Computational Vision

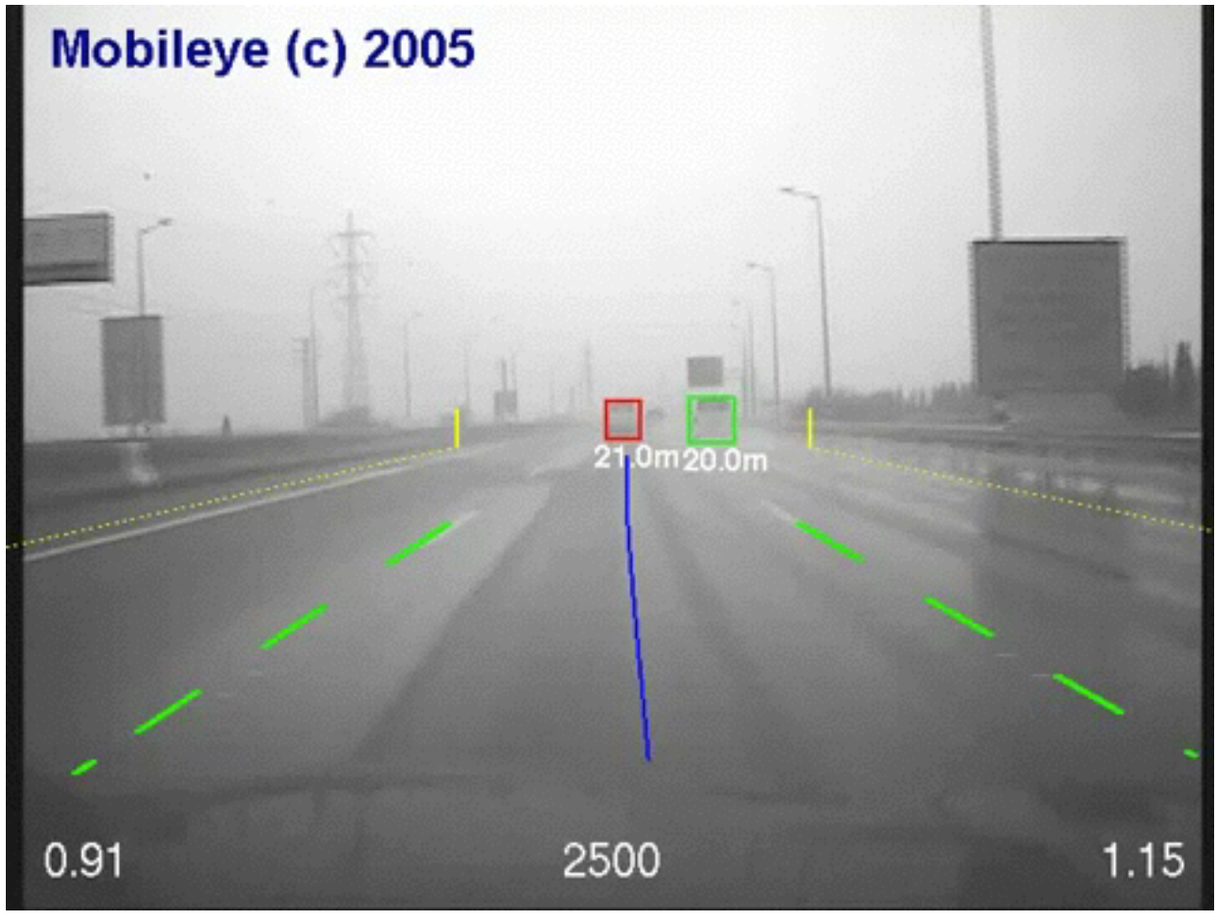
Foundations

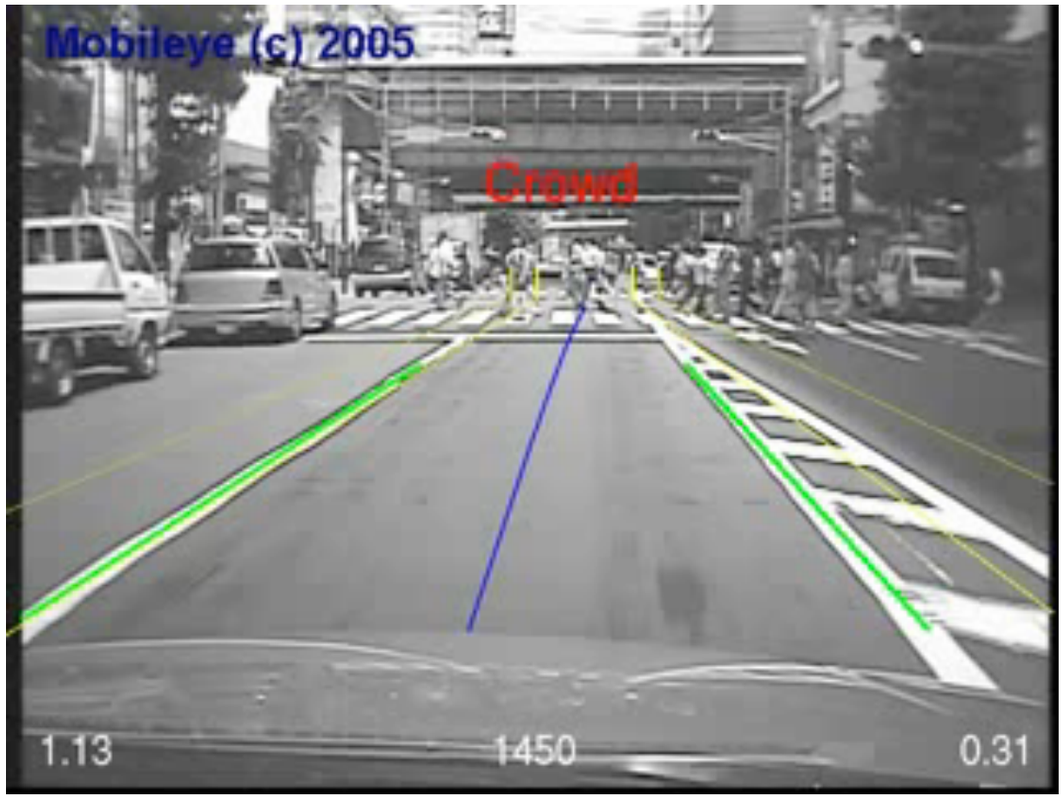
- Why studying biological vision?
- Fundamentals of primate vision

