The Senses

Lecture
- Sensory receptors
- General senses
- Vision
- Chemical senses

Lab:
- Hearing and equilibrium
- Anatomy of the ear

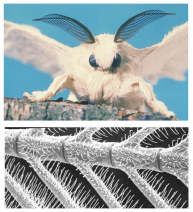
1

2

3

4

Moth following trail of pheromones



http://highered.mcgraw-hill.com/sites/0070371348/student_view0/chapter32/elearning.html

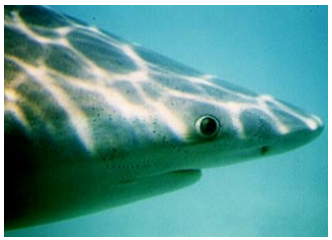
Courtesy of:

http://cas.bellarmine.edu/tietjen/Animal%20Behavior/a_male_silkworm_moth.htm

5

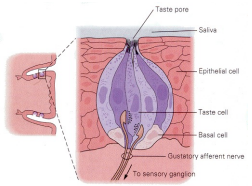
- Viper

6



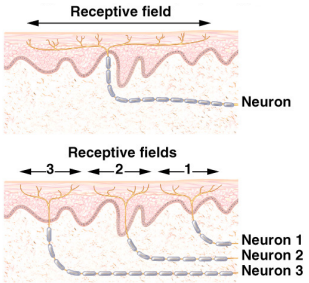
7

Properties of Receptors



8

Receptive Fields



9

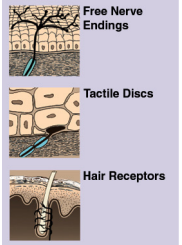
Classification of Receptors

- By modality:
- By origin of stimuli
- By distribution

10

The General Senses
Unencapsulated Nerve Endings

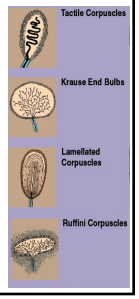
- Found as receptors for the general senses
- Dendrites not wrapped in connective tissue



11

Encapsulated Nerve Endings

- Dendrites wrapped by glial cells or connective tissue



12

Somesthetic Projection Pathways

- First-order neuron or afferent neuron
- Second-order neuron
- Third-order neuron

13

Pain

- Nociceptors make us conscious of tissue injuries
- Found in all tissues except the brain
- Fast pain travels in myelinated fibers at 30 m/sec
- Slow pain travels unmyelinated fibers at 2 m/sec
- Somatic pain arises from skin, muscles & joints
- Visceral pain from stretch, chemical irritants or ischemia of viscera (poorly localized)
- Injured tissues release chemicals that stimulate pain fibers (bradykinin, histamine, prostaglandin)

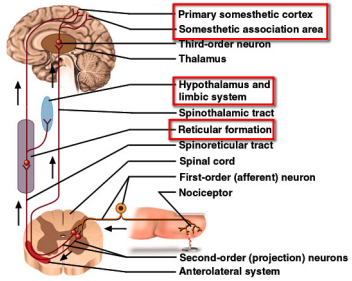
14

Projection Pathway for Pain

- General pathway
- Spinoreticular tract
- Referred pain is misinterpreted pain

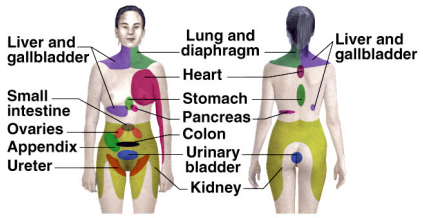
15

Pain Signal Destinations



16

Referred Pain



17

CNS Modulation of Pain

- Intensity of pain is affected by state of mind
- Endogenous opiods (enkephalins, endorphins 7 dynorphins)
- Spinal gating stops pain signals at dorsal horn

