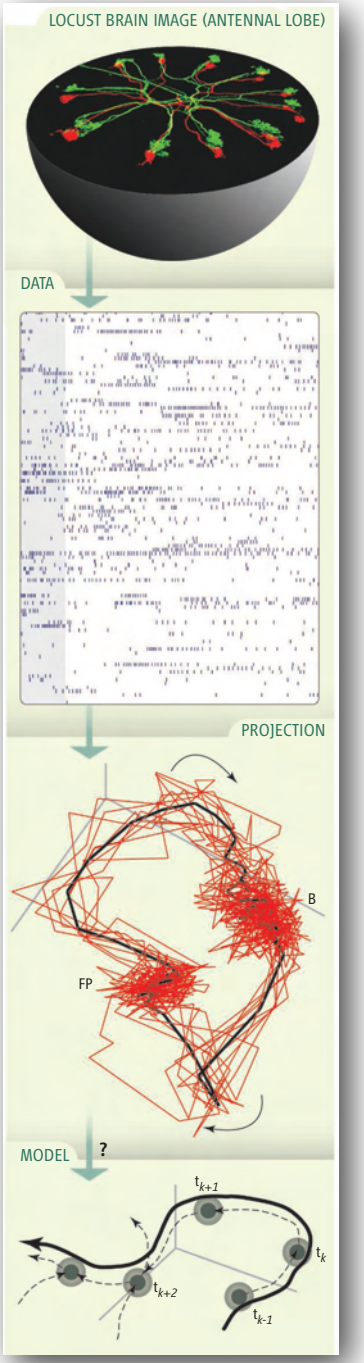
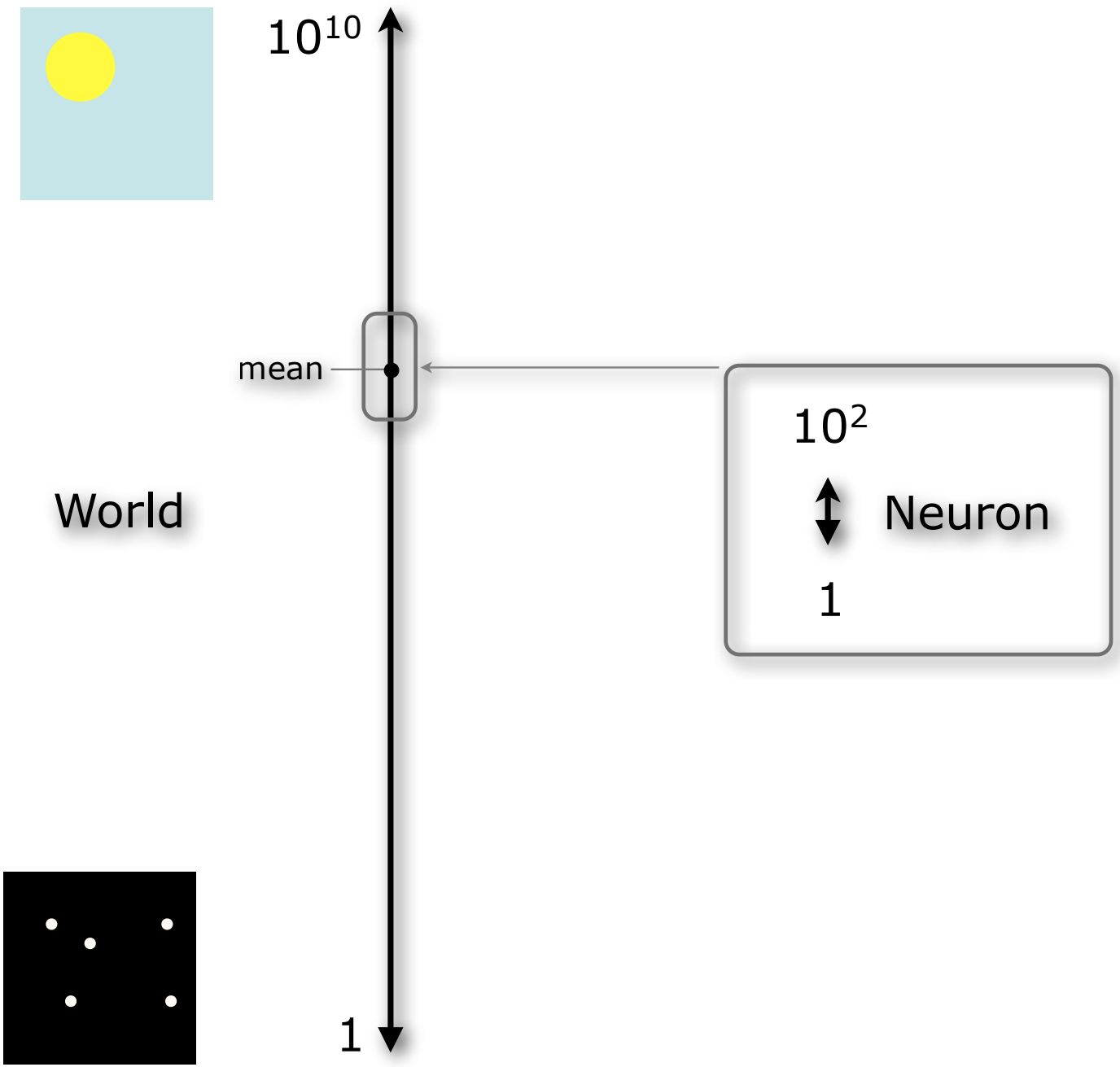


