The Nervous System: The Brain, Cranial Nerves, Autonomic Nervous System, and the Special Senses

CHAPTER OBJECTIVES

After studying this chapter, you should be able to:

1. List the principal parts of the brain.
2. Name the functions of the cerebrospinal fluid.
3. List the principal functions of the major parts of the brain.
4. List the 12 cranial nerves and their functions.
5. Name the parts of the autonomic nervous system and describe how it functions.
6. Describe the basic anatomy of the sense organs and explain how they function.
KEY TERMS

Abducens nerve VI .......... 254
Accessory nerve XI .......... 255
Aqueous humor ............. 259
Auditory or eustachian tube .......... 261
Auricle ............. 261
Autonomic nervous system .......... 252
Brainstem .......... 248
Cerebellum .......... 252
Cerebral aqueduct/aqueduct of Sylvius .......... 247
Cerebral cortex .......... 251
Cerebral hemispheres .......... 251
Cerebrum .......... 251
Cerumen .......... 261
Ceruminous glands .......... 261
Choroid .......... 259
Ciliary body .......... 259
Cornea .......... 259
Corpus callosum .......... 251
Decussation of pyramids .......... 248
Diencephalon .......... 250
Dorsal tectum .......... 250
External auditory meatus .......... 261
Facial nerve VII .......... 254
Fovea centralis .......... 260
Frontal lobe .......... 252
Glossopharyngeal nerve IX .......... 255
Gyri .......... 251
Hypoglossal nerve XII .......... 255
Hypothalamus .......... 251
Incus .......... 261
Infundibulum .......... 251
Infundibular foramen .......... 252
Interventricular foramen/foramen of Monroe .......... 247
Iris .......... 259
Lens .......... 259
Longitudinal fissure .......... 251
Malleus .......... 261
Mamillary bodies .......... 251
Medulla oblongata .......... 248
Midbrain/mesencephalon .......... 250
Occipital lobe .......... 252
Oculomotor nerve III .......... 254
Olfactory nerve I .......... 254
Olfactory sense .......... 256
Optic chiasma .......... 251
Optic disk .......... 260
Optic nerve II .......... 254
Optic tracts .......... 251
Oval window .......... 261
Papillae .......... 257
Parasympathetic division .......... 252
Parietal lobe .......... 252
Pineal gland .......... 251
Pituitary gland .......... 251
Pons varolii .......... 250
Pupil .......... 259
Retina .......... 259
Rhodopsin .......... 260
Round window .......... 261
Sclera .......... 259
Stapes .......... 261
Sulci .......... 251
Sympathetic division .......... 252
Taste buds .......... 257
Taste cells .......... 257
Temporal lobe .......... 252
Thalamus .......... 250
Trigeminal nerve V .......... 254
Trochlear nerve IV .......... 254
Tympanic membrane .......... 261
Vagus nerve X .......... 255
Ventral cerebral peduncles .......... 250
Ventricles .......... 247
Vestibulocochlear nerve VIII .......... 254
Vitreous humor .......... 259
INTRODUCTION

This chapter is a continuation of the discussion of the nervous system that begins in Chapter 10. The brain is divided into four main parts. The brainstem controls breathing, heartbeat rates, and reactions to visual and auditory stimuli. The diencephalon includes the thalamus and the hypothalamus, which controls many functions, including those related to homeostasis. The cerebrum controls intellectual processes and emotions, while the cerebellum maintains body posture and balance. The autonomic nervous system controls all the involuntary functions of the body such as regulating our internal organs and controlling glands. The special senses are part of the nervous system and include sight, hearing and balance, smell, and taste.


THE PRINCIPAL PARTS OF THE BRAIN

The brain is one of the largest organs of the body (Figure 11-1). It weighs about 3 pounds in an average adult. It is divided into four major parts: (1) the brainstem, which consists of three smaller areas, the medulla oblongata (meh-DULL-ah ob-long-GAH-tah), the pons...
varolii (PONZ vah-ROH-lee-eye) and the midbrain; (2) the diencephalon, (dye-en-SEFF-ah-lon), consisting of the thalamus (THAL-ah-muss) and the hypothalamus; (3) the cerebrum (seh-REE-brum); and (4) the cerebellum (seh-ree-BELL-unm).

The brain is protected by the cranial bones and the meninges. The cranial meninges is the name given to the meninges that protect the brain, and they have the same structure as the spinal meninges: the outer dura mater, the middle arachnoid mater, and the inner pia mater (discussed in Chapter 10). The brain, like the spinal cord, is further protected by the cerebrospinal fluid that circulates through the subarachnoid space around the brain and spinal cord and through the ventricles of the brain. The ventricles are cavities within the brain that connect with each other, with the subarachnoid space of the meninges and with the central canal of the spinal cord. The cerebrospinal fluid serves as a shock absorber for the central nervous system and circulates nutrients.

The brain has four ventricles (Figure 11-2). There are two lateral ventricles in each side or hemisphere of the cerebrum under the corpus callosum (KOR-pus kah-LOH-sum). The third ventricle is a slit between and inferior to the right and left halves of the thalamus, and situated between the lateral ventricles. Each lateral ventricle connects with the third ventricle by a narrow oval opening called the interventricular foramen or foramen of Monroe. The fourth ventricle lies between the cerebellum and the lower brainstem. It connects with the third ventricle via the cerebral aqueduct also known as the aqueduct of Sylvius. The roof of this fourth ventricle has three openings through which it connects with the subarachnoid space of the brain and spinal meninges, thus allowing a flow of cerebrospinal fluid through the spinal cord, the brain, and the ventricles of the brain.

CONCEPT MAP 11-2. The cranial nerves.
THE ANATOMY AND FUNCTIONS OF THE BRAINSTEM

The brainstem consists of the medulla oblongata, the pons varolii, and the midbrain. It connects the brain to the spinal cord. It is a very delicate area of the brain because damage to even small areas could result in death. Figure 11-3 shows the parts of the brain and areas of brain function.

The medulla oblongata contains all the ascending and descending tracts that connect between the spinal cord and various parts of the brain. These tracts make up the white matter of the medulla. Some motor tracts cross as they pass through the medulla. The crossing of the tracts is called **decussation of pyramids** and explains why motor areas on one side of the cortex of the cerebrum control skeletal muscle movements on the opposite side of the body. The medulla also contains an area of dispersed gray matter containing some white fibers. This area is called the **reticular formation**, which functions in maintaining consciousness and arousal. Within the medulla are three vital reflex centers of this reticular system: the vasomotor center, which regulates the diameter of blood vessels; the cardiac center, which regulates the force of contraction and heartbeat; and the medullary rhythmicity area, which adjusts your basic rhythm of breathing.

**CONCEPT MAP 11-3.** The autonomic nervous system and the special senses.
CHAPTER 11 The Nervous System: The Brain, Cranial Nerves, Autonomic Nervous System, and the Special Senses

FIGURE 11-1. The principal parts of the brain.

FIGURE 11-2. The ventricles of the brain, the cranial meninges, and the flow pattern of the cerebrospinal fluid.
The **pons varolii** is a bridge (**pons** is Latin for “bridge”) that connects the spinal cord with the brain and parts of the brain with each other. Longitudinal fibers connect with the spinal cord or medulla with the upper parts of the brain, and transverse fibers connect with the cerebellum. Its pneumotaxic and apneustic area help control breathing.

