What the other 85% of V1 is doing

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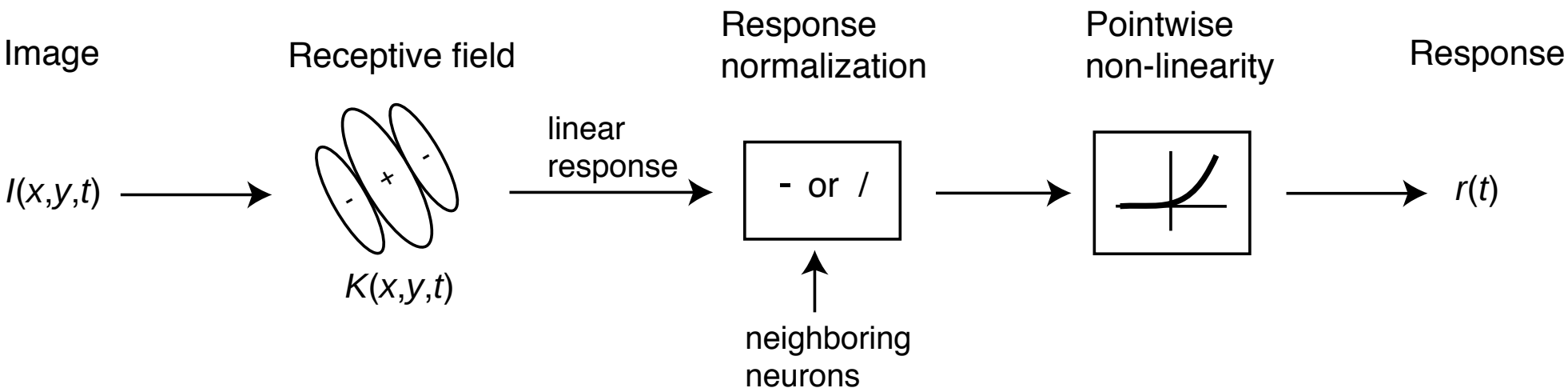
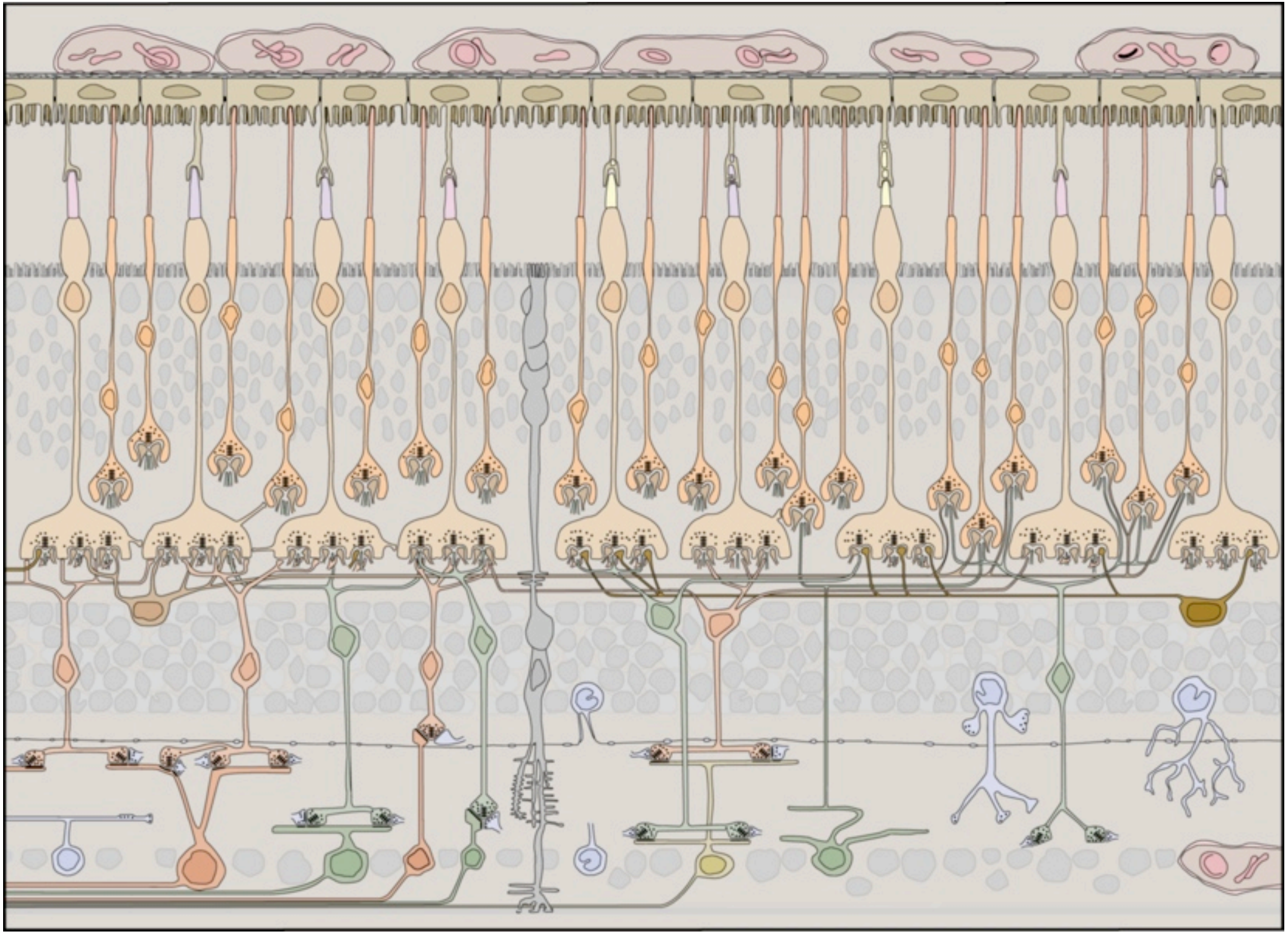
The “standard model” of V1



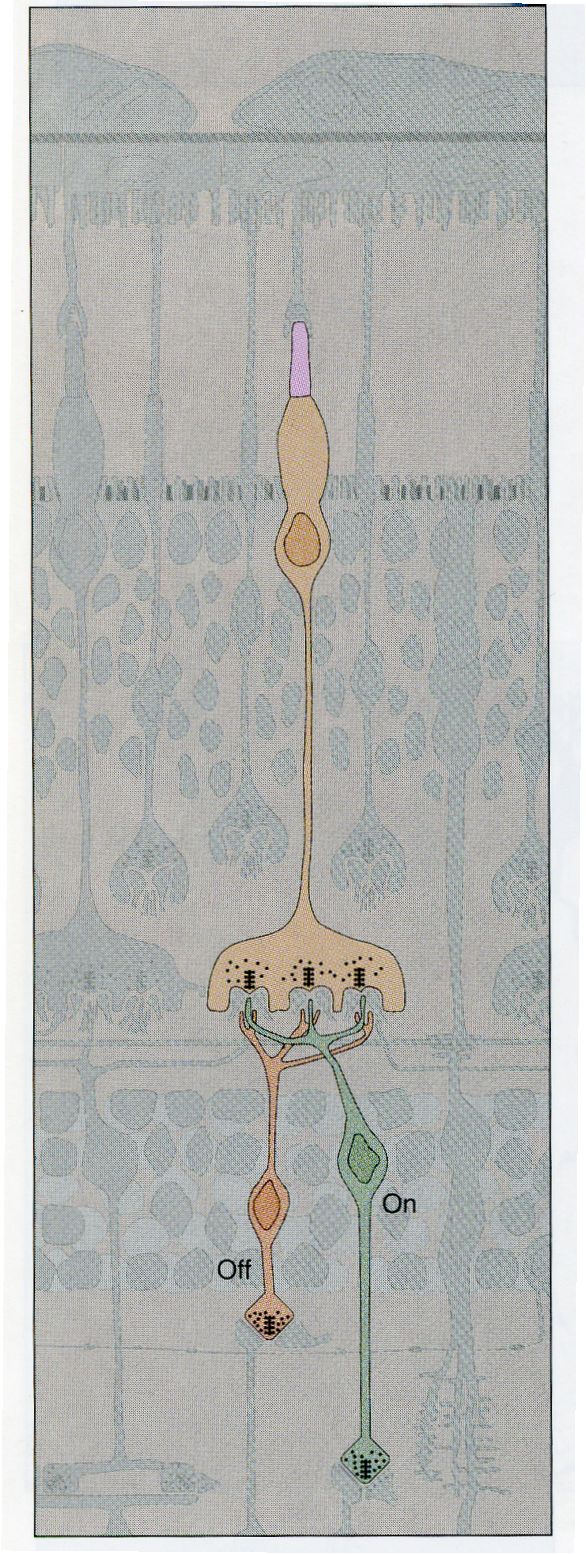
Why I am skeptical of the standard model

- Lessons from the retina
- Lessons from invertebrates
- Vast overcompleteness of V1
- Non-linearities of cortical neurons
- Difficulty of predicting neural responses to time-varying natural images

