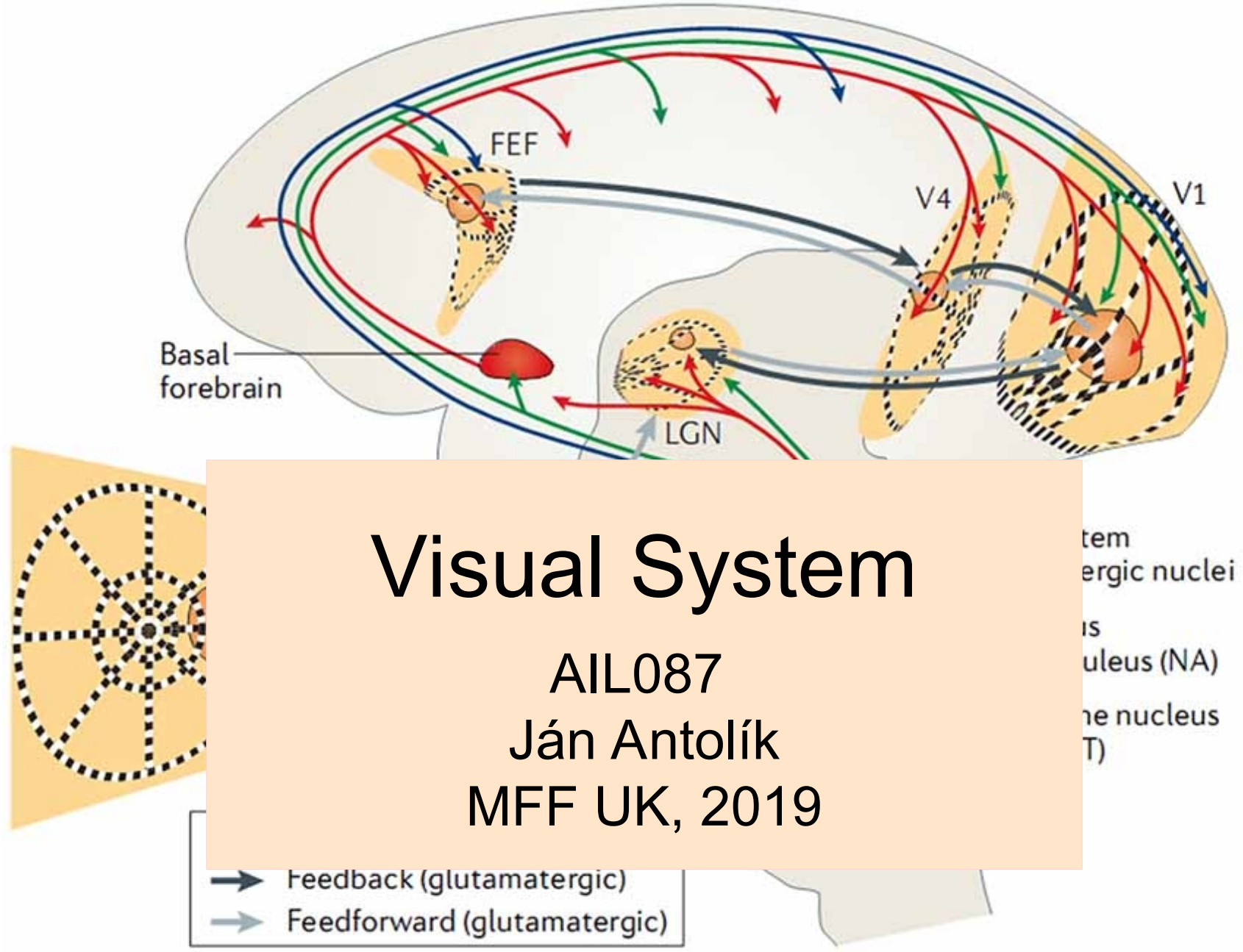
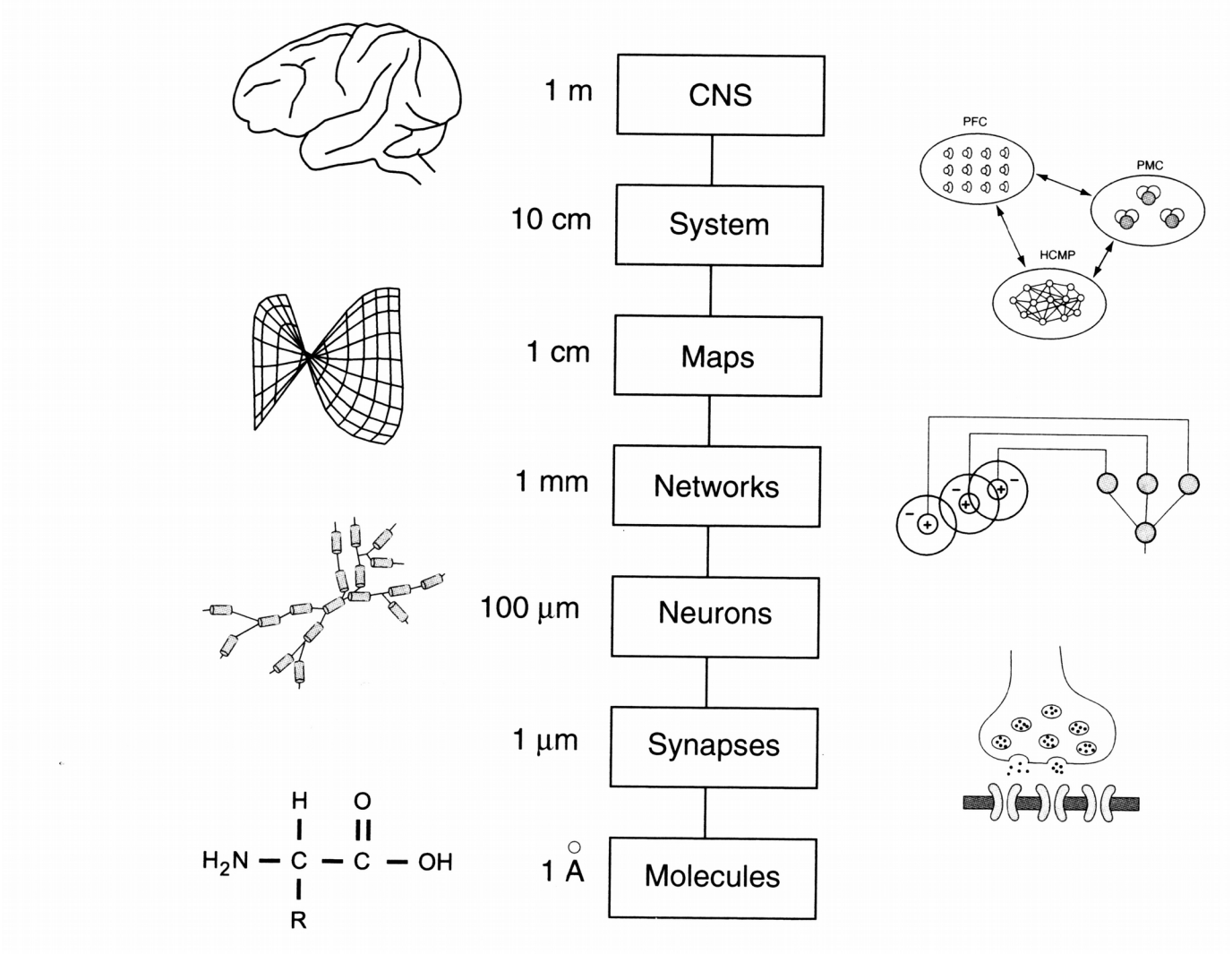


Visual System

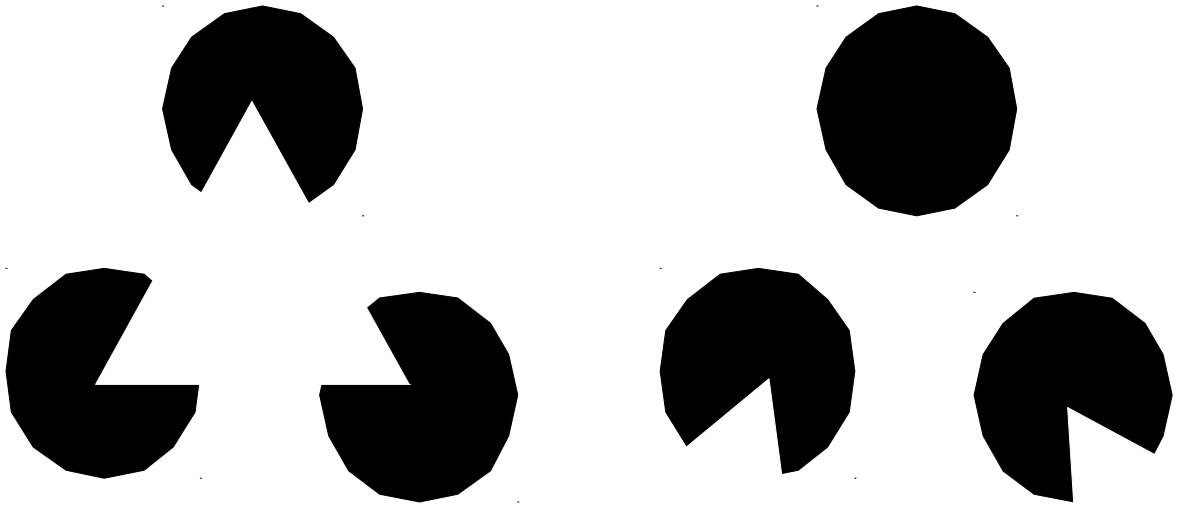
AIL087

Ján Antolík
MFF UK, 2019

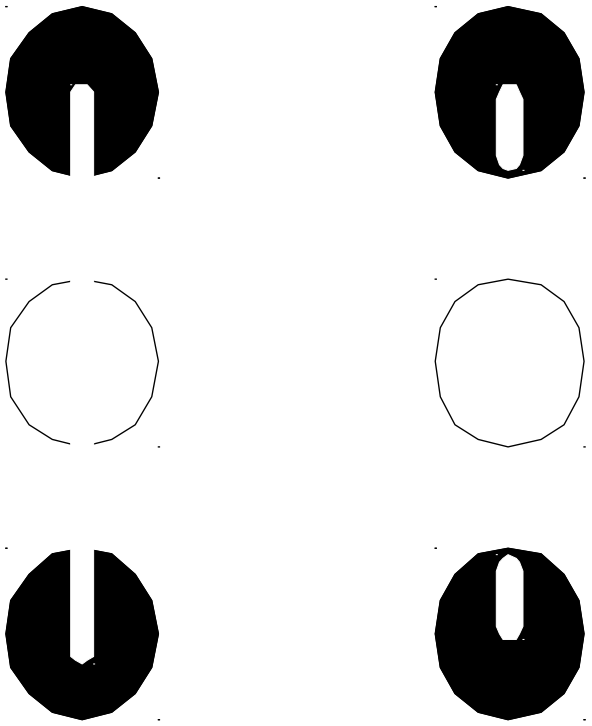
Brain as a multi-scale system



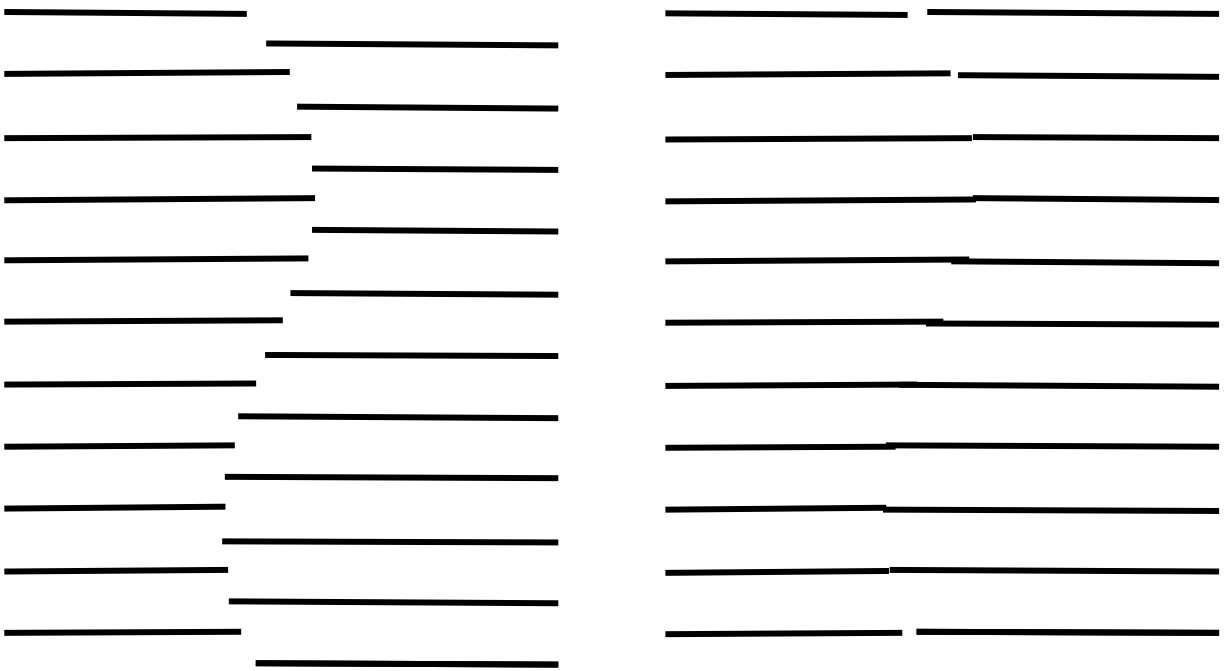
Can you see the white triangle?



Can you see the bar?

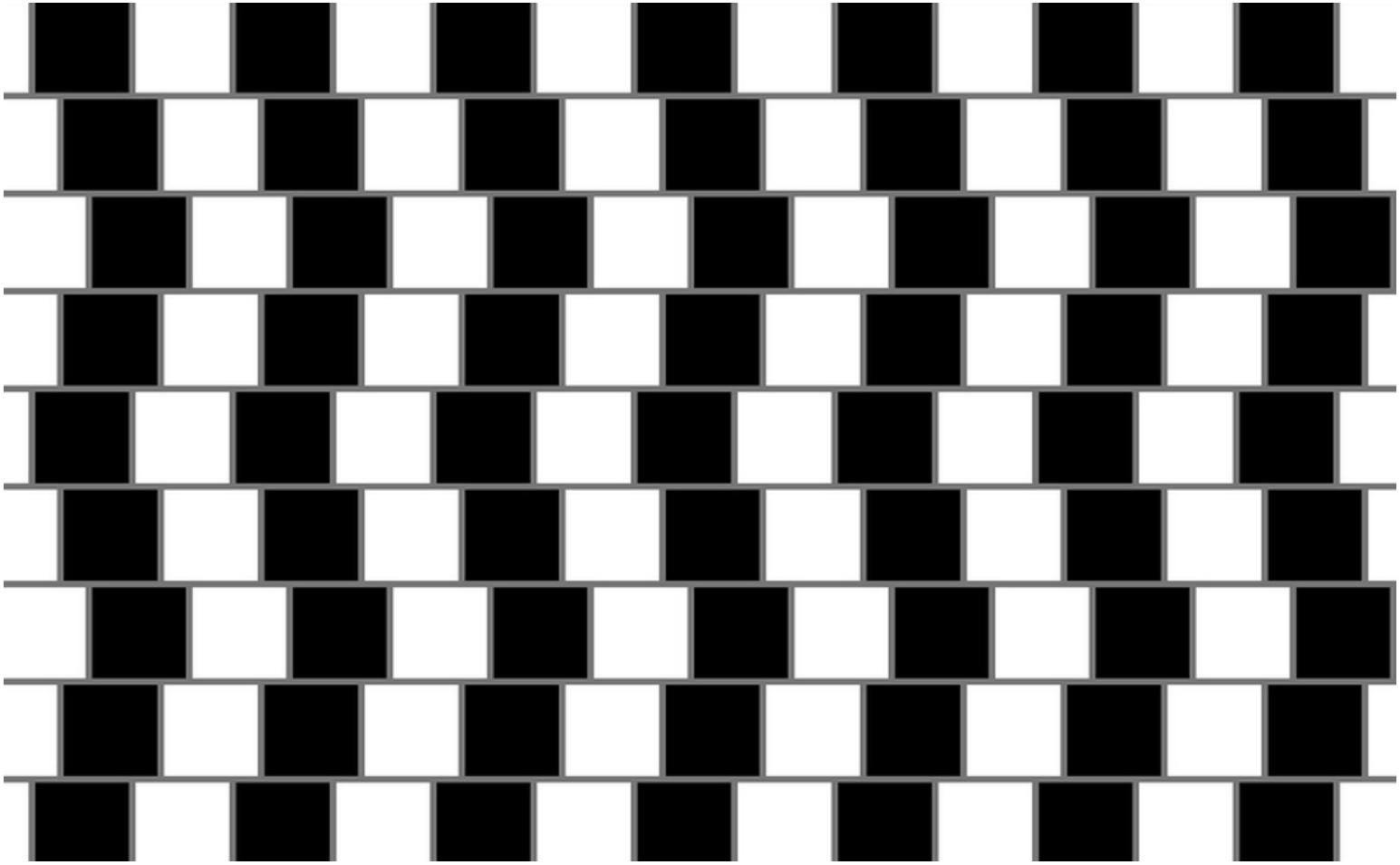


Can you see the wave?

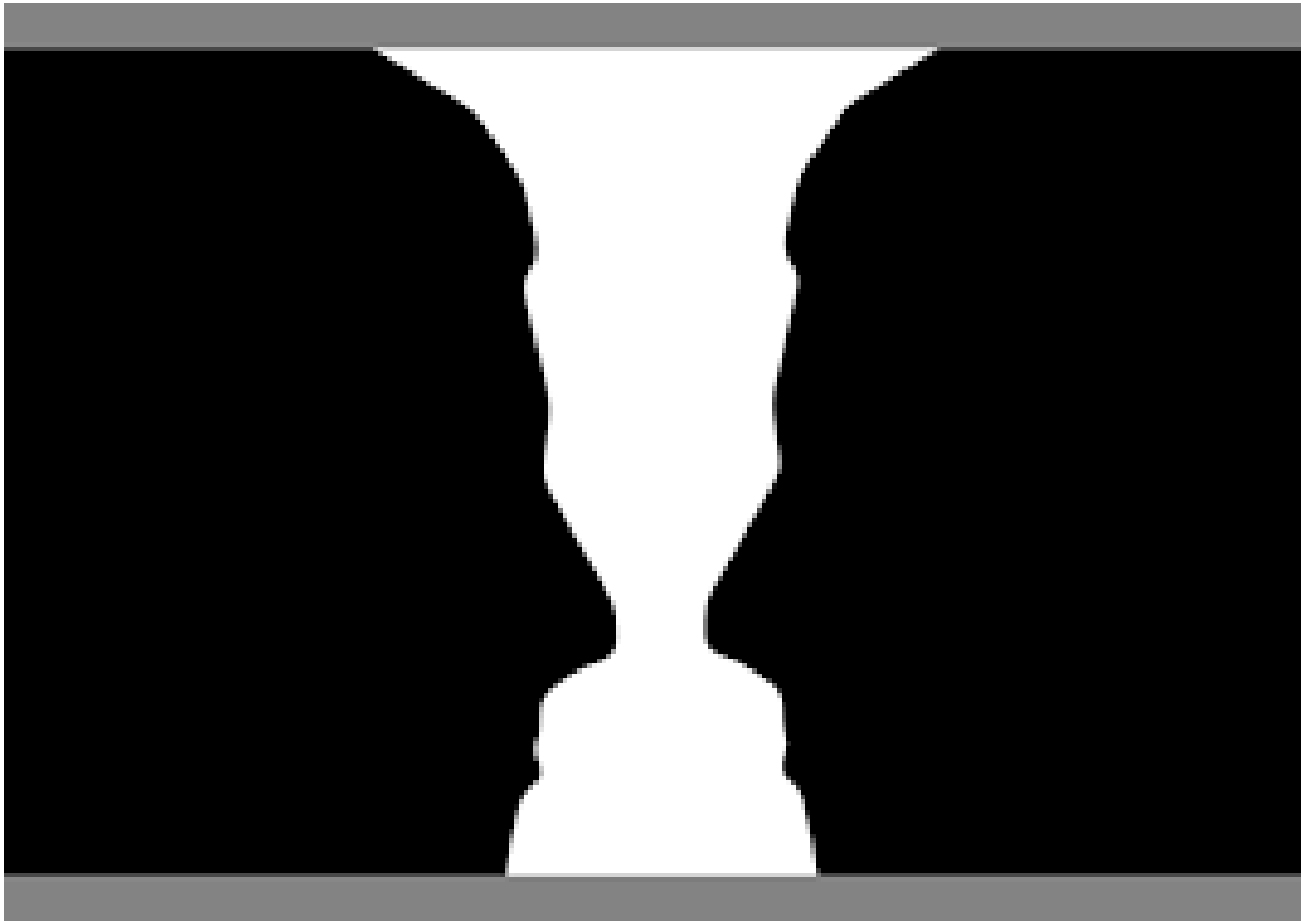


Which central square is darker?

Which central square is darker?



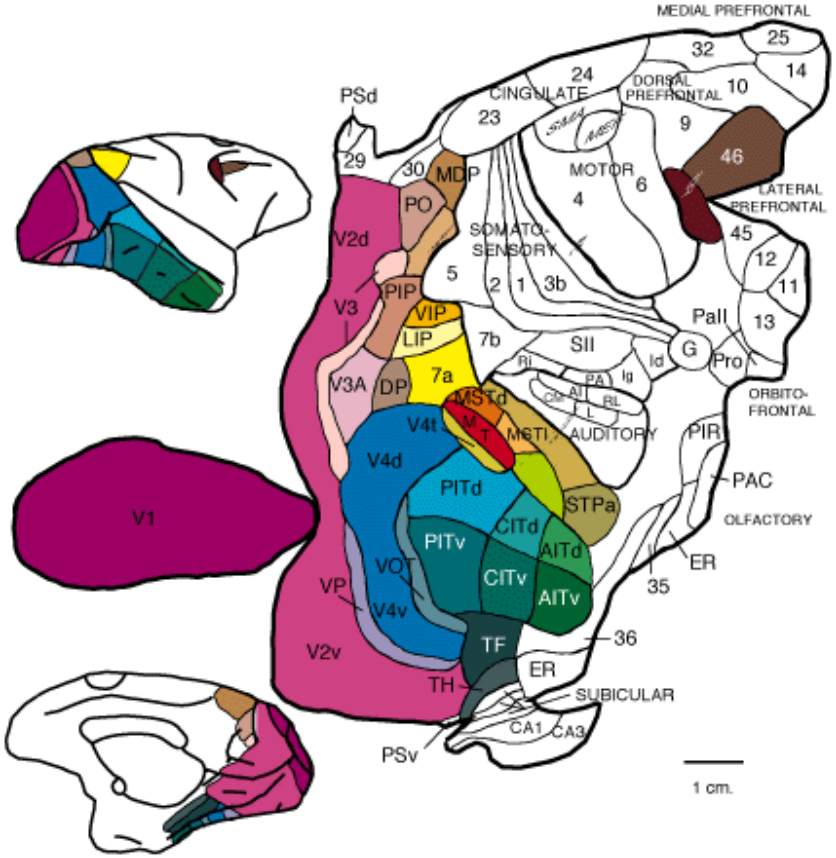
What is in the figure?

