The Visual System

Cortical Architecture

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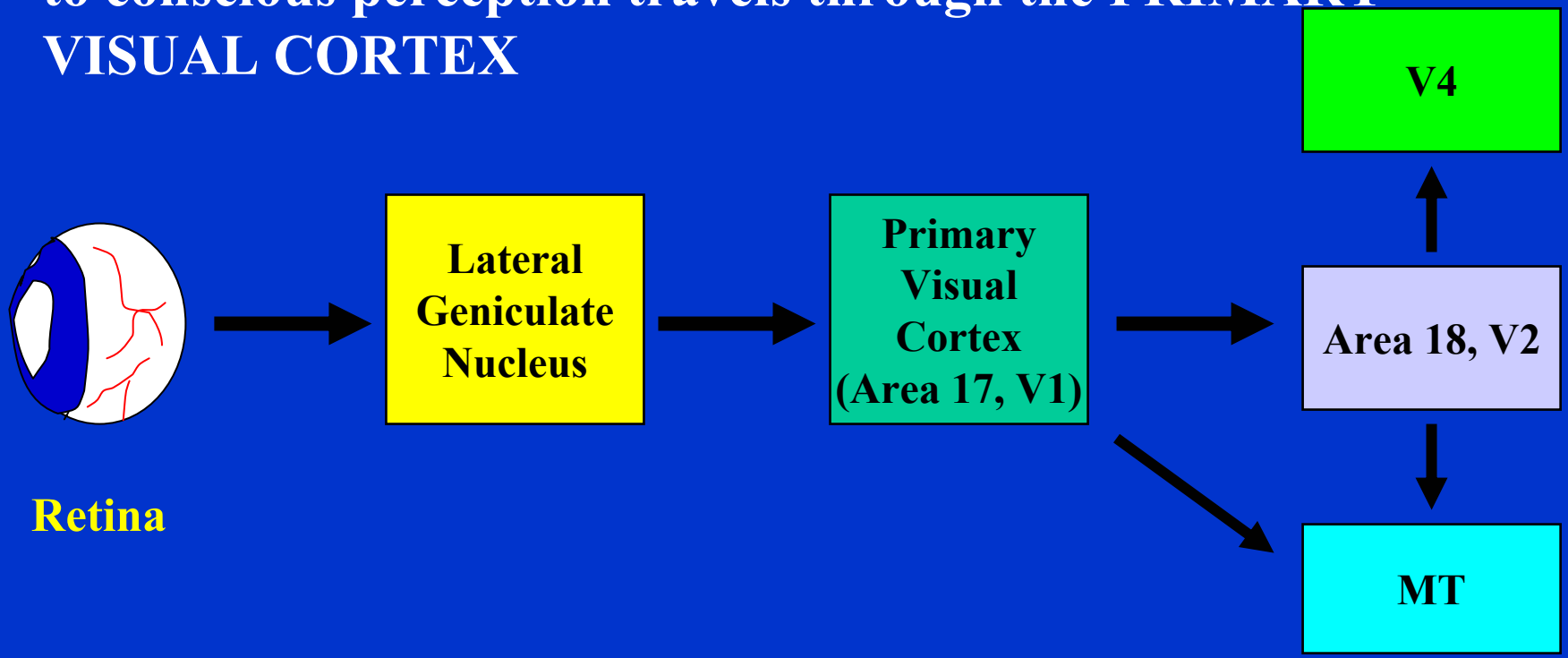
- Required Reading
  - Adler's Physiology of the Eye Chapters 29
  - TovJe Chapter 4 (short summary)

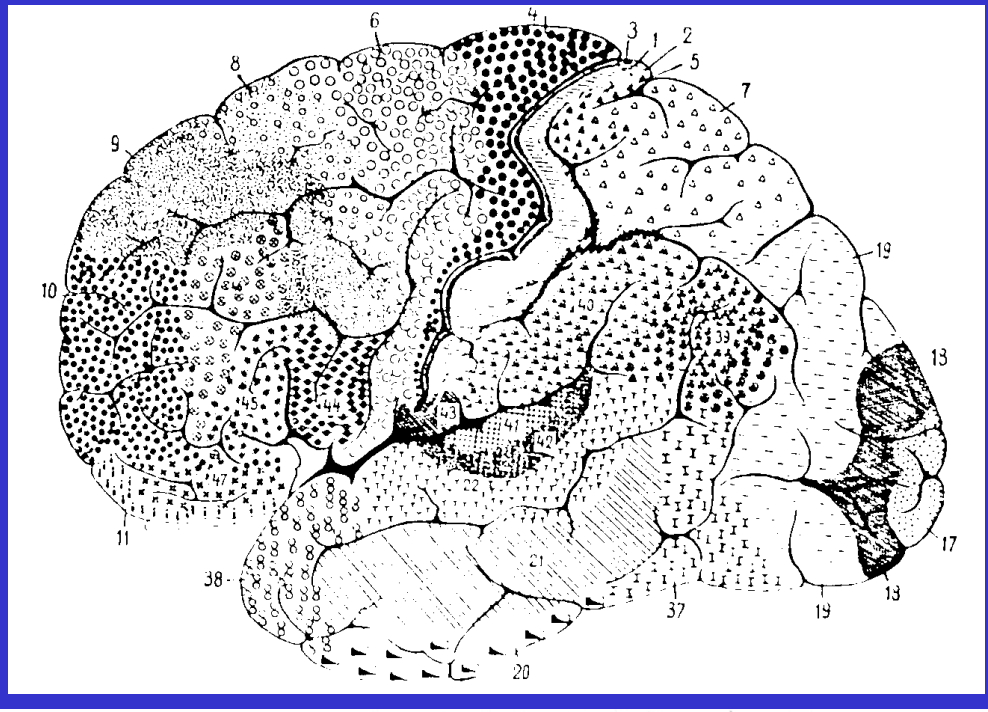
- Recommended Reading
  - McIlwain Chapters 7 & 8 (more complete overview)
  - Purves et al. Neuroscience (1997) Chapter 11
  - Hubel Eye, Brain, and Vision (1988) Chapter 9 pp 191-219.

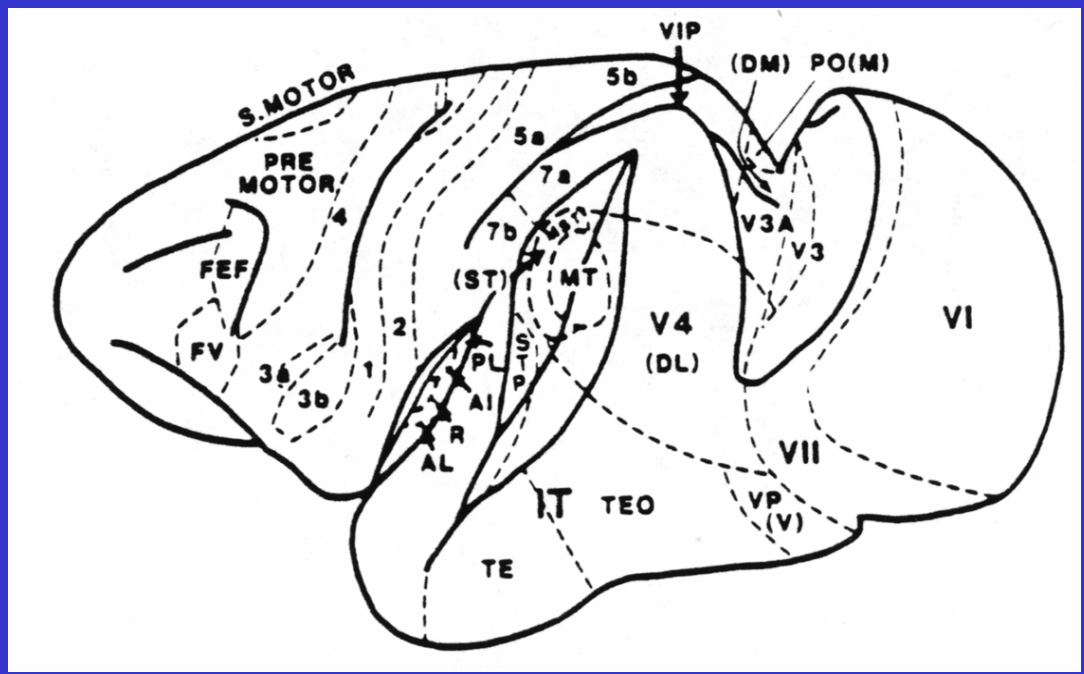
Primary Visual Pathway

In primates all visual information from the retina critical to conscious perception travels through the PRIMARY VISUAL CORTEX

