

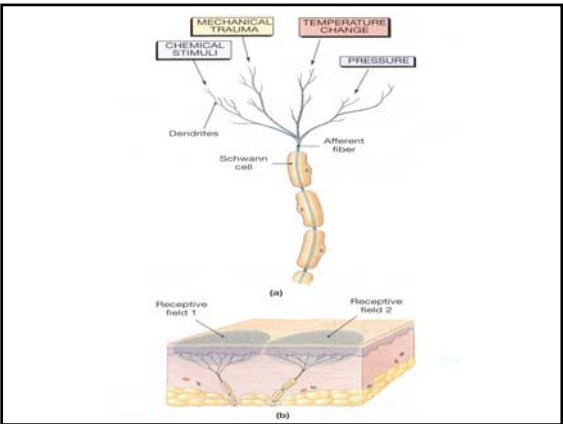
Senses

General Senses

- The general senses are **pain, temperature, touch, pressure, vibration, and proprioception**. Receptors for those sensations are distributed throughout the body.
- A sensory receptor is a specialized cell that, when stimulated, sends a sensation to the CNS.

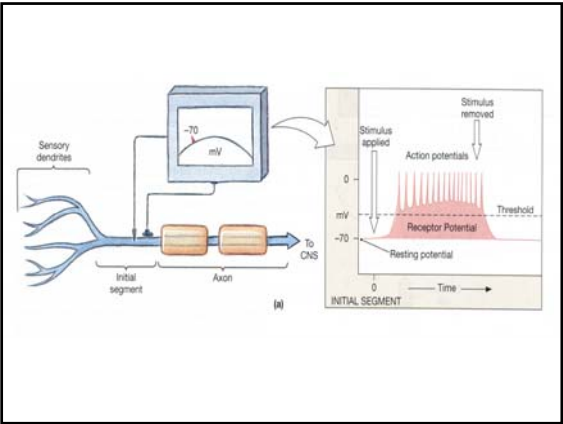
Specificity

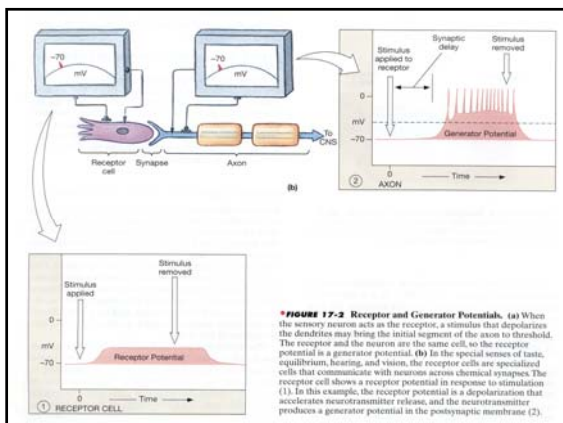
- Receptor specificity** allows each receptor to respond to a particular stimuli. The simplest receptors are **free nerve endings**. The area is monitored by a single receptor cell in a **receptive field**.



Transduction

- Transduction** is the translation of a stimulus into an action potential. This process involves the development of **receptor potentials** that can summate to produce **generator potentials** in an afferent fiber. The resulting action potential travels to the CNS.





Central Processing & Adaptation

• **Adaptation** is a reduction in sensitivity in the presence of a constant stimuli.

i.e.- olfactory fatigue

• Temperature receptors (thermoreceptors) are **fast-adapting**; you seldom notice room temperature unless it changes suddenly.

• Pain receptors (nociceptors) are **slow-adapting**, and that's one reason why pain sensations remind you of an injury long after the initial damage has occurred.

General Sense Receptors

Three basic types

1. **exteroceptors**: provide info about external environment
2. **proprioceptors**: provide info about skeletal muscles & joints
3. **interoceptors**: provide info about visceral organs & functions

These however can be classified into 4 specific types based

1. Nociceptors (pain receptors)

Common in:

- *Superficial portions of the skin
 - *Joint capsules
 - *Periosteum of bone
 - *Around walls of blood vessels
- Pain receptors are free nerve endings with large receptive fields
 - Because of this it is often difficult to find the exact source of a painful sensation

Two types of axons carry painful sensations:

Type A fibers (myelinated) carry fast pain (prickling pain). An injection or deep cut produce this type of pain. Mostly this pain receives a somatic response, and permits a close localization of the pain stimulus.

Type C fibers (unmyelinated) carry slow pain (burning, aching). These cause general activation of the reticular formation & thalamus. Individual knows there is pain, but it cannot be localized.

2. Thermoreceptors (temperature sensors)

Free nerve endings located in:

- *Dermis of the skin
 - *Skeletal muscles
 - *Liver
 - *Hypothalamus
- Cold receptors are 3 – 4x more numerous than warm receptors
 - Structurally there are no differences b/n. warm and cold receptors

3. Mechanoreceptors

- Sensitive to stimuli that distort the cell membrane

There are 3 classes of mechanoreceptors:

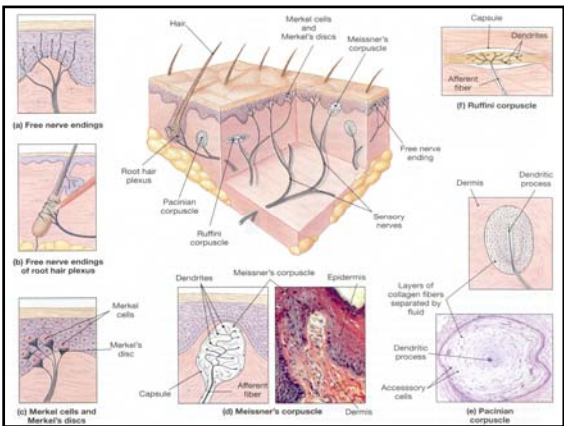
A. Tactile Receptors: provide the sensation of touch, pressure and vibration

B. Baroreceptors: detect pressure changes on walls of blood vessels and in portions of the digestive, reproductive and urinary tracts

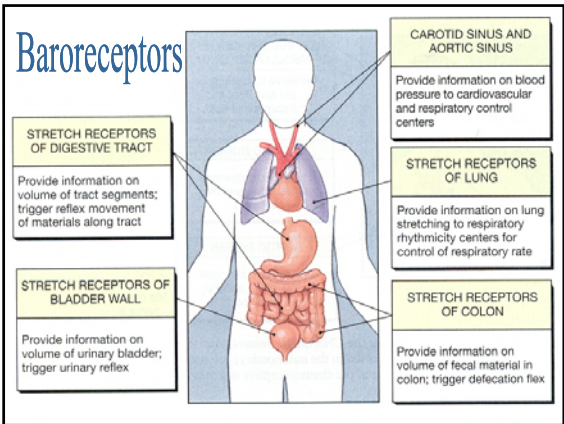
C. Proprioceptors: monitor the position of joints

