Carlson (7e)

PowerPoint Lecture Outline

Chapter 6: Vision

Sensory Systems

- The brain detects events in the external environment and directs the contractions of the muscles
  - Afferent neurons carry sensory messages to brain
  - Efferent neurons carry motor messages to the muscles
- Stimulus: any energy capable of exciting a receptor
  - Mechanical
  - Chemical
  - Thermal
  - Photic
- Sensory energies are measurable (unlike ESP)

Sensory Receptors

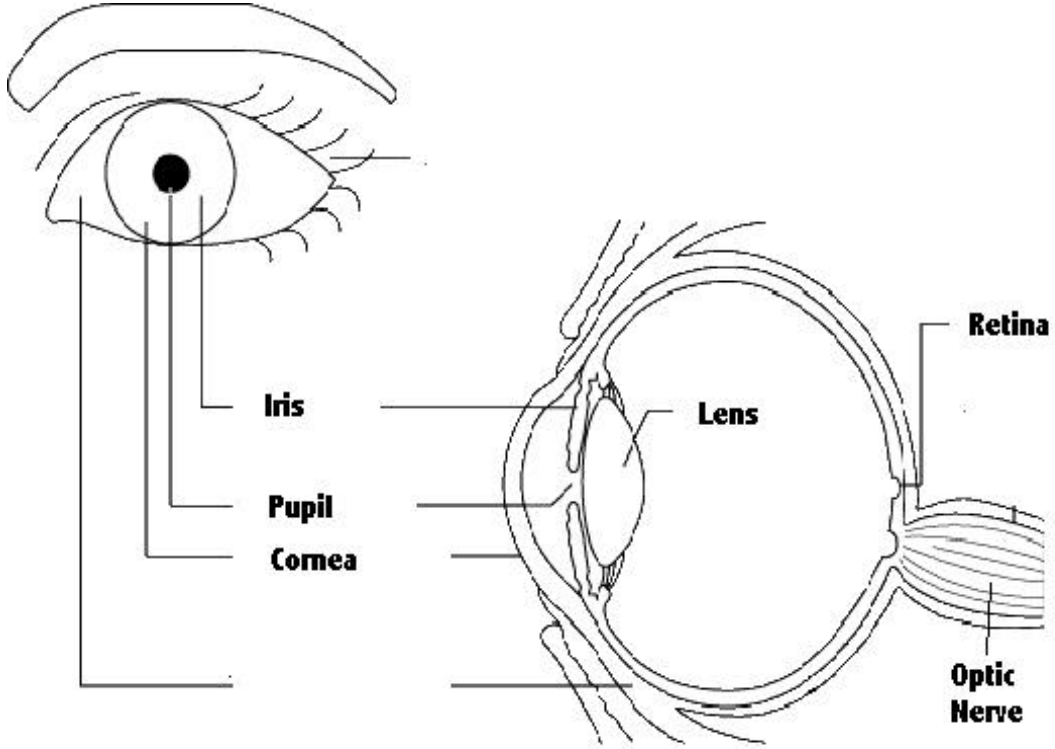
- Receptors are specialized nerve cells that transduce energy into neural signals
  - Receptors lack axons, form synapses with dendrites of other sensory neurons
- Receptors are "mode" specific
  - "Law of Specific Nerve Energies": sensory messages are carried on separate channels to different areas of the brain
- Receptors detect a small range of energy levels
  - Eye: 400-700 nM
  - Ear: 20-20,000 Hz
  - Taste buds: specific chemicals

Visual Systems

- The function of a visual system is to detect electromagnetic radiation (EMR) emitted by objects
- Humans can detect light with a wavelength between 400-700 nM
  - Perceived color (hue) is related to the wavelength of light
  - Brightness is related to the intensity of the radiation
- Functions of vision
  - Discriminate figure from background (food or rock?)
  - Detect movement (predator/prey?)
  - Detect color (adaptive value of color vision)

Eye Details

- An eye consists of:
  - Aperture (pin hole, pit, or pupil) to admit light
  - Lens that focuses light
  - Photoreceptive elements (retina) that transduce the light stimulus