Invariant recognition in natural images

Computer vision successes

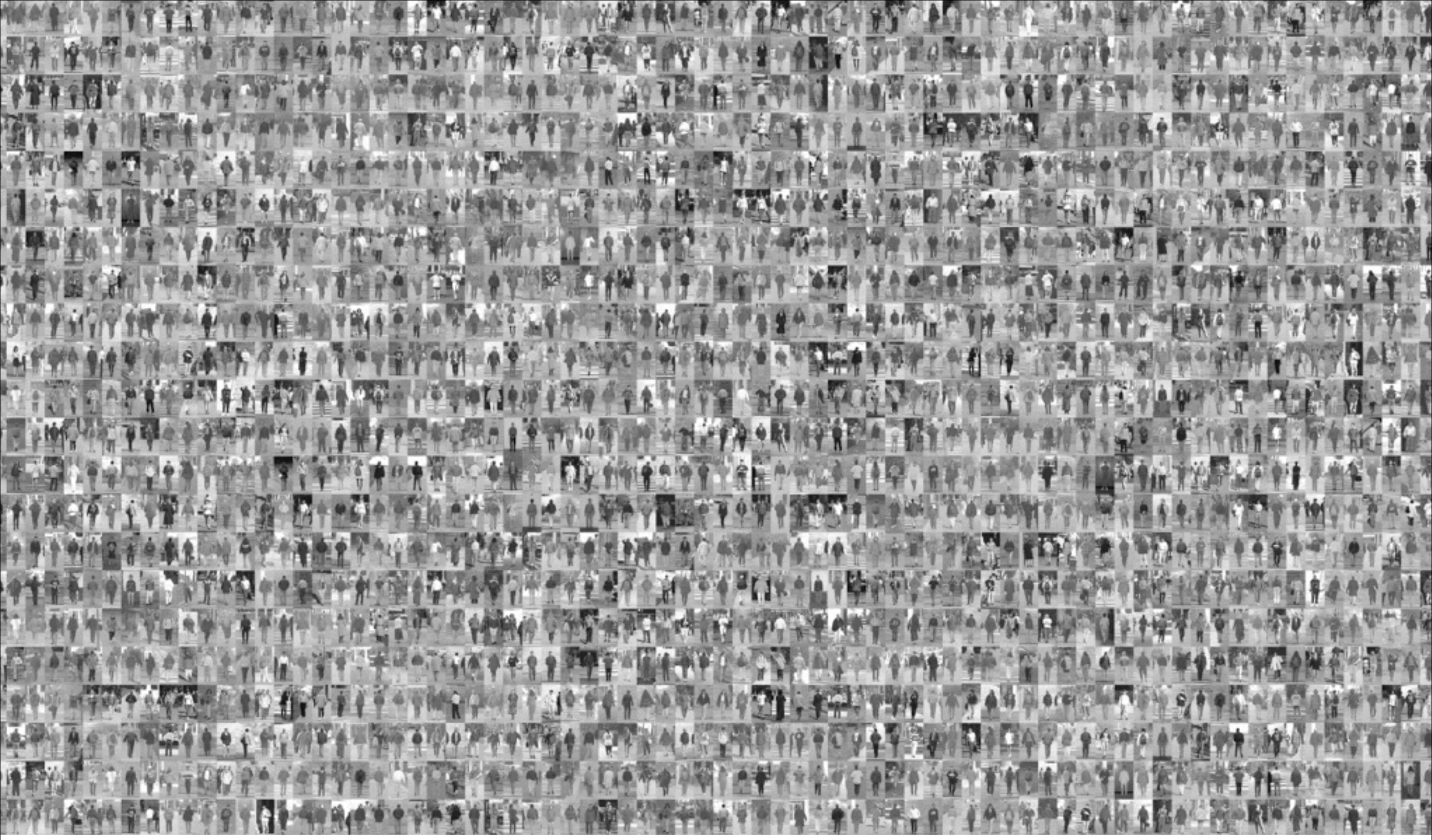
Face detection





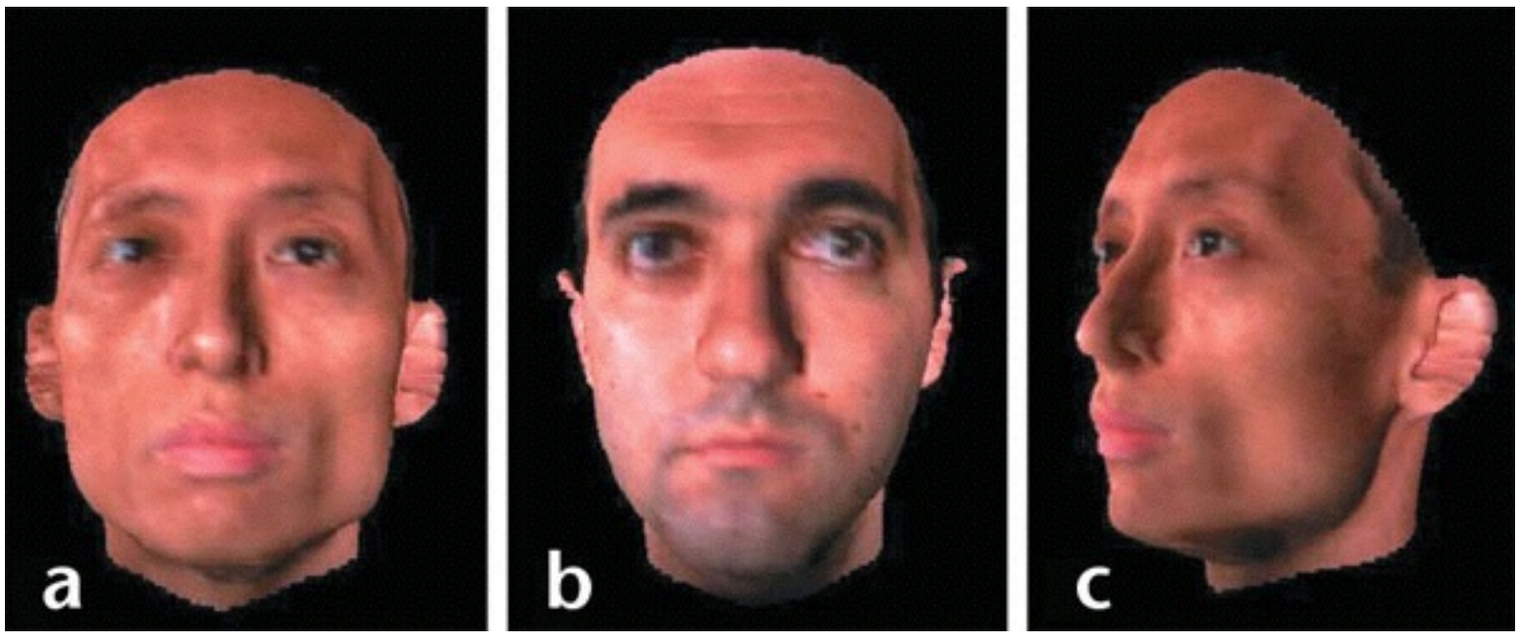
Mobileye system

Already available on volvo S60 and soon on most car manufacturers



Machine: Millions of labeled examples for real-world applications

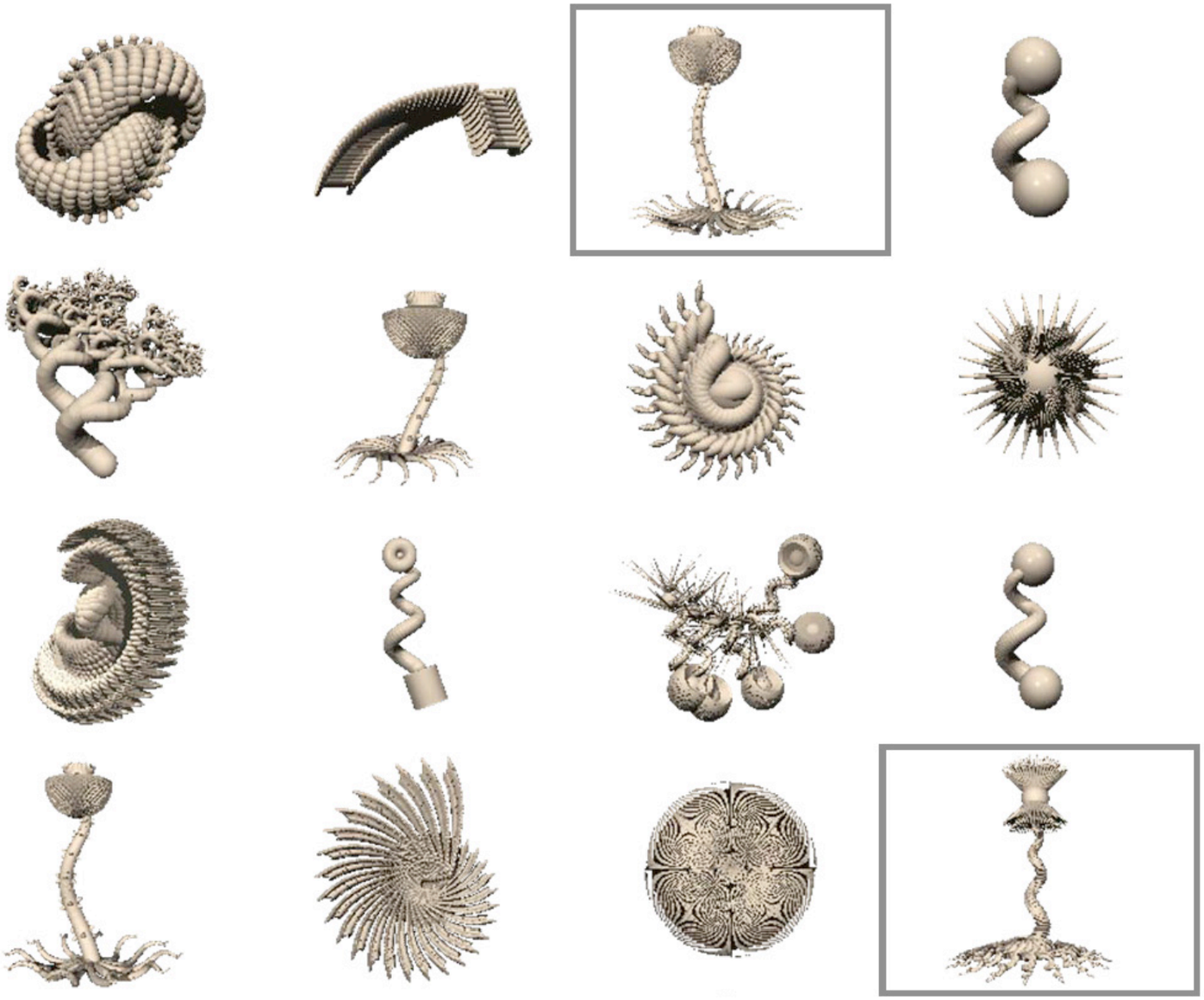
e.g., Mobileye pedestrian detection system



Visual recognition is hard

Yet we excel at it!

Yip & Sinha 2002



Source: Tenenbaum

Yet we excel at it!

