LABORATORY

41

Control—The Nervous System

OVERVIEW

To survive and reproduce, animals must maintain a relatively constant internal state in the midst of wide fluctuations of factors in the environment. This constancy, called **homeostasis,** is maintained by the nervous and endocrine systems, which interact to control an animal's internal functioning (**physiology**) and external activity (**behavior**). In the nervous system, sensors (**affectors**) monitor an animal's internal and external environments. When physiological adjustments are required, these are mediated by the nervous system and facilitated by chemical messengers (hormones) secreted by the endocrine system, under close control of the nervous system. When external action is called for, **effectors**—muscles and bones and glands—coordinate various behaviors. The activities of the nervous and endocrine systems can be directed or regulated by genetic information and by learning.

In this laboratory you will study three levels of components of the mammalian nervous system: the structural unit of the nervous system, the **neuron,** or nerve cell; several sensory receptors (sense organs); and the brain, the major component of the central nervous system.

STUDENT PREPARATION

Prepare for this laboratory by reviewing the text pages indicated by your instructor. Familiarizing yourself in advance with the information and procedures covered in this laboratory will give you a better understanding of the material and improve your efficiency.

PART 1. NEURONS

✓ EXERCISE A Examining Nerve Cells (Neurons)

Nerve tissue is composed of two types of cells: (1) neurons, which are highly specialized for irritability and conduction of nerve impulses, and (2) sheath cells and glial elements, which provide both nourishment and support; some also help to conduct impulses.

Objectives

☐ Diagram the neuron and state the function of each part.

Procedure

1. On demonstration you will find a microscope slide of several neurons. Examine this slide and diagram a neuron on a separate sheet of paper. Label the neuron cell body, its axon, and any dendrites that may be visible.

2. Use your knowledge of nerve tissue to answer the following questions. (If you performed Laboratory 32, Animal Tissues, reviewing your notes on that lab will be helpful.)

   a. Identify the functions of each of the following parts of a neuron.

   Cell body ______________________________

   Axon ______________________________

   Dendrite ______________________________

   b. Distinguish among the functions of the following types of neurons. Where in the nervous system is each type of neuron located?

   Sensory (afferent) neurons ______________________________

   Interneurons ______________________________

   Motor (efferent) neurons ______________________________

   c. What is the difference between a neuron and a nerve? ______________________________

   ____

   d. The functional junction between two neurons is the **synapse.** *What happens at this junction and why are these events important? How does the synapse control the direction of information flow?*

   ____

   ____

PART II. SENSORY RECEPTORS

Before an organism can respond to its external or internal environment, it must receive relevant information about its position within the environment and about the environment itself. Sensory receptors (sensors or affectors) transmit this information to the **central nervous system** (the brain and spinal cord), thus enabling the organism to coordinate its activities.

Prominent sensory receptors are sensitive to changes in particular forms of environmental energy such as heat, pressure, light, and vibration (sound). Others are sensitive to various ions or chemical molecules, some are sensitive to gravity, and others to the position of various skeletal elements and muscles. With the exception of receptors for smell and the free nerve endings occurring in various regions of the body, sensory cells are *not* derived from neurons. Sensors are specialized epithelial elements that synapse with one or more sensory neurons.

Some sensory receptors are functional parts of conspicuous sense organs (for example, the eyes, ears, and nose). However, diffuse receptors, such as those sensing touch, pain, temperature, and muscle or joint position, are equally important to an organism.

In Exercises B through J, work in pairs wherever necessary. Alternate the role of experimenter and experimental subject whenever appropriate.

EXERCISE B Chemoreception: The Sense of Taste

In humans, the specialized receptor organs for the sense of taste (gustation) are clusters of cells called **taste buds** (Figure 41B-1), located on the tongue, especially on the tip, edges, and posterior third.

Taste sensations are traditionally divided into four basic groups: sweet, sour, salty, and bitter. Receptors for each group of substances are found in different areas of the tongue. Receptors are thought to register different gradations of intensity depending on the substance present.

Objectives

- ☐ Determine which areas of the tongue are sensitive to specific tastes.

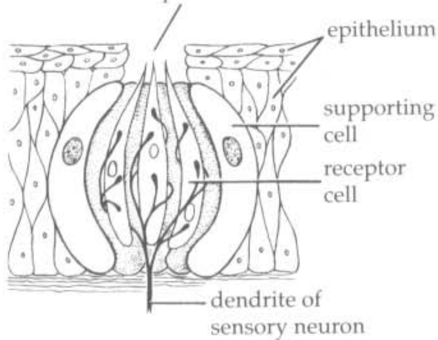


Figure 41B-1 *Human taste bud. Cells of the taste bud may be classified as* receptor (hair) cells, *responsible for transducing sensory information, and* supporting (sustentacular) cells. *The external (distal) ends of the receptor cells project from a pore in the taste bud, enabling them to make direct contact with chemical substances. The internal (basal) ends of the receptor cells synapse with sensory neurons that enter the brain through one of two cranial nerves. Sustentacular cells can transform into taste cells.*

Procedure

Five unknown solutions (A through E) are located at your lab station. Each student should obtain five cotton swabs for tasting the solutions and a paper cup for rinsing the mouth with water. Use only one end of each swab and discard it after use. *Do not place a used swab into the test solution.* Work in pairs, alternating the role of experimenter and subject. Record either your own or your partner's taste results.