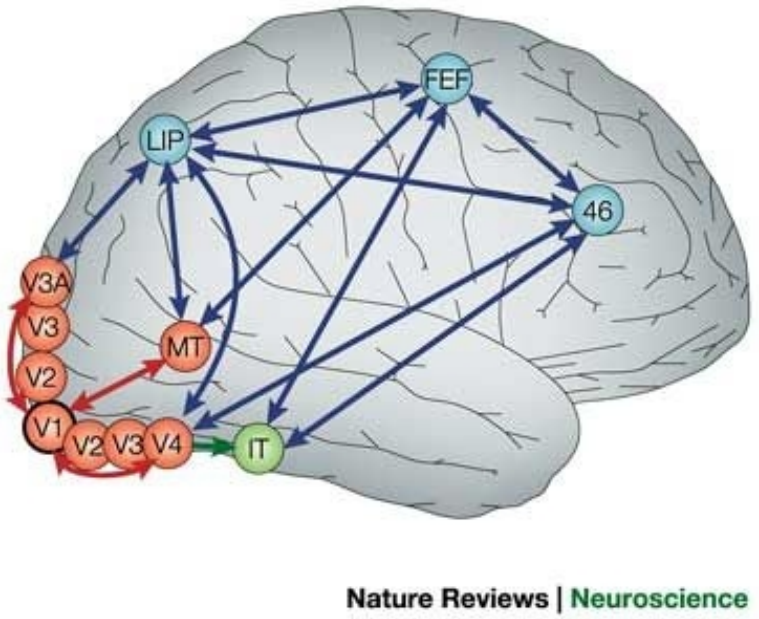


The goal of visual system is **not** to offer us precise reflection of environment around us.

The goal of our visual system is to guide our behavior towards advantageous outcomes.

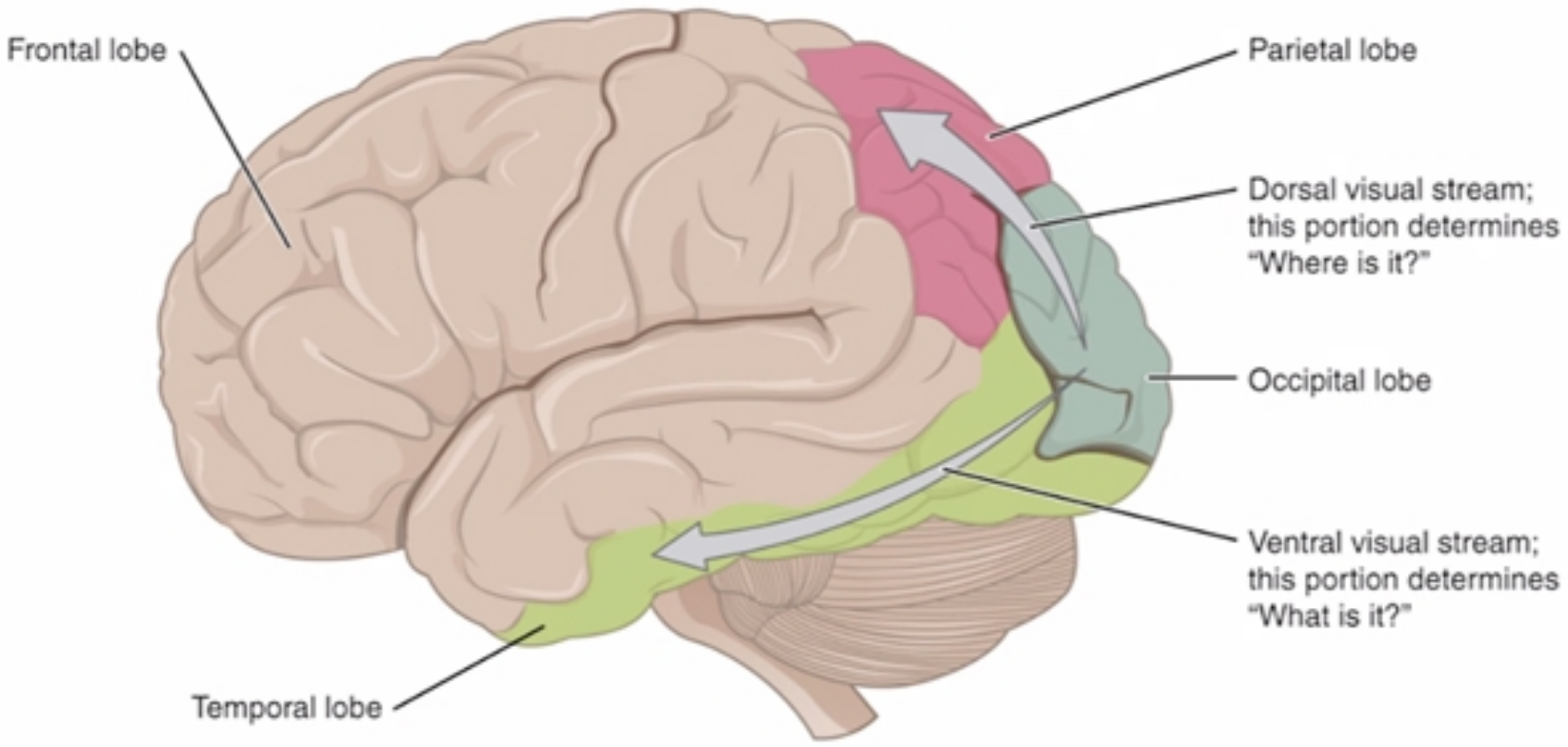
40% of cortex belongs to vision



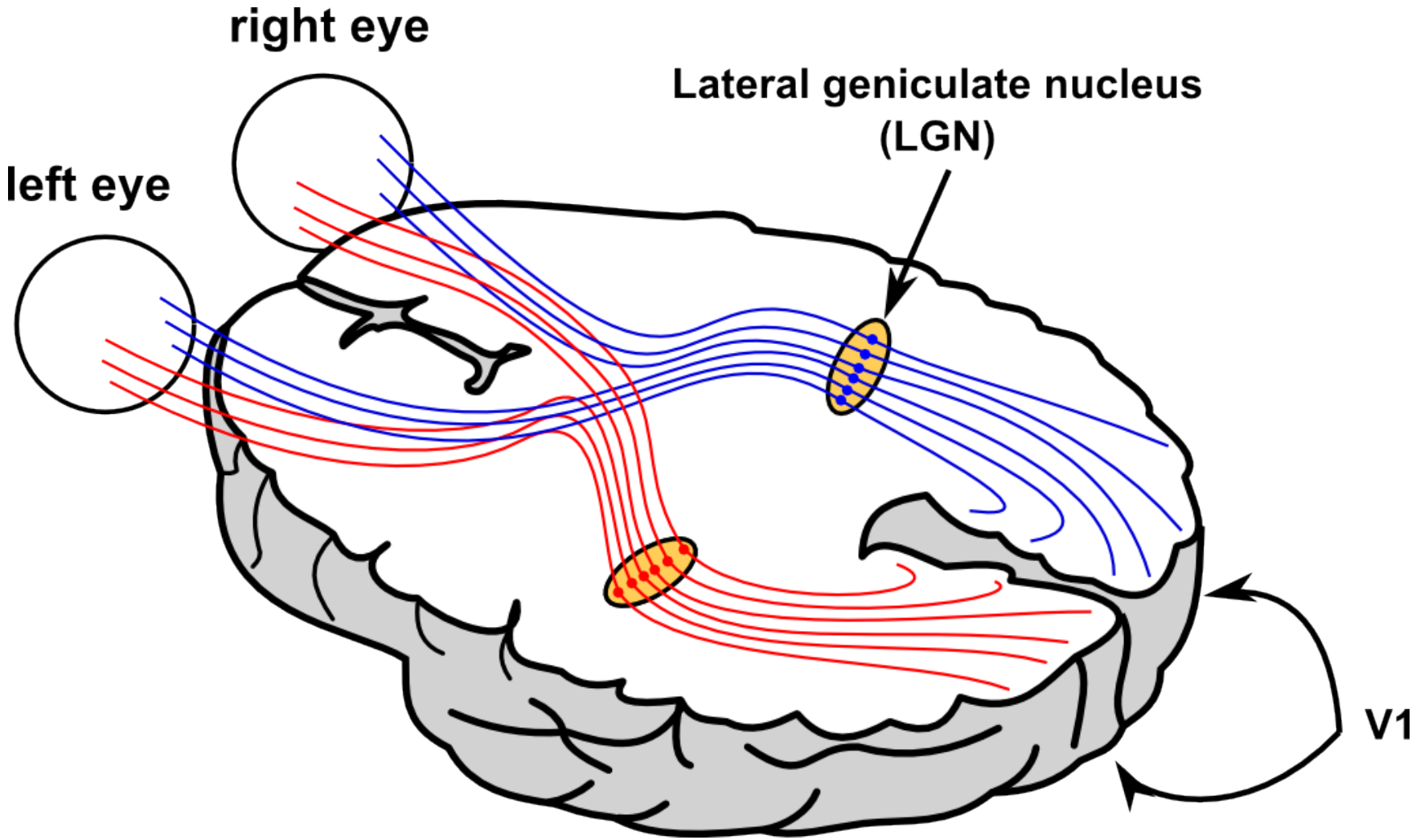


Nature Reviews | Neuroscience

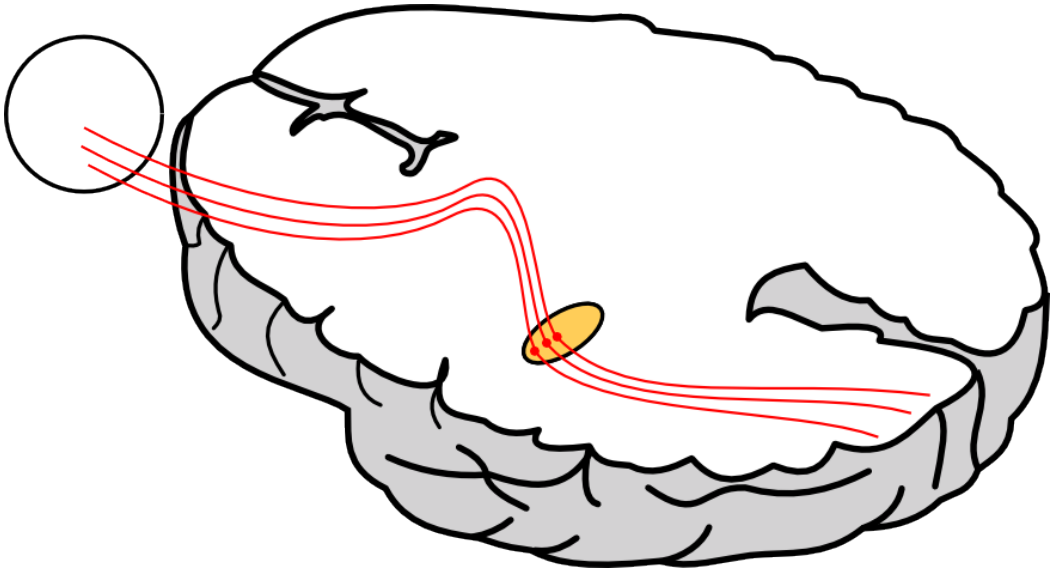
WHAT vs. WHERE



Early visual system

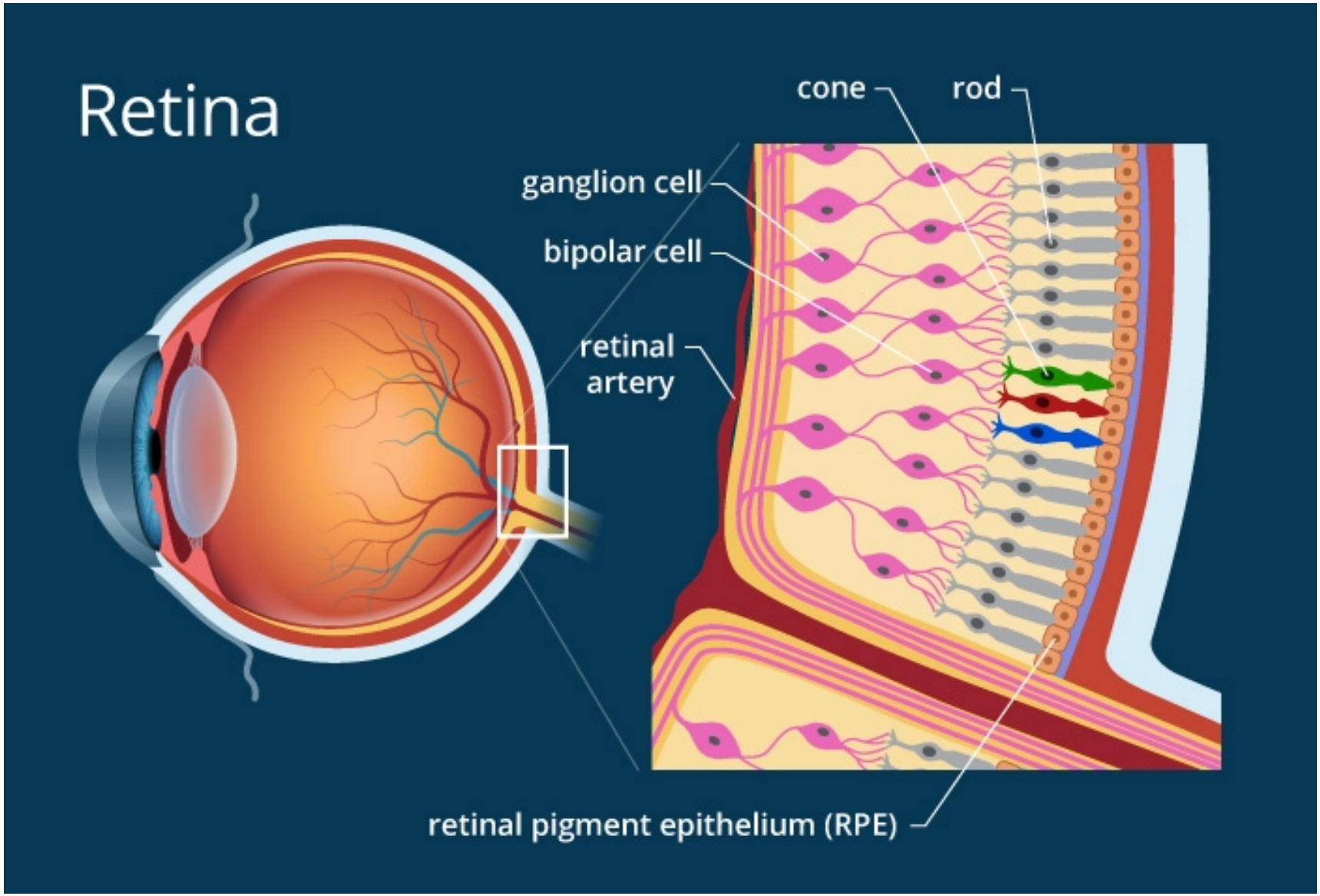


Today we will ignore binocular vision

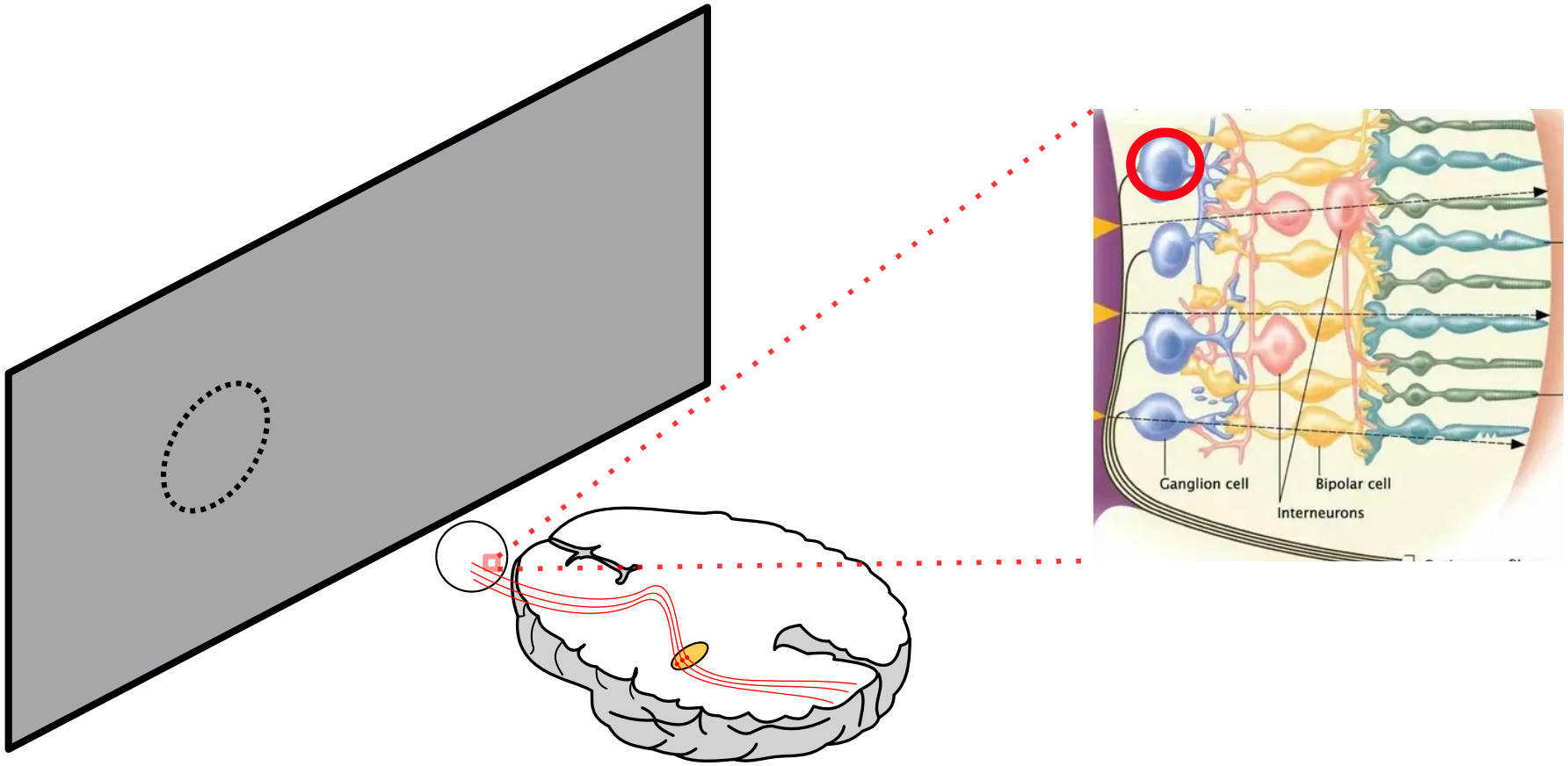


RETINA

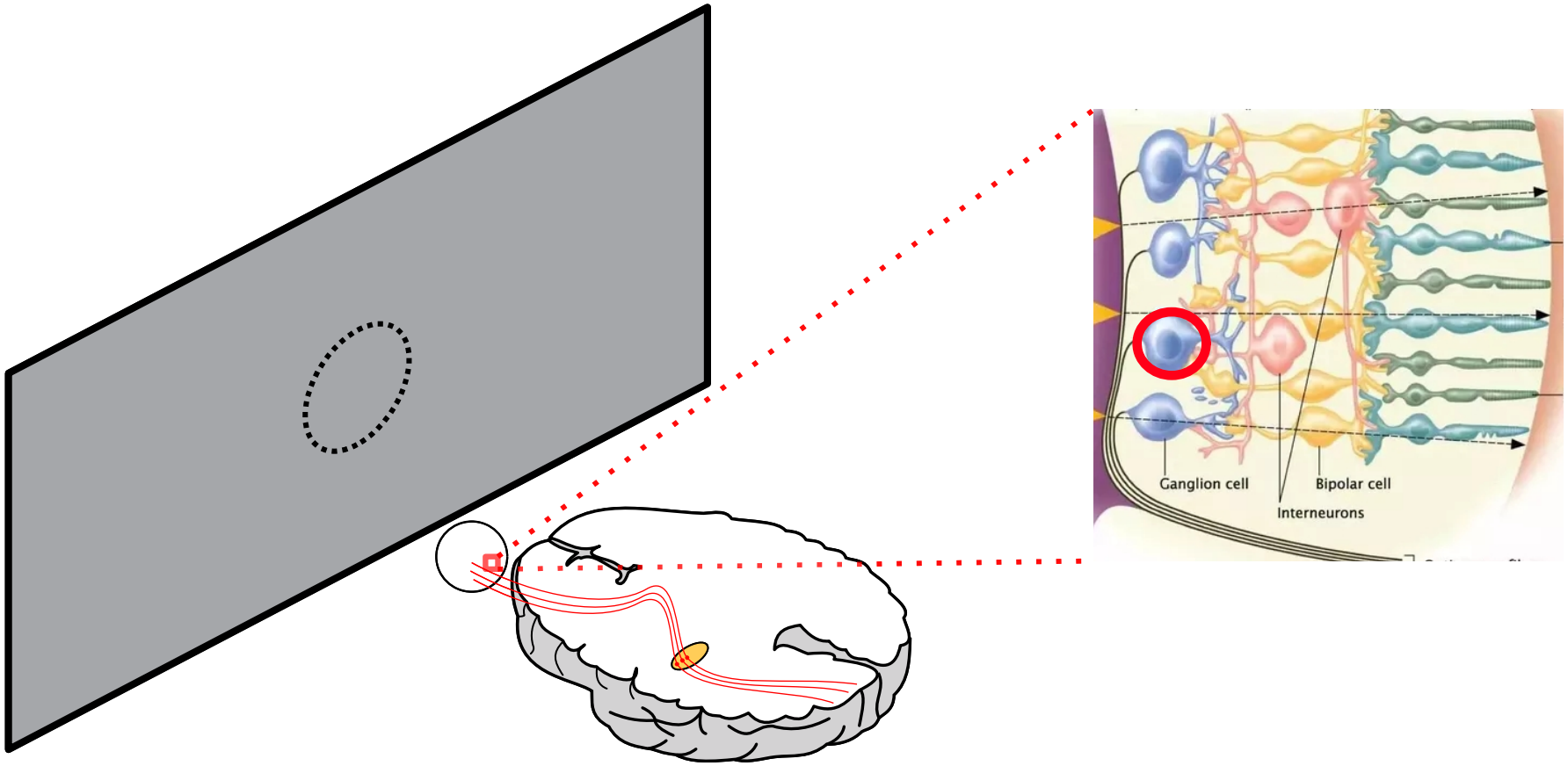
The EYE


Retina
cone
rod
ganglion cell
bipolar cell
retinal artery
retinal pigment epithelium (RPE)

