CHAPTER 10
SENSORY PHYSIOLOGY

CHAPTER SCOPE

Earlier (chapter 8), we explored the CNS brain and spinal cord, pointing out important regions such as the **sensory cortex** (postcentral gyrus), the **auditory cortex** (temporal lobe) the **visual cortex** (occipital lobe) and the deeper, specialized nuclei for interpretation of **taste** and **smell**. This chapter examines characteristics of the many specialized structures known as *sensory receptors* that respond to stimuli that allow us to perceive the wide variety of disturbances in our environment. When appropriately stimulated, these sensory receptors generate electrical impulses or action potentials that are directed to the brain for interpretation and provide us with our perception of "sense".

Sensory receptors in the skin (**cutaneous**) such as those sensitive to changes in temperature, pressure, touch, and pain provide us our most familiar contact with the surrounding world. Other specialized sensory receptors such as those for taste (*gustation*), smell (*olfaction*), and sensation of balance (*vestibular equilibrium*) are not as familiar to us, yet they use many of the same principles that apply to the cutaneous receptors. In addition, highly specialized organs such as the ear and the eye serve as unique receptors for **hearing** and **vision**. Each of these types of receptors generates nerve impulses that the brain interprets, incorporates with sensory input from other sources, and then enables us to respond appropriately.

I. CHARACTERISTICS OF SENSORY RECEPTORS

Each type of sensory receptor responds to a particular modality of environmental stimulus by causing the production of action potentials in a sensory neuron. These impulses are conducted to parts of the brain that provide the proper interpretation of sensory information when that particular neural pathway is activated.

A. Multiple Choice

___ 1. Which of the following is *not* a chemoreceptor?
   a. taste bud
   b. olfactory epithelium
   c. hot and cold receptors
   d. aortic and carotid bodies
   e. All of these are chemoreceptors.

___ 2. Which of the following is *not* a mechanoreceptor?
   a. touch receptor
   b. pain receptor
   c. pressure receptor
   d. inner ear hair cell (for hearing)
   e. vestibular hair cell (for balance)

___ 3. Which of the following is *not* a proprioceptor?
   a. muscle spindle
   b. Golgi tendon organ
   c. touch and pressure receptors
   d. joint receptors

___ 4. Which of the following is *not* a cutaneous receptor?
   a. touch receptor
   b. joint receptor
   c. pain receptor
   d. temperature receptor
   e. All of these are cutaneous receptors.

___ 5. Which of the following sensations does *not* adapt quickly, if at all, to constant stimuli?
   a. temperature
   b. touch
   c. pain
   d. odor
   e. All of these sensations adapt quickly.

___ 6. Which of the following does *not* apply to the *law of specific nerve energies*?
   a. Stimulation of a sensory nerve fiber produces only one sensation, such as touch, cold, pain, and so on.
   b. Each sensory neuron responds to its own normal, or adequate, stimulus with a characteristic sensation.
   c. Sensory neurons may respond to "injury currents" as readily as they do to "normal" stimuli.
   d. Paradoxical cold is an example of the law of specific nerve energies.
   e. All of these apply.

___ 7. The *pacinian*, or *lamellated corpuscle* is a cutaneous receptor for perception of
   a. heat.
   b. cold.
   c. touch.
   d. pressure.
   e. pain.

___ 8. The difference between a strong stimulus (for example, *hot*) and a weak stimulus (for example, *warm*) is that the strong stimulus
   a. produces a greater number of action potentials per unit of time (frequency).
   b. produces action potentials having greater strength (amplitude).
   c. routes action potentials to more sensitive brain areas.
   d. produces action potentials that last a longer period of time (duration).

B. True or False/Edit

___ 9. The term "modality" refers to the quality of sensation, such as sound, light, pressure, and so on.

___ 10. Sensory receptors are actually specialized neurons or dendrites of such neurons that may be free or encapsulated within nonneural structures.

___ 11. *Nociceptors* provide us with a sense of body position.

___ 12. Receptors that produce a relatively constant rate of firing as long as the stimulus is maintained are known as *phasic* receptors.

___ 13. Receptor potentials are the same as generator potentials since they are formed in sensory nerve endings (receptors) and serve to generate action potentials.

___ 14. All generator potentials reach threshold and fire action potentials from the periphery toward the brain.

II. CUTANEOUS SENSATIONS

There are several different types of sensory receptors in the skin, each of which is specialized to be maximally sensitive to one modality of sensation. A receptor will be activated when a given area of the skin is stimulated; this area is the receptive field of that receptor. A process known as lateral inhibition helps to sharpen the perceived location of the stimulus on the skin.

A. Multiple Choice

___ 15. The *medial lemniscus* is a sensory fiber tract of second-order neurons relaying cutaneous information to the
   a. thalamus.
   b. medulla oblongata.
   c. spinal cord.
   d. cerebral cortex.
   e. None of these regions receives information from the medial lemniscus.

