Large scale cortical models in NeuroML format on Open Source Brain

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University College London
CNS 2018, Seattle

Overview

NeuroML

Open Source Brain

Cortical models on OSB

Issues with current usage

NeuroMLlite

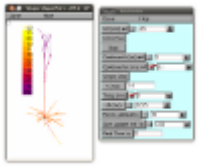
NeuroML

Standardised XML language for computational neuroscience

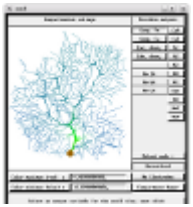
Version 1.x allowed specification of:

- Detailed neuronal morphologies
- Ion channels
- Synapses
- 3D network structure

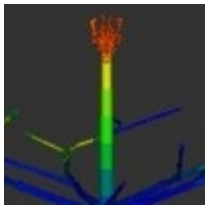
30+ simulators/applications/databases/libraries support NeuroML



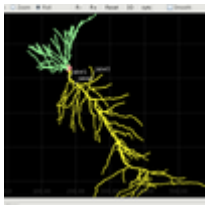
NEURON



GENESIS

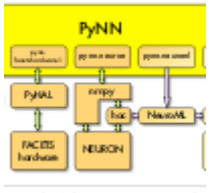


MOOSE



PSICS

NeuroSpaces



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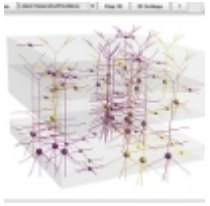
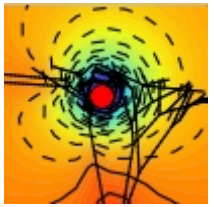


neuroConstruct

OpenWorm



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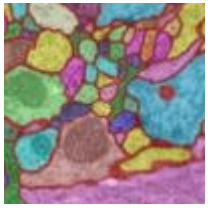

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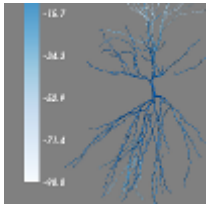
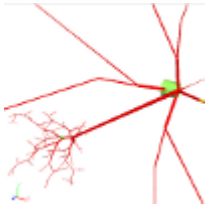
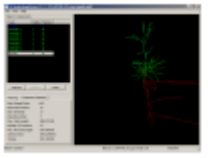


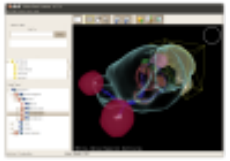
Neuronvisio



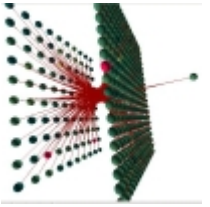
Moogli



NeuronLand

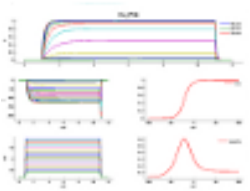


Whole Brain Catalog

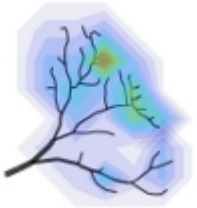


NeurAnim

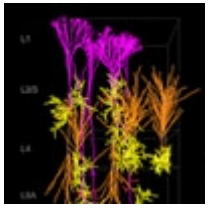
NeuroMorpho



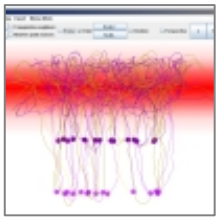
Channelpedia



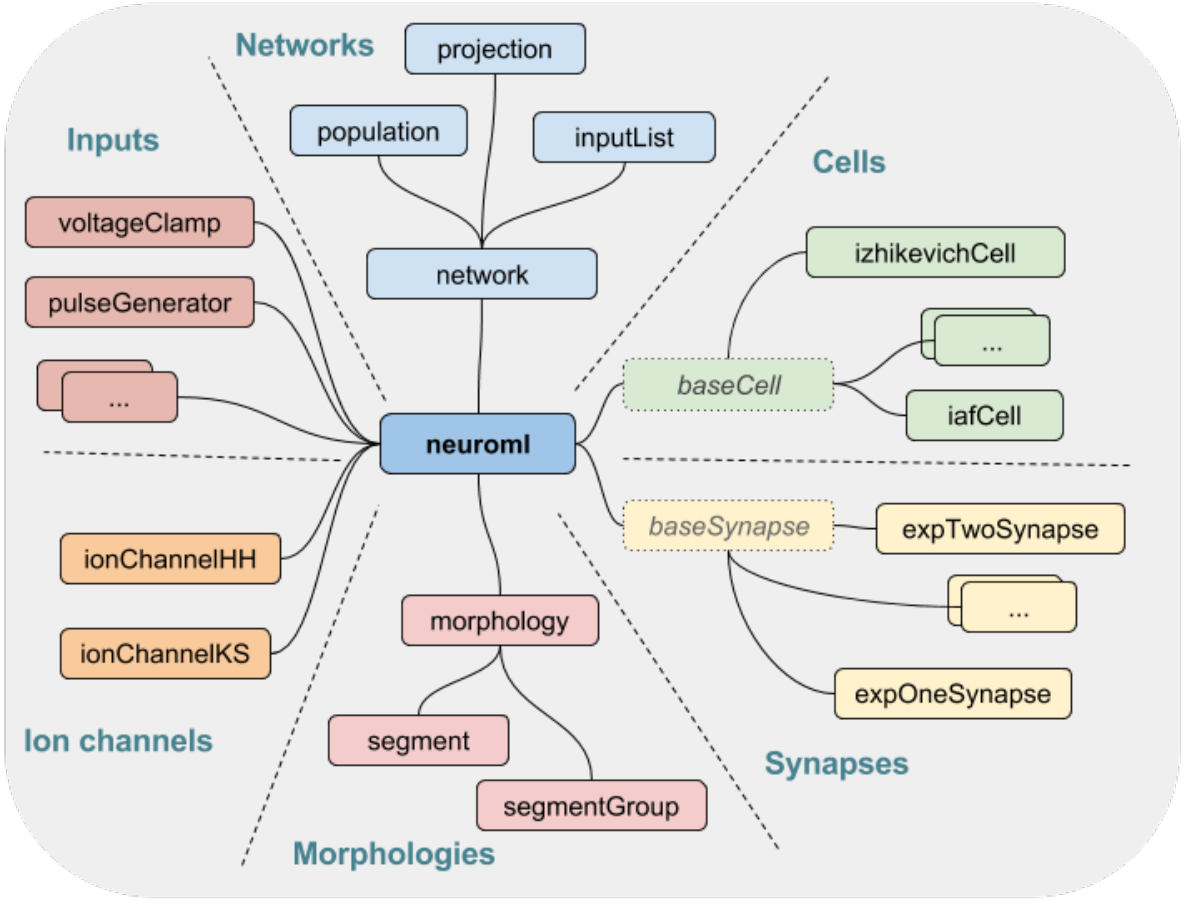
TREES toolbox



NeuGen



CX3D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inputList
Inputs
Cells
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network
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pulseGenerator
...
baseCell
...
iafCell
neuroml
baseSynapse
expTwoSynapse
ionChannelHH
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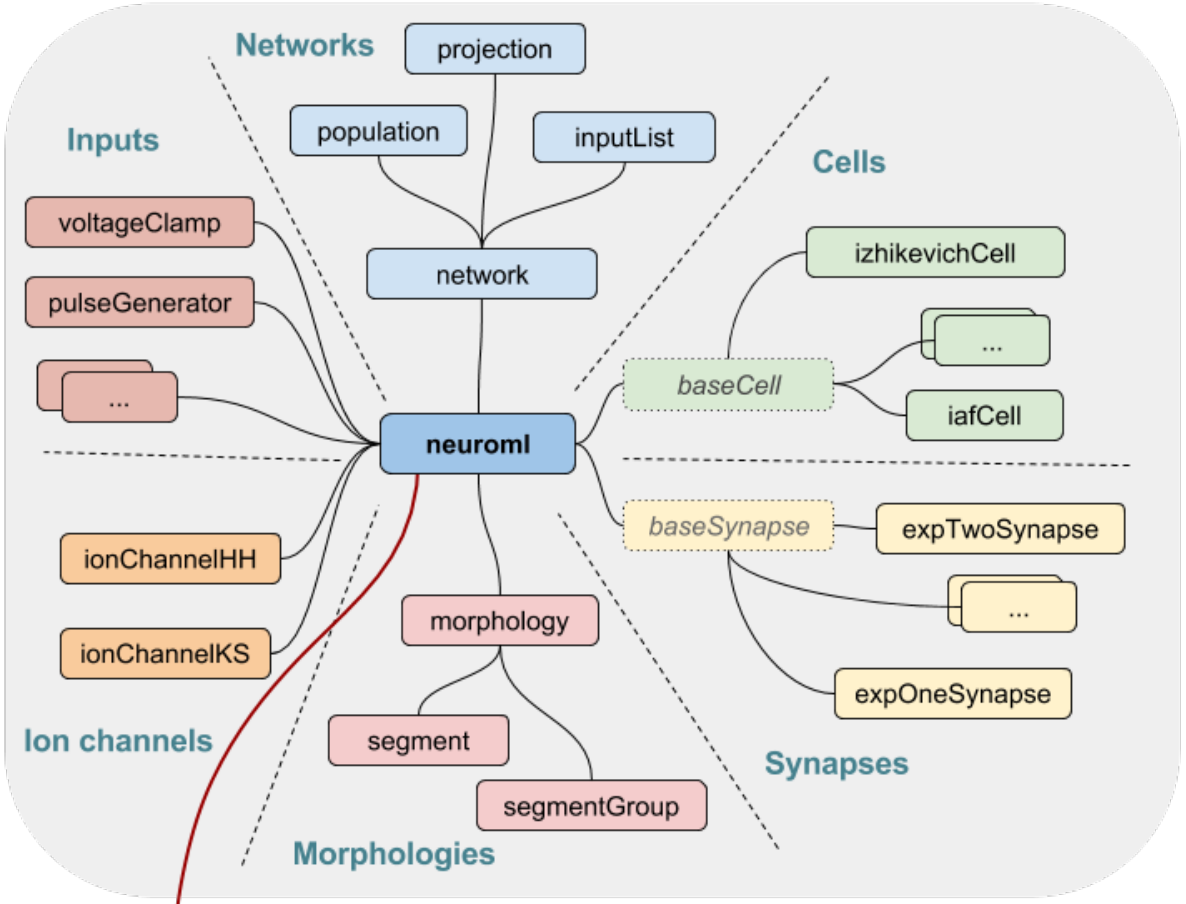
morphology
ionChannelKS
expOneSynapse
Ion channels
segment
Synapses
segmentGroup
Morphologies

