

The visual system of rodents:
How are neuronal networks in the visual cortex
changed by visual experience?

Part II

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28 January 2016

Coach: Stefan Rotter

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Why the visual cortex?

Orientation Selectivity

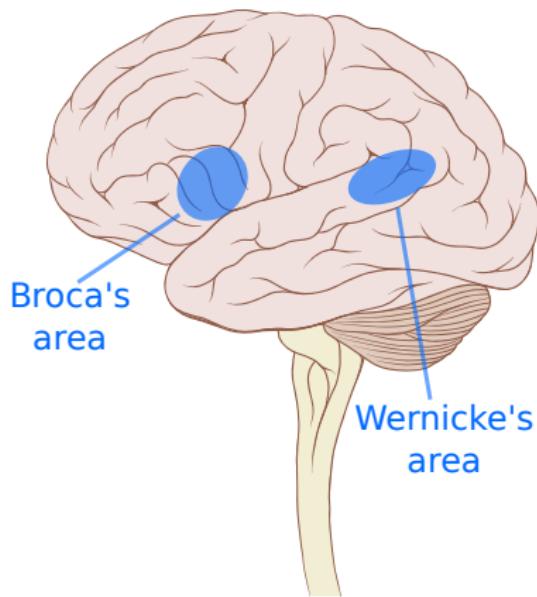
Emergence of functional specificity

Conclusion

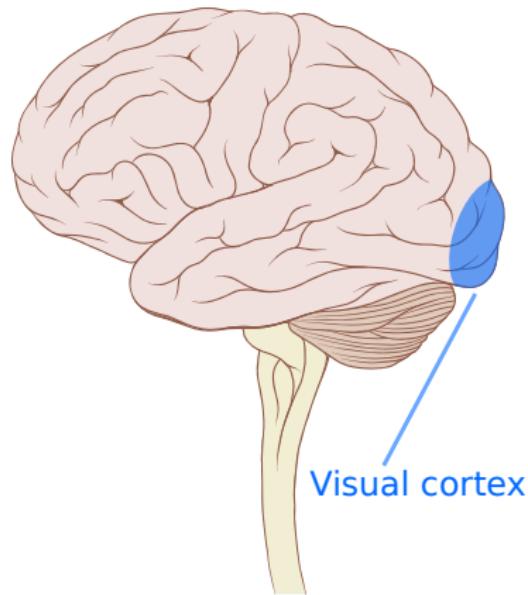
Language in the brain



Language in the brain

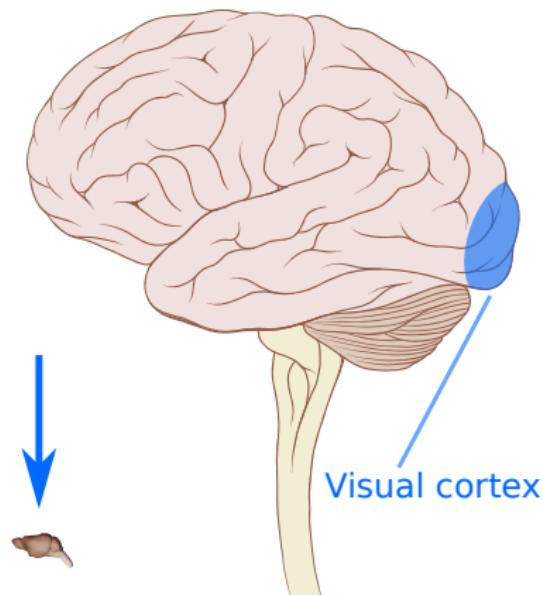


Language in the brain



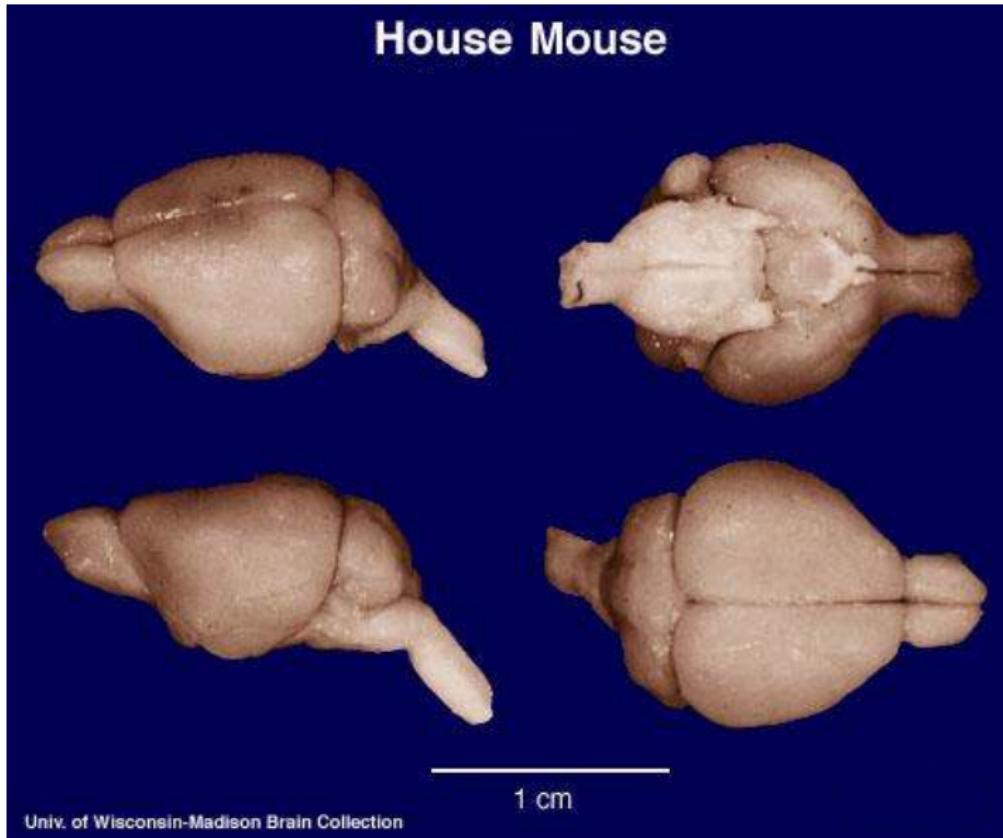
Visual cortex

Language in the brain

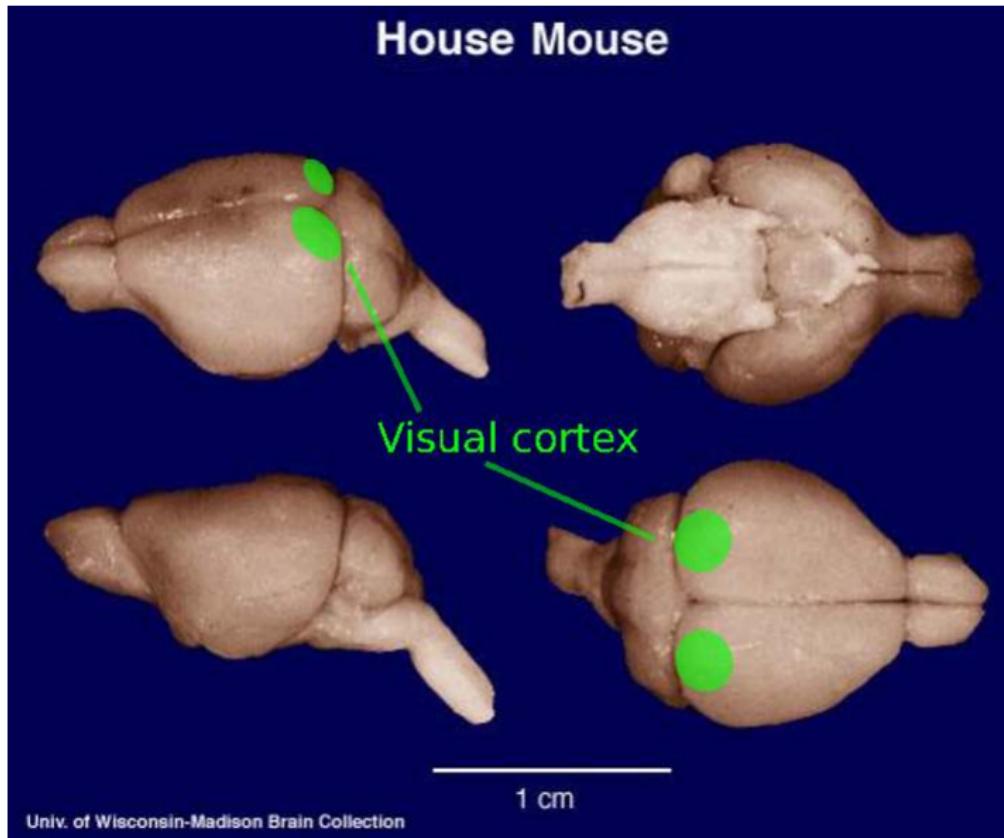


Visual cortex

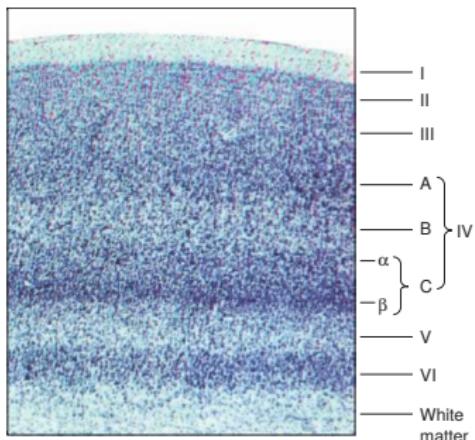