___ 16. *Somatesthetic* action potentials are perceived by the
a. thalamus.
b. medulla oblongata.
c. spinal cord.
d. cerebral cortex (postcentral gyrus).

___ 17. The tip of the index finger is very sensitive because
a. the size of each receptive field is very small.
b. the density of its touch receptors is very high.
c. its representative area on the cortex is very large.
d. All of these help explain this fingertip sensitivity.

___ 18. Which statement about **lateral inhibition** is *false*?
a. It occurs via inhibitory interneurons in the central nervous system (CNS).
b. Weaker, neighboring input is inhibited from reaching the brain.
c. It is characteristic only of receptors in the skin (cutaneous).
d. It results in a sharpening of sensation with perception that is more well-defined than the original stimulus that was applied.

B. True or False/Edit

___ 19. The capsaicin receptor for pain is activated by intense heat, whereas other pain receptors (nociceptors) may be activated by ATP molecules released from damaged cells or by a local fall in pH during infection or inflammation.

___ 20. Similar to the way capsaicin evokes heat sensation, cold or menthol can activate a membrane ion channel (receptor) of certain sensory neurons producing depolarization and the formation of sensory action potentials

___ 21. Somatesthetic sensors include sensations from cutaneous receptors and proprioceptors.

___ 22. Somatesthetic information is projected to the postcentral gyrus of the ipsilateral cerebral hemisphere for interpretation.

___ 23. The larger area of the cortex devoted to the interpretation of face and hand sensation is due to the higher density of sensory receptors in the face and hands.

___ 24. *Referred pain*, such as that of angina pectoris, is believed to occur because seldom-used incoming neurons from the viscera can intersect with often-used somatic sensory neurons, resulting in pain from an internal organ being "felt" as coming from some remote somatic region, such as the left arm.

___ 25. Current theories regarding the phenomenon of the phantom limb propose that such sensations perceived may be produced by brain reorganization after the limb has been amputated and normal sensations are no longer present.

___ 26. In the fingertips, where a small area of skin is served by a large number of cutaneous receptors, the receptive field of each sensory neuron is correspondingly large.

___ 27. The two-point threshold test is used to measure the minimum distance on the skin between neighboring receptive fields for touch.

___ 28. Helping the brain distinguish borders of visual light and dark more sharply; or distinguish sounds of different pitch; or distinguish closely related odors; are all phenomena made possible by lateral inhibition.

III. TASTE AND SMELL

The receptors for taste and smell respond to molecules that are dissolved in fluid; hence, they are classified as chemoreceptors. Although there are only four basic modalities of taste, they combine in various ways and are influenced by the sense of smell, thus permitting a wide variety of different sensory experiences.

A. Multiple Choice

___ 29. Which of the following is *not* characteristic of taste buds?
   a. They have long microvilli at their apical (top) opening to the surface.
   b. They are characterized as interoceptors.
   c. They respond to chemicals dissolved in saliva.
   d. Along the tongue, they are innervated by two different cranial nerves.
   e. Although taste bud cells are not neurons, they are able to depolarize and release chemical transmitters when stimulated.

___ 30. Which is *not* one of the four basic taste modalities?
   a. bitter
   b. metallic
   c. salty
   d. sour
   e. sweet

___ 31. Which of the following taste modality evokes a pleasant, "meaty" sensation in response to specific amino acid molecules in food proteins?
   a. salty
   b. sour
   c. bitter
   d. umami
   e. sweet

___ 32. Which is *not* a characteristic of olfactory sensation?
   a. Olfactory receptors can be classified as chemoreceptors and exteroceptors.
   b. Olfactory receptors are bipolar neurons that are unique, dividing by mitosis to replace themselves every month or two.
   c. Olfactory information (smell) is perceived in the limbic system region of the cerebral cortex.
   d. Smells can affect both memory and emotion.
   e. All of these are characteristic of olfactory sensation.

B. True or False/Edit

___ 33. Chemoreceptors can be characterized as interoceptors or exteroceptors based on the source of the chemical stimuli.

___ 34. Both salt and sour tastes are mediated by membrane receptors that are coupled to G-proteins that, in turn, activate second-messenger systems within the cytoplasm of the taste receptor cell.

___ 35. The particular type of G-protein receptor found in the membranes of taste buds involved in the sensation of sweet, bitter, and umami has been identified and given the name *transducin*.

___ 36. Although all sweet taste receptors act via G-proteins that, in turn, activate second messenger systems, the sweet taste of sugar molecules may trigger a different second messenger system than does the sweet taste of artificial sweeteners (such as saccharin and cyclamate).

___ 37. Smell is the only sensation that does not synapse in the thalamus region of the brain; instead, smell is transmitted directly to the cerebral cortex for processing.

