The Lateral Geniculate Nucleus

Coronal section of monkey LGN

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Please refer to lecture video or Figure 4a from Schiller, Peter H., and Edward J. Tehovnik. "Visual prosthesis." *Perception* 37, no. 10 (2008): 1529.

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Please refer to lecture video.

Coronal section, tree shrew LGN

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Please refer to lecture video or Figure 3 of Conway, Janet L., and Peter H. Schiller. "Laminar organization of tree shrew dorsal lateral geniculate nucleus." *J. Neurophysiol* 50 (1983):1330-42.

Sagittal section, Galago LGN

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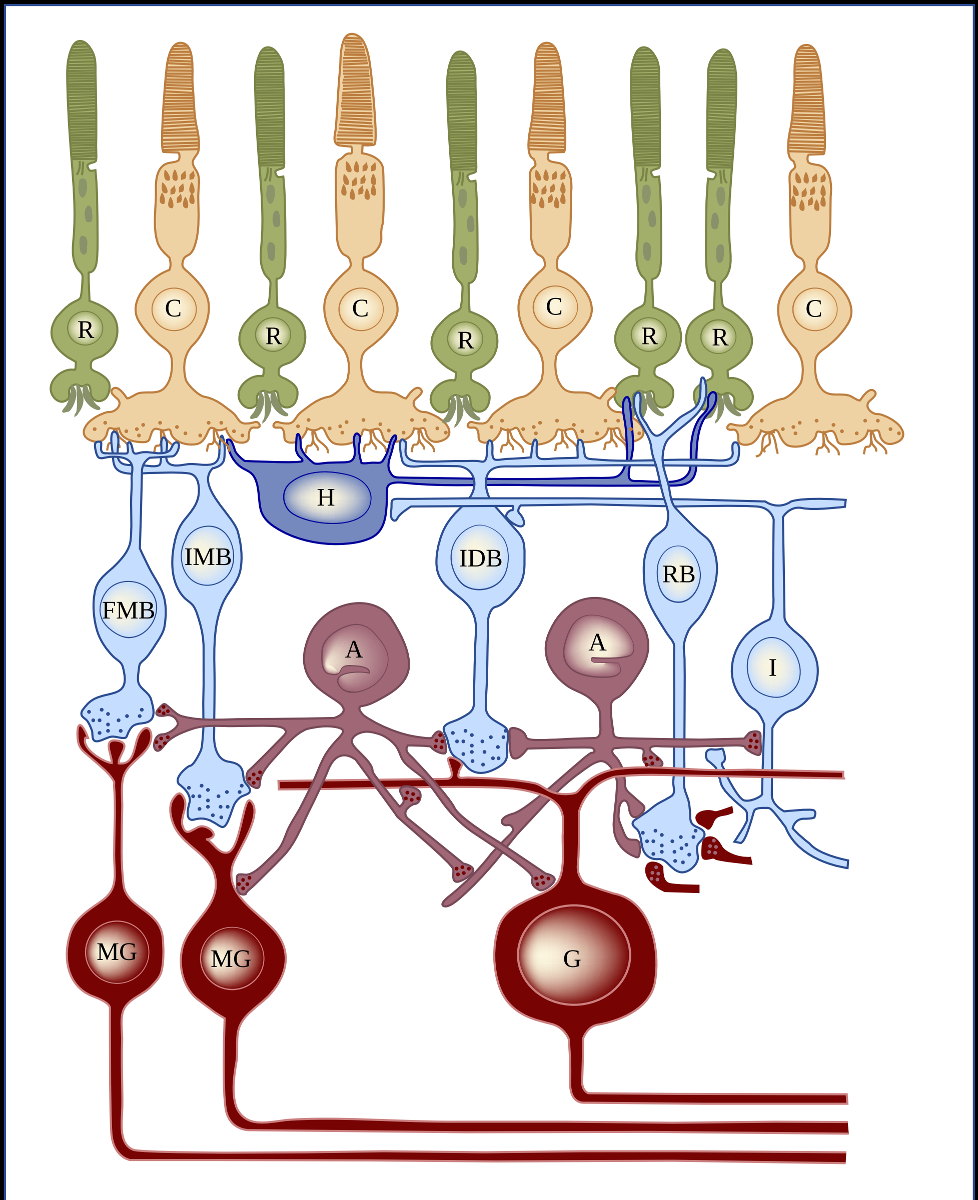
Please refer to lecture video or Figure 1c of Fitzpatrick, David, and I. T. Diamond. "The laminar organisation of the lateral geniculate body in Galago senegalensis: A pair of layers identified by acetylcholinesterase activity." *Brain research* 170, no. 3 (1979): 538 - 542.



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Overview of retinal connections:

Photoeceptors all hyperpolarize to light. They produce only graded potentials. Glutamate is the neurotransmitter.

Horizontal cells all hyperpolarize to light and produce only graded potentials.

Some bipolar cells depolarize (ON) and some hyperpolarize (OFF) to light. Bipolars produce only graded potentials.

Some amacrine cells produce action potentials. There are many classes 37including ON and OFF.

Ganglion cells produce action potentials. There are many classes including midget and parasol that come either as ON or OFF.

Summary:

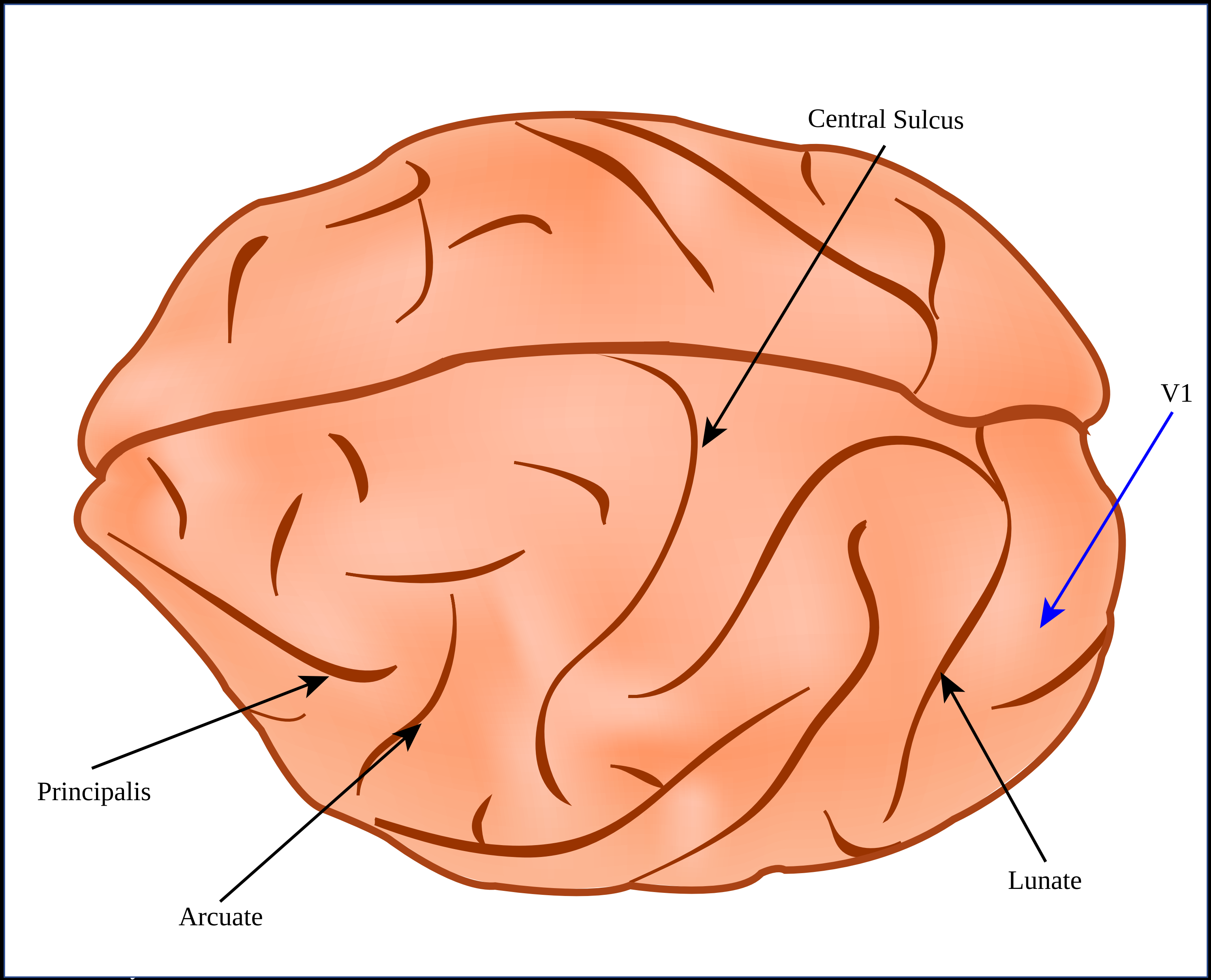
1. In primates the right brain receives input from the left visual hemifield and the left brain from the right hemifield.
2. There are five major classes of retinal cells: photorecptors (rods and cones), horizontal cells, bipolar cells, amacrine cells, and retinal ganglion cells (RGC).
3. The receptive fields of RGCs have antagonistic center/surround organization.
4. There are several classes of RGCs, two of which are (a) the ON and OFF and (b) the Midget and Parasol.
5. All photoreceptors and horizontal cells hyperpolarize to light.
6. There are both hyperpolarizing and depolarizing bipolar cells.
7. Action potentials in the retina are generated only by amacrine and RGC cells.
8. The lateral geniculate nucleus of the thalamus is a laminated structure. What is segregated in the laminae varies with species.
9. The parvocellular layers receive input from the midget cells and the magnocellular layers from the parasol cells. Inputs from the left and right eyes are segregated in the laminae.
10. The receptive field properties of LGN cells are similar to those of the retinal ganglion cells.

The visual cortex

V1

Anatomical Layout

Monkey brain



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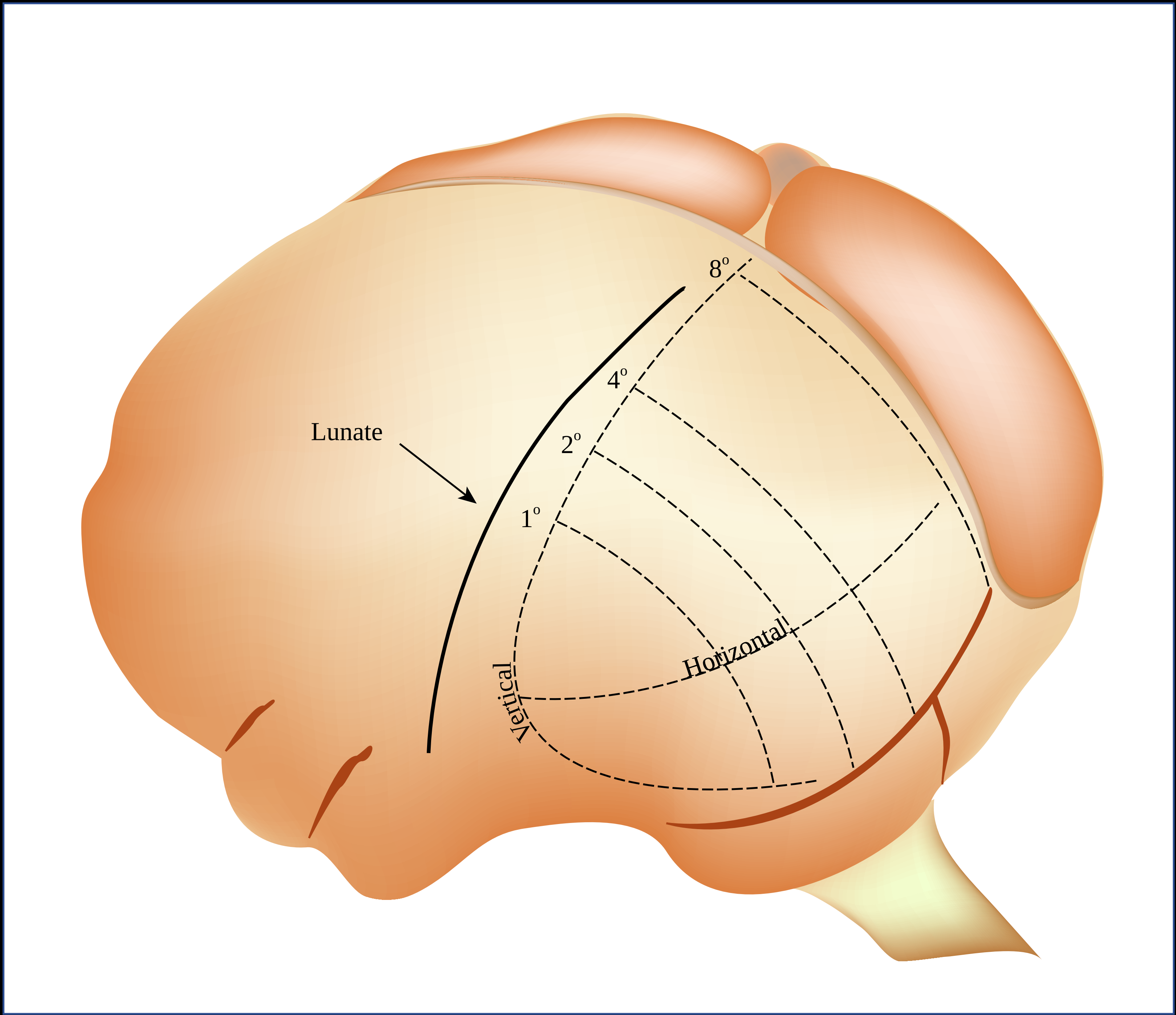
Monkey brain, back view



