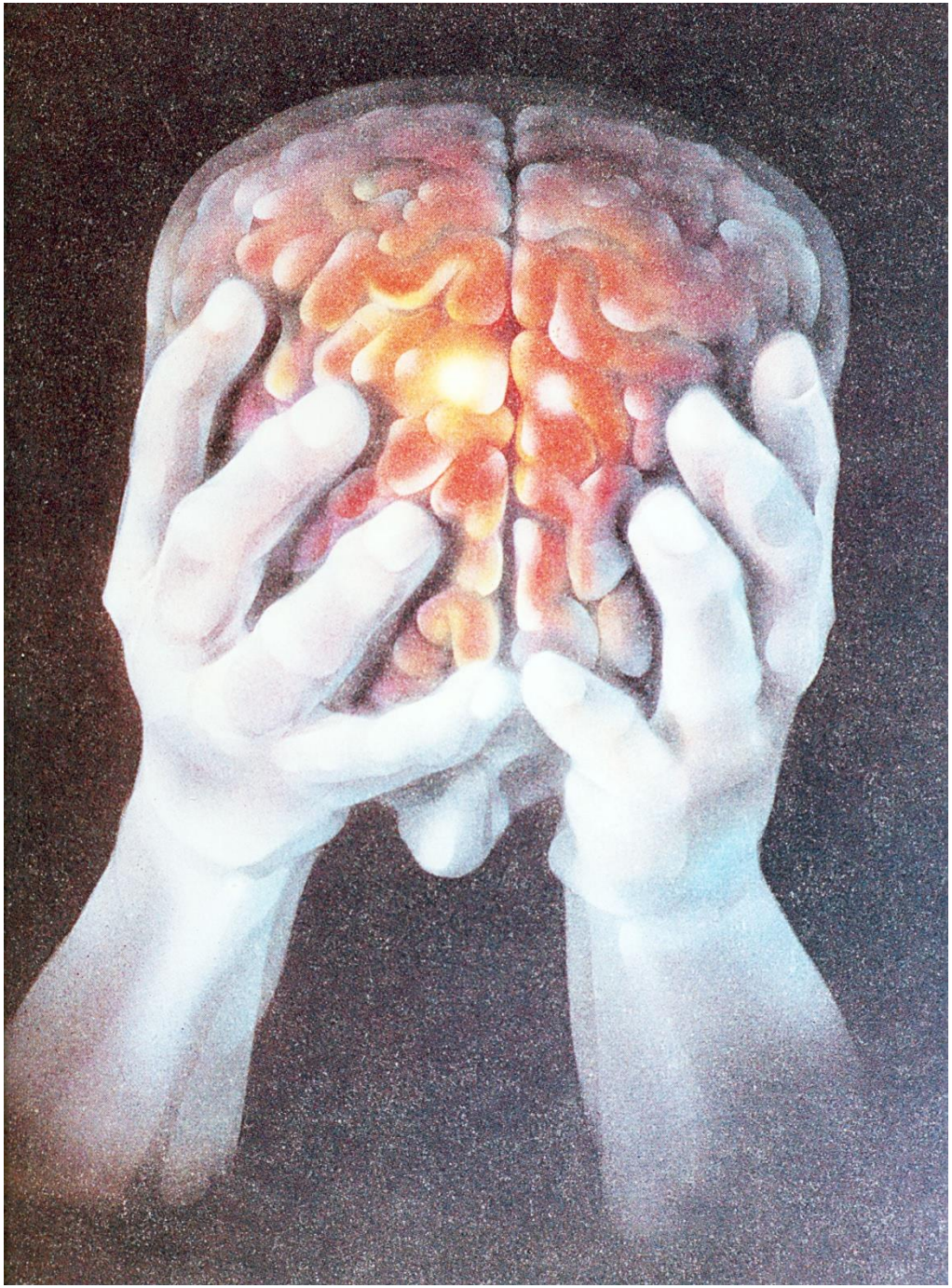
A custom-made brain: how?

Stéphane Molotchnikoff

- Dépt. Sciences Biologiques
  - Université de Montréal

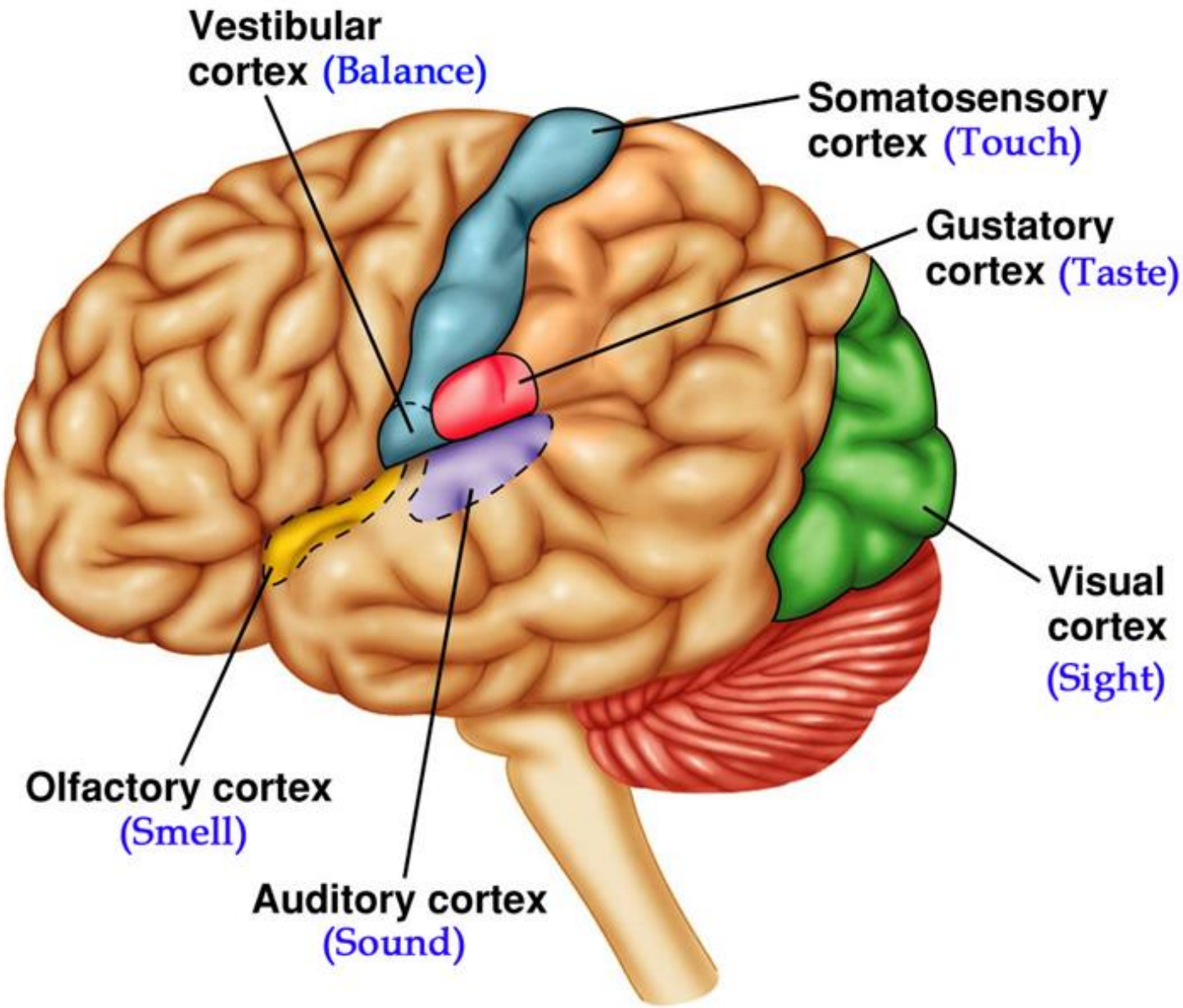
- Dépt Génie Électrique et Génie Informatique
  - Université de Sherbrooke

