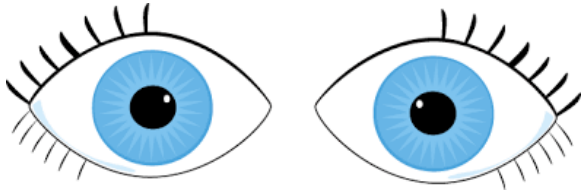
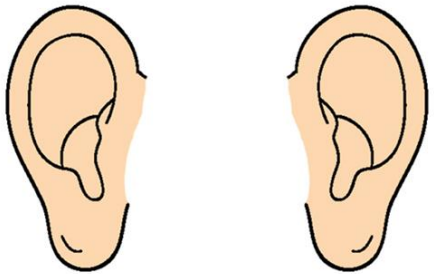


Vision & Hearing:
From Molecules to Sensory Loss

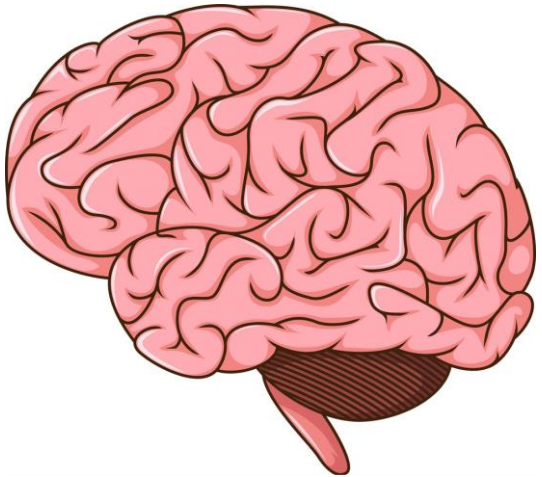
Tuesday, October 22nd, 2019

Jane Burton, Au.D., CCC-A
Sarah Naguib, B.S.



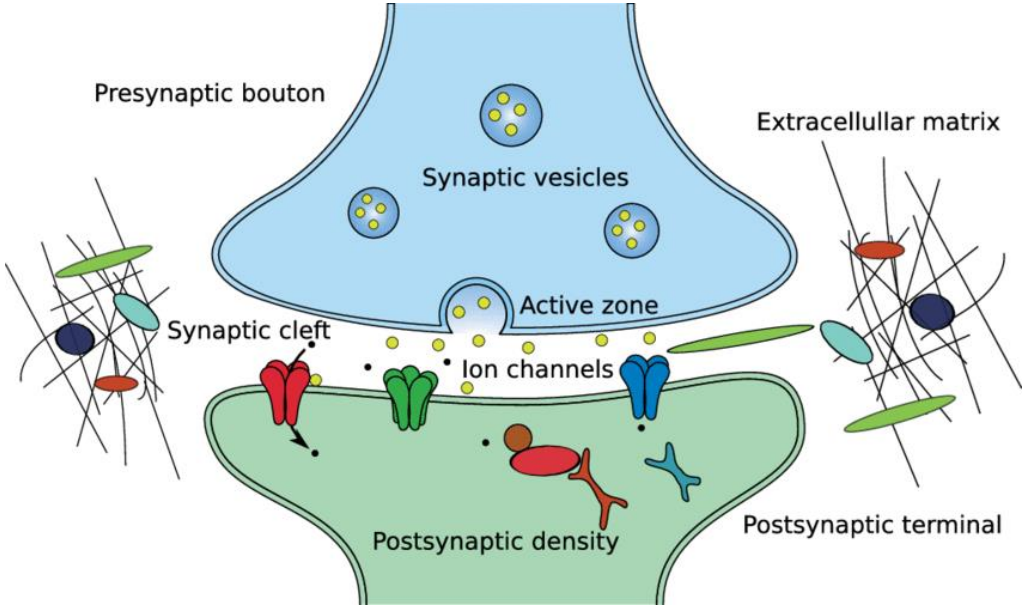
Outline

- Brief Overview of Neurotransmission
- The Senses and the Brain
  - Vision
  - Hearing
- Sensory Loss and the Brain
  - Vision Loss
  - Hearing Loss



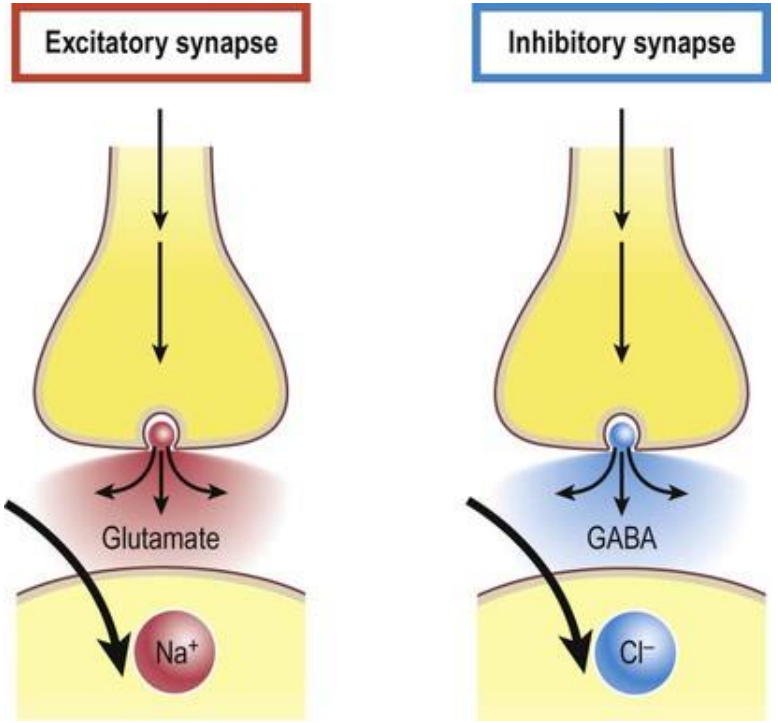
Neurons communicate via synapses

- Synapses: junctions between two neurons
- Neurotransmitters: chemical messengers released from neurons at synapses so they can communicate with neighboring cells



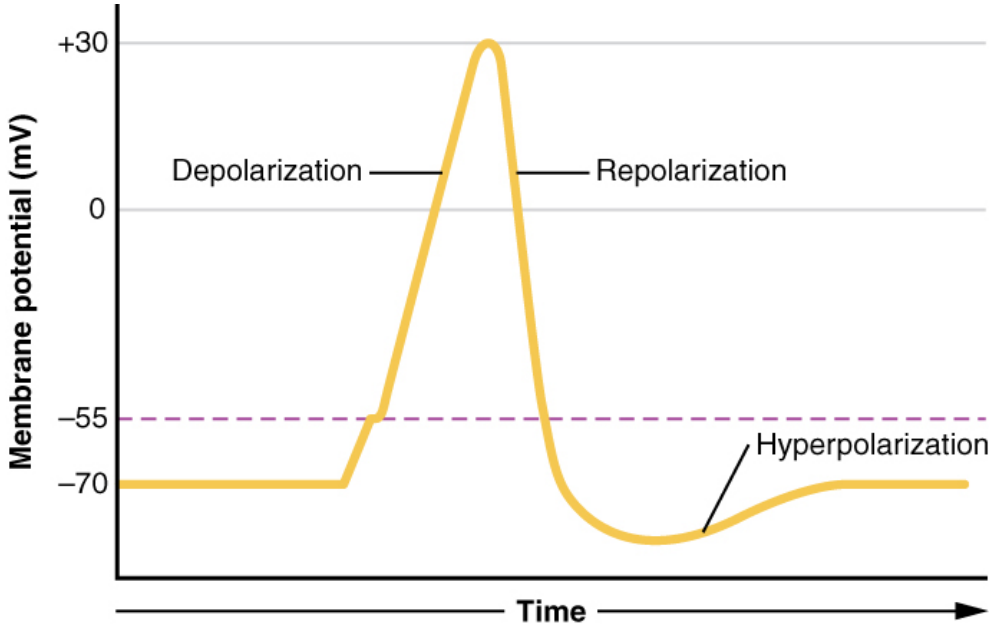
Release of neurotransmitters can cause depolarization or hyperpolarization

- Some neurotransmitters are viewed as “excitatory”
  - Target neurons are more likely to fire an action potential
- Some neurotransmitters are viewed as “inhibitory”
  - Target neurons are less likely to fire an action potential



Brief review of action potentials

- When a neuron is not sending signals, it is at rest
- An action potential occurs when a neuron sends information down an axon, away from the cell body
- If the signal is strong enough, it will trigger the action potential
- The neuron becomes hyperpolarized



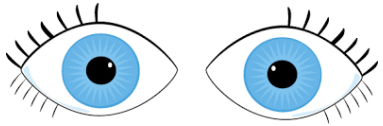
The Senses: Interacting with the World

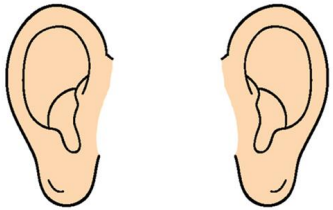
- Vision
- Audition
- Somatosensation
- Olfaction
- Gustation
- Balance
- Nociception
- Proprioception
- Thermoception

