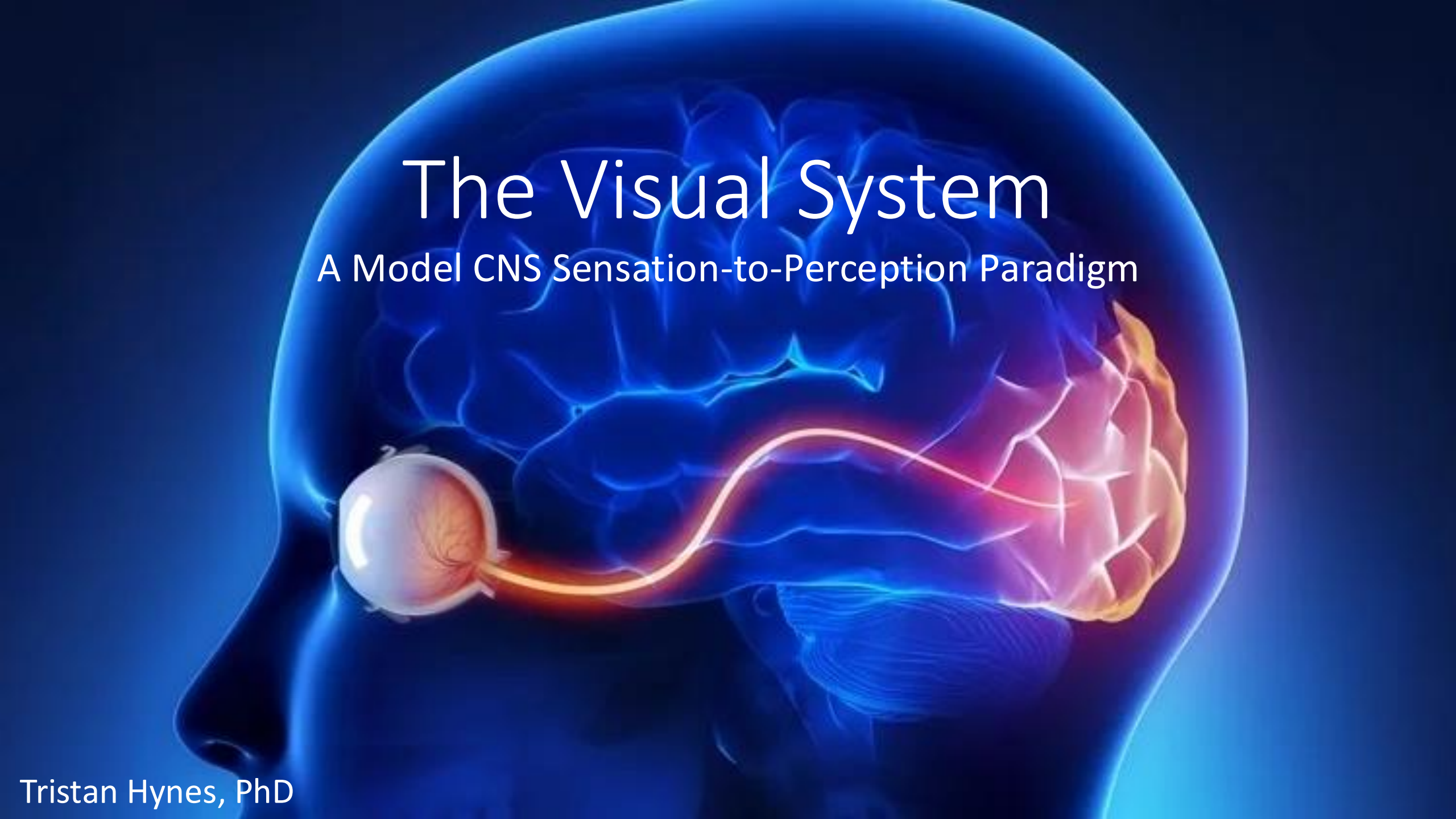


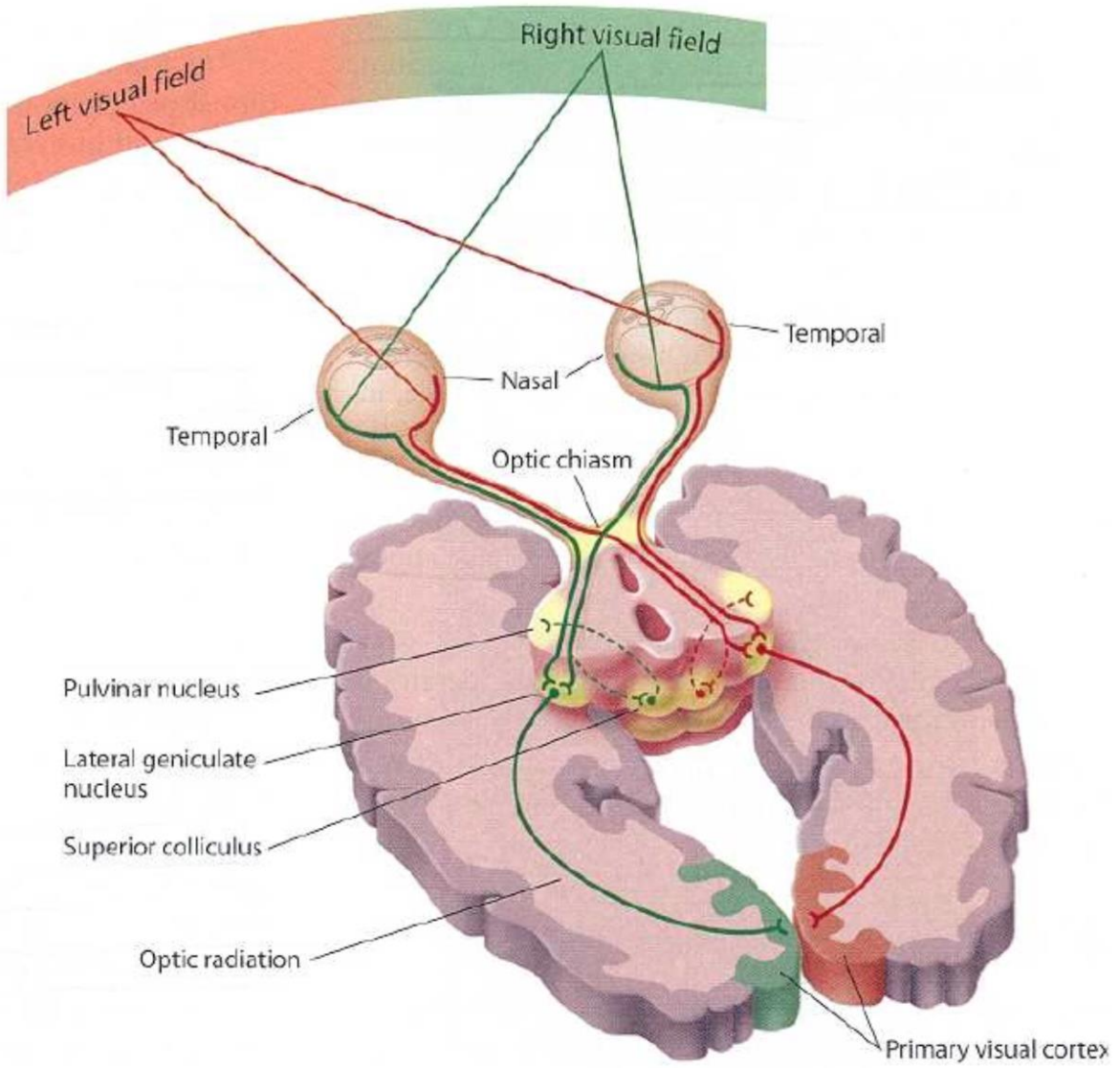
The Visual System

A Model CNS Sensation-to-Perception Paradigm

Tristan Hynes, PhD

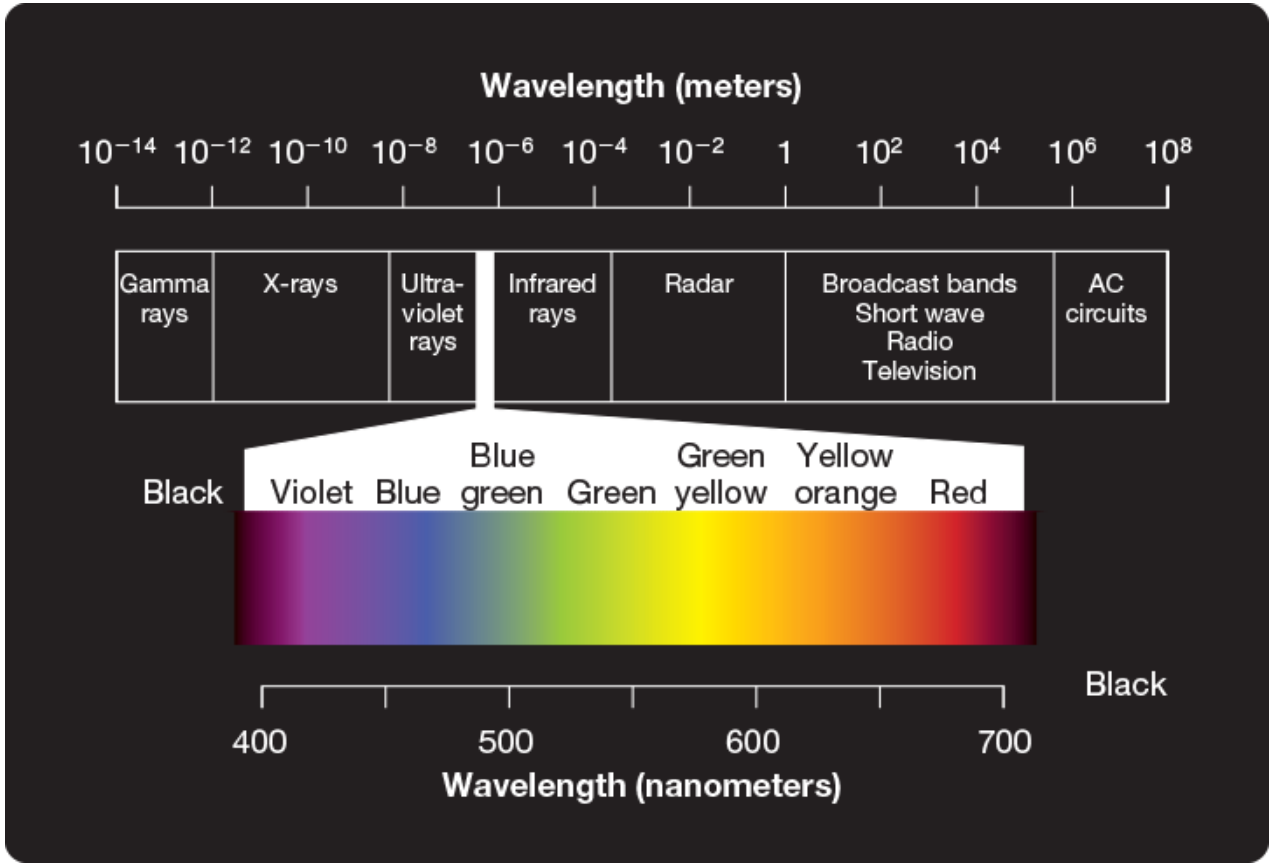
The Visual System: A Great Model for CNS

