The National Medical Series for Independent Study

physiology

John Bullock
Joseph Boyle, III
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Robert R. Ajello

- **An outline: for independent study**
- **Board-type questions: for exam review**
- **Annotated answers: to clarify material**

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Preface

Physiology, as part of *The National Medical Series for Independent Study,* represents a unique approach to the teaching of physiologic concepts. The text is designed for students of medicine and other health sciences as well as graduate physicians.

Physiology is a comprehensive and up-to-date treatment of physiologic principles focusing on both normal and pathophysiologic aspects of human physiology. The outline format of *Physiology* provides a coherent, organized framework for study, which saves the reader time in learning or reviewing the conceptual and factual core of this discipline. Therefore, this book is equally useful as a supplementary textbook for a formal course and as a review book for independent study.

The study questions are designed to provide self-evaluation of knowledge derived from the information presented in each chapter of *Physiology.* In addition, the questions grouped in the pretest and post-test allow the student to identify topics requiring further study. These tests are designed to evaluate the student's ability to accumulate factual information, integrate diverse physiologic concepts, and solve scientific and clinical problems. Problem solving is the ultimate skill of the practicing physician, and this ability is tested in *Physiology* using case histories that provide models for the application of physiologic information.

The questions are followed by extensive explanations that discuss the answers in the context of the proposed clinical situations. In this way, the student can practice a skill that he or she must learn in clinical rotations, that is, the ability to develop and support a thesis on the basis of clinical findings.

Physiology was written by professionals with a common interest in the education of students of the health sciences. The authors' collective teaching experience has made them aware of how students grasp physiologic principles and has identified areas that students often find difficult. The authors have attempted to clarify these areas with figures and tables.

John Bullock

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Publisher's Note

The objective of the *National Medical Series* is to present an extraordinarily large amount of information in an easily retrievable form. The outline format was selected for this purpose of reducing to the essentials the medical information needed by today's student and practitioner.

While the concept of an outline format was well received by the authors and publisher, the difficulties inherent in working with this style were not initially apparent. That the series has been published and received enthusiastically is a tribute to the authors who worked long and diligently to produce books that are stylistically consistent and comprehensive in content.

The task of producing the *National Medical Series* required more than the efforts of the authors, however, and the missing elements have been supplied by highly competent and dedicated developmental editors and support staff. Editors, compositors, proofreaders, and layout and design staff have all polished the outline to a fine form. It is with deep appreciation that I thank all who have participated, in particular, the staff at Harwal—Debra L. Dreger, Jane Edwards, Gloria Hamilton, Jeanine Kosteski, Wieslawa B. Langenfeld, Keith LaSala, June A. Sangiorgio, Mary Ann C. Sheldon, and Jane Velker.

The Publisher

Introduction

Physiology is one of seven basic science review books in a series entitled *The National Medical Series for Independent Study*. This series has been designed to provide students and house officers, as well as physicians, with a concise but comprehensive instrument for self-evaluation and review within the basic sciences. Although *Physiology* would be most useful for students preparing for the National Board of Medical Examiners examinations (Part I, FLEX, and FMGEMS), it should also be useful for students studying for course examinations. These books are not intended to replace the standard basic science texts but, rather, to complement them.

The books in this series present the core content of each basic science area, using an outline format and featuring a total of 300 study questions. The questions are distributed throughout the book at the end of each chapter and in a pretest and posttest. In addition, each question is accompanied by the correct answer, a paragraph-length explanation of the correct answer, and specific reference to the outline points under which the information necessary to answer the question can be found.

We have chosen an outline format to allow maximal ease in retrieving information, assuming that the time available to the reader is limited. Considerable editorial time has been spent to ensure that the information required by all medical school curricula has been included and that each question parallels the format of the questions on the National Board examinations. We feel that the combination of the outline format and board-type study questions provides a unique teaching device.

We hope you will find this series interesting, relevant, and challenging. The authors, as well as the John Wiley and Harwal staffs, welcome your comments and suggestions.

Contents

Pretest

QUESTIONS

Directions: Each question below contains five suggested answers. Choose the **one best** response to each question.

