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Physiology Review

4th EDITION

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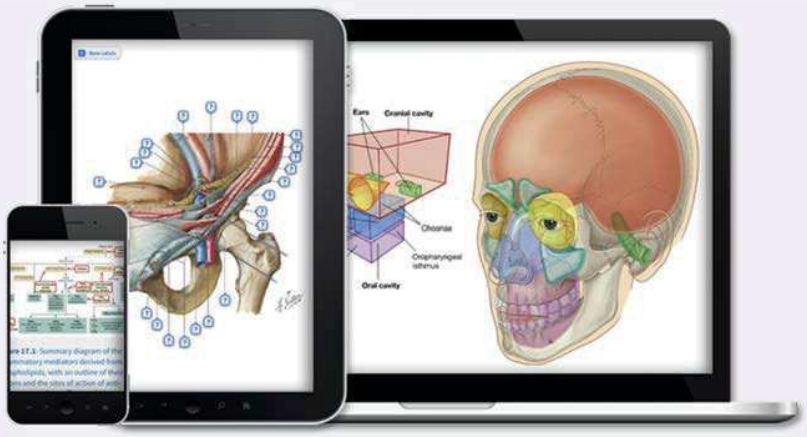

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Guyton and Hall Physiology Review

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FOURTH EDITION

Guyton and Hall Physiology Review

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Preface

The main purpose of this book is to provide students a tool for assessing their mastery of physiology as presented in the *Guyton and Hall Textbook of Medical Physiology,* 14th edition.

Self-assessment is an important component of effective learning, especially when studying a subject as complex as medical physiology. *Guyton & Hall Physiology Review* is designed to provide a comprehensive review of medical physiology through multiple-choice questions and explanations of the answers. Medical students preparing for the United States Medical Licensure Examinations (USMLE) will also find this book useful because many of the test questions have been constructed according to the USMLE format.

The questions and answers in this review are based on *Guyton and Hall Textbook of Medical Physiology*, 14th edition (TMP 14). More than 1000 questions and answers are provided, and each answer is referenced to the *Textbook of Medical Physiology* to facilitate a more complete understanding of the topic. Illustrations are used to reinforce basic concepts. Some of the questions incorporate information from multiple chapters to test your ability to apply and integrate the principles necessary for mastery of medical physiology.

An effective way to use this book is to allow an average of 1 minute for each question in a unit, approximating the time limit for a question in the USMLE examination. As you proceed, indicate your answer next to each question. After finishing the questions and answers, verify your answers and carefully read the explanations provided. Read the additional material referred to in the *Textbook of Medical Physiology*, especially when incorrect answers were chosen.

Guyton and Hall Physiology Review should not be used as a substitute for the comprehensive information contained in the *Textbook of Medical Physiology*. Its main purpose is to assess your knowledge of physiology gained from study of the *Textbook of Medical Physiology* and other sources and to strengthen your ability to apply and integrate this knowledge.

We have attempted to make this review as accurate as possible, and we hope that it will be a valuable tool for your study of physiology. We invite you to send us your critiques, suggestions for improvement, and notifications of any errors.

I am grateful to each of the contributors for their careful work on this book. I also wish to express my thanks to Kathleen Nahm, Manikandan Chandrasekaran, Jennifer Schreiner, Rebecca Gruliow, Elyse O'Grady, and the rest of the Elsevier staff for their editorial and production excellence.

John E. Hall

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UNIT I

Introduction to Physiology: The Cell and General Physiology

1. If the feedback gain of a control system is -3.0, this means that the system is
   A) A negative feedback system capable of correcting 1/3 of the initial disturbance to the system
   B) A negative feedback system capable of correcting 2/3 of the initial disturbance to the system
   C) A negative feedback system capable of correcting 3/4 of the initial disturbance to the system
   D) A positive feedback system capable of correcting 1/3 of the initial disturbance to the system

2. Most cells, except for fat cells, are composed mainly of
   A) Proteins
   B) Ions
   C) Water
   D) Microfilaments/cell cytoskeleton
   E) Secretory vesicles

3. Organelles that neutralize drugs and toxins are
   A) Nuclei
   B) Mitochondria
   C) Lysosomes
   D) Peroxisomes
   E) Endoplasmic reticulum

4. The most abundant cell membrane lipids are
   A) Sphingolipids
   B) Phospholipids
   C) Cholesterol
   D) Triglycerides
   E) Sterols

5. The first stage of mitosis is called
   A) Anaphase
   B) Prophase
   C) Prometaphase
   D) Metaphase
   E) Telophase

6. The region of repetitive nucleotide sequences located at each end of a chromatid is called
   A) Okazaki fragment
   B) Replication fork
   C) Telomere
   D) Centriole
   E) Lagging strand

7. Which of the following statements about DNA replication is incorrect?
   A) Both strands of the DNA in each chromosome are replicated
   B) Both strands of the DNA helix are replicated in small portions and then assembled, similar to the transcription of RNA
   C) Before DNA can be replicated, the double stranded molecule must be "unzipped" into two single strands
   D) Uncoiling of DNA helixes is achieved by DNA helicase enzymes
   E) Once the DNA strands have been separated, a short piece of RNA called an RNA primer binds to the 3' end of the leading strand

8. Which of the following statements about cell differentiation is correct?
   A) Differentiation results from selective loss of different genes from cells
   B) Differentiation results from selective repression of different gene promoters
   C) Differentiation results from selective activation of telomerase in different cells
   D) Differentiation results mainly from mutations of genes

9. Which statement about microRNAs (miRNAs) is correct?
   A) miRNAs are formed in the cytoplasm and repress translation or promote degradation of messenger RNA (mRNA) before it can be translated
   B) miRNAs are formed in the nucleus and then processed in the cytoplasm by the dicer enzyme
   C) miRNAs are short (21 to 23 nucleotide) double-stranded RNA fragments that regulate gene expression
   D) miRNAs repress gene transcription

10. Compared with the intracellular fluid, the extracellular fluid has _____ sodium ion concentration, _____ potassium ion concentration, _____ chloride ion concentration, and _____ phosphate ion concentration.
    A) Lower, lower, lower, lower
    B) Lower, higher, lower, lower

C) Lower, higher, higher, lower
D) Higher, lower, higher, lower
E) Higher, higher, lower, higher
F) Higher, higher, higher, higher

11. Which of the following events does not occur during the process of mitosis?
    A) Condensation of the chromosomes
    B) Replication of the genome
    C) Fragmentation of the nuclear envelope
    D) Alignment of the chromatids along the equatorial plate
    E) Separation of the chromatids into two sets of 46 "daughter" chromosomes

12. The term "glycocalyx" refers to what?
    A) The negatively charged carbohydrate chains that protrude into the cytosol from glycolipids and integral glycoproteins
    B) The negatively charged carbohydrate layer on the outer cell surface
    C) The layer of anions aligned on the cytosolic surface of the plasma membrane
    D) The large glycogen stores found in "fast" muscles
    E) A mechanism of cell–cell attachment

13. Which statement is incorrect?
    A) The term "homeostasis" describes the maintenance of nearly constant conditions in the body
    B) In most diseases, homeostatic mechanisms are no longer operating in the body
    C) The body's compensatory mechanisms often lead to deviations from the normal range in some of the body's functions
    D) Disease is generally considered to be a state of disrupted homeostasis

Questions 14–16

A) Nucleolus
B) Nucleus
C) Agranular endoplasmic reticulum
D) Granular endoplasmic reticulum
E) Golgi apparatus
F) Endosomes
G) Peroxisomes
H) Lysosomes
I) Cytosol
J) Cytoskeleton
K) Glycocalyx
L) Microtubules

For each of the scenarios described below, identify the most likely subcellular site listed above for the deficient or mutant protein.

14. The abnormal cleavage of mannose residues during the post-translational processing of glycoproteins results in the development of a lupus-like autoimmune disease in mice. The abnormal cleavage is due to a mutation of the enzyme α-mannosidase II.

15. The observation that abnormal cleavage of mannose residues from glycoproteins causes an autoimmune disease in mice supports the role of this structure in the normal immune response.

16. Studies completed on a 5-year-old boy show an accumulation of cholesteryl esters and triglycerides in his liver, spleen, and intestines and calcification of both adrenal glands. Additional studies indicate the cause to be a deficiency in acid lipase A activity.

Questions 17–20

A) Nucleolus
B) Nucleus
C) Agranular endoplasmic reticulum
D) Granular endoplasmic reticulum
E) Golgi apparatus
F) Endosomes
G) Peroxisomes
H) Lysosomes
I) Cytosol
J) Cytoskeleton
K) Glycocalyx
L) Microtubules

Match the cellular location for each of the steps involved in the synthesis and packaging of a secreted protein listed below with the correct term from the list above.

17. Protein condensation and packaging

18. Initiation of translation

19. Gene transcription

20. Worn-out organelles are transferred to lysosomes by which of the following?
    A) Autophagosomes
    B) Granular endoplasmic reticulum
    C) Agranular endoplasmic reticulum
    D) Golgi apparatus
    E) Mitochondria

21. Which of the following does not play a direct role in the process of transcription?
    A) Helicase
    B) RNA polymerase
    C) Chain-terminating sequence
    D) "Activated" RNA molecules
    E) Promoter sequence

22. Which statement is true for *both* pinocytosis and phagocytosis?
    A) Involves the recruitment of actin filaments
    B) Occurs spontaneously and nonselectively

C) Endocytotic vesicles fuse with ribosomes that release hydrolases into the vesicles
D) Is only observed in macrophages and neutrophils
E) Does not require ATP

23. Which statement is incorrect?
A) Proto-oncogenes are normal genes that code for proteins that control cell growth
B) Proto-oncogenes are normal genes that code for proteins that control cell division
C) Inactivation of anti-oncogenes protects against the development of cancer
D) Several different simultaneously activated oncogenes are often required to cause cancer

24. Which statement about feedback control systems is incorrect?
A) Most control systems of the body act by negative feedback
B) Positive feedback usually promotes stability in a system
C) Generation of nerve actions potentials involves positive feedback
D) Feed-forward control is important in regulating muscle activity

25. Which of the following cell organelles is responsible for producing adenosine triphosphate (ATP), the energy currency of the cell?
A) Endoplasmic reticulum
B) Mitochondria
C) Lysosomes
D) Golgi apparatus
E) Peroxisomes
F) Ribosomes

26. Which statement about mRNA is correct?
A) mRNA carries the genetic code to the cytoplasm
B) mRNA carries activated amino acids to the ribosomes
C) mRNA is composed of single-stranded RNA molecules of 21 to 23 nucleotides that can regulate gene transcription
D) mRNA forms ribosomes

27. "Redundancy" or "degeneration" of the genetic code occurs during which step of protein synthesis?
A) DNA replication
B) Transcription
C) Post-transcriptional modification
D) Translation
E) Protein glycosylation

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ANSWERS

1. **C)** The feedback gain of a control system is calculated as the amount of correction divided by the remaining error of the system. A feedback gain of -3.0 means that 3/4 of the initial error was corrected by the system. For example, if the initial error was 4 units and 1 unit of error remains after correction, then the amount of correction is -3 (from 4 to 1), the remaining error is 1, and the feedback gain is -3.0.

   TMP14 pp. 8–9

2. **C)** Most cells, except for fat cells, are composed mainly of water in a concentration of 70% to 85 %. After water, the most abundant substances in most cells are proteins, which normally constitute 10% to 20 % of the cell mass.

   TMP14 p. 13

3. **D)** Peroxisomes contain oxidases capable of combining oxygen with hydrogen ions derived from different intracellular chemicals to form hydrogen peroxide (H_2O_2), a highly oxidizing substance used in association with catalase, another oxidase enzyme present in large quantities in peroxisomes. These enzymes oxidize and neutralize many drugs and toxins that might otherwise be poisonous to the cell.

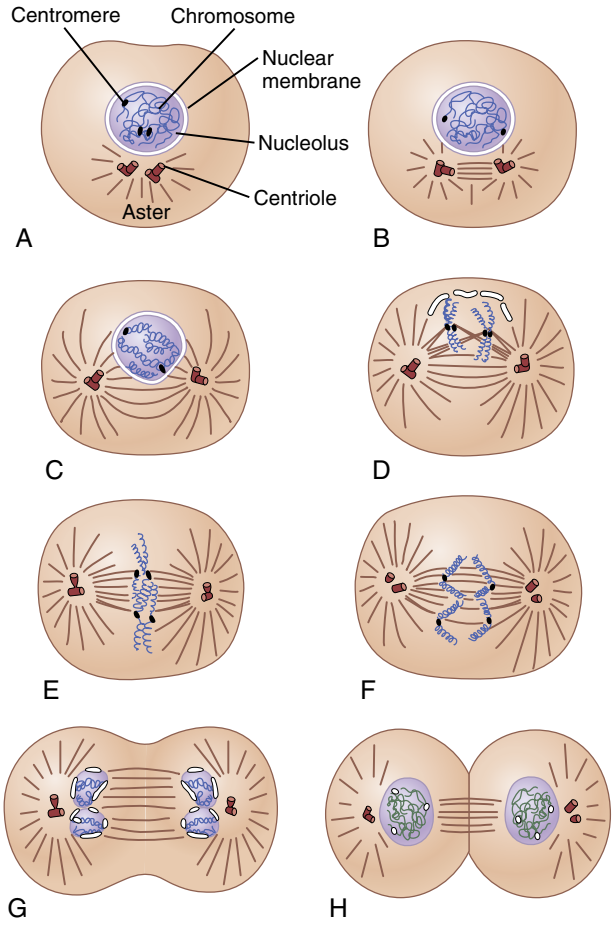
   TMP14 p. 18

4. **B)** The basic cell membrane lipid bilayer is composed of proteins and three main types of lipids: phospholipids, sphingolipids, and cholesterol. The approximate composition is 55% proteins, 25% phospholipids, 13% cholesterol, 4% other lipids, and 3% carbohydrates.

   TMP14 pp. 15–16

5. **B)** The first stage of mitosis, the process by which the cell splits into two new cells, is called prophase (see figure below).

   TMP14 pp. 41–43



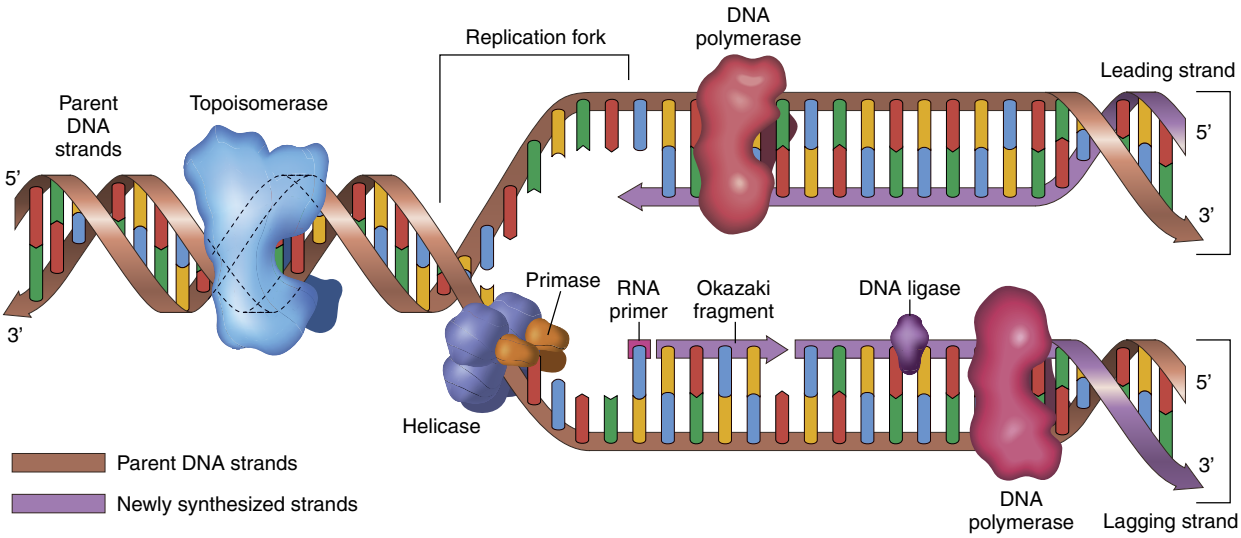
Stages of cell reproduction. A, B, and C, Prophase. D, Prometaphase. E, Metaphase. F, Anaphase. G and H, Telophase

6. C) Telomeres are repetitive nucleotide sequences located at each end of a chromatid and serve as protective caps that prevent the chromosome from deterioration during cell division. Without telomeres, the genomes would progressively lose information and be truncated after each cell division.

TMP14 p. 44

7. B) Both entire strands of the DNA helix in each chromosome are replicated from end to end, rather than small portions of them, as occurs in the transcription of RNA (see figure below).

TMP14 pp. 41–42



The helical double-stranded structure of the gene. The outside strands are composed of phosphoric acid and the sugar deoxyribose. The inner molecules connecting the two strands of the helix are purine and pyrimidine bases, which determine the "code" of the gene.

8. B) Cell differentiation refers to changes in physical and functional properties of cells as they proliferate in the embryo to form different bodily structures and organs and results not from loss of genes but from selective repression of different gene promoters.

TMP14 p. 45

9. A) The miRNAs are formed in the cytoplasm from pre-miRNAs and processed by the enzyme dicer that ultimately assembles RNA-induced silencing complex, which then generates miRNAs. The miRNAs regulate gene expression by binding to the complementary region of the RNA and repressing translation or promoting degradation of messenger RNA before it can be translated by the ribosome.

TMP14 pp. 36–37

10. D) The extracellular fluid has relatively high concentrations of sodium and chloride ions but lower concentrations of potassium and phosphate than the intracellular fluid.

TMP14 p. 4

11. B) DNA replication occurs during the S phase of the cell cycle and precedes mitosis. Condensation of the chromosomes occurs during the prophase of mitosis. Fragmentation of the nuclear envelope occurs during the prometaphase of mitosis. The chromatids align at the equatorial plate during metaphase and separate into two complete sets of daughter chromosomes during anaphase.

TMP14 p. 43

12. B) The cell "glycocalyx" is the loose negatively charged carbohydrate coat on the outside of the surface of the cell membrane. The membrane carbohydrates usually occur in combination with proteins or lipids in the form of glycoproteins or glycolipids, and the "glyco" portion of these molecules almost invariably protrudes to the outside of the cell.

TMP14 p. 16

13. B) The term *homeostasis* describes the maintenance of nearly constant conditions in the internal environment of the body, and diseases are generally considered to be states of disrupted homeostasis. However, even in diseases, homeostatic compensatory mechanisms continue to operate in an attempt sustain body functions at levels that permit life to continue. These compensations may result in deviations from the normal level of some body functions as a "trade-off" that is necessary to maintain vital functions of the body.

TMP14 p. 4

14. E) Membrane proteins are glycosylated during their synthesis in the lumen of the rough endoplasmic reticulum. Most post-translational modification of the oligosaccharide chains, however, occurs dur-

ing the transport of the protein through the layers of the Golgi apparatus matrix, where enzymes such as α-mannosidase II are localized.

TMP14 pp. 16–17

15. K) The oligosaccharide chains that are added to glycoproteins on the luminal side of the rough endoplasmic reticulum, and subsequently modified during their transport through the Golgi apparatus, are attached to the extracellular surface of the cell. This negatively charged layer of carbohydrate moieties is collectively called the glycocalyx. It participates in cell–cell interactions, cell–ligand interactions, and the immune response.

TMP14 p. 16

16. H) Acid lipases, along with other acid hydrolases, are localized to lysosomes. Fusion of endocytotic and autolytic vesicles with lysosomes initiates the intracellular process that allows cells to digest cellular debris and particles ingested from the extracellular milieu, including bacteria. In the normal acidic environment of the lysosome, acid lipases use hydrogen to convert lipids into fatty acids and glycerol. Other acid lipases include a variety of nucleases, proteases, and polysaccharide-hydrolyzing enzymes.

TMP14 pp. 17–18

17. E) Secreted proteins are condensed, sorted, and packaged into secretory vesicles in the terminal portions of the Golgi apparatus, also known as the trans-Golgi network. It is here that proteins destined for secretion are separated from those destined for intracellular compartments or cellular membranes.

TMP14 p. 17

18. I) Initiation of translation, whether of a cytosolic protein, a membrane-bound protein, or a secreted protein, occurs in the cytosol and involves a common pool of ribosomes. Only after the appearance of the N-terminus of the polypeptide is it identified as a protein destined for secretion. At this point, the ribosome attaches to the cytosolic surface of the rough endoplasmic reticulum. Translation continues, and the new polypeptide is extruded into the matrix of the endoplasmic reticulum.

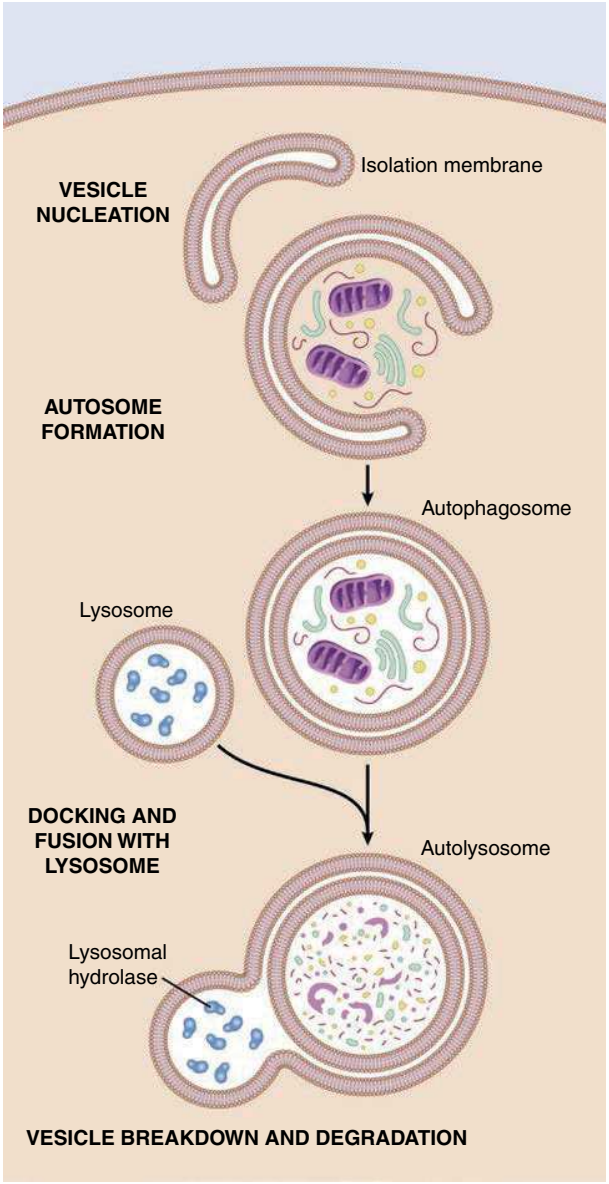
TMP14 pp. 37–38

19. B) All transcription events occur in the nucleus, regardless of the final destination of the protein product. The resulting messenger RNA molecule is transported through the nuclear pores in the nuclear membrane and translated into either the cytosol or the lumen of the rough endoplasmic reticulum.

TMP14 pp. 33–34

20. A) Autophagy is a housekeeping process by which obsolete organelles and large protein aggregates are degraded and recycled (see figure at right). Worn-out cell organelles are transferred to lysosomes by double membrane structures called autophagosomes that are formed in the cytosol.

TMP14 pp. 22–23



Schematic diagram of autophagy steps

21. A) Helicase is one of the many proteins involved in the process of DNA replication. It does not play a role in transcription. RNA polymerase binds to the promoter sequence and facilitates the addition of "activated" RNA molecules to the growing RNA molecule until the polymerase reaches the chain-terminating sequence on the template DNA molecule.

TMP14 pp. 33–34, 42

22. A) Both pinocytosis and phagocytosis involve movement of the plasma membrane. Pinocytosis involves invagination of the cell membrane, whereas phago-

cytosis involves evagination. Both events require the recruitment of actin and other cytoskeleton elements. Phagocytosis is not spontaneous and is selective, being triggered by specific receptor-ligand interactions.

TMP14 pp. 21–22

23. C) Inactivation of anti-oncogenes, also called tumor suppressor genes, can allow activation of oncogenes that lead to cancer. All the other statements are correct.

TMP14 pp. 46–47

24. B) Positive feedback in a system generally promotes instability, rather than stability, and in some cases even death. For this reason, positive feedback is often called a "vicious cycle." However, in some instances, positive feedback can be useful. One example is the nerve action potential where stimulation of the nerve membrane causes a slight leakage of sodium that causes more opening of sodium channels, more change of potential, and more opening of channels until an explosion of sodium entering the interior of the nerve fiber creates the action potential. Feed-forward control is used to apprise the brain whether a muscle movement is performed correctly. If not, the brain corrects the feed-forward signals that it sends to the muscles the next time the movement is required. This mechanism is often called adaptive control.

TMP14 pp. 8–10

25. B) Mitochondria are often called the "powerhouses" of the cell and contain oxidative enzymes that permit oxidation of the nutrients, thereby forming carbon dioxide and water and at the same time releasing energy. The liberated energy is used to synthesize "high-energy" ATP.

TMP14 pp. 18–19

26. A) mRNA molecules are long, single RNA strands that are suspended in the cytoplasm and are composed of several hundred to several thousand RNA nucleotides in unpaired strands. The mRNA carries the genetic code to the cytoplasm for controlling the type of protein formed. The *transfer RNA* transports activated amino acids to the ribosomes. *Ribosomal RNA*, along with about 75 different proteins, forms ribosomes. MicroRNAs are single-stranded RNA molecules of 21 to 23 nucleotides that regulate gene transcription and translation.

TMP14 p. 35

27. D) During both replication and transcription, the new nucleic acid molecule is an exact complement of the parent DNA molecule as a result of predictable, specific, one-to-one base pairing. During the process of translation, however, each amino acid in the new polypeptide is encoded by a codon—a series of three consecutive nucleotides. Whereas each codon encodes a specific amino acid, most amino acids can be encoded for by multiple codons. Redundancy results because 60 codons encode a mere 20 amino acids.

TMP14 pp. 34–36

Membrane Physiology, Nerve, and Muscle

1. A patch clamp experiment shows a single sodium ion channel that opens and closes repeatedly causing the electrical current through the channel to change from one value to another. The open time of the sodium channel averages 0.4 milliseconds in this experiment. Which of the following best describes the electrical current of this sodium channel during the open and closed states (in picoamperes)?

   A) Open: 3.2; closed: 3.3
   B) Open: 0.4; closed: 0.4
   C) Open: 0.4; closed: 3.2
   D) Open: 3.1; closed: 0.4
   E) Open: 0.4; closed: 2.0
   F) Open: 0.4; closed: 0.6

2. Which of the following best describes the osmolarity of a solution containing 150 millimolar NaCl, assuming a temperature of 37°C and a dissociation constant of 0.93 (in milliosmoles)?

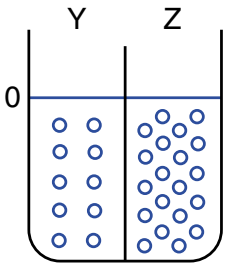
   A) 150
   B) 279
   C) 300
   D) 322
   E) 393

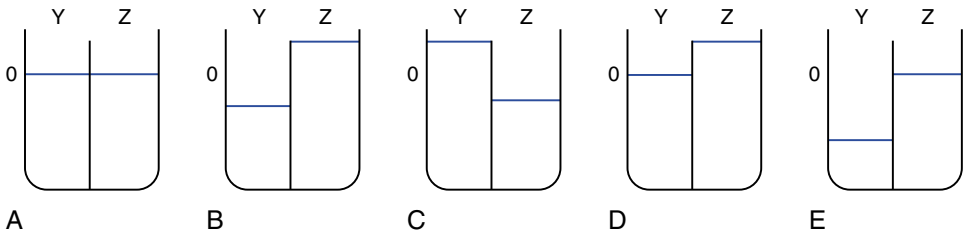
3. A 64-year-old man has serum potassium of 2.8 mEq/l (reference range, 3.5–5.0 mEq/l). Which of the following sets of changes best describe the resting membrane potential (Vm) and K^+ Equilibrium potential (EK) in a typical neuron in this man compared with normal? *(Assume normal intracellular concentration of K^+.)*

   A) EK, less negative; Vm, less negative
   B) EK, less negative; Vm, no change
   C) EK, less negative; Vm, more negative
   D) EK, more negative; Vm, less negative
   E) EK, more negative; Vm, more negative
   F) EK, more negative; Vm, no change
   G) EK, no change; Vm, less negative
   H) EK, no change; Vm, more negative
   I) EK, no change; Vm, no change

Questions 4 and 5

In the figure shown, two compartments (Y and Z) are separated by an artificial lipid bilayer without protein transporters. The relative concentrations of test substances in compartments Y and Z at time zero are shown. Different water volumes in compartments Y and Z are shown as diagrams A to E. Use this information to answer the next two questions.





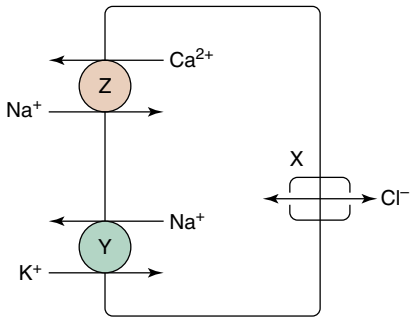
4. Which of the diagrams best represent the volumes of compartments Y and Z at equilibrium when the test substance is NaCl?

   A) A
   B) B
   C) C
   D) D
   E) E

5. Which of the diagrams best represent the volumes of compartments Y and Z at equilibrium when the test substance is urea?

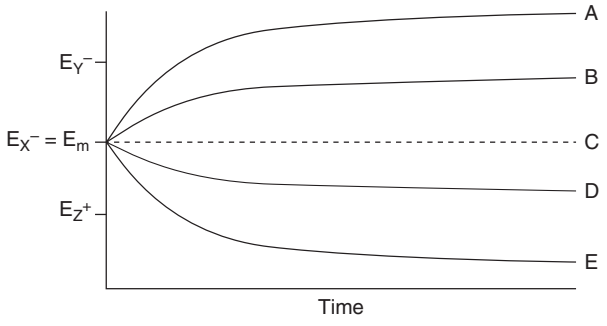
   A) A
   B) B
   C) C
   D) D
   E) E

6. A model cell with three different transporters (X, Y, and Z) and a resting membrane potential of –90 millivolts is shown. Consider the intracellular and extracellular concentrations of all three ions to be typical of a normal cell. Inhibition of transporter Y with ouabain is most likely to cause which of the following changes in the intracellular concentrations of sodium and calcium ions?

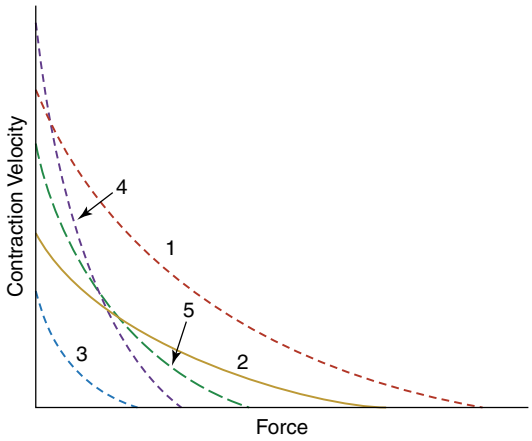


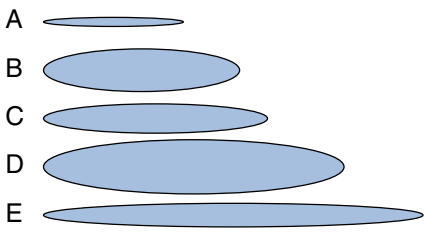
   A) Decreased sodium; decreased calcium
   B) Decreased sodium; increased calcium
   C) Increased sodium; decreased calcium
   D) Increased sodium; increased calcium

7. In the diagram shown, E_m represents the measured initial membrane potential for a hypothetical cell in vivo. In relation to this membrane potential, the equilibrium potentials of three ions (X^-, Y^-, Z^+) are represented. Pick the path most likely taken by the membrane potential when membrane conductance to ion Y is increased.

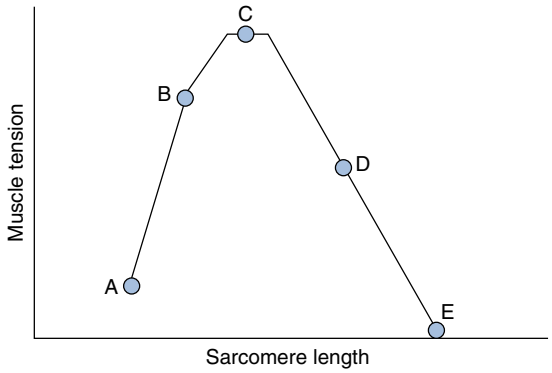


8. The relationship between contraction velocity and force for five different skeletal muscles is shown. Which of the following muscles (A–E) is most likely to correspond to muscle number 1 on the figure shown? *(Assume that all muscles shown are at their normal resting lengths.)*





9. The diagram shows the relationship between muscle tension and sarcomere length for skeletal muscle. Which point on the curve represents tension development at a normal resting length?



   A) A
   B) B
   C) C
   D) D
   E) E

10. The following events occur in a skeletal muscle during a normal contraction: (1) increased calcium concentration in sarcoplasm, (2) activation of ryanodine receptor, (3) calcium release from terminal cisternae, and (4) activation of dihydropyridine voltage sensor. Which of the following best describes the correct temporal order of events for a normal contraction in a skeletal muscle fiber?

A) 1, 2, 3, 4
B) 1, 4, 2, 3
C) 1, 3, 2, 4
D) 3, 2, 1, 4
E) 3, 1, 2, 4
F) 4, 2, 1, 3
G) 2, 1, 4, 3
H) 2, 3, 4, 1
I) 4, 2, 3, 1

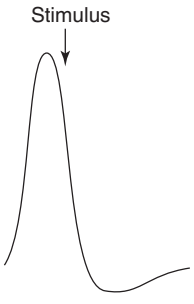
11. A 64-year-old man undergoes general anesthesia to remove a tumor from his colon. Within a few minutes following administration of a halogenated anesthetic, the patient develops muscle rigidity and a rectal temperature of 108°F. His heart rate is 105 beats/min and respiration rate is 29 breaths/min. Which of the following is most likely to be decreased in this patient compared with normal resting conditions?

A) Anaerobic metabolism
B) Calcium binding to calsequestrin
C) CO_2 production by muscles
D) Muscle temperature
E) O_2 usage by muscles

12. Which of the following best describes the selectivity filter of a potassium ion channel in bacteria?

A) Glutamate
B) Carbonyl oxygens
C) Oxygen radicals
D) Gluten
E) Glycine
F) Carbon dioxide

13. During the course of a nerve action potential (shown), a 10-mV electrical stimulus is delivered at the time indicated by the arrow. In response to the electrical stimulus, a second action potential will:



A) be identical to the first
B) have a higher amplitude
C) have a lower amplitude
D) not occur
E) have a slower velocity
F) have a faster velocity

14. Which of the following best describes myasthenia gravis (MG) and Lambert-Eaton myasthenic syndrome (LEMS)?

A) MG, postsynaptic disease; LEMS, presynaptic disease
B) MG, presynaptic disease; LEMS, presynaptic disease
C) MG, postsynaptic disease; LEMS, postsynaptic disease
D) MG, presynaptic disease; LEMS, postsynaptic disease

15. Electrical coupling between adjacent cells in visceral smooth muscle can be attributed to which of the following?

A) Dense bodies
B) Gap junctions
C) Intermediate fibers
D) Mechanical junctions
E) Potassium channels

16. A 45-year-old man goes to the local gym to lift weights. He begins by bench-pressing 130 lb as a warm-up procedure and then gradually increases the weight. Which of the following sets of changes occur as he adds more weight?

	Activation of motor units	Frequency of motor nerve action potentials
A)	Decreased	Decreased
B)	Decreased	Increased
C)	Decreased	No change
D)	Increased	Decreased
E)	Increased	Increased
F)	Increased	No change

17. Which of the following substances have a higher extracellular concentration compared with the intracellular concentration?

A) Calcium and chloride
B) Potassium and sodium
C) Calcium and potassium
D) Potassium and proteins
E) Chloride and proteins

18. Which of the following allows smooth muscle to maintain a sustained contraction with minimal energy usage compared to a similar level of sustained contraction of skeletal muscle?

A) Dense body
B) Gap junctions
C) Intermediate filaments
D) Latch state
E) Syncytial nature

Questions 19–21
The table shows the concentrations of four ions across the plasma membrane of a hypothetical cell. Use this table to answer the next three questions.

Intracellular (mM)	Extracellular (mM)
140 K^+	5 K^+
12 Na^+	145 Na^+
5 Cl^-	125 Cl^-
0.0001 Ca^{2+}	5 Ca^{2+}

19. Which of the following best describes the equilibrium potential for Cl^- (in millivolts)?
A) 0
B) 170
C) −170
D) 85
E) −85

20. Which of the following best describes the equilibrium potential for K^+ (in millivolts)?
A) 0
B) 176
C) −176
D) 88
E) −88

21. The net driving force is greatest for which ion when the membrane potential of this cell is −85 millivolts?
A) Ca^{2+}
B) Cl^-
C) K^+
D) Na^+

22. A single contraction of skeletal muscle is most likely to be terminated by which of the following actions?
A) Closure of the postsynaptic nicotinic acetylcholine receptor
B) Removal of acetylcholine from the neuromuscular junction
C) Removal of Ca^{2+} from the terminal of the motor neuron
D) Removal of sarcoplasmic Ca^{2+}
E) Return of the dihydropyridine receptor to its resting conformation

23. The resting potential of a myelinated nerve fiber is primarily dependent on the concentration gradient of which of the following ions?
A) Ca^{2+}
B) Cl^-
C) HCO_3^-
D) K^+
E) Na^+

24. A neurotransmitter activates its receptor on an ion channel of a neuron, which causes the water-filled channel to open. When the channel is open, ions move through the channel down their respective electrochemical gradients. A change in membrane potential follows. Which of the following best describes the type of channel and mechanism of ion transport?

	Type of Channel	Mechanism of Transport
A)	Ligand gated	Primary active transport
B)	Ligand gated	Diffusion
C)	Ligand gated	Secondary active transport
D)	Voltage gated	Primary active transport
E)	Voltage gated	Diffusion
F)	Voltage gated	Secondary active transport

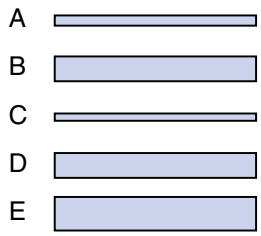
25. Which of the following decreases in length during the contraction of a skeletal muscle fiber?
A) A band of sarcomere
B) I band of sarcomere
C) Thick filaments
D) Thin filaments
E) Z disks of sarcomere

E_{Q^-} = −75 millivolts
E_{R^+} = +75 millivolts
E_{S^+} = −85 millivolts

26. Equilibrium potentials for three unknown ions are shown in the above figure. Note that ions S and R are positively charged and that ion Q is negatively charged. Assume that the cell membrane is permeable to all three ions and that the cell has a resting membrane potential of −90 millivolts. Which of the following best describes the net movement of the various ions across the cell membrane by passive diffusion?

	Q^-	R^+	S^+
A)	Inward	Inward	Inward
B)	Inward	Inward	Outward
C)	Inward	Outward	Inward
D)	Inward	Outward	Outward
E)	Outward	Inward	Inward
F)	Outward	Inward	Outward
G)	Outward	Inward	Outward

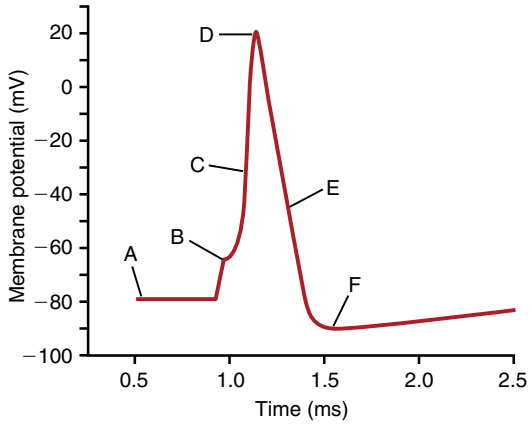
27. Weightlifting can result in a dramatic increase in skeletal muscle mass. This increase in muscle mass is primarily attributable to which of the following?
    A) Fusion of sarcomeres between adjacent myofibrils
    B) Hypertrophy of individual muscle fibers
    C) Increase in skeletal muscle blood supply
    D) Increase in the number of motor neurons
    E) Increase in the number of neuromuscular junctions



28. Five hypothetical nerve axons are shown in the above figure. Axons A and B are myelinated, whereas axons C, D, and E are nonmyelinated. Which axon is most likely to have the fastest conduction velocity for an action potential?
    A) A
    B) B
    C) C
    D) D
    E) E

Questions 29 and 30

The figure below shows the change in membrane potential during an action potential in a giant squid axon. Refer to it when answering the next two questions.



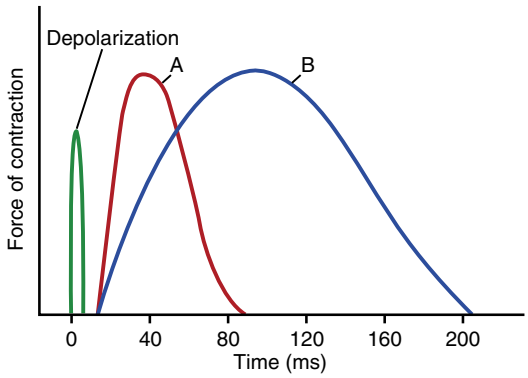
29. Which of the following is primarily responsible for the change in membrane potential between points B and D?
    A) Inhibition of the Na^+, K^+-ATPase
    B) Movement of K^+ into the cell
    C) Movement of K^+ out of the cell
    D) Movement of Na^+ into the cell
    E) Movement of Na^+ out of the cell

30. Which of the following is primarily responsible for the change in membrane potential between points D and E?
    A) Inhibition of the Na^+, K^+-ATPase
    B) Movement of K^+ into the cell
    C) Movement of K^+ out of the cell
    D) Movement of Na^+ into the cell
    E) Movement of Na^+ out of the cell

31. The axon of a neuron is stimulated experimentally with a 25-millivolt pulse, which initiates an action potential with a velocity of 50 m per second. The axon is then stimulated with a 100-millivolt pulse. What is the action potential velocity after the 100-millivolt stimulation pulse (in meters per second)?
    A) 25
    B) 50
    C) 100
    D) 150
    E) 200

Questions 32 and 33

The figure below illustrates the single isometric twitch characteristics of two skeletal muscles, A and B, in response to a depolarizing stimulus. Refer to it when answering the next two questions.



32. Which of the following best describes muscle B compared with muscle A?
    A) Adapted for rapid contraction
    B) Composed of larger muscle fibers
    C) Fewer mitochondria
    D) Innervated by smaller nerve fibers
    E) Less extensive blood supply

33. The delay between the termination of the transient depolarization of the muscle membrane and the onset of muscle contraction observed in both muscles A and B reflects the time necessary for which of the following events to occur?
    A) ADP to be released from the myosin head
    B) ATP to be synthesized

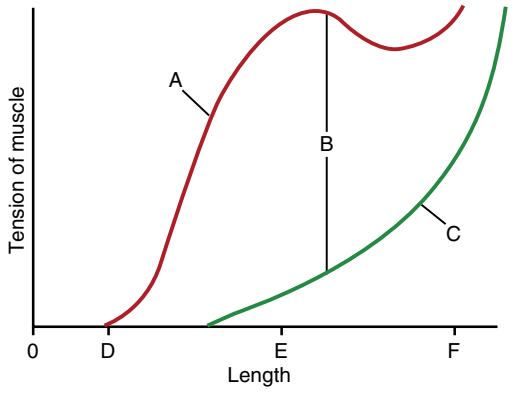
C) Ca^{2+} to accumulate in the sarcoplasm
D) G-actin to polymerize into F-actin
E) Myosin head to complete one cross-bridge cycle

Questions 34 and 35
A 32-year-old woman visits her physician because of double vision, eyelid droop, difficulty chewing and swallowing, and general weakness in her limbs. All these symptoms worsen with exercise and occur more frequently late in the day. The physician suspects myasthenia gravis and orders a Tensilon test. The test is positive. Use this information when answering the next two questions.

34. The increased muscle strength observed during the Tensilon test is due to an increase in which of the following?
    A) Amount of acetylcholine (ACh) released from the motor nerves
    B) Levels of ACh at the muscle end-plates
    C) Number of ACh receptors on the muscle end-plates
    D) Synthesis of norepinephrine

35. Which of the following drugs would likely alleviate this patient's symptoms?
    A) Atropine
    B) Botulinum toxin antiserum
    C) Curare
    D) Halothane
    E) Neostigmine

Questions 36–38
The figure below illustrates the isometric length–tension relationship in a representative intact skeletal muscle. Match the descriptions in the next three questions to one of the points on the figure.



36. So-called "active" or contraction-dependent tension

37. The muscle length at which active tension is maximal

38. The contribution of noncontractile muscle elements to total tension

39. Smooth muscle contraction is terminated by which of the following?
    A) Dephosphorylation of myosin kinase
    B) Dephosphorylation of myosin light chain
    C) Efflux of Ca^{2+} ions across the plasma membrane
    D) Inhibition of myosin phosphatase
    E) Uptake of Ca^{2+} ions into the sarcoplasmic reticulum

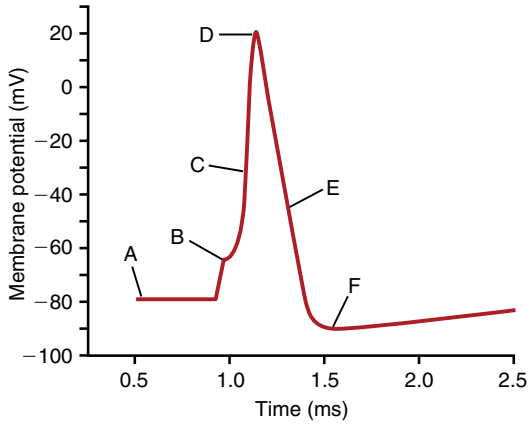
Questions 40 and 41
A 73-year-old man sees a neurologist because of weakness in his legs that improves over the course of the day or with exercise. Extracellular electrical recordings from a single skeletal muscle fiber reveal normal miniature end-plate potentials. Low-frequency electrical stimulation of the motor neuron, however, elicits an abnormally small depolarization of the muscle fibers. The amplitude of the depolarization is increased after exercise. Use this information to answer the next three questions.

40. Based on these findings, which of the following is the most likely cause of this patient's leg weakness?
    A) Acetylcholinesterase deficiency
    B) Blockade of postsynaptic acetylcholine receptors
    C) Impaired presynaptic voltage-sensitive Ca^{2+} influx
    D) Inhibition of Ca^{2+} re-uptake into the sarcoplasmic reticulum
    E) Reduced acetylcholine synthesis

41. A preliminary diagnosis is confirmed by the presence of which of the following?
    A) Antibodies against the acetylcholine receptor
    B) Antibodies against the voltage-sensitive Ca^{2+} channel
    C) Mutation in the gene that codes for the ryanodine receptor
    D) Relatively few vesicles in the presynaptic terminal
    E) Residual acetylcholine in the neuromuscular junction

42. The molecular mechanism underlying these symptoms is most like which of the following?
    A) Acetylcholine
    B) Botulinum toxin
    C) Curare
    D) Neostigmine
    E) Tetrodotoxin

Questions 43–45
Match each of the descriptions in the next three questions to one of the points of the nerve action potential shown in the figure.

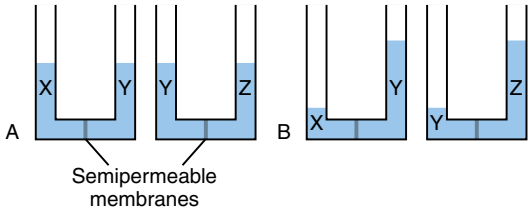


43. Point at which the membrane potential (V_m) is closest to the Na^+ equilibrium potential

44. Point at which the driving force for Na^+ is the greatest

45. Point at which the ratio of K^+ permeability to Na^+ permeability (P_K/P_{Na}) is the greatest

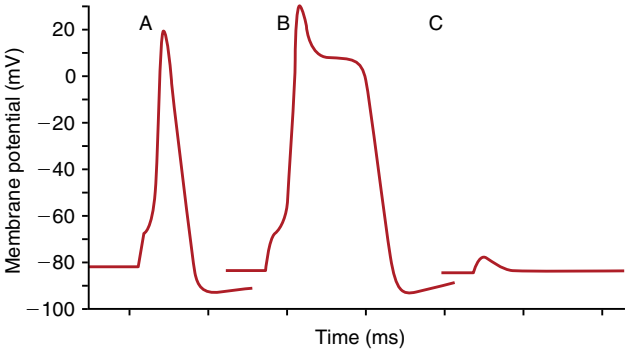
46. A physiology experiment is conducted in which a motoneuron that normally innervates a predominantly fast Type II muscle is anastomosed to a predominantly slow Type I muscle. Which of the following is most likely to decrease in the Type I muscle after the transinnervation surgery?
    A) Fiber diameter
    B) Glycolytic activity
    C) Maximum contraction velocity
    D) Mitochondrial content
    E) Myosin ATPase activity



47. In the experiment illustrated in part **A** of the figure, equal volumes of solutions X, Y, and Z are placed into the compartments of the two U-shaped vessels shown. The two compartments of each vessel are separated by semipermeable membranes (i.e., membranes that are impermeable to ions and large polar molecules). Part **B** illustrates the fluid distribution across the membranes at equilibration. Assuming complete dissociation, identify each of the solutions shown.

	Solution X	Solution Y	Solution Z
A)	1 M $CaCl_2$	1 M NaCl	1 M glucose
B)	1 M glucose	1 M NaCl	1 M $CaCl_2$
C)	1 M NaCl	2 M glucose	3 M $CaCl_2$
D)	2 M NaCl	1 M NaCl	Pure water
E)	Pure water	1 M $CaCl_2$	2 M glucose

Questions 48 and 49
Use the figure shown below for the next two questions.



48. Trace A in the figure represents a typical action potential recorded under control conditions from a normal neuron in response to a depolarizing stimulus. Which of the following perturbations would explain the conversion of the response shown in trace A to the action potential shown in trace B?
    A) Blockade of voltage-sensitive Na^+ channels
    B) Blockade of voltage-sensitive K^+ channels
    C) Blockade of Na-K "leak" channels
    D) Replacement of the voltage-sensitive K^+ channels with "slow" Ca^{2+} channels
    E) Replacement of the voltage-sensitive Na^+ channels with "slow" Ca^{2+} channels

49. Which of the following perturbations would account for the failure of the same stimulus to elicit an action potential in trace C?
    A) Blockade of voltage-sensitive Na^+ channels
    B) Blockade of voltage-sensitive K^+ channels
    C) Blockade of Na-K "leak" channels
    D) Replacement of the voltage-sensitive K^+ channels with "slow" Ca^{2+} channels
    E) Replacement of the voltage-sensitive Na^+ channels with "slow" Ca^{2+} channels

50. A 16-year-old soccer player sustained a fracture to the left tibia. After her lower leg has been in a cast for 8 weeks, she is surprised to find that the left gastrocnemius muscle is significantly smaller in circumference than it was before the fracture. What is the most likely explanation?
    A) Decrease in the number of individual muscle fibers in the left gastrocnemius
    B) Decrease in blood flow to the muscle caused by constriction from the cast

C) Temporary reduction in actin and myosin protein synthesis
D) Increase in glycolytic activity in the affected muscle
E) Progressive denervation

Questions 51–55

Match each of the processes described in the next five questions with the correct type of transport listed. Answers may be used more than once.

A) Diffusion
B) Exocytosis
C) Primary active transport
D) Co-transport
E) Counter-transport

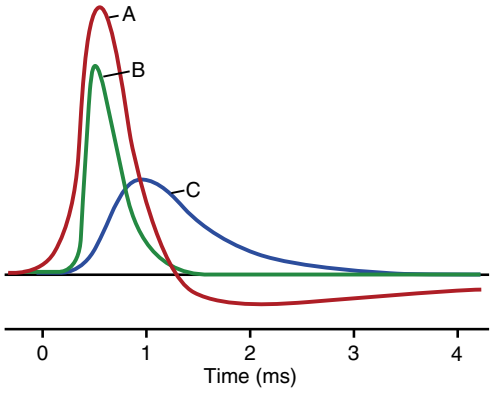
51. Ouabain-sensitive transport of Na^+ ions from the cytosol to the extracellular fluid

52. Glucose uptake into skeletal muscle

53. Na^+-dependent transport of Ca^{2+} from the cytosol to the extracellular fluid

54. Transport of glucose from the intestinal lumen into an intestinal epithelial cell

55. Movement of Na^+ ions into a neuron during the upstroke of an action potential

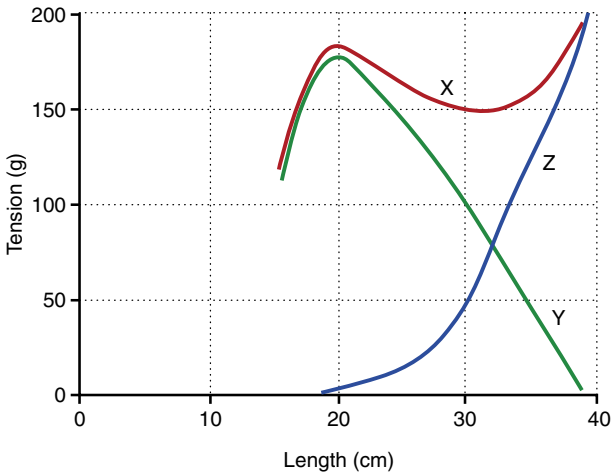


56. Traces A, B, and C in the figure above summarize the changes in membrane potential (V_m) and the underlying membrane permeabilities (P) that occur in a neuron over the course of an action potential. Choose the combination below that identifies each of the traces.

	Trace A	Trace B	Trace C
A)	P_K	V_m	P_{Na}
B)	P_K:P_{Na}	V_m	P_K
C)	P_{Na}	V_m	P_K
D)	V_m	P_K	P_{Na}
E)	V_m	P_{Na}	P_K

57. A 45-year-old woman is admitted as an emergency to University Hospital after an automobile accident in which severe lacerations to the left wrist severed a major muscle tendon. The severed ends of the tendon were overlapped by 6 mm to facilitate suturing and reattachment. Which of the following would be expected after 3 weeks compared with the preinjured muscle? Assume that series growth of sarcomeres cannot be completed within 3 weeks.

	Passive Tension	Maximal Active Tension
A)	Decrease	Decrease
B)	Decrease	Increase
C)	Increase	Increase
D)	Increase	Decrease
E)	No change	No change



58. The length–tension diagram above was obtained from a skeletal muscle with equal numbers of red and white fibers. Supramaximal tetanic stimuli were used to initiate an isometric contraction at each muscle length studied. The resting length was 20 cm. What is the maximum amount of active tension that the muscle can generate at a preload of 100 grams?

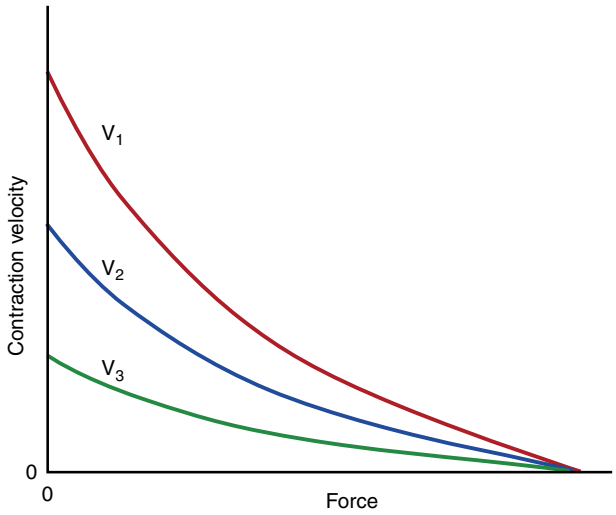
A) 145 to 155 g
B) 25 to 35 g
C) 55 to 65 g
D) 95 to 105 g
E) Cannot be determined

59. The sensitivity of the smooth muscle contractile apparatus to calcium is known to increase in the steady state under normal conditions. This increase in calcium sensitivity can be attributed to a decrease in the levels of which of the following substances?

A) Actin
B) Adenosine triphosphate (ATP)
C) Calcium–calmodulin complex
D) Calmodulin
E) Myosin light chain phosphatase (MLCP)

60. Which of the following best describes a physiological difference between the contraction of smooth muscle compared with the contraction of cardiac muscle and skeletal muscle?
    A) Ca^{2+} independent
    B) Does not require an action potential
    C) Requires more energy
    D) Shorter in duration

61. The figure on the right column shows the force–velocity relationship for contractions of skeletal muscle. The differences in the three curves result from differences in which of the following?
    A) Frequency of muscle contraction
    B) Hypertrophy
    C) Muscle mass
    D) Myosin ATPase activity
    E) Recruitment of motor units



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ANSWERS

1. **D)** The electrical current through a sodium channel caused by movement of sodium ions is close to zero picoamperes when the channel is closed; the current increases markedly when the channel is open. Only choice D shows a low current (0.4 picoamperes) during the closed phase and a higher current (3.1 picoamperes) during the open phase. It is not necessary to know the open time of the channel to answer this question correctly; however, an open time of 0.4 milliseconds is typical.

   TMP14 pp. 54–55

2. **B)** A 150-millimolar solution of a solute has an osmolarity of 150 milliosmoles when the solute molecule does not dissociate. However, NaCl dissociates into two molecules. In the human body with a typical temperature of 37°C, about 93% of NaCl molecules are dissociated at any given time (i.e., the dissociation constant is 0.93). Therefore, 150 millimoles NaCl × 2 = 300 milliosmoles (without dissociation), and 300 milliosmoles x 0.93 = 279 milliosmoles (with a dissociation constant of 0.93).

   TMP14 p. 58

3. **E)** The equilibrium potential of an ion can be calculated using the Nernst equation as follows: E_{ion} (in millivolts) = ± 61 × log (intracellular concentration/extracellular concentration). The intracellular concentration of potassium is relatively high compared to the extracellular concentration in most cells of the body; this causes potassium to have a negative equilibrium potential that averages about –90 millivolts in a typical neuron. A decrease in extracellular potassium concentration (with no change in intracellular concentration) would cause the potassium equilibrium potential to become even more negative, according to the Nernst equation. The resting membrane potential therefore would also become more negative because this is dictated by the potassium equilibrium potential in normal cells of the body.

   TMP14 pp. 56–57

4. **B)** Sodium and chloride are nonpermenant ions that cannot move readily through a lipid bilayer in either direction; this is typical of all charged ions including potassium, calcium, bicarbonate, and hydrogen ions and others. Because side Z in the figure has a greater initial concentration of NaCl molecules compared with side Y, water will move down its concentration gradient by osmosis from side Y to side Z, which will cause a decrease in the volume of side Y and an increase in the volume of side Z. The total volume of sides Y and Z together will not change, which excludes choices D and E.

   TMP14 pp. 56, 58

5. **A)** Urea is a permeant molecule that can move through a lipid bilayer in either direction. Hence, the concentration of urea will become equal in compartments Y and Z within a fraction of a second. Water molecules can more through the membrane more rapidly compared with urea, so the volume in compartment Z will increase transiently. But again, the concentration of urea will become equal on both sides of the membrane within a fraction of a second, so the water volume will be the same in compartments Y and Z at equilibrium.

   TMP14 pp. 56, 58

6. **D)** Under basal conditions, the intracellular concentrations of sodium, calcium, and chloride are less than the extracellular concentrations, whereas potassium has a higher intracellular concentration compared with its extracellular concentration. Transporter Y in the figure moves both potassium and sodium ions against their concentration gradients, which is primary active transport and is powered by ATP at the pump. Therefore, when transporter Y is inhibited by ouabain, the intracellular concentration of sodium increases (and the intracellular concentration of potassium decreases). This increase in intracellular sodium concentration decreases the sodium concentration gradient across the cell membrane. Now because the energy required to move calcium ions out of the cell is powered by the sodium concentration gradient (via secondary active transport), a decrease in the transmembrane sodium gradient leads to an increase in the intracellular calcium concentration. So, inhibition of transporter Y leads to increases in the intracellular concentrations of both sodium and calcium ions. Cardiac glycosides increase intracellular calcium concentration in cardiac muscle cells by this mechanism.

   TMP14 pp. 59–61

7. **B)** The resting membrane potential of a typical cell in the body is closest to the equilibrium potential of the ion with the highest conductance (i.e., permeability). In most cells of the body, the conductance to potassium is relatively high, causing the membrane potential to approach the potassium equilibrium potential. In the diagram shown, the initial membrane potential (E_m) is represented by the level of line C. When the membrane conductance to ion Y is increased, the membrane potential approaches the equilibrium potential of ion Y; this eliminates answers C, D, and E. Answer A can also be eliminated because the membrane potential cannot

become greater than the equilibrium potential of the ion.

TMP14 pp. 66–67

8. D) The maximum velocity of shortening of a muscle is dependent on the predominant type of muscle fiber in the muscle as well as the overall length of the muscle. In general, type II glycolytic muscles have a higher maximum velocity of shortening compared with type I oxidative muscles. However, the student must assume that all the muscles shown have similar proportions of type I and type II fibers because this was not stated in the problem. Because muscle 1 in the diagram has the second highest maximum velocity of shortening, it corresponds with the second longest muscle (muscle D) shown in the answer choices. Also, muscle D has the greatest diameter and thus corresponds to Muscle 1, which is shown to exert the greatest force at zero conduction velocity. Muscle diameter does not affect the maximum velocity of shortening because this is extrapolated to a force of 0.

TMP14 pp. 85–86

9. C) A typical resting sarcomere length of 2 micrometers in skeletal muscle provides optimal overlap of actin and myosin filaments, and thus, the development of muscle tension is maximal at the resting length.

TMP14 p. 85

10. I) A normal contraction of a skeletal muscle fiber begins with depolarization of the muscle fiber membrane which activates dihydropyridine voltage sensors (event 4) of the transverse tubules. Activation of the dihydropyridine voltage sensor leads to activation of the ryanodine receptor (event 2) with subsequent release of calcium from the terminal cisternae (event 3); this release of calcium increases the calcium concentration in the sarcoplasm (event 1). Contraction of the muscle fiber follows.

TMP14 pp. 97–99

11. B) Malignant hyperthermia is a pharmacogenetic disorder of skeletal muscle in which ryanodine receptors respond to certain halogenated anesthetics (as well as the muscle relaxant succinylcholine) by opening their associated calcium channels within the muscle fiber and thus causing an increase in myoplasmic calcium. This increase in myoplasmic calcium concentration causes continual contraction of the skeletal muscles everywhere in the body. The results are increased body temperature, increased anaerobic metabolism, increased CO_2 production, and increased O_2 usage by all skeletal muscles. Calsequestrin is a protein molecule that binds calcium within the sarcoplasmic reticulum of the muscle fiber. Because calcium is continually leaking from the sarcoplasmic reticulum, the binding of calcium to calsequestrin is decreased during an episode of malignant hyperthermia.

TMP14 pp. 98, 100

12. B) Potassium channels in bacteria were found to have a tetrameric structure consisting of four identical protein subunits surrounding a central pore. At the top of the channel pore are *pore loops* that form a narrow *selectivity filter.* Lining the selectivity filter are *carbonyl oxygens***.** When hydrated potassium ions enter the selectivity filter, they interact with the carbonyl oxygens and shed most of their bound water molecules, permitting the dehydrated potassium ions to pass through the channel. The carbonyl oxygens are too far apart, however, to enable them to interact closely with the smaller sodium ions, which are therefore effectively excluded by the selectivity filter from passing through the pore.

TMP14 p. 53

13. D) A new action potential cannot occur in an excitable fiber when the membrane is still depolarized from the preceding action potential. The reason for this restriction is that shortly after the action potential is initiated, the sodium channels (or calcium channels, or both) become inactivated, and no amount of excitatory signal applied to these channels at this point will open the inactivation gates. The only condition that will allow them to reopen is for the membrane potential to return to or near the original resting membrane potential level. Then, within another small fraction of a second, the inactivation gates of the channels open and a new action potential can be initiated.

TMP14 p. 76

14. A) Both myasthenia gravis (MG) and Lambert-Eaton myasthenic syndrome (LEMS) can cause muscle weakness. In MG, antibodies attack the acetylcholine receptors on the postsynaptic muscle fiber membrane. Damage to the acetylcholine channels results in small endplate potentials that do not reach a threshold value required for generation of an action potential in the muscle fiber. In LEMS, antibodies attack the voltage-gated calcium channels on the presynaptic membrane; without proper function of these channels, insufficient amounts of acetylcholine are released into the neuromuscular junction, again, resulting in small endplate potentials.

TMP14 p. 97

15. B) In visceral smooth muscle, the cell membranes are joined by many *gap junctions* through which ions can flow freely from one muscle cell to the next so that action potentials, or simple ion flow without action potentials, can travel from one fiber to the next and cause the muscle fibers to contract together at the same time. This type of smooth muscle is also known as *syncytial smooth muscle* because of its syncytial interconnections among fibers. It is also called *visceral smooth muscle* because it is found in the walls of most viscera of the body, including the gastrointestinal tract, bile ducts, ureters, uterus, and many blood vessels.

TMP14 pp. 105–106

16. E) Summation of muscle contractions occurs when a person attempts to lift heavy weights. Summation occurs in two ways: (1) by increasing the number of motor units contracting simultaneously, which is called *multiple fiber summation*, and (2) by increasing the frequency of contraction of individual muscle fibers, which is called *frequency summation.* So, when a person attempts to lift a heavy weight, an increased number of motor units is activated, and, the frequency of motor nerve action potentials to the motor units of the muscle is also increased.

TMP14 pp. 88–89

17. A) The extracellular fluid contains a large amount of sodium, calcium, and chloride but only a small amount of potassium. The opposite is true of the intracellular fluid. However, the concentrations of phosphates and proteins in the intracellular fluid are considerably greater than those in the extracellular fluid. These differences are extremely important to the life of the cell, as discussed in Chapter 4.

TMP14 p. 51

18. D) When smooth muscle has developed full contraction, the amount of continuing excitation can usually be reduced to far less than the initial level even though the muscle maintains its full force of contraction. This mechanism is called the "latch" mechanism.

TMP14 p. 103

19. E) The equilibrium potential for chloride ($E_{Cl}-$) can be calculated using the Nernst equation as follows: $E_{Cl}-$ (in millivolts) = $+61 \times \log (C_i/C_o)$, where C_i is the intracellular concentration and C_o is the extracellular concentration. Hence, $E_{Cl}- = +61 \times \log (5/125) = -85$ millivolts.

TMP14 p. 63

20. E) The equilibrium potential for potassium (E_{K^+}) can be calculated using the Nernst equation as follows: E_{K^+} (in millivolts) = $-61 \times \log (C_i/C_o)$. In this problem, $E_{K^+} = -61 \times \log (140/5) = -88$ millivolts.

TMP14 p. 63

21. A) The net driving force on any ion is the difference in millivolts between the membrane potential (V_m) and the equilibrium potential for that ion (E_{ion}). In this cell, $E_{K^+} = -88$ millivolts, $E_{Cl}- = -85$ millivolts, $E_{Na^+} = +66$ millivolts, and $E_{Ca^{2+}} = +145$ millivolts. Therefore, Ca^{2+} is the ion with the equilibrium potential farthest from V_m. This means that Ca^{2+} would have the greatest tendency to cross the membrane and enter the cell through an open channel in this hypothetical cell.

TMP14 p. 63

22. D) Skeletal muscle contraction is tightly regulated by the concentration of Ca^{2+} in the sarcoplasm. As long as sarcoplasmic Ca^{2+} is sufficiently high, none of the remaining events—removal of acetylcholine from the neuromuscular junction, removal of Ca^{2+} from the presynaptic terminal, closure of the acetylcholine receptor channel, and return of the dihydropyridine receptor to its resting conformation—would have any effect on the contractile state of the muscle.

TMP14 pp. 97–98

23. D) The resting potential of any cell is dependent on the concentration gradients of the permeant ions and their relative permeabilities (Goldman equation). In the myelinated nerve fiber, as in most cells, the resting membrane is predominantly permeable to K^+. The negative membrane potential observed in most cells (including nerve cells) is due primarily to the relatively high intracellular concentration and high permeability of K^+.

TMP14 p. 64

24. B) A neurotransmitter is considered to be a ligand, so when a neurotransmitter binds to its receptor on an ion channel, causing the channel to open, the channel is said to be ligand gated; voltage-gated channels open and close in response to changes in electrical potential across the cell membrane. The mechanism of transport through all water-filled channels is diffusion. Secondary active transport and primary active transport require special transport proteins rather than water-filled channels in the membrane.

TMP14 p. 53

25. B) The physical lengths of the actin and myosin filaments do not change during contraction. Therefore, the A band, which is composed of myosin filaments, does not change either. The distance between Z disks decreases, but the Z disks themselves do not change. Only the I band decreases in length as the muscle contracts.

TMP14 p. 82

26. E) The equilibrium potential of an ion (also called the Nernst potential) is the membrane potential at which there is no net movement of that ion across the cell membrane. The various ions (Q, R, and S) move across the cell membrane in the direction required to reach their individual equilibrium potentials given the resting membrane potential of –90 millivolts. Negatively charged Q ions must move out of the cell (outward) to achieve an equilibrium potential of –75 millivolts (i.e., negatively charged ions must be removed from the cell to cause the membrane potential to change from a resting value of –90 millivolts to a value of –75 millivolts). Because the positively charged R ion has an equilibrium potential of +75 millivolts, the R ion must move into the cell to cause the membrane potential to change from –90 millivolts to +75 millivolts. Ion S is a posi-

tively charged ion with an equilibrium potential of –85 mV; this ion must move into the cell (inward) to cause the membrane potential to change from –90 millivolts to –85 millivolts.

TMP14 pp. 64–65

27. B) Prolonged or repeated maximal contraction results in a concomitant increase in the synthesis of contractile proteins and an increase in muscle mass. This increase in mass, or hypertrophy, is observed at the level of individual muscle fibers.

TMP14 pp. 90–91

28. B) The velocity of an action potential increases in proportion to the diameter of the axon for both myelinated and nonmyelinated axons. Myelination increases the velocity of an action potential by several orders of magnitude more compared with the effect of an increase in axon diameter, which means that a large myelinated axon has the highest velocity of conduction. Therefore, even though unmyelinated axon E has the greatest diameter, myelinated axon B can conduct an action potential at a much greater velocity.

TMP14 pp. 74–75

29. D) At point B in this action potential, V_m has reached threshold potential and has triggered the opening of voltage-gated Na^+ channels. The resulting Na^+ influx is responsible for the rapid, self-perpetuating depolarization phase of the action potential.

TMP14 pp. 67–68

30. C) The rapid depolarization phase is terminated at Point D by the inactivation of the voltage-gated Na^+ channels and the opening of the voltage-gated K^+ channels. The latter results in the efflux of K^+ from the cytosol into the extracellular fluid and repolarization of the cell membrane.

TMP14 pp. 67–68

31. B) The velocity of an action potential is a function of the physical characteristics of the axon (e.g., myelination, axon diameter). A given axon will always conduct any action potential at the same velocity under normal conditions. Therefore, stimulation of the axon with a 25-millivolt pulse or 100 millivolts will produce an action potential with the same velocity, which is why action potentials are said to be "all or none." However, the level of stimulation must be sufficient to achieve a critical threshold level of potential before an action potential can be initiated in an axon.

TMP14 p. 72

32. D) Muscle B is characteristic of a slow-twitch muscle (type I) composed of predominantly slow-twitch muscle fibers. These fibers are smaller in size and are innervated by smaller nerve fibers. They typically have a more extensive blood supply, a greater number of mitochondria, and large amounts of myoglobin, all of which support high levels of oxidative phosphorylation.

TMP14 p. 88

33. C) Muscle contraction is triggered by an increase in sarcoplasmic Ca^{2+} concentration. The delay between the termination of the depolarizing pulse and the onset of muscle contraction, also called the "lag," reflects the time necessary for the depolarizing pulse to be translated into an increase in sarcoplasmic Ca^{2+} concentration. This process involves a conformational change in the voltage-sensing, or dihydropyridine receptor, located on the T tubule membrane, along with the subsequent conformational change in the ryanodine receptor on the sarcoplasmic reticulum and the release of Ca^{2+} from the sarcoplasmic reticulum.

TMP14 pp. 97–99

34. B) Myasthenia gravis is an autoimmune disease in which antibodies damage postsynaptic nicotinic acetylcholine receptors. This damage prevents the firing of an action potential in the postsynaptic membrane. Tensilon (edrophonium) is a readily reversible acetylcholinesterase inhibitor that increases acetylcholine levels in the neuromuscular junction, thereby increasing the strength of muscle contraction.

TMP14 p. 97

35. E) Neostigmine is an acetylcholinesterase inhibitor. Administration of this drug would increase the amount of ACh present in the synapse and its ability to sufficiently depolarize the postsynaptic membrane and trigger an action potential. Botulinum toxin antiserum is effective only against botulinum toxicity. Curare blocks the nicotinic ACh receptor and causes muscle weakness. Atropine is a muscarinic ACh receptor antagonist, and halothane is an anesthetic gas. Neither atropine nor halothane has any effect on the neuromuscular junction.

TMP14 pp. 96, 97

36. B) In this figure, "active" or contraction-dependent tension is the difference between total tension (trace A) and the passive tension contributed by noncontractile elements (trace C). The length-tension relationship in intact muscle resembles the biphasic relationship observed in individual sarcomeres and reflects the same physical interactions between actin and myosin filaments.

TMP14 p. 85

37. E) "Active" tension is maximal at normal physiological muscle lengths. At this point, there is optimal overlap between actin and myosin filaments to support maximal cross-bridge formation and tension development.

TMP14 p. 85

38. C) Trace C represents the passive tension contributed by noncontractile elements, including fascia, tendons, and ligaments. This passive tension accounts for an increasingly large portion of the total tension recorded in intact muscle as it is stretched beyond its normal length.

TMP14 p. 85

39. B) Smooth muscle contraction is regulated by both Ca^{2+} and myosin light chain phosphorylation. When the cytosolic Ca^{2+} concentration decreases after the initiation of contraction, myosin kinase becomes inactivated. However, cross-bridge formation continues, even in the absence of Ca^{2+}, until the myosin light chains are dephosphorylated through the action of myosin light chain phosphatase.

TMP14 pp. 103–104

40. C) The normal miniature endplate potentials indicate sufficient synthesis and packaging of ACh and the presence and normal function of ACh receptor channels. The most likely explanation for this patient's symptoms is a presynaptic deficiency—in this case, an impairment of the voltage-sensitive Ca^{2+} channels responsible for the increase in cytosolic Ca^{2+} that triggers the release of ACh into the synapse. The increase in postsynaptic depolarization observed after exercise is indicative of an accumulation of Ca^{2+} in the presynaptic terminal after multiple action potentials have reached the nerve terminal.

TMP14 pp. 93–94

41. B) Inhibition of the presynaptic voltage-sensitive Ca^{2+} channels is most consistent with the presence of antibodies against this channel. Antibodies against the ACh receptor, a mutation in the ryanodine receptor, and residual ACh in the junction are all indicative of postsynaptic defects. Although it is a presynaptic defect, a deficit of ACh vesicles is unlikely in this scenario, given the normal miniature endplate potentials recorded in the postsynaptic membrane.

TMP14 pp. 93–94

42. B) Botulinum toxin inhibits muscle contraction presynaptically by decreasing the amount of ACh released into the neuromuscular junction. In contrast, curare acts postsynaptically, blocking the nicotinic ACh receptors and preventing the excitation of the muscle cell membrane. Tetrodotoxin blocks voltage-sensitive Na^+ channels, affecting both the initiation and the propagation of action potentials in the motor neuron. Both ACh and neostigmine stimulate muscle contraction.

TMP14 pp. 95–96

43. D) During an action potential in a nerve cell, V_m approaches E_{Na} during the rapid depolarization phase when the permeability of the membrane to Na^+ (P_{Na}) increases relative to its permeability to K^+ (P_K). In a "typical" cell, E_{Na} is close to 60 millivolts. V_m is closest to E_{Na} at point D in this figure. At this point, the ratio of P_{Na} to P_K is the greatest.

TMP14 pp. 70–71

44. F) The driving force for Na^+ is greatest at the point at which V_m is the farthest from E_{Na}. If E_{Na} is very positive ($\approx$ 60 millivolts), V_m is farthest from E_{Na} at point F, or when the cell is the most hyperpolarized.

TMP14 pp. 70–71

45. F) Generally, V_m is closest to the equilibrium potential of the most permeant ion. In nerve cells, $P_K >> P_{Na}$ at rest. As a result, V_m is relatively close to E_K. During the after-potential or the hyperpolarization phase of the action potential, the ratio of P_K to P_{Na} is even greater than it is at rest because of the residual opening of voltage-gated K^+ channels and the inactivation of the voltage-gated Na^+ channels. P_K:P_{Na} is greatest at point F, at which point V_m comes closest to E_K.

TMP14 pp. 70–71

46. D) Muscle fibers have significant plasticity, which means that their characteristics can change depending on the frequency at which they are stimulated. When a nerve that innervates a predominantly fast type II muscle is anastomosed to a predominantly slow type I muscle, the type I muscle is converted to a type II muscle. Compared with type I muscle fibers, type II fibers have a larger diameter, higher glycolytic activity, greater maximum velocity of contraction, lower mitochondrial content, and higher myosin ATPase activity. Therefore, only mitochondrial content decreases when a type I fiber is converted to a type II fiber.

TMP14 p. 88

47. B) The redistribution of fluid volume shown in part **B** reflects the net diffusion of water, or osmosis, because of differences in the osmolarity of the solutions on either side of the semipermeable membrane. Osmosis occurs from solutions of high water concentration to low water concentration or from low osmolarity to high osmolarity. In part **B**, osmosis has occurred from X to Y and from Y to Z. Therefore, the osmolarity of solution Z is higher than that of solution Y, and the osmolarity of solution Y is higher than that of solution X.

TMP14 pp. 57–58

48. E) These so-called slow Ca^{2+} channels have a slower inactivation rate, thereby lengthening the time during which they are open. This phenomenon, in turn, delays the repolarization phase of the action potential, creating a "plateau" before the channels inactivate.

TMP14 pp. 72–73

49. A) In the absence of hyperpolarization, the inability of an otherwise excitatory stimulus to initiate an action potential is most likely the result of the blockade of the

voltage-gated channels responsible for the generation of the all-or-none depolarization. In nerve cells, these channels are the voltage-gated Na^+ channels.

TMP14 pp. 68, 70

50. C) Skeletal muscle continuously remodels in response to its level of use. When a muscle is inactive for an extended period, the rate of synthesis of the contractile proteins in individual muscle fibers decreases, resulting in an overall reduction in muscle mass. This reversible reduction in muscle mass is called *atrophy.*

TMP14 pp. 90–91

51. C) Ouabain inhibits Na^+, K^+-ATPase. This ATP-dependent enzyme transports three Na^+ ions out of the cell for every two K^+ ions it transports into the cell. It is a classic example of primary active transport.

TMP14 p. 59

52. A) Glucose is transported into skeletal muscle cells via insulin-dependent facilitated diffusion.

TMP14 p. 56

53. E) The activity of Na^+, K^+-ATPase maintains the relatively high K^+ concentration inside the cell and the relatively high Na^+ concentration in the extracellular fluid. This large concentration gradient for Na^+ across the plasma membrane, together with the net negative charge on the inside of the cell, continuously drives Na^+ ions from the extracellular fluid into the cytosol. This energy is used to transport other molecules, such as Ca^{2+} , against their concentration gradients. Because ATP is required to maintain the Na^+ gradient that drives this counter-transport, this type of transport is called *secondary active transport.*

TMP14 pp. 60–61

54. D) Much like Na^+- Ca^{2+} countertransport, the strong tendency for Na^+ to move across the plasma membrane into the cytosol can be harnessed by transport proteins and used to co-transport molecules against their concentration gradients into the cytosol. An example of this type of secondary co-transport is the transport of glucose into intestinal epithelial cells.

TMP14 p. 61

55. A) During the rapid depolarization phase of a nerve action potential, voltage-sensitive Na^+ channels open and allow the influx of Na^+ ions into the cytosol. Transport through membrane channels is an example of diffusion.

TMP14 p. 68

56. E) Trace A exhibits the characteristic shape of an action potential, including the rapid depolarization followed by a rapid repolarization that temporarily overshoots the resting potential. Trace B best illustrates the change in P_{Na} that occurs during an action potential. The rapid increase in P_{Na} closely parallels the rapid depolarization phase of the action potential. Trace C best illustrates the slow onset of the increase in P_K that reflects the opening of the voltage-gated K^+ channels.

TMP14 p. 70

57. D) Stretching the muscle to facilitate reattachment of the tendons leads to an increase in passive tension or preload. This increase in passive tension increases the muscle length beyond its ideal length, which in turn leads to a decrease in the maximal active tension that can be generated by the muscle. The reason maximal active tension decreases is that interdigitation of actin and myosin filaments decreases when the muscle is stretched; the interdigitation of a muscle is normally optimal at its resting length.

TMP14 p. 85

58. C) The figure shows the relationship between preload or passive tension (curve Z), total tension (curve X), and active tension (curve Y). Active tension cannot be measured directly: it is the difference between total tension and passive tension. To answer this question, the student must first find where 100 g intersects the preload curve (passive tension curve) and then move down to the active tension curve. One can see that a preload of 100 g is associated with a total tension of a little more than 150 g and an active tension of a little more than 50 g. Note that active tension equals total tension minus passive tension, as previously discussed. Drawing these three curves in a manner that is mathematically correct is not an easy task. The student should thus recognize that active tension may not equal total tension minus passive tension at all points on the figure shown here, as well as on United States Medical Licensing Examination figures.

TMP14 p. 85

59. E) Smooth muscle is unique in its ability to generate various degrees of tension at a constant concentration of intracellular calcium. This change in calcium sensitivity of smooth muscle can be attributed to differences in the activity of MLCP. Smooth muscle contracts when the myosin light chain is phosphorylated by the actions of myosin light chain kinase (MLCK). MLCP is a phosphatase that can dephosphorylate the myosin light chain, rendering it inactive and therefore attenuating the muscle contraction. Choice A: Both actin and myosin are important components of the smooth muscle contractile apparatus, much like that of skeletal muscle and cardiac muscle, but these components do not play a role in calcium sensitivity. Choice B: ATP is required for smooth muscle contraction. Decreased ATP levels would be expected to decrease the ability of smooth muscle to contract even in the face of high calcium levels. Choice C: The calcium–calmodulin complex binds with MLCK, which leads to phosphorylation of the myosin light chain. A decrease in the calcium-

calmodulin complex should attenuate the contraction of smooth muscle. Choice D: Again, the binding of calcium ions to calmodulin is an initial step in the activation of the smooth muscle contractile apparatus.

TMP14 p. 105

60. B) Smooth muscle can be stimulated to contract without the generation of an action potential, whereas both cardiac muscle and skeletal muscle require an action potential. Smooth muscle can contract in response to any stimulus that increases the cytosolic Ca^{2+} concentration, which includes Ca^{2+} channel openers, subthreshold depolarization, and a variety of tissue factors and circulating hormones that stimulate the release of intracellular Ca^{2+} stores. Smooth muscle contraction uses less energy and lasts longer compared with that of skeletal muscle and cardiac muscle. Smooth muscle contraction is heavily Ca^{2+} dependent.

TMP14 p. 108

61. D) The figure shows that the maximum velocity of shortening (V_{max}) occurs when there is no afterload on the muscle (force = 0). Increasing afterload decreases the velocity of shortening until a point is reached at which shortening does not occur (isometric contraction) and contraction velocity is thus 0 (where curves intersect the x-axis). The maximum velocity of shortening is dictated by the ATPase activity of the muscle, increasing to high levels when the ATPase activity is elevated. Choice A: Increasing the frequency of muscle contraction will increase the load that a muscle can lift within the limits of the muscle, but it will not affect the velocity of contraction. Choices B, C, and E: Muscle hypertrophy, increasing muscle mass, and recruiting additional motor units will increase the maximum load that a muscle can lift, but they will not affect the maximum velocity of contraction.

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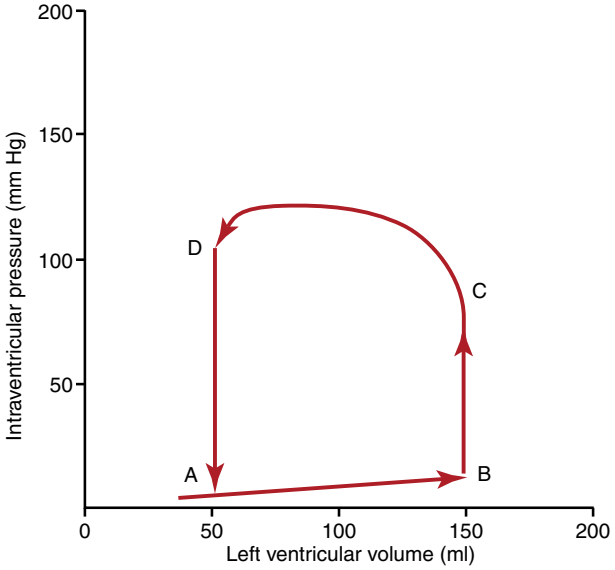
The Heart

Questions 1–4
A patient has a resting heart rate of 82 beats/min, normal blood pressure, and normal body temperature. Use the pressure-volume diagram of the left ventricle below to answer Questions 1–4.



1. What is the stroke volume in milliliters?
   A) 150
   B) 100
   C) 85
   D) 50
   E) 70

2. What is the cardiac output of this patient?
   A) 7000 ml/min
   B) 50000 ml/min
   C) 8200 ml/min
   D) 8500 ml/min
   E) 5000 ml/min

3. What is the extent of diastole in the ventricular pressure-volume relationship?
   A) At point B
   B) From point D to point A
   C) From point A to point C
   D) From point D and point B
   E) From point A and point B

4. What is correct about isovolumetric contraction?
   A) Extends from B to C in the ventricular pressure-volume curve
   B) Extends from D to A in the ventricular pressure-volume curve
   C) Represents afterload in the ventricular pressure-volume curve
   D) Represents a decrease in pressure with preserved volume
   E) Depends on ventricular ejection

5. Which statement about action potential of cardiac muscle is most accurate?
   A) The calcium from T-tubules is less important as it is for skeletal muscle
   B) Phase 0 is predominantly dependent on slow potassium channels
   C) The end of the action potential (phase 2) causes an opening of slow potassium channels
   D) Action potential cause myofibrils to contract
   E) Mucopolysaccharides inside the T-tubules provide chloride ions to trigger phase 0

6. A 47-year-old man has an ejection fraction of 0.32 and an end-diastolic volume of 160 ml. What is (approximately) the value of end-systolic volume?
   A) 48 ml
   B) 83 ml
   C) 109 ml
   D) 51 ml
   E) 170 ml

7. In a resting adult, the typical ventricular ejection fraction has what value?
   A) 20%
   B) 30%
   C) 40%
   D) 60%
   E) 80%

8. In which phase of the ventricular muscle action potential is the potassium permeability the highest?
   A) 0
   B) 1
   C) 2
   D) 3
   E) 4

9. A 48-year-old man's ECG shows that he has an R-R interval of 1.8 seconds at rest. Which statement best explains his condition?
   A) He has fever
   B) He may have an A-V block
   C) He has decreased parasympathetic stimulation of the S-A node
   D) He is a trained athlete after exercise
   E) He has augmented sympathetic stimulation of sinus node

10. Which of the following is most likely to cause the heart to go into spastic contraction?
    A) Increased body temperature
    B) Increased sympathetic activity
    C) Decreased extracellular fluid potassium ions
    D) Excess extracellular fluid potassium ions
    E) Excess extracellular fluid calcium ions

11. What happens at the end of ventricular isovolumic relaxation?
    A) The A-V valves close
    B) The aortic valve opens
    C) The aortic valve closes
    D) The mitral valve opens
    E) The pulmonary valve closes

12. Which event is associated with the first heart sound?
    A) Closing of the aortic valve
    B) Inrushing of blood into the ventricles during diastole
    C) Beginning of diastole
    D) Opening of the A-V valves
    E) Closing of the A-V valves

13. Which condition will result in a dilated, flaccid heart?
    A) Excess calcium ions in the blood
    B) Excess potassium ions in the blood
    C) Excess sodium ions in the blood
    D) Increased sympathetic stimulation
    E) Increased norepinephrine concentration in the blood

14. A 25-year-old well-conditioned athlete weighs 80 kg (176 lb). During maximal sympathetic stimulation, what is the plateau level of his cardiac output function curve?
    A) 3 l/min
    B) 5 l/min
    C) 10 l/min
    D) 13 l/min
    E) 25 l/min

15. Which phase of the cardiac cycle follows immediately after the beginning of the QRS wave?
    A) Isovolumic relaxation
    B) Ventricular ejection
    C) Atrial systole
    D) Diastasis
    E) Isovolumic contraction

16. Which of the following structures will have the slowest rate of conduction of the cardiac action potential?
    A) Atrial muscle
    B) Anterior internodal pathway
    C) A-V bundle fibers
    D) Purkinje fibers
    E) Ventricular muscle

17. What is the normal total delay of the cardiac impulse in the A-V node + bundle?
    A) 0.22 second
    B) 0.18 second
    C) 0.16 second
    D) 0.13 second
    E) 0.09 second

18. Sympathetic stimulation of the heart does which of the following?
    A) Releases acetylcholine at the sympathetic endings
    B) Decreases sinus nodal discharge rate
    C) Decreases excitability of the heart
    D) Releases norepinephrine at the sympathetic endings
    E) Decreases cardiac contractility

19. If the S-A node discharges at 0.00 seconds, when will the action potential normally arrive at the epicardial surface at the base of the left ventricle?
    A) 0.22 second
    B) 0.18 second
    C) 0.16 second
    D) 0.12 second
    E) 0.09 second

20. Which condition at the A-V node will cause a decrease in heart rate?
    A) Increased sodium permeability
    B) Decreased acetylcholine levels
    C) Increased norepinephrine levels
    D) Increased potassium permeability
    E) Increased calcium permeability

21. Which statement best explains how sympathetic stimulation affects the heart?
    A) The permeability of the S-A node to sodium decreases
    B) The permeability of the A-V node to sodium decreases

C) The permeability of the S-A node to potassium increases
D) There is an increased rate of upward drift of the resting membrane potential of the S-A node
E) The permeability of the cardiac muscle to calcium decreases

22. What is the membrane potential (threshold level) at which the S-A node discharges?
A) –40 millivolt
B) –55 millivolt
C) –65 millivolt
D) –85 millivolt
E) –105 millivolt

23. Which condition at the S-A node will cause the heart rate to decrease?
A) Increased norepinephrine level
B) Increased sodium permeability
C) Increased calcium permeability
D) Increased potassium permeability
E) Decreased acetylcholine level

24. In which phase of the ventricular muscle action potential is the sodium permeability the highest?
A) 0
B) 1
C) 2
D) 3
E) 4

25. If the S-A node discharges at 0.00 seconds, when will the action potential normally arrive at the A-V bundle (bundle of His)?
A) 0.22 second
B) 0.18 second
C) 0.16 second
D) 0.12 second
E) 0.09 second

26. If the Purkinje fibers, situated distal to the A-V junction, become the pacemaker of the heart, what is the expected heart rate?
A) 30/min
B) 50/min
C) 60/min
D) 70/min
E) 80/min

27. What is correct about the sinus node?
A) Delays the cardiac conduction if sympathetic activity increases
B) Acts as a pacemaker because the membrane constantly leaks Na^+ from extracellular fluid
C) The constant leak of K^+ makes resting potential in the sinus node gradually rise
D) Feedback from the Purkinje fibers defines the sinus node discharge
E) The resting membrane potential of the sinus node is +55 to +60mV

28. What is correct about the conduction system?
A) The longest delay of the cardiac impulse is in the A-V bundles
B) The lack of GAP junctions is responsible for the fast conduction of Purkinje fibers
C) The A-V node inhibit the sinus node during exercise (overdrive suppression)
D) If sinus node fails, lower portions of the conduction system can act as pacemaker

29. A patient had an ECG at the local emergency department. The attending physician stated that the patient had an A-V nodal rhythm. What is the likely heart rate?
A) 30/min
B) 50/min
C) 65/min
D) 75/min
E) 85/min

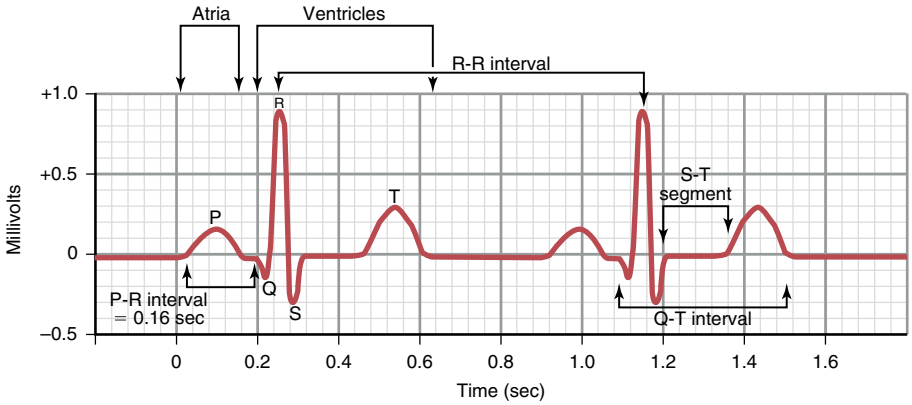
30. Which of the following is correct about ECG?
A) The mean vector of depolarization moves from negative to positive, from front to back, from left to right
B) The P wave represents atrial depolarization and repolarization
C) The Q-T interval approximates the time of ventricular contraction
D) The P-R interval includes ventricular repolarization
E) The T wave always opposes QRS polarity

31. When recording lead aVL on an ECG, which is the positive electrode?
A) Left arm
B) Left leg
C) Right leg
D) Left arm + left leg
E) Right arm + left leg

32. When recording lead II on an ECG, the right arm is the negative electrode and the positive electrode is the
A) Left arm
B) Left leg
C) Right leg
D) Left arm + left leg
E) Right arm + left leg

33. Sympathetic stimulation of the heart normally causes which condition?
A) Acetylcholine release at the sympathetic endings
B) Decreased heart rate
C) Decreased rate of conduction of the cardiac impulse
D) Decreased force of contraction of the atria
E) Increased force of contraction of the ventricles

Questions 34 and 35
A 70-year-old woman had an ECG at her annual checkup. Use her lead II recording below to answer Questions 34 and 35.



34. What is her heart rate in beats/min?
    A) 70
    B) 78
    C) 84
    D) 94
    E) 104

35. According to Einthoven's law, if the QRS voltage in lead III is 0.4 millivolt, what is the QRS voltage in lead I?
    A) 0.05 millivolt
    B) 0.50 millivolt
    C) 1.05 millivolts
    D) 1.25 millivolts
    E) 2.05 millivolts

36. What is the normal QT interval?
    A) 0.03 second
    B) 0.13 second
    C) 0.16 second
    D) 0.20 second
    E) 0.35 second

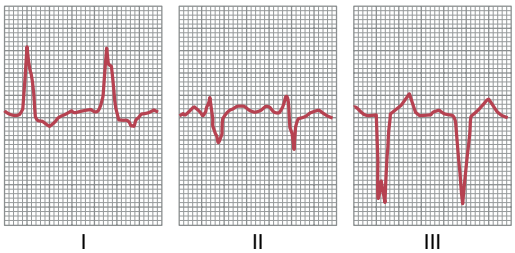
37. When recording lead II on an ECG, the negative electrode is the
    A) Right arm
    B) Left leg
    C) Right leg
    D) Left arm + left leg
    E) Right arm + left leg

38. When recording aVF on an ECG, the negative electrode/s is/are in which area?
    A) Left arm, left leg
    B) Right arm, left arm
    C) Left leg
    D) Left leg, right leg
    E) Chest

39. A 65-year-old man had an ECG at a local emergency department after a biking accident. His weight was 80 kg (176 lb), and his aortic blood pressure was 160/90 mm Hg. The QRS voltage was 0.5 millivolt in lead I and 1.5 millivolts in lead III. What is the QRS voltage in lead II?
    A) 0.5 millivolt
    B) 1.0 millivolt
    C) 1.5 millivolts
    D) 2.0 millivolts
    E) 2.5 millivolts

40. What is correct about ECG leads?
    A) The anterior or posterior origin of the current of injury is defined by precordial (chest) leads
    B) The anterior or posterior origin of the current of injury is defined by bipolar leads
    C) Displaced J point in aVF lead suggest lateral ischemia
    D) ST elevation in aVR suggests ischemia in the apex of the left ventricle
    E) The T wave is always positive in all leads.

Questions 41–43
A 60-year-old woman had an ECG recorded at a local emergency department after an automobile accident. Her weight was 70 kg (154 lb), and her aortic blood pressure was 140/80 mm Hg. Use this information and the figure below to answer Questions 41–43.



41. What is the mean electrical axis calculated from standard leads I, II, and III shown in the woman's ECG?
    A) –90 degrees
    B) –50 degrees
    C) –12 degrees
    D) +100 degrees
    E) +170 degrees

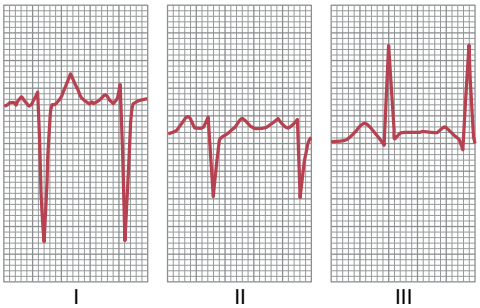
42. What is the heart rate using lead I for the calculation?
    A) 70
    B) 88
    C) 100
    D) 112
    E) 148

43. What is her likely diagnosis?
    A) Tricuspid valve stenosis
    B) Left bundle branch block
    C) Pulmonary valve stenosis
    D) Pulmonary valve insufficiency
    E) Aortic insufficiency

44. Which event is most often associated with deviation of electrical axis to the left?
    A) Pulmonary stenosis
    B) Right bundle branch block
    C) Aortic stenosis
    D) Tetralogy of Fallot
    E) Third degree A-V block

45. A ventricular depolarization wave, when traveling 60 degrees in the frontal plane, will cause a large positive deflection in which of the following leads?
    A) aVR
    B) aVL
    C) Lead I
    D) Lead II
    E) aVF

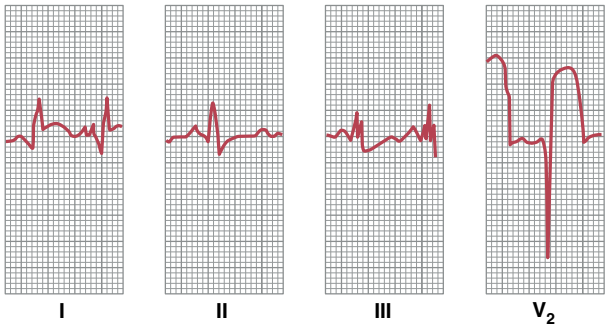
A 50-year-old woman was admitted to a local emergency department after a motorcycle accident. The following ECG was obtained.



46. What is her heart rate? Use lead I for the calculation.
    A) 56
    B) 66
    C) 76
    D) 103
    E) 152

47. Which condition or individual may show increased voltage of ECG leads?
    A) A 76-year old patient with old infarcts
    B) A 37-year old patient with old infarcts
    C) A trained athlete
    D) Pericardial effusion (increased conductance)
    E) Pleural effusion

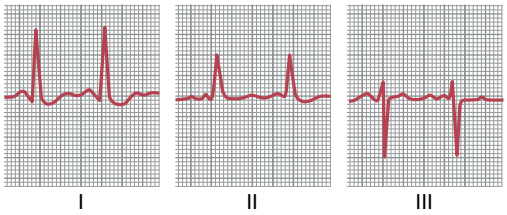
48. Mr. Smith had an ECG at a local hospital, but his records were lost. The ECG technician remembered that the QRS deflection was large and positive in lead II and 0 in aVL. What is his mean electrical axis in the frontal plane?
    A) 90 degrees
    B) 60 degrees
    C) 0 degree
    D) –60 degrees
    E) –90 degrees



49. A 70-year-old woman came to a hospital emergency department because she was experiencing chest pain. Based on the ECG shown above, what is the likely diagnosis?
    A) Acute anterior infarction in the left ventricle of the heart
    B) Acute anterior infarction in the right ventricle of the heart
    C) Acute posterior infarction in the left ventricle of the heart
    D) Acute posterior infarction in the right ventricle of the heart
    E) Right ventricular hypertrophy

50. A 55-year-old man underwent an ECG at an annual physical examination and his net deflection (R wave minus Q or S wave) in standard limb lead I was –1.2 millivolts. Standard limb lead II has a net deflection of +1.2 millivolts. What is the mean electrical axis of his QRS?
    A) –30 degrees
    B) +30 degrees
    C) +60 degrees
    D) +120 degrees
    E) –120 degrees

51. During the T-P interval in an ECG of a patient with a damaged cardiac muscle, which of the following is true?
    A) The entire ventricle is depolarized
    B) The entire ventricle is depolarized except for the damaged cardiac muscle
    C) About half the ventricle is depolarized
    D) The entire ventricle is repolarized
    E) The entire ventricle is repolarized except for the damaged cardiac muscle

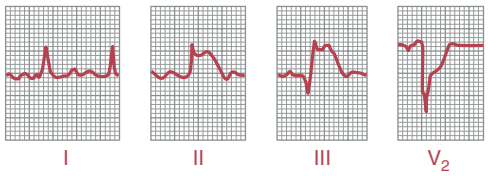


52. A 50-year-old man is a new employee at ABC Software. The above ECG was recorded during a routine physical examination. What is his likely diagnosis?
    A) Chronic systemic hypertension
    B) Chronic pulmonary hypertension
    C) Second-degree heart block
    D) Paroxysmal tachycardia
    E) Tricuspid valve stenosis

53. A 30-year-old man had an ECG at his physician's office, but his records were lost. The ECG technician remembered that the QRS deflection was large and positive in lead aVF and 0 in lead I. What is the mean electrical axis in the frontal plane?
    A) 90 degrees
    B) 60 degrees
    C) 0 degree
    D) −60 degrees
    E) −90 degrees

54. A 60-year-old woman tires easily. Her ECG shows a QRS complex that is positive in the aVF lead and negative in standard limb lead I. What is a likely cause of this condition?
    A) Chronic systemic hypertension
    B) Pulmonary hypertension
    C) Aortic valve stenosis
    D) Aortic valve regurgitation

55. A 65-year-old patient with a heart murmur has a mean QRS axis of 120 degrees, and the QRS complex lasts 0.18 second. What is the likely diagnosis?
    A) Aortic valve stenosis
    B) Aortic valve regurgitation
    C) Mitral valve regurgitation
    D) Right bundle branch block
    E) Left bundle branch block



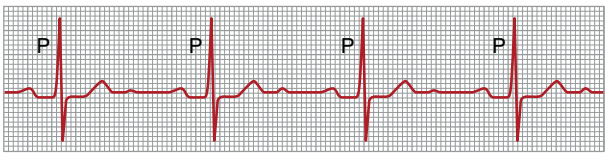
56. A 60-year-old woman came to the hospital emergency department and reported chest pain. Based on the ECG tracing shown above, what is the most likely diagnosis?
    A) Acute anterior infarction in the base of the heart
    B) Acute anterior infarction in the apex of the heart
    C) Acute posterior infarction in the base of the heart
    D) Acute posterior infarction in the apex of the heart
    E) Right ventricular hypertrophy

57. A 50-year-old man has been having fainting "spells" for about 2 weeks. During the episodes, his ECG shows a ventricular rate of 25 beats/min and 100 P waves/min. After about 30 seconds of fainting, a normal sinus rhythm recurs. What is his likely diagnosis?
    A) Atrial flutter
    B) First-degree A-V block
    C) Second-degree A-V block
    D) Third-degree A-V block
    E) Stokes-Adams syndrome

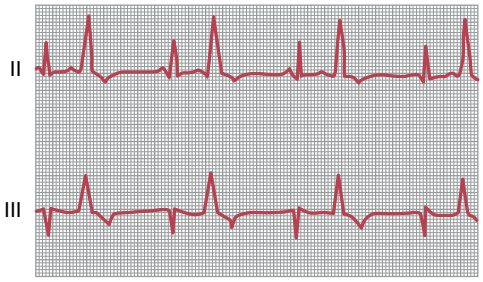
58. An 80-year-old man had an ECG taken at his local doctor's office, and the diagnosis was atrial fibrillation. Which condition is likely in someone with atrial fibrillation?
    A) Ventricular fibrillation, which normally accompanies atrial fibrillation
    B) Strong P waves on the ECG
    C) An irregular and fast rate of ventricular contraction
    D) A normal atrial "a" wave
    E) A smaller atrial volume than normal

59. Circus movements in the ventricle can lead to ventricular fibrillation. Which condition in the ventricular muscle will increase the tendency for circus movements?
    A) Decreased refractory period
    B) Low extracellular potassium concentration
    C) Increased refractory period
    D) Shorter conduction pathway (decreased ventricular volume)
    E) Increase in parasympathetic impulses to the heart

60. A 50-year-old man has a blood pressure of 140/85 mm Hg and weighs 90.7 kg (200 lb). He reports that he is not feeling well, his ECG has no P waves, he has a heart rate of 46 beats/min, and the QRS complexes occur regularly. What is his likely condition?
    A) First-degree heart block
    B) Second-degree heart block
    C) Third-degree heart block
    D) Sinoatrial heart block
    E) Sinus bradycardia



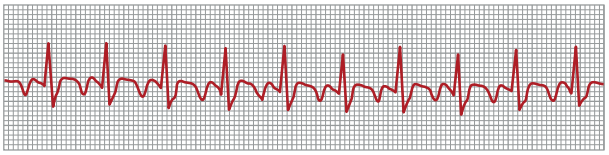
61. The following ECG tracing was obtained for a 60-year-old man who weighs 99.8 kg (220 lb). Standard lead II is shown above. What is his diagnosis?
    A) A-V nodal rhythm
    B) First-degree A-V heart block
    C) Second-degree A-V heart block
    D) Third-degree A-V heart block
    E) Atrial flutter



62. A 35-year-old woman had unusual sensations in her chest after she smoked a cigarette. Her ECG tracing is shown above. What is the likely diagnosis?
    A) Premature contraction originating in the atrium
    B) Premature contraction originating high in the A-V node
    C) Premature contraction originating low in the A-V node
    D) Premature contraction originating in the apex of the ventricle
    E) Premature contraction originating in the base of the ventricle

Questions 63 and 64

A 55-year-old man had the below ECG tracing recorded at his doctor's office at a routine physical examination. Use this tracing to answer Questions 63 and 64.

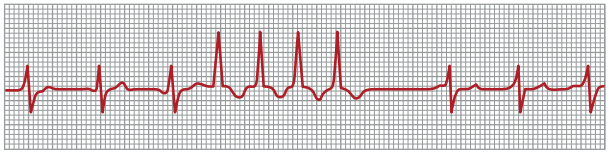


63. What is his diagnosis?
    A) Normal ECG
    B) Atrial flutter
    C) A high A-V junctional pacemaker
    D) A middle A-V junctional pacemaker
    E) A low A-V junctional pacemaker

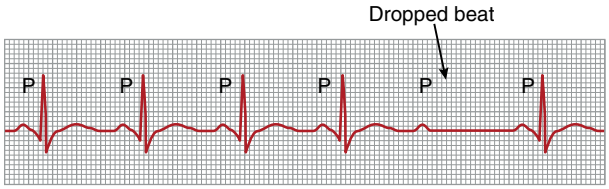
64. What is his ventricular heart rate in beats/min?
    A) 37.5
    B) 60
    C) 75
    D) 100
    E) 150

65. Which of the following is correct about ventricular fibrillation (VF)?
    A) Circus movements (a potential mechanism of VF) from the atria are conducted to the ventricles and back
    B) A potential trigger for a circus movements (a potential mechanism of VF) is a longer refractory period
    C) A potential trigger for a circus movements (a potential mechanism of VF) is a decreased in velocity of conduction
    D) VF usually reverses spontaneously
    E) If heart rate is not over 120/min, VF does not need to be treated

66. Which of the following will usually result in an inverted P wave that occurs after the QRS complex?
    A) Premature contraction originating in the atrium
    B) Premature contraction originating high in the A-V junction
    C) Premature contraction originating in the middle of the A-V junction
    D) Premature contraction originating low in the A-V junction
    E) Atrial fibrillation



67. A 65-year-old woman who had a myocardial infarction 10 days ago returned to her family physician's office and reported that her pulse rate felt rapid. Based on the above ECG tracing, what is the likely diagnosis?
    A) Stokes-Adams syndrome
    B) Atrial fibrillation
    C) A-V nodal tachycardia
    D) Atrial paroxysmal tachycardia
    E) Ventricular paroxysmal tachycardia



68. A 65-year-old man had the above ECG tracing recorded at his annual physical examination. What is the likely diagnosis?
    A) Atrial paroxysmal tachycardia
    B) First-degree A-V block
    C) Second-degree A-V block
    D) Third-degree A-V block
    E) Atrial flutter

69. A 60-year-old woman has been diagnosed with atrial fibrillation. Which statement best describes this condition?
    A) The ventricular rate of contraction is 140 beats/min
    B) The P waves of the ECG are pronounced
    C) Ventricular contractions occur at regular intervals
    D) The QRS waves are more pronounced than normal
    E) The atria are smaller than normal

70. What occurs after electrical shock of the heart with a 60-cycle alternating current?
    A) A normal arterial pressure
    B) A decreased ventricular refractory period
    C) Increased electrical conduction velocity
    D) A shortened conduction pathway around the heart
    E) Normal cardiac output

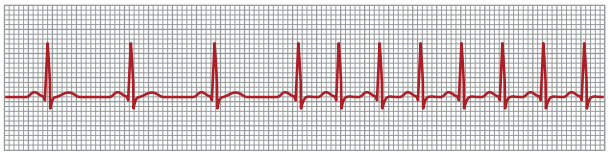
71. A 55-year-old man has been diagnosed with Stokes-Adams syndrome. Two minutes after the syndrome starts to cause active blockade of the cardiac impulse, which of the following is the pacemaker of the heart?
    A) Sinus node
    B) A-V node
    C) Purkinje fibers
    D) Inter-atrial septum
    E) Left atrium

72. The T wave represents ventricular repolarization. Which of the following is correct about the T wave and repolarization?
    A) Septum and endocardium are last to depolarize and first to repolarize and results in negative T wave in V6
    B) Repolarized areas will have a - charge first; therefore, a + net vector occurs, and a flat T wave (points towards the apex) develops
    C) In healthy individuals, last area to repolarize is near the apex, resulting in negative T waves in all chest leads
    D) Ischemia can alter repolarization and induce T abnormalities (e.g., flat T waves, taller, inverted)
    E) Potassium levels are normally between 3.5 and 5.0 mEq/l. Values higher than this can result in flat T waves and shorter PR interval.