Tactile Receptors

1. Free nerve endings
2. Root hair plexus
3. Merkel Discs
4. Meissner's corpuscles
5. Pacinian corpuscles
6. Ruffini corpuscles

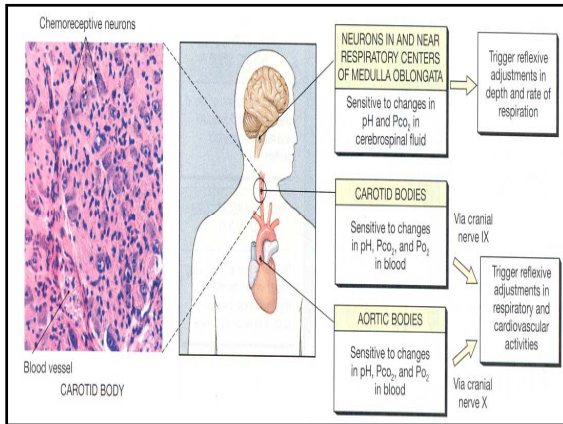


- Tickling and itching are probably varying levels of stimulation of the same tactile receptors. The process is not well understood



4. Chemoreceptors

- Can detect small changes in the conc. of specific chemicals or compounds
- Generally, only respond to water soluble and lipid soluble substances dissolved in surrounding fluid
- Most commonly used as O₂ & CO₂ detectors in blood vessels



Five Special Senses

*The five special senses are:

1. **olfaction** (smell)
2. **gustation** (taste)
3. **vision** (sights)
4. **equilibrium** (balance)
5. **hearing**

•Receptors for these senses are located in specialized areas called sense organs.

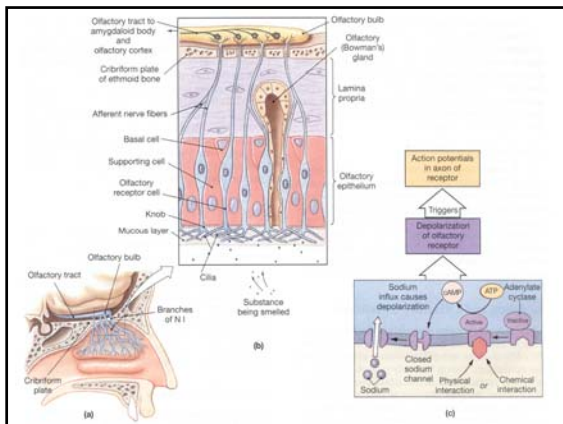
Olfaction

1. Olfaction

- Sense of smell
- Provided by paired olfactory organs on either side of the nasal septum

The olfactory organs contain two layers

1. **olfactory epithelium:** contain olfactory receptors and does actual "smelling"
2. **lamina propria:** contains olfactory (or Bowman's) glands that produces a thick pigmented mucous, and contains blood vessels.



•Normal inspiration delivers about 2% of incoming air to the olfactory organs.

•Olfactory receptors are highly modified neurons

•10 – 20 million olfactory receptors are packed into an area of $\approx 5\text{cm}^2$. So for humans, the entire olfactory sensory surface is about the area of a human body.

•A dog's olfactory sensory surface area is about 72x bigger than a humans, thus they can sense smells more acutely.

The Olfactory System is very sensitive

- As few as 4 molecules of a substance can activate an olfactory receptor.
- Olfactory data is the only type of sensory information to reach the cerebral cortex without first going through (being processed by) the thalamus.
- The limbic system connects smells with emotion.
- The perfume industry develops odors that trigger sexual responses.

- We can distinguish b/n. about 2000 – 4000 different olfactory stimuli.
- There are at least 50 different “primary smells” (basic odor types).
- The total number of receptors declines with age and the remaining ones decline in sensitivity. (the elderly must put on more perfume in order to smell it)
- Olfactory fatigue

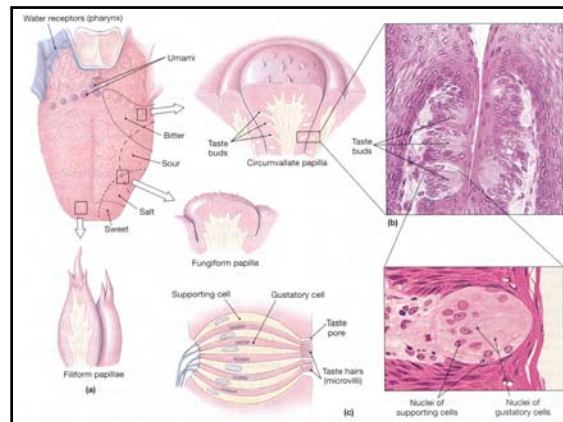
Gustation

2. Gustation

- Sense of taste
- Provides information about the foods and liquids we consume.
- Gustatory or taste receptors are distributed over the superior surface of the tongue, and the adjacent portions of the pharynx and larynx.
- Adults have \approx 3000 taste buds

The Surface of the tongue

- The surface of the tongue is rough because it contains three types of epithelium projections called lingual papillae.
- 1) **Filiform papillae**: provide friction on the tongue surface, they do not contain taste buds.
 - 2) **Fungiform papillae**: contain 5 taste buds each.
 - 3) **Circumvallate papillae**: contain as many as 100 taste buds. Circumvallate papillae form a “V” at the back of the tongue.



- Each taste bud contains ≈40 gustatory cells, and many supporting cells.
- Each gustatory cell lasts for only about 10 days before it is replaced by a surrounding epithelial cells.

Gustatory Sensation

- A conscious perception of taste is produced as the information from the taste buds is correlated with other sensory data (esp. olfaction)
- You are several thousand times more sensitive to tastes when your olfactory organs are fully functional.

Primary Tastes Sensations

- 1) **Sweet**
- 2) **Salt**
- 3) **Sour**
- 4) **Bitter**

At least two other taste sensations have been discovered in humans

- 5) **Umami**
 - Pleasant taste characteristics of beef & chicken broth
- 6) **Water**
 - Most say water has no taste
 - Research shows the presence of water receptors at the back of your tongue & pharynx

*Our tasting abilities change with age. Start with 10,000 taste buds, but the number declines drastically by age 50.

