

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 B₁₂
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?
 - A) Cataracts
 - B) Glaucoma
 - C) Hyperopia
 - D) Myopia
 - E) Presbyopia
 11. Which of the following is the middle ear ossicle that is attached to the tympanic membrane?
 - A) Columella
 - B) Incus
 - C) Malleus
 - D) Modiolus
 - E) Stapes
 12. Light entering the eye passes through which retinal layer first?
 - A) Inner nuclear layer
 - B) Outer nuclear layer
 - C) Outer plexiform layer
 - D) Photoreceptor layer
 - E) Retinal ganglion layer
 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?
 - A) Thicker lens, contraction of ciliary muscle
 - B) Thicker lens, relaxation of ciliary muscle
 - C) Thinner lens, contraction of ciliary muscle
 - D) 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?
 - A) Decreased hydraulic resistance of trabecular meshwork
 - B) Decreased production of aqueous humor
 - C) Increased hydraulic resistance of trabecular meshwork
 - D) Increased production of aqueous humor
 15. Ganglion cells attached to photoreceptors located on the temporal portion of the retina project to which structure?
 - A) Contralateral lateral geniculate nucleus
 - B) Ipsilateral lateral geniculate nucleus
 - C) Ipsilateral medial geniculate nucleus
 - D) Calcarine fissure
 - E) Contralateral medial geniculate nucleus
 16. When parallel light rays pass through a concave lens, which of the following will occur?
 - A) The rays converge toward each other
 - B) The rays diverge away from each other
 - C) The rays maintain a parallel relationship
 - D) The rays reflect back in the direction from where they came
 - E) 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?
 - A) Acute angle-closure glaucoma
 - B) Chronic glaucoma
 - C) Conjunctivitis
 - D) Corneal abrasion
 - E) Open-angle glaucoma
 - F) Optic neuritis
 18. Which compartment of the cochlea contains the organ of Corti?
 - A) Ampulla
 - B) Saccule
 - C) Scala media
 - D) Scala tympani
 - E) Scala vestibuli
 19. Which molecules combine to form rhodopsin?
 - A) Bathorhodopsin and 11-cis-retinal
 - B) Bathorhodopsin and all-trans-retinal
 - C) Bathorhodopsin and scotopsin
 - D) Scotopsin and 11-cis-retinal
 - E) Scotopsin and all-trans-retinal
 20. Analysis of visual detail occurs in which secondary visual area?
 - A) Brodmann's area 18
 - B) Inferior ventral and medial regions of the occipital and temporal cortex
 - C) Frontal lobe
 - D) Occipitoparietal cortex
 - E) Posterior midtemporal area
- 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?
 - A) Cyclic adenosine monophosphate (cAMP)
 - B) Cyclic guanosine monophosphate (cGMP)
 - C) Metarhodopsin II
 - D) Rhodopsin
 - E) 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 photo-transduction 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 extra-ocular 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

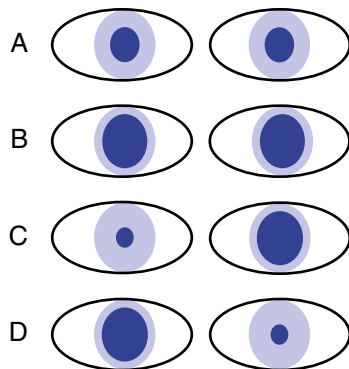
45. Which statement regarding the transmission of auditory information from the ear to the cerebral cortex is correct?
 - A) Inferior colliculus neurons synapse in the cochlear nuclei of the brain stem
 - B) Neurons with cell bodies in the spiral ganglion of Corti synapse in the inferior colliculus
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

