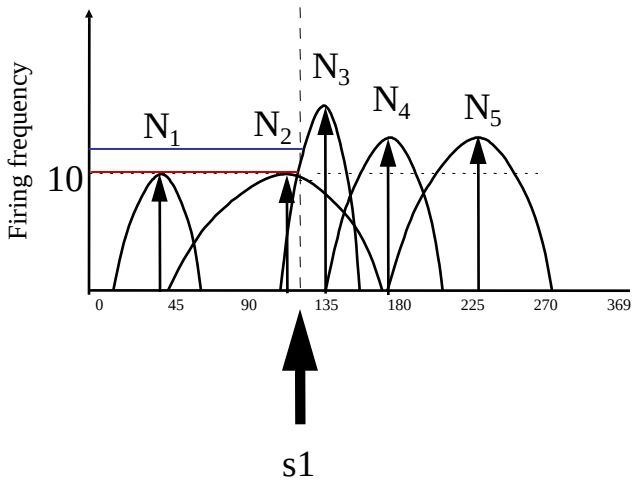
Tuning tuning curves

So far:
Receptive fields
Representation of stimuli
Population vectors

Today: Contrast enhancment, cortical processing



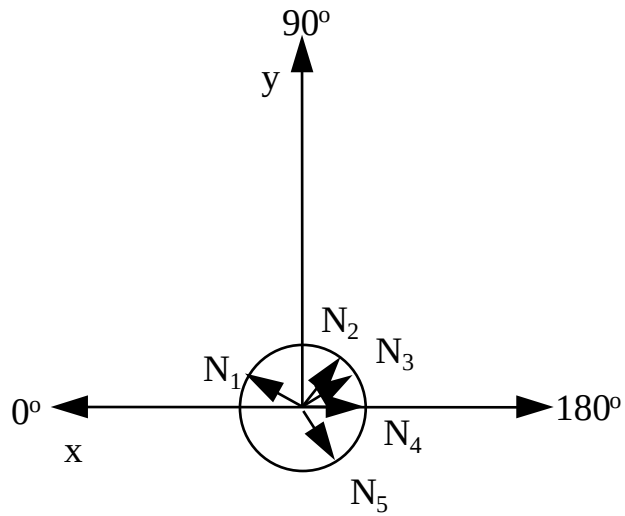
$s_{max}(N_1) = 40^o$

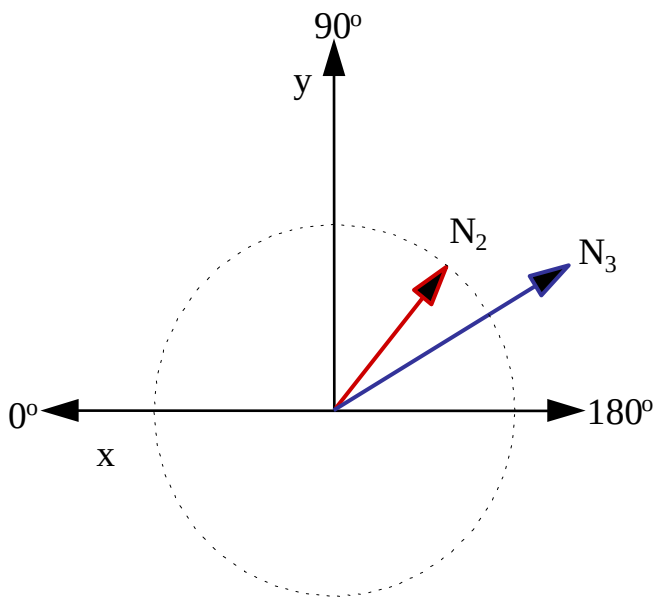
$s_{max}(N_2) = 110^o$

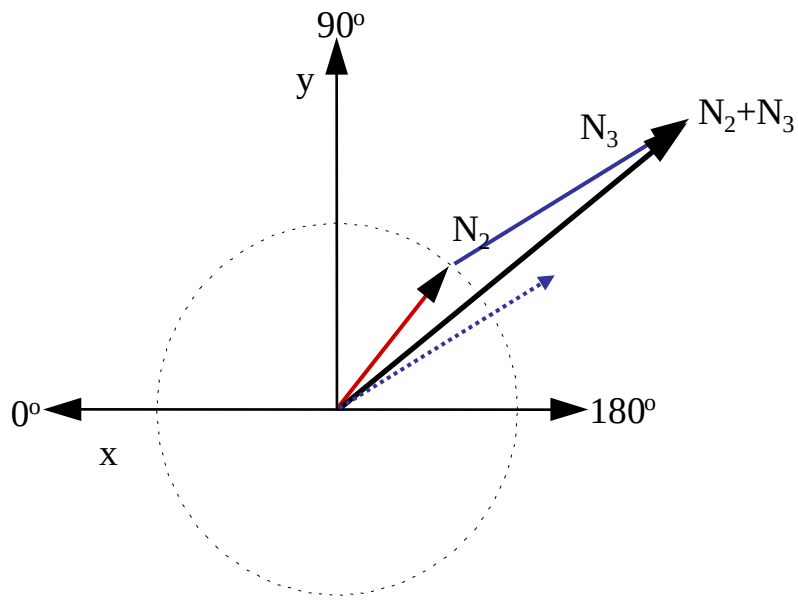
$s_{max}(N_3) = 135^o$

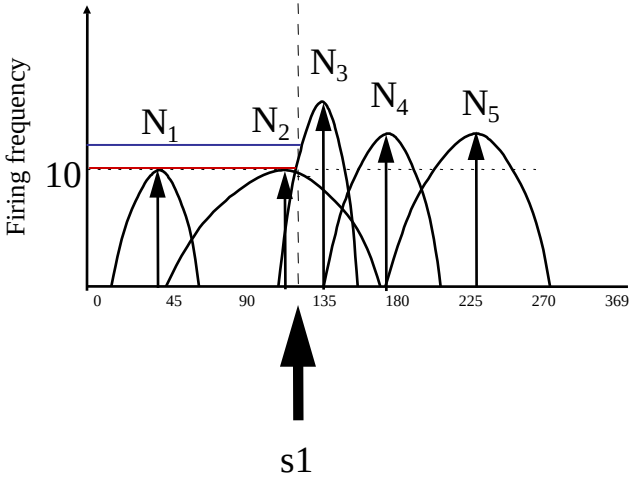
$s_{max}(N_4) = 180^o$

$s_{max}(N_5) = 230^o$









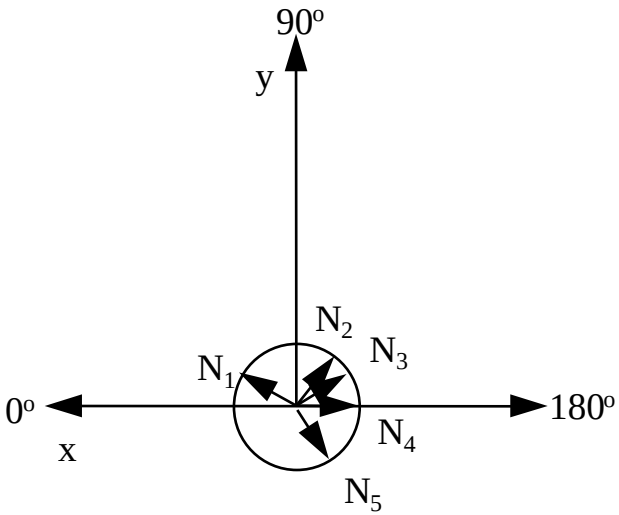
$s_{max}(N_1) = 40^o$

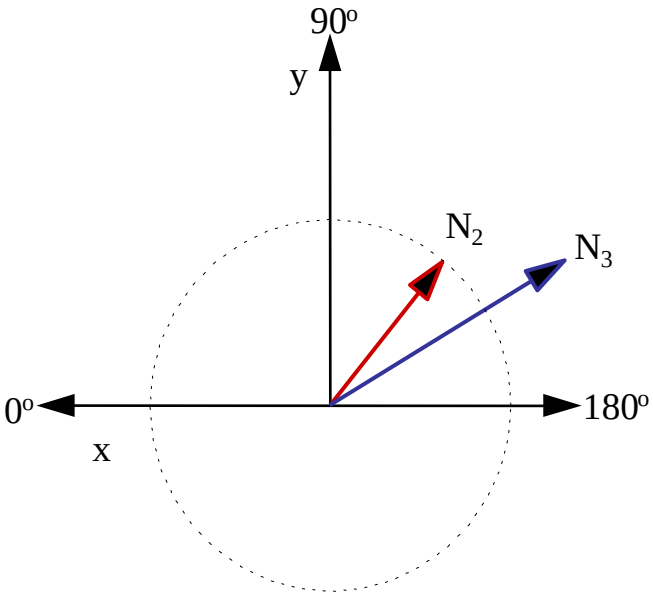
$s_{max}(N_2) = 110^o$

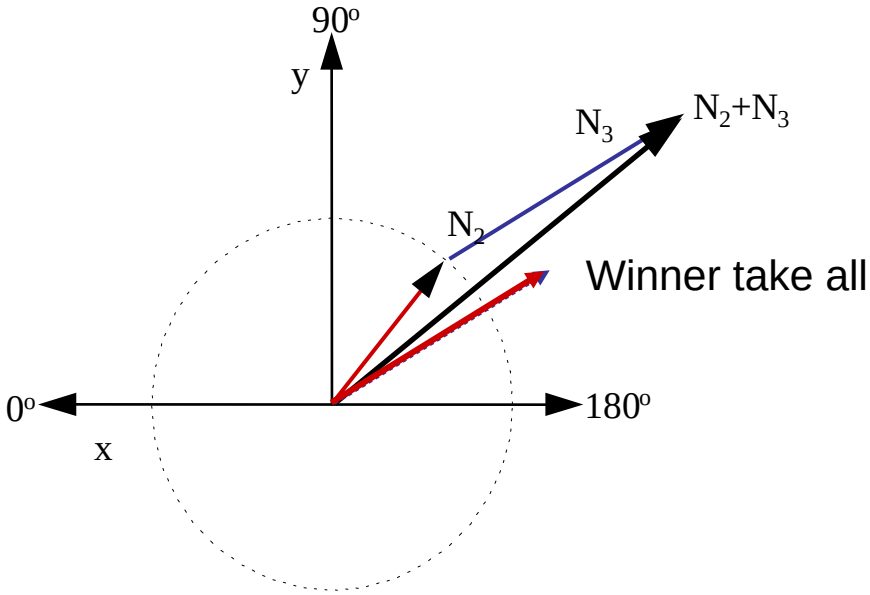
$s_{max}(N_3) = 135^o$

$s_{max}(N_4) = 180^o$

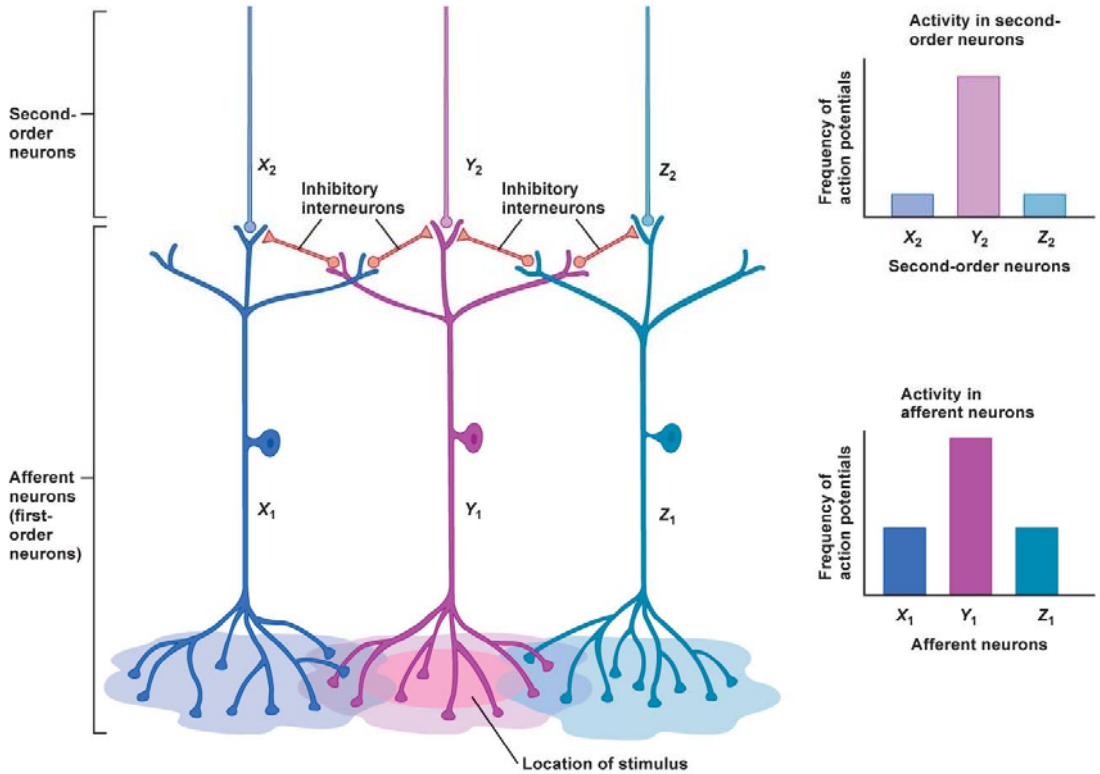
$s_{max}(N_5) = 230^o$







In many sensory systems, the tuning curves of neurons are not identical to the receptive fields projected to these neurons by sensory neurons. They may be more narrow, include inhibitory parts of the curve, they may be wider or more separated from each other. There are a number of processes that “tune” tuning curves, these include interactions between neurons such as inhibition, excitation and feedback interactions. As we noted before, sensory receptive fields are often broad and relatively non-specific, for example frequency tuning curves in the auditory nerve can span a large range of frequencies.