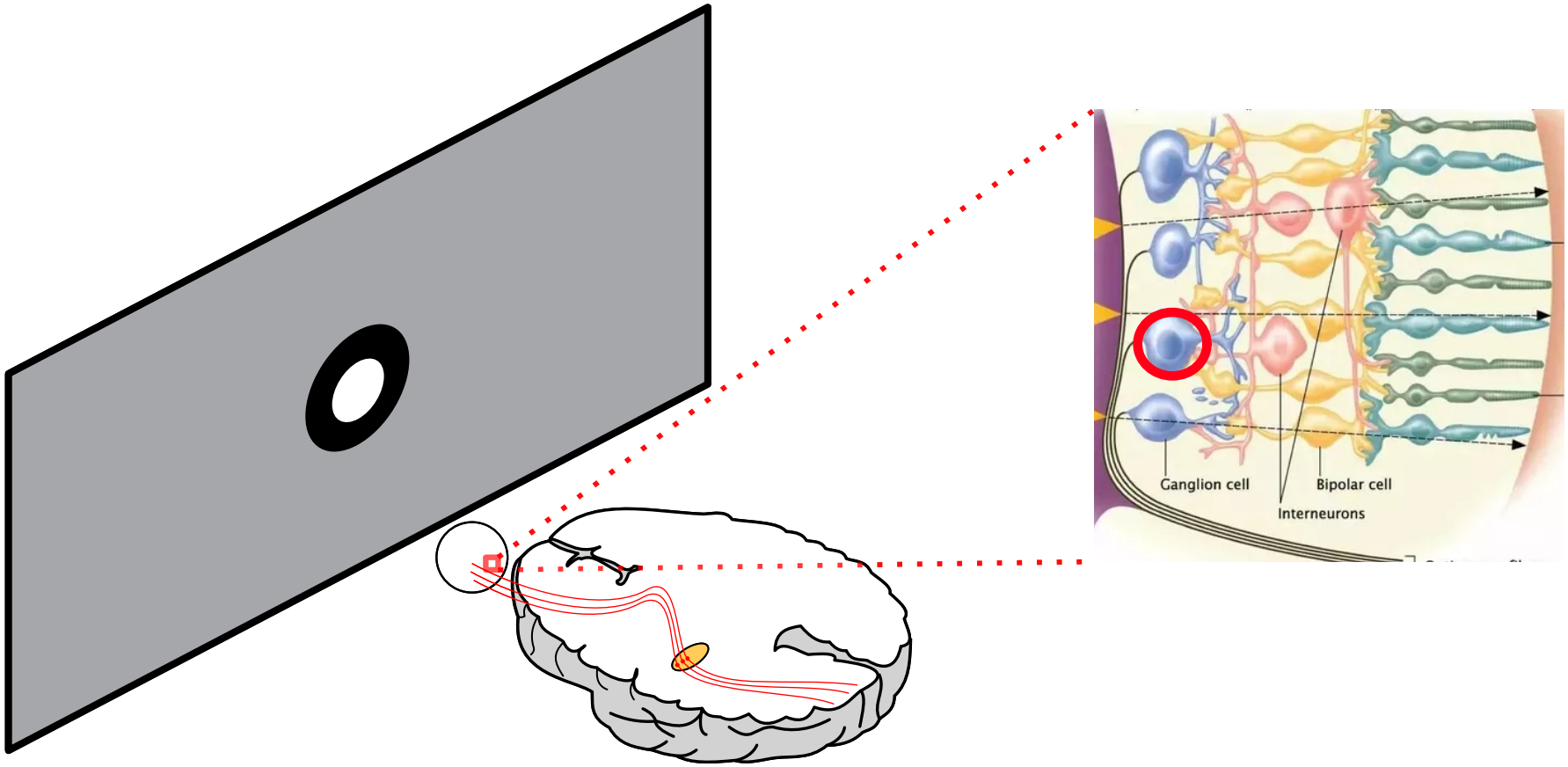
Receptive field



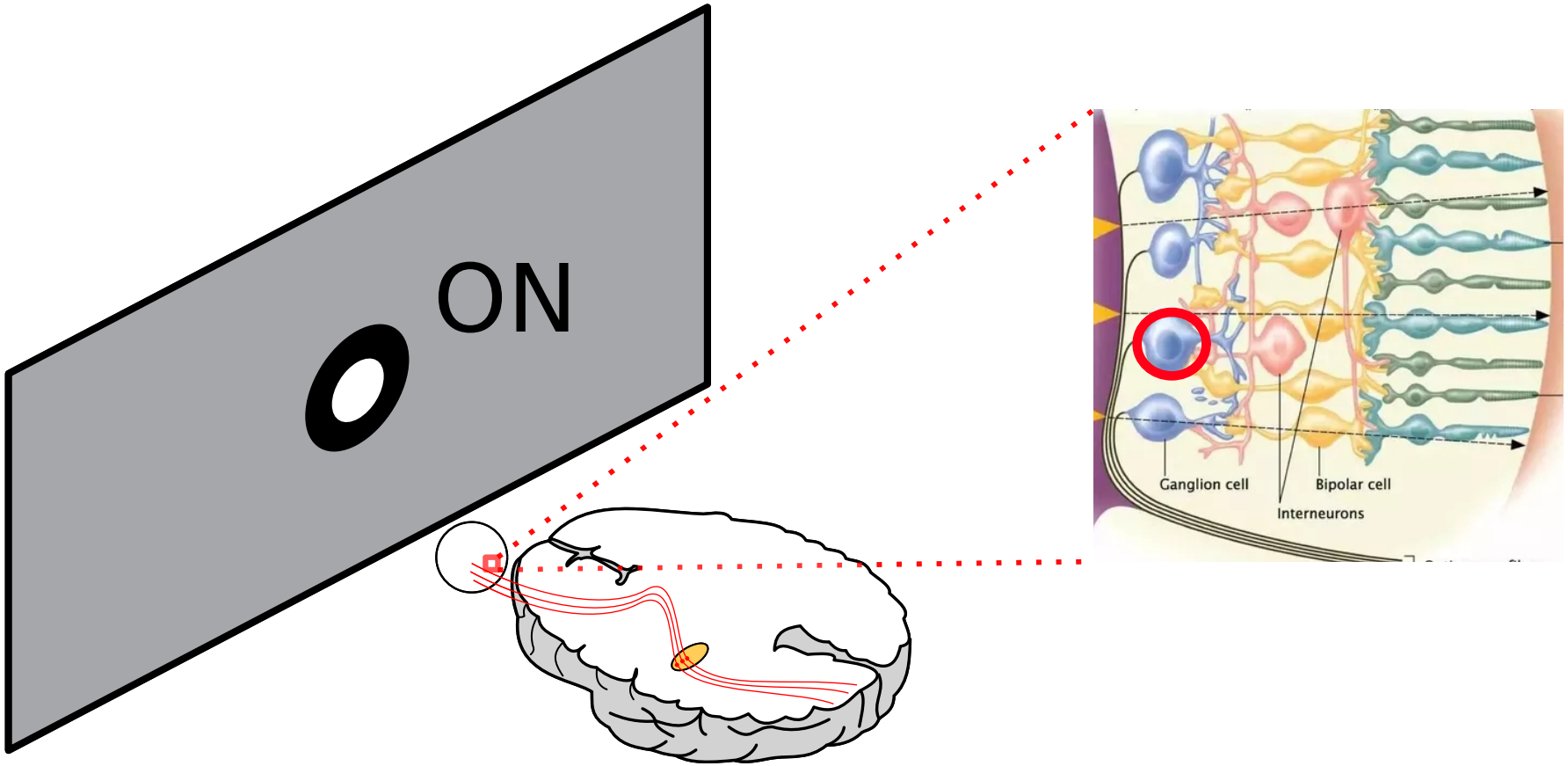
Receptive field



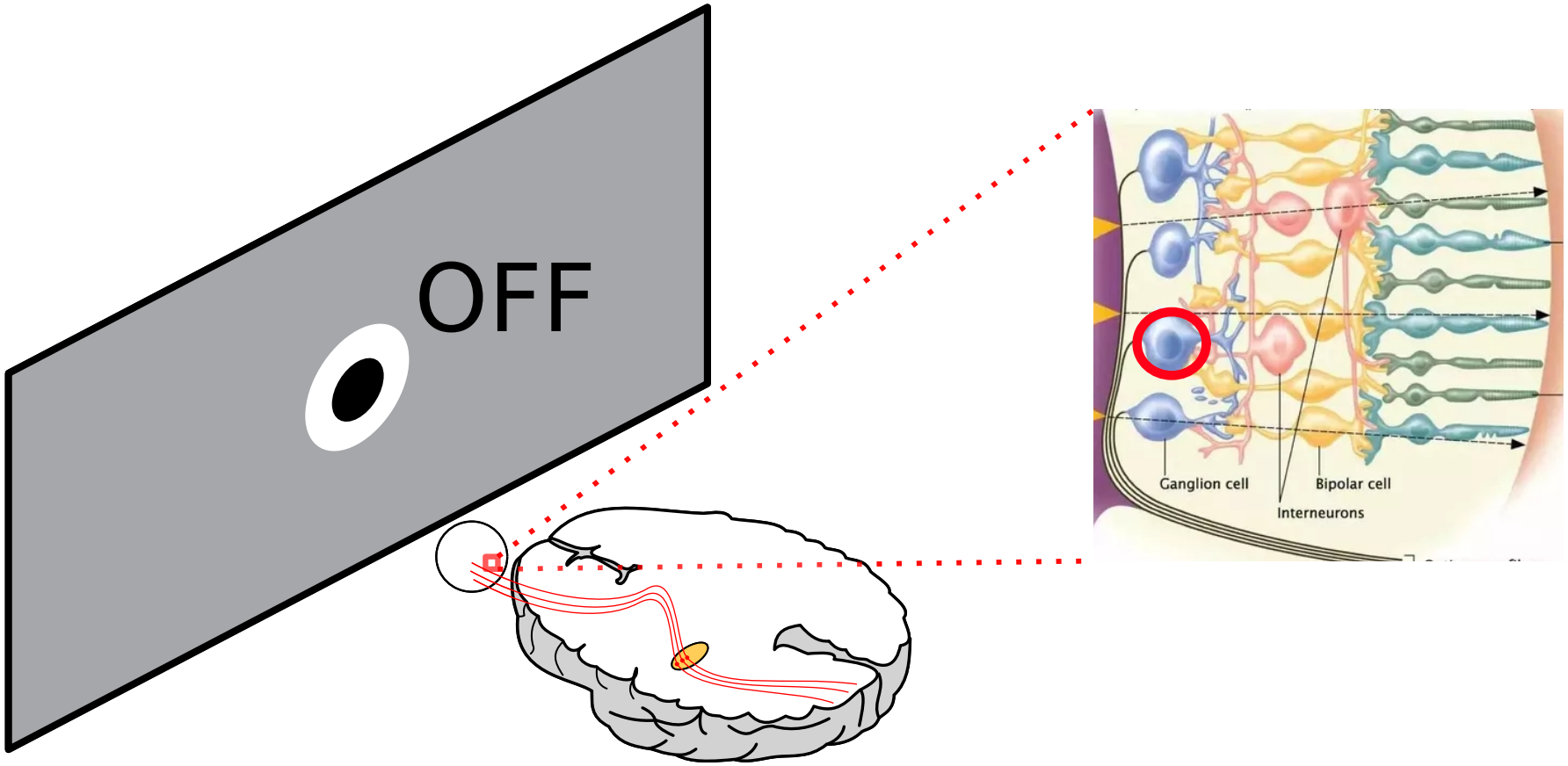
Receptive field



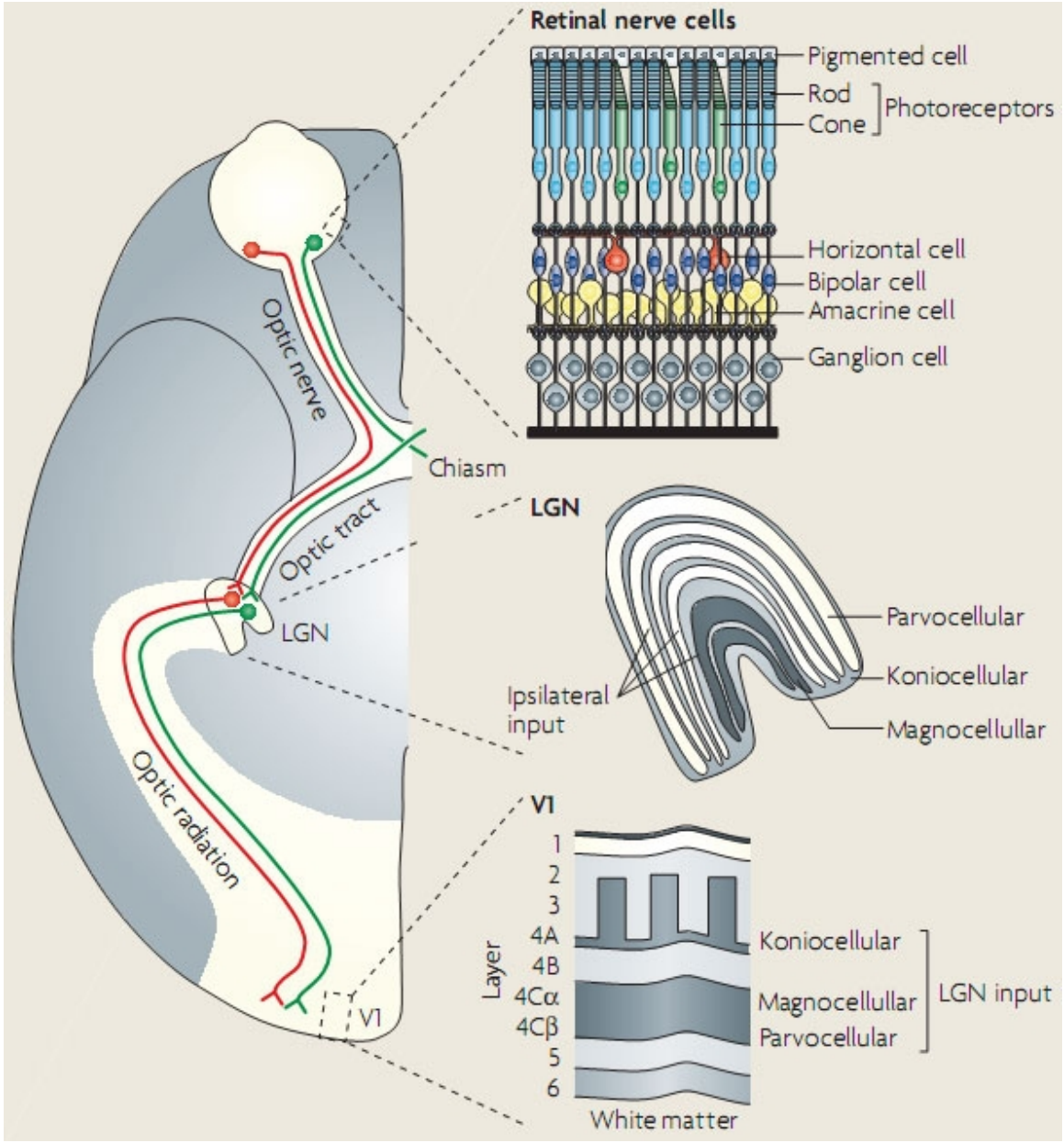
Receptive field



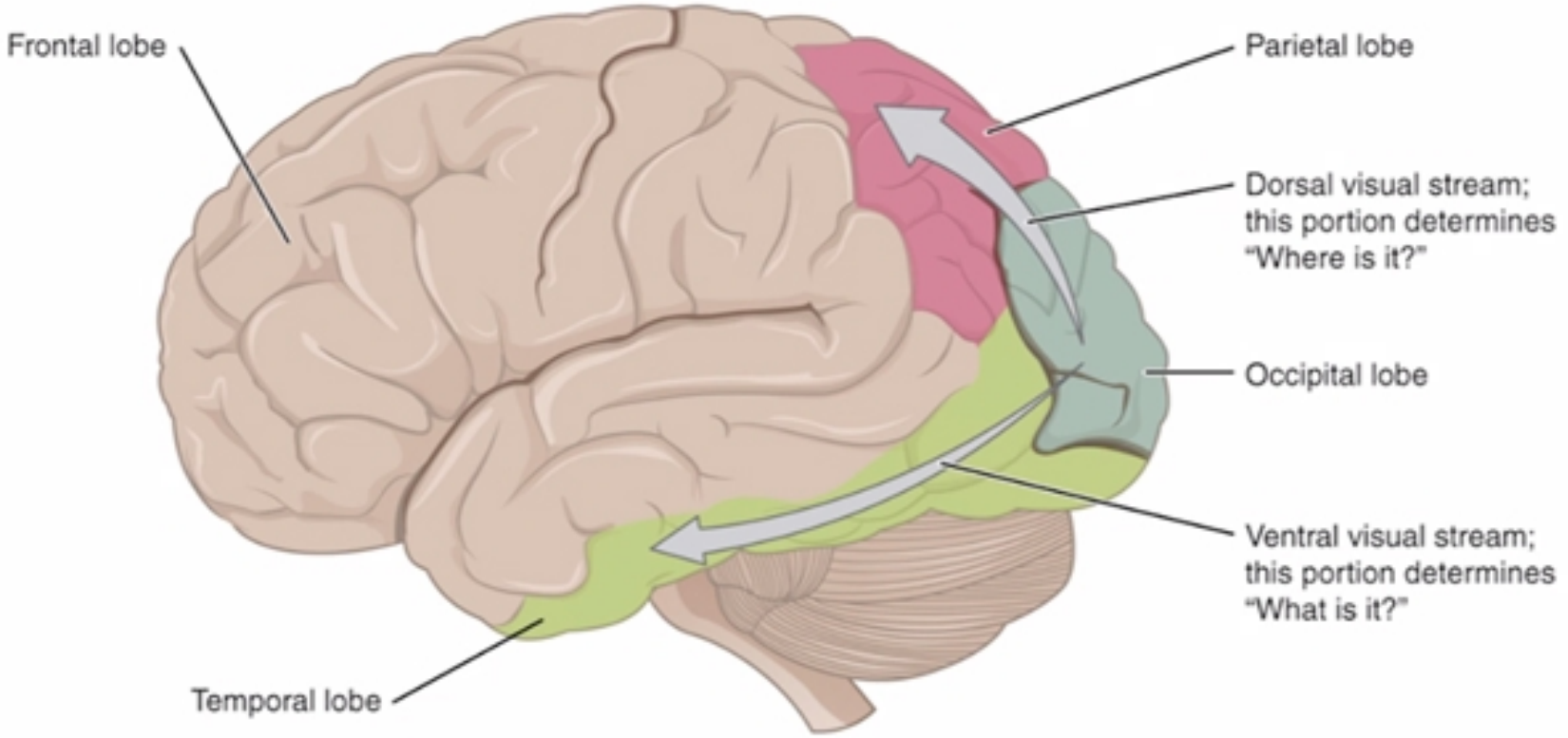
Receptive field



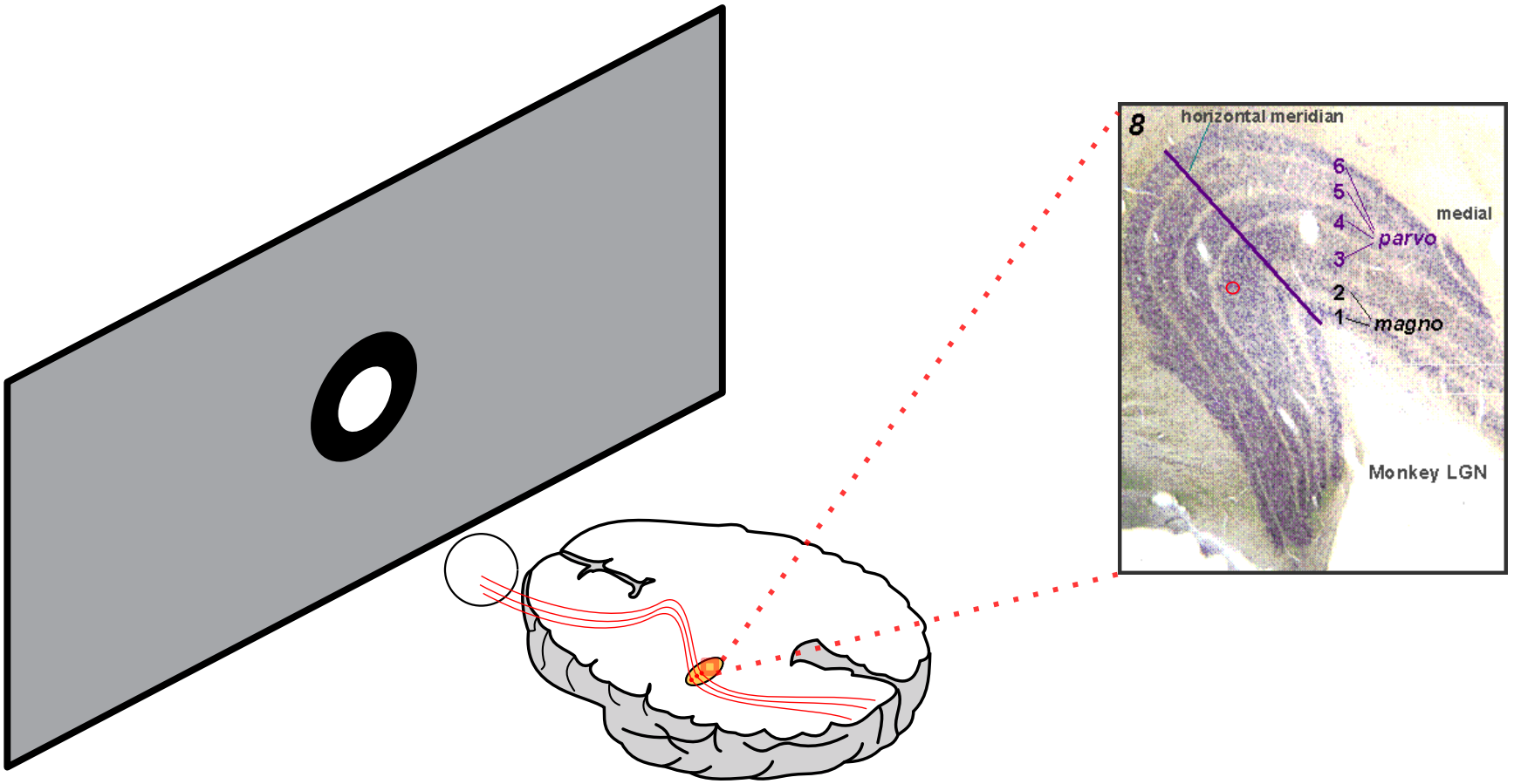
LATERAL GENICULATE NUCLEUS (LGN)


Retinal nerve cells
Pigmented cell
Rod
Cone
Photoreceptors
Horizontal cell
Bipolar cell
Amacrine cell
Ganglion cell
Optic nerve
Chiasm
Optic tract
LGN
Optic radiation
V1
LGN
Parvocellular
Koniocellular
Magnocellullar
Ipsilateral input
V1
1
2
3
4A
4B
4Cα
4Cβ
5
6
Layer
Koniocellular
Magnocellullar
Parvocellular
LGN input
White matter

Where do you think the Parvo vs. Magno stream goes to?



