CHAPTER 11

The Sensory System

Overview

The sensory system enables us to detect changes taking place both internally and externally. These changes are detected by specialized structures called receptors. Any change that acts on a receptor to produce a response in the nervous system is termed a stimulus. The special senses, so called because the receptors are limited to a few specialized sense organs in the head, include the senses of vision, hearing, equilibrium, taste, and smell. The receptors of the eye are the rods and cones located in the retina. The receptors for both hearing (the organ of Corti) and equilibrium (the vestibule and semicircular canals) are located within the inner ear. Receptors for the chemical senses of taste and smell are located on the tongue and in the upper part of the nose, respectively. The general senses are scattered throughout the body; they respond to touch, pressure, temperature, pain, and position. Receptors for the sense of position, known as proprioceptors, are found in muscles, tendons, and joints. The nerve impulses generated in a receptor cell by a stimulus must be carried to the central nervous system by way of a sensory (afferent) neuron. Here, the information is processed and a suitable response is made. Disorders of the eye and ear are common. They are associated with aging, infection, environmental factors, inherited malfunctions, and injury.

This chapter is quite challenging, because it contains both difficult concepts and large amounts of detail. You can use concept maps to assemble all of the details into easy-to-remember frameworks.

Addressing the Learning Outcomes

1. Describe the function of the sensory system.

EXERCISE 11-1.

INSTRUCTIONS

Fill in the blanks in the following paragraph using these terms:

central nervous system, homeostasis, sensory neuron, sensory receptor

The sensory system protects people by detecting changes in the internal and external environment that threaten to disrupt _____ (1), which is the maintenance of a constant internal environment. The change is detected by a _____ (2), which sends an impulse through a _____ (3) to the _____ (4).

2. Differentiate between the special and general senses and give examples of each.

EXERCISE 11-2.

INSTRUCTIONS

Classify each of the following senses as general senses (G) or special senses (S).

1. sense of position _____
2. smell _____
3. vision _____
4. touch _____
5. temperature _____
6. equilibrium _____

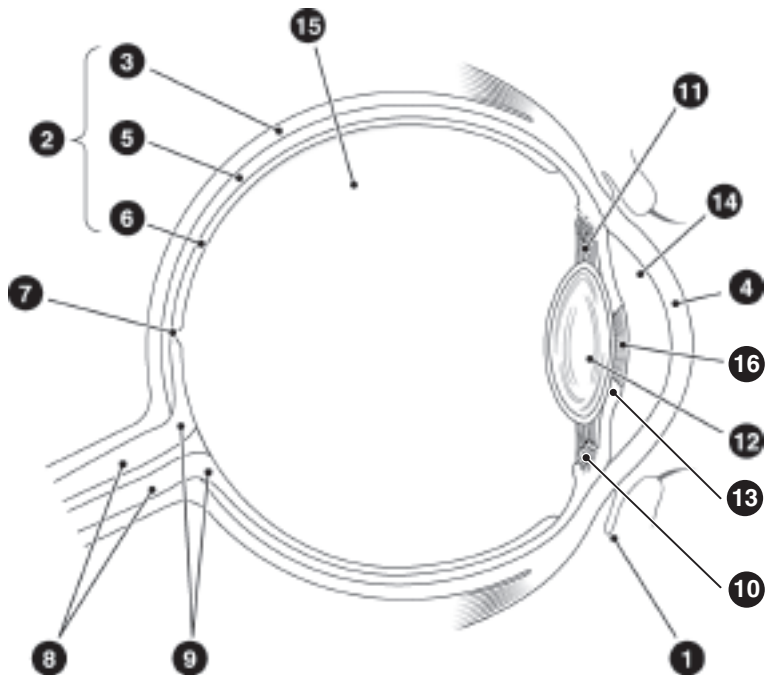
3. Describe the structure of the eye.

EXERCISE 11-3: The Eye (Text Fig. 11-3)

INSTRUCTIONS

1. Write the name of each labeled part on the numbered lines in different colors. Use the same color for structures 3 and 4 and structures 6 to 9 (inclusive). Write the name of structures 1 and 2 in black, because they will not be colored.
2. Color the different structures on the diagram with the corresponding color. Some structures are present in more than one location on the diagram. Try to color all of a particular structure in the appropriate color. For instance, only one of the suspensory ligaments is labeled, but color both suspensory ligaments.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____
12. _____
13. _____
14. _____
15. _____
16. _____



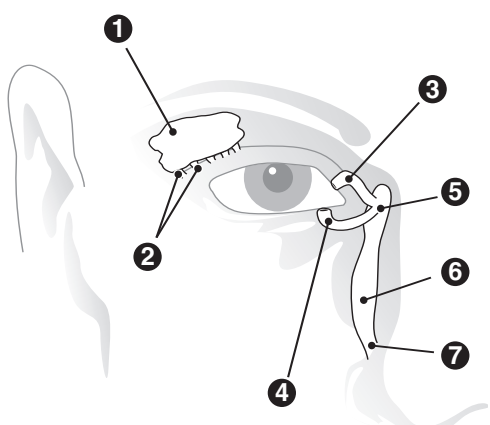
4. List and describe the structures that protect the eye.