- Active, not passive
- Relative, not absolute
- Parallel processing
- Convergence and divergence
- Contralateral
- -topic organization



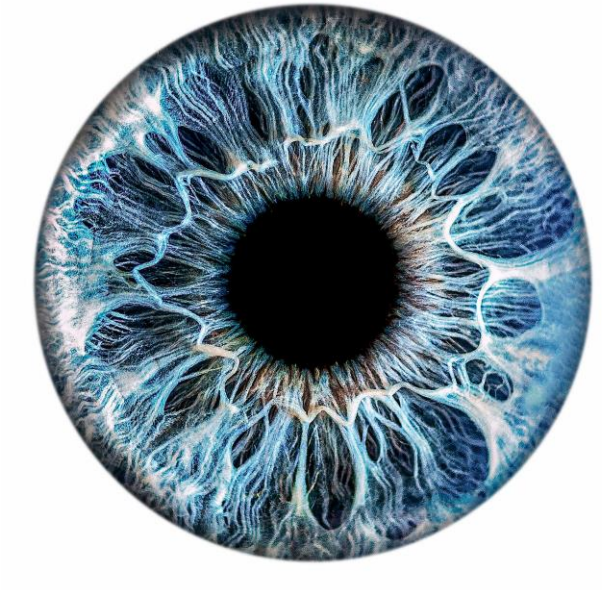
What Is “Light”?

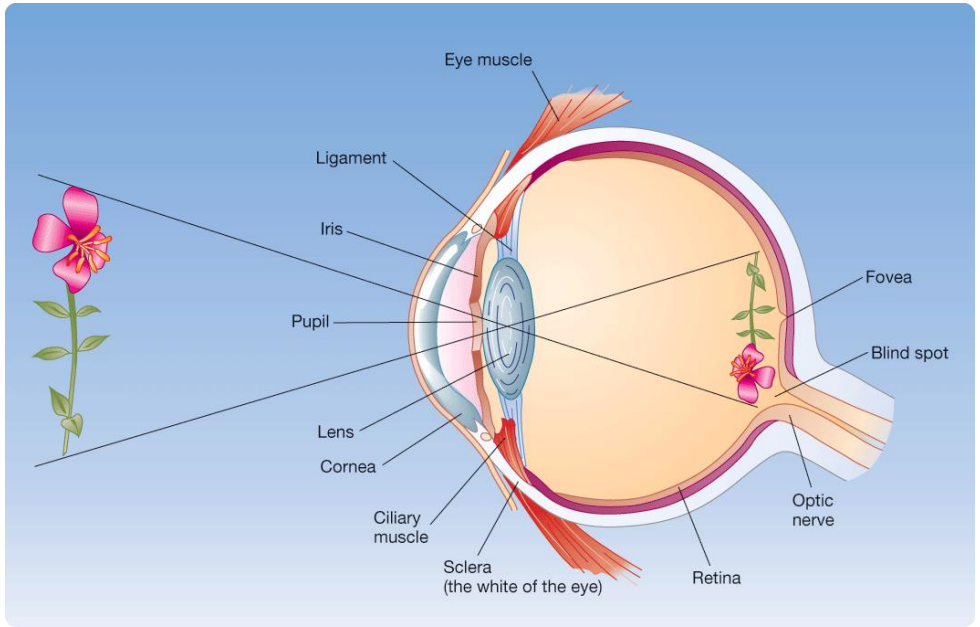
- Electromagnetic radiation
- Photons
- Most light is invisible to humans
- Visible spectrum
- Properties of light: wavelength/colour, intensity/brightness



The Human Eye

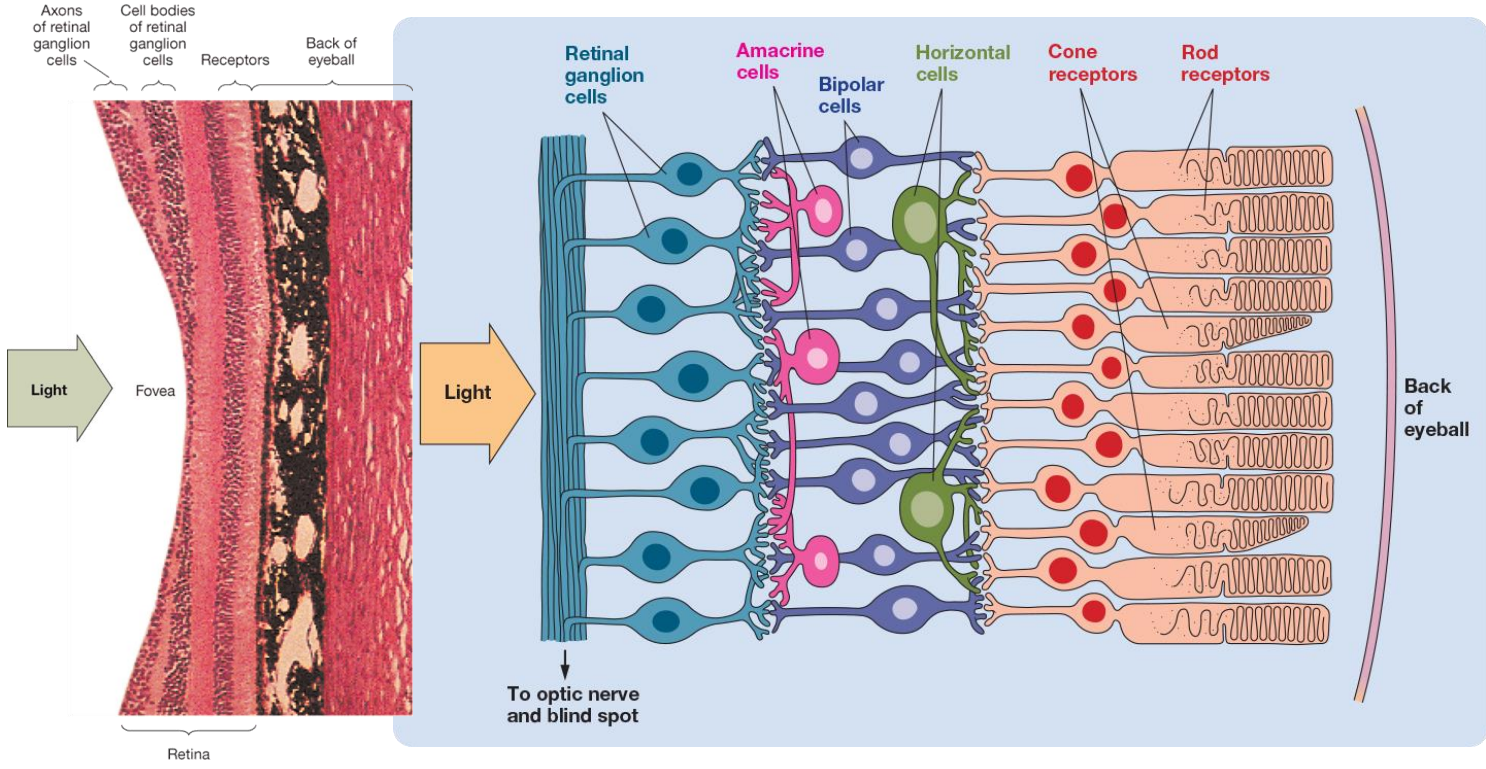
- Pupil
  - Size is regulated by iris
  - Size is compromise between sensitivity and acuity
- Lens
  - Focuses light on the retina
  - Focus is called accommodation
  - When focused on something near, lens is cylindrical
  - When focused on something far away, lens is flattened





