Νευροφυσιολογία και Αισθήσεις

Διάλεξη 8

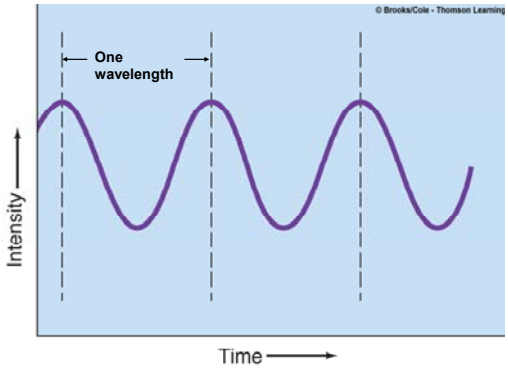
The Eye (Το Μάτι)

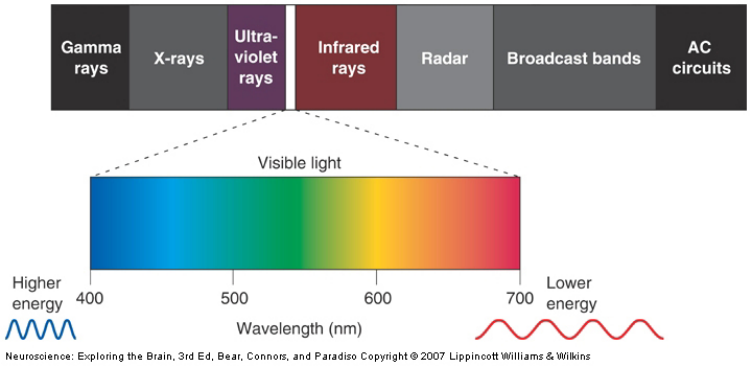
Introduction

- **Sensation ≠ Perception**
- **Perception**
  - Our understanding (conscious interpretation) of the physical world
  - An interpretation of the senses
  - Different from what is out there because
    - Our receptors detect limited number of existing energy forms
    - The information does not reach our brain unaltered. Some features are accentuated and some are suppressed
    - The brain interprets the information and often distorts it ("completes the picture" or "feels in the gaps") to extract conclusions.
    - Interpretation is affected by cultural, social and personal experiences stored in our memory

Properties of Light

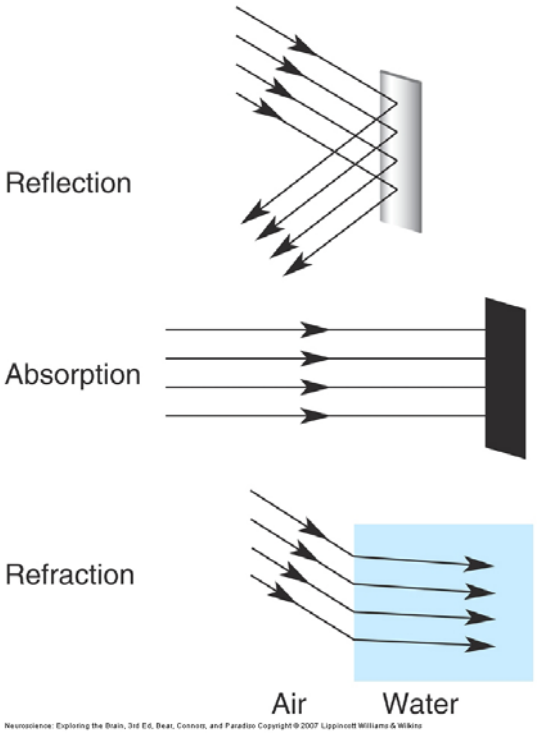
- **Light**
  - Wavelength (distance between two peaks of the electromagnetic wave) → color
  - Intensity
  - Photoreceptors perceive only a small range → visible light
  - Hot colors: Orange, red
  - Cool colors: blue, violet





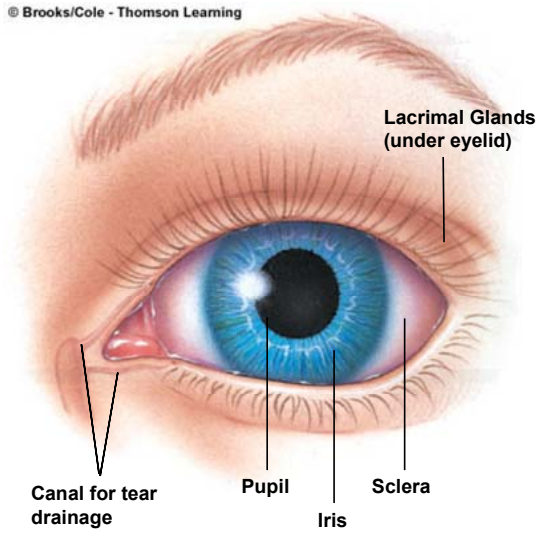
Properties of Light

- **Optics**
  - Study of light rays and their interactions
    - Reflection
      - Bouncing of light rays off a surface
    - Absorption
      - Transfer of light energy to a particle or surface
    - Refraction
      - Bending of light rays from one medium to another