1. Quantitatively, the major anion in the ICF compartment is

(A) Bicarbonate
(B) Chloride
(C) Phosphate
(D) Protein
(E) Sulfate

2. Hypercapnia has its greatest effect on minute ventilation through stimulation of which of the following receptors?

(A) Aortic bodies
(B) Carotid bodies
(C) Baroreceptors
(D) Central chemoreceptors
(E) J receptors

3. Which of the following statements best characterizes taste receptors?

(A) Each of the primary taste qualities is encoded by a specific sensory nerve fiber
(B) The afferent fibers of the tongue all are carried in a single cranial nerve
(C) All areas of the tongue are equally sensitive to each of the primary taste qualities
(D) Taste receptors are very slowly adapting, so taste sensations do not disappear until the stimulus is washed away
(E) Taste receptors live for only a few days and must be regenerated continuously by the taste buds

4. Spironolactone is a substance that is used to

(A) reduce the GFR
(B) increase the renal excretion of Na^+ and decrease the renal excretion of K^+
(C) enhance the action of aldosterone on the distal tubule
(D) antagonize the action of antidiuretic hormone on the collecting duct
(E) maintain Na^+-K^+ balance in adrenalectomized patients

5. A patient who is admitted to the emergency room with hyperpnea has the following data obtained from a laboratory work-up of the serum: $[HCO_3^-]$ = 8 mmol/L; PCO_2 = 20 mm Hg; and pH = 7.22. On the basis of these findings, what is the primary cause of this patient's hyperpnea?

(A) Metabolic acidosis
(B) Respiratory alkalosis
(C) Respiratory acidosis
(D) Hypocapnia
(E) Hyperventilation

6. Which of the following auditory functions is the primary responsibility of the middle ear ossicular chain?

(A) Sound pressure amplification
(B) Auditory signal detection
(C) Sound localization
(D) Pitch discrimination
(E) Auditory adaptation

7. Which of the following conditions produces an increase in the compliance of the lung?

(A) Atelectasis
(B) Surgical removal of one lobe of the lung
(C) Emphysema
(D) Fibrosis of the lung
(E) Abnormal pulmonary surfactant

8. Aldosterone stimulates Na^+ transport mainly in the

(A) ascending limb of the loop of Henle
(B) descending limb of the loop of Henle
(C) proximal convoluted tubule
(D) pars recta of the proximal tubule
(E) distal tubule and collecting duct

9. Which of the following is the major factor that limits expiratory flow rate during most of a maximal forced expiration?

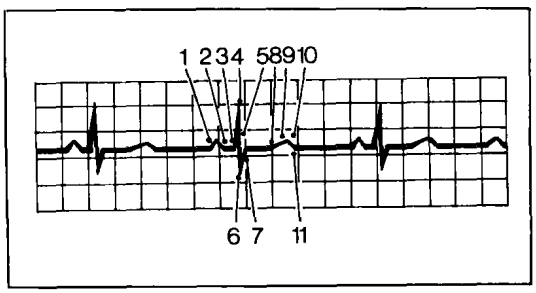
(A) Turbulence in the peripheral airways
(B) Turbulence in the central airways
(C) Maximal velocity of contraction of intercostal muscles
(D) Contraction of the diaphragm
(E) Compression of the airways

10. A thalamic relay is a component of the central pathway for all of the following sensations EXCEPT

(A) vision
(B) olfaction
(C) touch
(D) taste
(E) audition

Questions 11–14

The EKG shown below is from a normal, 35-year-old woman. For each description of events in the cardiac cycle, choose the points on this EKG that designate the appropriate interval.



11. The spread of atrial depolarization occurs between points

(A) 1 and 2
(B) 1 and 3
(C) 1 and 4
(D) 2 and 3
(E) 2 and 4

12. The conduction time through the AV node is measured from point

(A) 1 to 2
(B) 1 to 3
(C) 1 to 4
(D) 2 to 3
(E) 2 to 4

13. The depolarization time through the ventricles is measured from point

(A) 2 to 7
(B) 3 to 10
(C) 3 to 7
(D) 4 to 7
(E) 4 to 10

14. The vulnerable period for the ventricles lies between points

(A) 3 and 5
(B) 3 and 7
(C) 7 and 9
(D) 8 and 9
(E) 9 and 10

(end of group question)

15. The PCO_2 at rest of mixed expired air is approximately

(A) 0.3 mm Hg
(B) 27 mm Hg
(C) 40 mm Hg
(D) 45 mm Hg
(E) 50 mm Hg

16. Which of the following transport processes requires the direct use of energy?

(A) Carrier-mediated transport of Na^+ out of the cell
(B) Facilitated diffusion of glucose into the cell
(C) Na^+-dependent transport of amino acids into the cell
(D) Osmosis of water into the cell
(E) Bulk flow of water out of the capillaries

17. Stimulation of the J receptors initiates which of the following responses?

(A) An increase in PCO_2
(B) Transient respiratory acidosis
(C) Rapid breathing
(D) Stimulation of the apneustic center
(E) Apnea

