature loss, as well as evaporation, is increased.

Diff: 5 Page Ref: 617

8) Outline how the body responds in the event that the hypothalamic thermoreceptors detect an increase in core temperature.

Answer: The thermoreceptor within the hypothalamus detects an error signal in the regulated variable. That positive error signal results in increased output to particular effectors. Sweat glands are stimulated to increase the rate of sweat production. This increases the amount of heat that the body can lose by evaporation of sweat from the skin, as long as the humidity is not too high. At the same time, the blood vessels in the skin dilate, thereby increasing the rates of conductive and radiative heat loss from the skin. The blood can carry the heat from the inner organs of the body to its cooler outer region (the skin). Both of these responses have the effect of increasing the rate at which heat is lost from the body, thereby reducing body temperature and returning core temperature to set point.

Diff: 5 Page Ref: 619

9) Describe the condition whereby the set point temperature of the body is increased in response to an infection.

Answer: The body typically maintains core temperature at 37°C. However, when we become sick, the temperature of the body is increased. In response to a bacterial or viral infection, white blood cells release pyrogens that stimulate an increase in hypothalamic set point temperature. This creates a negative error signal that must be corrected by decreased sweating, decreased skin blood flow, and muscle shivering. This decrease in the rate of sweat production reduces the amount of heat lost by evaporation. The rates of radiative and conductive heat loss from the skin are reduced as the blood vessels that feed the skin are constricted and blood flow is reduced. One of the byproducts of muscle contraction is heat. Thus, the involuntary bursts of skeletal muscle contraction (shivering) produce heat in an attempt to correct the error signal. This increase in temperature stimulates the immune system to fight the infection.

Diff: 5 Page Ref: 620
10) Growth involves the contribution of many hormones and modifiers in its regulation. However, the primary regulator of growth is growth hormone. Describe the role of growth hormone in the regulation of growth.

Answer: Growth hormone (GH) is a peptide released from the anterior pituitary. Its secretion is affected by two hypothalamic hormones: growth hormone inhibiting hormone (GHIH or somatostatin) and growth hormone releasing hormone (GHRH). These hormones, as their names suggest, are antagonistic. However, GHRH seems to be the primary regulator of GH release. In addition, GH limits its own secretion through a short negative feedback loop, whereby GH alters the hypothalamic release of GHIH and GHRH. Plasma insulin-like growth factors exert a long negative feedback loop on the hypothalamus and anterior pituitary by inhibiting the release of GHRH and GH respectively. GHRH release is regulated by neural inputs in addition to being stimulated by a reduction in plasma glucose or fatty acids and an increase in plasma amino acids. GH secretion is stimulated by stress, exercise, and sleep. Interestingly, the release of GH follows a circadian rhythm that peaks several hours after the onset of sleep. Finally, the secretion of GH decreases with age after reaching a maximum during puberty. Once released, GH affects the growth of soft tissue and bone in two ways: hypertrophy (an increase in protein synthesis and, therefore, cell size) and hyperplasia (an increase in cell division, which increases cell number). As a consequence, GH produces linear growth due to the elongation of bone, an increase in lean body mass due to an increased growth of muscle, and an increase in the size of individual organs. However, an adequate diet is essential for normal growth. There must be a sufficient supply of amino acids to support the increase in total protein mass that accompanies growth. This includes essential amino acids that we are unable to synthesize. We require adequate intake of calcium for bone growth. Finally, energy content must be available. Many of the growth promoting activities of GH act through intermediaries like insulin-like growth factors. Their synthesis from the liver is stimulated by GH to further growth.
11) The growth of bone is one of the important processes that results in an increase in height. Describe the process of bone growth, including the cells and processes involved in that growth.

Answer: Bones are composed of an epiphysis and shaft. Growth of bone involves changes in these structures. In particular, it requires the elongation of the shaft as well as its thickening. Elongation of bone occurs at the epiphyseal plate. In growing children, the epiphyseal plate is composed of chondrocytes and cartilage. The chondrocytes divide and increase in number and size. The chondrocytes near bone have a tendency to die and be replaced by osteoblasts from the bone (cells within bone that lay down bone) that move into the cartilage and begin to convert cartilage to bone. The cartilage is like osteoid, which is composed of collagen fibers in a gel-like matrix that gives bone its tensile strength. The compressive strength of bone is determined by the calcium phosphate (hydroxyapatite) crystals that are the mineral component of bone. Osteoblasts deposit bone by a process called calcification. That osteoblast will become immobilized within bone where it is transformed into an osteocyte, which functions to maintain the surrounding matrix. Osteocytes have long processes that extend along canaliculi to communicate with neighboring osteocytes to transfer nutrients and waste from cell to cell via gap junctions. The growth of the epiphyseal plate is terminated by sex hormones that induce epiphyseal plate closure. The thickening of the shaft is mediated by two processes: an increased internal diameter of the marrow cavity of the shaft and an increase in the outer diameter of the shaft. Osteoclasts are responsible for the resorption of bone that increases the diameter of the marrow cavity. These cells secrete acid, which degrades the calcium phosphate matrix of bone, and enzymes that degrade osteoid.

Diff: 7 Page Ref: 618
12) Thyroid hormone plays a role in a number of processes from metabolism to growth. Describe the regulation of thyroid hormone, how it is synthesized, and its actions.

Answer: Thyroid hormone is synthesized in the colloid of follicles in the thyroid gland. The colloid contains substances secreted from follicular cells, including thyroglobulin, iodide, and enzymes necessary for the synthesis of thyroid hormone. Thyroglobulin is the precursor for the thyroid hormones. Thyroglobulin is a protein with tyrosine residues, which become iodinated. The tyrosine can have one iodide attached to it to form monoiodotyrosine (MIT) or two iodides to form diiodotyrosine (DIT). Within a single thyroglobulin molecule, coupling takes place between either an MIT and DIT, or two DIT, in which a covalent bond is formed resulting in the production of T3 and T4, the two thyroid hormones.

T3 and T4 remain attached to the thyroglobulin in the colloid for up to three months. Release of the thyroid hormones is under control of the anterior pituitary tropic hormone TSH (which is under control of the hypothalamic tropic hormone TRH). TSH binds to receptors on the plasma membrane of follicular cells, activating the enzyme adenylate cyclase, which then converts ATP to cAMP. cAMP produces a variety of responses that lead to the release of thyroid hormones. First, thyroglobulins with attached thyroid hormones are brought into the follicular cell by phagocytosis. The resulting phagosome fuses with a lysosome. Enzymes in the lysosome catalyze the release of T3 and T4 from thyroglobulin, and these two thyroid hormones diffuse out of the follicular cell and into the bloodstream.

Ten times more T4 is released than T3, but T3 is four times more active at target cells than T4. After its release, T4 is converted into T3 by the liver, kidneys, and target cells. T4 also provides long-loop negative feedback to the release of TRH and TSH.

Thyroid hormone receptors are located in the nucleus of target cells, where thyroid hormones alter the transcription of mRNA.

The primary action of thyroid hormone is to increase metabolic rate (increase oxygen consumption). Thyroid hormone increases metabolic rate by increasing Na+/K+ pump activity, increasing the number of mitochondria, and increasing the concentration of oxidative phosphorylation enzymes. In addition to increased energy use, high concentrations of thyroid hormone increase energy mobilization by promoting glycogenolysis, degradation of protein to amino acids, lipolysis, gluconeogenesis, and ketone synthesis. Lower concentrations of thyroid hormone promote glycogenesis and protein synthesis. Many of the effects of thyroid hormone are permissive. Thyroid hormone promotes synthesis of beta adrenergic receptors, which enhance a cell’s responses to sympathetic nervous activity. Also, thyroid hormone is necessary for normal growth and development of nerves. Thyroid hormone stimulates growth hormone release and is permissive to the action of growth hormone.

Diff: 8   Page Ref: 621
13) Glucocorticoids can have an influence on metabolic processes. Describe the regulation of glucocorticoids, how they are synthesized, released, and their action.

Answer: Glucocorticoids are steroid hormones released from the adrenal cortex. The secretion of glucocorticoids is regulated by hypothalamic corticotropin releasing hormone (CRH) and anterior pituitary adrenocorticotropic hormone (ACTH). Glucocorticoids provide negative feedback for the release of CRH and ACTH. Cortisol is one of the glucocorticoids that is released in bursts. Any change in the release of cortisol involves an increase in burst frequency, not the amplitude of each burst. The release of cortisol also has a circadian rhythmicity, with the greatest release during the morning. Stress (physical or emotional) is an important stimulus for the release of cortisol. The primary action of glucocorticoids is to maintain enzymes necessary for the breakdown of proteins, fats, and glycogen, and the conversion of amino acids to glucose in the liver. Glucocorticoids are necessary for surviving a prolonged fast. Glucocorticoids are also required for the release of growth hormone and normal responsiveness of blood vessels, in addition to altering the function of the immune system, nervous system, and kidneys. An increase in glucocorticoid concentration will promote energy mobilization and spare glucose by decreasing the uptake of glucose and amino acids, stimulating lipolysis, stimulating protein breakdown in muscle, inhibiting protein synthesis, and stimulating gluconeogenesis. Glucocorticoids affect immune functions by inhibiting inflammation and allergic reactions.

Diff: 7  Page Ref: 623

Short Answer Questions

1) Iodide is bound to the _______ residues on the thyroglobulin to form either _______ or _______.
   Answer: tyrosine : monoiodotyrosine : diiodotyrosine
   Diff: 5  Page Ref: 622

2) _______ binds to its receptor on the _______ cell to stimulate the release of thyroid hormone.
   Answer: Thyroid stimulating hormone : follicle
   Diff: 4  Page Ref: 622

3) Binding of TSH to its receptor increases _______ which activates protein kinases that phosphorylate proteins that induce the _______.
   Answer: cAMP : phagocytosis of iodinated thyroglobulin
   Diff: 4  Page Ref: 622

4) Metabolism consists of _______, which is the synthesis of large molecules, and _______, which is the breakdown of large molecules into small molecules.
   Answer: anabolism : catabolism
   Diff: 3  Page Ref: 604

5) Energy intake is (continuous / intermittent).
   Answer: intermittent
   Diff: 2  Page Ref: 605
6) Once absorbed into the bloodstream, the molecule glucose requires a _______ to move into a cell.
   Answer: glucose transporter
   Diff: 4       Page Ref: 605

7) Lipids are transported in the blood from the intestinal tract to the liver in _______, and from the liver to body cells in _______.
   Answer: chylomicrons : very low density lipoproteins (VLDLs)
   Diff: 7       Page Ref: 606

8) The enzyme located on capillary endothelial cells that breaks down triglycerides is called _______.
   Answer: lipoprotein lipase
   Diff: 4       Page Ref: 606

9) In the vasculature surrounding adipocytes, the uptake of _______ from the cleavage of a triglyceride leaves the _______ behind in the blood to be metabolized by the liver.
   Answer: fatty acids : monoglyceride
   Diff: 5       Page Ref: 606

10) A majority of the energy stored in the body is converted to (heat / work) when metabolized.
    Answer: heat
    Diff: 2       Page Ref: 607

11) Excess glucose in the bloodstream that enters an adipocyte is converted to _______ for storage.
    Answer: triglyceride
    Diff: 5       Page Ref: 610

12) In the skeletal muscle, following glycogenolysis the absence of the enzyme _______ prevents the release of glucose into the bloodstream.
    Answer: glucose-6-phosphatase
    Diff: 5       Page Ref: 610

13) Most of the glycogen stores in the body are located in the (liver / skeletal muscle).
    Answer: skeletal muscle
    Diff: 4       Page Ref: 610

14) Most of the mobilizable proteins are located in the (liver / skeletal muscle).
    Answer: skeletal muscle
    Diff: 5       Page Ref: 610

15) Most energy stores in the body are in the form of (glycogen / triglyceride).
    Answer: triglyceride
    Diff: 3       Page Ref: 610

16) Glucose transport into skeletal muscle cells is (increased / decreased) by exercise, independent of insulin.
    Answer: increased
    Diff: 5       Page Ref: 613
17) Gluconeogenesis and glycogenolysis occur primarily in the _______ during the (absorptive/postabsorptive) state.
   Answer: liver : postabsorptive
   Diff: 5   Page Ref: 611

18) Insulin inserts what type of glucose transporters into body cells?
   Answer: GLUT 4
   Diff: 3   Page Ref: 613

19) What tissue is not affected by insulin?
   Answer: brain
   Diff: 6   Page Ref: 613

20) Prolonged exposure to a hot environment, where the error signal for body temperature continues to increase in a positive direction (body temperature is above set point), is called _______.
   Answer: hyperthermia
   Diff: 4   Page Ref: 617

21) What is the process whereby energy is consumed in the transition of water from liquid to a gaseous state?
   Answer: evaporation
   Diff: 4   Page Ref: 618

22) What is released by white blood cells in response to an infection, causing an increase in set point temperature?
   Answer: Pyrogens
   Diff: 3   Page Ref: 620

23) What is the range of external temperatures within which the body needs only to make adjustments in skin blood flow to maintain set point temperature?
   Answer: thermoneutral zone
   Diff: 4   Page Ref: 619

24) What growth spurt is stimulated by sex hormones?
   Answer: pubertal
   Diff: 3   Page Ref: 617

25) Insulin–like growth factors can act locally as _______ or distantly as _______.
   Answer: a paracrine : a hormone
   Diff: 4   Page Ref: 618

26) What tropic hormone(s) affects growth hormone release?
   Answer: growth hormone releasing hormone and growth hormone inhibiting hormone
   Diff: 5   Page Ref: 618

27) When does the peak release of growth hormone occur?
   Answer: at the onset of sleep
   Diff: 5   Page Ref: 618
28) Cells located within channels through bone called _______ contain gap junctions, which allow for transfer of nutrients between cells within bone.

Answer: canaliculi
Diff: 5  Page Ref: 618

29) Osteoclasts secrete _______ that dissolve calcium phosphate to initiate the _______ of bone.

Answer: acids : resorption
Diff: 5  Page Ref: 619

30) _______ stimulate the closure of the epiphyseal plate, thereby ending growth.

Answer: Sex hormones
Diff: 4  Page Ref: 620

31) (Red/Yellow) bone marrow produces red and white blood cells.

Answer: red
Diff: 4  Page Ref: 620

32) What second messenger triggers release of thyroid hormones?

Answer: cAMP
Diff: 4  Page Ref: 622

33) How many iodide residues are in T3? T4?

Answer: 3, 4
Diff: 4  Page Ref: 622

34) Name the three proteins that transport thyroid hormones in blood.

Answer: thyroxine-binding globulin, transthyretin, and albumin
Diff: 6  Page Ref: 622

35) The release of thyrotropin releasing hormone is stimulated by (warm / cold) temperatures.

Answer: cold
Diff: 4  Page Ref: 622

36) Glucocorticoids (increase/decrease) plasma glucose levels.

Answer: increase
Diff: 4  Page Ref: 624

37) Glucocorticoids are used pharmacologically to treat (obesity / inflammation).

Answer: inflammation
Diff: 4  Page Ref: 624
38) Identify the structures labeled in the figure below.

Answer: A. epiphyseal plate  
B. chondrocytes  
C. osteoblasts  

Diff: 5 Page Ref: 620
Chapter 22  The Reproductive System

Multiple Choice Questions

1) ________ is the process whereby gametes from each parent fuse to produce a new cell.
   A) Independent assortment  
   B) Gametogenesis  
   C) Fertilization  
   D) Oogenesis  
   E) Spermatogenesis  
   Answer: C  
   Diff: 3  Page Ref: 633

2) Autosomes are described as ________ because they are formed into matching pairs.
   A) heterologous  
   B) homologous  
   C) haploid  
   D) zygotic  
   E) clonal  
   Answer: B  
   Diff: 3  Page Ref: 633

3) What describes the process where portions of homologous chromosomes exchange segments with one another?
   A) Meiotic overlap  
   B) Clonal exchange  
   C) Homologous exchange  
   D) Crossing over  
   E) Independent assortment  
   Answer: D  
   Diff: 4  Page Ref: 634

4) After the second meiotic division, each cell contains ________.
   A) a random mixture of maternal and paternal alleles on each of two sister chromatids  
   B) a maternal and a paternal sister chromatid  
   C) either two maternal or two paternal sister chromatids  
   D) either a maternal or a paternal sister chromatid  
   E) a random mixture of maternal and paternal alleles on one sister chromatid  
   Answer: E  
   Diff: 5  Page Ref: 635

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5) ________, the general term for the primary reproductive organs, are responsible for the secretion of ________ in females.
   A) Gonads : androgens (testosterone)
   B) Gonads : estrogens (estradiol) and progesterone
   C) Testes : androgens (testosterone)
   D) Ovaries : estrogens (estradiol) and progesterone
   E) Ovaries : androgens (testosterone)

Answer: B
Diff: 4    Page Ref: 635

6) What are gonadotrophs?
   A) cells of the hypothalamus that secrete GnRH
   B) cells of the anterior pituitary that secrete FSH and LH
   C) hormones of the gonads
   D) cells of the gonads that secrete sex hormones
   E) growth factors for sexual differentiation

Answer: B
Diff: 4    Page Ref: 641

7) What is the function of the accessory reproductive organs?
   A) secondary sex characteristics only
   B) the secretion of sex hormones only
   C) secretion of fluids into the reproductive tract only
   D) transport of gametes only
   E) both secretion of fluids into the reproductive tract and transport of gametes

Answer: E
Diff: 4    Page Ref: 635

8) Sex determination of a fetus is controlled by the production of ________, which is coded for by the ________ gene.
   A) gonad−determining factor : gdY
   B) testis−determining factor : tdY
   C) testis−determining factor : srY
   D) ovary−determining factor : srY
   E) ovary−determining factor : odY

Answer: C
Diff: 5    Page Ref: 635

9) The absence of ________ in the fetus will further the development of the ________ into the female reproductive tract.
   A) androgens : Wolffian ducts
   B) Müllerian−promoting substance : Wolffian ducts
   C) androgens : Müllerian ducts
   D) Wolffian−inhibiting substance : Wolffian ducts
   E) Müllerian−inhibiting substance : Müllerian ducts

Answer: E
Diff: 6    Page Ref: 637
10) In the female reproductive cycle, _______ is/are normally produced every 28 days.
   A) millions of sperm
   B) several ova
   C) two ova
   D) a single ovum
   E) a single sperm

   Answer: D
   Diff: 3 Page Ref: 638

11) The loss of reproductive capacity that occurs as females age is caused by ________.
   A) changes in hormone secretory patterns
   B) inability to release an ovum in the presence of luteinizing hormone (LH) surge
   C) the release of incompetent ova
   D) the complete cessation of sex hormone release
   E) altered length of the menstrual cycle

   Answer: A
   Diff: 4 Page Ref: 638

12) In what region of the testes are sperm produced?
   A) vas deferens
   B) seminiferous tubules
   C) epididymis
   D) efferent ductules
   E) rete testes

   Answer: B
   Diff: 4 Page Ref: 639

13) Which of the following best describes the function of the blood-testis barrier?
   A) The blood-testis barrier maintains a differential fluid composition of the seminiferous
      tubule lumen that facilitates development of sperm and protects sperm from the immune
      system.
   B) The blood-testis barrier maintains a differential fluid composition of the seminiferous
      tubule lumen that facilitates the development of sperm and blocks the access of
      androgens to the lumen.
   C) The blood-testis barrier maintains a differential fluid composition of the seminiferous
      tubule lumen that facilitates the entry of inhibin into the lumen, thereby decreasing
      sperm production.
   D) The blood-testis barrier maintains a differential fluid composition of the epididymis
      tubule lumen that facilitates movement of sperm during emission.
   E) The blood-testis barrier maintains a differential fluid composition of the epididymis
      tubule lumen that favors maintaining high concentrations of androgens in the lumen to
      facilitate sperm production.

