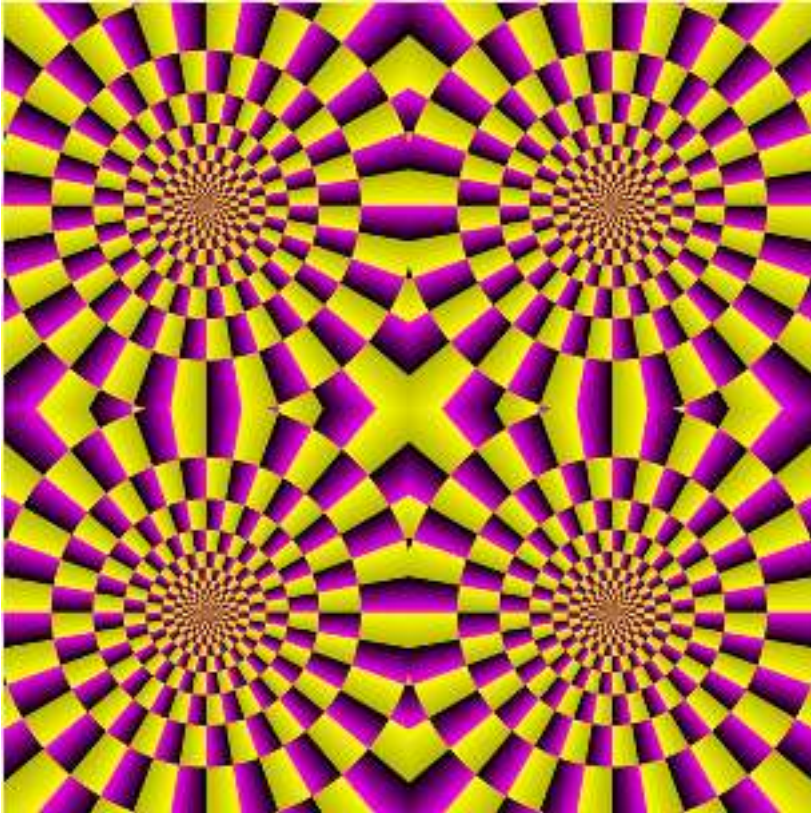


# Visual Cognition I

# An Aside: Peripheral Drift Illusion



Illusion of motion is strongest when reading text (such as this) while viewing the image in your periphery. Blinking your eyes repeatedly also strengthens the illusion.

Why does this occur? One explanation is that sudden changes such as eye movements or eye blinks lead to transients in the motion detection cells.

# Craik-Cornsweet-O'Brien Illusion



Left part of the picture seems to be darker than the right one. In fact they have the same brightness.



The same image as above, but the edge in the middle is hidden. Left and right part of the image look to be equally dark

How is this different from mach bands?

# Object recognition system must be flexible to recognize variations in object shapes



Letter "A"

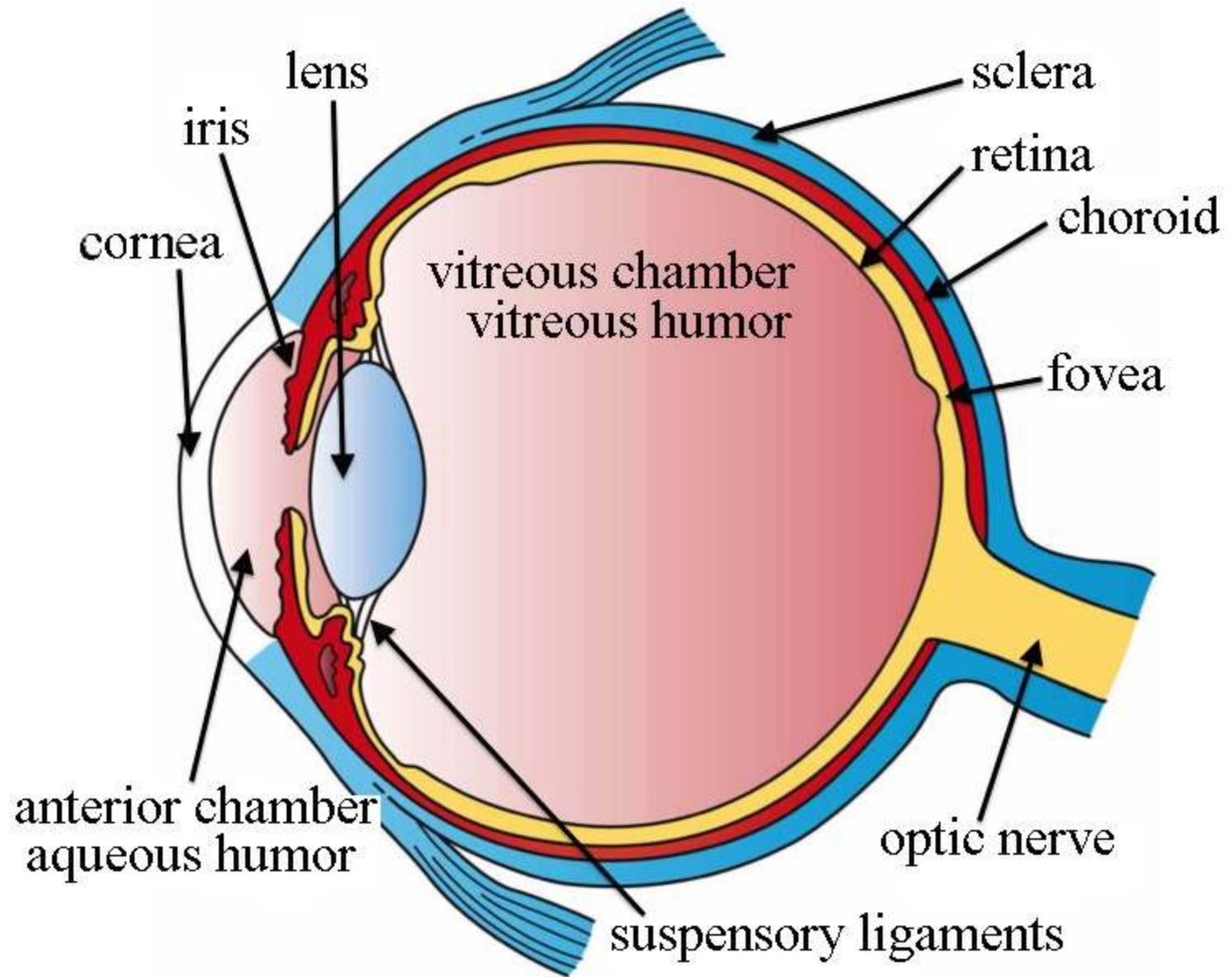


"Dog"

