The NeuroML ecosystem for standardised multi-scale modelling in neuroscience

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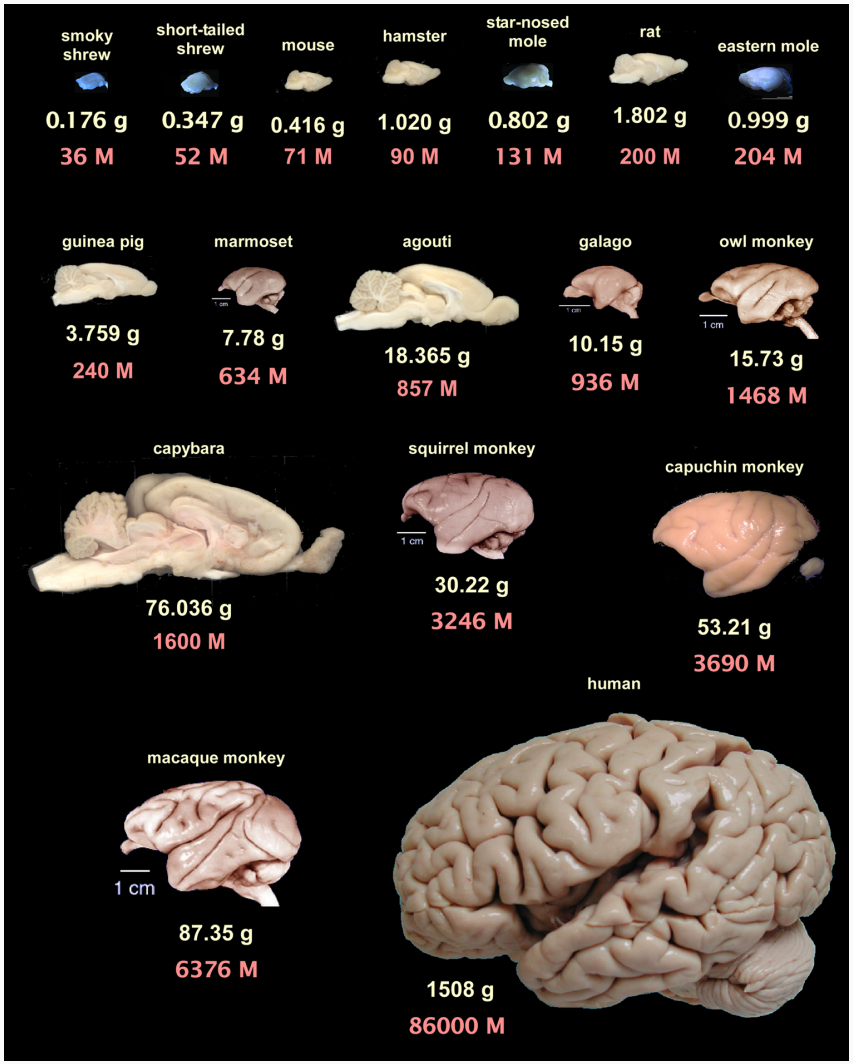
An understanding of the brain



- ~86B neurons
- ~100T synapses
- also ~85B glia

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

[1] von Bartheld, C. S. *et al.* **The search for true numbers of neurons and glial cells in the human brain: A review of 150 years of cell counting.** *Journal of Comparative Neurology* **524,** 3865–3895. ISSN: 1096-9861 (June 2016)

