**9.1 SENSATION**

- The senses allow the brain to receive information about the environment and body.

- Sensation begins by stimulating sensory receptors, while perception is the conscious awareness of stimuli.

- Sensory receptors generate action potentials that travel to the spinal cord and brain, leading to perception when they reach the cerebral cortex.

- The thalamus also plays a role in pain perception.

- Historically, five senses were recognized: smell, taste, vision, hearing, and touch.

- Today, senses are divided into two groups: general and special senses.

- General senses have receptors throughout the body and are divided into somatic (body/environment) and visceral (internal organs) senses.

- Special senses include smell, taste, vision, hearing, and balance, with specialized receptors in specific body parts.

**9.2 SENSORY RECEPTORS**

- Sensory receptors respond to stimuli by developing action potentials.

- Receptors are associated with both general and special senses, each responding to different stimuli.

- Mechanoreceptors respond to mechanical stimuli (bending or stretching).

- Chemoreceptors respond to chemicals (e.g., smell perception).

- Photoreceptors respond to light.

- Thermoreceptors respond to temperature changes.

- Nociceptors respond to stimuli that cause the sensation of pain.

**9.3 GENERAL SENSES**

- General senses include touch, pressure, pain, temperature, vibration, itch, and proprioception (sense of movement and position).

- General sense receptors are found in skin, tendons, ligaments, and muscles.

- Free nerve endings, the simplest receptors, respond to pain, temperature, itch, and movement.

- Cold receptors stop responding below 12°C; warm receptors stop above 47°C, where pain receptors are activated.

- Merkel disks detect light touch and pressure; hair follicle receptors detect light touch.

- Meissner corpuscles provide fine, discriminative touch; Ruffini corpuscles detect continuous pressure.

- Pacinian corpuscles detect deep pressure, vibration, and body position.

- Proprioception helps maintain posture and balance; proprioceptors and balance receptors adjust body position.

- Pain can be sharp and localized or diffuse and aching, depending on action potential speed.

- Superficial pain is highly localized; deep or visceral pain is diffuse due to fewer tactile receptors.

- Local anesthesia suppresses pain by blocking action potentials, while general anesthesia affects the reticular activating system to induce unconsciousness.

- Pain perception can be reduced by tactile stimulation (e.g., rubbing) or mental/physical activity.

- Referred pain occurs when pain from deeper structures is felt in superficial areas, such as heart attack pain felt in the left shoulder/arm.

**9.4 SPECIAL SENSES**

- Smell, taste, vision, hearing, and balance involve specialized, localized sensory receptors.

- Smell and taste are initiated by chemicals interacting with chemoreceptors .

- Vision is initiated by light interacting with photoreceptors .

- Hearing and balance involve mechanoreceptors responding to mechanical stimuli.

- Hearing responds to sound waves, while balance responds to gravity or motion.

**9.5 OLFACTION**

- Olfaction (sense of smell) occurs in response to airborne molecules (odorants) entering the nasal cavity.

- Olfactory neurons are bipolar, located in the olfactory epithelium with specialized cilia in a mucous film.

- Mucus traps, dissolves odorants, and aids in their removal from the nasal epithelium.

- Odorants bind to receptor molecules on olfactory neuron cilia, initiating action potentials sent to the olfactory cortex.

- Humans have 400 functional olfactory receptors, allowing detection of approximately 10,000 different smells.

- Olfactory receptors desensitize after binding odorants, aiding in odor adaptation.

- The detection threshold for odors is low, with greater olfactory sensitivity in some animals (e.g., dogs).

- Olfactory neurons send signals via the olfactory nerve (cranial nerve I) to the olfactory bulb , then to the olfactory cortex .

- The olfactory cortex in the temporal and frontal lobes handles conscious smell perception and emotional responses to odors.

- Prolonged exposure to an odor leads to adaptation, with reduced smell perception due to receptor desensitization and feedback inhibition.

**9.6 TASTE**

- Taste buds are oval structures on certain papillae of the tongue, and also found on the palate, root of the tongue, and epiglottis.

- Each taste bud contains specialized epithelial cells and about 40 taste cells with taste hairs extending through a taste pore.

- Dissolved molecules bind to receptors on taste hairs, initiating action potentials sent to the insula of the cerebral cortex.

- Basic taste sensations : sour, salty, bitter, sweet, and umami (savory).

- Taste buds can detect all five tastes but are usually most sensitive to one type.

- Heat damage to taste buds can cause temporary or, if severe, long-term loss of taste.

- Olfactory influence : Taste is strongly affected by smell; pinching the nose reduces taste perception.

- Neuronal pathways :

- Facial nerve (VII) transmits taste from the anterior two-thirds of the tongue.

- Glossopharyngeal nerve (IX) carries taste from the posterior one-third.

- Vagus nerve (X) carries some taste from the root of the tongue.

- Taste sensations travel from these nerves to brainstem nuclei, then to the thalamus, and finally to the taste area in the insula of the cerebrum.

**9.7 VISION**

- Visual system : Comprises the eyes, accessory structures, and sensory neurons.