EXERCISE 11-4: The Lacrimal Apparatus (Text Fig. 11-2)

INSTRUCTIONS

Label the indicated parts.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____



5. Define *refraction* and list the refractive parts of the eye.

EXERCISE 11-5.

INSTRUCTIONS

List 4 eye structures that bend (refract) light in the spaces below.

1. _____
2. _____
3. _____
4. _____

6. Differentiate between the rods and the cones of the eye.

EXERCISE 11-6.

INSTRUCTIONS

Write the appropriate term in each blank below.

cone	cornea	rhodopsin	sclera
optic disk	retina	rod	fovea centralis

1. A vision receptor that is sensitive to color _____
2. The part of the eye that light rays pass through first as they enter the eye _____
3. Another name for the blind spot, the region where the optic nerve connects with the eye _____
4. The innermost coat of the eyeball, the nervous tissue layer that includes the receptors for the sense of vision _____
5. A vision receptor that functions well in dim light _____
6. A pigment needed for vision _____
7. The depressed area in the retina that is the point of clearest vision _____

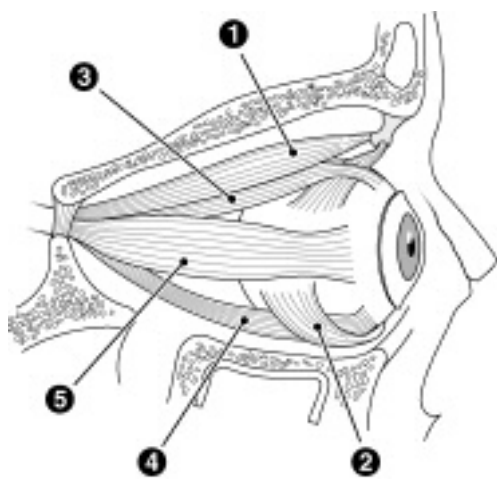
7. Compare the functions of the extrinsic and intrinsic muscles of the eye.

EXERCISE 11-7: Extrinsic Muscles of the Eye (Text Fig. 11-6)

INSTRUCTIONS

1. Write the name of each labeled muscle on the numbered lines in different colors.
2. Color the different muscles on the diagram with the corresponding color.

1. _____
2. _____
3. _____
4. _____
5. _____



EXERCISE 11-8.

INSTRUCTIONS

Write the appropriate term in each blank.

aqueous humor	vitreous body	lens	ciliary muscle
choroid	conjunctiva	pupil	iris

1. The structure that alters the shape of the lens for accommodation _____
2. The watery fluid that fills much of the eyeball in front of the crystalline lens _____
3. The vascular, pigmented middle tunic of the eyeball _____
4. Structure with two sets of muscle fibers that regulate the amount of light entering the eye _____
5. The jellylike material located behind the crystalline lens that maintains the spherical shape of the eyeball _____
6. The central opening of the iris _____
7. The membrane that lines the eyelids _____

8. Describe the nerve supply to the eye.

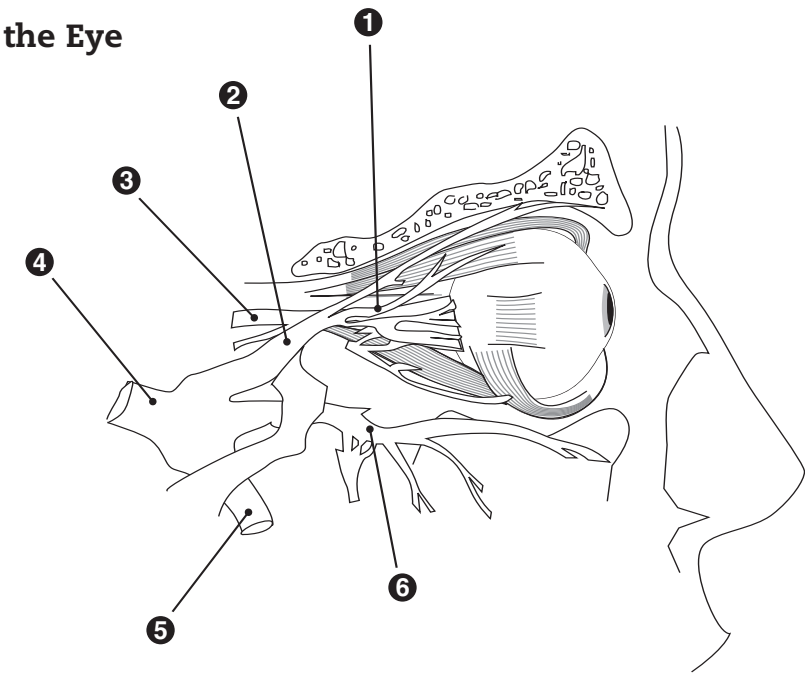
EXERCISE 11-9: Nerves of the Eye (Text Fig. 11-10)

