Perception, Part 3
Gleitman *et al*. (2011), Chapter 5

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Psych 9A / Psy Beh 11A
March 4, 2014

- Visual neuroscience and perception
- More on shape processing

- Visual neuroscience and perception
- More on shape processing

- But first, let’s finish up our look at motion perception

Motion Cues to Depth: Structure From Motion

We are quite good at interpreting biological motion, and can recover object identity from very sparse descriptions of its motion

Gunnar Johannson was the first to explore this systematically.

Try this flash shockwave:

http://www.journalofvision.org/content/suppl/2011/01/13/2.5.2.DCSupplementaries/genderclass.swf

Eye movements and motion perception

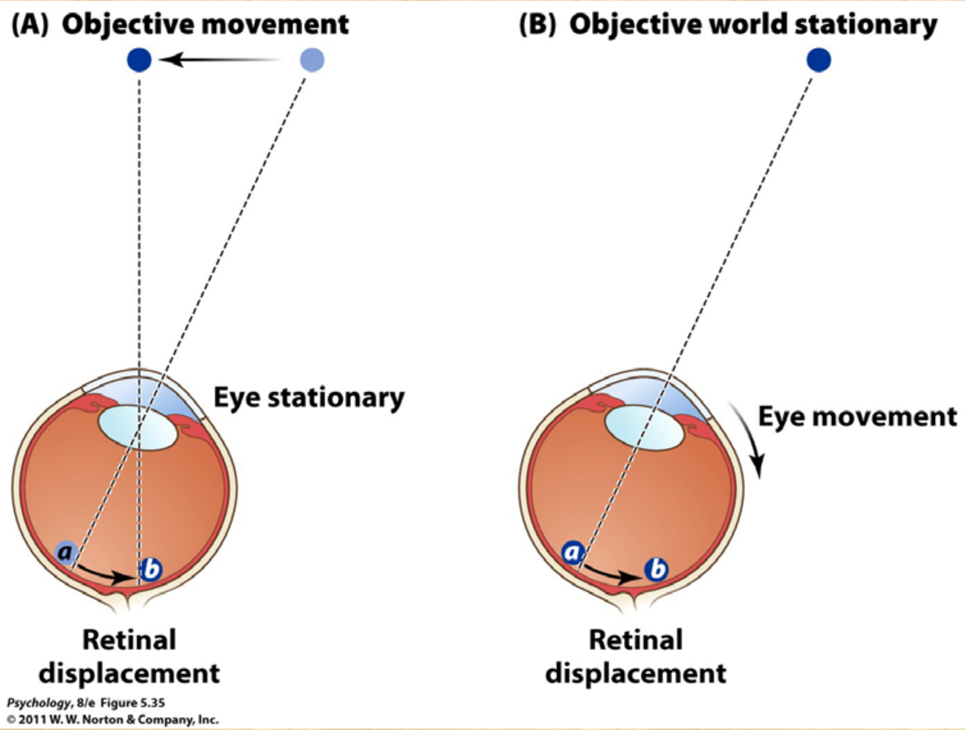
Saccade – extremely rapid movement of the eyes of which we are usually not aware

Psychology, 8/e Figure 5.37

Eye movements and motion perception

Saccade – extremely rapid movement of the eyes of which we are usually unaware

Our visual systems *compensate* for eye movements so that the world does not appear to move when the eyes move



What caused the retinal image motion?

Eye movements and motion perception

Saccade – extremely rapid movement of the eyes of which we are usually not aware

Our visual systems *compensate* for eye movements so that the world does not appear to move when the eyes move

Cover one eye, jiggle the other eye by pressing gently on its corner, and watch the world move. Contrast the jiggling visual scene to what you see when voluntary eye movements are made.

Voluntary eye movements involve not only signals to eye muscles but also feedback signals to visual mechanisms concerning the resulting eye movement. This lets the visual mechanisms shift the world appropriately so that it appears stable.

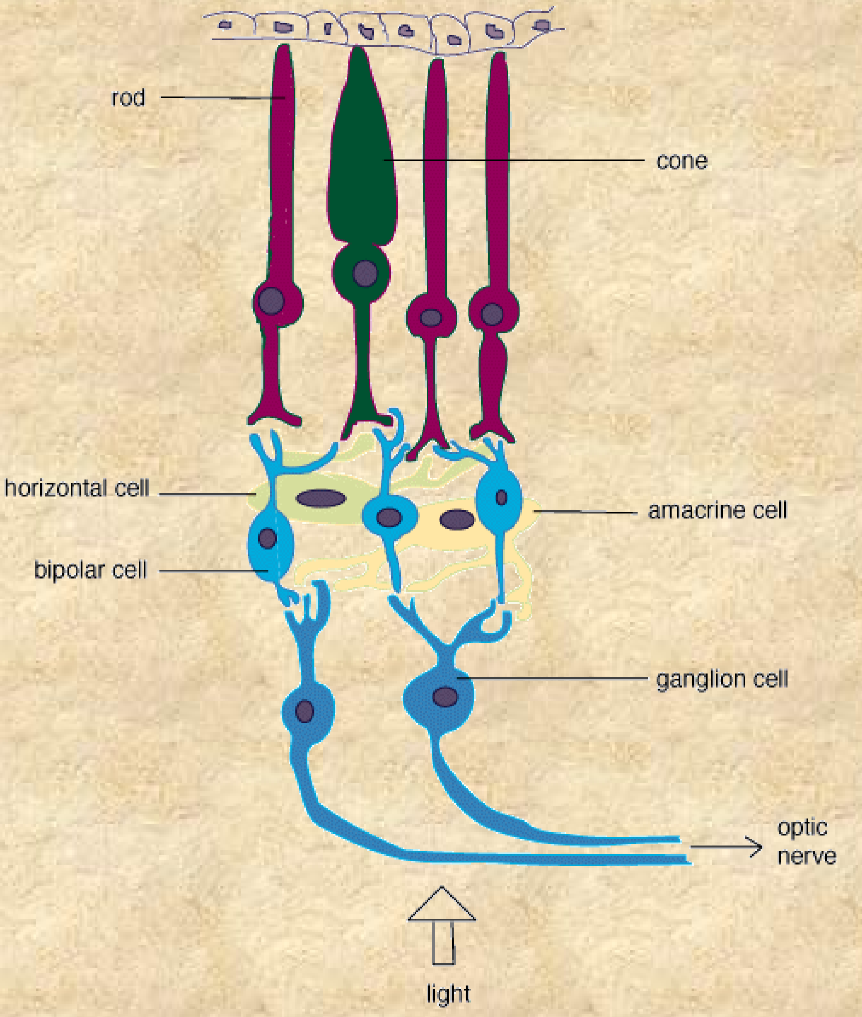
Induced Motion

The moon, when seen behind moving clouds, sometimes appears to move while the clouds appear stationary. The visual system appears to favor the interpretation that small pieces of the visual field move in the real world, large areas do not.

Traffic standstill on a freeway: have you ever had the experience that your car is drifting toward the car in front and stamped on the brakes, only to find that your foot was on the brake anyway and that your car was not moving at all? If all of the cars next to you start moving and they are perceived as stationary, then it must be you that are moving!

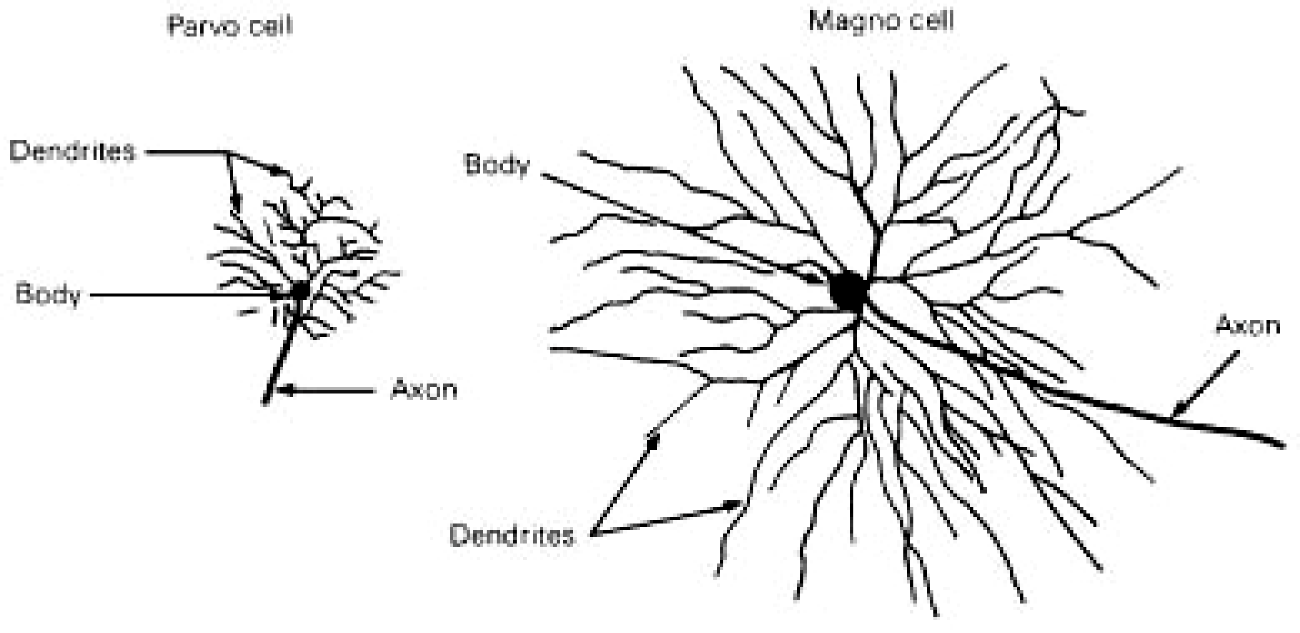
Visual Neuroscience and Perception

Retinal Circuitry



Retinal Ganglion Cells

Several different kinds, including
parvo (small) and *magno* (large) cells



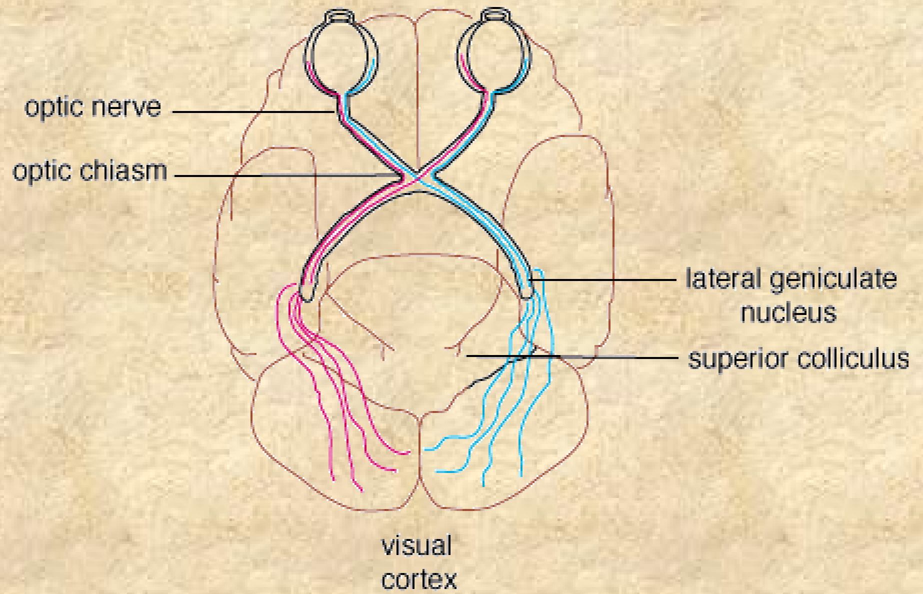
Retinal Ganglion Cells

Parvo (small) and magno (large) cells

	parvo	magno
anatomical	small majority of cells	large minority of cells
physiological	slow, sustained, color-sensitive	fast, transient high sensitivity
functional	form/color	time/motion/depth

Mapping of the visual field

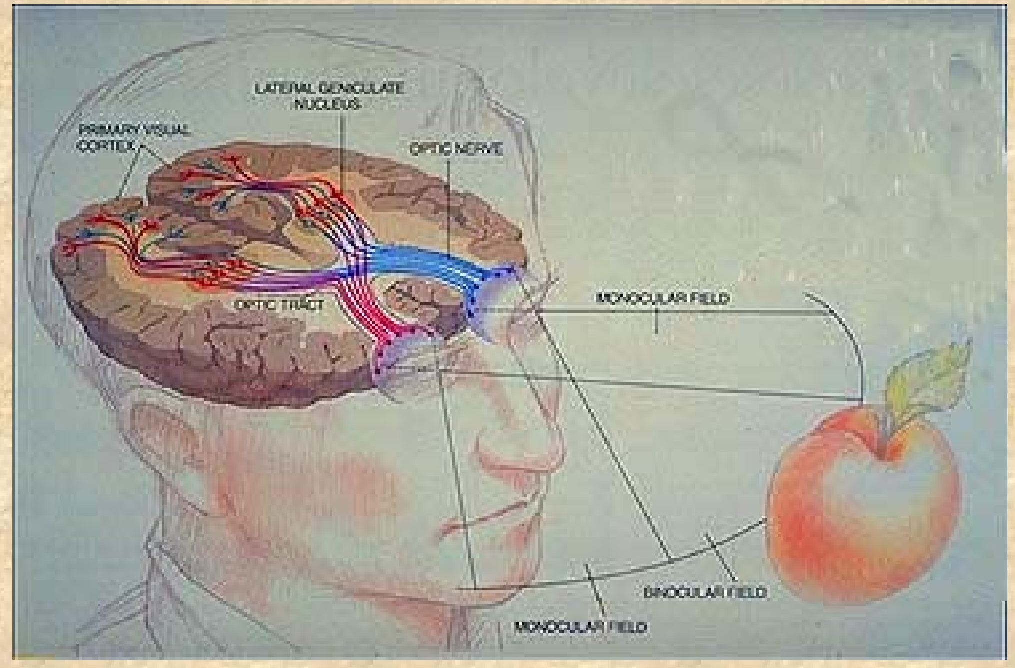
Optic Chiasm



Retinal ganglion cell axons cross in a way that projects
the *left* side of the visual field to the *right* side of the brain
the *right* side of the visual field to the *left* side of the brain

Mapping of the visual field

The lateral geniculate nucleus (LGN) receives information from both eyes.
The left half of the LGN receives information from the right side of the visual field.
The right half of the LGN receives information from the left side of the visual field.
This also holds true for neurons in primary visual cortex (area V1).



