

The special senses: smell, taste, sight, hearing, equilibrium.

I. Taste (chemical sense).

- receptors for taste are chemoreceptors, respond to chemicals in aqueous solution, excited by chemicals dissolved in saliva.

A. Taste buds: sensory organs for taste.

- located primarily in the oral cavity

- found in peg-like projections of the tongue mucosa, papillae, filiform, fungiform, circumvalate; fungiform papillae are scattered over the entire tongue surface, most abundant on tip/sides, taste buds in epithelium on top of papillae; circumvalate papillae are the largest, least numerous, form inverted "v" toward the back of the tongue, taste buds in epithelium on side walls.

1. Microanatomy.

- supporting cells form bulk of taste buds; insulate receptor cells.

- gustatory cells are the receptor cells.

- both of the above have microvilli (gustatory hairs) that project from the tips and extend through taste pore to surface epithelium where they are bathed by saliva; gustatory hairs are the sensitive portions of gustatory cells.

- sensory dendrites coil around gustatory cells, forming initial part of gustatory pathway; each afferent fiber receives signals from several gustatory cells within the taste bud.

- due to location taste buds are subjected to abrasion and therefore shed every 7-10 days; they are replaced by a division of the stem cells (basal cells).

2. Basic taste sensations.

- taste sensation is a complicated mixture of qualities, it is really a mixture of 4 basic qualities: sweet, sour, salty, bitter; sweet is elicited by many organic substances such as sugar and amino acids; sour taste elicited by acids (hydrogen ions in solution); salty taste by metal ions; bitter taste by alkaloids.

- there are NO structural differences between taste buds in different areas of the tongue; however, the TIP of the tongue is most sensitive to sweet and salty substances, the SIDES are sensitive to sour, and the BACK is most sensitive to bitter substances.

- most taste buds respond to 2, 3, or all 4 taste qualities

3. Physiology of taste.

- chemicals dissolved in saliva, diffuse into taste pores, contact gustatory hairs; food chemicals bind to gustatory cell membranes which induces a graded depolarizing potential.

- this causes a release of a neurotransmitter substance that binds receptors in associated sensory dendrite and may cause an action potential; the higher the concentration of the chemical, more intense is its perceived taste due to increased frequency of AP generation in associated dendrites.

- taste transduction: each taste quality has its own special mechanism of excitation of taste cells -- for example salty taste causes a sodium ion influx

II. Smell.

- smell receptors, olfactory receptors, detect chemicals in solution.

- the organ of smell is a yellow-tinged patch of pseudostratified epithelium, olfactory epithelium.

A. Olfactory Epithelium--microanatomy

- located in the nasal cavity.

- consists of columnar supporting cells surrounding millions of olfactory receptor cells; at the base of the epithelium are basal cells.

- olfactory receptor cells are modified bipolar neurons.

- each has a thin apical dendrite that terminates in a knob from which several long cilia radiate (olfactory hairs).

- olfactory hairs lie flat on the nasal epithelium, covered by thin coat of mucus; mucus "captures" and dissolves airborne molecules for "odor detection".

B. Physiology of smell.

- activation of olfactory receptors: chemicals in solution bind to receptors in olfactory hairs, opening of specific sodium and potassium ion channels, graded receptor potentials produced that may lead to APs.

- mechanism of smell transduction: G protein-mediated responses leading to opening sodium ion channels (via cAMP second messenger).

- olfactory tracts: relayed to thalamus, hypothalamus (limbic system involvement), eventually conscious interpretation at level of cortex.

III. Eye & vision.

- 70% of sensory receptors in the body are in the eyes.

- photoreceptors encode and sense patterns made by light in our surroundings.

- the eye is a complex structure and only a small portion of tissues are actually involved in photoreception.

A. Accessory structures of the eye.

- eyebrows: help shade and protect eye.

- eyelids: important in reflex blinking, protect the eye, associated glands help lubricate the eye.

- conjunctiva: mucous membrane that lines the eyelid; covers only the white of the eye; provides protection and lubrication.

