Materials

For Vision
- Dissectible eye model
- Chart of eye anatomy
- Preserved cow or sheep eye
- Dissecting tray and instruments
- Disposable gloves
- Metric ruler
- Common straight pins
- Snellen eye chart (floor marked with chalk to indicate 20-ft distance from posted Snellen chart)
- Ishihara’s color-blindness plates

For Hearing and Equilibrium
- Three-dimensional dissectible ear model and/or chart of ear anatomy
- Otoscope (if available)
- Alcohol swabs
- Prepared microscope slide of cochlea
- Absorbent cotton
- Pocket watch or clock that ticks
- 12-inch ruler
- Tuning forks (range of frequencies)
- Rubber mallet
- Demonstration area: Cochlea slide set up under a compound microscope for student observation

For Smell and Taste
- Small mirror
- Paper towels
- Granulated sugar
- Cotton-tipped swabs
- Disposable autoclave bag
- Paper cups; paper plates
- Beaker containing 10% bleach solution
- Prepared dropper bottles of oil of cloves, oil of peppermint, and oil of wintergreen or corresponding flavorings found in the condiment section of a supermarket
- Equal-sized cubes of foods, such as cheese, apple, dried prunes, banana, and hard-cooked egg white (in an opaque container, such as a foil-lined egg carton)
- Chipped ice
- Absorbent cotton

Objectives
- Describe the structure and function of the accessory visual structures.
- Identify the internal structures of the eye when provided with a model, diagram, or preserved animal eye, and list the functions of each.
- Define blind spot, refraction, hyperopia, myopia, and astigmatism, and discuss image formation on the retina.
- Discuss the importance of the accommodation and convergence reflexes.
- Identify the structures of the external, middle, and internal ear by correctly labeling a diagram.
- Describe the anatomy of the spiral organ and explain its role in hearing.
- Describe how one is able to localize sounds and to differentiate sensorineural from conduction deafness.
- Describe the anatomy of the equilibrium organs of the internal ear, and explain their relative roles in maintaining balance.
- State the purpose of the Romberg test, and describe the role of vision in maintaining equilibrium.
- Describe the location, structure, and function of the olfactory and taste receptors.
- List several factors that influence taste.

In contrast to the small and widely distributed general receptors (touch, temperature, pressure, and pain), the special sense receptors are large, complex sensory organs (eyes and ears) or localized clusters of receptors (taste buds and olfactory epithelium). This chapter focuses on the functional anatomy of each of the special sense organs individually, but keep in mind that sensory inputs are overlapping.

Anatomy of the Eye

Accessory Structures
The adult human eye is a sphere some 2.5 cm (1 inch) in diameter. Only about one-sixth of the eye’s anterior surface is observable (Figure 17.1); the remainder is protected by a cushion of fat and the walls of the bony orbit. The accessory structures of the eye include the eyebrows, eyelids, conjunctivae, lacrimal apparatus, and extrinsic eye muscles (Table 17.1, Figure 17.1 and Figure 17.2).
Figure 17.1 External anatomy of the eye and accessory structures. (a) Lateral view; some structures shown in sagittal section. (b) Anterior view with lacrimal apparatus.

Table 17.1 Accessory Structures of the Eye (Figures 17.1 and 17.2)

<table>
<thead>
<tr>
<th>Structure</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eyebrows</td>
<td>Short hairs located on the supraorbital margins</td>
<td>Shade and prevent sweat from entering the eyes.</td>
</tr>
<tr>
<td>Eyelids (palpebrae)</td>
<td>Skin-covered upper and lower lids, with eyelashes projecting from their free margin</td>
<td>Protect the eyes and spread lacrimal fluid (tears) with blinking.</td>
</tr>
<tr>
<td>Tarsal glands</td>
<td>Modified sebaceous glands embedded in the tarsal plate of the eyelid</td>
<td>Secrete an oily secretion that lubricates the surface of the eye.</td>
</tr>
<tr>
<td>Ciliary glands</td>
<td>Typical sebaceous and modified sweat glands that lie between the eyelash follicles</td>
<td>Secrete an oily secretion that lubricates the surface of the eye and the eyelashes. An infection of a ciliary gland is called a sty.</td>
</tr>
<tr>
<td>Conjunctivae</td>
<td>A clear mucous membrane that lines the eyelids (palpebral conjunctivae) and the anterior white of the eye (bulbar conjunctiva)</td>
<td>Secrete mucus to lubricate the eye. Inflammation of the conjunctiva results in conjunctivitis, (commonly called “pinkeye”).</td>
</tr>
<tr>
<td>Medial and lateral commissures</td>
<td>Junctions where the eyelids meet medially and laterally</td>
<td>Form the corners of the eyes. The medial commissure contains the lacrimal caruncle.</td>
</tr>
<tr>
<td>Lacrimal caruncle</td>
<td>Fleshy reddish elevation that contains sebaceous and sweat glands</td>
<td>Secretes a whitish oily secretion for lubrication of the eye (can dry and form “eye sand”).</td>
</tr>
<tr>
<td>Lacrimal apparatus</td>
<td>Includes the lacrimal gland and a series of ducts that drain the lacrimal fluid into the nasal cavity</td>
<td>Protects the eye by keeping it moist. Blinking spreads the lacrimal fluid.</td>
</tr>
<tr>
<td>Lacrimal gland</td>
<td>Located in the superior and lateral aspect of the orbit of the eye</td>
<td>Secretes lacrimal fluid, which contains mucus, antibodies, and lysozyme.</td>
</tr>
<tr>
<td>Lacrimal puncta</td>
<td>Two tiny openings on the medial margin of each eyelid</td>
<td>Allow lacrimal fluid to drain into the superior and inferiorly located lacrimal canaliculi.</td>
</tr>
<tr>
<td>Lacrimal canaliculi</td>
<td>Two tiny canals that are located in the eyelids</td>
<td>Allow lacrimal fluid to drain into the lacrimal sac.</td>
</tr>
<tr>
<td>Lacrimal sac</td>
<td>A single pouch located in the medial orbital wall</td>
<td>Allows lacrimal fluid to drain into the nasolacrimal duct.</td>
</tr>
<tr>
<td>Nasolacrimal duct</td>
<td>A single tube that empties into the nasal cavity</td>
<td>Allows lacrimal fluid to flow into the nasal cavity.</td>
</tr>
<tr>
<td>Extrinsic eye muscles</td>
<td>Six muscles for each eye; four recti and two oblique muscles (see Figure 17.2)</td>
<td>Control the movement of each eyeball and hold the eyes in the orbits.</td>
</tr>
</tbody>
</table>
Internal Anatomy of the Eye

The eye itself is a hollow sphere. Anatomically, the wall is constructed of three layers: the fibrous layer, the vascular layer, and the inner layer.