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Visual stimulation method for 2DG labeling of V

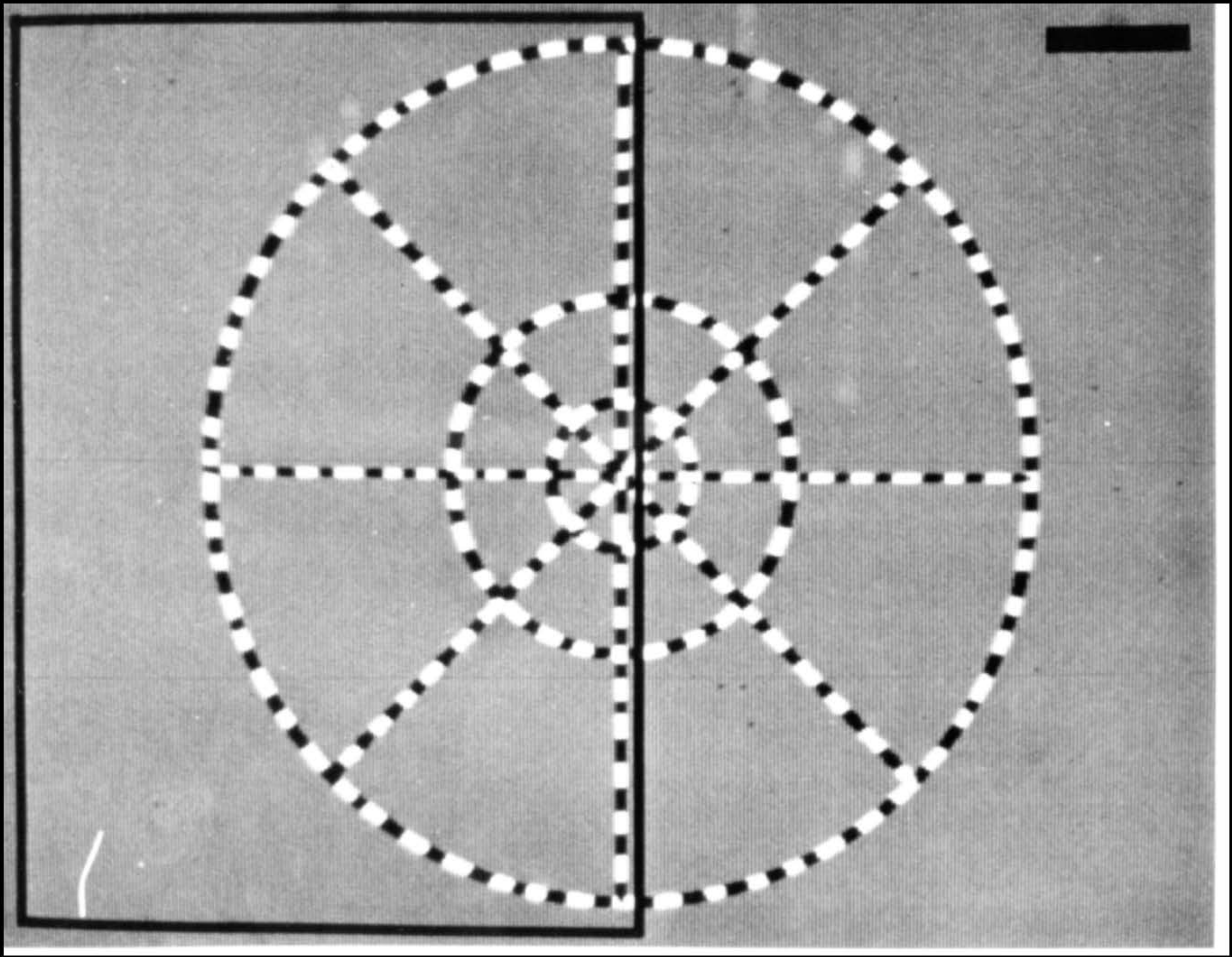


Figure 1, 2B. Tootell, Robert B., Eugene Switkes, et al. "Functional Anatomy of Macaque Striate Cortex. II. Retinotopic Organization." *The Journal of Neuroscience* 8, no. 5 (1988): 1531-68. Available under Creative Commons BY-NC-SA.

Labeled regions of V1 after exposure to previously shown display

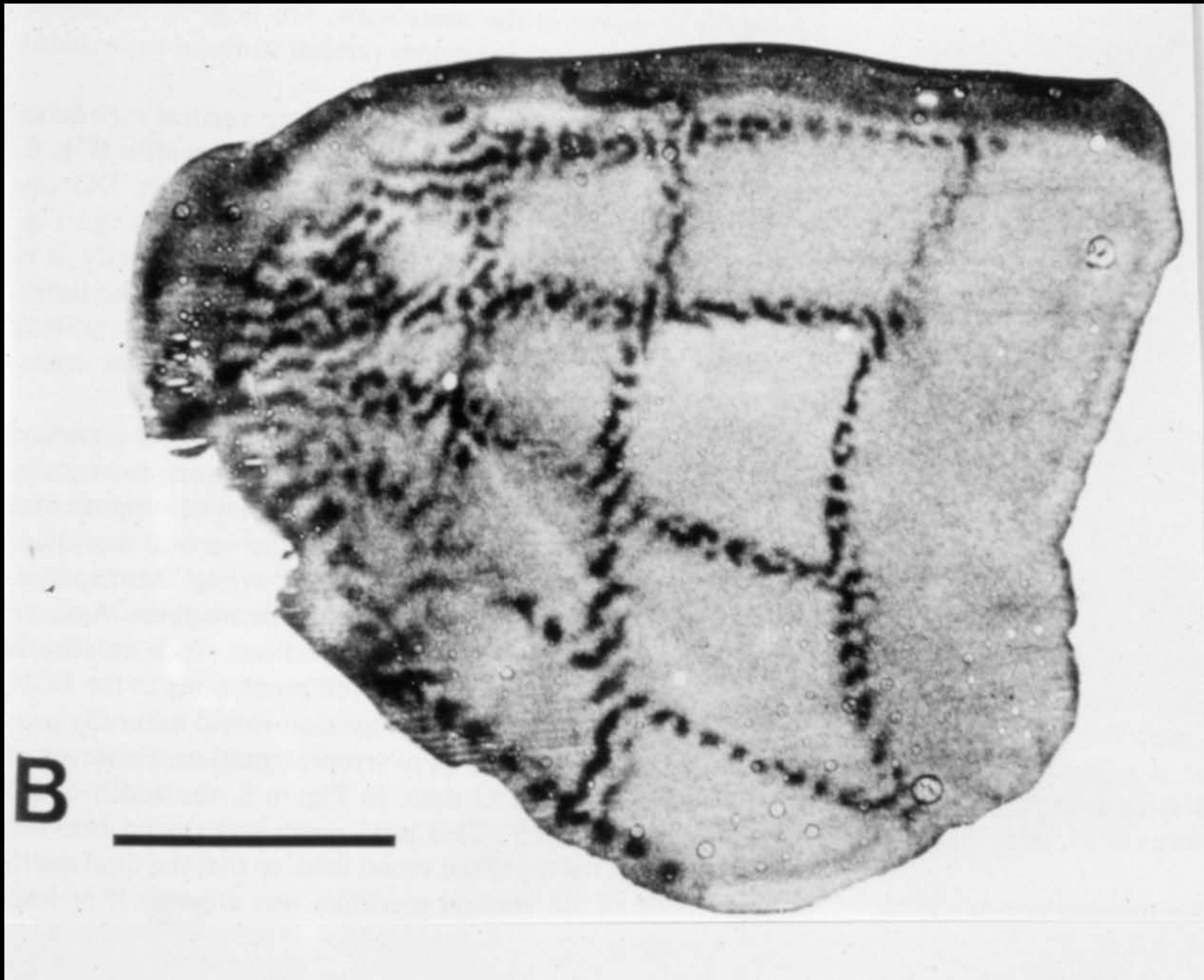
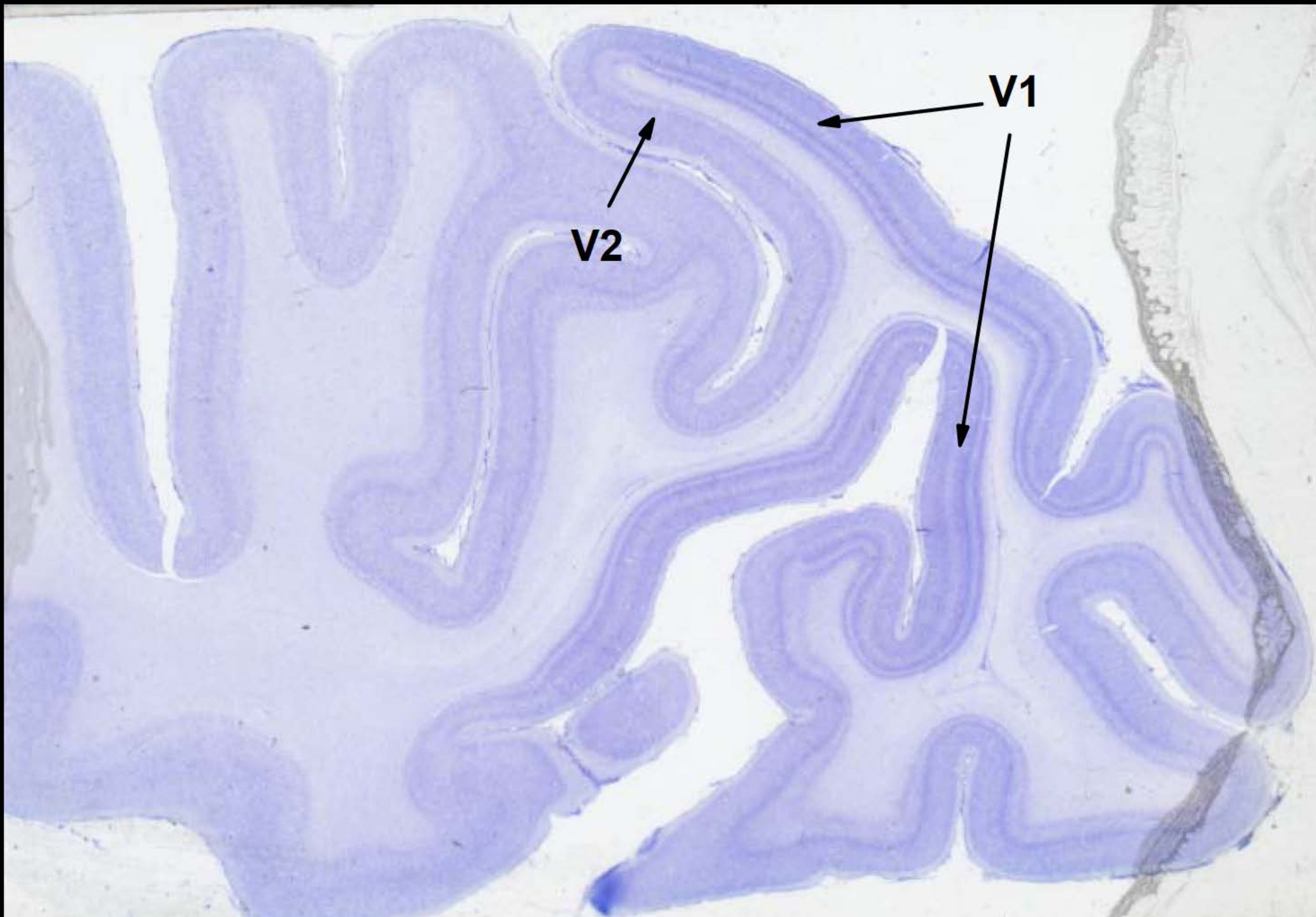


Figure 1, 2B. Tootell, Robert B., Eugene Switkes, et al. "Functional Anatomy of Macaque Striate Cortex. II. Retinotopic Organization." *The Journal of Neuroscience* 8, no. 5 (1988): 1531-68. Available under Creative Commons BY-NC-SA.