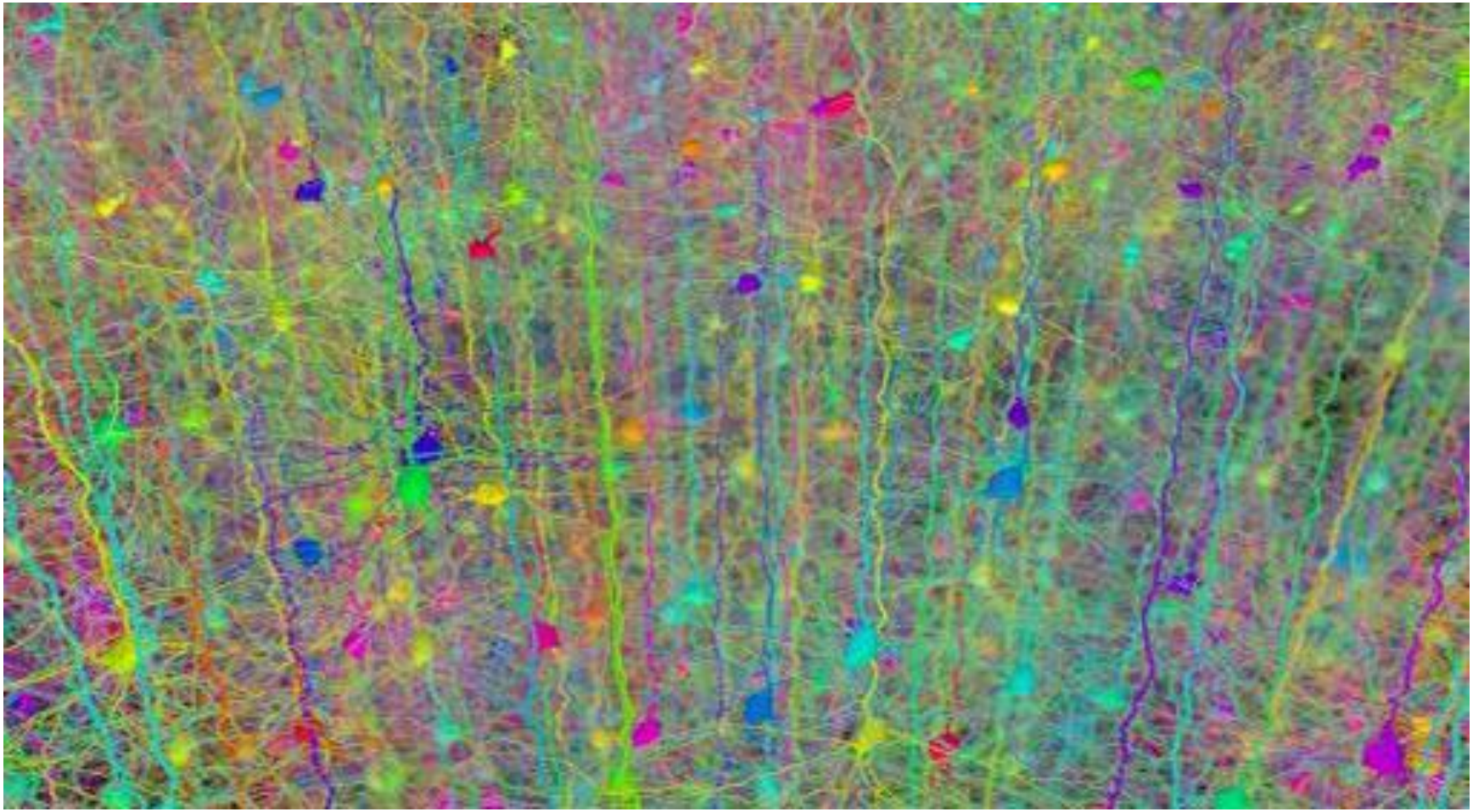
- Canada

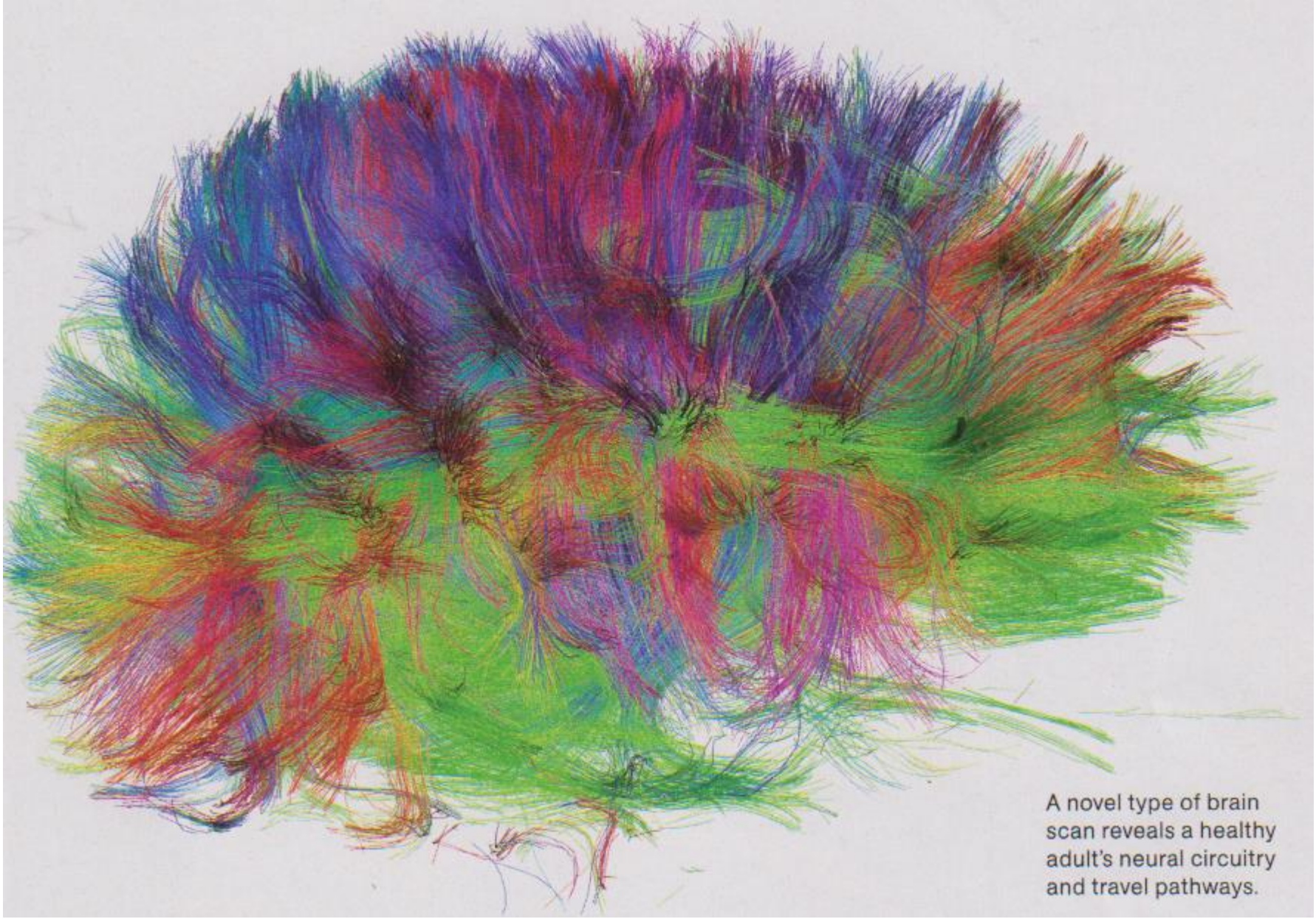


Basic organization

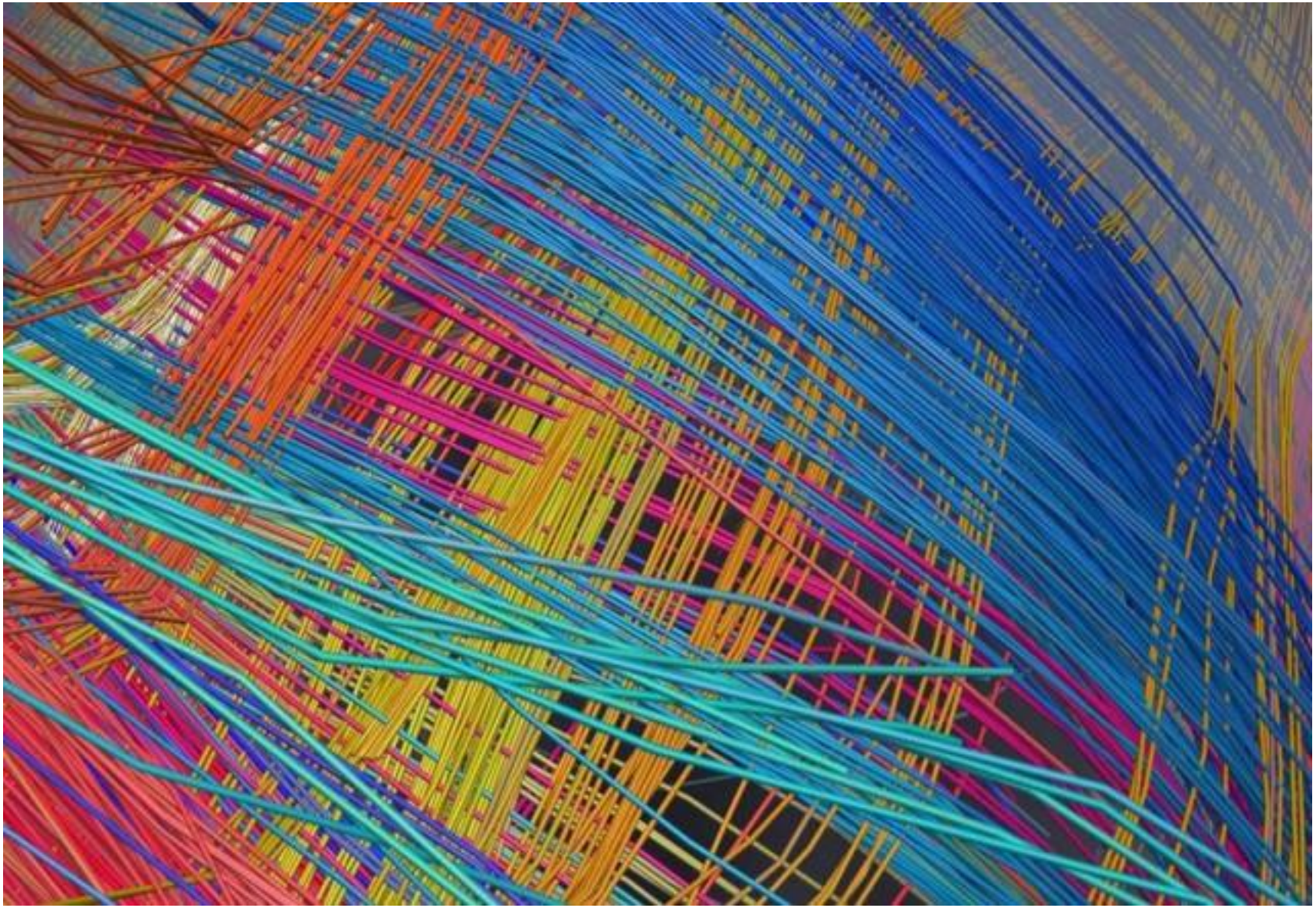
- The odyssey from whole brain to tiny spines

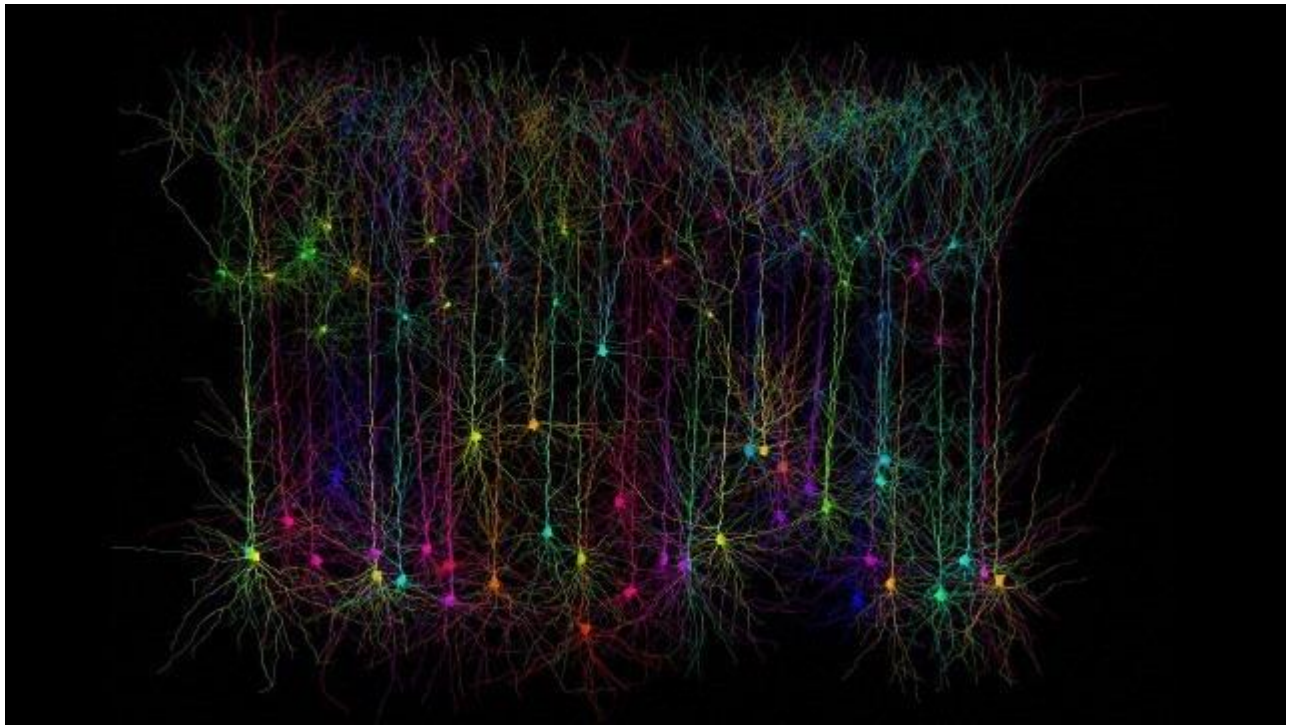


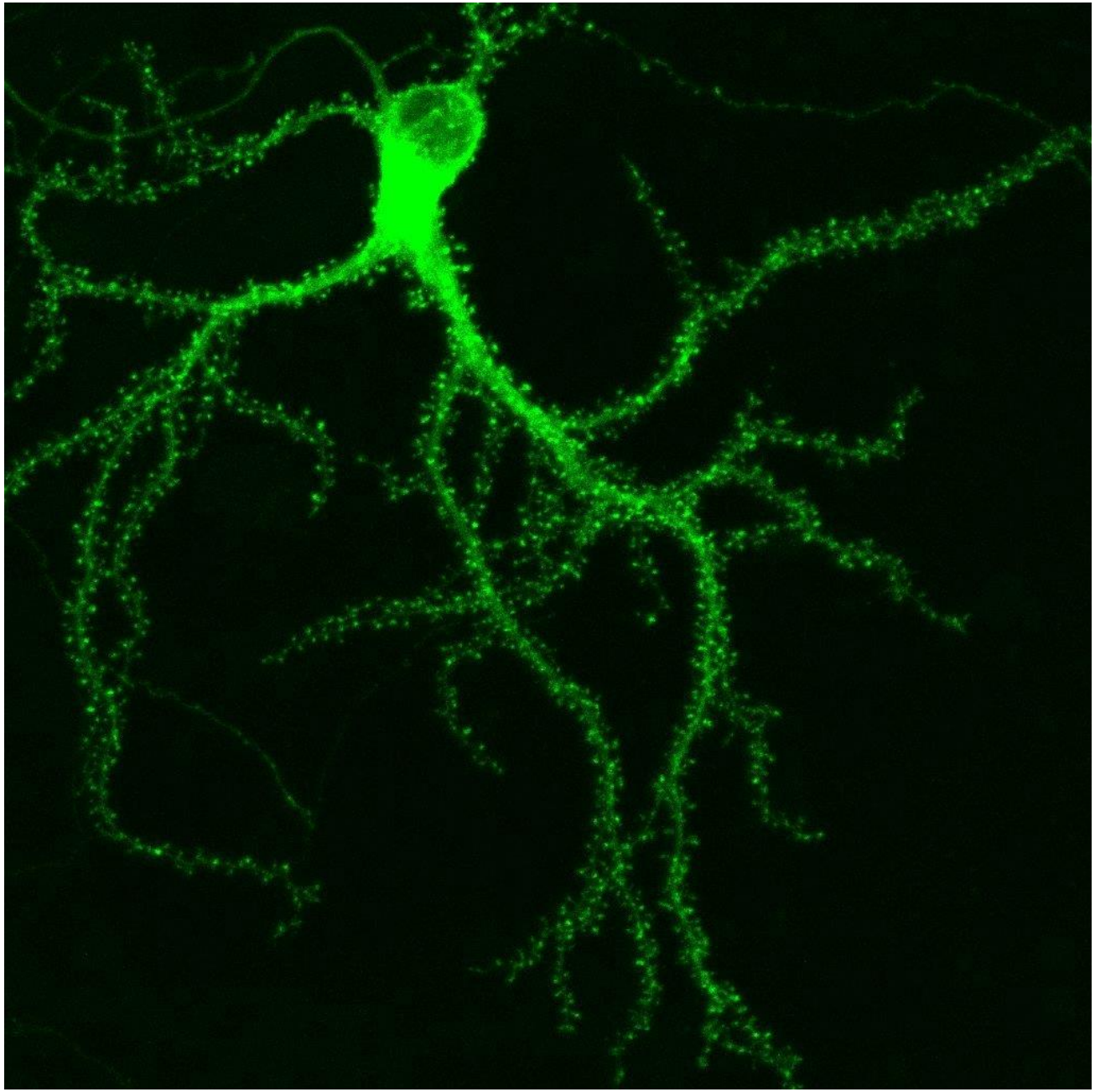


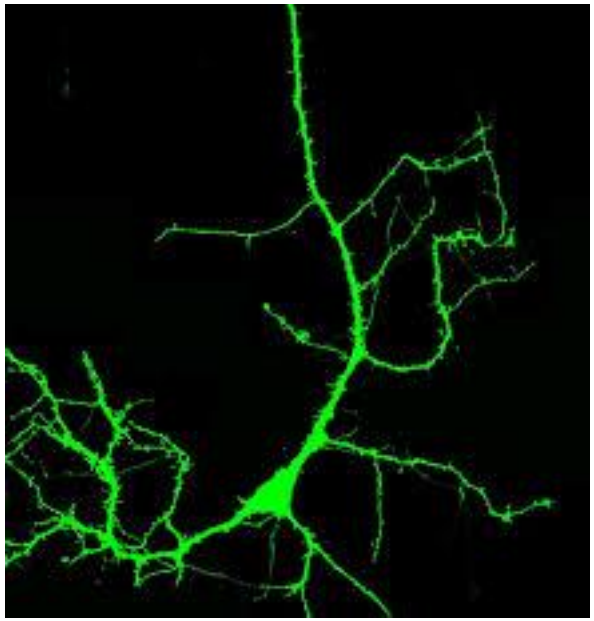


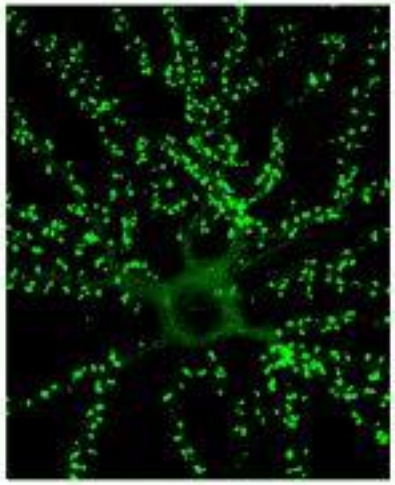
A novel type of brain scan reveals a healthy adult's neural circuitry and travel pathways.