Lessons from the retina

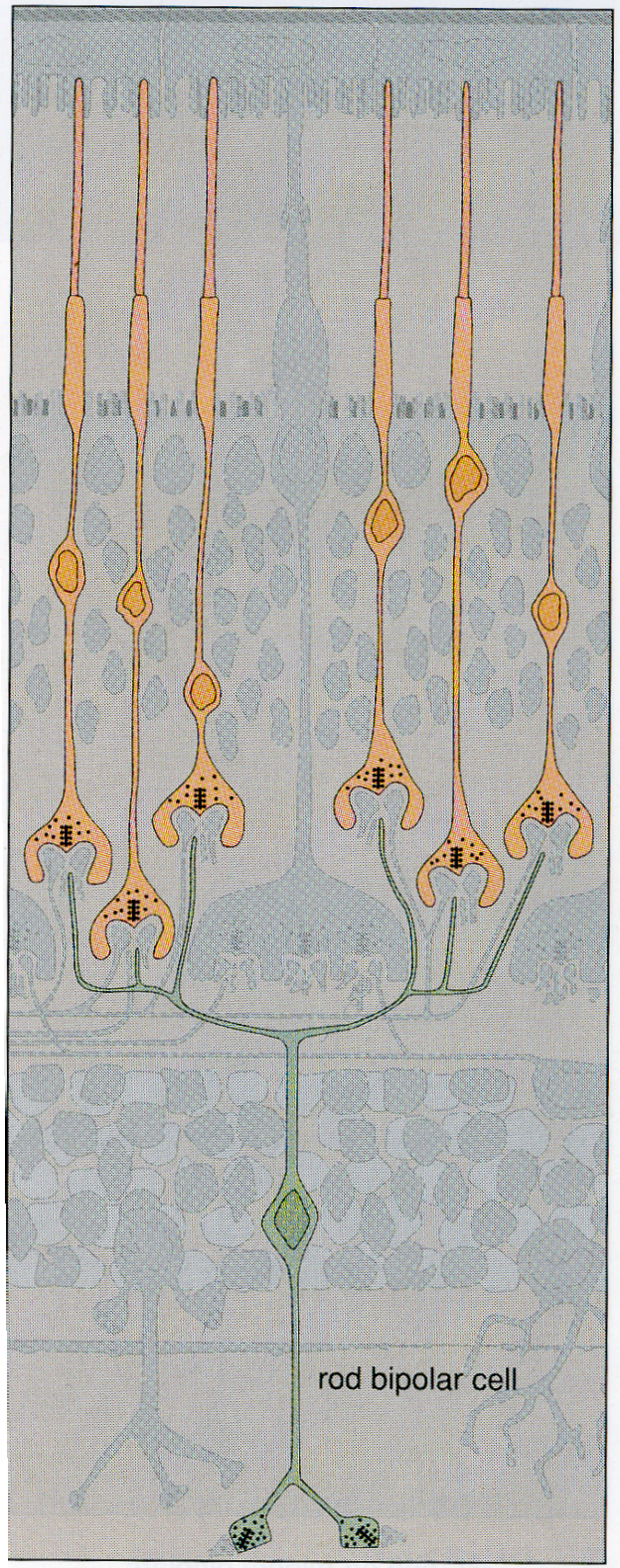


On vs. off cone bipolar cells

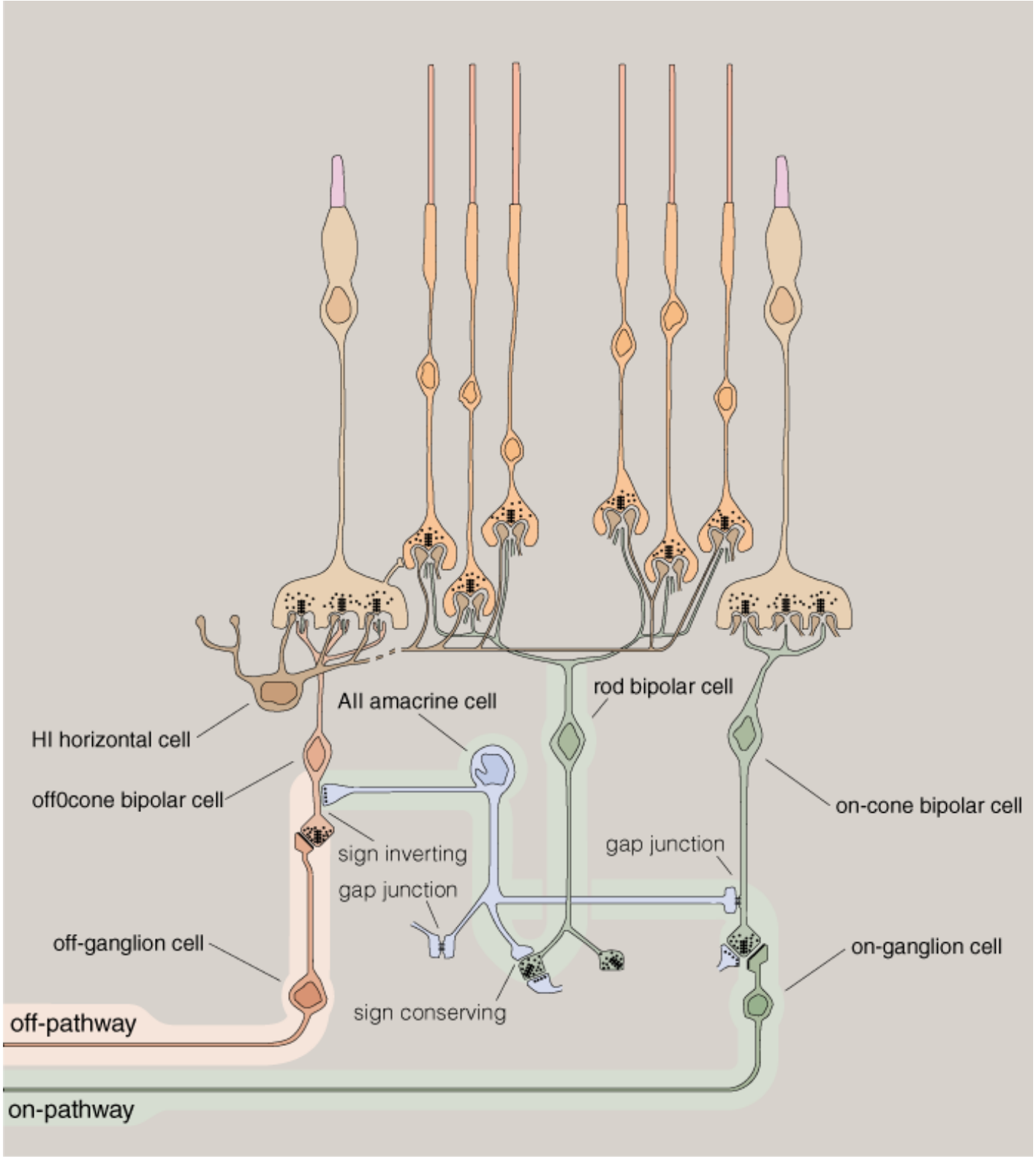


Rod bipolar cell is of on-type only

Net convergence of rods to bipolar cells

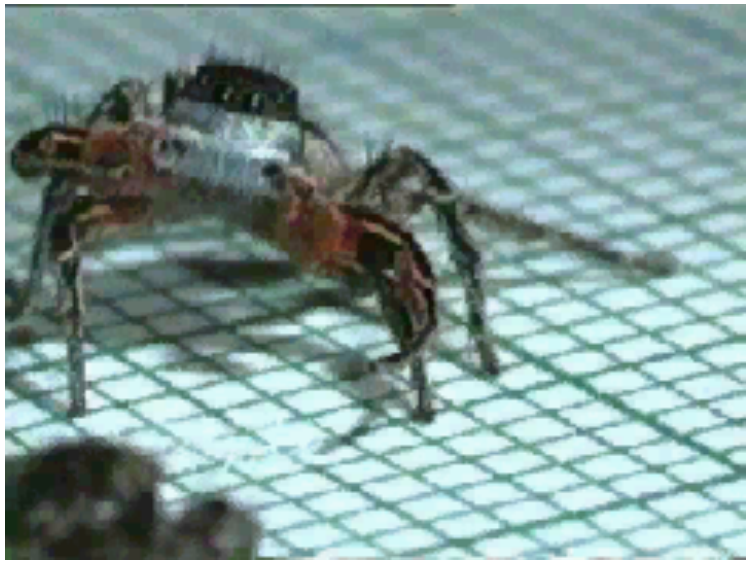


AII amacrine cell links rod bipolar cells to ganglion cells



Lessons from invertebrates

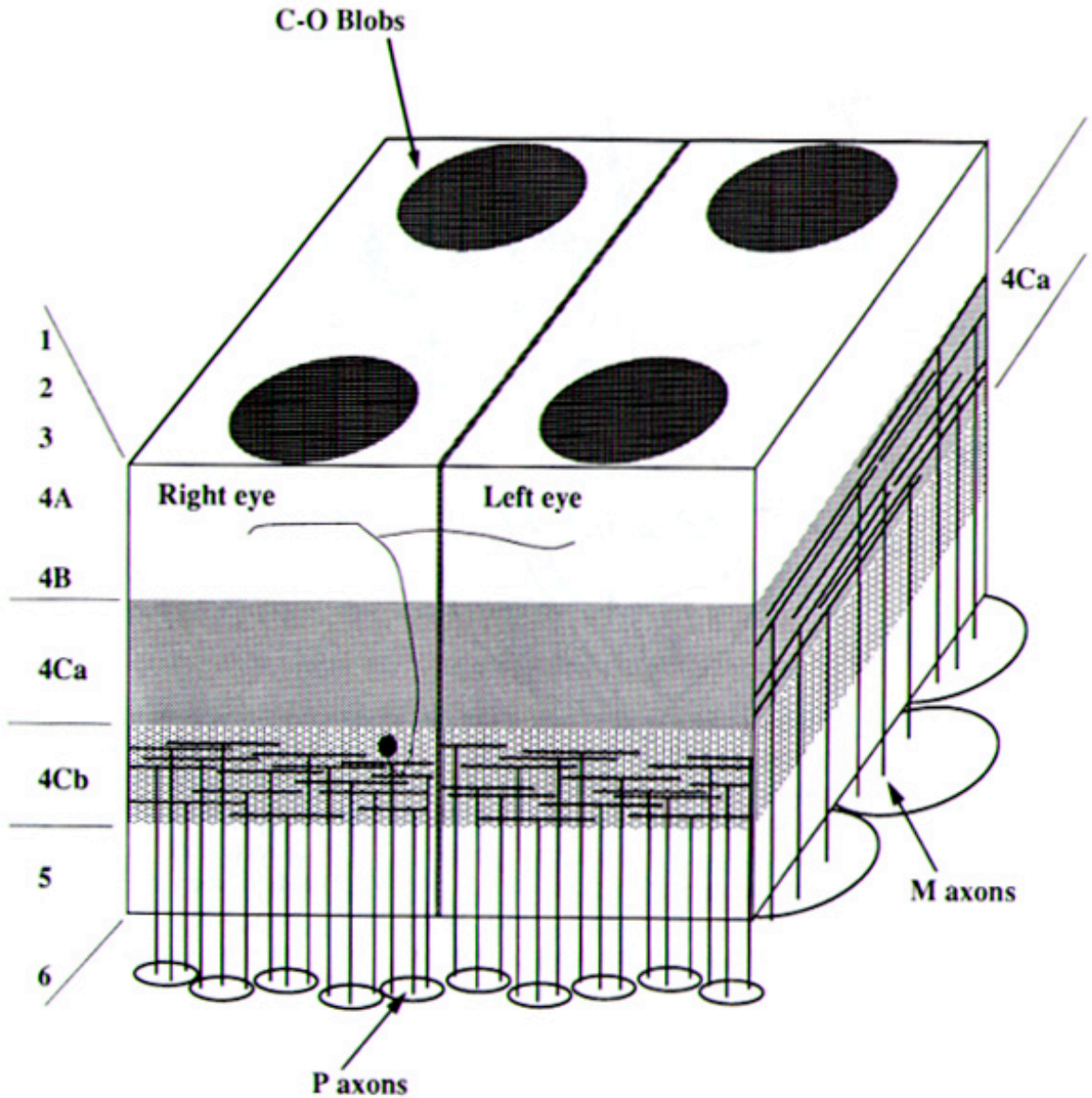
Jumping spiders

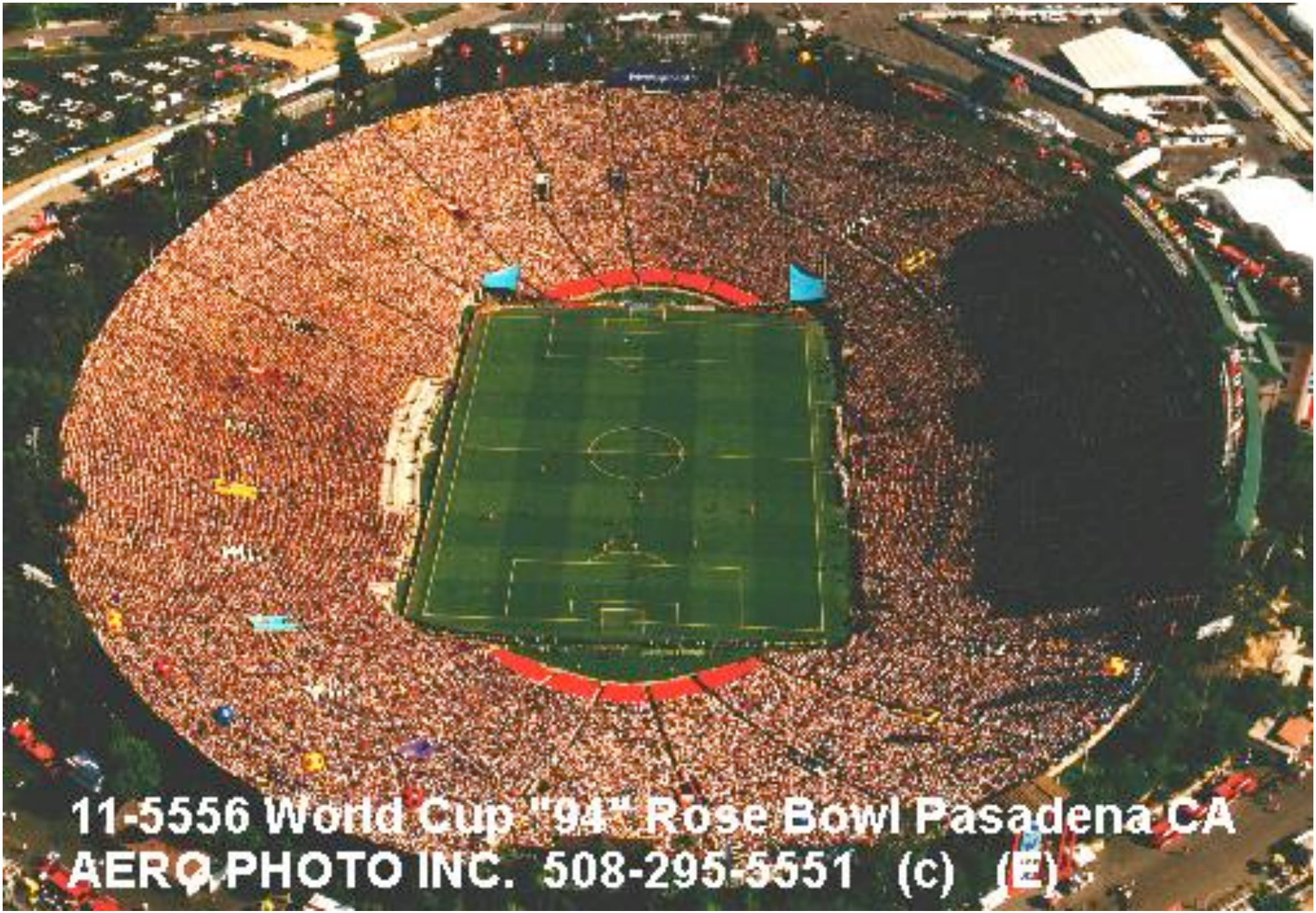


Jumping spiders

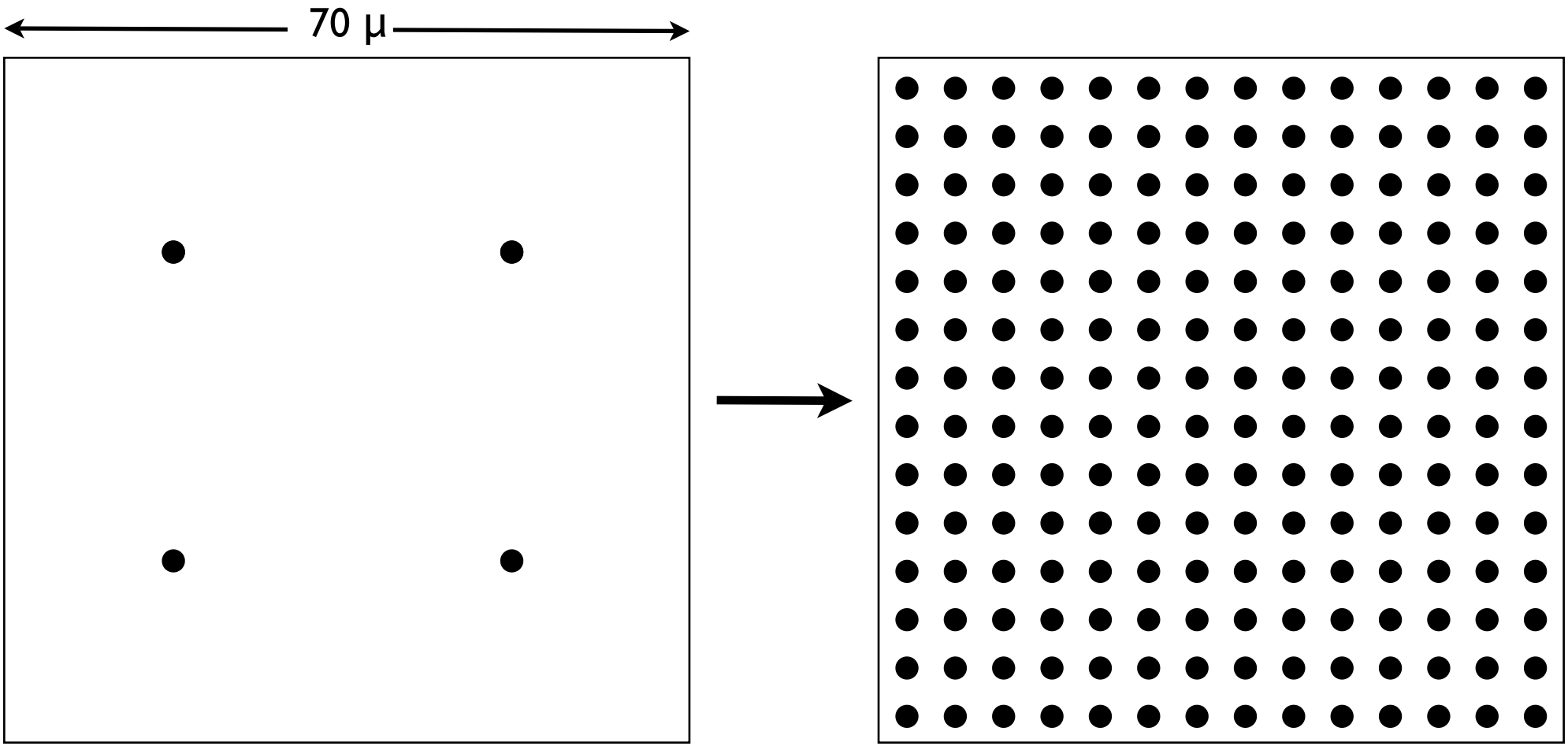
Vast overcompleteness of V1