   Answer: A
   Diff: 5 Page Ref: 640
14) What is the function of androgen-binding protein?
   A) transport androgens in blood
   B) transport androgens across the blood-testis barrier
   C) maintain steady levels of androgens in the lumen of seminiferous tubules
   D) provides negative feedback for the release of follicle stimulating hormone
   E) provides positive feedback for the release of luteinizing hormone

Answer: C
Diff: 4  Page Ref: 640

15) Which of the following is NOT a function of Sertoli cells?
   A) secrete fluid into the lumen of seminiferous tubules to support sperm development
   B) secrete androgens
   C) provide nutrients for developing sperm
   D) form the blood-testis barrier
   E) secrete paracrines that stimulate spermatogenesis

Answer: B
Diff: 4  Page Ref: 640

16) Follicle-stimulating hormone (FSH) and testosterone stimulate the growth and development of sperm ________.
   A) directly by binding to sperm
   B) indirectly by binding to Sertoli cells
   C) indirectly by binding to Leydig cells
   D) indirectly by binding to androgen-binding protein
   E) indirectly by binding to interstitial cells

Answer: B
Diff: 4  Page Ref: 640

17) What is the function of Leydig cells?
   A) secrete androgens only
   B) secrete Müllerian inhibiting substance only
   C) provide nutrients for developing sperm only
   D) both secrete androgens and provide nutrients for developing sperm
   E) secrete androgens, provide nutrients for developing sperm, and secrete Müllerian inhibiting substance

Answer: A
Diff: 4  Page Ref: 639

18) What cells secrete Müllerian inhibiting substance in fetal life?
   A) follicle cell
   B) theca cell
   C) granulosa cell
   D) Leydig cell
   E) Sertoli cell

Answer: E
Diff: 4  Page Ref: 640
19) The ______ erectile tissue increases during sexual arousal, causing the penis to become erect.
   A) amount of
   B) reduction of blood pressure within the
   C) tightening of the connective tissue within the
   D) contraction of the
   E) volume of blood within the

   Answer: E
   Diff: 4   Page Ref: 640

20) What is the function of the scrotum?
   A) transports sperm from testes to penis
   B) keeps the temperature of the testes less than body temperature for normal sperm development
   C) contains vascular spaces that become engorged with blood to induce an erection
   D) provides blood flow to the erectile tissue
   E) secretes chemicals into the male reproductive track during emission

   Answer: B
   Diff: 3   Page Ref: 640

21) What transports sperm from the epididymis to the ejaculatory duct?
   A) scrotum
   B) vas deferens
   C) rete testis
   D) seminal vesicles
   E) urethra

   Answer: B
   Diff: 4   Page Ref: 641

22) What secretes an alkaline fluid containing fructose, enzymes, and prostaglandins into the ejaculatory duct?
   A) seminal vesicle
   B) prostate gland
   C) bulbourethral gland
   D) epididymis
   E) Sertoli cell

   Answer: A
   Diff: 4   Page Ref: 641

23) What secretes several enzymes and citrate into the urethra during ejaculation?
   A) seminal vesicle
   B) prostate gland
   C) bulbourethral gland
   D) epididymis
   E) Sertoli cell

   Answer: B
   Diff: 4   Page Ref: 641
24) What does luteinizing hormone (LH) cause in males?
   A) growth of accessory reproductive organs
   B) promoting spermatogenesis
   C) stimulating ejaculation
   D) secretion of androgens from the Leydig cells
   E) secretion of chemicals from Sertoli cells that stimulate sperm maturation
   Answer: D
   Diff: 4   Page Ref: 641

25) Inhibin is secreted from the _______ and acts to reduce the secretion of ________.
   A) Leydig cells: follicle-stimulating hormone (FSH)
   B) hypothalamus: luteinizing hormone (LH)
   C) anterior pituitary: FSH
   D) Leydig cells: LH
   E) Sertoli cells: FSH
   Answer: E
   Diff: 5   Page Ref: 641

26) Spermatogenesis is directly stimulated by ________.
   A) FSH only
   B) LH only
   C) testosterone only
   D) both FSH and testosterone
   E) both LH and testosterone
   Answer: D
   Diff: 5   Page Ref: 641

27) What hormone is responsible for secondary sex characteristics in males?
   A) LH
   B) FSH
   C) testosterone
   D) inhibin
   E) Wolffian factor
   Answer: C
   Diff: 3   Page Ref: 641

28) Which of the following is NOT stimulated by the surge of testosterone that occurs at puberty?
   A) the release of gonadotropin-releasing hormone (GnRH)
   B) secretion of growth hormone from the anterior pituitary
   C) increased protein synthesis in muscle
   D) secretion of a thick oil by sebaceous glands
   E) spermatogenesis
   Answer: A
   Diff: 4   Page Ref: 642
29) Enzymes that facilitate entry of sperm into the ova are contained within the _______ of the spermatozoa.
   A) midpiece
   B) tail
   C) acrosome
   D) mitochondria
   E) flagella
   Answer: C
   Diff: 4   Page Ref: 642

30) Where are spermatogonia located?
   A) anywhere within the seminiferous tubules
   B) attached to Leydig cells
   C) on the luminal surface of the Sertoli cell
   D) at the basement membrane–Sertoli cell interface
   E) in the epididymis
   Answer: D
   Diff: 4   Page Ref: 642

31) Which of the following is the correct order of sperm development?
   A) spermatid — primary spermatocyte — secondary spermatocyte — spermatogonia — spermatozoa
   B) spermatid — secondary spermatocyte — primary spermatocyte — spermatogonia — spermatozoa
   C) spermatozoa — spermatogonia — primary spermatocyte — secondary spermatocyte — spermatid
   D) spermatogonia — primary spermatocyte — secondary spermatocyte — spermatid — spermatozoa
   E) spermatogonia — primary spermatocyte — secondary spermatocyte — spermatozoa — spermatid
   Answer: D
   Diff: 4   Page Ref: 643

32) How do males continue to produce sperm through their adult lives?
   A) Spermatozoa can undergo cell division daily.
   B) When a spermatogonium undergoes mitosis, only one undergoes further differentiation to become a mature sperm; the other stays a spermatogonium.
   C) Testosterone levels remain elevated throughout adulthood.
   D) Secondary spermatocytes produce an endless supply of primary spermatocytes.
   E) Sperm cells never die.
   Answer: B
   Diff: 5   Page Ref: 643
33) During spermatogenesis, the ________ are haploid cells that require further differentiation in order to become functional spermatozoa.
   A) primary spermatocytes
   B) spermatogonia
   C) spermatids
   D) secondary spermatocytes
   E) tertiary spermatocytes

   Answer: C
   Diff: 5   Page Ref: 643

34) When do sperm acquire motility?
   A) after they enter the vagina
   B) after they enter the efferent ductule
   C) after they pass through the epididymis
   D) after they have been exposed to bulbourethral fluid
   E) after they have been exposed to fluid in the female reproductive tract

   Answer: C
   Diff: 4   Page Ref: 643

35) What neurotransmitter is released from parasympathetic nerves to dilate the penile arterioles to increase blood flow to the erectile tissue?
   A) nitric oxide
   B) acetylcholine
   C) norepinephrine
   D) serotonin
   E) histamine

   Answer: A
   Diff: 4   Page Ref: 644

36) Erectile function requires an increase in _______, whereas ejaculation involves increases in ________.
   A) parasympathetic nervous activity : myogenic constriction of the vas deferens
   B) sympathetic nervous activity : parasympathetic nervous activity
   C) parasympathetic nervous activity : sympathetic nervous activity
   D) myogenic dilation of vessels within erectile tissue : sympathetic nervous activity
   E) myogenic dilation of vessels within erectile tissue : myogenic constriction of the vas deferens

   Answer: C
   Diff: 4   Page Ref: 644

37) Which of the following structures does NOT contract during ejaculation?
   A) epididymis
   B) vas deferens
   C) ejaculatory duct
   D) erectile tissue
   E) skeletal muscles at the base of the penis

   Answer: D
   Diff: 4   Page Ref: 644
38) The mixture of sperm with fluid from the seminal vesicles and prostate gland is called ________.
   A) erection  
   B) ejaculation  
   C) insemination  
   D) emission  
   E) micturition
   Answer: D  
   Diff: 4  Page Ref: 644

39) Within the ovaries, each follicle contains ________.
   A) a single oocyte  
   B) multiple oocyte  
   C) a single fertilized ovum  
   D) a single dense body  
   E) two dense bodies and two ova
   Answer: A  
   Diff: 3  Page Ref: 647

40) Mature ova develop from a pool of oogonia that ________.
   A) will expand until puberty when the ova begin to mature  
   B) continue to expand after birth with few of those ever developing into mature ova  
   C) are fixed in number at birth with each one developing into a mature ova  
   D) undergo mitosis to maintain the number of oogonia as they mature into ova  
   E) are fixed at birth with few ever developing into mature ova
   Answer: E  
   Diff: 4  Page Ref: 648

41) Each ova is embedded within a ________ and only a small proportion will advance beyond ________.
   A) follicle: granulosa stage  
   B) follicle: primordial follicle  
   C) granulosa: primordial follicle  
   D) theca: granulosa stage  
   E) follicle: thecal stage
   Answer: B  
   Diff: 4  Page Ref: 648

42) Which of the following is NOT a function of the granulosa cells?
   A) secretion of inhibin  
   B) secretion of estrogens  
   C) secretion of a substance that forms the zona pellucida  
   D) secretion of androgen-binding protein  
   E) secretion of paracrines that support follicle development
   Answer: D  
   Diff: 4  Page Ref: 647
43) What is the outer epithelial and connective tissue layer of the uterus?
   A) perimetrium
   B) myometrium
   C) endometrium
   D) epimetrium
   E) sarcometrium
   Answer: A
   Diff: 4 Page Ref: 647

44) Most of the uterine wall thickness is composed of the ________.
   A) perimetrium
   B) myometrium
   C) endometrium
   D) epimetrium
   E) parametrium
   Answer: B
   Diff: 4 Page Ref: 647

45) A follicle in its earliest stage of development is called a ________ and contains a ________.
   A) primordial follicle: oogonia
   B) primordial follicle: primary oocyte
   C) Graafian follicle: oogonia
   D) Graafian follicle: primary oocyte
   E) primary follicle: primary oocyte
   Answer: A
   Diff: 6 Page Ref: 647

46) What structure(s) forms the birth canal?
   A) vagina only
   B) uterus only
   C) cervical canal only
   D) both vagina and cervical canal
   E) vagina, cervical canal, and uterus
   Answer: D
   Diff: 4 Page Ref: 647

47) Where does fertilization usually occur?
   A) vagina
   B) cervical canal
   C) uterus
   D) uterine tube
   E) ovary
   Answer: D
   Diff: 3 Page Ref: 647
48) What secretes a lubricating fluid into the vagina that facilitates the entry of the penis during copulation?
   A) vestibular gland  
   B) cervix  
   C) uterus  
   D) labia minor  
   E) hymen  
   Answer: A  
   Diff: 4 Page Ref: 647

49) Each oocyte remains under meiotic arrest until just before _______.  
   A) birth  
   B) puberty  
   C) ovulation  
   D) the third month of embryonic life  
   E) fertilization  
   Answer: C  
   Diff: 4 Page Ref: 648

50) When does the second meiotic division in oogenesis occur?  
   A) when the female reaches puberty  
   B) when the ovum has been fertilized  
   C) when the ovum reaches the uterine tube  
   D) when the ovum is released from the ovary  
   E) when stimulated by the first polar body  
   Answer: B  
   Diff: 4 Page Ref: 648

51) What is meiotic arrest?  
   A) the pause in spermatogenesis that occurs following an ejaculation  
   B) the pause in oogenesis that occurs between birth and ovulation  
   C) the termination of oogenesis that occurs after menopause  
   D) the pause in oogenesis that occurs after fertilization  
   E) the switch from meiosis to mitosis that occurs after fertilization  
   Answer: B  
   Diff: 4 Page Ref: 648

52) When is the second polar body produced?  
   A) following meiosis I in males  
   B) following meiosis I in females  
   C) following meiosis II in males  
   D) following meiosis II in females  
   E) following differentiation of cells in the zygote  
   Answer: D  
   Diff: 4 Page Ref: 648
53) The follicular phase of the ovarian cycle corresponds with what phase(s) of the uterine cycle?
   A) menstrual phase only
   B) proliferative phase only
   C) secretory phase only
   D) both menstrual and proliferative phases
   E) both proliferative and secretory phases

   Answer: D
   Diff: 4 Page Ref: 649

54) During the follicular phase of the ovarian cycle, one follicle (the dominant follicle) will continue to develop because its cells ________.
   A) maintain estrogen secretion
   B) have a diminished response to follicle-stimulating hormone (FSH)
   C) are unresponsive to luteinizing hormone (LH)
   D) are no longer able to secrete estrogen
   E) no longer respond to FSH

   Answer: A
   Diff: 5 Page Ref: 649

55) When does the zona pellucida develop?
   A) when follicles are in the primordial phase
   B) when follicles are in the preantral stage
   C) when follicles are in the early antral stage
   D) when follicles are in the late antral stage
   E) after fertilization

   Answer: B
   Diff: 5 Page Ref: 649

56) What is the cumulus oophorus?
   A) a fluid-filled cavity in the follicle
   B) a thick membrane between the oocyte and granulosa cells
   C) a degenerated follicle after ovulation
   D) granulosa cells that connect the oocyte to the wall of the Graafian follicle
   E) the remnants of a non-dominant follicle after it has undergone atresia

   Answer: D
   Diff: 6 Page Ref: 649

57) What hormone stimulates follicle growth?
   A) FSH only
   B) progesterone only
   C) estrogens only
   D) both FSH and estrogens
   E) FSH, estrogens, and progesterone

   Answer: D
   Diff: 5 Page Ref: 649
58) Which of the following is a correct association between oocyte development and follicular phase?
   A) Graafian follicle – oogonia
   B) Graafian follicle – primary oocyte
   C) Graafian follicle – secondary oocyte
   D) primordial follicle – primary oocyte
   E) primordial follicle – ovum
Answer: C
Diff: 6 Page Ref: 649

59) During ovulation, how is an oocyte released by the ovary?
   A) exocytosis
   B) primary active transport
   C) diapedesis
   D) margination
   E) the follicle with the oocyte bursts
Answer: E
Diff: 3 Page Ref: 649

60) What does the surge in plasma luteinizing hormone that occurs at the beginning of the luteal phase trigger?
   A) ovulation only
   B) development of the corpus luteum only
   C) stimulation of the first meiotic division only
   D) both ovulation and development of the corpus luteum
   E) both ovulation and stimulation of the first meiotic division
Answer: D
Diff: 4 Page Ref: 654

61) The migration of sperm into the uterus, where they can contact the ovum, is facilitated by the secretion of ________ into the ________.
   A) estrogen : uterine tube
   B) progesterone : uterine tube
   C) a thin mucus : cervical canal
   D) an acidic solution : cervical canal
   E) an alkaline solution : uterine tube
Answer: C
Diff: 4 Page Ref: 651

62) Which of the following changes in the uterus does NOT occur during the secretory phase of the uterine cycle?
   A) enhanced secretion of fluids rich in fructose
   B) endometrium enriched with more arterial branches
   C) enlargement of endometrial glands
   D) enhanced secretion of fluids rich in glycogen
   E) increased viscosity of secretions from cervical glands
Answer: A
Diff: 4 Page Ref: 652
63) The changes in the uterus that occur during the secretory phase of the uterine cycle are mediated by _______.
   A) increased estrogen from the adrenal cortex
   B) increased progesterone from the corpus luteum
   C) decreased estrogen from the adrenal cortex
   D) increased estrogen from the ovaries
   E) increased progesterone from the ovaries
   
   Answer: B
   Diff: 4 Page Ref: 654

64) In the absence of the implantation of a fertilized embryo, the menstrual phase of the uterine cycle is initiated by the degeneration of the _______.
   A) myometrium
   B) corpus albicans
   C) endometrium
   D) corpus luteum
   E) Graafian follicle
   
   Answer: D
   Diff: 4 Page Ref: 652

65) In the uterine cycle, the proliferative phase is promoted by _______, whereas the secretory phase is promoted by _______.
   A) estrogen : progesterone
   B) progesterone : estrogen
   C) progesterone : progesterone
   D) LH : FSH
   E) FSH : LH
   
   Answer: A
   Diff: 4 Page Ref: 653

66) The reduction in progesterone and estrogen that occurs at the beginning of the follicular phase is responsible for stimulating follicular development through _______.
   A) stimulating the release of progesterone
   B) stimulating the release of luteinizing hormone (LH)
   C) inhibiting the release of LH
   D) inhibiting the release of follicle-stimulating hormone (FSH)
   E) stimulating the release of FSH
   
   Answer: E
   Diff: 4 Page Ref: 653

67) The secretory activity of the anterior pituitary begins to change during late follicular phase such that _______.
   A) estrogen increases the release of luteinizing hormone (LH)
   B) estrogen decreases the release of follicle-stimulating hormone (FSH)
   C) inhibin stimulates the release of FSH
   D) gonadotropin increases the release of LH
   E) inhibin stimulates the release of LH
   
   Answer: A
   Diff: 4 Page Ref: 654
68) Which of the following is NOT a response of the dominant follicle to stimulation by luteinizing hormone (LH) during the late follicular phase?
   A) the secretion of paracrines by the granulosa cells that stimulates the completion of meiosis I
   B) the decrease in estrogen secretion by granulosa cells
   C) the decrease in expression of LH receptors by granulosa cells
   D) the secretion of enzymes by the granulosa cells that degrades the follicle wall
   E) the onset of differentiation of granulosa cells into the corpus luteum

   Answer: C
   Diff: 5    Page Ref: 654

69) What hormone(s) is secreted by the corpus luteum?
   A) progesterone only
   B) inhibin only
   C) estrogens only
   D) both progesterone and estrogens
   E) progesterone, estrogens, and inhibin

   Answer: E
   Diff: 5    Page Ref: 654

70) The hormonal trigger for menstruation involves a ________.
   A) drop in plasma luteinizing hormone (LH)
   B) reduction of inhibin secretion
   C) loss of estrogen secretion from the adrenal cortex
   D) reduction of plasma follicle-stimulating hormone (FSH)
   E) loss of progesterone secretion from the corpus luteum

   Answer: E
   Diff: 4    Page Ref: 654

71) The elevated plasma concentration of estrogen early in the luteal phase has little effect on the secretion of luteinizing hormone (LH) because ________.
   A) inhibin strongly inhibits LH release
   B) progesterone strongly inhibits LH release
   C) gonadotropin-releasing hormone (GnRH) is reduced
   D) the corpus luteum degenerates
   E) secretin release is inhibited

   Answer: B
   Diff: 6    Page Ref: 654

72) Which of the following conditions is NOT induced by the reduction in estrogen release that occurs during menopause?
   A) decreased breast size
   B) loss of ovulation
   C) increased risk of heart disease
   D) increased risk for osteoporosis
   E) absence of sexual arousal

   Answer: E
   Diff: 5    Page Ref: 655
73) Sperm are unable to fertilize the egg upon entry into the vagina and must undergo ______, allowing them to ______, which facilitates fertilization.
   A) resituation : activate the acrosome
   B) resituation : move faster
   C) capacitation : more readily adhere to the ovum
   D) capacitation : activate the acrosome
   E) implantation : move faster

Answer: C
Diff: 4    Page Ref: 655

74) Which of the following best describes the events that take place when the first sperm binds to the oocyte?
   A) The entire sperm is transported into the cytoplasm of the oocyte, where the nucleus of the sperm releases its DNA to combine with the DNA of the oocyte and replication occurs. The oocyte then undergoes the first meiotic division.
   B) The entire sperm is transported into the cytoplasm of the oocyte, where the nucleus of the sperm releases its DNA to combine with the DNA of the oocyte and transcription occurs. The oocyte then undergoes the second meiotic division.
   C) The head of the sperm is transported into the cytoplasm of the oocyte, where the nucleus of the sperm releases its DNA to combine with the DNA of the oocyte and transcription occurs. The oocyte then undergoes the first meiotic division.
   D) The head of the sperm is transported into the cytoplasm of the oocyte, where the nucleus of the sperm releases its DNA to combine with the DNA of the oocyte and replication occurs. The oocyte then undergoes the second meiotic division.
   E) The head of the sperm is transported into the cytoplasm of the oocyte, where the nucleus of the sperm releases its DNA to combine with the DNA of the oocyte and transcription occurs. The oocyte then undergoes the second meiotic division.