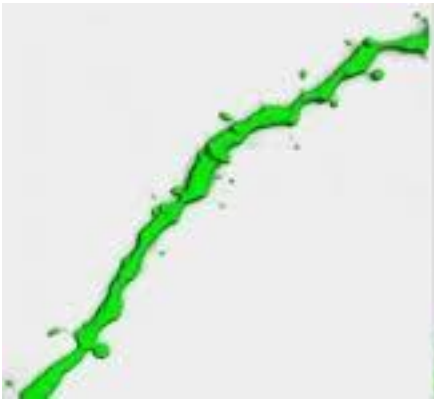


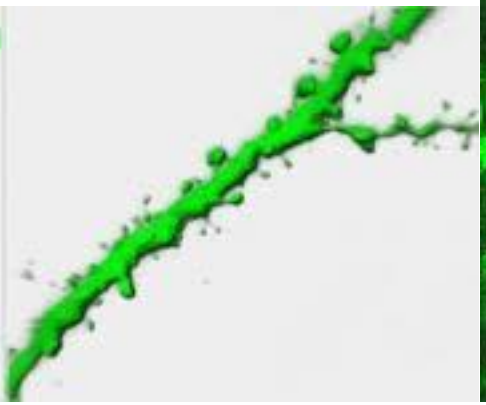


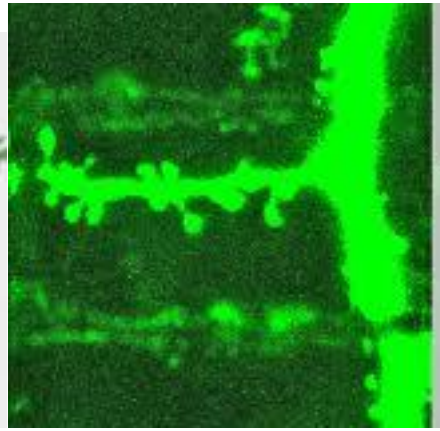






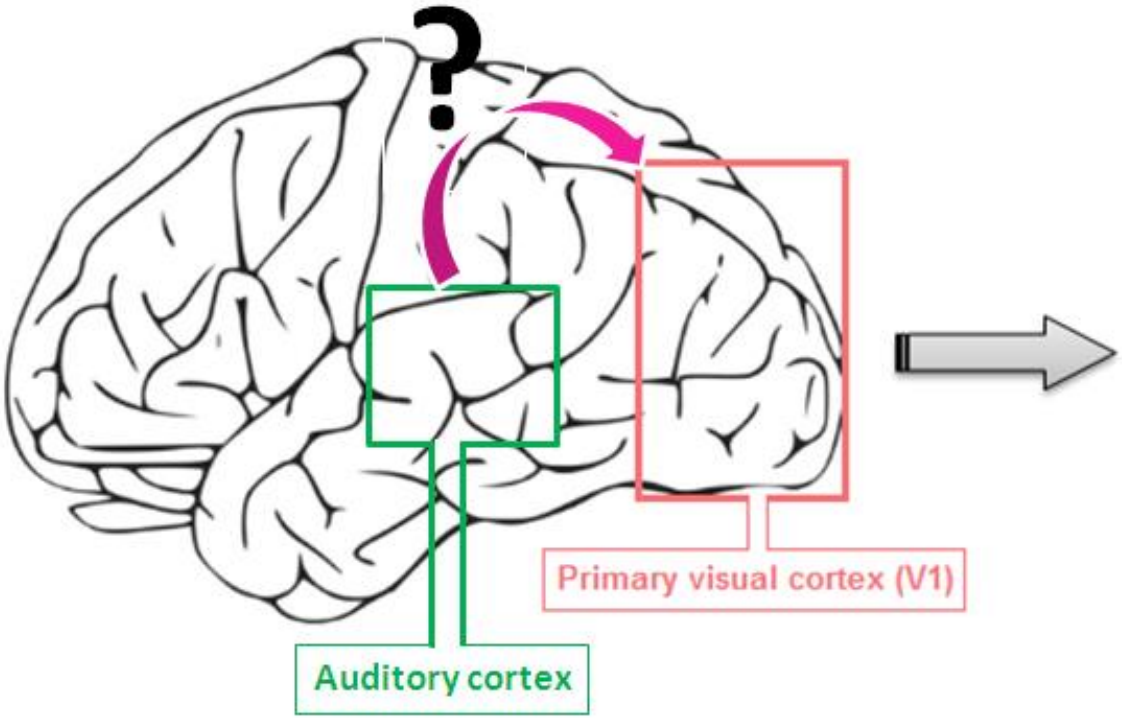


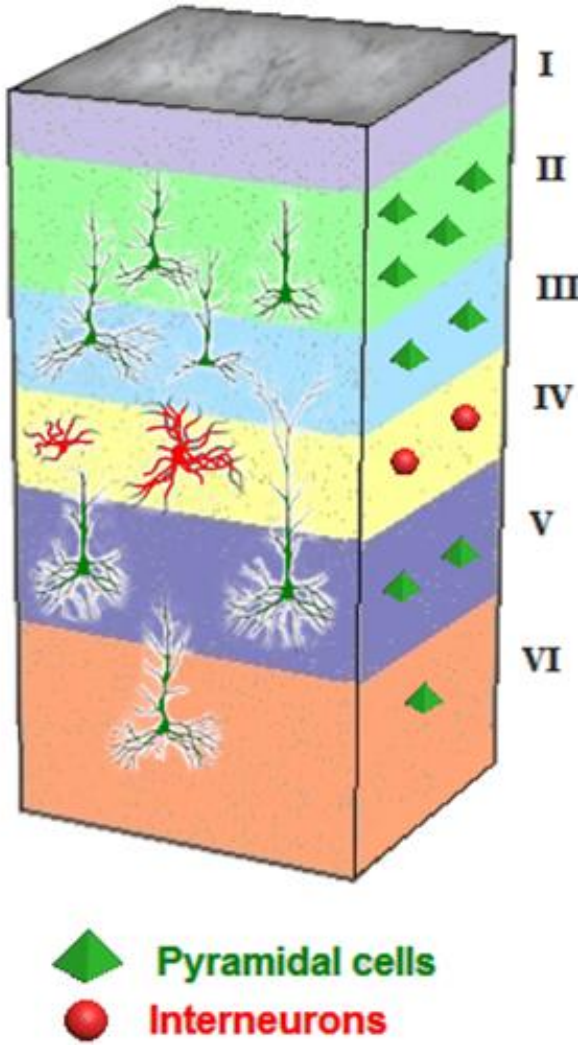




- Neurons are not working in isolation
- The number of connections between them is unimaginable
- Yet all brain processing depends upon these connections

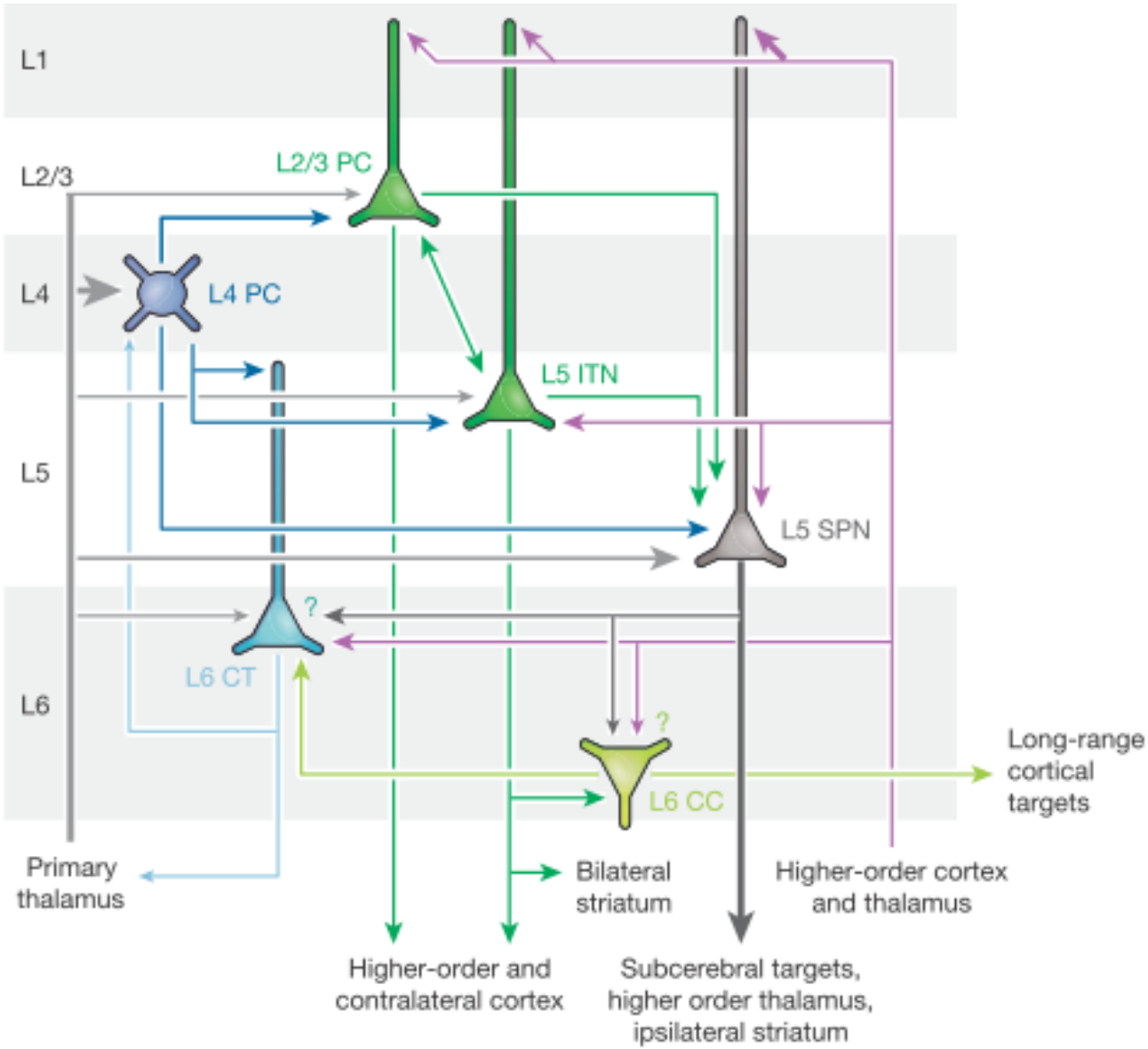
ORGANISATION OF VISUAL CORTEX





Bachatene et al., 2012

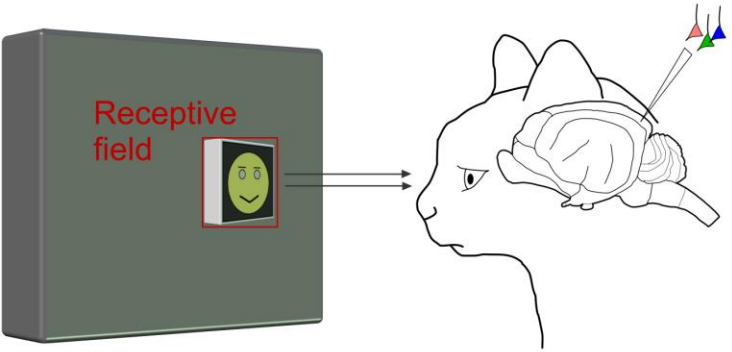
CORTICAL LAYERS INTERACT WITH EACH OTHER

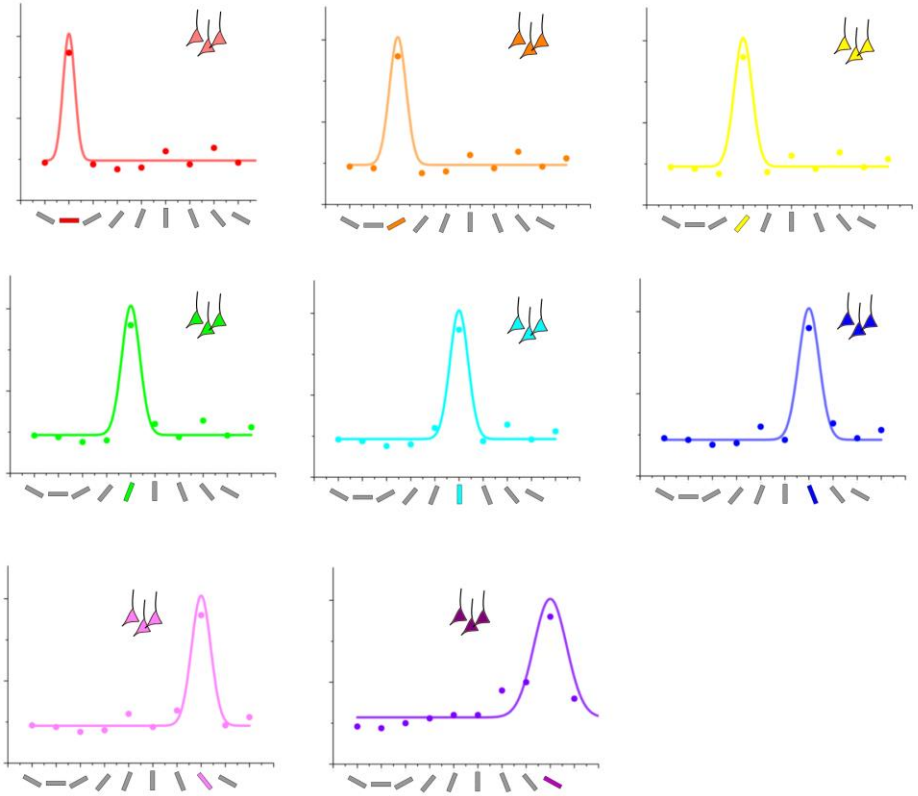


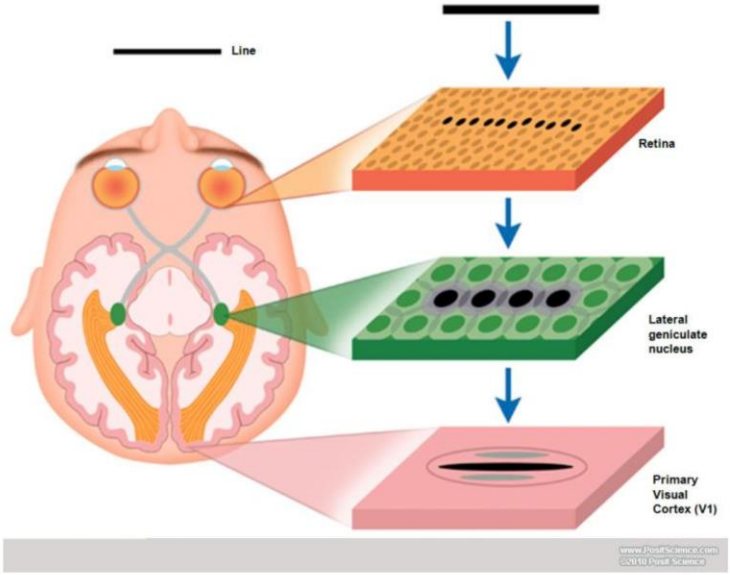
Harris & Flogel, Nature Reviews ,2013

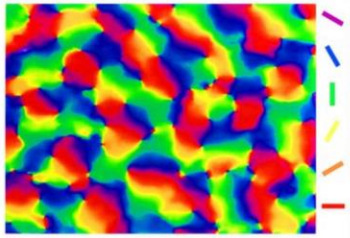
How does the brain process ?

