THE SPECIAL SENSES

Karen Marshall, Associate Professor
Montgomery College
Takoma Park Campus

The Senses

- taste, smell, sight and hearing
  - four traditional senses
- touch *(studied in Chapter 13)*
  - fifth traditional sense
  - reflects the activity of the general senses
- special senses
  - the four traditional senses
  - smell, taste, sight and hearing
    - referred to as the special senses
  - fifth special sense
    - equilibrium

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Special Sensory Receptors

- distinct receptor cells
- confined to the head region
- highly localized
  - housed within complex sensory organs
    - eyes and ears
  - housed within distinct epithelial structures
    - taste buds and olfactory epithelium

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The Chemical Senses

- taste (gustation)
- smell (olfaction)
- receptors are classified as chemoreceptors
  - respond to chemicals in an aqueous solution

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The Chemical Senses

- smell receptors
  - excited by airborne chemicals
    - dissolve in fluids coating nasal membranes
- taste receptors
  - excited by food chemicals
    - dissolved in saliva

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Chemical Receptors

- receptors for taste and smell complement each other
- respond to many of the same stimuli

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Sense of Taste

- Tasting:
  - the intimate testing or juding of our environment
  - one of the most pleasurable of the special senses

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Taste Buds

- receptor organs of taste
- located primarily in the oral cavity
- approximately, 10,000 of them
- location
  - few are scattered
    - soft palate
    - inner surface of the cheeks
    - pharynx
    - epiglottis of the larynx

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Taste Buds

- location
  - most are on the tongue
    - found in papillae
      - peglike projections of the tongue mucosa
        - give the tongue surface a slightly abrasive feel
      - contain taste buds
      - openings in the surface known as taste pores
        - allow chemicals to reach the taste buds

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Taste Bud Cells

- each taste bud consists of 40 -100 epithelial cells
- three major types
  - supporting cells
  - receptor cells
  - basal cells

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Supporting Cells

- form the bulk of the taste bud
- insulate the receptor cells
  - from each other
  - from the surrounding tongue epithelium
- have gustatory hairs
- keep the gustatory cells healthy

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Receptor Cells

- AKA gustatory cells or taste cells
- sensory dendrites coil around the cells
  - initial part of the gustatory pathway to the brain

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Receptor Cells

- have long microvilli
  - AKA gustatory hairs
  - modified dendrites of gustatory cells
  - project from the tips and extend through a taste pore to the surface of the epithelium
    - where they are bathed by saliva
  - sensitive portions (receptor membranes) of the gustatory cells

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Basal Cells

- act as stem cells
- divide and differentiate into supporting cells
  - give rise to new gustatory cells

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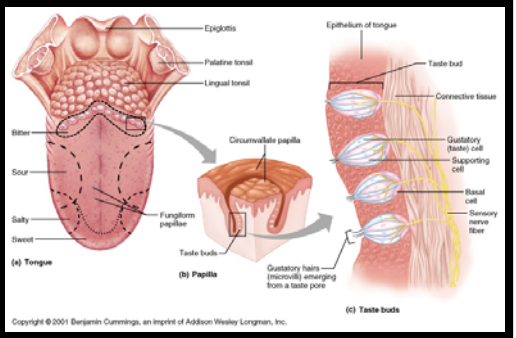
Taste Buds (fig 16.1)



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Basic Taste Sensations

- four basic qualities
  - sweet
  - sour
  - salty
  - bitter

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Basic Taste Sensations

- sweet
  - elicited by organic substances
    - sugars
    - saccharides
    - alcohols
    - some amino acids
    - some lead salts
- sour
    - produced by acids
    - specifically their hydrogen ions in solution

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Basic Taste Sensations

- salty
  - produced by metal ions (inorganic salts)
- bitter
  - elicited by alkaloids
    - nicotine
    - caffeine
  - elicited by nonalkaloid substances
    - aspirin

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Taste Bud Sensitive Areas

- sensed best at different regions on the tongue
- sides of the tongue
  - most sensitive to sour substances
- back of the tongue (near its root)
  - most sensitive to bitter substances
- tip of the tongue
  - most sensitive to sweet and salty substances

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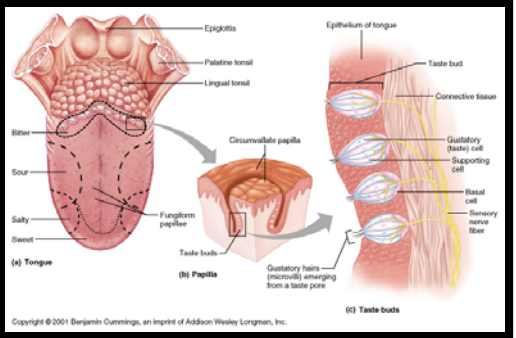
Taste Buds (fig 16.1)



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Taste Sensations

- most taste buds respond to two, three or all four taste qualities
- many substances produce a mixture of the basic taste sensations
- some substances change in flavor as they move through the mouth

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Physiology of Taste

- Series of events for a chemical to be tasted:
- 1) the chemical must dissolve in saliva
- 2) the chemical must diffuse into the taste pore
- 3) the chemical must bind to and stimulate the gustatory hairs
- 4) generation of APs in the gustatory cells
- 5) impulse transfer to the sensory neuron
- 6) impulse transmission of the taste sensation to cranial nerves in the brain