1 mm^2 of cortex analyzes ca. 14 x 14 array of retinal sample nodes and contains 100,000 neurons




11-5556 World Cup "94" Rose Bowl Pasadena CA
AERO PHOTO INC. 508-295-5551 (c) (E)

V1 output is overcomplete by a factor of 50:1

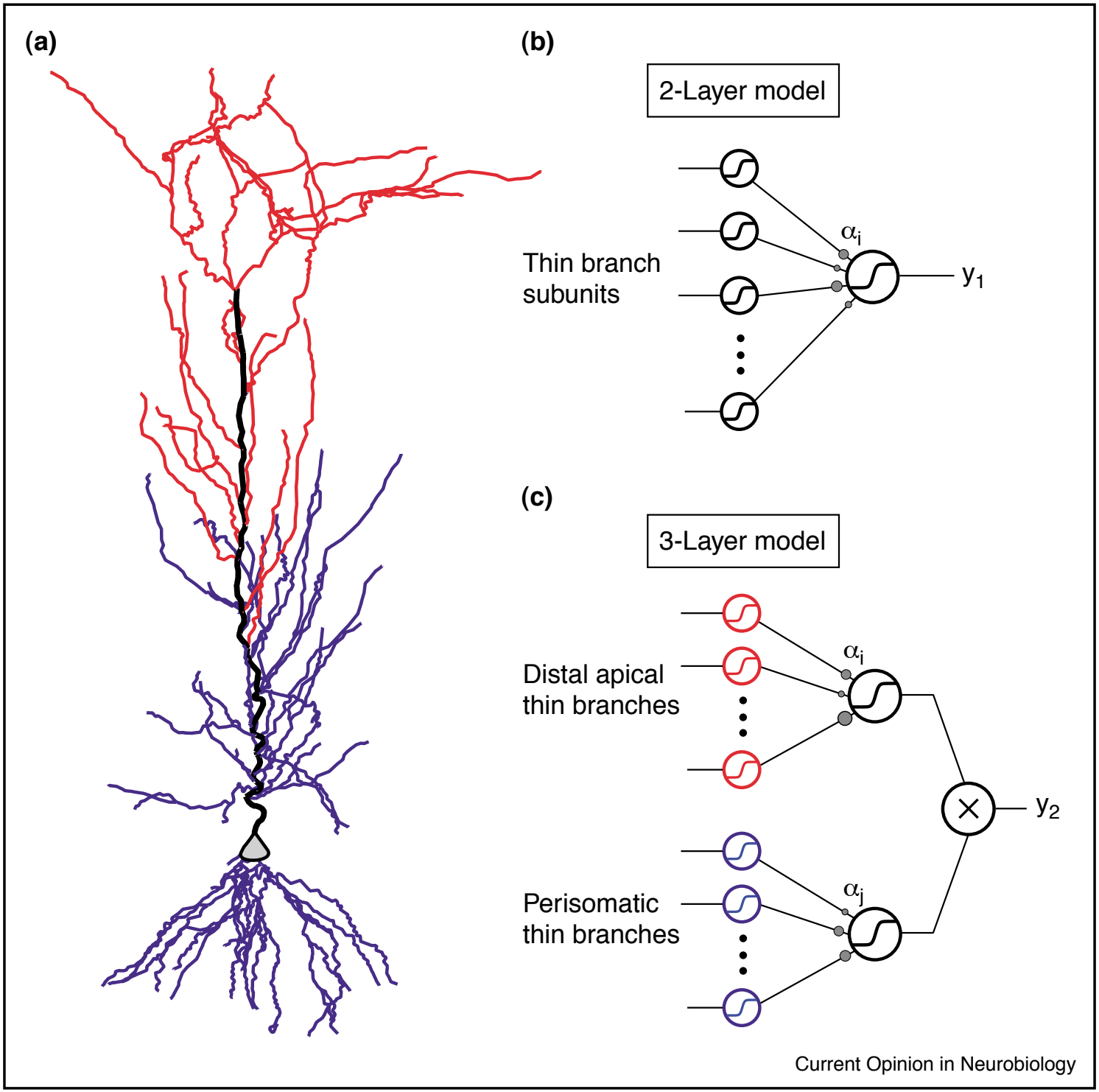


Parvo cell input fibers

V1 output fibers (layer 2/3)

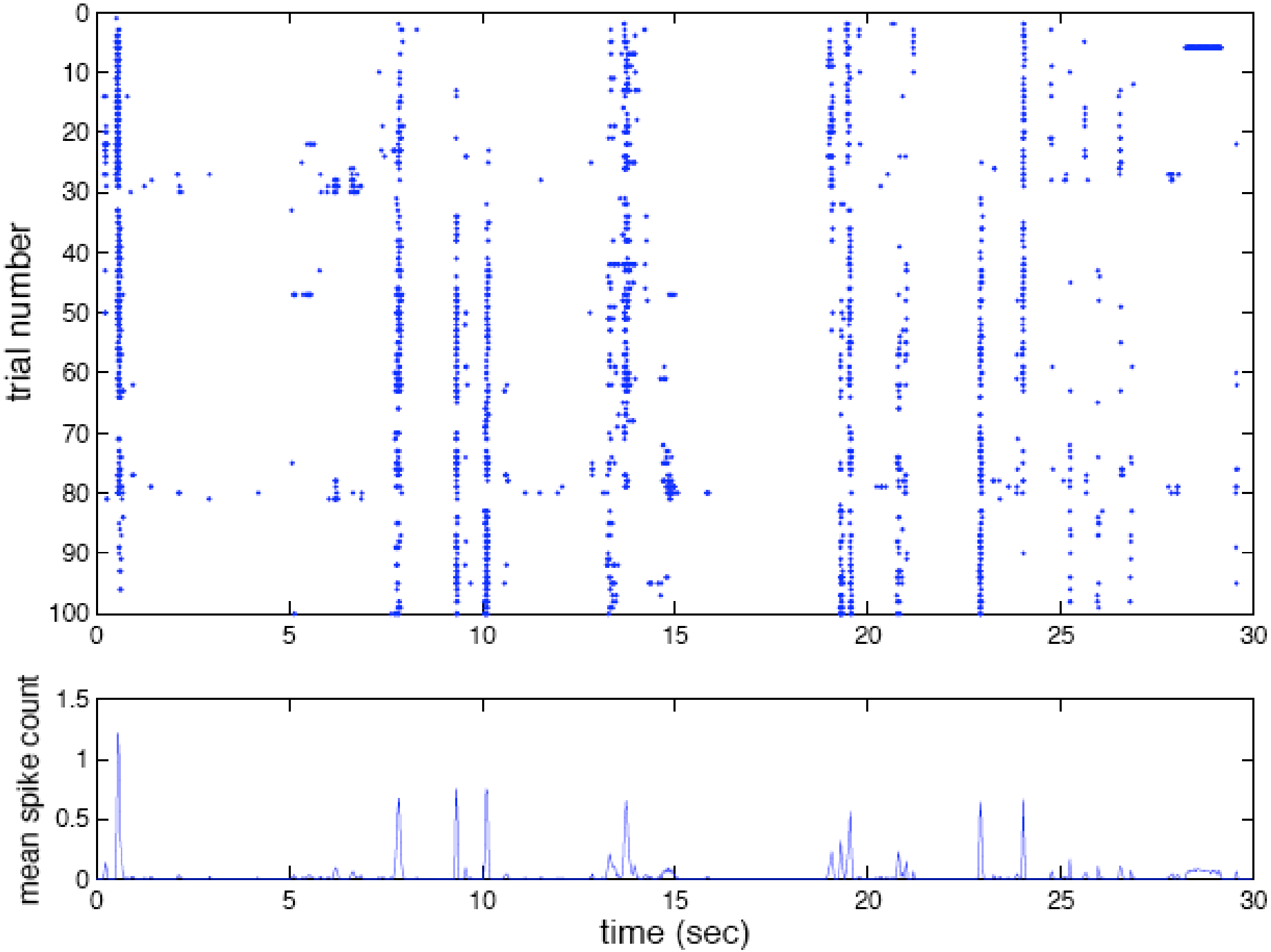
Non-linearities of cortical neurons

Hausser & Mel (2003)



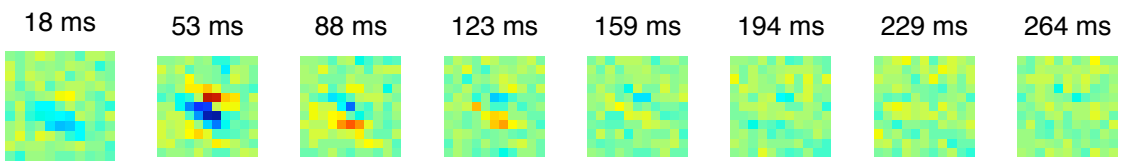
Difficulty of predicting V1 neural responses to time-varying natural images

