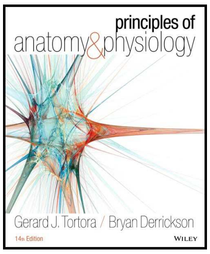


Principles of Anatomy and Physiology

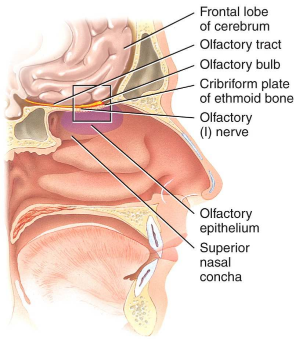
14th Edition

CHAPTER 17
The Special Senses

Olfaction: Sense of Smell

- Smell and taste are **chemical senses.** The human nose contains 10 million to 100 million receptors for smell (**olfaction**) in the **olfactory epithelium** of the superior part of the nasal cavity.
- The **olfactory epithelium** covers the inferior surface of the **cribriform plate** (of the **ethmoid bone** of the skull) and extends along the **superior nasal concha**.

Olfaction: Sense of Smell



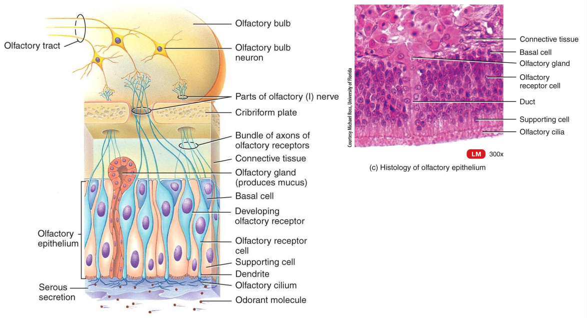
(a) Sagittal view

Olfaction: Sense of Smell

There are 3 types of cells:

1. Olfactory receptor cells
2. Supporting cells
3. Basal cells

Olfaction: Sense of Smell



(b) Enlarged aspect of olfactory receptors

(c) Histology of olfactory epithelium

Olfaction: Sense of Smell

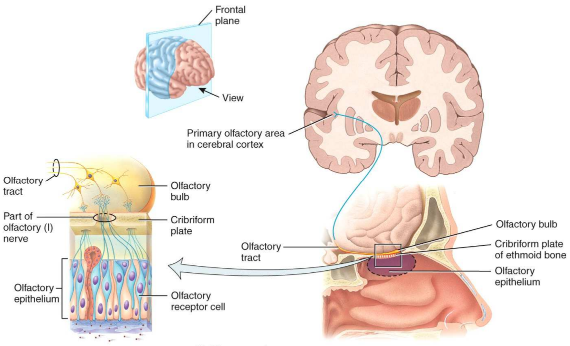
- **Supporting cells (columnar epithelium)**: located in the mucous membrane lining the nose. Used for physical support, nourishment and electrical insulation for olfactory receptor cells.
- **Basal stem cells** undergo mitosis to replace olfactory receptor cells.
- **Olfactory glands (Bowman's glands)** produce mucus that is used to dissolve odor molecules so that **transduction (conversion into electrical impulses)** may occur.

Olfaction: Sense of Smell

Receptors in the nasal mucosa send impulses along branches of olfactory (I) nerve.

- Through the **cribriform plate**
- Synapse with the **olfactory bulb**
- Impulses travel along the **olfactory tract**
- Interpretation in the **primary olfactory area** in the **cerebral cortex (temporal lobe)**

Olfaction: Sense of Smell

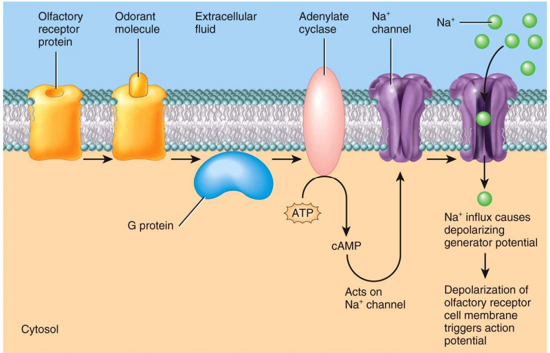


(d) Olfactory pathway

Olfaction: Sense of Smell

- **Olfactory transduction**: binding of an **odorant molecule** to an **olfactory receptor protein**.
- Chemical reactions involving **cyclic AMP (cAMP)** cause depolarization
- Action potential travels to the **primary olfactory area**.
- Impulse travels to the **frontal lobe (orbitofrontal area)** for odor identification.

Olfaction: Sense of Smell



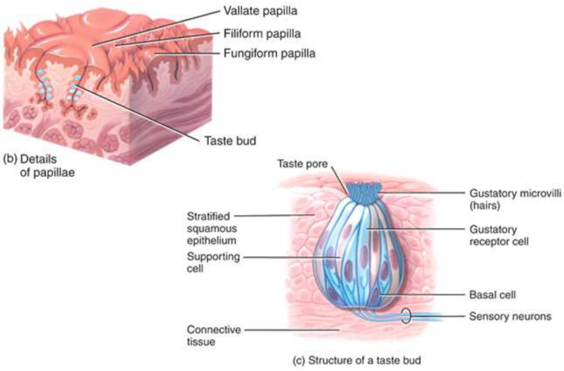
Gustation: Sense of Taste

Taste is a chemical sense, but it is much simpler than olfaction. There are only 5 primary tastes: **sour**, **sweet**, **bitter**, **salt** and **umami** (meaty, savory). Flavors other than umami are combinations of the other four primary tastes.