- Eyes : Located in bony cavities called orbits; process visual information about light, dark, movement, and color.

- Visual input starts as action potentials in the eyes, which travel along visual pathways to the brain.

- Accessory structures :

- Eyebrows : Protect the eyes from debris and sweat.

- Eyelids : Provide protection and distribute tears.

- Conjunctiva : Moistens and protects the eye surface.

- Lacrimal apparatus : Produces and drains tears.

- Extrinsic eye muscles : Facilitate eye movement.

- Eyebrows : Prevent perspiration and shade eyes from sunlight.

- Eyelids : Protect from foreign objects, close rapidly (blink reflex), and spread tears for lubrication.

- Conjunctiva : Thin mucous membrane covering inner eyelids and eye surface; secretes lubricating fluid; inflammation is called conjunctivitis.

- Lacrimal Apparatus : Includes lacrimal gland (produces tears), lacrimal canaliculi (collect excess tears), lacrimal sac, and nasolacrimal duct (drains tears into nasal cavity); tears lubricate and cleanse the eye and help combat infections.

- Extrinsic Eye Muscles : Six muscles responsible for eye movement:

- Rectus Muscles : Superior, inferior, medial, and lateral.

- Oblique Muscles : Superior and inferior (located at an angle).

**Anatomy of the Eye**

- Eyeball Structure : Hollow, fluid-filled sphere with three tissue layers:

- Outer Fibrous Tunic :

- Sclera : Firm, white connective tissue; maintains eye shape and protects internal structures.

- Cornea : Transparent, refracts light to aid focusing.

- Middle Vascular Tunic :

- Choroid : Contains blood vessels and melanin; absorbs light to prevent internal reflection.

- Ciliary Body : Contains smooth muscles that adjust lens shape via suspensory ligaments.

- Iris : Colored part; regulates pupil size to control light entry; responds to light intensity changes via parasympathetic (constriction) and sympathetic (dilation) stimulation.

- Inner Nervous Tunic :

- Retina : Covers posterior eye, consists of:

- Pigmented Retina : Absorbs light and prevents reflection.

- Sensory Retina : Contains photoreceptors (rods and cones); rods are sensitive to dim light but do not detect color, while cones detect color and require more light. Cones are specialized in blue, green, and red vision.

- Special Features :

- Macula : Central spot with high cone density for detailed vision.

- Fovea Centralis : Center of macula; area with the greatest visual acuity.

- Optic Disc : Blind spot where optic nerve exits; lacks photoreceptors.

- Chambers of the Eye :

- Anterior Chamber : Between the cornea and iris; filled with aqueous humor.

- Posterior Chamber : Between the iris and lens; also filled with aqueous humor.

- Vitreous Chamber : Larger chamber posterior to the lens; filled with vitreous humor.

- Aqueous Humor : Watery fluid in the anterior and posterior chambers; maintains eye pressure, refracts light, and provides nutrients. Produced by the ciliary body and drained through a venous ring. Blockage can cause glaucoma, increasing pressure and potentially leading to blindness.

- Vitreous Humor : Transparent, jelly-like substance in the vitreous chamber; maintains eye pressure, holds the lens and retina in place, and refracts light. Unlike aqueous humor, it does not circulate.

**Functions of the Eye**

- Eye as a Camera : The eye functions similarly to a camera. It focuses light to create a clear image, with light altering the activity of photoreceptors in the retina.

- Refraction of Light : Light bends (refracts) when passing from air into a denser substance. Concave lenses cause light rays to diverge, while convex lenses (like the cornea) cause light rays to converge.

- Focal Point : The point where light rays converge is called the focal point. In the eye, this point is just before the retina, creating an inverted image on the retina.

- Focusing Images on the Retina : The eye's lens changes shape to focus light. The cornea provides most of the convergence, while the lens adjusts for fine focus through accommodation. The ciliary muscles alter lens shape to focus on objects at varying distances.

- Vision Testing : Standardized charts test visual acuity at 20 feet. 20/20 vision indicates normal vision at this distance. Poorer vision, like 20/40, suggests the need for corrective lenses.

- Effects of Aging : Aging reduces lens flexibility, impairing the ability to focus on close objects.

- Action Potential Generation at the Retina : Photoreceptors in the retina, including rods and cones, respond to light and generate action potentials. Rods contain rhodopsin, which is crucial for vision in low light. Cones are responsible for color vision and are sensitive to different wavelengths of light.

- Night Blindness : Caused by vitamin A deficiency or retinal detachment, night blindness affects vision in dim light due to the impaired function of rods.

- Photoreceptor Pigments : Rods use rhodopsin for low-light vision, while cones have pigments for color vision (blue, green, red). The combination of cone stimulation allows for the perception of various colors.

- Retinal Neurons : Rods and cones synapse with bipolar cells, which then connect to ganglion cells. The ganglion cells' axons form the optic nerve, transmitting visual information to the brain.

