Visual Pathways

- The visual field is divided in half:
  - The right visual field
  - The left visual field

Visual Pathway (continued)

- The left visual field falls on the nasal portion of the left eye and the temporal portion of the right eye.
- The right visual field falls on the nasal portion of the right eye and the temporal portion of the left eye.

Visual Pathway (continued)

- Optic Nerve (prechiasmatic nerve) carries information from an eye.
- Optic chiasm
- Optic tract (postchiasmatic nerve) carries information from a visual field.
- Superior colliculus (visual reflex)

Visual Pathway (continued)

Geniculostriate system

- The visual pathway consists of two fundamental channels of processing.
  - The dominant channel for humans and other advanced species involves:
    - 1) the eye
    - 2) the lateral geniculate nucleus (LGN)
    - 3) the striate cortex (because of its striped appearance)
- These structures, for the most part, can be considered to be connected sequentially.
- This channel of processing is referred to as the geniculostriate system
Visual Pathway (continued)

Corticofugal system

Visual Pathway (continued)

Tectopulvinar system

- The second channel of processing involves:
  - 1) the eye
  - 2) the superior colliculus of the tectum
  - 3) the pulvinar nucleus and lateral posterior nucleus of the thalamus
- This channel is often referred to as the tectopulvinar system.
- The cortical destination of this channel is not the striate cortex but a region just anterior to the striate cortex called the prestriate cortex.
- The prestriate cortex receives input from the striate cortex.
- Both channels of processing converge at this point.

Visual Pathway (continued)

Tectopulvinar system

- In higher species (including humans), the tectopulvinar system serves to process sensory information relating to the location of images in the visual field.
- It also enables the eye muscles to fixate upon specific images in a coordinated way.
- These eye muscles are innervated by three cranial nerves
  - 3rd cranial nerve (Oculomotor nerve)
  - 4th cranial nerve (Trochlear nerve)
  - 6th cranial nerve (Abducens nerve)
- These cranial nerves originate from the tectum.

Information Processing

- As we move away from the receptors and towards the brain
  - Our major concern will be to answer the question:
    - What kinds of information are carried by neurons at different levels of the visual system?
  - How do we process patterns of light so that eventually we arrive at recognizable forms?
  - How do we go from reactions to light to the perception of objects?
  - Until the 1950s, very little was known about how the features of an image were processed by the visual pathway.
- The development of single-cell recording techniques revolutionized this area of research.

Receptive Field

- In order to understand the data arising from single-cell recording studies of pattern vision
  - It is critically important first to understand the basic experimental procedure and the concept of the receptive field.
- Recording electrodes are implanted to monitor action potentials in individual cells.
  - at the ganglionic, thalamic or cortical level of the visual pathway
- Experimental subjects (usually cats or monkeys) are shown images projected on a screen.
  - The animals are kept immobile with their eyes open.
- As a result, it is possible to monitor a single cell's activity while the animal is viewing the image.
- A particular location of the image on the screen relates directly to a particular area of the animals' retina.
Receptive Field (continued)
• A baseline rate of responding for the neuron under study has to be first determined.
• This baseline measure is simply the average number of action potentials emitted in one second's time.
• When this is accomplished, various points of the screen are illuminated until some change from baseline rate is noted.
• An increase
• Or decrease from baseline
• There can be no a priori notion of what kind if image or pattern of light the neuron will respond to.
• It has to be, at least initially, a matter of trial and error.
• Eventually, it is possible to determine the optimal pattern on the screen that induces either an excitatory response or inhibitory response for a specific neuron.