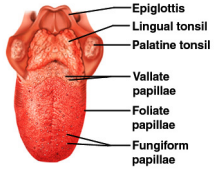
18

Homework: read insight 16.5, page 632

19

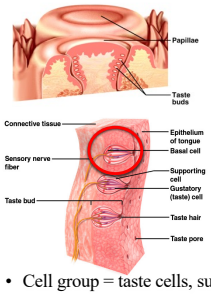
The Chemical Sense -- Taste

- Gustation is the sensation of taste resulting from the action of chemicals on the taste buds
- ANATOMY OF THE TONGUE
- Lingual papillae
  - filiform (no taste buds)
    - important for texture
  - foliate (no taste buds)
  - fungiform
    - at tips & sides of tongue
  - vallate (circumvallate)
    - at rear of tongue
    - contains 1/2 of taste buds



20

Taste Bud Structure



- Cell group = taste cells, supporting cells, and basal cells

21

Physiology of Taste

22

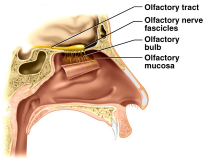
Projection Pathways for Taste

- Innervation of the taste buds
- All fibers project to solitary nucleus in medulla
- Cells project to hypothalamus & amygdala
- Cells project to thalamus & then postcentral gyrus of the cerebrum

23

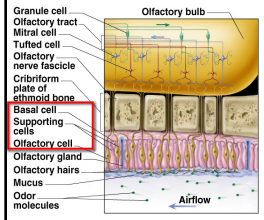
The Chemical Sense -- Smell

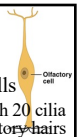
- Receptor cells for olfaction form olfactory mucosa
  - smell is highly sensitive (more so in women than men)
  - distinguish as many as 10,000 odors



24

Olfactory Epithelial Cells





- Olfactory cells
  - neurons with 20 cilia called olfactory hairs
    - binding sites for odor molecules in thin layer of mucus
  - axons pass through cribriform plate
  - survive 60 days
- Supporting cells
- Basal cells divide

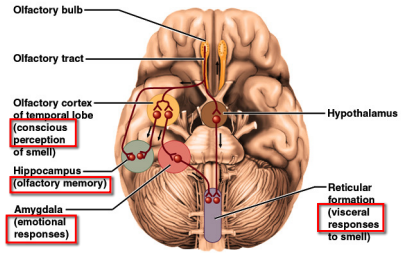
25

Physiology of Smell

- Odor molecules must be volatile
- Receptors adapt quickly due to synaptic inhibition in the olfactory bulbs
- Bulb cells form the axons of the olfactory tracts
  - lead to temporal lobe, amygdala, hypothalamus
  - cerebral cortex sends feedback to bulb cells

26

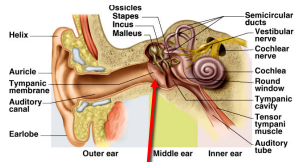
Olfactory Projection Pathways



27

The Nature of Sound

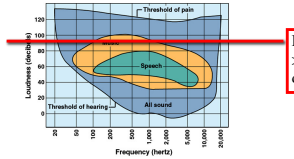
- Sound is any audible vibration of molecules
- Vibrating object pushes air molecules into eardrum making it vibrate



Molecules collide with eardrum & make it vibrate.

28

Pitch and Loudness

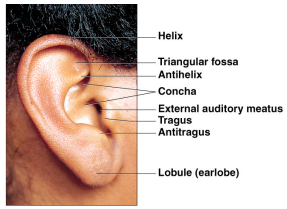


Prolonged Sounds > 90 dB can cause damage.

- The frequency at which parts of the ear vibrate give us sense of pitch (high or low pitched sounds)
  - hearing range is 20 - 20,000 Hz (cycles/sec)
  - speech is within 1500-4000 where hearing is most sensitive
- Loudness is perception of intensity of sound energy
  - how much the air molecules are compressed in decibels (dB)

29

Outer Ear



- Fleshy auricle (pinna) directing air vibrations down auditory canal (external auditory meatus)
  - cartilagenous & bony, S-shaped tunnel ending at eardrum

