COMS30127/COMSM2127
Computational Neuroscience

Lecture 11: Visual system (g)

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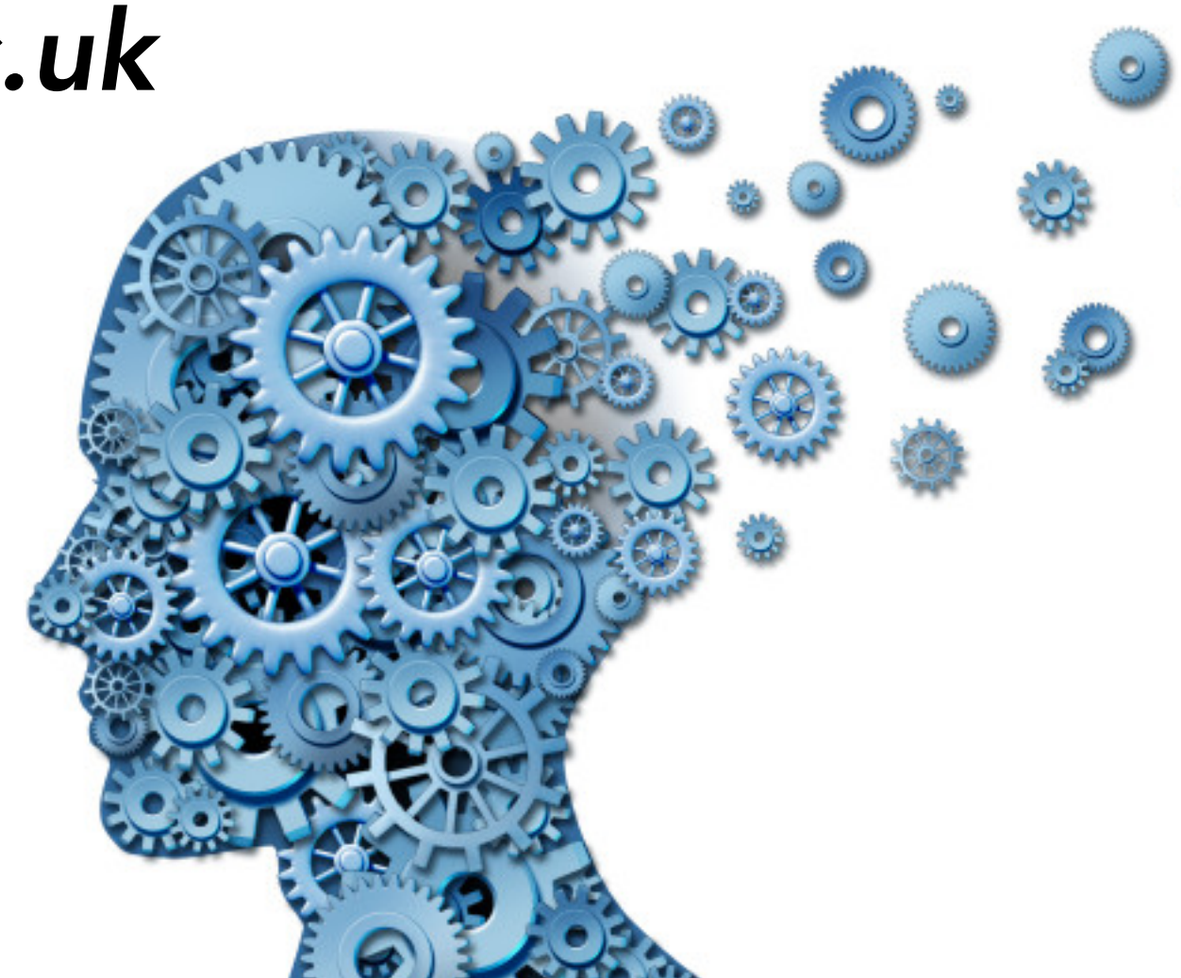
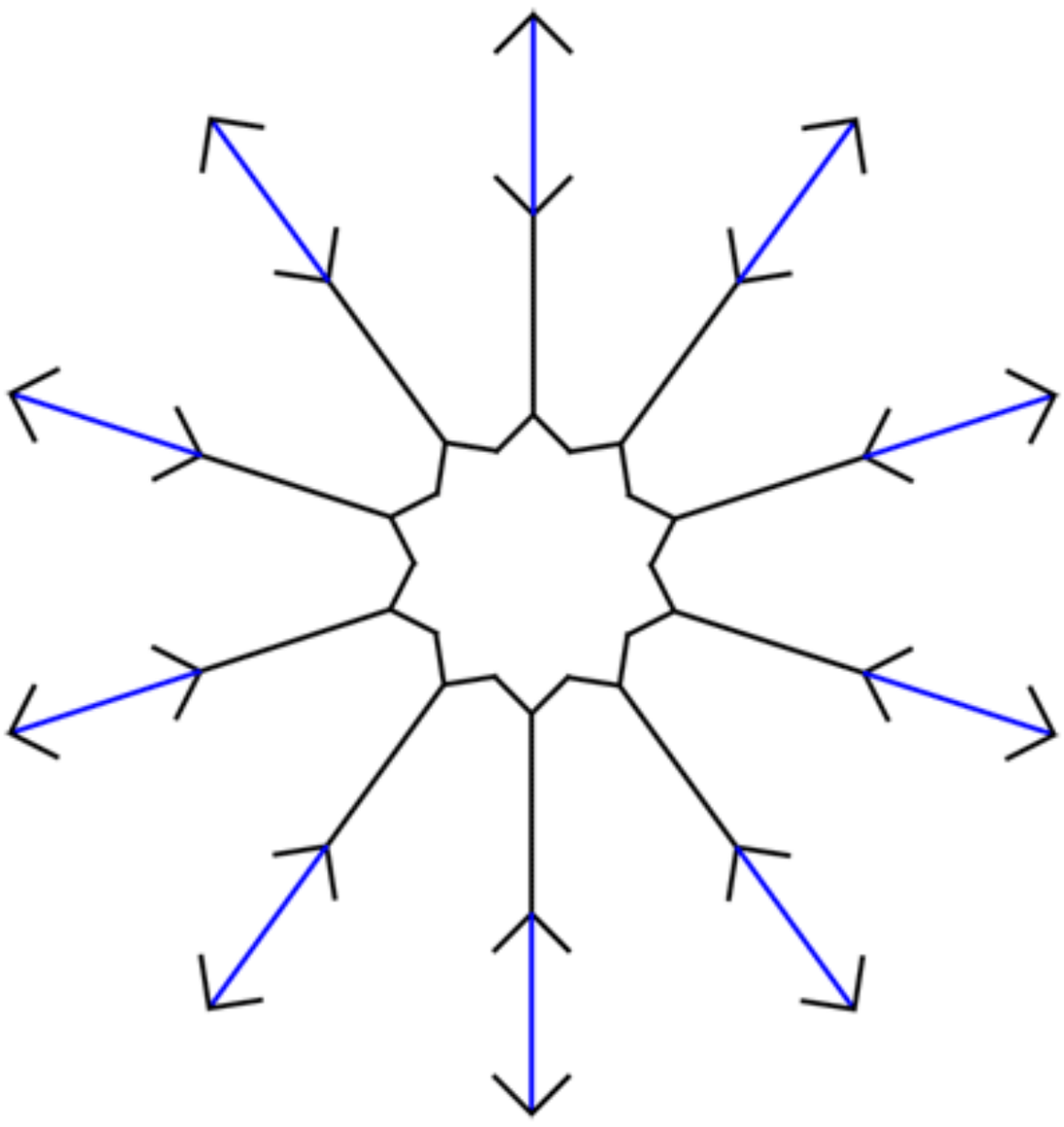


Müller-Lyer Pulsating Star

by Gianni A. Sarcone

Though the star seems to pulsate, the **blue** and **black** segments of the radial structure are always the **same length**!