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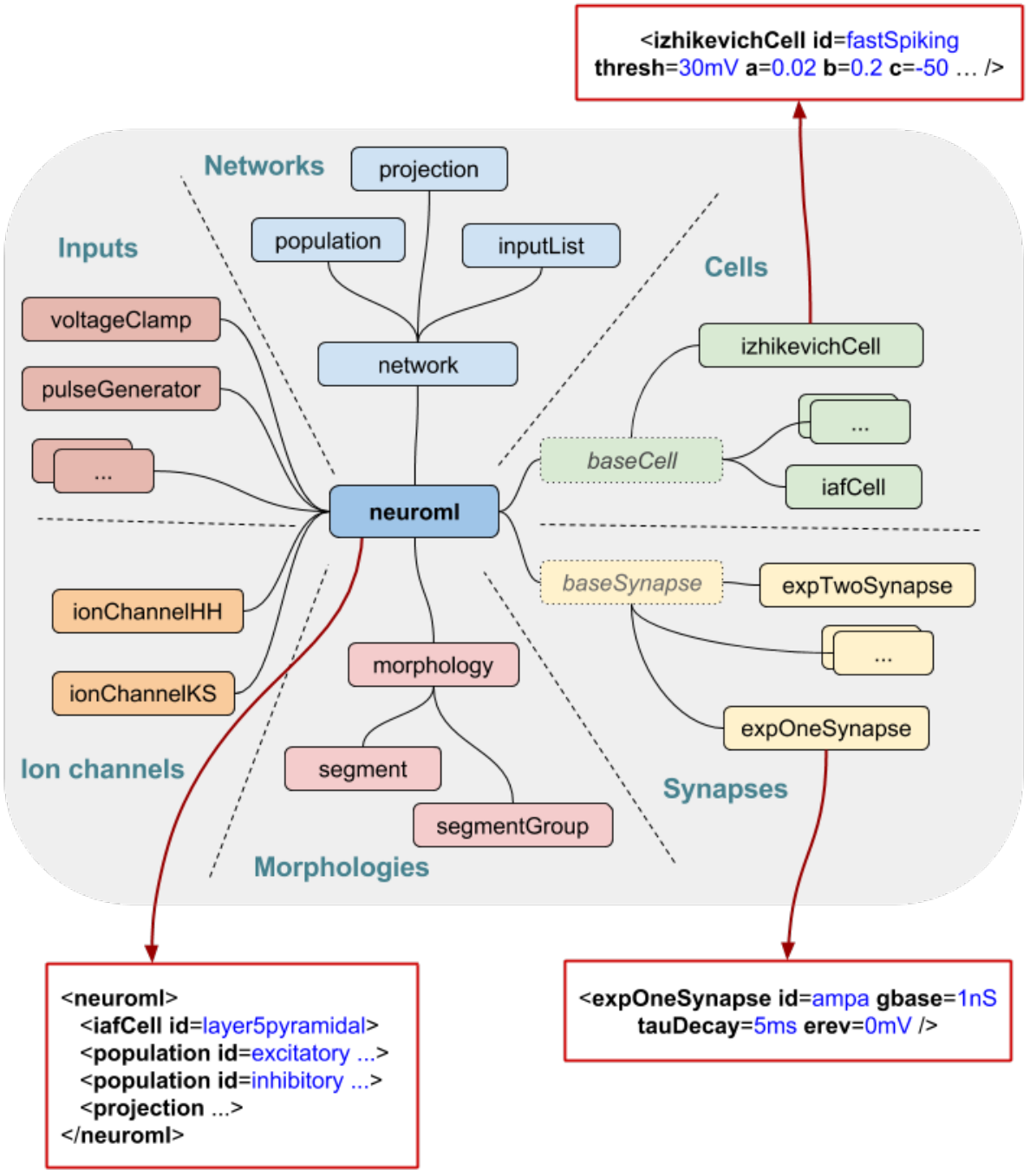
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Networks
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inputList
Inputs
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iafCell
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segmentGroup
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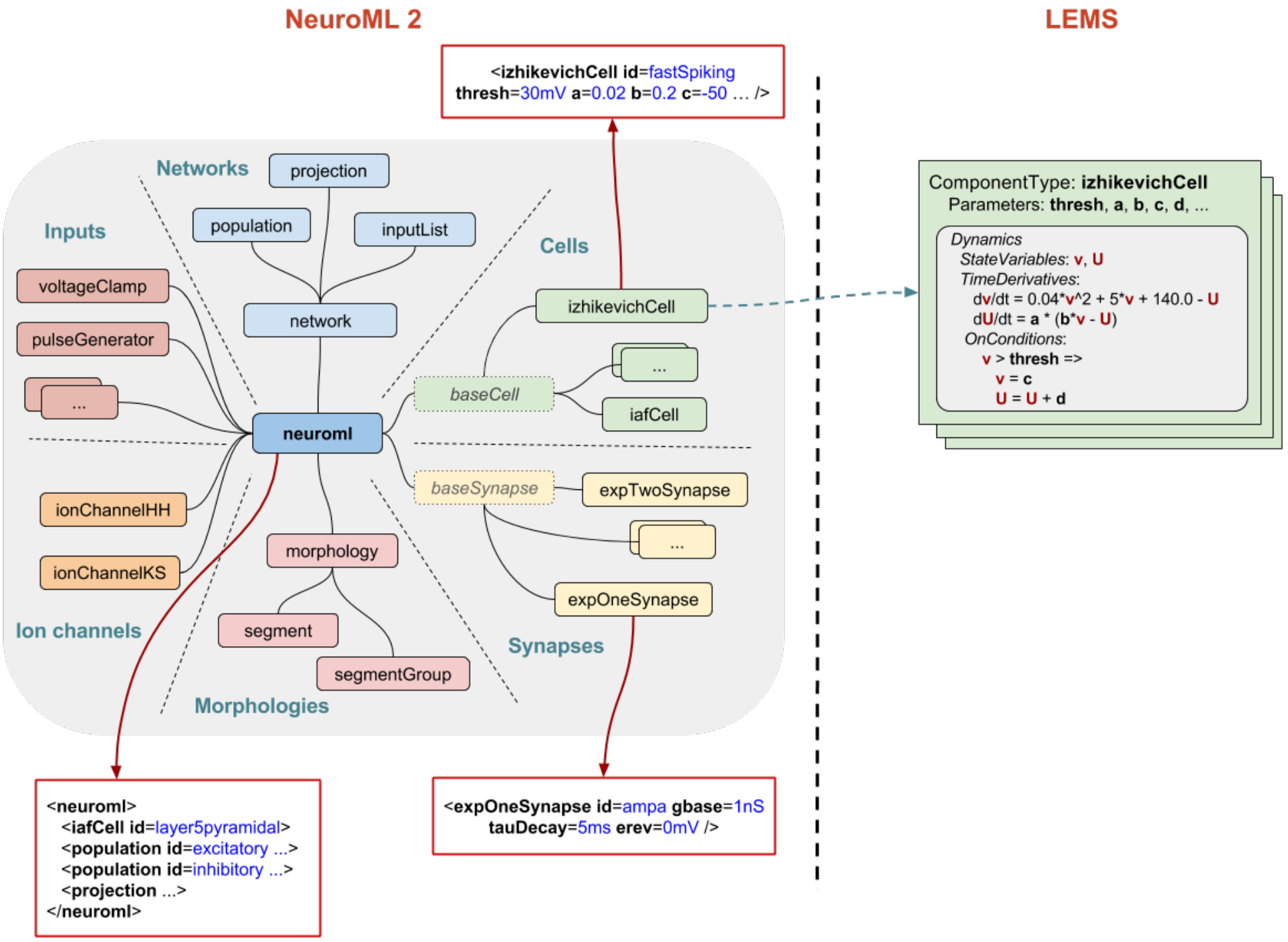
NeuroML 2
LEMS
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Networks
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Inputs
Cells
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baseCell
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neuroml
baseSynapse
expTwoSynapse
ionChannelHH
...
morphology
ionChannelKS
expOneSynapse
Ion channels
segment
Synapses
segmentGroup
Morphologies
ComponentType: izhikevichCell
Parameters: thresh, a, b, c, d, ...
Dynamics
StateVariables: v, U
TimeDerivatives:
dv/dt = 0.04*v^2 + 5*v + 140.0 - U
dU/dt = a * (b*v - U)
OnConditions:
v > thresh =>
v = c
U = U + d
<neuroml>
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<population id=excitatory ...>
<population id=inhibitory ...>
<projection ...>
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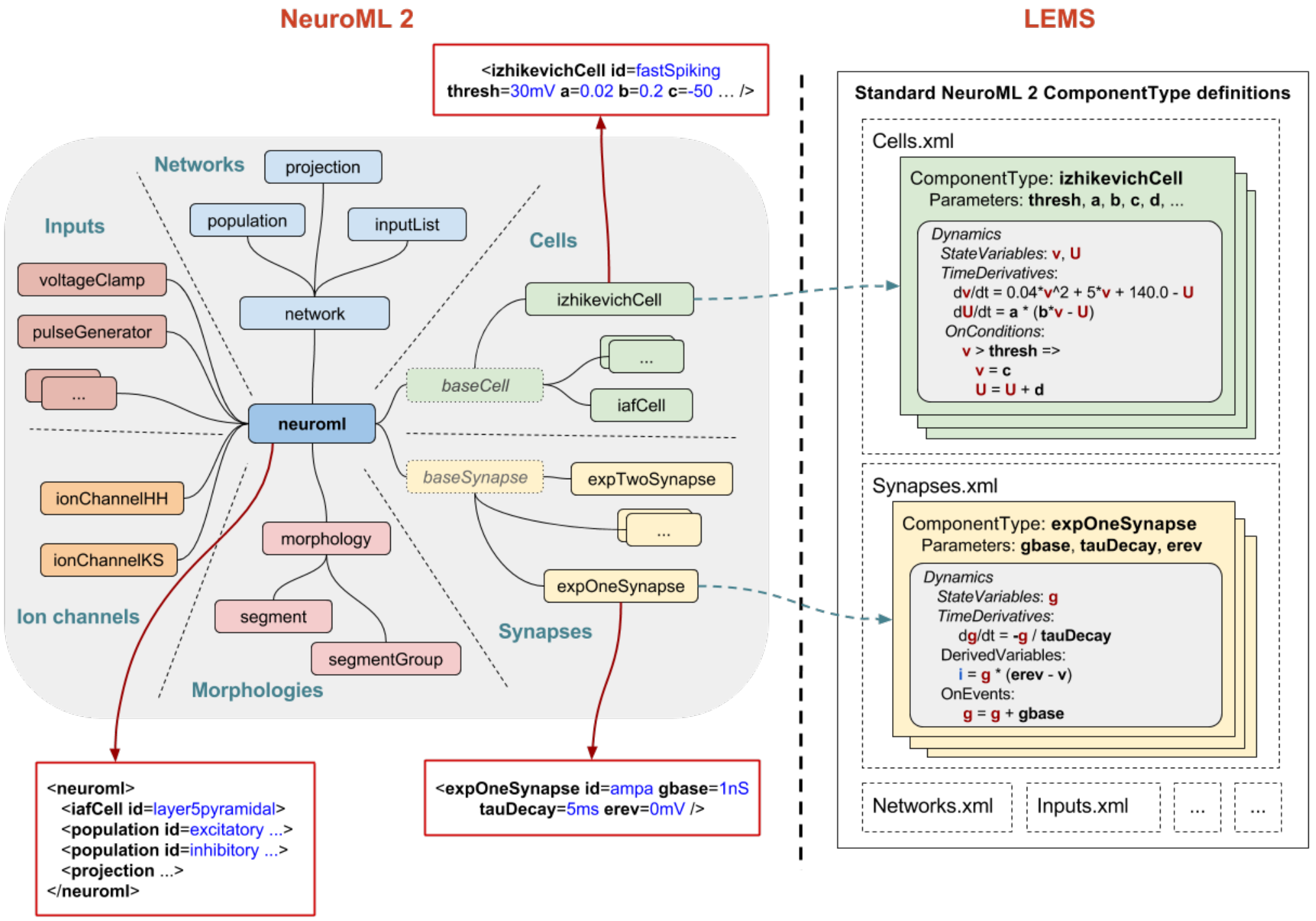
tauDecay=5ms erev=0mV />


NeuroML 2
LEMS
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segmentGroup
Morphologies
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<projection ...>
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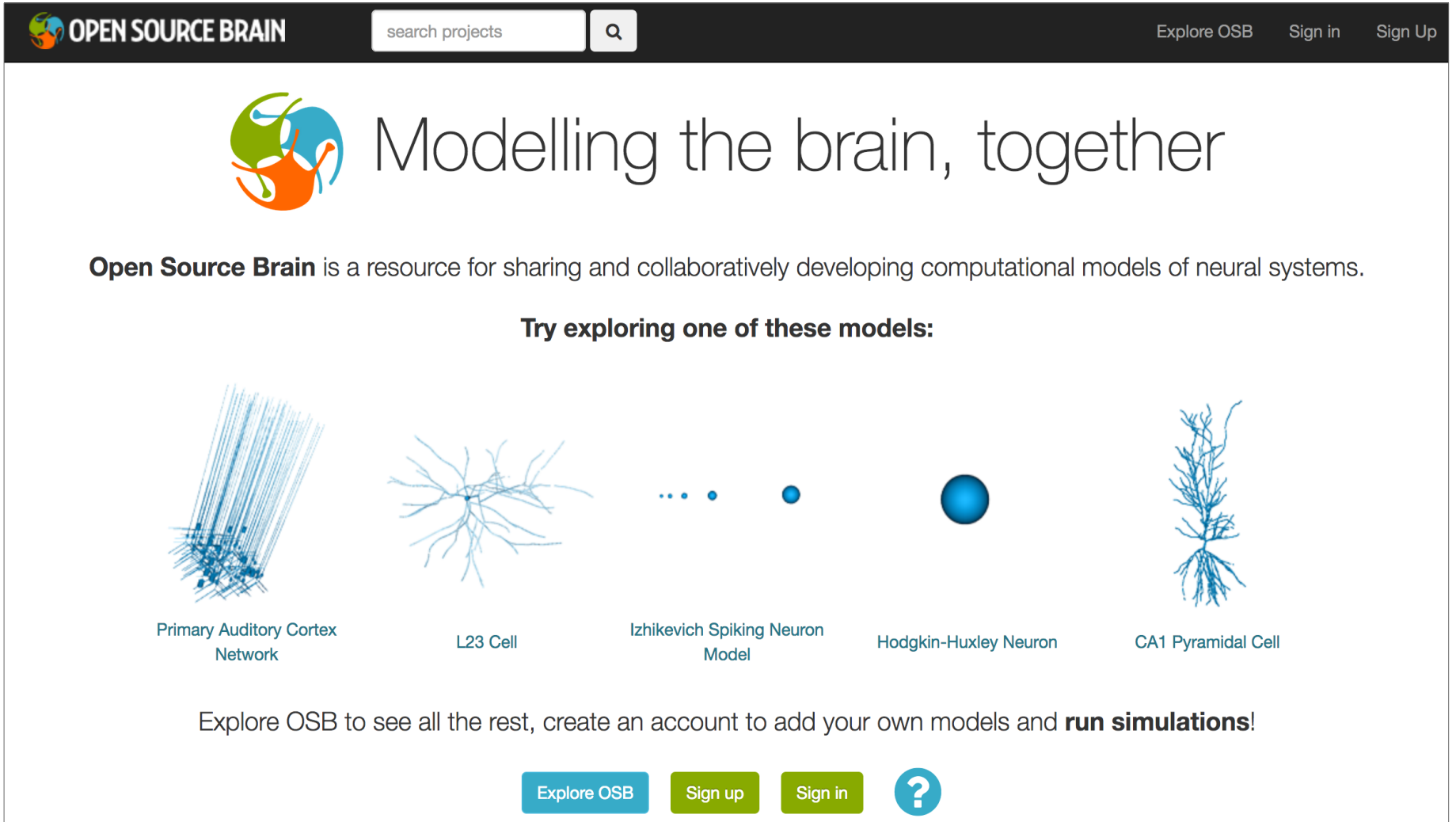
tauDecay=5ms erev=0mV />
Standard NeuroML 2 ComponentType definitions
Cells.xml
ComponentType: izhikevichCell
Parameters: thresh, a, b, c, d, ...
Dynamics
StateVariables: v, U
TimeDerivatives:
dv/dt = 0.04*v^2 + 5*v + 140.0 - U
dU/dt = a * (b*v - U)
OnConditions:
v > thresh =>
v = c
U = U + d
Synapses.xml
ComponentType: expOneSynapse
Parameters: gbase, tauDecay, erev
Dynamics
StateVariables: g
TimeDerivatives:
dg/dt = -g / tauDecay
DerivedVariables:
i = g * (erev - v)
OnEvents:
g = g + gbase
Networks.xml
Inputs.xml
...
...

The Open Source Brain repository



The Open Source Brain repository

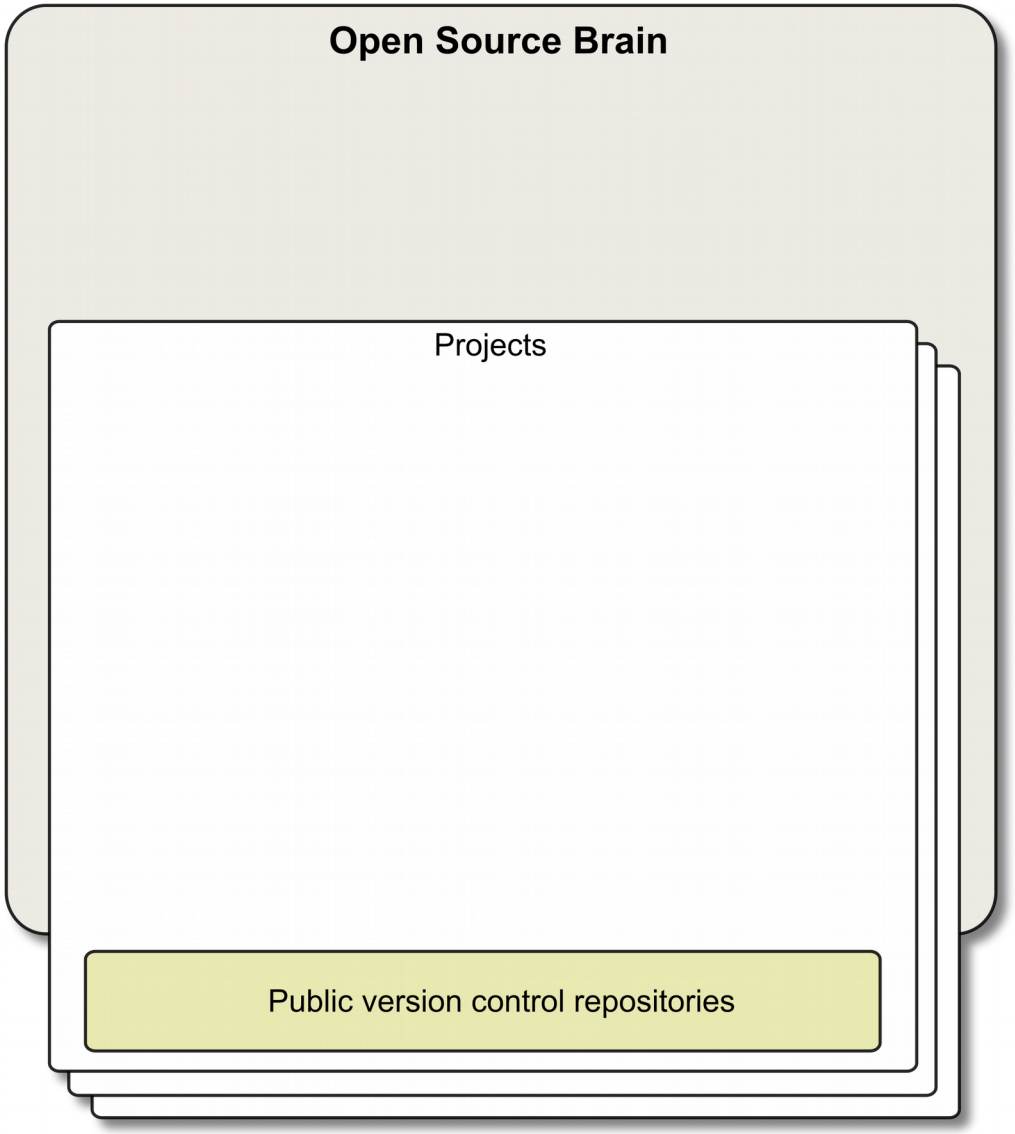
Wellcome Trust funded project

Open source model development repository for computational neuroscience

Structured database of well tested **spiking neuron & network models** in standardised formats

Allow anyone to comment on, extend, reuse models & run them across multiple simulators: **a collaboration platform**

