Chapter 6

Vision
Anatomy of vision

- Primary visual cortex (striate cortex, V1)
- Prestriate cortex, Extrastriate cortex (Visual association cortex)
- Second level association areas in the temporal and parietal lobes
  - Parietal cortex --- dorsal stream of visual information
  - Inferotemporal (lower part of temporal lobe) --- the ventral stream of visual information
- Other areas in brain also play role in vision such as the hypothalamus & tectum:
  - Tectum (midbrain) receive visual info. via the superior colliculi
  - Hypothalamus (forebrain) helped with arousal, control of attention to stimuli & help with day-night cycle
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
  – Saturation is related to the purity of the radiation
• Function of vision
  – Discriminate figure from the background (food or rock?)
  – Detect movement (predator/prey?)
  – Detect color (adaptive value of color vision)
The eye

- The **iris** is colored blue, green, brown or other shades of those colors, the colored portion of the eyes
- The **pupil**, opening in the iris, dilates (recall that indicates attractiveness or interest)
- The amount of light that enters the eye is regulated by the size of the pupil (test this by standing in front of a mirror in a dimly lit room vs. a bright room)
- The **cornea** would be the place one might put a contact lens
- The shape of the lens, altered by the **ciliary muscles**, allow us to focus on near or distant objects; process called **accommodation**
- **Retina** is the interior lining of the back of the eye with photoreceptor cells called rods and cones
- **Fovea** is central region of retina with only color sensitive cones
- Axons with visual info group together at the optic disk as get ready to leave thru optic nerve and produce a **blind spot** (no receptors)
- An eye consists of
  - Aperture (pupil to admit light)
  - Lens that focuses light
  - Photoreceptive elements (retina) that transduce the light stimulus
Retina

- Light passed 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 (in vision and audition)
  - Photoreceptor layer: receptor in this layer transduce light
- The ganglion cell layer is the outmost layer and the photoreceptor layer is the innermost layer.
Retinal Circuitry

- Light needs to pass through the outer two layers of the retina in order to reach the photoreceptor layer.
- The ganglion cells axons give rise to the optic nerve.
- Horizontal cells (here blue) and amacrine cells (here pink) combine messages and transmit info to retinal surface.

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
    - High acuity
- The outer segments of a rod or a cone contain different photopigments that react to light
  - Photopigment is special chemical that is the first step in visual perception: opsin + retinal

(from R. Young, Sci. Am. 223: 81-91 (1970))
Visual transduction

- **Transduction**
  - sensory events are transferred into changes in the cell's membrane potential (i.e., how receptor potentials come about in photoreceptor cells)

- **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, synthesized from Vitamin A)
  - 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 photodiesterase---
    - Reduces cGMP---close Na+ channels

- The net effect of light is to hyperpolarize the retinal receptor and reduce the release of glutamate

- Photoreceptors & bipolar cells do NOT produce Action Potentials (ganglion cells do)

- End result: light shining on the photoreceptors causes the ganglion cells to be excited.

Ganglion cells in the retinal periphery receive input from many photoreceptors.
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
  – Light placed in center ring increases firing rate
  – Light placed on surround decreases firing rate
  – ON cells help us detect light objects against dark backgrounds
  – Rod bipolar cells are all of the ON type

• OFF-Cell
  – Light placed in center ring reduces firing rate
  – Light placed on surround increased firing rate
  – OFF cells help us to detect dark objects against light backgrounds

• Interactive Java
Color vision theories

• Trichromatic theory argues there are 3 different receptors in the eye, with each sensitive to a single hue
  – Any color could be account 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 a red and blue-green light
  – Negative color afterimages suggest that red and green are complementary colors as are blue and yellow
• 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
• Protanopia, red and green hues confused, no red cones
• Deuteranopia, red and green hues confused, no green cones
• Tritanopia, blue cones lacking or faulty
Ganglion color coding

