

# The Nervous System: A. General Principles and Sensory Physiology

1. 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
2. A 2-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
3. 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
4. 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
5. The release of neurotransmitter at a chemical synapse in the central nervous system is dependent upon 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
6. Which of the following is best described as an elongated, encapsulated receptor found in the dermal pegs of glabrous skin that is especially abundant on lips and fingertips?
  - A) Merkel disc
  - B) Free nerve endings
  - C) Meissner corpuscle
  - D) Ruffini endings
7. 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
8. A 43-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
9. A 15-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

10. Which of the following best describes the concept of specificity in sensory nerve fibers that transmit only one modality of sensation?
- Frequency coding principle
  - Concept of specific nerve energy
  - Singularity principle
  - Labeled line principle
11. 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)?
- Pacinian corpuscle
  - Meissner's corpuscle
  - Free nerve endings
  - Ruffini endings
12. Which substance enhances the sensitivity of pain receptors but does not directly excite them?
- Bradykinin
  - Serotonin
  - Potassium ions
  - Prostaglandins
13. Which of the following is an important functional parameter of pain receptors?
- Exhibit little or no adaptation
  - Not affected by muscle tension
  - Signal only flexion at joint capsules
  - Can voluntarily be inhibited
14. The excitatory or inhibitory action of a neurotransmitter is determined by which of the following?
- The function of its postsynaptic receptor
  - Its molecular composition
  - The shape of the synaptic vesicle in which it is contained
  - The distance between the pre- and postsynaptic membranes
15. A 39-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?
- Activation of G protein
  - Decreased ion permeability
  - Decreased transmitter release
  - Increased ion permeability
  - Increased transmitter release
  - Inhibition of G protein
16. Which ion has the lowest electrochemical driving force in a typical neuron with a resting membrane potential of  $-65$  millivolts?
- Chloride
  - Potassium
  - Sodium
17. A physiology experiment is conducted in which a glass microelectrode is inserted into a Pacinian corpuscle to record receptor potentials during different levels of stimulation (from 0 percent to 100 percent). Increasing stimulus strength from 10 percent of maximum to 30 percent of maximum causes a 40 percent increase in the amplitude of the receptor potential. Increasing the stimulus potential from 70 percent of maximum to 90 percent of maximum is most likely to cause which increase in the amplitude of the receptor potential (in percent)?
- 10
  - 40
  - 60
  - 80
18. Interneurons that utilize the neurotransmitter enkephalin to inhibit afferent pain signals are most likely to be found in which region of the central nervous system?
- Dorsal horn of spinal cord
  - Postcentral gyrus
  - Precentral gyrus
  - $\delta$ -type A
  - Type C fiber
  - Ventral horn of spinal cord
19. Which system transmits somatosensory information with the highest degree of temporal and spatial fidelity?
- Anterolateral system
  - Dorsal column-medial lemniscal system
  - Corticospinal system
  - Spinocerebellar system
20. 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?
- Anterolateral system
  - Dorsal column-medial lemniscal system
  - Corticospinal system
  - Spinocerebellar system
21. Neurons located in which area release serotonin as their neurotransmitter?
- Periaqueductal gray area
  - Interneurons of the spinal cord
  - Periventricular area
  - Nucleus raphe magnus
22. Which system conveys information concerning highly localized touch sensation and body position (proprioceptive) sensation?
- Anterolateral
  - Dorsal column-medial lemniscal
  - Corticospinal
  - Spinocerebellar

23. The first-order (primary afferent) cell bodies of the dorsal column-medial lemniscal system are found in which structure?
- Spinal cord dorsal horn
  - Spinal cord ventral horn
  - Dorsal root ganglia
  - Nucleus cuneatus
24. Which structure carries axons from the nucleus gracilis to the thalamus?
- Fasciculus gracilis
  - Fasciculus lemniscus
  - Lateral spinothalamic tract
  - Medial lemniscus
25. A 10-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?
- $\alpha$ -type A
  - $\beta$ -type A
  - $\delta$ -type A
  - Type C
26. A pool of presynaptic neurons innervate the dendrites of a postsynaptic neuron. Electrical signals are transferred from the dendrites to the soma of the postsynaptic neuron by which process?
- Action potential
  - Active transport
  - Capacitive discharge
  - Diffusion
  - Electrotonic conduction
27. Which structure carries axons from neurons in the ventral posterolateral nucleus of the thalamus to the primary somatosensory cortex?
- Medial lemniscus
  - External capsule
  - Internal capsule
  - Extreme capsule
28. Which of the following is characteristic of the events occurring at an excitatory synapse?
- There is a massive efflux of calcium from the pre-synaptic terminal
  - Synaptic vesicles bind to the postsynaptic membrane
  - Voltage-gated potassium channels are closed
  - Ligand-gated channels are opened to allow sodium entry into the postsynaptic neuron
29. Stimulation of which brain area can modulate the sensation of pain?
- Superior olfactory complex
  - Locus ceruleus
  - Periaqueductal gray area
  - Amygdala
30. Which body part is represented superiorly and medially within the postcentral gyrus?
- Upper limb
  - Lower limb
  - Abdomen
  - Genitalia
31. Which of the following is a group of neurons in the pain suppression pathway that uses enkephalin as a neurotransmitter?
- Postcentral gyrus
  - Nucleus raphe magnus
  - Periaqueductal gray area
  - Type AB sensory fibers

**Questions 32 and 33**

A 19-year-old man has an automobile accident that completely eliminates all nerve traffic in the right half of the spinal cord at C2. Use this information to answer Questions 32 and 33.

32. Loss of which function is most likely in the right hand of this man?
- Crude touch and pain sensation
  - Crude touch and temperature sensation
  - Motor function and temperature sensation
  - Motor function and vibration sense
  - Vibration sense and crude touch
  - Vibration sense and pain sensation
33. Loss of which function is most likely in the left hand of this man?
- Crude touch and pain sensation
  - Crude touch and vibration sense
  - Motor function and temperature sensation
  - Motor function and vibration sense
  - Vibration sense and pain sensation
  - Vibration sense and crude touch
34. The highest degree of pain localization comes from which of the following?
- Simultaneous stimulation of free nerve endings and tactile fibers
  - Stimulation of free nerve endings by bradykinin
  - Nerve fibers traveling to the thalamus by way of the paleospinothalamic tract
  - Stimulation of  $\delta$ -type A fibers

35. Which of the following is the basis for referred pain?

- A) Visceral pain signals and pain signals from the skin synapse with separate populations of neurons in the dorsal horn
- B) Visceral pain transmission and pain transmission from the skin are received by a common set of neurons in the thalamus
- C) Visceral pain signals are rarely of sufficient magnitude to exceed the threshold of activation of dorsal horn neurons
- D) Some visceral pain signals and pain signals from the skin provide convergent input to a common set of neurons in the dorsal horn

36. Post-tetanic facilitation is thought to be the result of 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

37. 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

38. 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

39. Which statement concerning visceral pain signals is correct?

- A) They are transmitted along sensory fibers that course mainly with sympathetic nerves in the abdomen and thorax
- B) They are not stimulated by ischemia in visceral organs
- C) They are transmitted only by the lightly myelinated δ-type A sensory fibers
- D) They are typically well localized

40. Pain from the stomach is referred to which area of the body?

- A) Upper right shoulder area
- B) Abdominal area above the umbilicus
- C) Proximal area of the anterior and inner thigh
- D) Abdominal area below the umbilicus

#### Questions 41–43

Each of the disorders in Questions 41–43 is characterized either by the production of excessive pain (hyperalgesia) or the loss of pain sensation.