Uses tools & best practices from Open Source software development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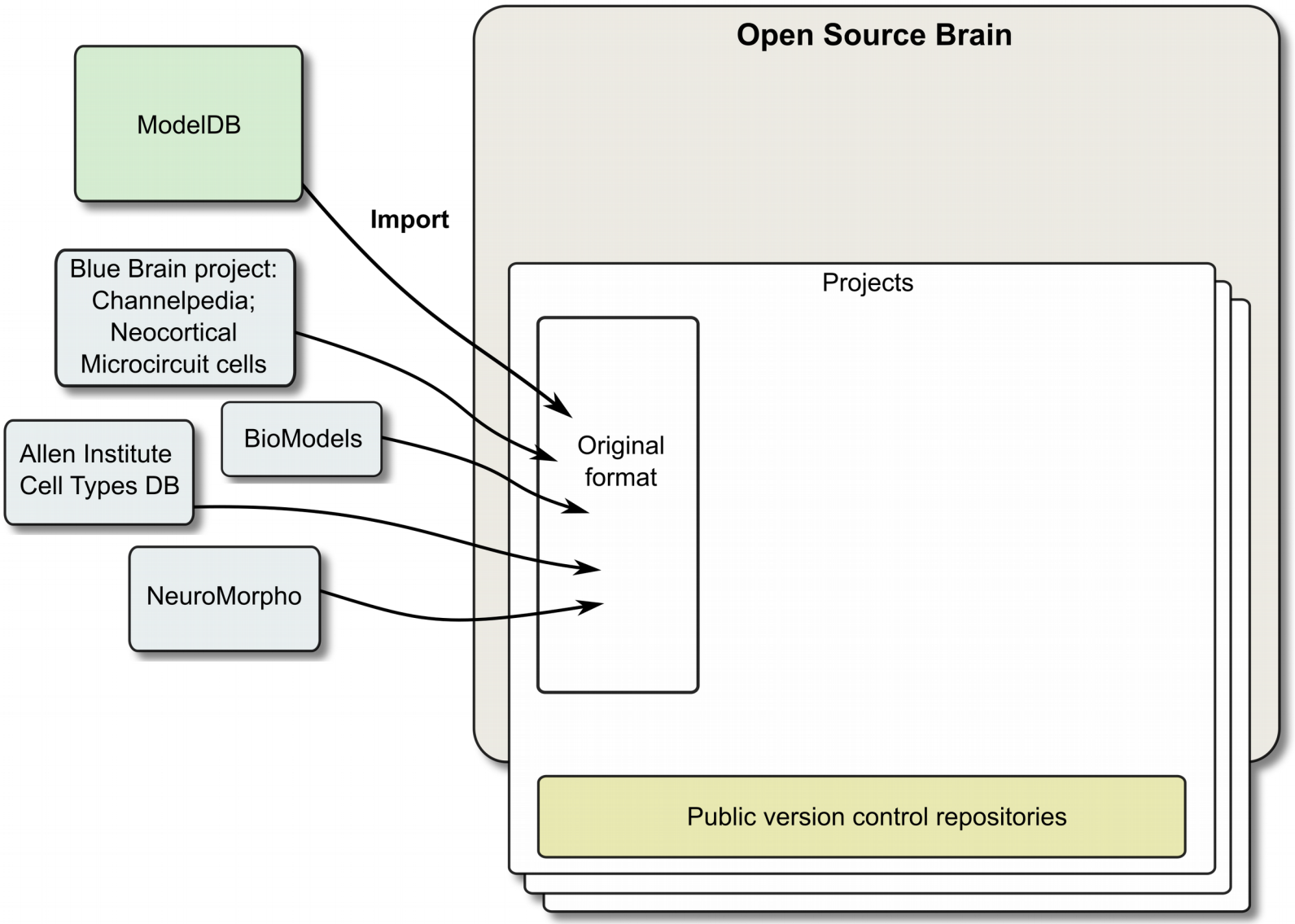
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Blue Brain project: Channelpedia; Neocortical Microcircuit cells
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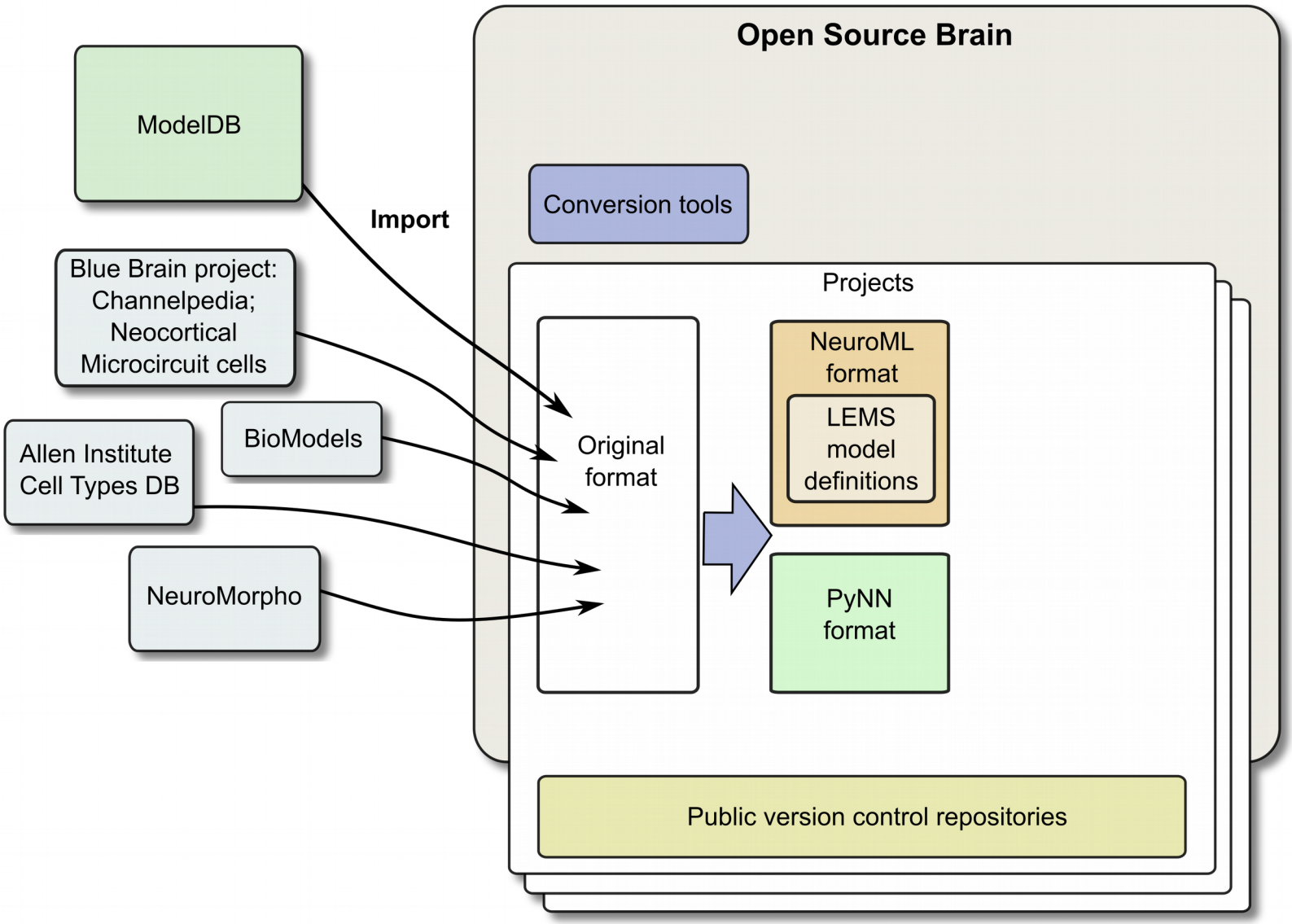
Original format
Public version control repositories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Allen Institute Cell Types DB
NeuroMorpho
PyNN format
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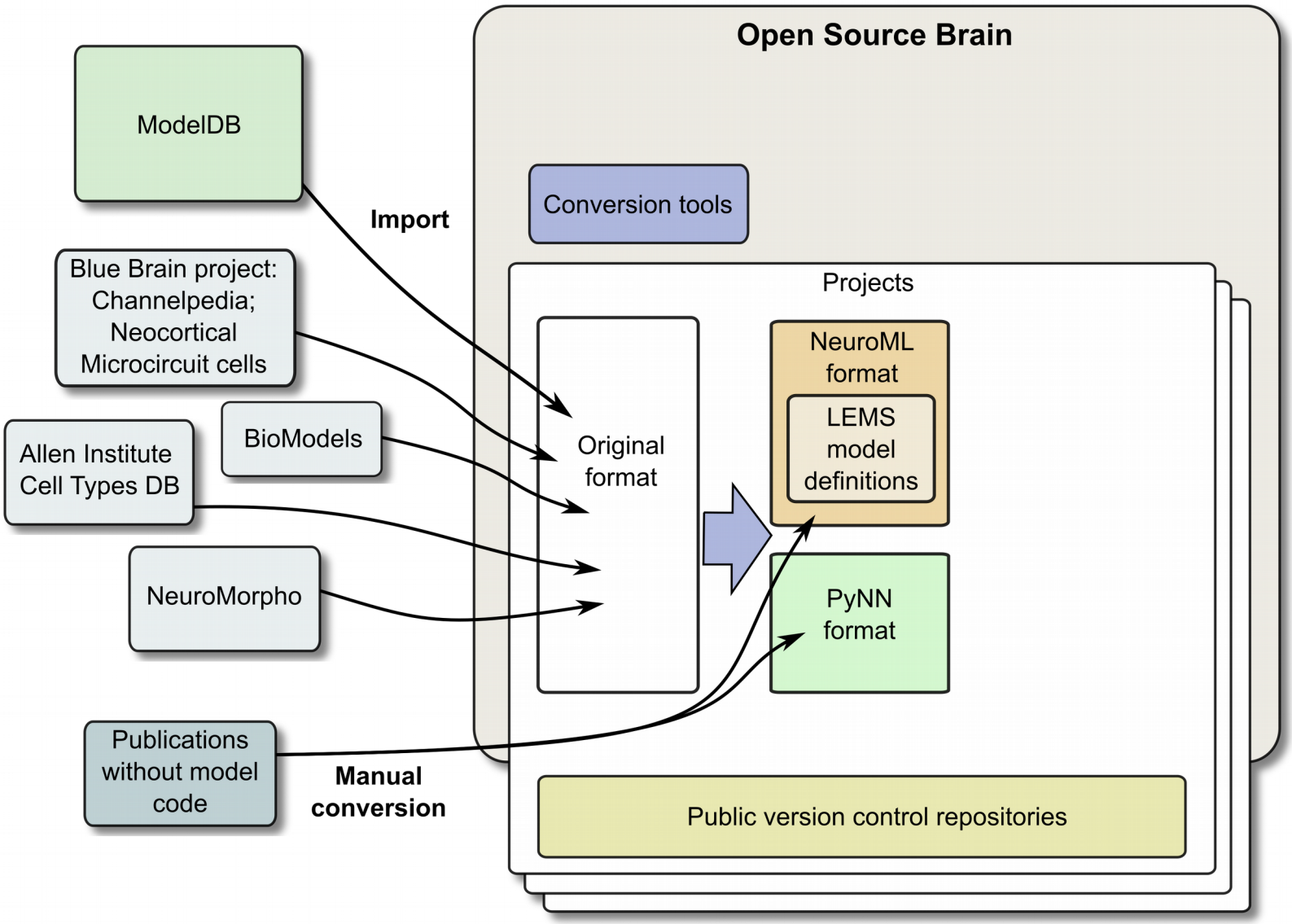