Lateral Geniculate Nucleus (LGN)

Layered topographic maps of the visual field

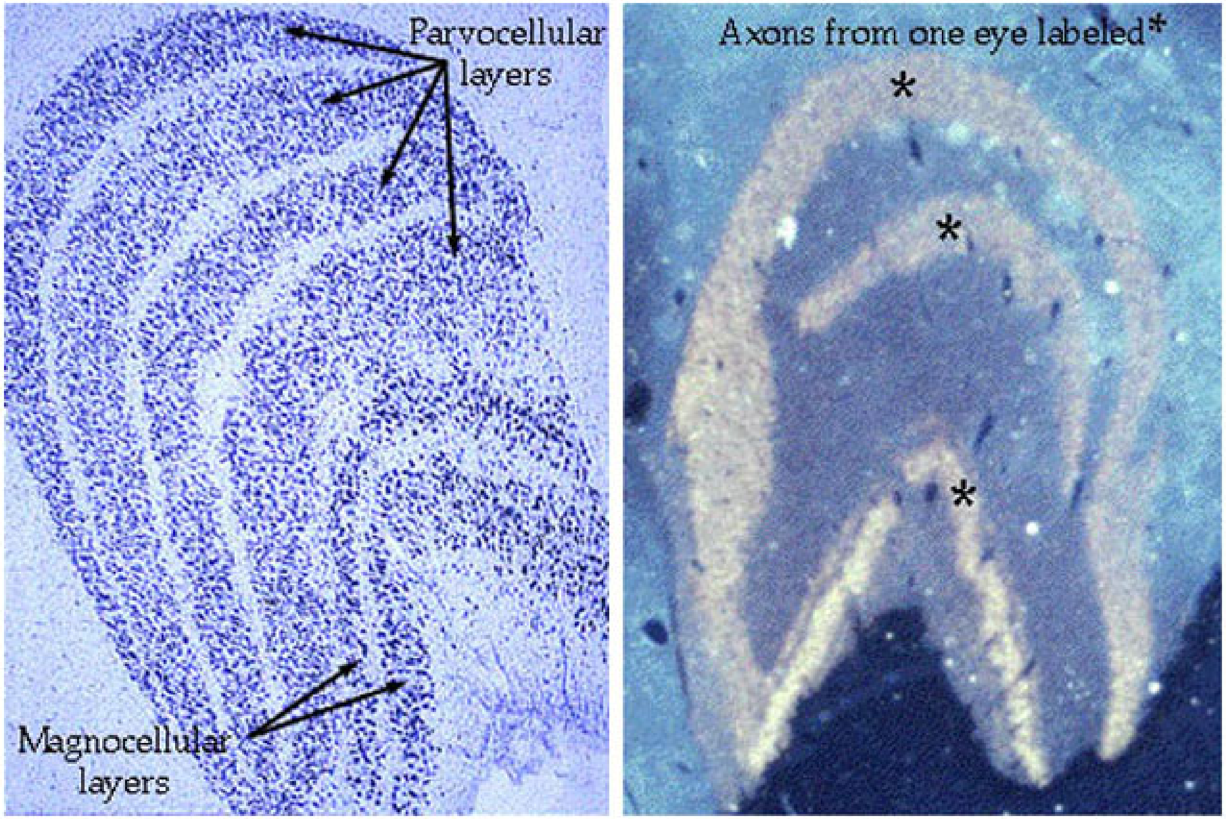
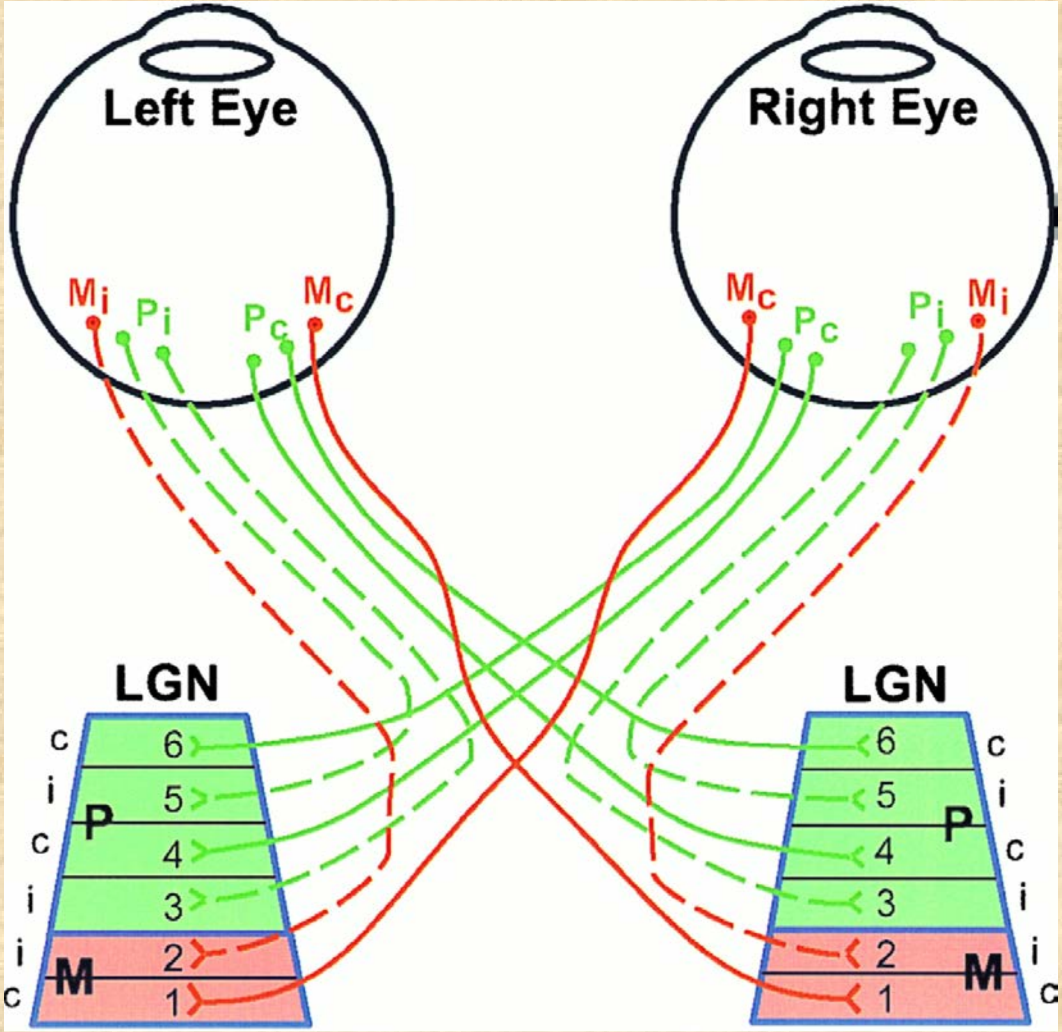


Figure 11. The projections of the small (P cells), and large (M cells) ganglion cells from the two eyes to parvocellular and magnocellular layers of the LGN respectively. Each eye projects to alternating layers as seen in the autoradiogram (right).

Lateral Geniculate Nucleus (LGN)



M – magnocellular
P - parvocellular

c – contralateral
i - ipsilateral

Neurons in LGN project (via their axons) to primary visual cortex (area V1) via the optic radiation

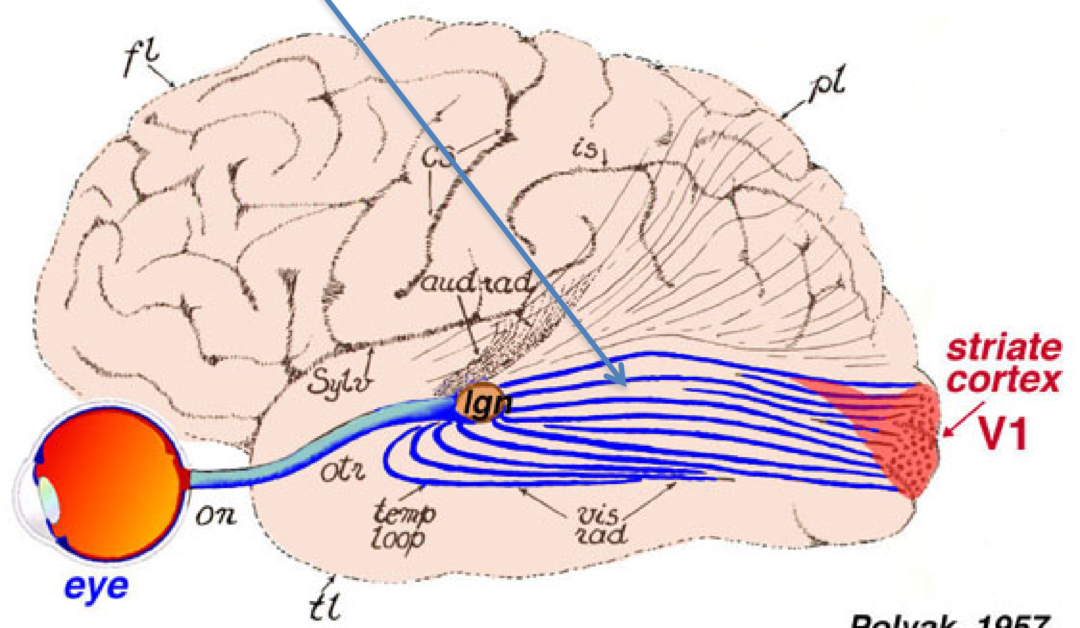
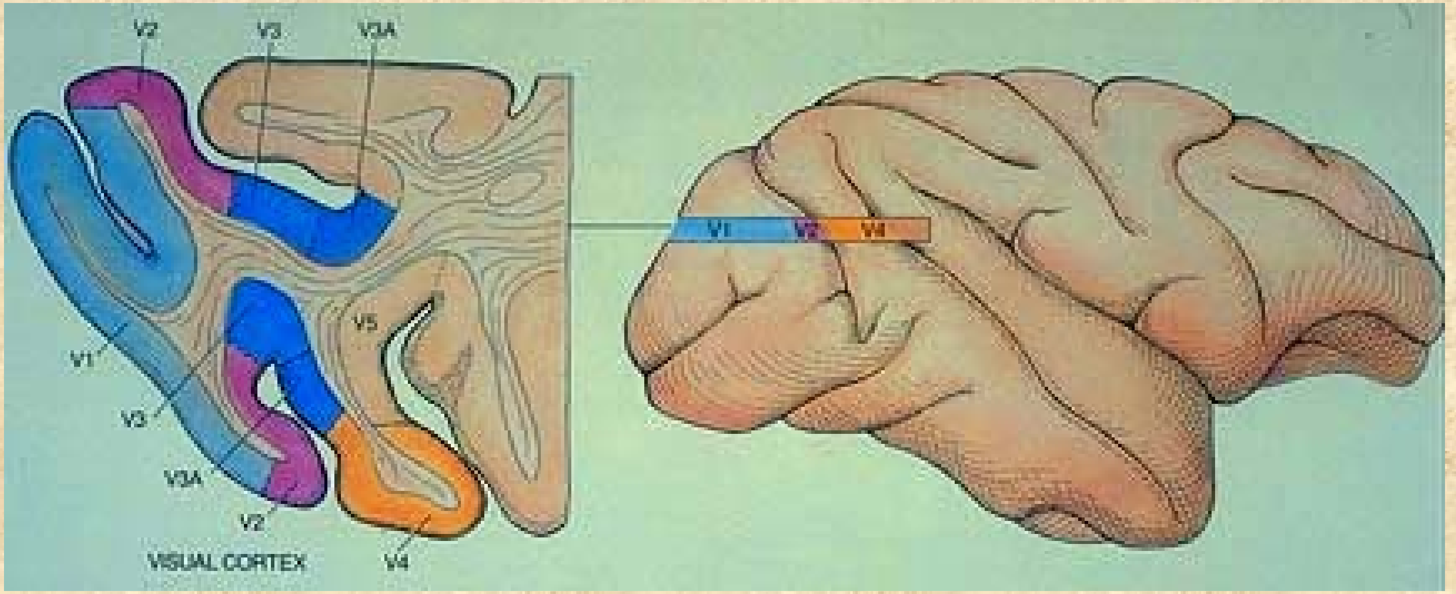


Figure 8. Visual input to the brain goes from eye to LGN and then to primary visual cortex, or area V1, which is located in the posterior of the occipital lobe.
Adapted from Polyak (1957).

There are also ***extrastriate*** visual areas of cortex engaged in visual processing, such as

V2, V3, V4 and V5 (MT)



So lets start with V1...

Parallel Processing of Visual Information

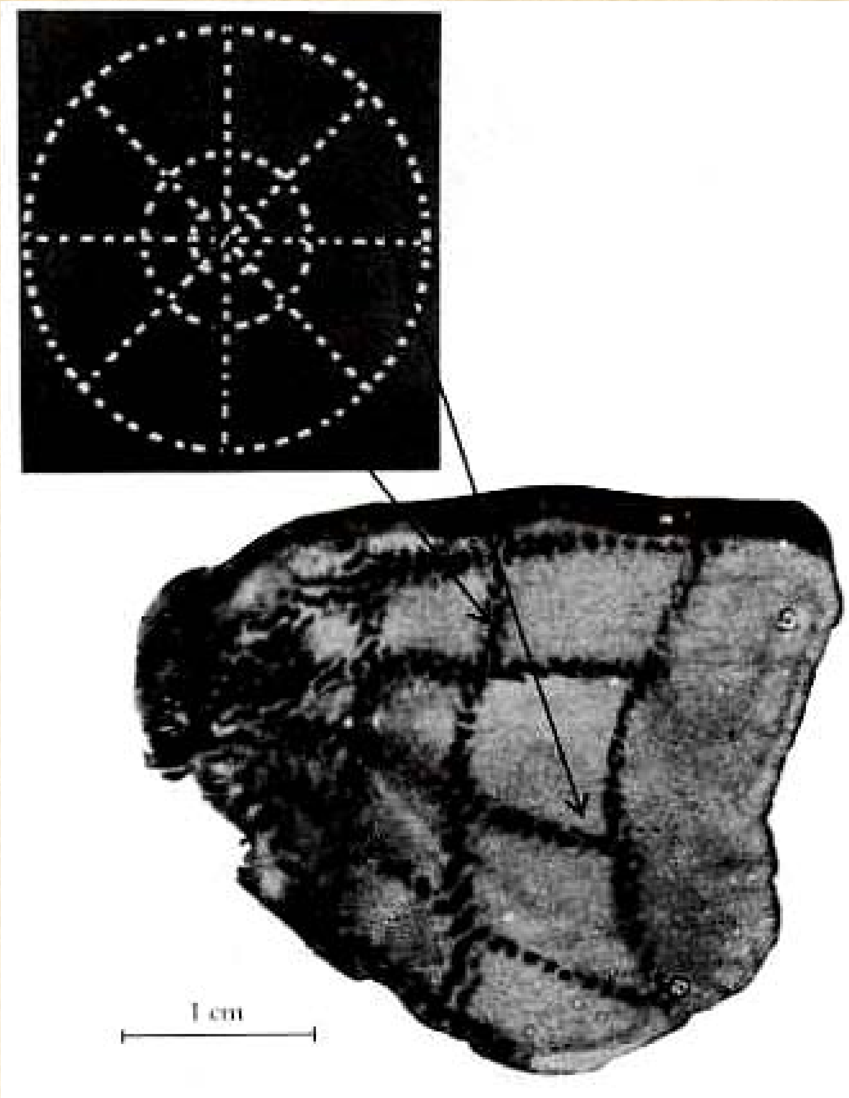
- Different neurons in visual cortex respond to different aspects of a stimulus.
- These different analyses go on in parallel; they proceed simultaneously at all locations across the visual field.
- For example, neurons that analyze forms are doing their work at the same time that other cells are analyzing motion and still others are analyzing color.
- In primary visual cortex (V1), these neurons are organized according to the visual field locations of their receptive fields

Primary Visual Cortex – V1

Retinotopic Mapping

Many more neurons are devoted to processing information from the central visual field, especially in the fovea

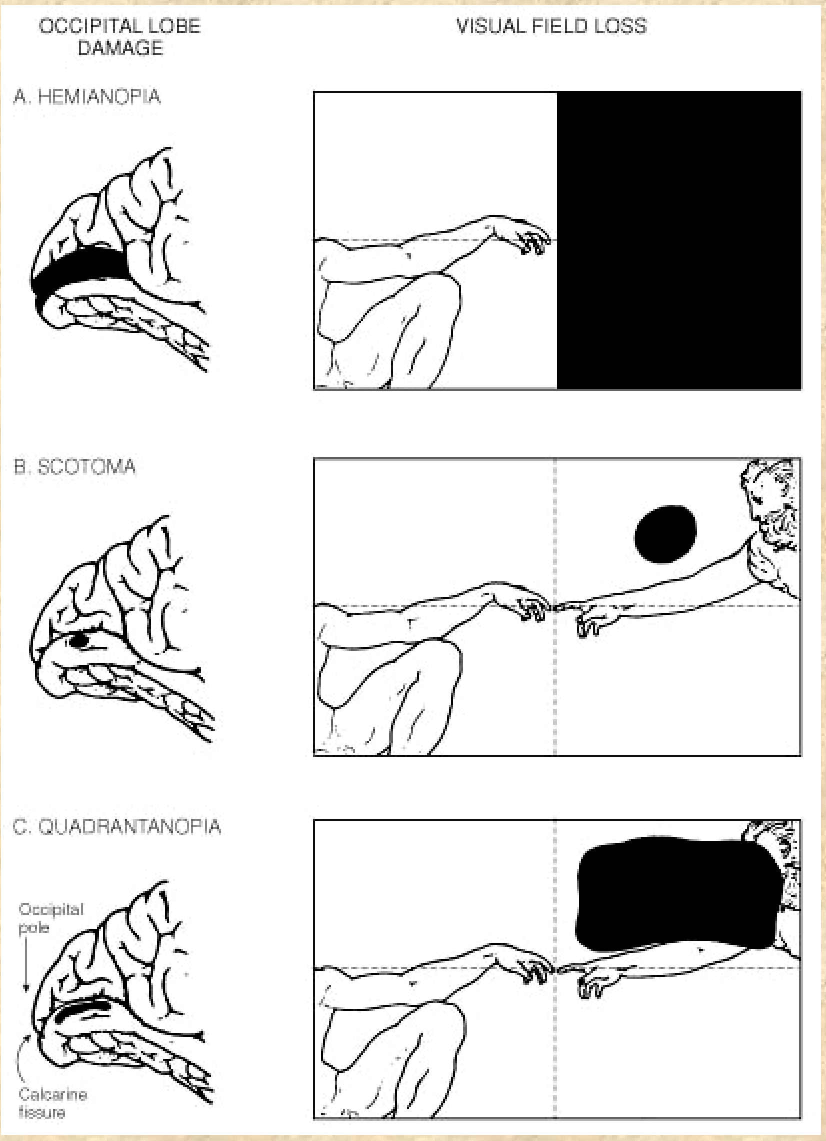
Neurons have receptive fields laid out **retinotopically,** so that sensitivity to visual field directions changes smoothly as one moves
across visual cortex.