73. A man had a myocardial infarction at age 55 years. He is now 63 years old. Use the standard limb lead I tracing on his ECG shown above to answer this question. What is his current diagnosis?
    A) Sinus tachycardia
    B) First-degree heart block
    C) Second-degree heart block
    D) ST segment depression
    E) Third-degree heart block

74. Which statement best describes a patient with premature atrial contraction?
    A) The pulse taken from the radial artery immediately after the premature contraction will be weak
    B) Stroke volume immediately after the premature contraction will be increased
    C) The P wave is never seen
    D) The probability of these premature contractions occurring is decreased in people with a large caffeine intake
    E) It causes the QRS interval to be lengthened

75. If the origin of the stimulus that causes atrial paroxysmal tachycardia is near the A-V node, which statement about the P wave in standard limb lead I is most accurate?
    A) The P wave will originate in the sinus node
    B) The P wave will be upright
    C) The P wave will be inverted
    D) The P wave will be missing



76. A 45-year-old man had the above ECG recorded at his annual physical. What is the likely diagnosis?
    A) Atrial paroxysmal tachycardia
    B) First-degree A-V block
    C) Second-degree A-V block
    D) Ventricular paroxysmal tachycardia
    E) Atrial flutter

77. Which of the following is a feature of premature ventricular contractions (PVCs)?
    A) The QRS is of shorter duration
    B) P is always present
    C) T shows opposing polarity to QRS
    D) They only appear in healthy individuals
    E) The PVC impulse always travels backward into atria and forward to the ventricles

78. Which of the following is a feature of a sinoatrial block?
    A) Cessation of normal P wave
    B) Prolonged but fixed P-R interval
    C) An increasing P-R interval and then a dropped beat
    D) A fixed long P-R interval and then a dropped beat
    E) A full compensatory pause

79. A 67-year old man with a history of hypertension has an ECG that shows no P waves, irregular heart rate (86–112 beats/min), ab electrical axis of +20 and QRS of 0.12 second. What is the most likely interpretation of the ECG and diagnosis?
    A) First degree A-V block and right bundle branch block
    B) Atrial paroxysmal tachycardia left ventricular ischemia
    C) Atrial flutter and left ventricular hypertrophy
    D) Atrial fibrillation and left bundle branch block
    E) Atrial fibrillation and left ventricular hypertrophy

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ANSWERS

1. **B)** Stroke volume (SV) of the heart is obtained by subtracting end-systolic volume (ESV, point D) from end-diastolic volume (EDV, point B) for a given ventricle. SV=EDV-ESV
   TMP14 pp. 119–120

2. **C)** Cardiac output can be calculated by multiplying SV times heart rate. If stroke volume is 100 ml and heart rate is 82 beats/min, then 100 × 82 = 8200 ml/min.
   TMP14 p. 125

3. **D)** Diastole includes the isovolumetric relaxation period (D to A) and ventricular filling (A-AV valve opening- to B -AV valve closure-). Thus, the diastole extends from point D to point B.
   TMP14 p. 122

4. **A)** The isovolumetric contraction phase starts immediately after AV valve closure and finishes when ejection phase starts. In this phase, there is a build-up in intraventricular pressure without changes in volume (both AV and aortic valves are closed). Thus, this period extends from point B to point C.
   TMP14 p. 122

5. **D)** The direct consequence of the action potential on cardiac muscle is the contraction of the myofibrils, which is known as the excitation/contraction coupling.
   TMP14 p. 127

6. **D)** Ejection fraction (EF) is calculated as follows: stroke volume (SV)/end-diastolic volume (EDV) multiplied by 100 and expressed in percent. If the EF of this patients is 0.32, that means 32%. If the end-diastolic volume is 160, then 0.32 of that value will represent the stroke volume (SV), and subtracting the SV from EDV will result in the end-systolic volume, which is exactly 108.8 ml (approximately 109 ml)
   TMP14 p. 119

7. **D)** The typical ejection fraction is 60%, and lower values are indicative of a weakened heart.
   TMP14 p. 119

8. **D)** During phase 3 of the ventricular muscle action potential, the potassium permeability of ventricular muscle greatly increases, which causes a more negative membrane potential.
   TMP14 p. 115

9. **B)** A R-R interval of 1.8 indicates that the heart beats every 1.8 seconds. Using the formula of heart rate calculation (heart rate = 60 seconds/0.83, which is the normal/average value of one beat every 0.83 seconds); the heart rate of this person is 33 beats/min (60/1.8). A heart rate of 33 beats/min indicates bradycardia and is suggestive abnormal/blocked conduction of the impulse.
   TMP14 pp. 136, 157–159

10. **E)** The heart goes into spastic contraction after a large increase in the calcium ion concentration surrounding the cardiac myofibrils, which occurs if the extracellular fluid calcium ion concentration increases too much. An excess potassium concentration in the extracellular fluids causes the heart to become dilated because of the decrease in resting membrane potential of the cardiac muscle fibers.
    TMP14 p. 125

11. **D)** At the end of isovolumic relaxation, the mitral and tricuspid valves open, which is followed by the period of diastolic filling.
    TMP14 pp.118, 121–122

12. **E)** The first heart sound by definition occurs just after the ventricular pressure exceeds the atrial pressure, which causes the A-V valves to mechanically close. The second heart sound occurs when the aortic and pulmonary valves close.
    TMP14 pp. 121–122

13. **B)** Having excess potassium ions in the blood and extracellular fluid causes the heart to become dilated and flaccid and slows the heart. This effect is important because of a decrease in the resting membrane potential in the cardiac muscle fibers. As the membrane potential decreases, the intensity of the action potential decreases, which makes the contraction of the heart progressively weaker. Excess calcium ions in the blood and sympathetic stimulation and increased norepinephrine concentration of the blood all cause the heart to contract vigorously.
    TMP14 p. 125

14. **E)** The normal plateau level of the cardiac output function curve is 13 L/min. This level decreases in any kind of cardiac failure and increases markedly during sympathetic stimulation.
    TMP14 p. 125

15. **E)** Immediately after the QRS wave, the ventricles begin to contract, and the first phase that occurs is isovolumic contraction. Isovolumic contraction occurs before the ejection phase and increases the ventricular pressure enough to mechanically open the aortic and pulmonary valves.
    TMP14 p. 118

16. C) The atrial and ventricular muscles have a relatively rapid rate of conduction of the cardiac action potential, and the anterior internodal pathway also has fairly rapid conduction of the impulse. However, the A-V bundle myofibrils have a slow rate of conduction because their sizes are considerably smaller than the sizes of the normal atrial and ventricular muscle. In addition, their slow conduction is partly caused by diminished numbers of gap junctions between successive muscle cells in the conducting pathway, causing a great resistance to conduction of the excitatory ions from one cell to the next.
TMP14 p. 129

17. D) The impulse from the S-A node travels rapidly through the internodal pathways and arrives at the A-V node at 0.03 second, at the A-V bundle at 0.12 second, and at the ventricular septum at 0.16 second. The total delay is thus 0.13 second.
TMP14 p. 129

18. D) Increased sympathetic stimulation of the heart increases heart rate, atrial contractility, and ventricular contractility and increases norepinephrine release at the ventricular sympathetic nerve endings. It does not release acetylcholine. It does cause an increased sodium permeability of the A-V node, which increases the rate of upward drift of the membrane potential to the threshold level for self-excitation, thus increasing the heart rate.
TMP14 pp. 123–125, 132

19. A) After the S-A node discharges, the action potential travels through the atria, through the A-V bundle system, and finally to the ventricular septum and throughout the ventricle. The last place that the impulse arrives is at the epicardial surface at the base of the left ventricle, which requires a transit time of 0.22 second.
TMP14 p. 130

20. D) The increase in potassium permeability causes a hyperpolarization of the A-V node, which will decrease the heart rate. Increases in sodium permeability actually partially depolarizes the A-V node, and an increase in norepinephrine levels increases the heart rate.
TMP14 p. 132

21. D) During sympathetic stimulation, the permeabilities of the S-A node and the A-V node increase. In addition, the permeability of cardiac muscle to calcium increases, resulting in an increased contractile strength. Furthermore, an upward drift of the resting membrane potential of the S-A node occurs. Increased permeability of the S-A node to potassium does not occur during sympathetic stimulation.
TMP14 p. 132

22. A) The normal resting membrane potential of the S-A node is –55 millivolts. As the sodium leaks into the membrane, an upward drift of the membrane potential occurs until it reaches –40 millivolts. This is the threshold level that initiates the action potential at the S-A node.
TMP14 pp. 127–129

23. D) Increases in sodium and calcium permeability at the S-A node result in an increase in heart rate. An increased potassium permeability causes a hyperpolarization of the S-A node, which causes the heart rate to decrease.
TMP14 p. 132

24. A) Sodium permeability is highest during phase 0. Calcium permeability is highest during phase 2, and potassium is most permeable in phase 3.
TMP14 p. 114–116

25. D) The action potential arrives at the A-V bundle at 0.12 second. It arrives at the A-V node at 0.03 second and is delayed 0.09 second in the A-V node, which results in an arrival time at the bundle of His of 0.12 second.
TMP14 p. 130

26. A) If the Purkinje fibers are the pacemaker of the heart, the heart rate ranges between 15 and 40 beats/min. In contrast, the rate of firing of the A-V nodal fibers are 40 to 60 times a minute, and the sinus node fires at 70 to 80 times/min. If the sinus node is blocked for some reason, the A-V node will take over as the pacemaker, and if the A-V node is blocked, the Purkinje fibers will take over as the pacemaker of the heart.
TMP14 p. 131

27. B) The inherent and constant leakiness to Na^+ (and movement of Ca^{2+}) are responsible for the automatic discharge (self-excitation) of the sinus node because it makes resting potential to gradually rise to the point (about –40 mV) of triggering the action potential.
TMP14 p. 128

28. D) If sinus node discharge does not get through, the next fastest area of discharge becomes the pacemaker of the heart beat but at a lower discharge rate because of a gradually more negative resting potential. The new pacemaker may be the AV node or penetrating part of AV bundle, and if these regions fail, Purkinje fibers will take the lead as the pacemaker of the heart.
TMP14 p. 131

29. B) The normal rhythm of the A-V node is 40 to 60 beats/min. Purkinje fibers have a rhythm of 15 to 40 beats/min.
TMP14 p. 131

30. C) The QRS complex represents ventricular depolarization, and the T wave represents ventricular repolarization. The Q-T interval is the time that the ventricle takes to depolarize-repolarize and represents the ven-

tricular contraction, as observed in the Wiggers' diagram.
TMP14 pp. 135–137

31. A) By convention, the left arm is the positive electrode for lead aVL of an ECG.
TMP14 p. 139

32. B) By convention, the left leg is the positive electrode for lead II of an ECG.
TMP14 p. 139

33. E) Sympathetic stimulation of the heart normally causes an increased heart rate, increased rate of conduction of the cardiac impulse, and increased force of contraction in the atria and ventricles. However, it does not cause acetylcholine release at the sympathetic endings because they contain norepinephrine. Parasympathetic stimulation causes acetylcholine release. The sympathetic nervous system firing increases in the permeability of the cardiac muscle fibers, the S-A node, and the A-V node to sodium and calcium.
TMP14 p. 132

34. A) The heart rate can be calculated by 60 divided by the R-R interval, which is 0.86 second. This results in a heart rate of 70 beats/min.
TMP14 p. 137

35. B) Einthoven's law states that the voltage in lead I plus the voltage in lead III is equal to the voltage in lead II. In this case, the voltage in lead II is 0.9 millivolt, and the voltage in lead III is 0.4 millivolt. The lead I voltage is thus 0.5 (0.9 – 0.4 millivolt = 0.5 millivolt).
TMP14 pp. 138–139

36. E) The contraction of the ventricles lasts almost from the beginning of the Q wave and continues to the end of the T wave. This interval is called the Q-T interval and ordinarily lasts about 0.35 second.
TMP14 p. 137

37. A) By convention, the right arm is the negative electrode for lead II of an ECG.
TMP14 p. 139

38. B) The augmented unipolar leads are obtained by connecting two terminals to negative and one to positive. In case of aVF, the positive terminal is connected to the left leg and the negative ones to the right and left arms.
TMP14 pp. 140–141

39. D) Einthoven's law states that the voltage in lead I plus the voltage in lead III is equal to the voltage in lead II, which in this case is 2.0 millivolts.
TMP14 pp. 138–139

40. A) Chest leads (precordial leads, V1 to V6) are very sensitive to electrical potential changes underneath the electrode and show the electrical activity of the heart from base to apex. ST (or J point) elevation or depression in precordial leads allows to identify the anterior or posterior origin of the current of injury. ST (or J point) elevation in bipolar and/or augmented unipolar leads help to refine the area of ischemia (e.g., lateral, inferior).
TMP14 pp. 138–141

41. B) The mean electrical axis can be determined by plotting the resultant voltage of the QRS for leads I, II, and III. The result is shown below and has a value of –50 degrees.
TMP14 pp. 143–146

42. B) The heart rate can be calculated by 60 divided by the R-R interval, which is 0.68 second. This calculation results in a heart rate of 88 beats/min.
TMP14 p. 137

43. B) In the figure, the QRS width is greater than 0.12 second, which indicates a bundle branch block. Right bundle branch block is not a listed answer. The correct answer is therefore left bundle branch block.
TMP14 pp. 149–150

44. C) Aortic stenosis induces left ventricular hypertrophy. Consequently, patients often show a significant left axis deviation in their ECGs. A third-degree A-V block will most likely not lead to any axis deviation. The other answers associate with right axis deviation.
TMP14 pp. 148–150

45. D) Lead II has a positive vector at the 60-degree angle. The negative end of lead II is at –120 degrees.
TMP14 pp. 143–146

46. D) Heart rate is calculated by 60/R-R interval and is 103 beats/min.
TMP14 p. 137

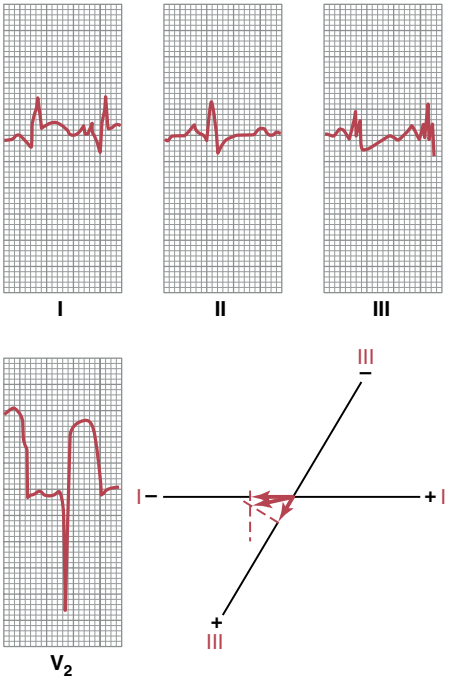
47. C) A high-voltage ECG (sum of voltages of leads I to III greater than 4 mV) is frequently observed in trained athletes driven by exercise-induced cardiac hypertrophy. Infarcts and pericardial or pleural effusion may result in lower voltage.
TMP14 pp. 150–151

48. B) The patient has a mean electrical axis of 60 degrees because of the large deflection in lead II and zero in lead aVL. The axis of aVL is –30 degrees, which is perpendicular to lead II, and this indicates that the axis must be 60 degrees.
TMP14 pp. 143–146

49. A) This patient has an acute anterior infarction in the left ventricle of the heart. This diagnosis can be determined by plotting the currents of injury from the different leads (see figure on the next page). The limb leads are used to determine whether the infarction is coming from the left or right side of the ventricle and from the

base or inferior part of the ventricle. The chest leads are used to determine whether it is an anterior or posterior infarct. When we analyze the currents of injury, a negative potential, caused by the current of injury, occurs in lead I and a positive potential, caused by the current of injury, occurs in lead III. This is determined by subtracting the J point from the TP segment. The negative end of the resultant vector originates in the ischemic area, which is therefore the left side of the heart. In lead V_2, the chest lead, the electrode is in a field of very negative potential, which occurs in patients with an anterior lesion.

TMP14 pp. 154–155



50. D) The QRS wave plotted on lead I was –1.2 millivolts, and lead II was +1.2 millivolts, so the absolute value of the deflections was the same. Therefore, the mean electrical axis must be exactly halfway in between these two leads, which is halfway between the lead II axis of 60 degrees and the lead I negative axis of 180 degrees, which provides a value of 120 degrees.

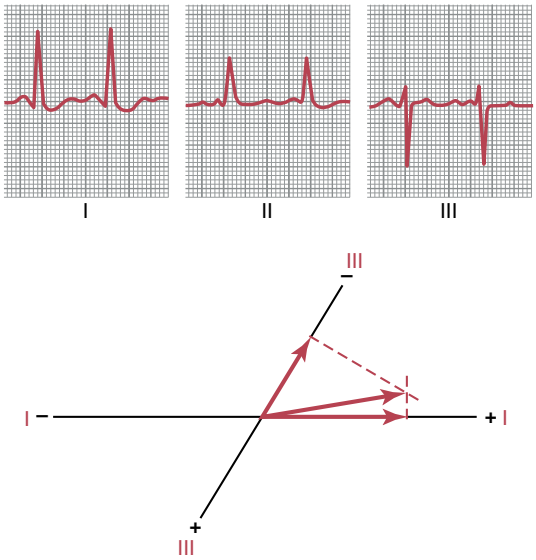
TMP14 pp. 143–146

51. E) During the T-P interval in a patient with a damaged ventricle, the only area depolarized is the damaged muscle. Therefore, the remainder of the ventricle is repolarized. At the J point, the entire ventricle is depolarized in a patient with a damaged cardiac muscle or in a patient with a normal cardiac muscle. The area of the heart that is damaged will not repolarize but remains depolarized at all times.

TMP14 pp. 152–154

52. A) Note in the figure in the next column that the QRS complex has a positive deflection in lead I and a negative in lead III, which indicates that there is a leftward axis deviation, which occurs during chronic systemic hypertension. Pulmonary hypertension increases the ventricular mass on the right side of the heart, which gives a right axis deviation.

TMP14 p. 149



53. A) Because the deflection in this ECG is 0 in lead I, the axis has to be 90 degrees away from this lead. Therefore, the mean electrical axis must be +90 degrees or –90 degrees. Because the aVF lead has a positive deflection, the mean electrical axis must be at +90 degrees.

TMP14 pp. 143–146

54. B) The ECG from this patient has a positive deflection in aVF and a negative deflection in standard limb lead I. Therefore, the mean electrical axis is between 90 degrees and 180 degrees, which is a rightward shift in the ECG mean electrical axis. Systemic hypertension, aortic valve stenosis, and aortic valve regurgitation cause hypertrophy of the left ventricle and thus a leftward shift in the mean electrical axis. Pulmonary hypertension causes a rightward shift in the axis and is therefore characterized by this ECG.

TMP14 pp. 149–150

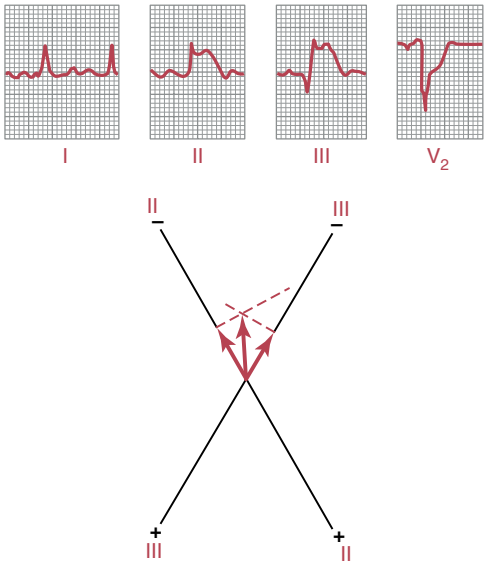
55. D) A QRS axis of 120 degrees indicates a rightward shift. Because the QRS complex is 0.18 second, this indicates a conduction block. Therefore, the diagnosis that fits with these characteristics is a right bundle branch block.

TMP14 pp. 149–150

56. D) In the figure on the next page, the current of injury is plotted at the bottom of the graph. This is not a plot of the QRS voltages but the current of injury voltages. They are plotted for leads II and III, which are both negative, and the resultant vector is nearly vertical. The negative end of the vector points to where the current of injury originated, which is in the apex of the ventricle. The

elevation of the TP segment above the J point indicates a posterior lesion. Therefore, the ECG is consistent with acute posterior infarction in the apex of the ventricle.

TMP14 pp. 152–155



57. E) This patient has a difference in the atrial rate of 100 and in the ventricular rate of 25. The 25 rate in the ventricles is indicative of a rhythm starting in the Purkinje fibers. A-V block is occurring, but it comes and goes, which is only fulfilled by Stokes-Adams syndrome.

TMP14 pp. 158–160

58. C) A person with atrial fibrillation has a rapid, irregular heart rate. The P waves are missing or are very weak. The atria exhibit circus movements, and atrial volume is often increased, causing the atrial fibrillation.

TMP14 pp. 166–167

59. A) Circus movements occur in ventricular muscle, particularly in persons with a dilated heart or decreases in conduction velocity. High extracellular potassium and sympathetic stimulation, not parasympathetic stimulation, increase the tendency for circus movements. A longer refractory period tends to prevent circus movements of the heart because when the impulses travel around the heart and contact the area of ventricular muscle that has a longer refractory period, the action potential stops at this point.

TMP14 pp. 163–165

60. D) When a patient has no P waves and a low heart rate, it is likely that the impulse leaving the sinus node is totally blocked before entering the atrial muscle, which is called sinoatrial block. The ventricles pick up the new rhythm, usually initiated in the A-V node at this point, which results in a heart rate of 40 to 60/min. In contrast, during sinus bradycardia, P waves are still associated with each QRS complex. In first-, second-, and third-degree heart block, P waves are present in each of these instances, although some are not associated with QRS complex.

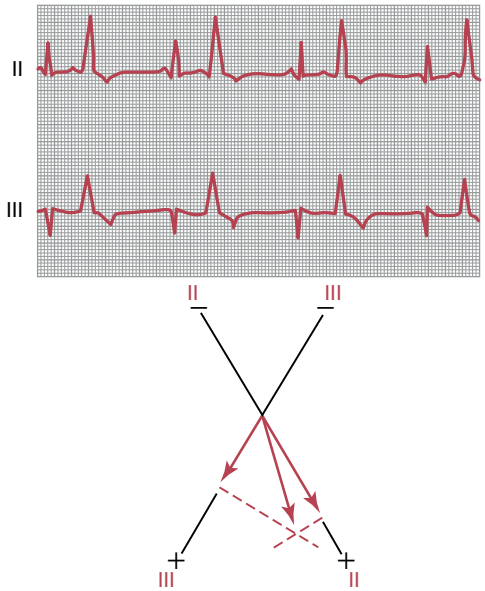
TMP14 p. 158

61. B) By definition, first-degree A-V heart block occurs when the P-R interval exceeds a value of 0.20 second but without any dropped QRS waves. This ECG shows first-degree block. In this figure, the P-R interval is about 0.30 second, which is considerably prolonged. However, there are no dropped QRS waves. During second-degree A-V block, QRS waves are dropped.

TMP14 pp. 158–159

62. E) In the figure below, note that the premature ventricular contractions (PVCs) have a wide and tall QRS wave in the ECG. The mean electrical axis of the premature contraction can be determined by plotting these large QRS complexes on the standard limb leads. The PVC originates at the negative end of the resultant mean electrical axis, which is at the base of the ventricle. Notice that the QRS of the PVC is wider and much taller than the normal QRS waves in this ECG.

TMP14 p. 161



63. B) This patient has atrial flutter, which is characterized by several P waves for each QRS complex. This ECG has two P waves for every QRS. Notice the rapid heart rate, which is characteristic of atrial flutter.

TMP14 p. 167

64. E) The average ventricular rate is 150 beats/min in this ECG, which is typical of atrial flutter. Again notice that the heart rate is irregular because of the inability of the impulses to quickly pass through the A-V node because of its refractory period.

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65. C) A decreased velocity of conduction is a major trigger for re-entry/circus movements and generation of ventricular fibrillation. The circus movements are multiple and generate in the ventricle, not from the atria, and travel to the ventricles. A shorter refractory period facilitates circus movements. Ventricular fibrillation is a medical emergency, always requires intervention, and does not reverse spontaneously.
TMP14 pp. 163–165

66. D) An inverted P wave occurs in patients with a premature contraction originating in the A-V junction. If the P wave occurs after the QRS complex, the junctional contraction started low in the A-V junction. Junctional contractions originating high in the A-V junction will have a P wave that occurs before the QRS, and likewise one originating in the middle of junction occurs during the QRS.
TMP14 pp. 160–161

67. E) The term "paroxysmal" means that the heart rate becomes rapid in paroxysms, with the paroxysm beginning suddenly and lasting for a few seconds, a few minutes, a few hours, or much longer. Then the paroxysm usually ends as suddenly as it began, and the pacemaker shifts back to the S-A node. The mechanism by which this phenomenon is believed to occur is by a re-entrant circus movement feedback pathway that sets up an area of local repeated self–re-excitation. The ECG shown is ventricular paroxysmal tachycardia. That the origin is in the ventricles can be determined because of the changes in the QRS complex, which have high voltages and look much different than the preceding normal QRS complexes. This is very characteristic of a ventricular irritable locus.
TMP14 pp. 162–163

68. C) Notice in this ECG that a P wave precedes each of the first four QRS complexes. After that we see a P wave but a dropped QRS wave, which is characteristic of second-degree A-V block.
TMP14 pp. 158–159

69. A) A person with atrial fibrillation has a rapid, irregular heart rate. The P waves are missing or are very weak. The atria exhibit circus movements and often are very enlarged, causing the atrial fibrillation.
TMP14 pp. 166–167

70. B) Ventricular fibrillation often occurs in a heart exposed to a 60-cycle alternating current. An increased conduction velocity through the heart muscle or a shortened conduction pathway around the heart decreases the probability of re-entrant pathways. A shortened ventricular refractory period increases the possibility of fibrillation. Thus, when the electrical stimulus travels around the heart and reaches the ventricular muscle that was again initially stimulated, the risk of ventricular fibrillation increases because the muscle will be out of the refractory period.
TMP14 pp. 164–165

71. C) During a Stokes-Adams syndrome attack, total A-V block suddenly begins, and the duration of the block may be a few seconds or even several weeks. The new pacemaker of the heart is distal to the point of blockade, usually in some part of the Purkinje fibers or the A-V bundle.
TMP14 pp. 159–160

72. D) One of the early ECG signs of cardiac ischemia is the development of repolarization abnormalities, reflected by changes in the T wave. These changes may occur without changes in J point-ST segments. Septum and endocardium depolarize first and repolarize last. Repolarized areas will have + charge and describe a + vector toward the apex. The first area to repolarize is toward the apex. High potassium may result in peaked T waves and a prolonged PR.
TMP14 p. 156

73. A) The relationship between the P waves and the QRS complexes appears to be normal, and there are no missing beats. Therefore, this patient has a sinus rhythm, and there is no heart block. There is also no ST-segment depression in this patient. Because we have normal P and QRS and T waves, this condition is sinus tachycardia.
TMP14 p. 157

74. A) The heartbeat immediately following a premature atrial contraction weakens because the diastolic period is very short in this condition. Therefore, the ventricular filling time is very short, and thus the stroke volume decreases. The P wave is usually visible in this arrhythmia unless it coincides with the QRS complex. The probability of these premature contractions increases in people with toxic irritation of the heart and local ischemic areas.
TMP14 p. 160

75. C) During atrial paroxysmal tachycardia, the impulse is initiated by an ectopic focus somewhere in the atria. If the point of initiation is near the A-V node, the P wave travels backward toward the S-A node and then forward into the ventricles at the same time. Therefore, the P wave will be inverted.
TMP14 pp. 160–161

76. A) This ECG has characteristics of atrial paroxysmal tachycardia, which means that the tachycardia may come and go at random times. The basic shape of the QRS complex and its magnitude are virtually unchanged from the normal QRS complexes, which eliminates the possibility of ventricular paroxysmal tachycardia. This ECG is not characteristic of atrial flutter because there is only one P wave for each QRS complex.
TMP14 162–163

77. C) In PVCs, QRS is prolonged because impulse is conducted through muscle, which has slow conduction, and QRS voltage is high because one side depolarizes ahead of the other. Consequently, the T wave is inverted because slow conduction causes the area to first depolarize to also repolarize first (opposite of normal). P waves are absent, PVCs can develop in individuals with healthy heart but also in pathological conditions, and the impulse does not travel backwards to the atria and then forward.

TMP14 p. 161

78. A) In rare instances, impulses from the S-A node are blocked. This causes cessation of P waves and a new pacemaker assuming the generation and conduction of the impulse. Usually, the next region of heart with the fastest discharge rate is the A-V node. B to C are features of A-V blocks. A full compensatory pause is a feature of PVCs.

TMP14 p. 158

79. E) The absence of P wave and fully irregular heart rate suggest atrial fibrillation and not flutter (sawtooth pattern, heart rate is not fully irregular), atrial tachycardia (P waves are present, may show altered shape, heart rate is regular), or first-degree A-V block (P waves are present, prolonged PR). The left axis deviation and QRS within normal limits (upper limit) suggest left ventricular hypertrophy, in the context of a "history of hypertension." There is no left or right bundle branch block because the QRS is normal in duration.

TMP14 pp. 166–167

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UNIT IV

The Circulation

1. Listed below are the hydrostatic and oncotic pressures within a microcirculatory bed.

   Plasma colloid osmotic pressure = 25 mm Hg
   Capillary hydrostatic pressure = 25 mm Hg
   Venous hydrostatic pressure = 5 mm Hg
   Arterial pressure = 80 mm Hg
   Interstitial fluid hydrostatic pressure = −5 mm Hg
   Interstitial colloid osmotic pressure = 10 mm Hg
   Capillary filtration rate = 150 ml/min

What is the capillary filtration coefficient (in ml/min/mm Hg) for this capillary wall?

A) 5
B) 10
C) 15
D) 20
E) 25

2. A healthy 60-year-old woman with a 10-year history of hypertension stands up from a supine position. Which set of cardiovascular changes is most likely to occur in response to standing up from a supine position?

	Sympathetic Nerve Activity	Cardiac Contractility	Heart Rate
A)	↑	↑	↑
B)	↑	↑	↓
C)	↑	↓	↓
D)	↑	↓	↑
E)	↓	↓	↓
F)	↓	↓	↑
G)	↓	↑	↑
H)	↓	↑	↓

3. In an experimental study, administration of a drug decreases the diameter of arterioles in the muscle bed of an animal subject. Which set of physiological changes would be expected to occur in response to the decrease in diameter?

	Vascular Conductance	Capillary Filtration	Blood Flow
A)	↑	↑	↑
B)	↑	↓	↑
C)	↑	↓	↓
D)	↑	↑	↓
E)	↓	↓	↓
F)	↓	↑	↓
G)	↓	↑	↑
H)	↓	↓	↑

4. A 60-year-old woman has experienced dizziness for the past 6 months when getting out of bed in the morning and when standing up. Her mean arterial pressure is 130/90 mm Hg while lying down and 95/60 while sitting. Which set of physiological changes would be expected in response to moving from a supine to an upright position?

	Parasympathetic Nerve Activity	Plasma Renin Activity	Sympathetic Activity
A)	↑	↑	↑
B)	↑	↓	↑
C)	↑	↓	↓
D)	↑	↑	↓
E)	↓	↓	↓
F)	↓	↑	↓
G)	↓	↑	↑
H)	↓	↓	↑

5. A 35-year-old woman visits her family practitioner for an examination. She has a blood pressure of 160/75 mm Hg and a heart rate of 74 beats/min. Further tests by a cardiologist reveal that the patient has moderate aortic regurgitation. Which set of changes would be expected in this patient?

	Pulse Pressure	Systolic Pressure	Stroke Volume
A)	↑	↑	↑
B)	↑	↓	↑
C)	↑	↓	↓
D)	↑	↑	↓
E)	↓	↓	↓
F)	↓	↑	↓
G)	↓	↑	↑
H)	↓	↓	↑

6. A healthy 27-year-old female medical student runs a 5K race. Which set of physiological changes is most likely to occur in this woman's skeletal muscles during the race?

	Arteriole Resistance	Tissue pH	Tissue Carbon Dioxide Concentration
A)	↑	↑	↑
B)	↑	↑	↓
C)	↑	↓	↓
D)	↑	↓	↑
E)	↓	↓	↓
F)	↓	↓	↑
G)	↓	↑	↑
H)	↓	↑	↓

7. Cognitive stimuli such as reading, problem solving, and talking all result in significant increases in cerebral blood flow. Which set of changes in cerebral tissue concentrations is the most likely explanation for the increase in cerebral blood flow?

	Carbon Dioxide	pH	Adenosine
A)	↑	↑	↑
B)	↑	↓	↑
C)	↑	↓	↓
D)	↑	↑	↓
E)	↓	↓	↓
F)	↓	↑	↓
G)	↓	↑	↑
H)	↓	↓	↑

8. Histamine is infused into the brachial artery. Which set of microcirculatory changes would be expected in the infused arm?

	Capillary Water Permeability	Capillary Hydrostatic Pressure	Interstitial Hydrostatic Pressure
A)	↑	↑	↑
B)	↑	↑	↓
C)	↑	↓	↓
D)	↑	↓	↑
E)	↓	↓	↓
F)	↓	↓	↑
G)	↓	↑	↑
H)	↓	↑	↓

9. An increase in shear stress in a blood vessel results in which change?
   A) Decreased endothelin production
   B) Decreased cyclic guanosine monophosphate production
   C) Increased nitric oxide release
   D) Increased renin production
   E) Decreased prostacyclin production

10. A 65-year-old man with a 10-year history of essential hypertension is being treated with an angiotensin-converting enzyme (ACE) inhibitor. Which set of changes would be expected to occur in response to the ACE inhibitor drug therapy?

	Plasma Renin Concentration	Total Peripheral Resistance	Blood Pressure
A)	↑	↑	↑
B)	↑	↑	↓
C)	↑	↓	↓
D)	↑	↓	↑
E)	↓	↓	↓
F)	↓	↓	↑
G)	↓	↑	↑
H)	↓	↑	↓

11. The diameter of a precapillary arteriole is decreased in a muscle vascular bed. An increase in which of the following would be expected?
   A) Capillary filtration rate
   B) Vascular conductance
   C) Capillary blood flow
   D) Capillary hydrostatic pressure
   E) Arteriolar resistance

12. A 55-year-old man with a history of normal health visits his physician for a checkup. The physical examination reveals that his blood pressure is 170/98 mm Hg. Further tests indicate that he has renovascular hypertension as a result of stenosis in the left kidney. Which set of findings would be expected in this man with renovascular hypertension?

	Total Peripheral Resistance	Plasma Renin Activity	Plasma Aldosterone Concentration
A)	↑	↑	↑
B)	↑	↓	↑
C)	↑	↓	↓
D)	↑	↑	↓
E)	↓	↓	↓
F)	↓	↑	↓
G)	↓	↑	↑
H)	↓	↓	↑

13. Under control conditions, flow through a blood vessel is 100 ml/min with a pressure gradient of 50 mm Hg. What would be the approximate flow through the vessel after increasing the vessel diameter by 100%, assuming that the pressure gradient is maintained at 50 mm Hg?

A) 200 ml/min
B) 400 ml/min
C) 800 ml/min
D) 1600 ml/min
E) 700 ml/min

14. A 24-year-old woman delivers a 6-lb, 8-oz baby girl. The newborn is diagnosed as having patent ductus arteriosus. Which set of changes would be expected in this baby?

	Pulse Pressure	Stroke Volume	Systolic Pressure
A)	↑	↑	↑
B)	↑	↓	↑
C)	↑	↓	↓
D)	↑	↑	↓
E)	↓	↓	↓
F)	↓	↑	↓
G)	↓	↑	↑
H)	↓	↓	↑

15. A 72-year-old man had surgery to remove an abdominal tumor. Pathohistological studies revealed that the tumor mass contained a large number of vessels. The most likely stimulus for the growth of vessels in a solid tumor is a decrease in which of the following?

A) Growth hormone
B) Plasma glucose concentration
C) Angiostatin growth factor
D) Vascular endothelial growth factor
E) Tissue oxygen concentration

16. Which set of changes would be expected to cause the greatest increase in the net movement of sodium across a muscle capillary wall?

	Wall Permeability to Sodium	Wall Surface Area	Concentration Difference Across Wall
A)	↑	↑	↑
B)	↑	↑	↓
C)	↑	↓	↓
D)	↑	↓	↑
E)	↓	↓	↓
F)	↓	↓	↑
G)	↓	↑	↑
H)	↓	↑	↓

17. While participating in a cardiovascular physiology laboratory, a medical student isolates an animal's carotid artery proximal to the carotid bifurcation and partially constricts the artery with a tie around the vessel. Which set of changes would be expected to occur in response to constriction of the carotid artery?

	Heart Rate	Parasympathetic Nerve Activity	Total Peripheral Resistance
A)	↑	↑	↑
B)	↑	↑	↓
C)	↑	↓	↓
D)	↑	↓	↑
E)	↓	↓	↓
F)	↓	↓	↑
G)	↓	↑	↑
H)	↓	↑	↓

18. A 35-year-old woman visits her family practice physician for an examination. She has a mean arterial blood pressure of 105 mm Hg and a heart rate of 74 beats/min. Further tests by a cardiologist reveal that the patient has moderate aortic valve stenosis. Which set of changes would be expected in this patient?

	Pulse Pressure	Stroke Volume	Systolic Pressure
A)	↑	↑	↑
B)	↑	↓	↑
C)	↑	↓	↓
D)	↑	↑	↓
E)	↓	↓	↓
F)	↓	↑	↓
G)	↓	↑	↑
H)	↓	↓	↑

19. A 60-year-old man visits his family practitioner for an annual examination. He has a mean blood pressure of 130 mm Hg and a heart rate of 78 beats/min. His plasma cholesterol level is in the upper 25th percentile, and he is diagnosed as having atherosclerosis. Which set of changes would be expected in this patient?

	Pulse Pressure	Arterial Compliance	Systolic Pressure
A)	↑	↑	↑
B)	↑	↓	↑
C)	↑	↓	↓
D)	↑	↑	↓
E)	↓	↓	↓
F)	↓	↑	↓
G)	↓	↑	↑
H)	↓	↓	↑

20. While participating in a cardiovascular physiology laboratory, a medical student isolates the carotid artery of an animal and partially constricts the artery with a tie around the vessel. Which set of changes would be expected to occur in response to constriction of the carotid artery?

	Sympathetic Nerve Activity	Renal Blood Flow	Total Peripheral Resistance
A)	↑	↑	↑
B)	↑	↓	↑
C)	↑	↓	↓
D)	↑	↑	↓
E)	↓	↓	↓
F)	↓	↑	↓
G)	↓	↑	↑
H)	↓	↓	↑

21. Which one of the following would tend to increase capillary filtration rate?
    A) Decreased capillary hydrostatic pressure
    B) Decreased plasma colloid osmotic pressure
    C) Decreased interstitial colloid osmotic pressure
    D) Decreased capillary water permeability
    E) Increased arteriolar resistance

22. A 72-year-old man had surgery to remove an abdominal tumor. Findings of pathohistological studies reveal that the tumor mass contains a large number of blood vessels. The most likely stimulus for the growth of vessels in a solid tumor is an increase in which of the following?
    A) Growth hormone
    B) Plasma glucose concentration
    C) Angiostatin growth factor
    D) Tissue oxygen concentration
    E) Vascular endothelial growth factor (VEGF)

23. The diameter of a precapillary arteriole is decreased in a muscle vascular bed. Which change in the microcirculation would be expected?
    A) Decreased capillary filtration rate
    B) Increased interstitial volume
    C) Increased lymph flow
    D) Increased capillary hydrostatic pressure
    E) Decreased arteriolar resistance

24. A 50-year-old man has a 3-year history of hypertension. He reports fatigue and occasional muscle cramps. There is no family history of hypertension. The patient has not had any other significant medical problems in the past. Examination reveals a blood pressure of 168/104 mm Hg. Additional laboratory tests indicate that the patient has primary hyperaldosteronism. Which set of findings would be expected in this man with primary hyperaldosteronism hypertension?

	Extracellular Fluid Volume	Plasma Renin Activity	Plasma Potassium Concentration
A)	↑	↑	↑
B)	↑	↓	↑
C)	↑	↓	↓
D)	↑	↑	↓
E)	↓	↓	↓
F)	↓	↑	↓
G)	↓	↑	↑
H)	↓	↓	↑

25. A decrease in which of the following would tend to increase lymph flow?
    A) Hydraulic conductivity of the capillary wall
    B) Plasma colloid osmotic pressure
    C) Capillary hydrostatic pressure
    D) Vascular conductance
    E) B and D

26. In control conditions, flow through a blood vessel is 100 ml/min under a pressure gradient of 50 mm Hg. What would be the approximate flow through the vessel after increasing the vessel diameter to four times normal, assuming that the pressure gradient was maintained at 50 mm Hg?
    A) 300 ml/min
    B) 1600 ml/min
    C) 1000 ml/min
    D) 16,000 ml/min
    E) 25,600 ml/min

27. A 50-year-old woman has a renal plasma flow of 600 ml/min and hematocrit of 50. Her arterial pressure is 125 mm Hg and renal venous pressure is 5 mm Hg. What is the total renal vascular resistance (in mm Hg/ml/min) in this woman?

A) 0.05
B) 0.10
C) 0.50
D) 1.00
E) 1.50

28. An increase in which of the following would be expected to decrease blood flow in a vessel?

A) Pressure gradient across the vessel
B) Radius of the vessel
C) Plasma colloid osmotic pressure
D) Viscosity of the blood
E) Plasma sodium concentration

29. Assuming that vessels A to D are the same length, which one has the greatest flow?

	Pressure Gradient	Radius	Viscosity
A)	100	1	10
B)	50	2	5
C)	25	4	2
D)	10	6	1

30. A 22-year-old man enters the hospital emergency department after severing a major artery in a motorcycle accident. It is estimated that he has lost approximately 700 ml of blood. His blood pressure is 90/55 mm Hg. Which set of changes would be expected in response to hemorrhage in this man?

	Heart Rate	Parasympathetic Nerve Activity	Plasma Renin Activity
A)	↑	↑	↑
B)	↑	↓	↑
C)	↑	↓	↓
D)	↑	↑	↓
E)	↓	↓	↓
F)	↓	↑	↓
G)	↓	↑	↑
H)	↓	↓	↑

31. A healthy 28-year-old woman stands up from a supine position. Moving from a supine to a standing position results in a transient decrease in arterial pressure that is detected by arterial baroreceptors located in the aortic arch and carotid sinuses. Which set of cardiovascular changes is most likely to occur in response to activation of the baroreceptors?

	Mean Circulatory Filling Pressure	Strength of Cardiac Contraction	Sympathetic Nerve Activity
A)	↑	↑	↑
B)	↑	↓	↑
C)	↑	↓	↓
D)	↑	↑	↓
E)	↓	↓	↓
F)	↓	↑	↓
G)	↓	↑	↑
H)	↓	↓	↑

32. An ACE inhibitor is administered to a 65-year-old man with a 20-year history of hypertension. The drug lowered his arterial pressure and increased his plasma levels of renin. Which mechanism would best explain the decrease in arterial pressure?

A) Inhibition of angiotensin I
B) Decreased conversion of angiotensinogen to angiotensin I
C) Decreased plasma levels of bradykinin
D) Decreased plasma levels of prostacyclin
E) Decreased formation of angiotensin II

33. A 25-year-old man enters the hospital emergency department after severing a major artery during a farm accident. It is estimated that the patient has lost approximately 800 ml of blood. His mean blood pressure is 65 mm Hg, and his heart rate is elevated as a result of activation of the chemoreceptor reflex. Which set of changes in plasma concentration would be expected to cause the greatest activation of the chemoreceptor reflex?

	Oxygen	Carbon Dioxide	Hydrogen
A)	↑	↑	↑
B)	↑	↓	↑
C)	↑	↓	↓
D)	↑	↑	↓
E)	↓	↓	↓
F)	↓	↑	↓
G)	↓	↑	↑
H)	↓	↓	↑

34. Under normal physiological conditions, blood flow to the skeletal muscles is determined mainly by which of the following?
    A) Sympathetic nerves
    B) Angiotensin II
    C) Vasopressin
    D) Local metabolic factors
    E) Capillary osmotic pressure

35. A healthy 22-year-old female medical student has an exercise stress test at a local health club. An increase in which of the following is most likely to occur in this woman's skeletal muscles during exercise?
    A) Vascular conductance
    B) Blood flow
    C) Carbon dioxide concentration
    D) Arteriolar diameter
    E) All the above

36. Which of the following segments of the circulatory system has the lowest velocity of blood flow?
    A) Aorta
    B) Arteries
    C) Capillaries
    D) Veins

37. Listed below are the hydrostatic and oncotic pressures within a microcirculatory bed.

    Plasma colloid osmotic pressure = 25 mm Hg
    Capillary hydrostatic pressure = 25 mm Hg
    Venous hydrostatic pressure = 5 mm Hg
    Arterial pressure = 80 mm Hg
    Interstitial hydrostatic pressure = −5 mm Hg
    Interstitial colloid osmotic pressure = 5 mm Hg
    Filtration coefficient = 15 ml/min/mm Hg

    What is the filtration rate (ml/min) of the capillary wall?
    A) 100
    B) 150
    C) 200
    D) 250
    E) 300

38. Which blood vessel has the highest vascular resistance?

	Blood Flow (ml/min)	Pressure Gradient (mm Hg)
A)	1000	100
B)	1200	60
C)	1400	20
D)	1600	80
E)	1800	40

39. A 2-fold increase in which of the following would result in the greatest increase in the transport of oxygen across the capillary wall?
    A) Capillary hydrostatic pressure
    B) Intercellular clefts in the capillary wall
    C) Oxygen concentration gradient
    D) Plasma colloid osmotic pressure
    E) Capillary wall hydraulic permeability

40. A balloon catheter is advanced from the superior vena cava into the heart and inflated to increase atrial pressure by 5 mm Hg. Which of the following would be expected to occur in response to the elevated atrial pressure?
    A) Decreased atrial natriuretic peptide
    B) Increased angiotensin II
    C) Increased aldosterone
    D) Decreased renal sympathetic nerve activity

41. Which of the following vessels has the greatest total cross-sectional area in the circulatory system?
    A) Aorta
    B) Small arteries
    C) Capillaries
    D) Venules
    E) Vena cava

42. An increase in atrial pressure results in which of the following?
    A) Increased plasma atrial natriuretic peptide
    B) Increase in plasma angiotensin II concentration
    C) Decrease in plasma aldosterone concentration
    D) Decrease in sodium excretion
    E) A and C

43. Autoregulation of tissue blood flow in response to an increase in arterial pressure occurs as a result of which of the following?
    A) Decrease in vascular resistance
    B) Initial decrease in vascular wall tension
    C) Excess delivery of nutrients such as oxygen to the tissues
    D) Decrease in tissue metabolism

44. Which component of the circulatory system contains the largest percentage of the total blood volume?
    A) Arteries
    B) Capillaries
    C) Veins
    D) Pulmonary circulation
    E) Heart

45. Which set of changes would be expected to occur 2 weeks after a 50% reduction in renal artery pressure?

	Plasma Renin	Plasma Aldosterone Concentration	Glomerular Filtration Rate
A)	↑	↑	↑
B)	↑	↑	↓
C)	↑	↓	↓
D)	↑	↓	↑
E)	↓	↓	↓
F)	↓	↓	↑
G)	↓	↑	↑
H)	↓	↑	↓

46. An increase in which of the following tends to decrease capillary filtration rate?
    A) Capillary hydrostatic pressure
    B) Plasma colloid osmotic pressure
    C) Interstitial colloid osmotic pressure
    D) Venous hydrostatic pressure
    E) Arteriolar diameter

47. A decrease in which of the following would be expected to occur in a person 2 weeks after an increase in sodium intake?
    A) Angiotensin II
    B) Sodium Excretion
    C) Aldosterone
    D) Atrial natriuretic peptide
    E) A and C

48. Which of the following would tend to increase lymph flow?
    A) Increase capillary hydrostatic pressure
    B) Increased plasma colloid osmotic pressure
    C) Increased interstitial volume
    D) Decreased arteriolar diameter
    E) A and C

49. An increase in the production of which of the following would most likely result in chronic hypertension?
    A) Aldosterone
    B) Prostacyclin
    C) Angiotensin II
    D) Nitric oxide
    E) A and C

50. Which of the following capillaries has the highest capillary permeability to plasma albumin?
    A) Glomerular
    B) Liver
    C) Muscle
    D) Intestinal
    E) Brain

51. Which of the following would be expected to occur during a Cushing reaction caused by brain ischemia?
    A) Increase in parasympathetic activity
    B) Decrease in arterial pressure
    C) Decrease in heart rate
    D) Increase in sympathetic activity

52. Which of the following tends to increase the net movement of glucose across a capillary wall?
    A) Increase in plasma sodium concentration
    B) Increase in the concentration difference of glucose across the wall
    C) Decrease in wall permeability to glucose
    D) Decrease in wall surface area without an increase in the number of pores
    E) Decrease in plasma potassium concentration

53. A 65-year-old man has congestive heart failure. He has a cardiac output of 4 l/min, arterial pressure of 115/85 mm Hg, and heart rate of 90 beats/min. Further tests by a cardiologist reveal that the patient has a right atrial pressure of 10 mm Hg. An increase in which of the following would be expected in this patient?
    A) Plasma colloid osmotic pressure
    B) Interstitial colloid osmotic pressure
    C) Arterial pressure
    D) Cardiac output
    E) Vena cava hydrostatic pressure

54. Which set of changes would be expected to occur in response to a direct increase in renal arterial pressure in kidneys without an intact tubuloglomerular feedback system?

	Glomerular Filtration	Sodium Excretion	Water Excretion Rate
A)	↑	↑	↑
B)	↑	↑	↓
C)	↑	↓	↓
D)	↑	↓	↑
E)	↓	↓	↓
F)	↓	↓	↑
G)	↓	↑	↑
H)	↓	↑	↓

55. Which part of the circulation has the highest compliance?
    A) Capillaries
    B) Large arteries
    C) Veins
    D) Aorta
    E) Small arteries

56. An increase in which of the following tends to increase pulse pressure?
    A) Systolic pressure
    B) Capillary hydrostatic pressure
    C) Arterial compliance
    D) Stroke volume
    E) A and D

57. Which set of physiological changes would be expected to occur in a person who stands up from a supine position?

	Venous Hydrostatic Pressure in Legs	Heart Rate	Renal Blood Flow
A)	↑	↑	↑
B)	↑	↑	↓
C)	↑	↓	↓
D)	↓	↓	↓
E)	↓	↓	↑
F)	↓	↑	↑

58. Which one of the following compensatory physiological changes would be expected to occur in a person who stands up from a supine position?
    A) Increased parasympathetic nerve activity
    B) Increased sympathetic nerve activity
    C) Decreased heart rate
    D) Decreased heart contractiltiy

59. Blood flow to a tissue remains relatively constant despite a reduction in arterial pressure (autoregulation). Which of the following would be expected to occur in response to the increases in arterial pressure?
    A) Increased conductance
    B) Increased tissue oxygen concentration
    C) Decreased vascular resistance
    D) Increased arteriolar diameter

60. Which of the following would have the slowest rate of net movement across the capillary wall?
    A) Sodium
    B) Albumin
    C) Glucose
    D) Oxygen

61. An increase in which of the following tends to increase capillary filtration rate?
    A) Capillary wall hydraulic conductivity
    B) Arteriolar resistance
    C) Plasma colloid osmotic pressure
    D) Interstitial hydrostatic pressure
    E) Plasma sodium concentration

62. The tendency for turbulent flow is greatest in which of the following?
    A) Arterioles
    B) Capillaries
    C) Small arterioles
    D) Aorta

63. A 60-year-old man has a mean arterial blood pressure of 130 mm Hg, a heart rate of 78 beats/min, a right atrial pressure of 0 mm Hg, and a cardiac output of 3.5 L/min. He also has a pulse pressure of 35 mm Hg and a hematocrit of 40. What is the approximate total peripheral vascular resistance in this man?
    A) 17 mm Hg/l/min
    B) 1.3 mm Hg/l/min
    C) 13 mm Hg/l/min
    D) 27 mm Hg/l/min
    E) 37 mm Hg/l/min

64. Which pressure is normally negative in a muscle capillary bed in the lower extremities?
    A) Plasma colloid osmotic pressure
    B) Capillary hydrostatic pressure
    C) Interstitial hydrostatic pressure
    D) Interstitial colloid osmotic pressure
    E) Venous hydrostatic pressure

65. What would tend to increase a person's pulse pressure?
    A) Decreased stroke volume
    B) Increased arterial compliance
    C) Hemorrhage
    D) Patent ductus
    E) Decreased venous return

66. Movement of solutes such as Na^+ across the capillary walls occurs primarily by which process?
    A) Filtration
    B) Active transport
    C) Vesicular transport
    D) Diffusion

67. What would increase venous hydrostatic pressure in the legs?
    A) Decrease in right atrial pressure
    B) Pregnancy
    C) Decreased movement of leg muscles
    D) Abdominal compression of vena cava by a solid tumor in the abdomen
    E) B and D

68. A nitric oxide donor is infused into the brachial artery of a 22-year-old man. Which set of microcirculatory changes would be expected in the infused arm?

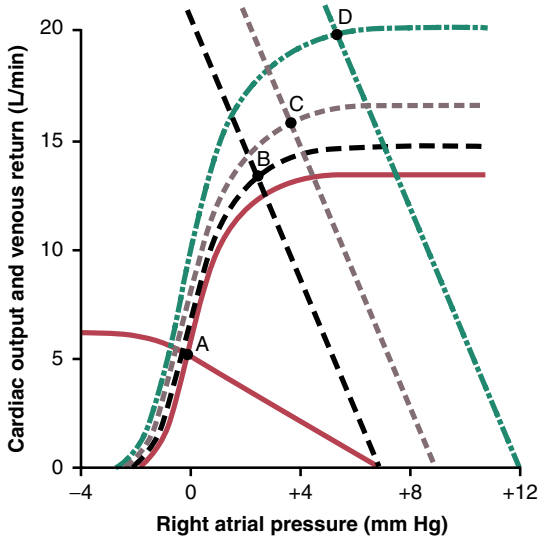
	Capillary Hydrostatic Pressure	Interstitial Hydrostatic Pressure	Lymph Flow
A)	↑	↑	↑
B)	↑	↑	↓
C)	↑	↓	↓
D)	↑	↓	↑
E)	↓	↓	↓
F)	↓	↓	↑
G)	↓	↑	↑
H)	↓	↑	↓

69. What often occurs in decompensated heart failure?
    A) Increased renal loss of sodium and water
    B) Decreased mean systemic filling pressure
    C) Increased norepinephrine in cardiac sympathetic nerves
    D) Orthopnea
    E) Weight loss

70. Which condition often occurs in progressive hemorrhagic shock?
    A) Vasomotor center failure
    B) Increased urine output
    C) Tissue alkalosis
    D) Decreased capillary permeability
    E) Increased mean systemic filling pressure

71. A 50-year-old woman received an overdose of furosemide, and her arterial pressure decreased to 70/40. Her heart rate is 120, and her respiratory rate is 30/min. What therapy would you recommend?
    A) Whole blood infusion
    B) Plasma infusion
    C) Infusion of a balanced electrolyte solution
    D) Infusion of a sympathomimetic drug
    E) Administration of a glucocorticoid

72. A 30-year-old woman comes to a local emergency department with severe vomiting. She has pale skin, tachycardia, an arterial pressure of 70/45, and trouble walking. What therapy do you recommend to prevent shock?
    A) Infusion of packed red blood cells
    B) Administration of an antihistamine
    C) Infusion of a balanced electrolyte solution
    D) Infusion of a sympathomimetic drug
    E) Administration of a glucocorticoid



Modified from Guyton AC, Jones CE, Coleman TB: Circulatory Physiology: Cardiac Output and Its Regulation, 2nd ed. Philadelphia: WB Saunders, 1973.

73. In the above figure, for the cardiac output and venous return curves defined by the solid red lines (with the equilibrium at A), which of the following options is true?
    A) Mean systemic filling pressure is 12 mm Hg
    B) Right atrial pressure is 2 mm Hg
    C) Resistance to venous return is 1.4 mm Hg/l/min
    D) Pulmonary arterial flow is approximately 7 l/min
    E) Resistance to venous return is 0.71 mm Hg/l/min

74. A 30-year-old man is resting, and his sympathetic output increases to maximal values. Which set of changes would be expected in response to this increased sympathetic output?

	Resistance to Venous Return	Mean Systemic Filling Pressure	Venous Return
A)	↑	↑	↑
B)	↑	↓	↑
C)	↑	↓	↓
D)	↑	↑	↓
E)	↓	↓	↓
F)	↓	↑	↓
G)	↓	↑	↑
H)	↓	↓	↑

75. If a patient has an oxygen consumption of 240 ml/min, a pulmonary vein oxygen concentration of 180 ml/l of blood, and a pulmonary artery oxygen concentration of 160 ml/l of blood units, what is the cardiac output in l/min?
    A) 8
    B) 10
    C) 12
    D) 16
    E) 20

76. What normally causes the cardiac output curve to shift to the right along the right atrial pressure axis?
    A) Changing intrapleural pressure to –1 mm Hg
    B) Increasing mean systemic filling pressure
    C) Taking a patient off a mechanical ventilator and allowing normal respiration
    D) Decreasing intrapleural pressure to –7 mm Hg
    E) Breathing against a negative pressure

77. What normally causes the cardiac output curve to shift to the left along the right atrial pressure axis?
    A) Surgically opening the chest
    B) Severe cardiac tamponade
    C) Breathing against a negative pressure
    D) Playing a trumpet
    E) Positive-pressure breathing

78. What will elevate the plateau of the cardiac output curve?
    A) Surgically opening the thoracic cage
    B) Connecting a patient to a mechanical ventilator
    C) Cardiac tamponade
    D) Increasing parasympathetic stimulation of the heart
    E) Increasing sympathetic stimulation of the heart

79. What is normally associated with an increased cardiac output?
    A) Increased parasympathetic stimulation
    B) Atrioventricular (A-V) fistula
    C) Decreased blood volume
    D) Polycythemia
    E) Severe aortic regurgitation

80. Which condition would be expected to decrease mean systemic filling pressure?
    A) Norepinephrine administration
    B) Increased blood volume
    C) Increased sympathetic stimulation
    D) Increased venous compliance
    E) Skeletal muscle contraction

81. A 35-year-old man undergoes several cardiac test during exercise. The following measurements are made:

Right atrial pressure	= +2 mm Hg
Left atrial pressure	= +7 mm Hg
Left ventricular end diastolic pressure	= +10 mm Hg
Mean systemic filling pressure	= +12 mm Hg
Cardiac output	= 10 l/min

    What is the resistance to venous return (mm Hg/l/min) in this individual?
    A) 0.1
    B) 0 .5
    C) 1.0
    D) 1.4
    E) 2.0

82. In which condition would you expect a decreased resistance to venous return?
    A) Anemia
    B) Increased venous resistance
    C) Increased arteriolar resistance
    D) Increased sympathetic output
    E) Obstruction of veins

83. Which of the following would decrease cardiac output?
    A) Increased stroke volume
    B) Increased heart rate
    C) Increased mean systemic filling pressure
    D) Increased resistance to venous return
    E) Increased venous return

84. In which condition would you normally expect to find a decreased cardiac output?
    A) Hyperthyroidism
    B) Beriberi
    C) A-V fistula
    D) Increased muscle mass
    E) Hypothyroidism

85. Which of the following sets of changes would tend to increase coronary blood flow?

	Coronary Arteriole Resistance	Cardiac Adenosine Concentration	Coronary Vascular Conductance	Cardiac Workload
A)	↑	↑	↑	↓
B)	↑	↓	↑	↓
C)	↑	↓	↓	↓
D)	↑	↑	↓	↓
E)	↓	↓	↓	↑
F)	↓	↑	↓	↑
G)	↓	↑	↑	↑
H)	↓	↓	↑	↑

86. What will usually increase the plateau level of the cardiac output curve?
    A) Myocarditis
    B) Severe cardiac tamponade
    C) Decreased parasympathetic stimulation of the heart
    D) Myocardial infarction
    E) Mitral stenosis

87. If a person has been exercising for 1 hour, which organ will have the smallest decrease in blood flow?
    A) Brain
    B) Intestines
    C) Kidneys
    D) Nonexercising skeletal muscle
    E) Pancreas

88. A 35-year-old man has been diagnosed with a vitamin B1 deficiency. Oxygen consumption in this man is 400 ml/min. In addition, pulmonary vein oxygen concentration is 200 ml/l of blood, and pulmonary artery oxygen concentration is 150 ml/l of blood. What is the cardiac output (l/min) in this man?
    A) 4.0
    B) 5.0

C) 6.0
D) 7.0
E) 8.0

89. Which vasoactive agent is usually the most important controller of coronary blood flow?

A) Adenosine
B) Bradykinin
C) Prostaglandins
D) Carbon dioxide
E) Potassium ions

90. What will elevate the plateau of the cardiac output curve?

A) Surgically opening the thoracic cage
B) Connecting a patient to a mechanical ventilator
C) Cardiac tamponade
D) Increasing parasympathetic stimulation of the heart
E) Increasing sympathetic stimulation of the heart

91. The most likely cause of cardiac pain in acute ischemic coronary disease is an increase in the extracellular concentration of the following:

A) Adenosine
B) Potassium
C) Nitric oxide
D) ATP
E) Lactic acid

92. Which condition normally causes arteriolar vasodilation during exercise?

A) Decreased plasma potassium ion concentration
B) Increased histamine release
C) Decreased plasma nitric oxide concentration
D) Increased plasma adenosine concentration
E) Decreased plasma osmolality

93. At the onset of exercise, the mass sympathetic nervous system strongly discharges. What would you expect to occur?

A) Increased sympathetic impulses to the heart
B) Decreased coronary blood flow
C) Decreased cerebral blood flow
D) Reverse stress relaxation
E) Venous dilation

94. A sudden occlusion that occurs in larger coronary arteries causes an increase in the following:

A) Dilation of small anastomoses in cardiac tissue
B) Increase collateral blood flow
C) Increase production of adenosine
D) All of the above
E) Only A and C

95. A 70-year-old man with a weight of 100 kg (220 lb) and a blood pressure of 160/90 mm Hg has been told by his doctor that he has angina caused by myocardial ischemia. Which treatment would be beneficial to this man?

A) Increased dietary calcium
B) Isometric exercise
C) A beta-1 receptor stimulator
D) Angiotensin II infusion
E) Nitroglycerin

96. Which event normally occurs during exercise?

A) Arteriolar dilation in exercising muscle
B) Decreased sympathetic output
C) Venoconstriction
D) Decreased release of norepinephrine by the adrenals
E) A and C

97. Which of the following is (are) responsible for the increase in stroke volume in response to increased venous return?

A) Stretch of right atrium initiates a nervous reflex called the Bainbridge reflex
B) Stretch of the sinus node in the wall of the right atrium has a direct effect on the rhythmicity of the node to increase the heart rate
C) Frank-Starling law of the heart
D) All of the above
E) A and C

98. A 60-year-old man sustained an ischemia-induced myocardial infarction and died from ventricular fibrillation. In this patient, what factor was most likely to increase the tendency of the heart to fibrillate after the infarction?

A) Low potassium concentration in the heart extracellular fluid
B) A decrease in ventricular diameter
C) Increased sympathetic stimulation of the heart
D) Low adenosine concentration
E) Decreased parasympathetic stimulation of the heart

99. A 60-year-old man has been told by his doctor that he has angina caused by myocardial ischemia. Which treatment would be beneficial to this man?

A) Angiotensin-converting enzyme inhibition
B) Isometric exercise
C) Chelation therapy such as ethylenediamine tetraacetic acid (EDTA)
D) Beta receptor stimulation
E) Increased dietary calcium

100. What is one of the major causes of death after myocardial infarction?
    A) Increased cardiac output
    B) A decrease in pulmonary interstitial volume
    C) Fibrillation of the heart
    D) Increased cardiac contractility

101. Which statement about the results of sympathetic stimulation is most accurate?
    A) Epicardial flow increases
    B) Venous resistance decreases
    C) Arteriolar resistance decreases
    D) Heart rate decreases
    E) Venous reservoirs constrict

102. What is normally associated with the chronic stages of compensated heart failure? Assume the patient is resting.
    A) Dyspnea
    B) Decreased right atrial pressure
    C) Decreased heart rate
    D) Sweating
    E) Increased mean systemic filling pressure

103. What normally occurs in a person with unilateral left heart failure?
    A) Decreased pulmonary artery pressure
    B) Decreased left atrial pressure
    C) Decreased right atrial pressure
    D) Edema of feet
    E) Increased mean pulmonary filling pressure

104. What normally causes renal sodium retention during compensated heart failure?
    A) Increased formation of angiotensin II
    B) Increased release of atrial natriuretic factor
    C) Sympathetic vasodilation of the afferent arterioles
    D) Increased glomerular filtration rate
    E) Increased formation of antidiuretic hormone (ADH)

105. Which intervention would normally be beneficial to a patient with acute pulmonary edema?
    A) Infuse a vasoconstrictor drug
    B) Infuse a balanced electrolyte solution
    C) Administer furosemide
    D) Administer a bronchoconstrictor
    E) Infuse whole blood

106. A 60-year-old man had a heart attack 2 days ago, and his blood pressure has continued to decrease. He is now in cardiogenic shock. Which therapy would be most beneficial?
    A) Placing tourniquets on all four limbs
    B) Administering a sympathetic inhibitor
    C) Administering furosemide
    D) Administering a blood volume expander
    E) Increasing dietary sodium intake

107. If a 21-year-old male patient has a cardiac reserve of 300% and a maximum cardiac output of 16 l/min, what is his resting cardiac output?
    A) 3 l/min
    B) 4 l/min
    C) 5.33 l/min
    D) 6 l/min
    E) 8 l/min

108. Which of the following occurs during heart failure and causes an increase in renal sodium excretion?
    A) Increased aldosterone release
    B) Increased atrial natriuretic factor release
    C) Decreased glomerular filtration rate
    D) Increased angiotensin II release
    E) Decreased mean arterial pressure

109. Which intervention would be appropriate therapy for a patient in cardiogenic shock?
    A) Placing tourniquets on the four limbs
    B) Withdrawing a moderate amount of blood from the patient
    C) Administering furosemide
    D) Infusing a vasoconstrictor drug

110. Which condition normally accompanies acute unilateral right heart failure?
    A) Increased right atrial pressure
    B) Increased left atrial pressure
    C) Increased urinary output
    D) Increased cardiac output
    E) Increased arterial pressure

111. What is normally associated with the chronic stages of compensated heart failure? Assume the patient is resting.
    A) Decreased mean systemic filling pressure
    B) Increased right atrial pressure
    C) Increased heart rate
    D) Sweating
    E) Dyspnea

112. Patients with pulmonary edema often have dyspnea because of accumulation of fluid in the lungs. Which of the following would normally be the most beneficial for a patient with acute pulmonary edema?
    A) Infusing furosemide
    B) Infusing dobutamine
    C) Infusing saline solution

D) Infusing norepinephrine
E) Infusing whole blood

113. Which of the following is associated with compensated heart failure?
A) Increased cardiac output
B) Increased blood volume
C) Decreased mean systemic filling pressure
D) Normal right atrial pressure

114. Which condition is normally associated with an increase in mean systemic filling pressure?
A) Decreased blood volume
B) Congestive heart failure
C) Sympathetic inhibition
D) Venous dilation

115. Which condition normally occurs during the early stages of compensated heart failure?
A) Increased right atrial pressure
B) Normal heart rate
C) Decreased angiotensin II release
D) Decreased aldosterone release
E) Increased urinary output of sodium and water

116. What often occurs during decompensated heart failure?
A) Hypertension
B) Increased mean pulmonary filling pressure
C) Decreased pulmonary capillary pressure
D) Increased cardiac output
E) Increased norepinephrine in the endings of the cardiac sympathetic nerves

117. Which of the following often occurs in decompensated heart failure?
A) Increased renal loss of sodium and water
B) Decreased mean systemic filling pressure
C) Increased norepinephrine in cardiac sympathetic receptors
D) Orthopnea
E) Weight loss

118. An 80-year-old man at a local hospital was diagnosed with a heart murmur. A chest radiograph showed an enlarged heart but no edema fluid in the lungs. The mean QRS axis of his ECG was 170 degrees. His pulmonary wedge pressure was normal. What is the diagnosis?
A) Mitral stenosis
B) Aortic stenosis
C) Pulmonary valve stenosis
D) Tricuspid stenosis
E) Mitral regurgitation

119. The fourth heart sound is associated with which mechanism?
A) In-rushing of blood into the ventricles from atrial contraction
B) Closing of the A-V valves
C) Closing of the pulmonary valve
D) Opening of the A-V valves
E) In-rushing of blood into the ventricles in the early to middle part of diastole

120. A 40-year-old woman has been diagnosed with a heart murmur. A " blowing" murmur of relatively high pitch is heard maximally over the left ventricle. The chest radiograph shows an enlarged heart. Arterial pressure in the aorta is 140/40 mm Hg. What is the diagnosis?
A) Aortic valve stenosis
B) Aortic valve regurgitation
C) Pulmonary valve stenosis
D) Mitral valve stenosis
E) Tricuspid valve regurgitation

121. In which disorder will left ventricular hypertrophy normally occur?
A) Pulmonary valve regurgitation
B) Tricuspid regurgitation
C) Mitral stenosis
D) Tricuspid stenosis
E) Aortic stenosis

122. Which heart murmur is heard during systole?
A) Aortic valve regurgitation
B) Pulmonary valve regurgitation
C) Tricuspid valve stenosis
D) Mitral valve stenosis
E) Patent ductus arteriosus

123. An increase in left atrial pressure is most likely to occur in which heart murmur?
A) Tricuspid stenosis
B) Pulmonary valve regurgitation
C) Aortic stenosis
D) Tricuspid regurgitation
E) Pulmonary valve stenosis

124. A 50-year-old woman at a local hospital has been diagnosed with a heart murmur. A murmur of relatively low pitch is heard maximally over the second intercostal space to the right of the sternum. The chest radiograph shows an enlarged heart. The mean QRS axis of the ECG is –45 degrees. What is the diagnosis?
A) Mitral valve stenosis
B) Aortic valve stenosis
C) Pulmonary valve stenosis
D) Tricuspid valve stenosis
E) Tricuspid valve regurgitation

125. A 40-year-old woman has been diagnosed with a heart murmur of relatively high pitch heard maximally in the second intercostal space to the left of the sternum. The mean QRS axis of his ECG is 150 degrees and the chest radiographs show an enlarged heart. The arterial blood oxygen content is normal. What is the likely diagnosis?
    A) Aortic stenosis
    B) Aortic regurgitation
    C) Pulmonary valve regurgitation
    D) Mitral stenosis
    E) Tricuspid stenosis

126. In which condition will right ventricular hypertrophy normally occur?
    A) Tetralogy of Fallot
    B) Mild aortic stenosis
    C) Mild aortic insufficiency
    D) Mitral stenosis
    E) Tricuspid stenosis

127. Which heart murmur is only heard during diastole?
    A) Patent ductus arteriosus
    B) Aortic stenosis
    C) Tricuspid valve regurgitation
    D) Interventricular septal defect
    E) Mitral stenosis

128. A person with which condition is most likely to have low arterial oxygen content?
    A) Tetralogy of Fallot
    B) Pulmonary artery stenosis
    C) Tricuspid insufficiency
    D) Patent ductus arteriosus
    E) Tricuspid stenosis

129. Which of the following is associated with the first heart sound?
    A) Inrushing of blood into the ventricles as a result of atrial contraction
    B) Closing of the A-V valves
    C) Closing of the pulmonary valve
    D) Opening of the A-V valves
    E) Inrushing of blood into the ventricles in the early to middle part of diastole

130. A 2-year-old girl had an echocardiogram. The results indicated a thickened right ventricle. Other data indicated that the patient had severely decreased arterial oxygen content and equal systolic pressures in both cardiac ventricles. What condition is present?
    A) Interventricular septal defect
    B) Tetralogy of Fallot
    C) Pulmonary valve stenosis
    D) Pulmonary valve regurgitation
    E) Patent ductus arteriosus

131. Which heart murmur is only heard during diastole?
    A) Patent ductus arteriosus
    B) Mitral regurgitation
    C) Tricuspid valve stenosis
    D) Interventricular septal defect
    E) Aortic stenosis

132. Which mechanism is associated with the third heart sound?
    A) Inrushing of blood into the ventricles as a result of atrial contraction
    B) Closing of the A-V valves
    C) Closing of the pulmonary valve
    D) Opening of the A-V valves
    E) Inrushing of blood into the ventricles in the early to middle part of diastole

133. Which condition often occurs in a person with progressive hemorrhagic shock?
    A) Increased capillary permeability
    B) Stress relaxation of veins
    C) Tissue alkalosis
    D) Increased urine output
    E) Increased mean systemic filling pressure

134. In which condition will administration of a sympathomimetic drug be the therapy of choice to prevent shock?
    A) Spinal cord injury
    B) Shock due to excessive vomiting
    C) Hemorrhagic shock
    D) Shock caused by excess diuretics

135. The blood pressure of a 60-year-old man decreased to 55/35 mm Hg during induction of anesthesia. His ECG still shows a normal sinus rhythm. What initial therapy do you recommend?
    A) Infusion of packed red blood cells
    B) Infusion of plasma
    C) Infusion of a balanced electrolyte solution
    D) Infusion of a sympathomimetic drug
    E) Administration of a glucocorticoid

136. A 65-year-old man enters a local emergency department a few minutes after receiving an influenza inoculation. He has pallor, tachycardia, arterial pressure of 80/50, and trouble walking. What therapy do you recommend to prevent shock?
    A) Infusion of blood
    B) Administration of an antihistamine
    C) Infusion of a balanced electrolyte solution such as saline
    D) Infusion of a sympathomimetic drug
    E) Administration of tissue plasminogen activator

137. Which condition often occurs in compensated hemorrhagic shock? Assume systolic pressure is 48 mm Hg.
   A) Decreased heart rate
   B) Stress relaxation of veins
   C) Decreased ADH release
   D) Decreased absorption of interstitial fluid through the capillaries
   E) Central nervous system (CNS) ischemic response

138. If a patient undergoing spinal anesthesia experiences a large decrease in arterial pressure and goes into shock, what would be the therapy of choice?
   A) Plasma infusion
   B) Blood infusion
   C) Saline solution infusion
   D) Glucocorticoid infusion
   E) Infusion of a sympathomimetic drug

139. A 25-year-old man who has been in a motorcycle wreck enters the emergency department. His clothes are very bloody, and his arterial pressure is decreased to 70/40 mm Hg. His heart rate is 120 beats/min, and his respiratory rate is 30/min. Which therapy would the physician recommend?
   A) Infusion of blood
   B) Infusion of plasma
   C) Infusion of a balanced electrolyte solution
   D) Infusion of a sympathomimetic drug
   E) Administration of a glucocorticoid

140. In which type of shock does cardiac output often increase?
   A) Hemorrhagic shock
   B) Anaphylactic shock
   C) Septic shock
   D) Neurogenic shock

141. A 20-year-old man who has been hemorrhaging as a result of a gunshot wound enters a local emergency department. He has pale skin, tachycardia, an arterial pressure of 60/40 mm Hg, and trouble walking. Unfortunately, the blood bank is out of whole blood. Which therapy would the physician recommend to prevent shock?
   A) Administration of a glucocorticoid
   B) Administration of an antihistamine
   C) Infusion of a balanced electrolyte solution
   D) Infusion of a sympathomimetic drug
   E) Infusion of plasma

142. A 10-year-old girl in the hospital had an intestinal obstruction, and her arterial pressure decreased to 70/40 mm Hg. Her heart rate is 120 beats/min, and her respiratory rate is 30/min. Which therapy would the physician recommend?
   A) Infusion of blood
   B) Infusion of plasma
   C) Infusion of a balanced electrolyte solution
   D) Infusion of a sympathomimetic drug
   E) Administration of a glucocorticoid

143. What often occurs during progressive shock?
   A) Patchy areas of necrosis in the liver
   B) Decreased tendency for blood to clot
   C) Increased glucose metabolism
   D) Decreased release of hydrolases by lysosomes
   E) Decreased capillary permeability

144. Release of which substance causes vasodilation and increased capillary permeability during anaphylactic shock?
   A) Histamine
   B) Bradykinin
   C) Nitric oxide
   D) Atrial natriuretic factor
   E) Adenosine

145. A 36-year-old female has a resting cardiac output (CO) of 4.8 l/min and after maximum exercise increased to 19.2 l/min. What is (approximately) her cardiac reserve?
   A) 400%
   B) 300%
   C) 500%
   D) Cannot be estimated without mean arterial pressure values
   E) Cannot be estimated without total peripheral resistance values

146. A 58-year-old patient with a history of atherosclerosis and hypertension suffers a heart attack. What are acute events that take place *immediately* (0–30 seconds) after heart damage?
   A) Increased cardiac output
   B) Blood accumulation in the aorta
   C) Sympathetic activation
   D) Parasympathetic activation
   E) Inhibition of angiotensin II

147. What is incorrect about cardiac failure?
   A) Moderate fluid retention is beneficial
   B) Cardiac reserve is decreased only when ejection fraction is less than 30%
   C) Cardiac failure may develop with high or low cardiac output
   D) Cardiac recovery is possible but cardiac reserve is always decreased
   E) A low cardiac output tends to decrease urinary output

148. An important reason why moderate fluid retention in low-output heart failure is beneficial is:
    A) Preserves isovolumetric contraction
    B) Increases afterload
    C) Improves preload
    D) Reduces aortic pressure
    E) Decreases peripheral edema

149. In *decompensated* heart failure, the failure of CO to rise enough will result in:
    A) Progressive fluid retention, increased mean filling pressure, and increased right atrial pressure
    B) Progressive parasympathetic activation, decreased aldosterone, increased heart rate.
    C) Moderate fluid retention, increased mean filling pressure, decreased venous return
    D) Vasoconstriction, bronchospasm, and decreased right atrial pressure
    E) Stable fluid retention, increased mean filling pressure, and increased right atrial pressure

150. A 67-year-old man has an ejection fraction of 0.32, no cyanosis, a history of dilated cardiomyopathy and heart failure, and a systolic murmur. What is your most likely diagnosis?
    A) Mitral stenosis
    B) Tetralogy of Fallot
    C) Mitral regurgitation
    D) Patent ductus arteriosus
    E) Tricuspid stenosis

151. The murmur in mitral stenosis is due to:
    A) Increased pulmonary pressures
    B) Narrowed outflow tract of the left ventricle
    C) Backflow from atria to the pulmonary vessels
    D) Narrowed mitral valve opening
    E) A and D

152. What is correct about interpretation of left ventricular pressure-volume loops in valve disease?
    A) Aortic stenosis shows a taller P-V loop with reduced preload.
    B) Isovolumetric systolic period is lost in aortic regurgitation but preserved in mitral regurgitation
    C) Aortic stenosis and regurgitation show a significantly increased afterload.
    D) Mitral stenosis and regurgitation show a significantly increased afterload.
    E) Isovolumetric diastolic period is lost in tricuspid stenosis.

153. A 6-month-old patient has a chest X-ray showing enlargement of the heart and blood work with low Po_2. Which situation best explains his condition?
    A) Patent ductus arteriosus
    B) A right-to-left shunt
    C) A left-to-right shunt
    D) Congenital tricuspid stenosis
    E) Interatrial septal defect

154. Which of the following is correct about hemorrhagic shock?
    A) Deterioration of the heart is probably the most important factor in progression of shock
    B) Deterioration of the liver is probably the most important factor in progression of shock
    C) Autoregulation in the brain reverses cellular deterioration in irreversible shock
    D) Autoregulation in the heart reverses cellular deterioration in irreversible shock
    E) Autoregulation in the kidneys reverses cellular deterioration in irreversible shock

155. A 48-year-old male suffers a massive heart attack that deteriorates over 70% of his left ventricle (LV) (EKG shows ST elevation from V1 to V6, in lead I, and in aVL). The blood pressure is 82/57 mm Hg, heart rate is 135 beats/min, pulse is weak and the patient displays generalized signs of hypoperfusion (lethargic, pale, sweat, cold skin). The diagnosis of the heart attack was done at his home 7 hours ago. The patient was admitted 55 minutes ago and has been receiving IV fluids, oxygen, and sympathomimetics He showed a brief improvement in blood pressure and cardiac dynamics but then continued to deteriorate with no further response to treatment. Which of the following statements is most likely to be correct?
    A) The delay between diagnosis and admittance at hospital complicated the patients' hemorrhagic shock with a progressive decrease in capillary permeability
    B) It is possible that fluids may have been insufficient and increased administration of blood + fluids may reverse cellular deterioration
    C) The patient is most likely at the irreversible stage of shock
    D) The diminished delivery of oxygen to the tissues leads to generalized tissue alkalosis and cellular deterioration
    E) Since the cause of shock is from cardiac origin, no toxins are released or accumulated and cellular deterioration may not develop.

156. The patient from the previous question, after 2 hours of therapeutic interventions, develops ventricular fibrillation. Which of the following will represent the most significant change in his left ventricular cardiovascular dynamics?
    A) A significant increase in preload
    B) A decrease in afterload with preserve preload
    C) A circulatory arrest
    D) An increased end-systolic volume
    E) A shift of the pressure-volume relationship to the left

157. Which of the following is correct about treatment of shock?

A) Dextran solution (if plasma is not available) is helpful as plasma substitution in cardiogenic shock since it increases interstitial pressure.
B) Anti-histamine agents in anaphylactic shock help to prevent development of disseminated intra-vascular coagulation
C) Dextran solution (if whole blood or plasma are not available) is helpful as plasma substitution since it increases intra-vascular hydrostatic pressure.
D) Dextran solution (if whole blood or plasma are not available) is helpful as plasma substitution since it increases intra-vascular colloid osmotic pressure.
E) Glucocorticoids stimulate release of enzymes from lysosomes that are crucial for tissue protection and to prevent cellular deterioration

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ANSWERS

1. **B)** The capillary filtration coefficient is calculated as rate of net fluid movement across a capillary wall divided by net filtration pressure. Net filtration pressure = capillary hydrostatic pressure – plasma colloid osmotic pressure + interstitial colloid osmotic pressure – interstitial hydrostatic pressure. The rate of net fluid movement across the capillary wall is 150 ml/min.
   Capillary filtration coefficient (K_f) = Filtration rate/ Net filtration pressure
   $Kf = 150 \text{ ml/min} / [Pc - \Pi c + \Pi i - P_I]$
   $Kf = 150 \text{ ml/min} / [25 - 25 + 10 - (-5)]$
   $Kf = 150 / 15 = 10 \text{ ml/min/mm Hg}$
   TMP14 p. 197

2. **A)** Moving from a supine to a standing position causes an acute fall in arterial pressure that is sensed by arterial baroreceptors located in the carotid bifurcation and aortic arch. Activation of the arterial baroreceptors leads to an increase in sympathetic outflow to the heart and peripheral vasculature and a decrease in parasympathetic outflow to the heart. The increase in sympathetic activity to peripheral vessels results in an increase in total peripheral resistance. The increase in sympathetic activity to the heart results in an increase in heart rate and strength of contraction. The decrease in parasympathetic outflow to the heart also contributes to the increase in heart rate.
   TMP14 pp. 222–223

3. **E)** Administration of a drug that decreases the diameter of arterioles in a muscle bed increases the vascular resistance. The increased vascular resistance decreases vascular conductance and blood flow. The reduction in arteriolar diameter also leads to a decrease in capillary hydrostatic pressure and capillary filtration rate.
   TMP14 pp. 174, 177, 197

4. **G)** Moving from a supine to a standing position causes an acute fall in arterial pressure that is sensed by arterial baroreceptors located in the carotid sinuses and aortic arch. Activation of the baroreceptors results in a decrease in parasympathetic activity (or vagal tone) and an increase in sympathetic activity, which leads to an increase in plasma renin activity (or renin release).
   TMP14 pp. 217–223

5. **A)** The difference between systolic pressure and diastolic pressure is the pulse pressure. The two major factors that affect pulse pressure are the stroke volume output of the heart and the compliance of the arterial tree. In patients with moderate aortic regurgitation (due to incomplete closure of aortic valve), the blood that is pumped into the aorta immediately flows back into the left ventricle. The backflow of blood into the left ventricle increases stroke volume and systolic pressure. The rapid backflow of blood also results in a decrease in diastolic pressure. Thus, patients with moderate aortic regurgitation have high systolic pressure, low diastolic pressure, and high pulse pressure.
   TMP14 pp. 184–185

6. **F)** The increase in local metabolism during exercise increases carbon dioxide production and decreases tissue oxygen concentration and tissue pH. The decrease in tissue oxygen concentration, tissue pH, and increase in carbon dioxide production increase arteriolar diameter (decrease arteriole resistance) and increase vascular conductance and blood flow to skeletal muscles.
   TMP14 pp. 206–208

7. **B)** Cognitive stimuli increase cerebral blood flow by decreasing cerebral vascular resistance. The diameter of cerebral vessels is increased by various metabolic factors in response to cognitive stimuli. Metabolic factors that enhance cerebral blood flow include increases in carbon dioxide, hydrogen ion (decreased pH), and adenosine.
   TMP14 pp. 205–207

8. **A)** Histamine is a vasodilator that is typically released by mast cells and basophils. Infusion of histamine into a brachial artery would decrease arteriolar resistance and increase water permeability of the capillary wall. The decrease in arteriolar resistance would also increase capillary hydrostatic pressure. The increase in capillary hydrostatic pressure and water permeability leads to an increase in capillary filtration rate, interstitial volume, and interstitial hydrostatic pressure.
   TMP14 pp. 174, 197

9. **C)** An increase in shear stress in blood vessels is one of the major stimuli for the release of nitric oxide by endothelial cells. Nitric oxide increases blood flow by increasing cyclic guanosine monophosphate.
   TMP14 p. 210

10. **C)** Angiotensin I is formed by an enzyme (renin) acting on a substrate called angiotensinogen. Angiotensin I is converted to angiotensin II by a converting enzyme. Angiotensin II also has a negative feedback effect on juxtaglomerular cells to inhibit renin secretion. Angiotensin II is a powerful vasoconstrictor and sodium-retaining hormone that increases arterial pressure. Administration of an ACE inhibitor would increase plasma renin concentration, decrease angiotensin II formation, and decrease total peripheral resistance and arterial pressure.
    TMP14 pp. 236–238

11. E) A decrease in the diameter of a precapillary arteriole would increase arteriolar resistance. The increase in arteriolar resistance would lead to a decrease in vascular conductance, capillary blood flow, hydrostatic pressure, and filtration rate.
TMP14 pp. 174, 197

12. A) Stenosis of one kidney results in the release of renin and the formation of angiotensin II from the affected kidney. Angiotensin II stimulates aldosterone production and increases total peripheral resistance by constricting most of the blood vessels in the body.
TMP14 p. 239

13. D) Blood flow in a vessel is directly proportional to the fourth power of the vessel radius. Increasing vessel diameter (or radius) by 100% (2 × control) would increase blood flow 2 to the fourth power × normal blood flow (100 ml/min). Thus, blood flow would increase to 100 ml/min × 16, or approximately 1600 ml/min.
TMP14 p. 177

14. A) In patent ductus arteriosus, a large quantity of the blood pumped into the aorta by the left ventricle immediately flows backward into the pulmonary artery and then into the lung and left atrium. The shunting of blood from the aorta results in a low diastolic pressure, while the increased inflow of blood into the left atrium and ventricle increases stroke volume and systolic pressure. The combined increase in systolic pressure and decrease in diastolic pressure results in an increase in pulse pressure.
TMP14 pp. 184–185

15. E) A decrease in tissue oxygen tension is thought to be an important stimulus for vascular endothelial growth factor and the growth of blood vessels in solid tumors.
TMP14 pp. 211–213

16. A) The net movement of sodium across a capillary wall is directly proportional to the wall permeability to sodium, wall surface area, and concentration gradient across the capillary wall. Thus, increases in permeability to sodium, surface area, and sodium concentration gradient wall would all increase the net movement of sodium across the capillary wall.
TMP14 pp. 195–196

17. D) Constriction of the carotid artery decreases blood pressure at the level of the carotid sinus. A decrease in carotid sinus pressure leads to a decrease in carotid sinus nerve impulses to the vasomotor center, which in turn leads to enhanced sympathetic nervous activity and decreased parasympathetic nerve activity. The increase in sympathetic nerve activity results in peripheral vasoconstriction and an increase in total peripheral resistance and heart rate. The decreased parasympathetic nerve activity to the heart would also contribute to the increase in heart rate.
TMP14 pp. 221–223

18. E) Pulse pressure is the difference between systolic pressure and diastolic pressure. The two major factors that affect pulse pressure are the stroke volume output of the heart and the compliance of the arterial tree. An increase in stroke volume increases systolic and pulse pressure, whereas an increase in compliance of the arterial tree decreases pulse pressure. Moderate aortic valve stenosis results in a decrease in stroke volume, which leads to a decrease in systolic pressure and pulse pressure.
TMP14 pp. 184–185

19. B) A person with atherosclerosis would be expected to have decreased arterial compliance. The decrease in arterial compliance would lead to an increase in systolic pressure and pulse pressure.
TMP14 pp. 184–185

20. B) Constriction of the carotid artery reduces blood pressure at the carotid bifurcation where the arterial baroreceptors are located. The decrease in arterial pressure activates baroreceptors, which in turn leads to an increase in sympathetic activity and a decrease in parasympathetic activity (or vagal tone). The enhanced sympathetic activity results in constriction of peripheral blood vessels, including the kidneys. The enhanced sympathetic activity leads to an increase in total peripheral resistance and a decrease in renal blood flow. The combination of enhanced sympathetic activity and decreased vagal tone also leads to an increase in heart rate.
TMP14 pp. 221–223

21. B) Filtration rate is the product of the filtration coefficient (K_f) and the net pressure across the capillary wall. The net pressure for fluid movement across a capillary wall is promoted by increases in capillary hydrostatic pressure and positive interstitial colloid osmotic pressure, whereas negative plasma colloid osmotic pressure and a positive interstitial hydrostatic pressure oppose filtration. Thus, increased capillary hydrostatic pressure, *decreased plasma colloid osmotic pressure*, and increased interstitial colloid osmotic pressure would all promote filtration. Increased arteriolar resistance would decrease filtration by decreasing capillary hydrostatic pressure. The filtration coefficient is the product of capillary surface area and the capillary water permeability. A decrease in capillary water permeability would decrease the filtration coefficient and reduce the filtration rate.
TMP14 pp. 196–197

22. E) Solid tumors are metabolically active tissues that need increased quantities of oxygen and other nutrients. When metabolism in a tissue is increased for a prolonged period, the vascularity of the tissue also increases. One of the important factors that increases growth of new blood vessels is VEGF. Presumably, a deficiency of tissue oxygen or other nutrients, or both, leads to the formation of VEGF.
TMP14 p. 212

23. A) A decrease in the diameter of a precapillary arteriole increases arteriolar resistance while decreasing vascular conductance and capillary blood flow, hydrostatic pressure, filtration rate, interstitial volume, and interstitial hydrostatic pressure.
TMP14 pp. 174, 197

24. C) Excess secretion of aldosterone results in enhanced tubular reabsorption of sodium and secretion of potassium. The increased reabsorption of sodium and water leads to an increase in extracellular fluid volume, which in turn suppresses renin release by the kidney. The increase in potassium secretion leads to a decrease in plasma potassium concentration, or hypokalemia.
TMP14 pp. 237–238

25. B) The two main factors that increase lymph flow are an increase in capillary filtration rate and an increase in lymphatic pump activity. A *decrease in plasma colloid osmotic* pressure increases capillary filtration rate, interstitial volume and hydrostatic pressure, and *lymph flow.* In contrast, an increase in hydraulic conductivity of the capillary wall and capillary hydrostatic pressure increase capillary filtration rate, interstitial volume and pressure, and lymph flow. An increase in arteriole resistance would *decrease* vascular conductance, capillary hydrostatic pressure, capillary filtration rate, interstitial volume and pressure, and *lymph flow.*
TMP14 pp. 195–203

26. E) According to Poiseuille's law, flow through a vessel increases in proportion to the fourth power of the radius. A 4-fold increase in vessel diameter (or radius) would increase 4 to the fourth power, or 256 times normal. Thus, flow through the vessel after increasing the vessel 4 times normal would increase from 100 to 25,600 ml/min.
TMP14 p. 177

27. B) Vascular resistance is equal to arterial pressure divided by blood flow. In this example, arterial pressure is 125 mm Hg, venous pressure is 5 mm Hg, and blood flow is 1200 ml/min (plasma flow/hematocrit). Thus, vascular resistance is equal to 120 divided by (600/.50 or 1200), or 0.10 mm Hg/ml/min.
TMP14 p. 174

28. D) The rate of blood flow is directly proportional to the fourth power of the vessel radius and to the pressure gradient across the vessel. In contrast, the rate of blood flow is inversely proportional to the viscosity of the blood. Thus, an increase in blood viscosity would decrease blood flow in a vessel.
TMP14 pp. 177–178

29. D) The flow in a vessel is directly proportional to the pressure gradient across the vessel and to the fourth power of the radius of the vessel. In contrast, blood flow is inversely proportional to the viscosity of the blood. Because blood flow is proportional to the fourth power of the vessel radius, the vessel with the largest radius (vessel D) would have the greatest flow.
TMP14 p. 177

30. B) The arterial baroreceptors are activated in response to a fall in arterial pressure. During hemorrhage, the fall in arterial pressure at the level of the baroreceptors results in enhanced sympathetic outflow from the vasomotor center and a decrease in parasympathetic nerve activity. The increase in sympathetic nerve activity leads to constriction of peripheral blood vessels, increased total peripheral resistance, and plasma renin activity, angiotensin II and a return of blood pressure toward normal. The decrease in parasympathetic nerve activity and sympathetic outflow would result in an increase in heart rate.
TMP14 pp. 221–223, 236–238

31. A) Activation of the baroreceptors leads to an increase in sympathetic activity, which in turn increases heart rate, strength of cardiac contraction, and constriction of arterioles and veins. The increase in venous constriction results in an increase in mean circulatory filling pressure, venous return, and cardiac output.
TMP14 pp. 221–223

32. E) The conversion of angiotensin I to angiotensin II is catalyzed by a converting enzyme that is present in the endothelium of the lung vessels and in the kidneys. The converting enzyme also serves as a kininase that degrades bradykinin. Thus, a converting enzyme inhibitor not only decreases the formation of angiotensin II but also inhibits kininases and the breakdown of bradykinin. Angiotensin II is a vasoconstrictor and a powerful sodium-retaining hormone. While plasma bradykinin increases, the major cause for the decrease in arterial pressure in response to an ACE inhibitor is the decrease in formation of angiotensin II.
TMP14 pp. 236–238

33. G) When blood pressure falls below 80 mm Hg, carotid and aortic chemoreceptors are activated to elicit a neural reflex to minimize the fall in blood pressure. The chemoreceptors are chemosensitive cells that are sensitive to oxygen lack, carbon dioxide excess, or hydrogen ion excess (or fall in pH). The signals transmitted from the chemoreceptors into the vasomotor center excite the vasomotor center to increase arterial pressure.
TMP14 p. 224

34. D) Although sympathetic nerves, angiotensin II, and vasopressin are powerful vasoconstrictors, blood flow to skeletal muscles under normal physiological conditions is mainly determined by local metabolic factors such as tissue adenosine, oxygen, hydrogen, and carbon dioxide concentrations. Capillary osmotic pressure plays a role in determining fluid movement across a capillary not blood flow.
TMP14 pp. 206–208

35. E) During exercise, tissue levels of carbon dioxide and lactic acid increase. These metabolites dilate blood vessels, decrease arteriolar resistance, and enhance vascular conductance and blood flow.
TMP14 pp. 208–209

36. C) The velocity of blood flow within each segment of the circulatory system is inversely proportional to the total cross-sectional area of the segment. Because the capillaries has the highest total cross-sectional area of all circulatory segments, it has the lowest velocity of blood flow.
TMP14 p. 172

37. B) Filtration rate is the product of the filtration coefficient (K_f) and the net pressure across the capillary wall. The net pressure for fluid movement across a capillary wall = capillary hydrostatic pressure – plasma colloid osmotic pressure + interstitial colloid osmotic pressure – interstitial hydrostatic pressure. The net pressure in this question calculates to be 10 mm Hg, and the K_f is 15. Thus, the filtration rate is 15 × 10, or 150 ml/min.
TMP14 p. 197

38. A) Resistance of a vessel = pressure gradient ÷ blood flow of the vessel. In this example, vessel A has the highest vascular resistance (100 mm Hg/1000 ml/min, or 0.1 mm Hg/ml/min).
TMP14 pp. 173–174

39. C) The transport of oxygen across a capillary wall is proportional to the capillary surface area, capillary wall permeability to oxygen, and oxygen gradient across the capillary wall. Thus, a 2-fold increase in the oxygen concentration gradient would result in the greatest increase in the transport of oxygen across the capillary wall. A 2-fold increase in intercellular clefts in the capillary wall would not have a significant impact on oxygen transport because oxygen can permeate the endothelial cell wall.
TMP14 pp. 195–196

40. D) Atrial natriuretic peptide is released from myocytes in the atria in response to increases in atrial pressure. ANP in turn inhibits the production of angiotensin II and aldosterone. Stretch of the atria also results in a nervous reflex to inhibit renal sympathetic nerve activity.
TMP14 p. 224

41. C) The capillaries have the largest total cross-sectional area of all vessels of the circulatory system. The venules also have a relatively large total cross-sectional area but not as great as the capillaries, which explains the large storage of blood in the venous system compared with that in the arterial system.
TMP14 p. 172

42. E) An increase in atrial pressure increases plasma levels of atrial natriuretic peptide, which in turn would decrease plasma levels of angiotensin II and aldosterone and increase sodium excretion.
TMP14 p. 224

43. C) An increase in perfusion pressure to a tissue results in excessive delivery of nutrients such as oxygen to a tissue. The increase in tissue oxygen concentration constricts arterioles and returns blood flow and nutrient delivery toward normal levels.
TMP14 pp. 209–210

44. C) The percentage of total blood volume in the veins is approximately 64%.
TMP14 p. 172

45. B) Constriction of the renal artery increases release of renin, formation of angiotensin II and aldosterone, and arterial pressure. A 50% reduction in renal artery pressure would be below the range of renal autoregulation and would result in a decrease in the glomerular filtration rate.
TMP14 pp. 239–240

46. B) An increase in plasma colloid osmotic pressure would reduce net filtration pressure and capillary filtration rate. Increases in capillary hydrostatic pressure and interstitial colloid osmotic pressure would also favor capillary filtration. An increase in venous hydrostatic pressure and arteriolar diameter would tend to increase capillary hydrostatic pressure and capillary filtration rate.
TMP14 pp. 194–201

47. E) A decrease in sodium intake would result in a decrease in sodium excretion to maintain sodium balance. Angiotensin II and aldosterone would increase in response to a chronic decrease in sodium intake, whereas plasma atrial natriuretic peptide levels would decrease.
TMP14 pp. 236–238

48. E) The rate of lymph flow increases in proportion to the interstitial hydrostatic pressure and the lymphatic pump activity. An increase in capillary hydrostatic pressure would increase filtration rate, interstitial volume, interstitial hydrostatic pressure, and lymph flow. An increase in plasma colloid osmotic pressure would decrease filtration rate, interstitial volume, interstitial hydrostatic pressure, and lymph flow. A decrease in interstitial volume would increase interstitial hydrostatic pressure and lymph flow. A decrease in arteriolar diameter would decrease capillary hydrostatic pressure, capillary filtration, interstitial volume, interstitial hydrostatic pressure and lymph flow.
TMP14 pp. 197–204

49. E) Nitric oxide and prostacyclin are potent vasodilator and natriuretic substances. Thus, increases in nitric oxide and prostacyclin production would result in a decrease in arterial pressure. In contrast, angiotensin II and aldosterone are anti-natriuretic and prohypertensive factors. An increase in the production of these factors would increase arterial pressure.
TMP14 p. 244

50. B) The liver endothelium contains many open pores, or fenestrae that allow extremely large molecules such as albumin to pass in or out of the liver tissues. Under normal conditions, very little if any albumin cross the capillary walls of muscle, glomerular, brain, or intestine.
TMP14 p. 195

51. D) The Cushing reaction is a special type of CNS ischemic response that results from increased pressure of the cerebrospinal fluid around the brain in the cranial vault. When the cerebrospinal fluid pressure rises, it decreases the blood supply to the brain and elicits a CNS ischemic response. The CNS ischemic response includes enhanced sympathetic activity, decreased parasympathetic activity, and increased heart rate, arterial pressure, and total peripheral resistance.
TMP14 p. 226

52. B) The factors that determine the net movement of glucose across a capillary wall include the wall permeability to glucose, the glucose concentration gradient across the wall, and the capillary wall surface area. Thus, an increase in the concentration difference of glucose across the wall would enhance the net movement of glucose.
TMP14 pp. 195–196

53. E) An increase in atrial pressure of 10 mm Hg would tend to decrease venous return to the heart and increase vena cava hydrostatic pressure. Plasma colloid osmotic pressure, interstitial colloid osmotic pressure, arterial pressure, and cardiac output would generally be low to normal in this patient.
TMP14 pp. 197–200

54. A) An increase in renal arterial pressure results in increases in sodium and water excretion. Normally, glomerular filtration rate would be normal or slightly increased in response to an increase in renal artery pressure. However, in the absence of an intact tubuloglomerular feedback system, an important renal autoregulatory mechanism, an increase in renal artery pressure would result in significant increases in glomerular filtration rate.
TMP14 p. 210

55. C) The vascular compliance is proportional to the vascular distensibility and the vascular volume of any given segment of the circulation. The compliance of a systemic vein is 24 times that of its corresponding artery because it is about 8 times as distensible and has a volume about 3 times as great.
TMP14 p. 183

56. E) The difference between systolic pressure and diastolic pressure is called the pulse pressure. The two main factors that affect pulse pressure are stroke volume and arterial compliance. Pulse pressure is directly proportional to the stroke volume and inversely proportional to the arterial compliance. Thus, increases in systolic pressure or stroke volume would tend to increase pulse pressure.
TMP14 pp. 184–185

57. B) Moving from a supine to a standing position results in pooling of blood in the lower extremities and a fall in blood pressure. The pooling of blood in the legs increases venous hydrostatic pressure. The fall in arterial pressure activates the arterial baroreceptors, which in turn increases sympathetic nerve activity and decreases parasympathetic nerve activity. The increase in sympathetic activity constricts renal vessels and reduces renal blood flow. The heart rate also increases.
TMP14 pp. 221–223

58. B) Moving from a supine to a standing position would tend to cause pooling of blood in the lower extremities and a reduction in arterial pressure. Decreased arterial pressure activates arterial the baroreceptor reflex which then leads to increased sympathetic nervous system activity, decreased parasympathetic activity, increased heart rate, and increased cardiac contractility.
TMP14 pp. 221–223

59. B) An increase in arterial pressure to a tissue leads to an increase in tissue oxygen concentration and a decrease in tissue carbon dioxide concentration. Both events lead to a decrease in arteriolar diameter, increased vascular resistance, and decreased vascular conductance.
TMP14 pp. 209–210

60. B) Because oxygen is lipid soluble and can cross the capillary wall with ease, it has the fastest rate of movement across the capillary wall. The ability of lipid-insoluble substances such as sodium, albumin, and glucose to move across a capillary wall depends on the permeability of the capillary to lipid-insoluble substances. Because the capillary wall is relatively impermeable to albumin, it has the slowest rate of net movement across the capillary wall.
TMP14 p. 195

61. A) An increase in capillary wall permeability to water would increase capillary filtration rate, whereas increases in arteriolar resistance, plasma colloid osmotic pressure, and interstitial hydrostatic pressure would all decrease filtration rate. Plasma sodium concentration would have no effect on filtration.
TMP14 pp. 197–1201

62. D) The tendency for turbulent flow occurs at vascular sites where the velocity of blood flow is high. The aorta has the highest velocity of blood flow.
TMP14 pp. 175–176

63. E) Total peripheral vascular resistance = (arterial pressure – right atrial pressure) ÷ cardiac output. In this example, total peripheral vascular resistance = 130 mm Hg ÷ 3.5 l/min, or approximately 37 mm Hg/l/min.
TMP14 p. 177

64. C) Interstitial hydrostatic pressure in a muscle capillary bed is normally negative (–3 mm Hg). Pumping by the lymphatic system is the basic cause of the negative pressure.
TMP14 pp. 202–203

65. D) The two main factors that affect pulse pressure are stroke volume and arterial compliance. Decreases in stroke volume decrease pulse pressure, and an increase in arterial compliance decreases pulse pressure. Hemorrhage and decreased venous return would decrease stroke volume and pulse pressure. In patients with patent ductus, stroke volume and pulse pressure are increased as a result of shunting of blood from the aorta to the pulmonary artery.
TMP14 pp. 184–186

66. D) The primary mechanism whereby solutes move across a capillary wall is simple *diffusion.*
TMP14 p. 196

67. E) Movement of the leg muscles causes blood to flow toward the vena cava, which reduces venous hydrostatic pressure. A decrease in right atrial pressure would increase venous return and decrease venous hydrostatic pressure. Pregnancy and the presence of abdominal tumor in the abdomen would tend to compress the vena cava and increase venous hydrostatic pressure in the legs.
TMP14 pp. 188–190

68. A) Nitric oxide is a vasodilator that is believed to play a role in regulating blood flow. Infusion of a nitric oxide donor into the brachial artery would increase arteriolar diameter and decrease arteriolar resistance. The decrease in arteriolar resistance would also result in an increase in capillary hydrostatic pressure and filtration rate. The increase in filtration rate leads to an increase in interstitial hydrostatic pressure and lymph flow.
TMP14 pp. 173–174, 197–200, 210

69. D) In persons with decompensated heart failure, the kidneys retain sodium and water, which causes a weight gain and an increase in blood volume. This effect increases the mean systemic filling pressure, which also stretches the heart. Therefore, a decreased mean systemic filling pressure does not occur in decompensated heart failure. The excess blood volume often will overstretch the sarcomeres of the heart, which will prevent them from achieving their maximal tension. An excess central fluid volume also results in orthopnea, which is the inability to breathe properly except in the upright position.
TMP14 pp. 273–274

70. A) During progressive hemorrhagic shock, the vasomotor center often fails, thus reducing sympathetic output. Decreases in arterial pressure will reduce urine output. Decreased blood flow throughout the body causes acidosis because of decreased removal of carbon dioxide. In progressive shock due to hemorrhage, capillary permeability increases and mean systemic filling pressure decreases.
TMP14 p. 296

71. C) With an overdose of furosemide there is a large loss of sodium and water from the body, resulting in dehydration and sometimes shock. The optimal therapy is to replenish the electrolytes that were lost as a result of the overdose of the furosemide. Therefore, infusion of a balanced electrolyte solution is the therapy of choice.
TMP14 pp. 301–302

72. C) Severe vomiting can lead to a large loss of sodium and water from the body, resulting in dehydration and sometimes shock. The best therapy is to replenish the depleted sodium and water lost by vomiting. Therefore, infusion of a balanced electrolyte solution is the therapy of choice.
TMP14 pp. 301–302

73. C) The formula for resistance to venous return is (mean systemic filling pressure – right atrial pressure)/cardiac output. In this example, the mean systemic filling pressure is 7 mm Hg, and the right atrial pressure is 0 mm Hg. The cardiac output is 5 l/min. Using these values in the previous formula indicates that the resistance to venous return is 1.4 mm Hg/l/min. Note that this formula only applies to the linear portion of the venous return curve.
TMP14 pp. 251–253

74. A) During increases in sympathetic output to maximal values, several changes occur. First, the mean systemic filling pressure increases markedly, but at the same time the resistance to venous return increases. Venous return is determined by the following formula: (mean systemic filling pressure – right atrial pressure)/resistance to venous return. During maximal sympathetic output, the increase in systemic filling pressure is greater than the increase in resistance to venous return. Therefore, in this formula, the numerator has a much greater increase than the denominator, which results in an increase in the venous return.
TMP14 p. 255

75. C) This problem concerns the Fick principle for determining cardiac output. The formula for cardiac output is oxygen absorbed per minute by the lungs divided by the arterial-venous oxygen difference. In this problem, oxygen consumption of the body is 240 ml/min, and in a steady-state condition, this would exactly equal the oxygen absorbed by the lungs. Therefore, by inserting these values into the equation, we see that the cardiac output will equal 12 l/min.
TMP14 p. 256

76. A) A shift to the right in the cardiac output curve involves an increase in the normal intrapleural pressure of –4 mm Hg. Changing the intrapleural pressure to –1 mm Hg will shift the curve to the right. Changing

the mean systemic filling pressure does not change the cardiac output curve. Taking a patient off of a ventilator, decreasing intrapleural pressure to –7 mm Hg, and breathing against a negative pressure shifts the cardiac output curve to the left.

TMP14 p. 250

77. C) Several factors can cause the cardiac output to shift to the right or to the left. Among those are surgically opening the chest, which makes the cardiac output curve shift 4 mm Hg to the right, and severe cardiac tamponade, which increases the pressure inside the pericardium, thus tending to collapse the heart, particularly the atria. Playing a trumpet or positive pressure breathing tremendously increases the intrapleural pressure, thus collapsing the atria and shifting the cardiac output curve to the right. Breathing against a negative pressure shifts the cardiac output curve to the left.

TMP14 p. 250

78. E) The plateau level of the cardiac output curve, which is one measure of cardiac contractility, decreases in several circumstances. Some of these circumstances include severe cardiac tamponade, which increases the pressure in the pericardial space, and increasing parasympathetic stimulation of the heart. Increased sympathetic stimulation of the heart increases the level of the cardiac output curve by increasing heart rate and contractility.

TMP14 p. 247

79. B) Cardiac output increases in several conditions because of increased venous return. A-V fistulae also cause a decreased resistance to venous return, thus increasing cardiac output. Cardiac output decreases in patients with hypovolemia, severe aortic regurgitation, and polycythemia. The hematocrit level is high in polycythemia, which increases resistance to venous return.

TMP14 pp. 248–250

80. D) Mean systemic filling pressure is a measure of the tightness of fit of the blood in the circulation. Mean systemic filling pressure is increased by factors that increase blood volume and decrease the vascular compliance. Therefore, decreased venous compliance, not increased compliance, would cause an increase in mean systemic filling pressure. Norepinephrine administration and sympathetic stimulation cause arteriolar vasoconstriction and decreased vascular compliance, resulting in an increase in mean systemic filling pressure. Increased blood volume and skeletal muscle contraction, which cause a contraction of the vasculature, also increase this filling pressure.

TMP14 pp. 252–253

81. C) Resistance to venous return (which is equal to cardiac output) is equal to the mean systemic filling pressure minus the right atrial pressure divided by venous return. Thus, resistance to venous return is equal to 12 minus 2 divided by 10 or 10/10 or 1 mm Hg/l per min.

TMP14 pp. 253–254

82. A) Anemia decreases resistance to venous return because of arteriolar dilation. The following mechanisms increase resistance to venous return: increased venous resistance, increased arteriolar resistance, increased sympathetic output, and obstruction of veins.

TMP14 pp. 253–254

83. D) Venous return (or cardiac output) is equal to the mean systemic filling pressure minus the right atrial pressure divided by resistance to venous return. Thus, an increase in resistance to venous return decreases venous return and cardiac output.

TMP14 p. 253

84. E) Cardiac output decreases in several conditions because of decreased venous return. Cardiac output decreases in hypothyroidism because of the decreased oxygen use by the peripheral tissues, resulting in arteriolar vasoconstriction and thus decreased venous return. Conversely, cardiac output increases with hyperthyroidism. Beriberi causes increased cardiac output because a lack of the vitamin thiamine results in peripheral vasodilation. A-V fistulae also cause decreased resistance to venous return, thus increasing cardiac output. Increased muscle mass is associated with increased tissue metabolism, decreased arteriolar resistance and resistance to venous return, and increased venous return to the heart and thus an increase in cardiac output.

TMP14 pp. 248–249

85. G) In response to increases in cardiac workload, there are increases in cardiac tissue metabolism and cardiac tissue adenosine concentration. Adenosine reduces arteriole resistance and increases vascular conductance.

TMP14 p. 263

86. C) The plateau level of the cardiac output curve, which is one measure of cardiac contractility, decreases in several circumstances. Some of these include myocarditis, severe cardiac tamponade that increases the pressure in the pericardial space, myocardial infarction, and various valvular diseases such as mitral stenosis. Decreased parasympathetic stimulation of the heart actually moderately increases the level of the cardiac output curve by increasing the heart rate.

TMP14 p. 247

87. A) During increases in sympathetic output, the main two organs that maintain their blood flow are the

brain and the heart. During exercise for 1 hour, the intestinal flow decreases significantly, as do the renal and pancreatic blood flows. The skeletal muscle blood flow to non-exercising muscles also decreases at this time. Cerebral blood flow remains close to its control value.