Sensation and Perception

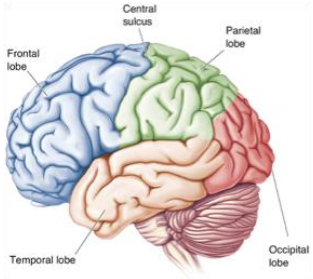
Input

Transduction





Processing

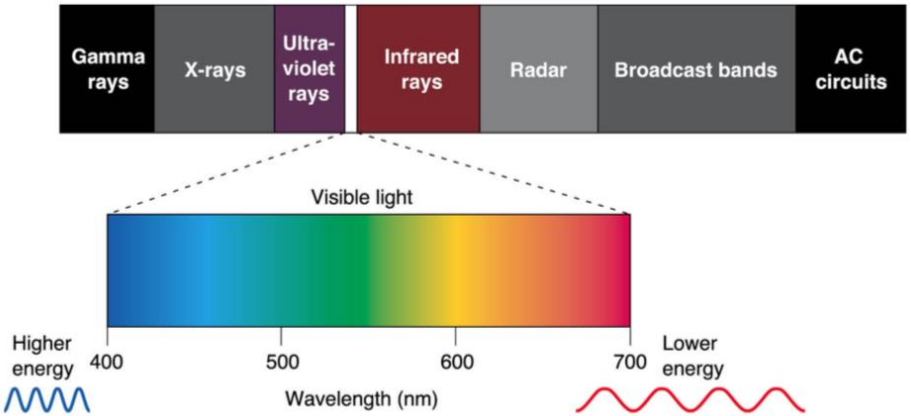


Perception

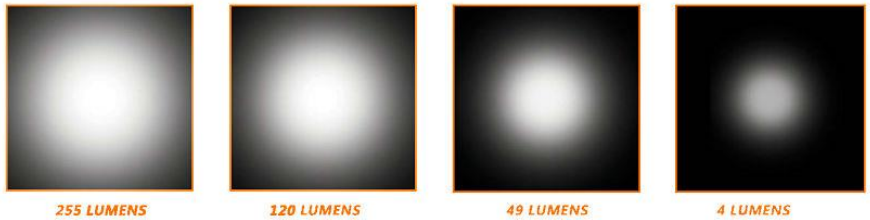
Vision

Visual Input: Light

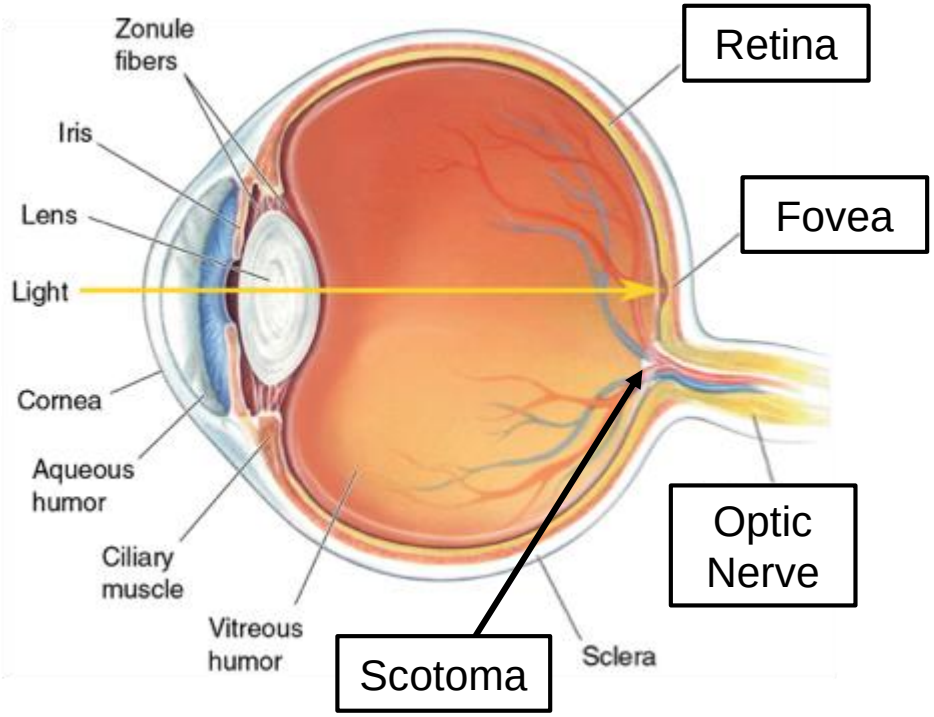
Spectrum



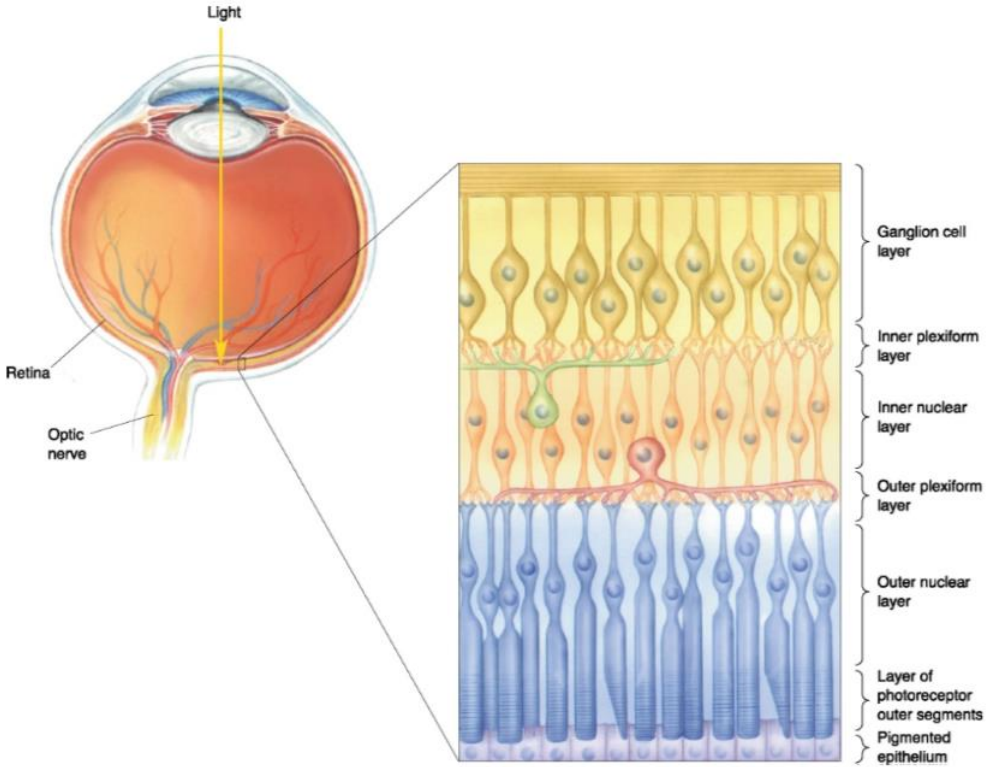
Intensity



Visual Sensory Transduction: The Eye



Visual Sensory Transduction: The Eye



Phototransduction

- Photoreceptors
  - Rods
  - Cones
- Bipolar cells
- Ganglion cells

Humans have two types of photoreceptors

Rods	Cones
High sensitivity	Low sensitivity
Single wavelength	Multiple wavelengths (color)
Peripheral retina	Central retina
Dim light vision	Bright light vision

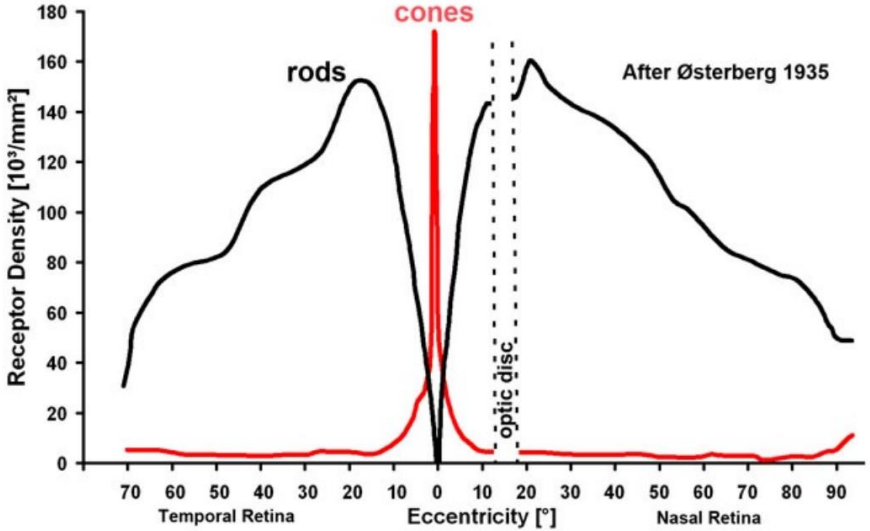
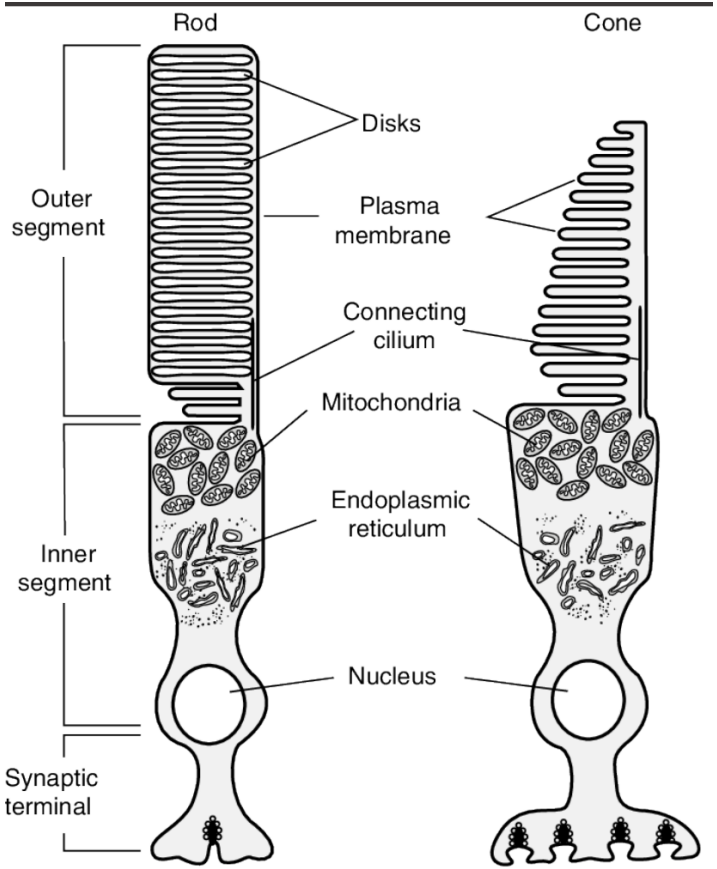


Fig. 20. Graph to show rod and cone densities along the horizontal meridian.

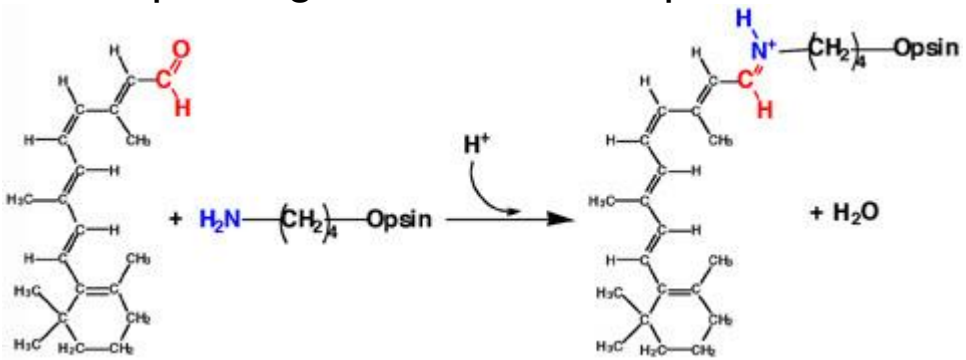
Photoreceptors are highly compartmentalized

- Phototransduction occurs in the outer segment
- Mitochondria and ER are for energy production
- Neurotransmitters are released from terminal

