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

University of Hertfordshire UH

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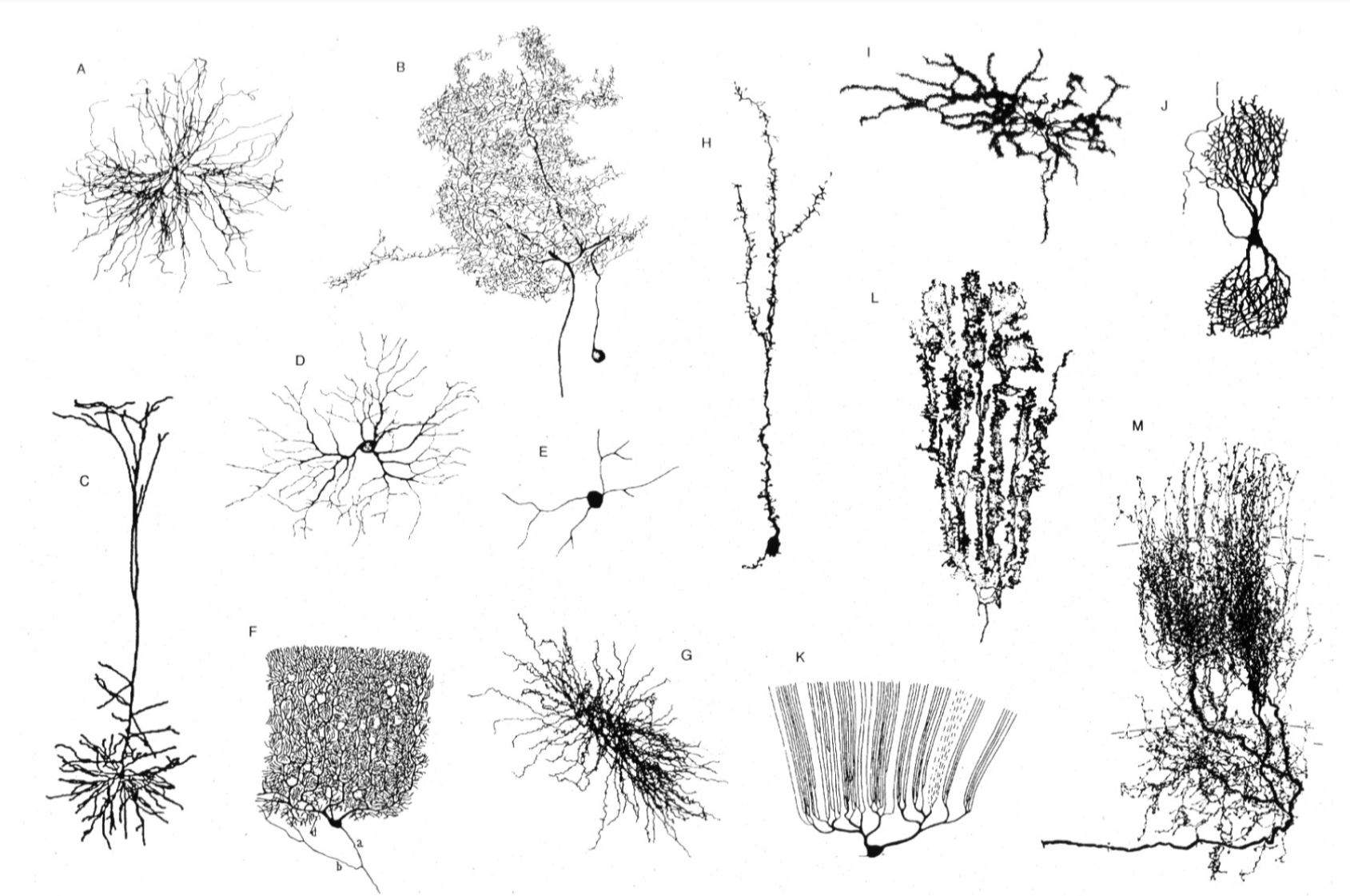
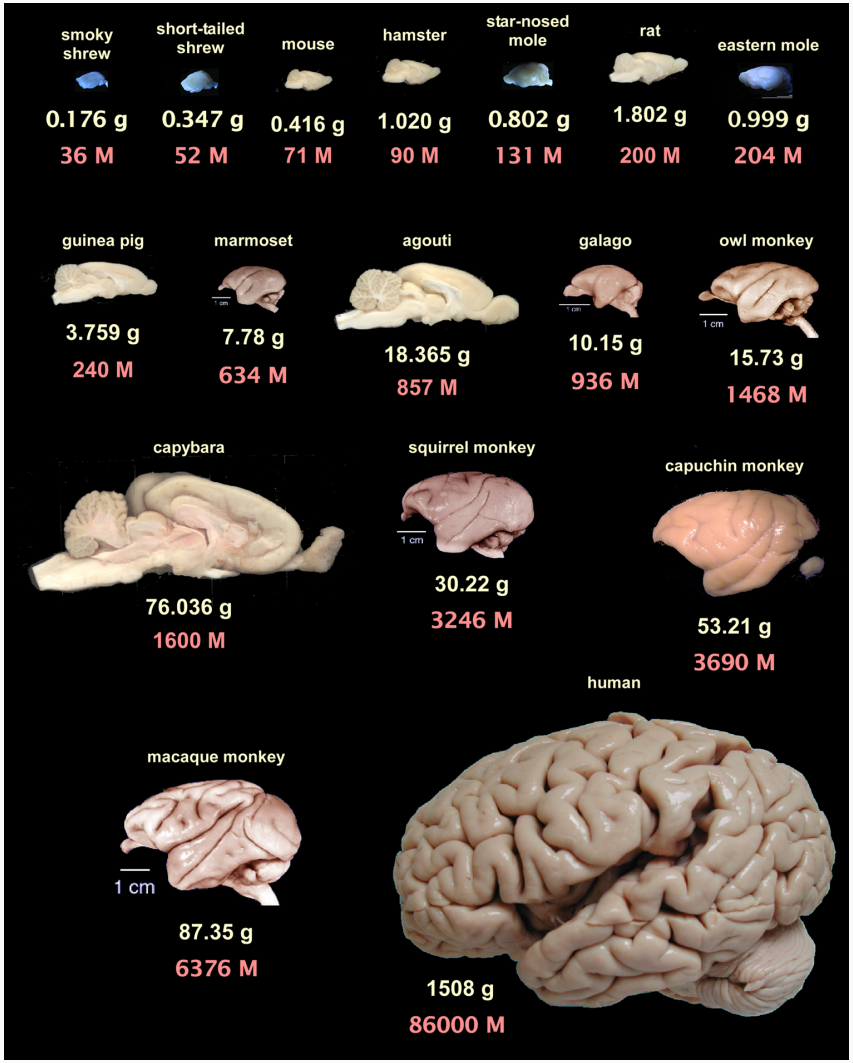
The brain: learning, plasticity, stability