from David Hubel’s *Eye, Brain, and Vision*, work by Roger Tootell

Primary Visual Cortex

Retinotopic Mapping



Primary Visual Cortex

Six Layers in V1

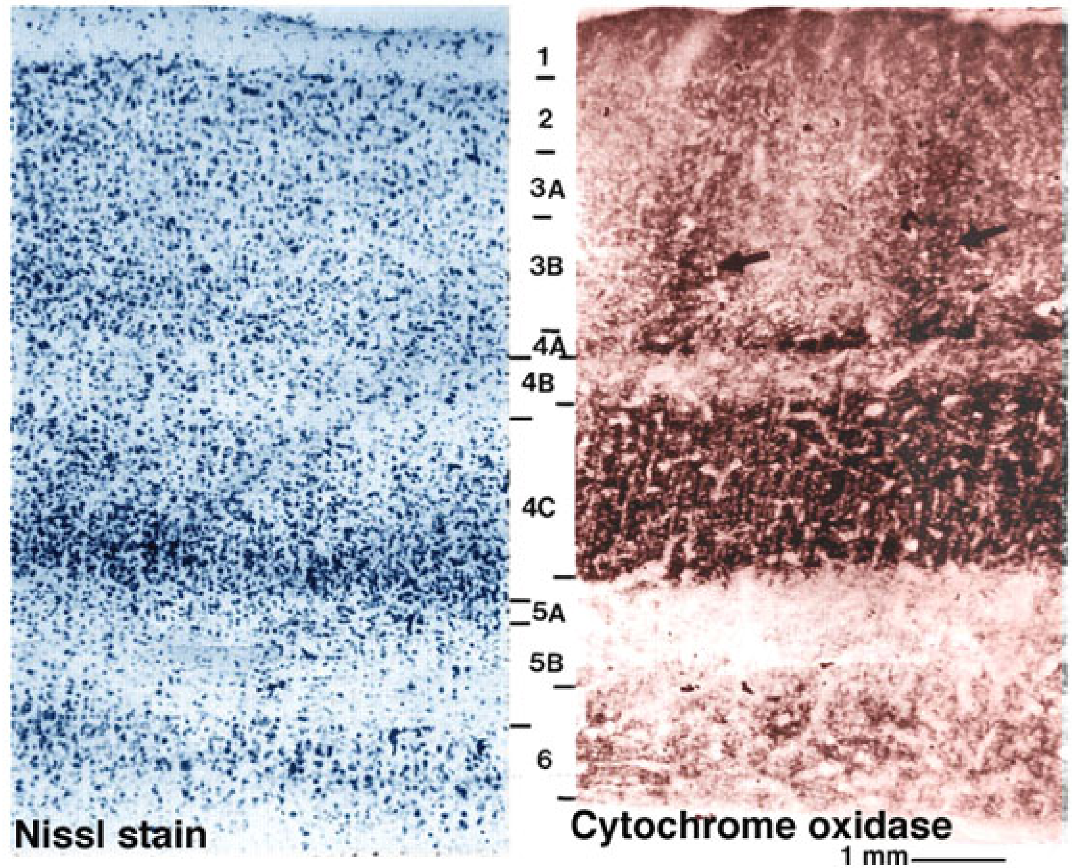
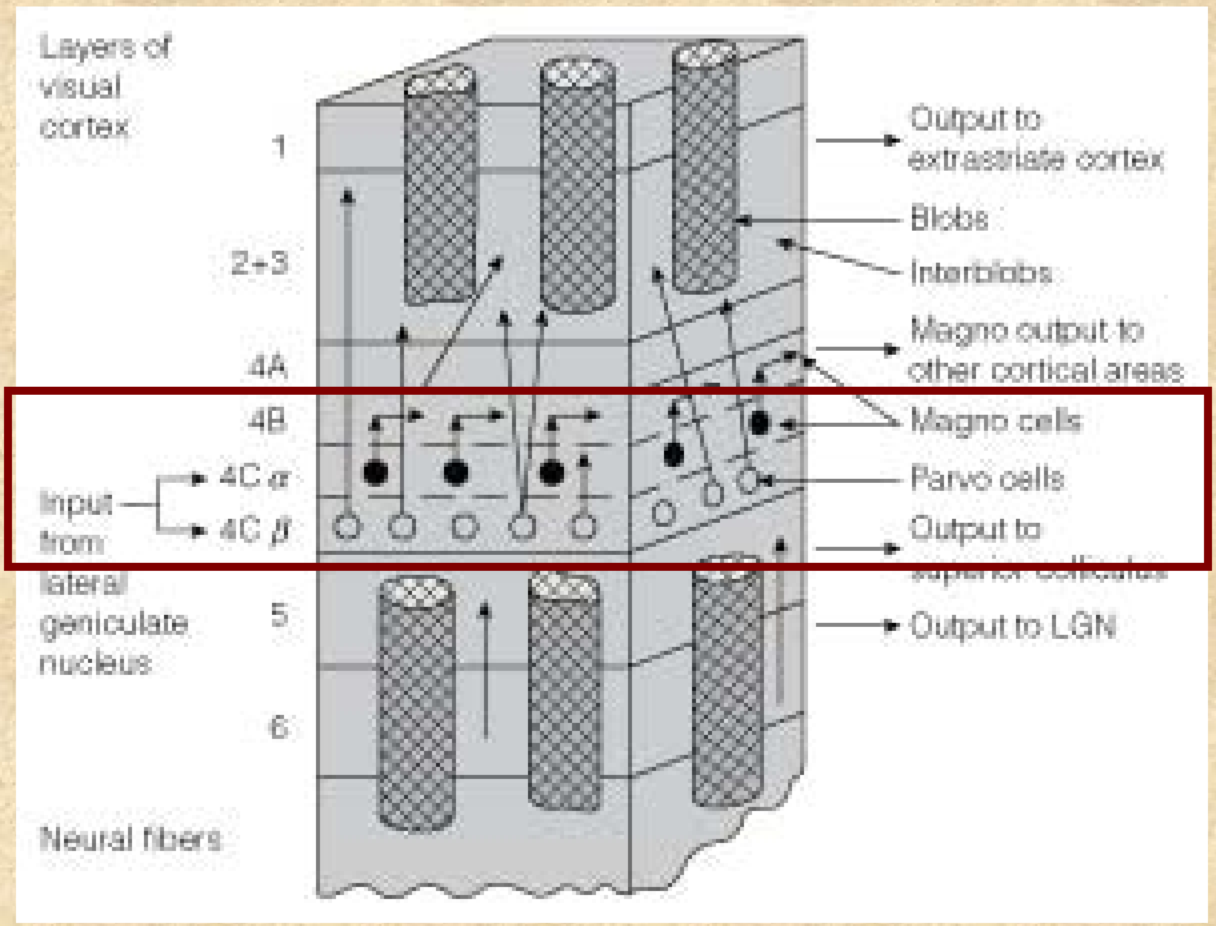


Figure 10. Nissl (left) and cytochrome oxidase (right) labeled cross sections of the visual cortex of a macaque monkey, showing the individual layers.

Primary Visual Cortex

Six Layers in V1

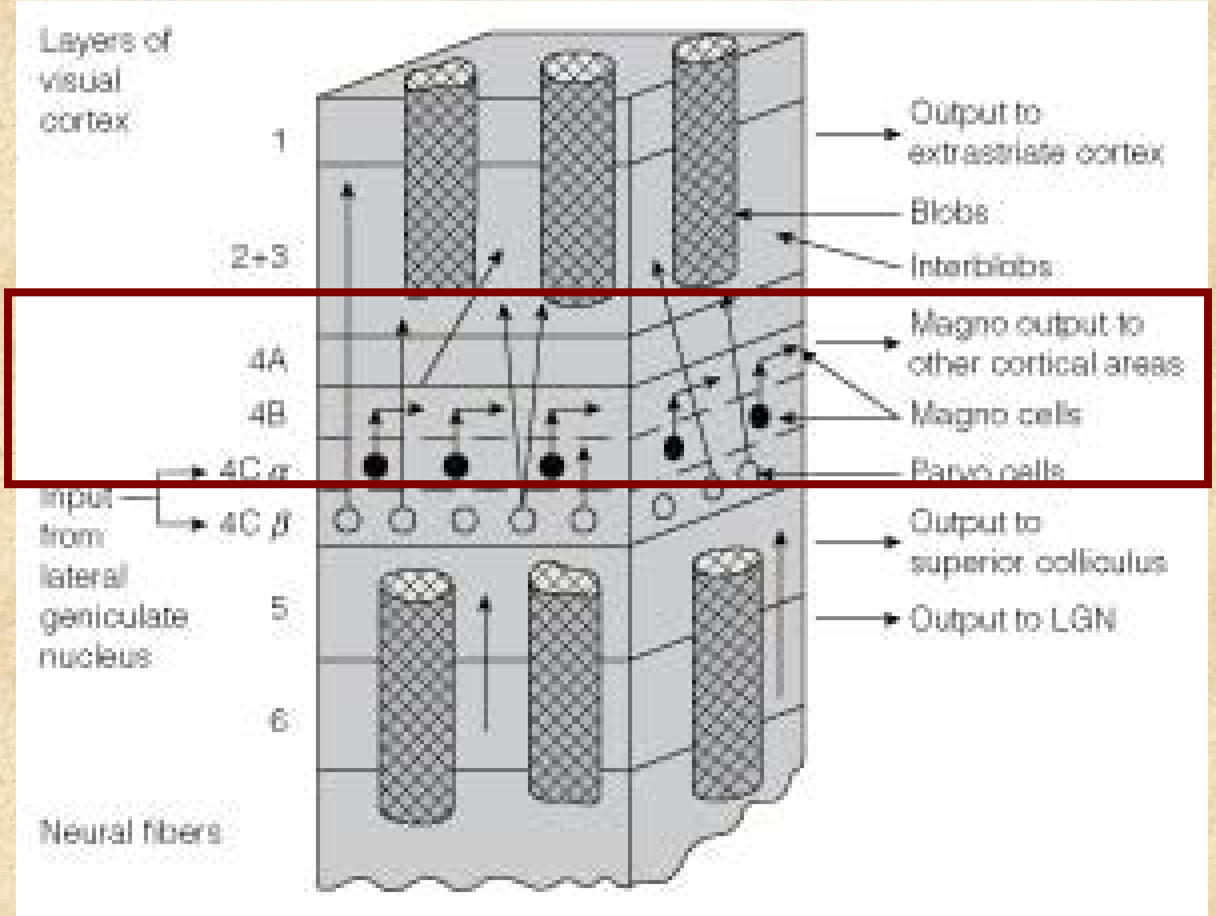
Primary Input
from LGN
Layer 4C
4C α – magno
4C β - parvo



Primary Visual Cortex

Motion Pathway

LGN magno layers ->
4Cα -> 4B
-> V2 thick stripes



Primary Visual Cortex

Color Pathway

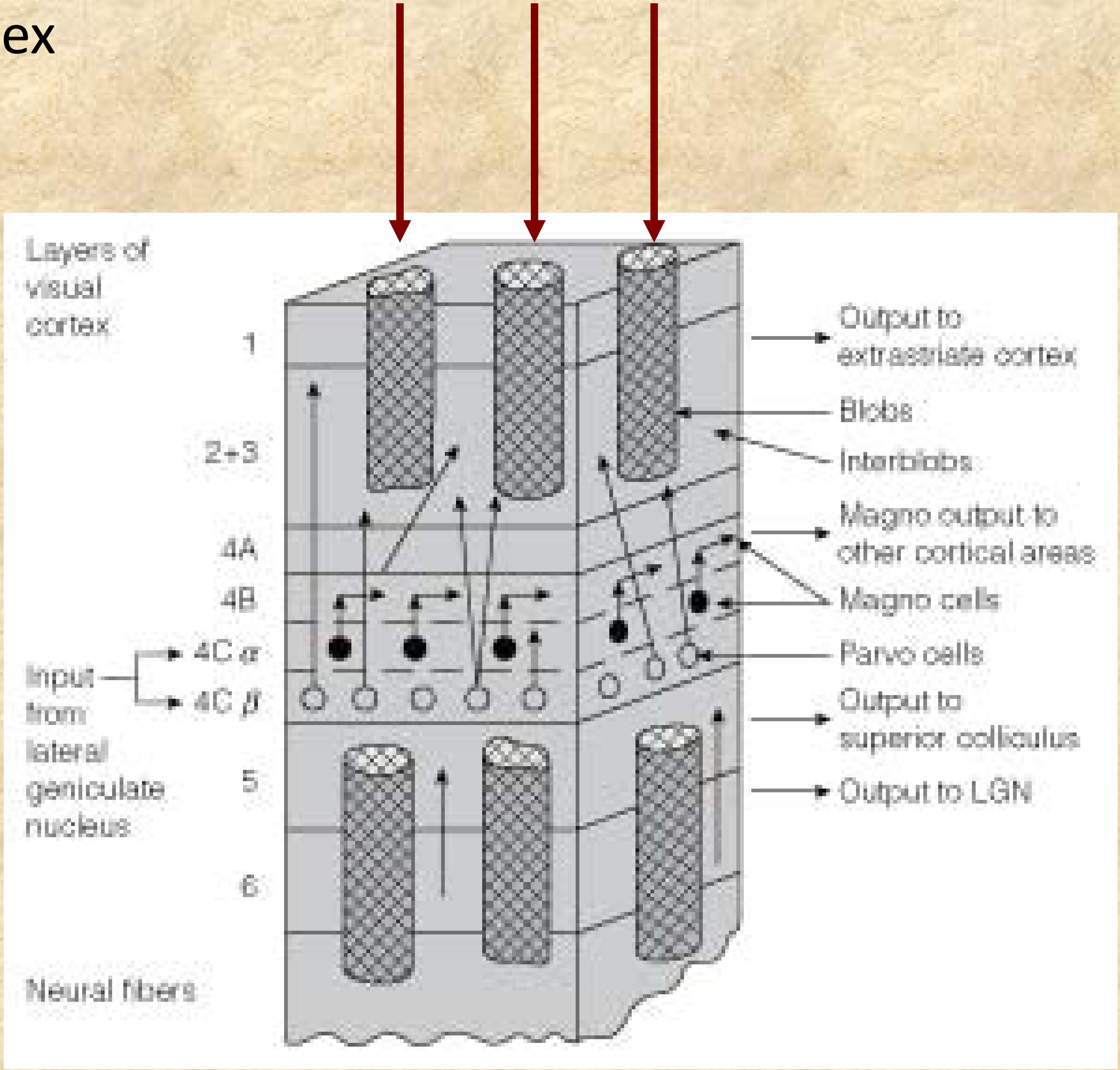
Blobs

color

vs.