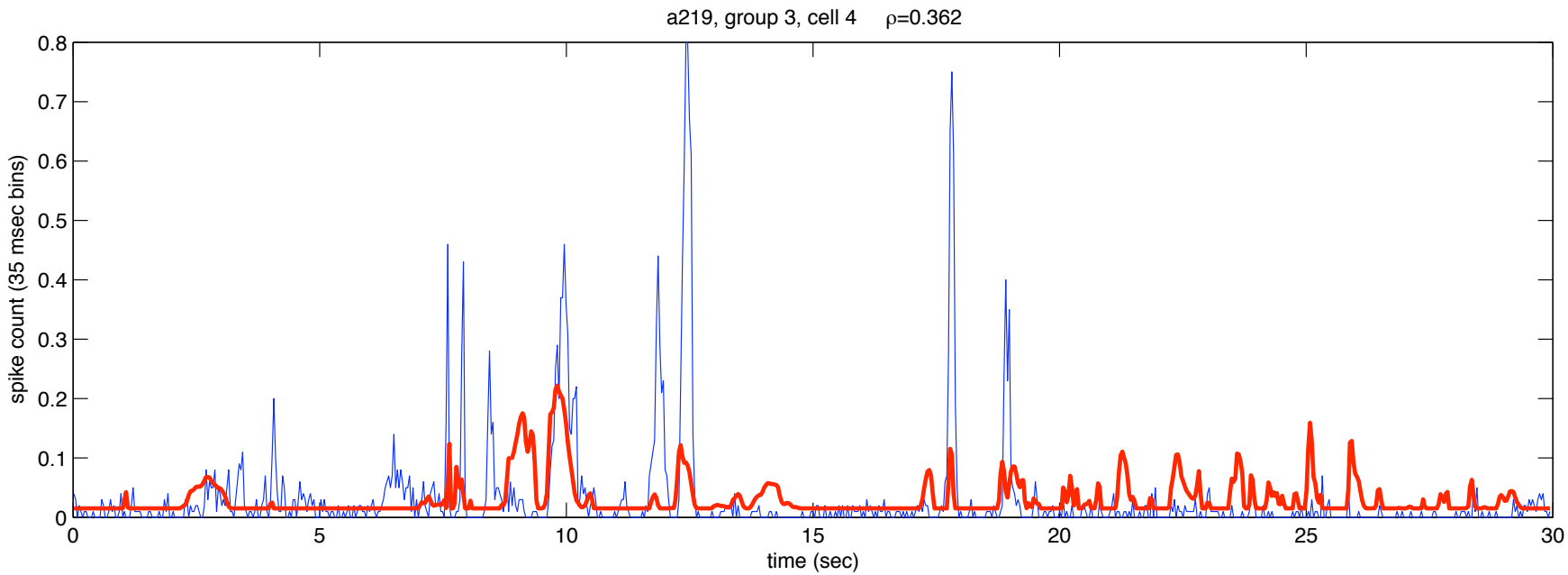
Cat V1 - natural movies (J. Baker, S.C. Yen, C.M. Gray, MSU Bozeman)



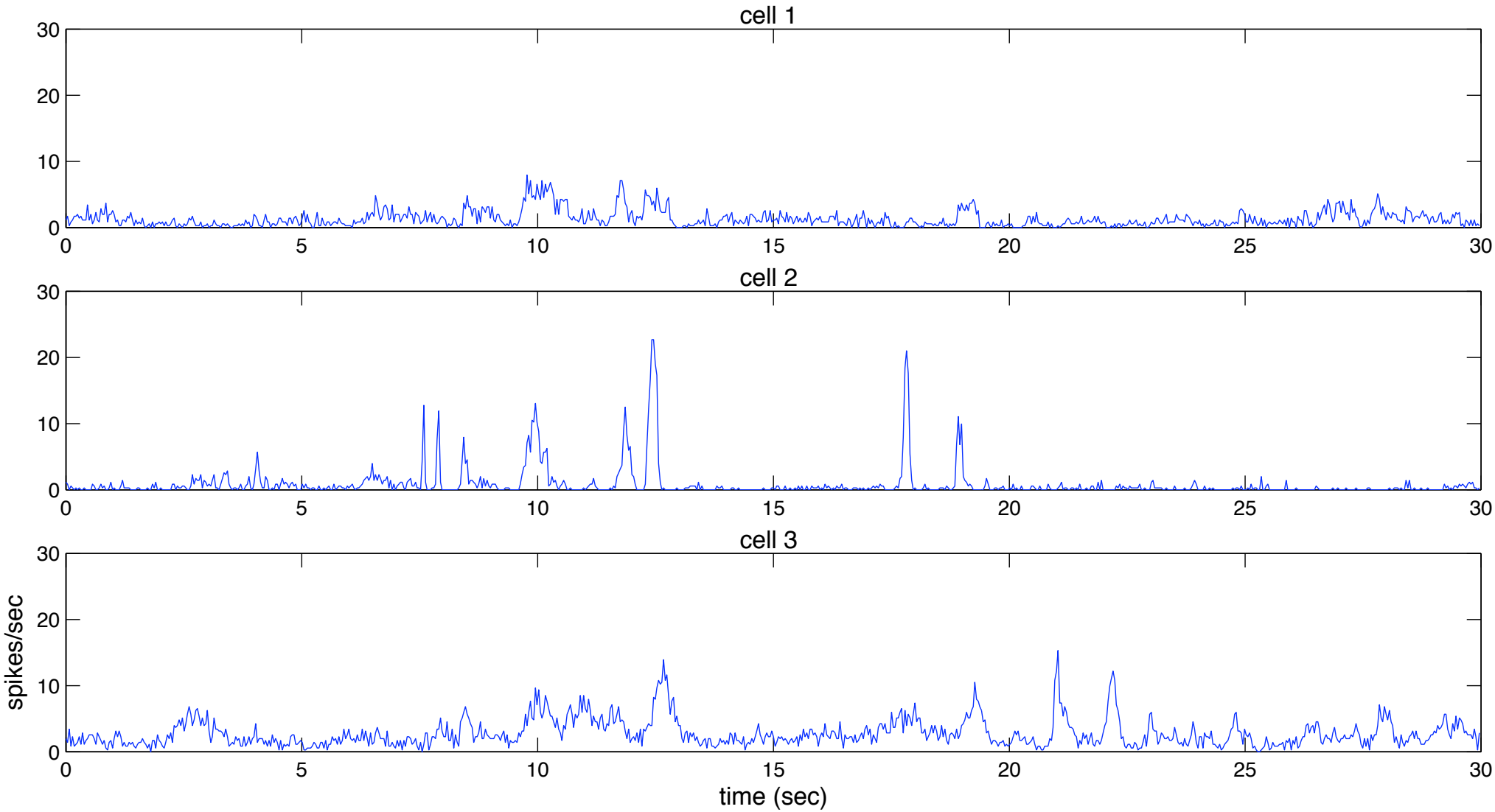
Responses of V1 neurons are not well predicted by RF models

receptive field:

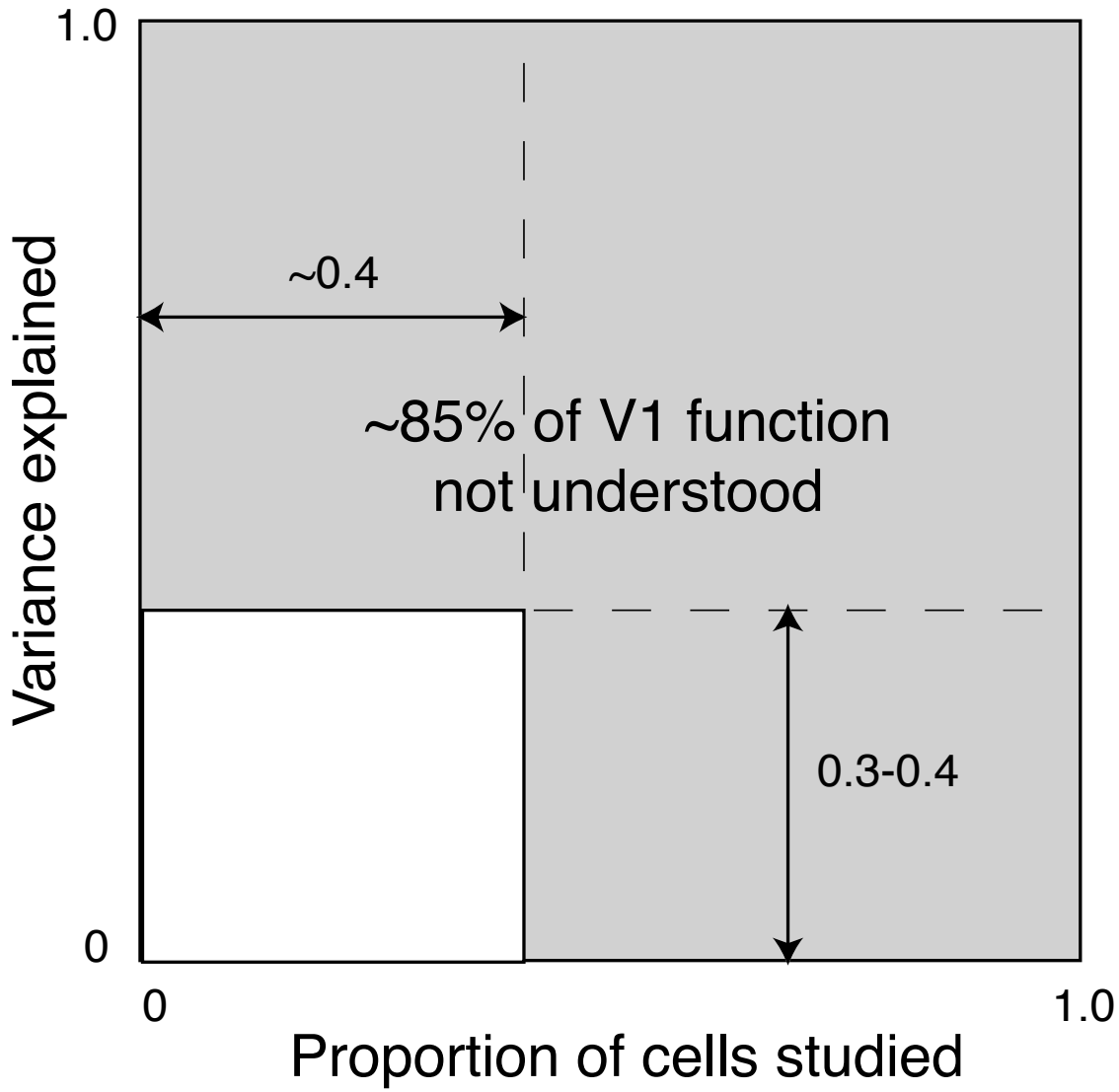




Responses of neighboring cells are heterogeneous



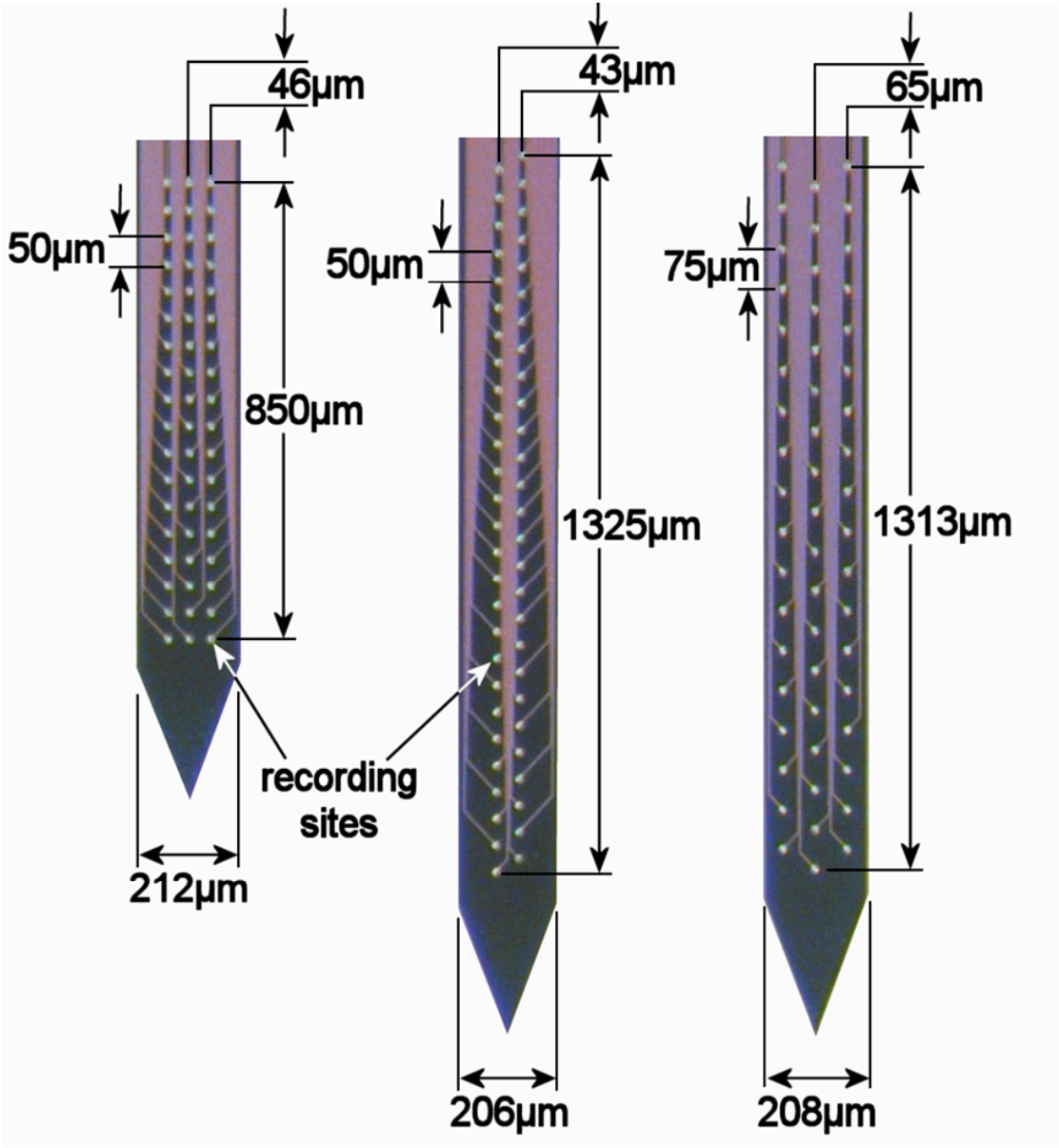
What is the other 85% doing?

