Institute of Neuroinformatics
UNI/ETH Zurich

Biological and Computational Vision

Lecture 4

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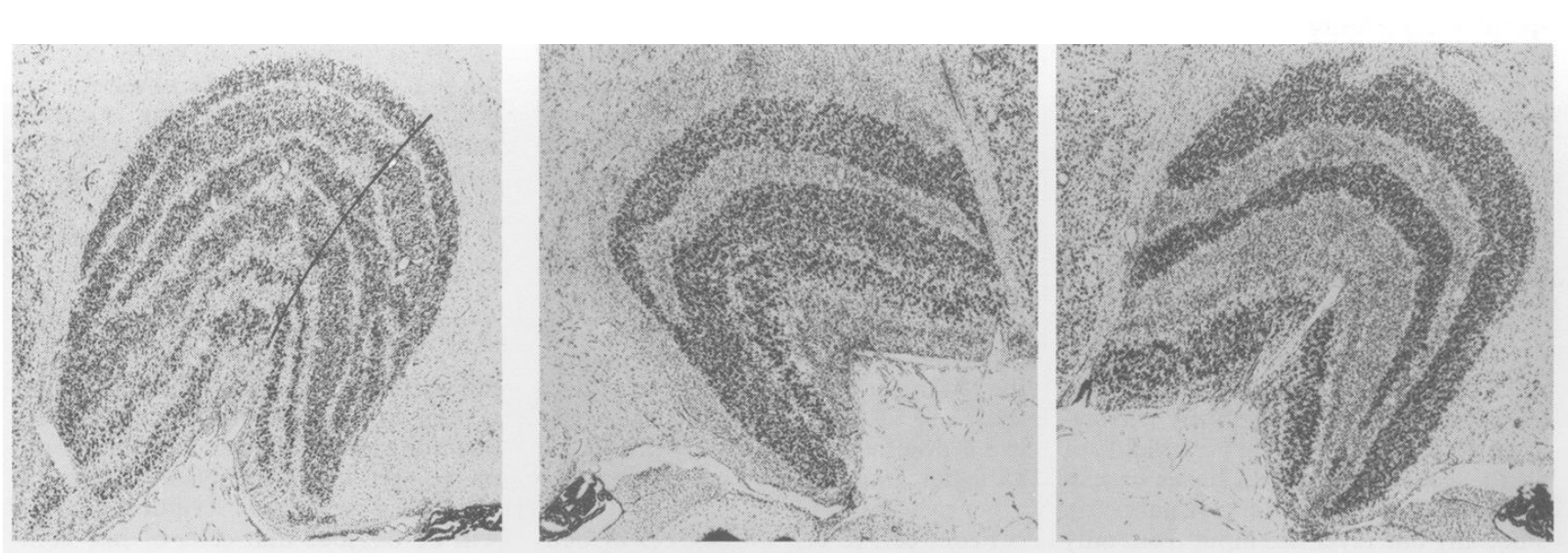
14.3.2024

www.ini.unizh.ch/~kiper/comp_vis/index.html

LGN: a few facts

The Lateral Geniculate Nucleus (LGN)

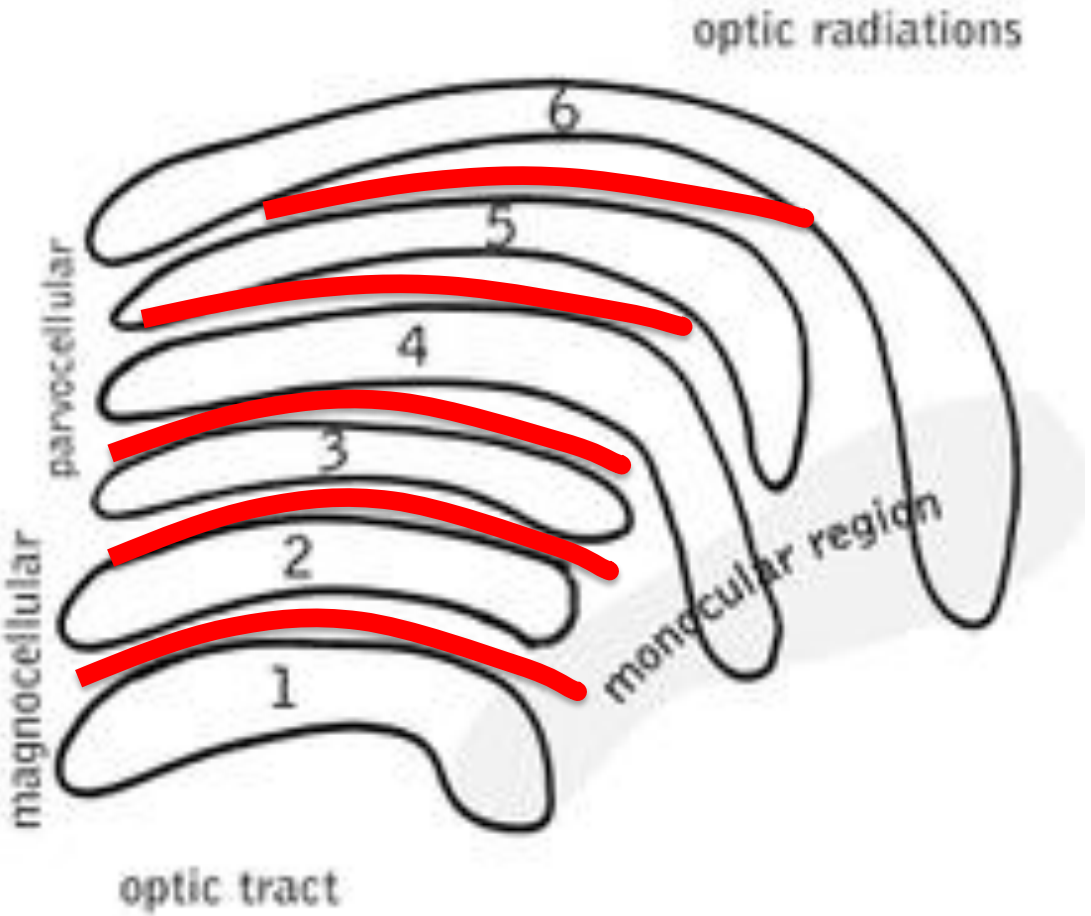


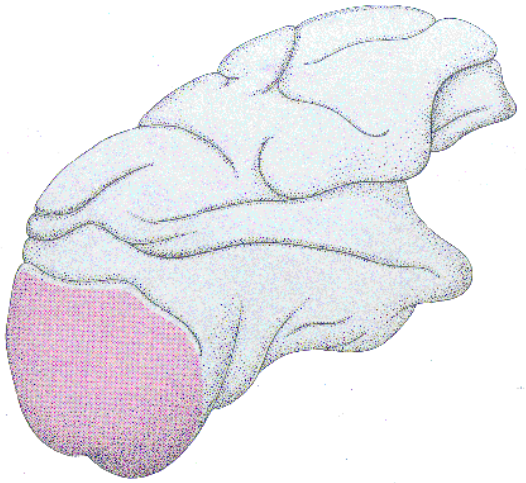
Hubel and Wiesel, 1979

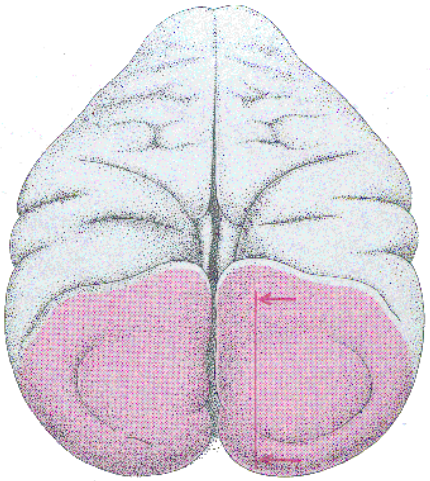
«Parvo» Cells/layers

«Konio» Cells/Layers

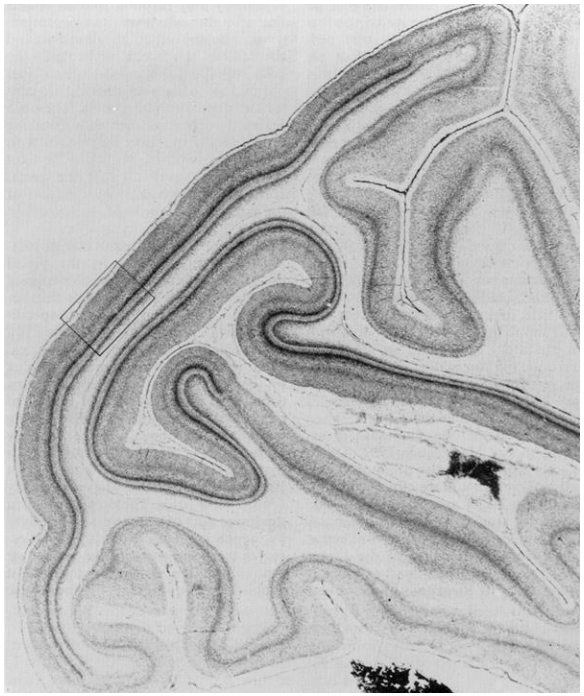
«Magno» Cells/Layers.



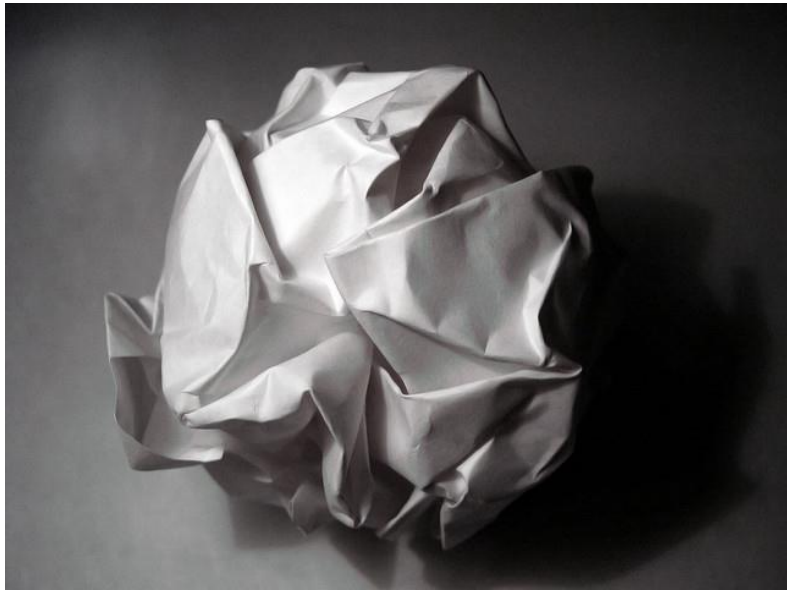




Primary visual cortex
(= V1 = Areal 17 = striate cortex)

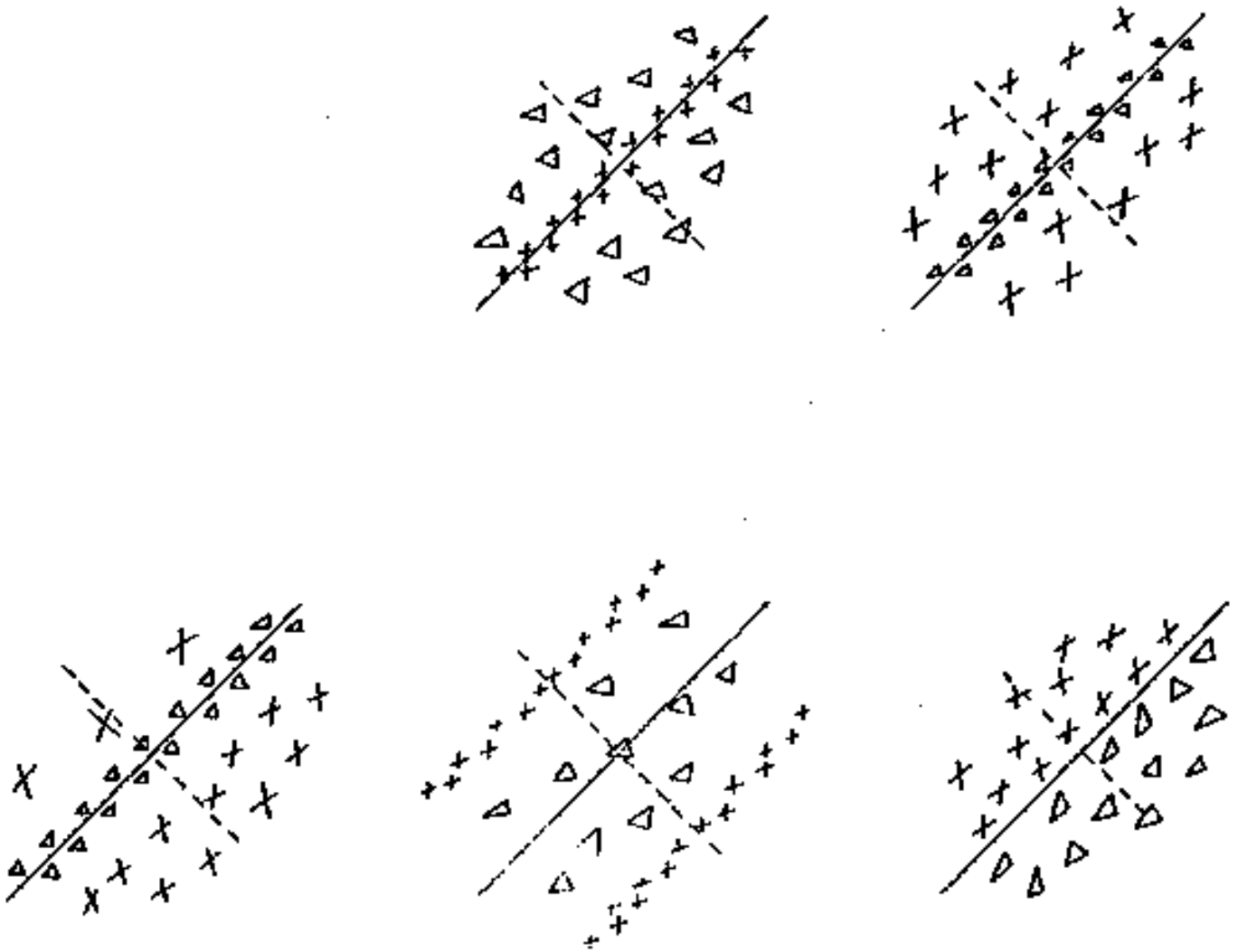


Hubel and Wiesel, 1979



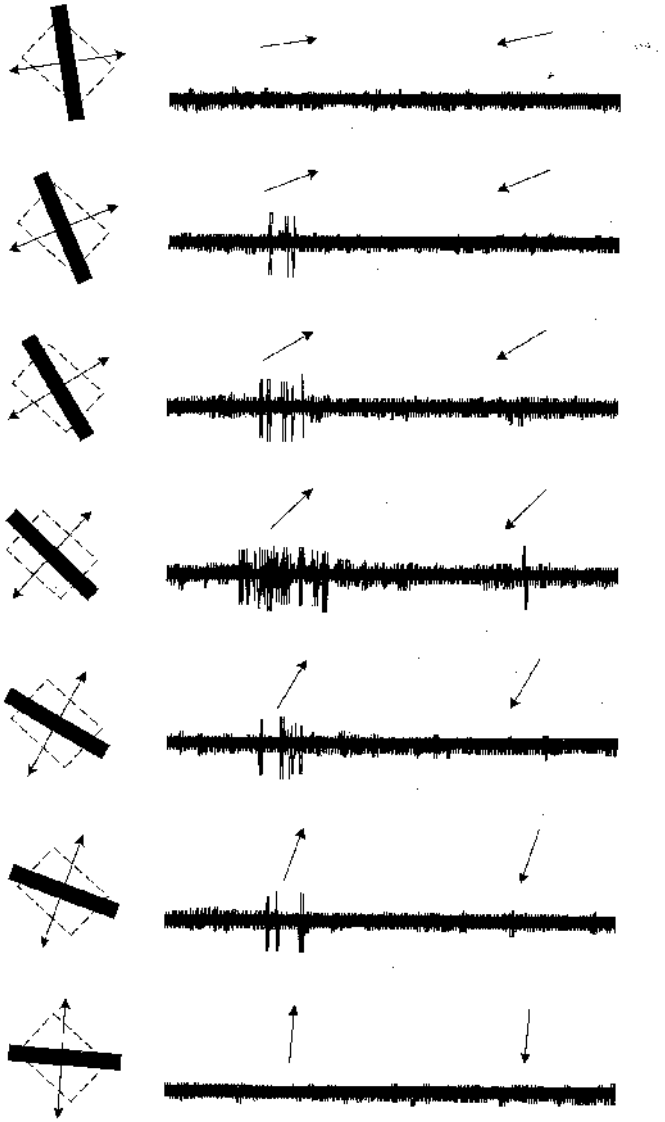
Cortical processing

V1 “simple cells”



