16  Sense Organs

Objectives
In this chapter we will study
• methods used to test the function of the general senses;
• the classification, treatment, and management of pain;
• methods used to test the special senses of hearing and vision;
• some treatments for deafness; and
• conjunctivitis and retinitis pigmentosa.

Investigating Disorders of the Senses
The general senses (also called the somesthetic senses) function through sensors that are widely distributed in the body rather than limited to specific localities. These receptors in the skin, muscles, tendons, joint capsules, and viscera detect touch, pressure, strength, heat, cold, and pain. The special senses are vision, hearing, equilibrium, taste, and smell. Their receptors are located only in the head, where they are innervated by the cranial nerves.

Investigating sensory disorders requires an understanding of the relationship between the sensory systems and the central nervous system. By examining the interactions among the sensory receptors, sensory nerves, ascending pathways, brain nuclei, and regions of the cerebral cortex, a clinician should be able to determine the location of a disorder and suggest a course of action.

The General Senses
Testing the General Senses
The general senses are typically tested during a neurological examination. Some of the methods of testing them are briefly described here:

• Light touch  The sense of light touch can be tested by touching various regions of the body with a few fibers teased from a cotton ball. It is important not to drag the cotton wisp across the skin because this induces the sensation of tickle rather than touch. The patient should be able to feel at least 18 of 20 touches on any area of skin.

• Superficial pain  The examiner touches the skin in several regions with both the point and the head of a common pin, asking the patient, “Is this sharp or dull? Does this feel the same as the previous touch?” and so forth.

• Temperature  A patient’s ability to detect heat and cold is tested by touching the skin with dry test tubes filled with hot and cold tap water. Thermoreceptors respond slowly, so the test tube must be held against the skin for at least 2 seconds at each spot tested. The examiner asks the patient whether the stimulus feels “as hot” or “as cold” in an area of suspected dysfunction as it feels in a normal area.

• Vibration  To test the vibration sense, the clinician touches the skin with the handle of a vibrating tuning fork and asks the patient to report whether he or she feels the vibration and when it stops. A little teaching is needed before the test to ensure that the patient can discern the difference between the vibration and the pressure of the tuning fork and between a vibrating and a nonvibrating tuning fork. (The latter is tested by placing the tuning fork on the jaw or sternum.) Then the clinician can test other areas of the body. The vibration of the tuning fork gets weaker with time, and the patient is typically asked whether he or she senses the vibration initially and when it stops.

• Proprioception  To test the patient’s knowledge of the movement of the joints, the clinician moves the terminal phalanges of the patient’s hands and feet up and down while the patient’s eyes are closed and asks the patient to identify which way the joint is being moved. Some neuropathies affect the distal parts of a nerve more than its more proximal regions. Therefore, if a patient fails to feel the movement
of a distal joint, more proximal joints are tested to assess the extent of the nerve damage.

- **Equilibrium (balance)** Lesions of the vestibular apparatus of the inner ear, the vestibulocochlear nerve, the cerebellum, and other parts of the nervous system can affect a person’s ability to maintain balance or execute smooth movements. Since people tend to visually compensate for and maintain their balance by viewing their surroundings, it is necessary to eliminate the visual component when testing for sensory, nerve, or CNS lesions. One way of doing this is the Romberg test. The patient is asked to stand with his or her feet as close together as possible, as long as he or she feels stable and comfortable, and then to close the eyes. Patients with a defective sense of balance lose their balance and do not merely teeter a little (which is normal), but fall to one side when they close their eyes.

When testing the skin senses, it is important to vary the timing and placement of stimuli so that the patient cannot predict when or where the next stimulus will occur. Most patients fail to feel some stimuli and imagine others when no stimulus has been applied. Skillful questioning is also necessary to elicit the most helpful responses from the patient.

The clinician looks for unusually high or low sensitivity, differences in sensitivity between one side of the body and the other, and differences from one dermatome to another. The distribution of any abnormalities helps distinguish lesions of the brain, spinal cord, and peripheral nerves.

**Diagnosing and Managing Pain**

Treatment for pain depends first on its proper diagnosis and classification. There are several ways to classify pain. One system is somatogenic versus psychogenic pain. Somatogenic pain has a physical cause, such as a twisted ankle or laceration, while psychogenic pain has a psychological cause. It is important to remember that psychogenic pain is no less “real” to the patient and requires appropriate treatment. In many cases, pain has a mixture of somatogenic and psychogenic causes—that is, we are often prone to think that an injury hurts more than it “really does,” and the level of pain we experience is often a matter of attitude.