- lacrimal apparatus: lacrimal gland and ducts that drain excess lacrimal secretions into the nasal cavity; tears are continually released to clean and protect eye.

- extrinsic eye muscles: control movement of the eye ball; include the rectus muscles, oblique muscles; eye movements can be saccade (jerky) or slow scanning movements.

B. Structure of the eyeball.

1. Tunics forming the eyeball.

- fibrous tunic: outermost coat of the eye; posterior portion is the sclera and the anterior portion is the cornea - "window".

- vascular tunic: pigmented area with three distinct regions; choroid, ciliary body and the iris

- sensory tunic: innermost tunic, two-layered retina-- the outermost pigmented layer and the inner neural layer; the three types of neurons found in the neural layer are photoreceptor, bipolar cells, and ganglion cells.

2. Optic disk: spot where optic nerves exits the eye, blind spot, no photoreceptors, located in posterior wall of the eye.

3. Photoreceptors.

a. rods: more numerous; dim-light and peripheral vision receptors; more sensitive to light than cones, but do not provide either sharp or color images.

b. cones: less numerous; operate in bright light and provide high acuity in vision; found concentrated in the oval macula lutea and its fovea centralis; macula lutea is lateral to the "blind spot", oval region where retinal structures abutting vitreous humor are displaced to the sides, light passes almost directly to photoreceptor; contains mostly cones.

4. Internal chambers & fluids.

- lens divides the eye into 2 segments, posterior segment and anterior segment.

a. Posterior segment: contains vitreous humor, a network of fine collagen fibers embedded in viscous ground substance; functions to transmit light, supports posterior surface of the lens and contributes to intraocular pressure.

b. Anterior segment: subdivided by the iris into anterior/posterior chambers, filled with aqueous humor.

5. Lens.

- biconvex, transparent, flexible, can change shape to focus light on retina; enclosed in a thin capsule, is held in place by suspensory ligaments.

- anterior surface of lens epithelium: differentiates into lens fibers, cells packed with highly organized proteins, crystallins.

C. Physiology of vision

- objects have color because they reflect some wavelengths and absorb others.

- when light changes speed as it goes from one medium to another, refraction occurs; lenses produce refractions; 2 types of lenses are convex & concave.

1. Lens of eye.

- the lens of the eye is convex, focuses light on the retina.

- distant vision: light from distant objects approaches the eye with nearly parallel rays; easily focused on retina by the lens at rest.

- close vision: light from close objects approaches the eye as diverging rays, a number of events occur to adequately focus image on the retina -- contraction of ciliary muscles removes tension from suspensory ligaments and the lens bulges, thus bending diverging

rays more sharply -- provides shorter focal length (lens accommodation); the pupils also constrict (pupil accommodation, pupillary reflex) and eyeballs converge; these last two events attempt to limit the number of divergent rays entering the eye and thus hitting the retina.

2. Photoreception.

a. Functional anatomy of photoreceptors.

- photoreceptors are modified neurons.

- outermost segment: receptor region; inner segment connects to cell bodies which in turn is continuous with the inner fiber bearing synaptic endings.

b. Chemistry of visual pigments: how light is transduced into electrical signals.

- light absorbing molecule (retinal) combines with proteins called opsins to form four types of visual pigments (one pigment common to rods, rhodopsin, the remaining three are found in cones, only one pigment per cone); depending upon the type of opsin that it is bound to, retinal preferentially absorbs different wavelengths of the visible spectrum; when retinal is struck by light and absorbs a specific wavelength or range of wavelengths, it changes its shape and detaches from opsin -- this is the only light dependent stage is photoreception.

3. Light transduction.

- in the dark, cGMP binds sodium ion channels holding them open; thus establishes a "dark current", permits continuous neurotransmitter release from photoreceptors to bipolar cells (inhibitory NT)

- in the light, pigment breaks down; free opsin eventually triggers closure of sodium ion channels, producing a hyperpolarization, thus inhibiting release of neurotransmitter.

IV. Ear: hearing and balance.

A. Structure of the ear.

1. Outer ear:

- auricle (pinna): elastic cartilage, directs sound waves to external acoustic meatus.