41. 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

42. 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

43. 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

44. Stimulation by touching or pulling on which structure is least likely to cause a painful sensation?

- A) The postcentral gyrus
- B) The dura overlying the postcentral gyrus
- C) Branches of the middle meningeal artery that lie superficial to the dura over the postcentral gyrus
- D) Branches of the middle cerebral artery that supply the postcentral gyrus

45. 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

46. The ability to detect two points simultaneously applied to the skin is based on which physiologic mechanism?

- A) Presynaptic inhibition
- B) Lateral inhibition
- C) Medial inhibition
- D) Feed-forward inhibition

47. Which electrical event is characteristic of inhibitory synaptic interactions?
- A neurotransmitter agent that selectively opens ligand-gated chloride channels is the basis for an inhibitory postsynaptic potential
  - Because the Nernst potential for chloride is about  $-70\text{ mV}$ , chloride ions tend to move out of the cell along its electrochemical gradient
  - A neurotransmitter that selectively opens potassium channels will allow potassium to move into the cell
  - An increase in the extracellular sodium concentration usually leads directly to an inhibitory postsynaptic potential
48. Which somatosensory deficit is NOT typically seen after the development of lesions that involve the postcentral gyrus?
- Inability to discretely localize touch sensation over the contralateral face and upper limb
  - Inability to judge the weight of easily recognizable objects
  - Inability to accurately assess the texture of common objects by touching them with the fingers
  - Inability to move the contralateral arm and leg
49. Which statement concerning sensory neurons or their functional properties is true?
- All sensory fibers are unmyelinated
  - In spatial summation, increasing signal strength is transmitted by using progressively greater numbers of sensory fibers
  - Increased stimulus intensity is signaled by a progressive decrease in the receptor potential
  - Continuous subthreshold stimulation of a pool of sensory neurons results in disinhibition of those neurons
  - Temporal summation involves signaling of increased stimulus strength by decreasing the frequency of action potentials in the sensory fibers
50. 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?
- Converging
  - Diverging
  - Inhibitory
  - Reverberatory
51. An input neuron to a diverging circuit causes the membrane potential of a target neuron to change from  $-65\text{ millivolts}$  to  $-55\text{ millivolts}$ . Which of the following best describes this change in membrane potential (in millivolts)?
- Excitatory postsynaptic potential =  $+10$
  - Excitatory postsynaptic potential =  $-10$
  - Inhibitory postsynaptic potential =  $+10$
  - Inhibitory postsynaptic potential =  $-10$
52. Prolonged changes in neuronal activity are usually achieved through the activation of which of the following?
- Voltage-gated chloride channels
  - Transmitter-gated sodium channels
  - G-protein-coupled channels
  - Voltage-gated potassium channels
53. Position sense, or more commonly proprioceptive sensation, involves muscle spindles and which of the following?
- Skin tactile receptors
  - Deep receptors in joint capsules
  - Both tactile and joint capsule receptors
  - Pacinian corpuscles
54. 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?
- Increased blood flow to brain tissue in the visual or other sensory cortex
  - A selective loss of gamma-aminobutyric acid neurons in the various sensory areas of cortex
  - Constipation
  - Vasospasm leading to ischemia and a disruption of neuronal activity in the relevant sensory areas of cortex
55. Which statement accurately describes a feature of temperature sensation by the nervous system?
- Cold receptors continue to be activated even if skin temperature is lowered well below its freezing point
  - Both cold and warm receptors each have very specific, nonoverlapping ranges of temperature sensitivity
  - Warm and cold receptors respond to both steady state temperatures and to changes in temperature
  - Temperature receptor function is the result of ion conduction changes and not changes in their metabolic rate
56. 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
- The right dorsal column nucleus
  - The left dorsal column nucleus
  - The dorsal horn of the right side of the spinal cord
  - The dorsal horn of the left side of the spinal cord

57. 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
58. Like other sensory systems, the somatosensory system has a descending component that functions to regulate the overall sensitivity of the system. Which of the following selections best describes the function of the corticofugal signals transmitted from the somatosensory cortex downward to the thalamus and dorsal column nuclei?
- A) Increase or decrease the perception of signal intensity
  - B) Decrease the ability to detect body position sense
  - C) Remove the thalamus from the processing of somatosensory signals
  - D) Allow ascending information to bypass the nucleus cuneatus and gracilis
59. Which statement concerning the generation of an action potential is correct?
- A) When the membrane potential in the soma/axon hillock dips below “threshold,” an action potential is initiated
  - B) The action potential is initiated in synaptic boutons
  - C) The least number of voltage-gated sodium channels in an axon is found near the node of Ranvier
  - D) Once an action potential is initiated, it will always run its course to completion
60. Which statement concerning synaptic transmission is correct?
- A) When a specific population of synaptic terminals is spread over the considerable surface of a neuron, their collective effects cannot spatially summate and lead to initiation of an action potential
  - B) Even if the successive discharges of an excitatory synapse occur sufficiently close in time, they cannot temporally summate and initiate an action potential
  - C) A neuron is “facilitated” when its membrane potential is moved in the less negative or depolarizing direction
  - D) Even when rapidly stimulated by excitatory synaptic input for a prolonged period, neurons typically do not exhibit synaptic fatigue

# ANSWERS

- 1. 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 calculator is available at [http://physiology-web.com/calculators/electrochemical\\_driving\\_force\\_calculator.html](http://physiology-web.com/calculators/electrochemical_driving_force_calculator.html). 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 force for these two ions is  $+21$  and  $+5$  millivolts, respectively (and both ions tend to be driven out of the cell).

**TMP13 pp. 587-588**

- 2. 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.

**TMP13 pp. 592, 787**

- 3. D)** Pain receptors in the skin are free nerve endings.

**TMP13 p. 621**

- 4. B)** Merkel discs are found in the dermis of hairy skin and signal continuous touch.

**TMP13 p. 608**

- 5. D)** The release of neurotransmitter depends on the influx of calcium through voltage-gated channels. When this influx occurs, synaptic vesicles fuse with the pre-synaptic membrane and release the transmitter agent into the synaptic cleft.

**TMP13 p. 582**

- 6. C)** Meissner corpuscles are found in the dermal pegs.

**TMP13 pp. 596, 607-608**

- 7. 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.

**TMP13 pp. 583-584**

- 8. 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.

**TMP13 pp. 623-624**

- 9. 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.

**TMP13 p. 592**

- 10. D)** The association of one sensory modality with one type of nerve fiber is the basis for the labeled line theory.

**TMP13 p. 595**

- 11. A)** Pacinian corpuscles detect pressure and movement across the skin surface and are encapsulated receptors found deep in the skin throughout the body.

**TMP13 pp. 597, 608**

- 12. D)** Prostaglandins are believed to enhance the sensitivity of pain receptors but do not actually excite them.

**TMP13 p. 621**

- 13. A)** Pain receptors exhibit little or no functional adaptation.

**TMP13 pp. 621-622**

- 14. A)** The function of a transmitter agent is solely dependent on the postsynaptic receptor to which it binds.

**TMP13 p. 582**

- 15. 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.

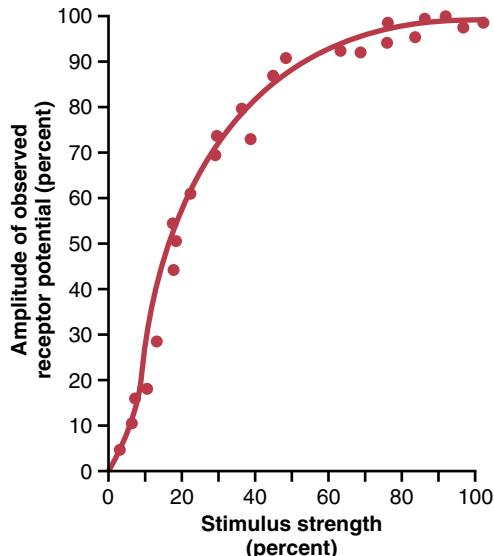
TMP13 pp. 582-583

- 16. A)** The equilibrium potential for chloride averages about  $-70$  millivolts in a typical neuron, so with a resting membrane potential of  $-65$  millivolts, the electrochemical driving force for chloride is  $5$  millivolts. The electrochemical driving force for sodium is about  $127$  millivolts; potassium has a value of about  $21$  millivolts during basal conditions.

