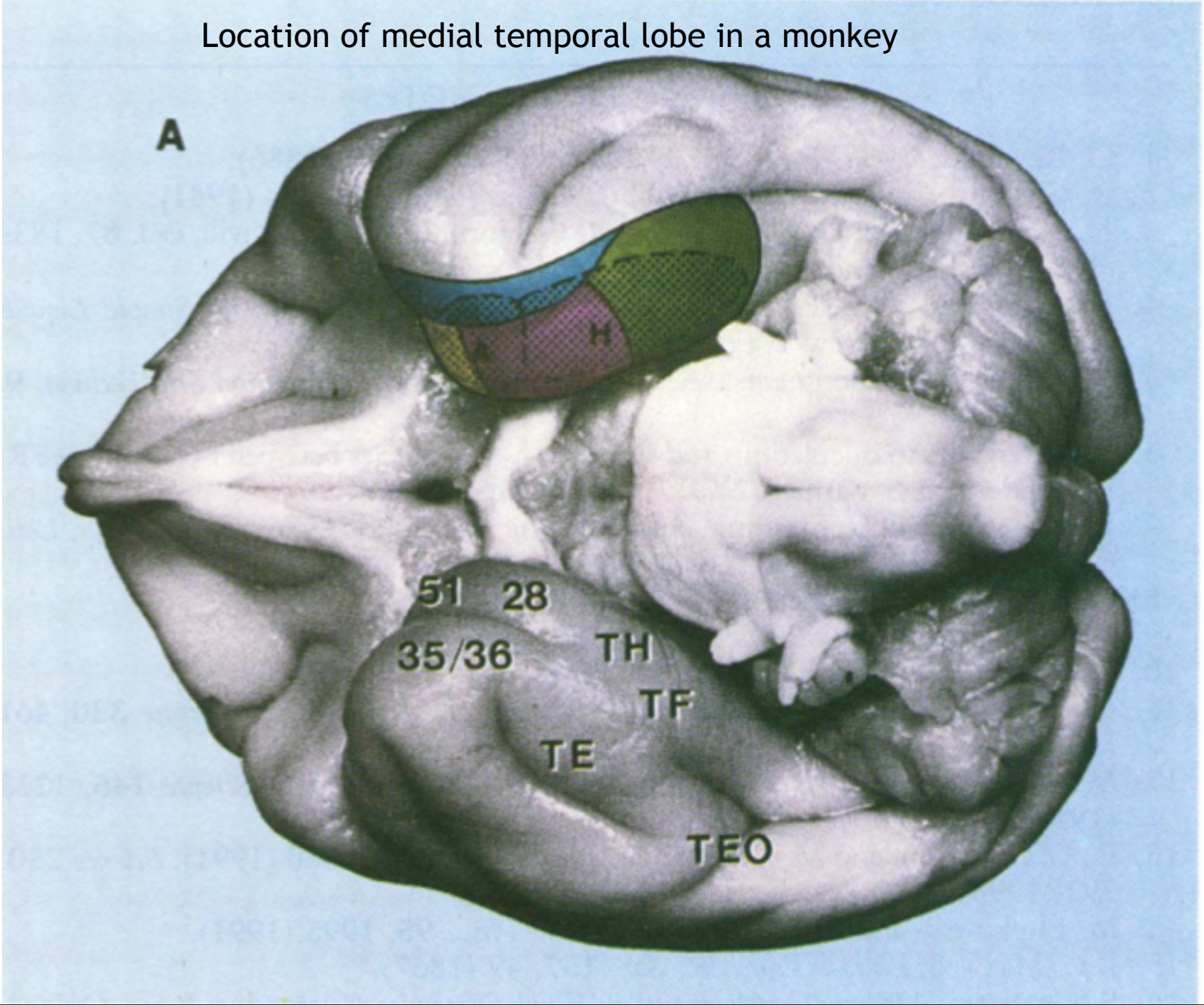
342 Computational Brain

Neurons

Location of medial temporal lobe in a monkey

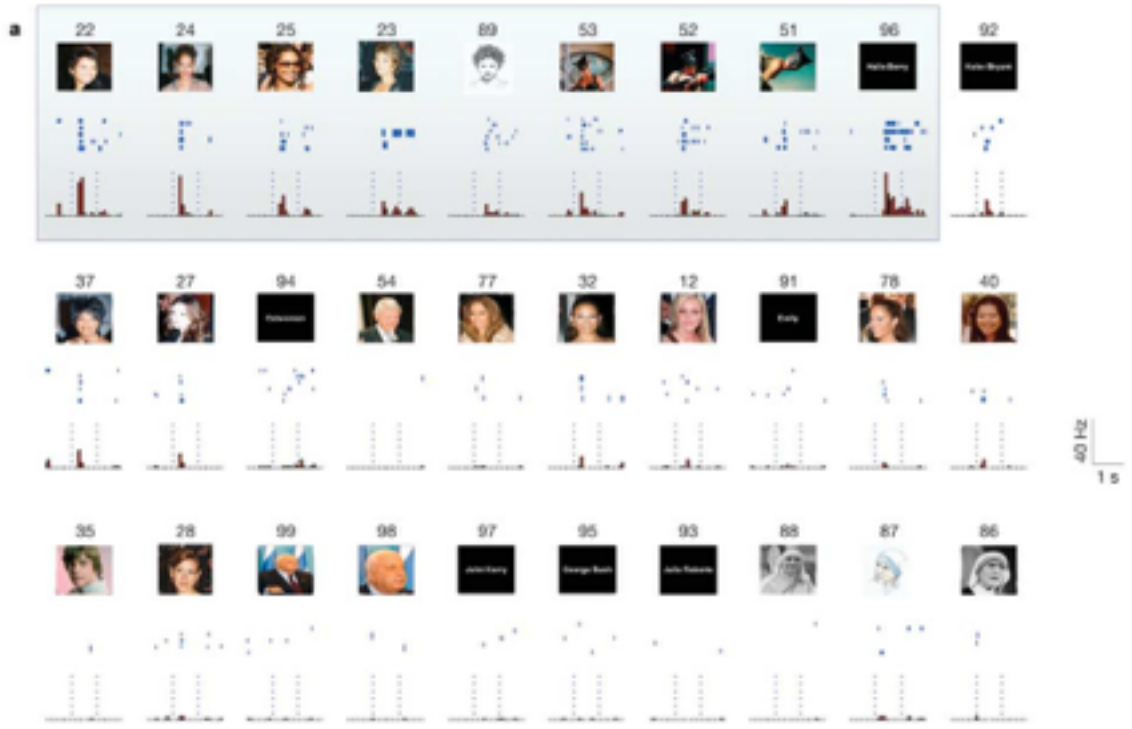


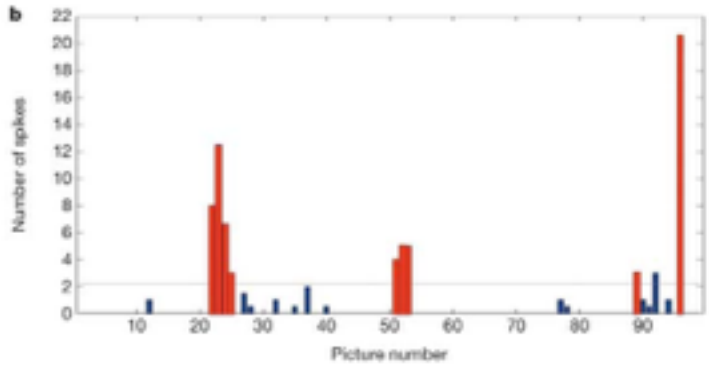
Electrode recordings
show specialized responses.

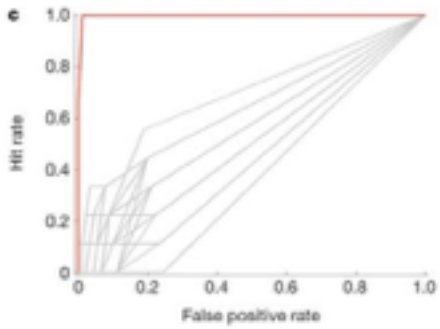
How could you construct
such a neuron?

Would you run out of synapses?

Could these neurons respond
to other things?
Why didn't they?