Receptive Fields of Ganglionic Cells
Stephen Kuffler

Receptive Fields of Ganglionic Cells
• In the early work by Kuffler (1953), two types of receptive fields in ganglionic cells were found.
• The first type was characterized as a circular excitatory zone with a concentric inhibitory zone around it.
• Ganglionic cells having fields of this type were termed on-center, off-surround cells.
• Any light projected on the excitatory zone would increase the response rate of the ganglionic cell.
• Any light projected on the inhibitory zone would decrease it.
• A maximal amount of increase would be achieved by a spot of light completely covering the excitatory zone.
• Likewise, a maximal amount of decrease would be achieved by a doughnut-shaped image of light covering the entire inhibitory zone.

Receptive Fields of Ganglionic Cells
• The second type of receptive field had the opposite characteristics.
• A circular area was the inhibitory (off) zone.
• And the surrounding area was the excitatory (on) zone.
• Ganglionic cells with receptive fields of this type were called off-center, on-surround cells.
• Kuffler found in his studies that diffused light over the entire screen failed to cause a significant change from baseline response rate.
• Presumably, this was a result of stimulating both excitatory and inhibitory zones simultaneously canceling each other out.
• How could ganglionic cells have such strange receptive fields?

Receptive Fields of Ganglionic Cells
• One possible explanation is that ganglionic cells receive input from two groups of bipolar cells.
• One group of bipolar cells might communicate by an excitatory synapse.
• The other group by an inhibitory one.
• The stimulation of receptors in an excitatory zone would involve the stimulation of bipolar cells excitatory to the ganglionic cell in question.
Receptive Fields of Ganglionic Cells

- More recently, another class of ganglionic cells (called W cells) have been discovered, bringing the total to three.
- The axons of W cells have a very slow conduction speed.
- Their receptive fields are very large, exceeding that of parvo or magno cells.
- Like magno cells, W cells are evenly distributed in the retina and extend to the LGN and superior colliculus.
- The functional significance of parvo, magno, and W cells might lie in the distinction between
  - perception of finely discriminated stimuli
  - the perception of moving stimuli.²⁵

Receptive Fields of Ganglionic Cells

- In subsequent studies of ganglionic cells receptive fields, two kinds of ganglionic cells have been identified:
  - parvo cells (X cells) and magno cells (Y cells)
    - parvo cells respond in a sustained manner as long as the light is presented in their receptive fields.
    - magno cells respond in a more transient manner.
    - The receptive fields of parvo cells are smaller than those of magno cells.
    - parvo cells are located near the fovea, while magno cells are distributed more evenly in the retina.
    - Finally, the two types of cells have different destinations further along the visual pathway:
      - Axons of parvo cells extend to the LGN exclusively.
      - Axons of magno cells extend to both the LGN and the superior colliculus.²⁵

Receptive Fields of Ganglionic Cells

- Figure 7-10. Three stimulation patterns affecting X and Y cells in different ways. If the illumination pattern in A were presented to a cell with a concentric receptive field then shifted to a new orientation (either B or C), a Y cell would respond to the change while an X cell would not. (From Coren, S., Ponec, S. & Ward, S.B., Sensation and Perception 2nd ed., New York: Academic Press, 1984, p. 75. Copyright © 1984 by Harcourt Brace Jovanovich, Inc., reproduced by permission of the publisher.)

Receptive Fields of Ganglionic Cells

- The W cells appear to be relatively poor in responding to detail or movement.
- Their overall function remains very obscure.
- With respect to parvo cells versus magno cells, it is perhaps significant that the cells that are sensitive to fine details
  - are the ones that project to the LGN alone,
  - while the cells that are sensitive to movement are the ones that have projections to the superior colliculus.
- This distinction would fit into the general orientations of the geniculostrate (parvo cells) and tectopulvinar (magno cells) system respectively.²⁵
Receptive Fields of Ganglionic Cells
- This view would be consistent with a recent hypothesis:
  - That magno cells provide the basis for a basic level of form vision,
  - whereas the parvo cells provide an extra improvement in pattern recognition by increasing the spatial resolution.
  - It would make sense that the basic system (magno cells) would be associated with the superior colliculus,
  - as an earlier processing system in evolution.
  - while an improved system (the parvo cells) would be associated with the LGN.