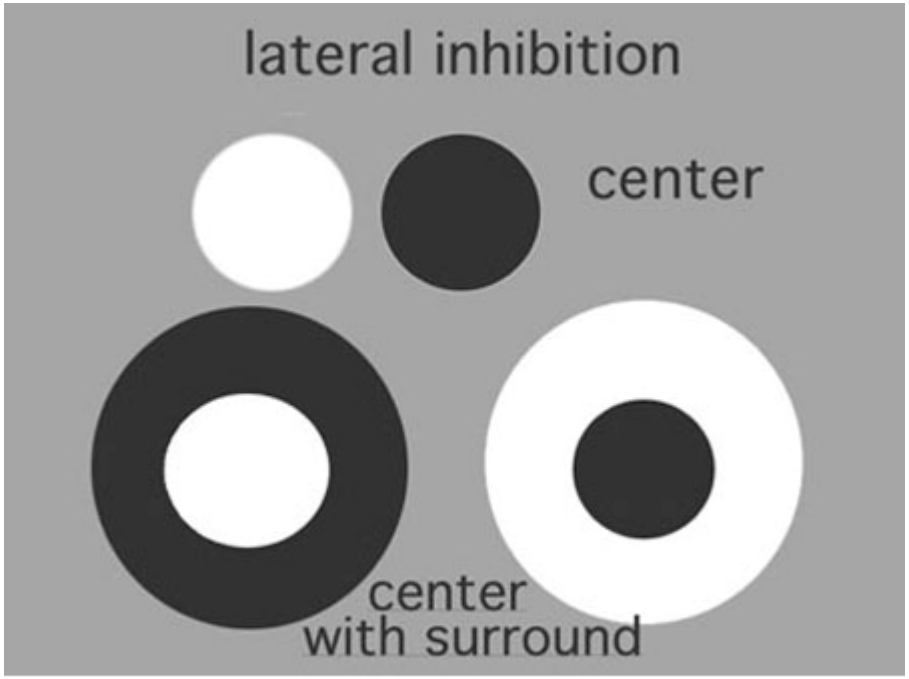
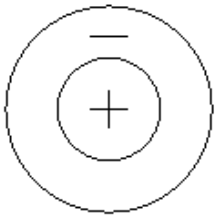
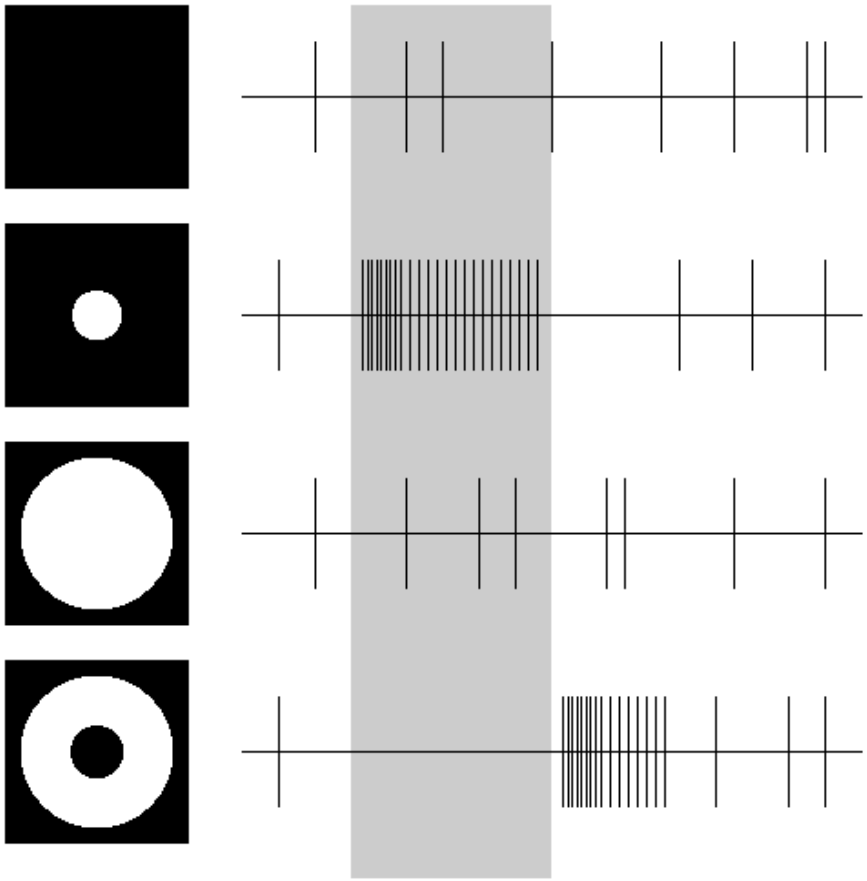


Fig. 10. Center-surround receptive fields can be ON center or OFF center with the oposite sign annular surround.

Lateral inhibition



Strong response when center is bright, surround is dark.



Stimulus

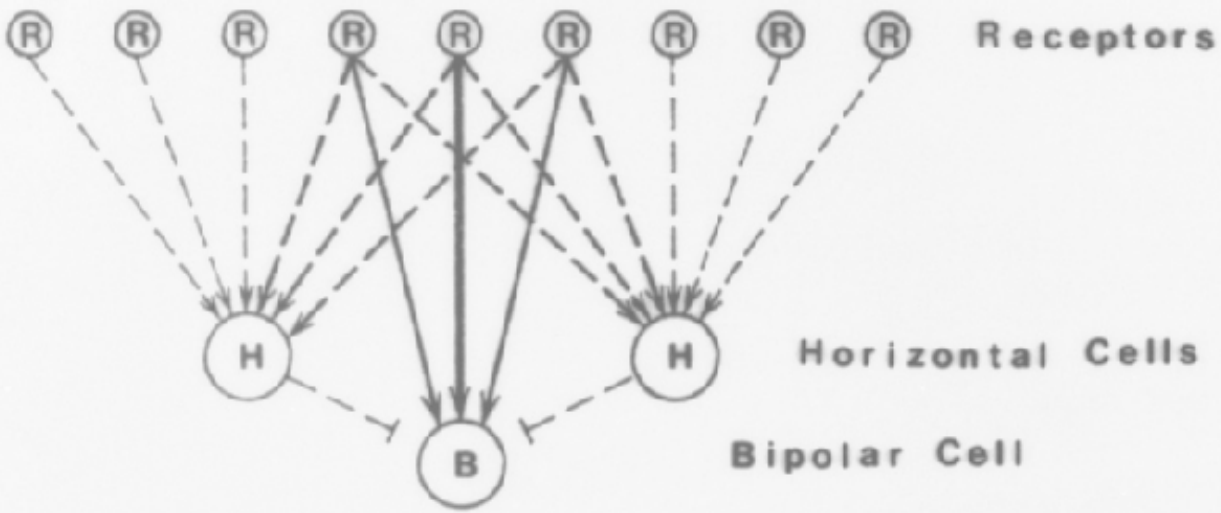
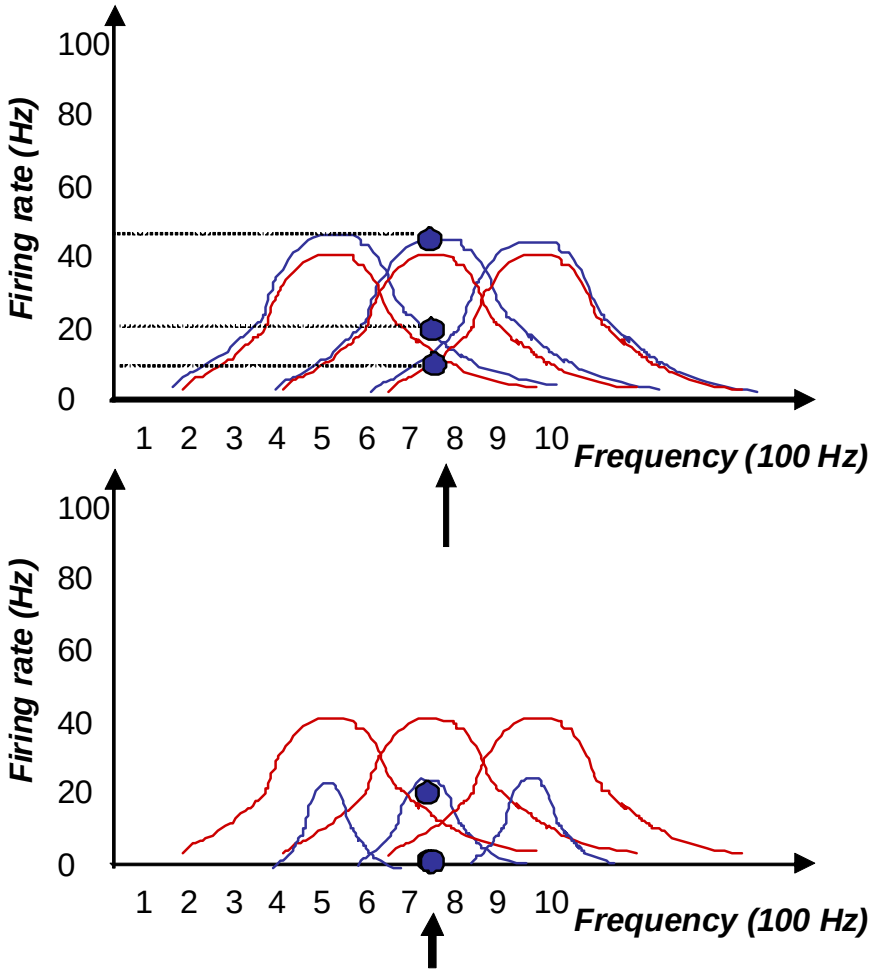
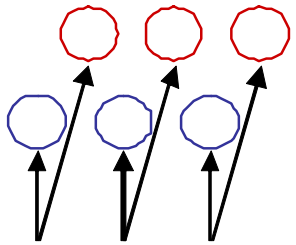
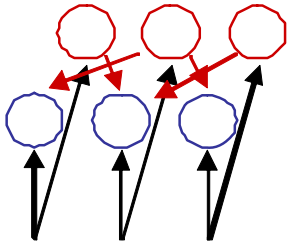


FIG. 3.15 Diagrammatic representation of the direct (solid lines) and indirect (dashed lines) inputs to a bipolar cell from receptors and horizontal cells. Note that the direct and indirect paths have opposite effects on the bipolar cell.





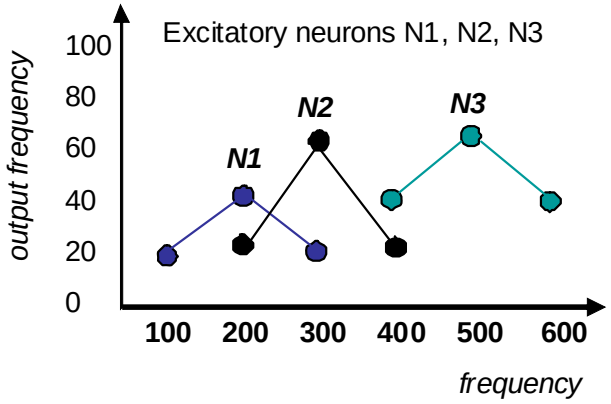
Stimulus

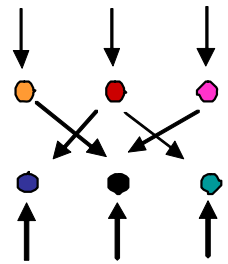


Stimulus

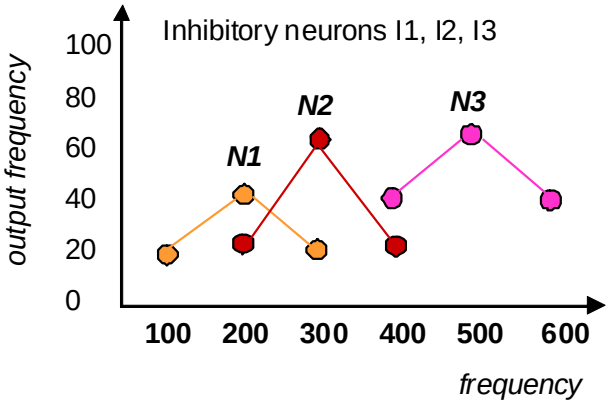
N1 = 20-50 = -30 (=0)
N2 = 50 – 20 – 10 = 20
N3 = 10-50 = -40 (=0)

Exercise: Assuming linear interactions and all synaptic weights being zero, construct the approximate resulting receptive fields for these neurons and this network:

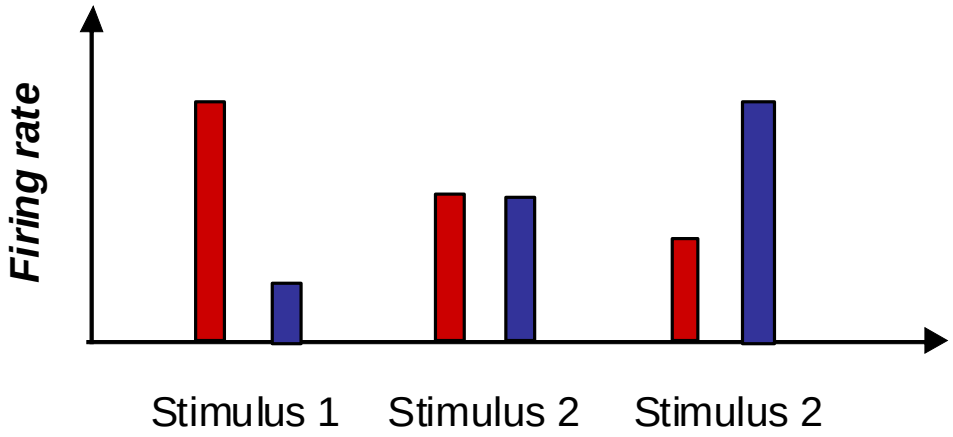




for all neurons: x = in
for all synapses: w=-1



Exercise: Look at the recordings below. Think about what you could learn from these and what additional information you would need to get useful information from this experiment.



Because of broad receptive fields and tuning curves, neural circuits are thought to enhance “contrast” or increase the difference between sensory stimuli in order to make them more easily recognizable, their features more salient, more distinguishable from each other.

Exercise: (a) You have a number of chairs and a number of tables. List features these have in common. Now list features that differentiate them. Write a list of yes no questions that would allow you to decide (i) if an object does belong to either category and (ii) if it is a chair or a table. Now find some examples that would not easily be classified. Create a neural network with a layer of feature detectors (respond to a specific feature), a layer of inhibitory neurons and one or two more layers of neurons including a layer of output neurons. At the output, you want to know if the object you detect is a chair or a table. Think about which features you want to suppress (inhibit) and which you want to have compete against each other.

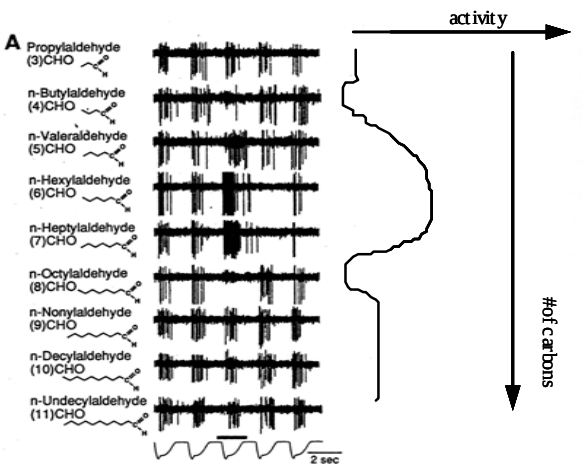
Exercise: (a) You have a number of chairs and a number of tables.

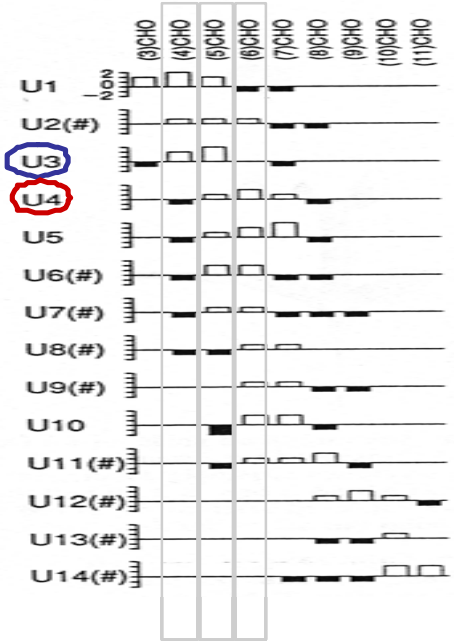
List features these have in common.