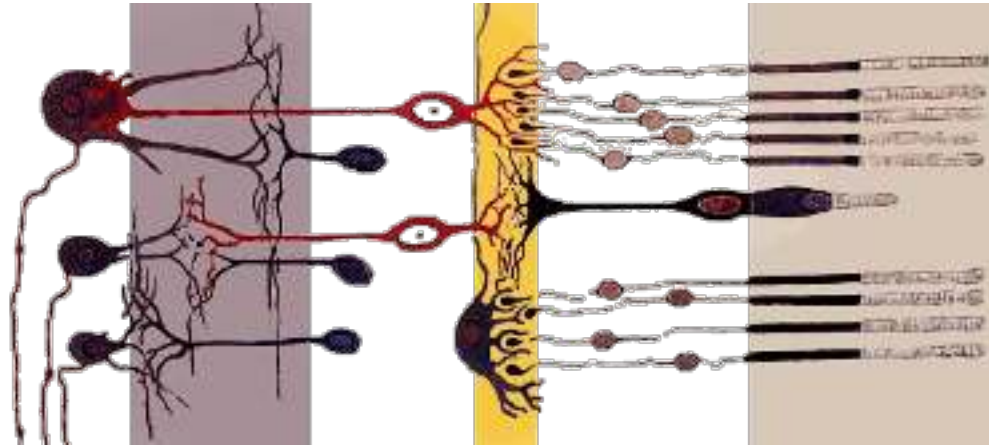
# Principles of Visual Perception



# Basic Processes in the Visual System



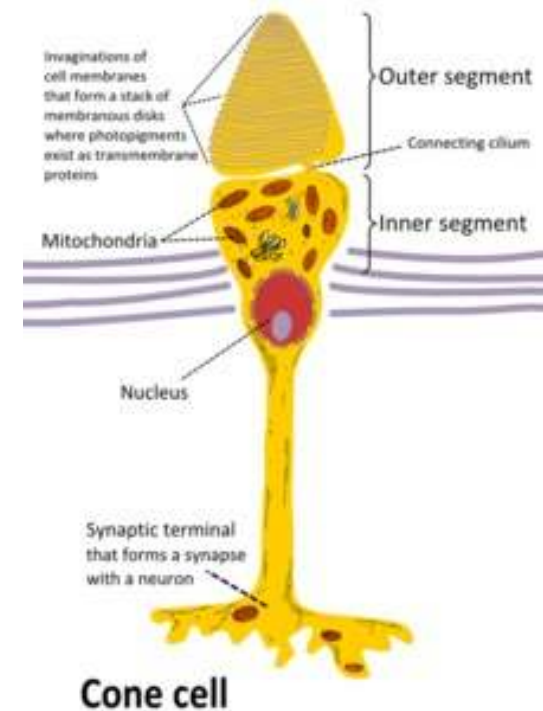
# Cross Section of the Retina



Rods, cones and nerve layers in the retina. The front (anterior) of the eye is on the left. Light (from the left) passes through several transparent nerve layers to reach the rods and cones (far right). A chemical change in the rods and cones send a signal back to the nerves. The signal goes first to the bipolar and horizontal cells (yellow layer), then to the amacrine cells and ganglion cells (purple layer), then to the optic nerve fibres. The signals are processed in these layers. First, the signals start as raw outputs of points in the rod and cone cells. Then the nerve layers identify simple shapes, such as bright points surrounded by dark points, edges, and movement. (Based on a drawing by [Ramón y Cajal](#).)

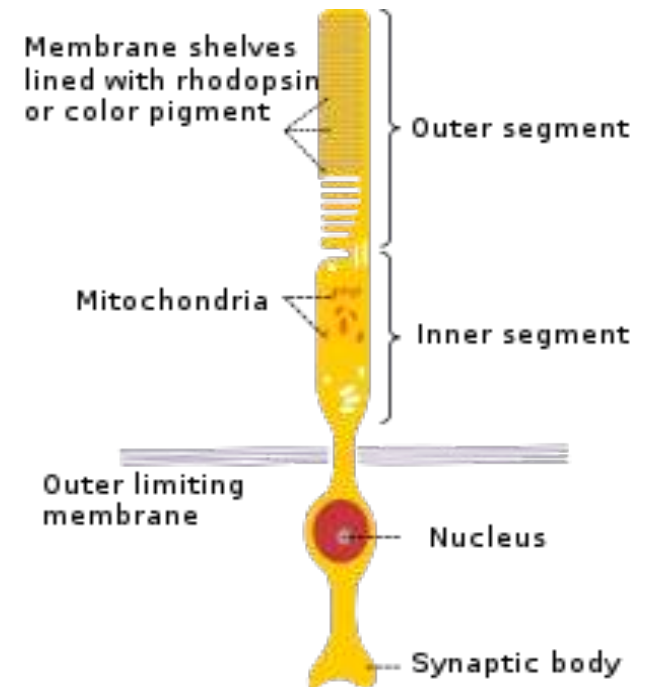
# Cone Cell

**Cone cells**, or **cones**, are [photoreceptor cells](#) in the retinas of vertebrate eyes (e.g. the [human eye](#)). They respond differently to light of different or [color vision](#) and function best in relatively bright [light](#), as opposed to [rod cells](#), which work better in dim light. Cone cells are densely packed in the [fovea centralis](#), a mm diameter rod-free area with very thin, densely packed cones which quickly reduce in number towards the periphery of the retina. There are about six to seven million cones in a human eye and are most concentrated towards the [macula](#).



# Rod Cell

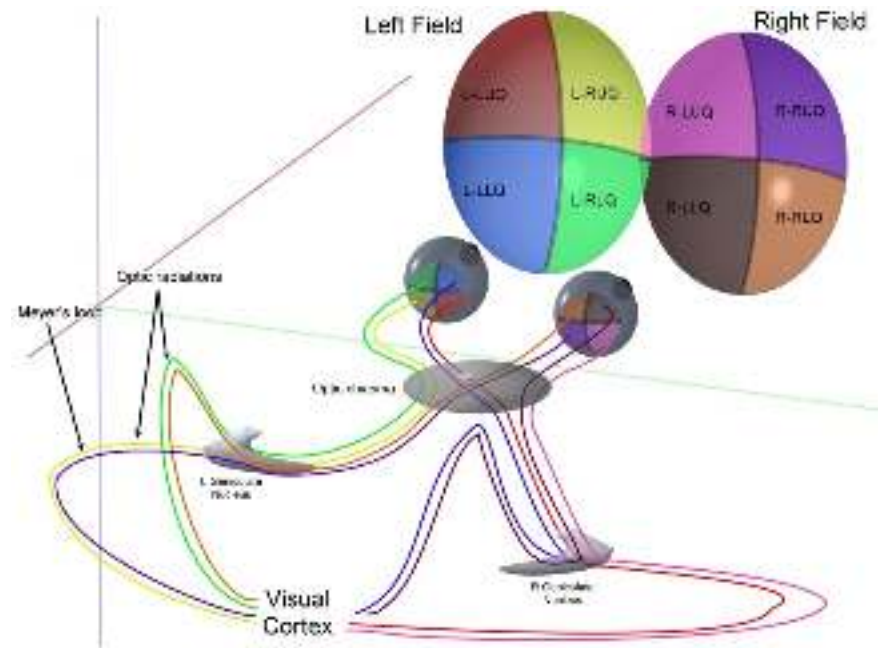
**Rod cells** are [photoreceptor cells](#) in the [retina](#) of the eye that can function in lower [light](#) than the other type of visual photoreceptor, [cone cells](#). Rods are usually found concentrated at the outer edges of the retina and are used in [peripheral vision](#). On average, there are approximately 92 million rod cells in the human retina. Rod cells are more sensitive than cone cells and are almost entirely responsible for [night vision](#). However, rods have little role in [color vision](#), which is the main reason why colors are much less apparent in dim light.



