

### Goal

- To familiarize with rough anatomy, structure and function of the visual system
- Basis: chapters 25-28 of Kandel et al
- To be done in two lectures

### Jobs of the Visual System

- To make sense of the structures/shapes/forms in our visual environment (≈ object categorization)
- To detect & follow motion
- To analyze/investigate/interpret the image in detail (depth, color)

→ many, many functions!

### Where does it work?

Figure 17-4 The major lobes of the cerebral cortex, some prominent sulci, and other brain regions are illustrated in lateral (left) and medial (right) views of the human brain. (Adapted from Martin 1989.)

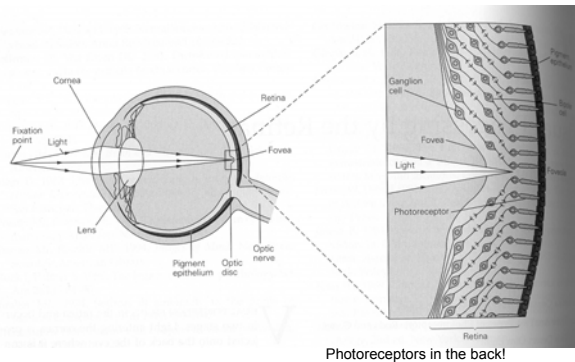
### Where does it work ? (II)

- it's not only the eye, but half of the brain

### Overview of Visual Machinery

Different pathways for different jobs

# The Eye – The Input Device



Photoreceptors in the back!

# Two Types of Photo-receptors: Rods and Cones

A Morphology of photoreceptors

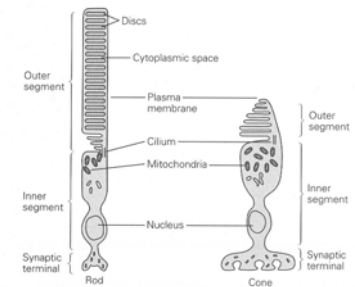


Figure 26-2 The two types of photoreceptors, rods and cones, have similar structures. (Adapted from O'Brien 1982 and Young 1970.)

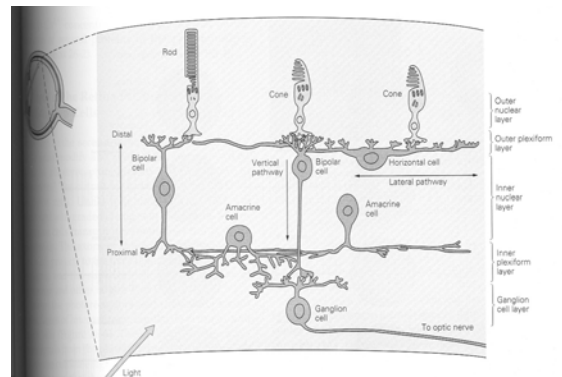
A. Both rod and cone cells have inner and outer segments connected by a cilium. The inner segment contains the cell's nucleus and most of its biosynthetic machinery. The outer segment contains the light-transducing apparatus.

# Rods for Night, Cones for Day (Color)

Table 26-1 Differences Between Rods and Cones and Their Neural Systems

Rods	Cones
High sensitivity to light, specialized for night vision	Lower sensitivity, specialized for day vision
More photopigment, capture more light	Less photopigment
High amplification, single photon detection	Lower amplification
Low temporal resolution: slow response, long integration time	High temporal resolution: fast response, short integration time
More sensitive to scattered light	Most sensitive to direct axial rays
<b>Rod system</b>	<b>Cone system</b>
Low acuity; not present in central fovea, highly convergent retinal pathways	High acuity; concentrated in fovea, dispersed retinal pathways
Achromatic; one type of rod pigment	Chromatic; three types of cones, each with a distinct pigment that is most sensitive to a different part of the visible light spectrum