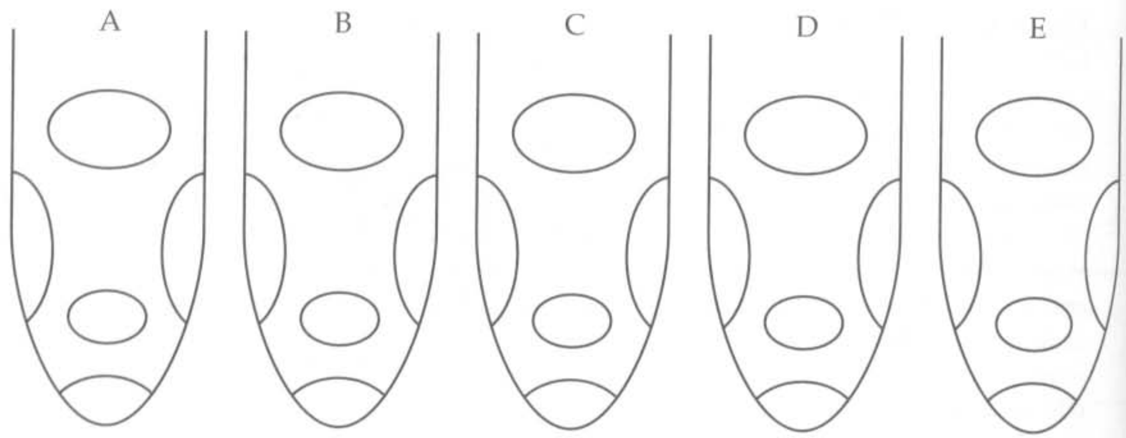
1. The subject rinses his or her mouth with water.
2. The experimenter dips a cotton swab into solution A and touches it to the tip of the subject's tongue. (Do not use a drop large enough to spread over the tongue—the moist tip of the swab will be sufficient.)
3. The subject determines whether this substance tastes salty, bitter, sweet, or sour, or has no taste at all.
4. If the subject can taste solution A on the tip of the tongue, record a "+" on the tip of tongue A in Figure 41B-2. If the subject cannot taste this solution on the tip of the tongue, record a "−" on the tip of tongue A. The subject now rinses his or her mouth again.
5. Repeat this process, testing solution A on the tip, the sides, the upper back, and the upper from of the tongue, as indicated in Figure 41B-2. In each case, record the ability to taste or not taste solution A on the appropriate part of the diagram of tongue A. In the space below the diagram, indicate how solution A tastes to the subject (salty, sour, sweet, bitter, or no taste).
6. Repeat this entire process with each of the other solutions (B through E), with the subject rinsing his or her mouth between each taste test. Record your observations on the corresponding diagram of the tongue. Make sure that in each case you record the taste of the solution.
7. When you have finished collecting your data, discard any remaining solutions and throw cups and swabs into the trash container.

   The five solutions you tasted were water, sugar, salt, acetic acid (sour), and quinine (bitter). In the spaces below Figure 41B-2, write the names of the solutions.

   a. Why can you taste certain substances on one part of the tongue but not on other parts?

   ____

8. Now obtain a small amount of magnesium sulfate solution and a cotton swab. Test the solution on the upper tip of the tongue. *b. How did it taste?* ____________________



taste ______ ______ ______ ______ ______

solution ______ ______ ______ ______ ______

Figure 41B-2 *Localization of taste sensations on the tongue.*

9. Next, test the solution on the upper back of the tongue. *c. How did it taste?* ______

d. How do you explain these differences in the taste of the same substance?

______

______

EXERCISE C Chemoreception: Individual Differences in Taste

When you were a child, did your parents ever tell you it was "all in your head" if you didn't like the taste of some of the food they fixed? Do you think your likes and dislikes might be influenced by genetics? If so, would you expect to find differences in the way in which a particular food tastes to different people? Do chemoreceptors differ from person to person?

Objectives

- ☐ Explain how individual differences in taste are related to food preferences.

During this exercise, you will have the opportunity to taste several specialized "taste papers" (PTC, thiourea, and sodium benzoate). Do you think these papers will taste the same to all members of your class? If you taste one of the taste papers as bitter while your laboratory partner tastes the same type of paper as sweet, do you think you would share the same food preferences?

Formulate a hypothesis relating chemoreception to individual differences in food preferences.

HYPOTHESIS:

NULL HYPOTHESIS:

Does your laboratory partner like the same types of foods as you do?

*a. What do you **predict** the two of you will find when you sample the taste papers?* ______

______

What is the **independent variable**?

What is the **dependent variable**?

Use the following procedure to test your hypothesis.

Procedure

1. Each student should obtain from the demonstration bench one piece of each of the four taste papers (PTC, thiourea, sodium benzoate, and a control paper). Be sure to keep these papers in order.
2. Taste the control paper first and record the taste as sour, bitter, salty, sweet, no taste, or whatever terms may be appropriate. Touch each of the other papers to your tongue.

RESULTS: Record your sensation of taste for each paper.

Control (white) ____________________

PTC (blue) ____________________

Thiourea (yellow) ____________________

Sodium benzoate (pink) ____________________

3. Discard your papers in the trash container when you are finished.

b. Which chemical did you find most distasteful? ____________________

c. Did most of the students in the class have this same reaction to this particular chemical? __________

d. How did sodium benzoate taste to other members of your laboratory section? ____________________

Although sodium benzoate is tasteless to some individuals, to those who are capable of tasting it, it may seem sweet, sour, bitter, or salty. Sodium benzoate is sometimes used as a food preservative (check your favorite soft drink label).

e. How do you think the use of sodium benzoate an an ingredient in food processing affects the taste of the product to different people? ____________________

____

It is also interesting to note that those people who taste PTC as bitter and sodium benzoate as salty tend to like the taste of buttermilk, sauerkraut, turnips, and other sour foods more than average. Those who taste both PTC and sodium benzoate as bitter tend to dislike the taste of such foods.

f. How do your food preferences relate to the observations reported here? ____________________

g. Do your observations support your hypothesis? ________

Your null hypothesis? ________

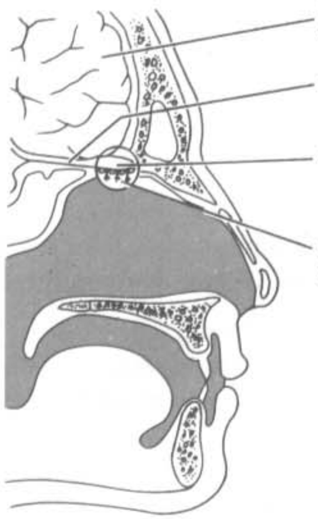
h. What do you conclude about chemoreception and food preferences in different individuals?

____

EXERCISE D Chemoreception: Smell Discrimination and Its Influence on Taste

Smell (olfaction) is another example of chemoreception. In this case, the receptors are part of a mucus-secreting membrane (hence, mucous membrane) in the upper part of the nasal cavity. The receptors, called **hair cells,** have hairlike cilia on one end extending into a layer of mucus (Figure 41D-1).

