Institute of Neuroinformatics
UNI/ETH Zurich

Biological and Computational Vision

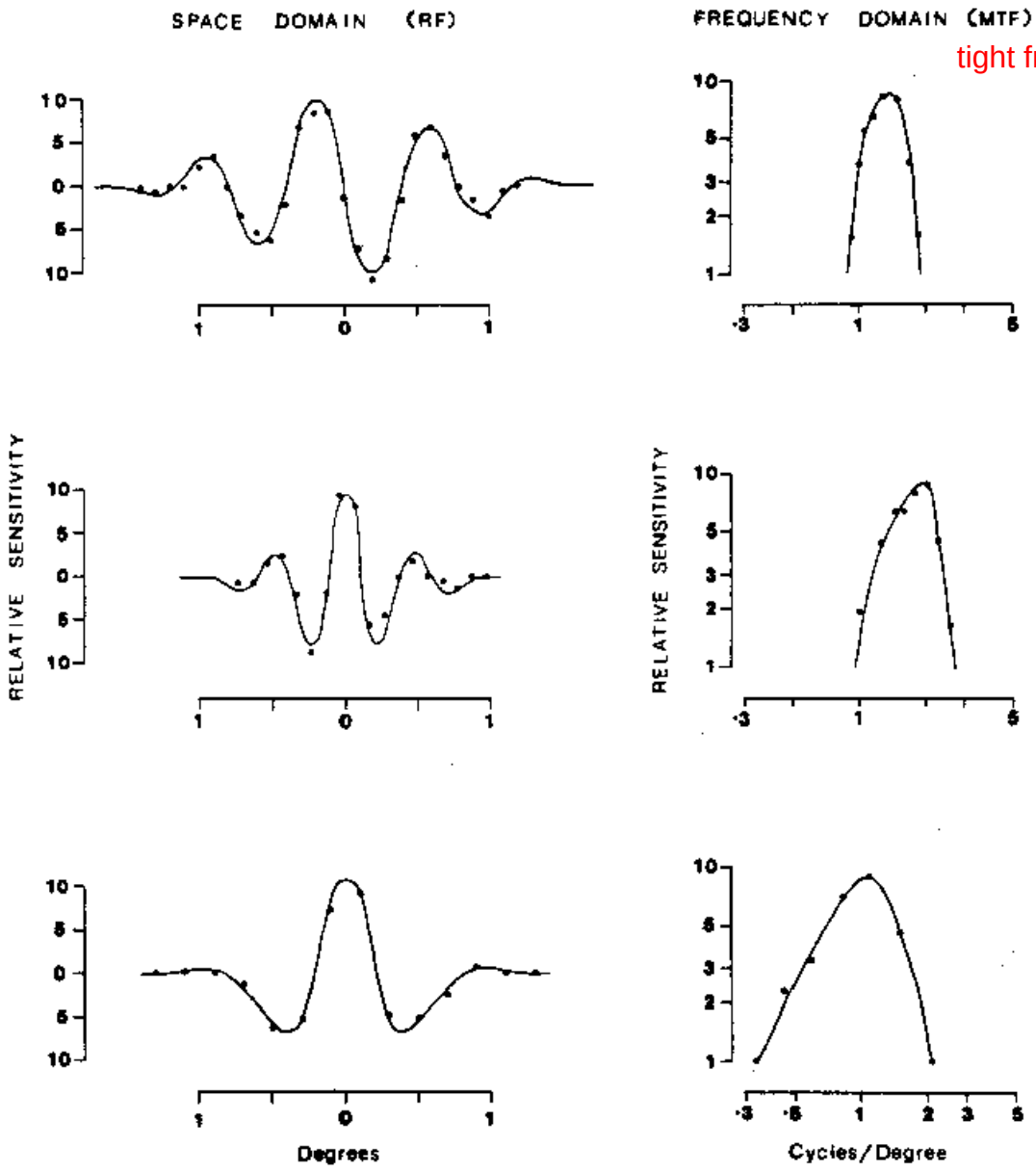
Lecture 5

Daniel Kiper

22 March 2018

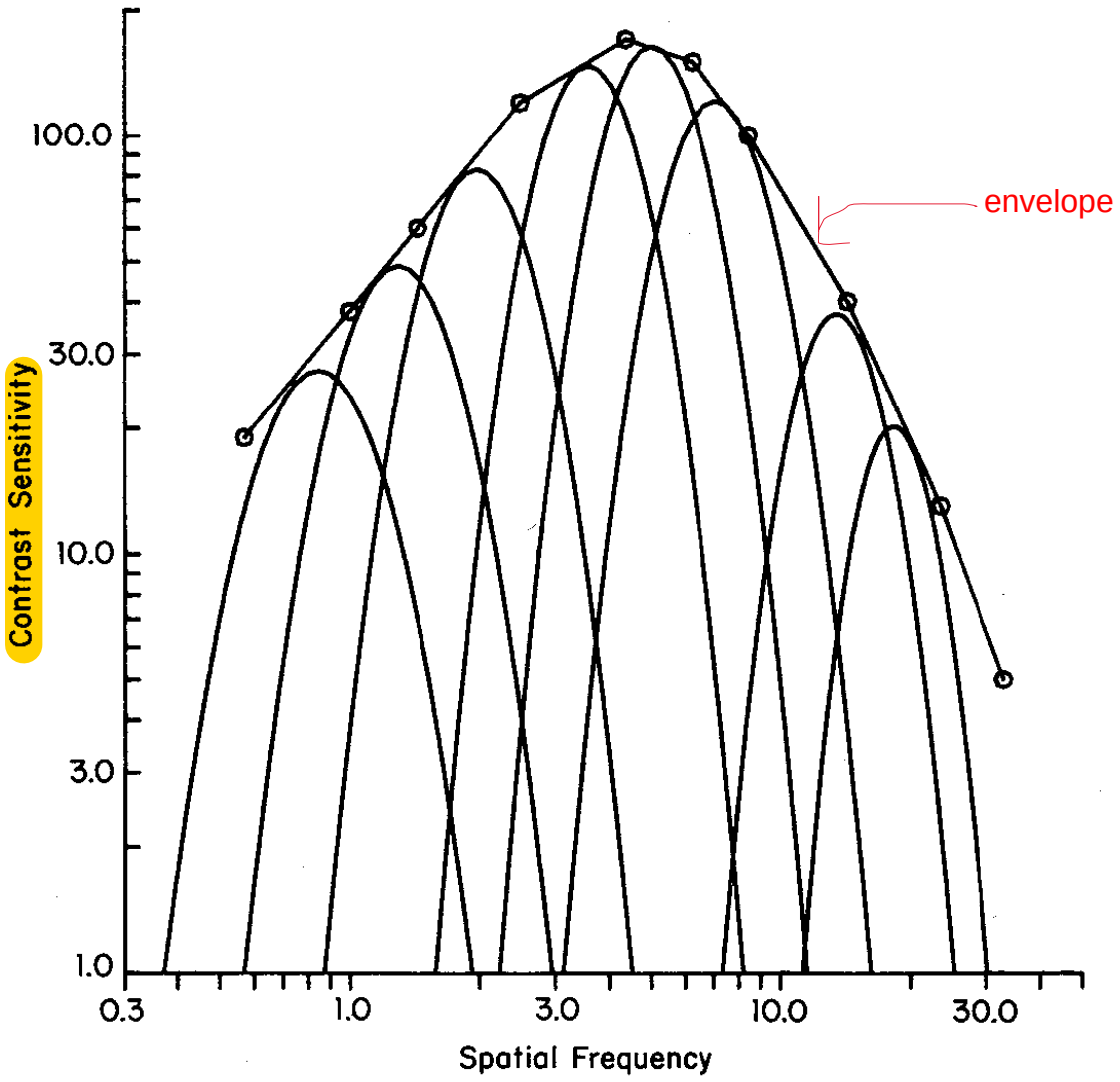
www.ini.unizh.ch/~kiper/comp_vis/index.html

Sharpness of tuning depends on number of subfields



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

Back to the model of perceptual sensitivity

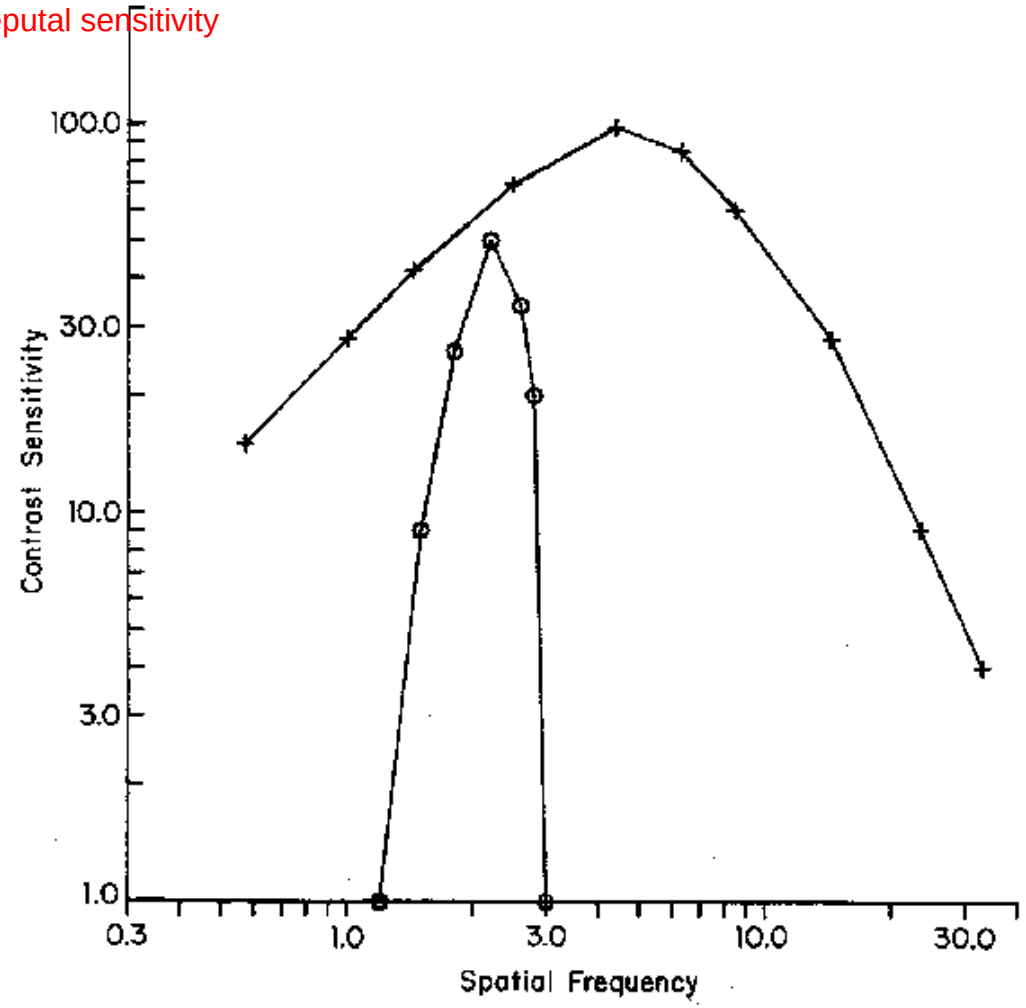


De Valois & De Valois (1990)