# Simplified Signal Flow

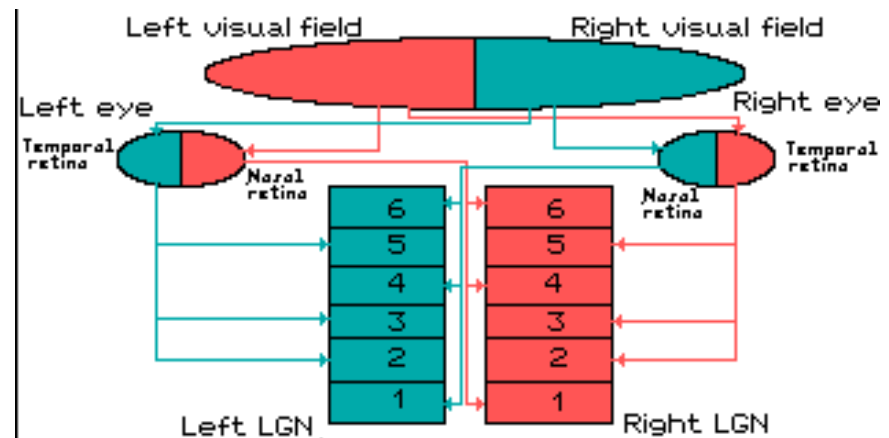
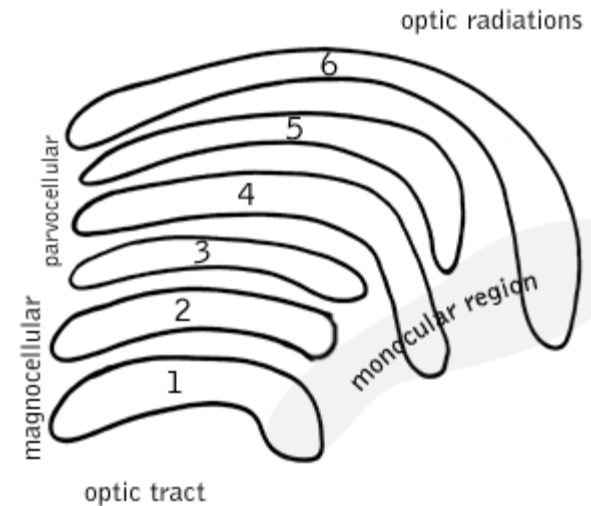
Photoreceptors → Bipolar → Ganglion → Chiasm → LGN → V1 cortex

Once the image is spatially encoded by the centre-surround structures, the signal is sent out along the optic nerve (via the axons of the ganglion cells) through the [optic chiasm](#) to the LGN ([lateral geniculate nucleus](#)). The exact function of the LGN is unknown at this time. The output of the LGN is then sent to the back of the brain. Specifically, the output of the LGN "radiates" out to the V1 [primary visual cortex](#).



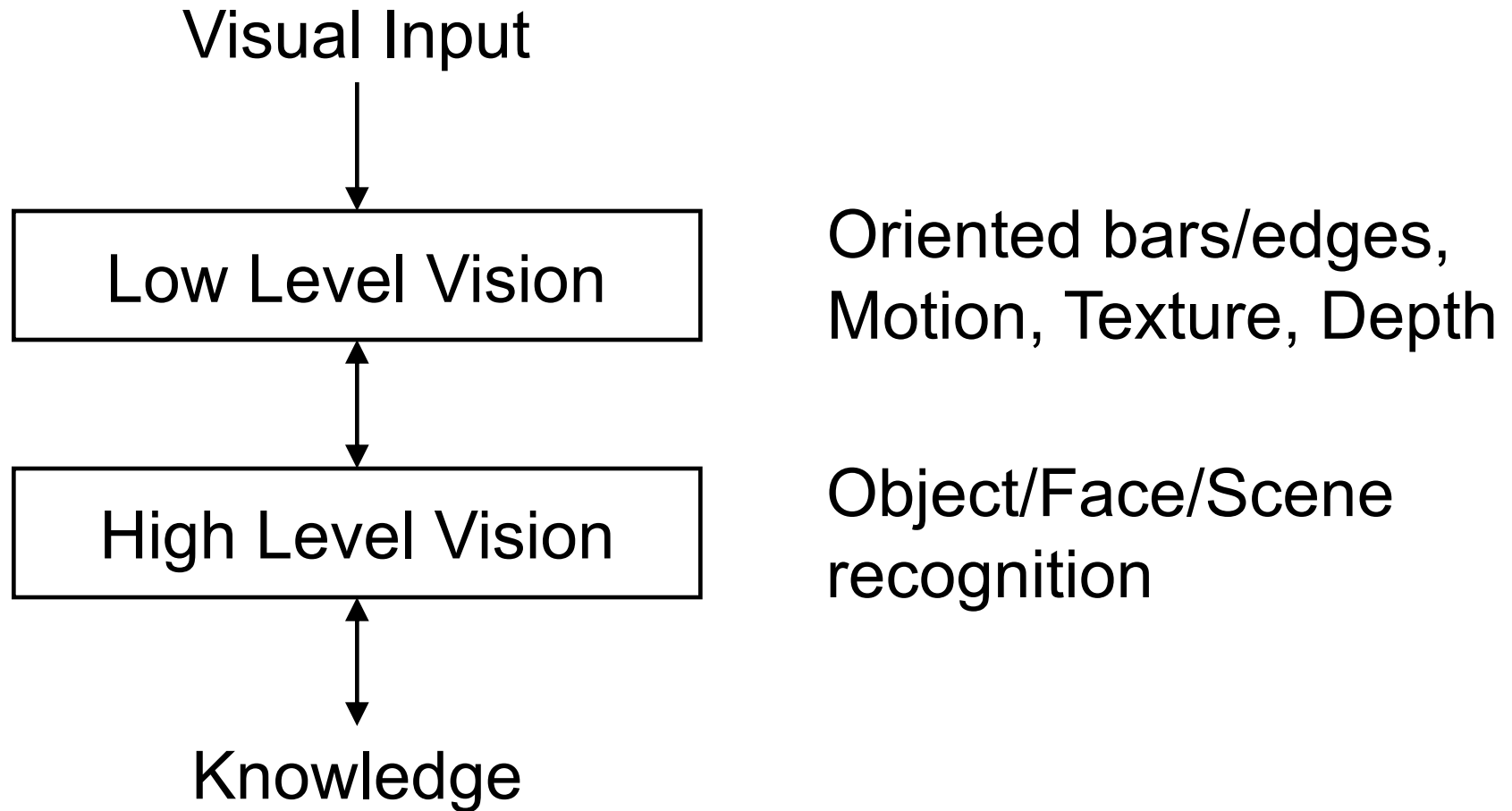
# Lateral Geniculate Nucleus

The **lateral geniculate nucleus (LGN)** is the primary relay center for visual information received from the retina of the eye. The LGN receives information directly from the ascending retinal ganglion cells via the optic tract and from the reticular activating system. Neurons of the LGN send their axons through the optic radiation, a direct pathway to the primary visual cortex. In addition, the LGN receives many strong feedback connections from the primary visual cortex.



# Visual Perception-How it works

# Hierarchical Organization



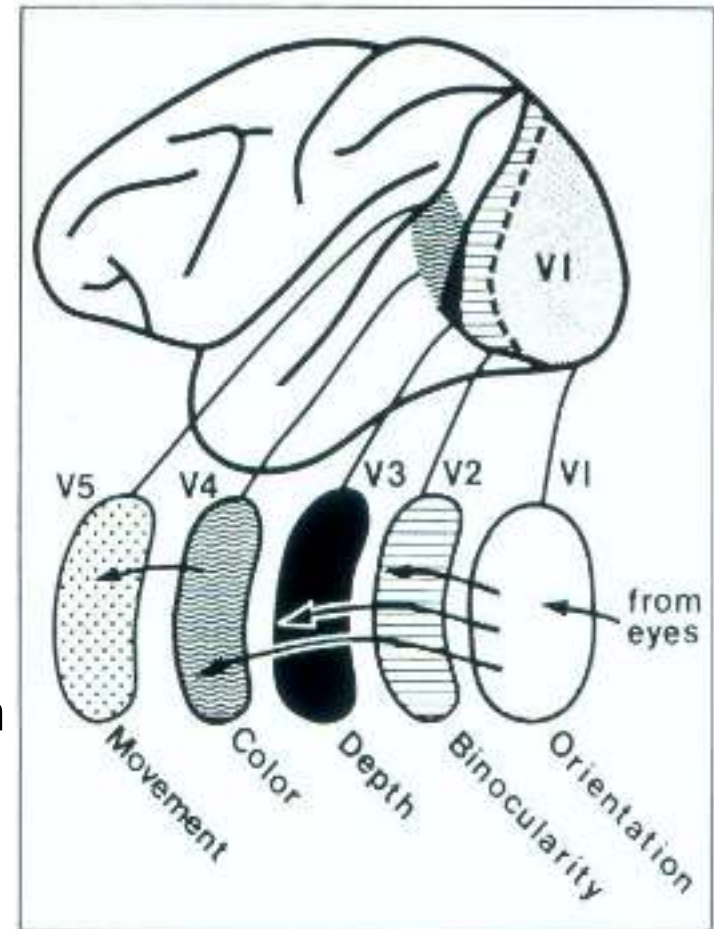
V2: Cells selective for orientation, direction, disparity, color (similar to V1); responses to subjective contours.