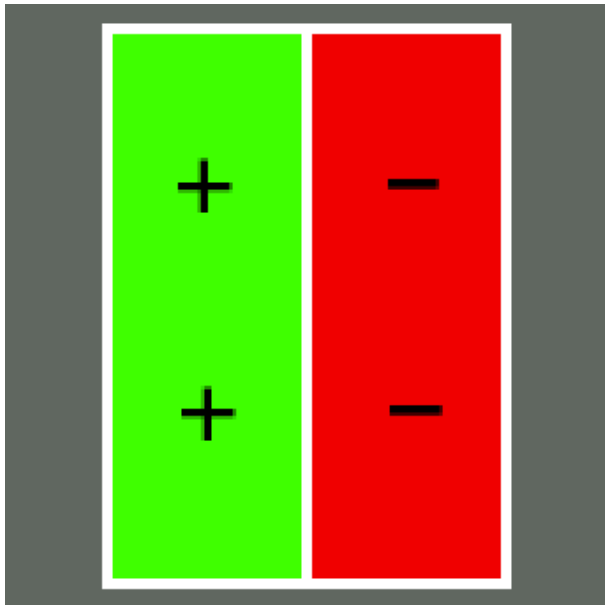
Hubel & Wiesel (1963)

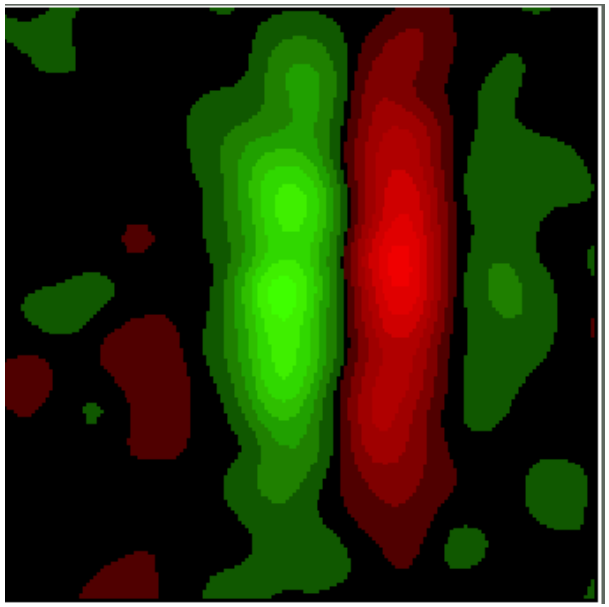
Selectivity for stimulus orientation and direction



Hubel and Wiesel (1968)
in Wandell (1995)

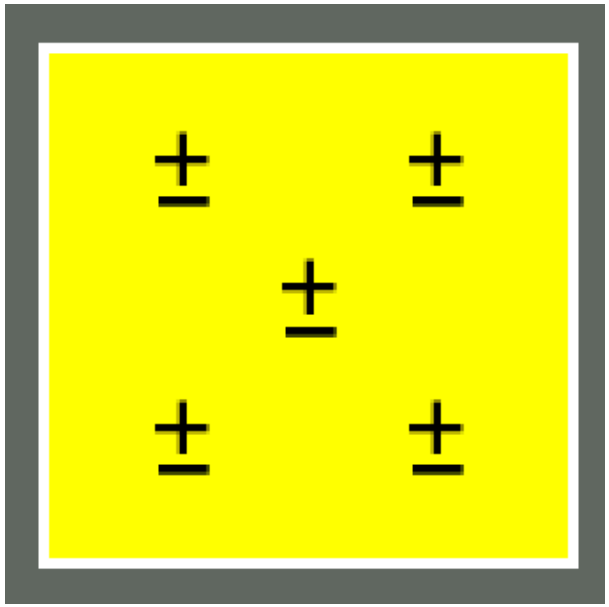
simple cell

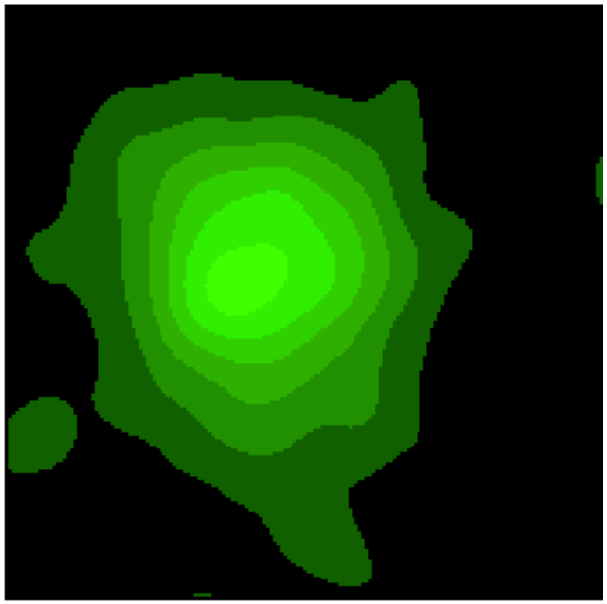




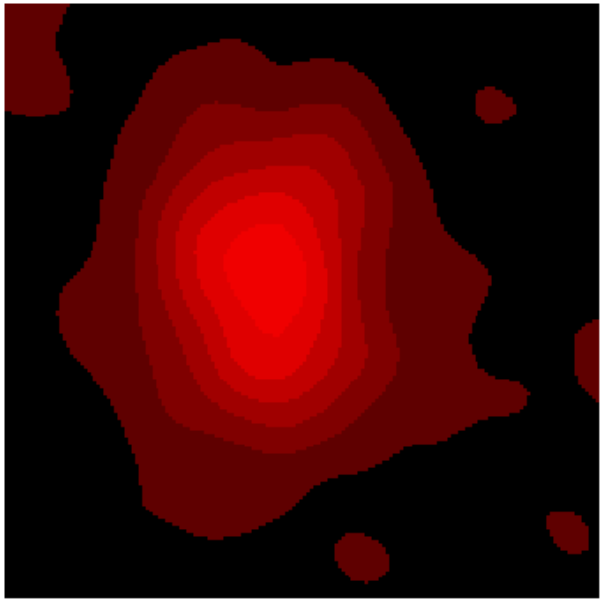
DeAngelis, Ohzawa & Freeman (1995)

Receptive field of a complex cell





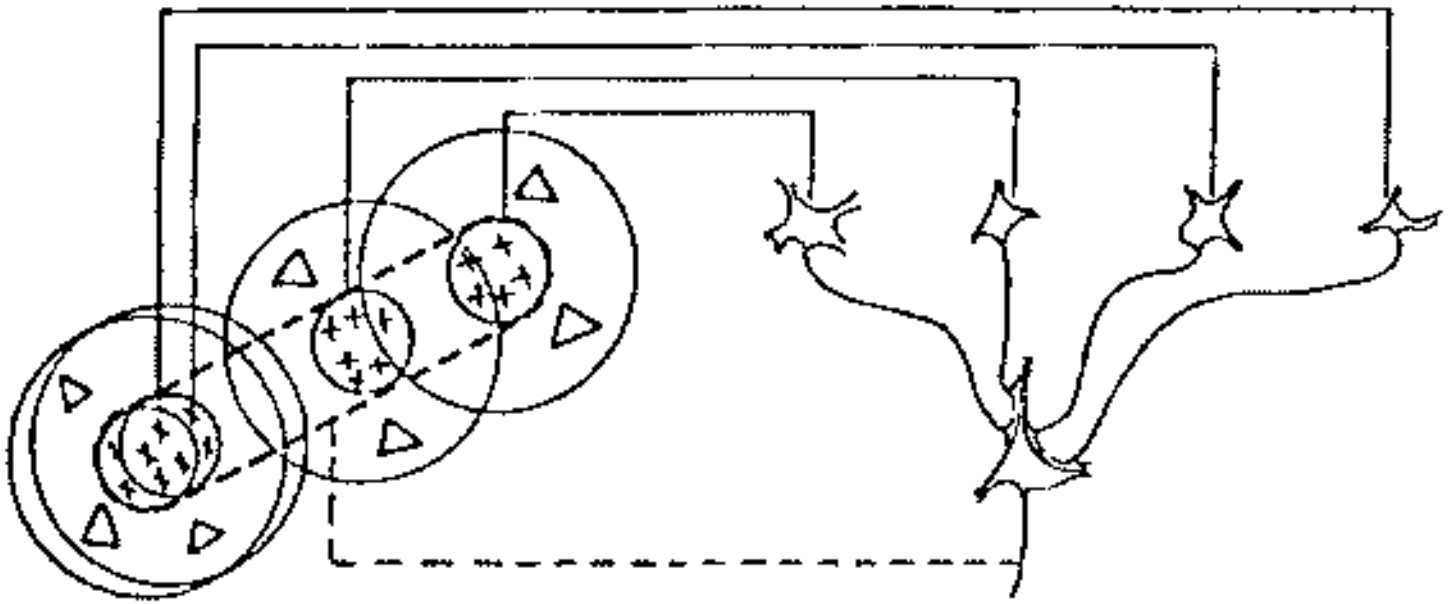
Responses to white dots



Responses to black dots

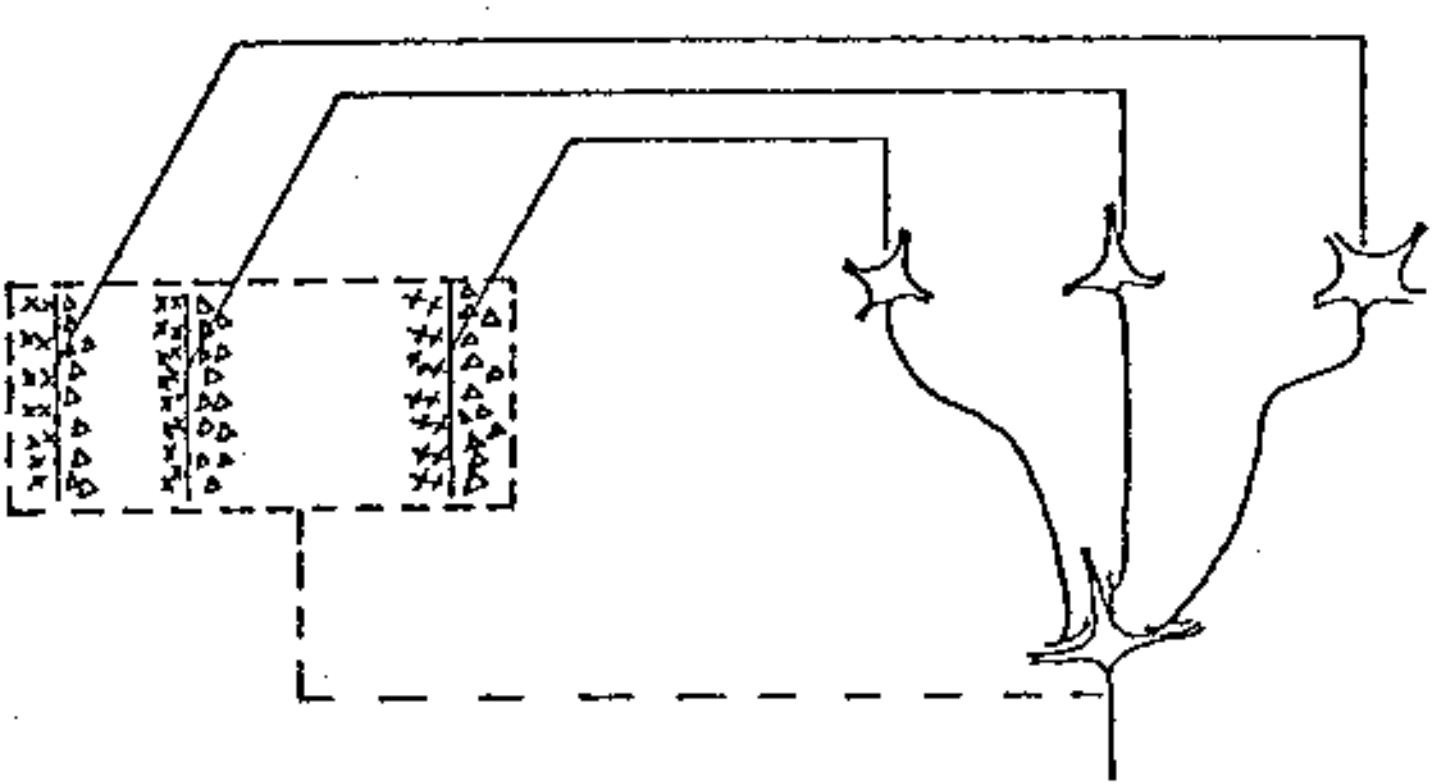
DeAngelis, Ohzawa & Freeman (1995)

Hubel & Wiesel's feedforward model of simple cells



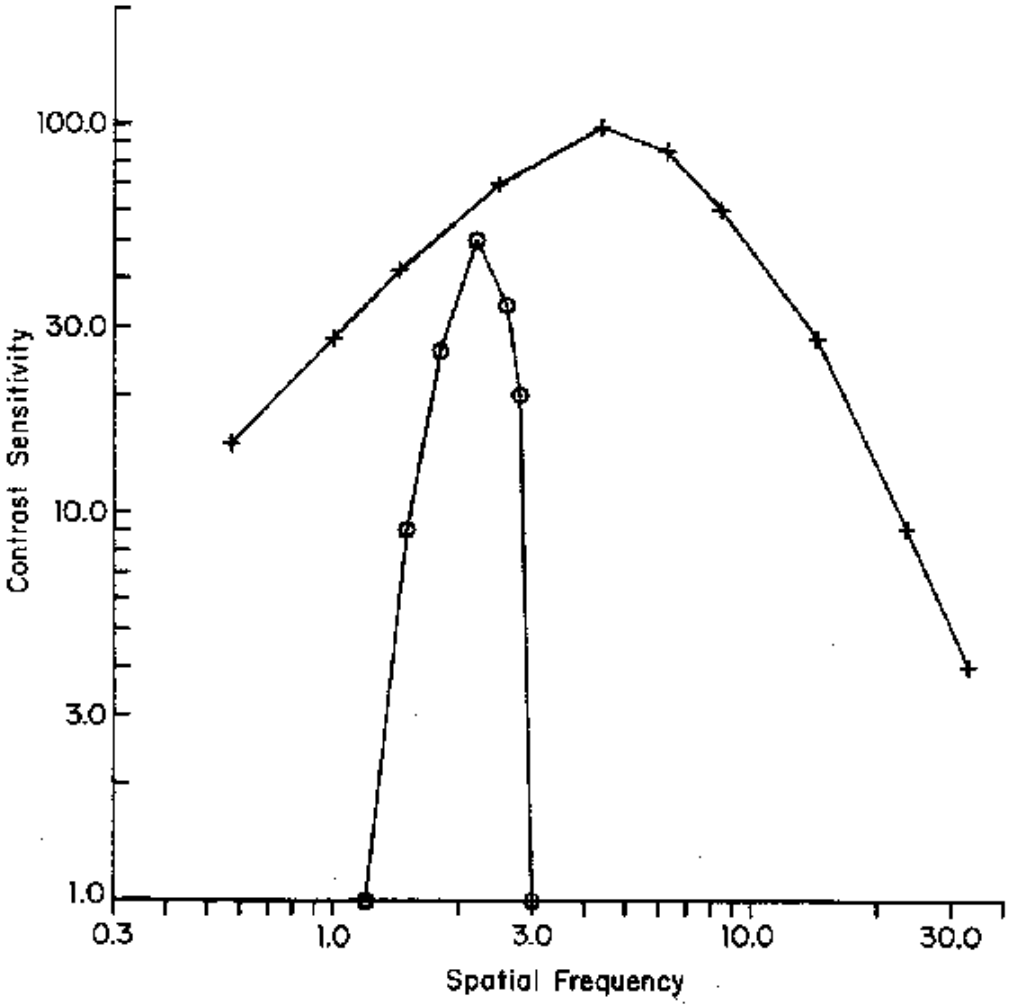
Hubel & Wiesel (1963)

Hubel & Wiesel's feedforward model of complex cells



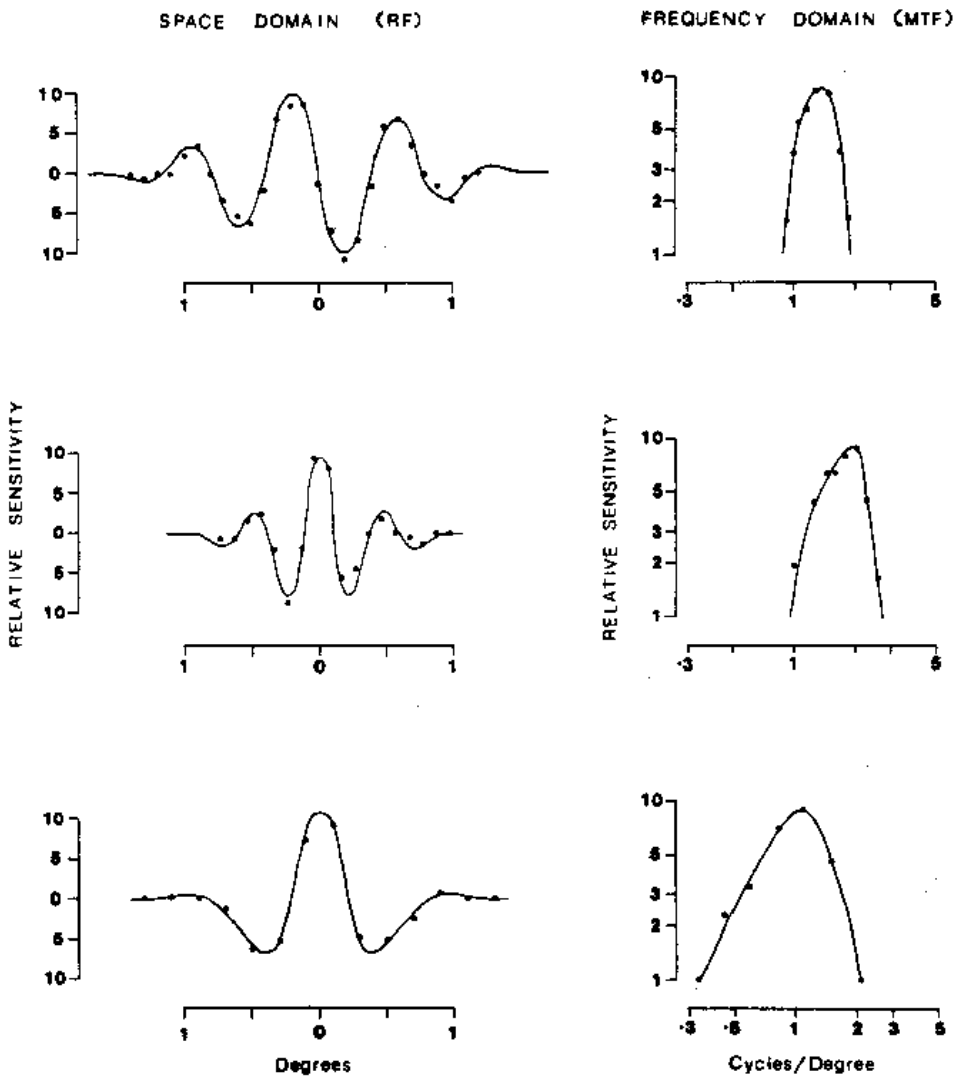
Hubel & Wiesel (1963)

Perceptual and neural sensitivity: data from a monkey



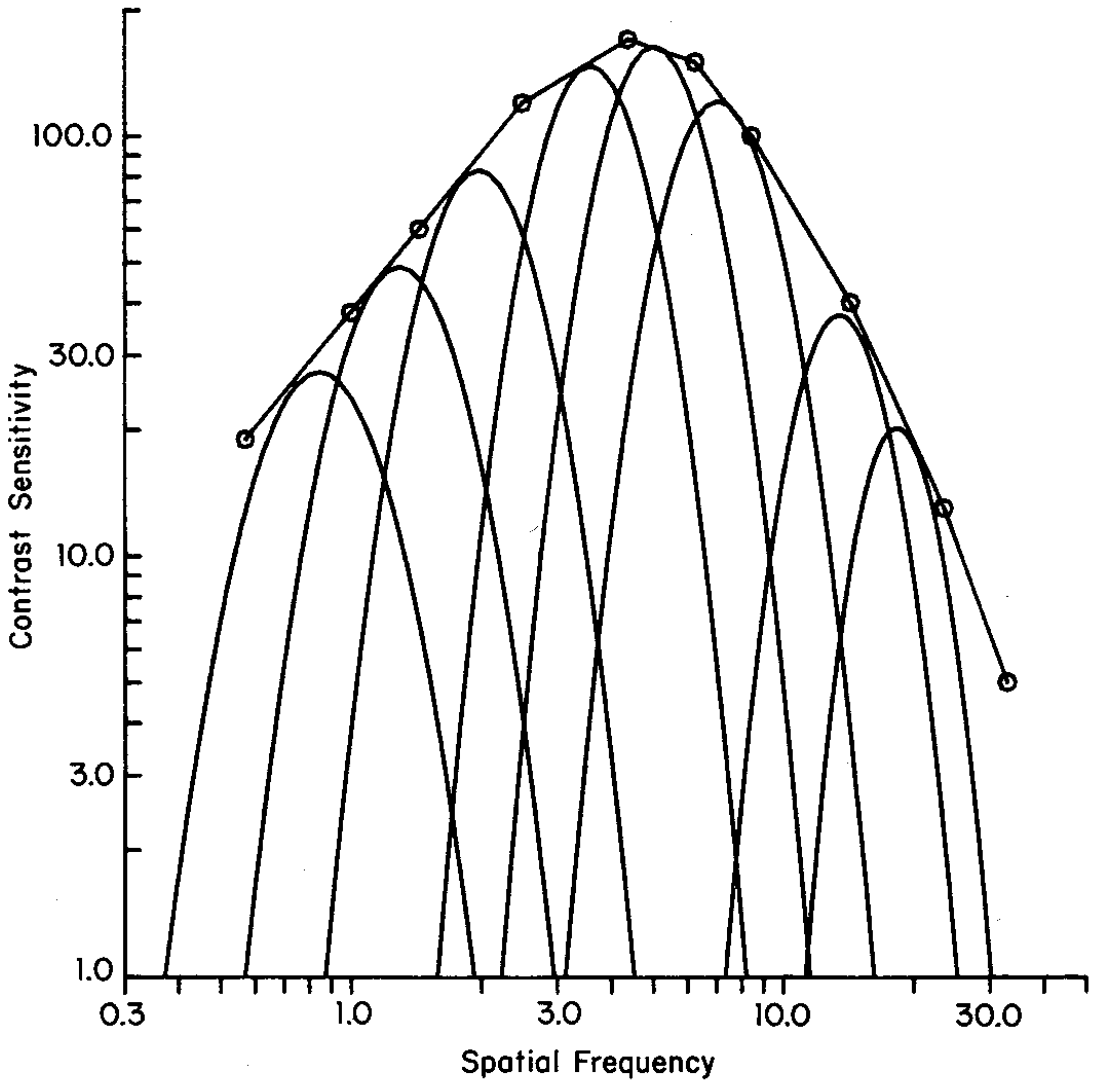
De Valois & De Valois (1990)

For simple cells, knowing the receptive field is knowing spatial frequency tuning



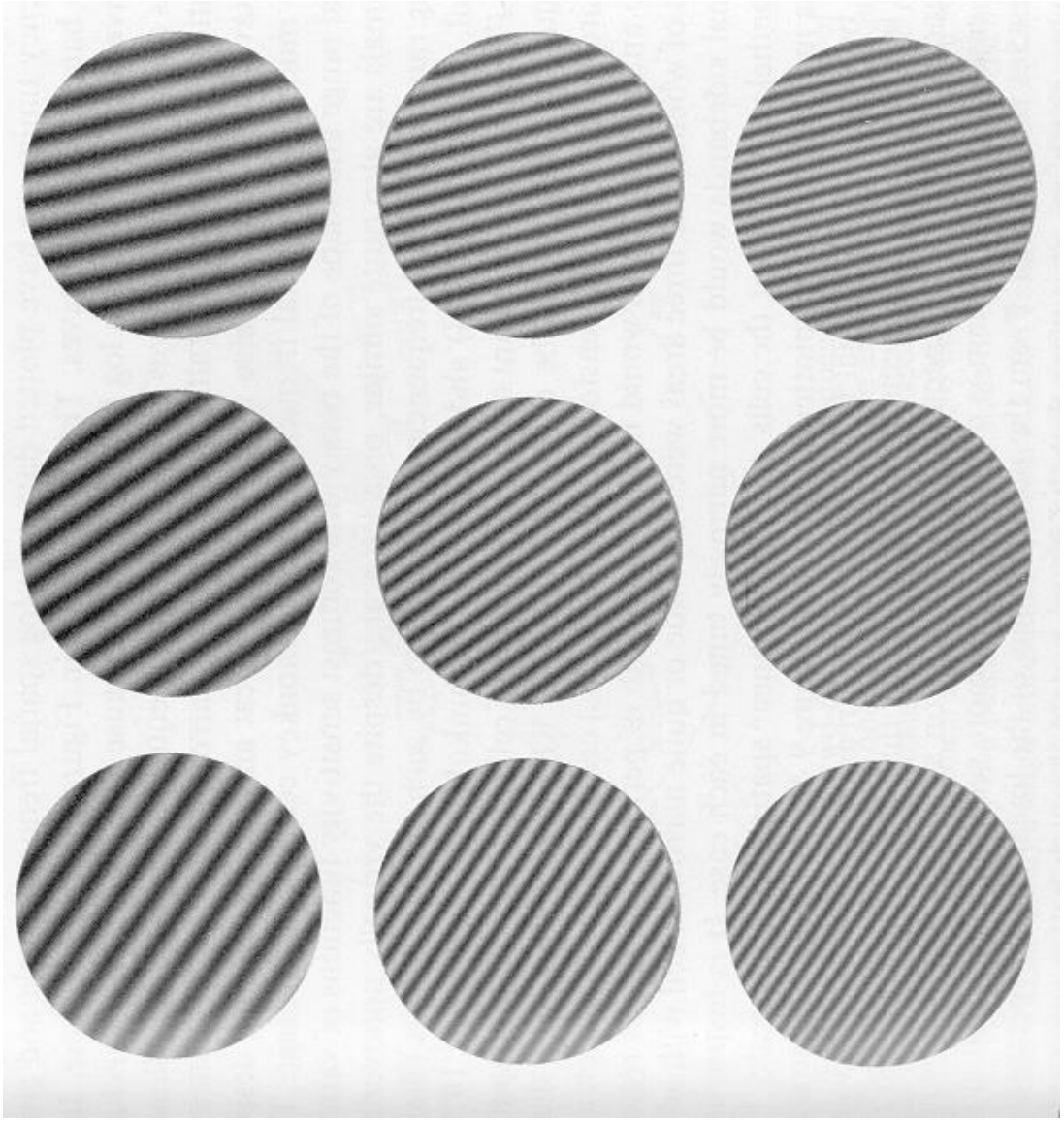
De Valois & De Valois (1990)
Albrecht (1978)

Back to the model of perceptual sensitivity



De Valois & De Valois (1990)