From retina to the visual cortex

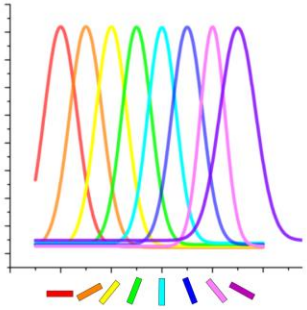


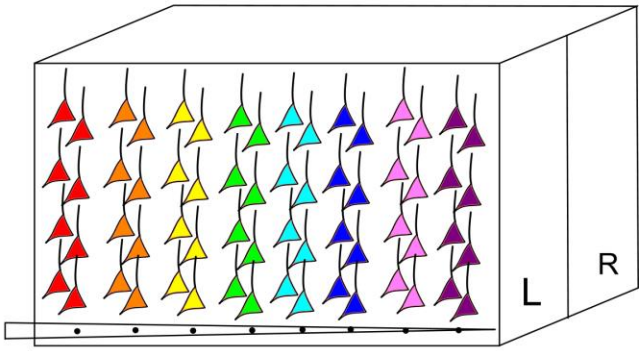




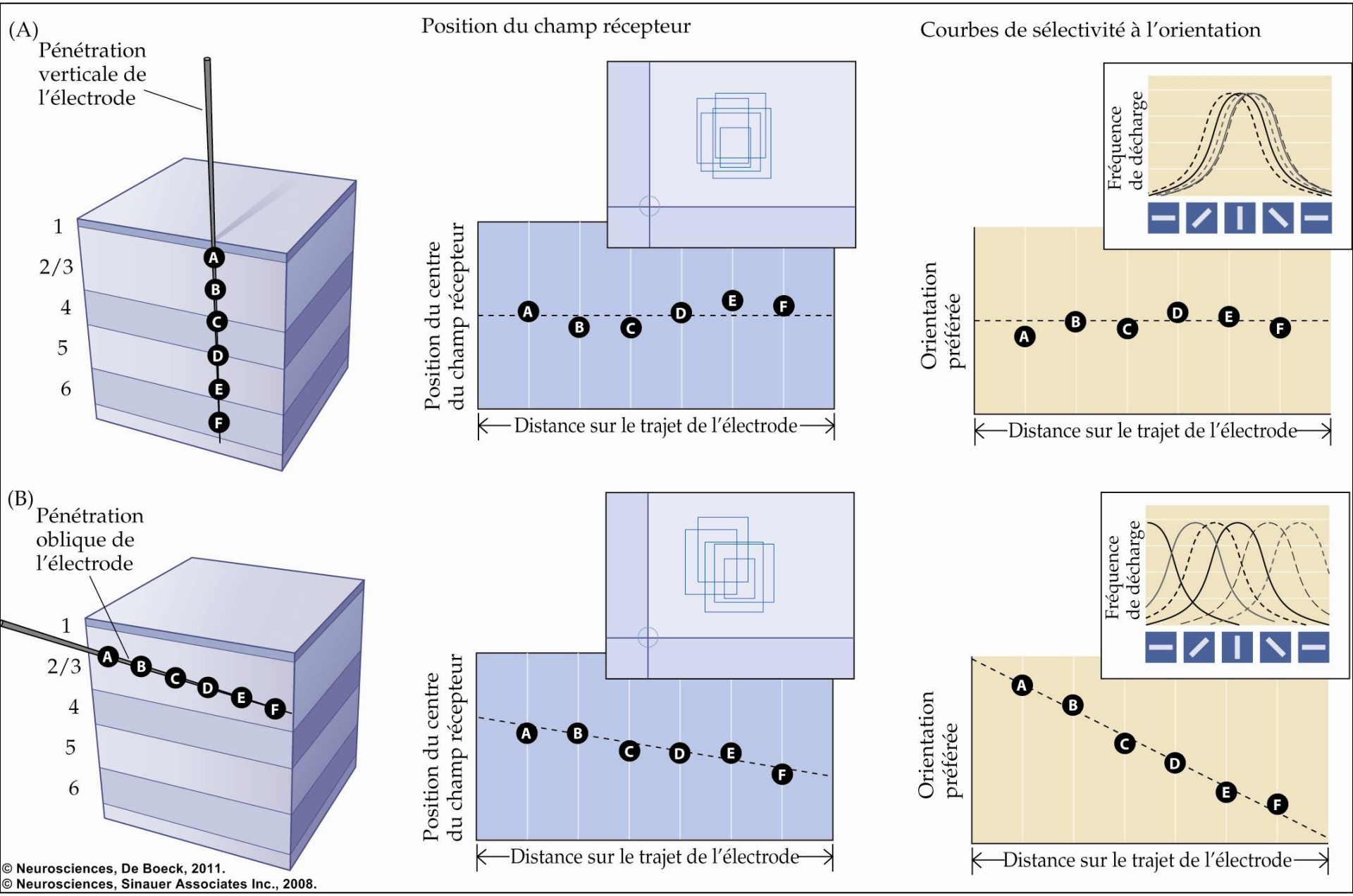


Orientation map

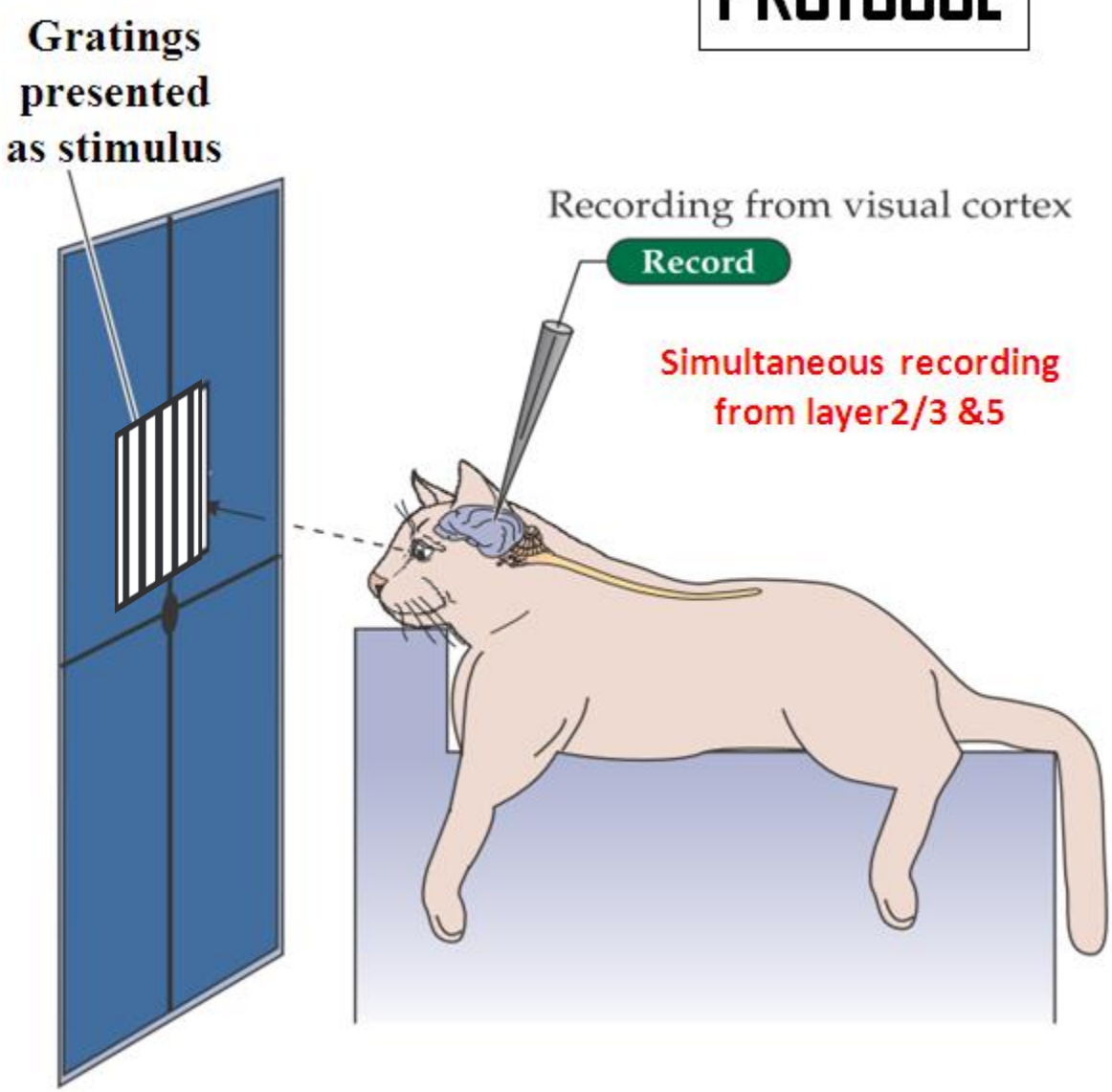


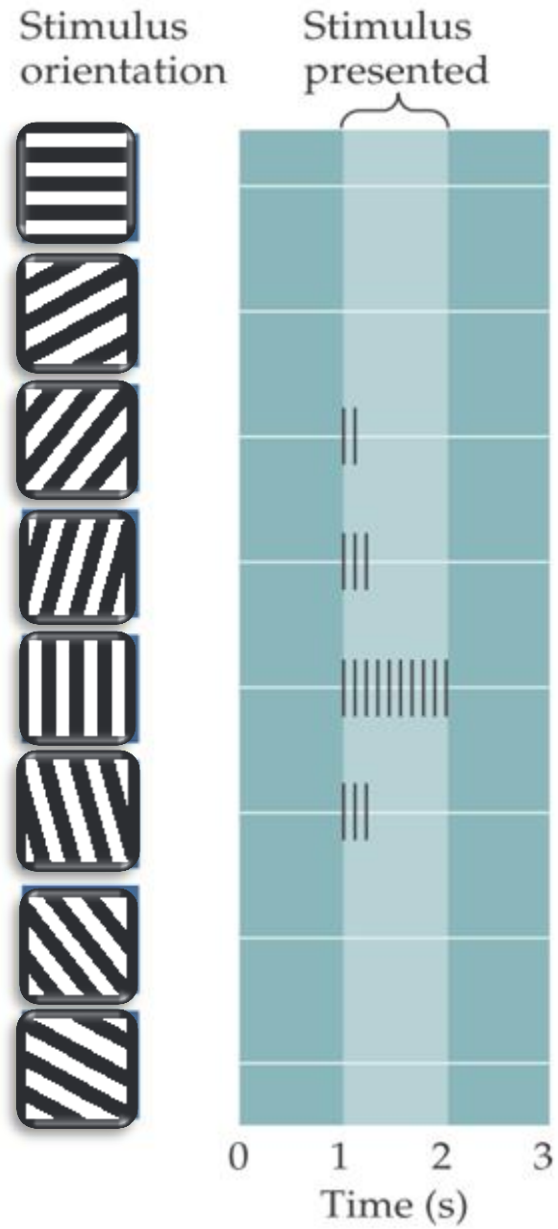


Cortical module



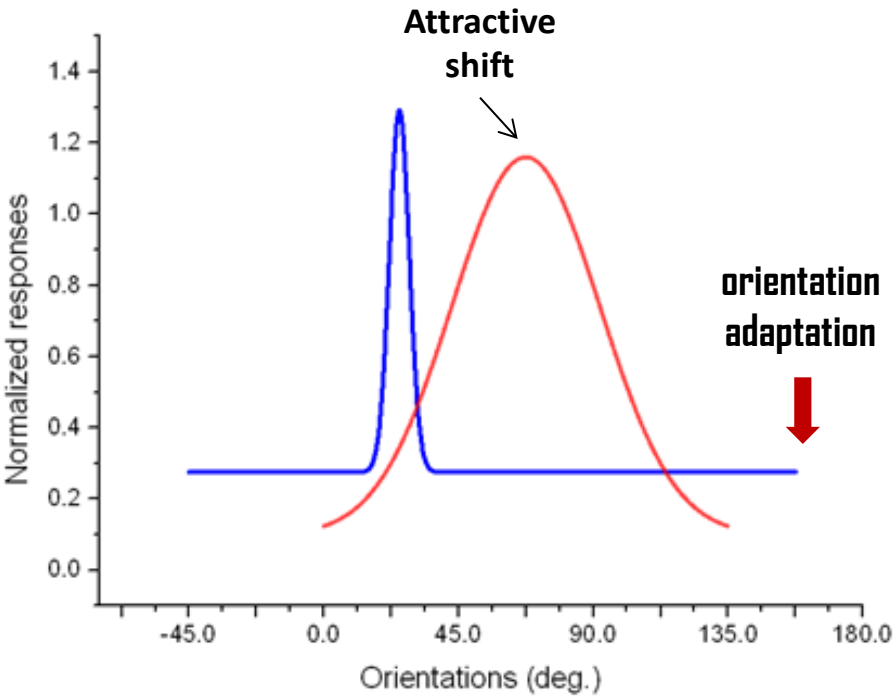
PROTOCOL



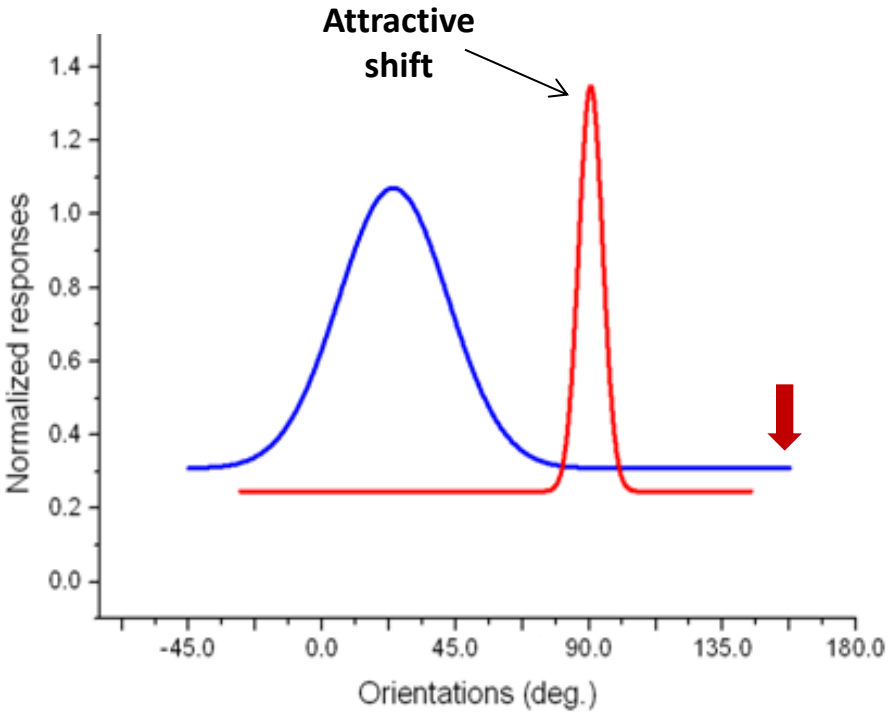


Purves et al., 2004

LAYER 5



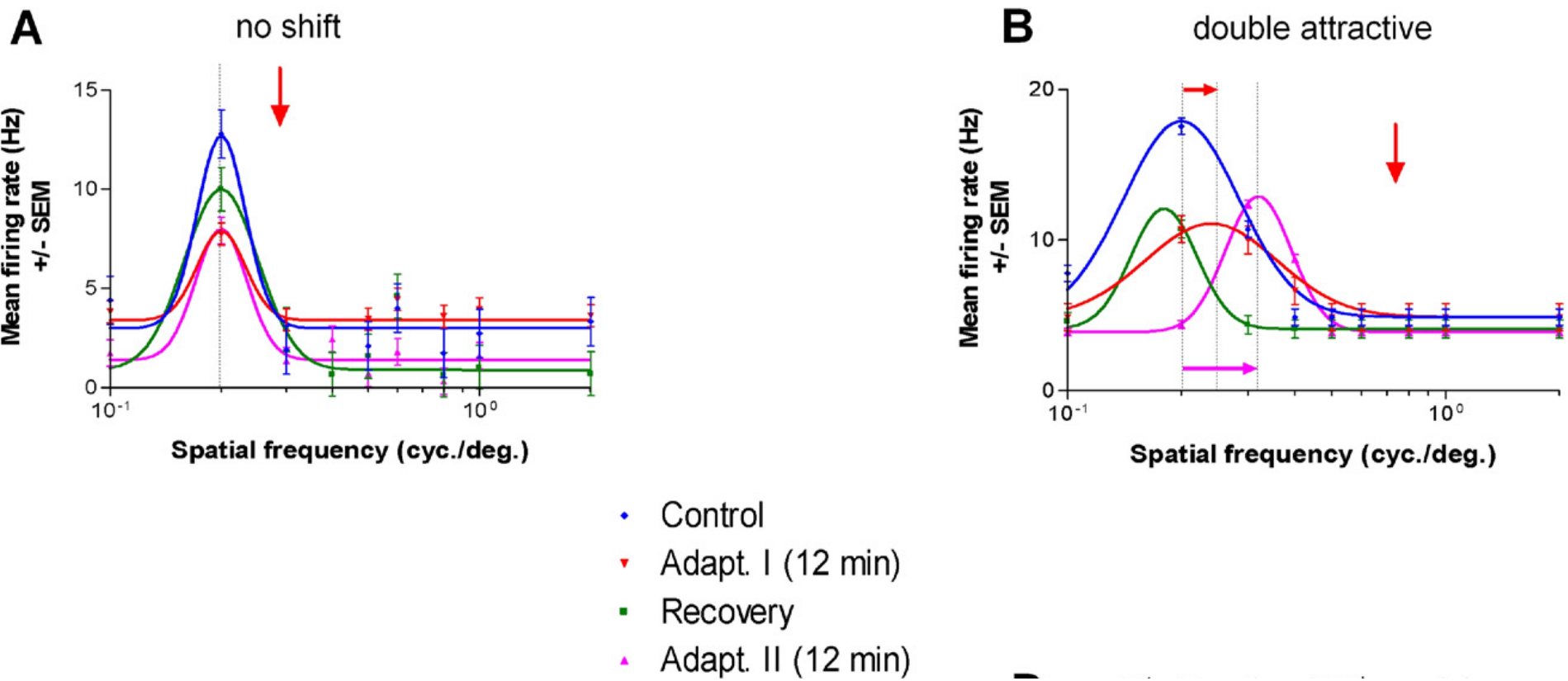
CELL 1



CELL 2

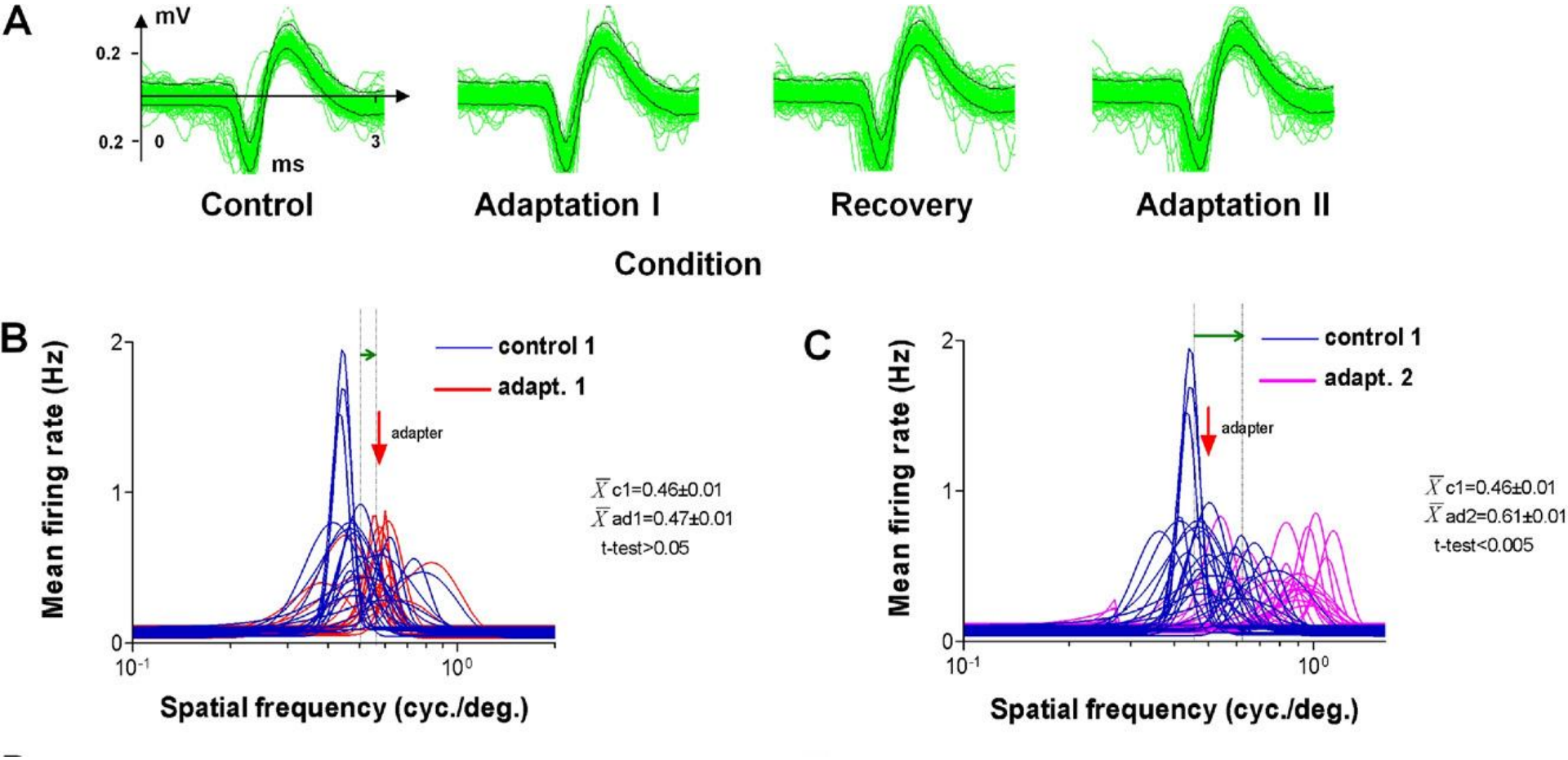
control
postadaptation

Spatial Frequency