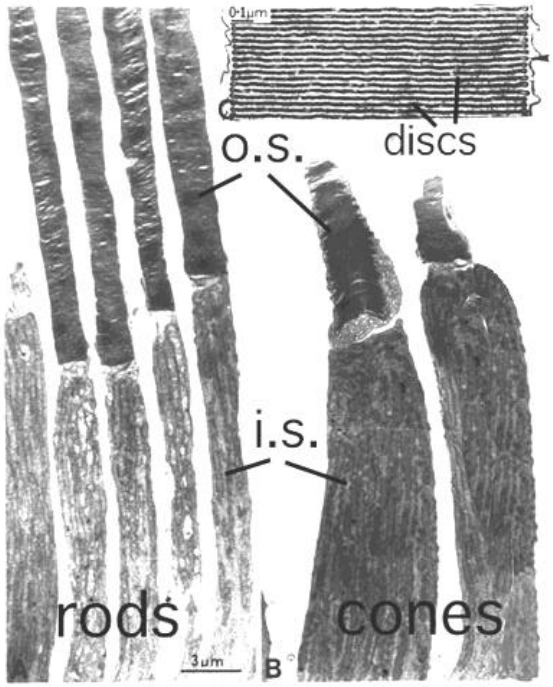
Source: http://www.nei.nih.gov/nei/vision/vision2.htm

Retina

- Light passes through the pupil and is focused by the lens onto the retina at the back of the eye
- The retina consists of three layers of cells
  - Ganglion cell layer
  - Bipolar layer
  - Photoreceptor layer: receptors in this layer transduce light
- The ganglion cell layer is the outermost layer and the photoreceptor layer is the innermost layer
  - In order to reach the photoreceptor layer, light actually passes through the outer two layers of the retina