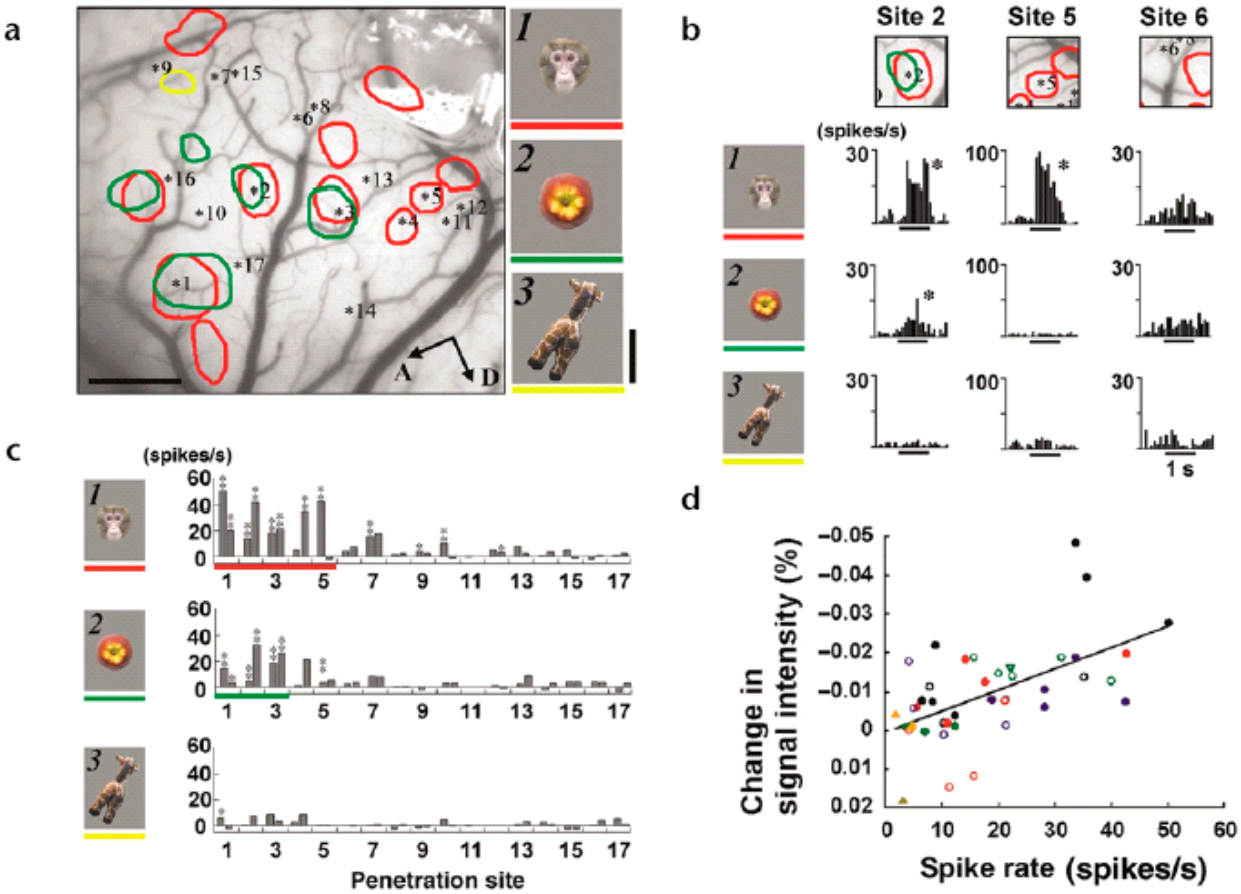




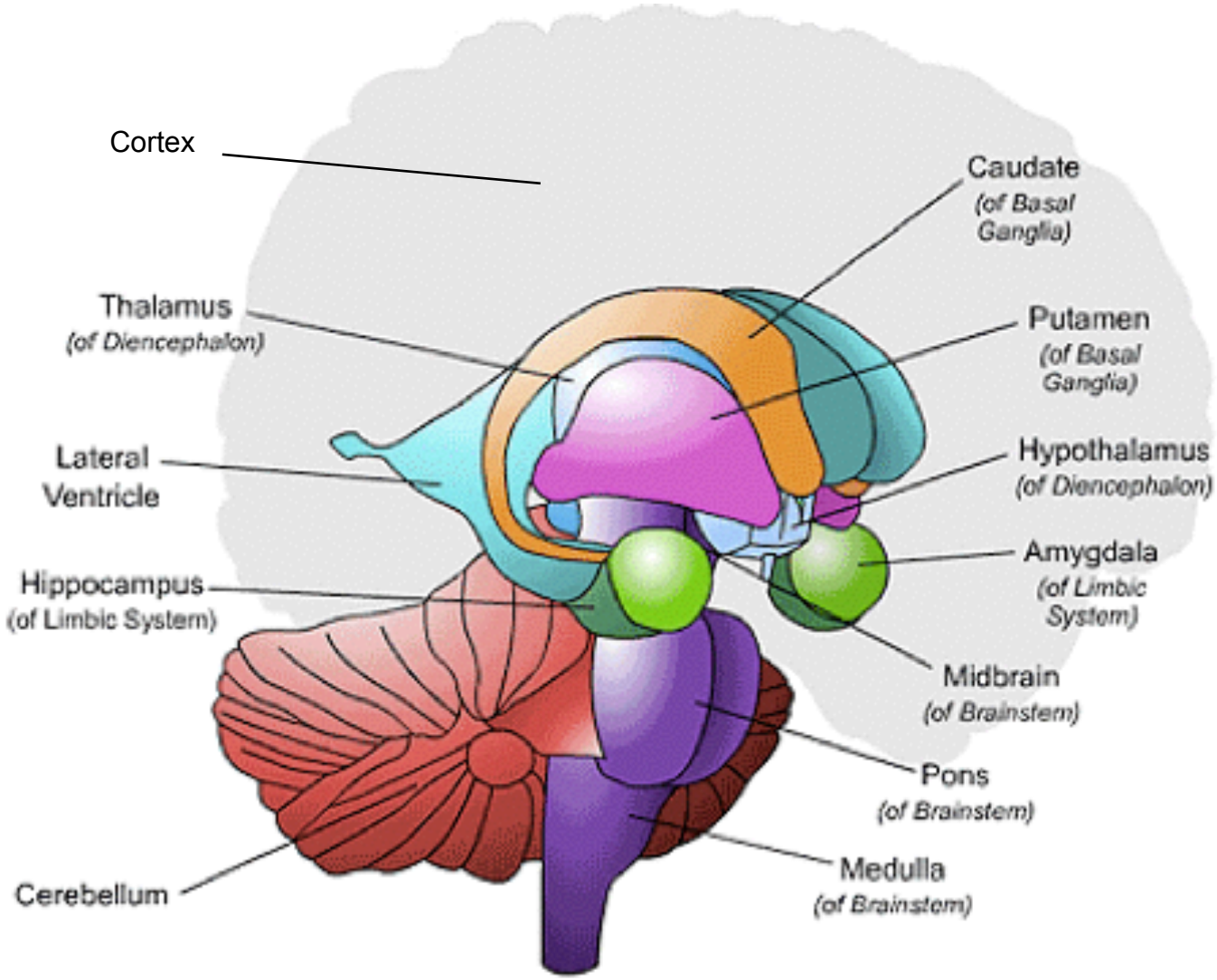


In a an area of cortex just lateral to MTL the coding of stimuli looks very distributed.

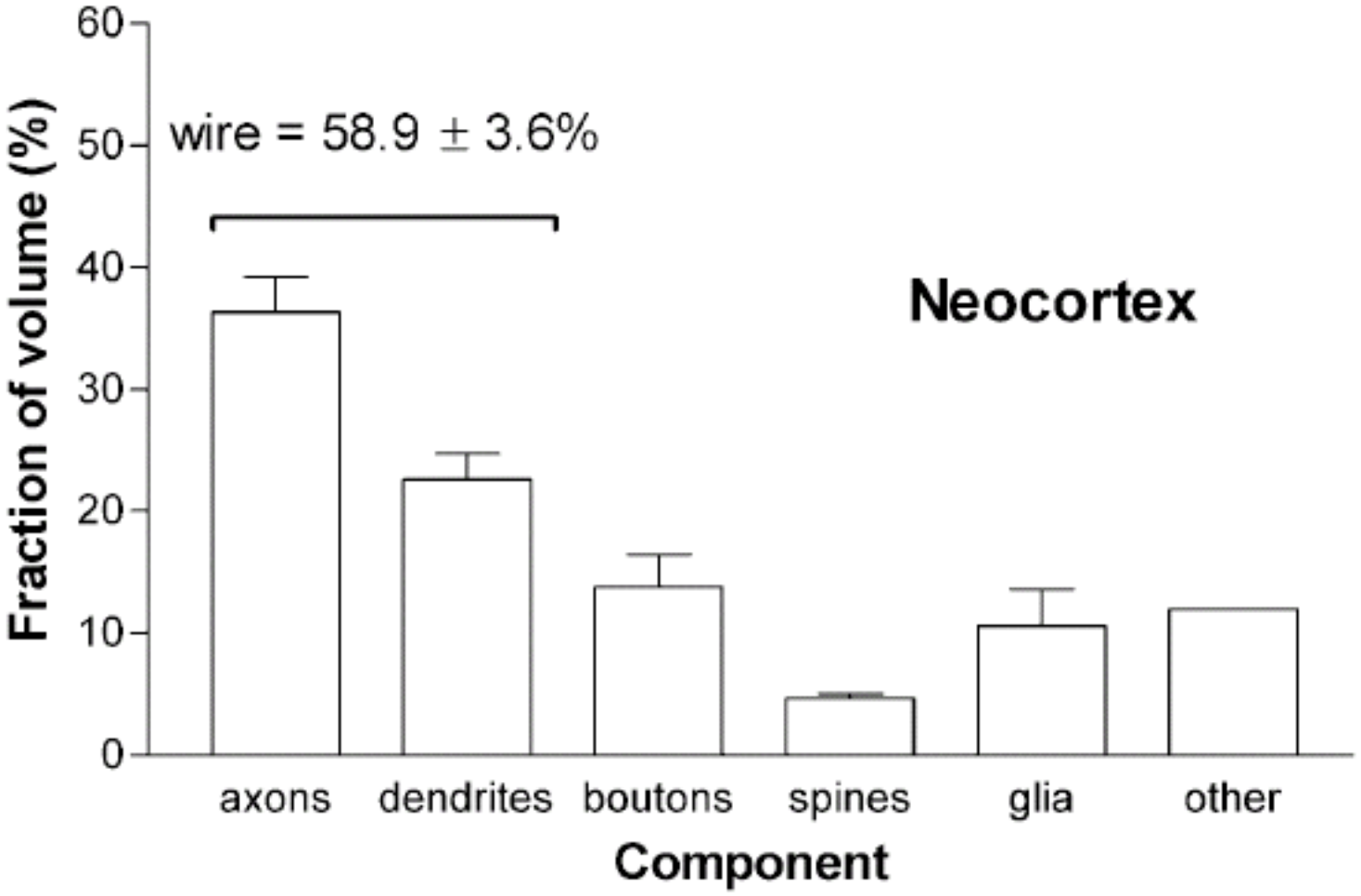
See text Ch4 for details and reference



Major Brain Components



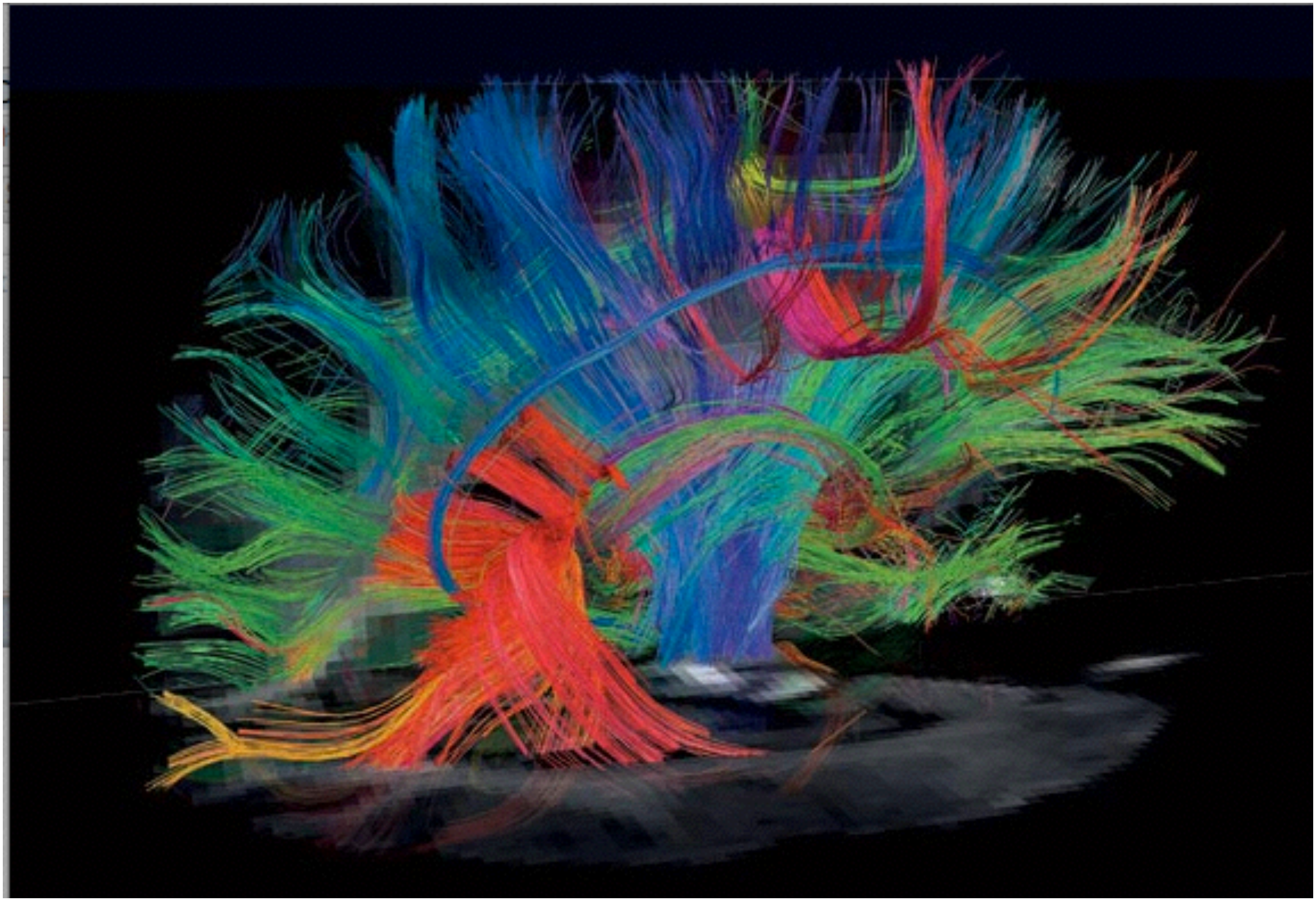
Most of the Neocortex (forebrain) is ‘wire’