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Example of the Mechanism of Taste

- Eating Chocolate Ice-cream
- within your mouth, the ice-cream melts releasing chemicals
- chemicals enter taste pores and bind to and stimulate gustatory hairs
- the generation of APs in the gustatory cells
  - by the chemical stimulation of the gustatory hairs
- the impulse transferred to the sensory neurons
  - which transmits the taste sensation of chocolate ice-cream in the cranial nerves to the brain

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Sense of Smell

- Organ of smell
  - yellow-tinged patch of pseudostratified epithelum
    - AKA olfactory epithelium
  - location
    - roof of the nasal cavity
      - not ideal
        - air entering the nasal cavity must make a hairpin turn
        - to stimulate the olfactory receptors
        - before entering the respiratory passageway below

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Sense of Smell

- Organ of smell
  - nasal conchae
    - direct inhaled air upward
      - to bring the inhaled molecules closer to the olfactory epithelium
  - sniffing
    - also brings the air superiorly
      - across the olfactory epithelium
      - intensifies the smell

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Olfactory Epithelium

- covers the superior nasal concha
  - on each side of the nasal septum
- contains millions of modified neurons
  - function as the sensory receptors
    - known as olfactory receptor cells
- surrounded and cushioned by supporting cells
  - make up the bulk of the epithelial membrane

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Olfactory Cells

- dendrites of each olfactory cell
  - called olfactory cilia
    - extend into the nasal cavity
- olfactory axons
  - project upward through the foramina in the cribriform plate of the ethmoid bone of the skull
    - synapse on neurons within the olfactory nerve

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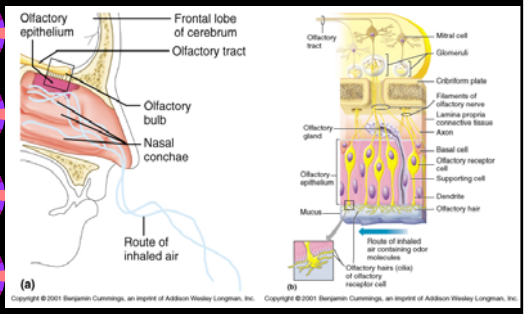
Olfactory Epithelium (fig 16.2)



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Physiology of Smell

- Series of events
- 1) the chemical must be volatile
  - it must be in the gaseous state as it enters the nasal cavity
- 2) the chemical must be water soluble
  - so that it can dissolve in the fluid containing the olfactory epithelium
- 3) the dissolved chemicals stimulate the olfactory receptors by binding to protein receptors in olfactory cilium membranes
- 4) the generation of APs in the olfactory cells
- 5) an impulse travels through the olfactory cell axons to the olfactory nerve where the smell sensation is transmitted to the brain

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Example of the Mechanism of Smell

- Smelling cofee
- coffee is brewing
- chemicals from the coffee enter your nose as part of the inhaled air
- the nasal conchae move the incoming air superiorly toward the olfactory epithelium
- the coffee chemicals bind to the olfactory cilia resulting in their stimulation
- generation of APs in the olfactory cells
- an impulse travels through the olfactory cell axons to the olfactory nerve
  - where the smell sensation of coffee is transmitted to the brain

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Homeostatic Imbalances of the Chemical Senses

- most dysfunctions are olfactory disorders or anosmias
  - one-third of all disorders is due to zinc deficiency
    - zinc is a growth factor (GF) for the receptors of the chemical senses
  - trt
    - zinc supplement

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Accessory Structures of the Eye

- eyebrows
- eyelids
- conjuctiva*
- lacrimal apparatus*
- extrinsic eye muscle

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Conjuctiva

- transparent mucous membrane
- lines the eyelids
- functions
  - major
    - produce a lubricating mucus
      - prevents the eyes from drying out
  - other
    - protection
      - prevens foreign objects from penetrating beyond the confines of its sac

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Conjuctiva

- conjuctival sac
  - slit-like space
  - located between eyeball & eyes

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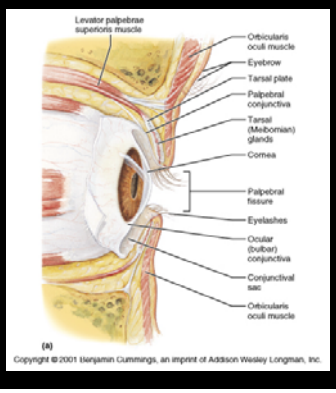
Anterior Portion of Eye (fig 16.5)



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Conjuctivitis

- inflammation of the conjunctiva
- results in reddened, irritated eyes
- pinkeye
  - conjuctival infection
  - caused by bacteria or viruses
  - highly contagious

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Lacrimal Apparatus

- 1) lacrimal gland
- 2) ducts
  - drain the excess lacrimal secretions into the nasal cavity

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Lacrimal Apparatus

- 1) the lacrimal gland
  - located superior and lateral to the eye
  - continuously releases a dilute saline solution into the superior part of conjunctival sac
    - through several excretory ducts
      - called lacrimal secretion *(tears)*

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Lacrimal Apparatus

- 2) the ducts that drain the excess lacrimal secretions into the nasal cavity
  - lacrimal canals
  - lacrimal sac
  - nasolacrimal duct

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Function of Tears

- cleanse and protect the eye surface
  - as it moistens and lubricates it
- increased tears spill over the eyelids
  - fill the nasal cavities
    - causes congestion and the sniffles
  - happens when the eyes are irritated and when we are emotionally upset