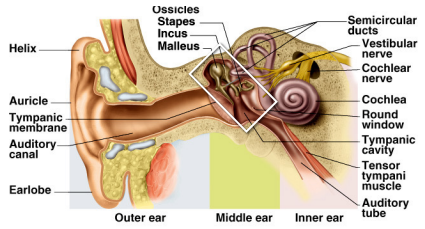
30

Middle Ear

- Air-filled cavity in temporal bone separated from air outside the head by tympanic membrane
  - 1 cm in diameter, slightly concave, freely vibrating membrane
- Tympanic cavity continuous with mastoid air cells
- Tympanic cavity filled with air by auditory tube (eustachian tube) connected to nasopharynx
  - opens during swallowing or yawning to equalize air pressure on both sides of eardrum
- Ear ossicles span tympanic cavity
  - malleus attached to eardrum, incus, stapes attached to membranous oval window of inner ear
  - stapedius & tensor tympani muscles attach to ossicles

31

Anatomy of Middle Ear

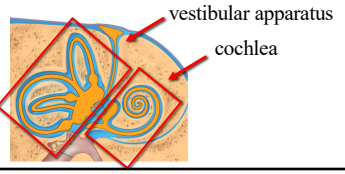


- Middle ear is cavity containing ear ossicles.

32

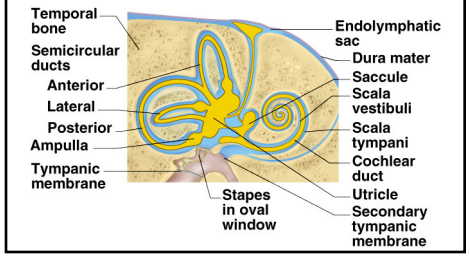
Inner Ear

- Passageways in temporal bone = bony labyrinth
- Fleshy tubes lining bony tunnels = membranous labyrinth
  - filled with endolymph (similar to intracellular fluid)
  - floating in perilymph (similar to cerebrospinal fluid)



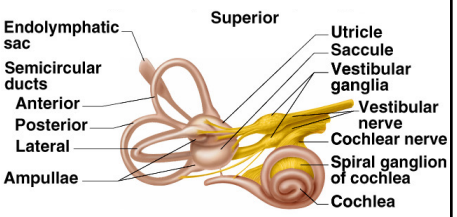
33

Details of Inner Ear



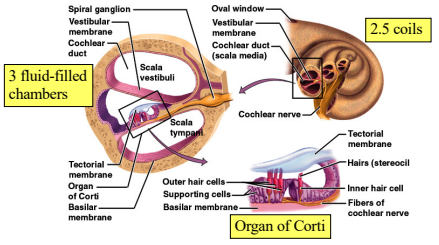
34

Details of Inner Ear



35

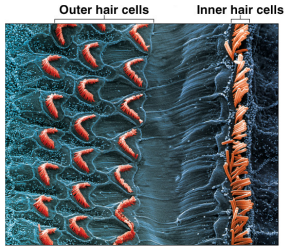
Anatomy of the Cochlea



- Stereocilia of hair cells attached to gelatinous tectorial membrane.
- Hearing comes from inner hair cells -- outer ones adjust cochlear responses to different frequencies increasing precision

36

SEM of Cochlear Hair Cells



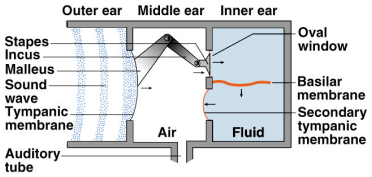
37

Physiology of Hearing -- Middle Ear

- Eardrum vibrates quite easily
- Protection of cochlea by muscle contraction in response to loud noises (tympanic reflex)

38

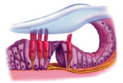
Stimulation of Cochlear Hair Cells

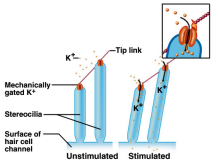


39

Potassium Gates of Cochlear Hair Cells

- Stereocilia bathed in high K+ concentration creating electrochemical gradient from tip to base
- Stereocilia of OHCs have tip embedded in tectorial membrane which is anchored
- Movement of basilar membrane bends stereocilia
- Bending pulls on tip links and opens ion channels
- K+ flows in -- depolarizing it & causing release of neurotransmitter stimulating sensory dendrites at its base