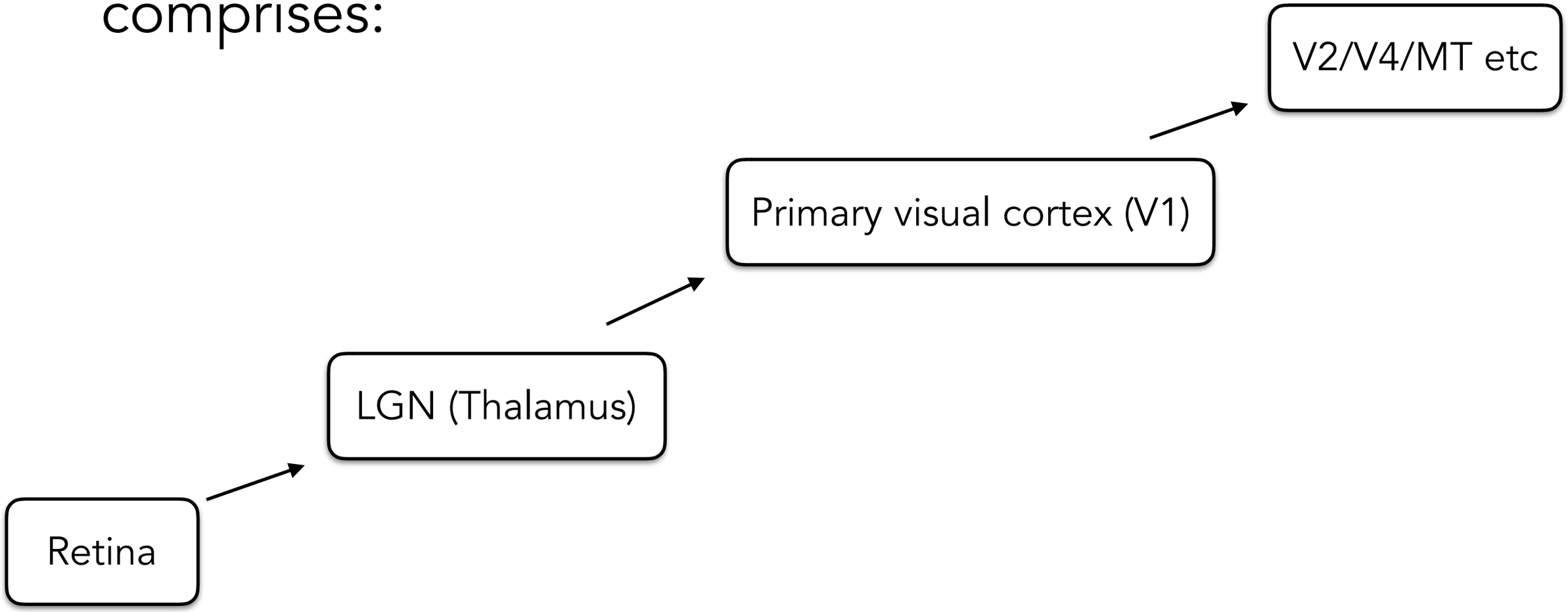
https://www.giannisarcone.com/3-MEDIA_Images/Muller_lyer_star_OR2.gif

What we will cover today

- Gross anatomy of the mammalian visual system.
- Receptive field properties along the visual hierarchy.
- The retinal microcircuit.

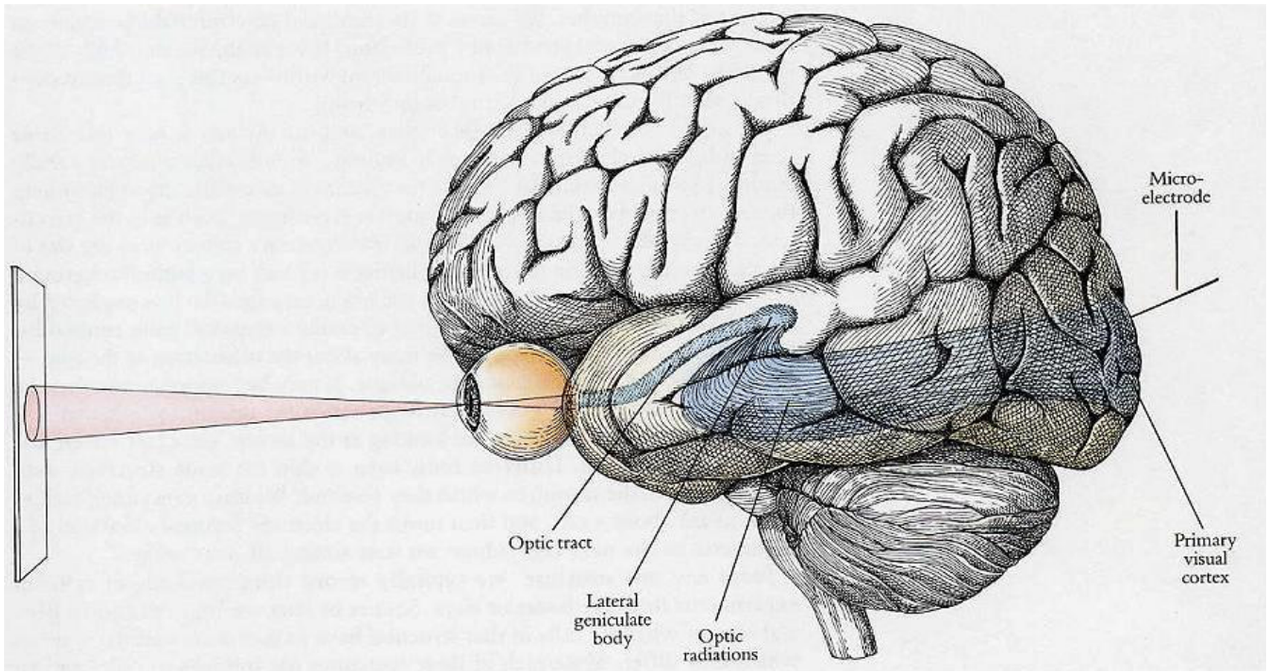
The visual system

- As a first approximation, the visual system comprises:

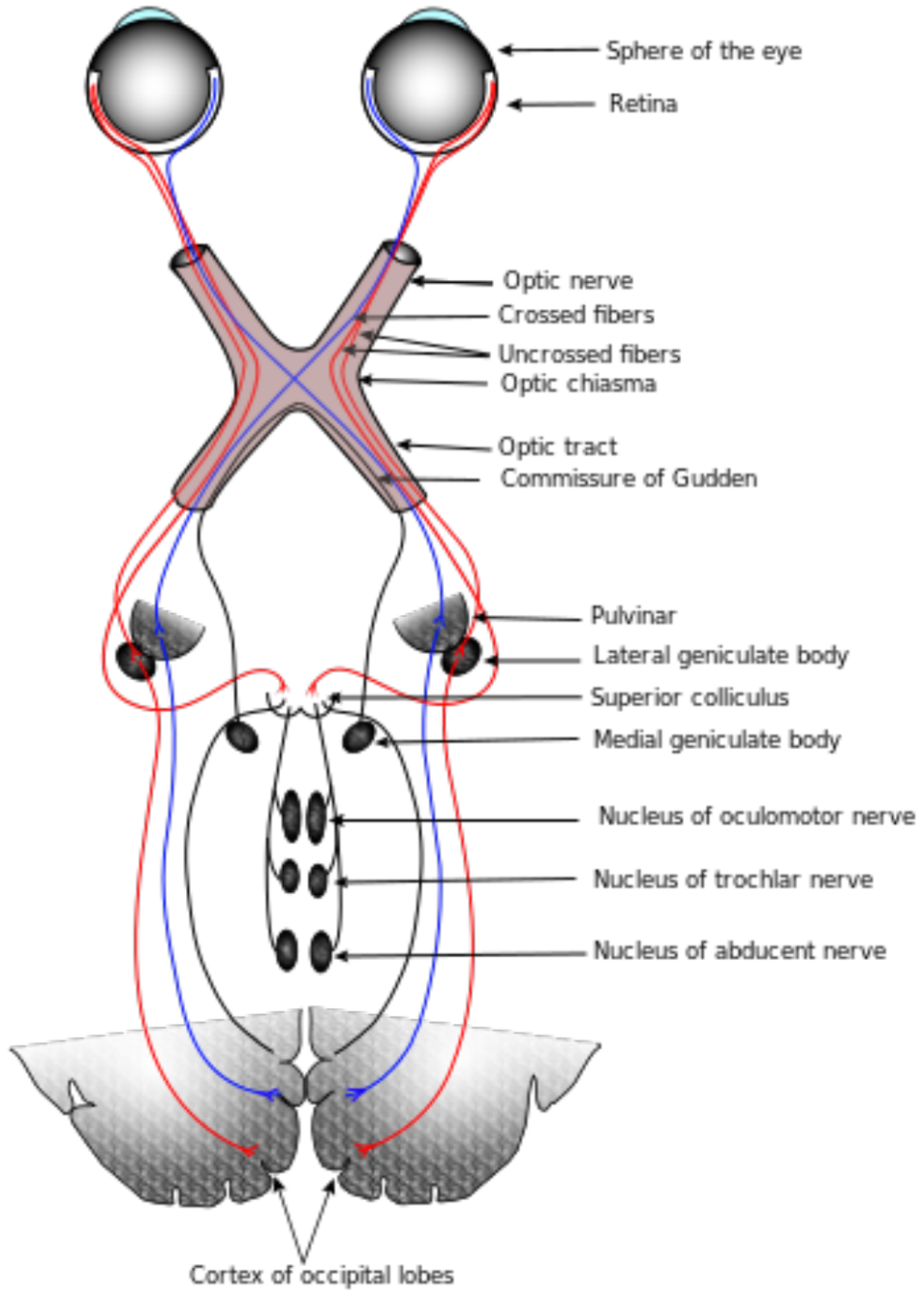


- However, reality is much more complicated (tens of visual regions, heterogeneity within regions, feedback connections down the hierarchy)

