UNIT 5 Lecture 15

CONTROL SYSTEMS - THE SPECIAL SENSES

OLFACTORY SENSATIONS: SMELL

Olfaction is one of the oldest senses. The receptors for olfaction, which are bipolar neurons, are in the nasal epithelium in the superior portion of the nasal cavity. Substances to be smelled must be volatile, water-soluble, and lipid-soluble. Adaptation to odors occurs quickly, and the threshold to smell is low; only a few molecules of a substance need be present in air to be smelled. Olfactory receptors convey nerve impulses to olfactory (I) nerves, olfactory bulbs, olfactory tracts, and the cerebral cortex and limbic system.
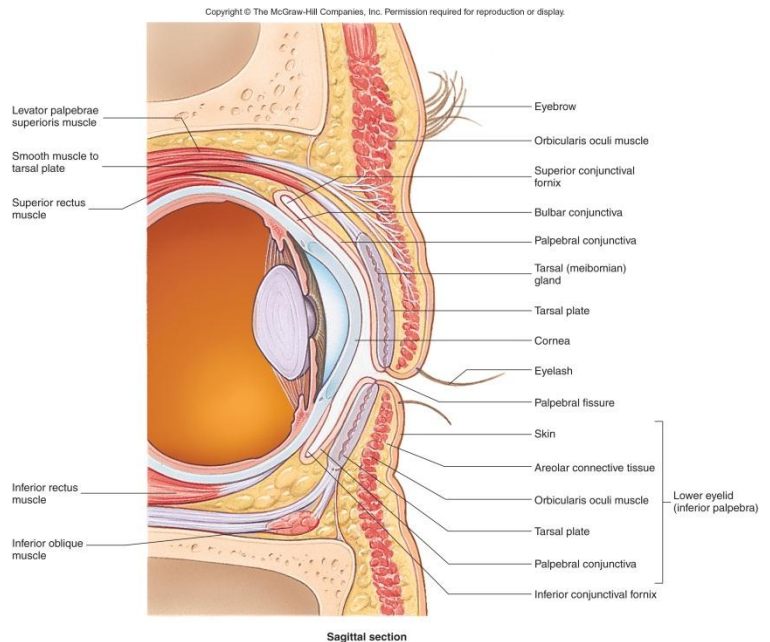
GUSTATORY SENSATIONS: TASTE

The gustatory receptor cells are located in taste buds. Substances to taste must be in solution in saliva. The four primary tastes are sour (mainly on the side of the tongue), salty (tip of tongue), bitter (back of tongue), and sweet (tip of tongue). The senses of smell and taste are very closely related; impaired ability to smell significantly affects one's ability to taste. Think about the ability to taste food when you have an upper respiratory tract infection. Adaptation to taste occurs quickly; the threshold varies with the taste involved. Taste ligands bind to receptors activating multiple intracellular pathways and create calcium signals that release neurotransmitters onto primary sensory neurons which in turn send action potentials to the brain. Taste receptor cells convey nerve impulses to cranial nerves V, VII, IX, and X, the medulla, the thalamus, and the parietal lobe of the cerebral cortex.

VISUAL SENSATIONS

Vision is the translation of reflected light into a mental image. Photoreceptors of the retina transducer light energy into an electrical signal that passes to the visual cortex for processing.

Accessory Structures of the Eye include eyebrows, eyelids, eyelashes, lacrimal apparatus, and extrinsic eye muscles (superior, inferior, lateral and medial rectus and the superior and inferior oblique move the eyeballs, usually in concert with each other). The conjunctiva is a thin mucous membrane that lines the inner aspect of the eyelids and is reflected onto the anterior surface of the eyeball. The lacrimal apparatus

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Levator palpebrae superioris muscle

Smooth muscle to tarsal plate

Superior rectus muscle

Inferior rectus muscle

Inferior oblique muscle

Eyebrow

Orbicularis oculi muscle

Superior conjunctival fornix

Bulbar conjunctiva

Palpebral conjunctiva

Tarsal (meibomian) gland

Tarsal plate

Cornea

Eyelash

Palpebral fissure

Skin

Areolar connective tissue

Orbicularis oculi muscle

Tarsal plate

Palpebral conjunctiva

Inferior conjunctival fornix

Lower eyelid (inferior palpebra)

Sagittal section

consists of structures that produce and drain tears. "Watery" eyes occur when the normal drainage for the lacrimal glands is overwhelmed or obstructed. Tears contain lysozyme which has antibacterial properties.