The **midbrain**, also called the **mesencephalon** (**mes-*in*-SEFF-ah-lon), contains the **ventral cerebral peduncles** (seh-REE-bral peh-DUN-klz) that convey impulses from the cerebral cortex to the pons and spinal cord. It also contains the **dorsal tectum**, which is a reflex center that controls the movement of the eyeballs and head in response to visual stimuli; it also controls the movement of the head and trunk in response to auditory stimuli, such as loud noises.

### THE ANATOMY AND FUNCTIONS OF THE DIENCEPHALON

The **diencephalon** is superior to the midbrain and between the two cerebral hemispheres. It also surrounds the third ventricle. It is divided into two main areas: the **thalamus**...
and the hypothalamus. It also contains the optic tracts and optic chiasma where optic nerves cross each other; the infundibulum, which attaches to the pituitary gland; the mamillary bodies, which are involved in memory and emotional responses to odor; and the pineal (PIN-ee-al) gland, which is part of the epithalamus. The pineal gland is a pinecone-shaped endocrine gland that secretes melatonin, which affects our moods and behavior. This is discussed further in Chapter 12.

The thalamus is the superior part of the diencephalon and the principal relay station for sensory impulses that reach the cerebral cortex coming from the spinal cord, brainstem, and parts of the cerebrum. It also plays an important role as an interpretation center for conscious recognition of pain and temperature and for some awareness of crude pressure and touch.

The epithalamus is a small area superior and posterior to the thalamus. It contains some small nuclei that are concerned with emotional and visceral responses to odor. It contains the pineal gland.

The hypothalamus is the inferior part of the diencephalon and, despite its small size, controls many bodily functions related to homeostasis. It controls and integrates the autonomic nervous system. It receives sensory impulses from the internal organs. It is the intermediary between the nervous system and the endocrine system because it sends signals and controls the pituitary gland. It is the center for mind-over-body phenomena. When we hear of unexplainable cures in people diagnosed with terminal illness but who refused to accept the diagnosis and recovered, the hypothalamus may have been involved in this mind controlling the body phenomenon. It is the hypothalamus that controls our feelings of rage and aggression. It controls our normal body temperature. It contains our thirst center, informing us of when and how much water we need to sustain our bodies. It maintains our waking state and sleep patterns, allowing us to adjust to different work shifts or jetlag travel problems within a day or so. It also regulates our food intake.

THE CEREBRUM: STRUCTURE AND FUNCTION

The cerebrum makes up the bulk of the brain. Its surface is composed of gray matter and is referred to as the cerebral cortex. Beneath the cortex lies the cerebral white matter. A prominent fissure, the longitudinal fissure, separates the cerebrum into right and left halves or cerebral hemispheres. On the surface of each hemisphere are numerous folds called gyri (JYE-rye) with intervening grooves called sulci (SULL-sigh). The folds increase the surface area of the cortex, which has motor areas for controlling muscular movements, sensory areas for interpreting sensory impulses, and association areas concerned with emotional and intellectual processes. A deep bridge of nerve fiber known as the corpus callosum connects the two cerebral hemispheres (Figure 11-4).
The lobes of the cerebral hemispheres are named after the bones of the skull that lie on top of them. The **frontal lobe** forms the anterior portion of each hemisphere. It controls voluntary muscular functions, moods, aggression, smell reception, and motivation. The **parietal lobe** is behind the frontal lobe and is separated from it by the central sulcus. It is the control center for evaluating sensory information of touch, pain, balance, taste, and temperature. The **temporal lobe** is beneath the frontal and parietal lobes and is separated from them by the lateral fissure. It evaluates hearing input and smell as well as being involved with memory processes. It also functions as an important center for abstract thoughts and judgment decisions. The **occipital lobe** forms the back portion of each hemisphere; its boundaries are not distinct from the other lobes. It functions in receiving and interpreting visual input (see Figures 11-1 and 11-3). A fifth lobe, the **insula**, is embedded deep in the lateral sulcus. The central sulcus separates the frontal and parietal lobes. The lateral sulcus separates the cerebrum into frontal, parietal, and temporal lobes.

**THE CEREBELLUM: STRUCTURE AND FUNCTION**

The **cerebellum** is the second largest portion of the brain. It is shaped somewhat like a butterfly. It is located beneath the occipital lobes of the cerebrum and behind the pons and the medulla oblongata of the brainstem (see Figure 11-3). It consists of two partially separated hemispheres connected by a centrally constricted structure called the vermis. The cerebellum is made up primarily of white matter with a thin layer of gray matter on its surface called the cerebellar cortex. It functions as a reflex center in coordinating complex skeletal muscular movements, maintaining proper body posture, and keeping the body balanced. If damaged, there can be a decrease in muscle tone, tremors, a loss of equilibrium, and difficulty in skeletal muscle movements.

**THE AUTONOMIC NERVOUS SYSTEM**

The **autonomic nervous system** is a subdivision of the efferent peripheral nervous system. It functions automatically without conscious effort. It regulates the functions of internal organs by controlling glands, smooth muscles, and cardiac muscle. It assists in maintaining homeostasis by regulating heartbeat and blood pressure, breathing, and body temperature. This system helps us to deal with emergency situations, emotions, and physical activities.

Receptors within organs send sensory impulses to the brain and spinal cord. Motor impulses travel along peripheral nerve fibers that lead to ganglia outside the central nervous system within cranial and spinal nerves. These ganglia are part of the autonomic nervous system.

There are two parts to the autonomic nervous system. The **sympathetic division** (Figure 11-5) prepares the body for stressful situations that require energy expenditure, such as increasing heartbeat and breathing rates to flee from a threatening situation. The fibers of the system arise from the thoracic and lumbar regions of the spinal cord. Their axons leave the cord through the ventral roots of the spinal nerves but then leave the spinal nerve and enter members of a chain of paravertebral ganglia extending longitudinally along the side of the vertebral column. Leaving the paravertebral ganglion, another neuron, the postganglionic fiber, goes to the effector organ. The sympathetic division uses acetylcholine in the preganglionic synapses as a neurotransmitter but uses norepinephrine (or noradrenaline) at the synapses of the postganglionic fibers.

The **parasympathetic division** operates under normal nonstressful conditions. It also functions in restoring the body to a restful state after a stressful experience, thus counterbalancing the effects of the sympathetic division. The preganglionic fibers of the parasympathetic division arise from the brainstem and the sacral region of the spinal cord (Figure 11-6). They lead outward in the cranial and sacral nerves to ganglia located close to the viscera. The postganglionic fibers are short and go to the muscles or glands within the viscera to bring about their effects. The preganglionic and the postganglionic fibers of the parasympathetic division use acetylcholine as the neurotransmitter into the synapses.