Interblobs

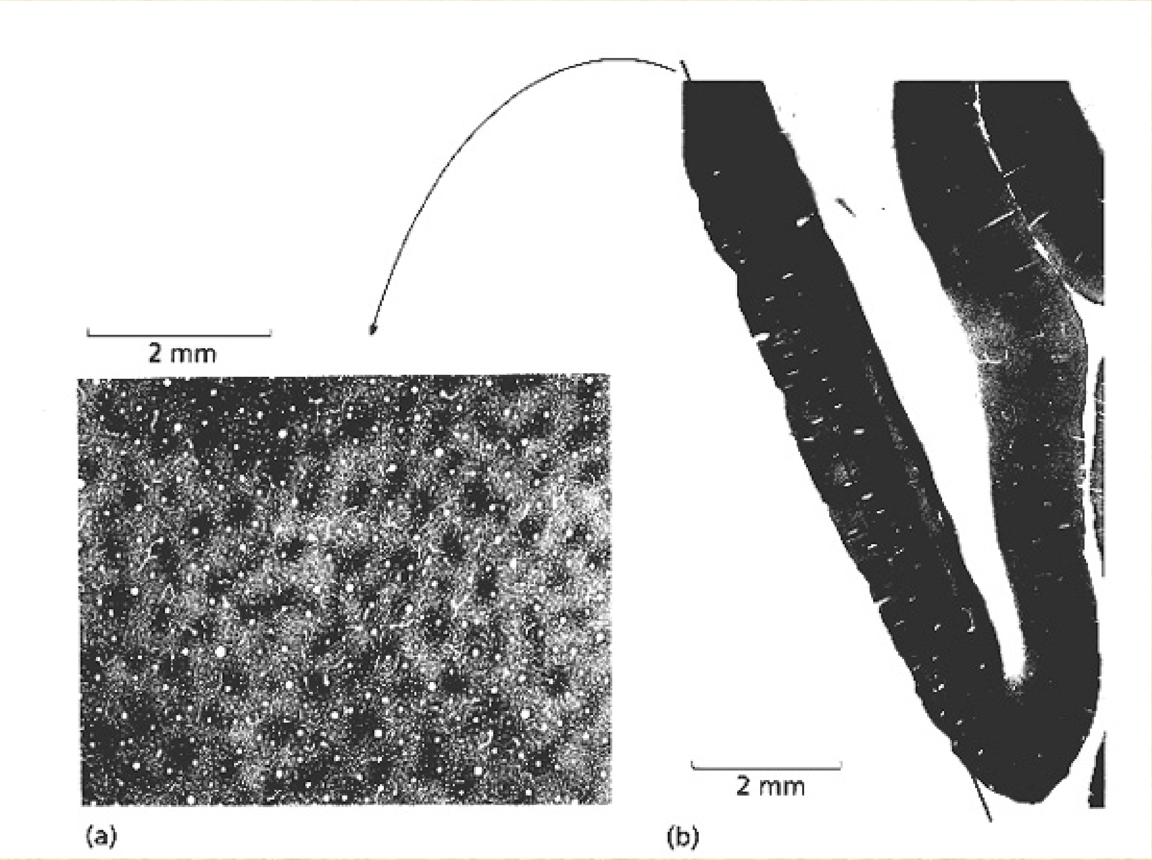
form



Primary Visual Cortex

cytochrome oxidase stain

Blobs



work by Margaret Wong-Riley

Primary Visual Cortex

Blobs
color
parvo

vs.

Interblobs
form

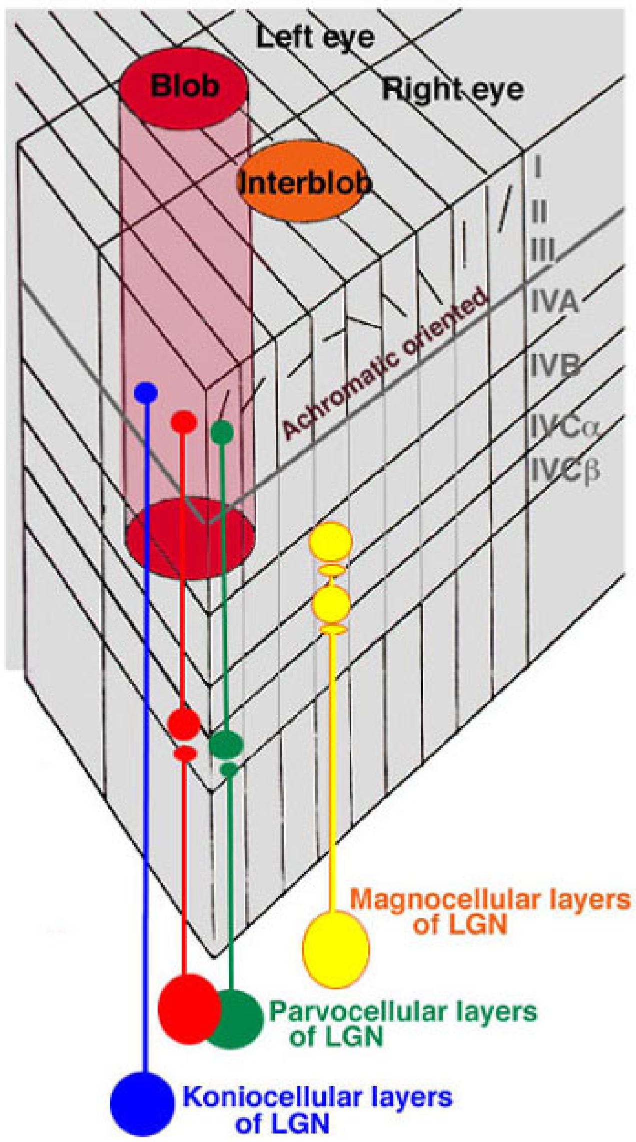
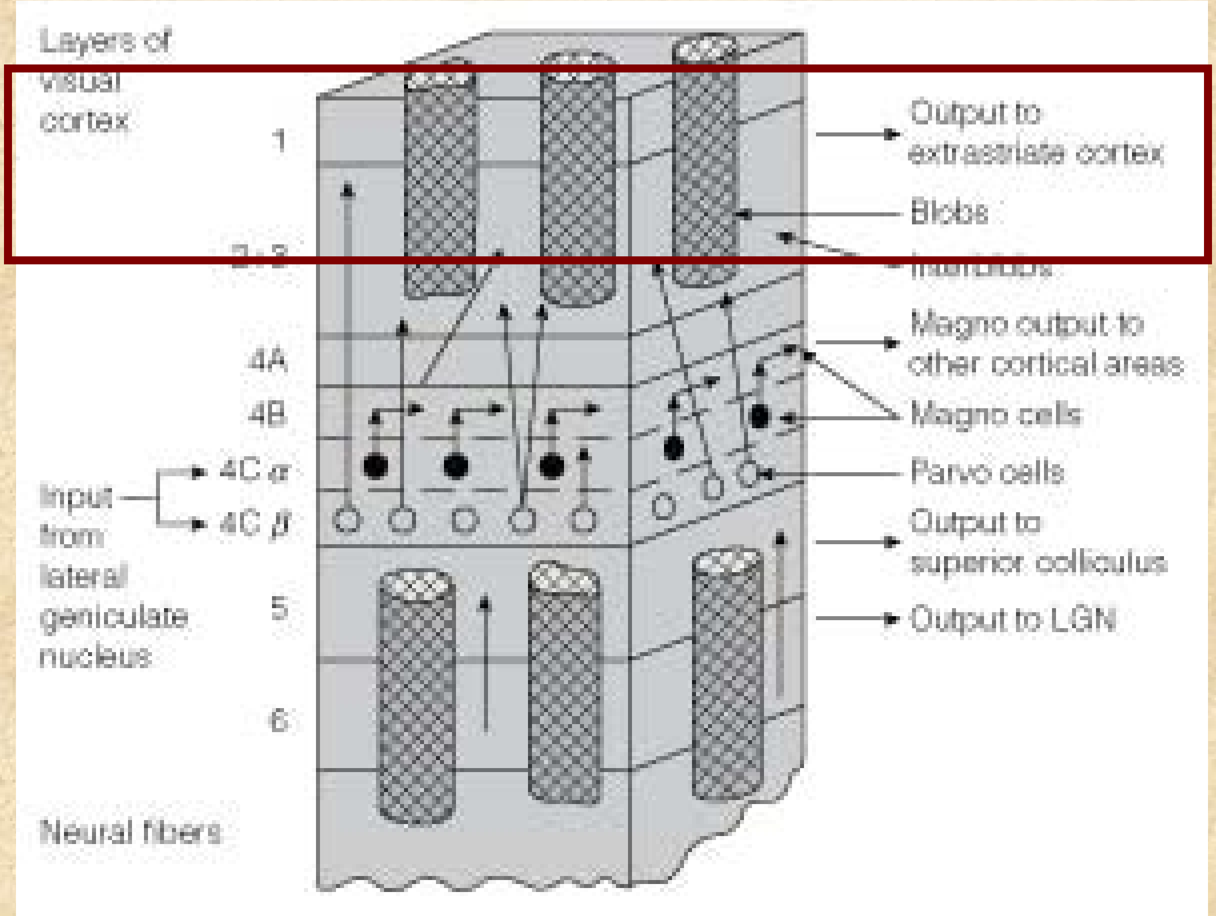


Fig. 27. Diagram of a slab of striate cortex (V1) of primate brain to show the composition of a hypercolumn. A hypercolumn consists of two ocular dominace columns (one from each eye) each containing stacks of orientation columns. A blob is a cylinder of cells running from I to IVB which receives direct input from blue/yellow cells of the koniocellular layers of the LGN, and the color-opponent red and green cells of the parvo-cellular layers of the LGN. The latter projections are secondary to the first synapses in layer IVCb. Magnocellular cells from the LGN project to layer IVCa.

Primary Visual Cortex

Form/Color

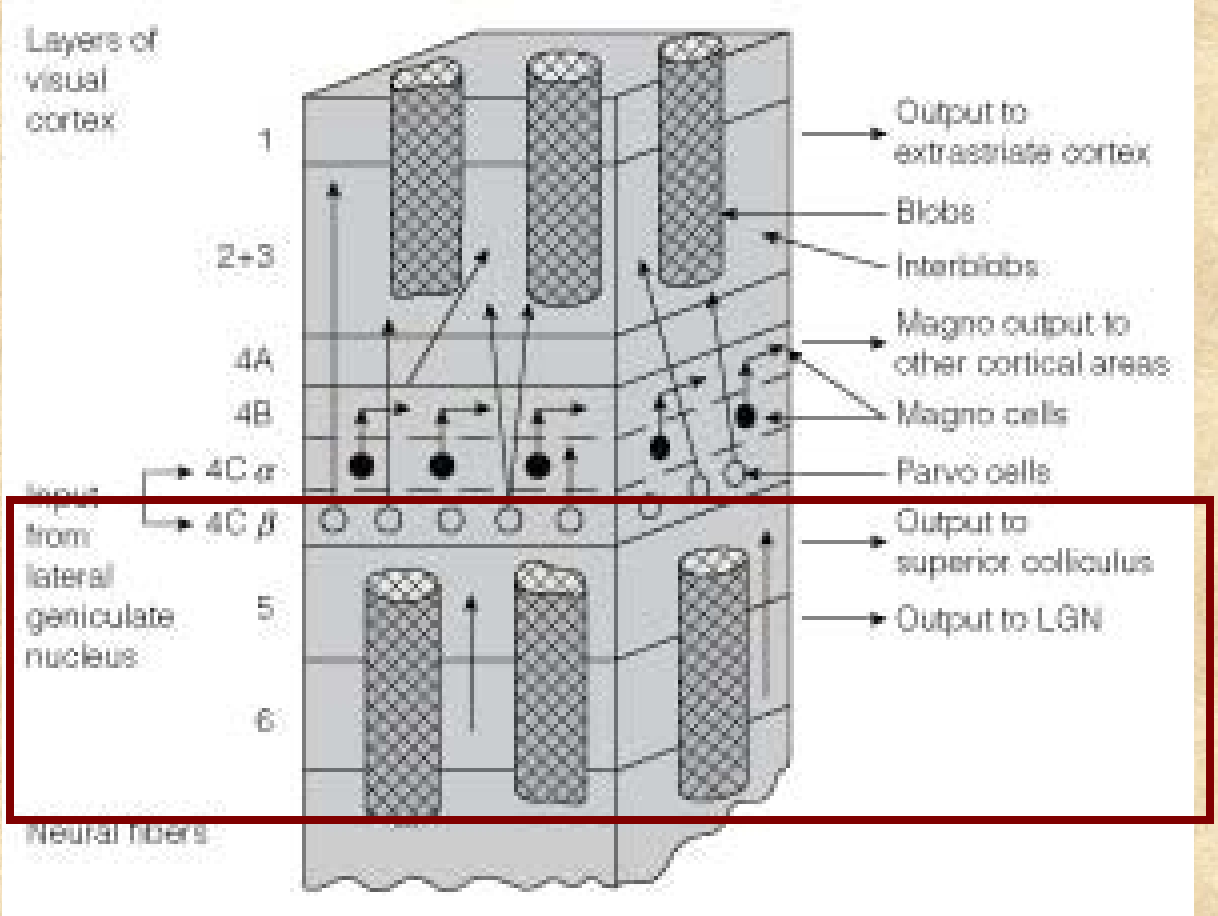
LGN parvo layers -> 4Cβ -> Layers 2+3,1 -> extrastriate areas



Primary Visual Cortex

Back Projections (modulate input to cortex)

Layers 5,6 not only receive some input from superior colliculus (SC) and LGN but also project back to these areas



Primary Visual Cortex

Ocular Dominance Columns

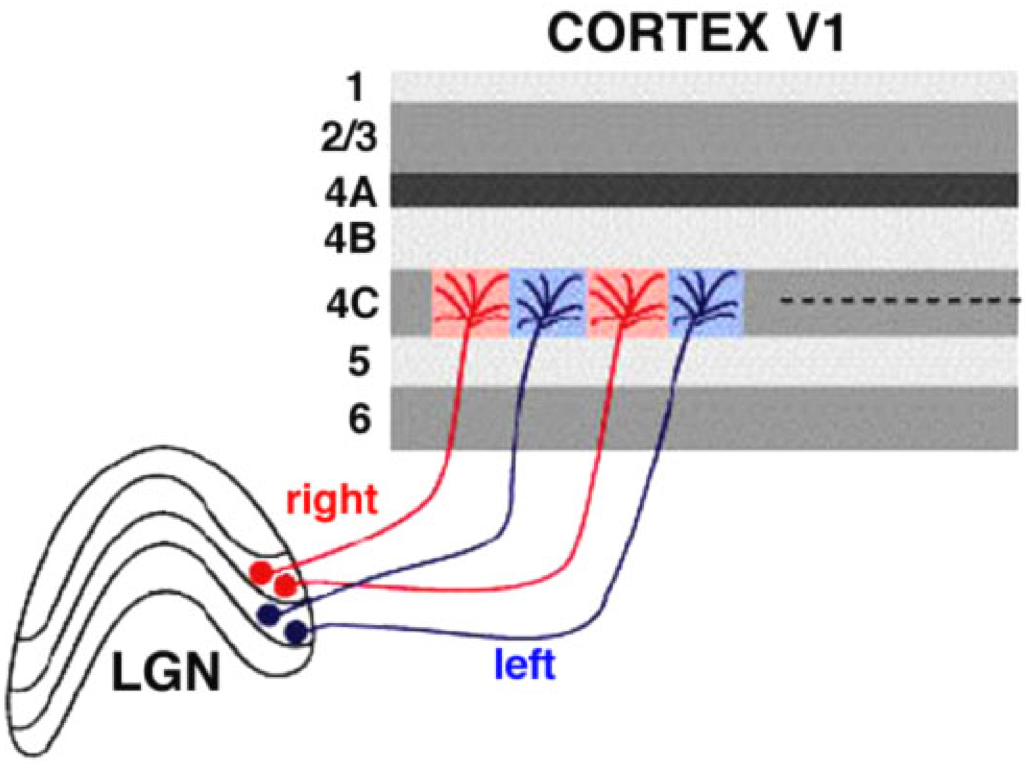
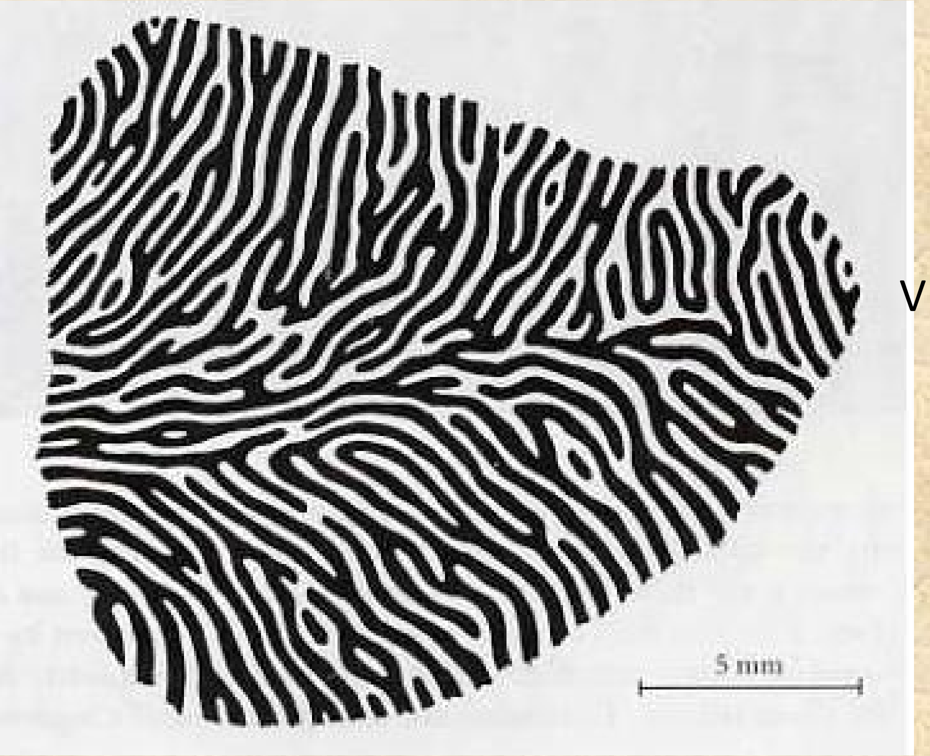


Figure 14. The signals from each eye are segregated within the LGN and go into different ocular dominance columns within area V1, layer 4C.