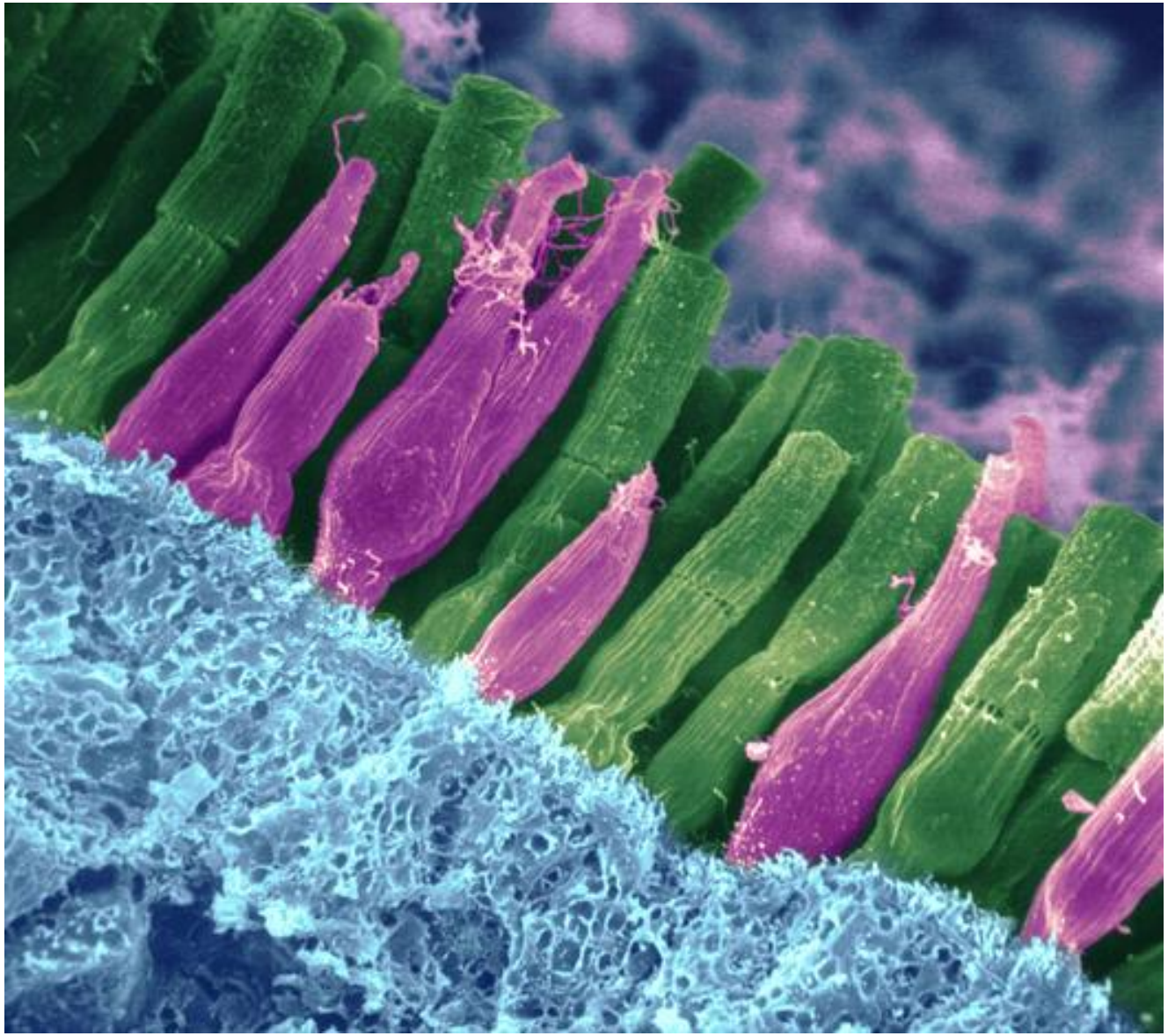
Structure of the Retina

- Five layers
  - Receptor layer
  - Horizontal cell layer
  - Bipolar layer
  - Amacrine cell layer
  - Retinal ganglion cell layer
  - Lateral communication
- Fovea
  - Location
  - High-acuity vision
- Optic disk
  - Blind spot
  - Completion/creativity
  - Surface interpolation

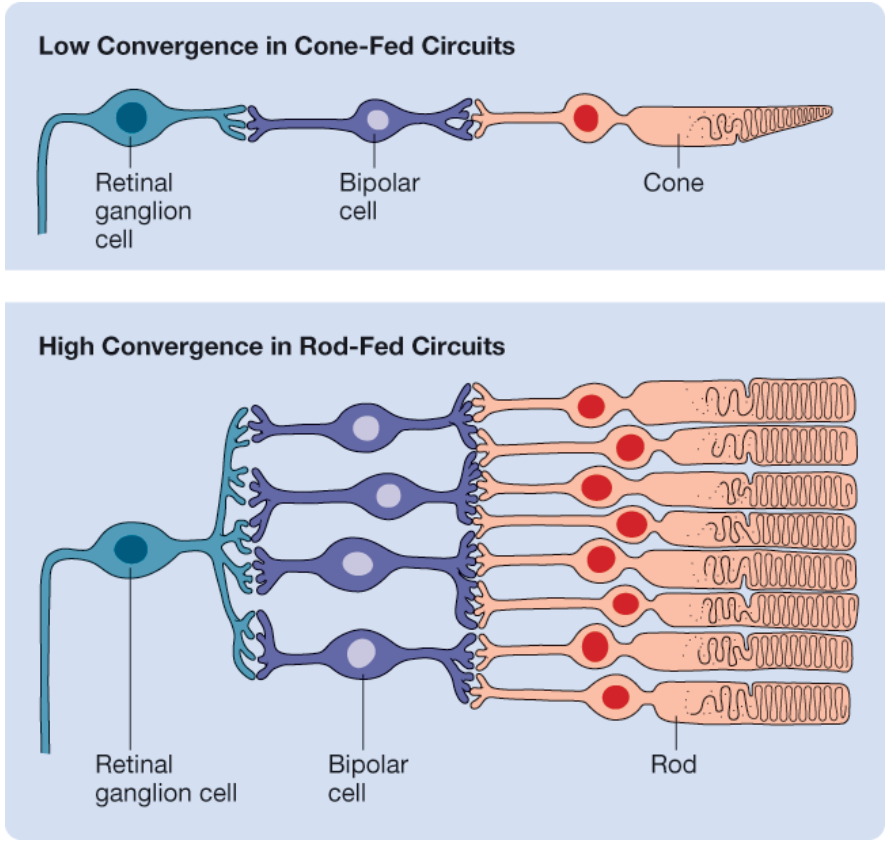


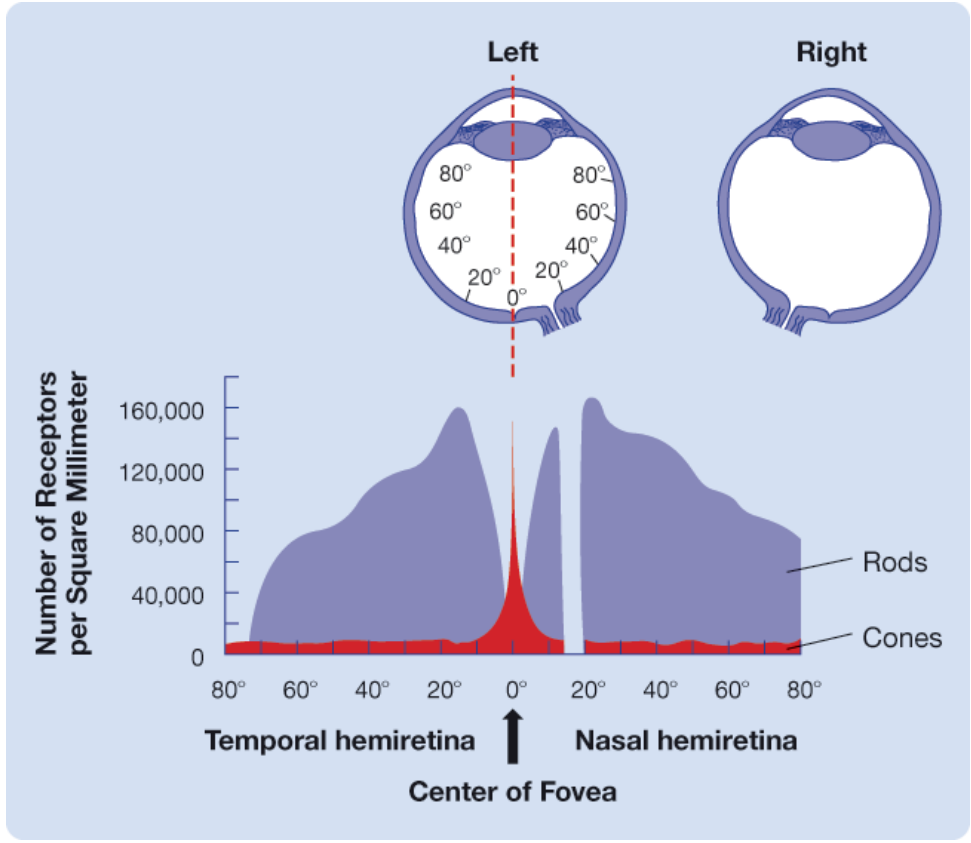
Cone and Rod Vision

- Duplexity theory
  - Rods and cones mediate different types of vision
- Photopic
  - Light vision
  - High acuity
  - Low sensitivity with few receptors
  - Low convergence
  - Fovea
  - Cones
- Scotopic
  - Dark/dim vision
  - Low acuity
  - High convergence
  - High sensitivity with many receptors
  - Periphery
  - Rods



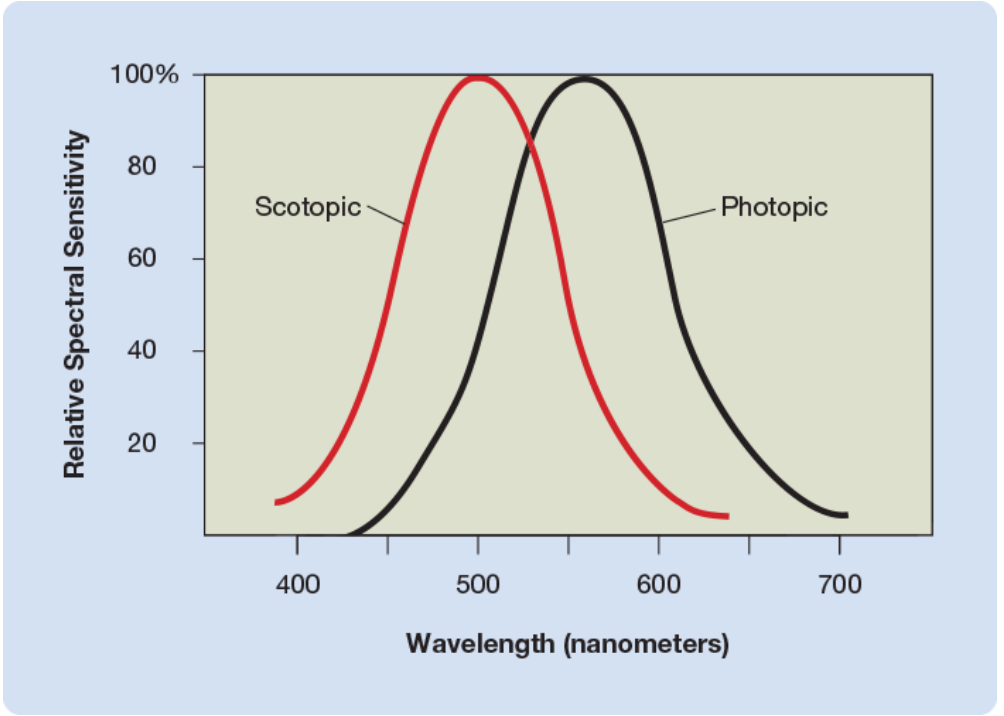
Convergence and Photoreceptor Distribution