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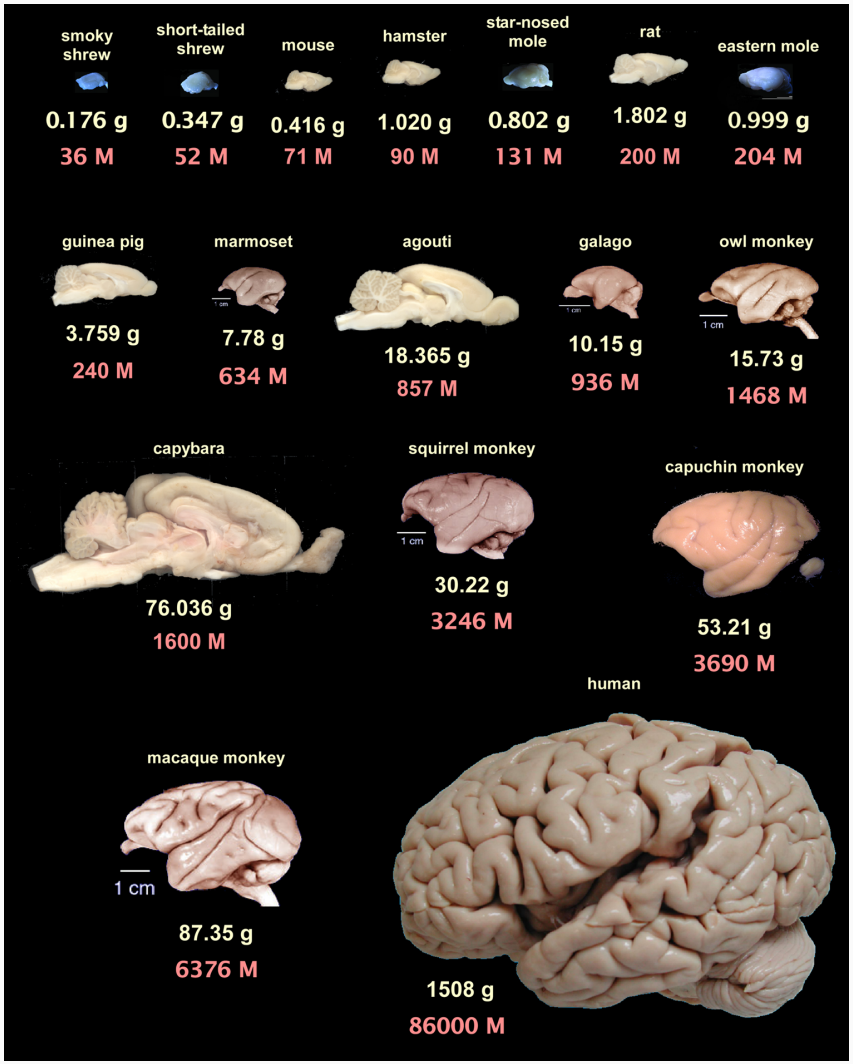

- specialised circuits
- different neuronal types
- synaptic connections
- complex sub-cellular processes

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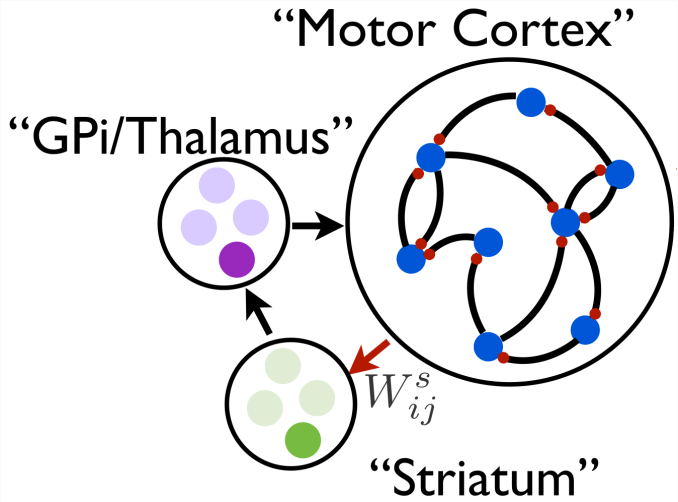
Experiments provide a window into the brain

Multiple scales of experiments/data sources go here

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)