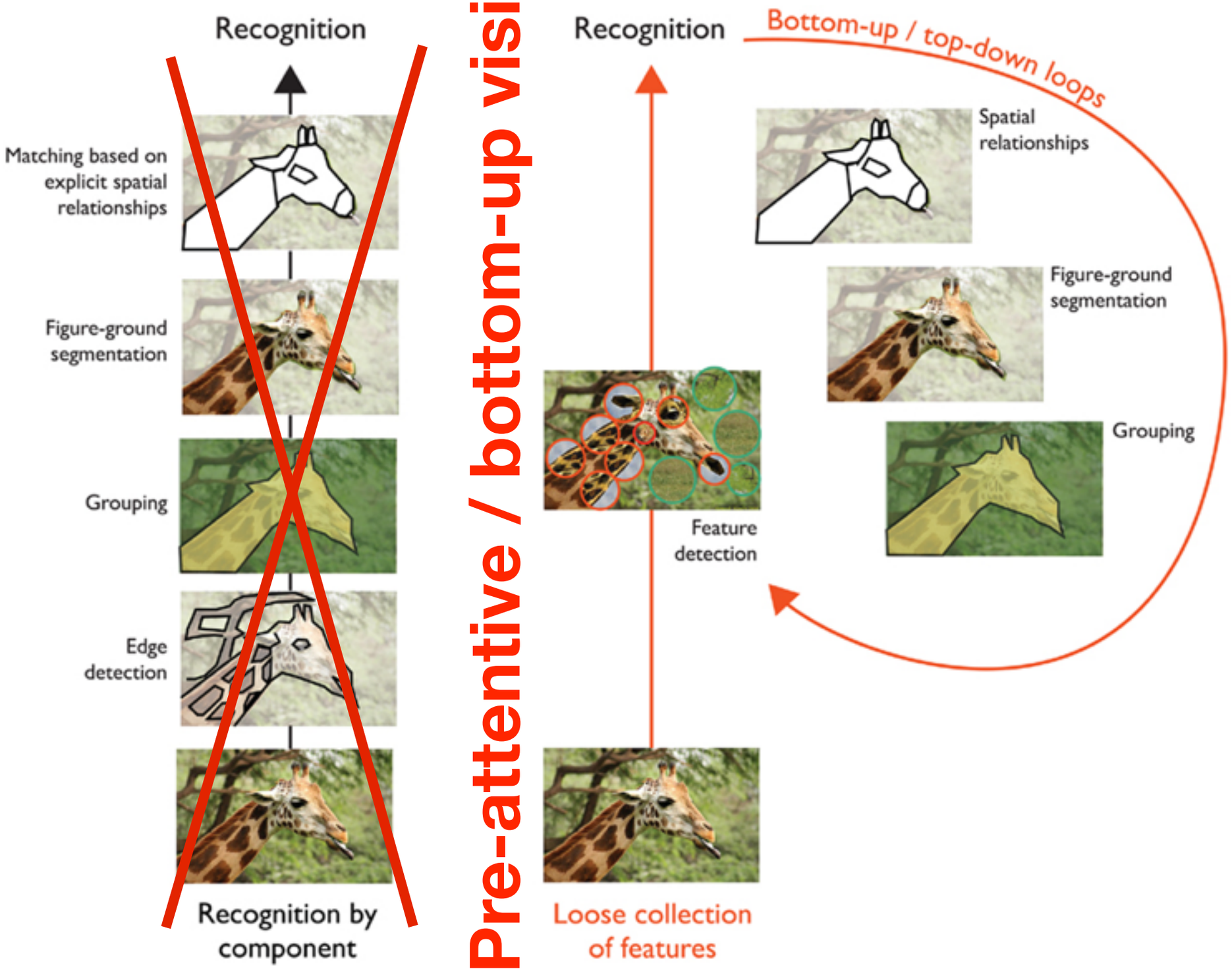
Invariant recognition in natural images

- Subjects get the gist of the scene at 7 images/s from unpredictable random sequence of images
  - No time for eye movements
  - No top-down / expectations

- Coarse initial base representation
  - Enables rapid object detection/ recognition (‘what is there?’)
  - Insufficient for object localization
  - Sensitive to presence of clutter

Potter 1971, 1975; see also Biederman 1972; Thorpe 1996

Two classes of models



Marr ‘82;
Biederman ’87

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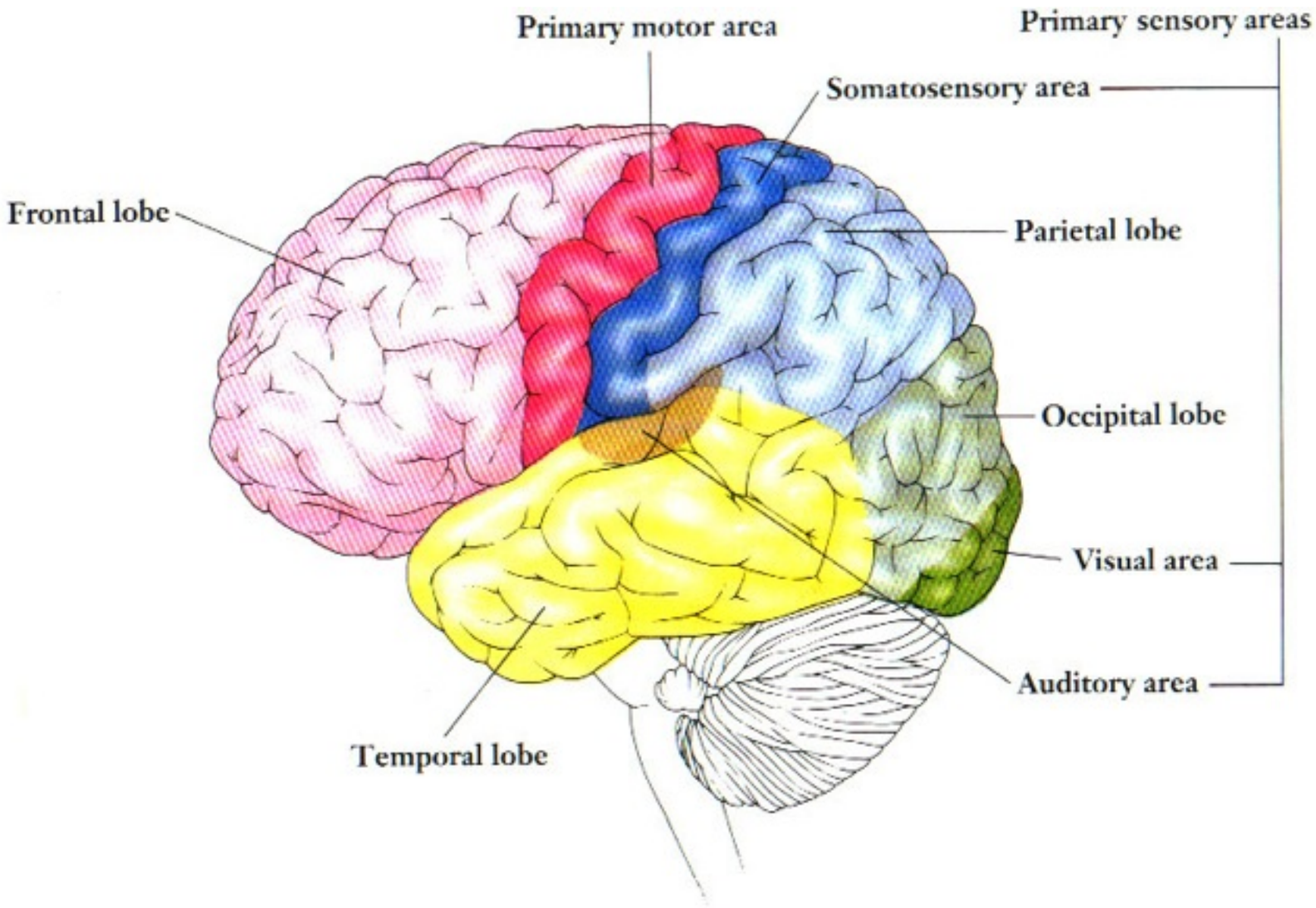
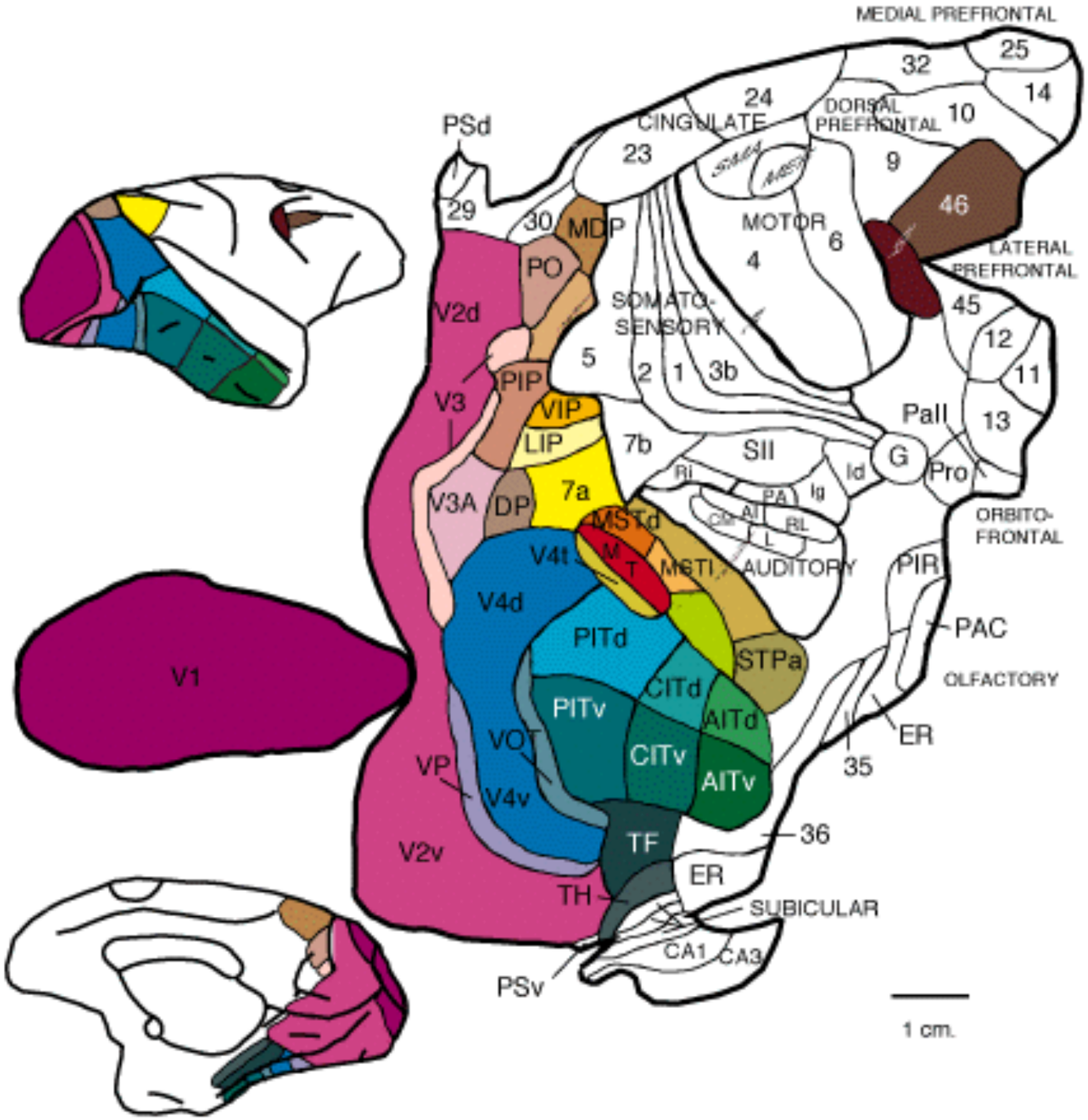