Primary Visual Cortex

Ocular Dominance Columns



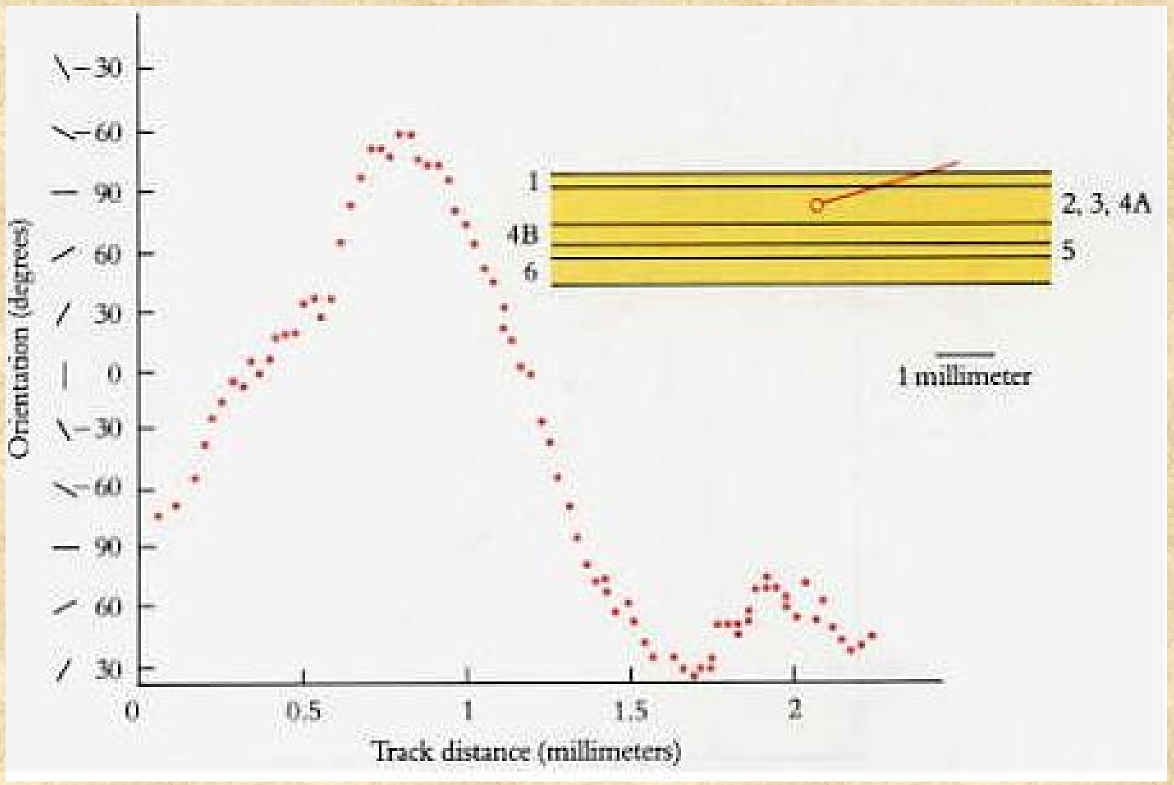
V1 fovea

from David Hubel's *Eye, Brain, and Vision*
Simon LeVay's reconstruction

Primary Visual Cortex

Change in Orientation Sensitivity

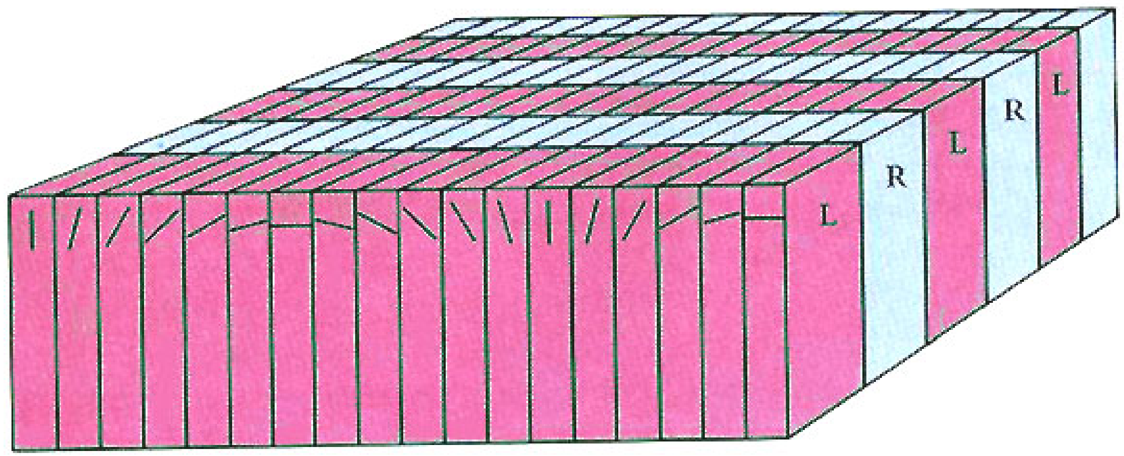
as one traverses the cortical surface



from David Hubel's *Eye, Brain, and Vision*

Primary Visual Cortex

Orientation and Ocular Dominance Relationship

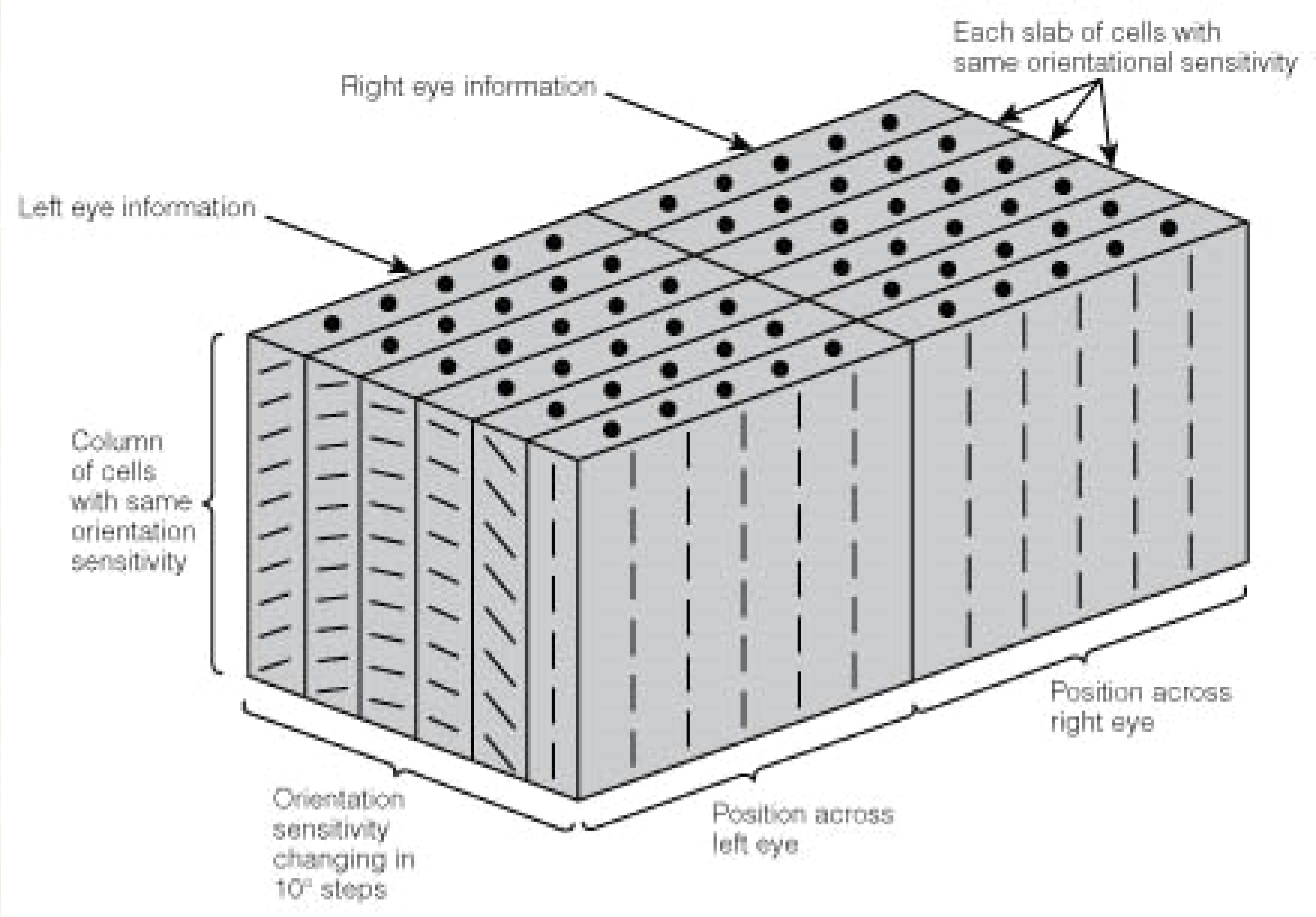


Orientation and ocular dominance columns

Figure 23. The ice-cube model of the cortex. It illustrates how the cortex is divided, at the same time, into two kinds of slabs, one set of ocular dominance (left and right) and one set for orientation. The model should not be taken literally: Neither set is as regular as this, and the orientation slabs especially are far from parallel or straight.

Primary Visual Cortex

Hypercolumn



Primary Visual Cortex

Hypercolumn

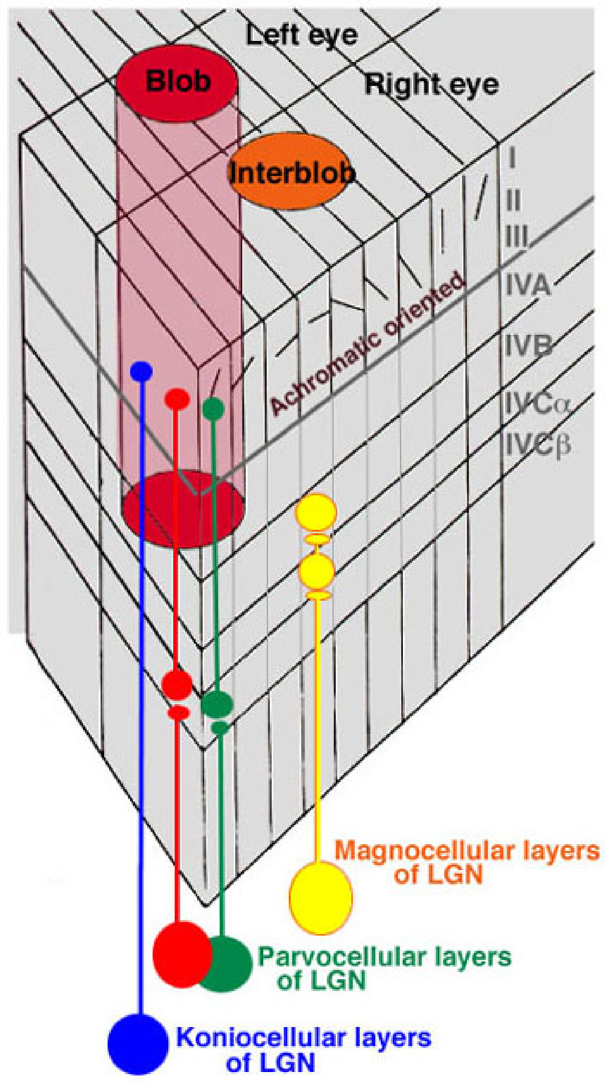
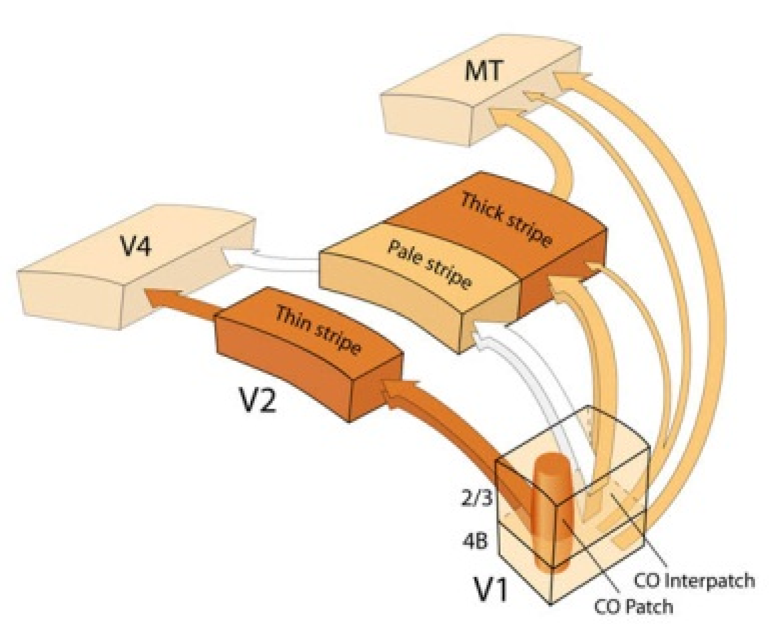
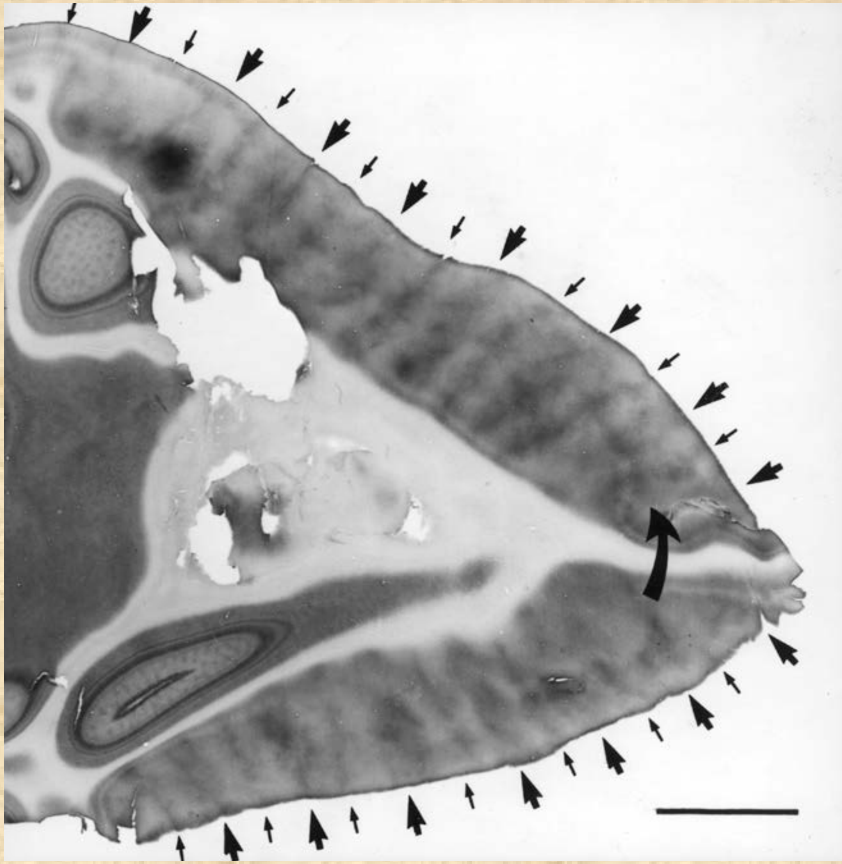


Fig. 27. Diagram of a slab of striate cortex (V1) of primate brain to show the composition of a hypercolumn. A hypercolumn consists of two ocular dominace columns (one from each eye) each containing stacks of orientation columns. A blob is a cylinder of cells running from I to IVB which receives direct input from blue/yellow cells of the koniocellular layers of the LGN, and the color-opponent red and green cells of the parvo-cellular layers of the LGN. The latter projections are secondary to the first synapses in layer IVCb. Magnocellular cells from the LGN project to layer IVCa.