Before the odor of a substance can be detected, the substance must release molecules that diffuse into the air and pass into the region of the olfactory receptors. These molecules then dissolve in the mucus and



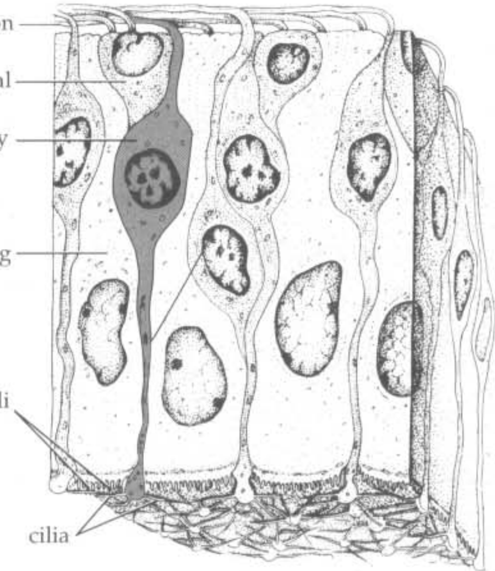


Figure 41D-1 *(a) A patch of special tissue, the olfactory epithelium, arching over the roof of each nasal cavity, is responsible for the sense of smell. (b) The olfactory epithelium is composed of three types of cells:* supporting cells, basal cells, *and* olfactory cells. *The olfactory cells are the sensory receptors. Cilia protruding from their upper surfaces are believed to be the odor receptors, although the way in which they function is not known. Note that the sensory cells are neurons that give rise to extensions (axons) that lead directly to the olfactory lobe of the brain.*

interact with receptor molecules in the cilia of the sensory cells. Exactly how these receptor cells and the brain distinguish odors is not understood. It is known, however, that we can distinguish a far greater number of odors than tastes. In fact, our enjoyment of food is actually the product of two sensations—the limited information conveyed by taste buds and the broader range provided by the olfactory receptors.

Do you think that information obtained by our olfactory receptors can influence how we think a particular food tastes? If you held your nose, would a cherry Life Saver® taste the same as a lemon Life Saver®? If you were blind-folded and given lemon Life Savers® to smell, but were fed cherry Life Savers®, what do you think you would report when asked how the candy tasted?

Formulate a hypothesis as a tentative explanation for how our sense of smell affects our sense of taste.

HYPOTHESIS:

NULL HYPOTHESIS:

a. What do you **predict** *you will find if you test your hypothesis?* ______________________________

____

What is the **independent variable**?

What is the **dependent variable**?

Use the following procedure to test your hypothesis.

Procedure

1. The experimenter should obtain a Life Saver® from the various flavors available on the demonstration bench, without letting the subject know what the flavor is.
2. The subject closes his or her eyes and holds his or her nose.
3. The experimenter gives the Life Saver® to the subject and the subject places it on the tongue.
4. The subject, while still holding his or her nose, guesses the flavor of the candy. The experimenter records the guess in step 5.
5. The subject releases his or her nose and guesses the flavor again. The experimenter records this guess and the actual flavor of the Life Saver.®

   Flavor while holding nose ________________

   Flavor without holding nose ________________

   Actual flavor ____________________________

   b. From your results, how would you say that smell affects the taste of Life Savers®?

   ____

   c. Do your results support your hypothesis? ______ *Your null hypothesis?* ______

   d. What do you conclude about the effect of smell on your sense of taste?

   ____

✓ EXERCISE E Photoreception: Vision—Structure of the Eye

The human eye has often been compared to a camera. The **lens** focuses light onto the **retina** at the back of the eye just as the lens of a camera focuses light onto the film. The amount of light entering the eye is regulated by the **iris**, which controls the size of its opening, the pupil; the diaphragm of a camera regulates the amount of light that enters in much the same way. The retina consists of light-sensitive cells (**rods** and **cones**) that transduce light energy into nerve impulses that are partially processed in the retina and transmitted to the brain via the optic nerve. We "see" the picture as the brain processes the transmitted information. During development of the organism, the eye forms from an out-pocketing of the forebrain and associated elements. The arrangement of the functional elements of the eye reflects this origin; for example, the retina is really a part of the brain, and the optic nerve is, in fact, a tract in the brain.

Objectives

- ☐ Identify the parts of the eye and state the function of each part.
- ☐ Trace the pathway of light through the eye and explain how the eye regulates the passage of light.

Procedure

1. Match the boldface letters in the following list to the letters in Figure 41E-1, and write the name of the structure in the space provided on the figure.

   a Optic nerve Located opposite the pupil. The stub of the second cranial nerve (actually a fiber tract of the brain).

   Extrinsic eye muscle Six external muscles attached to the sclera, which appear as discrete masses of slightly darker tissue in the connective and fat tissue surrounding the eye. Responsible for movement of the eyeball within its socket (**orbit**).

   b Sclera Tough outer layer of the eye, continuous with the protective dura mater covering the brain. Attaches to extrinsic muscles.