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Function of Tears

- enhanced tearing during eye irritation
  - to wash away or dilute the irritating substance
- enhanced tearing during emotional upset
  - is not clearly understood

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Movement of Tears

- ***through the lacrimal apparatus***
- tears are released through *excretory ducts*
- blinking spreads the tears downward and across the eyeball to the medial commissure where they enter the paired *lacrimal canals* (canaliculi) via two tiny openings called lacrimal puncta
- from the canals, the tears drain into the *lacrimal sac* and then into the *nasolacrimal duct* which empties into the *nasal cavity* at the inferior nasal meatus

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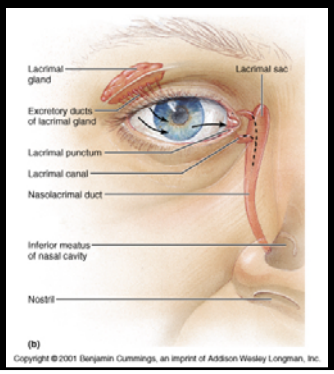
Lacrimal Apparatus (fig 16.5)



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Vision

- dominant sense
- 70% of all sensory receptors are in the eyes
- nearly half of the cerebral cortex is involved in the processing of visual information
- visual receptor cells (photoreceptors) sense and encode patterns of light that enter the eye
- brain uses these signals to give us images

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Eye

- complex structure
- spherical with a diameter of approximately 1 inch
- only the anterior 1/6th of the eye surface is visible
  - rest is enclosed and protected by a cushion of fat and the walls of the bony orbit
    - fat pad occupies most of the orbit

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Structure of the Eyeball

- slightly irregular hollow sphere
- shaped roughly like the globe of the earth
  - poles
    - most anterior point
      - anterior pole
    - most posterior point
      - posterior pole
- walls are composed of three coats (tunics)
  - fibrous (outer)
  - vascular (middle)
  - sensory (inner)
- the internal cavity is filled with fluids that help it maintain its shape
  - known as humors
- lens is the adjustable focusing apparatus
  - supported vertically within the internal cavity
    - dividing it into anterior and posterior segments

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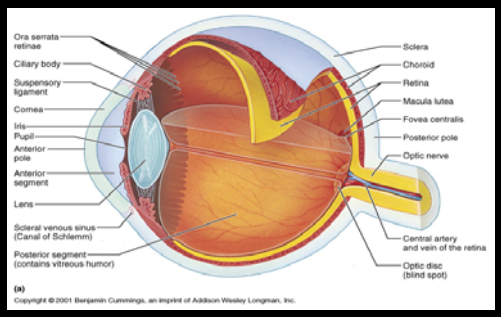
Structure of the Eyeball (fig 16.7)



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Wall of Eyeball

- consists of tunics
  - outermost
    - fibrous tunic
      - sclera
      - cornea
  - middle
    - vascular tunic
      - choroid
      - ciliary body
      - iris
  - innermost
    - sensory tunic
      - retina

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Outermost Coat (Fibrous Tunic)

- consists of the two regions - sclera & cornea
- sclera
  - forms the posterior portion and the bulk of the coat
  - glistening white and opaque
  - seen anteriorly as the “white of the eye”

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Outermost Coat (Fibrous Tunic)

- sclera
  - tough and hard
  - protects and shapes the eyeball and provides a sturdy anchoring site for the extrinsic eye muscles
  - continuous with the dura mater posteriorly where it is pierced by the optic nerve

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Outermost Coat (Fibrous Tunic)

- cornea
  - transparent
  - bulges anteriorly from its junction with the sclera
  - crystal clear due to the arrangement of its collagen fibers
  - part of the light-bending apparatus of the eye

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Outermost Coat (Fibrous Tunic)

- cornea
  - allows light to enter the eye
  - covered with epithelial sheets that help protect the cornea from abrasion
  - capable of regeneration and repair
  - well-supplied with nerve endings *(mostly pain receptors)*

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Cornea

- only tissue in the body that can be transplanted from one person to another with little or no possibility of rejection
  - has no blood vessels
    - beyond the reach of the immune system

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Middle coat (tunic)

- pigmented vascular coat
- also called the uvea
- consists of three regions
  - choroid
  - ciliary body
  - iris

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Middle coat (tunic)

- choroid
  - highly-vascular dark brown membrane
  - blood vessels provide nutrients to the entire eye
  - prevents light scattering within the eye
  - anteriorly
    - it becomes the ciliary body
  - posteriorly
    - incomplete where the optic nerve leaves the eye

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Middle coat (tunic)

- ciliary body
  - consists primarily of interlacing smooth muscle bundles
  - ciliary muscles control the lens shape
  - contains folds (ciliary processes) posteriorly that contain capillaries

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Middle coat (tunic)

- ciliary body
  - secretes the fluid that fills the cavity of the anterior segment
  - suspensory ligament (zonule) extends from the ciliary processes to the lens
    - helps hold the lens in an upright position

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Middle coat (tunic)

- iris
  - most anterior portion of the uvea
  - visible, colored part of the eye
  - shaped like a flattened doughnut
  - lies between the cornea and the lens

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Middle coat (tunic)