Visual cortex in the mouse



Visual cortex in the mouse



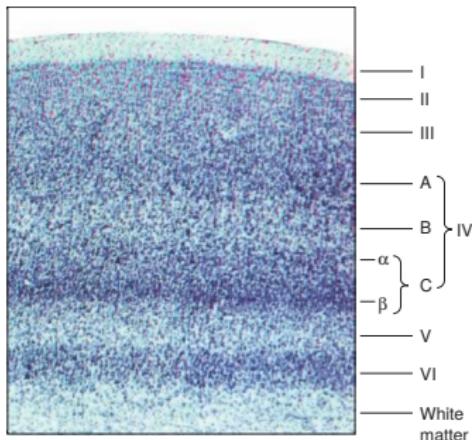
Universal structure of the neocortex



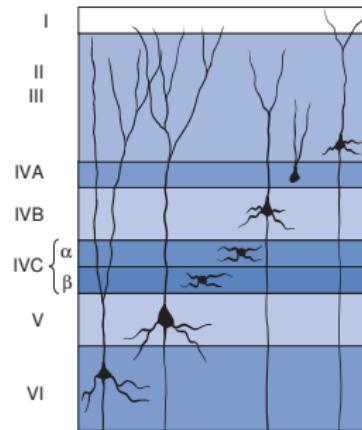
Nissel stain: Cell bodies
appear as black dots

Bear, Connors, Paradiso, *Neuroscience*. Vol. 2.
Lippincott Williams & Wilkins, 2007.

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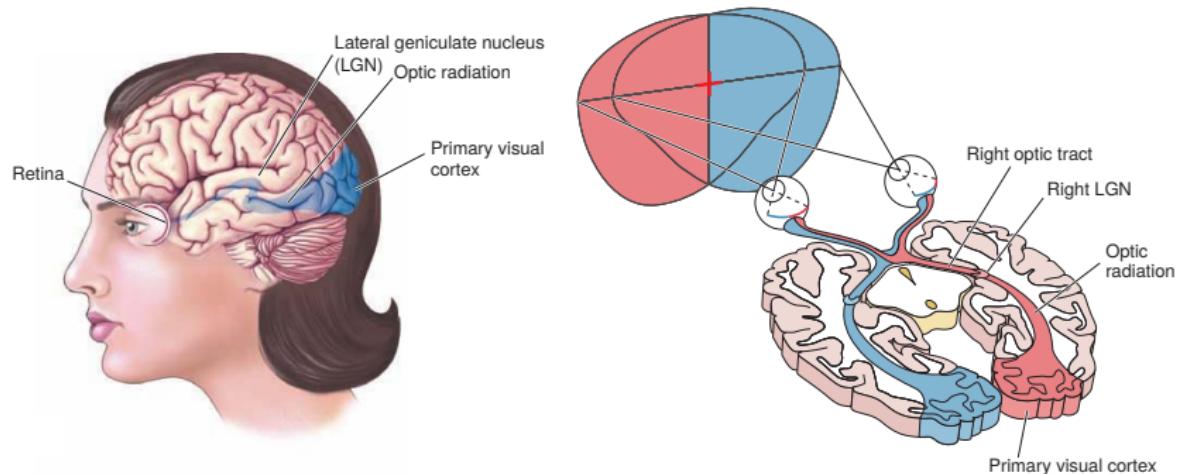


Nissl stain: Cell bodies
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Different morphologies

Vision

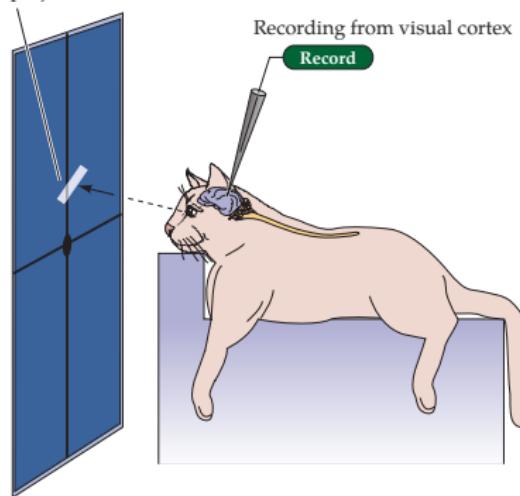


The visual pathway

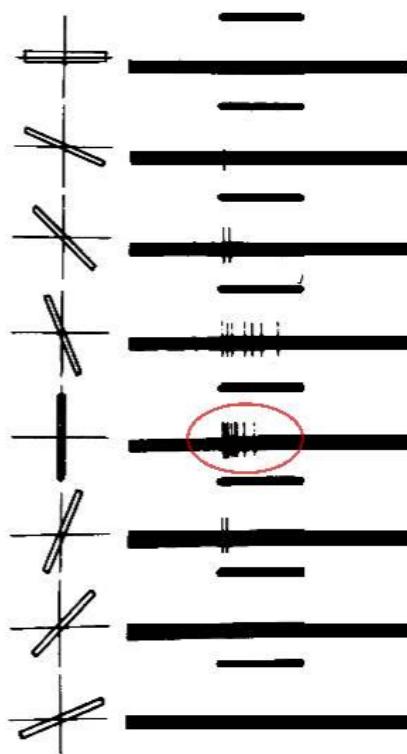
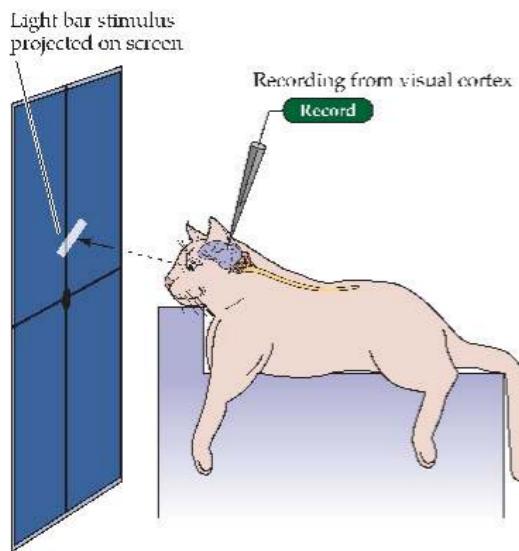
Bear, Connors, Paradiso, *Neuroscience*. Vol. 2.
Lippincott Williams & Wilkins, 2007.