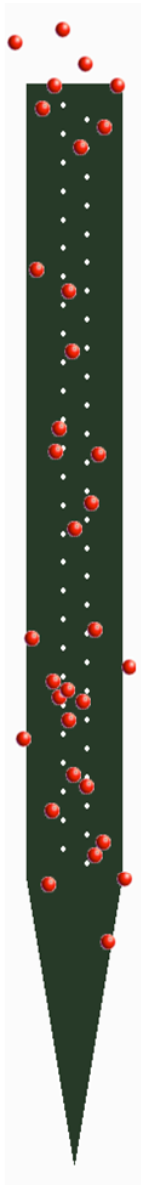


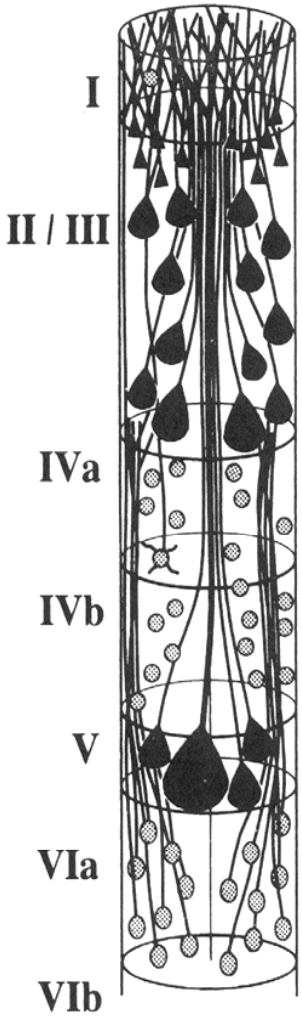
There’s hope.

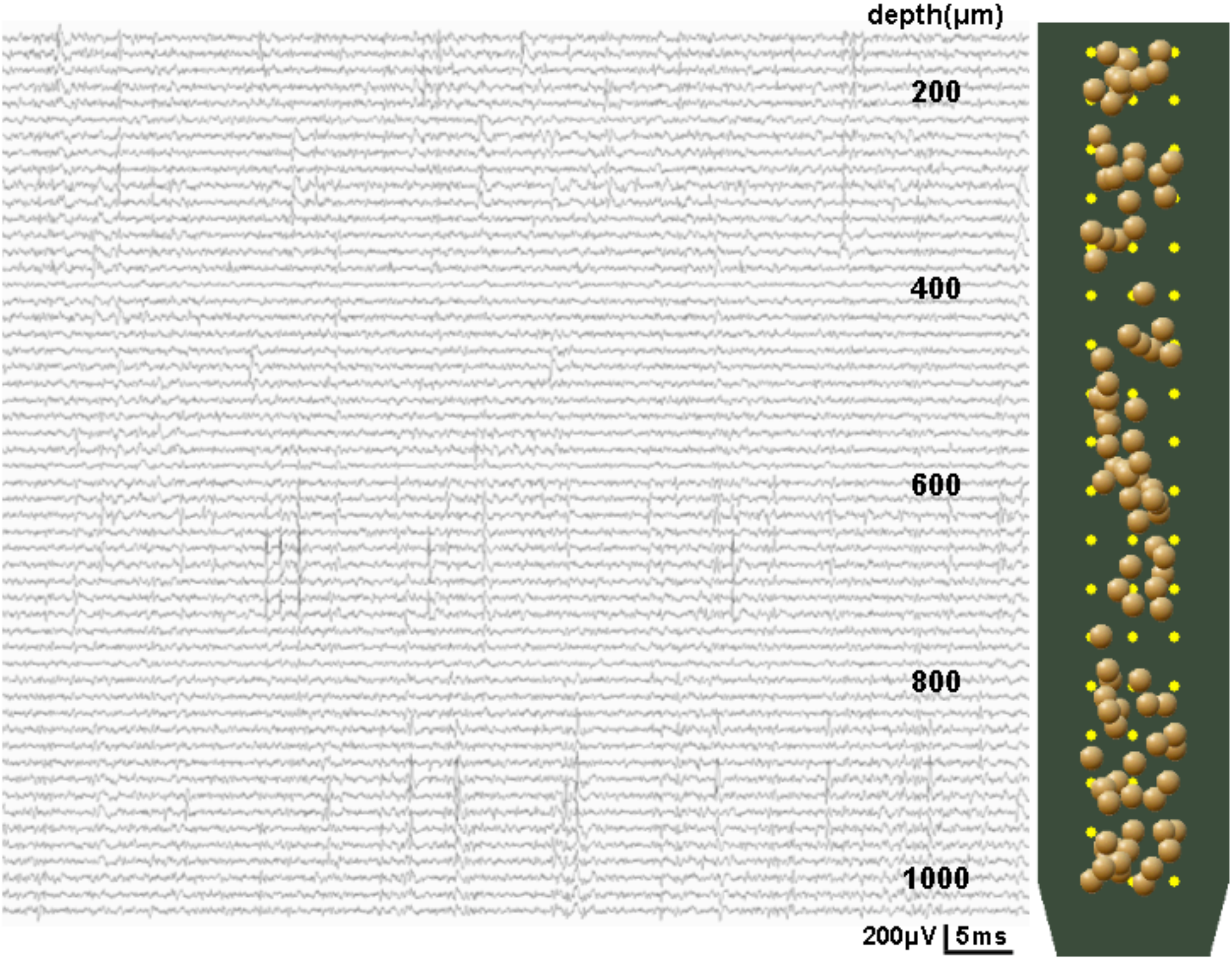
Silicon polytrodes

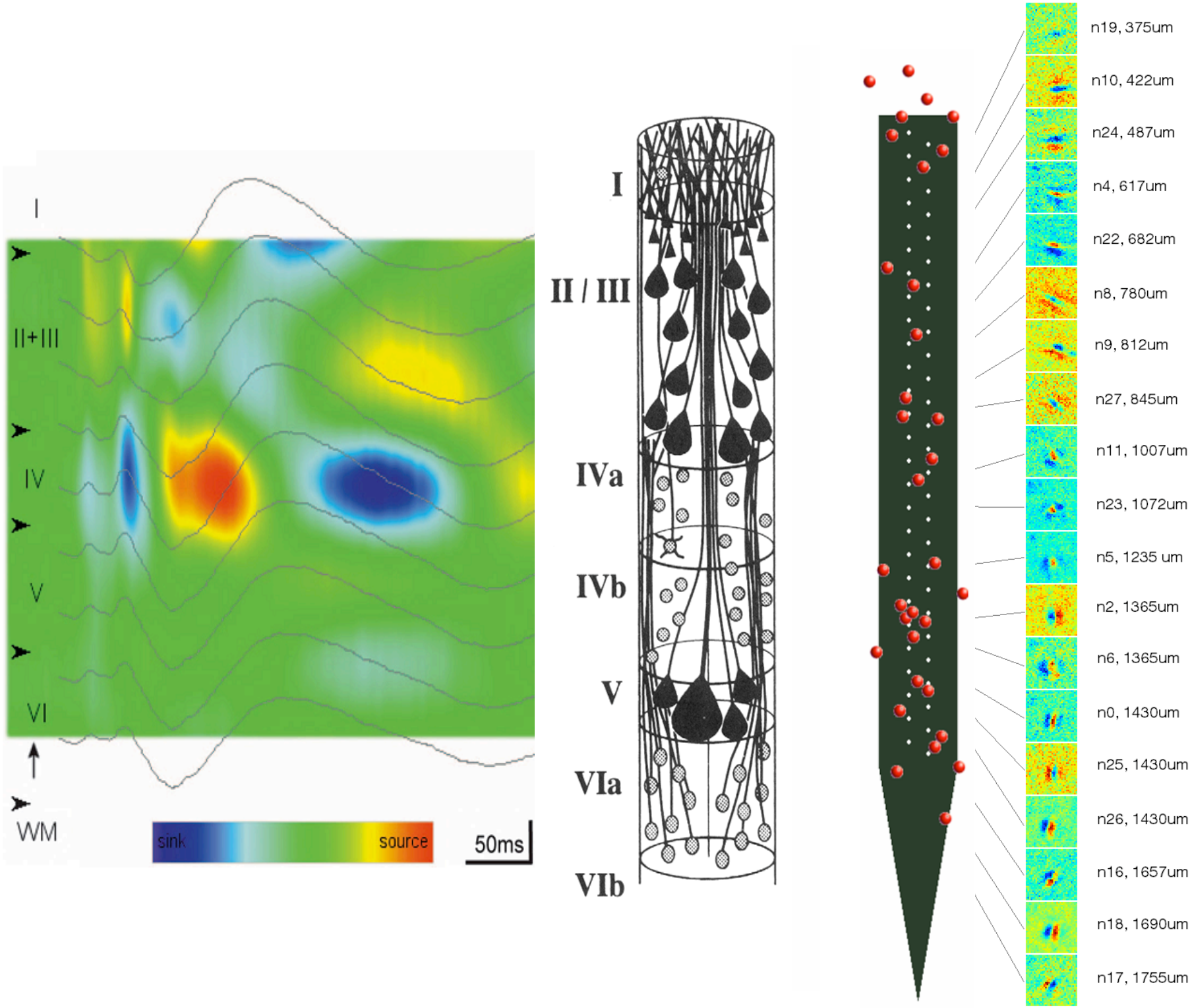
(Swindale, Blanche, Spacek)







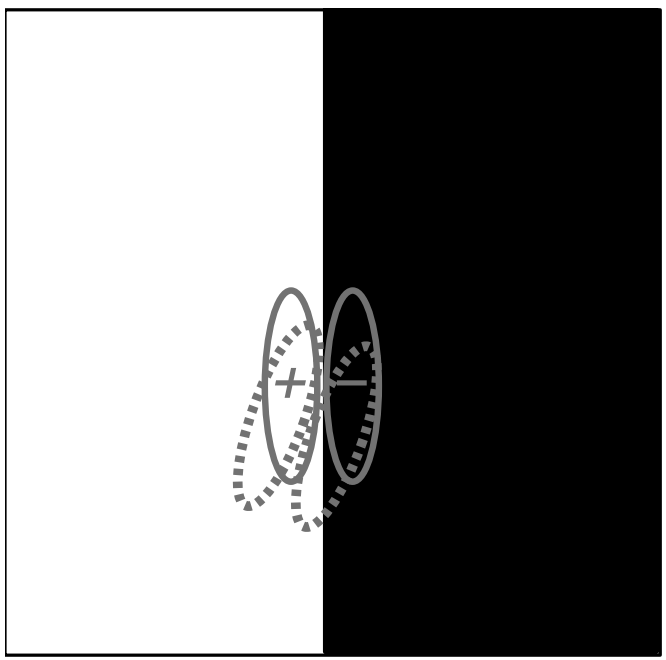

depth(μm)
200
400
600
800
1000
200μV
5ms

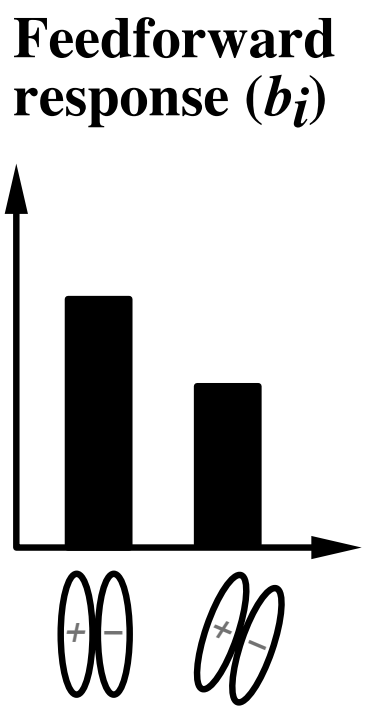

I
II+III
IV
V
VI
WM
sink
source
50ms
I
II / III
IVa
IVb
V
VIa
VIb
n19, 375um
n10, 422um
n24, 487um
n4, 617um
n22, 682um
n8, 780um
n9, 812um
n27, 845um
n11, 1007um
n23, 1072um
n5, 1235 um
n2, 1365um
n6, 1365um
n0, 1430um
n25, 1430um
n26, 1430um
n16, 1657um
n18, 1690um
n17, 1755um