- At the ganglion cell level, the system responds in an opponent-process fashion.
- Ganglion level has red-green & blue-yellow (opponent-process); receptive field illuminated with the color shown, the cell rate of firing increases.
- E.g. red-green ganglion cells excited by red and inhibited by green.
• Information from each visual field crosses over at the optic chiasm and projects to the opposite side of the primary visual cortex
• Contralateral connection
• Interactive Java
Lateral Geniculate Nucleus (LGN)

- Retinal ganglion cells to thalamus via the optic nerve.
- 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)
    - perception of form, movement, depth, differences in brightness
    - in all mammals
  - The outer 4 layers contain small cells (parvocellular)
    - fine detail, and color (red, green)
    - in primates
  - Koniocellular cublayers are ventral to each of the 6 layers
    - color information (from short-wavelength blue cones)
    - Only in primates
- LGN neurons project through the optic radiations to primary visual cortex.
Primary Visual Cortex

• Primary Visual Cortex (Striate cortex, V1) is organized into 6 layers
  – 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 (different levels of information filtering)
  – Retinal disparity: most from magnocellular layer in LGN—binocular neurons in V1, response best when each eye sees a stimulus in a slightly different location. (permits 3D viewing)
  – Color: color sensitive ganglion cells—parvocellular and koniocellular layers in LGN--- special cells grouped in cytochrome oxidase (CO) blobs
Orientation Sensitivity

Response Characteristics of Neurons to Orientation in the Primary Visual Cortex

- Simple cell: orientation and location
- Complex cell: movement
- Interactive Java
- Hypercomplex cells: ends of lines
Modular organization of V1

- Striate modules show:
  - Ocular dominance: cells in each half of the module respond to only one eye
  - Orientation columns: orientation-sensitive
- V1 is organized into modules (~2500)
- Two ‘CO blobs’ in each module
  - Cells within each CO blob are sensitive to color and to low frequency information
    - Cerebral achromatopia– black and white
  - Outside each blob, neurons respond to orientation, movement, spatial frequency and texture, but not to color information
Visual association cortex

• Visual information is transmitted to extrastriate cortex (visual associated cortex) via two streams
  – Dorsal stream: ‘where’ an object is
    • Receives mostly magnocellular input
    • Projects to posterior parietal association cortex
  – Ventral stream: ‘what’ an object is (analysis of forms)
    • Receives an equal mix of magnocellular and parvocellular input
    • Projects to extrastriate cortex and to inferior temporal cortex
Responses to Objects and Location

Ventral stream--Agnosia

• Agnosia refers to a failure to perceive or identify a stimulus by means of a sensory modality, visual association cortex related

• Visual agnosia: the failure to recognize visual stimuli
  – Apperceptive visual agnosia
    • Normal visual acuity, but cannot recognize objects based on their shape
    • But by feeling or touching it they may be able to come up with the name
    • Cannot draw or copy an object
    • Damage to ventral stream
  – Prosopagnosia
    • Visual agnosia for faces
    • Recognize it’s a face but not whose face it is
    • Eg. Severe AD patients don’t recognize themselves
    • Fusiform face area (FFA)—faces and expertise recognition
  – Associate visual agnosia
    • Cannot name what they see
    • Can draw or copy an object
    • Disconnection between ventral stream and verbal systems
Dorsal stream—Balint’s syndrome

• Balint’s syndrome: a syndrome caused by bilateral damage to the parieto-occipital region
• Optic ataxia
  – Difficulty in reaching for objects under visual guidance
• Ocular apraxia
  – Difficulty in visual scanning, no fixation
  – See things but not able to direct gaze towards target
• Simultanaonosia
  – Difficulty in perceiving more than one object at a time
Summary of Visual Cortex

- **V1**—general scanning
- **V2**—stereo scanning
- **V3**—depth & distance
  - ‘Where’ (dorsal-post. parietal) path: V1-V2-V3-V5-V6, Balint’s syndrome
- **V4**—color
  - ‘What’ path (ventral-inferotemporal): V1-V2-V4, agnosia
- **V5**—motion: responds to movement—akinetopia
  - MSTd analyzes ‘optic flow’
- **V6**—objective position of object