TMP14 pp. 259–262

88. E) According to the Fick principle,
Cardiac output = Oxygen absorbed by lungs (ml/min) (400) divided by
Arterio-venous oxygen difference (200 – 150 ml/l)
Cardiac output = 400/50 or 8 l/min

TMP14 pp. 256–257

89. A) Although bradykinin, prostaglandins, carbon dioxide, and potassium ions serve as vasodilators for the coronary artery system, the major controller of coronary blood flow is adenosine. Adenosine is formed as adenosine triphosphate degrades to adenosine monophosphate. Small portions of the adenosine monophosphate are then further degraded to release adenosine into the tissue fluids of the heart muscle, and this adenosine vasodilates the coronary arteries.

TMP14 p. 263

90. E) Sympathetic stimulation directly increases the strength of cardiac contraction and increases the heart rate. In this way, the plateau of the Starling curve elevates. Surgically opening the chest and undergoing mechanical ventilation shifts the cardiac output curve to the right. Cardiac tamponade rotates the curve downward, and parasympathetic stimulation depresses the curve.

TMP14 pp. 247–248

91. E) Ischemia causes the cardiac muscle to release lactic acid, which stimulates pain nerve endings in cardiac muscle, sending impulses through sensory afferent nerve fibers into the central nervous system.

TMP14 pp. 263–264, 268

92. D) Several factors cause arteriolar vasodilation during exercise, including increases in potassium ion concentration, plasma nitric oxide concentration, plasma adenosine concentration, and plasma osmolality. Although histamine causes arteriolar vasodilation, histamine release does not normally occur during exercise.

TMP14 pp. 259–260

93. A) At the beginning of exercise, increases in sympathetic stimulation of the heart strengthens the heart and increases the heart rate. Coronary and cerebral blood flow are spared from any decrease. Reverse stress relaxation does not occur. Venous constriction, not dilation, occurs.

TMP14 p. 261

94. D) When a sudden occlusion occurs in one of the larger coronary arteries, cardiac tissue adenosine concentration increases as a result of ATP breakdown. The small anastomoses in cardiac tissue begin to dilate immediately. Then over the next several days, collateral blood flow increases to partially restore blood flow to the ischemic tissue.

TMP14 p. 265

95. E) Several drugs have proven to be helpful to patients with myocardial ischemia. Beta receptor blockers (not stimulators) inhibit the sympathetic effects on the heart and are very helpful. ACE inhibition prevents the production of angiotensin II and thus decreases the afterload effect on the heart. Nitroglycerin causes nitric oxide release, resulting in coronary vasodilation. Isometric exercise increases blood pressure markedly and can be harmful, and increased dietary calcium would be of little benefit.

TMP14 pp. 268–269

96. E) During exercise, the sympathetic output increases markedly, which causes arteriolar constriction in many places of the body, including non-exercising muscle. The increased sympathetic output also causes venoconstriction throughout the body. During exercise, there also is an increased release of norepinephrine and epinephrine by the adrenal glands. These changes all help maintain blood pressure during exercise. Arterioles in the exercising muscle dilate to increase blood flow to meet the metabolic needs of the tissue.

TMP14 pp. 260–261

97. D) When increased quantities of blood flows into the heart, the resulting stretch in the heart wall results in an increase in force of contraction (Frank-Starling law of the heart) and stroke volume. Stretch of the sinus node in the wall of the right atrium has a direct effect on the rhythmicity of the node to increase the heart rate. Stretch of right atrium also initiates a nervous reflex called the Bainbridge reflex that increases heart rate.

TMP14 p. 245

98. C) Increased sympathetic stimulation excites the cardiac myocytes and makes them much more susceptible to fibrillation. High (not low) potassium increases fibrillation tendency. An increase (not a decrease) in ventricular diameter allows the cardiac muscle to be out of the refractory period when the cardiac impulse next arrives and can increase the tendency to fibrillate. A low adenosine level probably only causes some coronary constriction. Decreased parasympathetics allow the heart rate to increase and has little to do with fibrillation.

TMP14 p. 268

99. A) In a patient with angina due to myocardial ischemia, oxygen use by the heart must be minimized.

Oxygen use can be minimized with ACE inhibition, which decreases angiotensin II formation. This reduces the arterial pressure and decreases myocardial tension and oxygen use. The use of beta sympathetic blockers (not stimulation) inhibits the effects of excess sympathetic output on the heart, thus reducing wall tension and oxygen use. Isometric exercise should be avoided because of the large increase in arterial pressure that occurs. Chelation therapy with EDTA and increased dietary calcium have little to do with cardiac function.

TMP14 pp. 268–269

100. C) The major causes of death after myocardial infarction include a decrease in cardiac output that prevents tissues of the body from receiving adequate nutrition and oxygen delivery and prevents removal of waste materials. Other causes of death are pulmonary edema, which reduces the oxygenation of the blood, fibrillation of the heart, and rupture of the heart. Cardiac contractility decreases after a myocardial infarction.

TMP14 p. 266

101. E) During sympathetic stimulation, venous reservoirs constrict, venous vascular resistance also increases, arterioles constrict (which increases their resistance), and the heart rate increases. The epicardial coronary vessels have a large number of alpha receptors, but the subendocardial vessels have more beta receptors. Therefore, sympathetic stimulation causes at least a slight constriction of the epicardial vessels. This results in a slight decrease in epicardial flow.

TMP14 pp. 262–264

102. E) Several factors change during compensated heart failure to stabilize the circulatory system. Because of increased sympathetic output, the heart rate increases during compensated heart failure. The kidneys retain sodium and water, which increases blood volume and thus right atrial pressure. The increased blood volume that results causes an increase in mean systemic filling pressure, which will help to increase the cardiac output. Dyspnea usually will occur only in the early stages of compensated failure.

TMP14 pp. 272–273

103. E) In unilateral left heart failure, the kidneys retain sodium and water and thus increase blood volume, and the pulmonary veins, in turn, become congested. Therefore, mean pulmonary filling pressure, pulmonary wedge pressure, and left atrial pressure increase. In contrast, in right heart failure, right atrial pressure increases, and edema of the lower extremities, including the feet and ankles, occurs.

TMP14 pp. 275–276

104. A) In compensated heart failure, an increased release of angiotensin II also occurs, which causes direct renal sodium retention and also stimulates aldosterone secretion that will, in turn, causes further increases in sodium retention by the kidneys. Because of the low arterial pressure that occurs in compensated heart failure, the sympathetic output increases. One of the results is a sympathetic vasoconstriction (not vasodilation) of the afferent arterioles of the kidney. This decreases the glomerular hydrostatic pressure and the glomerular filtration rate, resulting in an increase in sodium and water retention in the body. The excess sodium in the body increases osmolality, which increases the release of antidiuretic hormone, which causes renal water retention (but not sodium retention).

TMP14 p. 276

105. C) During acute pulmonary edema, the increased fluid in the lungs diminishes the oxygen content in the blood. This decreased oxygen weakens the heart even further and causes arteriolar dilation in the body. This results in increases in venous return of blood to the heart, which cause further leakage of the fluid in the lungs and further decreases in oxygen content in the blood. It is important to interrupt this vicious circle to save a patient's life. This can be interrupted by placing tourniquets on all four limbs, which effectively removes blood volume from the chest. The patient can also breathe oxygen, and a bronchodilator can be administered. Furosemide can be administered to reduce some of the fluid volume in the body and especially in the lungs. One thing you do not want to do is infuse whole blood or an electrolyte solution in this patient because it may exacerbate the pulmonary edema that is already present.

TMP14 p. 277

106. D) Cardiogenic shock results from a weakening of the cardiac muscle many times after coronary thrombosis, which can result in a vicious circle because of low cardiac output resulting in a low diastolic pressure. This causes a decrease in coronary flow, which decreases the cardiac strength even more. Therefore, arterial pressure, particularly diastolic pressure, must be increased in patients with cardiogenic shock with either vasoconstrictors or volume expanders. In this patient, the best answer is to infuse plasma. Placing tourniquets on all four limbs decreases the central blood volume, which would worsen the condition of the patient in shock.

TMP14 p. 275

107. B) This patient has a resting cardiac output of 4 l/min, and his cardiac reserve is 300% of this resting cardiac output or 12 l/min. This gives a total maximum cardiac output of 16 l/min. Therefore, the cardiac reserve is the percentage increase that the cardiac output can be elevated over the resting cardiac output.

TMP14 pp. 277–278

108. B) Several factors cause sodium retention during heart failure, including aldosterone release, decreased glomerular filtration rate, and increased angiotensin II release. A decrease in mean arterial pressure also

results in decreases in glomerular hydrostatic pressure and causes a decrease in renal sodium excretion. During heart failure, blood volume increases, resulting in an increased cardiac stretch. In particular, the atrial pressure increases, causing a release of atrial natriuretic factor, resulting in an increase in renal sodium excretion.

TMP14 pp. 276–277

109. D) There is a vicious circle of cardiac deterioration in cardiogenic shock. A weakened heart causes a decreased cardiac output, which decreases arterial pressure. The decreased arterial pressure, particularly the decrease in diastolic pressure, decreases the coronary blood flow and further weakens the heart and thus further decreases cardiac output. The therapy of choice for a patient in cardiogenic shock is to increase the arterial pressure either with a vasoconstrictor drug or with a volume-expanding drug. Placing tourniquets on the four limbs, withdrawing a moderate amount of blood, or administering furosemide decreases the thoracic blood volume and thus worsens the condition of the patient in cardiogenic shock.

TMP14 p. 275

110. A) In unilateral right heart failure, the right atrial pressure increases, and the overall cardiac output decreases, which results in a decrease in arterial pressure and urinary output. However, left atrial pressure does not increase but in fact decreases.

TMP14 p. 275

111. B) During compensated heart failure, many factors combine to increase cardiac output so it returns to normal. The kidneys decrease their urinary output of sodium and water to increase the blood volume. This action, when combined with a depressed cardiac output curve, increases right atrial pressure. Mean systemic filling pressure increases (not decreases), and the venous return of blood back toward the heart thus increases right atrial pressure. Heart rate is normal, and sweating and dyspnea are absent in the chronic stages of compensated failure.

TMP14 pp. 272–273, 278–279

112. A) Reduction of fluid in the lungs can prevent rapid deterioration in patients with acute pulmonary edema. Furosemide causes venodilation, which reduces thoracic blood volume and acts as a powerful diuretic. These both reduce excess fluid in the lungs. Blood can actually be removed in moderate quantities from the patient to decrease the volume of blood in the chest. Patients should also breathe oxygen to increase the oxygen levels in the blood. However, they should never be given a volume expander, such as saline, plasma, whole blood, or dextran, because it could worsen the pulmonary edema. Norepinephrine would be of little help in treating pulmonary edema.

TMP14 p. 277

113. B) In compensated heart failure, mean systemic filling pressure increases because of hypervolemia, and cardiac output is often at normal values. The patient has air hunger, called dyspnea, and excess sweating occurs in the early phases of compensated heart failure. However, right atrial pressure becomes elevated to very high values in these patients and is a hallmark of this disease.

TMP14 pp. 272–273, 278–279

114. B) Mean systemic pressure is increased by factors that increase blood volume or decrease vascular capacity. Sympathetic inhibition and venous dilation both decrease the mean systemic filling pressure. In congestive heart failure, the kidneys retain great quantities of sodium and water, resulting in an increase in blood volume, which causes large increases in mean systemic filling pressure.

TMP14 pp. 272–274

115. A) During compensated heart failure, release of angiotensin II and aldosterone is increased, causing the kidneys retain sodium and water, which increases the blood volume in the body and the venous return of blood to the heart. This situation results in an increase in right atrial pressure. Increased sympathetic output during compensated heart failure increases heart rate. Air hunger, called dyspnea, occurs during any type of exertion. The patient also has orthopnea, which is the air hunger that occurs from being in a recumbent position.

TMP14 pp. 271–273

116. B) During decompensated heart failure, cardiac output decreases because of weakness of the heart and edema of the cardiac muscle. Pressures in the pulmonary capillary system increase, including the pulmonary capillary pressure and the mean pulmonary filling pressure. Depletion of norepinephrine in the endings of the cardiac sympathetic nerves is another factor that causes weakness of the heart.

TMP14 pp. 273–274, 279–280

117. D) In decompensated heart failure, the kidneys retain sodium and water, which causes weight gain and an increase in blood volume. This situation increases the mean systemic filling pressure, which also stretches the heart. Therefore, decreased mean systemic filling pressure does not occur in decompensated heart failure. The excess blood volume often overstretches the sarcomeres of the heart, which prevents them from achieving their maximal tension. An excess central fluid volume also results in orthopnea, which is the inability to breathe properly except in the upright position.

TMP14 pp. 273–274, 279–280

118. C) The mean electrical axis of the QRS of this patient is shifted rightward to 170 degrees, which indicates that the right side of the heart is involved. Both

aortic stenosis and mitral regurgitation cause a leftward shift of the QRS axis. Mitral stenosis does not affect the left ventricle, but in severe enough circumstances, it could cause an increase in pulmonary artery pressure, which would cause an increase in pulmonary capillary pressure at the same time. Tricuspid stenosis does not affect the right ventricle. Therefore, pulmonary valve stenosis is the only condition that fits this set of symptoms.

TMP14 pp. 286–287, 290

119. A) The fourth heart sound occurs at the end of diastole and is caused by inrushing of blood into the ventricles due to atrial contraction. The first heart sound is caused by closing of the A-V valves. The closing of the aortic and pulmonary valves at the end of systole causes the second heart sound. This initiates a vibration throughout the ventricles, aorta, and pulmonary artery. The third heart sound is caused by inrushing of blood into the ventricles in the early to middle part of diastole.

TMP14 p. 284

120. B) Blowing murmurs of relatively high pitch are usually murmurs associated with valvular insufficiency. The key pieces of data to identify this murmur are the systolic and diastolic pressures. Aortic valve regurgitation typically has a high pulse pressure, which is the systolic – diastolic pressure and in this case is 100 mm Hg. Also notice that the diastolic pressure decreases to very low values of 40 mm Hg as the blood leaks back into the left ventricle.

TMP14 pp. 286–287

121. E) Left ventricular hypertrophy occurs when the left ventricle either has to produce high pressure or when it pumps extra volume with each stroke. During aortic regurgitation, extra blood leaks back into the ventricle during the diastolic period. This extra volume must be expelled during the next heartbeat. During mitral regurgitation, some blood gets pumped out into the aorta, while at the same time blood leaks back into the left atrium. Therefore, the left ventricle is pumping extra volume with each heartbeat. During aortic stenosis, the left ventricle must contract very strongly, producing high wall tension to increase the aortic pressure to the values high enough to expel blood into the aorta. During mitral stenosis, the ventricle is normal because the atrium produces the extra pressure to get blood through the stenotic mitral valve.

TMP14 pp. 286–287

122. E) Several diastolic murmurs can be heard easily with a stethoscope. During diastole, aortic and pulmonary valve regurgitation occur through the insufficient valves causing the heart murmur at this time. Tricuspid and mitral stenosis are diastolic murmurs because blood flows through the restricted valves during the diastolic period. Patent ductus arteriosus is heard in both systole and diastole.

TMP14. pp. 289–290

123. C) Aortic stenosis has a very high ventricular systolic pressure. Diastolic filling of the ventricle requires a much higher left atrial pressure. However, tricuspid stenosis and regurgitation, pulmonary valve regurgitation, and pulmonary stenosis are associated with an increase in right atrial pressure and should not affect pressure in the left atrium.

TMP14 pp. 286–287

124. B) This patient has a QRS axis of –45 degrees, indicating a leftward axis shift. In other words, the left side of the heart is enlarged. In aortic valve stenosis, the left side of the heart is enlarged because of the extra tension the left ventricular walls must exert to expel blood out the aorta. Therefore, these symptoms fit with a patient with aortic stenosis. In pulmonary valve stenosis, the right side of the heart hypertrophies, and in mitral valve stenosis, there is no left ventricular hypertrophy. In tricuspid valve regurgitation, the right side of the heart enlarges, and in tricuspid valve stenosis, no ventricular hypertrophy occurs.

TMP14 pp. 286–287

125. C) This patient has a heart murmur heard maximally in the "pulmonary area of cardiac auscultation." The high pitch indicates regurgitation. The rightward axis shift indicates that the right side of the heart has hypertrophied. The two choices that have a rightward axis shift are pulmonary valve regurgitation and tetralogy of Fallot. In tetralogy of Fallot, the arterial blood oxygen content is low, which is not the case with this patient. Therefore, pulmonary valve regurgitation is the correct answer.

TMP14 pp. 283–288

126. A) Right ventricular hypertrophy occurs when the right heart has to pump a higher volume of blood or pump it against a higher pressure. Tetralogy of Fallot is associated with right ventricular hypertrophy because of the increased pulmonary valvular resistance, and this also occurs during pulmonary artery stenosis. Tricuspid insufficiency causes an increased stroke volume by the right heart, which causes hypertrophy. However, tricuspid stenosis does not affect the right ventricle.

TMP14 pp. 290–291

127. E) Mitral stenosis is heard during diastole only. Aortic stenosis, tricuspid valve regurgitation, interventricular septal effect, and patent ductus arteriosus are clearly heard during systole. However, patent ductus arteriosus is also heard during diastole.

TMP14 p. 286

128. A) In tetralogy of Fallot, there is an interventricular septal defect as well as stenosis of either the pulmo-

nary artery or the pulmonary valve. Therefore, it is very difficult for blood to pass into the pulmonary artery and into the lungs to be oxygenated. Instead the blood partially shunts to the left side of the heart, thus bypassing the lungs. This situation results in low arterial oxygen content.

TMP14 pp. 290–291

129. B) The first heart sound by definition is always associated with the closing of the A-V valves. The heart sounds are usually not associated with opening of any of the valves but with the closing of the valves and the associated vibration of the blood and the walls of the heart. One exception is an opening snap in some mitral valves.

TMP14 p. 283

130. B) In tetralogy of Fallot, an interventricular septal defect and increased resistance in the pulmonary valve or pulmonary artery cause partial blood shunting toward the left side of the heart without going through the lungs. This situation results in a severely decreased arterial oxygen content. The interventricular septal defect causes equal systolic pressures in both cardiac ventricles, which causes right ventricular hypertrophy and a wall thickness very similar to that of the left ventricle.

TMP14 p. 290

131. C) Mitral regurgitation and aortic stenosis are murmurs heard during the systolic period. A ventricular septal defect murmur is normally heard only during the systolic phase. Tricuspid valve stenosis and patent ductus arteriosus murmurs are heard during diastole. However, a patent ductus arteriosus murmur is also heard during systole.

TMP14 pp. 286, 289–290

132. E) The third heart sound is associated with inrushing of blood into the ventricles in the early to middle part of diastole. The next heart sound, the fourth heart sound, is caused by inrushing of blood in the ventricles caused by atrial contraction. The first heart sound is caused by the closing of the A-V valves, and the second heart sound is caused by the closing of the pulmonary and aortic valves.

TMP14 pp. 283–284

133. A) A number of things occur in progressive shock, including increased capillary permeability, which allows fluid to leak out of the vasculature, thus decreasing the blood volume. Other deteriorating factors include vasomotor center failure, peripheral circulatory failure, decreased cellular mitochondrial activity, and acidosis throughout the body. Usually, urine output strikingly decreases; therefore, the increased urinary output answer is incorrect. Tissue pH decreases, and reverse stress relaxation of the veins occurs.

TMP14 pp. 296–298

134. A) Sympathomimetic drugs are given to counteract hypotension during a number of conditions. These conditions include spinal cord injury in which the sympathetic output is interrupted. Sympathomimetic drugs are also given during very deep anesthesia, which decreases the sympathetic output, and during anaphylactic shock that results from histamine release and the accompanying vasodilatation. Sympathomimetic drugs, such as norepinephrine, increase blood pressure by causing a vasoconstriction. Shock caused by excess vomiting, hemorrhage, or excessive administration of diuretics results in fluid volume depletion, resulting in decreased blood volume and decreased mean systemic filling pressure. Administering a balanced electrolyte solution best counteracts this condition.

TMP14 pp. 299–301

135. D) Too deep a level of anesthesia can decrease sympathetic tone and reduce arterial pressure enough to induce shock. To replace the sympathetic tone that was lost, the optimal therapy is infusion of a sympathomimetic drug. Infusion of red blood cells, plasma, or electrolytes would be of little benefit.

TMP14 pp. 299–301

136. D) The patient received an influenza inoculation and quickly went into shock, which leads one to believe that he may be in anaphylactic shock. Anaphylactic shock is a state of extreme vasodilation because of histamine release. Antihistamines would be somewhat helpful, but they are very slow acting, and the patient could die in the meantime. Therefore, a very rapid-acting agent must be used, such as a sympathomimetic drug.

TMP14 pp. 299–301

137. E) In compensated hemorrhagic shock, a number of factors prevent the progression of the shock, including increased heart rate. Also occurring is reverse stress relaxation in which the vasculature, particularly the veins, constrict around the available blood volume. Increased ADH release also occurs, which causes water retention from the kidney but also vasoconstriction of the arterioles. A CNS ischemic response also occurs if the blood pressure drops to very low values, causing an increase in sympathetic output. Increased absorption of interstitial fluid through the capillaries also occurs, which increases the volume in the vasculature.

TMP14 p. 295

138. E) Spinal anesthesia, especially when the anesthesia extends all the way up the spinal cord, can block the sympathetic nervous outflow from the spinal cord. This can be a very potent cause of neurogenic shock. The therapy of choice is to replace the sympathetic tone that was lost in the body. The best way to in-

crease the sympathetic tone is by infusing a sympathomimetic drug.
TMP14 pp. 299–301

139. A) This patient has obviously lost a lot of blood because of the motorcycle wreck. The most advantageous therapy is to replace what was lost in the accident. This would be whole blood, which is much superior to a plasma infusion, because the patient is also receiving red blood cells that have a much superior oxygen-carrying capacity than the plasma component of blood. Sympathetic nerves are firing very rapidly in this condition, and an infusion of a sympathomimetic agent would be of little advantage.
TMP14 p. 301

140. C) In hemorrhagic shock, anaphylactic shock, and neurogenic shock, the venous return of blood to the heart markedly decreases. However, in septic shock, the cardiac output increases in many patients because of vasodilation in affected tissues and a high metabolic rate causing vasodilation in other parts of the body.
TMP14 p. 300

141. E) This patient has been hemorrhaging, and the optimal therapy is to replace the blood he has lost. Unfortunately, no blood is available, and therefore we must choose next best therapy, which is increasing the volume of his blood. Thus, plasma infusion is the next best therapy because its high colloid osmotic pressure will help the infused fluid stay in the circulation much longer than would a balanced electrolyte solution.
TMP14 p. 301

142. B) Intestinal obstruction often causes severe reduction in plasma volume. Obstruction causes a distention of the intestine and partially blocks the venous blood flow in the intestines. This partial blockage results in an increased intestinal capillary pressure, which causes fluid to leak from the capillary into the walls of the intestines and into the intestinal lumen. The leaking fluid has a high protein content very similar to that of the plasma, which reduces the total plasma protein and the plasma volume. Therefore, the therapy of choice would be to replace the fluid lost by infusing plasma.
TMP14 pp. 299, 301

143. A) In progressive shock, because of the poor blood flow, the pH in the tissues throughout the body decreases. Many vessels become blocked because of local blood agglutination, which is called "sludged blood." Patchy areas of necrosis also occur in the liver. Mitochondrial activity decreases and capillary permeability increases. There is also an increased release of hydrolases by the lysosomes and a decrease in cellular metabolism of glucose.
TMP14 pp. 296–298

144. A) Anaphylaxis is an allergic condition that results from an antigen-antibody reaction that takes place after exposure of an individual to an antigenic substance. The basophils and mast cells in the pericapillary tissues release histamine or histamine-like substances. The histamine causes venous dilation, dilation of arterioles, and greatly increased capillary permeability with rapid loss of fluid and protein into the tissue spaces. This response reduces venous return and often results in anaphylactic shock.
TMP14 pp. 300–301

145. B) This patient has a resting cardiac output of 4.8 l/min, and a cardiac output of 19.2 l/min after maximum exercise. The cardiac reserve [(19.2 – 4.8)/4.8 =3.0)] is the percentage increase that the cardiac output can be elevated *over the resting cardiac output.* Therefore, her cardiac reserve is 300% (3-fold) greater than her resting cardiac output.
TMP14 pp. 277–278

146. C) Immediately after heart damage, a compensatory activation of the sympathetic nervous system develops, which helps attenuate the *decreased* cardiac output (heart muscle is damaged) and improve cardiovascular dynamics (e.g. mean systemic filling pressures, venous return). Damming of blood develops in the failing heart due to depressed contraction. Parasympathetics are not activated as a compensatory mechanism. The renin-angiotensin system activates later.
TMP14 pp. 271–273

147. B) Cardiac reserve is always reduced in heart failure, even when compensatory mechanisms and/or treatments have been effective in restoring cardiovascular hemodynamics at rest. Cardiac failure is *the failure of the heart to pump enough blood to satisfy the needs of the body*, which may develop with low or high cardiac output. A low cardiac output will result in low blood flow into the kidneys, reduced glomerular filtration, and a low urinary output.
TMP14 pp. 271–273, 277–278

148. C) The pumping ability of the heart is compromised in low-output heart failure. Moderate fluid retention will improve venous return and "prime" the partially damaged heart in order to increase cardiac output. Based on the Frank-Starling law of the heart (the student should be familiar with this mechanism), this will result in an increased preload of the heart. Afterload and isovolumetric contraction are unchanged. Aortic pressure would be preserved. Peripheral edema may develop if fluid retention progresses.
TMP14 p. 272

149. A) The severe damage of the heart and the failure to increase CO enough to satisfy the needs of the body will lead to a *progressive* fluid retention (constant low

flow to the kidneys will continuously activate mechanisms of fluid retention), increased mean filling pressures, and increased right atrial pressure. The progressive fluid retention in an already weak heart will lead to a deleterious cycle that will progresses until the heart is so overstretched and/or edematous that it fails completely.

TMP14 pp. 273–274, 279–280

150. C) Mitral regurgitation produces a systolic murmur. The history of dilated cardiomyopathy suggests mitral regurgitation. The lack of cyanosis and age of the patients eliminates tetralogy of Fallot as a likely diagnosis. The characteristics of the murmur eliminates patent ductus arteriosus (machinery murmur), mitral and tricuspid stenosis (diastolic murmurs).

TMP14 pp. 286, 288

151. D) The diastolic murmur of mitral stenosis is due to the narrow opening of the mitral valve, making it difficult for the blood to move from the left atria to the left ventricle. A *consequence* of mitral stenosis is an increase in pressure of pulmonary vessels, but this is not a *cause* of the murmur.

TMP14 pp. 286, 288

152. C) Abnormalities of the aortic valve (outflow tract of the left ventricle) associates with significant increases in LV pressure and as such, increases in afterload (which does not occur in mitral stenosis/regurgitation). Preload is unchanged in aortic stenosis. Isovolumetric systolic period is lost in aortic and in mitral regurgitation. Tricuspid stenosis does not associate with loss of *left ventricular* isovolumetric diastolic period.

TMP14 pp. 286–287

153. B) A right-to-left shunt as observed in tetralogy of Fallot results in almost 2/3 of the blood passing from the right ventricle into aorta without oxygenation, bypassing the lungs (right-to-left shunt). As a result, oxygen in the blood is low and the infant develops cyanosis (blue baby) and rapidly shows a significant enlargement of the right ventricle. Patent ductus arteriosus (a left-to-right shunt) will not show cyanosis at this stage and the blood is usually hyper-oxygenated. An interatrial septal defect associates with a left-to-right shunt. Tricuspid stenosis does not cause low oxygen in blood or associate with enlargement of the right ventricle.

TMP14 pp. 289–290

154. A) Without intervention (i.e. volume replacement) or after entering into the progressive phase, cardiac function progressively declines, which constitutes the most important factor for the progression towards irreversibility of shock. Autoregulation cannot prevent (or reverse) the *irreversible* phase of shock.

TMP14 pp. 295–297

155. C) Based on the information included that states a massive heart attack, a significant delay to initiate treatment, and the lack of responses to treatments, the patient is most likely at the irreversible stage of shock from cardiogenic origin (not hemorrhagic). More fluids will not change the course of shock at this stage. Diminished delivery of oxygen will lead to tissue acidosis, and tissue ischemia facilitates release of toxins that further contribute to the generalized cellular deterioration.

TMP14 pp. 296–299

156. C) The patient is in ventricular fibrillation, thus in cardiac/circulatory arrest. There is no effective mechanical activity in the left ventricle.

TMP14 pp. 301–302

157. D) Dextran is a large polysaccharide that do not pass through the capillary pores and serves as a colloid osmotic agent (as do plasma proteins). Anti-histamine agents target histamine, which is massively released in anaphylactic shock. Glucocorticoids stabilize lysosomes and help to prevent their disruption and, consequently, the release of enzymes to the cellular cytoplasm.

TMP14 p. 301

UNIT V

The Body Fluids and Kidneys

1. All of the following changes would tend to cause interstitial fluid edema in a tissue EXCEPT one. Which one is the EXCEPTION?

   A) Increased venous resistance
   B) Increased venous pressure
   C) Decreased arteriolar resistance
   D) Increased capillary filtration coefficient
   E) Increased plasma protein concentration

2. Calculate the approximate extracellular fluid osmolarity of a patient after administration of 2.0 l of 5% glucose solution, assuming complete metabolism of the glucose, osmotic equilibrium and no excretion of water or electrolytes. Also assume the following initial conditions prior to infusing the glucose solution:

   Body weight = 50 kg
   Plasma sodium concentration = 170 mmol/l
   Plasma osmolarity = 360 mOsm/l
   Intracellular fluid volume = 40% of body weight
   Extracellular fluid volume = 20% of body weight
   Molecular wt of glucose = 180 g/mole

   A) 264 mOsm/l
   B) 282 mOsm/l
   C) 306 mOsm/l
   D) 319 mOsm/l
   E) 338 mOsm/l
   F) 355 mOsm/l
   G) 360 mOsm/l

3. Calculate the approximate extracellular fluid volume of a patient after administration of 3.0 l of 5% glucose solution, assuming complete metabolism of the glucose, osmotic equilibrium, and no excretion of water or electrolytes. Also assume the following initial conditions prior to infusing the glucose solution:

   Body weight = 50 kg
   Plasma sodium concentration = 170 mmol/l
   Plasma osmolarity = 360 mOsm/l
   Intracellular fluid volume = 40% of body weight
   Extracellular fluid volume = 20% of body weight
   Molecular wt of glucose = 180 g/mole

   A) 8.0 l
   B) 10.7 l
   C) 11.7 l
   D) 130 l
   E) 20.3 l
   F) 21.3 l
   G) 30.0 l

4. A patient with cirrhosis experiences a doubling of his serum creatinine over a 6-month period after sustained heavy ingestion of a nonsteroidal antiinflammatory drug (NSAID) for his arthritis. Which of the following is the best explanation for his increased serum creatinine?

   A) Increased efferent arteriolar resistance which reduced glomerular filtration rate (GFR)
   B) Decreased Bowman's capsule pressure which reduced GFR
   C) Increased afferent arteriolar resistance which reduced GFR
   D) Increased glomerular capillary filtration coefficient which reduced GFR
   E) Increased renal prostaglandins due to the NSAID
   F) Increased nitric oxide formation due to the NSAID

5. Administration of empagliflozin, an inhibitor of sodium-glucose co-transporter 2 (SGLT2), would be expected to cause which of the following sets of changes compared with normal?

	GFR	Resistance Afferent Arteriole	Renal Blood Flow
A)	↔	↔	↔
B)	↔	↔	↓
C)	↓	↑	↓
D)	↓	↑	↔
E)	↓	↓	↓
F)	↑	↓	↑

6. Given the following measurements, calculate the approximate filtration fraction:

   Glomerular capillary hydrostatic pressure = 60 mm Hg
   Colloid osmotic pressure in the glomerular capillaries = 30 mm Hg
   Bowman's space hydrostatic pressure = 20 mm Hg
   Glomerular capillary filtration coefficient (Kf) = 10 ml/min/mm Hg
   Renal plasma flow = 600 ml/min
   Hematocrit = 0.4

A) 10 mm Hg
B) 100 ml/min
C) 0.100
D) 0.167
E) 0.200
F) 0.333

7. Which of the following statements is *incorrect*?
   A) Creatinine concentration in the urine is normally higher than in the glomerular filtrate.
   B) Urea concentration in the urine is normally higher than in the glomerular filtrate.
   C) The proximal tubules normally reabsorb almost all of the glucose filtered by the glomerular capillaries.
   D) HCO_3^- concentration in the urine is normally higher than in the glomerular filtrate.
   E) Organic acids and bases are secreted mainly by the proximal tubules.
   F) Sodium concentration remains relatively constant as tubular fluid flows along the proximal tubule.

8. A patient with diabetes mellitus has a glomerular filtration rate of 100 ml/min, a urine flow rate of 4.0 ml/min, and a urine glucose concentration of 2 mg/ml. If he has a kidney transport maximum for glucose of 200 mg/min, what would be his approximate rate of glucose excretion?
   A) 0 mg/min
   B) 8 mg/min
   C) 100 mg/min
   D) 180 mg/min
   E) 300 mg/min
   F) Urinary excretion rate of glucose cannot be determined from these data

9. As tubular fluid passes along a juxtamedullary nephron of a person with severe central diabetes insipidus and essentially no antidiuretic hormone, where is the osmolarity lowest?
   A) Bowman's capsule (glomerular filtrate)
   B) Fluid leaving the proximal tubule and entering the loop of Henle
   C) Fluid leaving the descending thin limb and entering the ascending thin limb of the loop of Henle
   D) Fluid leaving the thick ascending segment of the loop of Henle and entering the early distal tubule
   E) Fluid in the cortical collecting tubules
   F) Fluid leaving the collecting ducts (urine)

10. If GFR = 60 ml/min, urine flow rate = 2.0 ml/min, plasma K^+ concentration = 4.0 mmol/l, and urine K^+ concentration = 80 mmol/l, what is the approximate rate of K^+ excretion?
    A) 0.08 mmol/min
    B) 0.16 mmol/min
    C) 0.32 mmol/min
    D) 16 mmol/min
    E) 160 mmol/min
    F) Excretion rate of K^+ cannot be determined from these data

11. If the glomerular filtration rate (GFR) of a patient is reduced to 50% of normal and sustained at that level, you would expect to find _____ renal creatinine excretion rate, _____ renal creatinine clearance, and _____ serum creatinine concentration 6 weeks after the decrease in GFR compared with normal. Assume steady-state conditions and that the patient has maintained the same diet.
    A) Decreased, decreased, increased
    B) Decreased, no change, increased
    C) No change, increased, increased
    D) No change, no change, increased
    E) No change, decreased, increased
    F) Decreased, no change, decreased

12. If glomerular filtration rate suddenly decreases by 50%, from 80 ml/min to 40 ml/min and tubular fluid reabsorption simultaneously decreases from 78 ml/min to 40 ml/min, which of the following changes in urinary excretion rate will occur (assuming that the changes in GFR and tubular fluid reabsorption are maintained)?
    A) Urine flow rate will decrease to zero
    B) Urine flow rate will not change
    C) Urine flow rate will decrease by 50%
    D) Urine flow rate will increase by 50%

13. Calculate the approximate total renal plasma flow given the following data:
    Urine PAH concentration = 200 μg/ml
    Urine flow rate = 2 ml/min
    Arterial plasma paraaminohippuric acid (PAH) concentration = 1.0 μg/ml
    Renal venous PAH concentration = 0.2 μg/ml
    Hematocrit = 0.4
    A) 120 ml/min
    B) 200 ml/min
    C) 400 ml/min
    D) 500 ml/min
    E) 667 ml/min
    F) 833 ml/min

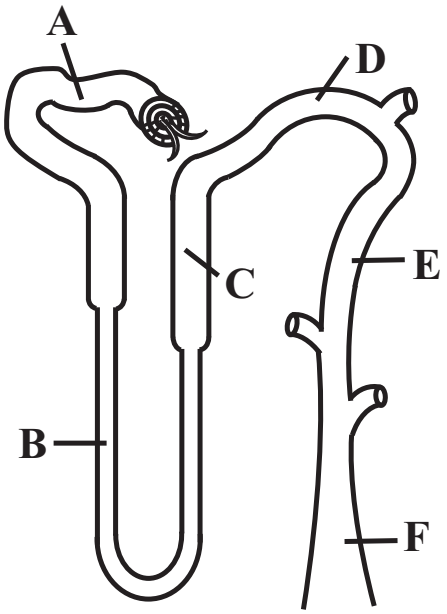
14. Which of the following occurs in type A intercalated cells of the collecting tubules?
    A) Secretion of H^+, reabsorption of HCO_3^-, and reabsorption of K^+
    B) Secretion of H^+, reabsorption of HCO_3^-, and secretion of K^+
    C) Secretion of K^+, reabsorption of Na^+, and reabsorption of HCO_3^-
    D) Reabsorption of H^+, secretion of HCO_3^-, and secretion of K^+
    E) Reabsorption of H^+, secretion of HCO_3^-, and reabsorption of K^+

15. Which of the following statements is *incorrect*?
    A) Beta-adrenergic stimulation would tend to cause hypokalemia by shifting potassium from the extracellular fluid into the cells

B) A powerful diuretic that inhibits proximal tubule or loop of Henle sodium reabsorption would tend to increase potassium secretion by the collecting tubules
C) Injection of excess insulin into a patient would tend to cause hypokalemia
D) Strenuous, sustained exercise may tend to cause significant hyperkalemia
E) Increased extracellular fluid osmolarity would tend to cause hypokalemia

16. Which of the following statements is *incorrect*?
A) Urea transporters UT-A1 and UTA-3 in the collecting ducts are activated by antidiuretic hormone (ADH)
B) Urea reabsorption in the inner medullary collecting duct is greater than in the distal tubule during dehydration
C) Increased ADH markedly increases urea reabsorption by the cortical collecting tubule
D) The inner medullary collecting tubule reabsorbs more urea during antidiuresis than the thick ascending limb of Henle's loop
E) The cortical collecting tubule is less permeable to urea than is the inner medullary collecting duct during antidiuresis
F) Passive diffusion of urea into the thin loops of Henle is facilitated by the urea transporter UT-A2

17. In a dehydrated person with normal kidneys and high ADH levels, which part of the nephron normally reabsorbs the smallest amount of water (see figure below of a renal tubule)?



A) A
B) B
C) C
D) D
E) E
F) F

18. Acute metabolic alkalosis tends to _____K^+ secretion by the cortical collecting tubules and _____ plasma K^+ concentration.
A) decrease, decrease
B) decrease, increase
C) increase, increase
D) increase, decrease
E) cause no change in, increase
F) cause no change in, cause no change in

19. Which of the following statements is *incorrect*?
A) Carbonic anhydrase inhibitors tend to cause metabolic acidosis.
B) Thiazide diuretics inhibit the Na-Cl co-transporter in the distal tubules.
C) Osmotic diuretics tend to increase potassium secretion.
D) Aldosterone antagonists (e.g., spironolactone) tend to cause hypokalemia.
E) Sodium channel blockers (e.g., amiloride) inhibit sodium transport across the luminal membrane of the collecting tubules.
F) Loop diuretics (e.g., furosemide) tend to cause hypokalemia.

20. Glomerular filtration rate (creatinine clearance) in a patient with uncontrolled type 2 diabetes has decreased from 100 ml/min to 50 ml/min over the past 4 years. She has poorly controlled hypertension, and her plasma pH is 7.16. Which of the following changes, compared with before she developed renal disease, would you expect to find, assuming steady-state conditions and no changes in protein or electrolyte intake?

	Sodium Excretion Rate	Creatinine Excretion Rate	Plasma Creatinine Concentration	Plasma Bicarbonate Concentration	Ammonium Excretion Rate
A)	↓	↓	↑	↑	↑
B)	↓	↓	↓	↓	↑
C)	↔	↔	↑	↓	↑
D)	↔	↔	↑	↓	↔
E)	↔	↓	↑	↓	↔
F)	↓	↓	↓	↓	↓

21. A patient has the following laboratory values:
Arterial pH = 7.18
Plasma HCO_3^- = 10 mEq/l
Plasma chloride concentration = 100 mEq/l
Arterial P_{CO_2} = 28 mm Hg
Plasma Na^+ concentration = 141 mEq/l

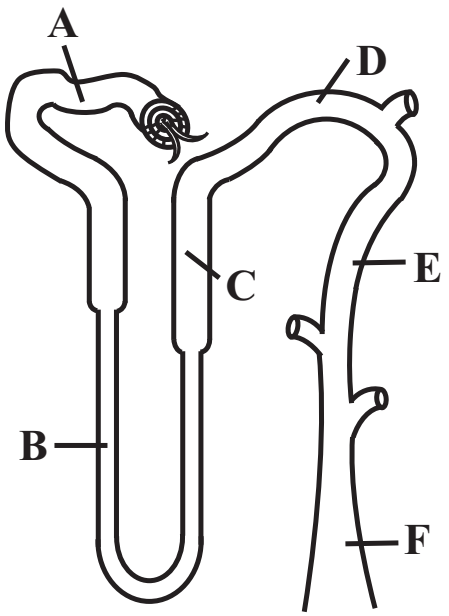
What is the most likely cause of his acid-base disturbance?

A) Emphysema
B) Renal tubular acidosis
C) Severe diarrhea
D) Methanol poisoning
E) Ingestion of excess sodium bicarbonate

22. Atrial natriuretic peptide causes which of the following effects?
    A) Reduced renal tubular sodium reabsorption
    B) Reduced renin secretion
    C) Increased renal sodium excretion
    D) Only A and C
    E) A, B, and C

23. If creatinine clearance = 100 ml/min, urine flow rate = 1.0 ml/min, plasma Na^+ concentration = 140 mmol/l, and urine Na^+ concentration = 80 mmol/l, what is the approximate rate of Na^+ excretion?
    A) 0.08 mmol/min
    B) 0.16 mmol/min
    C) 16 mmol/min
    D) 160 mmol/min
    E) Excretion rate of Na^+ cannot be calculated from these data

24. If a person maintains a high (150 mmol/day) potassium diet, which part of the nephron would be expected to reabsorb the most potassium? Choose the appropriate nephron site in the figure below.



    A) A
    B) B
    C) C
    D) D
    E) E
    F) F

25. Which of the following would tend to cause hypokalemia by shifting potassium from the extracellular fluid into the intracellular fluid?
    A) Metabolic alkalosis
    B) Insulin deficiency
    C) Aldosterone deficiency
    D) Beta-adrenergic receptor blockade
    E) Increased extracellular fluid osmolarity

26. What is the theoretical maximum clearance rate possible for a substance X that is freely filtered, actively secreted by the renal tubules, and completely cleared from the plasma given the following data?

    Glomerular filtration rate = 100 ml/min
    Plasma concentration of a substance X = 2 mg/ml
    Urine flow= 5 ml/min
    Renal plasma flow = 800 ml/min

    A) 5 ml/min
    B) 100 ml/min
    C) 200 ml/min
    D) 500 ml/min
    E) 800 ml/min
    F) 1000 ml/min

27. Which of the following solutions, when infused intravenously, would result in an increase in extracellular fluid volume, a decrease in intracellular fluid volume, and an increase in total body water after osmotic equilibrium?
    A) 1 l of 0.9% sodium chloride (NaCl) solution
    B) 1 l of 0.45% NaCl solution
    C) 1 l of 3% NaCl solution
    D) 1 l of 5% dextrose solution
    E) 1 l of pure water

28. Partial obstruction of a major vein draining a tissue would tend to _____ lymph flow rate, _____ interstitial fluid hydrostatic pressure, and _____ interstitial fluid protein concentration in the tissue drained by that vein.
    A) increase, increase, increase
    B) increase, increase, decrease
    C) increase, decrease, decrease
    D) decrease, decrease, decrease
    E) decrease, increase, increase
    F) decrease, increase, decrease

29. A 36-year-old woman reports headaches and frequent urination. Laboratory values reveal the following information.

    Urine specific gravity = 1.003
    Urine protein = negative
    Plasma sodium (Na^+) = 165 mmol/l
    Plasma potassium (K^+) = 4.4 mmol/l
    Plasma creatinine = 1.4 mg/dl
    Blood pressure = 88/40 mm Hg
    Heart rate = 115 beats/min

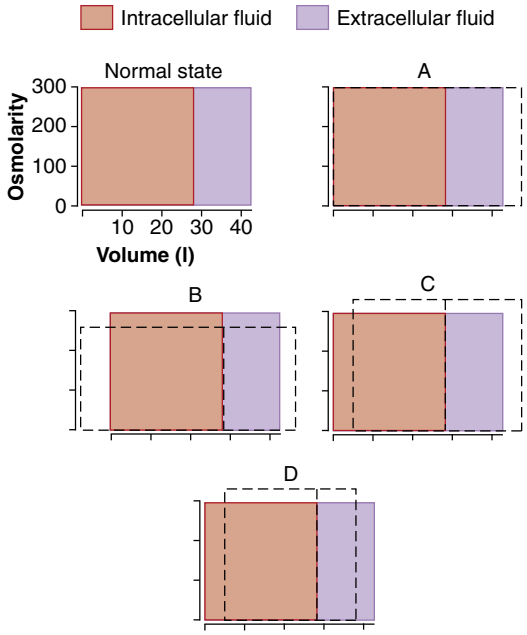
    What is the most likely cause of her elevated plasma Na^+ concentration?
    A) Primary aldosteronism
    B) Diabetes mellitus
    C) Diabetes insipidus
    D) Simple dehydration caused by insufficient water intake and heavy exercise

E) Bartter syndrome
F) Liddle syndrome

30. After receiving a kidney transplant, a patient has severe hypertension (170/110 mm Hg). A renal arteriogram indicates severe renal artery stenosis in his single remaining kidney, with a reduction in glomerular filtration rate (GFR) to 25% of normal. Which of the following changes, compared with normal, would be expected in this patient, assuming steady-state conditions?

A) A large increase in plasma sodium concentration
B) A reduction in urinary sodium excretion to 25% of normal
C) A reduction in urinary creatinine excretion to 25% of normal
D) An increase in serum creatinine to about four times normal
E) Normal renal blood flow in the stenotic kidney due to autoregulation

Questions 31–33



The figure above represents various states of abnormal hydration. In each diagram, the normal state (orange and lavender) is superimposed on the abnormal state (dashed lines) to illustrate the shifts in the volume (width of rectangles) and total osmolarity (height of rectangles) of the extracellular and intracellular fluid compartments. Use this figure to answer Questions 31–33.

31. Which diagram represents the changes (after osmotic equilibrium) in extracellular and intracellular fluid volume and osmolarity after the infusion of 1% dextrose?

A) A
B) B
C) C
D) D

32. Which diagram represents the changes (after osmotic equilibrium) in extracellular and intracellular fluid volume and osmolarity in a patient with the syndrome of inappropriate antidiuretic hormone (ADH; i.e., excessive secretion of ADH)?

A) A
B) B
C) C
D) D

33. Which diagram represents the changes (after osmotic equilibrium) in extracellular and intracellular fluid volumes and osmolarities after the infusion of 3% NaCl?

A) A
B) B
C) C
D) D

34. Which of the following tends to decrease potassium secretion by the cortical collecting tubule?

A) Increased plasma potassium concentration
B) A diuretic that decreases proximal tubule sodium reabsorption
C) A diuretic that inhibits the action of aldosterone (e.g., spironolactone)
D) Acute alkalosis
E) High sodium intake

35. Because the usual rate of phosphate filtration exceeds the transport maximum for phosphate reabsorption, which statement is true?

A) All the phosphate that is filtered is reabsorbed
B) More phosphate is reabsorbed than is filtered
C) Phosphate in the tubules can contribute significantly to titratable acid in the urine
D) The "threshold" for phosphate is usually not exceeded
E) Parathyroid hormone must be secreted for phosphate reabsorption to occur

Questions 36 and 37

Use the following clinical laboratory test results to answer Questions 36 and 37.

Urine flow rate = 1 ml/min
Urine inulin concentration = 100 mg/ml
Plasma inulin concentration = 2 mg/ml
Urine urea concentration = 50 mg/ml
Plasma urea concentration = 2.5 mg/ml

36. What is the GFR?

A) 25 ml/min
B) 50 ml/min
C) 100 ml/min
D) 125 ml/min
E) None of the above

37. What is the net urea reabsorption rate?

A) 0 mg/min
B) 25 mg/min
C) 50 mg/min

D) 75 mg/min
E) 100 mg/min

38. In normal kidneys, which of the following is true of the osmolarity of renal tubular fluid that flows through the early distal tubule in the region of the macula densa?
A) Usually isotonic compared with plasma
B) Usually hypotonic compared with plasma
C) Usually hypertonic compared with plasma
D) Hypertonic, compared with plasma, in antidiuresis

39. Which of the following changes would be expected in a patient with diabetes insipidus due to a lack of ADH secretion, assuming free access to water and normal thirst mechanisms for controlling water intake?

	Plasma Osmolarity Concentration	Plasma Sodium Concentration	Plasma Renin Concentration	Urine Volume
A)	↔	↔	↓	↑
B)	↔	↔	↑	↑
C)	↑	↑	↑	↑
D)	↑	↑	↔	↔
E)	↓	↓	↓	↔

40. A 26-year-old woman recently decided to adopt a healthier diet and eat more fruits and vegetables. As a result, her potassium intake increased from 80 to 160 mmol/day. Which of the following conditions would you expect to find 2 weeks after she increased her potassium intake, compared with before the increase?

	Potassium Excretion Rate	Sodium Excretion Rate	Plasma Aldosterone Concentration	Plasma Potassium Concentration
A)	↔	↔	↑	Large increase (>1 mmol/l)
B)	↔	↓	↑	Small increase (<1 mmol/l)
C)	↑ 2×	↔	↑	Small increase (<1 mmol/l)
D)	↑ 2×	↑	↓	Large increase (>1 mmol/l)
E)	↑ 2×	↑	↔	Large increase (>1 mmol/l)

41. When the dietary intake of K^+ increases, body K^+ balance is maintained by an increase in K^+ excretion primarily by which of the following?
A) Decreased glomerular filtration of K^+
B) Decreased reabsorption of K^+ by the proximal tubule
C) Decreased reabsorption of K^+ by the thick ascending limb of the loop of Henle
D) Increased K^+ secretion by the late distal and collecting tubules
E) Shift of K^+ into the intracellular compartment

42. Which of the following would cause the greatest decrease in GFR in a person with otherwise normal kidneys?
A) Decrease in renal arterial pressure from 100 to 80 mm Hg in a normal kidney
B) 50% increase in glomerular capillary filtration coefficient
C) 50% increase in proximal tubular sodium reabsorption
D) 50% decrease in afferent arteriolar resistance
E) 50% decrease in efferent arteriolar resistance
F) 5 mm Hg decrease in Bowman's capsule pressure

43. An 8-year-old boy is brought to your office with extreme swelling of the abdomen. His parents indicate that he had a very sore throat a "month or so" ago and that he has been "swelling up" since that time. He appears to be edematous, and when you check his urine, you find that large amounts of protein are being excreted. Your diagnosis is nephrotic syndrome subsequent to glomerulonephritis. Which of the following changes would you expect to find, compared with normal?

	Thoracic Lymph Flow	Interstitial Fluid Protein Concentration	Interstitial Fluid Hydrostatic Pressure	Plasma Renin Concentration
A)	↑	↓	↑	↑
B)	↑	↓	↑	↔
C)	↑	↓	↔	↑
D)	↓	↑	↔	↔
E)	↓	↓	↓	↓

44. A patient with severe hypertension (blood pressure 185/110 mm Hg) is referred to you. A renal magnetic resonance imaging scan shows a tumor in the kidney, and laboratory findings include a very high plasma renin activity of 12 ng angiotensin I/ml/h (normal = 1). The diagnosis is a renin-secreting tumor. Which of the following changes would you expect to find in this patient, under steady-state conditions, compared with normal?

	Plasma Aldosterone Concentration	Sodium Excretion Rate	Plasma Potassium Concentration	Renal Blood Flow
A)	↔	↓	↓	↑
B)	↔	↔	↓	↑
C)	↑	↔	↓	↓
D)	↑	↓	↔	↓
E)	↑	↓	↓	↔

45. The clinical laboratory returned the following values for arterial blood taken from a patient: plasma pH = 7.28, plasma HCO_3^- =32 mEq/l , and plasma partial pressure of carbon dioxide (P_{CO_2}) = 70 mm Hg. What is this patient's acid-base disorder?

A) Acute respiratory acidosis without renal compensation
B) Respiratory acidosis with partial renal compensation
C) Acute metabolic acidosis without respiratory compensation
D) Metabolic acidosis with partial respiratory compensation

46. The following laboratory values were obtained in a 58-year-old man:

Urine volume = 4320 ml of urine collected during the preceding 24 hours
Plasma creatinine = 3 mg/100 ml
Urine creatinine = 50 mg/100 ml
Plasma potassium = 4.0 mmol/l
Urine potassium = 30 mmol/l

What is his approximate GFR, assuming that he collected all of his urine in the 24-hour period?
A) 20 ml/min
B) 30 ml/min
C) 40 ml/min
D) 50 ml/min
E) 60 ml/min
F) 80 ml/min
G) 100 ml/min

Questions 47 and 48

A 65-year-old man had a heart attack and experiences cardiopulmonary arrest while being transported to the emergency department. Use the following laboratory values obtained from arterial blood to answer Questions 47 and 48.

Plasma pH = 7.12
Plasma P_{CO_2} = 60 mm Hg
Plasma HCO_3^- concentration = 19 mEq/l

47. Which of the following options best describes his acid-base disorder?
A) Respiratory acidosis with partial renal compensation
B) Metabolic acidosis with partial respiratory compensation
C) Mixed acidosis: combined metabolic and respiratory acidosis
D) Mixed alkalosis: combined respiratory and metabolic alkalosis

48. In this patient, which of the following laboratory results would be expected, compared with normal?
A) Increased renal excretion of bicarbonate (HCO_3^-)
B) Decreased urinary titratable acid
C) Increased urine pH
D) Increased renal excretion of ammonia (NH_4^+)

49. What would cause the greatest degree of hyperkalemia?
A) Increase in potassium intake from 60 to 180 mmol/day in a person with normal kidneys and a normal aldosterone system
B) Chronic treatment with a diuretic that inhibits the action of aldosterone
C) Decrease in sodium intake from 200 to 100 mmol/day
D) Chronic treatment with a diuretic that inhibits loop of Henle Na^+-$2Cl^-$-K^+ co-transport
E) Chronic treatment with a diuretic that inhibits sodium reabsorption in the collecting ducts

50. Which of the following changes would be expected in a patient with Liddle syndrome (i.e., excessive activity of amiloride-sensitive sodium channel in the collecting tubule) under steady-state conditions, assuming that the intake of electrolytes remained constant?

	Plasma Renin Concentration	Blood Pressure	Sodium Excretion Concentration	Plasma Aldosterone Concentration
A)	↔	↑	↓	↔
B)	↑	↑	↔	↑
C)	↑	↑	↓	↓
D)	↓	↑	↔	↓
E)	↓	↑	↓	↓
F)	↓	↓	↑	↑

51. A patient is referred for treatment of hypertension. After testing, you discover that he has a very high level of plasma aldosterone, and your diagnosis is Conn's syndrome. Assuming no change in electrolyte intake, which of the following changes would you expect to find, compared with normal?

	Plasma pH	Plasma K^+ Concentration	Urine K^+ Excretion	Urine Na^+ Excretion	Plasma Renin Concentration
A)	↑	↓	↔	↔	↓
B)	↓	↓	↔	↔	↓
C)	↑	↓	↑	↓	↓
D)	↑	↑	↔	↓	↑
E)	↑	↑	↑	↑	↑

52. Which change tends to increase GFR?
A) Increased afferent arteriolar resistance
B) Decreased efferent arteriolar resistance
C) Increased glomerular capillary filtration coefficient
D) Increased Bowman's capsule hydrostatic pressure
E) Decreased glomerular capillary hydrostatic pressure

53. Which of the following changes, compared with normal, would you expect to find 3 weeks after a patient ingested a toxin that caused sustained impairment of proximal tubular NaCl reabsorption? Assume that there has been no change in diet or ingestion of electrolytes.

	Glomerular Filtration Rate	Afferent Arteriolar Resistance	Sodium Excretion
A)	↔	↔	↑
B)	↔	↔	↑
C)	↓	↑	↑
D)	↓	↑	↔
E)	↑	↓	↔

54. A patient has the following laboratory values: arterial pH = 7.13, plasma HCO_3^- = 15 mEq/l, plasma chloride concentration = 118 mEq/l, arterial P_{CO_2} = 28 mm Hg, and plasma Na^+ concentration = 141 mEq/l. What is the most likely cause of his acidosis?
    A) Salicylic acid poisoning
    B) Diabetes mellitus
    C) Diarrhea
    D) Emphysema

55. The GFR of a 26-year-old man with glomerulonephritis decreases by 50% and remains at that level for one month. For which substance would you expect to find the greatest increase in plasma concentration?
    A) Creatinine
    B) K^+
    C) Glucose
    D) Na^+
    E) Phosphate
    F) H^+

56. Which changes would you expect to find after administering a vasodilator drug that caused a 50% decrease in afferent arteriolar resistance and no change in arterial pressure?
    A) Decreased renal blood flow, decreased GFR, and decreased peritubular capillary hydrostatic pressure
    B) Decreased renal blood flow, decreased GFR, and increased peritubular capillary hydrostatic pressure
    C) Increased renal blood flow, increased GFR, and increased peritubular capillary hydrostatic pressure
    D) Increased renal blood flow, increased GFR, and no change in peritubular capillary hydrostatic pressure
    E) Increased renal blood flow, increased GFR, and decreased peritubular capillary hydrostatic pressure

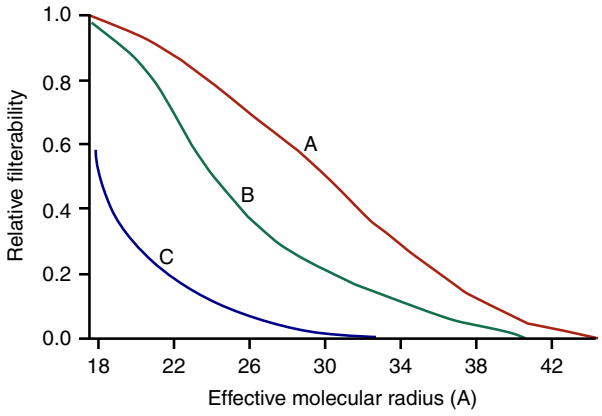
57. If the average hydrostatic pressure in the glomerular capillaries is 50 mm Hg, the hydrostatic pressure in the Bowman's space is 12 mm Hg, the average colloid osmotic pressure in the glomerular capillaries is 30 mm Hg, and there is no protein in the glomerular ultrafiltrate, what is the net pressure driving glomerular filtration?
    A) 8 mm Hg
    B) 32 mm Hg
    C) 48 mm Hg
    D) 60 mm Hg
    E) 92 mm Hg

58. In a patient who has chronic, uncontrolled diabetes mellitus, which set of conditions would you expect to find, compared with normal?

	Titratable Acid Excretion	NH^+ Excretion	HCO_3^- Excretion	Plasma P_{CO_2}
A)	↔	↑	↓	↔
B)	↓	↑	↔	↓
C)	↑	↑	↔	↑
D)	↑	↑	↓	↓
E)	↓	↓	↓	↓
F)	↔	↑	↓	↔

59. Intravenous infusion of 1 l of 0.45% NaCl solution (molecular weight of NaCl = 58.5) would cause which of the following changes, after osmotic equilibrium?

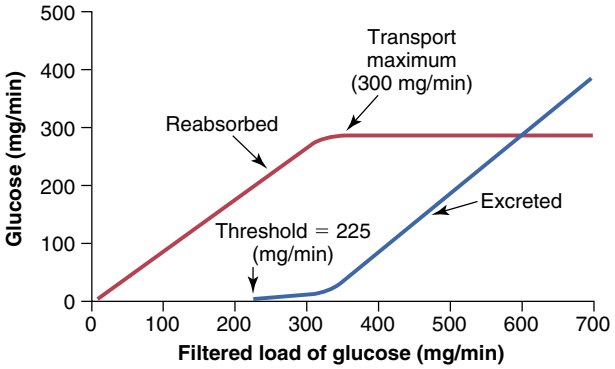
	Intracellular Fluid Volume	Intracellular Fluid Osmolarity	Extracellular Fluid Volume	Extracellular Fluid Osmolarity
A)	↑	↑	↑	↑
B)	↑	↓	↑	↓
C)	↔	↑	↑	↑
D)	↓	↑	↑	↑
E)	↓	↓	↓	↓



60. Lines A, B, and C on the figure above show the relative filterability by the glomerular capillaries of dextran molecules as a function of their molecular radius and electrical charges. Which lines on the graph best describe the electrical charges of the dextrans?
    A) A = polycationic; B = neutral; C= polyanionic
    B) A = polycationic; B = polyanionic; C = neutral
    C) A = polyanionic; B = neutral; C = polycationic
    D) A = polyanionic; B = polycationic; C = polycationic
    E) A = neutral; B = polycationic; C = polyanionic
    F) A = neutral; B = polyanionic; C = polycationic

61. If distal tubule fluid creatinine concentration is 5 mg/100 ml and plasma creatinine concentration is 1.0 mg/100 ml, what is the approximate percentage of the water filtered by the glomerular capillaries that remains in the distal tubule?
    A) 5%
    B) 10%
    C) 20%
    D) 50%
    E) 80%
    F) 95%

62. Which change tends to increase peritubular capillary fluid reabsorption?
    A) Increased blood pressure
    B) Decreased filtration fraction
    C) Increased efferent arteriolar resistance
    D) Decreased angiotensin II
    E) Increased renal blood flow



63. A 32-year-old man reports frequent urination. He is overweight (280 lb [127 kg], 5 feet 10 inches [178 cm] tall). After measuring the 24-hour creatinine clearance, you estimate his GFR to be 150 ml/min. His plasma glucose level is 300 mg/dl. Assuming that his renal transport maximum for glucose is normal, as shown in the figure above, what would be this patient's approximate rate of urinary glucose excretion?
    A) 0 mg/min
    B) 100 mg/min
    C) 150 mg/min
    D) 225 mg/min
    E) 300 mg/min
    F) Information provided is inadequate to estimate the glucose excretion rate

64. An adrenal tumor that causes excess aldosterone secretion would tend to _____ plasma K^+ concentration, _____ plasma pH, _____ renin secretion, and _____ blood pressure.
    A) decrease, decrease, decrease, decrease
    B) decrease, increase, decrease, increase
    C) decrease, decrease, decrease, increase
    D) decrease, increase, increase, increase
    E) increase, increase, decrease, increase
    F) increase, decrease, decrease, increase

65. Which of the following tends to increase potassium secretion by the cortical collecting tubule?
    A) A diuretic that inhibits the action of aldosterone (e.g., spironolactone)
    B) A diuretic that decreases loop of Henle sodium reabsorption (e.g., furosemide)
    C) Decreased plasma potassium concentration
    D) Acute metabolic acidosis
    E) Low sodium intake

66. A diabetic patient has chronic renal disease and is referred to your nephrology clinic. According to his family physician, his creatinine clearance has decreased from 100 ml/min to 40 ml/min during the past 4 years. His glucose level has not been well controlled, and his plasma pH is 7.14. Which changes, compared with before the development of renal disease, would you expect to find, assuming steady-state conditions and no change in electrolyte intake?

	Sodium Excretion Rate	Creatinine Excretion Rate	Plasma Creatinine Concentration	Plasma HCO_3^- Concentration	NH_4^+ Excretion Rate
A)	↓	↓	↑	↑	↑
B)	↔	↔	↑	↓	↑
C)	↔	↔	↑	↓	↔
D)	↔	↓	↑	↓	↔
E)	↓	↓	↓	↓	↑
F)	↓	↓	↓	↓	↓

67. A 20-year-old woman comes to your office because of rapid weight gain and marked fluid retention. Her blood pressure is 105/65 mm Hg, her plasma protein concentration is 3.6 g/dl (normal = 7.0), and she has no detectable protein in her urine. Which changes would you expect to find, compared with normal?

	Thoracic Lymph Flow	Interstitial Fluid Protein Concentration	Capillary Filtration	Interstitial Fluid Pressure
A)	↓	↓	↓	↓
B)	↓	↑	↔	↔
C)	↑	↓	↑	↑
D)	↑	↓	↑	↔
E)	↑	↑	↑	↑

68. A 48-year-old woman reports severe polyuria (producing about 0.5 l of urine each hour) and polydipsia (drinking two to three glasses of water every hour). Her urine contains no glucose, and she is placed on overnight water restriction for further evaluation. The

next morning, she is weak and confused, her sodium concentration is 160 mEq/l, and her urine osmolarity is 80 mOsm/l. Which of the following is the most likely diagnosis?

A) Diabetes mellitus
B) Diabetes insipidus
C) Primary aldosteronism
D) Renin-secreting tumor
E) Syndrome of inappropriate ADH

69. Which substance is filtered most readily by the glomerular capillaries?

A) Albumin in plasma
B) Neutral dextran with a molecular weight of 25,000
C) Polycationic dextran with a molecular weight of 25,000
D) Polyanionic dextran with a molecular weight of 25,000
E) Red blood cells

70. A 22-year-old woman runs a 10-km race on a hot day and becomes dehydrated. Assuming that her ADH levels are very high and that her kidneys are functioning normally, in which part of the renal tubule is the most water reabsorbed?

A) Proximal tubule
B) Loop of Henle
C) Distal tubule
D) Cortical collecting tubule
E) Medullary collecting duct

71. Furosemide (Lasix) is a diuretic that also produces natriuresis. Which of the following is an undesirable side effect of furosemide due to its site of action on the renal tubule?

A) Edema
B) Hyperkalemia
C) Hypercalcemia
D) Decreased ability to concentrate the urine
E) Heart failure

72. A female patient has unexplained hypernatremia (plasma Na^+ = 167 mmol/l) and reports frequent urination and large urine volumes. A urine specimen reveals that the Na^+ concentration is 15 mmol/l (very low) and the osmolarity is 155 mOsm/l (very low). Laboratory tests reveal the following data: plasma renin activity = 3 ng angiotensin I/ml/h (normal = 1.0), plasma ADH = 30 pg/ml (normal = 3 pg/ml), and plasma aldosterone = 20 ng/dl (normal = 6 ng/dl). Which of the following is the most likely reason for her hypernatremia?

A) Simple dehydration caused by decreased water intake
B) Nephrogenic diabetes insipidus
C) Central diabetes insipidus
D) Syndrome of inappropriate ADH
E) Primary aldosteronism
F) Renin-secreting tumor

73. Which change would you expect to find in a dehydrated person deprived of water for 24 hours?

A) Decreased plasma renin activity
B) Decreased plasma antidiuretic hormone concentration
C) Increased plasma atrial natriuretic peptide concentration
D) Increased water permeability of the collecting duct

74. Juvenile (type 1) diabetes mellitus is often diagnosed because of polyuria (high urine flow) and polydipsia (frequent drinking) that occur because of which of the following?

A) Increased delivery of glucose to the collecting duct interferes with the action of antidiuretic hormone
B) Increased glomerular filtration of glucose increases Na^+ reabsorption via the sodium-glucose cotransporter
C) When the filtered load of glucose exceeds the renal threshold, a rising glucose concentration in the proximal tubule decreases the osmotic driving force for water reabsorption
D) High plasma glucose concentration decreases thirst
E) High plasma glucose concentration stimulates ADH release from the posterior pituitary

75. Which of the following would cause the most serious hypokalemia?

A) A decrease in potassium intake from 150 mEq/day to 60 mEq/day
D) An increase in sodium intake from 100 to 200 mEq/day
C) Excessive aldosterone secretion plus high sodium intake
D) Excessive aldosterone secretion plus low sodium intake
E) A patient with Addison's disease
F) Treatment with a beta-adrenergic blocker
G) Treatment with spironolactone

76. A 26-year-old woman reports that she has had a severe migraine and has taken six times more than the recommended dose of aspirin for the past 3 days to relieve her headaches. Her plasma pH is 7.24. Which of the following would you expect to find (compared with normal)?

	Plasma HCO_3^- concentration	Plasma P_{CO_2}	Urine HCO_3^- Excretion	Urine NH_4^+ Excretion	Plasma Anion Gap
A)	↑	↓	↑	↑	↑
B)	↑	↑	↑	↓	↑
C)	↓	↓	↓	↓	↓
D)	↓	↓	↓	↑	↑
E)	↓	↓	↓	↑	↓
F)	↓	↔	↓	↓	↔

77. Under conditions of normal renal function, which of the following statements is true of the concentration of urea in tubular fluid at the end of the proximal tubule?
    A) It is higher than the concentration of urea in tubular fluid at the tip of the loop of Henle
    B) It is higher than the concentration of urea in the plasma
    C) It is higher than the concentration of urea in the final urine in antidiuresis
    D) It is lower than plasma urea concentration because of active urea reabsorption along the proximal tubule

78. You begin treating a hypertensive patient with a powerful loop diuretic (e.g., furosemide). Which changes would you expect to find, compared with pretreatment values, when he returns for a follow-up examination 2 weeks later?

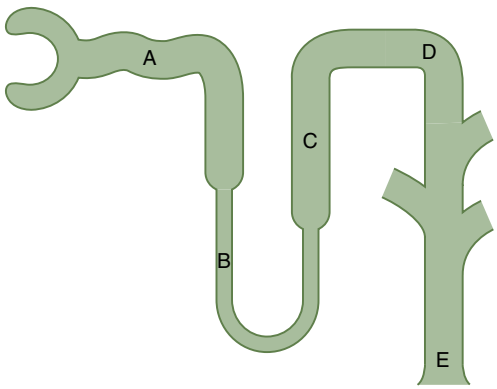
	Urine Sodium Excretion	Extracellular Fluid Volume	Blood Pressure	Plasma Potassium Concentration
A)	↑	↓	↓	↓
B)	↑	↓	↔	↔
C)	↔	↓	↓	↓
D)	↔	↓	↔	↔
E)	↑	↔	↓	↑

79. Which change, compared with normal, would be expected to occur, under steady-state conditions, in a patient whose severe renal disease has reduced the number of functional nephrons to 25% of normal?
    A) Increased GFR of the surviving nephrons
    B) Decreased urinary creatinine excretion rate
    C) Decreased urine flow rate in the surviving nephrons
    D) Decreased urinary excretion of sodium
    E) Increased urine-concentrating ability

80. Which statement is correct?
    A) Urea reabsorption in the medullary collecting tubule is less than in the distal convoluted tubule during antidiuresis
    B) Urea concentration in the interstitial fluid of the renal cortex is greater than in the interstitial fluid of the renal medulla during antidiuresis
    C) The thick ascending limb of the loop of Henle reabsorbs more urea than the inner medullary collecting tubule during antidiuresis
    D) Urea reabsorption in the proximal tubule is greater than in the cortical collecting tubule

81. A patient's urine is collected for 2 hours, and the total volume is 600 ml during this time. Her urine osmolarity is 150 mOsm/l, and her plasma osmolarity is 300 mOsm/l. What is her "free water clearance"?
    A) +5.0 ml/min
    B) +2.5 ml/min
    C) 0.0 ml/min
    D) −2.5 ml/min
    E) −5.0 ml/min

Questions 82–85



For Questions 82–85, choose the appropriate nephron site in the above figure.

82. In a patient with severe central diabetes insipidus caused by a lack of ADH secretion, which part of the tubule would have the lowest tubular fluid osmolarity?
    A) A
    B) B
    C) C
    D) D
    E) E

83. In a person on a very low potassium diet, which part of the nephron would be expected to reabsorb the most potassium?
    A) A
    B) B
    C) C
    D) D
    E) E

84. Which part of the nephron normally reabsorbs the most water?

A) A
B) B
C) C
D) D
E) E

85. In a normally functioning kidney, which part of the tubule has the lowest permeability to water during antidiuresis?

A) A
B) B
C) C
D) D
E) E

86. Which substances are best suited to measure interstitial fluid volume?

A) Inulin and heavy water
B) Inulin and 22Na
C) Heavy water and 125I-albumin
D) Inulin and 125I-albumin
E) 51Cr red blood cells and 125I-albumin

87. Long-term administration of furosemide (Lasix) would do what?

A) Inhibit the Na^+-Cl^- co-transporter in the renal distal tubules
B) Inhibit the Na^+-Cl^--K^+ co-transporter in the renal tubules
C) Tend to reduce renal concentrating ability
D) Tend to cause hyperkalemia
E) A and C
F) B and C
G) B, C, and D

88. A patient with normal lungs who has uncontrolled type 1 diabetes and a plasma glucose concentration of 400 mg/100 ml (normal ~100 mg/100 ml) would be expected to have which set of blood values?

	pH	HCO_3^- (mmol / l)	Pco_2 (mm Hg)	Na^+ (mmol/l)	Cl^- (mmol/l)
A)	7.66	22	20	143	111
B)	7.52	38	48	146	100
C)	7.29	14	30	143	117
D)	7.25	12	28	142	102
E)	7.07	14	50	144	102

89. Which of the following would be expected to cause a decrease in extracellular fluid potassium concentration (hypokalemia) at least in part by stimulating potassium uptake into the cells?

A) α-Adrenergic blockade
B) Insulin deficiency
C) Strenuous exercise
D) Aldosterone deficiency (Addison disease)
E) Metabolic alkalosis

90. If a person has a kidney transport maximum for glucose of 350 mg/min, a GFR of 100 ml/min, a plasma glucose level of 150 mg/dl, a urine flow rate of 2 ml/min, and no detectable glucose in the urine, what would be the approximate rate of glucose reabsorption, assuming normal kidneys?

A) Glucose reabsorption cannot be estimated from these data
B) 0 mg/min
C) 50 mg/min
D) 150 mg/min
E) 350 mg/min

91. Which diuretic inhibits Na^+-$2Cl^-$-K^+ co-transport in the loop of Henle as its primary action?

A) Thiazide diuretic
B) Furosemide
C) Carbonic anhydrase inhibitor
D) Osmotic diuretic
E) Amiloride
F) Spironolactone

92. A selective decrease in *efferent* arteriolar resistance would _____ glomerular hydrostatic pressure, _____ GFR, and _____ renal blood flow.

A) increase, increase, increase
B) increase, decrease, increase
C) increase, decrease, decrease
D) decrease, increase, decrease
E) decrease, decrease, increase
F) decrease, increase, increase

93. A patient with renal tubular acidosis would be expected to have which set of blood values?

	pH	HCO_3^- (mmol / l)	Pco_2 (mm Hg)	Na^+ (mmol/l)	Cl^- (mmol/l)
A)	7.66	22	20	143	111
B)	7.52	38	48	146	100
C)	7.07	14	50	144	102
D)	7.25	12	28	142	102
E)	7.29	14	30	143	117

94. A patient reports that he is always thirsty, and his breath has an acetone smell. You suspect that he has diabetes mellitus, and the diagnosis is confirmed by a urine sample that tests positive for glucose and a blood sample that shows a fasting blood glucose concentration of 400 mg/dl. Compared with normal, you would expect to find which changes in his urine?

	Urine pH	NH_4^+ Excretion	Urine volume (ml/24 h)	Renal HCO_3^- Production
A)	↓	↓	↓	↓
B)	↓	↑	↓	↓
C)	↑	↓	↓	↓
D)	↓	↑	↑	↑
E)	↑	↑	↑	↑

Questions 95–97

A person with normal body fluid volumes weighs 60 kg and has an extracellular fluid volume of approximately 12.8 l, a blood volume of 4.3 l, and a hematocrit of 0.4; 57% of his body weight is water. Use this information to answer Questions 95–71.

95. What is the approximate intracellular fluid volume?
    A) 17.1 l
    B) 19.6 l
    C) 21.4 l
    D) 23.5 l
    E) 25.6 l

96. What is the approximate plasma volume?
    A) 2.0 l
    B) 2.3 l
    C) 2.6 l
    D) 3.0 l
    E) 3.3 l

97. What is the approximate interstitial fluid volume?
    A) 6.4 l
    B) 8.4 l
    C) 10.2 l
    D) 11.3 l
    E) 12.0 l

98. Which nephron segment is the primary site of magnesium reabsorption under normal conditions?
    A) Proximal tubule
    B) Descending limb of the loop of Henle
    C) Ascending limb of the loop of Henle
    D) Distal convoluted tubule
    E) Collecting ducts

99. Which changes would you expect to find in a newly diagnosed 10-year-old patient with type 1 diabetes and uncontrolled hyperglycemia (plasma glucose = 300 mg/dl)?

	Thirst (Water Intake)	Urine Volume	Glomerular Filtration Rate	Afferent Arteriolar Resistance
A)	↑	↓	↑	↓
B)	↑	↑	↓	↑
C)	↑	↑	↑	↓
D)	↓	↑	↑	↑
E)	↓	↓	↓	↓

Questions 100 and 101

To evaluate kidney function in a 45-year-old woman with type 2 diabetes, you ask her to collect her urine for a 24-hour period. She collects 3600 ml of urine in that period. The clinical laboratory returns the following results after analyzing the patient's urine and plasma samples: plasma creatinine = 4 mg/dl, urine creatinine = 32 mg/dl, plasma potassium = 5 mmol/l, and urine potassium = 10 mmol/l.

100. What is this patient's approximate GFR, assuming that she collected all her urine in the 24-hour period?
    A) 10 ml/min
    B) 20 ml/min
    C) 30 ml/min
    D) 40 ml/min
    E) 80 ml/min

101. What is the net renal tubular reabsorption rate of potassium in this patient?
    A) 1.050 mmol/min
    B) 0.100 mmol/min
    C) 0.037 mmol/min
    D) 0.075 mmol/min
    E) Potassium is not reabsorbed in this example

Questions 102–106

Match each of the patients described in Questions 102–106 with the correct set of blood values in the following table (the same values may be used for more than one patient).

	pH	HCO_3^- (mEq/l)	P_{CO_2} (mm Hg)	Na^+ (mEq/l)	Cl^- (mEq/l)
A)	7.66	22	20	143	111
B)	7.28	30	65	142	102
C)	7.24	12	29	144	102
D)	7.29	14	30	143	117
E)	7.52	38	48	146	100
F)	7.07	14	50	144	102

102. A patient with severe diarrhea

103. A patient with primary aldosteronism

104. A patient with proximal renal tubular acidosis

105. A patient with diabetic ketoacidosis and emphysema

106. A patient treated chronically with a carbonic anhydrase inhibitor

107. Which change would you expect to find in a patient who developed acute renal failure after ingesting poisonous mushrooms that caused renal tubular necrosis?
    A) Increased plasma bicarbonate concentration
    B) Metabolic acidosis
    C) Decreased plasma potassium concentration

D) Decreased blood urea nitrogen concentration
E) Decreased hydrostatic pressure in Bowman's capsule

108. Which of the following has similar values for both intracellular and interstitial body fluids?
A) Potassium ion concentration
B) Colloid osmotic pressure
C) Sodium ion concentration
D) Chloride ion concentration
E) Total osmolarity

109. Which of the following is true of the tubular fluid that passes through the lumen of the early distal tubule in the region of the macula densa?
A) It is usually isotonic
B) It is usually hypotonic
C) It is usually hypertonic
D) It is hypertonic in antidiuresis
E) It is hypertonic when the filtration rate of its own nephron decreases to 50% below normal

110. In a person with normal kidneys and normal lungs who has chronic metabolic acidosis, you would expect to find all of the following, compared with normal, EXCEPT:
A) Increased renal excretion of NH_4Cl
B) Decreased urine pH
B) Decreased urine HCO_3^- excretion
D) Increased plasma HCO_3^- concentration
E) Decreased plasma P_{CO_2}

111. Assume that you have a patient who needs fluid therapy and you decide to administer by intravenous infusion 2.0 l of 0.45% NaCl solution (molecular weight NaCl = 58.5). After osmotic equilibrium, which changes would you expect, compared with before infusion of the NaCl?

	Intracellular Volume	Intracellular Osmolarity	Extracellular Volume	Extracellular Osmolarity
A)	↑	↑	↑	↑
B)	↑	↓	↑	↓
C)	↔	↑	↑	↑
D)	↓	↑	↑	↑
E)	↓	↓	↓	↓

112. If the renal clearance of substance X is 300 ml/min and the glomerular filtration rate is 100 ml/min, it is most likely that substance X is
A) Filtered freely but not secreted or reabsorbed
B) Bound to plasma proteins
C) Secreted
D) Reabsorbed
E) Bound to tubular proteins
F) Clearance of a substance cannot be greater than the GFR

113. Which change tends to increase urinary calcium (Ca^{2+}) excretion?
A) Extracellular fluid volume expansion
B) Increased plasma parathyroid hormone concentration
C) Decreased blood pressure
D) Increased plasma phosphate concentration
E) Metabolic alkalosis

114. Which change would you expect to find in a patient consuming a high-sodium diet (200 mEq/day) compared with the same patient on a normal-sodium diet (100 mEq/day), assuming steady-state conditions?
A) Increased plasma aldosterone concentration
B) Increased urinary potassium excretion
C) Decreased plasma renin activity
D) Decreased plasma atrial natriuretic peptide
E) An increase in plasma sodium concentration of at least 5 mmol/l

115. What would tend to decrease GFR by more than 20% in a normal kidney?
A) Decrease in renal arterial pressure from 100 to 85 mm Hg
B) 50% decrease in afferent arteriolar resistance
C) 50% decrease in efferent arteriolar resistance
D) 50% increase in the glomerular capillary filtration coefficient
E) Decrease in plasma colloid osmotic pressure from 28 to 20 mm Hg

116. Acute metabolic acidosis tends to _____ intracellular K^+ concentration and _____ K^+ secretion by the cortical collecting tubules.
A) Increase, increase
B) Increase, decrease
C) Decrease, increase
D) Decrease, decrease
E) Cause no change in, increase
F) Cause no change in, cause no change in

117. Which statement is true?
A) ADH increases water reabsorption from the ascending loop of Henle
B) Water reabsorption from the descending loop of Henle is normally less than that from the ascending loop of Henle
C) Sodium reabsorption from the ascending loop of Henle is normally less than that from the descending loop of Henle
D) Osmolarity of fluid in the early distal tubule would be less than 300 mOsm/l in a dehydrated person with normal kidneys and increased ADH levels
E) ADH decreases the urea permeability in the medullary collecting tubules

118. In a person on a high-potassium (200 mmol/day) diet, which part of the nephron would be expected to secrete the most potassium?

A) Proximal tubule
B) Descending loop of Henle
C) Ascending loop of Henle
D) Early distal tubule
E) Collecting tubules

119. Which of the following would you expect to find in a patient who has chronic diabetic ketoacidosis?

A) Decreased renal HCO_3^- excretion, increased NH_4^+ excretion, increased plasma anion gap
B) Increased respiration rate, decreased arterial P_{CO_2}, decreased plasma anion gap
C) Increased NH_4^+ excretion, increased plasma anion gap, increased urine pH
D) Increased renal HCO_3^- production, increased NH_4^+ excretion, decreased plasma anion gap
E) Decreased urine pH, decreased renal HCO_3^- excretion, increased arterial P_{CO_2}

120. Using the indicator dilution method to assess body fluid volumes in a 40-year-old man weighing 70 kg, the inulin space is calculated to be 16 l, and ^{125}I-albumin space is 4 l. If 60% of his total body weight is water, what is his approximate interstitial fluid volume?

A) 4 l
B) 12 l
C) 16 l
D) 26 l
E) 38 l
F) 42 l

121. What would tend to decrease plasma potassium concentration by causing a shift of potassium from the extracellular fluid into the cells?

A) Strenuous exercise
B) Aldosterone deficiency
C) Acidosis
D) β-adrenergic blockade
E) Insulin excess

122. A 26-year-old construction worker is brought to the emergency department with a change in mental status after working a 10-hour shift on a hot summer day (average outside temperature was 97°F [36°C]). The man had been sweating profusely during the day but did not drink fluids. He has a fever of 102°F [39°C], a heart rate of 140 beats/min, and a blood pressure of 100/55 mm Hg in the supine position. Upon examination, he has no perspiration, appears to have dry mucous membranes, and is poorly oriented to person, place, and time. Assuming that his kidneys were normal yesterday, which set of hormone levels describes his condition, compared with normal?

A) High ADH, high renin, low angiotensin II, low aldosterone
B) Low ADH, low renin, low angiotensin II, low aldosterone
C) High ADH, low renin, high angiotensin II, low aldosterone
D) High ADH, high renin, high angiotensin II, high aldosterone
E) Low ADH, high renin, low angiotensin II, high aldosterone

123. A 23-year-old man runs a 10-km race in July and loses 2 l of fluid by sweating. He also drinks 2 l of water during the race. Which changes would you expect, compared with normal, after he absorbs the water and assuming osmotic equilibrium and no excretion of water or electrolytes?

	Intracellular Volume	Intracellular Osmolarity	Extracellular Volume	Extracellular Osmolarity
A)	↓	↑	↓	↑
B)	↓	↓	↓	↓
C)	↔	↓	↔	↓
D)	↔	↑	↓	↑
E)	↑	↓	↓	↓
F)	↑	↓	↑	↓

124. Which change would tend to increase Ca^{2+} reabsorption in the renal tubule?

A) Extracellular fluid volume expansion
B) Increased plasma parathyroid hormone concentration
C) Increased blood pressure
D) Decreased plasma phosphate concentration
E) Metabolic acidosis

125. A young man is found comatose, having taken an unknown number of sleeping pills an unknown time before. An arterial blood sample yields the following values: pH = 7.02, HCO_3^- = 14 mEq/l, and P_{CO_2} = 68 mm Hg. Which of the following describes this patient's acid-base status most accurately?

A) Uncompensated metabolic acidosis
B) Uncompensated respiratory acidosis
C) Simultaneous respiratory and metabolic acidosis
D) Respiratory acidosis with partial renal compensation
E) Respiratory acidosis with complete renal compensation

126. In a person with chronic respiratory acidosis who has partial renal compensation, you would expect to find which changes, compared with normal? _____ urinary excretion of NH_4^+; _____ plasma HCO_3^- concentration; and _____ urine pH.

A) Increased, increased, decreased
B) Increased, decreased, decreased
C) No change in, increased, decreased
D) No change in, no change in, decreased
E) Increased, no change in, increased

127. Increases in both renal blood flow and GFR are caused by which mechanism?
   A) Dilation of the afferent arterioles
   B) Increased glomerular capillary filtration coefficient
   C) Increased plasma colloid osmotic pressure
   D) Dilation of the efferent arterioles

128. A 55-year-old male patient with hypertension has had his blood pressure reasonably well controlled by administration of a thiazide diuretic. At his last visit (6 months ago), his blood pressure was 130/75 mm Hg, and his serum creatinine was 1 mg/100 ml. He has been exercising regularly for the past 2 years but recently has reported knee pain and began taking large amounts of a nonsteroidal antiinflammatory drug. When he arrives at your office, his blood pressure is 155/85 mm Hg, and his serum creatinine is 2.5 mg/100 ml. What best explains his increased serum creatinine level?
   A) Increased efferent arteriolar resistance that reduced GFR
   B) Increased afferent arteriolar resistance that reduced GFR
   C) Increased glomerular capillary filtration coefficient that reduced GFR
   D) Increased angiotensin II formation that decreased GFR
   E) Increased muscle mass due to the exercise

129. An older adult patient reports muscle weakness and lethargy. A urine specimen reveals a Na^+ concentration of 600 mmol/l and an osmolarity of 1200 mOsm/l. Additional laboratory tests provide the following information: plasma Na^+ concentration = 167 mmol/l, plasma renin activity = 4 ng angiotensin I/ml/h (normal = 1 ml/h), plasma ADH = 60 pg/ml (normal = 3 pg/ml), and plasma aldosterone = 15 ng/dl (normal = 6 ng/dl). What is the most likely reason for this patient's hypernatremia?
   A) Dehydration caused by decreased fluid intake
   B) Syndrome of inappropriate ADH
   C) Nephrogenic diabetes insipidus
   D) Primary aldosteronism
   E) Renin-secreting tumor

ANSWERS

1. E) Increased plasma protein concentration would reduce the net force favoring capillary filtration and would oppose edema formation. All of the other changes would increase capillary filtration rate and tend to cause edema.

TMP14 pp. 316–318.

2. E) The total body water would initially be 60% of body weight or ~30 l. The initial total mOsm in the body fluids would be 30 l × 360 mOsm/l, or 10,800 mOsm. After adding the glucose solution, total body water would be 30 l + 2 l or 32 l. If we assume that all of the glucose is metabolized, the final mOsm would also be 10,800. Therefore, the extracellular and intracellular osmolarity would be 10,800 mOsm/32 l, or approximately 338 mOsm/l.

TMP14 pp. 312–314

3. B) The initial total body water would be 60% of body weight or ~30 L. The initial total mOsm in the body fluids would be 30 l × 360 mOsm/l, or 10,800 mOsm. The initial extracellular fluid volume would be 20% of body weight, or ~10 l. The initial total mOsm in the extracellular fluid would be 360 mOsm/l × 10 l, or 3600 mOsm. After adding the glucose solution, total body water would be 30 l + 2 l or 32 l. If we assume that all of the glucose is metabolized, the final mOsm would also be 10,800. Therefore, the extracellular and intracellular osmolarity would be 10,800 mOsm/32 l, or approximately 338 mOsm/l. The extracellular fluid would continue to have a total of 3600 mOsm. Therefore, the final extracellular fluid volume would be 3600 mOsm/338 mOsm per l, or ~10.7 l.

TMP14 pp. 312–314

4. C) A doubling of serum creatinine implies a reduction in glomerular filtration rate (GFR). Non-steroidal anti-inflammatory drugs (NSAIDS) inhibit prostaglandin synthesis, which would tend increase afferent arteriolar and reduce GFR.

TMP14 pp. 337–342, 362.

5. C) Inhibition of sodium-glucose co-transporter 2 (SGLT2) would reduce glucose and sodium chloride reabsorption in the proximal tubules, causing increased sodium chloride delivery to the macula densa, which would, in turn, cause a feedback-mediated vasoconstriction of afferent arterioles and reductions in glomerular filtration rate and renal blood flow.

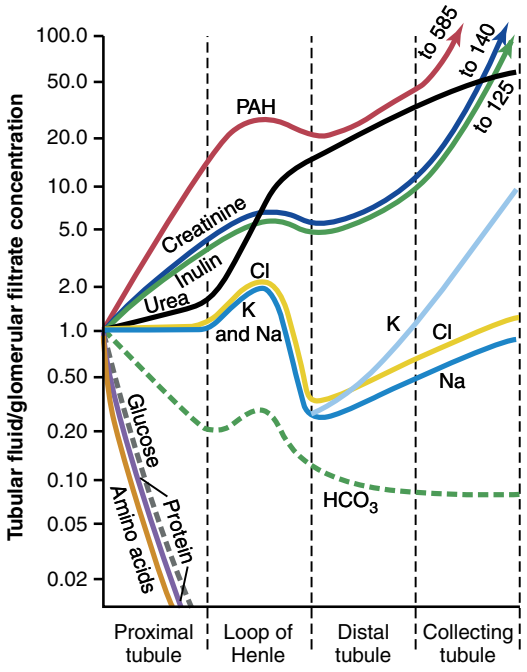
TMP14 pp. 339–340, 345–346

6. D) Filtration fraction (FF) = glomerular filtration rate (GFR)/renal plasma flow. GFR = Kf x (P_G - Π_C – P_B) where Kf is the glomerular capillary filtration coefficient, P_G is glomerular hydrostatic pressure, Π_C is glomerular capillary colloid osmotic pressure, and P_B is Bowman's space hydrostatic pressure. Therefore, GFR= 10 × (60 – 20 – 10) = 100 ml/min. Since renal plasma flow is 600 ml/min, FF= 100 ml/min/600 ml/min = 0.167.

TMP14 pp. 333–336.

7. D) Bicarbonate is more avidly reabsorbed in the proximal tubules than water, and therefore concentration decreases along the proximal tubules and has a lower concentration in the urine than in the glomerular filtrate. Approximately 85% of the filtered load of HCO_3^- is normally reabsorbed in the proximal tubules. All of the other statements are correct.

TMP14 pp. 354, 410–412.

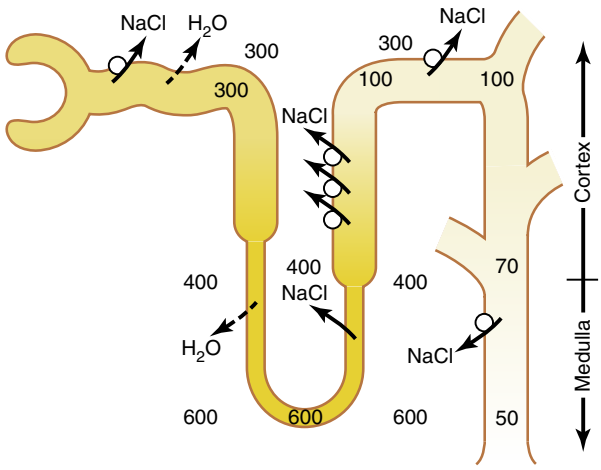


8. B) With a glomerular filtration rate of 100 ml/min and a plasma glucose concentration of 4 mg/ml, the filtered load of glucose would be 400 mg/min. Since the transport maximum for glucose in this case is 200 mg/min, the maximum rate of glucose reabsorption is 200 mg/min. Glucose excreted rate is therefore the difference between the filtered load of glucose (400 mg/min) and the glucose reabsorption rate (200 mg/min), or 200 mg/min.

TMP14 pp. 346–347

9. F) Fluid in the ascending loop of Henle becomes dilute as electrolytes are reabsorbed and water remains in the tubule. When antidiuretic hormone (ADH) levels are very low, as occurs in central diabetes insipidus, fluid in the distal and collecting tubules, and the collecting ducts is further diluted by the reabsorption of sodium chloride and the failure to reabsorb water. This lead to a very dilute urine (see figure below).

TMP14 p. 366

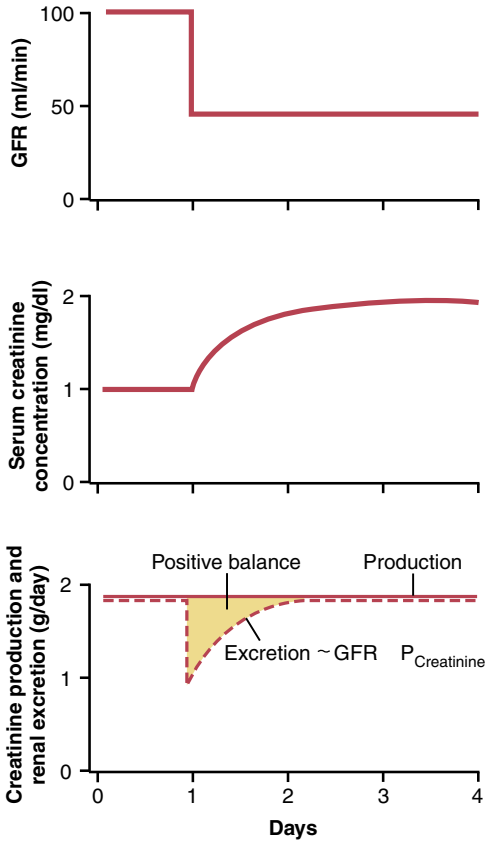


10. B) Potassium excretion in this case is equal to urine concentration of K^+ (80 mmol/l) multiplied by the urine flow rate (2.0 ml/min, or 0.002 l/min) which is 0.16 mmol/min.

TMP14 pp. 363–364

11. E) A 50% reduction in glomerular filtration rate (GFR) would initially cause a reduction in creatinine excretion rate. However, within a few days, the filtered load and excretion of creatinine would return to normal as serum creatinine concentration increased to approximately twice the normal level under steady-state conditions (see figure in next column). Creatinine clearance is approximately equal to GFR and would also be reduced by approximately 50%.

TMP14 pp. 361–362



12. A) Urine excretion rate is equal to glomerular filtration rate (GFR) minus tubular reabsorption rate. In this example, the final is 40 ml/min, and the tubular reabsorption rate is 40 ml/min. Therefore, the urine excretion rate is zero.

TMP14 p. 343

13. D) Total renal plasma flow (RPF) is equal to the clearance of paraaminohippuric acid (PAH) divided by the renal PAH extraction ratio (E_{PAH}).

Clearance of PAH (C_{PAH}) = (U_{PAH} × V) / A_{PAH} = (200 µg/ml × 2 ml/min)/1.0 µg/ml = 400 ml/min (E_{PAH}) = (A_{PAH} – V_{PAH})/A_{PAH} = (1.0 µg/ml – 0.2 µg/ml)/1.0 µg/ml = 0.8

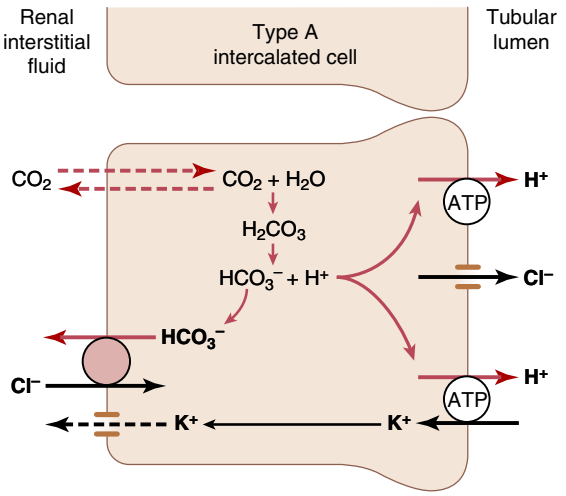
RPF = 400 ml/min / 0.8 = 500 ml/min

Where U_{PAH} is urine PAH concentration, A_{PAH} is arterial PAH concentration, V_{PAH} is renal venous PAH concentration, and V is urine flow rate.

TMP14 pp. 362–363

14. A) Type A intercalated cells of the collecting tubules secrete H^+ by a hydrogen-ATPase transporter and by a hydrogen-potassium-ATPase transporter. They also reabsorb HCO_3^- and K^+ (see figure on next page).

TMP14 pp. 352–354



15. E) Increased extracellular fluid osmolarity would tend to cause *hyperkalemia*, rather than hypokalemia due to cell dehydration, which raise intracellular potassium concentration and promotes potassium diffusion into the extracellular fluid. All of the other statements are correct.
TMP14 pp. 383–384

16. C) The cortical collecting tubule is relatively impermeable to urea, and very little reabsorption occurs in this tubular segment, even in the presence of ADH. All of the other statements are correct.
TMP14 pp. 370–371

17. C) The thick ascending loop of Henle is relatively impermeable to water even in the presence of high levels of ADH. The other tubular segments reabsorb significant amounts of water.
TMP14 pp. 368–369, 372–373

18. D) Acute metabolic alkalosis tends to shift K^+ from the extracellular fluid into the cells, including the renal tubular cells, contributing to increased K^+ secretion and decreased plasma K^+ concentration (hypokalemia).
TMP14 pp. 384, 389

19. D) Aldosterone antagonists such as spironolactone tend to cause *hyperkalemia* rather than hypokalemia by shifting potassium from the intracellular to the extracellular fluid and by inhibiting potassium secretion in the principal cells of collecting tubules. All of the other statements are correct.
TMP14 pp. 384, 387

20. C) Under steady-state conditions and no changes in protein or electrolyte intake, excretion rate of sodium would not change and would be equal to sodium intake. Creatinine excretion rate would also be unchanged in the steady-state due to increased plasma creatinine concentration, which would return the filtered load of creatinine to normal despite a 50% reduction in glomerular filtration rate (creatinine clearance). Uncontrolled diabetes mellitus can also result in metabolic acidosis, which would reduce plasma bicarbonate concentration and stimulate a compensatory increased in renal ammonium production and increased ammonium excretion rate.
TMP14 pp. 420, 428–429.

21. D) The patient has a low pH (7.18) and a low plasma HCO_3^-, indicating metabolic acidosis. The plasma anion gap is (Na^+ - HCO_3^- - chloride) = 141 - 10 - 100 = 31 mEq/l. This is far above normal (8-16 mEq/l), indicating unmeasured anions and excess nonvolatile acids. Therefore, the most likely explanation for the patient's metabolic acidosis is methanol poisoning. Patients with emphysema would have respiratory acidosis. Patients with diarrhea or renal tubular acidosis would have metabolic acidosis due to bicarbonate loss and normal anion gap with hyperchloremia. Ingestion of excess sodium bicarbonate would cause metabolic alkalosis.
TMP14 pp. 418–420

22. E) Atrial natriuretic peptide decreases renal sodium reabsorption through direct effects on the renal tubules as well as indirectly by inhibiting renin secretion. Both of these effects contribute to increased renal sodium excretion.
TMP14 p. 360

23. A) Urine excretion rate of Na^+ is equal to urine flow rate (1.0 ml/min or 0.001 l/min) multiplied by urine Na^+ concentration (80 mmol/l), or 0.08 mmol/min.
TMP14 pp. 361–363

24. A) Approximately 65% of the filtered load of potassium is reabsorbed in the proximal tubule. Variations in renal excretion of potassium during change in potassium intake are achieved mainly by changes in potassium *secretion* in collecting tubules. With high potassium intake, the proximal tubule still reabsorbs a high fraction of the filtered load of potassium.
TMP14 pp. 384–386

25. A) Metabolic alkalosis shifts potassium from the extracellular fluid into the cells and contributes to hypokalemia. Insulin deficiency, aldosterone deficiency, beta-adrenergic blockade, and increased extracellular fluid osmolarity all cause a shift of potassium from the cells to the extracellular fluid.
TMP14 pp. 383–384

26. E) Theoretically, if all of the plasma flowing through the kidneys was cleared of a substance, the clearance rate would be equal to the total renal plasma flow. In this example, renal plasma flow is equal to 800 ml/min.
TMP14 pp. 362–363

27. C) A 3% NaCl solution is hypertonic, and when infused intravenously, it would increase extracellular fluid volume and osmolarity, thereby causing water to flow out of the cell. This action would decrease intracellular fluid volume and further increase extracellular fluid volume. The 0.9% NaCl solution and 5% dextrose solution are isotonic and therefore would not reduce intracellular fluid volume. Pure water and the 0.45% NaCl solution are hypotonic, and when infused, they would increase both intracellular and extracellular fluid volumes.

TMP14 pp. 311–314

28. B) Partial obstruction of a major vein draining a tissue would increase capillary hydrostatic pressure in the tissue, which, in turn, would raise capillary fluid filtration and cause increases interstitial fluid volume, interstitial fluid hydrostatic pressure, and lymph flow. The increased lymph flow would "wash out" proteins from the interstitial fluid, decreasing interstitial fluid protein concentration.

TMP14 pp. 316–317

29. C) The hypernatremia (plasma Na^+ = 165 mmol/l) associated with a low blood pressure (88/44 mm Hg) suggests dehydration. The frequent urination and low urine specific gravity (1.003, which implies a urine osmolarity of about 100-120 mOsm/l) despite hypernatremia and dehydration suggests diabetes insipidus due to either insufficient secretion of ADH (central diabetes insipidus) or failure of the kidneys to respond to ADH (nephrogenic diabetes insipidus).

TMP14 pp. 315–316, 374, 432

30. D) A severe renal artery stenosis that reduces GFR to 25% of normal would also decrease renal blood flow but would cause only a transient decrease in urinary creatinine excretion. The transient decrease in creatinine excretion would increase serum creatinine (to about four times normal), which would restore the filtered creatinine load to normal and therefore return urinary creatinine excretion to normal levels under steady-state conditions. Urinary sodium secretion would also decrease transiently but would be restored to normal so that intake and excretion of sodium are balanced. Plasma sodium concentration would not change significantly because it is carefully regulated by the ADH–thirst mechanism.

TMP14 pp. 362, 428–429

31. B) A 1% solution of dextrose is hypotonic, and when infused, it would increase both intracellular and extracellular fluid volumes while decreasing the osmolarity of these compartments.

TMP14 pp. 311–313

32. B) Excessive secretion of ADH would increase renal tubular reabsorption of water, thereby increasing extracellular fluid volume and reducing extracellular fluid osmolarity. The reduced osmolarity, in turn, would cause water to flow into the cells and raise intracellular fluid volume. In the steady state, both extracellular and intracellular fluid volumes would increase, and osmolarity of both compartments would decrease.

TMP14 pp. 314, 375–376

33. C) A 3% solution of NaCl is hypertonic, and when infused into the extracellular fluid, it would raise osmolarity, thereby causing water to flow out of the cells into the extracellular fluid until osmotic equilibrium is achieved. In the steady state, extracellular fluid volume would increase, intracellular fluid volume would decrease, and osmolarity of both compartments would increase.

TMP14 pp. 311–313

34. C) Aldosterone stimulates potassium secretion by the principal cells of the collecting tubules. Therefore, blockade of the action of aldosterone with spironolactone would inhibit potassium secretion. Other factors that stimulate potassium secretion by the cortical collecting tubule include increased potassium concentration, increased cortical collecting tubule flow rate (as would occur with high sodium intake or a diuretic that reduces proximal tubular sodium reabsorption), and acute alkalosis.

TMP14 pp. 386–389

35. C) Phosphate excretion by the kidneys is controlled by an overflow mechanism. When the transport maximum for reabsorbing phosphate is exceeded, the remaining phosphate in the renal tubules is excreted in the urine and can be used to buffer hydrogen ions and form titratable acid. Phosphate normally begins to spill into the urine when the concentration of extracellular fluid rises above a threshold of 0.8 mmol/l, which is usually exceeded.

TMP14 pp. 391–392

36. B) GFR is equal to inulin clearance, which is calculated as the urine inulin concentration (100 mg/ml) × urine flow rate (1 ml/min)/plasma inulin concentration (2 mg/ml), which is equal to 50 ml/min.

TMP14 pp. 360–361

37. D) The net urea reabsorption rate is equal to the filtered load of urea (GFR [50 ml/min] × plasma urea concentration [2.5 mg/ml]) – urinary excretion rate of urea (urine urea concentration [50 mg/ml] × urine flow rate [1 ml/min]). Therefore, net urea reabsorption = (50 ml/min × 2.5 mg/ml) – (50 mg/ml × 1 ml/min) = 75 mg/min.

TMP14 pp. 360–363

38. B) As water flows up the ascending limb of the loop of Henle, solutes are reabsorbed, but this segment is relatively impermeable to water; progressive dilution of the tubular fluid occurs so that the osmolarity decreases to approximately 100 mOsm/l by the time the fluid reaches the early distal tubule. Even during maximal antidiuresis, this portion of the renal tubule is relatively impermeable to water and is therefore called the diluting segment of the renal tubule.

TMP14 pp. 372–373

39. C) In the absence of ADH secretion, a marked increase in urine volume occurs because the late distal and collecting tubules are relatively impermeable to water. As a result of increased urine volume, there are dehydration, increased plasma osmolarity and high plasma sodium concentration, and increased thirst which leads to increased water intake. The dehydration reduces extracellular fluid volume increases renin secretion and plasma renin concentration.

TMP14 pp. 375–376, 378–379

40. C) When potassium intake is doubled (from 80 to 160 mmol/day), potassium excretion also approximately doubles within a few days, and the plasma potassium concentration increases only slightly. Increased potassium excretion is achieved largely by increased secretion of potassium in the cortical collecting tubule. Increased aldosterone concentration plays a significant role in increasing potassium secretion and in maintaining a relatively constant plasma potassium concentration during increases in potassium intake. Sodium excretion does not change markedly during chronic increases in potassium intake.

TMP14 pp. 386–389

41. D) Most of the daily variation in potassium excretion is caused by changes in potassium secretion in the late distal tubules and collecting tubules. Therefore, when the dietary intake of potassium increases, the total body balance of potassium is maintained primarily by an increase in potassium secretion in these tubular segments. Increased potassium intake has little effect on GFR or on reabsorption of potassium in the proximal tubule and loop of Henle. Although high potassium intake may cause a slight shift of potassium into the intracellular compartment, a balance between intake and output must be achieved by increasing the excretion of potassium during high potassium intake.

TMP14 pp. 384–386

42. E) A 50% decrease in efferent arteriolar resistance would cause a substantial decrease in GFR. A decrease in renal arterial pressure from 100 to 80 mm Hg in a normal kidney would cause only a slight reduction in GFR in a normal kidney because of autoregulation. All of the other changes would tend to increase GFR.

TMP14 pp. 333–336

43. A) The patient described has protein in the urine (proteinuria) and reduced plasma protein concentration as a result of glomerulonephritis caused by an untreated streptococcal infection ("strep throat"). The reduced plasma protein concentration, in turn, decreased the plasma colloid osmotic pressure and resulted in leakage from the plasma to the interstitium. The extracellular fluid edema raised interstitial fluid pressure and interstitial fluid volume, causing increased lymph flow and decreased interstitial fluid protein concentration. Increasing lymph flow causes a "washout" of the interstitial fluid protein as a safety factor against edema. The decreased blood volume would tend to lower blood pressure and stimulate the secretion of renin by the kidneys, raising the plasma renin concentration.

TMP14 pp. 316–319

44. C) In a patient with a very high rate of renin secretion, there would also be increased formation of angiotensin II, which in turn would stimulate aldosterone secretion. The increased levels of angiotensin II and aldosterone would cause a transient decrease in sodium excretion, which would cause expansion of the extracellular fluid volume and increased arterial pressure. The increased arterial pressure, as well as other compensations, would return sodium excretion to normal so that intake and output are balanced. Therefore, under steady-state conditions, sodium excretion would be normal and equal to sodium intake. The increased aldosterone concentration would cause hypokalemia (decreased plasma potassium concentration), whereas the high level of angiotensin II would cause renal vasoconstriction and decreased renal blood flow.

TMP14 pp. 358, 387

45. B) This patient has respiratory acidosis because the plasma pH is lower than the normal level of 7.4, and the plasma P_{CO_2} is higher than the normal level of 40 mm Hg. The elevation in plasma bicarbonate concentration above normal (~24 mEq/l) is due to partial renal compensation for the respiratory acidosis. Therefore, this patient has respiratory acidosis with partial renal compensation.

TMP14 pp. 415–416

46. D) GFR is approximately equal to creatinine clearance, which is calculated as the urine creatinine concentration (50 mg/100 ml) × urine flow rate (3 ml/min)/plasma creatinine concentration (3 mg/100 ml), which is equal to 50 ml/min. Urine flow rate = 4320 ml/24 h = 4320 ml/1440 min = 3 ml/min.

TMP14 pp. 360–361

47. C) Because the patient has a low plasma pH (normal = 7.4), he has acidosis. The fact that his plasma bicarbonate concentration is also low (normal = 24 mEq/l) indicates that he has metabolic acidosis. However, he also appears to have respiratory acidosis because his plasma P_{CO_2} is high (normal = 40 mm Hg). The rise in P_{CO_2} is due to his impaired breathing as a result of cardiopulmonary arrest. Therefore, the patient has a mixed acidosis with combined metabolic and respiratory acidosis.

TMP14 pp. 415–416

48. D) An important compensation for respiratory acidosis is increased renal production of NH_4^+ and increased NH_4^+ excretion. In acidosis, urinary excretion of HCO_3^- would be reduced, as would urine pH, and urinary titratable acid would be slightly increased as a compensatory response to the acidosis.

TMP14 pp. 412–414

49. B) Inhibition of aldosterone causes hyperkalemia by two mechanisms: (1) shifting potassium out of the cells into the extracellular fluid and (2) decreasing cortical collecting tubular secretion of potassium. Increasing potassium intake from 60 to 180 mmol/day would cause only a very small increase in plasma potassium concentration in a person with normal kidneys and normal aldosterone feedback mechanisms. A reduction in sodium intake also has very little effect on plasma potassium concentration. Chronic treatment with a diuretic that inhibits loop of Henle Na^+-$2Cl^-$-K^+ co-transport would tend to cause potassium loss in the urine and hypokalemia. However, chronic treatment with a diuretic that inhibits sodium reabsorption in the collecting ducts, such as amiloride, would have little effect on plasma potassium concentration.