*Food children find too spicy are bland and unappetizing to older adults.

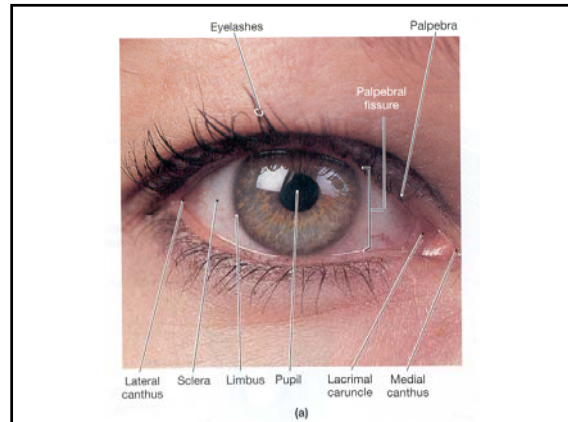
Vision

Vision

- Humans rely on vision more than any other special sense. (light energy into nerve impulses)

Accessory Structures of the eye**1. Eyelids (palpebrae)**

- Act like windshield wipers
- Keep surface of the eye well lubricated and free from dust & debris
- Also close firmly to protect the surface of the eye



- Eye lashes are associated with the **Glands of Zeis** (large sebaceous glands).

- Meibomian glands** are just under the lids and secrete a lipid rich product that acts as a lubricant.

- A cyst in the meibomian gland or any other gland associated with the eye is known as a **sty**.

The epithelium lining of the eye lid and covering the outer surface of the eye is known as the conjunctiva

- Inside of eyelid palpebral conjunctiva
- Outside of eyelid ocular conjunctiva
- These surfaces are kept moist by secretions from various glands

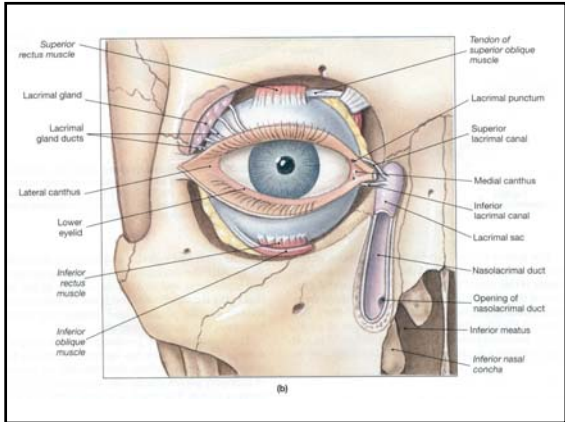
Conjunctivitis

- aka pink eye
- Results from damage to and irritation of the conjunctival surface
- Most obvious symptom is reddening due to dilation of blood vessels.
- Can be caused by pathogenic infection, or by chemical or physical irritation

The lacrimal apparatus

- Produces, distributes, and removes tears
- Tears reduce friction, remove debris, prevent bacterial infection, and provide nutrients and O₂ to portions of the conjunctiva.
- The lacrimal gland produces tears:
 - Secretions are watery, slightly alkaline and contain the enzyme lysozyme which attacks bacteria.

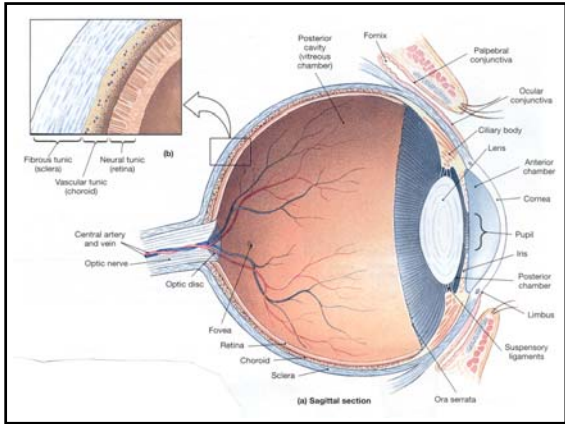
- Produce tears at the rate of ≈ 1 ml/day
- Blinking sweeps tears across the ocular surface and they accumulate in the medial canthus in an area known as the lacrimal lake (lake of tears).
- From here the tears get drained to the nasal cavity.



- The Eye**
- Very complex
 - Avg. dia 24 mm (about an inch)
 - Weight on avg. 8g
 - In the socket, orbital fat provides padding and insulation.

- The wall of the eye is three layers thick**
- Outer layer:** fibrous tunic
- Middle layer:** vascular tunic
- Inner layer:** neural tunic
-the photoreceptors are located in the neural tunic

- The eyeball is hollow there are essentially two chambers**
- 1) **Anterior cavity** - Located between the cornea and the lens. This chamber is filled with a watery fluid called **aqueous humor**.
 - 2) **Posterior cavity** - Located behind the lens, this chamber is filled with a thick jelly-like substance called **vitreous humor**.



1. fibrous tunic

- outer layer
- provides mechanical support & physical protection
- **Sclera** (whites of the eye) contains small blood vessels and nerves
- **Cornea** is transparent and physically continuous with the sclera

Vascular Tunic

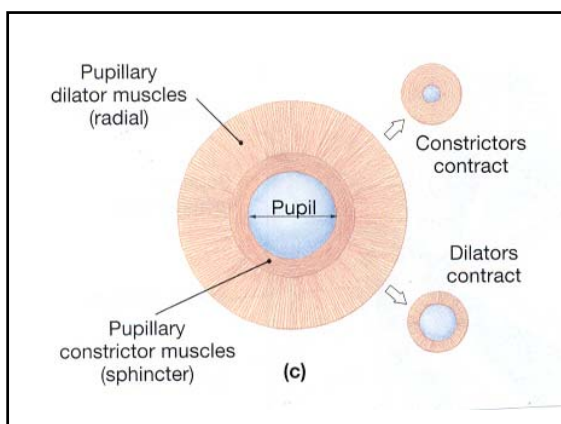
- a.k.a. uvea
 - contains vessels, lymphatics, and intrinsic eye muscles
- functions:**
- provide a route for blood vessels & lymphatics
 - regulating the amount of light that enters the eye
 - secreting and reabsorbing the aqueous humor that circulates in the eye
 - controlling the shape of the lens (important in focusing)

Structures include the

1. Iris
2. the ciliary body
3. the choroid

The Iris

- The color disk in your eye
 - Contains blood vessels, pigment cells, and two layers of smooth muscle fibers
 - When these muscle contract, they change the diameter of the central opening (**pupil**)
- Pupil** - The opening in the iris. The diameter of the pupil varies with light intensity. Dilated pupils are also a sign of an unconscious state

**The Ciliary Body**

- Connects edge of iris to edge of retina
- Contains ciliary muscle
- Hold the eyes lens in place

The Choroid Body

- Pad btn. retina and sclera
- Contains extensive capillary network that supplies nutrients and O₂ to the retina.