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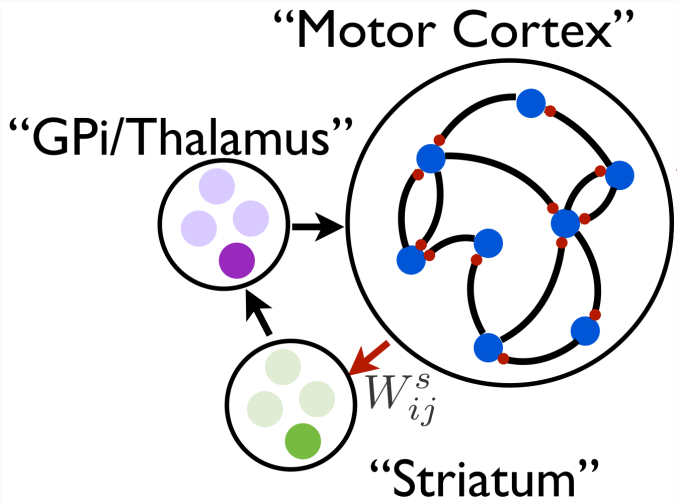

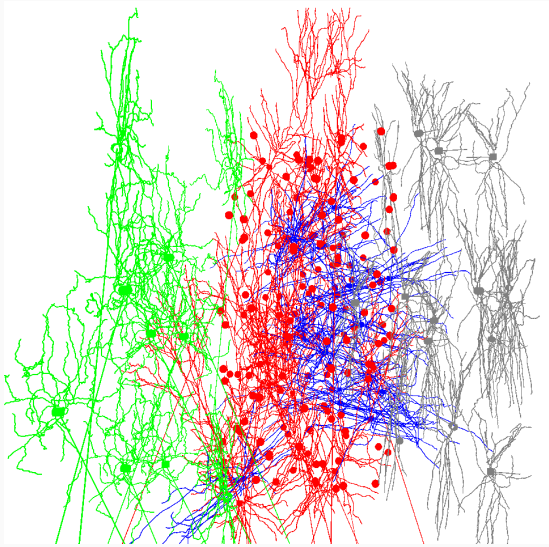

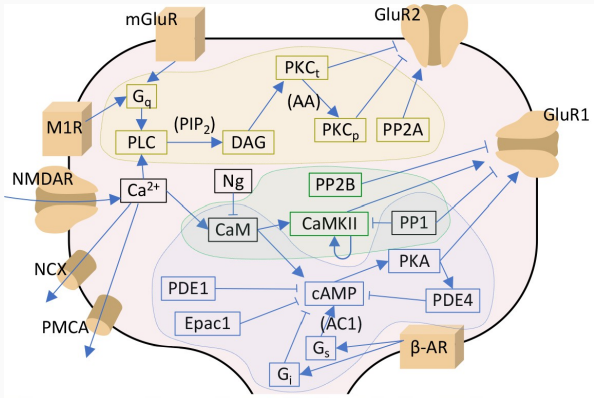

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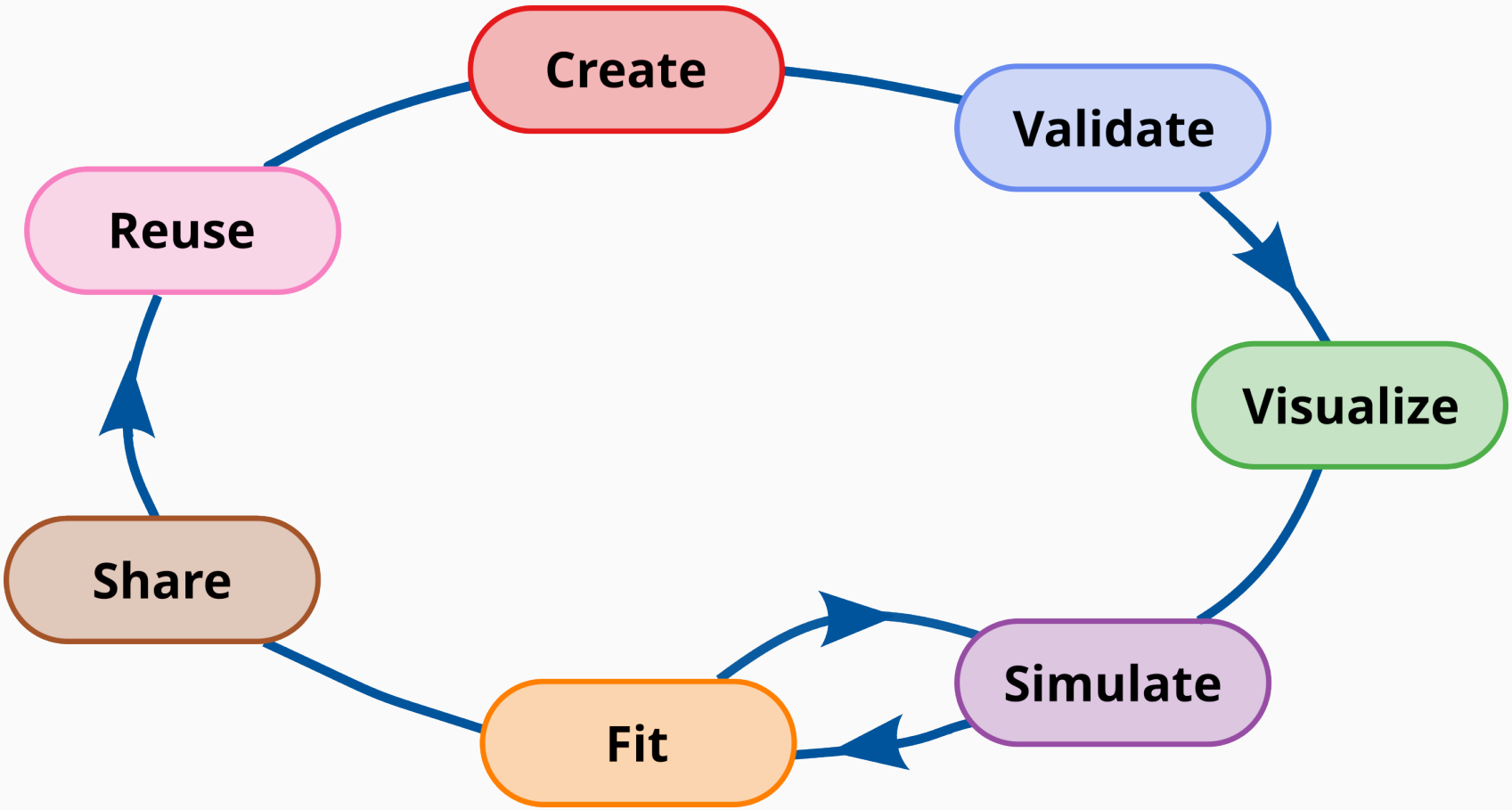
A *mechanistic* understanding of the brain requires biophysically detailed modelling

The model life cycle



Computational modelling software ecosystem is fragmented

- many specialist tools:
  - simulation: NEURON, NEST, Brian, GENESIS, MOOSE, STEPS, ANNarchy, TVB, LFPy, NeuroLib, EDEN, Arbor, NetPyNE
  - fitting: BluePyOpt, NeuroTune, SciUnit

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  - fitting: BluePyOpt, NeuroTune, SciUnit
- but:
  - different APIs, syntax
  - not well defined model descriptions
  - custom machine readable internal representations
  - ad-hoc utilities

Makes computational neuroscience not FAIR
(Findable, Accessible, Interoperable, Reusable)

Standards enable FAIR neuroscience

COMBINE

[1] Abrams, M. B. *et al.* **A Standards Organization for Open and FAIR Neuroscience: the International Neuroinformatics Coordinating Facility.** *Neuroinformatics* **20,** 25–36. ISSN: 1559-0089. https://doi.org/10.1007/s12021-020-09509-0 (2022): https://incf.org

[1] COmputational Modeling in BIology NEtwork (COMBINE): https://co.mbine.org/

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NeuroML ecosystem supports all stages of the model cycle