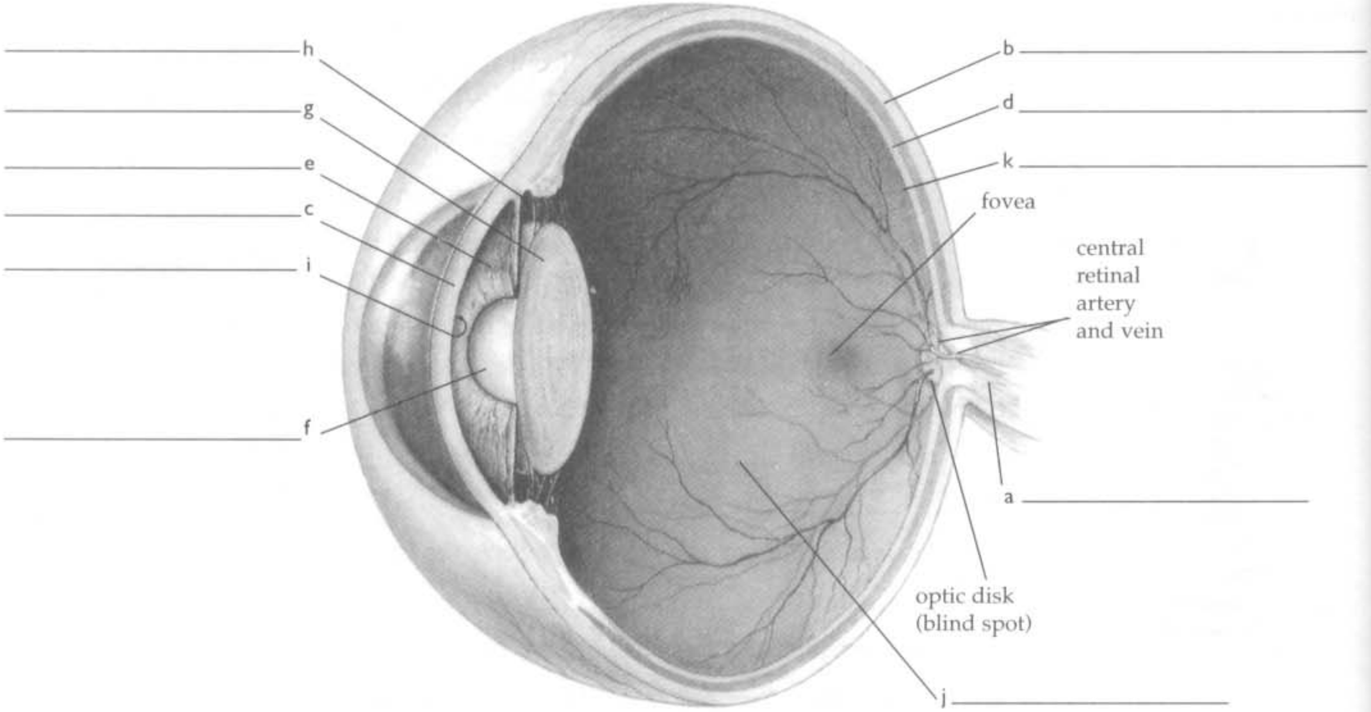


Figure 41E-1 *Structure of the eye.*

c Cornea Transparent anterior part of the sclera that admits light to the eye and focuses it on the retina. The transparent covering layer of epithelium is the **conjunctiva.** Asymmetries in the cornea (departures from a spherical shape) produce astigmatism.

d Choroid Middle layer of the eye providing a nutritive vascular blood supply. The anterior portion is modified into parts of the **iris, suspensory ligament,** and **ciliary body.** In nocturnal animals, the posterior portion behind the retina contains pigment that reflects light, causing "night shine."

e Iris A pigmented, diaphragm-like structure. Separates the aqueous chamber into anterior and posterior chambers (see **i**).

f Pupil Opening in the iris through which light passes.

g Lens Hard, transparent, rounded structure inside the eye; elastic in the living eye. The **ciliary body h,** a circle of smooth muscle, changes the shape of the lens to focus on near or distant objects. With age, the elasticity of the lens may be reduced, hence the progression to bifocal and trifocal glasses. Cataracts result from the loss of lens transparency.

i Aqueous chamber Chamber located in front of the lens; contains liquid **aqueous humor.** Divided into anterior and posterior chambers by the iris. Secretions of fluid maintain both the shape of the corneal surface and the proper pressure in the aqueous chamber. Excess pressure in the aqueous chamber causes glaucoma and can lead to blindness.

j Vitreous chamber Chamber of the eye behind the lens; contains jellylike **vitreous humor.** Transparent in the living eye.

k Retina Inner sensory layer of the eye. Contains sense elements (**rods** and **cones**), sensory neurons, and associative neurons. Technically, the retina is part of the brain. Fibers project from the retina to the brain through the optic tract or "nerve."

2. Examine a preserved sheep's eye. With a scalpel or razor blade, make a cut into the eye approximately 5 mm posterior to the edge of the cornea and continue the incision all the way

around the eye. Remove the cornea and the lens, leaving the jellylike vitreous body in the back portion of the eye.

3. Referring to Figure 41E-1 and the list in step 1, identify as many of the parts as you can. Note that the retina appears black. This is due to a pigment layer behind the sensory cells. The iridescent appearance in this area is due to a reflecting pigment in the posterior portion of the choroid coat behind the retina, the *tapetum lucidum*.

4. The eye is actually composed of three layers of tissue that form a fluid-filled sphere. Organize your study of the structures of the eye by listing each of the following as part of the outer, middle, or inner layers of the eye: sclera, iris, cornea, lens, ciliary muscles, retina, choroid, sensory elements (rods and cones).

Outer Layer	Middle Layer	Inner Layer
______	______	______
______	______	______
______	______	______
______	______	______
______	______	______

a. List in sequence those structures of the eye through which light must pass before arriving at the retina. ______

______

EXERCISE F Photoreception: How We See

Light entering the eye passes through the chamber containing aqueous humor, then through the lens, and finally through the chamber containing vitreous humor before it falls on the retina. The retina is the sensitive layer of the eye and it is here that the energy of light is transduced into nerve impulses.

The light must pass through several layers of neurons on the retina before striking the photosensitive cells. In the human retina, there are two types of photoreceptor elements: cones and rods.

Cones are responsible for vision in bright light and for the perception of fine detail and color. Cones are concentrated in the **fovea centralis** at the center of the retina. Light-sensitive **rods** function in dim light and are insensitive to colors. Rods are more numerous in the periphery of the retina. Information from the cones and rods travels back toward the anterior of the retina through the layer of nerve cells. The first cell receiving information from the rods or cones is a bipolar cell, the sensory neuron (Figure 41F-1). Impulses from particular rods and cones may be modified by impulses from other rods or cones or sensory elements by means of transverse connections. Bipolar cells synapse with ganglion cells at the anterior of the retina. Axons of these neurons join together to form the optic nerve, which relays information to the brain.

a. Which area would have the sharpest vision—the fovea or the periphery? ______

b. Why? ______

c. If you are trying to see an object in dim light, is it best to look at the object directly so that the image falls on the cones, or to look at it out of the side of your eye so that the image falls on the rods? ______

d. Why? ______

______

Objectives

☐ Relate the structure of the eye to its ability to perceive color, maintain peripheral vision, and compensate for the blind spot on the retina.