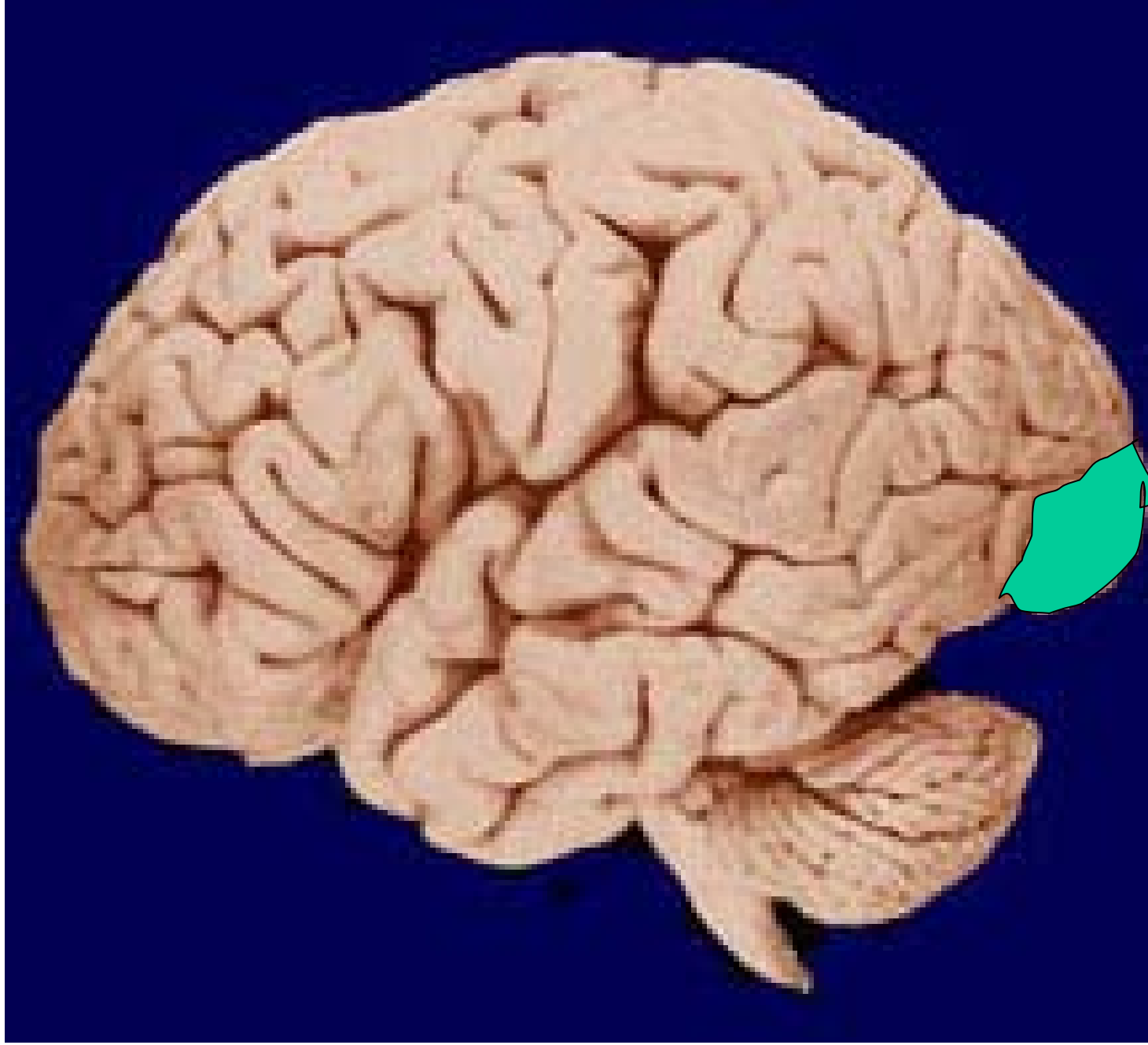


Brodmann's area 17 is also called primary visual cortex, V1 or striate cortex





V1 is located in the occipital lobe. V1 receives its main input from the LGN

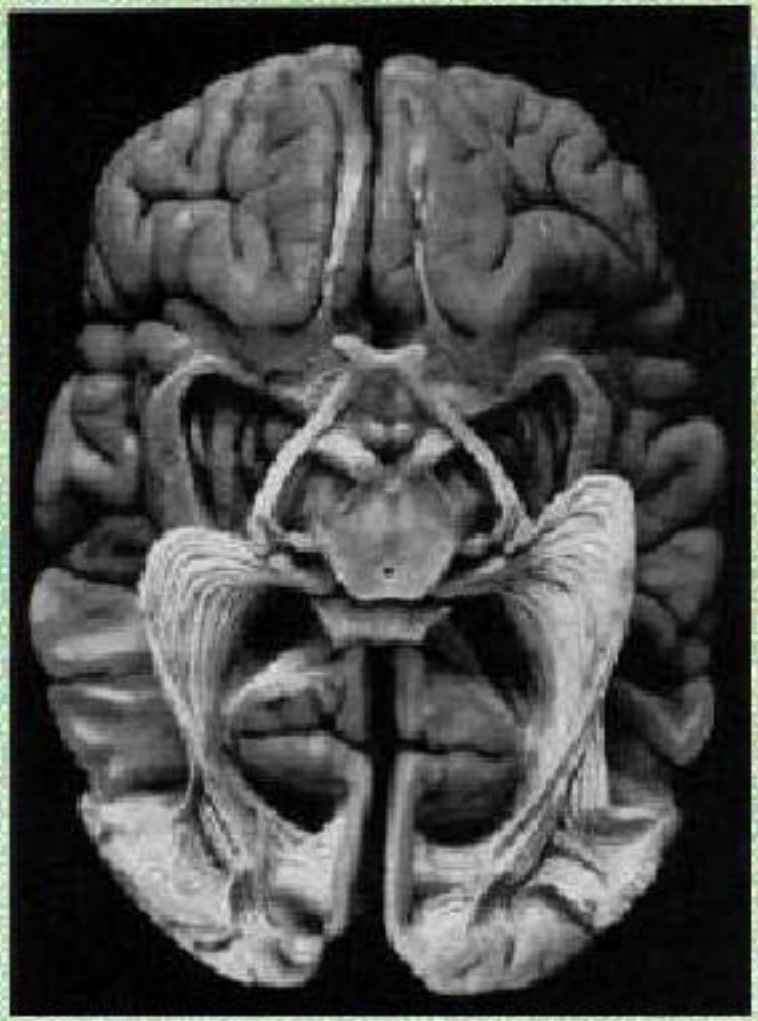


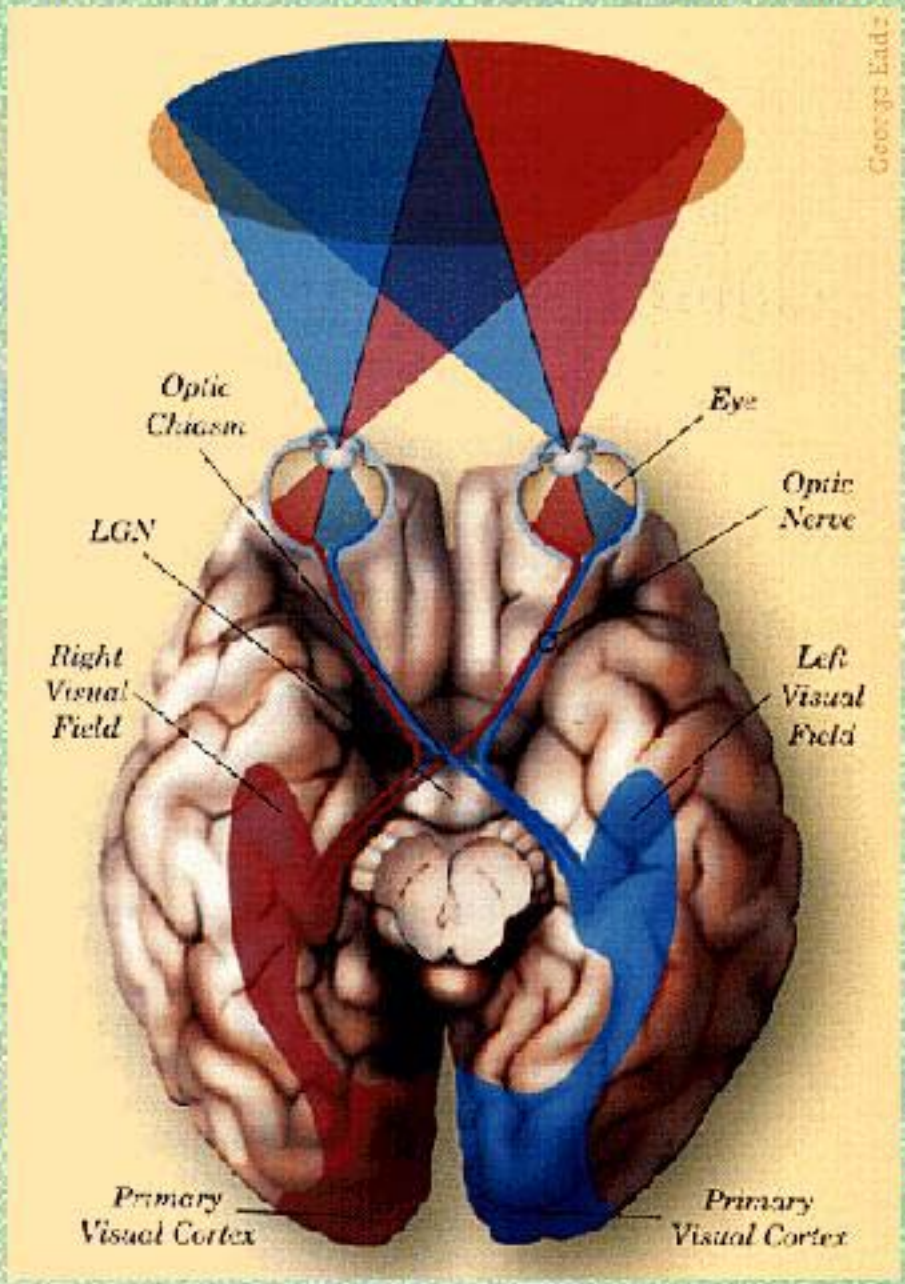
Question from Readings

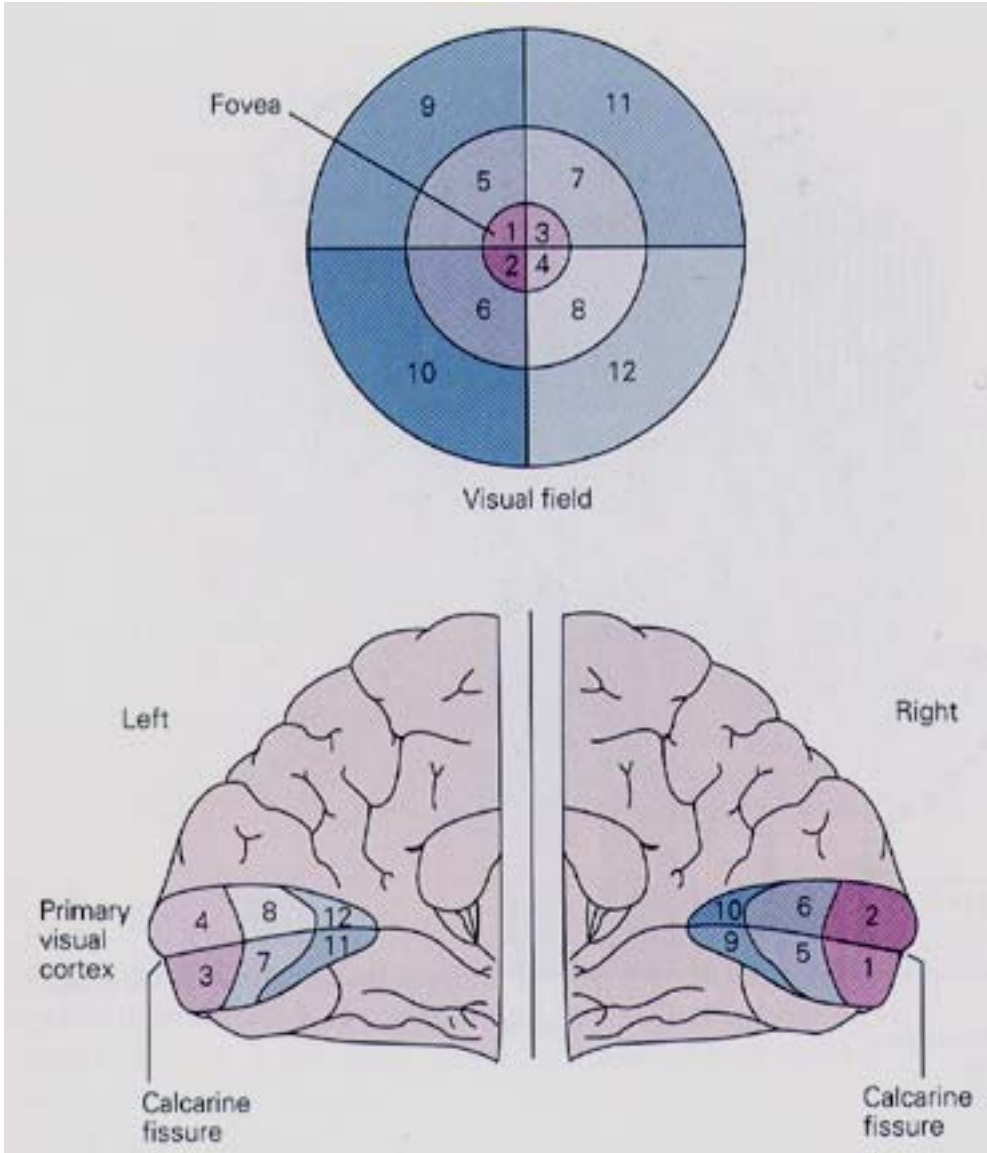
- Where is the fovea represented in V1 anterior or posterior?

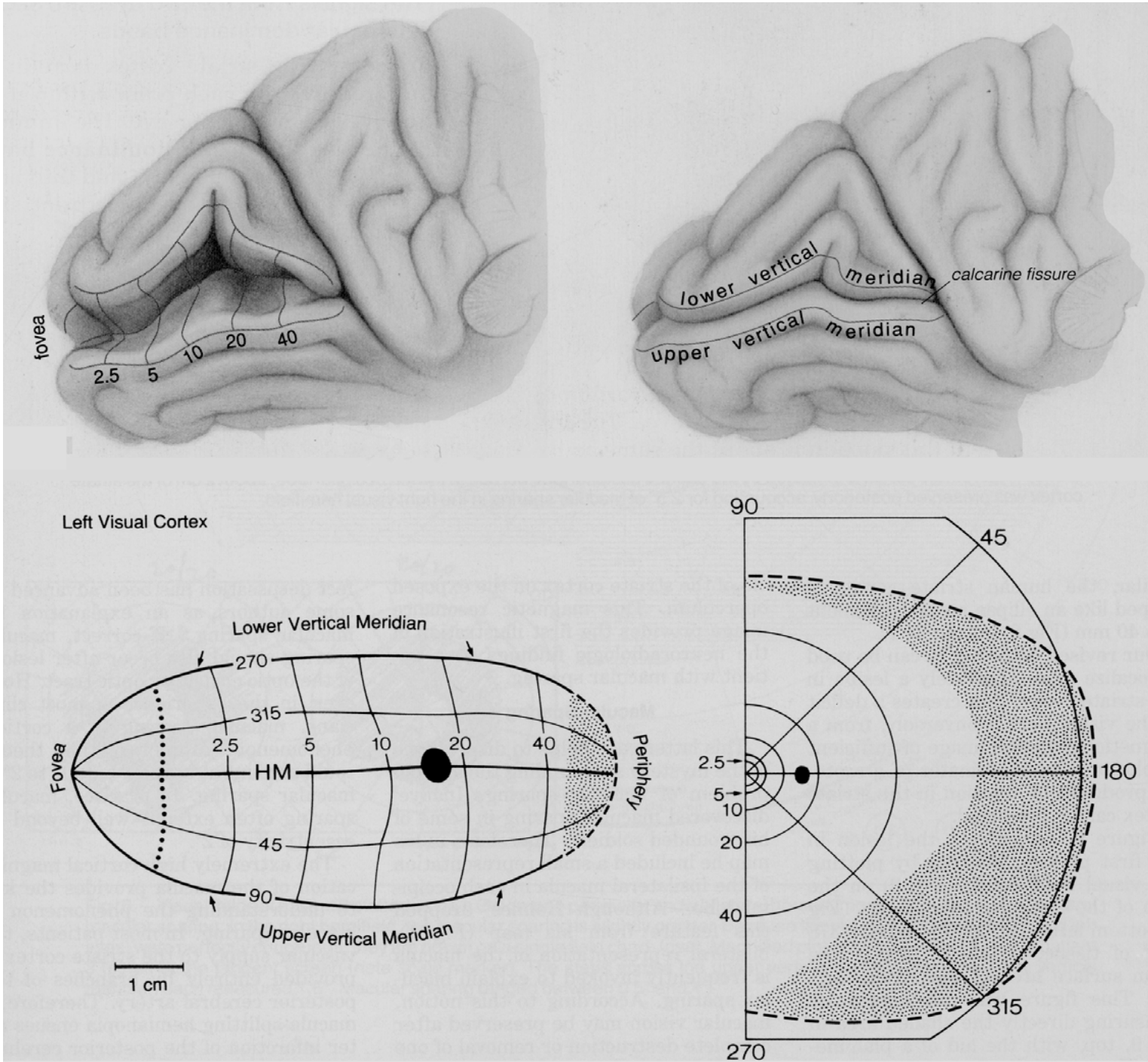
MAPS

The Primary Visual Pathway






Fovea
9
11
5
7
1
3
2
4
6
8
10
12
Visual field
Left
Right
Primary visual cortex
4
8
12
3
7
11
10
6
2
9
5
1
Calcarine fissure
Calcarine fissure


fovea
2.5
5
10
20
40
lower vertical meridian
calcarine fissure
upper vertical meridian
Left Visual Cortex
Lower Vertical Meridian
270
315
2.5
5
10
20
40
Fovea
HM
Periphery
45
90
Upper Vertical Meridian
1 cm
90
45
2.5
5
10
20
40
180
315
270

LAYERS

V1 has 6 main layers. These layers can be revealed by a variety of stains such as the Nissl stain (a stain for cell bodies).