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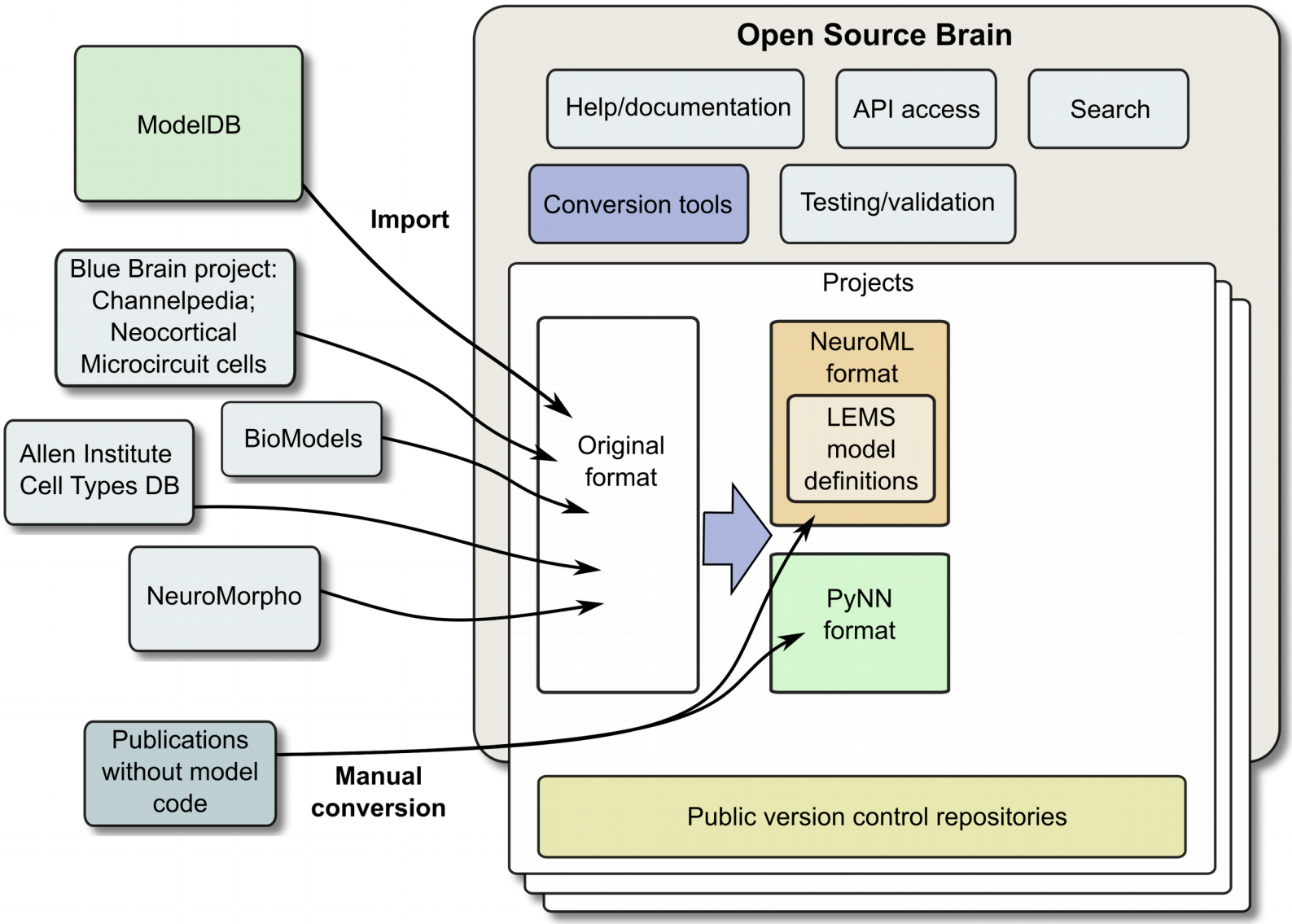
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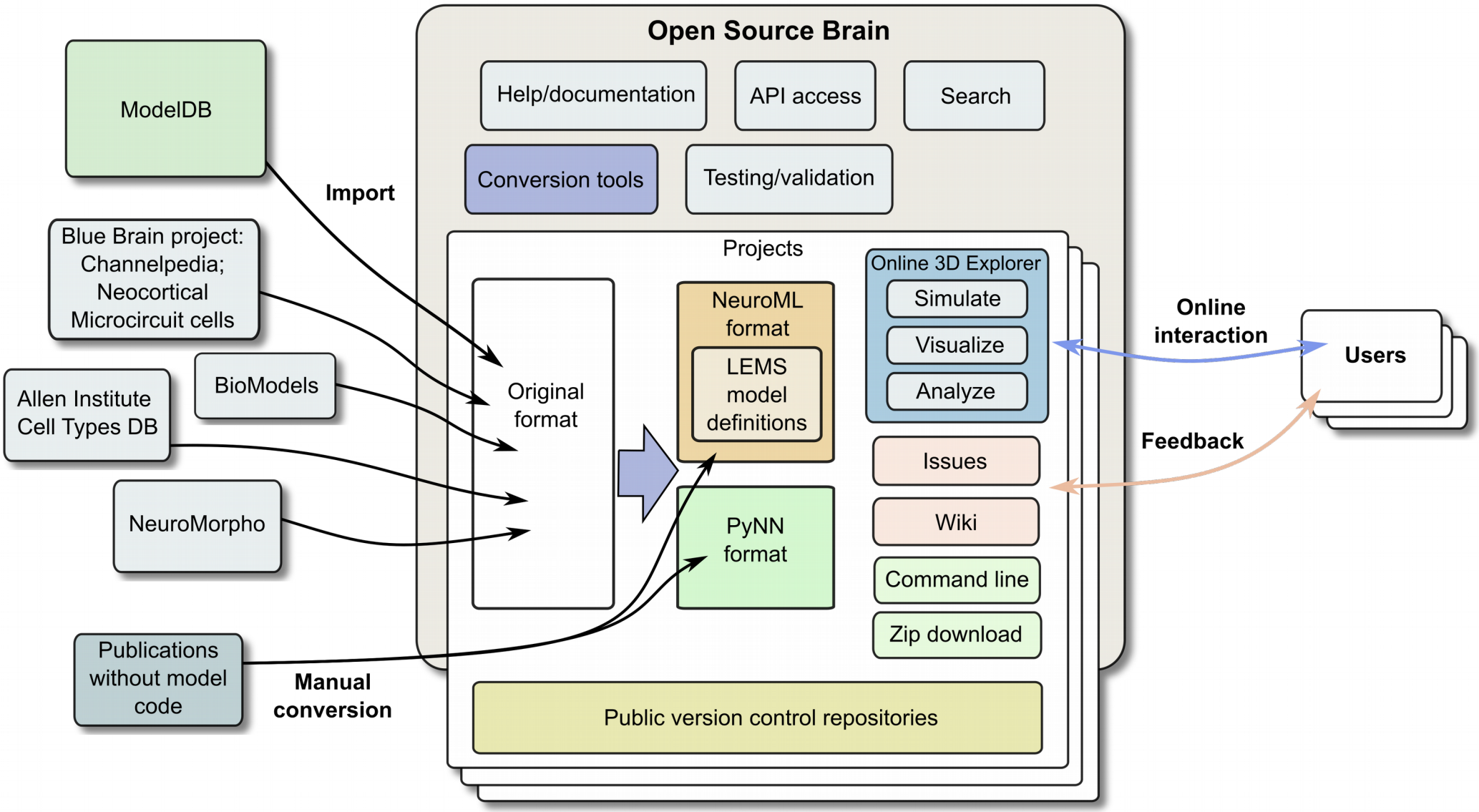
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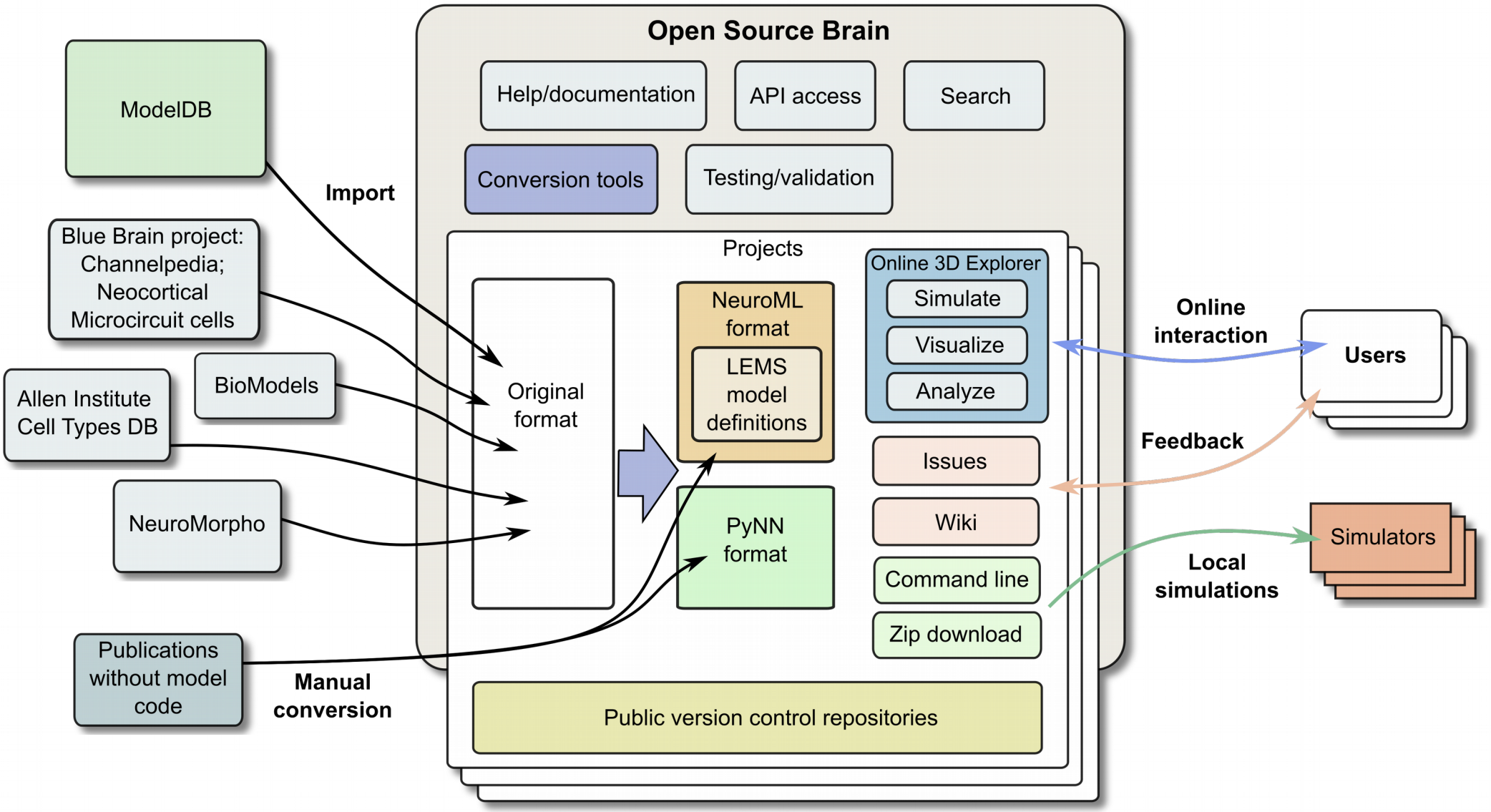
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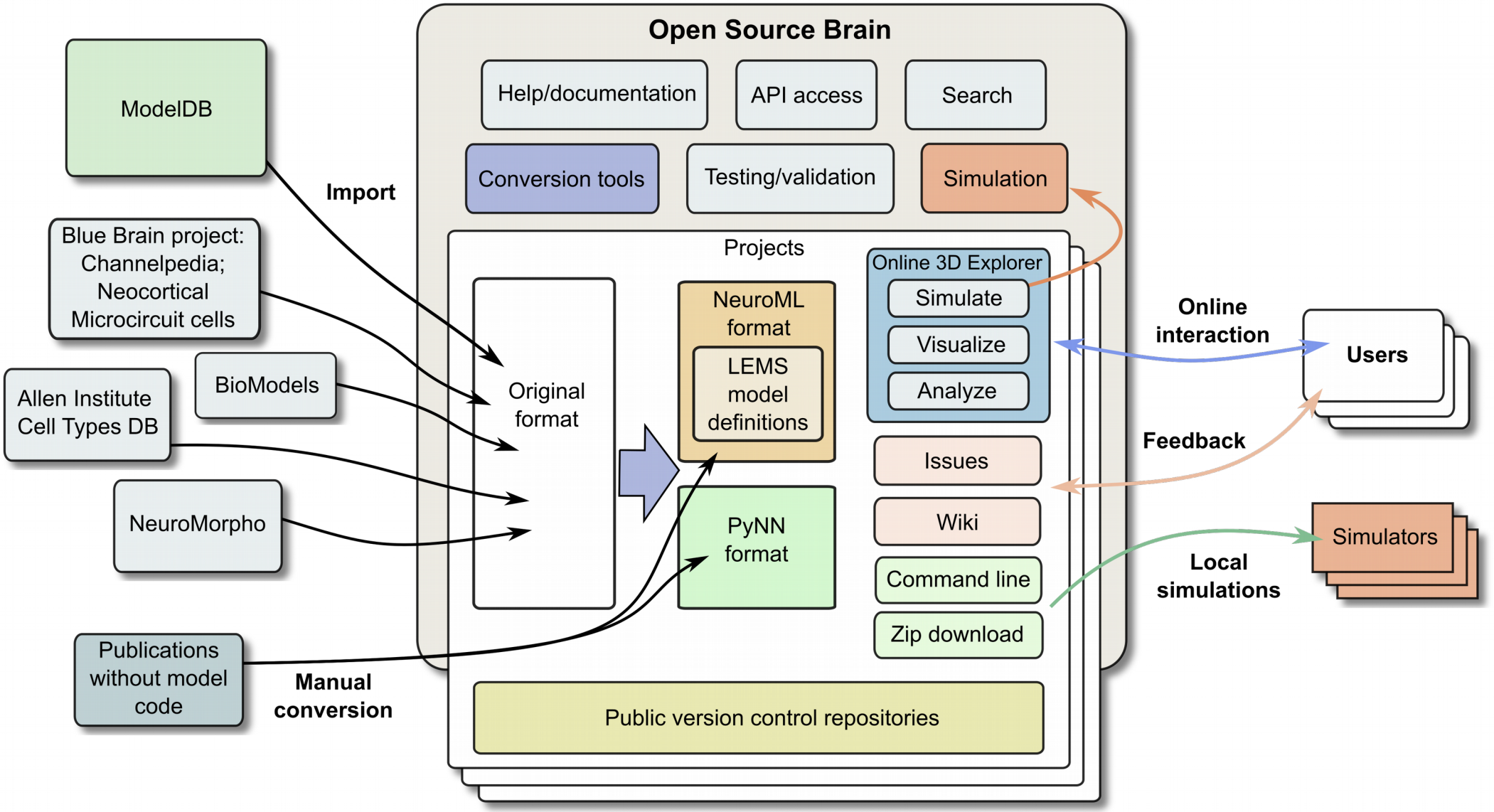
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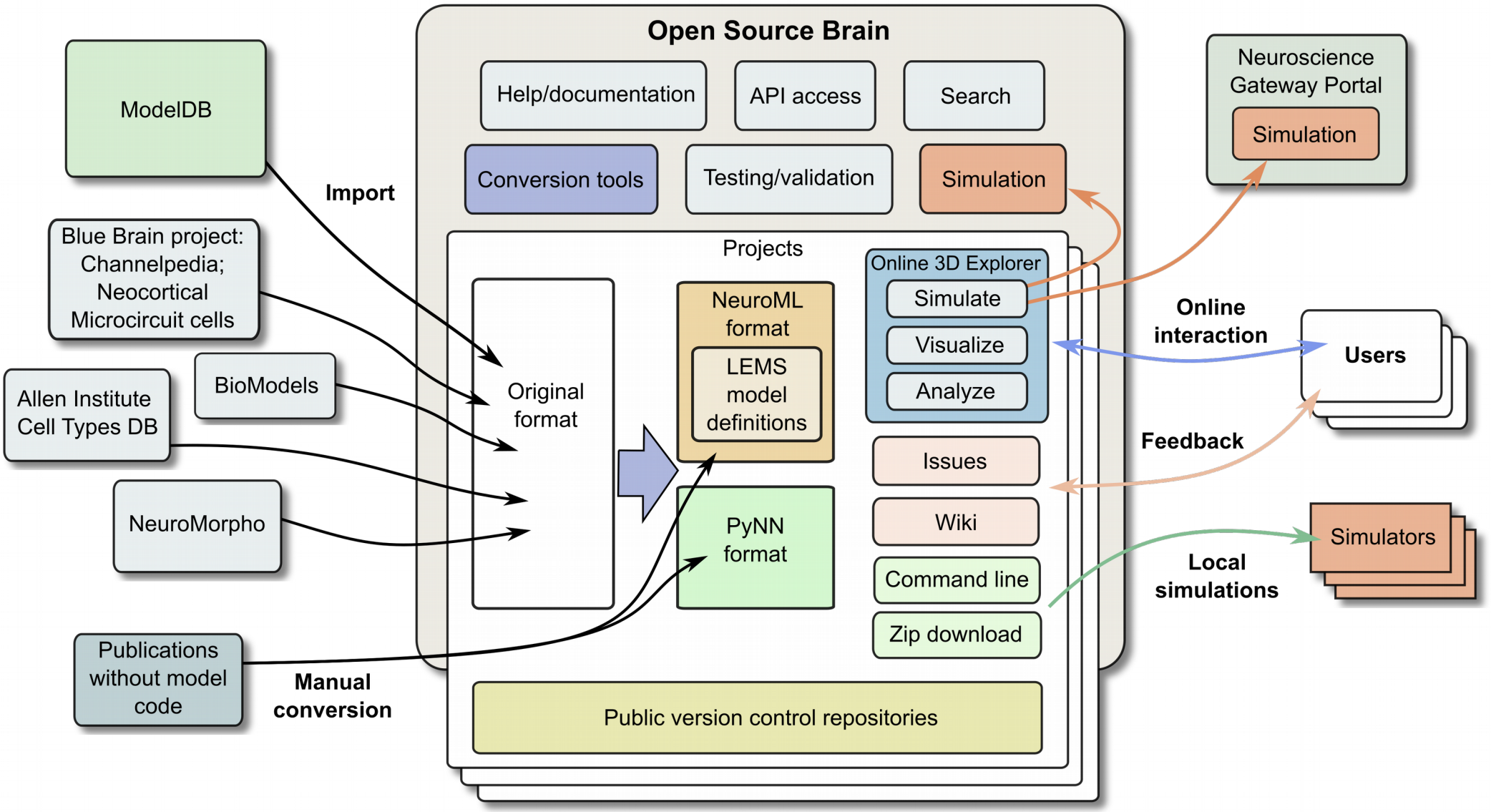
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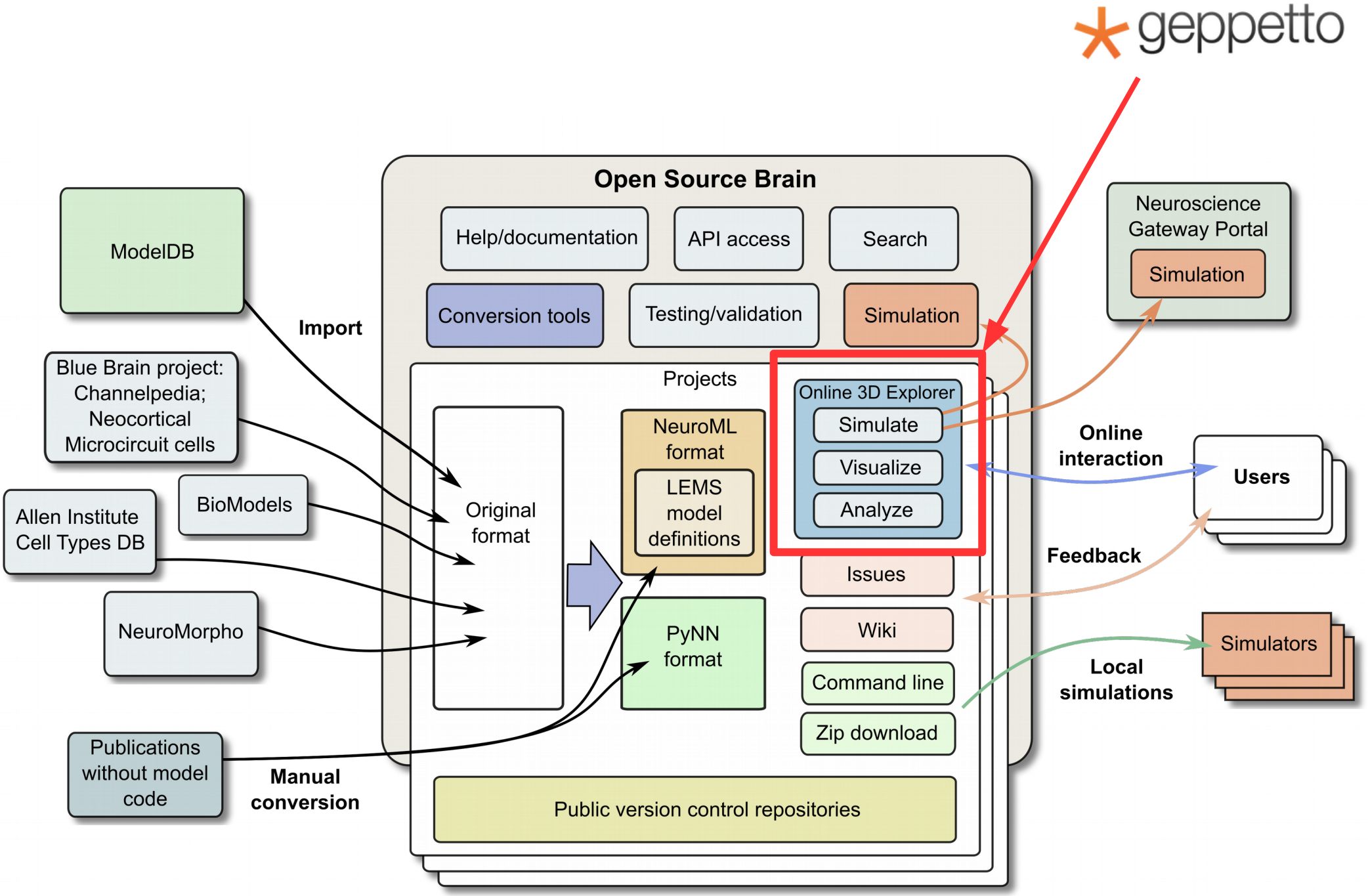
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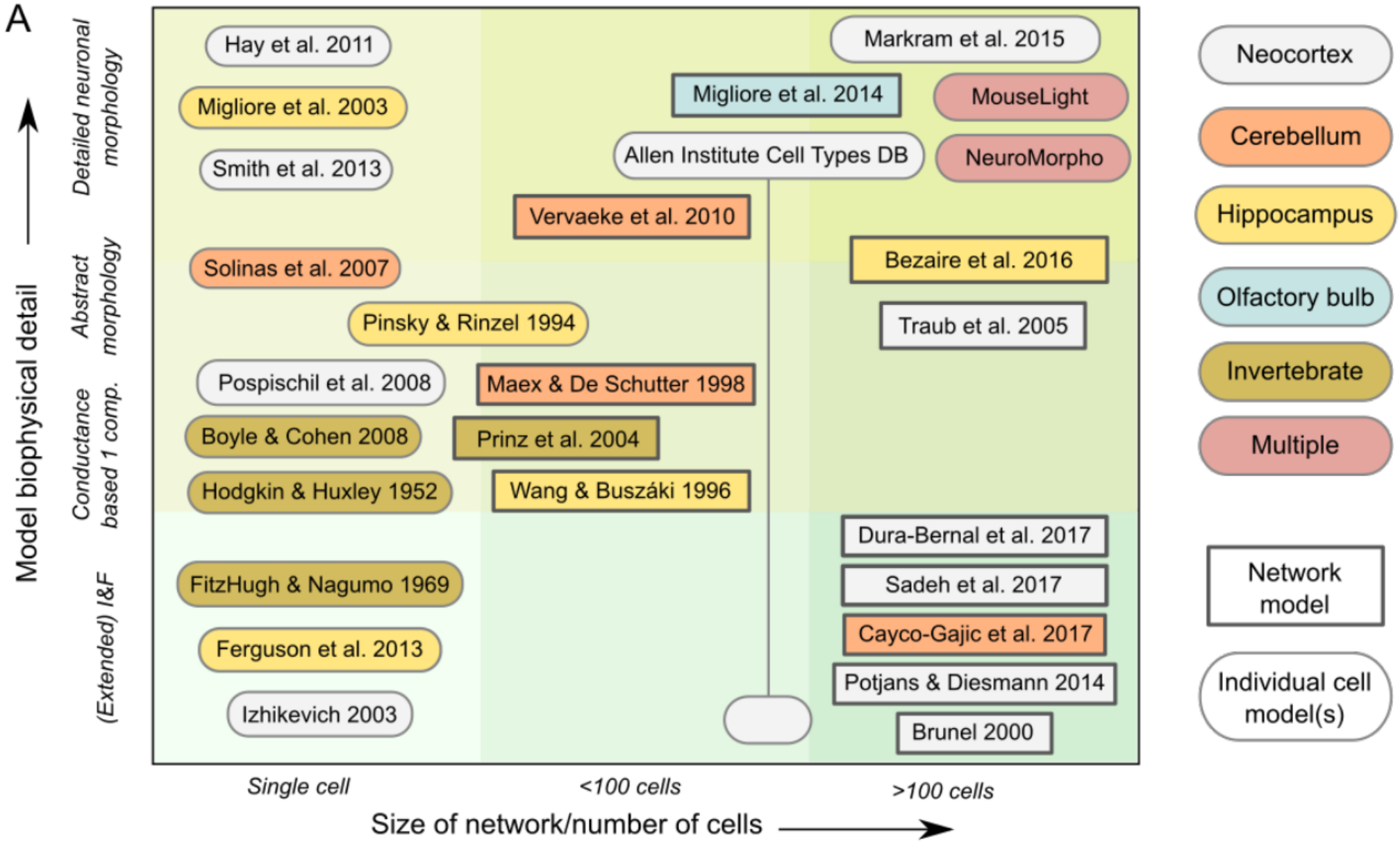
What's there at the moment