18. Arterial blood studies in a patient with hyperventilation show a PCO_2 of 25 mm Hg and a $[HCO_3^-]$ of 21.5 mmol/L. The most likely diagnosis is

(A) respiratory acidosis
(B) respiratory alkalosis
(C) metabolic acidosis
(D) metabolic alkalosis
(E) indeterminate because the pH is not given

19. The major determinant of cerebral blood flow rate is

(A) arterial PCO_2
(B) plasma adenosine concentration
(C) aortic blood pressure
(D) neurogenic regulation
(E) body temperature

20. Reciprocal innervation is most accurately described as

(A) inhibition of flexor muscles during an extension
(B) activation of contralateral extensors during a flexion
(C) reduction of Ia fiber activity during a contraction
(D) simultaneous stimulation of alpha and gamma motoneurons
(E) inhibition of alpha motoneurons during a contraction

21. In an animal experiment, a midpontine transection is performed coupled with a bilateral vagotomy. Which of the following responses occurs as a result of this procedure?

(A) Apneustic breathing
(B) Ataxic breathing
(C) Dyspneic breathing
(D) Increased respiratory rate
(E) Apnea

Directions: Each question below contains four suggested answers of which **one or more** is correct. Choose the answer

A if **1, 2, and 3** are correct
B if **1 and 3** are correct
C if **2 and 4** are correct
D if **4** is correct
E if **1, 2, 3, and 4** are correct

22. Inhibitory postsynaptic responses are produced by increasing the membrane conductance to

(1) Na^+
(2) K^+
(3) Ca^{2+}
(4) Cl^-

23. The HCO_3^-/CO_2 system is quantitatively the most significant buffer in the

(1) interstitial fluid
(2) intracellular fluid
(3) plasma
(4) erythrocyte

24. Pulse pressure increases as a result of an increase in which of the following measurements?

(1) Heart rate
(2) Stroke volume
(3) Peripheral resistance
(4) Arterial elastance

25. Reactions that occur due to closure of some airways during expiration include

(1) an increase in the work of breathing
(2) an increase in local pulmonary vascular resistance
(3) an uneven distribution of the tidal volume
(4) a decrease in the minute ventilation in the closed areas

SUMMARY OF DIRECTIONS

A	B	C	D	E
1, 2, 3 only	1, 3 only	2, 4 only	4 only	All are correct

26. A patient who is given a physiologic dose of antidiuretic hormone would be expected to show an increased urinary concentration of

(1) Cl^-
(2) Na^+
(3) K^+
(4) urea

27. Statements that accurately describe the state of sleep include

(1) during periods of REM sleep, violent muscular activity is prevented by an inhibition of alpha motoneuron activity
(2) O_2 consumption and blood flow to the brain both decrease during sleep
(3) the progression from light to deep SWS is associated with an increase in the amplitude of the EEG waves
(4) the state of sleep is induced by the periodic reduction in the activity of the ascending reticular activating system

28. Conditions associated with an increase in the closing volume of the lung include

(1) emphysema
(2) old age
(3) airway disease
(4) restrictive lung disease

29. A myopic individual has eyes that

(1) are too long for the refractive power of the lens
(2) require glasses with convex lenses
(3) have a far point that is nearer than 6 m
(4) have a near point that is farther than it is in emmetropic eyes

30. The vital capacity is defined as

(1) the sum of functional residual capacity and inspiratory capacity
(2) the maximal volume expired after a maximal inspiration
(3) the sum of expiratory reserve volume and residual volume
(4) the total lung capacity minus residual volume

31. The receptor cell communicates with its afferent neuron by synaptic transmission in the

(1) Merkle disk
(2) ear
(3) tongue
(4) nose

32. An increased arteriovenous (A-V) PO_2 difference occurs in hypoxia that is

(1) hypokinetic (stagnant)
(2) hypoxic (arterial)
(3) hypemic (anemic)
(4) histotoxic

33. Conditions that are associated with an increase in the total CO_2 content of blood include

(1) metabolic alkalosis
(2) hyperventilation
(3) respiratory acidosis
(4) metabolic acidosis

34. Proteins that play an important role in the contractile activity of smooth muscle include

(1) myosin
(2) actin
(3) ATPase
(4) troponin

35. Mechanisms that decrease airway resistance include

(1) stimulation of sympathetic efferent fibers to the lung
(2) increases in lung volume
(3) increases in the elastance forces of the lung
(4) increases in expiratory effort

36. Statements that accurately describe thermoreceptors include

(1) the skin has more cold fibers than warm fibers
(2) the static firing rate of warm fibers always is higher at warm temperatures than it is at cold temperatures
(3) cold fibers always increase their firing rate when the skin temperature decreases
(4) both warm and cold fibers cease firing at temperatures within the neutral zone

Directions: The groups of questions below consist of lettered choices followed by several numbered items. For each numbered item select the **one** lettered choice with which it is **most** closely associated. Each lettered choice may be used once, more than once, or not at all.