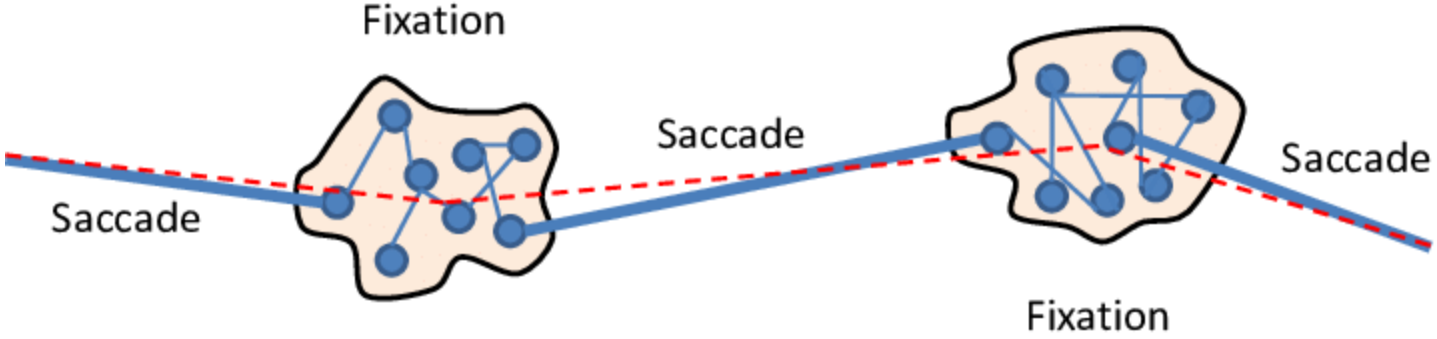
Spectral Sensitivity

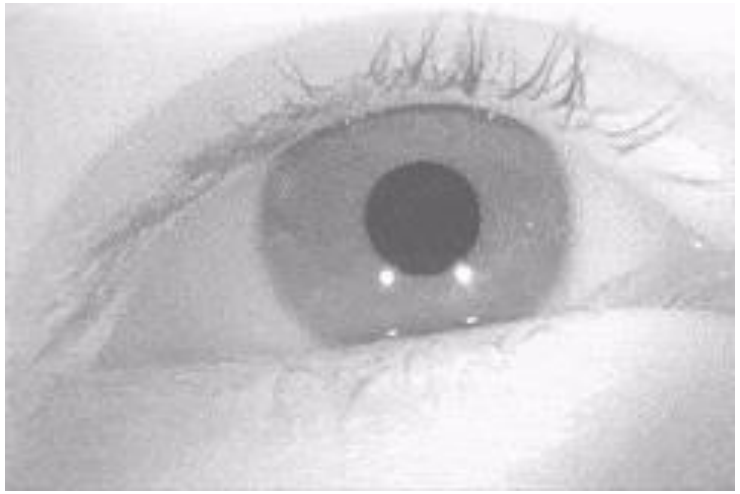
- More intense lights appear brighter
- Wavelength can impact brightness
- Differential sensitivity to wavelengths
- Spectral sensitivity curves
- Purkinje Effect



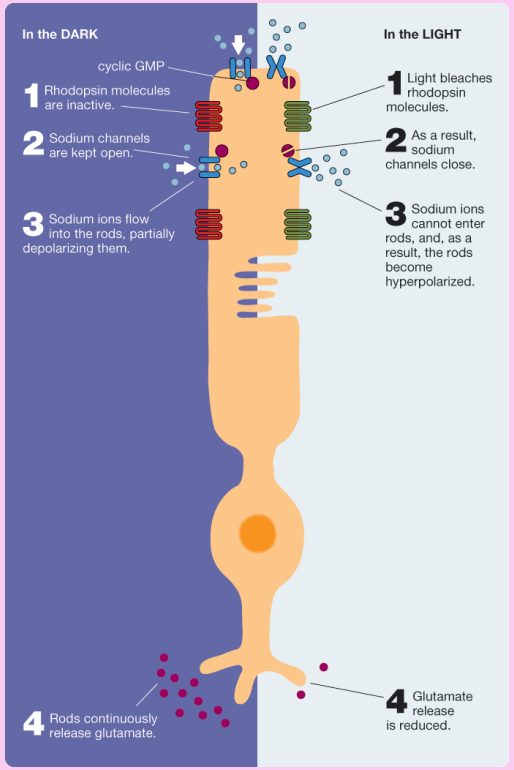
Eye Movement

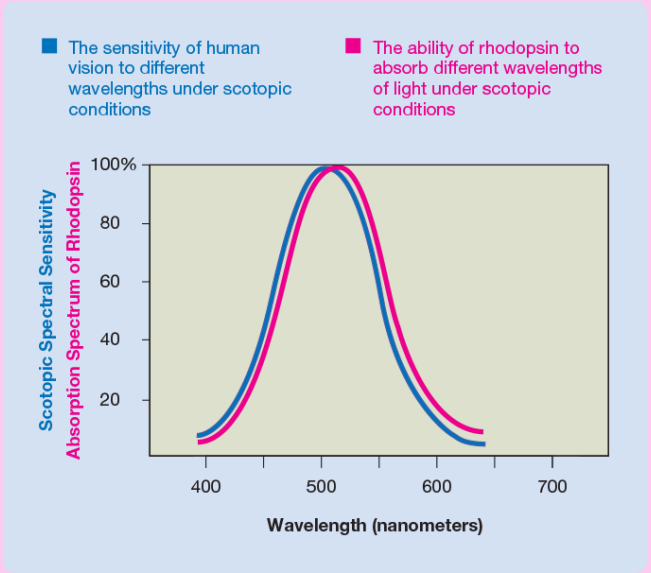
- Fixations
- Saccades
- Stabilized retinal images disappear
- Temporal integration
  - Sum of the inputs
  - Explains why images are detailed, colored, and wide-angled
  - Explains why things don't disappear when we blink





Visual Transduction

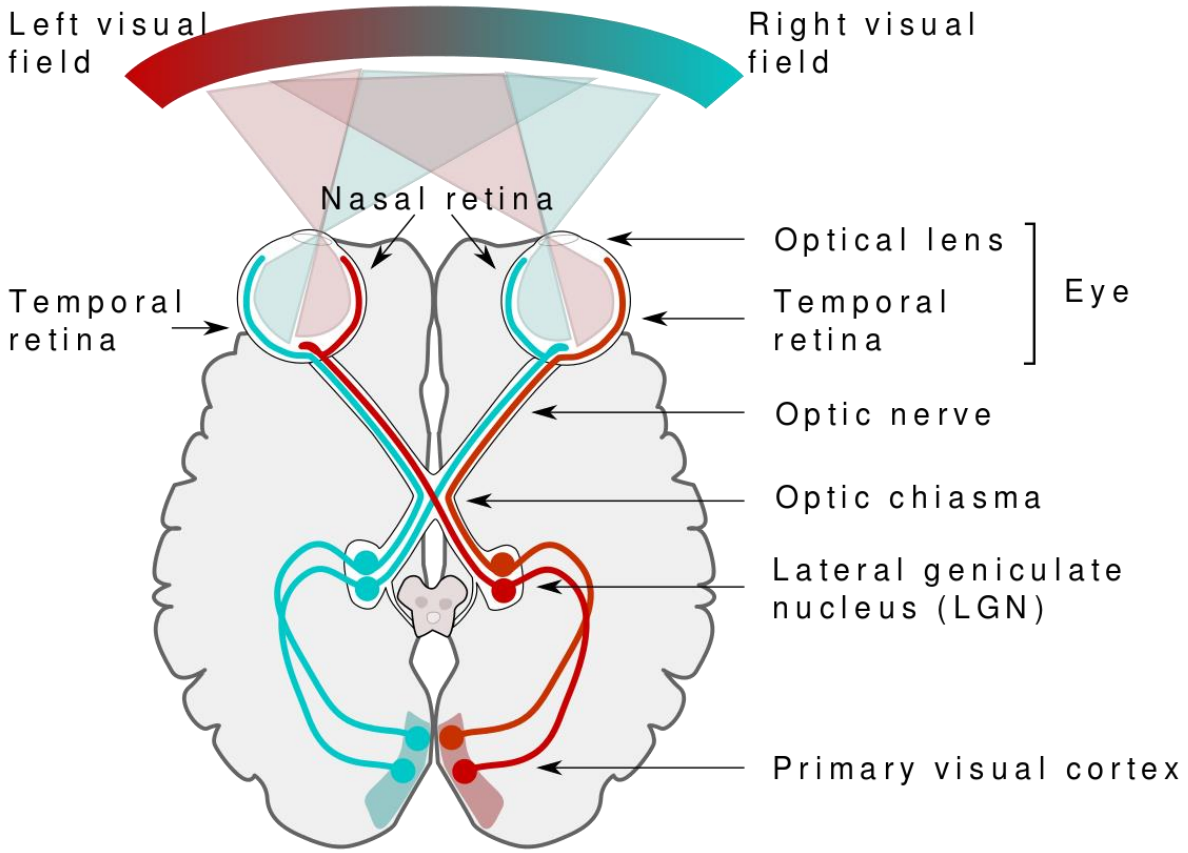




- Transduction is the conversion of energy
- Transduction by rods
  - Rhodopsin is bleached
  - Separates into retinal and opsin
  - Hyperpolarizes the rods
  - At rest, rods are slightly depolarized
  - Rods transmit signals through inhibition