___ 38. During the processing and identification of odors, impulses passing through the spherically shaped *glomeruli* of the olfactory bulb are dulled by the phenomenon known as **lateral inhibition**.

___ 39. Olfactory receptor proteins are located in nonmotile cilia of receptor neurons and when stimulated by an odorant molecule, dissociate G-proteins that lead to the production of cyclic AMP, the influx of Na^{+} and Ca^{+2} ions, depolarization and firing of action potentials.

___ 40. Despite the recent discovery of a large family of genes (thousands in number) that code for olfactory receptor proteins, the fact that humans can distinguish up to 10,000 different odors continues to be unexplained.

___ 41. Before taste buds and olfactory receptors can respond, the stimulating chemicals must first be dissolved in a fluid medium.

IV. VESTIBULAR APPARATUS AND EQUILIBRIUM

The sense of equilibrium is provided by structures in the inner ear, collectively known as the vestibular apparatus. Movements of the head cause fluid within these structures to bend extensions of sensory hair cells, and this bending results in the production of action potentials.

A. Multiple Choice

___ 42. Which of the following is *not* part of the vestibular apparatus?
- a. cochlea
- b. otolith organs
- c. utricle
- d. saccule
- e. semicircular canals

___ 43. Information about *linear* acceleration is sensed by
- a. the utricle only.
- b. the saccule only.
- c. the semicircular canals.
- d. both the utricle and saccule.

___ 44. The receptors for the sense of equilibrium are modified epithelial cells called
- a. chemoreceptors.
- b. proprioceptors.
- c. stereocilia.
- d. hair cells.
- e. kinocilia.

___ 45. Arrange the following events in proper sequence.
1. Hair cell membrane is depressed; hair cells depolarize.
2. Stereocilia are bent in the direction of the kinocilium.
3. Newly generated action potentials race along the eighth cranial nerve.
4. The body (and head) move or accelerate linearly.
5. Hair cells release synaptic transmitter substances.

- a. 2, 5, 4, 1, 3
- b. 4, 3, 2, 1, 5
- c. 4, 2, 1, 5, 3
- d. 2, 3, 1, 5, 4

___ 46. The *otolith* membrane is an important part of the
- a. utricle and saccule.
- b. vestibular apparatus.
- c. semicircular canals.
- d. cochlea.

___ 47. Hair cells, ampulla, and cupula are located in the
- a. utricle and saccule.
- b. vestibular apparatus.
- c. semicircular canals.
- d. cochlea.

___ 48. Angular or rotational acceleration is sensed by
- a. the utricle only.
- b. the saccule only.
- c. the semicircular canals.
- d. both the utricle and saccule.

B. True or False/Edit

___ 49. The sense of equilibrium can be described as the orientation of the body with respect to the pull of gravity.

___ 50. The sensory receptors of the vestibular apparatus and cochlea are located within a tubular “membranous labyrinth” filled with fluid, called perilymph.

___ 51. Perilymph is similar in ionic composition to cerebrospinal fluid (CSF).

___ 52. Rotational or angular acceleration is sensed by the semicircular canals.
___ 53. Hyperpolarization of hair cell membranes reduces the quantity of synaptic transmitter released that, in turn, reduces the frequency (impulses per minute) of action potentials.
___ 54. The *utricle* is most sensitive to vertical acceleration, while the *saccule* is most sensitive to horizontal acceleration.
___ 55. The portion of the vestibular apparatus featuring an ampulla, crista ampullaris, and cupula, is known as the *saccule*.
___ 56. When a gymnast performs forward somersaults, the hair cells located in the anterior semicircular canal of the vestibular apparatus are stimulated, whereas when doing cartwheels, those cells of the posterior semicircular canals are stimulated.
___ 57. Vestibular nystagmus refers to involuntary oscillations of the eyes, which may occur after a spinning person is stopped abruptly; and is also a symptom of Meniere's disease.
___ 58. The duct of Hensen is a tiny hole that permits the continuous flow of endolymph from the vestibular apparatus to the cochlea, thereby linking symptoms of vertigo to those of hearing deficits, such as in Meniere's disease.

V. THE EARS AND HEARING

Sound causes vibrations of the tympanic membrane. These vibrations, in turn, produce movements of the middle-ear ossicles, which press against a membrane called the oval window in the cochlea. Movements of the oval window produce pressure waves within the fluid of the cochlea, which in turn cause movements of a membrane called the basilar membrane. Sensory hair cells are located on the basilar membrane, and the movements of this membrane in response to sound result in the bending of the hair cell processes. This stimulates action potentials that are transmitted to the brain in sensory fibers and interpreted as sound.