Nyssl stained sagittal section through posterior monkey brain



Cross section of V1, Nissl and Golgi stains

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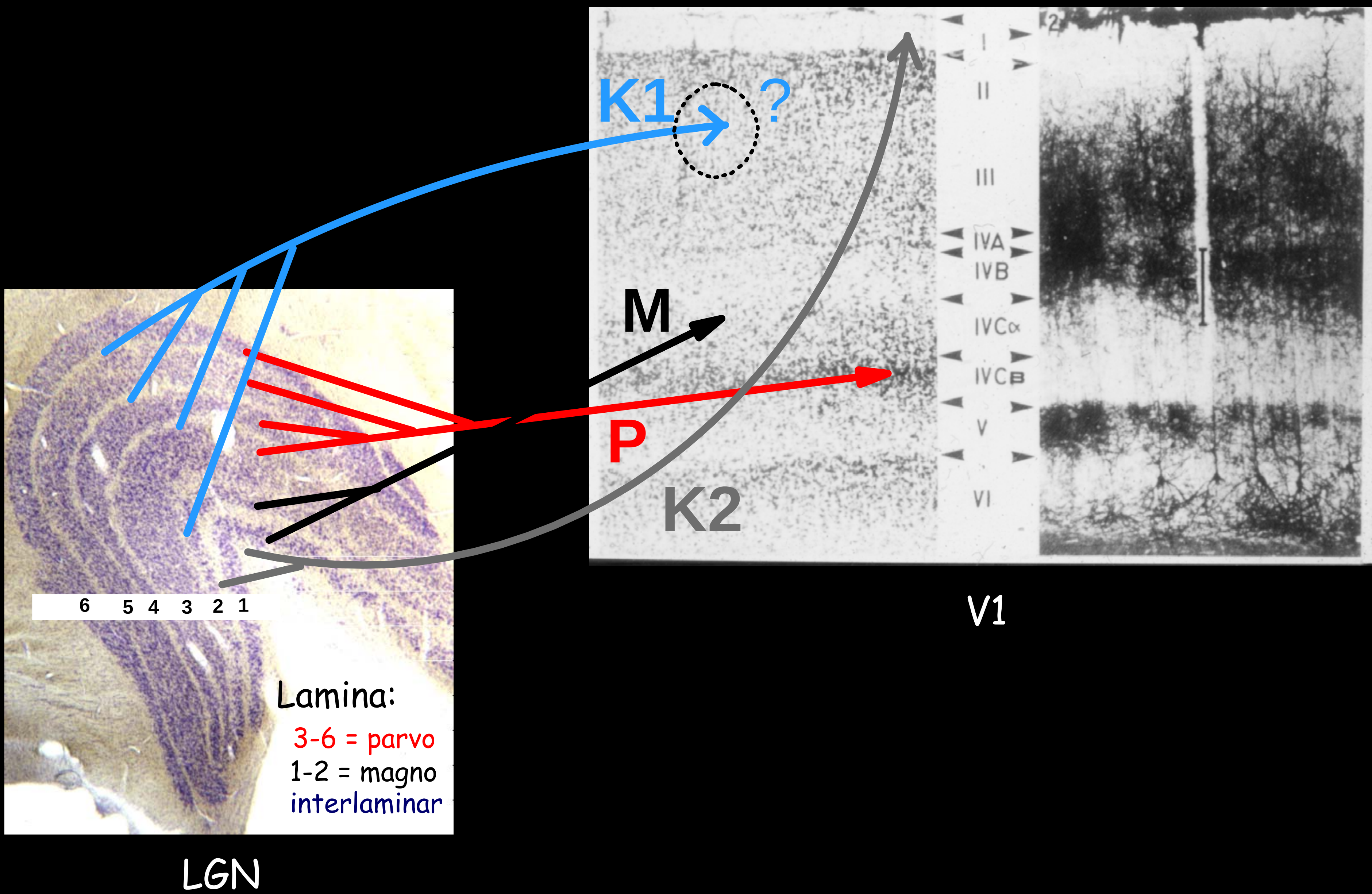
Please refer to lecture video or Plate 1 of Lund, Jennifer S. "Organization of neurons in the visual cortex, area 17, of the monkey (Macaca mulatta)." *Journal of Comparative Neurology* 147, no. 4 (1973): 455-495.

Cortical projections from LGN



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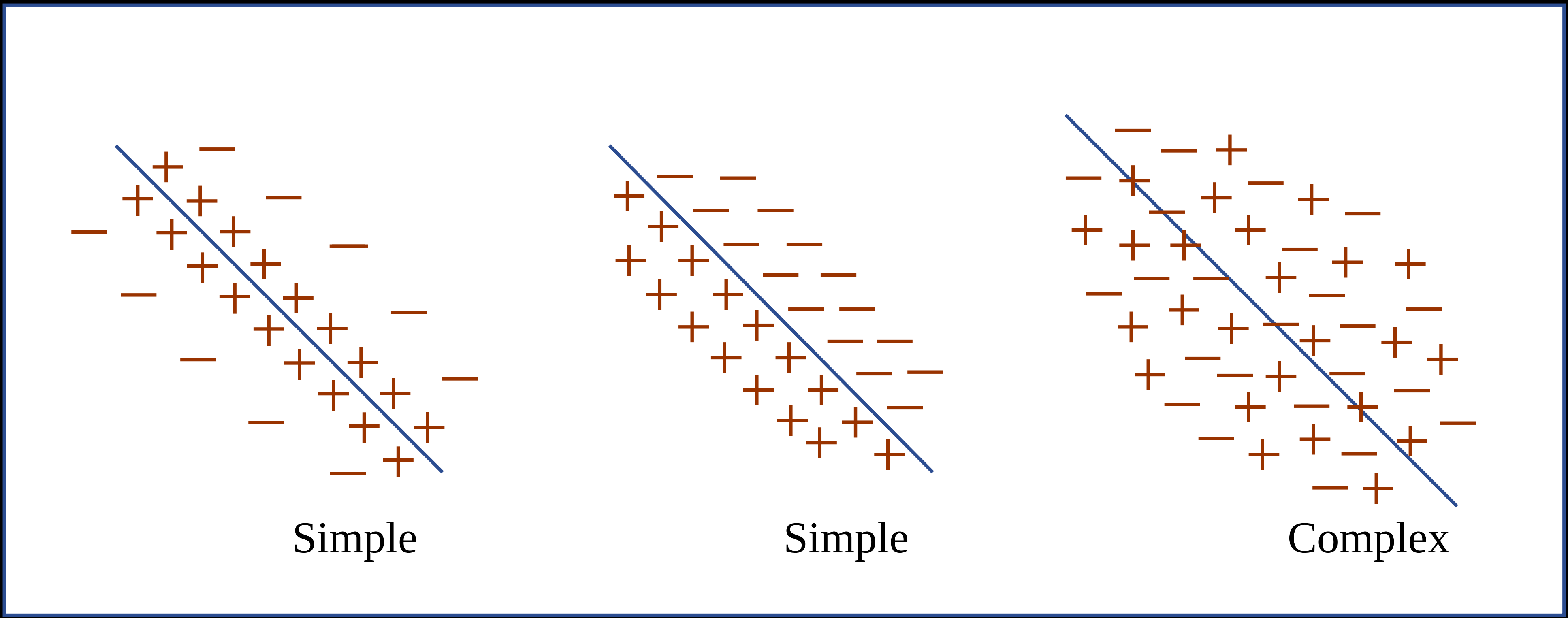
V1

Receptive Field Organization

Receptive field plots of cat V1 cells using small spots



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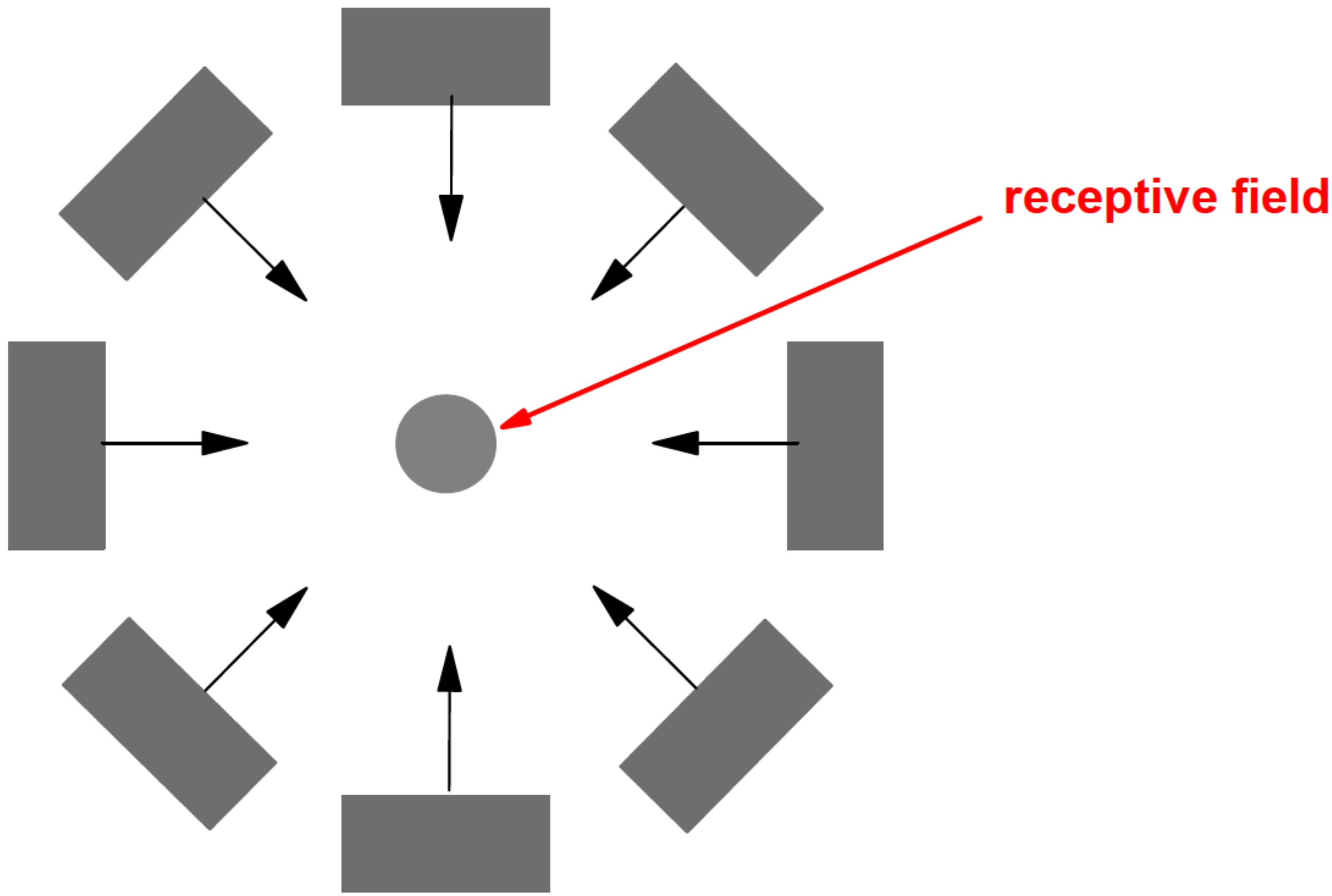
Assessing orientation and direction specificity of a V1 cell



Response of monkey V1 cell to sweeping bars of different orientations

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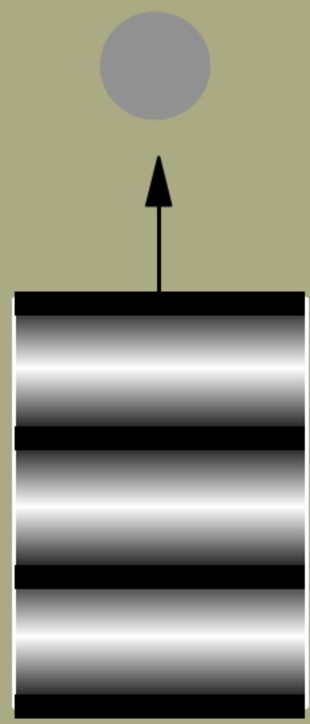
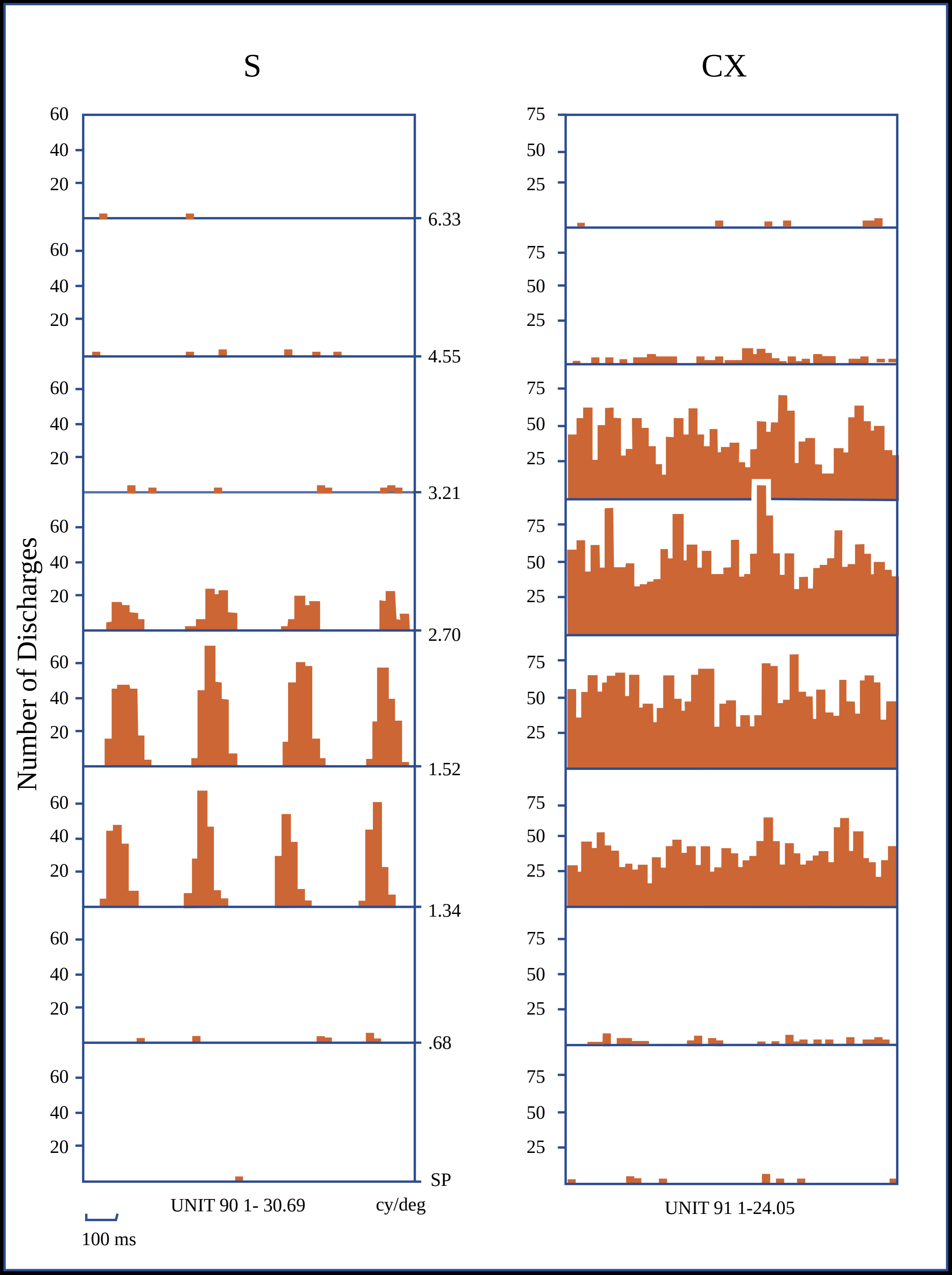
Please refer to lecture video or Figure 1 of Schiller, Peter H., Barbara L. Finlay, and Susan F. Volman. "Quantitative studies of single-cell properties in monkey striate cortex. II. Orientation specificity and ocular dominance." *J Neurophysiol* 39, no. 6 (1976): 1320-1333.