Gustation: Sense of Taste

- **Taste buds** contain receptors for the sensation of taste. Approximately 10,000 taste buds are found on the **tongue** of a young adult and on the **soft palate**, **pharynx**, and **epiglottis**.
- Taste buds contain 3 kinds of **epithelial cells**: **supporting cells**, **gustatory receptor cells** and **basal stem cells**.

Gustation: Sense of Taste



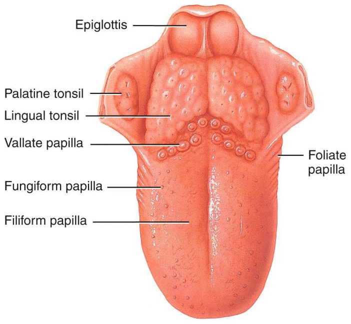
Gustation: Sense of Taste

- Taste buds are located in elevations on the tongue called **papillae**.
- 3 types of papillae that contain taste buds: **vallate papillae** (about 12 that contain 100–300 taste buds)
- **Fungiform papillae** (scattered over the tongue with about 5 taste buds each)
- **Foliate papillae** (located in lateral trenches of the tongue—most of their taste buds degenerate in early childhood).

Gustation: Sense of Taste

- **Filiform papillae** cover the entire surface of the tongue.
- Contain **tactile receptors** but no taste buds.
- Increase friction to make it easier for the tongue to move food within the mouth.

Gustation: Sense of Taste

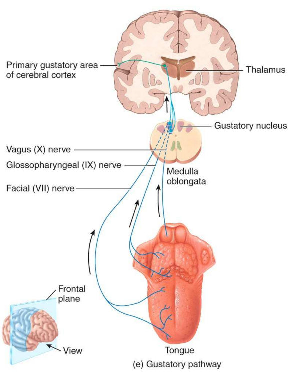


(a) Dorsum of tongue showing location of papillae

Gustation: Sense of Taste

- Three **cranial nerves** are involved the sense of taste.
- **Facial (VII) nerve** carries taste information from the **anterior 2/3 of the tongue**.
- **Glossopharyngeal (IX)** nerve carries taste information from the **posterior 1/3 of the tongue**.
- **Vagus (X) nerve** carries taste information from **taste buds on the epiglottis and in the throat**.

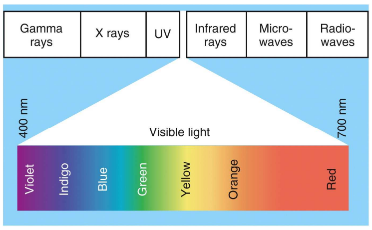
Gustation: Sense of Taste



(e) Gustatory pathway

Vision

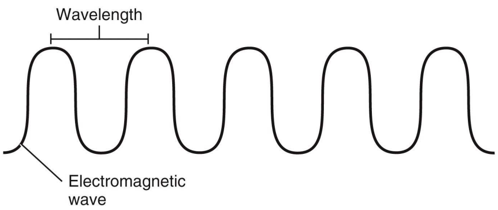
Vision uses **visible light** which is part of the **electromagnetic spectrum** with wavelengths from about 400 to 700 nm.



(a) Electromagnetic spectrum

Vision

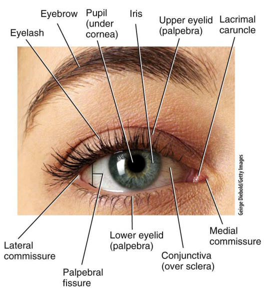
Wavelength is defined as the **distance between two consecutive peaks of an electromagnetic wave**.



(b) An electromagnetic wave

Vision

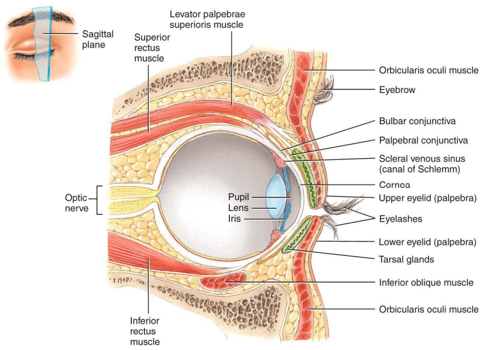
Accessory structures of the eyes include the **eyelids**, **eyelashes**, **eyebrows**, **lacrimal (tear-producing) apparatus** and **extrinsic eye muscles**.



Vision

- **Palpebral muscles** control eyelid movement and **extrinsic eye muscles** are responsible for moving the eyeball itself in all directions.
- The **conjunctiva** is a thin, protective mucous membrane that lines the eyelids and covers the sclera.
- The **tarsal plate**: a fold of connective tissue that gives form to the eyelids. Contains a row of sebaceous glands (**tarsal glands/Meibomian glands**) that keeps the eyelids from sticking to each other.

Vision

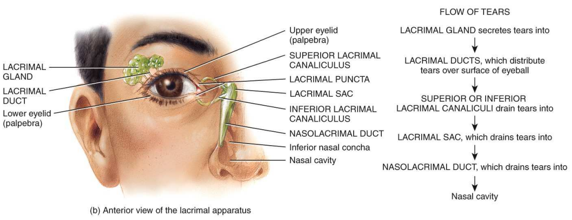


(a) Sagittal section of eye and its accessory structures

Vision

- The **lacrimal apparatus** produces and drains **tears**. The pathway for tears is:
- The **lacrimal glands**
- The **lacrimal ducts**
- The **lacrimal puncta**
- The **lacrimal canaliculi**
- The **lacrimal sac**
- The **nasolacrimal ducts** that carry the tears into the nasal cavity.