- standard/specification
- software ecosystem

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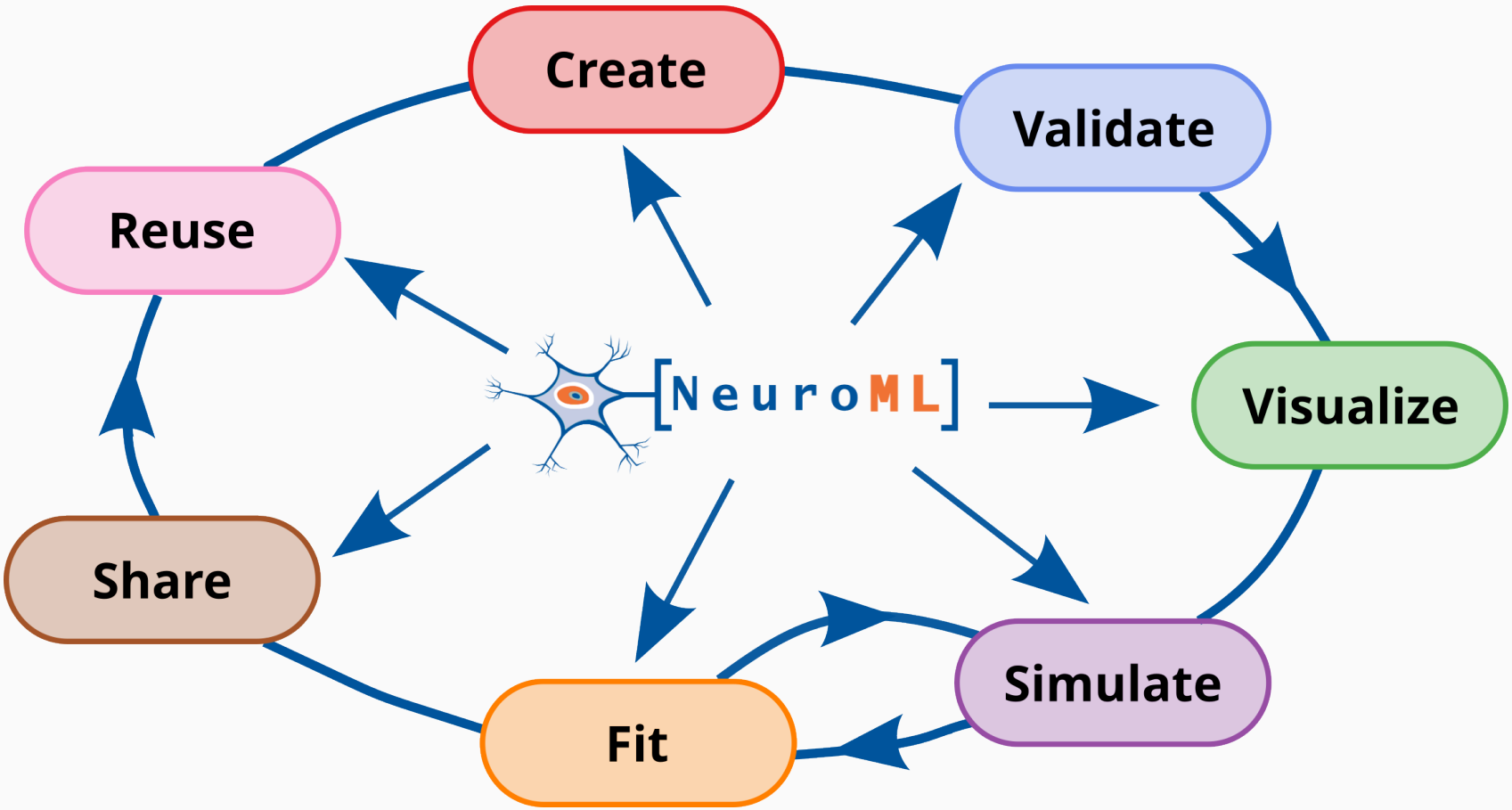