Assessing spatial frequency selectivity of a V1 cell



Responses of a simple and complex cell to gratings of different spatial frequencies



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Transforms in V1

Orientation

Direction

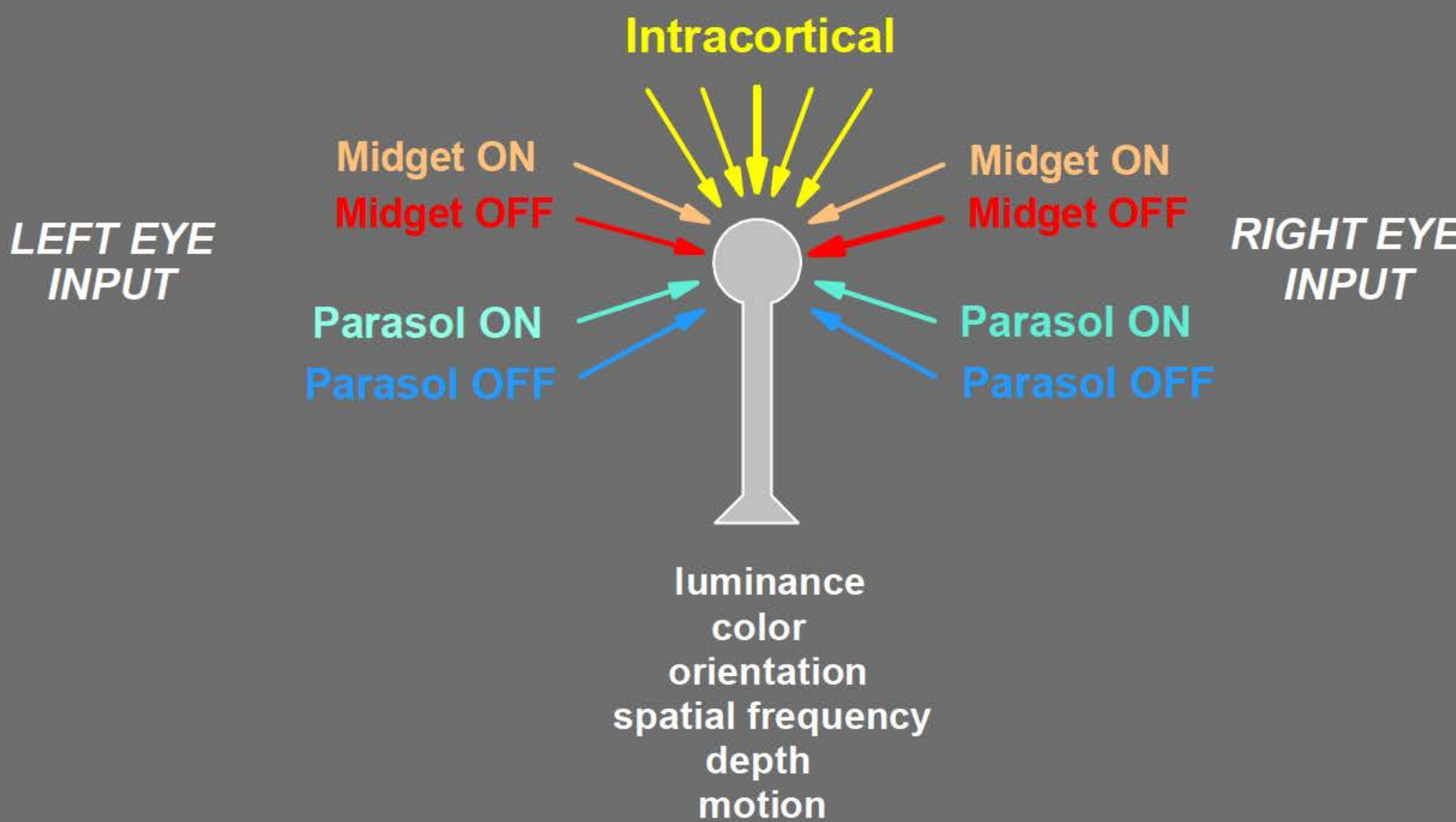
Spatial Frequency

Binocularity

ON/OFF Convergence

Midget/Parasol Convergence

Striate Cortex Output Cell



V1

Cytoarchitecture

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Please refer to lecture video or Figure 12 of Hubel, David H., Thorsten N. Wiesel, and Simon LeVay. "Plasticity of ocular dominance columns in monkey striate cortex." *Philosophical Transactions of the Royal Society of London.* Series B, Biological Sciences (1977): 377-409.

Left eye columns labeled in monkey V1

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Please refer to lecture video or Figure 20 of Hubel, David H., Thorsten N. Wiesel, and Simon LeVay. "Plasticity of ocular dominance columns in monkey striate cortex." *Philosophical Transactions of the Royal Society of London.* Series B, Biological Sciences (1977): 377-409.

V1 ocular dominance columns

David Hubel's thumbprint

Figure 1, 5. Hubel, David H., and David C. Freeman. "Projection into the Visual Field of Ocular Dominance Columns in Macaque Monkey." *Brain Research* 122, no. 2 (1977): 336-43. Courtesy of Elsevier, Inc., http://www.sciencedirect.com. Used with permission.

V1 ocular dominance columns projected into visual field

Figure 1, 5. Hubel, David H., and David C. Freeman. "Projection into the Visual Field of Ocular Dominance Columns in Macaque Monkey." *Brain Research* 122, no. 2 (1977): 336-43. Courtesy of Elsevier, Inc., http://www.sciencedirect.com. Used with permission.

V1 orientation columns in tree shrew

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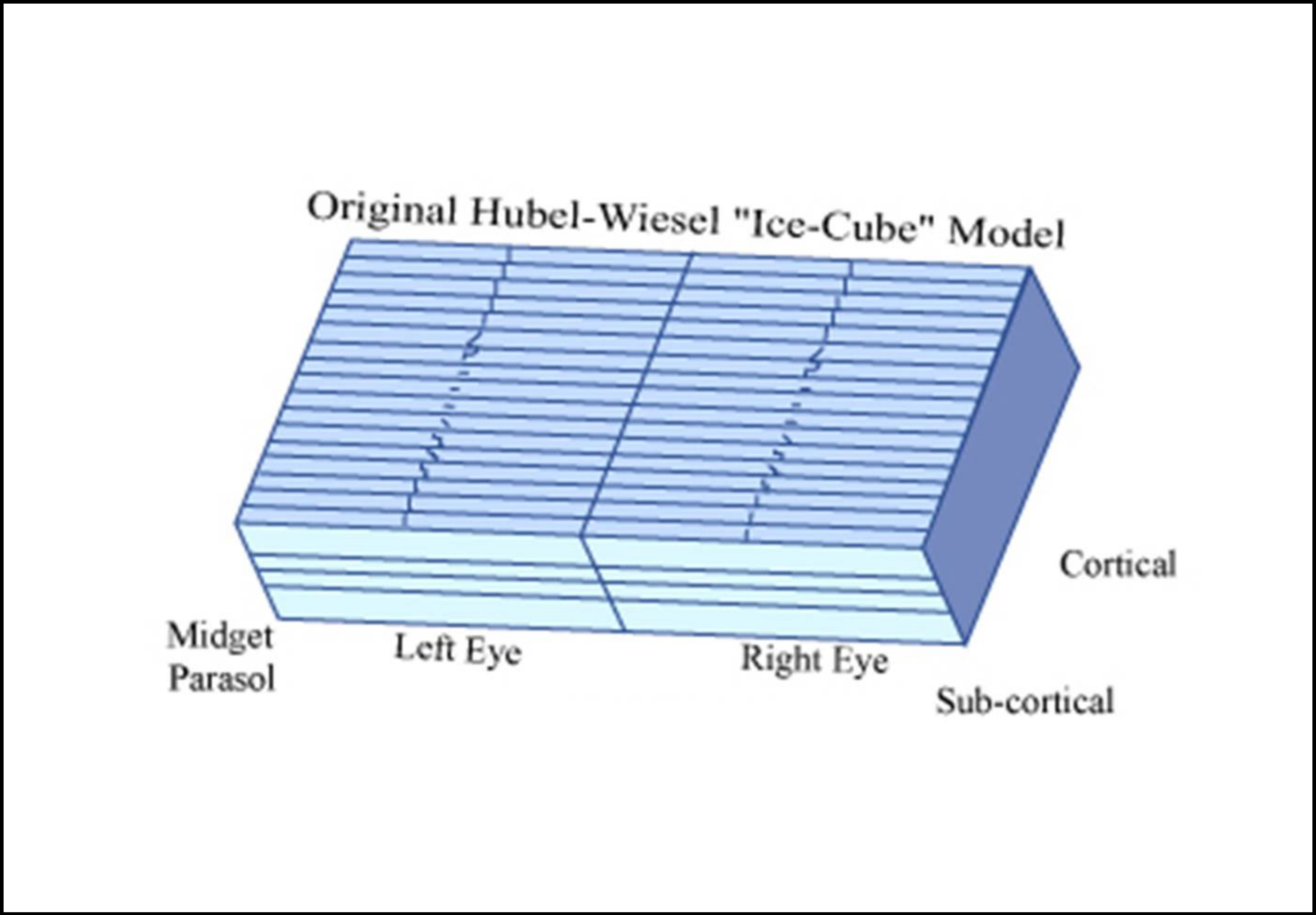
Please refer to lecture video or Figure 6 of Humphrey, Allen L., Leslie C. Skeen, and Thomas T. Norton. "Topographic organization of the orientation column system in the striate cortex of the tree shrew (Tupaia glis). II. Deoxyglucose mapping." *Journal of Comparative Neurology* 192, no. 3 (1980): 549-566.



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Please refer to lecture video or Figure 8 of Hubel, David H., Torsten N. Wiesel, and Michael P. Stryker. "Anatomincal demonstration of orientation columns in macaque monkey." *Journal of Comparative Neurology* 177, no. 3 (1978): 361-379.

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Please refer to lecture video or Figure 9 of Hubel, David H., Torsten N. Wiesel, and Michael P. Stryker. "Anatomincal demonstration of orientation columns in macaque monkey." *Journal of Comparative Neurology* 177, no. 3 (1978): 361-379.