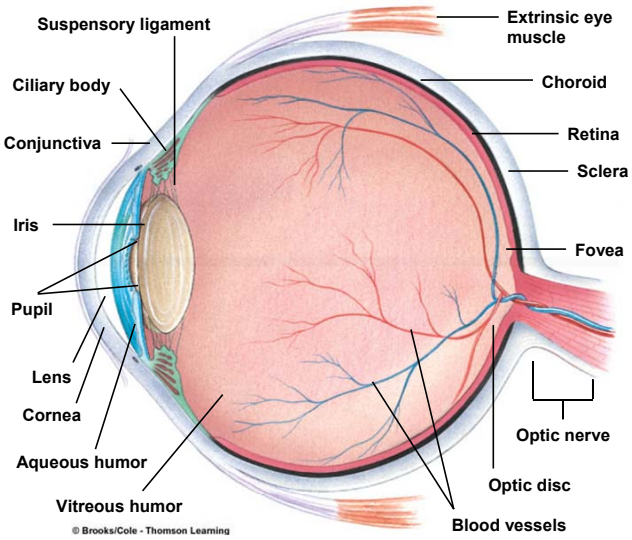
The Eye

- **Sensory organ for vision**
- **Mechanisms that help protect eyes from injury**
  - Eyeball is sheltered by bony socket in which it is positioned
  - Eyelids
    - Act like shutters to protect eye from environmental hazards
  - Eyelashes
    - Trap fine, airborne debris such as dust before it can fall into eye
  - Tears
    - Continuously produced by lacrimal glands
    - Lubricate, cleanse, bactericidal



The Eye

- **Cross-Sectional Anatomy of the Eye**
  - Spherical, fluid-filled structure enclosed by three tissue layers
  - Sclera/cornea
    - Sclera – tough outer layer of connective tissue; forms visible white part of the eye
    - Cornea – anterior, transparent outer layer through which light rays pass into interior of eye
  - Choroid/ciliary body/iris
    - Choroid - middle layer underneath sclera which contains blood vessels that nourish retina
    - Choroid layer is specialized anteriorly to form ciliary body and iris
  - Retina
    - Innermost coat under choroid
    - Consists of outer pigmented layer and inner nervous-tissue layer
      - Rods and cones



The Eye

- **Ophthalmoscopic Appearance of the Eye**

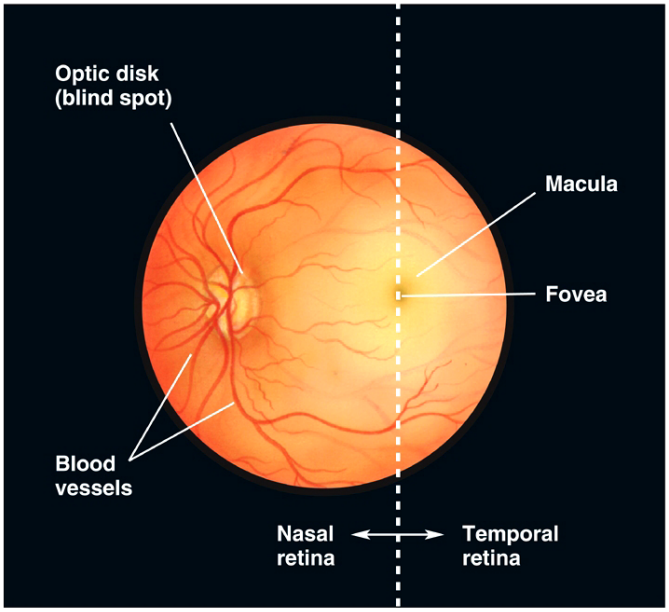
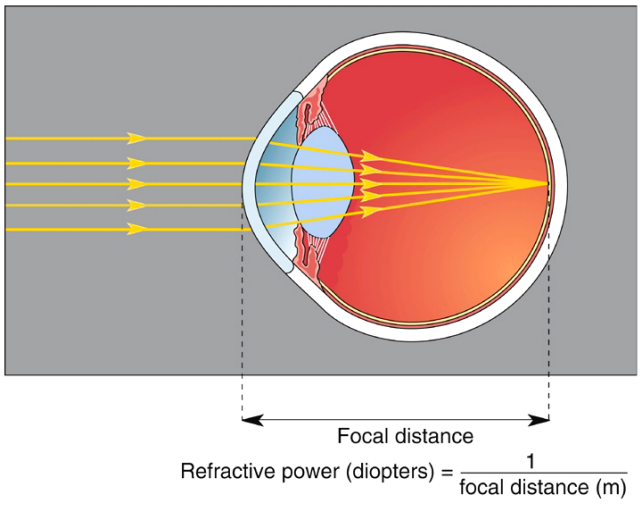