INSTRUCTIONS

Label the indicated nerves.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____

(also see Exercise 11-15)



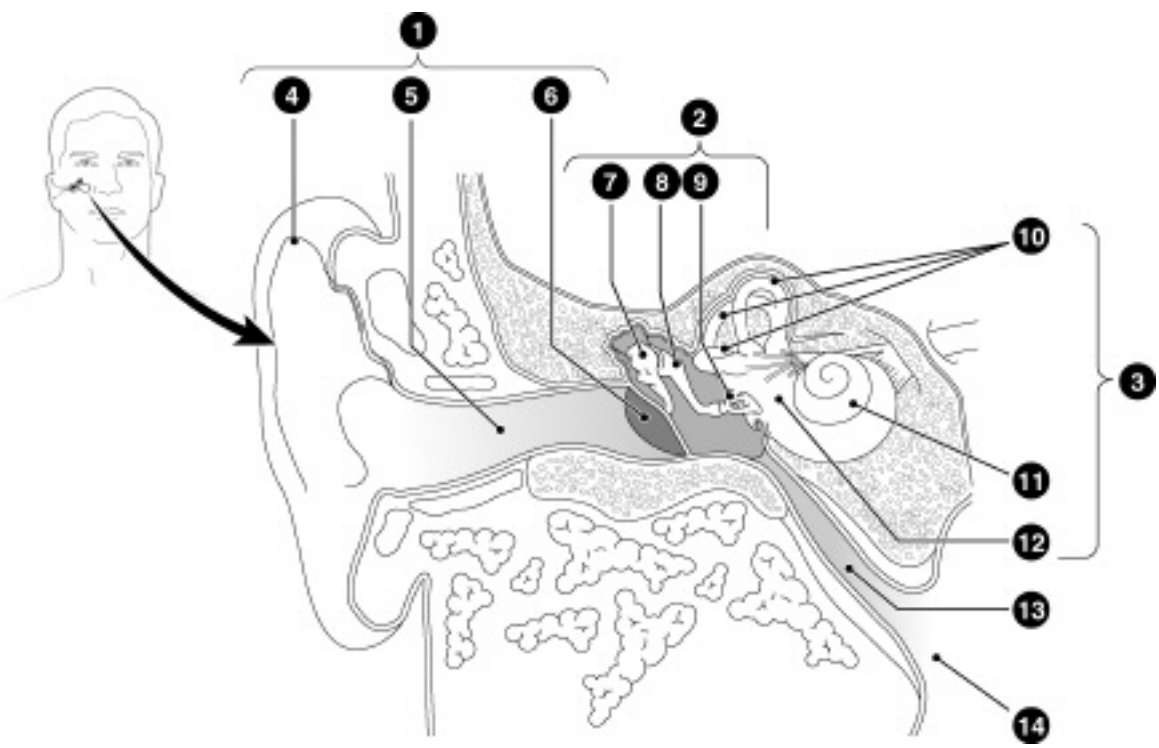
9. Describe the three divisions of the ear.