TMP13 pp. 587-588

- 17. 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 in the figure below. 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.

TMP13 pp. 597-598



*Data from Loewenstein WR: Excitation and inactivation in a receptor membrane. Ann NY Acad Sci 94:510, 1961.*

- 18. 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 are thought to use enkephalin to inhibit pain transmission. Myelinated  $\delta$ -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.

TMP13 pp. 625-626

- 19. B)** Temporal and spatial fidelity is enhanced in the dorsal column-medial lemniscal system compared with the anterolateral system.

TMP13 p. 610

- 20. 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.

TMP13 pp. 616-617

- 21. 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.

TMP13 p. 625

- 22. B)** The sensations of highly localized touch and body position are carried in the dorsal column-medial lemniscal system.

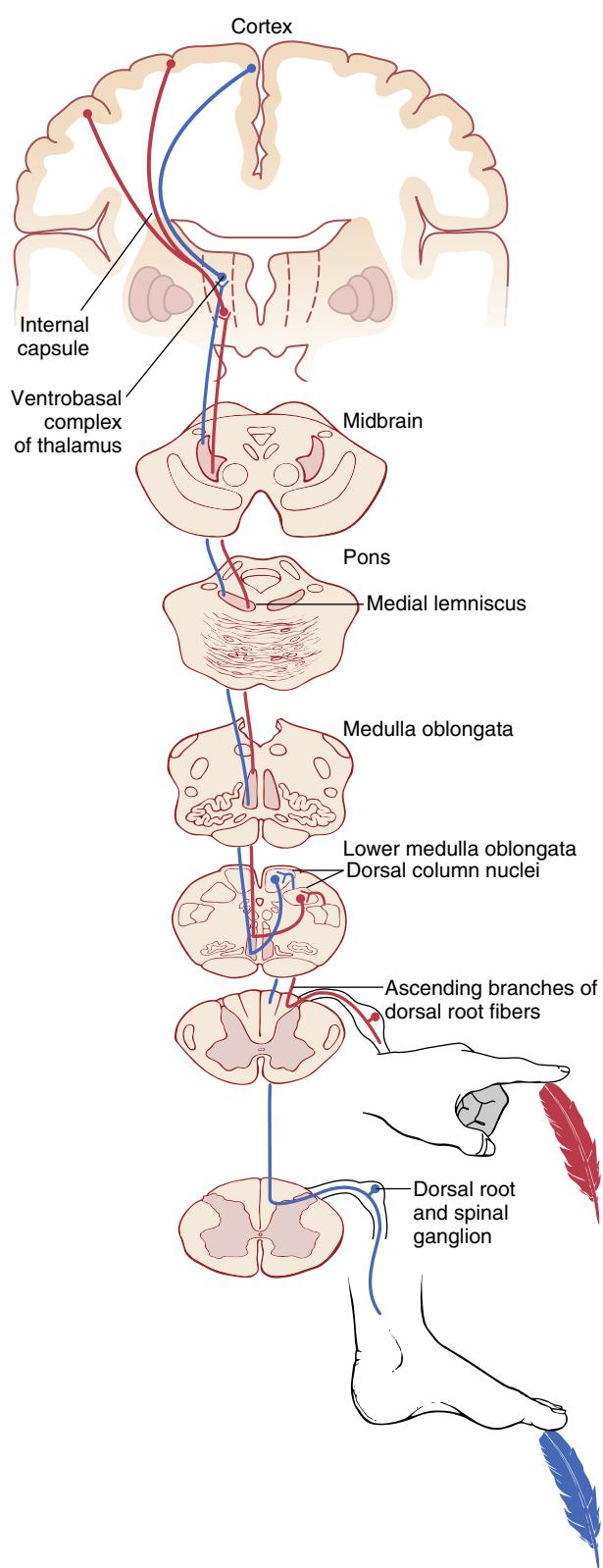
TMP13 p. 610

- 23. C)** Primary afferent neuronal cell bodies are found in the dorsal root ganglia.

TMP13 pp. 609-610

- 24. D)** The medial lemniscus conveys axons from the nucleus gracilis and cuneatus to the thalamus (see the figure below).

TMP13 p. 610



- 25. B)** Stimulation of  $\beta$ -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.  $\alpha$ -Type A neurons project to skeletal muscles, causing them to contract.  $\delta$ -Type A fibers and type C fibers conduct pain signals to the dorsal column of the spinal cord.

TMP13 pp. 599-600

- 26. E)** Transmission of electrical signals in dendrites occurs by electrotonic conduction. Dendrites have few voltage-gated sodium channels, which makes it virtually 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.

TMP13 pp. 590-591

- 27. C)** The internal capsule conveys axons from the ventral posterolateral thalamic nucleus to the primary somatosensory cortex.

TMP13 p. 610

- 28. 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.

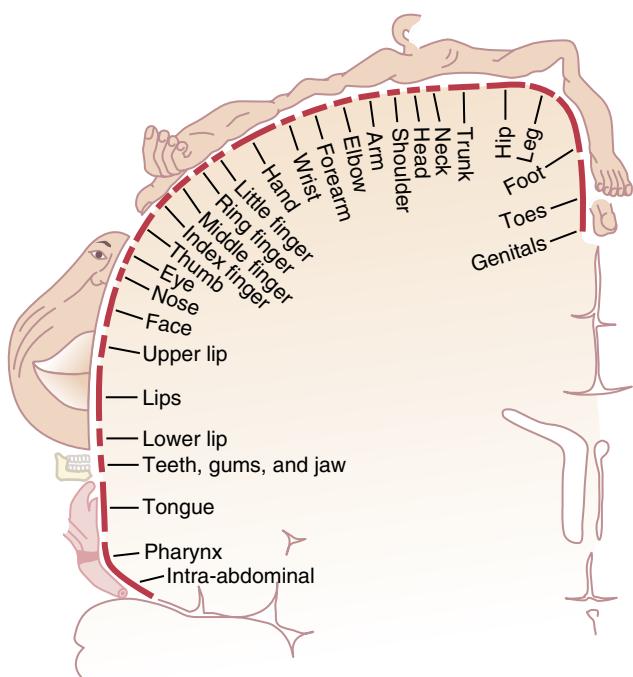
TMP13 pp. 582-583

- 29. C)** The periaqueductal gray area in the midbrain contains neurons that contribute to the descending pain suppression system.

TMP13 p. 625

- 30. B)** The lower limb representation is found in the superior and medial portion of the postcentral gyrus (see the figure below).

TMP13 p. 612



From Penfield W, Rasmussen T: *The Cerebral Cortex of Man*. Copyright 1950 Gale, a part of Cengage Learning, Inc. Reproduced by permission. www.cengage.com/permissions.

- 31. C)** Neurons in the periaqueductal gray area use enkephalin as a transmitter agent.

TMP13 p. 625

- 32. 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.

TMP13 pp. 610, 709

- 33. 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.

TMP13 pp. 609-610

- 34. 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.

TMP13 p. 624

- 35. D)** Visceral pain fibers can provide input to anterolateral tract cells that also receive somatic pain from the skin surface. The convergence of these two types of pain signals onto single spinal cord neurons is thought to be the basis for referred pain.

TMP13 p. 626

- 36. C)** Post-tetanic 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.

TMP13 pp. 589-590

- 37. 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.