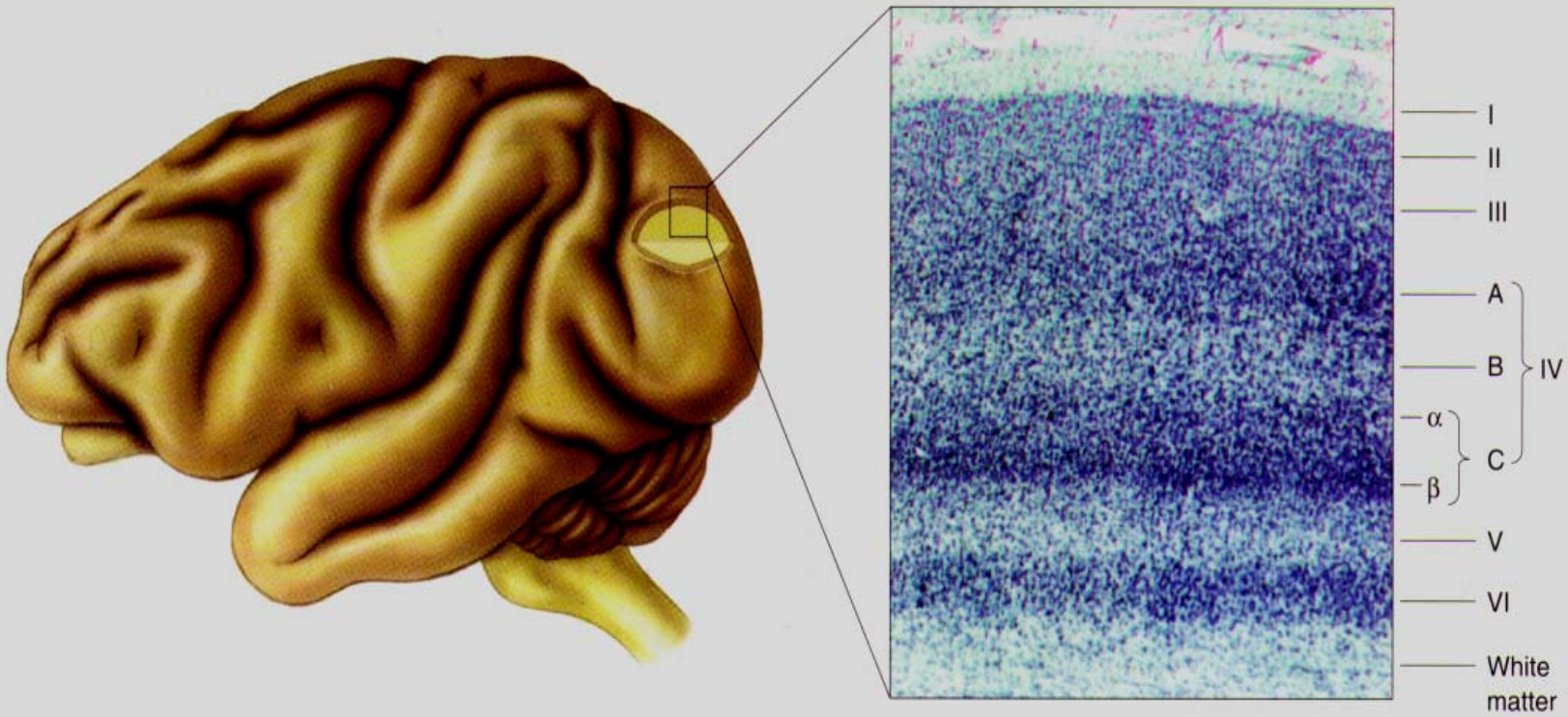
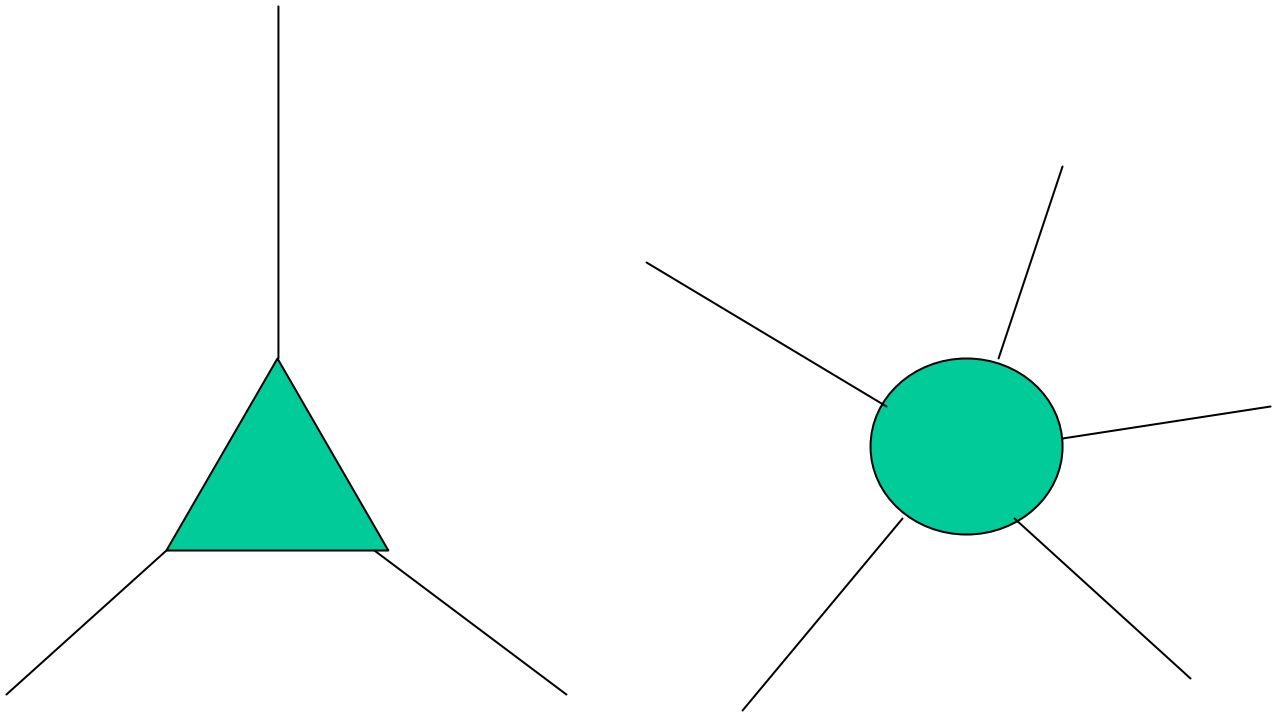


Figure 10.12
The cytoarchitecture of the striate cortex. The tissue has been Nissl stained to show cell bodies, which appear as dots. (Source: Adapted from Hubel, 1988; p. 97.)

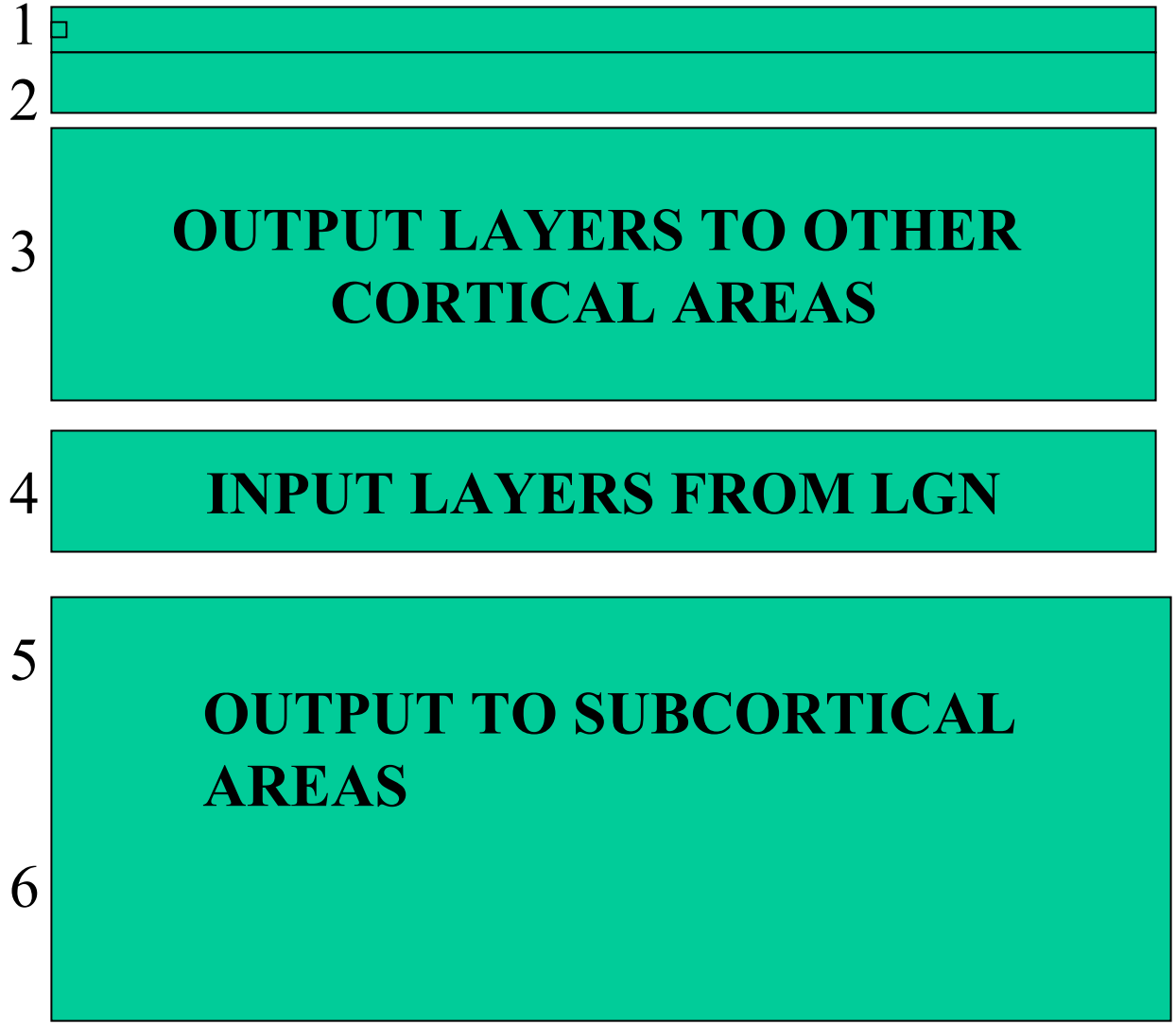
There are two main cell types in cortex. These cells are connected with each other in complex circuits within area V1



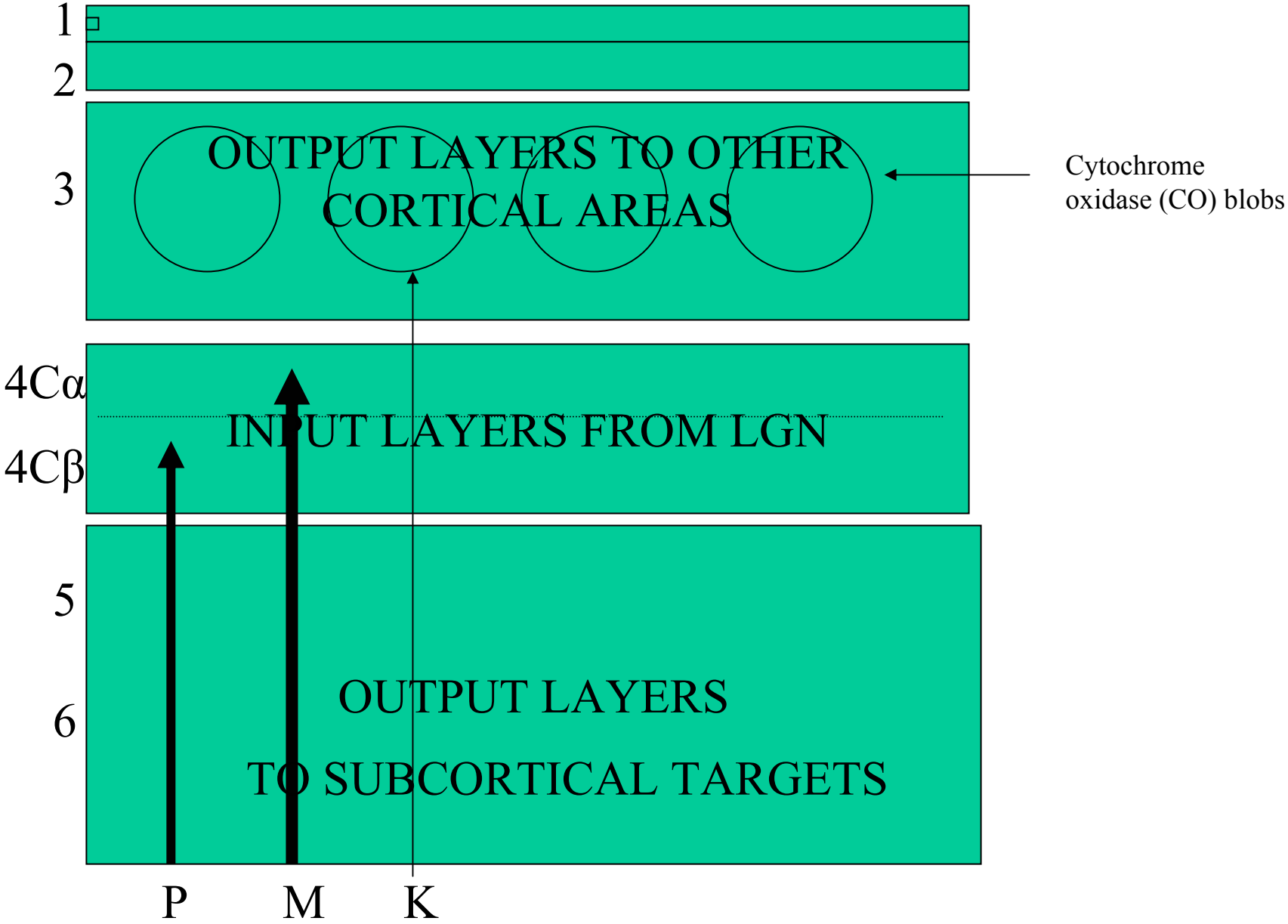
Pyramidal
80% (glutamate)