Adaptive Mechanisms in An Olfactory Circuit

Gilles Laurent,

Caltech, Pasadena CA

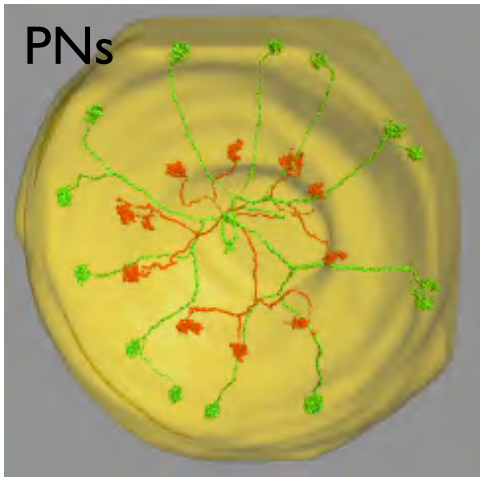
MPI Brain Research, Frankfurt

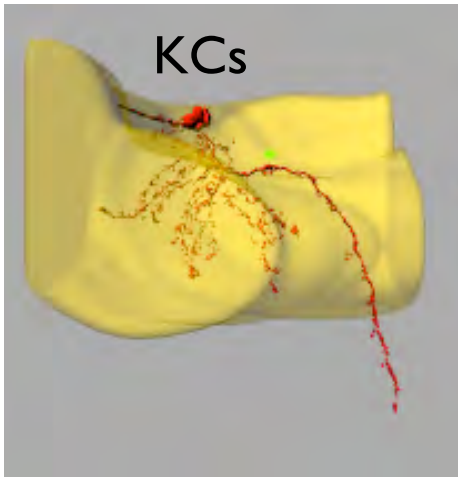

10^{10}
mean
World
10^2
Neuron
1
1

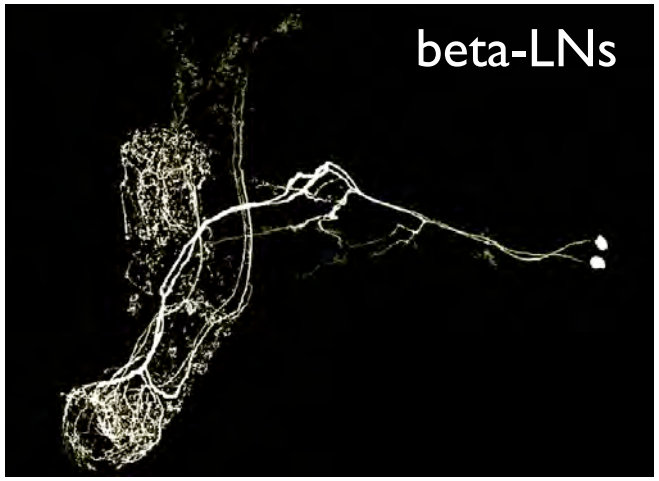
Antennal Lobe

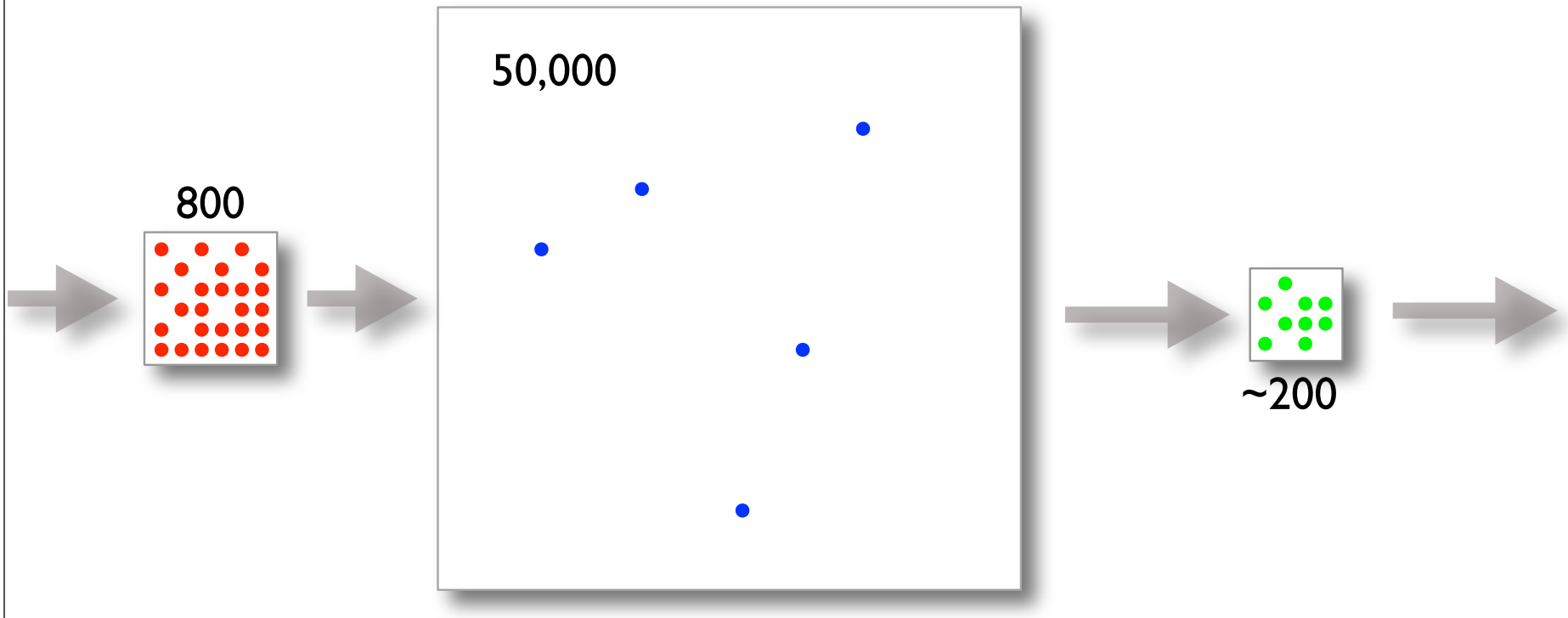
Mushroom Body

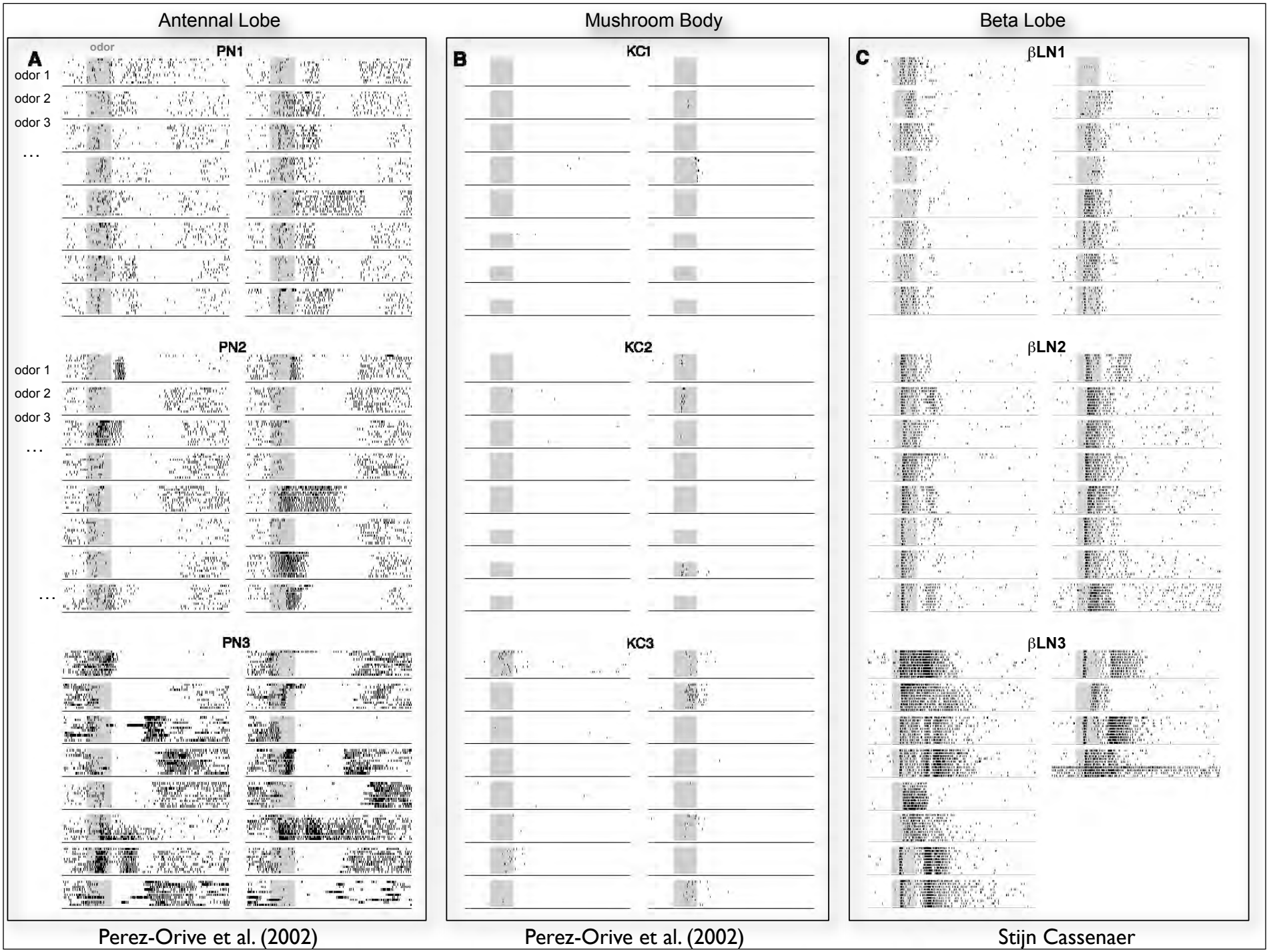
Mushroom Body Lobes





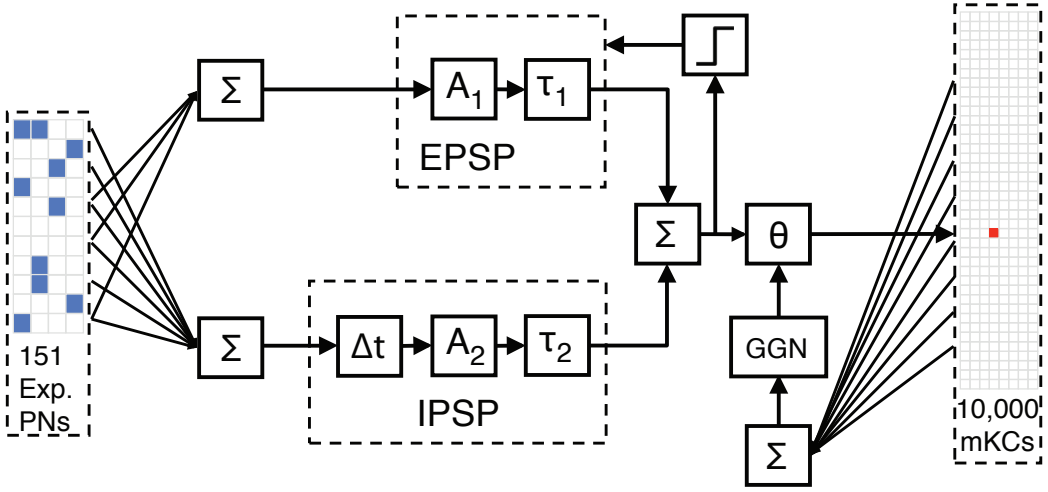





Antennal Lobe
Mushroom Body
Beta Lobe
A
odor
PN1
odor 1
odor 2
odor 3
...
PN2
odor 1
odor 2
odor 3
...
...
PN3
B
KC1
KC2
KC3
C
βLN1
βLN2
βLN3
Perez-Orive et al. (2002)
Perez-Orive et al. (2002)
Stijn Cassenaer