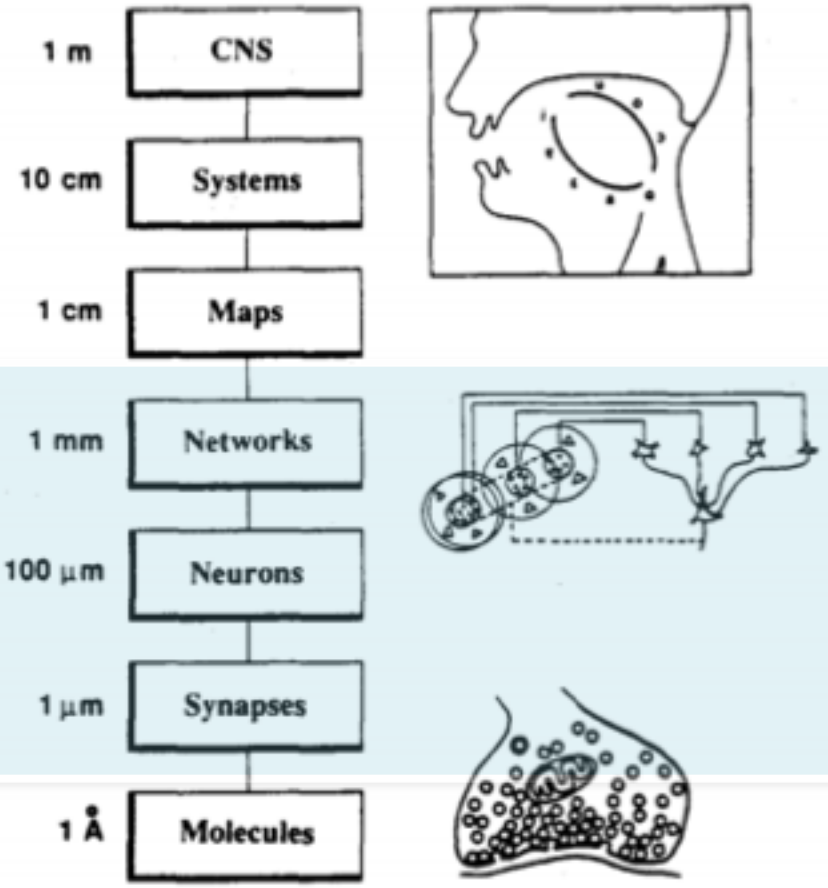


Computation with slow circuitry

Feature	**Value**
Number of neurons	10^{11}
Ave. no. connections per neuron	10^{4}
Total connections	10^{15}
Speed of communication	10 meters/sec
Average signaling rate	10 voltage spikes/sec
Sum of all axonal lengths	10^{6} km

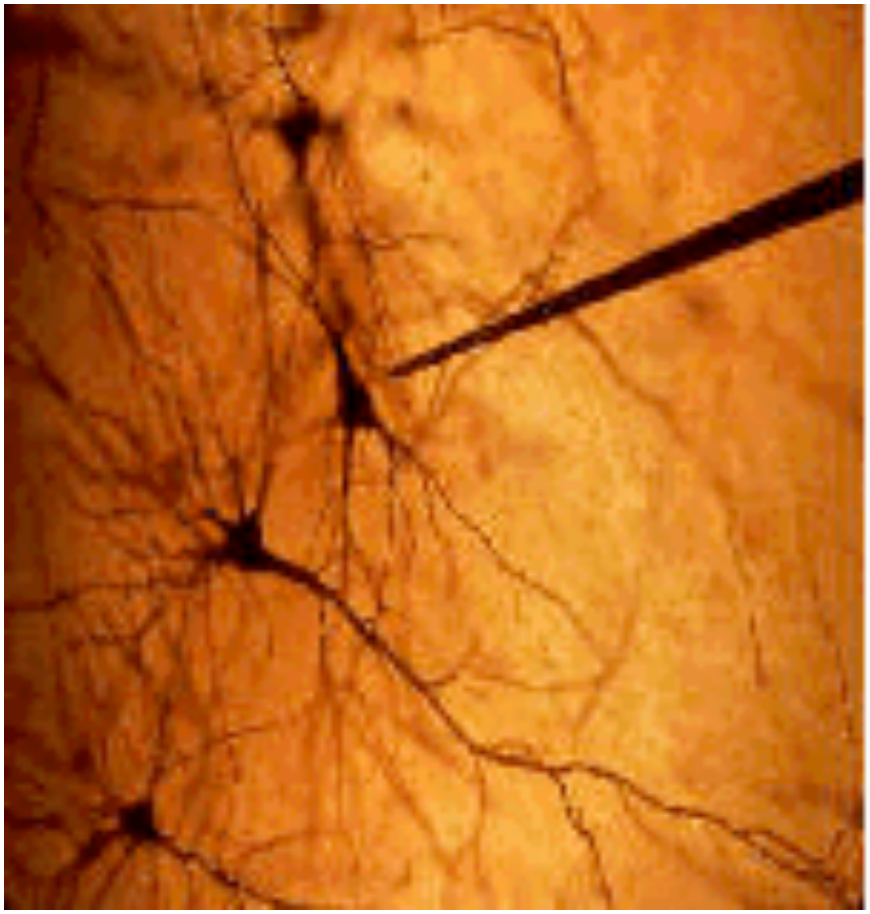
Diffusion tensor imaging of the main cortical `buses'