Stellate
20% GABA

BASIC WIRING OF PRIMARY VISUAL CORTEX

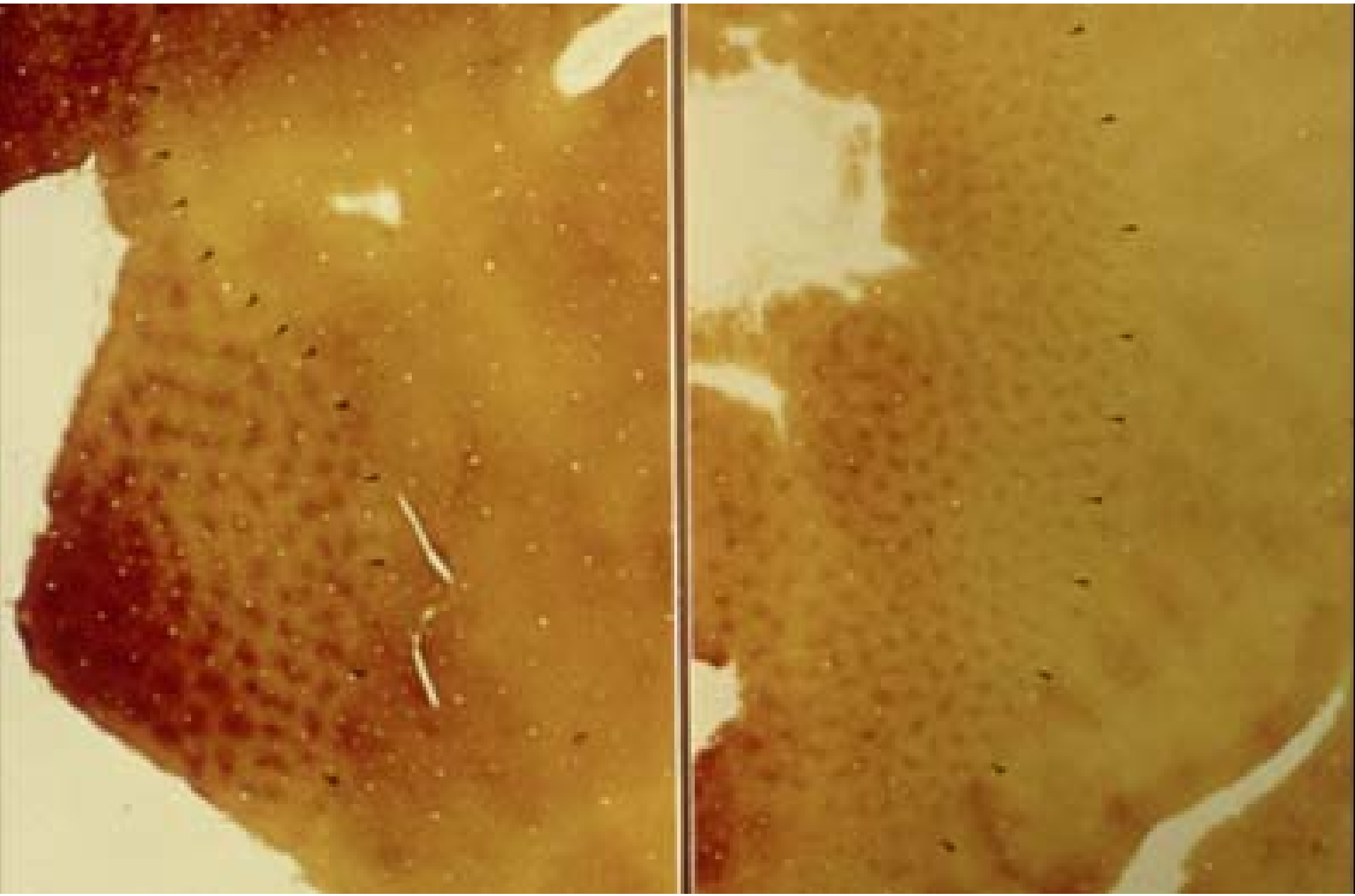


BASIC WIRING OF PRIMARY VISUAL CORTEX: INPUTS

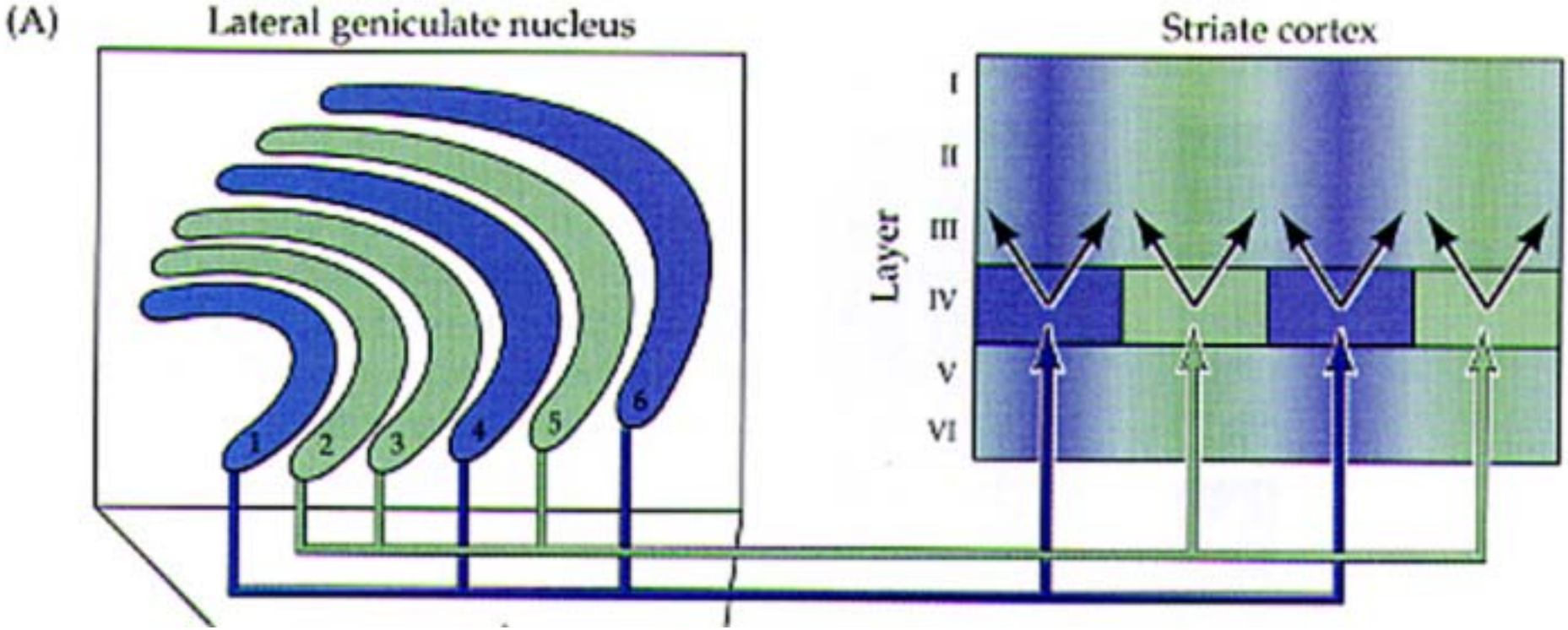


Question from Readings

- What are “cytochrome oxidase blobs” and what is their proposed function?



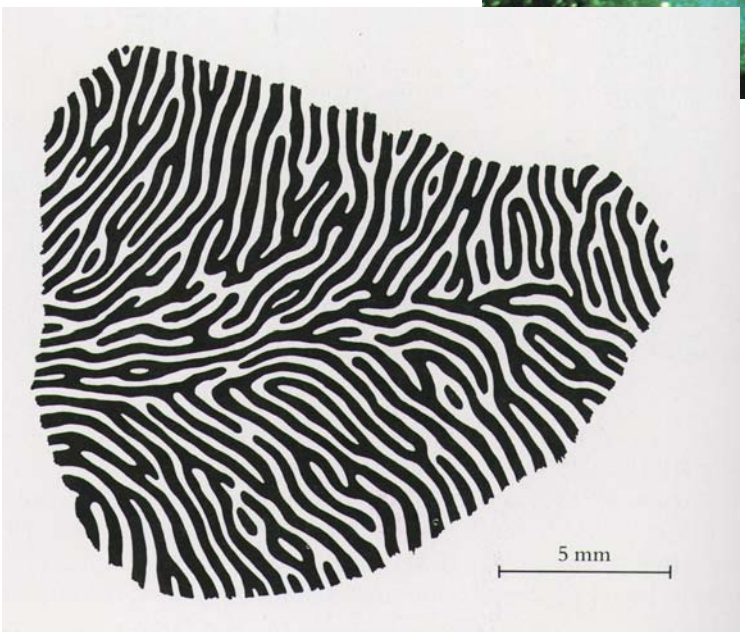
LGN Input from the left and right eye is kept separate in ocular dominance columns within layer 4 and combined within the upper and lower layers of V1(striate cortex or area 17)



Question from Readings

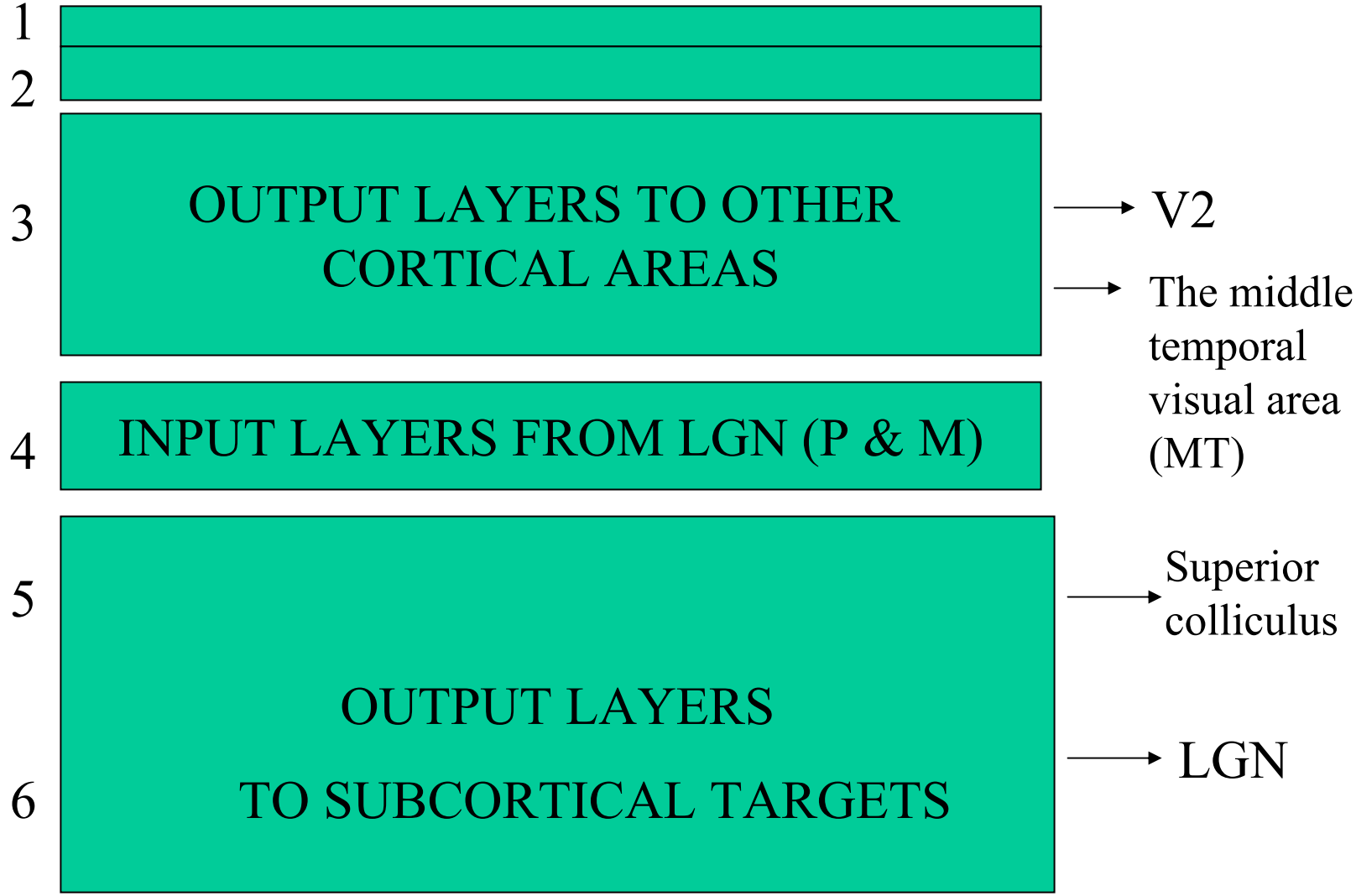
- Do humans have ocular dominance columns?
- Yes

Input to cortex following an injection of label into one eye. Ocular dominance columns from one eye are shown here in white patches in this darkfield photo of a parasagital section.