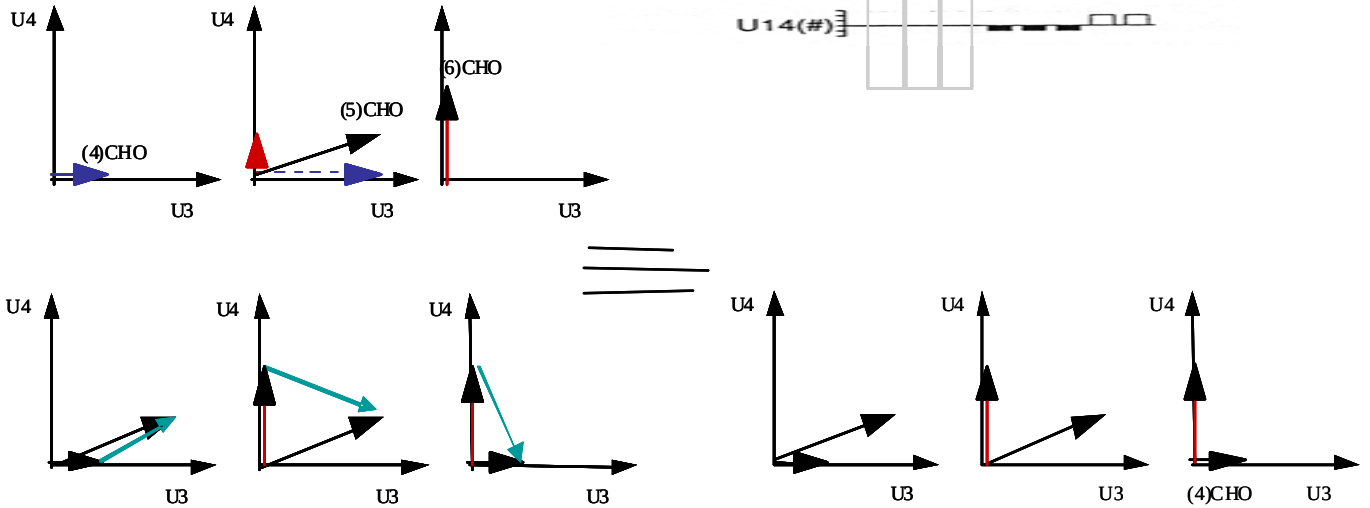
Now list features that differentiate them.

Write a list of yes no questions that would allow you to decide (i) if an object does belong to either category and (ii) if it is a chair or a table.

Now find some examples that would not easily be classified. Create a neural network with a layer of feature detectors (respond to a specific feature), a layer of inhibitory neurons and one or two more layers of neurons including a layer of output neurons. At the output, you want to know if the object you detect is a chair or a table. Think about which features you want to suppress (inhibit) and which you want to have compete against each other.





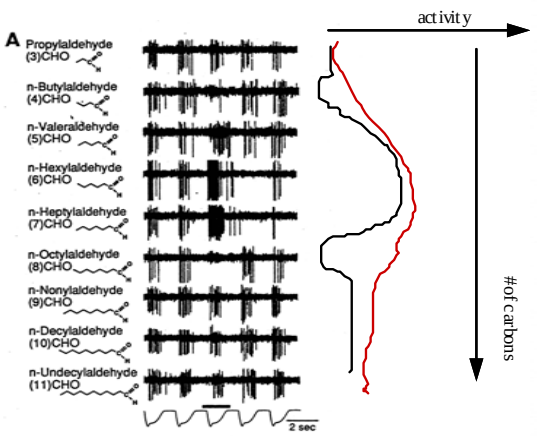


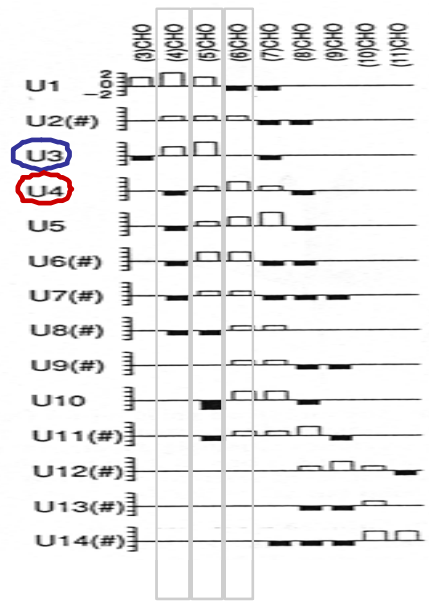
Distance: $D = \sqrt{(U3 - U4)^2}$

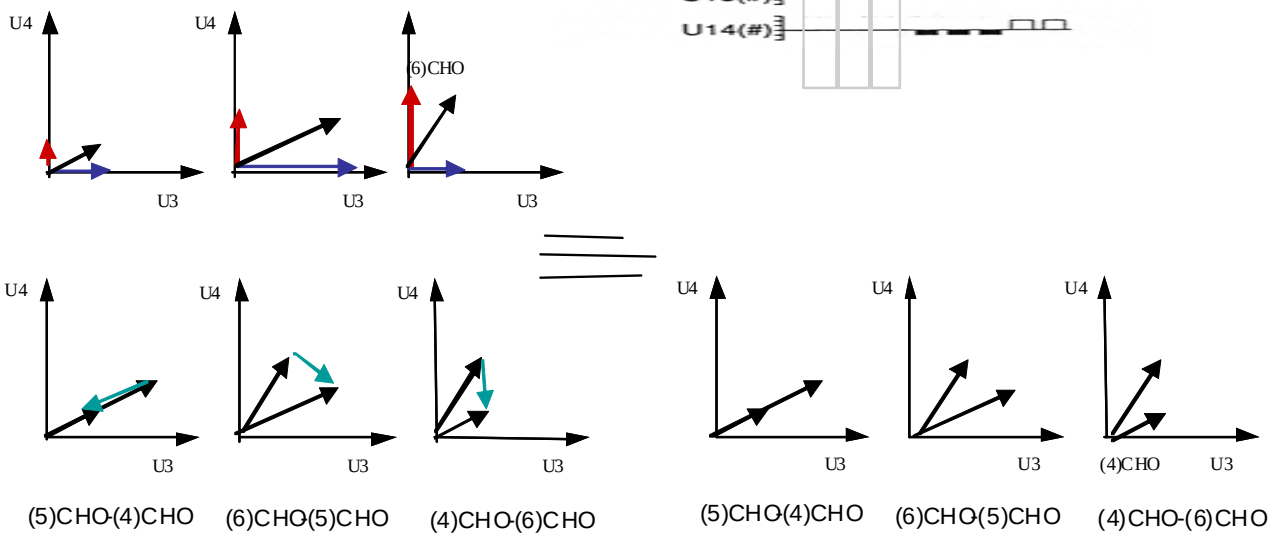
(5)-(4) < (4)-(5) < (5)-(6)

Dot product $\vec{A}\vec{B} = |A| * |B| * \cos(\alpha)$

How to compare vectors





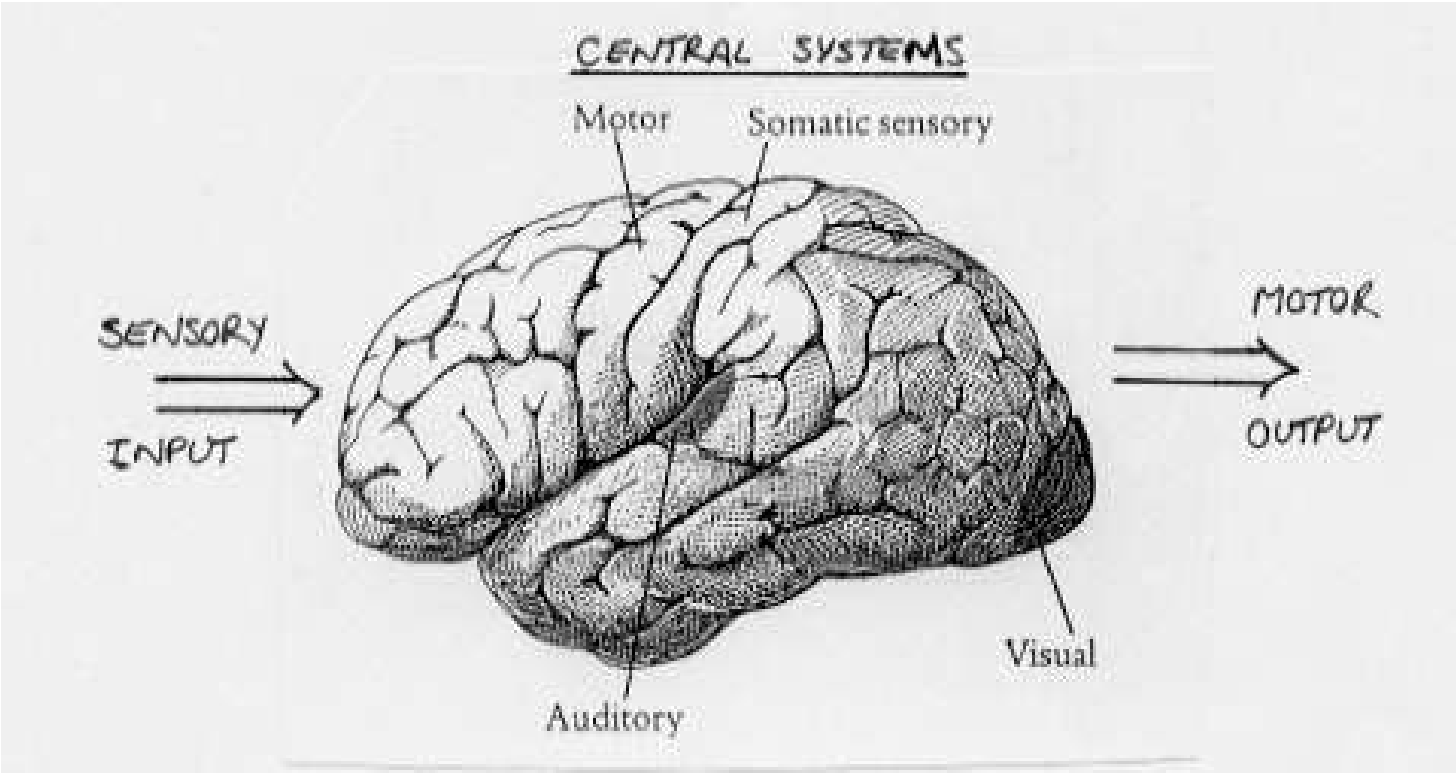


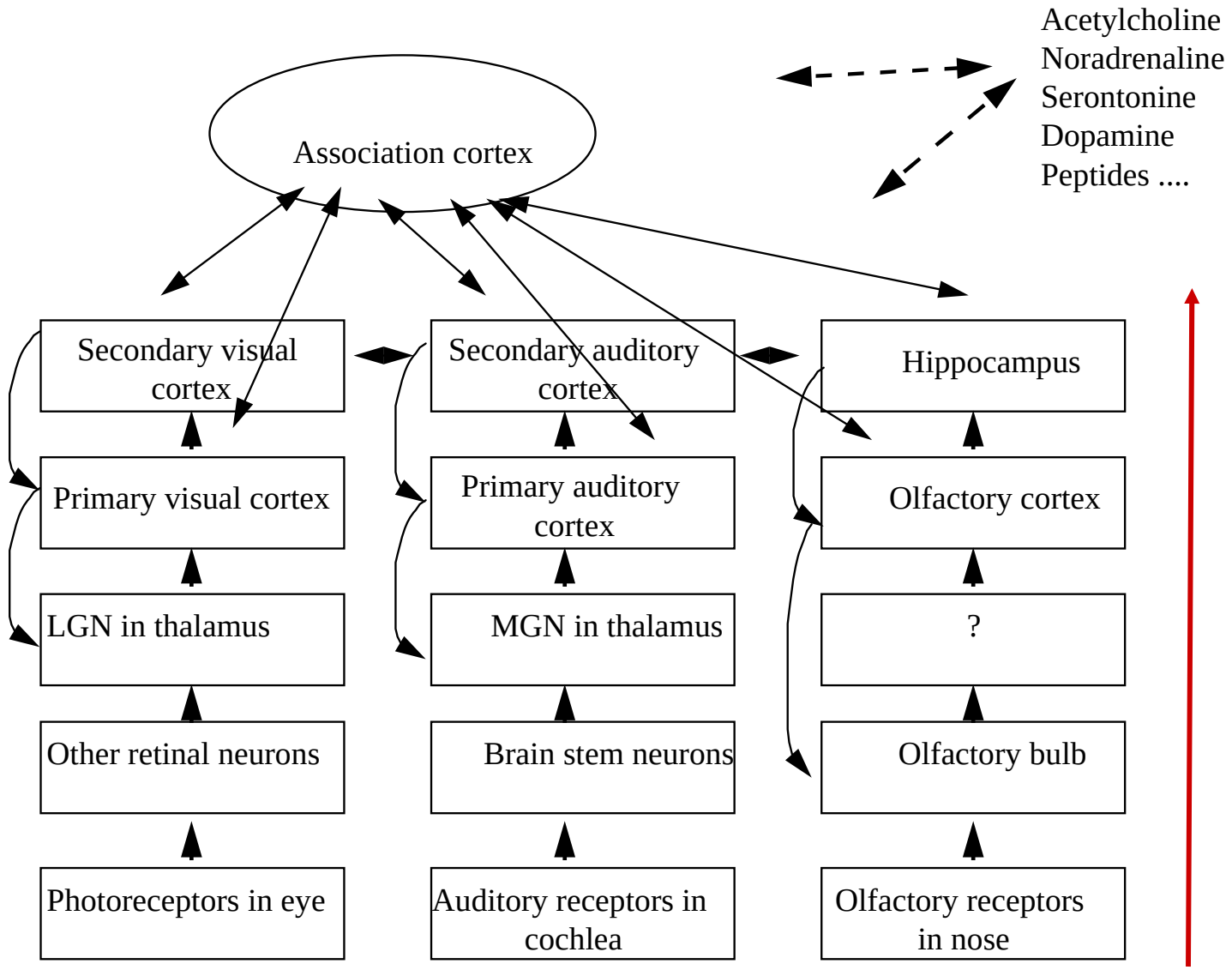
Distance: $D = \sqrt{(U3 - U4)^2}$

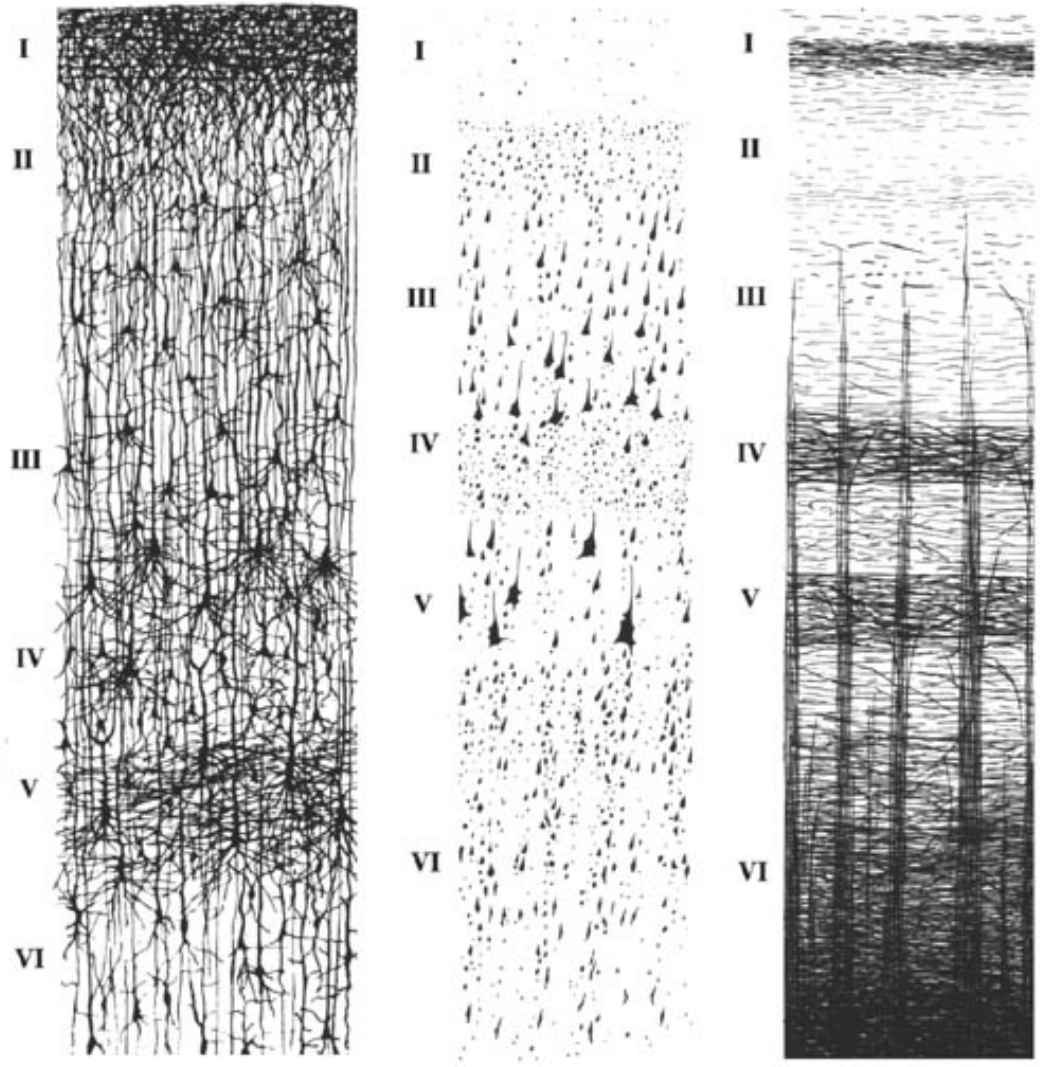
Dot product $\vec{A}\vec{B} = |A| * |B| * \cos(\alpha)$

(5)-(4) < (4)-(5) < (5)-(6)

Exercise: What happens to the distance measure and dot product measure if the vectors are “normalized” first (this means they all have length 1.0 and span the unit circle).


