9.01 Introduction to Neuroscience
Fall 2007

Chapter 9 and 10 Review – Vision

http://www.brown.edu/Courses/BN01/images/review/vision1.pdf
http://www.brown.edu/Courses/BN01/images/review/vision2.pdf
http://www.brown.edu/Courses/BN01/images/review/vision3.pdf

General
Properties of light (wavelength, color)
Refraction

- bending of light that occurs when light rays travel from one medium to another
- from air to water, light rays bend toward a line that is perpendicular to the water surface

The Big Picture
Visual stimuli → Eye (photoreceptors, bipolar cells, ganglion cells) → optic nerve (chiasm, tract) → LGN (thalamus) → primary visual cortex → dorsal and ventral visual areas

Eye

- Anatomy: iris, aqueous humor, ciliary muscles, vitreous humor, sclera, optic nerve, **retina**, **fovea** (highest acuity, only photoreceptors, no blood vessels), **cornea**, **lens**, extraocular muscles, optic disk (blind spot, where optic nerve exists retina, where blood vessels originate), macula, pupil
- Focusing an image on the retina requires:
    - Refraction by the cornea
    - Accommodation by the lens (important for focusing objects that are close)
        - Ciliary muscles contract (swell) → ligaments loosen → fatter lens, more refraction
        - Too fat a lens → myopia (nearsightedness), correct with concave eyeglass; too flat a lens → hyperopia (farsightedness), correct with convex eyeglass
- Retinal organization
    - Photoreceptors – hyperpolarize to light; depolarize (release glutamate) when dark
        - Two types: rods and cones
            - fovea has cones, periphery has more rods
            - rods specialized for low light and are used at night
            - cones specialized for color, used during the day
            - **higher photoreceptor-to-ganglion ratio in the periphery = less acuity**
        - Transduction: photoreceptors have steady influx of sodium ions because cGMP keeps channels open; light activates opsin (or photopigment; called rhodopsin for rods); opsin activates G-protein which activates phosphodiesterase; phosphodiesterase breaks down cGMP, closing channels; cell hyperpolarizes
    - Bipolar cells (retinal processing)
        - **Antagonistic center-surround receptive fields** (important for contrast)
        - OFF bipolar (responds to glutamate by depolarizing; gated cation channels)
        - ON bipolar (responds to glutamate by hyperpolarizing; G-protein-coupled receptors)
    - Ganglion cells (retinal output)
        - Also center-surround; receive input from corresponding type of bipolar cell
        - Mainly responsive to differences in illumination
        - Types: P-type (small, 90%), M-type (large, 5%), nonM-nonP (5%)
        - Color opponency
- Other topics: horizontal and amacrine cells; light and dark adaptation; pupillary light reflex

Optic Nerve, Chiasm, Tract

- At chiasm, axons from nasal retinas **decussate**; result: left visual field information carried by right optic tract; right visual field information carried by left optic tract
- What parts of your vision is lost when:
  - Left optic nerve is cut? Input from left
  - Chiasm is cut down the middle? Peripheral vision
  - Left optic tract is cut? Right visual field
- Targets of projection: LGN (thalamus) to striate cortex, hypothalamus, superior colliculus.

Lateral Geniculate Nucleus

- Six layers labeled 1 through 6 (most ventral layer is 1)
- Retinal information separated by eye and ganglion cell type:
  - Ipsilateral axons synapse on LGN layers 2, 3, 5; contralateral axons on 1, 4, 6
  - Magnocellular LGN layers (1 and 2) receive input from M-type ganglion cells; parvocellular LGN layers (3-6) receive input from P-type; and koniocellular layers (lie just ventral to each numbered layer) receive input from non-M-non-P
- **LGN neuron receptive fields almost identical to those of ganglion cells that innervate them**
  - Magnocellular LGN neurons: large center-surround fields, insensitive to differences in wavelength, respond to stimulation with transient burst of action potentials
  - Parvocellular LGN neurons: small center-surround; many exhibit color opponency; sustained increase in frequency of action potentials
  - Koniocellular LGN neurons: center-surround; light/dark or color opponency

Striate Cortex (V1, Area 17, primary visual cortex)

- Six layers (I through VI; IV divided into A, B, and C; IVC into α and β)
- Input
  - Most axons from LGN terminate in IVC – cell type and eye separation maintained in IVC
    - Magnocellular LGN neurons project to IVCα; parvocellular to IVCβ
    - Right, left eye inputs separated via **ocular dominance columns** (autoradiography)
  - Koniocellular LGN axons project to II and III blob regions
- Processing
  - Radial connections (perpendicularly across all layers), horizontal connections (in one layer)
  - Blobs (seen with **cytochrome oxidase**) run along II, III, V, VI
  - IVC neurons project to II, III, IVB → some information integrated, processed; II and III receive binocular input
- Output
  - II, III, IVB → cortical areas
  - V → superior colliculus, pons
  - VI → back to LGN
- Receptive fields
  - Binocularity
  - Orientation selectivity
  - Direction selectivity
  - Simple and complex receptive fields
  - Blob receptive fields
- Other: cortical modules

Beyond Striate Cortex

- Dorsal stream ("where" pathway) – motion processing
  - Area MT (V5) – respond to movement in range of directions
  - Area MST – additional movement sensitivity (linear, radial, circular motion)
- Ventral stream ("what" pathway) – object shape, color processing
  - Area V4 – shape and color perception (**achromatopsia** – loss of color vision)
  - Area IT – faces (**prosopagnosia** – difficulty recognizing faces)

Coding

- Retinotopy (2D surface of retina is mapped onto 2D surface of LGN, striate)
  - Mapping of visual field often distorted (greater representation of fovea)
  - Discrete point of light can activate many cells in the retina, more in target structures, because of overlapping receptive fields; activity in cortex is broad distribution with peak at specific retinotopic location
  - Not literal map; no pictures in the brain
- Parallel processing
  - Left and right eyes
  - ON and OFF bipolar and ganglion cells
  - M- and P-type ganglion cells
  - Three channels in V1
    - Analysis of **MOTION**: magnocellular pathway = M-type ganglion cells → magnocellular layers of LGN → IVCα of cortex → IVB; receptive fields = binocular simple/complex, orientation selective, direction selective
    - Analysis of **SHAPE/FORM**: parvo-interblob pathway = P-type ganglion cells → parvocellular layers of LGN → IVCβ of cortex → II and III interblob regions; receptive fields = orientation selective, simple/complex
    - Analysis of **COLOR**: blob pathway = convergence of parvocellular, magnocellular, and koniocellular inputs; receptive fields = center-surround, color opponency monocular