Receptive field in LGN



PRIMARY VISUAL CORTEX

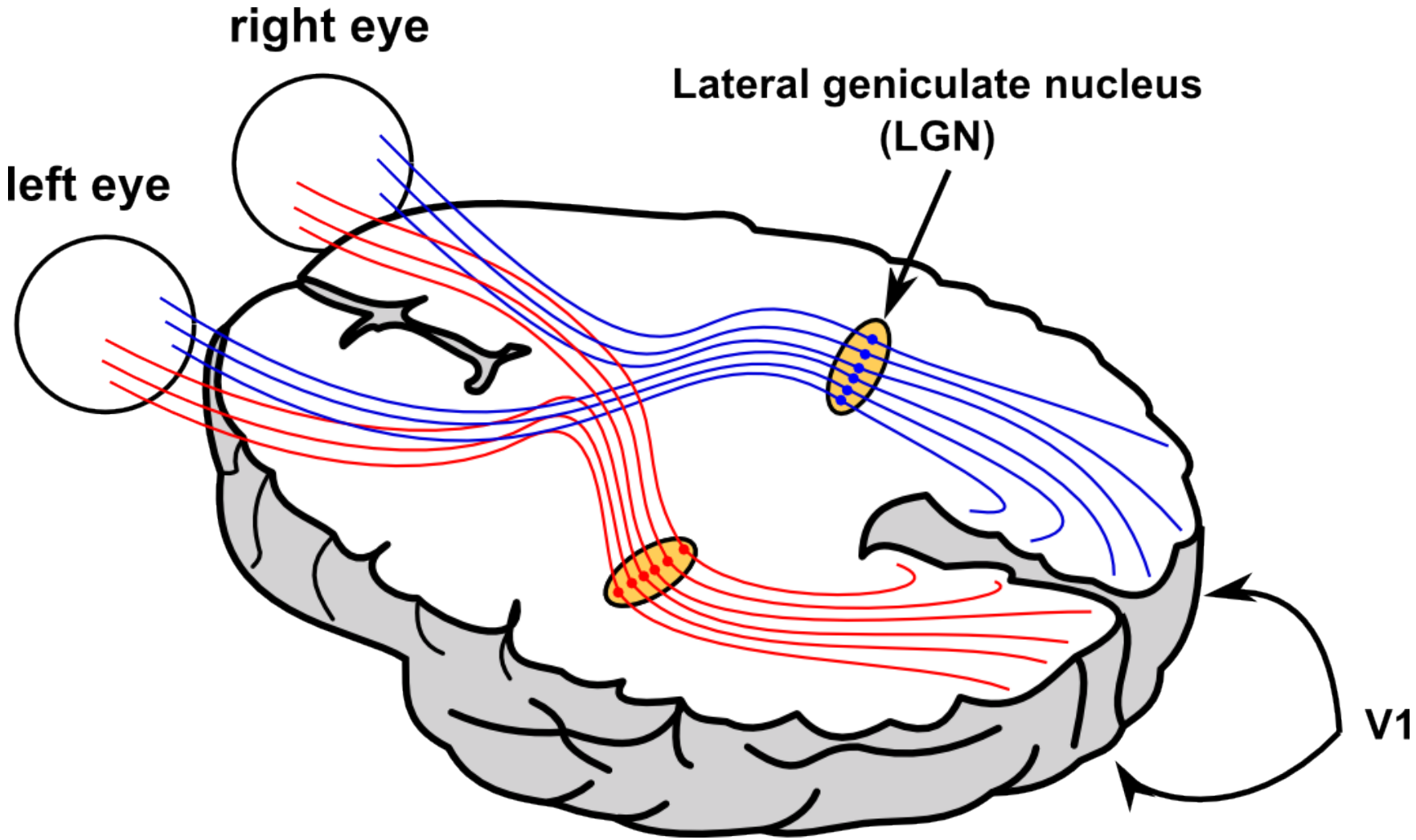
aka

STRIATE CORTEX

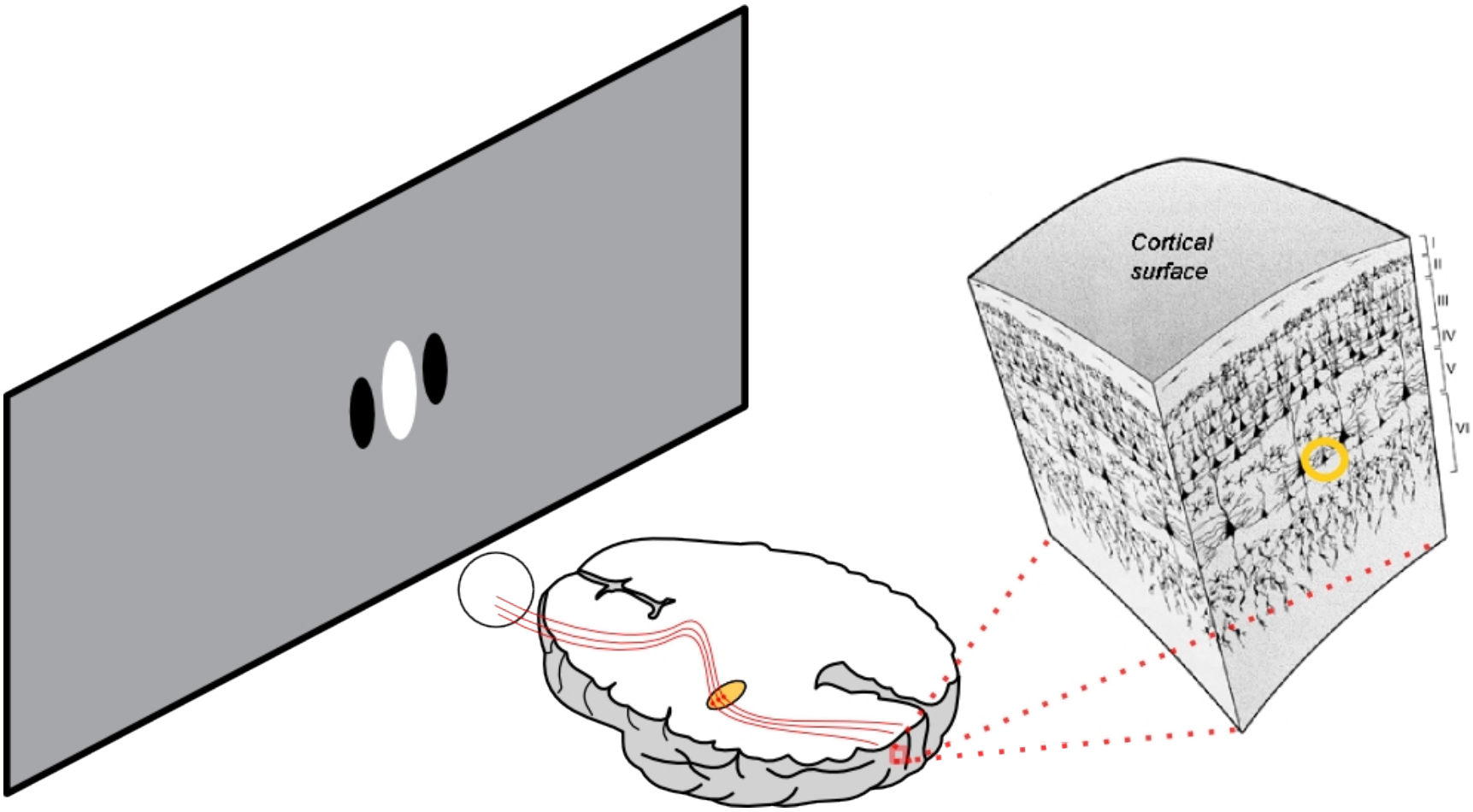
aka

V1

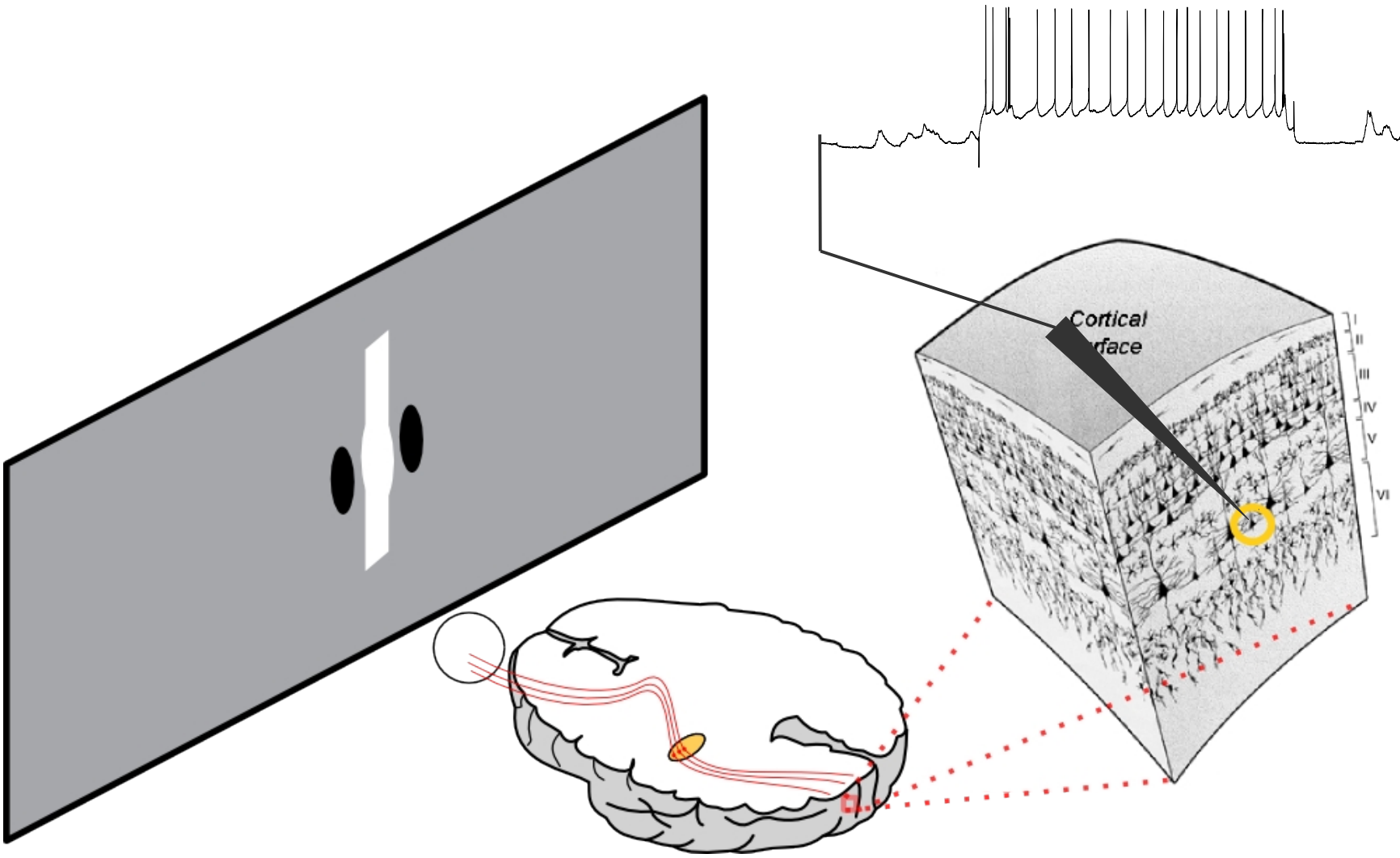
Early visual system



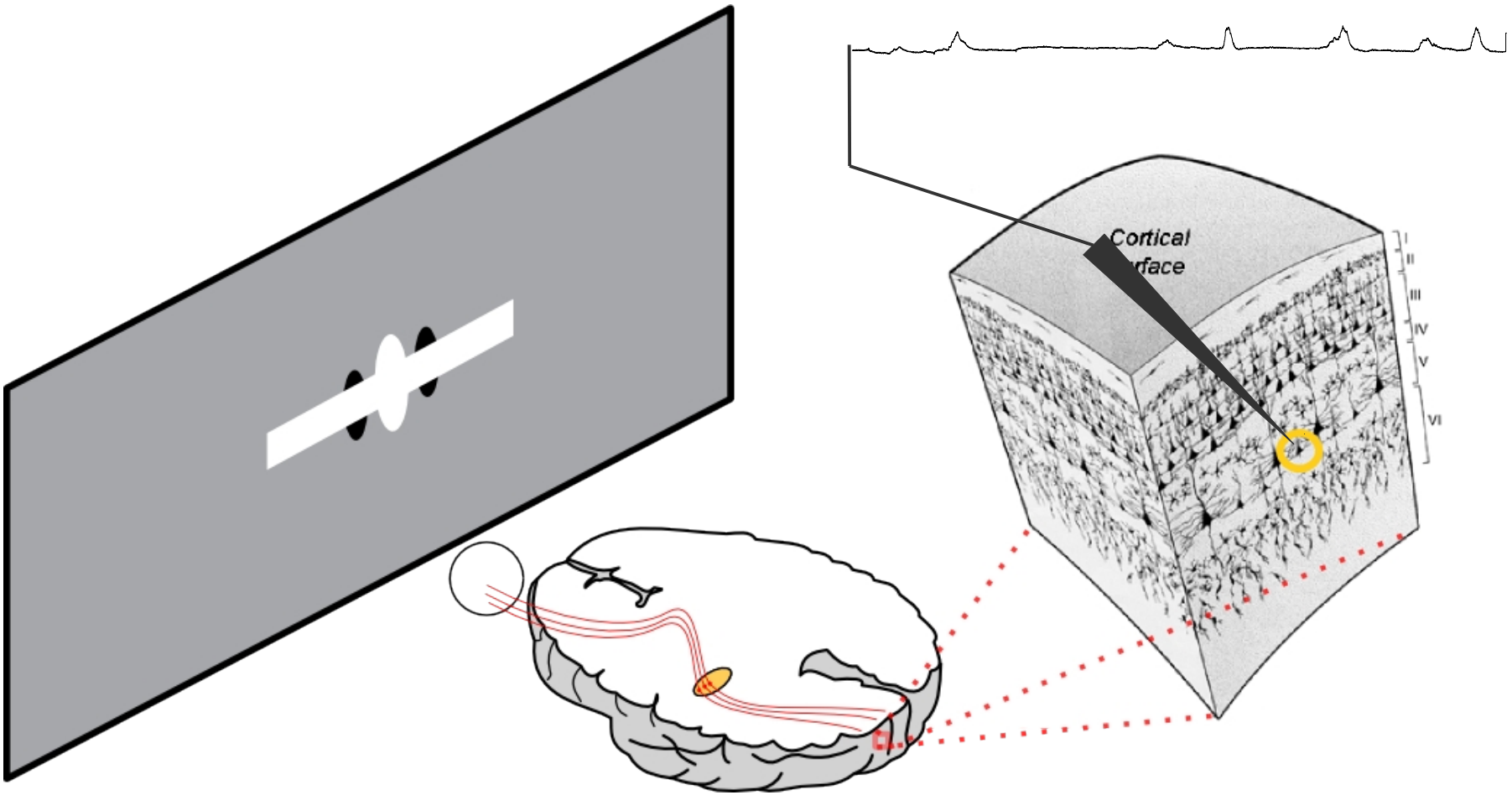
Receptive field – simple cells



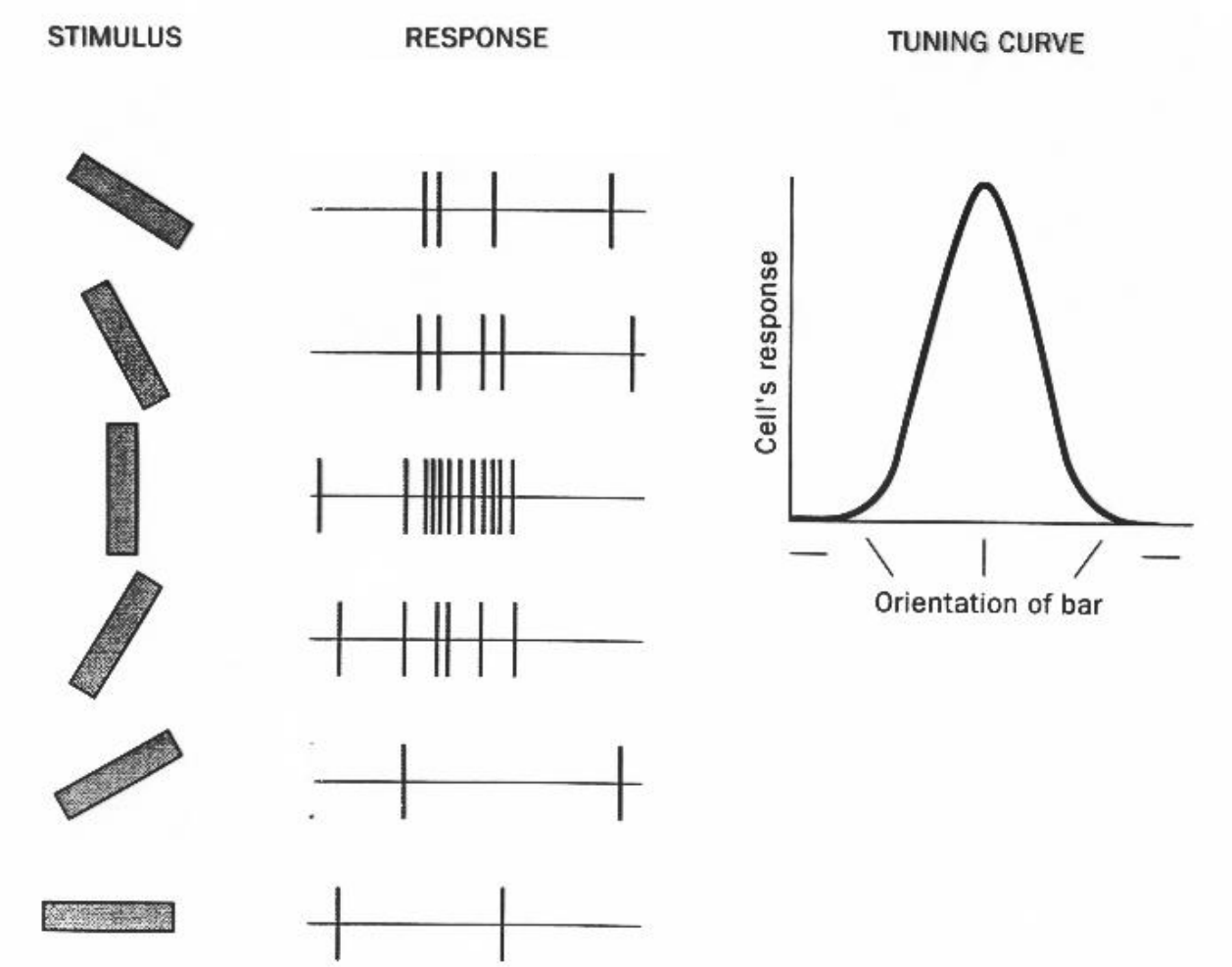
Receptive field – simple cells



Receptive field – simple cells



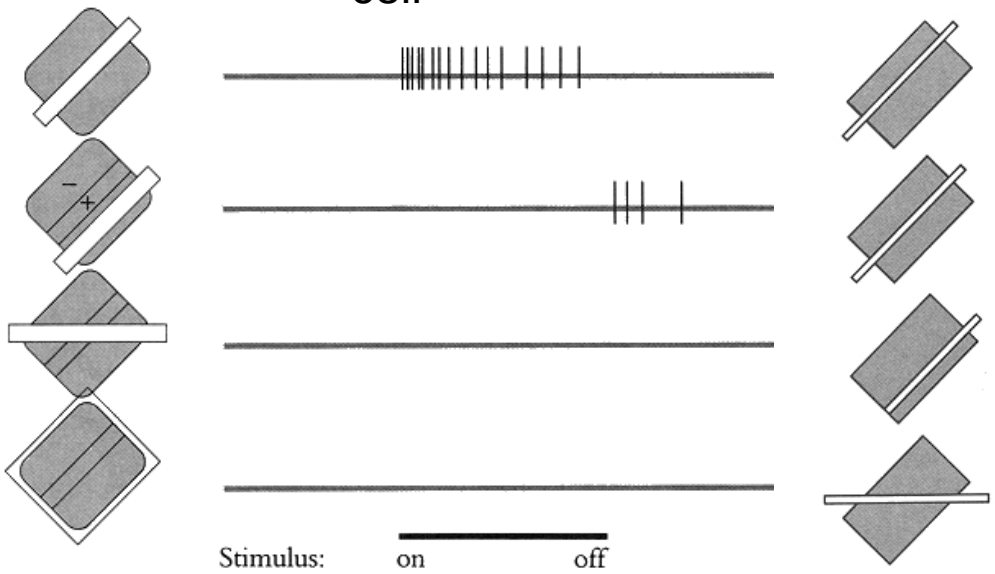
Orientation tuning curve



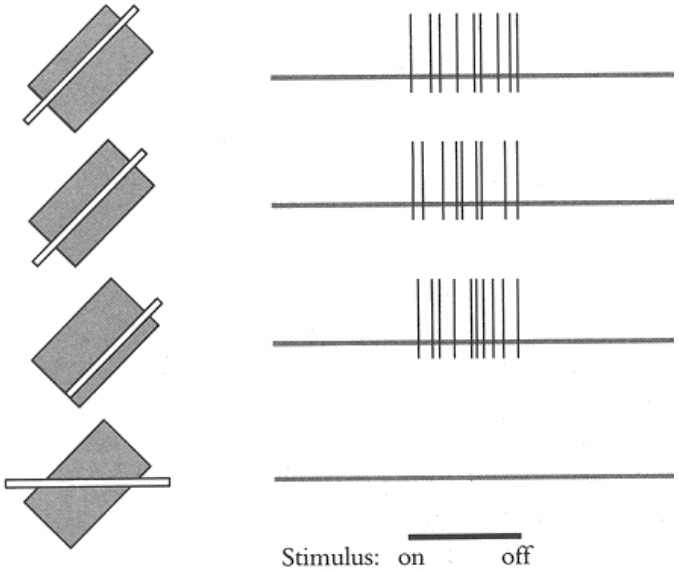
Complex cells

Flashed bar

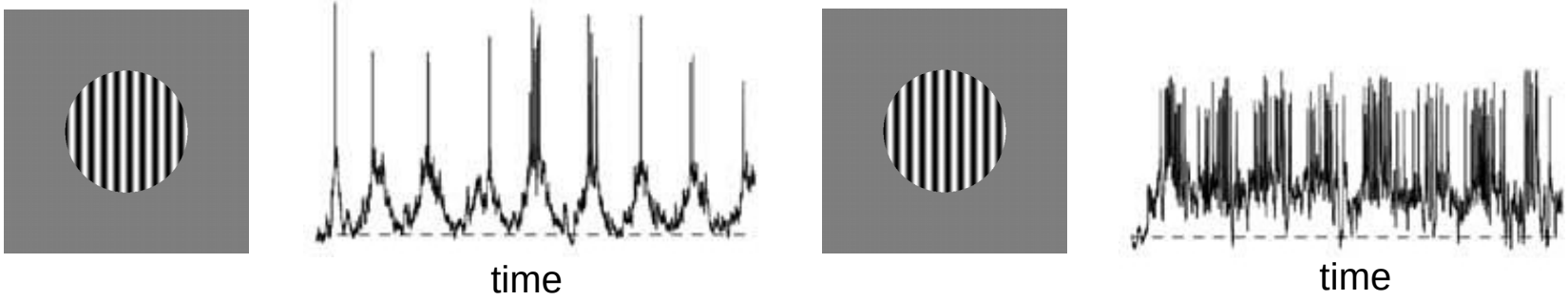
Simple cell



Complex cell

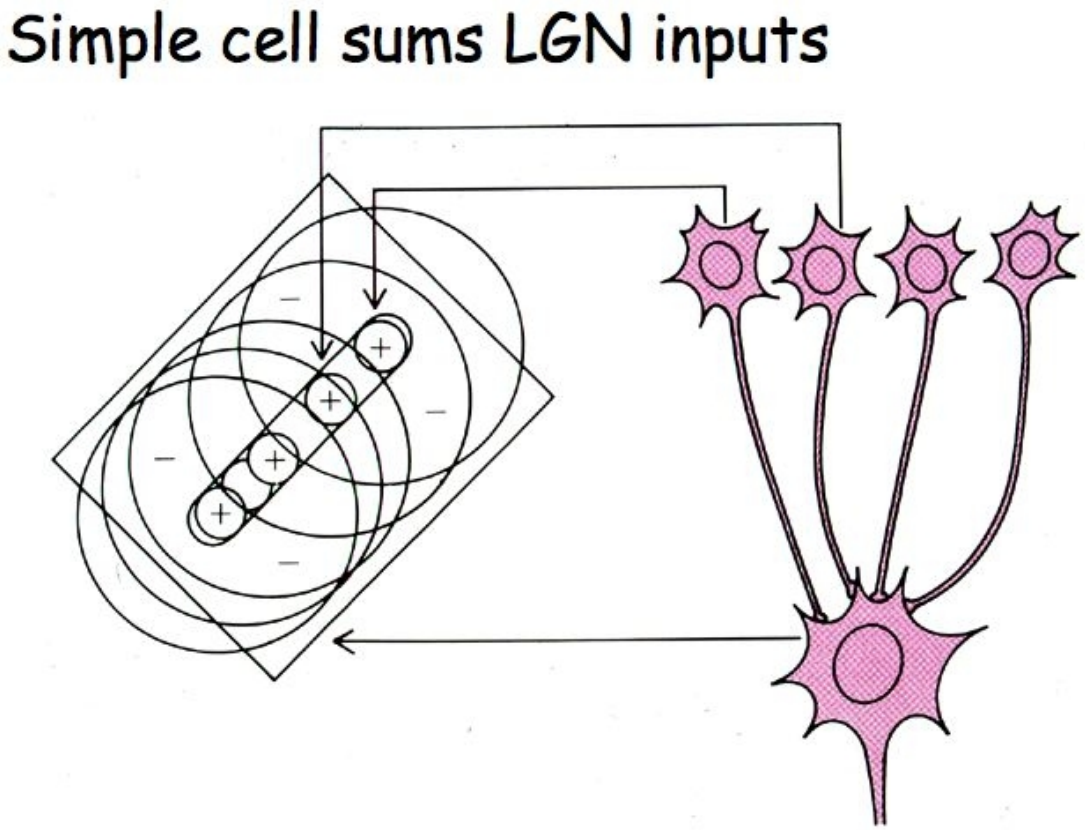


Drifting grating