Image Formation by the Eye

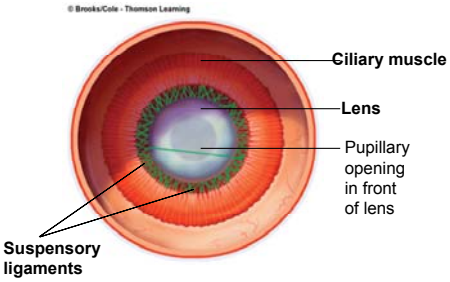
- **Introduction**
  - Eye collects light, focuses on retina, forms images
- **Refraction of light by the cornea**
  - Major element
- **Refraction of light by lens**

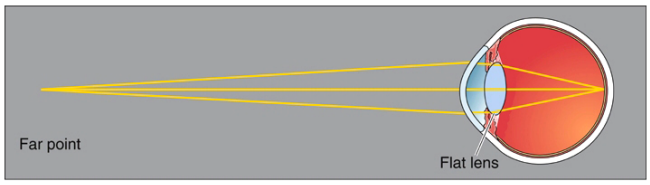


$$\text{Refractive power (diopters)} = \frac{1}{\text{focal distance (m)}}$$

Image Formation by the Eye

- **Accommodation by the Lens**
  - Change in strength and shape of lens
  - Accomplished by action of ciliary muscle and suspensory ligaments
  - Age-related reduction in accommodation ability - presbyopia





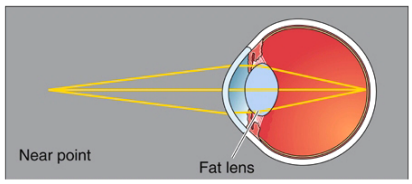


Image Formation by the Eye

- **Iris**
  - Controls
    - Amount of light entering eye
    - Depth of focus (↓ diam → ↑depth of focus)
  - Contains two sets of smooth muscle networks
    - Circular (or constrictor) muscle
    - Radial (or dilator) muscle
  - Pigment in iris is responsible for eye color
  - Unique for each individual
  - Basis for latest identification technology
- **Pupillary light reflex**
  - Consensual

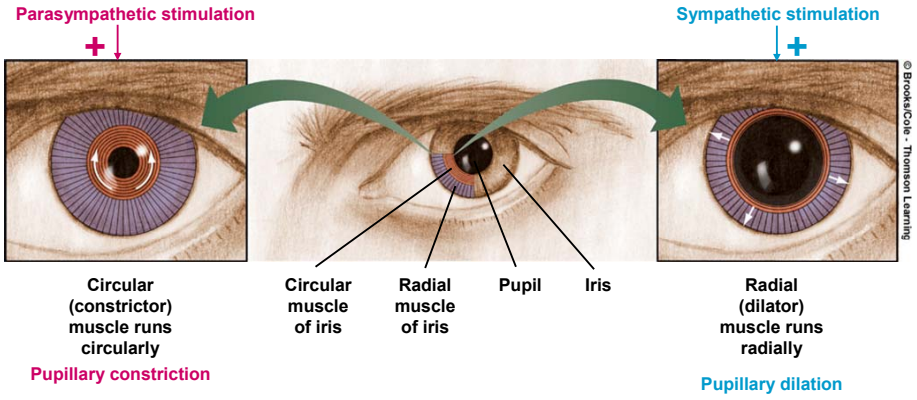
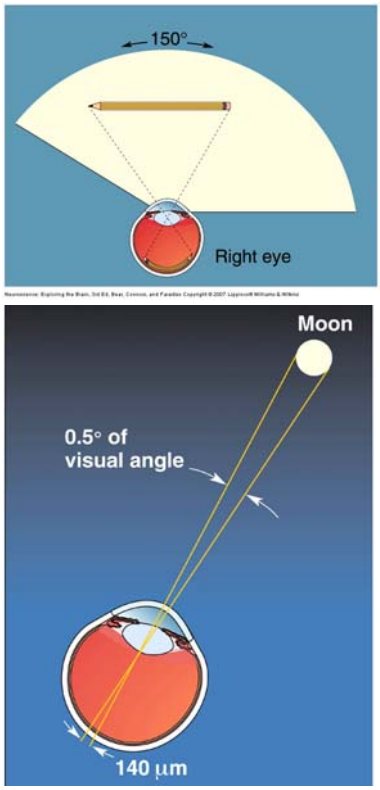


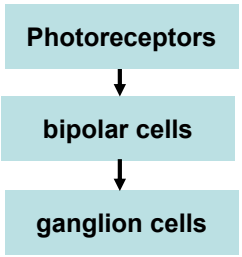
Image Formation by the Eye

- **The Visual Field**
  - Amount of space viewed by the retina when the eye is fixated straight ahead
- **Visual Acuity**
  - Ability to distinguish two nearby points
  - Visual Angle: Distances across the retina described in degrees
  - 20/20 vision
    - Can recognize a letter 0.083º at 20 ft