Answer: D
Diff: 5    Page Ref: 657

75) Which of the following prevents polyspermy?
   A) inactivation of sperm-binding proteins in the zona pellucida and release of toxins to sperm by the fertilized ovum
   B) release of toxins to sperm by the fertilized ovum and hardening of the zona pellucida
   C) inactivation of sperm-binding proteins in the zona pellucida and hardening of the zona pellucida
   D) sealing of the corona radiata and hardening of the zona pellucida
   E) sealing of the corona radiata and release of toxins to sperm by the fertilized ovum

Answer: C
Diff: 5    Page Ref: 657

76) A morula develops by ______.
   A) meiosis I
   B) meiosis II
   C) mitosis
   D) cell cleavage
   E) cell differentiation

Answer: D
Diff: 4    Page Ref: 657
77) Implantation of the blastocyst into the endometrium results from _______.
   A) blastocoele secretion of paracrines that initiates cell cleavage
   B) trophoblast secretion of paracrines that initiates cell cleavage
   C) blastocoele secretion of paracrines that initiates the decidual response
   D) trophoblast secretion of endocrine hormones that initiates the decidual response
   E) trophoblast secretion of paracrines that initiates the decidual response

   Answer: E
   Diff: 4    Page Ref: 657

78) How do monozygotic twins develop?
   A) splitting of the blastocyst
   B) splitting of the morula while cells are still totipotent
   C) inappropriate implantation of the embryo into the endometrium
   D) fertilization of more than one ova
   E) polyspermy

   Answer: B
   Diff: 4    Page Ref: 657

79) The placenta forms from _______.
   A) the trophoblast only
   B) the blastocoele only
   C) endometrial tissue of the mother only
   D) both the trophoblast and endometrial tissue of the mother
   E) both the blastocoele and endometrial tissue of the mother

   Answer: D
   Diff: 4    Page Ref: 657

80) What is the function of the amniotic fluid?
   A) float the developing embryo
   B) protect the uterus from the embryo
   C) provide the intrauterine pressure that facilitates embryonic development
   D) cushion the developing embryo against physical trauma
   E) provide nutrients for the developing embryo

   Answer: D
   Diff: 4    Page Ref: 658

81) Once diffusion from the endometrium becomes inadequate for delivery of oxygen, the placenta develops from projections of the _______, which facilitates exchange of nutrients and waste by the _______.
   A) chorionic villi into the embryo: short distance between maternal and fetal blood
   B) chorionic villi into the embryo: mixing of maternal and fetal blood
   C) amnionic villi into the endometrium: short distance between maternal and fetal blood
   D) chorionic villi into the endometrium: mixing of maternal and fetal blood
   E) chorionic villi into the endometrium: short distance between maternal and fetal blood

   Answer: E
   Diff: 4    Page Ref: 659
82) The secretion of estrogen and progesterone by the corpus luteum is maintained during pregnancy by ________ until the corpus luteum degenerates and the ________ takes over secretion of these hormones.
   A) human chorionic gonadotropin (hCG) : placenta
   B) luteinizing hormone (LH) : placenta
   C) hCG : fetus
   D) LH : endometrium
   E) hCG : endometrium

Answer: A
Diff: 4   Page Ref: 659

83) Which of the following is NOT a mechanism whereby estrogen maintains the body during pregnancy and prepares the body for delivery?
   A) the development of tissue that carries milk to the nipples
   B) the deposition of fatty tissues in the breast
   C) the secretion of prolactin
   D) the growth of glandular tissue in the breast
   E) the growth of uterine smooth muscle cells

Answer: D
Diff: 5   Page Ref: 660

84) Which of the following is NOT one of the effects of progesterone that maintains the body for pregnancy and prepares the body for parturition?
   A) the maintenance of thickened myometrium
   B) the maintenance of thickened endometrium
   C) the secretion of prolactin
   D) the growth of glandular tissue in the breast
   E) the suppression of contractile activity of uterine smooth muscle cells

Answer: C
Diff: 6   Page Ref: 660

85) The activity of smooth muscle cells of the myometrium is regulated by estrogen, which increases responsiveness of the myometrium to what hormone?
   A) progesterone
   B) prolactin
   C) oxytocin
   D) human chorionic gonadotropin (hCG)
   E) norepinephrine

Answer: A
Diff: 4   Page Ref: 660

86) The ________ in secretion of luteinizing hormone (LH) and follicle-stimulating hormone (FSH) during pregnancy is regulated primarily by ________.
   A) decrease : progesterone
   B) decrease : estrogen
   C) decrease : gonadotropin-releasing hormone (GnRH)
   D) decrease : human chorionic gonadotropin (hCG)
   E) increase : oxytocin

Answer: A
Diff: 5   Page Ref: 661
87) The ripening of the cervix in the weeks prior to parturition involves _______.
   A) slow opening of the birth canal
   B) increased flexibility of the cervix
   C) rupture of the amniotic sac
   D) rotation of the fetus in the uterus
   E) frequent uterine contractions

   Answer: B
   Diff: 4 Page Ref: 661

88) Which of the following is a function of oxytocin?
   A) inhibits uterine contractions
   B) stimulates prolactin release
   C) inhibits contraction of breast myoepithelial cells
   D) stimulates release of estrogens and progesterone
   E) stimulates the release of prostaglandins from myometrial cells

   Answer: E
   Diff: 5 Page Ref: 662

89) What is the function of prostaglandins during parturition?
   A) stimulate mucus secretion to lubricate the cervix and vagina
   B) stimulate the softening of the cervix so it can dilate
   C) stimulate uterine contraction
   D) inhibit blood flow through the umbilical cord to prevent excessive bleeding
   E) inhibit the inflammatory response as tissue is abraded during delivery

   Answer: C
   Diff: 4 Page Ref: 662

90) Fetal release of _______ appears to be partly responsible for stimulating parturition.
   A) human chorionic gonadotropin (hCG)
   B) gonadotropin–releasing hormone (GnRH)
   C) corticotropin–releasing hormone (CRH)
   D) estrogen
   E) progesterone

   Answer: C
   Diff: 5 Page Ref: 662

91) Abnormally elevated thirst and urination can be signs of what disease that occurs in pregnant women?
   A) gestational diabetes
   B) hyperprolactinemia
   C) placental insufficiency
   D) miscarriage
   E) ectopic pregnancy

   Answer: A
   Diff: 5 Page Ref: 660
92) Which of the following is NOT one of the nutrients found in breast milk after the first week?
   A) colostrum  
   B) fat  
   C) lactose  
   D) growth factors  
   E) antibodies

   Answer: A  
   Diff: 4   Page Ref: 663

93) The ejection of milk that occurs while the infant is suckling is mediated by _______.
   A) prolactin–induced myoepithelial cell contraction  
   B) local reflex–induced myoepithelial cell contraction  
   C) myogenic contraction of myoepithelial cells  
   D) oxytocin–induced myoepithelial cell contraction  
   E) acetylcholine–induced myoepithelial cell contraction

   Answer: D  
   Diff: 4   Page Ref: 663

94) The production of milk is stimulated by release of _______ from the hypothalamus.
   A) corticotropin–releasing hormone (CRH)  
   B) gonadotropin–releasing hormone (GnRH)  
   C) oxytocin  
   D) prolactin–inhibiting hormone (PIH)  
   E) prolactin–releasing hormone (PRH)

   Answer: E  
   Diff: 4   Page Ref: 664

95) Which part of the blastocyst develops into the fetus?
   A) blastocoele  
   B) morula  
   C) inner cell mass  
   D) outer cell mass  
   E) trophoblast

   Answer: C  
   Diff: 3   Page Ref: 657

96) Which of the following is TRUE of Sertoli cells, but not granulosa cells?
   A) secretes paracrine factors that support gamete development  
   B) provides nutrients for developing gametes  
   C) forms a barrier between the fluid surrounding the gamete and blood  
   D) secretes inhibin  
   E) secretes androgen–binding protein

   Answer: E  
   Diff: 5   Page Ref: 640
True/False Questions

1) The X chromosome is necessary for life, meaning that a YY individual with no X chromosome will not survive.
   Answer: TRUE
   Diff: 3  Page Ref: 633

2) The srY gene is located on the Y chromosome and determines a person's sex.
   Answer: TRUE
   Diff: 3  Page Ref: 635

3) Sex differentiation depends on the presence or absence of the srY gene, whereas sex determination depends on the presence or absence of testes.
   Answer: FALSE
   Diff: 4  Page Ref: 637

4) The Müllerian ducts are precursors for the male reproductive tract.
   Answer: FALSE
   Diff: 3  Page Ref: 635

5) In the years before puberty, the reproductive organs are immature and incapable of generating sperm or ova.
   Answer: TRUE
   Diff: 2  Page Ref: 637

6) Men are capable of producing sperm throughout their entire adult life.
   Answer: TRUE
   Diff: 3  Page Ref: 638

7) Each Sertoli cell is joined to its neighbors by tight junctions.
   Answer: TRUE
   Diff: 3  Page Ref: 640

8) Spermatogenesis occurs in the epididymis.
   Answer: FALSE
   Diff: 3  Page Ref: 637

9) Testosterone acts as a paracrine in the testes to promote spermatogenesis.
   Answer: TRUE
   Diff: 3  Page Ref: 639

10) Changes in brain activity stimulate hypothalamic secretion of gonadotropin–releasing hormone (GnRH), which initiates puberty.
    Answer: TRUE
    Diff: 4  Page Ref: 642

11) The acrosome is a vesicle in the head of the sperm that contains enzymes for fusion with the oocyte.
    Answer: TRUE
    Diff: 3  Page Ref: 642
12) Ejaculation is controlled by a spinal reflex, which activates the sympathetic nervous system.
   Answer: TRUE  
   Diff: 4  Page Ref: 644

13) The outer layer of the follicle is populated by theca cells that synthesize androgens.
   Answer: TRUE  
   Diff: 4  Page Ref: 647

14) The endometrium is a muscular layer of the uterus.
   Answer: FALSE  
   Diff: 3  Page Ref: 647

15) Fertilization of the ovum usually occurs within the uterus.
   Answer: FALSE  
   Diff: 3  Page Ref: 647

16) During the follicular phase, 10–25 follicles begin to develop but only one will usually be released at ovulation.
   Answer: TRUE  
   Diff: 4  Page Ref: 647

17) A female is born with all the oogonia she will ever have, but a male can continually replace his spermatogonia.
   Answer: TRUE  
   Diff: 4  Page Ref: 648

18) The granulosa cells provide nutrients for the developing oocyte via gap junctions.
   Answer: TRUE  
   Diff: 4  Page Ref: 649

19) A corpus albicans is produced during each meiotic division of an oocyte.
   Answer: FALSE  
   Diff: 4  Page Ref: 651

20) During the menstrual phase, all of the endometrium is shed in the menstrual flow.
   Answer: FALSE  
   Diff: 3  Page Ref: 651

21) Both the corpus luteum and placenta secrete estrogens and progesterone.
   Answer: TRUE  
   Diff: 4  Page Ref: 654

22) The corpus luteum degenerates once fertilization occurs.
   Answer: FALSE  
   Diff: 3  Page Ref: 652

23) Once ejaculation occurs during copulation, the sperm can remain viable for only two days.
   Answer: FALSE  
   Diff: 3  Page Ref: 655
24) During the earliest stages of development, the embryo can derive its nutrients from the endometrium without any specialized structure.
   Answer: TRUE
   Diff: 3   Page Ref: 657

25) If a mother develops gestational diabetes, then both the mother and fetus can suffer from hyperglycemia.
   Answer: TRUE
   Diff: 4   Page Ref: 660

26) Placental hormones induce insulin-resistance.
   Answer: TRUE
   Diff: 5   Page Ref: 660

27) Once oxytocin secretion increases, milk production will be initiated.
   Answer: FALSE
   Diff: 4   Page Ref: 663

28) Fraternal twins are a result of polyspermy.
   Answer: FALSE
   Diff: 3   Page Ref: 651
Matching Questions

Match the following terms with their definitions.

1) Chromosomes other than the sex chromosomes.
   Diff: 2   Page Ref: 633
   A) haploid

2) X and Y chromosomes.
   Diff: 2   Page Ref: 633
   B) sex chromosomes

3) Having one set of 23 chromosomes.
   Diff: 3   Page Ref: 633
   C) alleles

4) Having two sets of 23 chromosomes.
   Diff: 3   Page Ref: 633
   D) diploid

5) Different variations of the same gene.
   Diff: 3   Page Ref: 633
   E) autosomes

6) Contains the srY gene.
   Diff: 3   Page Ref: 635

7) Represents the chromosome number in gametes.
   Diff: 4   Page Ref: 633

8) Represents the chromosome number in a zygote.
   Diff: 4   Page Ref: 633

Answers:  1) E  2) B  3) A  4) D  5) C
          6) B  7) A  8) D
CHAPTER 22 The Reproductive System

Match the cell type with its function.

9) Releases androgens in males.
   \[\text{Diff: 3} \quad \text{Page Ref: 639}\]
   A) Sertoli cell
   B) Leydig cell
   C) theca cell
   D) granulosa cell

10) Releases androgens in females.
    \[\text{Diff: 5} \quad \text{Page Ref: 647}\]
11) Secretes paracrines that support spermatogenesis.
    \[\text{Diff: 3} \quad \text{Page Ref: 640}\]
12) Secretes paracrines that support oogenesis.
    \[\text{Diff: 3} \quad \text{Page Ref: 647}\]
13) Provides nutrients to the developing gamete via gap junctions.
    \[\text{Diff: 3} \quad \text{Page Ref: 649}\]
14) Secrete Müllerian inhibiting substance.
    \[\text{Diff: 4} \quad \text{Page Ref: 640}\]


Match the following accessory glands to their functions.

15) Secretes an alkaline fluid with fructose into the ejaculatory duct.
    \[\text{Diff: 3} \quad \text{Page Ref: 641}\]
   A) prostate gland
   B) vestibular glands
   C) seminal vesicles
   D) bulbourethral glands

16) Secretes a fluid containing citrates and enzymes into the urethra during ejaculation.
    \[\text{Diff: 3} \quad \text{Page Ref: 641}\]

17) Secretes a viscous mucus just prior to ejaculation.
    \[\text{Diff: 3} \quad \text{Page Ref: 641}\]

18) Secretes a fluid that lubricates the vagina.
    \[\text{Diff: 3} \quad \text{Page Ref: 647}\]

Match the following hormones to their functions.

19) Stimulates gametogenesis in both males and females.
   Diff: 4   Page Ref: 641
   A) progesterone
   B) estrogens
   C) LH
   D) inhibin
   E) FSH

20) Stimulates androgen synthesis in both males and females.
   Diff: 4   Page Ref: 641
   A) progesterone
   B) estrogens
   C) LH
   D) inhibin
   E) FSH

21) Provides negative feedback to FSH secretion, but not LH in both males and females.
   Diff: 5   Page Ref: 642
   A) progesterone
   B) estrogens
   C) LH
   D) inhibin
   E) FSH

22) Triggers ovulation in females.
   Diff: 3   Page Ref: 654
   A) progesterone
   B) estrogens
   C) LH
   D) inhibin
   E) FSH

23) Inhibits uterine contractions.
   Diff: 4   Page Ref: 654
   A) progesterone
   B) estrogens
   C) LH
   D) inhibin
   E) FSH

24) Permissive to the actions of progesterone by inducing expression of progesterone receptors in the endometrium.
   Diff: 4   Page Ref: 653
   A) progesterone
   B) estrogens
   C) LH
   D) inhibin
   E) FSH

25) Promotes growth of glandular tissue of the breasts.
   Diff: 4   Page Ref: 660
   A) progesterone
   B) estrogens
   C) LH
   D) inhibin
   E) FSH

26) Stimulates prolactin secretion.
   Diff: 4   Page Ref: 660
   A) progesterone
   B) estrogens
   C) LH
   D) inhibin
   E) FSH


Match the component of a blastocyst with its fate.

27) Develops into the fetus.
   Diff: 3   Page Ref: 657
   A) inner cell mass
   B) blastocoele
   C) trophoblast

28) Forms the fetal component of the placenta.
   Diff: 3   Page Ref: 657
   A) inner cell mass
   B) blastocoele
   C) trophoblast

29) Forms a fluid filled sac around the developing embryo.
   Diff: 3   Page Ref: 657
   A) inner cell mass
   B) blastocoele
   C) trophoblast
Essay Questions

1) The reproductive cycle requires both mitotic and meiotic processes. Describe the basic properties of gametogenesis in males and females.

Answer: Gametogenesis is the development of haploid cells for sexual reproduction. In the male, this process is termed spermatogenesis, while in the female the process is called oogenesis. For spermatogenesis, spermatogonia (the germ cells) are located at the base of the Sertoli cell within the seminiferous tubule. These cells undergo mitosis and meiosis continuously. Once males reach puberty, mitosis occurs throughout their lifetimes to replace those spermatogonia that have entered meiosis. The process of meiosis starts like mitosis, with duplication of the chromosomes (2 × 2N) to form the primary spermatocyte. The copies of each chromosome (sister chromatids) remain joined by a centromere. The proximity of these homologous sister chromatids allows alleles to cross over and independently sort. These processes alter the genetic composition of the chromatids, allowing mixing of maternal and paternal alleles. Mixing helps to ensure genetic diversity of the offspring (the alternative would be to pass the paternal or maternal chromosomes directly to our offspring). As the primary spermatocyte moves along between the Sertoli cells, the first meiotic division occurs and two secondary spermatocytes are generated, each containing one chromosome from each pair in the primary spermatocytes. Thereafter, the second meiotic division occurs and the chromosomes are split into sister chromatids in each cell for a total of four spermatids. Those spermatids will develop further into sperm, which contain a sister chromatid (1N). In females, the general process is quite similar. However, the timing of these events is very different, as is the ultimate development of the haploid gamete. First, the oogonia undergo mitosis only until the third month of maternal embryonic development. Thus, no new oogonia are formed after the third fetal month, and those oogonia that have formed are maintained in meiotic arrest until they are ready to ovulate or meiosis terminates at menopause. The primary oocyte does not undergo the first meiotic division until ovulation occurs and only one secondary oocyte is generated. The second copy of DNA, which remains in the first polar body, eventually degenerates and is lost. Once the ovum is fertilized, it undergoes the second meiotic division with the same result; only one ovum is generated with the second meiotic division, and a second polar body is degraded and lost.

Diff: 8 Page Ref: 633
2) The human genome is composed of 23 pairs of chromosomes, of which one pair are the sex chromosomes. Describe the processes of sex determination and sex differentiation.

Answer: Because every female germ cell contains two X chromosomes, every ovum she produces will contain an X chromosome. Thus, the sex of the offspring is determined entirely by the sex chromosome from the sperm. Although a person’s sex is usually determined by the genes, all they do is determine whether the fetus will develop testes or ovaries. Which gonadal structure develops is determined by a gene on the Y chromosome called sry. This gene codes for the protein testis-determining factor. The presence of this gene causes the fetus to develop testes, whereas its absence leads to ovary development. The development of the gonads sets the stage for the development of other sex characteristics. Whether these characteristics are male or female is determined by the secretion of testosterone and Müllerian-inhibiting substance (MIS). If these hormones are present, the fetus develops male characteristics. In the first weeks of development, the fetus is indifferent, possessing the rudimentary male and female reproductive systems called the Wolffian ducts and Müllerian ducts, respectively. When the testes are generated by the presence of the sry gene, the production of testosterone by the testes will act on the Wolffian ducts to facilitate the development of male reproductive organs as MIS promotes the regression of the Müllerian ducts. If the sry gene is not present (i.e., XX chromosome), then the absence of testosterone allows the Wolffian ducts to regress while the absence of MIS allows the Müllerian ducts to develop into female reproductive organs. Thus, in the absence of testosterone, the fetus will develop as a female.