Perceptual and neural sensitivity: data from a monkey

contrast sensitivity of monkey observer: measured response of indiv cells

this is exp evidence for perceputal sensitivity



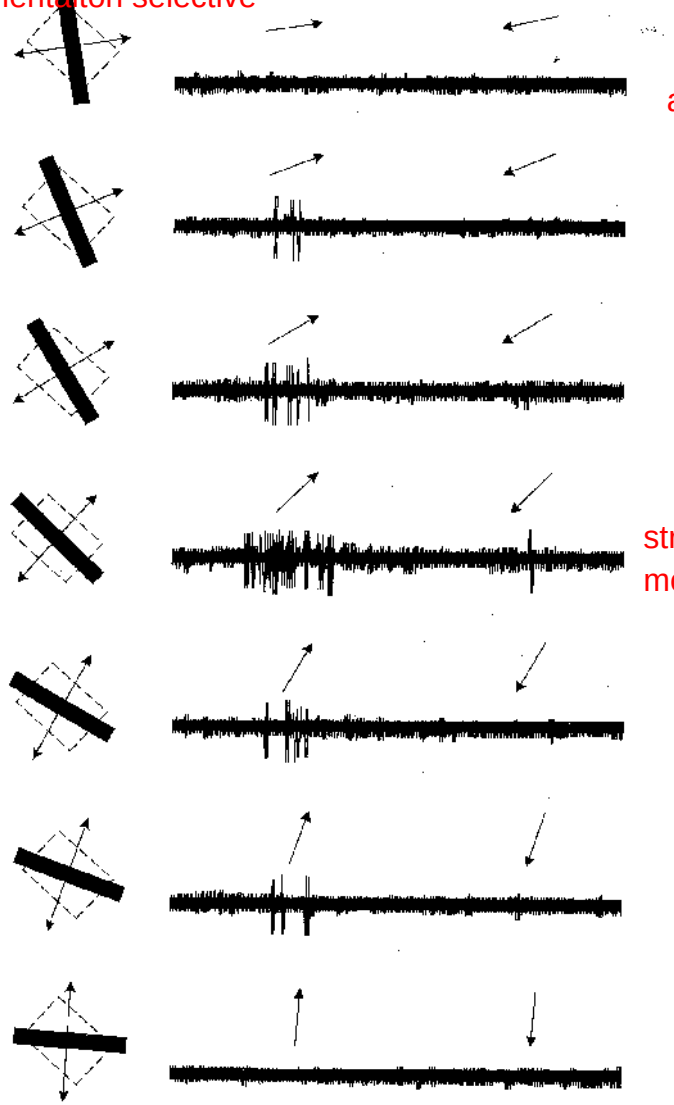
intesection with curve is what is max spatial freq what we can see: eye doctorsdo that with the smaller getting rotated E

some ppl might be more sensitive at certain spatial frequencies and normal seeing test cannot detect that

De Valois & De Valois (1990)

Selectivity for stimulus orientation and direction

this cell of the V1 is direction and orientaiton selective

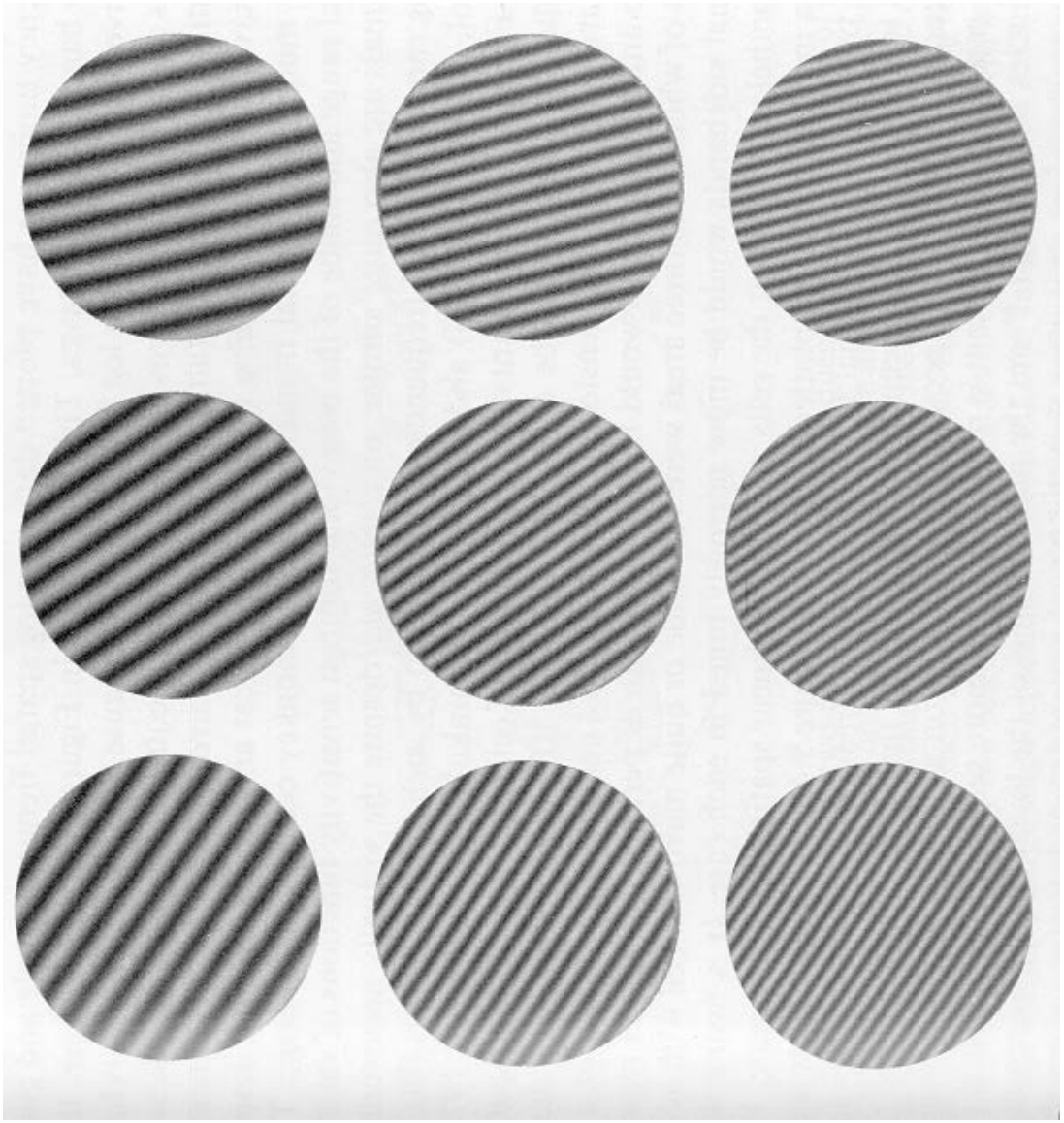


almost no resp here of the cell

strong response here, depends if bar moves up or down

Hubel and Wiesel (1968)
in Wandell (1995)

Selectivity in V1 is extremely sharp



De Valois & De Valois (1990)

V1 is retinotopically organized: two points in the world next to each other are projected like this in the retina and even all the way to the primary visual cortex (also in the LGN)
this is not trivial: cells that project stuff always project retinotopically

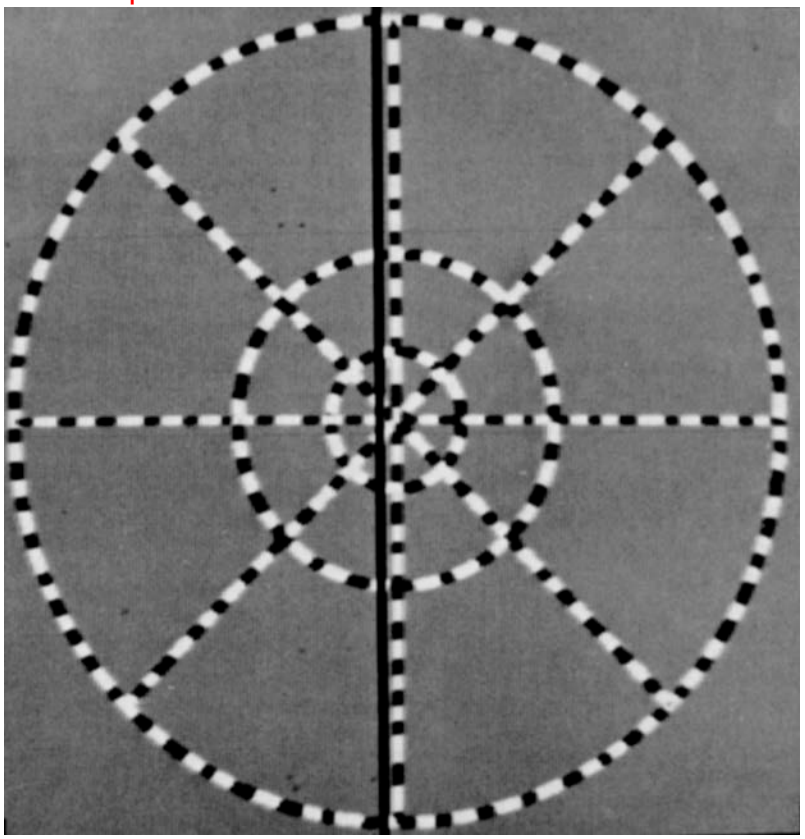
Retinotopy

two points in the visual field that are neightbours will be treated by neighboring cells as well

measure with fMRI - has good resolution

Cortical representation measured with 2-deoxy-glucose

those stripes flicker in black and white. activates cortical cells very strongly



injected into monkeys blood flow was radioactive glucose. the radioactive glucose is taken up by active cells and their activity can be detected like that

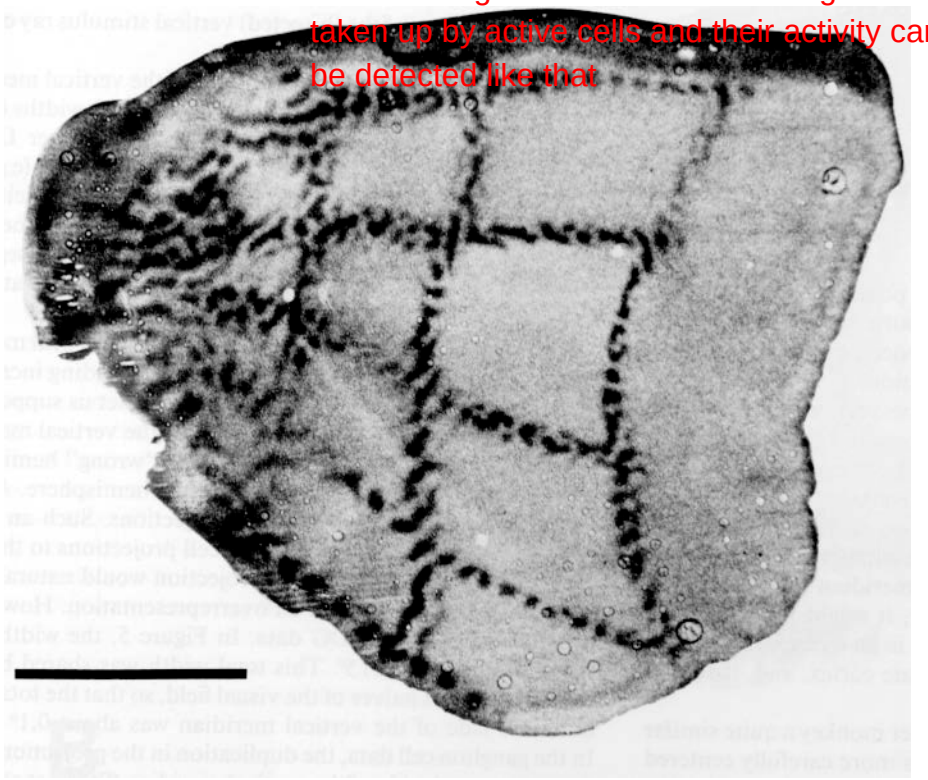


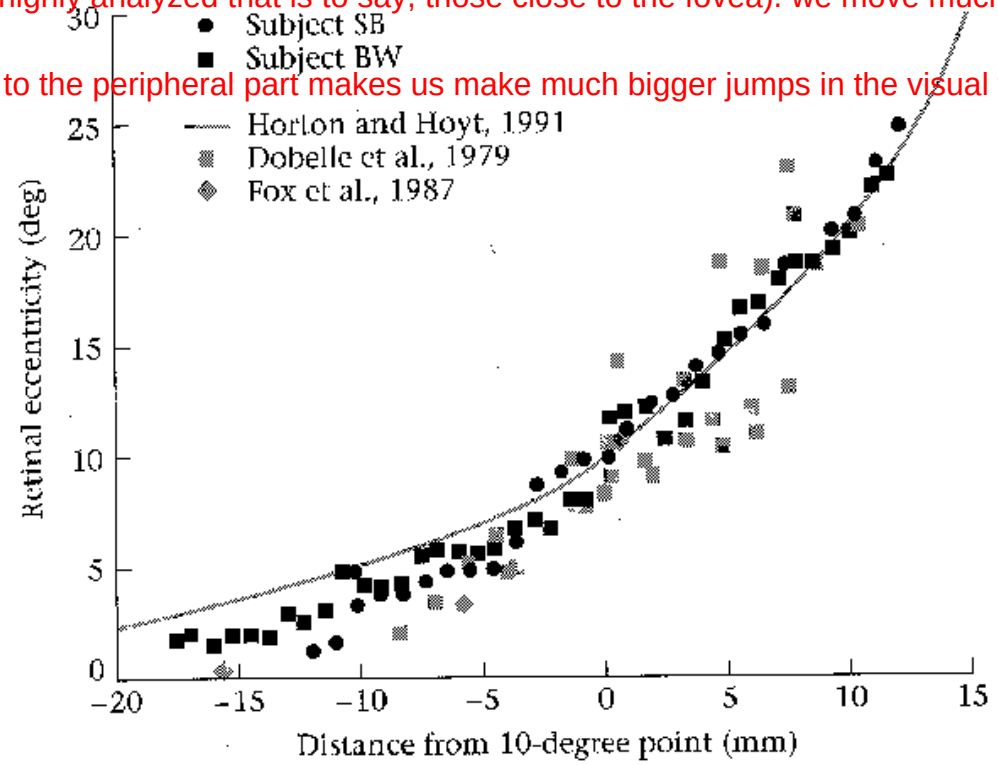
image imperfect with distortions: the representation of the fovea is magnified, there is more tissue dedicated to the analysis of fovea output than compared to peripheral areas