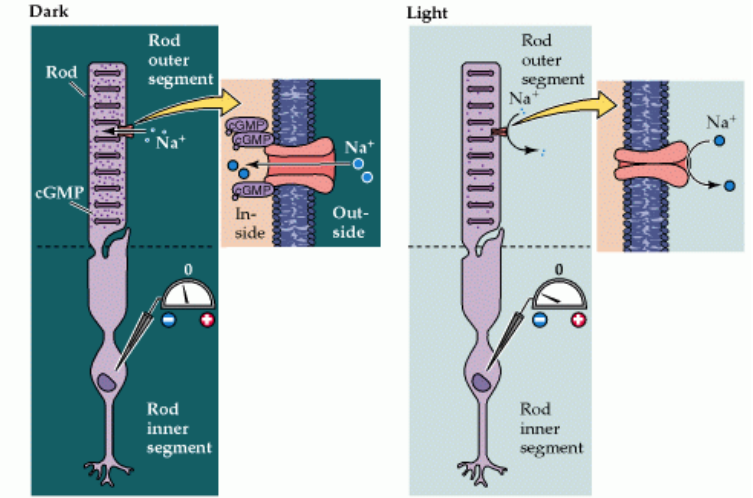


Major players in phototransduction

Opsin: light-sensitive receptor

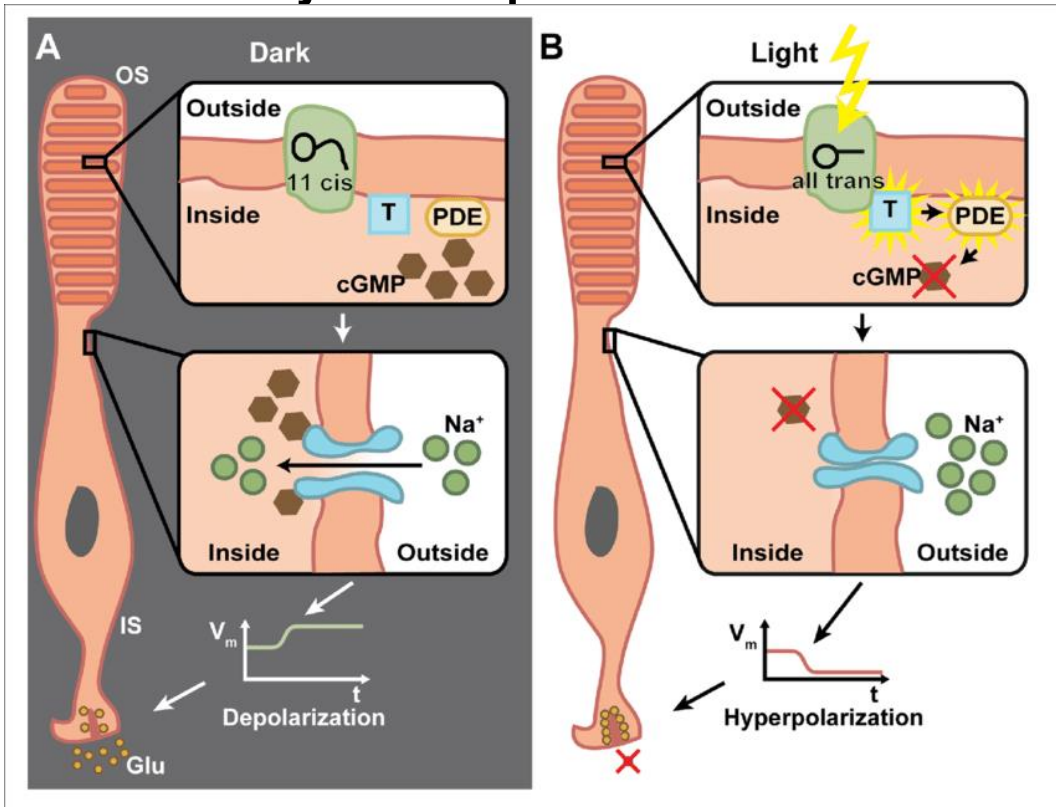


cGMP: second messenger that keeps photoreceptors in depolarized state

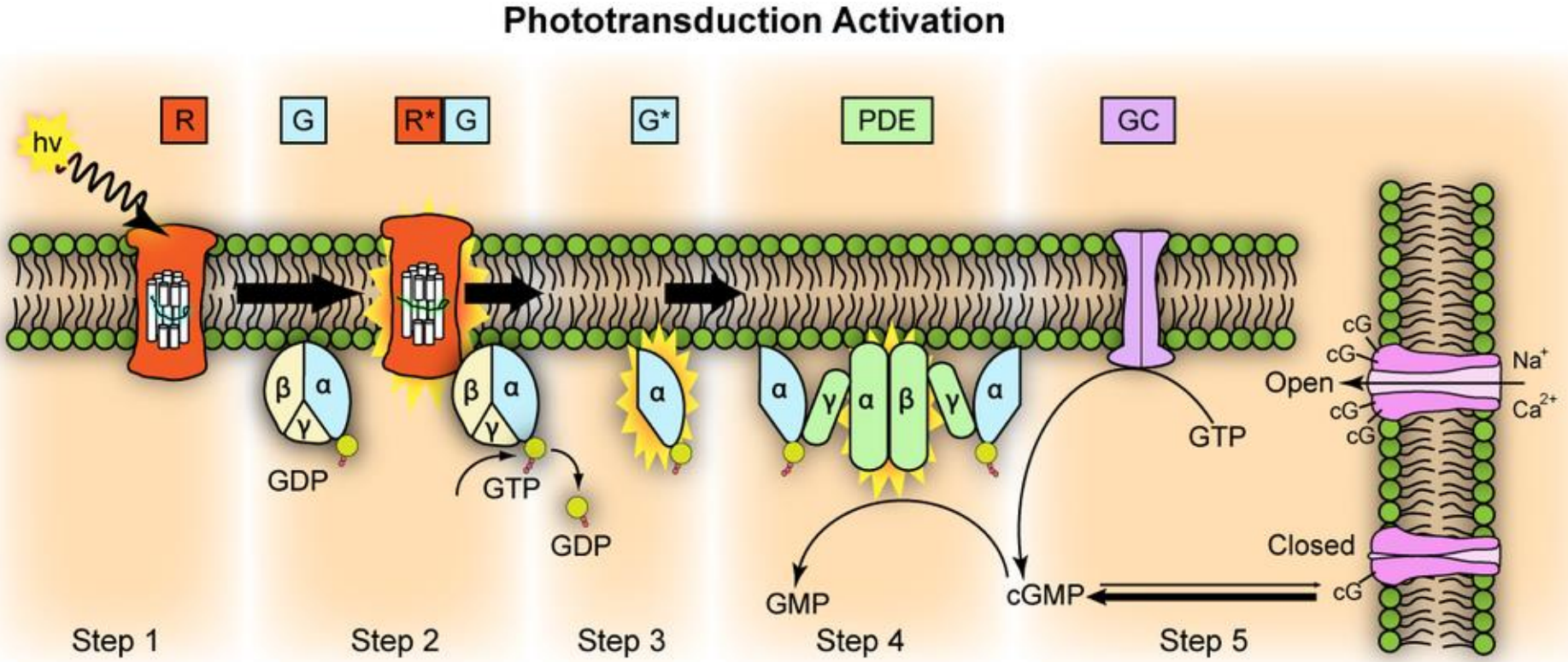


Phototransduction involves 3 major steps

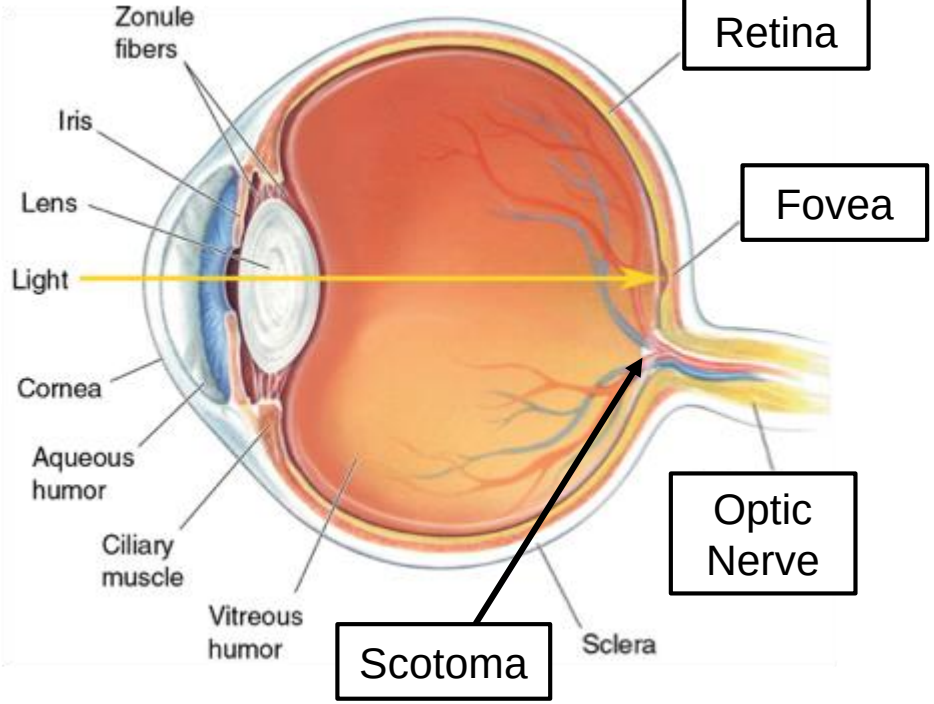
1. Light enters the eye and activates the opsin molecules inside the photoreceptors
2. Activated rhodopsin causes a reduction in cGMP
3. Photoreceptor is hyperpolarized following light exposure

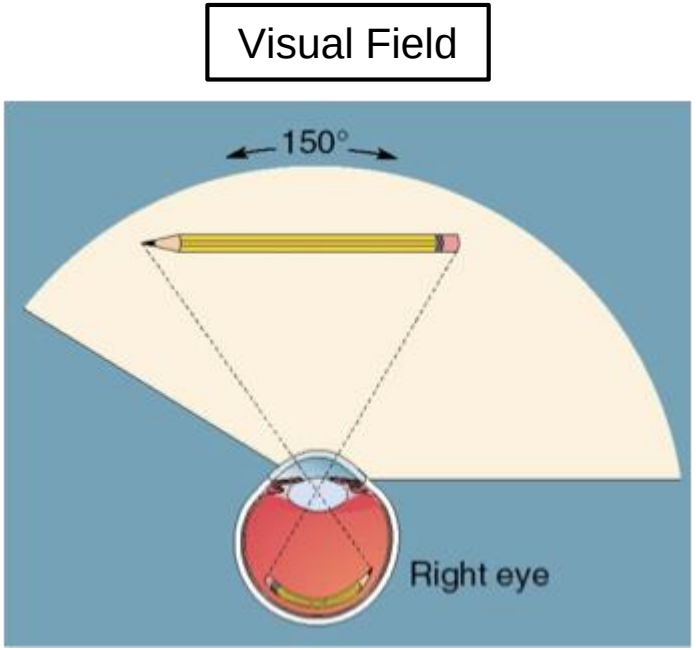


Inactivation of phototransduction



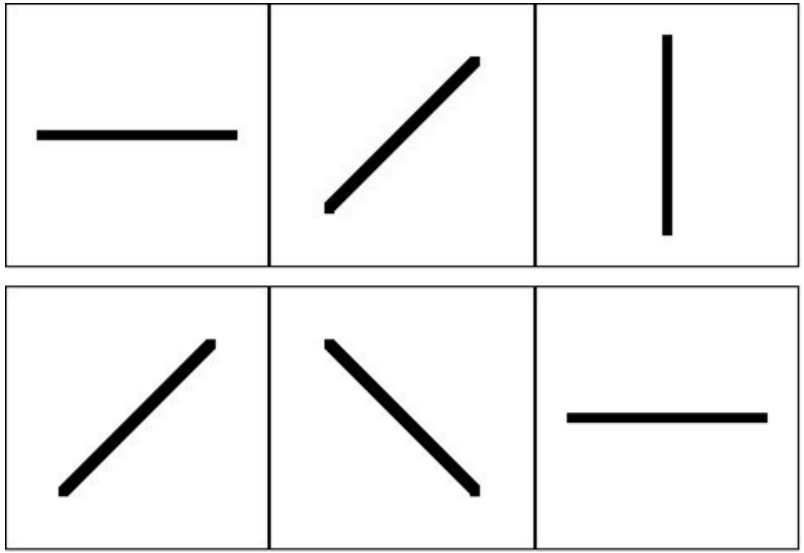
Visual Sensory Transduction: The Eye



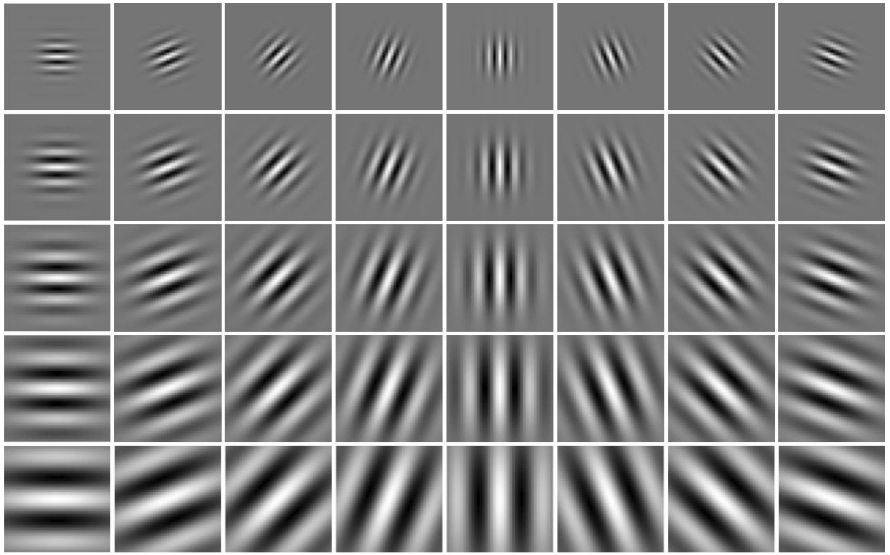


Visual Processing

Orientation

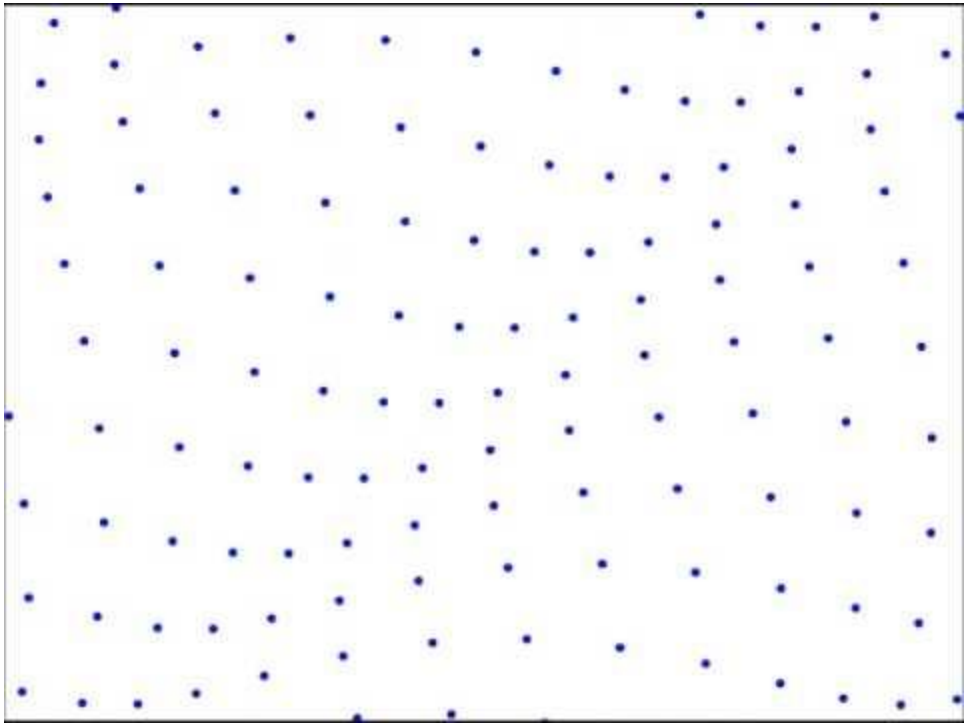


Contrast



Visual Processing

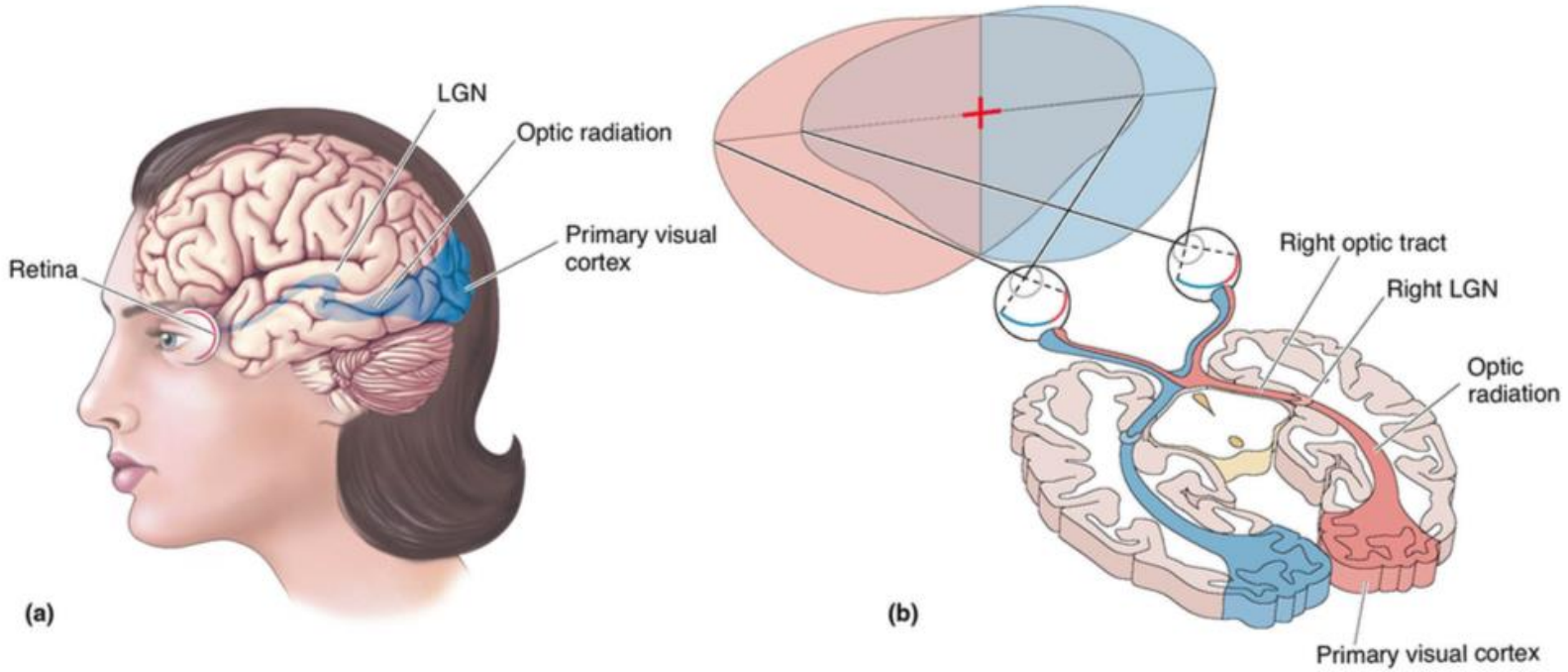
Motion



Visual Processing: Visual Neurons

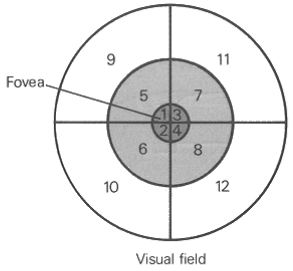
- Receptive Field
  - Orientation
  - Color
  - Motion