54. The function of the round window can best be described by which statement?
- It provides the connection point for the stapes
 - It serves to damp out low frequency sounds such as your own voice
 - It transmits the frequency information into the cochlea from the tympanic membrane
 - It serves as the pressure relief valve for the cochlea
 - It transmits amplitude information into the cochlea from the tympanic membrane
55. Which muscle is contracted as part of the pupillary light reflex?
- Ciliary muscle
 - Pupillary dilator muscle
 - Pupillary sphincter muscle
 - Radial fibers of the iris
 - 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?
- Cone-rod dystrophy
 - Horner's syndrome
 - Iris heterochromia
 - Retinoblastoma
 - Xerophthalmia



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

58. Which neurotransmitter is released by both rods and cones at their synapses with bipolar cells?
- Acetylcholine
 - Dopamine
 - Glutamate
 - Glycine
 - Serotonin
59. Which of the following allows the visual apparatus to accurately determine the distance of an object from the eye (depth perception)?
- Monocular vision
 - The location of the retinal image on the retina
 - The phenomenon of stationary parallax
 - The phenomenon of stereopsis
 - 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?
- Anterior surface of the cornea
 - Anterior surface of the lens
 - Iris
 - Posterior surface of the cornea
 - Posterior surface of the lens
61. Which photoreceptor responds to the broadest spectrum of wavelengths of light?
- Rod receptors
 - Green cone receptors
 - Blue cone receptors
 - Red cone receptors
 - Cells containing melanin in the pigment layer
62. Which structure secretes the intraocular fluid of the eye?
- Ciliary processes
 - Cornea
 - Iris
 - Lens
 - Trabeculae
63. Which type of papillae is located in the posterior part of the tongue?
- Circumvallate
 - Foliate
 - Fungiform
 - Fungiform and circumvallate
 - 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
 - Dark current results from the efflux of potassium ions via c-GMP-dependent potassium channels
 - Dark current results from the efflux of sodium ions via c-GMP-dependent sodium channels
 - 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

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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.
TMP13 pp. 637-638
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.
TMP13 p. 665
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.
TMP13 pp. 648-649
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.
TMP13 pp. 648-649
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 administered 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

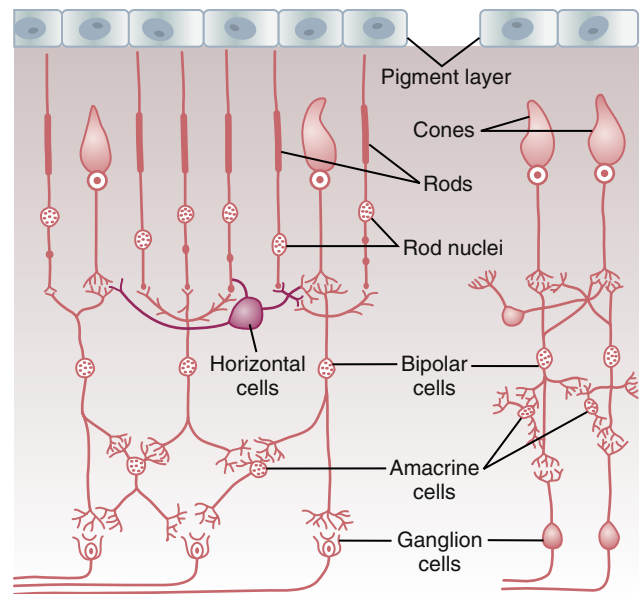
- 56. B)** This woman has Horner's syndrome, which is not a disease but rather a symptom of a disease or other problem. In this problem, lacerations to the right side of the neck have damaged the sympathetic nerves to the right eye and right side of the face. Other causes of Horner's syndrome include 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 α -adrenergic agonist (such as apraclonidine) to both eyes. The pupillary dilator muscle responds to denervation by increasing the number of its α -1 receptors. The weak α -1 adrenergic properties of apraclonidine have no effect on the normal pupillary dilator muscle but cause extensive dilation of the hypersensitive, denervated pupillary dilator muscle. Thus, with application of apraclonidine, the correct answer would be C because the right eye is denervated and thus hypersensitive to α -1 adrenergic stimulation.

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.