- iris
  - continuous with the ciliary body posteriorly
  - round, opening (pupil) allows light to enter the eye
  - muscle fibers allow it to vary pupil size
    - dependent
      - distance and amount of light
      - our interests
      - emotional reactions
        - (boring or appealing)

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Middle coat (tunic)

- iris
  - different colors
  - contains only one pigment (brown)
    - presence of a lot of pigment
      - eyes appear brown or black
    - presence of a small amount of pigment
      - restricted to the posterior surface
        - eyes appear blue, green or gray
        - scattering of light on the unpigmented parts
    - newborn babies eyes are slate gray
      - iris pigment is not yet developed

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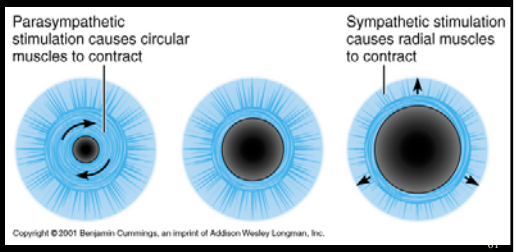
Iris

- In close vision and bright light - contraction of circular muscles *(pupil constriction) - parasympathetic effect*
- In distant vision and dim light - contraction of radial muscles *(pupil dilation) - sympathetic effect*



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Inner Coat (Tunic)

- delicate, two-layered retina
  - outer, pigmented layer
  - inner, transparent neural layer

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Inner Coat (Tunic)

- outer, pigmented layer
  - pigmented epithelial cells
    - absorb light
      - prevent it from scattering in the eye
    - act as phagocytes
    - store vitamin A
      - needed by the photoreceptor cells

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Inner Coat (Tunic)

- inner, transparent neural layer
  - only this layer plays a direct role in vision
  - composed of three main types of neurons
    - either transduce light energy or process light stimuli
      - 1) photoreceptors (rods and cones)
      - 2) bipolar cells
      - 3) ganglion cells

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Photoreceptors

- modified neurons
- rods
  - more numerous
  - dim light and peripheral vision receptors
  - more sensitive to light
  - do not provide sharp images or color vision
    - in dim light colors are indistinct
- cones
  - operate in bright light
  - provide high acuity color vision

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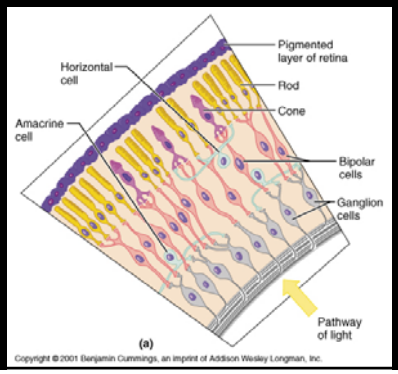
Photoreceptors (fig. 16.9a)



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Physiology of Vision

- light
  - packets of energy (photons)
    - travel in wavelike patterns at various speeds
  - vibration of pure energy

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Physiology of Vision

- when visible light passes through an object
  - each of its waves bends to a different degree
    - beam of light is dispersed
    - a band of colors
      - (visible spectrum)
        - progresses from red to violet
        - varying wavelengths

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Physiology of Vision

- objects have color
  - they absorb some wavelengths
  - they reflect some wavelengths
    - things that look white reflect all wavelengths
    - black objects absorb all wavelengths
    - a red apple reflects mostly red light
    - grass reflects more of the green

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Physiology of Vision

- three types of cones
  - red
  - blue
  - green
- each cone type responds maximally (more strongly) to one color of light
- most light stimulates more than one cone type
  - allows us to see a full range of colors

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Ganglion Cells

- ganglion cell axons form the optic nerve
  - exit via the optic disc
- optic disc ~ blind spot
  - weak spot in the posterior wall
    - not reinforced by the sclera
  - lacks photoreceptors
    - light focused on it cannot be seen
      - the brain utilizes a process called "*filling in*" so we do not realize gaps in our vision

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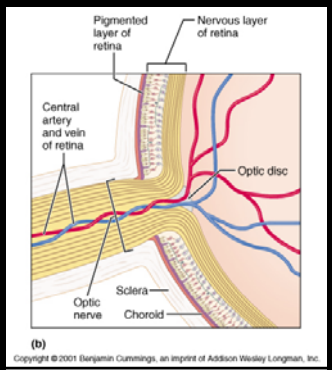
Retina Anatomy (fig 16.9b)



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Generation and Transmission of a Visual Message

- 1) light passes through the retina
  - passes two layers of neurons
    - ganglion and biopolar cells
- 2) light stimulates the photoreceptors (rods & cones)
  - located near the choroid
    - absorb light
- 3) light-sensitive pigments within the photoreceptors change shape

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Generation and Transmission of a Visual Message

- 4) shape change initiates a series of chemical reactions
  - result in the generation of an action potential
- 5) the impulse travels from the rods and cones to the bipolar neurons and then through the ganglion neurons
- 6) ganglion neurons conduct the impulse to the brain via the optic nerve *(make right angle turns)*

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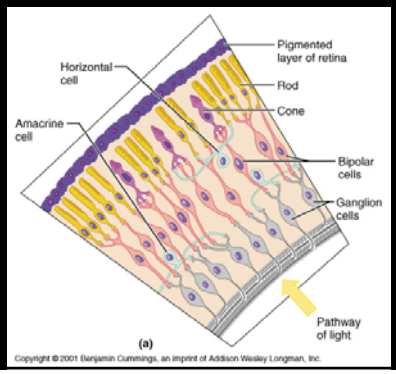
Pathway of Light (fig 16.9)