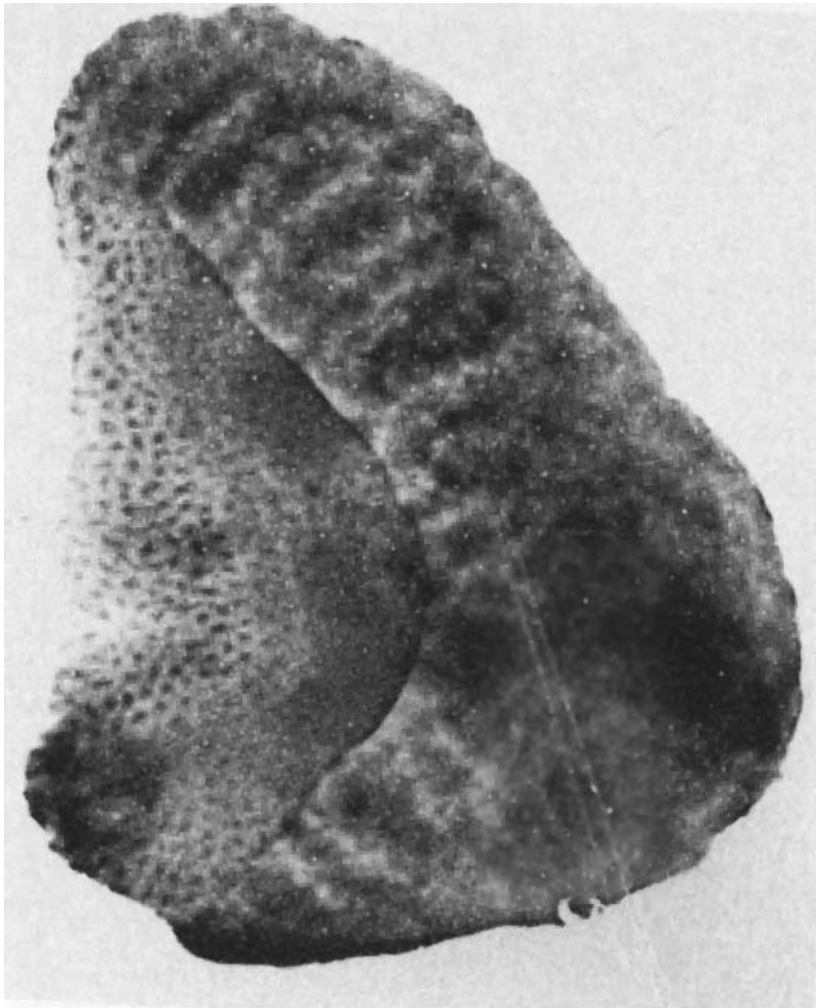


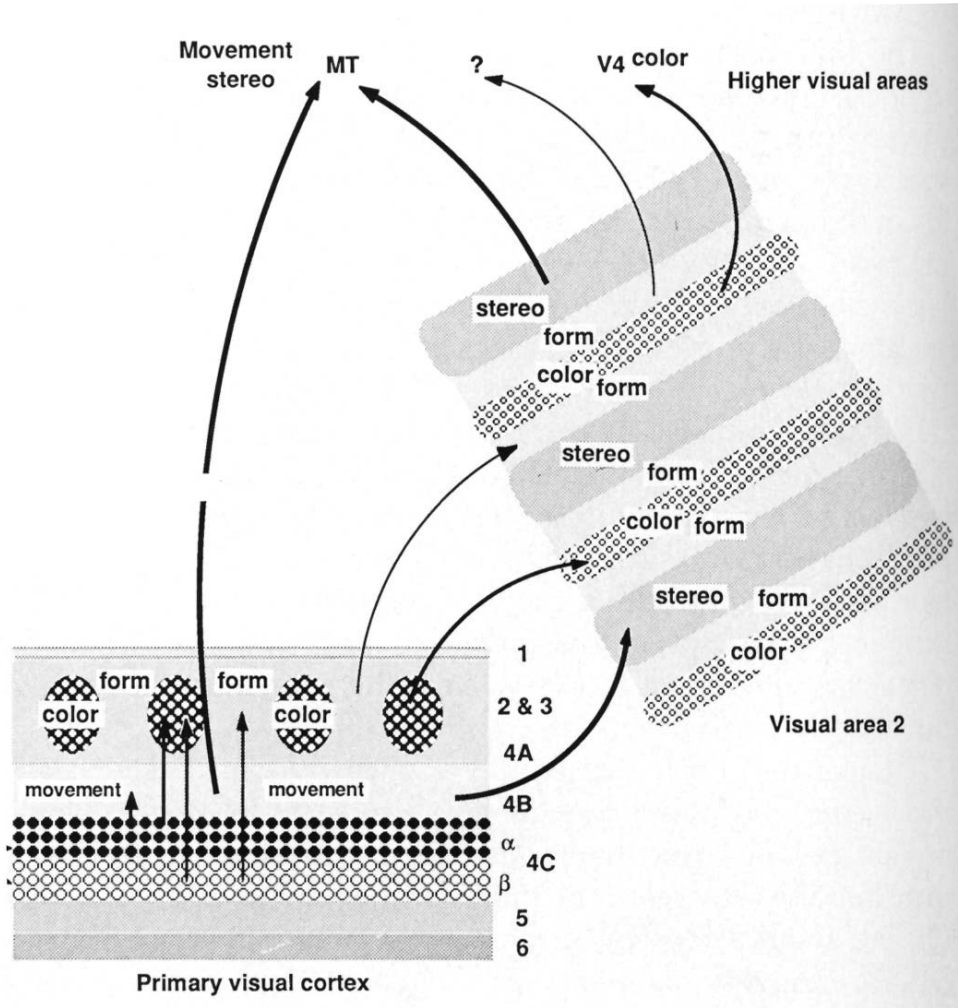
A complete reconstruction of the ocular dominance columns in a tangential section through layer 4 of monkey V1 after the brain has been flattened. Black bands represent one eye and white bands the other eye