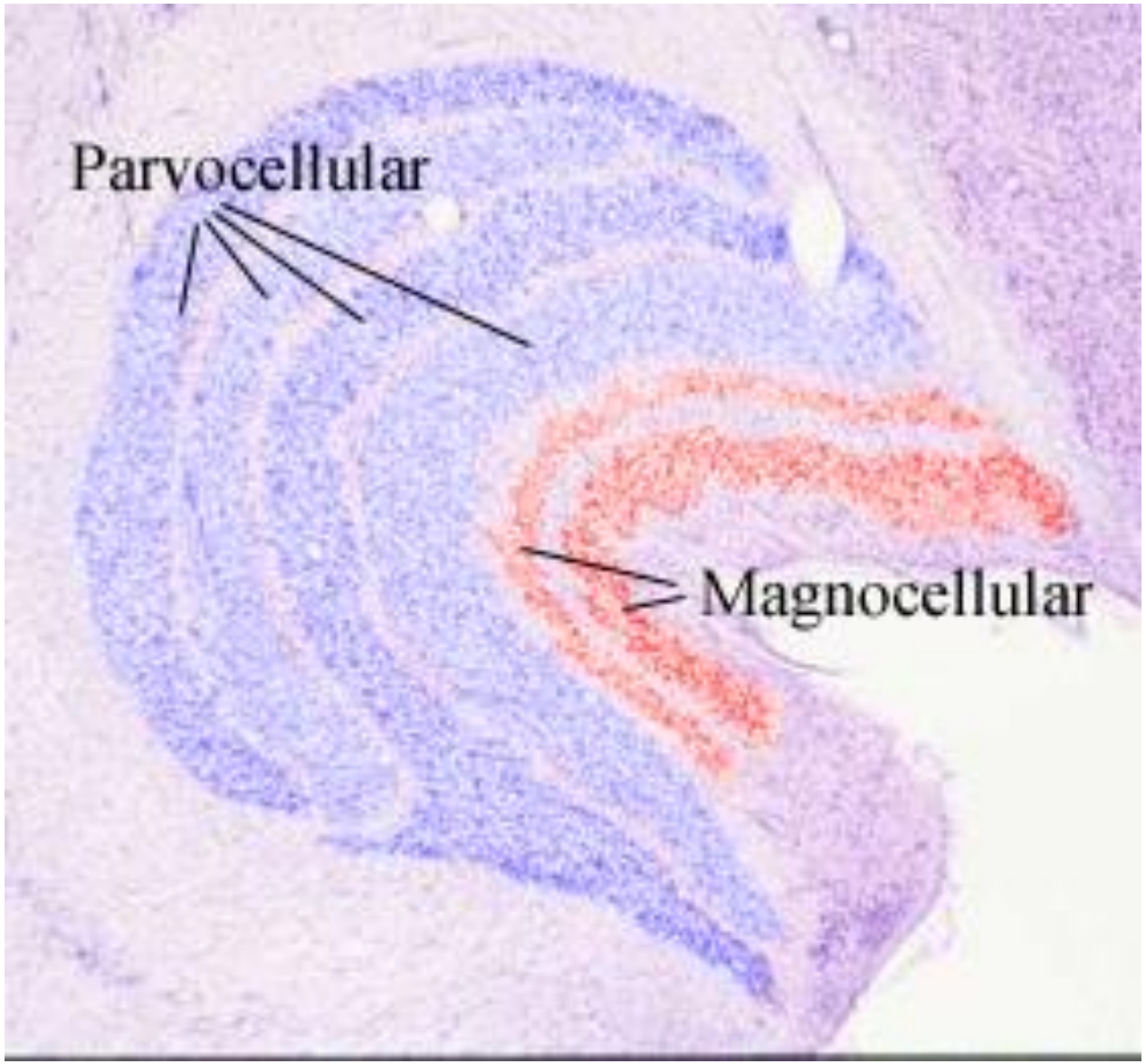
Retina-Geniculate-Striate System

- Visual information travels from:
  - Retina
    - From rods and cones
  - Geniculate (located in thalamus)
  - Striate cortex (occipital lobe)
    - Primary visual cortex
- Pathway
  - Nasal hemiretinas decussate at optic chiasm
  - Temporal hemiretinas stay ipsilateral



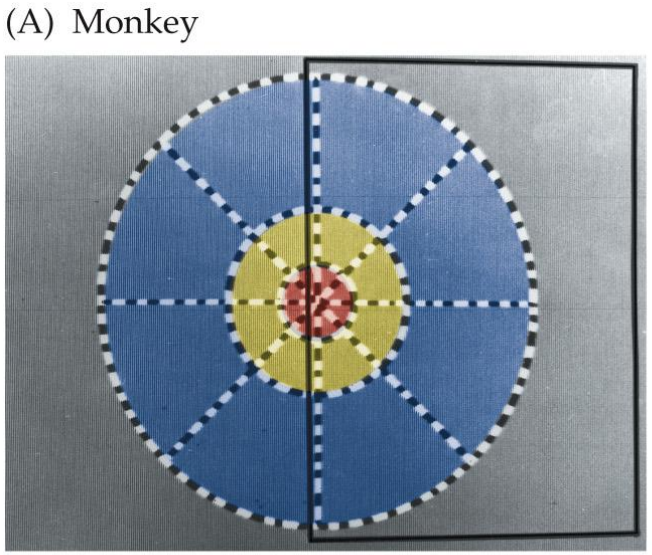
The M and P Channels

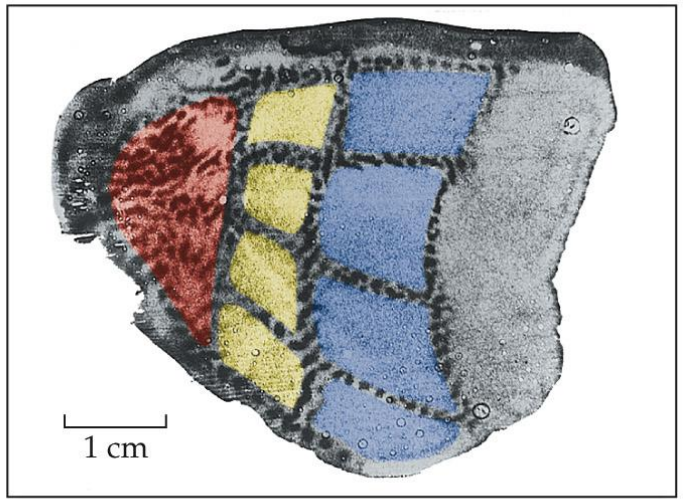
- Magnocellular layers
  - Bottom two layers of lateral geniculate nucleus
  - Composed of large body neurons
  - Responsive to rods and movement
- Parvocellular layers
  - Top four layers of lateral geniculate nucleus
  - Composed of small-body neurons
  - Responsive to color, fine detail, slow/stationary objects



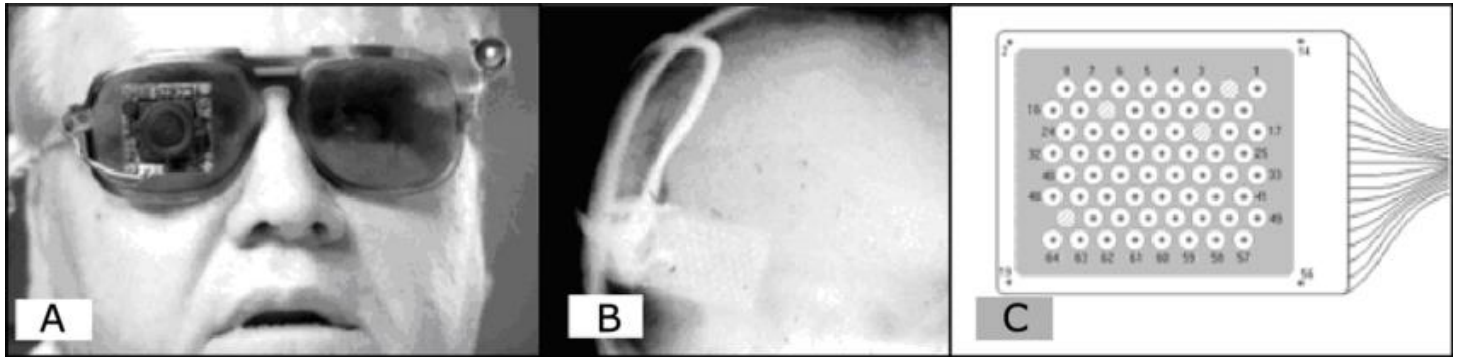
Retinotopic Organization

- Retinotopic layout
  - The surface of the visual cortex is a map of the retina
  - Study by Dobelle et al. (1974)
    - Stimulated visual cortex of blind participants
    - Patients reported pattern of light corresponded to electrode placement





BEHAVIORAL NEUROSCIENCE 8e, Figure 10.11 (Part 1)



Contrast Enhancement

- Seeing edges
  - Contrast enhancement is brightness contrast
  - Mach bands illusion
    - Light areas near border appear dark

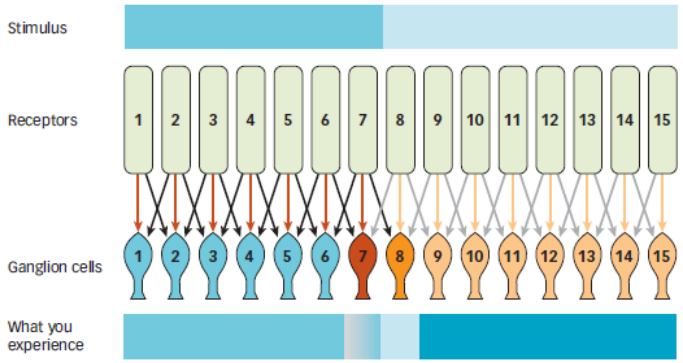
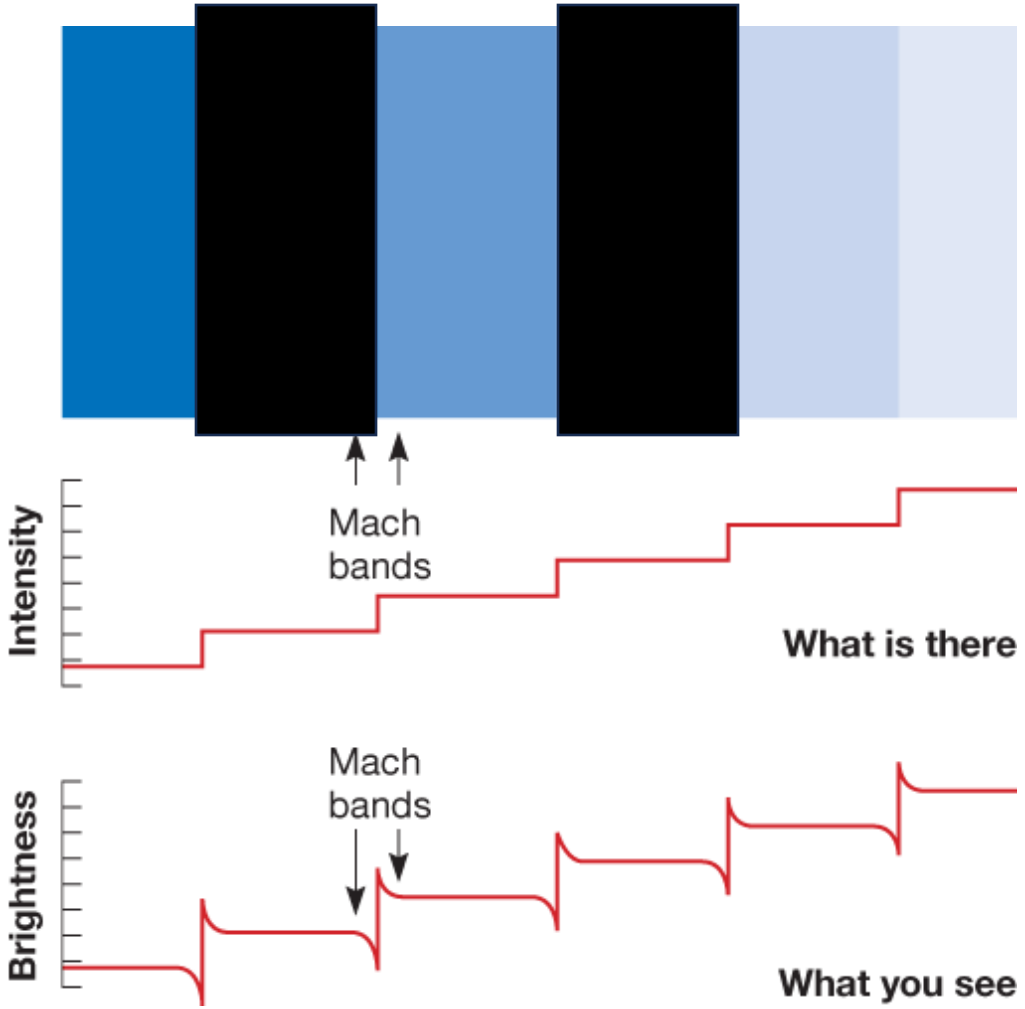