The Neural Tunic

- Retina

Two layers thick:

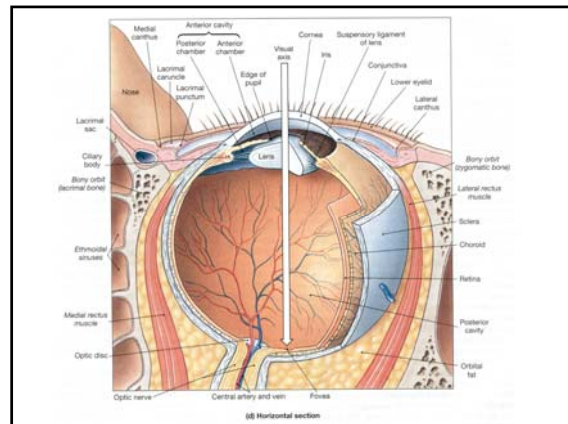
- thin, outer pigmented layer
- thick inner neural retina

Neural Retina Contains

- 1) the photoreceptor
- 2) supporting cells and neurons (preliminary visual info)
- 3) blood vessels

Retinal Organization

- Photoreceptors are adjacent to the pigmented layer.
- In a **detached retina** the neural retina separates from the pigmented layer
- If the retina is not reattached, vision will be lost (reattachment is by means of "spot welding" w/a YAG laser)



These are two types of photoreceptors

1) Rods

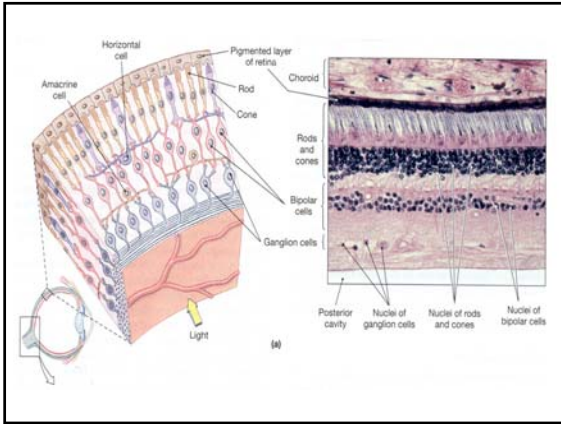
- Do not discriminate among colors
- Very light sensitive
- Enable us to see in dimly lit rooms

2) Cones

- Provide us with color vision
- 3 types and their pattern of stimulation provide color vision
- Give sharper, clearer vision than rods, but require much more intense light

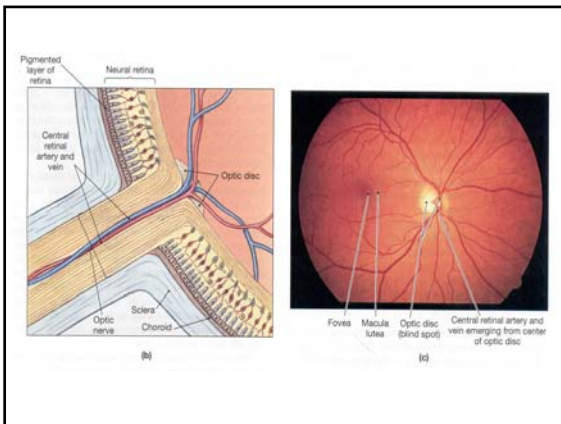
- Rods and cones are not evenly distributed

- When you look at a distant star directly there is not enough light to stimulate the fovea, but if you look to the side, the star is visible to the more sensitive rod



Optic Disk

- Nerves from photoreceptors converge on the optic disk (≈ 1 million)
- Optic disk is medial to the fovea
- Origin of the optic nerve
- No photoreceptors here, so it's known as the blind spot



NOTE:

Where the optic nerve, veins and arteries attach to the retina, no rods or cones are found. This area is called the **optic disc** or **blind spot**. The area of the retina where vision is most acute is called the **fovea centralis**. Many cones (no rods) are concentrated in this fovea. The fovea is located in the center of a yellow disc called the **macula lutea**.