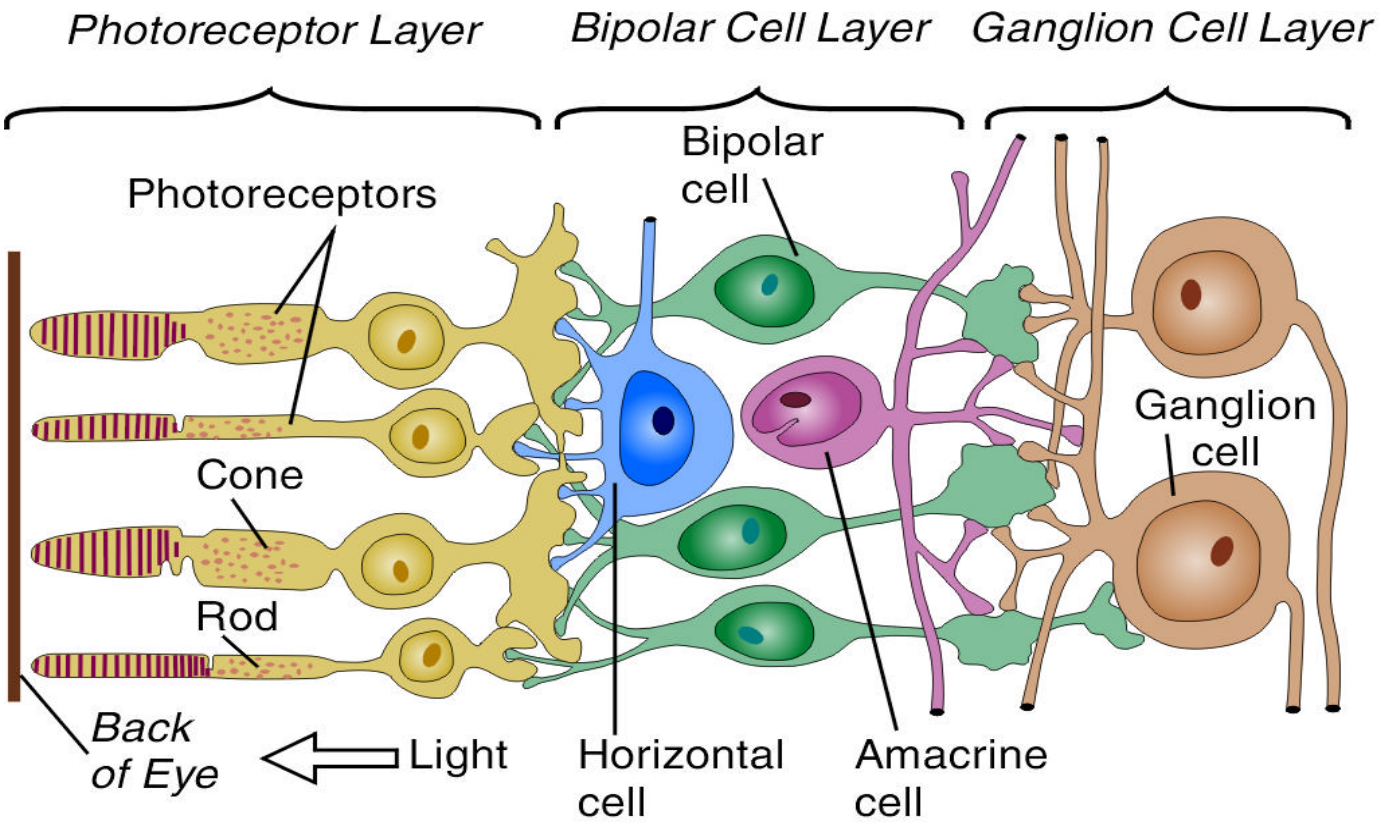
Rods and Cones

- Two types of photoreceptors are located within the retina
  - Rods: 120 million
    - Light sensitive (not color)
    - Found in periphery of retina
    - Low activation threshold
  - Cones: 6 million
    - Are color sensitive
    - Found mostly in fovea
- The outer segments (O.S.) of a rod or a cone contain different photopigments that react to light



Source: http://insight.med.utah.edu/Webvision/imageswv/rodcoEM.jpeg

Retinal Circuitry

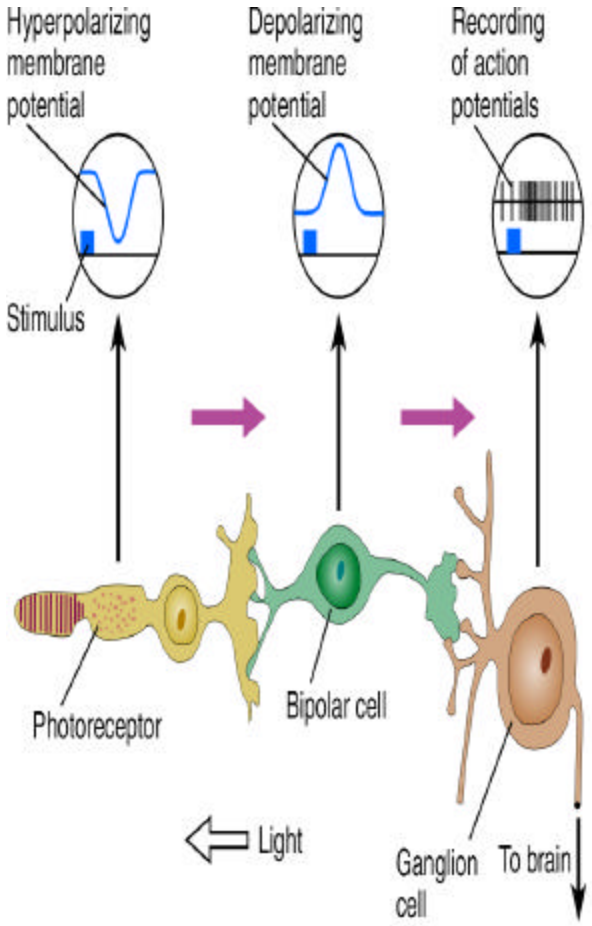


Adapted from Dowling, J.E., and Boycott, B.B. *Proceedings of the Royal Society of London*, B., 1966, *166*, 80-111.

Visual Transduction

- Photopigments are located in the membrane of the outer segment of rods and cones
- Each pigment consists of an opsin (a protein) and retinal (a lipid)
  - In the dark, membrane NA^+ channels are open -> glutamate is released which depolarizes the membrane
  - Light splits the opsin and retinal apart->
    - Activates transducin (G protein)->
    - Activates phosphodiesterase->
    - Reduces cGMP -> closes NA^+ channels
- The net effect of light is to hyperpolarize the retinal receptor and reduce the release of glutamate