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Light-Sensitve Pigment & Vitamin A

- photoreceptors contain light-sensitive pigment molecules
- vitamin A is a component of this pigment in both rods and cones
- vitamin A can be obtained from foods
  - carrots, spinach and eggs
- **the pigmented layer of the retina stores vitamin A*

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Color Blindness

- congenital lack of cone types
  - one or more
- sex-linked ds
- more common in males
  - 8-10 %
- most common type
  - red-green
  - deficit or absence of red or green cones
  - seen as same color
    - either red or green

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Internal Chambers and Fluids

- suspensory ligaments
  - divide eye into anterior and posterior segments (lens)

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Internal Chambers and Fluids

- posterior segment
  - vitreous humor *(clear gel)*
    - forms in embryo
    - lasts a lifetime
    - fine collagen fibrils in viscous ground substance
    - transmits light
    - supports posterior surface
    - holds the neural retina firmly against the pigmented layer
    - helps maintain IOP

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Internal Chambers and Fluids

- anterior segment
  - subdivided into anterior and posterior chambers (iris)
    - anterior chamber
      - between cornea and iris
    - posterior chamber
      - between the iris and lens

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Internal Chambers and Fluids

- aqueous humor *(clear fluid)*
  - composition ~ blood plasma
  - forms and drains continually
  - supplies nutrients and O_2
    - lens, cornea, ~ retinal cells
  - removes metabolic wastes
  - helps maintain IOP
    - supports the eyeball

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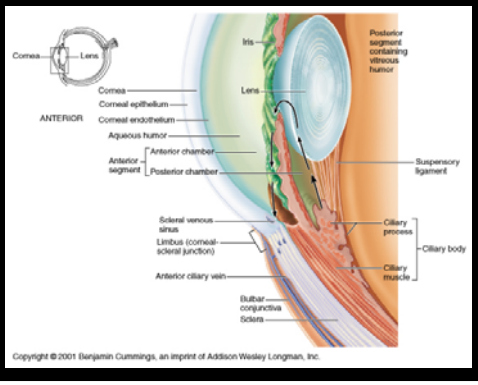
Internal Chambers (fig 16.11)



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Retinal Detachment

- pigmented and nervous retinal layer separation (detachment)
  - results in vitreous humor between the layers
- nutrient deprivation to neural layer
- permanent blindness
- causes
  - torn retina
    - traumatic blow to head
    - jerk in opposite direction

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Retinal Detachment

- symptoms
  - spots
  - flashes
  - curtain drawn
- trt (early dx)
  - before permanent photoreceptor damage
  - reattachment
    - laser
    - cryosurgery

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Glaucoma

- compression of retina and optic nerve
- aqueous humor blockage
- increased IOP
- can result in blindness
- signs
  - halos around lights
  - blurred vision
- trt
  - eye drops
    - decrease IOP
  - surgery

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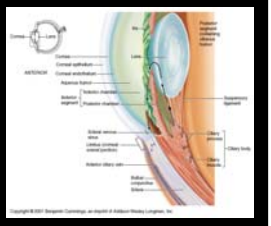
Lens (fig 16.11)

- biconvex
- transparent
- flexible
- curved *(at both surfaces)*
- changes shape for precise focusing of light on the retina
- held in place
  - suspensory ligaments
- avascular *(like cornea)*



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Cataract

- cloudy lens
  - distorted view
- inadequate nutrient delivery to deeper lens fibers
- causes
  - congenital
  - age-related hardening, thickening of lens*
  - secondary result of DM
- risk factors
  - heavy smoking
  - frequent exposure to intense sunlight

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Refraction

- bending of a light ray
  - when it meets the surface of different medium
- light reflects or bounces off surfaces
- light travels in straight lines
  - easily blocked by any nontransparent object

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Refraction

- speed is constant
  - when traveling in a given medium
- speed changes
  - when passing from one medium to different one
    - less dense medium
      - speeds up
    - more dense medium
      - slows down

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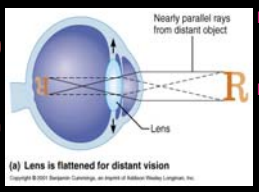
Refraction of Light Rays



- convex lens surface is thicker in the center
- light rays bend
  - converge or intersect at a single point (focal point)
- image formed
  - real image
  - upside down
  - reversed from left to right

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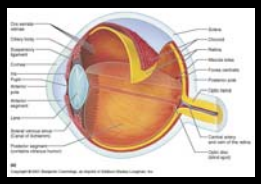
Refraction of Light Rays



- refraction of light rays
  - three times
- moves sequentially from:
  - air to cornea to aqueous humor to lens to vitreous humor to entire thickness of neural retinal layer to excite photoreceptor cells
- light falls on retina:
  - as an upside-down, left-right-reversed image
- brain interprets image as:
  - right-side-up, correctly oriented left to right

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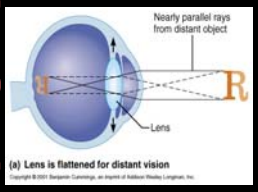
Focusing for Distant Vision



- lens
  - focusing of different distances
- cornea
  - most refraction
- lens are best adapted
  - distant vision
  - aim and fixate at a spot
- far point of vision
  - distance requires no change in lens shape *(accommodation)*
  - normal *(emmetropic)* ~ 20 ft
- near point of vision
  - closest clearly focusing point ~ 4 in
  - maximum lens bulge