A. Multiple Choice

___ 59. The *pitch* of a sound is directly related to the _____of sound waves and is measured in units called _____.
a. amplitude; hertz
b. frequency; hertz
c. amplitude; decibels
d. frequency; decibels

___ 60. Which of the following is *not* part of the functional unit of the cochlea known as the *organ of Corti*?
a. Reissner's membrane
b. basilar membrane
c. tectorial membrane
d. inner and outer hair cells with sensory fibers

___ 61. The louder the sound intensity entering the ear, the greater the
a. amplitude of action potentials formed by sensory hair cells.
b. frequency of action potentials formed by sensory hair cells.
c. displacement of the basilar membrane.
d. Both a and c are correct.
e. Both b and c are correct.

___ 62. Which of the following does *not* occur during pitch discrimination of sound performed by the spiral organ (Organ of Corti)?
a. Outer hair cells shorten and stiffen along the most stimulated regions of the basilar membrane.
b. Higher pitched sounds will produce peak displacement closer to the base of the spiral organ.
c. The displacement of stereocilia by pressure waves in the endolymph (sound) depolarizes hair cells that release a neurotransmitter such as glutamate.
d. Neurons in the CNS may apply lateral inhibition to sharpen the discrimination of pitch.
e. All of these occur during pitch discrimination.

___ 63. Which of the following is *not* part of the neural pathway leading to the interpretation of sound by the brain?
a. the sensory hair cells of the organ of Corti
b. the inferior colliculus of the midbrain (corpora quadrigemina)
c. the vestibulocochlear (eighth cranial) nerve
d. the thalamus (medial geniculate)
e. All of these are part of the neural pathway for sound.

___ 64. Which of the following is *not* true of *conduction* deafness?
a. It impairs hearing at all sound frequencies.
b. It results when the transmission of sound waves from the air through the middle ear to the oval window is impaired.
c. It may be caused by otitis media or otosclerosis.
d. It is the cause of age-related hearing deficits known as presbycusis.
e. All of these are true regarding conduction deafness.

B. True or False/Edit

___ 65. The intensity or loudness of a sound is directly related to the amplitude of the sound waves, and it is measured in units known as decibels.

___ 66. The auditory (eustachian) tube is a normally collapsed passageway leading from the inner ear to the nasopharynx.

___ 67. Damage to the tympanic membrane or middle ear ossicles, such as that caused by otitis media or otosclerosis, results in conduction deafness.

___ 68. The cochlear duct conducts pressure waves created by sound, and contains endolymph that bathes the sensory hair cells of the organ of Corti.

___ 69. The greater the displacement of the basilar membrane and the bending of the stereocilia, the greater the frequency of action potentials produced which will be perceived as a louder sound.

___ 70. High pitched sounds produce peak displacement closer to the base of the basilar membrane, while lower pitched sounds cause peak displacement further toward the apex.

___ 71. As was true of the phantom limb syndrome, the brain shows a plasticity or an ability to reorganize the auditory cortex following trauma or deficit – such as in those with sensorineural deafness requiring implants.

___ 72. Nerve or sensory deafness can be caused by otitis media.

VI. THE EYES AND VISION

Light from an observed object is focused by the cornea and lens onto the photoreceptive retina at the back of the eye. The focus is maintained on the retina at different distances between the object and the eyes by muscular contractions that change the thickness and degree of curvature of the lens.

A. Multiple Choice

___ 73. The structures of the eye that transmit and refract light are the
a. lens and cornea.
b. lens and choroids.
c. cornea and iris.
d. cornea and choroids.
e. lens and sclera.

___ 74. The structure of the eye that is darkly pigmented to absorb light within the eyeball, and thereby prevent reflection, is the
a. cornea.
b. sclera.
c. choroids.
d. ciliary body.
e. retina.

___ 75. Which of the following statements about the autonomic nerve control over smooth muscles of the pupil is *true*?
a. Parasympathetic stimulation of circular muscles causes the iris to dilate.
b. Parasympathetic stimulation of radial muscles causes the iris to constrict.
c. Sympathetic stimulation of the radial muscles causes the iris to constrict.
d. Sympathetic stimulation of the radial muscles causes the iris to dilate.

___ 76. *Glaucoma* is best described as a condition in which the
a. lens and cornea may become cloudy or translucent, making it difficult for light to be transmitted.
b. retina may become detached, resulting in blindness.
c. canal of Schlemm is blocked, causing the intraocular pressure to rise.
d. normal pigments of the retina are not synthesized, so that light reflection interferes with vision.

___ 77. The portion of the eye with the greatest *refractive index* (where light is refracted most) is the
a. cornea.
b. aqueous humor.
c. lens.
d. vitreous body.
e. retina.

___ 78. Which statement about visual field halves and the retina halves is correct?
a. The left visual field focuses on the left half-retina.
b. The left visual field focuses on the right half-retina.
c. The nasal half-retina of the right eye receives the same image as the temporal half-retina of the left eye.
d. The nasal half-retina of the right eye receives the same image as the nasal half-retina of the left eye.
e. Both b and c are correct.