Pain is also classified as either acute or chronic according to its duration. Acute pain is usually short-lived and serves as a protective mechanism, alerting the body to damage. It has a sudden onset and is relieved fairly readily by taking analgesics or removing the stimulus. Chronic pain is usually of extended duration (longer than 3 months). Its cause is often unknown, and it is therefore more difficult to treat.

The body responds differently to acute and chronic pain. Acute pain stimulates autonomic responses such as increased heart and respiratory rates, blood pressure, and blood glucose concentration, dilation of the pupils, and decreased gastrointestinal secretion and motility. In effect, the body is responding to actual or potential tissue injury in such a way as to restore homeostasis. Chronic pain produces fewer obvious physiological effects because, over the long run, the body adapts to it and maintains homeostasis. Chronic pain does, however, produce significant psychological and behavioral changes, such as depression, insomnia, anorexia, preoccupation with the pain, and feelings of helplessness. Patients experiencing chronic pain may exhibit adaptive behaviors in an attempt to alleviate the pain or to maintain a “normal” appearance to others. Some individuals tend to not report the pain or even to deny it. Neglect of the underlying cause can then make the pain grow more severe.

The point at which an individual perceives a stimulus as painful is the pain threshold. In general, there is not a large degree of variation in the pain threshold among individuals or within the same person over time. The subjective intensity of pain, or the length of time an individual can endure it before responding noticeably, is pain tolerance. A great degree of variation in pain tolerance exists among individuals and within the same individual over time. Several factors affect a person’s pain tolerance, including physical and mental state, cultural background, gender role, age, and expectations. In general, pain tolerance is decreased by fatigue, anger, apprehension, boredom, and repeated exposure to pain. It is increased by medication, alcohol, hypnosis, warmth, distracting activities, and strong beliefs or faith.

Infants cannot articulate their pain as a child or adult can, but they do show stereotyped responses that indicate they are in pain: brows drawn together
and lowered, vertical furrows in the forehead, bulges between the brows, tightly closed eyes, raised cheeks, a bulging, broadened nose, quivering chin, and an open, squarish mouth. The blood pressure, heart rate, and respiratory rate are elevated, and the infant may sweat and appear flushed.

In evaluating patients who complain of either acute or chronic pain, the clinician first obtains a detailed history of the pain—its severity, location, duration, course, timing, factors causing it to worsen or ease, drug use (either for pain relief or other reasons), and any other associated symptoms (for example, psychological state). The patient’s level of function is also determined. A physical examination is completed to identify whether any underlying causes exist and to determine the need for laboratory tests. Based on these results, the clinician decides on a course of action to manage the pain.

Pain management varies considerably from patient to patient and may include analgesics, physical therapy, rest, or surgery. For some patients, psychogenic pain can be alleviated with placebos, hypnosis, or biofeedback.

The Special Senses

Hearing

Deafness is any partial or complete loss of hearing. There are many types of deafness, but they all fall into the two categories of conductive deafness and sensorineural deafness. Conductive deafness results from the inability to transfer vibrations through the auditory canal and middle-ear ossicles to the inner ear. Its causes range from impacted earwax to otosclerosis, a pathological calcification of the middle-ear ossicles that “freezes” them so that they cannot vibrate freely. Sensorineural deafness (formerly called nerve deafness) results from defects in the cochlea, vestibulocochlear nerve, or CNS. The most common cause is cochlear damage resulting from exposure to loud noise; this condition is frequently seen in musicians (especially those who play in bands with amplified music and in symphony orchestras), people who listen to excessively loud recorded music, machinery operators, and people who use firearms without ear protection.

The two forms of deafness can be distinguished from each other by a variety of hearing tests.

Hearing Tests As a preliminary assessment of a patient’s hearing, an examiner may ask if the patient can hear on the telephone through both ears. Another method is conducted in a quiet examination room by standing 6 feet to one side of the patient and asking him or her to put a finger in the opposite ear and try to repeat a series of numbers that the examiner whispers. A normal person should be able to repeat at least 9 out of 10 numbers.

If a hearing deficiency is reported or observed, it is important to determine whether the cause is conductive or sensorineural. This can be done with the Rinne test. The clinician strikes a tuning fork and holds the stem against the mastoid process behind the patient’s ear. The patient normally hears a vibration because of bone conduction—that is, the tuning fork vibrates the skull, and this stimulates the cochlea. When the patient no longer hears it, the examiner immediately holds the tuning fork (still faintly vibrating) next to the patient’s auditory meatus. People with normal hearing or partial sensorineural deafness again hear the hum because air conduction is more efficient than bone conduction. But in people with conductive deafness, the airborne sound disappears more quickly than the bone-conducted sound, so by the time the tuning fork is moved from the mastoid process to the auditory meatus, the vibration is too faint for the patient to hear.