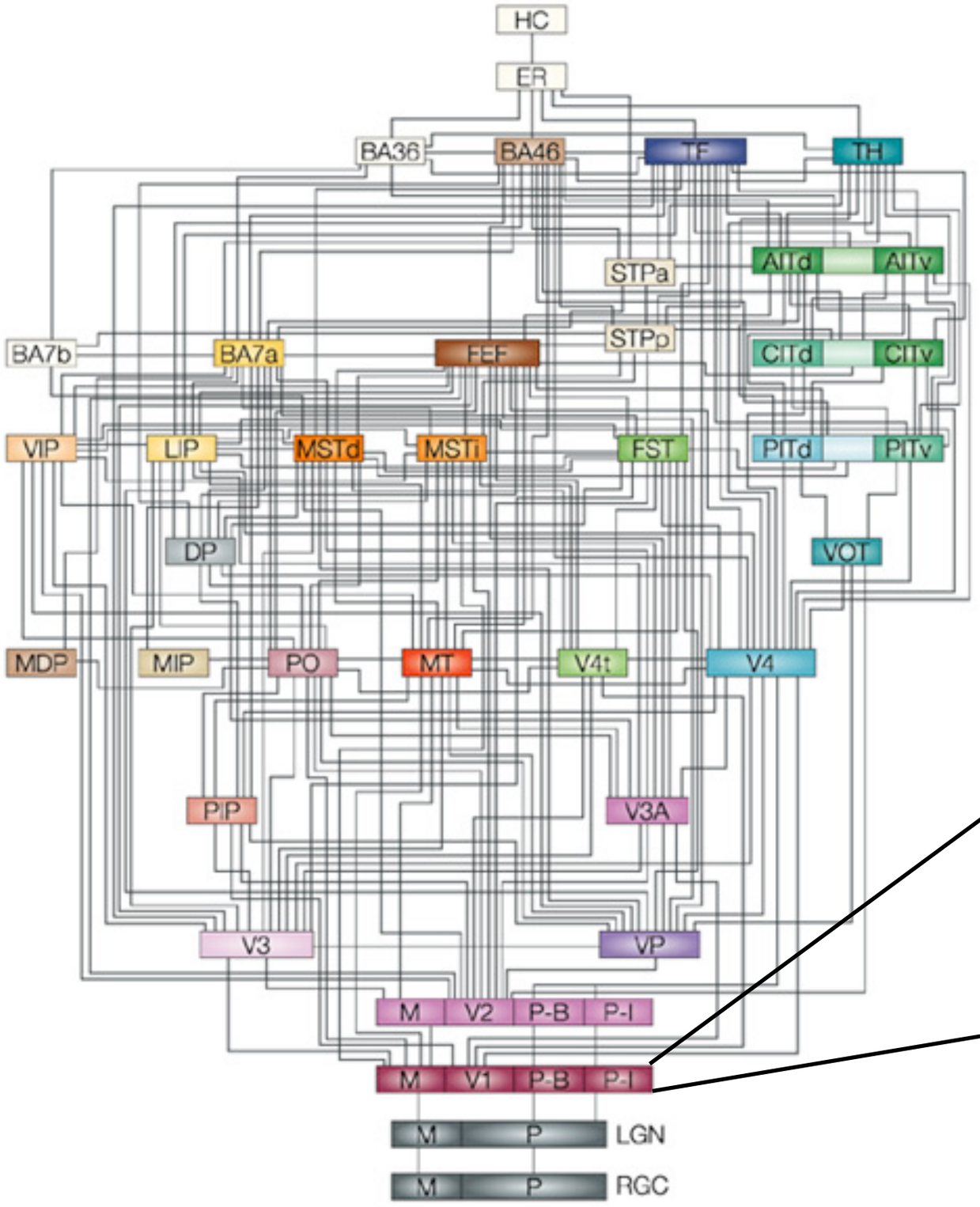
Gross Brain Anatomy

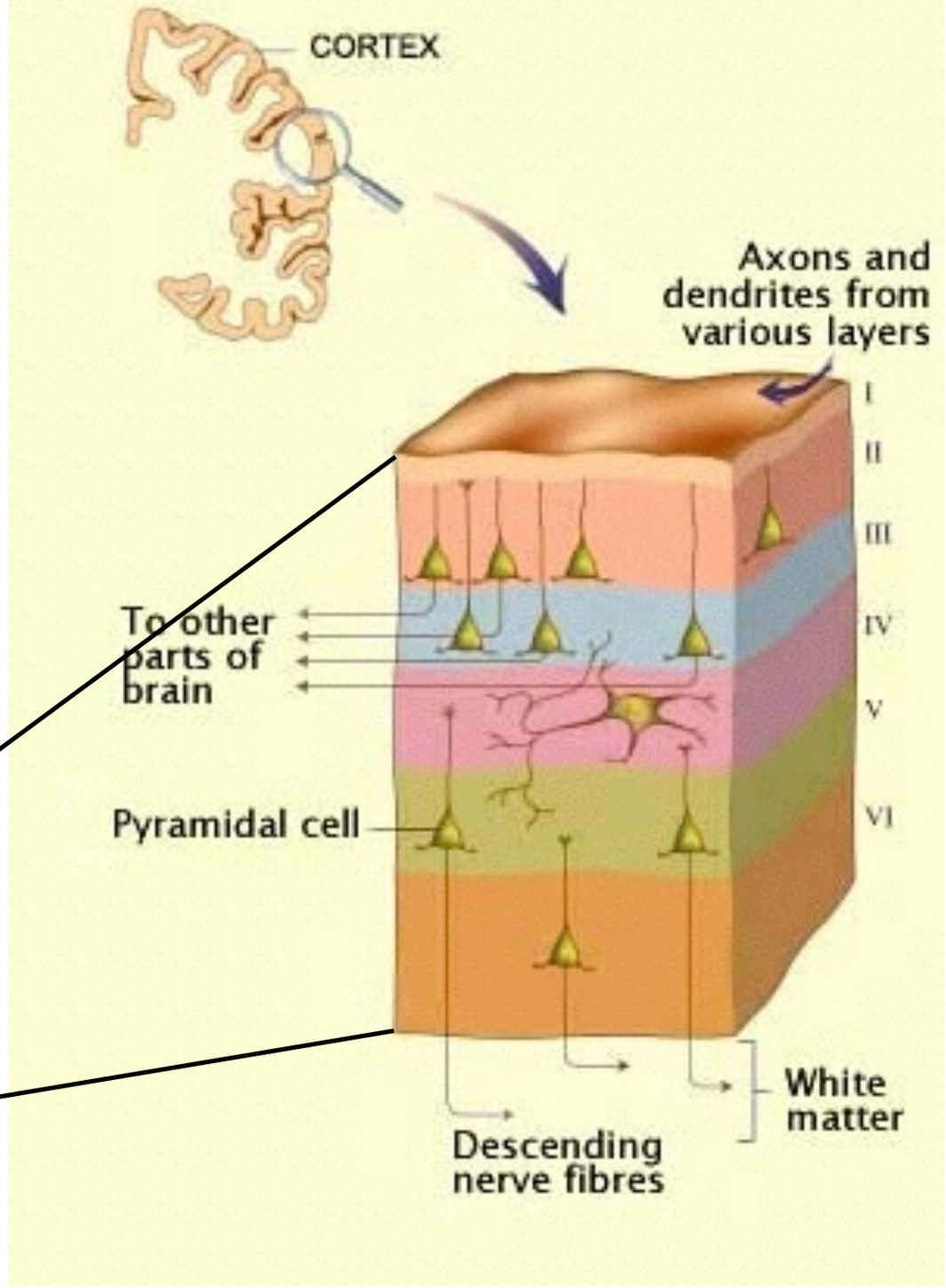
50-60% of the brain devoted to vision!