V3: Emergence of new properties: evidence for integration of complex motion ("pattern" motion; like MT).

V4: Cells selective for orientation and color; some directionally selective cells.

V5: Larger receptive fields selective for motion direction, disparity and stimulus orientation; no selectivity for color; responses to complex motion ("pattern" motion).

Lesions: selectively affect direction and speed discrimination, as well as motion integration. deficits more pronounced in the presence of motion noise. Partial or complete recovery with training.



# Functional Specialization

- Spatially different areas are **functionally specialized** for processing visual attributes such as shape, color, orientation, and direction of motion
- **Achromatopsia** (damage to V4) **全色盲**
  - cortical color blindness all color vision is lost and the world appears in shades of gray. And in achromatopsia, unlike as in blindness caused by damage to the eyes or optic nerve, even memory of color is gone
- **Akinetopsia** (damage to V5 or MT) **运动失认症**
  - or motion blindness—the loss of the ability to see objects move. Those affected report that they perceive a collection of still images.

# Face Agnosia



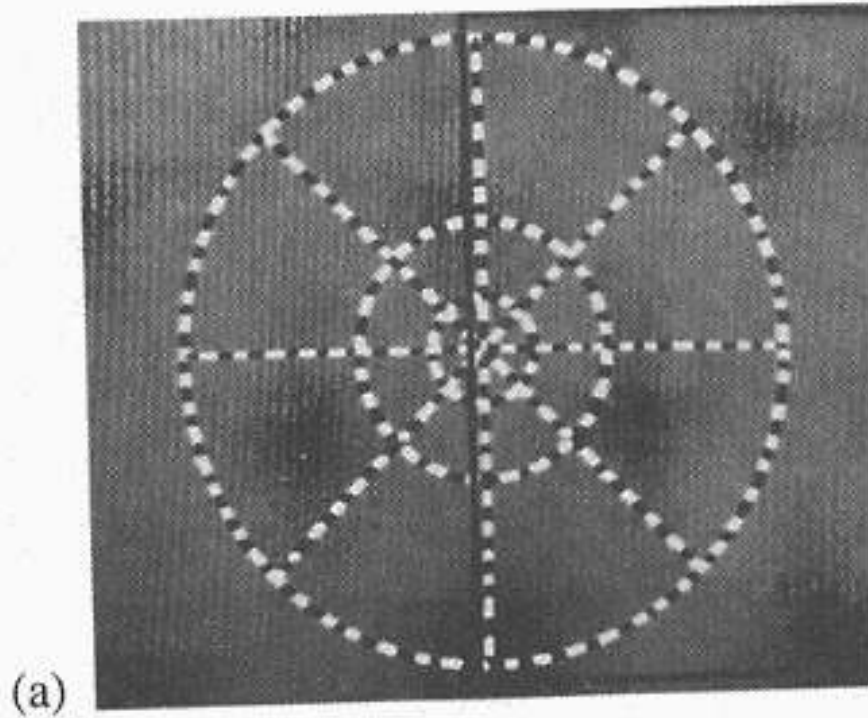
Face agnosia



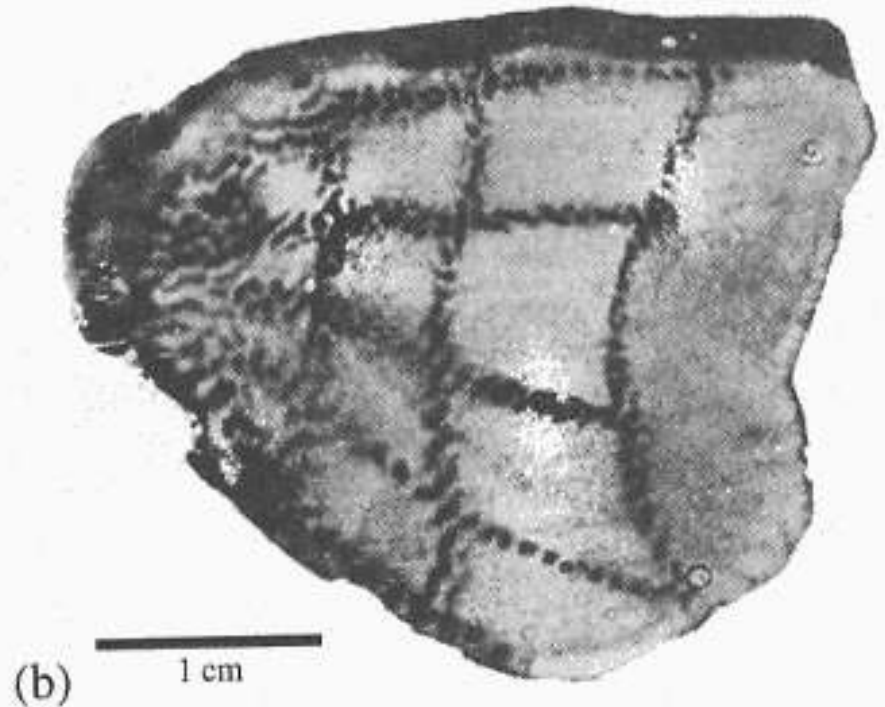
# Primary and Secondary Visual Cortex (V1 and V2)

- Retinotopic maps
- Receptive fields:
  - On-off cells; Off-on cells
  - Orientation sensitive cells (“simple” cells)
- Lateral inhibition