___ 79. *Accommodation*, the ability of the eyes to keep the image focused on the retina as distance is changed, results from contraction of the
a. circular muscles.
b. ciliary muscles.
c. radial muscles.
d. pupil.

___ 80. Which of the following about *myopia* is *false*?
a. It is also known as nearsightedness.
b. It may result from an eyeball that is too short.
c. It is corrected by glasses with concave lenses.
d. The blurry image is focused in front of the retina.

___ 81. A cylindrical lens is prescribed to correct for
a. astigmatism.
b. myopia.
c. hyperopia.
d. presbyopia.
e. Cylindrical lenses are not used for correction.

B. True or False/Edit

___ 82. Light of longer wavelengths (infrared) or shorter wavelengths (ultraviolet) than the visible light spectrum, cannot be seen by the human eye.

___ 83. The anterior and posterior chambers are filled with a fluid called the vitreous body.

___ 84. At the optic disc region of the eyeball neurons exit only, whereas blood vessels both enter and exit from the optic disc.

___ 85. Both the visual field and the retina of each eye are divided into halves because light entering the eye is bent (refracted).

___ 86. An image will be seen in perfect focus only when the light waves from an object are bent (refracted) to a point on the retina itself.

___ 87. As an object moves away from you, the ciliary muscle relaxes, placing tension on the zonular fibers that pull the lens flatter or less convex to keep the image in focus.

___ 88. Myopia is also known as farsightedness.

___ 89. Astigmatism can be an abnormal curvature of either the cornea or the lens or both.

C. Label the Figure — Anatomy of the Eye

Identify each structure indicated by the lines in figure 10.1 below that features the internal anatomy of the eyeball. As you write each term in the space provided, verbally (to your study partner) state the function of each structure. Check your anatomy recall here with figure 10.26 in your text; and check your physiology responses with the discussion in this chapter.

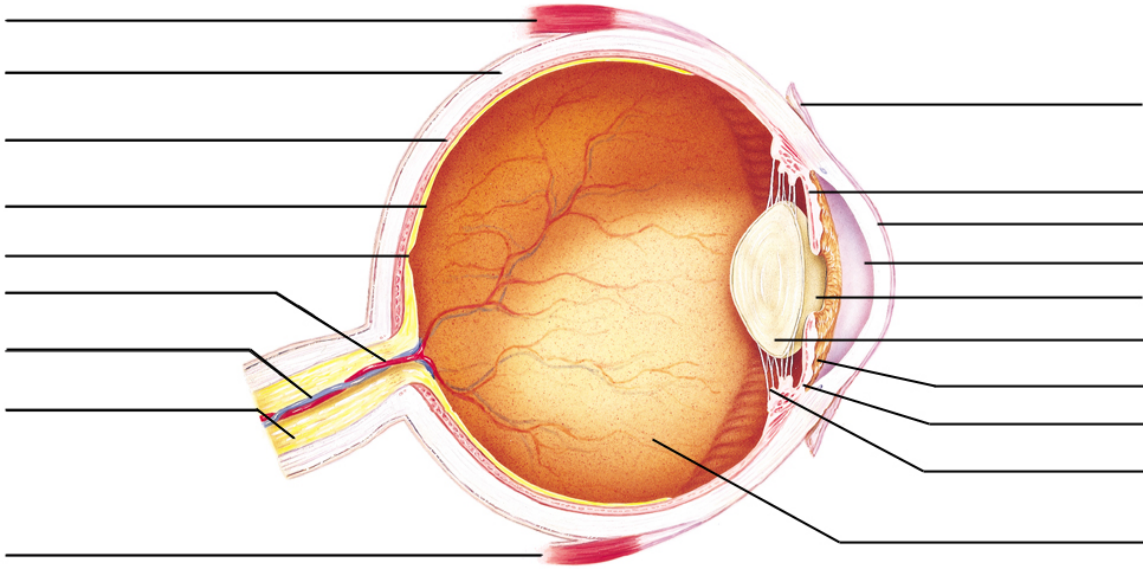

Figure 10.1 The internal anatomy of the eyeball.

VII. THE RETINA

There are two types of photoreceptor neurons: rods and cones. Both receptor cell types contain pigment molecules that undergo dissociation in response to light, and it is this photochemical reaction that eventually results in the production of action potentials in the optic nerve. Rods provide black-and-white vision under conditions of low light intensities, whereas cones provide sharp color vision when light intensities are greater.

A. Multiple Choice

___ 90. The outer layer of neurons in the retina whose axons gather to form the optic nerve tract are called
a. bipolar cells.
b. ganglion cells.
c. horizontal cells.
d. amacrine cells.
e. photoreceptor cells.

___ 91. Which of the following statements about the rod and cone photoreceptors is *false*?
a. each consists of an inner and an outer segment
b. each inner segment contains hundreds of flattened membranous sacs, or discs
c. each outer segment contains photopigment molecules required for vision
d. retinal pigment epithelial cells have important interactions with rods and cones during vision
e. All of these statements about photoreceptors are true.