New Results

Previous Next

Open Source Brain: a collaborative resource for visualizing, analyzing, simulating and developing standardized models of neurons and circuits

Padraig Gleeson, Matteo Cantarelli, Boris Marin, Adrian Quintana, Matt Earnshaw, Eugenio Piasini, Justas Birgiolas, Robert C Cannon, N Alex Cayco-Gajic, Sharon Crook, Andrew P Davison, Salvador Dura-Bernal, Andras Ecker, Michael L Hines, Giovanni Idili, Stephen Larson, William W Lytton, Amit Majumdar, Robert A McDougal, Subhashini Sivagnanam, Sergio Solinas, Rokas Stanislovas, Sacha J van Albada, Werner Van Geit, R Angus Silver

doi: https://doi.org/10.1101/229484

This article is a preprint and has not been peer-reviewed [what does this mean?].

Abstract | Info/History | Metrics | Preview PDF

Abstract

Computational models are powerful tools for investigating brain function in health and disease. However, biologically detailed neuronal and circuit models are complex and implemented in a range of specialized languages, making them inaccessible and opaque to many neuroscientists. This has limited critical evaluation of models by the scientific community and impeded their refinement and widespread adoption. To address this, we have combined advances in standardizing models, open source software development and web technologies to develop Open Source Brain, a platform for visualizing, simulating, disseminating and collaboratively developing standardized models of neurons and circuits from a range of brain regions. Model structure and parameters can be visualized and their dynamical properties explored through browser-controlled simulations, without writing code. Open Source Brain makes neural models transparent and accessible and facilitates testing, critical evaluation and refinement, thereby helping to improve the accuracy and reproducibility of models, and their dissemination to the wider community.

Posted January 11, 2018.

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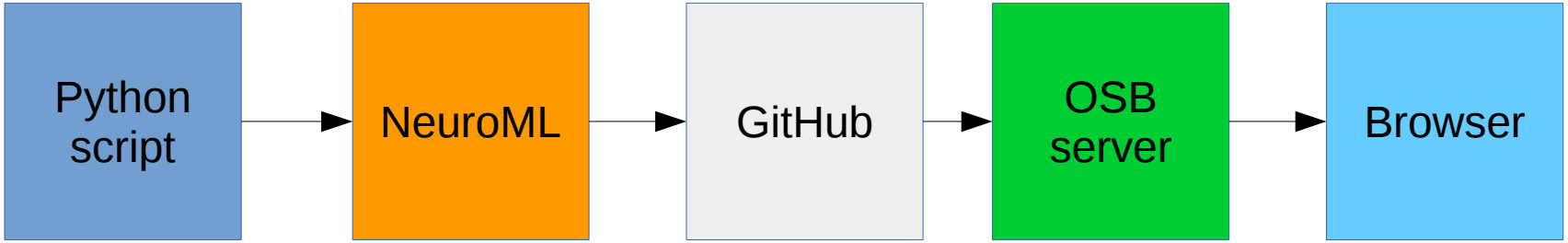
Video

What's missing

Currently NeuroML files are generated offline (e.g. from Python script) & single instance of network can be seen on OSB



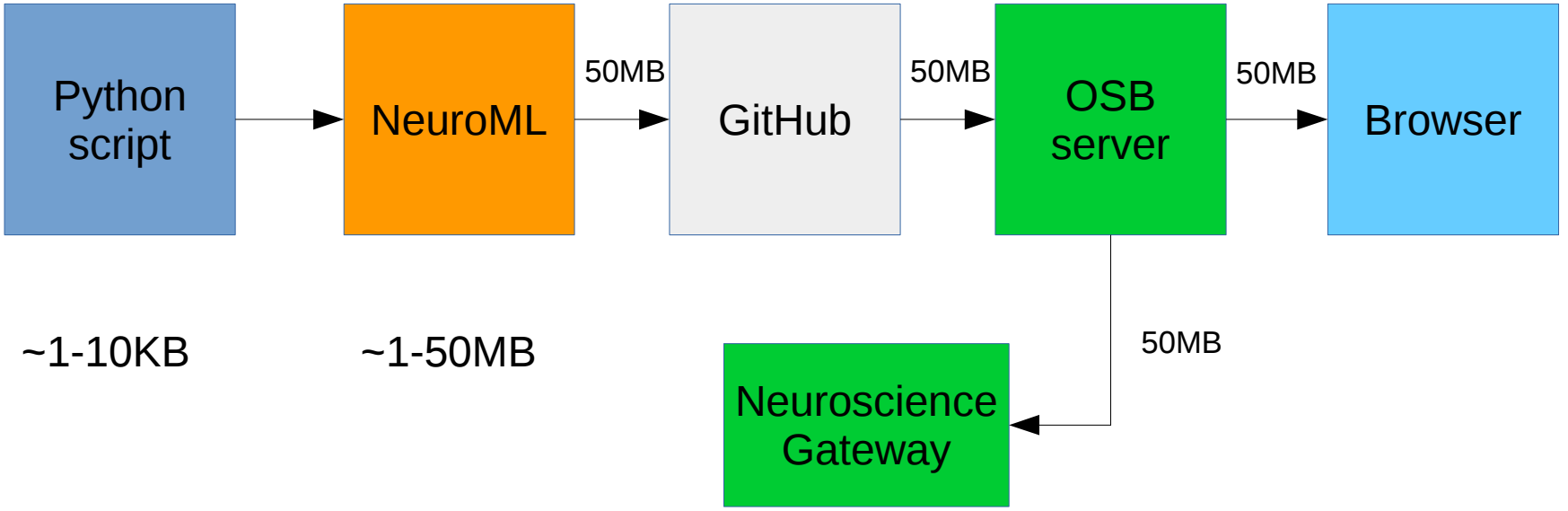
What's missing

Bottleneck is size of NeuroML instance

~1-10KB ~1-50MB

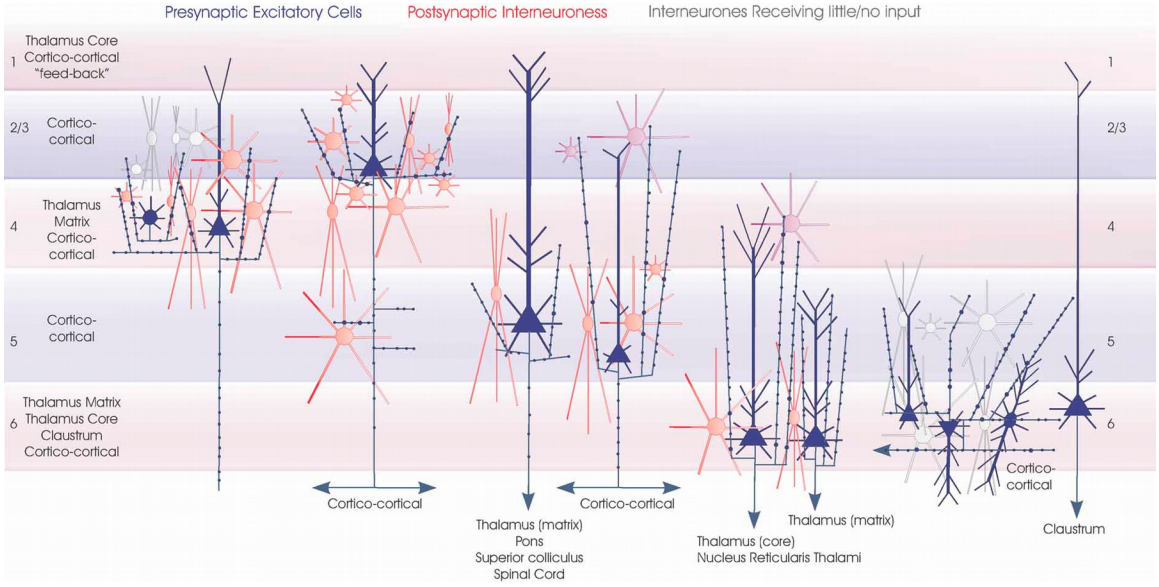
What's missing

Bottleneck is size of NeuroML instance

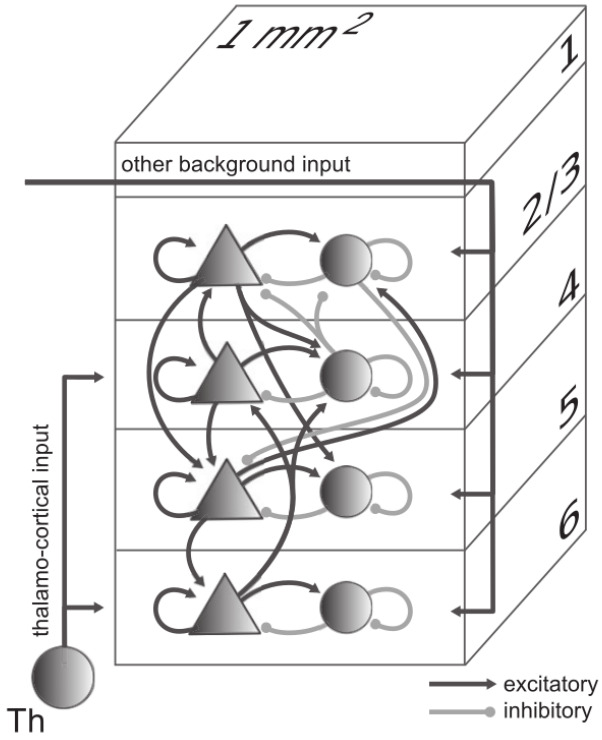


What's missing

There is a lot of experimental data out there on (cortical) connectivity, as well as high level/conceptual models of network structure

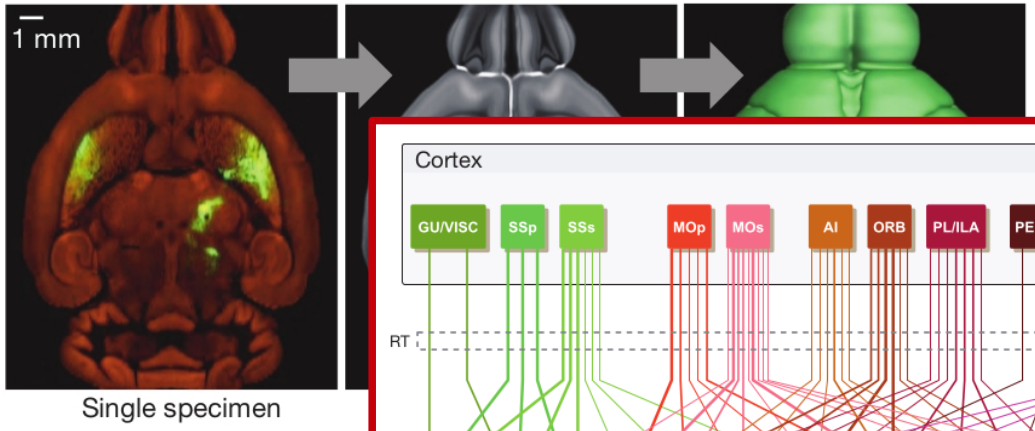


Functional maps of neocortical local circuitry, Thomson & Lamy, Front. Neurosci. 2007