# Retinotopic maps in V1



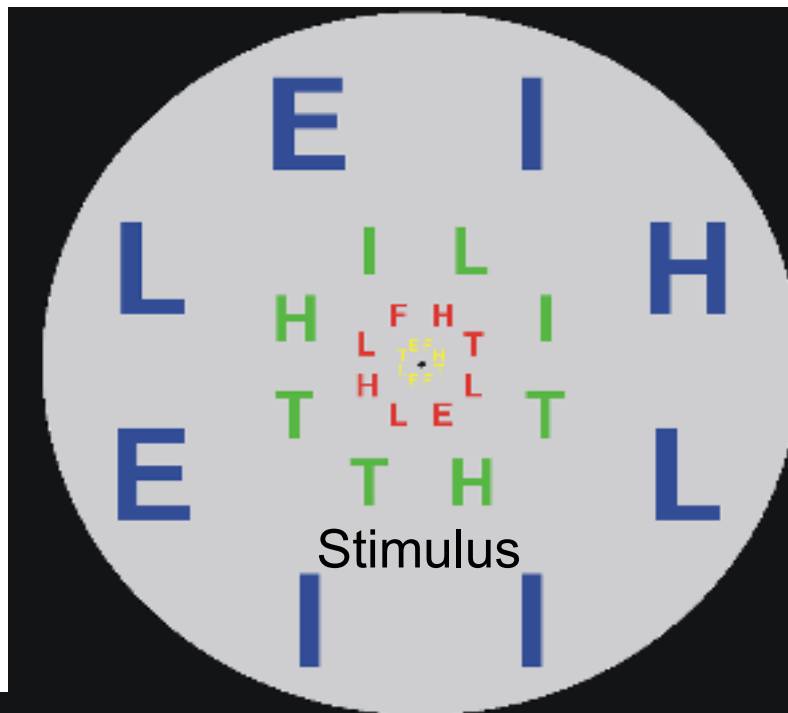
Stimulus pattern



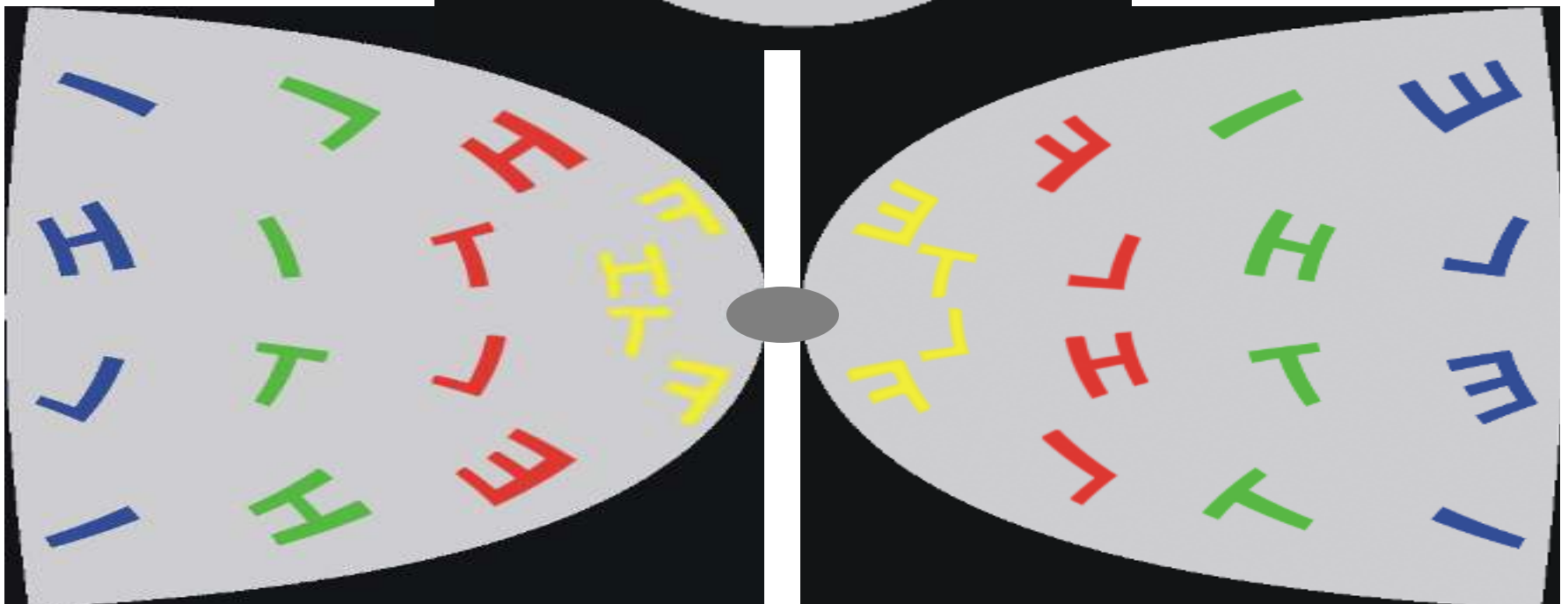
Response in monkey primary visual cortex (V1) measured by radio-active tracers

- **Retinotopic mapping**: locations on retina are mapped to cortex in orderly fashion. Note: more of visual cortex is dedicated to foveal vision