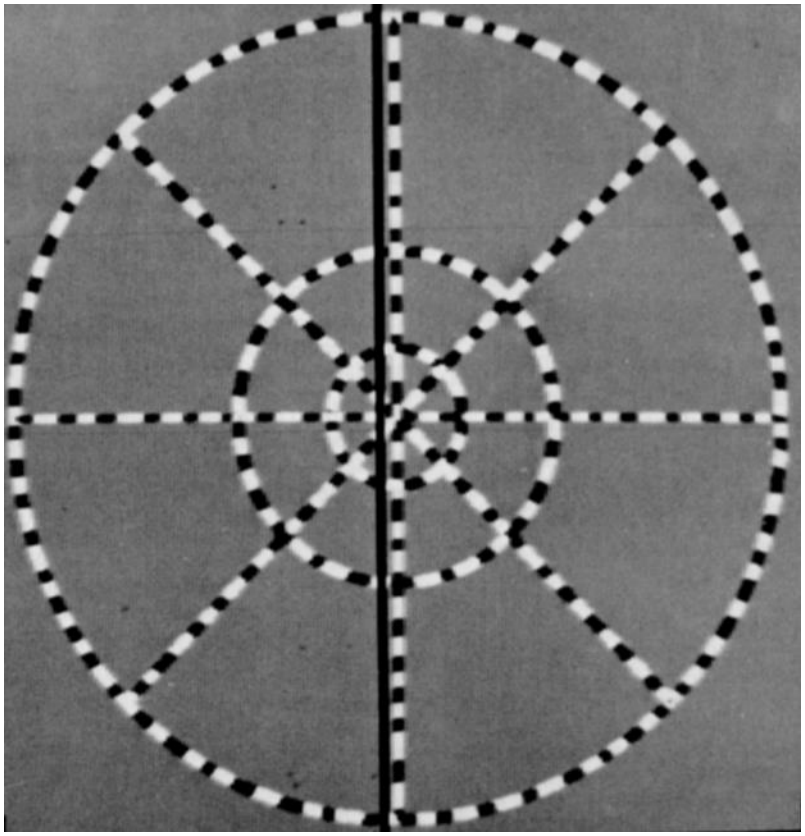
Selectivity in V1 is extremely sharp

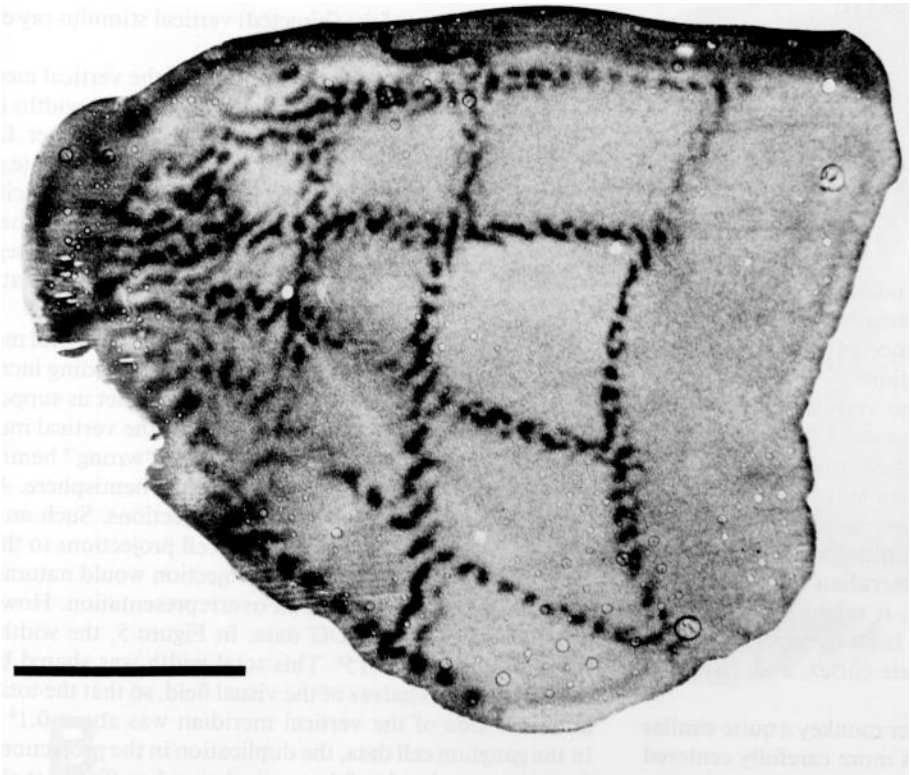


De Valois & De Valois (1990)

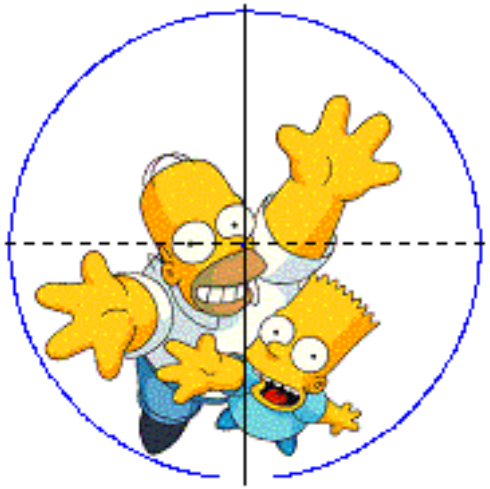
Retinotopy

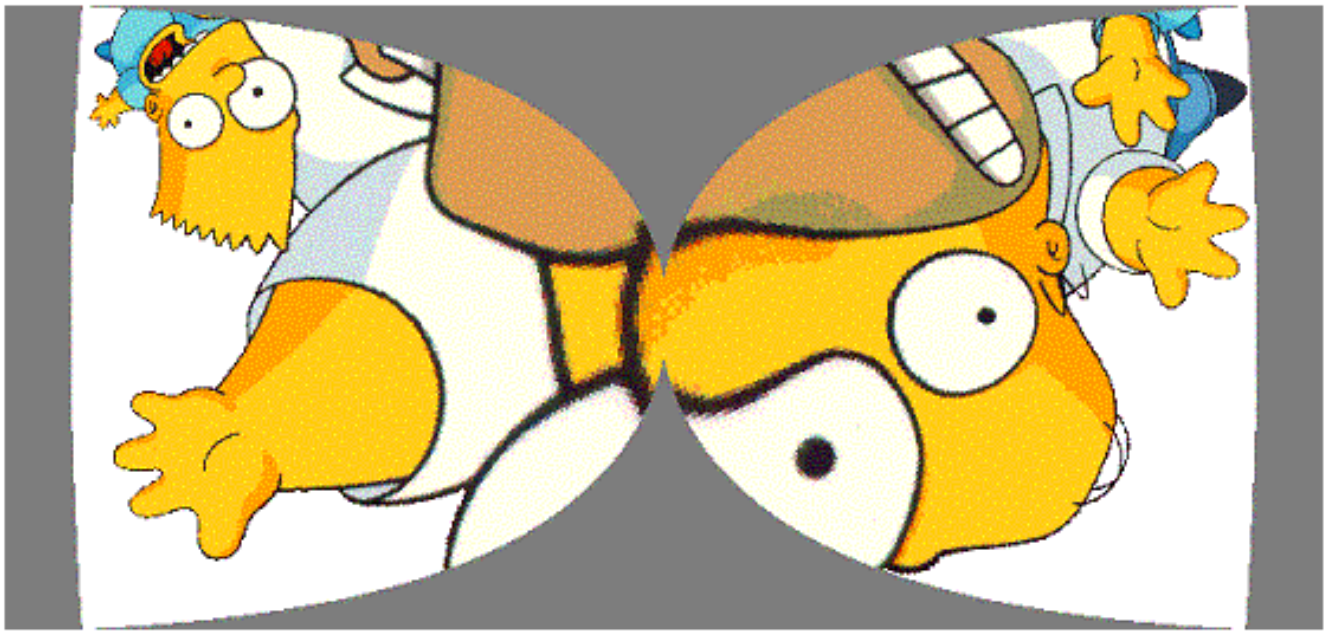
Cortical representation measured with 2-deoxy-glucose





Tootell et al. (1988)

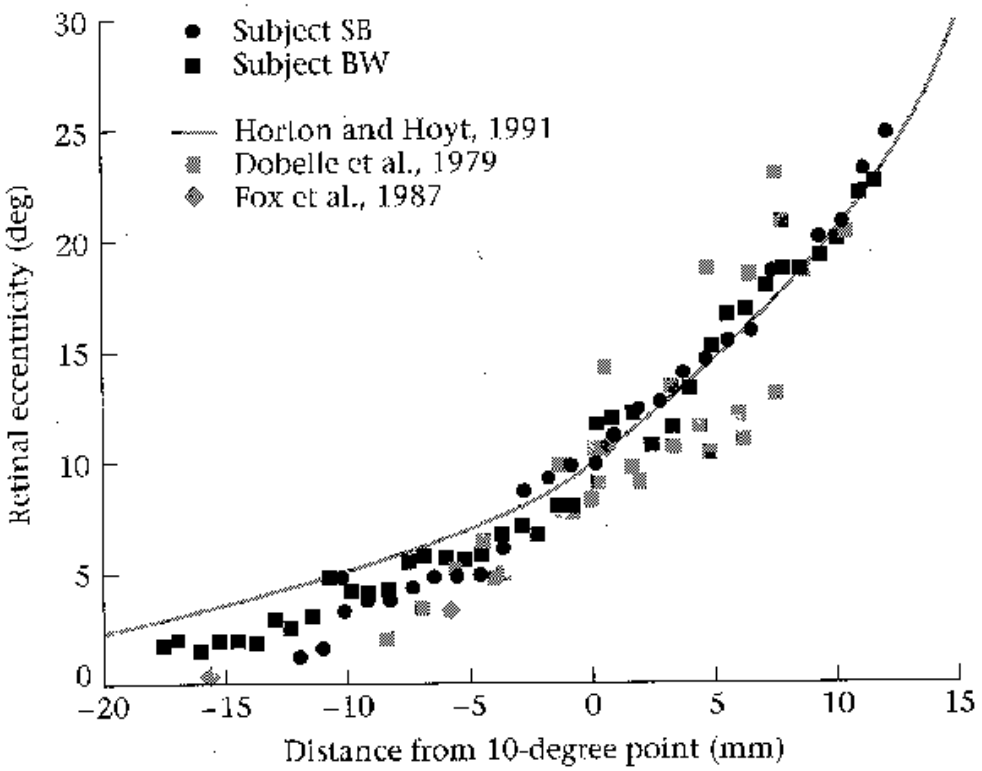




Left V1

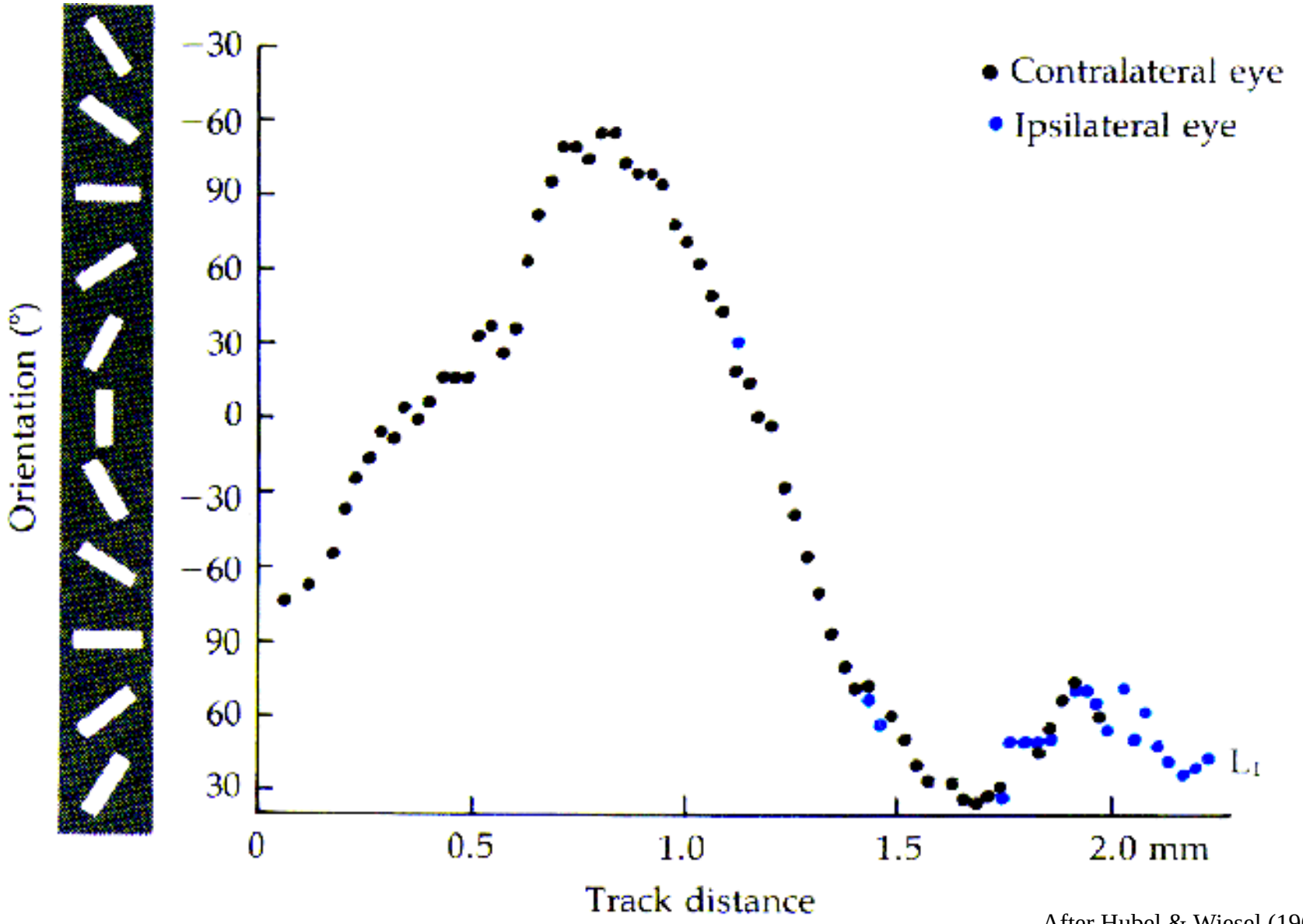
Right V1

Cortical magnification



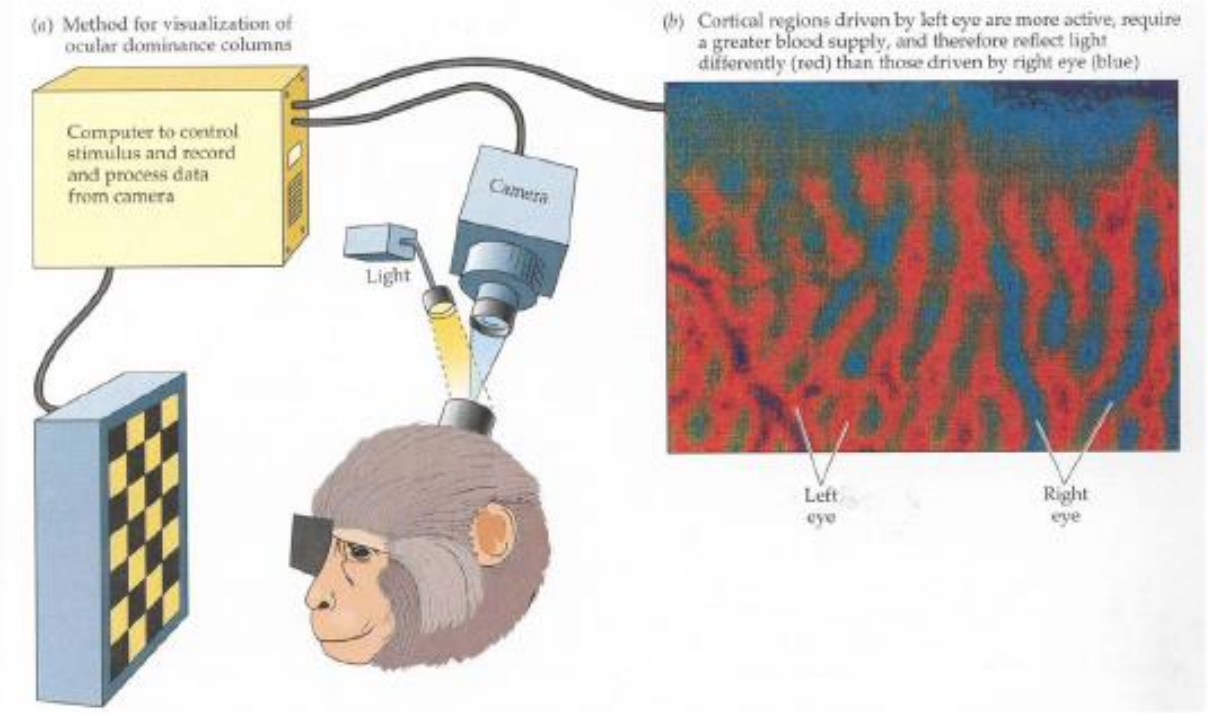
Methods:
- fMRI
- estimate from strokes + primate cells
- microstimulation in a blind volunteer
- PET in 5 observers

Engel et al. (1994)
in Wandell (1995)



After Hubel & Wiesel (1962)
in Nicholls et al. (1992)

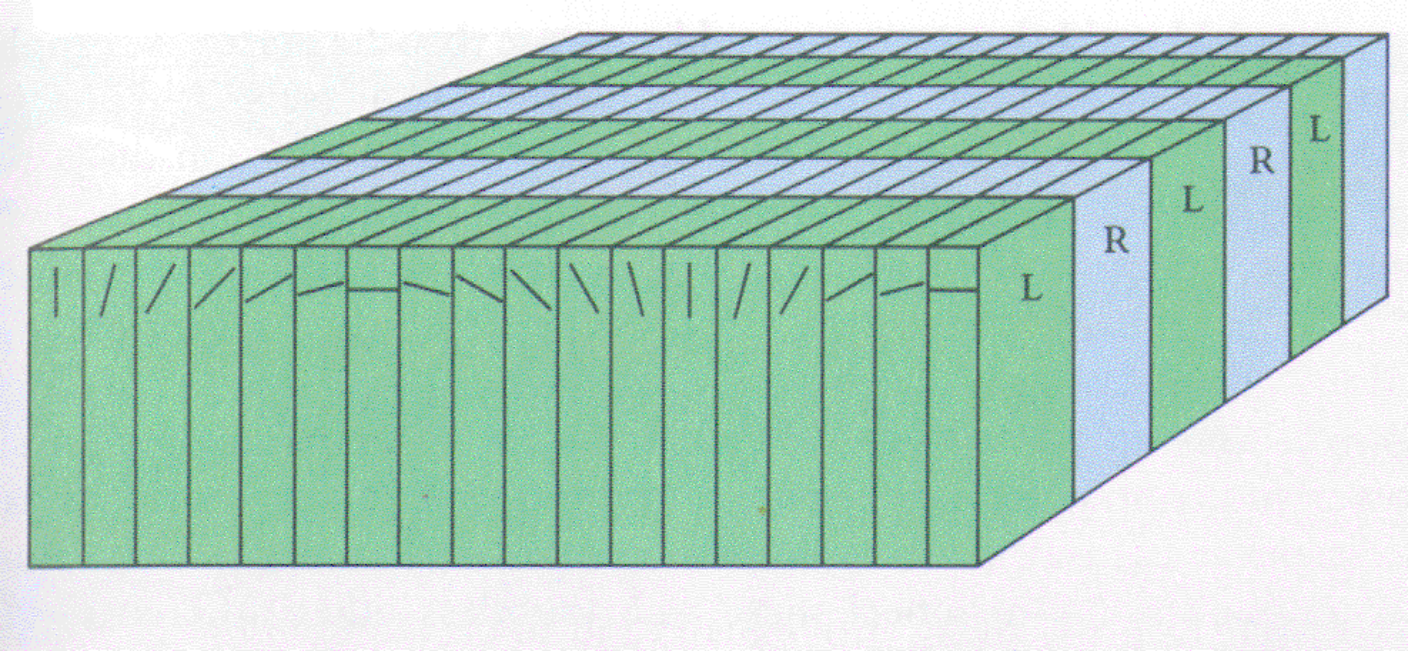
Okulare Dominanz



In V1 werden zum ersten Mal die Informationen aus dem linken und rechten Auge kombiniert.

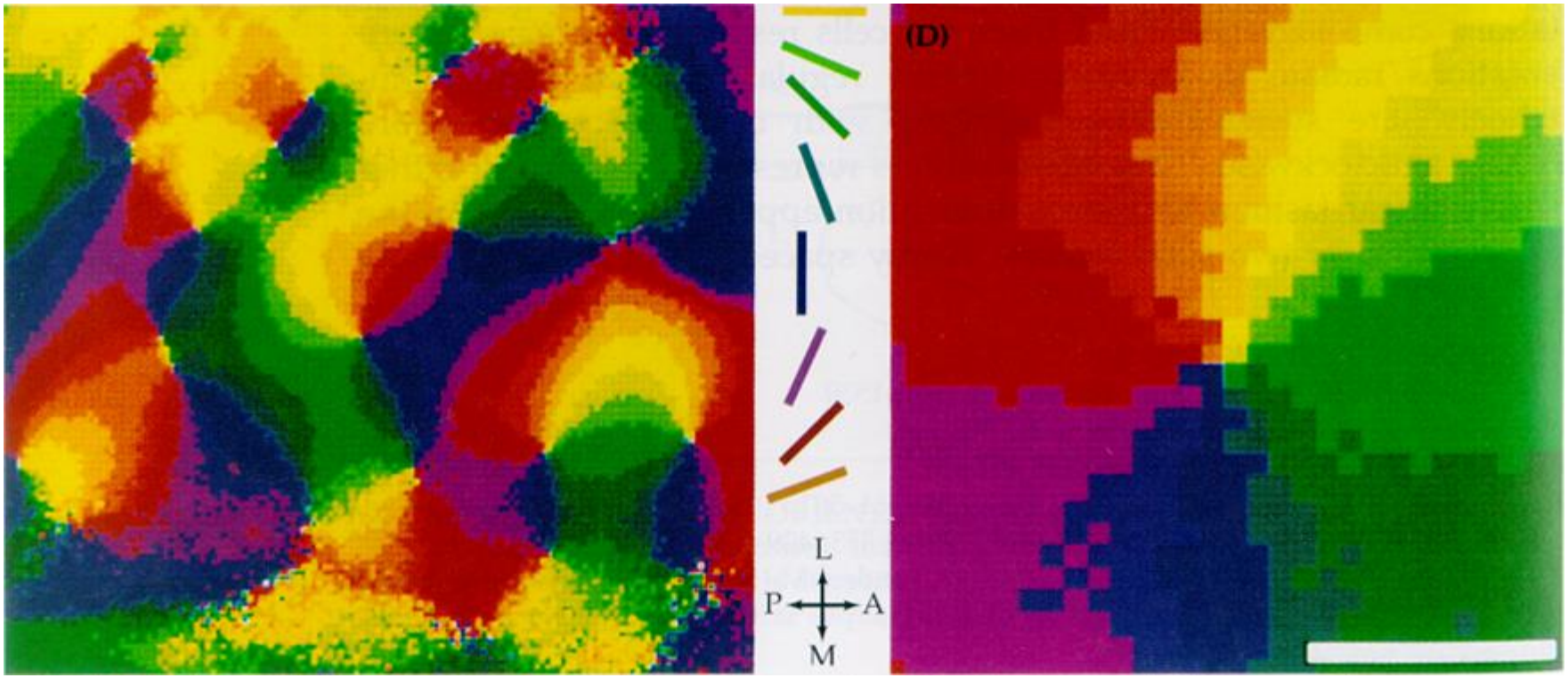

ocular
dominance
stripes

The “ice-cube” model of Hubel and Wiesel



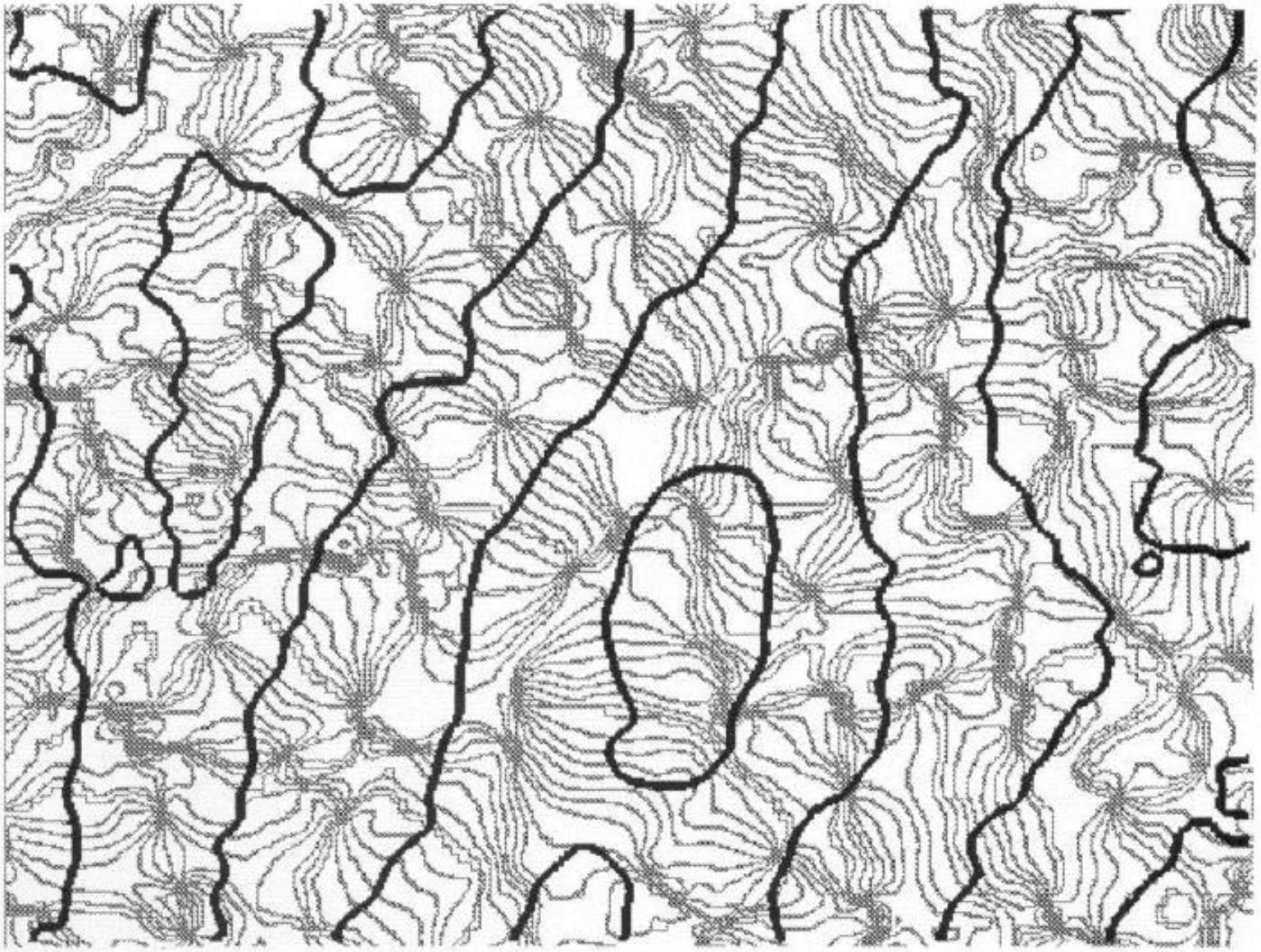
Hubel (1988), in *Eye, Brain, and Vision*, p. 131.

Orientation columns measured with optical imaging



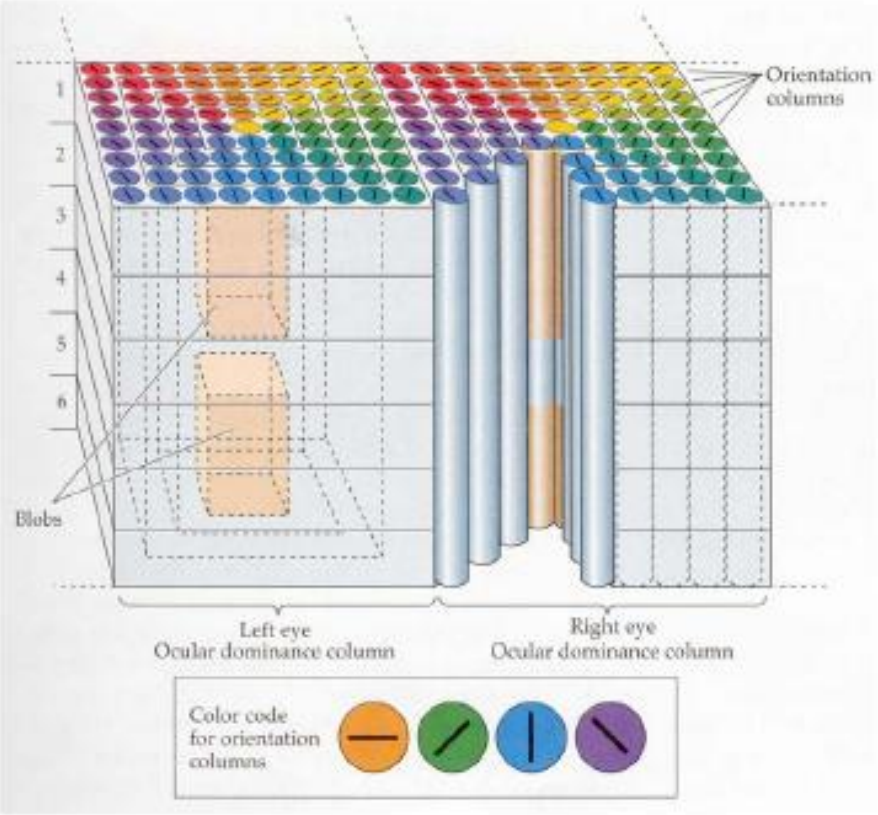
Bonhoeffer and Grinvald (1991)
in Nicholls et al. (1992)

Orientation and ocular dominance columns



Obermayer and Blasdel, 1983

Kolumnare Organisation

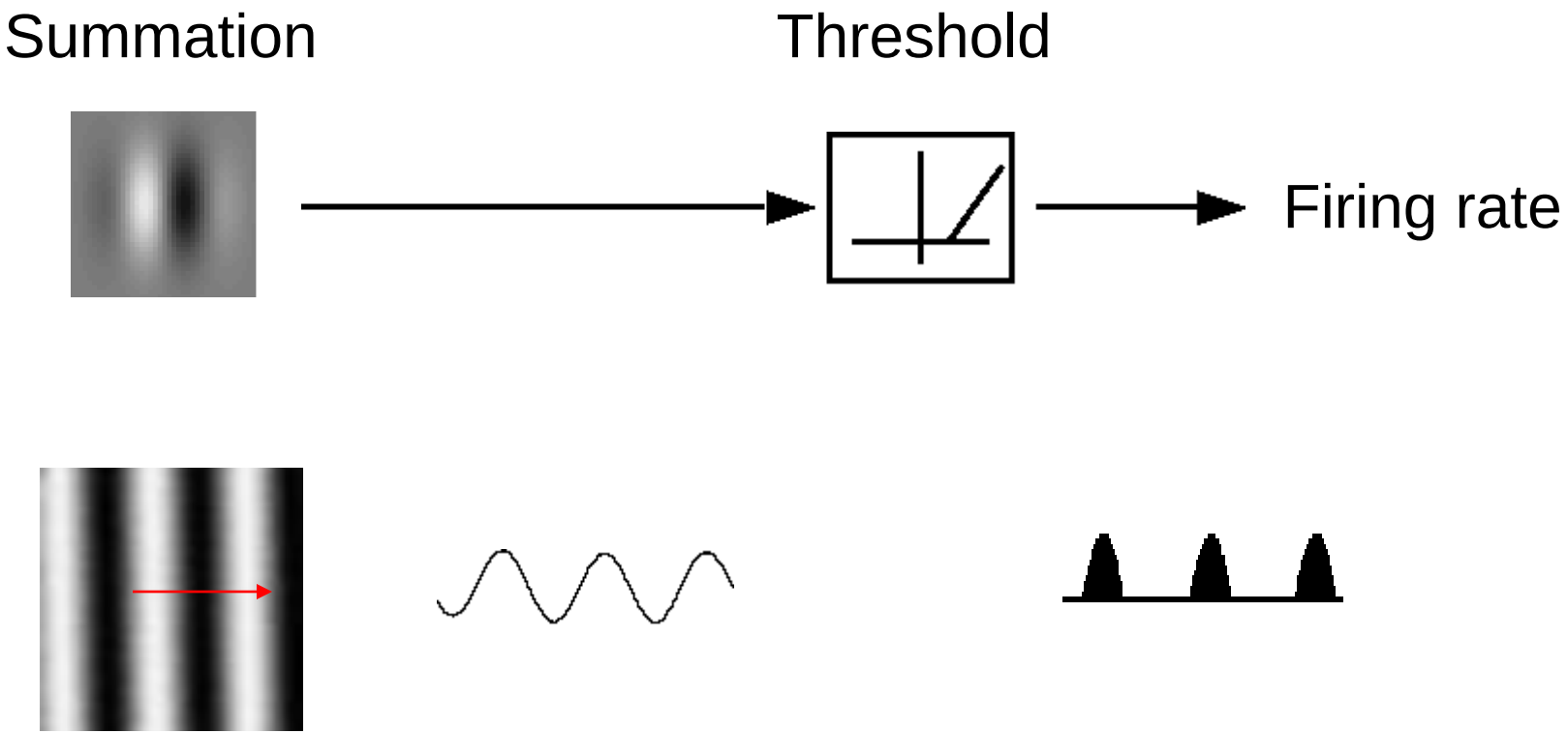


Die Kolumne ist die elementare Recheneinheit im visuellen Kortex. In einer Kolumne sind die Signale aus beiden Augen für alle Orientierungen repräsentiert.

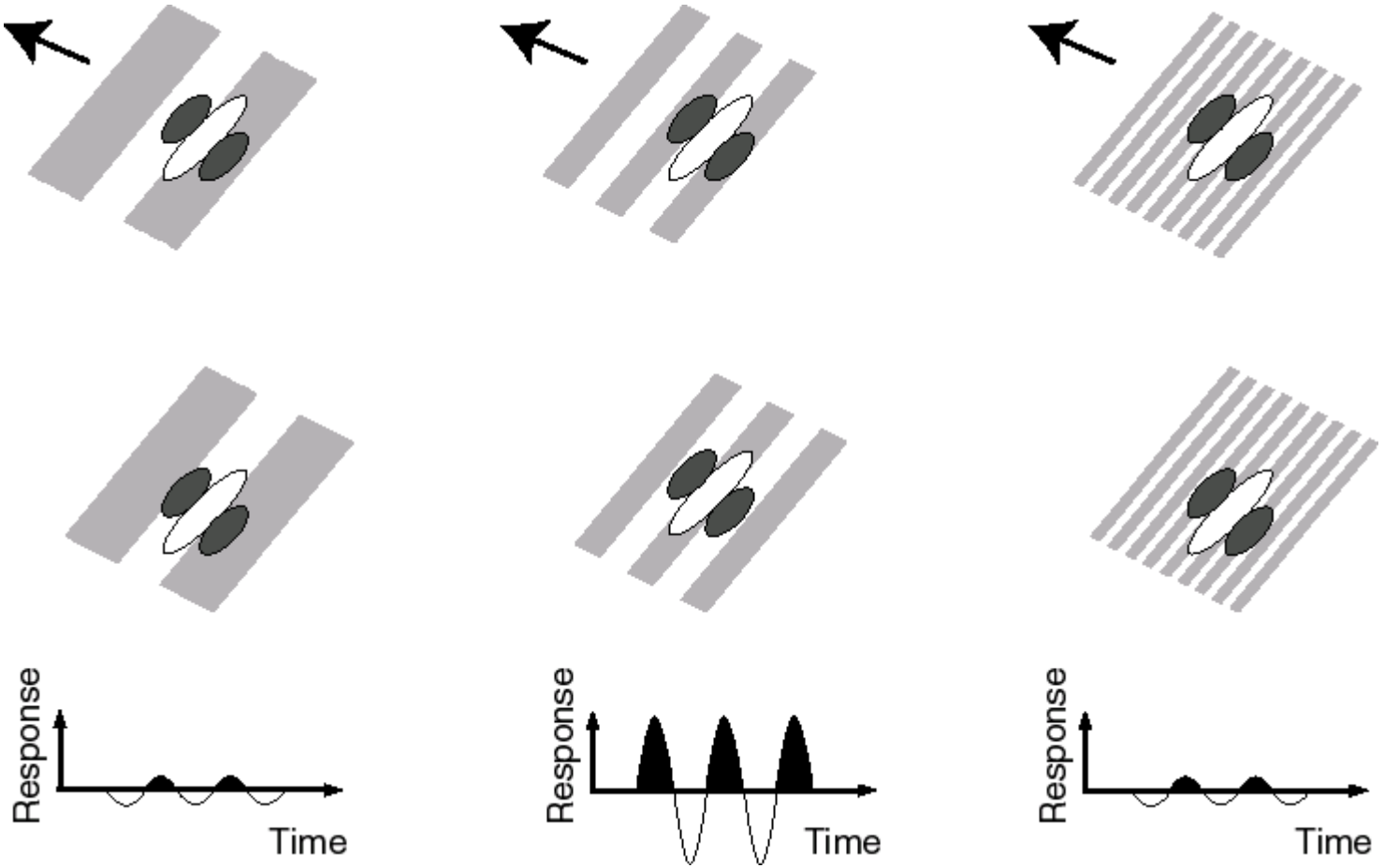
Linear model of V1 simple cells

Responses are a weighted average of the stimulus intensity, where the receptive field is the map of the weights.

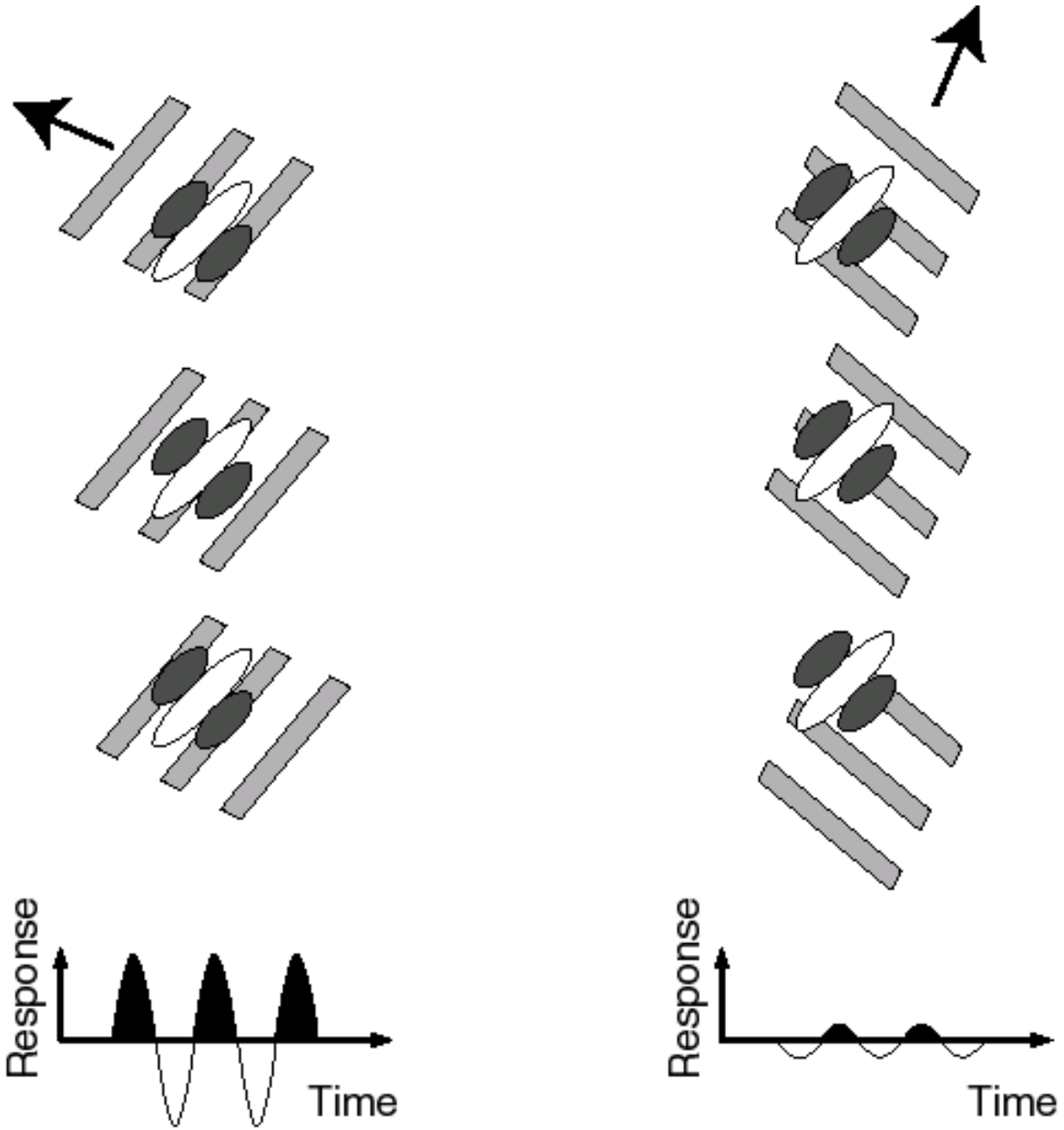
The linear model



For a linear cell, knowing the receptive field is knowing everything



Dependence of responses on orientation



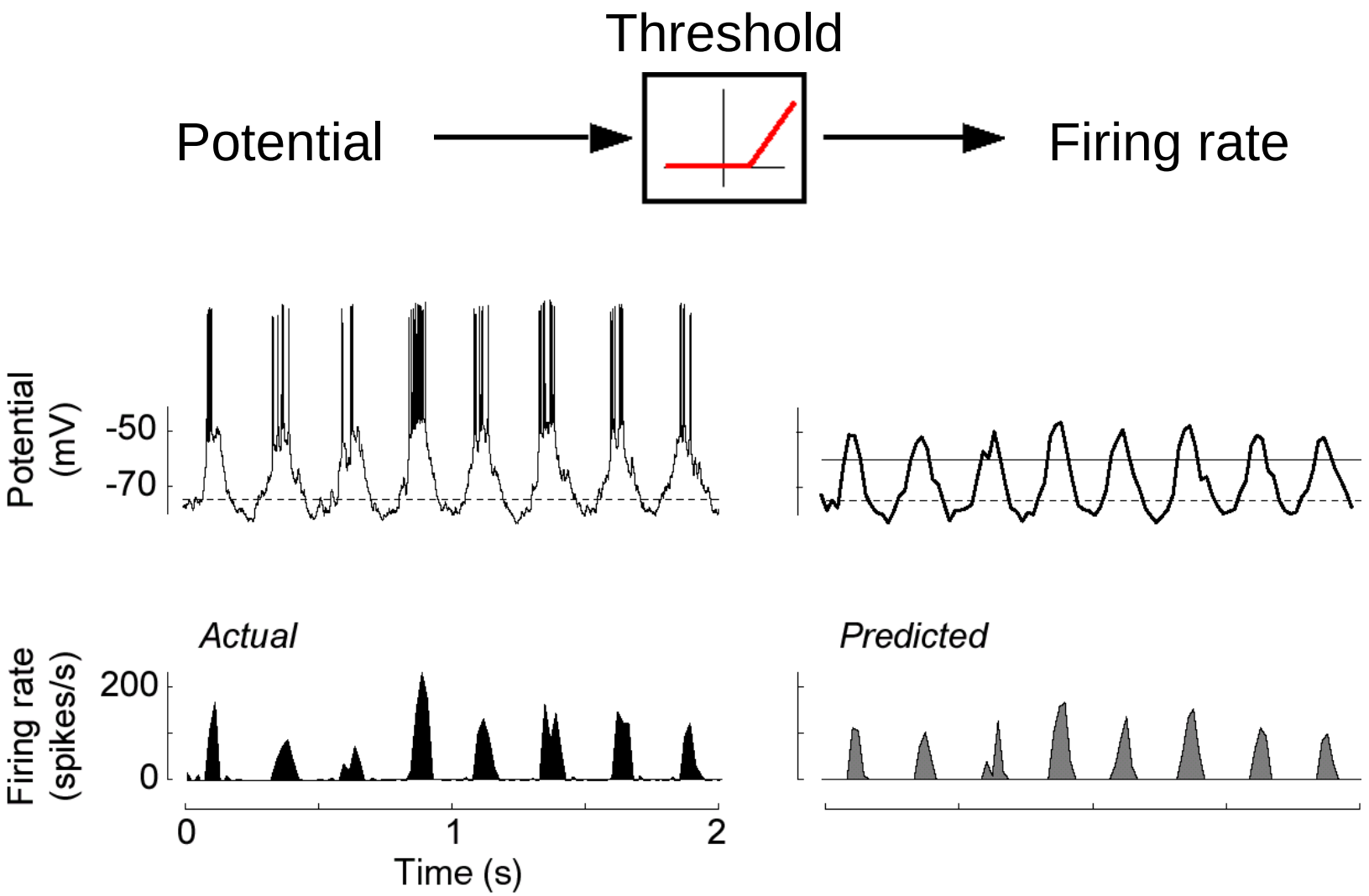
Nonlinearities in V1 responses

Linear model:

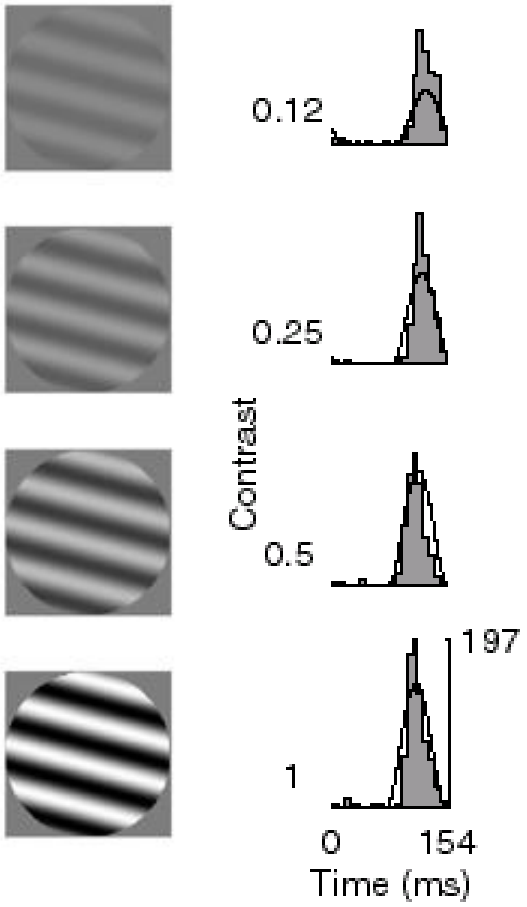
Linear systems L(x) obey

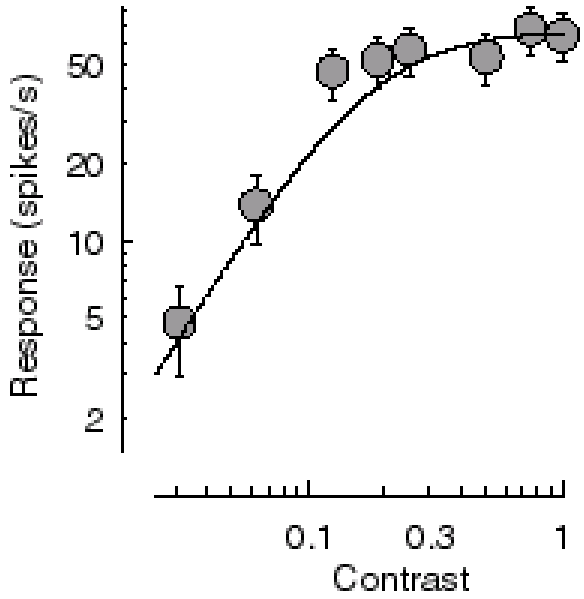
- homogeneity: $L(a\,x) = a\,L(x)$
- superposition: $L(x+y) = L(x) + L(y)$

A basic nonlinearity: Thresholding



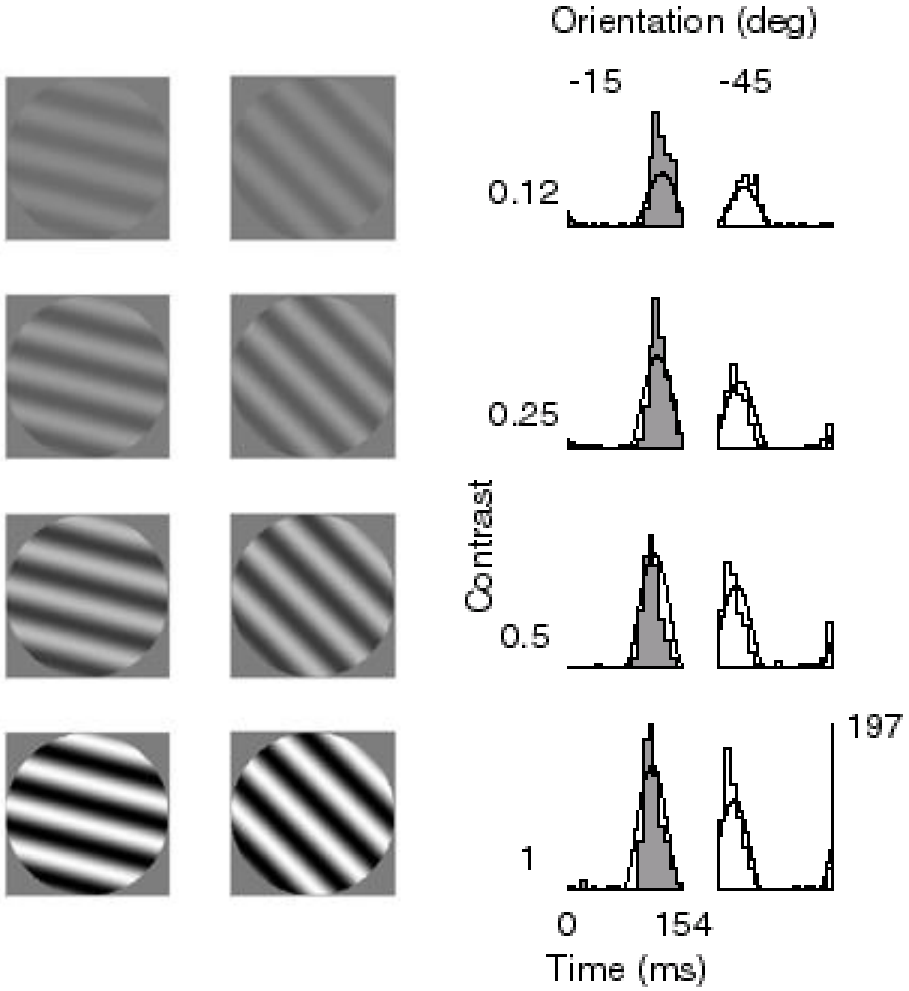
A violation of homogeneity: Saturation

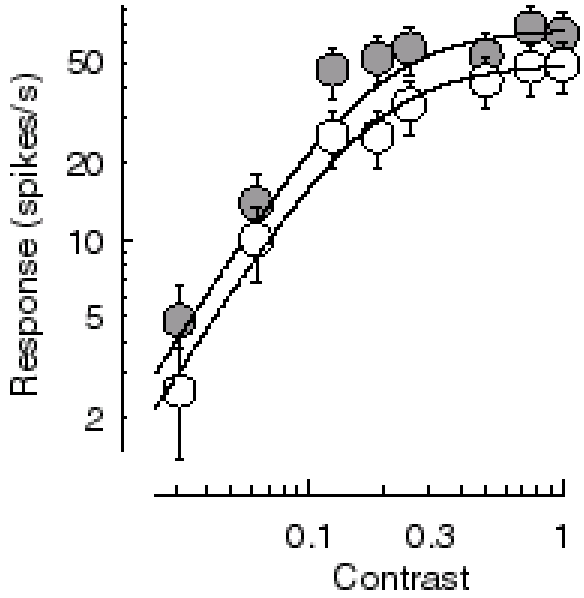




Carandini, Heeger & Movshon (1996)

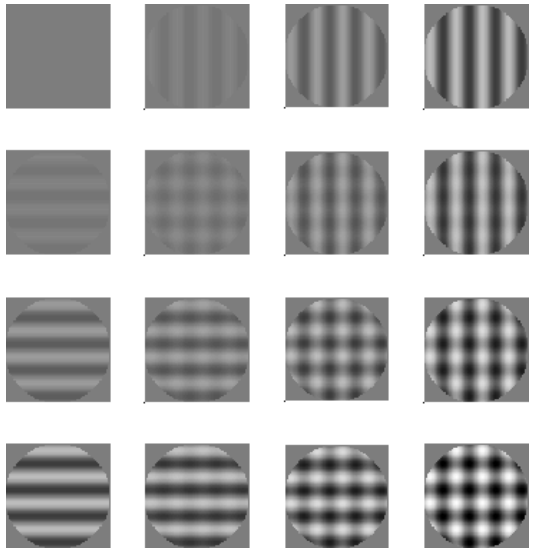
Saturation depends on contrast

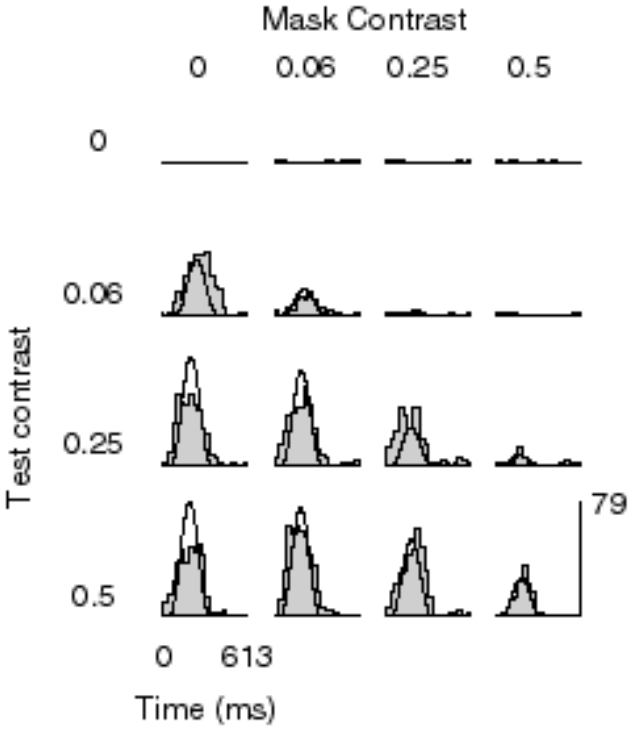


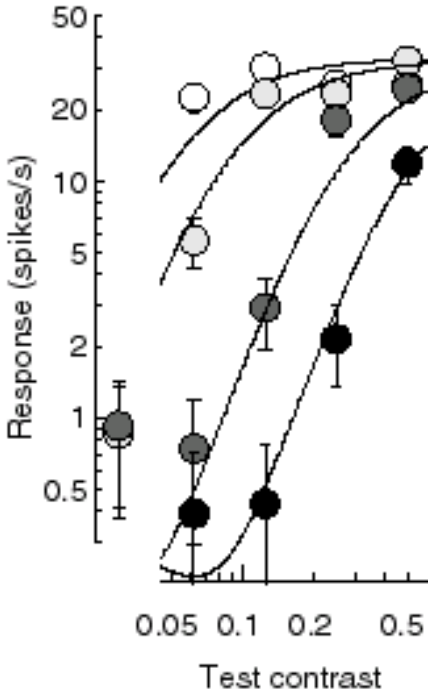


Carandini, Heeger & Movshon (1996)

A violation of superposition: Masking

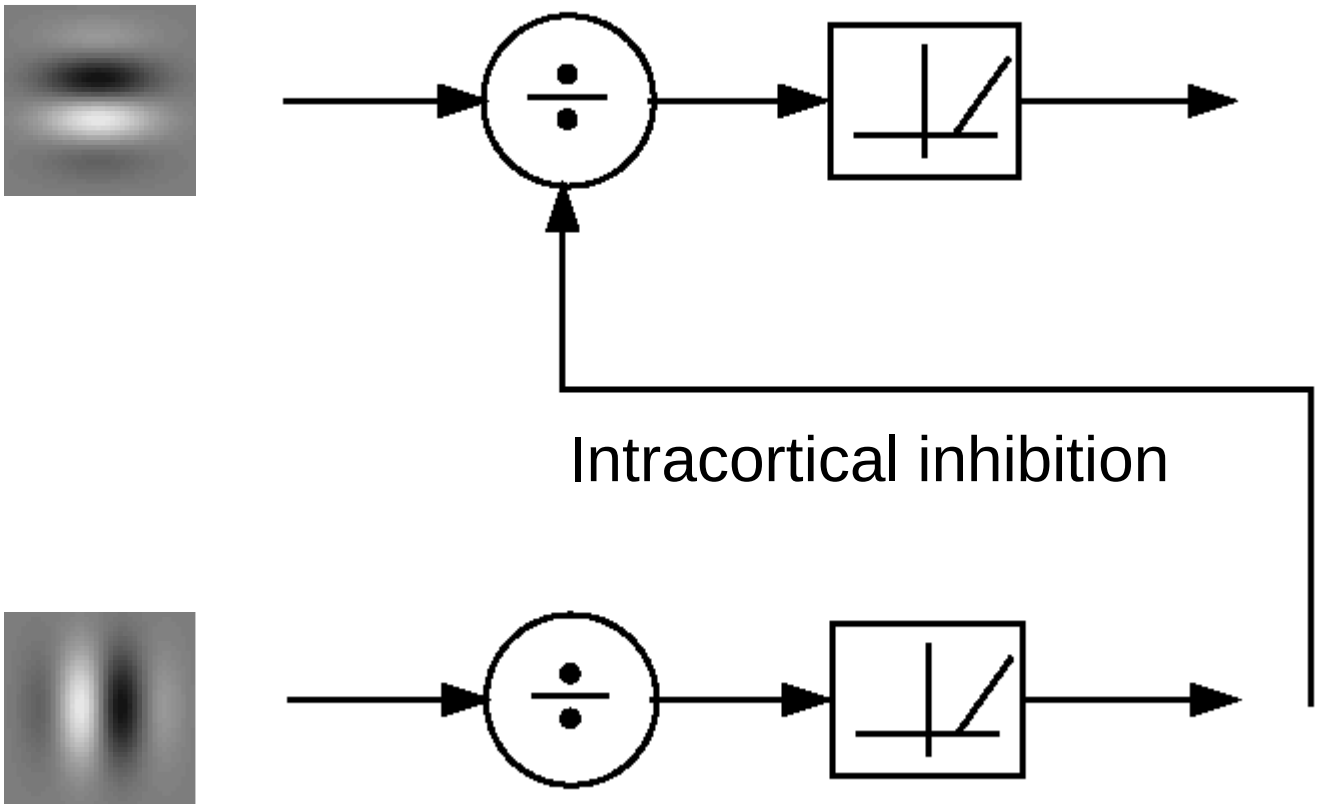




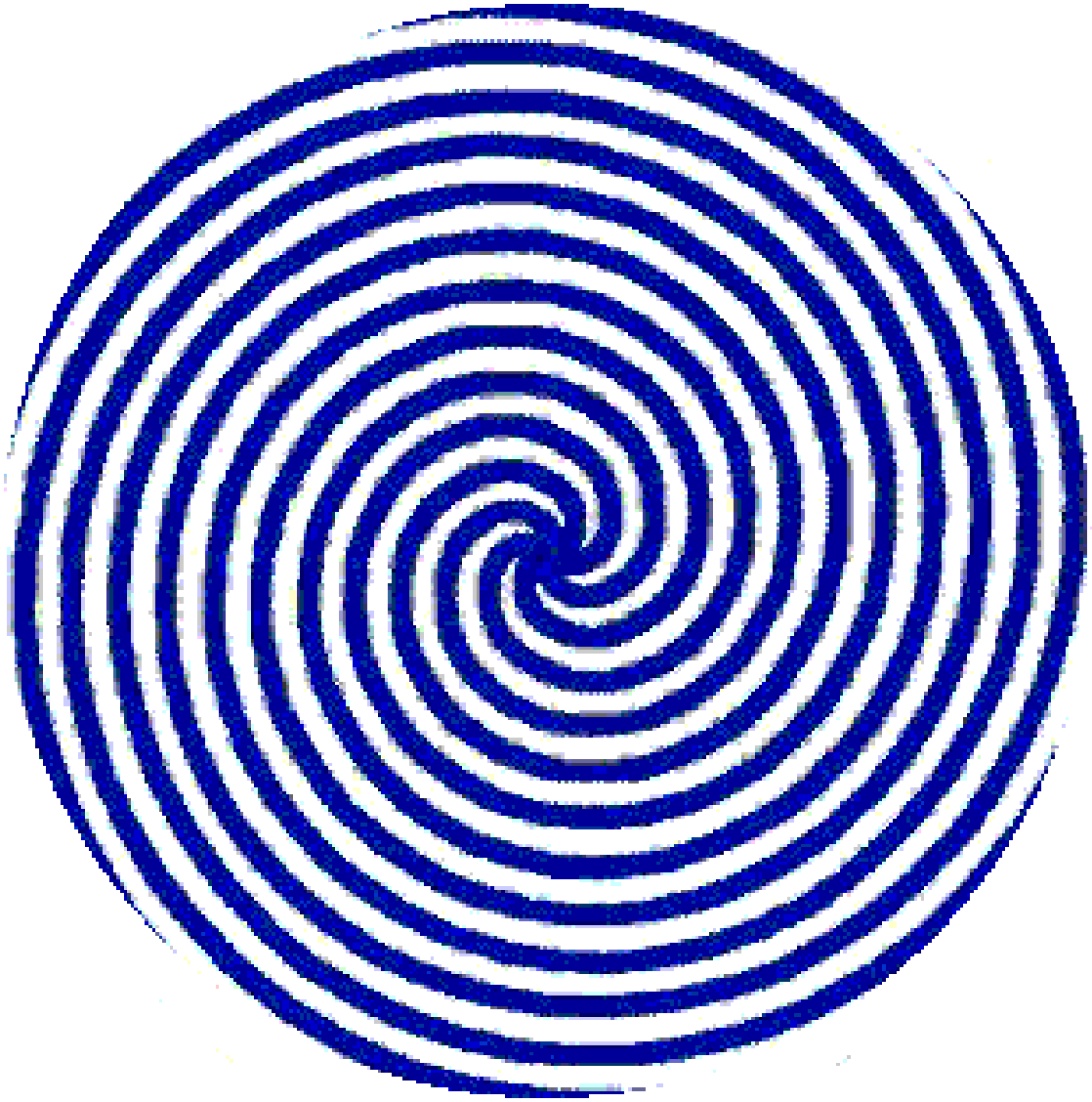


Carandini, Heeger & Movshon (1996)