Tootell et al. (1988)

didnt go into details of this slide

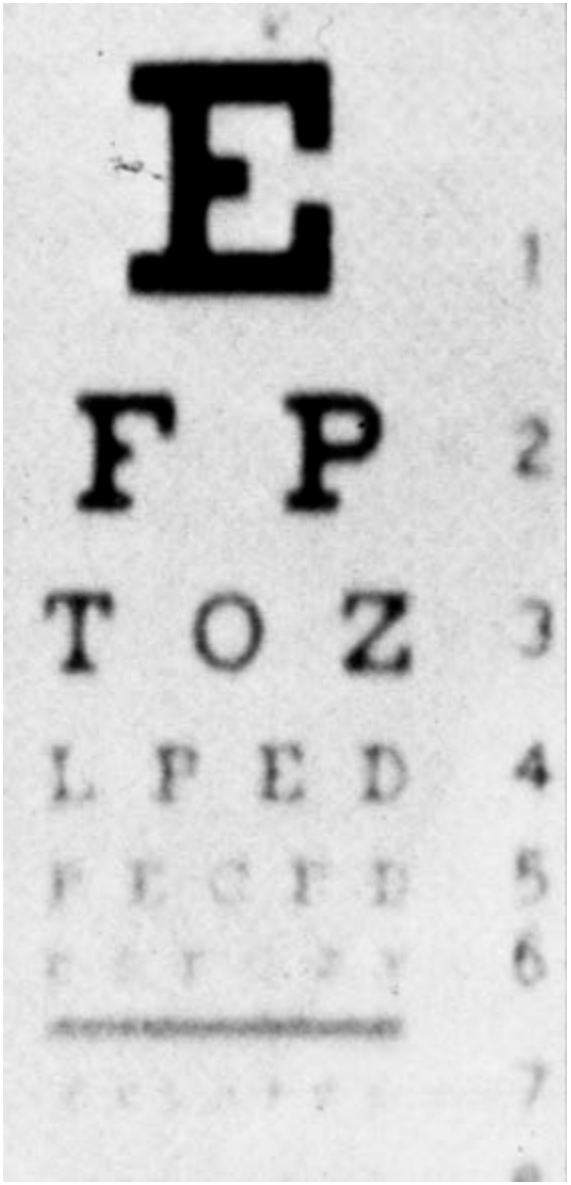
Cortical magnification

metastudy: how much cortex is neccessary to cover a distance in the visual field.
retinal exxenctriciy: different locaiton of retina from fovea to 30 deg eccentric
this basically means: how much do we have to move in the cortex to move in the visual field (it is no y=f(x)=x simply, cortex tissue occurs more for areas that are highly analyzed that is to say, those close to the fovea). we move much faster in the visual field as we move in the cortex.
moving in the cortex dedicated to the peripheral part makes us make much bigger jumps in the visual field



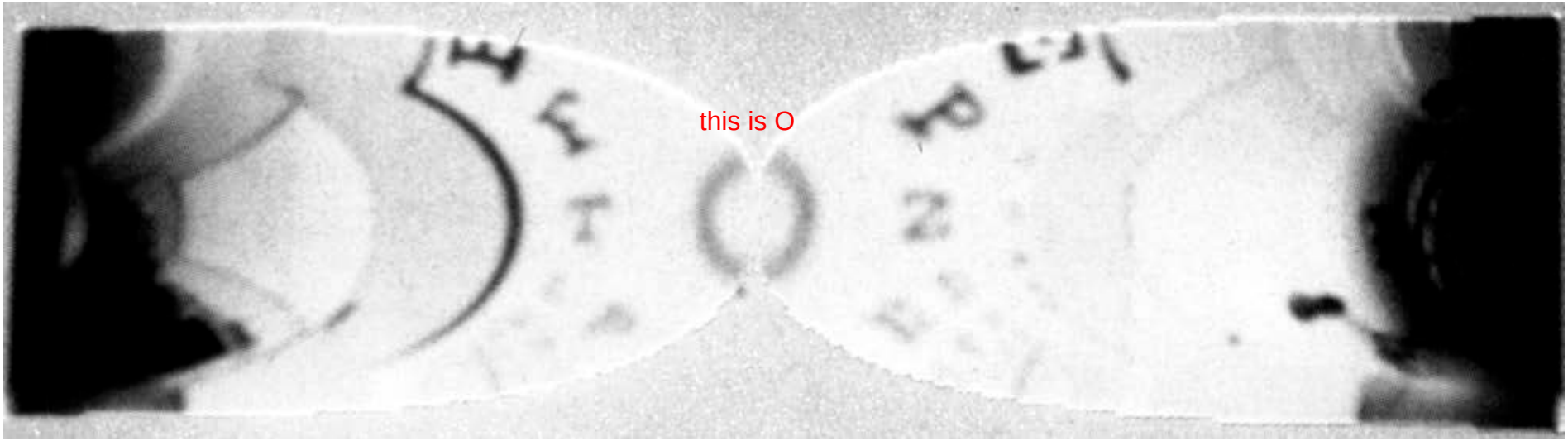
Methods:
- fMRI
- estimate from strokes + primate cells
- microstimulation in a blind volunteer
- PET in 5 observers

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



Schwartz et al. (1988)

why retinotopic organztation: very efficient way for visual cortex organizatoin
cells close to each other that compute points close in reality are good to be like this, because their communication is shorter when they are next to each other (shorter axons)



fixate on O from the previous slide. this is the "cortex tissue representation" how the pic looks like in the cells of the cortex
O is magnified in the cortex while the others are very small

dream reading: high res fMRI: representation of lots of pics to humans and see what kind of activity was associated (they gathered neural response maps). then, ppl slept in scanner and looked at V1 activity during dreaming: the pimary sensory cortices are active during dream. they looked at their activity and guessed if they can say something about their neural responses (they tried to guess what pics they dreamed and asked them afterwards and guessed better than chance, which is nice)

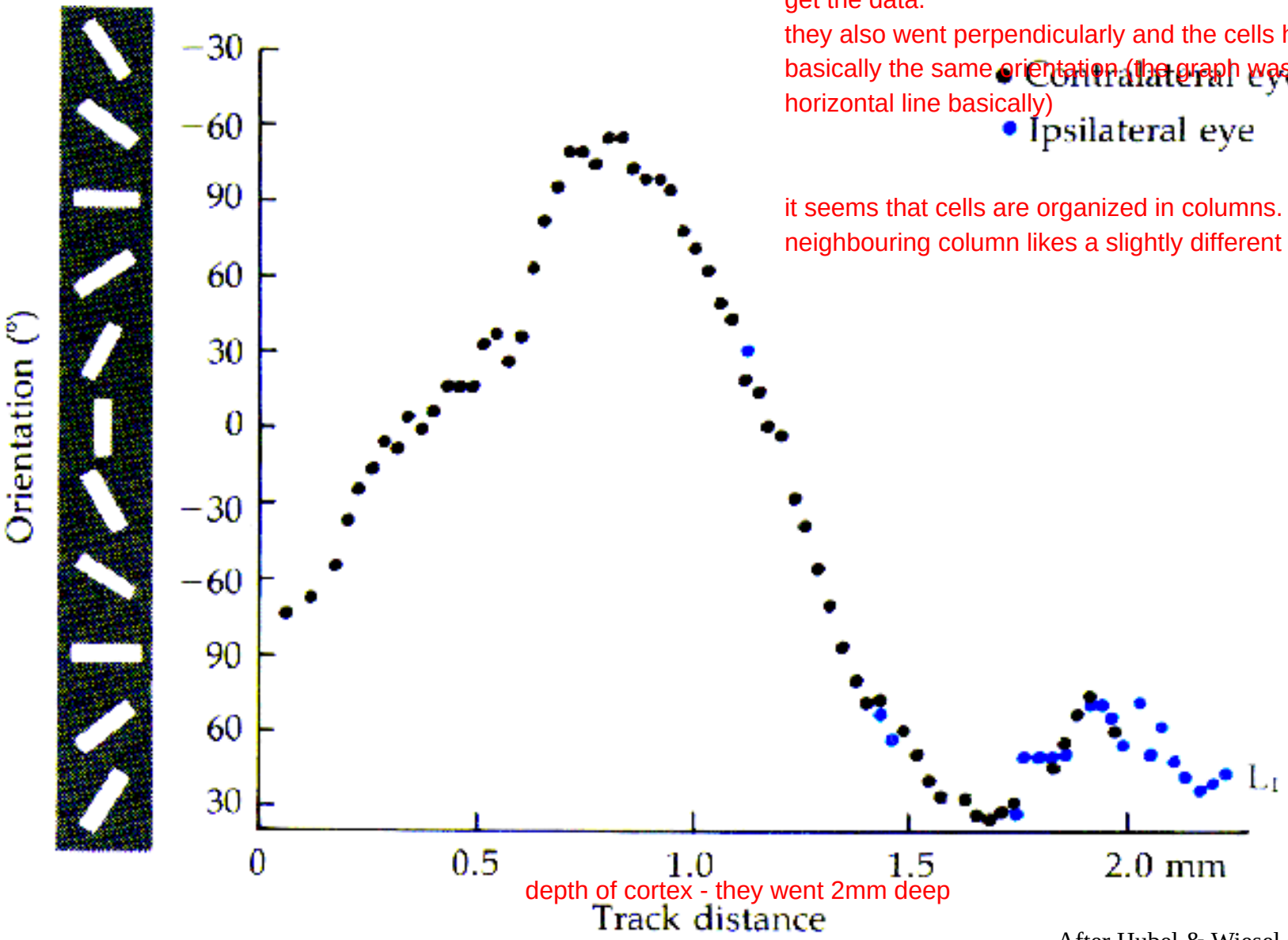
Schwartz et al. (1988)
Frederick and Schwartz (1990)

orderly fashion: no response to random oritentation it seems

hubel and wiesel very important: maybe check out for exam prep

they didnt penetrate the cortex perpendicularly, but had an angle of around 30-45deg maybe. this is how they get the data.
they also went perpendicularly and the cells had basically the same orientation (the graph was a horizontal line basically)

it seems that cells are organized in columns. the neighbouring column likes a slightly different orientation



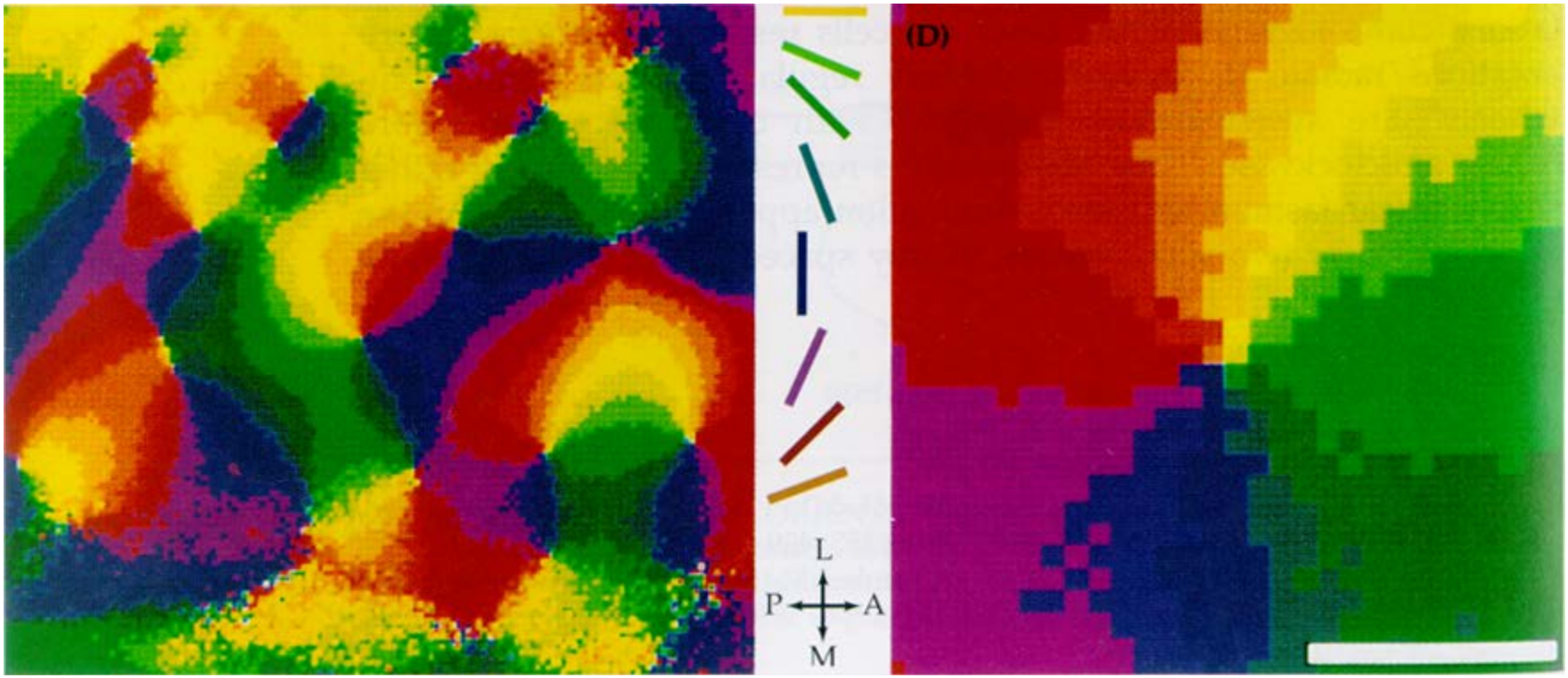
depth of cortex - they went 2mm deep

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

in rodents: no orientation colkumns. they are orientation selective, but are not so nicely orgnaized: rodents not so visual animals because not so important for the it seems

Orientation columns measured with optical imaging

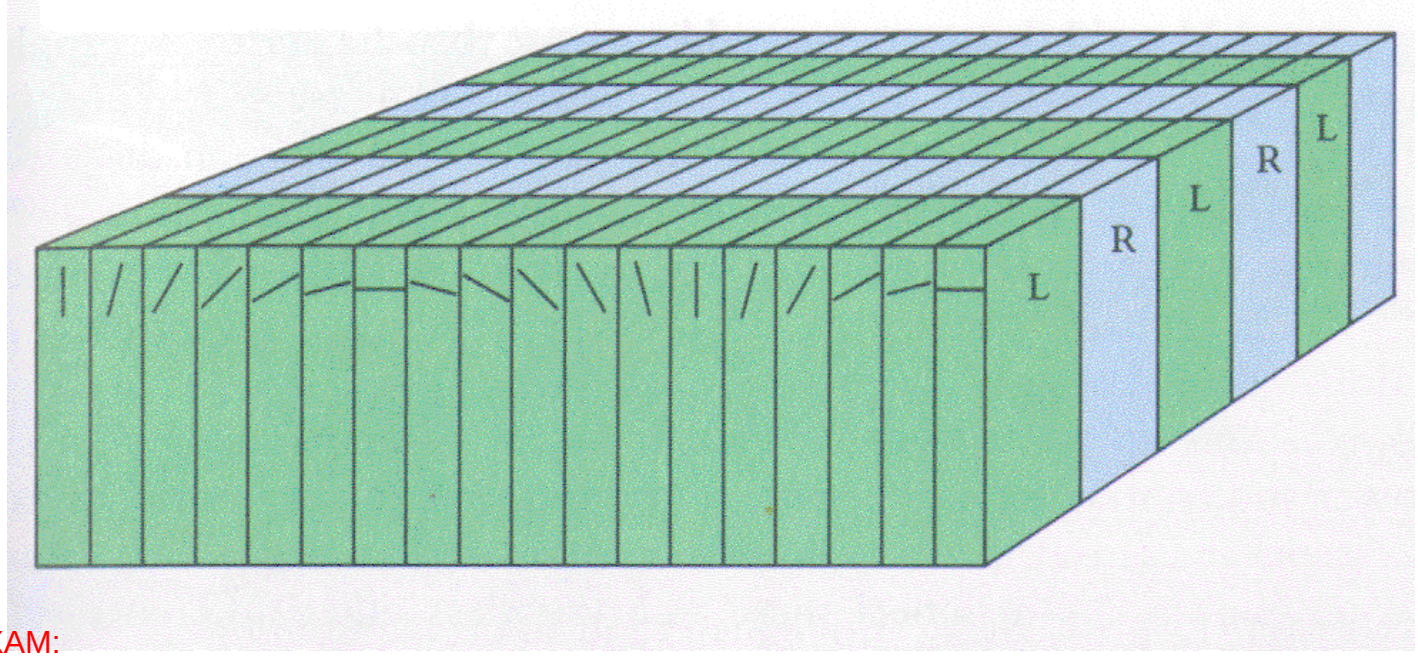
there are no spatial freq columns. proposal: maybe spatial freq layers, but apparently not as precise as for orientation
also no column organization for directional selectivity, but probably rather layer organization (direciton selective cells make up 20%)



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

The “ice-cube” model of Hubel and Wiesel

L, R stands for ocular dominance, some cells like one eye more than other and it is always in columns. it is not as orderly though (see next slide)



NOT PART OF EXAM:

ptical imaging technqiues: two optical imaging technques: expose piece of cortex. make opening. one can see the folds of cortex then. film exposed region. realization: piece of cortex when active reflexts wavelengths differntly when inactiv. shine light on cortex, then light is reflected and sensed by camera. reddish wavelengths reflected differently due to increased blood supply. one can map regions then, since they are sensed by cam. called: intrinsic imaging.

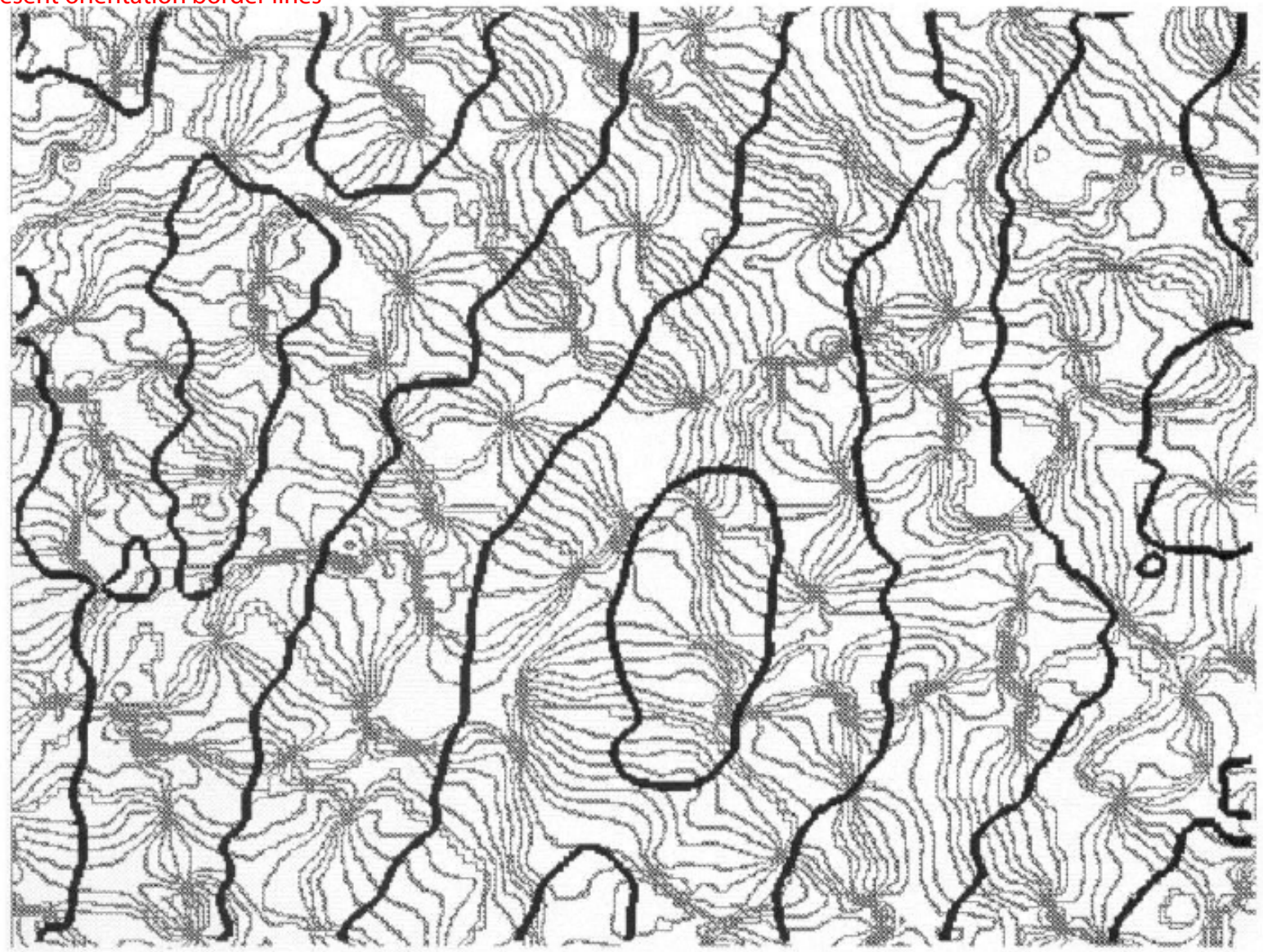
2nd method: cover cortex with liquid which is sensitive to voltage dye with a voltage sensitive dye. liquid changes color when elec pot of tissue underneath changes. this gives precise maps of the cortex. those dyes are toxic, they damage the tissue

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

big fat black lines represent ocular dominance borders

Orientation and ocular dominance columns

grey lines represent orientation border lines



tendency: two types of lines cross each other in right angles approx!

where orientation columns meat are pinuial centers around in the middle of the area

Obermayer and Blasdel, 1983

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.

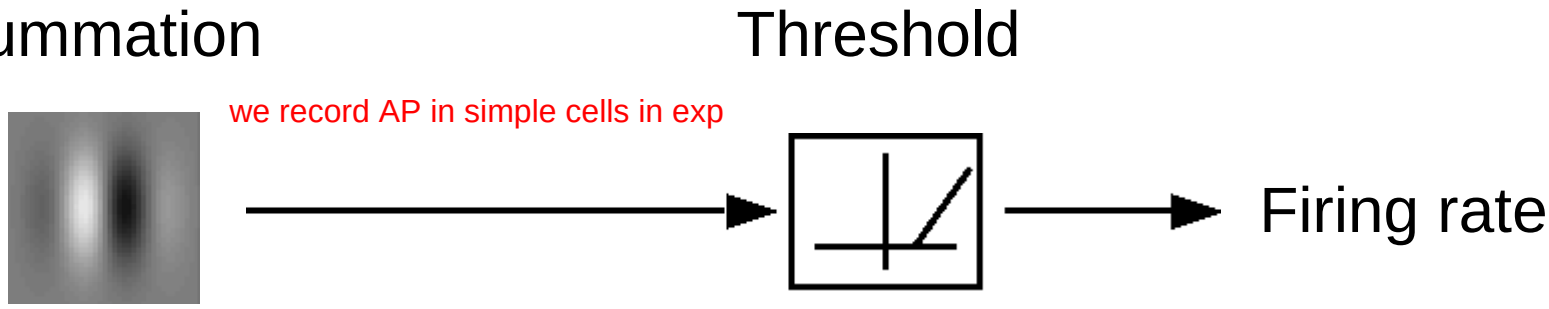
The linear model

(cells are not always linear though)

sinmple cells: brr-nothing-brr etc

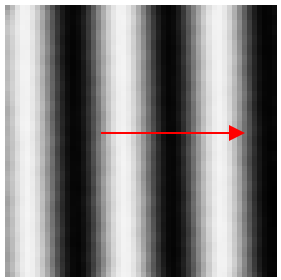
complex cells: either constant brr (continous firing) or frequency of firing doubled (or so)

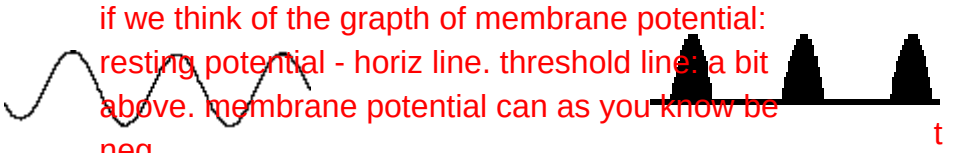
schematic representation



we record AP in simple cells in exp

we can predict response of simple cells with a since wave basically (but has a threshold which means no neg values are observed, since sine can be neg too)



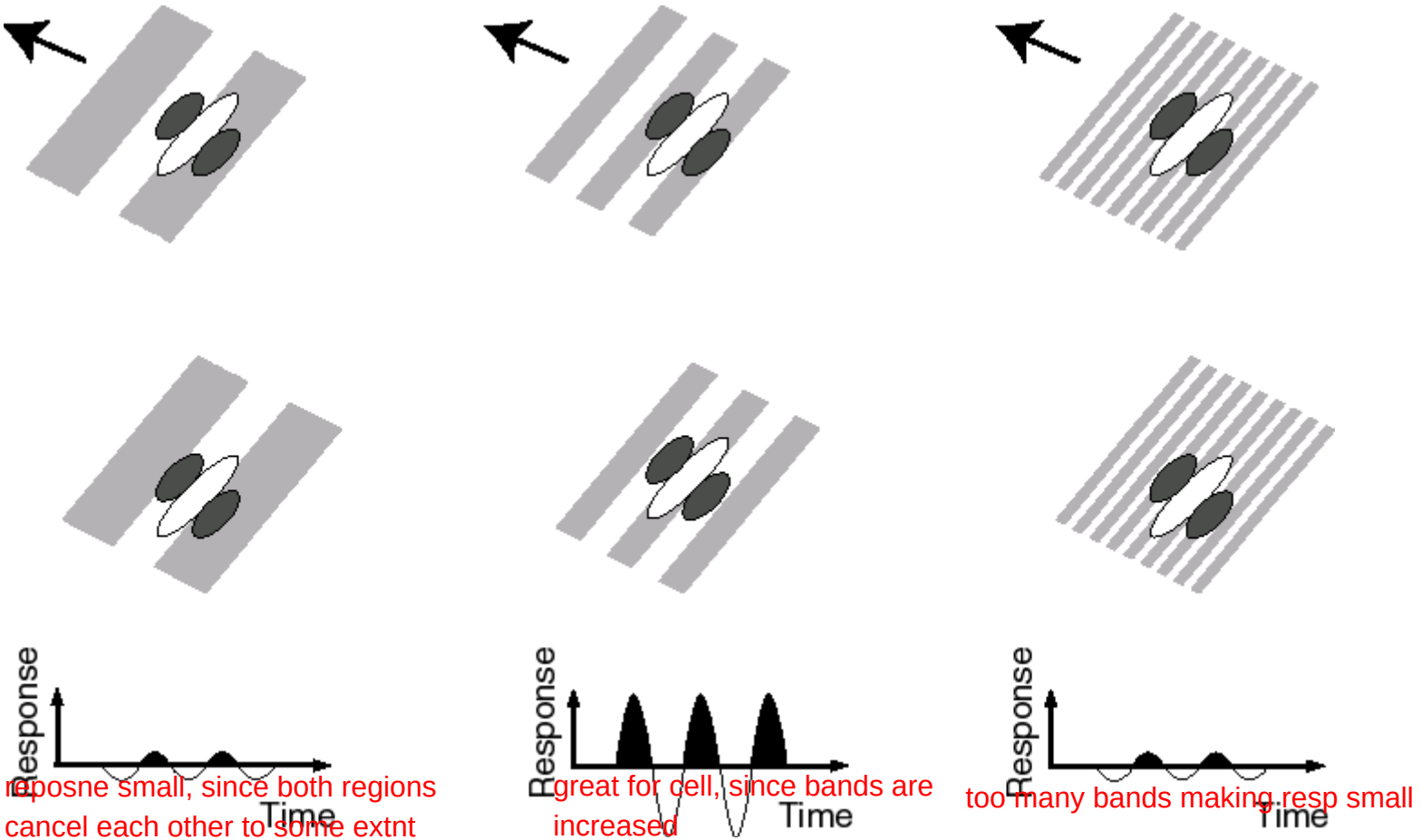


if we think of the grapth of membrane potential: resting potential - horiz line. threshold line: a bit above. membrane potential can as you know be neg

#spikes per sec

spontaneous firing rate of simple cells = 0 (when in darkness or constant input: d(input)/dt = 0)

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

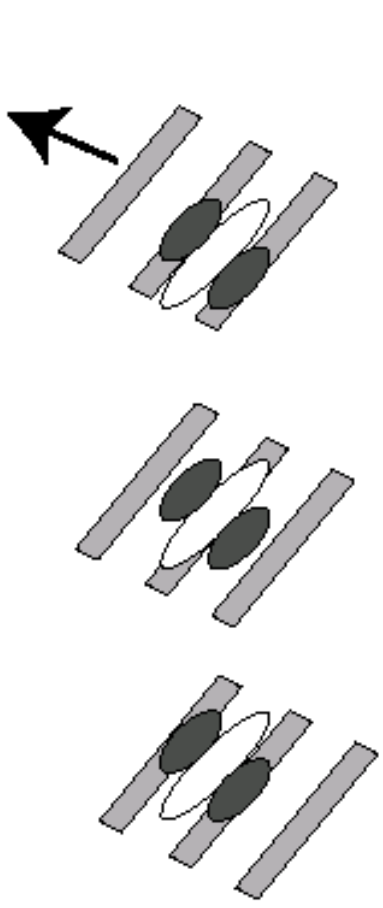


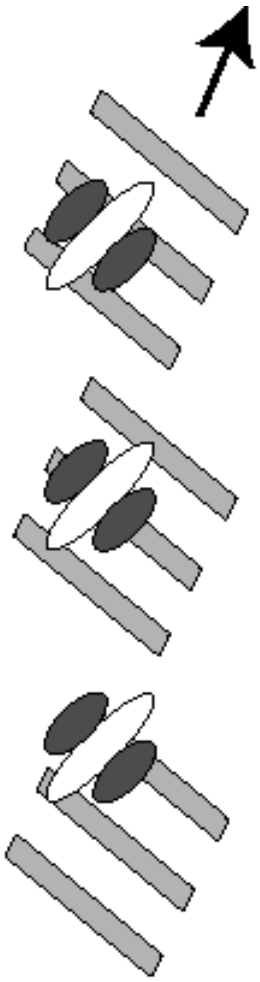
reposne small, since both regions cancel each other to some extnt

great for cell, since bands are increased

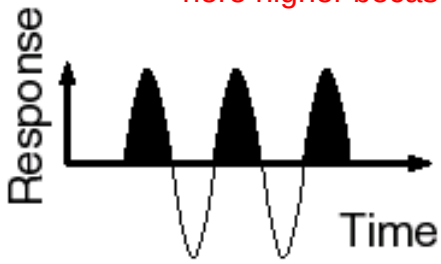
too many bands making resp small

Dependence of responses on orientation

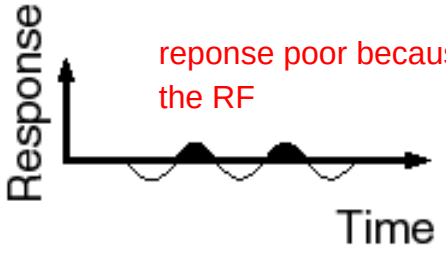




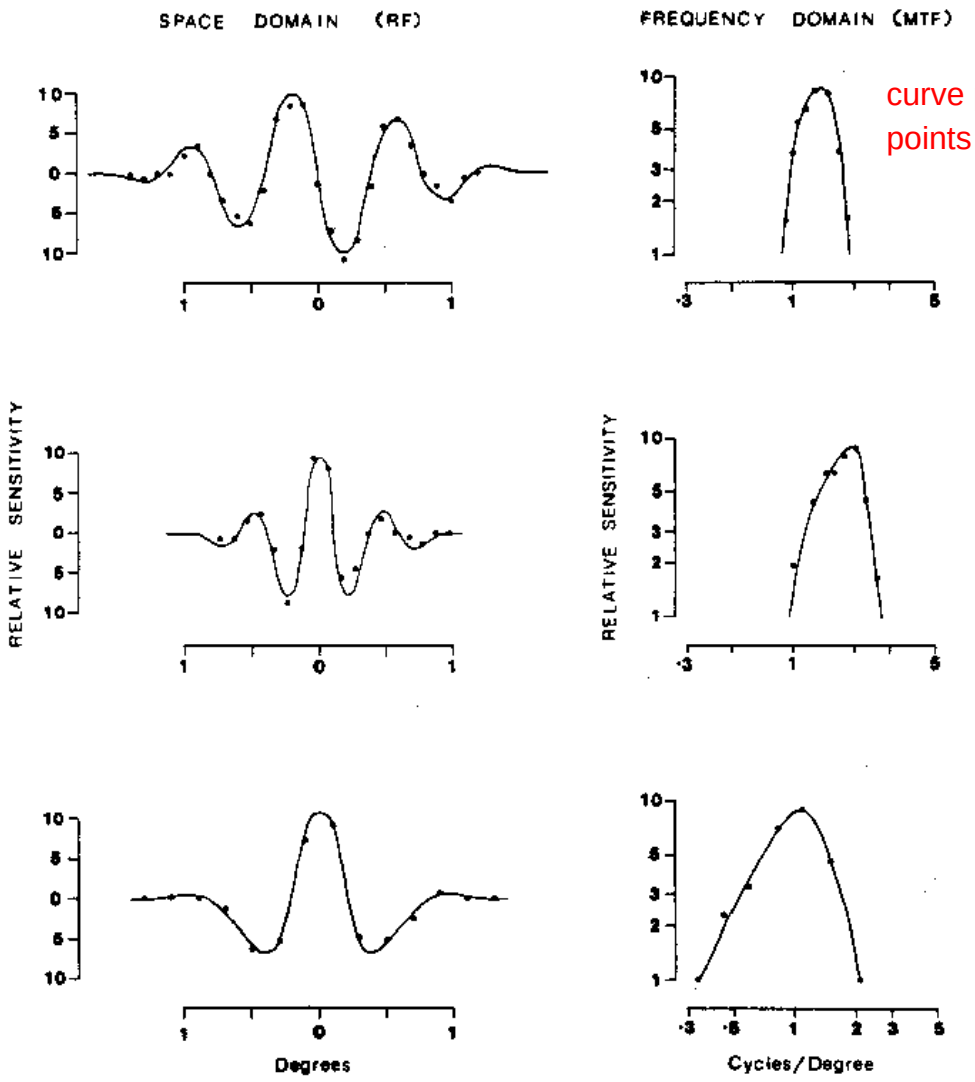
here higher becase object aligned to RF



reponse poor because object not aligned to the RF



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



curve pred
points measurements

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

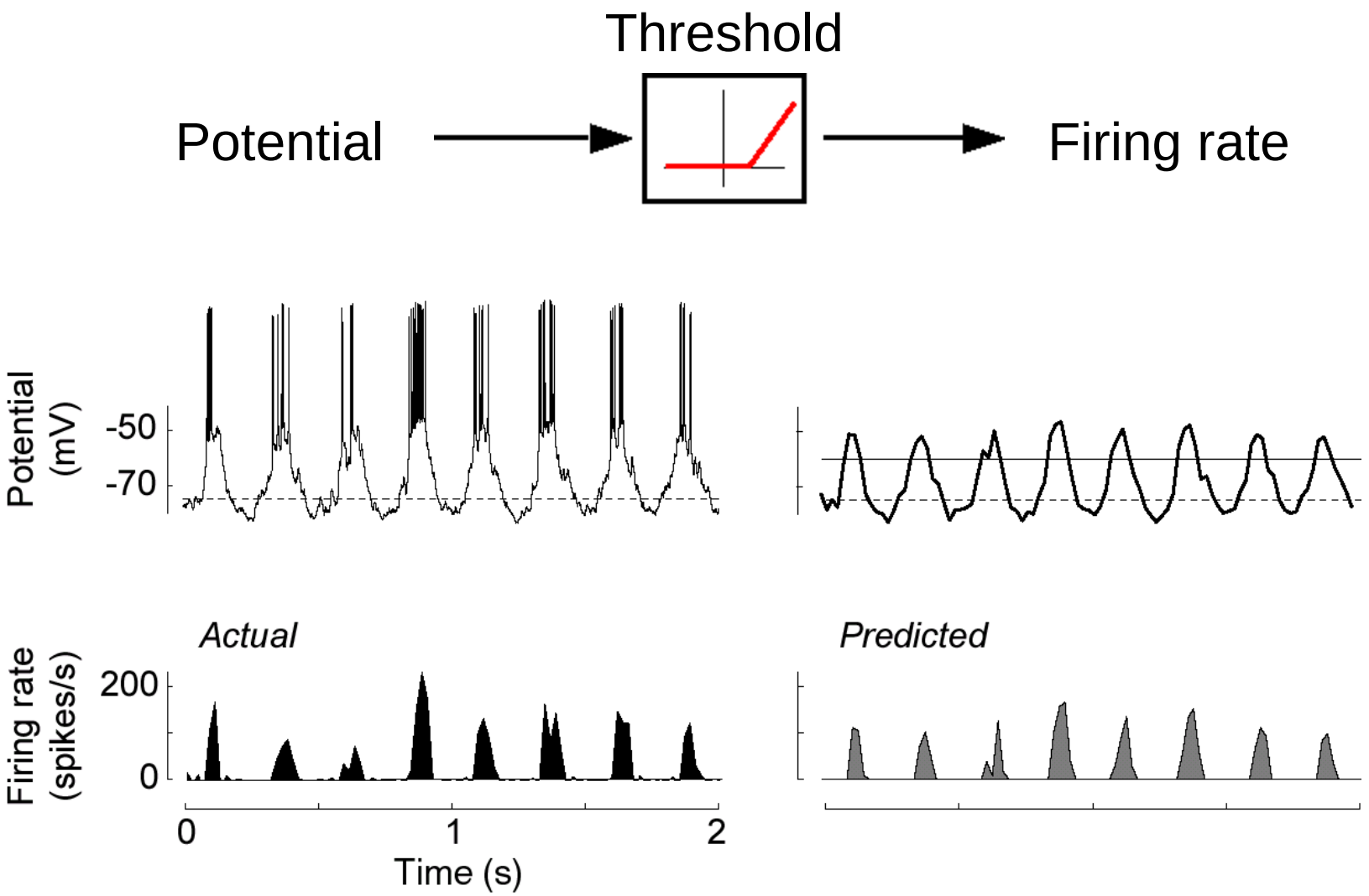
Nonlinearities in V1 responses

Linear model:

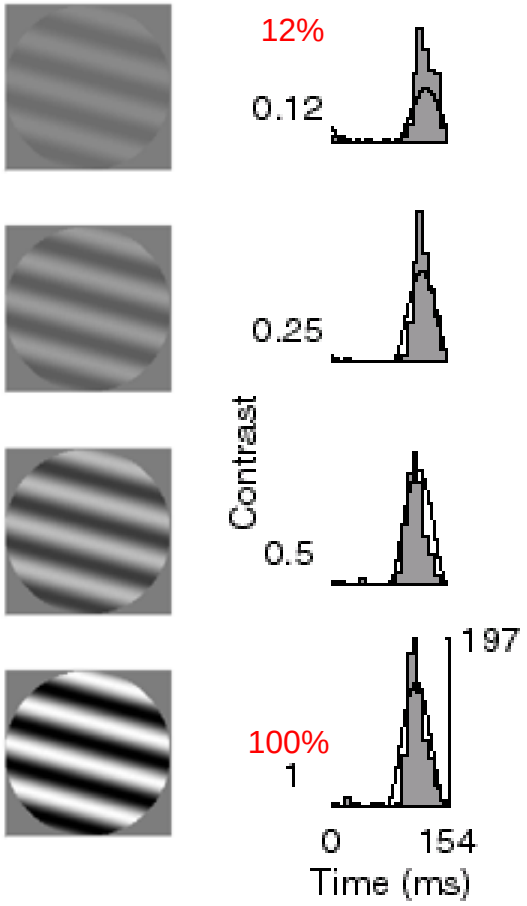
Linear systems L(x) obey

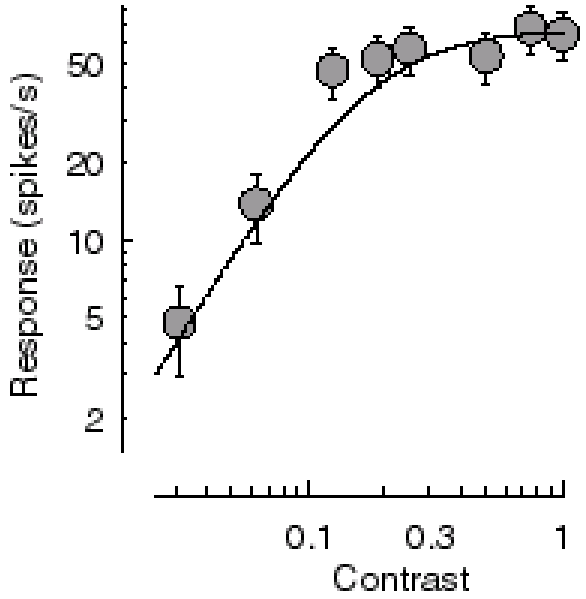
- homogeneity: $L(a\,x) = a\,L(x)$
- superposition: $L(x+y) = L(x) + L(y)$

A basic nonlinearity: Thresholding



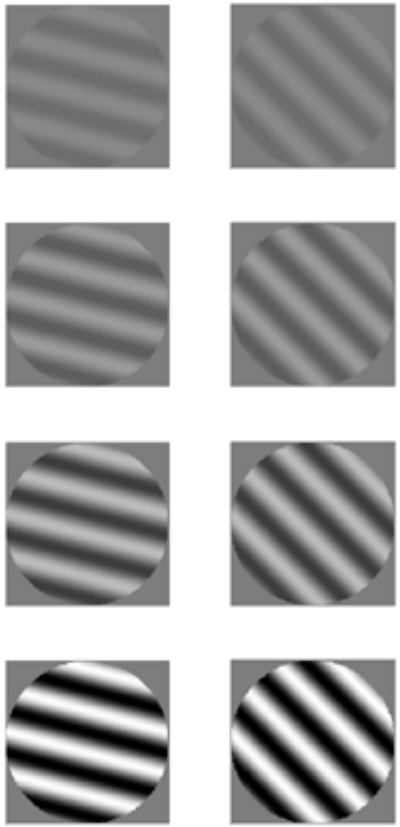
A violation of homogeneity: Saturation

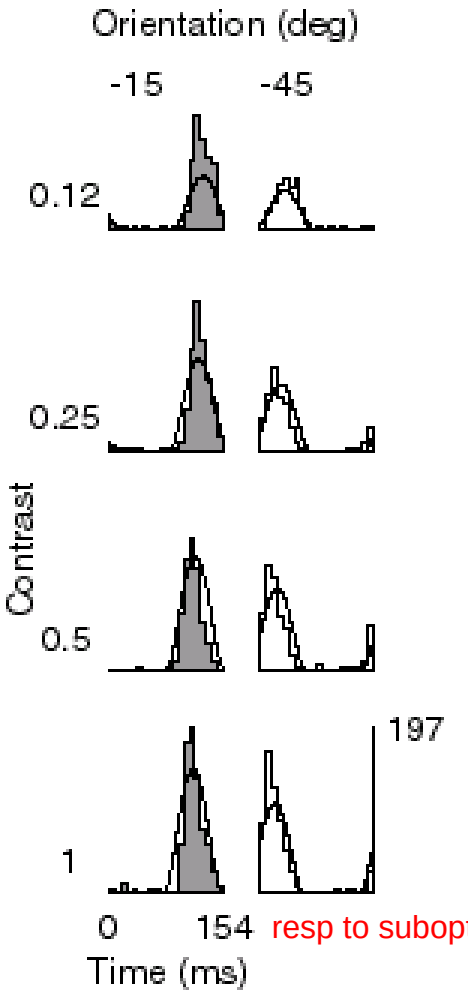




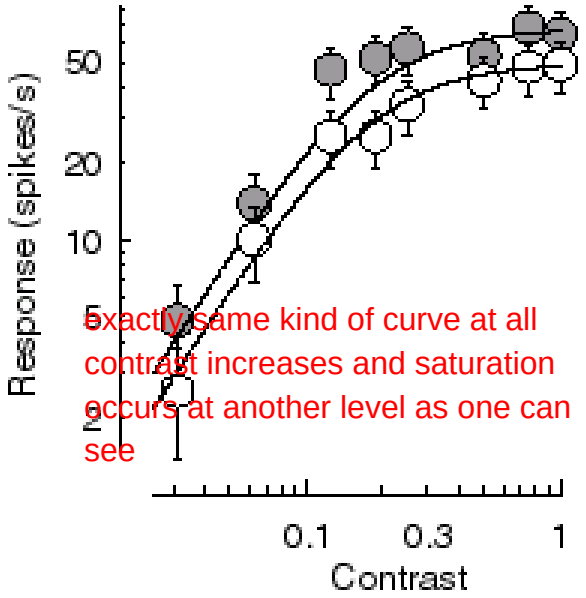
Carandini, Heeger & Movshon (1996)

Saturation depends on contrast





resp to suboptimal orientation

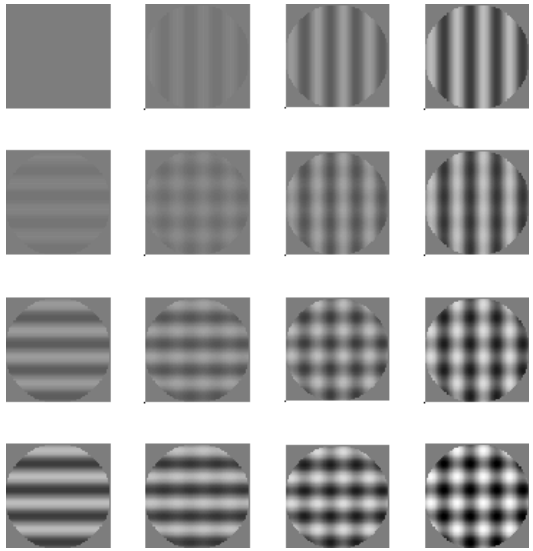


exactly same kind of curve at all contrast increases and saturation occurs at another level as one can see

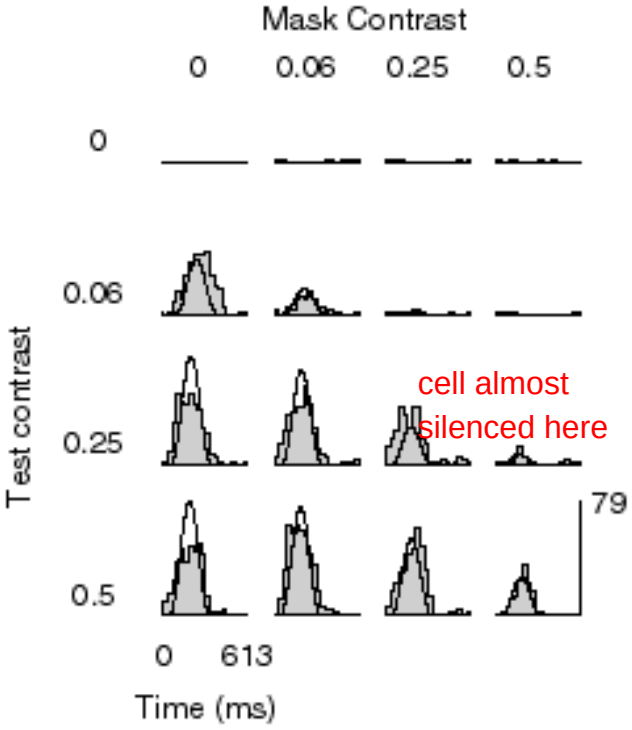
Carandini, Heeger & Movshon (1996)

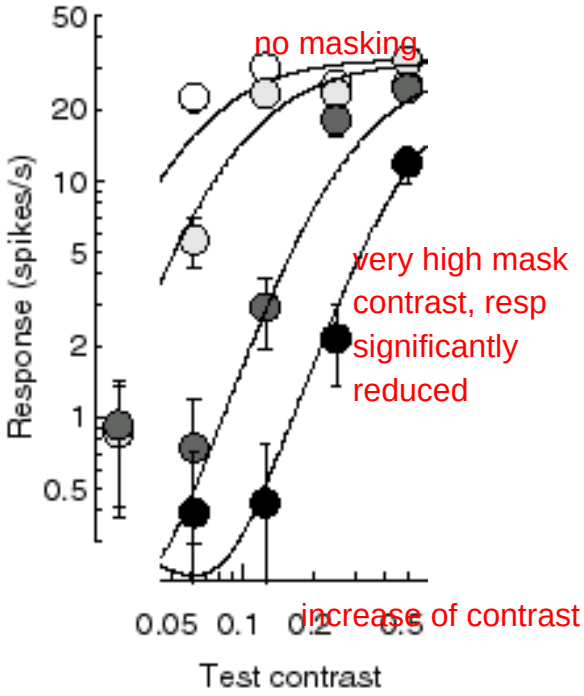
A violation of superposition: Masking

if it was linear, the response of overlapping should be simply the sum of it, but it is not the sum, it's less



destructive inference



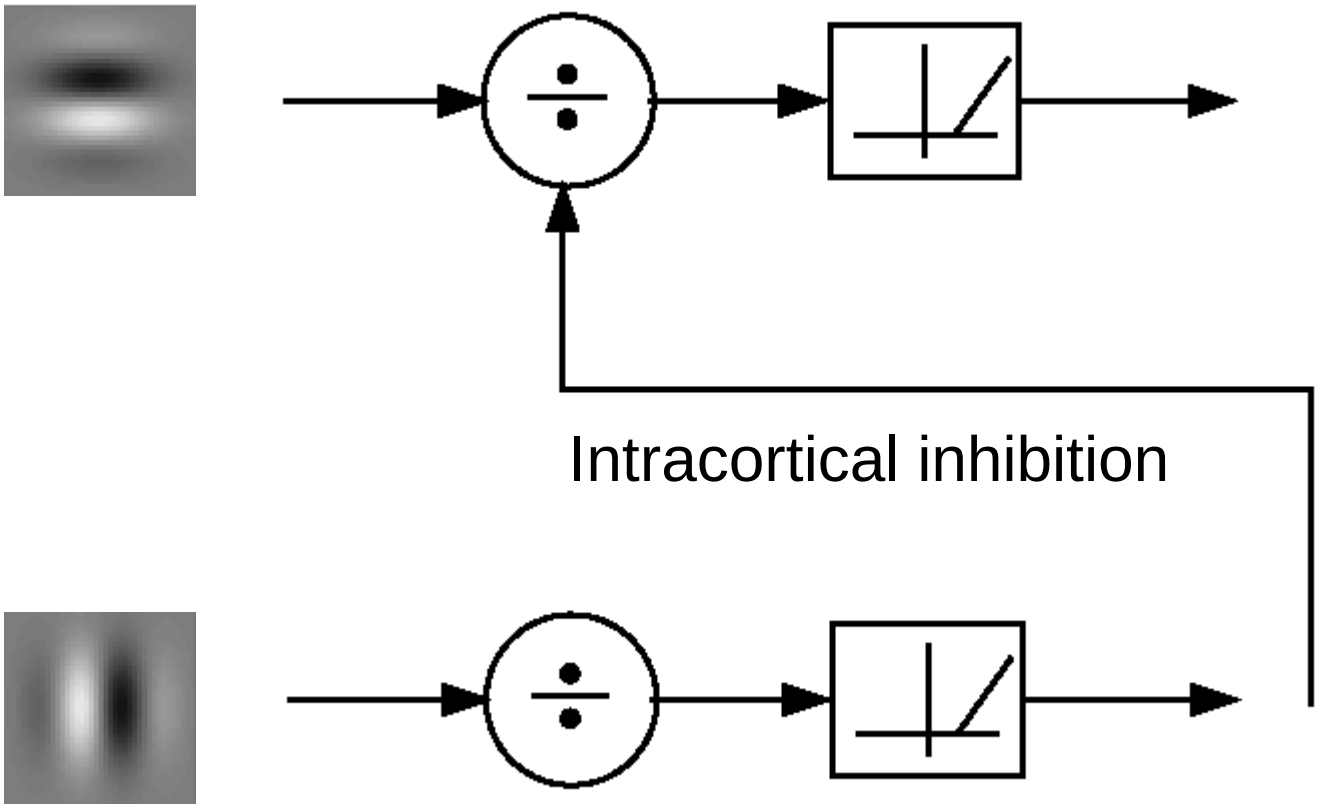


Carandini, Heeger & Movshon (1996)

A nonlinear model of V1 simple cells

output is divided by cells in the vicinity

the neurons have inhib connections in the vicinity (local inhibition = intracortical inhibition)



basically, one cell likes horiztonal gradients and fires a lot. a neighbouring cell has a slightly different orientation preference and will also have an AP, but it will be an inhibitory output to the cell that preferes horizontal gradients, so it's AP are lower due to inhibition

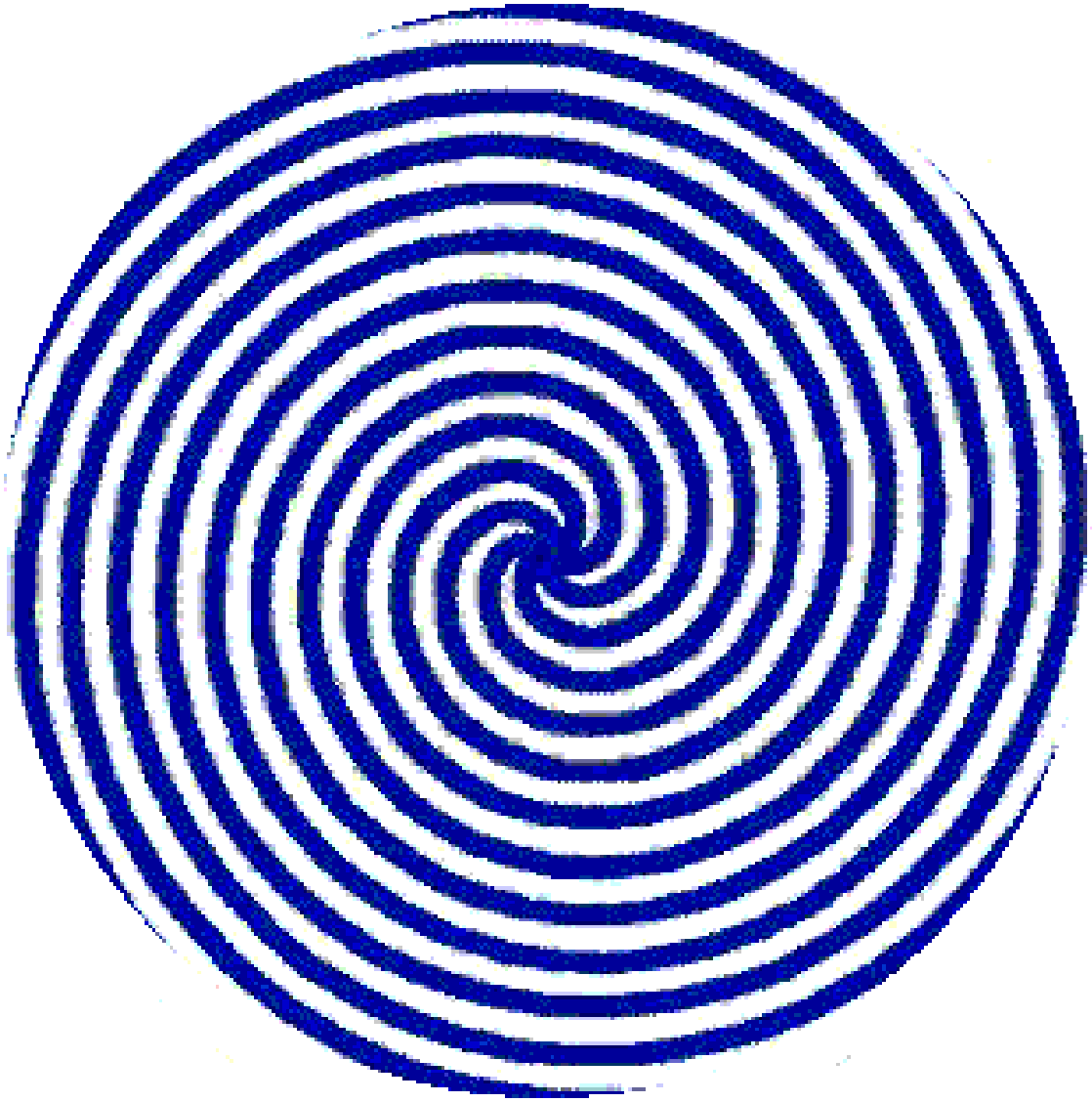
Therefore: intracortical inhibition: when double contrast, the first cell does not have higher AP firiing, due to inhibition that is also doubled from neighbouring cells.

it also depends on level of contrast, the inhibiotiry cells do not respond to really low contrasts when there is suboptimal stimulus

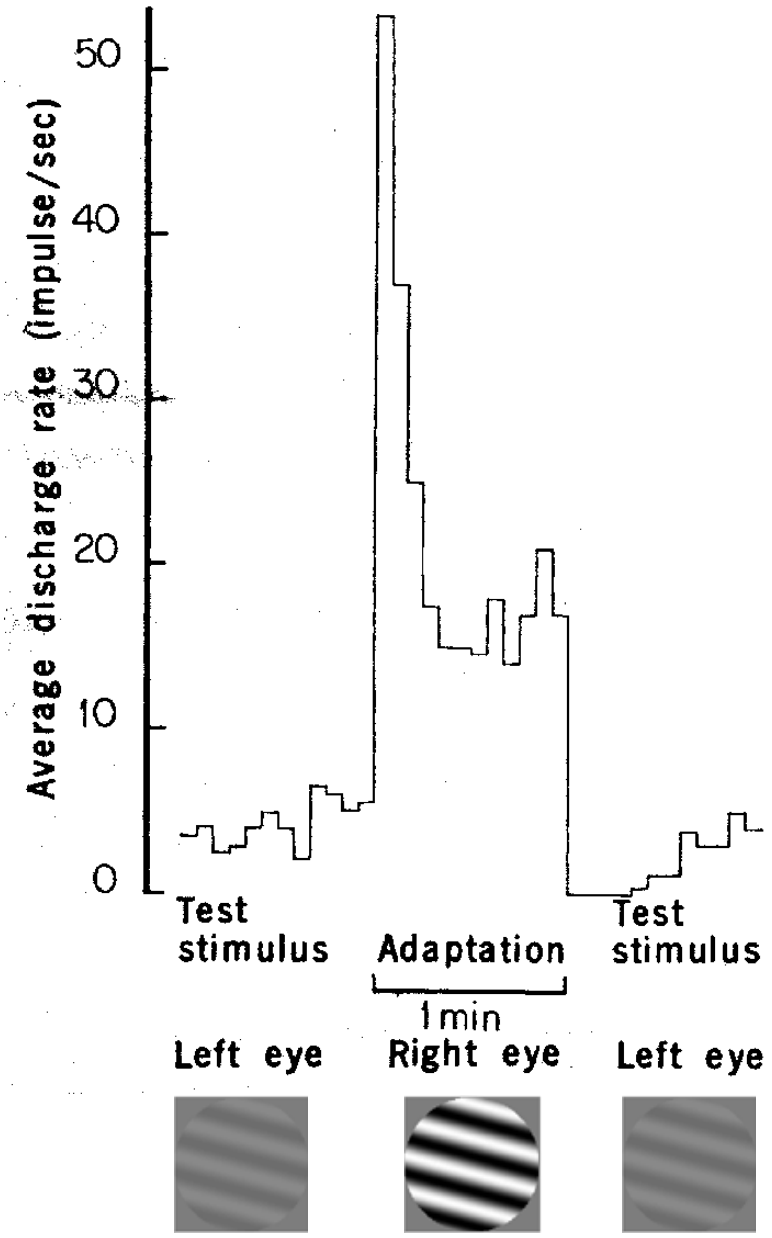
Adaptation

also a non-linearity

this moves in one direction and when it stops we see it moving back theoretically
=> waterfall illusion

