(D) Preganglionic neurons release acetylcholine (ACh)
(E) Preganglionic neurons originate in the thoracolumbar spinal cord
(F) Postganglionic neurons synapse on effector organs
(G) Postganglionic neurons release epinephrine
(H) Postganglionic neurons release ACh

8. Which autonomic receptor mediates an increase in heart rate?
(A) Adrenergic α_1 receptors
(B) Adrenergic β_1 receptors
(C) Adrenergic β_2 receptors
(D) Cholinergic muscarinic receptors
(E) Cholinergic nicotinic receptors

9. Cutting which structure on the left side causes total blindness in the left eye?
(A) Optic nerve
(B) Optic chiasm
(C) Optic tract
(D) Geniculocalcarine tract

10. Which reflex is responsible for monosynaptic excitation of ipsilateral homonymous muscle?
(A) Stretch reflex (myotatic)
(B) Golgi tendon reflex (inverse myotatic)
(C) Flexor withdrawal reflex
(D) Subliminal occlusion reflex

11. Which type of cell in the visual cortex responds best to a moving bar of light?
(A) Simple
(B) Complex
(C) Hypercomplex
(D) Bipolar
(E) Ganglion

12. Administration of which of the following drugs is contraindicated in a 10-year-old child with a history of asthma?
(A) Albuterol
(B) Epinephrine
(C) Isoproterenol

(D) Norepinephrine
(E) Propranolol

13. Which adrenergic receptor produces its stimulatory effects by the formation of inositol 1,4,5-triphosphate (IP3) and an increase in intracellular [Ca^{2+}]?
(A) α_1 Receptors
(B) α_2 Receptors
(C) β_1 Receptors
(D) β_2 Receptors
(E) Muscarinic receptors
(F) Nicotinic receptors

14. The excessive muscle tone produced in decerebrate rigidity can be reversed by
(A) stimulation of group Ia afferents
(B) cutting the dorsal roots
(C) transection of cerebellar connections to the lateral vestibular nucleus
(D) stimulation of α-motoneurons
(E) stimulation of γ-motoneurons

15. Which of the following parts of the body has cortical motoneurons with the largest representation on the primary motor cortex (area 4)?
(A) Shoulder
(B) Ankle
(C) Fingers
(D) Elbow
(E) Knee

16. Which autonomic receptor mediates secretion of epinephrine by the adrenal medulla?
(A) Adrenergic α_1 receptors
(B) Adrenergic β_1 receptors
(C) Adrenergic β_2 receptors
(D) Cholinergic muscarinic receptors
(E) Cholinergic nicotinic receptors

17. Cutting which structure on the right side causes blindness in the temporal

field of the left eye and the nasal field of the right eye?

(A) Optic nerve
(B) Optic chiasm
(C) Optic tract
(D) Geniculocalcarine tract

18. A ballet dancer spins to the left. During the spin, her eyes snap quickly to the left. This fast eye movement is

(A) nystagmus
(B) postrotatory nystagmus
(C) ataxia
(D) aphasia

19. Which of the following has a much lower concentration in the cerebrospinal fluid (CSF) than in cerebral capillary blood?

(A) Na^+
(B) K^+
(C) Osmolarity
(D) Protein
(E) Mg^{2+}

20. Which of the following autonomic drugs acts by stimulating adenylate cyclase?

(A) Atropine
(B) Clonidine
(C) Curare
(D) Norepinephrine
(E) Phentolamine
(F) Phenylephrine
(G) Propranolol

21. Which of the following is a step in photoreception in the rods?

(A) Light converts all-*trans* retinal to 11-*cis* retinal
(B) Metarhodopsin II activates transducin
(C) Cyclic guanosine monophosphate (cGMP) levels increase
(D) Rods depolarize
(E) Glutamate release increases

22. Pathogens that produce fever cause

(A) decreased production of interleukin-1 (IL-1)
(B) decreased set-point temperature in the hypothalamus
(C) shivering
(D) vasodilation of blood vessels in the skin