BASIC WIRING OF PRIMARY VISUAL CORTEX: OUTPUTS

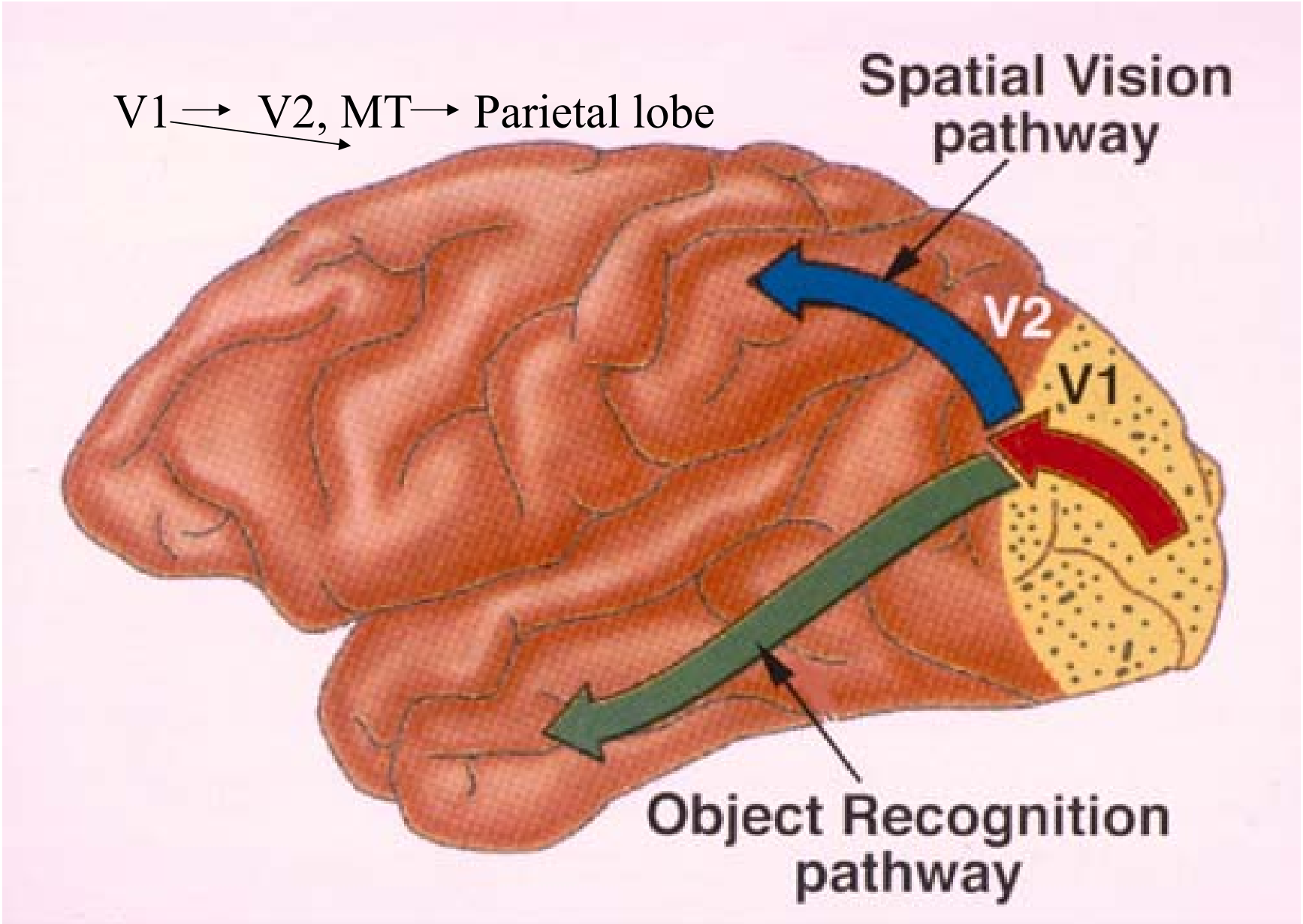


CO Modules in visual cortex

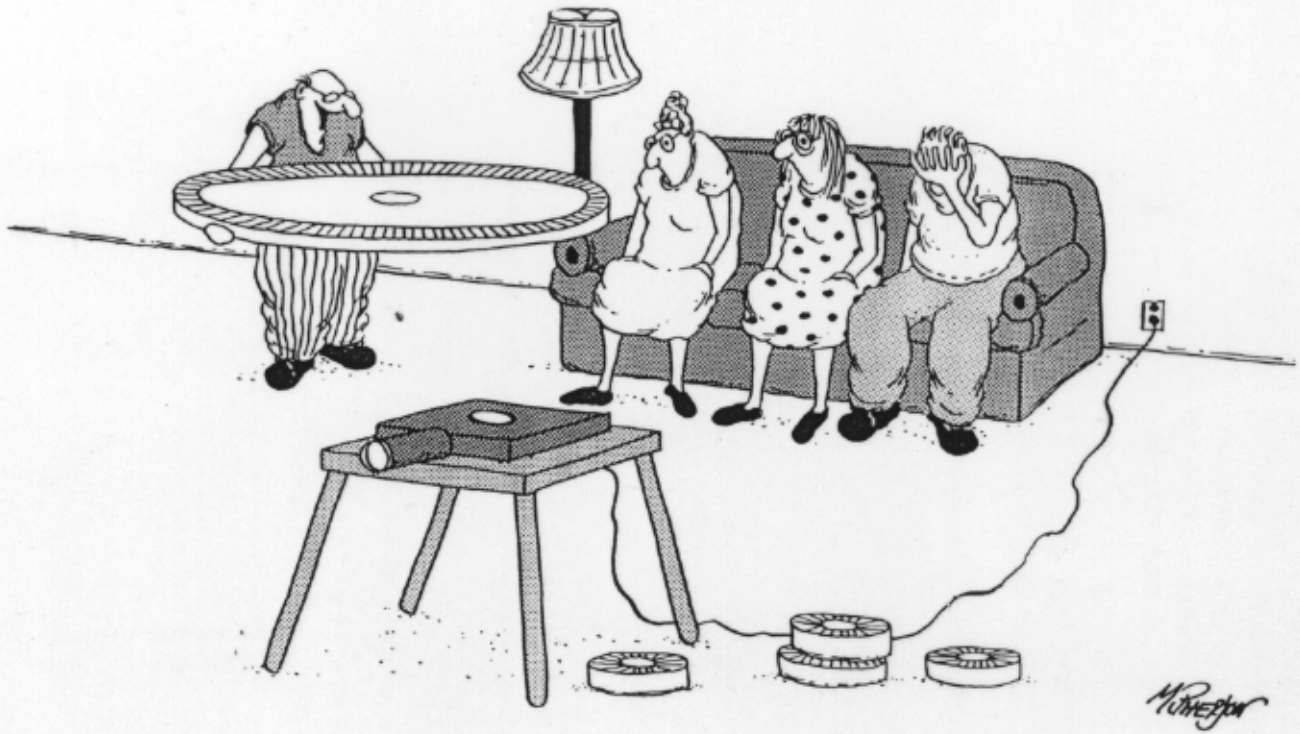




Livingstone & Hubel, 1988



V1 → V2 → V4 → Temporal lobe

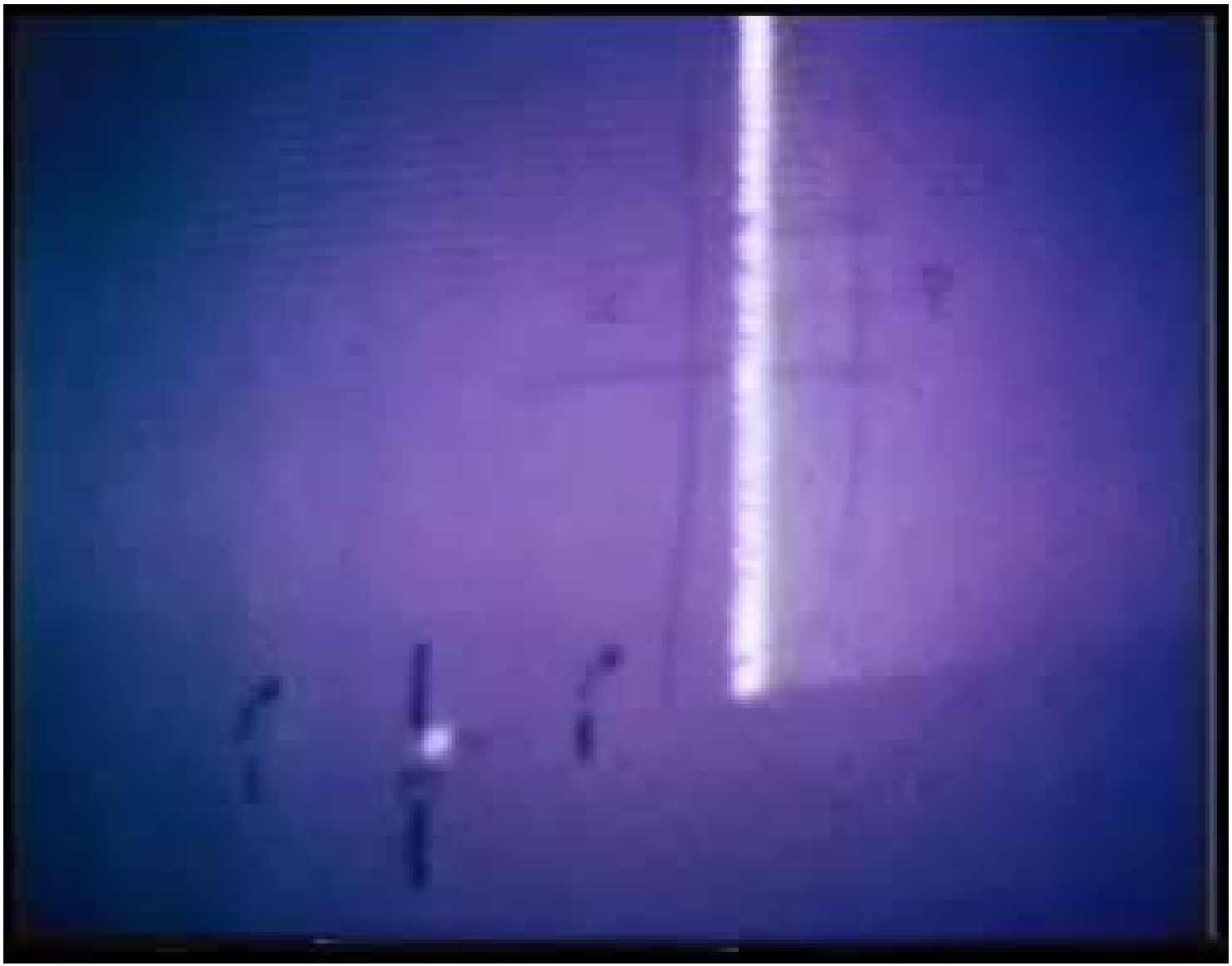


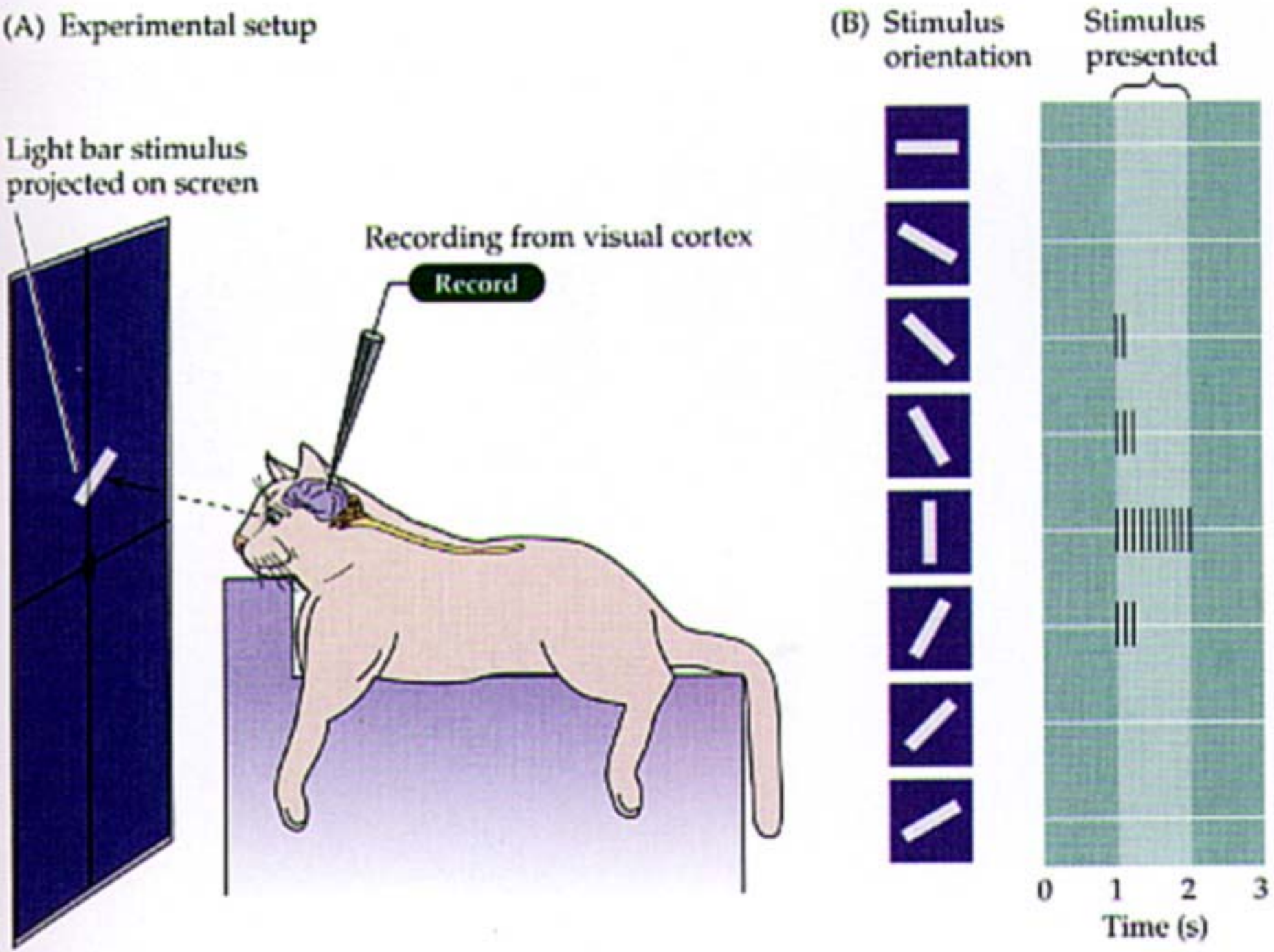
"I saved the new jumbo slide carousel for last!"

Recordings made from V1 of cats and monkeys have shown that cortical receptive fields are different from those in the LGN and retina.

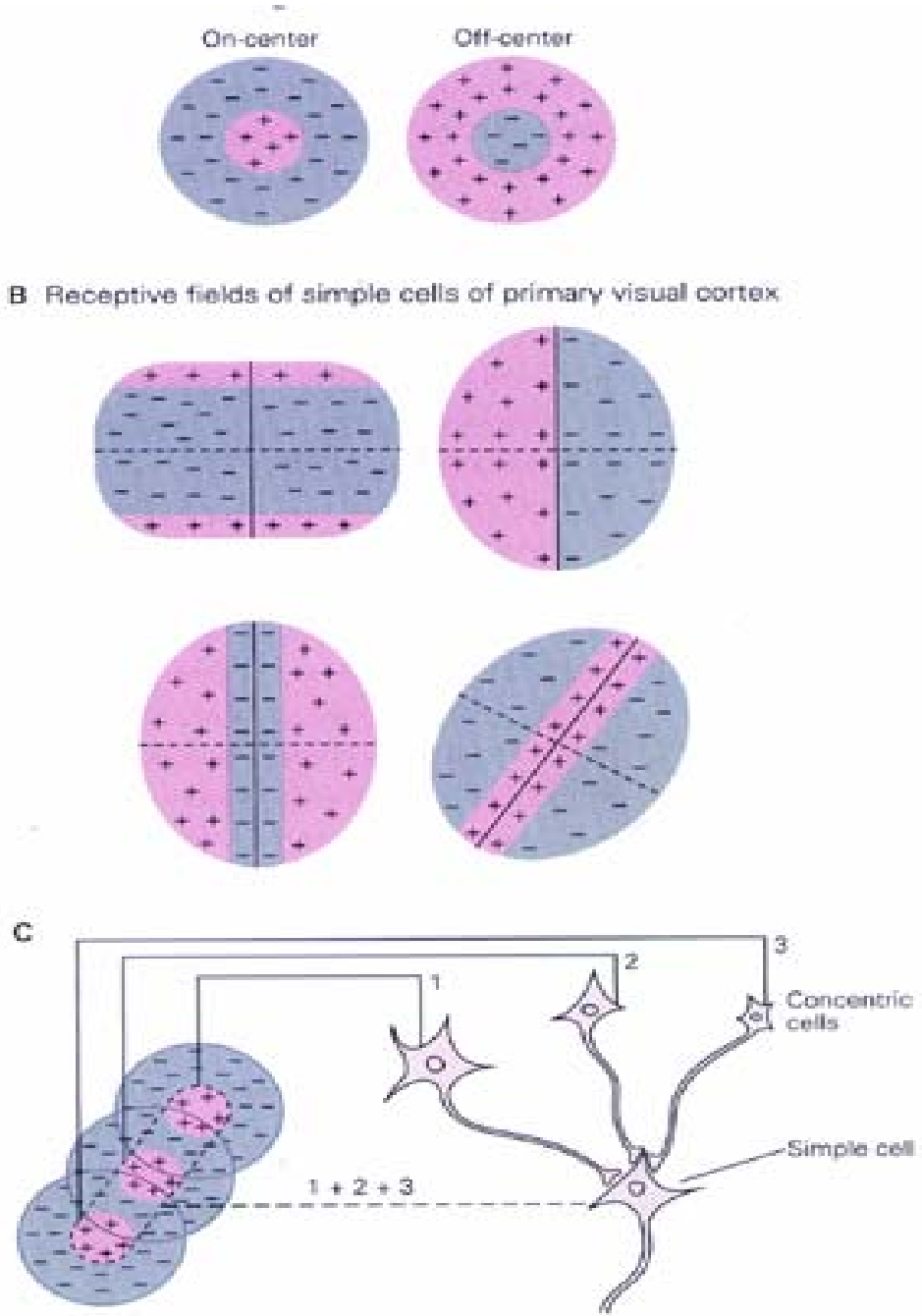
Hubel maps the ON and OFF fields of an orientation selective cell

Hubel plots a monocular cell




(A) Experimental setup
Light bar stimulus projected on screen
Recording from visual cortex
Record
(B) Stimulus orientation
Stimulus presented
0
1
2
3
Time (s)

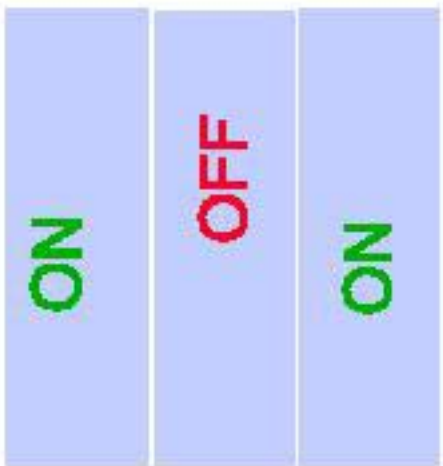
Cortical cells are selective for orientation.

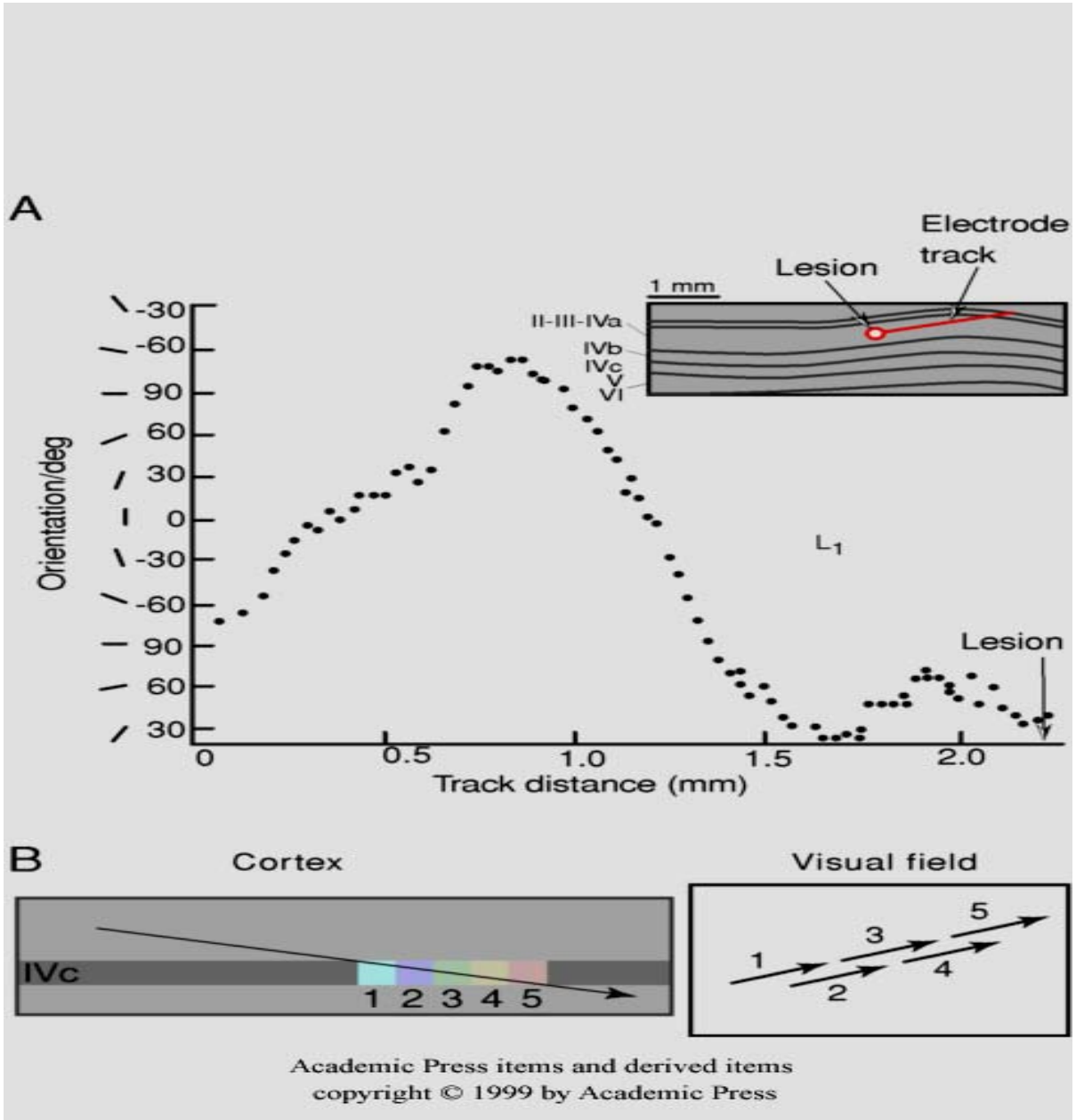


Receptive Fields in V1

Symmetrical

Asymmetrical (left/right polarity)