# The Retinal Layers



# Vertical Pathway

- Parallel pathways:
  - Off: responds to offset
  - On: responds to onset

- analog to 'digital' conversion

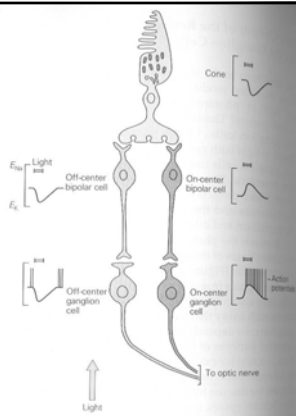
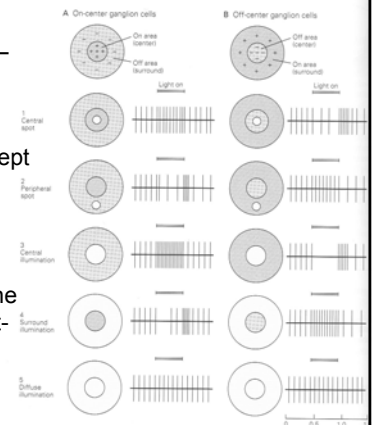


Figure 26-9 On-center and off-center bipolar cells establish parallel pathways.

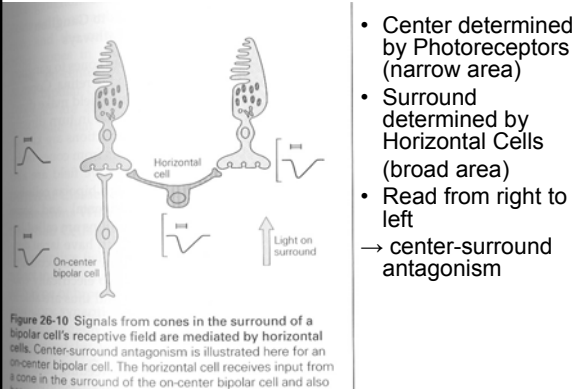
# Ganglion Cell Responses – A Systematic Investigation

- receptive field concept
- circular stimulation works best

- bipolar cells have the same response patterns just without spikes



## How are Receptive Fields Created?



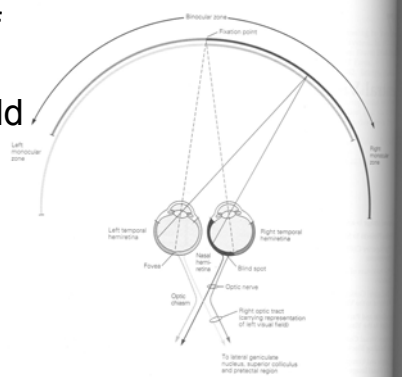
## Ganglion Cells: M and P

Table 27-1 Differences in the Sensitivity of M and P Cells to Stimulus Features

Stimulus feature	Sensitivity	
	M cells	P cells
Color contrast	No	Yes
Luminance contrast	Higher	Lower
Spatial frequency	Lower	Higher
Temporal frequency	Higher	Lower

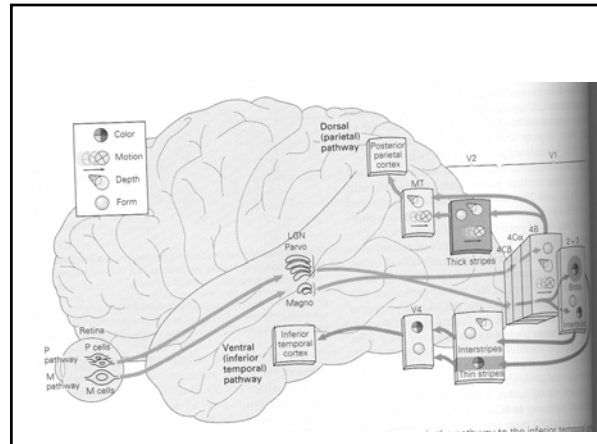
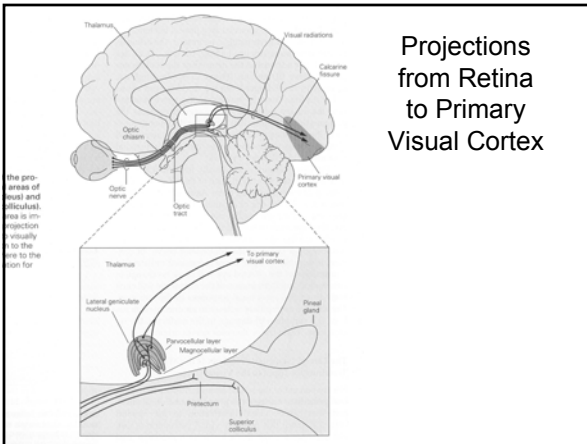
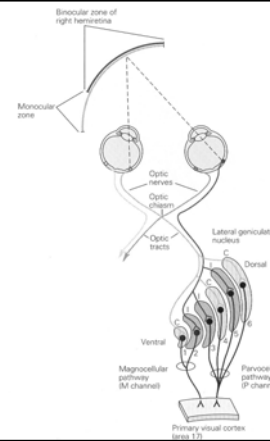
- Starting point of motion (magnocellular) and object (parvocellular) pathways