The visual system



http://hubel.med.harvard.edu/book/b3.htm



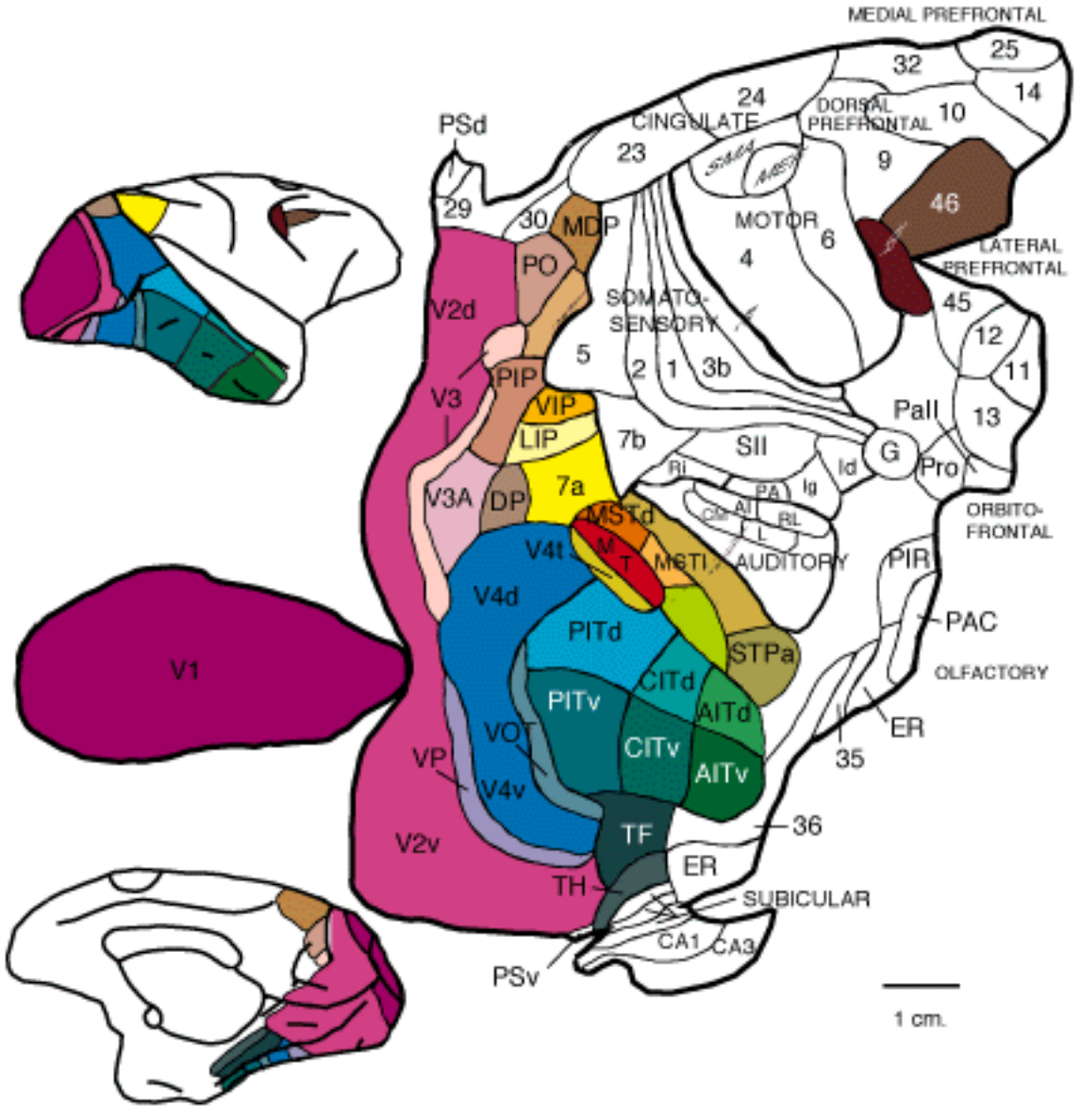
https://en.wikipedia.org/wiki/Visual_system#/media/File:Gray722-svg.svg

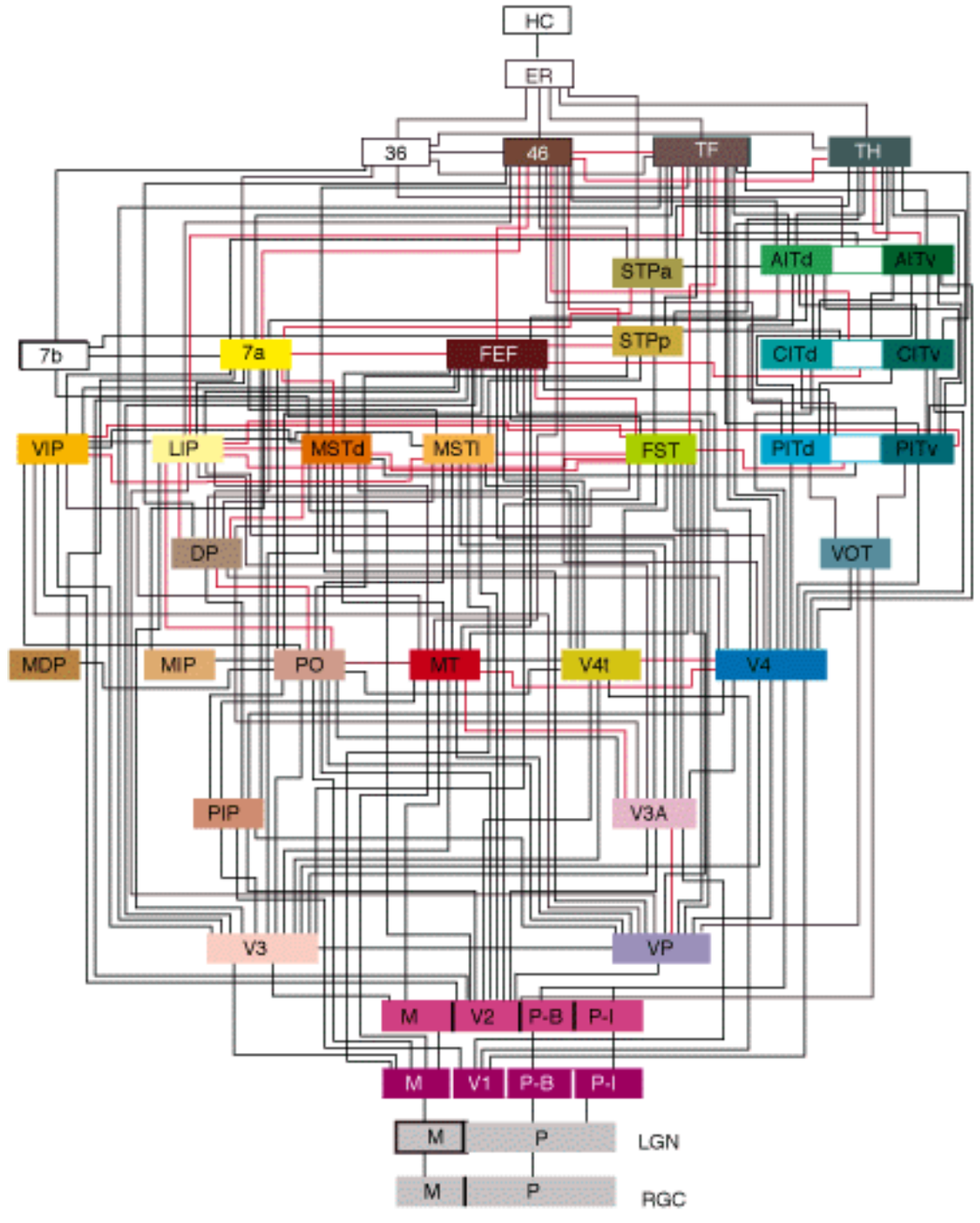
The visual system

https://youtu.be/aCv4K5aStdU?t=83

Split-brain patients without a corpus callosum (typically cut to treat epilepsy) tend to separately process sensory stimuli from each side of the world.