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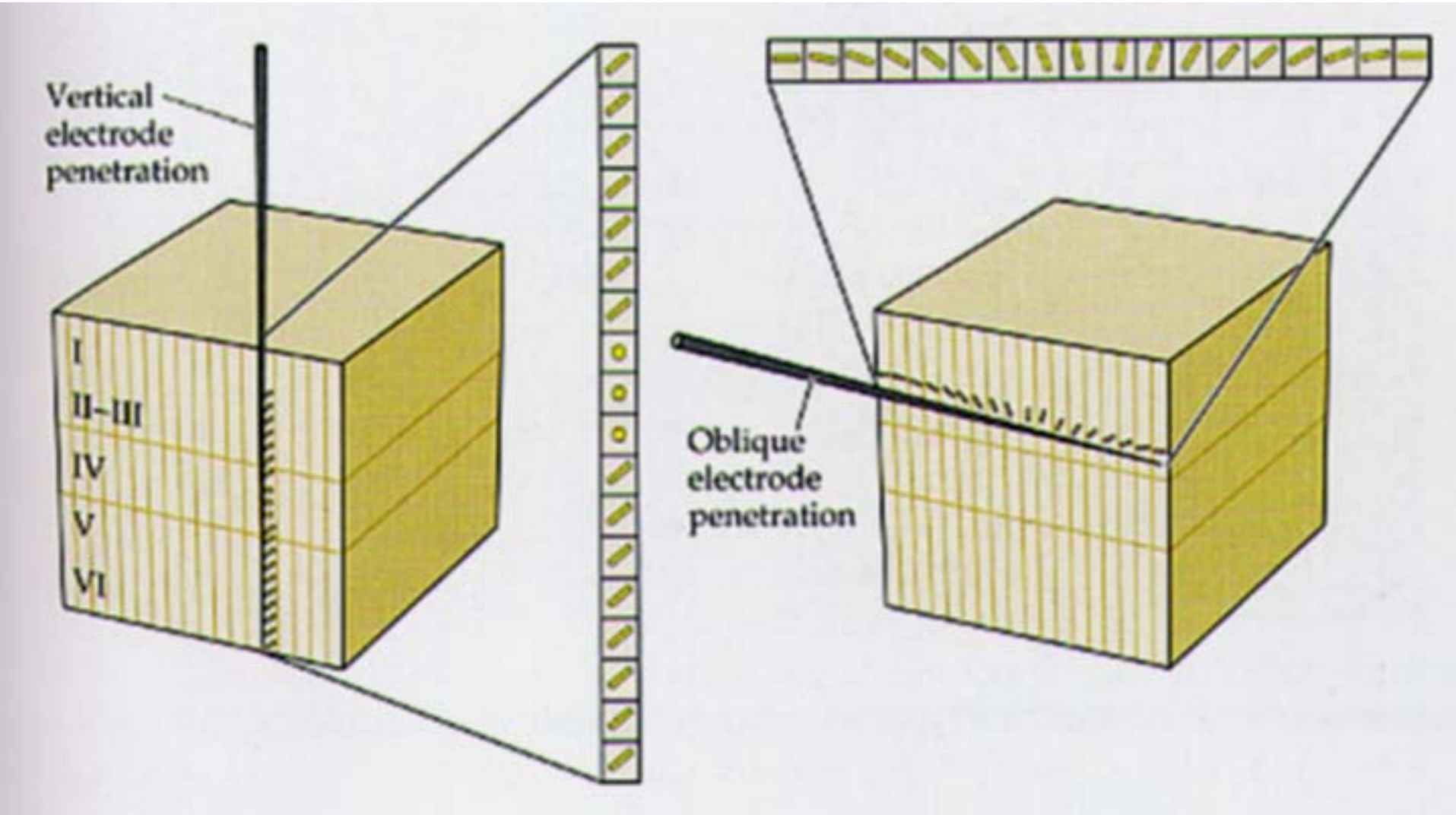
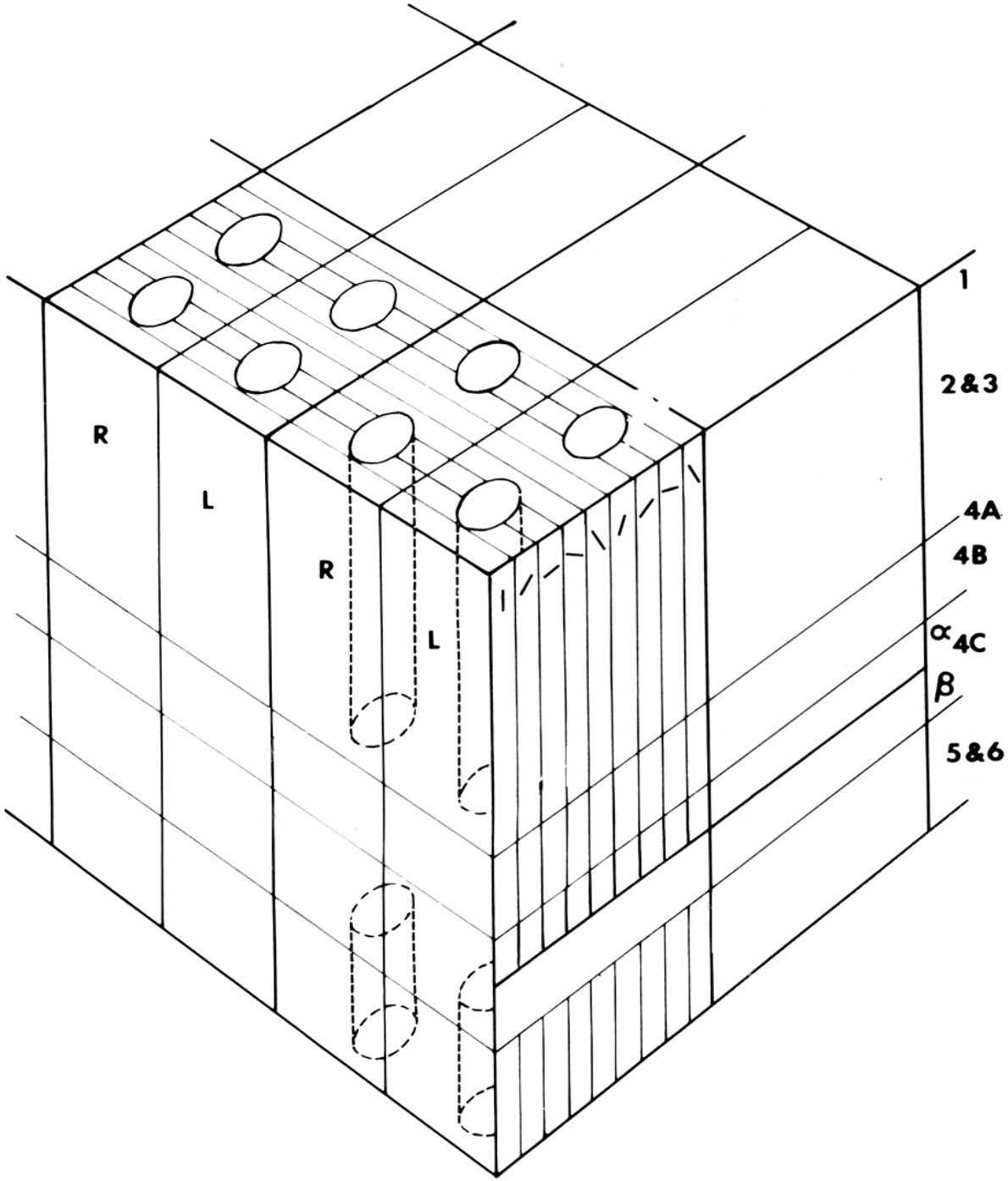
ORIENTATION COLUMNS

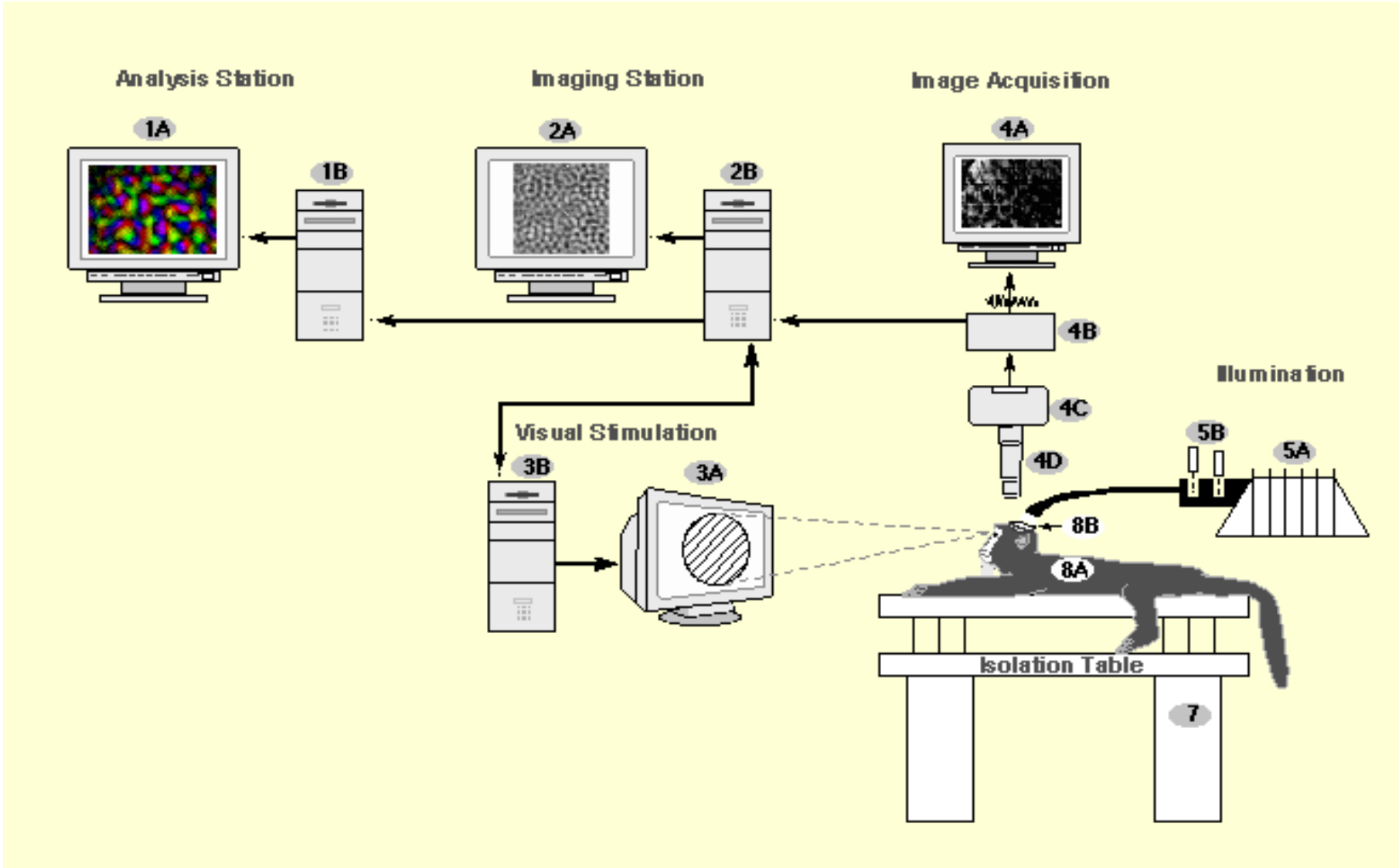


Hypercolumns

Hubel and Wiesel proposed the idea that the cortex is composed of 2.0 mm^3 units of tissue containing 2 180 cycles of orientation and one left and one right eye ocular dominance column. These hypercolumns should contain all the neural machinery necessary for analysis of each topographic local in V1.