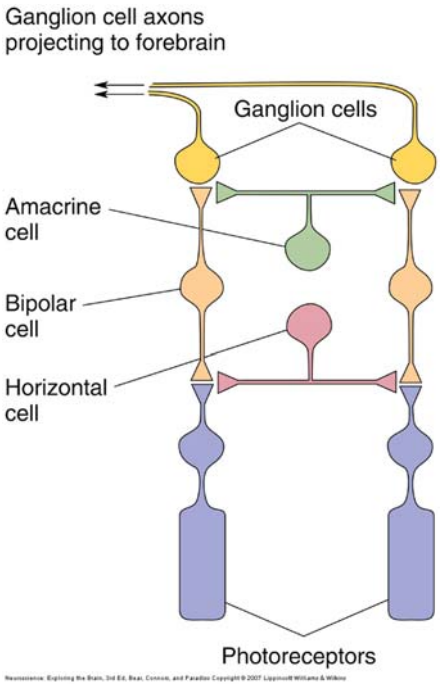


Microscopic Anatomy of the Retina

- **Photoreceptors:**
  - Cells that convert light energy into neural activity
- **Ganglion Cells:**
  - Retinal output (Action Potentials)
- **Direct (vertical) pathway:**

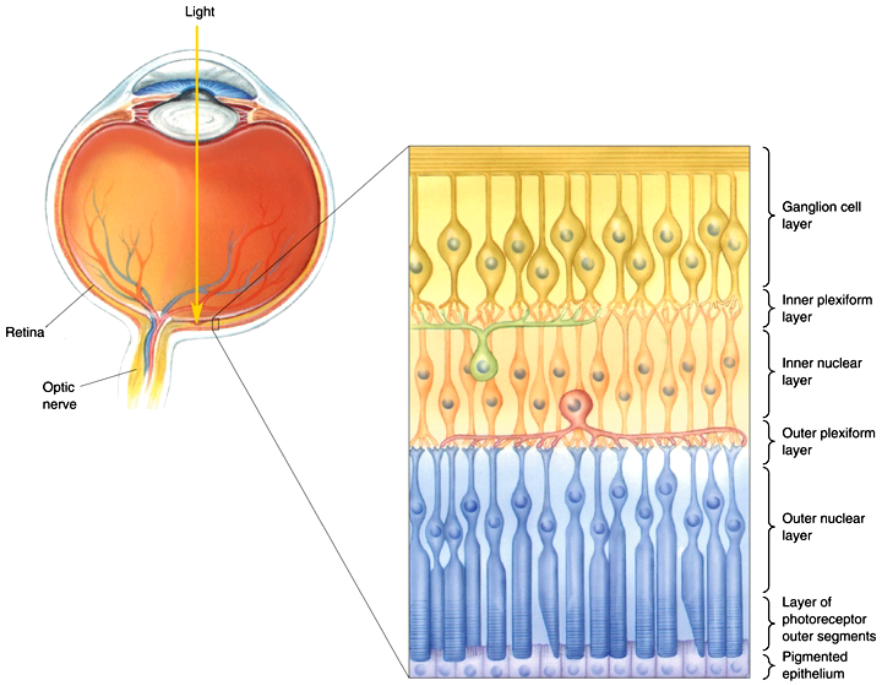


- **Other**
  - Horizontal cells
  - Amacrine cells
  - Ganglion cells



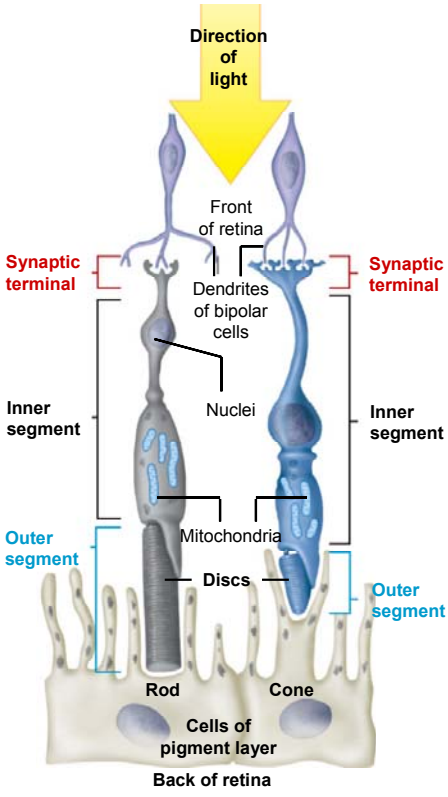
Microscopic Anatomy of the Retina

- **The Laminar Organization of the Retina**
  - Cells organized in layers
    - Inside-out