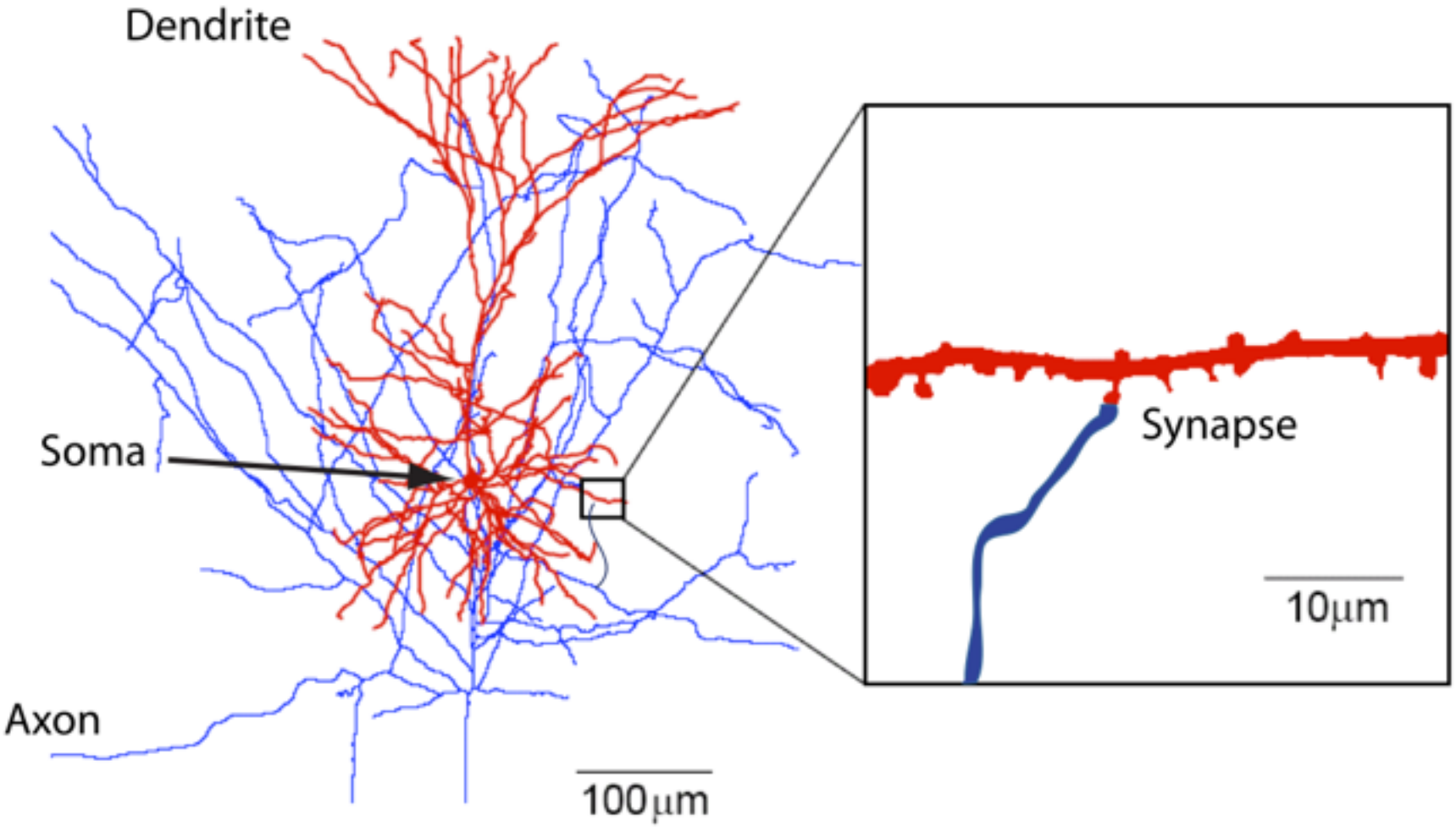


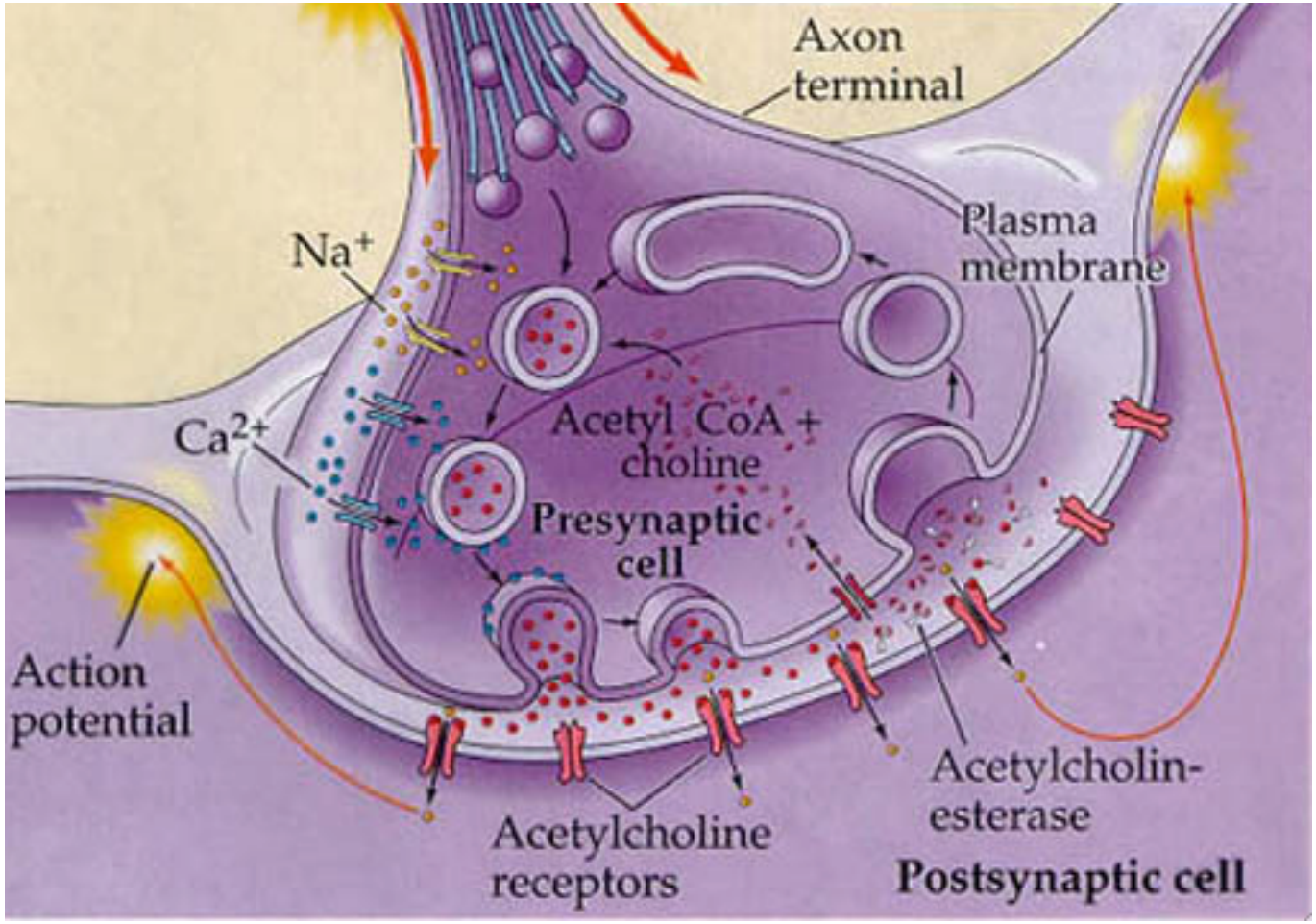


Level	Function
CNS	Overall brain function
Sub-systems	Behavior sub-functions
Maps	Large-scale collections of circuits
Circuits	Collections of neurons organized with a specific function
Neuron	Basic long-range signaling unit
Synapse	Charge regulation in a neuron
Molecules	modulation of function

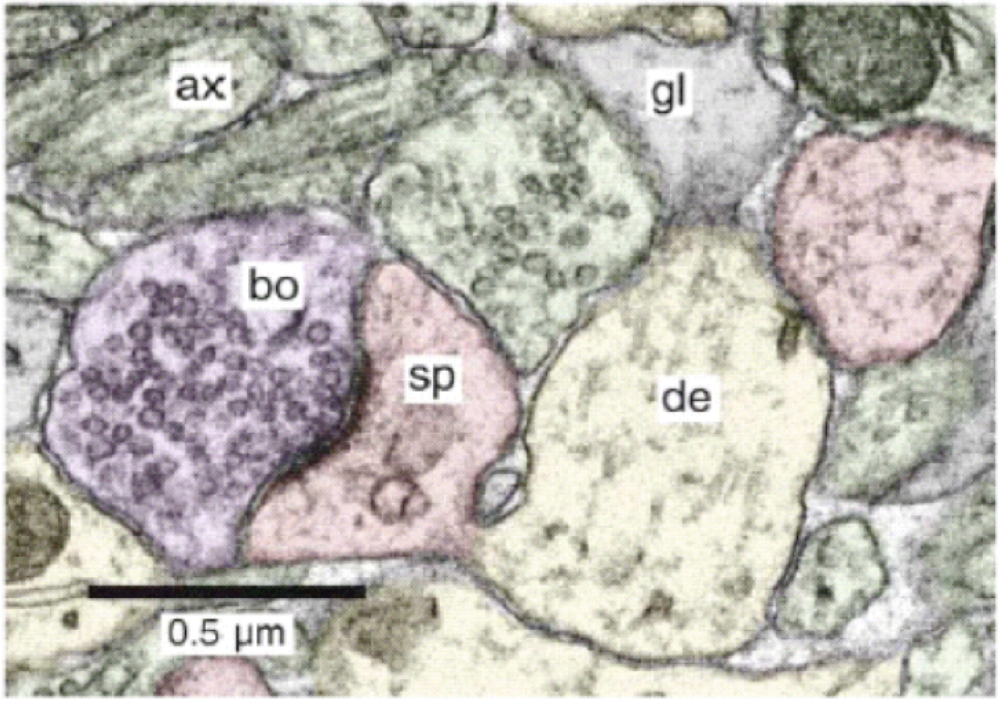
Recording electrode next to the soma of a Golgi-stained neuron




Dendrite
Soma
Axon
100 μm
Synapse
10μm


Axon terminal
Plasma membrane
Na^+
Ca^{2+}
Acetyl CoA + choline
Presynaptic cell
Action potential
Acetylcholin-esterase
Acetylcholine receptors
Postsynaptic cell