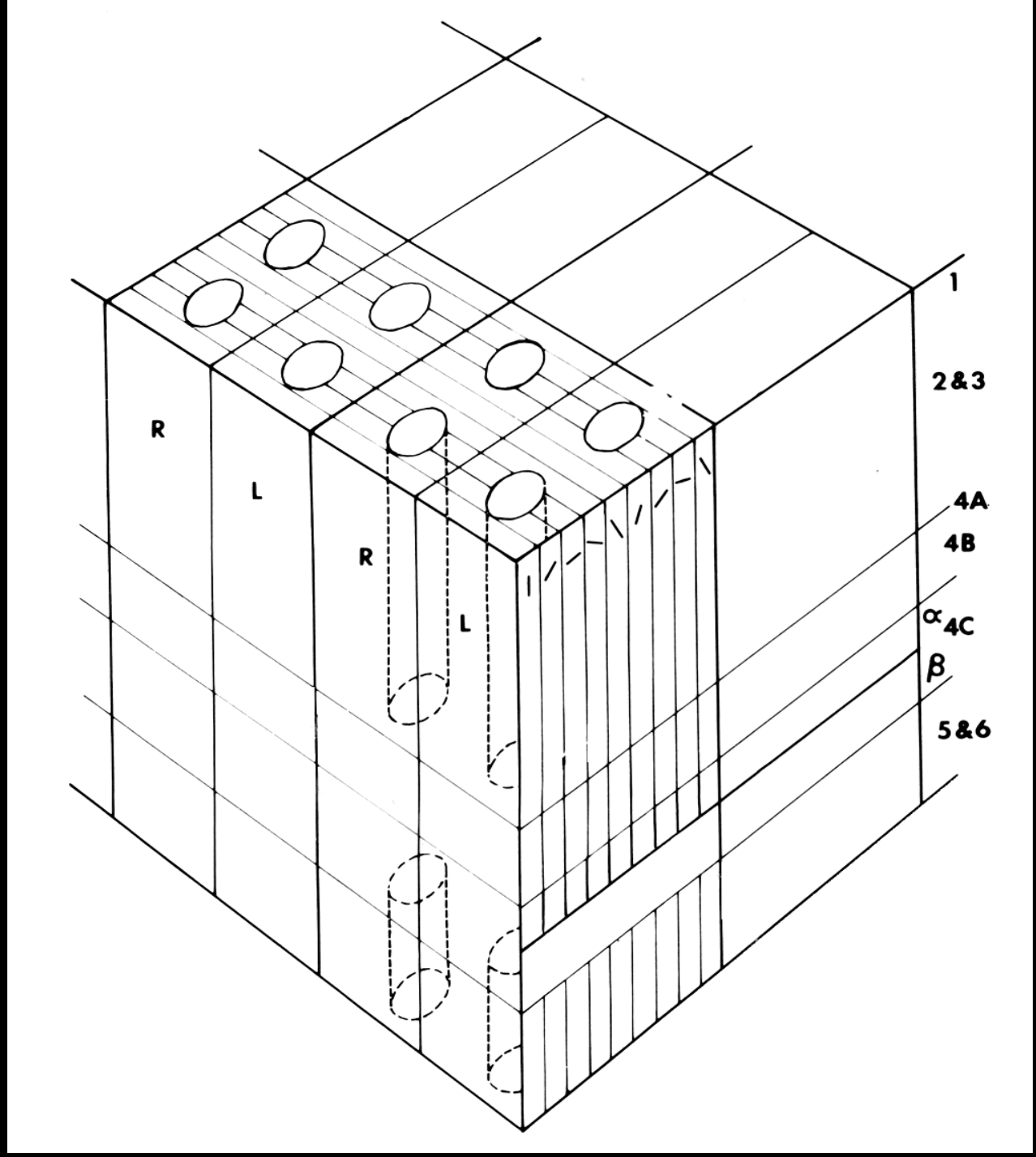


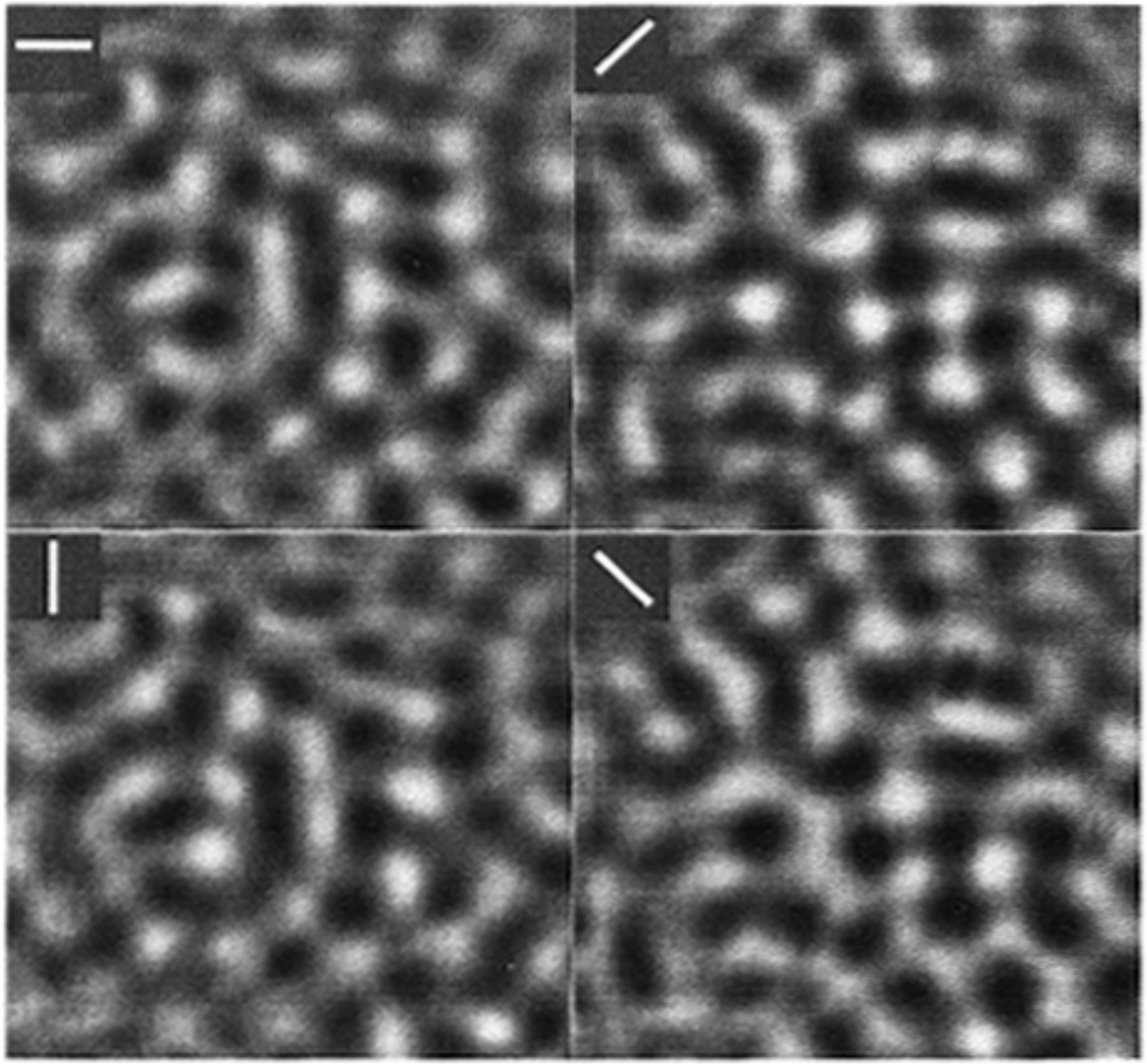
Methods used for optically imaging stimulus related neural activity changes



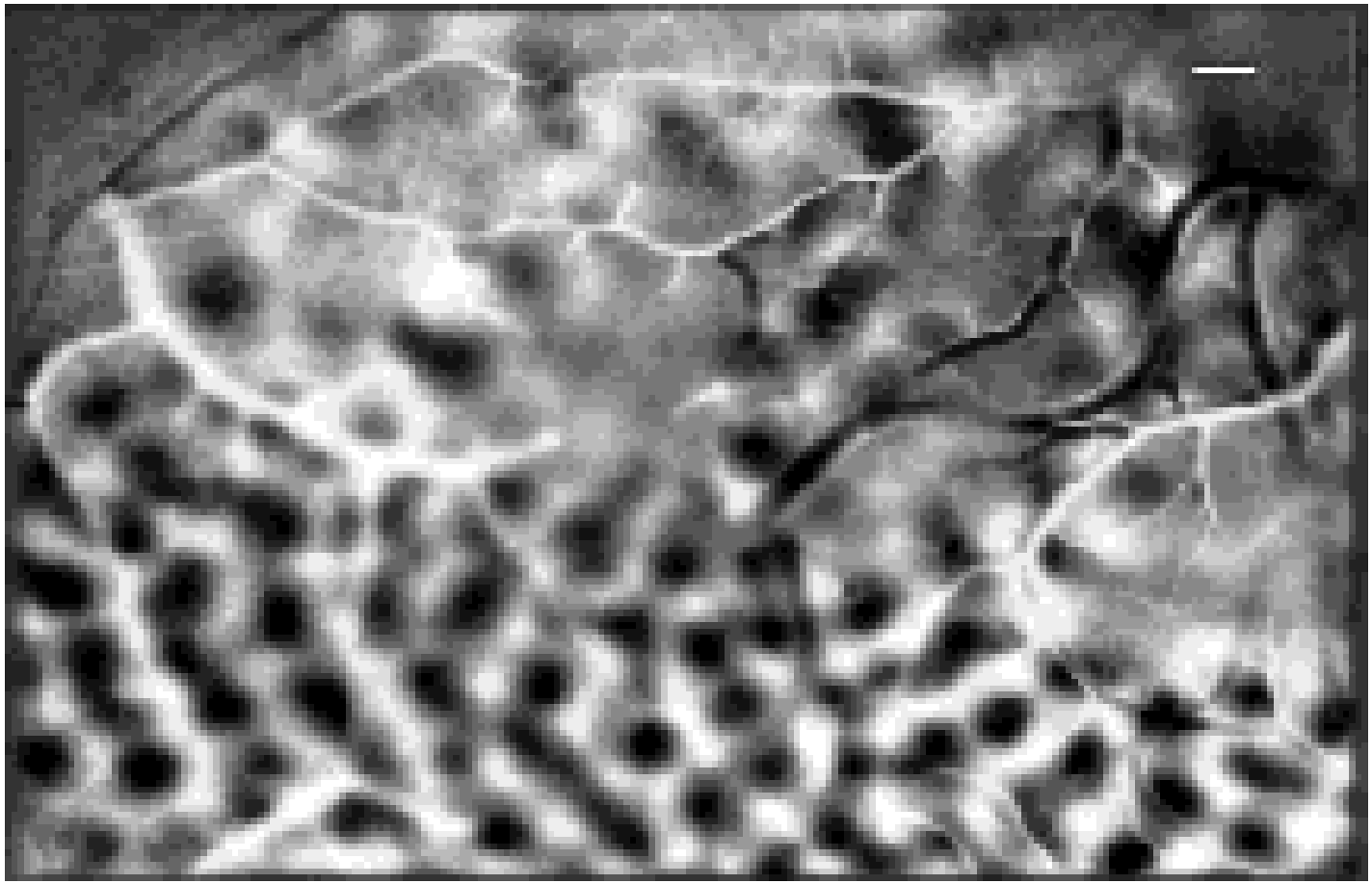
The issue is how to geometrically fit all the properties that V1 represents into a map that has no holes in it for any particular property.

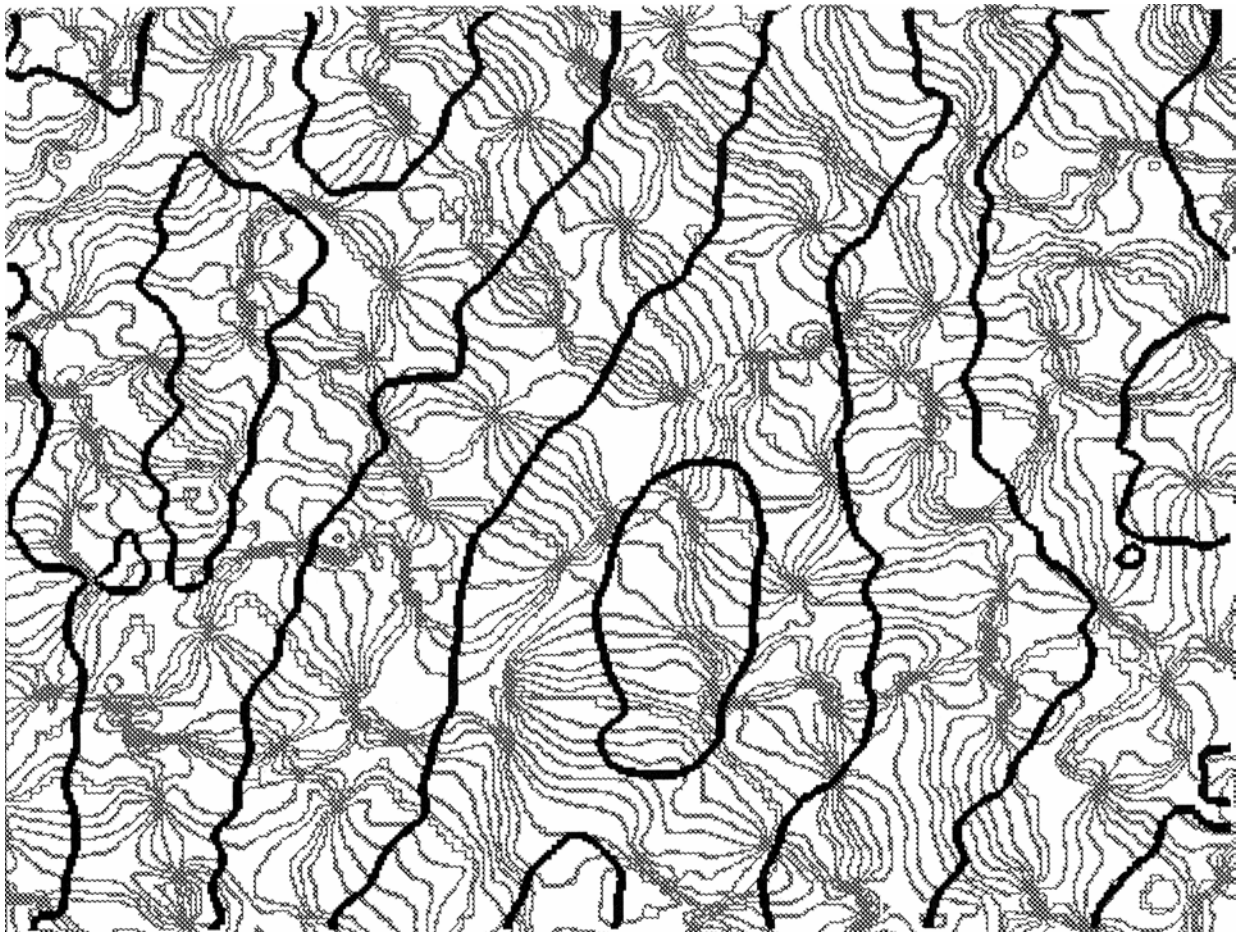
The original proposal for a hypercolumn containing three variables is shown here.




1 mm

Orientation domains in V1 and V2 - Owl monkey





Example of a contour plot of orientation preferences in overlay with the borders of ocular dominance bands imaged from macaque monkey V1. Iso-orientation lines (*gray*) are drawn in intervals of 11.25^{o}. *Black lines* indicate the border of ocular dominance bands. From Obermayer and Blasdel (1993)

Key Points (Visual Cortex)

- **M, P and K and left and right eye input from the LGN to V1 remains separate at the first synapse.**

- **Circuits within V1 involving excitatory and inhibitory neurons modify the messages arriving from the LGN and combine signals in different ways to create new receptive field properties (orientation and direction selectivity and binocularity).**

- **Different stimulus attributes represented in an iterated fashion across V1 in such a way that all properties are represented in each visuotopic location without "holes" in the visual field.**

- **Output axons from V1 provide information to two main hierarchies of visual areas concerned with 1) spatial vision/vision for action and 2) object vision**