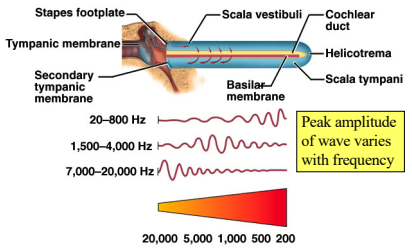
40

Sensory Coding

- Loudness produces more vigorous vibrations & excites more hair cells over a larger area
- Determination of pitch depends on which part of basilar membrane is vibrated at peak amplitude of standing wave

41

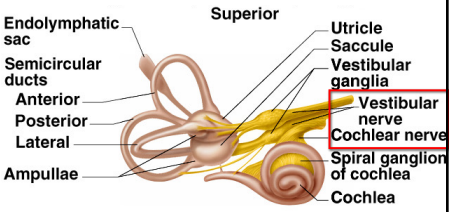
Frequency Response of Basilar Membrane



- Notice the high & low frequency ends of the basilar membrane

42

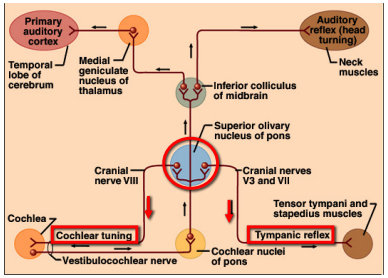
Innervation of Internal Ear



- Vestibular ganglia is visible in vestibular nerve
- Spiral ganglia is buried in modiolus of cochlea

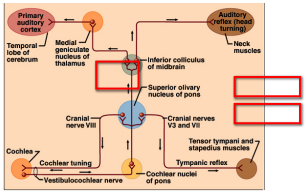
43

Pathways for Control of Hearing



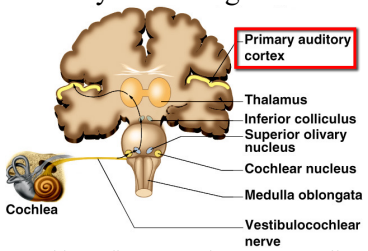
44

Auditory Projection Pathway



45

Auditory Processing Centers



- Damage to either auditory cortex does not cause unilateral deafness due to extensive decussation in pathway

46

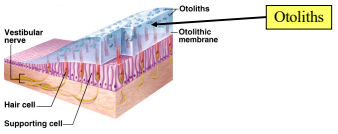
Equilibrium

- Control of coordination and balance
- Receptors in vestibular apparatus
  - semicircular ducts contain crista
  - saccule & utricle contain macula
- Static equilibrium is perception of head orientation
  - perceived by macula
- Dynamic equilibrium is perception of motion or acceleration
  - linear acceleration perceived by macula
  - angular acceleration perceived by crista

47

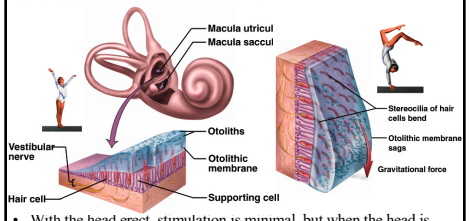
The Saccule and Utricle

- Saccule & utricle chambers containing macula



48

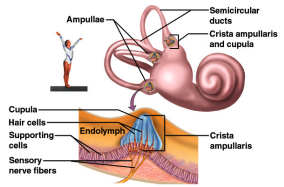
Macula Saccule and Macula Utricle



- With the head erect, stimulation is minimal, but when the head is tilted, weight of membrane bends the stereocilia (static equilibrium)