Cytochrome oxidase patches in monkey V1

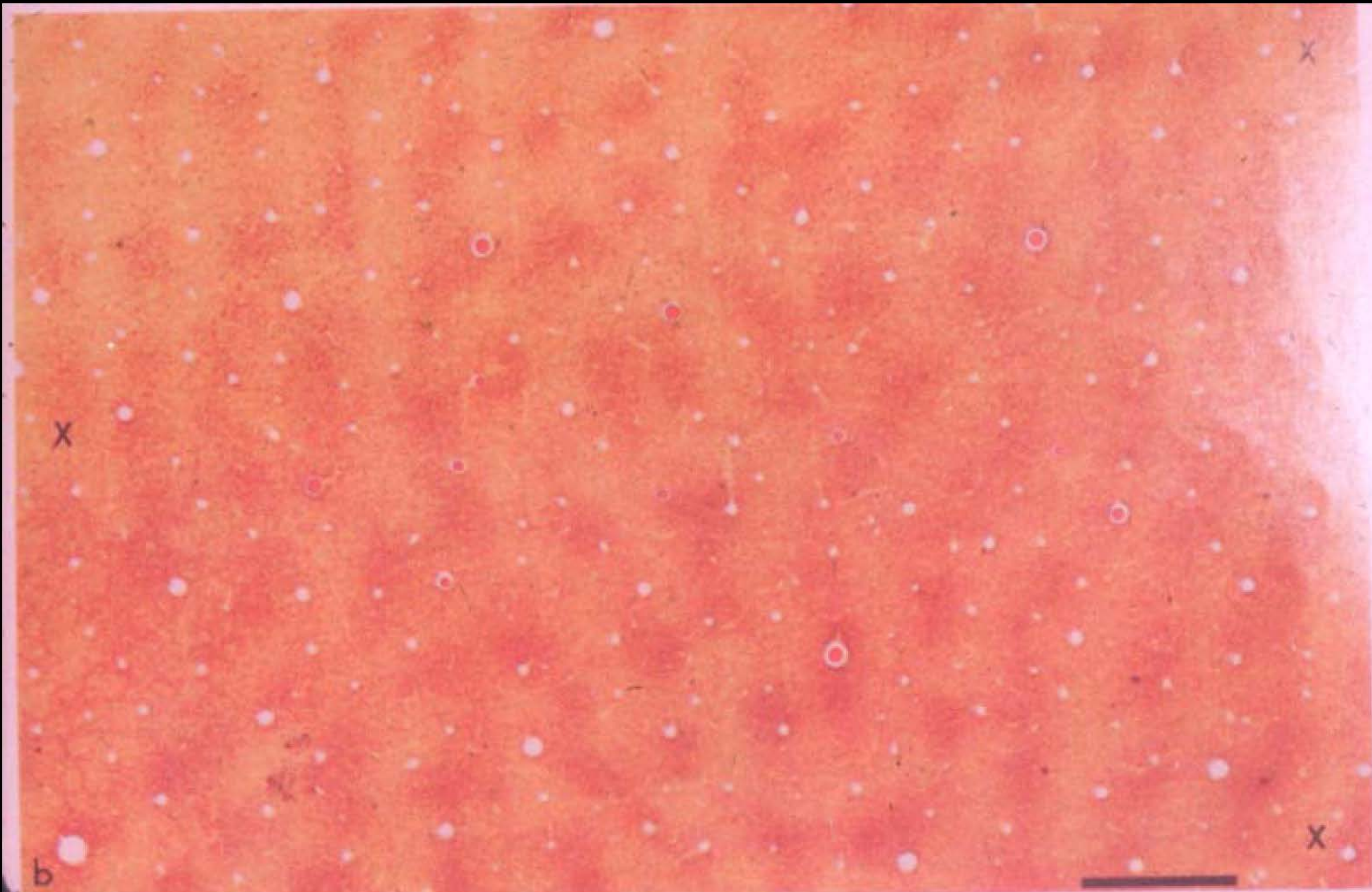
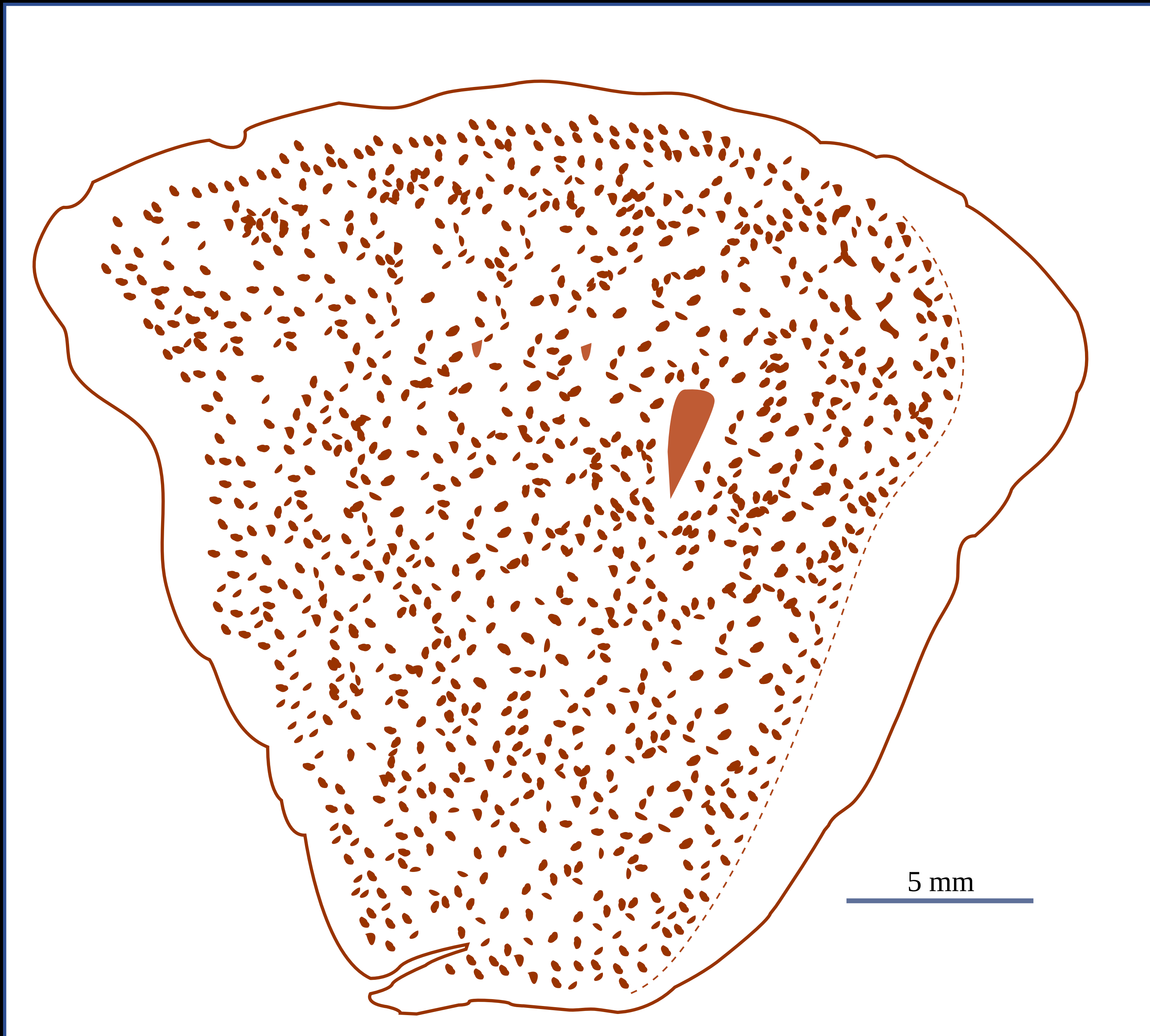


Figure 3. Livingstone, M. S., and D. H. Hubel. "Specificity of Intrinsic Connections in Primate Primary Visual Cortex." *The Journal of Neuroscience* 4, no. 11 (1984): 2830-5. Available under Creative Commons BY-NC-SA.

Cytochrome oxidase patches in monkey V1



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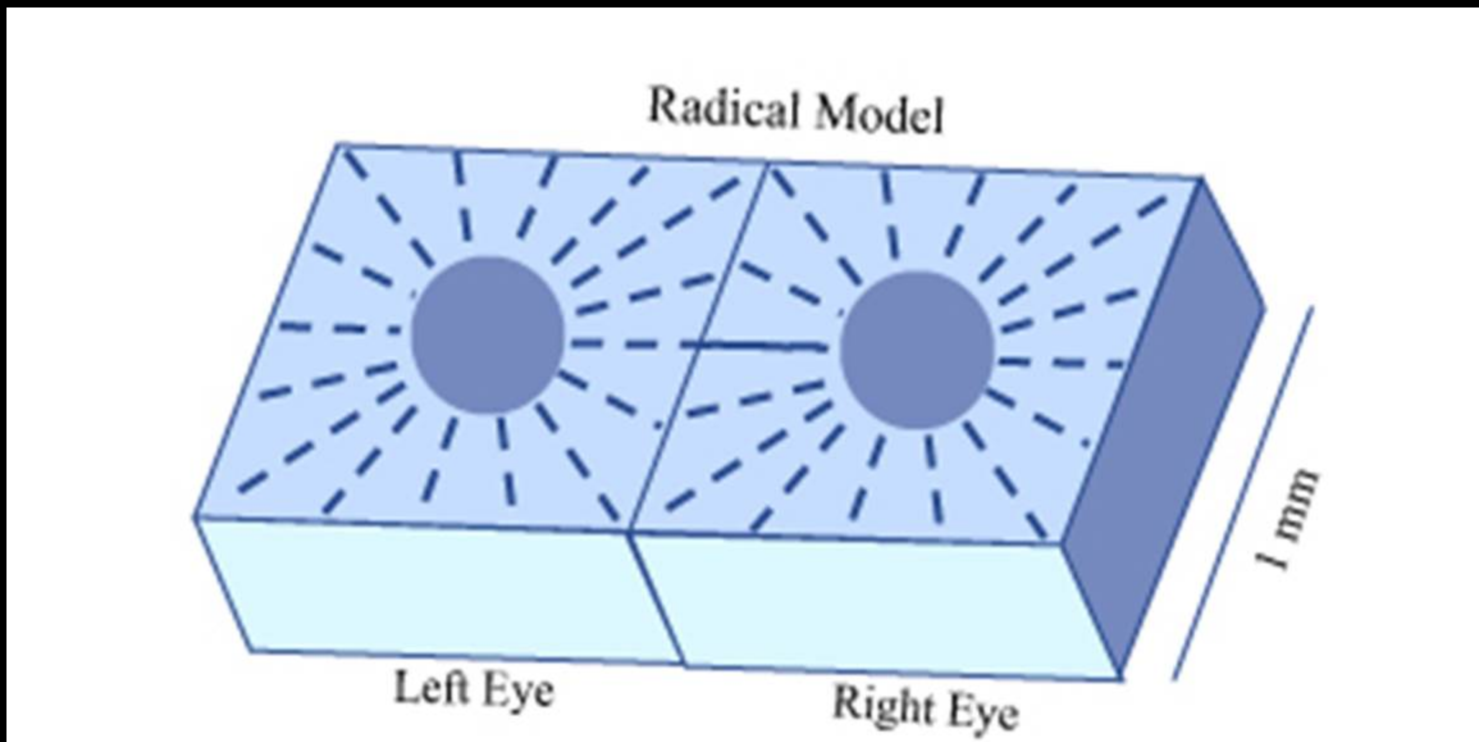

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Layout of orientations in monkey V1 as determined with optical recording

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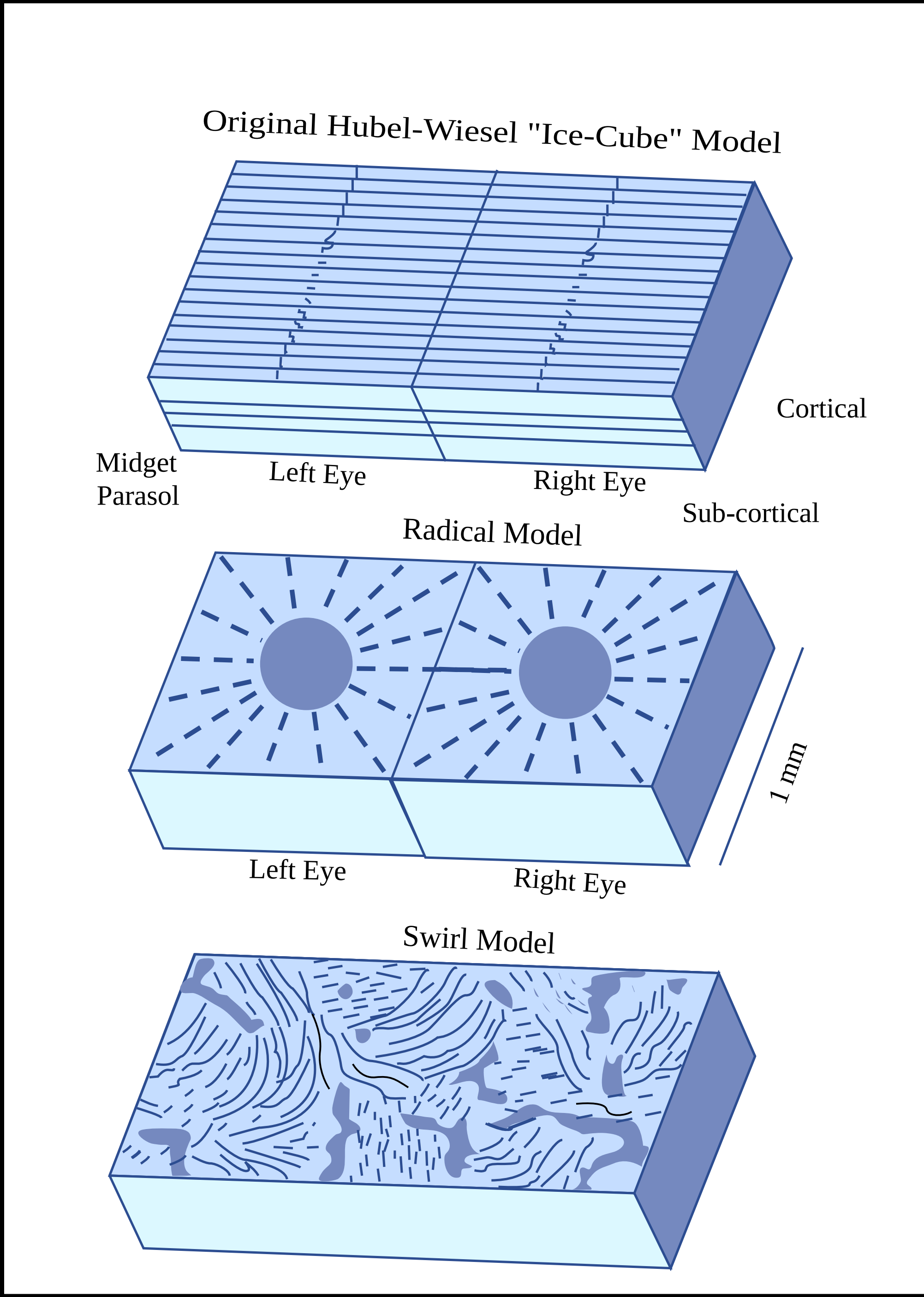
Please refer to lecture video or Figure 10b of Blasdel, Gary G. "Orientation selectivity, preference, and continuity in monkey striate cortex." *The Journal of Neuroscience* 12, no. 8 (1992): 3139-3161.