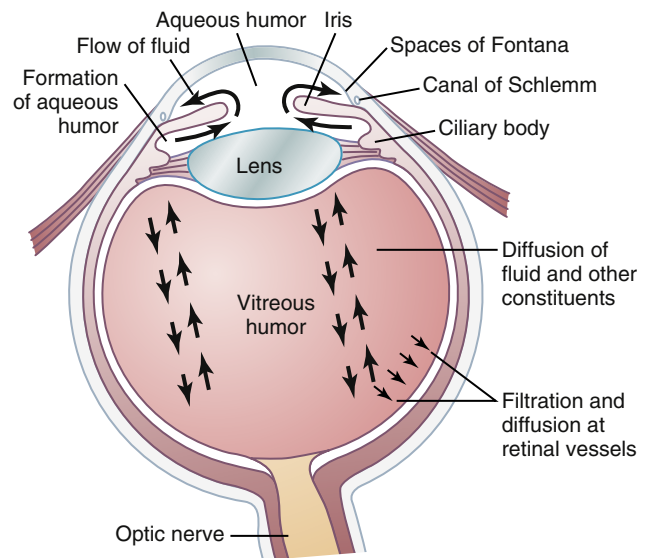
TMP13 pp. 687-688

- 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.

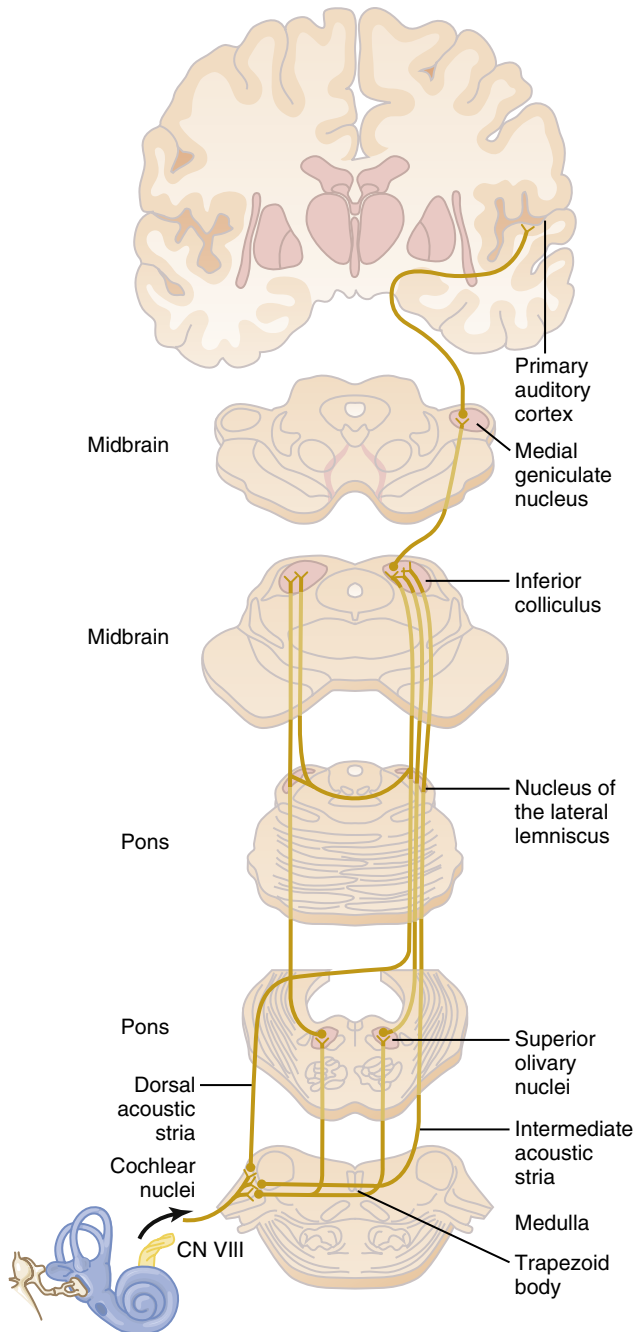
TMP13 p. 666



- 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