Visual hierarchy (macaque)

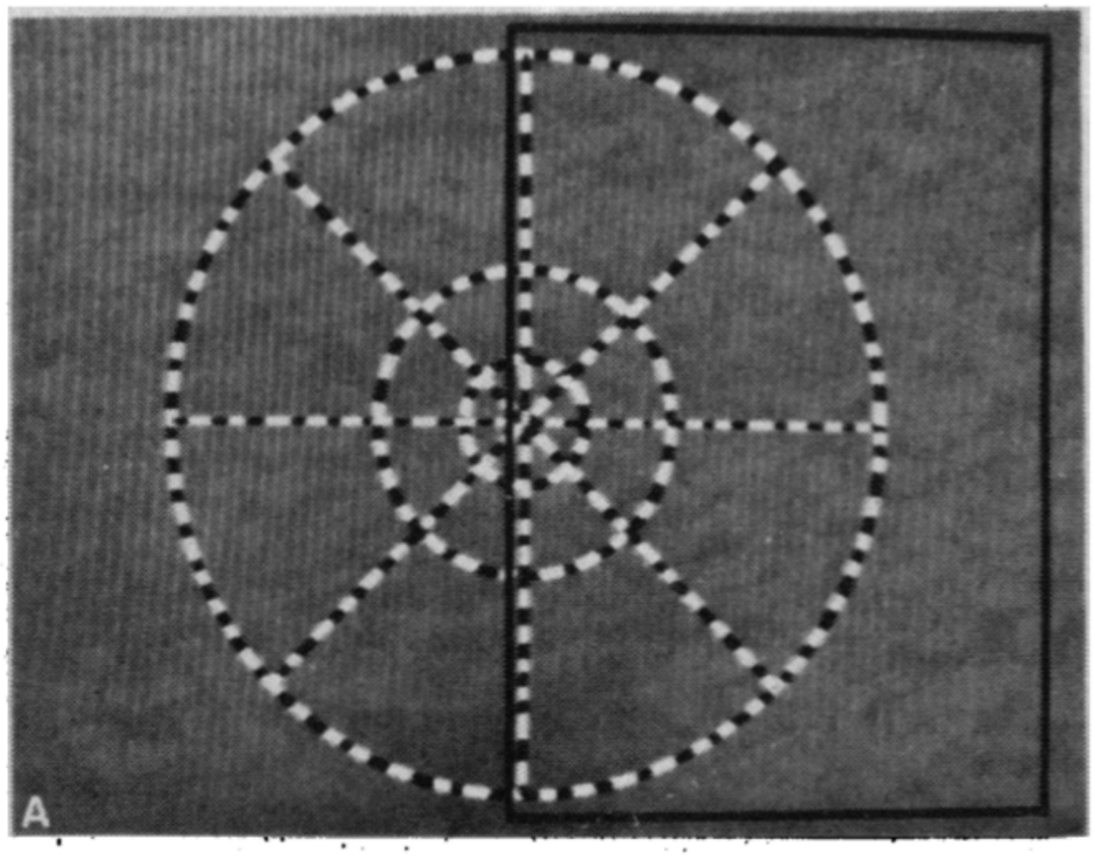




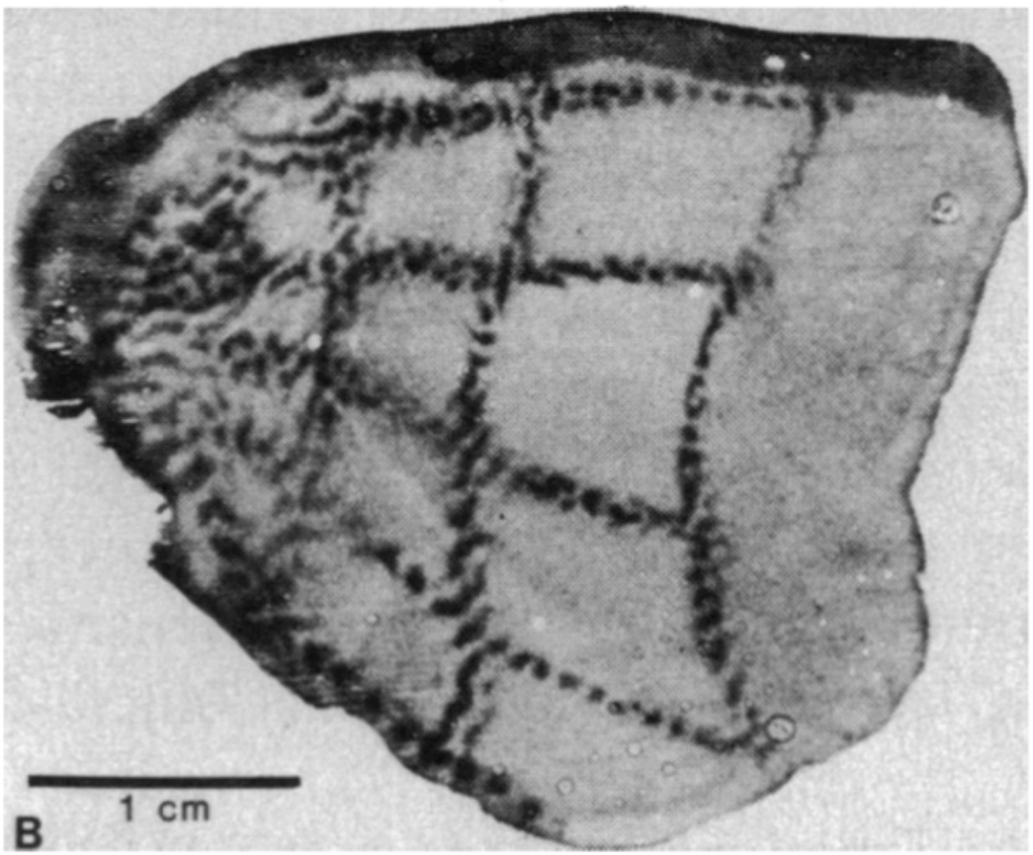
[Felleman and van Essen, *Cerebral Cortex* (1991)]

Retinotopy

- Anatomically neighbouring neurons tend to respond to neighbouring parts of the visual field.
- This retinotopy is preserved along the visual hierarchy.



Stimulus



Visual cortex response pattern

[Tootell et al., *Science* (1982)]

Coding along the visual hierarchy

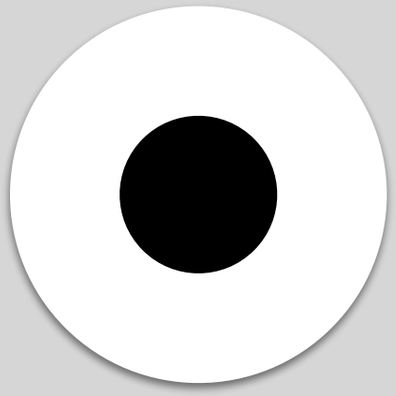
Receptive fields tend to change from level to level up the visual processing hierarchy.
They:

- Become larger.
- Become sensitive to complicated aspects of the visual stimulus.
- Become more multimodal (i.e. also depend on non-visual sensory signals).
- Become more sensitive to top-down, contextual information (e.g. task context, animal's behavioural state, attention)

Coding along the visual hierarchy: retinal ganglion cells/LGN

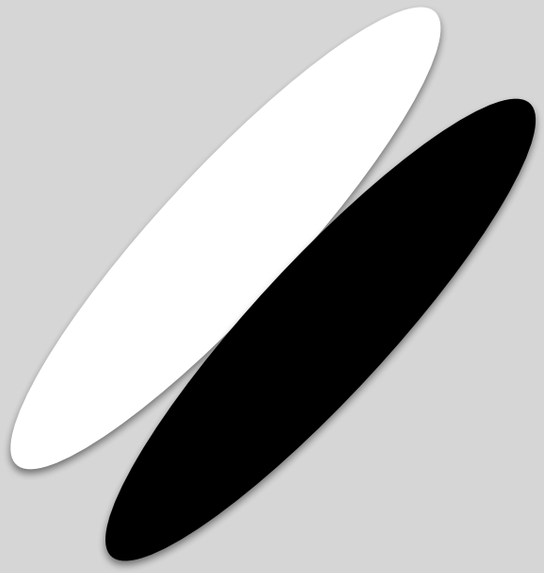
"ON centre"

Coding along the visual hierarchy: retinal ganglion cells/LGN



"OFF centre"