Anatomy of the Eyeball

The eye is composed of three layers. The fibrous tunic is the outer coat of the eyeball: divided into posterior sclera and anterior cornea. The sclera, "white' of the eye is a white coat of dense fibrous tissue covers the entire eyeball except the most anterior portion, gives the eyeball its shape, protects the inner parts. The posterior area is pierced by the optic nerve (II). The cornea is a nonvascular, transparent, fibrous coat through which the iris can be seen; acts in refraction of light; contains many nerve fibers with low pain thresholds. Corneal transplants are the most common organ transplant.

The vascular tunic is the middle layer and is composed of three portions; the choroid absorbs light rays so they are not reflected and scattered within the eyeball; it also provides nutrients to the posterior surface of the retina. The ciliary body consists of the ciliary processes and ciliary muscle. The processes consist of folds on the internal surface of the ciliary body where the epithelial lining cells secrete aqueous humor. The muscle is a smooth muscle that alters the shape of the lens for near or far vision. The iris is the colored portion seen through the cornea and consists of circular iris and radial iris smooth muscle fibers arranged to form a doughnut-shaped structure. The black hole in the center of the iris is the pupil, the area through which light enters the eyeball. The function of the iris is to regulate the amount of light entering the posterior cavity of the eyeball.

The third and inner coat is the retina (nervous tunic), lines the posterior three-quarters of the eyeball. Its primary function is image formation. It consists of a pigmented epithelium (nonvisual portion) and a neural portion (visual portion). The pigmented epithelium aids the choroid in absorbing stray light rays. The macula lutea is in the exact center of the posterior portion of the retina to the visual axis of the eye. The fovea centralis is found in a depression in the macula lutea.

The neural portion contains three zones of neurons: photoreceptor neuron, bipolar neurons, and ganglion neurons. Photoreceptor neurons are called rods or cones because of their outer segments. Rods are specialized for black-and-white vision in dim light: allow us to discriminate between different shades of dark and light and permit us to see shapes and movement. Cones are specialized for color vision and sharpness of vision in bright light; most densely concentrated in the central fovea, a small depression in the macula lutea. The fovea is the area of sharpest vision because of the high concentration of cones. Rods are absent from the fovea.

The nonvascular lens is located just behind the pupil and the iris. Its function is to fine-tune light rays for clear vision. Loss of transparency is a cataract and is usually found with aging. The interior of the eyeball is a large space divided into two cavities by the lens: anterior cavity and posterior (vitreous) cavity. The anterior cavity is divided into anterior chamber and posterior chamber. The anterior cavity is

filled with aqueous humor (AH) that is constantly being secreted by the ciliary processes behind the iris. The aqueous humor flows forward from the posterior chamber to the anterior chamber and drains into the scleral venous sinus and then into the blood. AH is replaced about every 90 minutes. Intraocular pressure is produced mainly by the aqueous humor. Excessive intraocular pressure is called glaucoma.

The posterior cavity (vitreous chamber) lies between the retina and the lens and is filled with a gel like substance called vitreous humor (VH). VH contributes to intraocular pressure, prevents the eyeball from collapsing, and holds the retina flush against the internal portions of the eyeball. VH is formed during embryonic development and is not replaced during life.

Image Formation

Image formation on the retina involves refraction of light rays by the cornea and lens, accommodation of the lens, and constriction of the pupil. The bending of light rays at the interface of two different media is called refraction; the anterior and posterior surfaces of the cornea and of the lens refract entering light rays so that they come into exact focus on the retina. Images are focused upside-down and right to left reversal on the retina; the images undergo a mirror reversal in the brain. Abnormalities of refraction are due to improper shape of the eyeball or to irregularities in the surface of the lens or cornea. Accommodation is an increase in the curvature of the lens, initiated by ciliary muscle contraction, which allows the lens to focus on near objects. To focus on far objects, the lens flattens out and the ciliary muscles relax. Constriction of the pupil means narrowing the diameter of the hole through which light enters the eye; this occurs simultaneously with accommodation of the lens and prevents light rays from entering the eye through the periphery of the lens. In convergence, the eyeballs move medially by action of the extrinsic eye muscles so that they are focused on the same object. Binocular vision permits both eyes to focus on one set of objects which allows for depth of vision (3-D).