TMP13 p. 612

- 38. D)** Layer IV of the somatosensory cortex receives the bulk of the input from the somatosensory nuclei of the thalamus.

TMP13 p. 612

- 39. A)** Visceral pain signals from structures in the abdomen and thorax travel toward the spinal cord in association with fibers of the sympathetic system.

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- 40. B)** Pain from the stomach is referred to the upper abdominal area. In general, it will be above the level of the umbilicus.

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- 41. 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.

TMP13 p. 628

- 42. D)** The Brown-Séquard syndrome is characterized by the 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.

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- 43. 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.

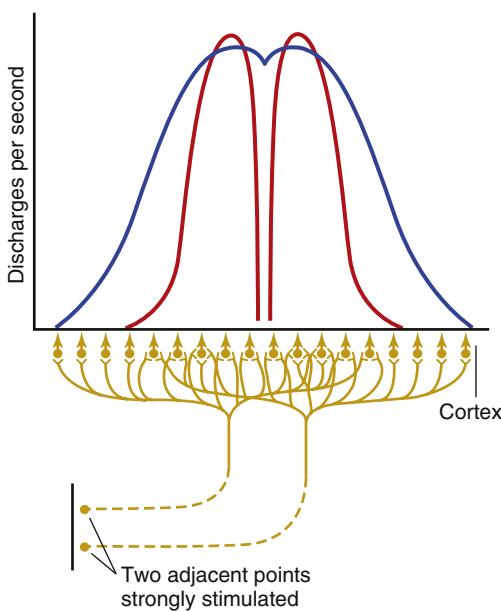
TMP13 p. 628

- 44. A)** Touching or pulling on the postcentral gyrus is least likely to evoke a painful sensation because brain tissue lacks pain receptors.

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- 45. C)** High-frequency repetitive stimulation (indentation/pressure) of the skin is sensed by Pacinian corpuscles.  
 TMP13 p. 608

- 46. B)** The process of lateral inhibition, illustrated in the figure below, underlies the ability to discriminate two points simultaneously applied.  
 TMP13 p. 603



- 47. A)** The opening of ligand-gated chloride channels and movement of chloride ions into the cell leads to hyperpolarization of the membrane. Neither increasing the extracellular sodium concentration nor the movement of potassium into the cell leads to hyperpolarization of the membrane.  
 TMP13 p. 589

- 48. D)** Paralysis of the contralateral arm and leg is a motor deficit, and such a deficit would not typically be observed after damage to the primary somatosensory cortex.  
 TMP13 p. 613

- 49. B)** In spatial summation, increasing signal strength is transmitted by using greater numbers of sensory fibers.  
 TMP13 p. 600

- 50. 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 on for a prolonged time.

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- 51. 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.  
 TMP13 p. 588

- 52. C)** Activation of G proteins usually changes the long-term response characteristics of the neuron.  
 TMP13 p. 583

- 53. C)** Proprioceptive sensation depends on tactile and joint capsule receptors.  
 TMP13 p. 628

- 54. 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.  
 TMP13 p. 629

- 55. C)** Both warm and cold receptors are able to respond to steady-state temperatures, as well as changes in temperature.  
 TMP13 p. 631

- 56. 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.  
 TMP13 p. 610

- 57. B)** Warm receptors mainly transmit signals along relatively slow-conducting type C fibers.  
 TMP13 p. 630

- 58. A)** Descending cortical modulation of somatosensation involves an increase or decrease in the perception of signal intensity.  
 TMP13 pp. 610-611

- 59. D)** The action potential is described as an “all or none” process. Once initiated, the action potential runs its course to completion.  
 TMP13 p. 589

- 60. C)** A facilitated neuron is one whose resting membrane potential is closer to the threshold for activation; that is, less negative or in the depolarizing direction.  
 TMP13 p. 590

# The Nervous System: B. The Special Senses

1. A 10-year-old boy looks at ants through a magnifying glass. He finds that the ants must be 10 centimeters 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
2. Which of the following best describes the "blind spot" of the eye?
  - A) Located 5 degrees lateral to the central point of vision
  - B) The exit point of the optic nerve
  - C) Contains only rods and thus has monochromatic vision
  - D) Contains no blood vessels
  - E) The area where chromatic aberration of the lens is the greatest
3. A 6-year-old boy with albinism is taken to the ophthalmologist because of difficulty seeing. Testing shows that his visual acuity is reduced. Which of the following is the most likely cause of the decrease in visual acuity in this boy?
  - A) Cataracts
  - B) Hyperopia
  - C) Myopia
  - D) Photophobia
  - E) Presbyopia
4. A 53-year-old woman with celiac disease visits the physician because of difficulty seeing at night. The woman has frequent, foul-smelling stools. Stool analysis reveals a high content of partially digested fat. A decrease in blood levels of which of the following is the most likely cause of her night blindness?
  - A) 2-Monoglycerides
  - B) Amino acids
  - C) Free fatty acids
  - D) Glucose
  - E) Vitamin A
  - F) Vitamin B<sub>12</sub>
5. Which substance will elicit the sensation of bitter taste?
  - A) Aldehydes
  - B) Alkaloids
  - C) Amino acids
  - D) Hydrogen ions
  - E) Ketones
6. Damage to the sixth cranial nerve will produce which deficit in eye movement?
  - A) Inability to move the eyes in a vertical up-and-down motion
  - B) Inability to rotate the eyes within the eye socket
  - C) Inability to move the eyes laterally toward the midline
  - D) Inability to move the eyes laterally away from the midline
  - E) Vertical strabismus
7. The condition of cataracts is usually the result of which process or condition?
  - A) Denaturation of the proteins in the lens of the eye
  - B) Elongated eye globe
  - C) Unresponsive and dilated pupil
  - D) Coagulation of the proteins in the lens of the eye
  - E) Increase in intraocular pressure
8. Which substance will elicit the sensation of sour taste?
  - A) Aldehydes
  - B) Alkaloids
  - C) Amino acids
  - D) Hydrogen ions
  - E) Ketones
9. Which taste sensation is the most sensitive (i.e., has the lowest stimulation threshold)?
  - A) Acid
  - B) Bitter
  - C) Salty
  - D) Sour
  - E) Sweet