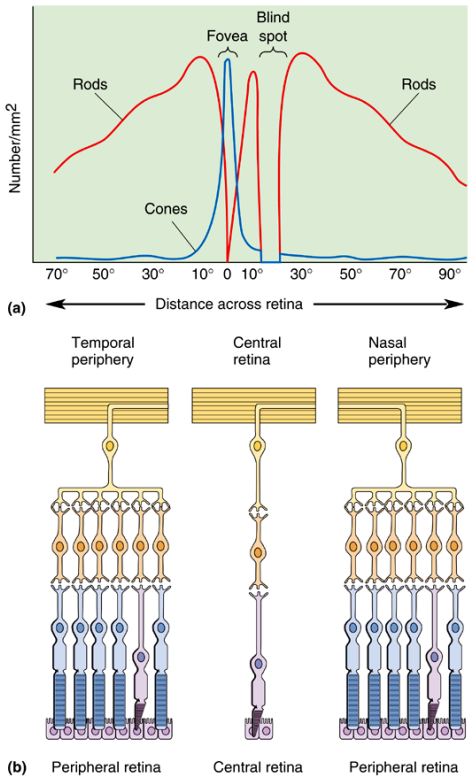
Microscopic Anatomy of the Retina

- **Photoreceptor Structure**
  - Electromagnetic radiation to neural signals
  - Four main regions
    - Outer segment
    - Inner segment
    - Cell body
    - Synaptic terminal
  - Types of photoreceptors
    - Rods and cones



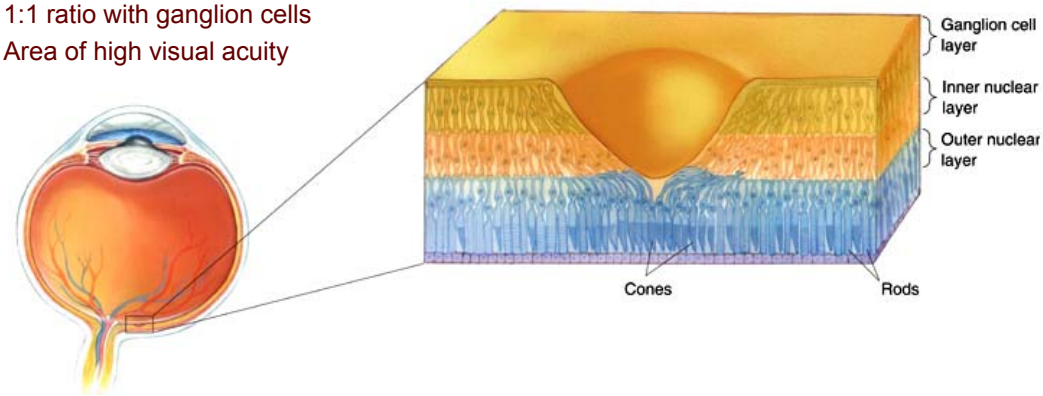
Microscopic Anatomy of the Retina

- **Regional Differences in Retinal Structure**
  - Varies from fovea to retinal periphery
  - Peripheral retina
    - Higher ratio of rods to cones
    - Higher ratio of photoreceptors to ganglion cells
    - More sensitive to light



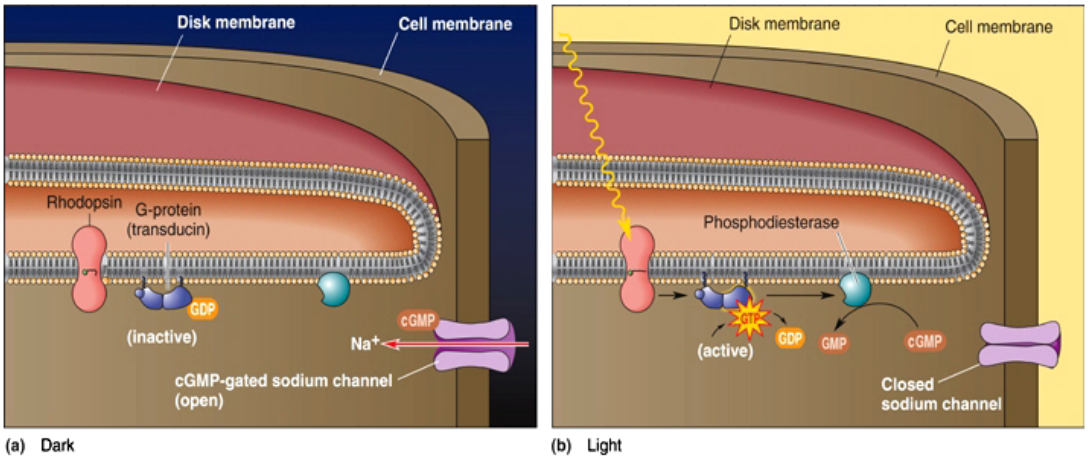
Microscopic Anatomy of the Retina

- **Regional Differences in Retinal Structure**
  - Fovea
    - Cross-section of fovea: Pit in retina
    - Structure: Maximizes visual acuity
    - Central fovea: All cones (no rods)
      - 1:1 ratio with ganglion cells
      - Area of high visual acuity