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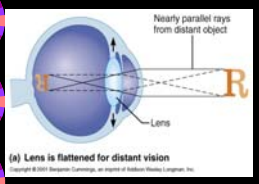
Focusing for Distant Vision



- light rays travel in almost parallel paths
- eye remains relaxed
- light focuses precisely on the retina
- focusing requires no special movements of the eye structures
- natural state

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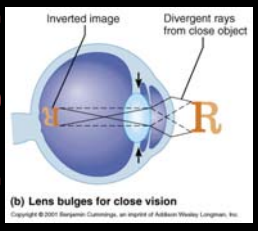
Focusing for Close Vision



- light rays travel in divergent (bent) paths
- eye unrelaxed
- cannot focus unparalleled rays on the retina

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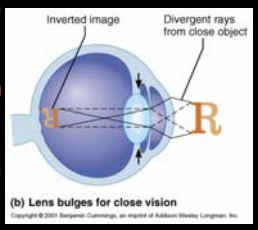
Focusing for Close Vision



- focusing requires special movements of the eye structures *(simultaneously)*
  - accommodation of lenses
  - constriction of pupils
  - convergence of eyeballs

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Special Movements for Close Vision

- accommodation of lenses
  - bulging of lens
    - to increase refraction of the light rays
- constriction of pupils ~ *2 mm*
  - act like a pinhole camera
    - to increase clarity and depth of focus
- convergence of eyeballs
  - medial rotation
    - to keep object on retinal foveae

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Focusing Experiment

- look at your handout at your normal reading distance
- bring the handout closer to your eyes by half
- try to read the print
- notice your eyes tiring
  - work to focus the image on the retina

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Homeostatic Imbalances of Refraction

- myopia *(nearsightedness)*
  - affects 1 in 4 Americans
  - image focused in front of retina
  - lens bends light rays inward too much
  - difficulty focusing on distant, parallel light rays
  - eyeball is too long
  - corrected
    - concave lens
      - bends light rays out to focus farther back and on retina
    - radial keratotomy or laser surgery

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Homeostatic Imbalances of Refraction

- hyperopia *(farsightedness)*
  - image focused behind the retina
  - lens bends light rays too short
  - difficulty focusing on close, divergent light rays
  - corrected
    - convex lens
      - bends light rays in to focus forward and directly on retina

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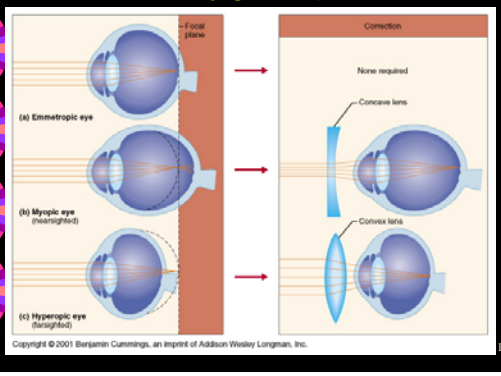
Homeostatic Imbalances of Refraction (fig 16.17)



100

Homeostatic Imbalances of Refraction

- astigmatism
  - unequal curvatures
    - cornea or lens
  - individual light rays refracted in different amounts
    - each focused differently as lines *(not points)* on retina
      - some just right, some near-sighted, some far-sighted
    - neither near nor far objects are focused
  - corrected
    - special lenses with uneven curvature
      - compensates for eye's asymmetry
        - allows the image to focus evenly on retina
    - laser

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Light and Dark Adaptation

- photoreceptor pigment molecule
  - active form *(stimulated by light)*
    - undergoes a chemical change *(bright light)*
      - bleaching of photoreceptors (process)
        - decreases amount of active pigment in photoreceptors
        - decreases eye's sensitivity to light
        - inactivation of photoreceptor molecule *(light adaptation)*

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Light and Dark Adaptation

- photoreceptor pigment molecule
  - inactive form *(stimulated by darkness)*
    - resynthesis of inactive from
  - active form
    - reverse of light adaptation
      - increases amount of active pigment in photoreceptors
      - increases eye's sensitivity to light
      - activation of photoreceptor molecule *(dark adaptation)*

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Dark Adaptation Example

- dark theatre in the afternoon
- bright afternoon sun has bleached *(inactivated)* many photoreceptors
- eyes *(due to light adaptation)* are desensitized to handle bright sunlight
  - not effectively stimulated by low light
- after a few minutes you begin to see
  - because the darkness has activated the pigment molecules
- dark adaptation made eyes sensitive enough to be stimulated by low light

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Dark Adaptation Example

- when you leave the dark theatre
- bright sunlight hurts your eyes
- everything appears too white
- dark adaptation
  - eyes have lots of active pigment
    - too sensitive to sunlight

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Night Blindness ~ Nyctalopia

- condition in which rod function is impaired
  - hampers one's ability to drive safely at night
- most common cause
  - prolonged vitamin A deficiency
    - leads to rod degeneration
- trt
  - vitamin A supplements
    - restore function
      - if administered before degenerative changes occur

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Ear: Hearing and Balance

- hearing apparatus
  - hear range of sounds
- equilibrium receptors
  - inform NS of head movements and position
- sound vibrations move fluid
  - stimulate hearing receptors