Vision

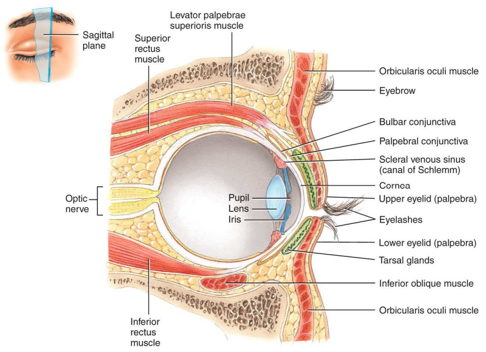


(b) Anterior view of the lacrimal apparatus

Vision

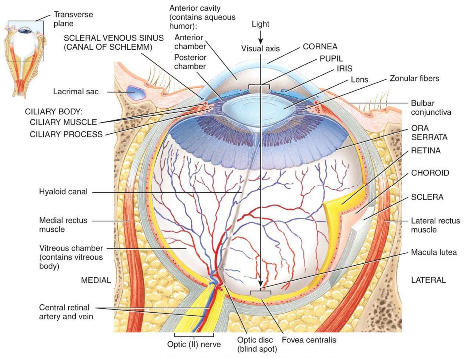
- Six **extrinsic eye muscles** move the eyes in almost any direction. These muscles include the **superior rectus**, **inferior rectus**, **lateral rectus**, **medial rectus**, **superior oblique** and **inferior oblique**.
- The eyeball contains two **tunics** (coats): the **fibrous tunic** (the cornea and sclera) and the **vascular tunic** (the choroid, ciliary body and iris).

Vision



(a) Sagittal section of eye and its accessory structures

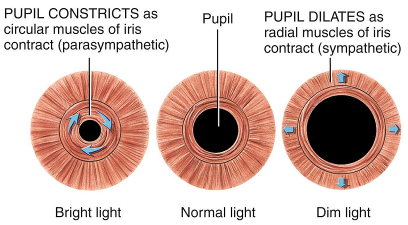
Vision



Superior view of transverse section of right eyeball

Vision

The **iris** (colored portion of the eyeball) controls the size of the **pupil based on autonomic reflexes**.

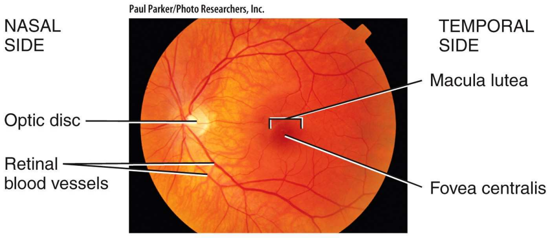


Anterior views

Vision

- The **retina** lines the posterior three-quarters of the inner layer of the eyeball. It may be viewed using an **ophthalmoscope**.
- The **optic (II) nerve** is also visible.
- The point at which the optic nerve exits the eye is the **optic disc (blind spot)**.
- The exact center of the retina is the **macula lutea**. In its center is the **fovea centralis** (area of highest visual acuity).

Vision

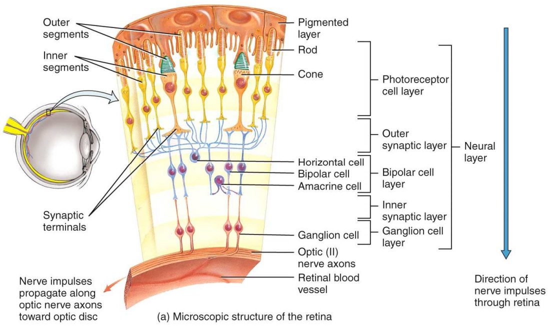


Left eye

Vision

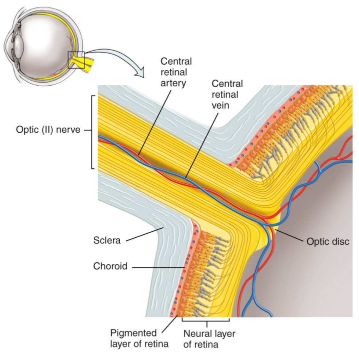
- The retina contains sensors (**photoreceptors**) known as **rods** and **cones**.
- Rods to see in dim light
- Cones produce color vision
- From these sensors, information flows through the **outer synaptic layer** to **bipolar cells** through the **inner synaptic layer** to **ganglion cells**. Axons of these exit as the **optic (II) nerve**.

Vision



(a) Microscopic structure of the retina

Vision



(b) Transverse section of posterior eyeball at optic disc

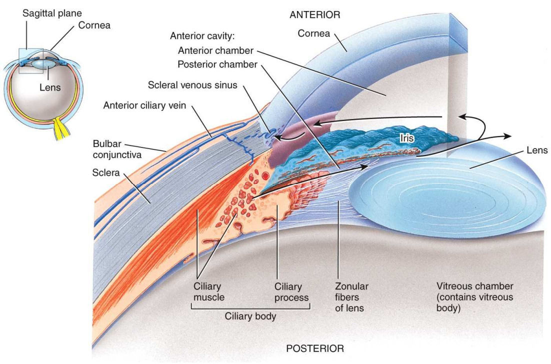
Vision

- The eye is divided into an **anterior chamber** and a **posterior chamber** by the **iris** (colored portion of the eyeball).
- The anterior chamber (between the iris and cornea) is filled with **aqueous humor** (a clear, watery liquid).
- The posterior chamber lies behind the iris and in front of the lens and is also filled with aqueous humor.
- Behind this is the **posterior cavity** (**vitreous chamber**) filled with a transparent, gelatinous substance, the **vitreous humor**.