Most organs that receive autonomic motor nerves are innervated by both the parasympathetic and sympathetic divisions. However, there are some exceptions: blood vessels and sweat glands are innervated by sympathetic neurons, and smooth muscles associated with the lens of the eye are controlled by parasympathetic neurons.
The sympathetic division prepares us for physical activity by increasing blood pressure and heartbeat rate, it dilates respiratory passageways for increased breathing rates, and it stimulates sweating. It also causes the release of glucose from the liver as a quick source of energy while inhibiting digestive activities. This system is occasionally called the fight-or-flight system because it prepares us to face a threat or flee quickly from it.

The parasympathetic division stimulates digestion, urination, and defecation. It also counteracts the effects of the sympathetic division by slowing down heartbeat rate, lowering blood pressure, and slowing the breathing rate. It is also responsible for the constriction of the pupil of the eye. This division is occasionally called the rest and repose system.
THE 12 CRANIAL NERVES AND THEIR FUNCTIONS

There are 12 pairs of cranial nerves. Ten pairs originate from the brainstem. All 12 pairs leave the skull through various foramina of the skull. They are designated in two ways: by Roman numerals indicating the order in which the nerves arise from the brain (from the front of the brain to the back) and by names that indicate their function or distribution. Some cranial nerves are only sensory or afferent; others are only motor or efferent. Cranial nerves with both sensory and motor functions are called mixed nerves (Figure 11-7).

The olfactory nerve (I) is entirely sensory and conveys impulses related to smell. The optic nerve (II) is also entirely sensory and conveys impulses related to sight. The oculomotor nerve (III) is a motor nerve. It controls movements of the eyeball and upper eyelid and conveys impulses related to muscle sense or position called proprioception. Its parasympathetic function causes constriction of the pupil of the eye. The trochlear nerve (IV) is a motor nerve. It controls movement of the eyeball and conveys impulses related to muscle sense. It is the smallest of the cranial nerves. The trigeminal nerve (V) is a mixed nerve and it is the largest of the cranial nerves. It has three branches: the maxillary, the mandibular, and the ophthalmic. It controls chewing movements and delivers impulses related to touch, pain, and temperature in the teeth and facial area. The abducens nerve (VI) is a motor nerve that controls movement of the eyeball. The facial nerve (VII) is a mixed nerve. It controls the muscles of facial expression and conveys sensations related to taste. Its parasympathetic function controls the tear and salivary glands. The vestibulocochlear nerve (VIII) (ves-tib-yoo-loh-KOK-lee-ar) is entirely sensory. It transmits impulses related to equilibrium and hearing. The

![Diagram of the cranial nerves](image)

FIGURE 11-7. The cranial nerves are named by Roman numerals or by name indicating distribution or function.
glossopharyngeal nerve (IX) (GLOSS-oh-fair-in-GEE-al) is a mixed nerve. It controls swallowing and senses taste. Its parasympathetic function controls salivary glands. The vagus nerve (X) is a mixed nerve. It controls skeletal muscle movements in the pharynx, larynx, and palate. It conveys impulses for sensations in the larynx, viscera, and ear. Its parasympathetic function controls viscera in the thorax and abdomen. The accessory nerve (XI) is a motor nerve. It originates from the brainstem and the spinal cord. It helps control swallowing and movements of the head. Finally, the hypoglossal nerve (XII) is a motor nerve. It controls the muscles involved in speech and swallowing and its sensory fibers conduct impulses for muscle sense. Table 11-1 provides a summary of the names and functions of the cranial nerves.

THE SPECIAL SENSES

The five special senses are smell, taste, vision, hearing, and balance. The senses of smell and taste are initiated by the interactions of chemicals with sensory receptors on the tongue and in the nose. Vision occurs due to the interaction of light with sensory receptors in the eye. Hearing and balance function due to the interaction of
mechanical stimuli (sound waves for hearing and motion for balance) with sensory receptors in the ear.

The Sense of Smell

The sense of smell is also known as the **olfactory** (ol-FAK-toh-ree) sense. Molecules in the air enter the nasal cavity and become dissolved in the mucous epithelial lining of the superior nasal conchae, the uppermost shelf area in the nose (Figure 11-8A). Here they come in contact with olfactory neurons modified to respond to odors. These neurons are bipolar neurons. Their dendrites are found in the epithelial surface of the uppermost shelf and contact the olfactory receptor sites in the nose. The odor molecules bind to these receptor sites. The olfactory neurons transmit the impulse along their axons whose ends become enlarged olfactory bulbs. From here, they connect with association neurons to the area of the brain called the olfactory cortex found in the temporal and frontal lobes of the cerebrum.

The receptor cells are neurons that have cilia at the distal ends of their dendrites (see Figure 11-8B). It is these cilia that function as chemoreceptors to detect odors. These molecules first become dissolved in the mucous membrane that lines the olfactory shelf in the nose and then are detected. The sense of smell is closely related to the sense of taste. We use these two senses to decide whether or not to eat a particular food. Our sense of smell is complex because a small number of receptors detect a great variety of odors. It is the brain that then interprets these receptor combinations into a type of olfactory code. The exact mechanism of how this works is still being investigated by biologists. However, we do know that olfactory receptors rapidly adapt to odors and after a short time we no longer perceive the odor as intensely as it was initially detected.

### Table 11-1 The Cranial Nerves

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Olfactory</td>
<td>Sensory: smell</td>
</tr>
<tr>
<td>II</td>
<td>Optic</td>
<td>Sensory: vision</td>
</tr>
<tr>
<td>III</td>
<td>Oculomotor</td>
<td>Motor: movement of the eyeball, regulation of the size of the pupil</td>
</tr>
<tr>
<td>IV</td>
<td>Trochlear</td>
<td>Motor: eye movements</td>
</tr>
<tr>
<td>V</td>
<td>Trigeminal</td>
<td>Sensory: sensations of head and face, muscle sense</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Motor: mastication</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Note: divided into three branches: the ophthalmic branch, the maxillary branch, and the mandibular branch</td>
</tr>
<tr>
<td>VI</td>
<td>Abducens</td>
<td>Motor: movement of the eyeball, particularly abduction</td>
</tr>
<tr>
<td>VII</td>
<td>Facial</td>
<td>Sensory: taste</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Motor: facial expressions, secretions of saliva</td>
</tr>
<tr>
<td>VIII</td>
<td>Vestibulocochlear</td>
<td>Sensory: balance, hearing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Note: divided into two branches: the vestibular branch responsible for balance and the cochlear branch responsible for hearing</td>
</tr>
<tr>
<td>IX</td>
<td>Glossopharyngeal</td>
<td>Sensory: taste</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Motor: swallowing, secretion of saliva</td>
</tr>
<tr>
<td>X</td>
<td>Vagus</td>
<td>Sensory: sensation of organs supplied</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Motor: movement of organs supplied</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Note: supplies the head, pharynx, bronchus, esophagus, liver, and stomach</td>
</tr>
<tr>
<td>XI</td>
<td>Accessory</td>
<td>Motor: shoulder movement, turning of head, voice production</td>
</tr>
<tr>
<td>XII</td>
<td>Hypoglossal</td>
<td>Motor: tongue movements</td>
</tr>
</tbody>
</table>
The Sense of Taste

Taste buds are the sensory structures found on certain papillae (pah-PILL-ee), which are elevations of the tongue, that detect taste stimuli (Figure 11-9). Taste buds are also found on the palate of the roof of the mouth, in certain regions of the pharynx, and on the lips of children. Each taste bud is composed of two types of cells. The first type are specialized epithelial cells that form the exterior capsule of the taste bud. The second type of cell forms the interior of the taste bud. These cells are called taste cells and function as the receptor sites for taste. The taste bud is spherical with an opening called the taste pore. Taste hairs are tiny projections of the taste cells that extend out of the taste pore. It is these taste hairs that actually function as the receptors of the taste cell. Cranial nerves VIII, IX, and X conduct the taste sensations to the brain, which perceives and interprets the taste.