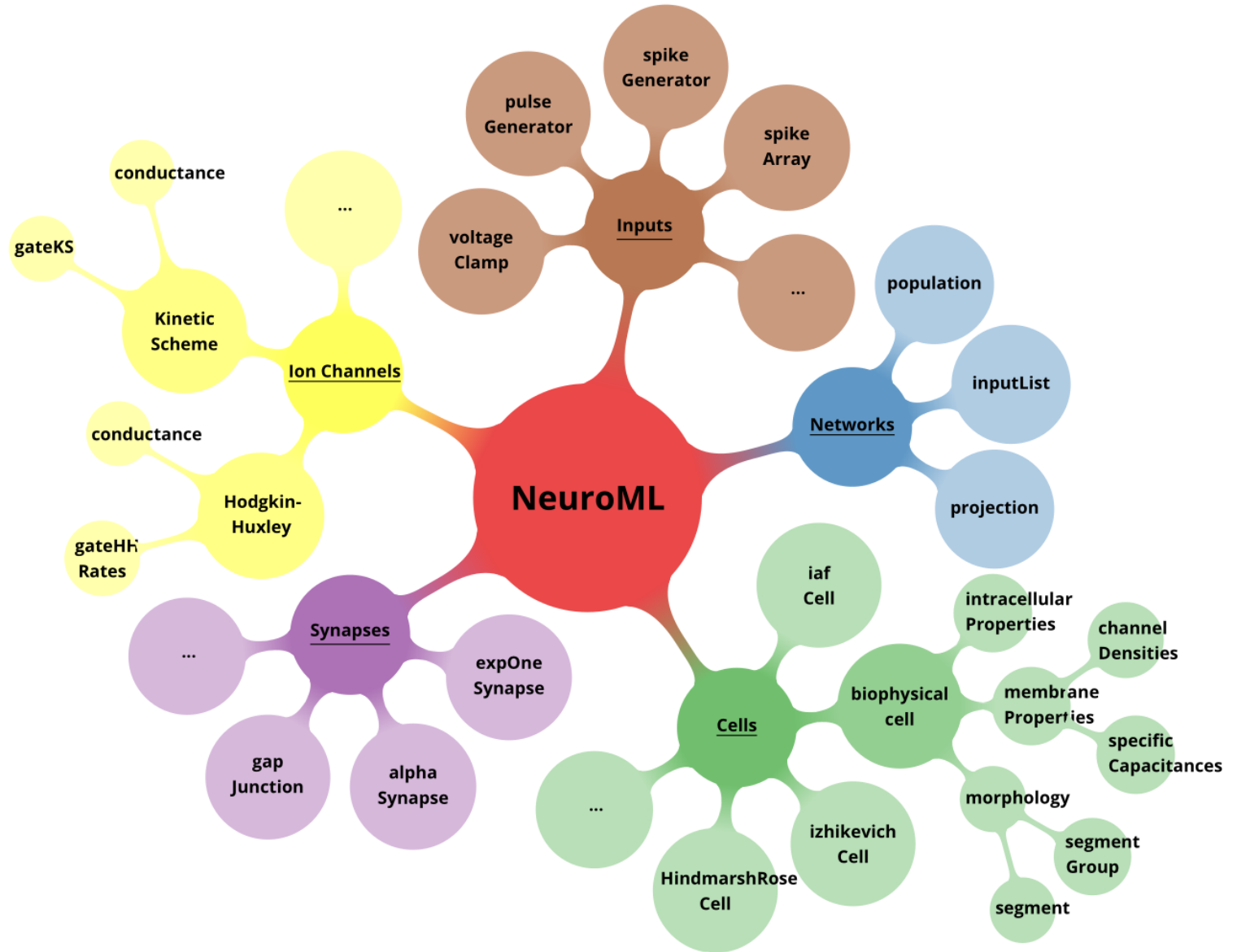
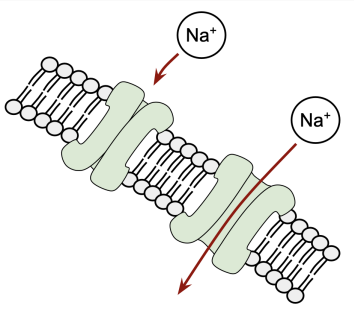
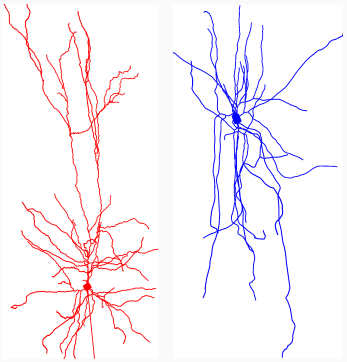


