The NeuroML ecosystem for standardised multi-scale modelling in neuroscience

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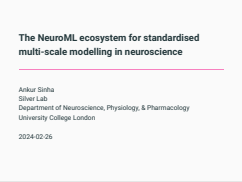
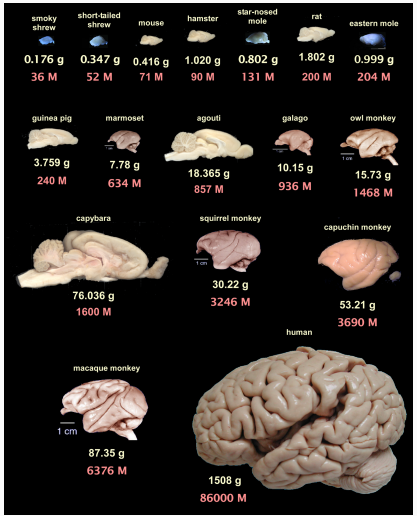
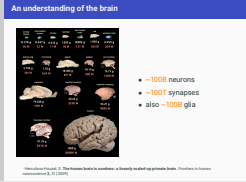


An understanding of the brain



- ~100B neurons
- ~100T synapses
- also ~100B glia

[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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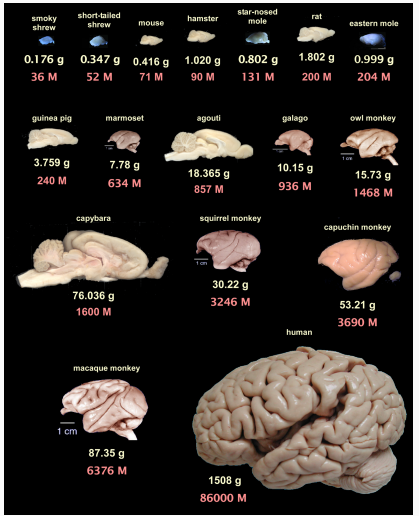
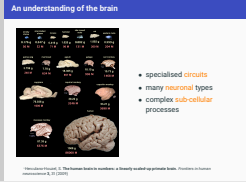


- specialised circuits
- many neuronal types
- complex sub-cellular processes

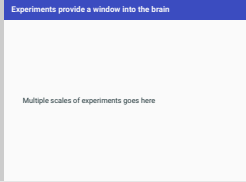
[1] Herculano-Houzel, S. **The human brain in numbers: a linearly scaled-up primate brain.** *Frontiers in human neuroscience* **3,** 31 (2009)



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.

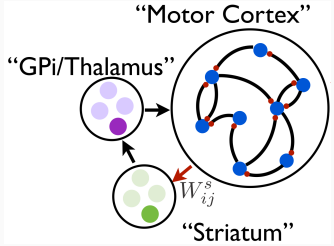
Experiments provide a window into the brain

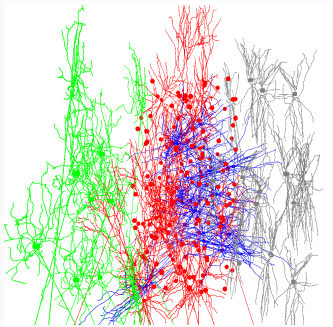
Multiple scales of experiments goes here

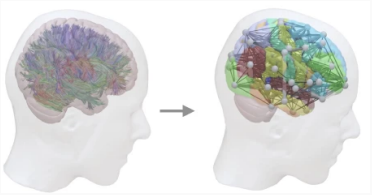


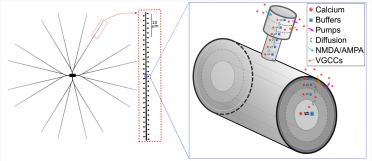
1. There is so much data out there now, as we embrace Open Science.
2. Models/theory are necessary for:
3. combining independent experimental results into unified theories
4. exploring these complex systems across wider range of conditions
5. generating new testable hypotheses
6. RNNs are appropriate 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.

Models test & unify experimental results; generate hypotheses







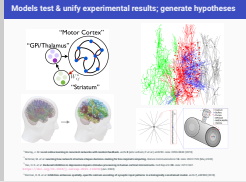


[1] Murray, J. M. **Local online learning in recurrent networks with random feedback.** *eLife* **8** (eds Latham, P. *et al.*) e43299. ISSN: 2050-084X (2019)

[1] Schirner, M. *et al.* **Learning how network structure shapes decision-making for bio-inspired computing.** *Nature Communications* **14.** ISSN: 2041-1723 (May 2023)

[1] Yao, H. K. *et al.* **Reduced inhibition in depression impairs stimulus processing in human cortical microcircuits.** *Cell Reports* **38.** ISSN: 2211-1247. https://doi.org/10.1016/j.celrep.2021.110232 (Jan. 2022)

[1] Dorman, D. B. *et al.* **Inhibition enhances spatially-specific calcium encoding of synaptic input patterns in a biologically constrained model.** *eLife* **7,** e38588 (2018)



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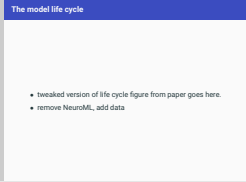
The model life cycle

- 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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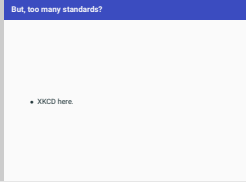
1. Standards allow the representation of data and models in specific, agreed formats.
2. They’re not neuroscience specific, of course—even programming languages have standards.
3. More importantly, if one knows what the data is going to look like, one can then develop tools and APIs around it.
4. And 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.

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

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NeuroML: scope

- Figure 2 from paper

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NeuroML: software ecosystem

- Figure 3

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- Figure 3

NeuroML: software ecosystem: core tools

- Figure 4

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- Figure 4

NeuroML: create models

- Figure 5
- Code example

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- Figure 5
- Code example

NeuroML: validate models

- Figure 6

NeuroML: validate models
- Figure 6

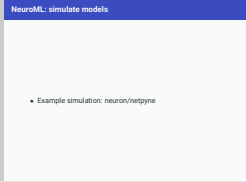
NeuroML: visualise models

- Figure 7
- Figure 8
- Figure 9

NeuroML: visualise models
• Figure 7
• Figure 8
• Figure 9

NeuroML: simulate models

- Example simulation: neuron/netpyne



NeuroML: fit models

- Figure from docs
- Mention inspyred

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NeuroML: share and re-use models

- GitHub, OSBv1, OSBv2, NeuroML-DB

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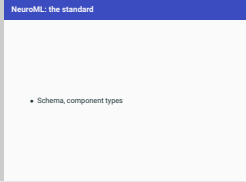
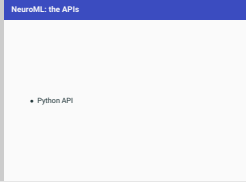
NeuroML: the standard

- Schema, component types



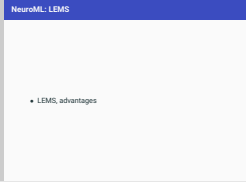
NeuroML: the APIs

- Python API



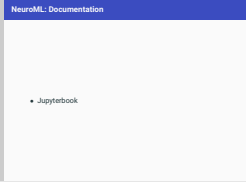
NeuroML: LEMS

- LEMS, advantages



NeuroML: Documentation

- Jupyterbook



NeuroML: projects

- GSoC, Outreachy, good computer science students