## Zones of the Visual Field



## Lateral Geniculate Nucleus (LGN)

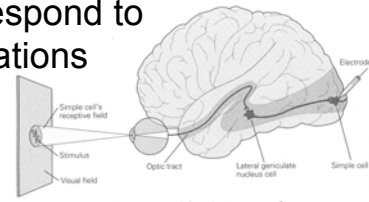
- Gateway between retina and V1
- Cell responses similar to ganglion cell responses



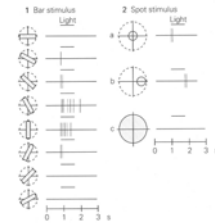
## V1

- = primary visual cortex
- = area 17 (Brodmann's classification)
- = striate cortex (staining patterns)
- What does it code for?
- Imagine the 50's and 60's
- Do V1 cells also respond to circular stimulation like in the retina, or may be even to objects?

## V1 cells respond to orientations



- orientation of specific angle
- 'orientation-selective'



### Receptive Field Shapes of Simple Cells

cells in the primary visual cortex are paired than those in the lateral geniculate nucleus. cells fall into two main fields of these but to antagonistic primary visual cortex (1) or (2), their receptive specific retinal zones, and (3) a receptive field of according to this visual cortex in three or more along a line of the y region, indicated below. The probably probably not shown as stated from Hubel

A. Receptive fields of concentric cells of retina and lateral geniculate nucleus

B. Receptive fields of simple cells of primary visual cortex

C. Diagram of a simple cell showing its receptive field and synaptic connections from the LGN.

- many different receptive field formations

### Complex Cells

A<sub>1</sub> Response to orientation of stimulus

A<sub>2</sub> Response to position of stimulus

B. Diagram of a complex cell showing its receptive field and synaptic connections from the LGN.

- orientation & motion sensitive

Figure 27-13 The receptive field of a complex cell in the primary visual cortex has no clearly excitatory or inhibitory zones. Orientation of the light stimulus is important, but position within the receptive field is not. (Adapted from Hubel and Wiesel, 1962).

Figure 27-14 The receptive field of a complex cell in the primary visual cortex has no clearly excitatory or inhibitory zones. Orientation of the light stimulus is important, but position within the receptive field is not. (Adapted from Hubel and Wiesel, 1962).

## Who discovered those orientation-selective cells?

- Described by Hubel and Wiesel in the 50's and 60's. Won Nobel Prize for discovery and characterization.
- Accidental detection:

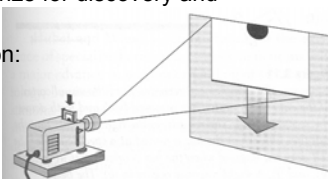


Figure 3.8 When Hubel and Wiesel dropped a slide into their slide projector, the image of the edge of the slide moving down unexpectedly triggered activity in a cortical neuron.

## Layers of V1/Cortex

A. Inputs from lateral geniculate nucleus

B. Resident cells

C. Information flow

Figure 27-10 The primary visual cortex has distinct anatomical layers, each with characteristic synaptic connections. (Adapted from Lund 1988)

A. Most afferent fibers from the lateral geniculate nucleus terminate in layer 4. The axons of cells in the parvocellular layers terminate primarily in layer 4CB, with minor inputs to 4A and 4B, while the axons of cells in the magnocellular layers (M) terminate primarily in layer 4CA. Cells of both types of cells terminate in layer 4C.

B. Inputs. Axons from M and P cells in the lateral geniculate nucleus end on spiny stellate cells in the sublayers of 4C, and these cells project axons to layer 4B or the upper layers 2 and 3. Axons from cells in the intralaminar zones of the lateral geniculate nucleus project directly to layers 2 and 3.

C. Intracortical connections. Axons collaterals of pyramidal cells project to layers 2 and 3. Axons of cells in the intralaminar zones of the lateral geniculate nucleus project directly to layers 2 and 3.