The Visual System

Van Essen & Anderson 1990



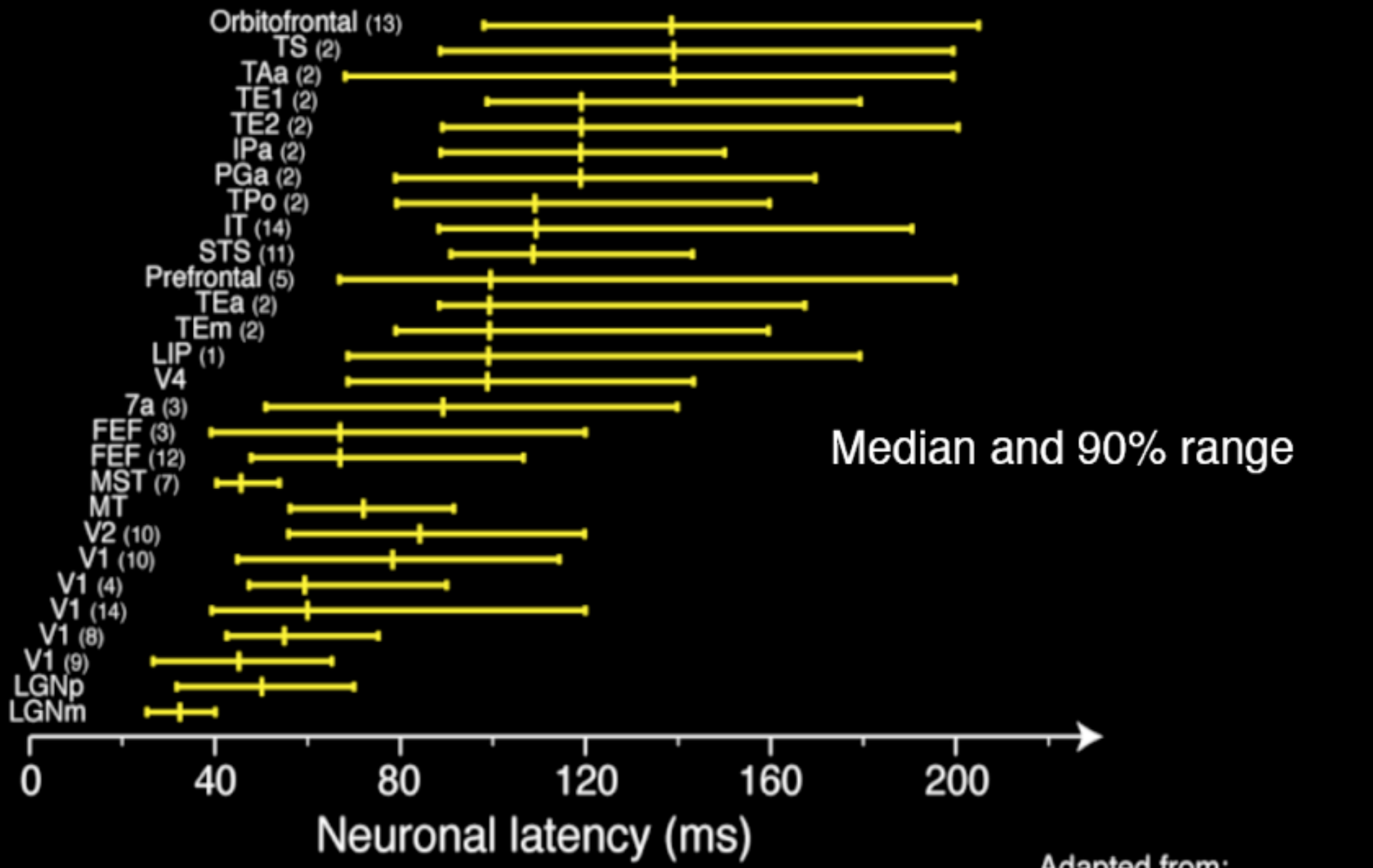


Hierarchical architecture: Anatomy

Rockland & Pandya ’79;
Maunsell & Van Essen ‘83;
Felleman & Van Essen ’91

Timing along the visual pathways consistent with anatomy

Observation: ~10 ms latency difference between each cortical area

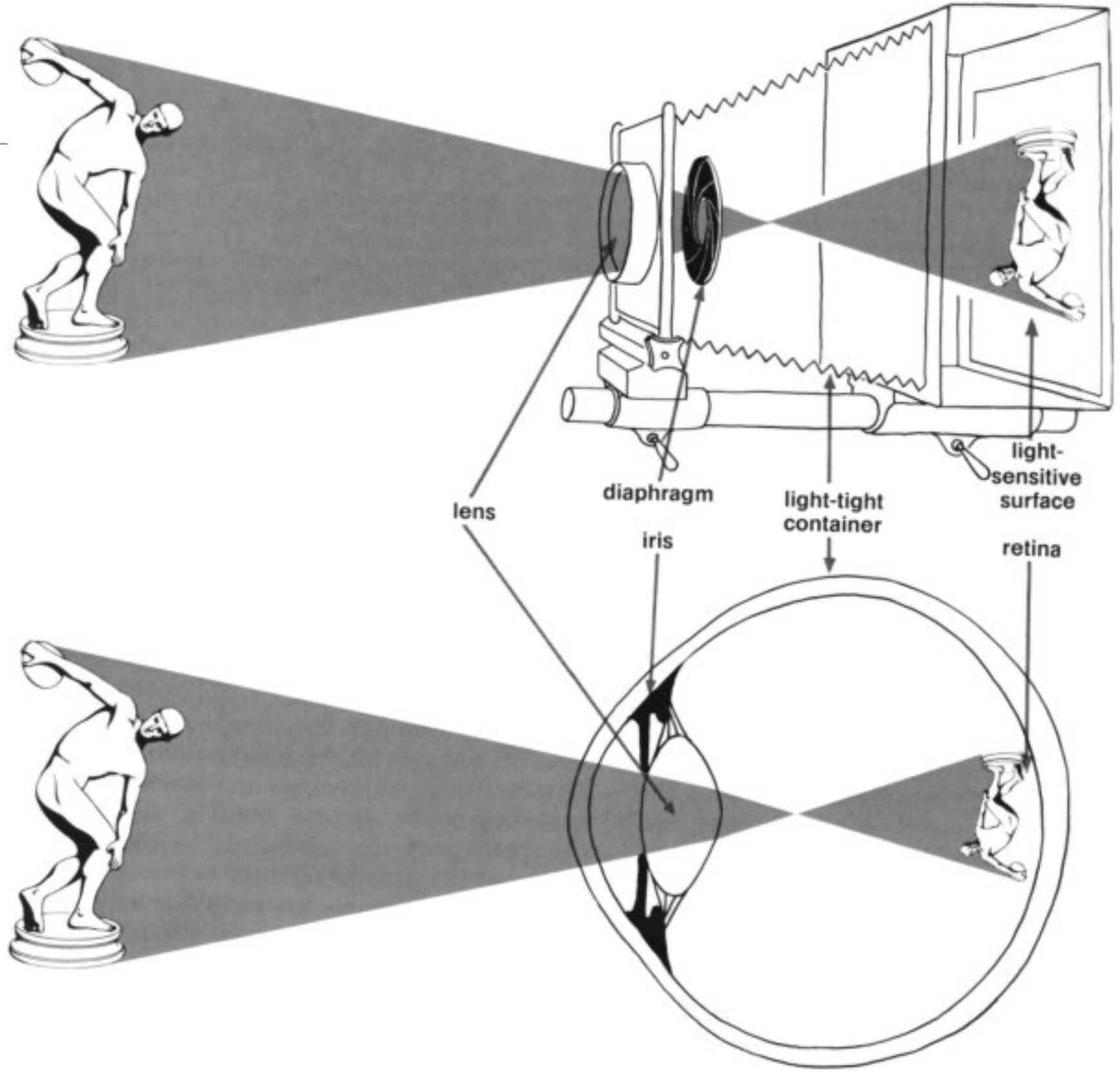


Adapted from:
Nowak and Bullier (1997)
Schmolesky et al. (1998)