EXERCISE 11-10: The Ear (Text Fig. 11-12)

INSTRUCTIONS

1. Write the names of the three ear divisions on the appropriate lines (1 to 3).
2. Write the names of the labeled parts on the numbered lines in different colors.
3. Color each part with the corresponding color.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____
12. _____
13. _____
14. _____

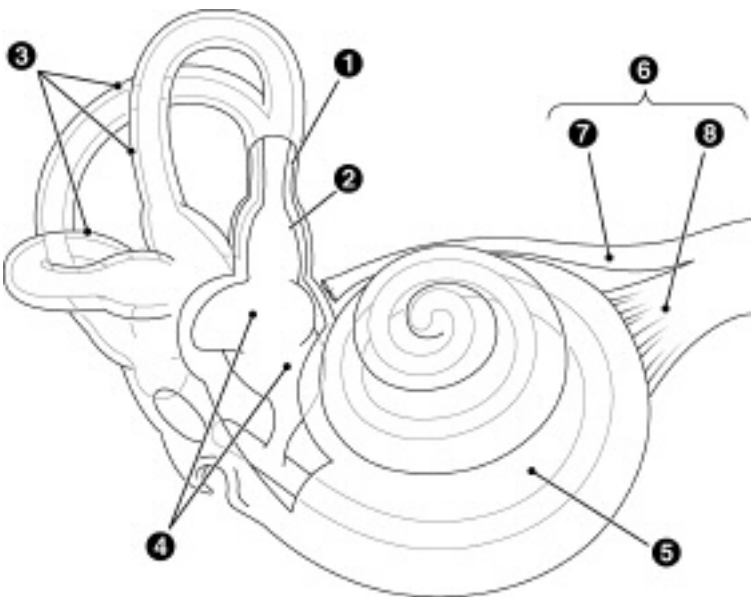


EXERCISE 11-11: The Inner Ear (Text Fig. 11-14)

INSTRUCTIONS

Label the indicated parts.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____



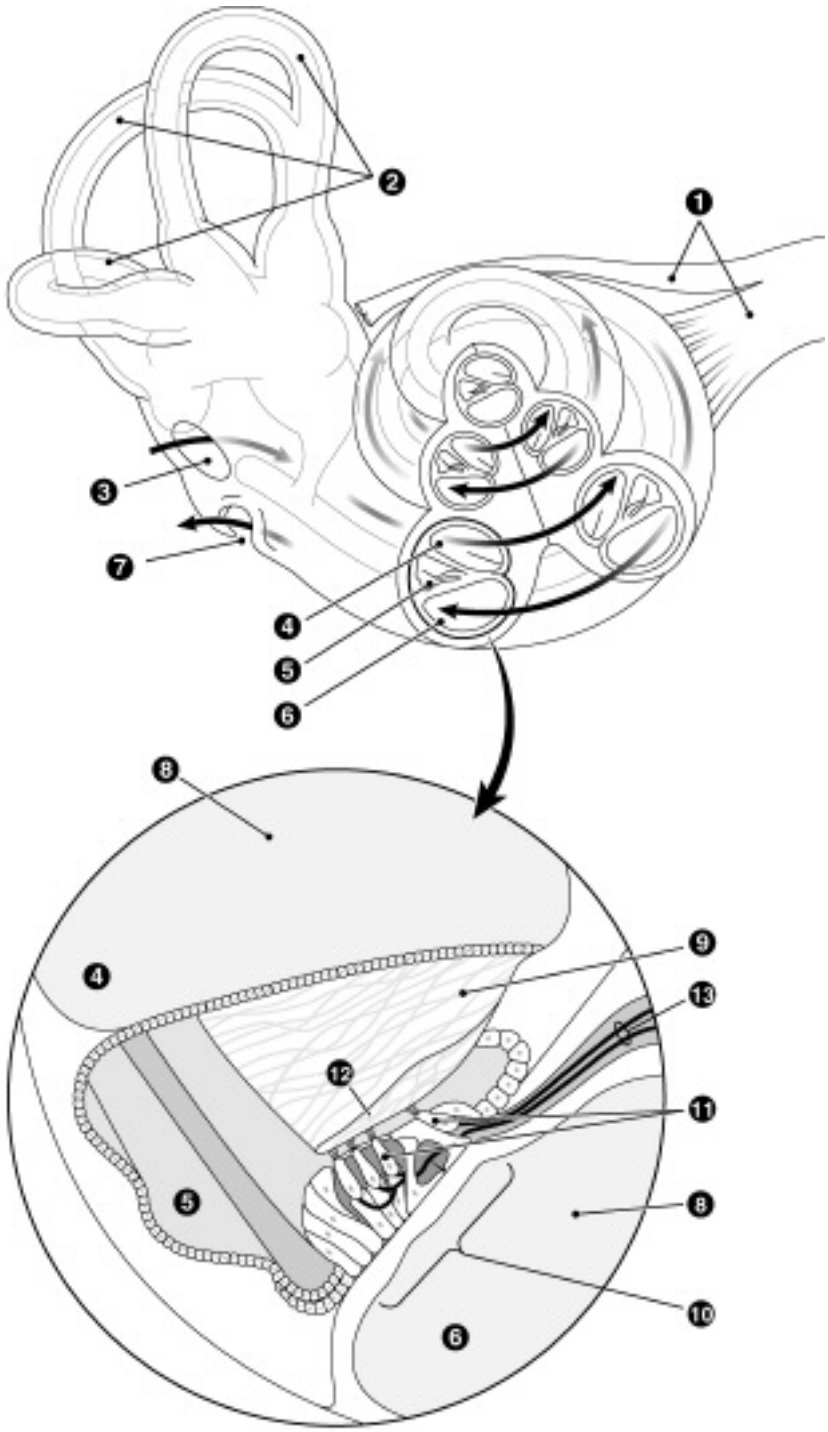
10. Describe the receptor for hearing and explain how it functions.