High resolution electron micrograph



ax = axon

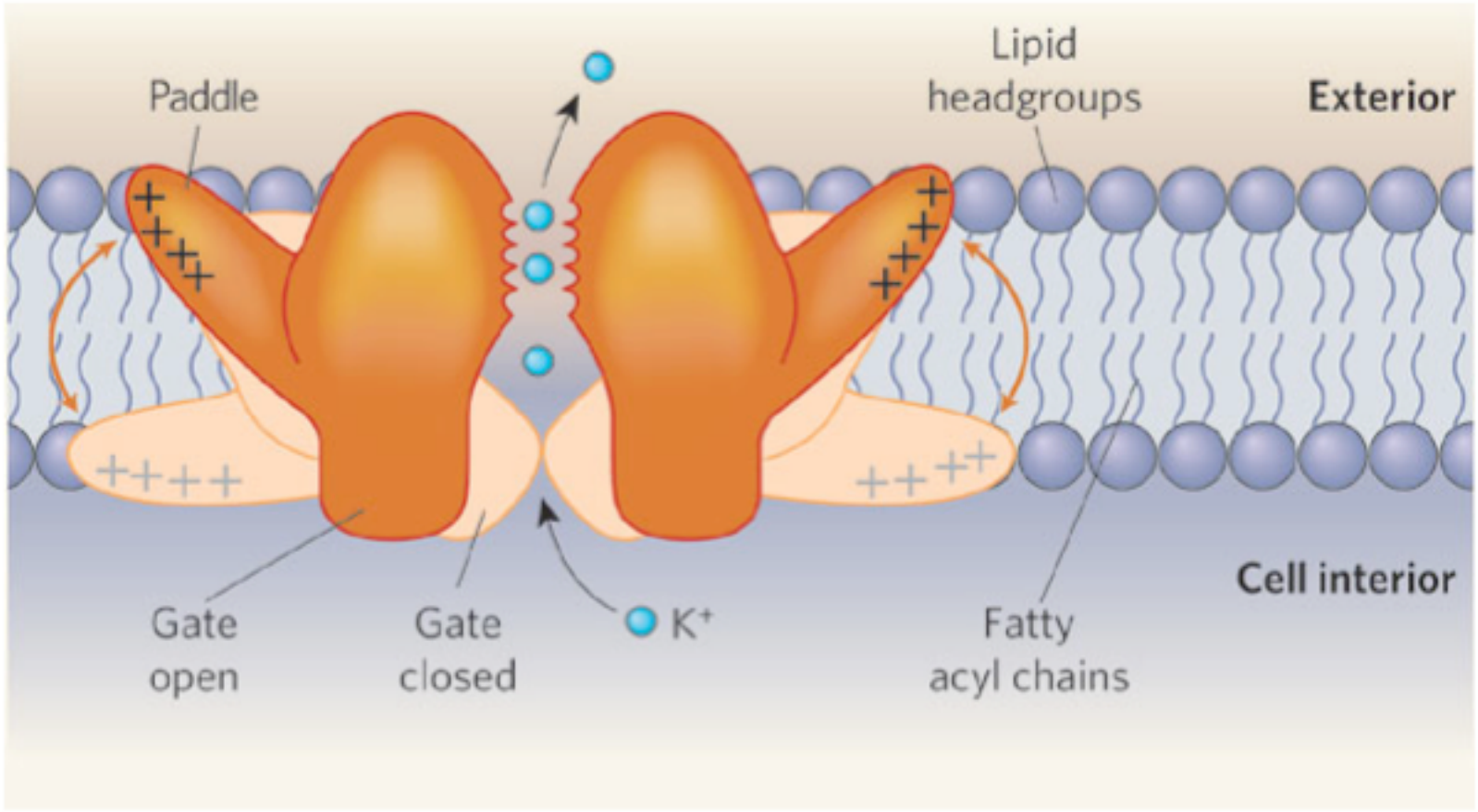
gl = glial cell

bo = buton

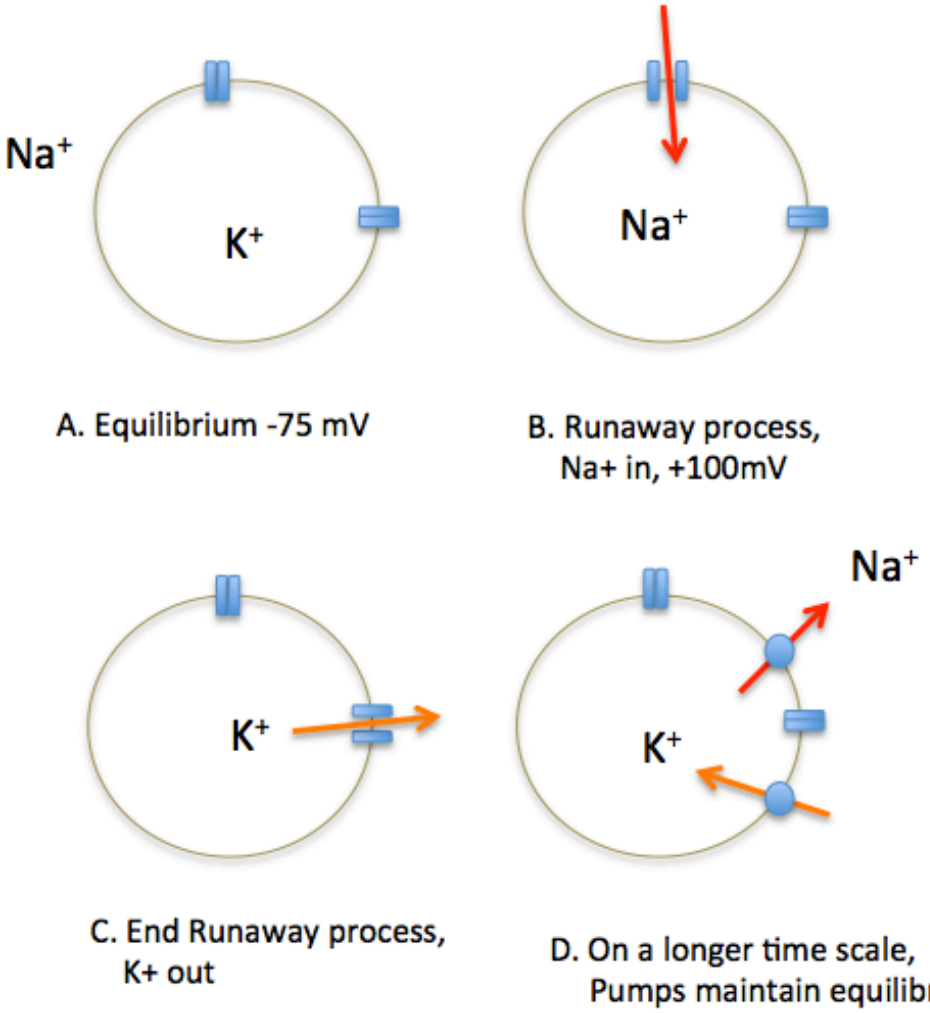
sp = spine

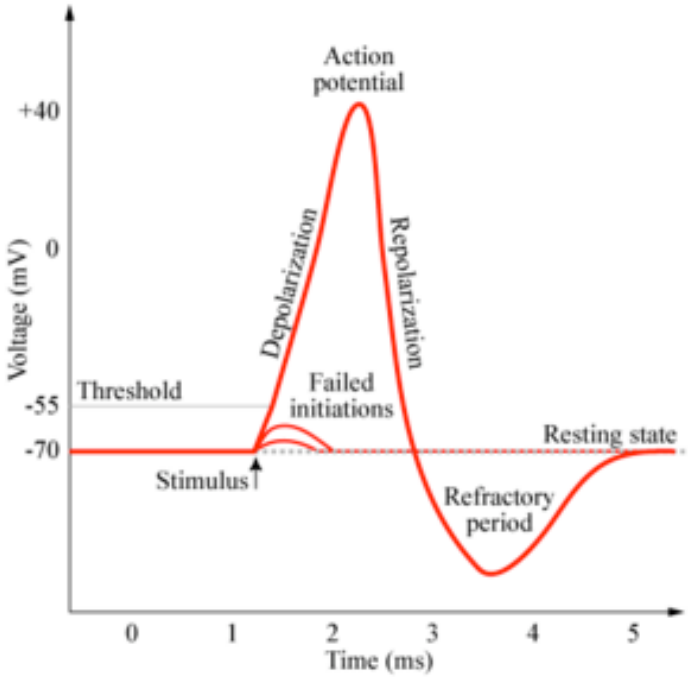
de = dendrite

Schematic of a voltage-gated potassium channel

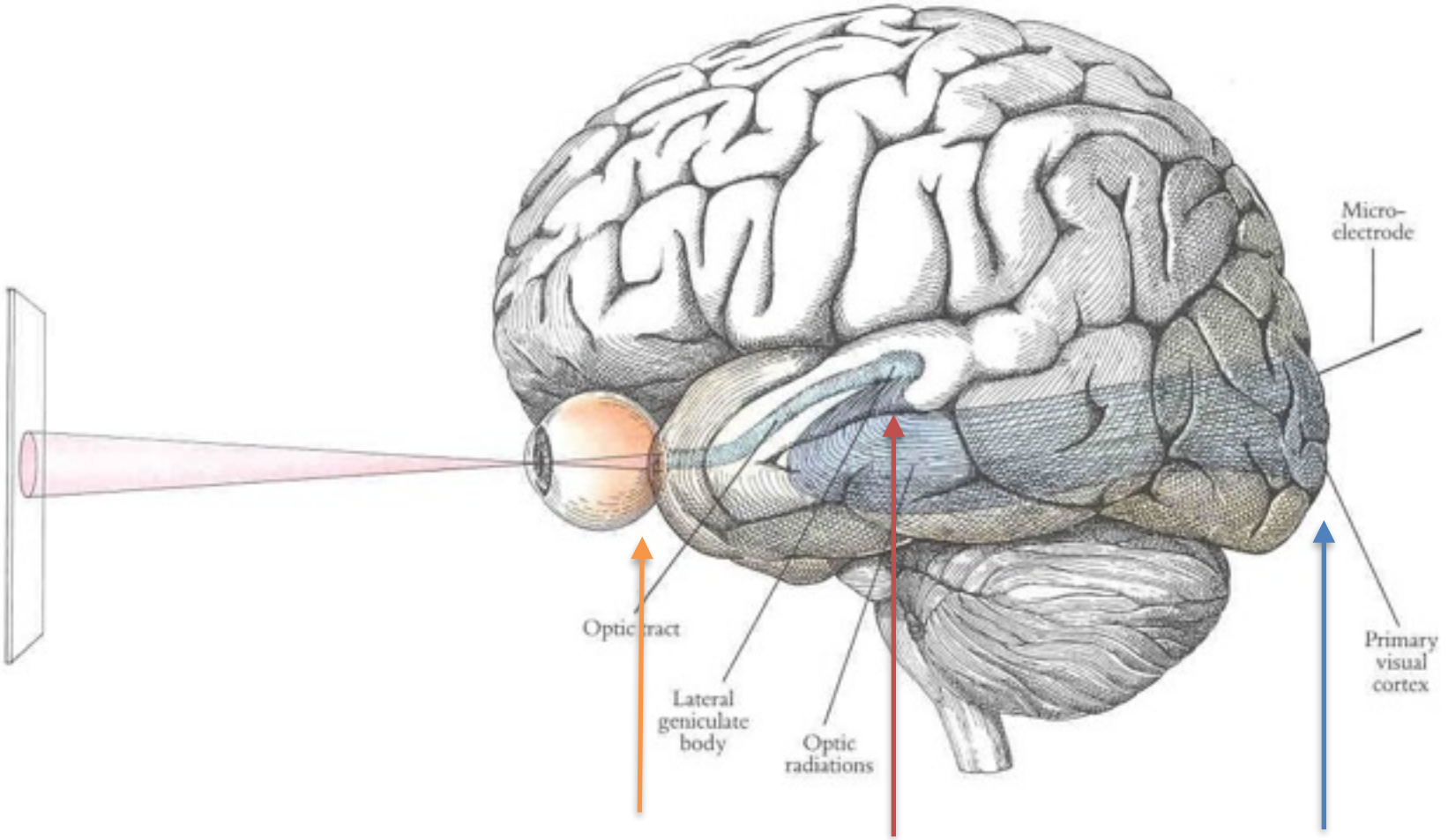


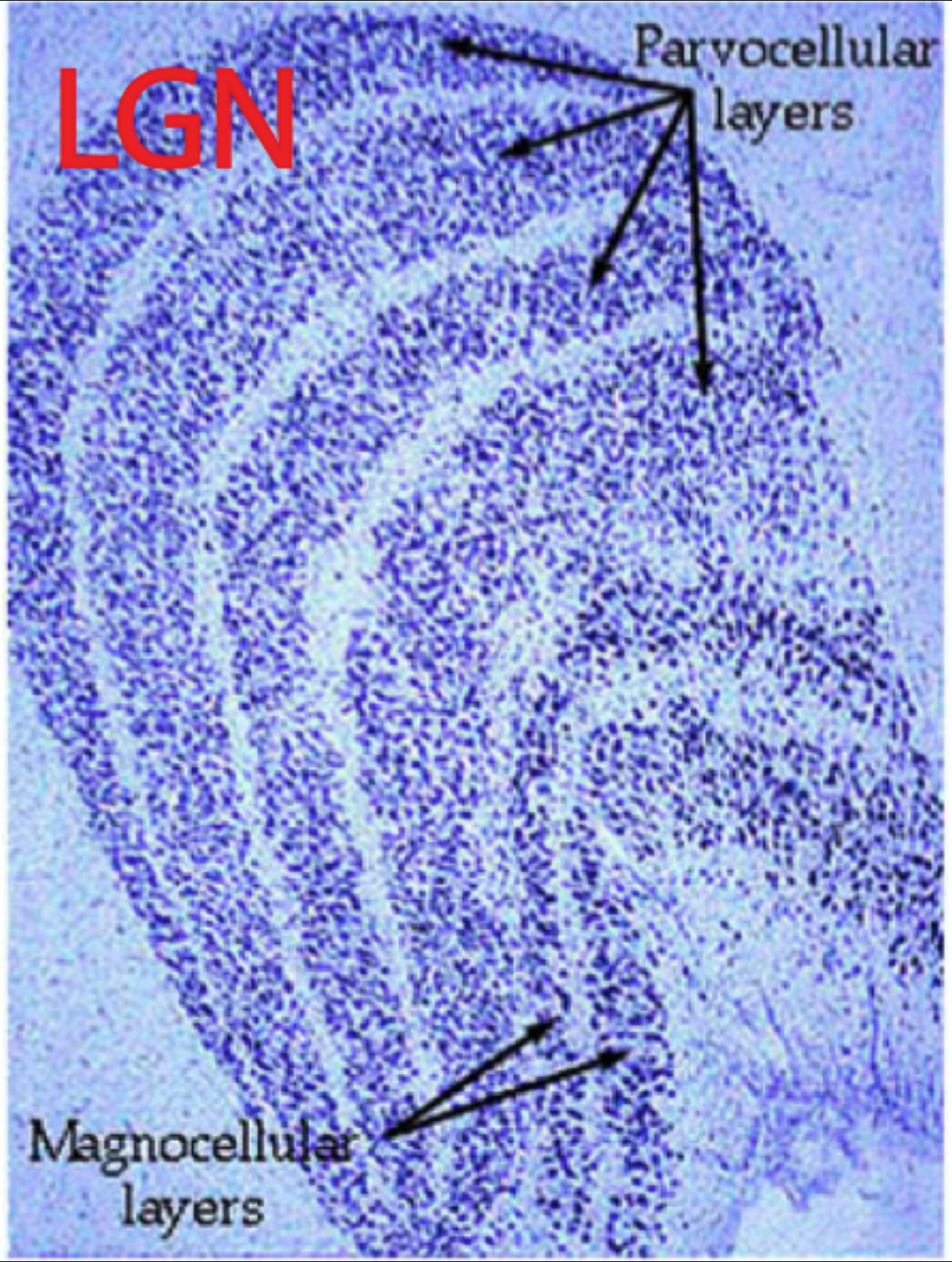