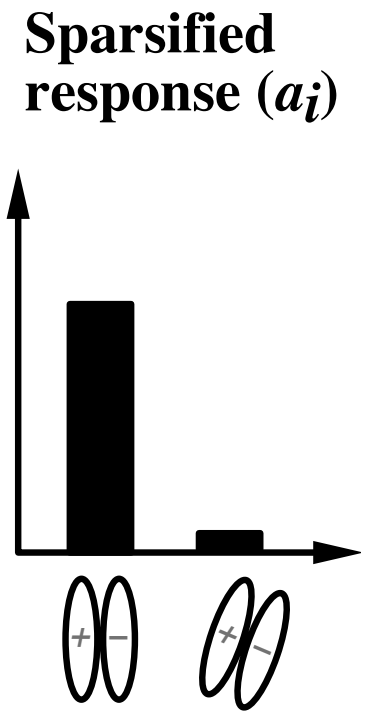
What to look for

- What does a "day in the life of V1" look like?
- Explaining away (sparsification)
- Phase
- Figure-ground
- Synchrony
- Laminar distribution of function (microcircuit)

Explaining away

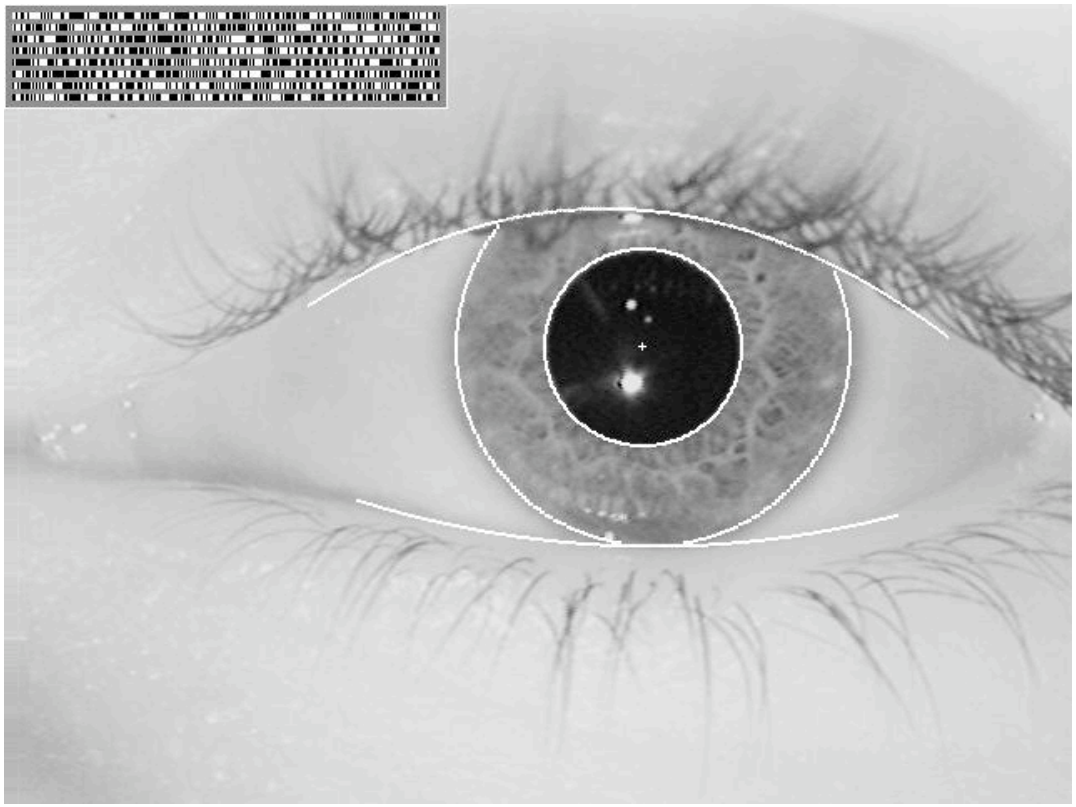




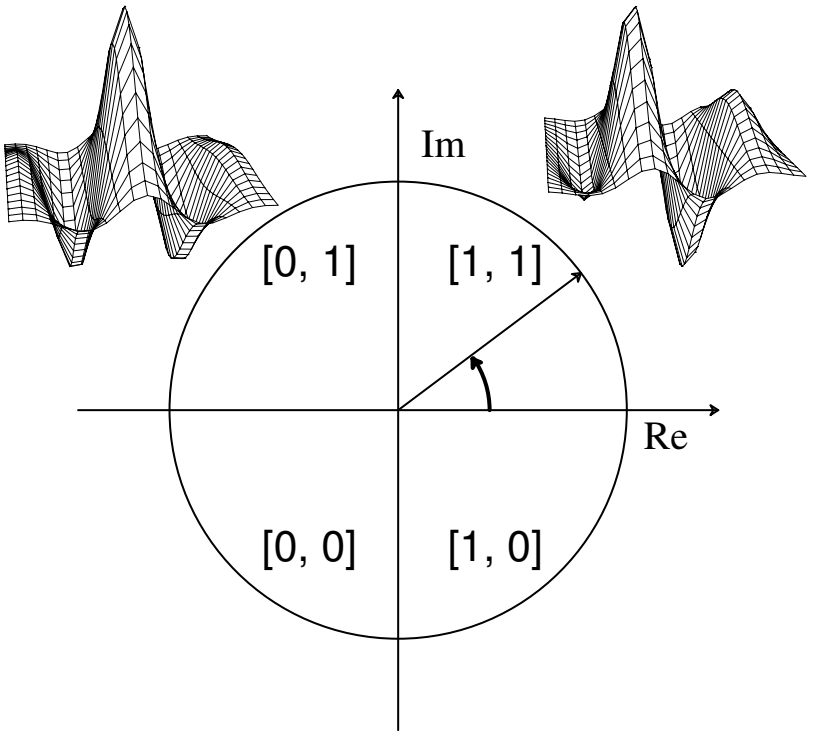


Phase

Iris recognition (Daugman)