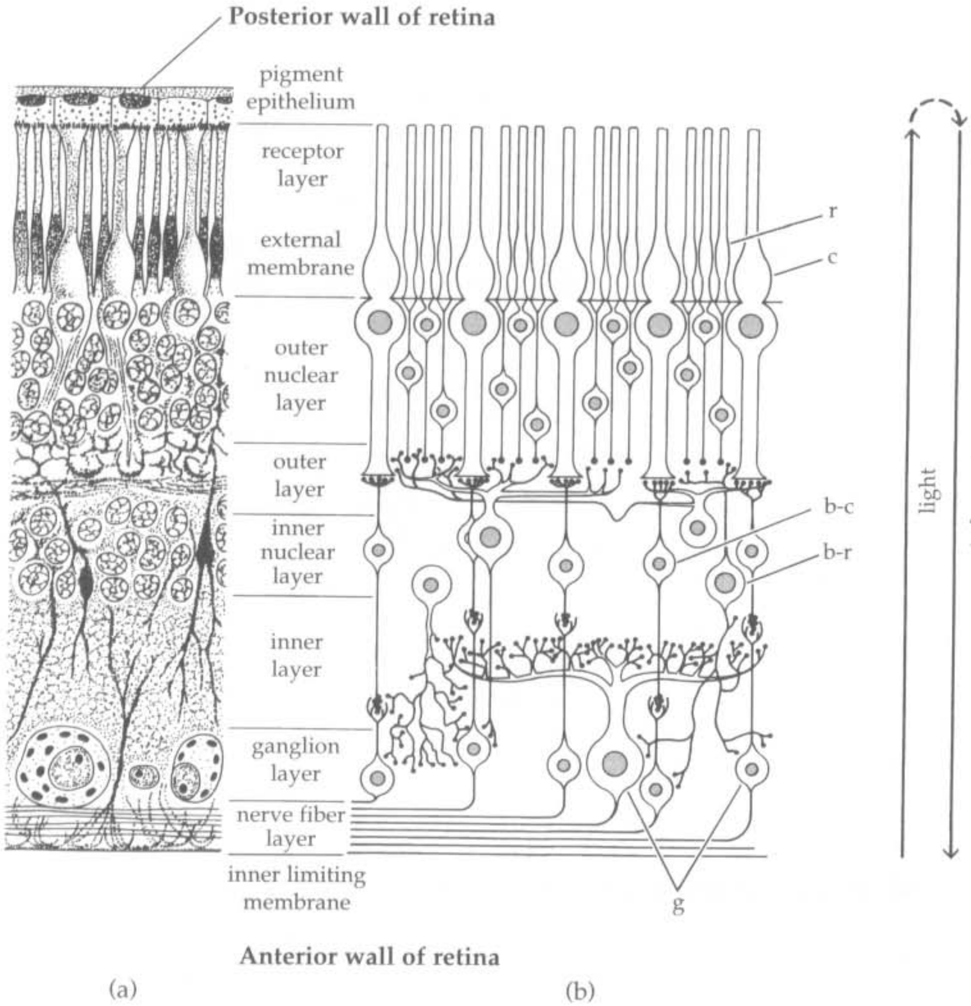


Figure 41F-1 *(a) Vertical section through the retina of a mammal. (b) Schematic drawing showing some of the connections among sensory and nervous elements in the retina:* **r**, *rods;* **c**, *cones;* **b-r**, *bipolar cells connecting with a series of rods;* **b-c**, *bipolar cells associated with a single cone;* **g**, *ganglion cells. Light enters at the anterior of the retina, traverses the nuclear layers, and arrives at the rods and cones at the posterior of the retina. Sensory information then travels from these sensory cells to the bipolar cells to the ganglion cells, which send it on its way to visual association areas in the brain. (After Alfred S. Romer and Thomas S. Parsons,* The Vertebrate Body, *6/e, p. 372, fig. 5B, CBS, New York, 1983.)*

PART I Peripheral Vision and Color Vision

Procedure

1. The experimenter chooses a colored object from the demonstration bench, without letting the subject see what that object is.
2. The subject closes one eye and focuses the other eye on some point straight ahead.
3. The experimenter moves the object into view from the side. The subject should *not* look directly at the object.

a. What can be determined first, the shape of the object or its color? Explain.

PART 2 The Blind Spot

The rods and cones make contact with neurons that conduct information from these receptor cells to the optic nerve fibers. Fibers from these cells located in all parts of the retina converge at a point on the retina known as the **optic disk.** This region has no rods or cones, thus producing a "**blind spot**": images falling on this area cannot be perceived. From the optic disk, nerve fibers proceed to the brain. Figure 41F-2 can be used to demonstrate the presence of the blind spot.

Figure 41F-2 *A test for the blind spot.*

Procedure

1. Close your left eye and focus your right eye on the **+** in Figure 41F-2.
2. Start with the figure about 12 cm (5 in) from your eye and gradually move the page away until the circle disappears.
3. Repeat this with your left eye, but focus on the circle and move the page until the **+** disappears.
   a. Even though you have a blind spot in each eye, why do you not experience a blind spot in your vision when you look at an object with both eyes?

   b. When you look at an object with only one eye, you do not notice a blind spot in your vision. Why do you suppose this happens? ?

EXERCISE G Mechanoreception: The Role of Sensory Receptors in Touch

A large number of diverse sense organs in the skin contribute to tactile sensitivity. Receptors for each of the different sensations (pain, touch, deep pressure, cold, and warmth) are localized in different places in the skin (Figure 41G-1). The concentration of particular receptors also varies from place to place.

One type of receptor, the **mechanoreceptor,** is sensitive to quantitative forces such as pressure, touch, stretching, sound, movement (acceleration), and gravity in the external and internal environments. Such receptors are abundant in the skin, muscles, tendons, various visceral organs, large blood vessels near the heart, and most connective tissues.