___ 92. As light enters the eye, the neurons of the retina directly responsible for generating the all-or-none action potentials that are conveyed out optic nerve are the
a. photoreceptor cells only.
b. bipolar cells and horizontal cells.
c. ganglion cells and amacrine cells.
d. horizontal cells only.

___ 93. As opposed to rods, the cones
a. are less sensitive in low light conditions.
b. provide color vision.
c. provide greater visual acuity (sharpness of detail).
d. are more responsive in the daylight.
e. All of these correctly describe cones.

___ 94. Which color (wavelength of light) is *not* designated as one of the three (trichromatic) types of cones?
a. blue
b. red
c. yellow
d. green

___ 95. A common visual impairment in older people whose vision loses clarity within the central fovea portion of the visual field; perhaps due to the loss of retinal pigment epithelium in this region, is
a. retinitis pigmentosa.
b. macular degeneration.
c. cataracts.
d .glaucoma.
e. Meniere's disease.

___ 96. The pitted portion of the retina upon which the image of the objects we look at falls, and which contains almost all cones for greatest visual acuity, is called the
a. ganglion cell layer.
b. optic disc.
c. fovea centralis.
d. pigmented epithelium.
e. choroid layer.

___ 97. Most (70% to 80%) of the ganglion cell axons from the retina exit the eye as the optic nerve and pass immediately to the
a. superior colliculus of the midbrain (optic tectum).
b. lateral geniculate nucleus of the thalamus.
c. striate cortex of the occipital lobe.
d. Brodmann areas 17, 18, and 19 of the occipital lobe.

B. True or False/Edit

___ 98. Light must pass through several neuron cell layers before striking the photoreceptors (rods and cones) located in the retina.

___ 99. Ganglion cells of the retina synapse with, and are interconnected laterally to, amacrine cells.

___ 100. Within the retina are the pigment epithelial cells that are required for normal visual functions because they remove the old tip regions from photoreceptors cells and because they contain melanin pigment to absorb light.

___ 101. Cones contain a purple pigment known as *rhodopsin*, which is partially derived from vitamin A obtained from food in the diet.

___ 102. During the *bleaching reaction*, there is a gradual increase in photoreceptor sensitivity, which reaches a maximum at about twenty minutes.

___ 103. The *dark current* describes the continuous leakage of Na^+ through special Na^+ channels as these ions diffuse into the photoreceptor cells.

___ 104. Light appears to hyperpolarize (inhibit) the rod and cone photoreceptors, causing the release of lower amounts of inhibitory neurotransmitter chemicals, and ultimately resulting in stimulation of the bipolar cells.

___ 105. The outer segment membranes of rods or cones have hundreds of regulatory G-proteins known as transducins that are activated by light, leading to the closure of Na^+ channels, hyperpolarization of that rod or cone, release of less inhibitory neurotransmitter, and the eventual firing of action potentials to the brain.

___ 106. The three types of cones responsible for human color vision contain retinene, as in rhodopsin; unlike rods, the retinene in the cones is associated with unique proteins called *photopsins*.

___ 107. Since the red (L) or green (M) types of cones are coded for by the Y chromosome in males, lack of such cones causes the more common red-green color blindness to occur in males rather than in females.

___ 108. The convergence of photoreceptors onto ganglion cells in the fovea centralis region of the retina is lower for the cones (1:1) than for the rods.

___ 109. The axons from the retina that pass through the superior colliculus of the midbrain (optic tectum) is needed to activate motor pathways and answer the visual question "What is it?"

___ 110. *Smooth pursuit movements*, *saccadic eye movements*, and *vergence movements* are three types of eye movements coordinated by the activity of neurons located in the midbrain, pons and medulla oblongata regions of the brain.

___ 111. The superior colliculus (tectal system) is involved in the parasympathetic stimulation and contraction of the ciliary muscles of the iris during both accommodation and the pupillary reflex.

___ 112. The pupillary reflex appears to be initiated by light striking the ganglion cell layer of the retina resulting in the release of a photoreceptive pigment, *melanopsin*, that also plays a role in regulation of the body's circadian (daily) rhythms.

VIII. NEURAL PROCESSING OF VISUAL INFORMATION

Electrical activity in ganglion cells of the retina and in neurons of the lateral geniculate nucleus and cerebral cortex is evoked in response to light on the retina. The way in which each type of neuron responds to light at a particular point on the retina provides information about how the brain interprets visual information.

A. Multiple Choice

___ 113. Which of the following types of neurons is *not* a cortical neuron found in the striate cortex region of the occipital lobe (Brodmann's areas 17, 18, and 19)?
a. simple
b. circular
c. complex
d. hypercomplex
e. rectangular

___ 114. Neurons of the visual (occipital) cortex respond to all of the following forms of stimuli *except*
a. slits or bars of light.
b. straight lines with a specific orientation and direction.
c. particular lengths, corners or edges.
d. circles with on and off centers with surrounds.