Three models of columnar organization in V1



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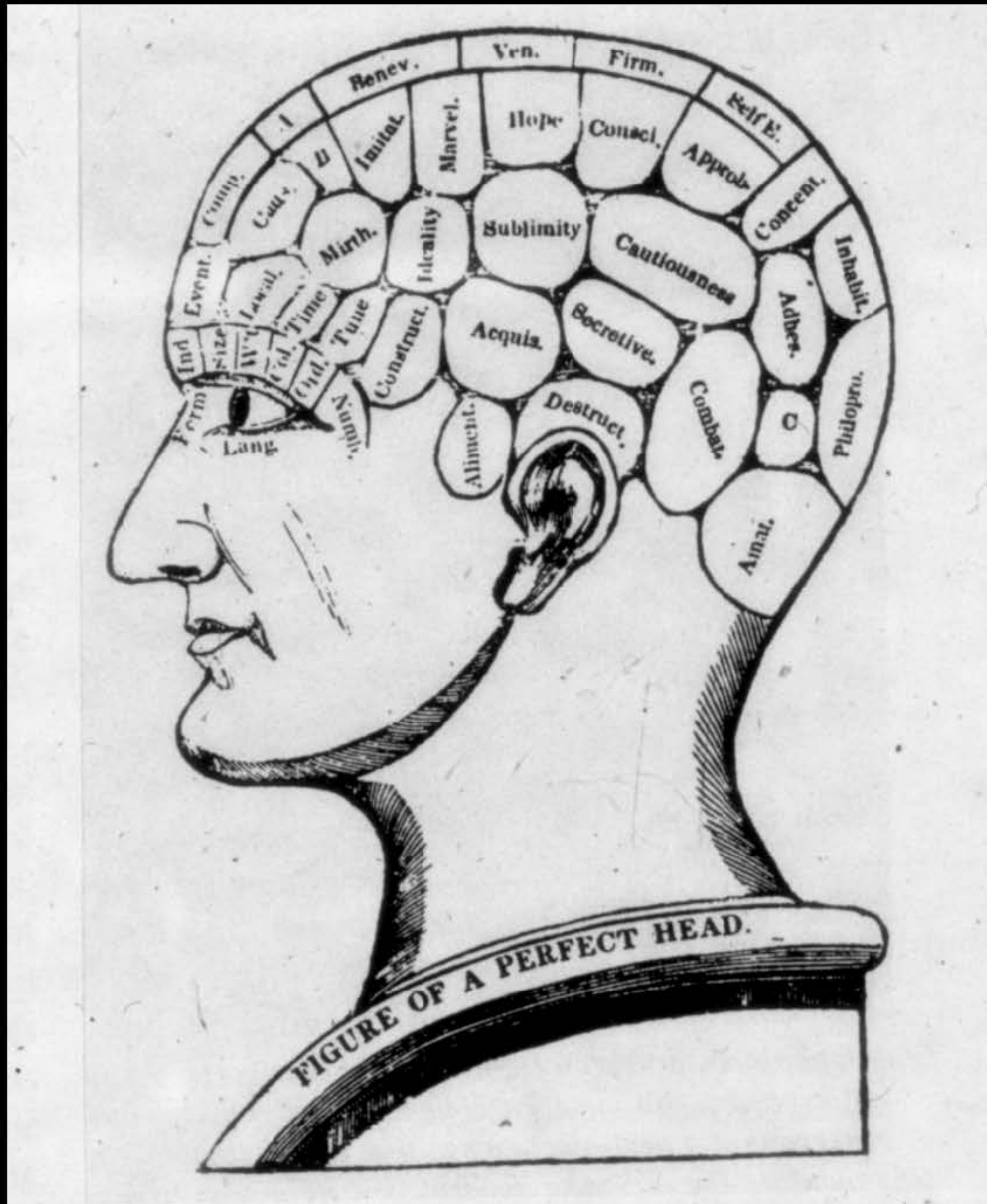
Extrastriate cortex



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Gall and Spurzheim

Methods for delineating extrastriate areas

architectonics

connections

topographic mapping

physiological characterization

lesions and behavioral testing

cerebral accidents and behavioral testing

imaging

Visual functions studied

Basic visual capacities

color

brightness

pattern

texture

motion

depth

Intermediate visual capacities

constancy

selection

recognition

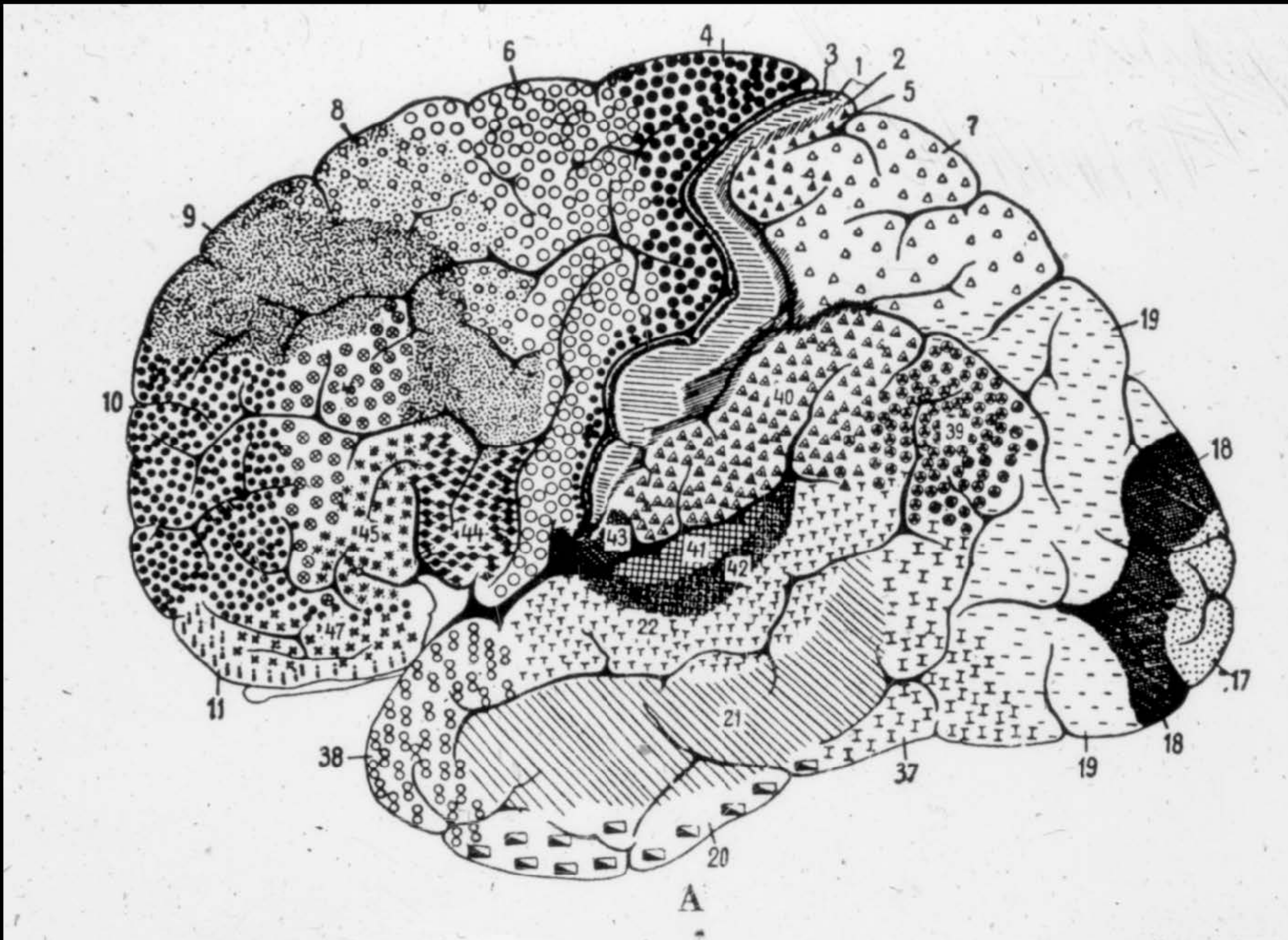
transposition

comparison

location

Layout of visual areas

Human brain



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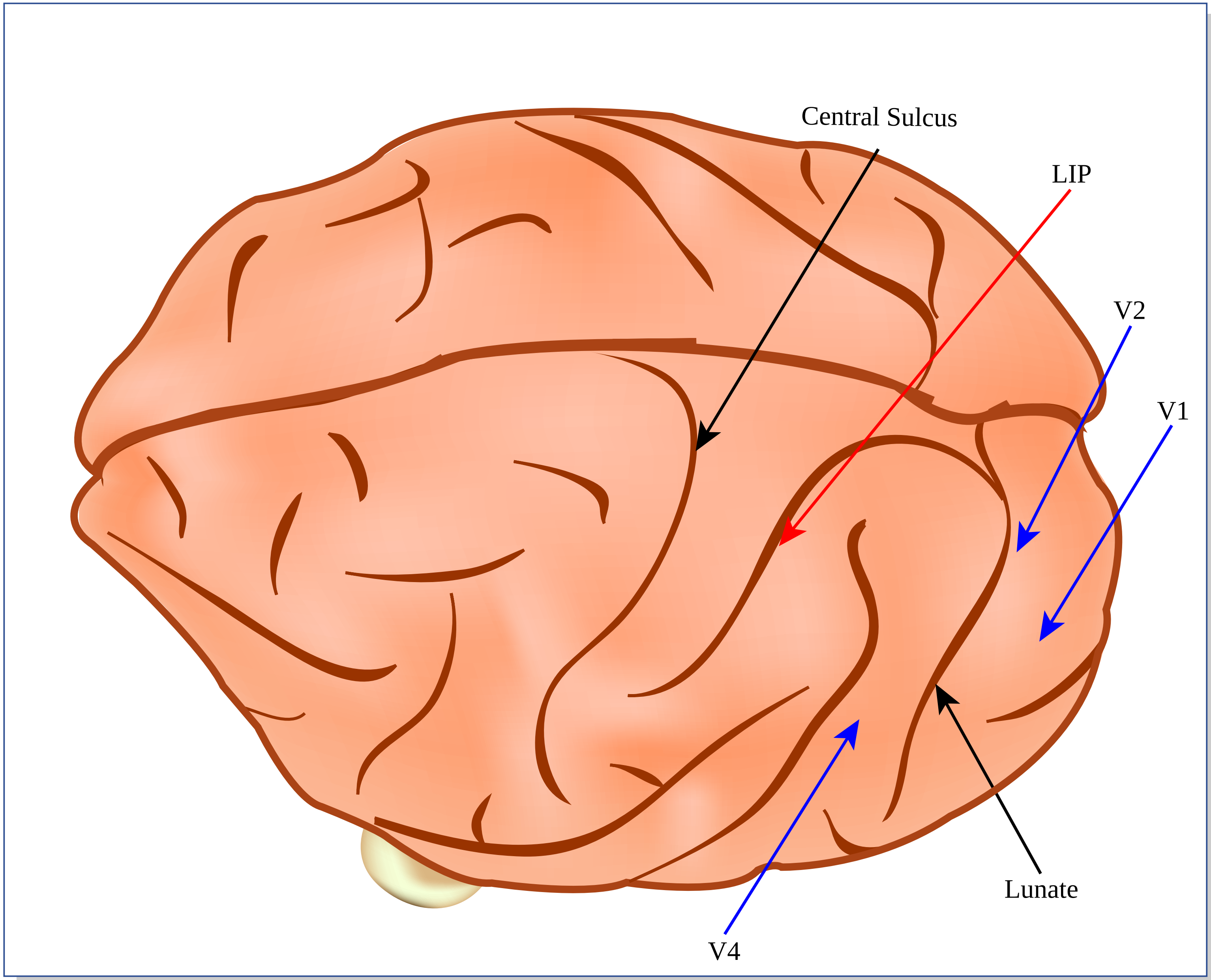

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Visual areas in monkey, flattened brain

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Please refer to lecture video or Figure 2 of Felleman, Daniel J., and David C. Van Essen. "Distributed hierarchical processing in the primate cerebral cortex." *Cerebral Cortex* 1, no. 1 (1991): 1-47.