23. Which of the following statements about the olfactory system is true?
(A) The receptor cells are neurons
(B) The receptor cells are sloughed off and are not replaced
(C) Axons of cranial nerve (CN) I are A-delta fibers
(D) Axons from receptor cells synapse in the prepiriform cortex
(E) Fractures of the cribriform plate can cause inability to detect ammonia

24. A lesion of the chorda tympani nerve would most likely result in
(A) impaired olfactory function
(B) impaired vestibular function
(C) impaired auditory function
(D) impaired taste function
(E) nerve deafness

25. Which of the following would produce maximum excitation of the hair cells in the right horizontal semicircular canal?
(A) Hyperpolarization of the hair cells
(B) Bending the stereocilia away from the kinocilia
(C) Rapid ascent in an elevator
(D) Rotating the head to the right

26. The inability to perform rapidly alternating movements (dysdiadochokinesia) is associated with lesions of the
(A) premotor cortex
(B) motor cortex
(C) cerebellum
(D) substantia nigra
(E) medulla

27. Which autonomic receptor is activated by low concentrations of epinephrine released from the adrenal medulla and causes vasodilation?
(A) Adrenergic α_1 receptors
(B) Adrenergic β_1 receptors
(C) Adrenergic β_2 receptors

(D) Cholinergic muscarinic receptors
(E) Cholinergic nicotinic receptors

28. Complete transection of the spinal cord at the level of T1 would most likely result in
(A) temporary loss of stretch reflexes below the lesion
(B) temporary loss of conscious proprioception below the lesion
(C) permanent loss of voluntary control of movement above the lesion
(D) permanent loss of consciousness above the lesion

29. Sensory receptor potentials
(A) are action potentials
(B) always bring the membrane potential of a receptor cell toward threshold
(C) always bring the membrane potential of a receptor cell away from threshold
(D) are graded in size, depending on stimulus intensity
(E) are all or none

30. Cutting which structure causes blindness in the temporal fields of the left and right eyes?
(A) Optic nerve
(B) Optic chiasm
(C) Optic tract
(D) Geniculocalcarine tract

31. Which of the following structures has a primary function to coordinate rate, range, force, and direction of movement?
(A) Primary motor cortex
(B) Premotor cortex and supplementary motor cortex
(C) Prefrontal cortex
(D) Basal ganglia
(E) Cerebellum

32. Which reflex is responsible for polysynaptic excitation of contralateral extensors?
(A) Stretch reflex (myotatic)
(B) Golgi tendon reflex (inverse myotatic)
(C) Flexor withdrawal reflex
(D) Subliminal occlusion reflex

33. Which of the following is a characteristic of nuclear bag fibers?

(A) They are one type of extrafusal muscle fiber
(B) They detect dynamic changes in muscle length
(C) They give rise to group Ib afferents
(D) They are innervated by α-motoneurons

34. Muscle stretch leads to a direct increase in firing rate of which type of nerve?

(A) α-Motoneurons
(B) γ-Motoneurons
(C) Group Ia fibers
(D) Group Ib fibers

35. A 42-year-old woman with elevated blood pressure, visual disturbances, and vomiting has increased urinary excretion of 3-methoxy-4-hydroxymandelic acid (VMA). A computerized tomographic scan shows an adrenal mass that is consistent with a diagnosis of pheochromocytoma. While awaiting surgery to remove the tumor, she is treated with phenoxybenzamine to lower her blood pressure. What is the mechanism of this action of the drug?

(A) Increasing cyclic adenosine monophosphate (cAMP)
(B) Decreasing cAMP
(C) Increasing inositol 1,4,5-triphosphate (IP3)/Ca^{2+}
(D) Decreasing IP3/Ca^{2+}
(E) Opening Na^{+}/K^{+} channels
(F) Closing Na^{+}/K^{+} channels

36. Patients are enrolled in trials of a new atropine analogue. Which of the following would be expected?

(A) Increased AV node conduction velocity
(B) Increased gastric acidity
(C) Pupillary constriction
(D) Sustained erection
(E) Increased sweating

Answers and Explanations

1. The answer is E [I C 2 a]. Hexamethonium is a nicotinic blocker, but it acts

only at ganglionic (not neuromuscular junction) nicotinic receptors. This pharmacologic distinction emphasizes that nicotinic receptors at these two locations, although similar, are not identical.