B. True or False/Edit

___ 115. Ganglion cells with on-center receptive fields are stimulated by light at the center of their visual fields, whereas those inhibited by light at the center and stimulated by light in the surround have off-center fields.

___ 116. Lateral geniculate neuron receptive fields of the thalamus, like ganglion cell receptive fields of the retina, are circular with an antagonistic center and surround areas.

CHAPTER REVIEW

A. Completion — Sensory Physiology

117. The type of receptor found in muscle, tendons, or joints is collectively known as a _____. In contrast, receptors such as carotid body, osmoreceptors, smell or taste receptors are known as _____ since they respond to specific molecules. Receptors that deform cell membranes or deform hair cells by movements are called _____. Pain receptors, or _____ have a higher threshold for activation than do other cutaneous receptors.
118. Among the cutaneous (skin) receptors, those around hair follicles that are sensitive to light touch; hot; cold; and pain (nociception) are called _____ _____ _____. At the base of the epidermis are _____ discs that sense sustained touch and pressure. Deep in the dermis lie dendrites encapsulated by concentric lamellae called _____ corpuscles for sensing deep pressure and fast vibrations. In the papillary layer of the upper dermis lie encapsulated receptors known as _____ corpuscles that detect changes in texture and slow vibrations. Finally, deep in the dermis or hypodermis are enlarged dendrite endings sensitive to sustained pressure, receptors called _____ corpuscles (endings).
119. That portion of the vestibular apparatus that helps us maintain balance when turning the head, spinning, or tumbling, includes 3 _____ canals which are oriented in 3 planes like the faces of a cube. The receptors for equilibrium are modified epithelial hair cells with twenty to fifty hair like extensions (stereocilia) with one larger, central _____. The otolith ("ear stone") organs have a gelatinous otolith membrane into which hair cells have been imbedded. Acceleration in a horizontal direction stimulates the _____; whereas acceleration in a vertical direction stimulates the _____.
120. At the base of each semicircular canal is an enlarged swelling called the _____. The semicircular duct contains fluid called _____ that moves as the head and body moves. An elevated area of the ampulla, called the _____ ampullaris, contains hair cells. The processes of these cells are embedded in a gelatinous membrane, the _____, which has a higher density than that of the surrounding endolymph.
121. The external auditory meatus channels sound waves to the eardrum, or_____ _____. The middle ear features the three middle ear ossicles: the _____, the _____ and the _____. The ossicles attach to the inner ear by way of a membrane known as the _____ window. Inward movement of this window compresses fluid in the cochlea that is compensated for by an outward movement of the _____ window. The hair cells of the cochlea are anchored to the _____ membrane within a more complex group of structures known as the _____ organ, or the organ of _____.
122. The eyeball has a tough outer sclera that is continuous anteriorly with the transparent _____ through which light passes. The anterior and posterior chambers of the eye contain fluid called _____humor. The colored portion of the eye is the _____, which is attached to muscles that can open and close the _____, thereby controlling the amount of light entering the eyeball. Light is refracted (bent) most by the _____ of the eye, before passing through the thick viscous substance called the _____ humor. Indeed, the most important layer (tunic) of the eye is the complex _____, composed of many cell layers with interconnecting neurons. Within this layer are the _____ and _____ photoreceptors. Sharpness of vision is known as visual _____, and is greatest in that rounded area on the back of the eyeball called the _____ centralis. The three major cell layers of the retina are the photoreceptor layer, the bipolar cell layer, and the _____ cell layer. Humans and other primates have *trichromatic* color vision, meaning that our perception of color is produced by only these 3 types of cone photoreceptors: _____, _____ and _____.

B. Essay

Essay Tutorial

This essay tutorial will answer the first essay question found in the "**Review Activities**" section of your *Human Physiology* textbook. Please read question 1 in the "**Test Your Understanding of Concepts and Principles**" section at the end of chapter 10 and let me guide you through one possible answer. Watch for key terms in boldface type, helpful tips and general suggestions on writing the essay or short-answer questions. Enjoy!

123. **Explain** what is meant by *lateral inhibition* and give examples of its **effects** in **three** sensory systems.