TMP14 pp. 383–384, 386–389

50. D) Excessive activity of the amiloride-sensitive sodium channel in the collecting tubules would cause a transient decrease in sodium excretion and expansion of extracellular fluid volume, which in turn would increase arterial pressure and decrease renin secretion, leading to decreased aldosterone secretion. Under steady-state conditions, sodium excretion would return to normal so that intake and renal excretion of sodium are balanced. One of the mechanisms that reestablishes this balance between intake and output of sodium is the rise in arterial pressure that induces a "pressure natriuresis."

TMP14 pp. 394, 433

51. A) Primary excessive secretion of aldosterone (Conn syndrome) would be associated with marked hypokalemia and metabolic alkalosis (increased plasma pH). Because aldosterone stimulates sodium reabsorption and potassium secretion by the cortical collecting tubule, there could be a transient decrease in sodium excretion and an increase in potassium excretion, but under steady-state conditions, both urinary sodium and potassium excretion would return to normal to match the intake of these electrolytes. However, the sodium retention and the hypertension associated with aldosterone excess would tend to reduce renin secretion.

TMP14 pp. 384, 387, 398, 417

52. C) The glomerular capillary filtration coefficient is the product of the hydraulic conductivity and surface area of the glomerular capillaries. Therefore, increasing the glomerular capillary filtration coefficient tends to increase GFR. Increased afferent arteriolar resistance, decreased efferent arteriolar resistance, increased Bowman's capsule hydrostatic pressure, and decreased glomerular hydrostatic pressure tend to decrease GFR.

TMP14 pp. 333–336

53. D) Impairment of proximal tubular NaCl reabsorption would increase NaCl delivery to the macula densa, which in turn would cause a tubuloglomerular feedback–mediated increase in afferent arteriolar resistance. The increased afferent arteriolar resistance would decrease the GFR. Initially there would be a transient increase in sodium excretion, but after 3 weeks, steady-state conditions would be achieved. Sodium excretion would equal sodium intake, and no significant change would occur in urinary sodium excretion.

TMP14 pp. 339–340

54. C) The patient has a lower than normal pH and is therefore acidotic. Because the plasma bicarbonate concentration is also lower than normal, the patient has metabolic acidosis with respiratory compensation (i.e., P_{CO_2} is lower than normal). The plasma anion gap ($Na^+ - Cl^- - HCO_3^- = 10$ mEq/l) is in the normal range, suggesting that the metabolic acidosis is not caused by excess nonvolatile acids such as salicylic acid or ketoacids caused by diabetes mellitus. Therefore, the most likely cause of the metabolic acidosis is diarrhea, which would cause a loss of HCO_3^- in the feces and would be associated with a normal anion gap and a hyperchloremic (increased chloride concentration) metabolic acidosis.

TMP14 pp. 415–416, 419–420

55. A) A 50% reduction of GFR would approximately double the plasma creatinine concentration because creatinine is not reabsorbed or secreted, and its excretion depends largely on glomerular filtration. Therefore, when GFR decreases, the plasma concentration of creatinine increases until the renal excretion of

creatinine returns to normal. Plasma concentrations of glucose, potassium, sodium, and hydrogen ions are closely regulated by multiple mechanisms that keep them relatively constant even when GFR falls to very low levels. Plasma phosphate concentration is also maintained near normal until GFR falls to below 20% to 30% of normal.

TMP14 pp. 429–430

56. C) A 50% reduction in afferent arteriolar resistance with no change in arterial pressure would increase renal blood flow and glomerular hydrostatic pressure, thereby increasing GFR. At the same time, the reduction in afferent arteriolar resistance would raise peritubular capillary hydrostatic pressure.

TMP14 pp. 333–336, 356–357

57. A) The net filtration pressure at the glomerular capillaries is equal to the sum of the forces favoring filtration (glomerular capillary hydrostatic pressure) minus the forces that oppose filtration (hydrostatic pressure in Bowman's space and glomerular colloid osmotic pressure). Therefore, the net pressure driving glomerular filtration is 50 – 12 – 30 = 8 mm Hg.

TMP14 p. 333

58. D) Uncontrolled diabetes mellitus results in increased blood acetoacetic acid levels, which in turn cause metabolic acidosis and decreased plasma HCO_3^- and pH. The acidosis causes several compensatory responses, including increased respiratory rate, which reduces plasma P_{CO_2}; increased renal NH^+ production, which leads to increased NH^+ excretion; and increased phosphate buffering of hydrogen ions secreted by the renal tubules, which increases titratable acid excretion.

TMP14 pp. 415–417

59. B) Infusion of a hypotonic solution of NaCl would initially increase extracellular fluid volume and decrease extracellular fluid osmolarity. The reduction in extracellular fluid osmolarity would cause osmotic flow of fluid into the cells, thereby increasing intracellular fluid volume and decreasing intracellular fluid osmolarity after osmotic equilibrium.

TMP14 pp. 312–313

60. A) For any given molecular radius, positively charged molecules (cations) are filtered more readily than negatively charged molecules (anions) because negative charges on the proteins of the basement membrane and podocytes of the glomerular capillaries tend to repel large negatively changed molecules (e.g., polycationic dextrans, curve C). Large positively charged molecules (curve A) are filtered more readily.

TMP14 pp. 332–333

61. C) Because water is reabsorbed by the renal tubules but creatinine is not reabsorbed, the concentration of creatinine in the renal tubular fluid will increase as fluid flows from the proximal to the distal tubule. An increase in the concentration from 1.0 mg/100 ml in the proximal tubule to 5.0 mg/100 ml in the distal tubule means that only about one fifth (20%) of the water that was in the proximal tubules remains in the distal tubule.

TMP14 pp. 349–350

62. C) Peritubular capillary fluid reabsorption is determined by the balance of hydrostatic and colloid osmotic forces in the peritubular capillaries. Increased efferent arteriolar resistance reduces peritubular capillary hydrostatic pressure and therefore increases the net force favoring fluid reabsorption. Increased blood pressure tends to raise peritubular capillary hydrostatic pressure and reduce fluid reabsorption. Decreased filtration fraction increases the peritubular capillary colloid osmotic pressure and tends to reduce peritubular capillary reabsorption. Decreased angiotensin II causes vasodilatation of efferent arterioles, raising peritubular capillary hydrostatic pressure, decreasing reabsorption, and decreasing tubular transport of water and electrolytes. Increased renal blood flow also tends to raise peritubular capillary hydrostatic pressure and decrease fluid reabsorption.

TMP14 pp. 355–357

63. C) The filtered load of glucose in this example is determined as follows: GFR (150 ml/min) × plasma glucose (300 mg/dl) = 450 mg/min. The transport maximum for glucose in this example is 300 mg/min. Therefore, the maximum rate of glucose reabsorption is 300 mg/min. The urinary glucose excretion is equal to the filtered load (450 mg/min) minus the tubular reabsorption of glucose (300 mg/min), or 150 mg/min.

TMP14 pp. 346–347, 360–361

64. B) Excess aldosterone increases sodium reabsorption and potassium secretion by the principal cells of the collecting tubules, causing sodium retention, increased blood pressure, and decreased renin secretion while increasing excretion of potassium and tending to decrease plasma potassium concentration. Excess aldosterone also causes a shift of potassium from the extracellular fluid into the cells, further reducing plasma potassium concentration. Aldosterone excess also stimulates hydrogen ion secretion and bicarbonate reabsorption by the intercalated cells and tends to increase plasma pH (alkalosis). Therefore, the classic manifestations of excess aldosterone secretion are hypokalemia, hypertension, alkalosis, and low renin levels.

TMP14 pp. 351–352, 384

65. B) Potassium secretion by the cortical collecting ducts is stimulated by (1) aldosterone, (2) increased plasma potassium concentration, (3) increased flow rate in the cortical collecting tubules, and (4) alkalosis. Therefore, a diuretic that inhibits aldosterone, decreased plasma potassium concentration, acute acidosis, and low sodium intake would all tend to decrease potassium secretion by the cortical collecting tubules. A diuretic that decreases loop of Henle sodium reabsorption, however, would tend to increase the flow rate in the cortical collecting tubule and therefore stimulate potassium secretion.

TMP14 pp. 386–389

66. B) This patient with diabetes mellitus and chronic renal disease has a reduction in creatinine clearance to 40% of normal, implying a marked reduction in GFR. He also has acidosis, as evidenced by a plasma pH of 7.14. The decrease in creatinine clearance would cause only a transient reduction in sodium excretion and creatinine excretion rate. As the plasma creatinine concentration increased, the urinary creatinine excretion rate would return to normal, despite the sustained decrease in creatinine clearance (creatinine excretion rate/plasma concentration of creatinine). Diabetes is associated with increased production of acetoacetic acid, which would cause metabolic acidosis and decreased plasma HCO_3^- concentration, as well as a compensatory increase in renal NH_4^+ production and increased NH_4^+ excretion rate.

TMP14 pp. 417, 428–429

67. C) A reduction in plasma protein concentration to 3.6 g/dl would increase the capillary filtration rate, thereby raising interstitial fluid volume and interstitial fluid hydrostatic pressure. The increased interstitial fluid pressure would, in turn, increase the lymph flow rate and reduce the interstitial fluid protein concentration ("washout" of interstitial fluid protein).

TMP14 pp. 316–319

68. B) The most likely diagnosis for this patient is diabetes insipidus, which can account for the polyuria and the fact that her urine osmolarity is very low (80 mOsm/l) despite overnight water restriction. In many patients with diabetes insipidus, the plasma sodium concentration can be maintained relatively close to normal by increasing fluid intake (polydipsia). When water intake is restricted, however, the high urine flow rate leads to rapid depletion of extracellular fluid volume and severe hypernatremia, as occurred in this patient. The fact that she has no glucose in her urine rules out diabetes mellitus. Neither primary aldosteronism nor a renin-secreting tumor would lead to an inability to concentrate the urine after overnight water restriction. Syndrome of inappropriate ADH would cause excessive fluid retention and increased urine osmolarity.

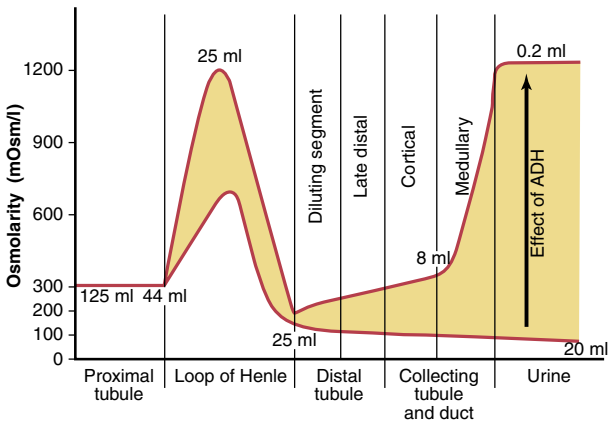
TMP14 pp. 374–376, 379–380

69. C) The filterability of solutes in the plasma is inversely related to the size of the solute (molecular weight). Also, positively charged molecules are filtered more readily than are neutral molecules or negatively charged molecules of equal molecular weight. Therefore, the positively charged polycationic dextran with a molecular weight of 25,000 would be the most readily filtered substance of the choices provided. Red blood cells are not filtered at all by the glomerular capillaries under normal conditions.

TMP14 pp. 332–333

70. A) In normally functioning kidneys, approximately two thirds of the water filtered by the glomerular capillaries is reabsorbed in the proximal tubule. Although dehydration increases ADH levels and water reabsorption by the distal tubules, collecting tubules, and collecting ducts and this action contributes importantly to decreased water excretion in dehydration, the total amount of water that remains in these tubular segments is small compared with the amount of water in the proximal tubules (see the figure below).

TMP14 pp. 372–373



71. D) Furosemide (Lasix) inhibits the Na^+-$2Cl^-$-K^+ co-transporter in the ascending limb of the loop of Henle. This action not only causes marked natriuresis and diuresis but also reduces the urine-concentrating ability. Furosemide does not cause edema; in fact, it is often used to treat severe edema and heart

failure. Furosemide also increases the renal excretion of potassium and calcium and therefore tends to cause hypokalemia and hypocalcemia rather than increasing the plasma concentrations of potassium and calcium.

TMP14 pp. 350–351, 388-389, 421–422

72. B) Hypernatremia can be caused by excessive sodium retention or water loss. The fact that the patient has large volumes of dilute urine suggests excessive urinary water excretion. Of the two possible disturbances listed that could cause excessive urinary water excretion (nephrogenic diabetes insipidus and central diabetes insipidus), nephrogenic diabetes insipidus is the most likely cause. Central diabetes insipidus (decreased ADH secretion) is not the correct answer because plasma ADH levels are markedly elevated. Simple dehydration due to decreased water intake is unlikely because the patient is excreting large volumes of dilute urine.

TMP14 pp. 315–316, 374

73. D) Dehydration due to water deprivation decreases extracellular fluid volume, which in turn increases renin secretion and decreases plasma atrial natriuretic peptide. Dehydration also increases the plasma sodium concentration, which stimulates the secretion of ADH. The increased ADH increases water permeability in the collecting ducts. The ascending limb of the loop of Henle is relatively impermeable to water, and this low permeability is not altered by water deprivation or increased levels of ADH.

TMP14 pp. 374–376

74. C) High urine flow occurs in type 1 diabetes because the filtered load of glucose exceeds the renal threshold, resulting in an increase in glucose concentration in the tubule, which decreases the osmotic driving force for water reabsorption. Increased urine flow reduces extracellular fluid volume and stimulates the release of ADH.

TMP14 pp. 346–347, 377

75. C) Excess aldosterone and a high-salt diet could cause serious hypokalemia because aldosterone stimulates potassium secretion by the renal tubules (and therefore tends to increase potassium excretion), as well as causing a shift of potassium from the extracellular fluid into the cells. A high-salt diet would exacerbate the hypokalemia because this would increase collecting tubular flow rate, which would tend to further increase renal potassium secretion. Treatment with spironolactone or a beta-adrenergic blocker or Addison disease (adrenal insufficiency) would tend to increase plasma potassium concentration. Changes in sodium and potassium intakes over the ranges indicated would have minimal effects on plasma potassium concentration.

TMP14 pp. 384–388

76. D) Ingestion of excess aspirin (acetylsalicylic acid) would tend to cause metabolic acidosis, which would lead to decreases in plasma HCO_3^-, decreased P_{CO_2} (due to respiratory compensation), decreased urine HCO_3^- excretion and increased NH_4^+ excretion (renal compensation), and increased anion gap due to increased unmeasured anions.

TMP14 pp. 417, 419–420

77. B) Approximately 30% to 40% of the filtered urea is reabsorbed in the proximal tubule. However, the tubular fluid urea concentration increases because urea is not nearly as permeant as water in this nephron segment. Urea concentration increases further in the tip of the loop of Henle because water is reabsorbed in the descending limb of the loop of Henle. Under conditions of antidiuresis, urea is further concentrated as water is reabsorbed and as fluid flows along the collecting ducts. Therefore, the final urine concentration of urea is substantially greater than the concentration in the proximal tubule or in the plasma.

TMP14 pp. 370–371

78. C) Diuretics that inhibit loop of Henle sodium reabsorption are used to treat conditions associated with excessive fluid volume (e.g., hypertension and heart failure). These diuretics initially cause an increase in sodium excretion that reduces extracellular fluid volume and blood pressure, but under steady-state conditions, the urinary sodium excretion returns to normal, due in part to the fall in blood pressure. One of the important adverse effects of loop diuretics is hypokalemia that is caused by the inhibition of Na^+-$2Cl^-$-K^+ co-transport in the loop of Henle and by the increased tubular flow rate in the cortical collecting tubules, which stimulates potassium secretion.

TMP14 pp. 388–389, 421–422

79. A) A reduction in the number of functional nephrons to 25% of normal would cause a compensatory increase in GFR and urine flow rate of the surviving nephrons and decreased urine concentrating ability. Under steady-state conditions, the urinary creatinine excretion rate and sodium excretion rate would be maintained at normal levels. (For further information, see TMP14, Table 32-6.)

TMP14 pp. 428–430

80. D) Approximately 40% to 50% of the filtered urea is reabsorbed in the proximal tubule. The distal

convoluted tubule and the cortical collecting tubules are relatively impermeable to urea, even under conditions of antidiuresis; therefore, little urea reabsorption takes place in these segments. Likewise, very little urea reabsorption takes place in the thick ascending limb of the loop of Henle. Under conditions of antidiuresis, the concentration of urea in the renal medullary interstitial fluid is markedly increased because of reabsorption of urea from the collecting ducts, which contributes to the hyperosmotic renal medulla.

TMP14 pp. 370–371

81. B) Free water clearance is calculated as urine flow rate (600 ml/2 h, or 5 ml/min) – osmolar clearance (urine osmolarity × urine flow rate/plasma osmolarity). Therefore, free water clearance is equal to +2.5 ml/min.

TMP14 p. 374

82. E) In the absence of ADH, the late distal tubule and collecting tubules are not permeable to water. Therefore, the tubular fluid, which is already dilute when it leaves the loop of Henle (~ 100 mOsm/l), becomes further diluted as it flows through the late distal tubule and collecting tubules as electrolytes are reabsorbed. Therefore, the final urine osmolarity in the complete absence of ADH is less than 100 mOsm/l.

TMP14 p. 372, Figure 29-8

83. A) About 65% of the filtered potassium is reabsorbed in the proximal tubule, and another 20% to 30% is reabsorbed in the loop of Henle. Although most of the daily variation in potassium excretion is caused by changes in potassium secretion in the distal and collecting tubules, only a small percentage of the filtered potassium load can be reabsorbed in these nephron segments. (For further information, see TMP14, Figure 30-2.)

TMP14 pp. 384–385

84. A) The proximal tubule normally absorbs approximately 65% of the filtered water, with much smaller percentages being reabsorbed in the descending loop of Henle and in the distal and collecting tubules. The ascending limb of the loop of Henle is relatively impermeable to water and therefore reabsorbs very little water.

TMP14 pp. 349–354

85. C) The thick ascending limb of the loop of Henle is relatively impermeable to water even under conditions of maximal antidiuresis. The proximal tubule and descending limb of the loop of Henle are highly permeable to water under normal conditions, as well as during antidiuresis. Water permeability of the late distal and collecting tubules increases markedly during antidiuresis because of the effects of increased levels of ADH.

TMP14 pp. 372–373

86. D) Interstitial fluid volume is equal to extracellular fluid volume minus plasma volume. Extracellular fluid volume can be estimated from the distribution of inulin or ^{22}Na, whereas plasma volume can be estimated from ^{125}I-albumin distribution. Therefore, interstitial fluid volume is calculated from the difference between the inulin distribution space and the ^{125}I-albumin distribution space.

TMP14 pp. 308–310, Table 25-3

87. F) Furosemide (Lasix) is a "loop" diuretic that inhibits the Na^+-Cl^--K^+ co-transporter in the thick ascending loop of Henle, thus reducing urine-concentrating ability; increasing renal excretion of Na^+, Cl^-, and K^+; and tending to cause hypokalemia.

TMP14 pp. 421–422

88. D) Uncontrolled type 1 diabetes would tend to cause metabolic acidosis (decreases in plasma pH and HCO_3^-) due to increased metabolism of fat and production of acetoacetic acid, which, in turn, would be associated with increased anion gap. The normal respiratory compensation would decrease plasma P_{CO_2}.

TMP14 p. 420

89. E) Metabolic alkalosis is associated with hypokalemia due to a shift of potassium from the extracellular fluid into the cells (see table below). Beta-adrenergic blockade, insulin deficiency, strenuous exercise, and aldosterone deficiency all cause hyperkalemia due to a shift of potassium out of the cells into the extracellular fluid.

TMP14 pp. 383–384, Table 5-1

Table 5-1 Factors That Can Alter Potassium Distribution Between Intracellular and Extracellular Fluids

Factors That Shift K^+ Into Cells (Decrease Extracellular[K^+])	Factors That Shift K- Out of Cells (Increase Extracellular[K^+])
Insulin	Insulin deficiency (diabetes mellitus)
Aldosterone	Aldosterone deficiency(Addison disease)
β-Adrenergic stimulation	β-Adrenergic blockade
Alkalosis	Acidosis
	Cell lysis
	Strenuous exercise
	Increased extracellular fluid osmolarity

90. D) In this example, the filtered load of glucose is equal to GFR (100 ml/min) × plasma glucose (150 mg/dl), or 150 mg/min. If there is no detectable glucose in

the urine, the reabsorption rate is equal to the filtered load of glucose, or 150 mg/min.
TMP14 pp. 346–347, 361

91. B) Furosemide is a powerful inhibitor of the Na^+-$2Cl^-$-K^+ co-transporter in the loop of Henle. Thiazide diuretics primarily inhibit NaCl reabsorption into the distal tubule, whereas carbonic anhydrase inhibitors decrease bicarbonate reabsorption in the tubules. Amiloride inhibits sodium channel activity, whereas spironolactone inhibits the action of mineralocorticoids in the renal tubules. Osmotic diuretics inhibit water and solute reabsorption by increasing osmolarity of the tubular fluid.
TMP14 p. 422

92. E) Decreased efferent arteriolar resistance would increase renal blood flow while reducing glomerular hydrostatic pressure, which, in turn, would tend to decrease the GFR.
TMP14 pp. 335–336

93. E) Renal tubular acidosis results from a defect of renal secretion or H^+, a defect in reabsorption of HCO_3^-, or both. This defect causes metabolic acidosis associated with decreases in plasma pH and HCO_3^- and a normal anion gap associated with hyperchloremia (increased plasma chloride concentration). Plasma P_{CO_2} is reduced because of respiratory compensation for the acidosis.
TMP14 p. 417

94. D) The patient has classic symptoms of diabetes mellitus: increased thirst, breath smelling of acetone (due to increased acetoacetic acids in the blood), high fasting blood glucose concentration, and glucose in the urine. The acetoacetic acids in the blood cause metabolic acidosis that leads to a compensatory decrease in renal HCO_3^- excretion, decreased urine pH, and increased renal production of ammonium and HCO_3^-. The high level of blood glucose increases the filtered load of glucose, which exceeds the transport maximum for glucose, causing an osmotic diuresis (increased urine volume) due to the unreabsorbed glucose in the renal tubules acts as an osmotic diuretic.
TMP14 pp. 346–347, 417

95. C) Intracellular fluid volume is calculated as the difference between total body fluid (0.57 × 60 g = 34.2 kg, or ~34.2 l) and extracellular fluid volume (12.8 l), which equals 21.4 l.
TMP14 pp. 309–310

96. C) Plasma volume is calculated as blood volume (4.3 l) × (1.0 – hematocrit), which is 4.3 × 0.6 = 2.58 l (rounded up to 2.6).
TMP14 pp. 309–310

97. C) Interstitial fluid volume is calculated as the difference between extracellular fluid volume (12.8 l) and plasma volume (2.6 l), which is equal to 10.2 l.
TMP14 pp. 309-310

98. C) The primary site of reabsorption of magnesium is in the loop of Henle, where about 65% of the filtered load of magnesium is reabsorbed. The proximal tubule normally reabsorbs only about 25% of filtered magnesium, and the distal and collecting tubules reabsorb less than 5%.
TMP14 p. 392

99. C) A plasma glucose concentration of 300 mg/dl would increase the filtered load of glucose above the renal tubular transport maximum and therefore increase urinary glucose excretion. The unreabsorbed glucose in the renal tubules would also cause an osmotic diuresis, increased urine volume, and decreased extracellular fluid volume, which would stimulate thirst. Increased glucose also causes vasodilatation of afferent arterioles, which increases GFR.
TMP14 pp. 341–342, 346–347, 378–379

100. B) GFR is approximately equal to the clearance of creatinine. Creatinine clearance = urine creatinine concentration (32 mg/dl) × urine flow rate (3600 ml/24 h, or 2.5 ml/min) ÷ plasma creatinine concentration (4 mg/dl) = 20 ml/min.
TMP14 pp. 361–362

101. D) The net renal tubular reabsorption rate is the difference between the filtered load of potassium (GFR × plasma potassium concentration) and the urinary excretion of potassium (urine potassium concentration × urine flow rate). Therefore, the net tubular reabsorption of potassium is 0.075 mmol/min.
TMP14 pp. 361–362

102. D) Severe diarrhea would result in loss of HCO_3^- in the stool, thereby causing metabolic acidosis that is characterized by low plasma HCO_3^- and low pH. Respiratory compensation would reduce P_{CO_2}. The plasma anion gap would be normal, and the plasma chloride concentration would be elevated (hyperchloremic metabolic acidosis) in metabolic acidosis caused by HCO_3^- loss in the stool.
TMP14 pp. 415–420

103. E) Primary excessive secretion of aldosterone causes metabolic alkalosis due to increased secretion of hydrogen ions and HCO_3^- reabsorption by the intercalated cells of the collecting tubules. Therefore, the metabolic alkalosis would be associated with increases in plasma pH and HCO_3^-, with a compensatory reduction in respiration rate and increased P_{CO_2}.

The plasma anion gap would be normal, with a slight reduction in plasma chloride concentration.

TMP14 pp. 417–420

104. D) Proximal tubular acidosis results from a defect of renal secretion of hydrogen ions, reabsorption of bicarbonate, or both. This defect leads to increased renal excretion of HCO_3^- and metabolic acidosis characterized by low plasma HCO_3^- concentration, low plasma pH, a compensatory increase in respiration rate and low P_{CO_2}, and a normal anion gap with an increased plasma chloride concentration.

TMP14 pp. 415–420

105. F) A patient with diabetic ketoacidosis and emphysema would be expected to have metabolic acidosis (due to excess ketoacids in the blood caused by diabetes), as well as increased plasma P_{CO_2} due to impaired pulmonary function. Therefore, the patient would be expected to have decreased plasma pH, decreased HCO_3^-, increased P_{CO_2}, and an increased anion gap ($Na^+ - Cl^- - HCO_3^- > 10-12$ mEq /l) due to the addition of ketoacids to the blood.

TMP14 pp. 416–420

106. D) Secretion of hydrogen ions and reabsorption of HCO_3^- depend critically on the presence of carbonic anhydrase in the renal tubules. After inhibition of carbonic anhydrase, renal tubular secretion of hydrogen ions and reabsorption of HCO_3^- would decrease, leading to increased renal excretion of HCO_3^-, reduced plasma HCO_3^- concentration, and metabolic acidosis. The metabolic acidosis, in turn, would stimulate the respiration rate, leading to decreased P_{CO_2}. The plasma anion gap would be within the normal range.

TMP14 pp. 410–411, 420, 422

107. B) Acute renal failure caused by tubular necrosis would cause the rapid development of metabolic acidosis due to the kidneys' failure to rid the body of the acid waste products of metabolism. The metabolic acidosis would lead to decreased plasma HCO_3^- concentration. Acute renal failure would also lead to a rapid increase in blood urea nitrogen concentration and a significant increase in plasma potassium concentration due to the kidneys' failure to excrete electrolytes or nitrogenous waste products. Necrosis of the renal epithelial cells causes them to slough away from the basement membrane and plug up the renal tubules, thereby increasing hydrostatic pressure in Bowman's capsule and decreasing GFR.

TMP14 pp. 425, 430

108. E) Intracellular and extracellular body fluids have the same total osmolarity under steady-state conditions because the cell membrane is highly permeable to water. Therefore, water flows rapidly across the cell membrane until osmotic equilibrium is achieved. The colloid osmotic pressure is determined by the protein concentration, which is considerably higher inside the cell. The cell membrane is also relatively impermeable to potassium, sodium, and chloride, and active transport mechanisms maintain low intracellular concentrations of sodium and chloride and a high intracellular concentration of potassium.

TMP14 pp. 310–311

109. B) Fluid entering the early distal tubule is almost always hypotonic because sodium and other ions are actively transported out of the thick ascending loop of Henle, whereas this portion of the nephron is virtually impermeable to water. For this reason, the thick ascending limb of the loop of Henle and the early part of the distal tubule are often called the diluting segment.

TMP14 pp. 350–351

110. D) Chronic metabolic acidosis is, by definition, associated with decreased plasma HCO_3^- concentration. Decreased excretion of NH_4Cl and HCO_3^- occurs with renal compensation for the acidosis, and respiratory compensation for the acidosis increases the ventilation rate, resulting in decreased plasma P_{CO_2}.

TMP14 pp. 415-418

111. B) A 0.45% NaCl solution is *hypotonic.* Therefore, administration of 2.0 l of this solution would reduce intracellular and extracellular fluid osmolarity and cause increases in intracellular and extracellular volumes.

TMP14 pp. 312-313

112. C) If the renal clearance is greater than the GFR, this implies that there must be secretion of that substance into the renal tubules. A substance that is freely filtered and not secreted or reabsorbed would have a renal clearance equal to the GFR.

TMP14 p. 364

113. A) In the proximal tubule, calcium reabsorption usually parallels sodium and water reabsorption. With extracellular volume expansion or increased blood pressure, proximal sodium and water reabsorption are reduced, and a reduction in calcium reabsorption also occurs, causing increased urinary excretion of calcium. Increased parathyroid hormone, increased plasma phosphate concentration, and metabolic alkalosis all tend to decrease the renal excretion of calcium.

TMP14 pp. 390–391

114. C) Increasing sodium intake would decrease renin secretion and plasma renin activity, as well as reduce plasma aldosterone concentration and increase plasma atrial natriuretic peptide because of a mod-

est expansion of extracellular fluid volume. Although a high sodium intake would initially increase distal NaCl delivery, which would tend to increase potassium excretion, the decrease in aldosterone concentration would offset this effect, resulting in no change in potassium excretion under steady-state conditions. Even very large increases in sodium intake cause only minimal changes in plasma sodium concentration as long as the ADH–thirst mechanisms are fully operative.

TMP14 pp. 388–389

115. C) A 50% reduction in efferent arteriolar resistance would cause a large decrease in GFR—greater than 10%. A decrease in renal artery pressure from 100 to 85 mm Hg would cause only a slight decrease in GFR in a normal, autoregulating kidney. A decrease in afferent arteriole resistance, a decrease in plasma colloid osmotic pressure, or an increase in the glomerular capillary filtration coefficient would all tend to increase GFR.

TMP14 pp. 333–336, 338–339

116. D) Acute metabolic acidosis reduces intracellular potassium concentration, which, in turn, decreases potassium secretion by the principal cells of the collecting tubules. The primary mechanism by which increased hydrogen ion concentration inhibits potassium secretion is by reducing the activity of the sodium-potassium adenosine triphosphatase pump. This action then reduces intracellular potassium concentration, which, in turn, decreases the rate of passive diffusion of potassium across the luminal membrane into the tubule.

TMP14 p. 389

117. D) In a dehydrated person, osmolarity in the early distal tubule is usually less than 300 mOsm/l because the ascending limb of the loop of Henle and the early distal tubule are relatively impermeable to water, even in the presence of ADH. Therefore, the tubular fluid becomes progressively more dilute in these segments compared with plasma. ADH does not influence water reabsorption in the ascending limb of the loop of Henle. The ascending limb, however, reabsorbs sodium to a much greater extent than does the descending limb. Another important action of ADH is to increase the urea permeability in the medullary collecting ducts, which contributes to the hyperosmotic renal medullary interstitium in antidiuresis.

TMP14 pp. 372–373

118. E) Most potassium secretion occurs in the collecting tubules. A high-potassium diet stimulates potassium secretion by the collecting tubules through multiple mechanisms, including small increases in extracellular potassium concentration, as well as increased levels of aldosterone.

TMP14 pp. 386–387

119. A) Diabetic ketoacidosis results in a metabolic acidosis that is characterized by a decrease in plasma bicarbonate concentration, increased anion gap (due to the addition of unmeasured anions to the extracellular fluid along with the ketoacids), and a renal compensatory response that includes increased secretion of NH_4^+. There is also an increased respiratory rate with a reduction in arterial P_{CO_2}, as well as decreased urine pH and decreased renal HCO_3^- excretion.

TMP14 pp. 415–420

120. B) Interstitial fluid volume cannot be measured directly, but it can be calculated as the difference between extracellular fluid volume (inulin space = 16 l) and plasma volume (^{125}I-albumin space = 4 l). Therefore, interstitial fluid volume is approximately 12 l.

TMP14 pp. 308–310

121. E) Increased levels of insulin cause a shift of potassium from the extracellular fluid into the cells. All the other conditions have the reverse effect of shifting potassium out of the cells into the extracellular fluid.

TMP14 pp. 383–384

122. D) This patient is severely dehydrated as a result of sweating and lack of adequate fluid intake. The dehydration markedly stimulates the release of ADH and renin secretion, which in turn stimulates the formation of angiotensin II and aldosterone secretion.

TMP14 pp. 359, 375

123. E) After running the race and losing both fluid and electrolytes, this person replaces his fluid volume by drinking 2 l of water. However, he did not replace the electrolytes. Therefore, he would be expected to experience a decrease in plasma sodium concentration, resulting in a decrease in both intracellular and extracellular fluid osmolarity. The decrease in extracellular fluid osmolarity would lead to an increase in intracellular volume as fluid diffused into the cells from the extracellular compartment. Therefore, after drinking the water and absorbing it, the total body volume would be normal but intracellular volume would be increased and extracellular volume would be reduced.

TMP14 pp. 312–314

124. B) Increased levels of parathyroid hormone stimulate calcium reabsorption in the thick ascending loops of Henle and distal tubules. Extracellular fluid volume expansion, increased blood pressure, decreased plasma phosphate concentration, and metabolic acidosis are all associated with decreased calcium reabsorption by the renal tubules.

TMP14 pp. 390–391

125. C) In this example, the acidosis is associated with a reduced plasma bicarbonate concentration, signifying metabolic acidosis. In addition, the patient also

has an elevated P_{CO_2}, signifying respiratory acidosis. Therefore, the patient has simultaneous respiratory and metabolic acidosis.

TMP14 pp. 415–420

126. A) Chronic respiratory acidosis is caused by insufficient pulmonary ventilation, resulting in an increase in P_{CO_2}. Acidosis, in turn, stimulates the secretion of hydrogen ions into the tubular fluid and increased renal tubular production of NH_4^+, which further contributes to the excretion of hydrogen ions and the renal production of HCO_3^-, thereby increasing plasma bicarbonate concentration. The increased tubular secretion of hydrogen ions also reduces urine pH.

TMP14 pp. 415–416

127. A) Dilation of the afferent arterioles leads to an increase in the glomerular hydrostatic pressure and therefore an increase in GFR, as well as an increase in renal blood flow. Increased glomerular capillary filtration coefficient would also raise the GFR but would not be expected to alter renal blood flow. Increased plasma colloid osmotic pressure or dilation of the efferent arterioles would both tend to reduce the GFR. Increased blood viscosity would tend to reduce renal blood flow and GFR.

TMP14 pp. 333–337

128. B) Nonsteroidal antiinflammatory drugs inhibit the synthesis of prostaglandins, which, in turn, causes constriction of afferent arterioles that can reduce the GFR. The decrease in GFR, in turn, leads to an increase in serum creatinine. Increased efferent arteriole resistance and increased glomerular capillary filtration coefficient would both tend to increase rather than reduce GFR. Increasing muscle mass due to exercise would cause very little change in serum creatinine.

TMP14 pp. 333–338

129. A) In this example, the plasma sodium concentration is markedly increased but the urine sodium concentration is relatively normal, and urine osmolarity is almost maximally increased to 1200 mOsm/l. In addition, there are increases in plasma renin, ADH, and aldosterone, which is consistent with dehydration caused by decreased fluid intake. The syndrome of inappropriate ADH would result in a decrease in plasma sodium concentration, as well as suppression of renin and aldosterone secretion. Nephrogenic diabetes insipidus, caused by the kidneys' failure to respond to ADH, would also be associated with dehydration, but urine osmolarity would be reduced rather than increased. Primary aldosteronism would tend to cause sodium and water retention with only a modest change in plasma sodium concentration and a marked reduction in the secretion of renin. Likewise, a renin-secreting tumor would be associated with increases in plasma aldosterone concentration and plasma renin activity but only a modest change in plasma sodium concentration.

TMP14 pp. 375–376, 378–380

UNIT VI

Blood Cells, Immunity, and Blood Coagulation

The following table of normal test values can be referenced throughout Unit VI.

Test	Normal Values
Erythrocyte count	Male: 4.3-5.9 million/μl
	Female: 3.5-5.5 million/μl
Hematocrit	Male: 41%-53%
	Female: 36%-46%
Hemoglobin, blood	Male: 13.5-17.5 g/dl
	Female: 12.0-16.0 g/dl
Mean corpuscular hemoglobin	25.4-34.6 pg/cell
Mean corpuscular hemoglobin concentration	31%-36% hemoglobin
Mean corpuscular volume	80-100 fl
Reticulocyte count	0.5%-1.5% of red blood cells
Platelet count	150,000-400,000/μl
Leukocyte count and differential	
Leukocyte count	4500-11,000/μl
Neutrophils	54%-62%
Eosinophils	1%-3%
Basophils	0-0.75%
Lymphocytes	25%-33%
Monocytes	3%-7%
Partial thromboplastin time (activated)	25-40 seconds
Prothrombin time	11-15 seconds
Bleeding time	2-7 minutes

1. A 40-year-old woman visits the clinic complaining of fatigue. She had recently been treated for an infection. Her laboratory values are as follows: red blood cell (RBC) count, 1.8 × 10^6/μl; hemoglobin (Hb), 5.2 g/dl; hematocrit (Hct), 15; white blood cell (WBC) count, 7.6 × 10^3/μl; platelet count, 320,000/μl; mean corpuscular volume (MCV), 92 fL; and reticulocyte count, 24%. What is the most likely explanation for this presentation?
   A) Aplastic anemia
   B) Hemolytic anemia
   C) Hereditary spherocytosis
   D) B_{12} deficiency

2. What RBC enzyme facilitates transport of carbon dioxide (CO_2)?
   A) Myeloperoxidase
   B) Carbonic anhydrase
   C) Superoxide dismutase
   D) Globin reductase

3. A patient presents with hemoglobin of 7.9 g/dl, hematocrit of 23%, and mean corpuscular volume of 89 fl. Erythropoietin level is quite low. What is the most likely diagnosis?
   A) Sickle cell anemia
   B) Pernicious anemia
   C) End-stage renal disease
   D) Chronic blood loss

4. A patient has a hematocrit of 63% and a reduced erythropoietin level. Based on this information alone, what is the most likely diagnosis?
   A) Prolonged and continued exposure to high altitude
   B) Polycythemia vera
   C) Chronic obstructive pulmonary disease with hypoxemia
   D) Hemochromatosis

5. A 74-year-old man has a hemoglobin of 6.0 g/dl, hematocrit of 19%, mean corpuscular volume of 117, and large, bizarrely shaped erythrocytes on peripheral blood smear. His serum folic acid levels are normal. What is the likely cause of this disorder?
   A) Insufficient intrinsic factor
   B) Vitamin K deficiency
   C) Hepatic cirrhosis
   D) Alpha thalassemia

6. When red blood cells break down, the porphyrin portion of hemoglobin is converted by macrophages to what product(s)?
   A) Xanthine
   B) Branched-chain amino acids
   C) Homocysteine
   D) Bilirubin

7. How many oxygen *atoms* can be transported by each hemoglobin molecule?
   A) 2
   B) 4
   C) 8
   D) 16

8. During the second trimester of pregnancy, where is the predominant site of RBC production in the embryo?
   A) Yolk sac
   B) Bone marrow
   C) Lymph nodes
   D) Liver

9. What function do vitamin B_{12} and folic acid perform that is critical to hematopoiesis?
   A) Support porphyrin production
   B) Serve as cofactors for iron uptake
   C) Support terminal differentiation of erythroid and myeloid cells
   D) Support production of thymidine triphosphate

10. A 62-year-old man complains of headaches, visual difficulties, and chest pains. Physical examination reveals a red complexion and a large spleen. His complete blood cell count (CBC) is as follows: Hct, 58%; WBC, 13,300/μl; and platelets, 600,000/μl. His arterial oxygen saturation is 97% on room air. Which treatment would you recommend?
    A) Chemotherapy
    B) Phlebotomy
    C) Iron supplement
    D) Inhaled oxygen therapy

11. A 38-year-old healthy woman comes to you for a routine visit. She has spent the past 2 months hiking through the Himalayas and climbed to the base camp of Mount Everest. Which results would you expect to see on her CBC?

	Hematocrit	RBC count	WBC count	MCV
A)	↑	↑	↑	↑
B)	↑	↑	↔	↑
C)	↑	↑	↔	↔
D)	↑	↔	↔	↔
E)	↔	↑	↑	↔
F)	↑	↔	↑	↑
G)	↔	↑	↔	↑

12. A 24-year-old African American man comes to the emergency department 3 hours after the onset of severe back and chest pain. These problems started while he was walking briskly through a hilly neighborhood. He has had similar episodes numerous times in the past. He is in obvious pain. Laboratory studies show the following values:

    Hemoglobin = 11 g/dl
    Leukocyte count = 22,000/μl^3
    Reticulocyte count = 3.5%

    What is this patient's diagnosis?
    A) Acute blood loss
    B) Sickle cell anemia
    C) Anemia of chronic disease
    D) End-stage renal disease

13. After a person is placed in an atmosphere with low oxygen, how long does it take for increased numbers of reticulocytes to develop?
    A) 6 hours
    B) 12 hours
    C) 3 days
    D) 5 days
    E) 2 weeks

14. A patient presents to your office complaining of extreme fatigue and shortness of breath on exertion that has gradually worsened during the past 2 weeks. Physical examination reveals a well-nourished woman who appears comfortable but somewhat short of breath. Her vital signs include a pulse of 120, a respiratory rate of 20, and blood pressure of 120/70. When she stands up, her pulse increases to 150, and her blood pressure falls to 80/50. Her hematologic values are as follows: Hb, 7 g/dl; Hct, 20%; RBC count, 2×10^6/μl; and platelet count, 400,000/μl. On a peripheral smear, her RBCs are microcytic and hypochromic. What is your diagnosis?
    A) Aplastic anemia
    B) Renal failure
    C) Chronic and acute blood loss with iron-deficiency anemia
    D) Sickle cell anemia
    E) Megaloblastic anemia

15. Which phagocytes can extrude digestion products and continue to survive and function for many months?
    A) Neutrophils
    B) Basophils
    C) Macrophages
    D) Eosinophils

16. What cells ingest foreign material and micro-organisms within the sinusoids of the liver?
    A) Dendritic cells
    B) Megakaryocytes
    C) Basophils
    D) Kupffer cells

17. A 45-year-old man presents to the emergency department with a 2-week history of diarrhea that has gotten progressively worse during the past several days. He has minimal urine output and is admitted to the hospital for dehydration. His stool specimen is positive

for parasitic eggs. Which type of WBC would have an elevated number?

A) Eosinophils
B) Neutrophils
C) T lymphocytes
D) B lymphocytes
E) Monocytes

18. A 24-year-old man came to the emergency department with a broken leg. A blood test revealed his WBC count to be $22 \times 10^3/\mu l$. Five hours later, a second blood test revealed a WBC count of $7 \times 10^3/\mu l$. What is the cause of the increased WBC count in the first test?

A) Increased production of WBCs by the bone marrow
B) Release of preformed, mature WBCs into the circulation
C) Decreased destruction of WBCs
D) Increased production of selectins

19. A 62-year-old man who was known to have a normal blood cell count and differential count 3 months ago presents with pallor, bone pain, bruising, and a WBC count of 42,000. Eighty-five percent of cells in the circulation appear to be immature granulocytes. What is the diagnosis?

A) Acute lymphocytic leukemia
B) Acute myelocytic leukemia
C) Chronic lymphocytic leukemia
D) Chronic myelocytic leukemia

20. What cell type can interact with IgE and release large amounts of histamine, bradykinin, serotonin, heparin, lysosomal enzymes, and other inflammatory mediators?

A) Neutrophils
B) Basophils and mast cells
C) Eosinophils
D) Monocytes

21. A 60-year-old man is noted on a routine physical examination to have a significantly elevated white blood cell (WBC) count of $22{,}000/\mu l^3$, and 80% of cells are mature-appearing cells with large, round nuclei and scant cytoplasm. A review of the record shows that the WBC count has been moderately elevated for at least 18 months. What is the likely diagnosis?

A) Acute lymphocytic leukemia
B) Chronic lymphocytic leukemia
C) Acute myelocytic leukemia
D) Chronic myelocytic leukemia

22. Where does the transmigration of WBCs occur in response to infectious agents?

A) Arterioles
B) Lymphatic ducts
C) Capillaries and venules
D) Inflamed arteries

23. An 8-year-old boy frequently comes to the clinic for persistent skin infections that do not heal within a normal time frame. He had a normal recovery from the measles. A check of his antibodies after immunizations yielded normal antibody responses. A defect in which of the following cells would most likely be the cause of the frequent and prolonged infections?

A) B lymphocytes
B) Plasma cells
C) Neutrophils
D) Macrophages
E) CD4 T lymphocytes

24. Which cell type migrates into inflammatory sites to clean up necrotic tissue and direct tissue remodeling?

A) Neutrophil
B) Macrophage
C) Dendritic cell
D) Eosinophil

25. A 3-year-old child who has had frequent ear infections is found to have reduced immunoglobulin levels and is unresponsive to vaccination with tetanus toxoid. However, the child has normal skin test reactivity (delayed redness and induration) to a common environmental antigen. Which cell lineage is not functioning normally?

A) Macrophages
B) Helper T cells
C) Cytotoxic T cells
D) B cells

26. Patients with human immunodeficiency virus (HIV) exhibit abnormal functioning of which of the following mechanisms?

A) Antibody production only
B) T cell–mediated cytotoxicity only
C) Degranulation of appropriately stimulated mast cells
D) Both antibody production and T cell–mediated cytotoxicity

27. What is the term for binding of IgG and complement to an invading microbe to facilitate recognition?

A) Chemokinesis
B) Opsonization
C) Phagolysosome fusion
D) Signal transduction

28. Presentation by a cell of a foreign antigen bound to major histocompatibility complex (MHC)-I will result in which of the following?

A) Generation of antibodies
B) Activation of cytotoxic T cells
C) Increase in phagocytosis
D) Release of histamine by mast cells

29. The variable and hypervariable regions of immunoglobulins that are responsible for antigen binding and specificity reside in which part(s) of the immunoglobulin molecule?
    A) The heavy chains
    B) The light chains
    C) The hinge regions
    D) Both the heavy chains and the light chains
    E) The FC region

30. Fluid exudation into the tissue in an acute inflammatory reaction is due to which of the following?
    A) Decreased blood pressure
    B) Decreased protein in the interstitium
    C) Obstruction of the lymph vessels
    D) Increased clotting factors
    E) Increased vascular permeability

31. Which immune molecules can bind intact antigen?
    A) T cell receptors
    B) MHC class I
    C) MHC class II
    D) Immunoglobulins

32. What mechanisms are primarily responsible for producing a lip ulcer from herpes simplex virus?
    A) Activation of bradykinin by antibodies directed against herpes antigens
    B) Rapid influx of neutrophils and dendritic cells in response to virally-derived chemotactic factors
    C) Presentation of viral antigens by MHC class I and engagement by cytotoxic T cells
    D) Presentation of viral antigens by MHC class II and engagement by cytotoxic T cells

33. What is the function of IL-2 in the immune response?
    A) Binds to and presents antigen
    B) Stimulates proliferation of T cells
    C) Kills virus-infected cells
    D) Is required for an anaphylactic response

34. Which of the following is true about helper T cells?
    A) They are activated by the presentation of antigen by an infected cell
    B) They require the presence of a competent B-cell system
    C) They destroy bacteria by phagocytosis
    D) They are activated by the presentation of antigen by macrophages or dendritic cells

35. Which of the following applies to cytotoxic T cells?
    A) They require the presence of a competent B-lymphocyte system
    B) They require the presence of a competent suppressor T-lymphocyte system
    C) They are activated by the presentation of foreign antigen by an infected cell
    D) They destroy bacteria by initiating macrophage phagocytosis

36. A 9-year-old girl has nasal discharge and itching of the eyes in the spring every year. An allergist performs a skin test using a mixture of grass pollens. Within a few minutes, the girl exhibits a focal redness and swelling at the test site. This response is most likely due to
    A) Antigen–antibody complexes being formed in blood vessels in the skin
    B) Activation of neutrophils due to injected antigens
    C) Activation of CD4 helper cells and the resultant generation of specific antibodies
    D) Activation of cytotoxic T lymphocytes to destroy antigens

37. Activation of the complement system results in which action?
    A) Binding of the invading microbe with IgG
    B) Inactivation of eosinophils
    C) Decreased tissue levels of complement
    D) Generation of chemotactic substances

38. Which statement is true concerning erythroblastosis fetalis (hemolytic disease of the newborn [HDN])?
    A) HDN occurs when an Rh-positive mother has an Rh-negative child
    B) HDN is prevented by giving the mother a blood transfusion
    C) A complete blood transfusion after the first birth will prevent HDN
    D) The father of the child must be Rh positive

39. A couple requests blood typing of a newborn male (man is AB, Rh-positive; woman is A, Rh-negative). Hemagglutination assays show that the child is type O, Rh-positive. Which of the following conclusions regarding the child's parentage is valid?
    A) The child could be the natural offspring of this couple
    B) The mother could be the natural mother, but the father could not be the natural father
    C) The father could be the natural father, but the mother could not be the natural mother
    D) Neither the father nor the mother could be the natural parents

40. A woman whose blood type is A, Rh positive, and a man whose blood type is B, Rh positive, come to the clinic with a 3-year-old girl whose blood type is O, Rh negative. What can be said about the relationship of these two adults to this child?
    A) The woman could be the child's natural mother, but the man could not be the natural father
    B) The man could be the child's natural father, but the woman could not be the natural mother
    C) Neither adult could be the natural parent of this child
    D) This couple could be the natural parents of this child

41. What is the appropriate treatment for an infant born with severe HDN (erythroblastosis fetalis)?
    A) Passive immunization with anti-Rh(D) immunoglobulin
    B) Immunization with Rh(D) antigen
    C) Exchange transfusion with Rh(D)-positive blood
    D) Exchange transfusion with Rh(D)-negative blood

42. Chronic allograft rejection results primarily from the actions of what effector cell type?
    A) Activated macrophages
    B) Helper T lymphocytes
    C) Cytotoxic T lymphocytes
    D) Dendritic cells

43. Which of the following transfusions will result in an immediate transfusion reaction?
    A) O Rh-negative whole blood to an O Rh-positive patient
    B) A Rh-negative whole blood to a B Rh-negative patient
    C) AB Rh-negative whole blood to an AB Rh-positive patient
    D) B Rh-negative whole blood to a B Rh-negative patient

44. Given optimal transplantation technique, the following types of grafts may be expected to succeed, with long-term graft acceptance.
    A) Allografts and xenografts
    B) Autografts and allografts
    C) Isografts and autografts
    D) Allografts and isografts
    E) Grafts with at least a 3/6 HLA match

45. After trauma, a person whose blood type is AB, Rh negative and who has never had a transfusion before receives four units of appropriately cross-matched type A, Rh positive blood. What is the likely outcome?
    A) Fever, chills, shortness of breath, circulatory shock, and renal shutdown
    B) Rapid hemolysis of the transfused cells
    C) Moderate, intracellular hemolysis over a period of a few weeks
    D) Anaphylactic shock

46. Which transfusion will result in an immediate transfusion reaction? Assume that the patient has never had a transfusion.
    A) Type O Rh-negative packed cells to an AB Rh-positive patient
    B) Type A Rh-positive packed cells to an A Rh-negative patient
    C) Type AB Rh-positive packed cells to an AB Rh-positive patient
    D) Type A Rh-positive packed cells to an O Rh-positive patient

47. Which antigens must be matched optimally between donors and recipients of solid organ transplants?
    A) Class I human leukocyte antigen (HLA) antigens only
    B) Class II HLA antigens only
    C) Class I and Class II HLA antigens only
    D) Class I and Class II HLA antigens and ABO antigens

48. A woman whose blood type is A positive and who has always been healthy just delivered her second child. The father's blood type is O negative. Because the child's blood type is O negative (O, Rh negative), what would you expect to find in this child?
    A) Erythroblastosis fetalis due to rhesus incompatibility
    B) Erythroblastosis fetalis due to ABO blood group incompatibility
    C) Both A and B
    D) The child would not be expected to have HDN

49. A 55-year-old man who has been undergoing stable and successful anticoagulation with warfarin for recurrent deep vein thrombosis is treated for pneumonia, and 8 days later he presents with lower intestinal bleeding. His prothrombin time is quite prolonged. What is the appropriate therapy?
    A) Treatment with tissue plasminogen activator
    B) Infusion of calcium citrate
    C) Treatment with fresh-frozen plasma and vitamin K
    D) Rapid infusion of protamine

50. A 2-year-old boy bleeds excessively from minor injuries and has previously had bleeding gums. The maternal grandfather has a bleeding disorder. The child's physical examination shows slight tenderness of his knee with fluid accumulation in the knee joint. You suspect this patient is deficient in which coagulation factor(s)?
    A) Prothrombin activator
    B) Factor II
    C) Factor VIII or Factor IX
    D) Factor X

51. A Viet Nam veteran with chronic, severe hepatitis C has developed an intractable nosebleed. His platelet count is 180,000, and his international normalized ratio (INR) is markedly increased at 7.0. In addition to local compression at the bleeding site what is the appropriate therapy?
    A) Coumarin
    B) Fresh-frozen plasma
    C) Platelet transfusion
    D) Fibrinogen infusion

52. Which agent is not effective as an in vitro anticoagulant?
    A) Heparin
    B) Warfarin (Coumadin)

C) Ethylenediamine tetraacetic acid (EDTA)
D) Sodium citrate

53. Hemophilia A affects which pathway of blood coagulation?
A) Intrinsic pathway only
B) Extrinsic pathway only
C) Intrinsic and extrinsic pathways only
D) Intrinsic, extrinsic, and common pathways

54. A homeless person is brought in from a vacant lot with signs of sepsis and with persistent bleeding from his gums, phlebotomy sites, and around IV catheters. His white blood cell count is 15,000 with normal cellular morphology and a few immature neutrophils (band cells), and his platelet count is somewhat reduced at 95,000. What is the most likely diagnosis?
A) Reduced fibrinogen concentration due to liver disease
B) Inhibition of platelet function by methyl alcohol ingestion
C) Dietary deficiency of vitamin B_{12} and folic acid
D) Disseminated intravascular coagulation

55. Which coagulation pathway begins with tissue thromboplastin?
A) Extrinsic pathway
B) Intrinsic pathway
C) Common pathway
D) Fibrin stabilization

56. A 56-year-old electrician has severe but undiagnosed gluten sensitivity with persistent diarrhea and weight loss. He has excessive bleeding after a dental extraction and is found to have a markedly prolonged prothrombin time of 37 seconds. What is the most likely cause of his excessive bleeding?
A) Hepatocellular disease
B) Vitamin K deficiency
C) Protein malnutrition with inadequate fibrinogen
D) Loss of clotting factors through the gastrointestinal mucosa

57. Which of the following would best explain a prolonged bleeding time test?
A) Hemophilia A
B) Hemophilia B
C) Thrombocytopenia
D) Coumadin use

58. Which of the following is appropriate therapy for a massive pulmonary embolism?
A) Citrated plasma
B) Warfarin
C) Aspirin
D) Tissue plasminogen activator

59. What is the primary mechanism by which heparin prevents blood coagulation?
A) Antithrombin III activation
B) Binding and inhibition of tissue factor
C) Binding available calcium
D) Inhibition of platelet-activating factor

60. A 14-year-old boy has a life long history of excessive bleeding, often involving bleeding into his joints (hemarthrosis). There is a positive history of a similar disorder in several male relatives. You may assume that he inherited this disorder from which parent(s)?
A) His father
B) His mother
C) Both parents
D) Penetrance of this disorder is variable and difficult to interpret

ANSWERS

1. **B)** This patient has increased production of RBCs as indicated by a markedly increased reticulocyte count in the setting of significant anemia (low red blood cell number, hemoglobin, and hematocrit). The RBCs being produced have a normal size (MCV = 90), and thus the patient does not have spherocytosis (small RBCs) or vitamin B_{12} deficiency (large RBCs). The normal WBC count and the increased reticulocyte count suggest that the bone marrow is functioning. The increased reticulocyte count means that a large number of RBCs are being produced. These laboratory values support an anemia due to some type of blood loss—in this case an anemia due to hemolysis.
   TMP14 pp. 440–443, 446

2. **B)** Carbonic anhydrase catalyzes the reaction of CO_2 with water to allow large amounts of CO_2 to be transported in blood as soluble bicarbonate ion.
   TMP14 p. 439

3. **C)** In end-stage renal disease, the kidneys cease to make erythropoietin, leading to severe anemia. The types of anemia in the other three possible answers lead to red blood cell loss or destruction and *increased* erythropoietin due to tissue hypoxemia.
   TMP14 p. 442

4. **B)** In polycythemia vera autonomous, clonal production of red blood cells results in increased hemoglobin, hematocrit, and red blood cell count and decreased erythropoietin, because hypoxemic drive for "epo" production is reduced. High-altitude exposure and chronic obstructive pulmonary disease are both associated with tissue hypoxemia that drives *increased* erythropoietin production. Hemochromatosis is a disorder of systemic iron overload with normal red blood cell production.
   TMP14 pp. 442, 447

5. **A)** The clinical presentation is that of a megaloblastic anemia, which can be caused by a deficiency of either vitamin B_{12} or folic acid. Because this patient's folic acid levels are normal, the cause must be vitamin B_{12} deficiency caused by atrophy of the gastric mucosa resulting in insufficient production of intrinsic factor, needed for normal gastrointestinal absorption of vitamin B_{12}.
   TMP14 p. 443

6. **D)** Macrophages convert the porphyrin portion of hemoglobin to bilirubin.
   TMP14 p. 445

7. **C)** Each hemoglobin molecule has four globin chains (in hemoglobin A, the predominant form in adults, the hemoglobin molecule includes two alpha and two beta chains). Each globin chain is associated with one heme group, containing one atom of iron. Each of the four iron atoms can bind loosely with one molecule (two atoms) of oxygen. Thus, each hemoglobin molecule can transport eight oxygen atoms.
   TMP14 p. 444

8. **D)** RBC production begins in the yolk sac for the first trimester. Production in the yolk sac decreases at the beginning of the second trimester, and the liver becomes the predominant source of RBC production. RBC production from the bone marrow increases during the third trimester and continues throughout life.
   TMP14 pp. 439–440

9. **D)** Cell proliferation requires DNA replication, which requires an adequate supply of thymidine triphosphate. Both vitamin B_{12} and folate are needed to make thymidine triphosphate.
   TMP14 p. 443

10. **B)** This patient has polycythemia vera: increased RBCs, WBCs, and platelets. Normal arterial oxygen saturation shows that there is no reason for a compensatory polycythemia. His increased hematocrit also increases the viscosity of the blood, resulting in increased afterload for the heart, which is probably the reason for his chest pain. Thus, phlebotomy (bleeding) is needed to decrease his elevated blood cell count and blood viscosity.
    TMP14 p. 447

11. **C)** Secondary polycythemia has developed because of exposure to low oxygen levels. She will have an increased hematocrit level and RBC count but a normal WBC count. The cells are normal, so the MCV will be normal.
    TMP14 p. 447

12. **B)** This African American man has sickle cell anemia, as demonstrated by his decreased hemoglobin concentration, moderately elevated reticulocyte count, and history of painful crises. His elevated WBC count suggests a response to stress hormones, with recruitment of mature leukocytes into the circulation. Increased oxygen demand from walking in hilly terrain likely produced tissue ischemia with resultant sickling of his RBCs.
    TMP14 p. 446

13. **C)** EPO levels increase in response to decreased arterial oxygen level, with the maximum EPO production

occurring within 24 hours. It takes 3 days for new reticulocytes to appear in the circulation, and after a total of 5 days from the beginning of hypoxemia, these reticulocytes will be circulating as mature erythrocytes. Because it takes 1 to 2 days for a reticulocyte to become an erythrocyte, the correct answer is 3 days until the person has an increased number of reticulocytes.

TMP14 pp. 441–442

14. C) The blood cell count shows that the patient is anemic. Her bone marrow is functioning and she has a normal platelet count, but she is generating a decreased number of abnormal RBCs. The microcytic (small), hypochromic (decreased intracellular hemoglobin) RBCs are a classic finding of iron-deficiency anemia, which suggests that blood loss has been sufficiently sustained to lead to iron depletion. A decrease in her blood pressure on standing (postural hypotension) suggests decreased intravascular volume, indicating that there may also be a component of acute blood loss. If she had renal failure, she would be anemic with normal RBCs. People with sickle cell anemia have misshapen RBCs. Megaloblastic anemia is characterized by macrocytic (large) RBCs.

TMP14 p. 446

15. C) Macrophages become activated and enlarged at sites of inflammation and can ingest up to 100 bacteria per macrophage. They can extrude digested material and remain viable and active for many months. Basophils are not phagocytic, and eosinophils are weak phagocytes. Neutrophils respond rapidly to infection or inflammation and ingest from 3 to 20 bacteria or other particles before dying.

TMP14 pp. 451–452, 456–457

16. D) Kupffer cells are tissue-specific macrophages that reside in the hepatic sinusoids.

TMP14 p. 453

17. A) Eosinophils normally constitute about 2% of the total WBC count, but they are produced in large numbers in people with parasitic infections.

TMP14 p. 456

18. B) The majority of WBCs are stored in the bone marrow, waiting for an increased level of cytokines or stress hormones (e.g., epinephrine, corticosteroids) to stimulate their release into the circulation. Trauma to bone can result in a release of WBCs into the circulation. This increase in WBC count is not primarily due to any inflammatory response but instead is attributed to mechanical trauma and associated stress responses.

TMP14 p. 455

19. B) The WBC count of 42,000 is higher than the range usually seen as a response to infection and suggests leukemia. The patient's florid clinical presentation suggests an acute process, and findings of a normal CBC 3 months previously confirm that this patient has an acute leukemia. Granulocytes are myeloid cells, and the fact that they are in the circulation while still being immature is wholly compatible with leukemia. Thus, the patient has acute myelocytic (also referred to as "myelogenous" or "myeloid") leukemia.

TMP14 p. 457

20. B) Cross-linking of IgE receptors on the surface of basophils and mast cells results in their degranulation, releasing an array of inflammatory mediators.

TMP14 p. 457

21. B) The white blood cell count has been elevated for more than a year and the cells that are in excess are mature-appearing cells that clearly are lymphocytes. Thus, this is chronic lymphocytic leukemia (CLL). Patients with CLL frequently remain asymptomatic for long periods, often many years.

TMP14 p. 457

22. C) Transmigration of WBCs occurs through parts of the vasculature that have very thin walls and minimal vascular smooth muscle layers. This includes capillaries and venules.

TMP14 p. 451

23. C) Bacterial killing in cutaneous infections is largely mediated by neutrophils, which produce bactericidal agents, including reactive oxygen species. For the acquired immune response to function normally, T and B lymphocytes and plasma cells, along with macrophages, are needed.

TMP14 pp. 452, 454–455

24. B) Macrophages follow the initial influx of neutrophils into an inflammatory site. Whereas neutrophils ingest a modest number of bacteria per cell before dying, macrophages persist at the site, ingesting and digesting infectious organisms and necrotic material and producing cytokines that direct tissue remodeling by fibroblasts and other cell types. Dendritic cells are resident antigen-presenting cells, whereas eosinophils are weakly phagocytic cells whose products (e.g., major basic protein) can kill parasites without the eosinophils ingesting them.

TMP14 p. 455

25. D) The presence of normal skin test reactivity, which is T cell mediated, indicates normal function of macrophages and other antigen-presenting cells, helper T cells, and cytotoxic T cells. This information, and the reduction in antibody production, localizes the defect to the B-cell lineage.

TMP14 pp. 462, 467–468

26. D) Patients with HIV have specific loss of T-helper cells, resulting in a loss of T-cell help for both antibody production and activation and proliferation of cytotoxic

T cells. Assuming that mast cells can be appropriately stimulated (i.e., bear sufficient residual surface-bound IgE and are exposed to relevant antigen), their processes for degranulation are intact.
TMP14 p. 467

27. B) Phagocytosis of bacteria is enhanced by the presence on their surfaces of both immunoglobulin and products of the complement cascade, which in turn bind to surface receptors on phagocytes. This "tagging" of bacteria and other particles for enhanced phagocytosis is called *opsonization.*
TMP14 p. 465

28. B) Presentation of a foreign antigen bound to MHC I on an infected cell results in activation of the cytotoxic T cells to kill the infected cell. Presentation of an antigen by MHC II on macrophages activates helper T cells, which promote antibody production and support proliferation of both helper and cytotoxic T cells.
TMP14 p. 466

29. D) Variable and hypervariable regions are present at the ends of both the heavy and light chains of immunoglobulin, allowing both chains to participate in antigen binding.
TMP14 pp. 463–464

30. E) Fluid leaks into the tissue because of an increase in capillary permeability.
TMP14 pp. 465–466

31. D) Only immunoglobulins bind intact antigen. T-cell receptors and MHC class I and II molecules bind processed peptides but do not bind intact antigen.
TMP14 pp. 464, 466

32. C) Infected labial cells process viral antigens and present them, bound to MHC class I molecules. Viral antigens in association with MHC class I molecules are recognized by antigen-specific cytotoxic T cells, which then destroy the virally infected cells, producing a lip ulcer.
TMP14 pp. 466–468

33. B) IL-2 is secreted by helper T cells when the T cells are activated by specific antigens. IL-2 plays an important role in the proliferation of helper, cytotoxic, and suppressor T cells.
TMP14 p. 467

34. D) Helper T cells are activated by the presentation of processed antigens by MHC class II molecules on the surface of antigen-presenting cells (primarily macrophages and dendritic cells). Helper T cells activate B cells to form antibodies, but B cells are not required for activation of helper T cells. Helper T cells help to enhance phagocytosis by macrophages but they do not have the ability to phagocytize bacteria themselves.
TMP14 pp. 466–467

35. C) Cytotoxic cells act on infected cells when the cells have the appropriate antigen located on their surfaces. Cytotoxic T cells are stimulated by lymphokines generated by activation of helper T cells. Cytotoxic T cells destroy an infected cell by expressing proteins that punch large holes in the membrane of the infected cells. There is no interaction between cytotoxic T cells and normal B cells.
TMP14 pp. 467–468

36. A) Because the person has previously demonstrated allergic reactions, the initial cutaneous response reflects the binding of antigen by specific IgE on the surfaces of basophils and mast cells, resulting in the release of an array of inflammatory mediators. In addition, activation of the complement system results in the production of C3a and C4a, which also activate basophils and mast cells. The influx of neutrophils activation of T-helper cells and the accumulation of antigen-specific T lymphocytes would take some time.
TMP14 pp. 469–470

37. D) Activation of the complement system results in a series of actions, including opsonization and phagocytosis by neutrophils, lysis of bacteria, agglutination of organisms, activation of basophils and mast cells, and chemotaxis. Fragment C5a of the complement system causes chemotaxis of neutrophils and macrophages.
TMP14 p. 465

38. D) HDN occurs when an Rh-negative mother gives birth to a second or subsequent Rh-positive child. Therefore, the father must be Rh positive. The mother becomes sensitized to the Rh antigens during the events surrounding the birth of an Rh-positive child. HDN in future pregnancies can be prevented by treating the mother with antibodies against Rh antigen around the birth of each Rh-positive child. This treatment destroys fetal RBCs in the mother and prevents the mother from being sensitized to the Rh antigen. A transfusion of the child after birth does not prevent HDN in future pregnancies because the mother has already been exposed to the Rh antigen during the birth process.
TMP14 pp. 473–474

39. B) The mother could be heterozygous for blood types A and O and thus could have a type O child. Rh positivity could have been determined by an allele from the actual father. The man in this couple is type AB and thus could not have contributed a blood type O allele (persons who are type O must receive an O allele from each parent).
TMP14 p. 472

40. D) Each parent needs only a single allele for either the A or B antigen or the Rh(D) antigen to express these antigens on their blood cells and other cell types. Thus, if each parent also carries an allele for blood type O, as

well as a null allele for the Rh(D) antigen, then the child can be homozygous for the recessive O allele and the Rh(D)-negative allele.

TMP14 pp. 472–473

41. D) The appropriate treatment is repetitive removal of Rh-positive blood, replacing it with Rh-negative blood (an exchange of about 400 ml over 90 minutes). This treatment may be performed several times over a few weeks. Maternal antibodies disappear over 1 to 2 months, so the newborn's endogenous Rh-positive cells cease to be a target. Exchange transfusions can actually be initiated in utero when there is evidence of an active immune reaction against the fetus's blood cells.

TMP14 p. 474

42. C) Allograft rejection occurs primarily through the actions of cytotoxic T cells. T-helper cells promote this reaction but are not the effector cells. Both macrophages and dendritic cells may present antigen that promotes the immune response, but the key effector cells are cytotoxic T cells.

TMP14 pp. 475–476

43. B) Type A blood has A antigen on the red blood cell surface and serum antibodies to the B antigen. Type B blood has B surface antigens and anti-A antibodies. Therefore, transfusing type A blood into a person with type B blood causes the A antibodies in the type B recipient to react with the donor blood. Transfusion of Rh-negative blood into an Rh-positive person with the same ABO type will not result in any reaction.

TMP14 pp. 472–473

44. C) Isografts and autografts are derived from genetically identical donors or from the recipient's own tissues, respectively. Therefore, they can be expected to be readily accepted because they present no foreign antigens to the recipient. Allografts and xenografts do result in the presentation of foreign antigens. Any HLA mismatch indicates that the transplanted tissue or organ is an allograft that carries known foreign antigens.

TMP14 p. 475

45. C) A person who has never been exposed to the Rh antigen before would not have anti-Rh antibodies and thus would not have an immediate transfusion reaction. Rather, such antibodies would develop over a few weeks, resulting in gradual opsonization and phagocytosis of the transfused cells with moderate, intracellular hemolysis.

TMP14 p. 473

46. D) Type A, Rh-positive cells express both the A and Rh antigens. Persons with type O blood develop antibodies to type A antigen through dietary and environmental exposure. Thus, transfusion of type A blood into a type O recipient results in an immediate transfusion reaction. Reaction to Rh antigens requires prior exposure through an Rh-incompatible blood transfusion. Reactions occur between the recipient's antibodies and donor antigens as shown in the following table.

TMP14 pp. 472–473

Donor	Donor Antigen	Recipient	Recipient Antibody	Reaction
O negative	None	AB positive	None	None
A positive	A, Rh	A negative	B	None
AB positive	A, B, Rh	AB positive	None	None
A positive	A, Rh	O positive	A, B	A (antigen) and A (antibody)

47. D) Unmatched donor HLA antigens of both classes are recognized as foreign by recipient T cells. In addition, blood group (ABO) antigens are expressed on the cells of solid organs and can lead to strong, immediate organ rejection.

TMP14 p. 475

48. D) HDN occurs when the mother is Rh negative and the father is Rh positive, resulting in an Rh-positive child. Because the child is O, Rh negative, HDN would not be expected to develop.

TMP14 p. 473

49. C) Antibiotic treatment for pneumonia can kill flora in the gastrointestinal tract that are critical for the production of vitamin K. Production of several active clotting factors (prothrombin and factors VII, IX, and X) has been suppressed in this patient by warfarin inhibition of VKOR c1, which normally chemically reduces vitamin K so that it can activate the listed clotting factors. Further quantitative reduction of vitamin K by the death of critical gut flora has produced excessive anticoagulation and resulted in bleeding in this patient. Fresh-frozen plasma is infused to provide active clotting factors immediately, and vitamin K is provided to promote endogenous production of active clotting factors. Both are needed in the setting of acute bleeding.

TMP14 pp. 484, 486–487

50. C) Inheritance of a bleeding disorder from the maternal grandfather is classic for an X-linked disorder—the grandfather transmits the affected X allele to his daughter, who transmits it to her son. Hemophilia A and B, resulting in deficiency of clotting factors VIII and IX, respectively, are both X-linked disorders that present in the manner described for this 2-year-old boy.

TMP14 p. 485

51. B) In this patient with chronic, severe viral hepatitis, liver damage has led to hepatic insufficiency, so that he is no longer able to manufacture sufficient quantities of

clotting factors. These must be provided in this emergent situation by treatment with fresh-frozen plasma. Fibrinogen production generally remains adequate in patients with liver failure.

TMP14 p. 484

52. B) Warfarin functions by interfering with the production of active clotting factors. It is not effective in inhibiting clotting factors *in vitro.*

TMP14 pp. 486–487

53. A) Hemophilia A is caused by a deficiency of clotting factor VIII, which functions in the intrinsic clotting pathway only.

TMP14 pp. 482, 485

54. D) In sepsis and particularly septic shock, bacteria and bacterial toxins such as endotoxin, plus the release of large amounts of tissue factor from traumatized or dying tissue, cause wide spread activation of the clotting system. This produces innumerable small clots that occlude small vessels and exacerbate tissue damage. Paradoxically, this consumes clotting factors to an extent that the clinical result is bleeding from multiple sites. Even if a toxin that could inhibit platelet function had been ingested, this usually is manifested by cutaneous petechiae (small, punctate hemorrhages) and bruising rather than widespread bleeding.

TMP14 p. 486

55. A) The extrinsic pathway begins with the release of tissue thromboplastin in response to vascular injury or contact between traumatized extravascular tissue and blood. Tissue thromboplastin is composed of phospholipids from the membranes of the damaged tissues.

TMP14 p. 481

56. B) Severe diarrhea can lead to fat malabsorption. Because vitamin K is a fat-soluble vitamin, this can result in vitamin K deficiency. Vitamin K is required for the production of active clotting factors. Thus, vitamin K deficiency can cause defective blood coagulation and excessive bleeding.

TMP14 p. 484

57. C) Bleeding time, measured by determining how long it takes for bleeding to stop from a small, standardized cut, reflects platelet aggregation and activation and the formation of platelet plugs in the small vessels that have been damaged. Blood coagulation involving the activation of thrombin and the accumulation of fibrin fibrils takes significantly longer.

TMP14 p. 487

58. D) Treating a massive pulmonary embolus is an emergency that requires lysis of an existing clot. This can be accomplished by infusing tissue plasminogen activator, which converts plasminogen to plasmin, which then actively lyses the clot. In this setting measures that inhibit clot formation are less relevant because a life-threatening clot already exists.

TMP14 p. 486

59. A) The primary function of heparin is to bind to and activate antithrombin III.

TMP14 p. 484

60. B) A familial disorder that occurs in males only suggests an X-linked disorder because males have a single X chromosome, and if it is defective, then that defect is expressed clinically (rather than being masked by a normally functioning X chromosome, as occurs in females). Males receive their X chromosome from their mothers and their Y chromosome from their fathers. The most common X-linked bleeding disorders are hemophilia A and hemophilia B, which are highly penetrant.

TMP14 p. 485

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UNIT VII

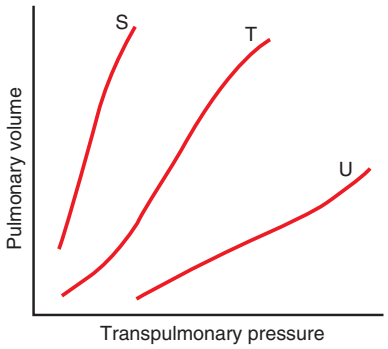
Respiration

1. A healthy 25-year-old medical student participates in a 10-km charity run for the American Heart Association. Which muscles does the student use (contract) during expiration?

   A) Diaphragm and external intercostals
   B) Diaphragm and internal intercostals
   C) Diaphragm only
   D) Internal intercostals and abdominal recti
   E) Scaleni
   F) Sternocleidomastoid muscles

2. Several students are trying to see who can generate the highest expiratory flow. Which muscle is most effective at producing a maximal effort?

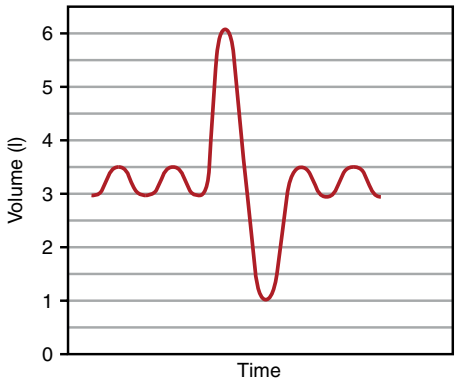
   A) Diaphragm
   B) Internal intercostals
   C) External intercostals
   D) Rectus abdominis
   E) Sternocleidomastoid



3. The above figure shows three different compliance curves (S, T, and U) for isolated lungs subjected to various transpulmonary pressures. Which of the following best describes the relative compliances for the three curves?

   A) S < T < U
   B) S < T > U
   C) S – T – U
   D) S > T < U
   E) S > T > U

Questions 4 and 5
Use the figure below to answer Questions 4 and 5.



4. Assuming a respiratory rate of 12 breaths/min, calculate the minute ventilation.

   A) 1 l/min
   B) 2 l/min
   C) 4 l/min
   D) 5 l/min
   E) 6 l/min

5. A 22-year-old woman inhales as much air as possible and exhales as much air as she can, producing the spirogram shown in the figure. A residual volume of 1.0 liter is determined using the helium dilution technique. What is her FRC (in liters)?

   A) 2.0
   B) 2.5
   C) 3.0
   D) 3.5
   E) 4.0
   F) 5.0

6. A 22-year-old woman has a pulmonary compliance of 0.2 l/cm H_2O and a pleural pressure of –4 cm H_2O. What is the pleural pressure (in cm H_2O) when the woman inhales 1.0 l of air?

   A) –6
   B) –7
   C) –8
   D) –9
   E) –10

7. A preterm infant has a surfactant deficiency. Without surfactant, many of the alveoli collapse at the end of each expiration, which in turn leads to pulmonary failure. Which set of changes is present in the preterm infant compared with a normal infant?

	Alveolar Surface Tension	Pulmonary Compliance
A)	Decreased	Decreased
B)	Decreased	Increased
C)	Decreased	No change
D)	Increased	Decreased
E)	Increased	Increased
F)	Increased	No change
G)	No change	No change

8. A patient has a dead space of 150 ml, FRC of 3 liters, tidal volume (VT) of 650 ml, expiratory reserve volume (ERV) of 1.5 l, total lung capacity (TLC) of 8 l, and respiratory rate of 15 breaths/min. What is the residual volume (RV)?

A) 500 ml
B) 1000 ml
C) 1500 ml
D) 2500 ml
E) 6500 ml

9. The various lung volumes and capacities include the total lung capacity (TLC), vital capacity (VC), inspiratory capacity (IC), tidal volume (VT), expiratory capacity (EC), expiratory reserve volume (ERV), inspiratory reserve volume (IRV), functional residual capacity (FRC), and residual volume (RV). Which of the following lung volumes and capacities can be measured using direct spirometry without additional methods?

	TLC	VC	IC	VT	EC	ERV	IRV	FRC	RV
A)	No	No	Yes	No	Yes	No	Yes	No	No
B)	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No
C)	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
D)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
E)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

10. A 34-year-old man sustains a bullet wound to the chest that causes a pneumothorax. What best describes the changes in lung volume and thoracic volume in this man compared with normal?

	Lung Volume	Thoracic Volume
A)	Decreased	Decreased
B)	Decreased	Increased
C)	Decreased	No change
D)	Increased	Decreased
E)	Increased	Increased
F)	No change	Decreased

11. A healthy 10-year-old boy breathes quietly under resting conditions. His tidal volume is 400 ml, and his ventilation frequency is 12/min. Which of the following best describes the ventilation of the upper, middle, and lower lung zones in this boy?

	Upper Zone	Middle Zone	Lower Zone
A)	Highest	Lowest	Intermediate
B)	Highest	Intermediate	Lowest
C)	Intermediate	Lowest	Highest
D)	Lowest	Intermediate	Highest
E)	Same	Same	Same

12. An experiment is conducted in two persons (subjects T and V) with identical VTs (1000 ml), dead space volumes (200 ml), and ventilation frequencies (20 breaths/min). Subject T doubles his VT and reduces his ventilation frequency by 50%. Subject V doubles his ventilation frequency and reduces his VT by 50%. What best describes the total ventilation (also called minute ventilation) and VA of subjects T and V?

	Total Ventilation	VA
A)	T < V	T – V
B)	T < V	T > V
C)	T – V	T < V
D)	T – V	T – V
E)	T – V	T > V
F)	T > V	T < V
G)	T > V	T – V

13. A person with normal lungs has an oxygen (O_2) consumption of 750 ml O_2/min. The hemoglobin (Hb) concentration is 15 g/dl. The mixed venous saturation is 25%. What is the cardiac output?

A) 2500 ml/min
B) 5000 ml/min
C) 7500 ml/min
D) 10,000 ml/min
E) 20,000 ml/min

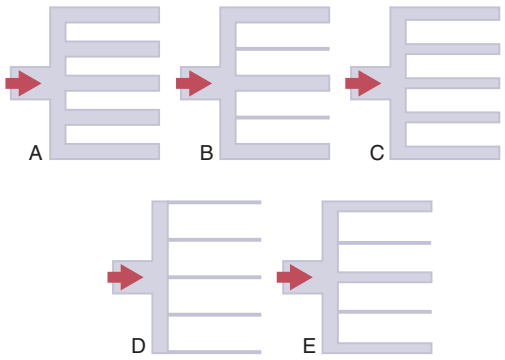
14. A cardiac catheterization is performed in a healthy adult. The blood sample withdrawn from the catheter shows 60% O_2 saturation, and the pressure recording shows oscillations from a maximum of 27 mm Hg to a minimum of 12 mm Hg. Where was the catheter tip located?

A) Ductus arteriosus
B) Foramen ovale
C) Left atrium
D) Pulmonary artery
E) Right atrium

15. A 67-year-old man is admitted emergently to the hospital because of severe chest pain. A Swan-Ganz catheter is floated into the pulmonary artery, the balloon is inflated, and the pulmonary wedge pressure is measured. The pulmonary wedge pressure is used clinically to monitor which pressure?

A) Left atrial pressure
B) Left ventricular pressure

C) Pulmonary artery diastolic pressure
D) Pulmonary artery systolic pressure
E) Pulmonary capillary pressure



16. Which diagram in the above figure best illustrates the pulmonary vasculature when the cardiac output has increased to a maximum extent?

A) A
B) B
C) C
D) D
E) E

17. A 19-year-old man sustains a full-thickness burn over 60% of his body surface area. A systemic *Pseudomonas aeruginosa* infection occurs, and severe pulmonary edema follows 7 days later. The following data are collected from the patient: plasma colloid osmotic pressure, 19 mm Hg; pulmonary capillary hydrostatic pressure, 7 mm Hg; and interstitial fluid hydrostatic pressure, 1 mm Hg. Which set of changes has occurred in the lungs of this patient as a result of the burn and subsequent infection?

	Lymph Flow	Plasma Colloid Osmotic Pressure	Pulmonary Capillary Permeability
A)	Decrease	Decrease	Decrease
B)	Increase	Decrease	Decrease
C)	Increase	Decrease	Increase
D)	Increase	Increase	Decrease
E)	Increase	Increase	Increase

18. Blood gas measurements are obtained in a resting patient who is breathing room air. The patient has an arterial content of 19 ml O_2/min with a P_{O_2} of 95. The mixed venous O_2 content is 4 ml O_2/100 ml blood. Which condition does the patient have?

A) An increase in physiological dead space
B) Pulmonary edema
C) A low Hb concentration
D) A low cardiac output

19. A normal male subject has the following initial conditions (in the steady state):

Arterial P_{O_2} = 92 mm Hg
Arterial O_2 saturation = 97%
Venous O_2 saturation = 20%
Venous P_{O_2} = 30 mm Hg
Cardiac output = 5600 ml/min
O_2 consumption = 256 ml/min
Hb concentration = 12 g/dl

If you ignore the contribution of dissolved O_2 to the O_2 content, what is the venous O_2 content?

A) 2.2 ml O_2/100 ml blood
B) 3.2 ml O_2/100 ml blood
C) 4 ml O_2/100 ml blood
D) 4.6 ml O_2/100 ml blood
E) 6.2 ml O_2/100 ml blood
F) 10.8 ml O_2/100 ml blood
G) 16 ml O_2/100 ml blood

20. A 30-year-old woman performs a Valsalva maneuver about 30 minutes after eating lunch. Which option best describes the changes in pulmonary and systemic blood volumes that occur in this woman?

	Pulmonary Volume	Systemic Volume
A)	Decreases	Decreases
B)	Decreases	Increases
C)	Decreases	No change
D)	Increases	Decreases
E)	Increases	Increases
F)	Increases	No change
G)	No change	Decreases
H)	No change	Increases
I)	No change	No change

21. A child who is eating round candies approximately 1.5 cm in diameter inhales one down his airway, blocking his left bronchiole. Which of the following describes the changes that occur?

	Left Lung Alveolar P_{CO_2}	Left Lung Alveolar P_{O_2}	Systemic Arterial P_{O_2}
A)	↑	↑	↔
B)	↑	↔	↑
C)	↓	↓	↓
D)	↑	↑	↑
E)	↑	↓	↓

22. The forces governing the diffusion of a gas through a biological membrane include the pressure difference across the membrane (ΔP), the cross-sectional area of the membrane (A), the solubility of the gas (S), the distance of diffusion (d), and the molecular weight of the gas (MW). Which changes increase the diffusion of a gas through a biological membrane?

	ΔP	A	S	D	MW
A)	Increase	Increase	Increase	Increase	Increase
B)	Increase	Increase	Increase	Increase	Decrease
C)	Increase	Decrease	Increase	Decrease	Decrease
D)	Increase	Increase	Increase	Decrease	Increase
E)	Increase	Increase	Increase	Decrease	Decrease

23. A person's normal VT is 400 ml with a dead space of 100 ml. The respiratory rate is 12 breaths/min. The person undergoes ventilation during surgery, and the VT is 700 with a rate of 12. What is the approximate alveolar P_{CO_2} for this person?

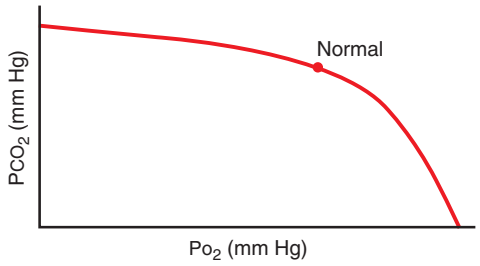
A) 10
B) 20
C) 30
D) 40
E) 45

24. A 45-year-old man at sea level has an inspired O_2 tension of 149 mm Hg, nitrogen tension of 563 mm Hg, and water vapor pressure of 47 mm Hg. A small tumor pushes against a pulmonary blood vessel, completely blocking the blood flow to a small group of alveoli. What are the O_2 and carbon dioxide (CO_2) tensions of the alveoli that are not perfused (in mm Hg)?

	CO_2	O_2
A)	0	0
B)	0	149
C)	40	104
D)	47	149
E)	45	149

25. In which conditions is alveolar P_{O_2} increased and alveolar P_{CO_2} decreased?

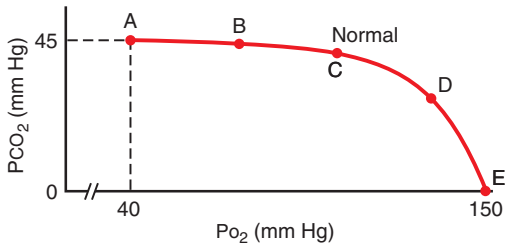
A) Increased Va and unchanged metabolism
B) Decreased Va and unchanged metabolism
C) Increased metabolism and unchanged Va
D) Proportional increase in metabolism and Va



26. The O_2-CO_2 diagram above shows a ventilation-perfusion (V / Q) ratio line for the normal lung. Which of the following best describes the effect of decreasing V / Q ratio on the alveolar P_{O_2} and P_{CO_2}?

	CO_2 Tension	O_2 Tension
A)	Decrease	Decrease
B)	Decrease	Increase
C)	Decrease	No change
D)	Increase	Decrease
E)	Increase	Increase

Questions 27 and 28

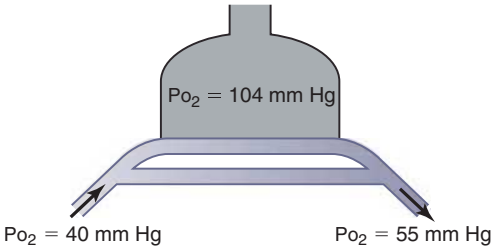


27. A 67-year-old man has a solid tumor that pushes against an airway, partially obstructing air flow to the distal alveoli. Which point on the V / Q line of the O_2-CO_2 diagram above corresponds to the alveolar gas of these distal alveoli?

A) A
B) B
C) C
D) D
E) E

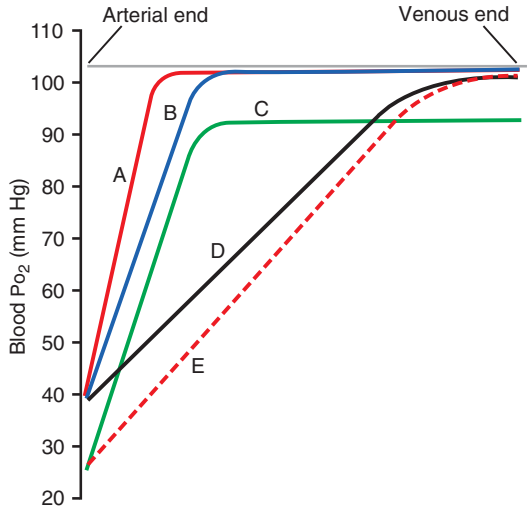
28. A 55-year-old man has a pulmonary embolism that completely blocks the blood flow to his right lung. Which point on the V / Q line of the O_2-CO_2 diagram above corresponds to the alveolar gas of his right lung?

A) A
B) B
C) C
D) D
E) E



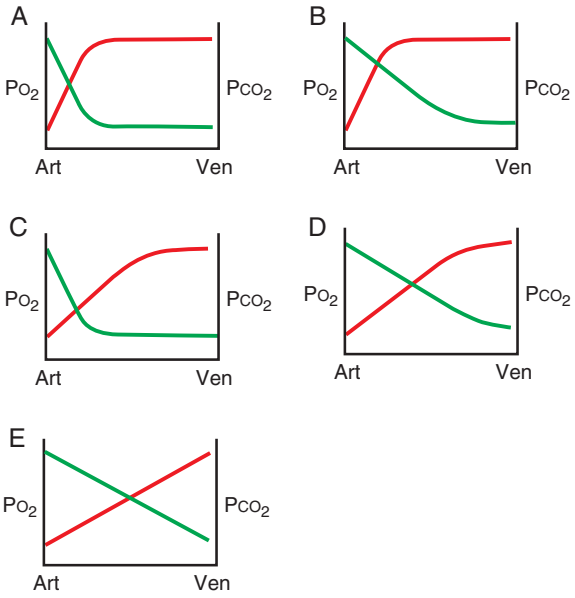
29. The figure above shows a lung with a large shunt in which mixed venous blood bypasses the O_2 exchange areas of the lung. Breathing room air produces the O_2 partial pressures shown on the diagram. What is the O_2 tension of the arterial blood (in mm Hg) when the person breathes 100% O_2 and the inspired O_2 tension is greater than 600 mm Hg?

A) 40
B) 55
C) 60
D) 175
E) 200
F) 400
G) 600



30. A 32-year-old medical student has a 4-fold increase in cardiac output during strenuous exercise. Which curve on the above figure most likely represents the changes in O_2 tension that occur as blood flows from the arterial end to the venous end of the pulmonary capillaries in this student?

A) A
B) B
C) C
D) D
E) E

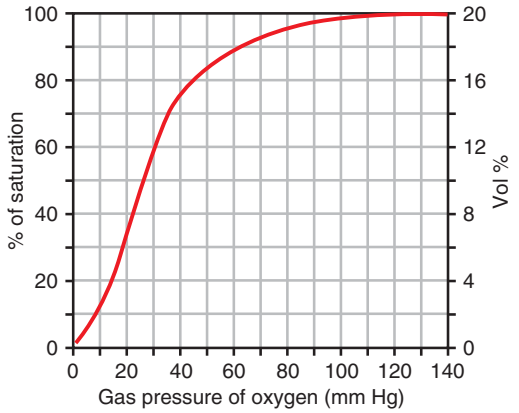


31. The above figure shows changes in the partial pressures of O_2 and CO_2 as blood flows from the arterial (Art) end to the venous (Ven) end of the pulmonary capillaries. Which diagram best depicts the normal relationship between P_{O_2} (red line) and P_{CO_2} (green line) during resting conditions?

A) A
B) B
C) C
D) D
E) E

32. Which of the following would be true if the blood lacked red blood cells and just had plasma and the lungs were functioning normally?

A) The arterial P_{O_2} would be normal
B) The O_2 content of arterial blood would be normal
C) Both A and B
D) Neither A nor B

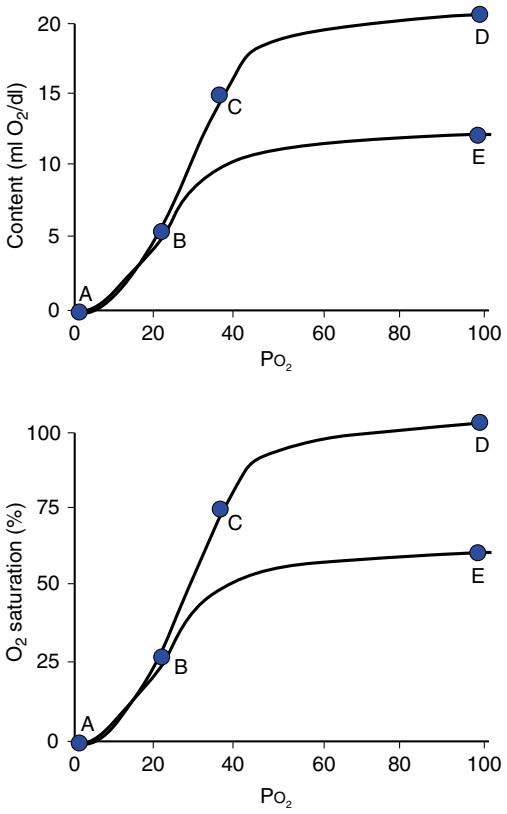


33. The above figure shows a normal O_2-Hb dissociation curve. What are the approximate values of Hb saturation (% Hb-O_2), Po_2, and O_2 content for oxygenated blood leaving the lungs and reduced blood returning to the lungs from the tissues?

	Oxygenated Blood			Reduced Blood		
	% Hb-O_2	Po_2	O_2 Content	% Hb-O_2	Po_2	O_2 Content
A)	100	104	15	80	42	16
B)	100	104	20	30	20	6
C)	100	104	20	75	40	15
D)	90	100	16	60	30	12
E)	98	140	20	75	40	15

34. A person with anemia has an Hb concentration of 12 g/dl. He starts exercising and uses 12 ml O_2/dl. What is the mixed venous Po_2?

A) 0 mm Hg
B) 10 mm Hg
C) 20 mm Hg
D) 40 mm Hg
E) 100 mm Hg



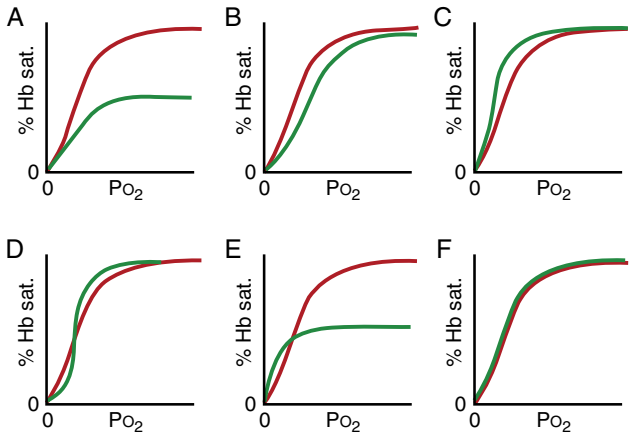
35. Which points on the above figure represent arterial blood in a severely anemic person?

	Top Graph	Bottom Graph
A)	D	D
B)	E	E
C)	D	E
D)	E	D

36. A stroke that destroys the respiratory area of the medulla would be expected to lead to which of the following?

A) Immediate cessation of breathing
B) Apneustic breathing
C) Ataxic breathing
D) Rapid breathing (hyperpnea)
E) None of the above (breathing would remain normal)

Questions 37 and 38



37. Which of the below O_2-Hb dissociation curves corresponds to normal blood (red line) and blood containing CO (green line)?
    A) A
    B) B
    C) C
    D) D
    E) E
    F) F

38. Which of the above O2-Hb dissociation curves corresponds to blood from an adult (red line) and blood from a fetus (green line)?
    A) A
    B) B
    C) C
    D) D
    E) E
    F) F

39. What is the *most important* pathway for the respiratory response to systemic arterial CO_2 (Pco_2)?
    A) CO_2 activation of the carotid bodies
    B) Hydrogen ion (H^+) activation of the carotid bodies
    C) CO_2 activation of the chemosensitive area of the medulla
    D) H^+ activation of the chemosensitive area of the medulla
    E) CO_2 activation of receptors in the lungs

40. The basic rhythm of respiration is generated by neurons located in the medulla. What limits the duration of inspiration and increases respiratory rate?
    A) Apneustic center
    B) Dorsal respiratory group
    C) Nucleus of the tractus solitarius
    D) Pneumotaxic center
    E) Ventral respiratory group

41. When the respiratory drive for increased pulmonary ventilation becomes greater than normal, a special set of respiratory neurons that are inactive during normal quiet breathing becomes active, contributing to the respiratory drive. These neurons are located in which structure?
    A) Apneustic center
    B) Dorsal respiratory group
    C) Nucleus of the tractus solitarius
    D) Pneumotaxic center
    E) Ventral respiratory group

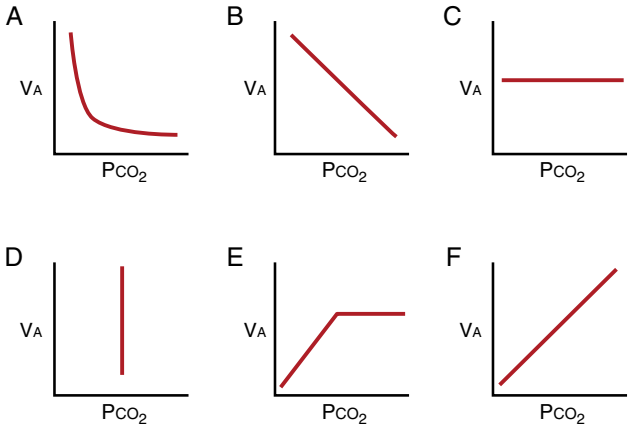
42. CO_2 is transported from the tissues to the lungs predominantly in the form of bicarbonate ion. Compared with arterial red blood cells, which of the following options best describes venous red blood cells?

	Intracellular Chloride Concentration	Cell Volume
A)	Decreased	Decreased
B)	Decreased	Increased
C)	Decreased	No change
D)	Increased	Decreased
E)	Increased	No change
F)	Increased	Increased
G)	No change	Decreased
H)	No change	Increased
I)	No change	No change

43. An anesthetized man is breathing with no assistance. He then undergoes artificial ventilation for 10 minutes at his normal VT but at twice his normal frequency. He undergoes ventilation with a gas mixture of 60% O_2 and 40% nitrogen. The artificial ventilation is stopped, and he fails to breathe for several minutes. This apneic episode is due to which of the following?
    A) High arterial Po_2 suppressing the activity of the peripheral chemoreceptors
    B) Decrease in arterial pH suppressing the activity of the peripheral chemoreceptors
    C) Low arterial Pco_2 suppressing the activity of the medullary chemoreceptors
    D) High arterial Pco_2 suppressing the activity of the medullary chemoreceptors
    E) Low arterial Pco_2 suppressing the activity of the peripheral chemoreceptors

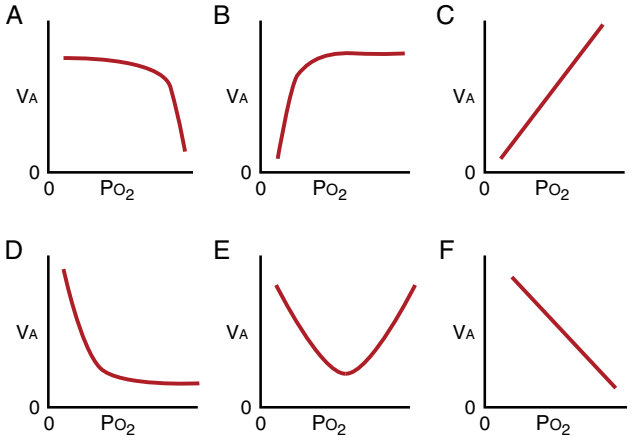
44. Which of the following describes a patient with constricted lungs compared with a normal patient?

	TLC	RV	Maximum Expiratory Flow
A)	Normal	Normal	Normal
B)	Normal	Normal	Reduced
C)	Normal	Reduced	Reduced
D)	Reduced	Normal	Normal
E)	Reduced	Reduced	Normal
F)	Reduced	Reduced	Reduced



45. Which diagram in the above figure best describes the relationship between VA and arterial CO_2 tension (P_{CO_2}) when the P_{CO_2} is changed acutely over a range of 35 to 75 mm Hg?

A) A
B) B
C) C
D) D
E) E
F) F



46. Which diagram in the above figure best describes the relationship between VA and arterial O_2 tension (P_{O_2}) when the P_{O_2} is changed acutely over a range of 0 to 160 mm Hg and the arterial P_{CO_2} and H^+ concentration remain normal?

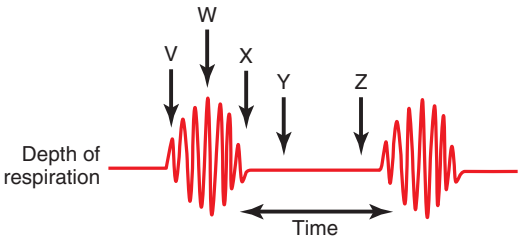
A) A
B) B
C) C
D) D
E) E
F) F

47. VA increases severalfold during strenuous exercise. Which factor is most likely to stimulate ventilation during strenuous exercise?

A) Collateral impulses from higher brain centers
B) Decreased mean arterial pH
C) Decreased mean arterial P_{O_2}
D) Decreased mean venous P_{O_2}
E) Increased mean arterial P_{CO_2}

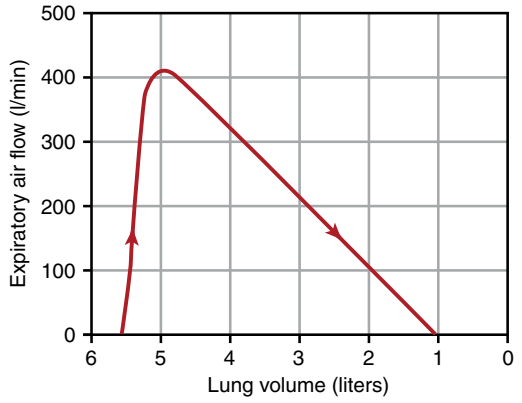
48. During strenuous exercise, O_2 consumption and CO_2 formation can increase as much as 20-fold. VA increases almost exactly in step with the increase in O_2 consumption. Which option best describes what happens to the mean arterial O_2 tension (P_{O_2}), CO_2 tension (P_{CO_2}), and pH in a healthy athlete during strenuous exercise?

	Arterial P_{O_2}	Arterial P_{CO_2}	Arterial pH
A)	Decreases	Decreases	Decreases
B)	Decreases	Increases	Decreases
C)	Increases	Decreases	Increases
D)	Increases	Increases	Increases
E)	No change	No change	No change



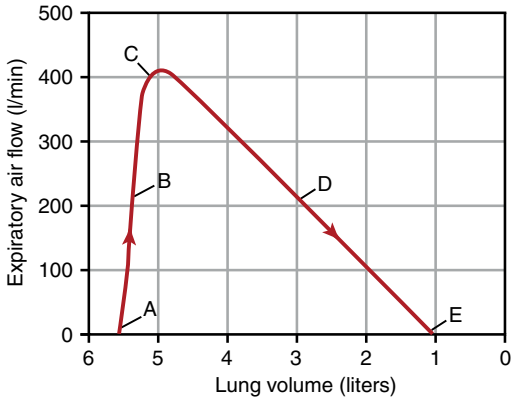
49. Cheyne-Stokes breathing is an abnormal breathing pattern characterized by a gradual increase in the depth of breathing, followed by a progressive decrease in the depth of breathing that occurs again and again approximately every minute. Which time points on the above figure (V-Z) are associated with the highest P_{CO_2} of lung blood and highest P_{CO_2} of the neurons in the respiratory center?

	Lung Blood	Respiratory Center
A)	V	V
B)	V	W
C)	W	W
D)	X	Z
E)	Y	Z



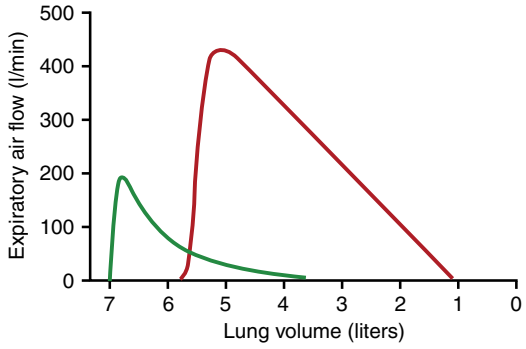
50. A 45-year-old man inhaled as much air as possible and then expired with a maximum effort until no more air could be expired. This action produced the maximum expiratory flow-volume (MEFV) curve shown in the below figure. What is the forced vital capacity (FVC) of this man (in liters)?

A) 1.5
B) 2.5
C) 3.5
D) 4.5
E) 5.5
F) 6.5



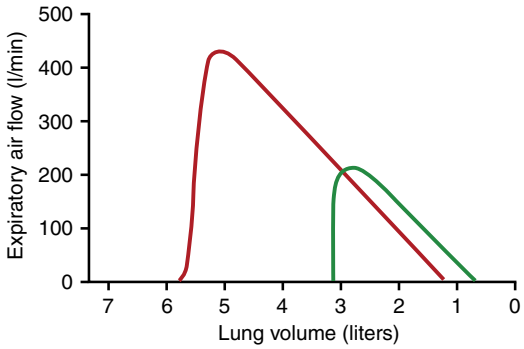
51. The MEFV curve shown in the above figure is used as a diagnostic tool for identifying obstructive and restrictive lung diseases. At which point on the curve does airway collapse limit maximum expiratory air flow?

A) A
B) B
C) C
D) D
E) E



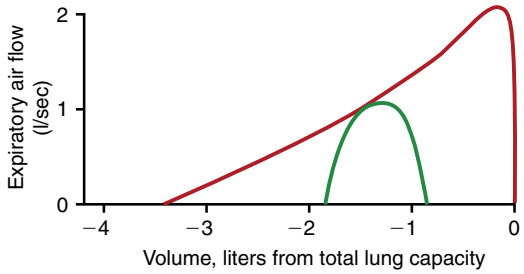
52. The MEFV curves shown in the above figure were obtained from a healthy person (red curve) and a 57-year-old man with shortness of breath (green curve). The man with shortness of breath likely has which disorder?

A) Asbestosis
B) Emphysema
C) Kyphosis
D) Scoliosis
E) Silicosis
F) Tuberculosis



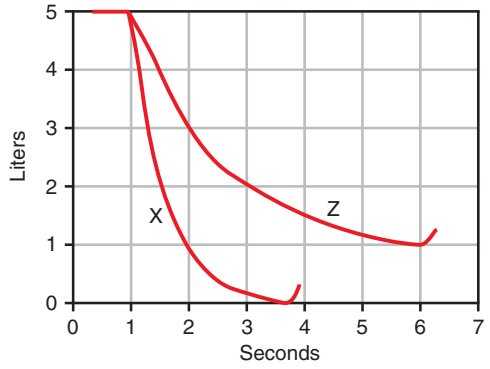
53. A 62-year-old man reports difficulty breathing. The above figure shows an MEFV curve from the patient (green line) and from a typical healthy individual (red curve). Which of the following best explains the MEFV curve of the patient?

A) Asbestosis
B) Asthma
C) Bronchospasm
D) Emphysema
E) Old age



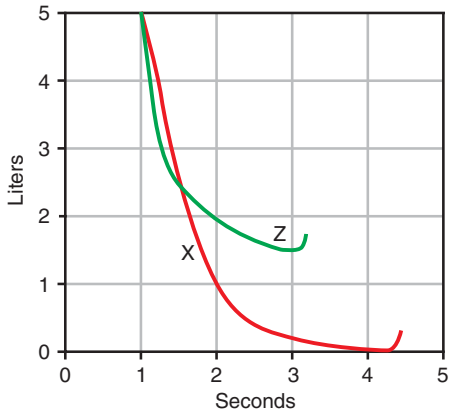
54. The MEFV curve shown in the above figure (red line) was obtained from a 75-year-old man who smoked 40 cigarettes per day for 60 years. The green flow-volume curve was obtained from the man during resting conditions. Which set of changes is most likely to apply to this man?

	Exercise Tolerance	TLC	RV
A)	Decreased	Decreased	Decreased
B)	Decreased	Increased	Increased
C)	Decreased	Normal	Normal
D)	Increased	Increased	Increased
E)	Normal	Decreased	Decreased



55. The above figure shows a forced expiration for a healthy person (curve X) and a person with a pulmonary disease (curve Z). What is the forced expiratory volume in the first second of expiration (FEV_1)/forced vital capacity (FVC) ratio (as a percent) in these persons?

	Person X	Person Z
A)	80	50
B)	80	40
C)	100	80
D)	100	60
E)	90	50
F)	90	60

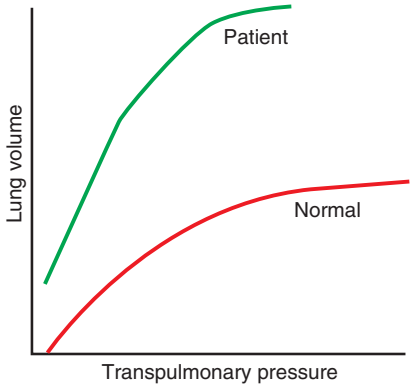


56. The above figure shows forced expirations from a person with healthy lungs (curve X) and from a patient (curve Z). The patient most likely has which condition?
    A) Asthma
    B) Bronchospasm
    C) Emphysema
    D) Old age
    E) Silicosis

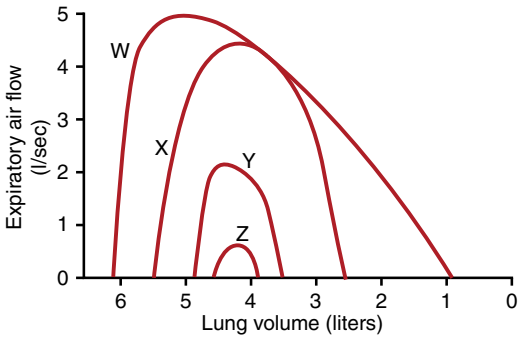
57. Which of the following describes blood gases during consolidated pneumonia?

	Arterial Po_2	Arterial O_2 Content	Arterial Pco_2
A)	Normal	Normal	Normal
B)	Normal	Normal	Increased
C)	Decreased	Normal	Normal
D)	Decreased	Decreased	Increased
E)	Decreased	Decreased	Decreased
F)	Decreased	Decreased	Normal

58. Which of the following occurs during atelectasis of one lung?
    A) Increase in arterial Pco_2
    B) A 40% decrease in Po_2
    C) Normal blood flow in the lung with atelectasis
    D) Slight decrease in arterial content



59. The volume–pressure curves in the above figure were obtained from a normal subject and patient with a pulmonary disease. Which abnormality is most likely present in the patient?
    A) Asbestosis
    B) Emphysema
    C) Mitral obstruction
    D) Rheumatic heart disease
    E) Silicosis
    F) Tuberculosis



60. A 34-year-old medical student generates the flow-volume curves shown in the above figure. Curve W is a normal MEFV curve generated when the student was healthy. Which of the following best explains curve X?
    A) Asthma attack
    B) Aspiration of meat into the trachea
    C) Heavy exercise
    D) Light exercise
    E) Normal breathing at rest
    F) Pneumonia
    G) Tuberculosis

61. Which of the following best describes comparison of the lung compliance and surfactant levels in a premature infant with respiratory distress syndrome versus a normal full-term infant?