Diff: 6 Page Ref: 635

3) In order to pass along his genetic material, the male of the species must generate sperm. Describe the production, maturation, and release of sperm, and how the sperm reach the ova.

Answer: The sperm develop from spermatogonia located within the seminiferous tubules of the testes. The spermatogonia are positioned at the outer portion of the tubule that surrounds the Sertoli cells. These cells begin to move between the Sertoli cells toward the lumen of the seminiferous tubules, going through meiosis as they traverse this gap. Development of these cells is mediated by differences between the chemical composition of the fluid within the basal and luminal compartments, which are separated by tight junctions between Sertoli cells. Differences in the composition of interstitial fluid in these compartments drives the meiosis. The Sertoli cells secrete the luminal fluid that contributes to sperm development and facilitates sperm movement into and through the tubules. In addition, Sertoli cells provide developing sperm with nutrients and release an androgen-binding protein, which acts as an androgen buffer to maintain a luminal concentration of testosterone that supports sperm development. The sperm are moved from the seminiferous tubules by the movement of fluid generated by the Sertoli cells and a peristaltic contraction of the seminiferous tubules. The sperm travel from the seminiferous tubules to the rete testes and onward to the efferent ductule until they reach the epididymis. The epididymis is a thin, coiled duct that leads to the vas deferens upon ejaculation. As the sperm pass through the epididymus, they further mature to become modal. There are three accessory glands that add fluid to the sperm. The first is the seminal vesicle, which secretes an alkaline fluid containing nutrients, enzymes, and prostaglandins into the ejaculation duct. The prostate gland releases enzymes and citrate into the urethra when the surrounding smooth muscle cells contract. Finally, the bulbourethral glands secrete a viscous, sticky mucus into the urethra to act as a lubricant.

Diff: 7 Page Ref: 642

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4) Describe, in general, the hypothalamic-pituitary axis regulation of reproductive function in males and females.

**Answer:** The hypothalamic-pituitary axis plays an important role in regulating reproductive function in males and females. In the hypothalamus, the release of gonadotropin-releasing hormone (GnRH) stimulates the anterior pituitary to release follicle-stimulating hormone (FSH) and luteinizing hormone (LH). In males, FSH acts on Sertoli cells to stimulate gametogenesis and inhibin secretion. Inhibin acts to inhibit FSH secretion from the anterior pituitary. The secretion of LH stimulates Leydig cells to produce androgens. Androgens, like testosterone, inhibit hypothalamic secretion of GnRH and make the anterior pituitary less responsive to GnRH, thereby decreasing FSH and LH secretion. At puberty, there is a dramatic rise in GnRH that continues until approximately the third decade of life. The release of GnRH occurs in bursts that peak every two hours. These bursts provide a relatively constant average plasma concentration of GnRH. In females, the release of GnRH, FSH, and LH is not as constant as that observed in males, but rather is modulated by feedback from estrogen, progesterone, and inhibin, whose releases vary by phase of the menstrual cycle. In early to mid-follicular phase, FSH stimulates granulosa cells to support oogenesis and release inhibin, which inhibits FSH secretion at the anterior pituitary. Secretion of LH stimulates theca cells to release androgens, that are converted to estrogen by granulosa cells. Estrogen and progesterone inhibit GnRH, FSH, and LH secretion. However, estrogen and progesterone decrease during early to mid-follicular phase due to the loss of the corpus luteum, which results in a steady increase in GnRH secretion and thereby enhances LH and FSH release. However, increasing inhibin release results in a decrease in FSH, which triggers atresia of immature follicles, as LH remains relatively constant. In late follicular phase, the response of cells changes such that the rising estrogen levels actually stimulate the secretion of LH, creating a positive feedback that further stimulates LH secretion and results in the LH surge that induces ovulation. In the luteal phase, the corpus luteum takes over secretion of estrogen and progesterone. It is the progesterone that acts to inhibit LH and FSH secretion during the luteal phase. In the absence of fertilization, the corpus luteum degrades, decreasing estrogen and progesterone concentration, which initiates the follicular phase.

*Diff: 8  Page Ref: 641*
5) Describe the structure of the sperm and the process of fertilization, including how polyspermy is prevented.

Answer: Spermatogonia are the germ cells from which all sperm originate. These cells can continue to undergo mitosis. Once meiosis is initiated, the spermatocytes move from the base of the Sertoli cell toward the lumen of the seminiferous tubules. As they move along this pathway, they develop into mature sperm. The mature sperm contain three basic structures: head, midpiece, and tail. The head is composed of the acrosome, which contains enzymes and other proteins that enable fusion with the ovum, and the nucleus, which contains the haploid genetic material. The midpiece contains the mitochondria that provide the energy for the movement of the flagellar tail. The tail acts in a whiplike manner to move the sperm. However, sperm remain immotile until they pass through the epididymis. As sperm are moved through the vas deferens, fluid from the seminal vesicles is added. This fluid is alkaline to neutralize the acidity of the vagina, which would suppress sperm motility. In the urethra, the prostate gland secretes citrate as a substrate for energy production. Once sperm enter the vagina, they move into the uterus through the cervix and even fewer make their way to the uterine tubules where fertilization occurs. They can remain active within the female reproductive tract for five days. In order to fertilize the ovum, they must undergo capacitation, which induces changes in the pattern of tail movement and alterations in the plasma membrane that allow sperm to adhere to the oocyte. Once a sperm contacts the oocyte, an acrosome reaction is initiated and the zona pellucida is digested by the acrosomal enzymes. The first sperm to reach the oocyte binds to a receptor, which causes it to be transported into the cytoplasm of the oocyte. The plasma membrane of the sperm disintegrates and its chromosomes move toward the center of the oocyte. The fusion of the sperm results in the second meiotic division of the oocyte. Polyspermy is prevented by the first sperm that makes contact with the oocyte. That fusion causes enzymes to be released from the oocyte, which inactivates the sperm-binding proteins on the oocyte. At the same time, the zona pellucida hardens and pulls away from the oocyte, creating a barrier to other sperm.

Diff: 7 Page Ref: 642, 655
6) The menstrual cycle is repeated every 28 days and involves changes within the ovaries and the uterus. Describe the changes that occur during the ovarian cycle.

Answer: The ovarian cycle is divided into two phases: the follicular phase and the luteal phase. In the beginning of the follicular phase, about 10–25 follicles develop. Within seven days, one of those follicles (the dominant follicle) will develop to full maturity. The remaining follicles will undergo atresia and be lost. As the follicles begin to develop, the oocyte grows in size. At the same time, the granulosa cells increase in size and number. This growth is stimulated by follicle-stimulating hormone (FSH) and the estrogens secreted by the follicles. There is also a thick layer of non-cellular material forming around the oocyte called the zona pellucida. At the outer layer of the follicle, theca cells begin to develop. A fluid-filled cavity (antrum) begins to form within the granulosa cell layer. This is the point at which many of the follicles stop their development. Follicles that have not developed adequately to maintain estrogen secretion in the face of decreasing FSH undergo atresia. As follicles develop further, the antrum continues to grow, displacing some of the cellular tissue around the oocyte, leading to a protrusion from the follicular wall (corona radiata). Eventually, the first meiotic division occurs and the secondary oocyte detaches from the follicle wall and floats freely in the antral fluid. The antrum continues to grow until it forms the Graafian follicle, just prior to ovulation. The luteinizing hormone (LH) surge that induces ovulation begins the luteal phase, during which the follicle bursts and the oocyte is released. The granulosa and theca cells of the ruptured follicle are transformed into the corpus luteum that secretes the estrogen and progesterone that prepare the uterus for implantation. In the absence of fertilization, the corpus luteum begins to degrade after ten days, reducing plasma estrogens and progesterone concentration, thereby initiating menstruation.

7) The menstrual cycle is repeated every 28 days and involves changes within the ovaries and the uterus. Describe the changes that occur during the uterine cycle.

Answer: The uterine cycle is composed of three phases that include the menstrual phase, the proliferative phase, and the secretory phase. The menstrual phase involves shedding a portion of the endometrial lining of the uterus. This is initiated by the decrease in estrogen and progesterone concentration that occurs because of corpus luteum degradation. This process is initiated by the constriction of the outer layer of blood vessels within the endometrium. This causes a decrease in blood flow that kills the tissue, which starts to separate from the underlying endometrial tissue. The dead tissue shed from the endometrium causes the rupture of blood vessels and bleeding. Over several days, the mixture of blood and tissue seeps into the vagina and exits the body. The proliferative phase involves the renewal of the uterus that is stimulated by estrogens. The endometrial tissue that survived the menstrual phase begins to grow along with smooth muscle cells of the myometrium. The glands in the endometrium increase in number and size, and blood vessels increase in density. At the same time, the cervical glands begin to secrete a thin mucus. In the secretory phase, the thickened endometrium is transformed into an environment that will allow the embryo to implant and provide nutrition for the developing embryo. The endometrial glands enlarge further and the secretion of the cervical glands becomes thicker and blocks the cervical canal, which isolates the uterus from the microorganisms in the outside environment. These changes in the uterus are promoted by progesterone. The degeneration of the corpus luteum removes the progesterone that supports the endometrium, thereby initiating the menstrual phase.
8) The entire menstrual cycle is driven by changes in the release of particular hormones. Describe the hormonal regulation of the menstrual cycle.

Answer: During the early and mid-follicular phases, estrogen and progesterone concentrations are reduced by the loss of the corpus luteum. This removes the block on follicle-stimulating hormone (FSH) and luteinizing hormone (LH) secretion by removing the progesterone-induced suppression. FSH stimulates follicular development by binding to granulosa cells and stimulating their growth and proliferation. This also stimulates the differentiation of theca cells that respond to LH by secreting androgens. These androgens are taken up by the granulosa cells and converted into estrogens. As the menstrual cycle progresses into later follicular phase, the increases in estrogen and inhibin secretion from granulosa cells cause a decrease in FSH concentrations. LH secretion is maintained under these conditions because inhibin does not affect LH secretion. These changes are responsible for the selection of a dominant follicle that is able to maintain its secretion of estradiol in the face of the decrease in FSH (which stimulates atresia). The increase in estrogen facilitates the changes in the uterus that are characteristic of the proliferative phase, which include promoting oocyte development and follicular growth. Estrogen induces LH receptor expression on granulosa cells that renders those cells responsive to LH. In addition, estrogen induces the expression of progesterone receptors on endometrial cells. In the late follicular phase, there is a switch in the response of cells to LH. Rather than acting through a negative feedback system, LH begins to act through a positive feedback system where increases in LH will further increase LH release from the anterior pituitary. The expression of LH receptors on the granulosa cells is partly responsible for stimulating changes in the dominant follicle that include: secretion of paracines that stimulate oocyte meiotic progression, a decrease in estrogen secretion from granulosa cells, an initiation of progesterone secretion by granulosa cells, secretion of enzymes and paracines that degrade the follicular wall, and the differentiation of granulosa and theca cells into the corpus luteum. During the early luteal phase, the secretion of estrogen from the corpus luteum is not enough to prevent the fall in estrogen concentration. This decrease in estrogen removes the stimulus for LH secretion, which ends the surge. However, progesterone concentrations begin to rise. The estrogen and progesterone concentrations rise as the corpus luteum matures. The rise in progesterone not only suppresses LH secretion but prevents the estrogen-induced increase in LH as well as decreasing plasma FSH concentrations.

Diff: 9  Page Ref: 652
9) Once the ovum has been fertilized, a number of changes occur that facilitate the development of the embryo. Describe the process of embryonic development, implantation, and the hormones involved in pregnancy.

Answer: Following fertilization, the ovum undergoes several mitotic divisions, creating the morula, a ball of cells. This structure develops by cell cleavage, where the size of cells does not increase before dividing (each cell gets progressively smaller). Each of the cells is totipotent, with the capacity to form into a complete human. Eventually, the morula develops into a blastocyst, which has shed the zona pellucida. The blastocyst has a spherical outer layer of trophoblast cells and a cluster of cells on its inside called the inner cell mass. A fluid-filled cavity called the blastocoele is adjacent to the inner cell mass. After seven days, the blastocyst attaches to the uterine wall. The trophoblast secretes enzymes that digest the endometrium and paracrine that promote local changes in endometrial tissue. These changes are part of the decidual response. The trophoblastic cells in contact with the endometrium begin to proliferate and infiltrate the endometrium. The embryo continues to grow in size and complexity. The trophoblast thickens at five weeks to form the chorion that encapsulates the embryo. A fluid-filled cavity (amniotic cavity) begins to form and grow inside the inner mass. The amniotic fluid provides a cushion for the fetus, protecting it from physical trauma. The placenta begins to develop as the chorion sends out projections (chorionic villi) that contain fetal capillaries and also secrete paracrine that alter endometrial tissue, such that the villi are surrounded by sinuses of maternal blood. Thus, maternal and fetal blood come in close, but not direct, contact with one another (there is no mixing of fetal and maternal blood cells). The corpus luteum is maintained during the early part of pregnancy by human chorionic gonadotropin (hCG), which is secreted by the chorion. In the presence of hCG, the corpus luteum secretes estrogen and progesterone. After two months, the secretion of hCG decreases and the corpus luteum degrades. However, estrogen and progesterone concentrations remain high and continue to rise until parturition, due to their secretion by the placenta. During pregnancy, estrogen acts to stimulate growth of ducts within the breast, stimulate prolactin secretion, and promote the growth and contractile response of the uterine smooth muscles (facilitate parturition). At the same time, progesterone facilitates the growth of glandular tissues in the breast, suppression of contractile activity of the smooth muscle cells until parturition, and maintenance of the secretory-phase uterus. During pregnancy, progesterone suppresses the hypothalamus and anterior pituitary, maintaining follicle-stimulating hormone (FSH) and luteinizing hormone (LH) at low concentrations. Thus, no new dominant follicles appear and there are no LH surges. In addition to estrogen and progesterone, the placenta secretes placental lactogen, which acts to promote breast growth and mobilization of energy stores.

Diff: 9  Page Ref: 657
10) Describe parturition, including the hormones involved in this process.

Answer: Shortly before parturition, the fetus assumes the head-down position, coming in contact with the closed cervix. This head-first arrangement allows the head to act as a wedge to force the cervix open (cervical dilation) and allow the remainder of the body through. If the fetus does not assume this position, it is considered a breech birth, making the birth more difficult because the umbilical cord can be compressed before the baby exits the canal. To facilitate delivery the cervix ripens, which means the cervical connective tissue softens (by enzymatic degradation) to allow the fetus to exit. The first reliable signal of parturition is the rupture of the amniotic sac. Soon afterwards, a series of strong uterine contractions begin (labor). Each contraction starts at the top of the uterus and travels to the cervix in an attempt to force the fetus into the cervix. During labor, the uterine contractions can be assisted by voluntary contractions of the abdominal muscles. The initial contractions are separated by 10–15 minutes. As the time between contractions decreases, uterine pressure increases, causing the cervix to further dilate. At that time, the fetus moves into the cervical canal from which it will be expelled. Thereafter, blood vessels in the umbilical cord begin to constrict as the placenta separates from the endometrium, and strong uterine contractions expel the placenta. The smooth muscle cells of the uterus are stretch-sensitive, like other smooth muscle cells. As the contractions push the fetus further down the uterus, the stretch causes a contraction in that region of the uterus to become more forceful. This stretch also activates receptors that stimulate the release of oxytocin from the posterior pituitary. Oxytocin acts directly on smooth muscle cells to increase their contractile force by stimulating the release of prostaglandins from the myometrium. The trigger for parturition may originate from the fetus itself through the release of corticotropin-releasing hormone (CRH) from the placenta. This increases the release of dehydroepiandrosterone (DHEA) from the adrenal glands, which is converted to estrogen.

*Diff: 7  Page Ref: 661*

11) Describe lactation, including the hormones involved in this process.

Answer: There is a dramatic decrease in estrogen and progesterone at parturition. In addition to their actions to stimulate uterine contractions, the drop in estrogen and progesterone initiates lactation. The milk produced in the first several days is called colostrum and is composed of water and a few proteins and nutrients. Subsequently, the milk is enriched with fat, lactose, growth factors, hormones, and antibodies. Milk is produced by the clusters of alveolar cells within the breast, whose densities were enhanced by progesterone during pregnancy. The ductile system is also enhanced during pregnancy by estrogen. The act of a baby suckling on the nipple triggers the flow of milk through the duct by inducing contraction of the myoepithelial cells that surround the ducts (causing ejection). During suckling, the stimulation of receptors on the nipple relays information to the hypothalamus to stimulate the secretion of oxytocin, which stimulates the myoepithelial cell contraction. Suckling also increases the release of prolactin-releasing hormone from the hypothalamus and inhibits the release of prolactin-inhibiting hormone, which acts to increase the release of prolactin from the anterior pituitary. Prolactin acts to increase the production of milk.

*Diff: 6  Page Ref: 663*
Short Answer Questions

Using Figure 22.1, answer the following questions:

1) Structure D in Figure 22.1 represents the ______, which function to ______.
   Answer: smooth muscle cells: propel sperm into the efferent ductule
   Diff: 5   Page Ref: 639

2) In Figure 22.1, the Sertoli cells are identified by the letter ______.
   Answer: A
   Diff: 2   Page Ref: 639

3) In Figure 22.1, the structure identified by C is a ______ that functions to ______.
   Answer: tight junction: regulate the constituents of the fluid compartments
   Diff: 4   Page Ref: 639

4) In Figure 22.1, the spermatogonia are located next to structure ______ and the mature sperm are located in the structure ______.
   Answer: E: B
   Diff: 4   Page Ref: 639

5) In Figure 22.1, the area represented by F is the ______ compartment, whereas the area represented by G is the ______ compartment.
   Answer: basal: lumenal
   Diff: 4   Page Ref: 639
Using Figure 22.2, answer the following questions:

6) In Figure 22.2, the outer ring of the follicle is composed of _______ cells, while the developing fluid sac, the _______, is secreted by _______.
   Answer: theca : antrum : granulosa cells
   Diff: 5    Page Ref: 650

7) In Figure 22.2, the ovum would have passed through the first meiotic division by step _______, while not experiencing the second meiotic division until ________.
   Answer: 4 : a sperm fuses to the ovum
   Diff: 6    Page Ref: 650

8) In Figure 22.2, step _______ of the maturation of an ovum indicates the Graafian follicle.
   Answer: 4
   Diff: 3    Page Ref: 650

9) The transition from step 4 to step 5 in the maturation of the ovum in Figure 22.2 is mediated by ________.
   Answer: luteinizing hormone (LH) surge
   Diff: 4    Page Ref: 650

10) In Figure 22.2, the structure identified in step 6 of the maturation of the ovum is the ________, which is involved in the secretion of ________ and ________.
    Answer: corpus leuteum : estrogen : progesterone
    Diff: 5    Page Ref: 650

11) In Figure 22.2, the decrease in the number of developing follicles indicated by the transition from step 1 to 2 is mediated by ________.
    Answer: a decrease in follicle-stimulating hormone (FSH)
    Diff: 5    Page Ref: 650
12) The passage from step 7 to 8 in the maturation of the ovum in Figure 22.2 will take months if the ovum is _______ and secreting _______.