Simple eye vs. camera

- ~10M pixels

- ~100M photoreceptors
  - ~5M cones
  - ~90M rods



Source: unknown

Eye stimulated by stuff in the world

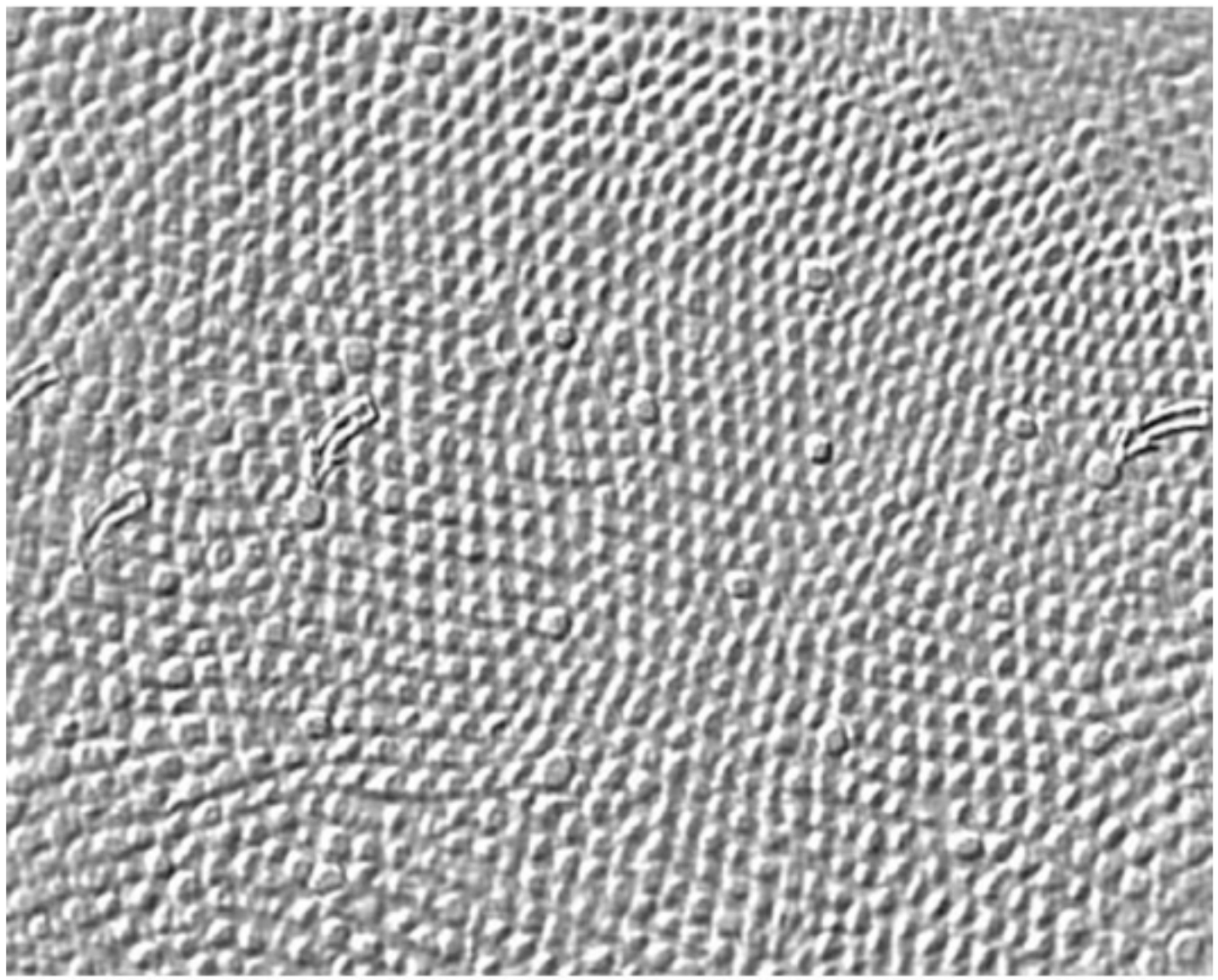


Fig. 13. Tangential section through the human fovea.
Larger cones (arrows) are blue cones. *From Ahnelt et al. 1987.*

Source: webvision

Eye stimulated by stuff in the world

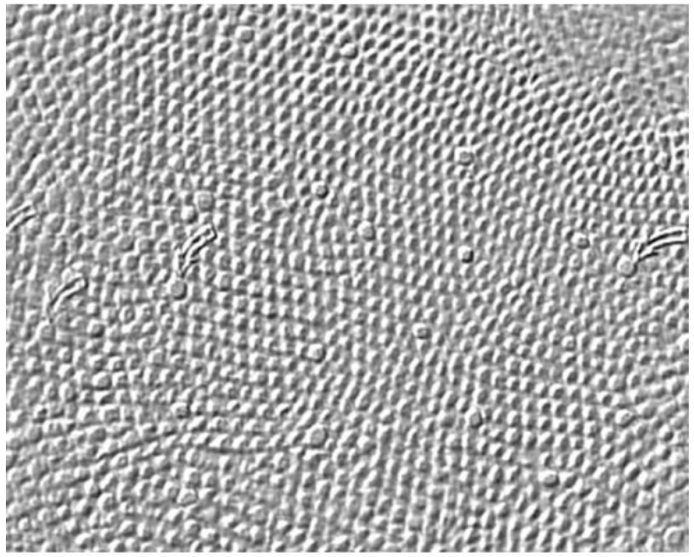
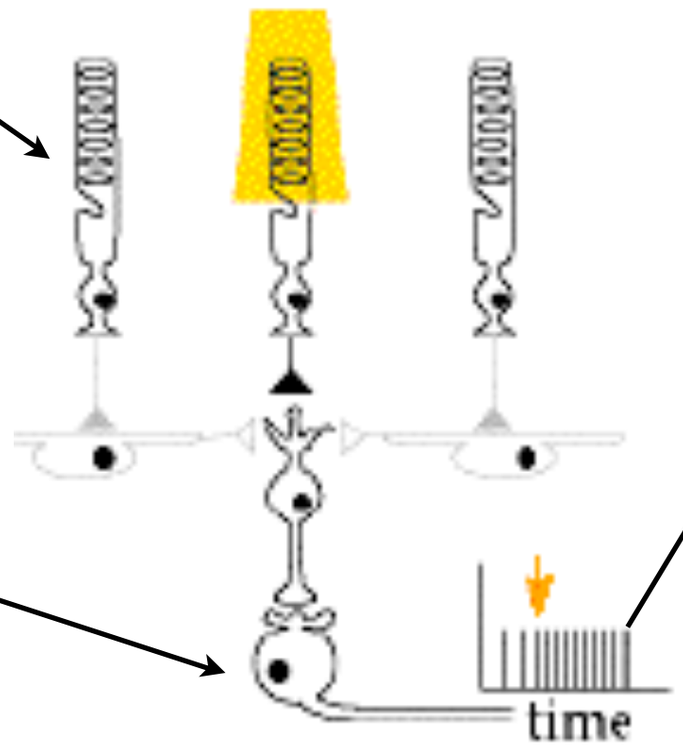
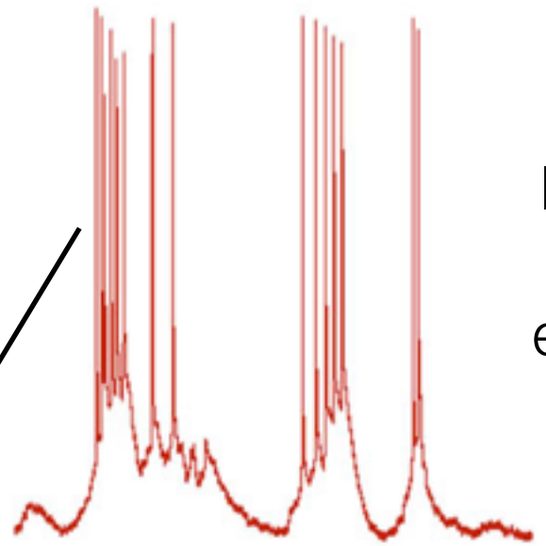


Fig. 13. Tangential section through the human fovea. Larger cones (arrows) are blue cones. From Ahnelt et al. 1987.

photoreceptors



Retinal output (ganglion cells)