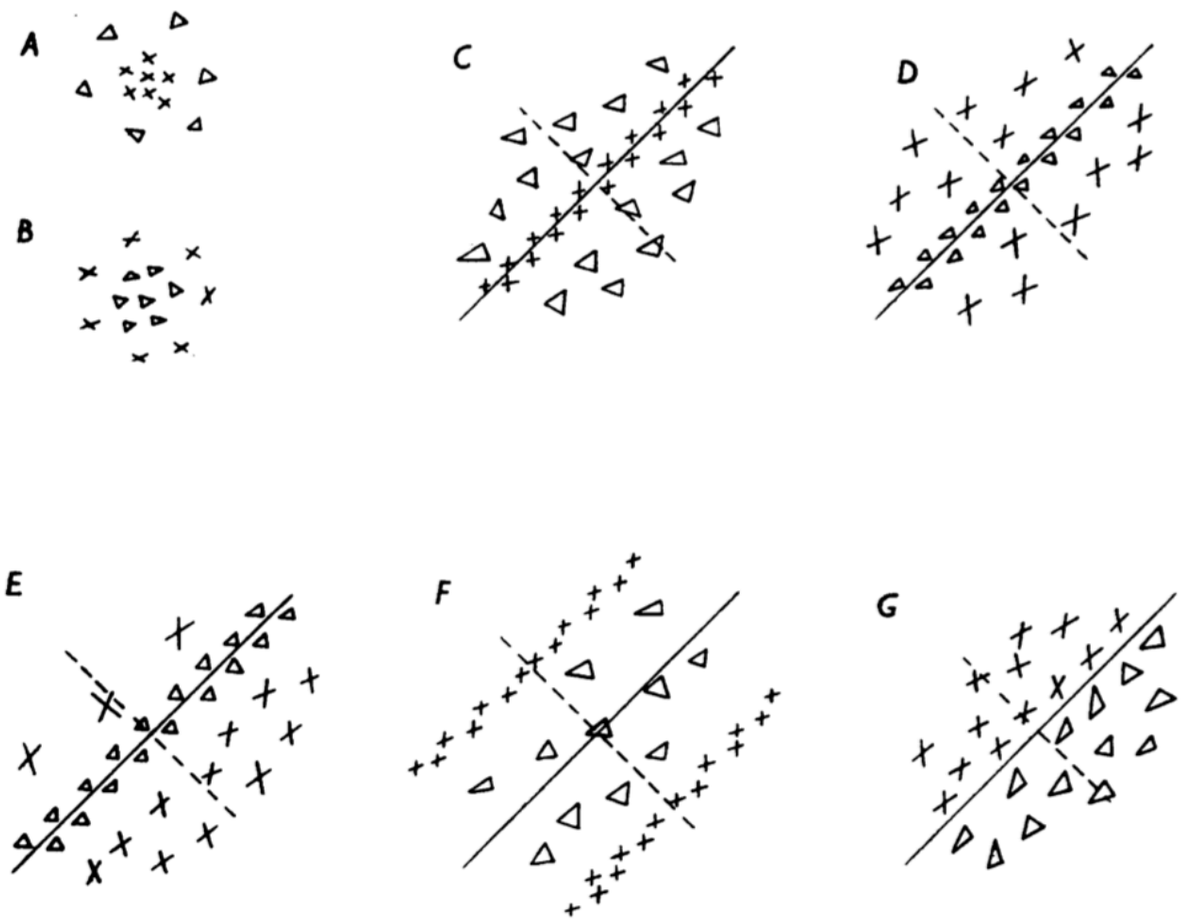
Coding along the visual hierarchy: V1



Orientation tuning,
Gabor-like.

Hubel and Wiesel cat vision experiments

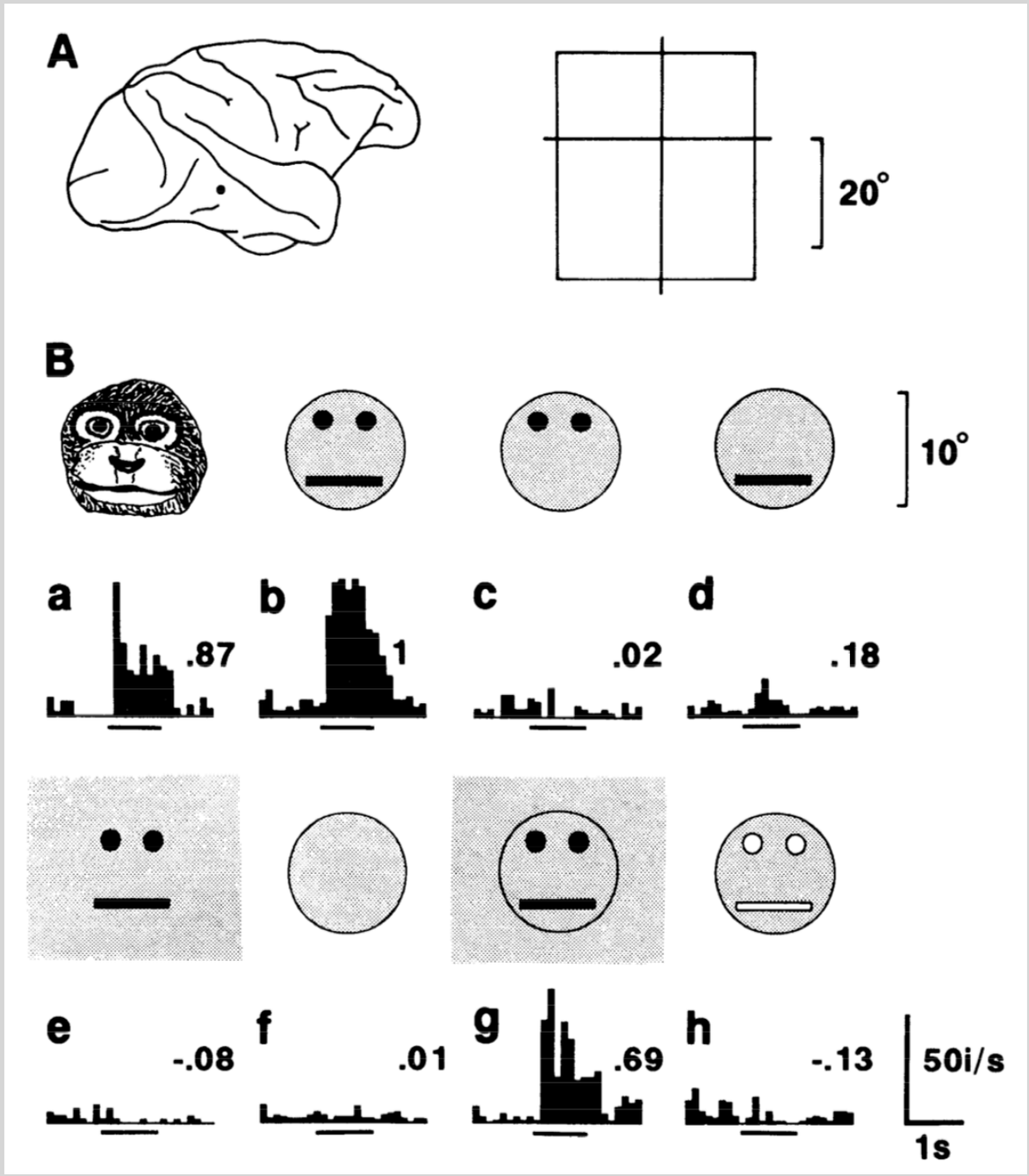
https://youtu.be/8VdFf3egwfg



Text-fig. 2. Common arrangements of lateral geniculate and cortical receptive fields. *A*. 'On'-centre geniculate receptive field. *B*. 'Off'-centre geniculate receptive field. *C–G*. Various arrangements of simple cortical receptive fields. ×, areas giving excitatory responses ('on' responses); △, areas giving inhibitory responses ('off' responses). Receptive-field axes are shown by continuous lines through field centres; in the figure these are all oblique, but each arrangement occurs in all orientations.