The brain: neurons



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

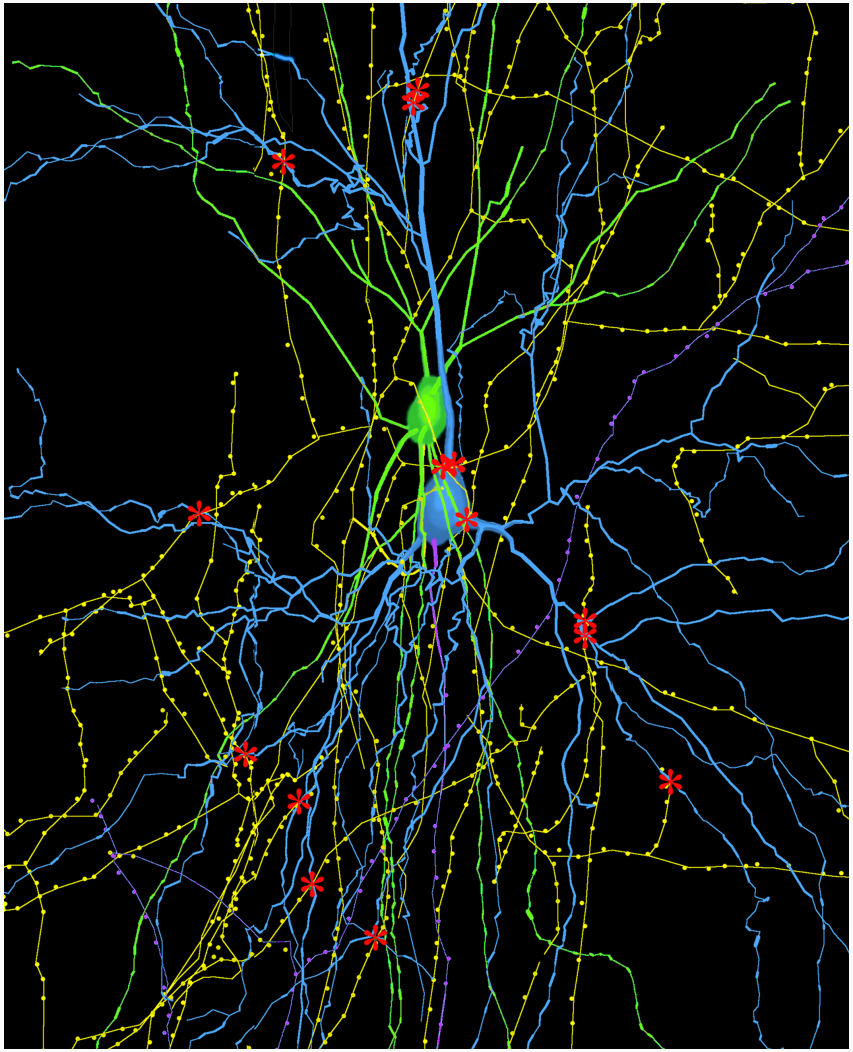
The brain: in numbers: neurons



- 86000M neurons[1].

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

The brain: in numbers: synapses



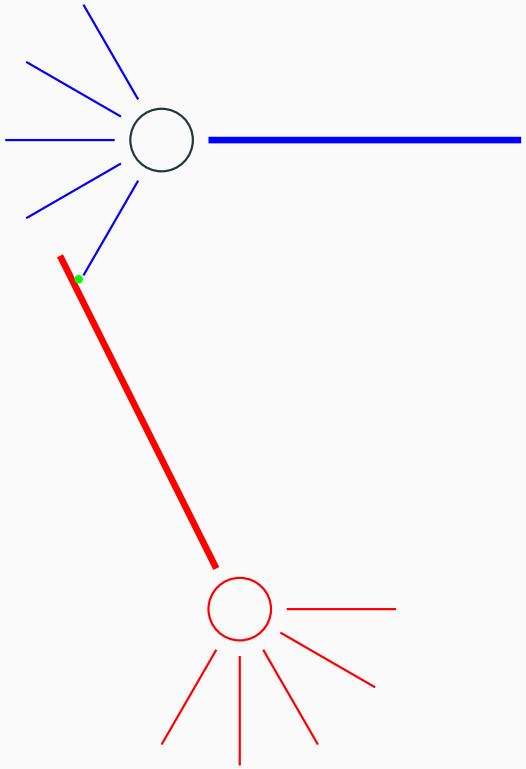
- Thousands of connections (synapses) between pairs[2].
- Synapses underlie learning[3].

[2] Image from The GAO lab

[3] Hebb, D. O. *The organization of behavior: A neuropsychological theory.* 1949

The brain: plasticity and learning

Food: curry!



Smell A

Food: curry!

The brain: plasticity and stability?