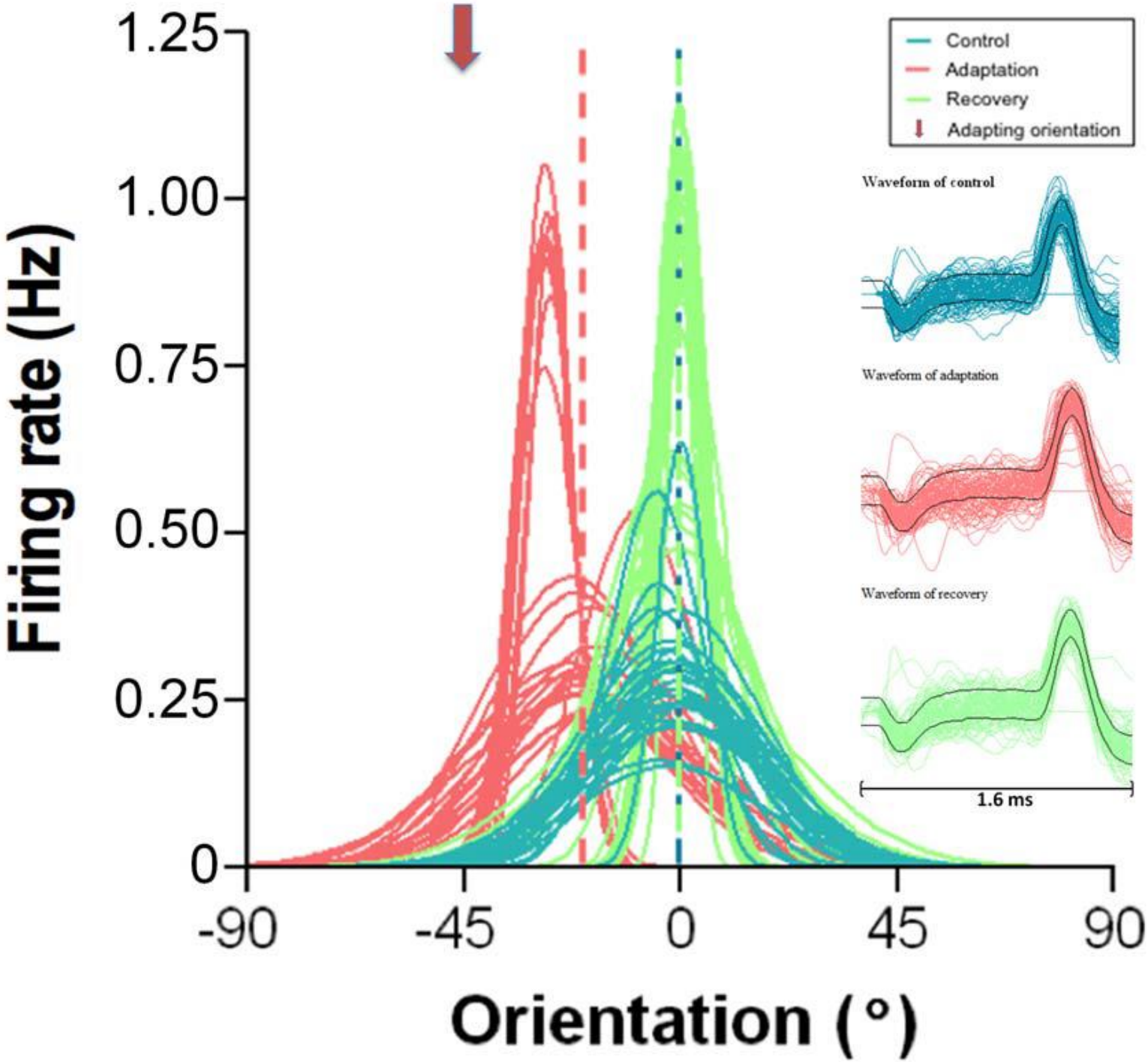
Marschansky et al., Neuroscience 2011

Neurons remember previous adaptation

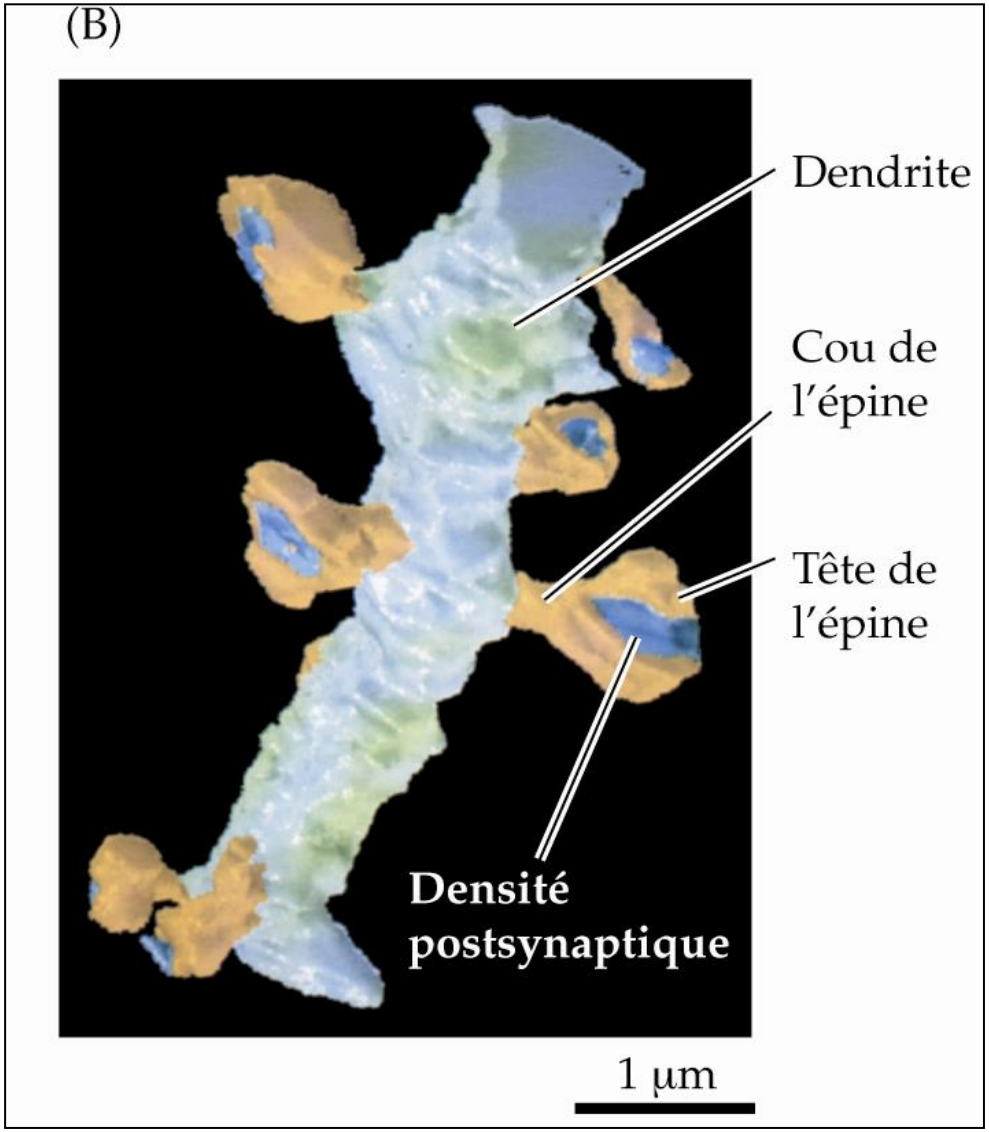


Marschansky et al., Neuroscience 2011

Mouse



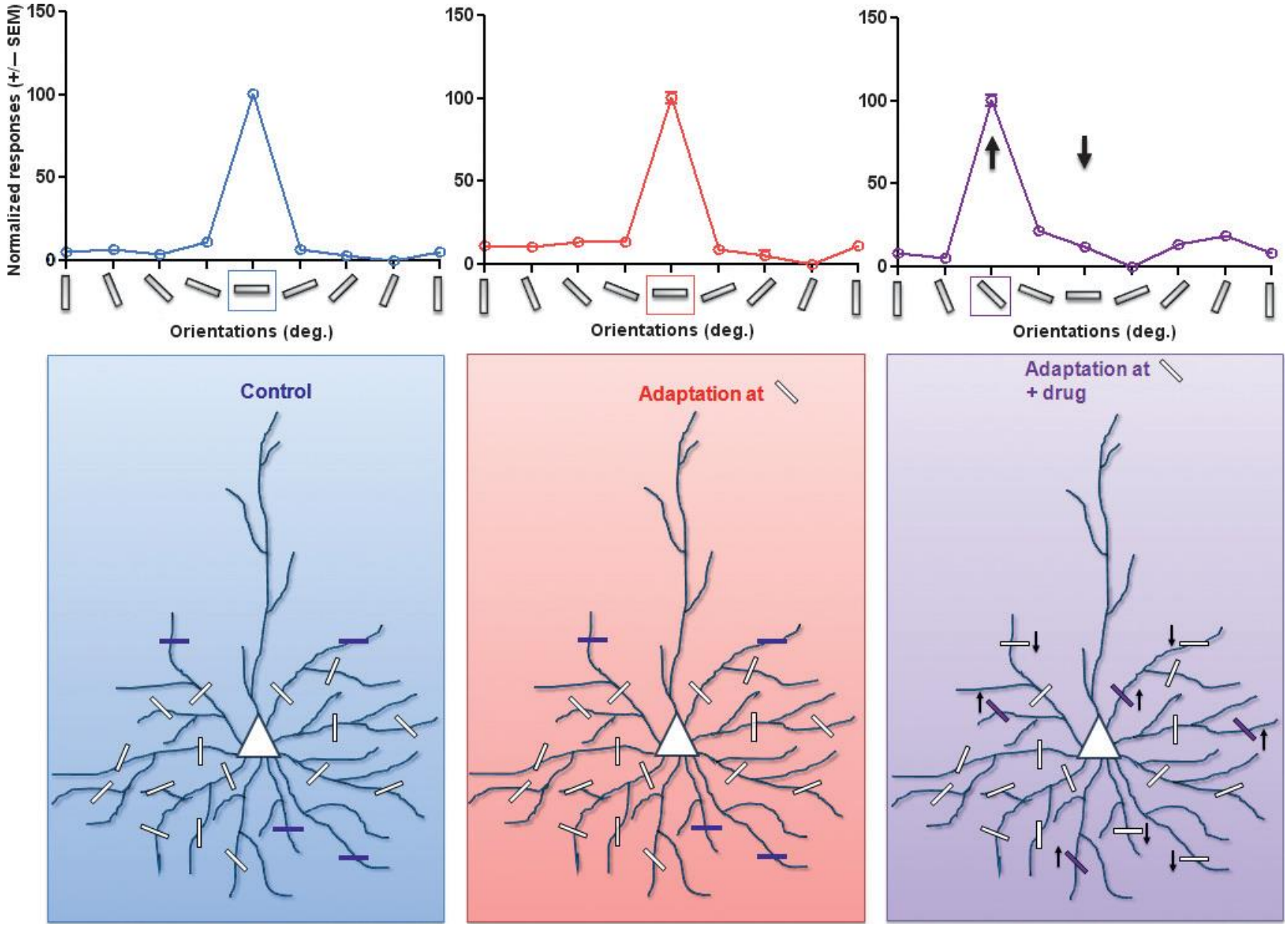
From lab PloS One 2013



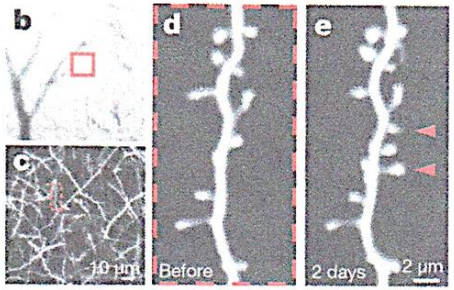
Spine stalk

Spine head

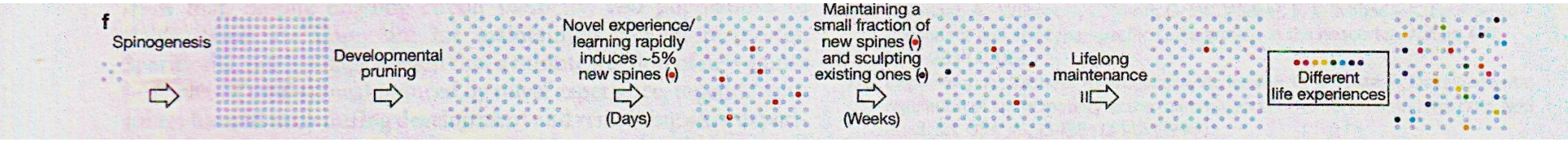
Post synaptique density

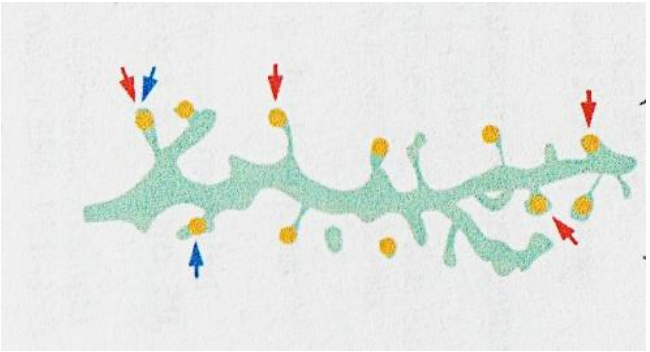

Normalized responses (+/— SEM)
150
100
50
0
Orientations (deg.)
Control
Adaptation at
Adaptation at
+ drug

Yang et al., 2009 Nature let.