[Hubel and Wiesel, *J Physiol* (1962)]

Coding along the visual hierarchy: higher visual areas

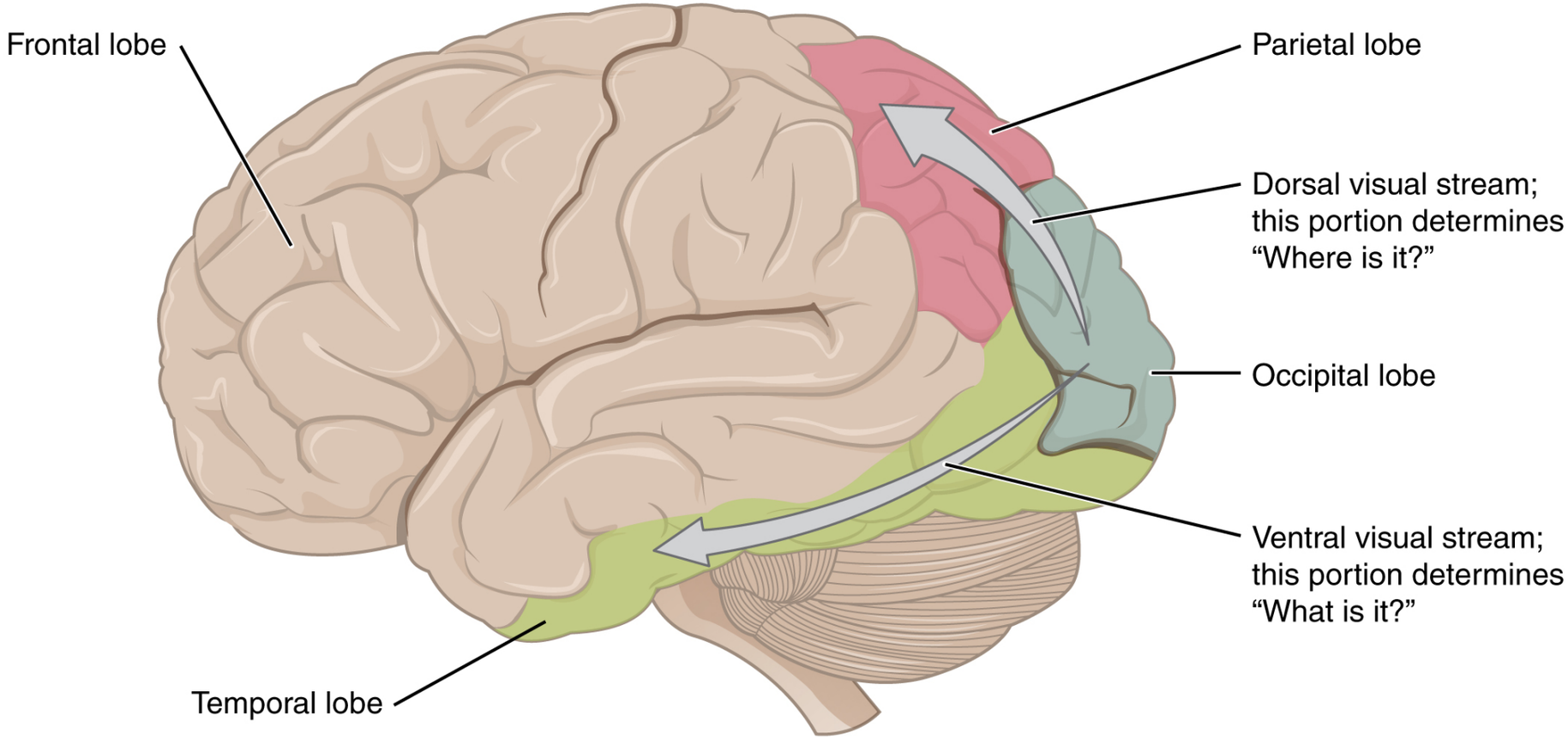


Objects, e.g. faces

[Kobatake and Tanaka, *J Neurophysiol* (1994)]

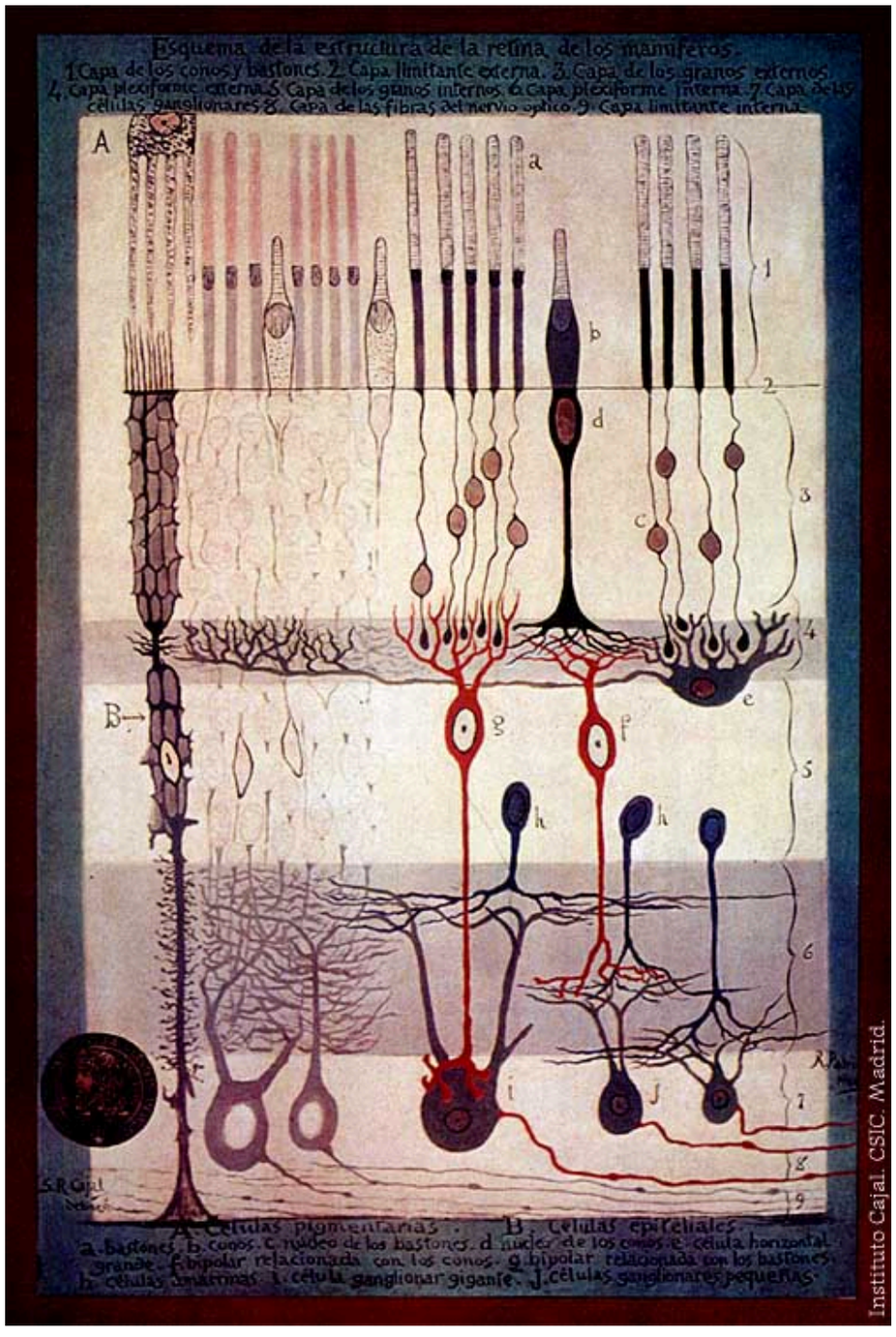
“What” vs “where” pathways

- The “two-streams” hypothesis suggests that the human brain splits visual information into two anatomically separate pathways.
- The “what” or ventral stream codes for object identity.
- The “where” or dorsal stream codes variables useful for action guidance.