2. The answer is J [I C 1 a; Table 2.2]. Prazosin is a specific antagonist of α_1 receptors, which are present in vascular smooth muscle, but not in the heart. Inhibition of α_1 receptors results in vasodilation of the cutaneous and splanchnic vascular beds, decreased total peripheral resistance, and decreased blood pressure.

3. The answer is B [I C 2 b; Table 2.6]. Miosis is a parasympathetic muscarinic response that involves contraction of the circular muscle of the iris. Dilation of the bronchioles, ejaculation, constriction of the gastrointestinal (GI) sphincters, and increased cardiac contractility are all sympathetic α or β responses.

4. The answer is A [II F 1 b; Table 2.5]. C fibers (slow pain) are the smallest nerve fibers and therefore have the slowest conduction velocity.

5. The answer is A [II C 2 c (2); Table 2.7]. Of the two types of photoreceptors, the rods are more sensitive to low-intensity light and therefore are more important than the cones for night vision. They adapt to darkness after the cones. Rods are not present in the fovea. The cones are primarily involved in color vision.

6. The answer is A [II D 4]. Sound frequencies can be encoded by the organ of Corti because of differences in properties along the basilar membrane. The base of the basilar membrane is narrow and stiff, and hair cells on it are activated by high frequencies. The apex of the basilar membrane is wide and compliant, and hair cells on it are activated by low frequencies.

7. The answer is E [I A, B; Table 2.1; Figure 2.1]. Sympathetic preganglionic neurons originate in spinal cord segments T1–L3. Thus, the designation is thoracolumbar. The sympathetic nervous system is further characterized by short preganglionic neurons that synapse in ganglia located in the paravertebral chain (not in the effector organs) and postganglionic neurons that release norepinephrine (not epinephrine). Common features of the sympathetic and parasympathetic nervous systems are preganglionic neurons that release acetylcholine (ACh) and postganglionic neurons that synapse in effector organs.

8. The answer is B [I C 1 c]. Heart rate is increased by the stimulatory effect of norepinephrine on β_1 receptors in the sinoatrial (SA) node. There are also sympathetic β_1 receptors in the heart that regulate contractility.

9. The answer is A [II C 3 a]. Cutting the optic nerve from the left eye causes blindness in the left eye because the fibers have not yet crossed at the optic chiasm.

10. The answer is A [III C 1]. The stretch reflex is the monosynaptic response to stretching of a muscle. The reflex produces contraction and then shortening of the muscle that was originally stretched (homonymous muscle).

11. The answer is B [II C 5 b (2)]. Complex cells respond to moving bars or edges with the correct orientation. Simple cells respond to stationary bars, and hypercomplex cells respond to lines, curves, and angles. Bipolar and ganglion cells are found in the retina, not in the visual cortex.

12. The answer is E [I C 1 d; Table 2.2]. Asthma, a disease involving increased resistance of the upper airways, is treated by administering drugs that produce bronchiolar dilation (i.e., β_2 agonists). β_2 Agonists include isoproterenol, albuterol, epinephrine, and, to a lesser extent, norepinephrine. β_2 Antagonists, such as propranolol, are strictly contraindicated because they cause constriction of the bronchioles.

13. The answer is A [I C 1 a]. Adrenergic α_1 receptors produce physiologic actions by stimulating the formation of inositol 1,4,5-triphosphate (IP_3) and causing a subsequent increase in intracellular [Ca^{2+}]. Both β_1 and β_2 receptors act by stimulating adenylate cyclase and increasing the production of cyclic adenosine monophosphate (cAMP). α_2 Receptors inhibit adenylate cyclase and decrease cAMP levels. Muscarinic and nicotinic receptors are cholinergic.