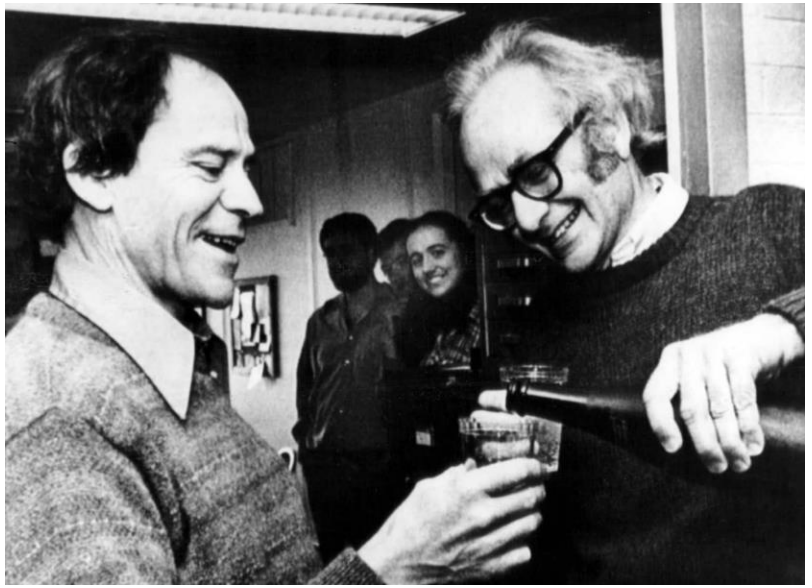
FIGURE 3.23 Mach bands.

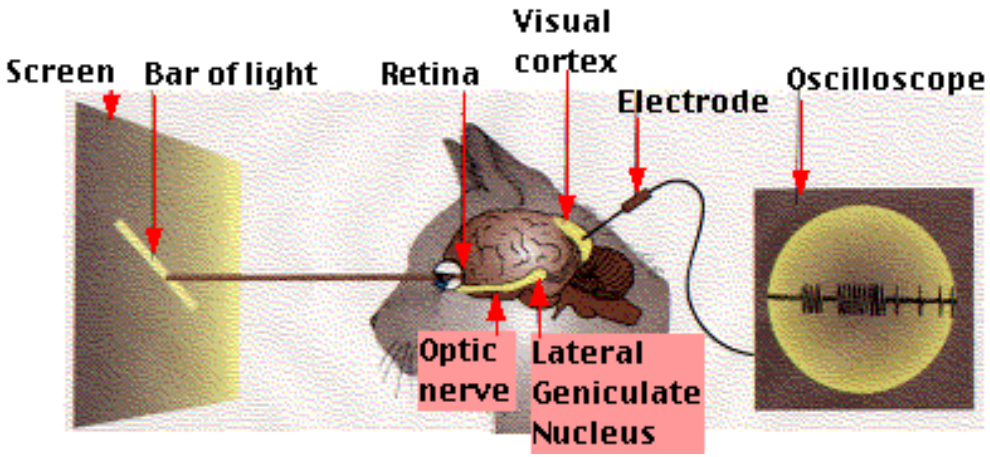
Each bar in this picture is uniform in lightness. However, we see a different level of lightness in each bar from left to right. For each bar, the left edge looks more black than the right edge, which looks lighter or whiter. This illusion is the result of processes of edge detection, such as lateral inhibition. When cells with receptive fields that straddle the bars detect the lightness contrast, they act to enhance the edges.



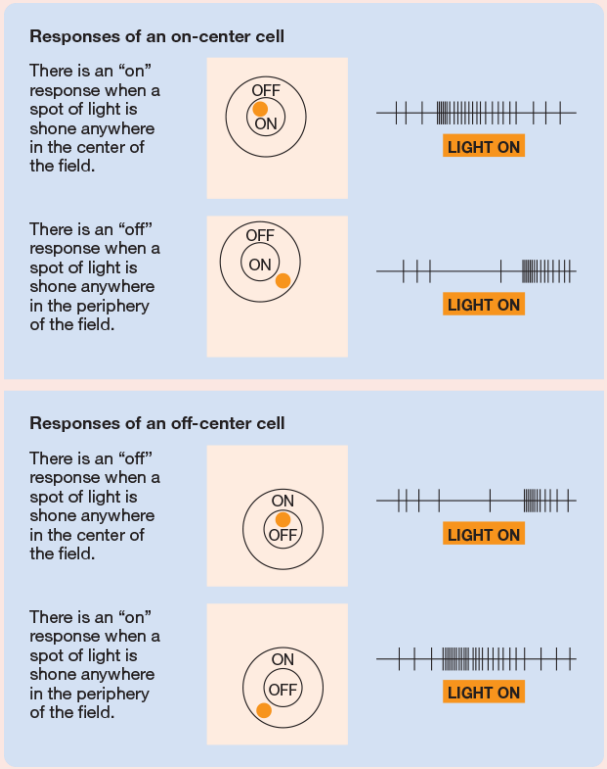
Receptive Fields of Visual Neurons

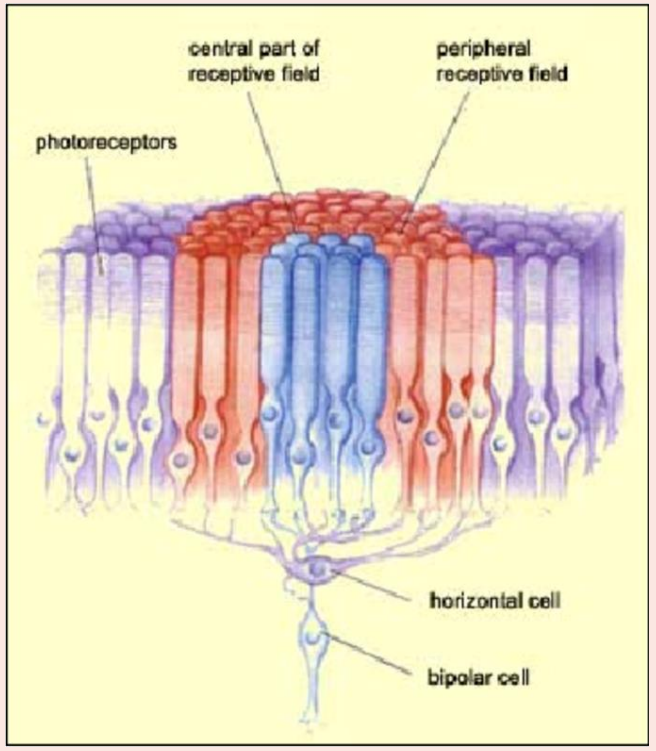
- Hubel and Wiesel methodology
  - Visual stimuli presented on a screen
  - Subject is curarized (treat with curare)
  - Extracellular electrode placed near one neuron
  - Neuron's receptive field is mapped
  - Receptive field defined
    - Area of visual field where stimuli fire that neuron





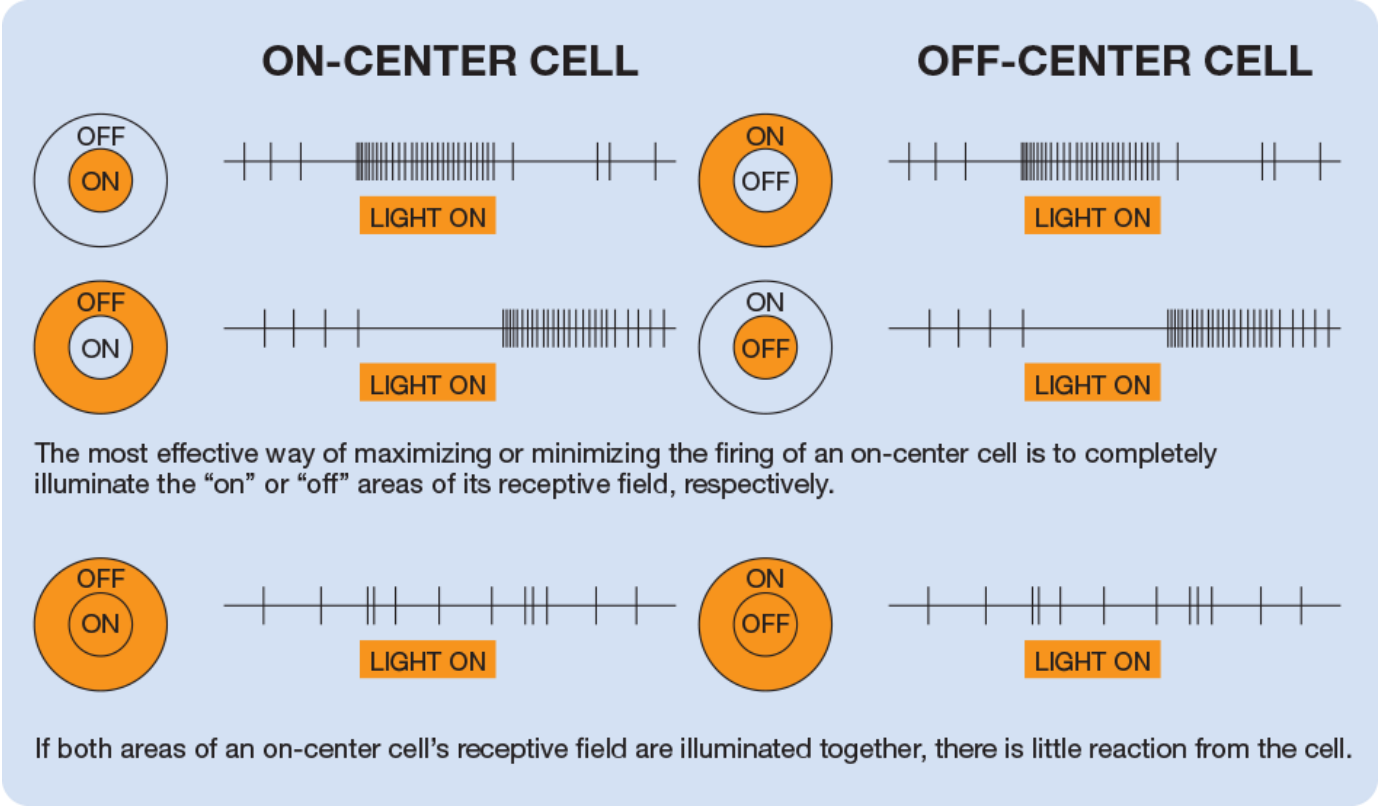
Receptive Fields of the Retina-Geniculate-Striate System