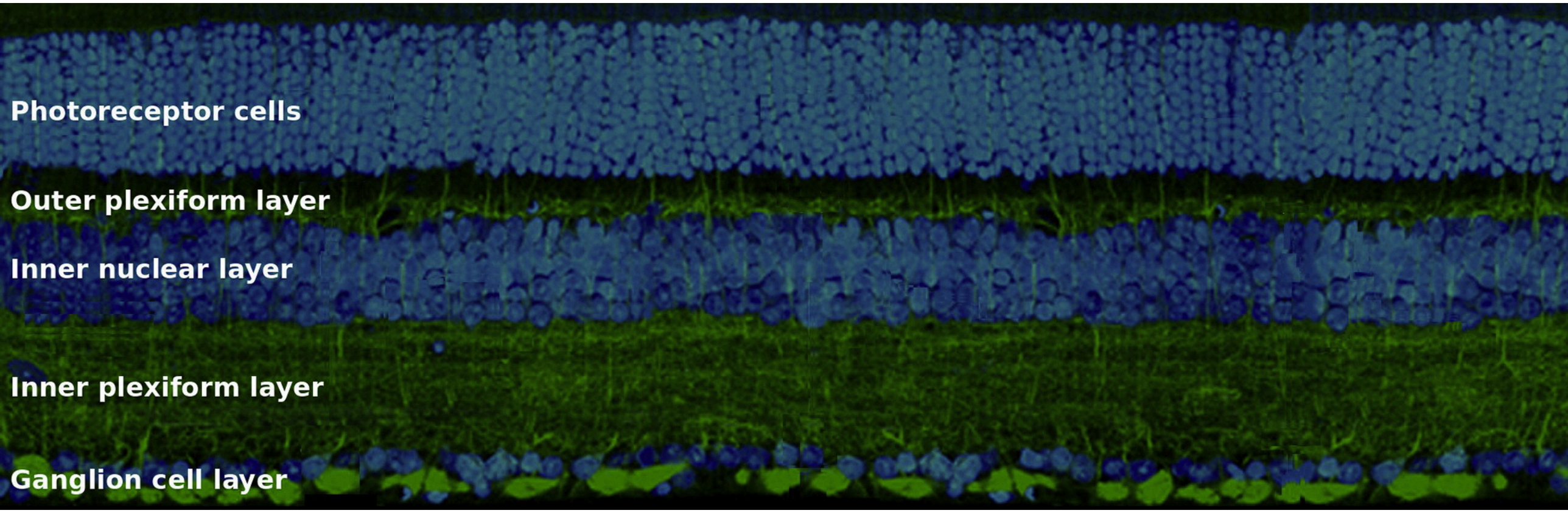
https://commons.wikimedia.org/wiki/File:1424_Visual_Streams.jpg

Retinal microcircuit



Ramon y Cajal (c.1900)

Mouse retina (side view)



[Seung and Sümbül, *Neuron* (2014)]

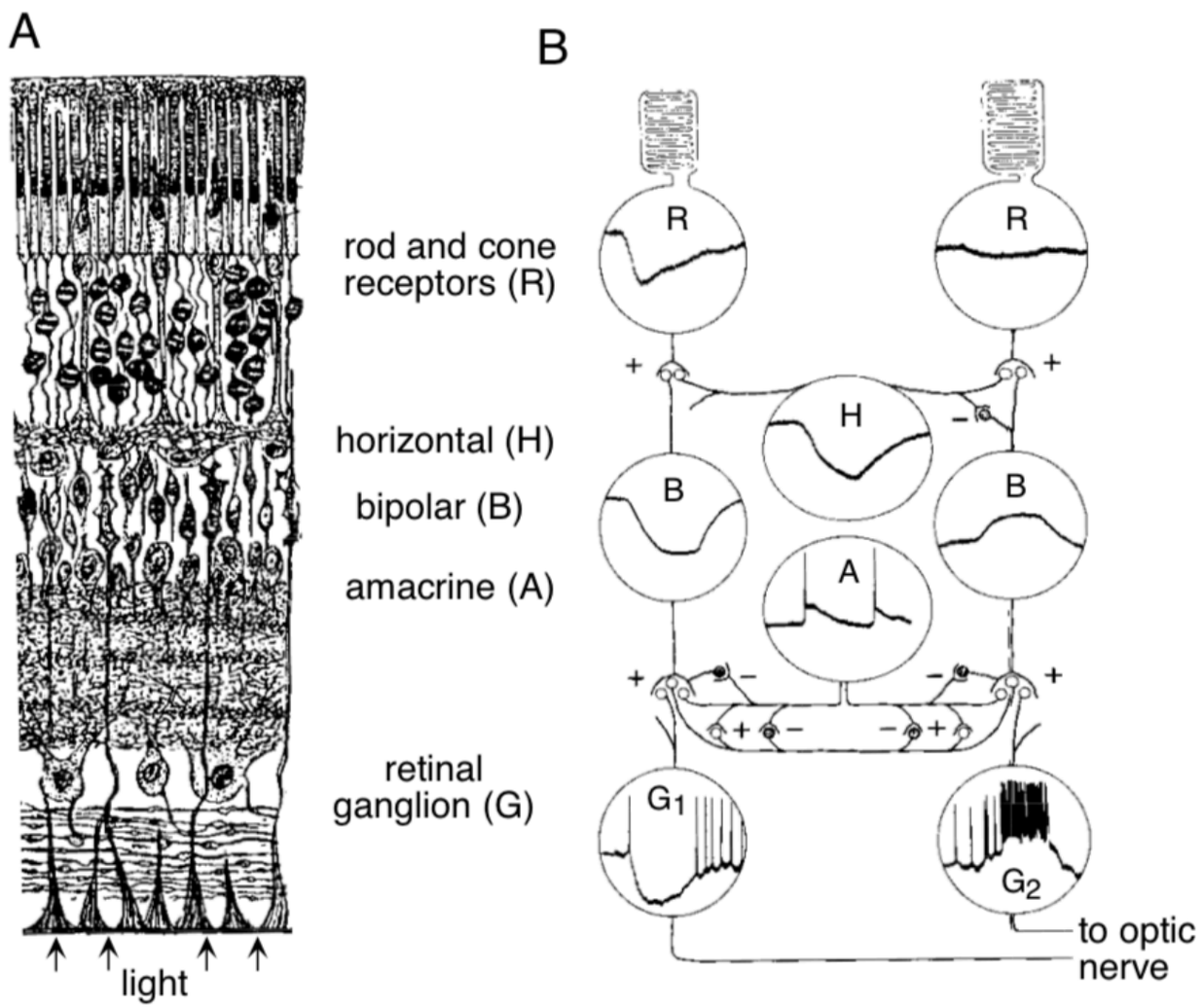
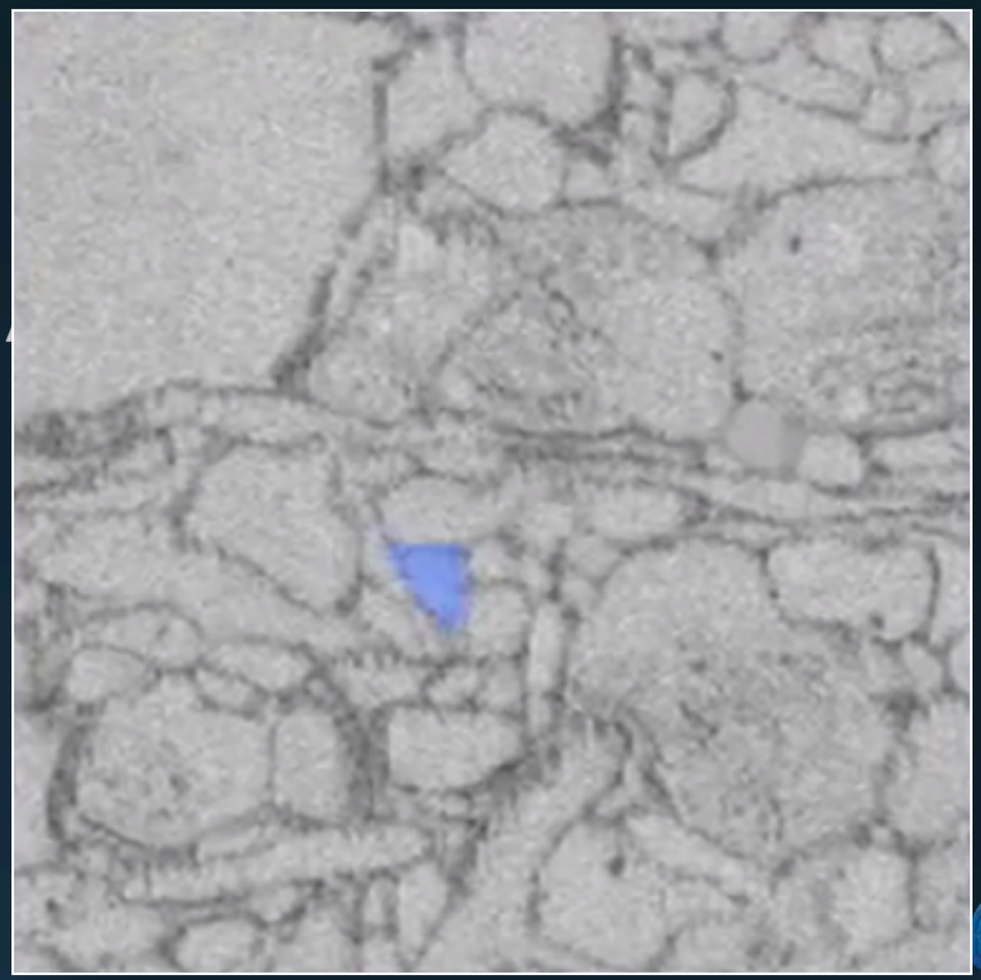


