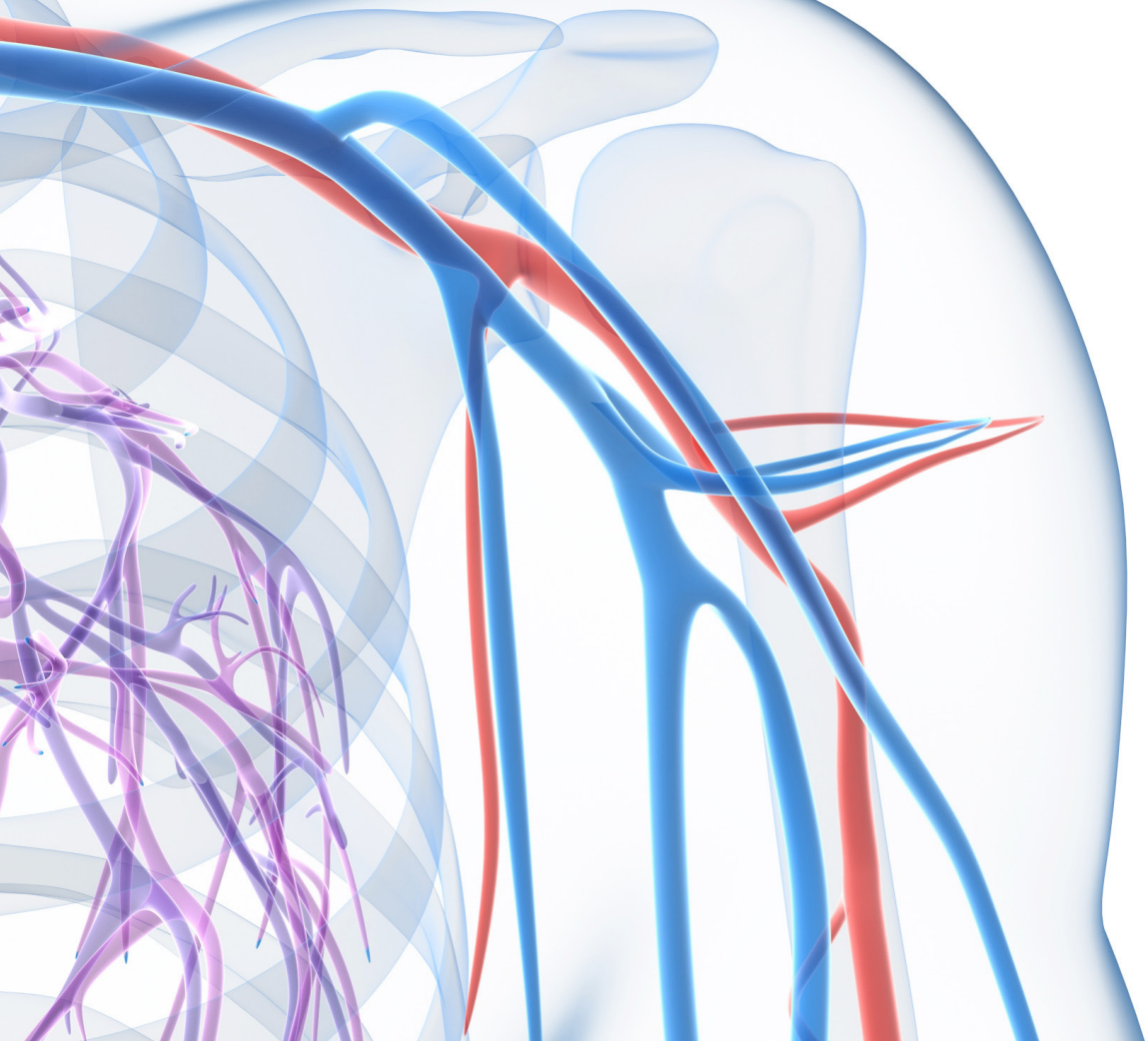
Special Senses

A Course Companion



MedCerts™

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Module 9 Special Senses

9.1 Module Outline

The special senses play an important role in collecting information about the world outside and inside our body. Without this information our brain struggles to responds to internal and external changes by activating appropriate muscles and glands.

9.2 Module Objectives

Upon completion of this module, you will be able to:

- Recognize, spell, and build words related to the special senses.
- Identify and describe the major structure of the special senses and their functions.
- Describe and understand pathological conditions and diagnostic and therapeutic procedures related to the special senses.
- Demonstrate your understanding of the content by completing the Test Your Knowledge section at the end of the module.

9.3 Key Vocabulary

This section introduces major definitions, combining forms, suffixes, and prefixes related to the special senses. For a more complete list, check Commonly Used Adjectives, Prefixes, and Suffixes in the Appendix.

Table 9.1 Overview of Major Definitions and Combining Forms

Term	Definition	
Eyes	Receptor organs for the sense of sight (vision).	
Iris	Controls the amount of light entering the eye by changing the size of the pupil.	
Lens	Helps focus light on the retina.	
Retina	Has sensors (photoreceptors) that convert light into electric signals.	
Optic nerve	Carries electric signals from the retina to the brain.	
Ears	Receptor organs for the sense of hearing and balance.	
Taste buds	Receptor organs for the sense of taste (gustation)	
Olfactory epithelium	Specialized tissue at the roof of the nasal cavity with receptors for the sense of smell (olfaction).	
Combining Form(s)	**Meaning**	**Example(s)**
acoust(o)-	Hearing; sound	*Acoustic* = relating to sound or the sense of hearing
aud-, audi(o)-, audit(o)-,	Hearing; ear	*Auditory* = relating to the sense of hearing

aur(i)-, aur(o)-		
blephar(o)-	Eyelid	*Blepharoptosis* = drooping of the eyelid
cochle(o)-	Spiral, snail	*Cochlear* = relating to the cochlea
conjunctiv(o)-	Conjunctiva	*Conjunctivitis* = inflammation of the conjunctiva
corne(o)-	Cornea	*Corneal* = relating to the cornea
dacry(o)-	Tears	*Dacryorrhea* = excessive flow of tears
dacryocyst(o)-	Tear duct	*Dacryocystitis* = inflammation of the nasolacrimal duct
gusto(o)-	Taste	*Gustatory* = relating to the sense of taste
ir(i)-, ir(o)-, irid(o)-, irit(o)-	Iris	*Iritis* = inflammation of the iris
kerat(o)-	Cornea	*Keratitis* = inflammation of the cornea
lacrim(o)-	Tears; tear duct	*Lacrimal* = relating to tears or the secretion of tears
myring(o)-	Tympanic cavity; tympanic membrane	*Myringotomy* = incision into the tympanic membrane
ocul(o)-, ophthalm(o)-, -opia	Eye	*Ophthalmologist* = specialist for the study and treatment of disorders of the eye
olfact(o)-	Smell	*Olfactory* = relating to the sense of smell
opt(i)-, optic(o)-, opt(o)-	Vision; eye	*Optician* = person qualified to make and supply eyeglasses and contact lenses for correction of vision
ot(o)-	Ear; hearing	*Otoliths* = tiny crystals inside the ear
phac(o)-, phak(o)-	Lens	*Phacoemulsification* = use of ultrasound to break up the lens in order to make it easier to remove
phot(o)-	Light	*Photoreceptor* = light sensor in the retina
retin(o)-	Retina	*Retinopexy* = treatment to reattach the retina
scler(o)-	Sclera	*Scleritis* = inflammation of the sclera
tympan(o)-	Tympanic cavity; tympanic membrane	*Tympanoplasty* = reconstruction of the tympanic membrane
vestibul(o)-	Vestibule	*Vestibular* = relating to the vestibule
vitre(o)-	Glass; glassy	*Vitreous* = glass-like in appearance