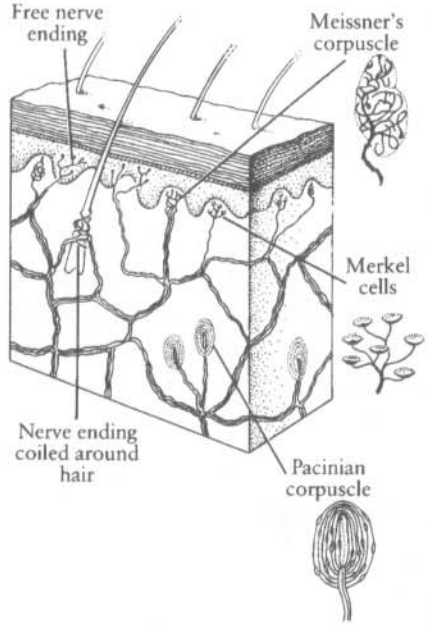
Objectives

- ☐ Describe the role of tactile sensory receptors in distinguishing the sensations of touch.

Procedure

This experiment will test your discrimination of various stimuli through receptors sensitive to light touch, the **Meissner's corpuscles.**

Figure 41G-1 *Sensory receptors present in the skin. Light touch is detected by Meissner's corpuscles and Merkel cells or by free nerve endings around hair follicles. Pacinian corpuscles are stimulated by deep pressure.*



1. Obtain a ruler and a pair of compasses from the demonstration bench. Touch the tips of the compasses to the skin of the subject who, *with eyes closed*, should try to determine whether one or two compass tips are in contact with the skin.
2. Vary the distance between the compass tips (1, 3, 6, 12, and 24 mm) and try using one or two tips in a given area. Test the following areas: lips, fingertips, palm, inner forearm, inner wrist, outer wrist, back of the hand, and outer forearm. Record the smallest distance at which the subject can distinguish the compass tips as two points: lips ______, fingertips ______, palm ______, back of hand ______, inner wrist ______, outer wrist ______, inner forearm ______, outer forearm ______.

   a. Explain why some areas of your body are better able than other parts to distinguish between two close stimuli. ____________________

   ____

   b. Referring to your data in step 2, determine which of the tested areas of your body are most sensitive to light touch. Suggest some possible advantages of greater sensitivity in these areas.

   ____

EXERCISE H Thermoreception: Discriminating Temperature

Many types of receptors cease to become excited when they are subjected to a single, continuous stimulus. This phenomenon is called **habituation.** This exercise demonstrates habituation by heat and cold receptors in the skin.

Objectives

- ☐ Describe the role of tactile sensory receptors in distinguishing sensations of hot and cold.
- ☐ Define habituation as applied to the function of receptors for temperature.

Procedure

1. Set up three beakers of water: one cold, one at room temperature, and one with tolerably hot water.
2. Place one index finger in cold water and one in hot water. *a. How does each finger feel?*

   ____

3. Leave your fingers in the water for several minutes. *b. How does each finger feel now?*

   ____

4. Now move the two fingers directly from the cold and hot beakers into the beaker of room temperature water. *c. How does each finger feel now?* ______________________________

   d. Is the stimulus the same for both fingers now? ______________________________

   e. When you move your finger from cold water into warmer water, do the receptors in your finger respond to heat gain or heat loss? ______________________________

   f. When you move your finger from hot water to cooler water, do the receptors in your finger respond to heat gain or heat loss? ______________________________

EXERCISE I Proprioception: The Role of Proprioceptors in Determining Position

The activation of proprioceptors in the joints, associated ligaments, and muscles sends impulses through the nervous system, giving rise to the conscious awareness of the position and movement of joints. Input from these receptors is integrated with visual information and input from the inner ear to provide an awareness of the position of the body in space.

The various proprioceptors are activated by mechanical stimuli such as stretching, twisting, and compression, or by painful stimuli. This exercise demonstrates the sensitivity of these receptors.

Objectives

- ☐ Describe the role of proprioceptors in maintaining the position of body members.

Procedure

1. Extend one of your arms and close your eyes. Extend your other arm.
2. Bring the two arms together and touch the tips of your two index fingers.

   a. Did your index fingers actually touch when you brought them together or did they miss each other? ______________

3. Repeat this exercise by putting your hands behind your back and trying to touch the tips of the index fingers. *b. Could you get them to touch?* ________
4. Obtain a piece of string. Close your eyes and tie a knot in the string. *c. Describe what happens.*

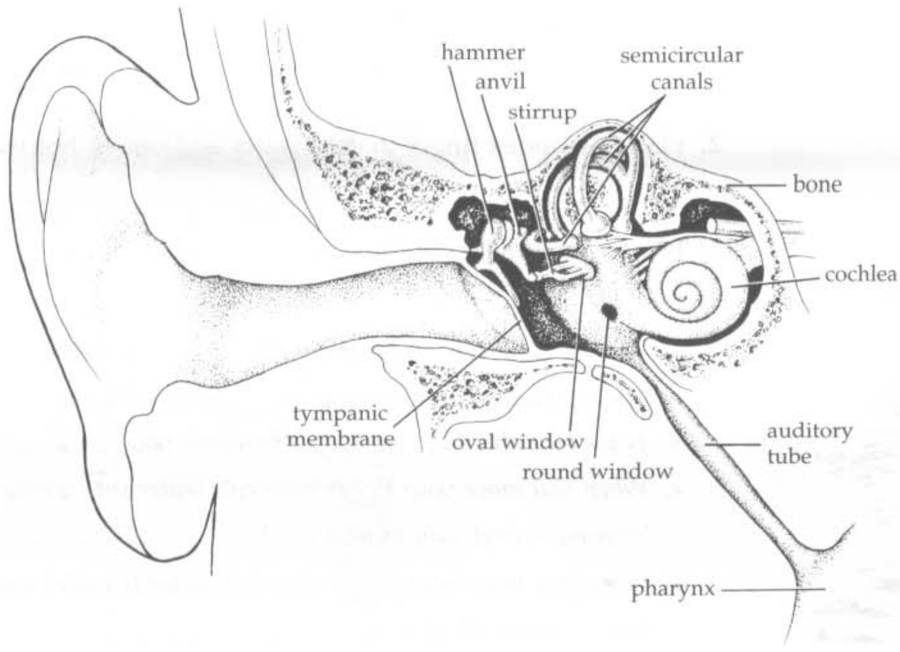
   ____

   d. How do you explain these results? ______________________________

   ____

EXERCISE J Mechanoreceptors of the Ear

In humans, equilibrium depends upon stimuli from several different sources: (1) the eye, (2) proprioceptors, (3) mechanoreceptors sensitive to pressure in the soles of the feet, and (4) organs of the inner ear.