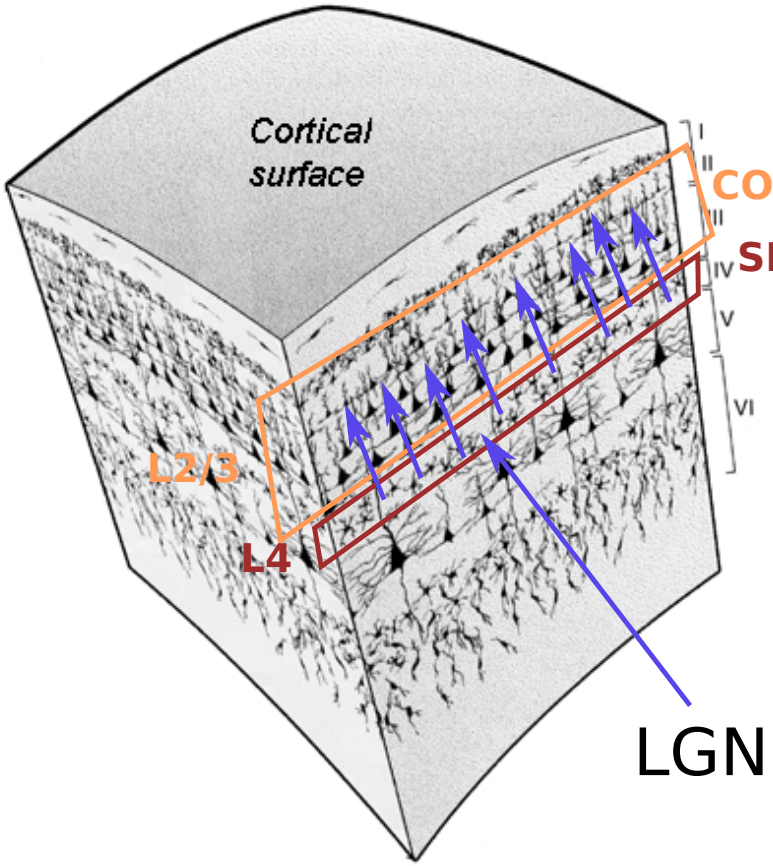


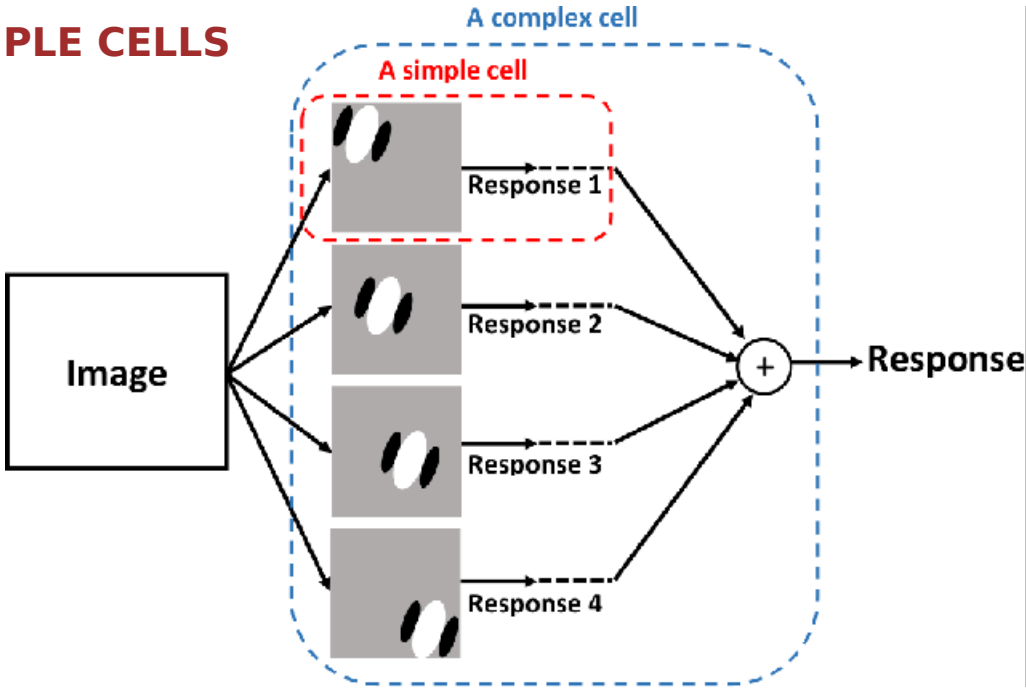
How is V1 simple cell formed from LGN inputs?

How is V1 simple cell formed from LGN inputs?

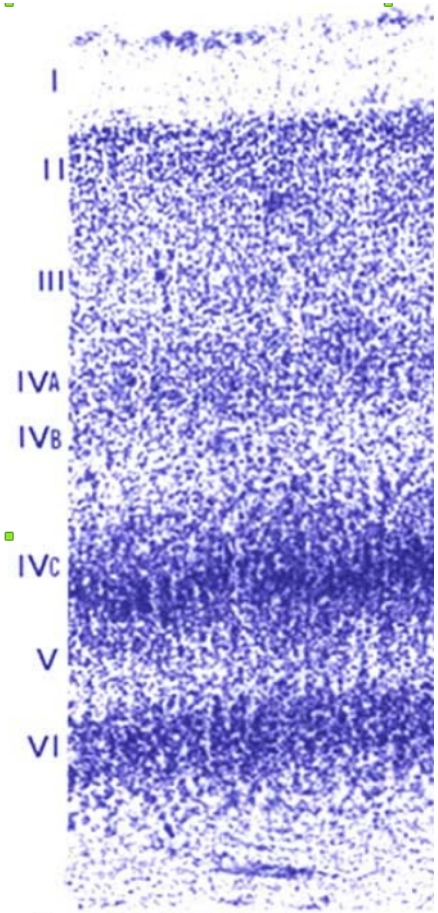


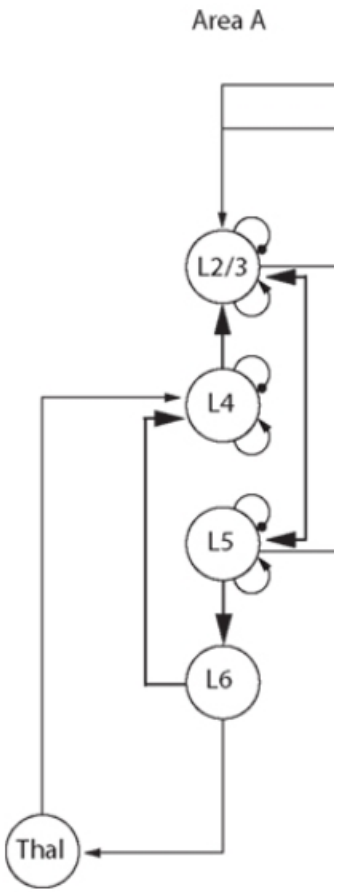
Simple to complex connectivity





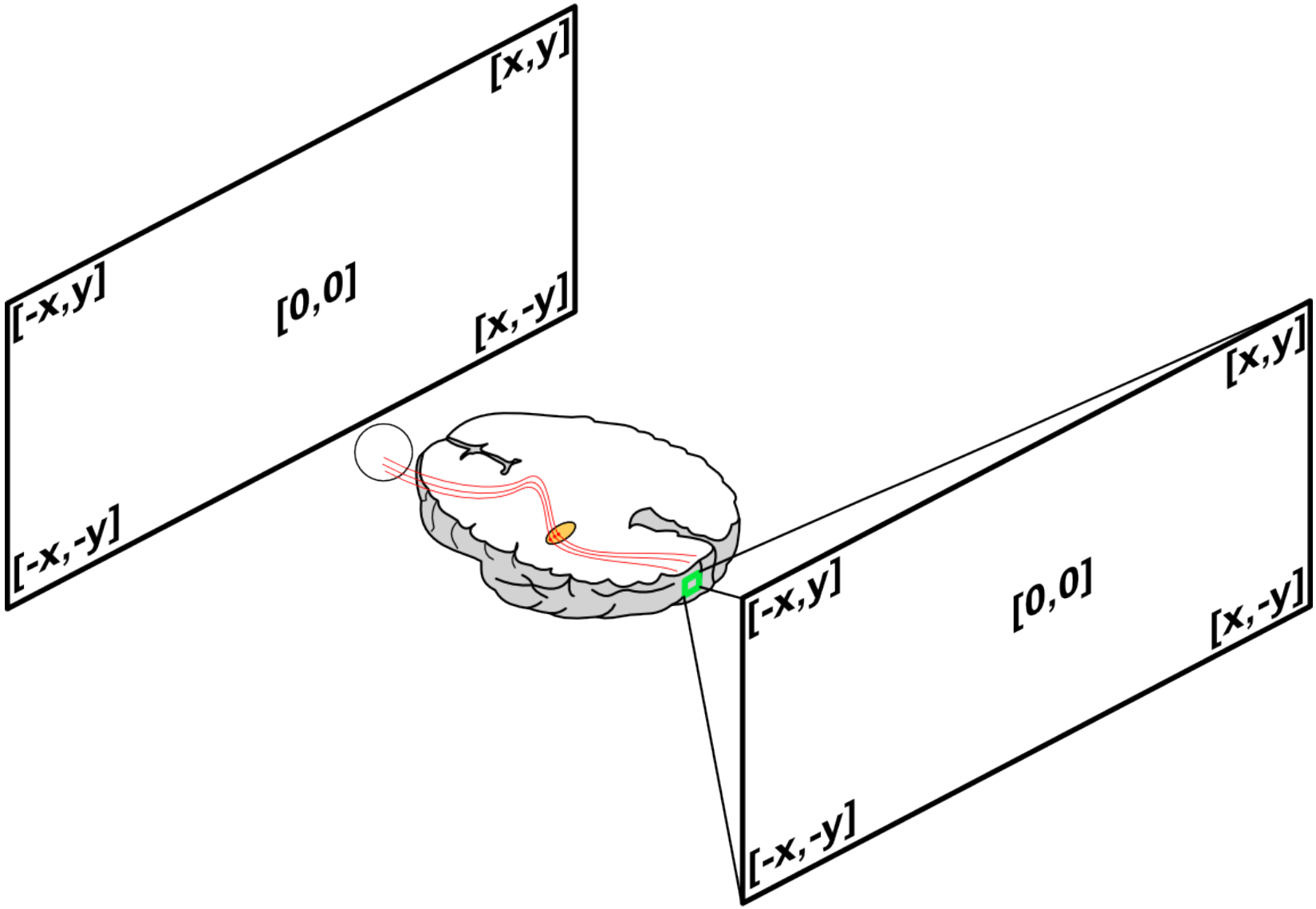
Cortical layers & Simple/Complex cells



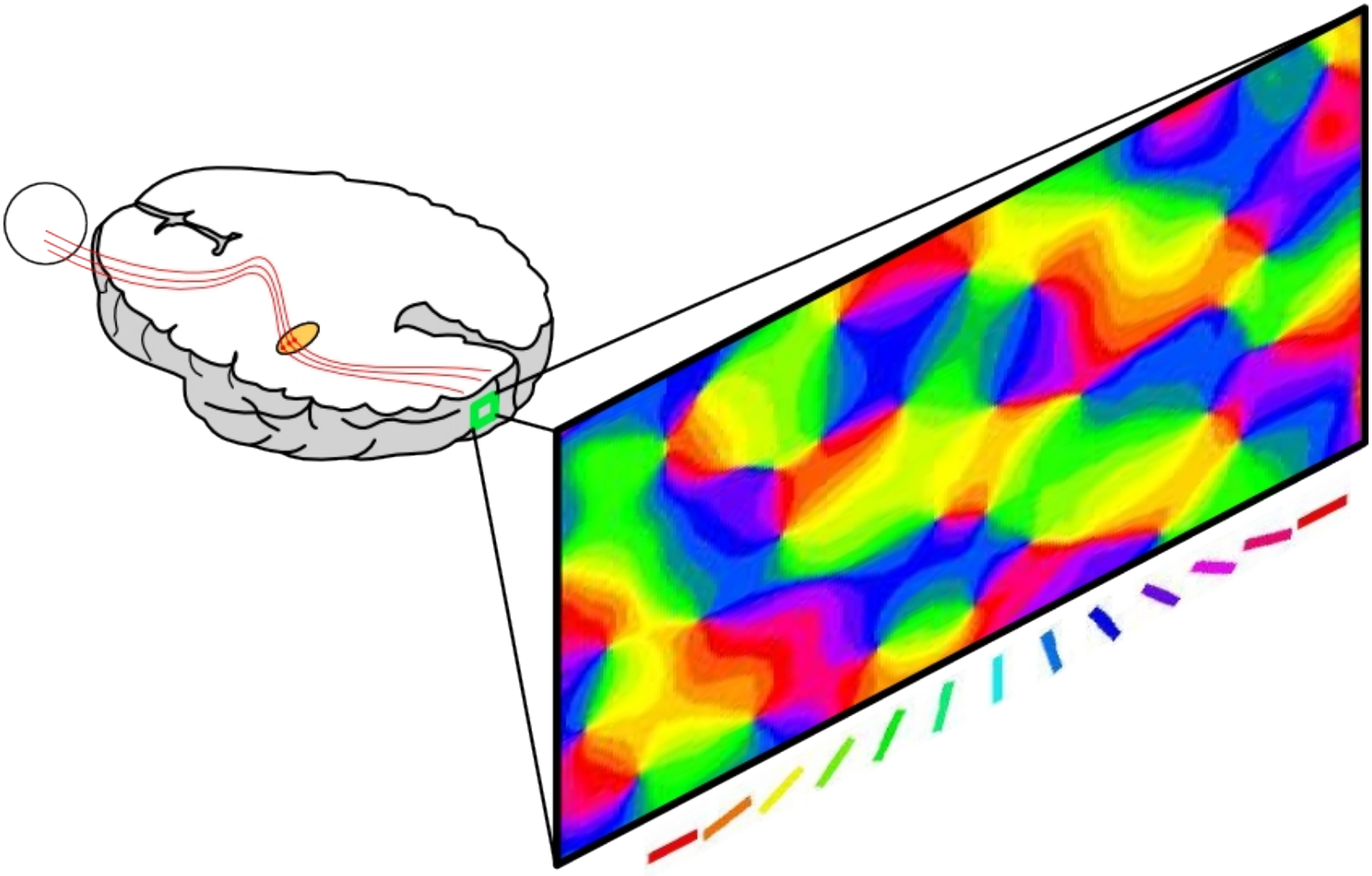


FUNCTIONAL ORGANIZATION

Retinotopic mapping in cortex



Functional topological maps in cortex



Other features are mapped on the surface of V1

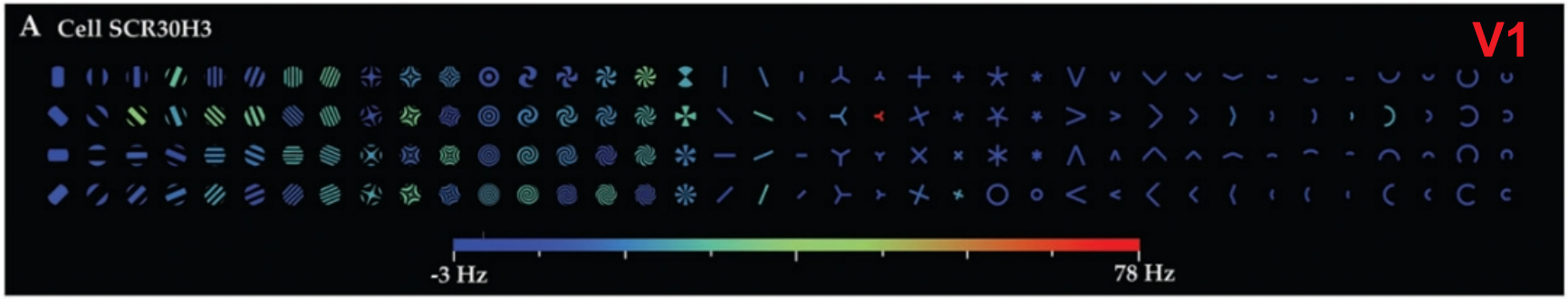
- Retinotopy
- Orientation
- Occular dominance
- Binocular disparity
- Color
- Spatial Frequency
- ?