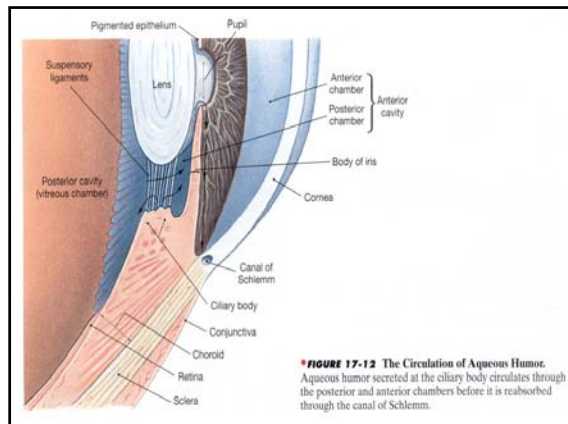
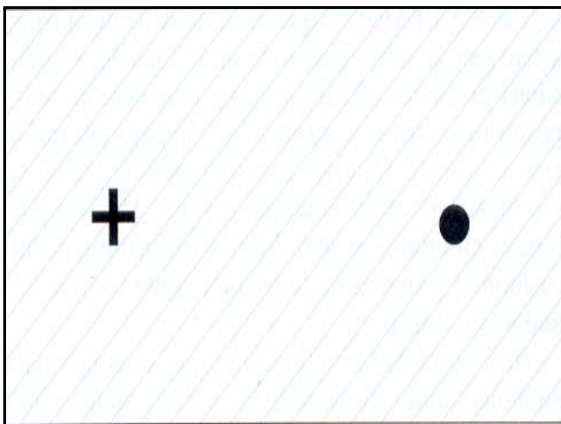
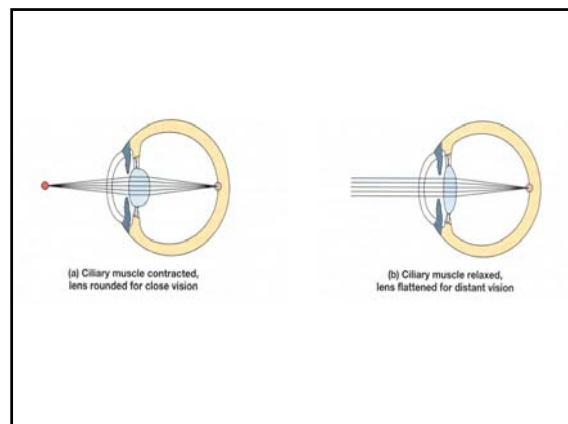
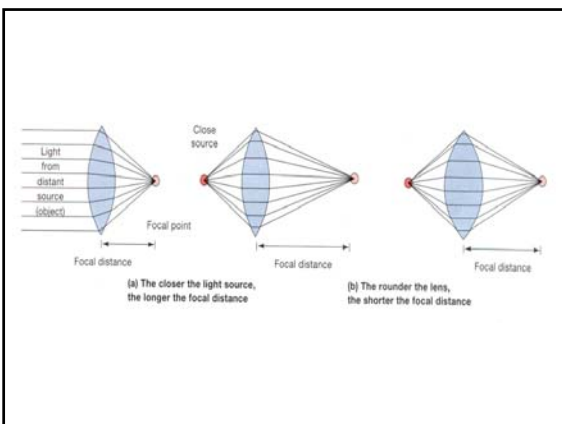
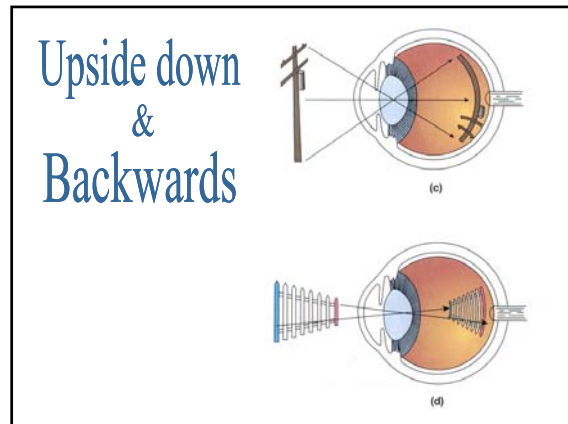
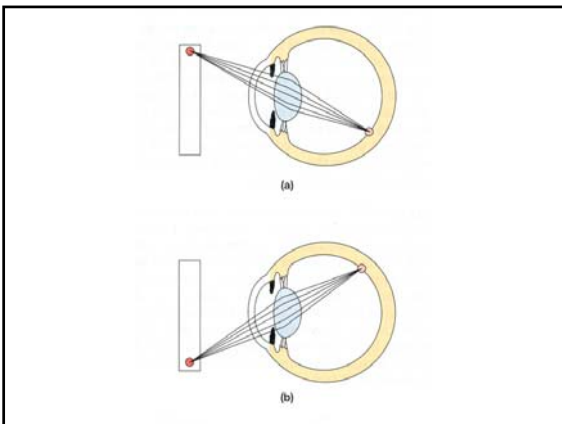
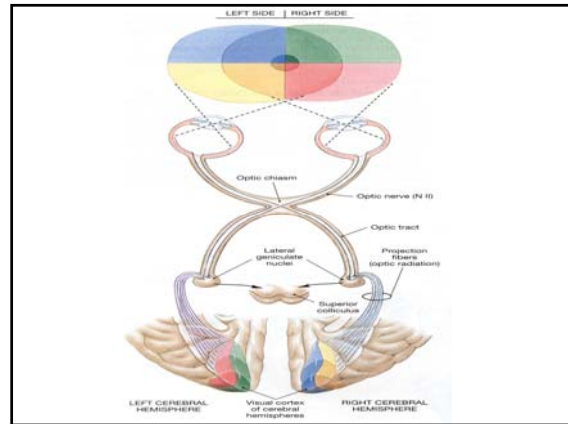


FIGURE 17-12 The Circulation of Aqueous Humor. Aqueous humor secreted at the ciliary body circulates through the posterior and anterior chambers before it is reabsorbed through the canal of Schlemm.

Visual Pathways

- Receptors transfer light energy into nerve impulses and transmit the information to the cortex of the brain's occipital lobe.
- Cranial nerve II (Optic)** is involved in the above activity. Some optic nerve fibers cross at a structure called the **optic chiasm**.



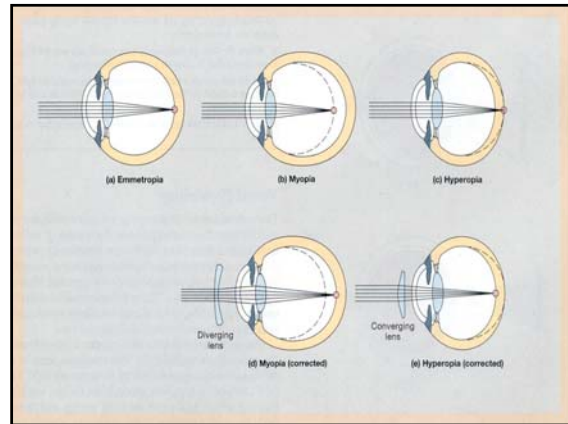
EYE DISORDERS

Astigmatism - Caused by irregularities in the surface of the cornea or lens. Eyestrain and headaches may result.

Myopia - *Nearsightedness*. Objects come into focus in front of the retina. The person can see close up objects without problems, but need *concave lenses* to see distant objects.

Hyperopia - *Farsightedness*. Objects come into focus behind the retina. The person can see distant objects without problems, but needs *convex lenses* to see up close.

Presbyopia - As you age there is a gradual loss in accommodation due to a loss in lens elasticity and weakened ciliary muscles. You have to hold books and papers farther away from your eyes.