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Ear: Hearing and Balance

- gross head movements
  - disturb fluids surrounding balance organs
- organs serving senses interconnected within ear
  - receptors respond different stimuli
  - activated independently

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Structure of the Ear

- three major areas
- outer ear
  - hearing only
- middle ear
  - hearing only
- inner ear
  - equilibrium and hearing

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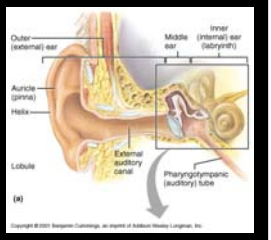
Structure of the Ear (fig 16.24)

- outer (external) ear
  - auricle (pinna)
  - external auditory canal (meatus)
- tympanic membrane (ear drum)
  - boundary between outer and middle ears



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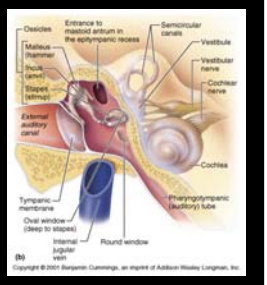
Structure of Ear (fig 16.24)

- middle ear (tympanic cavity)
  - small chamber in temporal bone
  - connected by pharyngotympanic (auditory) tube to nasopharynx
  - ossicles
    - help amplify sound
    - three small bones
      - malleus (hammer)
      - incus (anvil)
      - stapes (stirrup)



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Otitis Media

- middle ear inflammation
- common result of sore throat
  - especially children
    - shorter and more horizontal auditory tube
      - links middle ear cavity with nasopharynx (superiormost part of throat)
- most frequent cause of hearing loss *(children)*
- acute
  - infectious bacteria present
  - eardrum bulges, inflammed
  - trt (most cases)
    - antibiotics

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Mechanics of Hearing

- sounds set up vibrations in air
- beat against the eardrum
- push a chain of tiny bones
- press fluid in inner ear against membranes
- set up forces that pull on hair cells
- stimulate neurons that send impulses to brain
- interpretation impulses
  - hearing

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Properties of Sound

- pressure disturbance
  - originates from a vibrating object
  - propagated by molecules in medium
- transmitted through an elastic medium
- travels more slowly than light
- speed is constant in a given medium
  - greatest in solids
  - lowest in gases (air)

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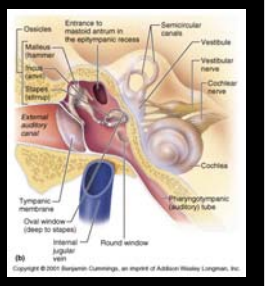
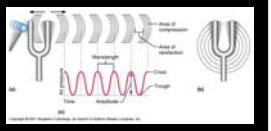
Structure of Ear (fig 16.24)

- inner ear (labyrinth)
  - deep within temporal bone behind eye socket
  - three unique regions
    - vestibule
      - two sacs: utricle, saccule
    - cochlea
      - duct houses the organ of Corti (receptor organ for hearing)
    - semicircular canals



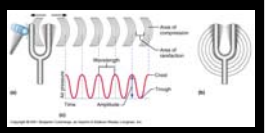
Vibrating Tuning Fork (fig 16.28)

- tuning fork struck on left
- prongs move first to right
  - creates an area of high pressure
    - compression of air molecules
- prongs rebound to left
- air on left becomes compressed
- area on right - rarefied (low pressure) area
- fork vibrates alternately from R to L
- produces series of compressions and rarefractions
  - *sound waves*
    - moves outward in all directions



Vibrating Tuning Fork

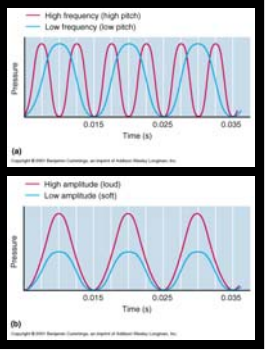
- individual air molecules
  - vibrate back and forth
    - short distances
  - bump other molecules and rebound
    - give up kinetic energy
    - energy is transferred in the direction sound wave is traveling
    - energy of the wave dies
      - with time and distance
      - sound dies



Sound wave is an S-shaped curve *(sine wave)* in which the compressed areas are crests and the rarefied areas are troughs

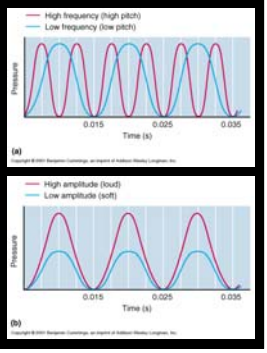
Physical Properties of Sound (fig 16.29)

- two properties
- frequency
  - hertz
  - number of waves passing a given point in a given time
- amplitude
  - height of peaks
  - sound's intensity
    - perceived as loudness
    - decibels (dB)



Physical Properties of Sound

- wavelength
  - distance from crest to crest
  - shorter wavelength- higher frequency
- pitch
  - different sound frequencies
  - higher frequency - higher pitch



Sound Intensities

- healthy adult ear
  - differences in sound intensity
    - 0.1 dB (barely audible)
    - 120 dB (loudest sound)
    - threshold of pain - 130 dB
    - normal conversation - 50 dB
    - noisy restaurants - 70 dB
    - amplified concert - 120 dB or more
- severe hearing loss
  - frequent or prolonged exposure intensities > 90 dB