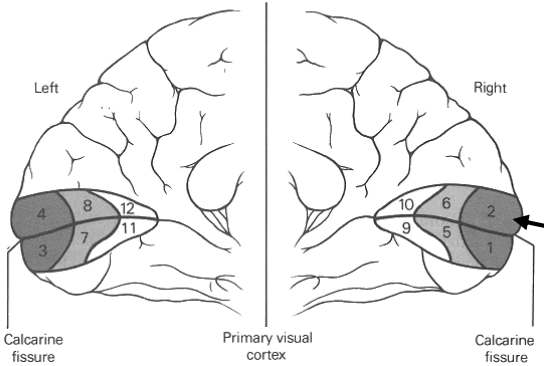
Visual Processing: The Visual Pathway



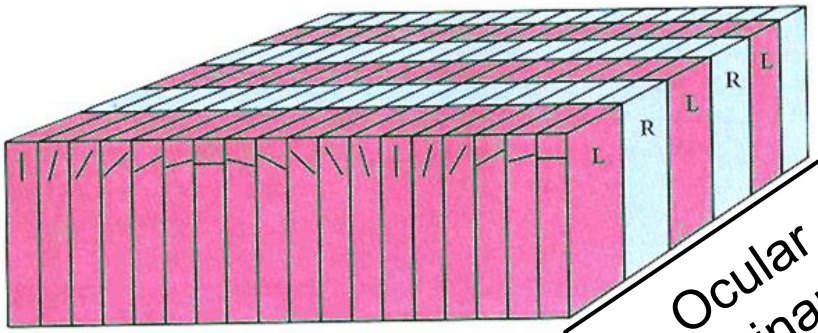
Visual Processing: Visual System Organization

Retinotopic Map





Cortical Magnification

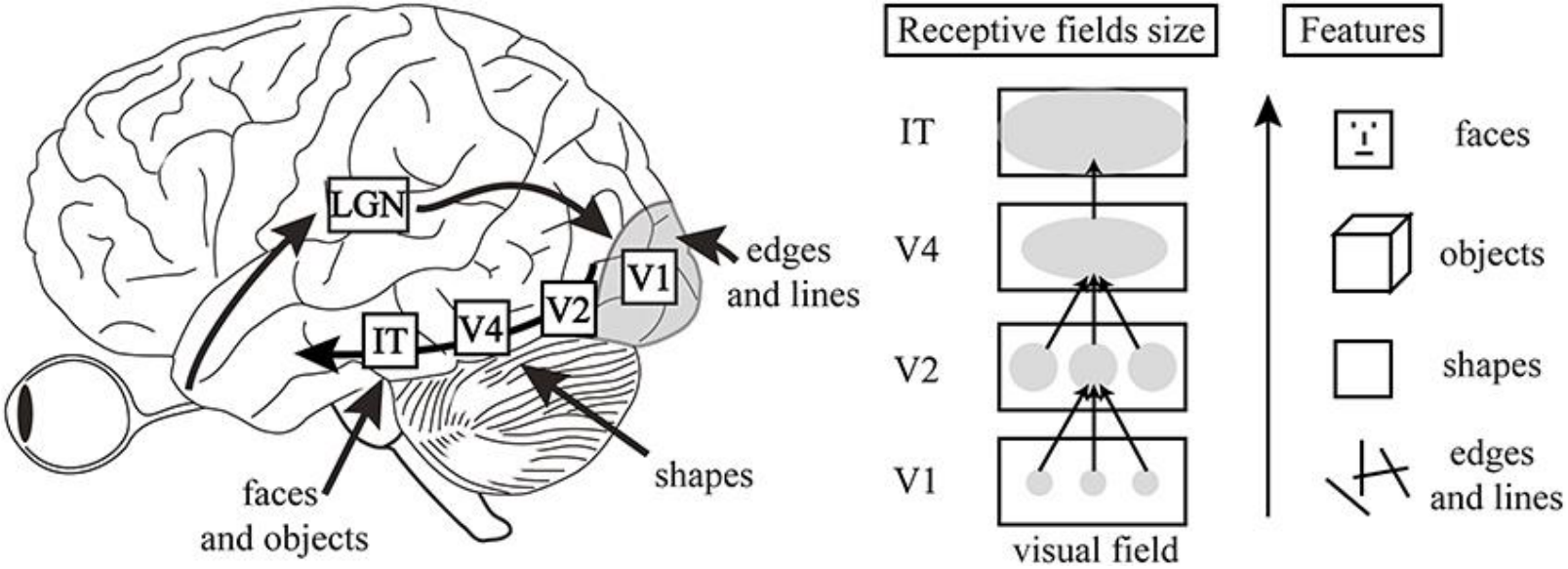


Orientation Columns

Ocular Dominance Columns

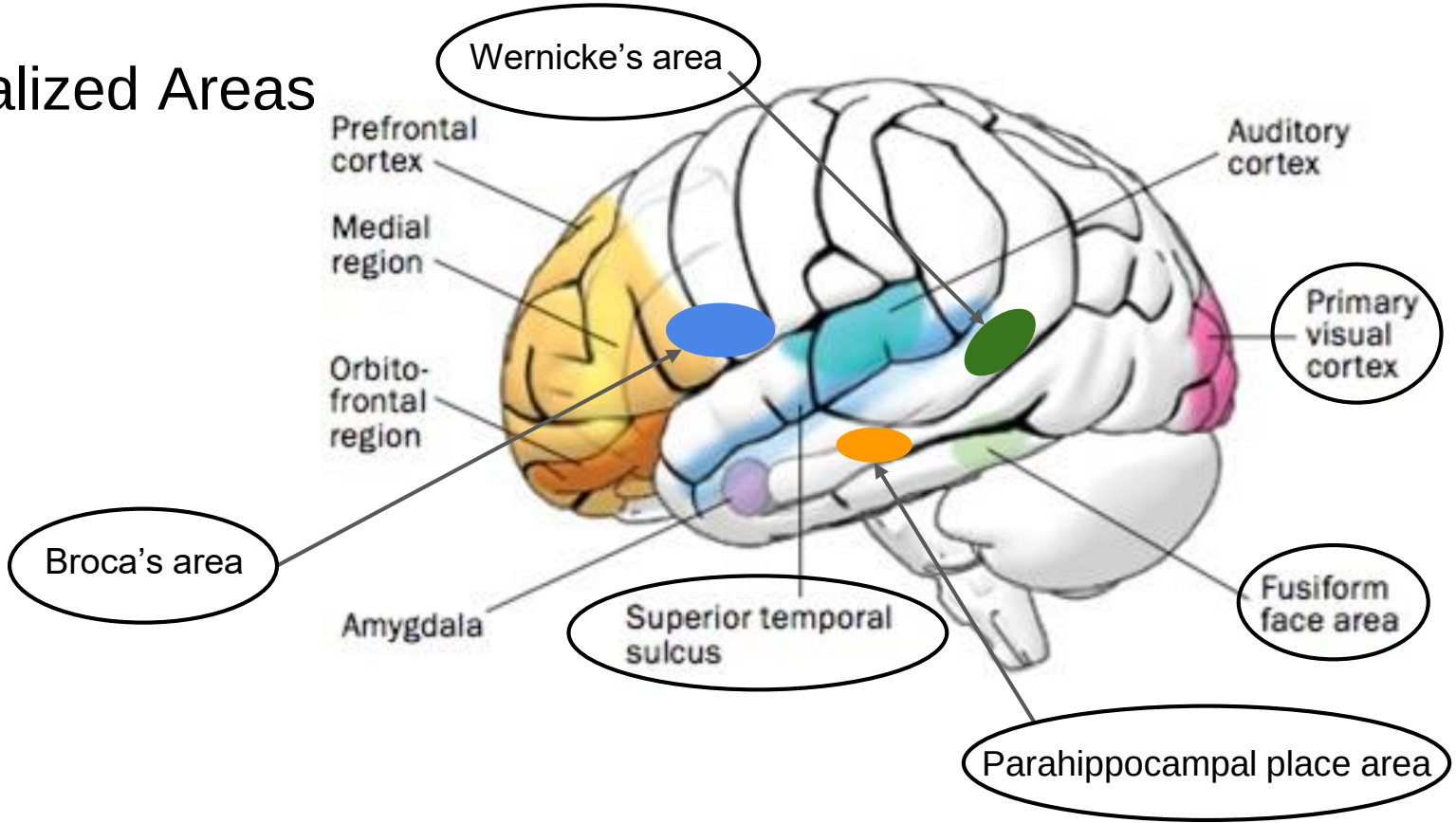
Visual Processing: Visual System Organization

- Hierarchical Organization



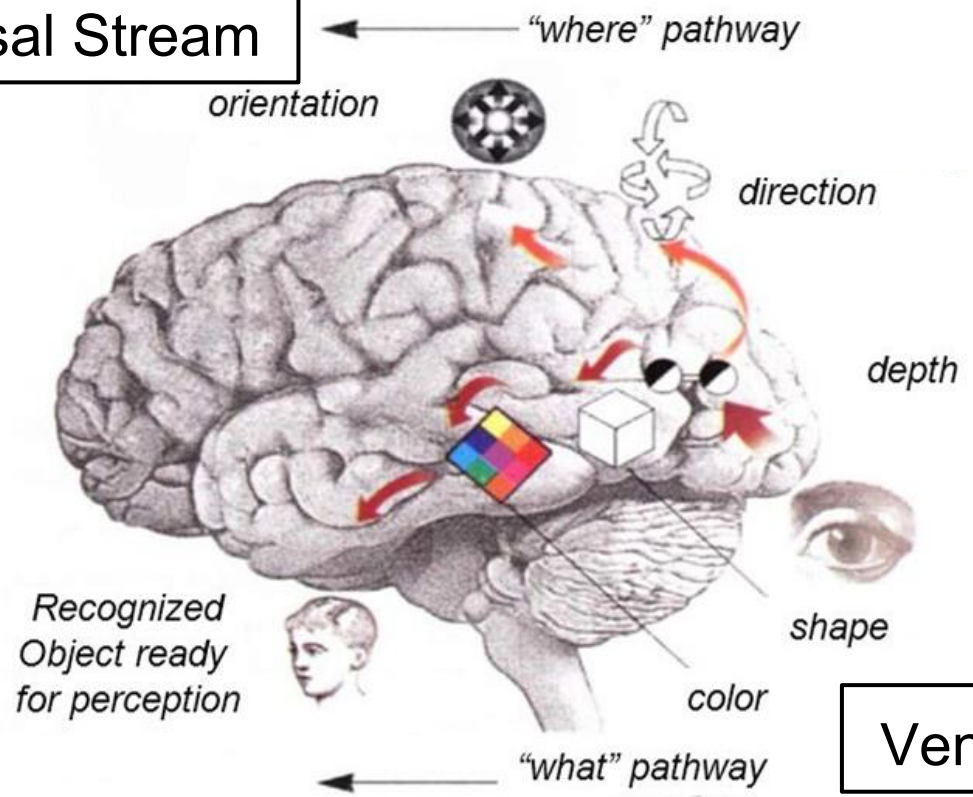
Visual Processing: Visual System Organization

- Specialized Areas



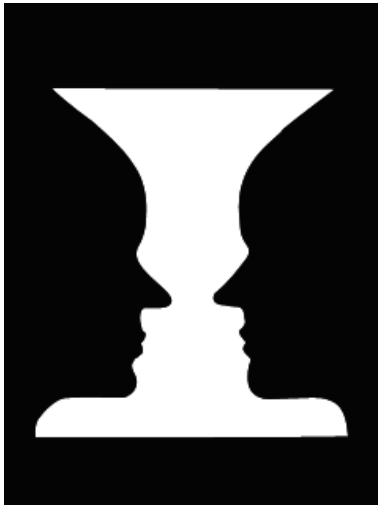
Visual Processing: Visual Pathways

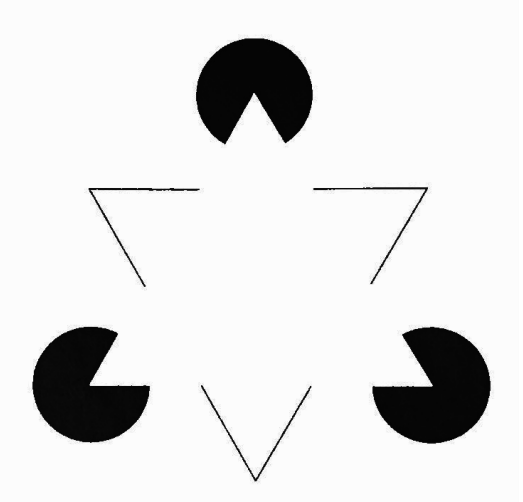
Dorsal Stream



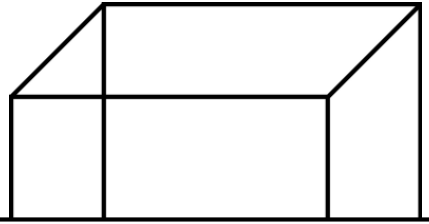
Ventral Stream

Visual Perception





- Gestalt psychology
- Visual illusions
  - Moving dot motion
  - Barber pole illusion



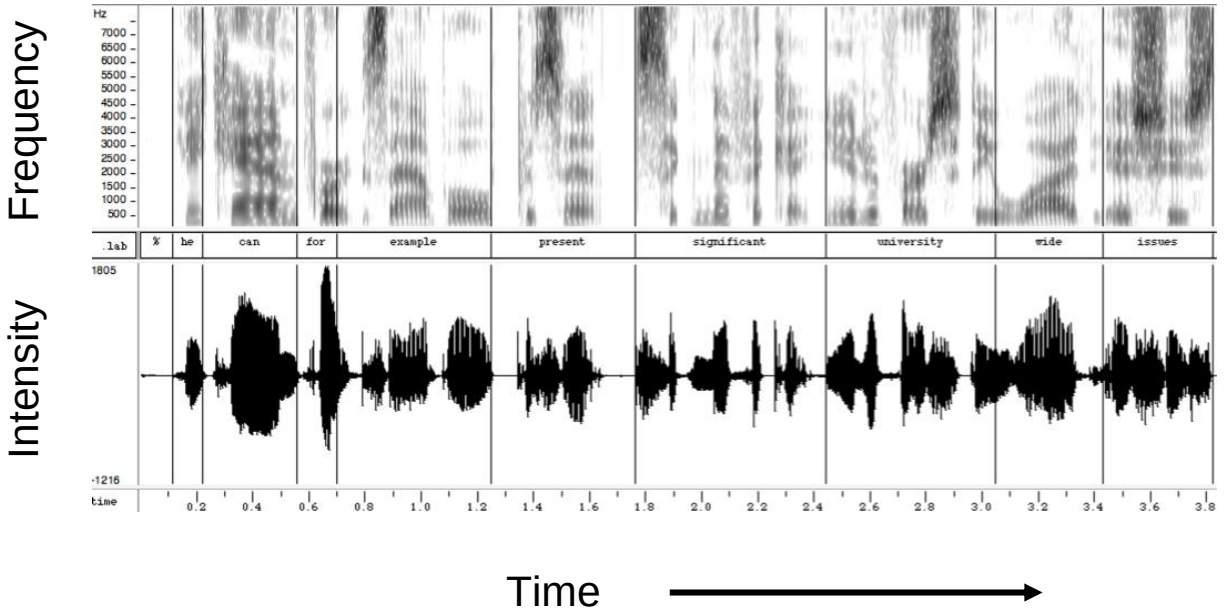
It deosn't mttaer in waht oredr the ltteers in a wrod are, the olny iprmoetnt tihng is taht the frist and lsat ltteer be at the rghit pclae. The rset can be a toatl mses and you can sitll raed it wouthit porbelm. Tihs is bcuseae the huamn mnid deos not raed ervey lteter by istlef, but the wrod as a wlohe.