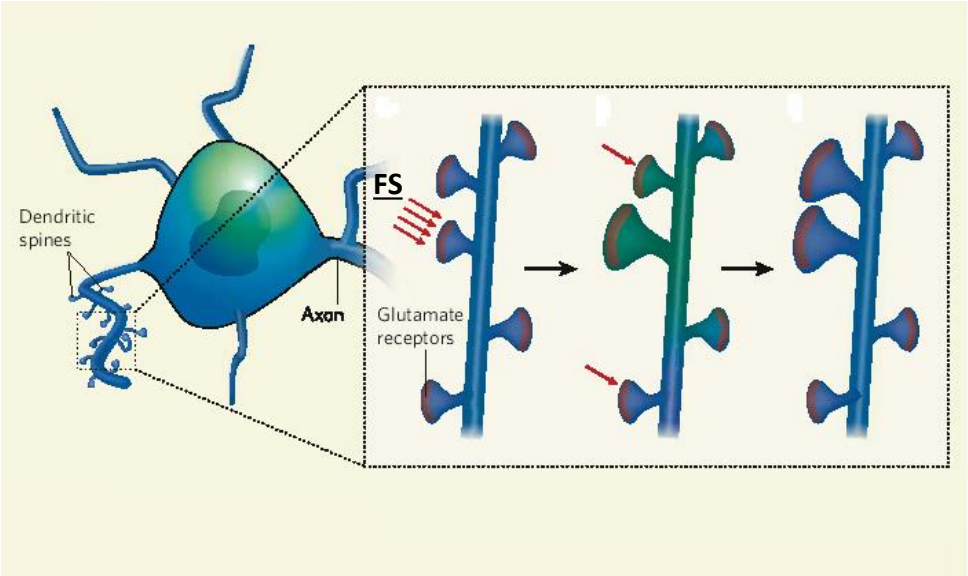
Spine maintenance in different cell types and layers



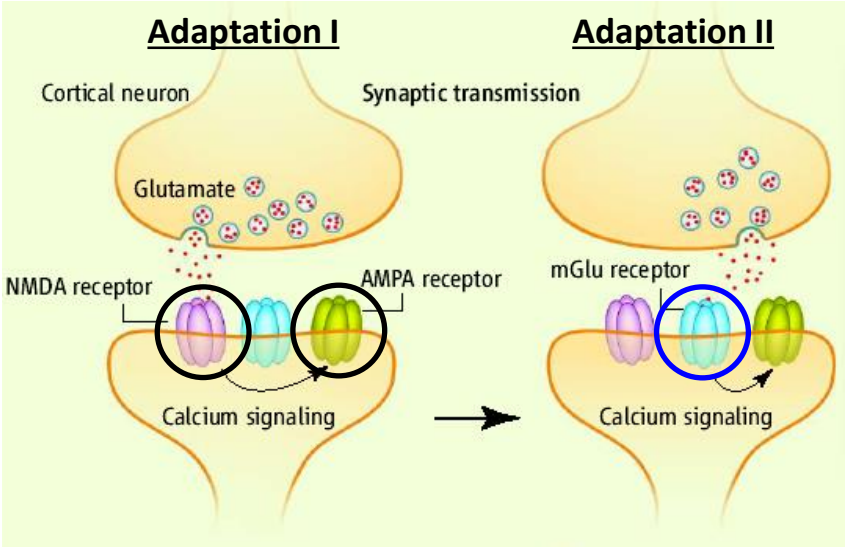


Spine activated by different properties
I.E. same dendrite are highly heteregenous

Chene et al., 2011 Nature let

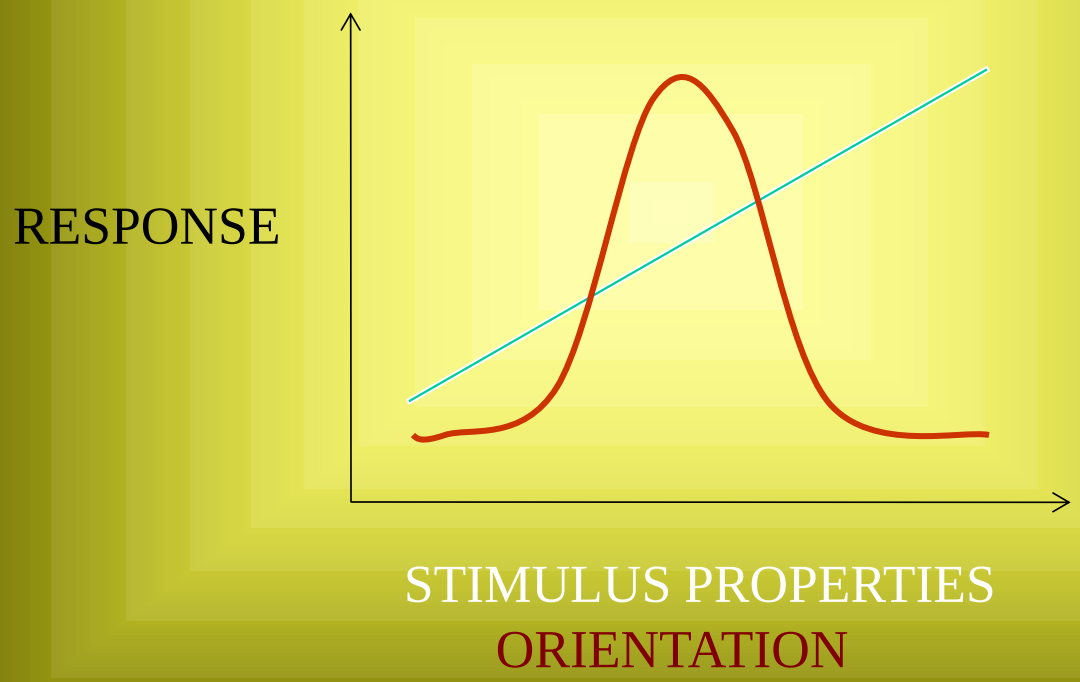


(Sabatini, 2007)



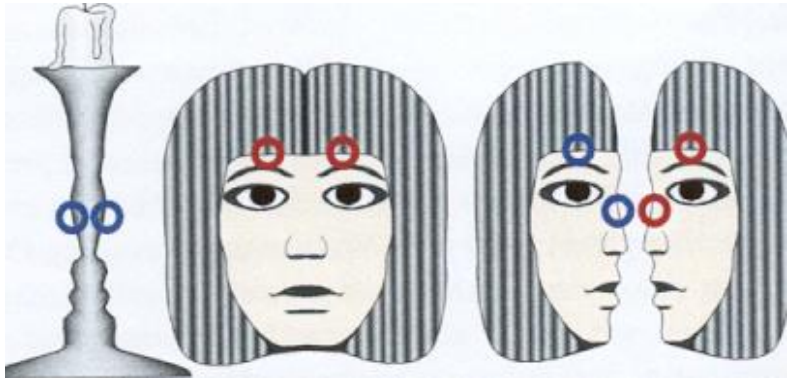
(Brecht et Schmitz. 2008)

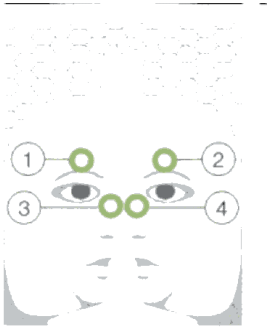
RATE CODE

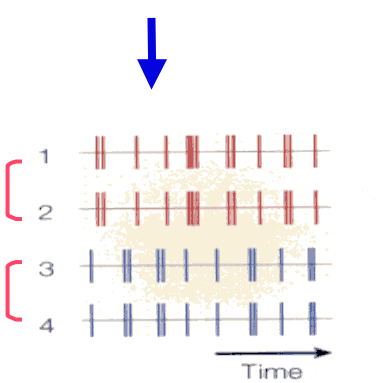


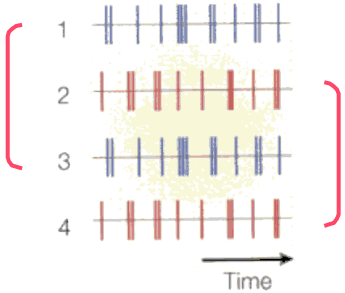
What is mine is mine, what is yours is mine?