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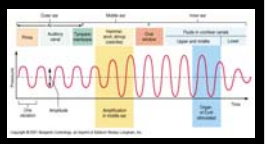
Sound Transmission (fig 16.30)

- sound waves propagated through air, membranes, bones, and fluid to reach and stimulate receptor cells in the organ of Corti
- hearing occurs when the auditory area (temporal lobe) is stimulated



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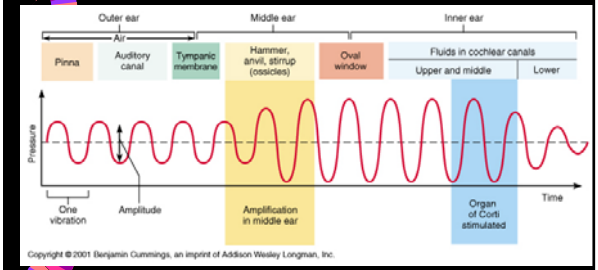
Sound Transmission

- sound waves propagated
  - air
  - membranes
  - bones
  - fluid
    - reach and stimulate receptor cells in the organ of Corti
- hearing occurs when the auditory area (temporal lobe) is stimulated

122

Sound Transmission (fig 16.30)



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Sound Transmission

- airborne sound entering the external auditory canal strikes the tympanic membrane
  - sets its vibrating at the same frequency
  - distance the membrane moves in its vibratory motion varies with sound intensity
  - greater the intensity, the farther the membrane is displaced
- motion of the tympanic membrane is amplified and transferred to oval window by ossicles

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Sound Transmission

- airborne sound entering the external auditory canal strikes the tympanic membrane
  - sets its vibration at the same frequency
  - distance the membrane moves in its vibratory motion varies with sound intensity
  - greater the intensity, the farther the membrane is displaced

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Sound Transmission

- motion of the tympanic membrane is amplified and transferred to oval window by ossicles
- pressure waves in cochlear fluids go into resonance
- hair cells are alternately depolarized and hyperpolarized by vibratory motion

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Homeostatic Imbalances

- deafness
  - any hearing loss
  - inability to hear sound or a certain pitch or intensity to a complete inability to detect sound
  - conduction or sensorineural

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Conduction Deafness

- conduction deafness
  - interference with conduction of sound vibrations to fluids of the inner ear
    - impacted earwax
      - blocks the auditory canal
      - hinders vibration of the eardrum
    - perforated or ruptured eardrum
      - prevents sound conduction from eardrum to ossicles

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Conduction Deafness

- most common causes
  - otitis media (middle ear)
  - otosclerosis (ossicles)
    - age-related ds
    - overgrowth of bony tissue

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Sensorineural Deafness

- damage to neural structures
  - any point from cochlear hair cells to and including auditory cells
  - partial or complete deafness
  - gradual loss of hearing receptors

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Sensorineural Deafness

- causes
  - single explosively loud noise (early age)
  - prolonged exposure to high-intensity sounds
    - music band
    - airport
      - stiffens or tears cilia
  - cochlear nerve degeneration
  - cerebral infarcts
  - tumors (auditory cortex)

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Equilibrium Sense

- responds to various head movements
- dependent on inputs
  - inner ear
  - vision
  - stretch receptors (muscles, tendons)

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Equilibrium Sense

- equilibrium receptors
  - vestibular apparatus
    - send signals to brain
    - initiate reflexes
    - changes in body position

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Equilibrium Sense

- damage to vestibular apparatus
  - system adaptation
- two functional sets of receptors
  - vestibule
  - semicircular canals

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Functional Receptors

- vestibule
  - monitors straight line changes in speed direction (static equilibrium)
  - receptors are maculae of the saccule and utricle
    - monitor position of head in space - control posture
- semicircular canals
  - located in all three planes
  - monitor rotary and angular movements (dynamic equilibrium)

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Equilibrium Sense

- 1) impulses from vestibular apparatus sent via vestibular nerve fibers
- 2) impulses sent to vestibular complex of brain stem and cerebrum
- 3) brain stem and cerebrum initiate responses
- 4) responses result in eyes being fixed on objects and muscles being activated to maintain balance

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Homeostatic Imbalance

- motion sickness
  - common equilibrium disorder
  - sensory input mismatch
  - preceding signs
    - vomiting
    - nausea
    - excessive salivation
    - pallor
    - rapid deep breathing
    - profuse sweating

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Motion Sickness Example

- inside a ship during a storm
- visual inputs
  - body is fixed in a stationary environment (cabin)
- ship tosses and rocks
- vestibular apparatus
  - detects movement and send impulses that "disagree" with visual information
- brain has conflicting information
  - confusion results in motion sickness
- trt
  - removal of stimulus
  - OTC anti-motion meds
    - depress the vestibular inputs

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Age-related Homeostatic Imbalances

- age 60
  - deterioraton of organ of Corti (noticeable)
    - decrease in number of hair cells
      - damaged or destroyed by loud noises, disease, drugs
      - replaced but too slowly
  - lose ability to hear high pitched sounds
    - presbycusis
      - type of sensorineural deafness
      - becoming more common in young people
        - loud noises

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Age-related Homeostatic Imbalances

- age 60
  - vasoconstriction
    - caused by loud noises
    - decreased blood delivery to ear
      - more sensitive to damaging effects

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Happy Studying!
Have a Great Summer!
See ya again next week!

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