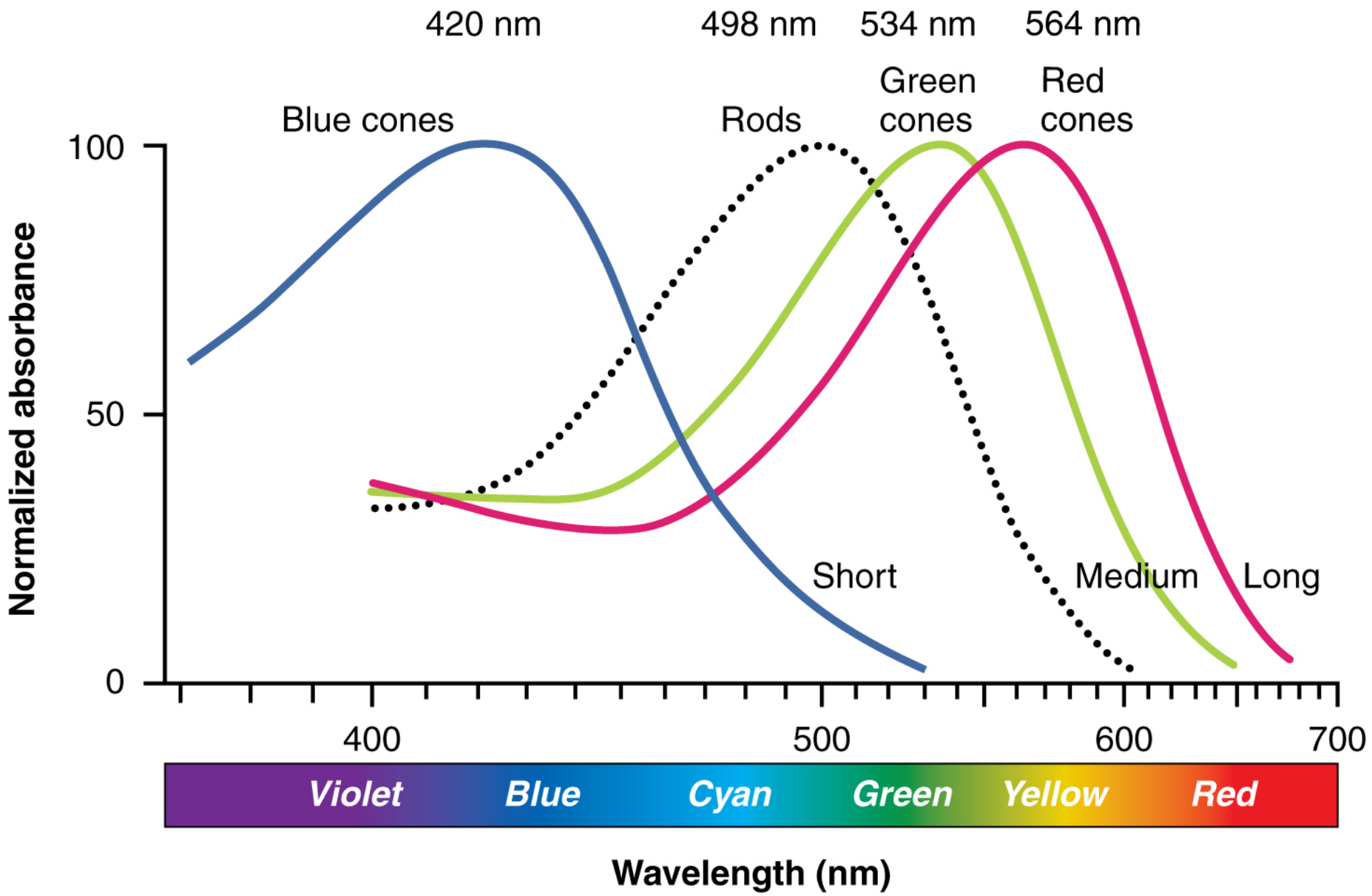
Figure 2.4: A) An anatomical diagram of the circuitry of the retina of a dog. Cell types are identified at right. In the intact eye, illumination is, counter-intuitively, from the bottom of this figure. B) Intracellular recordings from retinal neurons of the mudpuppy responding to flash of light lasting for one second. In the column of cells on the left side of the diagram, the resulting hyperpolarizations are about 4 mV in the rod and retinal ganglion cells, and 8 mV in the bipolar cell. Pluses and minuses represent excitatory and inhibitory synapses respectively. (A adapted from Nicholls et al., 1992; drawing from Cajal, 1911. B data from Werblin and Dowling 1969; figure adapted from Dowling, 1992.)

[Dayan and Abbott, *Theoretical Neuroscience* (2000)]

eyewire.org

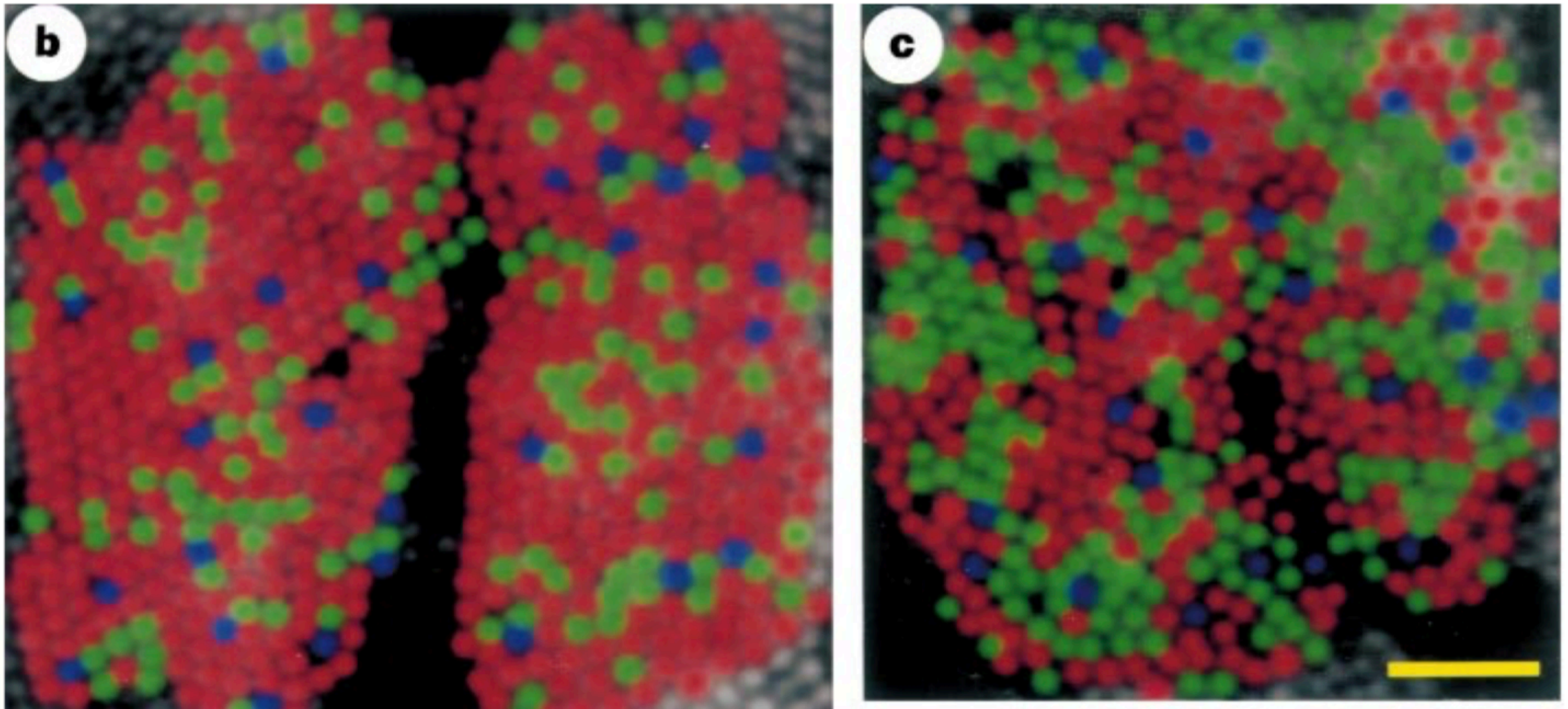


Colour sensitivity in the retina



https://en.wikipedia.org/wiki/Photoreceptor_cell#/media/File:1416_Color_Sensitivity.jpg
[Bowmaker and Dartnall, *J Physiol* (1990)]

Colour sensitivity in the retina



[Roorda and Williams, *Nature* (1999)]

End