Quiz questions
– Which two structures in the eye are responsible for refracting light so that it is in focus on the back of the retina?
– Which type of ganglion cell is more sensitive to light? (midget/parasol)
– On-center off-surround cells give their maximal response to what kind of stimulus?

Retinal Ganglion Cells and Stripes
– Retinal cells: like spots of light
– Visual Acuity: Oh Say, Can You See?
– Selective Adaptation: The Psychologist’s Electrode

Response of ON-center Retinal Ganglion Cell

Visual Acuity: Oh Say, Can You See? (cont’d)
– What is the path of image processing from the eyeball to the brain?
Mapping of Objects in Space onto the Striate Cortex

The Lateral Geniculate Nucleus

- Two lateral geniculate nuclei (LGNs):
  - axons of retinal ganglion cells synapse there

The Lateral Geniculate Nucleus (cont'd)

- Two types of layers in LGN:
  - magnocellular
  - parvocellular
- visual space in the brain
  - left visual hemifield
    - right hemisphere
  - right visual hemifield
    - left visual hemisphere

The Lateral Geniculate Nucleus (cont'd)

- ipsilateral:
  - to the same side of the body (or brain)
- contralateral:
  - to the opposite side of the body (or brain)

Striate Cortex

- Striate cortex
  - also known as primary visual cortex or V1
  - major transformation of visual information takes place in striate cortex
  - 200 million cells!
    - photoreceptors (100 million)
    - optic nerve fibers (1 million)
• Two important features of striate cortex:
  – topographical mapping
  – cortical magnification
    • dramatic scaling of information from different parts of visual field

• Visual acuity declines in an orderly fashion with eccentricity

• Binocularly driven cells
  – each LGN cell responds to one eye or the other, but never to both
  – each striate cortex cell can respond to input from both eyes (although most have a preferred eye)

• Many cortical cells respond especially well to:
  – moving lines
  – bars
  – edges
  – gratings
  – direction of motion

• Hubel and Wiesel (1962)
  – architecture of visual cortex of the cat
  – Recorded from cells in cat V1
Orientation Tuning Function of a Cortical Cell

Receptive Fields in Striate Cortex (cont'd)

- How are the circular receptive fields in the LGN transformed into the elongated receptive fields in striate cortex?
  - Hubel and Wiesel:
    - scheme to accomplish this transformation

Receptive Fields in Striate Cortex (cont'd)

- Selective Responsiveness:
  - orientation tuning
    - tendency of neurons in striate cortex to respond optimally to certain orientations, and less to others
  - ocular dominance
    - cells respond to “matched” input from both eyes but prefer one eye

Orientation and Ocular Dominance Columns in the Cortex

Columns and Hypercolumns

- **orientation column**: vertical arrangement of neurons
  - systematic, progressive change in preferred orientation; all orientations were encountered in a distance of about 0.5 mm (Hubel & Wiesel)
- **hypercolumn**:  
  - a 1-mm block of striate cortex containing “all the machinery necessary to look after everything the striate cortex is responsible for, in a certain small part of the visual world” (Hubel, 1982)
**Receptive Fields in Striate Cortex (cont'd)**

- Simple cells vs. complex cells
  - **Simple cells**
    - Receptive field has well defined excitatory and inhibitory regions
  - **Complex cells**
    - Respond well to a preferred stimulus anywhere in the receptive field
  - **End-stopped cells**

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**Response of Simple vs. Complex Cells**

- Stimulus extending beyond the receptive field

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**Columns and Hypercolumns (cont'd)**

- Regular array of “CO blobs” in systematic columnar arrangement (discovered by using cytochrome oxidase staining technique)

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**Visual Acuity & Contrast**
• **contrast:**
  – the difference in illumination between a figure and its background
  \[ \frac{(L_{\text{max}} - L_{\text{min}})}{(L_{\text{max}} + L_{\text{min}})} \]

• **acuity:**
  – the smallest spatial detail that can be resolved

• Measuring visual acuity:
  – eye doctors use distance (e.g., 20/20)
  – vision scientists use the smallest visual angle of a cycle of grating

• Herman Snellen invented method for designating visual acuity in 1862

  - Snellen acuity
    – Distance at which one can just identify the letters
    – %
    – Distance at which person with "normal" vision can identify letters
  
  - "normal" vision
    – 1 cycle of a grating subtends .017 degs of VA
  
  - Center-to-center cone spacing in fovea .008 degs

• Simple acuity test
• sine wave gratings
  – spatial frequency (cycles/degree)
  – amplitude (contrast)
  – visual thresholds
    • defined by lowest contrast at which a grating of a certain frequency can be resolved

The visual system "samples" the grating discretely

• spatial frequency:
  – number of cycles of a grating per unit of visual angle (usually specified in degrees)
  – (measure relative to viewing distance)

• cycles per degree: number of dark and bright bars per degree of visual angle

• Why sine gratings?
  – patterns of stripes with fuzzy boundaries are quite common
  – edge of any object produces a single stripe, often blurred by a shadow, in the retinal image
  – visual system appears to break down images into vast number of components, each is a sine wave grating with particular spatial frequency
Adaptation

- Selective Adaptation: The Psychologist’s Electrode
  - method of adaptation:
    - diminishing response of a sense organ to a sustained stimulus

Selective Adaptation (Part 1)

Selective Adaptation (Part 2)

Stimuli for Demonstrating Selective Adaptation

- Tilt aftereffect: perceptual illusion of tilt, following adaptation to a pattern of a given orientation
  - supports the idea that the human visual system contains individual neurons selective for different orientations
Selective Adaptation: The Psychologist’s Electrode (cont’d)

- Selective Adaptation to spatial frequencies:
  - evidence that human visual system contains neurons selective for spatial frequency

- Source of adaptation effects
  - Cortex? LGN?
- Interocular transfer of adaptation?
  - adaptation experiments provide strong evidence that orientation and spatial frequency are coded by neurons somewhere in the human visual system
    - cats, monkeys:
      - striate cortex, not in retina or LGN
    - humans operate the same way as cats and monkeys with respect to selective adaptation

- spatial frequency channels
  - Why would the visual system use spatial frequency filters to analyze images?
    - different spatial frequencies emphasize different types of information
The Girl Who Almost Couldn’t See Stripes

• Story of Jane:
  – abnormal early visual experience resulting in possibly permanent consequences

The Girl Who Almost Couldn’t See Stripes (cont’d)

• Monocular from deprivation can cause massive changes in cortical physiology, resulting in devastating and permanent loss of spatial vision

The Girl Who Almost Couldn’t See Stripes (cont’d)

• Cataracts: strabismus can lead to serious problems, but early detection and care can prevent such problems