Hearing

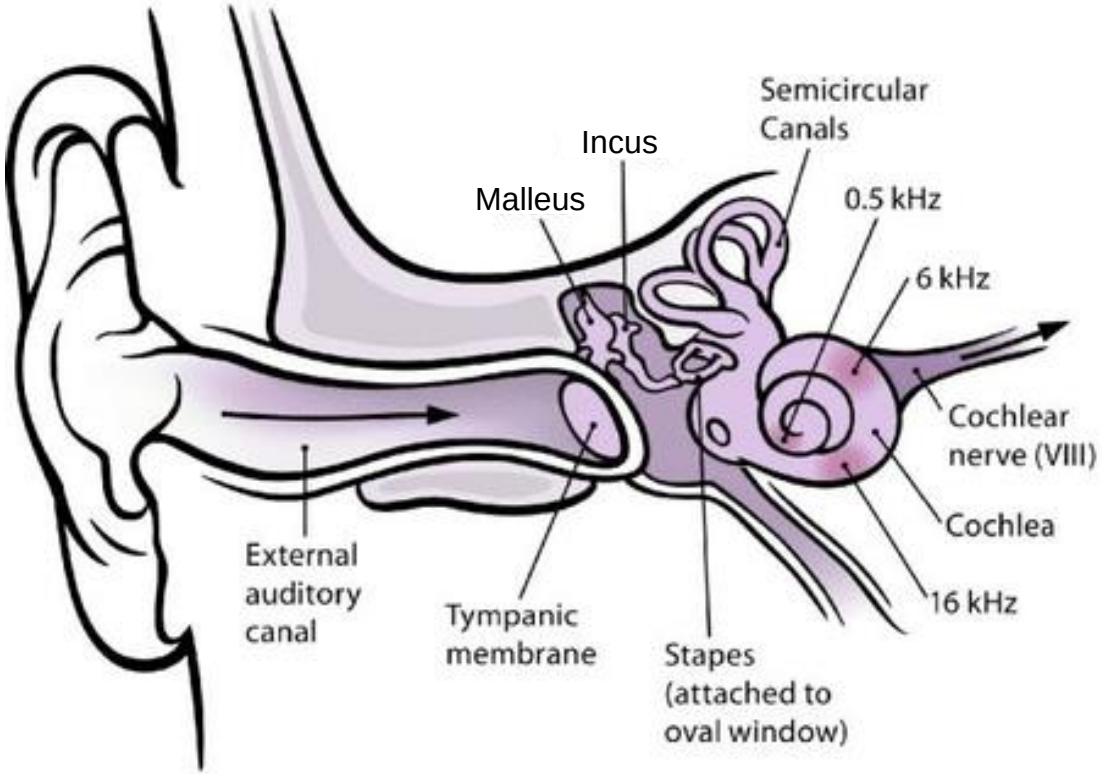
Auditory Input: Sound

Spectrogram

Waveform



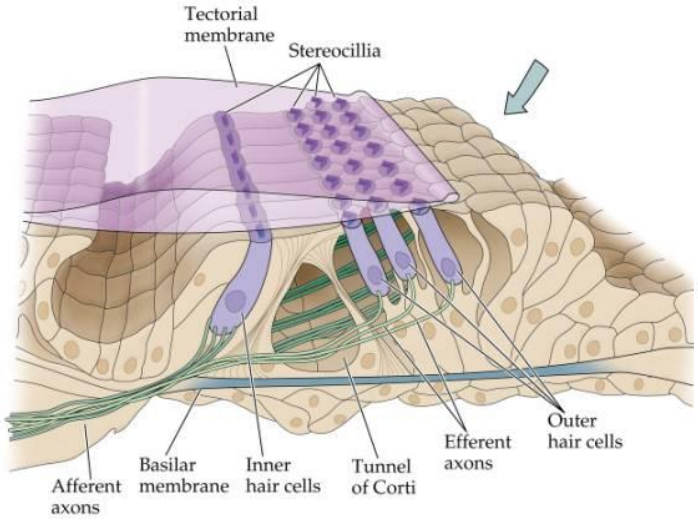
Auditory Sensory Transduction: The Ear

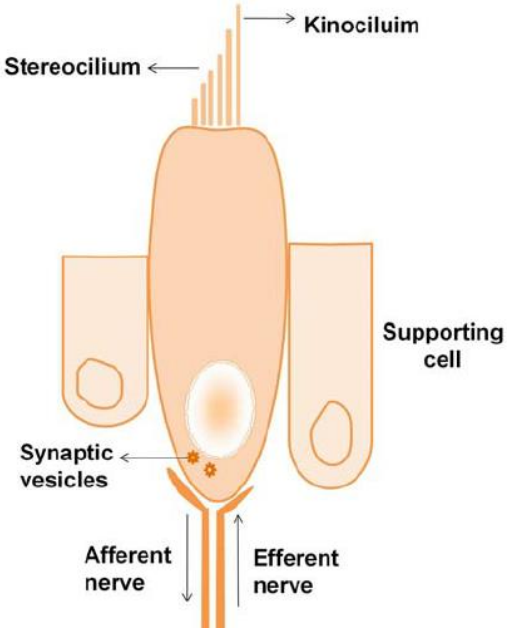


Mechanotransduction

- Pinna & ear canal
- Ear drum
- Ossicles
  - Malleus
  - Incus
  - Stapes

Auditory Sensory Transduction: The Cochlea

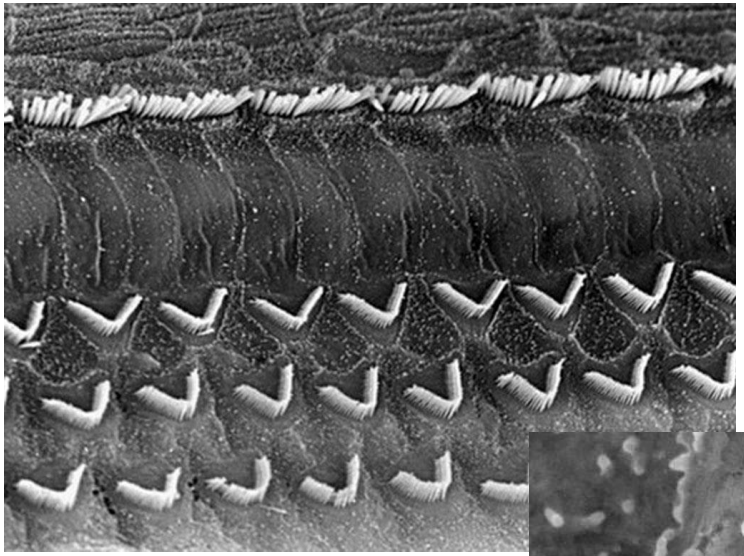


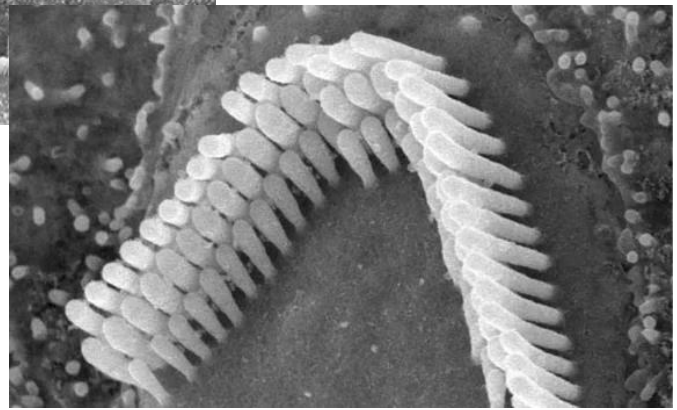


Mechanotransduction

- Basilar membrane
- Hair cells with stereocilia

Auditory Sensory Transduction: The Cochlea

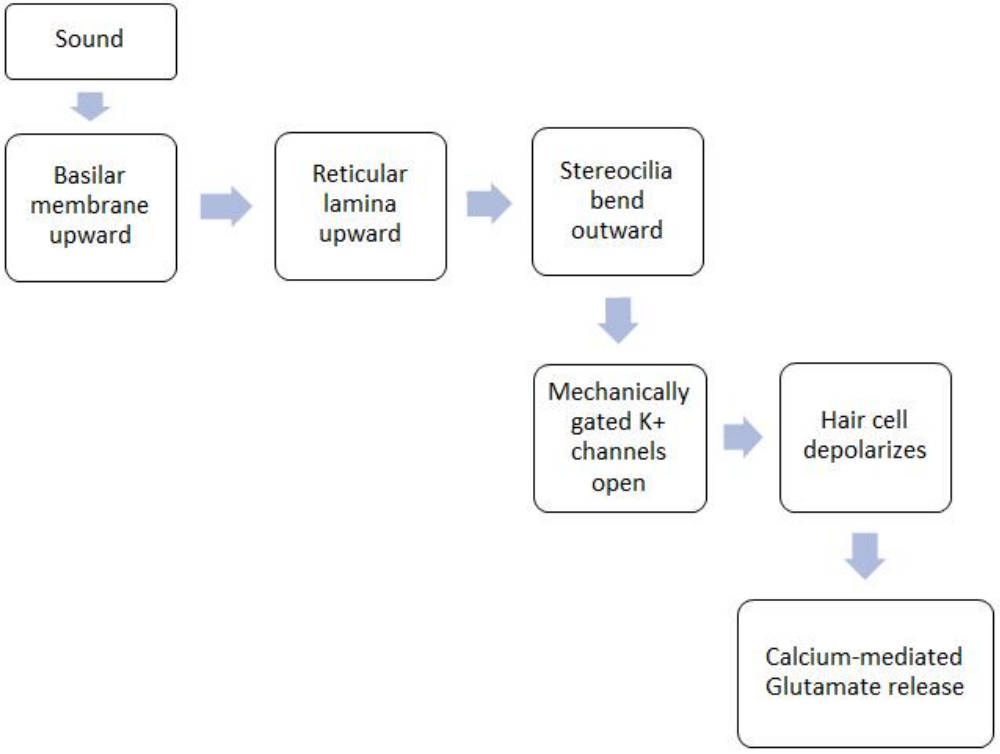


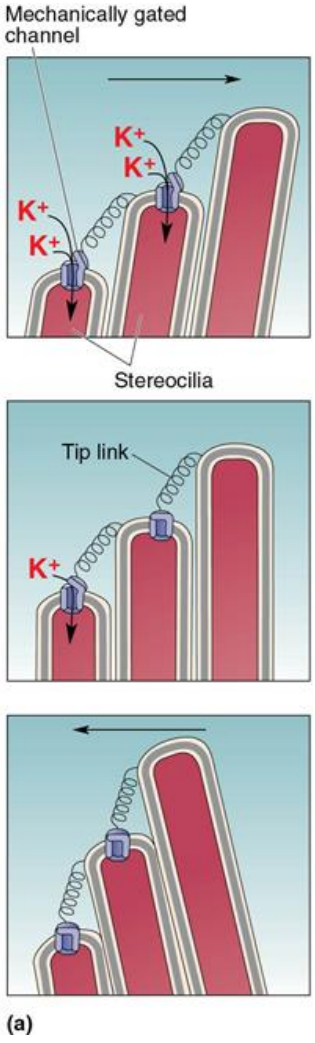


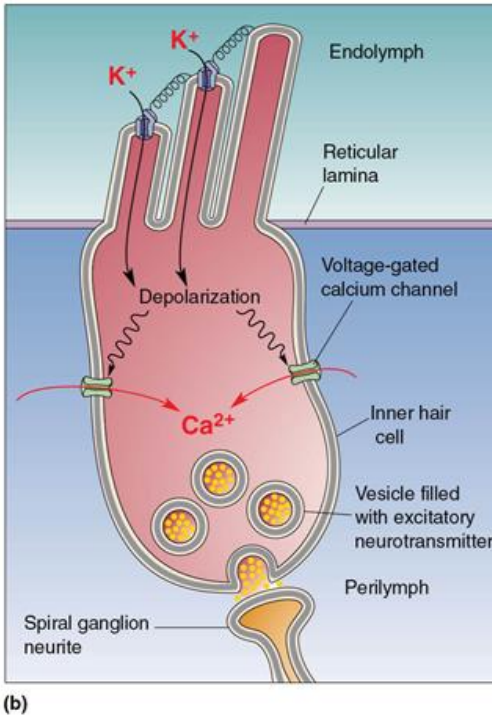
Mechanotransduction

- Basilar membrane
- Hair cells with stereocilia

Mechanotransduction by Hair Cells

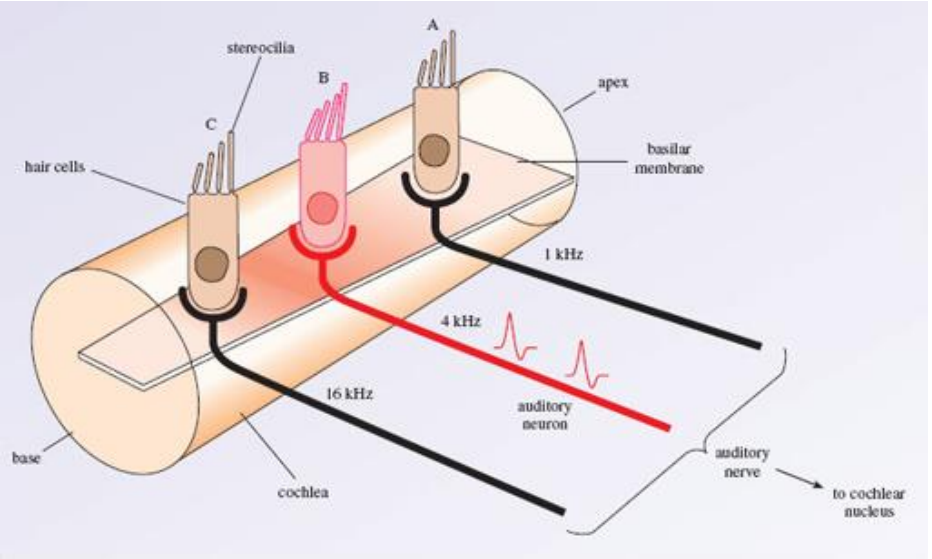




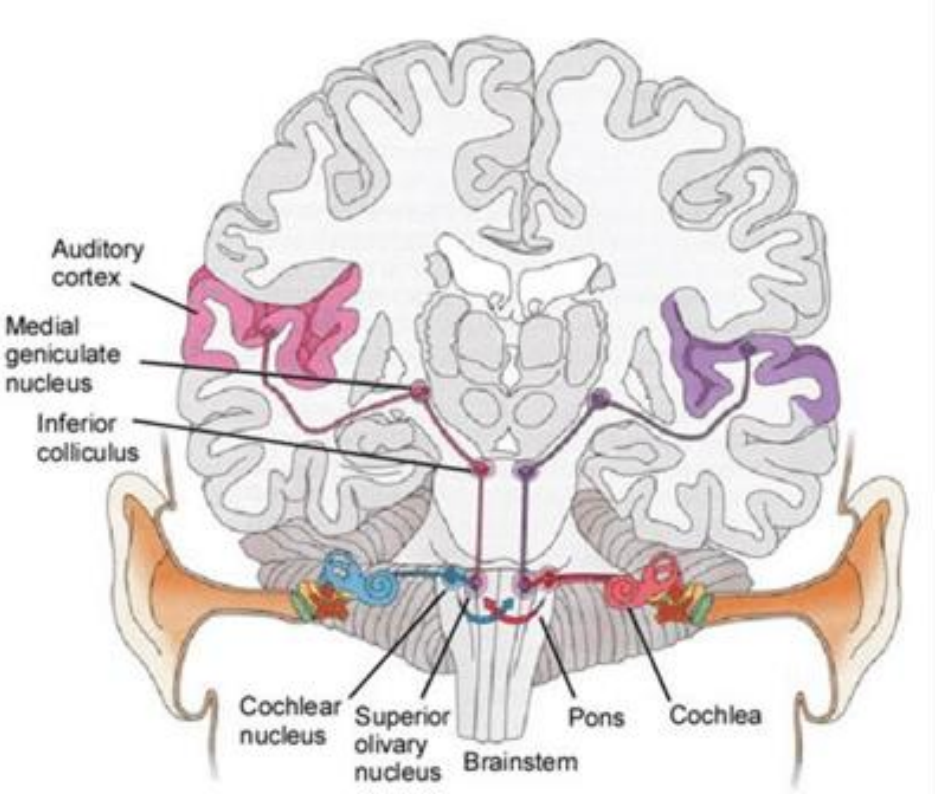


Auditory Processing: Auditory Neurons

- Receptive Field
  - Frequency
  - Intensity
  - Timing

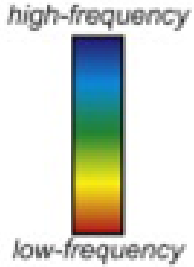