Subway map of brain connections

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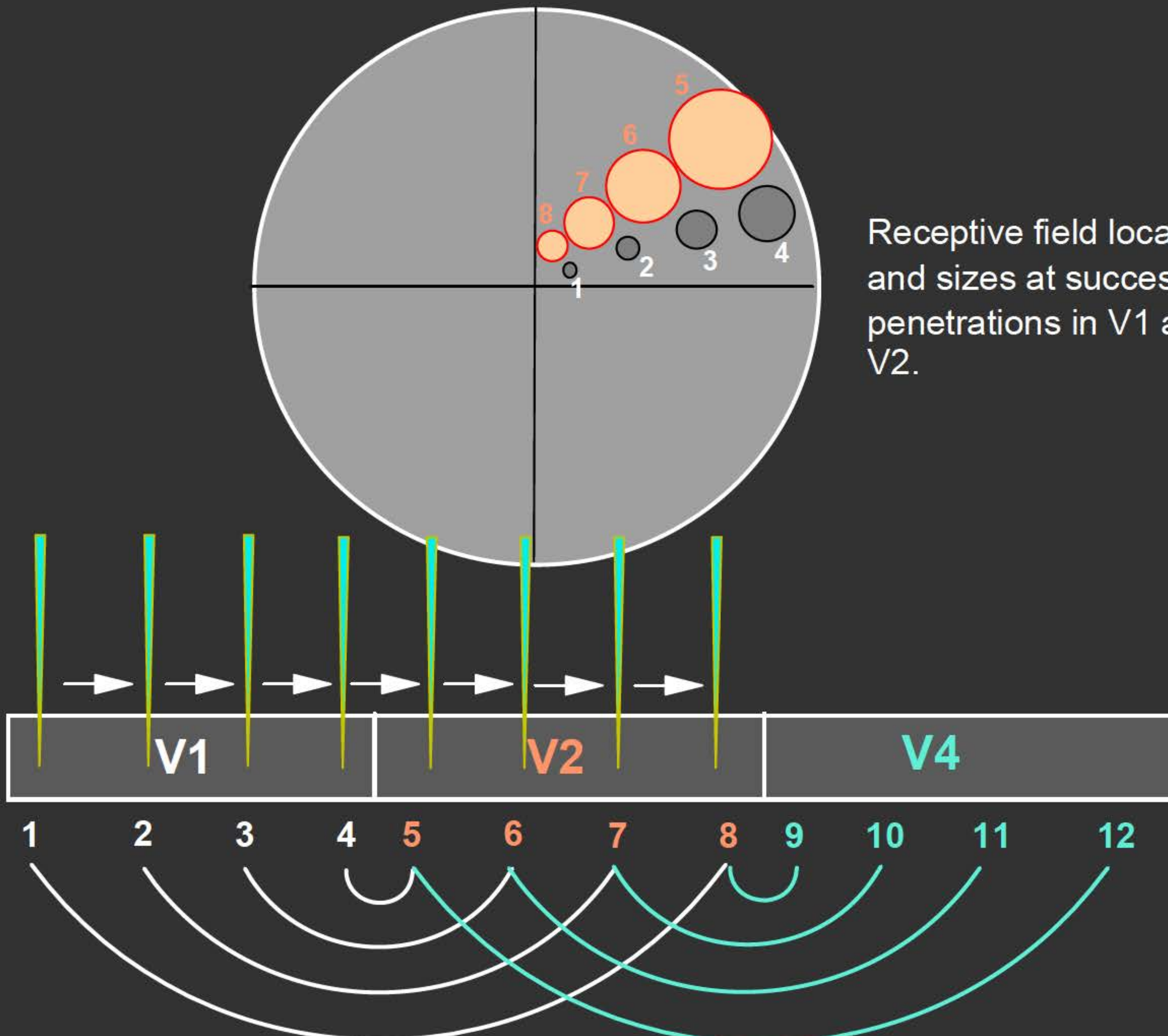
Please refer to lecture video or Figure 4 of Felleman, Daniel J., and David C. Van Essen. "Distributed hierarchical processing in the primate cerebral cortex." *Cerebral Cortex* 1, no. 1 (1991): 1-47.

Major cortical visual areas:

Occipital	**V1**	
	V2	
	V3	
	V4	
	MT	(medial temporal)
Temporal	**IT**	(inferotemporal)
Parietal	**LIP**	(lateral intraparietal)
	VIP	(ventral intraparietal)
	MST	(medial superior temporal)
Frontal	**FEF**	(frontal eye fields)

Connections among adjacent visual areas



Receptive field locations and sizes at successive penetrations in V1 and V2.

Area V2

Cytochrome oxidase labeling in V1 and V2

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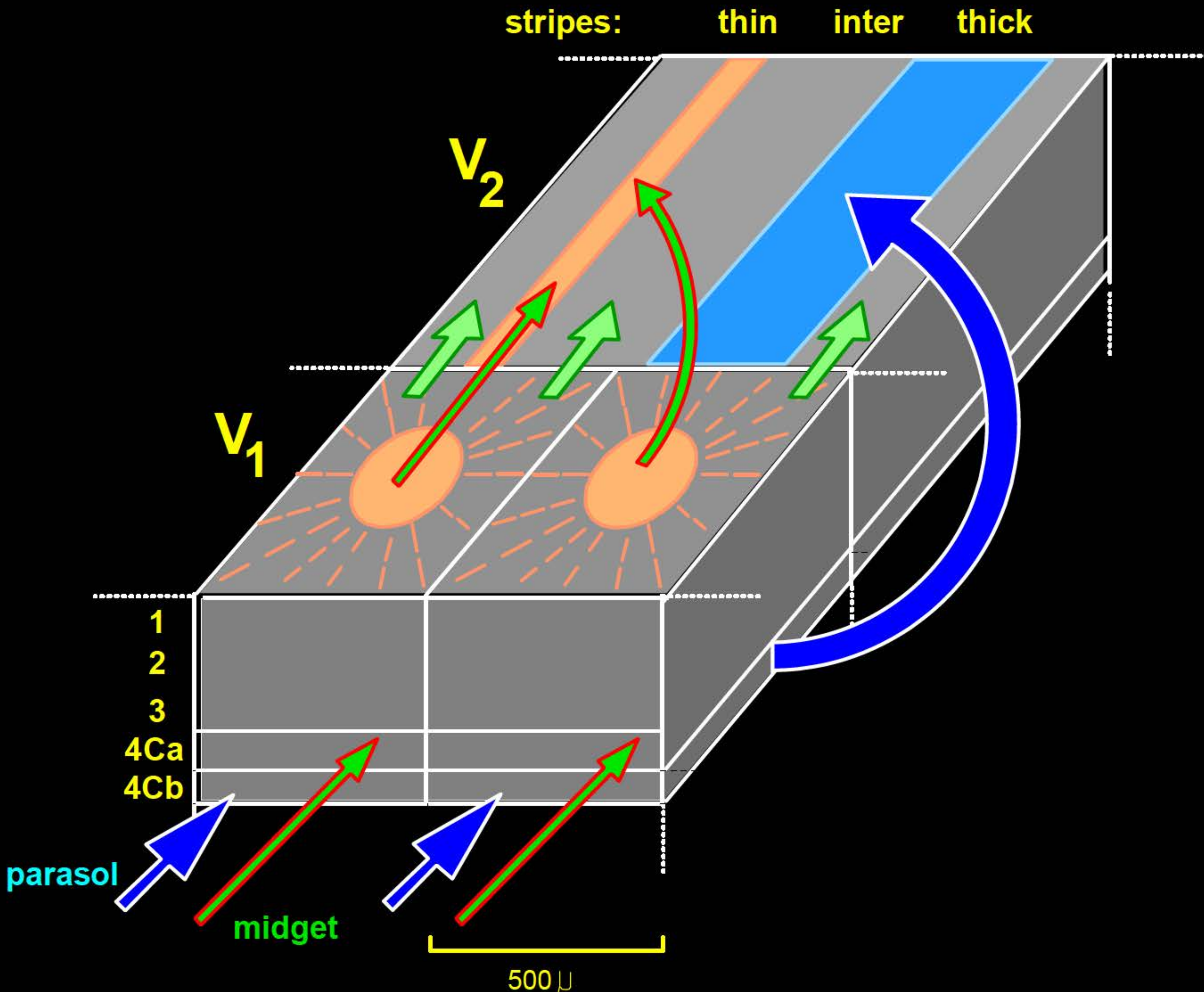
Please refer to lecture video or Figure 13 of Hubel, David H., and Margaret S. Livingstone. "Segregation of form, color, and stereopsis in primate area 18." *The Journal of Neuroscience* 7, no. 11 (1987): 3378-3415.


stripes:
thin
inter
thick
V2
V1
1
2
3
4Ca
4Cb
parasol
midget
500 µ

Functional Segregation in Area V2

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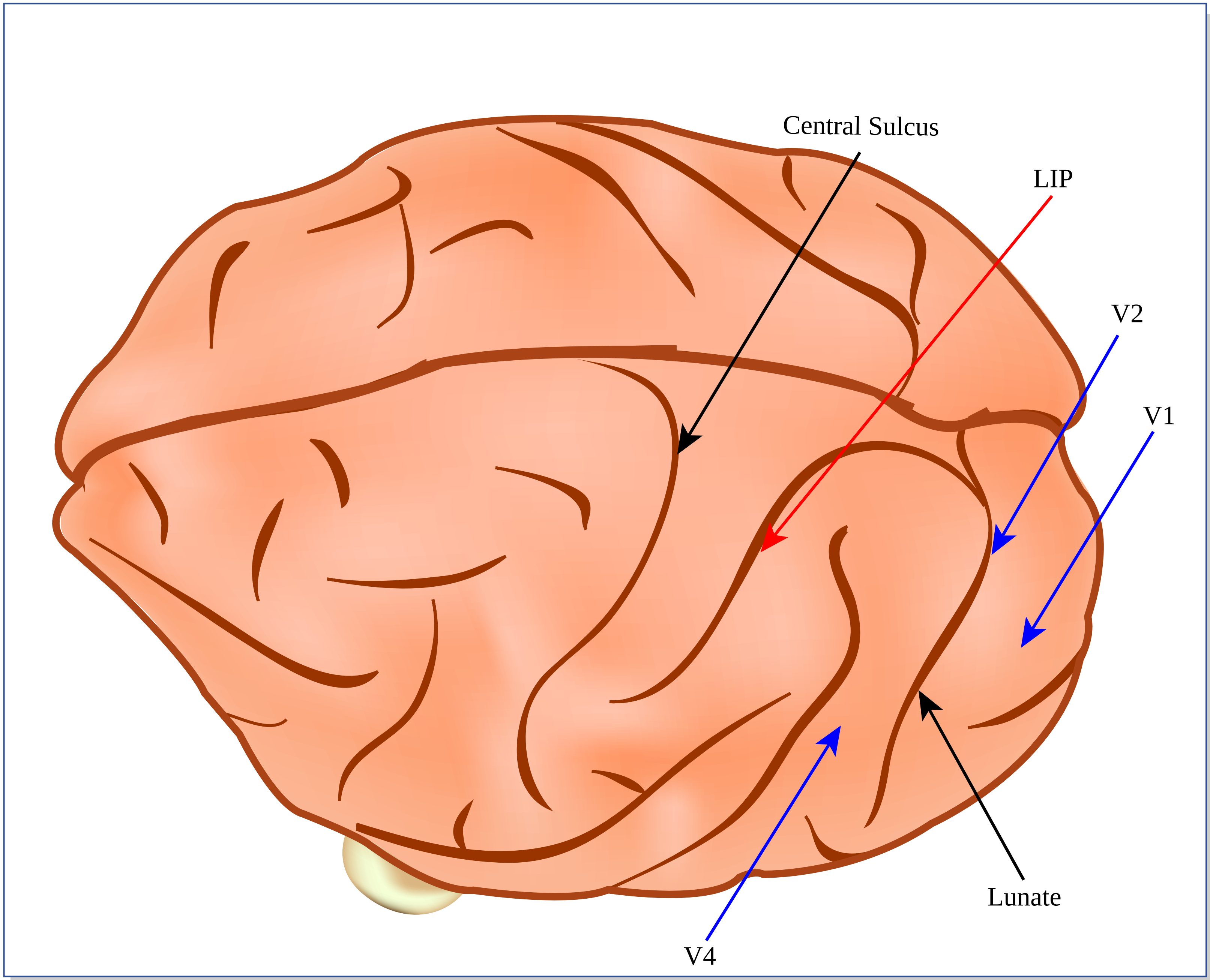
Please refer to lecture video or Table 1 in Chapter 8 from Rockland, Kathleen S., Alan Peters, Edward G. Jones, and Jon H. Kaas, eds. *Cerebral Cortex: Volume 12: Extrastriate cortex in Primates*. Vol. 12. Springer, 1997.

Area V4



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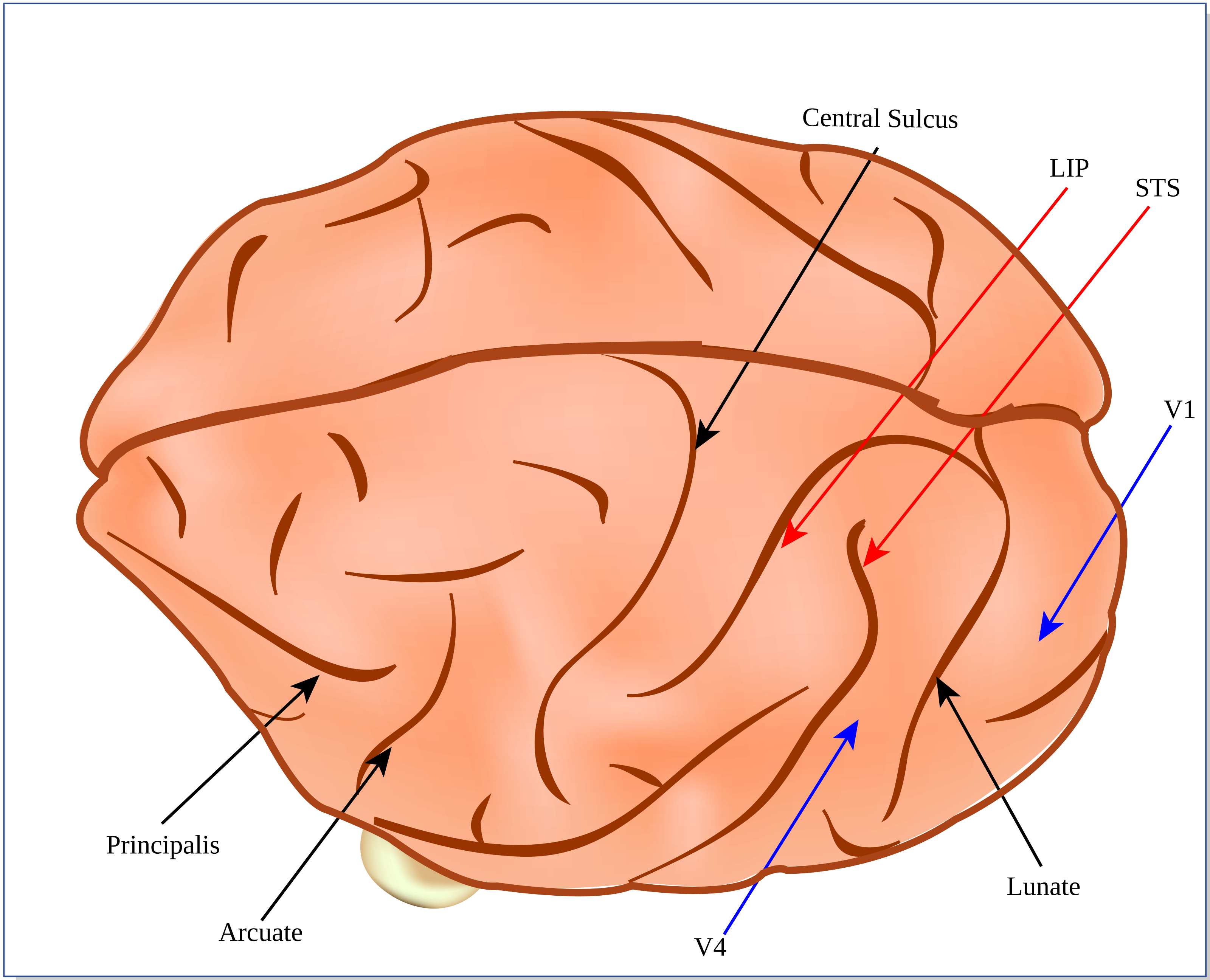
Area V4 attributes:

1. Large receptive fields
2. Complex receptive field properties
3. Responses are task and intent modulated
4. Response can also be modulated by eye movements
5. Not just a color area

Area MT and MST



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Response of an MT and MST neuron to sweeping bars

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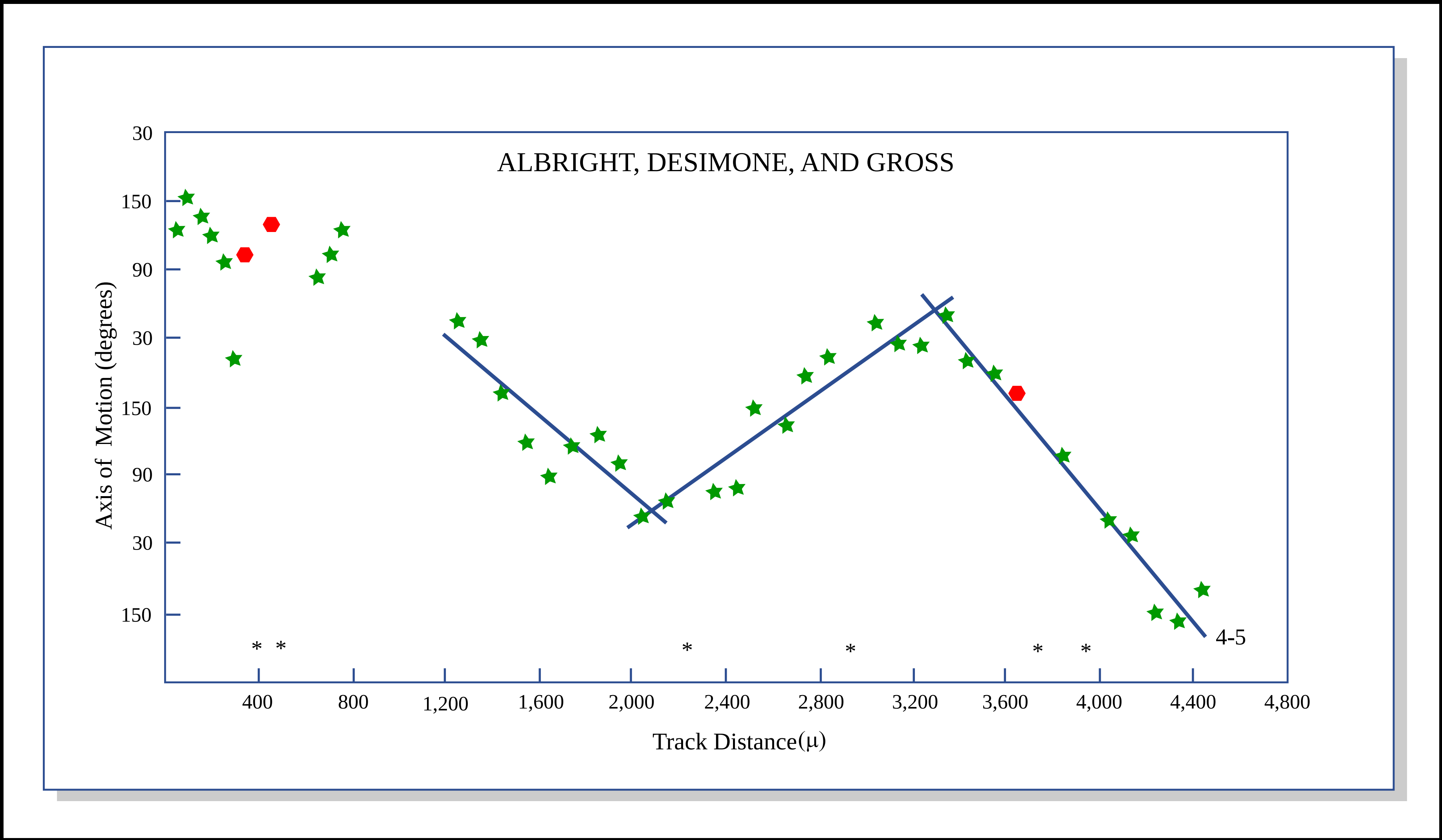
Please refer to lecture video.

Direction specificity as a function of track distance in MT



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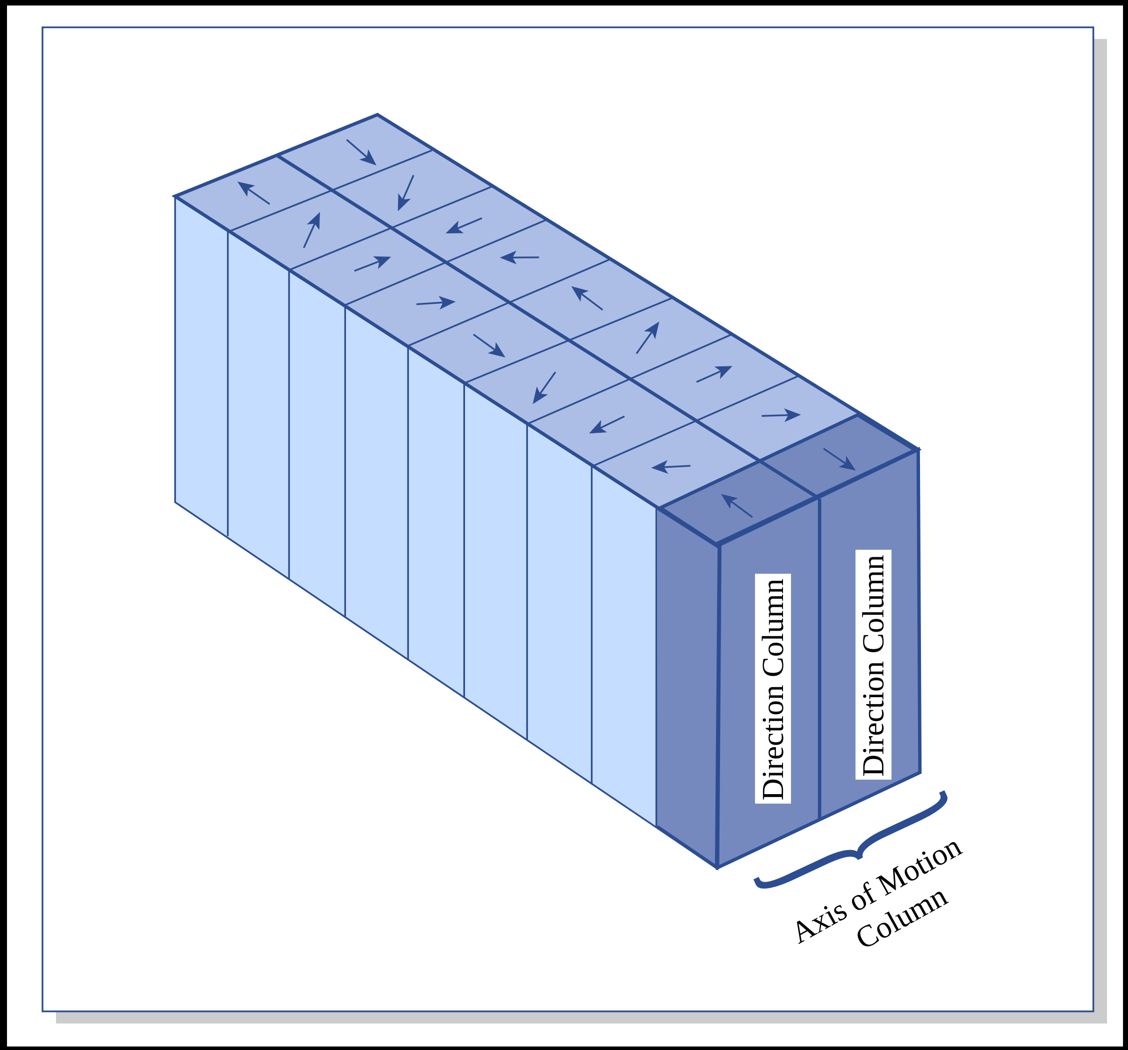
Layout of directions in MT



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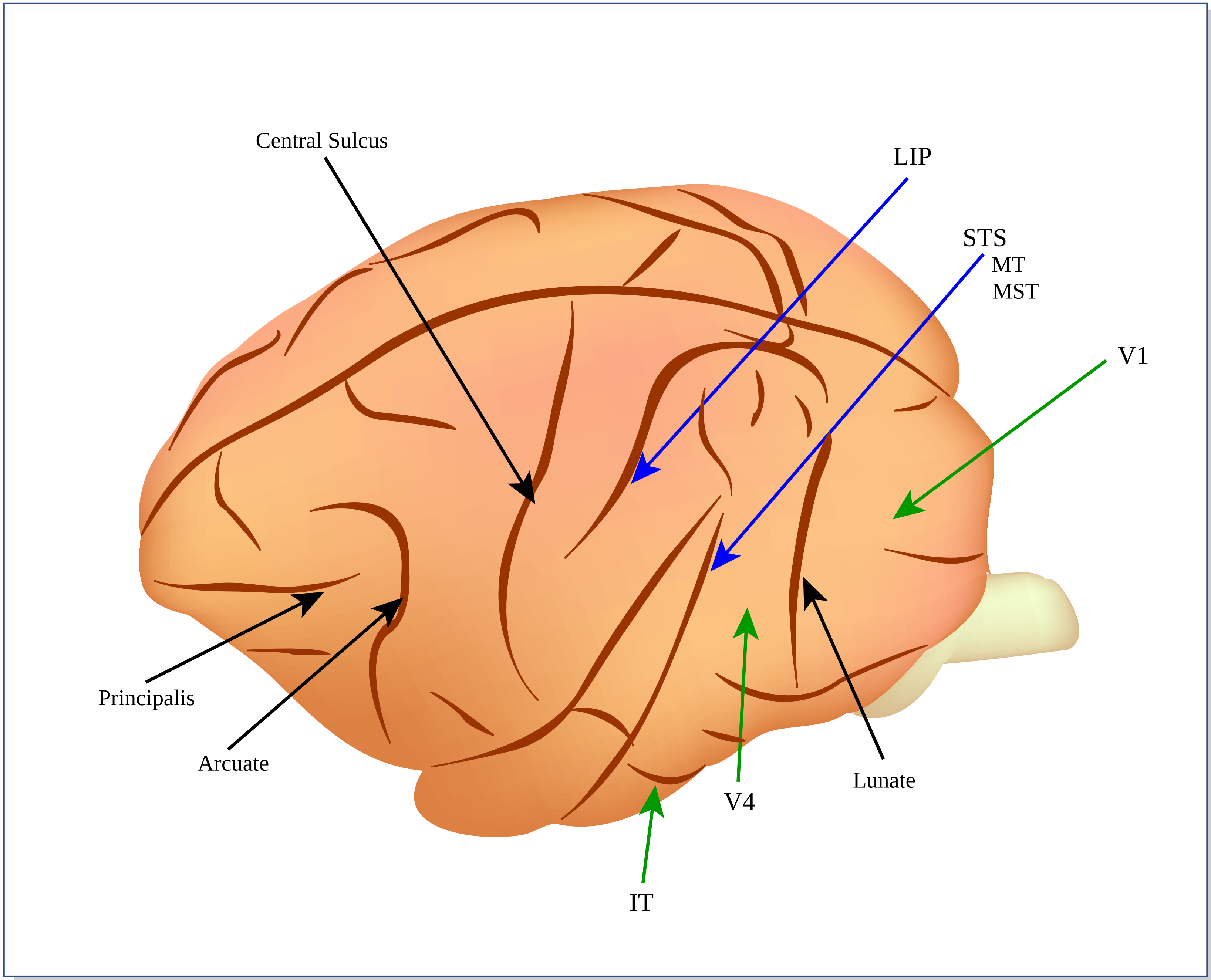
Inferotemporal cortex



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Summary:

1. The contralateral visual hemifield is laid out topographically in V1 of each hemisphere.
2. V1 transforms are: orientation, direction, spatial frequency, binocularity, ON/OFF convergence and midget/parasol convergence.
3. V1 is organized in a modular fashion. Three models of the layout of the modules are the ice cube, radial and swirl models
4. There are more than 30 visual areas that make more than 300 interconnections.
5. Extrastriate areas do not specialize in any single function.
6. The receptive field size of neurons increases greatly in progressively higher visual areas.
7. Area MT is involved in the analysis of motion , depth, and flicker.
8. Area V4 engages in many aspects of analysis; neurons have dynamic properties.
9. In inferotemporal cortex high level analysis takes place that includes object recognition.
10. Single cells in cortex are multifunctional.

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9.04 Sensory Systems
Fall 2013

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