Questions 37–41

The table below shows the arterial blood acid-base data for five individuals who are designated by the letters A–E. For each of the following descriptions of acid-base status, choose the individual with the appropriate acid-base data.

	PCO_2 (mm Hg)	$[HCO_3^-]$ (mmol/L)	pH	$[H^+]$ (nmol/L)
(A)	29	22.0	7.50	31.6
(B)	33	32.0	7.61	24.8
(C)	35	17.5	7.32	48.0
(D)	40	25.0	7.41	38.4
(E)	60	37.5	7.42	38.4

37. Normal
38. Partially compensated metabolic acidosis
39. Fully compensated respiratory acidosis
40. Uncompensated respiratory alkalosis
41. Combined respiratory and metabolic alkalosis

Questions 42–45

For each description of signs of valve dysfunction, choose the valve lesion with which it is most closely associated.

(A) Mitral stenosis
(B) Mitral insufficiency
(C) Aortic stenosis
(D) Aortic insufficiency
(E) None of the above

42. Wide pulse pressure
43. Presystolic murmur
44. Ejection murmur
45. Wide changes in left atrial pressure

Questions 46–50

For each example of solute transport, select the renal tubular segment that is the major site of that transport process.

(A) Proximal convoluted tubule
(B) Distal convoluted tubule
(C) Thin ascending limb of the loop of Henle
(D) Thick ascending limb of the loop of Henle
(E) Collecting duct

46. H^+ secretion
47. PAH secretion
48. Glucose reabsorption
49. Hormone-mediated K^+ secretion
50. Active Cl^- transport

Questions 51–54

For each condition or substance listed below, select the type of diarrhea most likely to be associated with it.

(A) Defective absorption diarrhea
(B) Motor diarrhea
(C) Osmotic diarrhea
(D) Cotransport diarrhea
(E) Secretory diarrhea

51. Cholera
52. Phenolphthalein
53. Stress
54. Magnesium sulfate

Questions 55–60

Match each of the following events of the ovarian cycle to the appropriate phase.

(A) During the preovulatory phase
(B) During the postovulatory phase
(C) During both the pre- and postovulatory phases
(D) During neither the pre- nor the postovulatory phase

55. Serum estradiol reaches its highest concentration
56. Extraovarian formation of progesterone is greatest
57. Progesterone is secreted in the greatest *amount*
58. Estradiol is secreted
59. LH becomes the dominant pituitary tropic hormone
60. FSH becomes the dominant pituitary tropic hormone

ANSWERS AND EXPLANATIONS

1. The answer is C. *(Chapter 4 II D 3; Table 4-3)* The major intracellular anion actually is a group of organic phosphates, which includes nucleotides (ATP), nucleic acid (DNA and RNA), phospholipids, and phosphoproteins. Thus, most of this intracellular anion is covalently bound to organic compounds. Organic phosphate is quantitatively the most important buffer in the ICF, where its valence as organic phosphate is not known.

2. The answer is D. *(Chapter 3 VIII A 3, B)* The major effect of CO_2 on respiratory drive is through the central chemoreceptors on the surface of the medulla. Although CO_2 does stimulate the aortic and carotid chemoreceptors, its overall effect on these receptors is very small. The J receptors are stimulated by distension of the alveolar walls by fluid and certain drugs, and the baroreceptors are stimulated when the aortic and carotid walls are stretched due to transmural pressure changes.

3. The answer is E. *(Chapter 1 X B 1, 3, C 3, D, E)* The encoding of the primary taste qualities depends on the pattern of sensory nerves activated by a stimulus; a labeled-line mechanism is not used. The front of the tongue is innervated by the facial nerve (cranial nerve VIII), and the back of the tongue is innervated by the glossopharyngeal nerve (cranial nerve IX). Each area of the tongue is particularly sensitive to one of the four primary taste qualities. Taste neurons adapt fairly rapidly so that gustatory sensations disappear quickly. Taste receptors are renewed continuously by cells that differentiate from nonreceptor cells at the base of the taste bud.