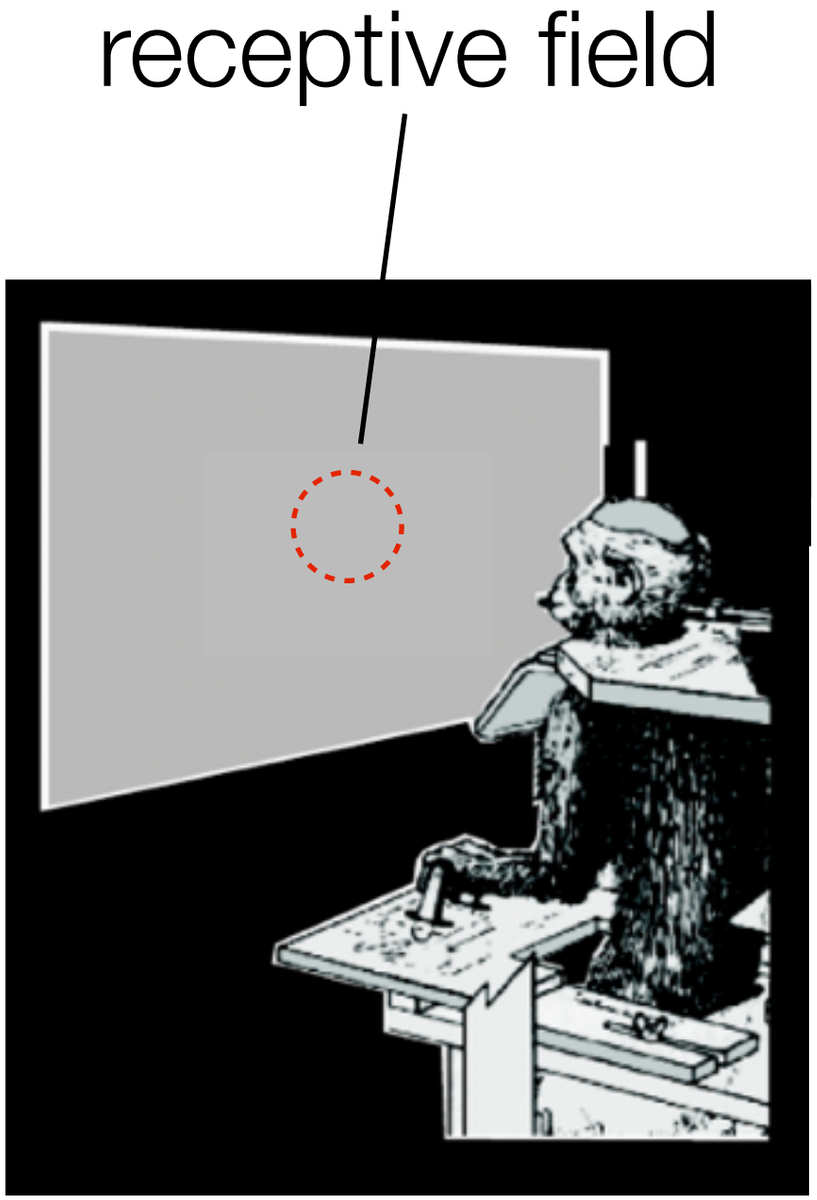


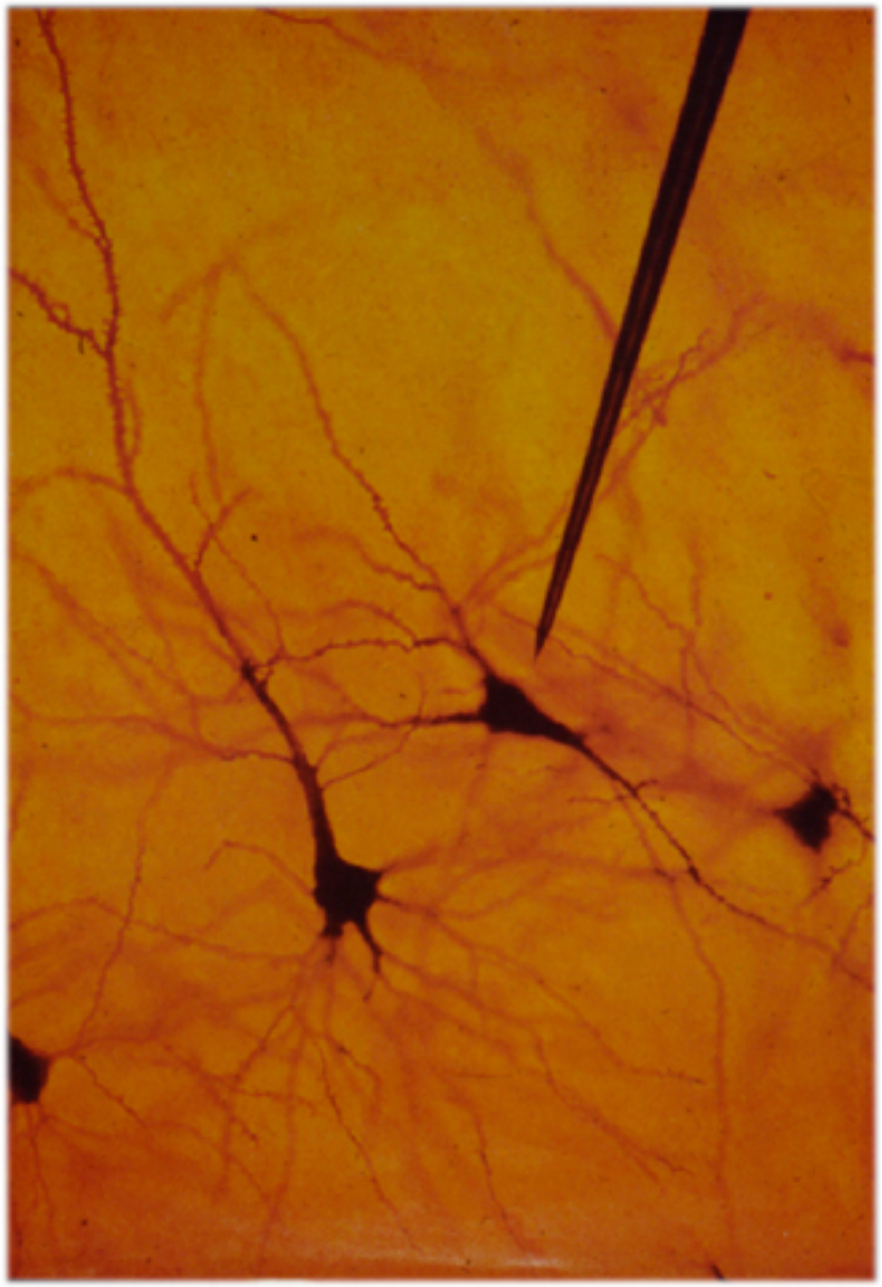
Increase in firing rate driven by external stimulus

10M optic visual nerve fibers

Modified from http://thalamus.wustl.edu/course/eyeret.html

Receptive fields





RF organization in LGN

source: webvision

photoreceptors

Retinal output (ganglion cells)

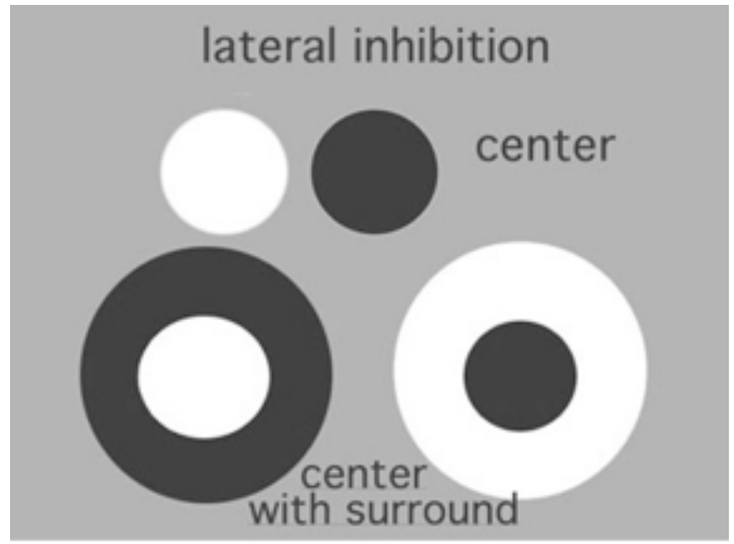
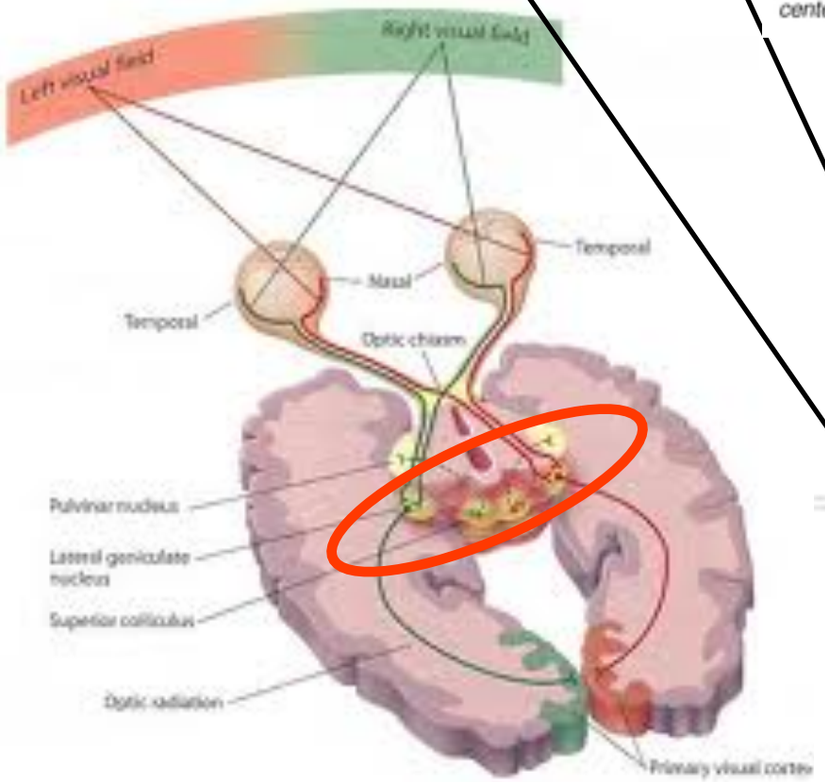
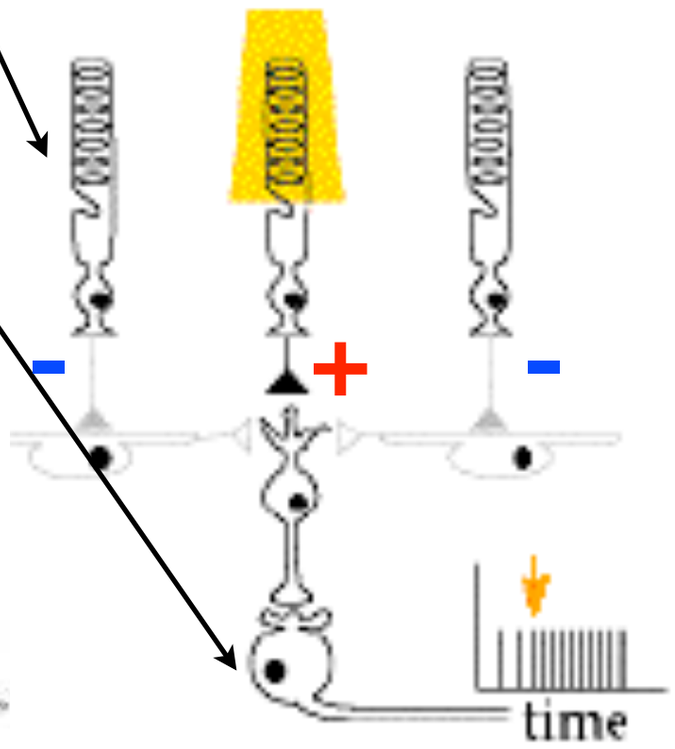


Fig. 10. Center-surround receptive fields can be ON center or OFF center with the oposite sign annular surround.