Answer: fertilized : human chorionic gonadotropin (hCG)
Diff: 6   Page Ref: 650

13) The diploid product of an ovum that has been fertilized by sperm is called a(n) _______.

Answer: zygote
Diff: 3   Page Ref: 633

14) In women, the (ovaries / adrenal cortex) is responsible for the production of (androgens / estrogens), which are responsible for promoting sex drive.

Answer: adrenal cortex : androgens
Diff: 4   Page Ref: 635

15) The gene that determines the sex of a person is the _______ gene located on the _______ chromosome.

Answer: srY : Y
Diff: 4   Page Ref: 635

16) During sex differentiation, the presence of _______ stimulates development of the _______ duct, whereas the presence of _______ inhibits development of the _______ ducts.

Answer: testosterone : Wolffian : Müllerian-inhibiting substance : Müllerian
Diff: 5   Page Ref: 637

17) Name two functions of the blood–testes barrier.

Answer: create an environment that facilitates the development of sperm : isolate the sperm from the body’s immune system
Diff: 4   Page Ref: 640

18) Gonadotropin–releasing hormone (GnRH) stimulates the release of _______ and _______ from the _______.

Answer: follicle–stimulating hormone (FSH) : luteinizing hormone (LH) : anterior pituitary
Diff: 4   Page Ref: 641

19) The (spermatogonia / spermatids) are located near the basement membrane of the Sertoli cells within the seminiferous tubules.

Answer: spermatogonia
Diff: 4   Page Ref: 642

20) What two mechanisms move sperm from the seminiferous tubules to the epididymis?

Answer: peristaltic contractions of the seminiferous tubules : flow of luminal fluid produced by the Sertoli cells
Diff: 5   Page Ref: 643

21) The release of the oocyte by _______ typically occurs every _______ days.

Answer: ovulation : 28
Diff: 2   Page Ref: 645
22) ______ synthesized by the theca cells are converted to ______ within the granulosa cells.
   Answer: Androgens : estrogen
   Diff: 5   Page Ref: 647

23) What two mechanisms move the oocyte through the uterine tube?
   Answer: ciliary action of the cells lining the tube : peristaltic contraction of the uterine tube
   Diff: 5   Page Ref: 647

24) The development of the second polar body occurs following (ovulation / fertilization).
   Answer: fertilization
   Diff: 5   Page Ref: 648

25) As a follicle develops into the Graafian follicle, the ______ continues to increase in size until
    it causes the follicle to ______ at ovulation.
   Answer: antrum : burst
   Diff: 4   Page Ref: 649

26) What layer(s) of the uterus proliferate during the proliferative phase of the uterine cycle?
   Answer: endometrium : myometrium (smooth muscle cells)
   Diff: 5   Page Ref: 651

27) During the follicular phase, estrogen induces the expression of ______ receptors on
    granulosa cells.
   Answer: luteinizing hormone (LH)
   Diff: 4   Page Ref: 649

28) What two events occur at fertilization to block polyspermy?
   Answer: release of enzymes that inactivate sperm-binding protein and the hardening of the zona
            pellucida
   Diff: 5   Page Ref: 657

29) Following implantation, what hormone is released from the chorionic portion of the placenta
    to maintain corpus luteal secretion of estrogen and progesterone?
   Answer: human chorionic gonadotropin (hCG)
   Diff: 4   Page Ref: 659

30) With respect to the structure of the breasts, ______ stimulates the growth of the ductal cells
    whereas ______ stimulates the growth of glandular cells.
   Answer: estrogen : progesterone
   Diff: 5   Page Ref: 660

31) The release of ______ from the placenta promotes breast growth as well as ______.
   Answer: lactogens : the mobilization of energy stores needed to meet the energy demands of the
            growing of breast and fetal tissue.
   Diff: 5   Page Ref: 661
Chapter 23  The Immune System

Multiple Choice Questions

1) What are phagocytic leukocytes that attack parasitic cells by releasing toxic molecules once they have attached themselves to the parasite?
   A) Eosinophils
   B) Neutrophils
   C) Basophils
   D) Monocytes
   E) Macrophages
   Answer: A
   Diff: 4  Page Ref: 668

2) What type of cell, once it enters the tissues, is converted into a macrophage that attacks invaders by phagocytosis?
   A) eosinophil
   B) lymphocyte
   C) basophil
   D) monocyte
   E) neutrophil
   Answer: D
   Diff: 4  Page Ref: 668

3) When a B cell contacts a foreign or abnormal antigen, it develops into a _______ that releases _______.
   A) macrophage : histamine
   B) plasma cell : histamine
   C) macrophage : antibody
   D) plasma cell : antibodies
   E) natural killer cell : antibodies
   Answer: D
   Diff: 4  Page Ref: 669

4) What type of cell found in the skin and mucosal linings secretes histamine?
   A) monocyte
   B) macrophage
   C) mast cell
   D) dendritic cell
   E) basophil
   Answer: C
   Diff: 4  Page Ref: 669
5) What type of phagocytic cell has long processes?
   A) monocyte
   B) macrophage
   C) mast cell
   D) dendritic cell
   E) basophil

   Answer: D
   Diff: 4   Page Ref: 669

6) Which of the following is NOT considered a peripheral lymphoid tissue?
   A) bone marrow
   B) spleen
   C) tonsils
   D) adenoids
   E) appendix

   Answer: A
   Diff: 3   Page Ref: 669

7) In order to be completely functional, a T cell must be activated by ________.
   A) the lymph nodes
   B) bone marrow
   C) the parathyroid gland
   D) the thyroid gland
   E) the thymus gland

   Answer: E
   Diff: 4   Page Ref: 669

8) Peyer’s patches are peripheral lymphoid tissue located where?
   A) liver sinusoids
   B) spleen
   C) gastrointestinal tract wall
   D) appendix
   E) thymus

   Answer: C
   Diff: 3   Page Ref: 669

9) Which of the following is NOT one of the body’s nonspecific defenses against pathogens?
   A) inflammation
   B) interferons
   C) natural killer cell
   D) cytotoxic T cell
   E) complement system

   Answer: D
   Diff: 4   Page Ref: 670
10) Mucus secreted by mucous membranes provides protection against infections by _______.
A) destroying pathogens by the complement system
B) forcing the pathogen to die in the struggle to free itself (like a fly strip)
C) drowning the pathogen
D) trapping and removing pathogens
E) phagocytosing pathogens by macrophages
Answer: D
Diff: 4 Page Ref: 670

11) What type of gland secretes an acidic oily substance that inhibits bacterial growth?
A) sweat glands
B) salivary glands
C) sebaceous glands
D) adenoids
E) lymph nodes
Answer: C
Diff: 3 Page Ref: 670

12) Which of the following steps initiates an inflammatory response?
A) Arterioles dilate.
B) Capillary permeability increases.
C) Leukocytes migrate to the infection.
D) Macrophages secrete cytokines.
E) Macrophages engulf the debris or foreign material.
Answer: E
Diff: 4 Page Ref: 671

13) The increase in blood flow to a site of infection acts to _______.
A) recruit more leukocytes to the site of infection
B) increase oxygen in the region to kill the invading bacteria
C) facilitate the migration of the leukocytes into the interstitial space
D) wash the invading bacteria from the region of the infection
E) bring more mast cells to the site of infection
Answer: A
Diff: 5 Page Ref: 671

14) What causes the increase in interstitial osmotic pressure that occurs during edema?
A) recruitment of leukocytes
B) increased blood flow
C) increased capillary permeability
D) stimulation of sensory neurons
E) leukocyte migration
Answer: C
Diff: 5 Page Ref: 672
15) The increase in interstitial hydrostatic pressure associated with an edema will lead to a(n) ________.
   A) sensation of pain
   B) increase in blood flow
   C) increased movement of water out of the capillaries
   D) release of bradykinin
   E) decrease in the recruitment of leukocytes to the site of infection

   Answer: A
   Diff: 5  Page Ref: 672

16) For leukocytes to battle an infection, adhesion molecules are necessary including ________, which loosely bind leukocytes to the blood vessel wall slowing down their movement, and ________, which tightly attaches leukocytes to the blood vessel wall in preparation for diapedesis.
   A) integrin : spectrin
   B) spectrin : selectin
   C) selectin : integrin
   D) spectrin : integrin
   E) integrin : selectin

   Answer: C
   Diff: 4  Page Ref: 672

17) Leukocyte movement from blood to the site of tissue damage or infection involves ________, leukocyte movement toward the blood vessel wall; ________, the movement of leukocytes between endothelial cells of the blood vessel; and ________, the movement within the tissue to the site of injury.
   A) margination : diapedesis : chemotaxis
   B) diapedesis : margination : chemotaxis
   C) chemotaxis : diapedesis : margination
   D) chemotaxis : margination : diapedesis
   E) margination : chemotaxis : diapedesis

   Answer: A
   Diff: 5  Page Ref: 672

18) While ________ is released early in the inflammatory response to inhibit blood clotting, the ________ that have leaked into the interstitial space become active and isolate the region of damage.
   A) bradykinin : defensive proteins
   B) histamine : defensive proteins
   C) histamine : clotting factors
   D) bradykinin : albumin molecules
   E) heparin : clotting factors

   Answer: E
   Diff: 5  Page Ref: 672
19) Which of the following is NOT one of the four steps involved in phagocytosis?
   A) attachment  
   B) internalization  
   C) degradation  
   D) exocytosis  
   E) interleukin release  
   
   Answer: E  
   Diff: 4   Page Ref: 672

20) At the site of infection, leukocytes are stimulated to express ________, which causes them to attach to the endothelial cells before moving into the vessel wall.
   A) selectins  
   B) integrins  
   C) chemotactic factor  
   D) attachins  
   E) marginin  
   
   Answer: B  
   Diff: 4   Page Ref: 672

21) Recruited leukocytes that have invaded the vessel wall are directed to the pathogen by the process of ________.
   A) opsonization  
   B) diapedesis  
   C) attachment  
   D) chemotaxis  
   E) migration  
   
   Answer: D  
   Diff: 4   Page Ref: 672

22) The attachment of phagocytic cells to damaged/infected cells is facilitated by the presence of ________ on the damaged cell.
   A) opsonin  
   B) cytokines  
   C) a smooth surface  
   D) phagosomes  
   E) regular features  
   
   Answer: A  
   Diff: 4   Page Ref: 672

23) Once a phagocyte has attached to foreign material, that material is ________.
   A) degraded externally by enzymes released from a lysosome  
   B) internalized in a lysosome  
   C) internalized in a phagosome  
   D) internalized in a secondary lysosome  
   E) internalized in the Golgi apparatus  
   
   Answer: C  
   Diff: 3   Page Ref: 672
24) Which of the following is NOT an action of interleukins released by phagocytic cells?
   A) increasing endothelial cell synthesis of adhesion molecules
   B) stimulation of the release of neutrophils from bone marrow
   C) acting as endogenous pyrogens to increase body temperature
   D) stimulating the production of acute phase proteins from the liver
   E) acting as opsonins to facilitate phagocytosis

   Answer: E  
   Diff: 5  Page Ref: 673

25) Interferons α and β are released from _______ and act to inhibit viral replication by _______.
   A) infected cells : degrading RNA
   B) neutrophils : digesting the virus
   C) phagocytic cells : digesting the virus
   D) phagocytic cells : degrading RNA
   E) T lymphocytes : degrading RNA

   Answer: A  
   Diff: 5  Page Ref: 674

26) The release of _______ by T cells activates natural killer cells in a specific immune response.
   A) interleukin-6
   B) interleukin-1
   C) interleukin-2
   D) interferon-γ
   E) tumor necrosis factor-α

   Answer: C  
   Diff: 5  Page Ref: 674

27) Natural killer cells can kill infected or abnormal cells by the release of _______, which form pores in the target cell’s membrane.
   A) fragmentins
   B) interferons
   C) antibodies
   D) perforins
   E) complement proteins

   Answer: D  
   Diff: 4  Page Ref: 674

28) The complement cascade can be activated by binding to ________.
   A) carbohydrates present on bacterial cells only
   B) antibodies attached to bacterial cells only
   C) natural killer cells only
   D) either carbohydrates or antibodies on bacterial cells
   E) either natural killer cells or carbohydrates on bacterial cells

   Answer: D  
   Diff: 5  Page Ref: 674
29) In the end, the complement system destroys invading bacteria by ______.
   A) phagocytosis
   B) forming a membrane attack complex
   C) release of lytic enzymes
   D) agglutination
   E) neutralization

   Answer: B
   Diff: 4  Page Ref: 674

30) What is/are a component of the complement system that coats the bacterial surface, acting as an opsonin to enhance phagocytosis of bacteria.
   A) CD8
   B) CD4
   C) Polysaccharides
   D) C3b
   E) C2c

   Answer: D
   Diff: 5  Page Ref: 675

31) If bacteria are exposed to a B cell in the spleen, they will initiate a(n) ______.
   A) inflammatory response
   B) nonspecific immune response
   C) cell-mediated immune response
   D) humoral immune response
   E) response from the complement system

   Answer: D
   Diff: 4  Page Ref: 675

32) Compared to humoral immunity, cell-mediated immunity is more likely to defend against which of the following?
   A) virally-infected cells only
   B) transplanted tissue only
   C) cancer cells only
   D) both virally-infected cells and cancer cells
   E) virally-infected cells, cancer cells, and transplanted tissue

   Answer: E
   Diff: 4  Page Ref: 675

33) Which of the following is NOT one of the important properties of the immune system that results from the action of B and T cells?
   A) redundancy
   B) specificity
   C) diversity
   D) memory
   E) self-tolerance

   Answer: A
   Diff: 4  Page Ref: 675
34) In order to mount a response, particular B or T cells must express the appropriate _______ that will bind to the _______.
   A) antigen : antigen receptor
   B) epitope : antigen
   C) antigen receptor : antigen
   D) antigenic determinant : antigen
   E) antigen : antibody
Answer: C
Diff: 4 Page Ref: 675

35) What are different recognition sites on the same antigen called?
   A) alleles
   B) epitopes
   C) antigen receptors
   D) variable regions
   E) perforins
Answer: B
Diff: 4 Page Ref: 675

36) The antigen-binding region of an antibody is formed by the _______.
   A) constant region composed of two light chains
   B) constant region composed of a heavy chain and a light chain
   C) variable region composed of two light chains
   D) variable region composed of two heavy chains
   E) variable region composed of a heavy chain and a light chain
Answer: E
Diff: 4 Page Ref: 676

37) Each antibody can bind _______.
   A) two different types of epitopes
   B) two epitopes of the same kind
   C) three epitopes of the same kind
   D) two epitopes of one kind and one epitope of a different kind
   E) one epitope only
Answer: B
Diff: 5 Page Ref: 676

38) Each B or T cell has _______.
   A) one antigen receptor
   B) two antigen receptors that recognize the same epitope
   C) two antigen receptors that recognize different epitopes
   D) many antigen receptors that recognize the same epitope
   E) many antigen receptors that recognize many epitopes
Answer: D
Diff: 5 Page Ref: 675
39) The process of clonal selection gives rise to short-lived clones called ________, which combat the antigen that stimulated their production.
   A) memory cells  
   B) effector cells  
   C) antibodies  
   D) antigens  
   E) helper cells  
   Answer: B  
   Diff: 4  Page Ref: 677

40) Which of the following is NOT a characteristic of a primary immune response?
   A) The response is especially strong.  
   B) Antigen selected B or T cells proliferate.  
   C) Antigen selected B or T cells differentiate into effector cells.  
   D) It requires 10-17 days to initiate.  
   E) The response is short-lived.  
   Answer: A  
   Diff: 3  Page Ref: 677

41) Why is a secondary immune response stronger?
   A) Effector cells produced during the primary response are still present circulating in the blood.  
   B) Memory cells produced during the primary response lead to a rapid proliferation of effector cells on subsequent exposure to the antigen.  
   C) Antibodies produced during the primary response are still present circulating in the blood.  
   D) Body cells develop resistance to the pathogen.  
   E) Body cells are primed to produce antibodies against the pathogen.  
   Answer: B  
   Diff: 4  Page Ref: 677

42) B cells are tested for their ability to bind to self in the ________, and are removed by ________ if they do bind to self.
   A) thymus : apoptosis  
   B) thymus : phagocytosis  
   C) bone marrow : phagocytosis  
   D) bone marrow : apoptosis  
   E) bone marrow : necrosis  
   Answer: D  
   Diff: 5  Page Ref: 677

43) Activation of a B cell by an antigen results in its proliferation and differentiation into ________, which secrete the antibodies that attack the antigen.
   A) cytotoxic T cells  
   B) T cells  
   C) plasma cells  
   D) memory cells  
   E) helper T cells  
   Answer: C  
   Diff: 4  Page Ref: 677
44) The lifespan of plasma cells is approximately several _______.
   A) minutes
   B) hours
   C) days
   D) weeks
   E) months
   Answer: C
   Diff: 4 Page Ref: 679

45) The development of memory B cells in response to an antigen requires the secretion of _______ from _______ cells.
   A) interferon-γ : cytotoxic T cells
   B) tumor necrosis factor-α : natural killer cells
   C) interleukin-6 : helper T cells
   D) interleukin-1 : cytotoxic T cells
   E) interleukin-2 : helper T cells
   Answer: E
   Diff: 5 Page Ref: 679

46) Polysaccharides on bacterial cells stimulate the production of antibodies by binding to _______.
   A) B cells that stimulate plasma cell proliferation
   B) B cells that stimulate plasma and memory cell proliferation
   C) helper T cells that release interleukin-1 to stimulate plasma cell proliferation
   D) helper T cells that directly stimulate plasma and memory cell proliferation
   E) B cells that release interleukin-2 to stimulate plasma cell proliferation
   Answer: A
   Diff: 5 Page Ref: 679

47) Antibodies are classified not only by their function, but by the _______.
   A) variable region
   B) type of heavy chain
   C) type of light chain
   D) number of disulfide bonds
   E) number of light chains
   Answer: B
   Diff: 3 Page Ref: 679

48) In the process of agglutination, IgD antibodies _______.
   A) remove the antigen from the pathogen
   B) block access to the antigenic site
   C) bind to antigens on two different cells
   D) stimulate the release of histamine from mast cells
   E) activate the complement system
   Answer: C
   Diff: 4 Page Ref: 680
49) Once IgM antibodies have bound to antigens, they are removed by _______.
   A) activating the alternate pathway of the complement system
   B) opsonizing the antigen, making it more susceptible to phagocytosis
   C) enhancing natural killer cell activity
   D) binding to mast cells to stimulate secretion of histamine
   E) activating the classical pathway of the complement system

   Answer: E  
   Diff: 5  Page Ref: 680

50) Which of the antibody classes is able to cross epithelial cells and is therefore present in breast milk?
   A) IgG only
   B) IgM only
   C) IgA only
   D) both IgG and IgM
   E) both IgM and IgA

   Answer: C  
   Diff: 5  Page Ref: 680

51) Which of the antibody classes is able to destroy an antigen by activating the nonspecific killing action of the natural killer cells?
   A) IgG only
   B) IgM only
   C) IgE only
   D) both IgG and IgM
   E) both IgM and IgE

   Answer: A  
   Diff: 5  Page Ref: 680

52) What secretes cytokines that enhance the activity of B cells, cytotoxic T cells, suppressor T cells, and helper T cells?
   A) Macrophages
   B) B cells
   C) Helper T cells
   D) Cytotoxic T cells
   E) Suppressor T cells

   Answer: C  
   Diff: 4  Page Ref: 682

53) Which type of T cell has antigen receptors?
   A) cytotoxic T cells only
   B) suppressor T cells only
   C) helper T cells only
   D) both cytotoxic and helper T cells
   E) cytotoxic, helper, and suppressor T cells

   Answer: E  
   Diff: 4  Page Ref: 681
54) Receptors on every T cell detect foreign antigens on cells of the body by their association with the ________ on the surface of the infected cells of the body.
   A) membrane attack complex
   B) CD4
   C) CD8
   D) major histocompatibility (MHC) molecule
   E) antibodies
   Answer: D
   Diff: 4 Page Ref: 681