4. The answer is B. *(Chapter 4 IX F)* Spironolactone, a synthetic steroid, is a competitive antagonist of the renal action of aldosterone. Therefore, it interferes with the aldosterone-mediated Na^+ reabsorption from the distal tubule and collecting duct of the nephron. It also reduces distal K^+ secretion and excretion. This substance can be used as an effective K^+-sparing diuretic in normal individuals but not in adrenalectomized patients. Thus, spironolactone is effective only when aldosterone is present.

5. The answer is A. *(Chapter 5 VIII D 3; IX B 3, C 1–2)* Metabolic acidosis is characterized by a low arterial pH, a reduced $[HCO_3^-]$, and a compensatory hyperventilation that results in a decreased PCO_2. Metabolic acidosis can be produced by the addition of H^+ or by the loss of HCO_3^-. Acid-base imbalances are defined as metabolic when the $[H^+]$ and the $[HCO_3^-]$ change in opposite directions. In this patient, the variable that showed the greater change is $[HCO_3^-]$, with a 67 percent decrease; the PCO_2 showed a relatively smaller decline of 50 percent. The decrease in the $[HCO_3^-]/S \times PCO_2$ ratio from the normal of 20 to 13 also is consistent with acidosis.

6. The answer is A. *(Chapter 1 VII B 2, 3)* As sound moves from air to water, most of its energy is lost. The middle ear ossicular chain amplifies the sound pressure because the surface area of the tympanic membrane is much larger than that of the oval window. Pitch discrimination is possible because sounds of different frequencies cause vibration in different areas of the basilar membrane (an inner ear component). Auditory detection also is a function of the inner ear. Sound localization and auditory adaptation are carried out by neurons within the brain.

7. The answer is C. *(Chapter 3 III B 3, E)* Emphysema causes an increased compliance of the lung by increasing the size of the air space, which reduces the surface forces, and by destroying the alveolar septa, which reduces the tissue forces. Compliance is a function of the amount of functional lung tissue that is present; thus, lobectomy and atelectasis reduce compliance by eliminating functional tissue. Fibrosis and abnormal surfactant reduce compliance by an increase in the tissue forces and the surface forces, respectively.

8. The answer is E. *(Chapter 4 IX B 1)* Aldosterone stimulates Na^+ transport (reabsorption) from the distal tubule and collecting duct. The total quantity of Na^+ reabsorption dependent on aldosterone is approximately 2 percent of the total filtered Na^+ or about 20 percent of the Na^+ entering the distal tubule.

9. The answer is E. *(Chapter 3 V C 2)* The pleural pressure becomes positive only if expiration is active (i.e., if the expiratory muscles contract forcefully to increase the rate of gas flow). The alveolar pressure always exceeds the pleural pressure, but the pressure in the airways decreases from alveolar to atmospheric pressure along the length of the airways. At some point in the airways, the pleural pressure will equal the pressure inside the airways (equal pressure point, EPP), and downstream from the EPP the airways are narrowed because of the pressure gradient. This narrowing limits the maximal expiratory flow rate so that flow rate is a function of lung volume rather than the effort exerted. This condition is termed effort-independent flow.

10. The answer is B. *(Chapter 1 XI E 4)* All of the sensory systems except the olfactory system project to

their cortical receiving areas through a relay in the thalamus. In the olfactory system, the olfactory neurons project directly from the olfactory bulb to the cortex.

11. The answer is A. *(Chapter 2 II E 1 a)* Atrial depolarization occurs during the P wave, which is designated by the segment that extends between points 1 and 2 on this EKG.

12. The answer is D. *(Chapter 2 II C 4 a)* The conduction time for depolarization to proceed through the AV node is measured from the end of the P wave to the beginning of the QRS complex. This interval includes the time for conduction over the bundle branches and the Purkinje fibers; however, conduction speed in these tissues is extremely rapid and so this period would be negligible.

13. The answer is C. *(Chapter 2 III E 1 c)* The ventricles are depolarized during the QRS complex. This interval is designated by the segment that extends from point 3 to point 7 on this EKG.

14. The answer is E. *(Chapter 2 III E 1 d)* During the vulnerable period, the ventricles are in a superexcitable state. This period occurs at about the peak of the T wave and is designated by the segment between points 9 and 10 on this EKG.

15. The answer is B. *(Chapter 3 VI C 2)* Normally, the PCO_2 in alveolar gas is 40 mm Hg; during expiration, however, the PCO_2 in the mixed expired gas is reduced by dilution with the dead space gas. A PCO_2 value of 0.3 mm Hg is much too low because it indicates that dead space ventilation is more than 100 times greater than the alveolar ventilation.