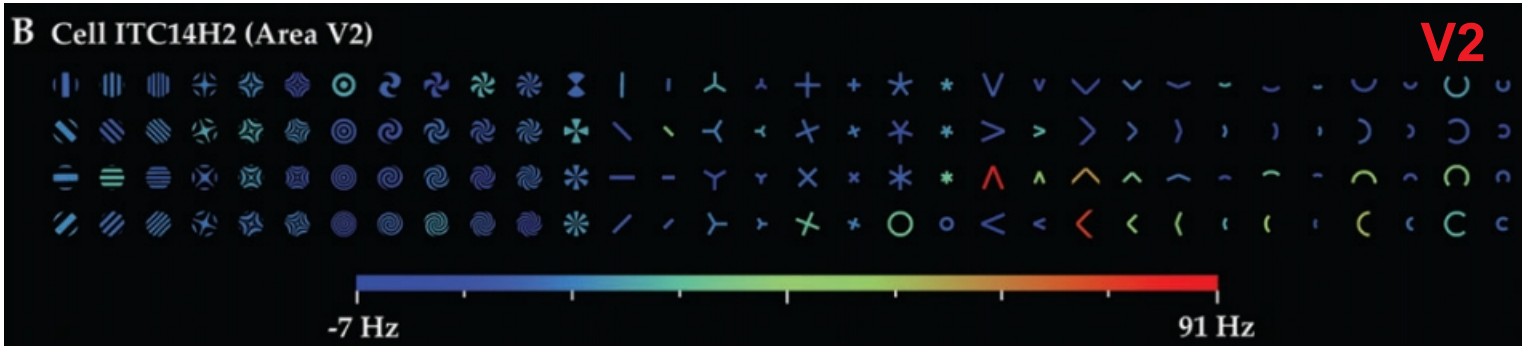
Secondary Visual Area

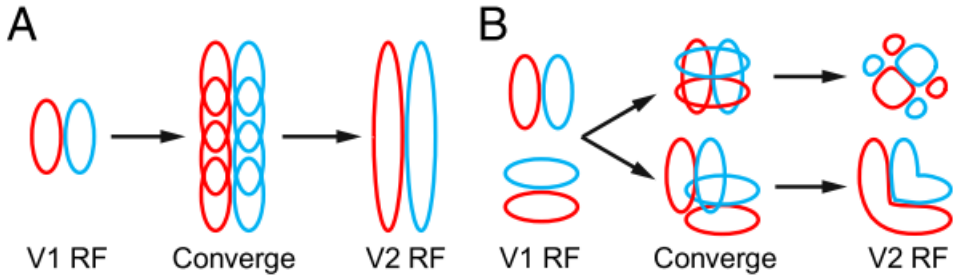
aka

V2

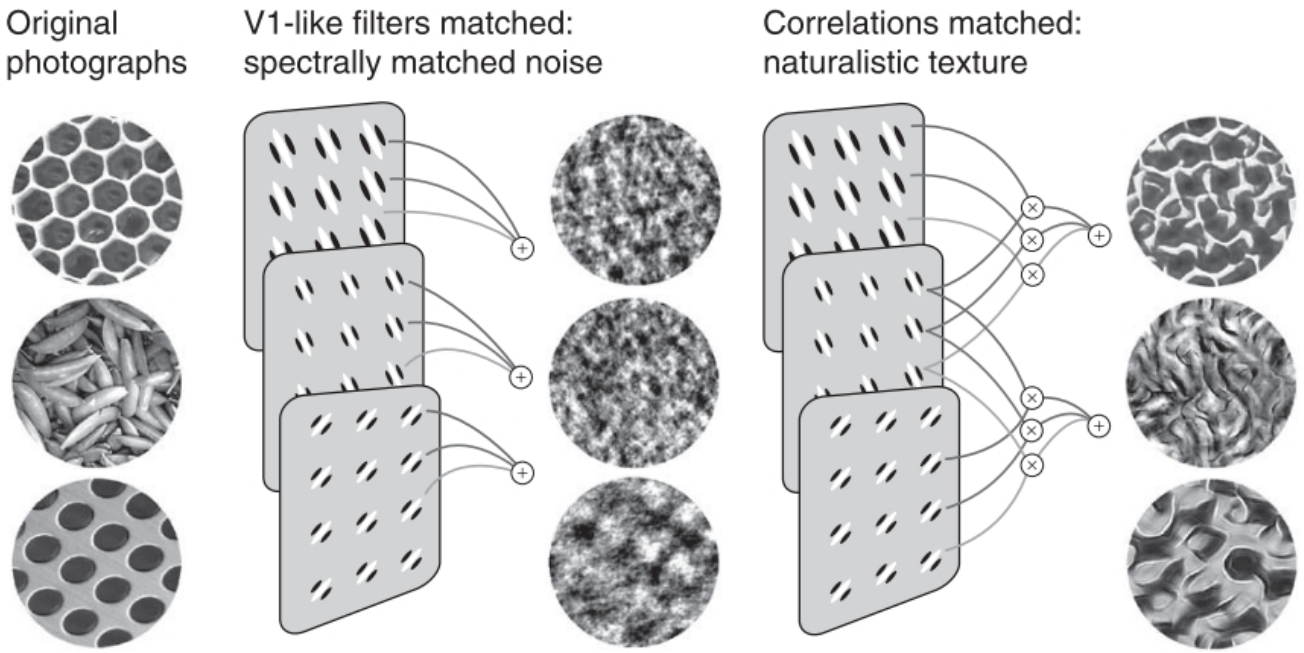
Receptive fields in V2

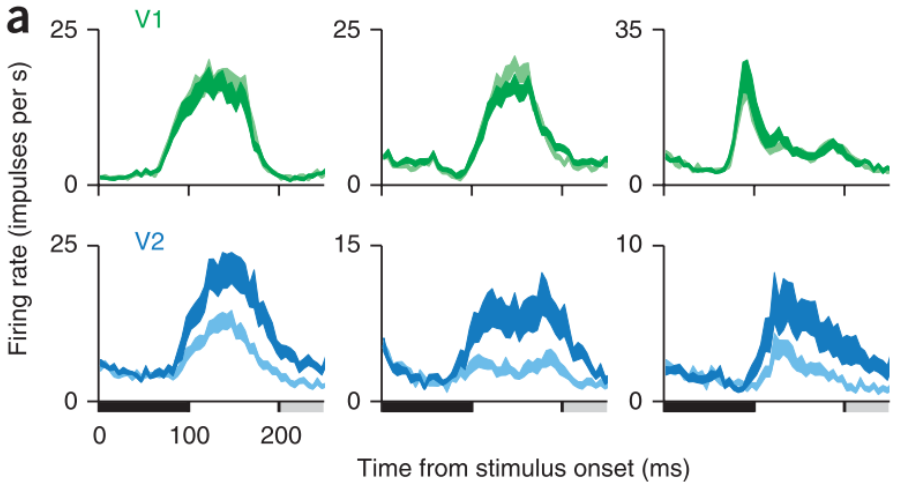




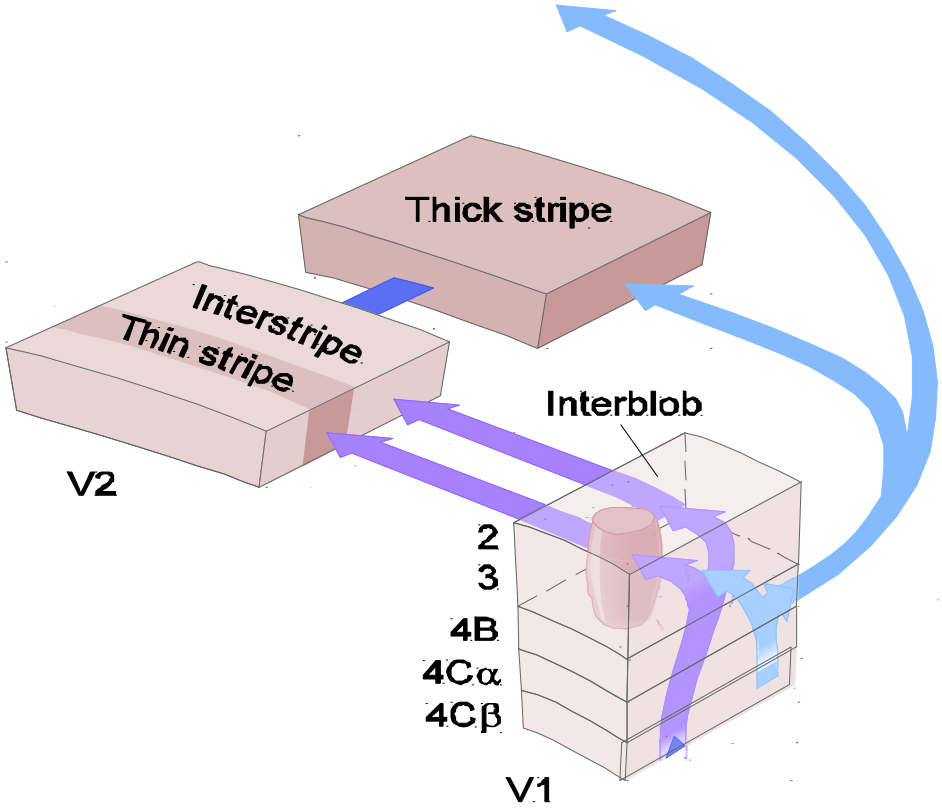


Processing of higher-order correlations

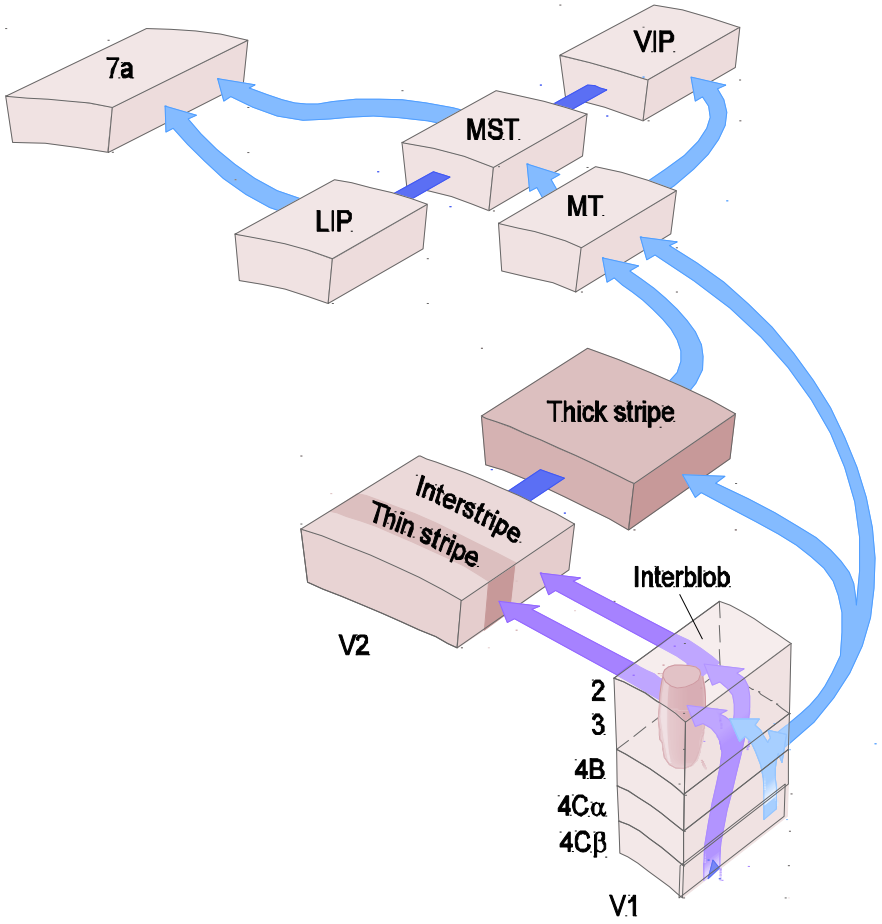




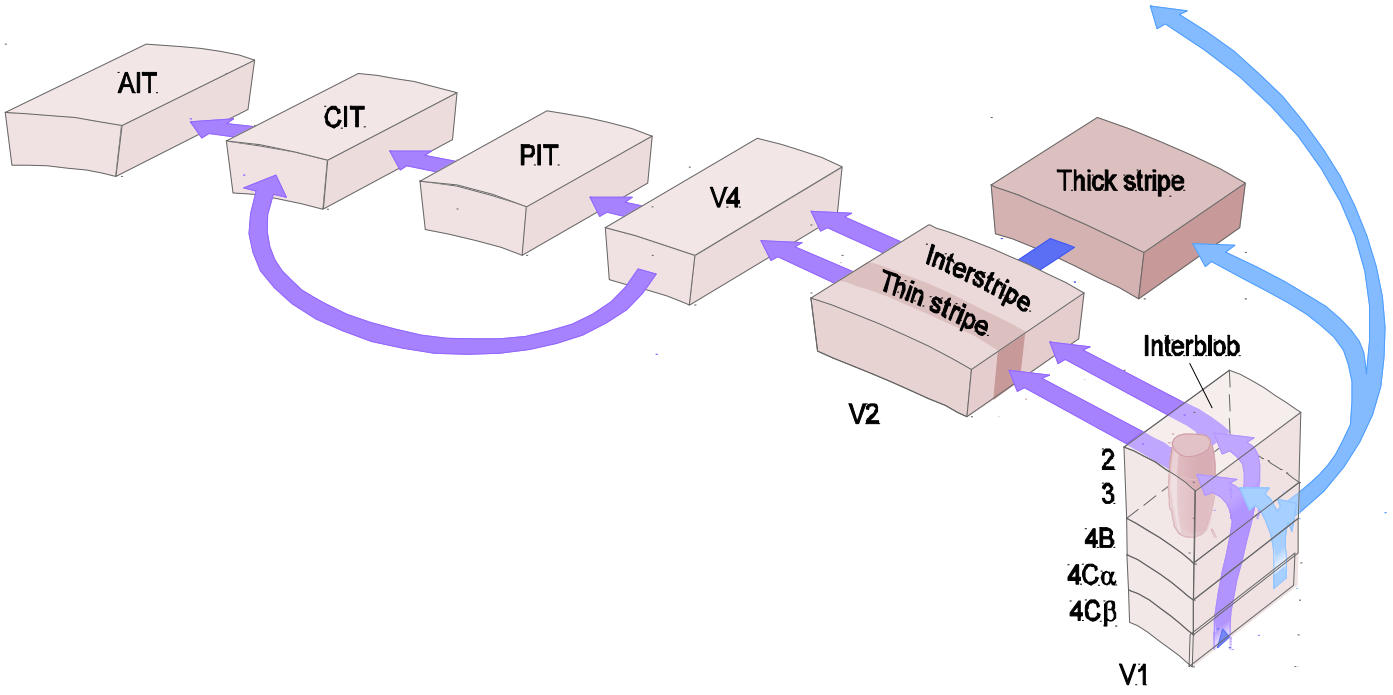
Beyond V2


Thick stripe
Interstripe
Thin stripe
V2
Interblob
2
3
4B
4Cα
4Cβ
V1

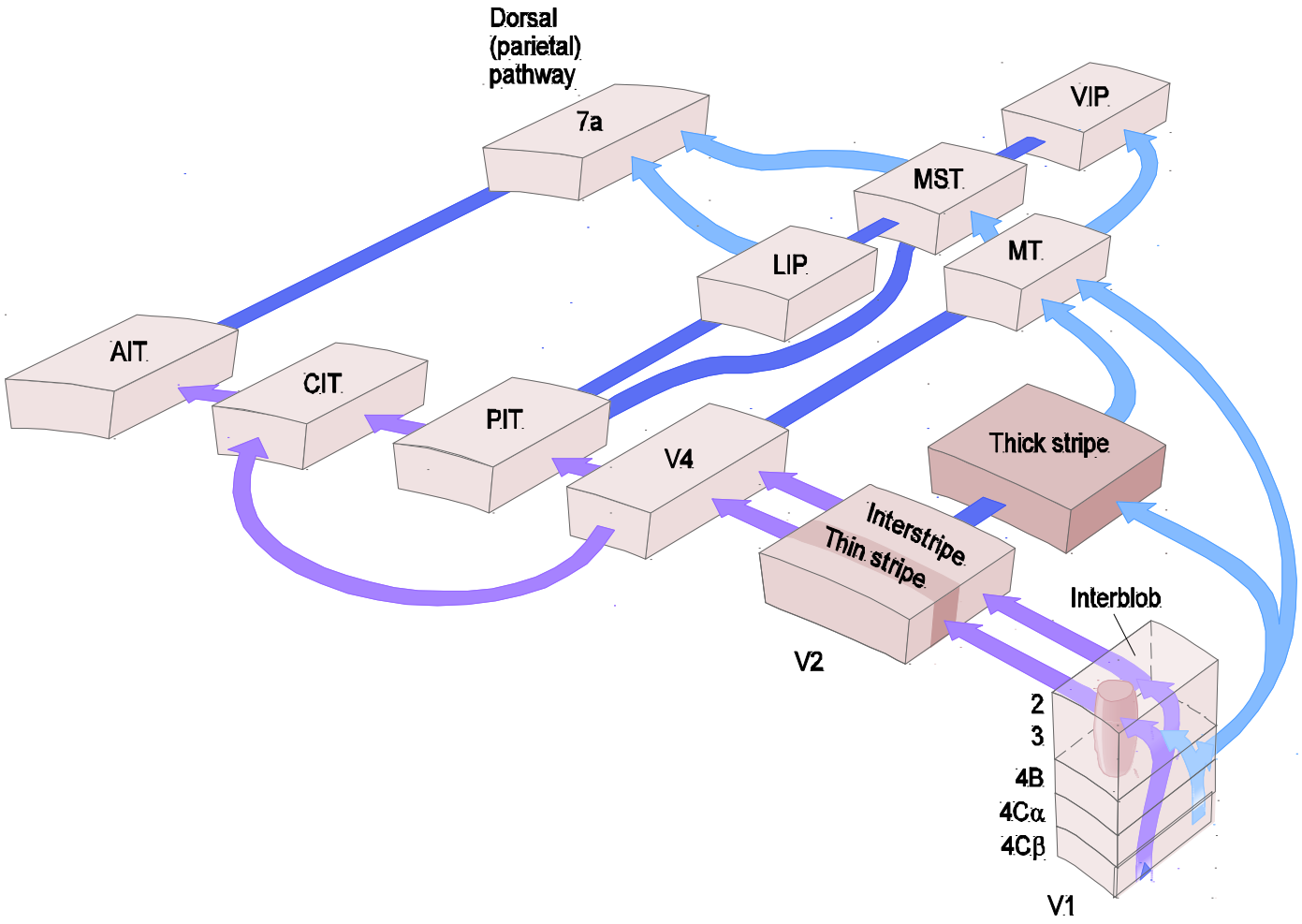
Dorsal stream - ‘where and why’



Ventral stream - ‘what’



And of course they are interconnnected



MODELS OF EARLY VISUAL SYSTEM

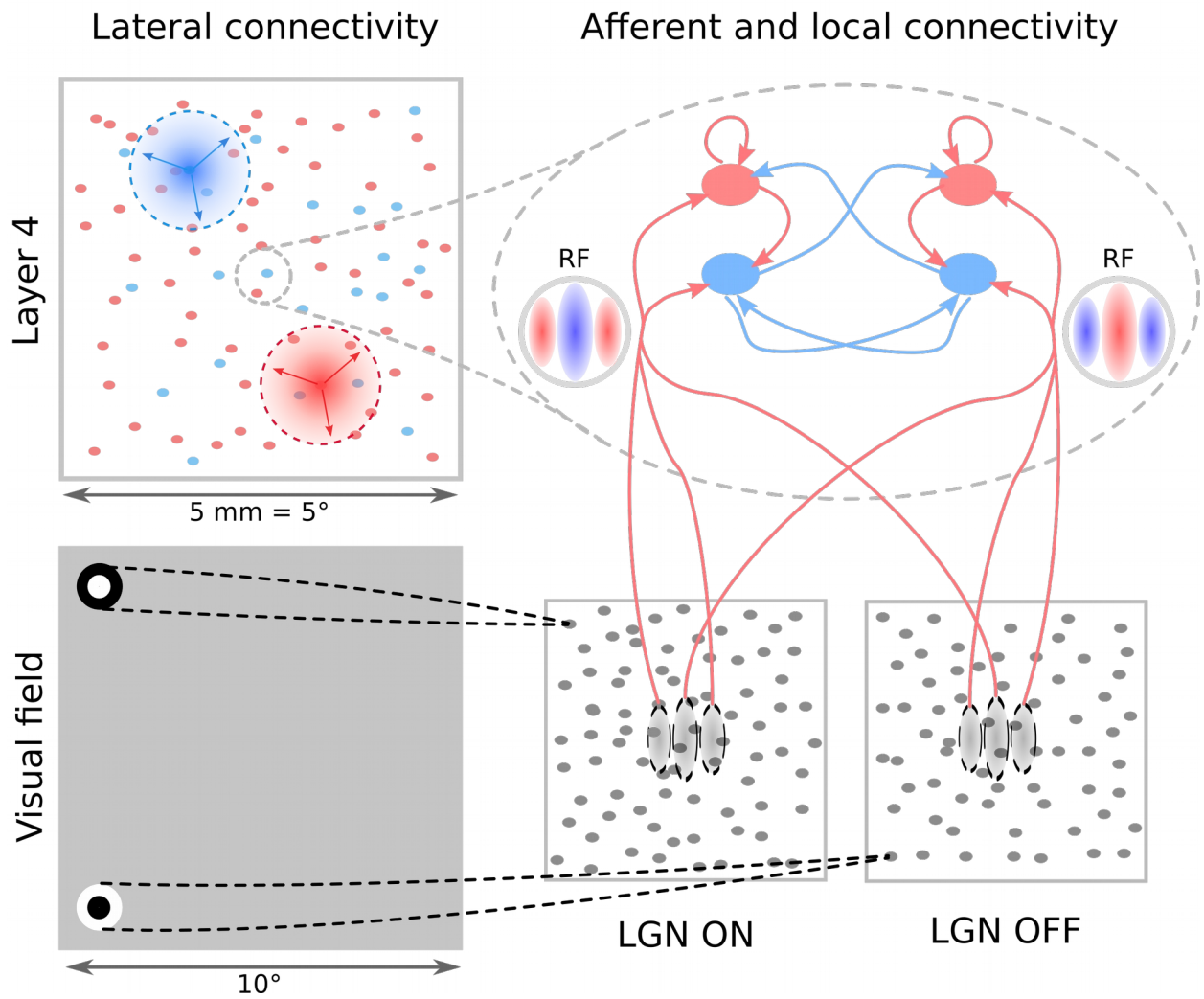
THE MODEL (neuron model)

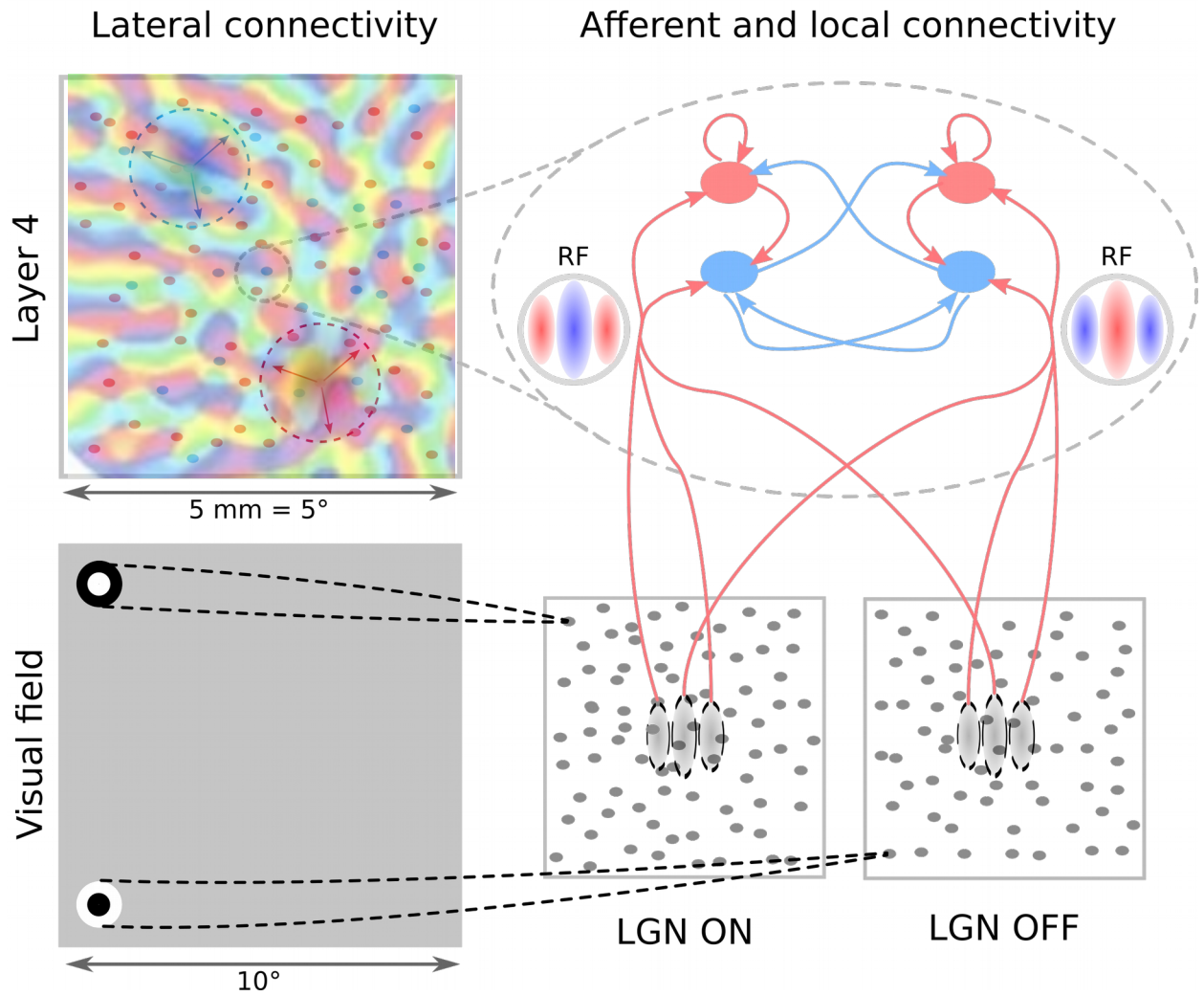
- 4:1 exc:inh ratio, ~10^5 neurons and ~10^8
- Adaptive exponential integrate and fire model

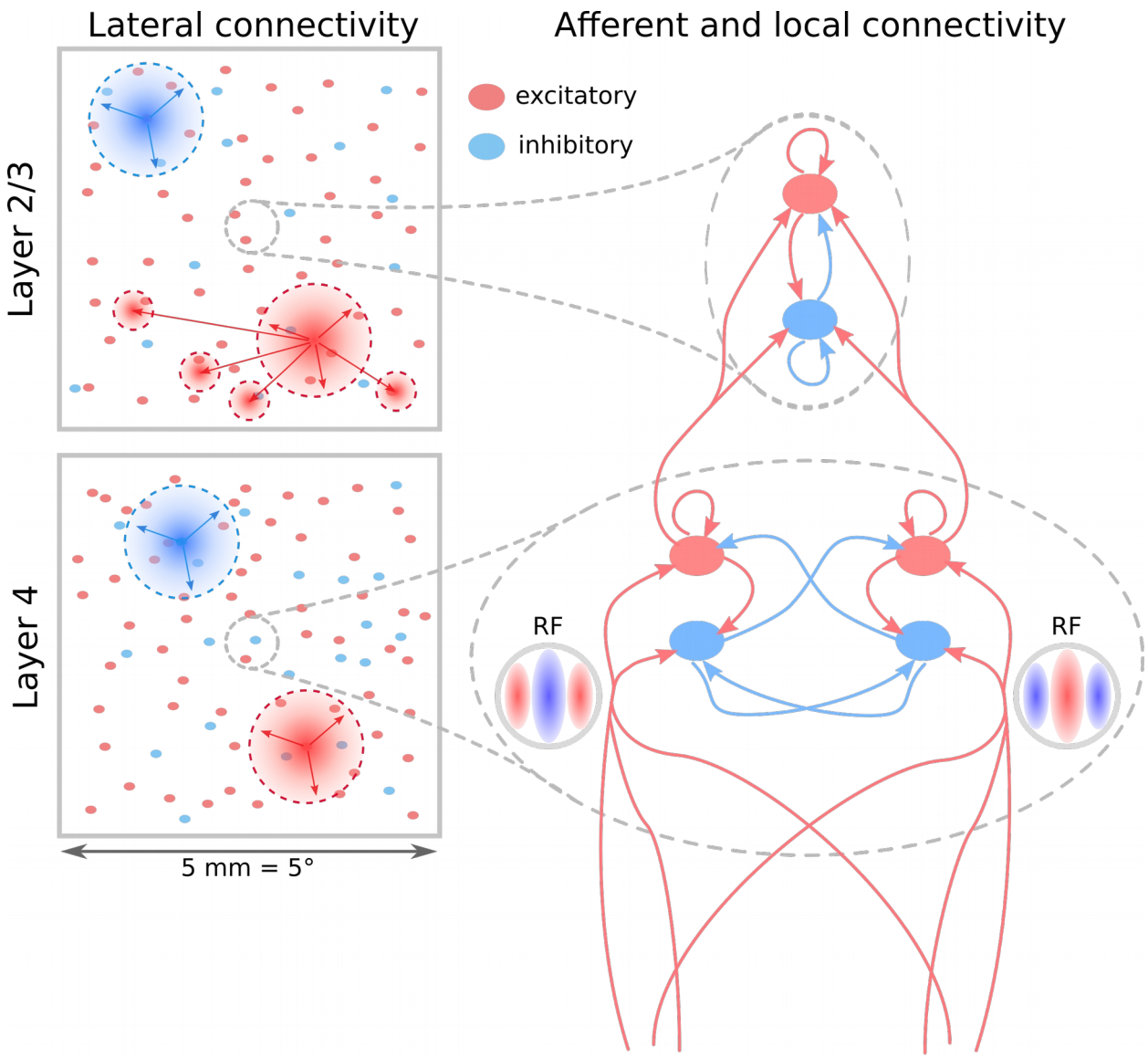
$$C\frac{dV}{dt} = -g_L(V - E_L) + g_L\Delta_T \exp(\frac{V - V_T}{\Delta_T}) - w + I \qquad (1)$$

$$\tau_w \frac{dw}{dt} = a(V - E_L) - w \qquad (2)$$

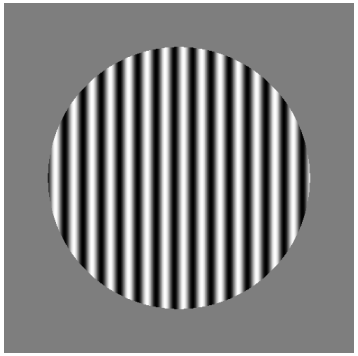
- Synaptic depression
  - Thalamo-cortical pathway
  - Cortico-cortical synapses