Distribution of Photoreceptors

The inner neural layer is composed of three major populations of neurons. There are, from outer to inner aspect, the photoreceptors (rods and cones), the bipolar cells, and the ganglion cells (Figure 17.3). The rods are the specialized photoreceptors for dim light. The cones are color photoreceptors that permit high levels of visual acuity, but they only function under conditions of high light intensity. The photoreceptor cells are distributed over the entire neural retina, except where the optic nerve (the bundled axons of the ganglion cells) leaves the eyeball. This site is called the optic disc, or blind spot (see Figure 17.4). Lateral to each blind spot is the macula lutea (yellow spot), an area of high cone density. In its center is the fovea centralis, a tiny pit that contains only cones and is the area of greatest visual acuity. Focusing for detailed color vision occurs in the fovea centralis.

Internal Chambers and Fluids

The lens divides the eye into two segments. The anterior segment (anterior to the lens) contains a clear, watery fluid called the aqueous humor. The posterior segment behind the lens is filled with the gel-like vitreous humor. The aqueous humor is continually formed by the capillaries of the ciliary process. It helps to maintain the intraocular pressure of the eye and provides nutrients for the avascular lens and cornea. Aqueous humor is drained into the scleral venous sinus, a drainage duct located at the junction of the sclera and cornea. The vitreous humor reinforces the posterior part of the eyeball, and helps to keep the retina pressed firmly against the wall of the eyeball.

Activity 1

Identifying Accessory Eye Structures

Observe the eyes of another student, and identify as many accessory structures as possible. Ask the student to look to the left. Which extrinsic eye muscles produce this action?

Right eye __________________________
Left eye __________________________

Ask your partner to look superiorly. Which two extrinsic muscles of each eye can bring about this motion?

Right eye __________________________
Left eye __________________________

Figure 17.2 Extrinsic muscles of the eye. (a) Lateral view of the right eye. (b) Summary of actions of the extrinsic eye muscles.
Activity 2

Identifying Internal Structures of the Eye

Obtain a dissectible eye model or observe a chart of eye anatomy to identify the structures described below. As you work, refer to Figure 17.4 and Table 17.2.

**Figure 17.4** Internal anatomy of the right eye.
The Cow (Sheep) Eye

1. Obtain a preserved cow or sheep eye, dissecting instruments, and a dissecting tray. Put on disposable gloves.

2. Examine the external surface of the eye, noticing the thick cushion of adipose tissue. Identify the optic nerve as it leaves the eyeball, the cut remnants of the extrinsic eye muscles, the conjunctiva, the sclera, and the cornea. Refer to Figure 17.5 as you work.

3. Trim away most of the fat and connective tissue, but leave the optic nerve intact. Holding the eye with the cornea facing downward, carefully make an incision with a sharp scalpel into the sclera, about ¼ inch above the cornea. Using scissors, cut around the circumference of the eyeball, paralleling the corneal edge.

4. Carefully lift the anterior part of the eyeball away from the posterior portion. Move some of the vitreous humor aside to view the following:

Pigmented choroid coat: Appears iridescent in the cow or sheep eye because of a modification, the tapetum lucidum. This specialized surface reflects the light within the eye and is found in the eyes of animals that live under conditions of dim light. It is not found in humans.

5. Examine the anterior part of the eye, and identify the following structures:

Ciliary body: Black, pigmented body that appears in a halo encircling the lens.

Lens: Biconvex structure that is opaque in preserved specimens.

Ciliary zonule: A halo of delicate fibers attaching the lens to the ciliary body.

Iris: Anterior continuation of the ciliary body penetrated by the pupil.

Cornea: More convex anteriormost portion of the sclera; normally transparent but cloudy in preserved specimens.

6. Examine the posterior portion of the eyeball. Remove the vitreous humor, and identify the following structure:

Retina: Appears as a delicate tan membrane that separates easily from the choroid.

Notice its posterior point of attachment. What is this point called?
Visual Tests and Experiments

**Activity 3**

**Demonstrating the Blind Spot**

1. Hold the blind spot test figure (Figure 17.6) about 18 inches from your eyes. Close your left eye, and focus your right eye on the X, which should be positioned so that it is directly in line with your right eye. Move the figure slowly toward your face, keeping your right eye focused on the X. When the dot focuses on the blind spot, which lacks photoreceptors, it will disappear.

2. Have your laboratory partner record in metric units the distance at which this occurs. The dot will reappear as the figure is moved closer. Distance at which the dot disappears:

   - **Right eye** ________________

   Repeat the test for the left eye. This time, close the right eye and focus the left eye, on the dot. Record the distance at which the X disappears:

   - **Left eye** ________________
Refraction, Visual Acuity, and Astigmatism

When light passes from one substance to another with a different density, its speed changes, and the rays are bent, or refracted. Thus, the light rays are refracted as they encounter the cornea, lens, and vitreous humor of the eye.

The bending power of the cornea and vitreous humor is constant. But the lens’s refractive strength can be varied by changing its shape. The greater the lens convexity, or bulge, the more the light will be bent.