16. The answer is A. *(Chapter 1 I C 1 b, 2, 3)* Na^+ transport by the Na^+-K^+ pump requires the direct hydrolysis of ATP. Carrier-mediated transport of amino acids also requires energy, but the energy is expended to create the Na^+ gradient and is not used directly in the transport process. Although glucose is too large to diffuse through membrane channels, it can be moved across the membrane by facilitated diffusion, a process that does not require the direct use of energy. Osmosis and bulk flow are translocation processes that also do not require the direct use of energy.

17. The answer is C. *(Chapter 3 VIII C 3)* Stimulation of the J receptors results in rapid breathing (tachypnea) due to afferent vagal impulses. These impulses cause an inhibition of the apneustic center to abbreviate inspiration.

18. The answer is B. *(Chapter 4 VIII D 2; IX B 2; XII B 3 b–c)* Respiratory alkalosis is characterized by a decreased $[H^+]$ ($\uparrow$pH), a low PCO_2, and a variable decrement in plasma $[HCO_3^-]$. The pH of the plasma of this patient can be determined with the equation:

$$pH = pK' + \log([HCO_3^-]/S \times PCO_2), \text{ or}$$
$$pH = 6.1 + \log(21.5/0.75) = 7.56.$$

Respiratory alkalosis must be differentiated from metabolic acidosis, in which the PCO_2 and $[HCO_3^-]$ are also diminished but the pH is decreased ($\uparrow[H^+]$).

The variable that exhibits the greater proportional change is PCO_2, which is decreased by 38 percent in this patient compared to the 10 percent decline in $[HCO_3^-]$. Therefore, the primary cause of this acid-base abnormality is respiratory. Since the $[HCO_3^-]/S \times PCO_2$ ratio is greater than 20, the patient has alkalosis. (Note that it is not necessary to calculate the pH to diagnose the abnormality.)

19. The answer is A. *(Chapter 2 VIII B 2)* The major factor controlling cerebral blood flow is the perivascular PCO_2, which depends largely on the arterial PCO_2. While adenosine is a major dilator in the skeletal muscle and coronary vascular beds, it generally is not recognized as a major factor in the cerebral circulation. The cerebral circulation has a powerful autoregulatory function so that changes in arterial pressure have a minimal effect on blood flow. Sympathetic and parasympathetic nerve fibers do not have a major role in controlling cerebral blood flow.

20. The answer is A. *[Chapter 1 XII A 1 b (2), c, B 2 d, C 1 b (2)]* Reciprocal innervation refers to the inhibition of the antagonist muscle during a contraction. Activation of the contralateral extensors during a withdrawal reflex is called a crossed extensor reflex. Reduction of Ia fiber activity during a contraction is called unloading. Inhibition of alpha motoneurons during a contraction is caused by Ib afferent fibers and is called autogenic inhibition.

21. The answer is A. *(Chapter 3 VIII A 2; Fig. 3-19)* The experimental procedure described removes the inhibitory effects of the vagus nerve and the pneumotaxic center from the apneustic center. This loss of inhibition allows the marked inspiratory tone of the apneustic center to produce inspiratory spasms or apneusis, which reduces the respiratory rate.

22. The answer is C (2, 4). *(Chapter 1 III B 2 b, C 2 a)* Parasympathetic neurons produce an inhibitory effect on the heart by increasing the permeability of the membrane to K^+. In the CNS, **inhibitory** postsynaptic potentials are caused by increasing the membrane conductance to Cl^-; **excitatory** postsynaptic potentials (i.e., membrane depolarizations) usually are produced by increasing the membrane conductance to Na^+ and K^+.

23. The answer is B (1, 3). *(Chapter 5 IV B 1 b, 2, 3)* The HCO_3^-/CO_2 system is the most important buffer of noncarbonic acid in both the plasma and the interstitial fluid (which includes lymph). These two fluid compartments have similar concentrations of HCO_3^-; the $[HCO_3^-]$ of plasma is 25 mmol/L, and the $[HCO_3^-]$ of the interstitial fluid is about 27 mmol/L. Although the HCO_3^-/CO_2 system also is important in the erythrocyte, hemoglobin is quantitatively the more important buffer. The ICF contains large amounts of intracellular protein (i.e., about 60 mmol/L) and organic phosphate compounds, making these systems the quantitatively significant nonbicarbonate buffers in this fluid compartment. The ICF has the capacity to buffer effectively both noncarbonic and carbonic acids as well as bases.