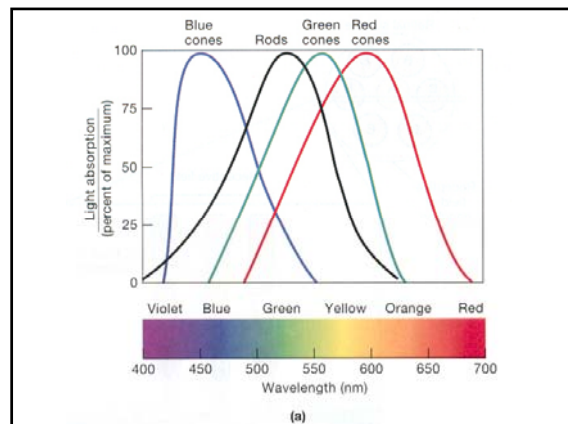
**Visual Acuity**

20/20

20/15

20/30

20/200

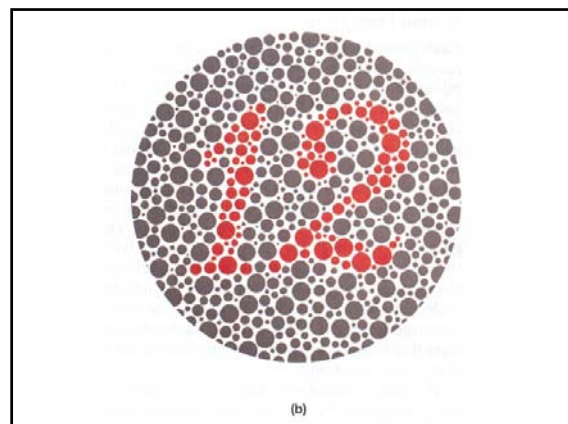


Color blindness - They are genetic defects. Some cone types may be missing.

Monochromats - Total color blindness.

Dichromats - Can see two of the three primary colors. (red, blue, and green)

Trichromats - See all three primary colors but have some problems determining wavelengths.



Diseases & Abnormalities (cont.)

Diabetic Retinopathy: degeneration & rupture of retinal blood vessels. Visual activity is lost, and photoreceptors die.

Glaucoma: aqueous humor drainage mechanism disrupted. Pressure builds in the eye. At twice normal pressure, optic nerve gets squeezed and stops action potential transmission

Scotomas: abnormal blind spots

Floater - Clumps of gel or crystals often occur in the vitreous humor as a person ages. They cast a shadow on the retina causing the person to see moving specs.

Cataracts: loss of transparency of eye lens

- May result from drug reactions, injuries, radiation, but senile cataracts are most common.
- Lens naturally begins to turn yellow w/ age
- Eventually the person w/very cloudy lens will become functionally blind even though photoreceptors work perfectly

Cataract Treatment

1. shatter defective lens w/sound waves
2. remove pieces
3. replace w/ prosthesis or donor lens
4. correct vision with glasses

Hearing & Equilibrium

Hearing & Equilibrium

•The inner ear provides two senses hearing & equilibrium

Equilibrium: provides information about the position of the head in space

Looks at:

- *Gravity
- *Linear acceleration
- *Rotation

Hearing

•Detecting & interpreting sound waves

The basic receptor mechanism for both senses is the same

- Receptors are hair cells (mechanoreceptors)
- Hair cells respond to stimuli by moving

Anatomy of the Ear

The ear is divided into 3 anatomical regions

1. External ear

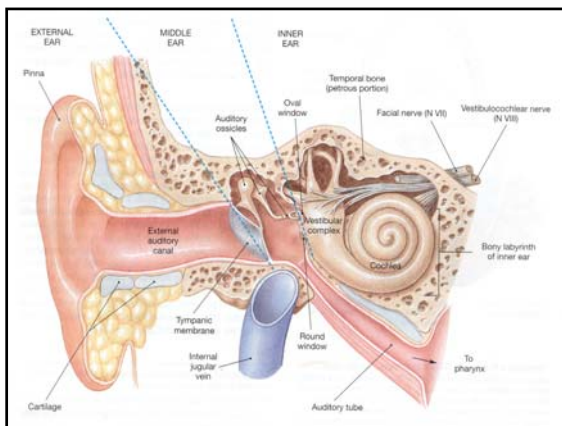
- *Visible
- *Collects sounds
- *Channels sounds to the ear drum

2. Middle Ear

- *Chamber located in the temporal bone
- *Extends from tympanic membrane (ear drum) to Vestibular Complex
- *Collects and transfers sounds to the inner ear

3. Inner Ear

- *Contains sensory organs for hearing & equilibrium



External Ear

- Fleshy, cartilaginous flap called the “pinna” or auricle, surrounds and directs sounds down the external auditory canal
- Pinna protects the opening of the canal
- Provides directional sensitivity to the ear (sounds from behind are blocked, sounds from side & front are caught and channeled)
- External auditory canal is a long tube that ends at the tympanic membrane (ear drum)

*According to an old Q-tip commercial “*the only thing you should put in your ear is your elbow*”

- Sound waves vibrate the tympanic membrane which in turn vibrates the auditory ossicles
- Ceruminous glands along the external auditory canal excrete a waxy material to deny access to foreign objects
- Ear wax or cerumin also slows the growth of microorganisms

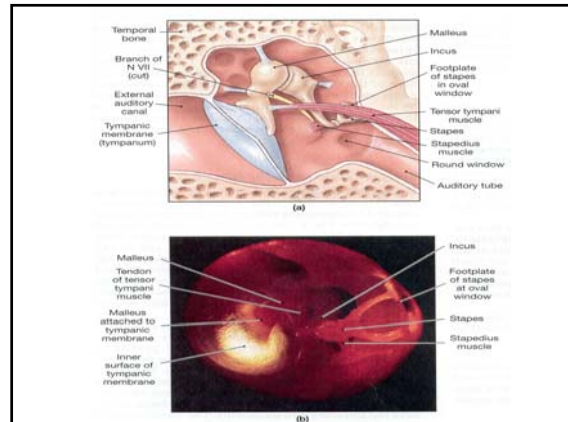
Middle Ear

- aka tympanic cavity
- filled with air
- It opens to the pharynx via the eustachian or auditory or pharyngotympanic tube
- Normally the auditory tube allows for equalization of the middle ear, but it can also allow the invasion of microorganisms which can cause a painful infection called otitis media

Auditory ossicles (the smallest human bones)
Connect the tympanic membrane with the receptor complex of the inner ear

-three tiny bones

1. **malleus** (hammer)
2. **incus** (anvil)
3. **stapes** (stirrup)



- Vibrations of the tympanic membrane converts sound waves to mechanical movements
- In/out motion of the tympanic membrane creates a rocking motion of the auditory ossicles
- The tympanic membrane is 22x larger than the oval window, so a 1µm movement of the tympanic membrane means a 22 µm movement at the oval window (an amplification effect)