Audiometry is a more precise measure of the type and degree of hearing loss. The patient listens with headphones to an electronic device called an audiometer that plays pure tones of specific frequencies and volumes. The audiometrist measures the volume (loudness) required for the patient to hear pure tones ranging from about 250 to 8,000 Hz and charts an audiogram showing the degree of hearing loss versus the sound frequency.

Auditory brainstem responses can be used to test hearing in patients who cannot or will not report whether they hear a sound, such as comatose patients, infants, and people feigning deafness. An electroencephalogram is recorded while the patient is given an auditory stimulus. If the ear, vestibulocochlear nerve, brainstem, and auditory cortex are functioning properly, the EEG shows characteristic responses to sounds.

Correcting Deafness Hearing aids can benefit some patients with conductive or sensorineural deafness, depending on the degree of hearing loss and the frequency range in which the loss exists. Several types of hearing aids are available, with
different benefits and drawbacks for different kinds of patients. Patients can also benefit from training in **speech reading** (lip reading) provided by speech pathologists associated with audiologists. Some people with hearing loss too profound to be helped by hearing aids can benefit from a **cochlear implant**. This is an electronic device implanted beneath the skin behind the ear, with electrodes that lead to the cochlear nerve. The implant detects sound and randomly stimulates cochlear nerve fibers. The resulting sensation does not resemble normal hearing, but patients can learn to associate the frequency responses they hear with the origin and relevance of a sound. It aids in distinguishing the rhythm of speech, when words begin and end, and other speech qualities that, combined with speech reading, can make conversation intelligible. A cochlear implant also helps deaf persons hear important environmental noises such as alarms and car horns.

**Vision**

Our ability to see relies on the structures of the eyes as well as various components of the central, somatic, and autonomic nervous systems. Thus, a vision examination can provide information about not only the eyes but also the thalamus, visual cortex, brainstem, cerebellum, autonomic nervous system, and cranial nerves.

**Eye Examinations**

Because the eye, its accessory organs, and the visual process are so complex, a comprehensive eye examination involves more tests and observations than does any other sensory examination. Following are the major tests and observations and some of the ways they can aid diagnosis.

- **External anatomy of the ocular region**
  
The eyebrows, eyelashes, underlying skin, and eyelids are examined for the quantity and distribution of hair, scaliness of the skin, edema of the eyelids, adequacy of eye closure, and other properties. Certain abnormalities can indicate hypothyroidism, seborrheic dermatitis, and other pathologies. Drooping eyelids (ptosis) may indicate an oculomotor nerve lesion or myasthenia gravis. The lacrimal apparatus and degree of eye moisture are also observed. Abnormalities can indicate conjunctival inflammation or obstruction of the nasolacrimal duct. The conjunctiva and sclera are examined by having the patient look up while the examiner depresses the lower eyelids looking for signs of inflammation (redness), jaundice (yellowness), and other abnormalities. The general position and alignment of the eyes are noted. Bulging eyes (exophthalmos) are a sign of hyperthyroidism (Graves disease).

- **Cornea, lens, iris, and pupil**
  
The cornea and lens are examined for clarity. Grayish-white scars in the cornea are signs of old eye injuries and inflammation. Clouding of the lens is known as **cataracts**, a condition frequently seen in elderly people. The iris should be flat and exhibit clearly defined markings. A rounded iris, which casts a shadow when illuminated from one side, can be a warning sign of glaucoma. Slight inequality of the pupils is common, but inequalities of more than 0.5 mm diameter and defective pupillary responses to light may indicate glaucoma, oculomotor nerve dysfunction, or other disorders.

- **Intraocular pressure**
  
Glaucoma is caused by a rise in intraocular pressure. Even people who do not need corrective lenses or a change in lens prescription should have periodic eye exams that include measurement of intraocular pressure. This is done with an instrument called a **tonometer**. The tonometer shines a small beam of light on the eye and tracks its movement as (in one design) a puff of air is blown on the eye. The greater the intraocular pressure, the more the eye resists indentation by the puff of air, and the less deflection of the light beam is recorded.

- **Eye movements**
  
The examiner asks the patient to visually follow a moving object, such as a finger or pencil, through an H-shaped pattern—to the extreme right, up and down on the right, to the extreme left, and up and down on the left—and then observes the convergence of the eyes as the object is moved toward the patient’s nose. This tests the extraocular muscles and the nerves that control eye movements—the oculomotor, trochlear, and abducens. A rhythmic oscillation or flickering of one or both eyes, called **nystagmus**, can indicate lesions of the vestibular apparatus or brainstem or result from the abuse of alcohol and other drugs. **Strabismus**, in which one eye looks in a
- different direction than the other, indicates weakness of one or more extraocular muscles.