10. An 85-year-old woman visits the ophthalmologist because of difficulty seeing. The patient is given an eye examination, and bifocal lenses are prescribed. The physician notes that the lenses of her eyes are clear. The woman sees well with her new prescription glasses. Which of the following best describes the most likely vision problem in this woman?
- Cataracts
  - Glaucoma
  - Hyperopia
  - Myopia
  - Presbyopia
11. Which of the following is the middle ear ossicle that is attached to the tympanic membrane?
- Columella
  - Incus
  - Malleus
  - Modiolus
  - Stapes
12. Light entering the eye passes through which retinal layer first?
- Inner nuclear layer
  - Outer nuclear layer
  - Outer plexiform layer
  - Photoreceptor layer
  - Retinal ganglion layer
13. A 25-year-old student with 20/20 vision looks up from his book to view his girlfriend sitting on the other side of the room. Which of the following is most likely to occur when the student changes his view from his book to his girlfriend?
- Thicker lens, contraction of ciliary muscle
  - Thicker lens, relaxation of ciliary muscle
  - Thinner lens, contraction of ciliary muscle
  - Thinner lens, relaxation of ciliary muscle
14. A 60-year-old woman visits the ophthalmologist because of eye pain. Tests show that her right eye has an intraocular pressure of 22 mm Hg and her left eye has an intraocular pressure of 25 mm Hg. Which of the following is the most likely cause of eye pain in this woman?
- Decreased hydraulic resistance of trabecular meshwork
  - Decreased production of aqueous humor
  - Increased hydraulic resistance of trabecular meshwork
  - Increased production of aqueous humor
15. Ganglion cells attached to photoreceptors located on the temporal portion of the retina project to which structure?
- Contralateral lateral geniculate nucleus
  - Ipsilateral lateral geniculate nucleus
  - Ipsilateral medial geniculate nucleus
  - Calcarine fissure
  - Contralateral medial geniculate nucleus
16. When parallel light rays pass through a concave lens, which of the following will occur?
- The rays converge toward each other
  - The rays diverge away from each other
  - The rays maintain a parallel relationship
  - The rays reflect back in the direction from where they came
  - The rays refract to one focal point
17. A 40-year-old woman is admitted emergently to the hospital because of sudden, severe pain in her right eye. Tests show an intraocular pressure of 30 mm Hg in her right eye; the intraocular pressure of her left eye is 15 mm Hg. Which of the following is the most likely cause of eye pain in this woman?
- Acute angle-closure glaucoma
  - Chronic glaucoma
  - Conjunctivitis
  - Corneal abrasion
  - Open-angle glaucoma
  - Optic neuritis
18. Which compartment of the cochlea contains the organ of Corti?
- Ampulla
  - Saccule
  - Scala media
  - Scala tympani
  - Scala vestibuli
19. Which molecules combine to form rhodopsin?
- Bathorhodopsin and 11-cis-retinal
  - Bathorhodopsin and all-trans-retinal
  - Bathorhodopsin and scotopsin
  - Scotopsin and 11-cis-retinal
  - Scotopsin and all-trans-retinal
20. Analysis of visual detail occurs in which secondary visual area?
- Brodmann's area 18
  - Inferior ventral and medial regions of the occipital and temporal cortex
  - Frontal lobe
  - Occipitoparietal cortex
  - Posterior midtemporal area

**Questions 21–23**

A 23-year-old student is trapped in an elevator with no light. Twenty minutes later the student finds an emergency light and turns it on. Use this information to answer Questions 21–23.

21. Which substance is most likely to increase in the rods of the retina when the light is turned on?
- Cyclic adenosine monophosphate (cAMP)
  - Cyclic guanosine monophosphate (cGMP)
  - Metarhodopsin II
  - Rhodopsin
  - Vitamin A

22. Which of the following best describes the permeability to sodium and potassium in rod cells in response to the light?
- Decreased sodium permeability, decreased potassium permeability
  - Decreased sodium permeability, increased potassium permeability
  - Decreased sodium permeability, no change in potassium permeability
  - Increased sodium permeability, decreased potassium permeability
  - Increased sodium permeability, increased potassium permeability
  - Increased sodium permeability, no change in potassium permeability
23. Which of the following best describes the electrical response of the rods to light?
- Action potential
  - Capacitive discharge
  - Depolarization
  - Hyperpolarization
24. Which substance is responsible for the umami taste sensation?
- Acetic acid
  - Potassium tartrate
  - Long-chained organic substances containing nitrogen
  - Fructose
  - Glutamate
25. Which cell type(s) have action potentials in the retina of the human eye?
- Bipolar cells and ganglion cells
  - Bipolar cells only
  - Bipolar cells, horizontal cells, and ganglion cells
  - Ganglion cells and horizontal cells
  - Ganglion cells only
  - Horizontal cells only
26. Olfactory receptor cells belong to which group of cells?
- Bipolar neurons
  - Fibroblasts
  - Modified epithelial cells
  - Multipolar neurons
  - Pseudounipolar neurons
27. Which of the following best describes when the transmission of sound waves in the cochlea occurs?
- When the foot of the stapes moves inward against the oval window and the round window bulges outward
  - When the foot of the stapes moves inward against the round window and the oval window bulges outward
  - When the head of the malleus moves inward against the oval window and the round window bulges outward
  - When the incus moves inward against the oval window and the round window bulges outward
  - When the incus moves inward against the round window and the oval window bulges outward
28. Under low or reduced light conditions, which chemical compound is responsible for the inward-directed sodium current in the outer segments of the photoreceptors?
- Metarhodopsin II
  - cGMP
  - 11-cis retinal
  - cAMP
  - 11-trans retinal
29. Which cells in layer IV of the primary visual cortex detect orientation of lines and borders?
- Border cells
  - Complex cells
  - Ganglion cells
  - Hypercomplex cells
  - Simple cells

**Questions 30 and 31**

A 20-year-old soldier sustains a noise-induced hearing loss over a period of 6 months from multiple exposures to loud sounds. Use this information to answer Questions 30 and 31.

30. Loss of which structure is most likely to contribute to the hearing deficit?
- Cochlea
  - Inner hair cells
  - Organ of Corti
  - Scala media
  - Scala vestibuli
31. An increase in which of the following is the most likely cause of this hearing loss?
- Connexin 26
  - Endolymph
  - Perilymph
  - Reactive oxygen species
32. Which event occurs in photoreceptors during phototransduction in response to light?
- Phosphodiesterase activity decreases
  - Transducin activity decreases
  - Hydrolysis of cGMP increases
  - Neurotransmitter release increases
  - The number of open voltage-gated calcium channels increases
33. During photoreception, all the following increase except
- cGMP phosphodiesterase
  - Transducin
  - cAMP
  - Metarhodopsin II
  - Sodium influx into the outer segment of the rod

**Questions 34 and 35**

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 Questions 34 and 35.

34. Which of the following is the most likely diagnosis?

- A) Acoustic neuroma
- B) Aural polyp
- C) Exostosis
- D) Incus erosion
- E) Meniere's disease

35. 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

36. 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

37. 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

38. Which sensory system has the smallest range of intensity discrimination?

- A) Auditory
- B) Gustatory
- C) Olfactory
- D) Somatosensory
- E) Visual

39. 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

40. The stereocilia of hair cells are embedded in which membrane?

- A) Basilar
- B) Reissner's
- C) Tectorial
- D) Tympanic
- E) Vestibular

41. 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

42. 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 involved?

- A) Calcium
- B) Chloride
- C) Hydrogen
- D) Potassium
- E) Sodium

43. For the eye to adapt to intense light, which of the following may occur?

- 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

44. 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

45. Which statement regarding the transmission of auditory information from the ear to the cerebral cortex is correct?
- Inferior colliculus neurons synapse in the cochlear nuclei of the brain stem
  - Neurons with cell bodies in the spiral ganglion of Corti synapse in the inferior colliculus
  - The majority of neurons from the cochlear nuclei synapse in the contralateral superior olivary nucleus
  - There is no crossing over of information between the right and left auditory pathways in the brain stem
  - Trapezoid neurons synapse in the cochlear nuclei of the brain stem
46. Which statement regarding color vision is correct?
- Green is perceived when only green cones are stimulated
  - The stimulation ratio of the three types of cones allows specific color perception
  - The wavelength of light corresponding to white is shorter than that corresponding to blue
  - When no stimulation of red, green, or blue cones occurs, there will be the sensation of seeing white
  - Yellow is perceived when green and blue cones are stimulated equally
47. Which event prompts the auditory system to interpret a sound as loud?
- A decreased number of inner hair cells become stimulated
  - A decreased number of outer hair cells become stimulated
  - Hair cells excite nerve endings at a diminished rate
  - The amplitude of vibration of the basilar membrane decreases
  - The amplitude of vibration of the basilar membrane increases
48. Which statement is correct concerning the elements of the retina?
- The total number of cones in the retina is much greater than the total number of rods
  - Each individual cone responds to all wavelengths of light
  - Photoreceptor activation (rods and cones) results in hyperpolarization of the receptor
  - The central fovea contains only rods
  - The pigment layer of the retina contains the photoreceptors
49. The condition of hyperopia is usually caused by which anomaly of the eye?
- Decreased production of melanin
  - Uneven curvature of the cornea
  - An eyeball that is shorter than normal
  - An eyeball that is longer than normal
  - A lens system that is too powerful and focuses the object in front of the retina
50. Which statement regarding the two types of deafness is correct?
- An audiogram of a person with conduction deafness would show much greater loss for air conduction than for bone conduction of sound
  - An audiogram of a person with nerve deafness would show much greater loss for bone conduction than for air conduction of sound
  - Conduction deafness occurs when the cochlea or cochlear nerve is impaired
  - Nerve deafness occurs when the physical structures that conduct the sound into the cochlea are impaired
  - Prolonged exposure to very loud sounds is more likely to cause deafness for high-frequency sounds than for low-frequency sounds
51. 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?
- While the head is turning, the eyes will be moving to the right and saccadic eye motion will be to the left
  - 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
  - While the head is turning, the eyes will be moving to the right and the saccadic eye motion will be to the right
  - While the head is turning, the eyes will remain stationary within the orbits and the saccadic eye motion will be to the right
  - While the head is turning, the eyes will be moving to the left and the saccadic eye motion will be to the right
52. Olfactory information transmitted to the orbitofrontal cortex passes through which thalamic nucleus?
- Dorsomedial
  - Lateral geniculate
  - Medial geniculate
  - Ventral posterolateral
  - Ventral posteromedial
53. 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?
- Lateral geniculate nucleus
  - Medial geniculate nucleus
  - Optic chiasm
  - Optic radiation
  - Superior cervical ganglion
  - Superior colliculus