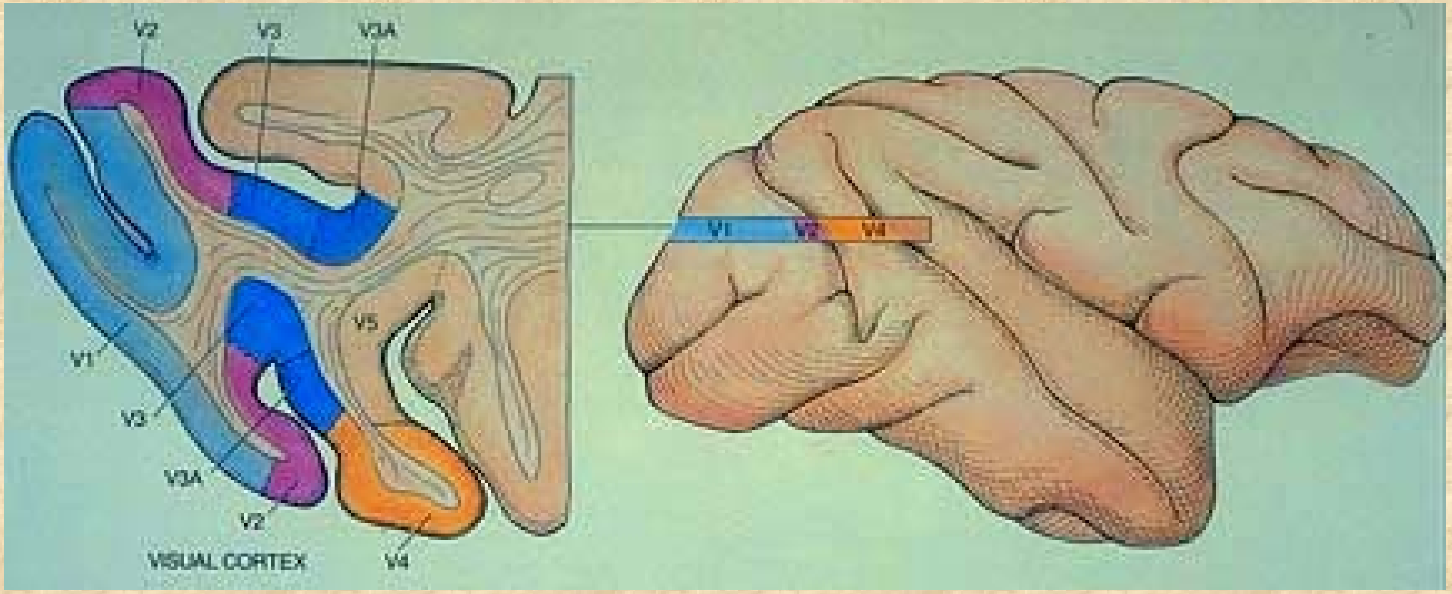
What about V2?





Extrastriate Cortex

V2 – * some LGN input
* lots of V1 input
* retinotopically mapped
* thin stripes (color)
* thick stripes (motion)
* interstripes (form)
* projects to V3, V4, V5 (MT)



Extrastriate Cortex

V3 – V1 and V2 input

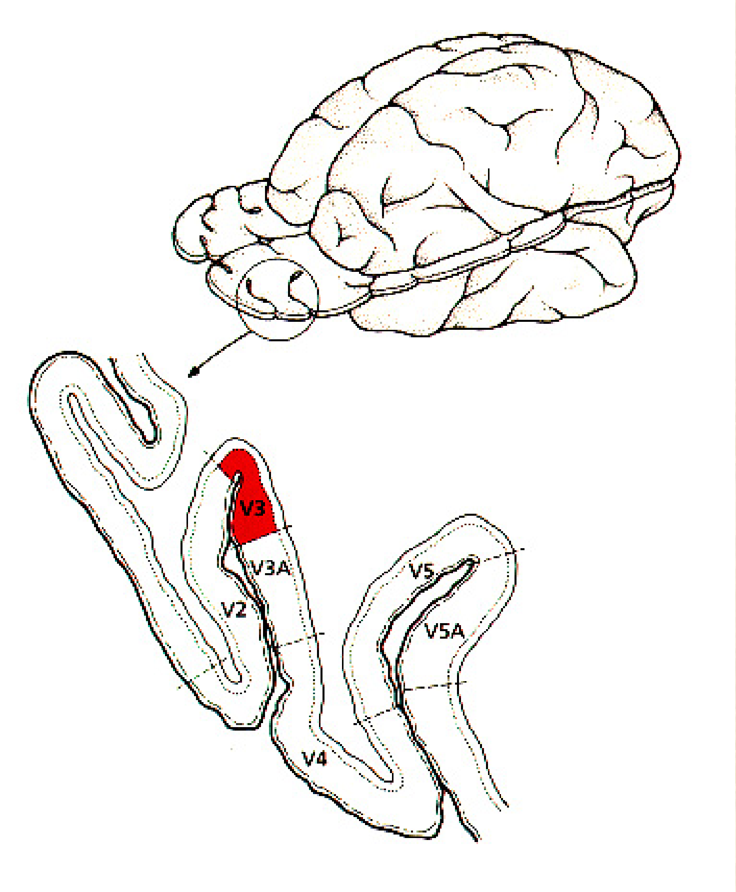
two retinotopic maps of foveal region

specialized for detailed visual processing

specialized for analysis of moving form

+ color sensitivity

+depth sensitivity



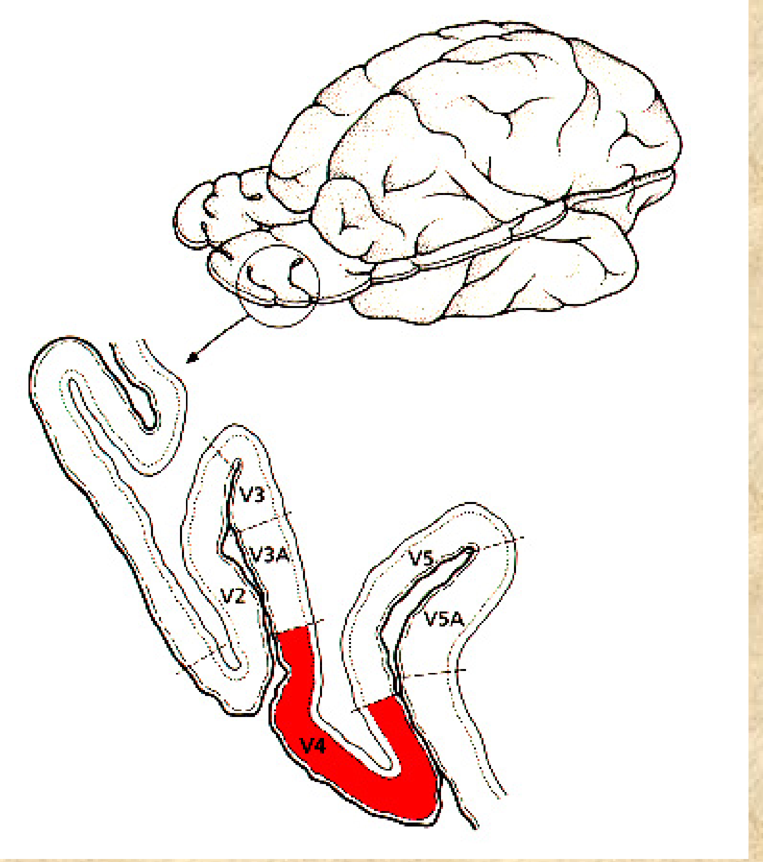
Extrastriate Cortex

V4 – specialized for color, among other things

cerebral achromatopsia
cannot see color!
-often accompanied by visual scotoma and visual agnosia

large receptive fields

thought to be sensitive to color of surface



Extrastriate Cortex

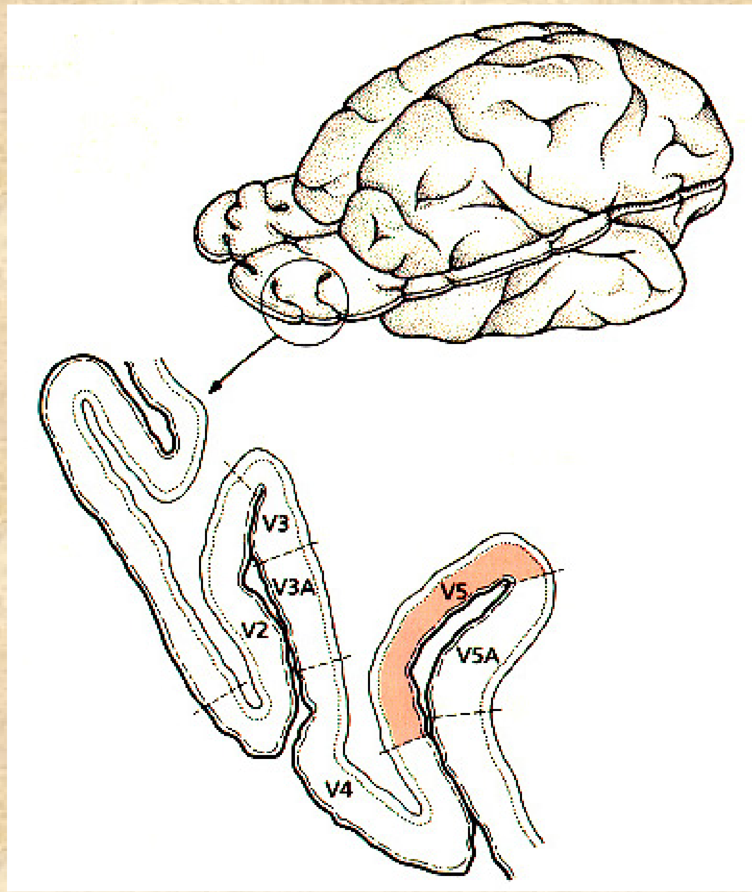
V5 – specialized for motion
also called area MT

cerebral akinetopsia
cannot see motion!