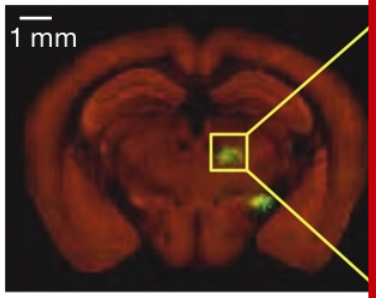


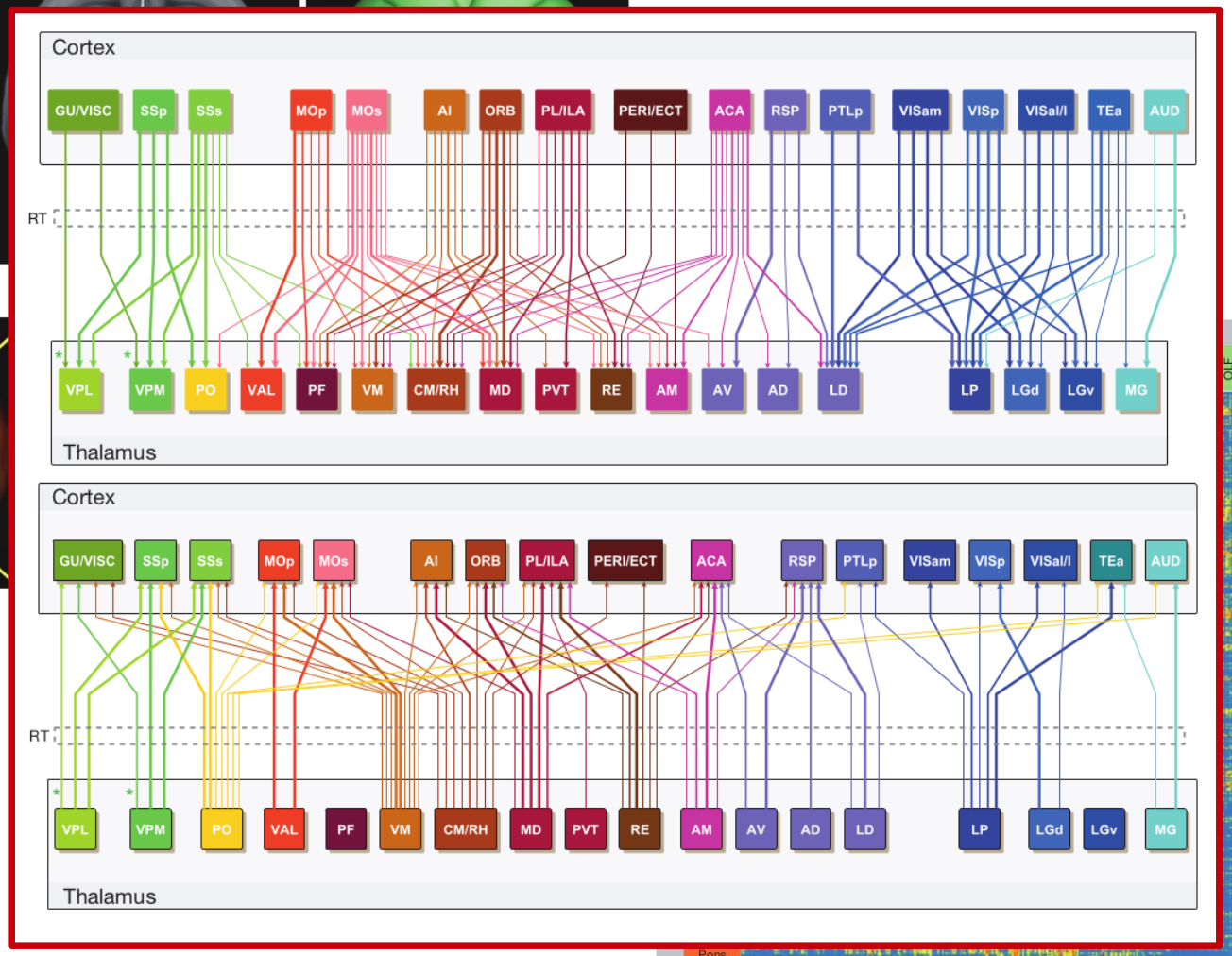
The cell-type specific cortical microcircuit: relating structure and activity in a full-scale spiking network model, Potjans & Diesmann, Cereb. Cortex 2014

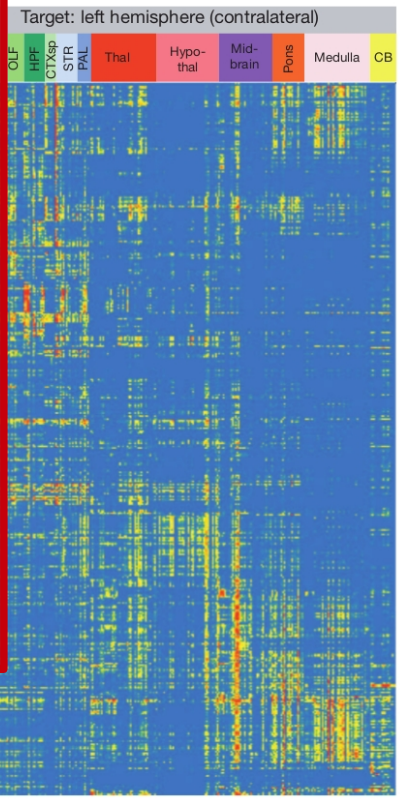
Experimental data: Allen Mesoscale Connectome



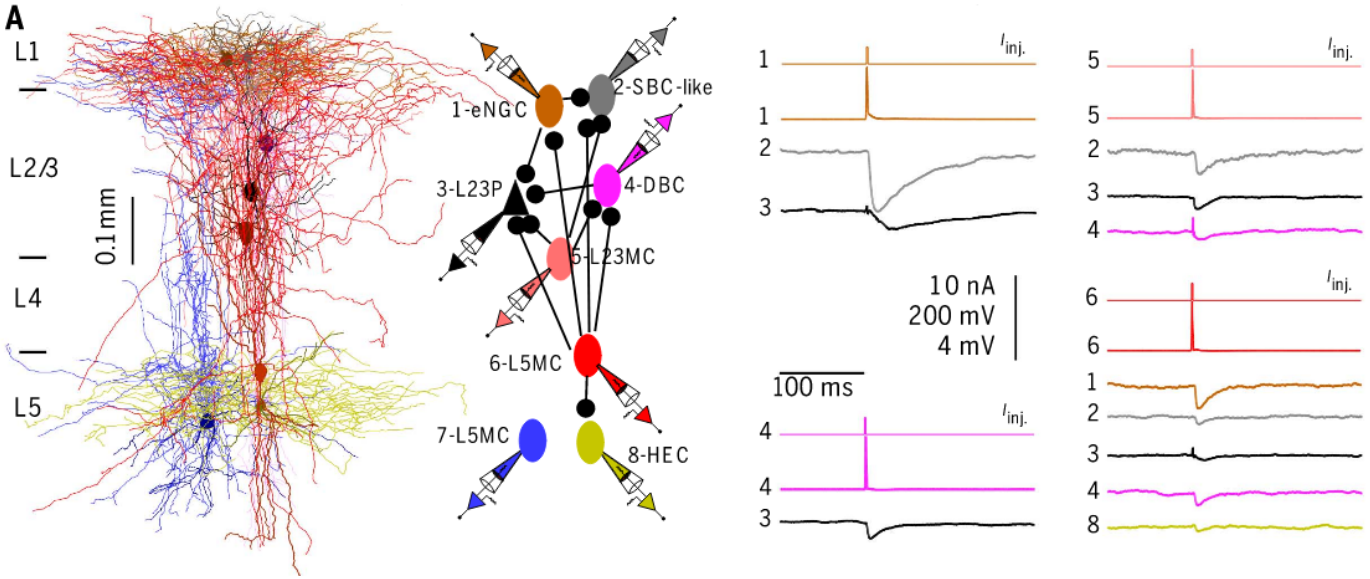
Single specimen

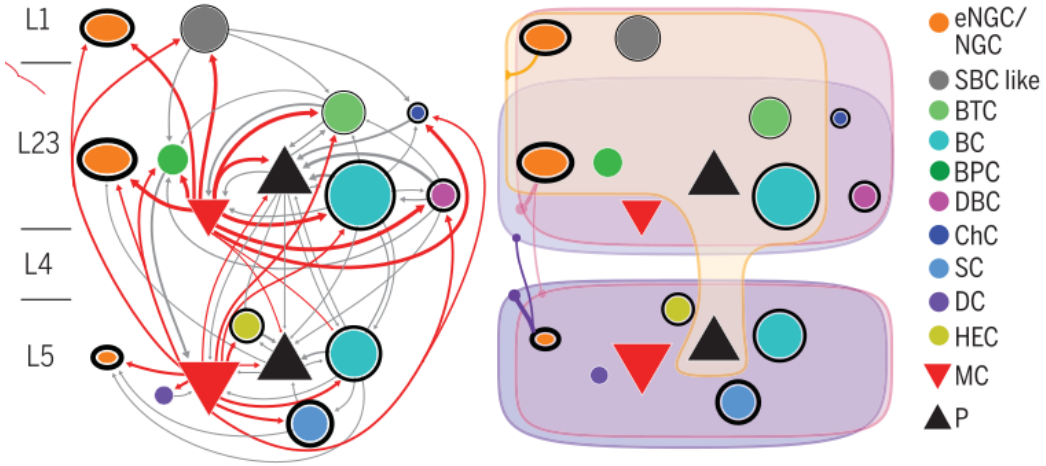


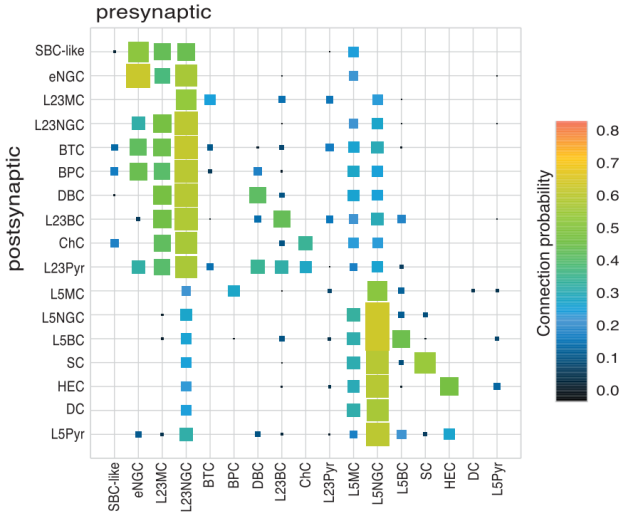




Experimental data: multiple whole-cell recording & morphological reconstruction







Principles of connectivity among morphologically defined cell types in adult neocortex, Jiang et al. Science 2015

Solution: NeuroMLlite...

Simple high level representation of network

JSON format (easier to read/write than XML)

Python classes for editing

Solution: NeuroMLlite...

JSON

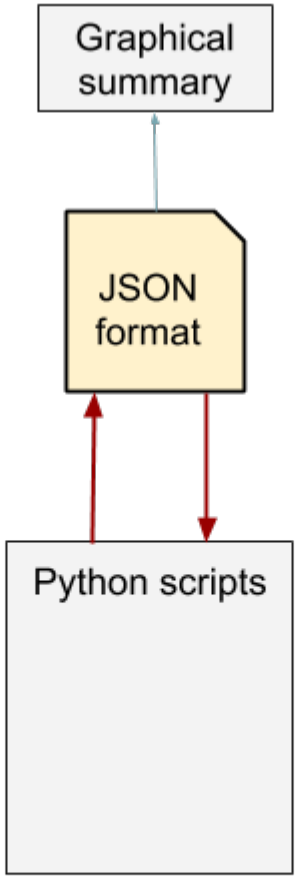
```
{
    "TestNetwork": {
        "populations": [
            {
                "pop0": {
                    "size": 5,
                    "component": "iaf",
                }
            },
            {
                "pop1": {
                    "size": 10,
                    "component": "iaf",
                }
            }
        ],
        "projections": [
            {
                "proj0": {
                    "presynaptic": "pop0",
                    "postsynaptic": "pop1",
                    "synapse": "ampa",
                    "random_connectivity": {
                        "probability": 0.5
                    }
                }
            }
        ]
    }
}
```

Python

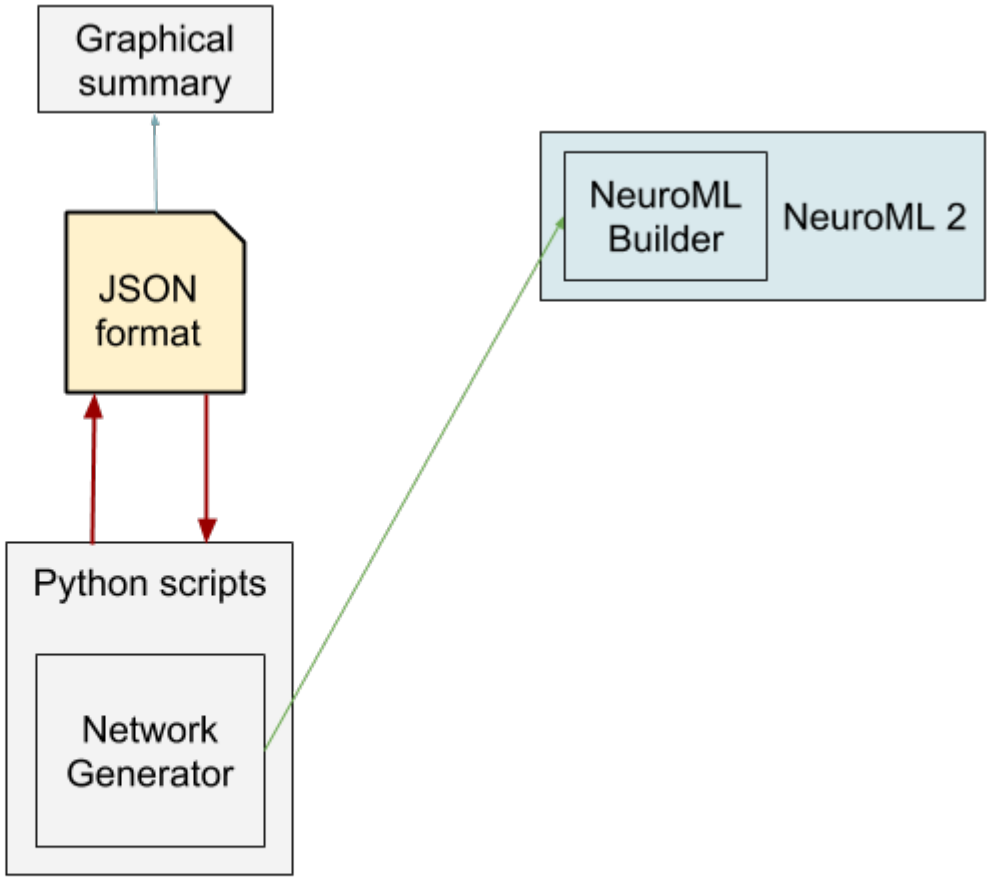
```
p0 = Population(id='pop0', size=5, component='iaf')
p1 = Population(id='pop1', size=10, component='iaf')


proj = Projection(id='proj0',
                  presynaptic=p0.id,
                  postsynaptic=p1.id,
                  synapse='ampa',
                  random_connectivity=
                     RandomConnectivity(probability=0.5))
```