In general, light from a distant source (over 20 feet) approaches the eye as parallel rays, and no change in lens shape is necessary for it to focus properly on the retina. However, light from a close source tends to diverge, and the convexity of the lens must increase to make close vision possible. To achieve this, the ciliary muscle contracts, decreasing the tension of the ciliary zonule attached to the lens and allowing the elastic lens to “round up.” The ability of the eye to focus differentially for close objects (less than 20 feet) is called accommodation.

The image formed on the retina as a result of the light-bending activity of the lens (Figure 17.7) is a real image (reversed from left to right, inverted, and smaller than the object).

Individuals in whom the image normally focuses in front of the retina have myopia, or “nearsightedness”; they can see close objects without difficulty, but distant objects are blurred or indistinct. Correction requires a concave lens, which causes the light reaching the eye to diverge.

If the image focuses behind the retina, the individual has hyperopia, or farsightedness. Such persons have no problems with distant vision but need glasses with convex lenses to boost the converging power of the lens for close vision.

Irregularities in the curvatures of the lens and/or the cornea lead to a blurred vision problem called astigmatism. Cylindrically ground lenses are prescribed to correct the condition.

The elasticity of the lens decreases dramatically with age, resulting in difficulty in focusing for near or close vision, especially when the person is reading. This condition is called presbyopia—literally, “old vision.” Lens elasticity can be tested by measuring the near point of accommodation.

Refraction of light in the eye, resulting in the production of a real image on the retina.

Figure 17.7 Refraction of light in the eye, resulting in the production of a real image on the retina.

Visual acuity, or sharpness of vision, is generally tested with a Snellen eye chart. The distance at which the normal eye can read a line of letters is printed at the end of that line.

Activity 4

Determining Near Point of Accommodation

To determine your near point of accommodation, hold a common straight pin (or other object) at arm’s length in front of one eye. Slowly move the pin toward that eye until the pin image becomes distorted. Have your lab partner use the metric ruler to measure the distance from your eye to the pin at this point, and record the distance. Repeat the procedure for the other eye.

Near point for right eye ______________________
Near point for left eye ________________________

Visual acuity, or sharpness of vision, is generally tested with a Snellen eye chart. The distance at which the normal eye can read a line of letters is printed at the end of that line.

Activity 5

Testing Visual Acuity

1. Have your partner stand 20 feet from the posted Snellen eye chart and cover one eye with a card or hand. As your partner reads each consecutive line aloud, check for accuracy. If this individual wears glasses, give the test twice—first with glasses off and then with glasses on. Do not remove contact lenses, but note that they were in place during the test.

2. Record the number of the line with the smallest-sized letters read. If it is 20/20, the person’s vision for that eye is normal. If it is 20/40, or any ratio with a value less than one, he or she has less than the normal visual acuity. (Such an individual is myopic, so a person with 20/40 vision is seeing objects clearly at 20 feet that a person with normal vision sees clearly at 40 feet.) If the visual acuity ratio is greater than 1, vision is better than normal. Give your partner the number of the line corresponding to the smallest letters read, to record in step 4.

3. Repeat the process for the other eye.

Text continues on next page. ➔
Activity 6

Testing for Astigmatism

The astigmatism chart (Figure 17.8) tests for defects in the refracting surface of the lens and/or cornea.

Figure 17.8 Astigmatism testing chart.

View the chart first with one eye and then with the other, focusing on the center of the chart. If all the radiating lines appear equally dark and distinct, your refracting surfaces are not distorted. If some of the lines are blurred or appear less dark than others, you have at least some degree of astigmatism.

Is astigmatism present in your left eye? __________
Right eye? ________________

Activity 7

Testing for Color Blindness

1. View the color plates in bright light or sunlight while holding them about 30 inches away and at right angles to your line of vision. Report to your laboratory partner what you see in each plate. Take no more than 3 seconds for each decision.

2. Your partner is to write down your responses and then check their accuracy with the correct answers provided in the color plate book. Is there any indication that you have some degree of color blindness?

_________ If so, what type? ___________

Repeat the procedure to test your partner’s color vision.

Eye Reflexes

Both intrinsic (internal) and extrinsic (external) muscles are necessary for proper eye function. The intrinsic muscles, controlled by the autonomic nervous system, are those of the ciliary body (which alters the lens curvature) and the sphincter pupillae and dilator pupillae muscles of the iris (which control pupil size and thus regulate the amount of light entering the eye). The extrinsic muscles are the rectus and oblique muscles, which are attached to the outside of the eyeball (see Figure 17.2). These muscles control eye movement and make it possible to keep moving objects focused on the fovea centralis. They are also responsible for convergence, or medial eye movements, which is essential for near vision. When convergence occurs, both eyes are aimed at the near object viewed. The extrinsic eye muscles are controlled by the somatic nervous system.

Activity 8

Demonstrating Reflex Activity of Intrinsic and Extrinsic Eye Muscles

Activity of both the intrinsic and extrinsic muscle types is brought about by reflex actions that can be observed with simple experiments. The convergence reflex mediated by the extrinsic eye muscles and the accommodation reflex mediated by the intrinsic eye muscles are described here.

Accommodation Pupillary Reflex

Have your partner gaze for approximately 1 minute at a distant object in the lab—not toward the windows or another light source. Observe your partner’s pupils. Then hold some printed material 6 to 10 inches from his or her face, and ask your partner to focus on it.

Color Blindness

Ishihara’s color-blindness plates are designed to test for deficiencies in the cones or color photoreceptor cells. There are three cone types—one type primarily absorbs the red wavelengths of visible light, another the blue wavelengths, and a third the green wavelengths. Nerve impulses reaching the brain from these different photoreceptor types are then interpreted (seen) as red, blue, and green, respectively. The intermediate colors of the visible light spectrum are interpreted as a result of simultaneous input from more than one cone type.
How does pupil size change as your partner focuses on the printed material?