9.4 Abbreviations, Acronyms, and Symbols

Table 9.2 lists a limited number of abbreviations, acronyms, and symbols. For more, see the list of Acronyms, Abbreviations, and Symbols in the Appendix.

Table 9.2 Abbreviations, Acronyms, and Symbols

AD	right ear (auris dexter)
ARMD	age-related macular degeneration
AS	left ear (auris sinister)
AsH	astigmatism (hyperopic)
AsM	astigmatism (myopic)
Astig	astigmatism
AU	each ear or both ears (auris uterque)

CAT	cataract
CI	conjunctivitis
D, dptr	diopter
dB	decibel
EM, em	emmetropia
FA, FAG	fluorescein angiography
G, glc	glaucoma
Hz	Hertz
LASIK	laser-assisted in situ keratomileusis
MD	macular degeneration
OD	right eye (oculus dexter)
OS	left eye (oculus sinister)
OU	each eye or both eyes (oculus uterque)
RD	retinal detachment
SC	Snellen chart
V, VA	visual acuity

9.5 Anatomy & Physiology

Sensory receptors (also called **receptors** or **sensors**) are specialized cells or groups of cells that respond to changes in their environment (stimuli) by generating an electric signal. These electric signals travel in nerve fibers to the central nervous system, where the transmitted information is analyzed.

Receptors can be **classified based on the stimulus to which they respond** into:

- Receptors that respond to touch, pressure, vibration, stretch, and itch (**mechanoreceptors**).
- Receptors that are sensitive to changes in temperature can respond to warm or cold stimuli (**thermoreceptors**).
- Receptors in the retina of the eye that respond to light energy (**photoreceptors**).
- Receptors that respond to chemicals, such as receptors for smell and taste (**chemoreceptors**).
- Receptors that respond to pain-causing stimuli, such as extreme heat or cold, excessive pressure, or inflammatory chemicals (**nociceptors**).

Most sensory fibers carrying information to the central nervous system terminate in the diencephalon, brain stem, or cerebellum. Because of this, we are not consciously aware of the information they carry. However, our body uses the information to make necessary adjustments, such as increasing our blood pressure to prevent fainting when we get up.

- **Only signals that terminate in sensory areas of the brain give us conscious awareness of a sensation**. We learned in Module 8 Nervous System that some sensory areas receive and process signals from the special senses, others from our skin, muscles, and joints (**somatosensation**) as well as from internal organs such as the stomach and the bladder (**visceral sensation**).
- **Association areas** integrate diverse information. They allow us to give meaning to information received, store it as memory, compare it to previous experience, and decide on which action to take.
- **Motor areas** enable us to perform precise, skilled, voluntary movements.

What makes the **special senses** so special is a) the complexity of their receptors and b) that we process the information gathered in special sensory areas in the brain. Our central nervous system combines the information from many senses to come to the best possible assessment of the situation. For example, we are able to deduct just from looking at a glass that it most likely contains cold milk. We may also be able to conclude that a dog running towards us is not going to attack us but will jump at us for joy.

9.5.1 Anatomy of the Eye

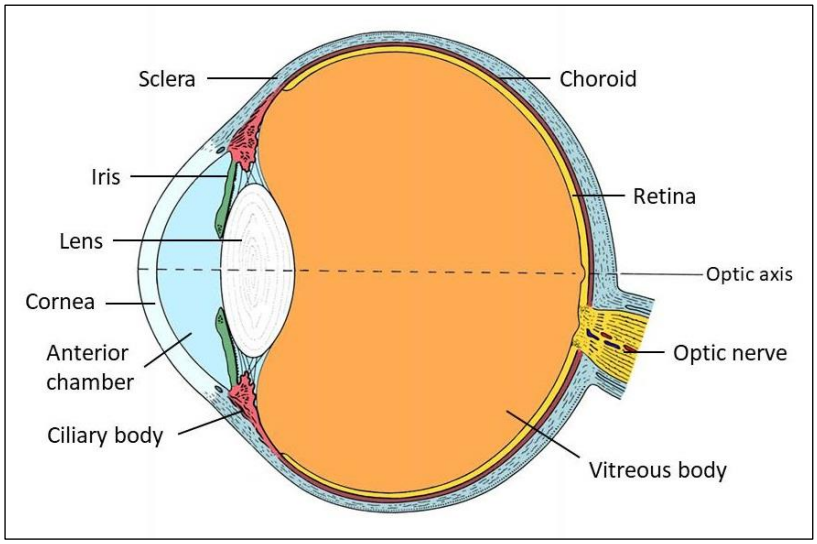
The visual sense is the most important of the special senses as no blind person can survive without help from others. It is a very complex sense (70% of all sensory receptors of the body are in the eye), and nearly half of the cerebral cortex is involved in processing of visual information.

The eye (or eyeball) has **five accessory structures**:

- The function of the **eyebrows** is to shade the eye and to prevent sweat from reaching the eye.
- The **eyelids** (palpebrae) protect the eye anteriorly. They have connective tissue plates called **tarsal plates** that provide stability. The lower eyelid is pulled down by gravity, but the upper lid needs to be lifted by a muscle (levator palpebrae) to open the eye. The secretions of three glands (tarsal or Meibomian glands, sebaceous glands, and ciliary glands) act as lubricant and prevent the eyelids from sticking together. The **eyelashes** have nerve endings that initiate the **blinking reflex** when activated.
- The transparent membrane covering the anterior part of the eye is called **conjunctiva**. It has two parts: a **palpebral conjunctiva** that lines the eyelid and a **bulbar conjunctiva** that covers the white of the eye. The cornea, the central part of the anterior eye, is not covered by the conjunctiva.
- The tear-producing **lacrimal apparatus** consists of the **lacrimal** or **tear gland** and a duct system that drains the tear liquid into the nose. Every time we blink, some liquid is squeezed out of the gland and spread across the eye. It is drained into the **nasolacrimal (tear) duct**, which then drains the fluid into the nasal cavity. **Tears** are a dilute saline solution containing mucus and substances to fight pathogens. However, its composition changes considerably depending on our emotional state. Laughter tears are different from sad tears. On average, we produce about 1 ml of tear fluid per day.
- The **six** strap-like **extrinsic** (outer) **eye muscles** have their origin on the skull behind the eye and insert into the sclera. They can move the eye to the left and right and up and down, as well as rotate it to the inside and outside. This allows us to move our eyeballs into the perfect position to look at objects and to follow them if they move.