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

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[4] 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)

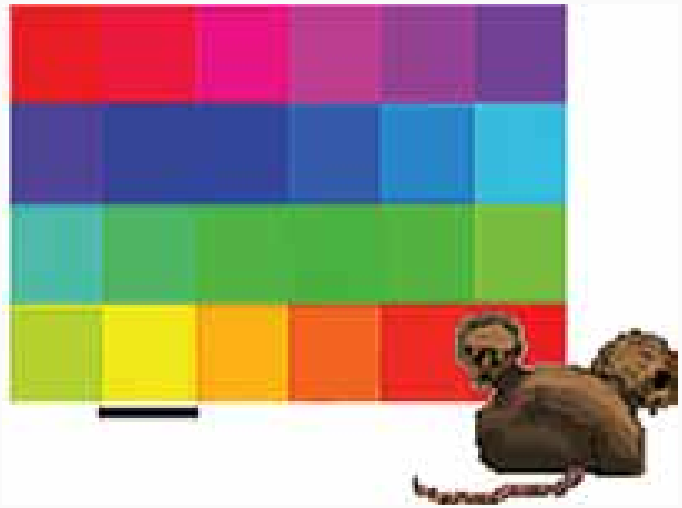
[5] Turrigiano, G. G. Homeostatic plasticity in neuronal networks: the more things change, the more they stay the same. *Trends in neurosciences* **22,** 221–227 (1999)

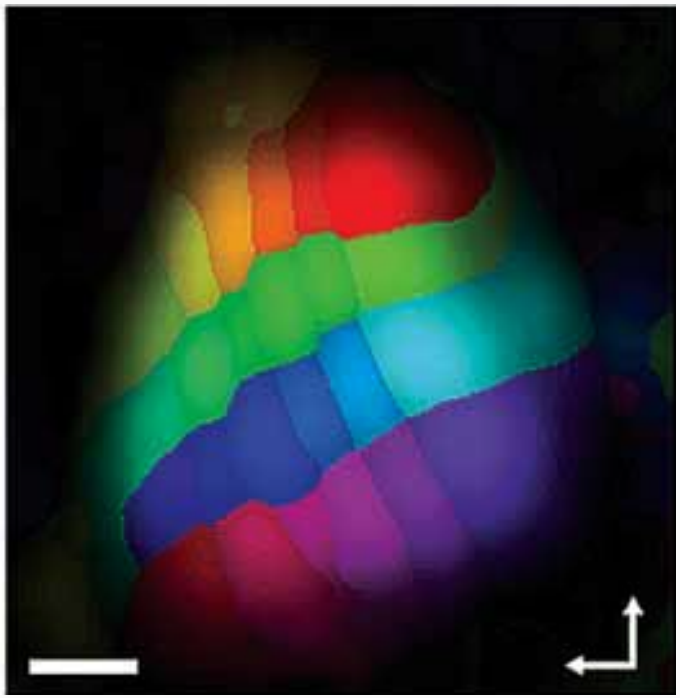
Our research focus

- We study homeostatic structural plasticity.