Vision

Light passes through the **cornea**, the **anterior chamber**, the **pupil**, the **posterior chamber**, the **lens**, the **vitreous humor**, and is projected onto the **retina.**

Vision



Vision

TABLE 17.1

Summary of the Structures of the Eyeball

STRUCTURE	FUNCTION	STRUCTURE	FUNCTION
Fibrous tunic (Cornea; Sclera)	***Cornea:*** Admits and refracts (bends) light. ***Sclera:*** Provides shape and protects inner parts.	**Lens** (Lens)	Refracts light.
Vascular tunic (Iris; Ciliary body; Choroid)	***Iris:*** Regulates amount of light that enters eyeball. ***Ciliary body:*** Secretes aqueous humor and alters shape of lens for near or far vision (accommodation). ***Choroid:*** Provides blood supply and absorbs scattered light.	**Anterior cavity** (Anterior cavity)	Contains aqueous humor that helps maintain shape of eyeball and supplies oxygen and nutrients to lens and cornea.
Retina (Retina)	Receives light and converts it into receptor potentials and nerve impulses. Output to brain via axons of ganglion cells, which form optic (II) nerve.	**Vitreous chamber** (Vitreous chamber)	Contains vitreous body that helps maintain shape of eyeball and keeps retina attached to choroid.

Vision

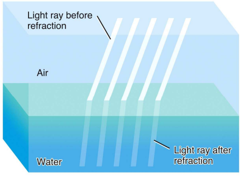
Anatomy Overview:

- Special Senses

You must be connected to the Internet and in Slideshow Mode to run this animation.

Vision

Light **refracts** (bends) when it passes through a transparent substance with one density into a second transparent substance with a different density. This bending occurs at the junction of the two substances.

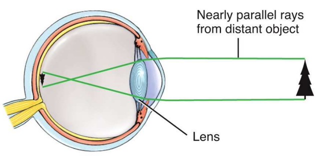


(a) Refraction of light rays

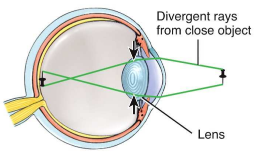
Vision

- Images focused on the **retina** are **inverted and right-to-left reversed** due to refraction. The brain corrects the image.
- The **lens** must **accommodate** to properly focus the object.
- The image is projected onto the **central fovea**, the site where vision is the sharpest.

Vision



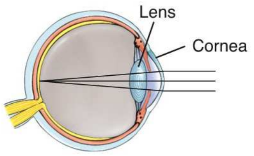
(b) Viewing distant object



(c) Accommodation

Vision

The normal (**emmetropic**) eye will refract light correctly and focus a clear image on the retina.

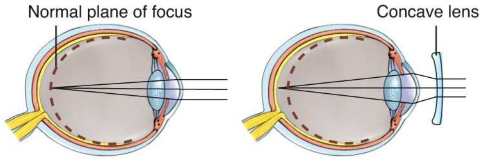


(a) Normal (emmetropic) eye

Vision

- In cases of **myopia (nearsightedness)** the eyeball is longer than it should be and the image **converges** (narrows down to a sharp focal point) in front of the retina. These people see close objects sharply, but perceive distant objects as blurry.
- A **concave lens** is used to correct the vision.

Vision

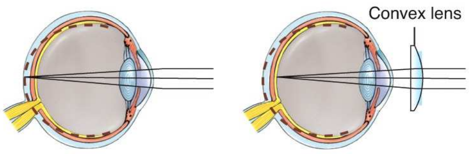


(b) Nearsighted (myopic) eye, uncorrected (c) Nearsighted (myopic) eye, corrected

Vision

- In cases of **hyperopia** (**farsightedness**) also known as **hypermetropia**, the eyeball is shorter than it should be and the image converges behind the retina. These individuals can see distant objects clearly, but have difficulty with close objects.
- A **convex lens** is used to correct this abnormality.

Vision



(d) Farsighted (hyperopic) eye, uncorrected

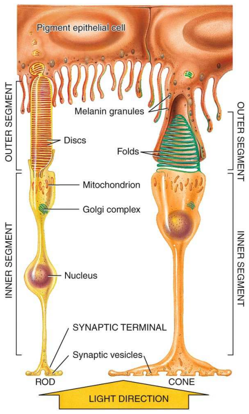
(e) Farsighted (hyperopic) eye, corrected

Vision

Astigmatism is a condition where either the **cornea** or the **lens** (or both) has an irregular curve. This causes blurred or distorted vision.

Vision

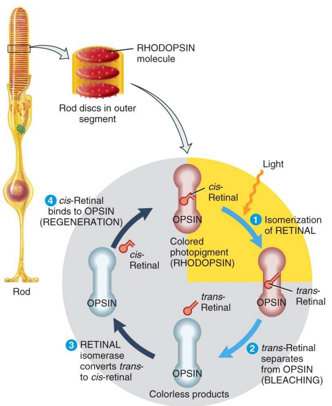
Rods and **cones**, the **photoreceptors** in the retina that convert light energy into neural impulses, were named for the appearance of their outer segments.