Inner Ear

- Senses of equilibrium and hearing provided hear
- The receptors lie in a collection of fluid filled chambers and tubes called the membranous labyrinth
- The membranous labyrinth is covered by a dense shell of bone called the bony labyrinth
- The fluid in the membranous labyrinth is known as the endolymph (has a different electrolyte composition than other body fluids)
- The space between the membranous labyrinth & bony labyrinth is filled with fluid called perilymph

The bony labyrinth can be divided into 3 sections

1. Vestibule

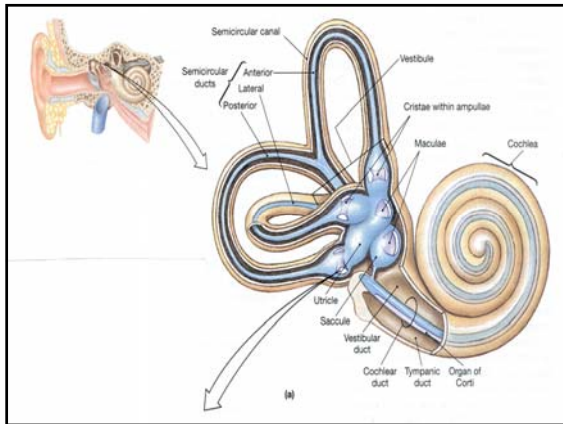
- Contains two sac: Sacculle & Utricle
- Receptors here provide sensation of gravity and linear acceleration

2. Semicircular canals

- Provide information on rotation of the head

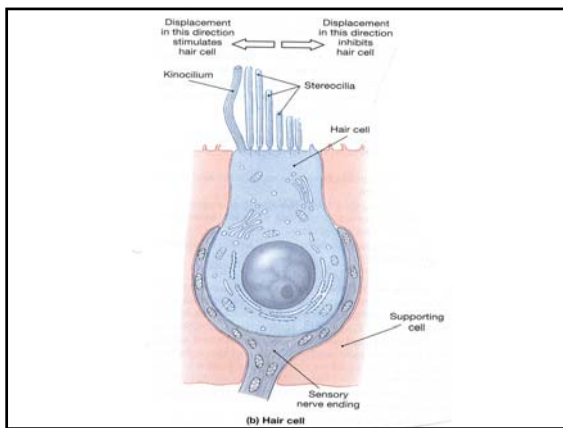
Cochlea

- Spiral-shaped bony chamber
- Contains the cochlear duct of the membranous labyrinth
- The M.L. makes 2½ turns around a central bony hub
- Contain hair cells which act as sound receptors



Receptor function in the Inner Ear

- Sensory receptors are called hair cells
- Surrounded by supporting cells
- Each free surface of the hair cell supports 80-100 long stereocilia and one kinocilium
- Outside mechanical movements push the stereocilia, stretching the cell membrane which alters the chemical transmitter released by the hair cell



**Hearing Process
six basic steps:**

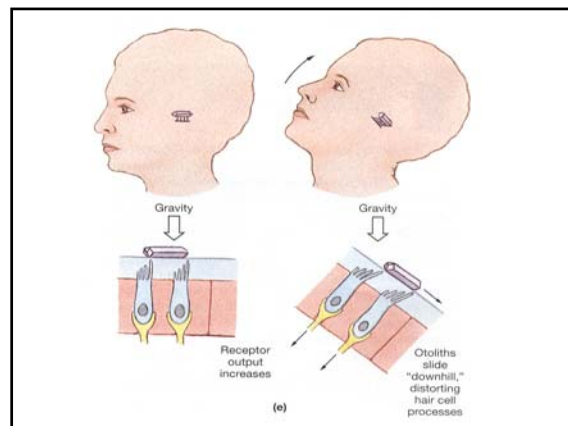
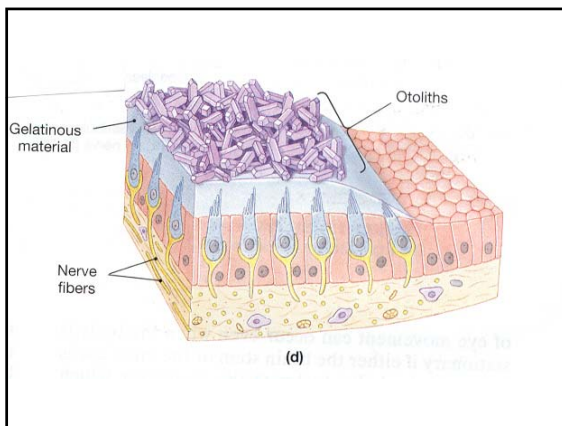
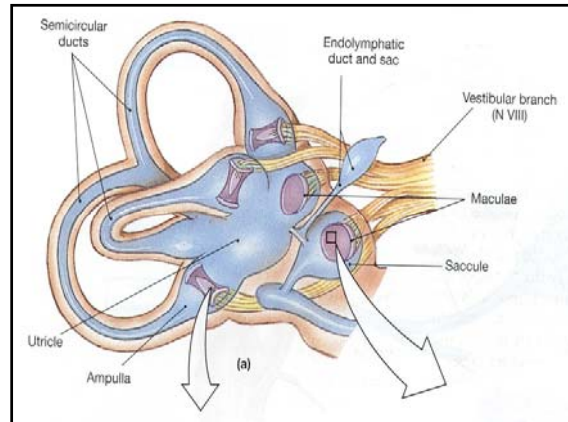
1. Sound waves arrive at the tympanic membrane
2. Movement of the tympanic membrane causes displacement of auditory ossicles
3. Movement of the stapes at the oval window establishes pressure waves in the perilymph of the vestibular duct
4. Pressure waves distort the basilar membrane on their way to the round window of the tympanic duct

5. Vibrations of the basilar membrane cause vibration of hair cells
6. Information is relayed to the CNS

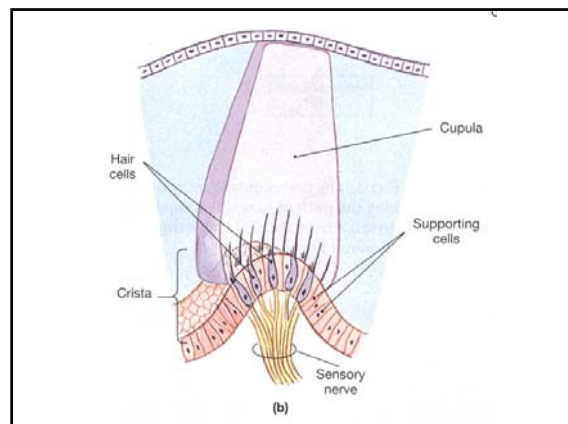
- Equilibrium**
- The inner ear is also involved with equilibrium.
- There are two types of equilibrium
1. *Static equilibrium*
 2. *Dynamic equilibrium*