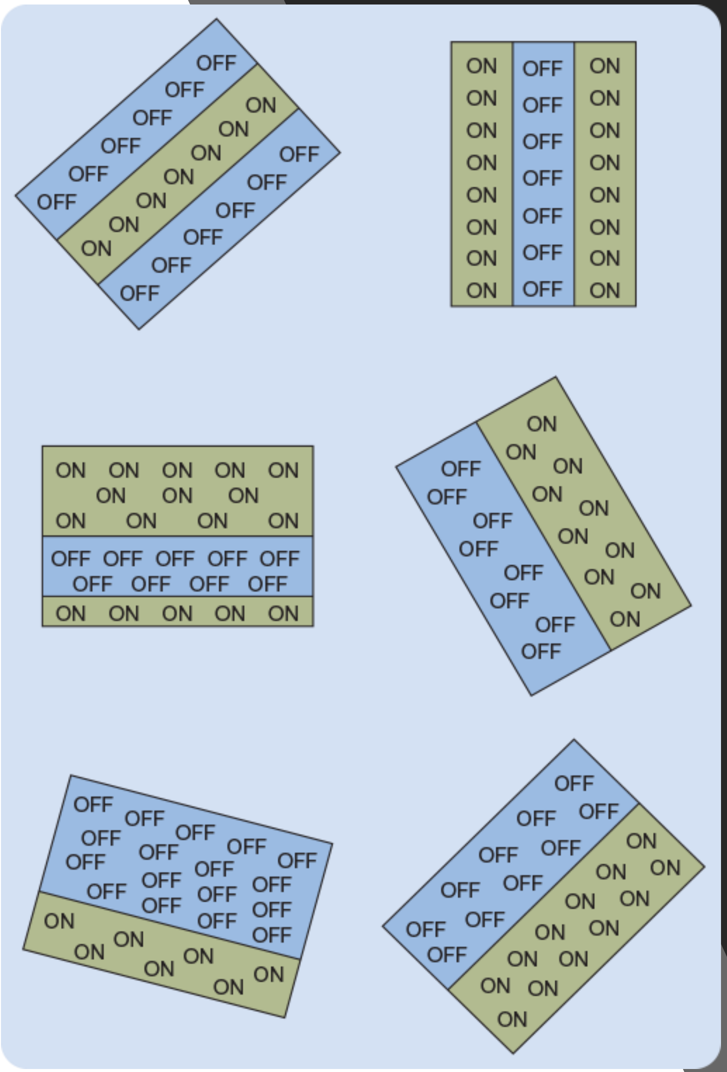




- Similar receptive fields
  - Retinal ganglion cells
  - Lateral geniculate nucleus neurons
  - Lower layer IV of striate cortex
- Two patterns of responding
  - On firing
  - Inhibition followed by off firing
- Characteristics of firing
  - Respond best to fully illuminated "on" area
  - Respond poorly to diffuse light
  - Respond to brightness contrast between centers and peripheries of their visual fields
  - Monocular

On/Off-Centre Cells and Contrast



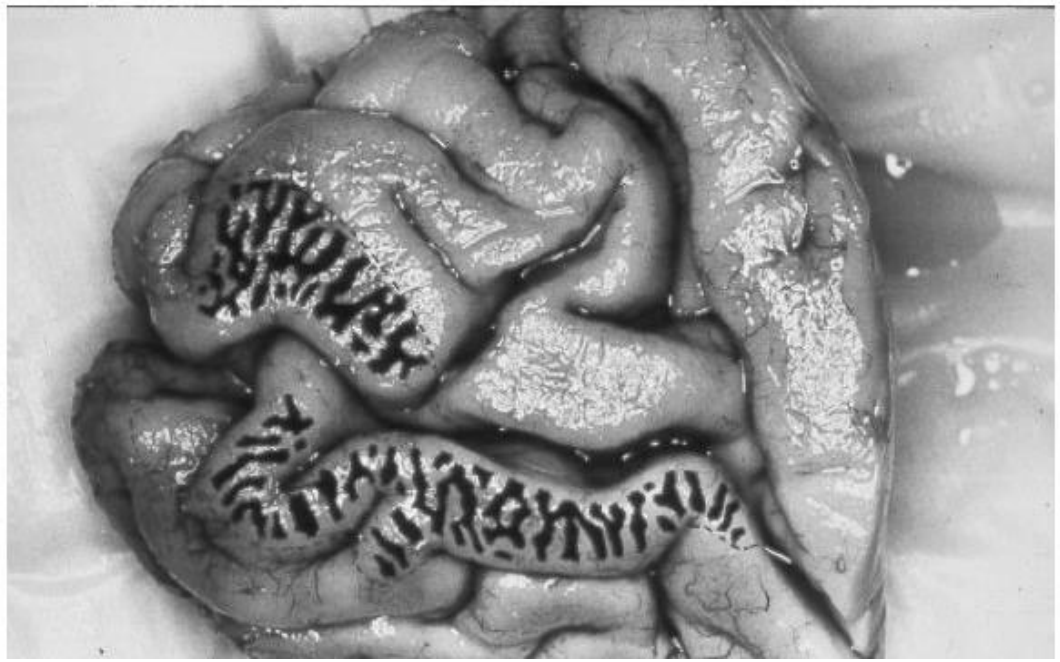


Receptive Fields of Primary Visual Cortex Neurons

- Simple striate cells
  - Respond best to bars or edges
  - Monocular
- Complex striate cells
  - Respond best to straight lines of particular orientation
- Binocular complex striate cells
  - Over half of complex cells are binocular
  - Half of those display ocular dominance

Organization of Primary Visual Cortex

Human ocular dominance columns



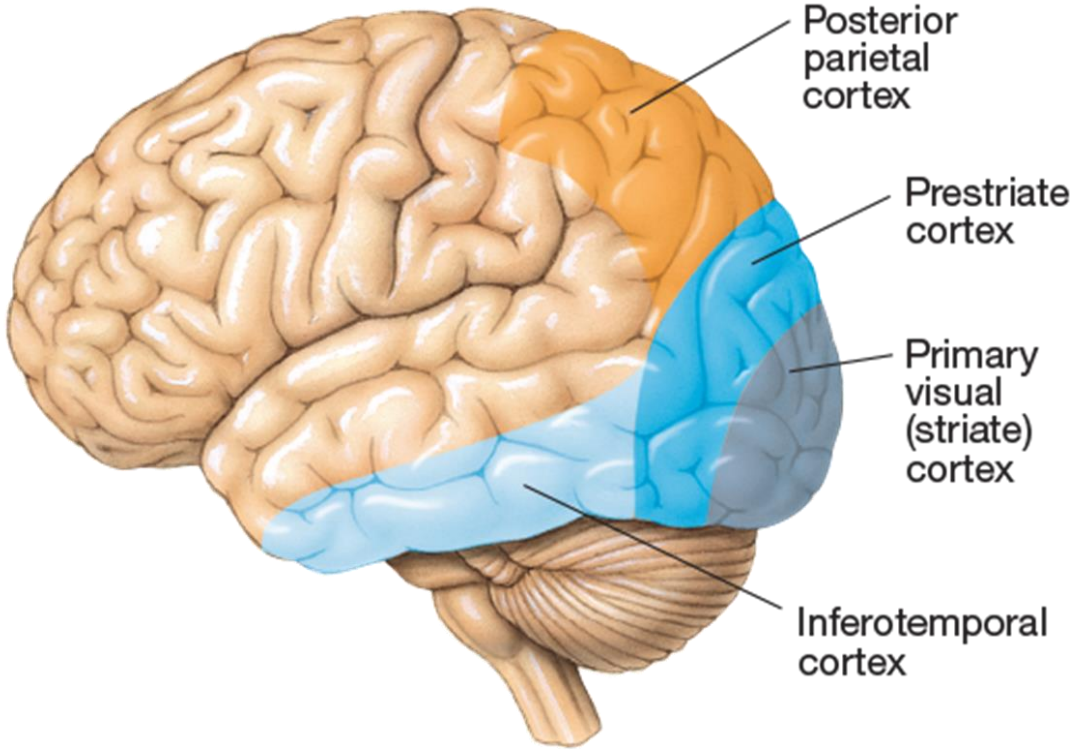
- Conclusions of Hubel and Wiesel
  - Neurons organized in vertical “columns”
  - Each neuron responds to stimuli from the same part of the retina
  - Related columns are “clustered”
  - Half cluster receives input from left eye/other half right eye
  - Preferred stimuli in neurons more complex closer to visual cortex

Changing Concept of the Characteristics of Visual Receptive Fields

- Retinal ganglion cells
- Lateral geniculate cells
- Assumptions of initial studies don’t hold
- Visual responses to natural scenes
- Contextual influences shape properties of the receptive field

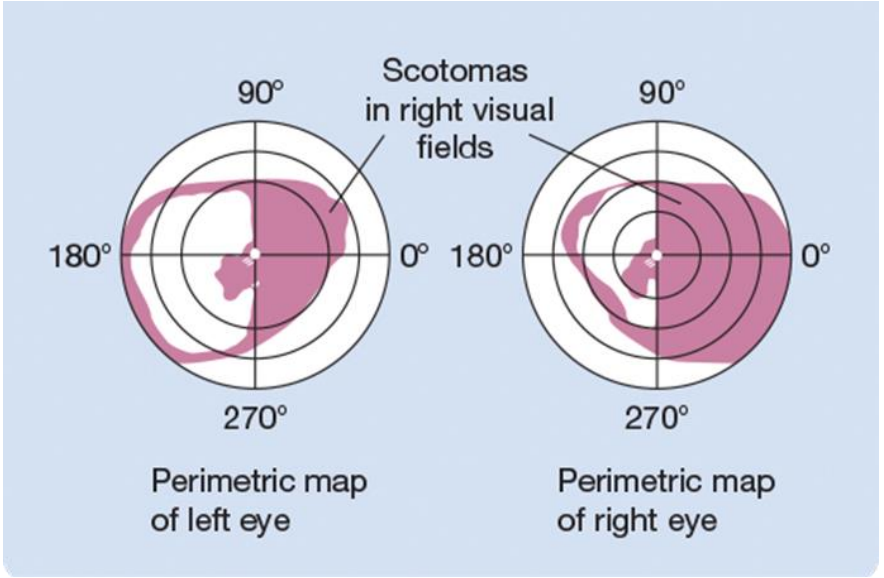
Three Different Classes of Visual Cortex