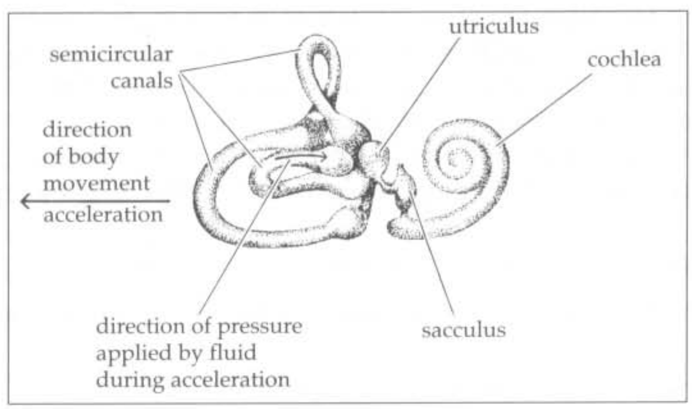


Figure 41J-1 *(a) The structure of the ear. (b) Within the interconnected, fluid-filled sacs of the* sacculus *and* utriculus *are sensory* otoliths *composed of bony material in which sensory "hairs" are embedded. Changes in the position of the otoliths relay information to the brain about changes in direction with respect to gravity.*

Each of the semicircular canals contains fluid and has a bulbous swelling at one end, the ampulla. These contain hair cells *sensitive to displacement of fluid by acceleration and deceleration. As you accelerate in one direction during rotation, the fluid in the semicircular canal parallel to your motion pushes against the hair cells in the ampulla.*

The body's position and balance are maintained by nerve impulses to the brain from the utriculus, sacculus, and all three semicircular canals of both ears.

Sensors of the inner ear (Figure 41J-1) monitor the position of the head relative to gravity and detect changes in the motion of the head.

Certain reflex actions may occur in response to the stimulation of cells of the inner ear. When a person is seated on a revolving stool and rotated, the eyes move in a peculiar manner. The eyes fix upon, and keep in view, a certain object, resulting in a slow movement of the eyes in a direction opposite to that of the body. When the object can no longer be seen, the eyes shift very swiftly, moving in the direction of rotation, and fix on another object. The process is repeated over and over. Movement of the eyes in this manner is referred to as **nystagmus.** When rotation suddenly stops, a postrotational nystagmus occurs and the eyes move as they would have if rotation had begun in the opposite direction. These reflexes are dependent on information from the semicircular canals.

Objectives

- ☐ Identify the structures of the ear that determine how a body reacts to changes in position.

Procedure

1. If a rotating stool or chair is available in the laboratory, have your partner sit down and hold on tightly as you rotate the stool.
2. After several rotations, stop the stool and immediately observe the movement of your partner's eyes.
   a. *Which way do they move?* ______________________
   b. *What could be stimulating the eyes to move in the manner observed after the subject has stopped rotating?* ______________________
   c. *Many times a dancer will turn his or her head in the direction opposite to that in which he or she is spinning. Why?* ______________________
   d. *Why do you become dizzy if you spin around and around?* ______________________

PART III. THE BRAIN

✓ EXERCISE K The Structure of the Mammalian Brain

Sensory receptors relay information over sensory neurons to appropriate areas of the **brain.** Sensory input may be stored in memory, and motor impulses may be sent out to effectors (muscles or glands).

The brain and spinal cord make up the central nervous system. The major regions of the brain are the forebrain, the midbrain, and the hindbrain. Marked functional advances and structural changes in these regions have occurred among the vertebrates during the course of evolution. For example, in non-mammalian vertebrates, each of these regions of the brain receives input from one of the major sensory channels: the forebrain receives chemosensory information from the nose, the midbrain receives visual information from the eye, and the hindbrain receives information from the ear. However, in mammals, the portions of these inputs that are relevant to conscious and voluntary activities have been rerouted to the forebrain, which assumes a dominant role in behavioral coordination.

Objectives

- ☐ Distinguish among the parts of the forebrain, midbrain, and hindbrain.
- ☐ State the functions of the major components of the forebrain, midbrain, and hindbrain.
- ☐ Describe how the brain processes information from sensory receptors.

Procedure

1. On the demonstration bench you will find several containers of sheep brains. These specimens are extremely delicate and you should be very careful in handling them. Obtain one of the brains and study it with your partner.
2. Examine the parts of the brain while referring to Figure 41K-1 and Table 41K-1. The boldface letters in the table refer to lettered structures in the figure. Label the diagram as you identify each part.
   a. *Name the part of the brain concerned with the following functions or activities:*
      Controlling body temperature ______________________
      Coordinating equilibrium ______________________