Before a chemical can be tasted, it must first be dissolved in a fluid (just like the odors in the nose). The saliva produced by the salivary glands provides this fluid medium. Nerve fibers surrounding the taste cells transmit the impulses to the brain for interpretation. The sensory impulses travel on the facial (VIII), glossopharyngeal (IX), and vagus (X) cranial nerves to the gustatory (taste) cortex of the parietal lobe of the cerebrum for interpretation. The four major types of taste sensations are sweet, sour, salty, and bitter. Although all taste buds can detect all four sensations, taste buds at the back of the tongue react strongly to bitter, taste buds at the tip of the tongue react strongly to sweet and salty, and taste buds on the side of the tongue respond more strongly to sour tastes (see Figure 11-9). Taste sensations are also influenced by olfactory sensations. Holding one’s nose while swallowing reduces the taste sensation. This is a common practice when taking bad-tasting medicine.

The Sense of Sight

The eyes are our organs of sight. They are protected by the orbits of the skull. See Chapter 7 to review the bones that make up the orbits. In addition, the eyebrows help shade the eye and keep perspiration from getting into the eye.
and causing an irritation to the eye. Eyelids and eye-
lashes protect the eye from foreign objects. Blinking of
the eyelids lubricates the surface of the eye by spreading
tears that are produced by the lacrimal gland. The tears
not only lubricate the eye but also help to combat bac-
terial infections through the enzyme lysozyme, salt, and
gamma globulin.

FIGURE 11-9. (A) Taste buds on the surface of the tongue are associated with elevations called papillae. (B) A taste bud contains
taste cells with an opening called the taste pore at its free surface. Colored sections indicate common patterns of taste receptors:
(C) sweet, (D) sour, (E) salt, (F) bitter.

Watch a animation that explains how we see on your StudyWARE™ CD-ROM.
The Anatomy of the Eye

The eye is a sphere filled with two fluids (Figure 11-10). The skeletal muscles that move the eye are discussed in Chapter 9. They are the rectus muscles and the oblique muscles.

The wall of the eye is composed of three layers, or tunics, of tissue. The outermost layer is the sclera (SKLAIR-ah). It is white and composed of tough connective tissue. We see it as the white of the eye when looking in a mirror. The cornea (COR-nee-ah) is the transparent part of this outermost layer that permits light to enter the eye. The second layer is the choroid (KOR-oyd). It contains numerous blood vessels and pigment cells. It is black in color and absorbs light so that it does not reflect in the eye and impair vision. The innermost layer of the eye is the retina (RET-ih-nah). It is gray in color and contains the light-sensitive cells known as the rods and cones.

The ciliary (SIL-ee-air-ee) body consists of smooth muscles that hold the biconvex, transparent, and flexible lens in place. The iris is the colored part of the eye consisting of smooth muscle that surrounds the pupil. The iris regulates the amount of light that enters through the diameter of the pupil. When we go into a dark room, the iris opens to allow more light to enter. When we go out into strong sunlight, the iris constricts, letting less light enter the pupil.

The interior of the eye is divided into two compartments. In front of the lens is the anterior compartment that is filled with a fluid called the aqueous humor. This fluid helps to bend light, is a source of nutrients for the inner surface of the eye, and maintains ocular pressure. It is produced by the ciliary body. The posterior compartment of the eye is filled with vitreous (VIT-re-ee-us) humor. It too helps to maintain ocular pressure, refracts or bends light and holds the retina and lens in place.

The retina is the innermost layer of the eye and contains the photosensitive cells (Figure 11-11). The retina has a pigmented epithelial layer that helps keep light from being reflected back into the eye. The sensory layer is made up of the rods and cones. There are more rods than cones in this layer. Rods are quite sensitive to light and function in dim light but do not produce color vision.
It is the cones that produce color and they require lots of light. Three different types of cones are sensitive to red, green, or blue. Combinations of these cones produce all the other colors we see.

The rod and cone cells synapse with the bipolar cells of the retina. The bipolar cells synapse with ganglia cells whose axons form the optic nerve. Eventually, the fibers of the optic nerve reach the thalamus of the brain and synapse at its posterior portion and enter as optic radiations to the visual cortex of the occipital lobe of the cerebrum for interpretation.

The yellowish spot in the center of the retina is called the macula lutea. In its center is a depression called the fovea centralis. This region produces the sharpest vision, like when we look directly at an object. Medial to the fovea centralis is the optic disk. It is here that nerve fibers leave the eye as the optic nerve. Because the optic disk has no receptor cells, it is called the blind spot.

Both rods and cones contain light-sensitive pigments. Rod cells contain the pigment called rhodopsin (roh-DOP-sin). Cone cells contain a slightly different pigment. When exposed to light the rhodopsin breaks down into a protein called opsin and a pigment called retinal. Manufacture of retinal requires vitamin A. Someone with a vitamin A deficiency may experience night blindness, which is difficulty seeing in dim light.

Sight is one of our most important senses. Humans depend on sight as their main sense to survive and interact with our environment. We educate ourselves via visual input through reading, color interpretations, and movement. People who lose their sight tend to develop acuity with the other senses like smell and sounds, senses that our dog and cat companions have developed to a high degree.

**StudyWARE™ Connection**

Play an interactive game labeling the structures of the eye on your StudyWARE™ CD-ROM.

**The Sense of Hearing and Equilibrium**

The external, inner, and middle ear contain the organs of balance and hearing (Figure 11-12). The external ear is that part of the ear that extends from the outside of the head to the eardrum. Medial to the eardrum is the air-filled chamber called the middle ear, which contains the auditory ossicles: the malleus, incus, and stapes. The external and middle ear are involved in hearing. The inner ear is a group of fluid-filled chambers that are involved in both balance and hearing.

![Diagram of the external, middle, and inner ear and their organs](image)
The external ear consists of the flexible, visible part of our ear called the **auricle** (AW-rih-kl) composed mainly of elastic cartilage. This connects with our ear canal known as the **external auditory meatus** (AW-diht-or-ee mee-ATE-us). The auricle allows sound waves to enter the ear canal, which then directs those waves to the delicate eardrum or **tympanic** (tim-PAN-ik) membrane. The ear canal is lined with hairs and modified sebaceous glands called **ceruminous** (seh-ROO-men-us) glands that produce earwax or **cerumen**. The hairs and earwax protect the eardrum from foreign objects. The thin tympanic membrane, which is silvery gray in color, is very delicate and sound waves cause it to vibrate.