- external auditory meatus: from auricle to tympanic membrane; contains specialized sebaceous glands, produce cerumen.

- tympanic membrane: thin translucent connective tissue membrane, covered by skin on its external surface, by mucosa internally; sound waves cause eardrum to vibrate.

2. Middle ear (tympanic cavity):

- small, air-filled, mucosa-lined space; flanked laterally by tympanic membrane, medially by a bony wall with two openings, the superior oval (vestibular) window and the inferior round (cochlear) window.

- pharyngotympanic (auditory) tube: connects middle ear to nasopharynx.

- three bones in middle ear are the malleus, incus & stapes, transfer sound vibrations from tympanic membrane to oval window.

3. Inner Ear:

- deep within the temporal bone.

- has two major divisions:

-- bony (osseous)labyrinth: a system of channels worming through bone; includes three structurally and functionally unique regions, the vestibule, cochlea, and semicircular canals; filled with perilymph.

-- membranous labyrinth: collection of interconnected membranous sacs and ducts contained within the osseous labyrinth; floats in perilymph, contains endolymph.

a. vestibule: egg shaped cavity of osseous labyrinth, oval window in its lateral wall; suspended in perilymph, has two membranous labyrinth structures, saccule and utricle; these latter two house equilibrium receptors called maculae.

b. semicircular canals: three of these structures; each projects from posterior aspect of the vestibule; each has an enlarged swelling called the ampulla which houses the equilibrium receptors called the cristae ampullares.

c. cochlea: spiral bony chamber; running through its center is the membranous cochlear duct which houses the organ of Corti, the receptor organ for hearing; on top of cochlear duct is the scala vestibuli, continuous with vestibule, abuts oval window; below the cochlear duct is the scala tympani, terminates in the round window and is separated by the cochlear duct by the basilar membrane; basilar membrane varies in thickness along its length; the organ of Corti rests atop the basilar membrane, composed of supporting cells and several cochlear hair cells.

- cochlear hair cells: ions row of inner hair cells, three rows of outer hair cells that protrude into a potassium rich endolymph, the largest of which touch overlying tectorial membrane; transduction of sound occurs when hairs bend by localized movements of the basilar membrane.

B. Properties of sound.

- sound is a pressure disturbance; a series of compression/rarefactions; needs a medium to propagate; dies off as it propagates.

- wavelength: distance between two consecutive crests/troughs.

- frequency: number of waves that pass a given point per unit time; different frequencies are perceived as different pitches; the intensity of a sound is related to its energy (amplitude of waves).

C. Transduction of sound.

- vibrations of stapes against the oval window sets perilymph of scala vestibuli into motion; extremely low frequency sounds create a pressure wave that takes complete route through the cochlea -- scala vestibuli, helicotrema, scala tympani, round window -- sound not "heard" since there is no deformation of basilar membrane/organ of Corti.

- higher frequency sounds fail to reach helicotrema; they take a short-cut, are transmitted through cochlear duct into perilymph of scala tympani; in the process a specific area of the basilar membrane is deformed, causes deformation of hair cells of the organ of Corti associated with that specific area of basilar membrane; hair cells are activated, opening of ion channels and creation of graded depolarization; the graded depolarization results in neurotransmitter release which will influence AP generation in the next neuron in the chain (second-order neuron).

- the area of basilar membrane deformed (and thus hair cells activated) depends on the frequency of sound; higher frequencies deform areas closer to the oval window (perceived as higher pitches), lower frequencies deform areas farther from oval window, closer to cochlear apex (perceived as lower pitches)-- thus pitch is "site specific", an area of organ of Corti is connected to specific area of auditory cortex via labeled line, activation of that labeled line associated with particular pitch.

- the loudness of sound is determined by extent of deformation of a specific area of organ of Corti; a large deformation, results in a greater graded potential and thus more neurotransmitter release than a smaller deformation; the amount of neurotransmitter release will influence the frequency of AP generation in the next neurons, which determines loudness of that specific pitch of sound.