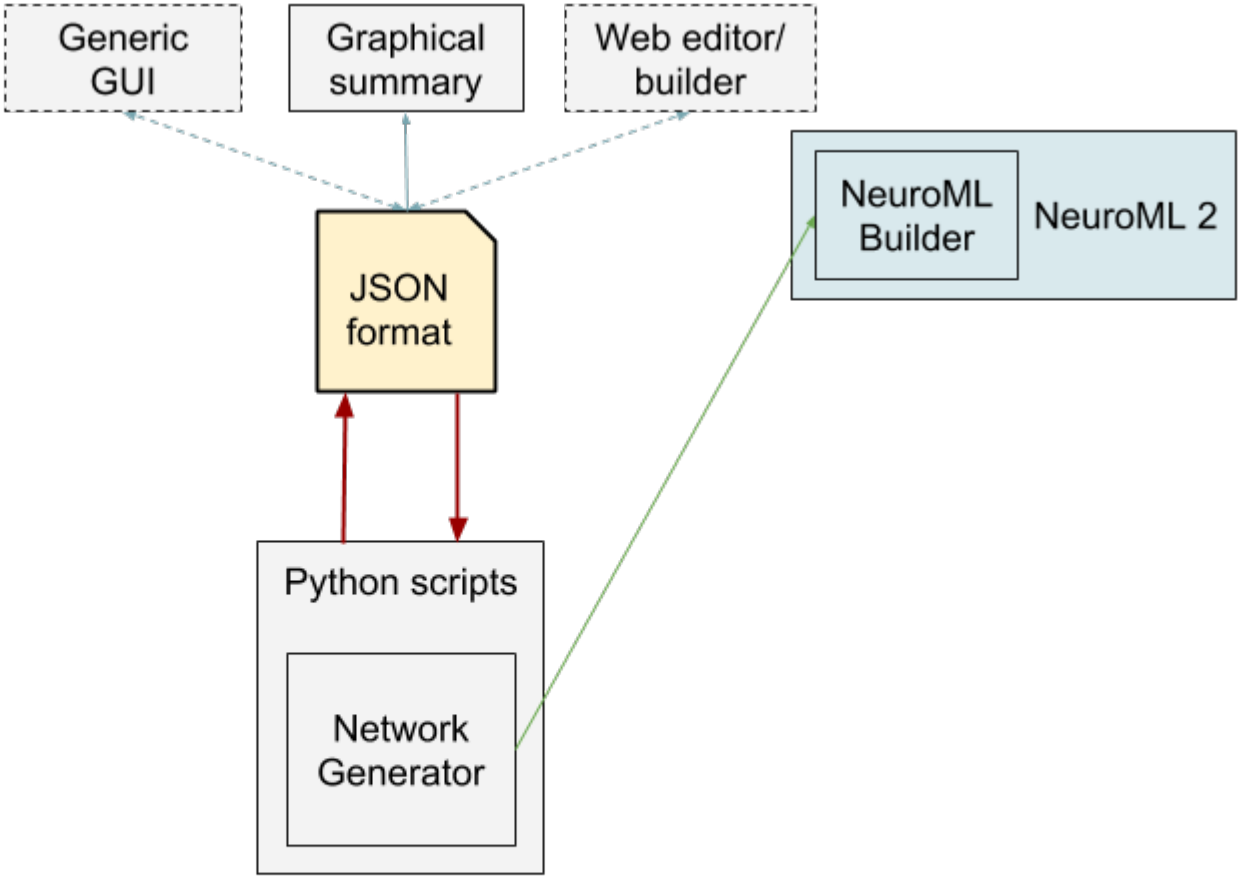
Solution: NeuroMLlite...



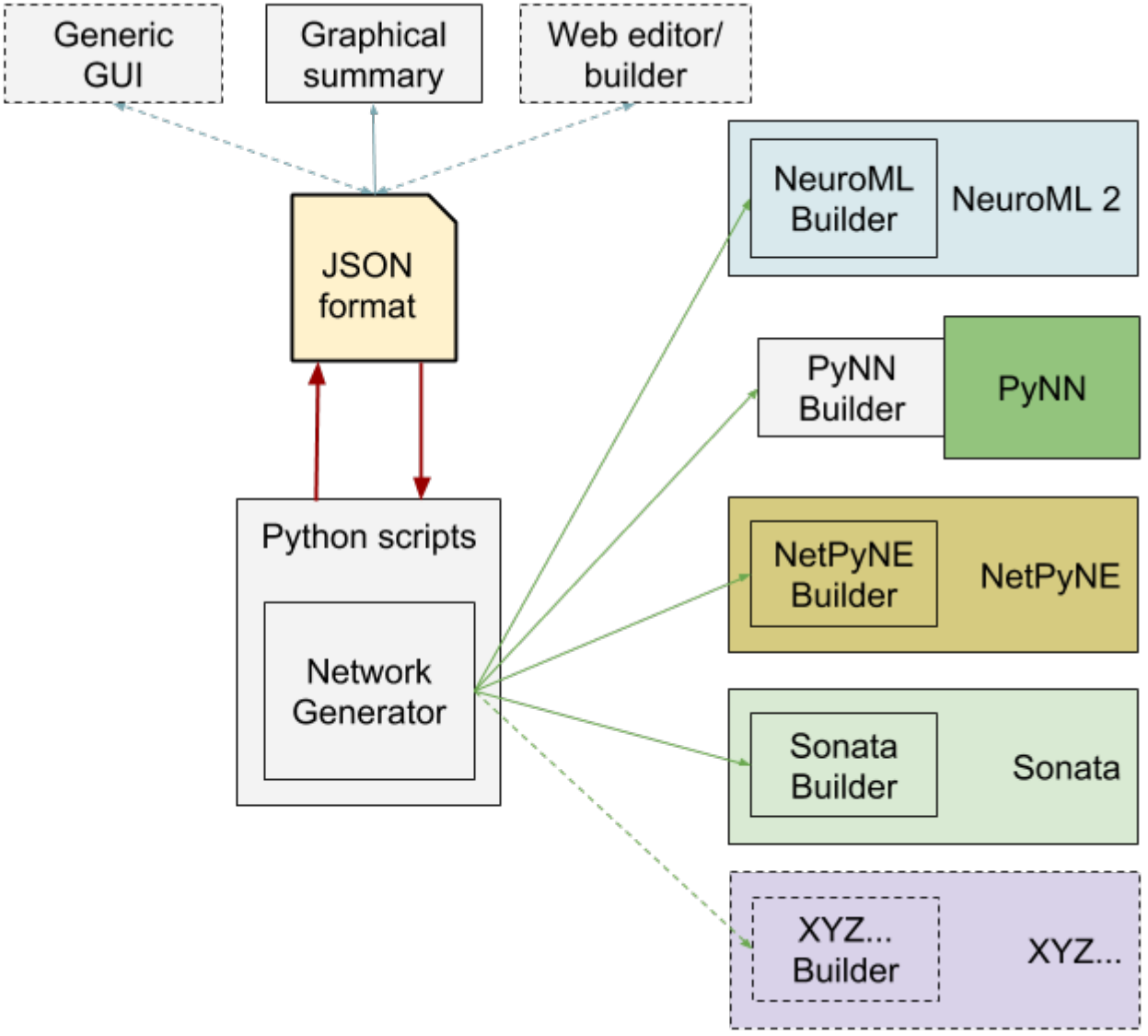
Solution: NeuroMLlite...



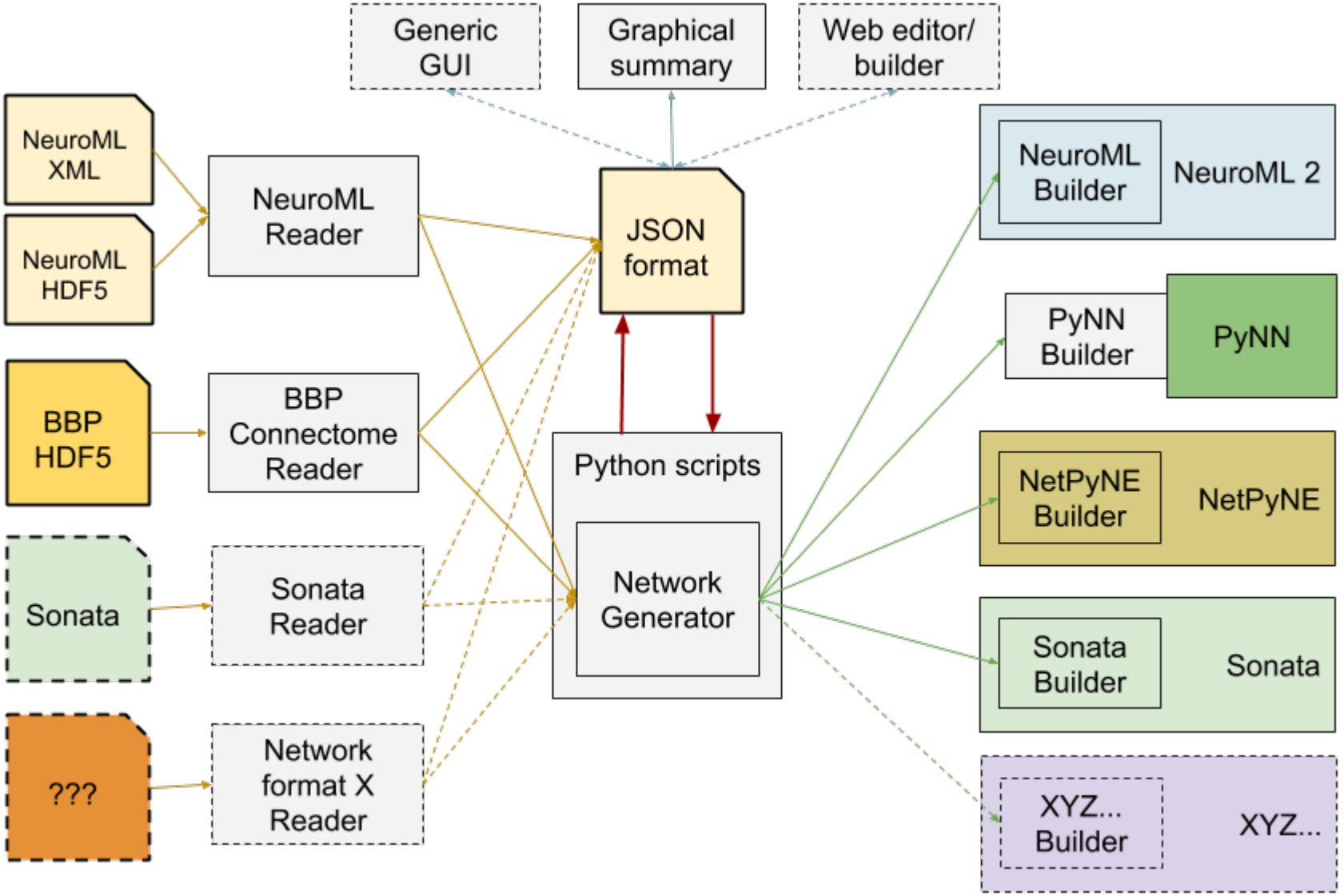
Solution: NeuroMLlite...



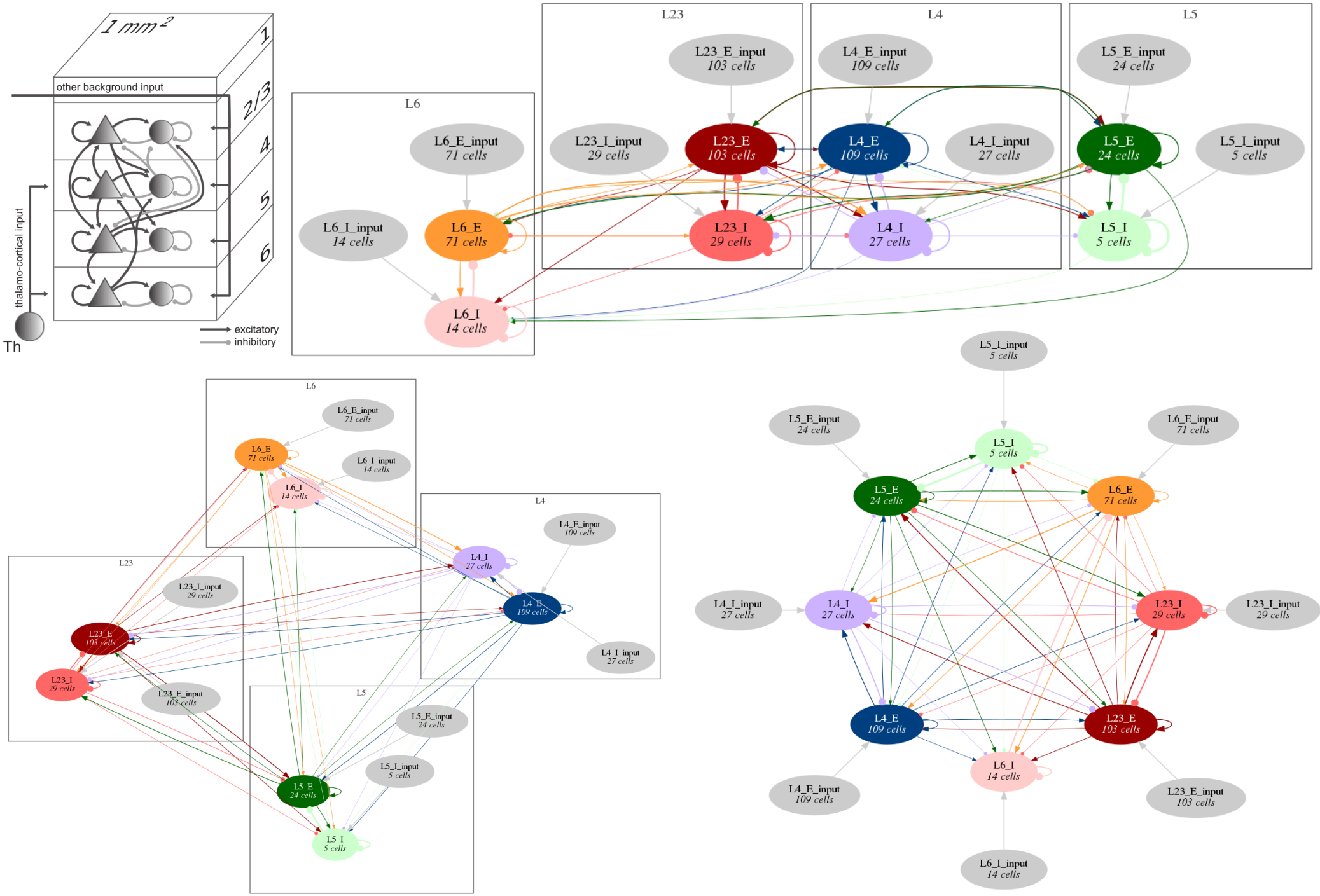
Solution: NeuroMLlite...



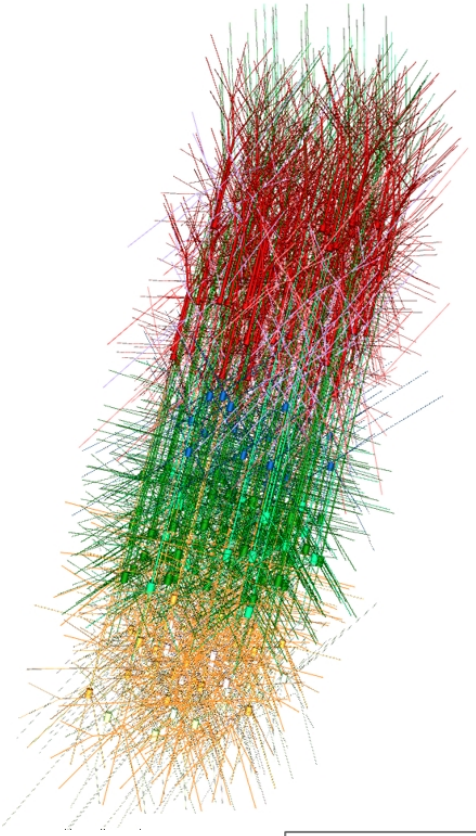
Solution: NeuroMLlite...