Spike generation process for a neuron





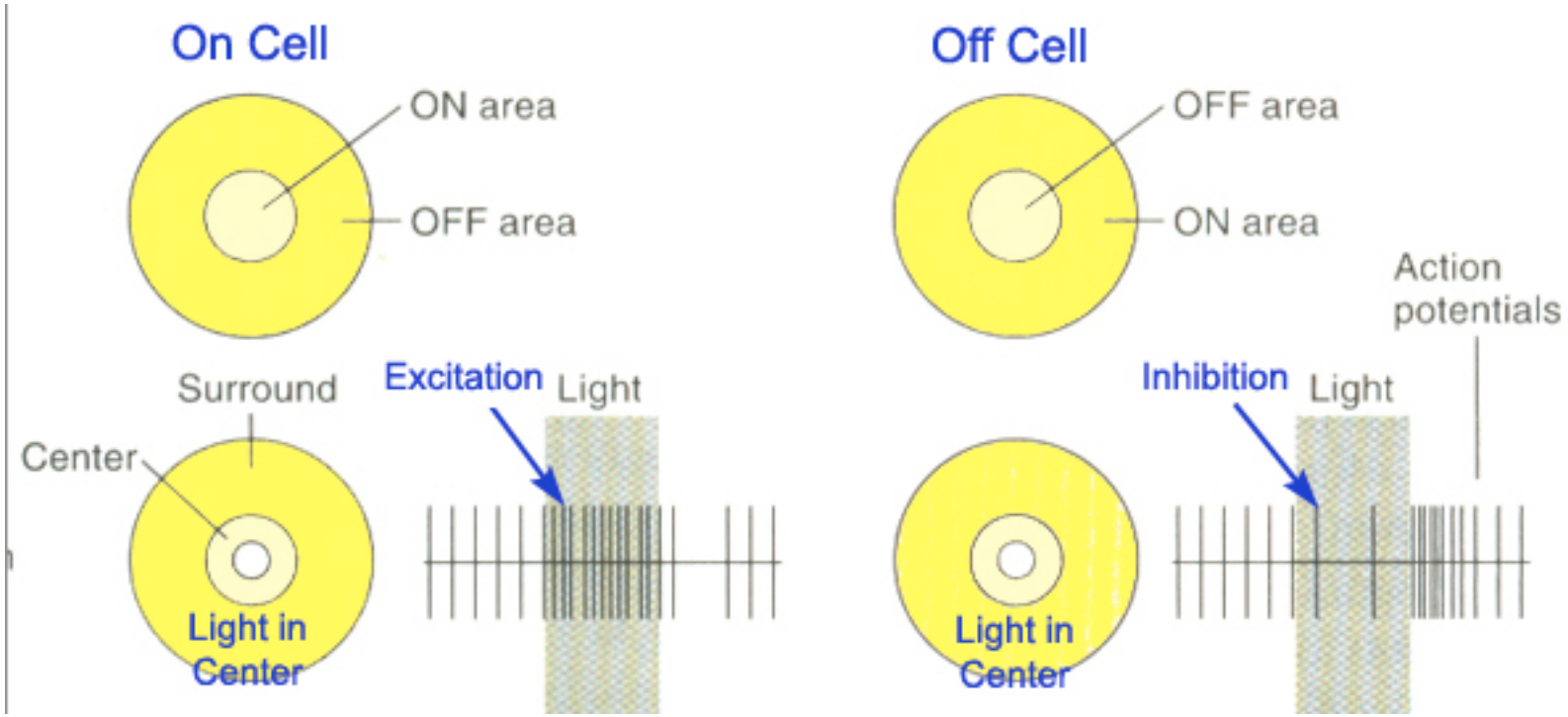
Major stages in early visual processing





Good spatial precision

Good temporal precision


On Cell
ON area
OFF area
Surround
Center
Light in Center
Excitation
Light
Off Cell
OFF area
ON area
Light in Center
Inhibition
Light
Action potentials

