

# Investigating activity dependent dynamics of synaptic structures using biologically plausible models of post-deafferentation network repair



Engineering and Computer Science Research Conference 2019

Ankur Sinha, UH Biocomputation Group

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## The brain: learning, plasticity, stability

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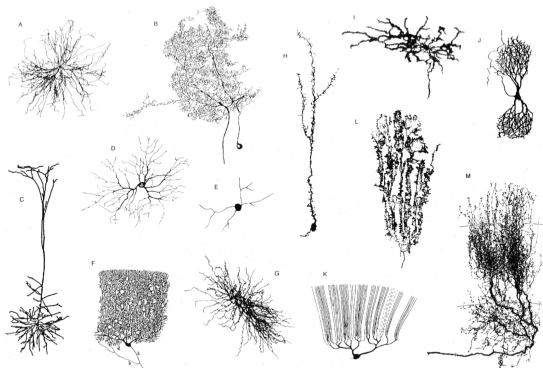
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## The brain: neurons



Dendrites, Oxford University Press, 2015; Modified from Mel, B.W. Neural Computation, 1994.

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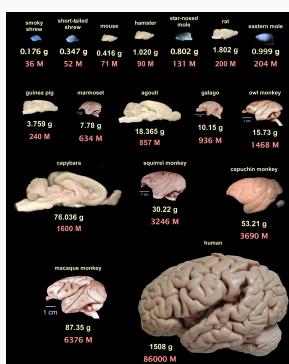
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## The brain: in numbers: neurons



• 86000M neurons<sup>1</sup>.

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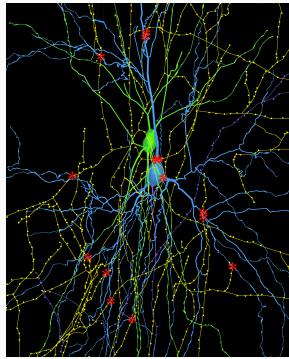
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<sup>1</sup> Herculano-Houzel, S. The human brain in numbers: a linearly scaled-up primate brain. *Frontiers in human neuroscience* 3, 31 (2009)

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## The brain: in numbers: synapses



- Thousands of connections (synapses) between pairs<sup>2</sup>.
- Synapses underlie learning<sup>3</sup>.

<sup>2</sup>Image from The GAO lab

<sup>3</sup>Hebb, D. O. *The organization of behavior: A neuropsychological theory*. 1949

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## The brain: plasticity and learning

Food: curry!



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## The brain: plasticity and stability?

- Learning occurs all the time.
- In fact, whole synapses are formed and removed all the time<sup>4</sup>: **structural plasticity**.
- Unregulated brain activity causes disorders: **epilepsy**.
- So, how does the brain remain **stable** despite changing all the time?
- Stabilising (**homeostatic**) processes<sup>5</sup>?

<sup>4</sup>Holtmaat, A. J. G. D. et al. Transient and Persistent Dendritic Spines in the Neocortex In Vivo. *Neuron* **45**, 279–291.  
ISSN: 0896-6273 (2005)

<sup>5</sup>Turrigiano, G. G. Homeostatic plasticity in neuronal networks: the more things change, the more they stay the same. *Trends in neurosciences* **22**, 221-227 (1999)

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Smell A

## Our research focus

- We study **homeostatic structural plasticity**.

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## Homeostatic structural plasticity

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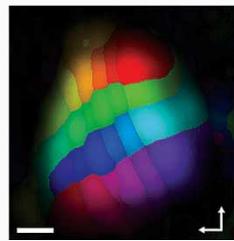
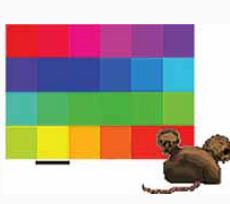
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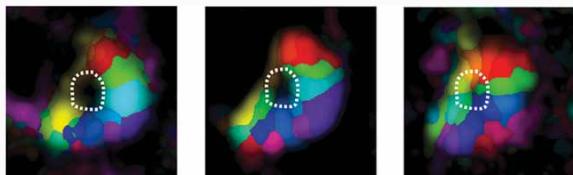
### Studying homeostatic structural plasticity: biologists



<sup>1</sup>Keck, T. et al. Massive restructuring of neuronal circuits during functional reorganization of adult visual cortex. *Nature neuroscience* 11, 1162–1167 (2008)

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### after injury ...



<sup>1</sup>Keck, T. et al. Massive restructuring of neuronal circuits during functional reorganization of adult visual cortex. *Nature neuroscience* 11, 1162–1167 (2008)

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### Our investigations: computational modelling

- We make **models of small parts of the brain** on computers.
- We try to **replicate** what biologists observe in their laboratories.
- Modelling gives us **flexibility**:
  - we can change whatever we want, record whatever we want.
  - analyse data, test different hypotheses.
- We then **send our ideas back to biologists** for validation.

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## Our model: replicates biological observations

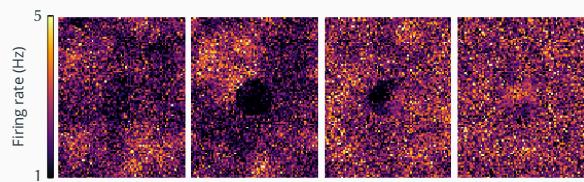


Figure 1: Our model: 1000 neurons. Simulation duration: 7 days on the cluster with 128 CPU nodes.

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## It suggests:

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