

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



University of **UH**

Engineering and Computer Science Research Conference 2019

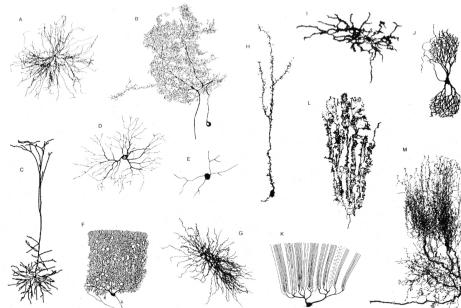
Ankur Sinha, UH Biocomputation Group

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The brain: learning, plasticity, stability

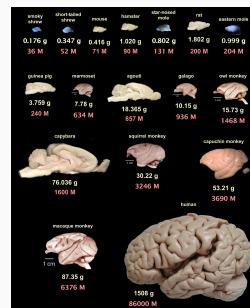
The brain: neurons



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

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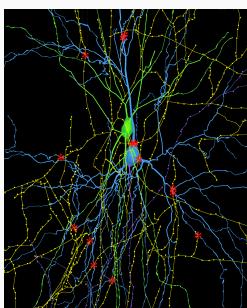
The brain: in numbers: neurons



¹ 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



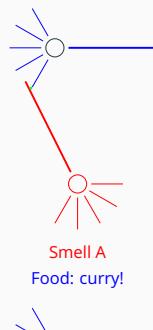
- Thousands of connections (**synapses**) between pairs².
- Synapses underlie **learning**³.
- Synapses can be excitatory or inhibitory.

²Image from The Gao lab, College of Medicine, Drexel University.
³Hebb, D. O. *The organization of behavior: A neuropsychological theory*. 1949

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The brain: plasticity and learning

Food: curry!



Smell A

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 time⁴: **structural plasticity**.
- Unregulated brain activity causes disorders: **epilepsy**.
- So, how does the brain remain **stable** despite changing all the time?
- Stabilising (**homeostatic**) processes⁵?

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

⁵Turrigiano, 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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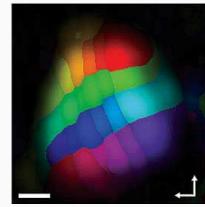
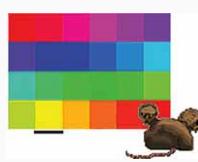
Our research focus

- We study **homeostatic structural plasticity**.

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Homeostatic structural plasticity

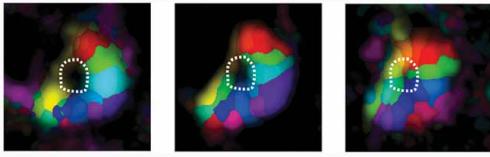
Studying homeostatic structural plasticity: biologists



¹Keck, 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 ...



¹Keck, 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 made a [new computer model](#) of a small part of the brain.
- We [replicated](#) what biologists observed in their laboratories.
- We [tested different ways](#) in which homeostatic structural plasticity may occur.
- We will now [send our ideas back to biologists](#) for validation.

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Our new model: replicates biological observations

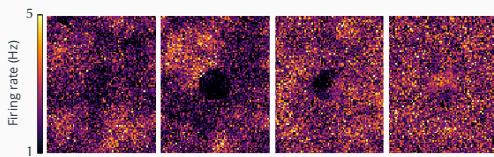
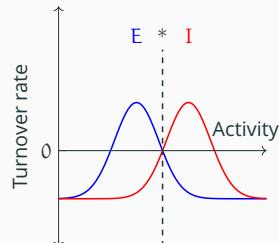


Figure 4: Our model: 1000 neurons. Simulation duration: 7 days on the cluster with 128 CPU nodes.

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It suggests:



- Neurons modify their [dendrites \(inputs\)](#) to maintain their activity.
- Too much: reduce excitatory inputs, increase inhibitory inputs.
- Too less: vice versa.

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