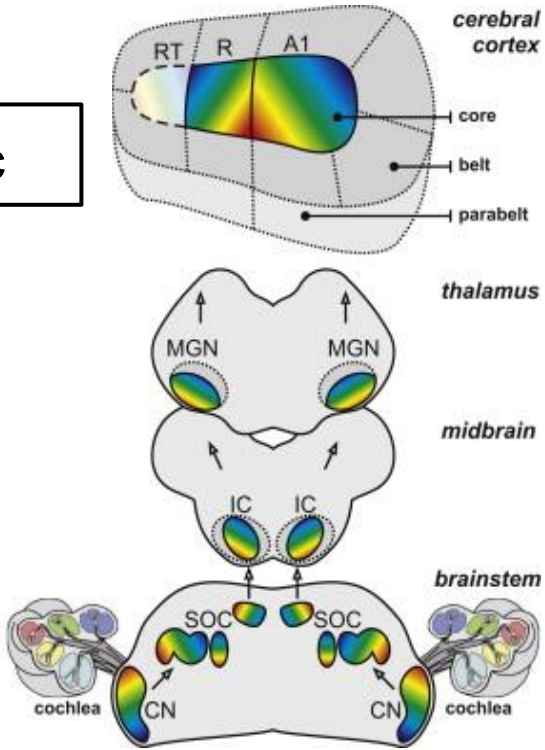
Auditory Processing: The Auditory Pathway

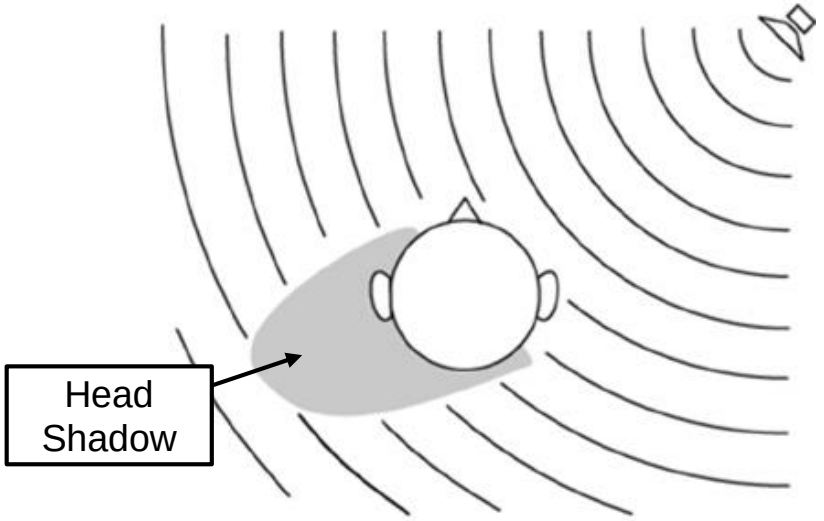


Auditory Processing: Auditory System Organization

Tonotopic



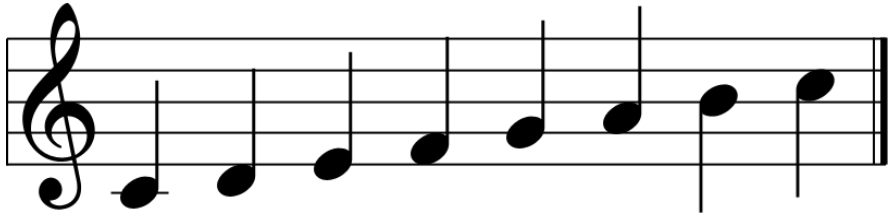




Monaural vs. Binaural Segregation

Auditory Perception

Pitch

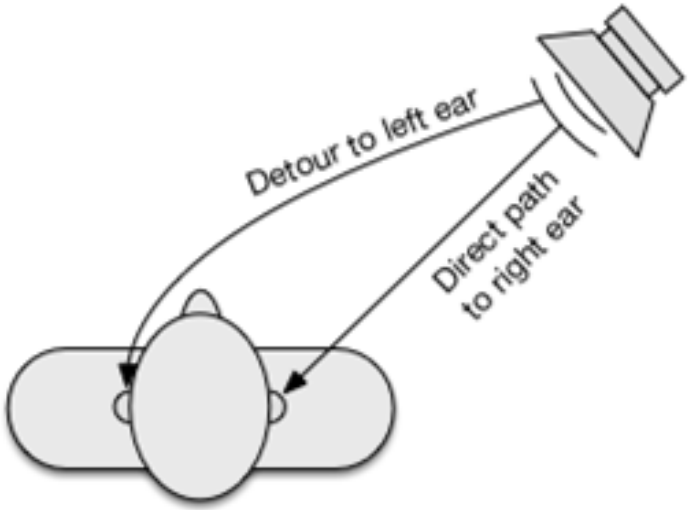


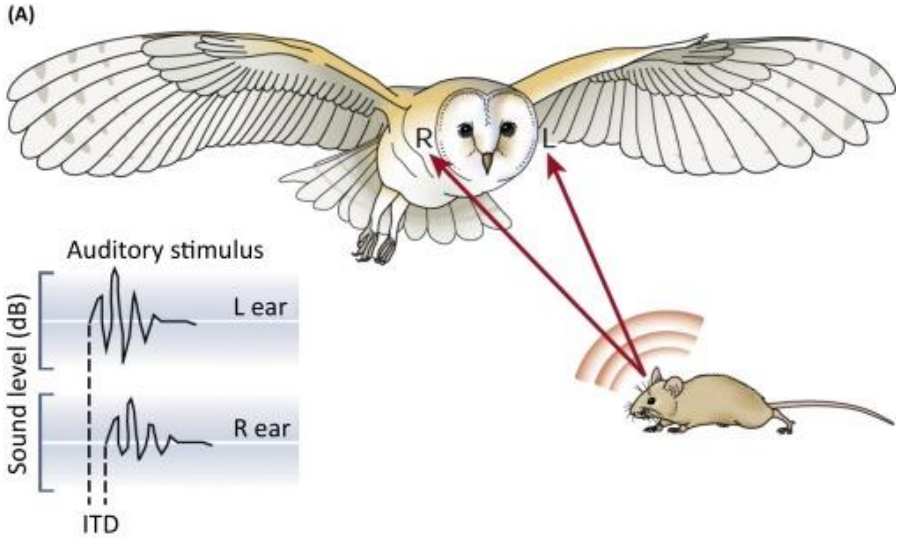
Timbre

Loudness

Auditory Perception

Sound Localization

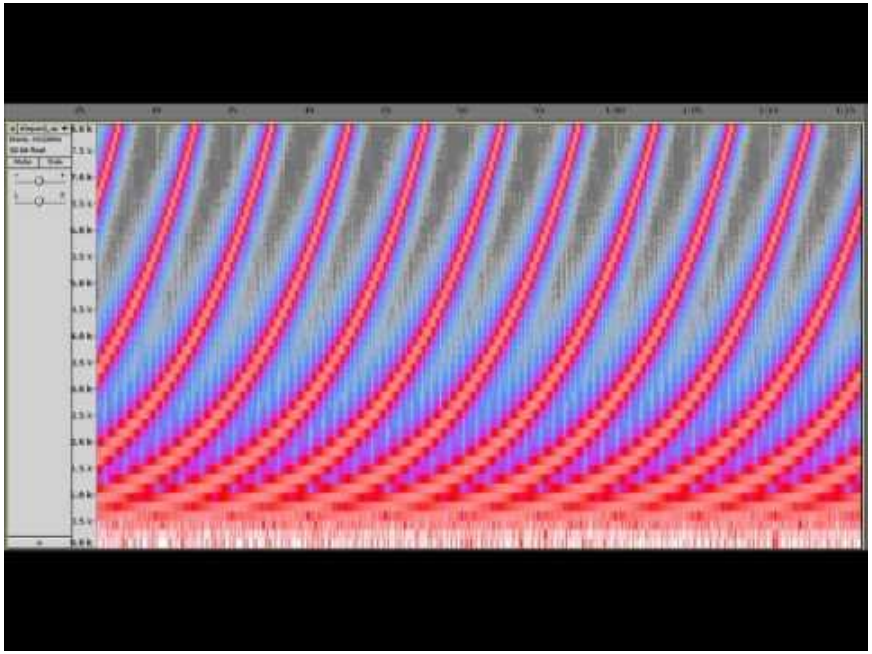




https://www.youtube.com/watch?v=dP15zlyra3c

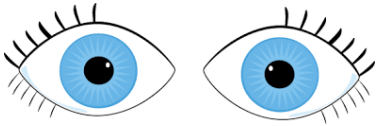
Auditory Perception

Shepard Tone

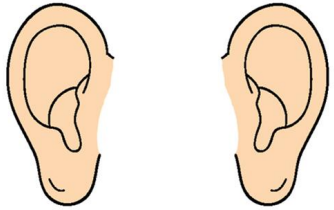


Jumbled Speech

Music

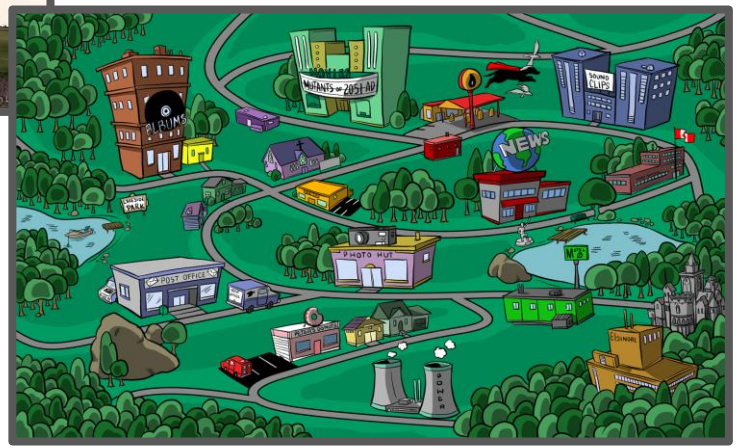


Vision vs. Hearing



Who	Facial recognition	Speech comprehension Sound discrimination
What	Object recognition Retinotopic map	Object recognition Tonotopic map
Where	**Spatial location** Retinotopic map	Spatial location Interaural timing/intensity differences
When	Temporal resolution	**Temporal resolution**