Vision

- Rods and cones contain **photopigments** necessary for the absorption of light that will initiate the events that lead to production of a **receptor potential**.
- **Rods** contain only **rhodopsin**.
- **Cones** contain three different photopigments, one for each of the three types of cones (red, green, blue).
- Photopigments respond to light in a **cyclical process**.

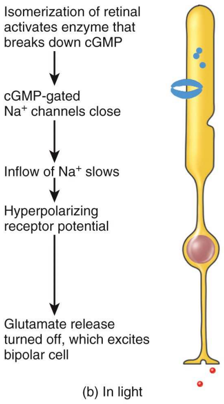
Vision



Vision

- **Light adaptation** occurs when an individual moves from dark surroundings to light ones. It occurs in seconds.
- **Dark adaptation** takes place when one moves from a lighted area into a dark one. This takes minutes to complete.
- Part of this difference is related to the rates of **bleaching** and **regeneration** of photopigments in rods and cones.
- Light causes rod photoreceptors to decrease their release of the inhibitory neurotransmitter **glutamate**.

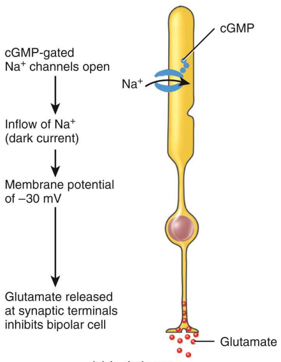
Vision



(b) In light

Vision

In darkness, rod photoreceptors release the inhibitory neurotransmitter **glutamate**. This inhibits bipolar cells from transmitting signals to ganglion cells which provide output from the retina to the brain.



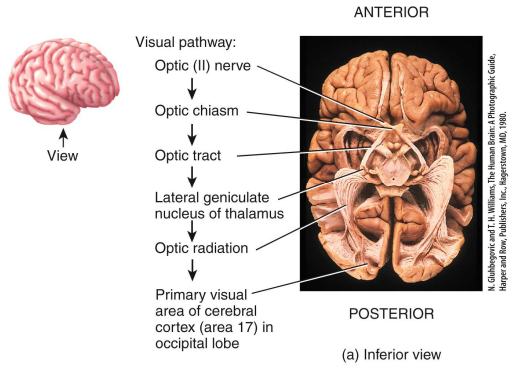
(a) In darkness

Vision

The neural pathway for vision begins when the rods and cones convert light energy into neural signals that are directed to the **optic (II) nerves**. The pathway is:

- The **optic chiasm**
- The **optic tract**
- The **lateral geniculate nucleus** of the **thalamus**
- **Optic radiations** allow the information to arrive at the **primary visual areas** of the **occipital lobes** for perception.

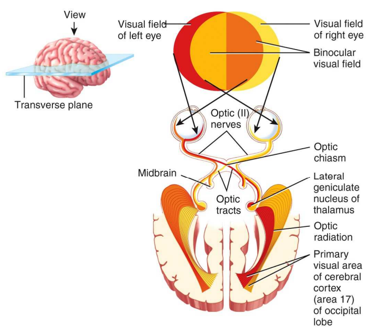
Vision



(a) Inferior view

Vision

The anterior location of our eyes leads to visual field overlap. This gives us **binocular vision**.

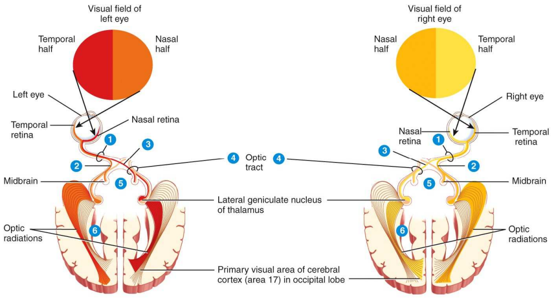


(b) Superior view of transverse section through eyeballs and brain

Vision

- The two visual fields of each eye are **nasal (medial)** and **temporal (lateral)**.
- Visual information from the right half of each visual field travels to the left side of the brain.
- Visual information from the left half of each visual field travels to the right side of the brain.

Vision

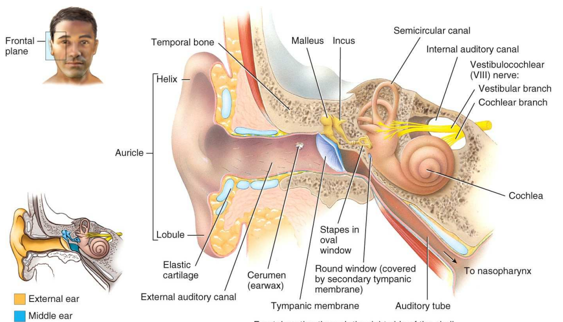


(c) Left eye and its pathways (d) Right eye and its pathways

Hearing and Equilibrium

- The **transduction of sound vibrations** by the ear's sensory receptors into electrical signals is 1000 times faster than the response to light by the eye's photoreceptors.
- The ear also contains receptors for **equilibrium**.
- The ear is divided into **3 regions**: the **external ear**, **middle ear** and **internal ear**.