**Convergence Reflex**

Repeat the previous experiment, this time noting the position of your partner’s eyeballs both while he or she is gazing at the distant object and then at the close object (a pen or pencil). Do they change position as the object of focus is changed?

In what way?

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**The Ear and Hearing and Balance**

**Gross Anatomy of the Ear**

The ear, which contains sensory receptors for hearing and equilibrium, is divided into three major areas: the external ear, the middle ear, and the internal ear (Figure 17.9). The external and middle ear structures serve the needs of the sense of hearing only, whereas internal ear structures function both in equilibrium and hearing.

**Activity 9**

**Identifying Structures of the Ear**

Obtain a dissectible ear model, and identify the structures summarized in Table 17.3.

Text continues on next page.
**Table 17.3** Structures of the External, Middle, and Internal Ear (Figure 17.9)

<table>
<thead>
<tr>
<th>External Ear Structure</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auricle (pinna)</td>
<td>Elastic cartilage covered with skin</td>
<td>Collects and directs sound waves into the external acoustic meatus</td>
</tr>
<tr>
<td>Lobule (“earlobe”)</td>
<td>Portion of the auricle that is inferior to the external acoustic meatus</td>
<td>Completes the formation of the auricle</td>
</tr>
<tr>
<td>External acoustic meatus</td>
<td>Short, narrow canal carved into the temporal bone; lined with ceruminous glands</td>
<td>Transmits sound waves from the auricle to the tympanic membrane</td>
</tr>
<tr>
<td>Tympanic membrane (eardrum)</td>
<td>Thin membrane that separates the external ear from the middle ear</td>
<td>Vibrates at exactly the same frequency as the sound wave(s) hitting it and transmits vibrations to the auditory ossicles</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Middle Ear Structure</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malleus (hammer)</td>
<td>Tiny bone shaped like a hammer; its “handle” is attached to the eardrum</td>
<td>Transmits and amplifies vibrations from the tympanic membrane to the incus</td>
</tr>
<tr>
<td>Incus (anvil)</td>
<td>Tiny bone shaped like an anvil that articulates with the malleus and the stapes</td>
<td>Transmits and amplifies vibrations from the malleus to the stapes</td>
</tr>
<tr>
<td>Stapes (stirrup)</td>
<td>Tiny bone shaped like a stirrup; its “base” fits into the oval window</td>
<td>Transmits and amplifies vibrations from the incus to the oval window</td>
</tr>
<tr>
<td>Oval window</td>
<td>Oval-shaped membrane located deep to the stapes</td>
<td>Transmits vibrations from the stapes to the perilymph of the scala vestibuli</td>
</tr>
<tr>
<td>Pharyngotympanic (auditory) tube</td>
<td>A tube that connects the middle ear to the superior portion of the pharynx (throat)</td>
<td>Equalizes the pressure in the middle ear cavity with the external air pressure so that the tympanic membrane can vibrate properly</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Internal Ear Structure</th>
<th>Membranous labyrinth (within the bony labyrinth)</th>
<th>Structure that contains the receptors</th>
<th>Function of the receptors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cochlea</td>
<td>Cochlea duct</td>
<td>Spiral organ</td>
<td>Hearing</td>
</tr>
<tr>
<td>Vestibule</td>
<td>Utricle and saccule</td>
<td>Maculae</td>
<td>Equilibrium: static equilibrium and linear acceleration of the head</td>
</tr>
<tr>
<td>Semicircular canals</td>
<td>Semicircular ducts</td>
<td>Ampullae</td>
<td>Equilibrium: rotational acceleration of the head</td>
</tr>
</tbody>
</table>

**Activity 10**

**Examining the Ear with an Otoscope (Optional)**

1. Obtain an otoscope and two alcohol swabs. Inspect your partner’s ear canal, and then select the speculum with the largest diameter that will fit comfortably into the ear and permit good visibility. Clean the speculum thoroughly with an alcohol swab, and then attach it to the battery-containing otoscope handle. Before beginning, check that the otoscope light beam is strong. If not, obtain another otoscope or new batteries.

2. When you are ready to begin the examination, hold the lighted otoscope securely between your thumb and forefinger (like a pencil), and rest the little finger of your otoscope-holding hand against your partner’s head. This maneuver forms a brace that allows the speculum to move as your partner moves and prevents it from penetrating too deeply into the ear canal during the unexpected movements.

3. Grasp the ear auricle firmly, and pull it up, back, and slightly laterally. If this causes your partner pain or discomfort, the external ear may be inflamed or infected. If this occurs, do not attempt to examine the ear canal.

4. Carefully insert the speculum of the otoscope into the external acoustic meatus in a downward and forward direction just far enough to permit examination of the tympanic membrane. Note its shape, color, and vascular network. The healthy tympanic membrane is pearly white. During the examination, notice whether there is any discharge or redness in the canal, and identify earwax.

5. After the examination, thoroughly clean the speculum with the second alcohol swab before returning the otoscope to the supply area.
The mechanism of hearing begins as sound waves pass through the external acoustic meatus and through the middle ear into the internal ear, where the vibration eventually reaches the spiral organ, which contains the receptors for hearing.

**Microscopic Anatomy of the Spiral Organ**

The snail-like cochlea (Figure 17.9 and Figure 17.10) contains the receptors for hearing. The cochlear membranous labyrinth, the cochlear duct, is a soft wormlike tube about 1.5 inches long that winds through the turns of the cochlea and separates the perilymph-containing cochlear cavity into upper and lower chambers. The upper chamber abuts the oval window, which “seats” the foot plate of the stapes located laterally in the tympanic cavity. The lower chamber is bounded by a membranous area called the round window. The cochlear duct, itself filled with endolymph, supports the spiral organ, which contains the receptors for hearing and nerve endings of the cochlear division of the vestibulocochlear nerve (VIII).