- Visual Field and Depth Perception : Each eye has its own visual field. Depth perception arises from the overlap of the visual fields of both eyes. This binocular vision allows the brain to combine slightly different views from each eye into a three-dimensional image. With only one eye functioning, the view lacks depth, resembling a flat image.

- Diplopia (Double Vision) : Usually caused by misalignment of the eyes due to muscle weakness. Adults may need to cover one eye to avoid seeing double. Children might not notice it as their brain may ignore one image. Diplopia can indicate serious conditions like brain tumors, so prompt medical evaluation is necessary.

**9.8 HEARING AND BALANCE**

- External Ear : Extends from the outside of the head to the tympanic membrane (eardrum). It conducts sound waves toward the middle ear.

- Middle Ear : An air-filled chamber medial to the tympanic membrane. It transmits sound vibrations from the tympanic membrane to the inner ear.

- Inner Ear : Fluid-filled chambers medial to the middle ear. It is responsible for both hearing and balance.

**Anatomy and Function of the Ear**

- External Ear :

- Auricle : Fleshy part of the ear that directs sound waves into the external auditory canal.

- External Auditory Canal : Passageway leading to the tympanic membrane, lined with hairs and ceruminous glands that produce earwax to protect the eardrum.

- Tympanic Membrane (Eardrum) : Thin membrane separating the external ear from the middle ear, vibrating in response to sound waves.

- Middle Ear :

- Auditory Ossicles : Three small bones (malleus, incus, stapes) that transmit vibrations from the tympanic membrane to the oval window, amplifying sound.

- Oval Window and Round Window : Openings connecting the middle ear to the inner ear.

- Auditory Tube (Eustachian Tube) : Connects the middle ear to the pharynx, equalizing air pressure to prevent distortion and pain.

- Inner Ear :

- Bony Labyrinth : Interconnecting tunnels and chambers within the temporal bone, containing the membranous labyrinth.

- Membranous Labyrinth : Filled with endolymph, surrounded by perilymph. Includes the cochlea (for hearing), vestibule, and semicircular canals (for balance).

- Cochlea : Snail-shaped structure with three channels (scala vestibuli, scala tympani, cochlear duct), containing the spiral organ (organ of Corti) with hair cells that detect sound.

- Hair Cells : Sensory cells in the cochlea with microvilli (stereocilia) embedded in the tectorial membrane, associated with sensory neurons forming the cochlear nerve.

**Hearing**

- Hearing Process :

1. Conduction of Sound Waves : Involves structures of the outer, middle, and inner ears.

2. Stimulation of Hearing Receptors : Occurs in the inner ear.

- Sound Characteristics :

- Pitch : Determined by the frequency or wavelength of the sound.

- Volume : Related to the amplitude of the sound wave.

- Basilar Membrane :

- Structure : Narrower and denser near the oval window, wider and less dense near the cochlea apex.

- Pitch Detection : Higher pitches distort the membrane near the oval window; lower pitches affect the apex.

- Volume Detection : Louder sounds cause greater distortion and stimulate hair cells more intensely, increasing action potentials.

- Hearing Impairment :

- Conduction Deafness : Results from mechanical issues, such as damage to the ossicle connections.

- Sensorineural Hearing Loss : Caused by damage to the spiral organ or auditory nerves, often due to loud sounds damaging hair cells.

Neuronal Pathways for Hearing:

- Vestibulocochlear Nerve (VIII): Transmits both hearing and balance information.

- Cochlear Nerve: Carries auditory signals.

- Vestibular Nerve: Carries balance information.

**Balance**

- Balance Components :

- Static Equilibrium : Evaluates head position relative to gravity; associated with the vestibule.

- Dynamic Equilibrium : Evaluates changes in head movement direction and rate; associated with semicircular canals.

- Vestibule :

- Divided into utricle and saccule .

- Contains maculae with hair cells and otolithic membrane .

- Otoliths in the membrane move with gravity, bending hair cell microvilli and generating action potentials.

- Action potentials travel via the vestibular nerve (VIII) to the brain for head position interpretation.

- Semicircular Canals :

- Three canals per ear, positioned at right angles.

- Base of each canal expands into an ampulla containing crista ampullaris .

- Cupula in the crista displaces with endolymph movement, bending hair cell microvilli.

- Bending of microvilli initiates action potentials in the vestibular nerves.

- Motion Sickness :

- Caused by conflicting sensory input from semicircular canals, eyes, and proprioceptors.

- Results in nausea and weakness due to continuous stimulation.

- Neuronal Pathways for Balance :

- Vestibulocochlear Nerve (VIII) : Projects to the vestibular nucleus in the brainstem.

- Vestibular Nucleus Connections : Sends signals to the cerebellum, cerebral cortex, and other CNS areas.

- Balance Sensation : Integrates input from the inner ear, limbs (proprioception), and visual system.

- Sobriety Tests :

- Procedure : Closing eyes while standing tests balance.

- Reason : Alcohol affects visual and vestibular components more than proprioception.

- Seasickness :

- Cause : Conflicting sensory input from eyes and semicircular canals.

- Symptoms : Vertigo and nausea due to the brain's reaction to mixed signals.