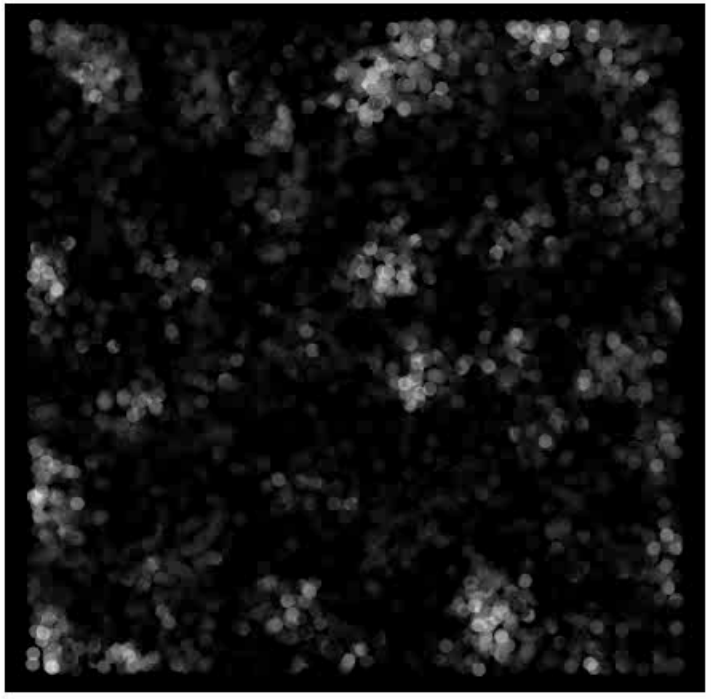

Lateral connectivity
Afferent and local connectivity
Layer 4
RF
RF
5 mm = 5°
Visual field
LGN ON
LGN OFF
10°

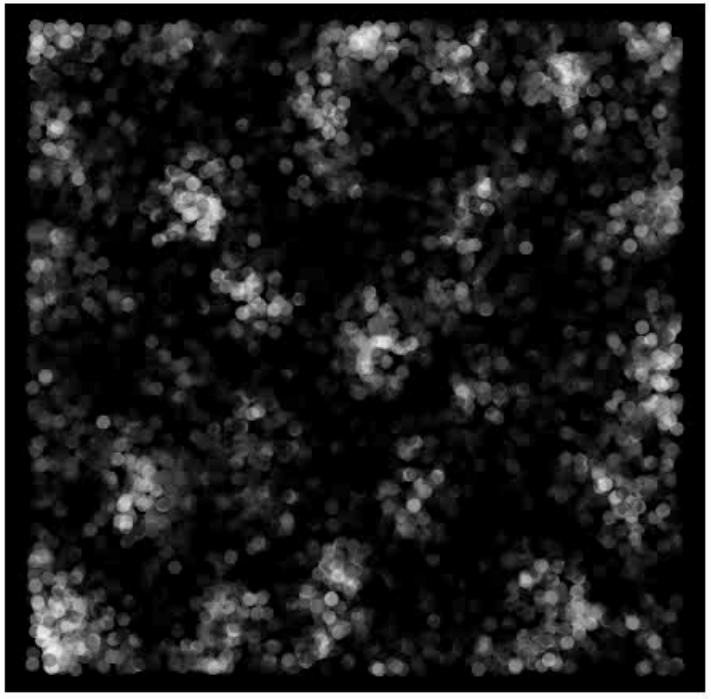

Lateral connectivity
Afferent and local connectivity
Layer 4
RF
RF
5 mm = 5°
Visual field
LGN ON
LGN OFF
10°


Lateral connectivity
Afferent and local connectivity
excitatory
inhibitory
Layer 2/3
Layer 4
RF
RF
5 mm = 5°

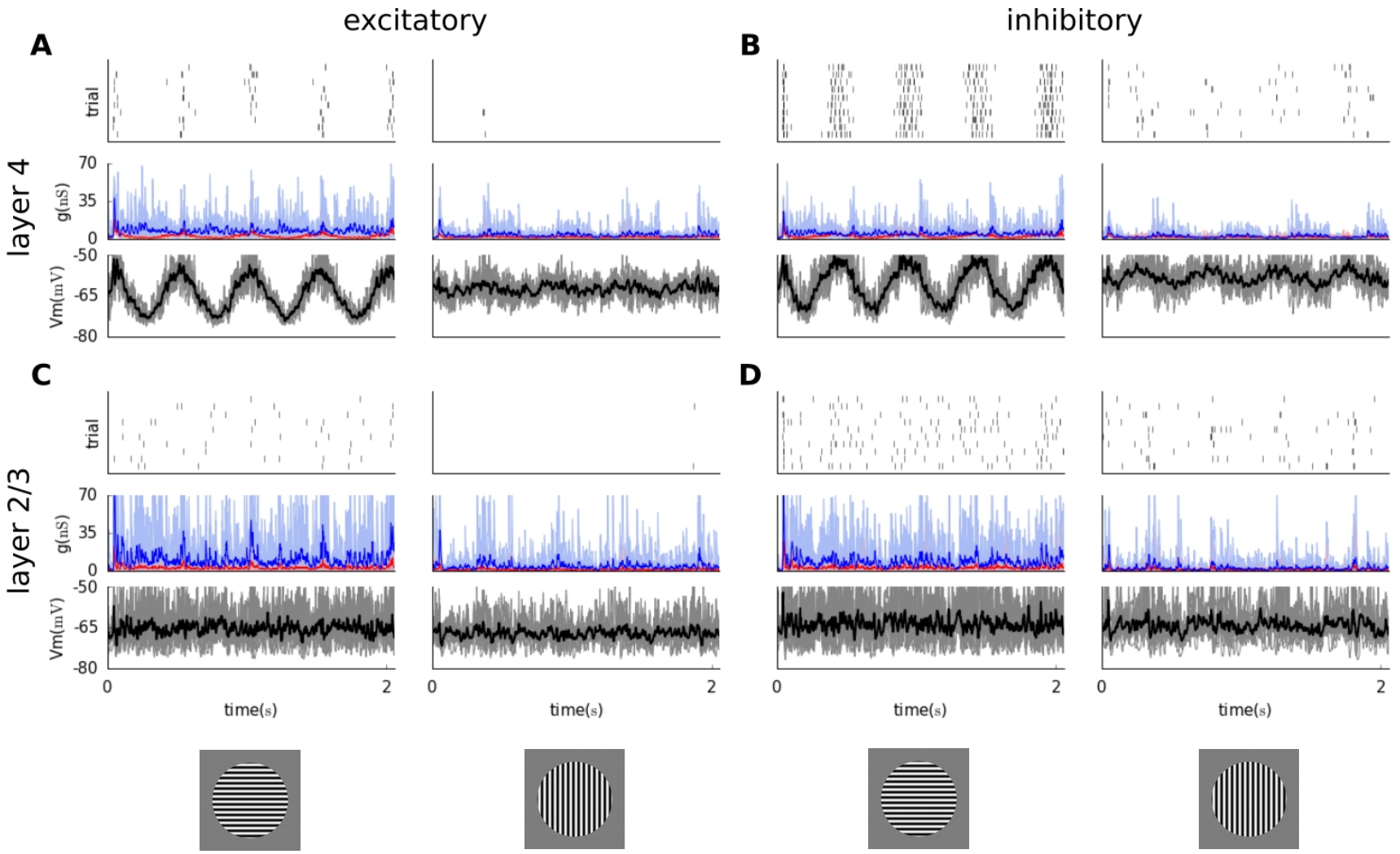
Grating response in layer 2/3



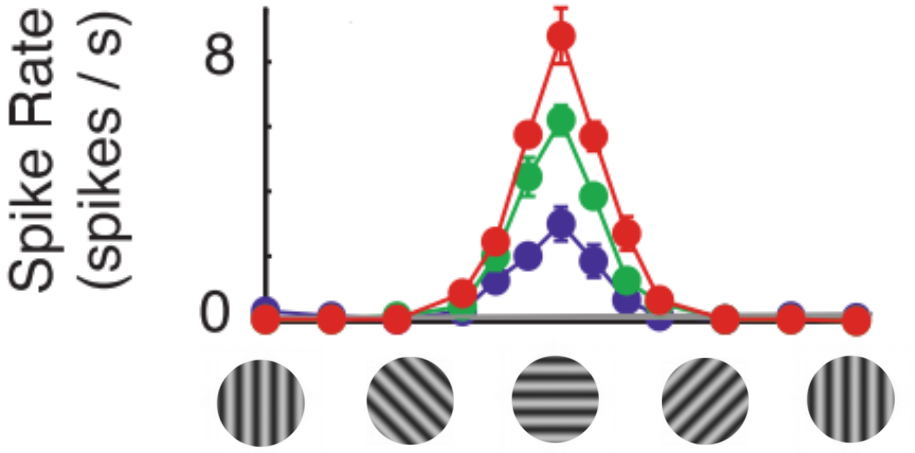




Grating response

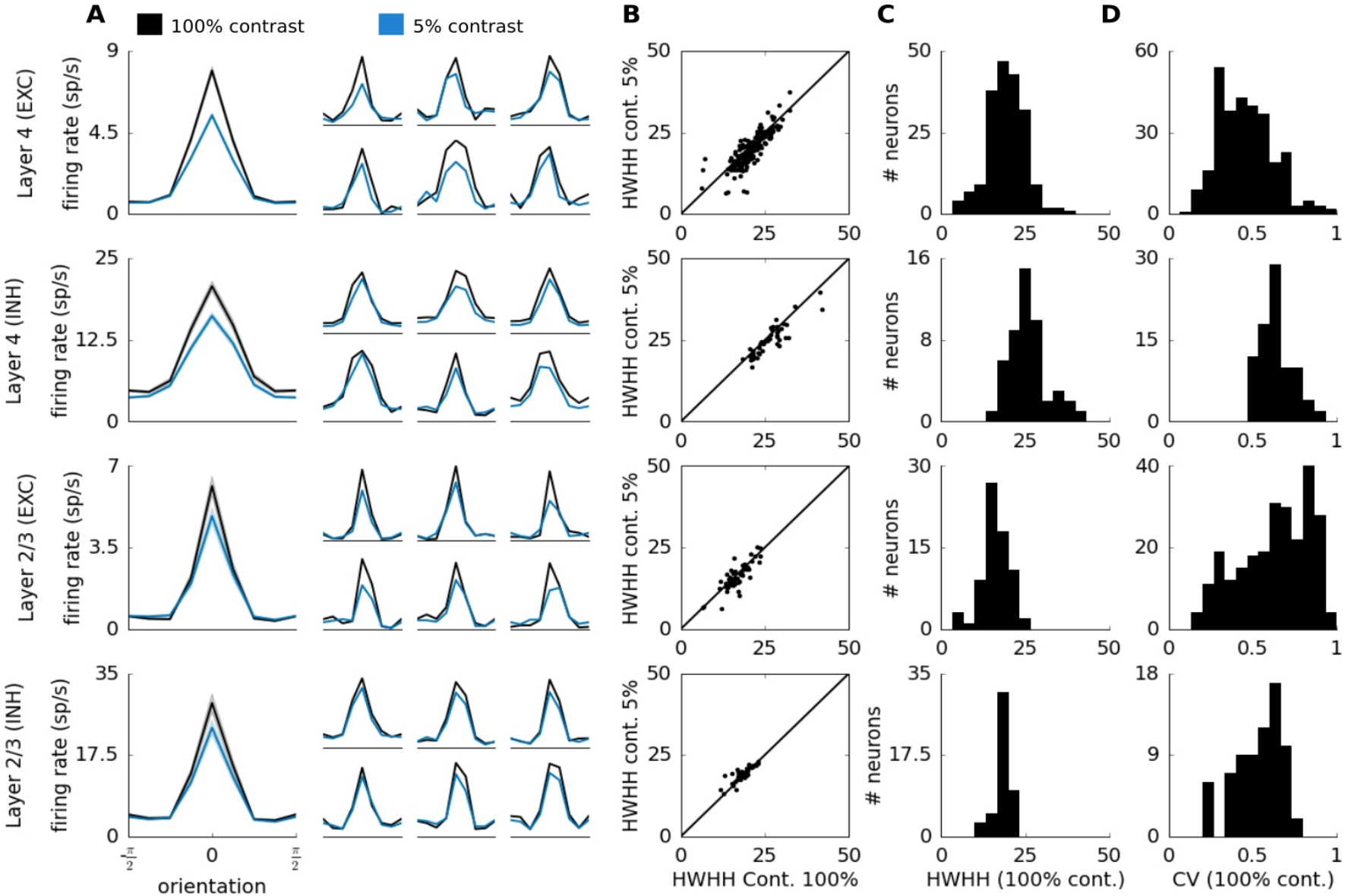


Orientation tuning (DATA)



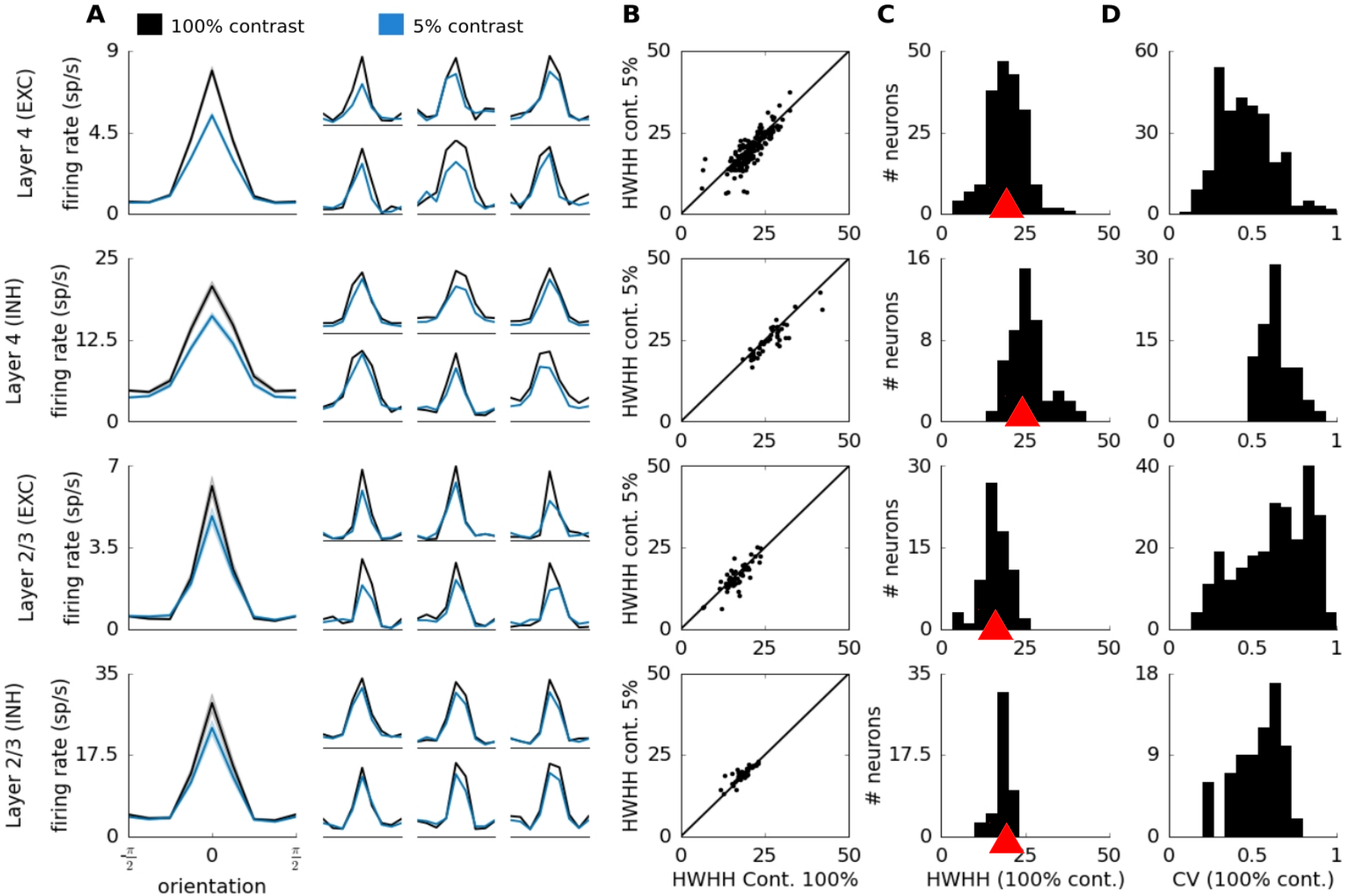
Cat, Anderson et al. (2000)