The middle ear is the air-filled cavity that contains the three auditory ossicles or ear bones: the **malleus** or hammer, the **incus** or anvil, and the **stapes** or stirrup. These bones transmit the sound vibrations from the eardrum to the **oval window**. The two openings on the medial side of the middle ear are the oval window and the **round window**. They connect the middle ear to the inner ear. As the vibrations of the sound waves are transmitted from the malleus to the stapes, they are amplified in the middle ear. In the middle ear we also find the **auditory or eustachian** (yoo-STAY-shun) **tube**. This tube opens into the pharynx and permits air pressure to be equalized between the middle ear and the outside air, thus ensuring that hearing is not distorted. When flying in an airplane, changing altitude changes pressure. We can allow air to enter or exit the middle ear through the auditory tube and thus equalize the pressure by yawning, chewing, or swallowing. Sometimes we hold our nose and mouth shut and gently force air out of our lungs through the auditory tube and pop our eardrum to equalize the pressure.

The inner ear is made of interconnecting chambers and tunnels within the temporal bone. This area contains the cochlea, which is involved in hearing, and the vestibule and the semicircular canals, which are involved in balance. Balance is also called equilibrium. Static equilibrium is controlled by the vestibule and determines the position of the head in relation to gravity; kinetic equilibrium is controlled by the semicircular canals and determines the change in regard to head rotational movements.

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**StudyWARE™ Connection**

- **Watch an animation that explains how we hear on your StudyWARE™ CD-ROM.**
- **Play an interactive game labeling structures of the ear on your StudyWARE™ CD-ROM.**

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**AS THE BODY AGES**

The nervous system forms very quickly in the developing embryo. By the first month, a brain and spinal cord can be seen with the beginnings of sense organs. When a child is born, the head is much larger in proportion to the rest of the body due to the developed nervous system and its neurons.

As we grow, the brain develops very rapidly during the first years of life as the neurons increase in size. The supporting cells or neuroglia grow and increase in numbers, and certain neurons develop myelinated sheaths while their dendrite branches develop and increase in number, resulting in more synapse contacts.

At maturity, the nervous system begins to undergo numerous changes. The brain actually begins to decrease in size and mass due to a loss of neurons that constitute the outer part of the cerebrum. Individuals in their mid-70s lose 7% of the weight of their brain. Accompanying this is a loss in synaptic contacts and neurotransmitters. This results in a diminished capacity to send impulses to and from the brain. Information processing is more difficult and muscular movement and responses slow down. These are all symptoms observed in older adults. A reduction in the size of the arteries supplying the brain results in less oxygen-carrying blood supplying these cells, increasing the possibilities of strokes in older adults.
CHAPTER 11 The Nervous System: The Brain, Cranial Nerves, Autonomic Nervous System, and the Special Senses

Muscular System
- Muscular contraction depends on nerve stimulation.
- Muscle sense and position of body parts are controlled by sensory neurons and interpretations by the nervous system.

Integumentary System
- Temperature receptors in the skin detect changes in the external environment and transmit this information to the nervous system for interpretation about hot and cold sensations.
- Pressure receptors in the skin detect changes in the external environment and transmit this information to the nervous system for interpretation about pleasure and pain sensations.

Skeletal System
- The skull bones and vertebrae protect the brain and spinal cord.
- Bones store calcium for release into the blood. Calcium is necessary for nervous transmission.

Endocrine System
- The hypothalamus of the brain, through neurosecretions, controls the actions of the pituitary gland, the master gland of the endocrine system, which controls the secretions of many hormones of other endocrine glands.

Cardiovascular System
- Nerve impulses control heartbeat and blood pressure.
- Nerve impulses control dilation and constriction of blood vessels, thus controlling blood flow.

Lymphatic System
- Nervous anxiety and stress can impair the immune response, a major function of the lymphatic system.

Career Focus

These are careers that are available to individuals who are interested in working with the nervous system.

- Anesthesiologists are physicians who administer anesthesia directly to patients during surgery or supervise nurse anesthetists in the delivery of anesthesia.
- Anesthesiologist assistants are allied health professionals who acquire preoperative information such as a history of health-related problems and perform physical examinations such as insertion of intravenous injections and catheters as well as being involved in recovery room care.
- Neurosurgeons are physicians specializing in surgery of the brain, spinal cord, and the peripheral nerves.
- Nurse anesthetists are registered nurses who have advanced training in anesthesia who manage the care of patients during the administration of anesthesia in certain surgical situations.
- Acupuncturists are individuals trained in the traditional Chinese method of dulling pain by inserting fine wire needles into the skin at specific sites to produce an anesthetic effect on certain parts of the body.
- Psychiatrists are physicians with advanced training in the diagnosis, prevention, and treatment of mental disorders.
- Psychologists are individuals who specialize in the study of the function of the brain. Clinical psychologists provide testing and counseling for patients with emotional and mental disorders and have graduate training.
The hypothalamus controls mind-over-body phenomena and boosts the immune response, thus fighting disease.

**Digestive System**
- The autonomic nervous system controls peristalsis, resulting in mixing of food with digestive enzymes and moving food along the digestive tract.
- Nerve impulses inform us when to empty the tract of indigestible waste.

**Respiratory System**
- Respiratory rates are controlled by the nervous system, thus controlling oxygen and carbon dioxide levels in the blood.
- The phrenic nerve controls the action of the diaphragm muscle, which controls breathing rates.

**Urinary System**
- Nerve impulses to the kidneys control the composition and concentration of urine.
- Stretch receptors in the bladder inform us when to eliminate urine from the body.

**Reproductive System**
- Sperm and egg production is stimulated by the nervous system at the beginning of puberty and throughout life in men and up to menopause in women.
- Sexual pleasure is determined by sensory receptors in various parts of the body.
- Smooth muscle contractions stimulated by the nervous system initiate childbirth and delivery.
- Sucking at the breast by the newborn stimulates milk production in the mammary glands.

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**COMMON DISEASE, DISORDER, OR CONDITION**

**ALZHEIMER’S DISEASE**

Alzheimer’s (ALTS-high-mers) disease results in severe mental deterioration. It is also known as senile dementia—Alzheimer type (SDAT). It usually affects older people but may begin in middle life with symptoms of memory loss and behavioral changes. The disease affects 10% of people older than 65 and nearly half of those 85 or older. Symptoms worsen dramatically in individuals older than 70. Symptoms include memory failure, confusion, a decrease in intellectual capacity, restlessness, disorientation, and, occasionally, speech disturbances. The disease produces a loss of neurons in the cerebral cortex of the brain, resulting in a decrease in brain size. The sulci widen and the gyri become narrowed. The temporal and frontal lobes of the cerebrum are particularly affected. Enlarged axons containing beta-amyloid protein, called plaques, form in the cortex. There is a genetic predisposition for the disease. The first symptoms of the disease usually begin with an inability to assimilate new information despite the ability to retain old knowledge, difficulty in recalling words, and a disorientation in common surroundings. Death usually occurs 8 to 12 years after the onset of symptoms. These patients should be kept comfortable and carefully observed to keep them from self-harm.

