Horseshoe crabs…
Astigmatism

• **What Causes It?**
  
  – Researchers don’t fully understand why some people develop astigmatism and others don’t. Some infants are born with astigmatism, however most people acquire it later in life. Most refractive errors tend to stabilize by age 25-30. Some explanations for acquired astigmatism include:
  
  • The weight of the upper eyelid resting on the eyeball
  • Healed corneal lacerations (scarring).
  • Blunt eye trauma (being hit in the eye).
  • Scarring in the cornea from other causes like infections.
  • Changes in corneal shape following eye surgery.
• **Acuity:** The smallest spatial detail that can be resolved

**Visual Acuity**

• Measuring visual acuity:
  - Eye doctors use distance (e.g., 20/20)
  - Vision scientists use the smallest visual angle of a cycle of grating
Sine wave gratings

The visual system “samples” the grating discretely
Visual Acuity

- **Spatial Frequency**: The number of cycles of a grating per unit of visual angle (usually specified in degrees)

- **Cycles per degree**: The number of dark and bright bars per degree of visual angle
Visual Acuity

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

Retinal Ganglion Cells and Stripes

• Retinal cells: like spots of light
Response of ON-center Retinal Ganglion Cell

- As the pattern of light reflected off objects in the world enters the eye, it is flipped upside-down.
- This upside-down pattern of light is the retinal image.

Representation of the Visual Field in the Brain

- The spatial structure of the retinal image is preserved as neurons from the retina connect to the LGN, and is still preserved further along in the cortex.
Visual Fields

• Although you have two eyes, and slightly different images in each eye, the brain does not keep the information from the two retinas separate
• Instead, it splits the world into a left and right visual field

Check out figures to understand this wiring pattern…
After leaving the retina, the outputs of each eye are split

- The *nasal* (toward the nose) half of each eye's visual field crosses from one side to the other at the optic chiasm
- The *temporal* half (towards the temple) remains on the same side as its eye-of-origin
  - *This splitting and crossing re-organizes the retinal outputs so that the left hemisphere processes information from the right visual field, and the right hemisphere processes information from the left visual field*

Visual processing beyond the retina

- **Major Pathways**
  - optic chiasm
    - medial fibers cross over
    - left visual field processed in right hemisphere
    - right visual field processed in left hemisphere
Mapping of Objects in Space onto the Striate Cortex
• Retinal ganglion cells actually come in (at least) 2 flavors:
  - M (magnocellular): resolve motion and course outlines (part of dorsal—*where*—pathway)
    • Operate with great speed...at the expense of detail
  - P (parvocellular): detail, including color (part of ventral—*what*—pathway)
    • Have greater spatial resolution, but worse temporal resolution, than their magno counterparts
    • Are phylogenetically more recent than magno neurons
Thalamus contains…

- **dorsal lateral geniculate nucleus (LGN)**
  - Left and right LGN
- Two types of layers in LGN: Magnocellular vs. Parvocellular
  - 6 layers in each
  - Forms a “retinotopic map”
    - Locations in LGN correspond to locations on the retina
  - Output of LGN forms the **optic radiations**

*A Photomicrograph of a Section Through the Right Lateral Geniculate Nucleus of a Rhesus Monkey*

Occipital Lobe

primary visual cortex ("striate cortex" due to "striped" appearance)
Striate Cortex Anatomy/Function

- six major “layers”
- mapped to contralateral half of visual field
  - Cortical magnification devotes 25% to foveal vision
- processes the “features” of visual stimuli
  - higher-order (that is, does not merely respond to “spots” of light)

Primary Visual Cortex: V1

- V1 has a topographic/retinotopic map of the visual world
- This means that there is a "neural image" retaining the spatial layout of the pattern of light that falls on the retina
- This map has several interesting characteristics

Characteristics of Retinotopic Map

- Remember that there are 2 V1s in each person (left and right hemispheres)
  - Each V1 has a representation of the opposite half of the visual field (e.g., left V1 has a map of the right visual field, and vice versa)
  - Each V1 does not simply receive input from the opposite eye; the outputs of each retina are split (left half/right half) and then run through the LGN to the appropriate V1
Characteristics of Retinotopic Map

• Just as the image of the world is inverted when projected onto the retina, the retinotopic V1 map is upside down (and the right hemisphere's V1 has a topographic map of the left visual field, and vice versa)

• Cortical magnification
  – more cortical space is dedicated to the fovea than the periphery (remember the higher density of photoreceptors in the fovea, hence clearer vision)

3 main types of cells in primary visual cortex

• Simple
• Complex
• End-stopped (formerly Hypercomplex)
Simple

- Receptive fields often have a long, narrow bar of light (ON) and flanking (OFF) parts
- Other types are the opposite (responding to dark bars) or simply respond to a light/dark edge

Complex

- Bars of light must be oriented correctly, but can appear anywhere in the receptive field
- Moving the bar through the field produces a sustained response
- Complex cells often show direction-selectivity:
  - they fire more when the bar moves in one direction, and are suppressed by motion in the opposite direction
End-stopped (formerly Hypercomplex)

- Many simple and complex cells exhibit *length summation*
  - if an appropriate bar is placed in the visual field, they fire action potentials; if the bar is made longer, they fire more, up to the extent of the full receptive field
- However, end-stopped cells increase their responses with increases in bar length up to a limit that is smaller than the receptive field

Ocular Dominance Columns
Ocular Dominance Columns

Architecture of V1

- Orientation columns:
  - as you move perpendicular to the surface, the preferred orientation of the cells changes gradually from horizontal to vertical and back again
Orientation Columns combine with Ocular Dominance Columns

FIGURE 4.17
Orientation and ocular dominance columns in the visual cortex. All cells in a column have the same orientation preference and the same ocular dominance. An aggregate of columns representing a complete range of preferences is known as a hypercolumn.
Columns and Hypercolumns

- **Column**: A vertical arrangement of neurons
  - Hubel and Wiesel: Found systematic, progressive change in preferred orientation; all orientations were encountered in a distance of about 0.5 mm

- **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)