Hubel & Wiesel 1959

Light bar stimulus
projected on screen

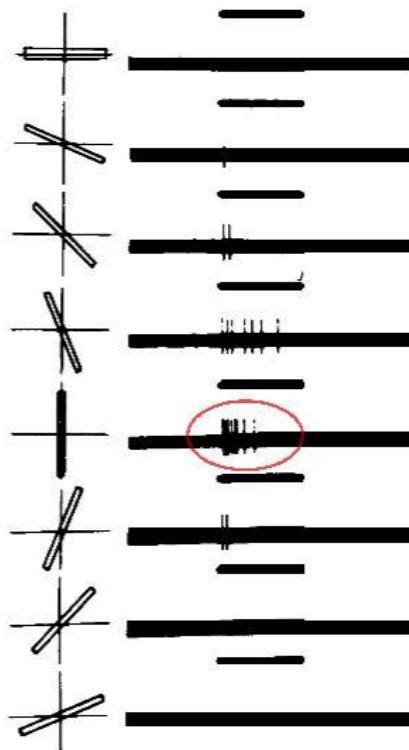
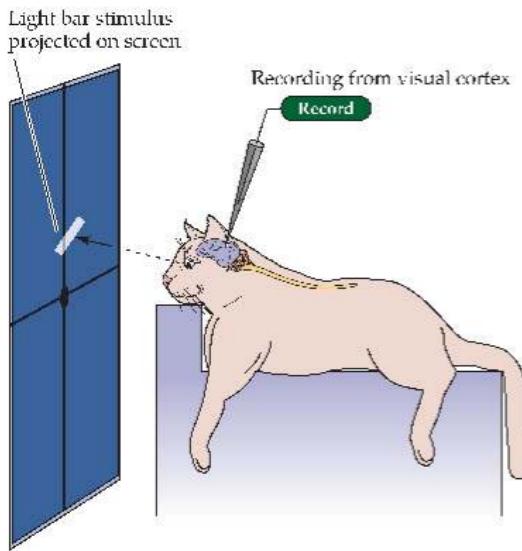


Hubel & Wiesel 1959



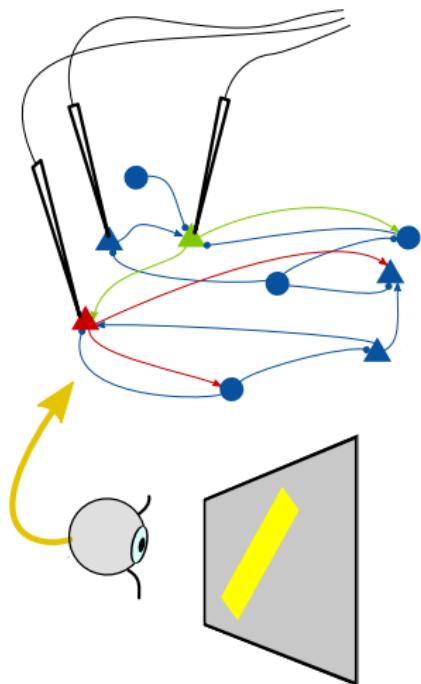
Purves et al., *Neuroscience*, Sinauer
Hubel and Wiesel. *The Journal of physiology* 148.3, 1959..

Hubel & Wiesel 1959

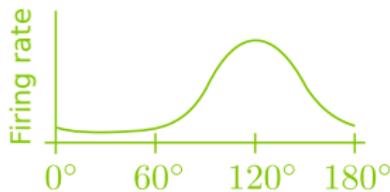
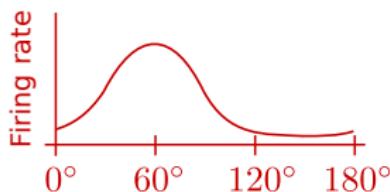
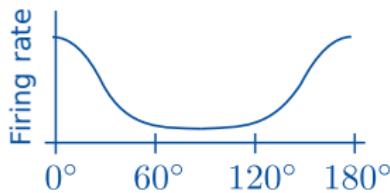


Purves et al., *Neuroscience*, Sinauer
Hubel and Wiesel. *The Journal of physiology* 148.3, 1959..

Tuning curves



Measure response
of single neurons
to stimulus



Tuning Curve



Preferred orientation

Basic idea



P0: birth
(p = postnatal)



P15: eyes open



P25: visual
experience

Basic idea



P0: birth
(p = postnatal)



P15: eyes open



P25: visual
experience



Natural movie

Basic idea



P0: birth
(p = postnatal)



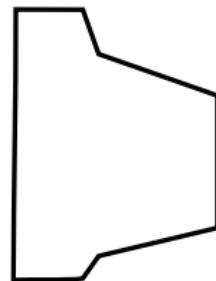
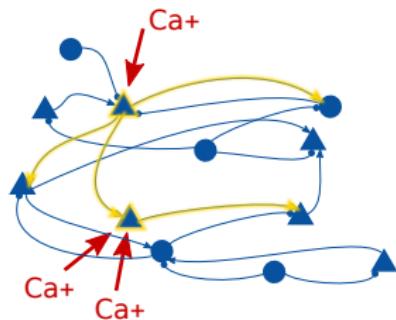
P15: eyes open



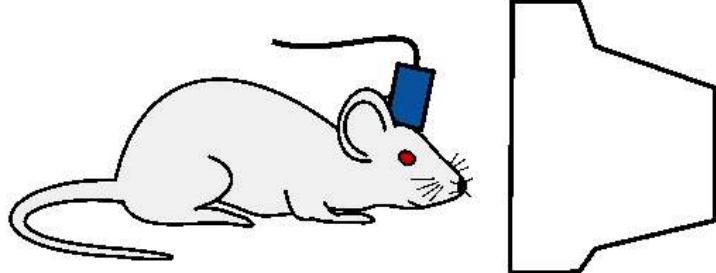
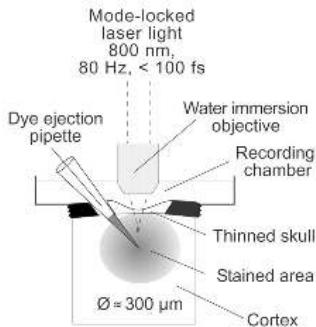
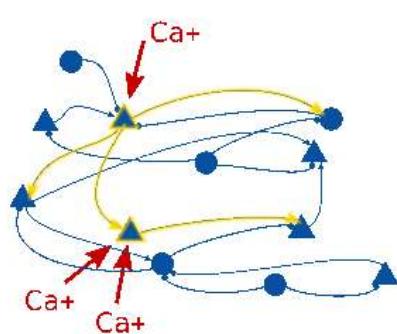
P25: visual
experience



Two-photon calcium imaging

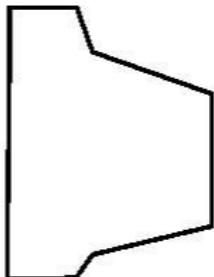
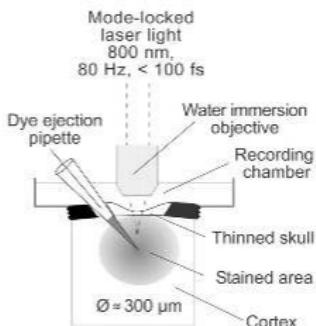
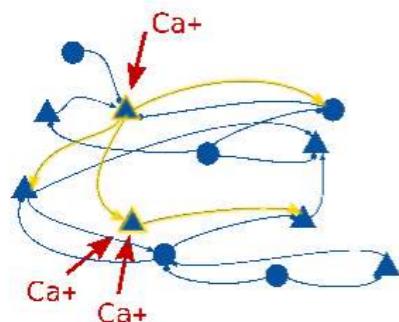


Two-photon calcium imaging

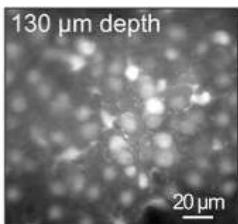
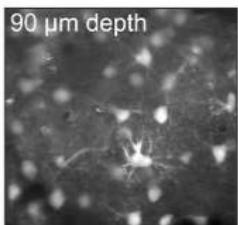
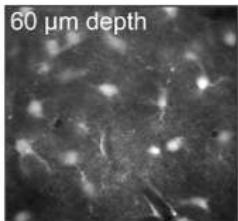


Stosiek, Christoph, et al.
Proc. of the Nat. Academy of Sciences 100.12, 2003.

Two-photon calcium imaging



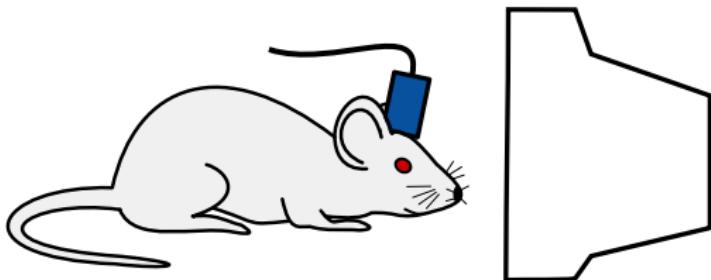
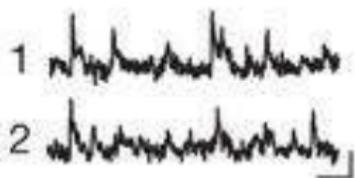
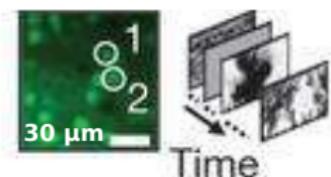
Imaging through
thinned skull



Stosiek, Christoph, et al.