Processing

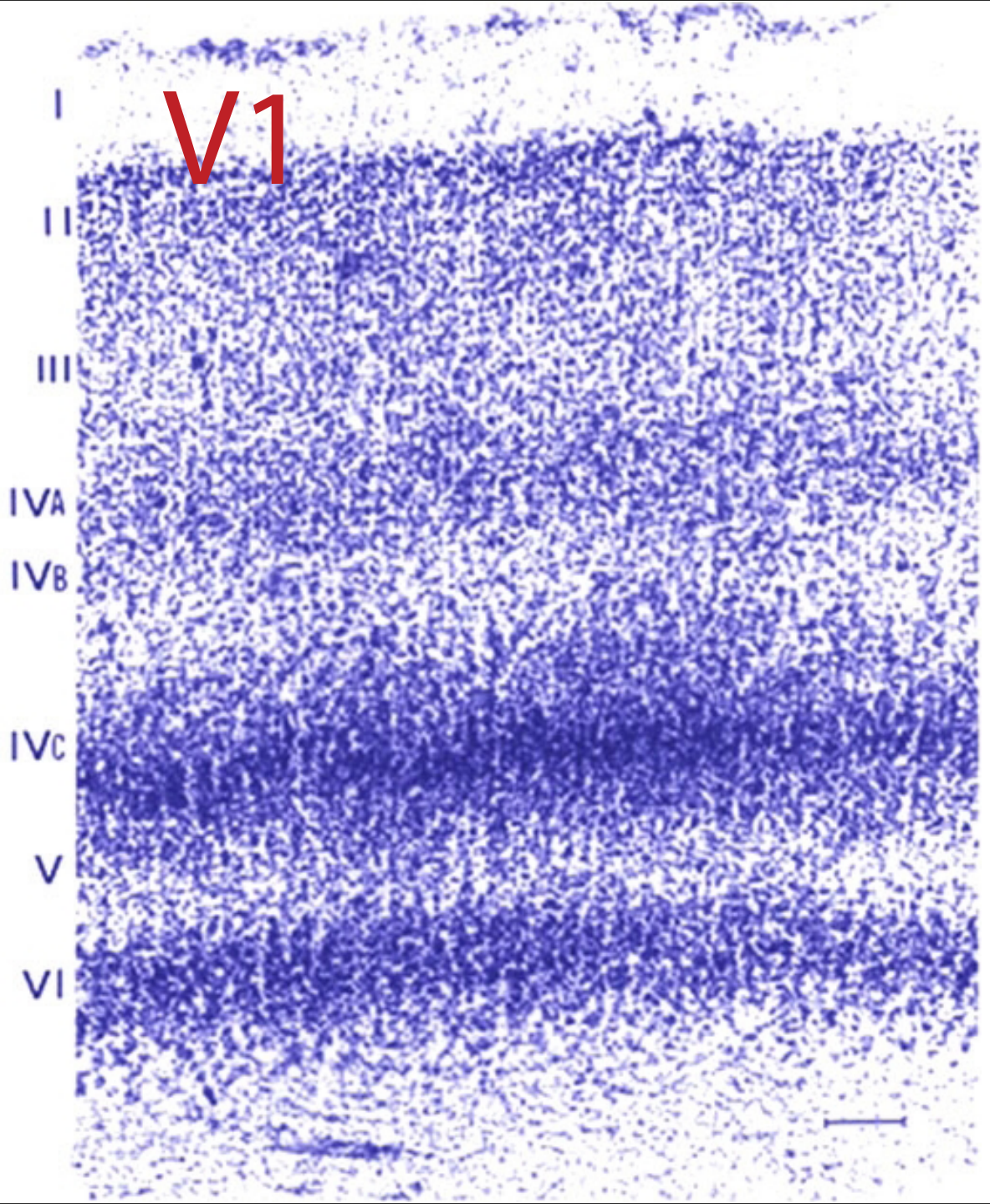
I - III

Input from LGN

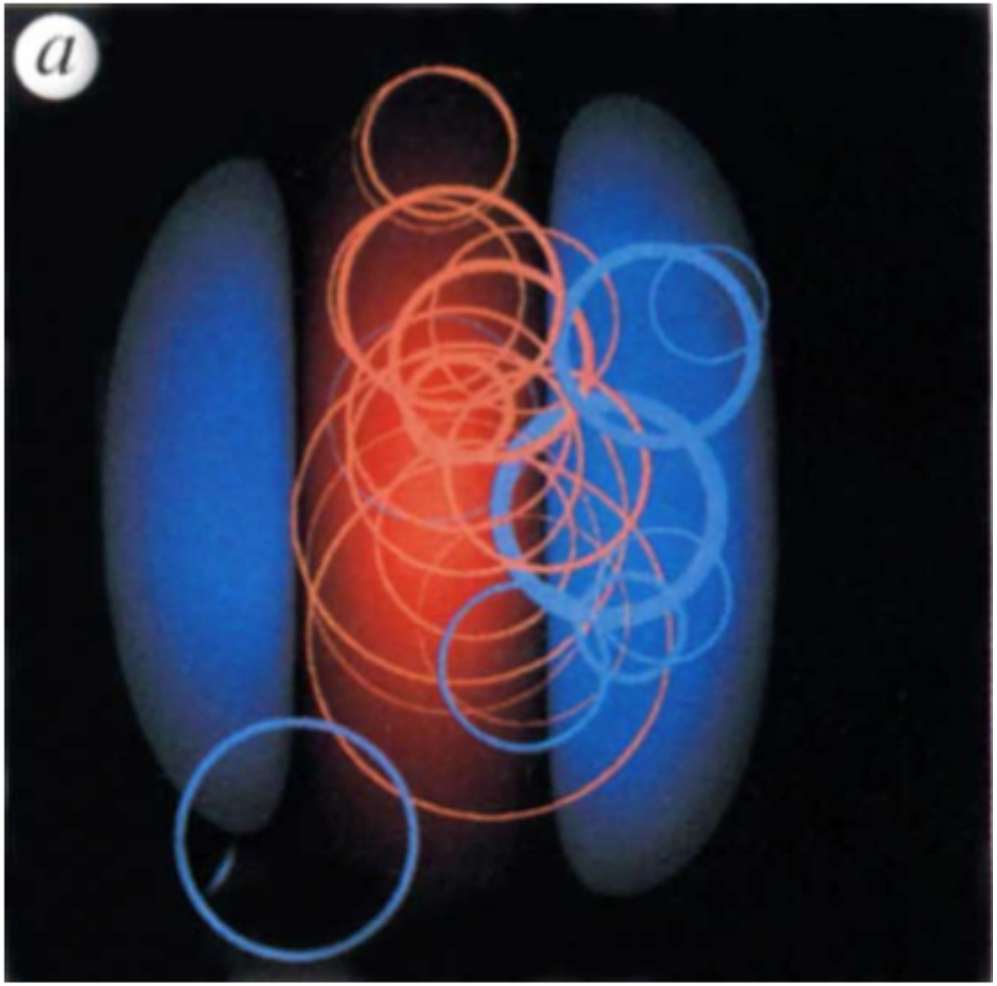
IV

Output to rest of Cortex

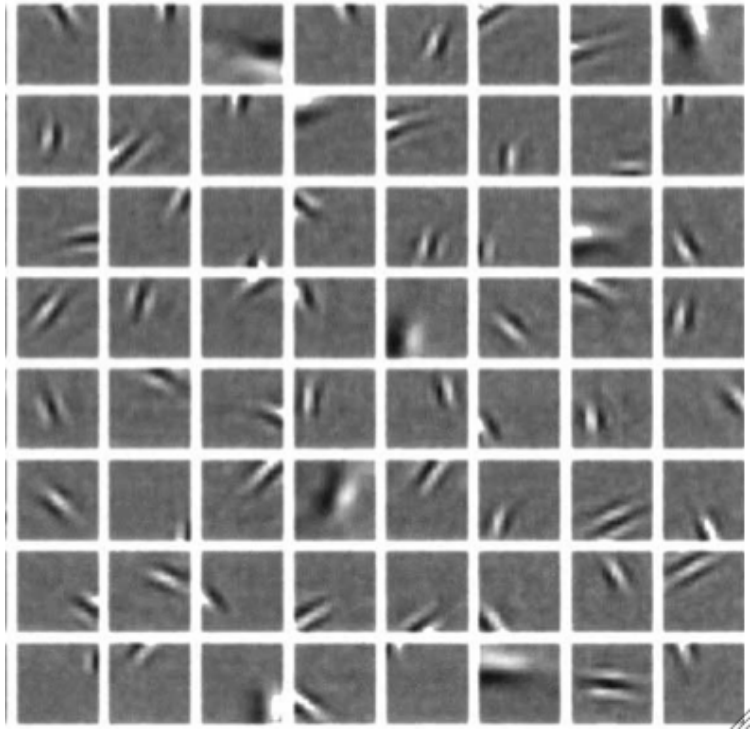
V, VI



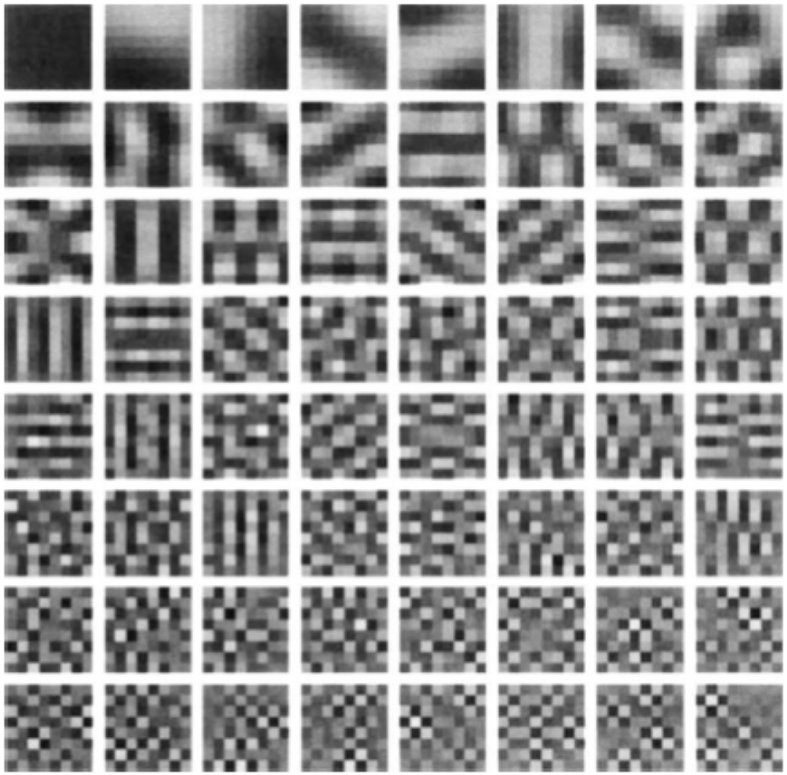
LGN cell's receptive fields for cells that are connected to a cortical cell have the correct polarity



Alonso et al



In generating a mathematical model of V1 receptive fields, charging for the number of cells that are firing leads to a good model



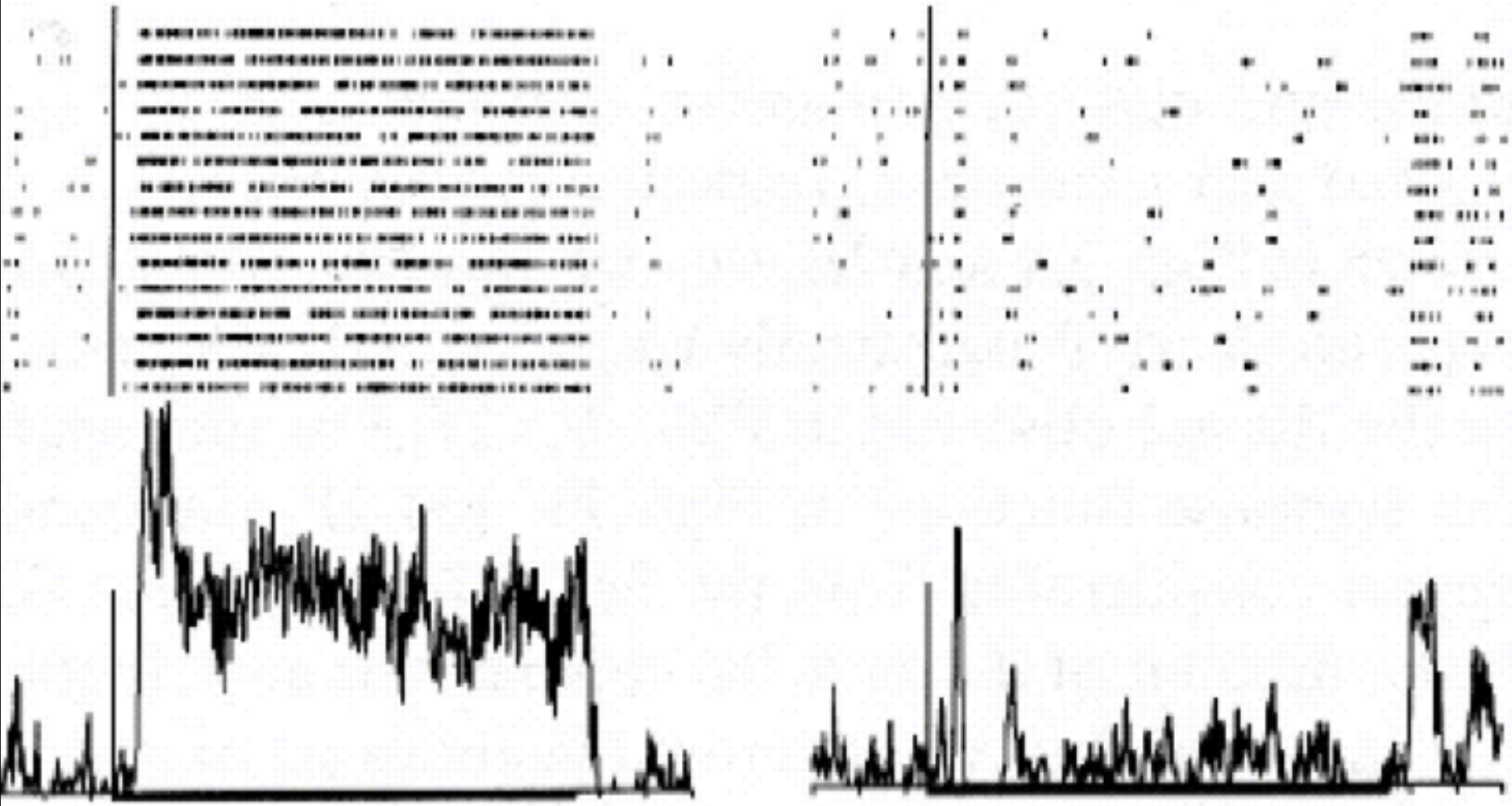
without this cost, all cells fire and the RF code is non-biological

Olshausen & Field

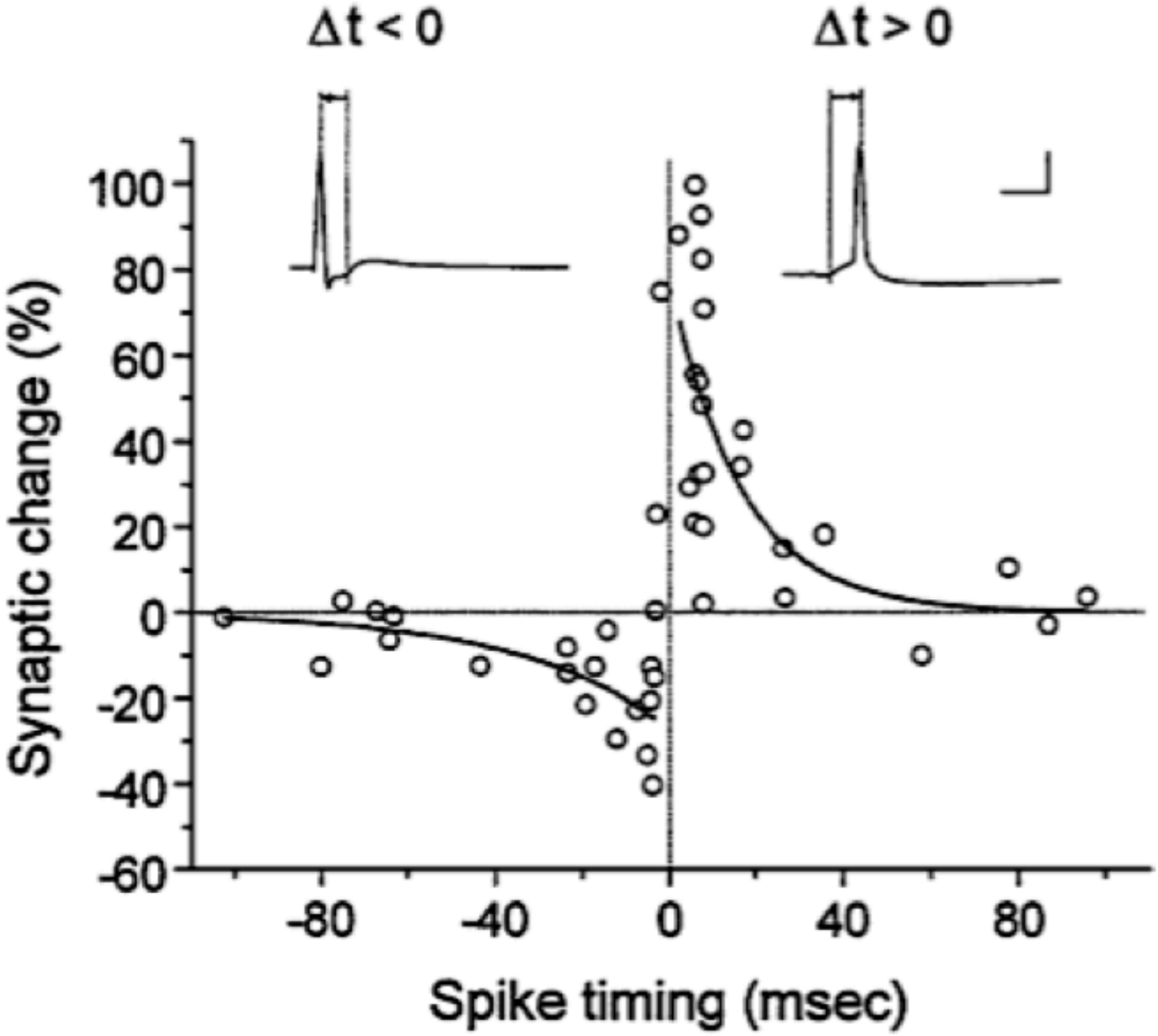
Motion sensitive cell in cortical area MT