24. The answer is C (2, 4). *(Chapter 2 VI B 2)* Pulse pressure is reduced by increases in heart rate and peripheral resistance, if stroke volume remains unchanged. In both instances, arterial volume increases so that pulse pressure decreases. An increase in stroke volume raises arterial uptake and pulse pressure, whereas an increased elastance (decreased compliance) also increases pulse pressure.

25. The answer is E (all). *(Chapter 3 V B–C)* Closure of airways during respiration indicates that additional work must be done to reopen these airways in the subsequent inspiration. In addition, closure of airways causes a reduction in the compliance of the lung. Closure also reduces the tidal volume in these areas and makes ventilation of the lung uneven. Due to reduced ventilation in the affected areas, there is local hypoxia and hypercapnia, which cause pulmonary vascular constriction and an increase in the vascular resistance.

26. The answer is C (2, 4). *(Chapter 4 VII E 1–3; VIII C)* Physiologic (moderate) amounts of antidiuretic hormone (ADH) increase the urine-to-plasma osmolality ratio (U_{osm}/P_{osm}) via the conservation of water, as reflected in the excretion of a low volume of hyperosmotic urine. ADH decreases free-water clearance, or, stated another way, ADH increases free-water reabsorption. ADH affects solute concentration by increasing the solvent (water) reabsorption from the late distal tubule and collecting duct.

27. The answer is B (1, 3). *(Chapter 1 XIV A 2 c–d, C 1)* Although periodic muscular twitching occurs during REM sleep, more powerful muscular activity is prevented by the generalized paralysis that accompanies REM sleep. As an individual passes from light to deep SWS, there is a decrease in the frequency and an increase in the amplitude of the EEG waves. O_2 consumption by the brain is the same whether an individual is asleep or awake. Sleep is induced by the activity of specific sleep centers within the brain.

28. The answer is A (1, 2, 3). *(Chapter 3 VI B 3)* In restrictive lung disease, the increased elastance forces dilate the airways more than normal and delay the onset of airway closure. The elastance forces are reduced in emphysema and old age so that airway closure begins at higher than normal lung volumes. Early airway closure also occurs with small airway disease because the disease narrows the airways, causing them to close at higher lung volumes.

29. The answer is B (1, 3). *(Chapter 1 VIII F 1)* In myopia, the eye ball is too long for the refractive power of the lens, so the image of an object at the far point (i.e., the focal point) falls in front of the retina. Correction requires the wearing of concave (diverging) lenses so that the focal point is moved back and onto the retina. To see an object clearly, it must be brought closer to the eye than the normal 6 m. Because an object can be seen clearly at this shorter distance without any accommodation, it ultimately can be brought closer than normal and still be seen clearly.

30. The answer is C (2, 4). *(Chapter 3 III C 2 a–d)* Vital capacity (VC) refers to the maximal volume of gas that can be expired after a maximal inspiration. Other expressions of lung capacity include: total lung capacity (TLC), functional residual capacity (FRC), and inspiratory capacity (IC). A lung capacity is a combination of two or more lung volumes. For example:

$$\begin{aligned} VC &= ERV + V_T + IRV, \\ TLC &= RV + ERV + V_T + IRV, \text{ and} \\ FRC &= RV + ERV, \end{aligned}$$

where ERV = expiratory reserve volume; IRV = inspiratory reserve volume; V_T = tidal volume; and RV = residual volume.

31. The answer is A (1, 2, 3). *[Chapter 1 VI A 3 b; VII B 3 b (1); X C; XI C–D]* The cutaneous receptor cells of Merkle disks are modified epithelial cells that communicate with their primary afferent neuron by synaptic transmission. A similar situation exists in the ear, for the hair cells of the cochlea, and on the tongue, for the taste receptor cells within the papillae. The olfactory receptors are found on the free nerve endings of the olfactory nerve fibers.

32. The answer is B (1, 3). *(Chapter 3 VII C 1–4)* In hypokinetic and anemic hypoxia, O_2 supply is limited by blood flow and arterial O_2 content, respectively. This effect reduces the venous PO_2 and, thus, widens the arteriovenous (A-V) PO_2 difference. By definition, hypoxic hypoxia is associated with a reduced PaO_2, which forces the body to function on the steep portion of the O_2-dissociation curve. This means that adequate O_2 can be withdrawn from the the hemoglobin for a smaller than normal change in PO_2, which narrows the A-V PO_2 difference. The A-V PO_2 difference is reduced by histotoxic hypoxia because the tissues do not remove as much O_2 from the blood.