Homeostatic structural plasticity

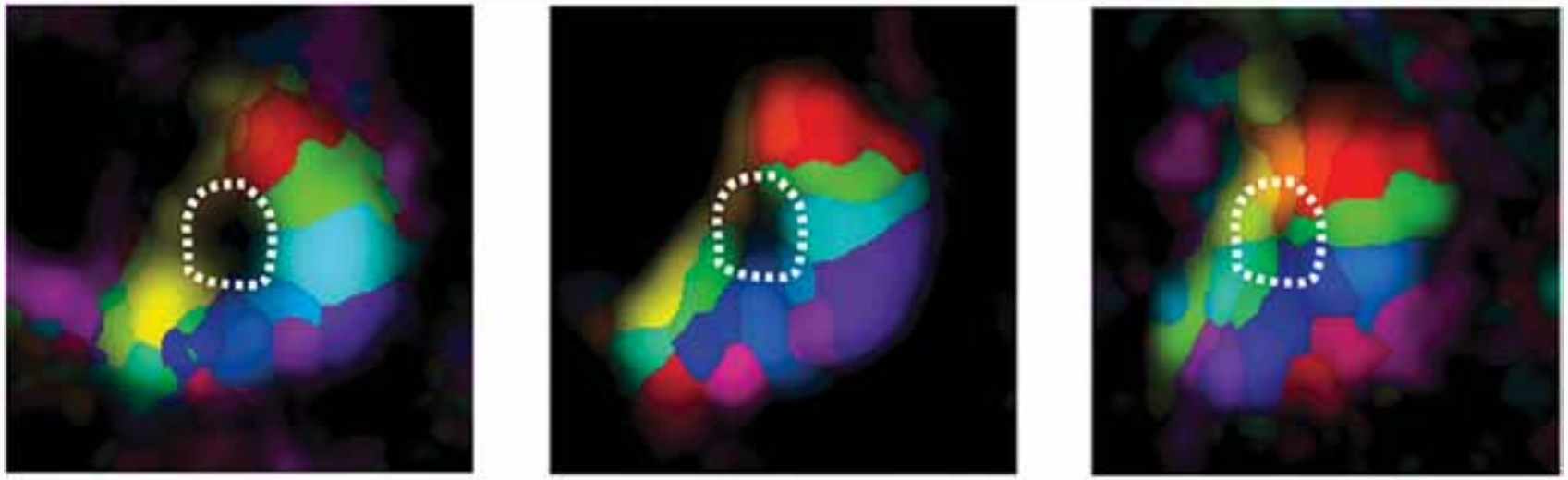
Studying homeostatic structural plasticity: biologists





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

after injury . . .



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

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.

Our model: replicates biological observations

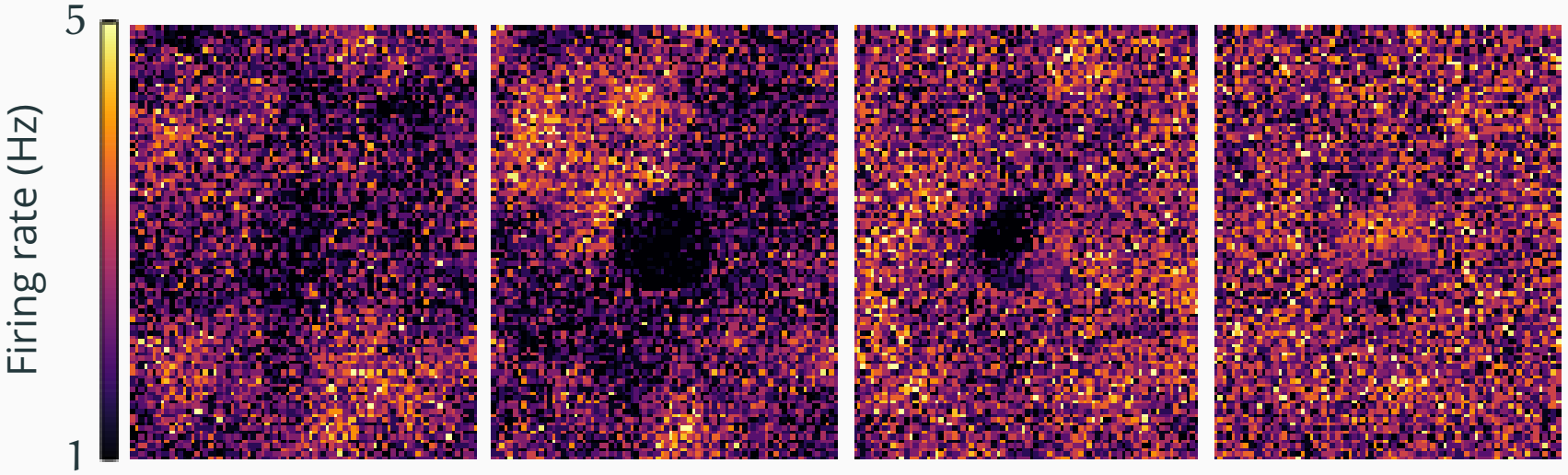


Figure 1: Our model: 1000 neurons. Simulation duration: 7 days on the cluster with 128 CPU nodes.

It suggests: