

UNIT 6 – NERVOUS SYSTEM / SPECIAL SENSES

STANDARDS AND OBJECTIVES

STANDARD

05 Students will describe the structures and functions of the nervous system and special senses.

OBJECTIVES

- 06.01 Restate the three broad functions of the nervous system:
(sensory, integration, motor)
- 06.02 Describe the general organization of the nervous system.
- 06.03 List the functions and structures of neurons and neuroglial cells:
(astrocytes, microglia, oligodendrocytes, ependymal cells, Schwann cells)
- 06.04 Sequence the major events when the nerve impulse (action potential) is initiated and transmitted through a neuron.
- 06.05 Contrast white and gray matter of nervous tissue.
- 06.06 Identify the structures responsible for the maintenance and protection of the central nervous system. (meninges [dura mater, arachnoid mater and pia mater])
- 06.07 Explain the role of each of the components of a reflex arc.
(reflex, reflex arc, receptor, sensory neuron, association [interneuron] neuron, motor neuron, effector)
- 06.08 Identify the four principle parts of the brain.
(cerebrum, cerebellum, brain stem, diencephalon)
- 06.09 Describe the location, and function of CSF.
(ventricles, subarachnoid space)
- 06.10 Describe the functions of the three structures of the brain stem.
(medulla oblongata, pons, midbrain)
- 06.11 Describe the structures and functions of the diencephalon.
(thalamus, hypothalamus)
- 06.12 Describe the locations and functions of the four lobes of the cerebrum.
(frontal, parietal, temporal, occipital)
- 06.13 Explain the major functions of the cerebellum.

- 06.14 Identify the following diseases or disorders of the nervous system.
(ALS, Alzheimer's, bacterial meningitis, cerebral palsy, epilepsy, multiple sclerosis, Parkinson's)
- 06.15 Describe the principle anatomical structures of the eye.
(accessory structures [eyelid, conjunctiva, lacrimal apparatus, extrinsic muscles]
layers of the eyeball (fibrous tunic [sclera, cornea], vascular tunic [choroid, ciliary body, iris, lens, pupil], nervous tunic [retina])
- 06.16 Describe the principle anatomical structures of the ear.
(outer ear [auricle, auditory canal], middle ear [tympanic cavity, tympanic membrane, auditory (Eustachian) tube, auditory ossicles (malleus, incus, stapes)], inner ear [bony labyrinth, membranous labyrinth, semicircular canals, vestibule, cochlea, Organ of Corti])
- 06.17 Identify the following diseases or disorders associated with special senses.
(presbyopia, myopia, hyperopia, cataracts, conjunctivitis, deafness [conductive, sensorineural], glaucoma, macular degeneration, middle ear infection, strabismus, tinnitus, vertigo)

UNIT 6 – NERVOUS SYSTEM / SPECIAL SENSES

LECTURE NOTES

6.01 THE THREE MAJOR FUNCTIONS OF THE NERVOUS SYSTEM

The nervous system is the control and communication center of the body. It monitors the state of the body, processes information, and initiates the appropriate responses.

The major functions of the nervous system are:

- A. Sensory
Perceives or senses changes that occur in the body.
- B. Integration
Interprets the incoming sensory information to formulate a response.
- C. Motor
The ability to initiate a response such body movement or the secretion from a gland.

6.02 GENERAL ORGANIZATION OF THE NERVOUS SYSTEM

A. Structural Classification

1. The Central Nervous System (CNS) consists of the brain and spinal cord which function to integrate and coordinate the body's response.
2. The Peripheral Nervous System (PNS) contains the nerves which extend from the brain and spinal cord.
 - a. There are 31 pairs of spinal nerves which carry impulses to and from the spinal cord supplying impulses to the body below the head.
 - b. There are 12 pairs of cranial nerves which transmit impulses to and from the brain and extending to the head and neck.
- c. The Autonomic Nervous System is composed of the Sympathetic and Parasympathetic Divisions.
 - (1) Sympathetic Division nicknamed "Fight or Flight" helps the body to cope with stress or emergency situations. This stimulates an increase in the heart rate, increase blood glucose levels, increases breathing rate, causes the pupils dilate, increases blood flow to the skeletal muscles, lungs, and heart while reducing blood flow to the visceral organs, and decreasing digestive activity.
 - (2) Parasympathetic Division nicknamed "Rest and Relaxation" helps the body return to homeostasis. The heart rate decreases, blood glucose levels return to normal, breathing rate decreases, blood flow is reduced to the skeletal muscles, while more blood flows to the visceral organs, causing an increase in digestive activity.
- d. Somatic Division controls the nerves to the skeletal muscles and the skin as well as the face, eyes, ears, and nose.

B. Functional Classification

1. The sensory or afferent nerves transmit nerve impulses to the brain and spinal cord. If the sensory nerves come from the skin, skeletal muscles, or joints, they are called somatic afferent nerves. If the sensory nerves come from the body organs, they are known as visceral afferent nerves.
2. The motor or efferent nerves transmit nerve impulses from the central nervous system to the organs, muscles, and glands. They bring about a response. There are two subdivisions of the motor nerves.
 - a. The voluntary nervous system, or the somatic nervous system, helps us to control the skeletal muscles.
 - b. The autonomic nervous system helps us to control automatic or involuntary processes such as the actions of smooth muscle, contraction of cardiac muscle, and glandular secretion.

6.03 NEURONS AND NEUROGLIAL CELLS

A. Neurons

1. Neurons or nerves are the basic units of the nervous system. They are responsible for transmitting nerve impulses which communicate with other nerves, muscles, and glands.
2. Nerves can be classified according to their functions.
 - a. Sensory Neurons (Afferent Neurons)
Sensory neurons detect information from the internal and external environments and transmit the information to the brain and spinal cord. They connect a sensory receptor in a tissue to the CNS.
 - b. Motor Neurons (Efferent Neurons)
Motor neurons transmit impulses which carry instructions from the brain and spinal cord to tissues, organs, and organ systems.
 - c. Interneurons (Association Neurons)
Interneurons are only located in the CNS. They are located between sensory and motor neurons and are responsible for the analysis of sensory inputs and coordinating the motor outputs.
3. There are three basic parts of a neuron -- the dendrites, the cell body, and the axon.
 - a. The dendrites are short, branching extensions which provide the receptive or input regions. They provide a large surface area for the reception of signals from other neurons. Dendrites conduct their electrical signals toward the cell body. (Please note: These signals are NOT action potentials).
 - b. The cell body contains a large nucleus, nucleolus, and cytoplasm. It contains the usual cellular organelles (endoplasmic reticulum, [Nissl Bodies], Golgi bodies, mitochondria, and pigment inclusions) with the exception of centrioles which are necessary for mitosis.
 - c. There is usually one long axon that extends from the cell body. The axon is responsible for carrying nerve impulses to other neurons, muscles or glands. It is the conducting portion of the neuron where the action

potential is seen. The axon may branch into smaller branches called collaterals and have bulbous endings known as synaptic knobs.

B. Neuroglial Cells

The neuroglial cells are the supporting cells for the neurons. There are four types of neuroglial cells found in the CNS and one type found in the PNS.

1. Astrocytes

Astrocytes are the largest and most numerous of all neuroglial cells. They are located in the CNS. They are star-shaped cells which have numerous projections. They are located between blood capillaries and neurons. They secrete chemicals which help to maintain the blood-brain barrier which isolates the brain from the general systemic circulation. Astrocytes help neurons receive nutrition from nearby capillaries. They also help to form scar tissue in the brain. Most tumors in the brain arise from astrocytes.

2. Microglia

Microglia cells are spider-like phagocytic cells found in the CNS. They perform phagocytosis to dispose of dead brain cells and infection.

3. Oligodendrocytes

Oligodendrocytes are cells with few projections. They are found in the CNS and are responsible for producing the myelin which insulates the axons. Myelin helps to increase the speed of the action potential along the axon.

4. Ependymal Cells

Ependymal cells are ciliated cells found in the CNS. Ependymal cells line the central canal of the spinal cord and the ventricles of the brain. They are responsible for producing cerebrospinal fluid (CSF) and the cilia help to circulate it within the spaces and canals.

5. Schwann Cells

Schwann cells are found in the peripheral nervous system. The Schwann cells produce myelin that surrounds the axons. Myelin helps to insulate the axons and increases the speed of the action potential along the axon.

6.04 THE ACTION POTENTIAL

The action potential is a synonym for nerve impulse conduction or nerve impulse transmission. Changes in the membrane occur as the neurons communicate signals for receiving, integrating, and sending information. The steps can be summarized as follows:

- A. The nerve membrane of a resting neuron is polarized which means there are fewer positively charged ions on the inside of the nerve membrane than on the outside of the nerve membrane. The extracellular fluid contains high amounts of sodium ions (Na^+) and chloride (Cl^-) ions, while the intracellular fluid contains higher concentrations of potassium (K^+) and many negatively charged proteins and ions. This creates a net positive charge on the outside of the axon membrane and a net negative charge on the inside of the axon membrane. The axon is considered to be polarized.

- B. When the neuron is stimulated, (by another neuron, light in the eye or a touch on the skin), a phase known as depolarization occurs. The sodium channels (gates) in the cell membrane open. This allows sodium to diffuse quickly into the axon. The inward rush of sodium ions changes the charge of the membrane. The inside now becomes positive while the outside become negative. This allows the neuron to transmit the action potential which continues down the length of the axon.
- C. The next phase is known as repolarization. Almost immediately after sodium has rushed inward, the potassium channels (gates) open which allow potassium ions to diffuse rapidly out of the axon. The outflow of positive ions restores the electrical condition to the polarized state or a net positive charge on the outside and a net negative charge on the inside.
- D. Although the charges have been restored, the original location and concentration of the ions have not been restored. This next phase is known as the refractory period. The sodium-potassium pump located in the axon membrane is activated and pumps excess sodium ions out of the axon while bringing potassium ions back inside the axon. It is during this time no nerve impulses can be sent. The nerve is restored to its polarized state and awaits new stimulation.

6.05 WHITE AND GRAY MATTER

- A. Regions of the CNS which contain myelinated axons are referred to as white matter.
- B. Regions of the CNS which contain mostly nerve cell bodies and unmyelinated axons are referred to as gray matter.

6.06 PROTECTION OF THE CNS

- A. The nervous tissue of the brain and spinal cord is very soft, delicate and irreplaceable. Nature has tried to protect the brain and spinal cord by enclosing these delicate organs in the skull and vertebrae and surrounding them with fluid known as the cerebrospinal fluid. The brain and spinal cord are also enclosed in three connective tissue membranes known as the meninges.
- B. Meninges
 - 1. The outer layer is the dura mater. The dura mater or "tough mother" is a double layered membrane. One layer is attached to the inner surface of the skull while the other layer forms the outer meningeal layer.
 - 2. The middle layer is the arachnoid mater. The arachnoid mater or "spider mother," has threadlike extensions to span the subarachnoid space and attach it to the innermost membrane. (The subarachnoid space is filled with cerebrospinal fluid).
 - 3. The most inner layer is the pia mater. The pia mater or "soft mother" clings tightly to the surface of the brain and spinal cord.

6.07 REFLEX ARCS

- A. Reflexes are rapid, predictable, unconscious, and involuntary responses to stimuli. They help to preserve homeostasis by making rapid adjustments in the function of an organ or organ system. Spinal reflexes are processed in the spinal cord while cranial reflexes are processed in the brain. A reflex response usually removes or opposes the original stimulus. Examples of common reflexes include the knee-jerk reflex, Babinski reflex on the sole of the foot, and the pupillary reflex.
- B. Reflex Arcs have five components:
1. A **(sensory) receptor** detects the incoming stimulus.
 2. A **sensory (afferent) neuron** transmits the action potential to the spinal cord or brain.
 3. An **interneuron** in the spinal cord or brain which processes the information.
 4. A **motor (efferent) neuron** takes the action potential away from the spinal cord or brain.
 5. An **effector** is the response by the muscle, gland, or organ.

6.08 THE FOUR PRINCIPLE PARTS OF THE BRAIN

- A. The **cerebrum** is the largest part of the brain and is divided into paired halves known as the cerebral hemispheres. They are connected by a band known as the corpus callosum. The cerebrum is divided into four lobes: frontal, parietal, temporal and occipital. Conscious thought processes, memory storage and retrieval, sensations, and complex motor patterns originate here. The cerebrum has a thin outer layer of gray matter, called the cerebral cortex. The outer surface contains a series of ridges called gyri which are separated by shallow depressions called sulci or by deeper grooves called fissures. This increases the surface area and the number of neurons. It contains thousands of neurons and is responsible for the major sensory and motor areas of the brain. The white matter is composed of fiber tracts which carry impulses to and from the cerebral cortex.
- B. The **cerebellum** is a large, cauliflower-like structure found inferior to the occipital lobe of the cerebrum. It has two hemispheres and contains both white and gray matter. The cerebellum provides the precise timing for coordinating skeletal muscle activity and controls balance and equilibrium. It also stores memories of previous movements.
- C. The **brain stem** is about the size of a thumb in diameter and approximately three inches long. It is the most inferior brain structure. Its sections include the medulla oblongata, the pons, and the midbrain (in ascending order, from the spinal cord). The brain stem functions to provide a pathway for both motor and sensory nerve impulses traveling away from and to the brain. The brain stem contains the nuclei for many of the cranial nerves, as well as regulates vital activities such as breathing, heart rate and blood pressure. A special group of neurons, the reticular formation, plays a vital role in the sleep/wake cycle and consciousness.

D. The **diencephalon** is superior to the brainstem and is surrounded by the cerebral hemispheres. The major structures of the diencephalon include the thalamus and the hypothalamus. The thalamus functions as a relay station for sensory impulses except for smell. As the impulses pass, we have a basic recognition of whether the sensation will be pleasant or unpleasant. The hypothalamus regulates body temperature, water balance and metabolism. It is also important in regulating thirst, hunger, blood pressure, pleasure, and the sex drive. It functions as a part of the limbic system or the emotional part of the brain. It also produces hormones that regulate the release of hormones from the pituitary gland and produces two hormones (ADH and oxytocin).

6.09 CEREBROSPINAL FLUID

- A Cerebrospinal fluid (CSF) is a clear, watery fluid similar to blood plasma. It is continuously formed from the blood by the choroid plexus. The choroid plexus is a cluster of capillaries found in each ventricle of the brain. The normal volume of CSF is 150 ml. The major solutes include glucose, proteins, and sodium chloride. The CSF is continuously produced and reabsorbed.
- B. CSF forms a watery cushion to protect the fragile nervous tissue from minor trauma associated with movement. CSF is found circulating in the ventricles of the brain and in the subarachnoid space surrounding the brain and spinal cord. The ventricles are the spaces within the brain and the subarachnoid space can be found below the arachnoid mater of the meninges.

6.10 THE BRAIN STEM

- The brain stem is the most inferior portion of the brain. It is responsible for regulating many vital, unconscious processes. It is composed of three sections -- the medulla oblongata, the pons, and the midbrain.
- A. The **medulla oblongata** is the most inferior section of the brain stem extending from the spinal cord. It serves as a relay station for both sensory and motor nerve impulses. It regulates the heart rate, blood pressure, breathing, swallowing, coughing, sneezing, and vomiting.
 - B. The **pons** is the rounded bulge superior to the medulla oblongata. It serves as relay station for both sensory and motor nerve impulses as well as regulating the rate and depth of breathing.
 - C. The **midbrain** is a small section of the brain stem superior to the pons. It serves as a relay station for both sensory and motor nerve impulses and contains reflex centers for hearing, vision, and posture.

6.11 THE DIENCEPHALON

The diencephalon is located deep within the cerebrum. It is composed of gray matter and is divided into two parts -- the thalamus and the hypothalamus.

- A. The thalamus is the largest section of the diencephalon. It serves as a relay station for sensory impulses, except for the sense of smell. As the impulses pass, we have a basic recognition of whether the sensation will be pleasant or unpleasant.
- B. The hypothalamus actually functions in two systems -- the nervous system and the endocrine system. It regulates body temperature, water balance and metabolism. It is also important in regulating thirst, hunger, blood pressure, pleasure, sex drive, and the sleep/wake cycle. It functions as a part of the limbic system or the emotional part of the brain. It produces hormones that regulate the pituitary gland, childbirth (oxytocin), and water balance (ADH).

6.12 THE LOBES OF THE BRAIN

There are four primary lobes of the brain: frontal, parietal, temporal, and occipital. Each of the four lobes is found in each hemisphere of the brain.

- A. The **frontal** lobe forms the anterior portion of each cerebral hemisphere. It is associated with the control of skeletal muscles, concentration, planning, problem solving, writing, and speech.
- B. The **parietal** lobe is posterior to the frontal lobes and is separated from the frontal lobe by a groove called the central sulcus. The parietal lobe is responsible for the sensations of temperature, touch, pressure, and pain from the skin. It is also responsible for understanding speech and helping us to use words to express thoughts and feelings.
- C. The **temporal** lobe is inferior to the frontal lobe and is separated from it by a groove called the lateral sulcus. The temporal lobe is responsible for hearing and balance as well as the interpretation of sensory experiences and in the memory of visual scenes and music.
- D. The **occipital** lobe forms the posterior portion of each hemisphere. There is no distinct boundary between the occipital lobe and the parietal or between the occipital lobe and temporal lobes. The occipital lobe is responsible for vision and combining visual images with other sensory experiences.

6.13 THE CEREBELLUM

The **cerebellum** is a fascinating brain part that communicates with the brain and spinal cord. It helps to integrate and analyze information from the spinal cord and the cerebrum and is able to send impulses to further stimulate or inhibit skeletal muscles at appropriate times to cause movement of body parts into desired positions. The activity of the cerebellum makes rapid and complex muscular movements possible. The cerebellum functions as a center for the control and coordination of skeletal muscles. The cerebellum also receives information from the inner ear to help us maintain our balance. The delicate wispy, white lines throughout the cerebellum are called the arbor vitae or tree of life.

6.14 Diseases and Disorders of the Nervous System

A. **Amyotrophic Lateral Sclerosis (ALS)**

Amyotrophic Lateral Sclerosis, or Lou Gehrig's Disease is the most common motor neuron disease of muscular atrophy. Onset typically occurs between the ages of 40 and 70. The causes of this disease include autoimmune disorders, disturbance in motor neuron enzyme metabolism, difficulty producing nucleic acids, severe stress, trauma, and physical exhaustion. The symptoms of ALS include muscle weakness, muscle atrophy, dysphasia, dysphagia, and dyspnea. The person usually becomes physically incapacitated. Mental deterioration usually does not occur, but depression is a common response to the disease process. Death usually occurs within 2 to 5 years after diagnosis as there is no effective treatment available.

B. **Alzheimer's Disease**

Alzheimer's Disease includes progressive changes in the neurons of the brain due to a lack of neurotransmitters in the brain, trauma, and genetics. The neurons will degenerate until they can no longer carry an impulse. The causes of Alzheimer's includes genetics, unspecified environmental factors (possibly aluminum), and other unknown causes. The onset of Alzheimer's is slow. In the beginning, the patient will have very mild changes such as memory loss, forgetfulness, and difficulty learning new information, deterioration in personal hygiene and appearance, and an inability to concentrate. As the disorder progresses, personality changes may be seen. Physical disability progresses and death usually results from infection. Stem cell research may be promising. Former President Ronald Reagan was afflicted with this disorder and passed away in 2004.

C. **Bacterial Meningitis**

In bacterial meningitis, the covering(s) of the brain and spinal cord (usually the pia mater) become inflamed, usually the result of bacterial infection. Treatment includes early recognition and antibiotic therapy. Symptoms of meningitis include a sore neck when the patient is lying down and the practitioner pulls the head forward and the patient flexes his hips and knees in response, as well as fever, chills, malaise, anorexia, and changes in the cerebrospinal fluid

D. Cerebral Palsy (CP)

Cerebral Palsy is the most common cause of crippling in children results from prenatal or postnatal CNS damage due to fetal anoxia. Motor impairment may be minimal or severely disabling. Associated defects, such as seizures, speech impairment, and mental retardation are common. This disorder cannot be cured but proper treatment can help the child reach his/her full potential.

E. Epilepsy

Epilepsy is a condition of the brain marked by susceptibility to recurrent seizures that are associated with abnormal electrical discharges in the neurons of the brain. The causes are unknown, but may include birth trauma, infection, anoxia, and brain tumors. Treatment includes medication such as dilantin, phenobarbital, and tegretol to control seizures. Experimental surgeries may also help to control seizures by removing the affected parts the brain.

F. Multiple Sclerosis

Multiple Sclerosis (MS) is characterized by a loss of myelin from the axons of the peripheral nerves. Hard, plaque-like structures replace the destroyed myelin and the affected areas are invaded by inflammatory cells. As the myelin is lost, nerve conduction is affected causing weakness, un-coordination, visual impairment, and speech problems. It is most common in women between the ages for 20 and 40. The cause of multiple sclerosis is an autoimmune disorder in which the body turns its immune response on itself. The disease is chronic, but has periods of exacerbations and remissions. There is no known cure, but medications can help slow the progression of the disease.

G. Parkinson's Disease

Parkinson's Disease is sometimes referred to as the shaking palsy as involuntary tremors are one of the cardinal signs. It is one of the most crippling diseases in the United States, striking 1 in every 100 people. There is a dopamine (neurotransmitter) deficiency, which prevents brain cells from performing their normal inhibition or stopping nerve impulses within the CNS. Muscle rigidity may occur. The exact cause of Parkinson's is unknown. Death usually occurs within 10 years after the disease is diagnosed. There is no cure for this disease. The primary goal of treatment is to relieve symptoms and keep the patient functional for as long as possible with the use of drugs and physical therapy. Stem cell research may be a promising venue for future medical care and cure. Michael J. Fox, Janet Reno, Pope John Paul II (died in April 2005) and Mohammed Ali both are all afflicted with this disorder.

SPECIAL SENSES

6. 15 THE EYE

A. Accessory Structures of the eye

1. Eyelid

- a. The eyelid is composed of thin skin with eyelashes on the edges. There are small glands which help to lubricate the eyelashes.
- b. The eyelid closes to protect the anterior surface of the eye. It is involved in the blink reflex. It also helps to wash tears over the surface of the eyeball.

2. Conjunctiva

- a. The conjunctiva is a thin, transparent membrane lining the eyelids and the outer surface of the cornea.
- b. It secretes mucous to moisten and lubricate the eyeball.

3. Lacrimal Apparatus

- a. The lacrimal apparatus consists of the lacrimal gland, the lacrimal sac, and the nasolacrimal ducts.
- b. The lacrimal gland produces tears, a dilute salt solution which also contains the enzyme lysozyme. The tears are flushed across the eye by blinking.
- c. The tears are collected by lacrimal canals located in the medial portion of the eye.
- d. Nasolacrimal ducts receive the tears which then move into the nasal cavity.

4. Extrinsic Muscles

- a. Six skeletal muscles located on the outside of the eye are responsible for the eye's movements and are known as the extrinsic muscles.
- b. The extrinsic muscles are controlled by three of the cranial nerves.

B. Structure of the Eyeball.

1. Fibrous Tunic

The fibrous tunic is the thick, outer layer of the eye. It is divided into two sections -- the cornea and the sclera.

a. Sclera

The sclera forms the majority of the fibrous tunic. It is composed of fibrous connective tissue and is often called the "white of the eye." It provides protection to the inner eye while giving the eye its shape. It has many blood vessels which may be seen when the

b. Cornea

The cornea is nicknamed the "window of the eye." This is the anterior, clear portion which bulges slightly outward and allows light to enter the eye. It forms 1/6 of the fibrous tunic.

2. Vascular Tunic

The vascular tunic is the middle layer of the eye. In addition to several structures, it contains blood vessels which nourish the eye.

a. Choroid

The choroid is a thin membrane containing the brown pigment (melanin) to absorb light coming in from the sides of the eye. The blood vessels also nourish the retina.

b. Ciliary Body

The ciliary body is the thickest part of the vascular tunic. It consists of smooth muscle fibers which are attached to the lens by the suspensory ligaments. These muscles contract and relax to control the thickness of the lens to aid in accommodation or changing the shape of the lens to help with distance and near vision.

c. Iris and Pupil

The iris is the colored portion of the eye. It contains muscle fibers to control the size of the opening (pupil) which regulates the amount of light entering the eye.

d. Lens

The lens is the crystalline epithelial structure located behind the iris and the pupil. It helps to focus light waves on the retina. The lens is held by suspensory ligaments to the muscles of the ciliary body. When the tension of the muscles is relaxed, the lens becomes more convex to help focus on near objects. When the tension of the muscles is increased, the lens becomes less convex to help focus on distant objects.

3. Nervous Tunic

The most inner, nervous layer.

a. Retina

The retina is a thin, fragile layer of neurons which forms the inner lining of the back wall of the eye. The retina receives light waves, converts the information to nerve impulses which are then transmitted to the optic nerve. The optic nerve takes the impulses through the thalamus to the temporal lobe of the brain where it is interpreted as sight.

b. Photoreceptors

There are two sets of photoreceptors for the detection of light in the retina, the rods and cones.

i. Rods

Rods are elongated, cylindrical dendrites which are sensitive to low levels of light. They assist us with vision in dim light, shapes of objects, and black and white vision.

ii. Cones

Cones are cells which have dendrites tapered like cones. These cells require bright light and are sensitive to color. They focus objects for us and provide detailed vision.

6.16 THE EAR

A. The Outer Ear

The outer ear is responsible for directing sound waves to the middle ear and the tympanic membrane.

1. Auricle

The auricle is also known as the pinna. This is an elastic cartilage structure covered with skin. It directs sound waves into the auditory canal.

2. Auditory Canal

The auditory canal is also known as the external auditory canal. This tube extends into the temporal bone. It is lined with hair and wax-producing ceruminous glands which help protect the middle ear. It directs sound waves to the tympanic membrane.

B The Middle Ear

The middle ear is an air filled space within the temporal bone. It contains a membrane and three small bones. It is also connected to the pharynx by the auditory (Eustachian) tube which helps to equalize pressure in this region.

1. Tympanic Cavity

The tympanic cavity is a space which contains the three auditory ossicles. It is lined with epithelial tissues and communicates with the auditory tube.

2. Tympanic Membrane

The tympanic membrane, or the eardrum, is a thin membrane found at the end of the auditory tube and is attached to the three auditory ossicles. It vibrates in response to sound waves received from the auditory canal. The vibrations are then transmitted to the three bones.

3. Auditory (Eustachian) Tube

The auditory tube is a small tube extending from the tympanic cavity into the pharynx. It helps to equalize pressure between the middle ear and atmosphere on both sides of the tympanic membrane.

4. Auditory Ossicles

The auditory ossicles are the smallest bones in the body. They include the malleus (hammer), incus (anvil), and the stapes (stirrup). The three bones form a bridge through the tympanic cavity. The malleus is connected to the tympanic membrane on the medial side and starts vibrating when the eardrum starts vibrating. The sound waves are transmitted and amplified as they are passed to the incus and the stapes. The foot of the stapes is on another membrane, the oval window, which will vibrate taking sound waves into the inner ear.

C. Inner Ear

A series of fluid-filled passageways.

1. Bony Labyrinth

A series of canals within the temporal bone. The bony labyrinth is filled with perilymph, a watery-fluid, for the transmission of sound waves. The bony labyrinth surrounds and protects the membranous labyrinth. It is divided into three regions - the vestibule, the semicircular canals, and the cochlea.

2. **Membranous Labyrinth**

The membranous labyrinth is located within the bony labyrinth. It is a collection of tubes filled with a watery fluid known as endolymph. It also contains the receptors for hearing.

3. **Vestibule**

The vestibule is the chamber found between the cochlea and the semicircular canals. It helps the body to maintain its static equilibrium or balancing the body when the body is not in motion.

4. **Semicircular Canals**

The semicircular canals are three fluid-filled loops. They help the body maintain dynamic equilibrium, or balancing the body when the body is in motion.

5. **Cochlea and the Organ of Corti**

The cochlea resembles a small shell as its canals are coiled. It consists of several fluid-filled chambers. When the oval window begins to vibrate, those vibrations are carried into these fluid-filled chambers which cause both the fluid and membranes to vibrate. Eventually, a membrane begins to vibrate which in turn causes the actual organ of hearing or the Organ of Corti to vibrate. It is at this point the sound vibrations are converted to nerve impulses. The nerve impulses continue through the thalamus to the temporal lobe of the brain where the sense of hearing is interpreted.

6.17 Diseases and Disorders Associated with Special Senses

A. Presbyopia

Presbyopia is the normal loss of accommodation power of the eye which occurs as a consequence of aging. It occurs because the lens becomes sclerotic and less flexible and less able to bulge or accommodate for near vision. The major symptom shows when the near point of vision has increased beyond 9 inches. It can be corrected by the use of "reading glasses" worn only for close work and are removed when someone wants to see distance. Some people prefer the use of bifocals, which use two different lenses in the top and bottom of the glasses.

B. Myopia

Myopia is the ability to see close objects but not distant ones and results from a defect in which the eye's focusing systems, the cornea and the lens, are optically too powerful or the eyeball is too long. As a result, the focal point is too near the lens and the image is not focused on the retina. It is corrected by a concave lens that reduces the refractive power of the eye by spreading out the light rays.

C. Hyperopia

Hyperopia is the ability to see distant objects but not near ones and results from a defect in which the eye's focusing systems, the cornea and the lens, are optically too weak or the eyeball is too short. As a result, the focal point is off and the image is projected posterior to the retina. It is corrected by convex lenses that cause light rays to converge as they approach the eye.

D. Cataracts

A cataract is the clouding of the lens resulting from the buildup of proteins and epithelial cells. The lens relies on the aqueous humor for its nutrition. Any loss of the nutrient source will lead to degeneration of the lens and ultimately opacity of the lens. Cataracts make vision in dim light difficult because weaker beams of light cannot pass through the cloudy spots making dim light vision or night vision difficult. Cataracts may occur with advancing age, infection, exposure to sunlight and trauma. The lens may be surgically removed and a transplant completed.

E. Conjunctivitis

Conjunctivitis, commonly called pinkeye, is the inflammation of the conjunctiva, or the lining of the eyelids and the anterior sclera. It is generally caused by a bacterial infection and is highly contagious. It is characterized by redness of the eye and extreme redness of the conjunctiva resulting in itchy, watery eyes, with a noticeable increase in the mucous discharge. It is treated with antibiotics.

F. Deafness

1. Conductive Deafness

Conductive deafness is a loss of hearing related to the impairment of the conduction of sound waves through the external and middle ear. The major cause of conduction impairment is wax build-up. Foreign objects, tumors, and other matter can block sound waves through the external or middle ear. Once the blockage is removed, the hearing problem generally improves. A hearing aid may also help conductive deafness by boosting the sound volume reaching the inner ear.

2. Sensorineural Deafness

Sensorineural deafness or nerve impairment deafness results from damage to the nerves or to the Organ of Corti. Hearing loss, or presbycusis, is a progressive hearing loss associated with degeneration of nerve tissue in the ear and the vestibulocochlear nerve. A similar type of hearing loss can occur after chronic exposure to loud noises which damage the receptors in the Organ of Corti. Cochlear implants may help improve hearing. Cochlear implants are made from a receiver and an antenna and are implanted under the skin near the auricle and a small lead is fed through the external auditory meatus, tympanic membrane, middle ear, and into the cochlea where the cochlear nerve can be directly stimulated by electrical impulses from the receiver.

G. Glaucoma

Glaucoma is the build-up of excessive aqueous humor in the anterior cavity of the eye. The fluid causes excess pressure against the retina which reduces the amount of blood reaching the retina. The reduced blood flow causes the degeneration of the retina resulting in vision loss. Some of the symptoms may include a gradual loss of peripheral vision or tunnel vision. Blurred vision and headaches may also occur. There may be halos seen around lights. If untreated, glaucoma may eventually can lead to blindness. It is treated with medications that help to dilate the vessels to improve the drainage of the aqueous humor.

H. Macular Degeneration

Macular degeneration is the progressive degeneration of the central part of the retina or the macula which is necessary for good vision. The exact cause is not known, but risk factors include age, cigarette smoking, and genetics. There is no cure.

I. Middle Ear Infection

Middle ear infection or otitis media is an infection of the middle ear usually the result of a bacterial infection spread from the mucous membrane of the pharynx through the auditory tube to the mucous lining of the middle ear. The symptoms include fever, lethargy, irritability, and in younger infants, pulling on the affected ear. The tympanic membrane is red and swollen. The infection may cause a temporary decrease or loss of hearing because the fluid build-up has dampened the tympanic membrane or ossicles. Bacterial infections are treated with antibiotics.

J. Strabismus

Strabismus or cross-eyed occurs when the eye cannot be coordinated. Strabismus is caused by paralysis, weakness, or other abnormality affecting the external muscles of the eye. The cause is generally unknown. It may cause diplopia (double vision) or other visual disturbances. Treatment may include patching the eye or corrective lenses

K. Tinnitus

Tinnitus is the ringing or clicking in the ears. These noises may occur as a result of other ear disorders in the middle or inner ear or along the central neuron pathways.

L. Vertigo

Vertigo is dizziness or the sensation of spinning.