In the spiral organ, the auditory receptors are hair cells that rest on the basilar membrane, which forms the floor of the cochlear duct, and their hairs are stereocilia that project into the gel-like tectorial membrane, overlying them (Figure 17.10b). The roof of the cochlear duct is called the vestribral membrane.

**Activity 12**

**Conducting Laboratory Tests of Hearing**

Perform the following hearing tests in a quiet area.

**Acuity Test**

Have your lab partner pack one ear with cotton and sit quietly with eyes closed. Obtain a ticking clock or pocket watch, and hold it very close to the unpacked ear. Then slowly move the clock or watch away from the ear until your partner signals that the ticking is no longer audible. Record the distance in inches at which ticking is inaudible.

<table>
<thead>
<tr>
<th>Right ear</th>
<th>Left ear</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Is the threshold of audibility sharp or indefinite?

**Sound Localization**

Ask your partner to close both eyes. Hold the pocket watch at an audible distance (about 6 inches) from the ear, and move it to various locations (front, back, sides, and above the head). Have your partner locate the position by pointing in each instance. Can the sound be localized equally well at all positions?

Text continues on next page.
If not, at what position(s) was the sound less easily located?

The ability to localize the source of a sound depends on two factors—the difference in the loudness of the sound reaching each ear and the time of arrival of the sound at each ear. How does this information help to explain your findings?

Weber Test to Determine Conductive and Sensorineural Deafness

Obtain a tuning fork and a rubber mallet. Strike the tuning fork with the rubber mallet, and place the handle of the tuning fork medially on your partner’s head (Figure 17.11a). Is the tone equally loud in both ears, or is it louder in one ear?

If it is equally loud in both ears, your partner has equal hearing or equal loss of hearing in both ears. If sensorineural deafness is present in one ear, the sound will be heard in the unaffected ear, but not in the ear with sensorineural deafness. If conduction deafness is present, the sound will be heard more strongly in the ear in which there is a hearing loss. Conduction deafness can be simulated by plugging one ear with cotton to interfere with the conduction of sound to the internal ear.

Rinne Test for Comparing Bone- and Air-Conduction Hearing

1. Strike the tuning fork, and place its handle on your partner’s mastoid process (Figure 17.11b).

2. When your partner indicates that he or she can no longer hear the sound, hold the still-vibrating prongs close to the acoustic meatus (Figure 17.11c). If your partner hears the fork again (by air conduction) when it is moved to that position, hearing is not impaired. Record the test result as positive (+). (Record below step 4.)

3. Repeat the test, but this time test air-conduction hearing first. After the tone is no longer heard by air conduction, hold the handle of the tuning fork on the bony mastoid process. If your partner hears the tone again by bone conduction after hearing by air conduction is lost, there is some conduction deafness, and the result is recorded as negative (−).

4. Repeat the sequence for the opposite ear.

Right ear __________ Left ear __________

Does the subject hear better by bone or by air conduction?
Anatomy of the Equilibrium Apparatus and Mechanisms of Equilibrium

The equilibrium receptors of the internal ear are collectively called the vestibular apparatus and are found in the vestibule and semicircular canal portions of the bony labyrinth (Figure 17.12). The vestibule contains the saclike utricle and saccule, and the semicircular chambers contain membranous semicircular ducts. Like the cochlear duct, these membranes (1) are suspended in perilymph within the bony chambers, (2) are filled with endolymph, and (3) contain receptor cells that are activated by the disturbance of the hairs on their hair cells.

The semicircular canals house dynamic equilibrium receptors. The canals are about ½ inch in circumference and are oriented in the three planes of space. At the base of each semicircular duct is an enlarged region, the ampulla, which contains a receptor region called a crista ampullaris. This receptor consists of a tuft of hair cells covered with a gelatinous cap, or ampullary cupula (Figure 17.13). These dynamic equilibrium receptors react to changes in angular motion rather than to motion itself (Figure 17.13b and c).

The membranous utricle and saccule within the vestibule contain maculae, static equilibrium receptors that respond to gravitational pull and to linear or straightforward changes in speed. The otolith membrane, a gelatinous material containing small grains of calcium carbonate (otoliths), overrides the hair cells in each macula. As the head moves, the otoliths roll in response to changes in gravitational pull (Figure 17.14). As they bend different hair cells, they modify the rate of impulse transmission along the vestibular nerve.

Figure 17.12 Internal ear. Right membranous labyrinth (blue) shown within the bony labyrinth (tan). The locations of sensory organs for hearing and equilibrium are shown in purple.

Figure 17.13 Structure and function of the crista ampullaris. (a) The semicircular ducts in the semicircular canals each have a swelling called an ampulla at their base. (b) Each ampulla contains a crista ampullaris. (c) Movement of the ampullary cupula during rotational acceleration of the head.
Figure 17.14  The effect of gravitational pull on a macula receptor in the utricle.
When movement of the otolith membrane bends the hair cells in the direction of the kinocilium, the hair cells depolarize, exciting the nerve fibers, which generates action potentials more frequently. When the hair cells are bent in the direction away from the kinocilium, the hair cells become hyperpolarized, inhibiting the nerve fibers and decreasing the action potential frequency.

Activity 13
Conducting Laboratory Tests on Equilibrium

The functions of the semicircular canals and vestibule are not routinely tested in the laboratory, but the following simple tests should serve to illustrate normal equilibrium apparatus functioning.

**Balance Test**

Have your partner walk a straight line, placing one foot directly in front of the other. Is he or she able to walk without noticeable wobbling from side to side?

Did he or she experience any dizziness? ________________

The ability to walk with balance and without dizziness, unless subject to rotational forces, indicates normal function of the equilibrium apparatus.

Was nystagmus* present? ________________

**Romberg Test**

The Romberg test determines the soundness of the dorsal white column of the spinal cord, which transmits impulses to the brain from the proprioceptors involved with posture.

1. Have your partner stand with the back to the blackboard or whiteboard.

2. Draw one line parallel to each side of your partner’s body. He or she should stand erect, with feet together, eyes open and staring straight ahead for 2 minutes while you observe any movements. Did you see any gross swaying movements?