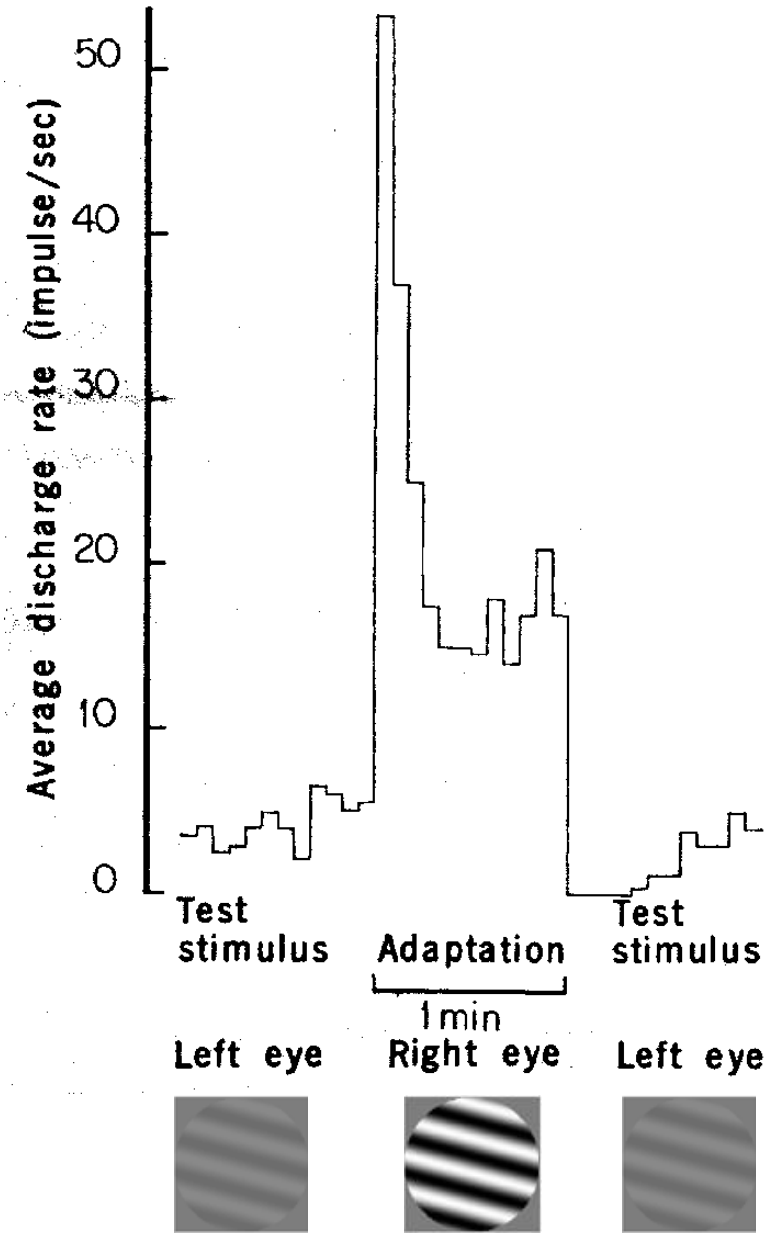
A nonlinear model of V1 simple cells



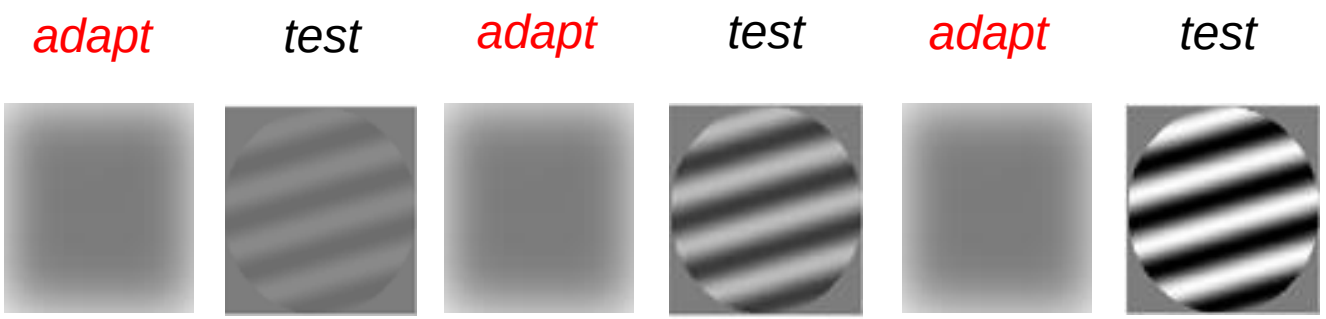
Adaptation

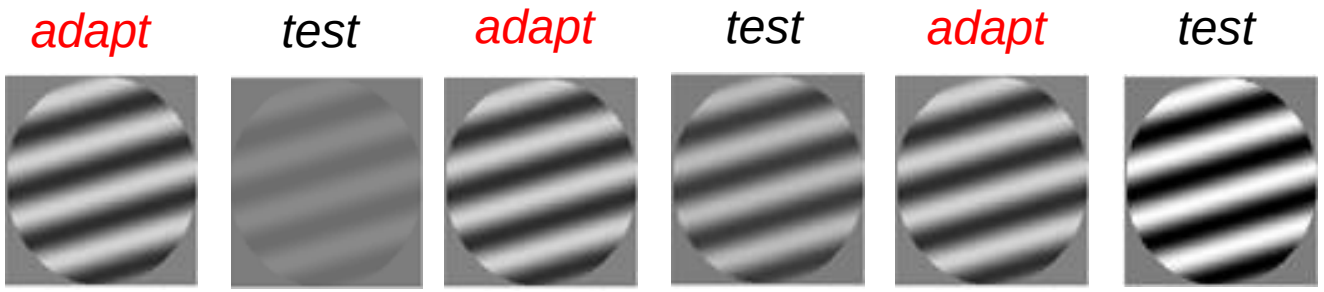


Adaptation in a V1 neuron



Maffei, Fiorentini and Bisti, 1973


adapt
test
adapt
test
adapt
test


adapt
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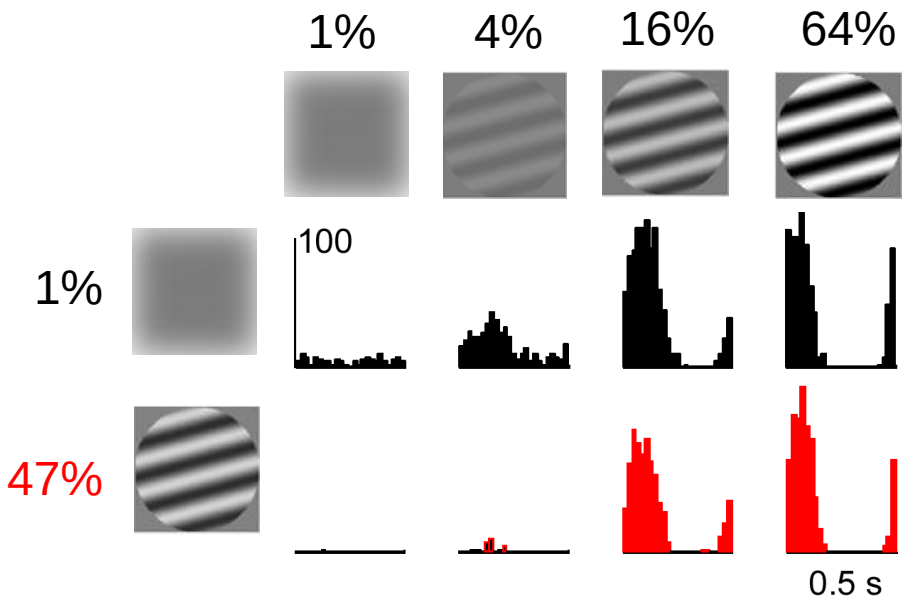
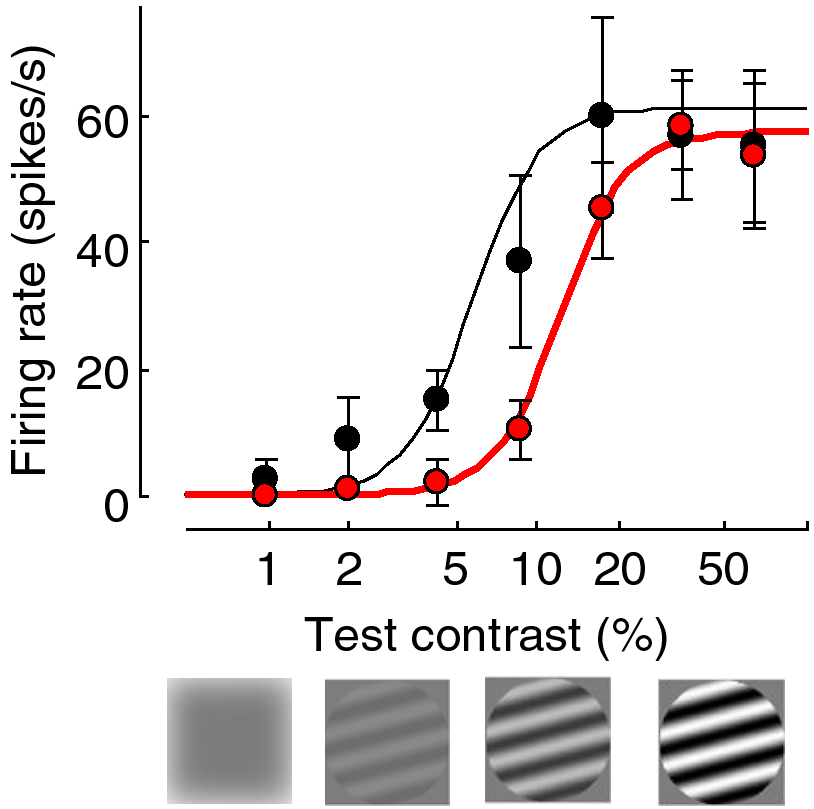
test

Contrast adaptation controls V1 neuron sensitivity



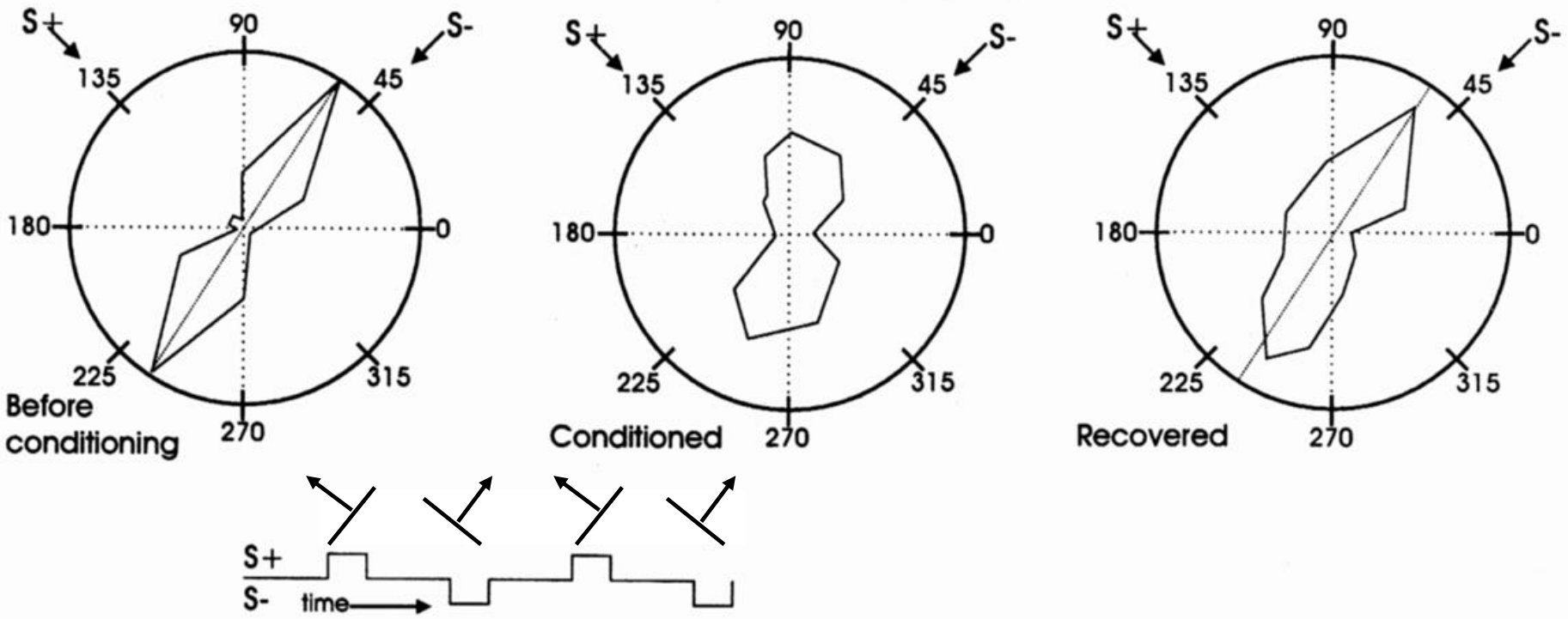


Learning

Hebbian learning

Das, 1997

Evidence for Hebbian learning in V1



Fregnac et al., 1992, in Das, 1997