Sensory Systems and Beyond

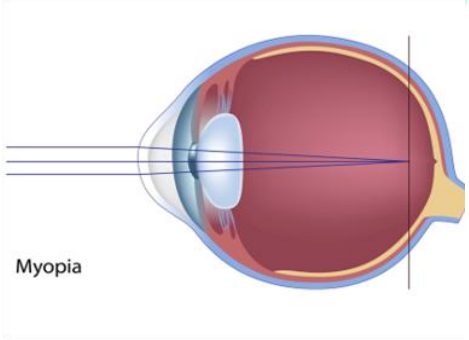


When Inputs Decline

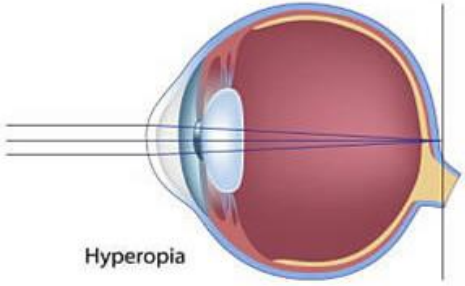
Vision Loss: Peripheral Mechanisms

Normal Vision

Myopia



Hyperopia

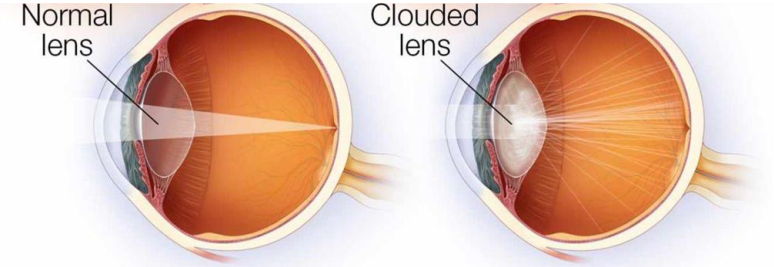


Vision Loss: Peripheral Mechanisms

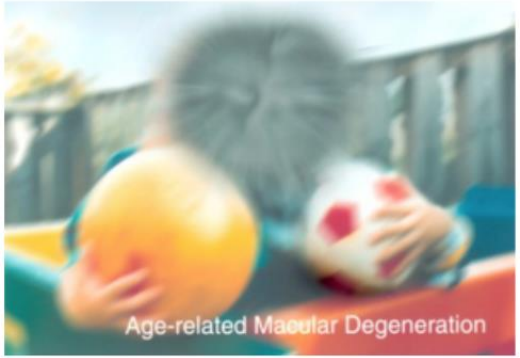
Normal Vision

Cataracts

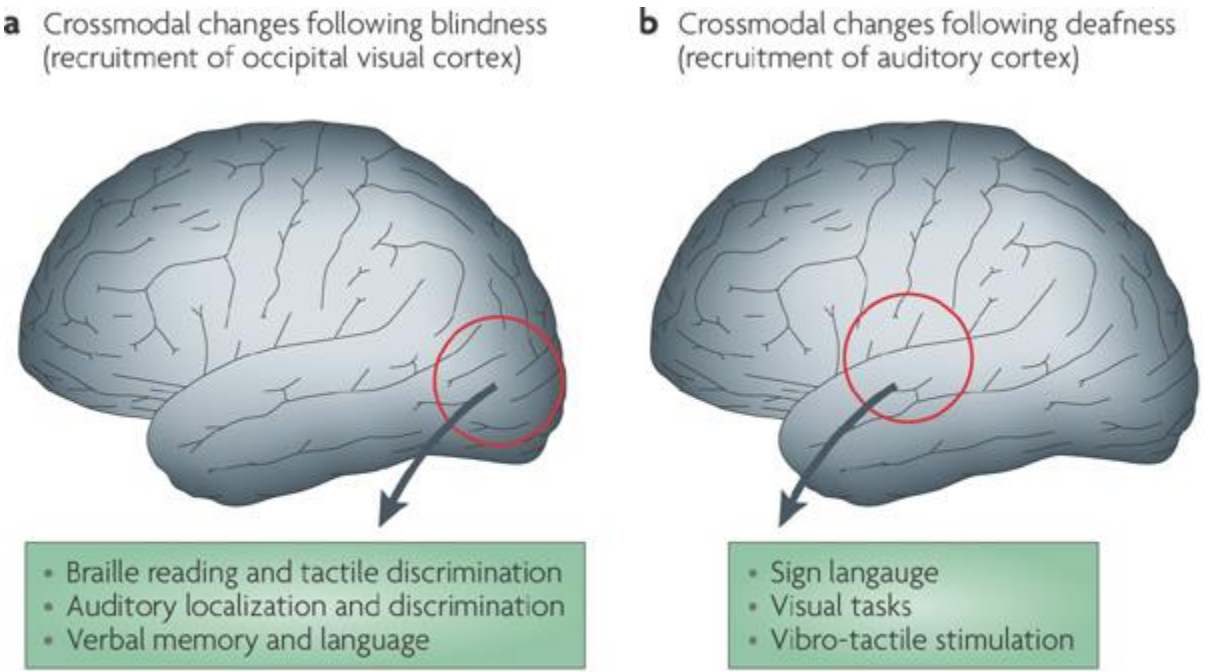
Glaucoma



Macular Degeneration

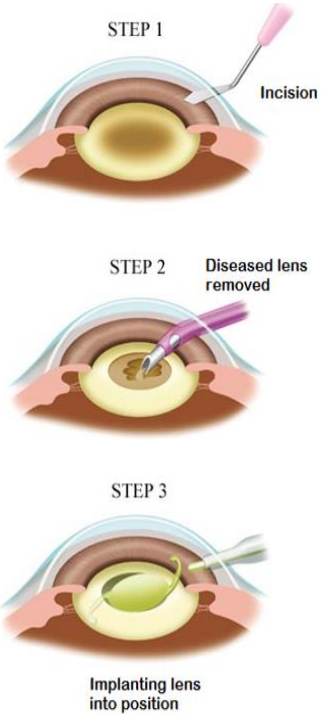


Vision Loss: Central Consequences



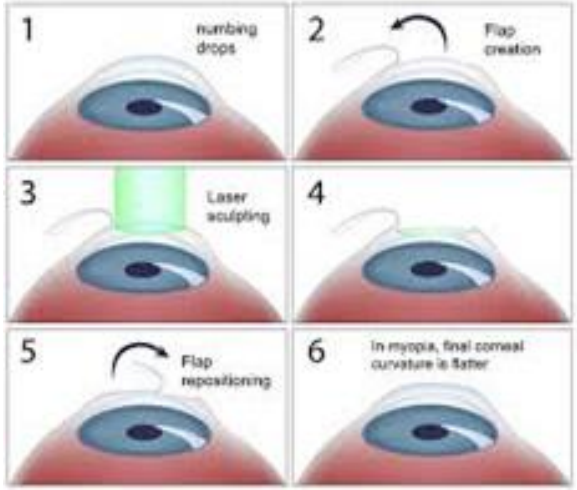
Vision Loss: Treatments

Cataract Removal



Corrective Lenses

Lasik Surgery



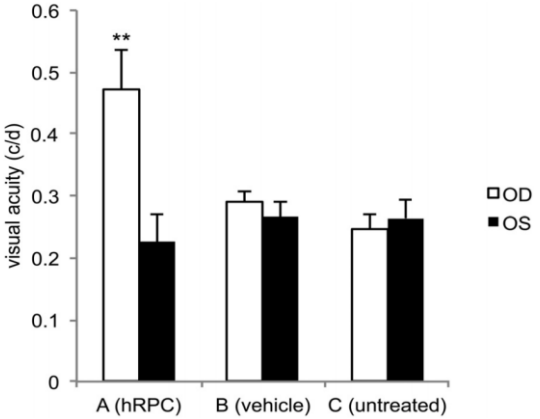
Drug and Regeneration Therapeutics

Sarah’s Research: Blast-Induced Vision Loss

- Between 2000-2010, almost 200,000 eye injuries occurred in military populations following blast exposure
- Up to 40% of monocular blindness is due to ocular trauma
- Our lab models blast-induced vision loss

Tree shrews to study ocular blast injury

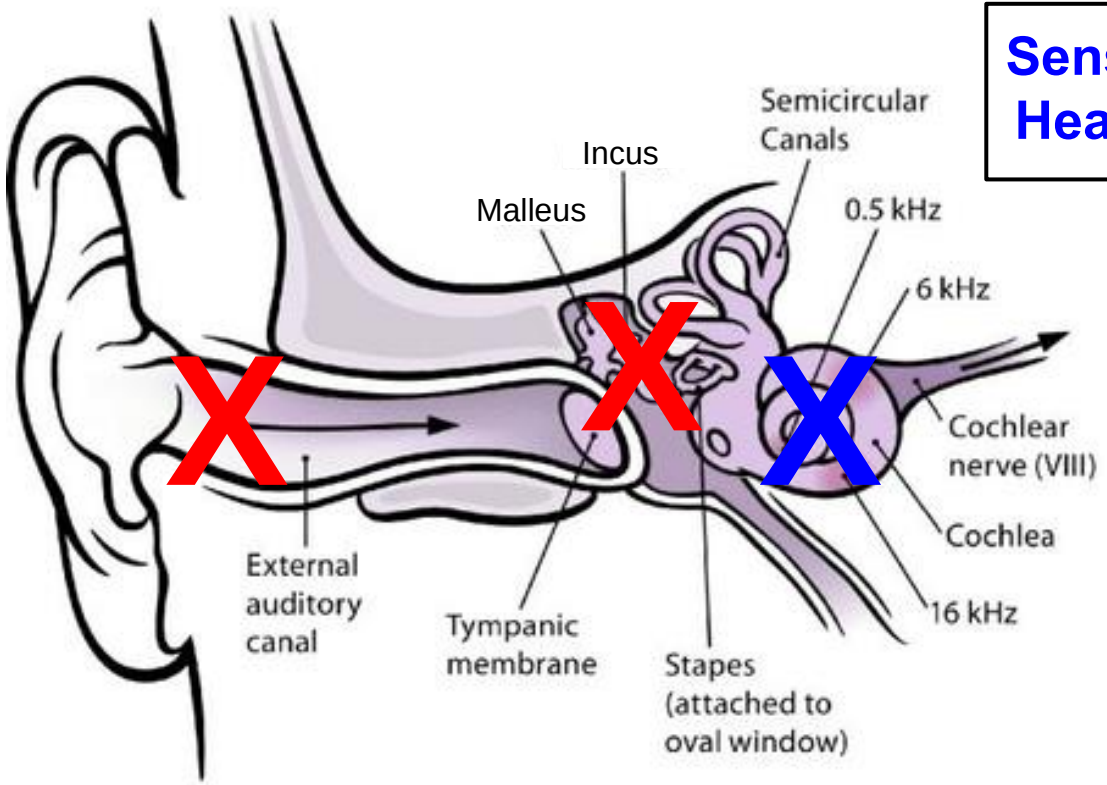
- Tree shrews have eyes that are very similar to humans!
- Repeat blast injury → regeneration of injury ganglion cells



Types of Hearing Loss

Conductive Hearing Loss

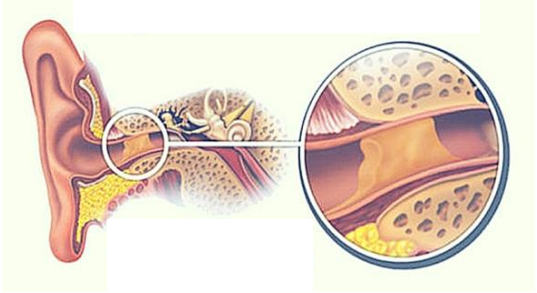
Sensorineural Hearing Loss

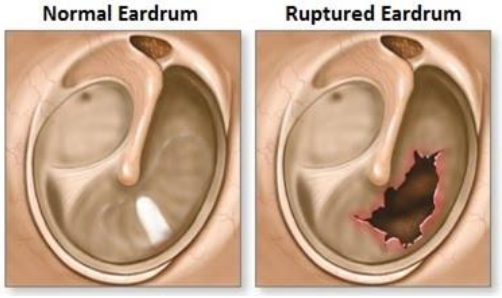


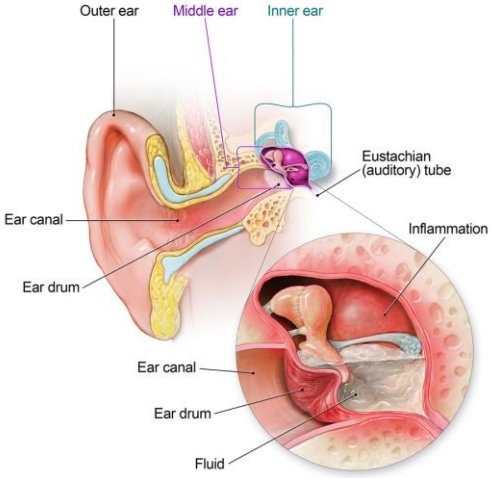
Hearing Loss: Peripheral Mechanisms

Conductive Hearing Loss

- Cerumen impaction
- Eardrum perforation
- Ear infection
- Cholesteatoma
- Otosclerosis