3. Repeat the test. This time the person’s eyes should be closed. Note and record the degree of side-to-side movement.

4. Repeat the test with the person’s eyes first open and then closed. This time, however, your partner should be positioned with the left shoulder toward, but not touching, the board so that you may observe and record the degree of front-to-back swaying.

Do you think the equilibrium apparatus of the internal ear was operating equally well in all these tests? ___________

The proprioceptors? ________________

Why was the observed degree of swaying greater when the eyes were closed? ________________

---

*Nystagmus* is the involuntary rolling of the eyes in any direction or the trailing of the eyes slowly in one direction, followed by their rapid movement in the opposite direction. It is normal after rotation; abnormal otherwise. The direction of nystagmus is that of its quick phase on acceleration.
What conclusions can you draw regarding the factors necessary for maintaining body equilibrium and balance?

Role of Vision in Maintaining Equilibrium

To further demonstrate the role of vision in maintaining equilibrium, perform the following experiment. (Ask your lab partner to record observations and act as a “spotter.”)

Stand erect, with your eyes open. Raise your left foot approximately 1 foot off the floor, and hold it there for 1 minute.

Record the observations: ____________________________

Rest for 1 or 2 minutes; then repeat the experiment with the same foot raised, but with your eyes closed.

Record the observations: ____________________________

The Chemical Senses: Smell and Taste

The receptors for smell (olfaction) and taste (gustation) are classified as chemoreceptors because they respond to chemicals in solution.

Localization and Anatomy of the Olfactory and Taste Receptors

A pseudostratified epithelium called the olfactory epithelium is the organ of smell. It occupies an area lining the roof of each nasal cavity (Figure 17.15 and Plate 18 in the Histology Atlas).

Three cell types are found within the olfactory epithelium:

- **Olfactory sensory neurons**: Specialized receptor cells that are bipolar neurons with nonmotile olfactory cilia.
- **Supporting cells**: Columnar cells that surround and support the olfactory sensory neurons.
- **Olfactory stem cells**: Located near the basal surface of the epithelium, they divide to form new olfactory sensory neurons.

**Figure 17.15 Olfactory receptors.** (a) Site of olfactory epithelium in the superior nasal cavity. (b) An enlarged view of the olfactory epithelium showing the course of the fibers (filaments of the olfactory nerve, through the ethmoid bone). These fibers synapse in the glomeruli of the overlying olfactory bulb. The mitral cells are the output cells of the olfactory bulb.
The axons of the olfactory sensory neurons form small fascicles called the filaments of the olfactory nerve (cranial nerve I), which penetrate the cribriform foramina and synapse in the olfactory bulbs.

The taste buds, containing specific receptors for the sense of taste, are widely distributed in the oral cavity. Most are located on the tongue (as described next). A few are found on the soft palate, pharynx, and inner surface of the cheeks.

The superior tongue surface is covered with small projections, or papillae, of three major types: foliate, fungiform, and vallate papillae. The taste buds are located primarily on the sides of the vallate papillae (arranged in a V-formation on the posterior surface of the tongue) and on the more numerous fungiform papillae. The latter look rather like minute mushrooms and are widely distributed on the tongue (Figure 17.16).

Each taste bud consists largely of an arrangement of two types of modified epithelial cells:

- **Gustatory epithelial cells:** The receptors for taste; they have long microvilli called gustatory hairs that project through the epithelial surface through a taste pore.
- **Basal epithelial cells:** Precursor cells that divide to replace the gustatory epithelial cells.

Several nerve fibers enter each taste bud and supply sensory nerve endings to each of the taste cells. The long gustatory hairs of the receptor cells penetrate the taste pore. When the gustatory hairs are stimulated by specific chemicals in the solution, the taste cells depolarize. The afferent fibers from the taste buds to the gustatory cortex of the brain are carried in three cranial nerves: the facial (VII), glossopharyngeal (IX), and vagus (X) nerves.

When taste is tested with pure chemical compounds, most taste sensations can be grouped into one of five basic qualities—sweet, salty, sour, bitter, and umami (u-mam’ë; “delicious”). Umami is responsible for the “meaty” taste of steak and of foods seasoned with monosodium glutamate.

**Activity 14**

**Identification of Papillae on the Tongue**

Use a mirror to examine your tongue. Can you pick out the various types of papillae? If so, which?
Laboratory Experiments

Activity 15

Stimulating Taste Buds
1. Obtain several paper towels and a disposable autoclave bag, and bring them to your bench.
2. With a paper towel, dry the superior surface of your tongue.
   ! Immediately dispose of the paper towel in the autoclave bag.
3. Place a few sugar crystals on your dried tongue. Do not close your mouth. How long does it take to taste the sugar? ________________ sec

Why couldn’t you taste the sugar immediately?

Activity 16

Examining the Combined Effects of Smell, Texture, and Temperature on Taste

Effects of Smell and Texture
1. Ask your partner to sit with eyes closed and to pinch the nostrils shut.
2. Using a paper plate, obtain samples of the food items listed in the chart. Do not let the person see the foods being tested.
3. Use an out-of-sequence order of food testing. For each test, place a cube of food in your partner’s mouth, and ask him or her to identify the food by using the following sequence of activities:
   • First, move the food around in the mouth with the tongue.
   • Second, chew the food.
   • Third, if the person cannot make a positive identification with the first two techniques and the taste sense, ask him or her to release the pinched nostrils and to continue chewing with the nostrils open to see whether a positive identification can be made.

Record the results on the Activity 16 chart by checking the appropriate column.

Was the sense of smell equally important in all cases?