CENTRAL SYSTEMS
Motor
Somatic sensory
SENSORY
INPUT
MOTOR
OUTPUT
Visual
Auditory


Acetylcholine
Noradrenaline
Serontonine
Dopamine
Peptides ....
Association cortex
Secondary visual cortex
Secondary auditory cortex
Hippocampus
Primary visual cortex
Primary auditory cortex
Olfactory cortex
LGN in thalamus
MGN in thalamus
?
Other retinal neurons
Brain stem neurons
Olfactory bulb
Photoreceptors in eye
Auditory receptors in cochlea
Olfactory receptors in nose



Golgi ***Nissl*** ***Weigert***

I. **Molecular Layer**

II. **External Granular Layer**

III. **External Pyramidal Layer**

Line of Kaes-Bechterew

IV. **Internal Granular Layer**

Outer band of Baillarger

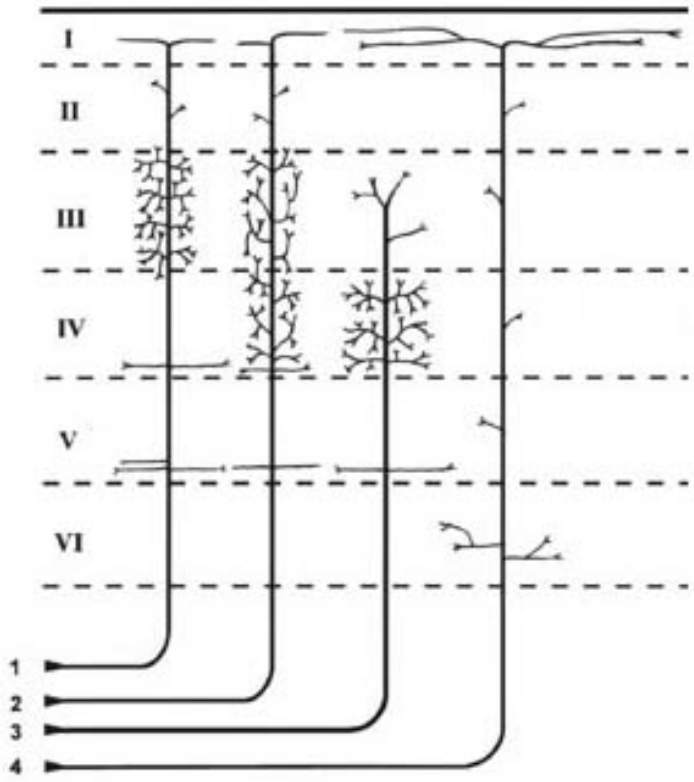
- *Line of Gennari* in area 17

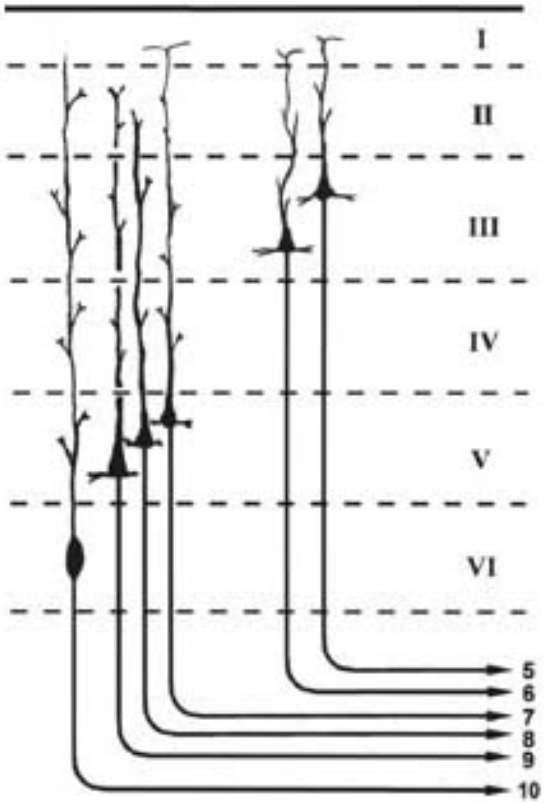
V. **Internal Pyramidal Layer**

Giant pyramidal cell of Betz

Inner Band of Baillarger

VI. **Polymorphic Layer**





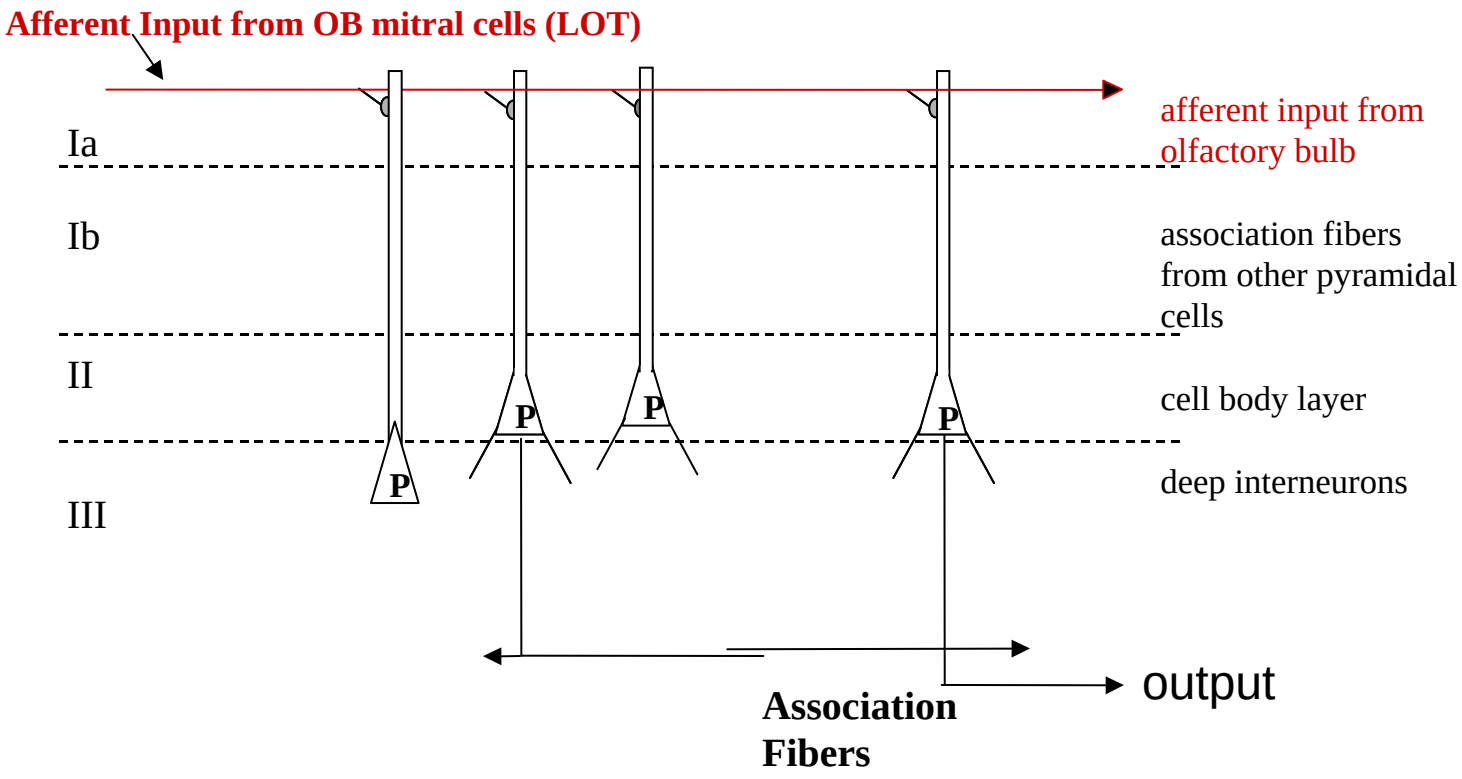
Inputs

Outputs

Pyramidal cell

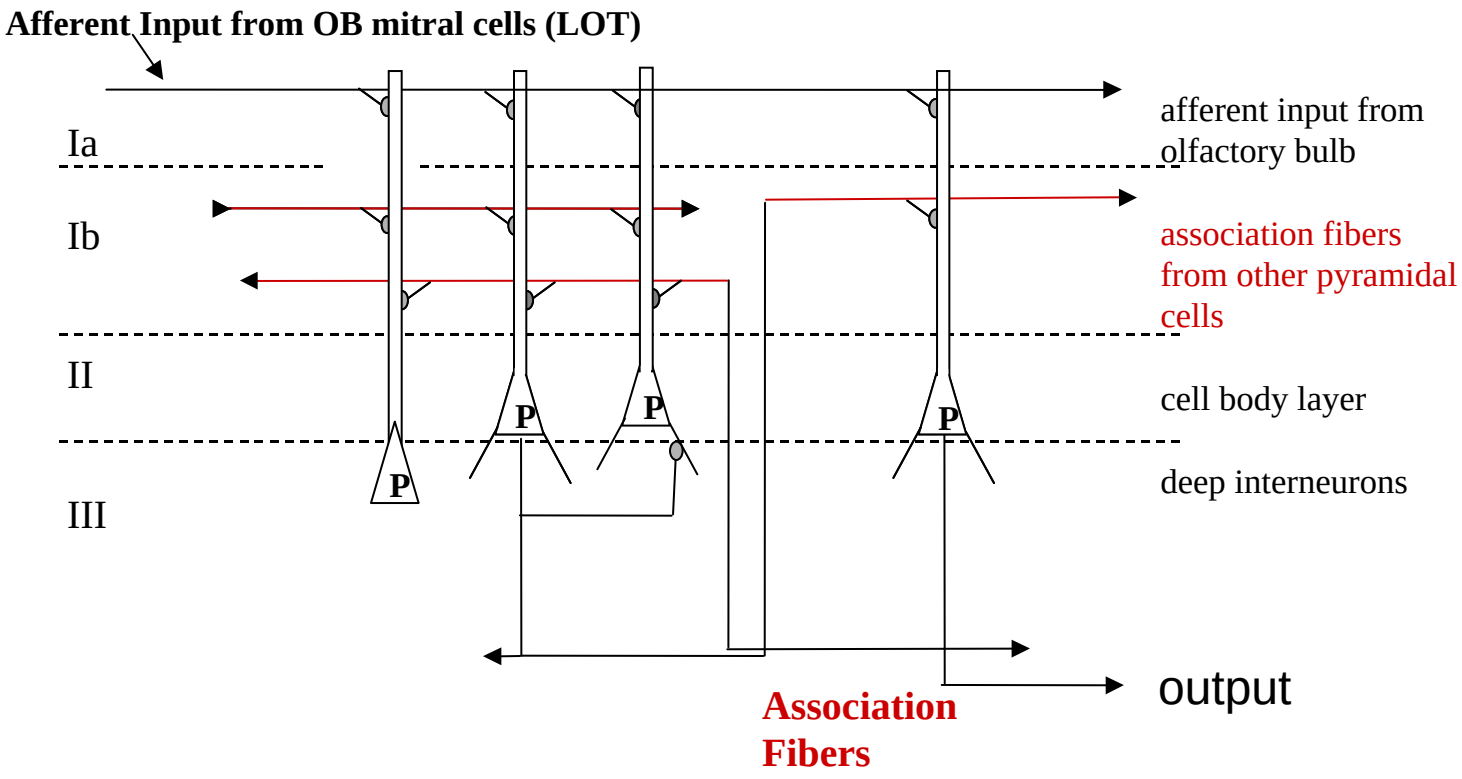
Cell body

Piriform cortex circuitry



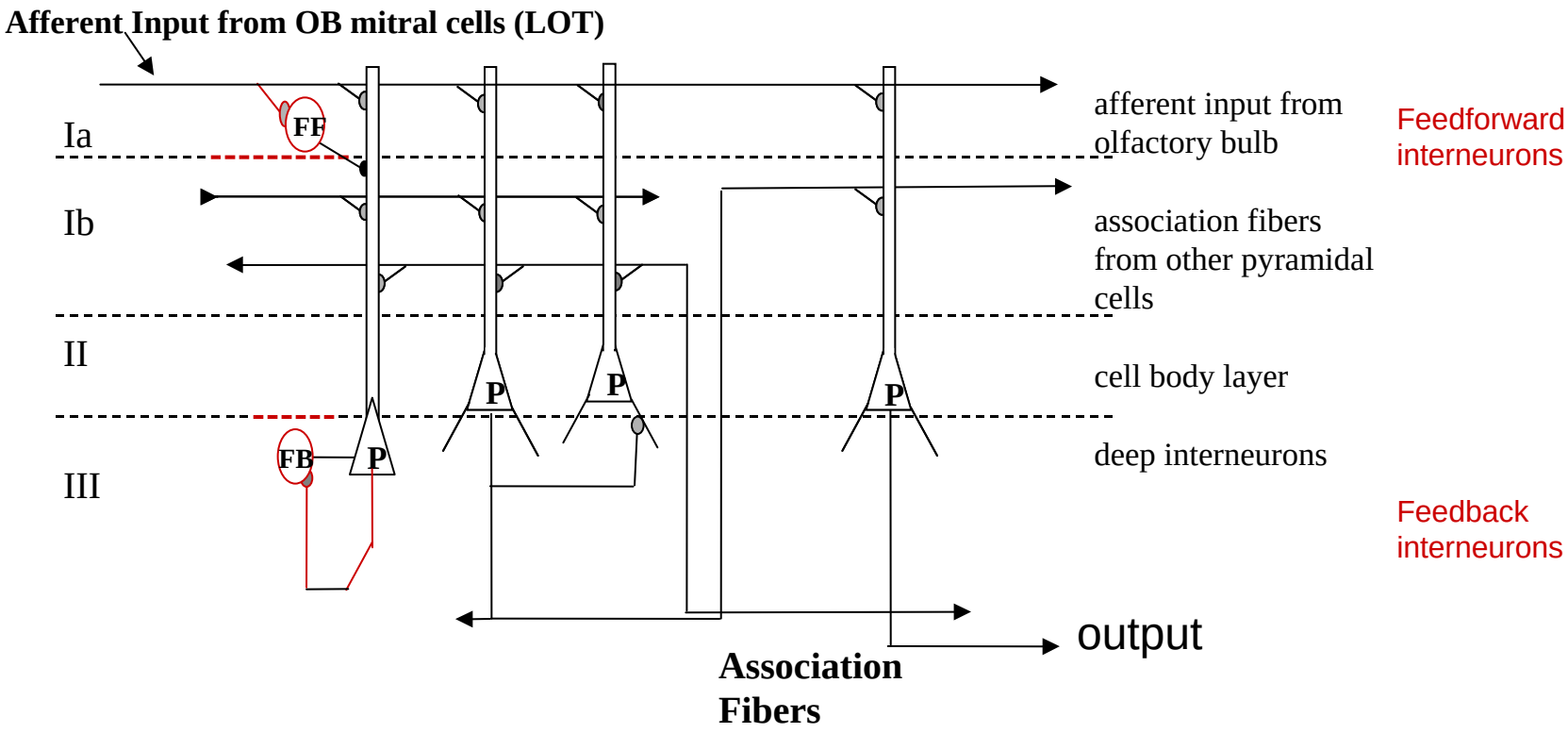
Haberly, L.B. Chem. Senses, 10: 219 -38 (1985)