	Lung Compliance (Premature vs. Full-Term Infant)	Surfactant Levels (Premature vs. Full-Term Infant)
A)	↑	↓
B)	↑	↑
C)	↓	↓
D)	↓	↑
E)	↔	↑
F)	↔	↓

62. Compared with a normal healthy person, how do total lung capactiy (TLC) and maximum expiratory flow (MEF) change with restrictive lung disease?

	TLC	MEF
A)	↑	↓
B)	↓	↓
C)	↑	↑
D)	↓	↑

63. A 78-year-old man who smoked 60 cigarettes per day for 55 years reports shortness of breath. The patient is diagnosed with chronic pulmonary emphysema. Which set of changes is present in this man compared with a healthy nonsmoker?

	Pulmonary Compliance	Lung Elastic Recoil	TLC
A)	Decreased	Decreased	Decreased
B)	Decreased	Decreased	Increased
C)	Decreased	Increased	Increased
D)	Increased	Decreased	Decreased
E)	Increased	Decreased	Increased
F)	Increased	Increased	Increased

64. While breathing room air, a patient with chronic obstructive pulmonary disease has a systemic arterial P_{CO_2} of 65 mm Hg and a P_{O_2} of 40 mm Hg. Supplemental oxygen is administered at a 40% fractional concentration of oxygen in inspired gas (F_{IO_2}), which resulted in an increase of P_{O_2} to 55 mm Hg and P_{CO_2} to 70 mm Hg. Which of the following describes the supplemental O_2?
    A) Restored arterial dissolved O_2 to normal
    B) Did not change breathing
    C) Reduced the hypoxic stimulation of breathing
    D) Increased the pulmonary excretion of CO_2

65. When he was in his early 40s, a 75-year-old man worked for 5 years in a factory where asbestos was used as an insulator. The man is diagnosed with asbestosis. Which set of changes is present in this man compared with a person with healthy lungs?

	Pulmonary Compliance	Lung Elastic Recoil	TLC
A)	Decreased	Decreased	Decreased
B)	Decreased	Increased	Increased
C)	Decreased	Increased	Decreased
D)	Increased	Decreased	Decreased
E)	Increased	Decreased	Increased
F)	Increased	Increased	Increased

66. Relative to atmospheric pressure the pleural pressure at rest is –5 cm H_2O. What would alveolar pressure be at the end of an inhalation?
    A) –5 cm H_2O
    B) –2 cm H_2O
    C) 0 cm H_2O
    D) +2 cm H_2O
    E) 5 cm H_2O

67. Compared with normal conditions, which of the following conditions will be present in a healthy individual who is running a half marathon?

	Blood Flow at the Top of the Lung	Pulmonary Vascular Conductance	Pulmonary Airway Conductance	Pulmonary Venous P_{O_2}	Mixed Venous P_{O_2}
A)	↔	↓	↓	↔	↔
B)	↔	↑	↓	↔	↑
C)	↑	↑	↑	↑	↔
D)	↑	↑	↑	↑	↓
E)	↑	↑	↓	↑	↓
F)	↔	↑	↓	↔	↑

68. Which of the following would be increase airway conductance?
    A) Stimulation of parasympathetic nerves to the lungs
    B) Low lung volumes
    C) Release of histamine by mast cells
    D) Inhalation to TLC

69. With the development of congestive heart failure and no other pathologies, which of the following mechanism is most important in preventing pulmonary edema?
    A) Retention of salt and water by the kidneys.
    B) Increase alveolar pressure due to forceful ventilation
    C) Increase in surfactant
    D) Washout of interstitial proteins due to increase in fluid filtration from capillaries

70. A person is lying at rest on a bed with a catheter in the femoral artery and vein. Arterial P_{O_2} is 95 mm Hg, and arterial P_{CO_2} is 38 mm Hg. Total blood flow to the muscles of the right leg is 350 ml/min. As a test, acetylcholine, a vasodilator, is infused into the right femoral artery. Which of the following will happen in the venous blood from the right leg?

	Venous P_{O_2}	Venous P_{CO_2}
A)	↑	↓
B)	↓	↑
C)	↓	↔
D)	↔	↑
E)	↑	↑
F)	↓	↓
G)	↔	↔

71. A 54-year-old woman with COPD is admitted to the hospital for shortness of breath. Her arterial blood gases are

    P_{O_2} = 75 mm Hg
    P_{CO_2} = 45 mm Hg
    pH = 7.29

What are some of the pulmonary changes occurring in this woman?
    A) Decreased ventilator drive leading to abnormal blood gases
    B) Decreased airway resistance
    C) Trapping of air in alveoli
    D) Normalization of V / Q ratio throughout the lungs.

72. After 40 years of smoking, a woman is diagnosed with COPD. Which set of changes is present in this woman compared with a person with healthy lungs?

	Forced Vital Capacity	FEV_1	TLC
A)	Decreased	Decreased	Decreased
B)	Decreased	Increased	Increased
C)	Decreased	Increased	Decreased
D)	Increased	Decreased	Decreased
E)	Decreased	Decreased	Increased
F)	Increased	Increased	Increased

73. If the mean pulmonary arterial and left atrial pressures are 25 and 5 mm Hg, respectively, and total blood flow is 5 l/min, what is the pulmonary vascular resistance?
    A) 0.001 mm Hg/ml/min
    B) 0.002 mm Hg/ml/min
    C) 0.004 mm Hg/ml/min
    D) 0.005 mm Hg/ml/min

74. Which of the following is true?
    A) Exhaled gases are equal to alveolar gases
    B) Exhaled P_{O_2} is higher than alveolar P_{O_2}
    C) Exhaled P_{CO_2} is higher than alveolar P_{CO_2}
    D) Exhaled P_{CO_2} is lower than atmospheric P_{CO_2}
    E) Exhaled P_{O_2} is lower than alveolar P_{CO_2}

75. A patient with no respiratory problems and normal blood gases is given a 500-ml blood transfusion consisting of 90% red cells. Which of the following will occur?
    A) Arterial P_{O_2} will increase
    B) Arterial P_{CO_2} will decrease
    C) Arterial saturation will increase
    D) Arterial oxygen content will decrease
    E) Arterial oxygen content will increase

76. A patient has nerve damage to the nerve that innervates the external intercostals. Which of the following would be affected?
    A) Normal inhalation
    B) Normal exhalation
    C) Forced inhalation
    D) Forced exhalation

77. George is a 55-year-old banker who started having chest discomfort 3 years ago. He did not see a doctor. He recently had an attack of severe chest pain and was admitted to the hospital. He became short of breath and started coughing up a frothy fluid. His chest radiograph showed an elevated ST segment. His arterial P_{O_2} is 59 mm Hg, P_{CO_2} is 35 mm Hg, and pH is 7.35. He is given 100% P_{O_2} to breathe, resulting in an increase in arterial P_{O_2} to 150 mm Hg. How does dead space and shunt blood flow in George's lungs compare with normal blood flow?

	Dead Space	Shunted Blood Flow
A)	↑	↑
B)	↑	↔
C)	↓	↓
D)	↔	↑
E)	↓	↑

78. In a normal subject at sea level breathing 50% O_2, which compartment has the lowest CO_2 partial pressure?
    A) Pulmonary vein in the basal region of lung
    B) Alveolar air in zone II
    C) Pulmonary arterial blood
    D) Anatomic dead space at the end of inspiration

79. Compared with a normal O_2 dissociation curve a right-shifted curve
    A) Allows more O_2 to be unloaded from the blood for a given P_{O_2}
    B) Allows less CO_2 to be unloaded from the blood for a given fall in P_{O_2}
    C) Allows a greater degree of oxygen loading of the blood within the lungs
    D) Reduces the amount of oxygen that can be maximally carried by the blood

80. In an anemic person with normal lungs,
    A) Systemic arterial CO_2 is normal
    B) Systemic venous O_2 is normal
    C) Systemic arterial O_2 is above normal
    D) Systemic venous CO_2 is below normal

81. A long-time smoker is referred to you by a colleague who has already ordered PFTs. The results are as follows (* indicates value outside the 95% CI):

	Predicted	Measured	% Predicted
FVC (L)	6.0	3.8	63*
FEV_1 (L)	5.0	2.2	44*
FEV_1/ FVC (%)	83	58*	67*
VC	6.0	4.0	67*
TLC	7.5	8.8	117*
RV	1.8	2.2	122*
FRC	3.5	3.9	111

    What is the diagnosis?
    A) Obstructed lung disease
    B) Constricted lungs
    C) Combined obstruction and constriction
    D) Pulmonary vascular disease

82. The peripheral chemoreceptors would produce the greatest increase in ventilation in replaced to which of the following?
    A) Breathing 30% oxygen
    B) Anemia that decrease hematocrit to 30%
    C) Moderate poisoning with carbon monoxide
    D) An infusion of lactic acid

83. In patients with a chronic hypercapnia (elevated P_{CO_2}), the normal __?___ drive to breathe is replaced with a ___?____ drive.
    A) hypoxic; hypercapnic
    B) hypercapnic; hypoxic
    C) apneustic; pneumotaxic
    D) pneumotaxic; apneustic

84. Which of the following changes in P_{O_2} would have the greatest effect on the O_2 saturation in the blood?
    A) from 0 mm Hg to 20 mm Hg
    B) from 20 mm Hg to 40 mm Hg
    C) from 40 mm Hg to 70 mm Hg
    D) from 80 mm Hg to 100 mm Hg

85. A(n) __?___ in the cerebrospinal fluid concentration of __?___ is considered to be the direct stimulus for the increase alveolar ventilation via the central chemoreceptors.
    A) increase; CO_2
    B) decrease; CO_2
    C) decrease; H^+
    D) increase; H^+

86. Acute hemorrhage causes a reduction of Hb concentration to 60% of normal in an otherwise health individual. If the alveolar ventilation and oxygen consumption rates remain the same as before the hemorrhage, which of the following will occur after the hemorrhage?
    A) Normal arterial P_{O_2}, normal venous P_{O_2}.
    B) Low arterial P_{O_2}, normal venous P_{O_2}.
    C) Low arterial P_{O_2}, low venous P_{O_2}.
    D) Normal arterial P_{O_2}, low venous P_{O_2}.
    E) High arterial P_{O_2}, normal venous P_{O_2}.

87. When a pneumothorax is induced, the chest wall_____, and the lungs____
    A) collapses in, expand out
    B) expands out, collapse in
    C) does not change, do not change
    D) collapses, collapse

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ANSWERS

1. **D)** Contraction of the internal intercostals and abdominal recti pulls the rib cage downward during expiration. The abdominal recti and other abdominal muscles compress the abdominal contents upward toward the diaphragm, which also helps to eliminate air from the lungs. The diaphragm relaxes during expiration. The external intercostals, sternocleidomastoid muscles, and scaleni increase the diameter of the chest cavity during exercise and thus assist with inspiration, but only the diaphragm is necessary for inspiration during quiet breathing.
   TMP14 pp. 491–492

2. **D)** The diaphragm and external intercostals are used for inhalation. The sternocleidomastoid is a muscle in the neck and is not used for inhalation or exhalation. The rectus abdominis and internal intercostals are used for exhalation. The majority of the force for exhalation is generated by the rectus abdominis.
   TMP14 p. 491

3. **E)** Compliance (C) is the change in lung volume (ΔV) that occurs for a given change in the transpulmonary pressure (ΔP): that is, $C = \Delta V / \Delta P$ (The transpulmonary pressure is the difference between the alveolar pressure and pleural pressure.) Because compliance is equal to the slope of the volume–pressure relationship, it should be clear that curve S represents the highest compliance and that curve U represents the lowest compliance.
   TMP14 p. 493

4. **E)** Minute ventilation is VT × respiratory rate. VT from the graph is 500 ml. Therefore, minute ventilation = 500 × 12 = 6 l/min.
   TMP14 p. 497

5. **C)** The FRC equals the ERV (2 liters) plus the RV (1.0 liter). This is the amount of air that remains in the lungs at the end of a normal expiration. FRC is considered to be the resting volume of the lungs because none of the respiratory muscles is contracted at FRC. This problem illustrates an important point: a spirogram can measure changes in lung volume but not absolute lung volumes. Thus, a spirogram alone cannot be used to determine RV, FRC, or TLC.
   TMP14 pp. 495–497

6. **D)** Because the compliance is 0.2 l/cm H_2O, it should be clear that a 1.0-l increase in volume will cause a 5 cm H_2O decrease in pleural pressure (1.0 l/0.2 l/cm H_2O = 5.0 cm H_2O), and because the initial pleural pressure was –4 cm H_2O before inhalation, the pressure is reduced by 5 cm H_2O (to –9 cm H_2O) when 1.0 liter of air is inhaled.
   TMP14 p. 493

7. **D)** Surfactant is formed relatively late in fetal life. Premature babies born without adequate amounts of surfactant can develop pulmonary failure and die. Surfactant is a surface-active agent that greatly reduces the surface tension of the water lining the alveoli. Water is normally attracted to itself, which is why raindrops are round. By reducing the surface tension of the water lining the alveoli (and thus reducing the tendency of water molecules to coalesce), the surfactant reduces the work of breathing—that is, less transpulmonary pressure is required to inhale a given volume of air. Because compliance is equal to the change in lung volume for a given change in transpulmonary pressure, it should be clear that pulmonary compliance is decreased in the absence of surfactant.
   TMP14 pp. 493–494, 1063–1064

8. **C)** Residual volume = FRC – ERV = 3 l – 1.5 l = 1.5 l
   TMP14 pp. 495–496

9. **B)** A spirometer can be used to measure changes in lung volume, but it cannot determine absolute volume. It consists of a drum filled with air inverted over a chamber of water. When the person breathes in and out, the drum moves up and down, recording the changes in lung volume. The spirometer cannot be used to measure RV because the RV of air in the lungs cannot be exhaled into the spirometer. The FRC is the amount of air left in the lungs after a normal expiration. FRC cannot be measured using a spirometer because it contains the RV. The TLC is the total amount of air that the lungs can hold after a maximum inspiration. Because the TLC includes the RV, it cannot be measured using a spirometer. TLC, FRC, and RV can be determined using the helium dilution method or a body plethysmograph.
   TMP14 pp. 495–496

10. **B)** Both the lung and thoracic cage are elastic. Under normal conditions, the elastic tendency of the lungs to collapse is exactly balanced by the elastic tendency of the thoracic cage to expand. When air is introduced into the pleural space, the pleural pressure becomes equal to atmospheric pressure—the chest wall springs outward, and the lungs collapse.
    TMP14 pp. 491–492

11. D) The lower zones of the lung ventilate better than the upper zones, and the middle zones have intermediate ventilation. These differences in regional ventilation can be explained by regional differences in pleural pressure. The pleural pressure is typically about −10 cm H_2O in the upper regions and about −2.5 cm H_2O in the lower regions. A less negative pleural pressure in the lower regions of the chest cavity causes less expansion of the lower zones of the lung during resting conditions. Therefore, the bottom of the lung is relatively compressed during rest but expands better during inspiration compared with the apex.

TMP14 pp. 518–519

12. E) Total ventilation is equal to the tidal volume (V_T) times the ventilation frequency. $V_A = (V_T - V_D) \times$ Frequency, where V_D is the dead space volume. Both persons have the same total ventilation: subject T, 1000 × 10 = 10 l/min; subject V, 500 × 20 = 10 l/min. However, subject T has a V_A of 18 l (i.e., (2000 – 200) × 10), whereas subject V has a V_A of only 12 l (i.e., (500 – 200) × 40). This problem further illustrates that the most effective means of increasing V_A is to increase the V_T, not the respiratory frequency.

TMP14 pp. 497–498

13. B) Arterial content = 15 g/dl × 1.34 ml O_2/g Hb = 20 ml O_2/dl (1 dl = 100 ml).

Venous saturation is 25%, so venous content is 20 ml O_2/dl × 0.25 = 5 ml O_2/dl.

Fick's principle is O_2 consumption = cardiac output (arterial content – venous content).

750 ml O_2/min = cardiac output × (20 ml O_2/dl – 5 ml O_2/dl).

Cardiac output = (750 ml O_2/min)/(15 ml O_2/dl) = 5000 ml/min

TMP14 pp. 256, 522–524

14. D) Ductus arteriosus is present in a fetus, not a healthy adult, in the segment that connects the pulmonary artery to the aorta. Either this is not present in an adult or the pressures would be higher than measured because this is connected to the aorta. The foramen ovale is a cardiac shunt in the fetal heart from right atrium to left atrium, so pressures would be very low. The left atrial pressure should be between 1 and 5 mm Hg. The pulmonary artery pressure ranges from 25 systolic to ~12 to 14 mm Hg diastolic. The right atrial pressure is ~0 to 2 mm Hg.

TMP14 p. 504

15. A) It is usually not feasible to measure the left atrial pressure directly in a normal human being because it is difficult to pass a catheter through the heart chambers into the left atrium. The balloon-tipped, flow-directed catheter (Swan-Ganz catheter) was developed nearly 30 years ago to estimate left atrial pressure for the management of acute myocardial infarction. When the balloon is inflated on a Swan-Ganz catheter, the pressure measured through the catheter, called the wedge pressure, approximates the left atrial pressure for the following reason: blood flow distal to the catheter tip has been stopped all the way to the left atrium, which allows left atrial pressure to be estimated. The wedge pressure is actually a few mm Hg higher than the left atrial pressure, depending on where the catheter is wedged, but this still allows changes in left atrial pressure to be monitored in patients with left ventricular failure.

TMP14 pp. 504, 507

16. A) The pulmonary blood flow can increase severalfold without causing an excessive increase in pulmonary artery pressure for the following two reasons: previously closed vessels open up (recruitment), and the vessels enlarge (distension). Recruitment and distension of the pulmonary blood vessels both serve to lower the pulmonary vascular resistance (and thus to maintain low pulmonary blood pressures) when the cardiac output has increased.

TMP14 pp. 505–506

17. C) A *P. aeruginosa* infection can increase the capillary permeability in the lungs and elsewhere in the body, which leads to excess loss of plasma proteins into the interstitial spaces. This leakage of plasma proteins from the vasculature caused the plasma colloid osmotic pressure to decrease from a normal value of about 28 mm Hg to 19 mm Hg. The capillary hydrostatic pressure remained at a normal value of 7 mm Hg, but it can sometimes increase to higher levels, exacerbating the formation of edema. The interstitial fluid hydrostatic pressure has increased from a normal value of about −5 mm Hg to 1 mm Hg, which tends to decrease fluid loss from the capillaries. Excess fluid in the interstitial spaces (edema) causes lymph flow to increase.

TMP14 pp. 507–509

18. D) With a P_{O_2} of 95 and a content of 19 ml O_2/dl on room air, the patient has no issues with V / Q ratio or pulmonary edema. An arterial content of 19 ml O_2/dl and a P_{O_2} of 95 suggest a normal Hb concentration. A low cardiac output would require a greater extraction of O_2 from the blood to supply O_2 to the tissue, resulting in a decreased mixed venous content.

TMP14 pp. 514, 522–523

19. B) Arterial content = 12 g Hb/dl × 1.34 ml O_2/dl = 16 ml O_2/dl.

Venous saturation = 20%, so venous content = 16 ml O_2/dl × 0.2 = 3.2 ml O_2/dl.

TMP14 pp. 524–525

20. B) When a person performs the Valsalva maneuver (forcing air against a closed glottis), high pressure builds up in the lungs that can force as much as 250 ml of blood from

the pulmonary circulation into the systemic circulation. The lungs have an important blood reservoir function, automatically shifting blood to the systemic circulation as a compensatory response to hemorrhage and other conditions in which the systemic blood volume is too low.

TMP14 p. 504

21. E) When an airway is blocked, no movement of fresh air occurs. Therefore, the air in the alveoli reaches an equilibration with pulmonary arterial blood. Therefore, P_{O_2} will decrease from 100 to 40, P_{CO_2} will increase from 40 to 45, and systemic P_{O_2} will decrease because there is a decrease in O_2 uptake from the alveoli and thus decreased O_2 diffusion from the alveoli.

TMP14 pp. 517–519

22. E) Fick's law of diffusion states that the rate of diffusion (D) of a gas through a biological membrane is proportional to ΔP, A, and S and inversely proportional to d and the square root of the MW of the gas (i.e., $D \alpha (\Delta P \times A \times S) / (d \times MW^{-2})$. The greater the pressure gradient, the faster the diffusion. The larger the cross-sectional area of the membrane, the higher will be the total number of molecules that can diffuse through the membrane. The higher the solubility of the gas, the higher will be the number of gas molecules available to diffuse for a given difference in pressure. When the distance of the diffusion pathway is shorter, it will take less time for the molecules to diffuse the entire distance. When the MW of the gas molecule is decreased, the velocity of kinetic movement of the molecule will be higher, which also increases the rate of diffusion.

TMP14 pp. 516–517

23. B) Normal alveolar P_{CO_2} is 40 mm Hg. Normal V_A for this person is 3.6 l/min. On the ventilator the V_A is 7.2 l/min. A doubling of V_A results in a decrease in alveolar P_{CO_2} by one-half. Thus, alveolar P_{CO_2} would be 20.

TMP14 pp. 498, 513–514

24. B) Alveolar air normally equilibrates with the mixed venous blood that perfuses them; thus, the gas composition of alveolar air and pulmonary capillary blood are identical. When a group of alveoli are not perfused, the composition of the alveolar air becomes equal to the inspired gas composition, which has an O_2 tension of 149 mm Hg and CO_2 tension of about 0 mm Hg.

TMP14 pp. 514–515, 518–519

25. A) Alveolar P_{O_2} depends on inspired gas and alveolar P_{CO_2}. Alveolar P_{CO_2} is a balance between V_A and CO_2 production. To decrease alveolar P_{CO_2}, there must be increased V_A in relation to metabolism. Low P_{O_2} will not directly affect P_{CO_2}, but it can stimulate respiration (if P_{O_2} is sufficiently low), which would then reduce P_{CO_2}. An increased metabolism with unchanged V_A will increase P_{CO_2}. A doubling in metabolism with a doubling in V_A will have no effect on P_{CO_2}.

TMP14 p. 514

26. D) A decrease in the V_A/Q is depicted by moving to the left along the normal ventilation-perfusion line shown in the figure. Whenever the V_A/Q is below normal, there is inadequate ventilation to provide the O_2 needed to fully oxygenate the blood flowing through the alveolar capillaries (i.e., alveolar P_{O_2} is low). Therefore, a certain fraction of the venous blood passing through the pulmonary capillaries does not become oxygenated. Poorly ventilated areas of the lung also accumulate CO_2 diffusing into the alveoli from the mixed venous blood. The result of decreasing V_A/Q (moving to the left along the V_A/Q line) on alveolar P_{O_2} and P_{CO_2} is shown in the figure; that is, P_{O_2} decreases, and P_{CO_2} increases.

TMP14 pp. 518–519

27. B) When the ventilation is reduced to zero ($V_A/Q = 0$), alveolar air equilibrates with the mixed venous blood entering the lung, which causes the gas composition of the alveolar air to become identical to that of the blood. This occurs at point A, where the alveolar P_{O_2} is 40 mm Hg and the alveolar P_{CO_2} is 45 mm Hg, as shown in the figure. A reduction in V_A/Q (caused by the *partially* obstructed airway in this problem) causes the alveolar P_{O_2} and P_{CO_2} to approach the values achieved when $V_A/Q = 0$.

TMP14 pp. 518–519

28. E) A pulmonary embolism decreases blood flow to the affected lung, causing ventilation to exceed blood flow. When the embolism completely blocks all blood flow to an area of the lung, the gas composition of the inspired air entering the alveoli equilibrates with blood trapped in the alveolar capillaries so that within a short time, the gas composition of the alveolar air is identical to that of inspired air. An increase in V_A/Q caused by the partially obstructed blood flow in this problem causes the alveolar P_{O_2} and P_{CO_2} to approach the values achieved when $V_A/Q = \infty$. The point at which V_A/Q is equal to infinity corresponds to point E in the figure (inspired gas).

TMP14 pp. 518–519

29. C) Breathing 100% O_2 has a limited effect on the arterial P_{O_2} when the cause of arterial hypoxemia is a vascular shunt. However, breathing 100% O_2 raises the arterial P_{O_2} to more than 600 mm Hg in a normal subject. With a vascular shunt, the arterial P_{O_2} is determined by (a) highly oxygenated end-capillary blood ($P_{O_2} > 600$ mm Hg) that has passed through ventilated portions of the lung and (b) shunted blood that has bypassed the ventilated portions of the lungs and thus has an O_2 partial pressure equal to that of mixed venous blood ($P_{O_2} = 40$ mm Hg). A mixture of the two bloods causes a large fall in P_{O_2} because the O_2 dissociation curve is so flat in its upper range.

TMP14 p. 519

30. E) The P_{O_2} of mixed venous blood entering the pulmonary capillaries is normally about 40 mm Hg, and

the P_{O_2} at the venous end of the capillaries is normally equal to that of the alveolar gas (104 mm Hg). The P_{O_2} of the pulmonary blood normally rises to equal that of the alveolar air by the time the blood has moved a third of the distance through the capillaries, becoming almost 104 mm Hg. Thus, curve B represents the normal resting state. During exercise, the cardiac output can increase severalfold, but the pulmonary capillary blood still becomes almost saturated with O_2 during its transit through the lungs. However, because of the faster flow of blood through the lungs during exercise, the O_2 has less time to diffuse into the pulmonary capillary blood, and therefore the P_{O_2} of the capillary blood does not reach its maximum value until it reaches the venous end of the pulmonary capillaries. Although curves D and E both show that O_2 saturation of blood occurs near the venous end, note that only curve E shows a low P_{O_2} of 25 mm Hg at the arterial end of the pulmonary capillaries, which is typical of mixed venous blood during strenuous exercise.

TMP14 pp. 517, 521–522

31. A) The P_{O_2} of mixed venous blood entering the pulmonary capillaries increases during its transit through the pulmonary capillaries (from 40 mm Hg to 104 mm Hg), and the P_{CO_2} decreases simultaneously from 45 mm Hg to 40 mm Hg. Thus, P_{O_2} is represented by the red lines, and P_{CO_2} is represented by the green lines in the various diagrams. During resting conditions, O_2 has a 64 mm Hg pressure gradient (104 – 64 = 64 mm Hg), and CO_2 has a 5 mm Hg pressure gradient (45 – 40 = 5 mm Hg) between the blood at the arterial end of the capillaries and the alveolar air. Despite this large difference in pressure gradients between O_2 and CO_2, both gases equilibrate with the alveolar air by the time the blood has moved a third of the distance through the capillaries in the normal resting state (choice A). This is possible because CO_2 can diffuse about 20 times as rapidly as O_2.

TMP14 pp. 522–523

32. A) O_2 diffuses from the lung into the blood and is both dissolved and bound to Hb. Despite having no red blood cells, the P_{O_2} would be normal as the O_2 is dissolved in the plasma. The content would be minimal, just due to the dissolved O_2 in the plasma.

TMP14 pp. 514, 524

33. C) Pulmonary venous blood is nearly 100% saturated with O_2 and has a P_{O_2} of about 104 mm Hg, and each 100 ml of blood carries about 20 ml of O_2 (i.e., O_2 content is about 20 vol%). Approximately 25% of the O_2 carried in the arterial blood is used by the tissues under resting conditions. Thus, reduced blood returning to the lungs is about 75% saturated with O_2, has a P_{O_2} of about 40 mm Hg, and has an O_2 content of about 15 vol%. Note that it necessary to know only one value for oxygenated and reduced blood and that the other two values requested in the question can be read from the O_2-Hb dissociation curve.

TMP14 pp. 524–525

34. C) Each gram of Hb can normally carry 1.34 ml of O_2. Hb = 12 g/dl. Arterial oxygen content = 12 × 1.34 = 16 ml O_2/dl. Using 12 ml O_2/dl yields a mixed venous saturation of 25%. With a saturation of 25%, the venous P_{O_2} should be close to 20 mm Hg.

TMP14 p. 524

35. D) When a person is anemic, there is a decrease in O_2 content. The O_2 saturation of Hb in the arterial blood and the arterial O_2 partial pressure are not affected by the Hb concentration of the blood.

TMP14 pp. 524–525, 527

36. A) The respiratory area of the medulla controls all aspects of respiration, so a destruction of this area would cause a cessation of breathing.

TMP14 pp. 531–532

37. E) CO combines with Hb at the same point on the Hb molecule as O_2 and therefore can displace O_2 from the Hb, reducing the O_2 saturation of Hb. Because CO binds with Hb (to form carboxyhemoglobin) with about 250 times as much tenacity as O_2, even small amounts of CO in the blood can severely limit the O_2-carrying capacity of the blood. The presence of carboxyhemoglobin also shifts the O_2 dissociation curve to the left (which means that O_2 binds more tightly to Hb), which further limits the transfer of O_2 to the tissues.

TMP14 pp. 527–528

38. C) Structural differences between fetal Hb and adult Hb make fetal Hb unable to react with 2,3 diphosphoglycerate (2,3-DPG) and thus to have a higher affinity for O_2 at a given P_{O_2}. The fetal dissociation curve is thus shifted to the left relative to the adult curve. Typically, fetal arterial O_2 pressures are low, and hence the leftward shift enhances the placental uptake of O_2.

TMP14 p. 1048

39. D) CO_2 is the major controller of respiration as a result of a direct effect of H^+ on the chemosensitive area of the medulla. H^+ do not cross the blood-brain barrier. Thus, CO_2 diffuses across the blood-brain barrier and then is converted to H^+, which acts on the chemosensitive area. CO_2 and H^+ activation of carotid bodies is minimal under normal conditions.

TMP14 p. 533

40. D) The pneumotaxic center transmits signals to the dorsal respiratory group that "switch off" inspiratory signals, thus controlling the duration of the filling phase of the lung cycle. This has a secondary effect of increasing the rate of breathing because limitation of inspiration also shortens expiration and the entire period of respiration.

TMP14 p. 532

41. E) The basic rhythm of respiration is generated in the dorsal respiratory group of neurons, which is located

almost entirely within the nucleus of the tractus solitarius. When the respiratory drive for increased pulmonary ventilation becomes greater than normal, respiratory signals spill over into the ventral respiratory neurons, causing the ventral respiratory area to contribute to the respiratory drive. However, neurons of the ventral respiratory group remain almost totally inactive during normal quiet breathing.

TMP14 p. 532

42. F) Dissolved CO_2 combines with water in red blood cells to form carbonic acid, which dissociates to form bicarbonate and H^+. Many of the bicarbonate ions diffuse out of the red blood cells, whereas chloride ions diffuse into the red blood cells to maintain electrical neutrality. The phenomenon, called the chloride shift, is made possible by a special bicarbonate-chloride carrier protein in the red blood cell membrane that shuttles the ions in opposite directions. Water moves into the red blood cells to maintain osmotic equilibrium, which results in a slight swelling of the red blood cells in the venous blood.

TMP14 pp. 528–530

43. C) This patient would have increased V_A, therefore resulting in a decrease in arterial P_{CO_2}. The effect of this decrease in P_{CO_2} would be an inhibition of the chemosensitive area and a decrease in ventilation until P_{CO_2} was back to normal. Breathing high O_2 does not decrease nerve activity sufficient to decrease respiration. The response of peripheral chemoreceptors to CO_2 and pH is mild and does not play a major role in the control of respiration.

TMP14 pp. 498, 514, 533–534

44. F) A person with constricted lungs has a reduced TLC and RV. Because the lung cannot expand to a normal size, the MEF cannot equal normal values.

TMP14 p. 542

45. F) V_A can increase by more than 8-fold when the arterial CO_2 tension is increased over a physiological range from about 35 to 75 mm Hg. This demonstrates the tremendous effect that CO_2 changes have in controlling respiration. By contrast, the change in respiration caused by changing the blood pH over a normal range from 7.3 to 7.5 is more than 10 times less effective.

TMP14 p. 534

46. D) The arterial O_2 tension has essentially no effect on V_A when it is higher than about 100 mm Hg, but ventilation approximately doubles when the arterial O_2 tension falls to 60 mm Hg and can increase as much as 5-fold at very low O_2 tensions. This quantitative relationship between arterial O_2 tension and V_A was established in an experimental setting in which the arterial CO_2 tension and pH were held constant. The student can imagine that the ventilatory response to hypoxia would be blunted if the CO_2 tension were permitted to decrease.

TMP14 p. 536

47. A) Because strenuous exercise does not significantly change the mean arterial P_{O_2}, P_{CO_2}, or pH, it is unlikely that these play an important role in stimulating the immense increase in ventilation. Although the mean venous P_{O_2} decreases during exercise, the venous vasculature does not contain chemoreceptors that can sense P_{O_2}. The brain, upon transmitting motor impulses to the contracting muscles, is believed to transmit collateral impulses to the brain stem to excite the respiratory center. Also, the movement of body parts during exercise is believed to excite joint and muscle proprioceptors that then transmit excitatory impulses to the respiratory center.

TMP14 pp. 536–538

48. E) It is remarkable that the arterial P_{O_2}, P_{CO_2}, and pH remain almost exactly normal in a healthy athlete during strenuous exercise despite the 20-fold increase in O_2 consumption and CO_2 formation. This interesting phenomenon begs the question: What is it during exercise that causes the intense ventilation?

TMP14 pp. 537–538

49. B) The basic mechanism of Cheyne-Stokes breathing can be attributed to a buildup of CO_2 that stimulates overventilation, followed by a depression of the respiratory center because of a low P_{CO_2} of the respiratory neurons. It should be clear that the greatest depth of breathing occurs when the neurons of the respiratory center are exposed to the highest levels of CO_2 (point W). This increase in breathing causes CO_2 to be blown off, and thus the P_{CO_2} of the lung blood is at its lowest value at about point Y in the figure. The P_{CO_2} of the pulmonary blood gradually increases from point Y to point Z, reaching its maximum value at point V. Thus, it is the phase lag between the P_{CO_2} at the respiratory center and the P_{CO_2} of the pulmonary blood that leads to this type of breathing. The phase lag often occurs with left heart failure due to enlargement of the left ventricle, which increases the time required for blood to reach the respiratory center. Another cause of Cheyne-Stokes breathing is increased negative feedback gain in the respiratory control areas, which can be caused by head trauma, stroke, and other types of brain damage.

TMP14 pp. 538–539

50. D) The FVC is equal to the difference between the TLC and the RV. The TLC and RV are the points of intersection between the abscissa and flow-volume curve; that is, TLC = 5.5 l and RV = 1.0 l. Therefore, FVC = 5.5 – 1.0 = 4.5 l.

TMP14 p. 543

51. D) The MEFV curve is created when a person inhales as much air as possible (point A, total lung capacity = 5.5 liters) and then expires the air with a maximum effort until no more air can be expired (point E, residual volume = 1.0 l). The descending portion of the curve indicated by the downward pointing arrow represents the MEF at each lung volume. This descending portion

of the curve is sometimes referred to as the "effort-independent" portion of the curve because the patient cannot increase expiratory flow rate to a higher level even when a greater expiratory effort is expended.

TMP14 p. 542

52. B) In obstructive diseases such as emphysema and asthma, the MEFV curve begins and ends at abnormally high lung volumes, and the flow rates are lower than normal at any given lung volume. The curve may also have a scooped-out appearance, as shown in the figure. The other diseases listed as answer choices are constricted lung diseases (often called restrictive lung diseases). Lung volumes are lower than normal in constricted lung diseases.

TMP14 pp. 542–543

53. A) Asbestosis is a constricted lung disease characterized by diffuse interstitial fibrosis. In constricted lung disease (more commonly called restrictive lung disease), the MEFV curve begins and ends at abnormally low lung volumes, and the flow rates are often higher than normal at any given lung volume, as shown in the figure. Lung volumes are expected to be higher than normal in asthma, bronchospasm, emphysema, old age, and in other instances in which the airways are narrowed or radial traction of the airways is reduced, allowing them to close more easily.

TMP14 p. 542

54. B) The figure shows that a maximum respiratory effort is needed during resting conditions because the MEF rate is achieved during resting conditions. It should be clear that his ability to exercise is greatly diminished. The man has smoked for 60 years and is likely to have emphysema. Therefore, the student can surmise that the TLC, FRC, and RV are greater than normal. The VC is only about 3.4 l, as shown in the figure.

TMP14 pp. 542, 544

55. A) The FVC is the VC measured with a forced expiration. The FEV_1 is the amount of air that can be expelled from the lungs during the first second of a forced expiration. The FEV_1/FVC for the normal individual (curve X) is 4 l/5 l = 80% and 2 l/4 l = 50% for the patient (curve Z). The FEV_1/FVC ratio has diagnostic value for differentiating between normal, obstructive, and constricted patterns of a forced expiration.

TMP14 p. 543

56. E) The FVC is the VC measured with a forced expiration. The FEV_1 is the amount of air that can be expelled from the lungs during the first second of a forced expiration. The FEV_1/FVC ratio for the healthy individual (X) is 4 l/5 l = 80%; FEV_1/FVC for patient Z is 3.0/3.5 = 86%. FEV_1/FVC is often increased in silicosis and other diseases characterized by interstitial fibrosis because of increased radial traction of the airways; that is, the airways are held open to a greater extent at any given lung volume, reducing their resistance to air flow. Airway resistance is increased (and therefore FEV_1/FVC is decreased) in asthma, bronchospasm, emphysema, and old age.

TMP14 pp. 542–543

57. D) With consolidated pneumonia, the lung is filled with fluid and cellular debris, which results in a decreased area for diffusion. In addition, the V / Q ratio is decreased, which will lead to hypoxia (decreased P_{O_2} and content) and hypercapnia (increased P_{CO_2}).

TMP14 pp. 544–545

58. D) With atelectasis of one lung, a collapse of the lung tissue occurs, which increases the resistance to blood flow. In addition, the hypoxia in the collapsed lung causes an additional vasoconstriction. The net effect is to shift blood to the opposite, ventilated lung, resulting in the majority of flow in the ventilated lung. A slight compromise in V / Q ratio will occur. With minimal changes in the V / Q ratio, there will be minimal changes in P_{O_2} and P_{CO_2}. Thus, there should be a slight decrease in arterial P_{O_2} and a slight decrease in saturation and content.

TMP14 pp. 518–519, 545

59. B) The loss of alveolar walls with destruction of associated capillary beds in the emphysematous lung reduces the elastic recoil and increases the compliance. The student should recall that compliance is equal to the change in lung volume for a given change in transpulmonary pressure; that is, compliance is equal to the slopes of the volume-pressure relationships shown in the figure. Asbestosis, silicosis, and tuberculosis are associated with deposition of fibrous tissue in the lungs, which decreases the compliance. Mitral obstruction and rheumatic heart disease can cause pulmonary edema, which also decreases the pulmonary compliance.

TMP14 pp. 493, 542–543

60. C) Curve X represents heavy exercise with a VT of about 3 l. Note that the expiratory flow rate has reached a maximum value of nearly 4.5 l/sec during the heavy exercise. This effect occurred because a maximum expiratory air flow is required to move the air through the airways with the high ventilatory frequency associated with heavy exercise. Normal breathing at rest is represented by curve Z; note that the VT is less than 1 l during resting conditions. Curve Y was recorded during mild exercise. An asthma attack or aspiration of meat would increase the resistance to air flow from the lungs, making it unlikely that expiratory air flow rate could approach its maximum value at a given lung volume. The VT should not increase greatly with pneumonia or tuberculosis, and it should not be possible to achieve a maximum expiratory air flow at a given lung volume with these diseases.

TMP14 pp. 542–543

61. C) A premature infant with respiratory distress syndrome has absent or reduced levels of surfactant. Loss of surfactant creates a greater surface tension. Because surface tension accounts for a large portion of lung elasticity, increasing surface tension will increase lung elasticity, making the lung stiffer and less compliant.
TMP14 pp. 535–536, 547

62. B) Total lung capacity and MEF are reduced in restrictive lung disease.
TMP14 pp. 542–543

63. E) Loss of lung tissue in emphysema leads to an increase in the compliance of the lungs and a decrease in the elastic recoil of the lungs. Pulmonary compliance and elastic recoil always change in opposite directions; that is, compliance is proportional to 1/elastic recoil. The TLC, RV, and FRC are increased in emphysema, but the VC is decreased.
TMP14 p. 543

64. C) There was an increase in P_{O_2} but not to normal levels. The increase in P_{CO_2} means that the V_A decreased. In this patient, the V_A was driven by the decreased O_2 levels. If P_{CO_2} increased, there is no increased pulmonary excretion of CO_2.
TMP14 pp. 493–494, 545

65. C) Asbestosis is associated with deposition of fibrous material in the lungs, which causes the pulmonary compliance (i.e., distensibility) to decrease and the elastic recoil to increase. Pulmonary compliance and elastic recoil change in opposite directions because compliance is proportional to 1/elastic recoil. It is somewhat surprising to learn that the elastic recoil of a rock is greater than the elastic recoil of a rubber band; that is, the more difficult it is to deform an object, the greater the elastic recoil of the object. The TLC, FRC, RV, and VC are decreased in all types of fibrotic lung disease.
TMP14 pp. 542–543

66. C) At the end of inspiration, there is no airflow, so the pressure gradient is 0. Therefore, alveolar pressure has to be 0 cm H_2O, relative to atmospheric pressure.
TMP14 p. 492

67. D) With exercise, there is an increased cardiac output, thus decreasing zone 1 areas of the lung. There is still greater flow at the base of the lungs but also more flow at the apex to improve gas exchange. With the increased flow, there is an increase in pulmonary blood vessel diameter, leading to an increased vascular conductance. With the increased ventilation, there is a greater negative pressure in the pleural space, thus opening airways and increasing airway conductance. Pulmonary venous P_{O_2} is blood after passing through the lungs. With exercise, there is a better V / Q ratio, so pulmonary venous P_{O_2} is elevated. Mixed venous P_{O_2} is blood coming from tissue, so this will fall due to increased metabolism.
TMP14 pp. 506–507, 517, 524–525

68. D) Stimulation of parasympathetic nerves to the lung decreases the airway diameter, leading to a decrease in conductance and an increase in resistance. With low lung volumes the airways collapse, decreasing conductance. Histamine directly decreases airway diameter, decreasing conductance. Inhalation to TLC results in a negative thoracic pressure, which helps to open airways and increases conductance, decreasing resistance.
TMP14 pp. 492, 499

69. D) As pulmonary capillary pressure increases, there is fluid filtration into the interstitial spaces. This fluid is removed by the lymphatics along with protein, thus decreasing interstitial osmotic pressure and minimizing fluid filtration from the capillaries.
TMP14 pp. 507–509

70. A) Venous oxygen in a tissue is dependent on the balance between flow and metabolism. If flow goes up, then venous P_{O_2} increases. If flow goes down the venous P_{O_2} decreases. Venous P_{CO_2} is a balance between tissue metabolism and flow. With a resting tissue metabolism, a decrease in flow results in increases in venous P_{CO_2} and less washout of CO_2. If flow increases, then there is a greater washout of P_{CO_2}, resulting in decreases in venous P_{CO_2}.
TMP14 pp. 524–526

71. C) COPD means excessive air in the lungs. This is due to a chronic infection that includes mucus plugging the airways leading to increased airway resistance, along with destruction of alveolar walls. The abnormal blood gases are due to diffusion and V / Q abnormalities. There is a decrease in diffusing capacity in the lungs. Some portions of the lung have low V / Q ratio, a shunt, and others have high V / Q ratio, dead space.
TMP14 p. 543

72. E) A person with COPD has airway obstruction leading to air trapping and an increased TLC. A person with airway obstruction exhales less air in the first second, FEV_1 due to greater resistance. The Forced Vital Capacity is slightly less in a person with COPD compared with a person without COPD.
TMP 542–543

73. C) Flow = ΔPressure/Resistance

5 l/min = 5000 ml/min = (25 – 5 = 20 mm Hg)/R

R = 20 mm Hg/5000 ml/min = 4 mm Hg/1000 ml/min = 0.004 mm Hg/ml/min
TMP14 pp. 503–504

74. B) Exhaled air is a combination of ~150 ml of dead space, high P_{O_2} (150 mm Hg) and low CO_2 (1 mm Hg), and 350 ml of alveolar air, P_{O_2}= 100 and P_{CO_2} = 40. Therefore, exhaled P_{O_2} is higher than alveolar P_{O_2}, and exhaled P_{CO_2} is lower than alveolar P_{CO_2}.
TMP14 p. 513

75. E) Arterial P_{O_2} and P_{CO_2} are a measure of what is dissolved in the plasma and do not change, with hematocrit. An anemic person with normal lungs will have normal blood gases. If P_{O_2} does not change, then saturation does not change. Adding just red cells will increase the hematocrit, which will increase the arterial oxygen content. Content = g Hb/100 ml x 1.34 ml O_2/g Hb.
TMP14 pp. 524–525

76. C) External intercostal are used for inspiration when there is a need for an active respiration. Therefore, this patient would have a problem with a forced inhalation.
TMP14 p. 491

77. D) The normal P_{CO_2} suggests that his ventilatory control is normal. If the addition of 100% P_{O_2} does not increase arterial P_{O_2}, this shows that there is blood that is not able to uptake the oxygen because of some problem with diffusion. His condition suggests severe pulmonary edema and inadequate diffusion across the lungs. Thus blood flowing by alveoli filled with fluid, pneumonia, are acting as a shunt, thus no diffusion of oxygen.
TMP14 pp. 512, 516, 518–519

78. D) Even breathing 50% O_2 the CO_2 levels in the pulmonary artery (45 mm Hg), vein (40 mm Hg), and alveoli (40 mm Hg) will not change. Anatomic dead space at the end of inhalation would be similar to atmospheric air and have less than 1 mm Hg CO_2.
TMP14 pp. 506, 513, 522

79. A) A shift in the curve results in a decreased affinity of hemoglobin to bind oxygen. A shift in the curve occurs in response to increased temperature, hydrogen ion, and CO_2. These increases normally occur within a metabolically active tissue. The shift in the curve maintains a gradient for diffusion but off loads more O_2 to tissue, a beneficial effect.
TMP14 pp. 525–526

80. A) In an anemic person, CO_2 values will be normal. Arterial and venous oxygen content will be decreased.
TMP14 pp. 524–525, 528–530

81. A) A decrease in FVC and FEV_1 with an increase in TLC is classified as airway obstruction.
TMP14 pp. 542–543

82. D) An increase in ventilation driven by the peripheral chemoreceptor is due to, in order of importance, a decrease in P_{O_2}, an increase in P_{CO_2} or an increase in H^+ ion concentration, and decreased pH. With 30% O_2, the P_{O_2} does not decrease. In anemia, there is no decrease in arterial P_{O_2}. Breathing CO results in a decrease in oxygen bound to hemoglobin and decreased content, but arterial P_{O_2} will not decrease. A decrease in pH, and increased H^+ ion following a lactic acid infusion will activate peripheral chemoreceptors to increase ventilation.
TMP14 pp. 534–535

83. B) Normally, the drive to breathe is through the pH changes at the central chemoreceptor. However, if P_{CO_2} increases due to severe lung disease, then the peripheral chemoreceptor hypoxic drive becomes more important.
TMP14 pp. 533–535

84. B) One looks at the hemoglobin dissociation curve and sees that at 0 mm Hg P_{O_2}, the saturation is 0, and at 20 mm Hg, the saturation is 25% (25% increase in saturation). At 40 mm Hg, the saturation is 75%, a 50% increase in saturation from 20 mm Hg.
TMP14 p. 524

85. D) Central chemoreceptors respond directly to changes in H^+ in response to increases in blood P_{CO_2}.
TMP14 p. 533

86. D) A hemorrhage will cause a refilling of fluid from the interstitial space to maintain blood volume. This results in a reduction in hematocrit. With a reduction in hematocrit, there will be a decrease in arterial content. However, arterial P_{O_2} will remain normal. Because the tissue metabolism remains the same, the tissues will use, on average, 5 ml O_2/100 ml blood. Starting from a lower arterial content caused by the hemorrhage, the venous oxygen content will be less, resulting in a lower venous P_{O_2}.
TMP14 pp. 524–525

87. B) The negative pressure in the pleural space tends to pull the chest wall in and expands the lungs. When there is a hole in the chest wall and the pleural pressure is atmospheric, the chest wall will expand outward, and the lungs will collapse. For a healthy person during normal breathing, inspiration is generally considered to be passive because of the natural tendency of the chest cage to expand.
TMP14 pp. 491–492

UNIT VIII

Aviation, Space, and Deep-Sea Diving Physiology

1. A diver is breathing 21% oxygen (O_2) at a depth of 132 feet. The diver's body temperature is 37°C, and partial pressure of carbon dioxide (P_{CO_2}) = 40 mm Hg. What is the alveolar partial pressure of oxygen (P_{O_2})?
   A) 149 mm Hg
   B) 380 mm Hg
   C) 578 mm Hg
   D) 738 mm Hg
   E) 3703 mm Hg

2. A man is planning to leave Miami (at sea level) and travel to Colorado to climb Mount Wilson (14,500 feet, barometric pressure = 450 mm Hg). Before his trip he takes acetazolamide, a carbonic anhydrase inhibitor that forces the kidneys to excrete bicarbonate. What response would be expected before he makes the trip?
   A) Alkalotic blood
   B) Normal ventilation
   C) Elevated ventilation
   D) Normal arterial blood gases

3. Which set of changes best describes a Himalayan native living in the Himalayas, compared with a sea-level native living at sea level?

	Hematocrit	Arterial P_{O_2}	Arterial O_2 Content
A)	Decreased	Decreased	Decreased
B)	Decreased	Decreased	No difference
C)	Decreased	Increased	Decreased
D)	Decreased	Increased	No difference
E)	Increased	Decreased	Decreased
F)	Increased	Increased	Decreased
G)	Increased	Increased	No difference
H)	Increased	Decreased	No difference

4. A pilot is flying a commercial, pressurized (730 mm Hg) airplane at 30,000 feet; the barometric pressure is 226 mm Hg. If the pilot's body temperature is normal and the alveolar P_{O_2} is 90 mm Hg, which of the following is true?
   A) Arterial P_{CO_2} is 40 mm Hg
   B) Alveolar ventilation will be increased
   C) Arterial pH will be 7.6
   D) Alveolar P_{CO_2} will be 45 mm Hg
   E) The pilot will be polycythemic

5. Which of the following arterial gases and pH were obtained from a healthy person 1 hour after arriving at an altitude of 10,000 ft? (Barometric pressure = 523 mm Hg.)

	P_{O_2}	P_{CO_2}	pH
A)	55	36	7.42
B)	70	20	7.42
C)	33	50	7.28
D)	70	15	7.53
E)	55	25	7.53

6. A scuba diver at a depth of 90 feet would be expected to
   A) have a smaller tidal volume than normal
   B) have a normal arterial P_{CO_2}
   C) have a decreased hemoglobin saturation
   D) have a decreased arterial oxygen content

7. During acclimation to altitude
   A) the sensitivity of carotid bodies to hypoxia increases
   B) the sensitivity of central chemoreceptors to hypoxia increases
   C) the sensitivity of carotid sinuses to hypoxia increases
   D) the HCO_3^- concentration in the blood increases
   E) the HCO_3^- concentration in the brain decreases

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ANSWERS

1. D) 132 feet is equivalent to 5 atmospheres of pressure (4 of water and 1 of air). The total barometric pressure is 760 × 5 = 3800. Alveolar P_{CO_2} would be normal at 40. Alveolar P_{O_2} = (3800 – 47) × 0.21 – (40/0.8) = 738 mm Hg.

TMP14 pp. 561–562

2. C) Acetazolamide is a medication that that forces the kidneys to excrete bicarbonate, the base form of CO_2. This excretion reacidifies the blood, balancing the effects of the hyperventilation that occurs at altitude in an attempt to get O_2. Such reacidification acts as a respiratory stimulant, particularly at night, reducing or eliminating the periodic breathing pattern common at altitude. This would increase ventilation, resulting in a decreased P_{CO_2}.

TMP14 pp. 554–555

3. H) Acclimatization to hypoxia includes an increase in pulmonary ventilation, an increase in red blood cells, an increase in diffusion capacity of the lungs, an increase in vascularity of the tissues, and an increase in the ability of the cells to use available O_2. The increase in hematocrit of high-altitude natives allows normal amounts of O_2 (or even greater than normal amounts of O_2) to be carried in the blood despite lower than normal arterial O_2 tension. For example, those native to elevations of 15,000 feet have an arterial O_2 tension of only 40 mm Hg, but because of greater amounts of hemoglobin in the blood, the quantity of O_2 carried in the blood is often greater than that in the blood of sea-level natives.

TMP14 pp. 554–556

4. A) Since the airline cabin is pressurized the pilot is not exposed to a decreased barometric pressure. Blood gases would be normal

TMP14 p 554

5. A) Note that there is an increase in ventilation upon arriving at high altitude. This will result in a decrease in P_{CO_2}. However, remember that H^+ ion at the central chemoreceptor is the major stimulus for the control of ventilation. The peripheral chemoreceptors will respond to the decreased P_{O_2} by wanting to increase ventilation, but the fall in H^+ ion will limit increase in ventilation. Therefore, there will be a small fall in P_{CO_2}. Additionally, you could use the following equation.

Alveolar P_{O_2} = (Barometric pressure–Water vapor pressure) * % O_2 inhaled –(Blood P_{CO_2} /0.8)
= (523–47) * 0.21–(Blood P_{CO_2}/0.8)
= 100–(Blood P_{CO_2}/0.8)

Predicted P_{O_2} based on P_{CO_2}

	P_{O_2}	P_{CO_2}	pH	Predicted P_{O_2}
A)	55	36	7.42	55
B)	70	20	7.42	75
C)	33	50	7.28	37.5
D)	70	15	7.53	81
E)	55	25	7.53	69

TMP14 p. 554

6. B) A scuba diver is breathing in gases at higher partial pressures, resulting in elevated systemic P_{O_2}. Therefore, hemoglobin will be 100% saturated and arterial oxygen content will be increased (due to increased dissolved oxygen levels). To remove the normal amount of C_{O_2} produced, the tidal volume has to be normal. P_{CO_2} has to be normal, or ventilation would change.

TMP14 pp. 561–563, 565

7. E) Upon going to high altitude and low barometric pressure, there is a decrease in atmospheric P_{O_2}. This leads to an increase in ventilation, resulting in a decrease in P_{CO_2} and thus alkalosis. The alkalosis results in a decrease in H^+ ions at the central chemoreceptor, thus preventing an increase in ventilation to increase P_{O_2}. To bring pH back to normal, the kidney excretes HCO_3^-, thus returning pH back toward normal, which allows the decreased P_{O_2} to have a greater stimulatory effect through the peripheral chemoreceptors.

TMP14 p. 555

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UNIT IX

The Nervous System: A. General Principles and Sensory Physiology

1. A pool of presynaptic neurons innervates the dendrites of a postsynaptic neuron. Postsynaptic potentials are then transferred from the dendrites to the soma of the postsynaptic neuron by which of the following processes?
   A) Action potential
   B) Active transport
   C) Capacitive discharge
   D) Diffusion
   E) Electrotonic conduction

2. A transmitter substance released from a presynaptic neuron causes the membrane potential of a postsynaptic neuron to change from −60 millivolts to −62 millivolts. Which of the following best describes this change in membrane potential (in millivolts)?
   A) Excitatory postsynaptic potential = +2
   B) Excitatory postsynaptic potential = −2
   C) Inhibitory postsynaptic potential = +2
   D) Inhibitory postsynaptic potential = −2

3. All the following neurotransmitters are released from vesicles EXCEPT one. Which one is the EXCEPTION?
   A) Acetylcholine
   B) Glutamate
   C) Glycine
   D. Nitric oxide
   E) Norepinephrine

4. Which of the following best describes the main inhibitory neurotransmitter in the spinal cord?
   A) Acetylcholine
   B) Glutamate
   C) Glycine
   D) Histamine
   E) Norepinephrine

5. Which of the following best describes the type of neurologic circuit shown?

   A) Converging circuit
   B) Diverging circuit
   C) Inhibitory circuit
   D) Reverberatory circuit

6. Which of the following best describes the chief inhibitory transmitter in the brain?
   A) Acetylcholine
   B) Gamma-aminobutyric acid (GABA)
   C) Norepinephrine
   D) Glutamate
   E) Serotonin

7. Inhibitory postsynaptic potentials (IPSPs) are most likely caused by opening of which of the following types of membrane channels?
   A) Ligand-gated calcium channels
   B) Ligand-gated potassium channels
   C) Ligand-gated sodium channels
   D) Voltage-gated calcium channels
   E) Voltage-gated potassium channels
   F) Voltage-gated sodium channels

8. Fatigue of synaptic transmission can result from all the following EXCEPT one. Which one is the EXCEPTION?
   A) Abnormal ion concentrations
   B) Diminished electrotonic potentials
   C) Receptor inactivation
   D) Transmitter depletion

9. Referred pain results from an intermingling of visceral and skin pain fibers in which of the following structures?
   A) Anterolateral system
   B). Dorsal horn of spinal cord
   C) Midbrain periaqueductal gray
   D) Primary somatosensory cortex
   E) Ralph nuclei

10. Which of the following serves to improve the two-point discrimination threshold in the tips of the fingers of a typical human being?
   A) Lateral inhibition
   B) Action potential
   C) Spatial resolution
   D) Pain
   E) Damage

11. Which of the following best describes a disorder of the trigeminal nerve that leads to paroxysmal facial pain triggered by touch or cold?
   A) Brown-Sequard syndrome
   B) Hyperalgesia
   C) Tic Douloureux
   D) Hemineglect
   E) Astereognosis
   F) Agraphesthesia

12. A 32-year-old woman involved in a motor vehicle collision received an injury to the spine at C5 that transected the left half of the spinal cord. On which side of the patient would you expect pain and temperature sensations to be absent?
   A) Left side
   B) Right side
   C) Neither side
   D) Both sides

13. Hyperventilation is most likely to have which of the following effects on a typical neuron in the central nervous system?
   A) Decreased neuronal activity
   B) Increased neuronal activity
   C) Increased synaptic delay
   D) Decreased synaptic delay

14. All the following factors contribute to synaptic delay EXCEPT one. Which one is the EXCEPTIOIN?
   A) Action of receptor to increase sodium conductance
   B) Action of transmitter on membrane receptor
   C) Diffusion of transmitter to postsynaptic membrane
   D) Outward diffusion of sodium to cause EPSP
   E) Transmitter discharge from presynaptic terminal

15. Signal amplification can be achieved by which of the following neuronal pools?
   A) Divergence in the same tract
   B) Convergence from multiple sources
   C) Lateral inhibition
   D) Reverberating circuit

16. Which ion has the greatest electrochemical driving force in a typical neuron with a resting membrane potential of –65 millivolts?
   A) Chloride
   B) Potassium
   C) Sodium

17. A 10-year-old girl with fever is hyperventilating. Which of the following is most likely to occur in this girl?
   A) Decreased brain oxygenation only
   B) Decreased brain oxygenation and increased neuronal activity
   C) Decreased neuronal activity only
   D) Increased brain oxygenation only
   E) Increased brain oxygenation and decreased neuronal activity
   F) Increased neuronal activity only

18. Pain receptors in the skin are typically classified as which of the following?
   A) Encapsulated nerve endings
   B) A single class of morphologically specialized receptors
   C) The same type of receptor that detects position sense
   D) Free nerve endings

19. Which of the following best describes an expanded tip tactile receptor found in the dermis of hairy skin that is specialized to detect continuously applied touch sensation?
   A) Free nerve endings
   B) Merkel disc
   C) Pacinian corpuscle
   D) Ruffini endings

20. The release of neurotransmitter at a chemical synapse in the central nervous system is dependent on which of the following?
   A) Synthesis of acetylcholinesterase
   B) Hyperpolarization of the synaptic terminal
   C) Opening of ligand-gated ion calcium channels
   D) Influx of calcium into the presynaptic terminal

21. A transmitter substance released from a presynaptic neuron activates a second messenger G-protein system in the postsynaptic neuron. Which one of the following postsynaptic responses to the transmitter substance is NOT a possible outcome?
   A) Activation of cyclic adenosine monophosphate (cAMP)
   B) Activation of cyclic guanosine monophosphate (cGMP)
   C) Activation of gene transcription
   D) Closing an ion channel
   E) Opening an ion channel

22. A 75-year-old man sustained a lower back injury that causes severe chronic pain. His physician prescribes benzodiazepine sedation medications to help him sleep. Which response best describes why this man has difficulty sleeping without medication?

A) Depression of the amygdala
B) Depression of reticular formation
C) Excitation of the amygdala
D) Excitation of reticular formation
E) Loss of somatic sensations
F) Loss of visceral sensations

23. A 13-year-old girl with epilepsy visits a physician for testing. The physician uses electroencephalography to study her brain waves during various activities. Which of the following is most likely to stimulate the greatest increase in brain activity in this girl?

A) Hyperventilation
B) Hypoventilation
C) Hyperventilation plus flashing lights
D) Hypoventilation plus flashing lights

24. Which of the following best describes the concept of specificity in sensory nerve fibers that transmit only one modality of sensation?

A) Frequency coding principle
B) Concept of specific nerve energy
C) Singularity principle
D) Labeled line principle

25. Which of the following is an encapsulated receptor found deep in the skin throughout the body, as well as in fascial layers, where it detects indentation of the skin (pressure) and movement across the surface (vibration)?

A) Pacinian corpuscle
B) Meissner's corpuscle
C) Free nerve endings
D) Ruffini endings

26. The excitatory or inhibitory action of a neurotransmitter is determined by which of the following?

A) The function of its postsynaptic receptor
B). Its molecular composition
C) The shape of the synaptic vesicle in which it is contained
D) The distance between the pre- and postsynaptic membranes

27. A 54-year-old neurosurgeon picks up a scalpel, which activates numerous sensory receptors in her hand. An increase in which of the following best describes the basis for transduction of the sensory stimuli into nerve impulses?

A) Activation of G protein
B) Decreased ion permeability
C) Decreased transmitter release
D) Increased ion permeability
E) Increased transmitter release
F) Inhibition of G protein

28. A physiology experiment is conducted in which a glass microelectrode in inserted into a Pacinian corpuscle to record receptor potentials during different levels of stimulation (from 0% to 100%). Increasing stimulus strength from 10% of maximum to 30% of maximum causes a 40% increase in the amplitude of the receptor potential. Increasing the stimulus potential from 70% of maximum to 90% of maximum is most likely to cause which increase in the amplitude of the receptor potential (in %)?

A) 10
B) 40
C) 60
D) 80

29. Interneurons that use the neurotransmitter enkephalin to inhibit afferent pain signals are most likely found in which region of the central nervous system?

A) Dorsal horn of spinal cord
B) Postcentral gyrus
C) Precentral gyrus
D) δ-type A
E) Type C fiber
F) Ventral horn of spinal cord

30. Which system transmits somatosensory information with the highest degree of temporal and spatial fidelity?

A) Anterolateral system
B) Dorsal column–medial lemniscal system
C) Corticospinal system
D) Spinocerebellar system

31. The pathway of which system crosses in the ventral white commissure of the spinal cord within a few segments of entry and then courses to the thalamus contralateral to the side of the body from which the signal originated?

A) Anterolateral system
B) Dorsal column–medial lemniscal system
C) Corticospinal system
D) Spinocerebellar system

32. Neurons located in which area release serotonin as their neurotransmitter?

A) Periaqueductal gray area
B) Interneurons of the spinal cord
C) Periventricular area
D) Nucleus raphe magnus

33. Which system conveys information concerning highly localized touch sensation and body position (proprioceptive) sensation?

A) Anterolateral
B) Dorsal column–medial lemniscal
C) Corticospinal
D) Spinocerebellar

34. The first order (primary afferent) cell bodies of the dorsal column–medial lemniscal system are found in which structure?
    A) Spinal cord dorsal horn
    B) Spinal cord ventral horn
    C) Dorsal root ganglia
    D) Nucleus cuneatus

35. Which structure carries axons from the nucleus gracilis to the thalamus?
    A) Fasciculus gracilis
    B) Fasciculus lemniscus
    C) Lateral spinothalamic tract
    D) Medial lemniscus

36. A 12-year-old boy cuts his finger with a pocketknife and immediately applies pressure to the damaged area with his other hand to partially alleviate the pain. Inhibition of pain signals by tactile stimulation of the skin is mediated by which type of afferent neurons from mechanoreceptors?
    A) α-type A
    B) β-type A
    C) δ-type A
    D) Type C

37. A pool of presynaptic neurons innervates the dendrites of a postsynaptic neuron. Electrical signals are transferred from the dendrites to the soma of the postsynaptic neuron by which process?
    A) Action potential
    B) Active transport
    C) Capacitive discharge
    D) Diffusion
    E) Electrotonic conduction

38. Which structure carries axons from neurons in the ventral posterolateral nucleus of the thalamus to the primary somatosensory cortex?
    A) Medial lemniscus
    B) External capsule
    C) Internal capsule
    D) Extreme capsule

39. Which of the following is characteristic of the events occurring at an excitatory synapse?
    A) There is a massive efflux of calcium from the presynaptic terminal
    B) Synaptic vesicles bind to the postsynaptic membrane
    C) Voltage-gated potassium channels are closed
    D) Ligand-gated channels are opened to allow sodium entry into the postsynaptic neuron

40. Stimulation of which brain area can modulate the sensation of pain?
    A) Superior olivary complex
    B) Locus coeruleus
    C) Periaqueductal gray area
    D) Amygdala

41. Which body part is represented superiorly and medially within the postcentral gyrus?
    A) Upper limb
    B) Lower limb
    C) Abdomen
    D) Genitalia

42. Which of the following is a group of neurons in the pain suppression pathway that uses enkephalin as a neurotransmitter?
    A) Postcentral gyrus
    B) Nucleus raphe magnus
    C) Periaqueductal gray area
    D) Type AB sensory fibers

Questions 43 and 44
A 19-year-old man has an automobile accident that eliminates all nerve traffic in the right half of the spinal cord at C2. Use this information to answer the next two questions.

43. Loss of which function is most likely in the right hand of this man?
    A) Crude touch and pain sensation
    B) Crude touch and temperature sensation
    C) Motor function and temperature sensation
    D) Motor function and vibration sense
    E) Vibration sense and crude touch
    F) Vibration sense and pain sensation

44. Loss of which function is most likely in the left hand of this man?
    A) Crude touch and pain sensation
    B) Crude touch and vibration sense
    C) Motor function and temperature sensation
    D) Motor function and vibration sense
    E) Vibration sense and pain sensation
    F) Vibration sense and crude touch

45. The highest degree of pain localization comes from which of the following?
    A) Simultaneous stimulation of free nerve endings and tactile fibers
    B) Stimulation of free nerve endings by bradykinin
    C) Nerve fibers traveling to the thalamus by way of the paleospinothalamic tract
    D) Stimulation of δ-type A fibers

46. Posttetanic facilitation is thought to result from which of the following?
    A) Opening of voltage-gated sodium channels
    B) Opening of transmitter-gated potassium channels
    C) A buildup of calcium in the presynaptic terminal
    D) Electrotonic conduction

47. Within the primary somatosensory cortex, the various parts of the contralateral body surface are represented in areas of varying size that reflect which of the following?
    A) The relative size of the body parts
    B) The density of the specialized peripheral receptors
    C) The size of the muscles in that body part
    D) The conduction velocity of the primary afferent fibers

48. The gray matter of the primary somatosensory cortex contains six layers of cells. Which layer(s) receive the bulk of incoming signals from the somatosensory nuclei of the thalamus?
    A) I
    B) II and III
    C) III only
    D) IV

Questions 49 and 50
Each of the disorders in the next two questions is characterized either by the production of excessive pain (hyperalgesia) or the loss of pain sensation.

49. Which disorder is characterized by excessive pain in a skin dermatomal distribution resulting from a viral infection of a dorsal root ganglion?
    A) Tic douloureux
    B) Thalamic pain syndrome
    C) Brown-Séquard syndrome
    D) Herpes zoster

50. Which disorder involves a loss of pain sensation on one side of the body coupled with the loss of proprioception, precise tactile localization, and vibratory sensations on the contralateral side of the body?
    A) Herpes zoster
    B) Thalamic pain syndrome
    C) Lateral medullary syndrome
    D) Brown-Séquard syndrome

51. Which disorder is characterized by the loss of pain sensation throughout one entire side of the body and the opposite side of the face?
    A) Brown-Séquard syndrome
    B) Thalamic pain syndrome
    C) Herpes zoster
    D) Lateral medullary syndrome

52. Stimulation by touching or pulling on which structure is least likely to cause a painful sensation?
    A) Postcentral gyrus
    B) Dura overlying the postcentral gyrus
    C) Branches of middle meningeal artery that lie superficial to the dura over the postcentral gyrus
    D) Branches of middle cerebral artery that supply the postcentral gyrus

53. Vibratory sensation depends on the detection of rapidly changing, repetitive sensations. The high-frequency end of the repetitive stimulation scale is detected by which structure?
    A) Merkel discs
    B) Meissner corpuscles
    C) Pacinian corpuscles
    D) Free nerve endings

54. A 23-year-old gymnast lifts her right leg above her head while in the standing position. Activation of a single pyramidal cell in the motor cortex leads to stimulation of 2000 muscle fibers in her right quadriceps muscle. Which of the following best describes the type of neuronal circuitry activated in this woman when she lifts her leg?
    A) Converging
    B) Diverging
    C) Inhibitory
    D) Reverberatory

55. An input neuron to a diverging circuit causes the membrane potential of a target neuron to change from −65 millivolts to −55 millivolts. Which of the following best describes this change in membrane potential (in millivolts)?
    A) Excitatory postsynaptic potential = +10
    B) Excitatory postsynaptic potential = −10
    C) Inhibitory postsynaptic potential = +10
    D) Inhibitory postsynaptic potential = −10

56. Prolonged changes in neuronal activity are usually achieved through the activation of which of the following?
    A) Voltage-gated chloride channels
    B) Transmitter-gated sodium channels
    C) G-protein–coupled channels
    D) Voltage-gated potassium channels

57. Position sense, or more commonly proprioceptive sensation, involves muscle spindles and which of the following?
    A) Skin tactile receptors
    B) Deep receptors in joint capsules
    C) Both tactile and joint capsule receptors
    D) Pacinian corpuscles

58. Migraine headaches often begin with a prodromal symptom such as nausea, loss of vision, visual aura, or other sensory hallucinations. Which of the following is believed to be the cause of such prodromes?
    A) Increased blood flow to brain tissue in visual or other sensory cortex
    B) A selective loss of gamma-aminobutyric acid neurons in various sensory areas of cortex
    C) Constipation
    D) Vasospasm leading to ischemia and disruption of neuronal activity in relevant sensory areas of cortex

59. For a sensory nerve fiber that is connected to a Pacinian corpuscle located on palmar surface of the right hand, the synaptic connection with the subsequent neuron in the corresponding sensory pathway is located in which of the following?
    A) Right dorsal column nucleus
    B) Left dorsal column nucleus
    C) Dorsal horn of right side of spinal cord
    D) Dorsal horn of left side of spinal cord

60. The sensation of temperature is signaled mainly by warm and cold receptors whose sensory fibers travel in association with the sensory fibers carrying pain signals. Which statement best characterizes the transmission of signals from warm receptors?
    A) Warm receptors are well characterized histologically
    B) Signals from warm receptors are mainly transmitted along slow-conducting type C sensory fibers
    C) Warm receptors are located well below the surface of the skin in the subcutaneous connective tissue
    D) There are 3 to 10 times more warm receptors than cold receptors in most areas of the body

ANSWERS

1. **E)** Most dendrites fail to transmit action potentials because their membranes have relatively few voltage-gated sodium channels, and their thresholds for excitation are too high for action potentials to occur. Yet they do transmit *electrotonic current* along the dendrites to the soma. Transmission of electrotonic current means direct spread of electrical current by ion conduction in the fluids of the dendrites but without generation of action potentials.
   TMP14 p. 583

2. **D)** The decrease in membrane potential to a more negative value is called the inhibitory postsynaptic potential (IPSP). Because the resting membrane potential is –60 millivolts and the final membrane potential is –62 millivolts, the IPSP is -2 millivolts. IPSPs are always negative. Excitatory postsynaptic potentials (EPSPs) are always positive because the membrane potential is increased to a less negative value.
   TMP14 pp. 580–581

3. **D)** Nitric oxide is different from other small-molecule transmitters in its mechanism of formation in the presynaptic terminal and in its actions on the postsynaptic neuron. It is not preformed and stored in vesicles in the presynaptic terminal as are other transmitters. Instead, it is synthesized almost instantly as needed and then diffuses out of the presynaptic terminals over a period of seconds rather than being released in vesicular packets.
   TMP14 pp. 576–577

4. **C)** Glycine is an inhibitory neurotransmitter secreted primarily at synapses in the spinal cord. When glycine receptors are activated, chloride ions enter the neuron by way of ionotropic receptors, causing an inhibitory postsynaptic potential.
   TMP14 pp. 577–578

5. **D)** One of the most important of all circuits in the entire nervous system is the *reverberatory* or *oscillatory* circuit. Such circuits are caused by positive feedback within the neuronal circuit that feeds back to re-excite the input of the same circuit. Consequently, once stimulated, the circuit may discharge repetitively for a long time. The simplest oscillatory circuit involves only a single neuron shown. In this case, the output neuron sends a collateral nerve fiber back to its own dendrites or soma to restimulate itself.
   TMP14 p. 595

6. **B)** GABA (gamma-aminobutyric acid) is secreted by nerve terminals in the spinal cord, cerebellum, basal ganglia, and many areas of the cortex. GABA is an inhibitory neurotransmitter because it blocks, or inhibits, certain brain signals and decreases activity in the nervous system.
   TMP14 p. 578

7. **B)** Both excitatory and inhibitory postsynaptic potentials are caused by chemical transmitters (ligands) released from presynaptic neurons that bind to ligand-gated receptors; this eliminates choices D–F). Opening of calcium or sodium channels would cause the membrane potential to move closer to the equilibrium potentials of the ions, which is positive for both ions, so opening sodium or calcium channels would cause an EPSP. Increasing the conductance to potassium channels (i.e., opening potassium channels) would cause the membrane potential to move closer to the equilibrium potential of potassium, which is usually about –94 mV. Hence, opening potassium channels causes an IPSP.
   TMP14 pp. 576, 581–582

8. **B)** When excitatory synapses are repetitively stimulated at a rapid rate, the number of discharges by the postsynaptic neuron is at first very great, but the firing rate becomes progressively less in succeeding milliseconds or seconds. This phenomenon is called *fatigue* of synaptic transmission. The mechanism of fatigue is mainly exhaustion or partial exhaustion of the stores of transmitter substance in the presynaptic terminals. The excitatory terminals on many neurons can store enough excitatory transmitter to cause only about 10,000 action potentials, and the transmitter can be exhausted in only a few seconds to a few minutes of rapid stimulation. Part of the fatigue process probably results from two other factors as well: (1) progressive inactivation of many of the postsynaptic membrane receptors and (2) slow development of abnormal concentrations of ions. Diminished electrotonic potentials (choice B) can be a result of fatigue, not a cause of fatigue.
   TMP14 p. 584

9. B) Often a person feels pain in a part of the body that is fairly remote from the tissue causing the pain. This phenomenon is called *referred pain.* For instance, pain in one of the visceral organs often is referred to an area on the body surface. Referred pain occurs when visceral pain fibers are stimulated and are conducted through at least some of the same neurons that conduct pain signals from the skin; this causes the person to feel that pain sensations originate in the skin. The intermingling of visceral and skin pain fibers occurs in the dorsal horn of the spinal cord.

TMP14 p. 618

10. A) A method frequently used to test tactile discrimination is to determine a person's so-called "two-point" discriminatory ability. In this test, two needles are pressed lightly against the skin at the same time, and the person determines whether one point or two points of stimulus is/are felt. On the tips of the fingers, a person can normally distinguish two separate points even when the needles are as close together as 1 to 2 mm. The capability to distinguish two points of stimulation is strongly influenced by *lateral inhibition.* Excitation of virtually every sensory pathway gives rise to lateral *inhibitory* signals; these inhibitory signals spread to the sides of the excitatory signal and inhibit adjacent neurons. The importance of *lateral inhibition* is that it blocks lateral spread of the excitatory signals and, therefore, increases the degree of contrast in the sensory pattern perceived in the cerebral cortex.

TMP14 p. 606

11. C) A lancinating or stabbing type of pain occasionally occurs in some people over one side of the face in the sensory distribution area (or part of the area) of the fifth or ninth cranial nerves; this phenomenon is called *tic douloureux* (or *trigeminal neuralgia* or *glossopharyngeal neuralgia*). The pain feels like sudden (i.e., paroxysmal) electrical shocks, and it may appear for only a few seconds at a time or may be almost continuous. Often it is set off by exceedingly sensitive trigger areas on the surface of the face, in the mouth, or inside the throat—almost always by a mechanoreceptive stimulus such as touch or cold rather than a pain stimulus.

TMP14 p. 620

12. B) Nerve fibers that transmit pain and temperature sensations enter the spinal cord and terminate in the dorsal horns; here they excite second-order neurons that give rise to long fibers that cross immediately to the opposite side of the cord through the anterior commissure and then turn upward, passing to the brain in the anterolateral columns. So, the left side of the spinal cord transmits pain information from the right side of the body.

TMP14 pp. 614–615

13. B) Most neurons are highly responsive to changes in pH of the surrounding interstitial fluids. Normally, alkalosis (caused by hyperventilation) greatly increases neuronal excitability. For instance, a rise in arterial blood pH from the 7.4 norm to 7.8 to 8.0 often causes cerebral epileptic seizures because of increased excitability of some or all the cerebral neurons. Conversely, acidosis greatly depresses neuronal activity; a fall in pH from 7.4 to below 7.0 usually causes a comatose state. For instance, in very severe diabetic or uremic acidosis, coma almost always develops.

TMP14 p. 584

14. D) Increasing membrane conductance to sodium leads to inward diffusion of sodium to cause an EPSP, not an outward diffusion. Opening sodium channels in the membrane allows sodium ions to move down the sodium electrochemical gradient that is directed from the extracellular fluid to the intracellular fluid.

TMP14 pp. 580–581

15. A) Amplifying divergence means simply that an input signal spreads to an increasing number of neurons as it passes through successive orders of neurons in its path. This type of divergence is characteristic of the corticospinal pathway in its control of skeletal muscles, with a single large pyramidal cell in the motor cortex capable, under highly facilitated conditions, of exciting as many as 10,000 muscle fibers.

TMP14 pp. 593–594

16. C) The electrochemical driving force (V_{DF}) for an ion can be calculated as follows: $V_{DF} = V_m - V_{eq}$, where V_m is the membrane potential and V_{eq} is the equilibrium potential of the ion. A positive value indicates outward flux of the ion, and a negative value indicates inward flux of the ion. A typical equilibrium potential for sodium (calculated using the Nernst equation) is +62 millivolts, so the electrochemical driving force for sodium is −65 − 62 = −127 millivolts. This means that a 127-millivolt force attempts to drive sodium into the cell. The equilibrium potential is about −86 millivolts for potassium and about −70 millivolts for chloride; hence, the electrochemical driving forces for these two ions are +21 and +5 millivolts, respectively (and both ions tend to be driven out of the cell).

TMP14 pp. 64–65, 576

17. B) Hyperventilation lowers the carbon dioxide tension of the blood, which leads to increases in the pH of the body tissues, including the brain. Alkalinity increases neuronal activity in the brain. Carbon dioxide also has the potent effect of increasing cerebral blood flow; thus, hyperventilation can lead to decreased cerebral blood flow with a subsequent decrease in oxygenation of the brain.

TMP14 p. 584

18. D) Pain receptors in the skin are free nerve endings.
TMP14 p. 613

19. B) Merkel discs are found in the dermis of hairy skin and signal continuous touch.
TMP14 pp. 599–600

20. D) The release of neurotransmitter depends on the influx of calcium through voltage-gated channels. When this influx occurs, synaptic vesicles fuse with the presynaptic membrane and release the transmitter agent into the synaptic cleft.
TMP14 p. 579

21. D) A so-called second messenger system can be activated by a transmitter substance released from an initial neuron by first causing the release of a G protein into the second neuron's cytoplasm. Neurotransmitter activation of G proteins is not known to cause closure of an ion channel. G proteins can activate G-protein–gated ion channels for both sodium and potassium, as well as gene transcription, and cAMP and cGMP. G proteins also can activate intracellular enzymes that have a variety of different functions.
TMP14 p. 575

22. D) Individuals experiencing severe chronic pain have difficulty sleeping because the ascending pain pathways provide excitatory input to reticular formation elements that constitute the reticular activating system; this system maintains the alert, waking state. The overall function of the amygdala is thought to make the person's behavioral response appropriate for each occasion; it does not play a major role in establishing the awake state. Loss of visceral sensations or somatic sensations would likely help the man sleep.
TMP14 pp. 615–616

23. C) Hyperventilation plus flashing lights can sometimes initiate an epileptic seizure in a susceptible person who is poorly medicated. Flashing lights alone activate neurons in the occipital cortex that can sometimes lead to increases in electrical activity throughout the brain. Hyperventilation (taking long, deep breaths) lowers carbon dioxide levels in the blood, causing the brain to become alkalotic; this activation method is commonly used to increase brain activity during electroencephalography.
TMP14 pp. 584, 779

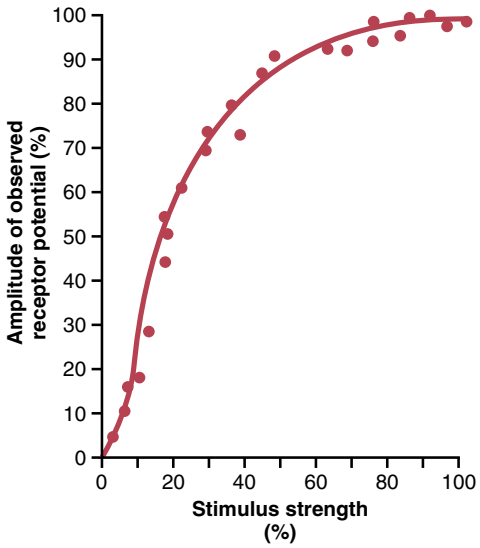
24. D) The association of one sensory modality with one type of nerve fiber is the basis for the labeled line theory.
TMP14 p. 587

25. A) Pacinian corpuscles detect pressure and movement across the skin surface and are encapsulated receptors found deep in the skin throughout the body.
TMP14 pp. 588–589

26. A) The function of a transmitter agent is solely dependent on the postsynaptic receptor to which it binds.
TMP14 p. 574

27. D) Virtually all mechanical stimuli cause an increase in ion permeability (usually to sodium) in mechanoreceptors. If the membrane potential of the mechanoreceptor reaches a critical threshold value, an action potential is initiated. The G-protein "second messenger" system is typically involved with prolonged postsynaptic neuronal excitation or inhibition; transduction in mechanoreceptors is rapid and transient. Transmitter release does not occur at the level of the mechanoreceptor, but if a mechanoreceptor is activated, afferent nerve impulses do stimulate transmitter release at the nerve terminal in the central nervous system.
TMP14 p. 588

28. A) The amplitude of the receptor potential from a Pacinian corpuscle increases greatly with a step increase in stimulus intensity at lower levels of stimulus strength and to a lesser extent with a similar step increase at higher levels of stimulus strength, as shown. This relationship between stimulus strength and amplitude of receptor potential allows the Pacinian corpuscle to discern small changes in stimulus strength at low levels of stimulation and yet still respond to changes in stimulus strength when the intensity of stimulation is high.
TMP14 p. 589



Relation of amplitude of receptor potential to strength of a mechanical stimulus applied to a Pacinian corpuscle. Data from Loëwenstein WR: Excitation and inactivation in a receptor membrane. *Ann N Y Acad Sci* **94:510, 1961.**

29. A) Interneurons in the dorsal horn of the spinal cord use enkephalin as a transmitter substance that effectively inhibits pain transmission from tissues of the body. The somatosensory cortex is located in the postcentral gyrus, and the primary motor cortex is located in the precentral gyrus; neither is thought to use enkephalin to inhibit pain transmission. Myelinated δ-type A fibers and unmyelinated type C fibers are not interneurons. Interneurons are physically short neurons that form a connection between other neurons that are usually close together. There are distinguished from "projection" neurons that project to more distant regions of the brain or spinal cord.
TMP14 p. 617

30. B) Temporal and spatial fidelity is enhanced in the dorsal column–medial lemniscal system compared with the anterolateral system.
TMP14 p. 602

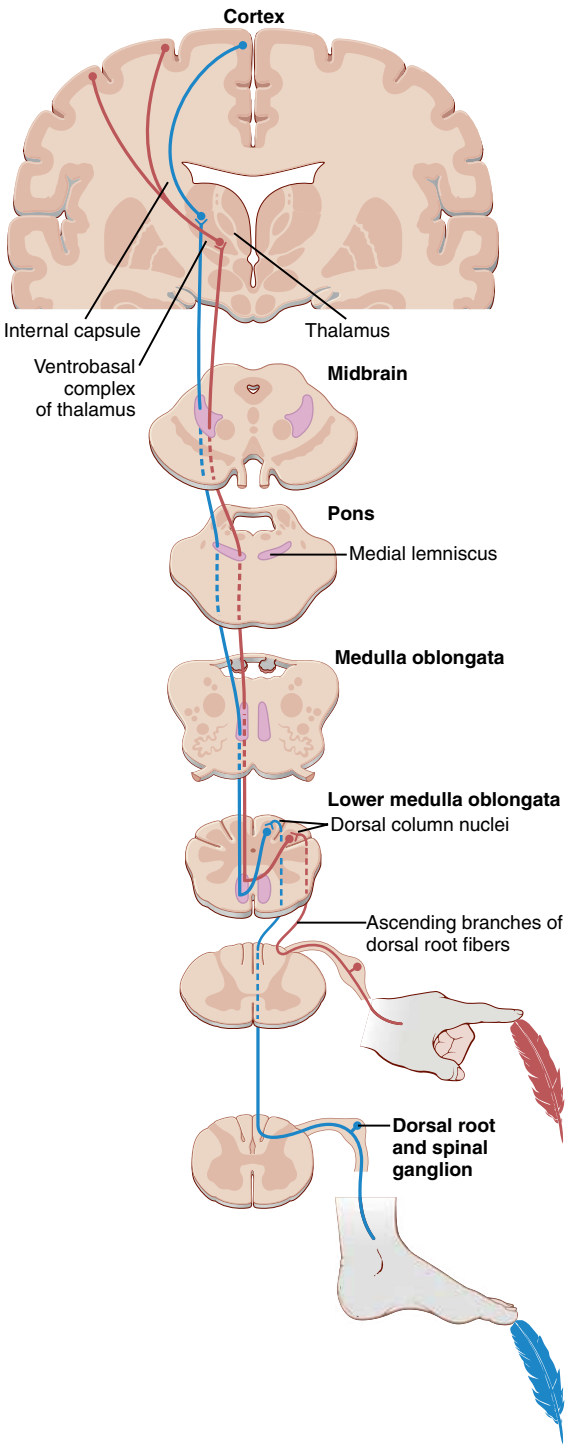
31. A) Fibers in the anterolateral system cross in the anterior white commissure within a few segments of their entry before ascending on the contralateral side. Signals ascending in the dorsal column–medial lemniscal system do not cross until they reach the dorsal column nuclei in the medulla.
TMP14 pp. 614–615

32. D) Neurons of the nucleus raphe magnus release serotonin at their nerve endings. In the endogenous pain suppression system, the termination of these neurons is in the spinal cord on interneurons that in turn release enkephalin and block the incoming signals from the pain fibers.
TMP14 p. 617

33. B) The sensations of highly localized touch and body position are carried in the dorsal column–medial lemniscal system.
TMP14 p. 602

34. C) Primary afferent neuronal cell bodies are found in the dorsal root ganglia.
TMP14 p. 602

35. D) The medial lemniscus conveys axons from the nucleus gracilis and cuneatus to the thalamus (see figure).
TMP14 p. 602



Dorsal column–medial lemniscal pathway for transmitting critical types of tactile signals.

36. B) Stimulation of β-type A fibers from peripheral tactile receptors can decrease transmission of pain signals by a type of lateral inhibition; this process is mediated by inhibitory interneurons in the dorsal column of the spinal cord. α-Type A neurons project to skeletal

muscles, causing them to contract. δ-Type A fibers and type C fibers conduct pain signals to the dorsal column of the spinal cord.
TMP14 pp. 617–618

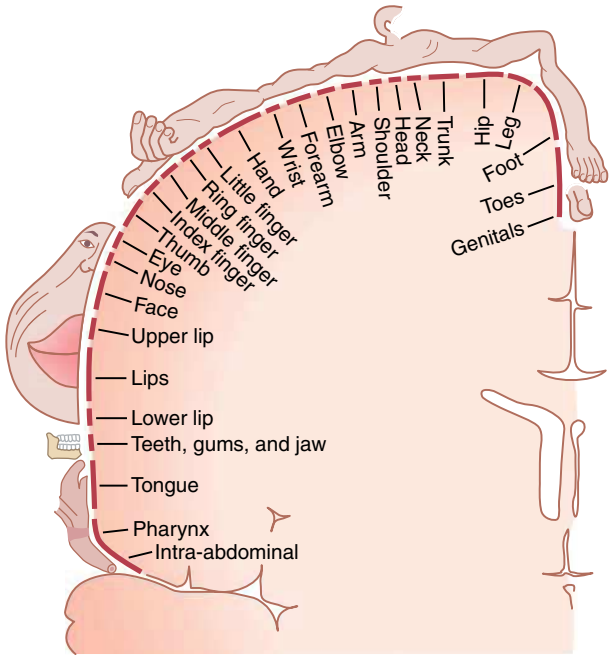
37. E) Transmission of electrical signals in dendrites occurs by electrotonic conduction. Dendrites have few voltage-gated sodium channels, which makes it impossible for action potentials to be initiated in this portion of a typical neuron. A neuron can be considered as a type of capacitor that discharges during an action potential, but this occurs in the axon, not the dendrites. Electrotonic conduction does not occur by diffusion or active transport.
TMP14 p. 574

38. C) The internal capsule conveys axons from the ventral posterolateral thalamic nucleus to the primary somatosensory cortex.
TMP14 p. 602

39. D) Ligand-gated channels open and allow entry of sodium. This entry is accompanied by the influx of calcium, binding of synaptic vesicles to the presynaptic membrane, and electrical changes in the postsynaptic membrane.
TMP14 pp. 572–574

40. C) The periaqueductal gray area in the midbrain contains neurons that contribute to the descending pain suppression system.
TMP14 pp. 616–617

41. B) The lower limb representation is found in the superior and medial portion of the postcentral gyrus (see figure).
TMP14 p. 604



Representation of the different areas of the body in somatosensory area I of the cortex. From Penfield W, Rasmussen T: *Cerebral Cortex of Man: A Clinical Study of Localization of Function.* **New York: Hafner, 1968.**

42. C) Neurons in the periaqueductal gray area use enkephalin as a transmitter agent.
TMP14 p. 617

43. D) Most motor neurons cross to the contralateral side in the pyramidal decussation of the medulla oblongata, which is proximal to the damaged area. Fine sensory sensations (vibration sense, fine touch, proprioception, and two-point discrimination) transmitted in the dorsal-column medial lemniscal pathway cross to the contralateral side in the medulla. Therefore, both motor function and vibration sense are lost on the same side (ipsilateral) as the cord lesion.
TMP14 pp. 602, 699

44. A) Crude touch, pain sensations, and temperature sensations travel in the anterolateral pathway of the spinal cord; the afferent neurons from the receptor organs decussate in the spinal cord close to the point of entry. Hence, these sensations are lost on the side opposite of the lesion.
TMP14 pp. 614–615

45. A) In general, the sensation of pain is poorly localized. However, when a tactile receptor and a pain receptor are stimulated simultaneously, the pain sensation is localized with greater accuracy.
TMP14 p. 615

46. C) Posttetanic facilitation is the neuronal phenomenon in which a neuron is more easily excited after a brief period of activity. This phenomenon is thought to be due to the buildup of calcium in the presynaptic membrane caused by the prior neuronal activity. Subsequent neuronal impulses release neurotransmitter more readily as a result of this preplaced calcium from the prior stimulus.
TMP14 p. 574

47. B) The size of the representation of various body parts in the primary somatosensory cortex is correlated with the density of cutaneous receptors in that body part.
TMP14 p. 604

48. D) Layer IV of the somatosensory cortex receives the bulk of the input from the somatosensory nuclei of the thalamus.
TMP14 pp. 604–605

49. D) Herpes zoster is a disorder characterized by excessive pain in a dermatomal distribution that results from a viral infection of a dorsal root ganglion.
TMP14 p. 620

50. D) Brown-Séquard syndrome is characterized by a loss of pain sensation on one side of the body coupled with a loss of discriminative sensations, such as proprioception and vibratory sensation, on the opposite side of the body.
TMP14 pp. 620–621

51. D) The lateral medullary syndrome exhibits one of the most characteristic patterns of sensory loss in clinical neurology; pain sensation is lost over one side of the body from feet to neck and on the opposite side of the face. Moreover, the side of facial pain loss indicates the side of the lesion.
TMP14 p. 620

52. A) Touching or pulling on the postcentral gyrus is least likely to evoke a painful sensation because brain tissue lacks pain receptors.
TMP14 p. 621

53. C) High-frequency repetitive stimulation (indentation/pressure) of the skin is sensed by Pacinian corpuscles.
TMP14 pp. 588–589

54. B) A diverging neuronal pathway amplifies nerve signals; activation of a single pyramidal cell in motor cortex can stimulate as many as 10,000 muscle fibers. In a converging circuit, multiple input fibers converge upon a single postsynaptic neuron, which allows summation of information from multiple sources. An inhibitory circuit often has inhibitory interneurons that stop the spread of a nerve signal. Reverberatory circuits have positive feedback elements that allow a nerve impulse to continue for a prolonged time.
TMP14 pp. 593–594

55. A) The positive increase in membrane potential to a less negative value is called the excitatory postsynaptic potential (EPSP). Because the resting membrane potential is –65 millivolts and the final membrane potential is –55 millivolts, the EPSP is +10 millivolts. EPSPs are always positive. Inhibitory postsynaptic potentials are always negative because the membrane potential is lowered to a more negative value.
TMP14 pp. 580–581

56. C) Activation of G proteins usually changes the long-term response characteristics of the neuron.
TMP14 pp. 575–576

57. C) Proprioceptive sensation depends on tactile and joint capsule receptors.
TMP14 p. 608

58. D) Vasospasm and eventually ischemia in a sensory area of cortex is thought to be the basis for the prodromal symptoms experienced by patients with migraines.
TMP14 p. 621

59. A) The Pacinian corpuscle transmits a modality of sensation (vibration) that is transmitted in the dorsal column–medial lemniscal system. The first synaptic connection in this sensory pathway is in the dorsal column nuclei on the ipsilateral side of the body.
TMP14 p. 602

60. B) Warm receptors mainly transmit signals along relatively slow-conducting type C fibers.
TMP14 p. 622

UNIT X

The Nervous System: B. The Special Senses

1. Which of the following best describes the refractive power of a lens that focuses incoming parallel light rays at a point that is two meters from the refractive center of the lens (in diopters)?
   A) 0.5
   B) 1.0
   C) 2.0
   D) 10.0
   E) 20.0

2. A 62-year-old man visits his physician because of difficulty seeing while driving at night. The man has frequent, foul smelling stools. Stool analyses reveal a high content of digested fat. A decrease in retinal levels of which of the following is the most likely cause of his night blindness?
   A) 2-Monoglycerides
   B) Amino acids
   C) Free fatty acids
   D) Glucose
   E) Vitamin A
   F) Vitamin C

Questions 3 and 4
A 42-year-old woman visits an ophthalmologist because of difficulty seeing. Tests show that her right eye has an intraocular pressure of 34 mm Hg, and her left eye has an intraocular pressure of 38 mm Hg (reference range, 12–20 mm Hg).

3. Which of the following is the most likely cause of this increase in intraocular pressure of both eyes?
   A) Decreased hydraulic resistance of trabecular spaces
   B) Decreased production of aqueous humor
   C) Increased hydraulic resistance of trabecular spaces
   D) Increased production of aqueous humor

4. All the following are likely to occur in the eyes of this patient EXCEPT one. Which one is the EXCEPTION?
   A) Axonal compression
   B) Blockade of axonal flow of cytoplasm
   C) Decreased nutrition of neuronal cell bodies
   D) Decreased retinal nutrition
   E) Lens hypertrophy
   F) Retinal ischemia

5. A 14-year-old girl sits in a dark movie theater for 2 hours and then walks outside. Which of the following best describes the permeability to sodium and potassium ions in rod cells in response to the onset of photopic conditions?
   A) Decreased sodium permeability, decreased potassium permeability
   B) Decreased sodium permeability, increased potassium permeability
   C) Decreased sodium permeability, no change in potassium permeability
   D) Increased sodium permeability, decreased potassium permeability
   E) Increased sodium permeability, increased potassium permeability
   F) Increased sodium permeability, no change in potassium permeability

6. A 32-year-old student with 20/20 vision redirects her gaze from a distant building back to her computer screen. Which of the following best describes the lens, ciliary muscle, and parasympathetic responses to changing her gaze to the computer screen?
   A) Thicker lens, contraction of ciliary muscle, increased parasympathetic stimulation
   B) Thicker lens, contraction of ciliary muscle, decreased parasympathetic stimulation
   C) Thicker lens, relaxation of ciliary muscle, increased parasympathetic stimulation
   D) Thicker lens, relaxation of ciliary muscle, decreased parasympathetic stimulation
   E) Thinner lens, contraction of ciliary muscle, increased parasympathetic stimulation
   F) Thinner lens, contraction of ciliary muscle, decreased parasympathetic stimulation
   G) Thinner lens, relaxation of ciliary muscle, increased parasympathetic stimulation
   H) Thinner lens, contraction of ciliary muscle, decreased parasympathetic stimulation

7. The human tongue typically has about how many taste buds?
   A) 30–100
   B) 100–3,000
   C) 3,000–10,000
   D) 10,000–30,000
   E) 30,000–100,000

8. A 25-year-old factory worker develops a noise-induced hearing loss over a period of 6 months because of repeated, prolonged exposures to loud sounds. The physical loss of which of the following structures is most likely to contribute to the hearing deficit?
   A) Cochlea
   B) Hair cells
   C) Organ of Corti
   D) Scala vestibuli
   E) Attenuation reflex

9. Which of the following structures provides a gating function for transmission of the visual signal from the retina to the central nervous system?
   A) Lateral geniculate nucleus
   B) Optic radiation
   C) Optic chiasm
   D) Optic nerve
   E) Visual cortex

10. Which of the following best describes the electrical response of rods in the retina to photopic conditions?
    A) Action potential
    B) Capacitive discharge
    C) Depolarization
    D) Hyperpolarization

11. A 43-year-old man wakes up at night and turns on a light. Which of the following substances is most likely to increase in the rods of the retina when the man is exposed to photopic conditions?
    A) cAMP
    B) cGMP
    C) Metarhodopsin II
    D) Rhodopsin
    E) Vitamin A

12. A 30-year-old woman is admitted as an emergency to University Hospital because of sudden, severe pain in the right eye. Tests show an intraocular pressure of 60 mm Hg in her right eye; the intraocular pressure of her left eye is 15 mm Hg (reference range: 12–20 mm Hg). Which of the following is the most likely cause of acute eye pain in this woman?
    A) Closed-angle glaucoma
    B) Chronic glaucoma
    C) Conjunctivitis
    D) Corneal abrasion
    E) Open-angle glaucoma
    F) Optic neuritis

13. A 90-year-old woman visits the ophthalmologist because of difficulty seeing. The patient is given an eye exam, and bifocal lenses are prescribed. The woman sees well with her new prescription glasses. Which of the following is the most likely vision problem in this woman?
    A) Cataracts
    B) Emmetropia
    C) Glaucoma
    D) Hyperopia
    E) Myopia
    F) Presbyopia

14. Which of the following cell types is most likely to play a central role in lateral inhibition to enhance visual contrast?
    A) Amacrine cells
    B) Bipolar cells
    C) Cones
    D) Ganglion cells
    E) Horizontal cells
    F) Rods

15. Ganglion cells attached to rods or cones located on the nasal portion of each retina terminate (or synapse) in which of the following structures?
    A) Calcarine fissure of occipital cortex
    B) Contralateral lateral geniculate nucleus
    C) Contralateral visual cortex
    D) Ipsilateral lateral geniculate nucleus
    E) Ipsilateral visual cortex

16. Which of the following is the leading cause of blindness worldwide?
    A) Albinism
    B) Cataracts
    C) Glaucoma
    D) Presbyopia

17. Topical application of atropine in the eye has which of the following effects?
    A) Miosis, inhibition of accommodation
    B) Miosis, stimulation of accommodation
    C) Mydriasis, inhibition of accommodation
    D) Mydriasis, stimulation of accommodation

18. Which of the following best describes myopia and hyperopia?
    A) Myopia: long eyeball, farsightedness; hyperopia: short eyeball, nearsightedness
    B) Myopia: long eyeball, nearsightedness; hyperopia: short eyeball, farsightedness
    C) Myopia: short eyeball, farsightedness; hyperopia: long eyeball, nearsightedness
    D) Myopia: short eyeball, nearsightedness; hyperopia: long eyeball, farsightedness

19. Low-frequency sound causes which portion of the basilar membrane to vibrate to the greatest extent?
    A) Near oval window
    B) Middle portion
    C) Along entire length
    D) Near helicotrema

20. A 9-year-old girl looks at a flower through a magnifying glass. She finds that the flower must be 10 cm from the convex lens to be in focus. Which value best describes the refractive power of the lens (in diopters)?
    A) 0.1
    B) 1.0
    C) 10
    D) 100
    E) 1000

21. Which of the following best describes the "blind spot" of the eye?
    A) Located 5 degrees lateral to central point of vision
    B) Exit point of the optic nerve
    C) Contains only rods and thus has monochromatic vision
    D) Contains no blood vessels
    E) Area where chromatic aberration of lens is greatest

22. A 10-year-old girl with albinism is taken to the ophthalmologist because of difficulty seeing. Testing shows that her visual acuity is reduced. Which of the following is the most likely cause of the decrease in visual acuity in this girl?
    A) Cataracts
    B) Hyperopia
    C) Myopia
    D) Photophobia
    E) Presbyopia

23. Which substance is most likely to elicit the sensation of bitter taste?
    A) Aldehydes
    B) Alkaloids
    C) Amino acids
    D) Hydrogen ions
    E) Ketones

24. Damage to the sixth cranial nerve is most likely to produce which deficit in eye movement?
    A) Inability to move eyes in a vertical up-and-down motion
    B) Inability to rotate eyes within the eye socket
    C) Inability to move eyes laterally toward the midline
    D) Inability to move the laterally away from the midline
    E) Vertical strabismus

25. The condition of cataracts is usually the result of which process or condition?
    A) Denaturation of the proteins in lens of eye
    B) Elongated eye globe
    C) Unresponsive and dilated pupil
    D) Coagulation of proteins in lens of the eye
    E) Increase in intraocular pressure

26. Which substance is most likely to elicit the sensation of sour taste?
    A) Aldehydes
    B) Alkaloids
    C) Amino acids
    D) Hydrogen ions
    E) Ketones

27. Which taste sensation is most likely to be the most sensitive (i.e., has the lowest stimulation threshold)?
    A) Acid
    B) Bitter
    C) Salty
    D) Sour
    E) Sweet

28. Which of the following best describes the middle ear ossicle that is attached to the tympanic membrane?
    A) Columella
    B) Incus
    C) Malleus
    D) Modiolus
    E) Stapes

29. Light entering the eye passes through which retinal layer first?
    A) Inner nuclear layer
    B) Outer nuclear layer
    C) Outer plexiform layer
    D) Photoreceptor layer
    E) Retinal ganglion layer

30. Ganglion cells attached to photoreceptors located on the temporal portion of the retina project to which structure?
    A) Contralateral lateral geniculate nucleus
    B) Ipsilateral lateral geniculate nucleus
    C) Ipsilateral medial geniculate nucleus
    D) Calcarine fissure
    E) Contralateral medial geniculate nucleus

31. Which of the following is most likely to occur when parallel light rays pass through a concave lens?
    A) Rays converge toward each other
    B) Rays diverge away from each other
    C) Rays maintain a parallel relationship
    D) Rays reflect back in the direction from where they came
    E) Rays refract to one focal point

32. Which compartment of the cochlea contains the organ of Corti?
    A) Ampulla
    B) Saccule
    C) Scala media
    D) Scala tympani
    E) Scala vestibuli

33. Which molecules combine to form rhodopsin?
    A) Bathorhodopsin and 11-cis-retinal
    B) Bathorhodopsin and all-trans-retinal
    C) Bathorhodopsin and scotopsin
    D) Scotopsin and 11-cis-retinal
    E) Scotopsin and all-trans-retinal

34. Analysis of visual detail occurs in which secondary visual area?
    A) Brodmann's area 18
    B) Inferior ventral and medial regions of the occipital and temporal cortex
    C) Frontal lobe
    D) Occipitoparietal cortex
    E) Posterior midtemporal area

35. Which substance is most likely to stimulate the umami taste sensation?
    A) Acetic acid
    B) Potassium tartrate
    C) Long-chained organic substances containing nitrogen
    D) Fructose
    E) Glutamate

36. Which cell type(s) have action potentials in the retina of the human eye?
    A) Bipolar cells and ganglion cells
    B) Bipolar cells only
    C) Bipolar cells, horizontal cells, and ganglion cells
    D) Ganglion cells and horizontal cells
    E) Ganglion cells only
    F) Horizontal cells only

37. Olfactory receptor cells belong to which group of cells?
    A) Bipolar neurons
    B) Fibroblasts
    C) Modified epithelial cells
    D) Multipolar neurons
    E) Pseudounipolar neurons

38. Under low or reduced light conditions, which chemical compound is responsible for the inward-directed sodium current in the outer segments of the photoreceptors?
    A) Metarhodopsin II
    B) cGMP
    C) 11-cis retinal
    D) cAMP
    E) 11-trans retinal

39. Which cells in layer IV of the primary visual cortex detect orientation of lines and borders?
    A) Border cells
    B) Complex cells
    C) Ganglion cells
    D) Hypercomplex cells
    E) Simple cells

40. Which event occurs in photoreceptors during phototransduction in response to light?
    A) Phosphodiesterase activity decreases
    B) Transducin activity decreases
    C) Hydrolysis of cGMP increases
    D) Neurotransmitter release increases
    E) The number of open voltage-gated calcium channels increases

Questions 41 and 42

A 50-year-old woman visits an otolaryngologist for sudden bouts of dizziness that subside after about 20 minutes. She also has temporary hearing losses and a feeling of fullness in her right ear; low-pitched buzzing sounds occur intermittently in her right ear. Physical examination shows nystagmus during a dizzy spell. Use this information to answer the next two questions.

41. Which of the following is the most likely diagnosis?
    A) Acoustic neuroma
    B) Aural polyp
    C) Exostosis
    D) Incus erosion
    E) Meniere's disease

42. An increase in which of the following is the most likely cause of this patient's condition?
    A) Endolymph pressure only
    B) Endolymph volume only
    C) Endolymph volume and pressure
    D) Perilymph pressure only
    E) Perilymph volume only
    F) Perilymph volume and pressure

43. The condition of myopia is usually corrected by which type of lens?
    A) Compound lens
    B) Convex lens
    C) Spherical lens
    D) Concave lens
    E) Cylindrical lens

44. Which lobe of the cerebral cortex contains the small bilateral cortical area that controls voluntary fixation movements?
    A) Frontal
    B) Limbic
    C) Occipital
    D) Parietal
    E) Temporal

45. Which sensory system is most likely to have the smallest range of intensity discrimination?
    A) Auditory
    B) Gustatory
    C) Olfactory
    D) Somatosensory
    E) Visual

46. Which molecules move from the endolymph into the stereocilia and depolarize the hair cell?
    A) Calcium ions
    B) Chloride ions
    C) Hydrogen ions
    D) Potassium ions
    E) Sodium ions

47. The stereocilia of hair cells are embedded in which membrane?
    A) Basilar
    B) Reissner's
    C) Tectorial
    D) Tympanic
    E) Vestibular

48. Which cranial nerve is correctly paired with the extraocular muscle it innervates?
    A) Abducens nerve–medial rectus
    B) Oculomotor nerve–inferior oblique
    C) Oculomotor nerve–lateral rectus
    D) Oculomotor nerve–superior oblique
    E) Trochlear nerve–superior rectus

49. After olfactory receptor cells bind odor molecules, a sequence of intracellular events occurs that culminates in the entrance of specific ions that depolarize the olfactory receptor cell. Which ions are most likely to be involved?
    A) Calcium
    B) Chloride
    C) Hydrogen
    D) Potassium
    E) Sodium

50. Which of the following is most likely to occur when the eye adapts to intense light?
    A) Bipolar cells will continuously transmit signals at the maximum rate possible
    B) Photochemicals in both rods and cones will be reduced to retinal and opsins
    C) The levels of rhodopsin will be very high
    D) The size of the pupil will increase
    E) Vitamin A will convert into retinal

51. In the central auditory pathway, which option represents the correct sequence of structures in the pathway?
    A) Cochlear nuclei–superior olive–inferior colliculus via the lateral lemniscus–medial geniculate–auditory cortex
    B) Cochlear nuclei–inferior olive–inferior colliculus via the medial lemniscus–medial geniculate–auditory cortex
    C) Cochlear nuclei–superior olive–superior colliculus via the lateral lemniscus–lateral geniculate–auditory cortex
    D) Cochlear nuclei–inferior olive–inferior colliculus via the lateral lemniscus–lateral geniculate–auditory cortex
    E) Cochlear nuclei–trapezoid body–dorsal acoustic stria–inferior colliculus via the lateral lemniscus–medial geniculate–auditory cortex

52. Which event prompts the auditory system to interpret a sound as loud?
    A) A decreased number of inner hair cells become stimulated
    B) A decreased number of outer hair cells become stimulated
    C) Hair cells excite nerve endings at a diminished rate
    D) The amplitude of vibration of the basilar membrane decreases
    E) The amplitude of vibration of the basilar membrane increases

53. The condition of hyperopia is usually caused by which anomaly of the eye?
    A) Decreased production of melanin
    B) Uneven curvature of the cornea
    C) An eyeball that is shorter than normal
    D) An eyeball that is longer than normal
    E) A lens system that is too powerful and focuses the object in front of the retina

54. When a person turns the head to the left about the axis of the neck, the motion begins when the chin is directly over the right shoulder and ends with the chin directly over the left shoulder. Which option best describes the eye movements associated with this type of head rotation in a normal person?
    A) While the head is turning, the eyes will be moving to the right and saccadic eye motion will be to the left
    B) While the head is turning, the eyes will be moving in the same direction as the head rotation and the saccadic eye motion will be to the left
    C) While the head is turning, the eyes will be moving to the right and the saccadic eye motion will be to the right
    D) While the head is turning, the eyes will remain stationary within the orbits and the saccadic eye motion will be to the right
    E) While the head is turning, the eyes will be moving to the left and the saccadic eye motion will be to the right

55. Olfactory information transmitted to the orbitofrontal cortex passes through which thalamic nucleus?
    A) Dorsomedial
    B) Lateral geniculate
    C) Medial geniculate
    D) Ventral posterolateral
    E) Ventral posteromedial

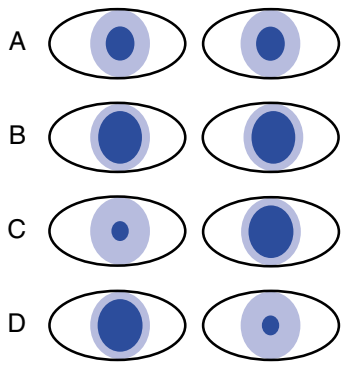
56. A 29-year-old student with 20/20 vision looks at a beautiful scene. The axons of ganglion cells transmitting visual signals in the form of action potentials to the primary visual cortex are most likely to synapse in which structure?
    A) Lateral geniculate nucleus
    B) Medial geniculate nucleus
    C) Optic chiasm
    D) Optic radiation
    E) Superior cervical ganglion
    F) Superior colliculus

57. Which muscle is contracted as part of the pupillary light reflex?
    A) Ciliary muscle
    B) Pupillary dilator muscle
    C) Pupillary sphincter muscle
    D) Radial fibers of the iris
    E) Superior oblique muscle

Questions 58 and 59

A 24-year-old woman sustains a laceration on the right side of the neck in a motor vehicle accident. Physical examination shows that her right pupil is constricted, her right eyelid droops, the skin is dry on the right side of her face, and the conjunctiva of her right eye is red. Use this information to answer the next two questions.