Effect of Olfactory Stimulation
There is no question that what is commonly called taste depends heavily on the sense of smell, particularly in the case of strongly scented substances. The following experiments should illustrate this fact.
1. Obtain paper cups; vials of oil of wintergreen, peppermint, and cloves; and some fresh cotton-tipped swabs. Ask your partner to sit so that he or she cannot see which vial is being used, and to dry the tongue and pinch the nostrils shut.
2. Apply a drop of one of the oils to the subject’s tongue. Can he or she distinguish the flavor?

3. Have your partner open the nostrils. Record the change in sensation he or she reports.

Activity 16: Method of Identification

<table>
<thead>
<tr>
<th>Food</th>
<th>Texture only</th>
<th>Chewing with nostrils pinched</th>
<th>Chewing with nostrils open</th>
<th>Identification not made</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Text continues on next page.
<table>
<thead>
<tr>
<th>Exercise 17</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4.</strong> Have your partner rinse the mouth well with water and dry the tongue.</td>
</tr>
<tr>
<td><strong>5.</strong> Prepare two swabs, each with one of the two remaining oils.</td>
</tr>
<tr>
<td><strong>6.</strong> Hold one swab under your partner’s open nostrils while touching the second swab to the tongue. Record the reported sensations.</td>
</tr>
</tbody>
</table>

Which sense, taste or smell, appears to be more important in properly identifying a strongly flavored volatile substance?

---

**Effect of Temperature**

In addition to the role that olfaction and food texture play in determining our taste sensations, the temperature of foods also helps determine whether we can appreciate or even taste the food. To illustrate this, have your partner hold some chipped ice on the tongue for approximately 1 minute and then close the eyes. Immediately place any of the foods previously identified in the mouth, and ask for an identification.

Results?

---

Dispose of the used swabs and paper towels in the autoclave bag before continuing.
The Eye and Vision: Anatomy

1. Several accessory eye structures contribute to the formation of tears and/or help lubricate the eyeball. Match the described accessory structures with their secretion by choosing answers from the key.

   Key: conjunctivae lacrimal glands tarsal glands

   _______ 1. mucus
   _______ 2. oil
   _______ 3. lysozyme

2. The eyeball is wrapped in adipose tissue within the orbit. What is the function of the adipose tissue?

   _________________________________________________________________

3. Why may it be necessary to blow your nose after having a good cry?

   _________________________________________________________________

4. What is a sty? 

   _________________________________________________________________

   Conjunctivitis?

   _________________________________________________________________

5. What seven bones form the bony orbit? (Think! If you can’t remember, check a skull or your textbook.)

   _________________________________________________________________

   _________________________________________________________________

   _________________________________________________________________
6. Identify the lettered structures on the diagram by matching each letter with one of the terms to the right.

- anterior chamber
- anterior segment
- bipolar cells
- choroid
- ciliary muscle
- ciliary process
- ciliary zonule
- cornea
- dura mater
- fovea centralis
- ganglion cells
- iris
- lens
- optic disc
- optic nerve
- photoreceptors
- posterior chamber
- retina
- sclera
- scleral venous sinus
- vitreous body in posterior segment

Notice the arrows drawn close to the left side of the iris in the diagram above. What do they indicate?
7. Match the key responses with the descriptive statements that follow.

<table>
<thead>
<tr>
<th>Key:</th>
<th>aqueous humor</th>
<th>cornea</th>
<th>lens</th>
<th>sclera</th>
<th>choroid</th>
<th>fovea centralis</th>
<th>optic disc</th>
<th>retina</th>
<th>scleral venous sinus</th>
<th>ciliary zonule</th>
<th>iris</th>
<th>vitreous humor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>attaches the lens to the ciliary body</td>
<td>2.</td>
<td>fluid filling the anterior segment of the eye</td>
<td>3.</td>
<td>the blind spot</td>
<td>4.</td>
<td>contains muscle that controls the size of the pupil</td>
<td>5.</td>
<td>drains the aqueous humor from the eye</td>
<td>6.</td>
<td>layer containing the rods and cones</td>
<td>7.</td>
</tr>
</tbody>
</table>

8. The intrinsic eye muscles are under the control of which of the following? (Circle the correct response.)

- autonomic nervous system
- somatic nervous system

Dissection of the Cow (Sheep) Eye

9. What modification of the choroid that is not present in humans is found in the cow eye? __________________________

What is its function? ____________________________________________________________________________________________

10. Describe the appearance of the retina. ________________________________________________________________________

At what point is it attached to the posterior aspect of the eyeball? ________________________________________________

Visual Tests and Experiments

11. Use terms from the key to complete the statements concerning near and distance vision. (Some terms may be used more than once.)

Key: contracted decreased increased loose relaxed taut

During distance vision: The ciliary muscle is ________, the ciliary zonule is ________, the convexity of the lens is ________, and light refraction is _________. During close vision: The ciliary muscle is __________, the ciliary zonule is __________, lens convexity is __________, and light refraction is __________.

12. Explain why the part of the image hitting the blind spot is not seen. _____________________________________________
13. Match the terms in column B with the descriptions in column A:

<table>
<thead>
<tr>
<th>Column A</th>
<th>Column B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. light bending</td>
<td>accommodation</td>
</tr>
<tr>
<td>2. ability to focus for close (under 20 ft) vision</td>
<td>astigmatism</td>
</tr>
<tr>
<td>3. normal vision</td>
<td>convergence</td>
</tr>
<tr>
<td>4. inability to focus well on close objects (farsightedness)</td>
<td>emmetropia</td>
</tr>
<tr>
<td>5. nearsightedness</td>
<td>hyperopia</td>
</tr>
<tr>
<td>6. blurred vision due to unequal curvatures of the lens or cornea</td>
<td>myopia</td>
</tr>
<tr>
<td>7. medial movement of the eyes during focusing on close objects</td>
<td>refraction</td>
</tr>
</tbody>
</table>

14. Record your Snellen eye test results below:

Left eye (without glasses) ____________________________ (with glasses) ____________________________

Right eye (without glasses) ____________________________ (with glasses) ____________________________

Is your visual acuity normal, less than normal, or better than normal? ____________________________