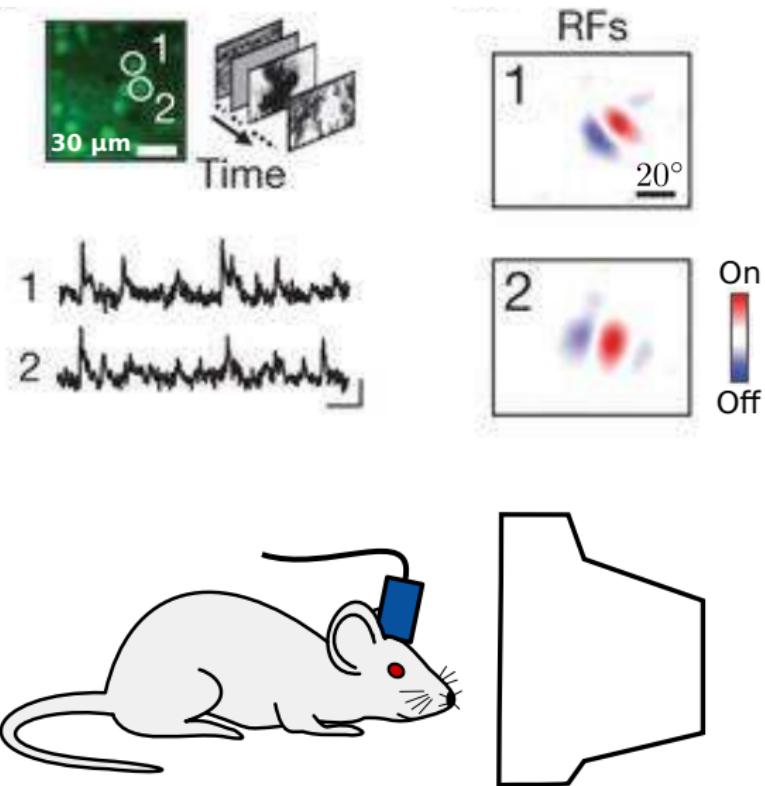
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Receptive fields



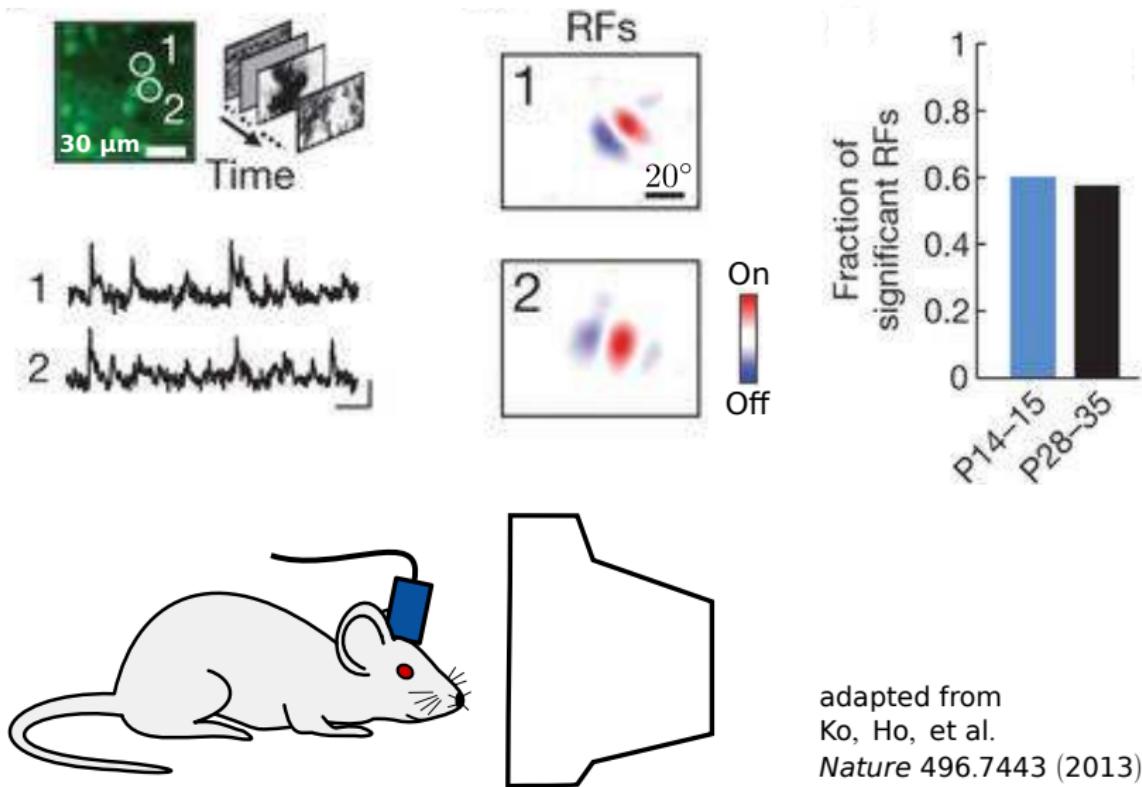
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Ko, Ho, et al.
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Receptive fields

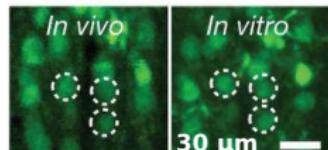


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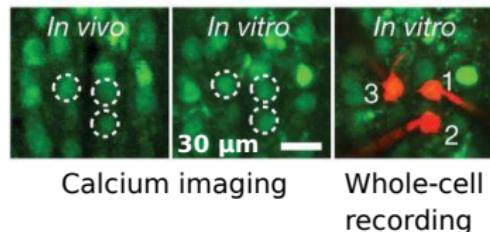
Experimental results



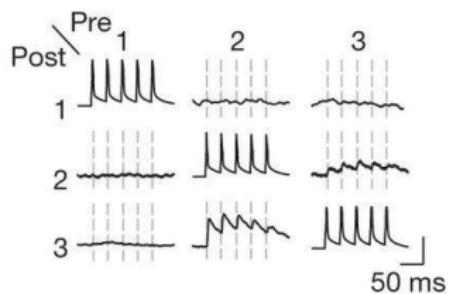
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Experimental results



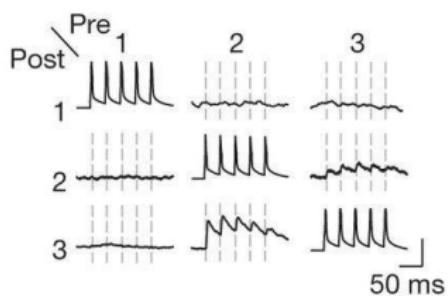
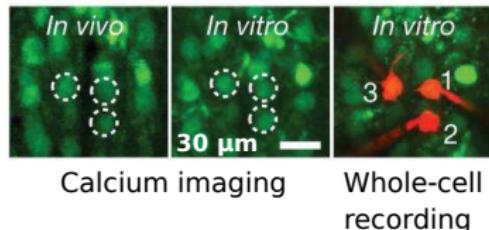
Calcium imaging

Whole-cell
recording

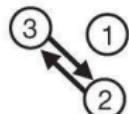
Response to evoked spikes

adapted from
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Experimental results