Piriform cortex circuitry



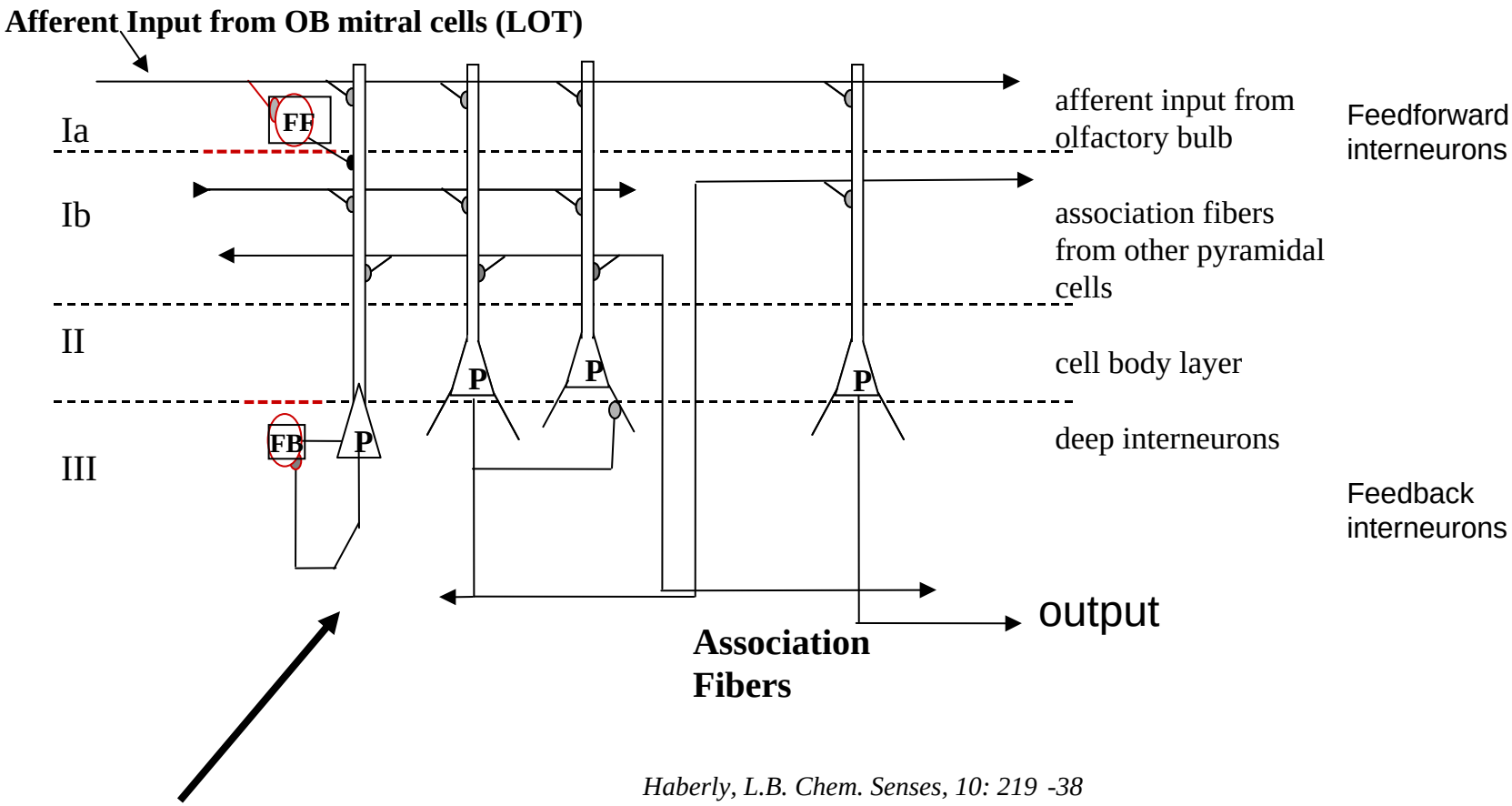
Haberly, L.B. Chem. Senses, 10: 219 -38 (1985)

Piriform cortex circuitry



Haberly, L.B. Chem. Senses, 10: 219 -38 (1985)

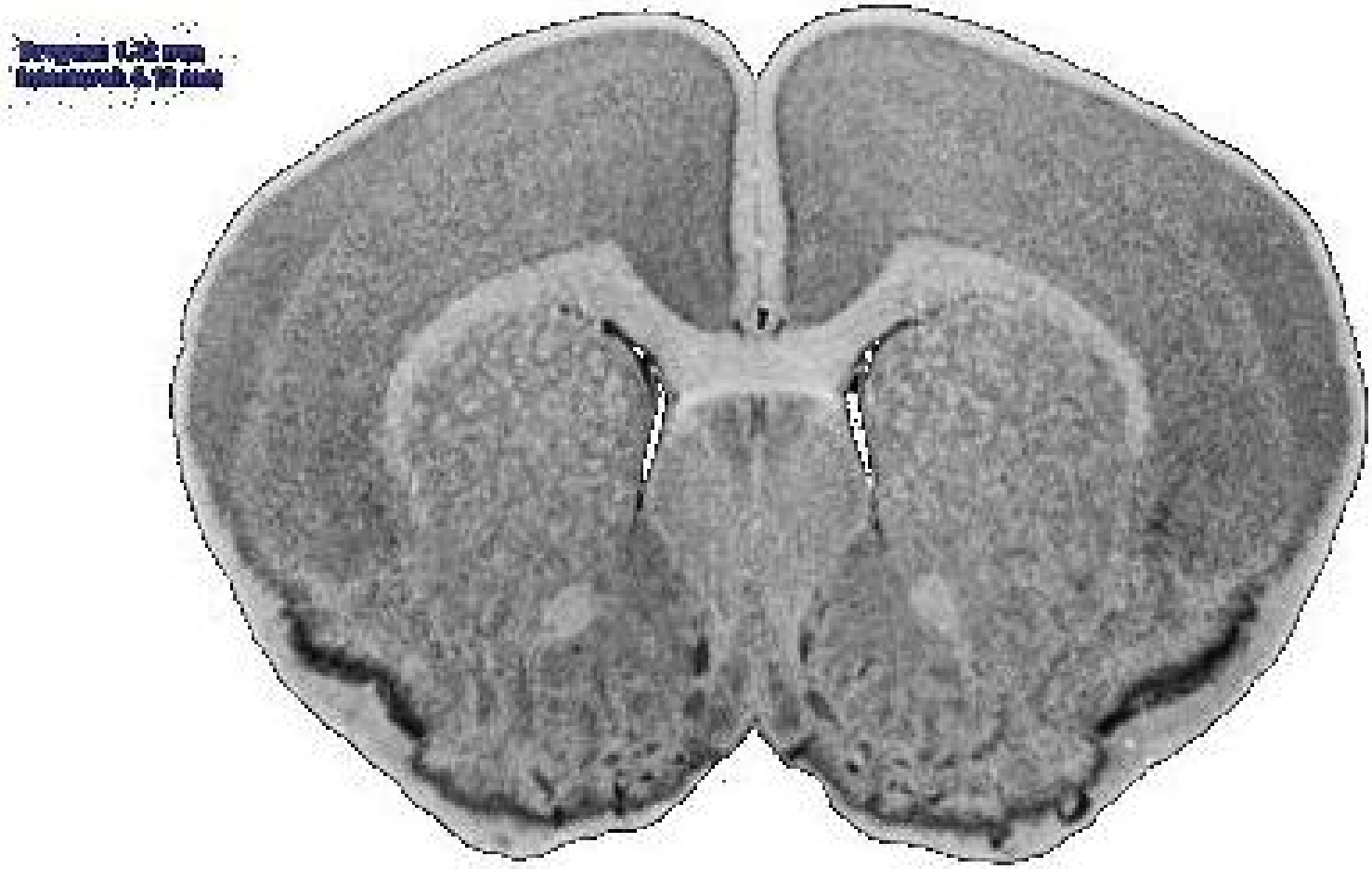
Piriform cortex circuitry

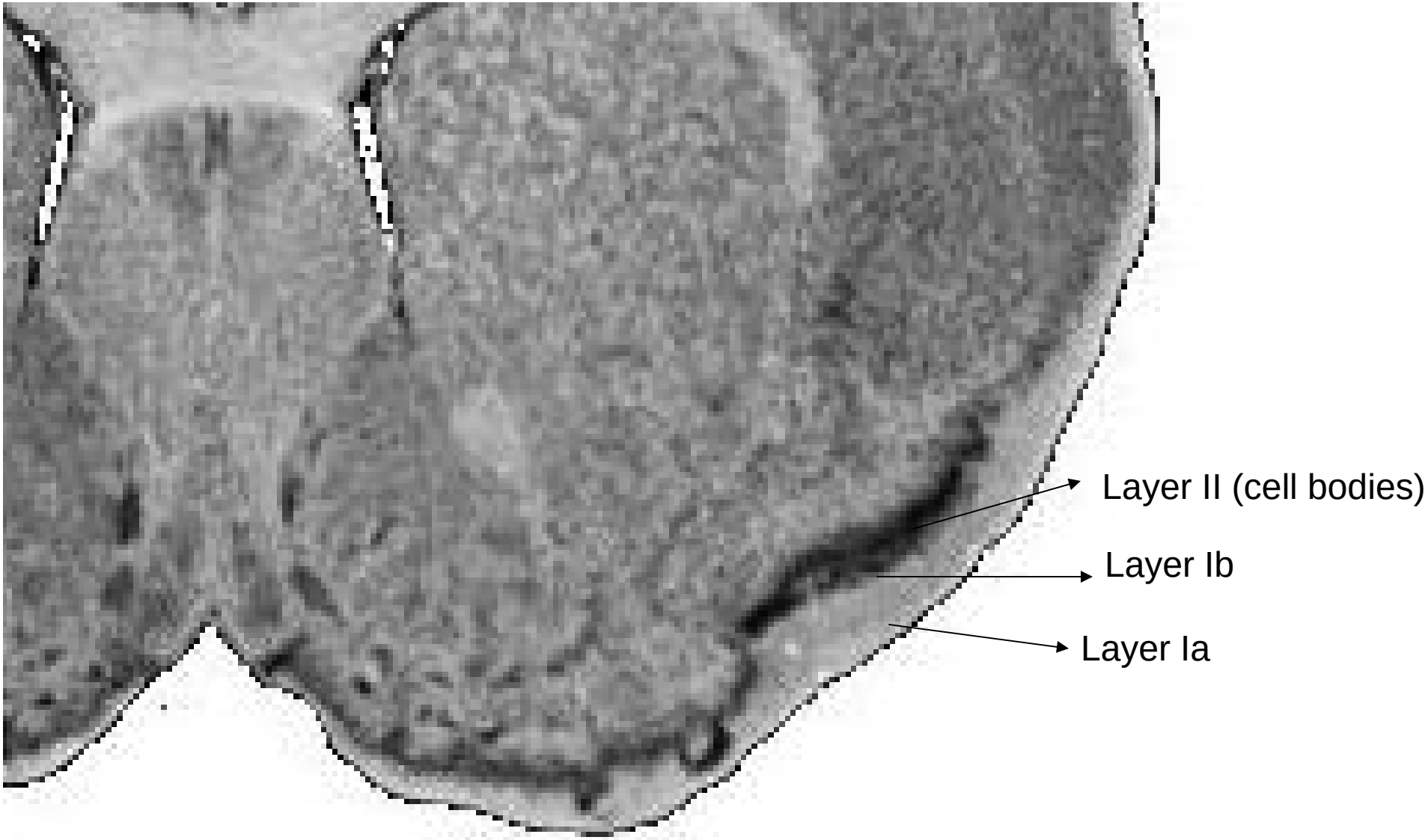


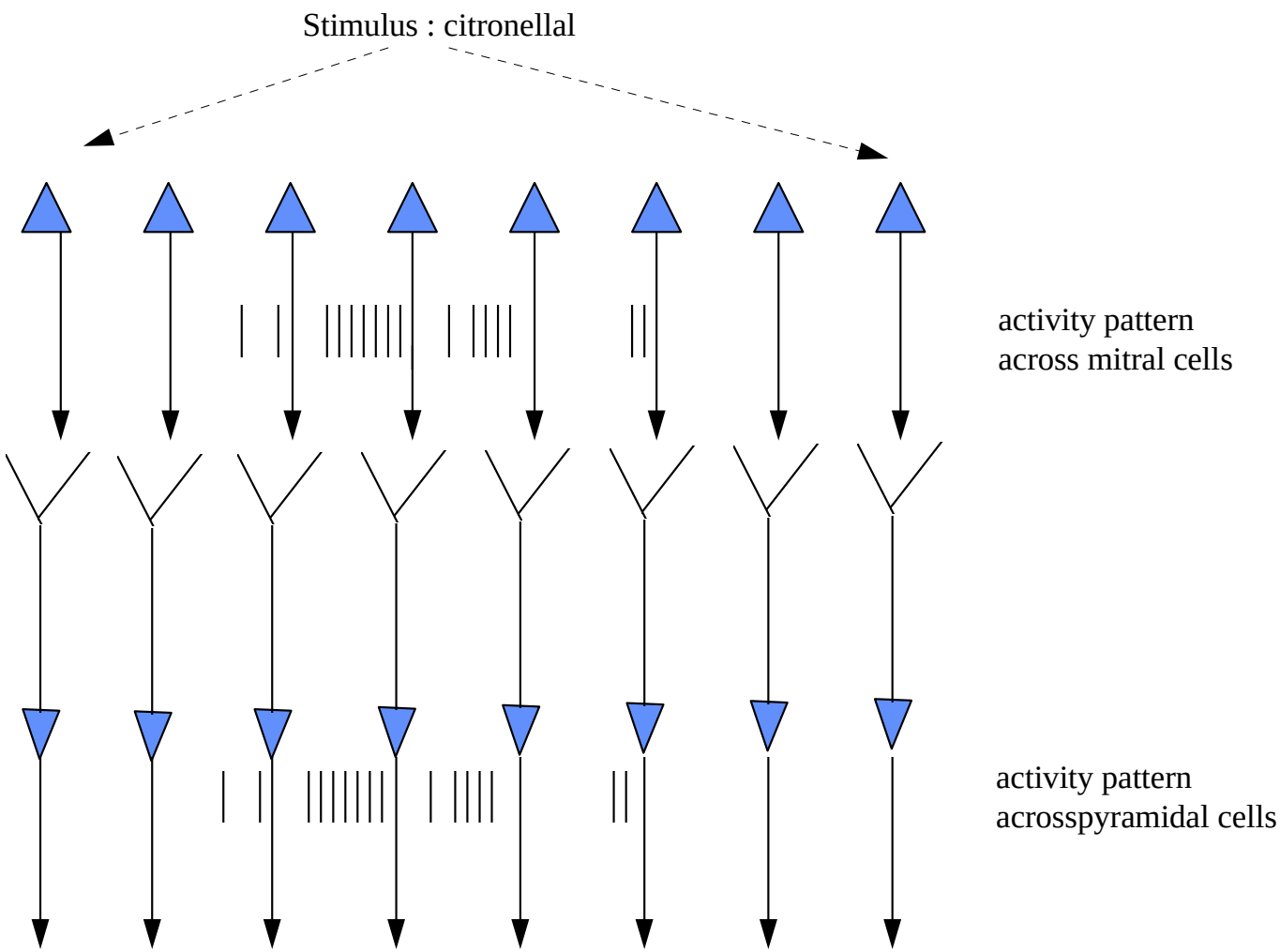
Haberly, L.B. Chem. Senses, 10: 219 -38 (1985)