Hearing and Equilibrium



Frontal section through the right side of the skull showing the three principal regions of the ear

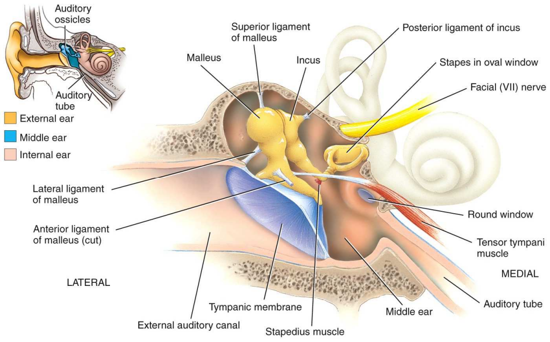
Hearing and Equilibrium

- The **external (outer) ear** contains the **auricle (pinna)**, **external auditory canal** and the **tympanic membrane (eardrum)**.
- The auricle captures sound
- The external auditory canal transmits sound to the eardrum.
- **Ceruminous glands** secrete **cerumen (earwax)** to protect the canal and eardrum

Hearing and Equilibrium

- The **middle ear** contains 3 **auditory ossicles** (smallest bones in the body). They are the **malleus** the **incus** which and the **stapes**. Sound vibrations are transmitted from the eardrum through these 3 bones to the **oval window** into which the stapes fits.
- The **auditory tube (pharyngotympanic tube, eustachian tube)** extends from the middle ear into the nasopharynx to regulate air pressure in the middle ear.

Hearing and Equilibrium

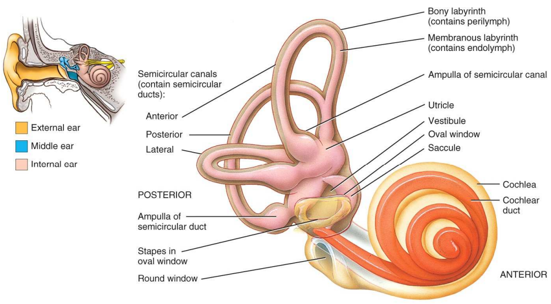


Frontal section showing location of auditory ossicles in the middle ear

Hearing and Equilibrium

The **internal (inner) ear (labyrinth)** contains the **cochlea** which translates vibrations into neural impulses that the brain can interpret as sound, and the **semicircular canals** that work with the cerebellum for **balance and equilibrium**.

Hearing and Equilibrium

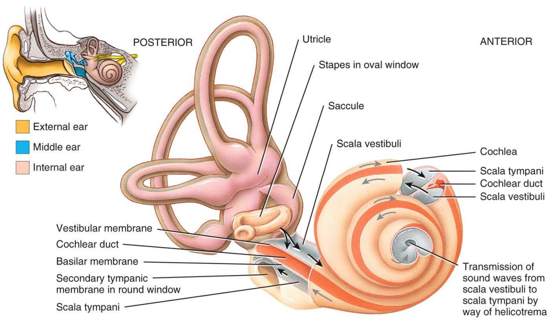


Components of right internal ear

Hearing and Equilibrium

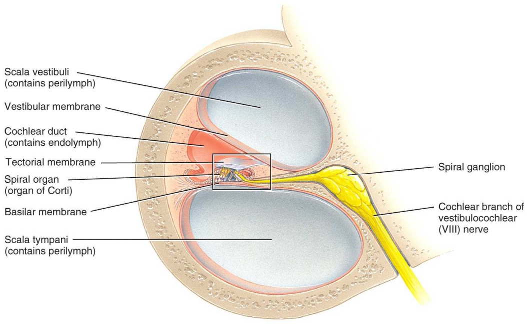
- Vibrations are transmitted from the **stapes** through the **oval window** (whose vibrations are about 20 times more vigorous than those of the tympanic membrane) to the cochlea as fluid pressure waves are transmitted into the **perilymph** of the **scala vestibuli**.
- From here, pressure waves travel to the **scala tympani** and then to the **round window** which bulges into the middle ear.

Hearing and Equilibrium



(a) Sections through the cochlea

Hearing and Equilibrium

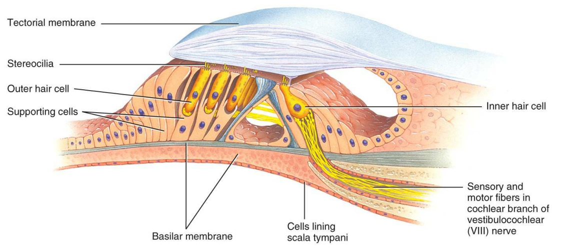


(c) Section through one turn of the cochlea

Hearing and Equilibrium

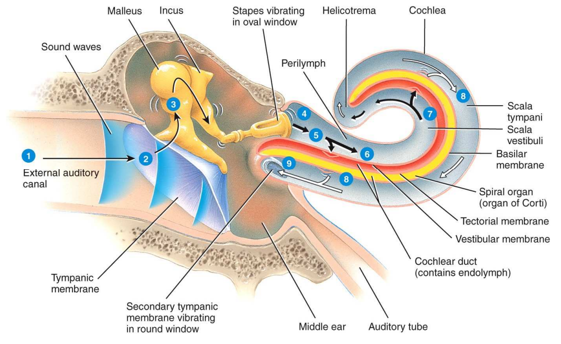
- Pressure waves travel from the **scala vestibuli** to the **vestibular membrane** to the **endolymph of the cochlear duct**.
- The **basilar membrane** vibrates. This moves the **hair cells of the spiral organ (organ of Corti)** against the **tectorial membrane**. These cells generate nerve impulses in cochlear nerve fibers.