Cortical Mapping:  
Left Hemisphere

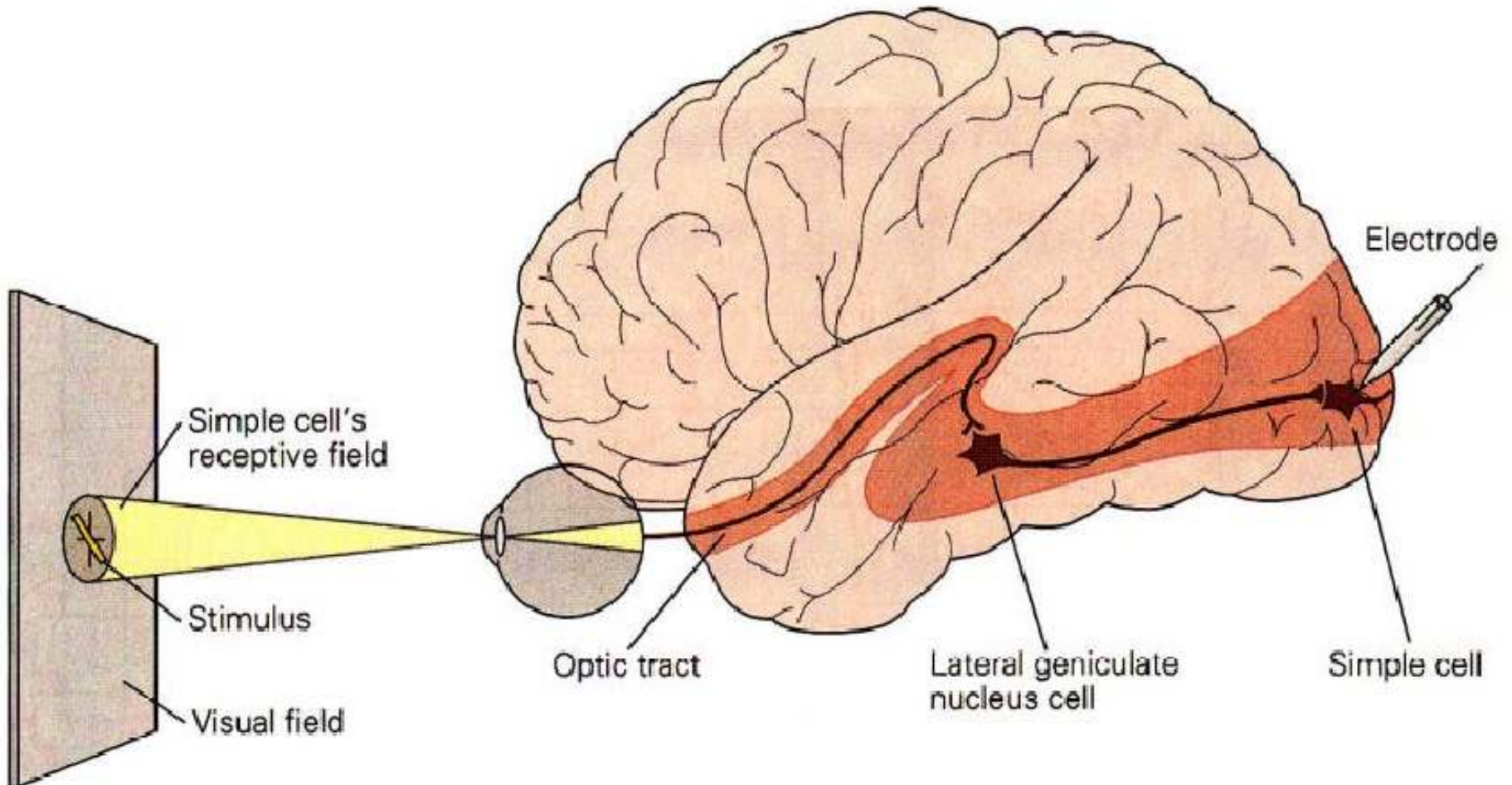


Cortical Mapping:  
Right Hemisphere



# Single Cell Recording (usually in animal studies)

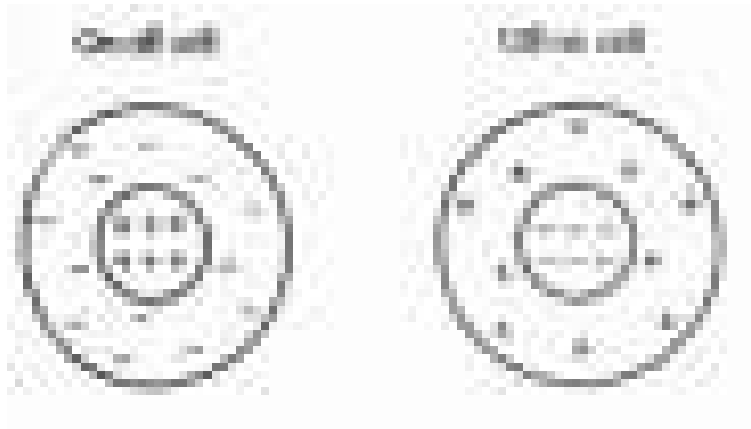
Measure neural activity with probes.  
E.g., research by Hubel and Wiesel:



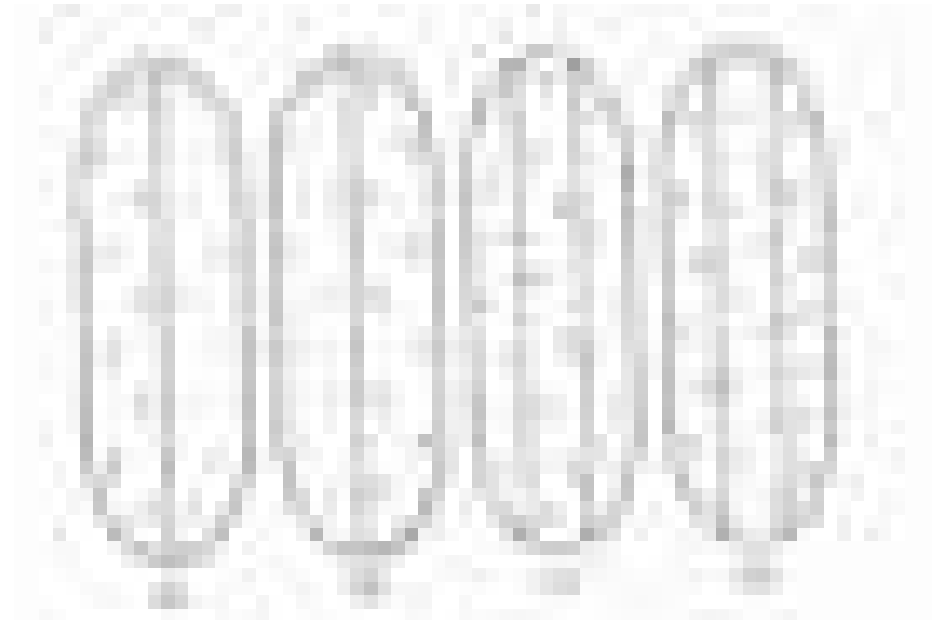
# Receptive Fields

- The **receptive field** (RF) of a neuron is the area of retina cells that trigger activity of that neuron