EXERCISE 11-12: Cochlea and Organ of Corti (Text Fig. 11-15)

INSTRUCTIONS

1. Write the name of each labeled part on the numbered lines. Use colors for structures 3 to 7, 11, and 12. Use black for the other structures.
2. Color structures 3 to 7, 11, and 12 with the corresponding color.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____
12. _____
13. _____



EXERCISE 11-13.

INSTRUCTIONS

Write the appropriate term in each blank.

oval window	organ of Corti	malleus	eustachian tube	bony labyrinth
perilymph	incus	pinna	cochlear duct endolymph	

1. The fluid contained within the membranous labyrinth of the inner ear _____
2. The bone that interacts with the tympanic membrane _____
3. Another name for the projecting part, or auricle, of the ear _____
4. The channel connecting the middle ear cavity with the pharynx _____
5. The fluid of the inner ear contained within the bony labyrinth and surrounding the membranous labyrinth _____
6. Ciliated receptor cells that detect sound waves _____
7. The skeleton of the inner ear _____

11. Compare static and dynamic equilibrium and describe the location and function of these receptors.

EXERCISE 11-14.

INSTRUCTIONS

Write the appropriate term in each blank.

vestibule	dynamic equilibrium	semicircular canals	cristae
cochlear duct	static equilibrium	otoliths	

1. The sense of knowing the position of the head in relation to gravity _____
2. Small crystals that activate maculae _____
3. The sense organ involved in dynamic equilibrium _____
4. The receptor cells involved in dynamic equilibrium _____
5. Two small chambers containing maculae _____
6. The sense of knowing one's head position when the body is spinning _____

12. Explain the function of proprioceptors.

EXERCISE 11-15.

INSTRUCTIONS

Write the appropriate term in each blank.

kinesthesia	proprioception	tactile corpuscle	cochlear nerve
vestibular nerve	oculomotor nerve	ophthalmic nerve	equilibrium
optic nerve	free nerve endings		

1. The branch of the vestibulocochlear nerve that carries hearing impulses _____
2. The nerve that carries visual impulses from the retina to the brain _____
3. The branch of the fifth cranial nerve that carries impulses of pain, touch, and temperature from the eye to the brain _____
4. The largest of the three cranial nerves that carry motor fibers to the eyeball muscles _____
5. The sense of knowing the position of one's body and the relative positions of different muscles _____
6. The sense of body movement _____
7. Receptors that detect changes in temperature _____

13. List several methods for treatment of pain.

EXERCISE 11-16.

INSTRUCTIONS

Write the appropriate term in each blank.

NSAID narcotic anesthetic endorphin analgesic

1. Term describing any drug that relieves pain _____
2. A substance produced by the brain that relieves pain _____
3. Drug that acts on the CNS to alter pain perception, such as morphine _____
4. Drug that acts locally to reduce inflammation _____

14. Describe sensory adaptation and explain its value.

EXERCISE 11-17.

INSTRUCTIONS

Define "sensory adaptation" in the space below.

_____

_____

15. List some disorders of the sensory system.

EXERCISE 11-18.

INSTRUCTIONS

Write the appropriate term in each blank.

macular degeneration	strabismus	glaucoma	myopia	hyperopia
ophthalmia neonatorum	cataract	trachoma	astigmatism	

1. A serious eye infection of the newborn that can be prevented with a suitable antiseptic _____
2. The scientific name for nearsightedness, in which the focal point is in front of the retina and distant objects appear blurred _____
3. The visual defect caused by irregularity in the curvature of the lens or cornea _____
4. Condition in which the eyes do not work together because the muscles do not coordinate _____
5. Condition caused by continued high pressure of the aqueous humor, which may result in destruction of the optic nerve fibers _____
6. The scientific name for farsightedness, in which light rays are not bent sharply enough to focus on the retina when viewing close objects _____
7. A chronic eye infection for which antibiotics and proper hygiene have reduced the incidence of reinfection and blindness _____

EXERCISE 11-19.