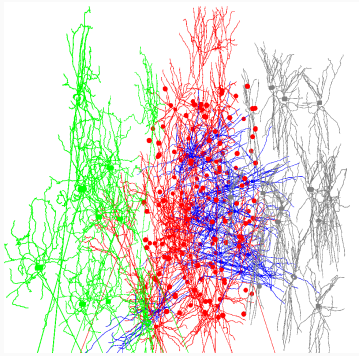
NeuroML provides a set of curated model elements

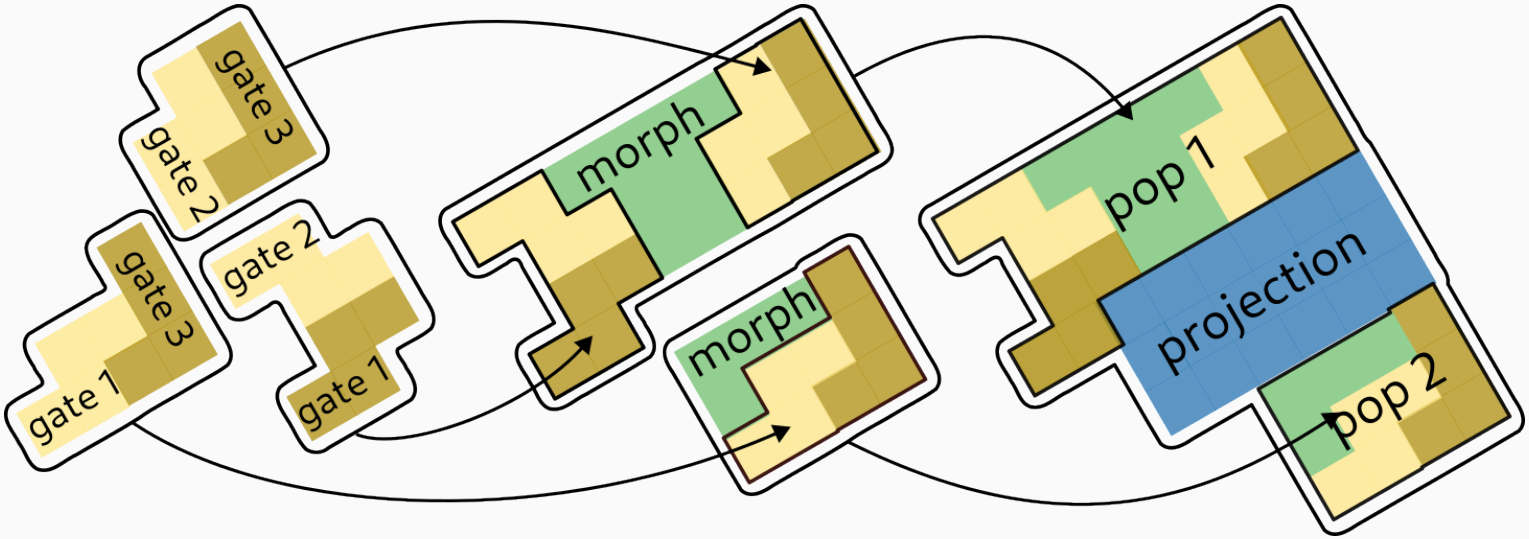


NeuroML is a modular, structured and hierarchical language

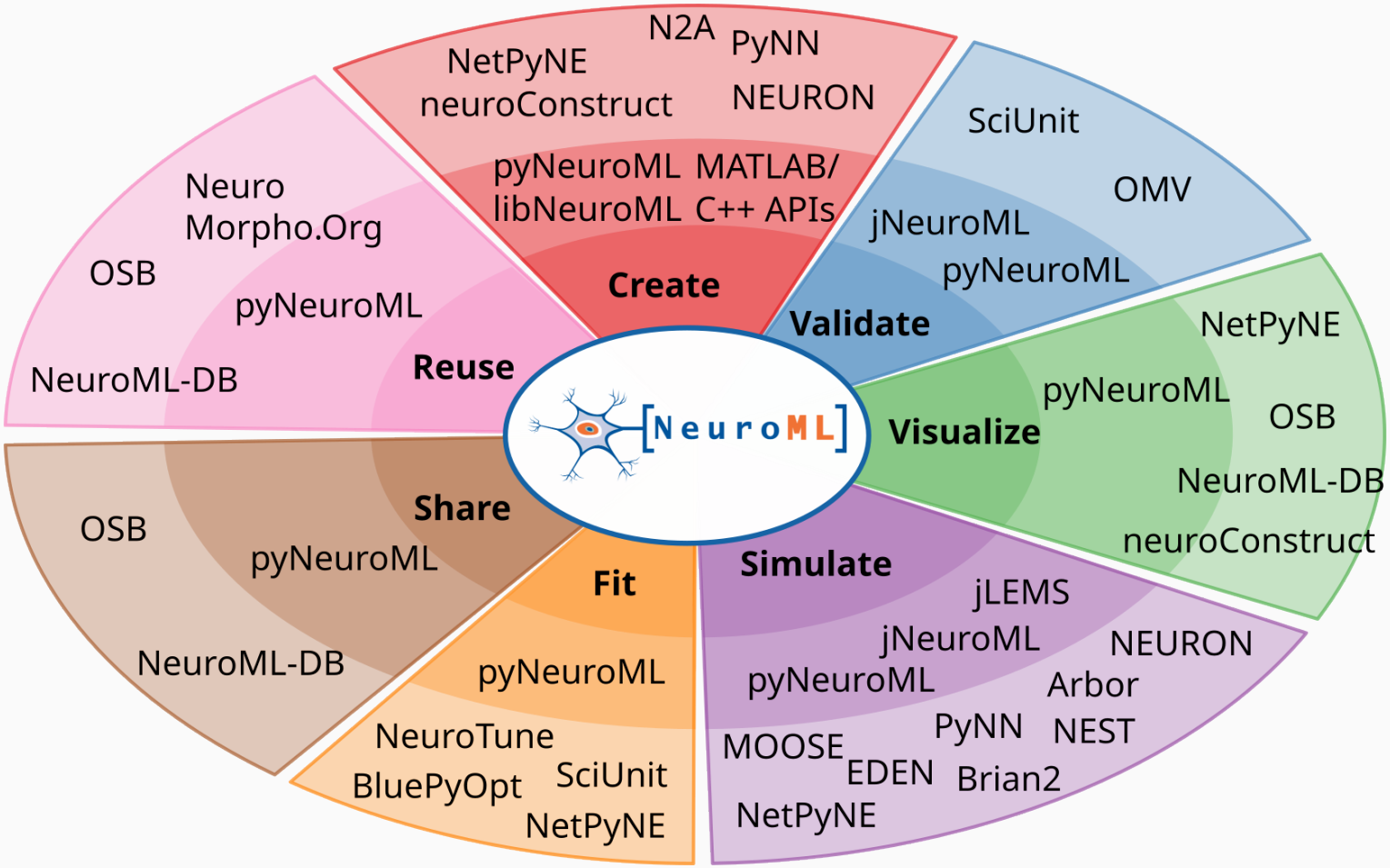








NeuroML: software ecosystem



NeuroML: software ecosystem: core tools

- Figure 4

NeuroML: create models

- Figure 5
- Code example

NeuroML: validate models

- Figure 6

NeuroML: visualise models

- Figure 7
- Figure 8
- Figure 9

NeuroML: simulate models

- Example simulation: neuron/netpyne

NeuroML: fit models

- Figure from docs
- Mention inspyred

NeuroML: share and re-use models

- GitHub, OSBv1, OSBv2, NeuroML-DB

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

But, too many standards?

- XKCD here.