inputs – V2 thick stripes

V5 neurons sensitive to
motion of object
V3 neurons sensitive to
motion of edges

large receptive fields

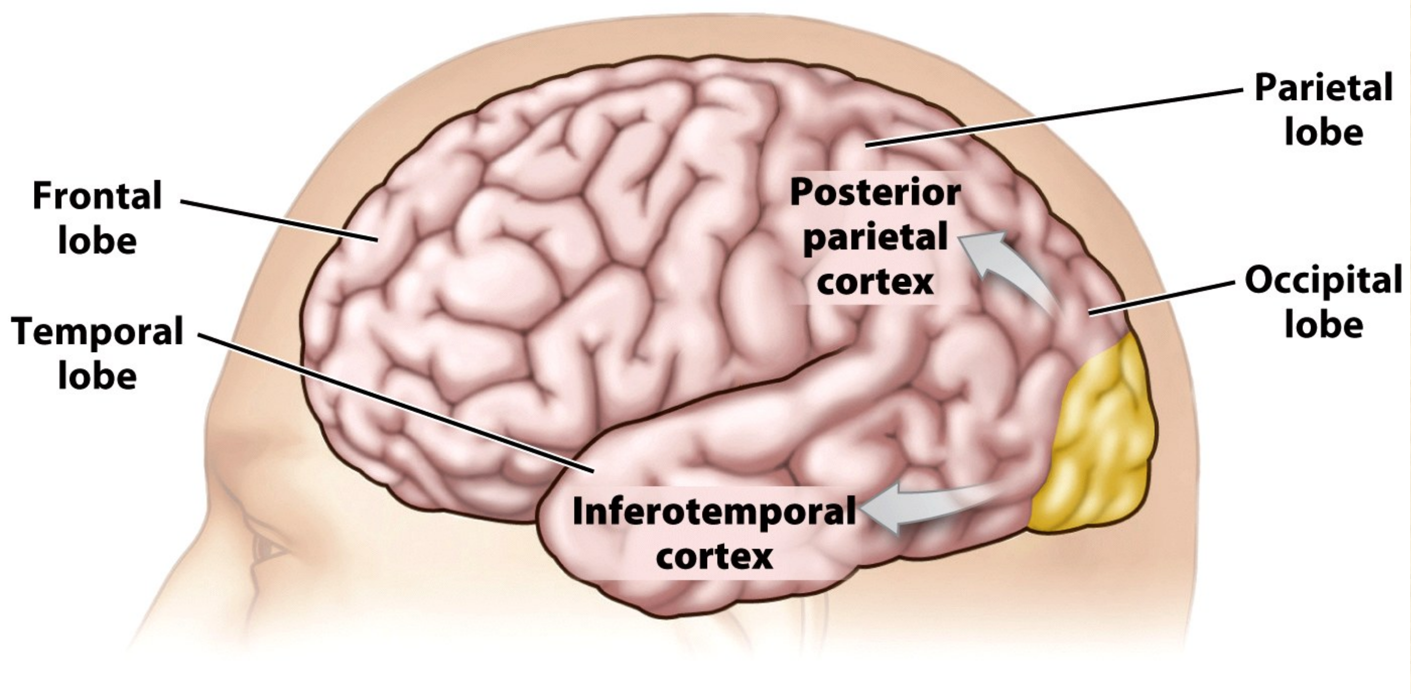


“Where” Visual Pathway

Occipital to Parietal Lobe

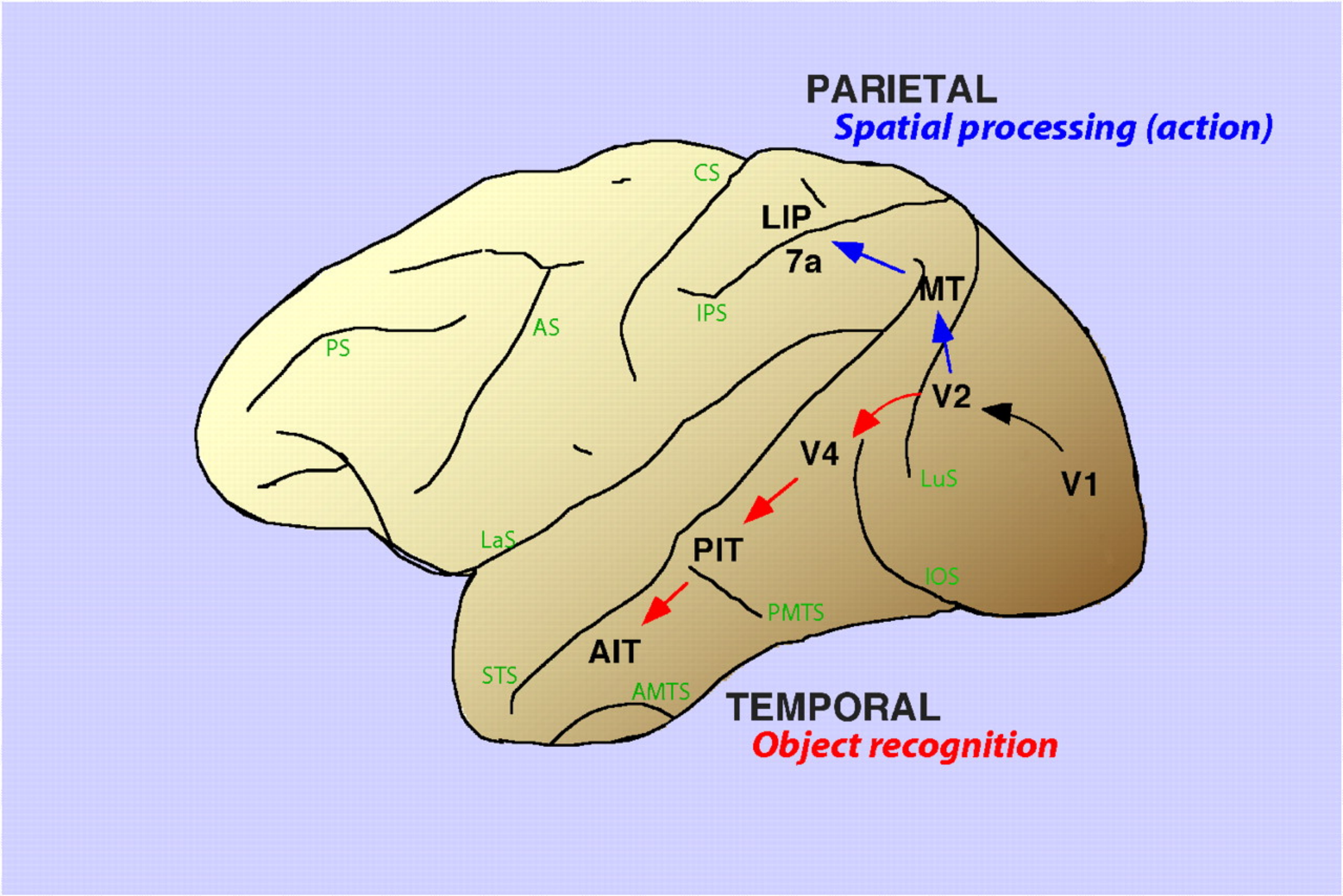
“What” Visual Pathway

Occipital to Temporal Lobe

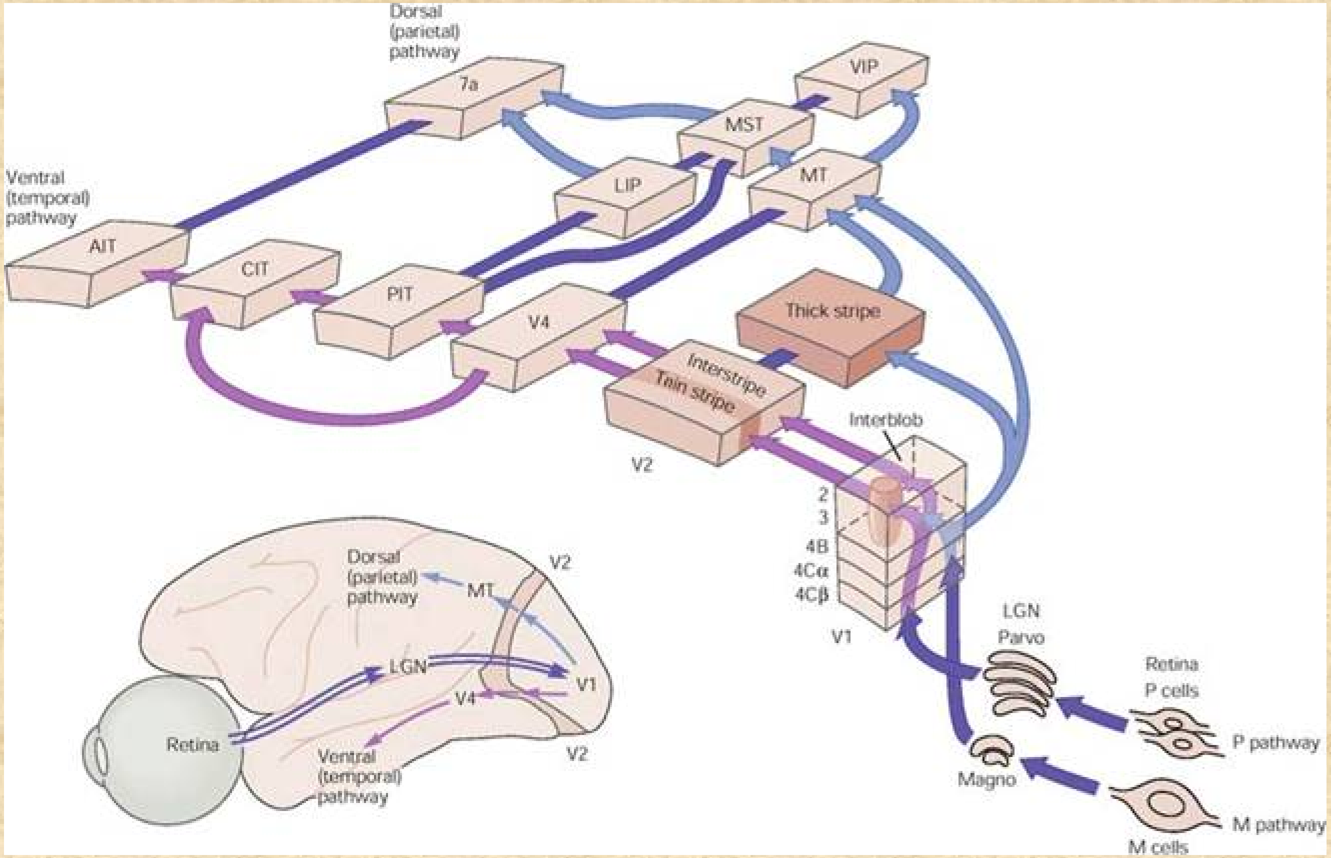


Psychology, 8/e Figure 5.19

After Mishkin and colleagues (1983)



Lehky S R , Sereno A B J Neurophysiol 2007;97:307-319


Dorsal
(parietal)
pathway
7a
VIP
MST
LIP
MT
Ventral
(temporal)
pathway
AIT
CIT
PIT
V4
Thick stripe
Interstripe
Tein stripe
V2
Interblob
2
3
4B
4Cα
4Cβ
V1
LGN
Parvo
Retina
P cells
P pathway
Magno
M pathway
M cells
Dorsal
(parietal)
pathway
MT
V2
LGN
V1
V4
Retina
Ventral
(temporal)
pathway
V2

Multiple Parallel Visual Pathways

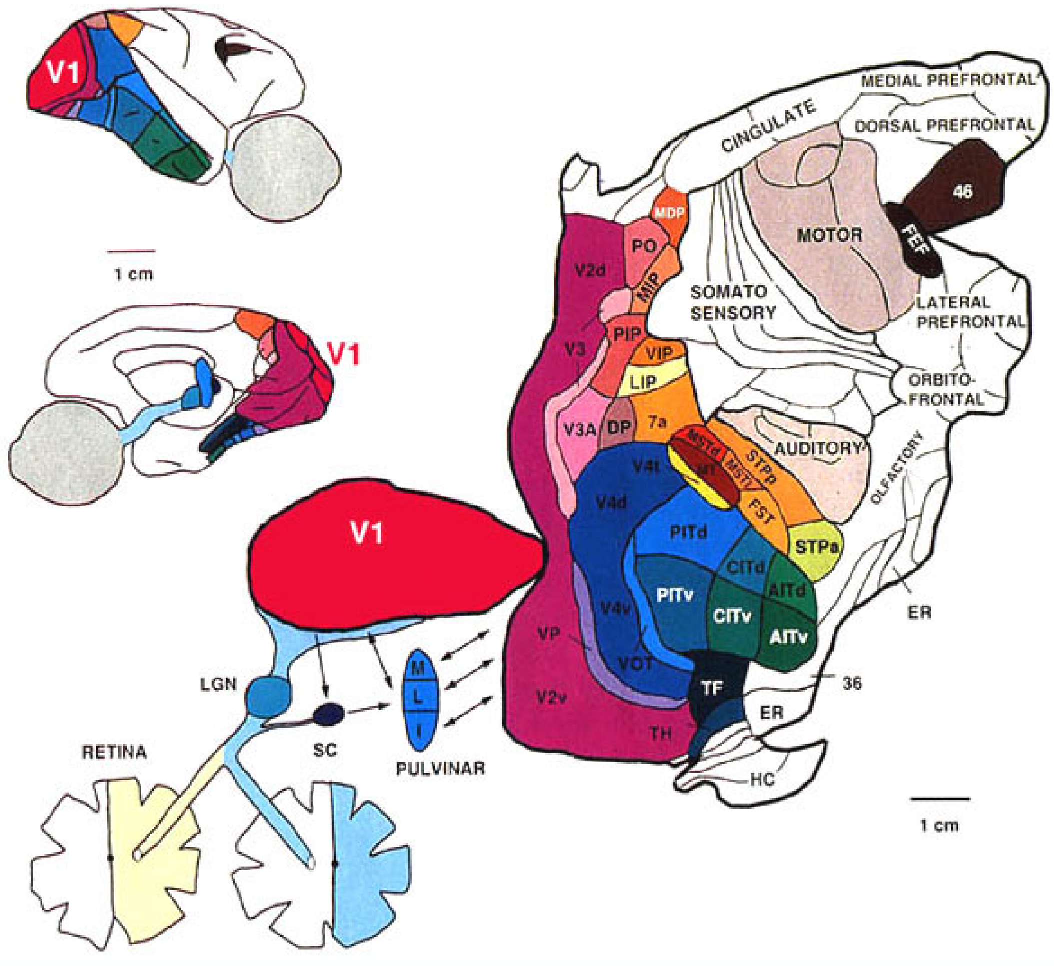
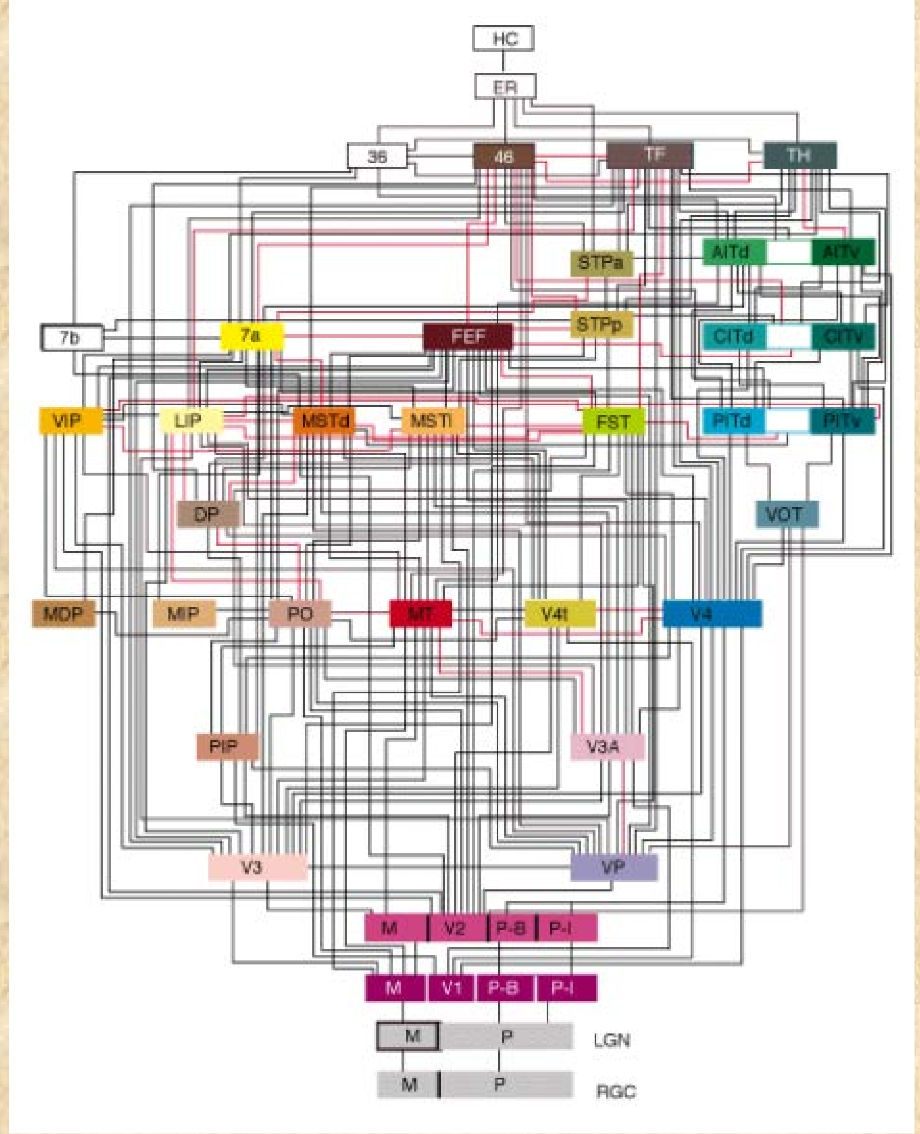


Figure 19. Much of V1 is located in the calcarine sulci and its relationship to other brain areas is best shown by unfolding the brain and showing it flattened open. The visually responsive areas of the macaque monkey are shown in color. From Van Essen et al. (1992).



Felleman & Van Essen, 1991

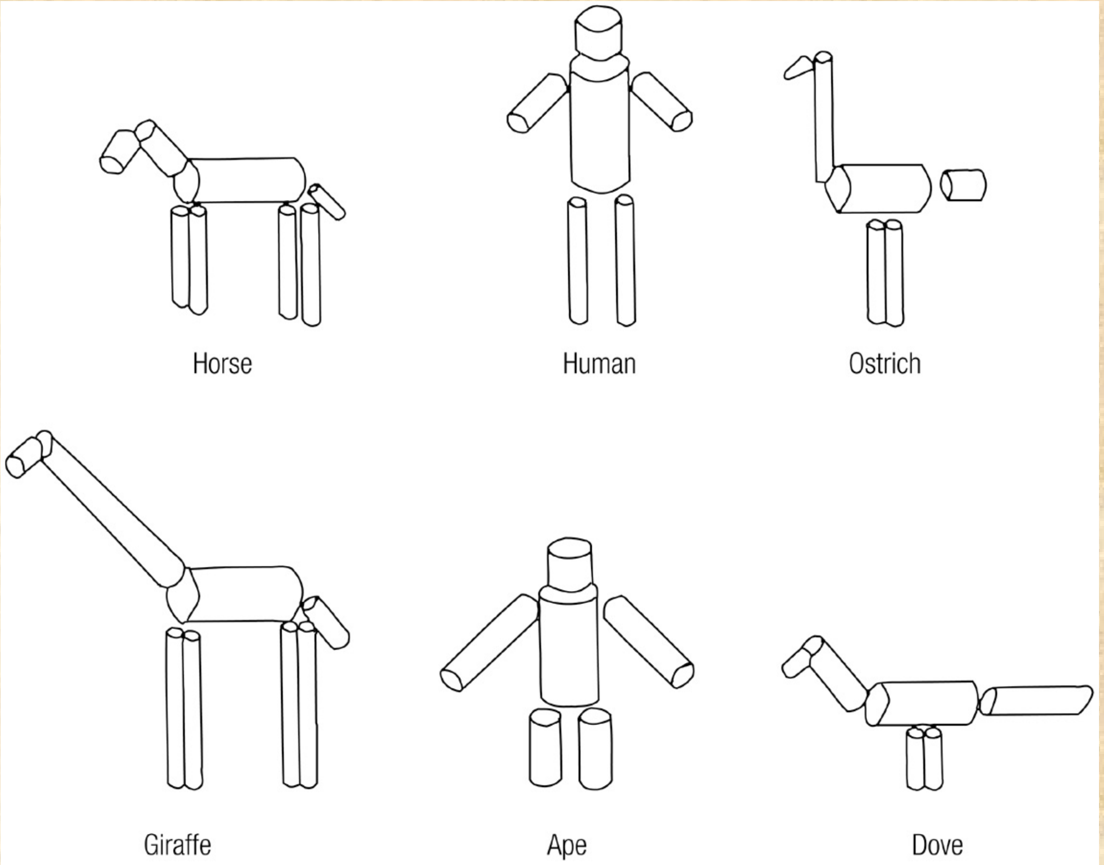
Visual object recognition

Binding problem: how are results determined by different systems (color, form, motion) bound together to provide a percept of a unified object?