The **wall of the eyeball** has three layers: fibrous, vascular, and sensory. Its internal (intraocular) cavity is filled with fluids called humors. The lens separates this cavity into an anterior and posterior segment or cavity.

Figure 9.1 Eyeball, cross-section



- The outermost layer is called **sclera**. It is a white (**white of the eye**), fibrous layer that protects and shapes the eyeball and anchors the extrinsic eye muscles.
- In the front, the sclera goes over into the **cornea**. This transparent layer allows light to enter the eye. It has a very high density of pain receptors that initiate blinking and tearing reflexes when irritated.
- The pigmented middle layer is called **uvea**. It has three regions:
  - The **choroid** forms the posterior part of the uvea. It supplies blood to all layers of the eyeball, and its brown pigment absorbs light to prevent visual confusion.
  - The **ciliary body** forms a ring surrounding the lens. Its smooth muscles fibers (ciliary muscle) regulate the tension of the so-called ciliary zonule, which holds the lens in position. At the back of the ciliary body are the **ciliary processes** that secrete aqueous humor (see below) into the intraocular cavity.
  - The most anterior part is the **iris**, the visible colored part of the eye. Its central opening forms the **pupil**, whose task is to regulate the amount of light that enters the eye. The size of the pupil changes depending on the ambient light but is also influenced by our emotional state – the pupils dilate when we are frightened or excited.

- The innermost, sensory layer is called the **retina**. It is a delicate two-layered membrane with an outer **pigmented layer** that **absorbs light** and stores vitamin A and an inner **neural layer** with **photoreceptors** that react to light energy. The axons of the photoreceptors form the **optic nerve**. The site where the nerve leaves the eyeball is called the **optic disc** or the **blind spot**, because there are no photoreceptors.
    - The optic axis of the eye runs through the center of an area called **macula lutea**. At the center of macula is a small depression called **fovea centralis**. The fovea has the highest concentration of photoreceptors for color vision; therefore, disorders that affect the macula have a pronounced effect on the vision of the patients.

The **lens**, together with the **ciliary zonule**, subdivides the intraocular cavity into an anterior and a posterior segment. The **posterior segment** contains the **vitreous humor** (*vitreous* = glass-like, *humor* = Latin for *liquid*). The vitreous humor is a jelly-type liquid surrounded by a thin capsule. It allows light to pass through on its way to the retina, supports the posterior surface of the lens, holds the retina in place, and contributes to the intraocular pressure.

The **anterior segment** is filled with a thin, watery liquid called **aqueous humor**. The aqueous humor is formed by the ciliary processes of the ciliary body. The humor is released into the posterior chamber behind the iris. It travels through the pupil into the anterior chamber and is drained though a special opening (scleral venous sinus or canal of Schlemm). The aqueous humor removes wastes and supplies nutrients and oxygen, mainly to the lens and cornea but also to the retina.

The lens itself is a biconvex, transparent, flexible, elastic, and avascular body that helps us focus light on the retina. It grows in layers of lens fibers that are filled with a transparent protein called crystalline.

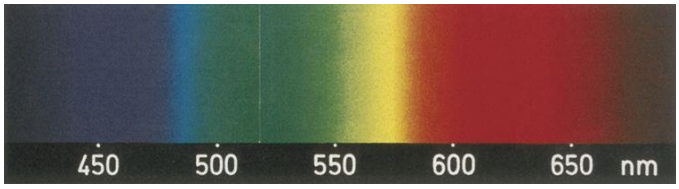
9.5.2 Physiology of Vision

Light coming in through the pupil is focused on the retina, where photoreceptors generate electric signals that are conducted to the brain by the optic nerve. The visual centers in the cerebral cortex analyze these signals to give them meaning.

The two types of photoreceptors are called **rods** and **cones** depending on their shape. **Rods** are more numerous at the peripheral region of the retina; **cones** are found mainly near the center of the retina in the so-called fovea centralis.

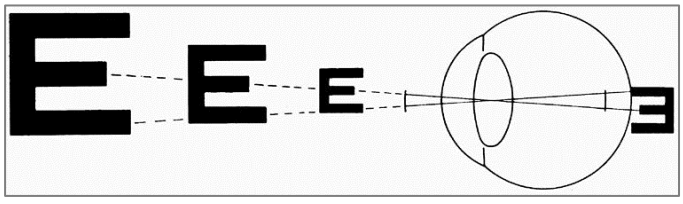
Light consists of packets of energy called photons that travel in a wavelike fashion. Our eyes only respond to **visible light** (400-700 nm). Rods and cones respond to different wavelengths of the visible spectrum.

Figure 9.2 The spectrum of visible light



In order to focus the light in a focal point on the retina, the light needs to be bent (refracted). Light enters the eye through the cornea and then travels through aqueous humor, lens, and vitreous humor to the receptors in the neural layer of the retina. Along the way, the light is bent in the cornea and the lens. The resulting image is upside-down and reversed right to left. It is up to our brain to make sense of this image.

Figure 9.3 Refraction of light and focusing on the retina



A normal (emmetropic) eye can see anything beyond 20 feet (distant vision). The eye has **20/20 vision**.
If an object is closer than 20 feet, the eye must make **adjustments for close vision**:

- The ciliary muscles relax, allowing the elastic lens to go from flat to round. This so-called **accommodation** increases the refractory power and helps to bend the rays and focus them on the retina.
- The pupil constricts to restrict the amount of light entering the eye.
- The eyes rotate to the inside to focus on the close object. This leads to double vision for objects further away.

The light arriving at the retina excites the photoreceptors.

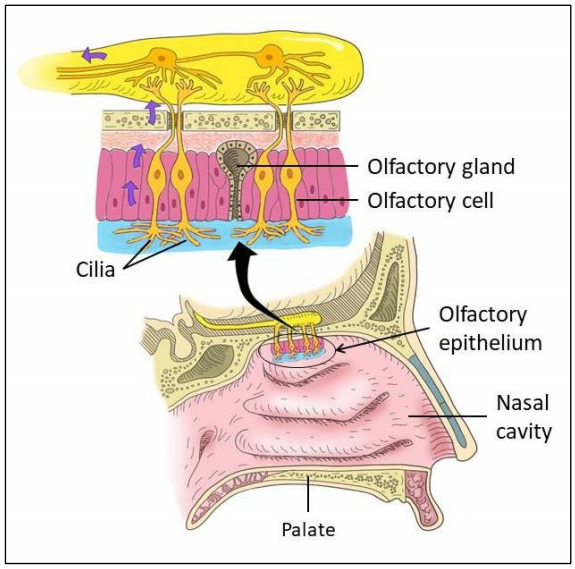
- The **rods** are found mainly in the **outer region of the retina**. They are very sensitive and, thus, can operate in **low light conditions**, making them best suited for **night** and **peripheral vision**. The image our brain creates using their signals is indistinct, fuzzy, and made of many shades of gray and black.
- The **cones**, on the other hand, are concentrated in center of the retina with the highest density in the fovea centralis. The **three types of cones**, named for the colors of light absorbed, are: **blue, green**, and **red**. Their pigments have a **low light sensitivity** and can only function in **bright light**. However, they give us **high-acuity color vision**.