Answer. As the question is asking, the first step in the answer is to define *lateral inhibition* — the central nervous system phenomenon by which sensory information is "sharpened" by inhibition of incoming neighboring (lateral) field information from the periphery of that region which is maximally stimulated. Three sensory systems utilizing lateral inhibition are the senses of touch (cutaneous), hearing, and vision. In the skin, a single touch is felt when a blunt object touches the skin because the surrounding fields have been "laterally inhibited" at the level of the central nervous system. Similarly, in the discrimination of different pitches of sounds with similar frequencies, neural activity is "laterally inhibited" so that the hair cells along the basilar membrane which are maximally displaced by sound waves are selected for interpretation by the auditory cortex of the brain while hair cells with neural activity from the surrounding regions are suppressed. Lateral inhibition is also at work in the processing of visual information at the level of the ganglion cells in the retina. Here, the receptive fields of each ganglion cell resembles a "bull's eye" with a central core area and an outer surround area that oppose one another, that is, are antagonistic. Those ganglion cells that have **on-center fields** are excited by light at the center of their visual fields while the surround is suppressed (or inhibited laterally). Those ganglion cells that have **off-center fields** are inhibited by light in the center and stimulated by light in the surround. Due to the distribution of these two types of ganglion cell fields along the retinal surface, incoming light excites some and inhibits some of these fields — which translates later at the occipital (striate) cortex as sharper visual acuity.

Note: Don't be frustrated if your answer doesn't resemble this one. These answers are intended to be as all-encompassing as possible using various concepts from the text. Try some more!

124. Congratulations! You are the "middle C" note entering the ear canal from a nearby piano. Carefully trace your pathway through the rest of the ear until your vibrations die at the round window. Now, describe *how* and *where* your vibrations formed action potentials in the cochlea.

125. Describe the location and response of the olfactory receptors to odors. Now trace their unique pathway to the brain for interpretation. How is smell different from other senses?

126. Distinguish between *tonic* and *phasic* receptors, including examples of each.

127. Explain the two-point touch threshold test and its possible application to acupressure and acupuncture treatment.

Answers — Chapter 10

I. Characteristics of Sensory Receptors
   A. 1. c, 2. b, 3. c, 4. b, 5. c, 6. e, 7. d, 8. a
   B. 9. T, 10. T, 11. F—Replace "nociceptor" with "proprioceptor,"
   12. F—Replace "phasic" with "tonic," 13. T,
   14. F—Generator potentials are graded, and thus may be subthreshold

II. Cutaneous Sensations
   A. 15. a, 16. d, 17. d, 18. c
   B. 19. T, 20. T, 21. T, 22. F—Replace "ipsilateral" with "contralateral," 23. T,
   24. T, 25. T, 26. F—Replace "large" with "small," 27. T, 28. T

III. Taste and Olfaction
   A. 29. b, 30. b, 31. d, 32. e
   B. 33. T, 34. F—Replace "salt and sour" with "sweet and bitter," 35. F—Replace "transducin" with "gustducin," 36. T, 37. T,
   38. F—Replace "dulled" with "sharpened,"
   39. T, 40. T, 41. T

IV. Vestibular Apparatus and Equilibrium
   A. 42. a, 43. d, 44. d, 45. c, 46. a, 47. c, 48. c
   B. 49. T, 50. F—Replace "perilymph" with "endolymph," 51. T, 52. T, 53. T,
   54. F—Switch "vertical" and "horizontal,"
   55. F—Replace "saccule" with "semicircular canals," 56. T, 57. T,
   58. T

V. The Ears and Hearing
   A. 59. b, 60. a, 61. e, 62. e, 63. e, 64. d
   B. 65. T, 66. F—Replace "inner" with "middle,"
   67. T, 68. T, 69. T, 70. T, 71. T, 72. F—Otitis media causes conduction deafness

VI. The Eyes and Vision
   A. 73. a, 74. c, 75. d, 76. c, 77. a, 78. e, 79. b, 80. b, 81. a
   B. 82. T, 83. F—Replace "vitreous body" with "aqueous humor," 84. T, 85. T, 86. T, 87. T,
   88. F—Replace "Myopia" with "Hyperopia,"
   89. T
   C. See figure 10.26 in the text.

VII. The Retina
   A. 90. b, 91. b, 92. c, 93. e, 94. c, 95. b, 96. c, 97. b
   B. 98. T, 99. T, 100. T, 101. F—Replace "Cones" with "Rods," 102. F—Replace "The bleaching reaction" with "Dark adaptation,"
   103. T, 104. T, 105. T, 106. T, 107. F—Replace "Y" with "X," 108. T, 109. F—Replace "What" with "Where," 110. T, 111. T, 112. T

VIII. Neural Processing of Visual Information
   A. 113. b, 114. d
   B. 115. T, 116. T

Chapter Review
   A. 117. proprioceptor, chemoreceptor, mechanoreceptors, nociceptors,
   118. free nerve endings, Merkel's, Pacinian, Meissner's, Ruffini,
   119. semicircular, kinocilium, utricle, saccule, 120. ampulla, endolymph, cristae, cupula, 121. tympanic membrane, malleus, incus, stapes, oval, round, basilar, spiral, Corti,
   122. cornea, aqueous, iris, pupil, lens, vitreous, retina, rods, cones, acuity, fovea, ganglion, red, blue, green