Retinal Responses to Light

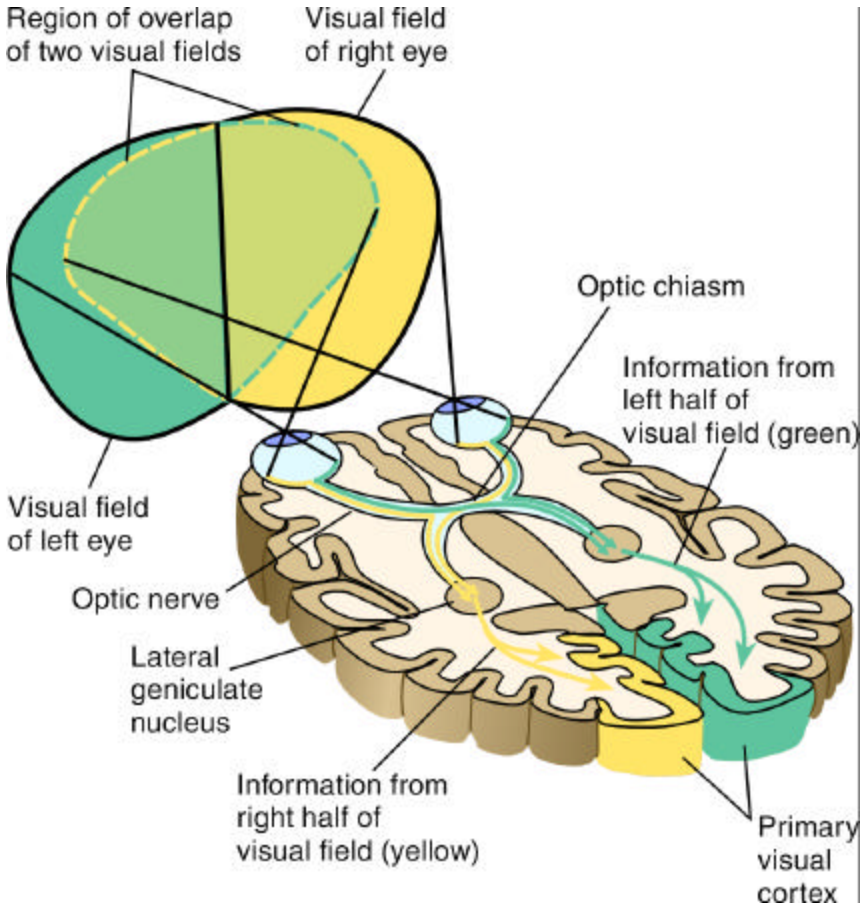


Visual Pathways

- Signals from the ganglion cells of the retina are sent to the thalamus via the optic nerve/tract
- The dorsal lateral thalamic nucleus (LGN) has 6 layers
  - Each layer receives input from only one eye
  - The inner 2 layers contain large cells (magnocellular)
  - The outer 4 layers contain small cells (parvocellular)
  - Koniocellular sublayers are ventral to each of the 6 layers
- Neurons of the LGN project through the optic radiations to a region of occipital cortex termed primary visual cortex (striate)

Primary Visual Pathway

- Information from each visual field crosses over at the optic chiasm and projects to the opposite side of the primary visual cortex

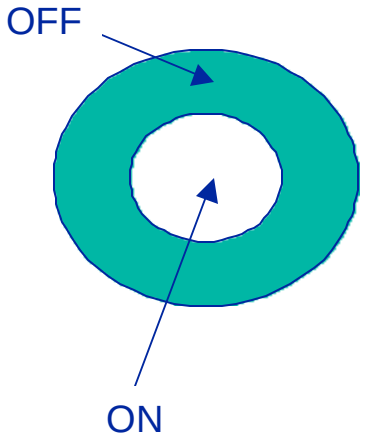


Receptive Fields

- Microelectrodes can be used to record the firing activity of a single sensory neuron
  - Sensory neurons have a background rate of firing (impulses/sec)
  - This rate of firing can increase or decrease in response to a stimulus
- Receptive Field (RF): Those attributes of a stimulus that will alter the firing rate of sensory cell
  - The general pattern of the RF can be recorded at each level of a sensory system (e.g. from a peripheral sensory receptor, the thalamus, or the cortex)
  - RF analyses can indicate the manner in which sensory information converges from level to level