Explain. __________________________________________

Explain why the examiner tests each eye separately when using the Snellen eye chart. ________________

Explain 20/40 vision. ____________________________

Explain 20/10 vision. ____________________________

15. Define astigmatism: ____________________________

16. Record the distance of your near point of accommodation as tested in the laboratory:

right eye ____________________________ left eye ____________________________

Is your near point within the normal range for your age? ____________________________

17. How can you explain the fact that we see a great range of colors even though only three cone types exist? ____________________________
18. In the experiment on the convergence reflex, what happened to the position of the eyeballs as the object was moved closer to the subject’s eyes? _______________________________________________________________________________________

Which extrinsic eye muscles control the movement of the eyes during this reflex? ___________________________________________

What is the value of this reflex? _______________________________________________________________________________________

If these muscles were unable to function, what would be the visual result? _____________________________________________

19. Many college students struggling through mountainous reading assignments are told that they need glasses for “eyestrain.” Why is looking at close objects more of a strain on the extrinsic and intrinsic eye muscles than looking at far objects?

________________________________________________________________________________________

________________________________________________________________________________________

The Ear and Hearing and Balance: Anatomy

20. Select the terms from column B that apply to the column A descriptions. (Some terms are not used, and others are used more than once.)

<table>
<thead>
<tr>
<th>Column A</th>
<th>Column B</th>
</tr>
</thead>
<tbody>
<tr>
<td>__________ 1. collectively called the auditory ossicles</td>
<td>auricle</td>
</tr>
<tr>
<td>__________ 2. ear structures involved with balance</td>
<td>cochlea</td>
</tr>
<tr>
<td>__________ 3. transmits sound vibrations to the auditory ossicles</td>
<td>endolymph</td>
</tr>
<tr>
<td>__________ 4. three circular passages, each in a different plane of space</td>
<td>external acoustic meatus</td>
</tr>
<tr>
<td>__________ 5. transmits the vibratory motion of the stapes to the fluid in the ear</td>
<td>incus</td>
</tr>
<tr>
<td>__________ 6. passage between the throat and the tympanic cavity</td>
<td>malleus</td>
</tr>
<tr>
<td>__________ 7. fluid contained within the membranous labyrinth</td>
<td>oval window</td>
</tr>
<tr>
<td></td>
<td>perilymph</td>
</tr>
<tr>
<td></td>
<td>pharyngotympanic (auditory) tube</td>
</tr>
<tr>
<td></td>
<td>round window</td>
</tr>
<tr>
<td></td>
<td>semicircular canals</td>
</tr>
<tr>
<td></td>
<td>stapes</td>
</tr>
<tr>
<td></td>
<td>tympanic membrane</td>
</tr>
<tr>
<td></td>
<td>vestibule</td>
</tr>
</tbody>
</table>
21. Identify all indicated structures and ear regions that are provided with leader lines or brackets in the following diagram.

22. Match the membranous labyrinth structures listed in column B with the descriptive statements in column A. (Some terms are used more than once.)

<table>
<thead>
<tr>
<th>Column A</th>
<th>Column B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>contains the spiral organ</td>
</tr>
<tr>
<td>2.</td>
<td>sites of the maculae</td>
</tr>
<tr>
<td>3.</td>
<td>hair cells of the spiral organ rest on this membrane</td>
</tr>
<tr>
<td>4.</td>
<td>gel-like membrane overlying the hair cells of the spiral organ</td>
</tr>
<tr>
<td>5.</td>
<td>contains the cristae ampullaris</td>
</tr>
<tr>
<td>6.</td>
<td>carries equilibrium information to the brain</td>
</tr>
<tr>
<td>7.</td>
<td>three internal ear structures oriented in the three planes of space</td>
</tr>
<tr>
<td>8.</td>
<td>carries auditory information to the brain</td>
</tr>
<tr>
<td>9.</td>
<td>gelatinous cap overlying hair cells of the crista ampullaris</td>
</tr>
<tr>
<td>10.</td>
<td>grains of calcium carbonate in the maculae</td>
</tr>
</tbody>
</table>
23. Describe how sounds of different frequency (pitch) are differentiated in the cochlea. ____________________________

24. Explain the role of the endolymph of the semicircular canals in activating the receptors during angular motion. ____________________________

25. Explain the role of the otoliths in perception of static equilibrium (head position). ____________________________

Hearing and Balance Tests
26. Was the hearing acuity measurement made during the experiment (page 205) the same or different for both ears? ____________________________ What factors might account for a difference in the acuity of the two ears? ____________________________

27. During the sound localization experiment (page 205), in which position(s) was the sound least easily located? ____________________________

How can you explain this observation? ____________________________

28. When the tuning fork handle was pressed to your forehead during the Weber test, where did the sound seem to originate? ____________________________

Where did it seem to originate when one ear was plugged with cotton? ____________________________

How do sound waves reach the cochlea when conduction deafness is present? ____________________________

29. The Rinne test evaluates an individual's ability to hear sounds conducted by air or bone. Which is typical of normal hearing? ____________________________

30. Define nystagmus: ____________________________
31. What is the usual reason for conducting the Romberg test? (Use your textbook if necessary.)

Was the degree of sway greater with the eyes open or closed? 

Why?

32. Normal balance, or equilibrium, depends on input from a number of sensory receptors. Name them.

Chemical Senses: Localization and Anatomy of Olfactory and Taste Receptors

33. Describe the cellular makeup and the location of the olfactory epithelium.

34. Name five sites where receptors for taste are found, and circle the predominant site: 

35. Describe the cellular makeup and arrangement of a taste bud. (Use a diagram, if helpful.)

Taste and Smell Experiments

36. Taste and smell receptors are both classified as because they both respond to

37. Why is it impossible to taste substances if your tongue is dry?

38. Explain why a cold, greasy hamburger is unappetizing to most people.

39. How palatable is food when you have a cold? Explain.