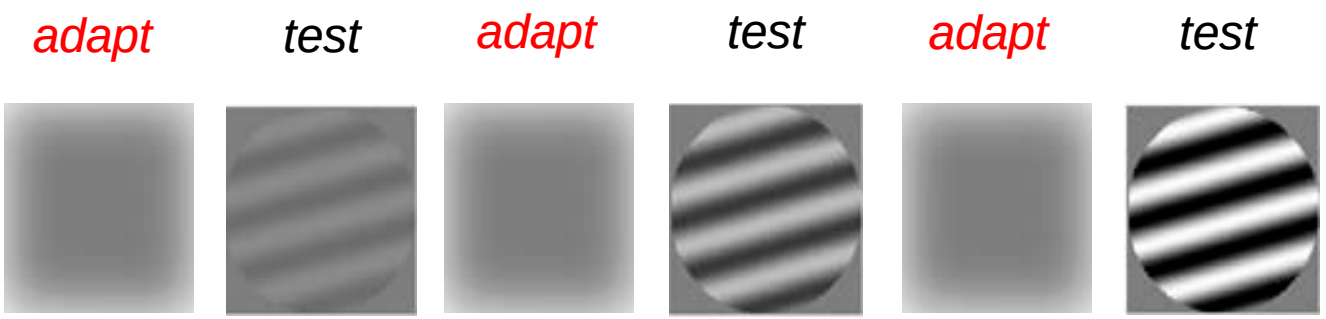


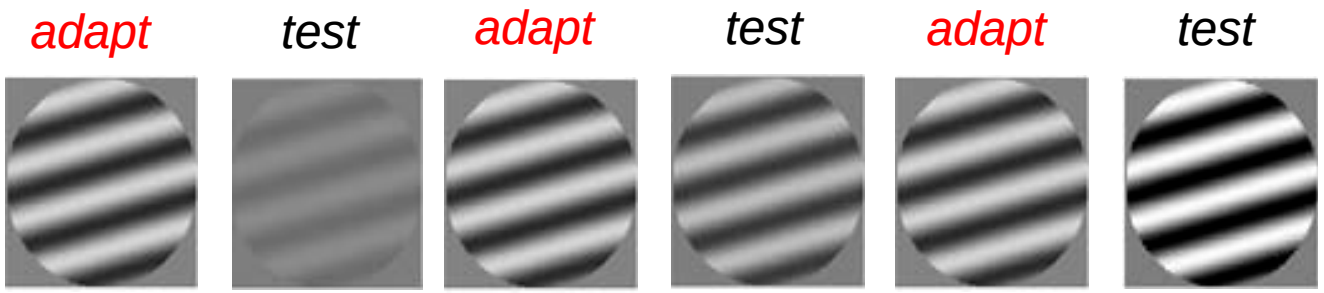
Adaptation in a V1 neuron



Maffei, Fiorentini and Bisti, 1973

adapt stim: extremely low contrast or high contrast

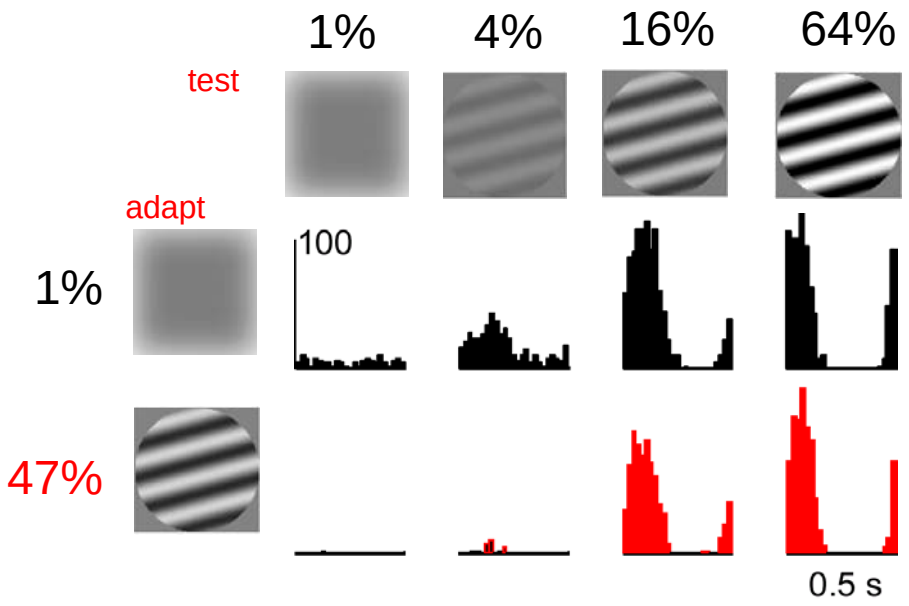


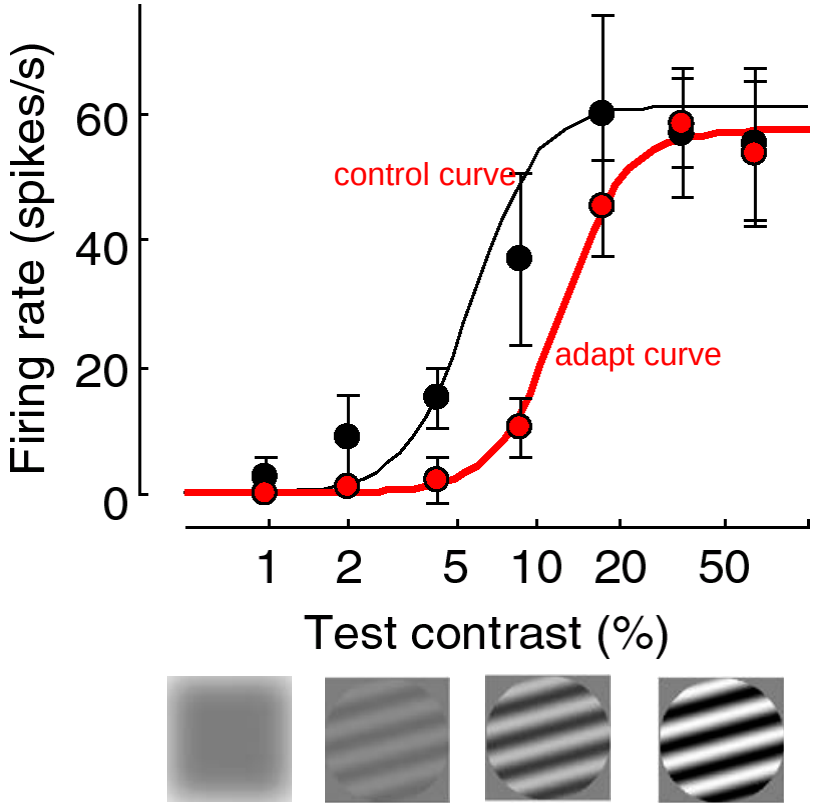


Contrast adaptation controls V1 neuron sensitivity

those are the responses that we see from prev slide

nonlinear behaviors: staruation, masking, contrast adaption, learning

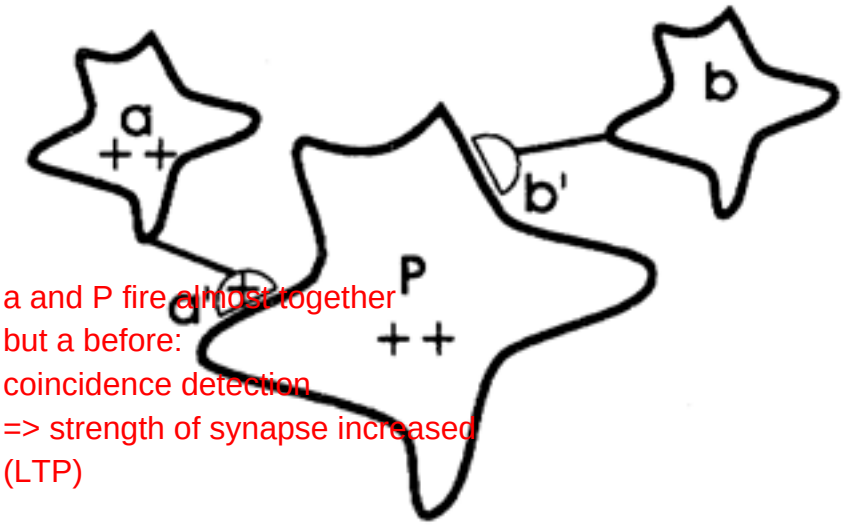




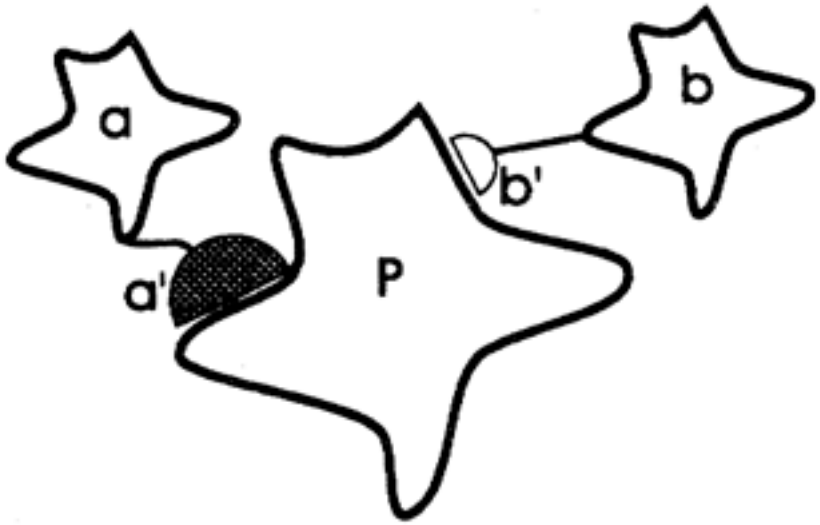
ask him for papers regarding this slide

Learning

Hebbian learning



a and P fire almost together
but a before:
coincidence detection
=> strength of synapse increased
(LTP)

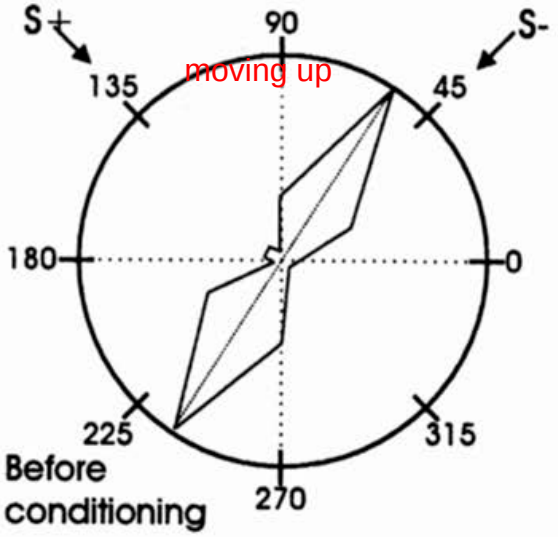


Das, 1997

Evidence for Hebbian learning in V1

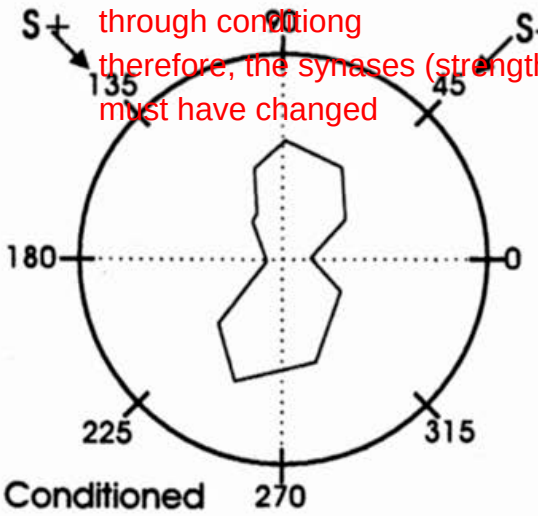
shows orienation and motion of bar

moving up

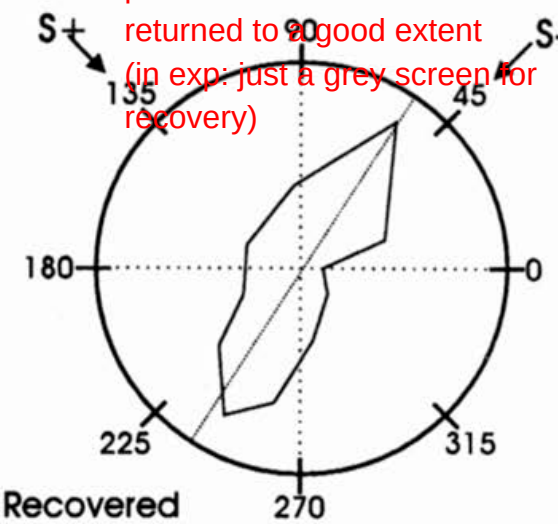


oreitnation preference modified through conditiong

therefore, the synases (strength) must have changed

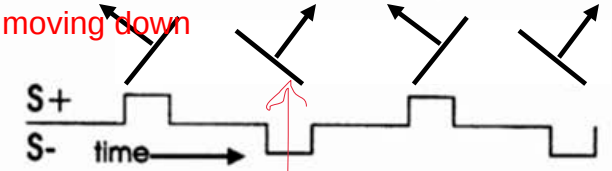


preferred orientation of neuron returned to a good extent (in exp: just a grey screen for recovery)



moving down

conditioning exp



if conditioning occurs long enough, there might be permament change to the circuits

npn-preferred orientation

Fregnac et al., 1992, in Das, 1997