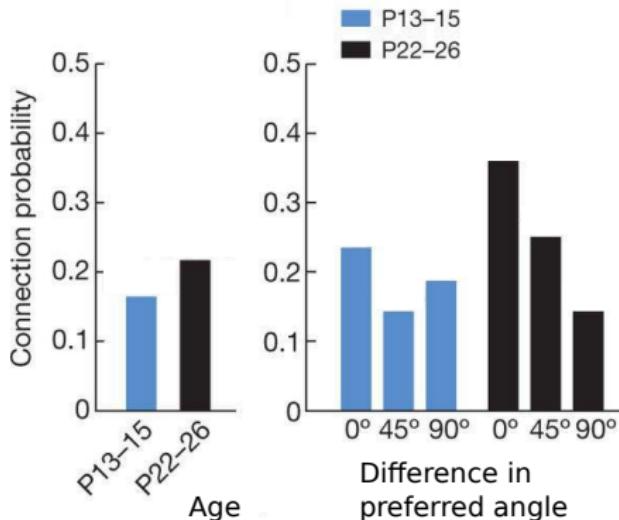
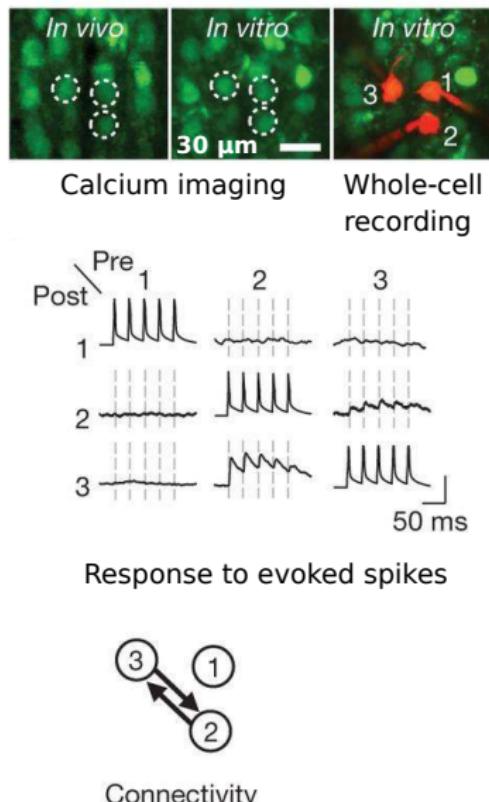
Response to evoked spikes



Connectivity

adapted from
Ko, Ho, et al.
Nature 496.7443 (2013).

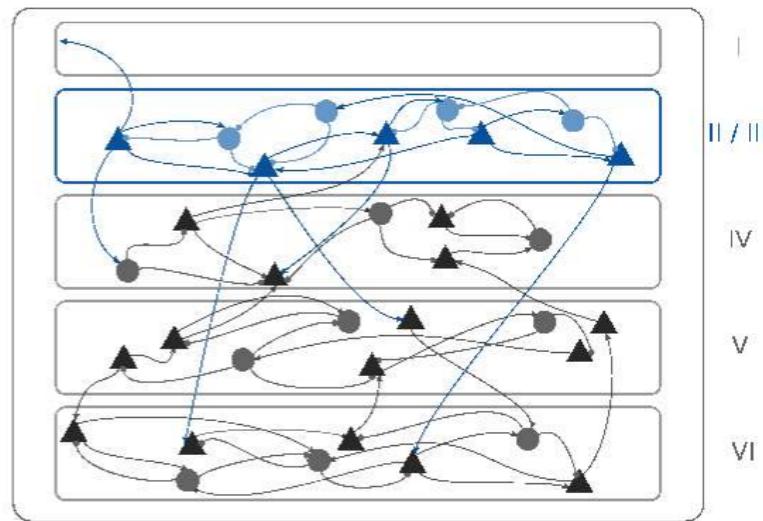
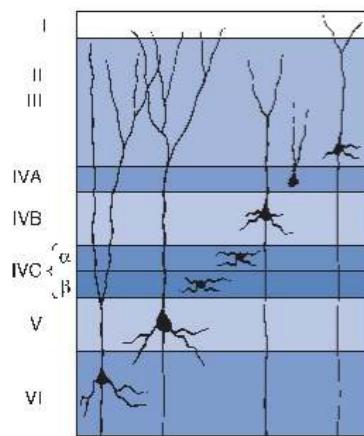
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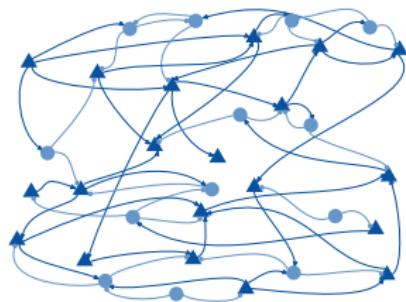
Experiment \Rightarrow Theory

Functional specificity in a model



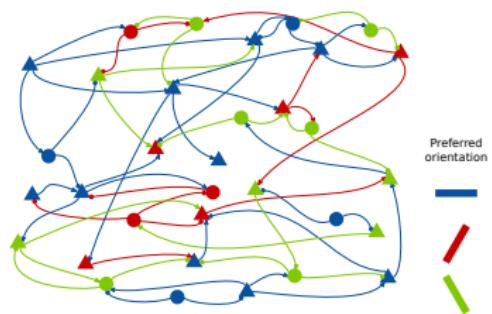
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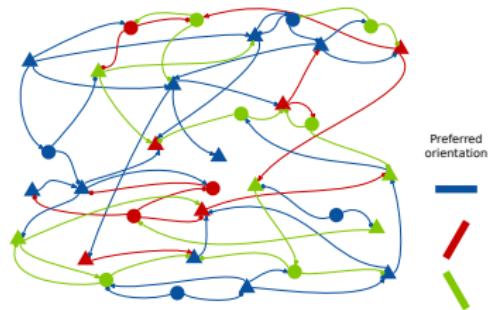
Balanced random network

Functional specificity in a model

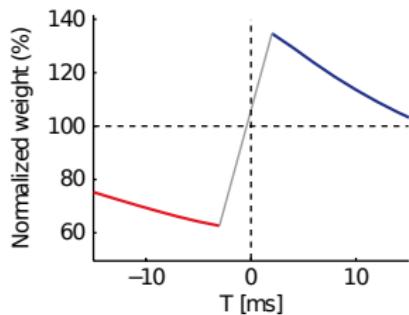


Balanced random network
with orientation selectivity

Functional specificity in a model



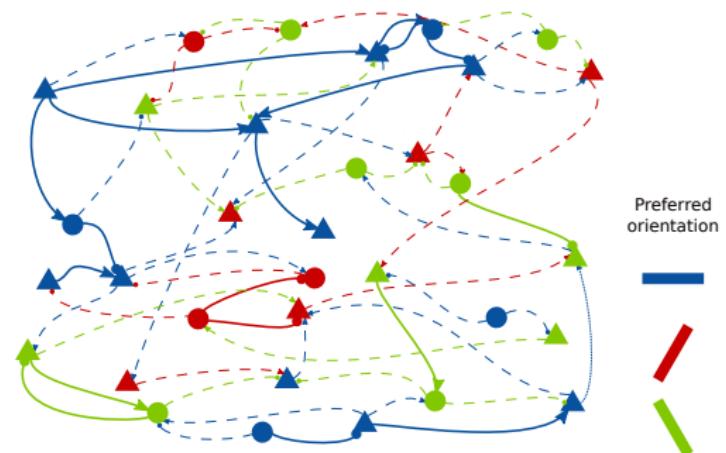
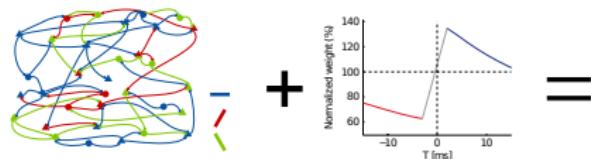
Balanced random network
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Synaptic plasticity

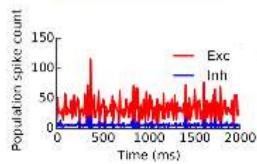
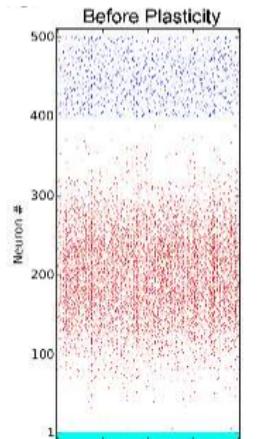
Clopath et al.,
Nature Neuroscience 13.3, 2010