55) Cells that leave the thymus with the ability to bind to class I major histocompatibility (MHC) molecules will develop into ________.
   A) cytotoxic T cells
   B) B cells
   C) helper T cells
   D) suppressor T cells
   E) macrophages
   Answer: A
   Diff: 5 Page Ref: 682

56) Cells that leave the thymus with the ability to bind to class II major histocompatibility (MHC) molecules will develop into ________.
   A) cytotoxic T cells
   B) B cells
   C) helper T cells
   D) suppressor T cells
   E) macrophages
   Answer: C
   Diff: 5 Page Ref: 682

57) In humans, the major histocompatibility (MHC) molecule is known as the ________.
   A) human leukocyte association
   B) human lymphoid antibody
   C) human leukocyte antigen
   D) human leukocyte antibody
   E) human lymphoid tissue
   Answer: C
   Diff: 3 Page Ref: 682

58) In order to be detected by a T cell, the class I major histocompatibility (MHC) molecule of infected cells must go through the process of ________.
   A) perforin incorporation
   B) antibody binding
   C) phagocytosis
   D) antigen presentation
   E) complement activation
   Answer: D
   Diff: 4 Page Ref: 682
59) In order to be detected by a T cell, the class II major histocompatibility (MHC) molecule of infected cells must go through the process of _______ before presenting the antigen.
   A) perforin incorporation
   B) antibody binding
   C) phagocytosis
   D) MHC molecule presentation
   E) complement activation

   Answer: C
   Diff: 4 Page Ref: 682

60) The _______ protein on the cytotoxic T cell binds to the _______ major histocompatibility (MHC) molecule on the infected cell.
   A) CD8 : class I
   B) CD8 : class II
   C) CD4 : class I
   D) CD4 : class II
   E) CD6 : class I

   Answer: A
   Diff: 5 Page Ref: 682

61) What cells are also called CD4 cells?
   A) B cells
   B) plasma cells
   C) cytotoxic T cells
   D) suppressor T cells
   E) helper T cells

   Answer: E
   Diff: 4 Page Ref: 682

62) Activation of helper T cell proliferation, once it has bound to its major histocompatibility (MHC) molecule, involves the release of _______ from _______.
   A) interleukin-10 : macrophages
   B) interleukin-2 : macrophages
   C) interleukin-1 : B cells
   D) interleukin-2 : B cells
   E) interleukin-4 : cytotoxic T cells

   Answer: C
   Diff: 6 Page Ref: 682

63) While some of the daughter helper T cells are secreting the appropriate interleukins, others form into _______.
   A) plasma cells
   B) memory T cells
   C) memory B cells
   D) cytotoxic T cells
   E) suppressor T cells

   Answer: B
   Diff: 3 Page Ref: 682

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64) Activation of cytotoxic T cells requires binding to class I MHC molecule complexed with a foreign antigen and the release of ________ from ________.
   A) interleukin-10 : macrophages
   B) interleukin-1 : helper T cells
   C) interleukin-1 : macrophages
   D) interleukin-2 : helper T cells
   E) interleukin-2 : macrophages
Answer: D
Diff: 6  Page Ref: 683

65) Cytotoxic T cells release two proteins to destroy infected cells: ________, which forms pores in the membrane of the infected cells, and ________, which enters the infected cell through these pores and triggers apoptosis.
   A) perforins : fragmentins
   B) fragmentins : perforins
   C) MHC class I : MHC class II
   D) complement system proteins : perforins
   E) complement system proteins : fragmentins
Answer: A
Diff: 5  Page Ref: 683

66) Which of the following cells are activated by the release of interleukin-10 from the helper T cells?
   A) B cells
   B) natural killer cells
   C) mast cells
   D) macrophages
   E) cytotoxic T cells
Answer: D
Diff: 6  Page Ref: 685

67) The primary mechanism whereby cytotoxic T cells are able to destroy infected cells involves ________.
   A) enzymatic degradation
   B) incorporation of the major attack complex
   C) phagocytosis
   D) activation of the complement system
   E) the incorporation of perforins into the cell membrane
Answer: E
Diff: 4  Page Ref: 683

68) Which of the following interleukins (IL) is NOT targeted to B cells?
   A) IL-10
   B) IL-2
   C) IL-4
   D) IL-5
   E) IL-γ
Answer: A
Diff: 5  Page Ref: 685
69) The incorporation of perforins into the cell membrane results in the cell’s _______.
   A) being marked for degradation by macrophages
   B) shrinkage and subsequent death
   C) swelling and subsequent lysis
   D) being bound by antibodies
   E) binding of the helper T cell

   Answer: C
   Diff: 4    Page Ref: 674

70) A number of tumors and viruses (e.g., Epstein–Barr) are able to escape cytotoxic T cell degradation by inhibiting what?
   A) the activation of the complement system
   B) tumor antigen expression
   C) the production of the class II major histocompatibility (MHC) molecule
   D) the production of the class I MHC molecule
   E) helper T cell activation

   Answer: D
   Diff: 6    Page Ref: 683

71) Vaccines are composed of _______ that stimulate an active immunity to the pathogen.
   A) the non–pathogenic portion of the microorganism
   B) the pathogenic portion of the microorganism
   C) antibodies to a microorganism
   D) memory B cells that respond to a microorganism
   E) memory T cells that respond to a microorganism

   Answer: A
   Diff: 4    Page Ref: 684

72) A natural form of passive immunity involves the transfer of _______.
   A) IgA antibodies across the placenta
   B) IgE antibodies by sneezing
   C) IgG antibodies by kissing
   D) IgA antibodies to an infant through the mother’s milk
   E) IgG antibodies to an infant through the mother’s milk

   Answer: D
   Diff: 5    Page Ref: 686

73) People who have type AB blood are considered _______ because they _______.
   A) universal recipients : have antibodies to A and B
   B) universal recipients : have no antibodies to A or B
   C) universal donors : have antibodies to A and B
   D) universal donors : have no antibodies to A and B
   E) universalists : cannot receive blood transfusions

   Answer: B
   Diff: 4    Page Ref: 686
74) People who have type O blood are considered _______ because they _______.
   A) universal recipients : have no A or B antigens
   B) universal recipients : have no antibodies to A or B
   C) universal donors : have no A or B antigens
   D) universal donors : have no antibodies to A or B
   E) universalists : cannot receive blood transfusions
   Answer: C
   Diff: 4    Page Ref: 686

75) Tissue transplantation has been made possible by our ability to _______.
   A) inhibit the binding of helper T cells to the HLA
   B) inhibit interleukin-5
   C) alter the expression of the HLA molecules
   D) match HLA molecules between individuals
   E) competitively inhibit HLA molecules
   Answer: D
   Diff: 4    Page Ref: 686

76) What antibody is most involved in the allergic response?
   A) IgG
   B) IgM
   C) IgA
   D) IgD
   E) IgE
   Answer: E
   Diff: 3    Page Ref: 687

77) Hay fever that occurs when people are exposed to pollen involves an excess release of IgE, which binds to _______ and causes them to _______.
   A) mast cells : degranulate, releasing histamine
   B) pollen : stimulate the release of histamine
   C) macrophages : destroy the pollen whose by-products stimulate histamine release
   D) T helper cells : stimulate the proliferation of cytotoxic T cells
   E) mast cells : stimulate the proliferation of cytotoxic T cells
   Answer: A
   Diff: 5    Page Ref: 687

78) The most acute allergic response is anaphylactic shock, which can be deadly due to the histamine-induced _______.
   A) increase in peripheral resistance that decreases cardiac output
   B) decrease in peripheral resistance that decreases mean arterial pressure
   C) decrease in peripheral resistance that increases cardiac output
   D) increase in capillary permeability
   E) local decrease in resistance with little effect on mean arterial pressure
   Answer: B
   Diff: 4    Page Ref: 687
79) Diabetes mellitus can be caused by a form of autoimmune disease that attacks _______.
A) insulin receptors, preventing insulin from acting on cells
B) alpha cells of the pancreas, which destroys insulin production
C) GLUT-4 proteins as they insert into the membrane
D) beta cells of the pancreas, which destroys insulin production
E) the exocrine portion of the pancreas
Answer: D
Diff: 5 Page Ref: 688

80) What hormone released in times of stress directly inhibits the function of the immune system?
A) Glucagon
B) Aldosterone
C) Epinephrine
D) ADH
E) Corticosteroid
Answer: E
Diff: 4 Page Ref: 689

True/False Questions

1) Eosinophils are phagocytes that also attack parasites.
   Answer: TRUE
   Diff: 3 Page Ref: 668

2) Cytotoxic T cells can mount an immune response more quickly than natural killer cells.
   Answer: FALSE
   Diff: 3 Page Ref: 669

3) Sebaceous and sweat glands can act as a first line of defense because their secretions are acidic.
   Answer: TRUE
   Diff: 3 Page Ref: 670

4) Macrophages are phagocytes that initiate inflammation.
   Answer: TRUE
   Diff: 4 Page Ref: 671

5) Macrophages release bradykinin during inflammation, causing the sensation of pain.
   Answer: FALSE
   Diff: 4 Page Ref: 671

6) The process of phagocytosis takes less than a tenth of a second.
   Answer: TRUE
   Diff: 4 Page Ref: 672

7) C-reactive protein is an acute phase protein released by neutrophils that acts as an opsonin when bound to bacteria.
   Answer: FALSE
   Diff: 5 Page Ref: 673
8) The membrane attack complex is formed by major histocompatibility proteins.
   Answer: FALSE
   Diff: 4 Page Ref: 674

9) Cell-mediated immunity involves the actions of the B cells, whereas humoral immunity involves the actions of T cells.
   Answer: FALSE
   Diff: 3 Page Ref: 675

10) The antigen receptors on T cells come from the same family of proteins as antibodies.
    Answer: TRUE
    Diff: 3 Page Ref: 675

11) The structure of the antigen receptor on the T cell is determined after the cell is exposed to a pathogen.
    Answer: FALSE
    Diff: 5 Page Ref: 677

12) The heavy chains of an antibody comprise portions of both the constant and variable regions of the antibody.
    Answer: TRUE
    Diff: 4 Page Ref: 676

13) The constant region of an antibody determines its specificity, whereas the variable region determines its mechanism of action.
    Answer: FALSE
    Diff: 4 Page Ref: 676

14) Clonal selection of B cells generally results in the production of two types of clones: plasma cells and memory cells.
    Answer: TRUE
    Diff: 4 Page Ref: 677

15) The complement system can be activated by both specific and nonspecific defenses.
    Answer: TRUE
    Diff: 3 Page Ref: 674

16) Antigens that evoke the production of both plasma cells and memory B cells are T-independent antigens.
    Answer: FALSE
    Diff: 4 Page Ref: 679

17) All classes of antibodies are capable of neutralization of antigen.
    Answer: TRUE
    Diff: 4 Page Ref: 679

18) The complement system can be activated by IgM, IgG, and IgA.
    Answer: FALSE
    Diff: 5 Page Ref: 680
19) Class II MHC molecules are found on macrophages.
   Answer: TRUE
   Diff: 4   Page Ref: 682

20) Cytotoxic T cells are also called CD4 cells.
   Answer: FALSE
   Diff: 4   Page Ref: 682

21) Helper T cells are able to directly kill any cell that they come into contact with.
   Answer: FALSE
   Diff: 2   Page Ref: 682

22) Cells expressing tumor antigens are attacked by cytotoxic T cells.
   Answer: TRUE
   Diff: 3   Page Ref: 683

23) Passive immunization induces long-term immunity.
   Answer: FALSE
   Diff: 3   Page Ref: 686

24) MHC molecules do not play a role in transfusion reaction because erythrocytes do not express the MHC molecule.
   Answer: TRUE
   Diff: 4   Page Ref: 686

25) Drugs like cyclosporin A are given to transplant patients to inhibit the production of interleukin-2 and thereby inhibit the immune response.
   Answer: TRUE
   Diff: 5   Page Ref: 687

26) A deficiency in the enzyme adenosine deaminase can lead to an immunodeficiency disease.
   Answer: TRUE
   Diff: 3   Page Ref: 688
Matching Questions

*Match the cell type to its function.*

1) Phagocyte that initiates inflammation.
   - Diff: 4   Page Ref: 668
   - A) macrophages

2) Secrete antibodies.
   - Diff: 3   Page Ref: 669
   - B) helper T cells

3) Secrete histamine at the site of an infection.
   - Diff: 4   Page Ref: 669
   - C) mast cells

4) Develop into plasma cells.
   - Diff: 3   Page Ref: 669
   - D) B cells

5) Secrete interleukin-2 to facilitate B cell proliferation into memory B cells in addition to effector cells.
   - Diff: 4   Page Ref: 679
   - E) natural killer cells

6) Secrete perforins as part of the nonspecific defense mechanism.
   - Diff: 4   Page Ref: 674
   - F) cytotoxic T cells

7) Kill cells infected by a virus as part of the specific immune response.
   - Diff: 4   Page Ref: 683
   - G) plasma cells

**Answers:**
1) A  2) G  3) C  4) D  5) B
6) E  7) F

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Match the antibody class to its description.

8) The most abundant class of antibody in the body, this antibody can function by neutralization, agglutination, opsonization, complement activation, and enhancement of natural killer cell activity.  
   Diff: 4  Page Ref: 680
   A) IgM  B) IgE  C) IgD  D) IgA  E) IgG

9) Secreted in breast milk, this class of antibody helps protect the newborn through neutralization and agglutination of antigen.  
   Diff: 4  Page Ref: 680

10) During allergic reactions, this class of antibody causes mast cells and basophils to release histamine.  
    Diff: 3  Page Ref: 680

11) This class of antibody functions through neutralization and agglutination of antigen, but cannot cross epithelial cells. It is also an antigen receptor on B cells.  
    Diff: 5  Page Ref: 680

12) This antibody class is the most common class of antibody produced in the primary response to an antigen. It acts through neutralization, agglutination, and activation of the complement system. 
    Diff: 5  Page Ref: 680

Match the cytokine to its description.

13) Helps induce proliferation and differentiation of B cells and T cells, stimulates release of acute phase proteins, and acts on the hypothalamus to induce fever.
   Diff: 5   Page Ref: 685

14) Secreted by virally infected cells to induce a virus-resistant state in nearby cells.
   Diff: 5   Page Ref: 674

15) Secreted by active T cells and natural killer cells, this cytokine inhibits viral replication, enhances phagocytosis in macrophages, boosts production of antibodies by B cells, and activates both natural killer cells and cytotoxic T cells.
   Diff: 5   Page Ref: 674

16) Secreted by helper T cells, this cytokine stimulates proliferation of helper T cells and cytotoxic T cells, proliferation and differentiation of B cells, and enhances the activity of natural killer cells.
   Diff: 5   Page Ref: 685

17) This cytokine stimulates plasma cell secretion of IgE and IgG, and increases the number of class II MHC molecules on B cells and macrophages.
   Diff: 6   Page Ref: 685

18) This cytokine stimulates plasma cells to secrete IgA.
   Diff: 6   Page Ref: 685
19) This cytokine inhibits cytokine production from macrophages to down-regulate the immune response.

Diff: 6 Page Ref: 685

18) A 19) B

Match the step of inflammation with its description.

20) Involves adhesion molecule expression in blood vessel walls and leukocytes.
Diff: 5 Page Ref: 672

21) Caused by histamine released from mast cells.
Diff: 4 Page Ref: 672

22) Delayed by heparin released from mast cells and basophils.
Diff: 4 Page Ref: 672

23) During this process, cytokines are released to initiate inflammation.
Diff: 4 Page Ref: 671

24) This step is enhanced by the presence of opsonins.
Diff: 4 Page Ref: 672

25) Includes the steps of margination, attachment, diapedesis, and chemotaxis.
Diff: 4 Page Ref: 672

26) This process involves activation of clotting factors.
Diff: 4 Page Ref: 672

25) E 26) D

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Essay Questions

1) The first line of defense against pathogens and foreign material is not directed toward any particular pathogen. Describe the general properties of the body’s internal nonspecific defenses.

Answer: Nonspecific defenses are directed against harmful substances without regard to their identity. The skin and mucous membranes form the body’s first line of defense. While the skin cells act as a physical defense, the mucus traps foreign matter or pathogens. In addition, the secretions from sebaceous and sweat glands of the skin are quite acidic and can destroy many pathogens. If the pathogens get through the skin, another nonspecific defense is activated—the inflammatory response. The inflammatory response is initiated by macrophages in the tissue that destroy damaged cells by phagocytosis and release the cellular debris, which further stimulates the inflammatory response. Blood flow to the site of infection increases, as does the permeability of the capillary endothelial cells. This recruits additional leukocytes to the site of infection, and isolates the infected material by the release of clotting factors. A third form of nonspecific defense involves the release of interferons (α and β) by virus–infected cells. Interferons act on nearby cells, making them resistant to viral replication due to the presence of RNA-degrading enzymes. Thus, while the virus–infected cells will die, the cells surrounding them are protected from infection. Another type of interferon (γ) is secreted from T cells and NK cells, and activates cytotoxic T cells and NK cells to kill virus–infected cells and cancer cells. A fourth form of nonspecific defense involves the natural killer (NK) cells that recognize the general features of infected cells and cause them to lyse. The activity of the NK cells is enhanced by interleukin–2 and antibodies. Finally, the complement system is a form of nonspecific defense that involves a cascade of proteins. Those proteins lead to the incorporation of a membrane attack complex (MAC) into bacteria, causing them to lyse. The complement system can be activated by either the alternative or classical pathways. The alternative pathway is activated by directly binding to carbohydrates on the bacterium. The classical pathway is activated by the binding of an antibody to bacteria. Some complement proteins also play a role in chemotaxis or bind to mast cells to stimulate histamine release. At the same time, the complement protein C3b attaches to the surface of bacteria to induce opsonization, which enhances bacterial degradation by phagocytosis.

Diff: 8  Page Ref: 670
2) One of the well-characterized pathways of nonspecific immunity is the inflammatory response. Describe the inflammatory response, including a discussion of the process of phagocytosis and the cytokines that mediate this response.

Answer: The inflammatory response is a nonspecific defense mechanism activated within the tissue by macrophages. These cells bind to bacteria and damaged cells, internalize them and degrade them with lysosomes (phagocytosis). The remains of this cellular degradation are released by exocytosis and stimulate cytokine secretion from macrophages, which contributes to the inflammatory response. This degradation product also stimulates mast cells to release histamine, which dilates arterioles (decreases resistance) and increases the permeability of capillary endothelial cells. The decreased resistance leads to increased blood flow and hydrostatic pressure, which causes the redness and elevated temperature that is characteristic of the inflammatory response. The elevated hydrostatic pressure and increased capillary permeability to proteins causes the tissue to swell (edema). That increased interstitial pressure can stimulate sensory nerve endings, causing the sensation of pain; sensory nerve endings are directly stimulated by the release of bradykinin as well. Heparin, released from basophils and mast cells, inhibits the activity of clotting factors. In time, the clotting factors become active, thereby isolating the damaged region of tissue. The cytokines released by the initial phagocytosis affect endothelial cells, causing them to increase their production of selectins. These selectin proteins are involved in margination, the slowing of leukocytes as they move through the vasculature of the injured tissue. Once leukocytes are slowed, the increased expression of integrins on those leukocytes will bind them tightly to endothelial cells. Expression of integrins is stimulated by interleukin-1, interleukin-6, and tumor necrosis factor-α. This attachment allows leukocytes to move across the endothelial cell wall and to the site of infection by the process of diapedesis. Leukocytes are drawn to the site of infection by cytokines through the process of chemotaxis. The bacteria and debris are destroyed through phagocytes by leukocytes (neutrophils and macrophages) that have entered. They are stimulated to bind to damaged cells by their appearance and their adhesion is enhanced by opsonization, which involves proteins (antibodies and others proteins) binding to the cell and enhancing leukocyte binding.
3) Along with nonspecific immunity is specific immunity, which is targeted at particular pathogens. Describe the general features of the specific immune response.