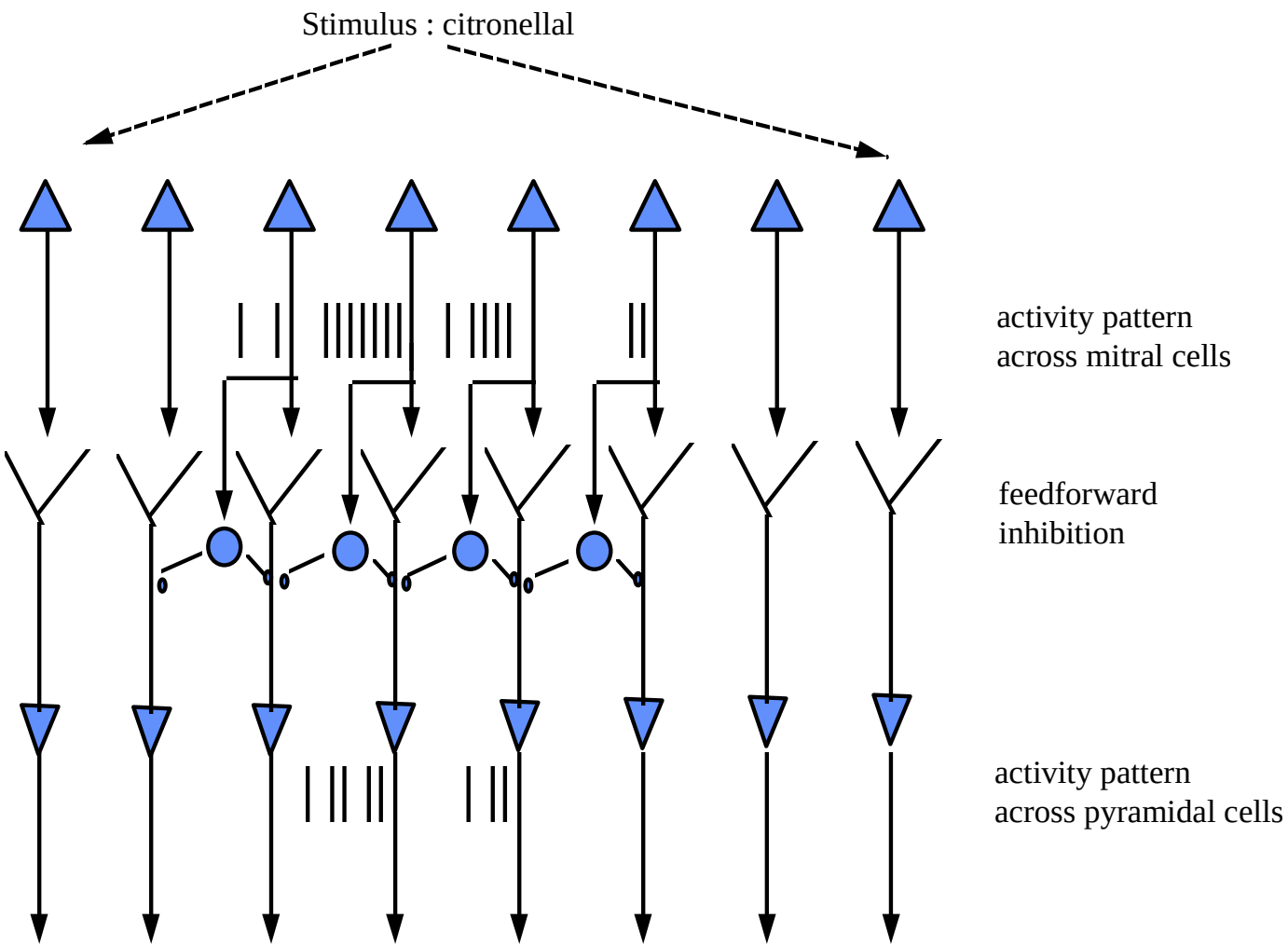
Neuromodulatory inputs
Other association fiber inputs

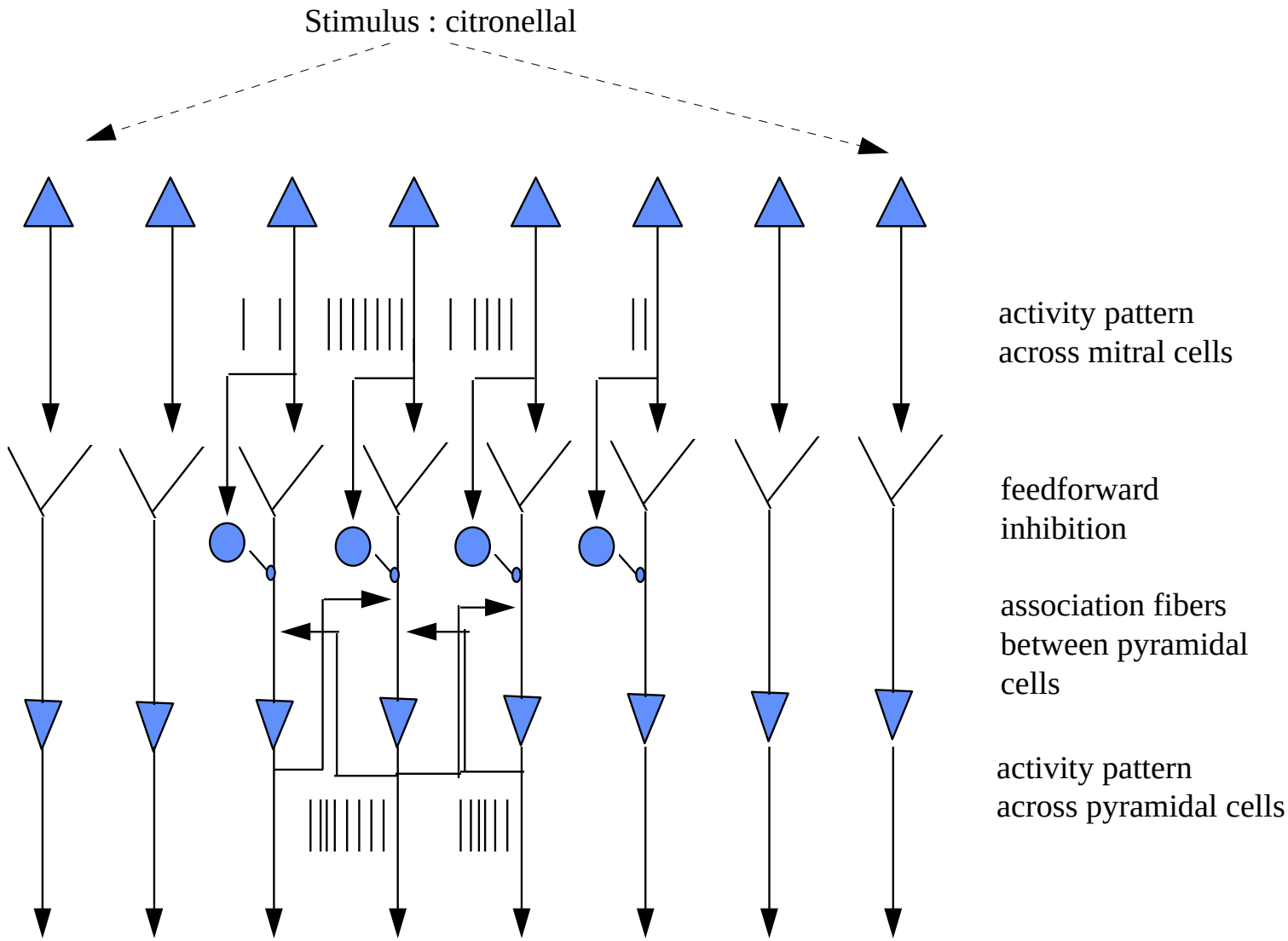

1
a




Layer II (cell bodies)
Layer Ib
Layer Ia

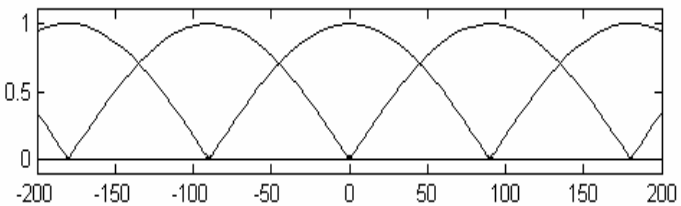

Stimulus : citronellal
activity pattern
across mitral cells
activity pattern
acrosspyramidal cells

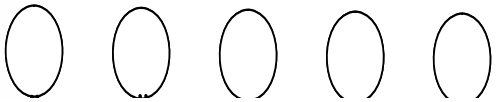

Stimulus : citronellal
activity pattern
across mitral cells
feedforward
inhibition
activity pattern
across pyramidal cells


Stimulus : citronellal
activity pattern
across mitral cells
feedforward
inhibition
association fibers
between pyramidal
cells
activity pattern
across pyramidal cells

$x_{sj} = \cos(\alpha\text{-offset}_j)$ when $\cos(\alpha\text{-offsetj}) >= \theta$
and
$X_{sj} = 0.0$ when $\cos(\alpha\text{-offset}_j) < \theta$

where offset_j = 0, -30, -60, -90 and -120.

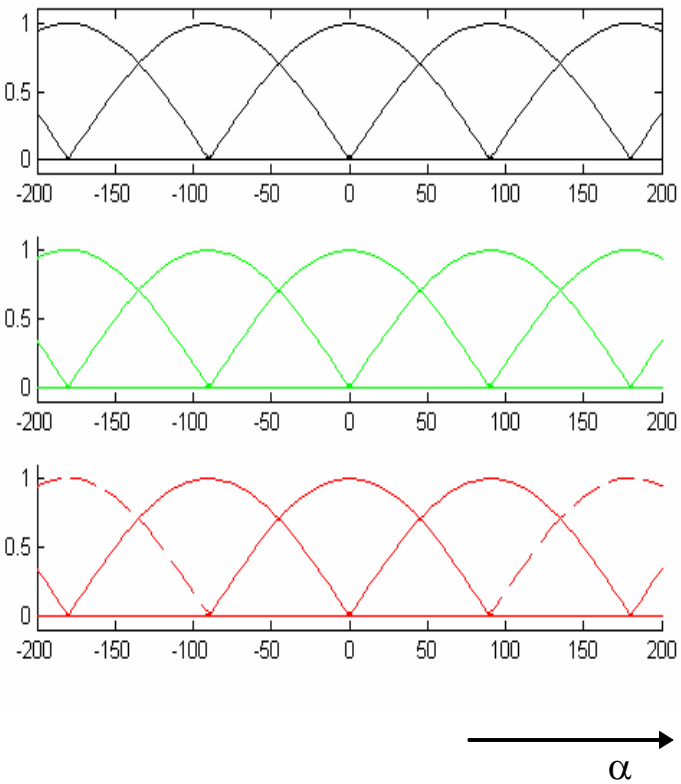


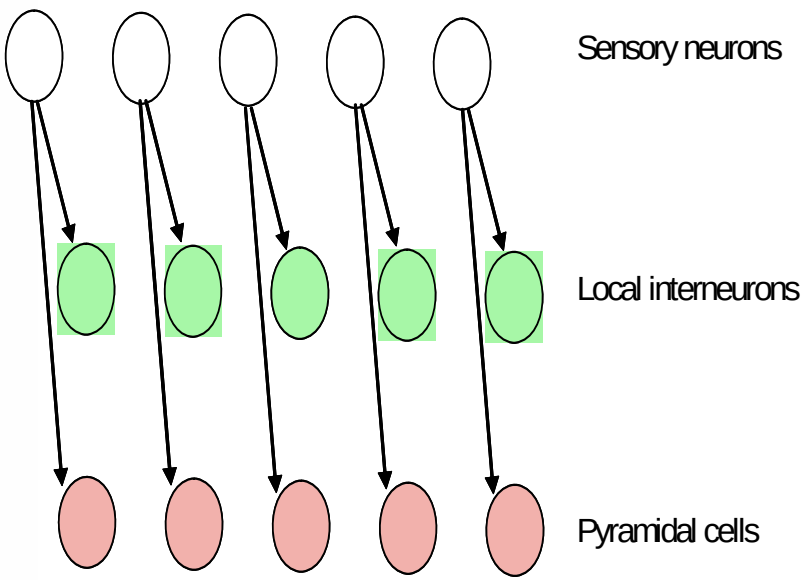


Sensory neurons

$I_{pj} = x_{sj}$; $I_{ij} = x_{sj}$

$x_{pj} = I_{pj}$ and $x_{ij} = I_{ij}$ if $I > \theta$ and xpj = 0 and $x_{ij} = 0$ if $I < \theta$.