mechanisms

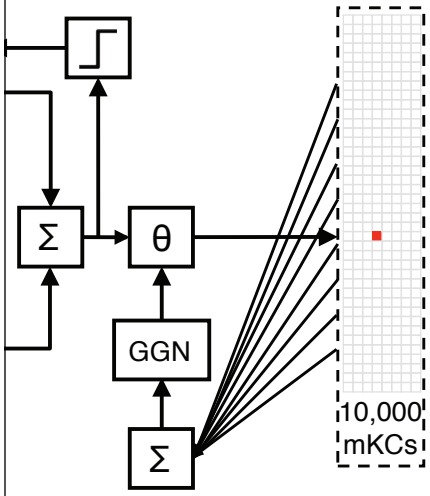
natural input



useful properties

compact code

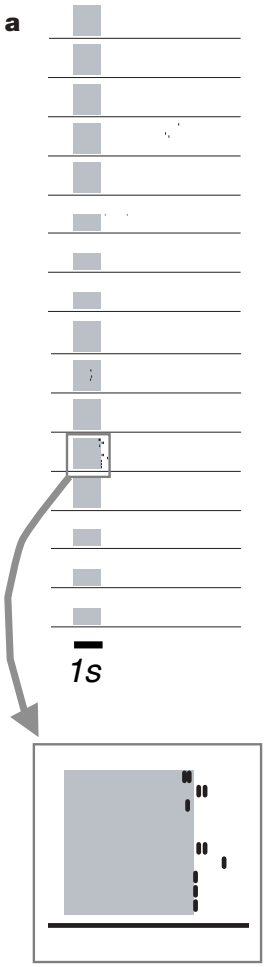
sparse code



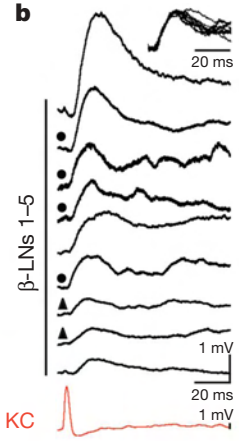
useful properties

sparse code

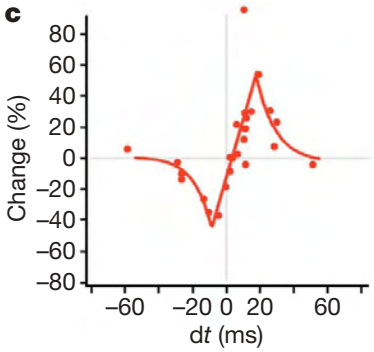
(1) sparse

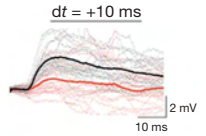


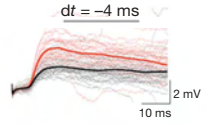
(2) hi gain



(3) plastic



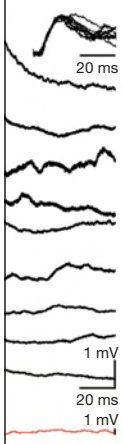




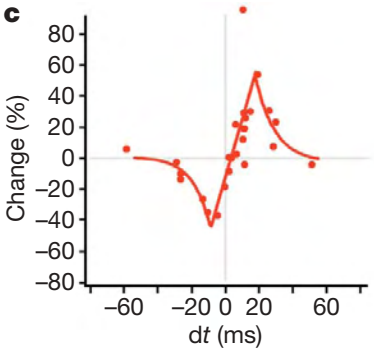
Perez-Orive et al., 2002

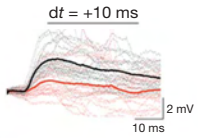
Cassenaer and Laurent, 2007

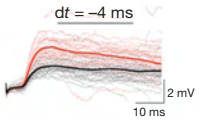
)
gain



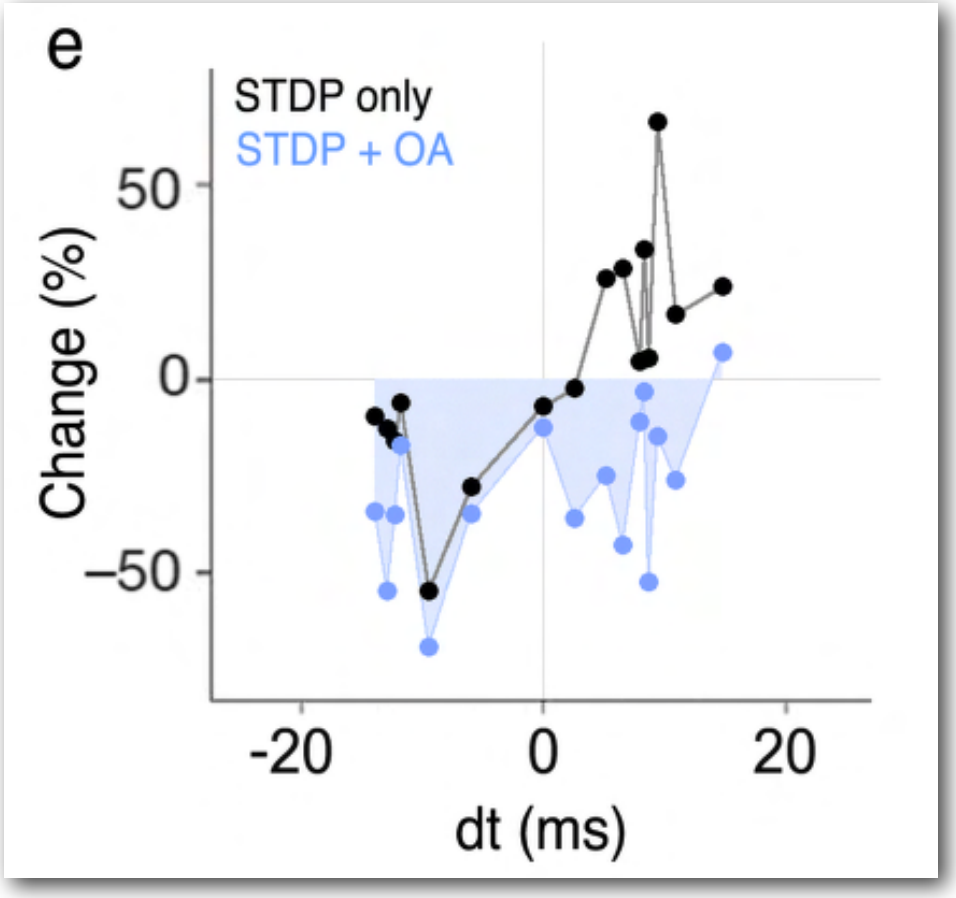
(3)
plastic







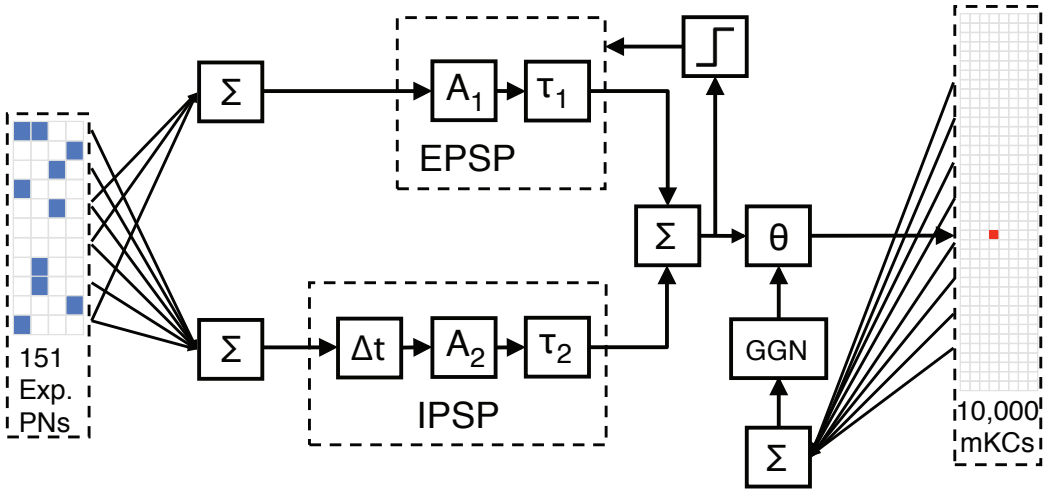
(4)
STDP rule is plastic



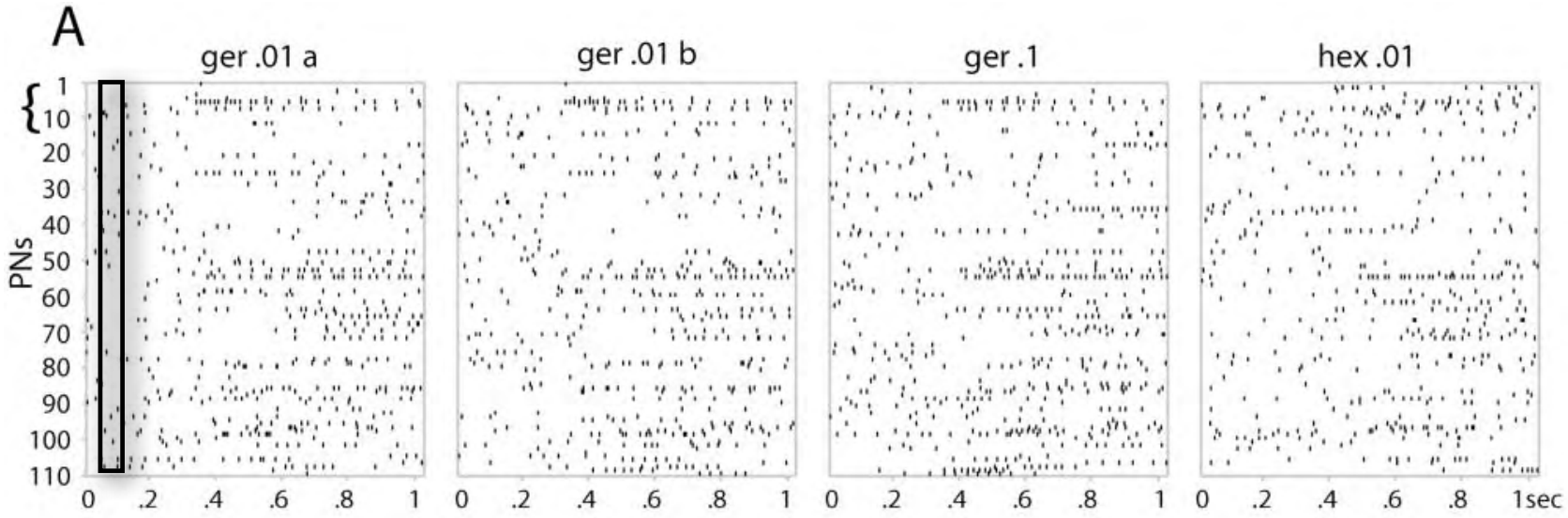
Cassenaer and Laurent, in prep.

a few details

natural input

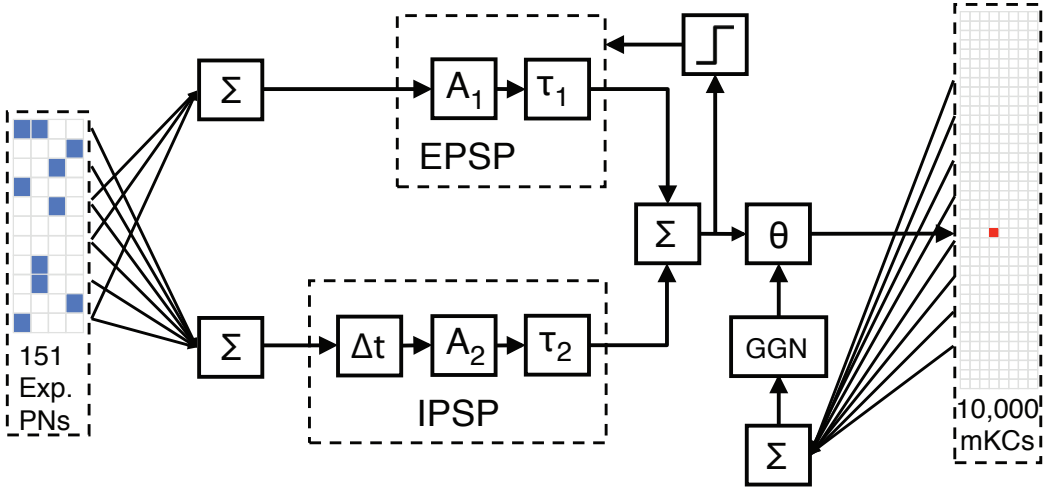


synthetic properties



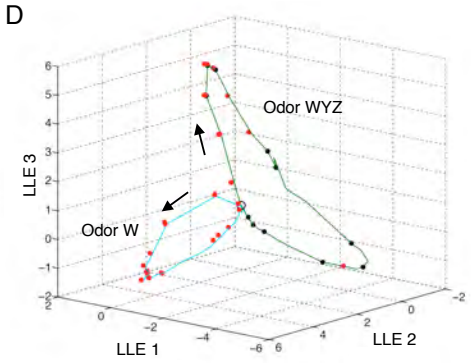
a few details (1)

natural input

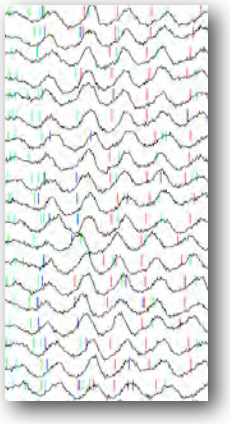


high-level properties

trajectories



piecewise decoding



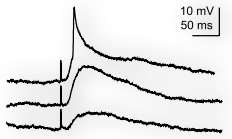
oscillations

integration unit = oscillation cycle

a few details (2)

non-linearity

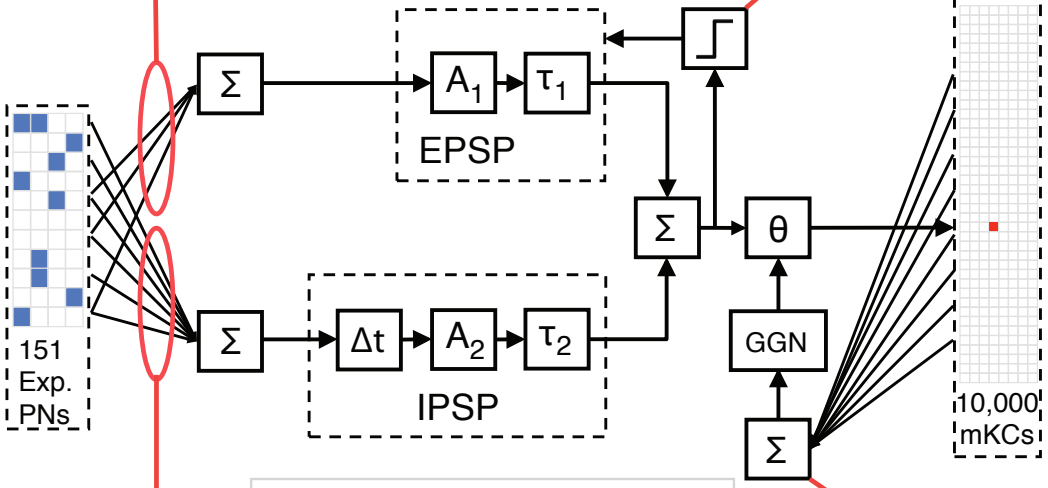
tau = 2-20ms



direct excitation

KC-specific (and 50%)

natural input

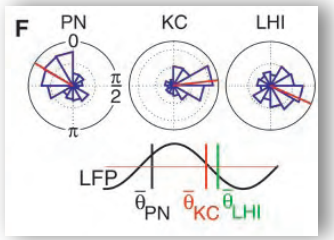


high-level properties

f-fwd inhibition

non-specific

delayed (τ)