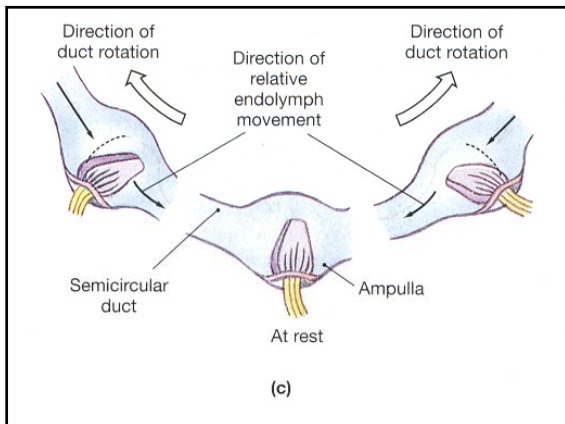
Static equilibrium -

- Senses the position of the head.
- The static equilibrium structure called a **macula** is located in the vestibule.
- The macula contains **hair cells** that project upward into a gelatinous substance. The hair cells connect to the vestibular nerve.
- Calcium carbonate crystals called **otoliths** press down giving the head a sense of position.

**Dynamic equilibrium -**

- Involves the semicircular canals which are filled with endolymph.
- The fluid is affected by inertia as the head moves in rotational or angular ways.
- At the end of each canal are receptors called the **crista ampullaris** which also contains hair cells.
- The crista ampullaris connects to the vestibular nerve.

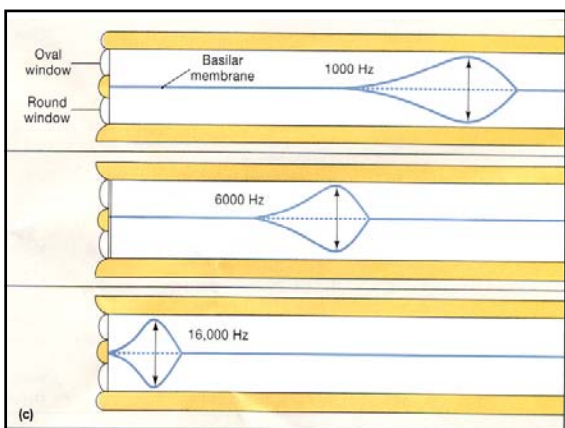
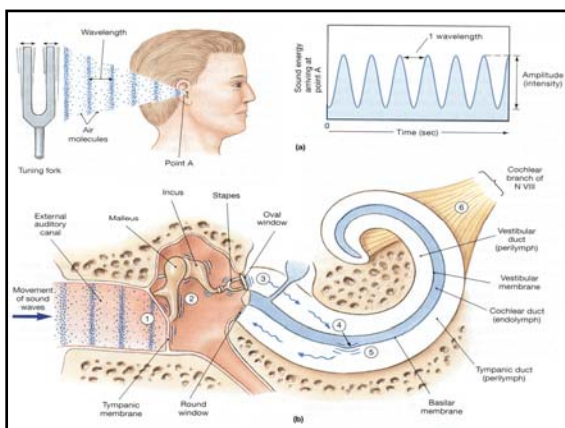




Sound Properties

- Unlike like light that can travel in a vacuum, sound depends upon an elastic medium. The sine wave of a pure tone is periodic. The distance between two consecutive crests or troughs is called **wavelength**. In dry air, sound travels at 331m/sec.

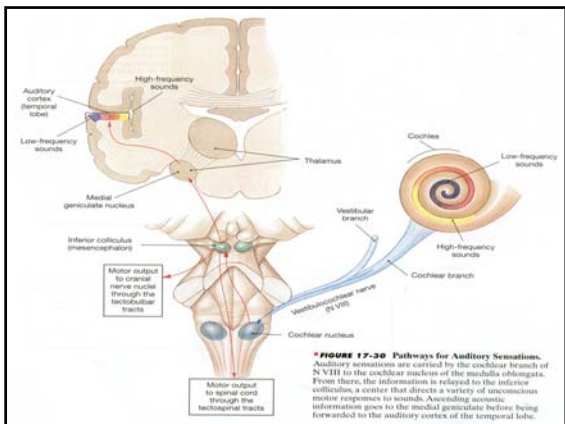
Frequency - Expressed in **hertz (Hz)**. The number of waves that pass a given point in a given time. The frequency range of human hearing is between 20 to 20,000Hz. We perceive different sound frequencies as differences in **pitch**. The higher the frequency, the higher the pitch. Most sounds are a mixture of several frequencies. This characteristic of sound is called **quality**. This enables us to distinguish between middle C on a piano and middle C being sung.



Amplitude - The **intensity** of a sound related to its energy. Measured in **decibels (dB)**. Involves the height of the wave crests.

- The decibel scale is **logarithmic**. Therefore, a 10dB is 10x louder than 0dB. 20dB is 100x louder than 0dB and 30dB is 1,000x louder than 0dB.
- Prolonged exposure to 90dB can cause permanent hearing loss.

40dB = whisper
 60-70dB = normal conversation
 80dB = heavy traffic
 120dB = rock concert
 130dB = pain threshold
 140dB = jet airplane at takeoff



EAR DISORDERS

Deafness - May be total or partial. It may be *conductive* (problems in the outer or middle ear) or *sensory* (inner ear or nerve damage)

Otosclerosis - Causes partial deafness. May be a hereditary disorder, the result of a vitamin deficiency, or a result of a middle ear infection. The ossicles fuse and lose their ability to vibrate.

Tinnitus - Head noises (ringing in the ears). May be temporary or permanent. You may not even notice the noises

Vertigo - A whirling sensation (dizziness) A variety of causes; infection, etc.

Motion sickness - Seems to be caused by sensory input mismatches. You are in a boat, the cabin is visually stable but the vestibular apparatus detects the boat being tossed about. Anti-motion drugs like Dramamine and Scopolamine-patches depress vestibular inputs.

Otitis media - Inflammation of the middle ear. Common in children following a sore throat. This is not surprising considering the short Eustachian tube of children. The usual treatment is with antibiotics. When a lot of pus is present the eardrum is lanced to relieve the pressure. A tiny tube is then inserted in order for the pus to drain. The tube falls out by itself within a year.