54. The function of the round window can best be described by which statement?

- A) It provides the connection point for the stapes
- B) It serves to damp out low frequency sounds such as your own voice
- C) It transmits the frequency information into the cochlea from the tympanic membrane
- D) It serves as the pressure relief valve for the cochlea
- E) It transmits amplitude information into the cochlea from the tympanic membrane

55. Which muscle is contracted as part of the pupillary light reflex?

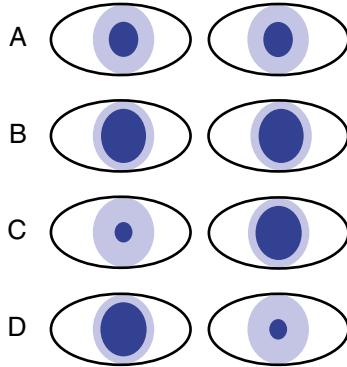
- A) Ciliary muscle
- B) Pupillary dilator muscle
- C) Pupillary sphincter muscle
- D) Radial fibers of the iris
- E) Superior oblique muscle

### Questions 56 and 57

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 Questions 56 and 57.

56. What is the most likely diagnosis?

- A) Cone-rod dystrophy
- B) Horner's syndrome
- C) Iris heterochromia
- D) Retinoblastoma
- E) Xerophthalmia



57. Which test result shown in the above figure is most likely after topical treatment with cocaine in both eyes?

- A) A
- B) B
- C) C
- D) D

58. 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

59. 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

60. 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

61. 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

62. Which structure secretes the intraocular fluid of the eye?

- A) Ciliary processes
- B) Cornea
- C) Iris
- D) Lens
- E) Trabeculae

63. Which type of papillae is located in the posterior part of the tongue?

- A) Circumvallate
- B) Foliate
- C) Fungiform
- D) Fungiform and circumvallate
- E) Papilla of Vater

64. Which statement regarding retinal ganglion cells is correct?
- One W ganglion cell from the periphery of the retina typically transmits information from one rod
  - One X ganglion cell from the fovea typically transmits information from as many as 200 cones
  - W ganglion cells respond best to directional movement or vision under very bright conditions
  - X ganglion cells respond best to color images and are the most numerous of the three types of ganglion cells
  - Y ganglion cells respond best to rapid changes in the visual image and are the most numerous of the three types of ganglion cells
65. Auditory information is relayed through which thalamic nucleus?
- Dorsomedial
  - Lateral geniculate
  - Medial geniculate
  - Ventral posterolateral
  - Ventral posteromedial
66. Which of the following describes the phenomenon of taste preference?
- A central nervous system process
  - The result of neonatal stimulation of circumvallate papilla
  - A learned behavior in animals
  - A result of taste bud maturation
  - A result of taste bud proliferation after exposure to glutamic acid
67. The primary auditory cortex lies primarily in which lobe of the cerebral cortex?
- Frontal
  - Limbic
  - Occipital
  - Parietal
  - Temporal
68. The first central synapse for neurons transmitting the sweet taste sensation is in which structure?
- Dorsal sensory nucleus of vagus nerve
  - Nucleus of solitary tract
  - Nucleus of olfactory nerve
  - Nucleus of hypoglossal nerve
  - Nucleus of facial nerve
69. Which statement best describes the underlying basis of the dark current in the outer segment of the photoreceptors?
- Dark current results from the influx of sodium ions via c-AMP-dependent sodium channels
  - Dark current results from the influx of sodium ions via c-GMP-dependent sodium channels
- C) Dark current results from the efflux of potassium ions via c-GMP-dependent potassium channels
- D) Dark current results from the efflux of sodium ions via c-GMP-dependent sodium channels
- E) Dark current results from the efflux of sodium ions via c-AMP-dependent sodium channels
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?
- Edinger-Westphal nucleus
  - Medial longitudinal fasciculus
  - Pretectal nucleus
  - Superior colliculus
  - Suprachiasmatic nucleus
71. The intraocular fluid of the eye flows from the canal of Schlemm into which location?
- Anterior chamber
  - Aqueous veins
  - Lens
  - Posterior chamber
  - Trabeculae
72. Which retinal cells have action potentials?
- Amacrine cells
  - Bipolar cells
  - Ganglion cells
  - Horizontal cells
  - Photoreceptors
73. Which brain stem structure plays a major role in determining the direction from which a sound originates?
- Cochlear nucleus
  - Inferior colliculus
  - Lateral lemniscus
  - Superior olivary nucleus
  - 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?
- Amacrine cells
  - Bipolar cells
  - Ganglion cells
  - Horizontal cells
75. Which type of papillae is located in the folds along the lateral surfaces of the tongue?
- Circumvallate
  - Foliate
  - Fungiform
  - Fungiform and circumvallate
  - Papilla of Vater

- 1. C)** The refractive power of a lens (in diopters) = 1 meter/focal length; if the subject matter is in focus when a convex lens is 1 meter from the subject matter, the lens has a refractive power of 1 meter/1 meter = 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 centimeters from the subject matter to be in focus (focal length = 100 millimeters); therefore, 1000 millimeters/100 millimeter = 10 diopters. Because the retina of the eye is about 17 millimeters behind the lens, the refractive power of the lens of the eye is about 59 diopters.

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- 2. 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.

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- 3. 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.

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- 4. E)** Vitamin A is a fat-soluble vitamin that can be excreted in the feces along with fat in persons with celiac disease and other diseases that cause malabsorption of intestinal contents. A lack of vitamin A can cause a decrease in production of retinal, which is necessary for synthesis of rhodopsin in the rods of the retina. Decreased levels of rhodopsin in the rods can lower the sensitivity of the retina to light, thus causing night blindness.

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- 5. B)** The taste sensation of bitter is caused by many organic substances that contain nitrogen, as well as by alkaloids.

TMP13 p. 685

- 6. 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*.

TMP13 pp. 665-666

- 7. 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 similar to the white of an egg turning opaque as it is cooked. Heating the egg white results in coagulation of the proteins contained within it.

TMP13 p. 642

- 8. 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.

TMP13 p. 685

- 9. 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.

TMP13 p. 686

- 10. E)** A person with presbyopia cannot accommodate for near and far vision, which means that the lenses of the eyes have lost their elasticity and thus cannot change their focal point. A child with good vision has 14 diopters of accommodation; this accommodation decreases throughout life until, at approximately 70 years, the lenses cannot change their shape and the power of accommodation is then zero. People with zero power of accommodation are said to be presbyopic.