Orientation tuning

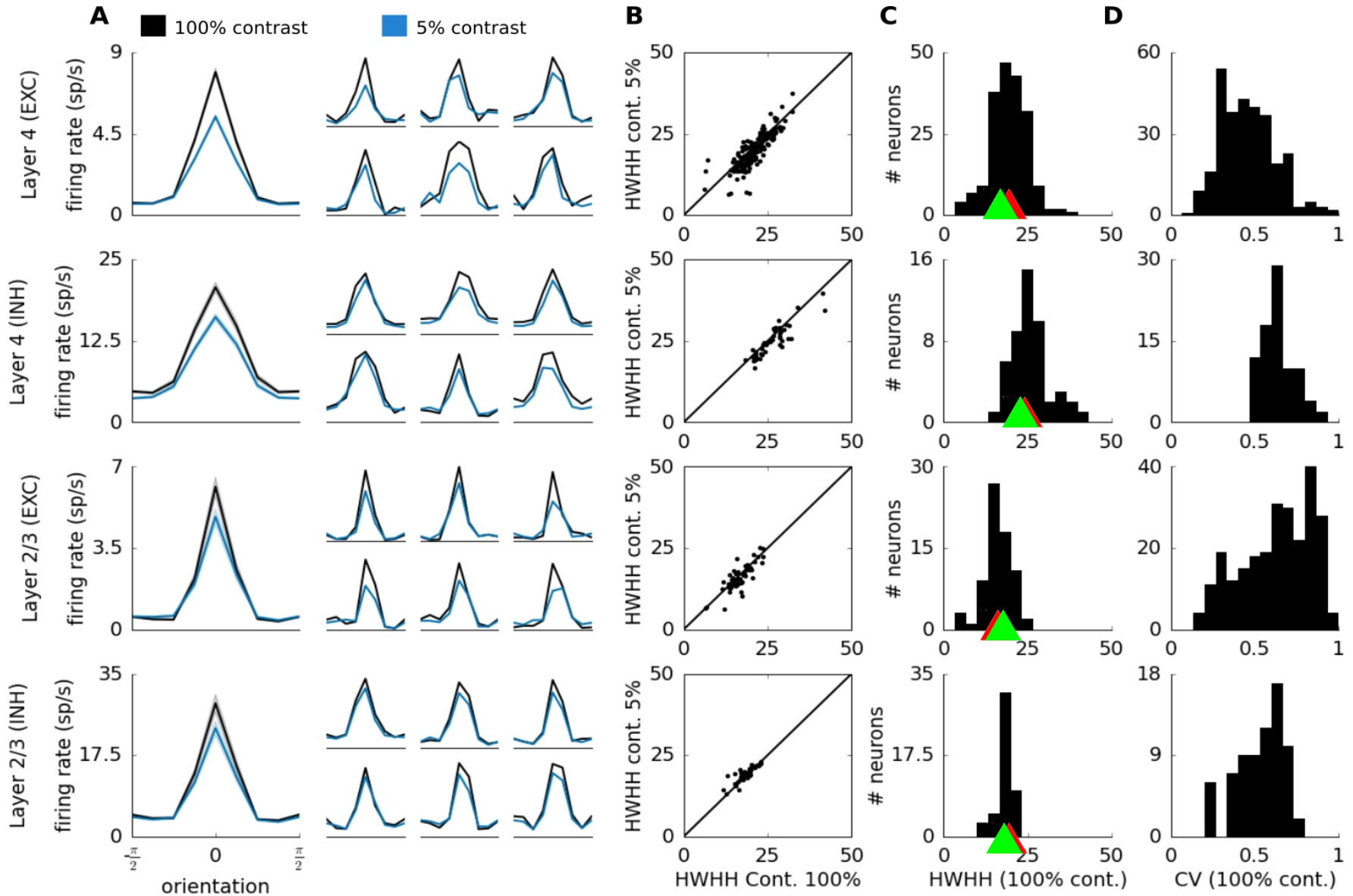


Orientation tuning

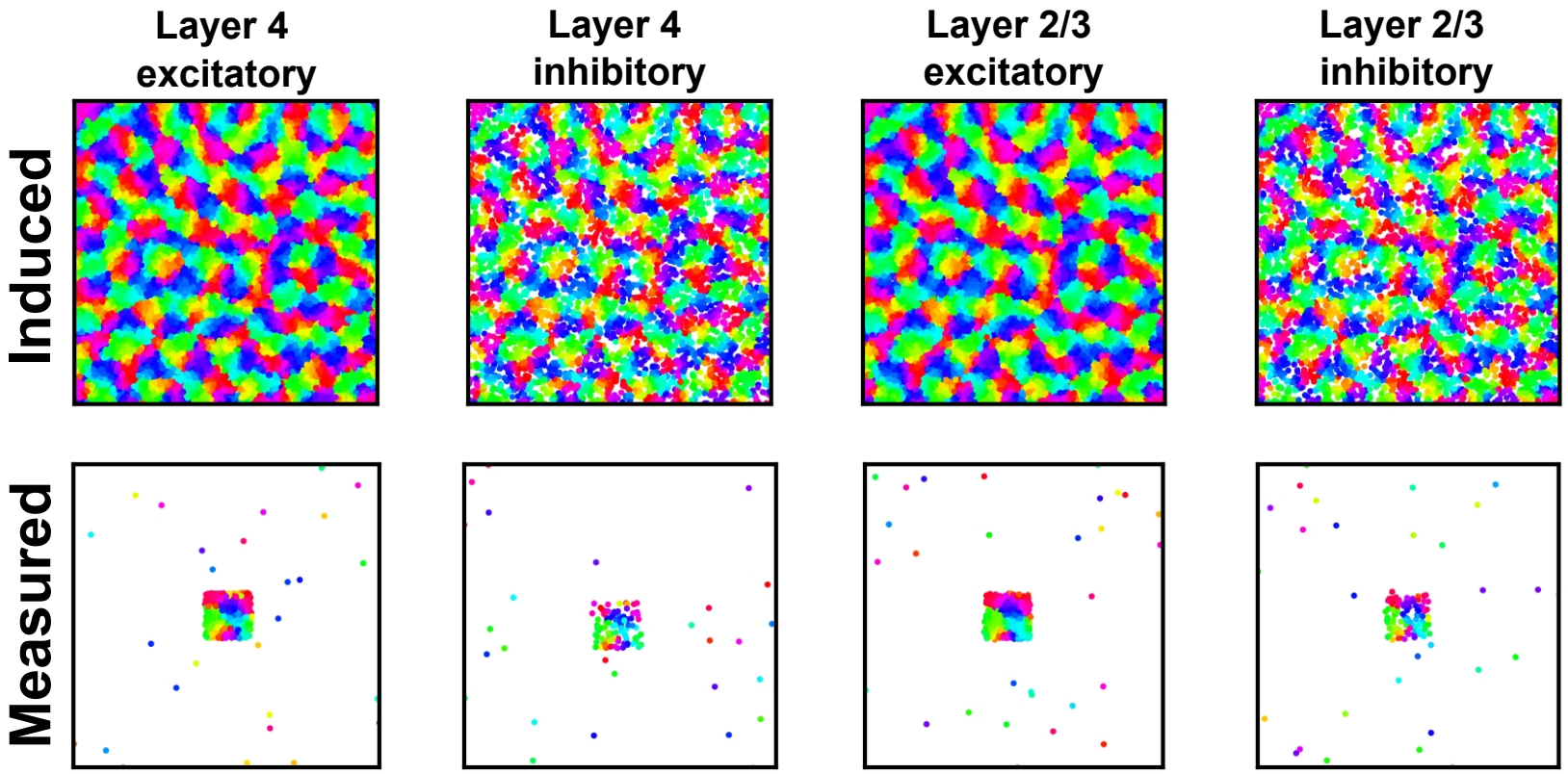
Model



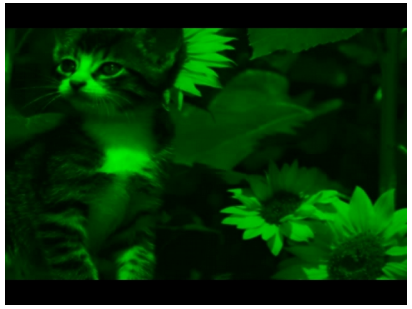
Orientation tuning

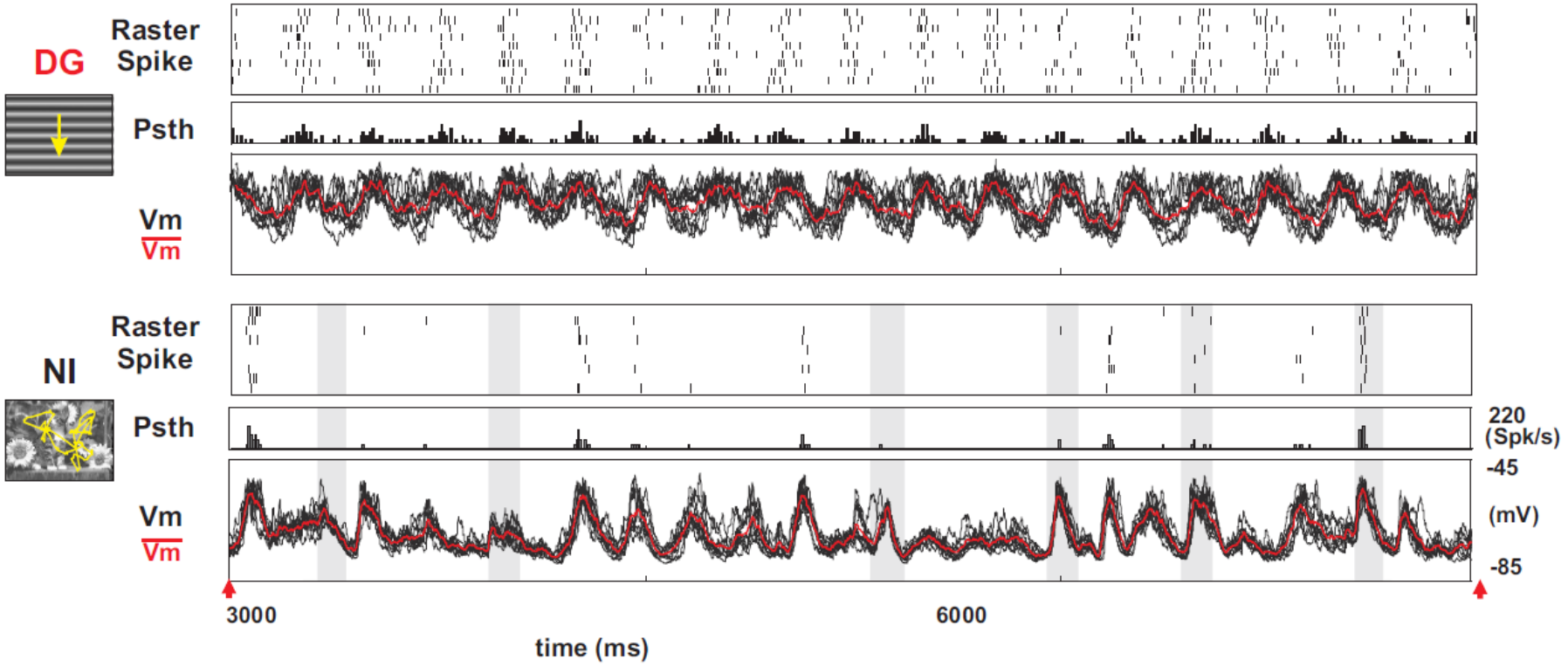


Orientation tuning – cortical view



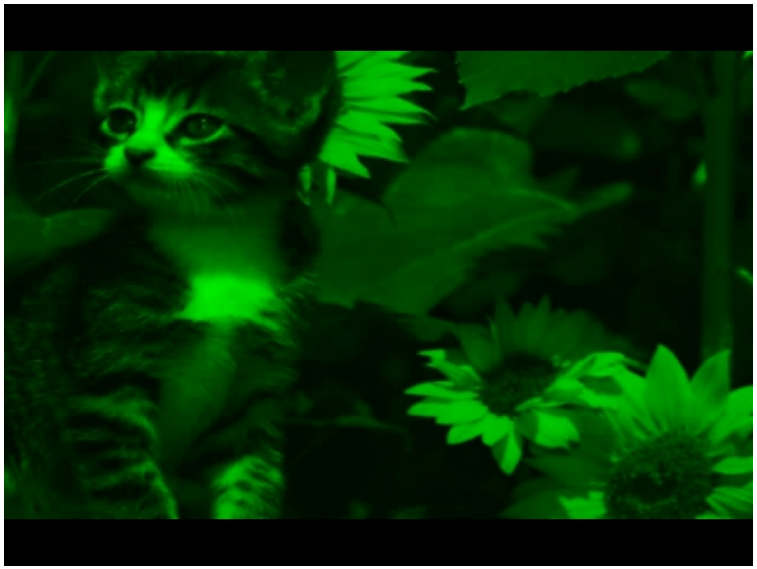
Sparse and precise neural code to natural with stimuli (DATA)

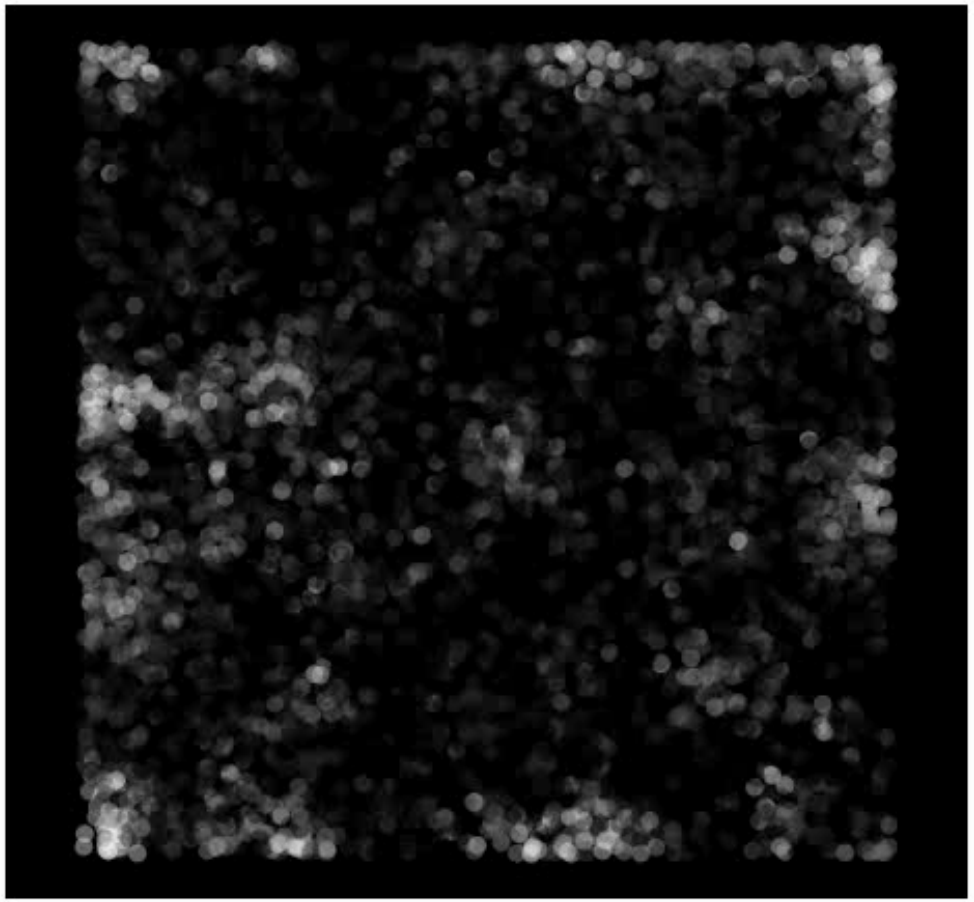




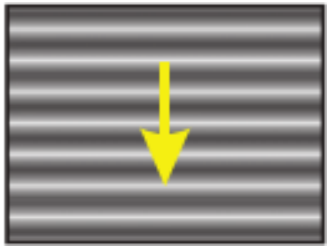
(Baudot,Levy,Marre, Monier & Yves Frégnac,

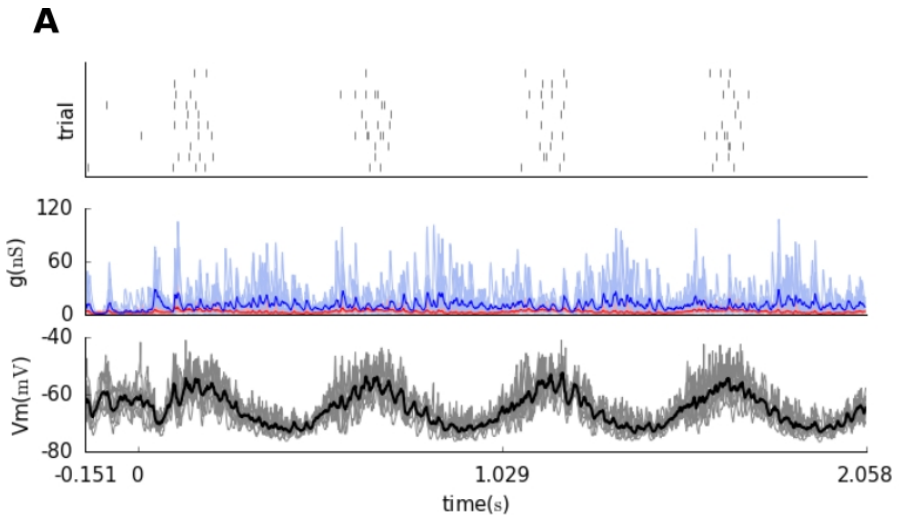
Natural image with eye-movements (L2/3)

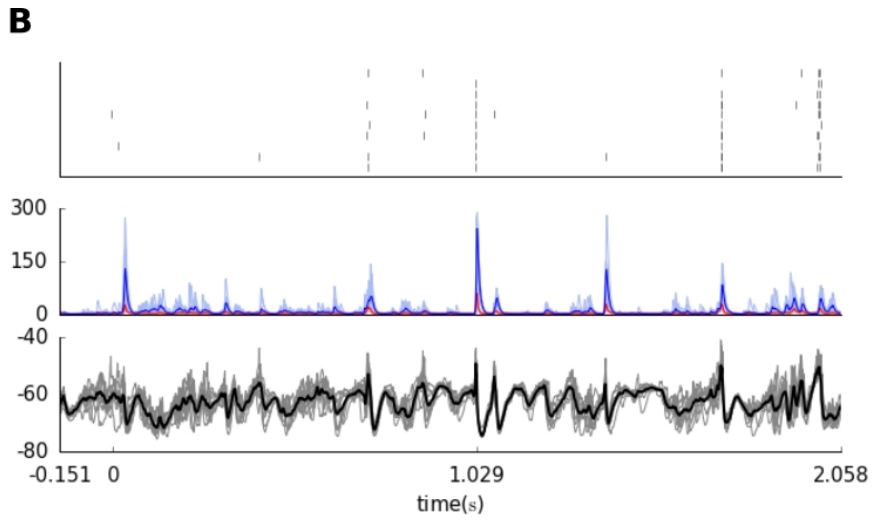




Sparse and precise neural code to natural with stimuli (MODEL)

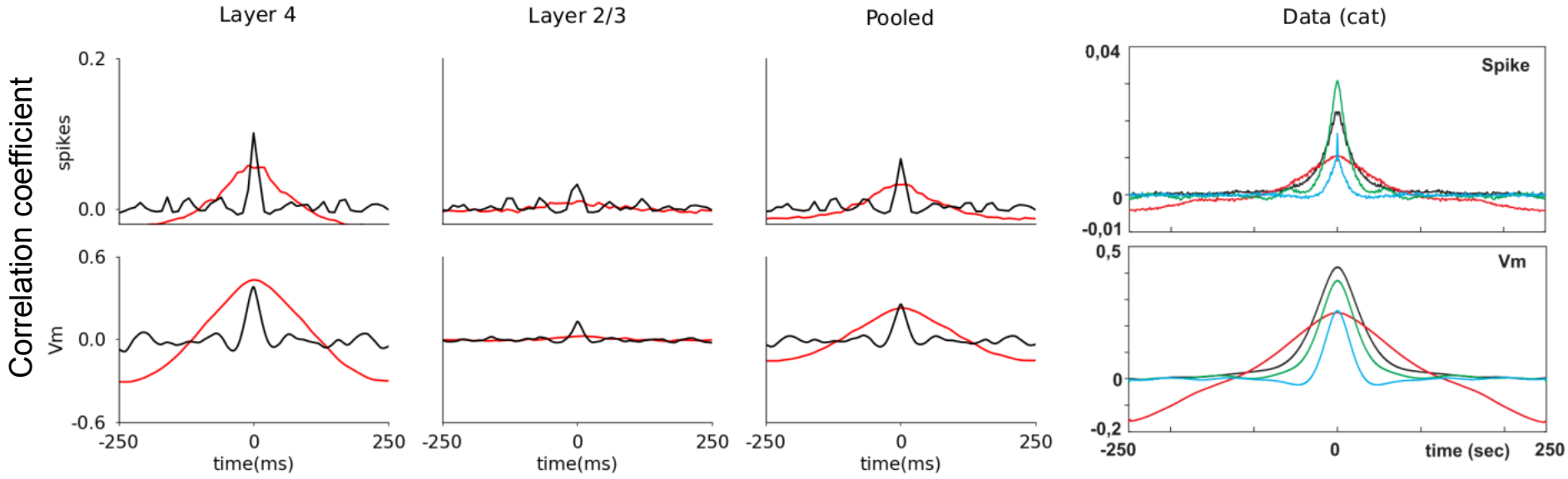




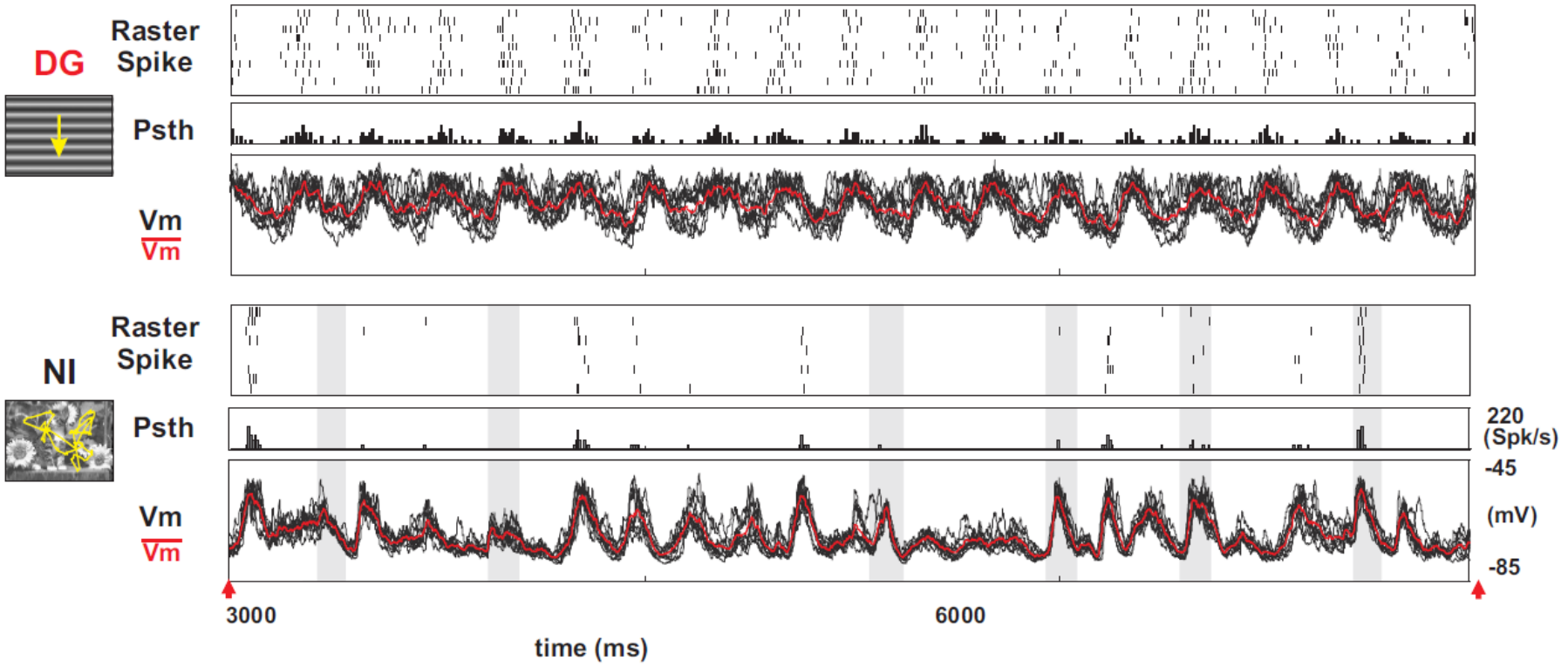


Response reliability and precision

- Trial-to-trial cross-correlation of PSTH or Vm
- Reliability can be viewed as the height of the peak
- Precision can be view as the width of the peak



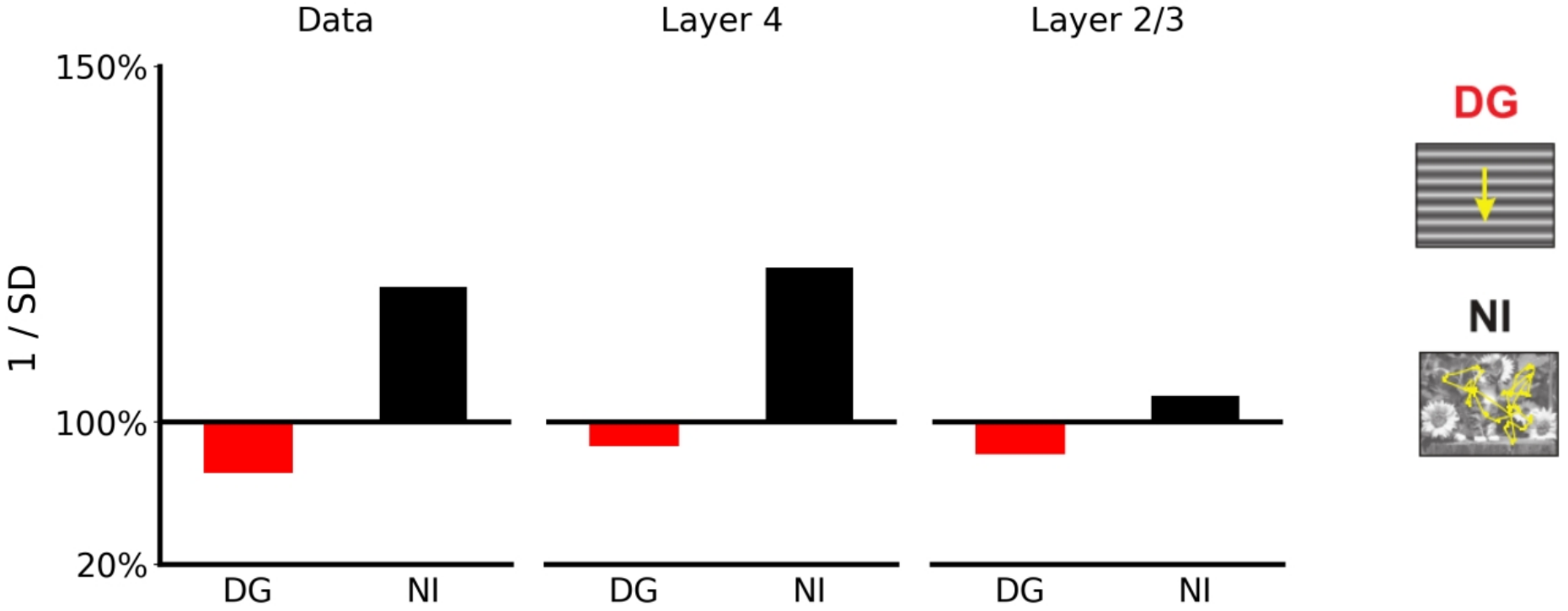
Sparse and precise neural code to natural with stimuli (DATA)



(Baudot,Levy,Marre, Monier & Yves Frégnac,

Vm variability

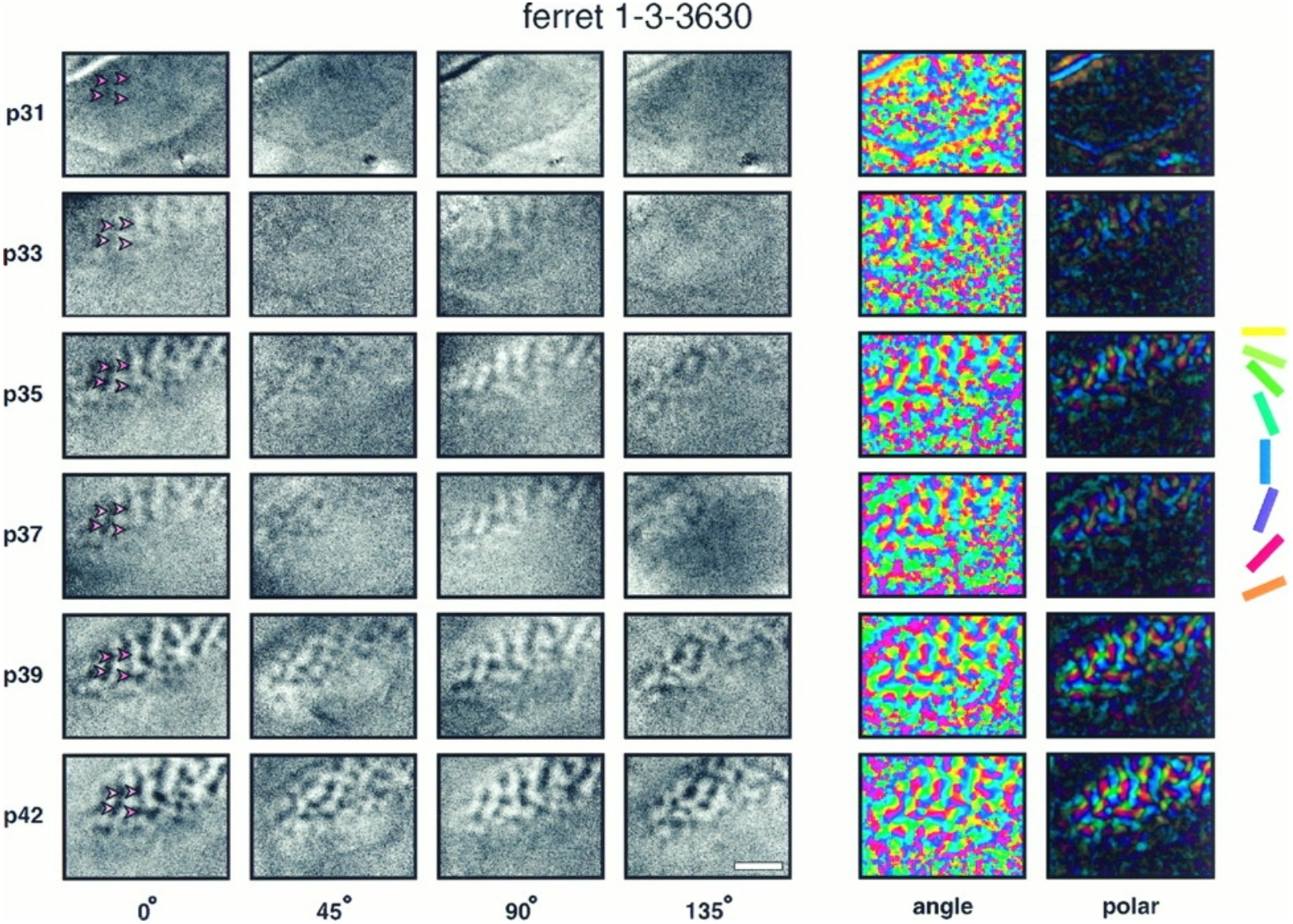
- Stimulus locked trial-to-trial variance of Vm
- Expressed as 1/std



DEVELOPMENT

Does anybody have any ideas on how might we acquire such intricate circuitry and function?

Development of orientation maps



DEMO

END