**CEREBROVASCULAR ACCIDENT (CVA)**

Cerebrovascular (seh-REE-bro-VAS-kyoo-lar) accident (CVA) or stroke can be caused by a clot or thrombus in a blood vessel, or by a piece of a clot or embolus that breaks loose and travels in the circulatory system until it lodges in a blood vessel and blocks circulation. It can also be caused by a hemorrhage in tissue or by the constriction of a cerebral blood vessel, known as a vasospasm. These situations can result in localized cellular death due to lack of blood supply to the tissue. This is known as an infarct. Symptoms are determined by the size and location of the infarct but can include paralysis or lack of feeling on the side of the body opposite the cerebral infarct, weakness, speech defects, or the inability to speak. Death may result. However, symptoms may subside in minor strokes when the resulting brain swelling subsides.

(continues)
MENINGITIS
Meningitis (men-in-JYE-tis) is an inflammation of the meninges caused by bacterial or viral infection, which results in headache, fever, and a stiff neck. Severe cases of viral meningitis can result in paralysis, coma, and death.

ENCEPHALITIS
Encephalitis (in-seff-ah-LYE-tis) is an inflammation of brain tissue usually caused by a virus transmitted by the bite of a mosquito. It is manifested by a wide variety of symptoms, including coma, fever, and convulsions and could result in death.

TETANUS
Tetanus is caused by the introduction of the bacterium *Clostridium tetani* into an open wound. The bacterium produces a neurotoxin that affects motor neurons in the spinal cord and brainstem. It also blocks inhibitory neurotransmitters, resulting in muscle contractions. The jaw muscles are affected earliest, locking the jaw in a closed position, hence the common name lockjaw. Death can result from spasms of the respiratory muscles and the diaphragm.

PARKINSON’S DISEASE
Parkinson’s disease is characterized by tremors of the hand when resting and a slow shuffling walk with rigidity of muscular movements. It is caused by damage to basal nuclei, resulting in deficient dopamine, an inhibitory neurotransmitter. The disease can be treated to a certain degree with L-dopa. New research uses the transplanting of fetal cells from discarded umbilical cords into the patient. These cells can produce dopamine in the individual with the disease.

CEREBRAL PALSY
Cerebral palsy (seh-REE-bral PAWL-zee) is a condition caused by brain damage during brain development or the birth process. The child’s motor functions and muscular coordinations are defective. Symptoms include awkward movements, head tossing, and flailing arms. Speaking is impaired with guttural sounds, and swallowing is difficult. Body balance is poor, with spasms and tremors of muscles. Careful prenatal and obstetric care is necessary to prevent this condition.

EPILEPSY
Epilepsy is caused by a disorder in the brain where certain parts of the brain are overactive, producing convulsive seizures (involuntary muscle contractions) and possible loss of consciousness.

HEADACHE
Headache or cephalalgia can be caused by a variety of factors, from muscle tension and anxiety to swollen sinuses and toothache. Headache can also be caused by inflammation of the meninges, brain tumors, and vascular changes in the blood supply to the brain.

ANEURYSM
An aneurysm (ANN-your-riz-em) is an enlargement or dilation of a blood vessel wall, commonly referred to as a ballooning. This may rupture, causing bleeding or hemorrhaging in the area. Hypertension may cause an aneurysm to burst. Aneurysms are commonly developed in the aorta and on arteries that supply the brain. Hemorrhaging in the brain destroys brain tissue. Older people occasionally develop aneurysms around the popliteal artery in the leg.

MULTIPLE SCLEROSIS (MS)
Multiple sclerosis, also known as MS, is a disease caused by progressive demyelination of nerve cells in the brain and spinal cord. It is currently considered to be an autoimmune disease. It produces lesions (continues)
on the brain and spinal cord, resulting in a hardening (sclerosis) of the fatty myelin sheaths, which produces poor conduction of nerve impulses. It usually develops early in adulthood with progression and occasional bouts of remission. Symptoms of the disease are muscle weakness, double vision, vertigo, abnormal reflexes, and occasionally difficulty in urination. There is no cure for the disease. Treatments include drugs that alleviate the symptoms. Patients are encouraged to live as normal a life as possible. Some individuals with the later stages of the disease need an authorized medical scooter to assist in their mobility.

**REYE’S SYNDROME**

Reye’s syndrome is named for Ralph Reye, an Australian pathologist. The condition usually affects individuals under 18 years of age. It usually develops after an acute viral infection like the flu, chicken pox, or an enterovirus. Symptoms include a rash, vomiting, and disorientation during the onset of the syndrome followed later by seizures, coma, and respiratory system collapse. The cause of the disease is unknown but appears to be related to the administration of aspirin. Brain cells swell and the kidneys and liver accumulate an abnormal amount of fat.

**RABIES**

Rabies is an acute viral, fatal disease that affects the central nervous system. It is transmitted to humans through a bite with virus-containing saliva of an infected mammal like unvaccinated dogs or cats or through the bite of wild animals such as bats, skunks, raccoons, or foxes. The virus travels to the brain and other organs. Symptoms include fever, headache, and muscle pain. If untreated, it results in encephalitis, severe muscle spasms, seizures, paralysis, coma, and eventually death. Treatment includes a series of vaccine injections administered intramuscularly. Prevention is through regular rabies shots to our domesticated cats and dogs. Since dogs with rabies are afraid of water and refuse to drink, the name hydrophobia (fear of water) is also used for the disease.

**BELL’S PALSY**

Bell’s palsy is also known as facial palsy. It results in paralysis of the facial nerve but only on one side of the face. An affected patient may not be able to control salivation or to close one eye. The absence of muscle tone causes the face to droop. The condition is usually temporary but in severe cases it can be permanent. Expression of the symptoms can result from trauma to the nerve, compression of the nerve, or a Herpes simplex viral infection.

**CONCUSSION**

A concussion is caused by violent shaking or jarring to the brain as a result of a severe blow. This results in brain damage, which causes a momentary loss of consciousness. In some cases symptoms such as a headache caused by muscle tension, personality changes, or fatigue can persist for a month or more.

**DEPRESSION**

Depression is a condition experienced to some degree by most individuals at some time in their lives. Although described for centuries, the exact cause is neither specific nor universal for all affected individuals. Its basis is probably both psychological and physiological. By definition, depression is an abnormal emotional state with feelings of sadness, rejection, hopelessness, and worthlessness that are out of proportion to reality. Certain types of depression can be treated with either antidepressant drugs or psychotherapy. There can be certain behavioral conditions consistent with depression, such as overeating, apathy, withdrawal, anger, or even aggression.
## COMMON DISEASE, DISORDER, OR CONDITION

### OTITIS MEDIA
Otitis media (oh-TYE-tis MEE-dee-ah) or middle ear infection is quite common in young children. It can result in a temporary loss of hearing due to fluid buildup near the tympanic membrane. Symptoms include fever and irritability, and on examination, a red eardrum.

### CONJUNCTIVITIS
Conjunctivitis (kon-junk-tih-VYE-tis) is caused by a bacterial infection of the conjunctiva of the eye. Contagious conjunctivitis is called pinkeye and is common in children. It can be transmitted easily by hand to eye contact or by contaminated water in a swimming pool.

### MYOPIA
Myopia (my-OH-pee-ah) is commonly called nearsightedness. It is the ability to see close objects but not distant ones.

### HYPEROPIA
Hyperopia (high-per-OH-pee-ah) is commonly called farsightedness. It is the ability to see distant objects but not close ones. Both myopia and hyperopia can be corrected by a corrective lens (a concave lens for myopia and a convex lens for hyperopia).

### PRESBYOPIA
Presbyopia (prez-bee-OH-pee-ah) is a decrease in the ability of the eye to accommodate for near vision. This is a normal part of aging and commonly occurs during the 40s. It can be corrected by the use of reading glasses.

### COLOR BLINDNESS
Color blindness is an X chromosome inherited genetic trait occurring more frequently in males. It results in the inability to perceive one or more colors.

### MOTION SICKNESS
Motion sickness is caused by a stimulation of the semicircular canals in the inner ear resulting from movements as those experienced in a boat or ship (seasickness), airplane (air sickness), or automobile (car sickness). Such actions cause the individuals to experience weakness and nausea leading to vomiting. Drugs, such as scopolamine, have been developed that can be administered via a patch placed on the skin usually behind or near the ear. It lasts up to three days to prevent motion sickness. It is usually used by individuals who take ocean cruises and those who are sensitive to motion sickness.

### CATARACTS
Cataracts usually develop in older individuals. The lens of the eye becomes cloudy due to a buildup of protein materials. The aqueous humor in front of the lens supplies nutrients to the lens. Decrease or loss of nutrients leads to degeneration and cataracts, also called opacity of the lens.

### GLAUCOMA
Glaucoma is caused by too much aqueous humor in front of the lens, which leads to increased pressure in the eye. Its main symptom is a narrowing of the field of vision. It occurs more often in African Americans than in Caucasians. Older individuals should be screened for developing glaucoma during their yearly eye examinations. This causes destruction of the retina or optic nerve resulting in blindness.
CHAPTER 11 The Nervous System: The Brain, Cranial Nerves, Autonomic Nervous System, and the Special Senses

SUMMARY OUTLINE

THE PRINCIPAL PARTS OF THE BRAIN

1. The brain is divided into four main parts: the brainstem consisting of the medulla oblongata, the pons varolii, and the midbrain; the diencephalon consisting of the thalamus and the hypothalamus; the cerebrum consisting of two hemispheres; and the cerebellum.

2. The brain is protected by the cranial bones, the cranial meninges, and the cerebrospinal fluid.

3. Cerebrospinal fluid acts as a shock absorber for the central nervous system and circulates nutrients. In the brain, it circulates in the subarachnoid space and the four ventricles.

THE ANATOMY AND FUNCTION OF THE BRAINSTEM

1. The medulla oblongata contains all the ascending and descending tracts that connect the spinal cord with the brain. Some of these tracts cross in the medulla, known as decussation of pyramids. This explains why motor functions on one side of the cerebrum control muscular movements on the opposite side of the body.

2. The reticular formation of the medulla controls consciousness and arousal. The three vital reflex centers control the diameter of blood vessels, heartbeat, and breathing rates.

3. The pons varolii is a bridge that connects the spinal cord with the brain and parts of the brain with each other. It also helps control breathing.

4. The midbrain or mesencephalon contains the dorsal tectum, a reflex center, that controls movement of the head and eyeballs in response to visual stimulation and movement of the head and trunk in response to auditory stimuli.

THE ANATOMY AND FUNCTIONS OF THE Diencephalon

1. The thalamus is a relay station for sensory impulses and an interpretation center for recognition of pain, temperature, and crude touch.

2. The hypothalamus controls functions related to homeostasis: it controls the autonomic nervous system; it receives sensory impulses from the viscera; it controls the pituitary gland; it is the center for mind-over-body phenomena; it controls our thirst center; and it maintains our waking and sleep patterns.

THE CEREBRUM: STRUCTURE AND FUNCTION

1. The surface of the cerebrum is composed of gray matter and is called the cerebral cortex. Below the cortex is the white matter.

2. A longitudinal fissure separates the cerebrum into two hemispheres. Folds on the surface of the hemispheres are called gyri with intervening grooves called sulci.

3. The corpus callosum is a bridge of nerve fibers that connects the two hemispheres.

4. The surface of the cortex has motor areas to control muscular movements, sensory areas for interpreting sensory impulses and association areas concerned with emotional and intellectual processes.

5. Each hemisphere is divided into four main lobes.

6. The frontal lobe controls voluntary muscular movements, moods, aggression, smell reception, and motivation.

7. The parietal lobe evaluates sensory information concerning touch, pain, balance, taste, and temperature.

8. The temporal lobe evaluates hearing, smell, and memory. It is a center for abstract thought and judgment decisions.

9. The occipital lobe evaluates visual input.

THE CEREBELLUM: STRUCTURE AND FUNCTION

1. The cerebellum consists of two partially separated hemispheres connected by a structure called the vermis. The cerebellum is shaped like a butterfly.

2. It functions as a center for coordinating complex muscular movements, maintaining body posture, and balance.

THE AUTONOMIC NERVOUS SYSTEM

1. The autonomic nervous system is a subdivision of the efferent peripheral nervous system.

2. It regulates internal organs by controlling glands, smooth muscle, and cardiac muscle. It maintains homeostasis by regulating heartbeat, blood pressure, breathing, and body temperature.

3. It helps us control emergency situations, emotions, and various physical activities.
4. It consists of two subdivisions: the sympathetic division and the parasympathetic division.

5. The sympathetic division deals with energy expenditure and stressful situations by increasing heartbeat rates and breathing. Its fibers arise from the thoracic and lumbar regions of the spinal cord. It uses acetylcholine as a neurotransmitter in the preganglionic synapses and norepinephrine or noradrenaline at postganglionic synapses.

6. The parasympathetic division functions in restoring the body to a nonstressful state. Its fibers arise from the brainstem and the sacral region of the spinal cord. It uses acetylcholine at both the preganglionic and postganglionic synapses as a neurotransmitter.

7. The sympathetic division prepares us for physical activity: it increases blood pressure, heart rate, breathing, and sweating; it releases glucose from the liver for quick energy. It is also known as the fight-or-flight system.

8. The parasympathetic division counteracts the effects of the sympathetic division: it slows down heart rate, lowers blood pressure, and slows breathing. It also controls digestion, urination, defecation, and constriction of the pupil. It is known as the rest or repose system.

9. Vestibulocochlear nerve (VIII) transmits impulses related to equilibrium and hearing. It is sensory.

10. Glossopharyngeal nerve (IX) controls swallowing and senses taste. Its parasympathetic function controls salivary glands. It is both sensory and motor.

11. Accessory nerve (XI) helps control swallowing and movement of the head. It is both sensory and motor.

12. Hypoglossal nerve (XII) controls muscles involved in swallowing and speech. It is both sensory and motor.

THE SPECIAL SENSES

1. The senses of smell and taste are initiated by the interactions of chemicals with sensory receptors on the tongue and in the nose.

2. The sense of vision occurs due to the interactions of light with sensory receptors in the eye.

3. The senses of hearing and balance occur due to the interaction of sound waves for hearing and motion for balance with sensory receptors in the ear.

The Sense of Smell

1. The sense of smell, or the olfactory sense, occurs because molecules in the air become dissolved in the mucous epithelial lining of the superior nasal conchae of the nose.