14. The answer is B [III E 3 a, b]. Decerebrate rigidity is caused by increased reflex muscle spindle activity. Stimulation of group Ia afferents would enhance, not diminish, this reflex activity. Cutting the dorsal roots would block the reflexes. Stimulation of α- and γ-motoneurons would stimulate muscles directly.

15. The answer is C [II B 4]. Representation on the motor homunculus is greatest for those structures that are involved in the most complicated movements—the fingers, hands, and face.

16. The answer is E [I C 2 a; Figure 2.1]. Preganglionic sympathetic fibers synapse on the chromaffin cells of the adrenal medulla at a nicotinic receptor. Epinephrine and, to a lesser extent, norepinephrine are released into the circulation.

17. The answer is C [II C 3 c]. Fibers from the left temporal field and the right

nasal field ascend together in the right optic tract.

18. The answer is A [II E 3]. The fast eye movement that occurs during a spin is nystagmus. It occurs in the same direction as the rotation. After the spin, postrotatory nystagmus occurs in the opposite direction.

19. The answer is D [V B; Table 2.9]. Cerebrospinal fluid (CSF) is similar in composition to the interstitial fluid of the brain. Therefore, it is similar to an ultrafiltrate of plasma and has a very low protein concentration because large protein molecules cannot cross the blood–brain barrier. There are other differences in composition between CSF and blood that are created by transporters in the choroid plexus, but the low protein concentration of CSF is the most dramatic difference.

20. The answer is D [I C 1 c, d; Table 2.2]. Among the autonomic drugs, only β_1 and β_2 adrenergic agonists act by stimulating adenylate cyclase. Norepinephrine is a $\beta_1$agonist. Atropine is a muscarinic cholinergic antagonist. Clonidine is an α_2 adrenergic agonist. Curare is a nicotinic cholinergic antagonist. Phentolamine is an α_1 adrenergic antagonist. Phenylephrine is an α_1 adrenergic agonist. Propranolol is a β_1 and β_2 adrenergic antagonist.

21. The answer is B [II C 4]. Photoreception involves the following steps. Light converts 11-*cis* retinal to all-*trans* retinal, which is converted to such intermediates as metarhodopsin II. Metarhodopsin II activates a stimulatory G protein (transducin), which activates a phosphodiesterase. Phosphodiesterase breaks down cyclic guanosine monophosphate (cGMP), so intracellular cGMP levels decrease, causing closure of Na^+ channels in the photoreceptor cell membrane and hyperpolarization. Hyperpolarization of the photoreceptor cell membrane inhibits release of the neurotransmitter, glutamate. If the decreased release of glutamate interacts with ionotropic receptors on bipolar cells, there will be inhibition (decreased excitation). If the decreased release of glutamate interacts with metabotropic receptors on bipolar cells, there will be excitation (decreased inhibition).

22. The answer is C [VI C 1]. Pathogens release interleukin-1 (IL-1) from phagocytic cells. IL-1 then acts to increase the production of prostaglandins, ultimately raising the temperature set point in the anterior hypothalamus. The hypothalamus now “thinks” that the body temperature is too low (because the core temperature is lower than the new set-point temperature) and initiates mechanisms for generating heat—shivering, vasoconstriction, and shunting of blood away from the venous plexus near the skin surface.

23. The answer is A [II F 1 a, b]. Cranial nerve (CN) I innervates the olfactory epithelium. Its axons are C fibers. Fracture of the cribriform plate can tear the delicate olfactory nerves and thereby eliminate the sense of smell (anosmia); however, the ability to detect ammonia is left intact. Olfactory receptor cells are unique in that they are true neurons that are continuously replaced from undifferentiated stem cells.

24. The answer is D [II G 1 b]. The chorda tympani (cranial nerve [CN] VII) is involved in taste; it innervates the anterior two-thirds of the tongue.