58. What is the most likely diagnosis?
    A) Cone-rod dystrophy
    B) Horner's syndrome
    C) Iris heterochromia
    D) Retinoblastoma
    E) Xerophthalmia



59. Which test result shown in the bottom of left column figure is most likely after topical treatment with cocaine in both eyes?
    A) A
    B) B
    C) C
    D) D

60. Which neurotransmitter is released by both rods and cones at their synapses with bipolar cells?
    A) Acetylcholine
    B) Dopamine
    C) Glutamate
    D) Glycine
    E) Serotonin

61. Which of the following allows the visual apparatus to accurately determine the distance of an object from the eye (depth perception)?
    A) Monocular vision
    B) The location of the retinal image on the retina
    C) The phenomenon of stationary parallax
    D) The phenomenon of stereopsis
    E) The size of the retinal image if the object is of unknown size

62. Which of the following provides about two thirds of the 59 diopters of refractive power of the eye?
    A) Anterior surface of the cornea
    B) Anterior surface of the lens
    C) Iris
    D) Posterior surface of the cornea
    E) Posterior surface of the lens

63. Which photoreceptor responds to the broadest spectrum of wavelengths of light?
    A) Rod receptors
    B) Green cone receptors
    C) Blue cone receptors
    D) Red cone receptors
    E) Cells containing melanin in the pigment layer

64. Which structure secretes the intraocular fluid of the eye?
    A) Ciliary processes
    B) Cornea
    C) Iris
    D) Lens
    E) Trabeculae

65. Which type of papillae is in the posterior part of the tongue?
    A) Circumvallate
    B) Foliate
    C) Fungiform
    D) Fungiform and circumvallate
    E) Papilla of Vater

66. Auditory information is relayed through which thalamic nucleus?
    A) Dorsomedial
    B) Lateral geniculate
    C) Medial geniculate
    D) Ventral posterolateral
    E) Ventral posteromedial

67. Which of the following describes the phenomenon of taste preference?
    A) A central nervous system process
    B) The result of neonatal stimulation of circumvallate papilla
    C) A learned behavior in animals
    D) A result of taste bud maturation
    E) A result of taste bud proliferation after exposure to glutamic acid

68. The primary auditory cortex lies primarily in which lobe of the cerebral cortex?
    A) Frontal
    B) Limbic
    C) Occipital
    D) Parietal
    E) Temporal

69. The first central synapse for neurons transmitting the sweet taste sensation is in which structure?
    A) Dorsal sensory nucleus of vagus nerve
    B) Nucleus of solitary tract
    C) Nucleus of olfactory nerve
    D) Nucleus of hypoglossal nerve
    E) Nucleus of facial nerve

70. Which structure functions to ensure that each of the three sets of extraocular muscles is reciprocally innervated so that one muscle of the pair relaxes while the other contracts?
    A) Edinger-Westphal nucleus
    B) Medial longitudinal fasciculus
    C) Pretectal nucleus
    D) Superior colliculus
    E) Suprachiasmatic nucleus

71. The intraocular fluid of the eye flows from the canal of Schlemm into which location?
    A) Anterior chamber
    B) Aqueous veins
    C) Lens
    D) Posterior chamber
    E) Trabeculae

72. Which retinal cells are most likely to have action potentials?
    A) Bipolar cells
    B) Ganglion cells
    C) Horizontal cells
    D) Photoreceptors

73. Which brain stem structure plays a major role in determining the direction from which a sound originates?
    A) Cochlear nucleus
    B) Inferior colliculus
    C) Lateral lemniscus
    D) Superior olivary nucleus
    E) Trapezoid

74. A 25-year-old student studies for a test in medical physiology. The visual contrast of the subject matter is enhanced due to lateral inhibition of the visual input by which cell type in the retina?
    A) Amacrine cells
    B) Bipolar cells
    C) Ganglion cells
    D) Horizontal cells

75. Which type of papillae is located in the folds along the lateral surfaces of the tongue?
    A) Circumvallate
    B) Foliate
    C) Fungiform
    D) Fungiform and circumvallate
    E) Papilla of Vater

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ANSWERS

1. **A)** The refractive power of a lens is measured in terms of *diopters.* The refractive power in diopters of a convex lens is equal to 1 m divided by its focal length. Thus, a spherical lens that converges parallel light rays to a focal point 1 m beyond the lens has a refractive power of 1.0 diopter. If the lens focuses parallel light rays at a point 2 m from the refractive center of the lens, the lens has a refractive power of 0.5 diopters (choice A). In addition, a lens capable of converging parallel light rays to a focal point only 10 cm (0.10 m) beyond the lens has a refractive power of +10 diopters.
   TMP14 pp. 629–630

2. **E)** Night blindness occurs in persons with severe vitamin A deficiency because without vitamin A, the amounts of retinal and rhodopsin that can be formed are severely depressed. This condition is called night blindness because the amount of light available at night is too little to permit adequate vision in vitamin A–deficient persons. The man is losing fat in his feces, and vitamin A is a fat-soluble vitamin that is also lost in the feces.
   TMP14 p. 642

3. **C)** Glaucoma, one of the most common causes of blindness, is a disease of the eye in which the intraocular pressure becomes pathologically high, sometimes rising acutely to 60 to 70 mm Hg. Pressures above 25 to 30 mm Hg can cause loss of vision when maintained for long periods. In most cases of glaucoma, the abnormally high pressure results from increased resistance to fluid outflow through the trabecular spaces (choice C) into the canal of Schlemm at the iridocorneal junction. For instance, in acute eye inflammation, white blood cells and tissue debris can block these trabecular spaces and cause an acute increase in intraocular pressure. In chronic conditions, especially in older persons, fibrous occlusion of the trabecular spaces appears to be the likely culprit.
   TMP14 p. 637

4. **E)** Extremely high intraocular pressures can cause blindness within days or even hours. As the pressure rises, the axons of the optic nerve are compressed where they leave the eyeball at the optic disc. This compression is believed to block axonal flow of cytoplasm from the retinal neuronal cell bodies into the optic nerve fibers leading to the brain. The result is lack of appropriate nutrition of the fibers, which eventually causes death of the involved fibers. It is possible that compression of the retinal artery, which enters the eyeball at the optic disc, also adds to the neuronal damage by reducing nutrition to the retina (i.e., retinal ischemia occurs). There is no reason to expect lens hypertrophy (choice E) in this patient with glaucoma.
   TMP14 p. 637

5. **C)** When rhodopsin in the outer segment of the rod is exposed to light, it is activated and begins to decompose. The cGMP-gated sodium channels are then closed, causing sodium permeability to decrease (choice C). The potassium channels are not gated, and therefore remain open in both photopic and scotopic conditions.
   TMP14 pp. 642–643

6. **A)** The ciliary muscle is controlled almost entirely by parasympathetic nerve signals transmitted to the eye through the third cranial nerve from the third nerve nucleus in the brain stem, as explained in Chapter 52. Stimulation of the parasympathetic nerves contracts both sets of ciliary muscle fibers, which relaxes the lens ligaments, thus allowing the lens to become thicker and increase its refractive power. With this increased refractive power, the eye focuses on objects nearer than when the eye has less refractive power.
   TMP14 pp. 631, 660–661

7. **C)** Adults have 3000 to 10,000 taste buds, and children have a few more. Beyond the age of 45 years, many taste buds degenerate, causing taste sensitivity to decrease in old age.
   TMP14 p. 677

8. **B)** Minute hairs, or *stereocilia*, project upward from the hair cells (choice B) and either touch or are embedded in the surface gel coating of the *tectorial membrane*, which lies above the stereocilia in the scala media. Bending of the hairs in one direction depolarizes the hair cells, and bending in the opposite direction hyperpolarizes them. This in turn excites the auditory nerve fibers synapsing with their bases. These hair cells are damaged when they are exposed to prolonged, loud sounds; the loss is permanent.
   TMP14 p. 667

9. **A)** The optic nerve fibers of the visual system terminate in the dorsal lateral geniculate nucleus (choice A), located at the dorsal end of the thalamus. The dorsal lateral geniculate nucleus serves two principal functions: First, it relays visual information from the optic tract to the visual cortex by way of the optic radiation. The second major function of the dorsal lateral geniculate nucleus is to "gate" the transmission of signals to the visual cortex—that is, to control how much of the signal can pass to the cortex.
   TMP14 pp. 653–654

10. D) The rod receptor potential is hyperpolarizing, not depolarizing. When the rod is exposed to photopic conditions (light), the resulting receptor potential is different from the receptor potentials in almost all other sensory receptors because excitation of the rod causes *increased negativity* of the intrarod membrane potential, which is a state of *hyperpolarization.* This is exactly opposite to the decreased negativity (the process of "depolarization") that occurs in almost all other sensory receptors.

TMP14 pp. 642–643

11. C) When the rhodopsin in the outer segment of the rod is exposed to light, it is activated to become metarhodopsin II (choice C), also called activated rhodopsin. The activated rhodopsin stimulates a G protein called transducin, which then activates cGMP phosphodiesterase, an enzyme that catalyzes the breakdown of cGMP to 5′-cGMP; the reduction in cGMP closes the cGMP-gated sodium channels and reduces the inward sodium current.

TMP14 pp. 641–642

12. A) In closed-angle glaucoma, the iridocorneal angle is completely closed because of forward displacement of iris against the cornea, resulting in the inability of the aqueous fluid to flow from the posterior to the anterior chamber and then out through the trabecular meshwork. The rapid accumulation of aqueous humor in closed-angle glaucoma causes an acute increase in pressure and pain. Closed-angle glaucoma is a medical emergency; blindness can occur rapidly if not treated.

TMP14 p. 637

13. F) As a person grows older, the lens grows larger and thicker and becomes far less elastic, partly because of progressive denaturation of the lens proteins. The ability of the lens to change shape decreases with age. The power of accommodation decreases from about 14 diopters in a child to less than 2 diopters by the time a person reaches 45 to 50 years and to essentially 0 diopters at age 70 years. Thereafter, the lens remains almost totally nonaccommodating, a condition known as presbyopia (choice F).

TMP14 p. 631

14. E) The horizontal cells connect laterally between the synaptic bodies of the rods and cones and also connect with the dendrites of the bipolar cells. The outputs of the horizontal cells are always inhibitory. Therefore, this lateral connection provides the same phenomenon of lateral inhibition that is important in other sensory systems—that is, helping to ensure transmission of visual patterns with proper visual contrast.

TMP14 pp. 639, 646–647

15. B) The visual nerve signals leave the retinas through the optic nerves. At the optic chiasm, the optic nerve fibers from the nasal halves of the retinas cross to the opposite sides, where they join the fibers from the opposite temporal retinas to form the optic tracts. The fibers of each optic tract then synapse in the dorsal lateral geniculate nucleus of the thalamus, and from there, geniculocalcarine fibers pass by way of the optic radiation to the primary visual cortex in the calcarine fissure area of the medial occipital lobe.

TMP14 p. 653

16. B) "Cataracts" are an especially common eye abnormality that occurs mainly in older people. A cataract is a cloudy or opaque area or areas in the lens. In the early stage of cataract formation, the proteins in some of the lens fibers become denatured. Later, these same proteins coagulate to form opaque areas in place of the normal transparent protein fibers. When a cataract has obscured light transmission so greatly that it seriously impairs vision, the condition can be corrected by surgical removal of the lens. When the lens is removed, the eye loses a large portion of its refractive power, which must be replaced by a convex plastic lens implanted in front of the eye.

TMP14 p. 634

17. C) The accommodation mechanism—that is, the mechanism that focuses the lens system of the eye—is controlled by the parasympathetic nerves. Hence, accommodation is inhibited when the acetylcholine muscarinic receptors are blocked by atropine. Stimulation of the parasympathetic nerves also excites the pupillary sphincter muscle, thereby decreasing the pupillary aperture; this process is called miosis. So, when the acetylcholine receptors are blocked by atropine, pupillary dilation occurs, a process called mydriasis.

TMP14 pp. 631, 660–661

18. B) Hyperopia, which is also known as "farsightedness," is usually due to either an eyeball that is too short or, occasionally, a lens system that is too weak. In myopia, or "nearsightedness," when the ciliary muscle is completely relaxed, the light rays coming from distant objects are focused in front of the retina. This condition is usually due to an eyeball that is too long, but it also can result from too much refractive power in the lens system of the eye.

TMP14 p. 632

19. D) High-frequency resonance of the basilar membrane occurs near the base, where the sound waves enter the cochlea through the oval window. However, low-frequency resonance occurs near the helicotrema (choice D), mainly because of the less stiff fibers but also because of increased "loading" with extra masses of fluid that must vibrate along the cochlear tubules.

TMP14 p. 665

20. C) The refractive power of a lens (in diopters) = 1 m/focal length; if the subject matter is in focus when a convex lens is 1 m from the subject matter, the lens has a refractive power of 1 m/1 m = 1 diopter. Thus, there is an inverse relationship between focal length and refractive power; a thicker convex lens has a shorter focal length and a greater refractive power. In this problem, the lens must be 10 cm from the subject matter to be in focus (focal length = 100 mm); therefore, 1000 mm/100 mm = 10 diopters. Because the retina of the eye is about 17 mm behind the lens, the refractive power of the lens of the eye is about 59 diopters.
TMP14 p. 629

21. B) The blind spot is located 15 degrees lateral to the central point of vision. It is the location where fibers that make up the optic nerve exit the globe of the eye. There are no photoreceptors in this location.
TMP14 p. 657

22. D) Photophobia is discomfort or pain to the eyes due to light exposure; it is a medical condition, not a fear or phobia. The lack of melanin (black pigment) in the irises of the eyes makes them somewhat translucent, so they cannot block light effectively. The lack of melanin in the pigment layer of the retina causes light to scatter inside the globe of the eye, which decreases contrast and visual acuity.
TMP14 p. 641

23. B) The taste sensation of bitter is caused by many organic substances that contain nitrogen, as well as by alkaloids.
TMP14 p. 675

24. D) The sixth cranial nerve is also known as the *abducens nerve.* The abducens nerve innervates the lateral rectus muscle, which is attached to the lateral surface of the globe of the eye. Contraction of the lateral rectus muscle results in movement of the eyeball laterally away from the midline of the face in an abducting manner—thus the name *abducens nerve.*
TMP14 pp. 657–658

25. D) The condition of cataracts causes the lens of the eye to become opaque and resemble the look of water in a waterfall or rapids in a river, thus the name, cataract. A cataract results from the progressive coagulation of the proteins that make up the lens. One can think of this coagulation as like the white of an egg turning opaque as it is cooked. Heating the egg white results in coagulation of the proteins contained within it.
TMP14 p. 634

26. D) The taste sensation of sour is proportional to the logarithm of the hydrogen ion concentration caused by acids. The taste sensation of sweet is caused by a long list of chemicals, including sugars, alcohols, aldehydes, ketones, and amino acids.
TMP14 p. 675

27. B) The bitter taste sense is much more sensitive than the other sensations because it provides an important protective function against many dangerous toxins in food.
TMP14 p. 676

28. C) The malleus is attached to the tympanic membrane, and the stapes is attached to the oval window. The incus has articulations with both of these bones.
TMP14 p. 663

29. E) Light passes through the eye to the retina in the posterior portion of the eye. The most anterior layer of the retina, through which light passes first, is the retinal ganglion layer. Light then passes through the other cell layers of the retina until it reaches the photoreceptors in the posterior region of the retina.
TMP14 p. 639

30. B) The axons of the ganglion cells make up the fibers of the optic nerve. The first synapse in the visual system takes place in the lateral geniculate nucleus. Ganglion cells attached to photoreceptors on the temporal side of the retina project to the same-sided or ipsilateral lateral geniculate nucleus. Fibers from the nasal side of the retina cross over to the opposite or contralateral lateral geniculate nucleus in the optic chiasm. The medial geniculate nucleus is a sensory relay for the auditory system.
TMP14 p. 653

31. B) A concave lens diverges light rays; in contrast, a convex lens will converge light rays toward each other. If a convex lens has the appropriate curvature, parallel light rays will be bent so that all pass through a single point, called the *focal point.*
TMP14 pp. 627–628

32. C) The ampulla and saccule are part of the vestibular apparatus, not the cochlear apparatus. The cochlea has three main compartments, with fluid movement occurring in the scala vestibuli and scala media in response to sound vibrations. The organ of Corti is contained within the scala media.
TMP14 p. 665

33. D) Rhodopsin is the light-sensitive chemical in rods. Scotopsin and all-trans retinal are the breakdown products of rhodopsin, which has absorbed light energy. The all-trans retinal is converted into 11-cis retinal, which can recombine with scotopsin to form rhodopsin.
TMP14 p. 642

34. B) Visual information from the primary visual cortex (Brodmann's area 17) is relayed to Brodmann's area 18 and then into other areas of the cerebral cortex for further processing. Analysis of three-dimensional position, gross form, and motion of objects occurs in the posterior midtemporal area and occipitoparietal cortex. Analysis of visual detail and color occurs in the inferior ventral and medial regions of the occipital and temporal cortex.
TMP14 pp. 654–655

35. E) The term *umami* is derived from the Japanese word for savory or delicious and is often described as similar to the taste of meat. Glutamate is the chemical believed to elicit the umami taste sensation.
TMP14 pp. 675–676

36. E) Ganglion cells are the only cell type in the retina that have action potentials. The axons of ganglion cells make up the optic nerve. Bipolar cells, cones, rods, horizontal cells, and other cell types in the retina signal information by electrotonic conduction, which allows a graded response proportional to light intensity.
TMP14 p. 648

37. A) The receptor cells for the smell sensation are bipolar nerve cells derived originally from the central nervous system itself.
TMP14 p. 679

38. B) In low light conditions, the level of cGMP is high. cGMP-dependent sodium channels in the outer portions of the rods and cones allow sodium ions to pass from the extracellular space to the intracellular space of the photoreceptor. This passage results in a membrane potential that is somewhat lower than the resting membrane potential of a typical neuron. The movement of the sodium ions and resulting electrical potential change as a result of this enhanced permeability is known as the *dark current.*
TMP14 pp. 643–644

39. E) The simple cells of the primary visual cortex detect orientation of lines and borders, whereas the complex cells detect lines oriented in the same direction but are not position specific. That is, the line can be displaced moderate distances laterally or vertically, and the same few neurons will be stimulated as long as the line is the same direction.
TMP14 p. 656

40. C) In the dark state, cGMP helps maintain the open state of the sodium channels in the outer membrane of the rod. Hydrolysis of cGMP by light causes these sodium channels to close. Less sodium is able to enter the rod outer segment, thus hyperpolarizing the rod.
TMP14 pp. 643–644

41. E) This woman has Meniere's disease, which is a disorder of the inner ear that affects hearing and balance. The disease results from excess endolymph in the scala media and membranous labyrinth. The cause is not known, but it appears to have a genetic component. Symptoms include vertigo, nystagmus, low-pitched tinnitus, and sudden but temporary hearing loss; hearing loss can become permanent. Acoustic neuroma is a slow-growing benign tumor that develops on the auditory nerve. An aural polyp is a growth in the auditory canal that may be attached to the tympanic membrane, or it may grow from the middle ear. An exostosis is the formation of new bone on the surface of an existing bone; it sometimes occurs in the auditory canal of swimmers after prolonged exposure to cold water and is sometimes called "surfer's ear." The incus bone is anvil-shaped and is one of the three ossicles in the middle ear.
TMP14 p. 672

42. C) Increases in both volume and pressure of endolymph in the membranous labyrinth produce the symptoms of Meniere's disease; the reason for this buildup of endolymph is unknown. The membranous labyrinth is composed mainly of the cochlea and balance organs (semicircular canals, utricle, and saccule). Repeated rupturing and healing of the endolymphatic sac of the membranous labyrinth can account for the intermittent symptoms of Meniere's disease. The endolymphatic sac is thought to regulate hydrostatic pressure of endolymph by simple expansion or collapse; it may also have secretory and absorption functions.
TMP14 p. 672

43. D) In myopia, the focal point of the lens system of the eye is in front of the retina. A concave lens will diverge light rays. By placing the proper concave lens in front of the eye, the divergence of light rays will move the focal point from in front of the retina to a position on the retina.
TMP14 pp. 632–633

44. A) A bilateral premotor cortical region of the frontal lobes controls voluntary fixation movements. A lesion of this region makes it difficult for a person to "unlock" the eyes from one point of fixation and then move them to another point.
TMP14 pp. 658–659

45. C) Concentrations that are only 10 to 50 times above threshold values evoke maximum intensity of smell, which is in contrast to most other sensory systems of the body, where the range of intensity discrimination may reach 1 trillion to 1. This phenomenon can perhaps be explained by the fact that smell is concerned more with detecting the presence or absence of odors than with quantitative detection of their intensities.
TMP14 p. 681

46. D) Although most cells in the nervous system depolarize in response to sodium entry, hair cells are one group of cells that depolarize in response to potassium entry.
TMP14 p. 668

47. C) The scala media is bordered by the basilar membrane and Reissner's membrane and contains a tectorial membrane. The apical border of hair cells has stereocilia that are embedded in the tectorial membrane.
TMP14 p. 667

48. B) The abducens nerve innervates the lateral rectus muscle. The trochlear nerve innervates the superior oblique muscle. The oculomotor nerve innervates the medial rectus, inferior oblique, superior rectus, and inferior rectus muscles.
TMP14 pp. 657–658

49. E) Even the minutest concentration of a specific odorant initiates a cascading effect that opens extremely large numbers of sodium channels. This phenomenon accounts for the exquisite sensitivity of the olfactory neurons to even the slightest amount of odorant.
TMP14 pp. 679–680

50. B) The reduction of rhodopsin and cone pigments by light reduces the concentrations of photosensitive chemicals in rods and cones. Thus, the sensitivity of the eye to light is correspondingly reduced. This phenomenon is called *light adaptation.*
TMP14 pp. 644–645

51. A) Auditory fibers enter the cochlear nucleus. Fibers from the cochlear nucleus pass to the inferior colliculus via the lateral lemniscus. Fibers from the inferior colliculus travel to the medial geniculate nucleus and from there to the primary auditory cortex.
TMP14 p. 670

52. E) The auditory system determines loudness in at least three ways. First, the amplitude of vibration of the basilar membrane increases so that hair cells excite nerve endings at more rapid rates. Second, more and more hair cells on the fringes of the resonating portion of the basilar membrane become stimulated. Third, outer hair cells become recruited at a significant rate.
TMP14 pp. 668–669

53. C) In hyperopia, the focal point of the eye's lens system is behind the retina. This is usually the result of an eyeball that is too short in the anterior to posterior direction.
TMP14 p. 632

54. A) In the situation described, the eyes fix on an object in the visual field and remain on that object while the head is turning to the left, resulting in eye movement to the right as the head is turned to the left. When the object is no longer in the central field of vision, the eyes will exhibit a quick jumping movement to the left (i.e., in the direction of the head rotation) and fix on a new object in the visual field. This jump is called a *saccade.* This process repeats until the head has turned all the way to the left. During saccadic eye movement, vision is suppressed.
TMP14 p. 659

55. A) A newer olfactory pathway has been found that projects to the dorsomedial thalamic nucleus and then to the orbitofrontal cortex. However, the older olfactory pathways bypass the thalamus to reach the cortex, in contrast to other sensory systems, which have thalamic relays.
TMP14 pp. 681–682

56. A) Ganglion cells of the retina have synaptic connections within the lateral geniculate nucleus (LGN); from there the visual signals (action potentials) are transmitted to the primary visual cortex. Ganglion cells in the nasal half of the retina synapse in the contralateral LGN, whereas ganglion cells from the temporal half of the retina synapse in the ipsilateral LGN. Decussation occurs in the optic chiasm. Postsynaptic neurons in the LGN travel in the optic radiations and synapse in a fan-shaped manner in the primary visual cortex.
TMP14 p. 653

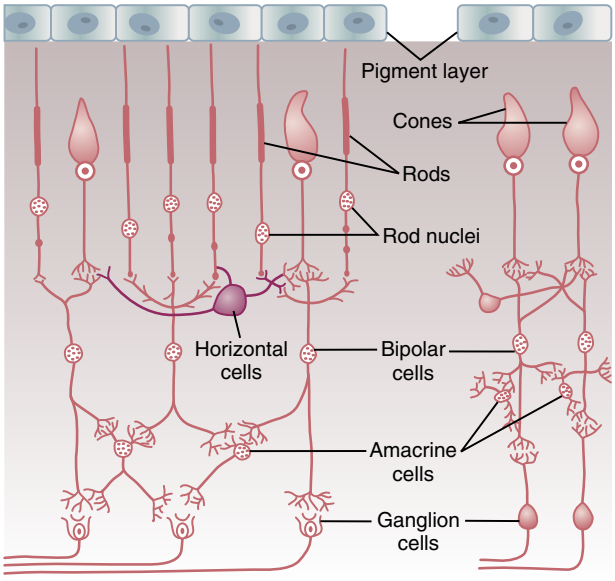
57. C) In a normal individual, shining a light in either eye will result in both pupils constricting due to contraction of the pupillary sphincter muscles. In contrast, the pupillary dilator muscle dilates the pupil. The ciliary muscle is involved in focusing the eye (accommodation).
TMP14 p. 662

58. B) This woman has Horner's syndrome, which is not a disease but rather a symptom of a disease or other problem. In this problem, lacerations to the right side of the neck have damaged the sympathetic nerves to the right eye and right side of the face. Other causes of Horner's syndrome include aortic dissection that compresses adjacent tissues, carotid dissection, Pancoast lung tumor, and tuberculosis, and it can also be congenital. Disruption of sympathetic nerves to the eye causes ipsilateral miosis, ptosis, and dilated blood vessels in the conjunctiva. Cone-rod dystrophy is a chronic disease in which the rods and cones deteriorate over time. Iris heterochromia is a difference in the color of the irises of the two eyes, which often occurs in persons with Horner's syndrome before the age of 2 years but not in adults, in whom eye color has been established. Retinoblastoma is a cancer of the eye in children. Xerophthalmia (also called *dry eye syndrome*) is a disease caused by dryness of the eye.
TMP14 p. 662

59. C) Cocaine blocks the reuptake of norepinephrine, increasing its concentration at the nerve terminal. Nor-

epinephrine relaxes the pupillary dilator muscle (also called the *pupillary sphincter*), causing the pupil to become larger. Failure of cocaine to cause pupillary dilation indicates disruption of the sympathetic nerves to the pupillary dilator muscle because norepinephrine is not being released at the nerve-muscle junction. A more recent approach is to apply an α-adrenergic agonist (such as apraclonidine) to both eyes. The pupillary dilator muscle responds to denervation by increasing the number of its α-1 receptors. The weak α-1 adrenergic properties of apraclonidine have no effect on the normal pupillary dilator muscle but cause extensive dilation of the hypersensitive, denervated pupillary dilator muscle. Thus, with application of apraclonidine, the correct answer would be C because the right eye is denervated and thus hypersensitive to α-1 adrenergic stimulation.

TMP14 p. 662



60. C) At least eight types of neurotransmitter substances have been identified for amacrine cells. The neurotransmitters used for bipolar and horizontal cells are unclear, but it is well established that rods and cones release glutamate at their synapses with bipolar cells (see figure above).

TMP14 pp. 647–648

61. D) Because one eye is a little more than 2 inches to the side of the other eye, the images on the two retinas differ from one another. This binocular parallax (stereopsis) allows a person with two eyes far greater ability than a person with only one eye to judge relative distances when objects are nearby.

TMP14 p. 635

62. A) The principal reason why the anterior surface of the cornea provides most of the refractive power of the eye is that the refractive index of the cornea is markedly different from that of air.

TMP14 p. 630

63. D) Intuitively, one might guess that the rod photoreceptor would have the greatest range of spectral sensitivity. However, it is the red cone that has the broadest spectral sensitivity, followed by the rods, the green cones, and finally the blue cones, which have the narrowest range of spectral sensitivity.

TMP14 pp. 645–646

64. A) Ciliary processes secrete all the aqueous humor of the intraocular fluid at an average rate of 2 to 3 µl/min. These processes are linear folds that project from the ciliary muscle into the space behind the iris. The intraocular fluid flows from behind the iris through the pupil into the anterior chamber of the eye.

TMP14 pp. 635–636

65. A) Circumvallate papillae are located in the posterior part of the tongue, fungiform papillae in the anterior part of the tongue, and foliate papillae on the lateral part of the tongue. The papilla of Vater empties pancreatic secretions and bile into the duodenum.

TMP14 p. 676

66. C) The medial geniculate nucleus is the thalamic nucleus that conveys auditory information from the brain stem to the primary auditory cortex.

TMP14 p. 669

67. A) Taste preference, although not completely understood, is believed to involve a central process.

TMP14 pp. 678–679

68. E) Most of the primary auditory cortex is in the temporal lobe, but the association auditory cortices extend over much of the insular lobe and even onto the lateral portion of the parietal lobe.

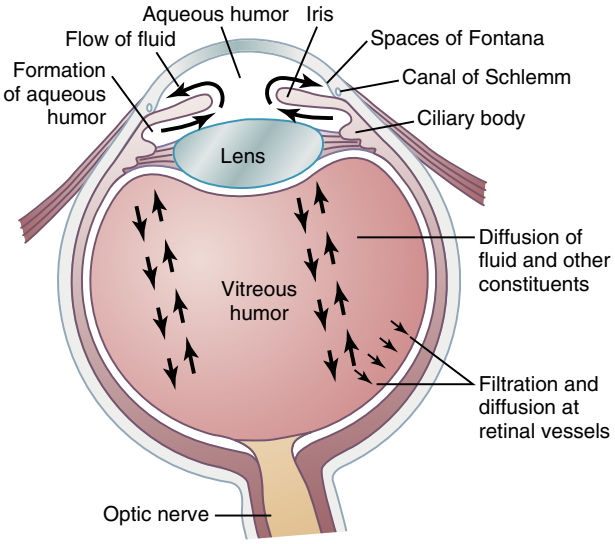
TMP14 pp. 669–670

69. B) The termination of taste fibers for all taste sensations is in the nucleus of the solitary tract in the medulla.

TMP14 p. 678

70. B) The medial longitudinal fasciculus is a pathway for nerve fibers entering and leaving the oculomotor, trochlear, and abducens nuclei of the brain stem, thus allowing communication to coordinate the contraction of the various extraocular eye muscles.

TMP14 p. 658



71. B) Intraocular fluid flows from the anterior chamber of the eye, between the cornea and the iris through a meshwork of trabeculae into the canal of Schlemm, which empties into extraocular aqueous veins (see the figure above).

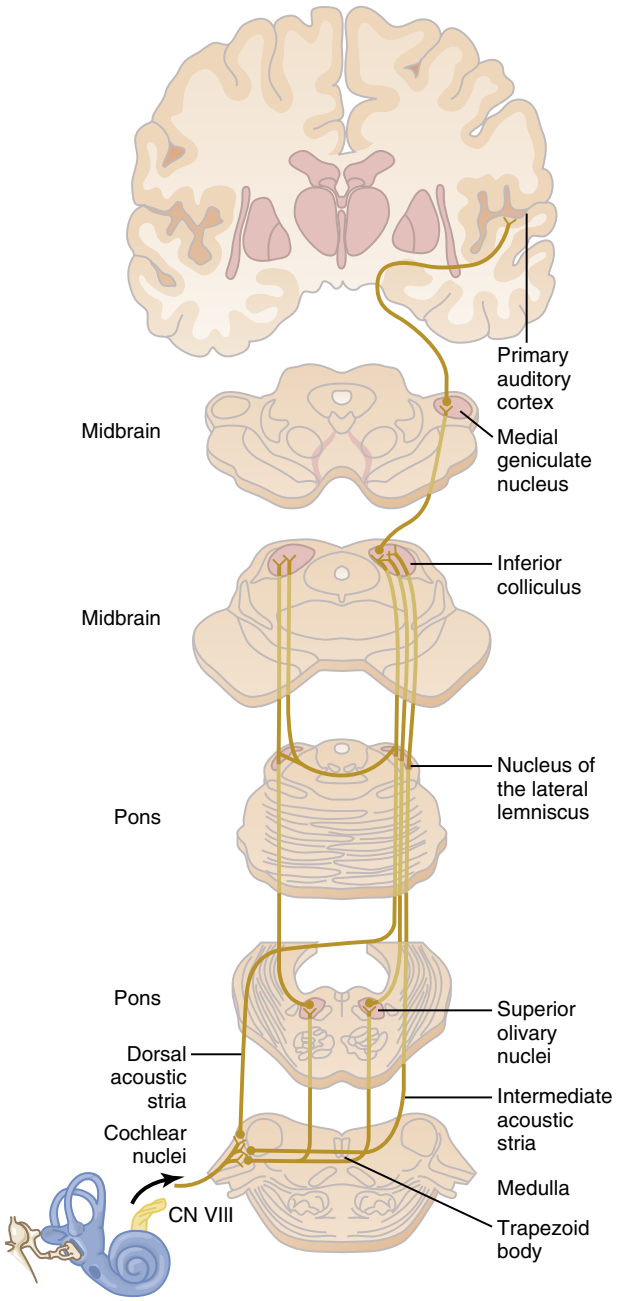
TMP14 pp. 635–636

72. B) Only ganglion cells have action potentials. Photoreceptors, bipolar cells, and horizontal cells all appear to operate through graded potentials.

TMP14 p. 648

73. D) The superior olivary nuclei (see figure on the right) receive auditory information from both ears and begin the process of detecting the direction from which a sound comes. The lateral part of the superior olivary nucleus does so by comparing the difference in intensities of sound reaching the two ears, whereas the medial part of the superior olivary nucleus detects time lag between signals entering both ears.

TMP14 pp. 669–670



Auditory nervous pathways. N., Nerve.

74. D) The outputs of horizontal cells are always inhibitory; their lateral connections with synaptic bodies of photoreceptors (rods and cones) and dendrites of bipolar cells provide lateral inhibition to ensure transmission of visual patterns with proper visual contrast. Lateral inhibition is critical in all sensory systems to sharpen the sensory signals. There are many types of amacrine cells with at least six types of functions; they transmit signals both horizontally and vertically, forming connections with many different cell types. Bipolar cells transmit signals vertically from photoreceptors and horizontal cells to ganglion cells and amacrine cells

in the inner plexiform layer of the retina. Ganglion cells transmit output signals from the retina through the optic nerve to the brain.

TMP14 p. 648

75. B) Foliate papillae are located in the folds along the lateral surfaces of the tongue, fungiform papillae are located in the anterior part of the tongue, and circumvallate papillae are located in the posterior part of the tongue. The papilla of Vater empties pancreatic secretions and bile into the duodenum.

TMP14 pp. 669–670

UNIT XI

The Nervous System: C. Motor and Integrative Neurophysiology

1. Which of the following best describes anterior motor neurons and their innervation targets?
   A) Alpha-extrafusal fibers; gamma-intrafusal fibers
   B) Alpha-intrafusal fibers; gamma-extrafusal fibers
   C) Alpha-extrafusal fibers; gamma-extrafusal fibers
   D) Alpha-intrafusal fibers; gamma-intrafusal fibers

2. Which of the following best describes the transmitter released from Renshaw cells and the primary action of Renshaw cells under normal physiological conditions?
   A) Glycine—inhibitory
   B) Glycine—excitatory
   C) Acetylcholine—inhibitory
   D) Acetylcholine—excitatory
   E) Strychnine—excitatory
   F) Strychnine—inhibitory

3. Which of the following best describes the reflex arc and muscle response of the Golgi tendon organ?
   A) Monosynaptic reflex arc; relaxation of muscle
   B) Monosynaptic reflex arc; contraction of muscle
   C) Disynaptic reflex arc; relaxation of muscle
   D) Disynaptic reflex arc; contraction of muscle
   E) Polysynaptic reflex arc; relaxation of muscle
   F) Polysynaptic reflex arc; contraction of muscle

4. Which of the following best describes the sensory capabilities of the muscle spindle under normal physiological conditions?
   A) Length only
   B) Tension only
   C) Rate of change in length only
   D) Length and tension only
   E) Length and rate of change in length
   F) Tension and rate of change in length

5. Which of the following types of muscle fibers is responsible for the dynamic response in a muscle spindle receptor?
   A) Extrafusal muscle fiber
   B) Static nuclear bag fiber
   C) Nuclear chain fiber
   D) Nuclear bag fiber
   E) Static nuclear chain fiber

6. Which of the following best describes the type of reflex arc and sensory receptor for the flexor withdrawal reflex?
   A) Reflex arc: disynaptic sensory receptor: Pacinian corpuscle
   B) Reflex arc: disynaptic sensory receptor: nociceptor
   C) Reflex arc: monosynaptic sensory receptor: Pacinian corpuscle
   D) Reflex arc: monosynaptic sensory receptor: Golgi tendon organ
   E) Reflex arc: polysynaptic sensory receptor: nociceptor
   F) Reflex arc: polysynaptic sensory receptor: muscle spindle

7. Which of the following has the greatest area of representation in the primary motor cortex?
   A) Hip
   B) Knee
   C) Thumb
   D) Toes
   E) Trunk

8. Afferent signals from the periphery of the body travel to the cerebellum in which of the following nerve tracts?
   A) Ventral spinocerebellar tract
   B) Fastigioreticular tract
   C) Vestibulocerebellar tract
   D) Reticulocerebellar tract

9. Neurologic disease associated with the cerebellum produces which of the following types of symptoms?
   A) Resting tremor only
   B) Athetosis and resting tremor
   C) Rigidity and resting tremor
   D) Ataxia and dysmetria

10. Which of the following best describes the Purkinje cell input to the deep nuclear cells of the cerebellum?
    A) Always stimulatory
    B) Always inhibitory
    C) Stimulatory only if it originates from inferior olivary complex
    D) Stimulatory only if it originates from mossy fibers

11. Neurologic disease associated with the globus pallidus produces which of the following symptoms?
    A) Rigidity
    B) Chorea
    C) Hemiballismus
    D) Athetosis

12. All the following structures are part of the basal ganglia EXCEPT one. Which one is this EXCEPTION?
    A) Caudate nucleus
    B) Red nucleus
    C) Substantia nigra
    D) Putamen

13. Hemiballismus is associated with damage or dysfunction of which of the following structures?
    A) Thalamus
    B) Caudate nucleus
    C) Subthalamus
    D) Red nucleus

14. Retrograde amnesia is usually the result of damage to, or dysfunction of which of the following structures?
    A) Hippocampus
    B) Subthalamus
    C) Hypothalamus
    D) Thalamus

15. Damage to Broca's area on the dominant side of the brain results in which of the following neurologic symptoms?
    A) Anterograde amnesia
    B) Intension tremor
    C) Ataxia
    D) Motor aphasia

16. Which of the following structures provides the connection between Wernicke's area and Broca's area in the cerebral cortex?
    A) Medial lemniscus
    B) Medial forebrain bundle
    C) Corpus callosum
    D) Arcuate fasciculus

17. Weak stimulation of which area in the brain gives an animal a sense of reward?
    A) Amygdala
    B) Dorsal raphe nucleus
    C) Periaqueductal gray region
    D) Tissue surrounding medial forebrain bundle

18. The neurons located in the substantia nigra release which of the following neurotransmitters?
    A) Norepinephrine
    B) Serotonin
    C) Dopamine
    D) Acetylcholine

19. Which of the following statements best describes the changes in sleep patterns that occur during the aging process from childhood to old age?
    A) Amount of time spent in stage 4 sleep increases
    B) Amount of time spent in REM sleep increases
    C) Amount of time one could record delta waves in an EEG during sleep decreases
    D) Incidence of nocturnal awakenings decrease

20. An excess of which of the following neurotransmitters is most likely to cause mania?
    A) Dopamine
    B) Serotonin
    C) GABA
    D) Acetylcholine

21. Which of the following structures is innervated almost entirely by the sympathetic division but not the parasympathetic division of the autonomic nervous system?
    A) Blood vessels
    B) Gastrointestinal tract
    C) Heart
    D) Reproductive organs
    E) Urinary bladder

22. Which of the following type of autonomic stimulation is correctly paired with its function?
    A) Sympathetic stimulation–ejaculation
    B) Sympathetic stimulation–blood vessel dilation
    C) Sympathetic stimulation–pupillary constriction
    D) Parasympathetic stimulation–increased heart rate
    E) Parasympathetic stimulation–constriction of coronary artery
    F) Parasympathetic stimulation–dilation of bronchi

23. Selective destruction of the right superior cervical ganglion would most likely result in which of the following?
    A) Dilated pupil in right eye
    B) Dilated pupil in left eye
    C) Constricted pupil in left eye
    D) Constricted pupil in right eye

24. Which of the following best describes the neurotransmitter in both sympathetic and parasympathetic autonomic ganglia?
    A) Acetylcholine
    B) Norepinephrine
    C) Epinephrine
    D) Dopamine

25. Physiological studies are conducted in mice to find new ways to facilitate entry of methotrexate into brain tissues for tumor control. Mice are infused with hypertonic mannitol via the internal carotid artery at various rates. The optimal rate of mannitol infusion that produced temporary blood-brain barrier disruption without neurological sequelae was 0.25 ml.s-1. kg-1 for 20 s. The duration of blood-brain barrier disruption was maximal for approximately 5 min and then rapidly reversed. Methotrexate levels in brain tissues were four to five times higher in the mannitol-infused brains compared with brain tissues of saline control mice. Which of the following is the most likely effect of the optimal mannitol infusion regimen on endothelial cell volume and brain capillary permeability in this experiment?
    A) Decreased endothelial cell volume; decreased capillary permeability
    B) Decreased endothelial cell volume; increased capillary permeability
    C) Decreased endothelial cell volume; no change in capillary permeability
    D) Increased endothelial cell volume; decreased capillary permeability
    E) Increased endothelial cell volume; increased capillary permeability
    F) Increased endothelial cell volume; no change in capillary permeability

26. A 46-year-old man is admitted to the emergency department after falling off his porch and hitting his head on a cement step. His Glasgow Coma Scale score is 10. The patient is intubated, and a CT scan shows a large subdural hematoma. He has bilateral papilledema. Which of the following best describes the most likely intracranial pressure (ICP), brain capillary pressure (Pc), and intracranial venous volume (ICVV) in this patient during a positive feedback cycle involving all three variables?
    A) Decreased ICP, decreased Pc, decreased ICVV
    B) Decreased ICP, decreased Pc, increased ICVV
    C) Decreased ICP, increased Pc, decreased ICVV
    D) Decreased ICP, increased Pc, increased ICVV
    E) Increased ICP, decreased Pc, decreased ICVV
    F). Increased ICP, decreased Pc, increased ICVV
    G) Increased ICP, increased Pc, decreased ICVV
    H) Increased ICP, increased Pc, increased ICVV

27. Which of the following best describes brain blood flow at mean arterial pressure levels between 140 mm Hg and 180 mm Hg in a normotensive person?
    A) Varies with level of arterial pressure
    B) Constant and not dependent on pressure
    C) Independent of arterial pressure
    D) Inversely proportional to arterial pressure

28. Which of the following best describes the total volume of cerebrospinal fluid in an adult human nervous system (in milliliters)?
    A) 150
    B) 500
    C) 50
    D) 300

29. An increase in which of the following has a direct action to increase cerebral blood flow?
    A) Arterial carbon dioxide levels
    B) Arterial hydrogen ion concentration
    C) Brain interstitial carbon dioxide levels
    D) Brain interstitial hydrogen ion concentration

30. Most strokes in the United States can be attributed to which of the following?
    A) Hemorrhage due to arterial rupture
    B) Hemorrhage due to venular trauma
    C) Ischemia due to systemic hypotension
    D) Ischemia due to thromboembolism

31. Which of the following best describes the rate of formation of cerebrospinal fluid in a normal adult human being (in milliliters per day)?
    A) 50
    B) 100
    C) 300
    D) 500
    E) 1000

32. A 98-year-old woman has a stroke that severely impairs her speech. Which area of her brain is most likely damaged?
    A) Primary motor cortex
    B) Premotor area
    C) Broca's area
    D) Cerebellum

33. A 23-year-old woman sustains serious head and neck trauma in a motorcycle accident. Physical examination shows a positive Babinski sign. What part of the brain has most likely been damaged in this woman?
    A) Anterior motor neurons
    B) Cerebellum
    C) Corticospinal tract
    D) Premotor cortex

34. Which statement best describes a functional role for the lateral hemispheres of the cerebellum?
    A) Control and coordinate movements of axial muscles, as well as shoulder and hip
    B) Control movements that involve distal limb musculature
    C) Function with cerebral cortex to plan movements
    D) Stimulate motor neurons through their connections to spinal cord

35. Which of the following would produce an increase in cerebral blood flow?
    A) Increase in carbon dioxide tension
    B) Increase in oxygen tension
    C) Decrease in the activity of cerebral cortex neurons
    D) Decrease in carbon dioxide tension
    E) Decrease in arterial blood pressure from 120 mm Hg to 90 mm Hg

36. As the axons of motor neurons leave the spinal cord and course peripherally to skeletal muscle, they must pass through which structure?
    A) Posterior column
    B) Posterior root
    C) Ventral white commissure
    D) Posterior horn
    E) Anterior root

37. Which spinal cord level contains the entire population of preganglionic sympathetic neurons?
    A) C5–T1
    B) C3–C5
    C) S2–S4
    D) T1–L2
    E) T6–L1

Questions 38 and 39
A left-side subdural hematoma develops in a 23-year-old man after an automobile accident. Physical examination shows papilledema 3 days after the accident. Use this information to answer the next two questions.

38. Which of the following is most likely to be increased in this patient?
    A) Cerebral blood flow
    B) Cerebrospinal fluid production
    C) Cerebrospinal fluid volume
    D) Intracranial pressure
    E) Intracranial venous volume

39. Collapse of which of the following structures is most likely to lead to a decrease in brain oxygenation in this patient?
    A) Arteries
    B) Capillaries
    C) Lateral ventricles
    D) Subarachnoid space
    E) Veins

40. Preganglionic sympathetic axons pass through which of the following structures?
    A) Dorsal root
    B) Dorsal primary rami
    C) White rami
    D) Gray rami
    E) Ventral primary rami

41. The gigantocellular neurons of the reticular formation release which neurotransmitter?
    A) Norepinephrine
    B) Serotonin
    C) Dopamine
    D) Acetylcholine
    E) Glutamate

42. Astrocytes participating in the metabolic control of cerebral blood flow have the following three events associated with the process: (1) prostaglandin release, (2) a calcium wave, and (3) glutamate spillover. Which sequence best describes the correct temporal order of these three events?
    A) 2, 1, 3
    B) 1, 2, 3
    C) 3, 1, 2
    D) 1, 3, 2
    E) 3, 2, 1
    F) 2, 3, 1

43. A 15-year-old girl is taken to see a physician because of a sore throat. An antibiotic is prescribed that can enter most tissues of the body but cannot penetrate the blood-brain barrier. The blood-brain barrier can be attributed primarily to which cell type?
    A) Astrocyte
    B) Endothelial cell
    C) Glial cell
    D) Macrophage
    E) Pericyte
    F) Smooth muscle cell

44. In which type of neuron does the axon form synaptic junctions with skeletal muscle cells (intrafusal fibers) within the muscle spindles?
    A) Alpha motor neuron
    B) Pyramidal neuron
    C) Gamma motor neuron
    D) Granule cell
    E) Purkinje cell

45. Which projection system is contained in the superior cerebellar peduncle?
    A) Pontocerebellar
    B) Cerebellothalamic
    C) Posterior spinocerebellar
    D) Corticospinal

Questions 46 and 47
A 54-year-old man steps on a broken bottle with his bare right foot. His right leg immediately lifts while his left leg extends before he can consciously react to the pain. Use this information to answer the next two questions.

46. This action is attributable to which reflex?
    A) Walking reflex
    B) Stretch reflex
    C) Patellar tendon reflex
    D) Golgi tendon reflex
    E) Flexor withdrawal reflex

47. Which of the following best describes the type of reflex arc and sensory receptor for this reflex?

	Reflex Arc	Sensory Receptor
A)	Disynaptic	Pacinian corpuscle
B)	Disynaptic	Nociceptor
C)	Monosynaptic	Pacinian corpuscle
D)	Monosynaptic	Golgi tendon organ
E)	Polysynaptic	Nociceptor
F)	Polysynaptic	Muscle spindle

48. Which brain structure serves as the major controller of the limbic system?
    A) Hypothalamus
    B) Hippocampus
    C) Amygdala
    D) Mammillary body
    E) Fornix

49. A large portion of the cerebral cortex does not fit into the conventional definition of motor or sensory cortex. Which term refers to the type of cortex that receives input primarily from several other regions of the cerebral cortex?
    A) Cortex that is agranular
    B) Secondary somatosensory cortex
    C) Association cortex
    D) Supplementary motor cortex
    E) Secondary visual cortex

50. The two hemispheres of the brain are connected by which nerve fibers or pathways?
    A) Lateral lemniscus
    B) Corticofugal fibers
    C) Corpus callosum
    D) Arcuate fasciculus
    E) Medial longitudinal fasciculus

51. The fibers of the corticospinal tract pass through which structure?
    A) Medial lemniscus
    B) Medullary pyramid
    C) Posterior funiculus
    D) Medial longitudinal fasciculus
    E) Anterior roots

52. The condition of prosopagnosia usually results from dysfunction or damage to which area of the cerebral cortex?
    A) Prefrontal area
    B) Junction of the parietal and temporal lobe on the nondominant side of the brain
    C) Frontal eye fields
    D) Underside of the medial occipital and temporal lobes
    E) Limbic association areas of frontal and anterior temporal lobes

53. Lesions of which area of the brain would have the most devastating effect on verbal and symbolic intelligence?
    A) Hippocampus
    B) Amygdala
    C) Wernicke's area on the nondominant side of brain
    D) Broca's area
    E) Wernicke's area on the dominant side of brain

54. A stroke involving the middle cerebral artery on the left side is likely to cause which symptom?
    A) Paralysis of the left side of the face and left upper extremity
    B) Paralysis of left lower extremity
    C) Complete loss of vision in both eyes
    D) Loss of ability to comprehend speech
    E) Loss of vision in the left half of both eyes

55. The creation of memory can be interrupted by which activity?
    A) Phosphorylation of a potassium channel to block activity
    B) Activation of adenylate cyclase
    C) Unnatural loss of consciousness
    D) Increase in protein synthesis
    E) Activation of cyclic guanosine monophosphate (cGMP) phosphodiesterase

56. Which of the following structures is innervated almost entirely by the sympathetic division but not the parasympathetic division of the autonomic nervous system?
    A) Blood vessels
    B) Gastrointestinal tract
    C) Heart
    D) Lungs
    E) Urinary bladder

57. Which projection system is contained in the inferior cerebellar peduncle?
    A) Pontocerebellar
    B) Cerebellothalamic
    C) Posterior spinocerebellar
    D) Corticospinal
    E) Dorsospinocerebellar

58. Signals from motor areas of the cortex reach the contralateral cerebellum after first passing through which structure?
    A) Thalamus
    B) Caudate nucleus
    C) Red nucleus
    D) Basilar pontine nuclei
    E) Dorsal column nuclei

59. Cerebrospinal fluid (CSF) provides a cushioning effect both inside and outside the brain. Which space that lies outside the brain or spinal cord contains CSF?
    A) Lateral ventricle
    B) Third ventricle
    C) Cisterna magna
    D) Epidural space
    E) Aqueduct of Sylvius

Questions 60 and 61
A 34-year-old woman visits the physician because of uncontrolled movements of her arms, legs, head, face, and upper body. These symptoms have increased progressively during the past 12 months. She is also depressed and irritable, and she repeats the same question six times during the 30-minute office visit. Gene analyses show expansion of a CAG triplet repeat on chromosome 4. Use this information to answer the next two questions.

60. Which diagnosis is most likely?
    A) Alzheimer disease
    B) Bipolar disorder
    C) Brain tumor
    D) Huntington's disease
    E) Parkinson's disease

61. Which of the following is most likely to be decreased in this woman?
    A) Acetylcholine neurons in the magnocellular forebrain nucleus
    B) Dopamine neurons in the substantia nigra
    C) γ-Aminobutyric acid (GABA) neurons in the caudate nucleus and putamen
    D) Serotonin neurons in the raphe nuclei

62. Which projection system is contained in the middle cerebellar peduncle?
    A) Pontocerebellar
    B) Cerebellothalamic
    C) Posterior spinocerebellar
    D) Corticospinal
    E) Ventrospinocerebellar

63. The peripheral sensory input that activates the ascending excitatory elements of the reticular formation comes mainly from which of the following?
    A) Pain signals
    B) Proprioceptive sensory information
    C) Corticospinal system
    D) Medial lemniscus
    E) Input from Pacinian corpuscles

64. Cells of the adrenal medulla receive synaptic input from which type of neuron?
    A) Preganglionic sympathetic
    B) Postganglionic sympathetic
    C) Preganglionic parasympathetic
    D) Postsynaptic parasympathetic
    E) Presynaptic parasympathetic

65. Which activity will increase the sensitivity of the stretch reflex?
    A) Cutting the dorsal root fibers associated with the muscle in which the stretch reflex is being examined
    B) Increasing the activity of the medullary reticular nuclei
    C) Bending the head forward
    D) Enhanced activity in the fusimotor (gamma motor neuron) system
    E) Stimulating the lateral hemispheres of the cerebellum

66. A complex spike pattern in the Purkinje cells of the cerebellum can be initiated by stimulation of which brain area?
    A) Inferior olivary complex
    B) Brain stem reticular nuclei
    C) Neurons in red nucleus
    D) Superior olivary complex
    E) Dorsal vestibular nucleus

67. Which structure serves as an "alternative pathway" for signals from the motor cortex to the spinal cord?
    A) Red nucleus
    B) Basilar pontine nuclei
    C) Caudate nucleus
    D) Thalamus
    E) Dorsal column nuclei

68. The phenomenon of decerebrate rigidity can be explained, at least in part, by which of the following?
    A) Stimulation of type 1b sensory neurons
    B) Loss of cerebellar inputs to the red nucleus
    C) Overactivity of the medullary reticular nuclei involved in motor control
    D) Unopposed activity of the pontine reticular nuclei
    E) Degeneration of the nigrostriatal pathway

69. The primary motor cortex is organized into vertical columns composed of cells linked together throughout the six layers of the cortex. The cells that contribute axons to the corticospinal tract are concentrated in which cortical layer?
    A) Layer I
    B) Layer II
    C) Layer III
    D) Layer IV
    E) Layer V

Questions 70 and 71
A 77-year-old man is taken to the physician because of a tremor in his hands, trouble sleeping, constipation, and dizziness. Physical examination shows a resting tremor, rigidity, and bradykinesia. The man is alert, engaging, and optimistic. He speaks in a low, soft voice. Use this information to answer the next two questions.

70. Which diagnosis is most likely?
    A) Alzheimer disease
    B) Bipolar disorder
    C) Brain tumor
    D) Huntington's disease
    E) Parkinson's disease

71. Which of the following is most likely to be decreased in this man?
    A) Serotonin neurons in the raphe nuclei
    B) GABA neurons in the caudate nucleus and putamen
    C) Dopamine neurons in the substantia nigra
    D) Acetylcholine neurons in the magnocellular forebrain nucleus

72. Motor cortex neurons receive feedback from muscles activated by the corticospinal system. This feedback arises from which of the following structures?
    A) Red nucleus
    B) Spinocerebellar tracts
    C) Skin surface of fingers used to grasp an object
    D) Muscle spindles in muscles antagonistic to those used to make the movement
    E) Vestibular nuclei

73. The sweat glands and piloerector muscles of hairy skin are innervated by which type of fibers?
    A) Cholinergic postganglionic parasympathetic
    B) Cholinergic postganglionic sympathetic
    C) Adrenergic preganglionic parasympathetic
    D) Adrenergic postganglionic sympathetic
    E) Adrenergic preganglionic sympathetic

74. In a neurophysiology experiment conducted with monkeys, the amygdalae are surgically ablated bilaterally. Which of the following is most likely to be increased 6 months after ablation of the amygdala?
    A) Despondence
    B) Memory
    C) Paranoia
    D) Sex drive
    E) Tremors

75. In controlling the fine muscles of the hands and fingers, corticospinal axons can synapse primarily with which of the following?
    A) Posterior horn neurons
    B) Spinal cord interneurons
    C) Spinal cord motor neurons
    D) Purkinje cells
    E) Renshaw cells

76. Which of the following foramina allows cerebrospinal fluid to pass directly from the ventricular system into the subarachnoid space?
    A) Foramen of Magendie
    B) Aqueduct of Sylvius
    C) Third ventricle
    D) Lateral ventricle
    E) Arachnoid villi

77. Which epileptic condition involves a postictal depression period lasting from several minutes to several hours?
    A) Generalized tonic-clonic seizure
    B) Absence seizure
    C) Jacksonian seizure
    D) Phase-out clonic seizure
    E) Temporal lobe seizure

78. Which cells receive direct synaptic input from Golgi tendon organs?
    A) Type Ia inhibitory interneurons
    B) Dynamic gamma motor neurons
    C) Alpha motor neurons
    D) Type Ib inhibitory interneurons
    E) Type II excitatory interneurons

79. Which neurotransmitter is used by the axons of locus coeruleus neurons that distribute throughout much of the brain?
    A) Norepinephrine
    B) Dopamine
    C) Serotonin
    D) Acetylcholine

Questions 80 and 81
A 41-year-old woman visits the physician because of difficulties performing simple tasks that involve repetitive movements. The physician asks the patient to turn one hand upward and downward at a rapid pace. The woman quickly loses all perception of the instantaneous position of the hand, which results in a series of stalled attempts and jumbled movements. Use this information to answer the next two questions.

80. Which term best describes this patient's movements?
    A) Agraphesthesia
    B) Astereognosis
    C) Dysarthria
    D) Dysdiadochokinesia
    E) Hemineglect

81. Which area of her brain is most likely to have a lesion?
    A) Cerebellum
    B) Limbic system
    C) Medulla oblongata
    D) Premotor cortex
    E) Primary motor cortex

82. The excitatory or inhibitory effect of a postganglionic sympathetic fiber is determined by which feature or structure?
    A) Function of the postsynaptic receptor to which it binds
    B) Specific organ innervated
    C) Ganglion where the postganglionic fiber originates
    D) Ganglion containing the preganglionic fiber
    E) Emotional state of the individual

83. A vascular lesion that causes degeneration of corticospinal axons in the basilar pons will most likely lead to which condition?
    A) Paralysis primarily involving muscles around the contralateral shoulder and hip joints
    B) Paralysis of the muscles of mastication
    C) Loss of voluntary control of discrete movements of the contralateral hand and fingers
    D) Inability to speak clearly
    E) Inability to convert short-term memory to long-term memory

84. Fine-motor movement of the middle finger can be elicited by stimulation of which brain area?
    A) Primary motor cortex
    B) Lateral cerebellar hemisphere
    C) Premotor cortex
    D) Supplemental motor area
    E) Red nucleus

85. Which type of cholinergic receptor is found at synapses between preganglionic and postganglionic neurons of the sympathetic system?
    A) Muscarinic
    B) Nicotinic
    C) Alpha
    D) Beta-1
    E) Beta-2

86. A 32-year-old basketball player mentally rehearses free throw shots while lying in bed. Which option best describes the area of the brain that is involved in generating a motor image of this action in the absence of actual movement?
    A) Basal ganglia
    B) Cerebellum
    C) Limbic system
    D) Premotor cortex
    E) Primary motor cortex

87. The formation of cerebrospinal fluid by the choroid plexus includes (1) osmosis of water, (2) active transport of sodium, and (3) passive diffusion of chloride. Which sequence best describes the correct temporal order of these processes?
    A) 2, 3, 1
    B) 3, 2, 1
    C) 1, 3, 2
    D) 3, 1, 2
    E) 1, 2, 3
    F) 2, 1, 3

Questions 88 and 89
A 12-year-old boy is taken to the physician because of difficulty walking. Physical examination shows loss of tendon reflexes in the knees and ankles and reduced two-point discrimination in the hands and feet. Repeat visits to the physician show a progressive worsening of these symptoms during the next 2 years. However, the boy is always alert and seems to have normal reasoning abilities. His aunt had similar problems at age 12 years and later developed scoliosis followed by loss of hearing and vision. Use this information to answer the next two questions.

88. What is the most likely diagnosis?
    A) Friedreich ataxia
    B) Huntington disease
    C) Multiple sclerosis
    D) Parkinson's disease
    E) Poliomyelitis

89. What is the most likely cause of these symptoms in this boy?
    A) A lesion in the premotor cortex
    B) A lesion in the primary motor cortex
    C) Malformation of the cerebellum
    D) Malformation of the frontal lobe
    E) Nerve degeneration
    F) Nerve proliferation

90. Which neurotransmitter is used by the axons of substantia nigra neurons that project to the caudate and putamen?
    A) Norepinephrine
    B) Dopamine
    C) Serotonin
    D) Acetylcholine
    E) GABA

91. Damage limited to the primary motor cortex (Brodmann area 4) is thought to cause hypotonia in the affected muscles. However, most cortical lesions, particularly those caused by vascular infarcts, generally involve the primary motor cortex in addition to surrounding areas of cortex or cortical efferent axons. The latter type of cortical lesion will cause which of the following?
    A) Spastic muscle paralysis
    B) Flaccid muscle paralysis
    C) No paralysis; only jerky, fast movements
    D) Complete blindness in the contralateral eye
    E) Loss of sensation in the contralateral foot

92. Which substance activates adrenergic alpha and beta receptors equally well?
    A) Acetylcholine
    B) Norepinephrine
    C) Epinephrine
    D) Serotonin
    E) Dopamine

93. The posterior and lateral hypothalamus, in combination with the preoptic area, are involved in the control of which of the following functions?
    A) Cardiovascular functions involving blood pressure and heart rate
    B) Regulation of thirst and water intake
    C) Stimulation of uterine contractility and milk ejection from the breast
    D) Signaling that food intake is sufficient (satiety)
    E) Secretion of hormones from the anterior lobe of the pituitary gland

94. In the patellar tendon reflex, which of the following items synapses directly on alpha motor neurons that innervate the muscle being stretched?
    A) Ia sensory fiber
    B) Ib sensory fiber
    C) Excitatory interneurons
    D) Gamma motor neurons
    E) Inhibitory interneurons

95. Occlusion of which structure would lead to communicating hydrocephalus?
    A) Aqueduct of Sylvius
    B) Lateral ventricle
    C) Foramen of Luschka
    D) Foramen of Magendie
    E) Arachnoid villi

96. Evaluation of a patient reveals the following deficits: (1) decreased aggressiveness, and ambition and inappropriate social responses, (2) inability to process sequential thoughts in order to solve a problem, and (3) inability to process multiple bits of information that could then be recalled instantaneously to complete a thought or solve a problem. Damage to which brain region could be responsible for such deficits?
    A) Premotor cortex
    B) Parieto-occipital cortex in the nondominant hemisphere
    C) Broca's area
    D) Limbic association cortex
    E) Prefrontal association cortex

97. A 23-year-old woman is a right-handed musician of considerable talent. Which brain structure is most likely to have been physically larger in the dominant hemisphere compared with the nondominant hemisphere at birth?
    A) Anterior temporal lobe
    B) Posterior temporal lobe
    C) Premotor cortex
    D) Primary motor cortex
    E) Primary somatosensory area
    F) Sensory association area

98. The neurons located in the locus coeruleus release which neurotransmitter at their synaptic terminals?
    A) Norepinephrine
    B) Dopamine
    C) GABA
    D) Acetylcholine
    E) Serotonin

99. Which portion of the cerebellum functions in the planning of sequential movement?
    A) Vermis and fastigial nucleus
    B) Intermediate zone and fastigial nucleus
    C) Lateral hemisphere and interposed nucleus
    D) Cerebrocerebellum and dentate nucleus
    E) Spinocerebellum and interposed nucleus

100. Which reflex is correctly paired with the sensory structure that mediates the reflex?
    A) Autogenic inhibition—muscle spindle
    B) Reciprocal inhibition—Golgi tendon organ
    C) Reciprocal inhibition—Pacinian corpuscle
    D) Stretch reflex—muscle spindle
    E) Golgi tendon reflex—Meissner corpuscle

101. Damage to which brain area leads to the inability to comprehend the written or the spoken word?
    A) Insular cortex on dominant side of brain
    B) Anterior occipital lobe
    C) Junction of parietal, temporal, and occipital lobes
    D) Medial portion of precentral gyrus
    E) Most anterior portion of temporal lobe

102. A computed tomography scan of a newborn boy shows agenesis of the corpus callosum. Which of the following is most likely to occur in this child during the next 5 years as he matures?
    A) Inability to form new memories
    B) Inability to understand spoken words
    C) Inability to verbally express words
    D) Reduction in communication between the two hemispheres
    E) Tameness and inability to recognize expressions of fear

103. A 32-year-old man has a stroke. One week later, he experiences sudden and uncontrolled flailing, ballistic movements of his limbs. Which part of the man's brain is most likely to have been damaged by the stroke?
    A) Globus pallidus
    B) Lateral hypothalamus
    C) Red nucleus
    D) Subthalamic nucleus
    E) Ventrobasal complex of thalamus

104. In an otherwise normal person, dysfunction of which brain area will lead to behavior that is not appropriate for the given social occasion?
    A) Ventromedial nuclei of hypothalamus
    B) Amygdala
    C) Corpus callosum
    D) Fornix
    E) Uncus

105. Schizophrenia is thought to be caused in part by excessive production and release of which of the following neurotransmitters?
    A) Norepinephrine
    B) Serotonin
    C) Acetylcholine
    D) Substance P
    E) Dopamine

106. Stimulation of which subcortical area can lead to contraction of a single muscle or small groups of muscles?
    A) Dentate nucleus of the cerebellum
    B) Ventrobasal complex of the thalamus
    C) Red nucleus
    D) Subthalamic nucleus
    E) Nucleus accumbens

107. Bilateral lesions involving the ventromedial hypothalamus is most likely to cause which of the following deficits?
    A) Decreased eating and drinking
    B) Loss of sexual drive
    C) Excessive eating, rage and aggression, hyperactivity
    D) Uterine contractility, mammary gland enlargement
    E) Obsessive compulsive disorder

108. Which of the following cerebellar structures has a topographical representation of the body?
    A) Dentate nucleus
    B) Lateral hemispheres
    C) Flocculonodular lobe
    D) Vermis and intermediate hemisphere
    E) Cerebellar peduncle

109. Which structure is an important pathway for communication between the limbic system and the brain stem?
    A) Mammillothalamic tract
    B) Fornix
    C) Anterior commissure
    D) Indusium griseum
    E) Medial forebrain bundle

110. A 77-year-old man is taken to the physician because of worsening forgetfulness. He recently got lost during a walk in the neighborhood where he has lived in for 35 years. Which substance is most likely to be increased in the brain of this man?
    A) Alpha-1 antitrypsin
    B) Alpha-amylase
    C) Beta-amyloid peptide
    D) Beta-endorphin
    E) Gamma-glutamyl hydrolase
    F) Gamma-glutamyl transferase

111. Which of the following best describes the cerebellar deficit in which there is a failure to perform rapid alternating movements indicating a failure of "progression" from one part of the movement to the next?
    A) Past-pointing
    B) Intention tremor
    C) Dysarthria
    D) Cerebellar nystagmus
    E) Dysdiadochokinesia

112. Which structure in the vestibular apparatus is responsible for the detection of angular acceleration?
    A) Statoconia
    B) Macula
    C) Semicircular canals
    D) Saccule
    E) Ampullae

Questions 113 and 114
A 55-year-old man is taken to the psychiatrist because of delusional behavior in the workplace. The man accused a coworker of scheming with his neighbor to transplant poison ivy in his backyard. This plot was revealed to the man by a voice in his head. Other examples of delusional thinking and voices in the man's head are abundant. Use this information to answer the next two questions.

113. What is the most likely diagnosis?
    A) Bipolar disorder
    B) Dissociative identity disorder
    C) Multiple personality disorder
    D) Schizophrenia

114. A decrease in size of which brain structure is most likely in this man?
    A) Globus pallidus
    B) Hippocampus
    C) Lateral hypothalamus
    D) Red nucleus
    E) Subthalamic nucleus

115. Which structure is maximally sensitive to linear head movement in the vertical plane?
    A) Macula of the utricle
    B) Macula of the saccule
    C) Crista ampullaris of the anterior semicircular duct
    D) Crista ampullaris of the horizontal semicircular duct

116. Retrograde amnesia is the inability to recall long-term memories. Damage to which brain region leads to retrograde amnesia?
    A) Hippocampus
    B) Dentate gyrus
    C) Amygdaloid complex
    D) Thalamus
    E) Mammillary nuclei of hypothalamus

117. Which component of the basal ganglia plays a major role in the control of cognitive (memory-guided) motor activity?
    A) Globus pallidus
    B) Substantia nigra
    C) Caudate nucleus
    D) Putamen
    E) Subthalamic nucleus

118. A 9-month-old boy is brought to the emergency department because of irritability and vomiting. Magnetic resonance imaging shows retinal hemorrhages in both eyes, a subdural hematoma, and cerebral edema. Which of the following is most likely to be increased in this infant?
    A) Brain oxygenation
    B) Cerebral venous volume
    C) Intracranial pressure
    D) Visual acuity

119. Stimulation of the punishment center can inhibit the reward center, demonstrating that fear and punishment can take precedence over pleasure and reward. Which of the following cell groups is considered the punishment center?
    A) Lateral and ventromedial hypothalamic nuclei
    B) Periventricular hypothalamus and midbrain central gray area
    C) Supraoptic nuclei of hypothalamus
    D) Anterior hypothalamic nucleus

120. Although the sympathetic nervous system is often activated in such a way that it leads to mass activation of sympathetic responses throughout the body, it can also be activated or inhibited to produce relatively discrete responses. Which option is an example of a local or discrete sympathetic action?
    A) Heating of a patch of skin causes a relatively restricted vasodilation in the heated region
    B) Food in the mouth causes salivation
    C) Emptying of the bladder may cause reflexive emptying of the bowel
    D) Dust particles in the eye cause increased tear fluid release
    E) Bright light introduced into one eye

121. An experimental drug is administered intravenously to six healthy volunteers. A unanimous finding in all six volunteers is decreased induction of sleep. A decrease in production of which substance is most likely in these volunteers after treatment with the experimental drug?
    A) Acetylcholine
    B) Dopamine
    C) Glutamate
    D) Norepinephrine
    E) Serotonin

122. A 10-year-old boy jumps off the porch and lands on the balls of his feet. The increase in muscle tension causes a sudden, complete relaxation of the affected muscles. Which sensory receptor is most likely to mediate this relaxation of muscles when tension is increased?
    A) Free nerve ending
    B) Golgi tendon organ
    C) Krause corpuscle
    D) Muscle spindle
    E) Pacinian corpuscle

123. A wide variety of neurotransmitters have been identified in the cell bodies and afferent synaptic terminals in the basal ganglia. A deficiency of which transmitter is typically associated with Parkinson's disease?
    A) Norepinephrine
    B) Dopamine
    C) Serotonin
    D) GABA
    E) Substance P

124. The condition of athetosis results when which area of the brain is dysfunctional?
    A) Globus pallidus
    B) Substantia nigra
    C) Putamen
    D) Subthalamus

ANSWERS

1. **A)** Alpha motor neurons innervate the extrafusal muscle fibers that make up the primary muscle itself. Gamma motor neurons innervate the smaller, intrafusal muscle fibers located in the muscle spindle.
   TMP14 p. 687

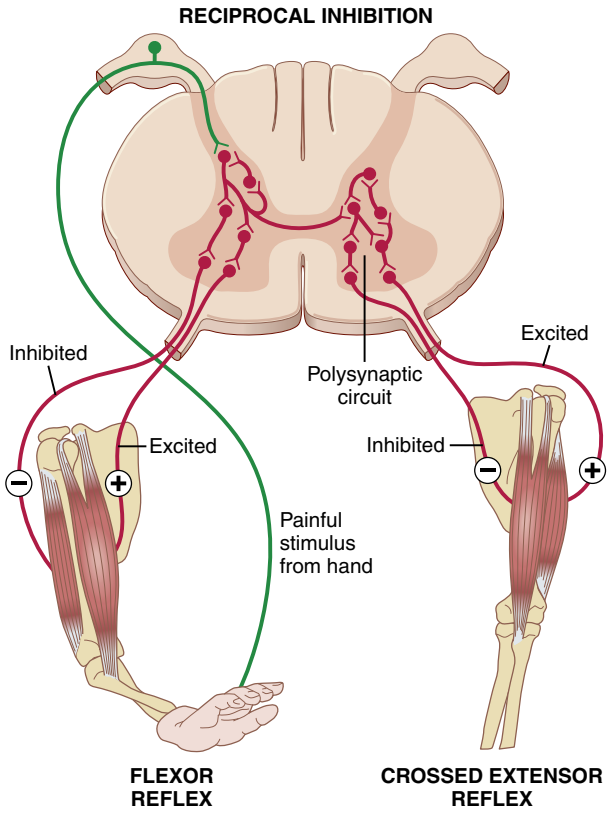
2. **A)** Renshaw cells are inhibitory cells that transmit inhibitory signals to the surrounding motor neurons by releasing glycine, an inhibitory neurotransmitter. Stimulation of each motor neuron tends to inhibit adjacent motor neurons, an effect called lateral inhibition. This effect is important for the following major reason: The motor system uses this lateral inhibition to focus, or sharpen, its signals in the same way that the sensory system uses the same principle to allow unabated transmission of the primary signal in the desired direction while suppressing the tendency for signals to spread laterally.
   TMP14 p. 686

3. **C)** Signals from the tendon organ are transmitted to the spinal cord through large, rapidly conducting type Ib nerve fibers. These fibers synapse with a single inhibitory interneuron that inhibits the anterior motor neuron through a second synapse (disynaptic reflex arc). This local circuit directly inhibits the individual muscle without affecting adjacent muscles.
   TMP14 pp. 690–691

4. **E)** When the receptor portion of the muscle spindle is stretched *slowly,* the number of impulses transmitted from both the primary and the secondary endings increases almost directly in proportion to the degree of stretching and the endings continue to transmit these impulses for several minutes. This effect, called the *static response* of the spindle receptor, estimates muscle length. When the length of the spindle receptor increases rapidly, the primary ending (but not the secondary ending) is stimulated powerfully. This stimulus of the primary ending is called the *dynamic response,* which means that the primary ending responds extremely actively to a rapid *rate of change* in length.
   TMP14 p. 688

5. **D)** There are two types of muscle spindle intrafusal fibers: (1) *nuclear bag muscle fibers* and (2) *nuclear chain fibers.* The nuclear bag fibers are responsible for the dynamic response of a muscle spindle receptor. The nuclear chain fibers are responsible for the static response of a muscle spindle receptor. Extrafusal muscle fibers make up the bulk of a skeletal muscle and are not part of the muscle spindle.
   TMP14 pp. 687–688

6. **E)** The flexor reflex is elicited most powerfully by stimulation of pain endings, for which reason it is also called a *nociceptive reflex,* or simply a *pain reflex.* A painful stimulus applied to the hand causes the flexor muscles of the upper arm to become excited, thus withdrawing the hand from the painful stimulus. The pathways for eliciting the flexor reflex do not pass directly to the anterior motor neurons but instead pass first into a pool of interneurons within the spinal cord and only secondarily to the motor neurons. The shortest possible circuit is a three- or four-neuron pathway with multiple synapses (polysynaptic) as shown in the figure below.
   TMP14 p. 692



Flexor reflex, crossed extensor reflex, and reciprocal inhibition.

7. C) The topographical representations of the different muscle areas of the body in the primary motor cortex shows that more than one half of the entire primary motor cortex is concerned with controlling the muscles of the hands and the muscles of speech; the thumb is particularly well-represented in the primary motor cortex.
   TMP14 p. 698

8. A) The cerebellum receives sensory signals directly from the peripheral parts of the body, mainly through

four tracts on each side, two of which are located dorsally in the cord and two ventrally. The two most important of these tracts are the *dorsal spinocerebellar tract* and the *ventral spinocerebellar tract* (choice A). The dorsal tract enters the cerebellum through the inferior cerebellar peduncle and terminates in the vermis and intermediate zones of the cerebellum on the same side as its origin. The ventral tract enters the cerebellum through the superior cerebellar peduncle, but it terminates in both sides of the cerebellum.
TMP14 p. 713

9. D) Two of the most important symptoms of cerebellar disease are *dysmetria* and *ataxia.* In the absence of the cerebellum, the subconscious motor control system cannot predict how far movements will go. Therefore, the movements ordinarily overshoot their intended mark; then the conscious portion of the brain overcompensates in the opposite direction for the succeeding compensatory movement. This effect is called *dysmetria,* and it results in uncoordinated movements that are called ataxia.
TMP14 p. 719

10. B) One characteristic of both Purkinje cells and deep nuclear cells is that normally both of them fire continuously; the Purkinje cell fires at about 50 to 100 action potentials per second, and the deep nuclear cells fire at much higher rates. Purkinje cells send inhibitory input to deep nuclear cells.
TMP14 p. 714

11. D) Lesions in the globus pallidus frequently lead to spontaneous and often continuous writhing movements of a hand, an arm, the neck, or the face. These movements are called athetosis.
TMP14 pp. 721–722

12. B) The basal ganglia are located on each side of the brain mainly lateral to and surrounding the thalamus; they consist of the caudate nucleus, putamen, globus pallidus, substantia nigra, and subthalamic nucleus. The red nucleus is located in the rostral midbrain and is involved in motor coordination.
TMP14 pp. 720–721

13. C) A lesion in the subthalamus often leads to sudden flailing movements of an entire limb, a condition called hemiballismus.
TMP14 p. 722

14. D) Damage in some thalamic areas may lead specifically to retrograde amnesia without causing significant anterograde amnesia. A possible explanation of this is that the thalamus may play a role in helping the person "search" the memory storehouses and thus "read out" the memories. That is, the memory process not only requires the storing of memories but also an ability to search and find the memory later.
TMP14 p. 739

15. D) Sometimes a person is capable of deciding what he or she wants to say but cannot make the vocal system emit words; instead, the person emits unintelligible noises. This effect, called *motor aphasia,* results from damage to *Broca's speech area,* which lies in the *prefrontal* and *premotor* facial region of the cerebral cortex—about 95% of the time in the left hemisphere.
TMP14 p. 734

16. D) Transmission of signals from Wernicke's area to Broca's area occurs by way of the *arcuate fasciculus.*
TMP14 p. 734

17. D) The major reward centers have been found to be located *along the course of the medial fo*rebrain bundle, especially in the lateral and ventromedial nuclei of the hypothalamus.
TMP14 p. 749

18. C) The substantia nigra lies anteriorly in the superior mesencephalon; it sends dopamine secreting neurons mainly to the caudate nucleus and putamen.
TMP14 p. 723

19. C) Delta waves include all the waves of the EEG with frequencies less than 3.5 cycles/sec, and they often have voltages two to four times greater than most other types of brain waves. They occur in very deep sleep, in infancy, and in persons with serious organic brain disease.
TMP14 p. 756

20. B) Some patients with mental depression alternate between depression and mania, which is called either bipolar disorder or manic-depressive psychosis, and fewer patients exhibit only mania without the depressive episodes. Drugs that diminish the formation or action of norepinephrine and serotonin, such as lithium compounds, can be effective in treating the manic phase of the condition.
TMP14 p. 760

21. A) Most systemic blood vessels, especially those of the abdominal viscera and skin of the limbs, are constricted by sympathetic stimulation. Parasympathetic stimulation has almost no effect on most blood vessels.
TMP14 p. 765

22. A) Sexual reflexes are initiated both by psychic stimuli from the brain and by stimuli from the sexual organs. Impulses from these sources converge on the sacral cord and, in men, result first in erection, mainly a parasympathetic function, and then ejaculation, partially a sympathetic function.
TMP14 pp. 765, 772

23. D) Stimulation of sympathetic fibers in the right superior cervical ganglion leads to contraction of the meridional fibers of the iris that dilate the pupil. Hence, destruction of the right superior cervical

ganglion would cause construction of the pupil of the eye on the same side.
TMP14 p. 768

24. A) All preganglionic neurons are cholinergic in both the sympathetic and the parasympathetic nervous systems. Acetylcholine or acetylcholine-like substances, when applied to the ganglia, will excite both sympathetic and parasympathetic postganglionic neurons.
TMP14 p. 765

25. B) The cause of the low permeability of the blood-brain barrier is the manner in which the endothelial cells of the brain tissue capillaries are joined to one another. They are joined by so-called tight junctions. That is, the membranes of the adjacent endothelial cells are tightly fused rather than having large slit pores between them, as is the case for most other capillaries of the body. Hypertonic solutions of mannitol cause brain endothelial cells to shrink (decreased endothelial cell volume), which, in turn, pulls adjacent endothelial cells apart thus increasing endothelial permeability.
TMP14 p. 783

26. G) One of the most serious complications of abnormal cerebral fluid dynamics is the development of brain edema. Because the brain is encased in a solid cranial vault, accumulation of extra edema fluid compresses the blood vessels, often causing seriously decreased blood flow and destruction of brain tissue. A common cause is a serious blow to the head, leading to brain concussion, in which the brain tissues and capillaries are traumatized and capillary fluid leaks into the traumatized tissues. When brain edema begins, the veins are compressed (reducing venous volume). The venous compression leads to increased capillary pressure, which further increases the formation of edema, and thus further increases the intracranial pressure.
TMP14 p. 783

27. A) During normal daily activities, arterial pressure can fluctuate widely, rising to high levels during states of excitement or strenuous activity and falling to low levels during sleep. However, cerebral blood flow is "autoregulated" extremely well between arterial pressure limits of 60 and 140 mm Hg. That is, mean arterial pressure can be decreased acutely to as low as 60 mm Hg or increased to as high as 140 mm Hg without significant change in cerebral blood flow. When the arterial pressure rises above about 140 mm Hg in a normotensive person, the blood flow to the brain then varies with the level of arterial pressure because this exceeds the autoregulatory limits of the brain vasculature.
TMP14 p. 779

28. A) The entire cerebral cavity enclosing the brain and spinal cord has a capacity of about 1600 to 1700 ml. About 150 ml (choice A) of this capacity is occupied by cerebrospinal fluid and the remainder by the brain and cord.
TMP14 p. 780

29. D) Carbon dioxide is believed to increase cerebral blood flow by combining first with water in the body fluids to form carbonic acid, with subsequent dissociation of this acid to form hydrogen ions. The hydrogen ions then cause vasodilation of the cerebral vessels, with the dilation being almost directly proportional to the increase in hydrogen ion concentration up to a blood flow limit of about twice normal. Hence, hydrogen ions have a direct action to increase cerebral blood flow; carbon dioxide has an indirect action to do the same.
TMP14 pp. 777–778

30. D) Most strokes are caused by arteriosclerotic plaques that occur in one or more of the feeder arteries to the brain. The plaques can activate the clotting mechanism of the blood, causing a blood clot to occur which can block blood flow in the artery (i.e., ischemia), thereby leading to acute loss of brain function in a localized area. Thromboembolism is obstruction of a blood vessel by a blood clot that has become dislodged from another site in the circulation.
TMP14 p. 780

31. D) Cerebrospinal fluid is formed at a rate of about 500 ml each day.
TMP14 p. 781

32. C) Broca's area is a region of the premotor area of one hemisphere (usually the left). Damage to Broca's area does not prevent a person from vocalizing but makes it impossible to speak whole words other than occasional simple words such as "yes" or "no." The primary motor cortex works with other areas of the brain to plan and execute movements. The cerebellum plays a critical role in motor control; it does not initiate movement but contributes to coordination, precision, and accurate timing of movements.
TMP14 pp. 729–730

33. C) A positive Babinski sign (also called the Babinski reflex) occurs normally in children up to 2 years of age. The reflex occurs after the sole of the foot has been stroked with a blunt instrument; the big toe moves upward, and the other toes fan out. A positive Babinski sign in adults can indicate damage to the corticospinal tract.
TMP14 p. 695

34. C) The lateral cerebellar hemispheres function with the cerebral cortex in the planning of complex movements.
TMP14 p. 719

35. A) The most potent stimulator of cerebral blood flow is a local increase in carbon dioxide tension, followed

in order by a decrease in oxygen tension and an increase in local neuronal activity.
TMP14 pp. 777–778

36. E) Axons of motor neurons in the anterior horn exit the spinal cord through the anterior root. The posterior root serves as the entry point for sensory fibers coming into the posterior horn region of the spinal cord. The posterior column and ventral white commissure are fiber tracts located solely within the spinal cord.
TMP14 pp. 685–686

37. D) All preganglionic sympathetic neurons are located in the intermediolateral cell column (lateral horn); this cell group extends from T1 to L2.
TMP14 p. 763

38. D) A subdural hematoma can lead to increased intracranial pressure because it takes up space in the cranium; papilledema (optic disc swelling) suggests an increase in intracranial pressure. The increase in intracranial pressure does not affect production of cerebrospinal fluid (CSF), but it may cause decreased CSF volume because the high pressure pushes CSF into venous blood through the arachnoidal villi and compresses the volume of brain structures that contain CSF. Cerebral blood flow should remain normal with small increases in intracranial pressure, but larger increases can decrease cerebral blood flow.
TMP14 pp. 782–783

39. E) The veins have lower pressures compared with arteries and capillaries, making them easier to compress. When the veins are compressed, the capillary pressure increases, which increases the ultrafiltration of fluid from the capillaries into the interstitial spaces, thereby increasing the intracranial pressure even more. The increase in intracranial pressure can cause compression of lateral ventricles and the subarachnoid space, but this mechanism is compensatory rather than a cause for deterioration of blood flow and brain oxygenation.
TMP14 pp. 782–783

40. C) Preganglionic sympathetic axons pass through the white communicating rami to enter the sympathetic trunk. Postganglionic sympathetic axons course through gray rami and might be found in dorsal and ventral primary rami.
TMP14 p. 763

41. D) The gigantocellular neurons of the reticular formation reside in the pons and mesencephalon. These neurons release acetylcholine, which functions as an excitatory neurotransmitter in most brain areas.
TMP14 p. 743

42. E) Increased neuronal activity in the brain causes the neurotransmitter glutamate to diffuse from the site of release at the synapses into the adjacent tissues. The glutamate triggers a calcium wave in astrocytes, which leads to astrocytic release of vasodilatory prostaglandins that cause arterioles to dilate. In this way, the local blood flow to the tissues can be matched with the metabolic activity of the neurons.
TMP14 pp. 777–778

43. B) The endothelial cells lining all blood vessels in the brain constitute the blood-brain barrier. The purpose of the blood-brain barrier is to protect the chemical environment of the brain from rapid changes in composition that occur normally in the rest of the body fluids. Brain capillary endothelial cells have special structural and biochemical attributes that impede diffusion of ions, nutrients, and fat-soluble substances; these substances can diffuse through the endothelial barrier and thereby enter all other tissues of the body.
TMP14 p. 783

44. C) Gamma motor neurons form direct synaptic contact with the skeletal muscle fibers known as intrafusal fibers. Extrafusal muscle fibers are innervated by alpha motor neurons, whereas Purkinje, granule, and pyramidal neurons have no synaptic contact with muscles in the periphery.
TMP14 p. 686

45. B) Cerebellothalamic projections are contained in the superior cerebellar peduncle.
TMP14 p. 714

46. E) In this example, the flexor withdrawal reflex is activated by a painful stimulus to the right foot. Flexor muscles in the right leg and extensor muscles in the left leg are simultaneously stimulated to contract, causing reflex removal of the foot from the painful stimulus while shifting body weight to the other leg. The patellar tendon reflex (also called knee jerk), which is activated by tapping the patellar tendon, is a type of stretch reflex. The Golgi tendon reflex provides a negative feedback mechanism that prevents the development of too much tension in a muscle.
TMP14 pp. 691–692

47. E) The flexor withdrawal reflex is a polysynaptic reflex arc activated by stimulation of nociceptors in the skin. Multiple excitatory and inhibitory interneurons in the spinal cord are involved. The stretch reflex is a monosynaptic reflex arc involving two neurons. The Golgi tendon reflex is a disynaptic reflex arc because the reflex involves two synapses—an afferent and efferent neuron synapse with an inhibitory interneuron in the spinal cord.
TMP14 pp. 691–692

48. A) The hypothalamus, despite its small size, is the most important control center for the limbic system. It controls most of the vegetative and endocrine functions of the body and many aspects of behavior.
TMP14 p. 745

49. C) The association cortex is defined by the fact that it receives multiple inputs from a wide variety of sensory areas of cortex. It is the true multimodal cortex.
TMP14 p. 729

50. C) The corpus callosum is the main fiber pathway for communication between the two hemispheres of the brain.
TMP14 pp. 731–732

51. B) Corticospinal fibers pass through the medullary pyramid.
TMP14 pp. 699–700

52. D) Prosopagnosia is the inability to recognize faces. This inability occurs in people who have extensive damage on the medial undersides of both occipital lobes and along the medioventral surfaces of the temporal lobes.
TMP14 p. 730

53. E) The somatic, visual, and auditory association areas all meet one another at the junction of the parietal, temporal, and occipital lobes. This area is known as *Wernicke's area.* This area on the dominant side of the brain plays the single greatest role for the highest comprehension levels we call intelligence.
TMP14 pp. 731–732

54. D) A stroke involving the left middle cerebral artery is likely to cause an aphasic syndrome that may involve the loss of speech comprehension and/or the loss of the ability to produce speech sounds. Any paralysis resulting from the lesion would affect the right side of the body; similarly, any visual field deficits would affect the right visual field of each eye.
TMP14 pp. 734, 780

55. C) For an event or sensory experience to be remembered, it must first be consolidated. The consolidation of memory takes time. A disruption of consciousness during the process of consolidation will prevent the development of memory for the event or sensory experience.
TMP14 p. 738

56. A) Sympathetic stimulation of blood vessels typically causes vasoconstriction; parasympathetic stimulation has little or no direct effect on blood vessels. The heart, lungs, gastrointestinal tract, and urinary bladder are affected significantly by both divisions of the autonomic nervous system.
TMP14 pp. 769–770

57. C) Posterior spinocerebellar fibers pass through the inferior cerebellar peduncle.
TMP14 p. 713

58. D) The main pathway linking the cerebral cortex and the cerebellum involves cortical projections to the ipsilateral basilar pontine nuclei, the cells of which then project to the contralateral cerebellum.
TMP14 pp. 712–713

59. C) The cerebrospinal fluid outside the brain and spinal cord is located within the subarachnoid space. Dilated regions of the subarachnoid space are identified as cisterns. The cisterna magna is one of the largest cisterns and is positioned at the caudal end of the fourth ventricle between the cerebellum and posterior surface of the medulla.
TMP14 pp. 780–781

60. D) This woman has Huntington's disease. This hereditary disorder results from expansion of a CAG triplet repeat in the Huntingtin gene on chromosome 4. Typical symptoms are listed in the question stem. Huntington's disease is a neurodegenerative disorder that at first causes flicking movements in individual muscles and then progresses to distortional movements of the entire body; severe dementia develops along with the motor dysfunctions.
TMP14 p. 724

61. C) The abnormal movements of Huntington's disease are thought to be caused by loss of GABA-secreting neurons in the caudate nucleus and putamen; acetylcholine-secreting neurons in many parts of the brain are also thought to be affected. The axon terminals of GABA-secreting neurons normally inhibit portions of the globus pallidus and substantia nigra. This loss of inhibition is thought to allow spontaneous outbursts of globus pallidus and substantia nigra activity that cause the distortional movements.
TMP14 p. 724

62. A) Pontocerebellar axons are contained in the middle cerebellar peduncle.
TMP14 p. 713

63. A) Pain signals traveling through the anterolateral system, but not any of the discriminative sensations coursing through the medial lemniscal system, provide input to the cells in the reticular formation that give rise to ascending projections to the intralaminar nuclei of the thalamus.
TMP14 pp. 741–742

64. A) Preganglionic sympathetic axons synapse on cells in the adrenal medulla that function as postganglionic sympathetic neurons.
TMP14 p. 764

65. D) Gamma motor neurons innervate the contractile ends of the muscle spindle receptor. Stimulation of gamma motor neurons will cause the ends of the spindle to contract, which in turn will stretch the center of the spindle receptor in the muscle in which the spindle receptor is embedded. The activity of the

gamma motor neurons is influenced by the fusimotor system. Enhanced activity of this system will lead to an increase in gamma motor tone and increase the sensitivity of the muscle spindle as a stretch receptor.
TMP14 pp. 688–689

66. A) Complex spike output from the Purkinje cells of the cerebellum is a response to activation of climbing fibers in cerebellar neural circuitry. All climbing fibers originate in the inferior olivary nucleus.
TMP14 pp. 715–716

67. A) Cortical projections to the red nucleus provide an alternative pathway for the cerebral cortex to control flexor muscles through the rubrospinal tract.
TMP14 pp. 700–701

68. D) The pontine reticular nuclei are tonically active. These nuclei have a stimulatory effect on the antigravity muscles of the body. The pontine nuclei are normally opposed by the medullary reticular nuclei. The medullary nuclei are not tonically active and require stimulation from higher brain centers to counterbalance the signal from the pontine nuclei. Decerebrate rigidity results when the stimulatory signal from higher brain areas to the medullary nuclei is absent. This absence allows an unopposed and vigorous activation of the antigravity muscles, resulting in extension of the arms and legs and contraction of the axial muscles of the spinal column.
TMP14 p. 704

69. E) Corticospinal axons originate from cell bodies (pyramidal neurons) in layer V of the motor areas of the cortex.
TMP14 pp. 727–728

70. E) This man has Parkinson disease. No laboratory biomarkers exist for Parkinson disease, and imaging results are unremarkable. Diagnosis requires two of three cardinal signs that include (1) resting tremor, (2) rigidity, and (3) bradykinesia (or slow movement); this man has all three signs. Parkinson disease affects about 1% of persons older than 60 years. Progressive disability can be slowed but not halted by treatment.
TMP14 pp. 723–724

71. C) This man with Parkinson disease has a loss of pigmented dopaminergic neurons of the substantia nigra pars compacta that send dopamine-secreting nerve fibers to the caudate nucleus and putamen. The causes of the abnormal motor movements are poorly understood; however, dopamine is an inhibitory transmitter in the caudate nucleus and putamen. It is therefore possible that overactivity of the caudate nucleus and putamen could result from decreased dopamine levels in this patient with Parkinson disease; these brain structures are largely responsible for voluntary movement.
TMP14 pp. 723–724

72. C) The palmar (volar) surfaces of the skin contain receptors that project through the medial lemniscal system to the primary somatosensory cortex. When these fingers are flexed and grasp an object, the cutaneous receptors send signals to the primary somatosensory cortex. These cortical neurons then project to the adjacent motor cortex and the pyramidal neurons that sent the original message down the corticospinal tract to cause contraction of the finger flexors. The motor cortex neurons are then said to be "informed of the muscle contractions" that they originally specified.
TMP14 pp. 701–702

73. B) Sweat glands and the piloerector smooth muscle of hairy skin are innervated by the population of cholinergic postganglionic sympathetic neurons.
TMP14 p. 765

74. D) Bilateral ablation of the amygdala causes behavioral changes known as *Klüver-Bucy syndrome.* These changes include lack of fear, extreme curiosity, forgetfulness, oral fixation, and a strong sex drive. The sex drive can be so strong that monkeys will attempt to copulate with immature animals, animals of the wrong sex, and even animals of the wrong species. Although similar brain legions in humans are rare, afflicted people have similar symptoms. The amygdala is thought to make the person's behavioral response appropriate for each occasion.
TMP14 p. 751

75. C) Although the majority of corticospinal axons synapse with the pool of spinal cord interneurons, some synapse directly with the motor neurons that innervate muscles controlling the wrist and finger flexors.
TMP14 p. 697

76. A) The foramen of Magendie and the two lateral foramina of Luschka form the communication channels between the ventricular system within the brain and the subarachnoid space that lies outside the brain and spinal cord.
TMP14 pp. 780–781

77. A) A generalized tonic-clonic epileptic seizure is associated with the sudden onset of unconsciousness and an overall steady but uncoordinated contracture of many muscles of the body followed by alternating contractions of flexor and extensor muscles—that is, tonic-clonic activity. This effect is the result of widespread and uncontrolled activity in many parts of the brain. It takes the brain from a few minutes to a few hours to recover from this vigorous activity.
TMP14 p. 759

78. D) Golgi tendon organs provide direct synaptic input to type Ib inhibitory interneurons. Type Ia interneurons and alpha motor neurons receive input from muscle spindle afferents, whereas dynamic gamma motor neurons and excitatory interneurons receive their input from supraspinal systems.
TMP14 p. 691

79. A) Neurons in the locus coeruleus utilize the neurotransmitter norepinephrine in their widespread projections throughout the brain.
TMP14 p. 743

80. D) Dysdiadochokinesia is the inability to perform rapid alternating movements. Patients with hemineglect are unaware of items to one side of space. Astereognosis is the inability to recognize objects by touch. Agraphesthesia is a disorientation of the skin's sensation across its space (e.g., it is difficult to identify a number or letter traced on the hand). Dysarthria is a failure of progression in talking.
TMP14 pp. 719–720

81. A) The cerebellum plays major roles in the timing of motor activities and in rapid, smooth progression from one muscle movement to the next. Lesions of the cerebellum can also cause dysmetria, ataxia, past pointing, nystagmus, dysarthria, intention tremor, and hypotonia. The premotor cortex and primary motor cortex plan and execute movements. The limbic system is involved with behavior, motivation, emotion, long-term memory, and olfaction.
TMP14 pp. 719–720

82. A) The excitatory or inhibitory effect of a postganglionic sympathetic fiber is determined solely by the type of receptor to which it binds.
TMP14 p. 767

83. C) The most characteristic deficit after damage to corticospinal tract neurons involves discrete voluntary movement of the contralateral hand and fingers.
TMP14 p. 702

84. A) A large area of the primary motor cortex is dedicated to activating the muscles that control the movements of the fingers. Stimulation of the primary motor cortex usually results in very discrete contractions of small groups of muscles. Stimulation of the premotor cortex results in the contraction of large groups of muscles, and stimulation of the supplemental motor area results in bilateral movements.
TMP14 pp. 697–698

85. B) Nicotinic cholinergic receptors are found at synapses between preganglionic and postganglionic sympathetic neurons.
TMP14 p. 767

86. D) The premotor cortex generates nerve signals for complex patterns of movement rather than discrete patterns generated in the primary motor cortex. The most anterior part of the premotor area first develops a motor image of the total muscle movement that is to be performed. Next, the successive pattern of muscle activity required to achieve the image excites neurons in the posterior premotor cortex; from here, signals are sent directly to the primary motor cortex to excite specific muscles or by way of the basal ganglia and thalamus and then to the primary motor cortex.
TMP14 p. 698

87. A) Active transport of sodium ions through the epithelial cells lining the choroid plexus is followed by passive diffusion of chloride ions to maintain electroneutrality. The osmotic gradient created by the sodium and chloride ions causes the immediate osmosis of water into the CSF. The osmolarity of CSF is identical to that of blood plasma.
TMP14 p. 781

88. A) This patient has Friedreich's ataxia, which is an autosomal-recessive ataxia resulting from a mutation on chromosome 9. It accounts for about 50% of all hereditary ataxias. Huntington's disease is a neurodegenerative disease that affects muscle coordination and causes a decline in cognitive function and psychiatric problems. Multiple sclerosis is an inflammatory disease in which the myelin covering of nerve cells in the brain and spinal cord is damaged, resulting in a wide range of symptoms that include physical, mental, and psychiatric problems.
TMP14 pp. 719–720

89. E) The major pathological finding in Friedreich's ataxia is degeneration and loss of axons, especially in the spinal cord and spinal roots; this effect increases with age and duration of disease. Most major nerve tracts in the spinal cord show demyelination, and the spinal cord itself becomes thin. There are no lesions in the premotor cortex or primary motor cortex, and the frontal lobe remains normal. The disorder does not affect cognitive functions, and unmyelinated sensory fibers are spared.
TMP14 pp. 719–720

90. B) Cells in the pars compacta portion of the substantia nigra use the neurotransmitter dopamine in their projections to the caudate and putamen.
TMP14 pp. 723–724

91. A) Lesions that damage primary motor cortex and other surrounding motor cortical areas lead to spastic paralysis in the affected muscles.
TMP14 pp. 702–703

92. C) Epinephrine activates alpha- and beta-adrenergic receptors equally well. Norepinephrine excites both types of receptors but has a markedly greater effect on alpha receptors.
TMP14 p. 768

93. A) The posterior and lateral hypothalamus, in combination with the preoptic hypothalamus, form an important group of cells controlling cardiovascular functions such as heart rate and blood pressure.
TMP14 p. 746

94. A) Ia sensory fibers synapse directly with alpha motor neurons, whereas Ib sensory fibers synapse with inhibitory interneurons. Excitatory interneurons play an important role in the withdrawal reflex. Gamma motor neurons receive input primarily from supraspinal systems.
TMP14 pp. 687–688

95. E) Noncommunicating hydrocephalus results when a blockage of CSF flow occurs within the ventricular system or at the sites of communication between the ventricular system and the subarachnoid space. Communicating hydrocephalus occurs when a blockage occurs either within the subarachnoid space or at the arachnoid villi, thus preventing communication between the subarachnoid space and the superior sagittal sinus.
TMP14 p. 783

96. E) Behavioral deficits, changes in personality, and diminished problem-solving ability are all signs of damage to the prefrontal association cortex.
TMP14 p. 730

97. B) The posterior temporal lobe is larger at birth in the dominant hemisphere of the brain, which is the left hemisphere in 95% of people. Because of the tendency to direct one's attention to the better developed region, the rate of learning in the cerebral hemisphere that gains the first start increases rapidly, whereas learning remains slight in the opposite, less-used side. Hence, the left hemisphere normally becomes dominant over the right.
TMP14 pp. 731–732

98. A) The neurons located in the locus coeruleus release norepinephrine at their nerve terminals.
TMP14 p. 743

99. D) The cerebrocerebellum and the dentate nucleus are involved with the thalamus and cortex in the planning of complex movements.
TMP14 p. 718

100. D) The stretch reflex is mediated by muscle spindles. Autogenic inhibition involves Golgi tendon organs. Reciprocal inhibition is also related to muscle spindles.
TMP14 pp. 688–689

101. C) The junction of the parietal, temporal, and occipital lobe is commonly referred to as Wernicke's area. This area of the brain is responsible for the ability to comprehend both the written and spoken word.
TMP14 pp. 729–730

102. D) The corpus callosum connects the left and right cerebral hemispheres and hence facilitates communication between them. Agenesis of the corpus callosum is a rare defect in which there is a complete or partial absence of the corpus callosum.
TMP14 pp. 699, 732

103. D) Damage to the subthalamic nucleus of the basal ganglia often leads to flailing movements of an entire limb; this condition is called *hemiballismus*. Stroke is the most common cause of hemiballismus in adults, but this condition is rare. The globus pallidus is part of the basal ganglia and is involved with movement; however, damage to the globus pallidus does not cause hemiballismus. The lateral hypothalamus is mostly concerned with hunger. The red nucleus serves as an alternative pathway for transmitting cortical signals to the spinal cord; it controls the crawling of babies and may be responsible for swinging the arms while walking. The ventrobasal complex of thalamus is a sensory relay area of the brain.
TMP14 pp. 721–723

104. B) The amygdala seems to function in behavioral awareness at a semiconscious level. The amygdala also is thought to project into the limbic system the individual's current status with respect to his or her surroundings. Therefore, the amygdala is believed to help pattern behavior appropriate for each occasion.
TMP14 pp. 750–751

105. E) Schizophrenia is thought to be caused in part by excessive release of dopamine. Occasionally, patients with Parkinson's disease exhibit schizophrenic symptoms because of uncontrolled L-dopa therapy and the subsequent production of dopamine.
TMP14 pp. 760–761

106. C) The magnocellular portion of the red nucleus has a somatographic representation of all the muscles of the body, similar to the motor cortex. Stimulation of this area in the red nucleus results in contraction of a single muscle or small groups of muscles.
TMP14 p. 700

107. C) Lesions involving the ventromedial hypothalamus lead to excessive eating (hyperphagia), excessive drinking, rage and aggression, and hyperactivity.
TMP14 pp. 746–747

108. D) The vermis and the intermediate zone of the cerebellar hemisphere have a distinct topographic representation of the body. These areas are responsible

for coordinating the contraction of the muscles of the body for intended motion.
TMP14 p. 712

109. E) The medial forebrain bundle extends from the septal and orbitofrontal regions of the cerebral cortex downward through the center of the hypothalamus to the brain stem reticular area. This structure serves as a communication system between the limbic system and the brain stem.
TMP14 p. 745

110. C) This man has Alzheimer's disease. Increased amounts of beta-amyloid peptide are found in the brains of patients with Alzheimer's disease. The peptide accumulates in amyloid plaques with diameters up to several hundred millimeters in widespread areas of the brain, including the cerebral cortex, hippocampus, basal ganglia, thalamus, and cerebellum. A key role for excess accumulation of beta-amyloid peptide in the pathogenesis of Alzheimer's disease is suggested by multiple observations.
TMP14 p. 761

111. E) Dysdiadochokinesia is a cerebellar deficit that involves a failure of progression from one part of a movement to the next. Consequently, movements that include rapid alternation between flexion and extension are most severely affected.
TMP14 pp. 719–720

112. C) Linear acceleration is in a straight line; angular acceleration is that which occurs by turning about a point. The semicircular canals respond to the turning motions of the head and body.
TMP14 pp. 706–707

113. D) This man has schizophrenia, which is characterized by a breakdown of cognitive and emotional responses. Dissociative identity disorder was formerly called *multiple personality disorder*. Bipolar disorder is characterized by episodes of elevated mood (mania) alternating with episodes of depression.
TMP14 pp. 760–761

114. B) A consistent finding in most individuals with schizophrenia is that the hippocampus is reduced in size. The hippocampus is part of the limbic system. Incoming sensory information activates various parts of the hippocampus that, in turn, initiate behavioral reactions for different purposes. Removal of the hippocampus makes it impossible to learn new information based on verbal symbolism; however, past memories are preserved.
TMP14 pp. 760–761

115. B) Hair cells in the macula of the saccule are maximally sensitive to linear head movement in the vertical plane.
TMP14 p. 706

116. D) Lesions involving the thalamus lead to retrograde amnesia because they are believed to interfere with the process of retrieving long-term memory stored in other portions of the brain.
TMP14 p. 739

117. C) The caudate nucleus is involved in the basal ganglia circuits that control memory-guided motor activity.
TMP14 p. 722

118. C) This infant has shaken baby syndrome. The subdural hematoma has increased intracranial pressure, which in turn has caused cerebral edema. The venous vasculature in the brain is compressed due to the high intracranial pressure. Continued compression of brain structures can lead to worsening cerebral edema with decreased oxygenation of the brain.
TMP14 p. 783

119. B) The punishment center is primarily localized to the periventricular hypothalamus and the midbrain central gray area.
TMP14 p. 749

120. A) An example of a relatively restricted or local sympathetic action is the vasodilation or vasoconstriction of blood vessels that occurs upon warming or cooling of a patch of skin. When a bright light is introduced to one eye, the pupils of both eyes constrict. The pupillary light reflex is a multiple-neuron event that involves the Edinger-Westphal nucleus of the brainstem; it is not a local event.
TMP14 p. 773

121. E) The most conspicuous stimulation area for causing sleep is the raphe nuclei in the lower half of the pons and in the medulla. Many nerve endings of fibers from raphe neurons secrete serotonin. When the formation of serotonin is blocked by drugs, sleep is often disrupted for hours to days. Therefore, it has been assumed that serotonin is a transmitter associated with the production of sleep.
TMP14 p. 754

122. B) The Golgi tendon organ senses tension in the tendons. When tension becomes exceedingly high, an inhibitory reflex is activated that causes relaxation of the entire muscle, which serves to protect the muscle from tearing. However, the Golgi tendon organ is also thought to play a key role in maintaining equal tension in the muscle fibers of a skeletal muscle so that imbalances in tension among the different muscle fibers can be equalized.
TMP14 pp. 690–691

123. B) Degeneration of the dopaminergic cells in the pars compacta of the substantia nigra is thought to be the primary defect in Parkinson's disease.
TMP14 pp. 723–724

124. A) Athetosis is a symptom characterized by spontaneous and often continuous writhing movements of a hand, an arm, the neck, or the face; it is caused by lesions in the globus pallidus. A lesion in the subthalamus often leads to sudden flailing movements of an entire limb, a condition called hemiballismus. Lesions of the substantia nigra lead to the common and extremely severe disease of rigidity, akinesia, and tremors known as Parkinson's disease. Multiple small lesions of the putamen lead to flicking movements in the hands, face, and other parts of the body, called chorea.

TMP14 p. 721

UNIT XII

Gastrointestinal Physiology

1. A 25-year-old man is severely injured in a motor vehicle collision. After 6 weeks of total parenteral nutrition (intravenous feeding), the stomach and small intestines have atrophied substantially. A lack of which of the following gastrointestinal hormones is most likely to account for the atrophy in this man?
   A) Cholecystokinin
   B) Gastrin
   C) Glucose-dependent insulinotropic peptide
   D) Motilin
   E) Secretin

2. A 43-year-old woman eats a meal consisting of 70% carbohydrate, 20% protein, and 10% fat. Six hours after consuming the meal, intense peristaltic contractions travel from the stomach to the colon over a period of about 90 minutes. Which of the following hormones is most likely to mediate the intense peristaltic contractions in this woman?
   A) Cholecystokinin
   B) Gastrin
   C) Glucose-dependent insulinotropic peptide
   D) Motilin
   E) Secretin

3. Dietary fat can cause the release of all gastrointestinal hormones EXCEPT one. Which one is the EXCEPTION?
   A) Cholecystokinin
   B) Gastrin
   C) Glucose-dependent insulinotropic peptide
   D) Motilin
   E) Secretin

4. A 90-year-old man with congestive heart failure explains to his physician that he has dull, aching chest pains when he consumes a large meal. Which of the following mechanisms can best explain the cause of ischemic chest pain following a large meal in this patient?
   A) Vasoconstriction of skeletal muscle arterioles
   B) Vasoconstriction of intestinal arterioles
   C) Vasodilation of skeletal muscle arterioles
   D) Vasodilation of intestinal arterioles

5. A clinical study is performed to test a newly developed pilocarpine analogue. Test subjects receiving the analogue experience very high increases in salivary flow. Which of the following changes are most likely to occur in salivary electrolytes following treatment with the pilocarpine analogue?
   A) Decreased sodium concentration; increased chloride concentration
   B) Decreased sodium concentration; increased potassium concentration
   C) Increased sodium concentration; decreased chloride concentration
   D) Increased sodium concentration; decreased potassium concentration

6. A 24-year-old student with an acute intestinal viral syndrome develops a new onset of intolerance to dairy products. The student had never experienced an intolerance to milk products prior to the infection. Which of the following recommendations would you include for this student?
   A) No recommendation to avoid any foods
   B) Permanent avoidance of dairy products
   C) Permanent avoidance of fruit
   D) Temporary avoidance of dairy products
   E) Temporary avoidance of fruit

7. A 46-year-old woman consumes a meal consisting of 60% carbohydrate, 30% protein, and 10% fat. Gastric acid secretion increases by 35-fold within 3 minutes of consuming the meal, reaches a peak value within 25 minutes, and then gradually decreases over the next 4 hours. Which of the following substances is most likely to mediate the decrease in gastric acid secretion in this woman?
   A) Gastrin only
   B) Secretin only
   C) Cholecystokinin only
   D) Somatostatin only
   E) Secretin and cholecystokinin
   F) Secretin and somatostatin
   G) Secretin, gastrin, and somatostatin

8. A 35-year-old woman is admitted to the emergency department because of severe upper right quadrant pain and fever. The woman has clay-colored stools. Her body mass index is 51 kg/m^2 (normal range, 18.5 - 25 kg/m^2). Physical examination shows a positive Murphy sign. Heart rate is 105 beats/min; blood pressure is 102/65 mm Hg. CT scan shows a mass at the sphincter of Oddi. This woman is at risk for developing which of the following acute problems?

