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
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)
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

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

Hyperpolarizing membrane potential
Depolarizing membrane potential
Recording of action potentials

Stimulus

Photoreceptor
Bipolar cell
Ganglion cell
To brain

Light

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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

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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

  ![Diagram showing the response of ganglion cells to different colors.]

  - 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 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 activates 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

Stimulus
On  Off

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

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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

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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 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)

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