Answer: Specific immune responses are directed toward particular pathogens through the actions of B cells and T cells. B cells secrete antibodies that are part of the humoral immunity, while T cells constitute the cell-mediated immunity. B cells have no direct effect on pathogens, except through the release of antibodies, whereas T cells affect pathogens directly. B and T cells bind to antigens, complex membrane proteins, or carbohydrates on the pathogens. Each antigen has a unique site (epitope) that is targeted by a specific B or T cell. These cells contain antigen receptors on their surface that bind to particular antigens. The antigen receptor on a B cell is similar in structure to an antibody’s. Antibodies (immunoglobulins) are composed of heavy and light chains arranged in a Y shape. The chains are bound by disulfide bridges. The two ends are the variable regions containing the antigen binding sites. The T cell antigen receptor is in the same family as the B cell membrane antibody, but is different in structure. Each B and T cell expresses thousands of antigen receptors on its surface (all similar to one another) that allows it to detect very low concentrations of pathogens. The specific antigen receptor is determined by a random series of genetic events in the development of the cell, leaving each cell with a unique antigen receptor. Thus, the body has millions of different receptors in order to respond to the multitude of pathogens to which it is exposed. When a pathogen first invades the body, at least one of the millions of different B or T cell antigenic receptors will bind to that pathogen. This initiates a clonal selection where the activated lymphocyte is stimulated to proliferate into effector cells (that either produce antibodies or attack the cell) and memory cells (which facilitate responses to this pathogen in the future). The effector cells are lost days after they are produced, whereas memory cells remain in the body. The process outlined above is referred to as a primary immune response. This response is the first to a particular pathogen, which requires 10–17 days to be activated, and the number of effector cells (T cells) and the amount of antibodies (B cells) produced are quite low. Upon subsequent exposures, specific memory cells initiate the secondary immune response. The response peaks in 2–7 days and produces much greater concentrations of plasma cells and antibodies. However, one might wonder why one of those millions of antigenic receptors is not specific for the body in which they reside. As B and T cells mature, they are screened for reactions to self. Those that respond to self are destroyed by apoptosis.

Diff: 8  Page Ref: 675
4) Immunity to specific pathogens occurs by two interrelated pathways: humoral immunity and cell-mediated immunity. Describe humoral immunity, including the details about the different classes of antibodies that mediate this immunity.

Answer: Humoral immunity involves the release of antibodies from B cells once they are exposed to specific antigens. When a B cell binds directly to a T-independent antigen (typically a bacterial polysaccharide), the B cell is stimulated to proliferate and differentiates into plasma cells exclusively (B cell effectors). The polysaccharide provides a strong enough signal to initiate proliferation in the absence of interleukin-2, which is necessary to stimulate proliferating cells' to differentiate into memory cells. The plasma cells secrete antibodies (2000 per second). These antibodies circulate in the blood for several weeks, binding to the antigens that originated their production. However, since no memory cells are generated in the absence of interleukin-2, repeated exposure will initiate a primary immune response (no secondary immune response). Helper T cells release the interleukin-2 that stimulates the proliferation and differentiation of B cells into plasma and memory cells. In the presence of a T-dependent antigen, a B cell binds to the antigen and presents a class II major histocompatibility (MHC) molecule to the helper T cell. When a helper T cell binds to the class II MHC molecule, it induces the secretion of interleukin-2 from the helper T cell. Interleukin-1 from the the B-cell acts to stimulate the proliferation of the helper T cell. There are five classes of antibodies (IgM, IgD, IgE, IgG, and IgA) that differ in the structure of their heavy chains. Antibodies do not directly kill pathogenic cells. However, all antibodies have the ability to neutralize an antigen's activity by binding to it and blocking access. In addition, all antibodies can cause agglutination, since each antibody has the potential to bind to two separate pathogenic cells. Once bound, the IgG and IgM antibodies can be opsonized, rendering the cell more susceptible to phagocytosis. The IgG antibody can also kill its target cells by activating the complement system or natural killer cells. IgM is one of the more common antibodies that produces the primary antigen response. IgD acts as an antigen receptor on B cells. IgG is another of the common classes of antibodies that produces secondary responses and can cross the placenta. IgE is involved in allergies and hay fever. Finally, IgA crosses epithelial cells and is therefore present on mucosal surfaces and in breast milk.

Diff: 7 Page Ref: 679
5) Immunity to specific pathogens occurs by two interrelated pathways: humoral immunity and cell-mediated immunity. Describe cell-mediated immunity, including the role of the MHC molecule.

Answer: Unlike humoral immunity, cell-mediated immunity does not rely on the indirect action of antibodies to kill cells. There are three major types of T cells involved in cell-mediated immunity: suppressor T cells, cytotoxic T cells, and helper T cells. Suppressor T cells are not well understood, and are thought to produce cytokines that suppress the activities of B cells, helper T cells, and cytotoxic T cells. Helper T cells are the primary regulators of immune function, because they use cytokines to activate B cells, cytotoxic T cells, suppressor T cells, and helper T cells. In addition, they secrete cytokines that enhance the activity of macrophages and natural killer cells. Cytotoxic T cells are directly responsible for cell-mediated immunity by killing cells infected with viruses, bacteria or other abnormal presentations. All three types have T cell receptors but they are only able to bind to cells when the antigen is presented with a major histocompatibility (MHC) molecule (known as human leukocyte antigen [HLA]). The MHC molecule that has bound to an antigen makes contact with a T cell receptor to activate the T cell. The coupling between the MHC molecule and antigen is referred to as antigen presentation. There are two general classes of MHC molecules: class I and class II. Class I MHC molecules are found on the surface of all nucleated cells, while class II are found on the surface of macrophages, activated B and T cells, and cells on the interior of the thymus. The MHC molecule is specific for an individual and allows the body to distinguish between self and nonself. The fidelity of the self signal is maintained within the thymus by the presence of class I and II MHC molecules. In order to continue to develop, a T cell must have an affinity for particular MHC molecules. T cells that bind to class I MHC molecules in the thymus develop into cytotoxic T cells, while those that bind to class II MHC molecules develop into helper T cells. As a newly synthesized MHC molecule makes its way to the membrane of an infected cell, it is able to capture antigen fragments from within the cell. Class I MHC molecules capture foreign or abnormal antigens within infected cells and tumor cells. Class II MHC molecules capture foreign antigens that have been internalized by phagocytosis or receptor-mediated endocytosis. Helper T cells express the CD4 protein on their surface that allows them to bind to class II MHC molecules, while cytotoxic T cells contain the CD8 protein, which binds to the class I MHC molecules. In cell-mediated responses, class II MHC molecule responses activate helper T cells by the release of interleukin~1, which causes the helper T cells to proliferate and differentiate into daughter cells, some of which become memory cells. Cytotoxic T cells are activated by two events occurring simultaneously: binding to class I MHC molecules and the release of interleukin~2 from the helper T cell. Once activated, the cytotoxic T cells release perforin, which creates pores in the membranes of pathogenic cells that cause them to lyse. The cytotoxic T cells can also release fragmentin that enters the cells and induces apoptosis. Cytotoxic T cells can also attack tumor cells expressing the class I MHC molecules.

Diff: 9  Page Ref: 681
6) Two important functions of the immune system, which involve antibodies that affect most people, are immunizations and allergies. Characterize the three types of immunities and the mechanisms that underlie allergic responses.

Answer: Immunization refers to exposure to a safe form of microorganism that is not expected to cause disease, but will stimulate the body to mount an immune response. The exposure initiates a primary immune response and produces memory cells such that, if the person is ever exposed to the infection again, the body will be able to mount a rapid and strong secondary immune response to the pathogen. Active immunity can be either artificial (as described above) or natural (previous exposure to the pathogen). Another form of immunity is passive immunity, where antibodies to a particular pathogen are injected into a person. Some disease occurs so rapidly that we are not able to mount an immune response in enough time to survive. Thus, injection of antibodies can fight the disease. However, these antibodies only remain in the body for a relatively short time and, because no memory cells are generated, there will not be a secondary response when exposed a second time. Passive immunity normally occurs in fetuses and babies. Maternal IgG crosses the placenta and provides passive immunity for the fetus, while the IgA present in the early breast milk (colostrum) will provide protection to the newborn for weeks to months.

Allergies are exaggerated reactions to environmental antigens that usually involve IgE antibodies. Excessive IgE release in response to pollen causes the tail of the IgE to bind with mast cells. When the IgE binds to pollen, the mast cells they are attached to are stimulated to degranulate and release histamine. Runny nose and sneezing are reflections of the inflammatory response (vasodilation and increased capillary permeability) in the respiratory tract. Anaphylactic shock is a life-threatening form of allergy, where the degranulation of mast cells is so widespread that the vasodilation causes a drop in peripheral resistance and thereby mean arterial pressure.

Diff: 7  Page Ref: 684

Short Answer Questions

1) Name the four types of fixed macrophages.
   Answer: microglia, alveolar macrophages, Kupffer cells, and histiocytes
   Diff: 4  Page Ref: 668

2) What type of leukocytes are phagocytes?
   Answer: neutrophils, eosinophils, and monocytes
   Diff: 4  Page Ref: 668

3) When leukocytes release the contents of their cytoplasmic granules, the process is called
   ________.
   Answer: degranulation
   Diff: 3  Page Ref: 668

4) Name the two central lymphoid tissues.
   Answer: bone marrow and thymus
   Diff: 3  Page Ref: 669

5) Inflammation is an example of a (nonspecific / specific) defense.
   Answer: nonspecific
   Diff: 3  Page Ref: 671

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6) During the inflammatory response (macrophages / mast cells) release (histamine / heparin), which causes vasodilation and increases capillary permeability.
   Answer: mast cells : histamine
   Diff: 4   Page Ref: 671

7) ________ is the process whereby leukocytes move across the endothelial layer and through the blood vessel wall.
   Answer: Diapedesis
   Diff: 4   Page Ref: 672

8) Proteins that bind to foreign matter making it easier for phagocytosis are called ________.
   Answer: opsonins
   Diff: 4   Page Ref: 672

9) Define a secondary lysosome.
   Answer: A lysosome that has fused with a phagosome
   Diff: 4   Page Ref: 673

10) In response to certain cytokines, the liver secretes ________, which help combat bacterial infections and induce inflammation.
    Answer: acute phase proteins
    Diff: 5   Page Ref: 673

11) Natural killer cells secrete ________, which forms pores in the membrane of infected or abnormal cells.
    Answer: perforins
    Diff: 4   Page Ref: 674

12) Interferon–γ is secreted by ________ and enhances ________.
    Answer: active T cells and natural killer cells : macrophage phagocytosis
    Diff: 6   Page Ref: 674

13) The complement system consists of several proteins that form a (n) ________ that forms a pore in the membrane of bacteria during the nonspecific immune response.
    Answer: membrane attack complex
    Diff: 4   Page Ref: 674

14) In specific defenses, B cells are responsible for ________ immunity, whereas cytotoxic T cells are necessary for ________ immunity.
    Answer: humoral : cell-mediated
    Diff: 3   Page Ref: 675

15) The process of antigen–induced lymphocyte proliferation is called ________.
    Answer: clonal selection
    Diff: 5   Page Ref: 677

16) The (memory / effector) cells provide for a rapid secondary immune response.
    Answer: memory
    Diff: 3   Page Ref: 677
17) (Agglutination / Opsonization) is dependent on antibodies being capable of binding more than one antigen.
   Answer: Agglutination
   Diff: 4 Page Ref: 679

18) During T cell development in the thymus, those cells with receptors for class I major histocompatibility molecules develop into _______ T cells, whereas those with receptors for class II major histocompatibility molecules develop into _______ T cells.
   Answer: cytotoxic : helper
   Diff: 5 Page Ref: 682

19) The activation of helper T cells involves two simultaneous events: _______ and _______.
   Answer: binding to cells with the class II major histocompatibility (MHC) molecule : the secretion of interleukin-1 by those cells, which stimulates proliferation and differentiation of helper T cells
   Diff: 5 Page Ref: 682

20) Cytotoxic T cells release (perforins / fragmentins), which enters bacterial cells and induces (lysis / apoptosis).
   Answer: fragmentins : apoptosis
   Diff: 5 Page Ref: 683

21) Active immunity through a natural pathway involves _______.
   Answer: previous exposure to the pathogen
   Diff: 3 Page Ref: 684

22) The inhibition of interleukin-2 synthesis by cyclosporin A and other anti-rejection drugs will act to inhibit the activity of what type(s) of cell?
   Answer: B cell and T cell
   Diff: 3 Page Ref: 687

23) When bone marrow is transplanted, the primary source of rejection is _______.
   Answer: transplanted lymphocytes initiating an immune response to the host
   Diff: 3 Page Ref: 687
Multiple Choice Questions

1) Which of the following best describes diabetes mellitus type 1?
   A) its an autoimmune disease that attacks insulin receptors
   B) its an autoimmune disease that attacks alpha cells of the pancreas
   C) its an autoimmune disease that attacks beta cells of the pancreas
   D) its a genetic disorder associated with the X chromosome
   E) its a genetic disorder associated with the Y chromosome
Answer: C
_Diff: 4  Page Ref: 694_

2) In diabetes mellitus type 1, the immune system attacks beta cell antigens. Which of the following is a potential antigen?
   A) preproinsulin
   B) glucose
   C) glucagon
   D) preproglucagon
   E) ketones
Answer: A
_Diff: 4  Page Ref: 694_

3) What is the significance of Coxsackie B virus in diabetes mellitus type 1?
   A) This virus attacks beta cells of the pancreas causing an immune response against these cells.
   B) A person with diabetes mellitus type 1 is more susceptible to infection with Coxsackie B.
   C) Coxsackie B increases the availability of lipids for energy.
   D) Coxsackie B increases the availability of glucose for energy.
   E) Coxsackie B increases the availability of proteins for energy.
Answer: A
_Diff: 4  Page Ref: 694_

4) By what percentage has the incidence of diabetes mellitus type 1 increased in the United States over the last twenty years?
   A) 0
   B) 10
   C) 25
   D) 50
   E) 100
Answer: D
_Diff: 4  Page Ref: 694_
5) At what age do symptoms of diabetes mellitus type 1 first appear?
   A) at conception
   B) at birth
   C) before age 5
   D) after age 7
   E) after age 40
   Answer: D
   Diff: 4 Page Ref: 694

6) Which of the following is NOT an effect of epinephrine?
   A) stimulate protein synthesis
   B) stimulate lipolysis
   C) stimulate gluconeogenesis
   D) increase blood fatty acid levels
   E) increase ketone production
   Answer: A
   Diff: 5 Page Ref: 695

7) Which of the following is NOT a symptom of ketoacidosis?
   A) dehydration
   B) fruity odor to breath
   C) decreased ventilation
   D) polyuria
   E) electrolyte imbalance
   Answer: C
   Diff: 5 Page Ref: 696

8) Which of the following can NOT cause coma?
   A) a person with diabetes mellitus taking too much insulin causing hypoglycemia
   B) a person with diabetes mellitus type 1 taking too little insulin causing hyperglycemia
   C) a blood osmolality greater than 350 mOsm
   D) a blood glucose concentration greater than 600 mg/dL
   E) a partial pressure of carbon dioxide of 40 mm Hg in arterial blood
   Answer: E
   Diff: 5 Page Ref: 696

9) Symptoms of hypoglycemia include all of the following EXCEPT ________.
   A) blurred vision
   B) hunger
   C) tingling sensation
   D) polyuria
   E) anxiety
   Answer: D
   Diff: 5 Page Ref: 696
10) Which of the following chemical messengers induces the sensation of feeling full (satiety effect)?
   A) insulin  
   B) glucagon  
   C) epinephrine  
   D) acetylcholine  
   E) somatostatin  

   Answer: A  
   Diff: 5  Page Ref: 697

11) In diabetes mellitus, polydipsia is triggered by what hormone?
   A) angiotensin II  
   B) angiotensin I  
   C) leptin  
   D) relaxin  
   E) glucagon  

   Answer: A  
   Diff: 4  Page Ref: 696

12) Glycosylation of what protein is used as a marker for measuring blood glucose levels?
   A) insulin  
   B) glucagon  
   C) albumin  
   D) fibrin  
   E) hemoglobin  

   Answer: E  
   Diff: 4  Page Ref: 697

13) Which of the following is NOT an adverse effect of glycosylation caused by hyperglycemia?
   A) delayed wound healing  
   B) increased capillary permeability lipolysis  
   C) beta cell degeneration  
   D) oxidative stress  
   E) atherosclerosis  

   Answer: C  
   Diff: 4  Page Ref: 697

14) What is the polyol associated with glucose?
   A) aldose  
   B) lactose  
   C) sorbitol  
   D) ascorbic acid  
   E) glycerol  

   Answer: C  
   Diff: 7  Page Ref: 697
15) In diabetes mellitus type 1, blood vessel damage occurs primarily through what process?
   A) shear stress on the blood vessels due to elevated pressure
   B) increase in nitric oxide release from endothelial cells
   C) increase in carbon dioxide build up in blood
   D) increase in oxygen levels in blood
   E) increase in histamine production

   Answer: A
   Diff: 7   Page Ref: 698

16) In diabetes mellitus type 2, blood vessel damage occurs primarily through what process?
   A) shear stress on the blood vessels due to elevated pressure
   B) increase in carbon dioxide levels in blood
   C) decrease in nitric oxide release from endothelial cells
   D) increase in histamine production
   E) sclerosis of the basement membrane

   Answer: C
   Diff: 4   Page Ref: 698

17) Damage to the microvasculature that occurs with diabetes contributes to which of the following conditions?
   A) retinopathy
   B) nephropathy
   C) neuropathy
   D) delayed wound healing
   E) all of the above

   Answer: E
   Diff: 3   Page Ref: 698

18) What is a microaneurysm?
   A) small leakage of blood from the microvasculature
   B) large leakage of blood from the microvasculature
   C) development of new blood vessels
   D) weak bulges in the walls of small blood vessels
   E) perforation of the basement membrane of fenestrated capillaries

   Answer: D
   Diff: 4   Page Ref: 698

19) What is angiogenesis?
   A) small leakage of blood from the microvasculature
   B) large leakage of blood from the large blood vessels
   C) development of new blood vessels
   D) weak bulges in the walls of small blood vessels
   E) developments of perforations in the basement membrane of fenestrated capillaries

   Answer: C
   Diff: 4   Page Ref: 698
20) What happens when excessive angiogenesis occurs?
   A) the new blood vessel walls are weak and tend to leak
   B) the new blood vessel walls are stiff and tend to clog
   C) the heart can no longer beat strongly
   D) the heart rate increases significantly
   E) hypotension occurs due to decreased total peripheral resistance
   Answer: A
   Diff: 4   Page Ref: 698

21) Which of the following is an early sign of diabetic nephropathy?
   A) glucose in the urine
   B) blood in the urine
   C) systemic edema
   D) proteinuria
   E) frequent urinary tract infections
   Answer: D
   Diff: 6   Page Ref: 698

22) What is end-stage renal disease?
   A) the kidneys fail and dialysis or kidney transplant is essential
   B) the glomerular membrane becomes leaky and proteins appear in the urine
   C) infection of the kidneys causes blood loss in the urine
   D) Bowman's capsule becomes leaky causing a systemic infection
   E) Bowman's capsule becomes leaky and proteins appear in the urine
   Answer: A
   Diff: 4   Page Ref: 698

23) What is parasthesia?
   A) simultaneous activation of afferent and efferent axons to the same region of the body
   B) abnormal sensation of the skin such as tingling or numbness
   C) abnormal activation of motor neurons causing muscle twitches
   D) unpleasant sensation produced by innocuous stimuli
   E) muscle spasms
   Answer: B
   Diff: 4   Page Ref: 699