Hearing and Equilibrium

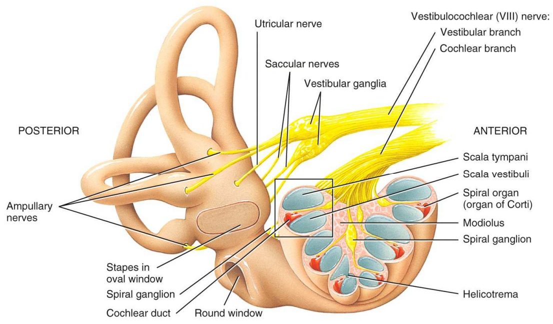


(d) Enlargement of spiral organ (organ of Corti)

Hearing and Equilibrium



Hearing and Equilibrium

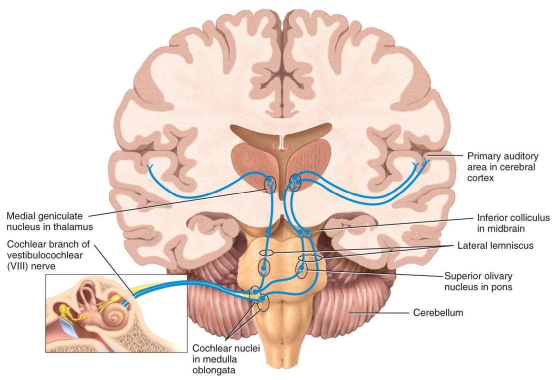


(b) Components of the vestibulocochlear (VIII) nerve

Hearing and Equilibrium

- The cochlear nerve fibers form the **cochlear branch** of the **vestibulocochlear (VIII) nerve**. The axons synapse with neurons in the **cochlear nuclei** in the **medulla oblongata**.
- The impulses travel to the **medial geniculate nucleus** of the **thalamus** and end in the **primary auditory area** of the **cerebral cortex in the temporal lobe**.

Hearing and Equilibrium



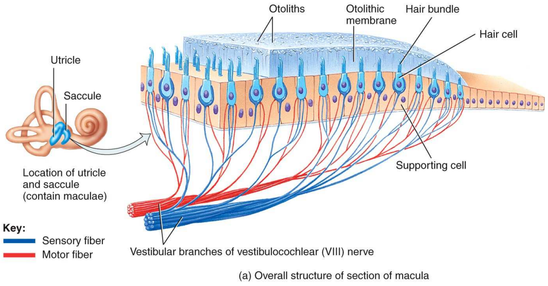
Hearing and Equilibrium

- **Equilibrium (balance)** exists in two forms:
- **Static equilibrium**: maintenance of the body's position relative to the force of gravity
- **Dynamic equilibrium**: the maintenance of the body's position in response to sudden movements.
- **Vestibular apparatus**: The organs that maintain equilibrium. Includes **saccule**, **utricle** (both **otolithic organs**) and **semicircular canals**.
- **Otoliths** are **calcium carbonate crystals**. The walls of the utricle and saccule contain a **macula**. The two maculae are receptors for **static equilibrium**.

Hearing and Equilibrium

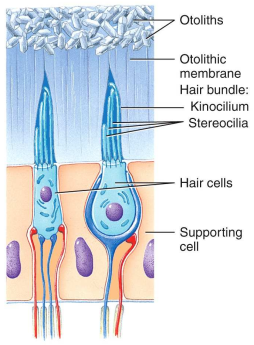
The **otolithic membrane** sits on top of the macula. Movement of the head causes gravity to move it down over **hair cells**. The hair cells synapse with neurons in the **vestibular branch of the vestibulocochlear (VIII) nerve**.

Hearing and Equilibrium



(a) Overall structure of section of macula

Hearing and Equilibrium

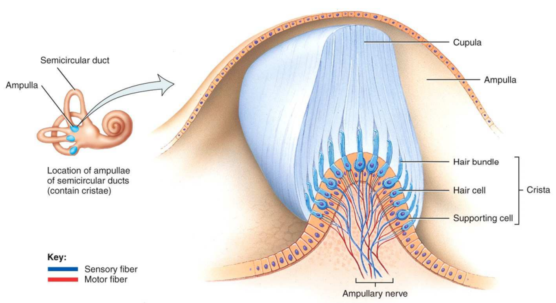


(b) Details of two hair cells

Hearing and Equilibrium

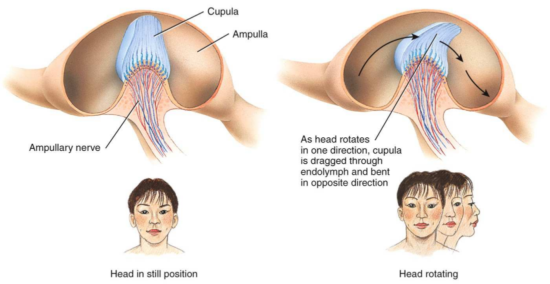
- Three **semicircular canals** are responsible for **dynamic equilibrium**. The ducts lie at right angles to each other which allows for **rotational acceleration** or **deceleration**.
- An **ampulla** in each canal contains the **crista** with a group of **hair cells**. Movement of the head affects the endolymph and hair cells.
- This generates a potential leading to nerve impulses that travel along the **vestibular branch of the vestibulocochlear (VIII) nerve**.