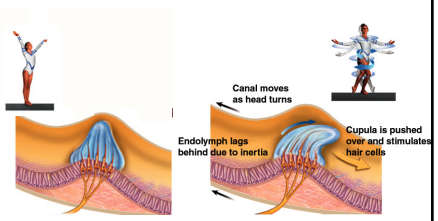
49

Crista ampullaris of Semicircular Ducts



50

Crista Ampullaris & Head Rotation



- As head turns, the endolymph lags behind pushing the cupula and stimulating its hair cells

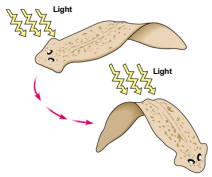
51

Equilibrium Projection Pathways

- Hair cells of macula sacculi, macula utriculi & semicircular ducts synapse on vestibular nerve
- Fibers end in vestibular nucleus of pons, cerebellum, nuclei of cranial nerves controlling eye, head and neck movements
- Reflex pathways allow us to fixate visually on a point while head is moving
  - move book while head is still, can not focus on it
  - look at book while head is moving, no problem

52

VISION



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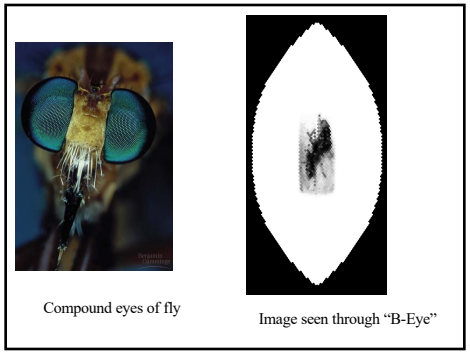
54



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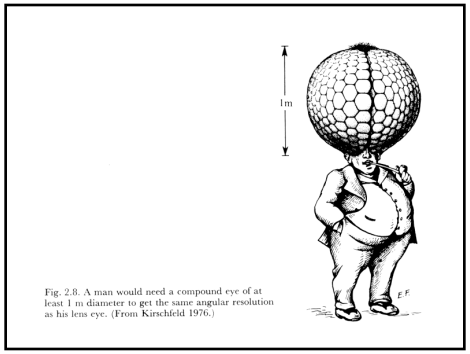
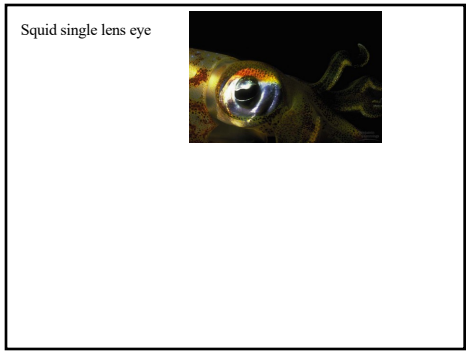
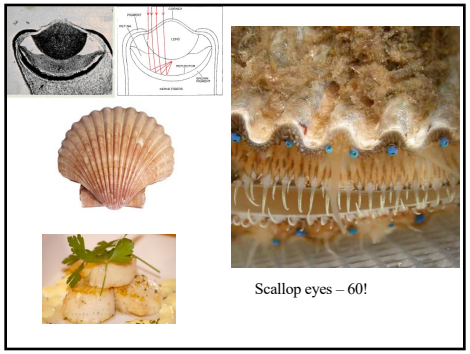
56



57



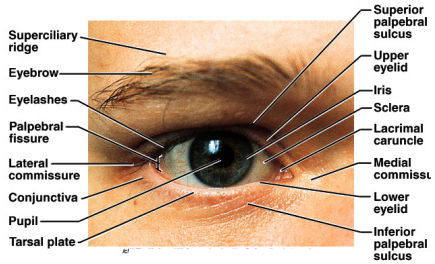
58



59

60

External Anatomy of Eye



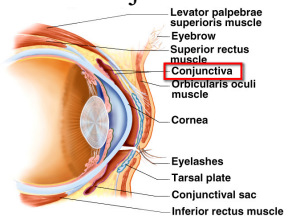
61

Eyebrows and Eyelids

- Eyebrows provide facial expression, protection from glare & perspiration
- Eyelids (palpebrae)