24) What is dysthesia?
   A) unpleasant sensation produced by innocuous stimuli
   B) numbness
   C) tingling sensation
   D) muscle twitches
   E) muscle spasms
   Answer: A
   Diff: 5   Page Ref: 699
25) Diabetic neuropathies generally affect what area of the nervous system?
   A) brain  
   B) spinal cord  
   C) peripheral nervous system  
   D) sensory receptors  
   E) glial cells  
   Answer: C  
   Diff: 4  
   Page Ref: 699  

26) Which of the following does NOT contribute to diabetes enhanced atherosclerosis?
   A) increased lipid transport in LDLs  
   B) increased production of reactive oxygen species  
   C) increased glycosylation  
   D) microvascular disease  
   E) increased lipid transport in HDLs  
   Answer: E  
   Diff: 6  
   Page Ref: 700  

27) Which of the following is characteristic of diabetic cardiomyopathy?
   A) decreased stroke volume  
   B) decreased heart rate  
   C) decreased size of the heart  
   D) decreased likelihood of myocardial infarction  
   E) All of the above  
   Answer: A  
   Diff: 6  
   Page Ref: 700  

28) What is silent myocardial ischemia?
   A) a heart attack without pain  
   B) a stroke  
   C) a cardiac arrhythmia that decreases contractility of the atria  
   D) a cardiac arrhythmia that decreases contractility of the ventricles  
   E) a cardiac arrhythmia that shuts down the pacemaker cells of the SA node  
   Answer: A  
   Diff: 4  
   Page Ref: 701  

29) Why do many diabetics have to have a foot amputated?
   A) decreased blood flow to the foot causes gangrene  
   B) decreased blood flow to the foot causes extreme pain that can only be relieved by amputation  
   C) neuropathy causes intense pain that can only be relieved by amputation  
   D) decreased blood flow to the foot causes wounds to develop that will not heal  
   E) abnormal wound healing coupled to lack of sensation from the foot can lead to gangrene  
   Answer: E  
   Diff: 7  
   Page Ref: 699
30) What is the correct order of the three steps of wound healing?
   A) inflammation – remodeling – proliferation
   B) proliferation – inflammation – remodeling
   C) remodeling – inflammation – proliferation
   D) proliferation – remodeling – inflammation
   E) inflammation – proliferation – remodeling

   Answer: E
   Diff: 6   Page Ref: 701

31) What two cytokines released by platelets during hemostasis promote inflammation?
   A) transforming growth factor beta and platelet derived growth factor
   B) interleukin 1 and thrombin
   C) interleukin 2 and platelet derived growth factor
   D) thrombin and leukotriene
   E) prostaglandin I2 and platelet factor 3

   Answer: A
   Diff: 8   Page Ref: 701

32) What cell type initiates the inflammatory response?
   A) macrophages
   B) neutrophils
   C) eosinophils
   D) fibroblasts
   E) lymphocytes

   Answer: A
   Diff: 4   Page Ref: 701

33) Phagocytosis of debris in the area of wound is carried out by what cell types?
   A) lymphocytes and fibroblasts
   B) neutrophils and fibroblasts
   C) eosinophils and neutrophils
   D) basophils and eosinophils
   E) macrophages and neutrophils

   Answer: E
   Diff: 4   Page Ref: 701

34) What cell type lays down the new extracellular matrix as a wound heals?
   A) neutrophils
   B) fibroblasts
   C) monocytes
   D) macrophages
   E) megakaryocytes

   Answer: B
   Diff: 4   Page Ref: 701
35) What cell type secretes collagen as a wound heals?
   A) neutrophils
   B) monocytes
   C) macrophages
   D) keratinocytes
   E) fibroblasts

   Answer: E
   Diff. 5  Page Ref. 701

36) What are epidermal cells that proliferate to cover the opening of a wound?
   A) fibroblasts
   B) macrophages
   C) keratinocytes
   D) neutrophils
   E) granule cells

   Answer: C
   Diff. 4  Page Ref. 701

37) Collagen becomes organized and cross-linked during what phase of wound healing?
   A) hemostasis
   B) proliferation
   C) remodeling
   D) inflammation
   E) angiogenesis

   Answer: C
   Diff. 5  Page Ref. 701

38) What effect does diabetes have on wound healing?
   A) speeds it up by increasing angiogenesis
   B) speeds it up by increasing the rate of proliferation
   C) speeds it up, but in the process leads to a larger scar formation
   D) slows it down by increasing inflammation
   E) delays it by slowing the rate of all phases

   Answer: E
   Diff. 4  Page Ref. 701

39) Adequate treatment of diabetes includes maintaining fasting blood glucose levels below what value?
   A) 60 mg/dL
   B) 85 mg/dL
   C) 100 mg/dL
   D) 115 mg/dL
   E) 130 mg/dL

   Answer: D
   Diff. 4  Page Ref. 703
40) Dietary control of diabetes mellitus type 1 includes limiting the intake of ________.
   A) carbohydrates
   B) proteins
   C) cholesterol
   D) triglycerides
   E) cellulose

   Answer: A
   Diff: 5   Page Ref: 703

41) What is the primary medicine for regulating diabetes mellitus type 1?
   A) insulin
   B) sulfonureas
   C) biguanides
   D) glucagon
   E) glucagon inhibitors

   Answer: A
   Diff: 4   Page Ref: 703

42) What diabetes medication stimulates insulin release from beta cells of the pancreas?
   A) none
   B) biguanides
   C) thiazolidinediones
   D) sulfonureas
   E) alpha-glucosidase inhibitors

   Answer: D
   Diff: 6   Page Ref: 703

43) How do alpha-glucosidase inhibitors decrease blood glucose levels?
   A) stimulating insulin release from beta cells of the pancreas
   B) inhibiting gluconeogenesis in the liver
   C) inhibiting glycogenesis in the liver
   D) inhibiting digestion of carbohydrates in the small intestine
   E) stimulating glycogenesis in the liver

   Answer: D
   Diff: 6   Page Ref: 703

44) What medicine for the treatment of diabetes sensitizes tissue to insulin?
   A) glucagon
   B) sulfonureas
   C) alpha-glucosidase inhibitors
   D) biguanides
   E) thiazolidinediones

   Answer: E
   Diff: 6   Page Ref: 703

True/False Questions

1) Diabetes mellitus type 1 is a genetic disorder that affects the genes for insulin synthesis.
   Answer: FALSE
   Diff: 3   Page Ref: 694
2) The diabetes epidemic is due to increases in diabetes mellitus 2 only; there has been no significant increase in diabetes mellitus type 1.

Answer: FALSE
Diff: 3 Page Ref: 694

3) The age of onset of diabetes mellitus type 2 is decreasing.

Answer: TRUE
Diff: 4 Page Ref: 695

4) Hyperglycemia can ultimately lead to activation of the sympathetic nervous system and release of epinephrine.

Answer: TRUE
Diff: 4 Page Ref: 695

5) When glucose levels exceed 600 mg/dL, a nonketotic coma can occur.

Answer: TRUE
Diff: 5 Page Ref: 696

6) Diabetic ketoacidosis is more common in diabetes mellitus type 2.

Answer: FALSE
Diff: 4 Page Ref: 695

7) People with diabetes mellitus suffer from polyphagia.

Answer: TRUE
Diff: 4 Page Ref: 696

8) People with diabetes are more prone to develop atherosclerosis.

Answer: TRUE
Diff: 5 Page Ref: 696

9) Diabetes mellitus types 1 and 2 are both associated with increased body weight.

Answer: FALSE
Diff: 4 Page Ref: 695

10) Diabetic retinopathy is the leading cause of blindness in adults.

Answer: TRUE
Diff: 3 Page Ref: 698

11) During the proliferative phase of diabetic retinopathy, new blood vessels are being synthesized but they are weak and tend to leak.

Answer: TRUE
Diff: 4 Page Ref: 698

12) Diabetic nephropathy is accompanied by an increase in glomerular filtration.

Answer: TRUE
Diff: 5 Page Ref: 698

13) Diabetic neuropathy is a disease of the central nervous system.

Answer: FALSE
Diff: 3 Page Ref: 699
14) Diabetic neuropathy can cause erectile dysfunction.
   Answer: TRUE
   Diff: 3   Page Ref: 699

15) Diabetes mellitus type 2 promotes obesity and obesity promotes diabetes mellitus type 2.
   Answer: TRUE
   Diff: 5   Page Ref: 695

16) The majority of people with diabetes die from microvascular diseases.
   Answer: FALSE
   Diff: 4   Page Ref: 695

17) Angiogenesis occurs during the normal wound healing process.
   Answer: TRUE
   Diff: 4   Page Ref: 697

18) Glycosylation decreases the ability of neutrophils and macrophages to phagocytose bacteria during inflammation.
   Answer: TRUE
   Diff: 5   Page Ref: 698

19) Diabetic foot ulcer is the leading cause of amputation in diabetes.
   Answer: TRUE
   Diff: 3   Page Ref: 703

20) Nasal inhalation of insulin is the newest innovation in diabetes treatment such that more patients use inhaled insulin instead of injected insulin.
   Answer: FALSE
   Diff: 3   Page Ref: 703

21) In diabetes mellitus type 2, the beta cells of the pancreas undergo apoptosis.
   Answer: FALSE
   Diff: 3   Page Ref: 695
Matching Questions

*Match the characteristic to Type 1 or Type 2 diabetes mellitus.*

1) Hyperglycemia
   - Diff: 3 Page Ref: 695
   - A) Both Type 1 DM and Type 2 DM
   - B) Both Type 1 DM and Type 2 DM

2) Polyuria
   - Diff: 3 Page Ref: 696
   - C) Neither Type 1 nor Type 2 DM
   - D) Type 2 DM
   - E) Type 1 DM

3) Caused by damage to beta cells of the pancreas
   - Diff: 3 Page Ref: 694
   - A) Both Type 1 DM and Type 2 DM
   - B) Both Type 1 DM and Type 2 DM
   - C) Neither Type 1 nor Type 2 DM
   - D) Type 2 DM
   - E) Type 1 DM

4) Caused by damage to alpha cells of the pancreas
   - Diff: 3 Page Ref: 694
   - A) Both Type 1 DM and Type 2 DM
   - B) Both Type 1 DM and Type 2 DM
   - C) Neither Type 1 nor Type 2 DM
   - D) Type 2 DM
   - E) Type 1 DM

5) Most common form of diabetes mellitus
   - Diff: 3 Page Ref: 695
   - A) Both Type 1 DM and Type 2 DM
   - B) Both Type 1 DM and Type 2 DM
   - C) Neither Type 1 nor Type 2 DM
   - D) Type 2 DM
   - E) Type 1 DM

6) Can occur secondary to obesity
   - Diff: 3 Page Ref: 695
   - A) Both Type 1 DM and Type 2 DM
   - B) Both Type 1 DM and Type 2 DM
   - C) Neither Type 1 nor Type 2 DM
   - D) Type 2 DM
   - E) Type 1 DM

7) Age of onset is usually in people over 40 years of age
   - Diff: 4 Page Ref: 695
   - A) Both Type 1 DM and Type 2 DM
   - B) Both Type 1 DM and Type 2 DM
   - C) Neither Type 1 nor Type 2 DM
   - D) Type 2 DM
   - E) Type 1 DM

8) Caused by inadequate insulin secretion
   - Diff: 3 Page Ref: 694
   - A) Both Type 1 DM and Type 2 DM
   - B) Both Type 1 DM and Type 2 DM
   - C) Neither Type 1 nor Type 2 DM
   - D) Type 2 DM
   - E) Type 1 DM

9) Caused by decreased response of tissue to insulin
   - Diff: 3 Page Ref: 695
   - A) Both Type 1 DM and Type 2 DM
   - B) Both Type 1 DM and Type 2 DM
   - C) Neither Type 1 nor Type 2 DM
   - D) Type 2 DM
   - E) Type 1 DM

Answers:
1) A  2) B  3) E  4) C  5) D  
  6) D  7) D  8) E  9) D
Match the cell type to its role in wound healing.

10) These are the first cells in the wound area and they contribute to inflammation while fighting the infection through phagocytosis and secreting cytokines.

   Diff: 5  Page Ref: 701

   A) neutrophils  B) macrophages  C) fibroblasts

11) These cells secrete collagen and are most active during the remodeling phase of wound healing.

   Diff: 5  Page Ref: 701

12) These cells arrive at the wound area by chemotaxis and assist in fighting the infection through phagocytosis and secreting cytokines.

   Diff: 5  Page Ref: 701

Answers: 10) B  11) C  12) A
Match the medication for treating diabetes with its mechanism of action.

13) Inhibit brush border enzymes that hydrolyze disaccharides, trisaccharides, and oligosaccharides to glucose or other monosaccharides, thereby decreasing absorption of glucose.
   Diff: 5 Page Ref: 703
   A) thiazolidinediones
   B) α-glucosidase inhibitors
   C) biguanides
   D) sulfonylureas

14) Sensitize tissue to insulin, thereby countering the resistance to insulin.
   Diff: 5 Page Ref: 703
   A) thiazolidinediones
   B) α-glucosidase inhibitors
   C) biguanides
   D) sulfonylureas

15) Reducing glucose production in the liver and increasing the sensitivity of receptors to insulin.
   Diff: 5 Page Ref: 703
   A) thiazolidinediones
   B) α-glucosidase inhibitors
   C) biguanides
   D) sulfonylureas

16) Close potassium channels on pancreatic beta cells causing a depolarization that triggers insulin release by exocytosis.
   Diff: 5 Page Ref: 703
   A) thiazolidinediones
   B) α-glucosidase inhibitors
   C) biguanides
   D) sulfonylureas


Essay Questions

1) How does hyperglycemia cause ketoacidosis?
   Answer: Hyperglycemia causes dehydration, which leads to a drop in blood pressure reflexively activating the sympathetic nervous system including the release of epinephrine from the adrenal medulla. Epinephrine mobilizes energy stores in several ways, including promoting lipolysis in adipose tissue thereby increasing blood levels of free fatty acids. These fatty acids can be taken up by the liver for beta oxidation, which leads to the production of ketones. Because ketones are an acid, ketoacidosis has occurred.
   Diff: 7 Page Ref: 696
2) What are some current research strategies that may lead to a "cure" for diabetes?

Answer: To "cure" diabetes mellitus type 1 would require increasing insulin levels whereas to "cure" diabetes mellitus type 2 would require increasing the response of tissue to insulin or other chemicals. In terms of type 1, getting the body to secrete insulin requires either generating new beta cells or causing other cells to release insulin. Research is on-going regarding both possibilities. Some researchers are trying to stimulate beta cells to self-replicate. Others are testing donor beta cells from health islets. A third mechanism to increase beta cells is to transplant stem cells into the pancreas and stimulate these cells to develop into beta cells. As for getting other cells to secrete insulin, gene therapy looks promising as mechanisms for stimulating genes for insulin to be expressed are being studied as are mechanisms of manipulating the genes responsible for initiating the autoimmune response.

In terms of type 2 diabetes mellitus, there are several causes of this disease and thus one therapy cannot cure all. A better understanding of the biochemical changes taking place in body cells is necessary before research can get a handle on a cure. For those whose diabetes is due to obesity, weight loss can cure the disease. In addition, bariatric surgery may cure the disease in some even if the person is not obese.

Diff: 8  Page Ref: 704

3) What are the three polys of diabetes mellitus and what is the cause of each?

Answer: The three polys are early symptoms of diabetes mellitus and include polyuria (excessive urination), polydipsia (excessive thirst), and polyphagia (excessive eating). Polyuria and polydipsia are ultimately caused by the same thing – a hyperglycemia induced osmotic gradient for more water to enter the renal tubules and be excreted. This directly causes polyuria, which decreases plasma volume and blood pressure. A drop in blood pressure will increase blood levels of angiotensin II, which acts on the anterior hypothalamus to trigger thirst causing polydipsia.

Polyphagia is a direct result of decreased insulin activity as insulin as appetite suppressing effects in the hypothalamus. Hyperglycemia may also decrease release of cholecystokinin, a hormone released from the small intestine that acts in the hypothalamus to induce satiety.

Diff: 6  Page Ref: 696

4) Describe the effects of neuropathy of the autonomic nervous system.

Answer: Neuropathy can have a wide range of effects on the autonomic nervous system, thus producing a wide variety of symptoms. Neuropathy of cardiac nerves can lead to arrhythmias. Neuropathy of renal nerves can lead to incontinence or hypotension. Neuropathy of nerves to the gastrointestinal tract can cause a decrease in muscle tone anywhere along the tract and it can decrease appetite. Neuropathy of nerves to the reproductive system can cause erectile dysfunction, impotence or decreased sexual arousal. In addition to these specific neuropathies, loss of autonomic function to various internal organs also impairs thermoregulation and the ability of the body to adapt to stressors including exercise.

Diff: 6  Page Ref: 697

Short Answer Questions

1) Which is more prevalent, diabetes mellitus type 1 or type 2?

Answer: type 2

Diff: 3  Page Ref: 695
2) In which form of diabetes mellitus is genetics a larger factor affecting incidence, type 1 or type 2?
   Answer: type 2
   Diff: 5 Page Ref: 695

3) What are the "three polys" of diabetes mellitus?
   Answer: polyuria, polydipsia, polyphagia
   Diff: 3 Page Ref: 696

4) Which of the following enzymes has a greater affinity for glucose: aldose reductase or hexokinase?
   Answer: hexokinase
   Diff: 5 Page Ref: 698

5) What is the leading cause of adult-onset blindness in the United States?
   Answer: diabetic retinopathy
   Diff: 4 Page Ref: 698

6) What are proteins called that have been glycosylated through a non-enzymatic process?
   Answer: advanced glycosylation end-products
   Diff: 5 Page Ref: 697

7) Under hyperglycemic conditions, what causes mesangial cells to secrete excess extracellular matrix in kidneys?
   Answer: protein kinase C
   Diff: 7 Page Ref: 698

8) What is the primary protein that appears in the urine with nephropathy?
   Answer: albumin
   Diff: 4 Page Ref: 698

9) Does diabetic neuropathy affect the central nervous system, peripheral nervous system, or both?
   Answer: peripheral nervous system
   Diff: 4 Page Ref: 699

10) What is a tingling sensation of the skin called?
    Answer: parasthesia
    Diff: 4 Page Ref: 699

11) Blood levels of what form of lipoproteins are decreased by diabetes mellitus?
    Answer: HDLs (or high density lipoproteins)
    Diff: 4 Page Ref: 700

12) Cardiomyopathy is a disease caused by decreasing ________.
    Answer: cardiac muscle contractility
    Diff: 5 Page Ref: 700

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13) What cell type initiates inflammation?
   Answer: macrophages
   Diff: 3   Page Ref: 701

14) What cell type lays down new extracellular matrix and collagen to form scar tissue?
   Answer: fibroblasts
   Diff: 4   Page Ref: 702

15) At the site of a wound, neutrophils remove debris by what process?
   Answer: phagocytosis
   Diff: 3   Page Ref: 701

16) What cell type produces proteoglycans and glycosaminoglycans?
   Answer: fibroblasts
   Diff: 6   Page Ref: 701

17) What phases of wound healing is/are delayed in diabetes mellitus?
   Answer: inflammatory and proliferative
   Diff: 6   Page Ref: 701

18) What is the normal fasting blood glucose level?
   Answer: 100 mg/dL
   Diff: 3   Page Ref: 703

19) Why must insulin be injected into patients with diabetes mellitus type 1 as opposed to oral administration?
   Answer: insulin would be degraded in the gastrointestinal tract and thus not absorbed
   Diff: 4   Page Ref: 704

20) What drug class used originally to treat typhoid fever during World War II is now used to treat diabetes mellitus type 2?
   Answer: sulfonureas
   Diff: 4   Page Ref: 704