Hearing and Equilibrium



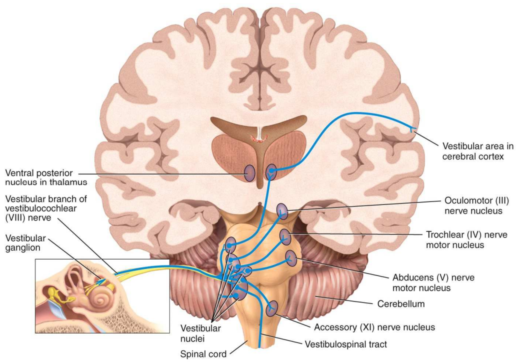
(a) Details of crista

Hearing and Equilibrium



(b) Position of cupula with head in still position (left) and when head rotates (right)

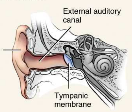
Hearing and Equilibrium



Hearing and Equilibrium

TABLE 17.2

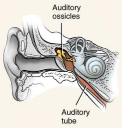
Summary of Structures of the Ear

REGIONS OF THE EAR AND KEY STRUCTURES	FUNCTION
External (outer) ear 	***Auricle (pinna):*** Collects sound waves. ***External auditory canal (external auditory meatus):*** Directs sound waves to eardrum. ***Tympanic membrane (eardrum):*** Sound waves cause it to vibrate, which in turn causes malleus to vibrate.

Hearing and Equilibrium

TABLE 17.2

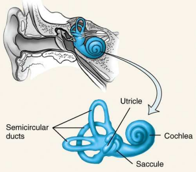
Summary of Structures of the Ear

REGIONS OF THE EAR AND KEY STRUCTURES	FUNCTION
Middle ear 	***Auditory ossicles:*** Transmit and amplify vibrations from tympanic membrane to oval window. ***Auditory tube (eustachian tube):*** Equalizes air pressure on both sides of tympanic membrane.

Hearing and Equilibrium

TABLE 17.2

Summary of Structures of the Ear

REGIONS OF THE EAR AND KEY STRUCTURES	FUNCTION
Internal (inner) ear 	***Cochlea:*** Contains a series of fluids, channels, and membranes that transmit vibrations to spiral organ (organ of Corti), the organ of hearing; hair cells in spiral organ produce receptor potentials, which elicit nerve impulses in cochlear branch of vestibulocochlear (VIII) nerve. ***Vestibular apparatus:*** Includes semicircular ducts, utricle, and saccule, which generate nerve impulses that propagate along vestibular branch of vestibulocochlear (VIII) nerve. ***Semicircular ducts:*** Contain cristae, site of hair cells for *dynamic equilibrium* (maintenance of body position, mainly the head, in response to rotational acceleration and deceleration movements). ***Utricle:*** Contains macula, site of hair cells for *static equilibrium* (maintenance of body position, mainly the head, relative to force of gravity). ***Saccule:*** Contains macula, site of hair cells for static equilibrium.

Hearing and Equilibrium

Anatomy Overview:

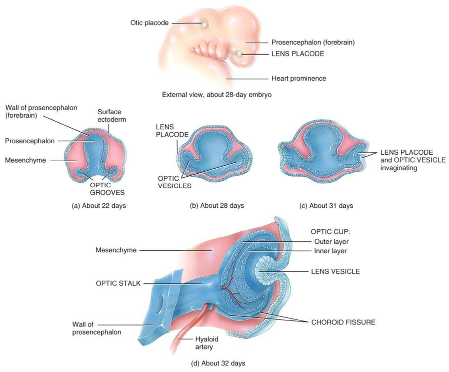
- Special Senses

You must be connected to the Internet and in Slideshow Mode to run this animation.

Development of the Eyes and Ears

- The eyes begin to develop about 22 days after fertilization.
- The **ectoderm of the forebrain (prosencephalon)** forms the **optic grooves**.
- They become the **optic vesicles**.
- The optic vesicles reach the surface ectoderm which thickens to form the **lens placodes**.
- The distal portion of the optic vesicles forms the **optic cups**. They remain attached to the prosencephalon by **optic stalks**.

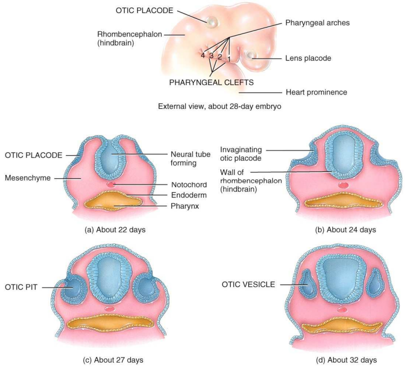
Development of the Eyes and Ears



Development of the Eyes and Ears

- The **internal ears** develop first. This also begins about 22 days after fertilization.
- The surface ectoderm thickens to form **otic placodes** that appear on either side of the **hindbrain (rhombencephalon)**.
- They form **otic pits** that pinch off to form **otic vesicles**.

Development of the Eyes and Ears



Aging and the Special Senses

- **Smell and taste** are not affected by aging until around age 50 when the gradual loss of receptors and the slower rate of regeneration have an affect.
- The lens begins to lose elasticity and has difficulty focusing on close objects (**presbyopia**). This begins around age 40.
- Muscles of the iris weaken and react more slowly to light and dark causing elderly people to have difficulty adjusting to changes in lighting.

Aging and the Special Senses

- **Retinal diseases** such as **macular disease**, **detached retina** and **glaucoma** (damage to the retina due to increased intraocular pressure) occur more frequently in the elderly.
- By about age 60, approximately 25% of individuals experience a noticeable hearing loss. Age associated loss is called **presbycusis**.
- **Tinnitus** (ringing in the ears) and **vestibular imbalance** also occur more frequently in the elderly.

End of Chapter 17