Ganglion Cell Receptive Fields

- Ganglion cells in the retinal periphery receive input from many photoreceptors while ganglion cells in the fovea receive input from one photoreceptor
  - The receptive fields of ganglion cells are circular with a center field and a surround field
  - "ON-Cell":
    - Cell exhibits a low baseline firing rate
    - Light placed in center ring increases firing rate
    - Light placed on surround decreases firing rate
  - "OFF-Cell"
    - Light placed in center ring reduces firing rate
    - Light placed on surround increases firing rate

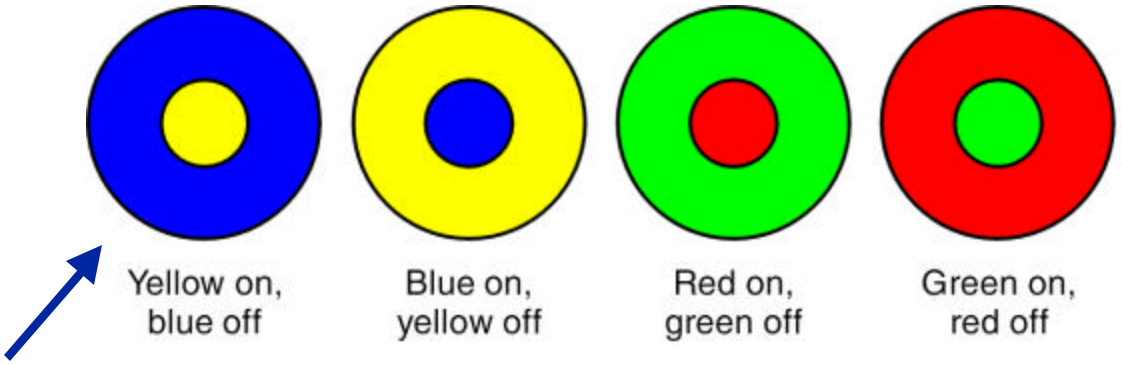


Color Vision Theories

- Trichromatic theory argued there are 3 different receptors in the eye, with each sensitive to a single hue
  - Any color could be accounted for by mixing 3 lights in various proportions
- Opponent theory notes that people perceive three primary colors: yellow, blue, and red
  - Yellow is a primary color rather than a mixture of red and blue-green light
  - Negative color afterimages suggest that red and green are complementary colors as are blue and yellow

Color Vision Systems

- Primate retina contains 3 types of photoreceptors
  - Each cone uses a different opsin which is sensitive to a particular wavelength (blue, red, green), supporting trichromatic theory
- At the ganglion cell level, the system responds in an opponent-process fashion

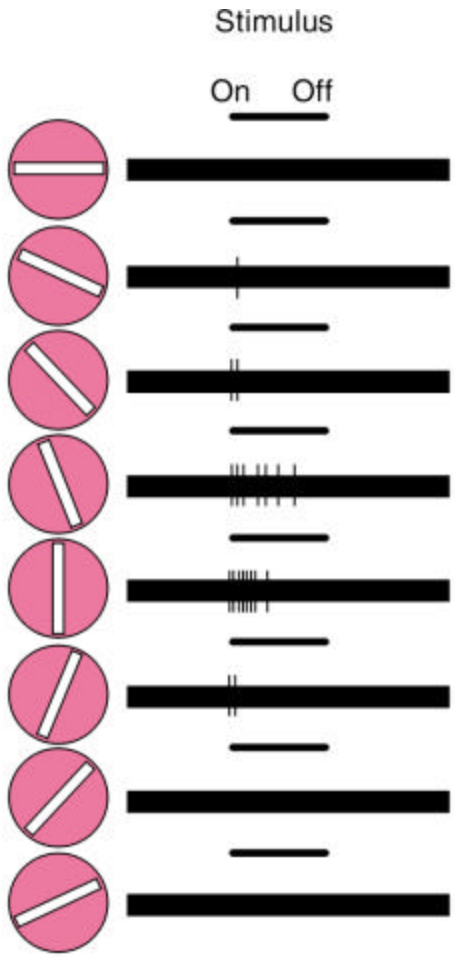


  - A given cell might increase its firing rate to yellow light in the center, but decrease it to blue light