Some people say that neurons in different visual areas fire synchronously to indicate that they have information concerning the same object.

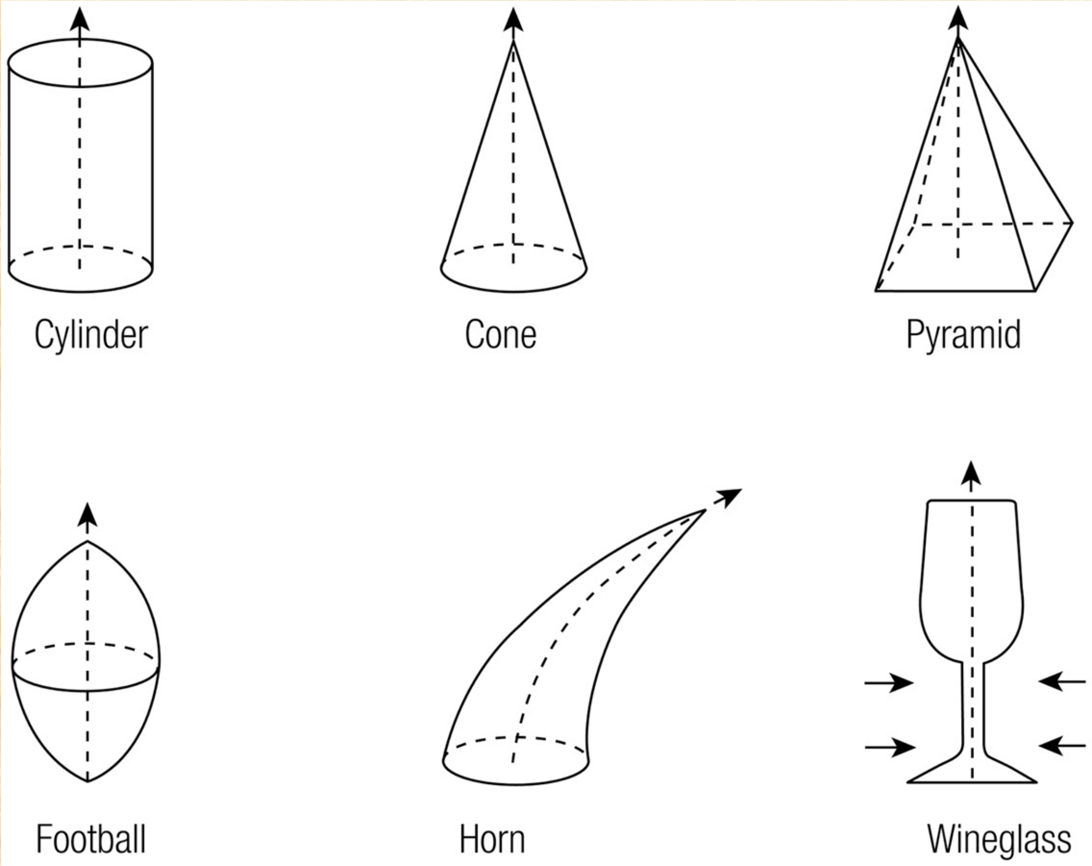
Here are two proposals for how different parts of a shape are brought together.

Visual object recognition



Divide things up into “generalized cylinders” (Marr & Nishihara)

Visual object recognition



Divide things up into “geons” (Biederman)

Visual object recognition

Some of the best current work on the topic comes from the field of computer vision.

Goal: have the computer process image or video input delivered by a camera (like a webcam) in a way that correctly detects and identifies things seen in the video.

Human, car, truck, bus, tree, grass, bush, road, sidewalk, traffic light, etc.—depends on the kind of scenery that is presented to the computer.

Most successful approaches use what are known as “machine learning” methods in which one trains a computer program to recognize various classes of objects.

Having received this training, the computer program is then able to detect and categorize objects presented in new images or video.

Visual agnosia – inability to recognize objects

two forms

1. apperceptive
   - cannot recognize by shape
   - cannot copy drawings
   - often involves *prosopagnosia* (face blindness)
2. associative
   - can copy but cannot recognize
   - difficulty transferring visual information
     into verbal descriptions

both forms are typically associated with some sort
of trauma to the brain

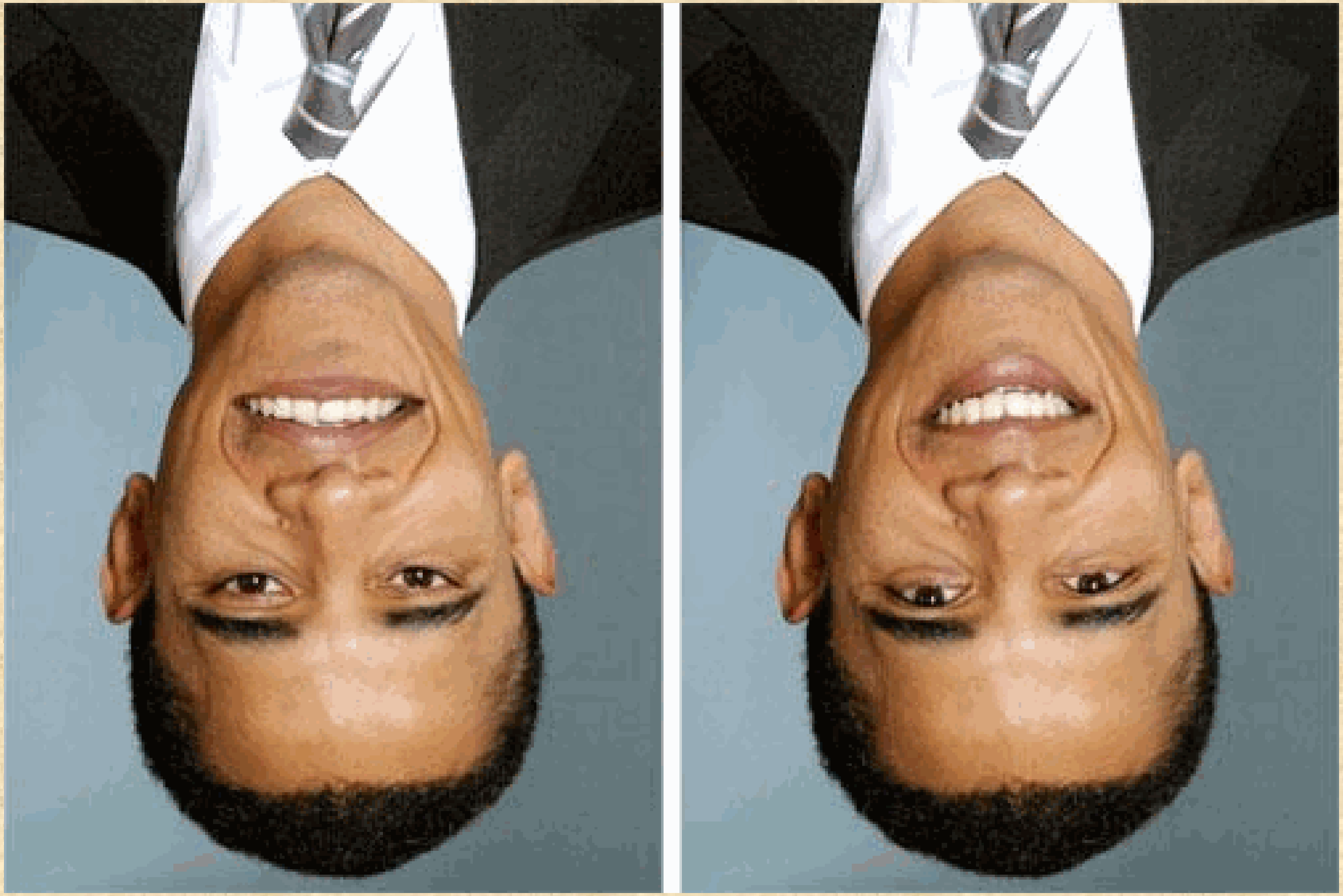
Face Recognition

-lots of research!

Thatcher illusion

Face Recognition

Thatcher illusion

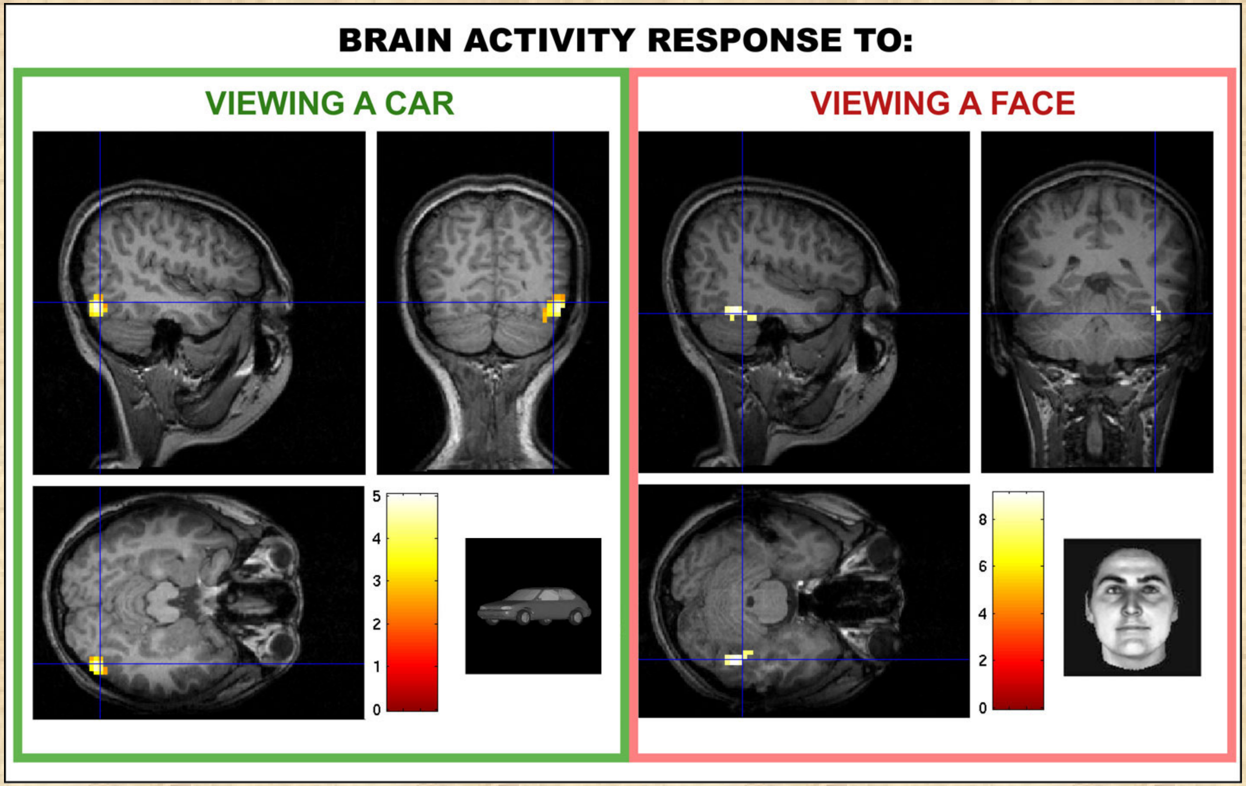


Face Recognition

Inverted Face Illusion

Face Recognition

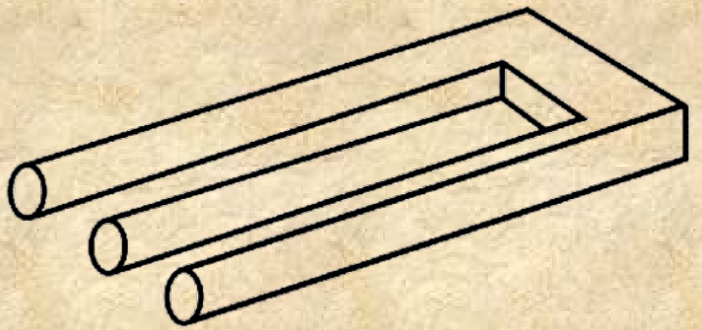
Fusiform Face Area – lots of work done by Nancy Kanwisher



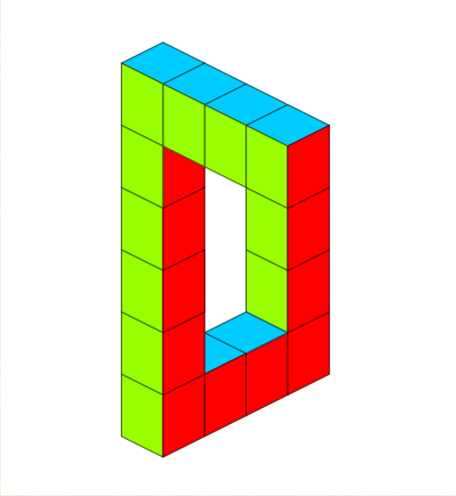
from Riesenhuber

Many people think that there is at least one area in the brain, the *fusiform gyrus*, located in the temporal lobes, specialized for processing face information and recognizing faces. Its damage can lead to *prosopagnosia.*

Impossible Figures



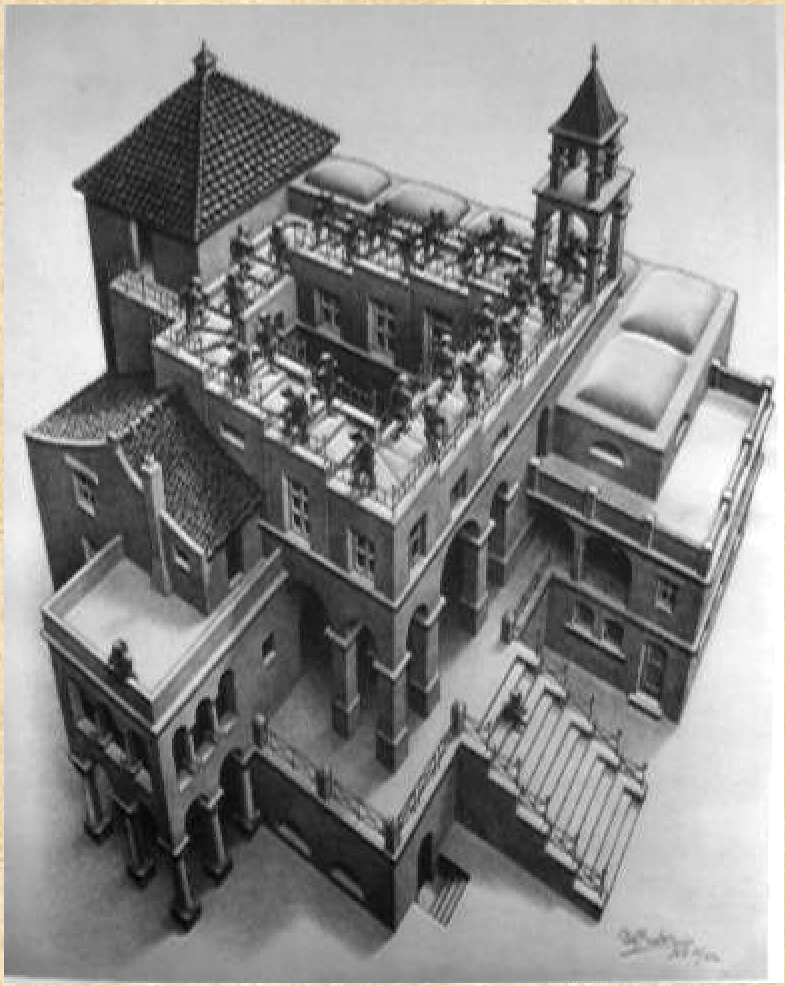
devil’s tuning fork
http://www.michaelbach.de/ot/cog_imposs1/index.html



Many of these suggest that our visual systems
1. use local information to try to infer 3D shape
2. glue the local descriptions together into a global shape without checking for consistency
3. can switch between global shape hypotheses

Impossible Figures

M.C. Escher...



Impossible Figures

another Escher...

Impossible Figures

a final Escher...

oldest known impossible figure (ca 1025 AD)

http://naute.com/illusions/magi.phtml