TMP13 p. 640

- 11. 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.

TMP13 p. 673

- 12. 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.

TMP13 p. 647

- 13. D)** Light rays from distant objects do not require as much refraction (bending) as do light rays from objects close at hand. Therefore, a thinner lens with less curvature is required for viewing distant objects. The process of accommodation adjusts the thickness of the lens for near and far vision by contracting or relaxing the ciliary muscle that surrounds the lens of the eye; contraction

of the ciliary muscle thickens the lens, and relaxation causes the lens to become thinner.

TMP13 pp. 639-640

- 14. C)** This woman has open-angle glaucoma, which is the most common type of glaucoma. Glaucoma is the second leading cause of blindness worldwide after cataracts. Blindness occurs because of damage to the optic nerve. The high intraocular pressure causes blood vessels and axons of the optic nerve to be compressed at the optic disc, which leads to poor nutrition with possible death of the neurons. The main cause of open-angle glaucoma is reduced flow of aqueous humor through the trabecular meshwork because of tissue debris, white blood cells, deposition of fibrous material, and other factors that increase the hydraulic resistance of the meshwork.

TMP13 p. 646

- 15. 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.

TMP13 p. 661

- 16. 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*.

TMP13 p. 636

- 17. A)** This woman has acute angle-closure glaucoma, which is a medical emergency. Sudden closure of the iridocorneal angle prevents aqueous humor from reaching its outflow pathway in the canal of Schlemm. Intraocular pressure can increase rapidly and cause blindness without immediate treatment. Chronic glaucoma and open-angle glaucoma are the same disease. Conjunctivitis (pinkeye) is an inflammation of the conjunctiva. A corneal abrasion is a scratch on the cornea; it can be very painful. Optic neuritis is inflammation of the optic nerve.

TMP13 p. 646

- 18. 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.

TMP13 pp. 674-675

- 19. 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.

TMP13 pp. 649-650

- 20. 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.

TMP13 pp. 662-664

- 21. C)** Photons activate rhodopsin to become metarhodopsin II in the rods of the retina, which means that exposure to light decreases the concentration of rhodopsin and increases the concentration of metarhodopsin II, also called *activated rhodopsin*. Metarhodopsin II leads to a decrease in cGMP through a series of biochemical reactions; cAMP levels are unchanged. Vitamin A levels are not likely to change with exposure to light.

TMP13 pp. 647, 649-651

- 22. C)** Activated rhodopsin (metarhodopsin II) closes cGMP-gated sodium channels by lowering levels of cGMP; this action decreases sodium permeability. Potassium permeability is not affected.

TMP13 pp. 650-651

- 23. D)** Exposure of rods to light causes cGMP-gated sodium channels in the cell membrane to close; this action causes rods to hyperpolarize from a resting value of about -40 millivolts to as low as -70 millivolts. Action potentials do not occur in rods or cones. A capacitive discharge occurs during the course of an action potential.

TMP13 p. 651

- 24. 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.

TMP13 p. 686

- 25. E)** Ganglion cells are the only cell type in the retina that have action potentials. The axons of ganglion cells comprise 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.

TMP13 pp. 655, 656, 658

- 26. A)** The receptor cells for the smell sensation are bipolar nerve cells derived originally from the central nervous system itself.

TMP13 p. 689

- 27. A)** The malleus is connected to the tympanic membrane, the incus articulates with the malleus and stapes, and the stapes is connected to the oval window.

TMP13 p. 673

- 28. 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*.

TMP13 pp. 650-651

- 29. 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.

TMP13 p. 664

- 30. B)** Noise-induced hearing loss (NIHL) is the most common acquired cause of hearing loss worldwide. NIHL is usually caused by damage and eventual death of the inner hair cells located in the organ of Corti of the cochlea; these cells do not grow back. The inner hair cells are the actual sensory receptors of the organ of Corti. The scala media and scala vestibuli are fluid-filled coiled tubes that comprise the cochlea.

TMP13 pp. 682, 683

- 31. D)** Prolonged exposure to excessive sound levels or loud sounds overstimulates hair cells, causing them to produce large amounts of reactive oxygen species, which can cause oxidative cell death. Animal studies have shown that antioxidant vitamins administrated the day after noise exposure can reduce the hearing loss, but pretreatment is more effective. Low levels of connexin 26 due to gene mutation are thought to constitute a congenital hearing loss. Perilymph is the fluid contained in the scala vestibuli and scala tympani of the cochlea; endolymph is the fluid contained in the scala media and membranous labyrinth.

TMP13 pp. 682-683

- 32. 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.

TMP13 pp. 651-652

- 33. E)** During photoreception, the active compound metarhodopsin is formed, which in turn activates a G protein called *transducin*. The transducin activates a cGMP phosphodiesterase that destroys cGMP. cGMP-dependent sodium channels close, and the influx of sodium ions into the outer segment of the photoreceptors decreases.

TMP13 pp. 650-652

- 34. 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.

TMP13 pp. 677, 678

- 35. 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.

TMP13 pp. 677, 678

- 36. 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.

TMP13 p. 641

- 37. 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" their eyes from one point of fixation and then move them to another point.

TMP13 pp. 666-667

38. C) Concentrations that are only 10 to 50 times above threshold values will 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.

TMP13 p. 690

39. 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.

TMP13 p. 677

40. 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.

TMP13 p. 677

41. 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.

TMP13 p. 666

42. 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.

TMP13 p. 690

43. 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*.

TMP13 pp. 652-653

44. 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.

TMP13 p. 679

45. C) Neurons with cell bodies in the spiral ganglion of Corti synapse in the cochlear nuclei. The majority of the cochlear nuclei neurons synapse in the contralateral superior olivary nucleus. Crossing over occurs in at least three places in the pathway, and a preponderance of auditory transmission is in the contralateral pathway. From the superior olivary nucleus, the auditory pathway then passes upward through the lateral lemniscus, with most auditory fibers terminating at the inferior colliculus. From there, the pathway continues on to the medial geniculate nucleus and then to the primary auditory cortex.

TMP13 p. 679

46. B) Research has shown that the nervous system perceives the sensation of a specific color by interpreting the set of ratios of stimulation of the three types of cones. Investigators used only red, green, and blue monochromatic lights mixed in different combinations. All gradations of colors the human eye can detect were detected with only these three colors.

TMP13 pp. 653-654

47. 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.

TMP13 pp. 676, 678

48. C) Unlike most other sensory receptors that depolarize when activated, the photoreceptors produce the opposite response, which is hyperpolarization. The total number of rods is much greater than the number of cones. Cones respond to a very specific range of wavelengths of light. The pigment layer is posterior to the retinal layer that contains the photoreceptors.

TMP13 p. 650

49. 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.

TMP13 p. 640

50. A) With nerve deafness, there is damage to the cochlea, auditory nerve, or neural pathway. The ability to hear sound as tested by both air conduction and bone conduction is greatly reduced or lost with nerve deafness. However, with conduction deafness, the person retains the ability to hear sound by bone conduction, but not by air conduction.

TMP13 p. 682

51. A) In the situation described, the eyes will 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 will repeat until the head has turned all the way to the left. During saccadic eye movement, vision is suppressed.

TMP13 pp. 667-668

52. 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.

TMP13 p. 691

- 53. 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.

TMP13 pp. 661-662

- 54. D)** The cochlea is a structure of tubes and chambers that is filled with fluid. The fluid is not compressible. As the stapes moves back and forth against the oval window, the increase and decrease in pressure caused by that in-and-out movement of the oval window is relieved by the opposite back-and-forth movement of the round window.

TMP13 p. 675

- 55. 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).