- Primary visual cortex
  - Located in occipital lobe
  - Receives most inputs from visual relay nuclei of thalamus
- Secondary visual cortex
  - Located in the prestriate cortex
  - Receives input from primary visual cortex
- Visual association cortex
  - Receives input from secondary visual cortex
  - Areas
    - Inferotemporal cortex
    - Posterior parietal cortex



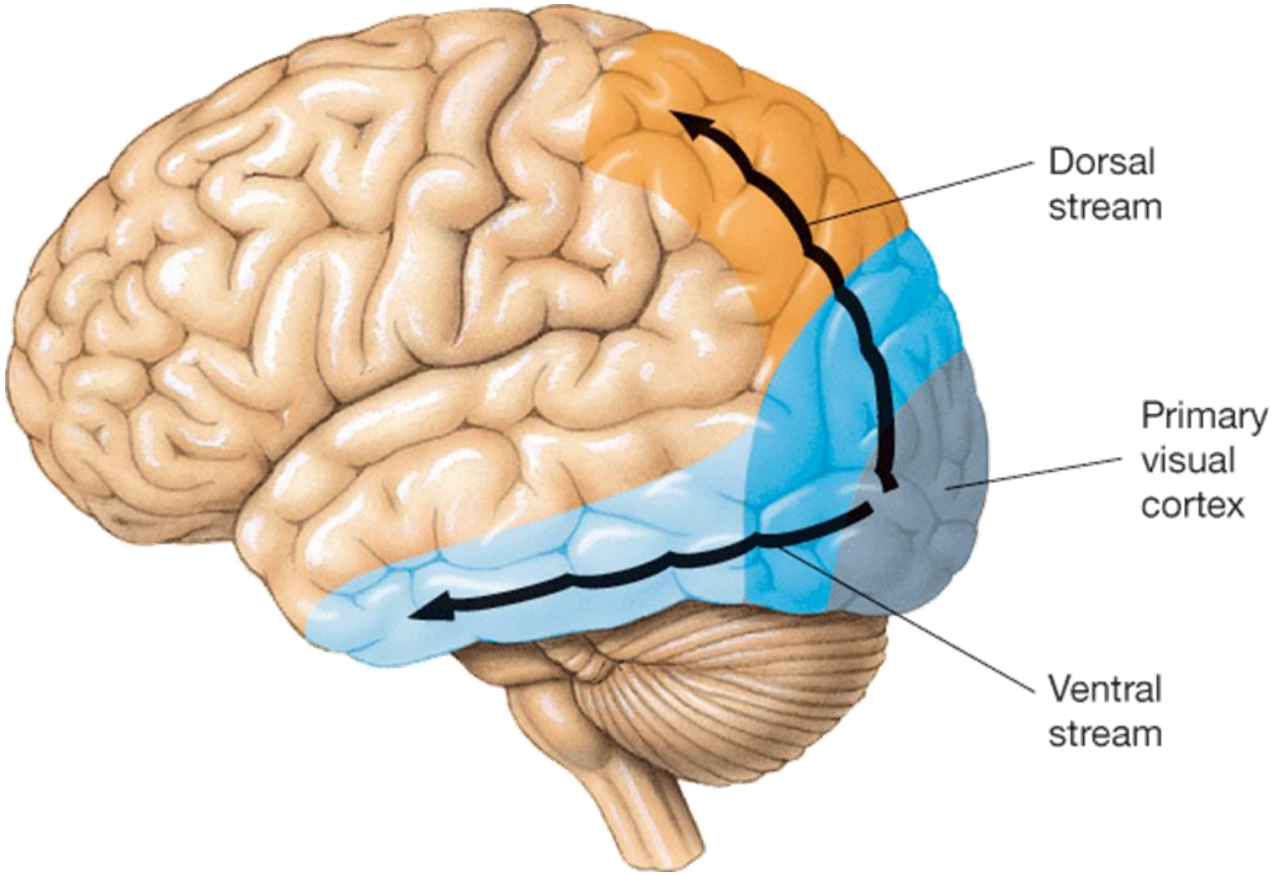
Damage to Primary Visual Cortex: Scotomas and Completion

- Damage to primary visual cortex results in scotomas
  - Areas of blindness in corresponding areas of visual field
  - Scotomas are plotted by perimetry tests
- Completion
- Blindsight
- These phenomena support parallel models rather than serial

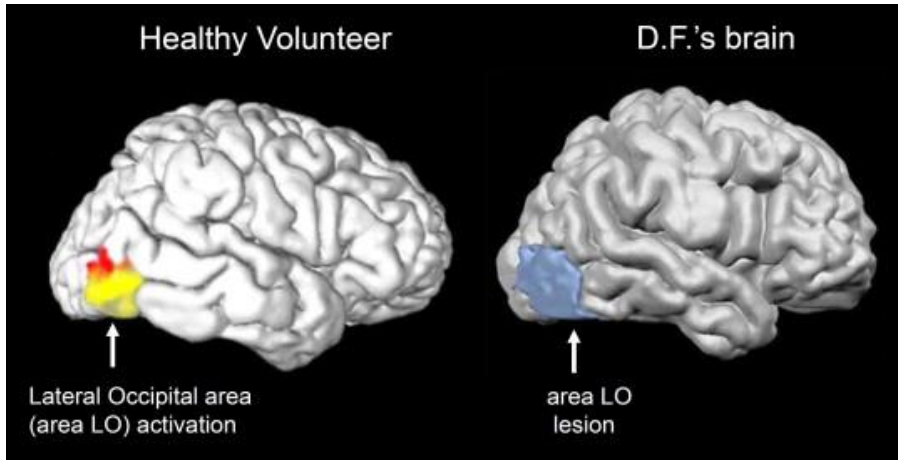


Dorsal and Ventral Streams

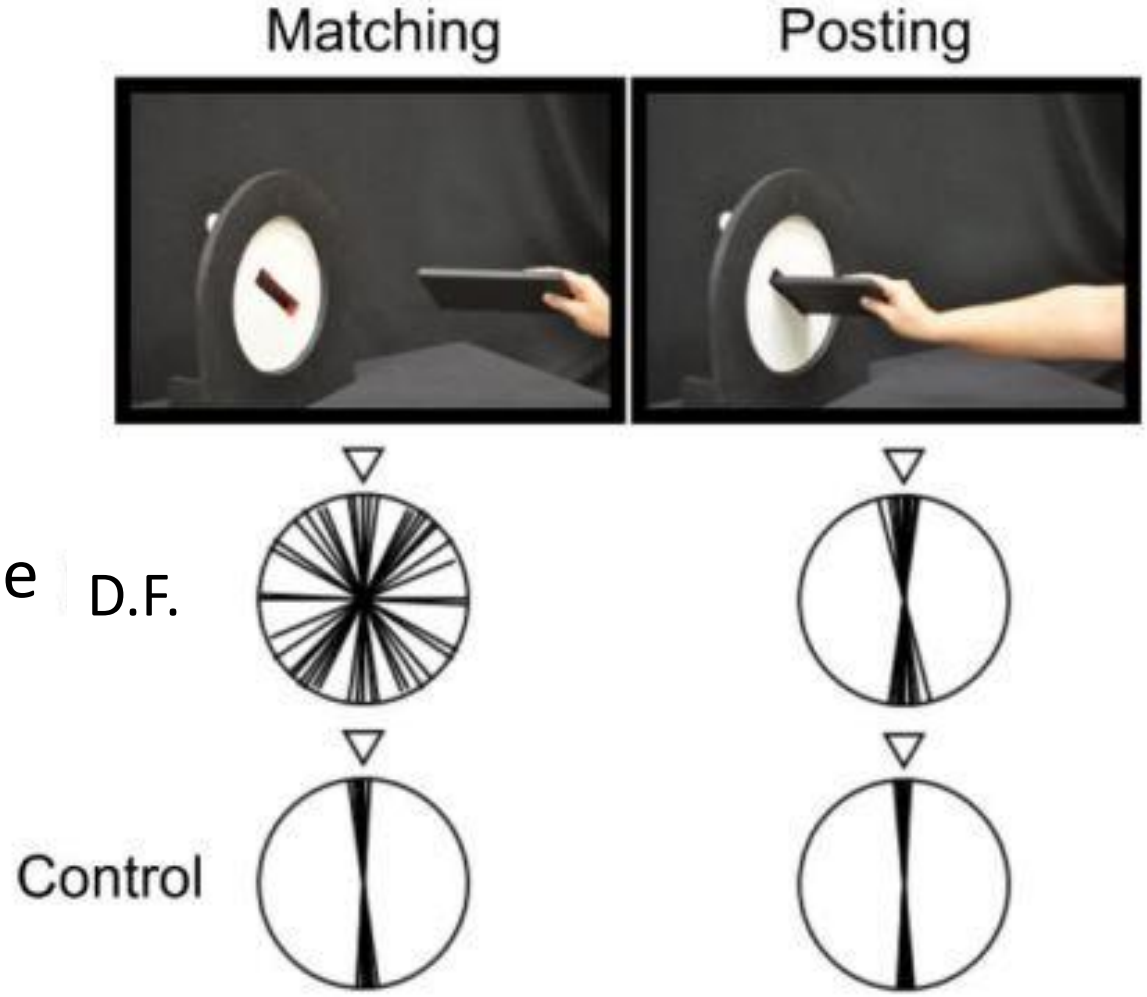
- Two anatomically and functionally distinct pathways
  - Dorsal stream
    - Information flows from primary visual cortex
    - Travels through dorsal prestriate secondary visual cortex
    - Ends in association cortex of posterior parietal region
    - Originally proposed to be “where” pathway
    - More recently proposed to be behavioral control path
  - Ventral stream
    - Information flows from primary visual cortex
    - Travels through the ventral prestriate secondary visual cortex
    - Ends in association cortex of posterior parietal region
    - Originally proposed to be “what” pathway
    - More recently proposed to be conscious perception pathway



Patient D.F. : Damage to The Ventral Stream



- Cannot visually perceive or name objects
- Can guide objects in the correct orientation (i.e., visuomotor processes intact)



Patient A.T. : Damage to The Dorsal Stream

- Can name objects, acknowledge their existence, but cannot properly grasp them
- Optic Ataxia
  - Difficulty guiding movements

Prosopagnosia: Damage to Ventral Stream

- Agnosia
- Prosopagnosia: inability to recognize faces
  - Specific area of brain dedicated to facial recognition
  - Possibly neurons of inferotemporal cortex
  - May not be specific to faces
    - May be difficult distinguishing between visually similar members of stimuli
  - Damage to fusiform face area
    - Confirmed prosopagnosia sufferers could recognize faces unconsciously
  - Prosopagnosia may not be a unitary disorder