1 2

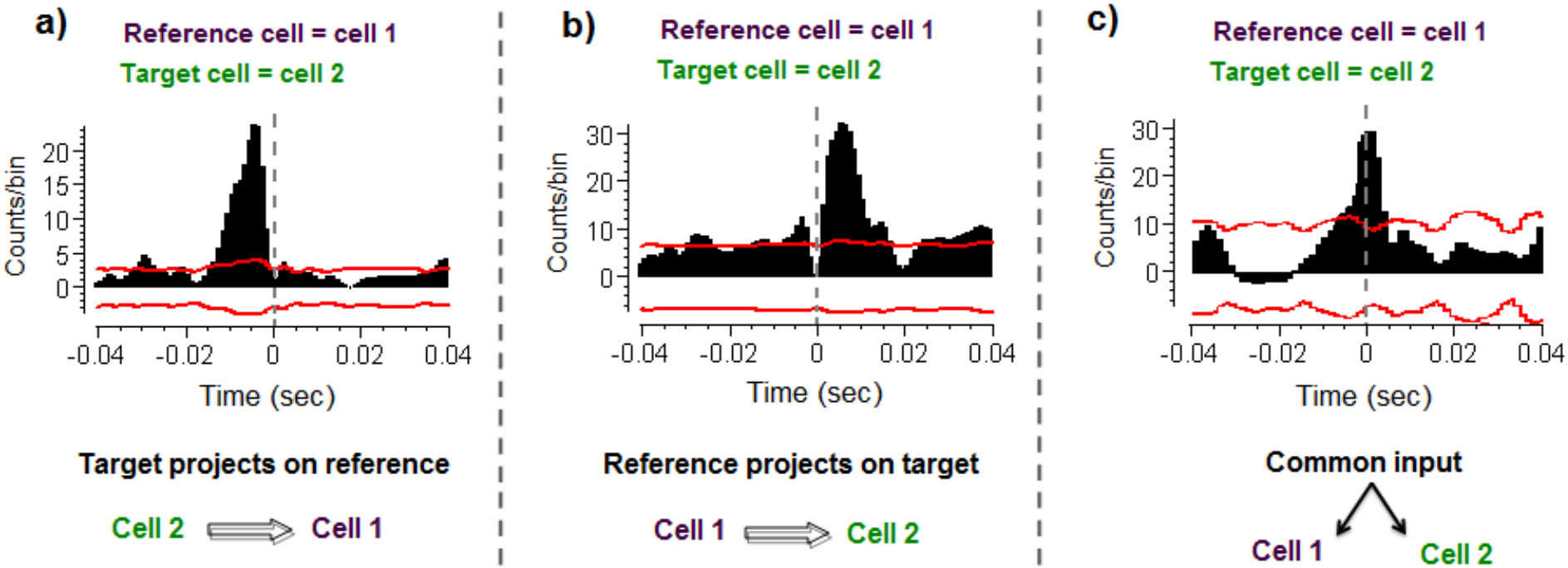


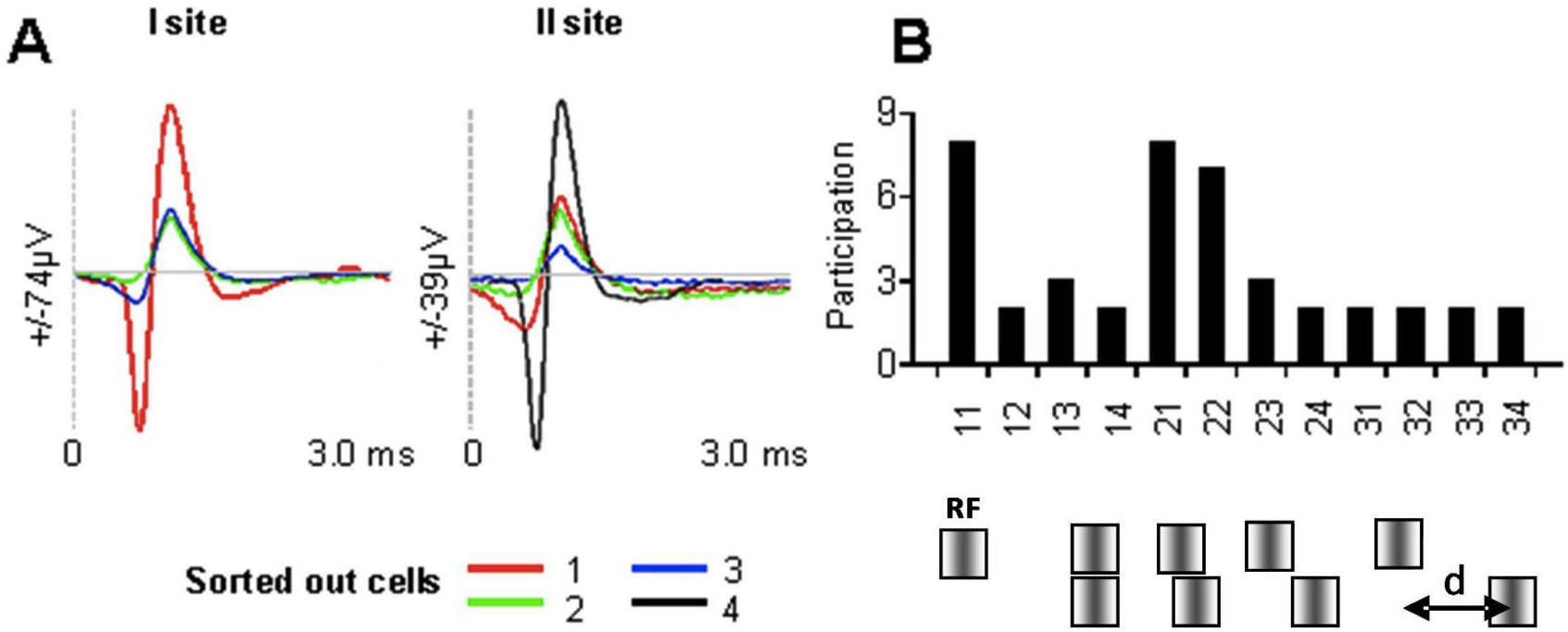






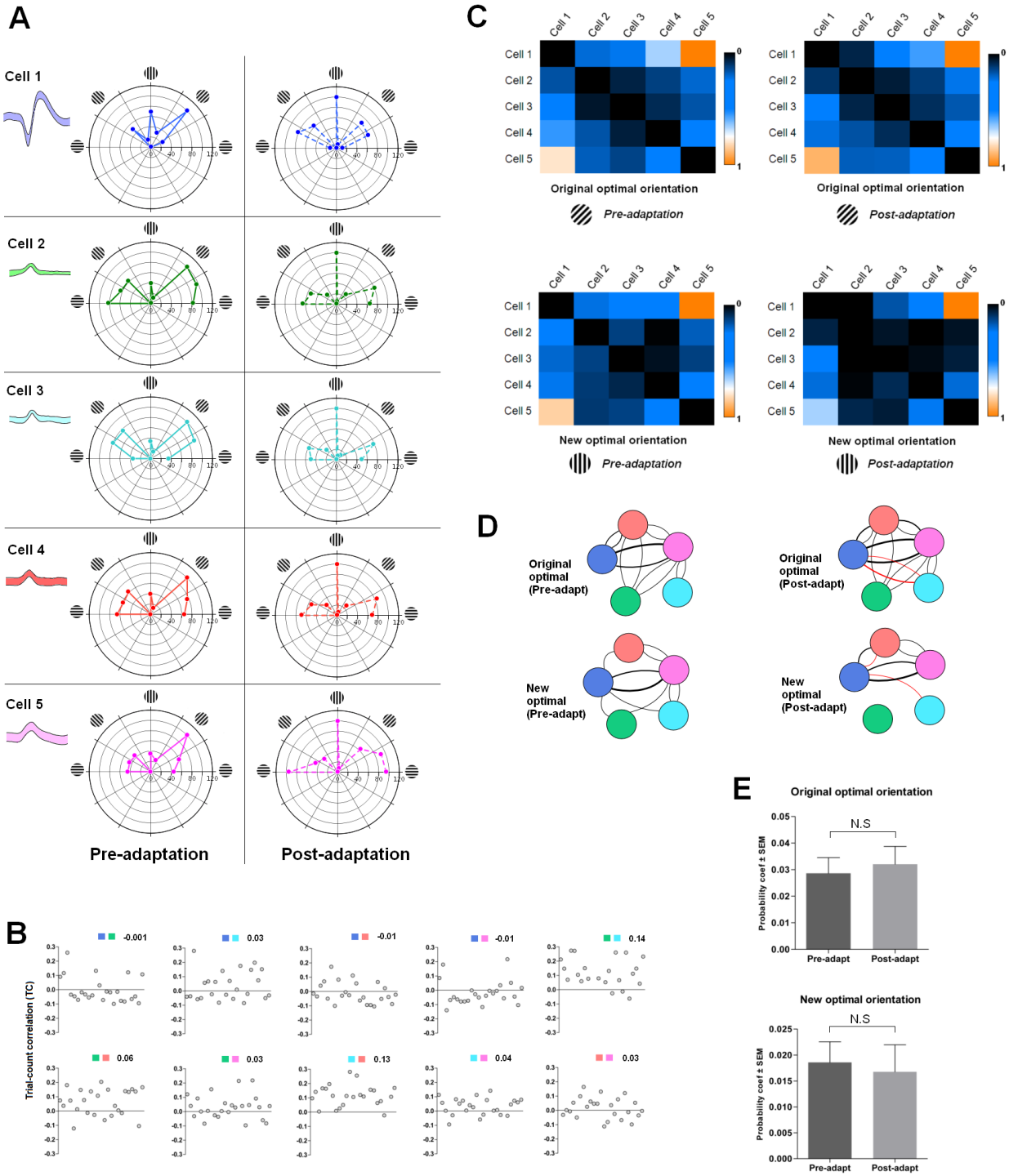
Engel AK., Fries P., Singer W. Nature Rev Vol 2 2001

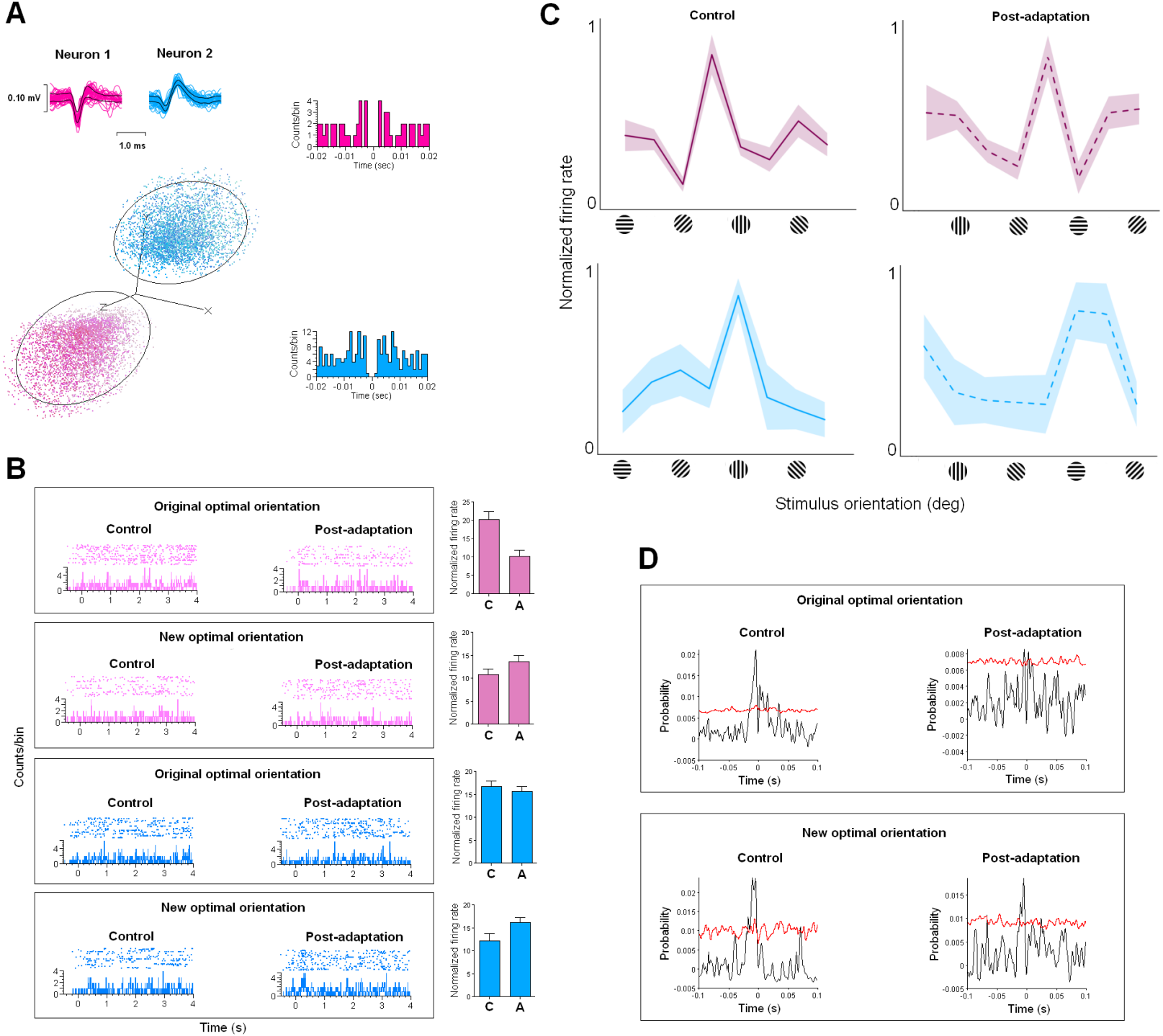

a)
Reference cell = cell 1
Target cell = cell 2
Counts/bin
20
15
10
5
0
-0.04
-0.02
0
0.02
0.04
Time (sec)
Target projects on reference
Cell 2
Cell 1
b)
Reference cell = cell 1
Target cell = cell 2
Counts/bin
30
20
10
0
-0.04
-0.02
0
0.02
0.04
Time (sec)
Reference projects on target
Cell 1
Cell 2
c)
Reference cell = cell 1
Target cell = cell 2
Counts/bin
30
20
10
0
-0.04
-0.02
0
0.02
0.04
Time (sec)
Common input
Cell 1
Cell 2

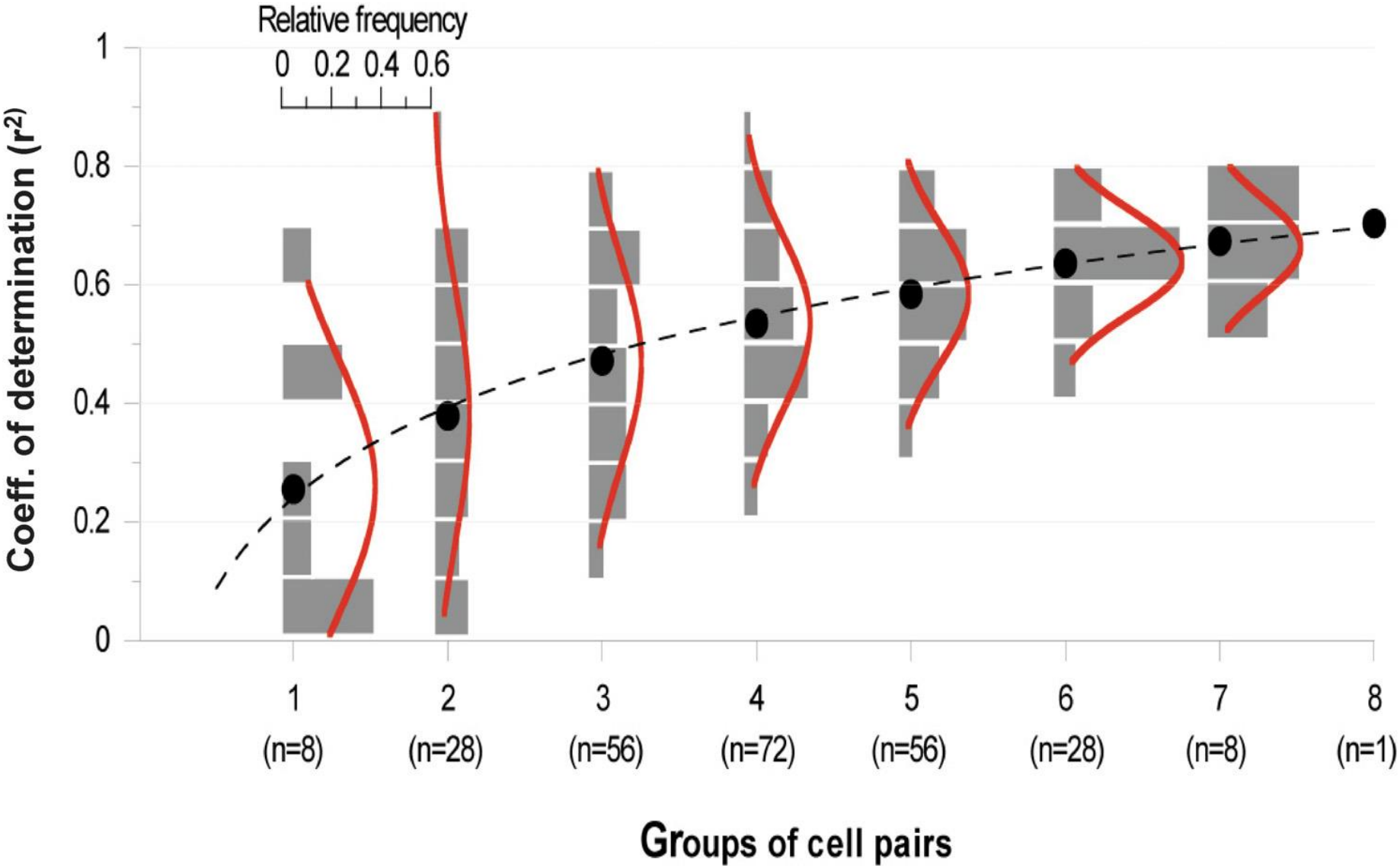

A
I site
II site
+/-74µV
+/-39µV
0
3.0 ms
0
3.0 ms
Sorted out cells
1
2
3
4
B
Participation
9
6
3
0
11
12
13
14
21
22
23
24
31
32
33
34
RF
d