Depth perception is based on both eyes viewing the same image from slightly different angles. The fusion of the slightly different images in the brain creates **three-dimensional vision**. People with one eye only have two-dimensional vision and struggle with estimating how far away objects are.

9.5.3 Chemical Senses: Smell and Taste

The senses of **smell** (or **olfaction**) and **taste** (or **gustation**) use chemoreceptors that respond to chemicals dissolved in water. Thus, only water-soluble substances can be tasted or smelled. For example, sugar is a water-soluble carbohydrate with a sweet taste. Flour, which is made of long chains of the same carbohydrates, is not water-soluble and does not taste sweet.

Figure 9.4 Olfactory epithelium

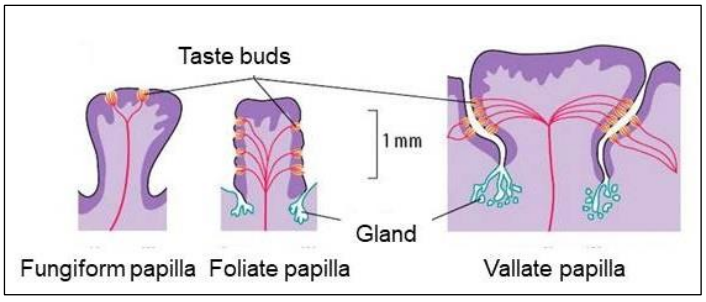


The **olfactory epithelium** with the **receptors for smell** is located in a small area up in the roof of the nose. The receptor cells have hair-like processes (cilia). Because we can only smell substances (**odorants**) dissolved in water, the epithelium has **olfactory glands** that secrete fluid to help dissolve the odorants. The fluid also washes them away so they do not block the receptors. The axons of the receptors cells form the **olfactory nerve** (cranial nerve I). The fibers travel through tiny holes in the cribriform plate of the ethmoid bone to the brain.

Signals from the smell receptors are sent to different areas in the brain so that we can make best use of the information. For example, smell information stored in our long-term memory can help us avoid dangerous or unpleasant situations as well as help us relax when we smell certain odorants.

The **receptors for taste** are mainly found on the anterior two-thirds of the tongue, although there can be some in the back part of the mouth and throat. There are **three kinds of papillae that carry taste buds**: **fungiform**, **foliate**, and **vallate** (or circumvallate) **papillae**. Foliate papillae are found on the lateral side of the tongue only; they disappear after adolescence. The large vallate papillae are aligned in a V-shape in front of the V sulcus, which forms the border to the root of the tongue. The fungiform papillae are spread out all over the anterior part of the tongue.

Figure 9.5 Taste buds



Each **taste bud** is a flask-shaped structure with receptor cells (**gustatory** or **taste cells**) and dynamic stem cells that replace sloughed off receptor cells. **Gustatory hairs** project through a **taste pore** and bind substances we can taste (so-called **tastants**).

There are glands at the base of the taste buds that secrete fluid to help dissolve substances so we can taste them. If you stick out your tongue, dry it with a cloth, and put sugar or salt on the dry tongue, you will not taste the sugar or salt at first. If you wait a bit, the fluid from the glands will dissolve the salt or sugar, and you will start tasting it.

Electric signals from the taste cells travel in three cranial nerves (facial nerve, glossopharyngeal nerve, vagus nerve) to different areas in the brain.

Taste is a much more complex sense than smell. As a matter of fact, 80% of taste actually is smell. We have all noticed that food tastes bland when our nose is stuffed due to a cold. It is still unknown how the brain recognizes that a certain substance irritating smell fibers is actually a tastant and not an odorant and subsequently processes this signal as taste.

There are **five basic taste sensations**:

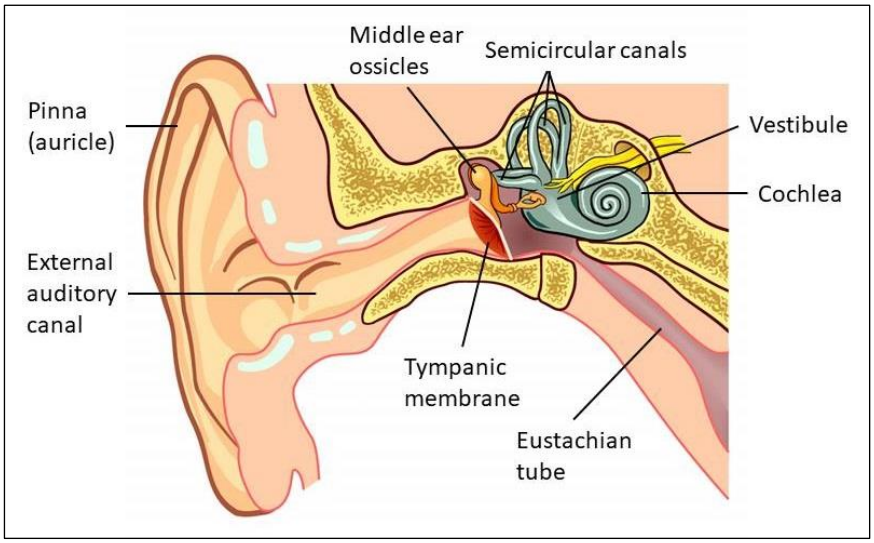
- **Sweet**: Initiated by sugars, saccharin, alcohol, and some amino acids.
- **Sour**: Initiated by acidic substances, such as vinegar.
- **Salty**: Initiated by metal ions, such as sodium.
- **Bitter**: Initiated mainly by alkaloids, such as quinine and nicotine.
- **Umami**: A meaty taste caused by the amino acids glutamate and aspartate.

However, signals from other receptors, such as thermoreceptors, mechanoreceptor, and pain receptors in the mouth influence taste as well. For example, cold pizza tastes differently than hot pizza. Even air pressure and humidity affects taste, which is why food on airplanes tastes rather bland.

9.5.4 Hearing and Balance

The ear has three parts: **outer** or **external ear**, **middle ear**, and **inner** or **internal ear**. The **outer** and **middle ears** are involved in **hearing** only, whereas the **inner ear** (labyrinth) is involved in both **hearing and balance** (equilibrium).