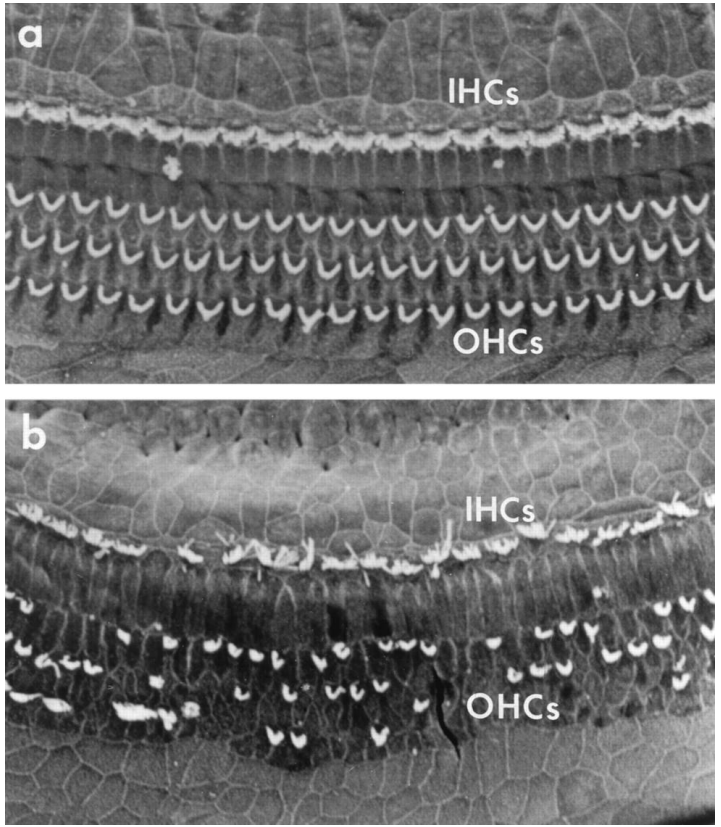




Hearing Loss: Peripheral Mechanisms

Sensorineural Hearing Loss

- Noise exposure
- Aging



Jane’s Research: Noise-Induced Hearing Loss

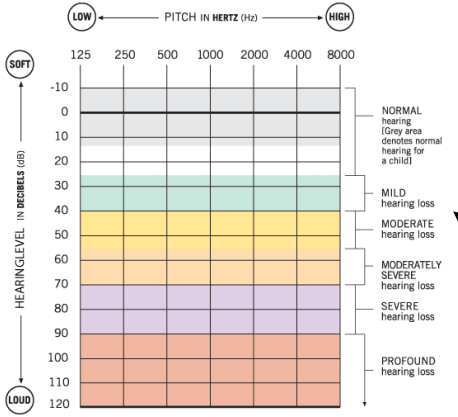
- High prevalence, especially among veterans
  - 1 in 6 U.S. adults have hearing loss
  - Tinnitus and hearing loss are #1 and #2 disabilities seen in the VA

- Most common complaint: difficulty hearing in noisy environments

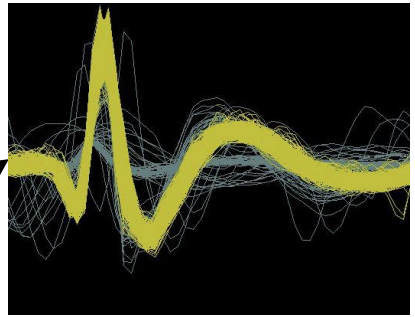
- Sensorineural hearing loss
  - Preceded by inner hair cell synapse loss (**synaptopathy** or “hidden hearing loss”)

Nonhuman Primate Model

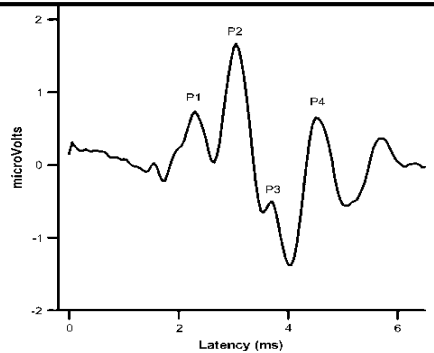
Behavioral Hearing Tests



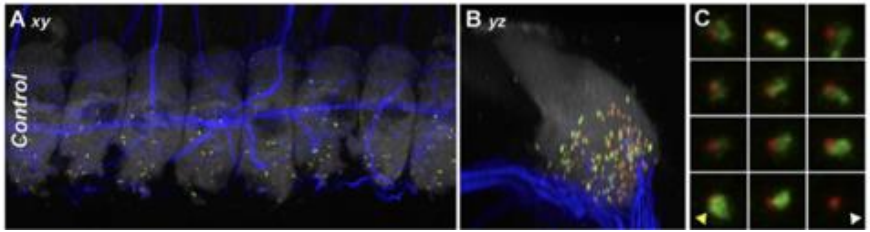
Invasive Brain Recordings



Clinical Objective Testing (Electrophysiology)

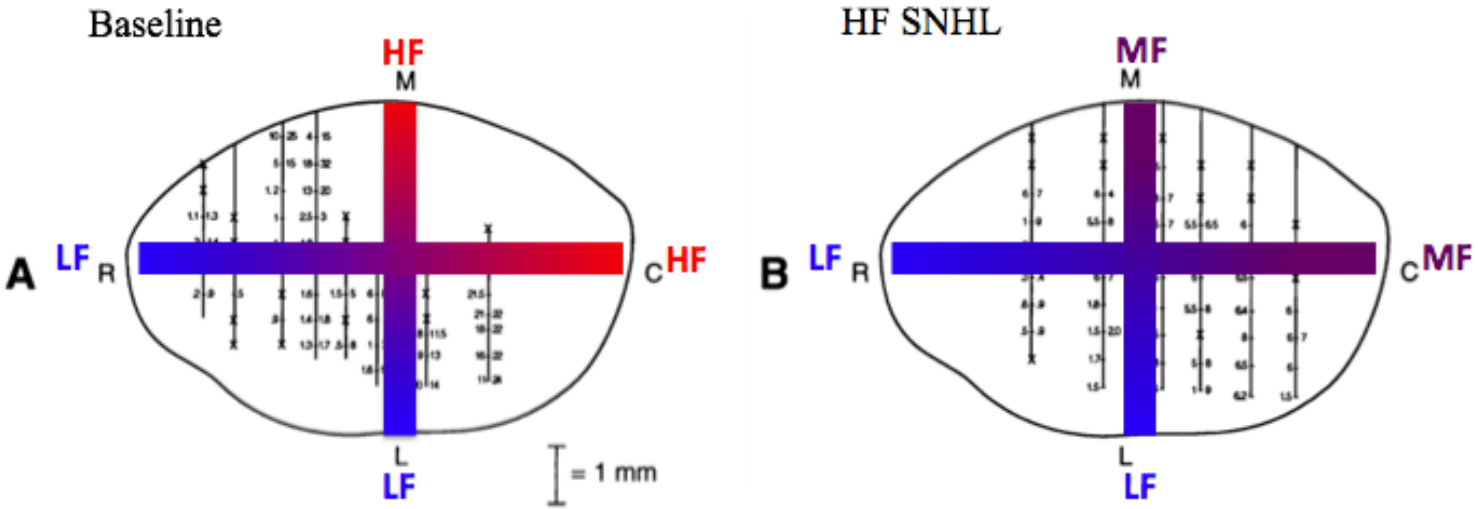


Anatomy of the Cochlea and the Brain

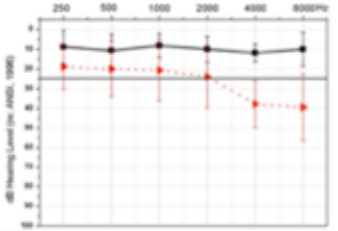


Hearing Loss: Central Consequences

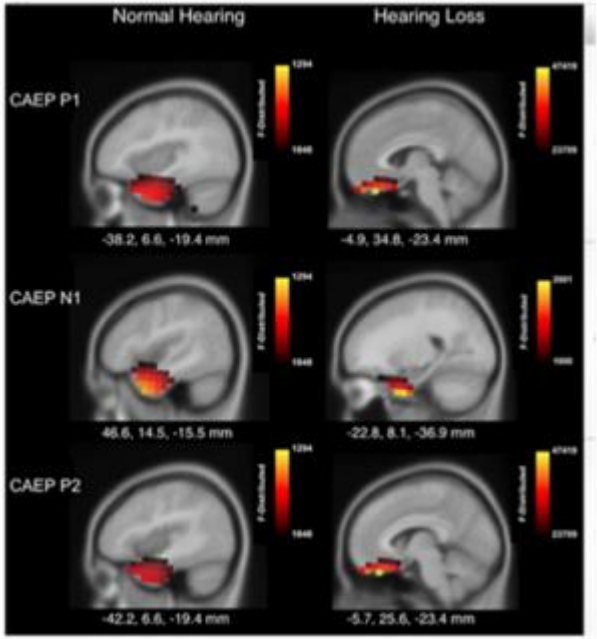
Tonotopic Reorganization



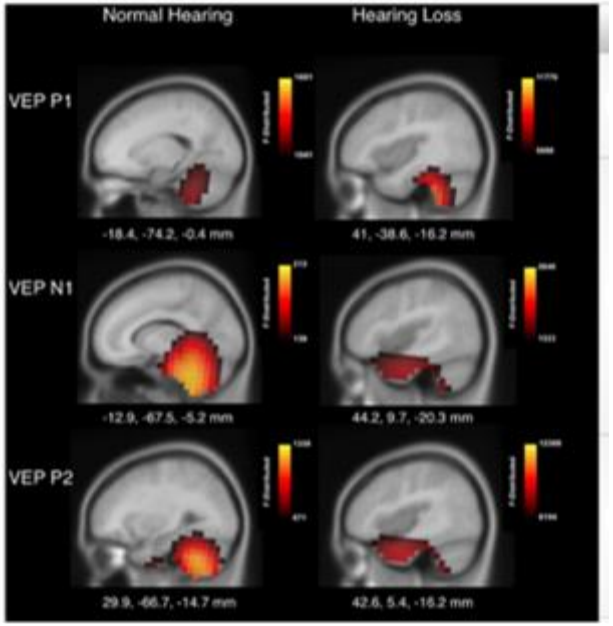
Hearing Loss: Central Consequences



Auditory Evoked Potentials



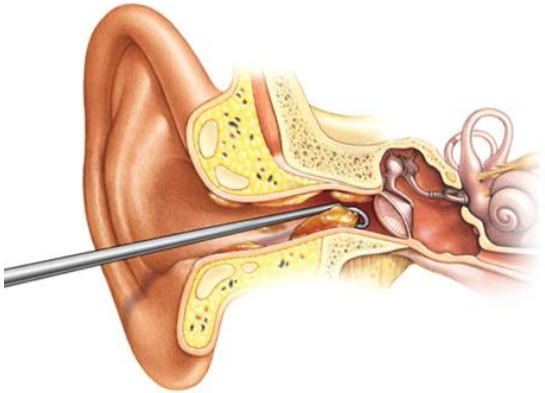
Visual Evoked Potentials



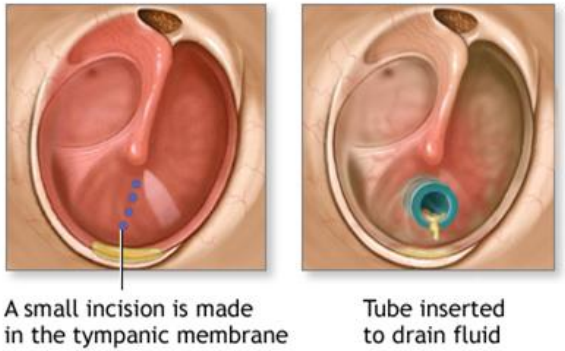
Crossmodal Reorganization

Hearing Loss: Treatments

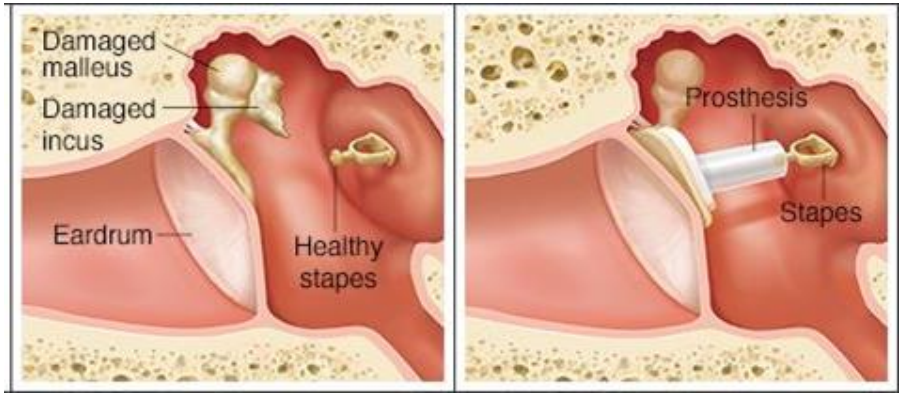
Cerumen Removal



P.E. Tubes



Surgery



Hearing Loss: Treatments

Hearing Aids

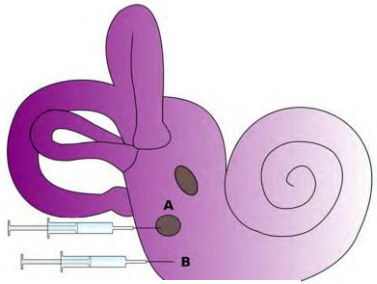
Remote Microphones

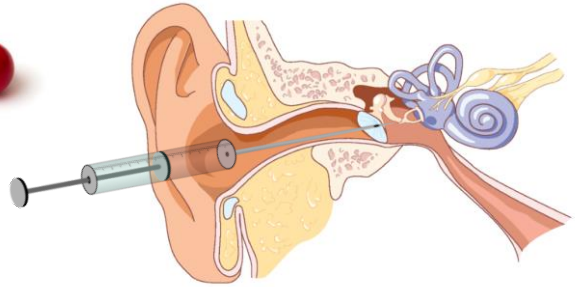
Hearing Loss: Treatments

Cochlear Implants

Hearing Loss: Treatments

Drug and Regeneration Therapeutics

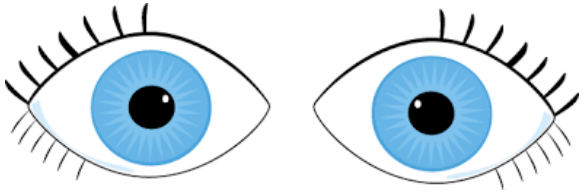




Aural Rehabilitation

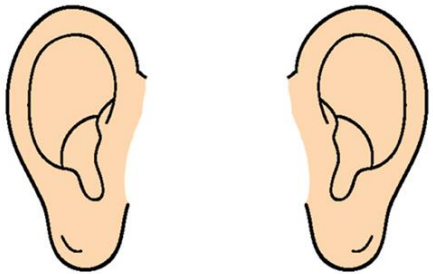
ClinicalTrials.gov
A service of the U.S. National Institutes of Health
Developed by the National Library of Medicine

Take Home Message



- Hearing and vision are special senses that allow us to communicate and perceive our environment

- Damage to the eyes or ears leads to changes in the brain



- Treatments for vision and hearing loss are on the horizon

Questions?

VANDERBILT

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