INSTRUCTIONS

Write the appropriate term in each blank.

otitis media	otitis externa	conductive hearing loss
otosclerosis	presbycusis	sensorineural hearing loss

1. The scientific name for swimmer's ear _____
2. A hereditary bone disorder that prevents normal vibration of the stapes _____
3. Slow, progressive hearing loss associated with aging _____
4. Hearing loss resulting from damage to the cochlea or to nerves associated with hearing _____
5. Infection and inflammation of the middle ear cavity _____

16. Show how word parts are used to build words related to the sensory system.

EXERCISE 11-20.

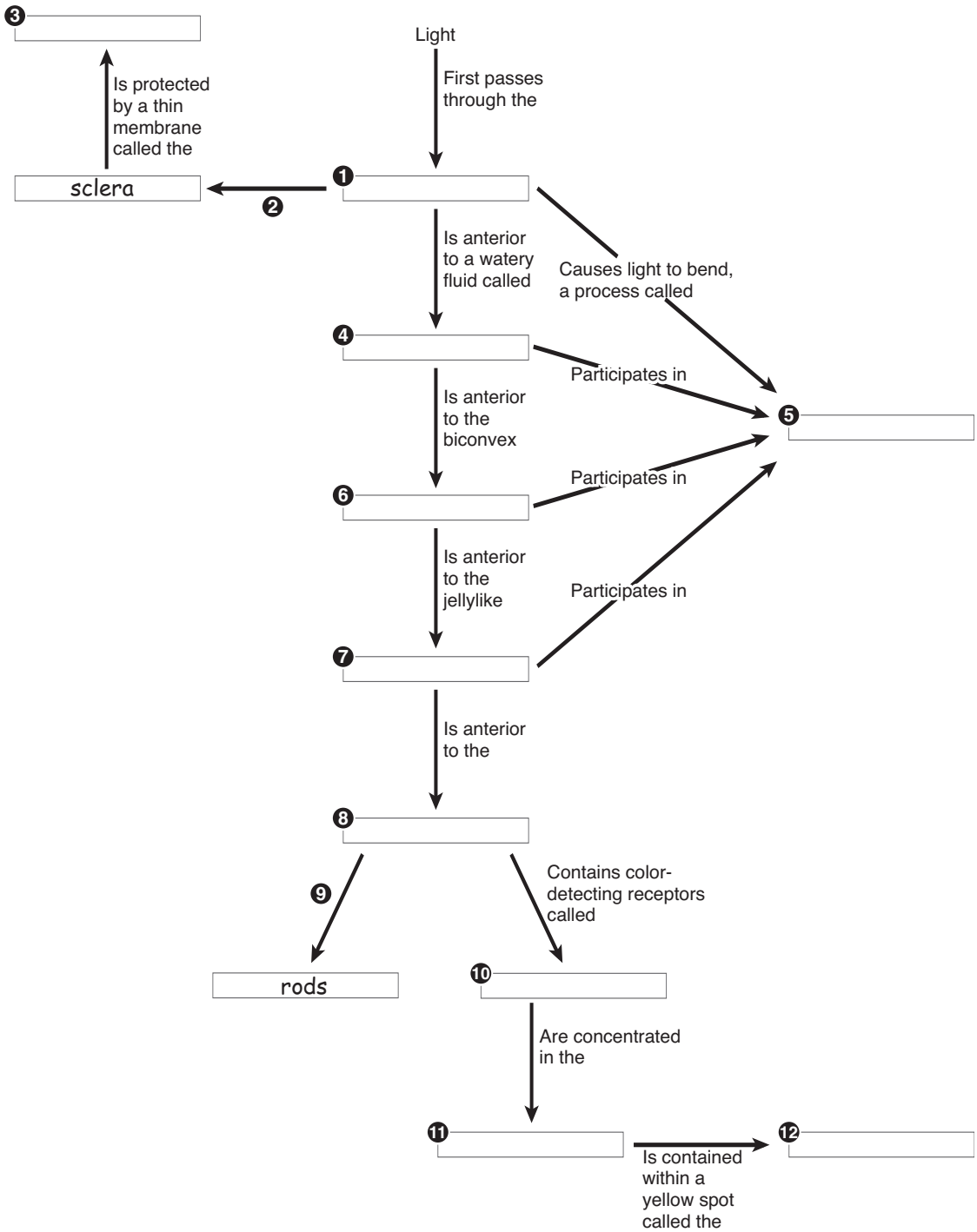
INSTRUCTIONS

Complete the following table by writing the correct word part or meaning in the space provided. Write a word that contains each word part in the Example column.