Physiology of Vision

The first step in vision transduction is the absorption of light by photo-pigments on rods (@ 100 million) and cones (@ 3 million) which causes the photopigments to decompose. Photopigments are colored proteins that undergo structural changes upon light absorption.

The single type of photopigment in rods is rhodopsin. Rhodopsin is composed of opsin and retinal. In the absence of light, retinal binds snugly to opsin. When light bleaches rhodopsin, retinal is released and transducin begins a second messenger cascade that hyperpolarizes the rod and releases les neurotransmitters onto the bipolar neurons. There are three types of photopigments in cones (RGB = red, green, blue). Bleaching and regeneration of the photopigments accounts for much but not all of the sensitivity change during light and dark adaptation. Once receptor

potentials develop in rods and cones, they release neurotransmitters that induce graded potentials in bipolar cells and horizontal cells.

Visual Pathway

Horizontal cells transmit inhibitory signals to bipolar cells; bipolar or amacrine cells transmit excitatory signals to ganglion cells, which depolarize and initiate nerve impulses.

Impulses from ganglion cells are conveyed through the retina to the optic (II) nerve, through the optic chiasma and the optic tract, to the thalamus, and finally to the cortex (occipital lobes). M cells carry information about movement, location and depth of field. P cells transmit signals that pertain to color, form, and texture of objects. Stereoscopic vision: perceives height, width, and depth of vision.

Glaucoma is abnormally high intraocular pressure, due to a buildup of aqueous humor inside the eyeball, which destroys neurons of the retina. It is usually seen in the elderly. In cataracts the lens becomes cloudy, opaque or yellow. Specks are floaters in the aqueous humor.

AUDITORY SENSATIONS AND EQUILIBRIUM

Anatomy of the ear

The outer ear consists of the auricle, external auditory canal and tympanic membrane. Ceruminous glands secrete cerumen into the external canal that helps prevent dust and foreign objects from entering the ear.

Middle Ear (Tympanic cavity) is a small, air-filled cavity in the temporal bone that is lined by epithelium. The middle ear consists of auditory (Eustachian) tube, auditory ossicles (malleus, incus, and stapes), and the oval and round windows.

The Internal (inner) ear (labyrinth) contains two main divisions; an outer bony labyrinth that encloses an inner membranous labyrinth. The bony labyrinth is a series of cavities named on the basis of shape; semicircular canals and the vestibule (contain receptors for equilibrium), and the cochlea which contains receptors for hearing. The inner ear is lined with periosteum and contains a fluid called perilymph which is chemically similar to CSF. The fluid surrounds the membranous labyrinth. The membranous labyrinth is a series of sacs and tubes inside of and having the same general shape as the bony labyrinth. It is lined with epithelium and contains a fluid called
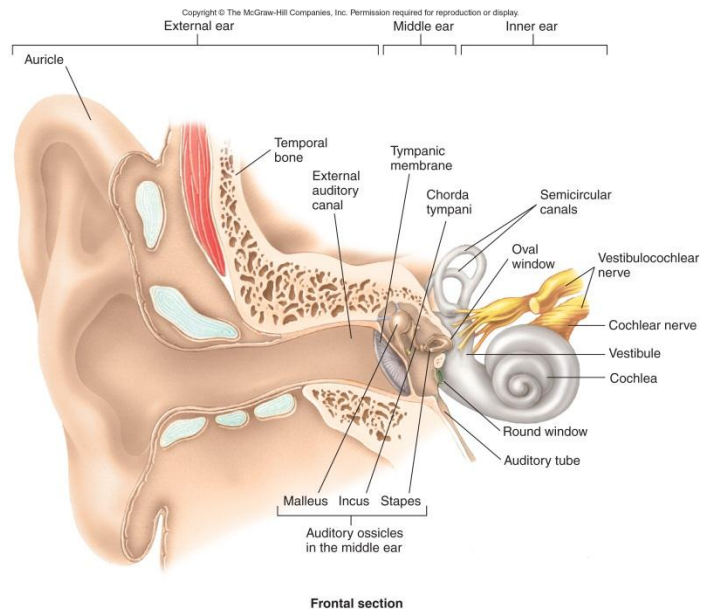
endolymph, which is chemically similar to interstitial fluid. The vestibule is the oval central portion containing two sacs: utricle and the saccule.