Motion in tuned RF direction

Motion in opposite direction



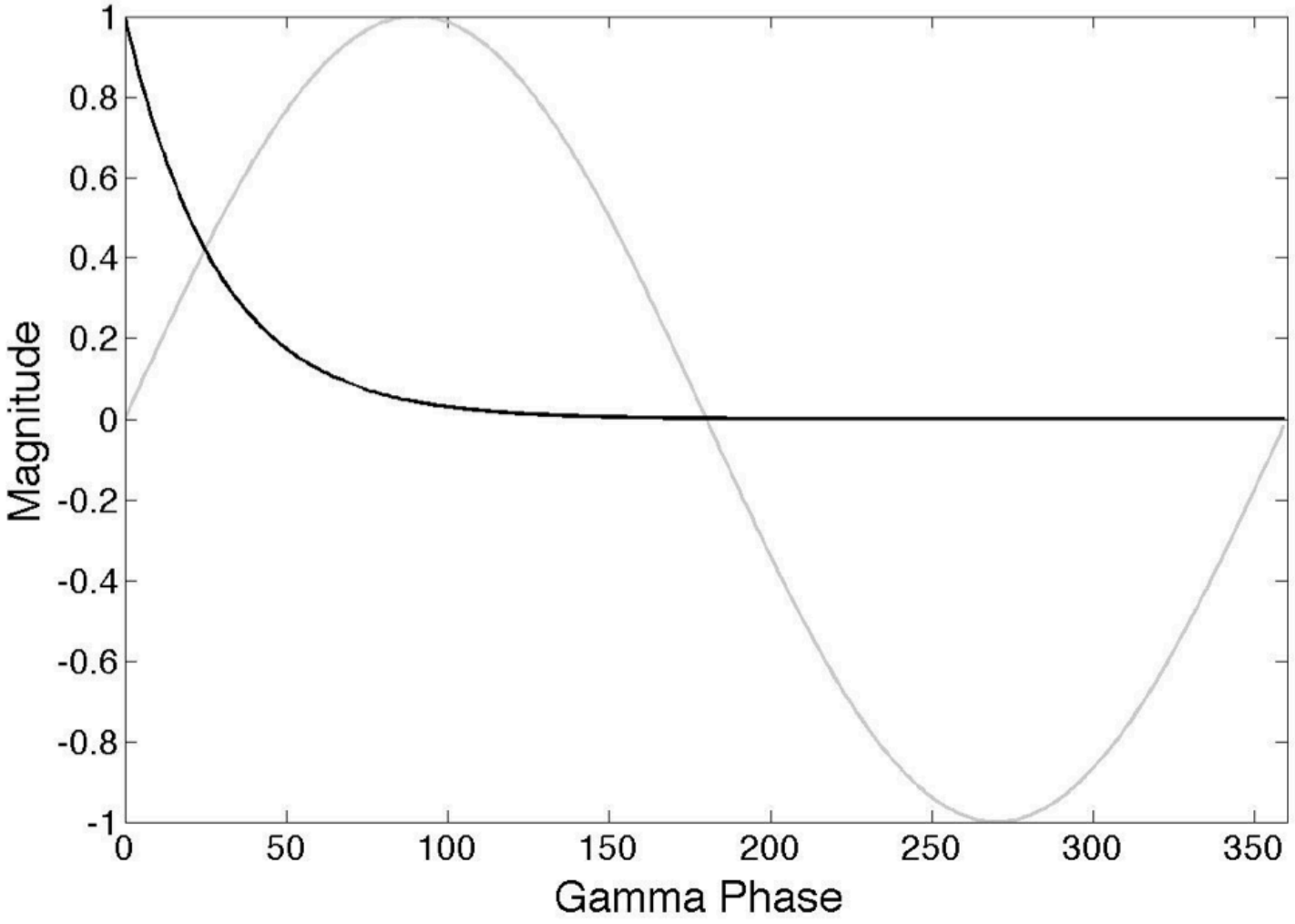
Newsome et al

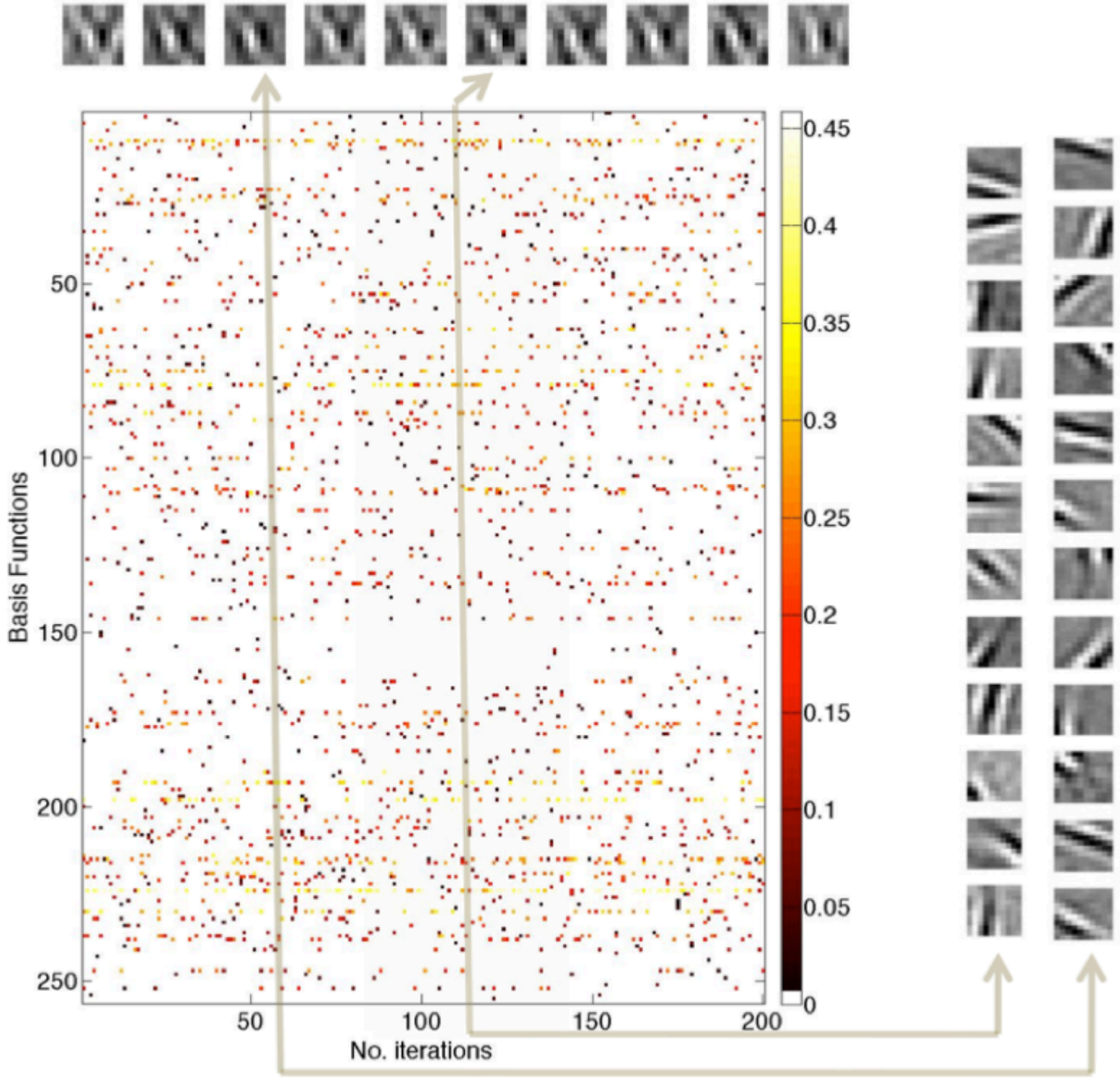

Δt < 0
Δt > 0
100
80
60
40
20
0
-20
-40
-60
Synaptic change (%)
-80
-40
0
40
80
Spike timing (msec)


50 100 150 200
Time [ms]


-30 0 30
Relative latency [ms]


0 4 8 12
Spike count


1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
Magnitude
0
50
100
150
200
250
300
350
Gamma Phase

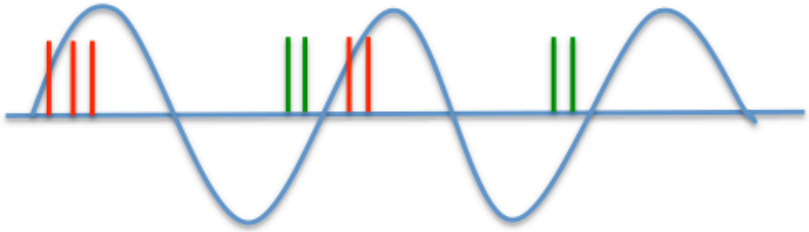

Basis Functions
50
100
150
200
250
50
100
150
200
No. iterations
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0

Spike are used in different ways for different tasks

A

Brainstem
Vestibulo-occular reflex:
Rate = number

B



Hippocampus
Theta phase organizes the beginning and end of a task

C

Basal Ganglia
TANS cells indicate subtask breakpoints with silence

Fiete lab model of
hippocampus grid cell
position coding

Conjunctions of firing
at different locations provides a
unique spatial code