Figure 9.6 Ear, cross-section



Receptors for hearing and balance respond to separate stimuli and activate independently from each other. They also travel in separate nerve fibers to different centers in the brain.

The outer ear consists of the **auricle** or **pinna**, which is made of elastic cartilage covered by skin. It has two parts: the **rim** or **helix** and the **earlobe** or **lobule**. The **external auditory canal** or external acoustic meatus is a short, curved tube. It is lined with skin bearing hairs (to keep insects out) and glands that produce oil (sebaceous glands) and a waxy substance (ceruminous glands). The **earwax** (**cerumen**) that comes out of the auditory canal is a mix of wax, oils, and dead cells. The taste of the wax is said to deter insects from crawling into the auditory canal.

The **eardrum** or **tympanic membrane** at the end of the auditory canal forms the boundary to the middle ear. It is a thin connective tissue membrane that vibrates in response to sound, transferring the sound energy to the bones of the middle ear.

The **middle ear** is also called the **tympanic cavity**, because it is a small, air-filled and mucosa-lined cavity in the temporal bone of the skull. The tube connecting it to the back part of the nose (nasopharynx) is called the **auditory**, **Eustachian**, or **pharyngotympanic** (*pharyng(o)-* pharynx, *-tympanic* eardrum) **tube**. Its task is to help equalize the pressure in the middle ear with the air pressure outside of it. The bony wall on the medial side of the cavity has two openings that are covered by membranes; these openings are called oval window and round window, respectively.

The three **middle ear ossicles** are tiny bones (ossicle = tiny bone) that connect the tympanic membrane with the oval window. The bones themselves are connected by the smallest synovial joints of the body. The first bone is attached to the tympanic membrane; because it seems to hammer on the second bone, it is called **malleus** or **hammer**. The second bone is called **incus** or **anvil**, because the malleus seems to hit it when it moves. The last bone, the **stapes**, looks like a **stirrup**. Its base fits perfectly into the oval window.

The **inner ear** is a rather complex structure and, therefore, also called the **labyrinth**. It has three fluid-filled parts and looks a bit like a mutated snail. The snail house is called the **cochlea**. It contains three ducts, one of which (the **cochlear duct**) houses the receptors for sound. What would be the body of the snail is called the **vestibule**. At the end of the vestibule are three **semicircular canals**. The vestibule and semicircular canals contain the receptors that inform our brain of the position of the head and whether it is moving.

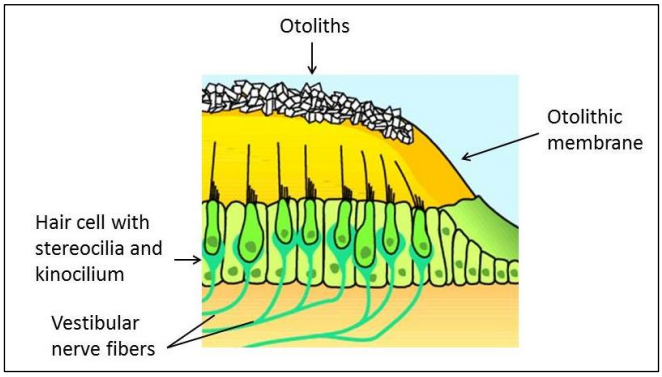
Sounds waves travel through the **auditory canal**, and their pressure leads to **vibrations of the tympanic membrane**. These vibrations are passed along the chain of **middle ear ossicles**. Due to the way these tiny bones are set up and connected, the ossicles amplify the sound ten times. They pass their vibrations on to the **fluid inside the cochlea**, converting vibrations into a pressure wave. This wave travels though the cochlear duct and leads to the formation of electric signals in the hearing receptors (**organ of Corti**). The signals then travel in fibers of the vestibulocochlear nerve to the brain.

This type of sound conduction is called **air conduction**. However, sound can also be transmitted to the inner ear via the bones of the skull; this is called **bone conduction**. Bones are denser than air and, therefore, conduct lower frequencies better. This is the reason why we perceive our own voice to be lower and fuller than others do and why, when we hear a

recording of our own voice, it usually sounds higher than we are used to. We can only hear sounds with frequencies between 20 and 20,000 Hz.

The **receptors for balance** are found in the **vestibule** and the **semicircular ducts**. Together, they form the **vestibular apparatus**. The two **sensory areas in the vestibule** are called **maculae** (macula = spot). The maculae contain receptors cells with hairs (stereocilia) and one long kinocilium that are embedded in a gel-like membrane. Tiny stones on top of the membrane are called **ear crystals** or **otoliths** (*oto-* ear, *-lith* stone). The membrane is called **otolithic membrane**.

Figure 9.7 Macula



Any change in the position of the head alters how gravity affects the membrane and the otoliths. The membrane will shift due to the change in gravitational pull, causing the stereocilia and the kinocilium to move, as well. This movement creates electric signals that travel in vestibular nerve fibers to the brain. This part of our balance is called **static balance**, because the electric signals depend on how we hold our head.

The receptors at the base of three semicircular canals are called **cristae ampullares**. They have hair cells that extend into a tall, gel-like mass called the **cupula**. There are, however, no otoliths. When our head moves around, the fluid inside the semicircular canals moves, as well, and makes the cupula wave as plants do in a water current. This movement of the cupula triggers the electric signals that travel in vestibular nerve fibers to the brain. Because the electric signals only occur when we move our head around, this part of our balance is called **dynamic balance**.

Balance and equilibrium form a complex sense that relies upon signals from the vestibular apparatus, our eyes (visual signals), and our joints and muscles (somatic signals). Sometimes, these signals may contain contradicting information. For example, when we sit in a car and look out of the window, our somatic signals indicate that we are not moving, whereas the visual signals tell our brain that we are moving compared to the world outside the window. If the brain becocmes confused by apparent contradiction, **motion sickness** develops.

9.6 Pathology

Impaired function of any special sense is a problem for us. Nevertheless, we are better at compensating for some problems, such as the color blindness, than others (blindness, for example).

9.6.1 Pathologies of Eye and Vision

Disorders of the eye and vision can be classified by disorders of the accessory structures (inflammation of the conjunctiva, for example), disorders affecting the eyeball and its parts, and disorders that affect the physiology of vision.

Different specialists treat conditions of the eye and vision.