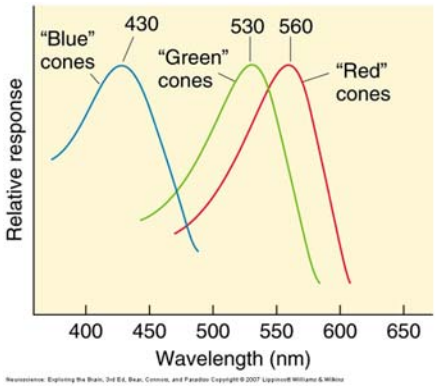
Phototransduction

- **Phototransduction in Rods**
  - Depolarization in the dark (“Dark current”) / Hyperpolarization in the light
  - One pigment in rods: Rhodopsin (Opsin + Retinal)
    - Receptor protein that is activated by light
  - Activation reduces cGMP → closes sodium channels



Phototransduction

- **Phototransduction in Cones**
  - Similar to rod phototransduction
  - Less sensitivity (need bright light)
  - Different opsins
    - Red, green, blue
- **Color detection**
  - Contributions of blue, green, and red cones to retinal signal
  - Spectral sensitivity
  - Young-Helmholtz trichromacy theory of color vision



Phototransduction

- **Dark and Light Adaptation**
  - Dark adaptation—factors
    - Dilation of pupils
    - Regeneration of unbleached rhodopsin
    - Adjustment of functional circuitry
  - Light adaptation
    - Opposite changes
  - Calcium's Role in Light Adaptation
    - Calcium concentration changes in photorteceptors
      - Na^+ channels admit Ca^{2+} too
    - Ca^{2+} reduces cGMP
    - Indirectly modulates Na^+ channels
      - When channels are open → Ca flows → less cGMP → channels close
      - When channels are closed → no more Ca → more cGMP → channels open

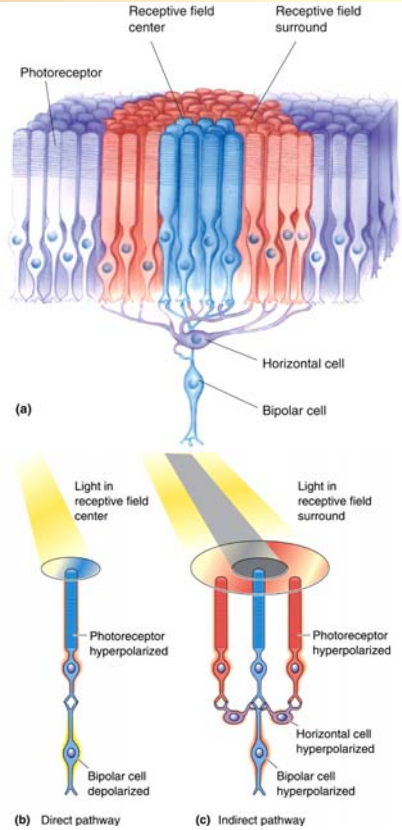
All-cone daytime vision

↓ 20–25 minutes

All-rod nighttime vision

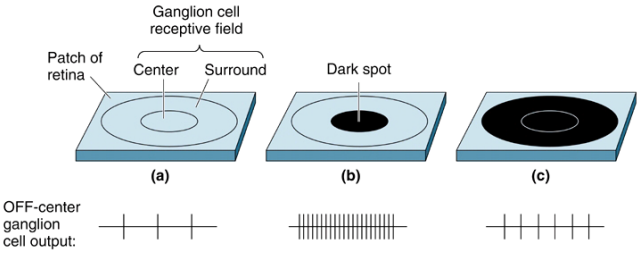
Retinal Processing

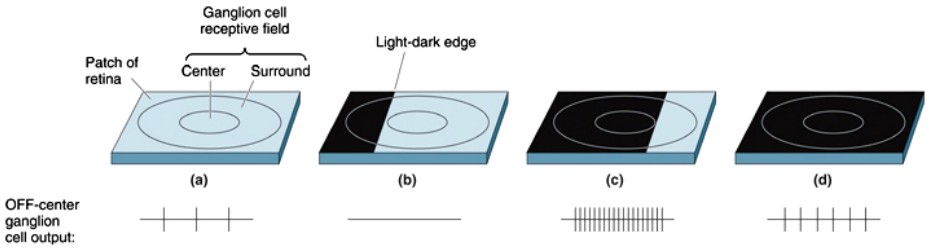
- **Transformations in the Outer Plexiform Layer**
  - Photoreceptors
    - Release neurotransmitter glutamate when depolarized
  - Bipolar Cells
    - OFF bipolar cells
      - Respond to dark
      - Glutamate cation channel → depolarizing
    - ON bipolar cells
      - Respond to light
      - Glutamate G-protein coupled → hyperpolarizing (i.e. depolarize in light when there is less glutamate
  - Bipolar Cell Receptive Fields
    - From one to thousand photoreceptors
    - Antagonistic center-surround receptive fields
    - Complex interaction of photoreceptors, bipolar and horizontal cells