   A) Ascites
   B) Crohn's disease
   C) Esophageal cancer
   D) Gastritis
   E) Pancreatitis
   F) Peptic ulcer disease

9. Which of the following best describes the mechanism for fructose movement across the luminal cell membrane of an enterocyte in a normal adult human?

   A) Endocytosis
   B) Exocytosis
   C) Facilitated diffusion
   D) Passive diffusion
   E) Primary active transport
   F) Secondary active transport

10. A 65-year-old man with a 30-year history of alcoholism and liver disease visits his physician because of swelling in his abdomen. Which of the following sets of changes are most likely in the splanchnic circulation of this man?

    A) High capillary hydrostatic pressure; low plasma colloid osmotic pressure
    B) Low capillary hydrostatic pressure; high plasma colloid osmotic pressure
    C) High capillary hydrostatic pressure; high plasma colloid osmotic pressure
    D) Low capillary hydrostatic pressure; low plasma colloid osmotic pressure
    E) Normal capillary hydrostatic pressure; high plasma colloid osmotic pressure
    F) High capillary hydrostatic pressure; normal plasma colloid osmotic pressure

11. The gastrointestinal assimilation of proteins includes (1) absorption by enterocytes, (2) proteolytic actions of pepsin, (3) release of cholecystokinin, and (4) proteolytic actions of pancreatic enzymes. Which of the following best describes the correct temporal order of events for the assimilation of proteins?

    A) 4, 3, 2, 1
    B) 2, 3, 4, 1
    C) 3, 4, 2, 1
    D) 3, 4, 1, 2
    E) 2, 1, 4, 3
    F) 4, 2, 1, 3
    G) 1, 2, 3, 4
    H) 2, 3, 1, 4
    I) 1, 3, 2, 4

12. All the following events are likely to occur during emesis EXCEPT one. Which one is the EXCEPTION?

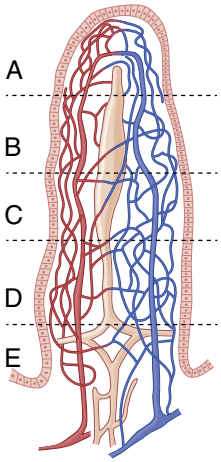
    A) Antiperistalsis
    B) Opening of lower esophageal sphincter
    C) A deep breath
    D) Contraction of diaphragm
    E) Opening of glottis

13. The single most quantitatively significant process for absorption of nutrients in the small intestine is establishment of an electrochemical gradient for which of the following ions?

    A) Calcium
    B) Chloride
    C) Magnesium
    D) Potassium
    E) Sodium

14. Which portion of the villus shown is most likely to have the lowest oxygen tension under normal physiological conditions?

    A) A
    B) C
    C) C
    D) D
    E) E



15. A 24-year-old student consumes a meal consisting of 50% carbohydrates, 30% proteins, and 20% fats. The student feels the urge to defecate 20 minutes after consuming the meal. Which of the following best describes a direct action that promotes the urge to defecate in this student?

    A) Relaxation of pylorus
    B) Relaxation of duodenum
    C) Distension of jejunum
    D) Distension of rectal wall
    E) Contraction of external anal sphincter
    F) Contraction of internal anal sphincter

16. The regulation of gastric acid secretion in response to a meal involves the following events: (1) a decrease in the pH of the gastric contents, (2) an increase in the pH of the gastric contents, (3) an increase in the rate of acid secretion, and (4) a decrease in the rate of acid secretion. Which of the following best describes the correct temporal order of events over a 4- or 5-hour period following a meal?

A) 4, 3, 2, 1
B) 3, 1, 4, 2
C) 3, 4, 1, 2
D) 2, 1, 4, 3
E) 4, 2, 1, 3
F) 1, 2, 3, 4
G) 2, 3, 1, 4
H) 1, 3, 2, 4

17. Biopsies are taken from the antral and duodenal mucosa of a 48-year-old woman. Which of the following hormones can be found in tissue homogenates from both locations?

A) Secretin
B) Gastrin
C) Cholecystokinin (CCK)
D) Motilin
E) Glucose-dependent insulinotropic peptide (GIP)

18. Swallowing a bolus of food involves the following: (1) relaxation of upper esophageal sphincter, (2) peristaltic contractions of pharynx, (3) upward movement of the soft palate, and (4) medial placement of palatopharyngeal folds. Which of the following best describes the correct temporal order of events during the swallowing process?

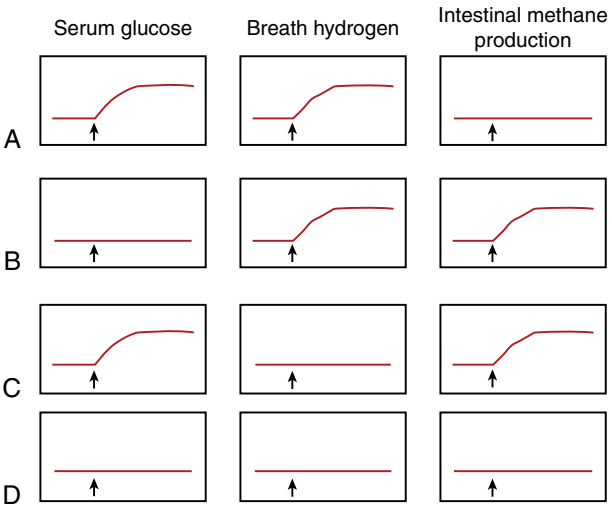
A) 4, 1, 2, 3
B) 3, 4, 2, 1
C) 2, 1, 4, 3
D) 2, 3, 1, 4
E) 3, 4, 1, 2

19. Oral administration of a histamine H2 receptor antagonist is most likely to cause which of the following changes in the ability of gastrin, acetylcholine, and histamine to stimulate gastric acid secretion?

A) Gastrin increased; acetylcholine increased; histamine increased
B) Gastrin decreased; acetylcholine decreased; histamine decreased
C) Gastrin no change; acetylcholine decreased; histamine no change
D) Gastrin increased; acetylcholine decreased; histamine decreased
E) Gastrin decreased; acetylcholine no change; histamine decreased

20. A 34-year-old physician visits a gastroenterologist because of nausea, abdominal pain, and diarrhea. The physician was exposed to raw sewage and polluted water on a recent mission trip to an underprivileged area. The gastroenterologist administers a proton pump inhibitor and tetracycline. All the symptoms go away in 2 weeks. Which of the following best describes the condition for which the physician was treated?

A) Excessive alcohol consumption
B) Ulcerative colitis
C) Psychogenic diarrhea
D) Posttraumatic stress syndrome
E) *Helicobacter pylori* infection

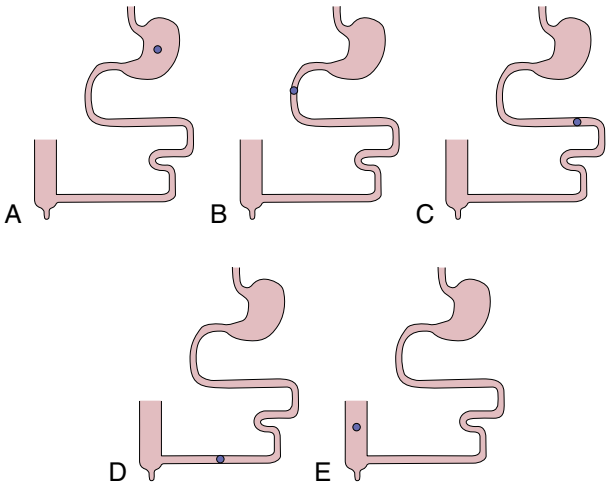


21. A 19-year-old woman visits her physician because of nausea, diarrhea, light-headedness, and flatulence. After an overnight fast, the physician administers 50 g of oral lactose at time zero (indicated by the arrows in the figures). Which combination is most likely in this patient during the next 3 hours?

A) A
B) B
C) C
D) D

22. A 43-year-old man eats a meal consisting of 40% protein, 10% fat, and 50% carbohydrate. Thirty minutes later, the man feels the urge to defecate. Which reflex results in the urge to defecate when the duodenum is stretched?

A) Duodenocolic
B) Enterogastric
C) Intestinointestinal
D) Rectosphincteric



23. A 43-year-old man consumes a meal containing 30% protein, 15% fat, and 55% carbohydrate. At which of the locations depicted in the figure are bile salts most likely to be absorbed by an active transport process?

A) A
B) B
C) C
D) D
E) E

24. The ileum and distal jejunum of a 28-year-old man are ruptured in an automobile accident. The entire ileum and a portion of the jejunum are resected. What is most likely to occur in this man?

A) Atrophic gastritis
B) Constipation
C) Gastric ulcer
D) Gastroesophageal reflux disease (GERD)
E) Vitamin B_{12} deficiency

25. A 10-year-old boy consumes a cheeseburger, fries, and a chocolate shake. The meal stimulates the release of several gastrointestinal hormones. The presence of fat, carbohydrate, or protein in the duodenum stimulates the release of which hormone from the duodenal mucosa?

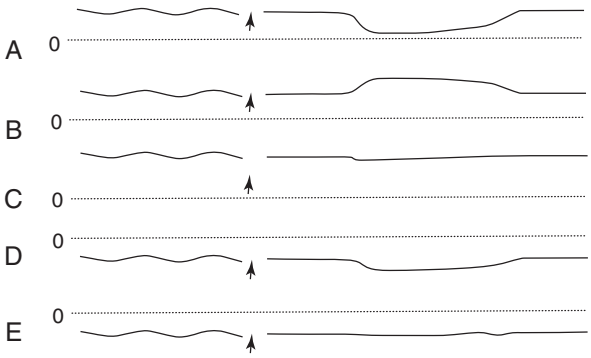
A) Cholecystokinin (CCK)
B) Glucose-dependent insulinotropic peptide (GIP)
C) Gastrin
D) Motilin
E) Secretin

26. A clinical experiment is conducted in which one group of subjects is given 50 g of glucose intravenously, and another group is given 50 g of glucose orally. Which factor can explain why the oral glucose load is cleared from the blood at a faster rate compared with the intravenous glucose load? (CCK, cholecystokinin; GIP, glucose-dependent insulinotropic peptide; VIP, vasoactive intestinal peptide.)

A) CCK-induced insulin release
B) CCK-induced VIP release
C) GIP-induced glucagon release
D) GIP-induced insulin release
E) VIP-induced GIP release

27. Digestion of which of the following is impaired to the greatest extent in patients with achlorhydria?

A) Carbohydrate
B) Fat
C) Protein



28. A 22-year-old man visits his physician because his chest hurts when he eats, especially when he eats meat. He also belches excessively and has heartburn. Physical exam shows halitosis. A radiograph shows a dilated esophagus. Which pressure tracing shown in the figure was most likely taken at the lower esophageal sphincter (LES) of this patient before and after swallowing (indicated by the arrow in the figure above)? The dotted line represents a pressure of 0 mm Hg.

A) A
B) B
C) C
D) D
E) E

29. The proenzyme pepsinogen is secreted mainly from which of the following structures?

A) Acinar cells of the pancreas
B) Ductal cells of the pancreas
C) Epithelial cells of the duodenum
D) Gastric glands of the stomach

30. Which hormone is released by the presence of fat and protein in the small intestine and has a major effect in decreasing gastric emptying?

A) Cholecystokinin
B) Glucose-dependent insulinotropic peptide
C) Gastrin
D) Motilin
E) Secretin

31. Which of the following can inhibit gastric acid secretion?

	Somatostatin	Secretin	GIP	Enterogastrones	Nervous Reflexes
A)	No	No	Yes	No	Yes
B)	No	Yes	No	No	No
C)	No	Yes	No	Yes	No
D)	Yes	No	No	Yes	Yes
E)	Yes	No	Yes	No	No
F)	Yes	Yes	Yes	Yes	Yes

32. The gastrointestinal hormones have physiological effects that can be elicited at normal concentrations, as well as pharmacological effects that require higher than normal concentrations. What is the direct physiological effect of the various hormones on gastric acid secretion?

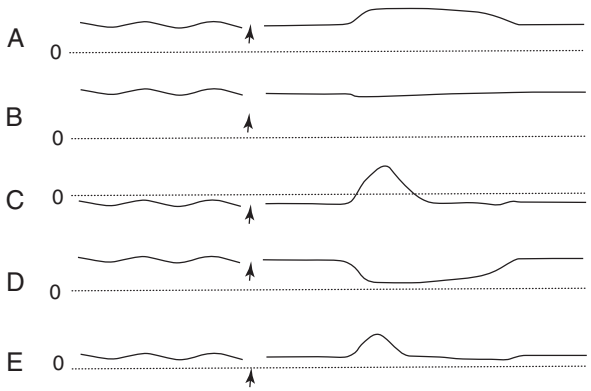
	Gastrin	Secretin	Cholecystokinin	GIP	Motilin
A)	No effect	Stimulate	Stimulate	No effect	No effect
B)	Stimulate	Inhibit	No effect	Inhibit	No effect
C)	Stimulate	Inhibit	No effect	No effect	No effect
D)	Stimulate	Inhibit	Inhibit	Stimulate	Stimulate
E)	Stimulate	Stimulate	Inhibit	Inhibit	No effect

33. The cephalic phase of gastric secretion accounts for about 30% of the acid response to a meal. Which of the following can eliminate the cephalic phase of gastric secretion?

A) Antacids
B) Antigastrin antibody
C) Atropine
D) Histamine H_2 blocker
E) Vagotomy
F) Sympathectomy

34. Migrating motility complexes (MMCs) occur about every 90 minutes between meals and are thought to be stimulated by the gastrointestinal hormone, motilin. An absence of MMCs causes an increase in which of the following?

A) Duodenal motility
B) Gastric emptying
C) Intestinal bacteria
D) Mass movements
E) Swallowing



35. Which manometric recording in the figure illustrates normal function of the esophagus at midthoracic level before and after swallowing (indicated by the arrow in the figure above)? The dotted lines represent a pressure of 0 mm Hg.

A) A
B) B
C) C
D) D
E) E

36. Gastric emptying is tightly regulated to ensure that chyme enters the duodenum at an appropriate rate. Which event promotes gastric emptying under normal physiological conditions in a healthy person?

	Tone of Orad Stomach	Segmentation Contractions in Small Intestine	Tone of Pyloric Sphincter
A)	Decrease	Decrease	Decrease
B)	Decrease	Increase	Decrease
C)	Increase	Decrease	Decrease
D)	Increase	Decrease	Increase
E)	Increase	Increase	Increase

Questions 37–39

A tropical hurricane hits a Caribbean island, and the people living there are forced to drink unclean water. Within the next several days, many people experience severe diarrhea, and about half of these people die. Samples of drinking water are positive for the bacterium *Vibrio cholerae*. Use this information to answer the next three questions.

37. A toxin from *V. cholerae* is most likely to stimulate an increase in which of the following in the epithelial cells of the crypts of Lieberkühn in the infected people?

A) Cyclic adenosine monophosphate (cAMP)
B) Cyclic guanosine monophosphate (cGMP)
C) Chloride absorption
D) Sodium absorption

38. Which type of ion channel is most likely to be irreversibly opened in the intestinal epithelial cells of the infected people?

A) Calcium
B) Chloride
C) Magnesium
D) Potassium
E) Sodium

39. Which range best describes the life span (in days) of an intestinal enterocyte infected with *V. cholerae* in a person who survives?

A) 1 to 3
B) 3 to 6
C) 6 to 9
D) 9 to 12
E) 12 to 15

40. The gastrointestinal hormones have physiological effects that can be elicited at normal concentrations as well as pharmacologic effects that require higher than normal concentrations. What is the physiological effect of the various hormones on gastric emptying?

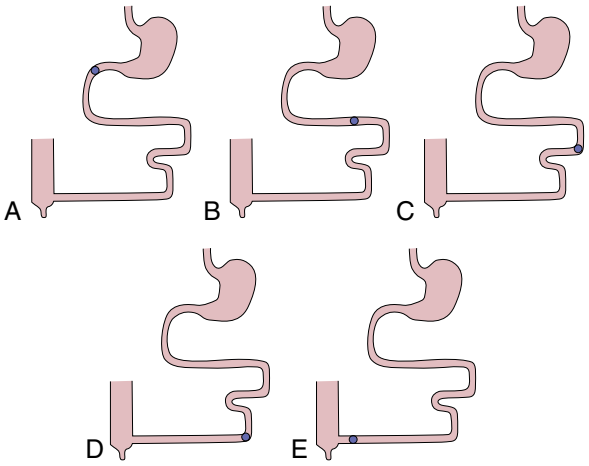
	Gastrin	Secretin	Cholecystokinin	GIP	Motilin
A)	Decrease	Decrease	Decrease	Decrease	Increase
B)	Increase	Decrease	None	Decrease	Increase
C)	Increase	None	None	Increase	Increase
D)	None	None	Decrease	Increase	Increase
E)	None	None	Decrease	None	None
F)	None	None	Increase	None	None

41. A healthy 12-year-old boy ingests a meal containing 20% fats, 50% carbohydrates, and 30% proteins. The gastric juice is most likely to have the lowest pH in this boy at which time after the meal (in hours)?

A) 0.5
B) 1.0
C) 2.0
D) 3.0
E) 4.0

42. CCK and gastrin share multiple effects at pharmacological concentrations. Which effects do CCK and gastrin share (or not share) at physiological concentrations?

	Stimulation of Acid Secretion	Inhibition of Gastric Emptying	Stimulation of Gastric Mucosal Growth	Stimulation of Pancreatic Growth
A)	Not shared	Not shared	Not shared	Not shared
B)	Not shared	Not shared	Shared	Not shared
C)	Not shared	Shared	Not shared	Not shared
D)	Shared	Shared	Not shared	Not shared
E)	Shared	Shared	Shared	Shared



43. A 48-year-old woman consumes a meal consisting of 50% carbohydrates, 30% proteins, and 20% fats. At which location in the figure above are smooth muscle contractions most likely to have the highest frequency?

A) A
B) B
C) C
D) D
E) E

44. The spinal cord of a 40-year-old woman is severed at T6 in an automobile accident. She devises a method to distend the rectum to initiate the rectosphincteric reflex. Rectal distention causes which of the following responses in this woman?

	Relaxation of the Internal Anal Sphincter	Contraction of the External Anal Sphincter	Contraction of the Rectum
A)	No	No	No
B)	No	No	Yes
C)	No	Yes	Yes
D)	Yes	No	Yes
E)	Yes	Yes	No
F)	Yes	Yes	Yes

45. A 91-year-old woman with upper abdominal pain and blood in the stool has been taking nonsteroidal anti-inflammatory drugs (NSAIDs) for arthritis. Endoscopy reveals patchy gastritis throughout the stomach. Biopsies are negative for *Helicobacter pylori.* Pentagastrin administered intravenously would most likely lead to a less than normal increase in which of the following?

A) Duodenal mucosal growth
B) Gastric acid secretion
C) Gastrin secretion
D) Pancreatic enzyme secretion
E) Pancreatic growth

46. Which substances have a physiological role in stimulating the release of hormones or stimulating nervous reflexes, which in turn can inhibit gastric acid secretion?

	Acid	Fatty Acids	Hyperosmotic Solutions	Isotonic Solutions
A)	No	No	Yes	No
B)	No	No	Yes	Yes
C)	Yes	Yes	No	Yes
D)	Yes	Yes	Yes	Yes
E)	Yes	Yes	Yes	No

47. A clinical study is conducted to determine the time course of gastric acid secretion and gastric pH in healthy volunteers after a meal consisting of 10% fat, 30% protein, and 60% carbohydrate. The results show an immediate increase in the pH of the gastric juice after the meal, which is followed several minutes later by a secondary increase in the rate of acid secretion. A decrease in which substance is most likely to facilitate the secondary increase in the rate of acid secretion in these volunteers?

A) Gastrin
B) Cholecystokinin
C) Somatostatin
D) Vasoactive intestinal peptide

48. Vomiting is a complex process that requires coordination of numerous components by the vomiting center located in the medulla. Which of the following occurs during the vomiting act?

	Lower Esophageal Sphincter	Upper Esophageal Sphincter	Abdominal Muscles	Diaphragm
A)	Contract	Contract	Contract	Contract
B)	Contract	Contract	Relax	Relax
C)	Relax	Contract	Contract	Relax
D)	Relax	Relax	Contract	Contract
E)	Relax	Relax	Relax	Relax

49. A 34-year-old woman has a recurrent history of duodenal ulcers associated with diarrhea, steatorrhea, and hypokalemia. Her fasting gastrin level is 550 pg/ml, and basal acid secretion is 18 mmol/hour. Human secretin at a dose of 0.4 μg/kg of body weight is administered intravenously over 1 minute. Postinjection blood samples are collected after 1, 2, 5, 10, and 30 minutes for determination of serum gastrin concentrations. Which serum gastrin concentration is considered diagnostic for gastrinoma in this woman (in pg/ml)?

A) 450
B) 500
C) 550
D) 600
E) 700

50. Various proteolytic enzymes are secreted in an inactive form into the lumen of the gastrointestinal tract. Which of the following substances can activate one or more proteolytic enzymes, converting them to an active form?

	Trypsin	Enterokinase	Pepsin
A)	No	No	No
B)	No	No	Yes
C)	No	Yes	No
D)	Yes	Yes	No
E)	Yes	Yes	Yes

51. A 71-year-old man with hematemesis and melena has a cresenteric ulcer in the duodenum. Lavage dislodged the clot, revealing an underlying raised blood vessel, which was successfully eradicated via cautery with a bipolar gold probe. Which of the following factors are diagnostic for duodenal ulcer?

	Endoscopy	Plasma Gastrin Levels	Rate of Acid Secretion
A)	No	No	No
B)	Yes	No	No
C)	Yes	No	Yes
D)	Yes	Yes	No
E)	Yes	Yes	Yes

52. A 23-year-old medical student consumes a cheeseburger, fries, and a chocolate shake. Which of the following hormones produce physiological effects at some point during the next several hours?

	Gastrin	Secretin	Cholecystokinin	GIP
A)	No	Yes	Yes	Yes
B)	Yes	No	Yes	Yes
C)	Yes	Yes	No	Yes
D)	Yes	Yes	Yes	Yes
E)	Yes	Yes	Yes	Yes

53. A 68-year-old woman with hematemesis has heartburn and stomach pain. Endoscopy shows inflammation involving the gastric body and antrum as well as a small gastric ulcer. Biopsies are positive for *H. pylori*. *H. pylori* damages the gastric mucosa primarily by increasing mucosal levels of which of the following?

A) Ammonium
B) Bile salts
C) Gastrin
D) NSAIDs
E) Pepsin

54. A physiology experiment is conducted in an isolated rat small intestine. The intestine is bathed with all essential nutrients, ions, and gases in a glass dish maintained at a temperature of 37°C. The proximal jejunum is observed to contract at a frequency of 5 contractions

per minute. A glass micropipette is then inserted into an interstitial cell of Cajal (pacemaker cell) at the same location in the jejunum, and a slow-wave frequency of 10 occurrences per minute is recorded. Norepinephrine is then added to the bathing solution. Which of the following best describes the most likely slow-wave frequency and contraction frequency after treatment with norepinephrine (in occurrences per minute)?

	Slow-Wave Frequency	Contraction Frequency
A)	0	0
B)	10	0
C)	10	10
D)	10	5
E)	5	10

55. A healthy 21-year-old woman eats a big meal and then takes a 3-hour ride on a bus that does not have a bathroom. Twenty minutes after eating, the woman feels a strong urge to defecate but manages to hold it. Which mechanisms have occurred in this woman?

	Relaxation of the Internal Anal Sphincter	Contraction of the External Anal Sphincter	Contraction of the Rectum
A)	No	No	No
B)	No	Yes	Yes
C)	Yes	No	Yes
D)	Yes	No	No
E)	Yes	Yes	Yes

56. A physiology experiment is conducted in an anesthetized rat. The distal duodenum is opened without disturbing its blood supply, and an oxygen-recording micropipette is inserted into the tip of a villus that is submerged in inert oil. An oxygen value of 10 mm Hg is recorded. The distal duodenum at the same location is then treated with the vasodilator, adenosine. Which value of oxygen is most likely in the tip of the villus within 2 minutes after treatment with adenosine (in mm Hg)?

A) 0
B) 5
C) 7
D) 10
E) 12

57. One of the following hormones can stimulate growth of the intestinal mucosa, and two other hormones can stimulate pancreatic growth. Which three hormones are these?

	Gastrin	Secretin	Cholecystokinin	GIP	Motilin
A)	No	Yes	Yes	Yes	No
B)	Yes	No	Yes	No	Yes
C)	Yes	No	Yes	Yes	No
D)	Yes	No	Yes	Yes	No
E)	Yes	Yes	Yes	No	No

58. A 65-year-old man eats a healthy meal consisting of 30% carbohydrates, 20% fats, and 50% proteins. Approximately 40 minutes later, the ileocecal sphincter relaxes, and chyme moves into the cecum. Gastric distention leads to relaxation of the ileocecal sphincter by way of which reflex?

A) Enterogastric
B) Gastroileal
C) Gastrocolic
D) Intestino-intestinal
E) Rectosphincteric

59. The gastric mucosal barrier has a physiological and an anatomical basis to prevent hydrogen ion accumulation in the mucosa. Some factors are known to strengthen the integrity of the gastric mucosal barrier, whereas other factors can weaken the barrier. Which factors strengthen or weaken the barrier?

	Bile Salts	Mucous	Aspirin	NSAIDs	Gastrin	Ethanol
A)	Strengthen	Strengthen	Weaken	Weaken	Strengthen	Strengthen
B)	Strengthen	Strengthen	Weaken	Weaken	Weaken	Strengthen
C)	Weaken	Strengthen	Strengthen	Weaken	Strengthen	Weaken
D)	Weaken	Strengthen	Weaken	Weaken	Strengthen	Weaken
E)	Weaken	Weaken	Weaken	Strengthen	Strengthen	Weaken

60. The assimilation of fats includes (1) micelle formation, (2) secretion of chylomicrons, (3) emulsification of fat, and (4) absorption of fat by enterocytes. Which sequence best describes the correct temporal order of these events?

A) 4, 3, 2, 1
B) 3, 1, 4, 2
C) 3, 4, 1, 2
D) 2, 1, 4, 3
E) 4, 2, 1, 3
F) 2, 4, 1, 3
G) 1, 2, 3, 4
H) 1, 3, 2, 4

61. A 62-year-old man with dyspepsia and a history of chronic gastric ulcer has abdominal pain. Endoscopy shows a large ulcer in the proximal gastric body. Biopsies are positive for *H. pylori.* Which substances are used clinically for treatment of gastric ulcers of various etiologies?

	Antibiotics	NSAIDs	H2 Blockers	Proton Pump Inhibitors
A)	No	No	Yes	Yes
B)	Yes	No	No	Yes
C)	Yes	No	Yes	Yes
D)	Yes	Yes	Yes	Yes
E)	No	Yes	Yes	Yes

62. Cystic fibrosis (CF) is an inherited disorder of the exocrine glands affecting children and young people. Mucus in the exocrine glands becomes thick and sticky and eventually blocks the ducts of these glands (especially in the pancreas, lungs, and liver), forming cysts. A primary disruption in the transfer of which ion across cell membranes occurs in CF, leading to decreased secretion of fluid?

A) Calcium
B) Chloride
C) Phosphate
D) Potassium
E) Sodium

63. A 43-year-old man presents with abdominal pain and hematemesis. An abdominal examination was relatively benign, and abdominal radiographs were suggestive of a perforated viscus. Endoscopy revealed a chronically perforated gastric ulcer, through which the liver was visible. Which mechanism is a forerunner to gastric ulcer formation?

A) Back-leak of hydrogen ions
B) Mucus secretion
C) Proton pump inhibition
D) Tight junctions between cells
E) Vagotomy

64. A 12-year-old girl consumes a glass of milk and two cookies. Her lower esophageal sphincter (LES) and fundus relax while the food is still in the esophagus. Which substance is most likely to cause relaxation of the LES and fundus in this girl?

A) Gastrin
B). Histamine
C) Motilin
D) Nitric oxide
E) Norepinephrine

65. Mass movements can be stimulated after a meal by distention of the stomach (gastrocolic reflex) and distention of the duodenum (duodenocolic reflex). Mass movements often lead to which of the following?

A) Bowel movements
B) Gastric movements
C) Haustrations
D) Esophageal contractions
E) Pharyngeal peristalsis

66. A 45-year-old woman with type 1 diabetes has an early feeling of fullness when eating. She is often nauseous after a meal and vomits about once each week after eating. Glucose-induced damage to which structure is most likely to explain her gastrointestinal problem?

A) Celiac ganglia
B) Enteric nervous system
C) Esophagus
D) Stomach
E) Vagus nerve

67. Which stimulus–mediator pair normally inhibits gastrin release?

	Stimulus	Mediator
A)	Acid	CCK
B)	Acid	GIP
C)	Acid	Somatostatin
D)	Fatty acid	Motilin
E)	Fatty acid	Somatostatin

68. A 55-year-old man consumes a meal consisting of 20% fat, 50% carbohydrate, and 30% protein. The following gastrointestinal hormones are released at various times during the next 6 hours: gastrin, secretin, motilin, glucose-dependent insulinotropic peptide, and cholecystokinin. Which structure is most likely to release all five hormones in this man?

A) Antrum
B) Colon
C) Duodenum
D) Esophagus
E) Ileum

69. A 79-year-old man has a cerebrovascular accident (stroke) in the medulla and pons that eliminates all vagal output to the gastrointestinal tract. Which function is most likely to be eliminated in this man?

A) Gastric acid secretion
B) Gastrin release
C) Pancreatic bicarbonate secretion
D) Primary esophageal peristalsis
E) Secondary esophageal peristalsis

70. A 74-year-old man with hematemesis and melena is diagnosed with a duodenal ulcer. Which of the following is most likely in this patient?

	Parietal Cell Density	Acid Secretion	Plasma Gastrin
A)	Decreased	Decreased	Decreased
B)	Decreased	Increased	Decreased
C)	Increased	Decreased	Increased
D)	Increased	Increased	Decreased
E)	Increased	Increased	Increased

71. A 61-year-old man with upper abdominal pain and blood in the stool takes NSAIDs for the pain and washes it down with vodka. Pentagastrin administration produced lower than predicted levels of gastric acid secretion. Secretion of which substance is most likely to be diminished in this patient with gastritis?

A) Intrinsic factor
B) Ptyalin
C) Rennin
D) Saliva
E) Trypsin

72. Gastric acid is secreted when a meal is consumed. Which factors have a direct action on the parietal cell to stimulate acid secretion?

	Gastrin	Somatostatin	Acetylcholine	Histamine
A)	No	No	Yes	Yes
B)	Yes	No	No	Yes
C)	Yes	No	Yes	Yes
D)	Yes	Yes	Yes	Yes
E)	Yes	Yes	No	Yes

73. A 37-year-old woman adds high-fiber wheat and bran foods to her diet to reduce her serum cholesterol levels. She had avoided eating foods containing wheat or rye since she was a child because her mother said they would make her sick. The woman loses 25 lb on her new diet but has frequent stomach cramps, gas, and diarrhea. She has also become weaker, finding it difficult to complete her morning walks. What is most likely to be increased in this woman?

A) Blood hemoglobin concentration
B) Carbohydrate absorption
C) Fecal fat
D) Protein absorption
E) Serum calcium

74. A newborn boy does not pass meconium within 48 hours of delivery. His abdomen is distended, and he begins vomiting. A suction biopsy of a distally narrowed segment of the colon shows a lack of ganglionic nerve cells. This newborn is at risk for developing which condition?

A) Achalasia
B) Enterocolitis
C) Halitosis
D) Pancreatitis
E) Peptic ulcer

75. A 41-year-old obese woman with a history of gallstones is admitted to the emergency department because of excruciating pain in the upper right quadrant. The woman is jaundiced, and a radiograph suggests obstruction of the common bile duct. Which values of direct and indirect bilirubin are most likely to be present in the plasma of this woman (in milligrams per deciliter)?

	Direct	Indirect
A)	1.0	1.3
B)	2.3	2.4
C)	5.0	1.7
D)	1.8	6.4
E)	6.8	7.5

76. Which mechanism for transport of substances across the luminal cell membrane of a duodenal enterocyte is present in newborns and infants but not in adults?

A) Endocytosis
B) Facilitated diffusion
C) Passive diffusion
D) Primary active transport
E) Secondary active transport

77. Cystic fibrosis is the most common cause of pancreatitis in children. Which option best explains the mechanism of cystic fibrosis-induced pancreatitis?

A) Activation of enterokinase
B) Activation of trypsin inhibitor
C) Autodigestion of pancreas
D) Excessive secretion of CCK
E) Gallstone obstruction

ANSWERS

1. **B)** Gastrin is secreted mainly by the G-cells of the antrum of the stomach. The primary actions of gastrin are (1) stimulation of gastric acid secretion and (2) stimulation of mucosal growth throughout the gastrointestinal tract.
   TMP14 p. 792

2. **D)** Motilin is secreted by the duodenum and jejunum during fasting, and the only known function of this hormone is to increase gastrointestinal motility. Motilin is released cyclically and stimulates waves of gastrointestinal motility called interdigestive myoelectric complexes (or migrating motility complexes) that move through the stomach and small intestine every 90 minutes in a person who has fasted. The purpose of these interdigestive myoelectric complexes is to remove food residue from the intestine, which lowers bacterial growth. Hence, interdigestive myoelectric complexes are also called housekeeping contractions.
   TMP14 pp. 792–793

3. **B)** Gastrin is secreted in response to vagal stimulation as well as stimuli associated with ingestion of a meal, such as distention of the stomach and the breakdown products of proteins. However, fat does not cause the release of gastrin as it does with other gastrointestinal hormones.
   TMP14 p. 792

4. **D)** Under normal conditions, the blood flow of the gastrointestinal tract is directly related to the level of local activity. For instance, after a meal, the motor activity, secretory activity, and absorptive activity all increase; likewise, the blood flow increases greatly. This increase in blood flow is caused by vasodilation of intestinal blood vessels. The increase in cardiac output associated with consuming a large meal is causing ischemic chest pain in this man.
   TMP14 pp. 794–795

5. **D)** Sodium ions are actively reabsorbed from the salivary ducts, and potassium ions are actively secreted in exchange for the sodium. When salivary flow is elevated, each unit portion of saliva spends less time in the salivary ducts. Hence, there is less time for absorption of sodium (increased sodium concentration) and less time for potassium secretion (decreased potassium concentration).
   TMP14 p. 808

6. **D)** This student has temporary lactose intolerance resulting from the temporary loss of the enzyme lactase. Lactase is a brush border enzyme; its production can be temporarily depressed following an intestinal viral infection (viral gastroenteritis).
   TMP14 p. 824

7. **F)** The presence of acid, fat, protein breakdown products, hyperosmotic or hypo-osmotic fluids, or any irritating factor in the upper small intestine causes release of several intestinal hormones. One of these hormones is secretin, which is especially important for stimulating pancreatic bicarbonate secretion. However, secretin opposes gastric acid secretion. Three other hormones—glucose-dependent insulinotropic peptide (formerly called gastric inhibitory peptide), vasoactive intestinal polypeptide, and somatostatin—also have slight to moderate effects in inhibiting gastric acid secretion.
   TMP14 pp. 792, 814

8. **E)** The same cells that secrete proteolytic enzymes into the acini of the pancreas simultaneously secrete another substance called trypsin inhibitor; this substance prevents activation of trypsin both inside the secretory cells and in the acini and ducts of the pancreas. When the pancreas becomes severely damaged or when a duct becomes blocked, large quantities of pancreatic juice can become pooled in the pancreas. Under these conditions, the effect of trypsin inhibitor is often overwhelmed, in which case the pancreatic secretions rapidly become activated and can literally digest large portions of the pancreas within a few hours, giving rise to the condition called *acute pancreatitis.* The obese woman described in this question has gallstone obstruction at the sphincter of Oddi, which causes pancreatic juice to pool within the pancreas, leading to autodigestion of the pancreas.
   TMP14 pp. 815, 835

9. **C)** Fructose transport does not occur by the sodium co-transport mechanism used for glucose and galactose absorption. Instead, fructose is transported by facilitated diffusion all the way through the intestinal epithelium and is not coupled with sodium transport.
   TMP14 p. 831

10. **A)** When liver parenchymal cells are destroyed, they are replaced with fibrous tissue that eventually contracts around the blood vessels, raising pressure in the entire portal vascular system of the gastrointestinal tract; this increases capillary hydrostatic pressure. This high capillary pressure causes fluid to transude into the abdominal cavity, creating ascites. The formation of ascitic fluid is further increased by lower than normal

levels of albumin (decreased plasma colloid osmotic pressure) because the production of albumin is lower than normal in the diseased liver.

TMP14 pp. 317–318, 872

11. B) Assimilation of proteins means digestion and absorption of proteins. Protein digestion begins in the stomach with the actions of pepsin (item 2). Next, the presence of fat and protein in the small intestine stimulates the release of cholecystokinin (item 3). Cholecystokinin then causes the release of proteolytic enzymes from the pancreas (item 4). The protein digestion products are then absorbed by enterocytes of the gut wall (item 1).

TMP14 pp. 824–825

12. E) Once the vomiting center has been sufficiently stimulated and the vomiting act has been initiated, the first effects are (1) a deep breath, (2) raising of the hyoid bone and larynx to pull the upper esophageal sphincter open, (3) closing of the glottis to prevent vomitus flow into the lungs, and (4) lifting of the soft palate to close the posterior nares. Next comes a strong downward contraction of the diaphragm along with simultaneous contraction of all the abdominal wall muscles, which squeezes the stomach between the diaphragm and the abdominal muscles, building the intragastric pressure to a high level. Finally, the lower esophageal sphincter relaxes completely, allowing expulsion of the gastric contents upward through the esophagus and into the mouth.

TMP14 pp. 837–838

13. E) The electrochemical gradient for sodium results from active transport of sodium ions through the basolateral membranes of the enterocytes and into the adjacent interstitial spaces. This electrochemical gradient for sodium powers the secondary active transport of many different nutrients into the epithelial cells of the gut wall. These nutrients include glucose, galactose, and several different amino acids.

TMP14 pp. 828–829

14. A) Arterial flow into the villus and the venous flow out of the villus are in directions opposite to each other, and the vessels lie in close apposition to each other. Because of this vascular arrangement, much of the blood oxygen diffuses out of the arterioles directly into the adjacent venules without ever being carried in the blood to the tips of the villi. As much as 80% of the oxygen may take this short-circuit route and is therefore not available for local metabolic functions of the villi.

TMP14 pp. 795–796

15. D) When feces enter the rectum, distention of the rectal wall initiates afferent signals that spread through the myenteric *plexus* to initiate peristaltic waves in the descending colon, sigmoid, and rectum, forcing feces toward the anus. As the peristaltic wave approaches the anus, the *internal* anal sphincter is relaxed by inhibitory signals from the myenteric plexus; if the *external* anal sphincter is also consciously, voluntarily relaxed at the same time, defecation occurs.

TMP14 pp. 805–806

16. G) When food enters the stomach, the pH of the gastric contents increases because the food buffers the acid (item 2). This increase in pH lowers somatostatin secretion from delta cells in the stomach wall, which leads to an increase in the rate of acid secretion (item 3). The pH of the gastric contents remains high until the buffering capacity of the food is saturated. Next, the pH of the gastric contents decreases (item 1), which stimulates the secretion of somatostatin. Somatostatin decreases the rate of acid secretion (item 4) by a direct action on parietal cells as well as by decreased gastrin release from G-cells.

TMP14 p. 814

17. B) Gastrin is the only gastrointestinal hormone listed that is produced and stored in the antrum of the stomach. All five gastrointestinal hormones are produced and stored in the duodenum and jejunum.

TMP14 p. 792

18. E) During the swallowing process, the soft palate is pulled upward to close the posterior nares to prevent reflux of food into the nasal cavities (item 3). Next, the palatopharyngeal folds on each side of the pharynx are pulled medially to approximate each other (item 4). The vocal cords of the larynx are strongly approximated, and the larynx is pulled upward and anteriorly by the neck muscles. The upper esophageal sphincter relaxes (item 1), and peristaltic contractions of the pharynx (item 2) move the bolus of food into the esophagus.

TMP14 pp. 797–798

19. B) The three secretagogues for gastric acid secretion are gastrin, histamine, and acetylcholine. These secretagogues have a synergistic or multiplicative action on acid secretion, which means that blocking the action of one secretagogue will cause the other secretagogues to be less effective. Hence, blocking the actions of histamine with an H_2 antagonist causes gastrin and acetylcholine to be less effective in stimulating acid secretion.

TMP14 p. 812

20. E) *Helicobacter pylori* is endemic in many underprivileged areas of the world. At least 75% of persons with peptic ulcers have been found to have chronic infection of the terminal portions of the gastric mucosa and initial portions of the duodenal mucosa, most often caused by the bacterium *H. pylori.* Once this infection begins, it can last a lifetime unless it is eradicated by antibacterial therapy.

TMP14 p. 835

21. B) Patients with a lactase deficiency cannot digest milk products that contain lactose (milk sugar). The operons of gut bacteria quickly switch over to lactose metabolism, which results in fermentation that produces copious amounts of gas (a mixture of hydrogen, carbon dioxide, and methane). This gas, in turn, may cause a range of abdominal symptoms including stomach cramps, bloating, and flatulence. The gas is absorbed by blood (especially in the colon) and exhaled from the lungs. Blood glucose levels do not increase because lactose is not digested to glucose and galactose in these patients.

TMP14 pp. 823, 838

22. A) The appearance of mass movements after meals is facilitated by gastrocolic and duodenocolic reflexes. These reflexes result from distention of the stomach and duodenum. They are greatly suppressed when the extrinsic autonomic nerves to the colon have been removed; therefore, the reflexes are likely transmitted by way of the autonomic nervous system. All the gut reflexes are named with the anatomical origin of the reflex as the prefix followed by the name of the gut segment in which the outcome of the reflex is observed. For example, the duodenocolic reflex begins in the duodenum and ends in the colon. When the duodenum is distended, nervous signals are transmitted to the colon, which stimulates mass movements. The enterogastric reflex occurs when signals originating in the intestines inhibit gastric motility and gastric secretion. The intestinointestinal reflex occurs when overdistention or injury to a bowel segment signals the bowel to relax. The rectosphincteric reflex, also called the *defecation reflex,* is initiated when feces enter the rectum and stimulates the urge to defecate.

TMP14 pp. 805–806

23. D) About 94% of the bile salts are reabsorbed into the blood from the small intestine, with about half of this by diffusion through the mucosa in the early portions of the small intestine and the remainder by an active transport process through the intestinal mucosa in the distal ileum.

TMP14 p. 819

24. E) Vitamin B_{12} is absorbed in the ileum; this absorption requires intrinsic factor, which is a glycoprotein secreted by parietal cells in the stomach. Binding of intrinsic factor to dietary vitamin B_{12} is necessary for attachment to specific receptors located in the brush border of the ileum. Atrophic gastritis is a type of autoimmune gastritis that is mainly confined to the acid-secreting corpus mucosa. The gastritis is diffuse, and severe atrophy eventually develops. Ileal resection is likely to cause diarrhea but not constipation. A gastric ulcer is possible but relatively unlikely. GERD is caused by gastric acid and bile reflux into the esophagus; mucosal damage and epithelial cell transformation lead to Barrett esophagus, which is a forerunner to adenocarcinoma, a particularly lethal cancer.

TMP14 p. 834

25. B) GIP is the only gastrointestinal hormone released by all three major foodstuffs (fats, proteins, and carbohydrates). The presence of fat and protein in the small intestine stimulates the release of CCK, but carbohydrates do not stimulate its release. The presence of protein in the antrum of the stomach stimulates the release of gastrin, but fat and carbohydrates do not stimulate its release. Fat has a minor effect to stimulate the release of motilin and secretin, but neither hormone is released by the presence of protein or carbohydrate in the gastrointestinal tract.

TMP14 p. 792

26. D) GIP is released by the presence of fat, carbohydrate, or protein in the gastrointestinal tract. GIP is a strong stimulator of insulin release and is responsible for the observation that an oral glucose load releases more insulin and is metabolized more rapidly than an equal amount of glucose administered intravenously. Intravenously administered glucose does not stimulate the release of GIP. Neither CCK nor VIP stimulates the release of insulin. GIP does not stimulate glucagon release, and glucagon has the opposite effect of insulin; that is, it would decrease the rate of glucose clearance from the blood. VIP does not stimulate GIP release.

TMP14 p. 792

27. C) Achlorhydria means simply that the stomach fails to secrete hydrochloric acid. This condition is diagnosed when the pH of the gastric secretions fails to decrease below 4 after stimulation by pentagastrin. When acid is not secreted, pepsin also usually is not secreted. Even when it is, the lack of acid prevents it from functioning because pepsin requires an acid medium for activity. Thus, protein digestion is impaired.

TMP14 pp. 812, 834

28. C) Achalasia is a condition in which the LES fails to relax during swallowing. As a result, food swallowed into the esophagus fails to pass from the esophagus into the stomach. Trace C shows a high, positive pressure that fails to decrease after swallowing, which is indicative of achalasia. Trace A shows a normal pressure tracing at the level of the LES, reflecting typical receptive relaxation in response to the food bolus. Trace E is similar to trace C, but the pressures are subatmospheric. Subatmospheric pressures occur only in the esophagus where it passes through the chest cavity.

TMP14 pp. 799, 833

29. D) Pepsinogen is the precursor of the enzyme pepsin. Pepsinogen is secreted from the peptic or chief cells of the gastric gland (also called the *oxyntic gland*). To be converted from the precursor form to the active form

(pepsin), pepsinogen must come in contact with hydrochloric acid or pepsin itself. Pepsin is a proteolytic enzyme that digests collagen and other types of connective tissue in meats.

TMP14 pp. 811–812

30. A) Cholecystokinin (CCK) is the only gastrointestinal hormone that inhibits gastric emptying under physiological conditions. This inhibition of gastric emptying keeps the stomach full for a prolonged time, which is one reason why a breakfast containing fat and protein "sticks with you" better than breakfast meals containing mostly carbohydrates. CCK also has a direct effect on the feeding centers of the brain to reduce further eating. Although CCK is the only gastrointestinal hormone that inhibits gastric emptying, all the gastrointestinal hormones except for gastrin are released to some extent by the presence of fat in the intestine.

TMP14 p. 792

31. F) All these factors can inhibit gastric acid secretion under normal physiological conditions. Gastric acid stimulates the release of somatostatin (a paracrine factor), which has a direct effect on the parietal cell to inhibit acid secretion, as well as an indirect effect mediated by suppression of gastrin secretion. Secretin and GIP inhibit acid secretion through a direct action on parietal cells as well as indirectly through suppression of gastrin secretion. Enterogastrones are unidentified substances released from the duodenum and jejunum that directly inhibit acid secretion. When acid or hypertonic solutions enter the duodenum, a neurally mediated decrease in gastric acid secretion follows.

TMP14 p. 814

32. B) Gastrin stimulates gastric acid secretion, and secretin and GIP inhibit gastric acid secretion under normal physiological conditions. It is important to differentiate the physiological effects of the gastrointestinal hormones from their pharmacologic actions. For example, gastrin and CCK have identical actions on gastrointestinal function when large pharmacologic doses are administered, but they do not share any actions at normal physiological concentrations. Likewise, GIP and secretin share multiple actions when pharmacologic doses are administered, but only one action is shared at physiological concentrations: inhibition of gastric acid secretion.

TMP14 p. 792

33. E) The cephalic phase of gastric secretion occurs before food enters the stomach. Seeing, smelling, chewing, and anticipating food are perceived by the brain, which "tells" the stomach to prepare for a meal. Stimuli for the cephalic phase thus include mechanoreceptors in the mouth, chemoreceptors (smell and taste), thought of food, and hypoglycemia. Because the cephalic phase of gastric secretion is mediated entirely by way of the vagus nerves, vagotomy can abolish the response. Antacids neutralize gastric acid, but they do not inhibit gastric secretion. An antigastrin antibody would attenuate (but not abolish) the cephalic phase because this would have no direct effect on histamine and acetylcholine stimulation of acid secretion. Atropine would attenuate the cephalic phase by blocking acetylcholine receptors on parietal cells; however, atropine does not abolish acetylcholine stimulation of gastrin secretion. A histamine H_2 blocker would attenuate the cephalic phase of gastric secretion but would not abolish it.

TMP14 p. 813

34. C) MMCs (sometimes called *interdigestive myoelectric complexes*) are peristaltic waves of contraction that begin in the stomach and slowly migrate in an aboral direction along the entire small intestine to the colon. By sweeping undigested food residue from the stomach, through the small intestine, and into the colon, MMCs function to maintain low bacterial counts in the upper intestine. Bacterial overgrowth syndrome can occur when the normally low bacterial colonization in the upper gastrointestinal tract increases significantly. It should be clear that an absence of MMCs would decrease duodenal motility and gastric emptying. MMCs do not have a direct effect on mass movements and swallowing.

TMP14 pp. 792–793

35. C) Trace C shows a basal subatmospheric pressure with a positive pressure wave caused by passage of the food bolus. Trace A does not correspond to any normal event in the esophagus. Trace B could represent the LES in a patient with achalasia. Trace D depicts normal operation of the LES. Trace E shows a basal positive pressure trace, which does not occur where the esophagus passes through the chest cavity.

TMP14 p. 799

36. C) Gastric emptying is accomplished by coordinated activities of the stomach, pylorus, and small intestine. Conditions that favor gastric emptying include (a) increased tone of the orad stomach, which helps to push chyme toward the pylorus; (b) forceful peristaltic contractions in the stomach that move chyme toward the pylorus; (c) relaxation of the pylorus, which allows chyme to pass into the duodenum; and (d) absence of segmentation contractions in the intestine, which can otherwise impede the entry of chyme into the intestine.

TMP14 pp. 800–801

37. A) The toxin from *V. cholerae* (cholera toxin) causes an irreversible increase in cAMP levels (not cGMP levels) in the enterocytes located in the crypts of Lieberkühn

of the small intestine. This increase in cAMP causes an irreversible opening of chloride channels on the luminal membrane. Movement of chloride ions into the gut lumen causes a secondary movement of sodium ions to maintain electrical neutrality. Water follows the osmotic gradient created by sodium and chloride, causing a tremendous increase in fluid loss into the gut lumen. Severe diarrhea follows.

TMP14 pp. 830, 836

38. B) Cholera toxin causes an irreversible opening of chloride channels in the enterocytes located in the crypts of Lieberkühn of the small intestine, as indicated in the explanation for the previous answer. Although sodium ions enter the gut lumen to maintain electrical neutrality after the flux of chloride ions into the gut lumen, the sodium ions move through relatively large paracellular pathways rather than through actual sodium channels. Calcium, potassium, and magnesium do not have a significant role during an infection with *V. cholerae.*

TMP14 pp. 830, 836

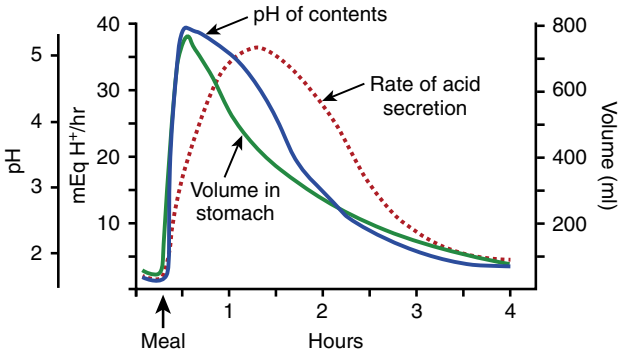
39. B) Enterocytes are derived from stem cells located in the crypts of Lieberkühn of the small intestine. They mature as they migrate upward toward the villus tip, where they are extruded into the gut lumen, becoming part of the ingesta. In humans, the entire population of epithelial cells is replaced in 3 to 6 days. Cholera also usually runs its course in 3 to 6 days. Because cholera toxin causes an irreversible opening of chloride channels in the enterocytes, it is thought that the time course of cholera is dictated by the life span of the enterocytes.

TMP14 pp. 830, 836

40. E) Cholecystokinin (CCK) is the only gastrointestinal hormone that inhibits gastric emptying under normal physiological conditions. CCK inhibits gastric emptying by relaxing the orad stomach, which increases its compliance. When the compliance of the stomach is increased, the stomach can hold a larger volume of food without excess buildup of pressure in the lumen. None of the gastrointestinal hormones increases gastric emptying under physiological conditions; however, gastrin, secretin, and GIP can inhibit gastric emptying when pharmacologic doses are administered experimentally.

TMP14 p. 792

41. E) The figure shows the time course of gastric pH, rate of acid secretion, and stomach volume immediately before and for 4 hours after a meal. Note that the pH of the gastric juice is lowest immediately before the meal (not an answer choice) and 4 hours after consuming the meal (the correct answer). It is a common misconception that the pH of the gastric juice is lowest (most acidic) after a meal, when acid secretion is highest.



TMP14 pp. 813–814

42. A) Gastrin and CCK do not share any effects on gastrointestinal function at normal physiological conditions; however, they have identical actions on gastrointestinal function when pharmacologic doses are administered. Gastrin stimulates gastric acid secretion and mucosal growth throughout the stomach and intestines under physiological conditions. CCK stimulates growth of the exocrine pancreas and inhibits gastric emptying under normal conditions. CCK also stimulates gallbladder contraction, relaxation of the sphincter of Oddi, and secretion of bicarbonate and enzymes from the exocrine pancreas.

TMP14 p. 792

43. A) The frequency of slow waves is fixed in various parts of the gut. The maximum frequency of smooth muscle contractions cannot exceed the slow-wave frequency. The slow-wave frequency averages about 3 per minute in the stomach, 12 per minute in the duodenum, 10 per minute in the jejunum, and 8 per minute in the ileum. Therefore, the duodenum is most likely to have the highest frequency of smooth muscle contractions.

TMP14 pp. 787–788

44. D) When feces enter the rectum, distention of the rectal wall initiates signals that spread through the myenteric plexus to initiate peristaltic waves in the descending colon, sigmoid colon, and rectum, all of which force feces toward the anus. At the same time, the internal anal sphincter relaxes, allowing the feces to pass. In people with transected spinal cords, the defecation reflexes can cause automatic emptying of the bowel because the external anal sphincter is normally controlled by the conscious brain through signals transmitted in the spinal cord.

TMP14 pp. 805–806

45. B) The use of NSAIDs may result in NSAID-associated gastritis or peptic ulceration. Chronic gastritis, by definition, is a histopathologic entity characterized by chronic inflammation of the stomach mucosa. When inflammation affects the gastric corpus, parietal cells

are inhibited, leading to reduced acid secretion. Although diagnosis of chronic gastritis can only be ascertained histologically, the administration of pentagastrin should produce a less than expected increase in gastric acid secretion. Pentagastrin is a synthetic gastrin composed of the terminal four amino acids of natural gastrin plus the amino acid alanine. It has all the same physiological properties of natural gastrin. Although gastrin and pentagastrin can both stimulate growth of the duodenal mucosa, it should be clear that intravenous pentagastrin would not cause substantial growth in the context of a clinical test. In any case, chronic administration of pentagastrin would not lead to a less than expected growth of the duodenal mucosa. Pentagastrin is not expected to increase gastrin secretion, pancreatic enzyme secretion, or pancreatic growth.

TMP14 pp. 833–834

46. E) The presence of acid, fatty acids, and hyperosmotic solutions in the duodenum and jejunum leads to suppression of acid secretion through a variety of mechanisms. Acid stimulates the secretion of secretin from the small intestine, which in turn inhibits acid secretion from parietal cells. Acidification of the antrum and oxyntic gland area of the stomach stimulates the release of somatostatin, which in turn inhibits acid secretion by a direct action on the parietal cells and an indirect action mediated by suppression of gastrin secretion. The presence of fatty acids in the small intestine stimulates the release of GIP, which inhibits acid secretion both directly (parietal cell inhibition) and indirectly (by decreasing gastrin secretion). Hyperosmotic solutions in the small intestine cause the release of unidentified enterogastrones, which directly inhibit acid secretion from parietal cells. Isotonic solutions have no effect on acid secretion.

TMP14 p. 814

47. C) Before a meal, when the stomach is empty, the pH of the gastric juice is at its lowest point, and acid secretion is suppressed. Acid secretion is suppressed in part because (a) the concentrated hydrogen ions in the gastric juice stimulate somatostatin release, which has a direct action to decrease the secretion of both gastrin and acid, and (b) the acid itself has a direct effect to suppress parietal cell secretions. When a meal is taken, the buffering effects of the food cause the gastric pH to increase, which in turn decreases somatostatin release. Cholecystokinin and vasoactive intestinal peptide do not have a role in the regulation of gastric acid secretion.

TMP14 p. 814

48. D) The act of vomiting is preceded by antiperistalsis that may begin as far down in the gastrointestinal tract as the ileum. Distention of the upper portions of the gastrointestinal tract (especially the duodenum) becomes the exciting factor that initiates the actual act of vomiting. At the onset of vomiting, strong contractions occur in the duodenum and stomach along with partial relaxation of the lower esophageal sphincter. From then on, a specific vomiting act ensues that involves (a) a deep breath, (b) relaxation of the upper esophageal sphincter, (c) closure of the glottis, and (d) strong contractions of the abdominal muscles and diaphragm.

TMP14 pp. 837–838

49. E) Secretin inhibits gastrin secretion from normal G-cells in the antrum and duodenum but stimulates gastrin secretion in gastrinoma cells. Any increase in serum gastrin concentration greater than 110 pg/ml above baseline after administration of human secretin is diagnostic of gastrinoma (also called *Zollinger-Ellison syndrome*). The secretin test is considered the most sensitive and accurate diagnostic method for gastrinoma.

TMP14 pp. 792, 814

50. E) Essentially all proteolytic enzymes are secreted in an inactive form, which prevents autodigestion of the secreting organ. Enterokinase is physically attached to the brush border of the enterocytes that line the inner surface of the small intestine. Enterokinase activates trypsinogen to become trypsin in the gut lumen. The trypsin then catalyzes the formation of additional trypsin from trypsinogen, as well as several other proenzymes (e.g., chymotrypsinogen, procarboxypeptidase, proelastase). Pepsin is first secreted as pepsinogen, which has no proteolytic activity. However, as soon as it comes into contact with hydrochloric acid, and especially in contact with previously formed pepsin plus hydrochloride acid, it is activated to form pepsin.

TMP14 p. 815

51. B) Neither plasma gastrin levels nor the rate of acid secretion is diagnostic for duodenal ulcer. However, when patients with a duodenal ulcer are pooled together, they exhibit a statistically significant increase in the rate of acid secretion and a statistically significant decrease in plasma gastrin levels. How is this possible? The basal and maximal acid secretion rates of normal subjects range from 1 to 5 mEq/h and from 6 to 40 mEq/h, respectively, which overlaps with the basal (2-10 mEq/h) and maximal (30-80 mEq/h) acid secretion rates of persons with a duodenal ulcer. The increase in acid secretion of the average person with a duodenal ulcer suppresses the secretion of gastrin from the antrum of the stomach. It should be obvious that endoscopy is diagnostic for duodenal ulcer.

TMP14 pp. 834–835

52. E) All of the gastrointestinal hormones are released after a meal, and all have physiological effects.

TMP14 p. 792

53. A) *H. pylori* is a bacterium that accounts for 95% of patients with a duodenal ulcer and virtually 100% of patients with a gastric ulcer when chronic use of aspirin or other NSAIDs are eliminated. *H. pylori* is characterized by high urease activity, which metabolizes urea to NH_3 (ammonia). Ammonia reacts with H^+ to become ammonium (NH_4^+). This reaction allows the bacterium to withstand the acid environment of the stomach. The ammonium production is believed to be the major cause of cytotoxicity because the ammonium directly damages epithelial cells, increasing the permeability of the gastric mucosal barrier. Bile salts and NSAIDs can also damage the gastric mucosal barrier, but these substances are not directly related to *H. pylori* infection. Pepsin can exacerbate the mucosal lesions caused by *H. pylori* infection, but pepsin levels are not increased by *H. pylori.* It should be clear that gastrin does not mediate the mucosal damage caused by *H. pylori.*

TMP14 p. 835

54. B) Slow-wave frequency is not affected significantly by either the autonomic nervous system or hormones; it is relatively constant at any given location in the small intestine. When a slow wave reaches a threshold value, a calcium spike potential (action potential) occurs, and calcium ions enter the smooth muscle cell, which causes it to contract. Norepinephrine hyperpolarizes smooth muscle cells in the intestine and thereby decreases the likelihood that the membrane potential can reach a threshold value. Therefore, norepinephrine does not affect the basal slow-wave frequency of 10 occurrences per minute but does lower the contraction frequency of the smooth muscle cells to zero occurrences per minute in this problem.

TMP14 pp. 788, 802–803

55. E) The defecation reflex (also called the *rectosphincteric reflex*) occurs when feces enter the rectum. When the rectum is stretched, the internal anal sphincter relaxes, and the rectum contracts, pushing the feces toward the anus. The external anal sphincter is controlled voluntarily and can be contracted when defecation is not possible. Therefore, when a person feels the urge to defecate, the internal anal sphincters are relaxed, the rectum contracts, and the external anal sphincter is either contracted or relaxed depending on the circumstances.

TMP14 pp. 805–806

56. E) Oxygen is shunted from the artery of a villus into its venous drainage so that by the time the arterial blood reaches the villus tip, the oxygen tension has been reduced to about 10 mm Hg. Adenosine dilates the villus artery, increasing blood flow to the villus tip. This increase in blood flow decreases the residence time for blood in the artery so that greater amounts of oxygen can reach the villus tip, thus increasing the oxygen tension at the villus tip. Factors that decrease intestinal blood flow (e.g., hemorrhagic shock and a severe degree of exercise) can lead to ischemic death of villi because of their low level of oxygenation.

TMP14 pp. 795–796

57. E) One of the most critical actions of gastrointestinal hormones is their trophic activity. Gastrin can stimulate mucosal growth throughout the gastrointestinal tract as well as growth of the exocrine pancreas. If most of the endogenous gastrin is removed by antrectomy, the gastrointestinal tract atrophies. Exogenous gastrin prevents the atrophy. Partial resection of the small intestine for tumor removal, morbid obesity, or other reasons results in hypertrophy of the remaining mucosa. The mechanism for this adaptive response is poorly understood. Both cholecystokinin and secretin stimulate growth of the exocrine pancreas. GIP and motilin do not appear to have trophic actions on the gastrointestinal tract.

TMP14 p. 792

58. B) Relaxation of the ileocecal sphincter occurs with or shortly after eating. This reflex has been termed the *gastroileal reflex.* It is not clear whether the reflex is mediated by gastrointestinal hormones (gastrin and cholecystokinin) or extrinsic autonomic nerves to the intestine. Note that the gastroileal reflex is named with the origin of the reflex first (gastro) and the target of the reflex named second (ileal). This method of naming is characteristic of all the gastrointestinal reflexes. The enterogastric reflex involves signals from the colon and small intestine that inhibit gastric motility and gastric secretion. The gastrocolic reflex causes the colon to evacuate when the stomach is stretched. The intestinointestinal reflex causes a bowel segment to relax when it is overstretched. The rectosphincteric reflex is also called the *defecation reflex.*

TMP14 p. 803

59. D) Damage to the gastric mucosal barrier allows hydrogen ions to back-leak into the mucosa in exchange for sodium ions. A low pH in the mucosa causes mast cells to leak histamine, which damages the vasculature, causing ischemia. The ischemic mucosa allows a greater leakage of hydrogen ions—leading to more cell injury and death—resulting in a vicious cycle. Factors that normally strengthen the gastric mucosal barrier include mucus (which impedes the influx of hydrogen ions), gastrin (which stimulates mucosal growth), certain prostaglandins (which can stimulate mucus secretion), and various growth factors that can stimulate growth of blood vessels, gastric mucosa, and other tissues. Factors that weaken the gastric mucosal barrier include *H. pylori* (a bacterium that produces toxic levels of ammonium), as well as aspirin, NSAIDs, ethanol, and bile salts.

TMP14 pp. 833–834

60. B) Fat entering the small intestine is first emulsified into smaller globules by bile released from the gallbladder. Pancreatic lipase in conjunction with the coenzyme colipase then digests the fat (which is mostly triglycerides) into monoglycerides and free fatty acids; these substances then become surrounded by bile salts to form water-soluble aggregates called *micelles.* When a micelle makes contact with an enterocyte of the intestinal wall, the monoglycerides and free fatty acids diffuse directly through the cell membrane into the enterocyte; triglycerides are too large to be absorbed. Once inside the enterocyte, the monoglycerides and free fatty acids form new triglyceride molecules that are subsequently packaged by the Golgi apparatus into chylomicrons. The chylomicrons exocytose at the basolateral membrane of the enterocyte and enter a lymphatic capillary (central lacteal) in the villus.

TMP14 p. 826

61. C) The medical treatment of gastric ulcers is aimed at restoring the balance between acid secretion and mucosal protective factors. Proton pump inhibitors are drugs that covalently bind and irreversibly inhibit the H^+/K^+ adenosine triphosphatase (ATPase) pump, effectively inhibiting acid release. Therapy can also be directed toward histamine release, that is, H2 blockers, such as cimetidine (Tagamet), ranitidine (Zantac), famotidine (Pepcid), and nizatidine (Axid). These agents selectively block the H_2 receptors in the parietal cells. Antibiotic therapy is used to eradicate the *H. pylori* infection. NSAIDs can cause damage to the gastric mucosal barrier, which is a forerunner of gastric ulcer.

TMP14 p. 835

62. B) Movement of chloride ions out of cells leads to secretion of fluid by cells. CF is caused by abnormal chloride ion transport on the apical surface of epithelial cells in exocrine gland tissues. The CF transmembrane regulator (CFTR) protein functions both as a cAMP-regulated Cl^- channel and, as its name implies, a regulator of other ion channels. The fully processed form of CFTR is found in the plasma membrane of normal epithelia. Absence of CFTR at appropriate cellular sites is often part of the pathophysiology of CF. However, other mutations in the CF gene produce CFTR proteins that are fully processed but are nonfunctional or only partially functional at the appropriate cellular sites.

TMP14 p. 830

63. A) Hydrogen ions leak into the mucosa when it is damaged. As the hydrogen ions accumulate in the mucosa, the intracellular buffers become saturated, and the pH of the cells decreases, resulting in injury and cell death. The hydrogen ions also damage mast cells, causing them to secrete excess amounts of histamine. The histamine exacerbates the condition by damaging blood capillaries within the mucosa. The result is focal ischemia, hypoxia, and vascular stasis. The mucosal lesion is a forerunner of gastric ulcer. Mucus secretion helps strengthen the gastric mucosal barrier because mucus impedes the leakage of hydrogen ions into the mucosa. Various proton pump inhibitors are used as a treatment modality for gastric ulcers because these inhibitors can decrease the secretion of hydrogen ions (protons). The tight junctions between cells within the mucosa help prevent the back-leak of hydrogen ions. Vagotomy was once used to treat gastric ulcer disease because severing or crushing the vagus nerve decreases gastric acid secretion.

TMP14 pp. 833–834

64. D) The fundus of the stomach and lower esophageal sphincter both relax during a swallow while the bolus of food is still higher in the esophagus. This phenomenon is called *receptive relaxation.* Receptive relaxation is mediated by afferent and efferent pathways in the vagus nerves. Nitric oxide is the neurotransmitter thought to mediate receptive relaxation at the smooth muscle cell. Motilin is a gastrointestinal hormone that mediates migrating motility complexes (also called *housekeeping contractions*); these contractions occur between meals. Gastrin and histamine do not have significant effects on smooth muscle contraction or relaxation at physiological levels. Norepinephrine can decrease smooth muscle contraction in the small intestine but is not involved in receptive relaxation.

TMP14 p. 799

65. A) Mass movements force feces into the rectum. When the walls of the rectum are stretched by the feces, the defecation reflex is initiated, and a bowel movement follows when this is convenient. Mass movements do not affect gastric motility. Haustrations are bulges in the large intestine caused by contraction of adjacent circular and longitudinal smooth muscle. It should be clear that mass movements in the colon do not affect esophageal contractions or pharyngeal peristalsis.

TMP14 pp. 805–806

66. E) This woman has gastroparesis (also called *delayed gastric emptying*). This disorder slows or at times even stops the movement of chyme from the stomach to the duodenum. Diabetes is the most commonly known cause of gastroparesis; it occurs in about 20% of persons with type 1 diabetes. The high blood glucose level is thought to damage the vagus nerves and thereby delay gastric emptying.

TMP14 pp. 800–801

67. C) Acid acts directly on somatostatin cells to stimulate the release of somatostatin. The somatostatin decreases acid secretion by directly inhibiting the acid-secreting parietal cells and indirectly by inhibiting gastrin secretion from G-cells in the antrum. Acid is a weak stimulus for CCK release, but CCK does not inhibit (or

stimulate) gastrin release. Acid does not stimulate GIP release. Fatty acids are a weak stimulus for motilin, but motilin does not affect gastrin release. Fatty acids are not thought to stimulate somatostatin release.

TMP14 pp. 792, 814

68. C) All five gastrointestinal hormones are released from both the duodenum and jejunum. Only gastrin is released from the antrum. Small amounts of cholecystokinin and secretin are also released from the ileum. No gastrointestinal hormones are released from the colon or esophagus.

TMP14 p. 792

69. D) Primary peristalsis of the esophagus is a continuation of pharyngeal peristalsis; central control originates in the swallowing center located in the medulla and pons. Visceral somatic fibers in the vagus nerves directly innervate smooth muscle fibers of the pharynx and upper esophagus, which coordinate pharyngeal peristalsis and primary peristalsis of the esophagus. Esophageal contractions can occur independently of vagal stimulation by a local stretch reflex initiated by the food bolus itself; this phenomenon is called *secondary peristalsis.* Although the vagus nerves can stimulate gastric acid secretion, gastrin release, and pancreatic bicarbonate secretion, these processes can be activated by other mechanisms. Thus, elimination of vagal stimulation does not completely eliminate them.

TMP14 p. 799

70. D) Persons with duodenal ulcers have about 2 billion parietal cells and can secrete about 40 mEq H^+ per hour. Unaffected individuals have about 50% of these values. Plasma gastrin levels are related inversely to acid secretory capacity because of a feedback mechanism by which antral acidification inhibits gastrin release. Thus, plasma gastrin levels are usually reduced in persons with duodenal ulcers. Maximal acid secretion and plasma gastrin levels are not diagnostic for duodenal ulcer disease because of significant overlap with the normal population among persons in each group.

TMP14 pp. 834–835

71. A) Intrinsic factor is a glycoprotein secreted from parietal cells (i.e., acid-secreting cells in the stomach) that is necessary for absorption of vitamin B_{12}. The patient has a diminished capacity to secrete acid because of chronic gastritis. Because acid and intrinsic factor are both secreted by parietal cells, a diminished capacity to secrete acid is usually associated with diminished capacity to secrete intrinsic factor. Ptyalin, also known as *salivary amylase*, is an enzyme that begins carbohydrate digestion in the mouth. The secretion of ptyalin is not affected by gastritis. Rennin, known also as *chymosin*, is a proteolytic enzyme synthesized by chief cells in the stomach. Its role in digestion is to curdle or coagulate milk in the stomach, a process of considerable importance in very young animals. It should be clear that saliva secretion is not affected by gastritis. Trypsin is a proteolytic enzyme secreted by the pancreas.

TMP14 p. 834

72. C) Parietal cells have receptors for all four substances shown. Stimulation of receptors for gastrin, acetylcholine, and histamine lead to increased secretion of gastric acid; stimulation of somatostatin receptors inhibits gastric acid secretion.

TMP14 p. 813

73. C) This woman has celiac disease, also called gluten-sensitive enteropathy, which is a chronic disease of the digestive tract that interferes with the absorption of nutrients from food. Mucosal lesions seen on upper gastrointestinal biopsy specimens are the result of an abnormal, genetically determined, cell-mediated immune response to gliadin, a constituent of the gluten found in wheat; a similar response occurs to comparable proteins found in rye and barley. Gluten is not found in oats, rice, or corn. When persons with celiac disease ingest gluten, the mucosa of their small intestine is damaged by an immunologically mediated inflammatory response, which results in malabsorption and maldigestion at the brush border. Digestion of fat is normal in persons with celiac disease because lipase secreted by the pancreas still functions normally. Malabsorption in celiac disease increases the stool content of carbohydrates, fat, and nitrogen. There is no cure for celiac disease, but a strict gluten-free diet can help manage symptoms and promote intestinal healing.

TMP14 pp. 835–836

74. B) This infant has Hirschsprung's disease, which is characterized by a congenital absence of ganglion cells in the distal colon, resulting in a functional obstruction. Prolonged fecal stasis can lead to enterocolitis (i.e., inflammation of the colon); full-thickness necrosis and perforation can occur in severe cases. In achalasia, the lower esophageal sphincter fails to relax during swallowing. Halitosis (bad breath) can occur in persons with Hirschsprung's disease, but this condition is not serious. Peptic ulcer and pancreatitis (inflammation of the pancreas) are not common in persons with Hirschsprung's disease.

TMP14 p. 836

75. C) About 20% of persons older than 65 years have gallstones (cholelithiasis) in the United States, and 1 million newly diagnosed cases of gallstones are reported each year. Gallstones are the most common cause of biliary obstruction. Regardless of the cause of gallstones, serum bilirubin values (especially direct or conjugated) are usually elevated. Indirect or unconjugated bilirubin values are usually normal or only slightly elevated. Only choice C shows a high level of direct bili-

rubin (conjugated bilirubin) compared with the level of indirect bilirubin (unconjugated bilirubin).

TMP14 pp. 835, 874–875

76. A) Intestinal absorption of immunoglobulins (present in colostrum) during early infancy occurs by endocytosis in the duodenum and jejunum. This ability to absorb large molecules by endocytosis occurs during the first several months of life but does not occur thereafter (except in the ileum for absorption of vitamin B_{12}). Facilitated diffusion, passive diffusion, and primary and secondary active transport are all normal transport processes in enterocytes.

TMP14 pp. 830–831

77. C) Pancreatitis is inflammation of the pancreas. The pancreas secretes digestive enzymes into the small intestine that are essential in the digestion of fats, proteins, and carbohydrates. Reduced secretion of fluid into the pancreatic ducts in cystic fibrosis (CF) cause these digestive enzymes to accumulate in the ducts. The digestive enzymes then become activated in the pancreatic ducts (which typically would not occur) and can begin to "digest" the pancreas, leading to inflammation and a myriad of other problems (cysts and internal bleeding). Enterokinase is located at the brush border of intestinal enterocytes, where it normally activates trypsin from its precursor, trypsinogen. Trypsin inhibitor is normally present in the pancreatic ducts, where it prevents trypsin from being activated and thus prevents autodigestion of the pancreas. When the ducts are blocked in cystic fibrosis, the available trypsin inhibitor is insufficient to prevent trypsin from being activated. Excessive secretion of CCK does not occur in persons with CF. Gallstone obstruction can lead to pancreatitis (by autodigestion) when the obstruction prevents pancreatic juice from entering the intestine, but this is unrelated to CF.

TMP14 pp. 815, 835

UNIT XIII

Metabolism and Temperature Regulation

1. A 54-year-old man eats a bowl of ice cream. Fifty minutes later, chylomicrons enter his venous system through the thoracic duct. Which of the following best describes the major constituent of a typical chylomicron in this man?

   A) Apoprotein B
   B) Cholesterol
   C) Monoglycerides
   D) Phospholipids
   E) Triglycerides

2. All the following tissues can use fatty acids for energy EXCEPT one. Which one is this EXCEPTION?

   A) Brain
   B) Heart
   C) Kidney
   D) Liver
   E) Skeletal muscle

3. A 56-year-old woman with chronic liver disease is brought to the physician because of confusion, a depressed level of consciousness, personality changes, and intellectual impairment. Laboratory tests support a diagnosis of liver encephalopathy. Which of the following blood factors is the most likely cause of this condition?

   A) Ammonia
   B) Arginine
   C) Citrulline
   D) Ornithine
   E) Urea

4. Elimination of bilirubin from the body requires several steps under normal conditions that include (1) conjugation of bilirubin with glucuronic acid, (2) carriage of bilirubin by albumin in plasma, (3) excretion of bilirubin into bile, and (4) uptake of free bilirubin by hepatocytes. Which of the following best describes the correct temporal order of events?

   A) 4, 3, 2, 1
   B) 3, 1, 4, 2
   C) 3, 4, 1, 2
   D) 2, 1, 4, 3
   E) 4, 2, 1, 3
   F) 2, 4, 1, 3
   G) 1, 2, 3, 4
   H) 1, 3, 2, 4

5. A 45-year-old physician binge drinks alcohol three to five times per week and does not eat during the alcoholic binges. Which of the following long-term complications are possible in this man?

	Jaundice	Ascites	Esophageal Varices	Peripheral Edema
A)	No	Yes	Yes	No
B)	No	No	Yes	Yes
C)	Yes	Yes	No	Yes
D)	Yes	Yes	Yes	No
E)	Yes	Yes	Yes	Yes

6. A 54-year-old woman visits the physician because of upper abdominal pain and vomiting. Physical examination shows upper abdominal tenderness and diminished bowel sounds. Blood tests show a 3-fold increase in plasma amylase levels compared with normal. CT scan shows a mass at the papilla of Vater. Activation of which of the following substances is the most likely cause of this woman's condition?

   A) Chymotrypsin
   B) Enterokinase
   C) Lipase
   D) Trypsin inhibitor
   E) Trypsinogen

7. A 64-year-old, unacclimatized man works outside on a hot day. Compared with an acclimatized person, this unacclimatized man is most likely to have which of the following?
   A) Decreased loss of sodium chloride in sweat only
   B) Decreased sweat production only
   C) Decreased sweat production and increased loss of sodium chloride in sweat
   D) Increased loss of sodium chloride in sweat only
   E) Increased sweat production only
   F) Increased sweat production and decreased loss of sodium chloride in sweat

8. A 29-year-old man sits nude in a room that has a temperature of 71°F and relative humidity of 50%. He is 6 feet, 2 inches tall and weighs 205 lb (body mass index = 26.3). The greatest amount of body heat is most likely to be lost by which of the following mechanisms?
   A) Conduction to air
   B) Conduction to objects
   C) Evaporation
   D) Radiation

9. The hypothalamic set-point temperature normally averages about 98.6°F. Which of the following factors can alter the set-point level for core temperature control?
   A) Skin temperature only
   B) Pyrogens only
   C) Thyroxin only
   D) Skin temperature and pyrogens only
   E) Skin temperature, pyrogens, and thyroxin

10. Which of the following describes the neurotransmitter released from neurons that innervate sweat glands?
    A) Norepinephrine
    B) Acetylcholine
    C) Epinephrine
    D) Dopamine
    E) Glycine

11. A 23-year-old student gets lost in a snowstorm and does not have proper clothing or supplies to make a fire. The body temperature of the student decreases slowly over the next 18 hours. At which of the following temperatures is the ability of the hypothalamus to regulate body temperature completely lost (in °F)?
    A) 95.0
    B) 92.5
    C) 90.0
    D) 87.5
    E) 85.0

12. Fatty acid degradation in mitochondria produces which two-carbon substance?
    A) Acetyl coenzyme A
    B) Carnitine
    C) Glycerol
    D) Glycerol 3-phosphate
    E) Oxaloacetic acid

13. The following events occurred during the course of a fever in a 12-year-old boy: (1) cutaneous vasodilation and sweating; (2) a return of the set-point temperature to normal; (3) an increase in the set-point temperature to 103°F; and (4) shivering, chills, and cutaneous vasoconstriction. Which of the following best describes the correct temporal order of events during the fever in this boy?
    A) 4, 3, 2, 1
    B) 3, 4, 2, 1
    C) 2, 1, 4, 3
    D) 4, 2, 1, 3
    E) 3, 4, 1, 2
    F) 1, 2, 3, 4
    G) 2, 3, 1, 4
    H) 1, 3, 2, 4

14. A 72-year-old man with a 25-year history of alcoholism and liver disease visits his physician because of sudden weight gain. One year ago, the man had a body mass index (BMI) of 24.9 kg/m^2; today his BMI is 28.5 kg/m^2. Physical examination shows +3 edema in his feet and moderate ascites. Which condition is most likely to have promoted the development of both ascites and peripheral edema in this man?
    A) Decreased capillary hydrostatic pressure
    B) Decreased plasma colloid osmotic pressure
    C) Increased capillary hydrostatic pressure
    D) Increased plasma colloid osmotic pressure

15. A 24-year-old student goes hiking in the Mojave Desert during spring break. The environmental temperature is 105°F, and the relative humidity is 20%. Which option best describes the major mechanism of heat loss in this student?
    A) Conduction to air
    B) Conduction to objects
    C) Convection
    D) Evaporation
    E) Radiation

16. A 32-year-old student consumes a meal containing 10% fat, 50% carbohydrate, and 40% protein. Four hours later, the metabolic rate has increased by about 30%, even though the student is sitting at rest. Which substance is most likely to cause the greatest increase in metabolic rate in this student 4 hours after consuming the meal?
    A) Carbohydrate
    B) Fat
    C) Protein

17. A 90-year-old man is found sitting in his yard, vomiting on a hot summer day with the lawnmower running. The man is confused and dizzy. He is admitted to the hospital as an emergency patient. His body temperature is 105°F, his heart rate is 110 beats/min, and his skin turgor is poor. Which symptom is unlikely in this man?

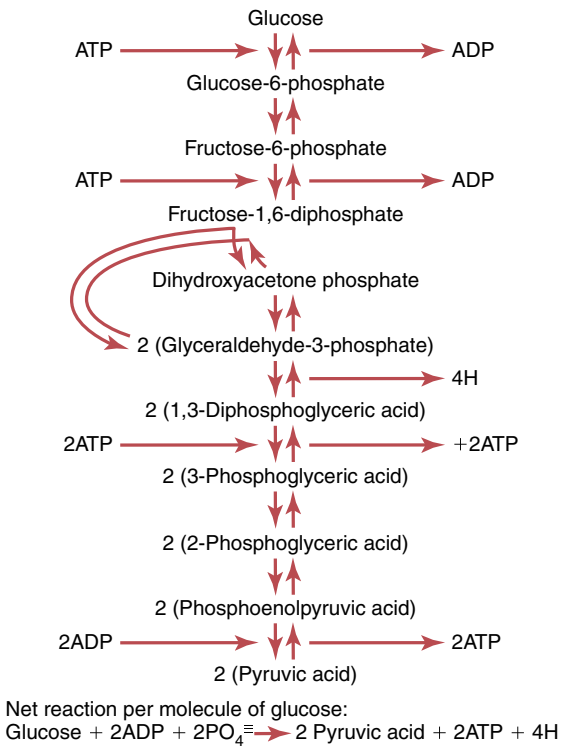
A) Headache
B) Hot skin
C) Hypotension
D) Nausea
E) Sweating

18. A 43-year-old woman on a camping trip has underestimated the cool evening temperatures, so she wraps herself in a thin sheet of polyester film with a reflective surface (Mylar), also known as an emergency blanket or space blanket. She feels warm immediately. Which heat loss mechanism most likely accounts for the effectiveness of this paper-thin, reflective Mylar blanket?

A) Conduction to air
B) Conduction to objects
C) Convection
D) Evaporation
E) Radiation

Questions 19 and 20

Refer to the following figure to answer the next two questions.



Net reaction per molecule of glucose:
Glucose + 2ADP + $2PO_4^{\equiv}$ → 2 Pyruvic acid + 2ATP + 4H

19. Abundant amounts of adenosine triphosphate (ATP) in the cytoplasm of the cell inhibit which step in glycolysis?

A) Conversion of glucose to glucose-6-phosphate
B) Conversion of fructose-6-phosphate to fructose-1,6-diphosphate
C) Conversion of 1,3-diphosphoglyceric acid to 3-phosphoglyceric acid
D) Conversion of phosphoenolpyruvic acid to pyruvic acid

20. Abundant amounts of adenosine diphosphate (ADP) or adenosine monophosphate (AMP) stimulate which step in glycolysis?

A) Conversion of glucose to glucose-6-phosphate
B) Conversion of fructose-6-phosphate to fructose-1,6-diphosphate
C) Conversion of 1,3-diphosphoglyceric acid to 3-phosphoglyceric acid
D) Conversion of phosphoenolpyruvic acid to pyruvic acid

21. A 44-year-old woman with hepatic cirrhosis comes to her physician for a checkup. Physical examination shows ascites. The woman's prothrombin time has doubled since her last visit 3 months ago, and her hematocrit is now 30%. What is the most likely cause of this low hematocrit?

A) Colon cancer
B) Esophageal varices
C) Jaundice
D) Acute pancreatitis
E) Scleral icterus

22. During resting conditions, about 75% of the blood flowing through the liver is from the portal vein, and the remainder is from the hepatic artery. Which option best describes the liver circulation in terms of resistance, pressure, and flow?

	Resistance	Pressure	Flow
A)	High	High	High
B)	High	Low	High
C)	Low	High	Low
D)	Low	Low	High
E)	Low	Low	Low

23. A scuba diver explores an underwater lava flow where the water temperature is 102°F. Which profile best describes the mechanisms of heat loss that are effective in this man?

	Evaporation	Radiation	Convection	Conduction
A)	No	No	No	Yes
B)	No	No	No	No
C)	Yes	Yes	No	Yes
D)	No	Yes	No	Yes
E)	Yes	Yes	Yes	Yes

24. A 34-year-old African American man is admitted to the hospital because of steadily increasing intense pain in the upper right side of the abdomen. He is nauseated and vomiting. His hematocrit is 30. Ultrasonography shows the presence of gallstones. Which of the following is the most likely major composition of the gallstones in this man?

A) Bile pigments
B) Calcium carbonate
C) Calcium oxalate
D) Cholesterol

25. *Deamination* means removal of the amino groups from the amino acids. Which substance is produced when deamination occurs by transamination?

A) Acetyl coenzyme A
B) Ammonia
C) Citrulline
D) Ornithine
E) α-Ketoglutaric acid

26. Most of the energy released from a glucose molecule occurs as a result of which process?

A) Citric acid cycle
B) Glycogenesis
C) Glycogenolysis
D) Glycolysis
E) Oxidative phosphorylation

27. A 32-year-old woman visits her physician because of loss of appetite, fatigue, nausea, and dizziness. Physical examination shows thinning hair. Blood tests show a hematocrit of 32. The woman began following a vegetarian diet suggested by a friend 1 year ago. The physician suspects a dietary deficiently of which substance?

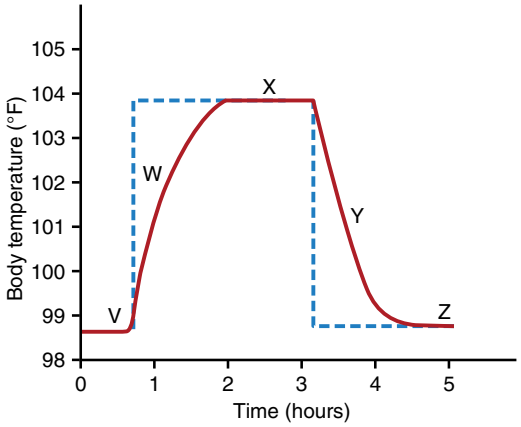
A) Alanine
B) Glycine
C) Lysine
D) Serine
E) Tyrosine

28. A 45-year-old man is admitted to the emergency department after he was found lying in the street in an inebriated state. He is markedly pale with icteric conjunctivae and skin. His abdomen is distended, and he has shifting dullness, indicating ascites. His liver is enlarged about 5 cm below the right costal margin and tender. His spleen cannot be palpated. He has bilateral grade 2 edema of the legs and feet. Which values of direct and indirect bilirubin (in milligrams per deciliter) are most likely to be present in this man's plasma?

	Direct	Indirect
A)	1.1	1.2
B)	1.7	5.4
C)	2.4	2.5
D)	5.2	1.8
E)	5.8	7.2

Questions 29–31

The diagram shows the effects of changing the set-point temperature of the hypothalamic temperature controller. The red line indicates the body temperature, and the blue line represents the hypothalamic set-point temperature. Use the figure to answer the next three questions.



29. Which set of changes occurs at point W compared with point V?

	Shivering	Sweating	Vasoconstriction	Vasodilation
A)	No	No	No	No
B)	No	Yes	No	Yes
C)	No	Yes	Yes	No
D)	Yes	No	No	Yes
E)	Yes	No	Yes	No
F)	Yes	Yes	Yes	Yes

30. Which set of changes occurs at point Y compared with point V?

	Shivering	Sweating	Vasoconstriction	Vasodilation
A)	No	No	No	No
B)	No	Yes	No	Yes
C)	No	Yes	Yes	No
D)	Yes	No	No	Yes
E)	Yes	No	Yes	No
F)	Yes	Yes	Yes	Yes

31. Which set of changes occurs at point X compared with point V?

	Shivering	Sweating	Vasoconstriction	Vasodilation
A)	No	No	No	No
B)	No	Yes	No	Yes
C)	No	Yes	Yes	No
D)	Yes	No	No	Yes
E)	Yes	No	Yes	No
F)	Yes	Yes	Yes	Yes

32. Which of the following is the most abundant source of high-energy phosphate bonds in the cells?

A) ATP
B) Phosphocreatine
C) ADP
D) Creatine
E) Creatinine

33. A 76-year-old man is admitted to the emergency department after being found lying in a field on a hot summer day. His body temperature is 106°F, his blood pressure is normal, and his heart rate is 160 beats/min. Which set of changes is most likely to be present in this man?

	Sweating	Hyperventilation	Vasodilation of Skin
A)	No	No	No
B)	No	Yes	Yes
C)	Yes	No	Yes
D)	Yes	Yes	No
E)	Yes	Yes	Yes

34. Most of the energy for strenuous exercise that lasts for more than 5 to 10 seconds but less than 1 to 2 minutes comes from what source?

A) ATP
B) Anaerobic glycolysis
C) Oxidation of carbohydrates
D) Oxidation of lactic acid
E) Conversion of lactic acid into pyruvic acid

35. Erythrocytes are constantly dying and being replaced. Heme from the hemoglobin is converted to what substance before being eliminated from the body?

A) Bilirubin
B) Cholesterol
C) Cholic acid
D) Globin
E) Glucuronic acid

36. A 32-year-old pregnant woman in her third trimester is admitted to the emergency department because of severe upper right quadrant pain after eating a meal of fried catfish. Her blood pressure is 130/84 mm Hg, heart rate is 105 beats/min, and respirations are 30/min. Her body mass index before pregnancy was 45 kg/m^2. Physical examination shows abdominal guarding and diaphoresis. Her serum bilirubin levels and white blood cell count are both normal. Which of the following best describes this patient's condition?

A) Cholelithiasis
B) Constipation
C) Hepatitis
D) Pancreatitis
E) Peritonitis

37. An experimental device containing hepatocytes is developed to provide effective support for patients with hepatic failure pending liver transplantation. Hepatocyte viability is best documented by an increase in which function?

A) Lactate dehydrogenase uptake
B) Ethanol output
C) Albumin output
D) Glucuronic acid uptake
E) Oxygen output
F) Carbon dioxide uptake

38. The metabolic rate of a person is typically expressed in terms of the rate of heat liberation that results from the chemical reactions of the body. Which factors tend to increase or decrease a person's metabolic rate?

	Growth Hormone	Fever	Sleep	Malnutrition
A)	Decrease	Decrease	Decrease	Decrease
B)	Decrease	Increase	Decrease	Increase
C)	Increase	Increase	Increase	Increase
D)	Increase	Increase	Decrease	Increase
E)	Increase	Increase	Decrease	Decrease

39. An 8-year-old girl is taken to the physician because of diarrhea and a red scaly rash. Physical examination shows mild cerebellar ataxia. She is suspected of having pellagra because of these chronic symptoms. However, she appears to be ingesting adequate amounts of niacin in her diet, which is rich in meat. A brother has a similar problem. Urine studies show large amounts of free amino acids. Which diagnosis is most likely?

A) Alkaptonuria
B) Beriberi
C) Hartnup's disease
D) Scurvy
E) Stickler's syndrome

40. In a person with type 1 diabetes who is not receiving insulin therapy and who has a fasting blood glucose of 400 mg/100 ml, what would the respiratory quotient likely be 2 hours after eating a light meal containing 60% carbohydrates, 20% protein, and 20% fat?

A) 0.5
B) 0.7
C) 0.9
D) 1.0
E) 1.2

41. A 3-year-old white boy is extremely obese (weight of 37.5 kg), and his parents report that he has a voracious appetite. What is the most likely cause of his hyperphagia and obesity?
    A) A lesion or destruction of the lateral hypothalamus
    B) Excessive stimulation of the ventromedial nuclei of the hypothalamus
    C) A mutation that produces nonfunctional melanocortin-4 receptor protein
    D) Excessive stimulation of pro-opiomelanocortin (POMC) neurons
    E) Excessive secretion of leptin
    F) A mutation that prevents neuropeptide Y (NPY) formation in hypothalamic neurons

42. Deficiency of which of the following would cause "night blindness" in humans?
    A) Vitamin A
    B) Vitamin B_1
    C) Vitamin B_6
    D) Vitamin B_{12}
    E) Vitamin C
    F) Niacin

43. Which changes would be expected to stimulate hunger in a person who has not eaten for 24 hours?
    A) Increased NPY in the hypothalamus
    B) Increased leptin secretion
    C) Increased peptide YY (PYY) secretion
    D) Decreased ghrelin secretion
    E) Activation of hypothalamic POMC neurons
    F) Increased cholecystokinin secretion

44. Which of the following would be most important in contributing to satiety after eating a large meal containing carbohydrates (50%), fat (40%), and protein (10%)?
    A) Release of cholecystokinin by the duodenum
    B) Decreased leptin secretion
    C) Increased release of endorphins
    D) Increased ghrelin release by the stomach
    E) Decreased release of PYY by the intestine

45. Deficiency of which vitamin is most likely to cause impaired blood clotting?
    A) Vitamin A
    B) Vitamin B_6
    C) Vitamin C
    D) Vitamin D
    E) Vitamin K

46. Deficiency of which vitamin is the main cause of beriberi?
    A) Vitamin A
    B) Thiamine (vitamin B_1)
    C) Riboflavin (vitamin B_2)
    D) Vitamin B_{12}
    E) Pyridoxine (vitamin B_6)

47. Which of the following would tend to decrease hunger?
    A) Increased release of endorphins
    B) Increased ghrelin release by the stomach
    C) Increased release of PYY by the intestine
    D) Increased release of NPY by the hypothalamus
    E) Increased release of cortisol by the adrenals

48. Which substance might be most useful in stimulating appetite in a patient with cancer who has anorexia or cachexia?
    A) Leptin
    B) α-Melanocyte-stimulating hormone
    C) PYY
    D) Melanocortin-4 receptor antagonist
    E) Ghrelin antagonist
    F) Neuropeptide YY antagonist

49. The first stage in using triglycerides for energy is hydrolysis of the triglycerides to which substances?
    A) Acetyl coenzyme A and glycerol
    B) Cholesterol and fatty acids
    C) Glycerol 3-phosphate and cholesterol
    D) Glycerol and fatty acids
    E) Phospholipids and glycerol

50. Urinary nitrogen excretion measured in a patient is 16.0 g in 24 hours. What is the approximate amount of protein breakdown in this patient for 24 hours in grams?
    A) 16
    B) 18
    C) 100
    D) 110
    E) 120

ANSWERS

1. E) During digestion, most triglycerides are split into monoglycerides and fatty acids. Then, while passing through the intestinal epithelial cells, the monoglycerides and fatty acids are resynthesized into new molecules of triglycerides that enter the lymph as minute, dispersed droplets called chylomicrons.

TMP14 pp. 853–854

2. A) The first stage in using triglycerides for energy is their hydrolysis into fatty acids and glycerol. Then, both the fatty acids and the glycerol are transported in the blood to the active tissues, where they will be oxidized to give energy. Almost all cells—with some exceptions, such as brain tissue and red blood cells—can use fatty acids for energy.

TMP14 p. 856

3. A) Essentially all urea formed in the human body is synthesized in the liver from ammonia. In the absence of the liver or in persons with serious liver disease, ammonia accumulates in the blood. This accumulation of ammonia is extremely toxic, especially to the brain, and can lead to a state called hepatic coma or liver encephalopathy.

TMP14 pp. 869, 874

4. F) Bilirubin is formed during the degradation of red blood cells by macrophages and released into plasma where it combines with albumin (item 2). The free bilirubin is then taken up by hepatocytes (item 4), where most of it is conjugated with glucuronic acid (item 1). The conjugated bilirubin is then excreted from the hepatocytes by an active transport process into the bile canaliculi and then into the intestines (item 3).

TMP14 pp. 874–875

5. E) When liver parenchymal cells are destroyed, they are replaced with fibrous tissue that eventually contracts around the blood vessels, thereby greatly impeding the flow of portal blood through the liver. This disease process is known as cirrhosis of the liver; it is a common consequence of chronic alcoholism. The blockage of blood flow through the liver raises the blood pressure in the upstream splanchnic organs, causing ascites fluid to collect in the abdomen and varices to develop in the lower esophagus. Peripheral edema can result from a failure of hepatocytes to produce normal amounts of albumin (low colloid osmotic pressure). Jaundice (hyperbilirubinemia) develops because of damage to hepatocytes.

TMP14 pp. 871–872

6. E) This woman has acute pancreatitis caused by blockage of the papilla of Vater by one or more gallstones. When a gallstone blocks the papilla of Vater, the main secretory duct from the pancreas and the common bile duct are blocked. The pancreatic enzymes are then dammed up in the ducts and acini of the pancreas. Eventually, so much trypsinogen accumulates that it overcomes the trypsin inhibitor in the secretions and a small quantity of trypsinogen becomes activated to form trypsin. When this happens, the trypsin activates still more trypsinogen, as well as chymotrypsinogen and carboxypeptidase, resulting in a vicious circle until most of the proteolytic enzymes in the pancreatic ducts and acini become activated. These enzymes rapidly digest large portions of the pancreas, sometimes completely and permanently destroying the ability of the pancreas to secrete digestive enzymes.

TMP14 p. 835

7. C) Although a normal, unacclimatized person seldom produces more than about 1 l of sweat per hour, when this person is exposed to hot weather for 1 to 6 weeks, he or she begins to sweat more profusely, often increasing maximum sweat production to as much as 2 to 3 l/hr. Also associated with acclimatization is a further decrease in the concentration of sodium chloride in the sweat, which allows progressively better conservation of body salt. Most of this effect is caused by increased secretion of aldosterone by the adrenocortical glands, which results from a slight decrease in sodium chloride concentration in the extracellular fluid and plasma. An unacclimatized person who sweats profusely often loses 15 to 30 g of salt each day for the first few days. After 4 to 6 weeks of acclimatization, the loss is usually only 3 to 5 g/day.

TMP14 p. 911

8. D) The various methods by which heat is lost from the skin to the surroundings include radiation, evaporation, and conduction to air and conduction to objects. In a nude person sitting inside at normal room temperature, about 60% of total heat loss is by radiation, 22% by evaporation, 15% by conduction to air, and 3% by conduction to objects.

TMP14 pp. 902–903

9. D) The set-point temperature in the hypothalamus is determined mainly by the degree of activity of the heat temperature receptors in the anterior hypothalamic-

preoptic area. However, temperature signals from the peripheral areas of the body, especially from the skin and certain deep body tissues (spinal cord and abdominal viscera), also contribute slightly to body temperature regulation. Many proteins, breakdown products of proteins, and certain other substances, especially lipopolysaccharide toxins released from bacterial cell membranes, can cause the set-point of the hypothalamic thermostat to rise. Substances that cause this effect are called pyrogens.

TMP14 pp. 909–910

10. B) The primary secretion of sweat is an active secretory product of the epithelial cells lining the coiled portion of the sweat gland. Sympathetic-cholinergic nerve fibers ending on or near the glandular cells elicit the secretion. These are postganglionic sympathetic fibers that release acetylcholine and hence are called sympathetic-cholinergic fibers; they innervate sweat glands and some blood vessels.

TMP14 p. 904

11. E) When the body temperature has fallen below about 85°F, the ability of the hypothalamus to regulate temperature is lost; it is greatly impaired even when the body temperature falls below about 94°F. Part of the reason for this diminished temperature regulation is that the rate of chemical heat production in each cell is depressed almost 2-fold for each 10°F decrease in body temperature. Also, sleepiness develops (later followed by coma), which depresses the activity of the central nervous system heat control mechanisms and prevents shivering.

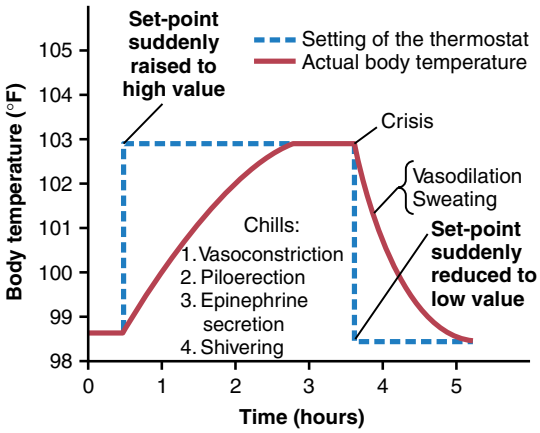
TMP14 p. 911

12. A) Fatty acids are degraded in mitochondria by the progressive release of two-carbon segments in the form of acetyl coenzyme A. This process is known as the beta-oxidation process for degradation of fatty acids.

TMP14 pp. 856–857

13. B) The typical series of events that occur during a fever are shown in the figure on the right. When pyrogens raise the set-point temperature above its normal value, the body activates heat conservation and heat production mechanisms that include cutaneous vasoconstriction, piloerection, epinephrine secretion, and shivering. Within several minutes, the body temperature increases to the elevated set-point value of 103°F in this example. If the factor that is causing the high temperature is removed, the hypothalamic set-point temperature returns to a normal value of about 98.6°F, which leads to activation of heat-loss mechanisms such as sweating and cutaneous vasodilation. The body temperature then returns to its basal level.

TMP14 p. 910



14. B) This man has cirrhosis of the liver. Fluid accumulates in the abdomen (ascites) for two main reasons: (1) decreased plasma colloid osmotic pressure (COP) and (2) increased capillary hydrostatic pressure in the splanchnic organs. The decrease in plasma COP results from decreased production of albumin by liver hepatocytes; albumin accounts for nearly 80% of the plasma COP. The low plasma COP also promotes edema formation in the periphery, especially the feet. Liver parenchymal cells are damaged or destroyed in persons with cirrhosis of the liver. The cells are replaced with fibrous tissue that eventually contracts around the blood vessels, thereby greatly impeding the flow of portal blood through the liver. This increase in vascular resistance leads to an increase in portal vein pressure, which in turn raises the capillary hydrostatic pressure of the splanchnic organs. There is no reason to assume that capillary hydrostatic pressure is also increased above normal in the feet of this man.

TMP14 pp. 401, 867, 871

15. D) Evaporation is the only mechanism of heat loss from the body when the environmental temperature is greater than the body temperature. Each gram of water that evaporates from the surface of the body causes 0.58 kcal of heat to be lost from the body. Even when a person is not sweating, water still evaporates insensibly from the skin and lungs at a rate of 450 to 600 ml/day, which amounts to about 12 to 16 kcal of heat loss per hour. Radiation, convection, and conduction are mechanisms of heat loss when the body temperature is greater than the environmental temperature.

TMP14 pp. 903–904

16. C) The metabolic rate increases after a meal because of various chemical reactions associated with digestion, absorption, and storage of food; this phenomenon is known as the thermogenic effect of food. After a meal containing mostly carbohydrates and fats, the metabolic rate usually increases by about 4%. However, a high-protein meal often increases the metabolic rate by as much as 30%; this effect can last from 3 to 12 hours after the meal and is called the specific dynamic action

of proteins. Clearly, assimilation of proteins requires far more energy expenditure compared with fats and carbohydrates.

TMP14 pp. 897–898

17. E) This man has heatstroke. When the body temperature rises into the range of 105°F to 108°F, heatstroke likely follows. Heat loss mechanisms are overwhelmed by excessive metabolic production of heat and excessive environmental heat. Heatstroke is usually accompanied by dehydration (poor skin turgor is common), which can produce nausea, vomiting, hypotension, and fainting or dizziness. Interestingly, the skin is frequently dry because the anterior hypothalamic-preoptic area of the brain that normally initiates sweating is often compromised by the elevation in body temperature.

TMP14 p. 911

18. E) Most of the heat loss from the body occurs by radiation in the form of infrared heat waves, which is a type of electromagnetic wave. Heat waves radiate from all objects toward the body, and the body radiates heat waves to all surrounding objects. The reflective surface of the Mylar blanket prevents heat loss by reflecting infrared heat waves from the body back to the body, which causes the body to warm. At room temperature, 60% of the heat loss occurs by radiation, 22% by evaporation, 15% by conduction to air, and 3% by conduction to objects. Convection (i.e., air currents) can increase heat loss by removing the unstirred layer of air close to the skin.

TMP14 p. 903

19. B) Continual release of energy from glucose when energy is not needed by the cells would be an extremely wasteful process. Both ATP and ADP control the rate of chemical reactions in the energy metabolism sequence. When ATP is abundant within the cell, it helps control energy metabolism by inhibiting the conversion of fructose-6-phosphate to fructose-1, 6-diphosphate. It does so by inhibiting the enzyme phosphofructokinase.

TMP14 p. 849

20. B) Both ADP and AMP increase the activity of the enzyme phosphofructokinase and increase the conversion of fructose-6-phosphate to fructose-1,6-diphosphate.

TMP14 p. 849

21. B) Esophageal varices are extremely dilated submucosal veins in the lower third of the esophagus. The submucosal veins have a normal diameter of about 1 mm and can enlarge to 1 to 2 cm with prolonged portal hypertension, which is common in persons with cirrhosis of the liver. The presence of ascites indicates that the patient has portal hypertension. The dilated esophageal veins often bleed and thus lower the hematocrit. Although colon cancers can also bleed, there is no reason to assume colon cancer in this woman. Pancreatitis can occur in persons with chronic alcoholism, but there is no evidence for this condition, and substantial bleeding is not common in persons with pancreatitis. Jaundice and scleral icterus (i.e., yellowing of the sclera) are common in persons with cirrhosis, but these conditions are unlikely to cause significant bleeding.

TMP14 pp. 871–872

22. D) The liver has a high blood flow, low vascular resistance, and low blood pressure. During resting conditions, about 27% of the cardiac output flows through the liver, yet the pressure in the portal vein leading into the liver averages only 9 mm Hg. This high flow and low pressure indicate that the resistance to blood flow through the hepatic sinusoids is normally very low.

TMP14 p. 871

23. B) None of the mechanisms of heat loss is effective when a person is placed in water that has a temperature greater than body temperature. Instead, the body will continue to gain heat until the body temperature becomes equal to the water temperature.

TMP14 p. 903

24. A) This man has sickle cell disease, which is a hemolytic disease that results in the premature destruction of red blood cells. Release of hemoglobin from damaged red blood cells leads to high levels of bilirubin in the blood plasma. This increase in bilirubin can lead to the development of pigment stones in the gallbladder that are composed primarily of bilirubin.

TMP14 pp. 446, 875

25. B) The degradation of amino acids occurs almost entirely in the liver, and it begins with deamination, which occurs mainly by the following transamination schema: The amino group from the amino acid is transferred to α-ketoglutaric acid, which then becomes glutamic acid. The glutamic acid then transfers the amino group to still other substances or releases it in the form of ammonia. In the process of losing the amino group, the glutamic acid again becomes α-ketoglutaric acid, so that the cycle can repeat again and again.

TMP14 pp. 868–869

26. E) About 90% of the total ATP produced by glucose metabolism is formed during oxidation of the hydrogen atoms released during the early stages of glucose degradation. This process is called *oxidative phosphorylation.* Only two ATP molecules are formed by glycolysis, and another two are formed in the citric acid cycle. ATP is not formed by glycogenesis or glycogenolysis.

TMP14 p. 848

27. C) Lysine is an essential amino acid, which means that it must be included in the diet because the body cannot synthesize it. Alanine, glycine, serine, and tyrosine can be synthesized by the body and are therefore considered nonessential amino acids. This woman has a lysine deficiency, which is common in poorly designed vegetarian diets; symptoms include nausea, fatigue, dizziness, anemia, loss of appetite, and thinning hair. Good dietary sources of lysine include eggs, meat, beans, legumes, soy, dairy products, and certain fish (such as cod and sardines). L-lysine is a building block for all proteins in the body.

TMP14 pp. 866, 868

28. D) This man has cirrhosis of the liver. In this condition, the rate of bilirubin production is normal, and the free bilirubin still enters the liver cells and becomes conjugated in the usual way. The conjugated bilirubin (direct) is mostly returned to the blood, probably by rupture of congested bile canaliculi, so that only small amounts enter the bile. The result is elevated levels of conjugated (direct) bilirubin in the plasma, with normal or near-normal levels of unconjugated (indirect) bilirubin.

TMP14 pp. 871, 874–875

29. E) When the hypothalamic set-point temperature is greater than the body temperature, the person feels cold and exhibits responses that lead to an elevation of body temperature. These responses include shivering and vasoconstriction, as well as piloerection and epinephrine secretion. Shivering increases heat production. The increase in epinephrine secretion causes an immediate increase in the rate of cellular metabolism, which is an effect called *chemical thermogenesis.* Vasoconstriction of the skin blood vessels decreases heat loss through the skin.

TMP14 p. 910

30. B) When the hypothalamic set-point temperature is lower than the body temperature, the person feels hot and exhibits responses that cause body temperature to decrease. These responses include sweating and vasodilation. Sweating increases heat loss from the body by evaporation. Vasodilation of skin blood vessels facilitates heat loss from the body by increasing the skin blood flow.

TMP14 p. 910

31. A) When the hypothalamic set-point temperature is equal to the body temperature, the body exhibits neither heat loss nor heat conservation mechanisms, even when the body temperature is far above normal. Therefore, the person does not feel hot even when the body temperature is 104°F.

TMP14 p. 910

32. B) Phosphocreatine contains high-energy phosphate bonds and is three to eight times as abundant as ATP or ADP in a cell. Creatine does not contain high-energy phosphate bonds. Creatinine is a breakdown product of creatine phosphate in muscle.

TMP14 p. 894

33. B) This patient has heatstroke. Patients with heatstroke commonly exhibit tachypnea and hyperventilation caused by direct central nervous system stimulation, acidosis, or hypoxia. The blood vessels in the skin are vasodilated, and the skin is warm. Sweating ceases in patients with true heatstroke, most likely because the high temperature itself causes damage to the anterior hypothalamic-preoptic area. The nerve impulses from this area are transmitted in the autonomic pathways to the spinal cord and then through sympathetic outflow to the skin to cause sweating.

TMP14 p. 911

34. B) Most of the extra energy required for strenuous activity that lasts for more than 5 to 10 seconds but less than 1 to 2 minutes is derived from anaerobic glycolysis. Release of energy by glycolysis occurs much more rapidly than oxidative release of energy, which is much too slow to supply the needs of the muscle in the first few minutes of exercise. ATP and phosphocreatine already present in the cells are rapidly depleted in less than 5 to 10 seconds. After the muscle contraction is over, oxidative metabolism is used to reconvert much of the accumulated lactic acid into glucose; the remainder becomes pyruvic acid, which is degraded and oxidized in the citric acid cycle.

TMP14 p. 894

35. A) Hemoglobin is metabolized by tissue macrophages (also called the *reticuloendothelial system*). The hemoglobin is first split into globin and heme, and the heme ring is opened to produce free iron and a straight chain of four pyrrole nuclei, from which bilirubin will eventually be formed. The free bilirubin is taken up by hepatic cells, and most of it is conjugated with glucuronic acid; the conjugated bilirubin passes into the bile canaliculi and then into the intestines.

TMP14 p. 875

36. A) Cholelithiasis is the presence of gallstones (choleliths) in the gallbladder or bile ducts. This patient exhibits typical symptoms caused by gallstones.

TMP14 p. 820

37. C) Hepatocytes produce essentially all the albumin normally present in blood. Viable hepatocytes use oxygen and produce carbon dioxide. Glucuronic acid produced by hepatocytes is used to conjugate bilirubin, forming bilirubin glucuronide. Lactate dehydrogenase is an enzyme that converts pyruvic acid to lactic acid under anaerobic conditions.