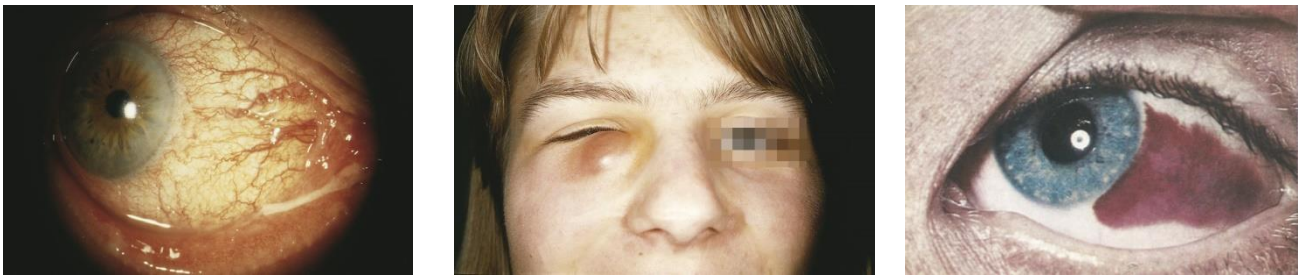
- An **ophthalmologist** (*ophthalmo(o)-* eye, *-ologist* specialist) is a physician who specializes in diagnosing and treating disorders of the eye and vision.
- An **optometrist** (*opt(o)-* vision, *-metrist* a person who measures something) is a Doctor of Optometry (D.O.) who specializes in measuring the accuracy of vision and prescribes corrective lenses.
- An **optician** (*opt(o)-* vision, *-ician* specialist) is person qualified to make and supply eyeglasses and contact lenses for the correction of vision.

Table 9.3 Pathologies of the Accessory Structures of the Eye

Conjunctivitis	Inflammation (*-itis*) of the conjunctiva can be caused by pathogens (such as bacteria and viruses) and allergies. Bacterial infection leads to pus formation and is highly contagious. Because the irritation leads to increased blood flow, the conjunctiva becomes bright red (**pink eye**). As a rule, conjunctivitis does not threaten our eyesight.
Trachoma	Conjunctivitis affecting the conjunctive on the back of the eyelids. Caused by the bacterium *Chlamydia trachomatis*. The inflammation leads to scar formation and roughing on the conjunctiva. The scar tissue scratches the cornea leading to blindness. More than one million people per year go blind

	due to trachoma. The active inflammation can be cured with antibiotics. The blindness can be cured by transplanting corneal tissues from a dead body.
Blepharoptosis	Also known as **drooping of the eyelid**. Develops when the upper eyelid (*blepharo-*) is hanging too low (*-ptosis*) because the levator palpebrae muscle is paralyzed.
Chalazion	Also known as an **internal stye**. A localized swelling on the inside of the eyelid caused by an enlarged sebaceous gland. Usually, the obstruction of the gland duct improves on its own in a few days, and the chalazion disappears.

Figure 9.8 Conjunctivitis (pink eye) (left), dacryocystitis (center), and subconjunctival hemorrhage (right)

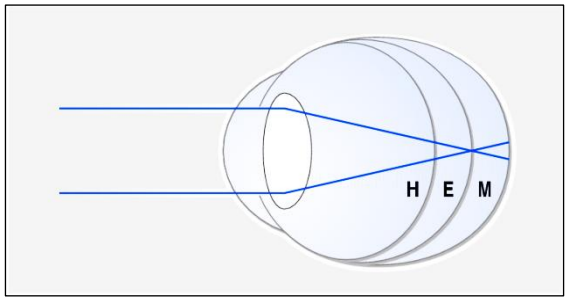


Hordeolum	Also known as a **stye**. A localized swelling on the inside of the eyelid caused by an inflamed, pus-filled sebaceous gland. Usually, the obstruction of the gland duct improves on its own in a few days, the pus drains, and the inflammation heals.
Dacryocystitis	Inflammation of the nasolacrimal duct (*dacryocyst(o)-* tear duct,-itis inflammation) can be caused by bacteria (usually leading to pus formation), viruses, or fungi.
Subconjunctival hemorrhage	Bleeding into the space between conjunctiva and sclera creates a dark red area. Often caused by increased pressure or injury. Commonly seen in women after delivery of a baby.

The most common function defects are strabismus and refractive disorders (ametropias). There are **three disorders of refraction**:

- In **myopia**, the eyeball is too long, the focal point is in front of the retina when we look into the distance, and we are unable to focus the image. Because we can still focus light from close images, this disorder is called **nearsightedness**. Concave lenses or **refractive surgery** such as LASIK can correct the problem.
- In **hyperopia**, the focal point is behind the retina because the eyeball is too short, and we are unable to focus light coming from close objects. But, we can still see distant objects, which is why we call this **farsightedness**. It can be corrected with the help of convex lenses.

Figure 9.9 Emmetropic [E], myopic [M], and hyperopic [H] refraction



- **Astigmatism** is caused by unequal curvatures in different parts of the cornea or lens. It can be corrected with cylindrical lenses, corneal implants, or laser procedures.

A decline in lens elasticity after age 50 leads to a loss of accommodation and the near point of vision moves further away from the lens. This is called **presbyopia** (*presby(o)-* old age, *-opia* eye, sight) and requires the use of reading glasses.

In **strabismus**, the two eyes point in different directions. Consequently, the brain may not be able to generate a sharp three-dimensional image. The two main forms are esotropia and exotropia. In **esotropia**, one or both eyes are turned inward (**cross-eyed**); in **exotropia**, one eye is turned outward relative to the other eye (**walleye**). Both conditions are usually caused by an imbalance between extrinsic eye muscles and can be corrected surgically.

Night blindness, also called **nyctalopia** (*nyct(o)-* night, *-opia* sight), is an acquired condition caused by a lack of rhodopsin due to a lack of vitamin A. For this reason, it can be cured by vitamin A ingestion.

Color blindness, on the other hand, is a congenital condition and, thus, cannot be cured. The most common form is **red-green color blindness**, followed by **yellow-green color blindness** and **total color blindness**. Some patients are missing one or more cone types (for example, red cones in protanopia); other patients have the cones, but they contain a mutated pigment that does not work as well (for example, red pigment in protanomaly).

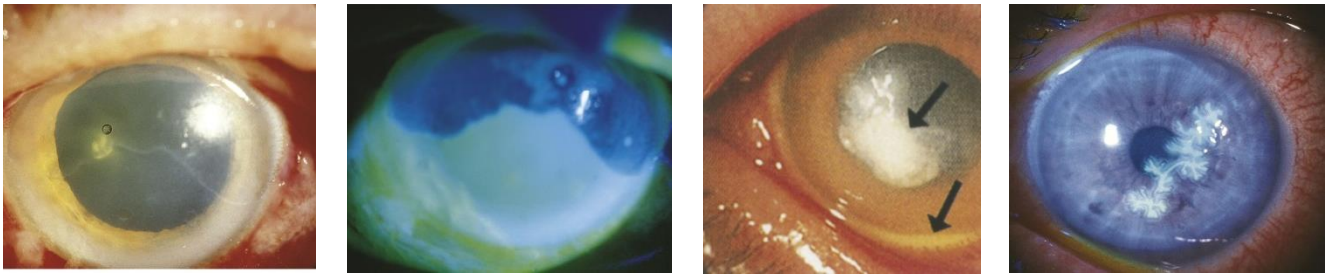
Blindness is an inability to see regardless of the underlying cause. People who are **legally blind** may still be able to have some vision. For example, patients with macular dystrophy are legally blind, yet they still retain night and peripheral vision.