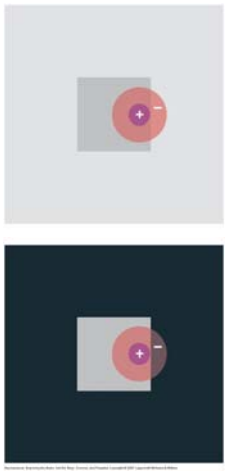


Retinal Output

- **Transformations in the Inner Plexiform Layer**
  - Ganglion Cell Receptive Fields
    - On-Center and Off-Center cells
    - Responsive to differences in illumination
    - Emphasize contrast at edges

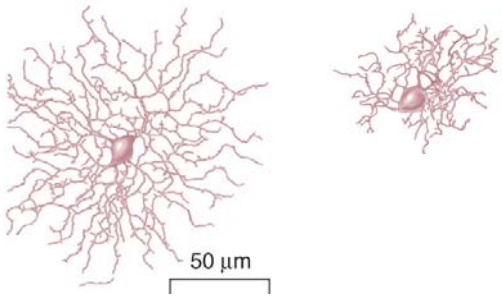


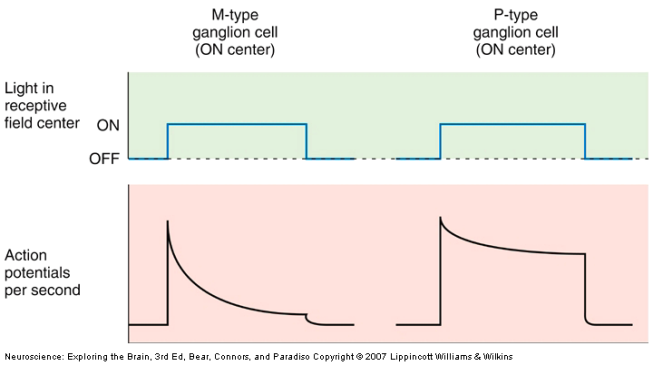




Retinal Output

- **Transformations in the Inner Plexiform Layer**
  - Types of Ganglion Cells
    - Categories based on appearance, connectivity, and electrophysiological properties
  - Three types of ganglion cells in monkey and human retina
    - M-type (Magno) vs. P-type (Parvo)
      - Larger receptieve fields
      - Contact APs more rapidly
      - More sensitive to low contrast
      - Respond with transient bursts
    - nonM-nonP
    - More on their projections and function next time

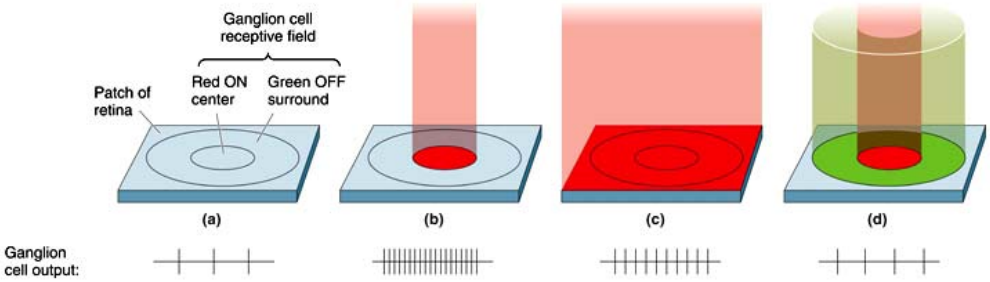




Biomedical Imaging and Applied Optics Laboratory

Retinal Output

- **Transformations in the Inner Plexiform Layer**
  - Color-Opponent Ganglion Cells
    - P-type or nonM-nonP
    - Red/Green or Blue/Yellow



Retinal Output

- **Parallel Processing**
  - Simultaneous input from two eyes
    - Information from two streams is compared in the central visual system
      - Depth and the distance of object
    - Information about light and dark: ON-center and OFF-center ganglion cells
  - Different receptive fields and response properties of retinal ganglion cells: M- and P- cells, and nonM-nonP cells