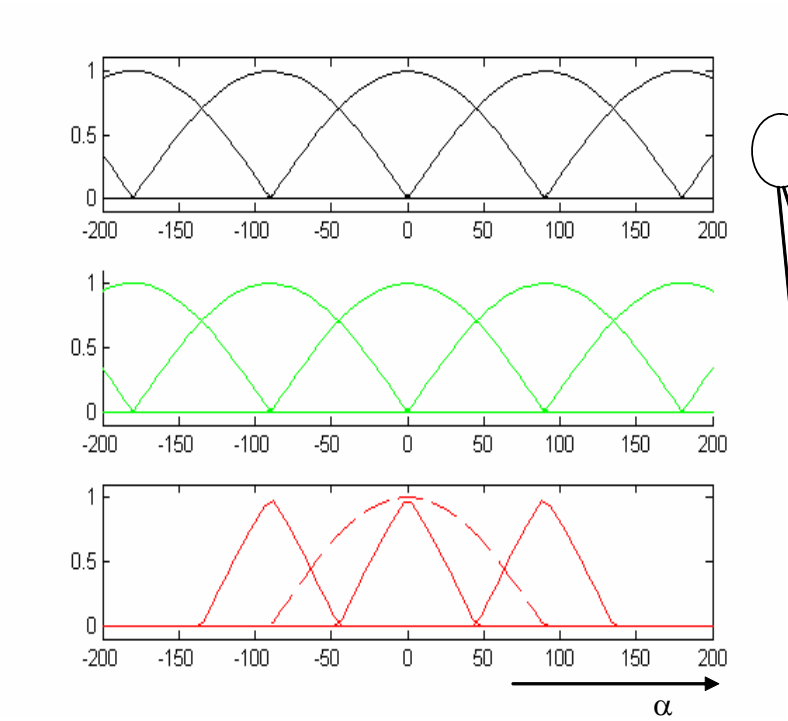


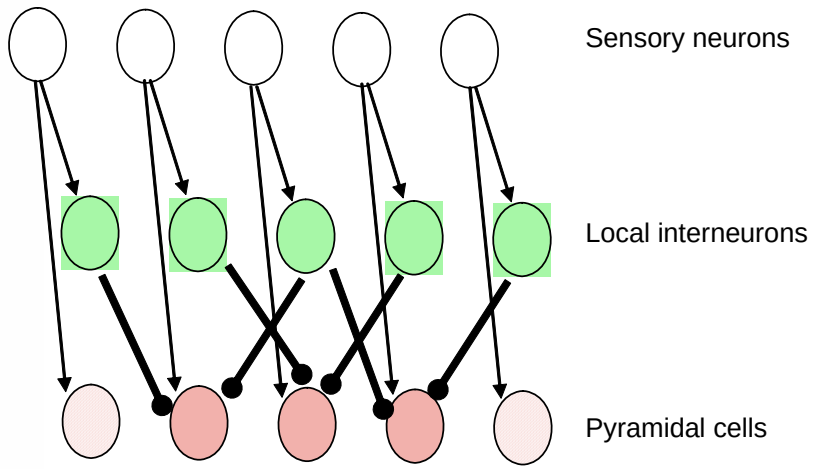
Exercise. Lets work through an example[1] to get used to writing and reading equations.
1) We will start by constructing a network of neurons in motor cortex receiving inputs from presynaptic neurons s with the following tuning curves as a function of the angle α of arm movement and α threshold θ: $x_{sj} = F(\cos(\alpha - \text{offset}_i), \theta)$ where offset_j = 0, -30, -60, -90 and -120.

Now, we will create 10 postsynaptic neurons (5 excitatory pyramidal cells and 5 inhibitory local interneurons), each receiving presynaptic neurons, assuming all synaptic weights w = 1:
$I_{pj} = x_{sj}$; $I_{inj} = x_{sj}$ with I_{pj} being the input to pyramidal cell j and I_{ij} the input to interneuron j. These are linear threshold neurons with continuous output for now, so $x_{pj} = I_{pj}$ and $x_{ij} = I_{inj}$ if $I > \theta$ and $x = 0$ and $x_{ij} = 0$ if $I < \theta$. In vector notation:

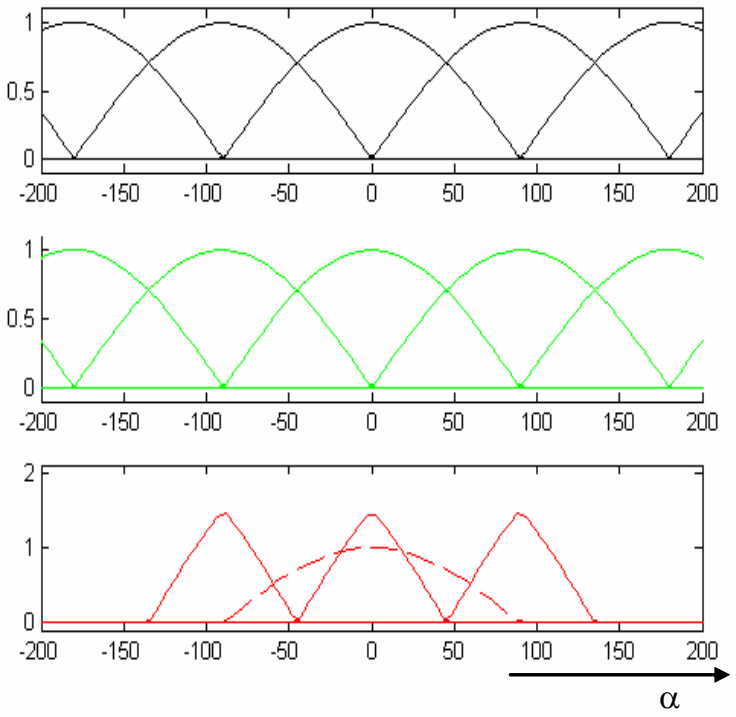
[1] Notations: I: input to a neuron; x: output from a neuron; j: neuron index; θ: threshold; α: movement angle; s: sensory neuron; p: pyramidal neuron; in: interneuron.

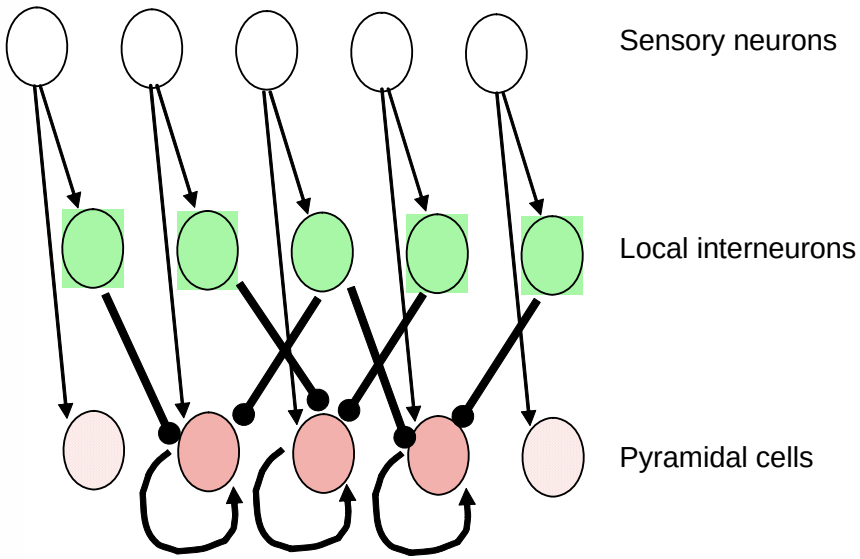
$$I_{pj} = x_{sj} - x_{i(j-1)} - x_{i(j+1)}$$



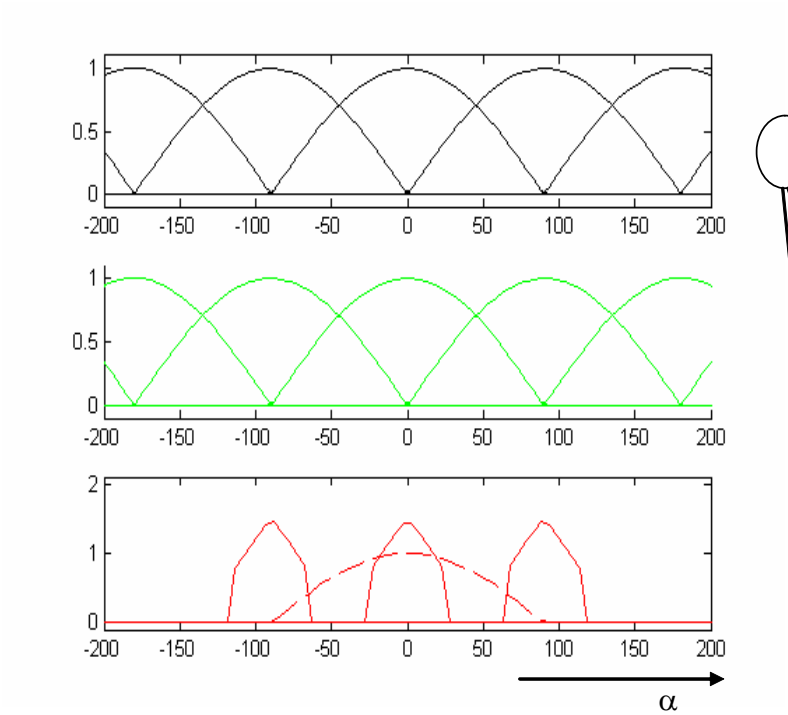


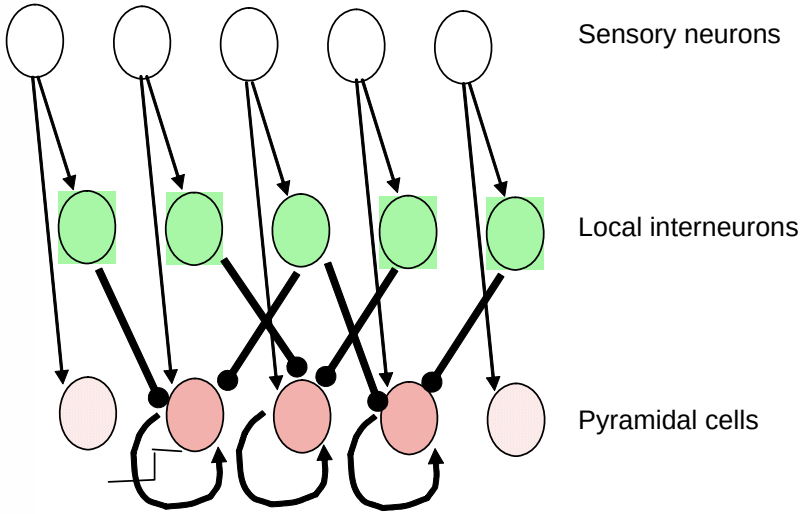
$$I_{pj} = x_{sj} - x_{i(j-1)} - x_{i(j+1)} + 0.5 * x_{pj}$$

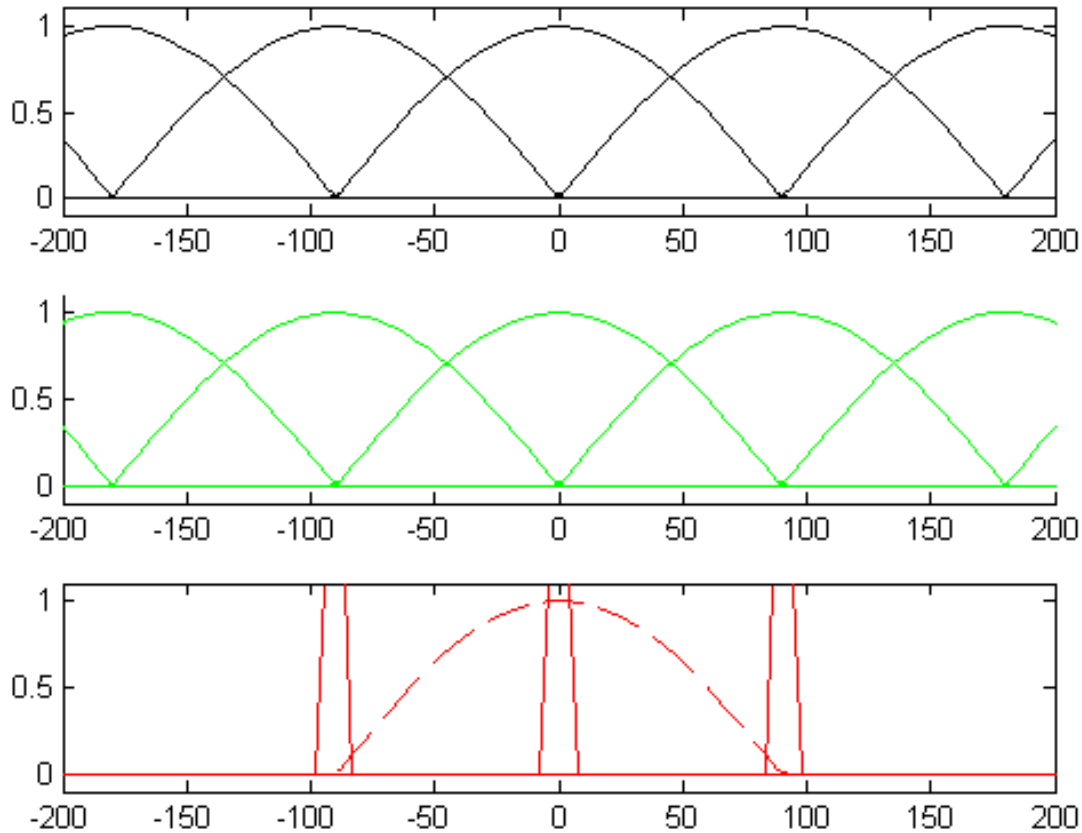




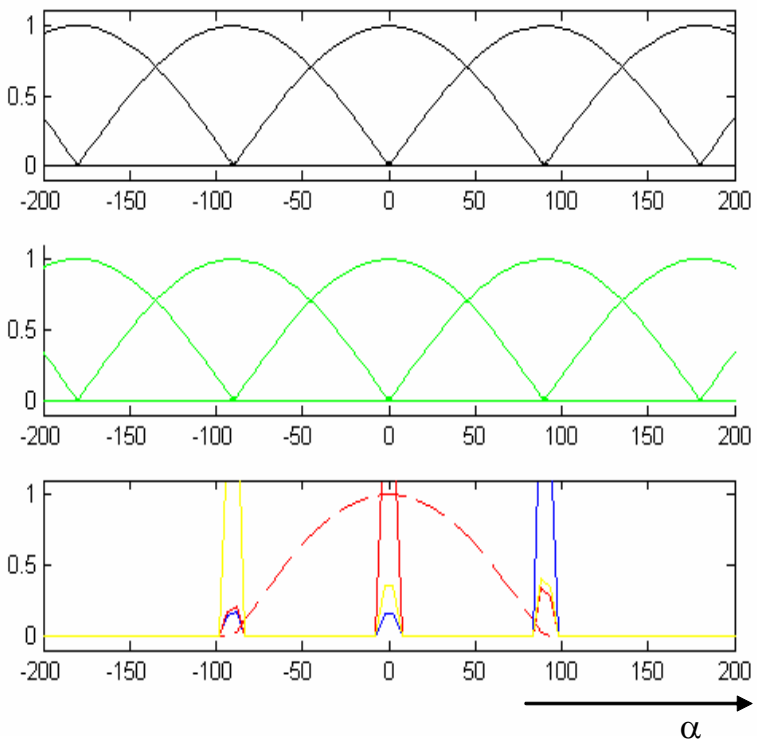
$$I_{pj} = x_{sj} - x_{i(j-1)} - x_{i(j+1)} + 0.5*F(I_{pj}, \Theta^2)$$