Controlling breathing ______

Intelligence ______

Sensory perception ______

Heart rate ______

Relaying impulses between lower brain centers and the cerebrum ______

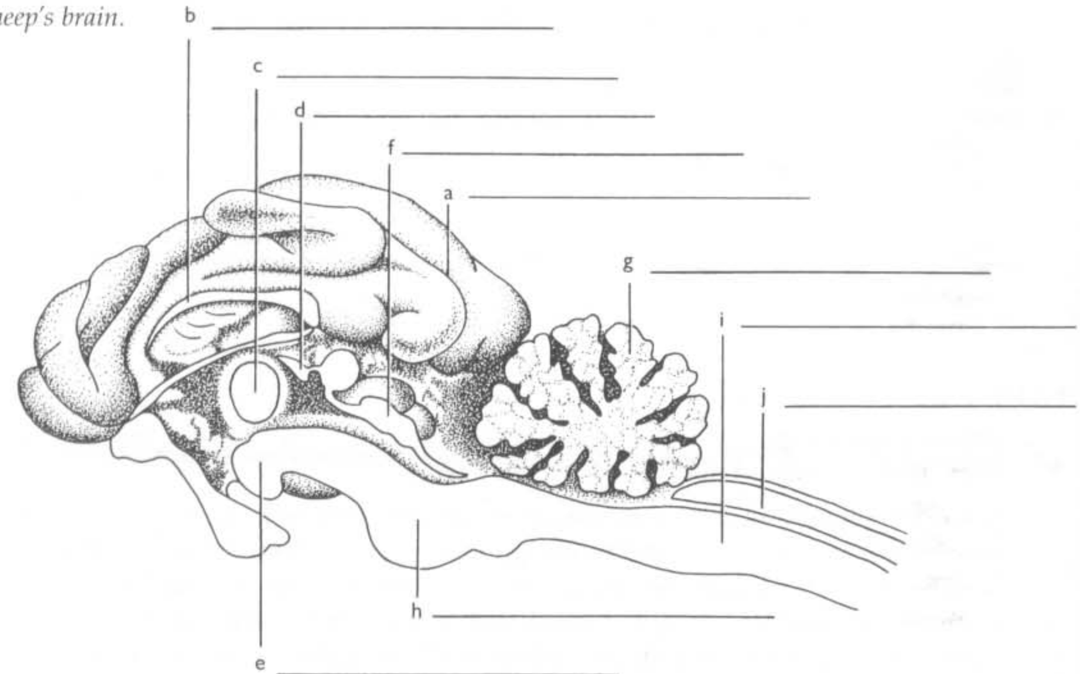


Figure 41K-1 *The sheep's brain.*

Table 41K-1 The Parts of the Mammalian Brain

Name	Location/Composition/Structure	Functions
Prosencephalon–Telencephalon Forebrain—Anterior Area		
a Cerebral hemispheres (olfactory lobes, basal nuclei, and cerebral cortex)	Most dorsal and anterior portion of brain. Most prominent and well-developed part of mammalian brain. Two lateral hemispheres. Convolutions increase surface area.	Highest integration center of the nervous system. Seat of psychic functions such as consciousness, sensation, perception, memory, and judgment (in humans).
Cortex (part of cerebral hemispheres)	Outer gray matter of cerebrum contains cell bodies; inner white matter composed of myelinated fibers and organized fiber tracts that connect cell masses in cerebral cortex to other parts of the brain.	Controls speech and voluntary movements. Functions may be mapped by studies of accidental injuries. Much of cortex is "silent," involved in associative activities. Visual and auditory information is projected to definite areas of the cortex.
b Corpus callosum	Located beneath the middle portion of cortex.	Fiber tracts interconnect the two halves of the cerebral hemispheres.

(continued next page)

Table 41K-1 ***(continued)***

Name	Location/Composition/Structure	Functions
Olfactory bulbs (oldest part of the forebrain)	Much reduced in mammals, but they lead to an older, more primitive part of the telencephalon where sensory information from the nose is integrated.	Integrate olfactory sensory information.
Lateral ventricles	Cavities in the cerebral hemispheres.	Contain cerebrospinal fluid.
Prosencephalon–Diencephalon Forebrain—Posterior Area		
c Thalamus	Located posterior to cerebrum; forms the side walls of this more posterior region of the forebrain	"Way station" for information traveling from lower brain centers to cerebrum. Visual and auditory information relayed to cortex in this area in mammals.
d Epithalamus	Non-nervous choroid *plexus* (tissue layer)	Produces the cerebrospinal fluid that fills the central cavities of the brain and spinal cord.
	Site of pineal gland.	Pineal gland is photoreceptive in some vertebrates. Produces melatonin, a hormone affecting rhythmic phenomena.
e Hypothalamus	Floor of the brain posterior to the cerebrum and below the thalamus.	Controls visceral nervous system, particularly emotions, temperature regulation, sleep, water balance, food and water intake, metabolic activity, and reproductive activity.
	Median eminence	Endocrine gland—produces neurohormones that regulate the anterior pituitary and other body functions.
	Optic chiasma	Optic nerve enters the brain through this area.
Mesencephalon Midbrain		
f Tectum	*Corpora quadrigemini*—four small bodies, two anterior and two posterior, constitute the midbrain roof. The first two correspond to a massive brain area, called the *optic lobes,* in nonmammalian vertebrates.	Anterior bodies associated with pupillary reflexes. Posterior bodies concerned with auditory reflexes (e.g., pricking of a dog's ears).
Tegmentum	Floor and sides of the midbrain.	Relays motor fibers and information traversing the ventral brainstem, including pyramidal tracts which relay information directly from the cerebral cortex to the spinal column. Controls a variety of involuntary processes.

(continued next page)

Table 41K-1 *(continued)*

Name	Location/Composition/Structure	Functions
Rhombencephalon–Metencephalon Hindbrain **g** Cerebellum	Anterior part of hindbrain; relatively large, rounded structure with a convoluted surface. In mammals the brain is folded so that the cerebellum lies directly behind the cerebrum. Surface contains cell bodies forming gray matter. White matter under the surface contains nerve fibers connecting the medulla and other areas of the brain.	Concerned with equilibrium, posture, and movement. Receives input from most sense organs, including proprioceptors in joints and the inner ear. Keeps track of the orientation of the body in space and the degree of contraction of skeletal muscles. Fine-tunes movements initiated in other areas of the brain. Injury to cerebellum results in impairment of muscular coordination but not in paralysis.
h Pons	Anterior end of medulla. Composed of thick bundles of myelinated (white) nerve fibers that carry impulses from one side of the cerebellum to the other in mammals.	Fiber tracts coordinate movements on both sides of the body.
Rhombencephalon–Myelencephalon **i** Medulla oblongata (begins in the metencephalon)	Located beneath and posterior to cerebellum; connects the spinal cord and midbrain. Roof has a second choroid plexus **j**	Contains nerve centers that control vital, largely subconscious activities such as respiration, heart rate, constriction and dilation of blood vessels, swallowing, and vomiting. Choroid plexus secretes cerebrospinal fluid.

Laboratory Review Questions and Problems

1. Define sensors (affectors) and effectors. Describe their relations to control systems in animals.

2. The structural units of the nervous system are neurons (and associated cells), but the functional units are synapses. What does this statement mean?

3. How are the senses of taste and smell alike? How are they different?

4. How is information from the inner ear related to information supplied by proprioceptors? Where in the brain is information from these sources integrated?

5. Identify the part of the brain associated with each of the following functions:

Vision ____________________

Smell ____________________

Hearing ____________________

Speech ____________________

Thought and voluntary behavior ____________________

Visceral functions and control of anterior pituitary ____________________

Respiration, heart rate, vasoconstriction and vasodilation ____________________

Equilibrium, posture, and fine control of voluntary movements ____________________