To other extrastriate cortical areas (e.g. V2, 3, 4, 5, MT)

To subcortical areas: to superior colliculus, pulvinar, pons, to LGN, claustrum

From LGN: (M) (P)

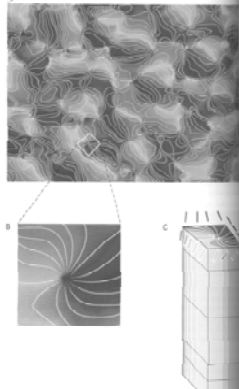
## How are V1 cells organized?...

Figure 27-14 Orientation columns in the visual cortex of the monkey. (Courtesy of Gary Buzsáki.)

A. Image of a 9 by 12 mm rectangle of cortical surface shows the monkey-reared surface of different orientations indicated on the right. This image was obtained through optical imaging and by comparing top changes in reflectance, which indicate activity. Areas that were most active during the presentation of a particular orientation are indicated by the color chosen to represent that orientation. Bars on the right. Complementary colors were chosen to represent orthogonal orientations. Hence, red and green indicate maximal activities in response to horizontal and vertical, while blue and yellow indicate greatest activation by left and right oblique.

B. Enlargement of a pinwheel-like area in A. Orientations producing the greatest activity remain constant along radial, extending outward from a center, but change continuously through  $\pm 180^\circ$ .

C. Three-dimensional organization of orientation columns in a  $1 \text{ mm} \times 1 \text{ mm} \times 2 \text{ mm}$  slice of primary visual cortex underlying the square surface region depicted in B.



- ... in 'orientation columns'

## There also exist blobs...

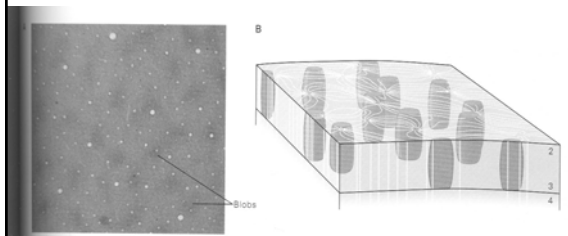
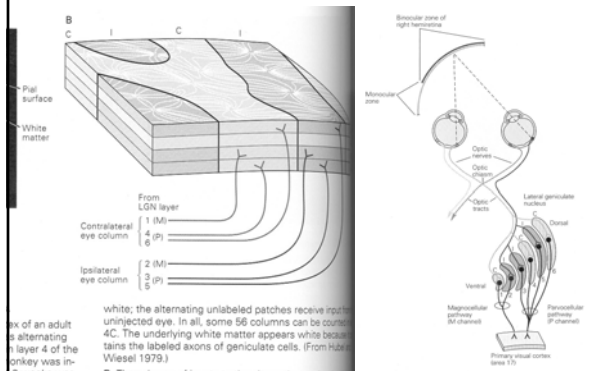


Figure 27-15 Organization of blobs in the visual cortex. A. Blobs are visible as dark patches in this photograph of a single layer of upper cortex that has been processed histochemically to reveal the density of cytochrome oxidase, a mitochondrial enzyme involved in energy production. B. Blobs interrupt organized enzymatic activity in the blobs is thought to

represent heightened neural activity. The cortex was sectioned tangentially. (Courtesy of D. Ts'o, C. Gilbert, and T. Wiesel.)

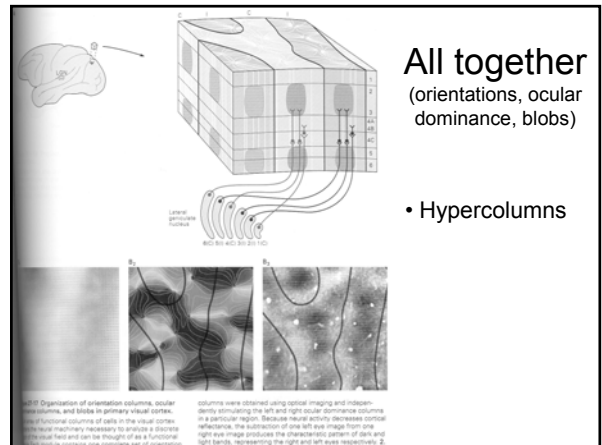
- cells in blob regions tend to respond to color stimuli

## Ocular Dominance Columns



... of an adult monkey was injected with white matter.

## All together (orientations, ocular dominance, blobs)



- Hypercolumns