Receptive Fields of the LGN Cells
- The lateral geniculate nucleus (LGN) is the first place that ganglion cells in the primary visual pathway synapse.
- When Hubel and Wiesel explored the receptive fields of the LGN cells in the thalamus,
  - they found roughly the same types that Kuffler had previously seen at the ganglionic cell level.
- Most LGN cells can also be classified as either parvo or magno cells.
- Many neurons in the LGN play an important role in color vision.
  - If we look at a cross section of the LGN we will notice that it has six layers.

Receptive Fields of the LGN Cells
- Each layer receives input from only one eye
  - with layers 2, 3, and 5 receiving input from the ipsilateral eye
  - layers 1, 4, and 6 receiving input from the contralateral eye.
- That is, the different layers receive information from the same visual field.
  - The topography of layer 6 matches that of the retina.
  - The receptive fields of neurons encountered along an electrode track perpendicular to the surface of the LGN all have approximately the same location on the retina.

Receptive Fields of the Visual Cortex
David Hubel & Torsten Wiesel
Receptive Fields of the Visual Cortex

- The cells of the visual cortex have been explored by David Hubel and Torsten Wiesel.
- The primary receiving area for visual information, and the first stop in the neocortex for visual processing, is designated Area 17 or striate cortex.
- Area 18 and 19 (preatistriate cortex), lying just anterior to Area 17, are considered secondary receiving areas for visual information.
  - Area 17 (striate cortex) and Areas 18 and 19 (preatistriate cortex) are sometime referred to as V1.

Receptive Fields of the Visual Cortex

- When Hube1 and Wiesel investigated the receptive fields of neurons in the visual cortex.
- They found that three functional groups existed:
  - simple cortical cells
  - complex cortical cells
  - and hypercomplex cortical cells
- The simple cortical cell, located in the striate cortex (Area 17) region of the visual cortex.
  - was found to have particular sensitivity to stimulation of light when the image was elongated.
  - oriented at a particular angle.
  - and localized to a specific region of the retina.

Receptive Fields of the Visual Cortex

- How could these receptive fields arise?
- Hubel and Wiesel offered an ingenious explanation.
  - According to their model, simple cortical cells receive input from a group of LGN cells.
  - each of which had receptive fields that were:
    - overlapping
    - and arranged in a linear fashion on the retinal surface.

Receptive Fields of the Visual Cortex

- One advantage of having simple cortical cells with this configuration would be that discrimination of linear forms could be made.

Receptive Fields of the Visual Cortex

- In other words, the perception of a vertical line would be possible
  - by the stimulation of simple cortical cells with a vertical oriented receptive field.
- The simple cortical cells have sometimes been referred to as edge detectors.
- The second type of cortical cell, the complex cortical cell, is located in the preistriate cortex (Areas 18 & 19).
  - Any straight-line stimulus was sufficient to cause some kind of response.
  - as long as a specific orientation was maintained.
  - Moreover, this cell could also be responsive to movement in a given direction across the retina.
  - Simple cortical cells showed no sensitivity towards directional movement.

Receptive Fields of the Visual Cortex

- A third type of cell, the hypercomplex cortical cell, also in Area 18 and 19.
  - was found to have similar receptive field characteristics to that of the complex cortical cell.
- The only difference was in the extra requirement that the straight-line image be of a certain length.
  - A light-slit, for example, in which the orientation was preserved but the length varied,
  - would not affect a complex cortical cell.
  - A hypercomplex cortical cell, however, would respond differently, with a maximal response to a specific length.
Receptive Fields of the Visual Cortex

- On the basis of the finding of Hubel and Wiesel, it is not difficult to come up with a model of pattern recognition at the cortical level.
- An object like a triangle could be processed in terms of three populations of complex or hypercomplex cortical cells.
- Each group responding to one of the three angled sides.