Functional specificity in a model



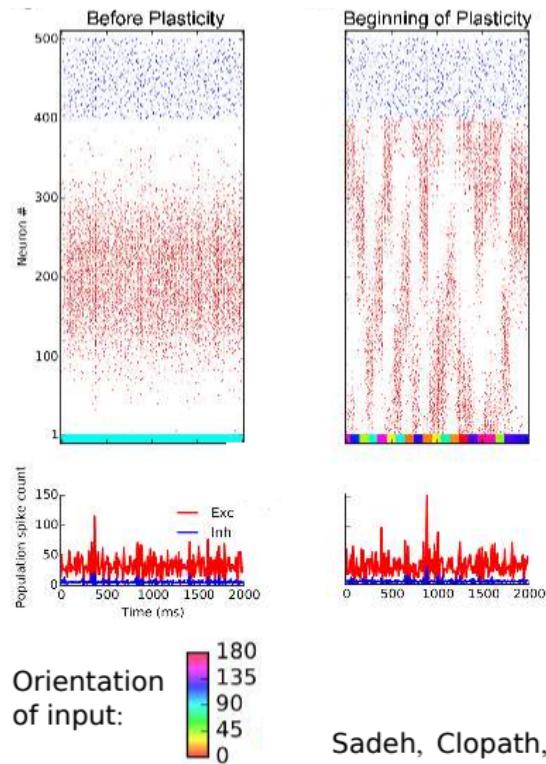
Functional specificity

Population activity



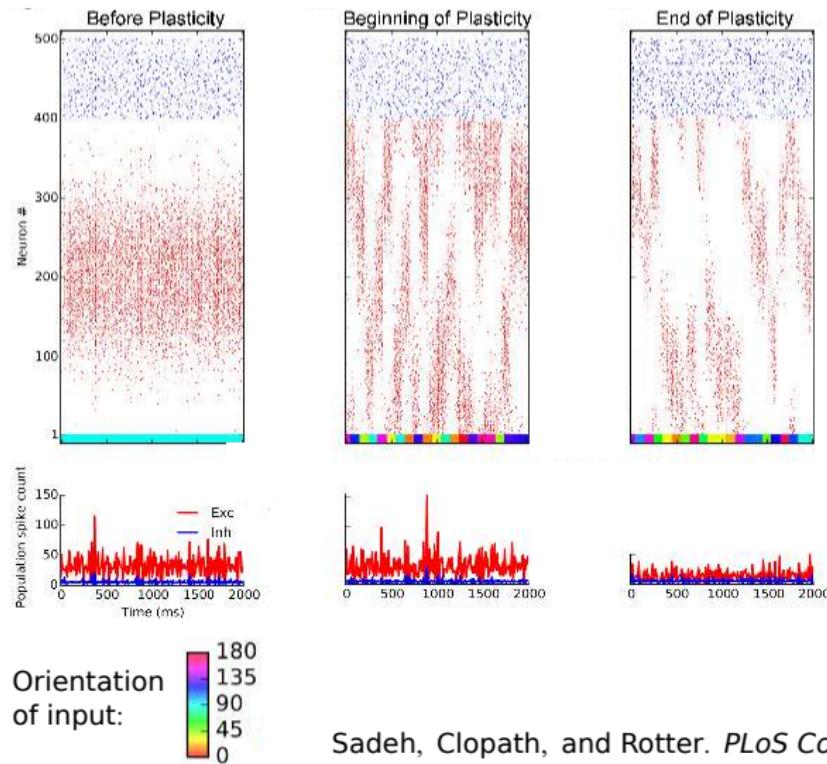
Sadeh, Clopath, and Rotter. *PLoS Comput Biology* 11.6, 2015.

Population activity



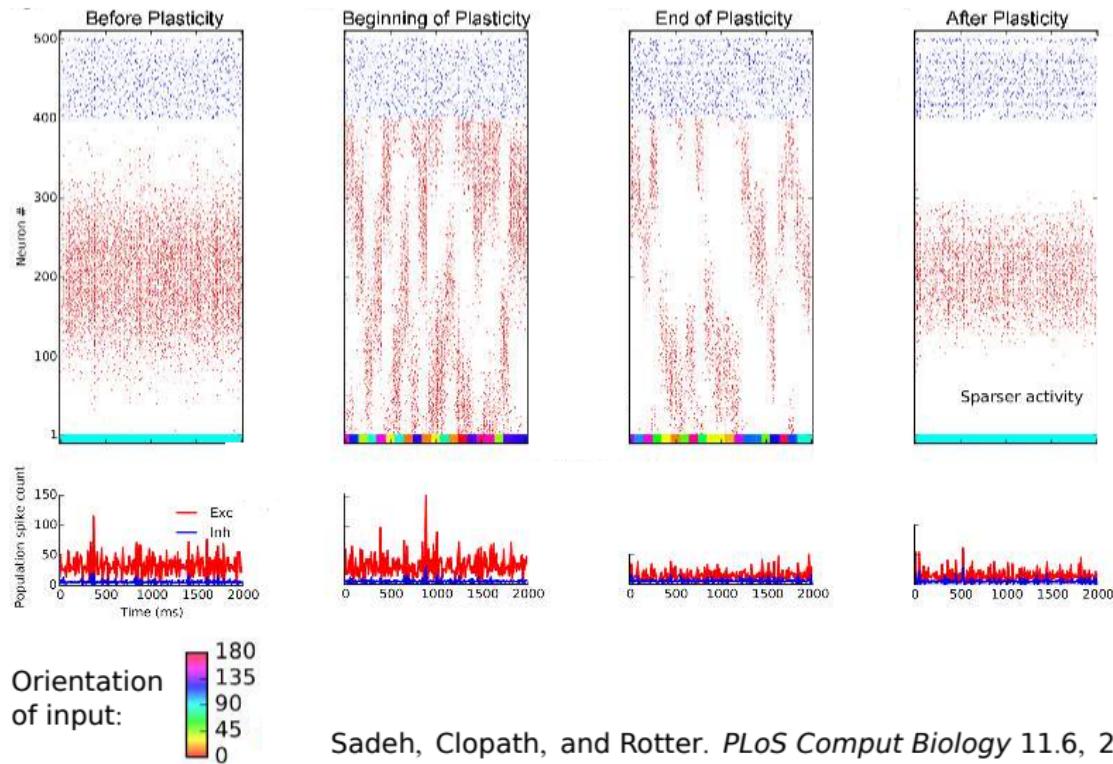
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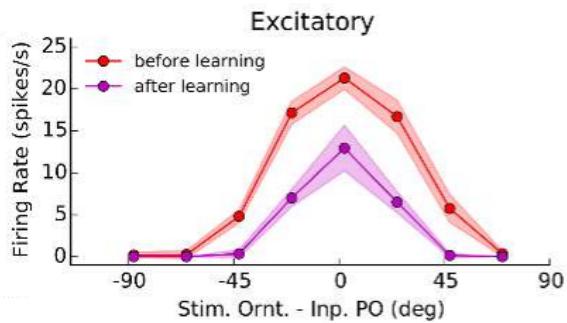
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Population activity