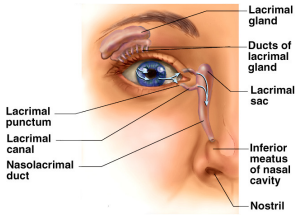
62

Conjunctiva



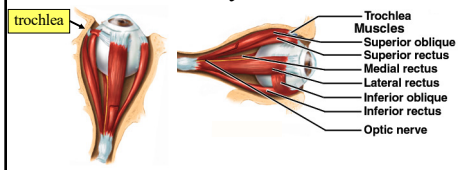
63

Lacrimal Apparatus



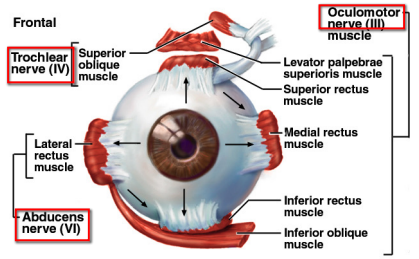
64

Extrinsic Eyes Muscles



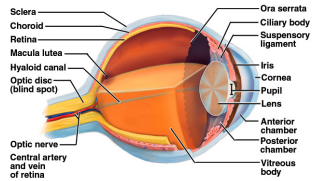
65

Innervation of Extrinsic Eye Muscles



66

The Tunics of the Eyeball



- Fibrous layer (tunica fibrosa) = sclera and cornea
- Vascular layer (tunica vasculosa) = choroid, ciliary body & iris
- Internal layer (tunica interna) = retina and optic nerve

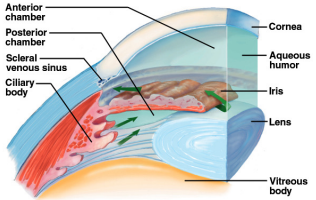
67

The Optical Components

- Series of transparent structures that bend or refract light rays to focus them on the retina

68

Aqueous Humor



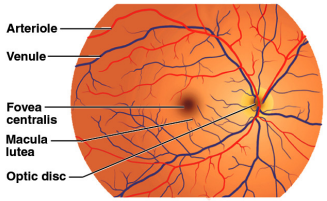
69

The Neural Components

- Neural apparatus includes the retina & optic nerve
- Retina forms as an outgrowth of the diencephalon
- Detached retina

70

Ophthalmoscopic Examination of Eye



71

Rear of Eye Through Ophthalmoscope

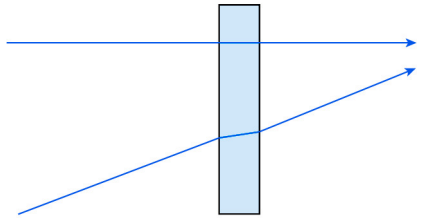
72

Test for Blind Spot

- Optic disk or blind spot is where optic nerve exits the posterior surface of the eyeball
  - no receptor cells are found in optic disk
- Blind spot can be seen using the above illustration
  - in the right position, stare at X and red dot disappears
- Visual filling is the brain filling in the green bar across the blind spot area

73

Principle of Refraction

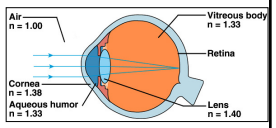


Light striking the lens or cornea at a 90 degree angle is not bent.

74

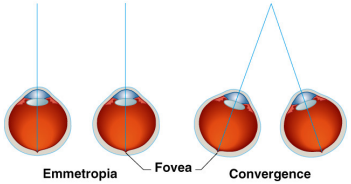
Refraction

- Bending of light rays occurs when light passes through substance with different refractive index at any angle other than 90 degrees
  - refractive index of air is arbitrarily set to n = 1
  - refractive index of cornea is n = 1.38
  - refractive index of lens is n = 1.40



75

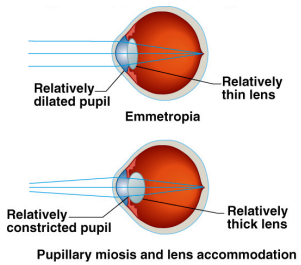
Emmetropia & Near Response



- Behaviour of eyes when focused on distant object (over 20 ft away) and onto close object