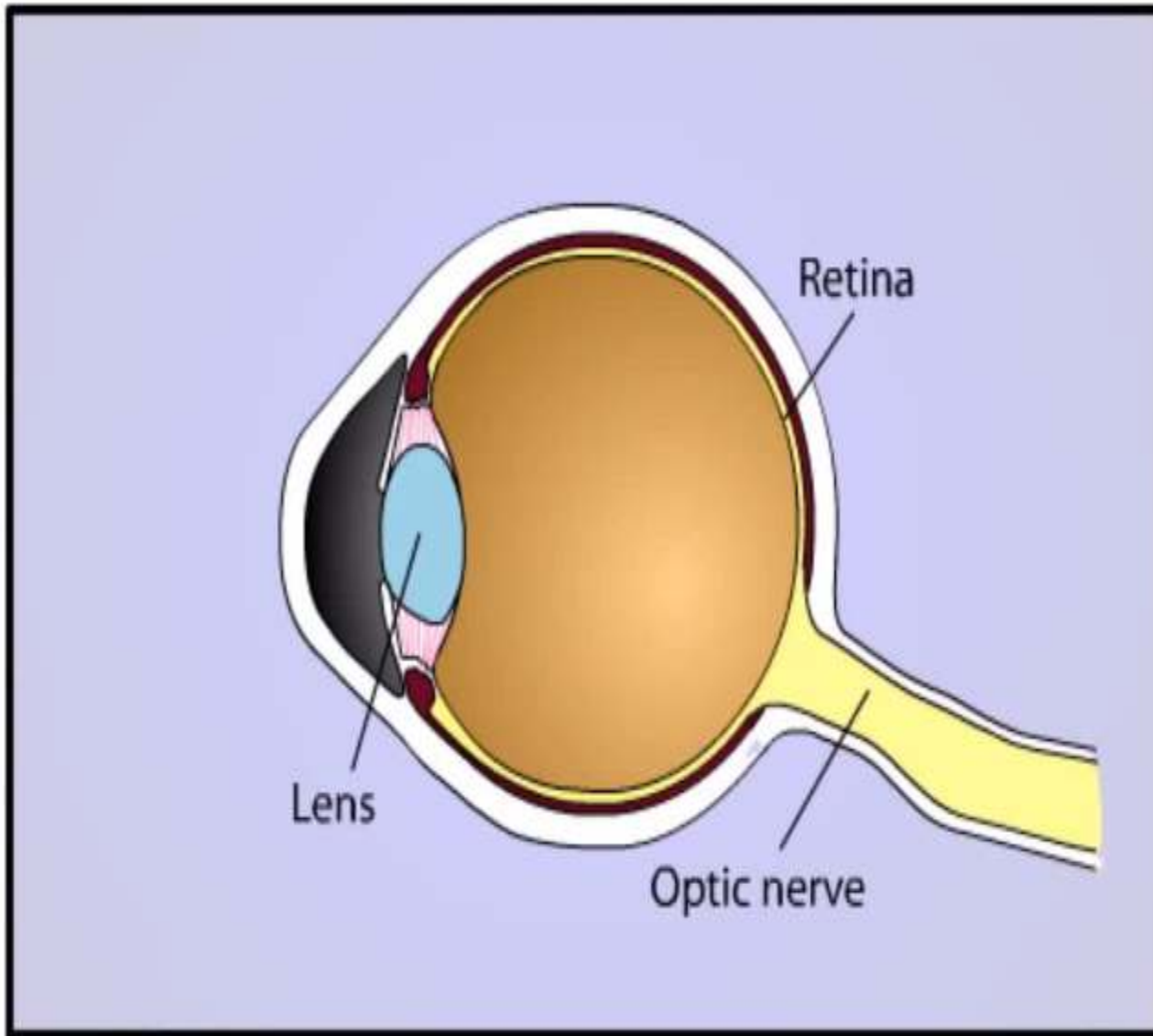
**On-off** cells and **off-on** cells



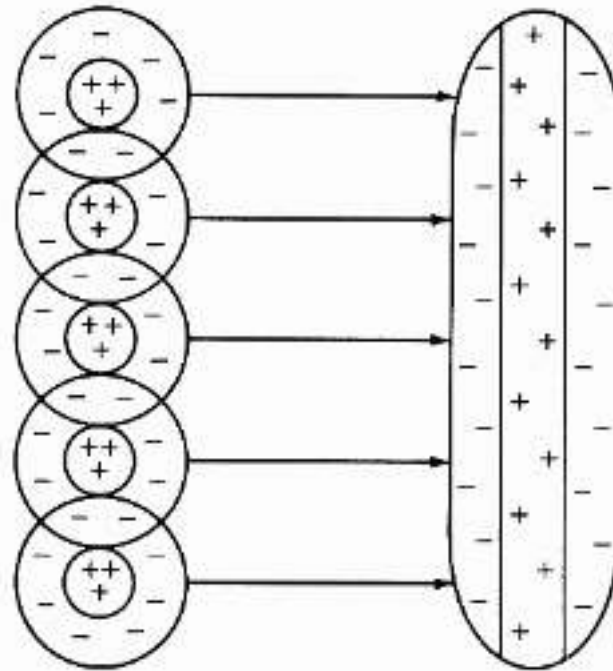
**Simple cells (bar detectors)**



# Receptive Fields



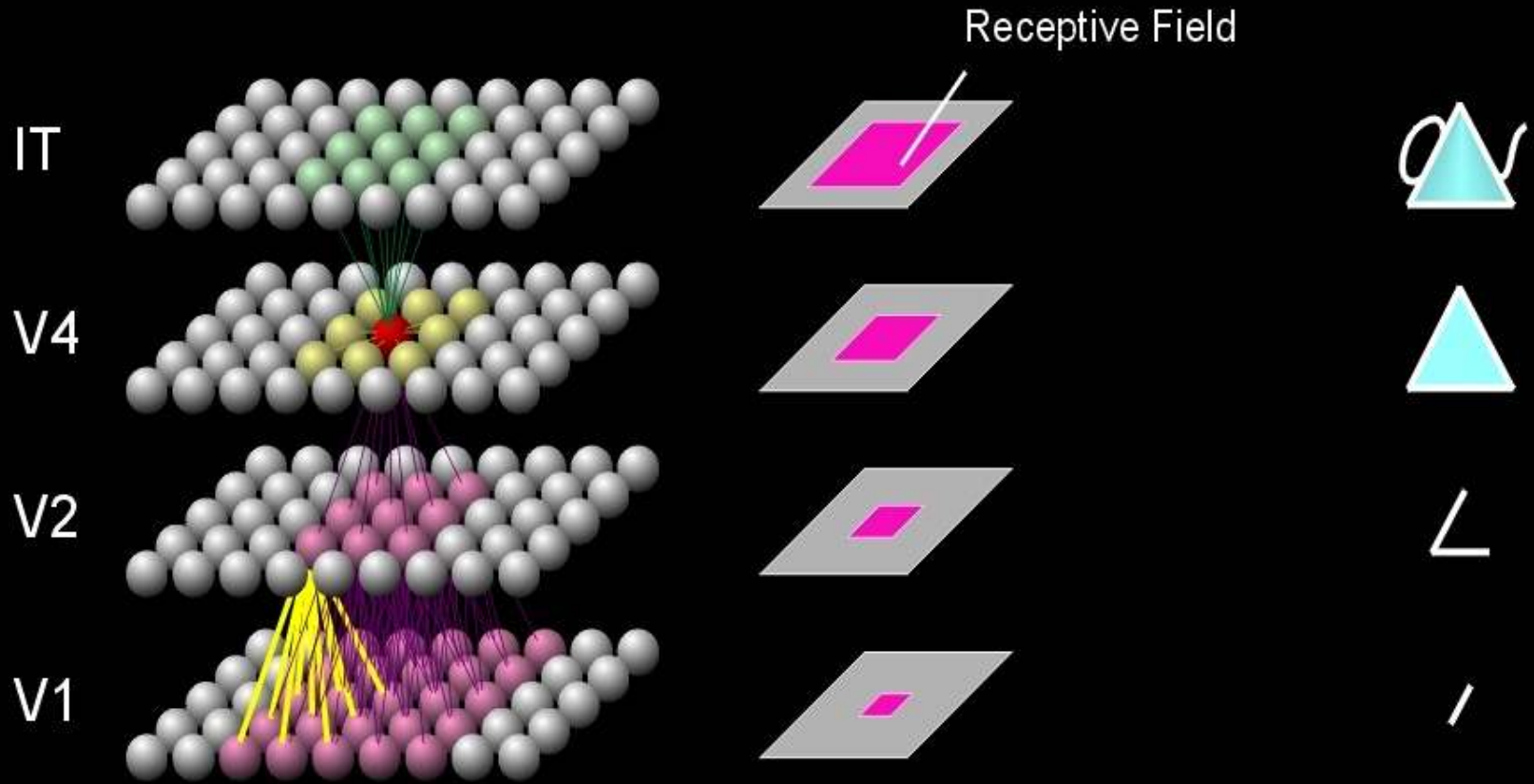
# A wiring diagram for building orientation-sensitive cells out of on-off cells



(a)

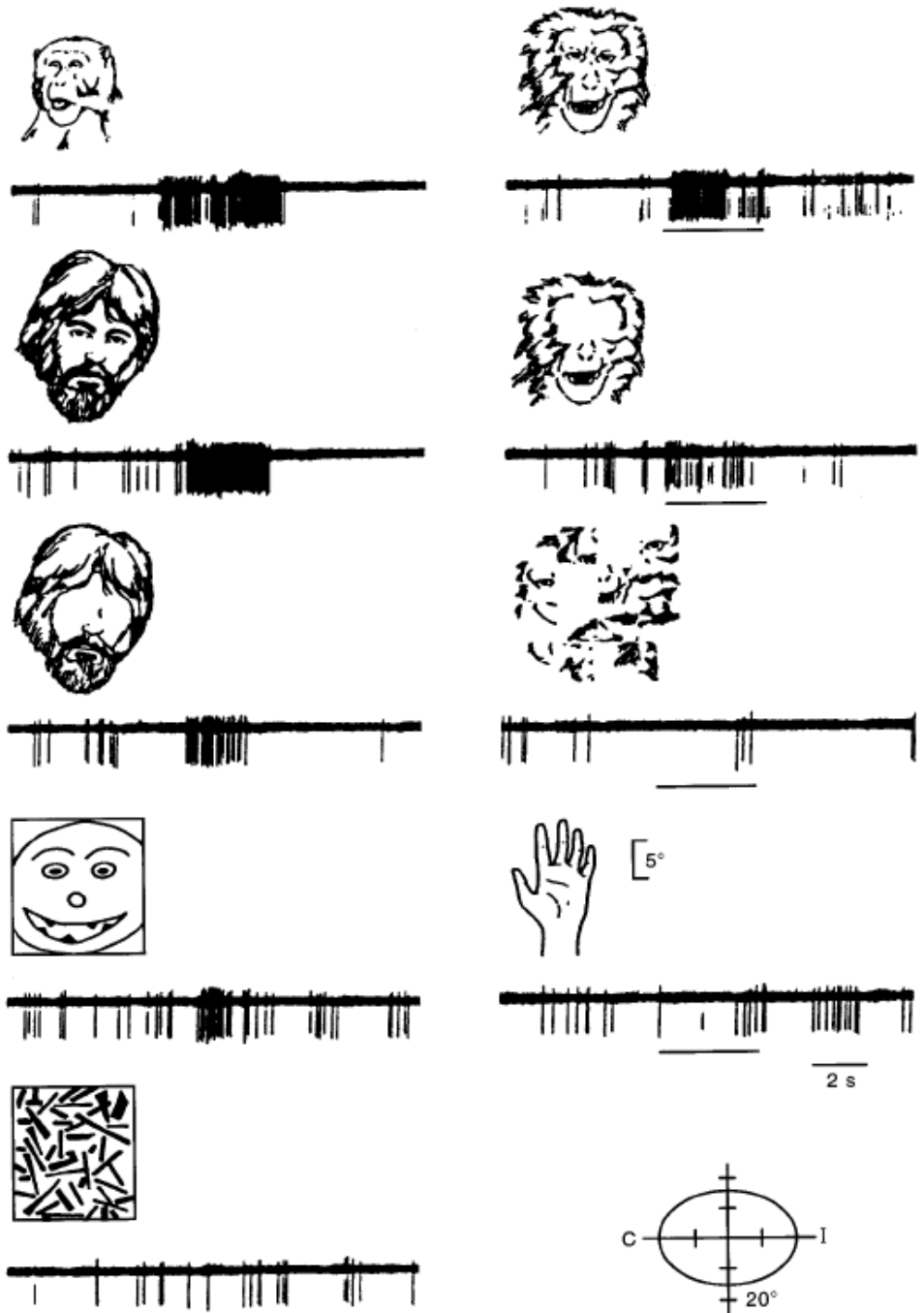
**Hierarchical organization** of the brain: by aggregating responses over several on-off cells, the brain can detect more complicated features (e.g. bars and edges)