**Visual acuity**  Visual acuity—the ability to see clear images—is usually tested with a *Snellen eye chart* mounted on a wall. Normally, the patient should be 20 feet from the chart, cover one eye, and read the smallest possible line of print with the other eye. Visual acuity is expressed as a ratio of two numbers, such as 20/30. An acuity of 20/30 means that with that eye, the patient can read print from a distance of 20 feet that a normal person can read at 30 feet. Each eye has its own acuity, so a person’s vision could be 20/30 in one eye and 20/40 in the other. In the United States, a person is considered legally blind if, with corrective lenses, he or she has a visual acuity of no better than 20/200 in either eye.

**Visual field**  The *visual field* is the area in space that a person can see without moving the head. To evaluate a patient’s visual field, the examiner can hold his or her arms outstretched to each side of the patient’s head, and slowly bring them forward while wiggling the fingers, following an arc as if tracing the surface of a glass bowl in front of the patient’s face. The patient is told to indicate when he or she first sees the examiner’s fingers in the peripheral vision. If a defect is noticed, the examiner uses more refined tests to identify the area and extent of the defect. Another U.S. definition of legal blindness is that neither eye can see a visual field of more than 20º. Field defects in vision include blindness in the right or left half of the visual field of one or both eyes (*homonymous hemianopsia*), blindness in the lateral half of the field in both eyes (*bitemporal hemianopsia*), blindness in one-quarter of the visual field (*quadrantic defects*), and patches of blindness surrounded by areas of normal vision (*scotomas*). Field defects can be caused by lesions of the retina, optic nerve, optic chiasm, optic tract, and optic radiations of the brain. A lesion in each of these locations produces its own characteristic field defect.

**Ophthalmoscopic examination**  A comprehensive eye examination also includes a visual inspection of the interior of the eye, using an illuminating, magnifying instrument called an *ophthalmoscope*. The retina appears as a red-orange circle. Toward the medial (nasal) side is the *optic disc*, the head of the optic nerve. It is much paler than the rest of the retina, with a pink to yellow-orange color, and has an array of retinal arteries and veins converging on it. At the center of the retina is a darker red patch, the *macula*, with a yellow-white depression, the *fovea centralis*, which is our area of sharpest vision. The examiner inspects the size, color, and shape of the optic disc and the health of the retinal arteries and veins, looking for pathologies such as cloudiness in the lens and vitreous body, hemorrhages or lesions of the retina, and retinal wrinkling or detachment. Hypertension and diabetes mellitus are among several diseases that can be detected in part by ophthalmoscopic examination.

**Eye Disorders**

Conjunctivitis is inflammation of the conjunctiva resulting from allergies, viruses, and bacteria. It is characterized by hyperemia (abnormally increased blood flow) of the eye and eyelids, redness of the conjunctiva, burning pain, and discharge. The discharge is usually cultured to determine the causative agent. Conjunctivitis is readily spread by contact, so it is important that the patient follow hygienic practices such as not sharing towels with other people. Treatment most often involves removing any irritating agent, keeping the eyes free of discharge, and applying antibiotic eyedrops.

Retinitis pigmentosa (RP) is a bilateral degeneration of the retina. It is an untreatable hereditary disorder that results in the progressive loss of night vision and peripheral vision, thus progressively narrowing the central visual field. Ophthalmoscopic examination shows a waxy, pale optic disc, constriction of the peripheral retinal blood vessels, and black “spicules” of pigment clustered around the vessels. The patient experiences ringlike or arclike scotomas encircling the central vision. The disease often appears early in childhood. Autosomal recessive, autosomal dominant, and X-linked forms of RP are known.
Roger, age 40, goes to his doctor for a regular physical examination. In the course of the interview, the doctor asks him if his hearing is okay. Roger says that his wife sometimes accuses him of being “half deaf” because he turns the stereo and television up louder than she likes it. He also says has been late for work a few times because he didn't hear the high-pitched beeping of his alarm clock, so he bought a clock radio and set it to wake him up to music instead. The doctor examines Roger’s ears but sees no impacted cerumen or other abnormalities. He asks if Roger would like to be referred to an otolaryngologist, and Roger agrees that it would be a good idea to have his hearing checked more thoroughly.