Disorders of the eyeball and its parts are more likely to impair vision than disorders of the accessory organs.

Table 9.4 Pathologies of the Eyeball and its Parts

Keratitis	Inflammation (*-itis*) of the cornea (*kerato-*) can be caused by pathogens such as bacteria, fungi, and viruses. If **corneal ulcers** develop, a cloudy scar that affects vision can be left behind.
Corneal abrasion	Injuries to the cornea are very painful, because the cornea has very high density of pain receptors. Most abrasions happen while inserting contact lenses.

Figure 9.10 Corneal abrasion native and with fluorescein (left images), corneal ulcer (upper arrow) with pus (lower arrow) in the anterior chamber (second from right), and herpes simplex keratitis (right)



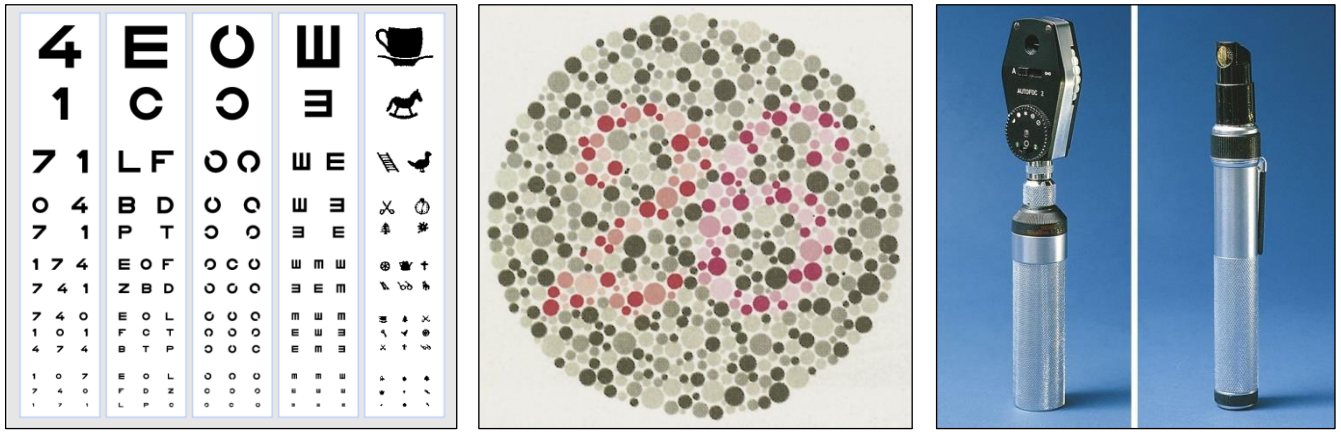
Iritis	Inflammation (*-itis*) of the iris (*ir(o)-*) is also known as **anterior uveitis**. It can lead the formation of adhesions between the iris and the lens (synechiae). This may affect the adjustment of the pupil to bright or low light and the flow of aqueous humor.
Scleritis	Inflammation (*-itis*) of the sclera (*scler(o)-*) is often caused by chemical injuries or autoimmune disorders.
Anisocoria	A condition in which the pupils are not the same size (*anis(o)-* unequal, *cor(o)-* pupil, *-ia* condition). Can be congenital or caused by injuries and inflammation (iritis).
Cataract	Clouding of the lens interferes with the passage of the light through the lens. If the lens is completely cloudy, no light will make its way to the retina, and the patient is blind. Its most common form is the **senile cataract** of older patients. There are congenital forms as well as others forms caused by injury or diseases, such as diabetes mellitus. In early stages, the clouded areas may be treated with laser; in late stages, the lens can be removed and replaced with a plastic lens. This will restore vision completely.
Floaters	Also known as **vitreous floaters** because they are caused by particles that float inside the vitreous body. They are often found in older patients, after intraocular (*intra-* inside, *ocular* eye) inflammations, and as a result of retinal detachment.
Retinitis pigmentosa	Progressive, degenerative disorder of the retina. Affects night vision and peripheral vision. Patients are legally blind but may still have some vision in bright light.
Retinal tears	Tears in the retina often develop in patients with a high degree of nearsightedness (see below). They may not affect vision although the

	experience of sudden flashes of lightning is unsettling.
Retinal detachment	When people age, the vitreous body may shrink, leading to parts of the retina to detach from the underlying choroid. People with a high degree of nearsightedness may develop retinal detachment at a younger age. The detachment impairs vision, but it may be reversed with injection of oily substances into the vitreous body to restore its original size. Oftentimes, laser is used to create tiny scars that fix the retina to the choroid to stop the detachment.
Glaucoma	A group of diseases caused by an increase in the intraocular pressure. Untreated, the high pressure will damage the retina and optic nerve leading to blindness. In **chronic** or **open-angle glaucoma**, the aqueous humor is not properly drained and gradually accumulates inside the eye. In **acute** or **closed-angle glaucoma**, the iris is gets too close to the cornea, acutely blocking the drainage of humor.
Macular degeneration (MD)	Gradually progressive degeneration of the macula in the center of the eye leading to a loss of central vision. Yet, the rods in the peripheral areas still work, and patients retain night and peripheral vision. There are some hereditary forms, but most patients suffer from **age-related macular degeneration** (ARMD) later in life.

There are a number of standard **diagnostic procedures for the eye and vision**. **Snellen charts** are used to test visual acuity, although ophthalmologists and optometrists prefer the use of electronic versions that allow the patients to see one line only. People with average vision will be able to read letters of a defined size from 20 feet away (20/20 vision). If they are nearsighted, they will only be able to read bigger letters and their vision will be 20/40, 20/60, and so on. People with above average vision will be able to read smaller letters, giving them a vision of 60/20, for example. Ophthalmologists and optometrists measure the refractive power of the eye in diopters (dp) as it allows for greater precision and better correction of refractive disorders.

The different types of color blindness can be diagnosed using defined color plates (**Ishihara test**). People with normal color vision will see different numbers than people with color deficits. People with normal color vision read ‘26’ in the Ishihara plate in Figure 9.19. People with red-green blindness will see either the ‘2’ or the ‘6’ only, depending on their type of color blindness.

Figure 9.19 Snellen chart (left) with numbers, letters, and symbols for use with patients that cannot read (yet), Ishihara plate (center), and ophthalmoscope (right)



Ophthalmoscopy (*ophthalm(o)-* eye, *-scopy* visual examination) is the visual examination of the inside of the eye using an ophthalmoscope (light source with a lens system). Because doctors look at the fundus of the eyeball, the technique is also called **funduscopy**. It allows for an examination of the retina, optic disk, choroid, and blood vessels. The retina is the only place in our body where we can directly examine blood vessels and acquire information about the health of the cardiovascular system or general conditions, such as high cholesterol levels or changes caused by diabetes mellitus.