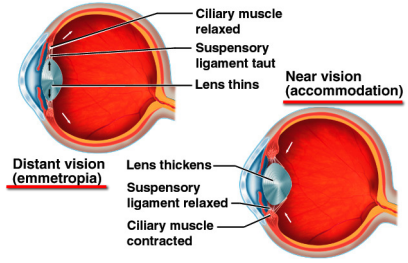
76

Emmetropia & Near Response



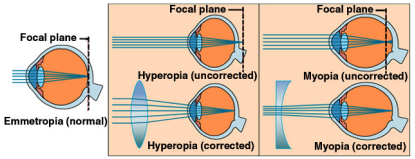
77

Accommodation of Lens



78

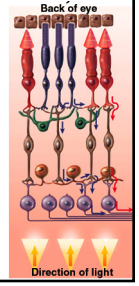
Effects of Corrected Lenses



79

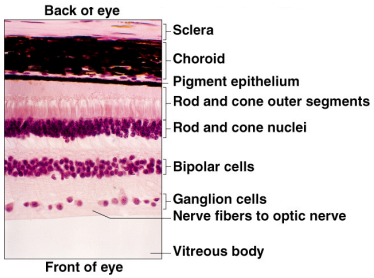
Retinal Cells

- Posterior layer of retina is pigment epithelium
  - purpose is to absorb stray light & prevent reflections
- Photoreceptors cells are next layer
  - derived from stem cells that produced ependymal cells



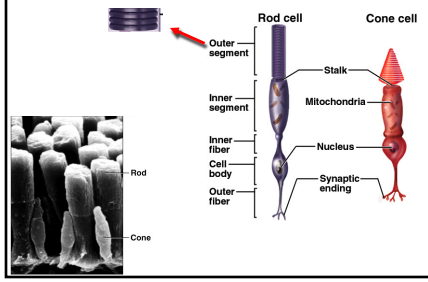
80

Histology of the Layers of Retina



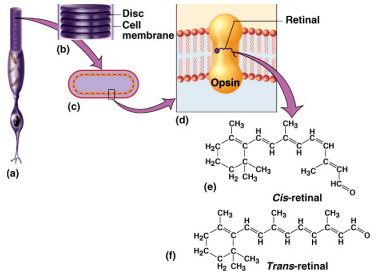
81

Cone and Rod Cell Details



82

Location of Visual Pigments



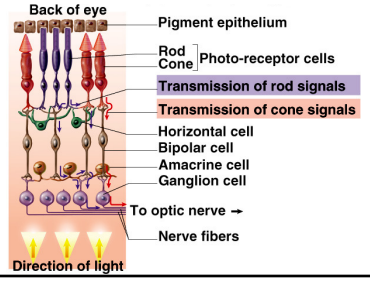
83

Nonreceptor Retinal Cells

- Bipolar cells (1st order neurons)
  - synapse on ganglion cells
  - large amount of convergence
- Ganglion cells (2nd order neurons)
  - axons of these form optic nerve
  - more convergence occurs (114 receptors to one optic nerve fiber
- Horizontal & amacrine cells lie form connections between other cells
  - enhance perception of contrast, edges of objects & changes in light intensity

84

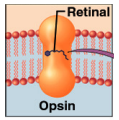
Schematic Layers of the Retina



85

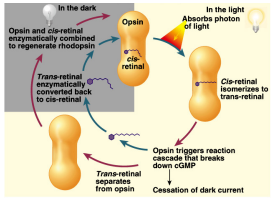
Visual Pigments

- Visual pigment of the rod cells is called rhodopsin (visual purple)
- 2 major parts to the molecule
  - protein called opsin
  - vitamin A derivative called retinal