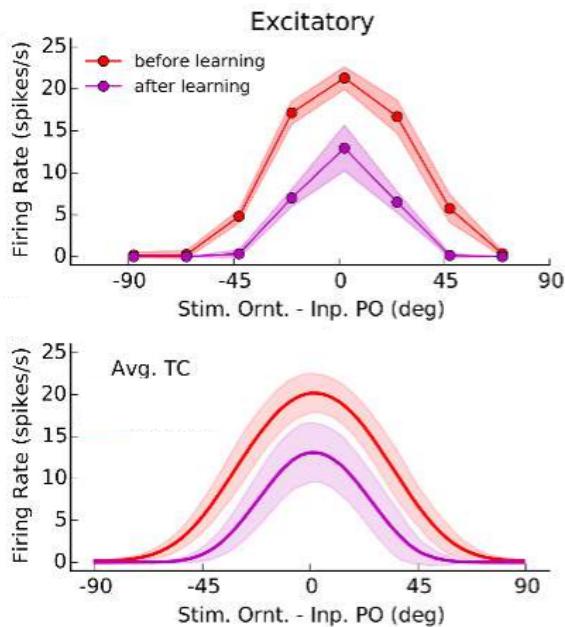


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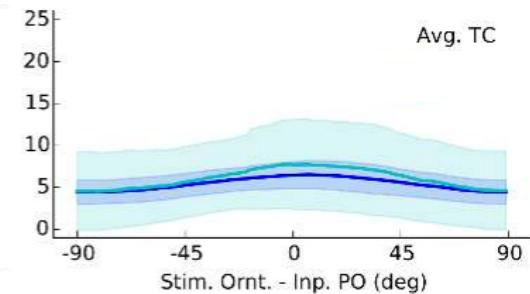
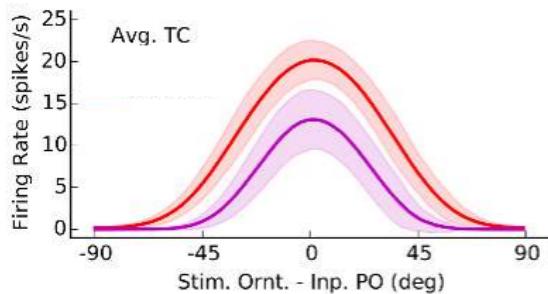
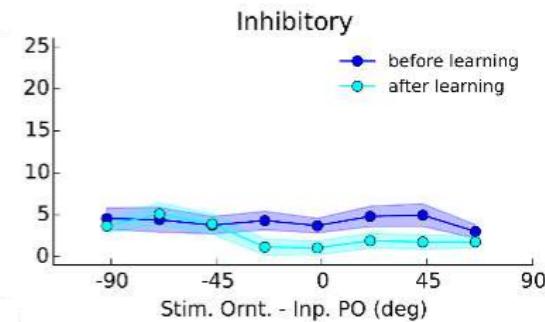
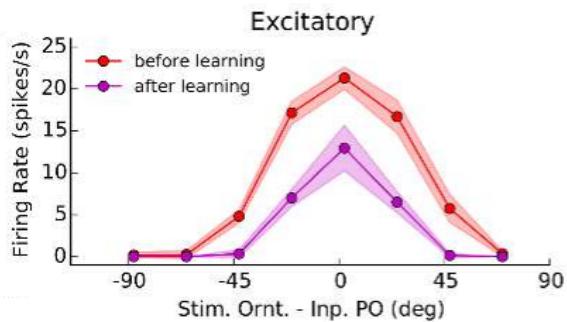
Changing tuning curves



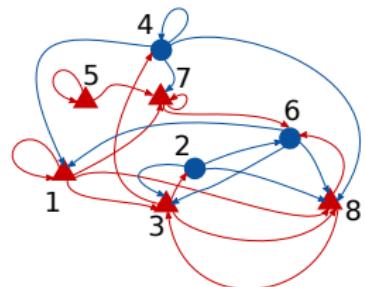
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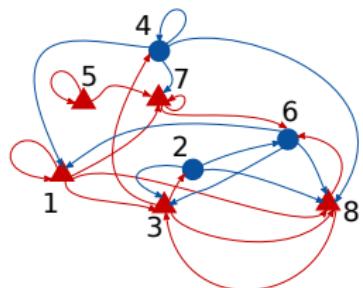
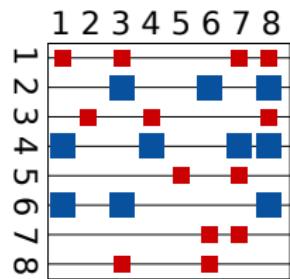
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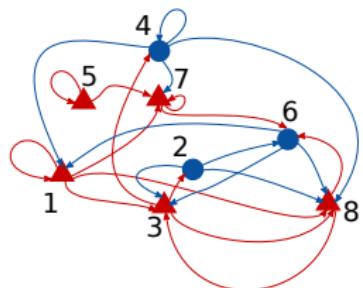
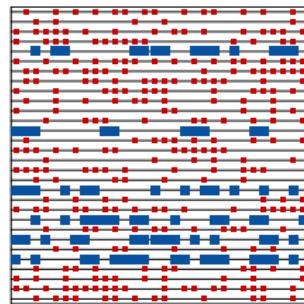
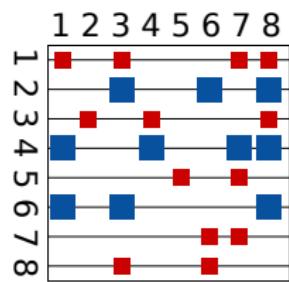
Connectivity matrix



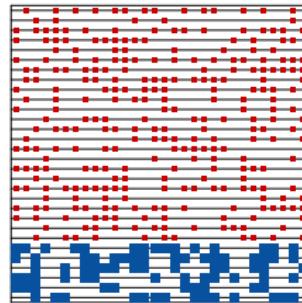
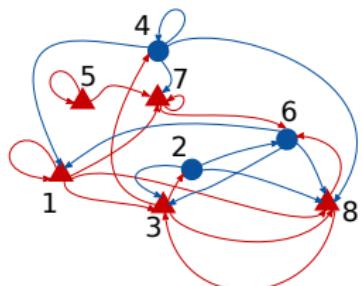
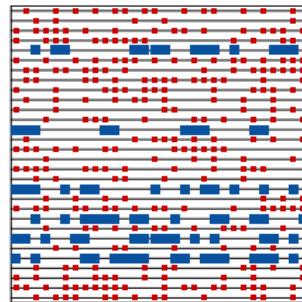
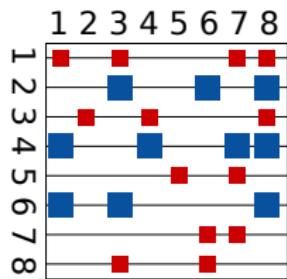
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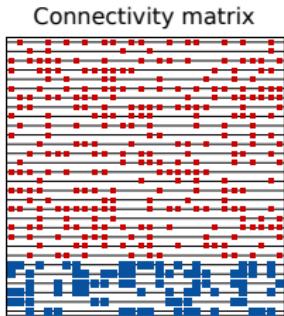
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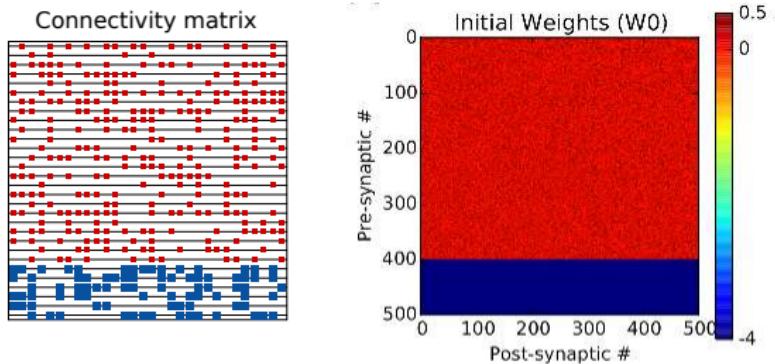
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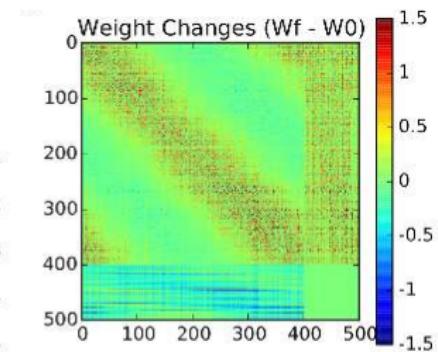
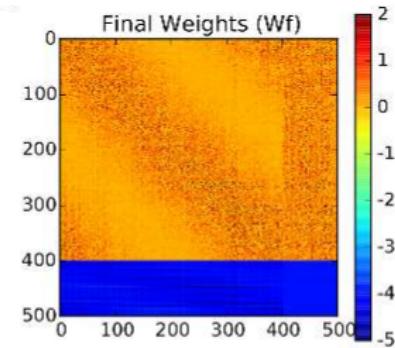
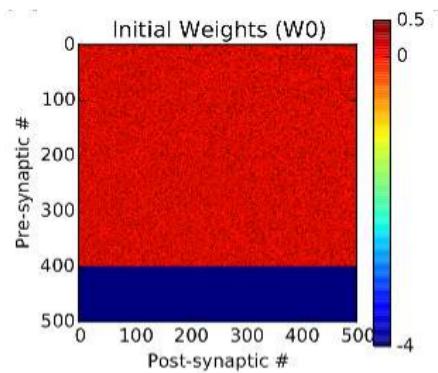
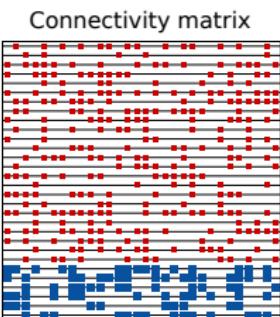
Changing connectivity



Changing connectivity



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Conclusion

Some features exists already at birth.: Orientation selectivity.

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Network structure can change drastically with sensory experience:
Feature specific microcircuits.

Conclusion

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Network structure can change drastically with sensory experience:
Feature specific microcircuits.

Balanced random networks and synaptic plasticity may explain the phenomenon.

References

Basics

- Bear, Mark F., Barry W. Connors, and Michael A. Paradiso, eds. *Neuroscience*. Vol. 2. *Lippincott Williams & Wilkins*, 2007.
Purves, Dale, et al. *Neuroscience*. *Sinauer Associates, Inc.*, 2004.