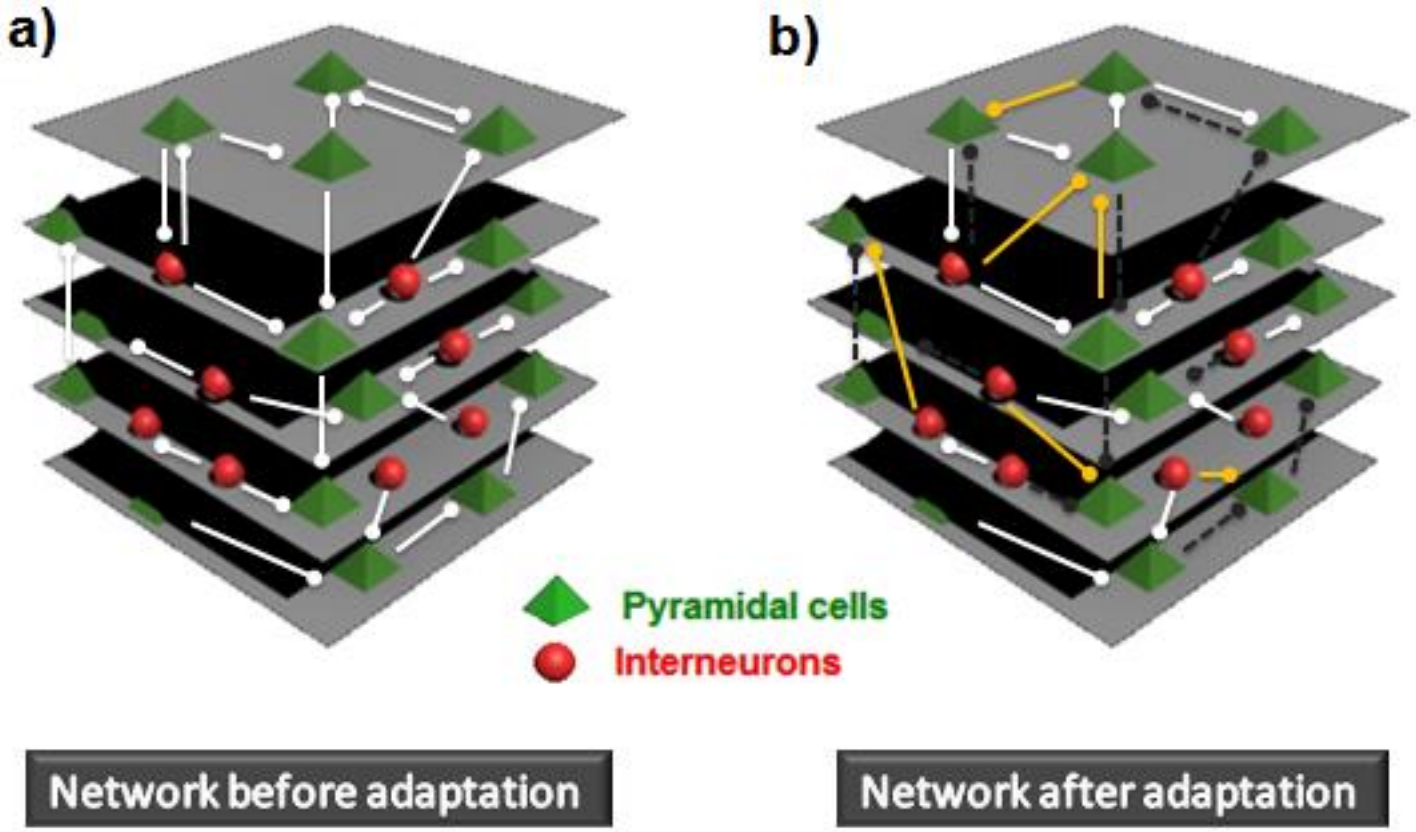
- Two basic mechanisms:

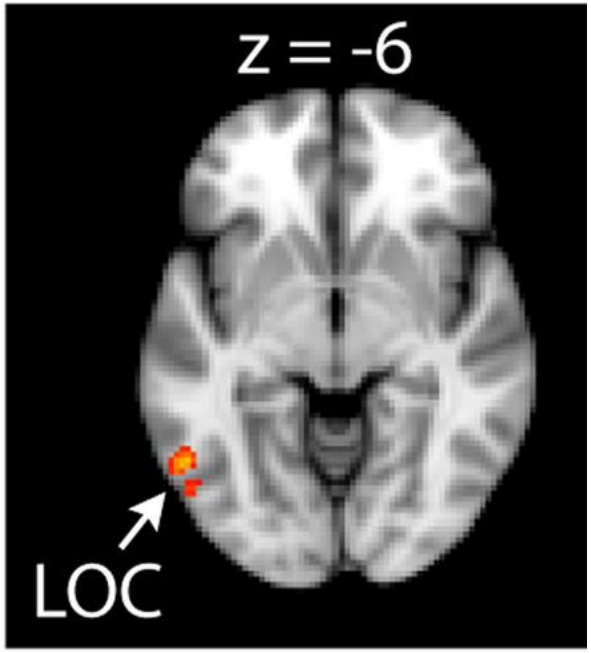
- The brain possess a cardinal cell that integrates the entire subject with the help of memory
- Or the brain establishes an encoding assembly that is based on time relationships between trains of action potentials


A
Cell 1
Cell 2
Cell 3
Cell 4
Cell 5
Pre-adaptation
Post-adaptation
B
Trial-count correlation (TC)
-0.001
0.03
-0.01
-0.01
0.14
0.06
0.03
0.13
0.04
0.03
C
Original optimal orientation
Pre-adaptation
Post-adaptation
New optimal orientation
D
Original optimal (Pre-adapt)
Original optimal (Post-adapt)
New optimal (Pre-adapt)
New optimal (Post-adapt)
E
Original optimal orientation
N.S
Probability coef ± SEM
Pre-adapt
Post-adapt
New optimal orientation


A
Neuron 1
Neuron 2
0.10 mV
1.0 ms
Counts/bin
Time (sec)
B
Original optimal orientation
New optimal orientation
Control
Post-adaptation
Counts/bin
Normalized firing rate
C
A
Time (s)
C
Control
Post-adaptation
Normalized firing rate
Stimulus orientation (deg)
D
Original optimal orientation
New optimal orientation
Control
Post-adaptation
Probability
Time (s)


Relative frequency
0 0.2 0.4 0.6
Coeff. of determination (r^2)
1
0.8
0.6
0.4
0.2
0
1 (n=8)
2 (n=28)
3 (n=56)
4 (n=72)
5 (n=56)
6 (n=28)
7 (n=8)
8 (n=1)
Groups of cell pairs

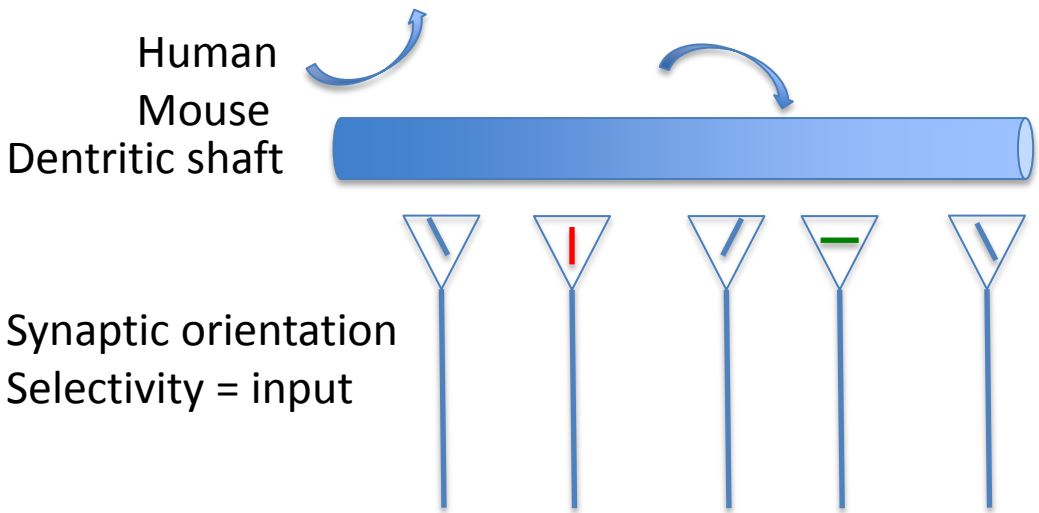

a)
b)
Pyramidal cells
Interneurons
Network before adaptation
Network after adaptation

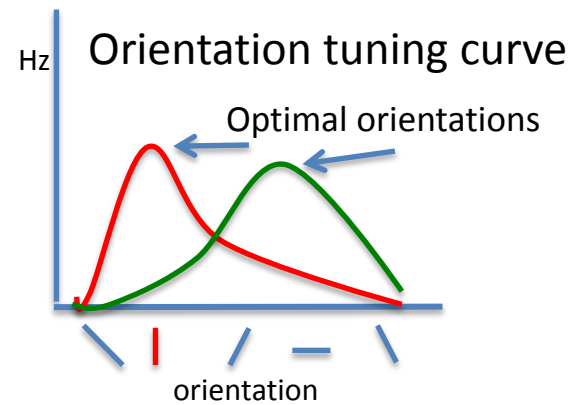


Functional reorganization of cortical activity can occur within minutes of neural disruption to maintain cognitive abilities.

To compensate for neural disruption by rapidly reorganizing cortical activity, notably the capacity to recruit neural areas for tasks in which they are not otherwise used.

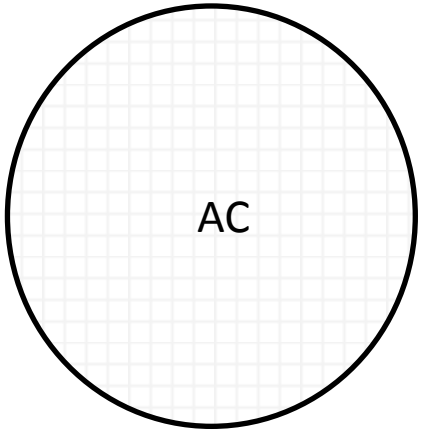
Zanto et al., J.Neurosci 2013



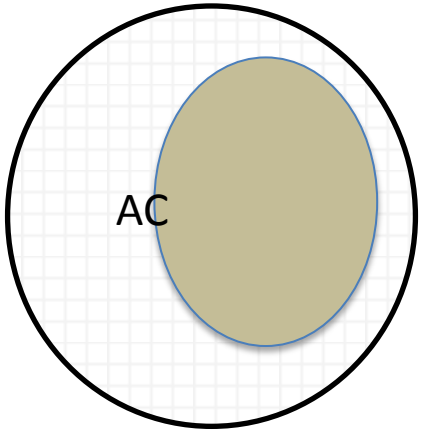


Orientation selectivity = preferred (optimal) orientation depends upon strongest synaptic drive

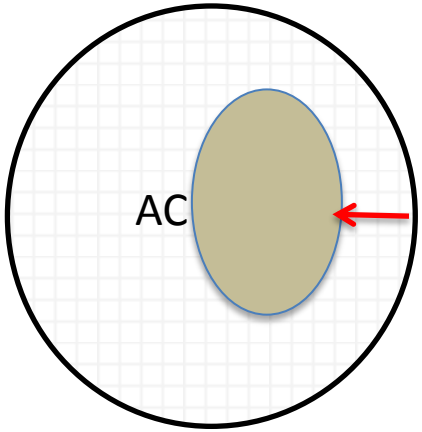
Normal Visual field



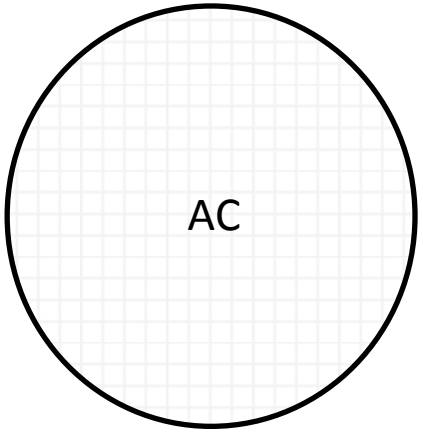
Accident = Blind spot



Training = Blind spot diminishes



Recovery



Ref

Acknowledgements

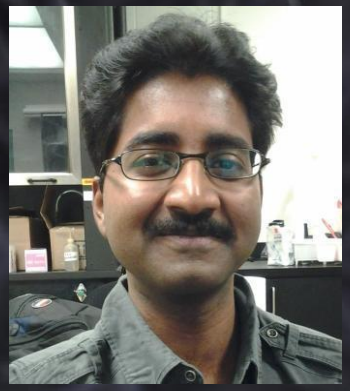
Dr. S. Molotchnikoff

Dr. J Rouat

L. Bachatene

S. Cattan

Nayan Chanauria



J. Jeyabalaratnam

NSERC CRSNG

Fonds de recherche sur la nature et les technologies Québec

NECOTIS

http://www.gel.usherbrooke.ca/necotis