Slit-lamp ophthalmoscopy uses a very narrow beam of light to assess the cornea, iris, and lens.

9.6.2 Pathologies of the Chemical Senses: Smell and Taste

Anosmia is a loss of the sense of smell (*an-* no, without, *-osmia* smell). It is sometimes also called **smell blindness**. Although acquired anosmia is much more common, there are rare congenital cases. Most of the time, it is a temporary condition caused by nasal congestion from a cold, allergy, or poor air quality. In **traumatic anosmia**, the olfactory nerve fibers have been damage, for example, by forceful impact of a baseball on the forehead and nasal bone. Most of the time, the sense of smell will recover.

Taste blindness may be limited to certain substances or affect all taste sensations (**ageusia**). For example, some people are born with an inability to taste the substance phenylthiourea (PTC). Our sense of taste depends on replacing taste buds sloughed off during eating. Over time, that replacement no longer occurs to a sufficient degree. Because of this, older people often complain about food not tasting as good anymore, and some chefs cannot season dishes as well when they are older.

9.6.2 Pathologies of Hearing and Balance

Pathologies of the outer and middle ears may affect hearing; pathologies of the inner ear, hearing and balance. **Ear pain** or **otalgia** (*ot(o)-* ear, *-algia* pain) is a term applied to pain in the outer ear. The most common reason for ear pain is **swimmer's ear**, a fungal infection (**otomycosis**; *ot(o)-* ear, *-mycosis* fungal infection) of the skin of the external auditory canal. It usually occurs after spending a lot of time in the water. Water softens the skin in the auditory canal and washes out the protective ear wax, allowing fungus to take hold and cause a rather painful infection.

Impacted cerumen can lead to a feeling of ear pressure and diminishes hearing. The cerumen can be washed out with warm water or removed by a health professional.

The most common disorder affecting the middle ear is **otitis media** (*ot(o)-* ear, *-itis* infection) or **middle ear infection**. **Acute otitis media** is frequently found in young children with an upper respiratory tract infection. It can be very painful and lead to a **ruptured eardrum** with pus coming out of the auditory canal. The eardrum usually heals on its own once the infection passes.

If children develop recurrent middle ear infections due to improper ventilation of the middle ear, they are at risk for developing hearing or speech problems. **Ear tubes** (also called tympanostomy tubes, myringotomy tubes, ventilation tubes, or PE [pressure equalization] tubes) are tiny cylinders placed through the tympanic membrane to allow flow into the middle ear. They will fall out on their own over time.

The pain and discomfort experienced during takeoff and landing of airplanes is a form of mild **barotrauma** (*baro-* pressure). Barotrauma is caused by a stretching of the tympanic membrane by the different air pressures of the middle ear and the outer ear. Chewing and swallowing helps equalize the pressure. Very strong pressure waves (for example, during an explosion) can lead to a rupture of the tympanic membrane, which will usually heal itself.

Otosclerosis (*oto(o)-* ear, *-sclerosis* hardening) is a condition in which the joints between the middle ear ossicles become stiff. As a result, the ossicles cannot amplify the vibrations they pick up from the tympanic membrane, and hearing loss develops (see below).

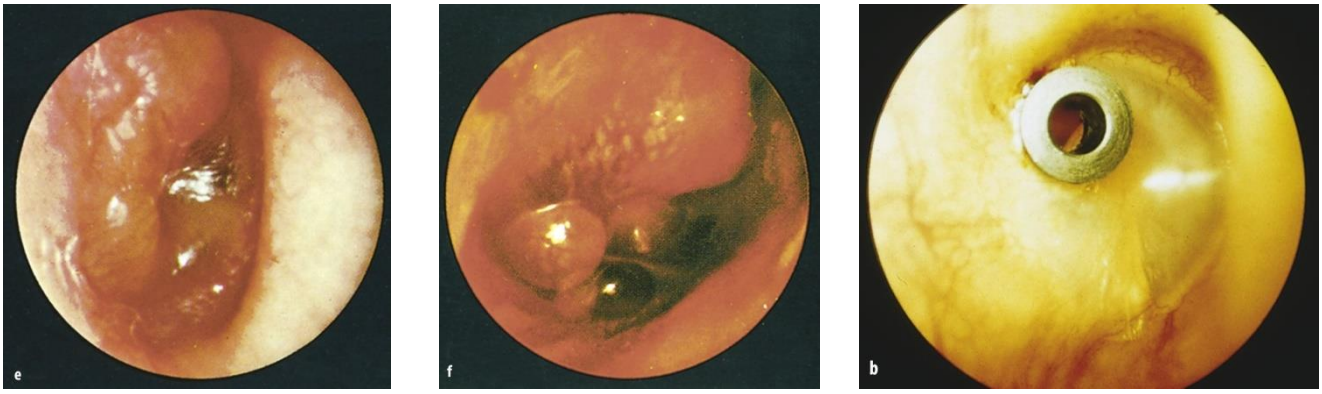
Table 9.5 Disorders of the Inner Ear

Vertigo	A sensation of dizziness, loss of balance, and spinning often combined with nausea and vomiting. Vertigo is a symptom, not a disease. To cure vertigo the underlying cause must be identified and cured.
Labyrinthitis	Inflammation (*-itis*) of the inner ear (*labyrinth*) can lead to vertigo and tinnitus.
Tinnitus	Ringing, buzzing, or roaring sound in one or both ears. Can be caused by prolonged exposure to loud noise and is often associated with hearing loss.
Ménière's disease	Chronic, recurring condition with a sudden loss of fluid inside the inner ear. Leads to vertigo, tinnitus, and hearing loss. The symptoms gradually improve and the patients are back to normal until the next episode.
Deafness	Complete or partial hearing loss. In **conduction deafness**, the sound is blocked from reaching the inner ear. It can result from impacted earwax, a perforated eardrum, or otosclerosis of the ossicles. Air conduction will be impaired but not bone conduction. **Sensorineural deafness** is caused by damage to neural structures in the

	inner ear, the nerve fibers running from the ear to the brain, or inside the sensory areas of the brain.
Presbycusis	Age-related hearing loss (*presby(o)-* old age, *-(a)cusis* no hearing). A form of sensorineural deafness.

An **otoscope** works similar to an ophthalmoscope. It allows for direct visual examination of the tympanic membrane.

Figure 9.20 Acute otitis media (left), otitis media in flu with bleeding into the ear (center), and ear tube (left)



Hearing tests can focus on measuring hearing acuity (**audiometry**) or the ability to hear and understand speech (**audiological evaluation**). In order to measure the loudness of sound, the **decibel scale** was developed. Normal conversation takes place at 35-40 dB, busy traffic in a city generates 60-70 dB, and power boats and chainsaws come in at 100 dB. Firearms and personal music devices can go up to 160 dB, which is very painful and can cause damage to the tympanic membrane and the inner ear. Most of the time, however, it is long-term exposure to moderately high sound levels (60-80 dB) that cause sensorineural deafness.