The otolaryngologist tells Roger that his receptionist will make an appointment for him to see an audiologist, but says that he can do a few simple tests in the meantime. Roger tells him the same things he told his regular doctor, but adds that he often finds it difficult to make out a person’s words—for example, when watching television or at the theater—making it hard for him to follow the plot of a movie. He says that he can still hear telephone conversations with both ears, however. Roger says that he has liked his music loud ever since college and often plays his car stereo loud and with heavy bass amplification. He also likes to go to drag races three or four times a year. The otolaryngologist asks if Roger has ever worked in a loud environment such as a factory, ever used firearms without ear protection, ever served in combat, and other questions—to all of which Roger answers no. To other questions, however, he answers yes: He had frequent middle-ear infections when he was a child, and he had mumps when he was 8 years old—conditions that can cause hearing loss.

The doctor performs a Rinne tuning fork test. With the tuning fork against his mastoid process, Roger hears the hum for 16 seconds in the left ear and 18 seconds in the right ear (bone conduction times). With the tuning fork then moved in front of the auditory meatus, Roger hears the hum for an additional 12 seconds with both ears (air conduction time). The doctor remarks that this suggests a sensorineural hearing loss, not a conductive hearing loss.

Roger sees the audiologist the following week. The audiometer plays pure tones at selected intensities and frequencies from 250 to 8,000 Hz. At frequencies from 300 to 3,000 Hz, the range of most conversation, Roger has a hearing loss in both ears ranging from 40 to 60 decibels (db). Specialized audimetric tests that distinguish bone conduction from air conduction confirm that Roger has sensorineural deafness rather than conductive deafness. The otolaryngologist tells Roger that his earlier middle-ear infections probably haven’t affected his hearing. His mumps could have something to do with it, but more likely, the loss is a result of inner-ear damage from the loud music. He advises Roger that he must be more careful to protect his hearing, and that if his hearing loss is too troublesome, he may want to consider a hearing aid and training in speech reading so that he will be able to better understand movies, conversations, and so forth.

Based on this case study and other information in this chapter, answer the following questions.

1. Suppose Roger had been a hunter and regularly used a shotgun without using ear protection. Which type of hearing loss—conductive or sensorineural—would most likely result from this activity?

2. Why did the otolaryngologist not suggest cochlear implants for Roger?

3. Suppose that at 2,000 Hz, Roger has a 50-db hearing loss in his left ear. How many times louder must a 2,000-Hz tone be for Roger to hear it than it would for a person with perfect hearing to hear it?

4. Why does the otolaryngologist conclude that Roger’s childhood middle-ear infections are not responsible for his hearing loss?

5. Suppose the doctor had held the tuning fork in front of Roger’s auditory meatus until Roger could no longer hear it, and then held the stem of the tuning fork against Roger’s mastoid process. How long do you think Roger would be able to hear it after it was moved?
6. If you were testing a drug for its analgesic effect, why would measuring the change in the patient’s pain threshold be more relevant than measuring the change in the patient’s pain tolerance?

7. Which of the following would not suggest conductive deafness?
   a. inability to hear your own words
   b. wax accumulation in the ears
   c. inability to hear softly spoken words
   d. inability to hear the bass in a musical piece
   e. inability to hear well after swimming

8. If conjunctivitis were left untreated, what part of the eye do you think would be affected next?

9. Do you think retinitis pigmentosa has an earlier and more serious effect on rod cells or on cone cells? Explain your answer.

10. Why would it be important not to let a patient watch your procedures if you were testing his or her general senses such as touch, pain, and proprioception?

### Selected Clinical Terms

- **audiometer**: An electronic device that produces pure tones of selected frequencies and volumes for the purpose of testing the threshold of hearing over a range of 250 to 8,000 Hz.

- **conductive deafness**: Hearing loss resulting from any failure to transmit sound vibrations to the inner ear, for example due to an obstructed auditory canal or abnormal ossification of the joints between the auditory ossicles.

- **conjunctivitis**: Inflammation of the conjunctiva.

- **retinitis pigmentosa**: A progressive, hereditary disease in which the inner layers of the retina atrophy and become infiltrated with pigment.

- **Rinne test**: A hearing test that uses a vibrating tuning fork held against the skull and then in front of the auditory meatus to distinguish between conductive deafness and sensorineural deafness.

- **Romberg test**: A test of equilibrium in which a patient’s balance is observed as he or she stands with the feet together and the eyes closed, so that visual cues cannot override any defects in the functionality of the vestibular system.

- **sensorineural deafness**: Hearing loss resulting from any defect in the cochlea, vestibulocochlear nerve, or auditory cortex of the brain.

- **tonometer**: An instrument used to measure pressure in the anterior chamber of the eye by measuring the resistance of the cornea to deflection by an external force such as a puff of air or a probe that taps the cornea.