Striate Cortex

- Striate cortex is organized into 6 layers
  - Layer 4c receives information from the parvocellular and magnocellular layers of the LGN
  - The visual information is the sent to layers above and below layer 4c for analysis
- Microelectrode receptive field studies have sought to identify the features of the external world that activate cells in striate cortex
  - Orientation sensitivity: some cells fire best to a stimulus of a particular orientation and fire less when orientation is shifted
  - Spatial frequency: cells vary firing rate according to the sine wave frequency of the stimulus

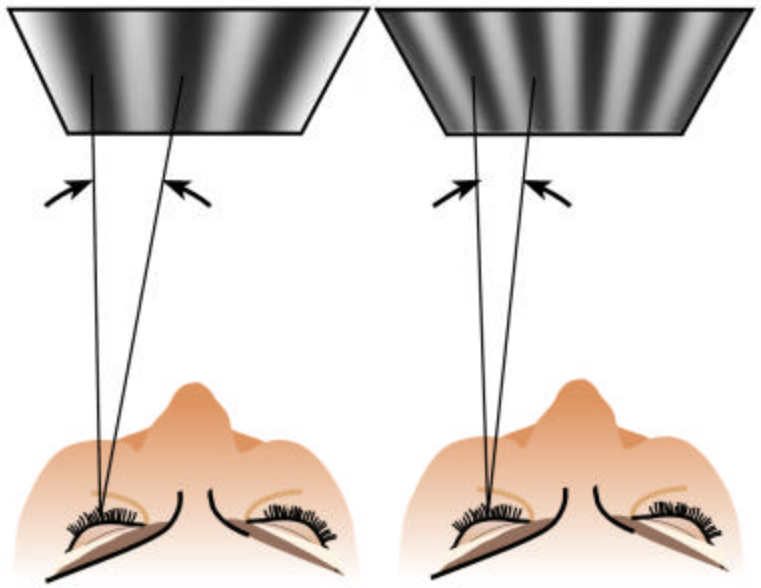
Orientation Sensitivity



← Best orientation

Spatial Frequency

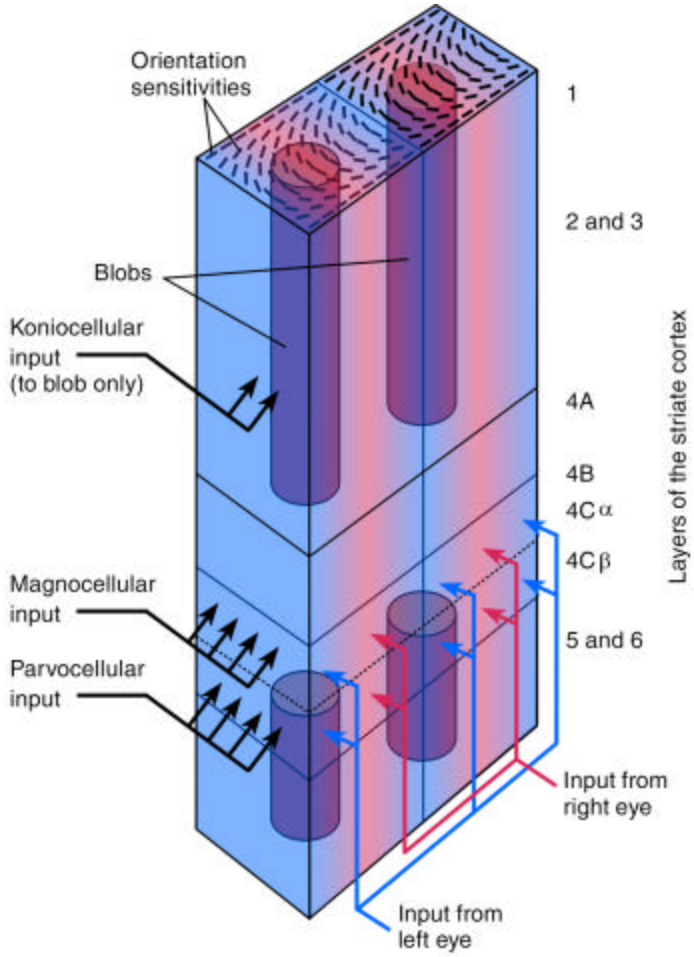
- Visual neurons respond to a sine wave grating:
  - Alternating patches of light and dark
    - Low frequency: large areas of light and dark
    - High frequency: fine details