Semicircular canals and Cochlea

The anterior and posterior canals are oriented vertically and the lateral one is oriented horizontally. One end of each canal enlarges into a swelling called an ampulla. The portions of the membranous labyrinth that lie inside the semicircular canals are called the semicircular ducts. The cochlea is divided into three channels. The channel above the bony portion is the scala vestibuli, which ends at the oval window. The channel below is the scala tympani, which ends at the round window. Both contain perilymph. The third channel is the cochlear duct (scala media). Membranes separate the cochlear duct from the other two channels. Resting on the basilar membrane is the spiral organ ([Organ of Corti](#)), the organ of hearing. Hair cells of the spiral organ are easily damaged by continual exposure to high intensity sounds and may degenerate, producing deafness. Projecting over and in contact with the hair cells is the tectorial membrane, a delicate and flexible gelatinous membrane.

[Events of Hearing](#)

The auricle directs the sound waves into the external auditory canal. Sound waves strike the tympanic membrane, causing it to vibrate back and forth. The vibration conducts from the tympanic membrane through the ossicles. The malleus, connected to the eardrum, moves, causing the incus and the stapes to move back and forth, pushing the membrane of the oval window in and out. The movement of the oval window sets up fluid pressure waves in the perilymph of the scala vestibuli. Pressure waves in the scala vestibuli are transmitted to the scala tympani and eventually the round window, causing it to bulge inward into the middle ear. As the pressure waves deform the walls of the scala vestibuli and scala tympani, they push the vestibular membrane back and forth causing increasing and decreasing pressure of the endolymph inside the cochlear duct. The pressure fluctuations of the endolymph move the basilar membrane slightly, moving the hair cells of the spiral organ against the tectorial membrane; the bending of the hairs produces receptor potentials that lead to the generation of nerve impulses in cochlear nerve fibers. Pressure changes in the scala tympani cause the round window to bulge outward into the middle ear.

Hearing is our perception of the energy carried by sound waves. The external (outer) ear collects the sound waves and passes them inwards. Sound is our interpretation of the amplitude, frequency, and duration of those waves. Pitch is high and low sounds we hear. Sound waves result from alternate compression and decompression of air molecules. Their frequency is measured in hertz or waves per second. Normal range of hearing is between 1000 and 3000 Hertz (cycles/second). The greater the intensity (size) of the vibration, the louder the sound as measured in decibels (dB). Normal conversation has a noise level of 60 dB. Sounds of >80 dB can damage sensitive hearing receptors.

Differences in pitch cause specific regions of the basilar membrane to vibrate more intensely than others. High-frequency sounds result in vibration near base of cochlea. Low-pitch sounds vibrate at apex of cochlea. Hair cells convert a mechanical force into an electrical signal; hair cells release a neurotransmitter, which initiates nerve impulses. Nerve impulses from the cochlear branch of the vestibulocochlear (VIII) nerve pass to the cochlear nuclei in the medulla. Most impulses then cross to the opposite side and then travel to the midbrain, to the thalamus, and finally to the auditory area of the temporal lobe of the cerebral cortex.

Deafness is significant or total hearing loss. Causes can be sensorineural (damage or destruction of nerve), conduction or mechanical. Otitis media refers to an acute infection of the middle ear, primarily by bacteria. Motion Sickness is a functional disorder precipitated by repetitive angular, linear, or vertical motion and characterized by nausea and vomiting. Preventative measures are more effective.

Physiology of equilibrium

Static equilibrium refers to the maintenance of the position of the body (mainly the head) relative to the force of gravity. The maculae of the utricle and the saccule are the receptors for equilibrium. Dynamic equilibrium is the maintenance of body position (mainly the head) in response to sudden movements, such as rotation, acceleration, and deceleration. The cristae in the ampulla of the semicircular ducts are the primary sense organs of dynamic equilibrium.

Why is this chapter important?

This chapter tells us about sensory and motor pathways, the process of sensations, the types and functions of sensory receptors, and the sensations they produce. The integrative function of the cerebrum is covered as wells as wakefulness and sleep, and the different types and stages of learning and memory. The information in this chapter provided us with information regarding the special senses of taste, smell, sight, and hearing and equilibrium. Especially important were the pathways of sight and sound. We also saw that we don't see with our eyes, hear with our ears, taste with our tongue, or smell with our nose. Rather, and this is extremely important, the nerve receptors located at those sites transfer the impulses generated to areas in our brain where PERCEPTIONS takes place.