TMP14 pp. 317, 873–874

38. E) Growth hormone can increase the metabolic rate 15% to 20% as a result of direct stimulation of cellular metabolism. Fever, regardless of its cause, increases the chemical reactions of the body by an average of about 120% for every 10°C rise in temperature. The metabolic rate decreases 10% to 15% below normal during sleep. Prolonged malnutrition can decrease the metabolic rate 20% to 30%, presumably because of the paucity of food substances in the cells.

TMP14 p. 898

39. C) This child has Hartnup's disease. This condition resembles pellagra (because of the symptoms of diarrhea, dementia, and dermatitis) and may be misdiagnosed as a nutritional deficiency of niacin. Hartnup's disease is an autosomal-recessive trait caused by a defective gene that codes for a sodium-dependent and chloride-independent neutral amino acid transporter expressed mainly in kidney and intestinal epithelium. Poor epithelial transport of neutral amino acids (such as tryptophan) leads to poor absorption of dietary amino acids, as well as excess amino acid excretion in the urine. Tryptophan is a precursor of niacin; it is an essential amino acid that must be included in the diet. Alkaptonuria, also called "black urine disease," is a genetic disorder of phenylalanine and tyrosine metabolism. Beriberi is caused by a nutritional deficit in thiamine. Scurvy results from a deficiency of vitamin C, which is required for collagen synthesis. Stickler's syndrome is a group of genetic disorders that affect connective tissues; it is characterized by eye problems, hearing loss, joint problems, and facial abnormalities.

TMP14 p. 889

40. B) Type 1 diabetes is characterized by a lack of insulin. In the absence of adequate insulin, little carbohydrate can be used by the body's cells, and the respiratory quotient remains near that for fat metabolism (0.70).

TMP14 p. 879

41. C) Mutations that produce a nonfunctional melanocortin-4 receptor cause extreme obesity and may account for as much as 5% to 6% of early onset, morbid obesity in children. All the other changes would tend to reduce food intake and/or increase energy expenditure and thus cause weight loss rather than obesity.

TMP14 pp. 880–881

42. A) One of the basic functions of vitamin A is in the formation of retinal pigments and therefore the prevention of night blindness.

TMP14 p. 888

43. A) NPY is an orexigenic neurotransmitter that stimulates feeding and is increased during food deprivation. Leptin, PYY, cholecystokinin, and activation of POMC neurons are all reduced by fasting. Ghrelin is increased, not decreased, by fasting.

TMP14 pp. 880–883

44. A) Cholecystokinin is released mainly in response to fats and proteins entering the duodenum and activates sensory receptors in the duodenum, sending messages to the brain stem via vagal afferents that contribute to satiation and meal cessation. All the other changes would tend to increase rather than decrease food intake.

TMP14 p. 882

45. E) Vitamin K is an essential co-factor to a liver enzyme that adds a carboxyl group to factors II (prothrombin), VII (proconvertin), IX, and X, all of which are important to blood coagulation. The other vitamins listed are not directly involved in coagulation.

TMP14 p. 891

46. B) Thiamine is needed for the final metabolism of carbohydrates and amino acids. Decreased utilization of these nutrients secondary to thiamine deficiency is responsible for many of the characteristics of beriberi, including peripheral vasodilation and edema, lesions of the central and peripheral nervous system, and gastrointestinal tract disturbances.

TMP14 pp. 888–889

47. C) PYY is released from most parts of the intestinal tract, but especially from the ileum and colon, in response to food intake. Increased levels of PYY have been shown to decrease food intake. All the other changes tend to increase food intake.

TMP14 pp. 880–881

48. D) Antagonists of melanocortin-4 receptors have been shown to markedly attenuate anorexia (i.e., reduced food intake due to decreased appetite) and cachexia (i.e., increased energy expenditure as well as decreased food intake) by blocking hypothalamic melanocortin-4 receptors. All the other choices would tend to decrease appetite and/or increase energy expenditure, exacerbating the anorexia or cachexia of a patient with cancer.

TMP14 p. 880–881, 887

49. D) Triglycerides are hydrolyzed to glycerol and fatty acids, which, in turn, are oxidized to provide energy. Almost all cells, with the exception of some brain tissue, can use fatty acids almost interchangeably with glucose for energy.

TMP14 pp. 856–857

50. D) The rate of protein metabolism can be estimated by measuring the nitrogen in the urine, then adding 10 percent (about 90% of the nitrogen in proteins is excreted in the urine) and multiplying by 6.25 (100/16) because the average protein contains about 16% nitrogen.

TMP14 p. 879

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UNIT XIV

Endocrinology and Reproduction

1. Which of the following is expected to exhibit the greatest biological activity?
   A) Insulin like growth factor-1 free in the plasma
   B) Cholecalciferol (vitamin D_3)
   C) Cortisol bound to corticosteroid binding globulin
   D) T_4 bound to thyroxine binding globulin
   E) Aldosterone bound to plasma albumin

2. Which receptor controls nitric oxide (NO) release to cause vasodilation during penile erection?
   A) Leptin receptor
   B) Angiotensin AT1 receptor
   C) Endothelin ETA receptor
   D) Muscarinic receptor

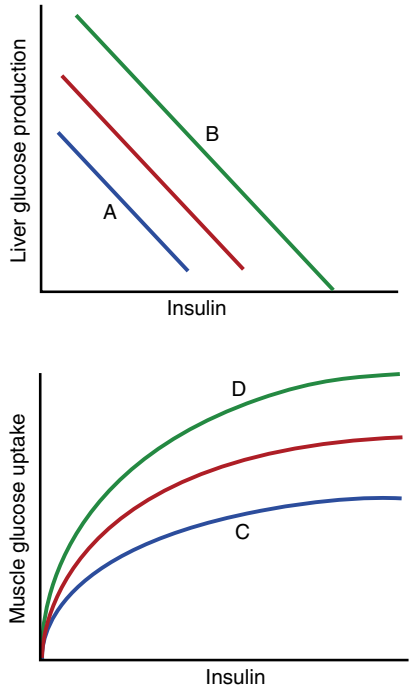
3. After menopause, hormone replacement therapy with estrogen-like compounds is effective in preventing the progression of osteoporosis. What is the mechanism of their protective effect?
   A) They stimulate the activity of osteoblasts
   B) They increase absorption of calcium from the gastrointestinal tract
   C) They stimulate calcium reabsorption by the renal tubules
   D) They stimulate parathyroid hormone (PTH) secretion by the parathyroid gland

4. Neurons that secrete antidiuretic hormone or oxytocin terminate in which of the following structures?
   A) Posterior pituitary
   B) Median eminence
   C) Mammillary body
   D) Paraventricular nucleus
   E) Supraoptic nucleus

5. Which of the following represents a physiological action of growth hormone?
   A) Increases the breakdown of muscle protein
   B) Increases utilization of glucose in muscle
   C) Decreases storage of lipids in adipose cells
   D) Decreases gene transcription
   E) Decreases gluconeogenesis in the liver

6. Which hormones antagonize the effect of NO and cause the penis to become flaccid after orgasm?
   A) Endothelin and norepinephrine
   B) Estrogen and progesterone
   C) Luteinizing hormone (LH) and follicle-stimulating hormone (FSH)
   D) Progesterone and LH

Questions 7–9



The red lines in the above figure illustrate the normal relationships between plasma insulin concentration and glucose production in the liver and between plasma insulin concentration and glucose uptake in muscle. Use this figure to answer Questions 7–9.

7. Which lines most likely illustrate these relationships in a patient with type 2 diabetes?
   A) A and C
   B) A and D
   C) B and C
   D) B and D

8. Which lines most likely illustrate these relationships in a patient with acromegaly?
   A) A and C
   B) A and D

C) B and C
D) B and D

9. Line D most likely illustrates the influence of which of the following?
   A) Exercise
   B) Obesity
   C) Growth hormone (GH)
   D) Cortisol
   E) Glucagon

10. Thecal cells in the follicle are not able to produce what sex steroid?
   A) Estradiol
   B) Testosterone
   C) Progesterone
   D) Dihydrotestosterone

11. A baby is born with a penis, a scrotum with no testes, no vagina, and XX chromosomes. This condition is referred to as hermaphroditism. What could cause this abnormality?
   A) Abnormally high levels of human chorionic gonadotropin (hCG) production by the trophoblast cells
   B) The presence of a testosterone-secreting tumor in the mother's right adrenal gland
   C) Abnormally high levels of LH in the maternal blood
   D) Abnormally low levels of testosterone in the maternal blood
   E) Abnormally low rates of estrogen production by the placenta

12. Antidiuretic hormone (ADH) is increased by which of the following?
   A) A hyperosmotic extracellular fluid in the hypothalamus
   B) A hyperosmotic extracellular fluid in the adenohypophysis
   C) A hypoosmotic extracellular fluid in the hypothalamus
   D) A hypoosmotic extracellular fluid in the adenohypophysis
   E) A hypoosmotic fluid in the atria of the heart

13. In an individual with panhypopituitarism, which selection below best describes the plasma hormone changes that would occur?
   A) ↓GHRH, ↓somatostatin, ↓growth hormone, ↓somatomedin C
   B) ↓GHRH, ↓somatostatin, ↓growth hormone, ↑somatomedin C
   C) ↑GHRH, ↑somatostatin, ↑growth hormone, ↓somatomedin C
   D) ↑GHRH, ↑somatostatin, ↓ growth hormone, ↓somatomedin C
   E) ↑GHRH, ↓somatostatin, ↓growth hormone, ↓somatomedin C

14. Which of the following could inhibit the initiation of labor?
   A) Administration of an antagonist of the actions of progesterone
   B) Administration of LH
   C) Administration of an antagonist of PGE_2 effects
   D) Mechanically dilating and stimulating the cervix
   E) Administration of oxytocin

15. A patient has nephrogenic diabetes insipidus. Which of the following would either be expected or a suggested intervention?
   A) Decreased plasma sodium concentration
   B) Increased secretion of ADH from the supraoptic nuclei
   C) High urine osmolality
   D) Increased AVPR2 function
   E) Decrease secretion of ADH from the supraoptic and paraventricular nuclei

16. Which of the following would most likely cause a decrease in the release of thyroid-stimulating hormone?
   A) Decreased iodinase enzyme
   B) Decreased iodine pump activity in thyroid gland
   C) Decreased body temperature
   D) Increased thyrotropin releasing hormone
   E) Increased plasma thyroxine by venous infusion

17. The increased cardiac output caused by elevated circulating levels of thyroid hormones is most likely caused by
   A) Direct actions of thyroid-stimulating hormone on the heart
   B) Direct actions of thyroid-stimulating hormone on the brain
   C) An increase in the metabolic demand of the tissues
   D) An increase in plasma cholesterol and triglycerides
   E) An increase in total body weight

18. If a radioimmunoassay is properly conducted and the amount of radioactive hormone bound to antibody is low, what would this result indicate?
   A) Plasma levels of endogenous hormone are high
   B) Plasma levels of endogenous hormone are low
   C) More antibody is needed
   D) Less radioactive hormone is needed

19. Which of the following depicts the most likely sequence of events in an individual exposed to cold?
   A) ↑Thyrotropin-releasing hormone, ↑thyroid-stimulating hormone, ↑thyroxine
   B) ↑Thyrotropin-releasing hormone, ↓thyroid-stimulating hormone, ↑thyroxine
   C) ↑Thyroid-stimulating hormone, ↑thyrotropin-releasing hormone, ↑thyroxine

D) ↑Thyroid-stimulating hormone, ↓thyrotropin-releasing hormone, ↑thyroxine
E) ↑Thyroxine, ↑thyrotropin-releasing hormone, ↑thyroid-stimulating hormone

20. Spermatogenesis is regulated by a negative feedback control system in which FSH stimulates the steps in sperm cell formation. Which negative feedback signal associated with sperm cell production inhibits pituitary formation of FSH?
A) Testosterone
B) Inhibin
C) Estrogen
D) LH

21. In an individual with a thyroid hormone producing adenoma, one might expect which of the following?
A) ↑ T_4, ↓ T_3, ↓ TRH, ↓ TSH
B) ↑ T_4, ↑ T_3, ↓ TRH, ↓ TSH
C) ↑ T_4, ↑ T_3, ↑ TRH, ↓ TSH
D) ↑ T_4, ↑ T_3, ↓ TRH, ↑ TSH
E) ↓ T_4, ↑ T_3, ↓ TRH, ↓ TSH

22. When do progesterone levels rise to their highest point during the female hormonal cycle?
A) Between ovulation and the beginning of menstruation
B) Immediately before ovulation
C) When the blood concentration of LH is at its highest point
D) When 12 primary follicles are developing to the antral stage

23. You suspect thyroid disease in a female patient. Based on the plasma values below, which of the following would be expected?

	[TSH]	Total [T_4]	[TBG]
Normal range	0.4-5.5 mU/l	5.6-14.7 µg/dl	1.7-3.6 µg/dl
Patient data	9.3	2.3	3.0

A) Graves' disease
B) Secondary hyperthyroidism
C) Hashimoto's disease
D) Secondary hypothyroidism
E) Euthyroid pregnant

24. Which of the following enzymes catalyzes the conversion of cholesterol to pregnenolone?
A) Aldosterone synthase
B) Lipoprotein lipase
C) Hormone sensitive lipase
D) 11β-Hydroxylase
E) Cholesterol desmolase

25. Which of the following would most likely occur if plasma aldosterone levels were low?
A) Hyperkalemia
B) Hypokalemia
C) Hypernatremia
D) Hypertension

26. A professional athlete in her mid-20s has not had a menstrual cycle for 5 years, although a bone density scan revealed normal skeletal mineralization. Which fact may explain these observations?
A) She consumes a high-carbohydrate diet
B) Her grandmother sustained a hip fracture at age 79 years
C) Her blood pressure is higher than normal
D) Her plasma estrogen concentration is very low
E) She has been taking anabolic steroid supplements for 5 years

27. During a chronic infusion of aldosterone in an experimental animal model, one would expect which of the following?
A) ↑Blood pressure, ↔extracellular fluid volume, ↓urinary sodium excretion
B) ↑Blood pressure, ↓extracellular fluid volume, ↔urinary sodium excretion
C) ↑Blood pressure, ↔extracellular fluid volume, ↑urinary sodium excretion
D) ↑Blood pressure, ↑extracellular fluid volume, ↔urinary sodium excretion
E) ↑Blood pressure, ↔extracellular fluid volume, ↔urinary sodium excretion

28. In the circulatory system of a fetus, which of the following is greater before birth than after birth?
A) Arterial Po_2
B) Right atrial pressure
C) Aortic pressure
D) Left ventricular pressure

29. In response to a physiological stimulus such as the stress of taking an important quiz, which of the following reflects the most likely sequence of events?
A) ↑Cortisol, ↑corticotropin, ↑corticotropin-releasing hormone
B) ↑Corticotropin-releasing hormone, ↑corticotropin, ↑cortisol
C) ↑Cortisol, ↓corticotropin, ↑corticotropin-releasing hormone
D) ↑Corticotropin-Releasing hormone, ↑corticotropin, ↓cortisol
E) ↑Cortisol, ↑corticotropin, ↓corticotropin-releasing hormone

30. Which of the following best characterizes the metabolic actions of cortisol?
    A) ↑Muscle glucose uptake, ↑muscle amino acid uptake, ↑adipose tissue fat uptake
    B) ↑Muscle glucose uptake, ↓muscle amino acid uptake, ↑adipose tissue fat uptake
    C) ↓Muscle glucose uptake, ↓muscle amino acid uptake, ↑adipose tissue fat uptake
    D) ↓Muscle glucose uptake, ↑muscle amino acid uptake, ↓adipose tissue fat uptake
    E) ↓Muscle glucose uptake, ↓muscle amino acid uptake, ↓adipose tissue fat uptake

31. Which of the following is most likely to occur as a result of chronic hyperglycemia associated with untreated type 1 diabetes mellitus?
    A) Increased intracellular fluid volume
    B) Decreased urinary glucose
    C) Metabolic alkalosis
    D) Osmotic diuresis and polyuria
    E) Improved eyesight

32. Which enzyme in the cytochrome P450 steroid synthesis cascade is directly responsible for estradiol synthesis?
    A) 17-Beta-hydroxysteroid dehydrogenase
    B) 5-Alpha reductase
    C) Aromatase
    D) Side chain cleavage enzyme

33. Which of the following is greater after birth than before birth?
    A) Flow through the foramen ovale
    B) Pressure in the right atrium
    C) Flow through the ductus arteriosus
    D) Aortic pressure

34. Immediately after consuming a meal consisting of a large burger, French fries, onion rings, and a diet cola, one might expect a DECREASE in which of following?
    A) Amino acid transport into cells
    B) Fatty acid synthesis
    C) Hormone sensitive lipase
    D) Liver glycogen
    E) Cell permeability to glucose

35. In an individual with untreated insulin dependent diabetes mellitus (type 1), one would expect which of the following?
    A) ↑Plasma free fatty acids, ↓liver glycogen, ↑skeletal muscle mass
    B) ↑Plasma free fatty acids, ↓liver glycogen, ↓skeletal muscle mass
    C) ↑Plasma free fatty acids, ↑liver glycogen, ↓skeletal muscle mass
    D) ↓Plasma free fatty acids, ↓liver glycogen, ↑skeletal muscle mass
    E) ↓Plasma free fatty acids, ↑liver glycogen, ↓skeletal muscle mass

36. Which of the following changes would be expected to help maintain plasma glucose in the postabsorptive?
    A) ↓Insulin, ↑glucagon, ↓growth hormone, ↓cortisol
    B) ↓Insulin, ↑glucagon, ↑growth hormone, ↓cortisol
    C) ↓Insulin, ↑glucagon, ↑growth hormone, ↑cortisol
    D) ↑Insulin, ↓glucagon, ↓growth hormone, ↑cortisol
    E) ↑Insulin, ↓glucagon, ↑growth hormone, ↑cortisol

37. For male differentiation to occur during embryonic development, testosterone must be secreted from the testes. What stimulates the secretion of testosterone during embryonic development?
    A) LH from the maternal pituitary gland
    B) hCG
    C) Inhibin from the corpus luteum
    D) GnRH from the embryo's hypothalamus

38. Which of the following best describes insulin?
    A) Lipid-soluble hormone tightly bound to plasma proteins
    B) Peptide hormone that activates an intracellular receptor
    C) Peptide hormone that activates a G-coupled protein receptor
    D) Peptide hormone that activates an enzyme-linked receptor
    E) Steroid hormone that activates an enzyme-linked receptor

39. If one were to experience a sudden decrease in extracellular fluid calcium, which of the following would most likely be the first physiological response to buffer the change in calcium?
    A) Increased calcium absorption in the gut
    B) Decreased phosphate absorption in the gut
    C) Increased parathyroid hormone from the anterior pituitary
    D) Decreased renal excretion of phosphate
    E) Increased exchange of calcium with the bone fluid

40. As menstruation ends, estrogen levels in the blood rise rapidly. What is the source of the estrogen?
    A) Corpus luteum
    B) Developing follicles
    C) Endometrium
    D) Stromal cells of the ovaries
    E) Anterior pituitary gland

41. A 30-year-old woman reports to the clinic for a routine physical examination. The examination reveals she is pregnant. Her plasma levels of TSH are high, but her total thyroid hormone concentration is normal. Which of the following best reflects the patient's clinical state?
    A) Graves' disease
    B) Hashimoto's disease
    C) A pituitary tumor secreting TSH

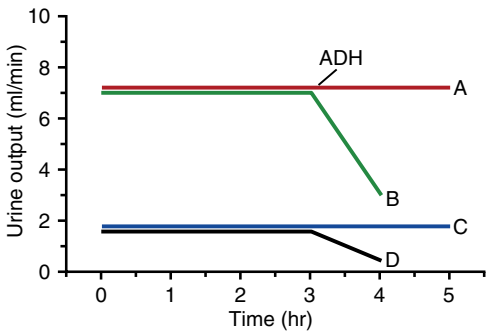
D) A hypothalamic tumor secreting thyrotropin-releasing hormone (TRH)
E) The patient is taking thyroid extract

42. Which of the following would be expected in a patient with chronic renal failure?

	Plasma[1,25-$(OH)_2D$]	Plasma [PTH]	Bone Resorption
A)	↑	↑	↑
B)	↑	↑	↓
C)	↑	↓	↓
D)	↓	↓	↑
E)	↓	↑	↓
F)	↓	↑	↑

43. A female athlete who took testosterone-like steroids for several months stopped having normal menstrual cycles. What is the best explanation for this observation?

A) Testosterone stimulates inhibin production from the corpus luteum
B) Testosterone binds to receptors in the endometrium, resulting in the failure of the endometrium to develop during the normal cycle
C) Testosterone binds to receptors in the anterior pituitary that stimulate the secretion of FSH and LH
D) Testosterone inhibits the hypothalamic secretion of GnRH and the pituitary secretion of LH and FSH



44. An experiment is conducted in which ADH is administered at hour 3 to four subjects (A to D). In the above figure, which lines most likely reflect the response to ADH administration in a normal patient and in a patient with central diabetes insipidus?

	Normal	Central Diabetes Insipidus
A)	B	A
B)	B	D
C)	D	A
D)	D	B

45. Which of the following decreases the resistance in the arteries leading to the sinuses of the penis?

A) Stimulation of the sympathetic nerves innervating the arteries
B) NO
C) Inhibition of activity of the parasympathetic nerves leading to the arteries
D) All the above

46. Using the three following statements, select the best answer.

1. Hydroxyapatite is the major crystalline salt in calcified bone
2. An osteon is made up of concentric layers of bone called lamellae
3. Osteocytes are the major cells responsible for the formation of new bone tissue

A) Only statement 1 is correct
B) Statement 1 and 2 are correct
C) Statements 1 and 3 are correct
D) All statements are correct
E) No statements are correct

47. All of the following statements about parathyroid hormone are true EXCEPT one. Which one is the EXCEPTION?

A) PTH directly activates osteoblasts and osteocytes
B) PTH inhibits the production of vitamin D hormones
C) PTH promotes bone resorption in response to decreased plasma calcium
D) PTH promotes the movement of calcium from bone fluid to the extracellular fluid
E) PTH promotes calcium reabsorption in the renal distal tubule and collecting duct

48. A 46-year-old man has "puffy" skin and is lethargic. His plasma TSH concentration is low and increases markedly when he is given TRH. What is the most likely diagnosis?

A) Hyperthyroidism due to a thyroid tumor
B) Hyperthyroidism due to an abnormality in the hypothalamus
C) Hypothyroidism due to an abnormality in the thyroid
D) Hypothyroidism due to an abnormality in the hypothalamus
E) Hypothyroidism due to an abnormality in the pituitary

49. Negative feedback on FSH release from the anterior pituitary in men that results in a reduction in estradiol production is due to which hormone?

A) Progesterone
B) Estradiol
C) Testosterone
D) Inhibin

50. During the first few years after menopause, FSH levels are normally extremely high. A 56-year-old woman completed menopause 3 years ago. However, she is found to have low levels of FSH in her blood. What is the best explanation for this finding?
    A) She has been receiving hormone replacement therapy with estrogen and progesterone since she completed menopause
    B) Her adrenal glands continue to produce estrogen
    C) Her ovaries continue to secrete estrogen
    D) She took birth control pills for 20 years before menopause

51. Blockade of what receptors will prolong erection in a man?
    A) Estrogen receptors
    B) Cholesterol receptors
    C) Muscarinic receptors
    D) Phosphodiesterase-5 receptors

52. Which of the following pairs of hormones and the corresponding action is incorrect?
    A) Glucagon—increased glycogenolysis in liver
    B) Glucagon—increased glycogenolysis in skeletal muscle
    C) Glucagon—increased gluconeogenesis
    D) Cortisol—increased gluconeogenesis
    E) Cortisol—decreased glucose uptake in muscle

53. A large dose of insulin is administered intravenously to a patient. Which set of hormonal changes is most likely to occur in the plasma in response to the insulin injection?

	Growth Hormone	Glucagon	Epinephrine
A)	↑	↓	↔
B)	↔	↑	↑
C)	↑	↑	↑
D)	↓	↑	↑
E)	↓	↓	↔

54. What is a frequent cause of delayed breathing at birth?
    A) Fetal hypoxia during the birth process
    B) Maternal hypoxia during the birth process
    C) Fetal hypercapnia
    D) Maternal hypercapnia

55. Which hormone is largely unbound to plasma proteins?
    A) Cortisol
    B) T_4
    C) ADH
    D) Estradiol
    E) Progesterone

56. What is the mechanism by which the zona pellucida becomes "hardened" after penetration of a sperm cell to prevent a second sperm from penetrating?
    A) A reduction in estradiol
    B) The proteins released from the acrosome of the sperm
    C) An increase in intracellular calcium in the oocyte
    D) An increase in testosterone that affects the sperm

57. Why is milk produced by a woman only after delivery, not before?
    A) Levels of LH and FSH are too low during pregnancy to support milk production
    B) High levels of progesterone and estrogen during pregnancy suppress milk production
    C) The alveolar cells of the breast do not reach maturity until after delivery
    D) High levels of oxytocin are required for milk production to begin, and oxytocin is not secreted until the baby stimulates the nipple

58. Which of the following increases the rate of excretion of calcium ions by the kidney?
    A) A decrease in calcitonin concentration in the plasma
    B) An increase in phosphate ion concentration in the plasma
    C) A decrease in the plasma level of PTH
    D) Metabolic alkalosis

59. A patient has hyperthyroidism due to a pituitary tumor. Which set of physiological changes would be expected?

	Thyroglobulin Synthesis	Heart Rate	Exophthalmos
A)	↑	↑	+
B)	↑	↑	–
C)	↑	↓	+
D)	↓	↓	+
E)	↓	↓	–
F)	↓	↑	–

60. A 25-year-old man is severely injured when hit by a speeding vehicle and loses 20% of his blood volume. Which set of physiological changes would be expected to occur in response to the hemorrhage?

	Atrial Stretch Receptor Activity	Arterial Baroreceptor Activity	ADH Secretion
A)	↓	↓	↑
B)	↓	↓	↓
C)	↔	↑	↑
D)	↑	↑	↑
E)	↑	↑	↓

61. If a woman has a tumor that is secreting large amounts of estrogen from the adrenal gland, which of the following will occur?
    A) Progesterone levels in the blood will be very low
    B) Her LH secretion rate will be totally suppressed
    C) She will not have normal menstrual cycles

D) Her bones will be normally calcified
E) All the above

62. When compared with the postabsorptive state, which set of metabolic changes would most likely occur during the postprandial state?

	Hepatic Glucose Uptake	Muscle Glucose Uptake	Hormone-Sensitive Lipase Activity
A)	↑	↑	↑
B)	↑	↓	↑
C)	↓	↑	↓
D)	↑	↑	↓
E)	↓	↑	↑

63. Very early in embryonic development, testosterone is formed within male embryos. What is the function of this hormone at this stage of development?
A) Stimulation of bone growth
B) Stimulation of development of male sex organs
C) Stimulation of development of skeletal muscle
D) Inhibition of LH secretion

64. During spermatogenesis, estrogen is produced by
A) Leydig cells in response to FSH
B) Sertoli cells in response to FSH
C) Leydig cells in response to LH
D) Sertoli cells in response to LH

65. A patient arrives in the emergency department apparently in cardiogenic shock due to a massive heart attack. His initial arterial blood sample reveals the following concentrations of ions and pH level:

Sodium	137 mmol/l
Bicarbonate	14 mmol/l
Free calcium	2.8 mmol/l
Potassium	4.8 mmol/l
pH	7.16

To correct the acidosis, the attending physician begins an infusion of sodium bicarbonate and after 1 hour obtains another blood sample, which reveals the following values:

Sodium	138 mmol/l
Bicarbonate	22 mmol/l
Free calcium	2.3 mmol/l
Potassium	4.5 mmol/l
pH	7.34

What is the cause of the decrease in calcium ion concentration?
A) The increase in arterial pH resulting from the sodium bicarbonate infusion inhibited PTH secretion
B) The increase in pH resulted in the stimulation of osteoblasts, which removed calcium from the circulation
C) The increase in pH resulted in an elevation in the concentration of HPO_4^-, which shifted the equilibrium between HPO_4^- and Ca^{2+} toward $CaHPO_4$
D) The increase in arterial pH stimulated the formation of 1,25-dihydroxycholecalciferol, which resulted in an increased rate of absorption of calcium from the gastrointestinal tract

66. The prostate fluid contributes the bulk of the volume of semen, which includes
A) Calcium, citrate, phosphate, and profibrinolysin
B) Fructose, citric acid, prostaglandins, and fibrinogen
C) Sex hormones
D) Mucus

67. A 30-year-old woman is breastfeeding her infant. During suckling, which hormonal response is expected in the woman?
A) Increased secretion of ADH from the supraoptic nuclei
B) Increased secretion of ADH from the paraventricular nuclei
C) Increased secretion of oxytocin from the paraventricular nuclei
D) Decreased secretion of neurophysin
E) Increased plasma levels of both oxytocin and ADH

68. A 30-year-old man has Conn's syndrome. Which set of physiological changes is most likely to occur in this patient compared with a healthy person?

	Arterial Pressure	Extracellular Fluid Volume	Sodium Excretion
A)	↔	↔	↔
B)	↑	↔	↔
C)	↑	↑	↔
D)	↔	↑	↓
E)	↑	↑	↓

69. Which of the following is important in the process of capacitation of sperm after ejaculation?
A) Microtubule reorganization
B) Increased testosterone secretion by spermatozoa
C) Washout of inhibitory factors
D) Influx of glucose

70. Dehydroepiandrosterone sulfate (DHEAS), the precursor for the high levels of estradiol that occur in pregnancy, is made in what tissue?
A) Fetal adrenal gland
B) Ovary of the mother
C) Placenta
D) Adrenal gland of the mother

71. What is the consequence of sporadic nursing of the neonate by the mother?
    A) An increase in prolactin-releasing hormone
    B) An increase in oxytocin
    C) Lack of birth control
    D) Lack of prolactin surge

72. Which of the following would be associated with parallel changes in aldosterone and cortisol secretion?
    A) Addison's disease
    B) Cushing's disease
    C) Cushing's syndrome (adrenal tumor)
    D) A low-sodium diet
    E) Administration of a converting enzyme inhibitor

73. The process of spermatogenesis begins with spermatogonia and results in which of the following?
    A) 1 diploid spermatid
    B) 4 diploid spermatids
    C) 1 haploid spermatid
    D) 2 haploid spermatids
    E) 4 haploid spermatids

74. RU486 causes abortion if it is administered before or soon after implantation. What is the specific effect of RU486?
    A) It binds to LH receptors, stimulating the secretion of progesterone from the corpus luteum
    B) It blocks progesterone receptors so that progesterone has no effect within the body
    C) It blocks the secretion of FSH by the pituitary
    D) It blocks the effects of oxytocin receptors in the uterine muscle

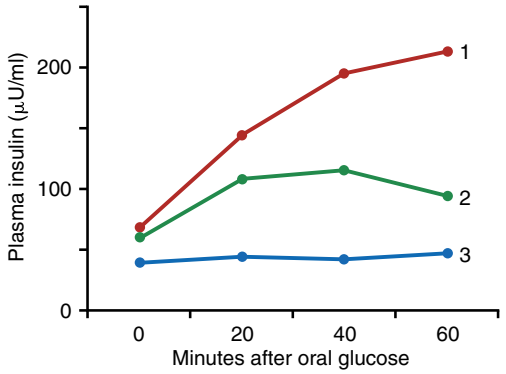
75. A 55-year-old man has developed the syndrome of inappropriate antidiuretic hormone secretion due to carcinoma of the lung. Which physiological response would be expected?
    A) Increased plasma osmolality
    B) Inappropriately low urine osmolality (relative to plasma osmolality)
    C) Increased thirst
    D) Decreased secretion of ADH from the pituitary gland

76. During pregnancy, the uterine smooth muscle is quiescent. During the ninth month of gestation, the uterine muscle becomes progressively more excitable. What factor contributes to the increase in excitability?
    A) Placental estrogen synthesis rises to high rates
    B) Progesterone synthesis by the placenta decreases
    C) Uterine blood flow reaches its highest rate
    D) PGE_2 synthesis by the placenta decreases
    E) Activity of the fetus falls to low levels

77. A 20-year-old woman is not having menstrual cycles. Her plasma progesterone concentration is found to be minimal. What is the explanation for the low level of progesterone?
    A) LH secretion rate is elevated
    B) LH secretion rate is suppressed
    C) FSH secretion rate is suppressed
    D) No corpus luteum is present
    E) High inhibin concentration in the plasma has suppressed progesterone synthesis

78. Before the preovulatory surge in LH, granulosa cells of the follicle secrete which hormone?
    A) Testosterone
    B) Progesterone
    C) Estrogen
    D) Inhibin

Questions 79 and 80



79. Based on the above figure, which set of curves most likely reflects the responses in a healthy individual and in patients with type 1 or type 2 diabetes mellitus (Diabetes mellitus)?

	Healthy	Type 1 Diabetes mellitus	Type 2 Diabetes mellitus
A)	3	2	1
B)	1	2	3
C)	1	3	2
D)	2	1	3
E)	2	3	1

80. Based on the above figure, which set of curves most likely reflects the responses in a healthy person and in a patient in the early stages of Cushing's syndrome?

	Healthy	Cushing's Syndrome
A)	3	2
B)	1	2
C)	1	3
D)	2	1
E)	2	3

81. Which hormone activates enzyme-linked receptors?
    A) ADH
    B) Insulin
    C) ACTH
    D) PTH
    E) Aldosterone

82. Which of the following is produced by the trophoblast cells during the first 3 weeks of pregnancy?
    A) Estrogen
    B) LH
    C) Oxytocin
    D) hCG
    E) None of the above

83. Which of the following is higher in a neonate than in a fetus?
    A) Flow through the foramen ovale
    B) Right atrial pressure
    C) Flow through the ductus arteriosus
    D) Aortic pressure

84. Which finding is most likely in a patient who has myxedema?
    A) Somnolence
    B) Palpitations
    C) Increased respiratory rate
    D) Increased cardiac output
    E) Weight loss

85. At birth, a large, well-nourished baby is found to have a plasma glucose concentration of 17 mg/dl (normal is 80 to 100 mg/dl) and a plasma insulin concentration twice the normal value. What is the explanation for these findings?
    A) The neonate experienced in utero malnutrition
    B) The mother was malnourished during pregnancy
    C) The mother has diabetes, with poorly controlled hyperglycemia
    D) The mother is obese

86. Degradation of the corpus luteum is prevented by which of the following?
    A) Increased estrogen secretion by the developing placenta
    B) Release of hCG from the trophoblasts
    C) Forward positive regulation by LH
    D) Placental derived prolactin

87. Which of the following stimulates the secretion of PTH?
    A) An increase in extracellular calcium ion activity above the normal value
    B) An increase in calcitonin concentration
    C) Respiratory acidosis
    D) Increased secretion of PTH-releasing hormone from the hypothalamus
    E) None of the above

88. A 40-year-old woman consumes a high-potassium diet for several weeks. Which hormonal change is most likely to occur?
    A) Increased secretion of DHEA
    B) Increased secretion of cortisol
    C) Increased secretion of aldosterone
    D) Increased secretion of ACTH
    E) Decreased secretion of CRH

89. After implantation into the uterus, nutrition of the blastocyst comes from which structure?
    A) Placenta
    B) Decidua
    C) Glomerulosa cells
    D) Corpus luteum

90. Which hormone is not stored in its endocrine-producing gland?
    A) T_4
    B) PTH
    C) Aldosterone
    D) ACTH
    E) Insulin

91. A young woman comes to the emergency department with a vertebral compression fracture. Radiographs of the spine indicate generalized demineralization. She is vegetarian, does not smoke or drink alcohol, and has a normal plasma potassium concentration of 5.4 mEq/l, a sodium concentration of 136 mEq/l, and a plasma calcium concentration of 7.0 mg/dl. Her vitamin D_3 value is several times greater than normal, although her 1,25-dihydroxycholecalciferol concentration is at the lower limit of detectability. She has been in renal failure for the past 5 years and undergoes hemodialysis three times each week. What is the cause of her low 1,25-dihydroxycholecalciferol level?
    A) Metabolic acidosis
    B) Metabolic alkalosis
    C) She is unable to form 1,25-dihydroxycholecalciferol because of her extensive kidney disease
    D) She is undergoing dialysis with a dialysis fluid that does not contain calcium
    E) She is taking receiving calcium supplements

92. A placenta is incapable of synthesizing which hormones?
    A) Estrogen
    B) Progesterone
    C) Androgens
    D) Estriol

93. Which of the following hormones is most closely associated with the secretory phase of the endometrial cycle?
    A) Progesterone
    B) Estrogen
    C) FSH

D) LH
E) Inhibin

94. Which finding would likely be reported in a patient with a deficiency in iodine intake?
A) Weight loss
B) Nervousness
C) Increased sweating
D) Increased synthesis of thyroglobulin
E) Tachycardia

95. A 37-year-old woman presents to her physician with an enlarged thyroid gland and high plasma levels of T_4 and T_3. Which of the following is likely to be decreased?
A) Heart rate
B) Cardiac output
C) Peripheral vascular resistance
D) Ventilation rate
E) Metabolic rate

96. Before intercourse, a woman irrigates her vagina with a solution that lowers the pH of the vaginal fluid to 4.5. What will be the effect on sperm cells in the vagina?
A) The metabolic rate will increase
B) The rate of movement will decrease
C) The formation of PGE_2 will increase
D) The rate of oxygen consumption will increase

97. Which hormonal responses would be expected after a meal high in protein?

	Insulin	Glucagon	Growth Hormone
A)	↑	↑	↓
B)	↑	↑	↑
C)	↑	↓	↓
D)	↓	↓	↑
E)	↓	↑	↑

98. Men who take large doses of testosterone-like androgenic steroids for long periods are sterile in the reproductive sense of the word. What is the explanation for this finding?
A) High levels of androgens bind to testosterone receptors in the Sertoli cells, resulting in overstimulation of inhibin formation
B) Overstimulation of sperm cell production results in the formation of defective sperm cells
C) High levels of androgen compounds inhibit the secretion of GnRH by the hypothalamus, resulting in the inhibition of LH and FSH release by the anterior pituitary
D) High levels of androgen compounds produce hypertrophic dysfunction of the prostate gland

99. Cortisone is administered to a 30-year-old woman for the treatment of an autoimmune disease. Which of the following is most likely to occur?
A) Increased ACTH secretion
B) Increased cortisol secretion
C) Increased insulin secretion
D) Increased muscle mass
E) Hypoglycemia between meals

100. In the hypothalamic-pituitary-gonadal axis of the female, what is the follicular cell type that produces inhibin?
A) Cytotrophoblasts
B) Synthiotrophoblasts
C) Granulosa
D) Thecal

101. The function of which of the following is increased by an elevated parathyroid hormone concentration?
A) Osteoclasts
B) Hepatic formation of 25-hydroxycholecalciferol
C) Phosphate reabsorptive pathways in the renal tubules
D) All the above

102. Which statement about peptide or protein hormones is usually true?
A) They have longer half-lives than steroid hormones
B) They have receptors on the cell membrane
C) They have a slower onset of action than both steroid and thyroid hormones
D) They are not stored in endocrine-producing glands

103. Which set of physiological changes would be most likely to occur in a patient with acromegaly?

	Pituitary Mass	Kidney Mass	Femur Length
A)	↓	↓	↑
B)	↓	↑	↑
C)	↑	↔	↔
D)	↑	↑	↔
E)	↑	↑	↑

104. Cortisol and GH are most dissimilar in their metabolic effects on which of the following?
A) Protein synthesis in muscle
B) Glucose uptake in peripheral tissues
C) Plasma glucose concentration
D) Mobilization of triglycerides

105. Why do infants of mothers who had adequate nutrition during pregnancy not require iron supplements or a diet rich in iron until about 3 months of age?

A) Growth of the infant does not require iron until after the third month
B) The fetal liver stores enough iron to meet the infant's needs until the third month
C) Synthesis of new red blood cells begins after 3 months
D) Muscle cells that develop before the third month do not contain myoglobin

106. Cortisone is administered to a patient for the treatment of an autoimmune disease. Which of the following would least likely occur in response to the cortisone treatment?

A) Hypertrophy of the adrenal glands
B) Increased plasma levels of C-peptide
C) Decreased CRH secretion
D) Increased blood pressure
E) Hyperglycemia

107. All of the following accurately describe the regulation of the female sexual cycle EXCEPT one. Which one is the EXCEPTION?

A) Estradiol inhibits GnRH release during the post ovulatory phase
B) Progesterone increases GnRH release during the post ovulatory phase
C) Estradiol increases LH in the days immediately preceding ovulation
D) Falling progesterone and estrogen late in the luteal phase allows LH and FSH to rise
E) LH and FSH increase estradiol release during the follicular phase

108. If a male is born without a penis and testes, a defect is likely in which gene on the Y chromosome?

A) ERE—estrogen response element
B) ARE—androgen response element
C) SRY—affecting Sertoli cells
D) ERG—early response genes

109. Where does fertilization normally take place?

A) Uterus
B) Cervix
C) Ovary
D) Ampulla of the fallopian tubes

110. Which finding is most likely to occur in a patient who has uncontrolled type 1 diabetes mellitus?

A) Decreased plasma osmolality
B) Increased plasma volume
C) Increased plasma pH
D) Increased release of glucose from the liver
E) Decreased rate of lipolysis

111. GH secretion would most likely be suppressed under which condition?

A) Acromegaly
B) Gigantism
C) Deep sleep
D) Exercise
E) Acute hyperglycemia

112. Pregnenolone is not in the biosynthetic pathway of which substance?

A) Cortisol
B) Estrogen
C) Aldosterone
D) 1,25(OH)2D
E) DHEA

113. Two days before the onset of menstruation, secretions of FSH and LH reach their lowest levels. What is the cause of this low level of secretion?

A) The anterior pituitary gland becomes unresponsive to the stimulatory effect of GnRH
B) Estrogen from the developing follicles exerts a feedback inhibition on the hypothalamus
C) The rise in body temperature inhibits hypothalamic release of GnRH
D) Secretion of estrogen, progesterone, and inhibin by the corpus luteum suppresses hypothalamic secretion of GnRH and pituitary secretion of FSH

114. Which condition contributes to "sodium escape" in persons with Conn's syndrome?

A) Decreased plasma levels of atrial natriuretic peptide
B) Increased plasma levels of angiotensin II
C) Decreased sodium reabsorption in the collecting tubules
D) Increased arterial pressure

115. Which of the following most accurately describes events in the female sexual cycle?

A) FSH causes the development of the corpus luteum
B) Estrogen and LH have a positive feedback relationship during the late follicular phase
C) Estrogens are primarily produced by theca cells in the developing ovary
D) During the luteal phase, estrogen increases to a greater degree than progesterone
E) LH is most responsible for the development of primary follicles

116. A 30-year-old woman reports to the clinic for a routine physical examination, which reveals she is pregnant. Her plasma levels of TSH are high, but her total T_4 concentration (protein bound and free) is normal. Which of the following best reflects this patient's clinical state?

A) Graves' disease
B) Hashimoto's disease
C) A pituitary tumor that is secreting TSH
D) A hypothalamic tumor that is secreting TRH
E) The patient is taking thyroid extract

117. A man has a disease that destroyed only the motor neurons of the spinal cord below the thoracic region. Which aspect of sexual function would not be possible?
A) Arousal
B) Erection
C) Lubrication
D) Ejaculation

118. Which of the following is responsible for invasion of the uterus and formation of the placenta?
A) Trophoblasts
B) Oocyte
C) Decidua
D) Endometrium

119. A sustained program of lifting heavy weights will increase bone mass. What is the mechanism of this effect of weightlifting?
A) Elevated metabolic activity stimulates parathyroid hormone secretion
B) Mechanical stress on the bones increases the activity of osteoblasts
C) Elevated metabolic activity results in an increase in dietary calcium intake
D) Elevated metabolic activity results in stimulation of calcitonin secretion

120. The hormone most responsible for maintaining milk production after parturition is
A) Estrogen
B) Progesterone
C) Oxytocin
D) Prolactin
E) Inhibin

121. Which of the following would be expected in a patient with a genetic deficiency of 11-β-hydroxysteroid dehydrogenase type II?
A) Hyperkalemia
B) Hypertension
C) Increased plasma renin activity
D) Increased plasma [aldosterone]
E) Hyperglycemia

122. Which physiological response is greater for T_3 than for T_4?
A) Secretion rate from the thyroid
B) Plasma concentration
C) Plasma half-life
D) Affinity for nuclear receptors in target tissues
E) Latent period for the onset of action in target tissues

123. A "birth control" compound for men has been sought for several decades. Which substance would provide effective sterility?
A) A substance that mimics the actions of LH
B) A substance that blocks the actions of inhibin
C) A substance that blocks the actions of FSH
D) A substance that mimics the actions of GnRH

124. For milk to flow from the nipple of the mother into the mouth of the nursing infant, what must occur?
A) Myoepithelial cells must relax
B) Prolactin levels must fall
C) Oxytocin secretion from the posterior pituitary must take place
D) The baby's mouth must develop a strong negative pressure over the nipple
E) All the above

125. A number of normal physiological changes occur during pregnancy. Which of the following best describes one of these changes in the mother?
A) Increase total peripheral resistance
B) Increased cardiac output
C) Decreased metabolic rate
D) Decreased body weight
E) Decreased uterine size

126. Which set of physiological changes would be expected in a nondiabetic patient with Cushing's disease?

	Plasma Aldosterone	Plasma Cortisol	Plasma Insulin
A)	↑	↑	↑
B)	↑	↑	↔
C)	↑	↔	↔
D)	↔	↔	↑
E)	↔	↑	↔
F)	↔	↑	↑

127. When compared with the late-evening values typically observed in normal subjects, plasma levels of both ACTH and cortisol would be expected to be higher in which persons?
A) Normal subjects after waking in the morning
B) Normal subjects who have taken dexamethasone
C) Patients with Cushing's syndrome (adrenal adenoma)
D) Patients with Addison's disease
E) Patients with Conn's syndrome

128. Which of the following conditions or hormones would most likely increase GH secretion?
A) Hyperglycemia
B) Exercise
C) Somatomedin
D) Somatostatin
E) Aging

129. Which set of findings would be expected in a person maintained on a long-term low-sodium diet?

	Plasma [Aldosterone]	Plasma [Atrial Natriuretic Peptide]	Plasma [Cortisol]
A)	↑	↑	↔
B)	↑	↓	↓
C)	↑	↓	↔
D)	↔	↔	↔
E)	↓	↓	↓
F)	↓	↑	↓

130. What would be associated with parallel changes in aldosterone and cortisol secretion?

A) Addison's disease
B) Cushing's disease
C) Cushing's syndrome (ectopic ACTH-producing tumor)
D) A high-sodium diet
E) Administration of a converting enzyme inhibitor

131. Which blood vessel in the fetus has the highest Po_2?

A) Ductus arteriosus
B) Ductus venosus
C) Ascending aorta
D) Left atrium

132. A 59-year-old woman has osteoporosis, hypertension, hirsutism, and hyperpigmentation. Magnetic resonance imaging indicates that the pituitary gland is not enlarged. Which condition is most consistent with these findings?

A) Pituitary ACTH-secreting tumor
B) Ectopic ACTH-secreting tumor
C) Inappropriately high secretion rate of CRH
D) Adrenal adenoma
E) Addison's disease

133. Which set of findings is an inappropriate hypophysial hormone response to the hypothalamic hormone listed?

	Hypothalamic Hormone Secretion	Hypophysial Hormone
A)	Somatostatin	↓ GH
B)	Dopamine	↑ Prolactin
C)	GnRH	↑ LH
D)	TRH	↑ TSH
E)	CRH	↑ ACTH

134. A patient is administered sufficient T_4 to increase plasma levels of the hormone several fold. Which set of changes is most likely in this patient after several weeks of T_4 administration?

	Respiratory Rate	Heart Rate	Plasma Cholesterol Concentration
A)	↑	↑	↑
B)	↑	↑	↓
C)	↑	↓	↑
D)	↓	↓	↑
E)	↓	↑	↓

135. Which of the following hormones is most critical for sustaining a successful pregnancy, even up through week 12 of gestation?

A) Estrogen
B) Progesterone
C) hCG
D) GnRH
E) Inhibin

136. What causes menopause?

A) Reduced levels of gonadotropic hormones secreted from the anterior pituitary gland
B) Reduced responsiveness of the follicles to the stimulatory effects of gonadotropic hormones
C) Reduced rate of secretion of progesterone from the corpus luteum
D) Reduced numbers of follicles available in the ovary for stimulation by gonadotropic hormones

137. What does not increase when insulin binds to its receptor?

A) Fat synthesis in adipose tissue
B) Protein synthesis in muscle
C) Glycogen synthesis
D) Gluconeogenesis in the liver
E) Intracellular tyrosine kinase activity

138. Release of which hormone is an example of neuroendocrine secretion?

F) GH
G) Cortisol
H) Oxytocin
I) Prolactin
J) ACTH

139. The ability of a fetus to effectively use the relatively low maternal Po_2 is facilitated by which of the following?

A) Decreased glucose transport in the placental villi
B) Increased production of amniotic fluid
C) Increased total fetal hemoglobin concentration
D) Decreased placental membrane permeability
E) Decreased fetal hemoglobin binding capacity

140. Inhibition of the iodide pump would be expected to cause which change?

A) Increased synthesis of T_4
B) Increased synthesis of thyroglobulin

C) Increased metabolic rate
D) Decreased TSH secretion
E) Extreme nervousness

141. Before implantation, the blastocyst obtains its nutrition from uterine endometrial secretions. How does the blastocyst obtain nutrition during the first week after implantation?

A) It continues to derive nutrition from endometrial secretions
B) The cells of the blastocyst contain stored nutrients that are metabolized for nutritional support
C) The placenta provides nutrition derived from maternal blood
D) The trophoblast cells digest the nutrient-rich endometrial cells and then absorb their contents for use by the blastocyst

142. Which pituitary hormone has a chemical structure most similar to that of ADH?

A) Oxytocin
B) ACTH
C) TSH
D) FSH
E) Prolactin

143. Which option would not be efficacious in the treatment of patients with type 2 diabetes?

A) Glucocorticoids
B) Insulin injections
C) Thiazolidinediones
D) Sulfonylureas
E) Weight loss

144. Which of the following is most likely to occur in the early stages of type 2 diabetes?

A) Increased insulin sensitivity
B) Decreased hepatic glucose output
C) Increased plasma levels of C-peptide
D) Increased plasma [β-hydroxybutyric acid]
E) Hypovolemia

145. What is the most common cause of respiratory distress syndrome in neonates born at 7 months' gestation?

A) Pulmonary edema due to pulmonary arterial hypertension
B) Formation of a hyaline membrane over the alveolar surface
C) Failure of the alveolar lining to form adequate amounts of surfactant
D) Excessive permeability of the alveolar membrane to water

146. Which of the following is an expected circulatory change that occurs after birth?

A) Opening of the ductus venosus
B) Opening of the foramen ovale
C) Opening of the ductus arteriosus
D) Closing of the ductus arteriosus
E) Closing of the inferior vena cava

147. A 45-year-old woman has a mass in the sella turcica that compresses the portal vessels, disrupting pituitary access to hypothalamic secretions. The secretion rate of which hormone would most likely increase in this patient?

A) ACTH
B) GH
C) Prolactin
D) LH
E) TSH

148. Which of the following is not produced by osteoblasts?

A) Alkaline phosphatase
B) RANK ligand
C) Collagen
D) Pyrophosphate
E) Osteoprotegerin

149. Which set of findings would be expected in a patient with primary hyperparathyroidism?

	Plasma [1,25-(OH)2D3]	Plasma [Phosphate]	Urinary Ca^{2+} Excretion
A)	↑	↑	↑
B)	↑	↓	↑
C)	↑	↓	↓
D)	↓	↓	↑
E)	↓	↑	↓
F)	↓	↑	↑

150. A man who has been exposed to high levels of gamma radiation is sterile due to destruction of the germinal epithelium of the seminiferous tubules, although he has normal levels of testosterone. Which of the following would be found in this patient?

A) A normal secretory pattern of GnRH
B) Normal levels of inhibin
C) Suppressed levels of FSH
D) Absence of Leydig cells

Questions 151 and 152

An experiment was conducted in which rats were injected with one of two hormones or saline solution (control) for 2 weeks. Autopsies were then performed, and organ weights were measured (in milligrams). Use this information to answer Questions 151 and 152.

	Control	Hormone 1	Hormone 2
Pituitary	12.9	8.0	14.5
Thyroid	250	500	245
Adrenal glands	40	37	85
Body weight	300	152	175

151. What is hormone 1?
    A) TRH
    B) TSH
    C) T4
    D) ACTH
    E) Cortisol

152. What is hormone 2?
    A) TSH
    B) T_4
    C) CRH
    D) ACTH
    E) Cortisol

153. An infant is born with yellow pigmentation in the skin and eyes. What is the most likely cause of this?
    A) Elevated circulating ACTH
    B) Poor renal clearance of bilirubin
    C) The lack of a fully functional liver at birth
    D) Failure of the foramen ovale to close
    E) Delayed onset of breathing

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ANSWERS

1. **A)** The freely circulating (unbound) hormone is the biologically active hormone. Cholecalciferol is a prohormone and thus is not the biologically active vitamin D hormone. In this question, cortisol, T_4, and aldosterone are all bound to carrier proteins.
   TMP14 p. 929

2. **D)** Parasympathetic postganglionic fibers release acetylcholine that activates muscarinic receptors on endothelium to produce NO and increases cyclic guanosine monophosphate, which activates protein kinase G, causing a reduction in intracellular calcium (also increasing NO by positive feedback) and causing vasodilation.
   TMP14 p. 1027

3. **A)** Estrogen compounds are believed to have an osteoblast-stimulating effect. When the amount of estrogen in the blood falls to very low levels after menopause, the balance between the bone-building activity of the osteoblasts and the bone-degrading activity of the osteoclasts is tipped toward bone degradation. When estrogen compounds are added as part of hormone replacement therapy, the bone-building activity of the osteoblasts is increased to balance the osteoclastic activity.
   TMP14 pp. 949, 1045

4. **A)** ADH is made in the supraoptic nuclei of the hypothalamus. It is transported in nerve fibers along with neurophysin carrier proteins that pass through the pituitary stalk and terminate in the posterior pituitary.
   TMP14 pp. 948–949

5. **C)** GH promotes several metabolic changes. These include a net increase in amino acid uptake in the muscle and liver, a decrease in glucose utilization and storage, and an increase in lipolysis. The net effect of GH is to decrease glucose and lipid storage in adipose cells.
   TMP14 pp. 943–944

6. **A)** Norepinephrine is released from the nerve terminals, and endothelin is released from endothelial cells in the vasculature, causing vasoconstriction of the vasculature.
   TMP14 p. 1027

7. **C)** Type 2 diabetes mellitus is characterized by diminished sensitivity of target tissues to the metabolic effects of insulin—that is, there is insulin resistance. As a result, hepatic uptake of glucose is impaired, and glucose release is enhanced. In muscle, the uptake of glucose is impaired.
   TMP14 pp. 985–986, 995

8. **C)** In acromegaly, high plasma levels of GH cause insulin resistance. Consequently, glucose production by the liver is increased, and glucose uptake by peripheral tissues is impaired.
   TMP14 pp. 943–944, 996–997

9. **A)** During exercise, glucose utilization by muscle is increased, which is largely independent of insulin.
   TMP14 p. 985

10. **A)** Thecal cells do not have the capacity to produce estradiol because they lack aromatase.
    TMP14 pp. 1040, 1043, 1044

11. **B)** A very high concentration of testosterone in a female embryo will induce formation of male genitalia. An adrenal tumor in the mother that synthesizes testosterone at a high, uncontrolled rate could produce the masculinizing effect.
    TMP14 pp. 1043, 1044

12. **A)** Osmoreceptors in, or near, the hypothalamus are important regulators of ADH. Hyperosmotic extracellular fluid causes the cells of the hypothalamus to shrink and stimulates the release of ADH, which promotes renal H_2O reabsorption to restore the extracellular fluid to isosmotic.
    TMP14 p. 949

13. **E)** An individual with panhypopituitarism has generalized dysfunction of the pituitary gland. GHRH from the hypothalamus is increased in an attempt to restore the pituitary function. For similar reasons, somatostatin is decreased. Because pituitary function is impaired, growth hormone production is reduced, and because growth hormone stimulates the production of somatomedin, its production is also reduced.
    TMP14 pp. 946–947

14. **C)** Antagonism of progesterone's effects, dilation of the cervix, and oxytocin all increase uterine smooth muscle excitability and facilitate contractions and the onset of labor. LH would have no effect. Prostaglandin E_2 strongly stimulates uterine smooth muscle contraction and is formed at an increasing rate by the placenta late in gestation.
    TMP14 pp. 1064, 1066

15. B) AVPR2 function is impaired in patients with nephrogenic diabetes insipidus, rendering ADH ineffective at increasing H_2O reabsorption in the distal nephron. This causes a compensatory increase in the release of ADH from the supraoptic nuclei of the hypothalamus. Patients with diabetes insipidus run the risk of developing hypernatremia, and they produce a large volume of dilute urine.
TMP14 pp. 381, 439

16. E) Thyroxine (T_4) is the major thyroid hormone, along with triiodothyronine (T_3). An increase in the thyroid hormones attenuates the production of thyroid-stimulating hormone (TSH) through negative feedback inhibition.
TMP14 pp. 958–959

17. C) Thyroid hormones cause a general increase in basal metabolic rate. With an increased metabolic rate, there is an increased metabolic demand of the tissues which is the primary determinant of cardiac output.
TMP14 p. 957

18. A) In a radioimmunoassay, there is too little antibody to completely bind the radioactively tagged hormone and the hormone in the fluid (plasma) to be assayed. Thus, there is competition between the labeled and endogenous hormone for binding sites on the antibody. Consequently, if the amount of radioactive hormone bound to antibody is low, this finding would indicate that plasma levels of endogenous hormone are high.
TMP14 p. 936

19. A) Cold exposure is an important physiological stimulus for the production and release of the thyroid hormones. Cold causes the hypothalamic production of thyrotropin-releasing hormone, which stimulates thyrotropes of the anterior pituitary to release thyroid-stimulating hormone (TSH). The increased TSH stimulates the production of the thyroid hormones, including thyroxine, which helps to relieve the physiological stress caused by the cold.
TMP14 pp. 958–959

20. B) The Sertoli cells of the seminiferous tubules secrete inhibin at a rate proportional to the rate of production of sperm cells. Inhibin has a direct inhibitory effect on anterior pituitary secretion of FSH. FSH binds to specific receptors on the Sertoli cells, causing the cells to grow and secrete substances that stimulate sperm cell production. The secretion of inhibin thereby provides the negative feedback control signal from the seminiferous tubules to the pituitary gland.
TMP14 p. 1033

21. B) A thyroid hormone–producing adenoma causes an increase in thyroid hormones. Thus, one would expect an increase in both circulating T_4 and T_3 caused by the adenoma. The increased T_4 and T_3 feeds back to inhibit the production and release of TRH from the hypothalamus and TSH from the anterior pituitary to halt further production of the thyroid hormones. However, the adenoma does not respond to normal feedback regulation, and thus T_3 and T_4 remain high.
TMP14 pp. 958–961

22. A) The corpus luteum is the only source of progesterone production, except for minute quantities **secreted** from the follicle before ovulation. The corpus luteum is functional between ovulation and the beginning of menstruation, during which time the concentration of LH is suppressed below the level achieved during the preovulatory LH surge.
TMP14 pp. 1046–1047

23. C) The high levels of TSH (outside the normal range) are indicative of hypofunction of the thyroid, and this is further observed with the low total T_4. Thyroxine-binding globulin remains in the normal range, making the best answer Hashimoto's disease, which is the most common form of hypothyroidism. Secondary hypothyroidism occurs in response to failure of the pituitary gland to stimulate the thyroid. Therefore, the high TSH rules out this possibility.
TMP14 pp. 961–962

24. E) Cholesterol desmolase is the key enzyme responsible for the conversion of cholesterol to pregnenolone for the process of steroid synthesis.
TMP14 p. 966

25. A) Aldosterone increases the Na^+K^+ ATPase in the basolateral membrane of the principal cells and increases ENaC channels in the luminal side. This creates a driving force for Na^+ reabsorption and K^+ excretion **leading** to hypokalemia. When aldosterone is low, K^+ excretion is attenuated, leading to hyperkalemia.
TMP14 pp. 969–970

26. E) Anabolic steroids bind to testosterone receptors in the hypothalamus, providing feedback inhibition of normal ovarian cycling and preventing menstrual cycling as well as stimulation of osteoblastic activity in the bones.
TMP14 pp. 1028, 1031

27. D) Chronically elevated aldosterone increases sodium and water retention leading to an expansion of extracellular fluid volume. Increased extracellular fluid leads to increased blood pressure, which promotes pressure natriuresis, causing urinary sodium excretion to come into balance. Thus, during a chronic infusion urinary sodium excretion is not changed.
TMP14 p. 970

28. B) Right atrial pressure falls dramatically after the onset of breathing because of a reduction in pulmonary vascular resistance, pulmonary arterial pressure, and right ventricular pressure.

TMP14 pp. 1073–1075

29. B) Physiological stimuli for glucocorticoids, such as stress, cause the hypothalamic production of corticotropin-releasing hormone (CRH). CRH stimulates corticotropes from the anterior pituitary to release corticotropin (or ACTH). Corticotropin promotes the production of cortisol from the adrenal cortex to help alleviate the physiological stressor.

TMP14 pp. 974–977

30. E) The metabolic actions of cortisol increase the availability of circulating fuel sources in response to physiological stressors. Cortisol impairs skeletal muscle glucose and amino acid uptake (although it promotes hepatic amino acid uptake) and promotes lipolysis from adipocytes. This has the net effect to increase plasma glucose, free fatty acids, and amino acids.

TMP14 pp. 972–973

31. D) Glucose is normally filtered in the glomerulus and reabsorbed in the proximal tubule. However, during untreated type I diabetes, the amount of filtered glucose exceeds (180 mg/dl) the reabsorptive capacity of the proximal tubule, increasing urinary osmolarity. This causes an increase in water filtration, leading to frequent urination (polyuria).

TMP14 pp. 995

32. C) Aromatase causes conversion of testosterone to estradiol.

TMP14 p. 1043

33. D) Because of the loss of blood flow through the placenta, systemic vascular resistance doubles at birth, which increases the aortic pressure as well as the pressure in the left ventricle and left atrium.

TMP14 pp. 1073, 1074

34. C) Consuming a meal consisting of carbohydrate, protein, and fat will stimulate the production and release of insulin, which promotes energy storage. Insulin increases cell permeability to glucose to promote its storage in the form of glycogen (liver) and fat through fatty acid synthesis and storage in the adipose. Hormone-sensitive lipase promotes the breakdown of fat to free fatty acids and is decreased in response to insulin.

TMP14 pp. 985–989

35. B) Type I diabetes is associated with low insulin and thus an impaired ability to store energy. Thus, in the absence of insulin, plasma free fatty acids are increased to be made available for energy, liver glycogen is depleted in an attempt to maintain plasma glucose, and skeletal muscle mass decreases as protein is metabolized to make amino acids available for energy.

TMP14 pp. 994–995

36. C) The postabsorptive state begins approximately 2 hours after a meal when plasma glucose has typically returned to normal. During the postabsorptive state, counter regulatory mechanisms are activated which help to maintain constant plasma glucose concentration. Thus, insulin is reduced to decrease the cellular uptake of glucose and glucagon is increased to promote hepatic production and release of glucose. After several hours, both growth hormone and cortisol are also increased to reduce skeletal muscle and adipose uptake of glucose. The net effect of these mechanisms is to prevent hypoglycemia.

TMP14 pp. 986, 991–992, 994

37. B) hCG also binds to LH receptors on the interstitial cells of the testes of the male fetus, resulting in the production of testosterone in male fetuses up to the time of birth. This small secretion of testosterone is what causes the fetus to develop male sex organs instead of female sex organs.

TMP14 pp. 1033, 1060–1061

38. D) Insulin is a peptide hormone that is derived from proinsulin. It binds to an enzyme linked receptor composed of 2 alpha and 2 beta subunits, leading to an increase in tyrosine kinase activity.

TMP14 pp. 984–985

39. E) The exchange of calcium between the bone fluid compartment and the ECF serves as a rapid and fast-acting mechanism to buffer changes in extracellular fluid calcium concentration.

TMP14 p. 1005

40. B) In nonpregnant woman, the only significant source of estrogen is ovarian follicles or corpus luteae. Menstruation begins when the corpus luteum degenerates. Menstruation ends when developing follicles secrete estrogen sufficiently to raise circulating concentration to a level that stimulates regrowth of the endometrium.

TMP14 pp. 1039, 1042, 1046–1047

41. B) As a result of negative feedback, plasma levels of TSH are a sensitive index of circulating levels of unbound (free) thyroid hormones. High plasma levels of TSH indicate inappropriately low levels of free thyroid hormones in the circulation, such as are present with autoimmune destruction of the thyroid gland in persons with Hashimoto's disease. However, because elevated plasma levels of estrogen in pregnancy increase hepatic production of TBG, the total amount (bound + free) of thyroid hormones in the

circulation is elevated. Plasma levels of thyroid hormones are elevated in persons with Graves' disease and in patients with a pituitary TSH-secreting tumor, as well in patients given thyroid extract for therapy.

TMP14 pp. 954, 958–962

42. F) The kidneys are essential for the conversion of inactive vitamin D prohormones to the biologically active vitamin D hormone (1,25-dihydroxycholecalciferol). This conversion is mediated by parathyroid hormone acting in the proximal tubule epithelial cells. Therefore, with impaired renal function, one would expect a decrease in plasma [1,25-$(OH)_2D$], along with a compensatory increase in PTH. The increased plasma PTH causes bone resorption of calcium.

TMP14 p. 1015

43. D) The cells of the anterior pituitary that secrete LH and FSH, along with the cells of the hypothalamus that secrete GnRH, are inhibited by both estrogen and testosterone. The steroids taken by the woman caused sufficient inhibition to result in cessation of the monthly menstrual cycle.

TMP14 pp. 1033, 1047–1048

44. D) Patients with central diabetes insipidus have an inappropriately low secretion rate of ADH in response to changes in plasma osmolality, but their renal response to ADH is not impaired. Because plasma levels of ADH are depressed, the ability to concentrate urine is impaired, and a large volume of dilute urine is excreted. Loss of water tends to increase plasma osmolality, which stimulates the thirst center and leads to a very high rate of water turnover.

TMP14 p. 949

45. B) NO is the vasodilator that is normally released, causing vasodilation in these arteries.

TMP14 pp. 1027, 1034

46. B) Hydroxyapatite is the major salt found in calcified bone, and the osteon is composed of concentric layers of calcified bone. However, an osteocyte is a quiescent cell that resides in lacunae (spaces). Osteoblasts are the cells that actively form new bone.

TMP14 pp. 1003, 1005–1006

47. B) One of the major physiological roles for PTH is to promote the conversion of 25-hydroxycholecalciferol, to the active 1,25-dihydroxycholecalciferol in the proximal tubular epithelium. The other choices represent normal physiological actions of PTH.

TMP14 pp. 1009–1012

48. D) Lethargy and myxedema are signs of hypothyroidism. Low plasma levels of TSH indicate that the abnormality is in either the hypothalamus or the pituitary gland. The responsiveness of the pituitary to the administration of TRH suggests that pituitary function is normal and that the hypothalamus is producing insufficient amounts of TRH.

TMP14 pp. 958–962

49. D) Inhibin prevents FSH release from the anterior pituitary, preventing Sertoli cells from causing aromatization to produce estradiol.

TMP14 p. 1032

50. A) After menopause, the absence of feedback inhibition by estrogen and progesterone results in extremely high rates of FSH secretion. Women taking estrogen as part of hormone replacement therapy for symptoms associated with postmenopausal conditions have suppressed levels of FSH as a result of the inhibitory effect of estrogen.

TMP14 pp. 1050, 1051

51. D) Phosphodiesterase-5 receptors prevent hydrolysis of cyclic guanosine monophosphate, thus keeping the levels high and maintaining vasodilation.

TMP14 p. 1034

52. B) Glucagon stimulates glycogenolysis in the liver, but it has no physiological effects in muscle. Both glucagon and cortisol increase gluconeogenesis, and cortisol impairs glucose uptake by muscle.

TMP14 pp. 972–973, 992

53. C) Injection of insulin leads to a decrease in blood glucose concentration. Hypoglycemia stimulates the secretion of GH, glucagon, and epinephrine, all of which have counter regulatory effects to increase glucose levels in the blood.

TMP14 pp. 945, 993–994

54. A) Prolonged fetal hypoxia during delivery can cause serious depression of the respiratory center. Hypoxia may occur during delivery because of compression of the umbilical cord, premature separation of the placenta, excessive contraction of the uterus, or excessive anesthesia of the mother.

TMP14 p. 1073

55. C) In general, peptide hormones are water soluble and are not highly bound by plasma proteins. ADH, a neurohypophysial peptide hormone, is virtually unbound by plasma proteins. In contrast, steroid and thyroid hormones are highly bound to plasma proteins.

TMP14 pp. 929–930

56. C) The rise in intracellular calcium in the oocyte triggers the cortical reaction in which granules that previously lay at the base of the plasma membrane undergo exocytosis. This process leads to the release of enzymes that "harden" the zona pellucida and prevent other sperm from penetrating.

TMP14 p. 1025

57. B) Although estrogen and progesterone are essential for the physical development of the breast during pregnancy, a specific effect of both these hormones is to inhibit the actual secretion of milk. Even though prolactin levels are increased 10- to 20-fold at the end of pregnancy, the suppressive effects of estrogen and progesterone prevent milk production until after the baby is born. Immediately after birth, the sudden loss of both estrogen and progesterone secretion from the placenta allows the lactogenic effect of prolactin to promote milk production.

TMP14 pp. 1066–1067

58. C) The concentration of PTH strongly regulates the absorption of calcium ion from the renal tubular fluid. A reduction in hormone concentration reduces calcium reabsorption and increases the rate of calcium excretion in the urine. The other choices either have little effect on or decrease calcium excretion.

TMP14 pp. 1011–1012

59. B) A pituitary tumor secreting increased amounts of TSH would be expected to stimulate the thyroid gland to secrete increased amounts of thyroid hormones. TSH stimulates several steps in the synthesis of thyroid hormones, including the synthesis of thyroglobulin. Increased heart rate is among the many physiological responses to high plasma levels of thyroid hormones. However, high plasma levels of thyroid hormones do not cause exophthalmos. Immunoglobulins cause exophthalmos in Graves' disease, the most common form of hyperthyroidism.

TMP14 pp. 952, 957, 961

60. A) Hemorrhage decreases the activation of stretch receptors in the atria and arterial baroreceptors. Decreased activation of these receptors increases ADH secretion.

TMP14 p. 949

61. E) Choices A to D are true: LH secretion will be suppressed (B) by the negative feedback effect of the estrogen from the tumor; consequently, she will not have menstrual cycles (C), and because she will not have normal cycles, no corpus luteae will develop, so no progesterone will be formed (A). The high levels of estrogen produced by the tumor will provide stimulation of osteoblastic activity to maintain normal bone activity (D).

TMP14 pp. 1044, 1045

62. D) After eating a meal, insulin secretion is increased. As a result, there is an increased rate of glucose uptake by both the liver and muscle. Insulin also inhibits hormone-sensitive lipase, which decreases hydrolysis of triglycerides in fat cells.

TMP14 pp. 985–987, 992

63. B) The primary function of testosterone in the embryonic development of males is to stimulate formation of the male sex organs.

TMP14 pp. 219–220, 364, 383, 405, 949–950

64. B) FSH stimulates the production of estrogens from Sertolis cells in the testis. The Sertoli cells receive testosterone from Leydig cells (stimulated by LH) and use the testosterone to make estrogen.

TMP14 p. 1023

65. C) The reduction in hydrogen ion indicated by the elevation in pH increases the concentration of negatively charged phosphate ion species available for ionic combination with calcium ions. Consequently, the free calcium ion concentration is reduced.

TMP14 pp. 1011–1012

66. A) Prostate fluid contains calcium, citrate, phosphate and fibrinolysin. The function of prostate fluid is to help neutralize the acidic environment associated with other seminal fluids and thus improve sperm motility.

TMP14 p. 1024

67. C) During suckling, stimulation of receptors on the nipples increases neural input to both the supraoptic and paraventricular nuclei. Activation of these nuclei leads to the release of oxytocin and neurophysin from secretion granules in the posterior pituitary gland. Suckling does not stimulate the secretion of appreciable amounts of ADH.

TMP14 pp. 1066, 1067

68. C) In Conn's syndrome, large amounts of aldosterone are secreted. Because aldosterone causes sodium retention, hypertension is a common finding in patients with this condition. However, the degree of sodium retention is modest, as is the resultant increase in extracellular fluid volume. This occurs because the rise in arterial pressure offsets the sodium-retaining effects of aldosterone, limiting sodium retention and permitting daily sodium balance to be achieved.

TMP14 pp. 970, 981

69. C) The activity of stored sperm is attenuated as a result of the acidic environment. After ejaculation, uterine and fallopian fluids wash away inhibitory factors, allowing for full activation of the spermatozoa.

TMP14 pp. 1024–1025

70. D) DHEA sulfate produced by the fetal adrenal gland diffuses to the placenta and is converted to DHEA and then to estradiol and provides estradiol to the mother.

TMP14 pp. 1060, 1061

71. D) Sporadic nursing of the mother results in a lack of prolactin surge because mechanosensors in the nipple cause prolactin release. Without prolactin release,

there is a lack of milk production, and the mother eventually will not be able to provide milk for the baby.

TMP14 pp. 1066, 1067

72. A) Persons with Addison's disease have diminished secretion of both glucocorticoids (cortisol) and mineralocorticoids (aldosterone). In persons with Cushing's disease or Cushing's syndrome, cortisol secretion is elevated, but aldosterone secretion is normal. A low-sodium diet is associated with a high rate of aldosterone secretion but a secretion rate of cortisol that is normal. By inhibiting the generation of angiotensin II and thus the stimulatory effects of angiotensin II on the zona glomerulosa, administration of a converting enzyme inhibitor would decrease aldosterone secretion without altering the rate of cortisol secretion.

TMP14 pp. 971–972, 979–980

73. E) Spermatogonia undergo two rounds of meiotic division, leading to the production of four haploid spermatids. The spermatids ultimately differentiate into mature sperm.

TMP14 pp. 1021–1022

74. B) Progesterone is required to maintain the decidual cells of the endometrium. If progesterone levels fall, as they do during the last days of a nonpregnant menstrual cycle, menstruation will follow within a few days, with loss of pregnancy. Administration of a compound that blocks the progesterone receptor during the first few days after conception will terminate the pregnancy.

TMP14 pp. 1060–1061

75. D) An inappropriately high rate of ADH secretion from the lung promotes excess water reabsorption, which tends to produce concentrated urine and a decrease in plasma osmolality. Low plasma osmolality suppresses both thirst and ADH secretion from the pituitary gland.

TMP14 pp. 404, 949

76. B) A very high plasma concentration of progesterone maintains the uterine muscle in a quiescent state during pregnancy. In the final month of gestation, the concentration of progesterone begins to decline, increasing the excitability of the muscle.

TMP14 pp. 971–972, 1027

77. D) The corpus luteum is the only source of progesterone. If she is not having menstrual cycles, no corpus luteum is present.

TMP14 p. 1048

78. C) FSH stimulates the granulosa cells of the follicle to secrete estrogen.

TMP14 pp. 1040, 1048

79. E) In response to increased blood levels of glucose, plasma insulin concentration normally increases during the 60-minute period following oral intake of glucose. In type 1 diabetes mellitus, insulin secretion is depressed. In contrast, in type 2 diabetes mellitus, insulin resistance is a common finding, and at least in the early stages of the disease, there is an abnormally high rate of insulin secretion.

TMP14 pp. 995–998

80. D) In Cushing's syndrome, high plasma levels of cortisol impair glucose uptake in peripheral tissues, which tends to increase plasma levels of glucose. As a result, the insulin response to oral intake of glucose is enhanced.

TMP14 pp. 996–998

81. B) In general, protein hormones cause physiological effects by binding to receptors on the cell membrane. However, of the four protein hormones indicated, only insulin activates an enzyme-linked receptor. Aldosterone is a steroid hormone and enters the cytoplasm of the cell before binding to its receptor.

TMP14 p. 932

82. D) hCG is secreted from the trophoblast cells beginning shortly after the blastocyst implants in the endometrium.

TMP14 pp. 1060–1061

83. B) Aortic pressure increases due to the increase in left ventricular pressure. The increase in left atrial pressure causes the foramen ovale to close. The ductus arteriosus also closes within a short time after birth.

TMP14 pp. 1073–1075

84. A) Somnolence is a common feature of hypothyroidism. Palpitations, increased respiratory rate, increased cardiac output, and weight loss are all associated with hyperthyroidism.

TMP14 pp. 957, 962–963

85. C) An infant born of a mother with untreated diabetes will have considerable hypertrophy and hyperfunction of the islets of Langerhans in the pancreas. As a consequence, the infant's blood glucose concentration may fall to lower than 20 mg/dl shortly after birth.

TMP14 pp. 1078–1079

86. B) If a successful fertilization event occurs, followed by implantation in the uterine wall, trophoblasts produce and secrete human chorionic gonadotropin, which maintains the corpus luteum and its production of estrogen and progesterone. Eventually, hCG levels decline in association with increased placental production of progesterone and estrogen.

TMP14 p. 1042

87. E) Choices A to D would not stimulate PTH secretion. An increase in calcium concentration (A) suppresses PTH secretion; calcitonin has little to no effect on PTH secretion (B); acidosis would increase free calcium in the extracellular fluid, thereby inhibiting PTH secretion (C); and PTH-releasing hormone does not exist (D).
TMP14 pp. 1001, 1011

88. C) Potassium is a potent stimulus for aldosterone secretion, as is angiotensin II. Therefore, a patient consuming a high-potassium diet would exhibit high circulating levels of aldosterone.
TMP14 p. 971

89. B) The decidua and trophoblasts provide the nutrition needed to provide nourishment of the blastocyst.
TMP14 pp. 1057, 1060–1062

90. C) Steroid hormones are not stored to any appreciable extent in their endocrine-producing glands. This is true for aldosterone, which is produced in the adrenal cortex. In contrast, there are appreciable stores of thyroid hormones and peptide hormones in their endocrine-producing glands.
TMP14 p. 928

91. C) 1,25-Dihydroxycholecalciferol is formed only in the renal cortex. Extensive renal disease reduces the amount of cortical tissue, eliminating the source of this active calcium regulating hormone.
TMP14 p. 1015

92. C) The placenta cannot produce androgens but can only produce DHEA by removal of the sulfate from DHEAS produced in the fetal adrenal glands.
TMP14 p. 1060

93. A) The secretory phase of the endometrial cycle aligns with the luteal phase of the ovarian cycle. Progesterone levels peak during this phase and promote the vascularization and thickening of the endometrial lining. If a fertilization event and subsequent implantation does not occur, the corpus luteum involutes causing progesterone levels to fall and the endometrial lining to slough off during menstruation.
TMP14 pp. 1046–1047

94. D) Because iodine is needed to synthesize thyroid hormones, the production of thyroid hormones is impaired if iodine is deficient. As a result of feedback, plasma levels of TSH increase and stimulate the follicular cells to increase the synthesis of thyroglobulin, which results in a goiter. Increased metabolic rate, sweating, nervousness, and tachycardia are all common features of hyperthyroidism, not hypothyroidism, due to iodine deficiency.
TMP14 pp. 960–963

95. C) Because of the effects of thyroid hormones to increase metabolism in tissues, tissues vasodilate, thus increasing blood flow and cardiac output. All the other choices increase in response to high plasma levels of thyroid hormones.
TMP14 pp. 956–957

96. B) Sperm cell motility decreases as pH is reduced below 6.8. At a pH of 4.5, sperm cell motility is significantly reduced. However, the buffering effect of sodium bicarbonate in the prostatic fluid raises the pH somewhat, allowing the sperm cells to regain some mobility.
TMP14 p. 1024

97. B) A protein meal stimulates all three hormones indicated.
TMP14 pp. 945, 991, 993

98. C) Testosterone secreted by the testes in response to LH inhibits hypothalamic secretion of GnRH, thereby inhibiting anterior pituitary secretion of LH and FSH. Taking large doses of testosterone-like steroids also suppresses the secretion of GnRH and the pituitary gonadotropic hormones, resulting in sterility.
TMP14 p. 1033

99. C) Steroids with potent glucocorticoid activity tend to increase plasma glucose concentration. As a result, insulin secretion is stimulated. Increased glucocorticoid activity also diminishes muscle protein. Because of feedback, cortisone administration leads to a decrease in adrenocorticotropic hormone secretion and therefore a decrease in plasma cortisol concentration.
TMP14 pp. 972–973

100. C) Inhibin is the hormone that has a negative feedback on the anterior pituitary to prevent FSH from being released. Inhibin is produced by the granulosa cells in the ovary.
TMP14 pp. 1040–1041

101. A) An increase in the concentration of PTH results in the stimulation of existing osteoclasts and, over longer periods, increases the number of osteoclasts present in the bone.
TMP14 pp. 1010–1011

102. B) In general, peptide hormones produce biological effects by binding to receptors on the cell membrane. Peptide hormones are stored in secretion granules in their endocrine-producing cells and have relatively short half-lives because they are not highly bound to plasma proteins. Protein hormones often have a rapid onset of action because, unlike steroid and thyroid hormones, protein synthesis is usually not a prerequisite to produce biological effects.
TMP14 pp. 926, 929–932

103. D) A pituitary tumor secreting GH is likely to present as an increase in pituitary gland size. The anabolic effects of excess GH secretion lead to enlargement of the internal organs, including the kidneys. Because acromegaly is the state of excess GH secretion after epiphyseal closure, increased femur length does not occur.

TMP14 p. 947

104. A) GH and cortisol have opposite effects on protein synthesis in muscle. GH is anabolic and promotes protein synthesis in most cells of the body, whereas cortisol decreases protein synthesis in extrahepatic cells, including muscle. Both hormones impair glucose uptake in peripheral tissues and therefore tend to increase plasma glucose concentration. Both hormones also mobilize triglycerides from fat stores.

TMP14 pp. 943–944, 972–973

105. B) If the mother has had adequate amounts of iron in her diet, the infant's liver usually has enough stored iron to form blood cells for 4 to 6 months after birth. However, if the mother had insufficient iron levels, severe anemia may develop in the infant after about 3 months of life.

TMP14 pp. 1072, 1077

106. A) High plasma levels of steroids with glucocorticoid activity suppress CRH and, consequently, ACTH secretion. Therefore, the adrenal glands would actually atrophy with chronic cortisone treatment. Increased plasma levels of glucocorticoids tend to cause sodium retention and increase blood pressure. They also tend to increase plasma levels of glucose and, consequently, stimulate insulin secretion and C-peptide, which is part of the insulin prohormone.

TMP14 pp. 972–973, 976–977, 979–980

107. B) During the postovulatory phase of the cycle, there is a negative feedback relationship between progesterone and estrogen and the hypothalamic pituitary axis. Therefore, progesterone suppresses GnRH release.

TMP14 pp. 1040–1042

108. C) SRY is the region on the Y chromosome that encodes a transcription factor that causes differentiation of Sertoli cells from precursors in testis. If SRY is not present, granulosa cells in the ovary are produced.

TMP14 p. 1029

109. D) Fertilization of the ovum normally takes place in the ampulla of one of the fallopian tubes.

TMP14 p. 1055

110. D) Because insulin secretion is deficient in persons with type 1 diabetes mellitus, there is increased (not decreased) release of glucose from the liver. Low plasma levels of insulin also lead to a high rate of lipolysis; increased plasma osmolality, hypovolemia, and acidosis are all symptoms of uncontrolled type 1 diabetes mellitus.

TMP14 pp. 995–996

111. E) Under acute conditions, an increase in blood glucose concentration will decrease GH secretion. GH secretion is characteristically elevated in the chronic pathophysiological states of acromegaly and gigantism. Deep sleep and exercise are stimuli that increase GH secretion.

TMP14 pp. 945–946

112. D) All the steroids listed include pregnenolone early in their biosynthetic pathway. 1,25(OH)2D is derived from vitamin D and does not include pregnenolone in its biosynthetic pathway.

TMP14 pp. 965–967, 1007–1008

113. D) Estrogen and, to a lesser extent, progesterone secreted by the corpus luteum during the luteal phase have strong feedback effects on the anterior pituitary gland to maintain low secretory rates of both FSH and LH. In addition, the corpus luteum secretes inhibin, which inhibits the secretion of FSH.

TMP14 p. 1042

114. D) Under chronic conditions, the effects of high plasma levels of aldosterone to promote sodium reabsorption in the collecting tubules are sustained. However, persistent sodium retention does not occur because of concomitant changes that promote sodium excretion. These changes include increased arterial pressure, increased plasma levels of atrial natriuretic peptide, and decreased plasma angiotensin II concentration.

TMP14 pp. 961, 981

115. B) For reasons that are not entirely clear, the negative feedback regulation between estrogen and LH that occurs throughout the ovarian cycle briefly changes to a positive feedback mechanism. This occurs late in the follicular phase, just prior to ovulation, when LH promotes estrogen production and estrogen feeds back to stimulate the further release of LH. This underlies the surge in LH just before ovulation.

TMP14 pp. 1040–1042

116. B) Circulating levels of free T_4 exert biological effects and are regulated by feedback inhibition of TSH secretion from the anterior pituitary gland. Protein-bound T_4 is biologically inactive. Circulating T_4 is highly bound to plasma proteins, especially to TBG, which increases during pregnancy. An increase in TBG tends to decrease free T_4, which then leads to an increase in TSH secretion, causing the thyroid to increase thyroid hormone secretion. Increased secretion of thyroid hormones persists until free T_4 returns to normal levels, at

which time there is no longer a stimulus for increased TSH secretion. Therefore, in a chronic steady-state condition associated with elevated TBG, high plasma total T_4 (bound and free) and normal plasma TSH levels would be expected. In this pregnant patient, the normal levels of total T_4, along with high plasma levels of TSH, would indicate an inappropriately low plasma level of free T_4. Deficient thyroid hormone secretion in this patient would be consistent with Hashimoto's disease, the most common form of hypothyroidism.

TMP14 pp. 954, 958–962

117. D) The motor neurons of the spinal cord of the thoracic and lumbar regions are the sources of innervation for the skeletal muscles of the perineum involved in ejaculation.

TMP14 pp. 1026, 1027

118. A) Trophoblasts invade the endometrial lining of the uterus and provide nutrients to the growing blastocyst until the placenta if formed.

TMP14 pp. 1056–1057

119. B) Bone is deposited in proportion to the compressional load that the bone must carry. Continual mechanical stress stimulates osteoblastic deposition and calcification of bone.

TMP14 pp. 1006–1007

120. D) Prolactin is produced in the anterior pituitary from lactotrope cells and is responsible for promoting milk production and secretion.

TMP14 pp. 1067–1068

121. B) In the absence of 11-β-hydroxysteroid dehydrogenase, renal epithelial cells cannot convert cortisol to cortisone; therefore, cortisol will bind to the mineralocorticoid receptor and mimic the actions of excess aldosterone. Consequently, this would result in hypertension associated with suppression of the renin-angiotensin-aldosterone system, along with hypokalemia.

TMP14 pp. 968–970, 980–981

122. D) In target tissues, nuclear receptors for thyroid hormones have a greater affinity for T_3 than for T_4. The secretion rate, plasma concentration, half-life, and onset of action are all greater for T_4 than for T_3.

TMP14 pp. 953–955

123. C) Blocking the action of FSH on the Sertoli cells of the seminiferous tubules interrupts the production of sperm. Choice C is the only option that is certain to provide sterility.

TMP14 p. 1033

124. C) Oxytocin is secreted from the posterior pituitary gland and carried in the blood to the breast, where it causes the cells that surround the outer walls of the alveoli and ductile system to contract. Contraction of these cells raises the hydrostatic pressure of the milk in the ducts to 10 to 20 mm Hg. Consequently, milk flows from the nipple into the baby's mouth.

TMP14 pp. 1068–1069

125. B) Resulting from the growing fetal-placental unit, there is a large increase in metabolic demand during a normal pregnancy. Given that metabolic demand is the major determinant for cardiac output, the increase in metabolic demand during pregnancy causes an increase in cardiac output.

TMP14 p. 1062

126. F) Persons with Cushing's disease have a high rate of cortisol secretion, but aldosterone secretion is normal. High plasma levels of cortisol tend to increase plasma glucose concentration by impairing glucose uptake in peripheral tissues and by promoting gluconeogenesis. However, at least in the early stages of Cushing's disease, the tendency for glucose concentration to increase appreciably is counteracted by increased insulin secretion.

TMP14 pp. 972–973, 979–980

127. A) In healthy patients, the secretory rates of ACTH and cortisol are low in the late evening but high in the early morning. In patients with Cushing's syndrome (adrenal adenoma) or in patients taking dexamethasone, plasma levels of ACTH are very low and are certainly not higher than normal early morning values. In patients with Addison's disease, plasma levels of ACTH are elevated as a result of deficient adrenal secretion of cortisol. The secretion of ACTH and cortisol would be expected to be normal in Conn's syndrome.

TMP14 pp. 977–980

128. B) Exercise stimulates GH secretion. Hyperglycemia, somatomedin, and the hypothalamic inhibitory hormone somatostatin all inhibit GH secretion. GH secretion also decreases as persons age.

TMP14 p. 945

129. C) A low-sodium diet would stimulate aldosterone but not cortisol secretion. Increased atrial stretch associated with volume expansion would stimulate atrial natriuretic peptide secretion but would not be expected during a low-sodium diet.

TMP14 pp. 364, 405, 971–972

130. A) Adrenal gland hypofunction with Addison's disease is associated with decreased secretion of both aldosterone and cortisol. In Cushing's disease and Cushing's syndrome associated with an ectopic tumor, the mineralocorticoid-hypertension induced by high plasma levels of cortisol would suppress aldosterone secretion. Neither a high-sodium diet nor administration of a converting enzyme inhibitor would affect cortisol secretion.

TMP14 pp. 971-972, 979–980

131. B) Blood returning from the placenta through the umbilical vein passes through the ductus venosus. The blood coming from the placenta has the highest concentration of oxygen found in the fetus.

TMP14 p. 1074

132. B) Osteoporosis, hypertension, hirsutism, and hyperpigmentation are all symptoms of Cushing's syndrome associated with high plasma levels of ACTH. If the high plasma ACTH levels were the result of either a pituitary adenoma or an abnormally high rate of corticotropin-releasing hormone secretion from the hypothalamus, the patient would likely have an enlarged pituitary gland. In contrast, the pituitary gland would not be enlarged if an ectopic tumor were secreting high levels of ACTH.

TMP14 pp. 979–980

133. B) Prolactin secretion is inhibited, not stimulated, by the hypothalamic release of dopamine into the median eminence. GH is inhibited by the hypothalamic-inhibiting hormone somatostatin. The secretion of LH, TSH, and ACTH are all under the control of the releasing hormones indicated.

TMP14 p. 942

134. B) Increased heart rate, increased respiratory rate, and decreased cholesterol concentration are all responses to excess thyroid hormone.

TMP14 pp. 956–958

135. C) hCG is produced by syncytial trophoblasts from the growing blastocyst. hCG is responsible for maintaining the corpus luteum which produces estrogens and progesterone up through approximately 12 weeks' gestation. After that time, the placenta makes enough estrogen and progesterone to sustain the pregnancy.

TMP14 pp. 1059–1060

136. D) By age 45 years, only a few primordial follicles remain in the ovaries to be stimulated by gonadotropic hormones, and the production of estrogen decreases as the number of follicles approaches zero. When estrogen production falls below a critical value, it can no longer inhibit the production of gonadotropic hormones from the anterior pituitary. FSH and LH are produced in large quantities, but as the remaining follicles become atretic, production by the ovaries falls to zero.

TMP14 pp. 1050, 1051

137. D) The binding of insulin to its receptor activates tyrosine kinase, resulting in metabolic events leading to increased synthesis of fats, proteins, and glycogen. In contrast, gluconeogenesis is inhibited.

TMP14 pp. 984–989

138. C) The secretion of chemical messengers (neurohormones) from neurons into the blood is referred to as neuroendocrine secretion. Thus, in contrast to the local actions of neurotransmitters at nerve endings, neurohormones circulate in the blood before producing biological effects at target tissues. Oxytocin is synthesized from magnocellular neurons whose cell bodies are located in the paraventricular and supraoptic nuclei and whose nerve terminals terminate in the posterior pituitary gland. Target tissues for circulating oxytocin are the breast and uterus, where the hormone plays a role in lactation and parturition, respectively.

TMP14 pp. 925, 948–950

139. C) The placenta is hypoxic under normal physiological conditions. The diffusion of oxygen from the maternal circulation to the fetal circulation is enhanced by the fact that fetal hemoglobin carries a greater quantity of oxygen at a given blood Po_2 than maternal hemoglobin. In addition, the hemoglobin concentration is greater in the fetal circulation than in the maternal circulation.

TMP14 p. 1058

140. B) Inhibition of the iodide pump decreases the synthesis of thyroid hormones but does not impair the production of thyroglobulin by follicular cells. Decreased plasma levels of thyroid hormones result in a low metabolic rate and lead to an increase in TSH secretion. Increased plasma levels of TSH stimulate the follicular cells to synthesize more thyroglobulin. Nervousness is a symptom of hyperthyroidism and is not caused by thyroid hormone deficiency.

TMP14 pp. 951–952, 956–960

141. D) As the blastocyst implants, the trophoblast cells invade the decidua, digesting and imbibing it. The stored nutrients in the decidual cells are used by the embryo for growth and development. During the first week after implantation, this is the only means by which the embryo can obtain nutrients. The embryo continues to obtain at least some of its nutrition in this way for up to 8 weeks, although the placenta begins to provide nutrition after about the 16th day beyond fertilization (a little more than 1 week after implantation).

TMP14 p. 1056

142. A) Both ADH and oxytocin are peptides containing nine amino acids. Their chemical structures differ in only two amino acids.

TMP14 p. 949

143. A) Because glucocorticoids decrease the sensitivity of tissues to the metabolic effects insulin, they would exacerbate diabetes. Thiazolidinediones and weight loss increase insulin sensitivity. Sulfonylureas increase insulin secretion. If weight loss and the aforementioned drugs are ineffective, exogenous insulin may be used to regulate blood glucose concentration.

TMP14 pp. 991, 996–997

144. C) In the early stages of type 2 diabetes, the tissues have a decreased sensitivity to insulin. As a result, there is a tendency for plasma glucose to increase, in part because decreased hepatic insulin sensitivity leads to increased hepatic glucose output. Because of the tendency for plasma glucose to increase, there is a compensatory increase in insulin secretion, including C-peptide, which is part of the insulin prohormone. Hypovolemia and increased production of ketone bodies, although commonly associated with uncontrolled type 1 diabetes, are not typically present in the early stages of type 2 diabetes.

TMP14 pp. 984, 994–998

145. C) One of the most characteristic findings in respiratory distress syndrome is failure of the respiratory epithelium to secrete adequate quantities of surfactant into the alveoli. Surfactant decreases the surface tension of the alveolar fluid, allowing the alveoli to open easily during inspiration. Without sufficient surfactant, the alveoli tend to collapse, and there is a tendency to develop pulmonary edema.

TMP14 p. 1074

146. D) Several circulatory changes occur in the fetal circulation after birth. These include the closing of physiological shunts. The ductus arteriosus is a shunt that carries blood from the fetal pulmonary artery into the descending aorta, thus bypassing the pulmonary circulation. At birth, this shunt closes as systemic resistance increases, causing blood to flow back into the pulmonary circulation through the shunt. Within hours of birth, the walls of the ductus arteriosus close, and eventually the closing becomes fibrous for permanent closure.

TMP14 pp. 1074–1075

147. C) The primary controllers of ACTH, GH, LH, and TSH secretion from the pituitary gland are hypothalamic-releasing hormones. They are secreted into the median eminence and subsequently flow into the hypothalamic-hypophysial portal vessels before bathing the cells of the anterior pituitary gland. Conversely, prolactin secretion from the pituitary gland is influenced primarily by the hypothalamic-inhibiting hormone dopamine. Consequently, obstruction of blood flow through the portal vessels would lead to reduced secretion of ACTH, GH, LH, and TSH but increased secretion of prolactin.

TMP14 p. 942

148. D) Osteoblasts secrete all of these except pyrophosphate. Secretions (alkaline phosphatase) from osteoblasts neutralize pyrophosphate, an inhibitor of hydroxyapatite crystallization. Neutralization of pyrophosphate permits the precipitation of calcium salts into collagen fibers.

TMP14 pp. 1004–1006

149. B) In primary hyperparathyroidism, high plasma levels of PTH increase the formation of 1,25-(OH)2D3, which increases intestinal absorption of calcium. This action of PTH, along with its effects to increase bone resorption and renal calcium reabsorption, leads to hypercalcemia. However, because of the high filtered load of calcium, calcium is excreted in the urine. High plasma levels of PTH also decrease phosphate reabsorption and increase urinary excretion, leading to a fall in plasma phosphate concentration.

TMP14 pp. 1009–1012, 1014–1015

150. A) Gamma radiation destroys the cells undergoing the most rapid rates of mitosis and meiosis, the germinal epithelium of the testes. The man described is said to have normal testosterone levels, suggesting that the secretory patterns of GnRH and LH are normal and that his interstitial cells are functional. Because he is not producing sperm, the levels of inhibin secreted by the Sertoli cells would be maximally suppressed, and his levels of FSH would be strongly elevated.

TMP14 p. 1033

151. B) In this experiment, the size of the thyroid gland increased because TSH causes hypertrophy and hyperplasia of its target gland and increased secretion of thyroid hormones. Increased plasma levels of thyroid hormones inhibit the secretion of TRH, which decreases stimulation of the pituitary thyrotropes, resulting in a decrease in the size of the pituitary gland. Higher plasma levels of thyroid hormones also increase metabolic rate and decrease body weight.

TMP14 pp. 955–957, 960

152. C) In this experiment, the size of the pituitary and adrenal glands increased because CRH stimulates the pituitary corticotropes to secrete ACTH, which in turn stimulates the adrenals to secrete corticosterone and cortisol. Higher plasma levels of cortisol increase protein degradation and lipolysis and therefore decrease body weight.

TMP14 pp. 972–974, 976–977

153. C) At birth, the neonatal liver is not fully functional. Therefore, it does not excrete bilirubin properly over the first several days of life. The increased concentration of circulating bilirubin gives infants a yellow pigmentation in the skin and eyes (jaundice).

TMP14 pp. 1076–1077

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UNIT XV

Sports Physiology

1. A Tour de France rider has the following values under resting conditions:

   Oxygen consumption = 250 ml O_2/min
   Hemoglobin concentration = 15 g Hg/dl
   Arterial partial pressure of oxygen (P_{O_2}) = 100 mm Hg
   Mixed venous saturation = 75 percent

   When exercising, he has the following values:

   Oxygen consumption = 3000 ml O_2/min
   Hemoglobin concentration = 15 g/dl
   Arterial P_{O_2} = 100 mm Hg
   Mixed venous saturation = 25%

   What is the absolute increase in cardiac output with exercise?

   A) 5 l/min
   B) 15 l/min
   C) 25 l/min
   D) 30 l/min

2. A female university student is comfortably running a 10K race. At 5 miles, which set of values would best describe her blood composition?

	Arterial P_{O_2}	Arterial P_{CO_2}	Mixed Venous P_{O_2}
A)	↑	↑	↓
B)	↑	↑	↔
C)	↑	↓	↔
D)	↑	↔	↓
E)	↑	↔	↑
F)	↔	↔	↔
G)	↓	↑	↓
H)	↓	↓	↓
I)	↓	↑	↔

3. Which statement about respiration in exercise is most accurate?

   A) Maximum oxygen consumption of a male marathon runner is less than that of an untrained average man
   B) Maximum oxygen consumption can be increased about 100% by training
   C) Maximum oxygen diffusing capacity of a male marathon runner is much greater than that of an untrained average man
   D) Blood levels of oxygen and carbon dioxide are abnormal during exercise

4. Olympic athletes who run marathons or cross-country ski have much higher maximum cardiac outputs than nonathletes. Which statement about the hearts of these athletes compared with nonathletes is most accurate?

   A) Stroke volume in the Olympic athletes is about 5% greater at rest
   B) The percentage increase in heart rate during maximal exercise is much greater in the Olympic athletes
   C) Maximum cardiac output is only 3% to 4% greater in the Olympic athletes
   D) Resting heart rate in the Olympic athletes is significantly higher

5. In athletes who use androgens to increase performance, which of the following would most likely occur?

   A) Decreased high-density blood lipoproteins
   B) Decreased low-density blood lipoproteins
   C) Increased testicular function
   D) Decreased incidence of hypertension

6. A person living in Maine trains regularly to run 10K races and continually finishes in the middle of the pack. What is the physiological limitation that prevents this person from improving?

   A) Limited ability to increase pulmonary ventilation
   B) Limited ability to use the oxygen delivered to the tissue
   C) Limited ability to increase cardiac output
   D) Limited ability to dissipate the heat generated with exercise
   E) Limited ability to convert glucose to adenosine triphosphate (ATP)

7. If muscle strength is increased with resistive training, which condition will most likely occur?

   A) A decrease in the number of myofibrils
   B) An increase in mitochondrial enzymes
   C) A decrease in the components of the phosphagen energy system
   D) A decrease in stored triglycerides

8. Which of the following normally occurs during exercise at aerobic levels?
   A) Increased arterial P_{CO_2}
   B) Increased alveolar P_{O_2}
   C) Increased alveolar-arterial P_{O_2} gradient
   D) Decreased alveolar-arterial P_{O_2} gradient

9. A 40-year-old man is performing a maximum oxygen consumption test. He is 4 minutes into this 15-minute test. Which of the following would best describe his blood composition?

	Arterial P_{O_2}	Arterial P_{CO_2}	Mixed venous P_{O_2}
A)	↓	↔	↓
B)	↓	↑	↓
C)	↑	↑	↑
D)	↑	↓	↑
E)	↑	↑	↔
F)	↑	↓	↓
G)	↑	↔	↑
H)	↓	↓	↓

10. Which of the following physiologic responses to acute exercise do not normally occur?
    A) Decreased blood flow to bone and gastrointestinal tract.
    B) Increased cardiac output.
    C) Increased minute ventilation
    D) Decrease in sympathetic stimulation

ANSWERS

1. **B)** At rest:
Arterial content (Ca) = 15 × 1.34 = 20 ml O_2/100 ml blood at 100% saturation
Venous content (Cv) = 20 × 0.75 = 15 ml O_2/100 ml blood
Arteriovenous O_2 difference = 5 ml O_2/100 ml blood

Answer:
V_{O_2} = Q (ml/min) (Ca – Cv) 250 ml O_2/min = Q (5 ml O_2/100 ml blood)
Q = 250 ml O_2/min ÷ 5 ml O_2/100 ml blood
Q = 5.0 l/min

Exercising:
Arterial content (Ca) = 15 × 1.34 = 20 ml O_2/100 ml blood
Venous content (Cv) = 20 × 0.25 = 5 ml O_2/100 ml blood
Arteriovenous O_2 difference = 15 ml O_2/100 ml blood

Answer:
V_{O_2} = Q (ml/min) (Ca – Cv) 3000 ml O_2/min = Q (15 ml O_2/100 ml blood)
Q = 3000 ml O_2/min ÷ 15 ml O_2/100 ml blood
Q = 20 l/min

The increase in V_{O_2} is 20 l/min – 5 l/min = 15 l/min.
TMP14 pp. 256, 525, 1079–1081

2. **D)** With exercise, an increase in arterial P_{O_2} occurs as a result of better ventilation/perfusion. Arterial P_{CO_2} may be normal or slightly decreased. Because of the increased metabolic rate, the venous P_{O_2} will decrease.
TMP14 pp. 1079–1081

3. **C)** During exercise, the maximum oxygen consumption of a male marathon runner is much greater than that of an untrained average man. However, athletic training increases the maximum oxygen consumption by only about 10%. Therefore, the maximum oxygen consumption in marathon runners is probably partly genetically determined. These runners also have a large increase in maximum oxygen diffusing capacity, and their blood levels of oxygen and carbon dioxide remain relatively normal during exercise.
TMP14 p. 1079

4. **B)** When comparing Olympic athletes and nonathletes, there are several differences in the responses of the heart. Stroke volume is much higher at rest in an Olympic athlete, and heart rate is much lower. The heart rate can increase approximately 270% in an Olympic athlete during maximal exercise, which is a much greater percentage than occurs in a nonathlete. In addition, the maximal increase in cardiac output is approximately 30% greater in the Olympic athlete.
TMP14 pp. 1080–1081

5. **A)** Use of male sex hormones (androgens) or other anabolic steroids to increase muscle strength may increase athletic performances under some conditions but can have adverse effects on the body. Anabolic steroids increase the risk of cardiovascular damage because they increase the prevalence of hypertension, decrease high-density blood lipoproteins, and increase low-density blood lipoproteins. These factors all promote heart attacks and strokes. These androgenic substances also decrease testicular function, which decreases the formation of sperm and the body's own production of natural testosterone.
TMP14 p. 1083

6. **C)** Pulmonary ventilation is not a limitation because people normally overventilate during exercise, and there are minimal changes in arterial blood gases. The muscles use the oxygen delivered to them. The limitation is the delivery of oxygen and nutrients to muscle based on the limitation of an increase in cardiac output. Increasing cardiac output increases exercise performance. Under hot conditions, heat dissipation can limit exercise performance. Muscles have minimal to no limitation in converting glucose to ATP.
TMP14 pp. 1078–1081

7. **B)** During resistive training, the muscles that are contracted with at least a 50% maximal force for at least three times a week experience an optimal increase in muscle strength. This increase in strength causes muscle hypertrophy, and several changes occur. There will be an increase in the number of myofibrils and up to a 120% increase in mitochondrial enzymes. As much as a 60% to 80% increase in the components of the phosphagen energy system can occur, and up to a 50% increase in stored glycogen can occur. Also, as much as a 75% to 100% increase in stored triglycerides can occur.
TMP14 p. 1078

8. **C)** During exercise at aerobic levels, the increase in respiration occurs to maintain a normal alveolar P_{O_2}, maybe a slight increase. There is no increase in arterial P_{CO_2}. With normal ventilation, there would be no decrease in the alveolar–arterial P_{O_2} gradient, which would actually decrease oxygen diffusion from

the alveoli into the blood. With a decreased venous P_{O_2} there will be an increased alveolar-arterial P_{O_2} gradient.

TMP14 pp. 517, 1080

9. F) Arterial P_{O_2} will increase because of a better V/Q match. Arterial P_{CO_2} will be normal or decreased. Mixed venous P_{O_2} will decrease.

TMP14 pp. 1079–1080

10. D) During exercise, there are increases in blood flow to muscle and decrease in blood flow to nonessential tissues. This is accomplished by an increase in sympathetic stimulation. There are also increases in cardiac output, ventilation, and cardiac contractility.

TMP14 pp. 260, 796, 1079–1081

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Normal Values for Selected Common Laboratory Measurements

Substance	Average ("Normal" Value)	Range	Comment/Unit of Measure
Electrolytes			
Sodium (Na^+)	142 mmol/l	135-145 mmol/l	mmol/l = millimoles per liter
Potassium (K^+)	4.2 mmol/l	3.5-5.3 mmol/l	
Chloride (Cl^-)	106 mmol/l	98-108 mmol/l	
Anion gap	12 mEq/l	7-16 mEq/l	mEq/l = milliequivalents per liter Anion gap = $Na^+ - Cl^- - HCO_3^-$
Bicarbonate (HCO_3^-)	24 mmol/l	22-29 mmol/l	
Hydrogen ion (H^+)	40 nmol/l	30-50 nmol/l	nmol/l = nanomoles per liter
pH, arterial	7.4	7.25-7.45	
pH, venous	7.37	7.32-7.42	
Calcium ion (Ca^{2+})	5.0 mg/dl	4.65-5.28 mg/dl	mg/dl = milligrams/deciliter Average normal value can also be expressed as ~ 1.2 mmol/l or 2.4 mEq/l
Calcium, total	10.0 mg/dl	8.5-10.5 mg/dl	
Magnesium ion (Mg^{2+})	0.8 mEq/l	0.6-1.1 mEq/l	
Magnesium, total	1.8 mEq/l	1.3-2.4 mEq/l	
Phosphate, total	3.5 mg/dl	2.5-4.5 mg/dl	In plasma, $HPO_4^=$ is ~1.05 mmol/l and $H_2PO_4^-$ is 0.26 mmol/l
Nonelectrolyte Blood Chemistries			
Albumin	4.5 g/dl	3.5-5.5 g/dl	g/dl = grams per deciliter
Alkaline phosphatase		M: 38-126 U/l F: 70-230 U/l	U/l = units per liter
Bilirubin, total		0.2-1.0 mg/dl	
Bilirubin, conjugated		0-0.2 mg/dl	
Blood urea nitrogen (BUN)	14 mg/dl	10-26 mg/dl	
Creatinine	1.0 mg/dl	0.6-1.3 mg/dl	Varies depending on muscle mass, age, and sex
Glucose	90 mg/dl	70-115 mg/dl	
Osmolarity	282 mOsm/l	275-300 mOsm/l	mOsm/l = milliosmoles per liter Osmolality is expresses as mOsm/kg of water
Protein, total	7.0 g/dl	6.0-8.0 g/dl	
Uric acid		M: 3.0-7.4 mg/dl F: 2.1-6.3 mg/dl	
Blood Gases			
O_2 saturation, arterial	98%	95%-99%	Percentage of hemoglobin molecules saturated with oxygen
Po_2, arterial	90 mm Hg	80-100 mm Hg	Po_2 = partial pressure of oxygen in millimeters of mercury
Po_2, venous	40 mm Hg	25-40 mm Hg	
Pco_2, arterial	40 mm Hg	35-45 mm Hg	Pco_2 = partial pressure of carbon dioxide in millimeters of mercury
Pco_2, venous	45 mm Hg	41-51 mm Hg	
Hematology			
Hematocrit (Hct)	M: 42% F: 38%	M: 39%-49% F: 35%-45%	
Hemoglobin (Hgb)	M: 15 g/dl F: 14g/dl	M: 13.5-17.5 g/dl F: 12-16 g/dl	
Red blood cells (RBCs)	M: 5.5×10^8/µl F: 4.7×10^8/µl	$4.3\text{-}5.7 \times 10^8$/µl $4.3\text{-}5.7 \times 10^8$/µl	Number of cells per microliter of blood
Mean corpuscular (RBC) volume (MCV)	90 fl	80-100 fl	fl = femtoliters
Prothrombin time (PT)		10-14 seconds	Time required for the plasma to clot during a special test
Platelets		$150\text{-}450 \times 10^3$/µl	
White blood cells, total		$4.5\text{-}11.0 \times 10^3$/µl	
Neutrophils		57%-67%	Percentage of total white blood cells
Lymphocytes		23%-33%	Percentage of total white blood cells
Monocytes		3%-7%	Percentage of total white blood cells
Eosinophils		1%-3%	Percentage of total white blood cells
Basophils		0%-1%	Percentage of total white blood cells
Lipids			
Total cholesterol		<200 mg/dl	
Low-density lipoprotein (LDL)		<130 mg/dl	
High-density lipoprotein (HDL)		M: >29 mg/dl F: >35 mg/dl	
Triglycerides		M: 40-160 mg/dl F: 35-135 mg/dl	

This table is not an exhaustive list of common laboratory values. Most of these values are approximate reference values used by the University of Mississippi Medical Center Clinical Laboratories; normal ranges may vary among different clinical laboratories. Average "normal" values and units of measure may also differ slightly from those cited in the *Guyton and Hall Textbook of Medical Physiology,* 14th edition. For example, electrolytes are often reported in milliequivalents per liter (mEq/l), a measure of electrical charge of an electrolyte, or in millimoles per liter (mmol/l).

F, Female; *M,* Male.