- **Mapping of visual space onto retinal ganglion cells not uniform**

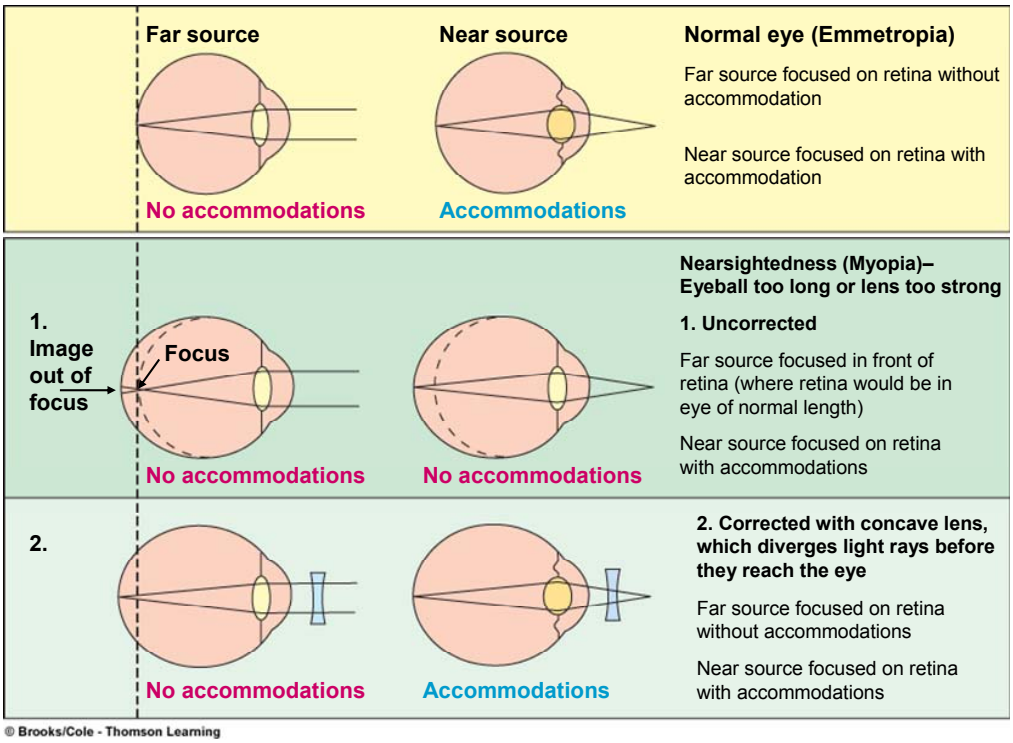
Επόμενη Διάλεξη …

Διάλεξη 9

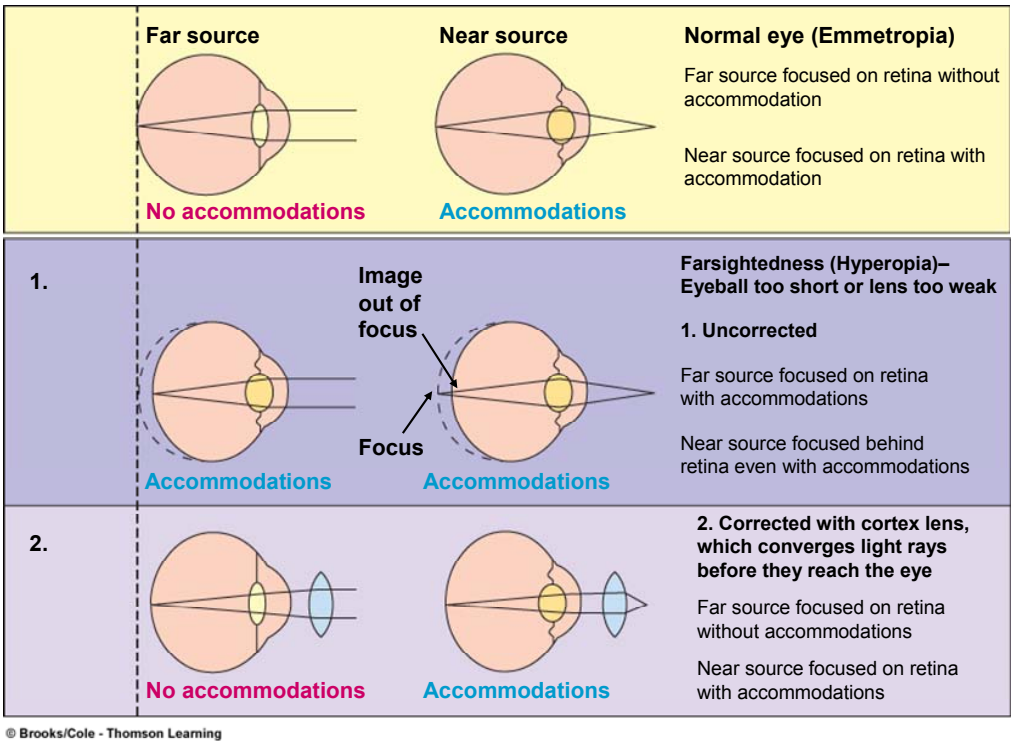
The Central Visual System

(Το Κεντρικό Οπτικό Σύστημα)

Vision



Vision



Vision