The NeuroML ecosystem for standardised multi-scale modelling in neuroscience

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2024-02-26

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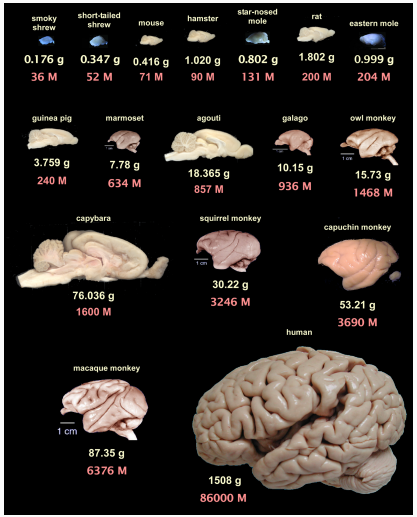
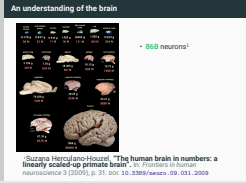
An understanding of the brain



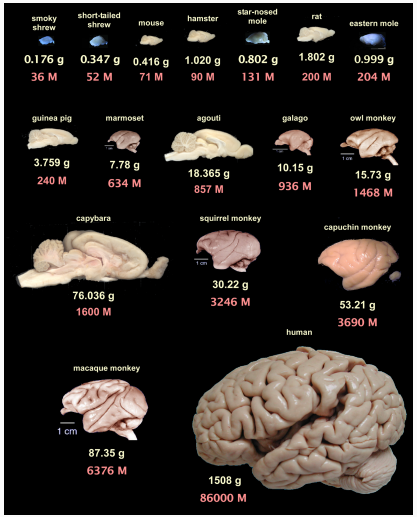
- 86B neurons[1]

[1] Suzana Herculano-Houzel. **"The human brain in numbers: a linearly scaled-up primate brain".** In: *Frontiers in human neuroscience* 3 (2009), p. 31. DOI: 10.3389/neuro.09.031.2009



1. These slides are from our previous talk in 2019, but we keep them on to remind us of the challenge here.
2. These are only larger brains—we now have a full description of some invertebrates like the C. elegans and the leech.
3. Neurons are complex, and different properties give them different electrophysiological properties.
4. For example, complex morphologies mean compartmentalization of current, different conductances, capacitances and so on.
5. Passive and active ion channels whose activity can depend on the potential difference across the cell membrane.
6. Inputs at different parts of the tree can cause the neuron to behave differently.
7. More and more information suggests that glia (support cells)

An understanding of the brain



- 86B neurons[1]
- complex morphologies: dendritic trees
- active and passive ion channels
- inputs spread out over the dendritic tree

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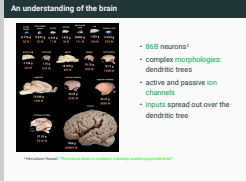

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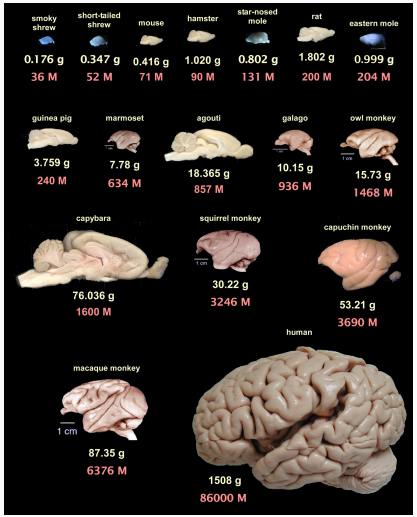

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- complex morphologies: dendritic trees
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- but: also 85B glia

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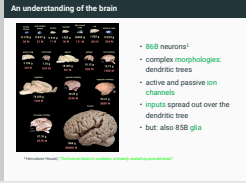

1. The most recent estimate puts the number of neurons in the human brain at 86B.
2. Experiments provide us with direct information.
3. They study the brain at different levels.
4. There's no right level. It depends on the question being investigated.

A *mechanistic* understanding of the brain

Figure showing multiple scales of modelling goes here.

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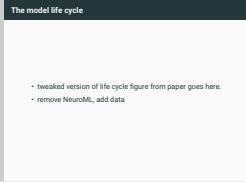
1. There is so much data out there now, as we embrace Open Science.
2. Models/theory are necessary for:
3. combining independent experimental results into unified theories
4. exploring these complex systems across wider range of conditions
5. generating new testable hypotheses
6. RNNs are appropriate for lots of projects, for example.
7. So are whole brain neural mass models.
8. But, to really understand the underlying mechanisms that give rise to emergent behaviour, we must model the brain at biophysically detailed levels.

The model life cycle

- tweaked version of life cycle figure from paper goes here.
- remove NeuroML, add data



1. The figure shows a simplified model life cycle. Can be much more complex in practice.
2. Lots of tools out there for each step.
3. But there's are issues—fragmentation, lack of interoperability, so many APIs.

Standards enable FAIR neuroscience

- NWB/BIDS for data
- NeuroML/SBML etc. for modelling
- Add logos

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1. Standards allow the representation of data and models in specific, agreed formats.
2. They're not neuroscience specific, of course—even programming languages have standards.
3. More importantly, if one knows what the data is going to look like, one can then develop tools and APIs around it.
4. And instead of everyone writing a tool for their own standard, every tool anyone writes for the one standard can be used with everyone's data.

But, too many standards?

- XKCD here.

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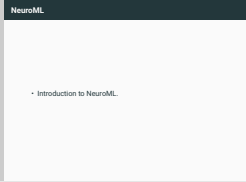
1. In neuroscience, we're fortunate enough to not have the issue of having too many standards.
2. There are only a few standards in biophysically detailed modelling, and as we'll see, we ensure that these few remain interoperable.

NeuroML

- Introduction to NeuroML.



NeuroML: scope

- Figure 2 from paper

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NeuroML: software ecosystem

- Figure 3

NeuroML: software ecosystem
• Figure 3

NeuroML: software ecosystem: core tools

- Figure 4

NeuroML: software ecosystem: core tools
• Figure 4

NeuroML: create models

- Figure 5
- Code example

NeuroML: create models
• Figure 5
• Code example

NeuroML: validate models

- Figure 6

NeuroML: validate models

- Figure 6

NeuroML: visualise models

- Figure 7
- Figure 8
- Figure 9

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NeuroML: simulate models

- Example simulation: neuron/netpyne

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NeuroML: fit models

- Figure from docs
- Mention inspyred

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NeuroML: share and re-use models

- GitHub, OSBv1, OSBv2, NeuroML-DB

NeuroML: share and re-use models
• GitHub, OSBv1, OSBv2, NeuroML-DB

NeuroML: the standard

- Schema, component types

NeuroML: the standard
- Schema, component types

NeuroML: the APIs

- Python API

NeuroML: the APIs
• Python API

NeuroML: LEMS

- LEMS, advantages

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NeuroML: Documentation

- Jupyterbook

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NeuroML: projects

- GSoC, Outreachy, good computer science students

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