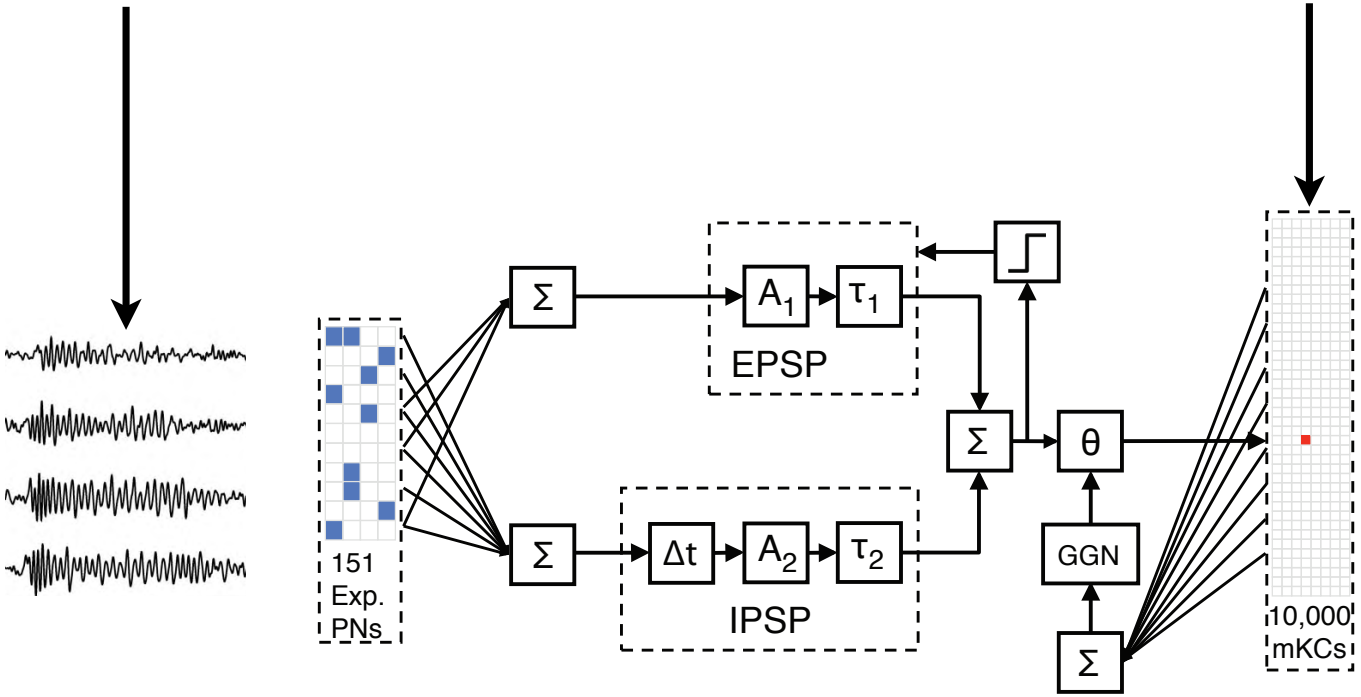


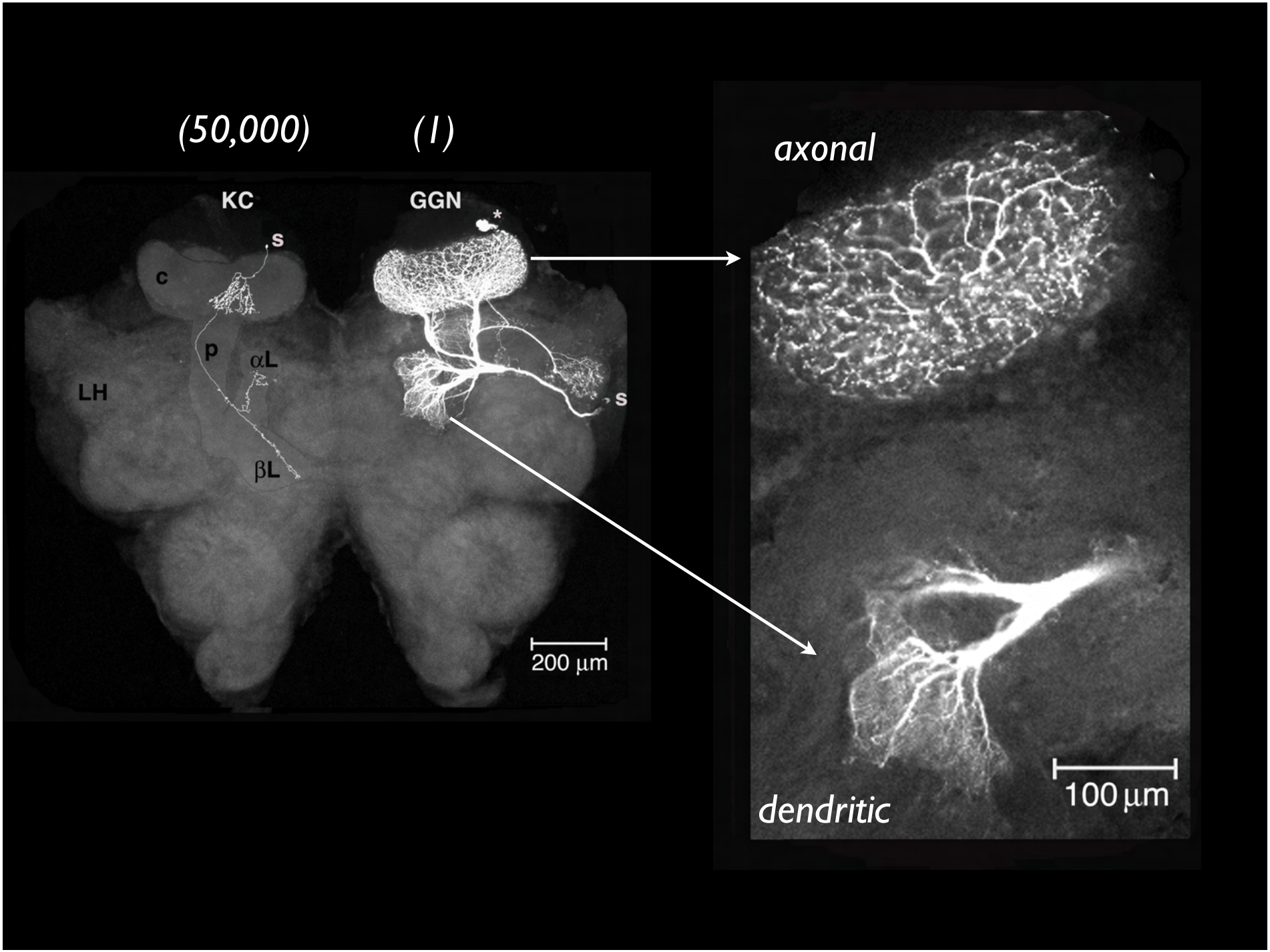
normalizing gain control

all-to-all

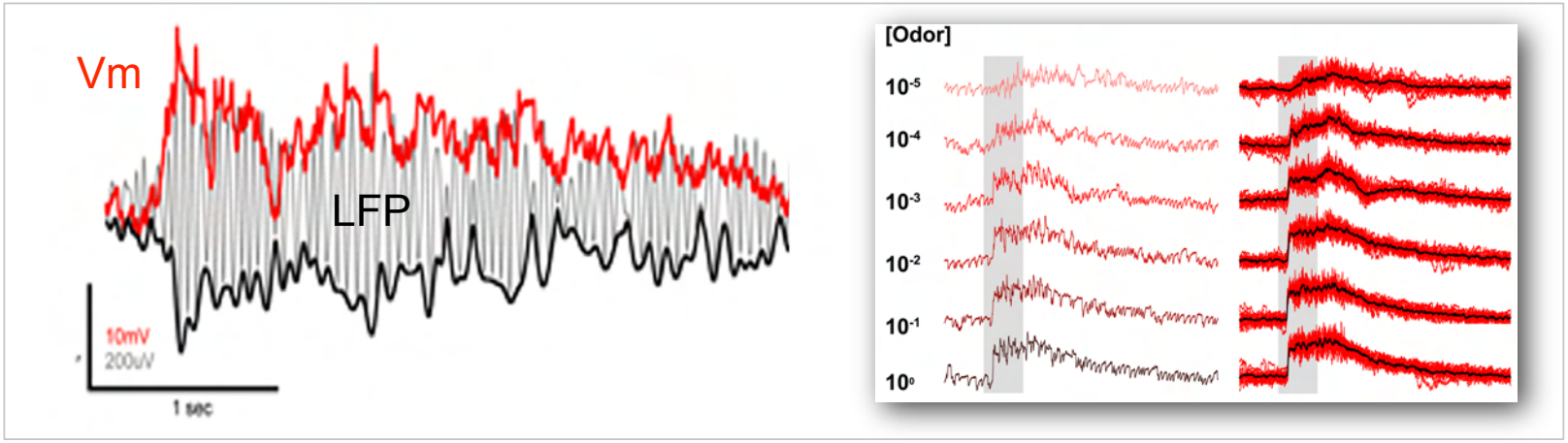
increased synchronization

coincidence detectors

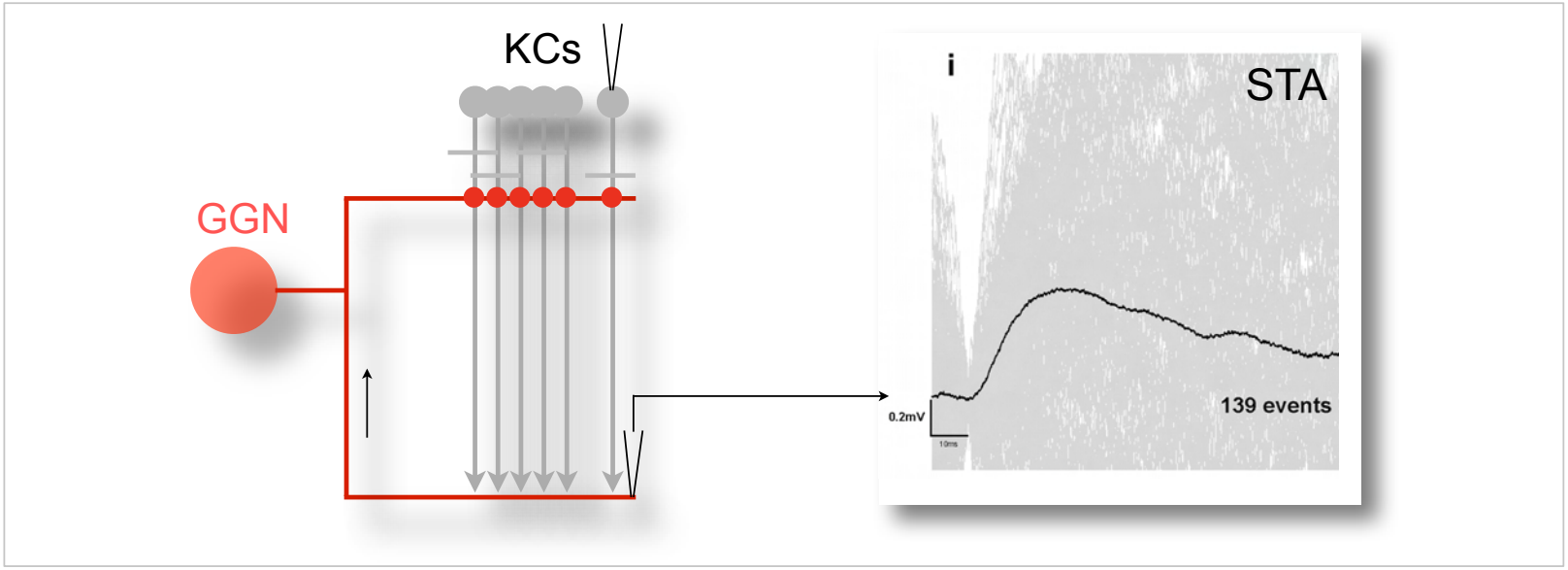



(50,000)
(1)
KC
GGN
s
c
p
αL
LH
βL
s
200 μm
axonal
dendritic
100 μm

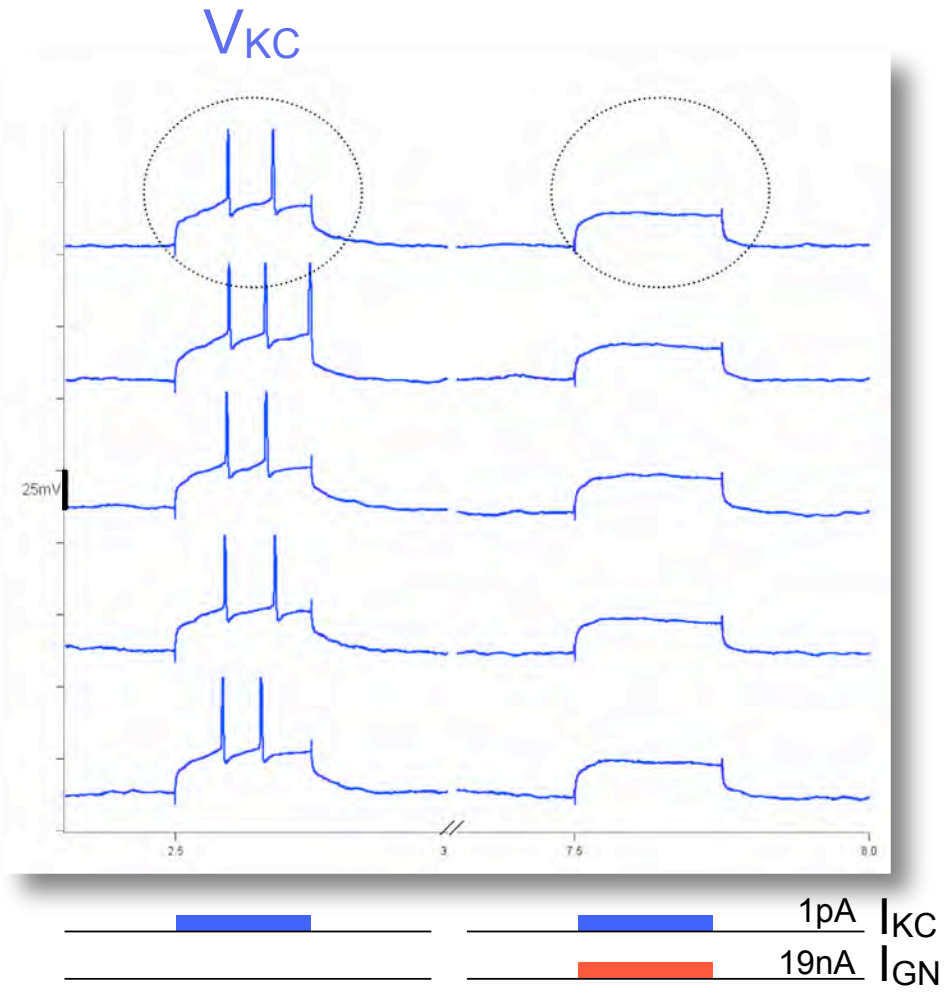
GGN membrane potential tracks input to/output from mushroom bodies:

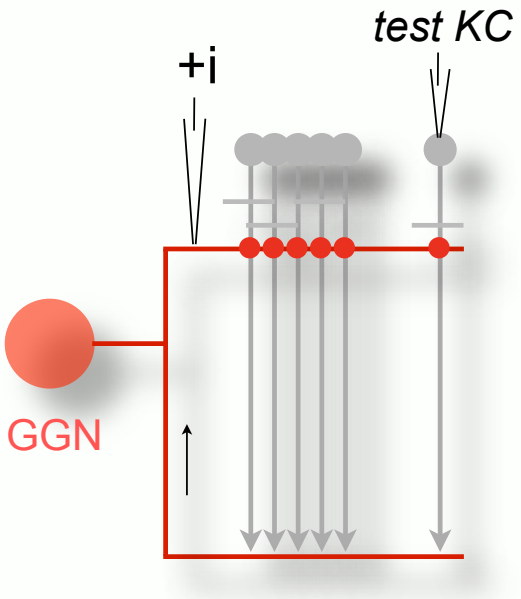


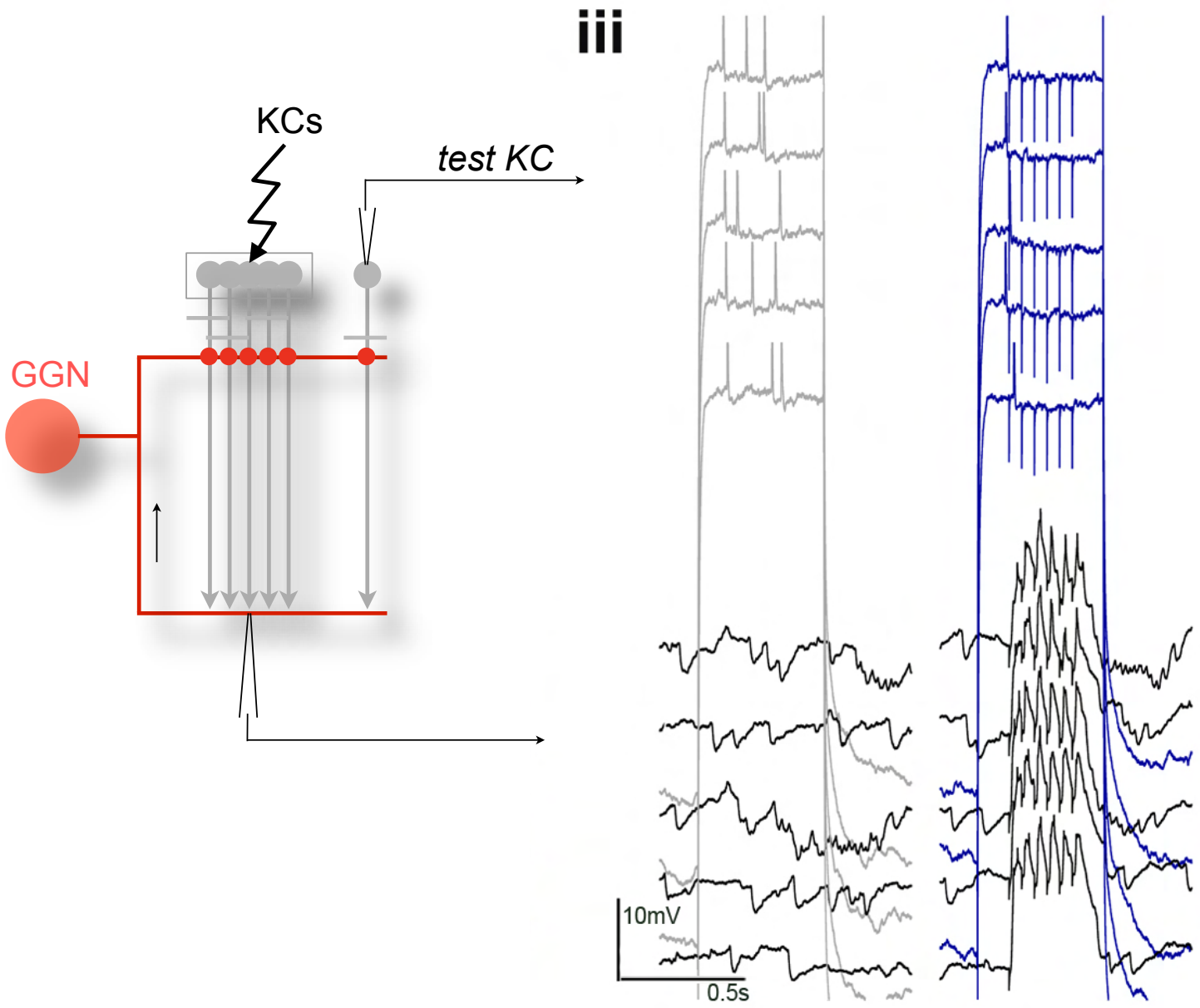
KCs excite GGN mono-synaptically:

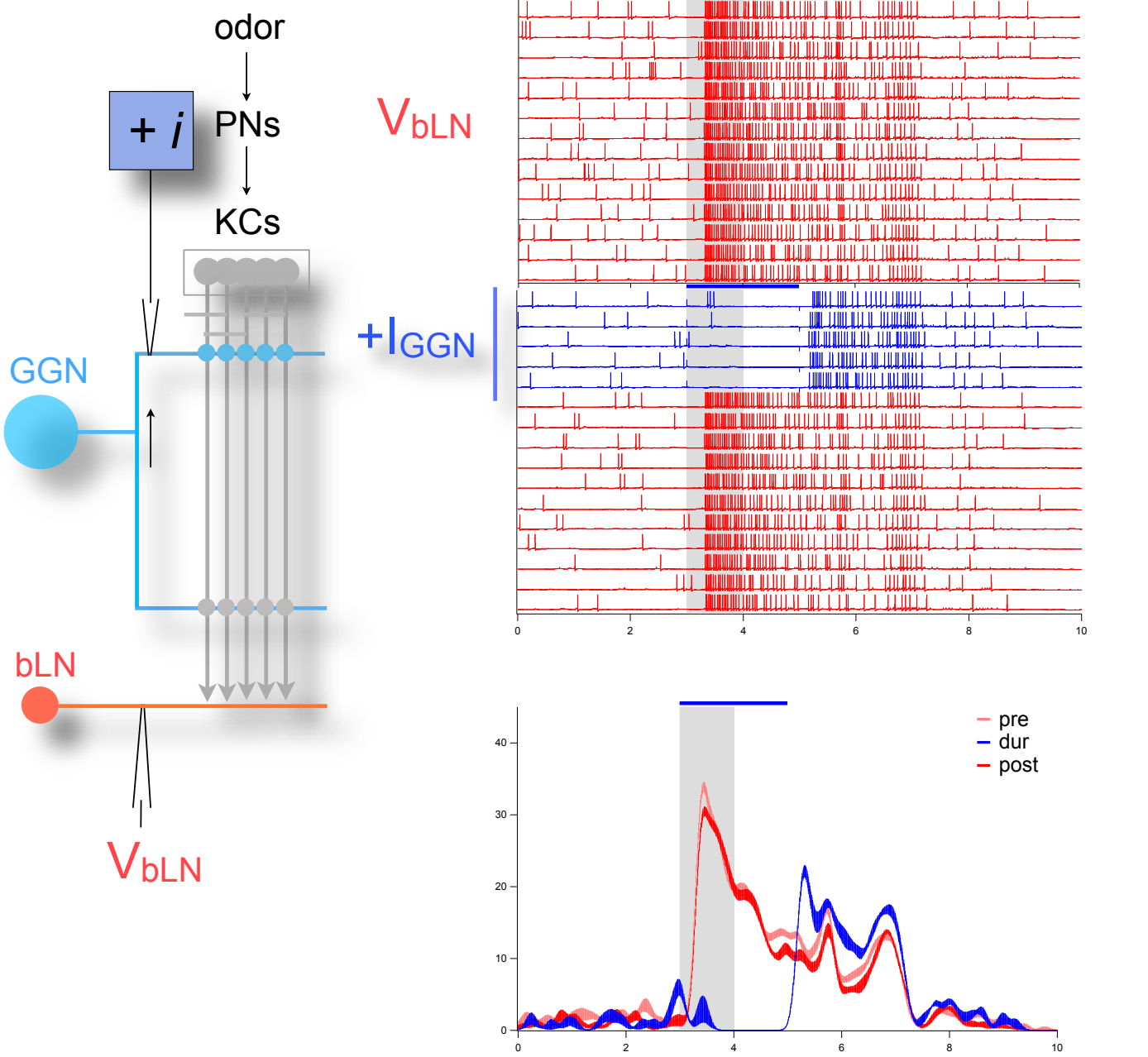


Threshold Control of GN on KCs

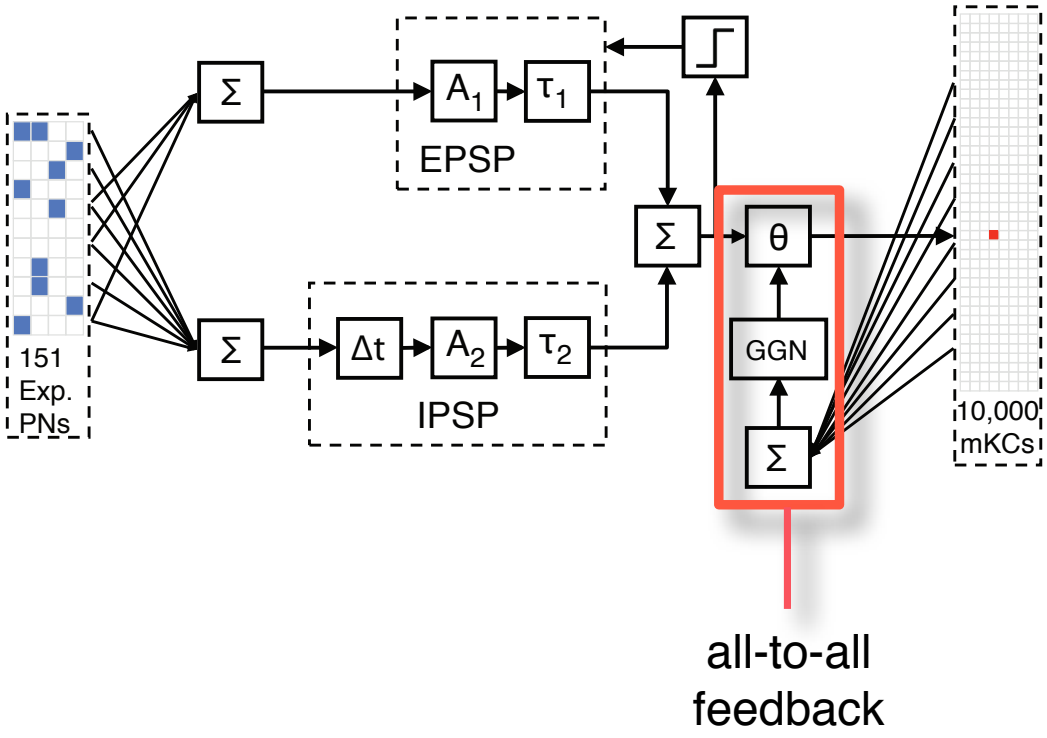




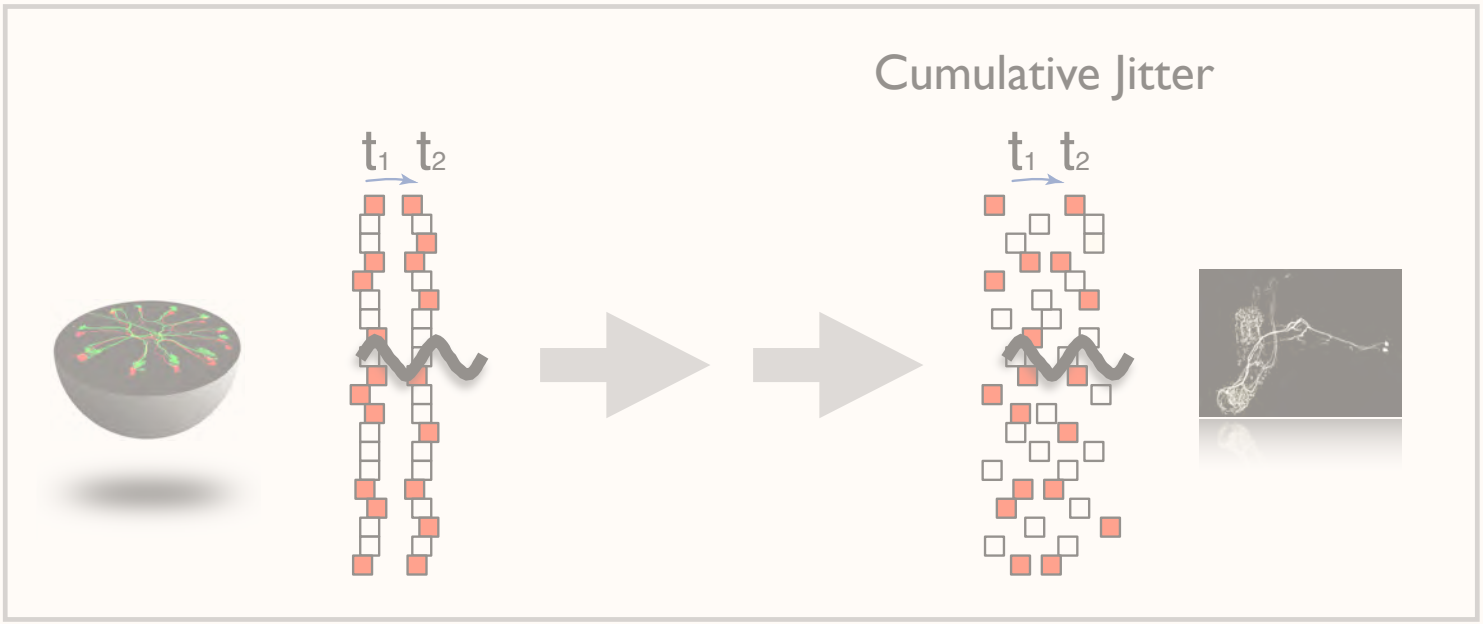

iii
KCs
test KC
GGN
10mV
0.5s


odor
+ i
PNs
KCs
GGN
bLN
VbLN
VbLN
+IGGN
50mV
0
2
4
6
8
10
40
30
20
10
0
pre
dur
post

Conclusion 1



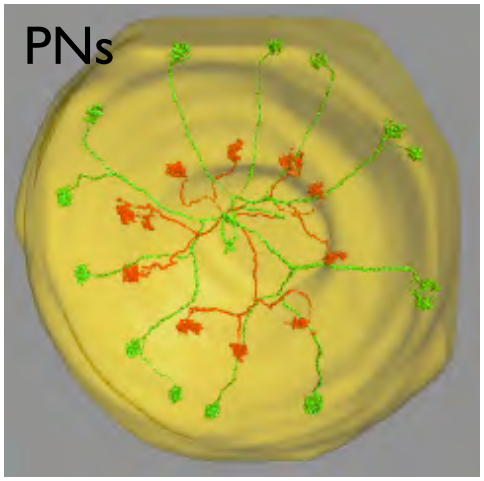
Adaptive control of Timing with STDP

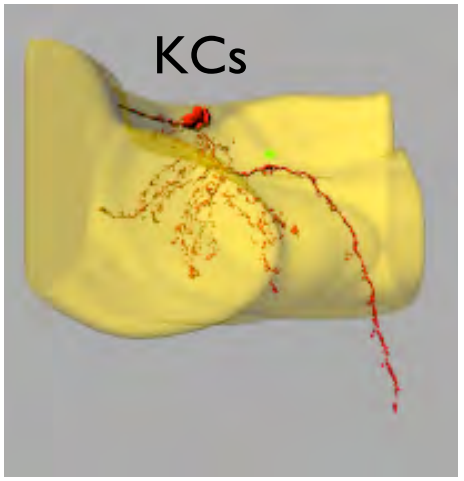


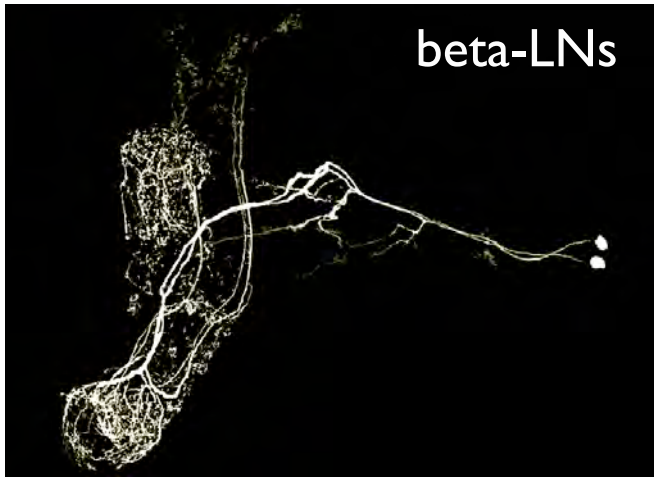
Antennal Lobe

Mushroom Body

Mushroom Body Lobes

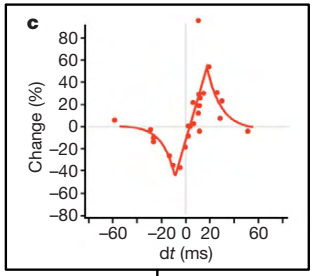






800

50,000

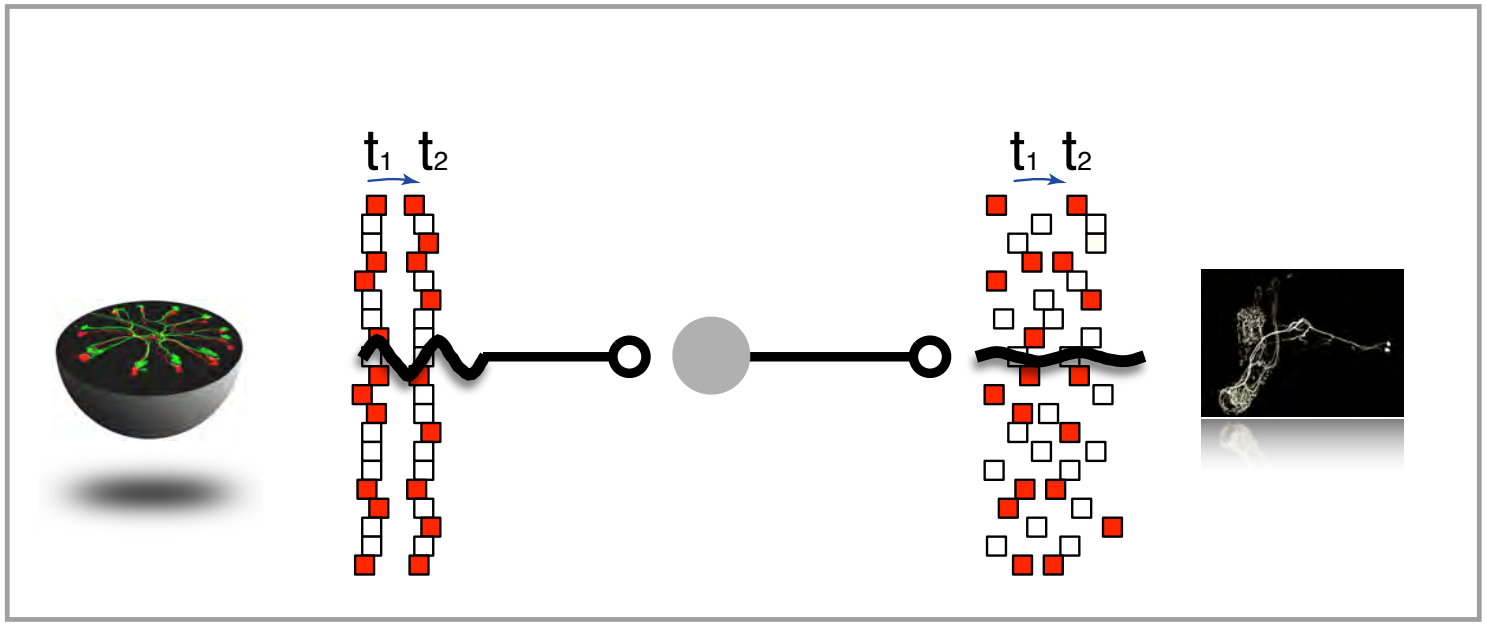


STDP

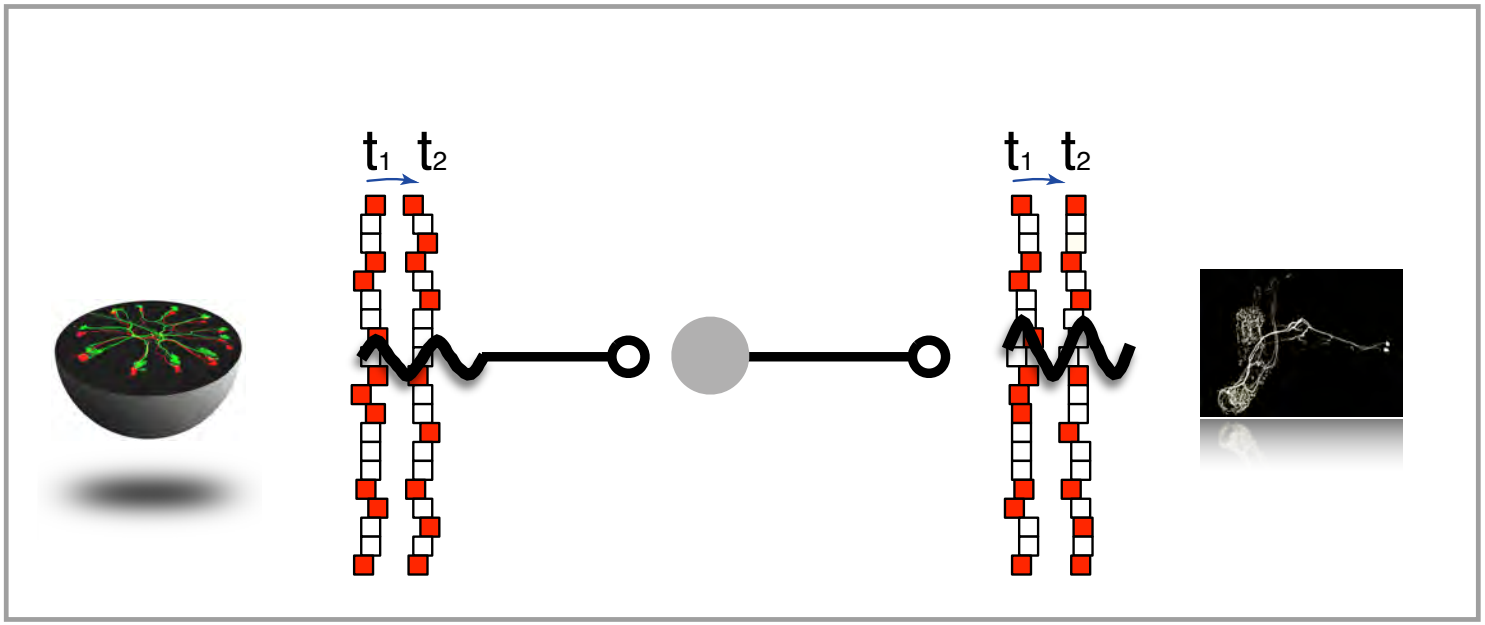
~200

Cassenaer & Laurent, 2007

Cumulative Jitter

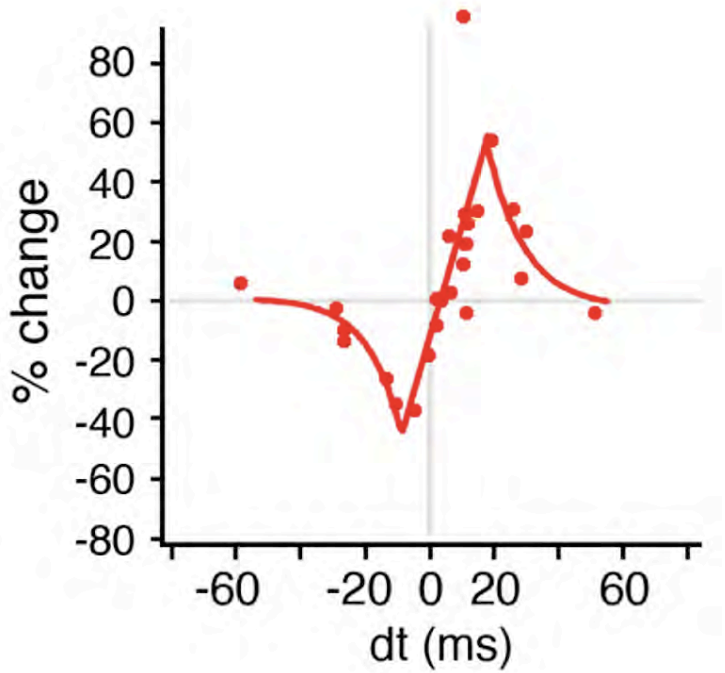


+STDP

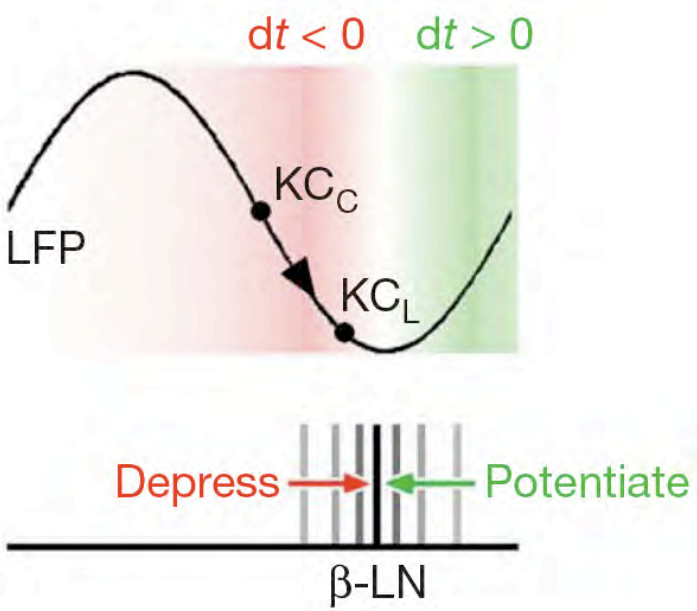


Principle

STDP rule

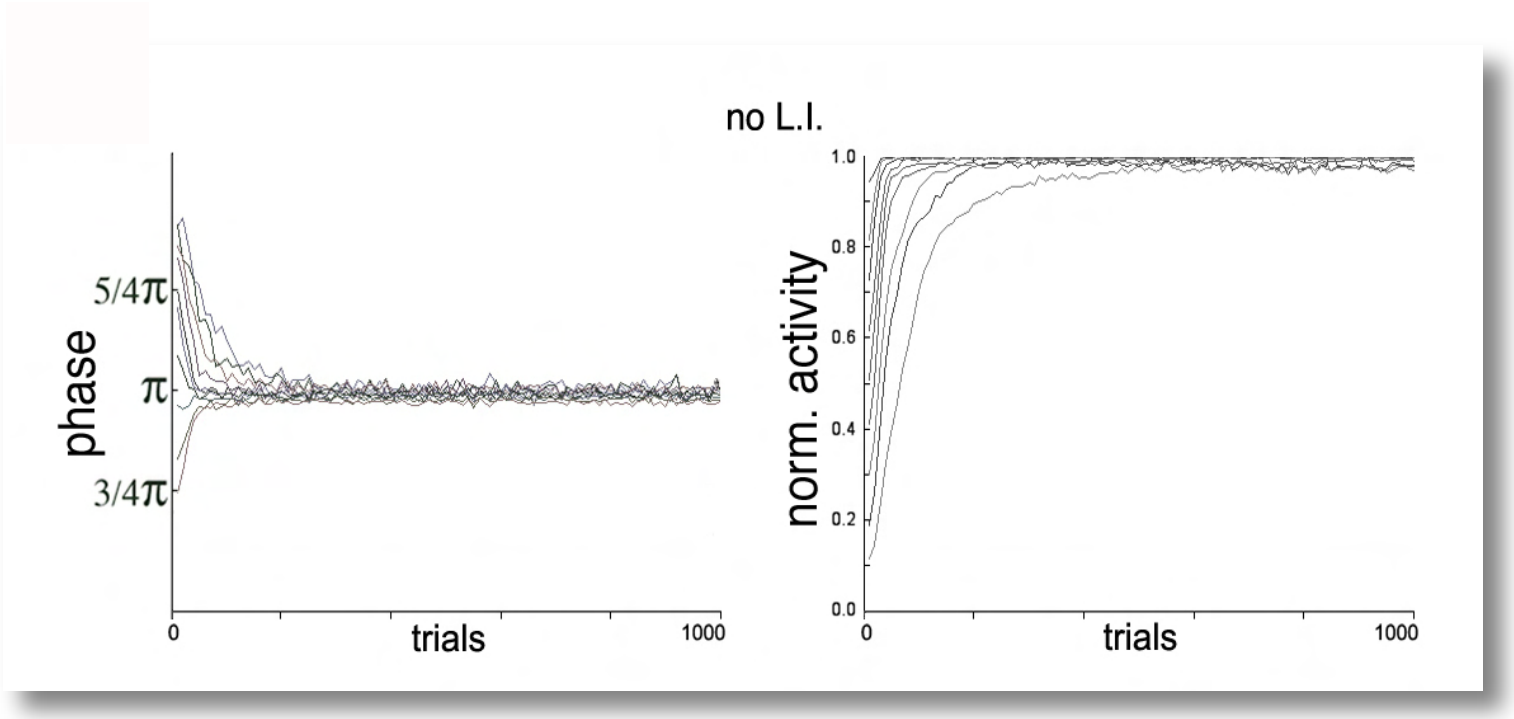


b-LN spike timing



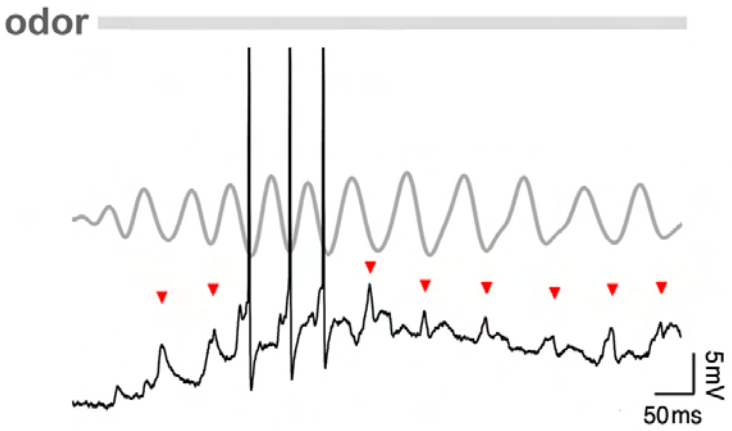
Cassenaer and Laurent, 2007

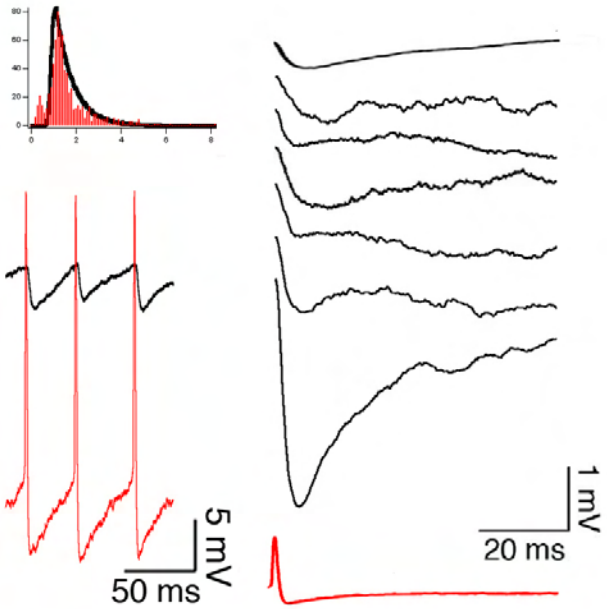
The problem with STDP



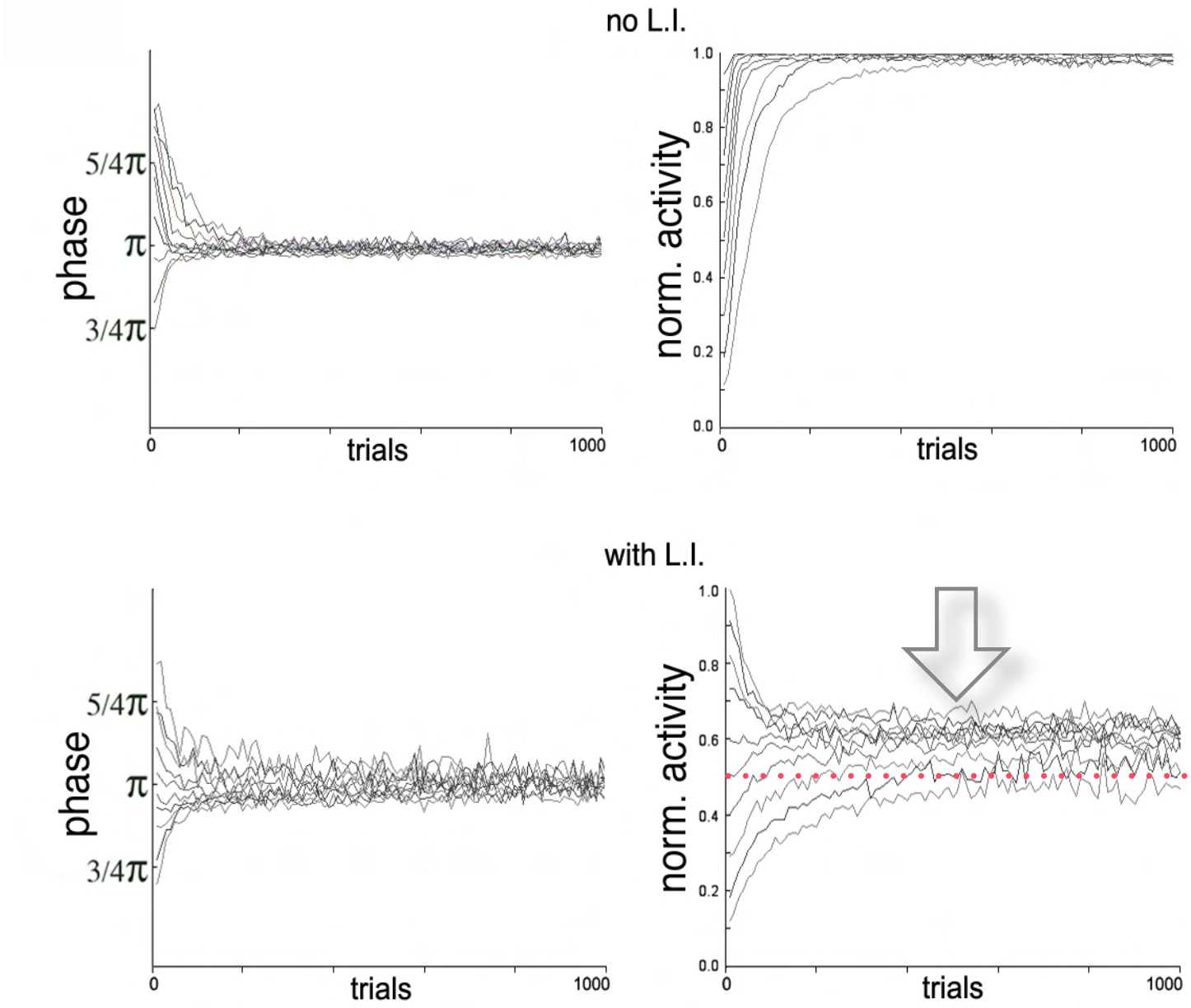
(simulations)

the solution: bLN lateral inhibition

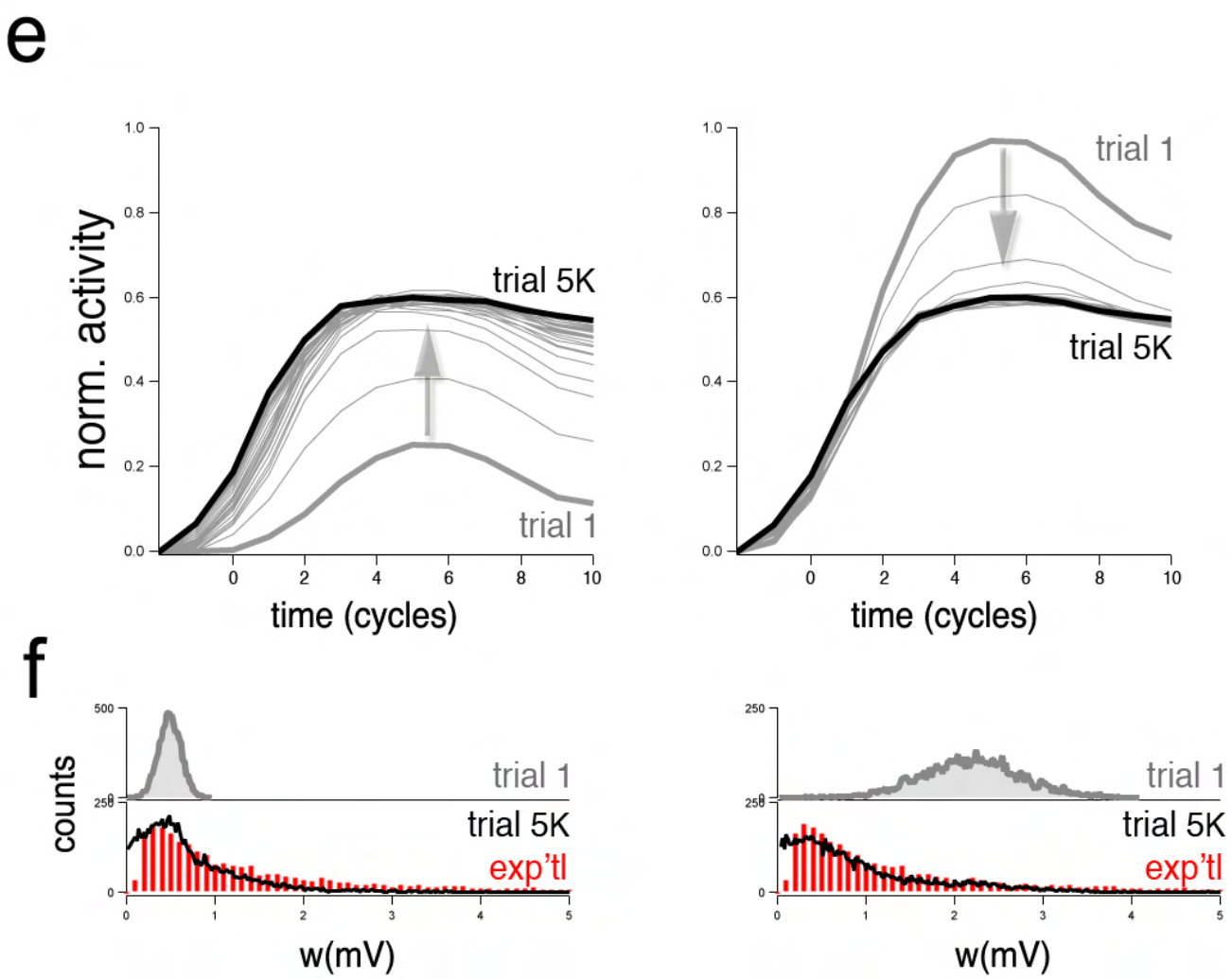




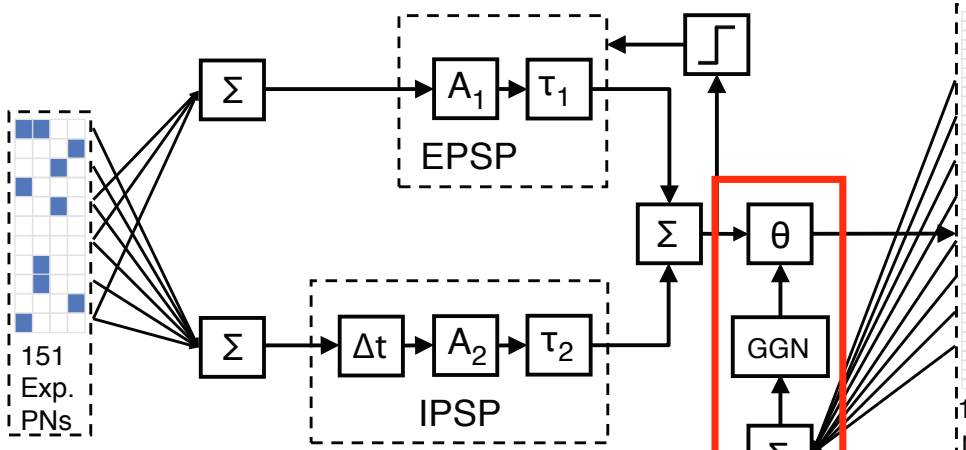
data


no L.I.
phase
5/4π
π
3/4π
0
trials
1000
norm. activity
1.0
0.8
0.6
0.4
0.2
0.0
0
trials
1000
with L.I.
phase
5/4π
π
3/4π
0
trials
1000
norm. activity
1.0
0.8
0.6
0.4
0.2
0.0
0
trials
1000

LI + STDP help set output near center of dyn. range

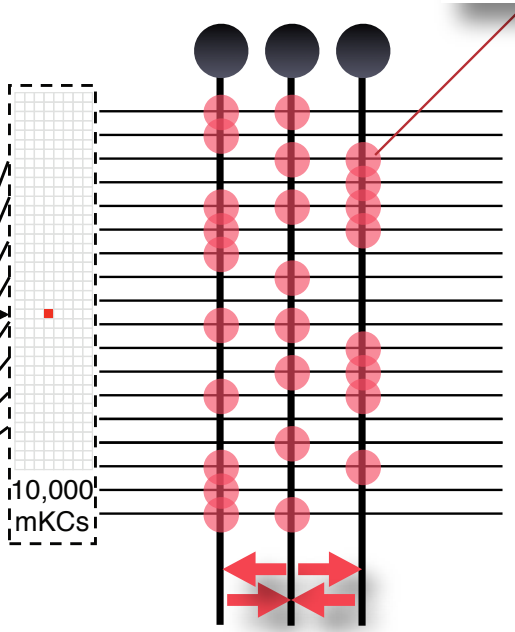


Adaptive mechanisms

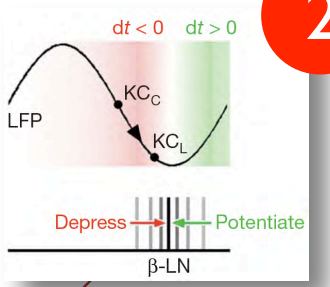


sparseness

1



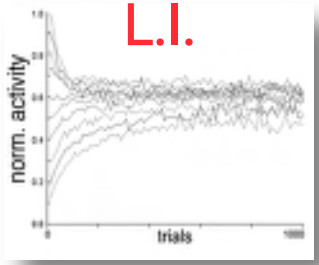
bLNs



STDP

2

sync

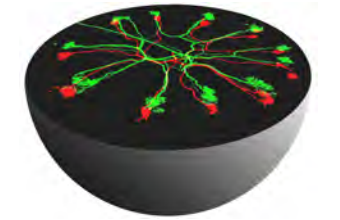


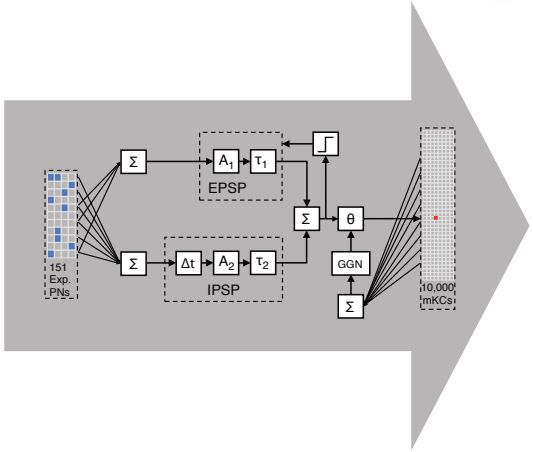
L.I.

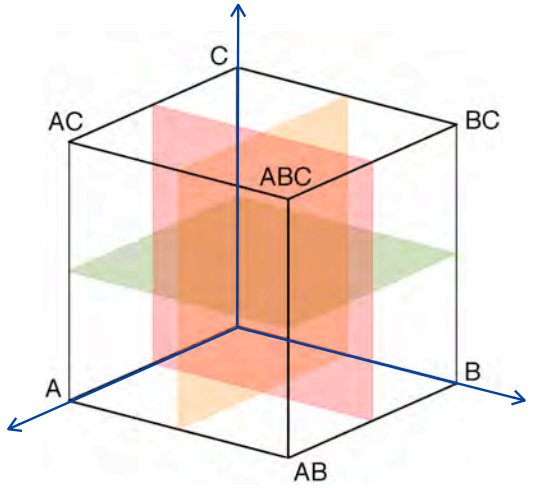
3

optimized compact code (~50%)

Conclusions







Small system

(<100,000 neurons)

Mechanisms

slow dynamics
decorrelation
oscillations: scale of time discretization
simple circuit module
connectivity/combinatorics
bias for segmentation
normalizing gain control
STDP
plasticity of STDP rule

High-level properties

decorrelated
invariant
segmented
categorized