25. The answer is D [II E 1 a, 2 a, b]. The semicircular canals are involved in angular acceleration or rotation. Hair cells of the right semicircular canal are excited (depolarized) when there is rotation to the right. This rotation causes bending of the stereocilia toward the kinocilia, and this bending produces depolarization of the hair cell. Ascent in an elevator would activate the saccules, which detect linear acceleration.

26. The answer is C [III F 1 c, 3 c]. Coordination of movement (synergy) is the function of the cerebellum. Lesions of the cerebellum cause ataxia, lack of coordination, poor execution of movement, delay in initiation of movement, and inability to perform rapidly alternating movements. The premotor and motor cortices plan and execute movements. Lesions of the substantia nigra, a component of the basal ganglia, result in tremors, lead-pipe rigidity, and poor muscle tone (Parkinson disease).

27. The answer is C [I C 1 d]. β_2 Receptors on vascular smooth muscle produce vasodilation. α_1 Receptors on vascular smooth muscle produce vasoconstriction. Because β_2 receptors are more sensitive to epinephrine than are α receptors, low doses of epinephrine produce vasodilation, and high doses produce vasoconstriction.

28. The answer is A [III E 2]. Transection of the spinal cord causes “spinal shock” and loss of all reflexes below the level of the lesion. These reflexes, which are local circuits within the spinal cord, will return with time or become hypersensitive. Proprioception is permanently (rather than temporarily) lost because of the interruption of sensory nerve fibers. Fibers above the lesion are intact.

29. The answer is D [II A 4 c]. Receptor potentials are graded potentials that may bring the membrane potential of the receptor cell either toward (depolarizing) or away from (hyperpolarizing) threshold. Receptor potentials are

not action potentials, although action potentials (which are all-or-none) may result if the membrane potential reaches threshold.

30. The answer is B [II C 3 b]. Optic nerve fibers from both temporal receptor fields cross at the optic chiasm.

31. The answer is E [III F 3 b]. Output of Purkinje cells from the cerebellar cortex to deep cerebellar nuclei is inhibitory. This output modulates movement and is responsible for the coordination that allows one to "catch a fly."

32. The answer is C [III C 3]. Flexor withdrawal is a polysynaptic reflex that is used when a person touches a hot stove or steps on a tack. On the ipsilateral side of the painful stimulus, there is flexion (withdrawal); on the contralateral side, there is extension to maintain balance.

33. The answer is B [III B 3 a (1)]. Nuclear bag fibers are one type of intrafusal muscle fiber that make up muscle spindles. They detect dynamic changes in muscle length, give rise to group Ia afferent fibers, and are innervated by γ-motoneurons. The other type of intrafusal fiber, the nuclear chain fiber, detects static changes in muscle length.

34. The answer is C [III B 3 b]. Group Ia afferent fibers innervate intrafusal fibers of the muscle spindle. When the intrafusal fibers are stretched, the group Ia fibers fire and activate the stretch reflex, which causes the muscle to return to its resting length.

35. The answer is D [I C; Tables 2.2 and 2.5]. Pheochromocytoma is a tumor of the adrenal medulla that secretes excessive amounts of norepinephrine and epinephrine. Increased blood pressure is due to activation of α_1 receptors on vascular smooth muscle and activation of β_1 receptors in the heart. Phenoxybenzamine decreases blood pressure by acting as an α_1 receptor antagonist, thus decreasing intracellular IP_3/Ca^{2+}.

36. The answer is A [I C 3; I D]. An atropine analogue would block muscarinic receptors and thus block actions that are mediated by muscarinic receptors. Muscarinic receptors slow AV node conduction velocity; thus, muscarinic blocking agents would increase AV node conduction velocity. Muscarinic receptors increase gastric acid secretion, constrict the pupils, mediate erection, and cause sweating (via sympathetic cholinergic innervation of sweat glands); thus, blocking muscarinic receptors will inhibit all of those actions.