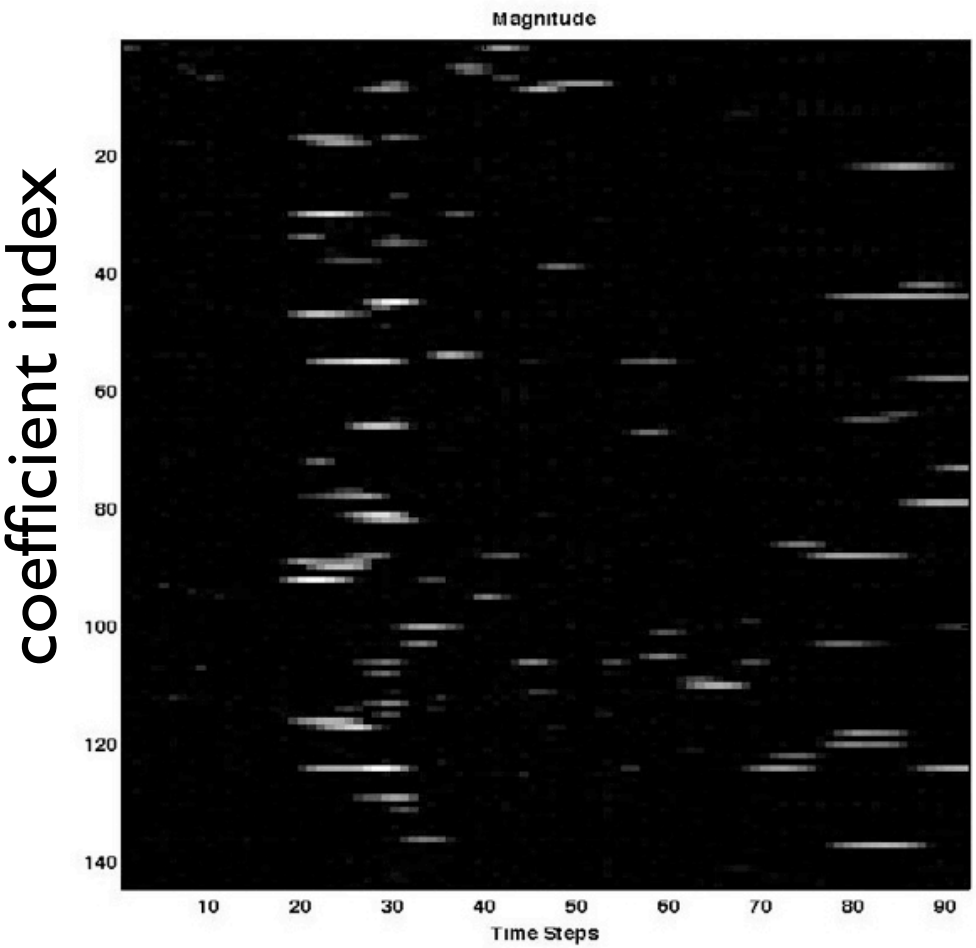
Phase-Quadrant Demodulation Code

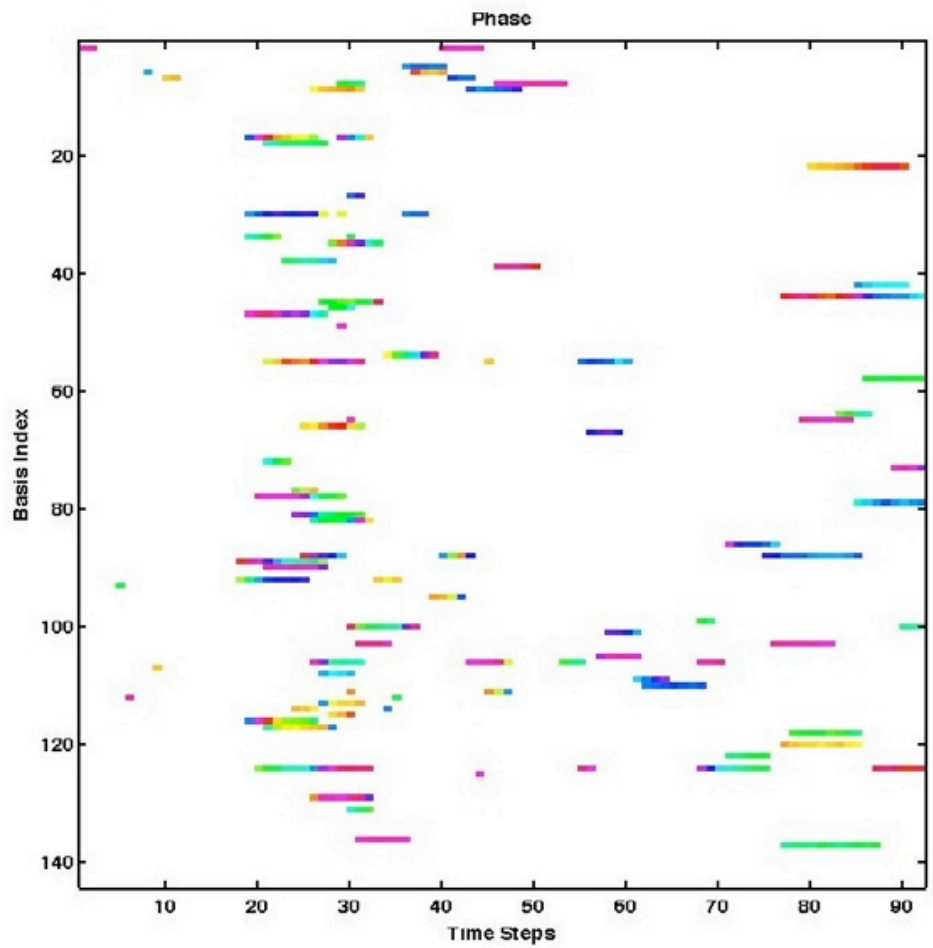


Time-varying phase encodes information about transformations

amplitude

phase





time

time

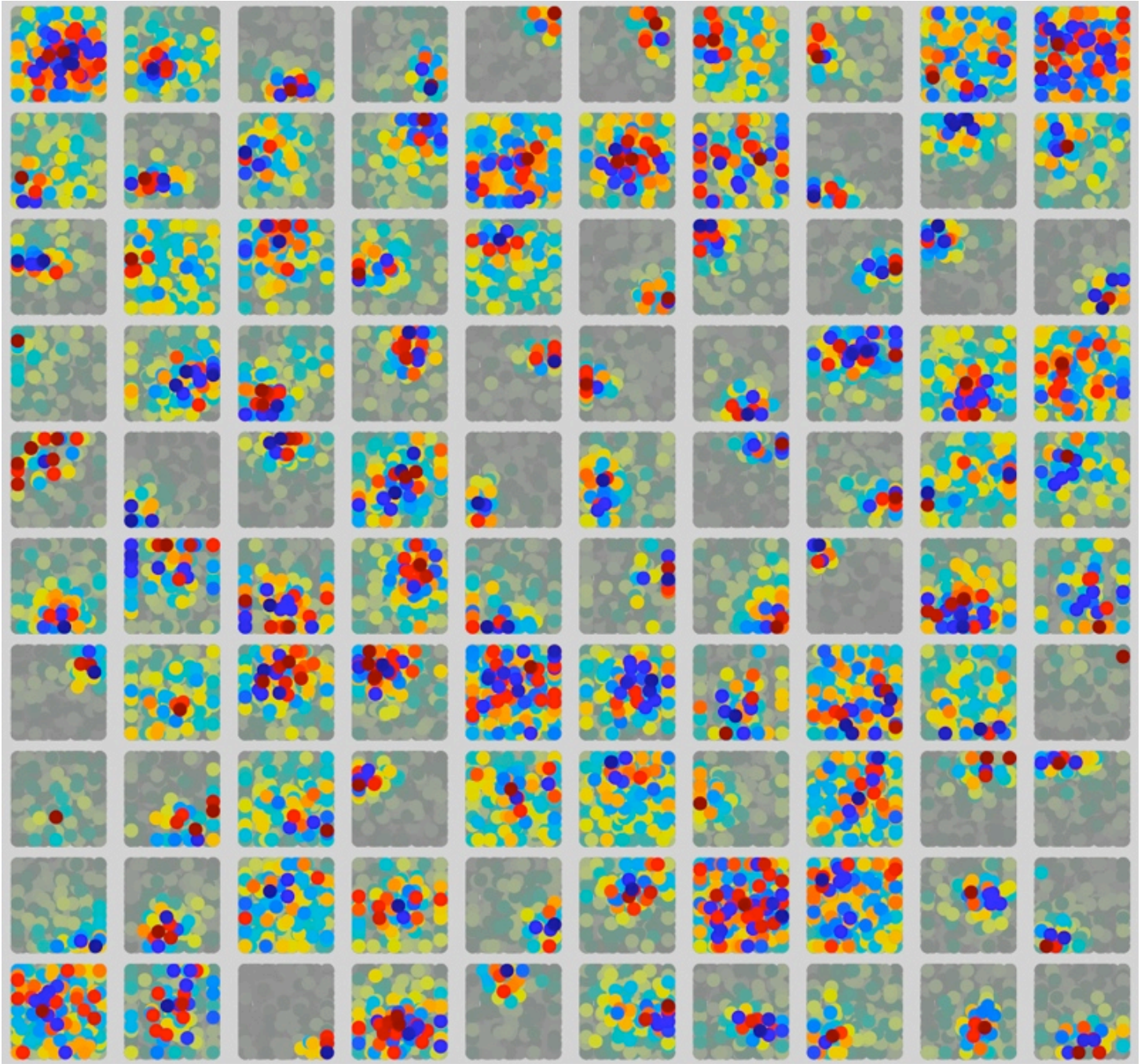
Modeling phase dependencies (Charles Cadieu)

$$\dot{\alpha}_i(t) = \sum_k D_{ik}\, w_k(t)$$

sparse

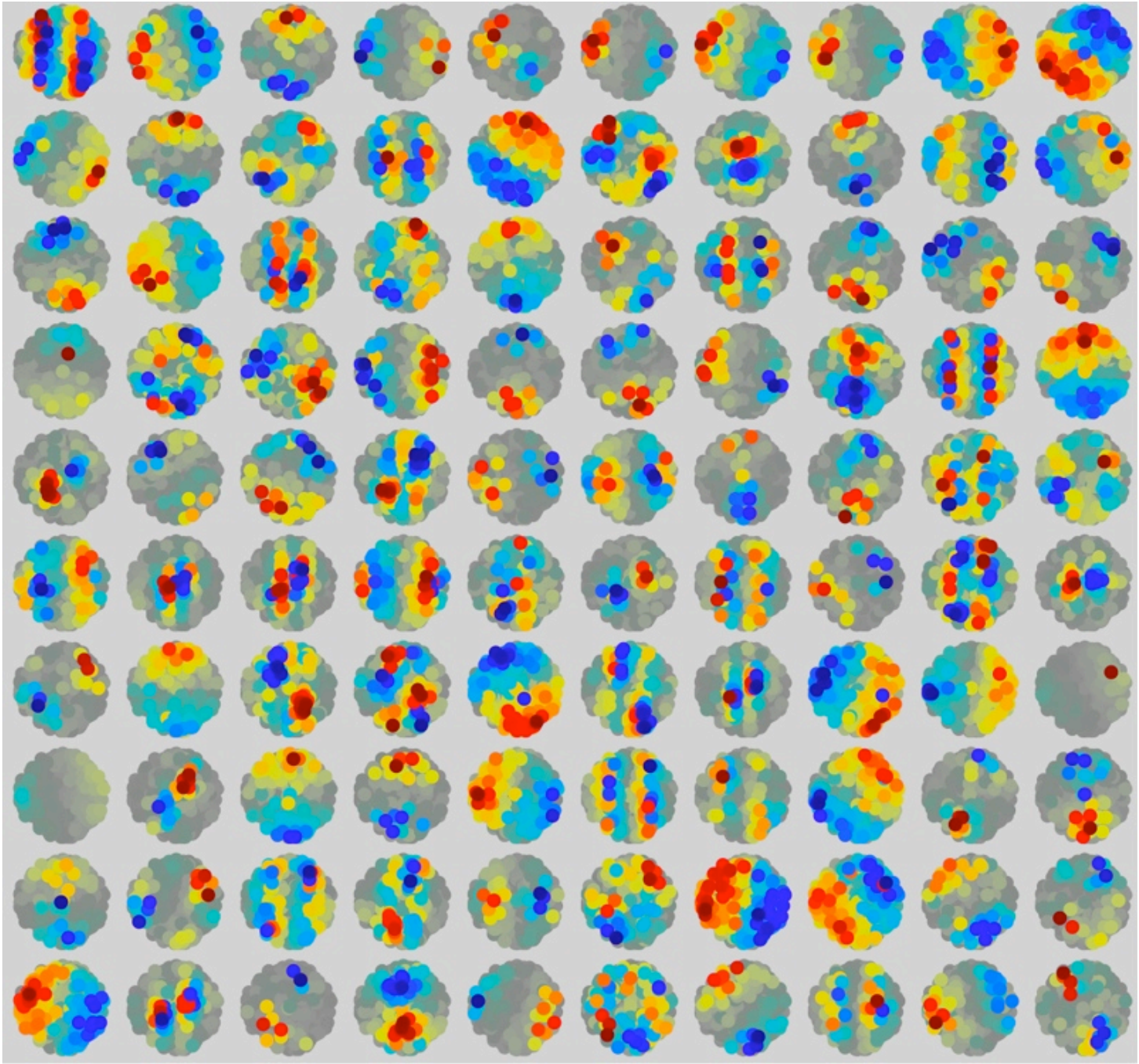
Learned D

(space domain)



Learned D

(frequency domain)



Learned D

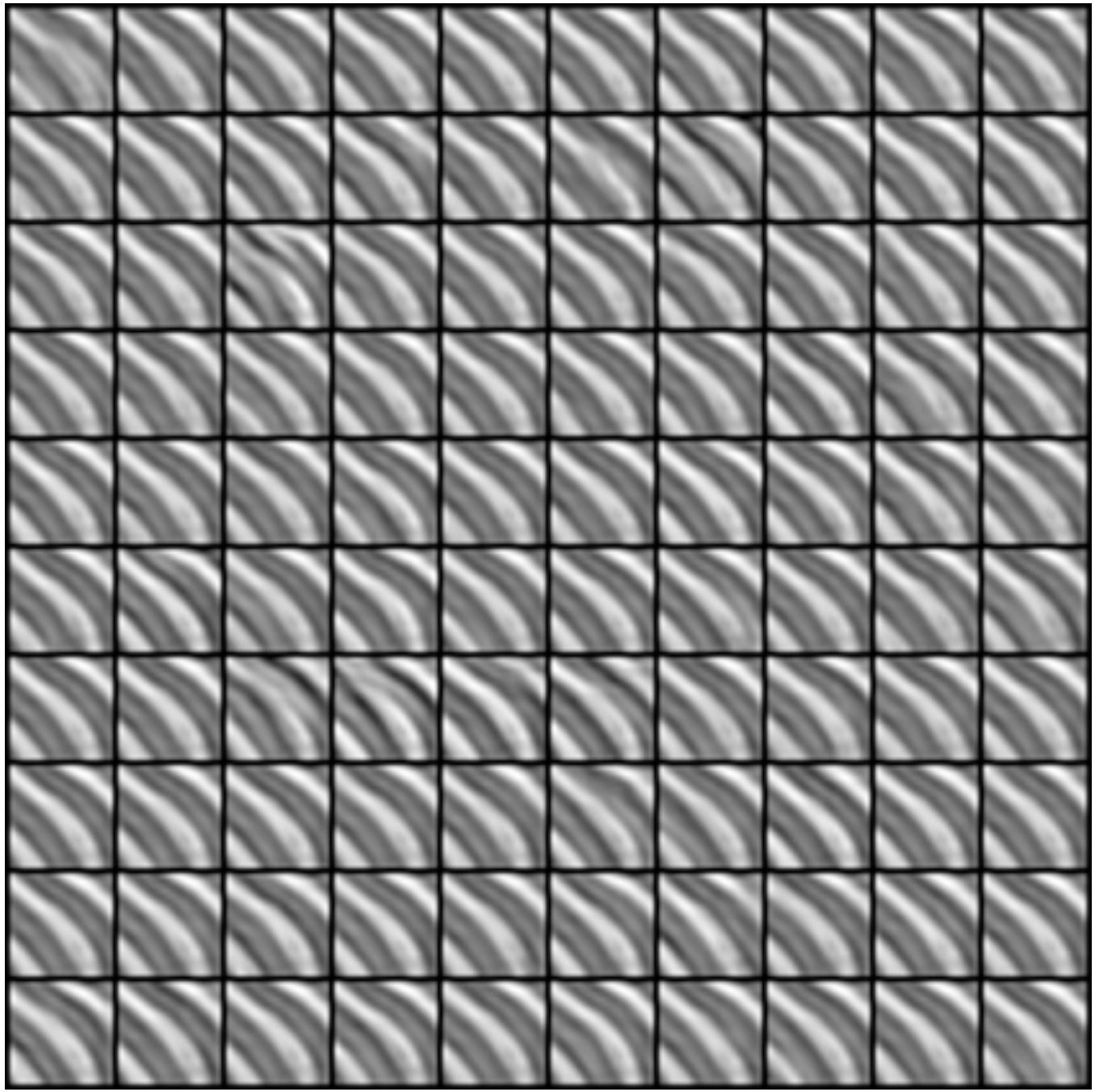
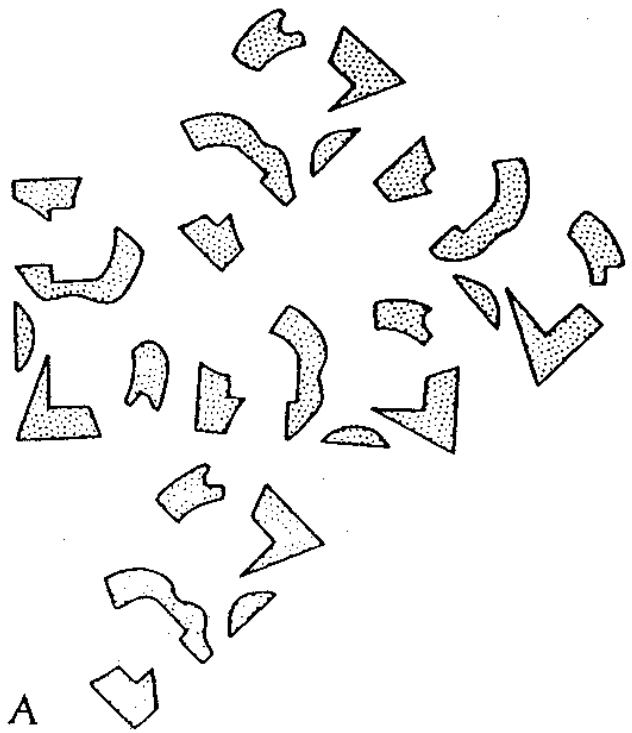
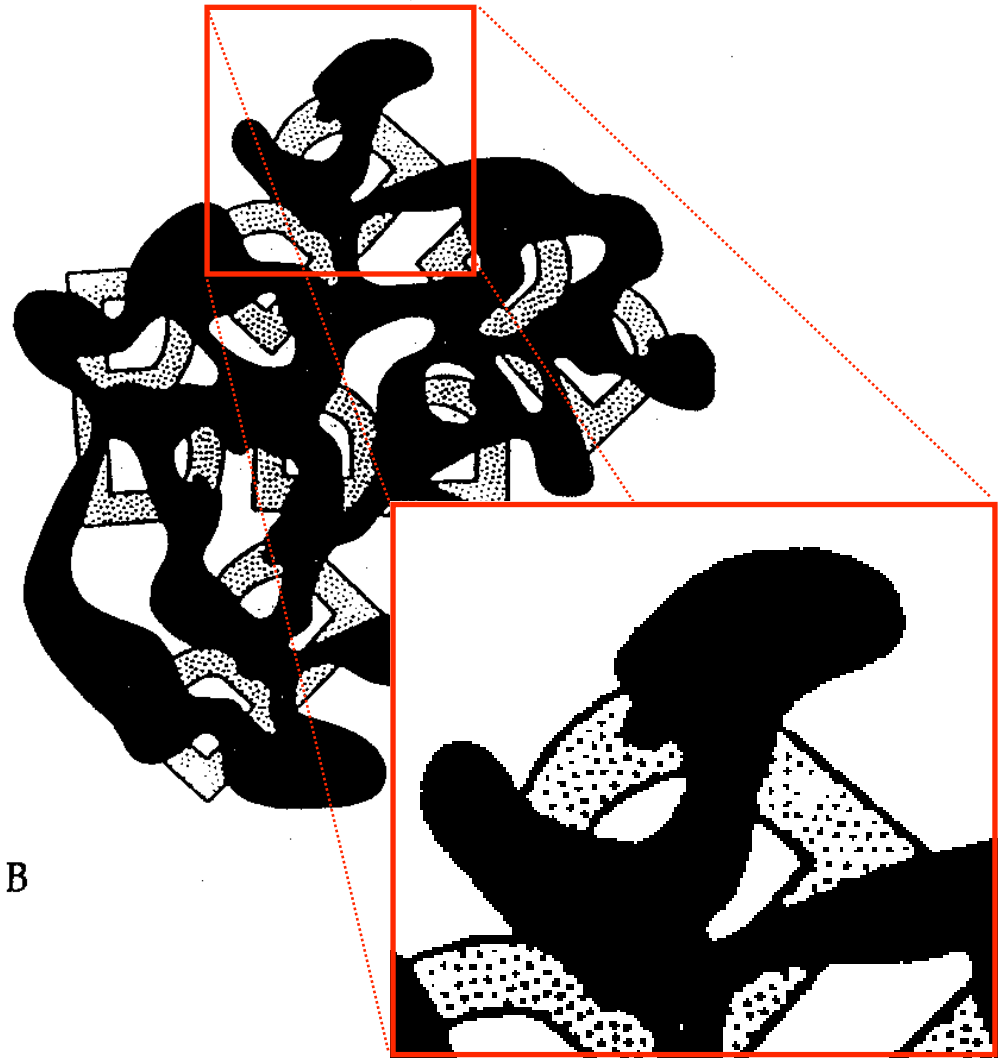
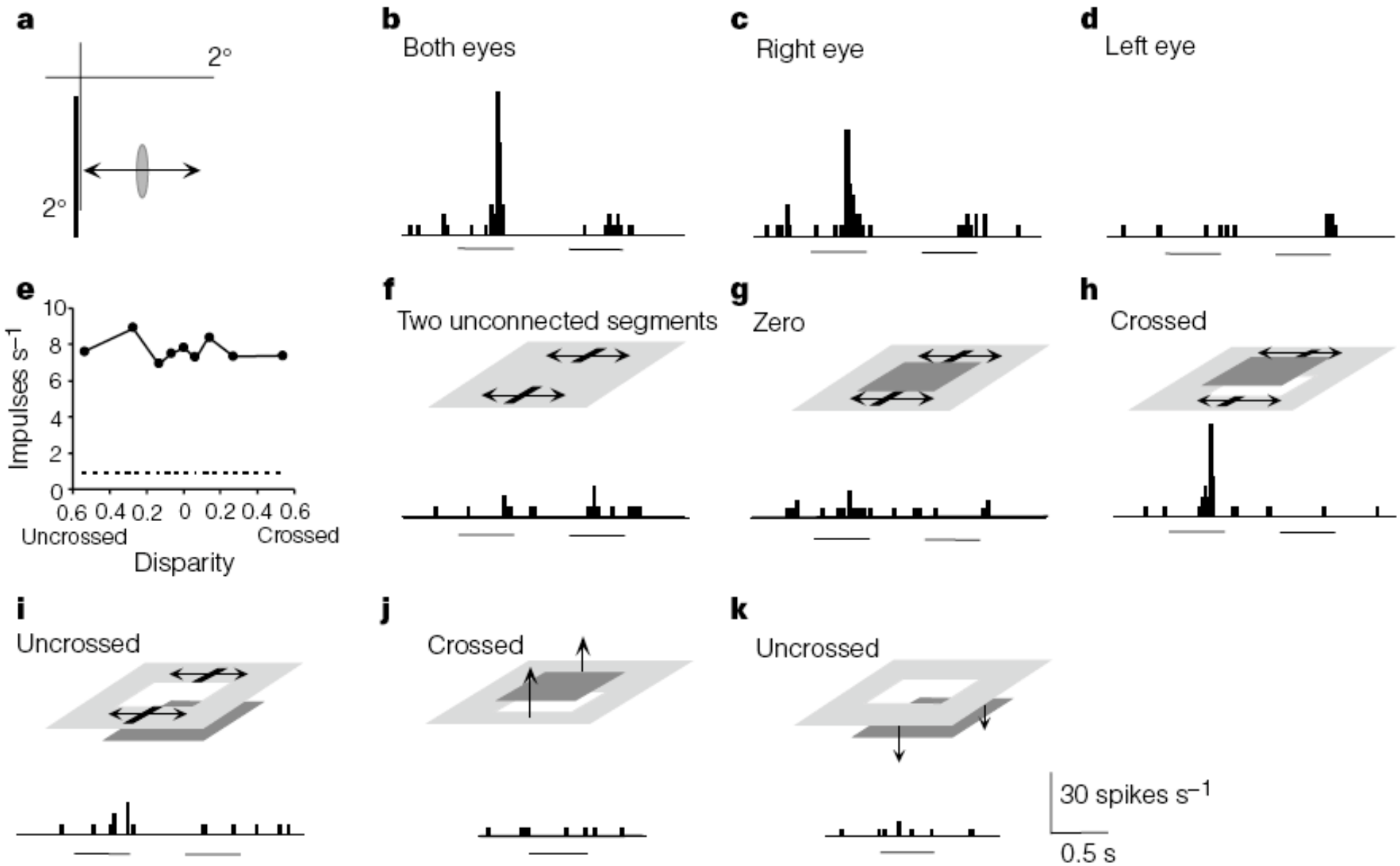