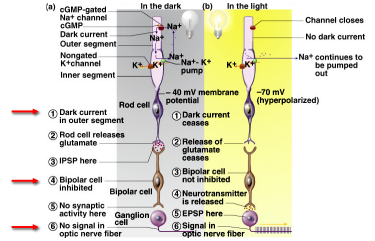
86

The Photochemical Reaction in Rod Cells



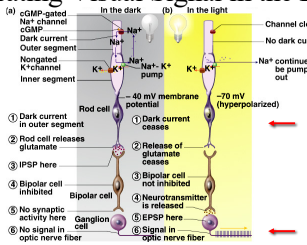
87

Generating Visual Signal in the Dark



88

Generating Visual Signal in the Light



89

Light and Dark Adaptation

- Light adaptation (wake up in middle of night and turn on bright light)
  - pupil constriction and pain from over stimulated retinas
  - color vision & acuity not optimal for 5 to 10 minutes

90

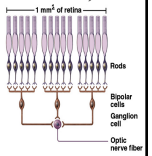
Duplicity Theory

- Explains why we have both rods and cones
- Single type of receptor cell incapable of providing high sensitivity and high resolution
  - sensitive night vision = one type of cell and neural circuitry
  - high resolution daytime vision = different cell type and neuronal circuitry

91

Scotopic System (Night Vision)

- Sensitivity of rods in dim light

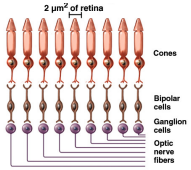


- Edges of retina with widely spaced rod cells is low-resolution system only alerting us to motion

92

Photopic System (Day Vision)

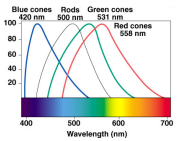
- Fovea contains only 4000 tiny cone cells and no rods
  - no neuronal convergence
  - each foveal cone cell has "private line to the brain"
- High-resolution vision, but little spatial summation and less sensitivity to light intensity



93

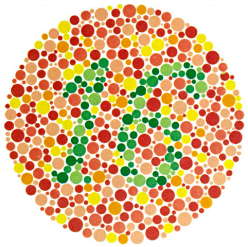
Color Vision

- Primates have well developed color vision
  - nocturnal vertebrates have only rods
- Cones are named for absorption peaks of photopsins
  - blue cones peak sensitivity at 420 nm
  - green cones peak at 531 nm
  - red cones peak at 558 nm (orange-yellow)



94

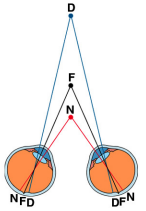
Test for Red-Green Color Blindness



95

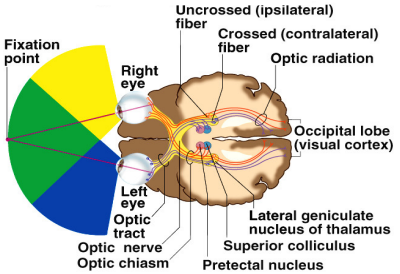
Stereoscopic Vision (Stereopsis)

- Depth perception is the ability to judge how far away objects are
- Requires 2 eyes with overlapping visual fields
  - panoramic vision has eyes on sides of head (horse)
- Fixation point is spot on which eyes are focused
  - objects farther away require image focus medial to the fovea
  - objects closer result in image focus lateral to fovea



96

Visual Projection Pathway



97

Visual Projection Pathway

- Bipolar & ganglion cells in retina are 1st & 2nd order neurons (axons of ganglion cells form CN II)
- Hemidecussation occurs in optic chiasm
  - 1/2 of fibers decussate so that images of all objects in the left visual field fall on right half of each retina
  - each side of brain sees what is on side where it has motor control over limbs
- 3rd order neurons in lateral geniculate nucleus of thalamus form optic radiation to 1° visual cortex where conscious visual sensation occurs
- Few fibers project to superior colliculi & midbrain for visual reflexes (photopupillary & accomodation)

98

Visual Information Processing

- Some processing occurs in the retina
  - adjustments for contrast, brightness, motion & stereopsis
- Visual association areas in parietal & temporal lobes process visual data
  - object location, motion, color, shape, boundaries
  - store visual memories (recognize printed words)

99