Word Part	Meaning	Example
1. presby-	_____	_____
2. _____	stone	_____
3. -opia	_____	_____
4. -stomy	_____	_____
5. _____	drum	_____
6. _____	yellow	_____
7. propri/o-	_____	_____
8. _____	pain	_____
9. -esthesia	_____	_____
10. _____	hearing	_____

Making the Connections

The concept map on the next page deals with the structure and function of the eye. Each pair of terms is linked together by a connecting phrase into a sentence. The sentence should be read in the direction of the arrow. Complete the concept map by filling in the appropriate term or phrase. There is one right answer for each term. However, there are many correct answers for the connecting phrases (2, 9).



Optional Exercise: Construct a concept map of terms relating to the ear using the following terms and any others you would like to include: tympanic membrane, stapes, malleus, incus, pinna, bony labyrinth, organ of Corti, oval window, round window, cochlear duct, tectorial membrane, and cochlear nerve. You may also want to construct concept maps relating to the other special senses (equilibrium, taste, smell) and the general senses (touch, pressure, temperature, proprioception).

Testing Your Knowledge

Building Understanding

I. Multiple Choice

1. A physician who specializes in disorders of the eye is a(n) 1. _____
   a. ophthalmologist
   b. internist
   c. allergist
   d. orthopedic surgeon
2. A term related to the sense of taste is 2. _____
   a. tactile
   b. gustatory
   c. proprioceptive
   d. thermal
3. Alterations in the lens' shape to allow for near or far vision is called 3. _____
   a. accommodation
   b. convergence
   c. divergence
   d. dark adaptation
4. The term *lacrimation* refers to the secretion of 4. _____
   a. mucus
   b. wax
   c. tears
   d. aqueous humor
5. Painkillers that are released from certain regions of the brain are 5. _____
   a. narcotics
   b. endorphins
   c. anaesthetics
   d. nonsteroidal anti-inflammatory drugs
6. A person who lacks cones in the retina will suffer from 6. _____
   a. blindness
   b. color blindness
   d. glaucoma
   d. trachoma
7. The organ of Corti is the receptor for 7. _____
   a. taste
   b. smell
   c. hearing
   d. equilibrium
8. A cataract is 8. _____
   a. an irregularity in the cornea's shape
   b. an infection of the conjunctiva
   c. an abnormally short eyeball
   d. loss of lens transparency

9. Inflammation of the membrane lining the eyelid is called 9. _____
   a. otitis
   b. conjunctivitis
   c. retinitis
   d. glaucoma

II. Completion Exercise

1. The transparent portion of the sclera is the _____
2. The glands that secrete ear wax are called _____
3. The nerve endings that aid in judging position and changes in location of body parts are the _____
4. The sense of position is partially governed by equilibrium receptors in the internal ear, including two small chambers in the vestibule and the three _____
5. The tactile corpuscles are the receptors for the sense of _____
6. Any drug that relieves pain is called a(n) _____
7. When you enter a darkened room, it takes a while for the rods to begin to function. This interval is known as the period of _____
8. The receptor tunic (layer) of the eye is the _____
9. The bending of light rays as they pass through the media of the eye is _____

Understanding Concepts

I. True/False

For each question, write *T* for true or *F* for false in the blank to the left of each number. If a statement is false, correct it by replacing the underlined term and write the correct statement in the blank below the question.

_____ 1. Extrinsic eye muscles control the diameter of the pupil.

_____

_____ 2. There are seven extrinsic muscles connected to each eye.

_____

_____ 3. The iris is an intrinsic muscle of the eye.

_____

_____ 4. The sense of temperature is a general sense.

_____

_____ 5. The rods of the eye function in bright light and detect color.

_____

_____ 6. When the eyes are exposed to a bright light, the pupils constrict.

_____

_____ 7. The scientific name for nearsightedness is hyperopia.

_____

_____ 8. The ciliary muscle contracts to allow thickening of the lens.

_____

_____ 9. The sense of smell is also called olfaction.

_____

II. Practical Applications

Study each discussion. Then write the appropriate word or phrase in the space provided.

➤ Group A

Baby L was brought in by his mother because he awakened crying and holding the right side of his head. He had been suffering from a cold, but now he seemed to be in pain. Complete the following descriptions relating to his evaluation and treatment.