Figure-ground



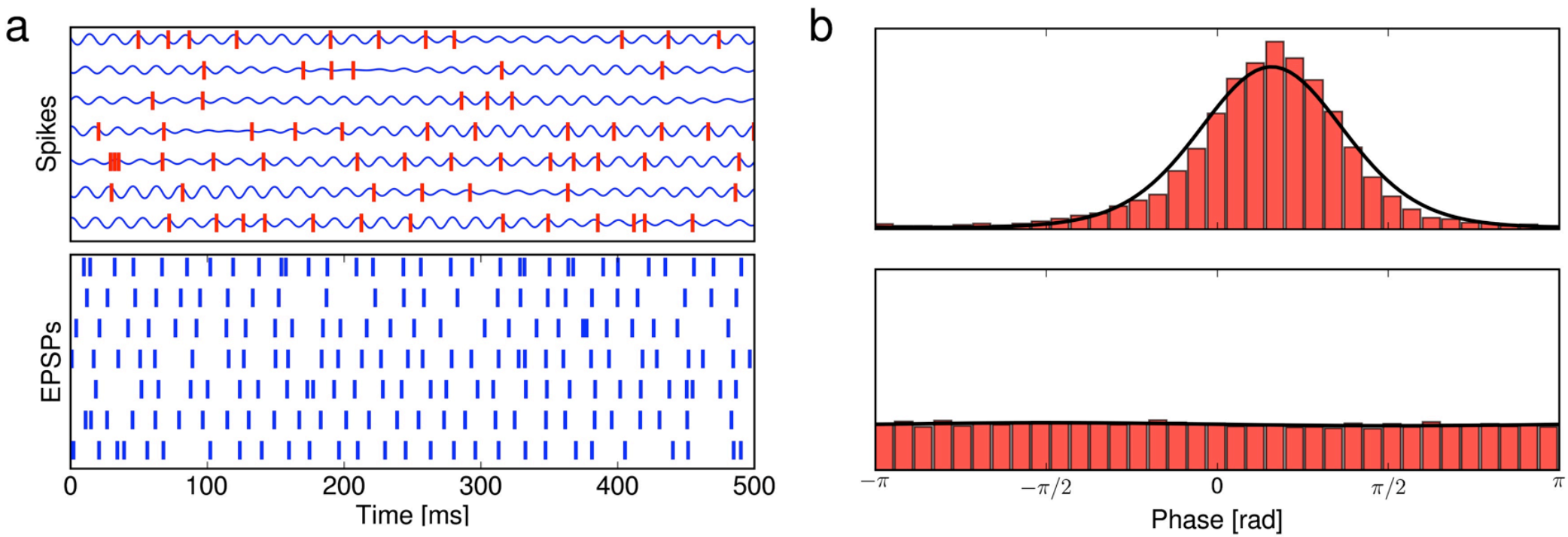


V1 simple cells can represent amodal completion
Sugita (1999)

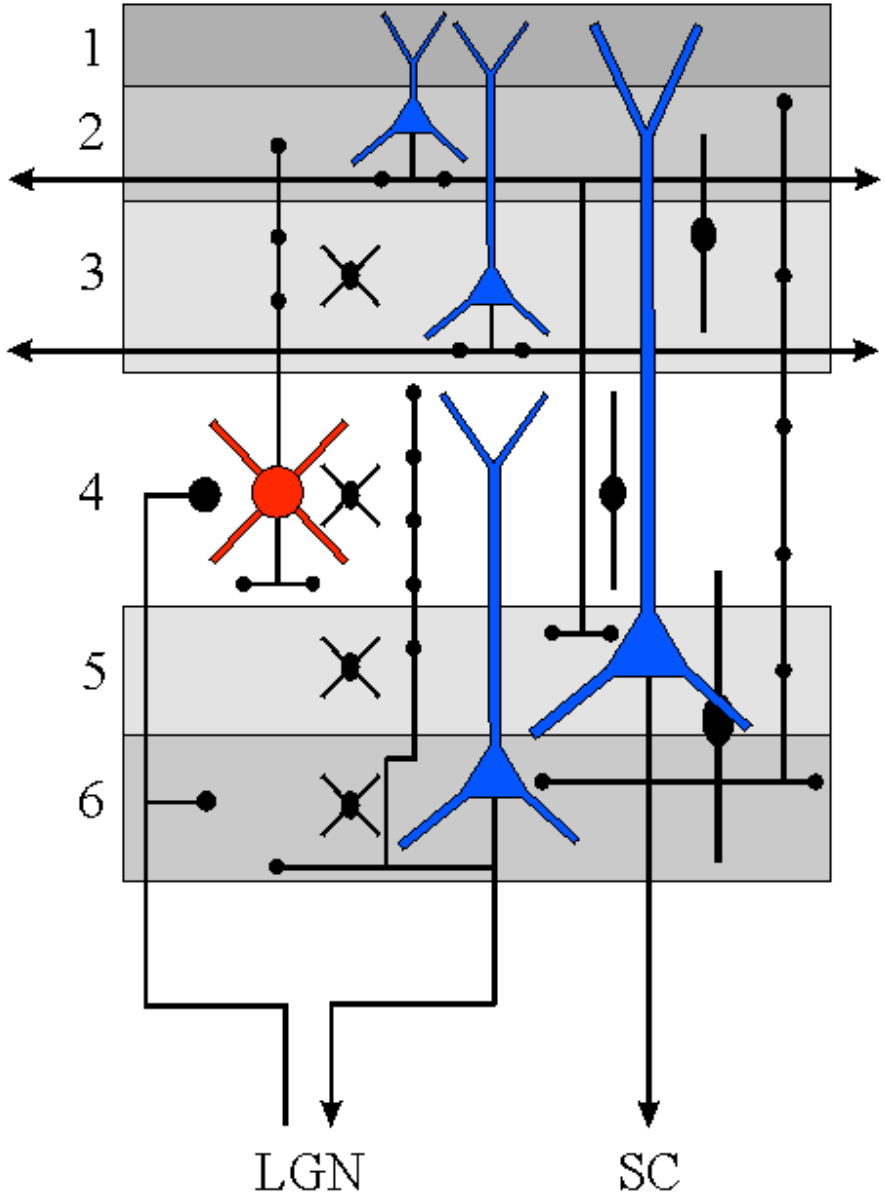


Synchrony

LGN spikes are phase-locked to ongoing retinal oscillations (Koepsell, Sommer, Hirsch)



Distribution of function across laminae



The Unknown

As we know,
There are known knowns.
There are things we know we know.
We also know
There are known unknowns.
That is to say
We know there are some things
We do not know.
But there are also unknown unknowns,
The ones we don't know
We don't know.

Feb. 12, 2002, Department of Defense news briefing

From: *The Poetry of Donald Rumsfeld*
Hart Seeley, Slate Magazine