TMP13 p. 672

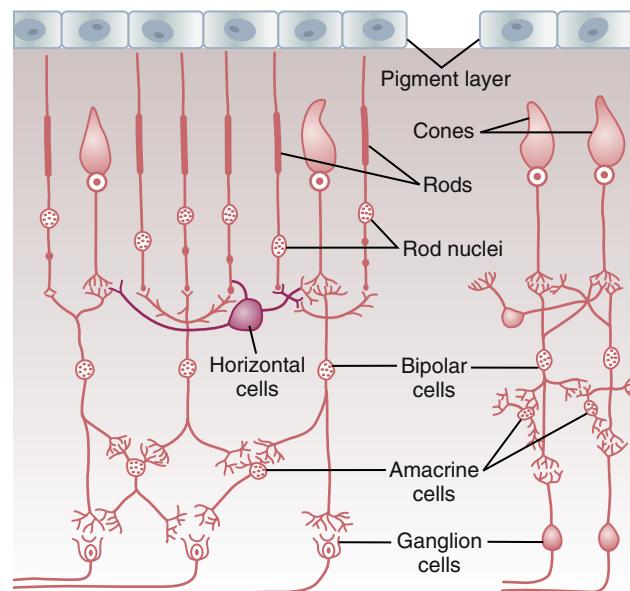
- 56. B)** This woman has Horner's syndrome, which is not a disease but rather a symptom of a disease or other problem. In this problem, lacerations to the right side of the neck have damaged the sympathetic nerves to the right eye and right side of the face. Other causes of Horner's syndrome include 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.

TMP13 p. 670

- 57. D)** Cocaine blocks the reuptake of norepinephrine, increasing its concentration at the nerve terminal. Norepinephrine 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  $\alpha$ -adrenergic agonist (such as apraclonidine) to both eyes. The pupillary dilator muscle responds to denervation by increasing the number of its  $\alpha$ -1 receptors. The weak  $\alpha$ -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  $\alpha$ -1 adrenergic stimulation.

TMP13 p. 670



- 58. 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).

TMP13 p. 655

- 59. 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.

TMP13 p. 644

- 60. 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.

TMP13 p. 638

- 61. D)** Intuitively, one would 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.

TMP13 p. 652

- 62. A)** Ciliary processes secrete all the aqueous humor of the intraocular fluid at an average rate of 2 to 3  $\mu\text{l}/\text{min}$ . 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.

TMP13 p. 645

- 63. 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.

TMP13 p. 687

- 64. D)** There are three distinct groups of retinal ganglion cells, designated as W, X, and Y cells. W cells transmit rod visual signals. Y cells are the least numerous and transmit information about rapid changes in the visual image. X cells are the most numerous and receive input from cones regarding the visual image and color vision.

TMP13 pp. 657-658

- 65. C)** The medial geniculate nucleus is the thalamic nucleus that conveys auditory information from the brain stem to the primary auditory cortex.

TMP13 p. 679

- 66. A)** Taste preference, although not completely understood, is believed to involve a central process.

TMP13 p. 688

- 67. 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.

TMP13 p. 680

- 68. B)** The termination of taste fibers for all taste sensations is in the nucleus of the solitary tract in the medulla.

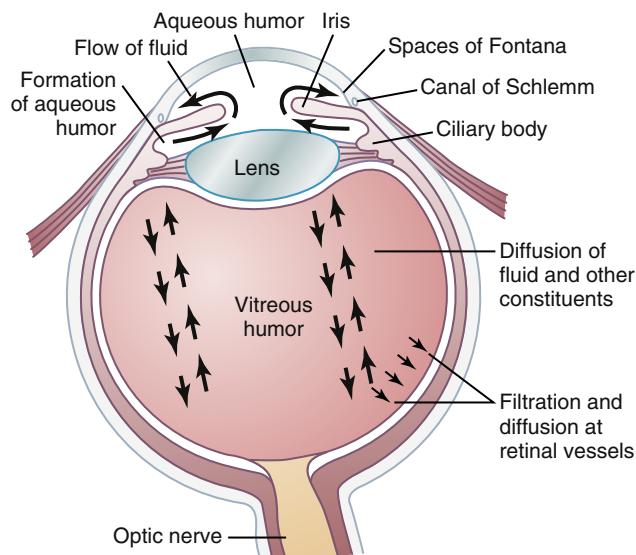
TMP13 pp. 687-688

- 69. B)** 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 process 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*.

TMP13 p. 650

- 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.

TMP13 p. 666

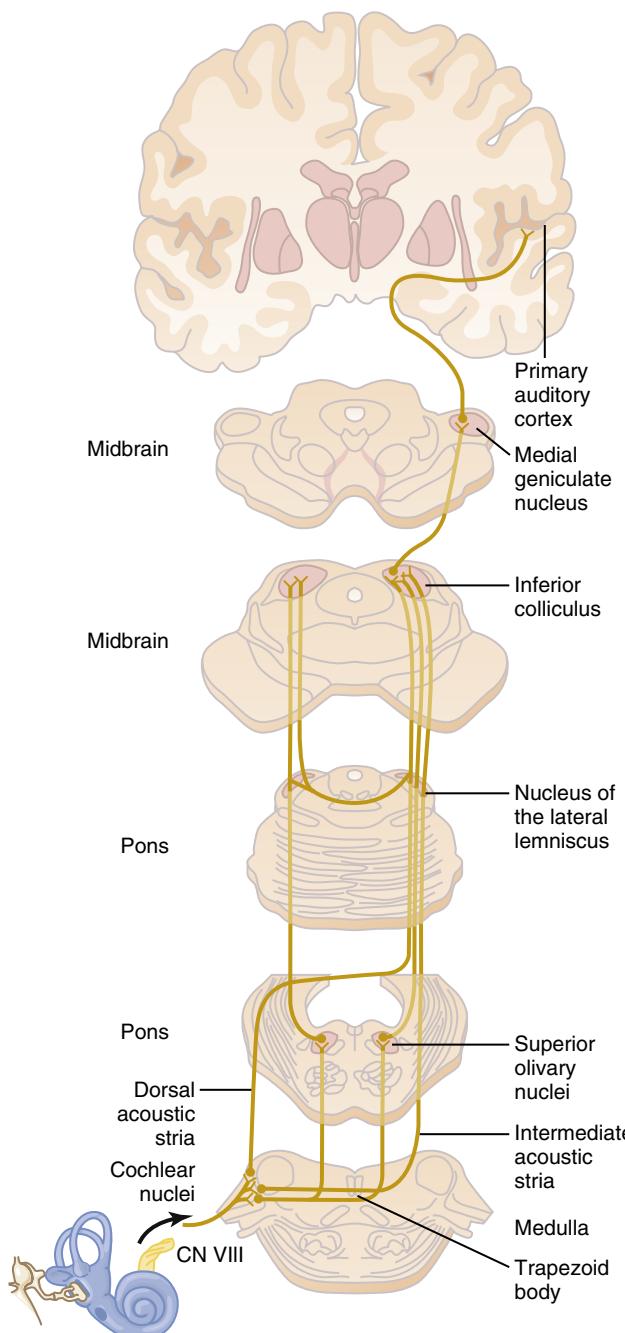


- 71. B)** Intraocular fluid flows from the anterior chamber of the eye, between the cornea and the iris through a meshwork of trabeculae into the canal of Schlemm, which empties into extraocular aqueous veins (see the figure above).

TMP13 p. 645

72. C) Only ganglion cells have action potentials. Photoreceptors, bipolar cells, amacrine cells, and horizontal cells all appear to operate through graded potentials.

TMP13 p. 655



73. D) The superior olivary nuclei (see the figure at left) 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.

TMP13 pp. 681-682

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.

TMP13 pp. 656-657

75. A) 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.

TMP13 p. 687