2. Bipolar sensory neurons transfer these chemical impulses to the olfactory bulbs that connect with association neurons of the olfactory cortex in the temporal and frontal lobes of the cerebrum.

3. A small number of receptors in the nose detect a great variety of odors via brain interpretation of receptor combinations.

The Sense of Taste

1. Taste buds are found on certain papillae of the tongue, on the palate of the roof of the mouth, and part of the pharynx.

2. Taste buds consist of two types of cells: epithelial cells that form the exterior capsule and taste cells that form the interior of the taste bud.
3. The taste chemical is first dissolved in the fluid of saliva. These sensory impulses are conducted by the facial, glossopharyngeal, and vagus nerves to the taste cortex of the parietal lobe of the cerebrum for interpretation.

4. There are four major types of taste sensations: bitter, strongly detected at the back of the tongue; sweet and salty, detected at the tip of the tongue; and sour, detected more strongly by the taste buds on the sides of the tongue.

5. Taste sensations are also influenced by olfactory sensations.

The Sense of Sight

1. The eyes are the organs of sight. Eyelids and eyelashes protect the eyes from foreign objects. Tears, produced by the lacrimal glands, lubricate the eyes.

2. Tears contain the bacteriolytic enzyme lysozyme.

The Anatomy of the Eye

1. The wall of the eye is composed of three layers: the sclera, the choroid, and the retina.

2. The sclera is the outermost, white, hard layer composed of tough collagenous connective tissue.

3. The cornea is the transparent part of the sclera that allows light to enter the eye.

4. The choroid is the second layer and contains blood vessels and pigment cells. It is black in color and absorbs light to prevent reflection that could impair vision.

5. The retina is the innermost layer of the eye. It contains the light-sensitive cells called rods and cones.

6. The ciliary body holds the hard, biconvex, transparent lens in place.

7. The iris is the colored part of the eye surrounding the pupil. It regulates the amount of light that can enter the pupil.

8. The interior of the eye is divided into two fluid-filled compartments. The anterior compartment is filled with aqueous humor; and the posterior compartment is filled with vitreous humor. These fluids help maintain ocular pressure, bend light, and hold the retina and lens in place.

9. There are more rods than cones in the retina. These light-sensitive cells have two functions. Rods are very sensitive to light and function in dim light; cones produce color sensations and require a lot of light.

10. The rods and cones synapse with the bipolar sensory cells of the retina. These cells synapse with the optic nerve, which reaches the thalamus of the brain to synapse with the visual cortex of the occipital lobe of the cerebrum for interpretation.

The Sense of Hearing and Equilibrium

1. The external, middle, and inner ear contain the organs of balance, or equilibrium, and hearing.

2. The visible, flexible, external ear is called the auricle. It directs sound waves to the ear canal called the external auditory meatus.

3. The ear canal is lined with hairs and ceruminous glands that produce earwax to protect the delicate eardrum, or tympanic membrane, from foreign objects.

4. The middle ear contains the auditory ossicles: the malleus or hammer, the incus or anvil, and the stapes or stirrup. These bones transmit sound vibrations from the tympanic membrane, which vibrates due to sound waves, to the oval window.

5. There are two openings on the medial side of the middle ear: the oval window and the round window, which connect the middle ear to the inner ear.

6. The middle ear also contains the auditory or eustachian tube, which connects to the pharynx and allows for equalized air pressure between the outside world and the middle ear, thus not impairing hearing.

7. The inner ear consists of fluid-filled interconnecting chambers and tunnels in the temporal bone. It contains the cochlea involved in hearing and the semicircular canals and vestibule involved in balance.

REVIEW QUESTIONS

1. Name the four principal parts of the brain and their subdivisions where appropriate.

2. Name the complex functions of the hypothalamus.

3. Name the 12 cranial nerves; include their Roman numeral designation and their functions.

4. Explain how the hypothalamus of the brain and the autonomic nervous system allow us to fight or flee in a stressful situation.

‘Critical Thinking Question
memset

Fill in the blank with the most appropriate term.

1. The brain is protected by the ______________ bones, the ________________, and ______________ fluid.

2. Cerebrospinal fluid acts as a ______________ and circulates ______________.

3. Cerebrospinal fluid circulates in the ______________ space and the four ______________ of the brain.

4. Crossing of tracts in the medulla oblongata is known as ______________.

5. The ______________ of the midbrain is a reflex center that controls movement of the head and eyeballs and head and trunk in response to visual and auditory stimuli.

6. Folds on the surface of the cerebrum are called ______________ and intervening grooves are called ______________.

7. The two hemispheres of the cerebrum are connected by a bridge of nerve fibers called the ______________.

8. The four main lobes of each cerebral hemisphere are: ______________, ______________, ______________, and ______________.

9. The cerebellum functions in coordinating ______________ movements and keeping the body ______________.

10. The two subdivisions of the autonomic nervous system are the ______________ system, which stimulates and involves energy expenditure, and the ______________ system, which is mainly restorative.

Place the most appropriate number in the blank provided.

- Olfactory cortex
- Taste cortex
- Tears
- Cornea
- Choroid layer
- Retina
- Iris
- Ciliary body
- Pupil
- Aqueous humor
- Vitreous humor
- Auricle
- Ceruminous glands
- Cochlea
- Semicircular canals

1. Transparent sclera
2. Regulates light entering eye
3. Rods and cones
4. Posterior compartment of eye
5. Holds lens in place
6. Visible lens in place
7. Temporal and olfactory lobes
8. Hearing
9. Balance
10. Earwax
11. Parietal lobe
12. Anterior compartment of eye
13. Colored part of eye
14. Blood vessels and pigment cells
15. Lacrimal gland
16. Outermost layer of the eye
17. Blind spot

Search and Explore

- Search the Internet for a famous person who was diagnosed with one of the diseases introduced in this chapter, such as Ronald Regan, 40th president of the United States, who had Alzheimer’s disease.
- Visit the Human Anatomy Online website at http://www.innerbody.com and explore the nervous system.
LABORATORY EXERCISE:

**THE NERVOUS SYSTEM**

**Materials needed:** A model of a human brain, a sheep or cow eye for dissection, a model of the external and internal ear, a dissecting pan, and a dissecting kit

1. Obtain a model of a preserved human brain showing a frontal and cross section. These are available from a biologic supply company and will be provided by your instructor. Identify the various parts of the brain, referring to Figure 11-1 in your text. In addition, identify the four ventricles of the brain.

2. Obtain a sheep or cow eye from your instructor. Make a transverse cut through the eye with your scalpel. Refer to Figure 11-10 in your text. Identify the three layers of the eye: the hard white outer sclera; the black choroid in the middle; and the innermost retina. Locate the biconvex lens. Anterior to the lens is the aqueous humor and posterior to the lens is the vitreous humor. Note the dark delicate iris surrounding the opening into the lens, the pupil. If you look carefully at the rear half of the eye, you will see a shiny greenish blue material. This is the tapetum. There is no tapetum in a human eye, but in a cow or sheep eye this area reflects light, causing the animal’s eye to glow in the dark when light is shined on it.

3. Obtain an anatomic model of the ear from your instructor. Identify the auricle and external auditory meatus of the outer ear, the middle ear, and the structures of the inner ear. Refer to Figure 11-12 in your text.