Modular Organization of Striate Cortex

- Striate cortex is organized into modules (~2500)
  - Stains for cytochrome oxidase (CO) reveal two ”CO blobs” in each module
    - Cells within each CO blob are sensitive to color and to low frequency information
    - Outside each blob, neurons respond to orientation, movement, spatial frequency and texture, but not to color information
- Striate modules show
  - Ocular dominance: cells in each half of the module respond to only one eye
  - Orientation columns:
    - Cells respond to same orientation, adjacent cells are shifted by 10 degrees
    - Are organized at right angles to the ocular dominance columns

Modules in Visual Cortex



Visual System Divisions

- Magnocellular system
  - Cells from retina terminate in LGN layers 1,2 and then project to layer 4Cβ of striate cortex
    - Carry info on contrast and movement (color insensitive)
    - System is found in all mammals
- Parvocellular system
  - Cells from retina terminate in LGN layers 3-6 and then project to layer 4Cα of striate cortex
    - Carry info on fine detail, and color (red, green)
    - System is found in primates
- Koniocellular system
  - System projects from LGN to blobs in striate cortex
    - System carries color information (blue)
    - System is found only in primates

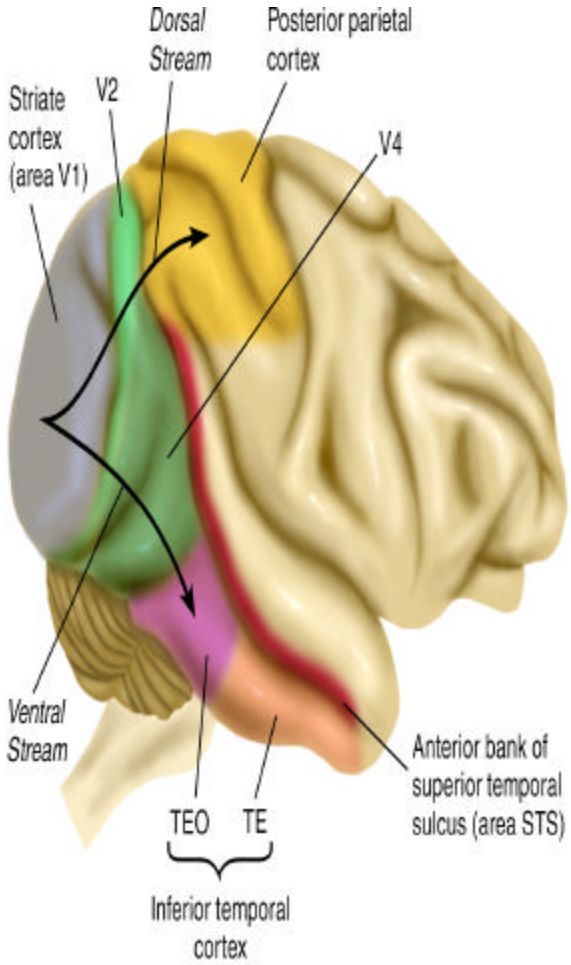
Visual Association Cortex

- Visual information is transmitted to extrastriate cortex (termed visual association cortex) via two streams
  - Dorsal stream: "where" an object is
    - Receives mostly magnocellular input
    - Projects to post. parietal association cortex
  - Ventral stream: "what" an object is (analysis of form)
    - Receives an equal mix of magnocellular and parvocellular input
    - Projects to extrastriate cortex (V2, V3, V4, V5) and to inferior temporal cortex (TEO, TE, STS)

Agnosia

- Agnosia refers to a failure to perceive or identify a stimulus by means of a sensory modality
  - Apperceptive visual agnosia is a failure in higher level perception
    - Person has normal visual acuity, but cannot recognize objects based on their shape
    - Prosopagnosia is a form of apperceptive visual agnosia in which the person cannot recognize a face visually, but can do when hearing their voice
  - Associative visual agnosia refers to a disconnection between perceptions and verbal systems
    - Person cannot name what they see

Visual Cortex



Summary of Visual Cortex

- V4: responds to color (and form perception)
  - Lesions of V4 impair color perception
- V5: responds to movement
- TEO: involved in color discrimination, 2-d pattern discrimination
  - TEO projects to area TE
- TE: neurons here respond to 3-d objects (a face or a hand)