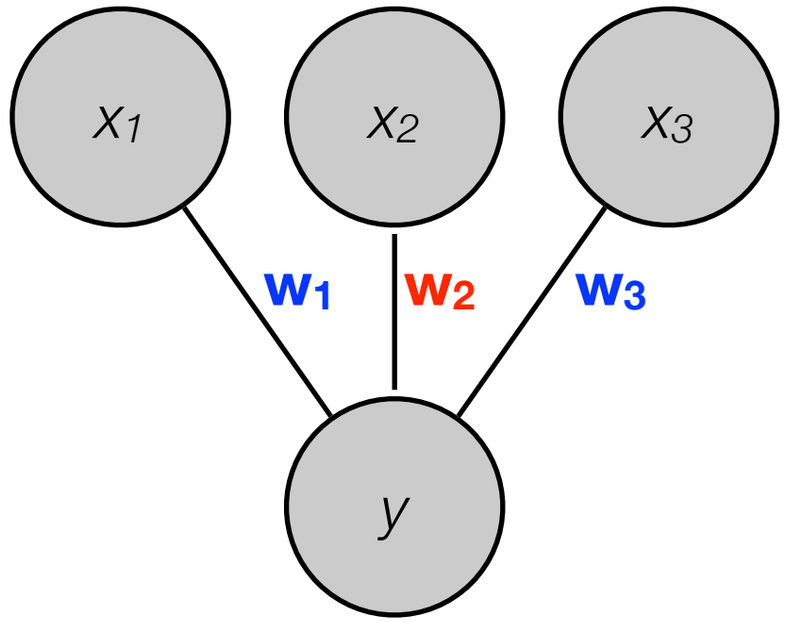


Summation at the soma

$$y = f\left(\sum w_i x_i\right)$$

Synaptic efficacies

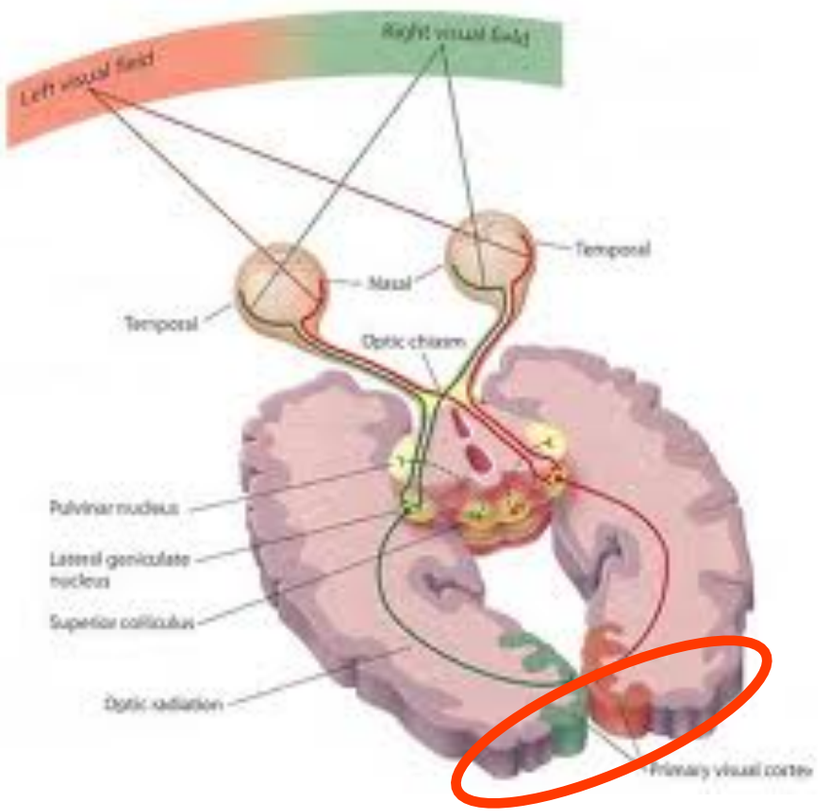
Afferent activity from neuron i



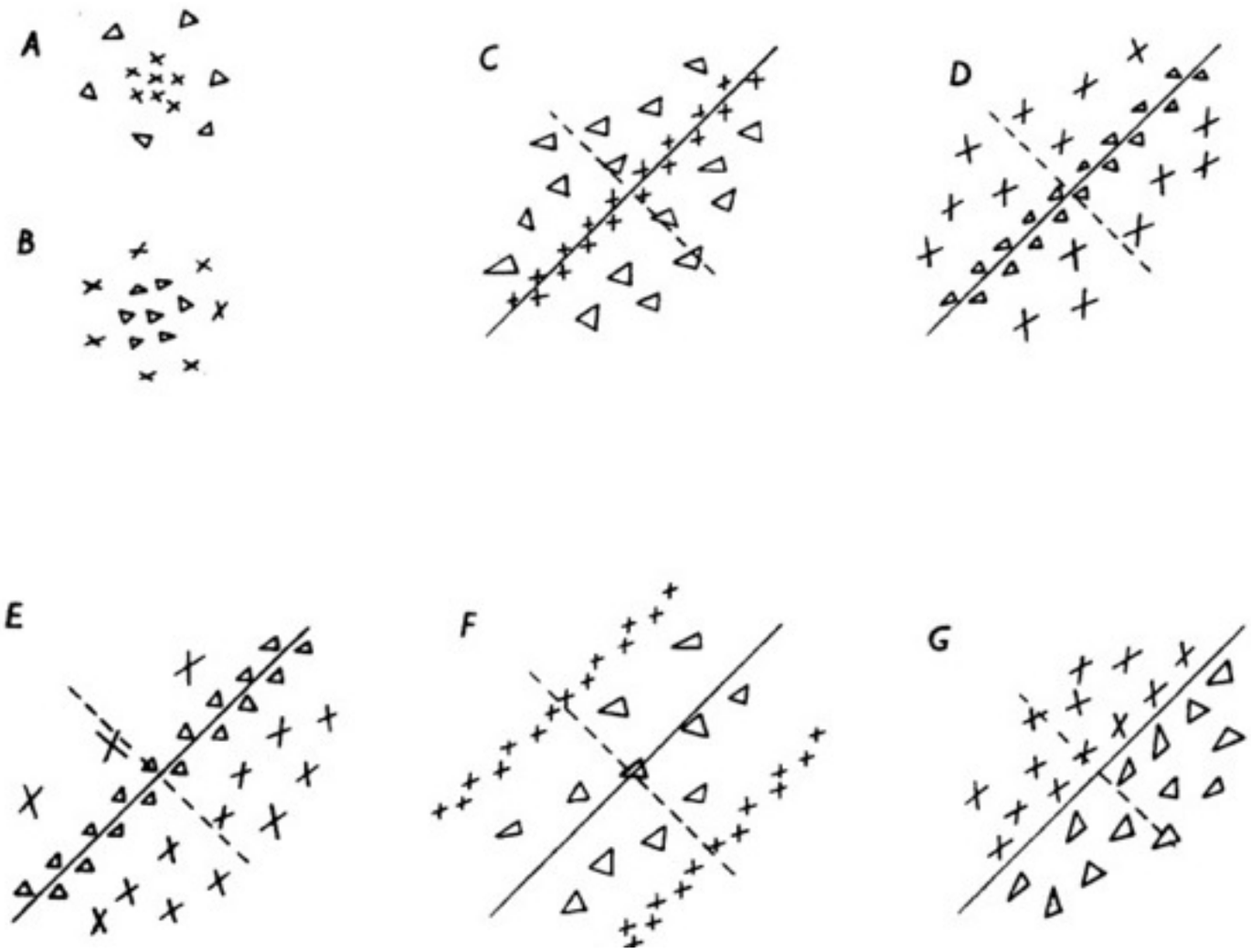
Modified from http://thalamus.wustl.edu/course/eyeret.html

RF organization in V1

Hubel & Wiesel



Simple cell



Hubel & Wiesel ’59 ’62 ’68