33. The answer is B (1, 3). *(Chapter 5 V A 2–3; VII A 5)* The term total CO_2 content ([total CO_2]) denotes the sum of the various chemical forms of CO_2 carried in the blood and is represented as:

$$[\text{total } CO_2] = [HCO_3^-] + [\text{dissolved } CO_2] + [H_2CO_3].$$

Since the $[H_2CO_3]$ is negligible and [dissolved CO_2] is equal to $0.03 \times PCO_2$, the [total CO_2] exceeds the $[HCO_3^-]$ by 1.2 mmol/L. The major contributor to the [total CO_2] of blood is $[HCO_3^-]$. The physician accepts serum CO_2, total CO_2, and $[HCO_3^-]$ as essentially interchangeable terms.

An increased CO_2 content is associated with the following acid-base conditions: uncompensated metabolic alkalosis, uncompensated respiratory acidosis, respiratory acidosis that is compensated by a metabolic alkalosis, and metabolic alkalosis that is compensated by a respiratory acidosis. Hyperventilation ($\downarrow PCO_2$) and metabolic acidosis ($\downarrow[HCO_3^-]$) are associated with a decreased CO_2 content.

34. The answer is A (1, 2, 3). *(Chapter 1 IV A 2, C 2)* Myosin, actin, and ATPase all are involved in generating contractile force in smooth muscle. Myosin is on the thick filament, actin is on the thin filament, and ATPase is on the cross-bridge. Troponin, the regulatory protein in striated muscle, is not present in smooth muscle.

35. The answer is A (1, 2, 3). *(Chapter 3 V B 1–2)* An increased expiratory effort causes a compression of the airways and an increase in airway resistance. Sympathetic stimulation causes a bronchodilation secondary to the stimulation of the β_2-adrenergic receptors, while increases in lung volume and elastance forces dilate the airways secondary to an increase in the radial traction exerted by the pulmonary septa.

36. The answer is B (1, 3). *(Chapter 1 VI B 1–3)* The static firing rate of thermoreceptors is a bell-shaped function of temperature. Both the warm and cold fibers fire when the skin temperature is in the neutral range. Cold fibers are defined as those thermoreceptors that increase their firing rate when the skin temperature is cooled.

37–41. The answers are: 37-D, 38-C, 39-E, 40-A, 41-B. *(Chapter 5 VIII D 2; IX B–C; XII; Fig. 5-15)* Metabolic acidosis is characterized by a low arterial pH ($\uparrow[H^+]$), a low plasma $[HCO_3^-]$, and a compensatory hyperventilation leading to a low PCO_2. The individual designated by (**C**) shows a change in the $[H^+]$ that is opposite in direction to the change in the $[HCO_3^-]$; this characteristic denotes a metabolic disturbance. The pH of this individual (7.32) indicates acidosis. The fact that partial respiratory compensation has occurred is evident from the decline in PCO_2.

Respiratory acidosis is characterized by a low arterial pH ($\uparrow[H^+]$), a high PCO_2 (hypercapnia), and a variable increase in the plasma $[HCO_3^-]$. The individual designated by (**E**) shows a compensatory change in the $[HCO_3^-]$ that is in the same direction as the primary change in PCO_2; this is a characteristic of a respiratory disturbance. In this individual, the greater degree of alteration is in the PCO_2. The pH of 7.42 together with the hypercapnia and increased $[HCO_3^-]$ are indicative of complete compensation for a respiratory acidosis. This individual has a $[HCO_3^-]/S \times PCO_2$ ratio that is almost 21:1.

The individual designated by (**A**) has uncompensated respiratory alkalosis as indicated by a 28 percent decrease in PCO_2 (hypocapnia) with only an 8 percent compensatory decrease in the plasma $[HCO_3^-]$.

The condition of respiratory alkalosis with a complicating metabolic alkalosis is characterized by a high pH ($\downarrow[H^+]$), a low PCO_2, and a high $[HCO_3^-]$. In acute respiratory alkalosis, the plasma $[HCO_3^-]$ should fall 2 mmol/L for each 10 mm Hg decrease in PCO_2. The acute decrease of PCO_2 to 33 mm Hg, shown by individual (**B**), should decrease the plasma $[HCO_3^-]$ to 22.6 mmol/L (pH of 7.46) in a case of acute respiratory alkalosis. The high $[HCO_3^-]$ shown by this individual, however, indicates that his or her condition is a combination of respiratory and metabolic alkalosis.