1. Examination revealed a bulging red eardrum. The eardrum is also called the _____.
2. The cause of Baby L's painful bulging eardrum was an infection of the middle ear, a condition called _____.
3. Antibiotic treatment of Baby L's middle ear infection was begun, because this early treatment usually prevents complications. In this case, however, it was necessary to cut the eardrum to prevent its rupture. Another name for this surgical procedure is _____.
4. The mother was warned that Baby L may be particularly susceptible to middle ear infections. To prevent further damage to his eardrum, a special tube was inserted. This tube is called a(n) _____.
5. Baby L will have to be careful in the future, because repeated middle ear infections can lead to a type of hearing loss called _____.
6. Baby L was returned to the emergency room the next day because he was falling down repeatedly. The physician suspected a problem with his sense of balance, or _____.
7. Baby L's mother asked how an ear infection could affect balance. The physician explained that two structures were located within the inner ear that are involved with balance, named the semicircular canals and the _____.
8. In particular, the physician feared that the middle ear infection had spread to the fluid within the membranous labyrinth. This fluid is called _____.

➤ Group B

Sixty-year-old Mr. S had ridden his scooter over some broken glass. A fragment of glass bounced up and flew into one eye. Complete the following descriptions relating to his evaluation and treatment.

1. Examination by the eye specialist showed that there was a cut in the transparent window of the eye, the _____.
2. On further examination of Mr. S, the colored part of the eye was seen to protrude from the wound. This part of the eye is the _____.
3. Mr. S's treatment included antiseptics, anesthetics, and suturing of the wound. Medication was instilled in the saclike structure at the anterior of the eyeball. This sac is lined with a thin epithelial membrane, the _____.
4. The eye specialist evaluated Mr. S's vision in his uninjured eye. Like virtually all elderly adults, Mr. S was shown to have difficulties with near vision. This condition is called _____.
5. The eye specialist also observed that the pressure in his aqueous humor was abnormally high. This finding signifies that Mr. S suffers from _____.
6. Mr. S returned to the emergency room 1 week later with a severe infection in the injured eye. Despite proper wound care and several changes of antibiotics, the damaging infection persisted. The eye specialist reluctantly decided to remove the eyeball, a procedure called _____.

➤ Group C

You are conducting hearing tests at a senior citizens' home. During the course of the afternoon, you encounter the following patients. Complete the following descriptions relating to the evaluation and treatment of hearing loss.

1. Mrs. B complained of some hearing loss and a sense of fullness in her outer ear. Examination revealed that her ear canal was plugged with hardened ear wax, which is scientifically called _____.
2. Mr. J, age 72, complained of gradually worsening hearing loss, although he had no symptoms of pain or other ear problems. Examination revealed that his hearing loss was due to nerve damage. The cranial nerve that carries hearing impulses to the brain is called the _____.
3. In particular, the endings of this nerve were damaged. These nerve endings are located in the spiral-shaped part of the inner ear, a part of the ear that is known as the _____.
4. Mr. J's hearing loss, because it reflects nerve damage, is known as _____.
5. Mrs. C complained of hearing loss that resembled the type from which her aunt and her mother suffered. She requested surgical treatment, which is often successful in such cases. This disorder, in which bony changes prevent the stapes from vibrating normally, is called _____.

III. Short Essays

1. Describe several different structural forms of sensory receptors and give examples of each.

_____

_____

_____

2. Describe some changes that occur in the sensory receptors with age.

_____

_____

_____

3. List three methods to relieve pain that do not involve administration of drugs.

_____

_____

_____

Conceptual Thinking

1. You have probably been sitting in a chair for quite a while, yet you have not been constantly aware of your legs contacting the chair. Why not?

_____

_____

_____

2. Write your name at the bottom of this sheet of paper. Explain the contributions of different sensory receptors that were required to successfully complete that simple task. For instance, proprioceptors are required to indicate the fingers' location at every moment.

_____

_____

_____

Expanding Your Horizons

Imagine if you could taste a triangle, or hear blue. This is reality for individuals with a disorder called synesthesia. Read about some exceptional artists that suffer from this disorder, and how synesthesia has helped us understand how the brain processes sensory information in the article below.

Here is an exercise you can do to find your own blind spot. Draw a cross (on the left) and a circle (on the right) on a piece of paper that are separated by a handwidth. Focus on the cross and notice (but do not focus on) the circle. Move the paper closer and further away until the circle disappears. Weird activities to investigate your blind spot can be found at the website http://serendip.brynmawr.edu/bb/blindspot1.html.

Resources

1. Ramachandran VS, Hubbard EM. Hearing colors, tasting shapes. *Sci Am* 2003; 288:52–59.