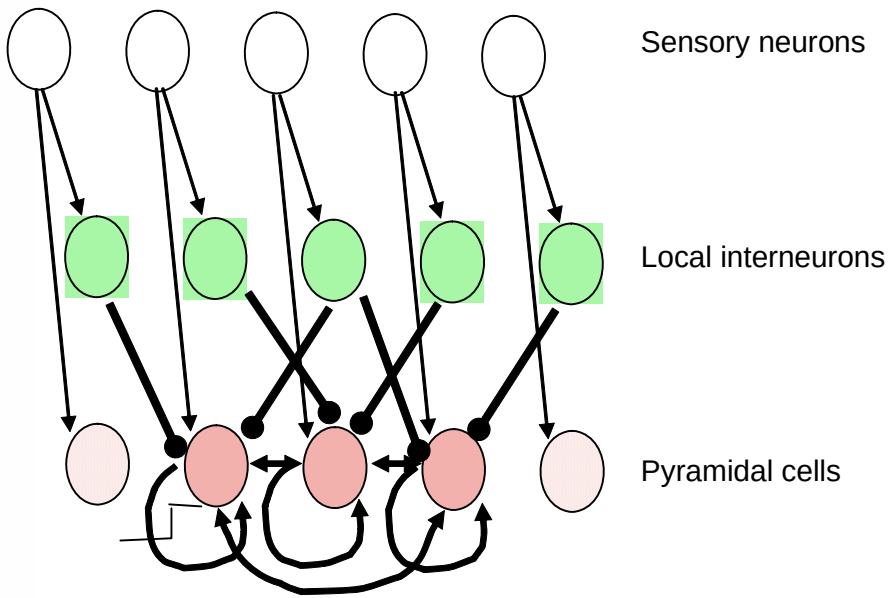




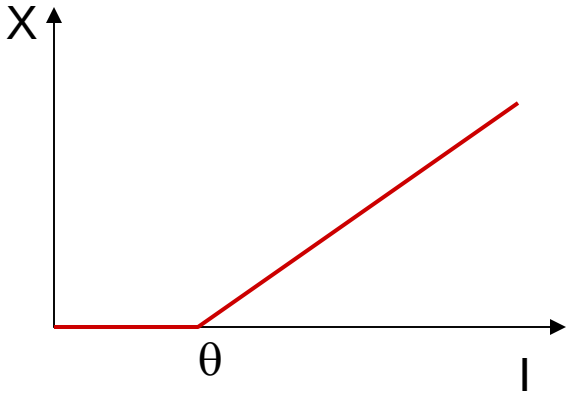

1
0.5
0
-200
-150
-100
-50
0
50
100
150
200

$$I_{pj} = x_{sj} - x_{i(j-1)} - x_{i(j+1)} + 0.5*F(I_{pj}, \Theta^2) + SUM_{k \neq j} (w_{jk}*x_{pk})$$





$$\text{prob}\ (x_{jp} = 1.0) = F\ (I_{jp}, \theta)$$

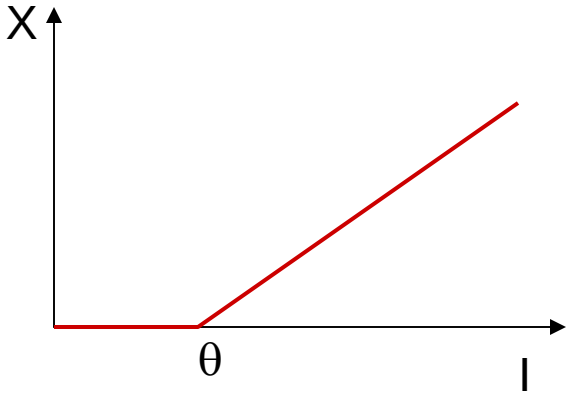


$X=F(I, \theta)$ linear threshold function

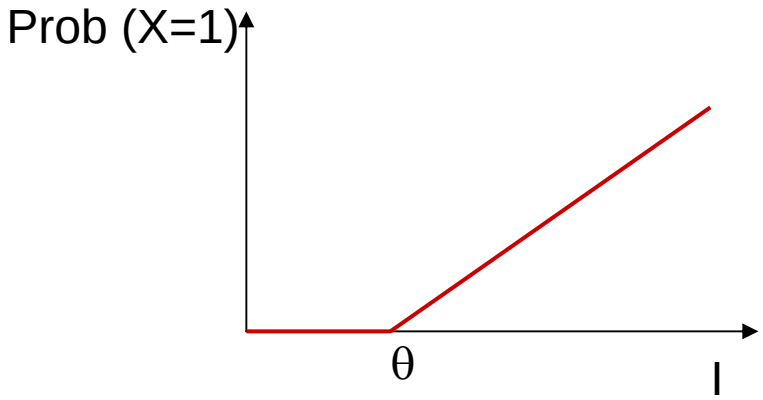
$X = 0$ if $I <= \theta$

$X = I$ if $I > \theta$

$$\text{prob}\ (x_{jp} = 1.0) = F\ (I_{jp}, \theta)$$

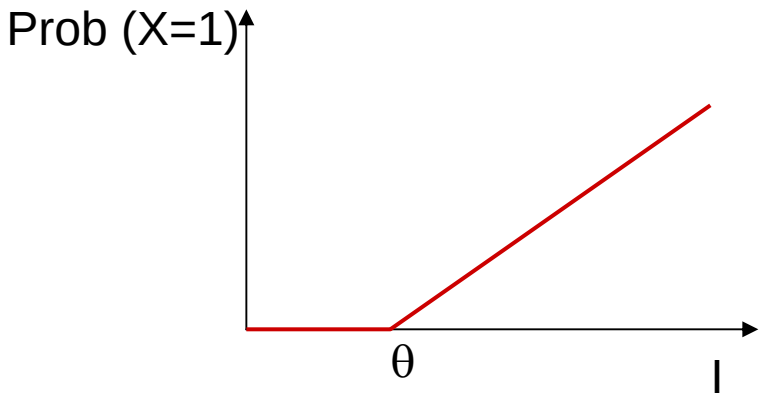


X=F(I, θ) linear threshold function
X = 0 if I <= θ
X = I if I > θ



Prob (x=1) = 0 if I <= θ
Prob (x=1) = I if I > θ

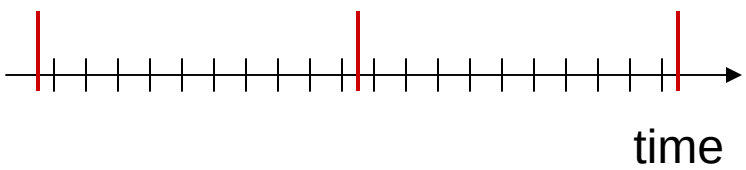
$$\text{prob}\ (x_{jp} = 1.0) = F\ (I_{jp}, \theta)$$



Prob (x=1) = 0 if I <= θ
Prob (x=1) = I if I > θ

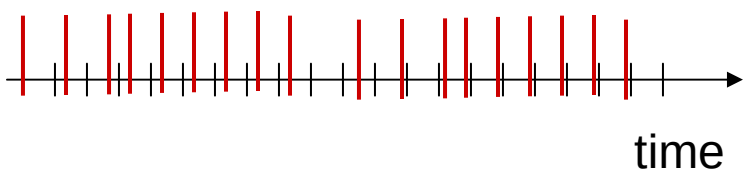
Θ = 0.0; I = 0.1 -> p = 0.1

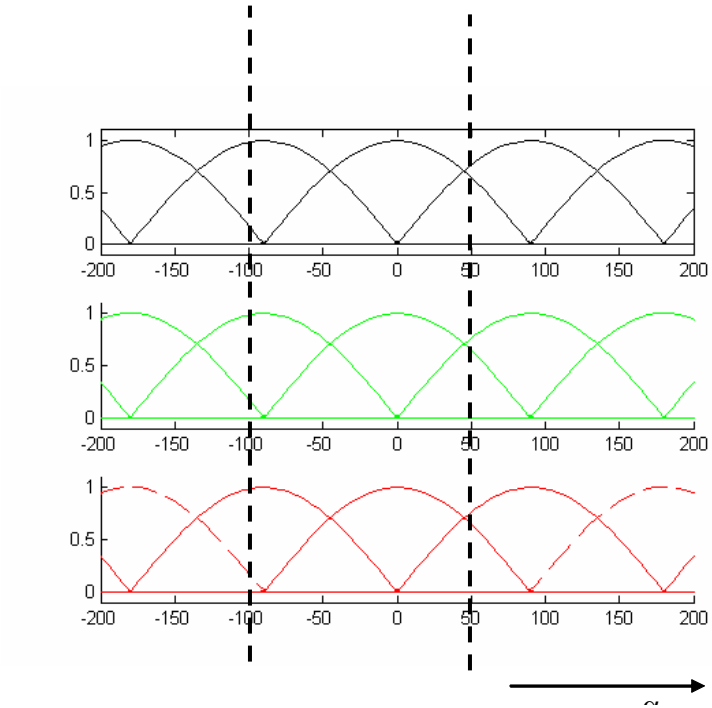
On average, one spike every 10 time steps

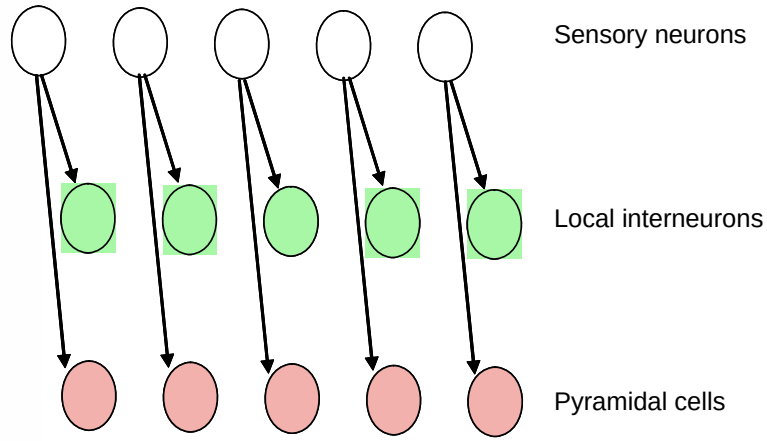


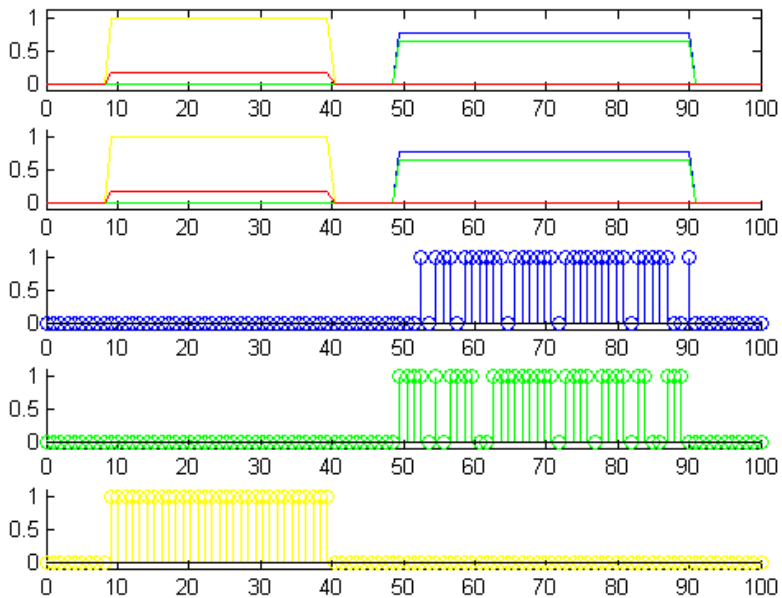
Θ = 0.0; I = 0.9 -> p = 0.9

On average, nine spikes every 10 time steps

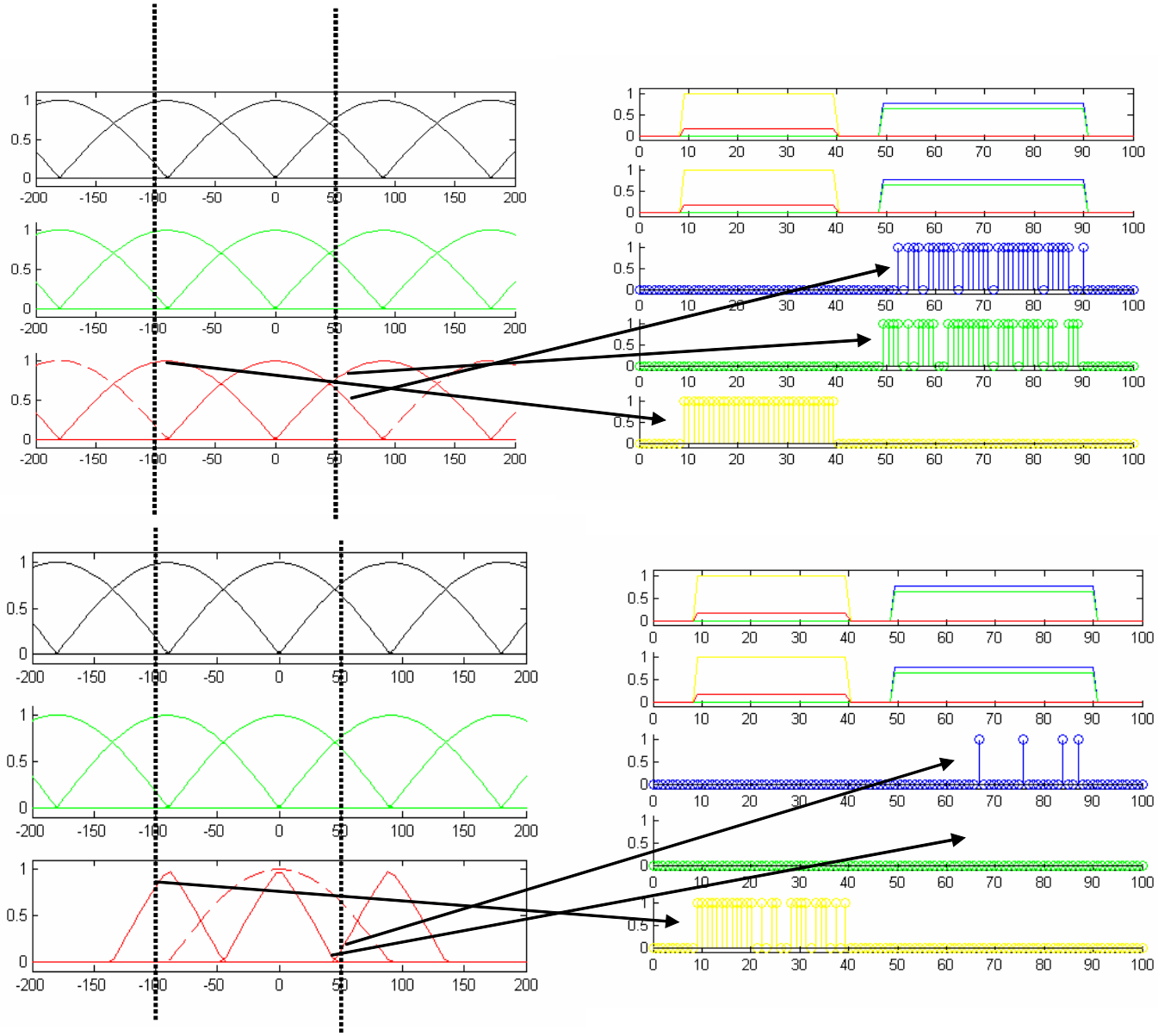








$\alpha = -100$ $\alpha = 50$


1
0.5
0
-200 -150 -100 -50 0 50 100 150 200
0 10 20 30 40 50 60 70 80 90 100