# Hierarchical Organization

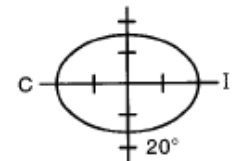


What is this cell coding for?

- a) any face
- b) monkey face
- c) human face
- d) eyes
- e) hands



“spike train” : each individual line represents a neuron firing. The axis represents time.



# Mach Bands and Lateral Inhibition

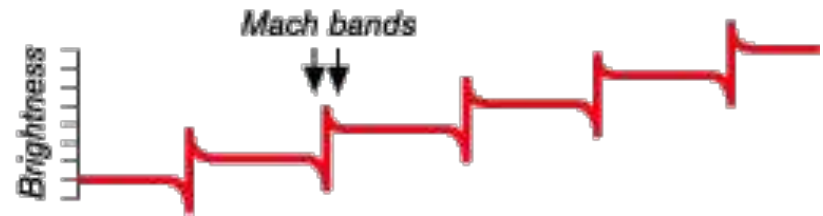
Six uniform rectangles are shown abutting one another, ordered from lightest to darkest. Even though the level of gray in each rectangle is uniform, it looks as if each one is a bit lighter on its right edge than its left edge and darker on its left edge and darker on its left edge. These edge effects come from the neighboring rectangle, and are predicted from the responses of ganglion cell neurons



What is there

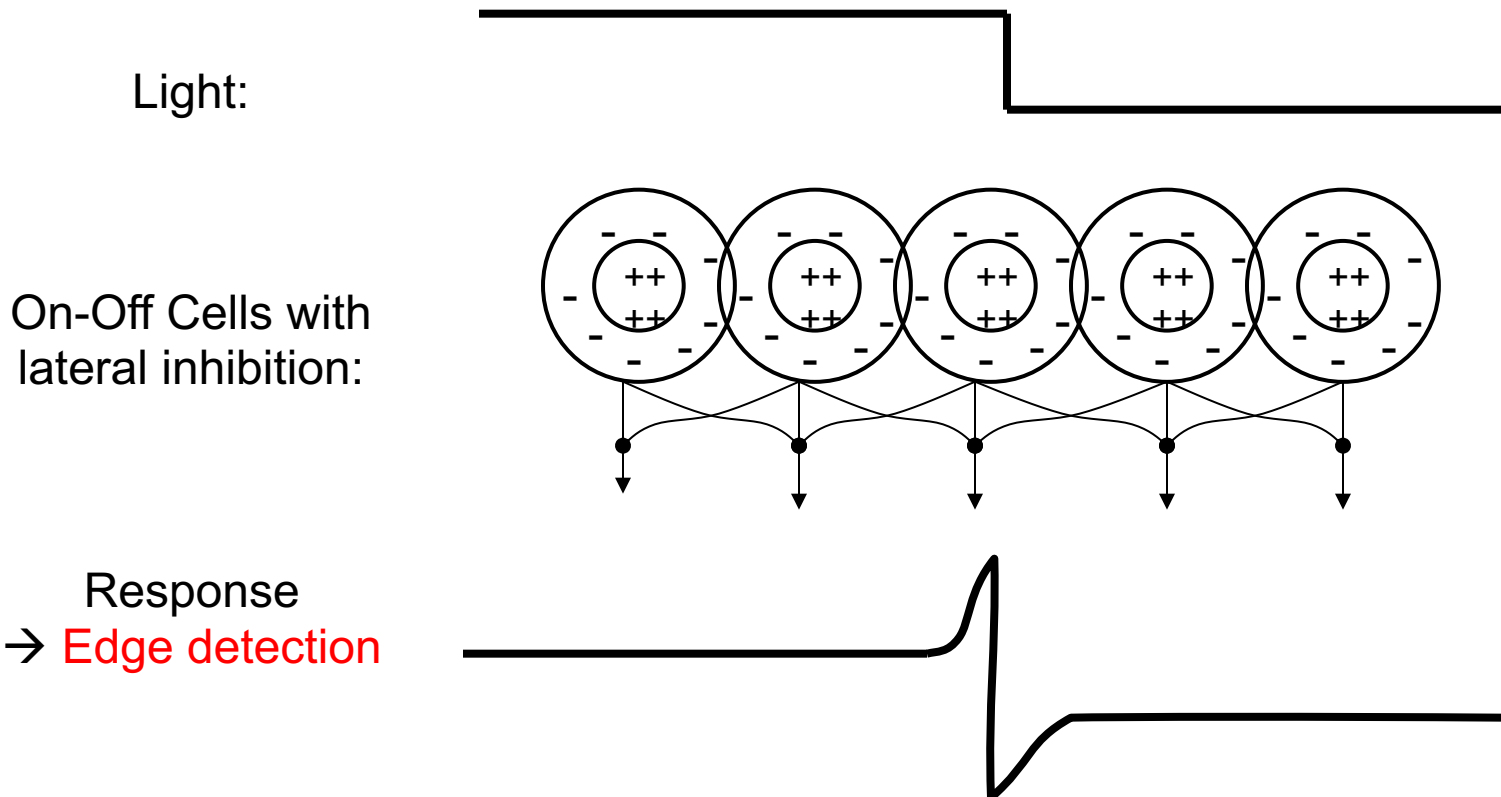


What you see



# Lateral Inhibition

- **Lateral inhibition** sets up competition between neurons so that if one neuron becomes adept at responding to a pattern, it inhibits other neurons from doing so.



DEMO APPLET:

<http://www.psychology.mcmaster.ca/4i03/demos/lateral-demo.html>

[http://serendip.brynmawr.edu/bb/latinhib\\_app.html](http://serendip.brynmawr.edu/bb/latinhib_app.html)

# Lateral Inhibition Enhances Edges



# Sensory Binding Problem

- If spatially different areas are functionally specialized for processing visual attributes such as shape, color, orientation, and direction of motion....
- then how does the brain then “bind” together the sensory attributes of an object to construct a unified perception of the object?

→ **Binding Problem**

# Binding Problem

How are separate neural representations combined?  
Engel & co-workers (e.g 1992) suggested that neurons representing the same object fire in synchrony