Orientation selectivity

- Hubel, David H., and Torsten N. Wiesel. Receptive fields of single neurones in the cat's striate cortex. *The Journal of physiology* 148.3, 1959.
- Hubel, David H., and Torsten N. Wiesel. Receptive fields, binocular interaction and functional architecture in the cat's visual cortex. *The Journal of physiology* 160.1, 1962.

Experimental evidence:

- Ko, Ho, et al. The emergence of functional microcircuits in visual cortex. *Nature* 496.7443, 2013.
- Stosiek, Christoph, et al. In vivo two-photon calcium imaging of neuronal networks. *Proceedings of the National Academy of Sciences* 100.12, 2003.

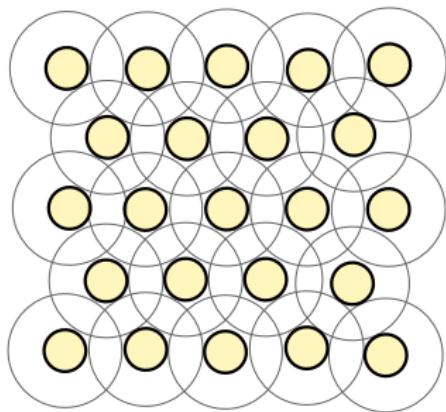
Computer model

- Clopath, Claudia, et al. Connectivity reflects coding: a model of voltage-based STDP with homeostasis. *Nature neuroscience* 13.3, 2010.
- Sadeh, Sadra, Claudia Clopath, and Stefan Rotter. Emergence of Functional Specificity in Balanced Networks with Synaptic Plasticity. *PLoS Comput Biology* 11.6, 2015.

Thank you for
your attention!

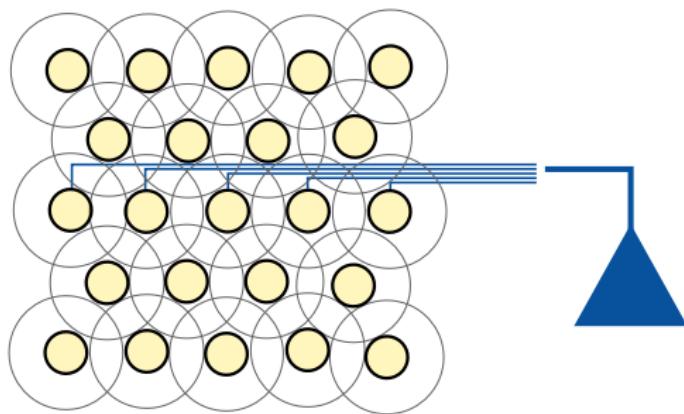


Orientation selectivity



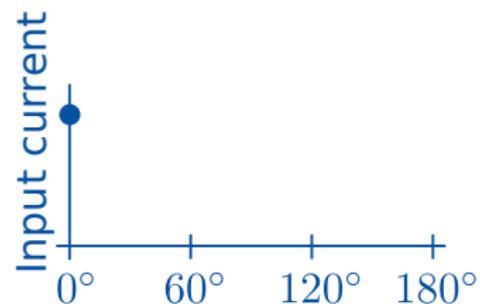
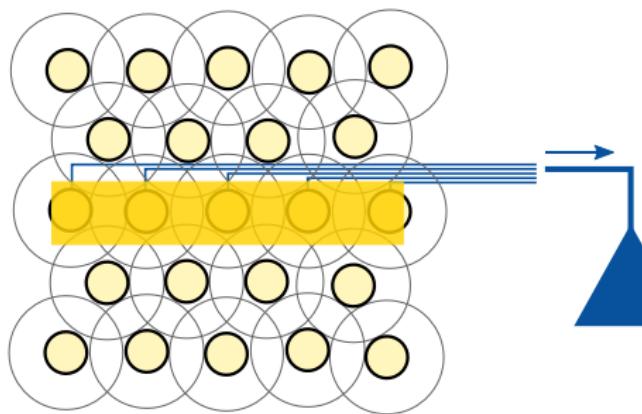
Receptive field

Orientation selectivity



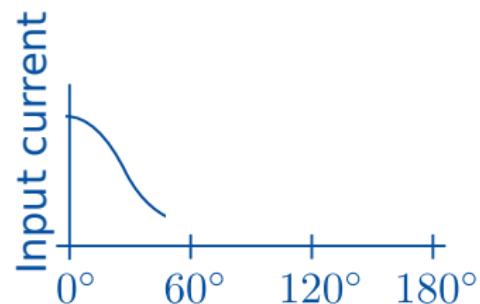
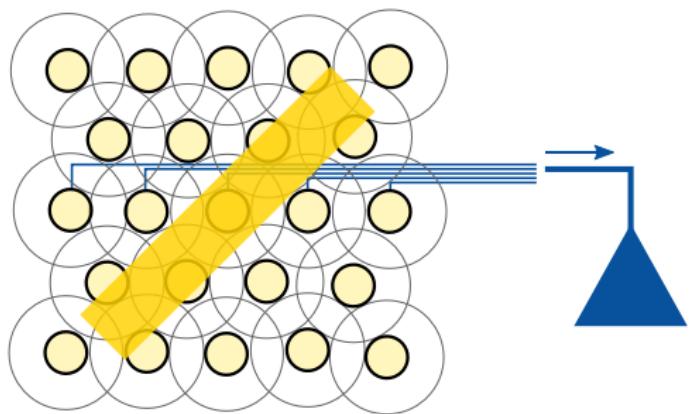
Receptive field

Orientation selectivity



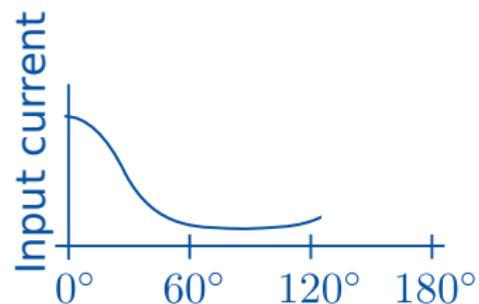
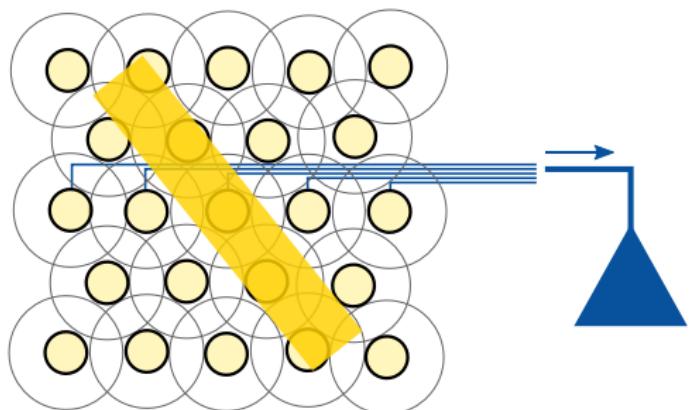
Receptive field

Orientation selectivity



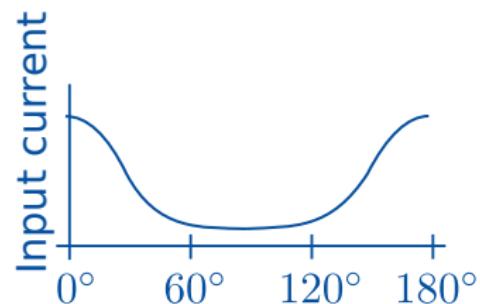
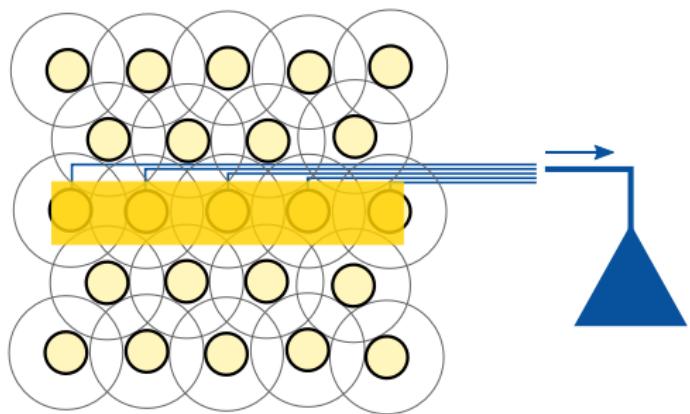
Receptive field

Orientation selectivity



Receptive field

Orientation selectivity



Receptive field

Tuning curves