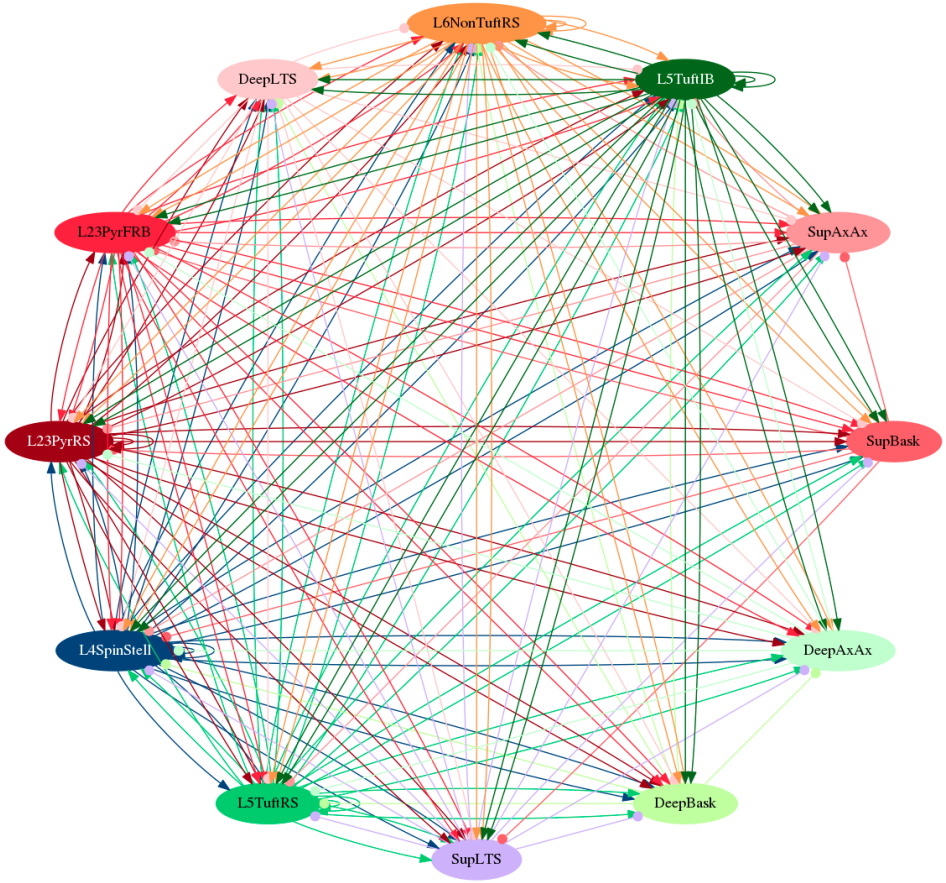


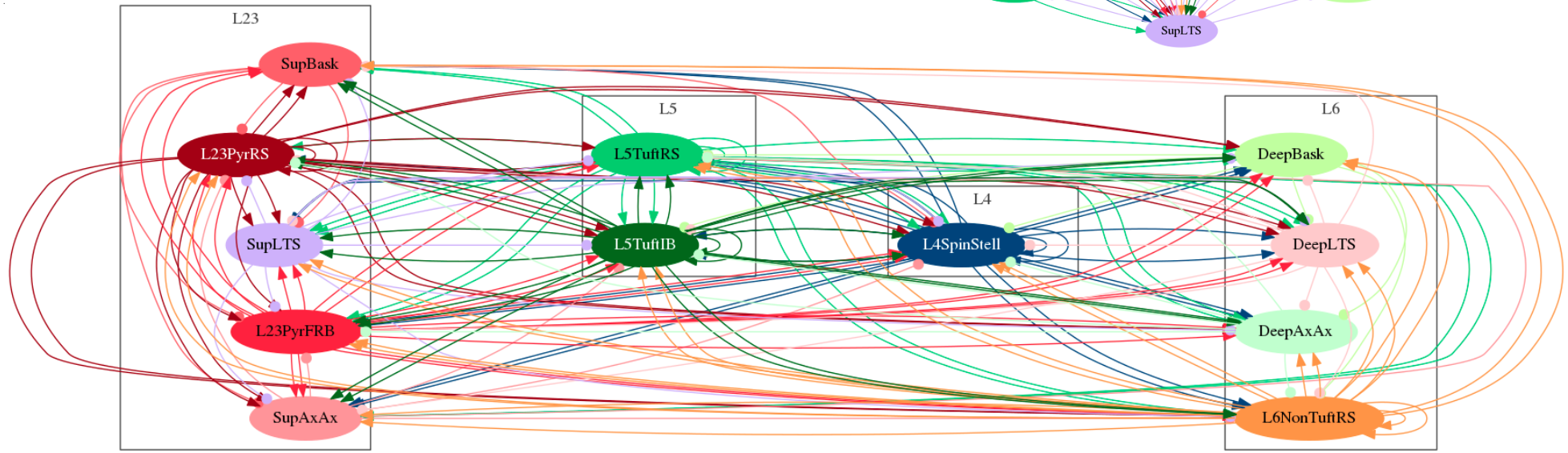
NeuroMLlite example: Potjans and Diesmann 2014



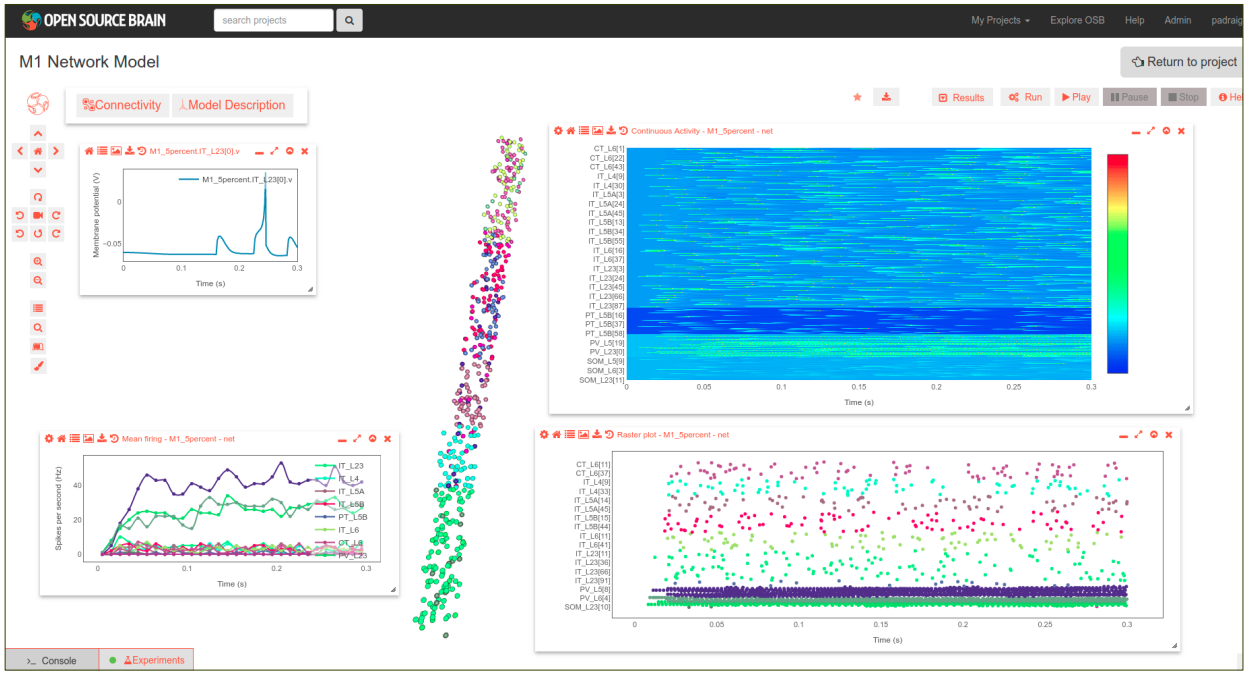
NeuroMLlite example: Traub et al. 2005

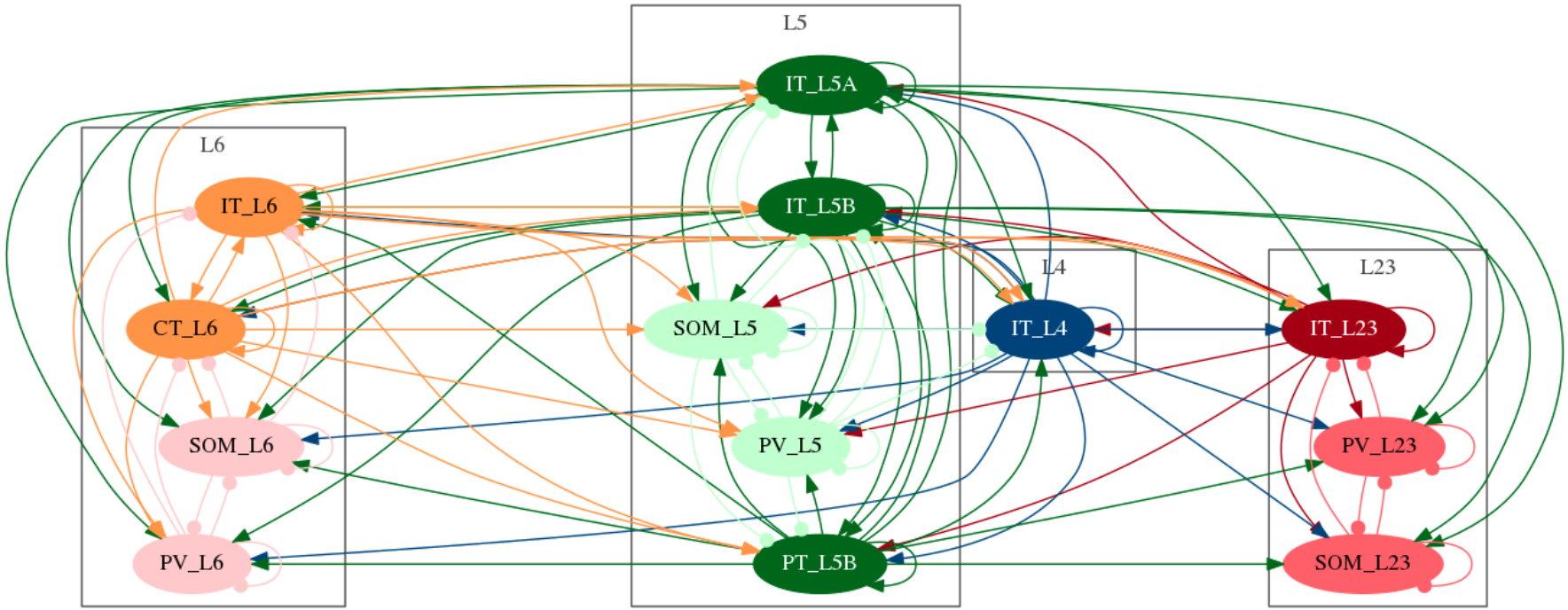




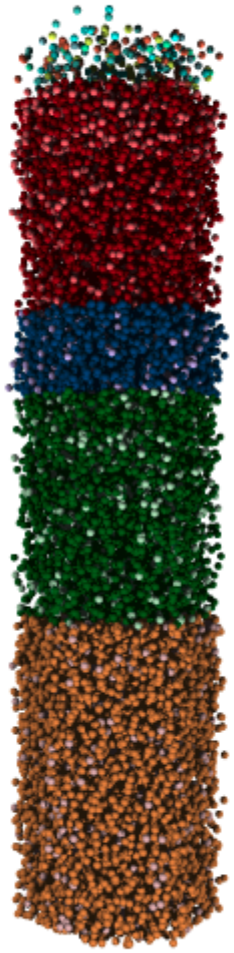


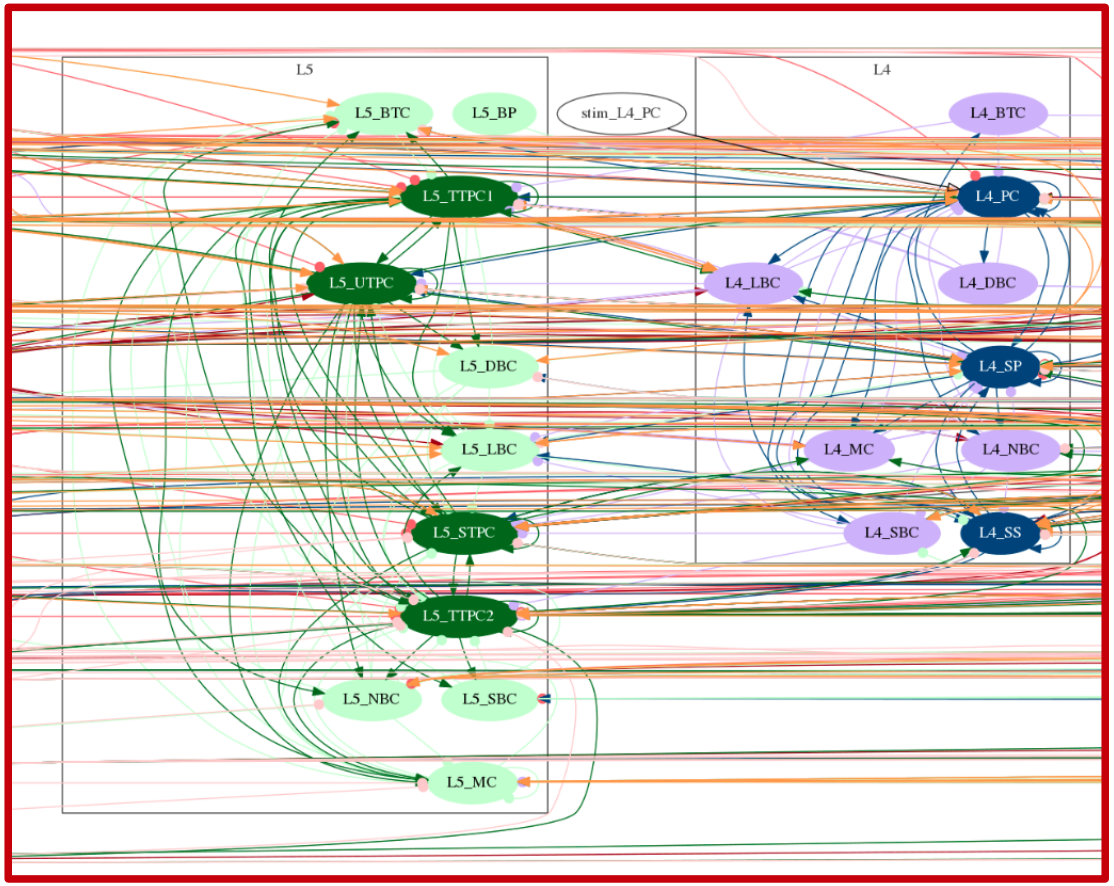
NeuroMLlite example: Dura-Bernal et al. M1 network

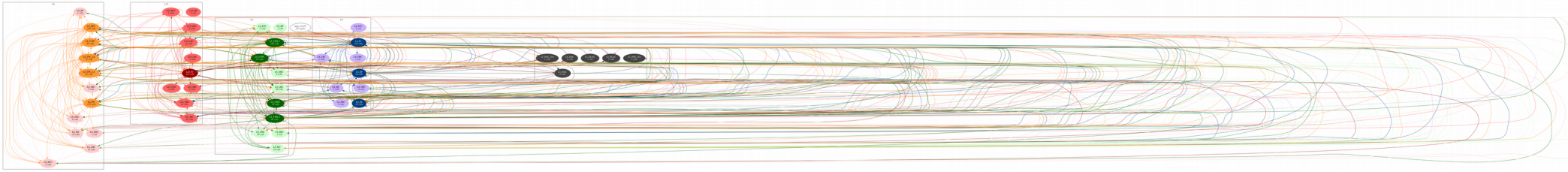




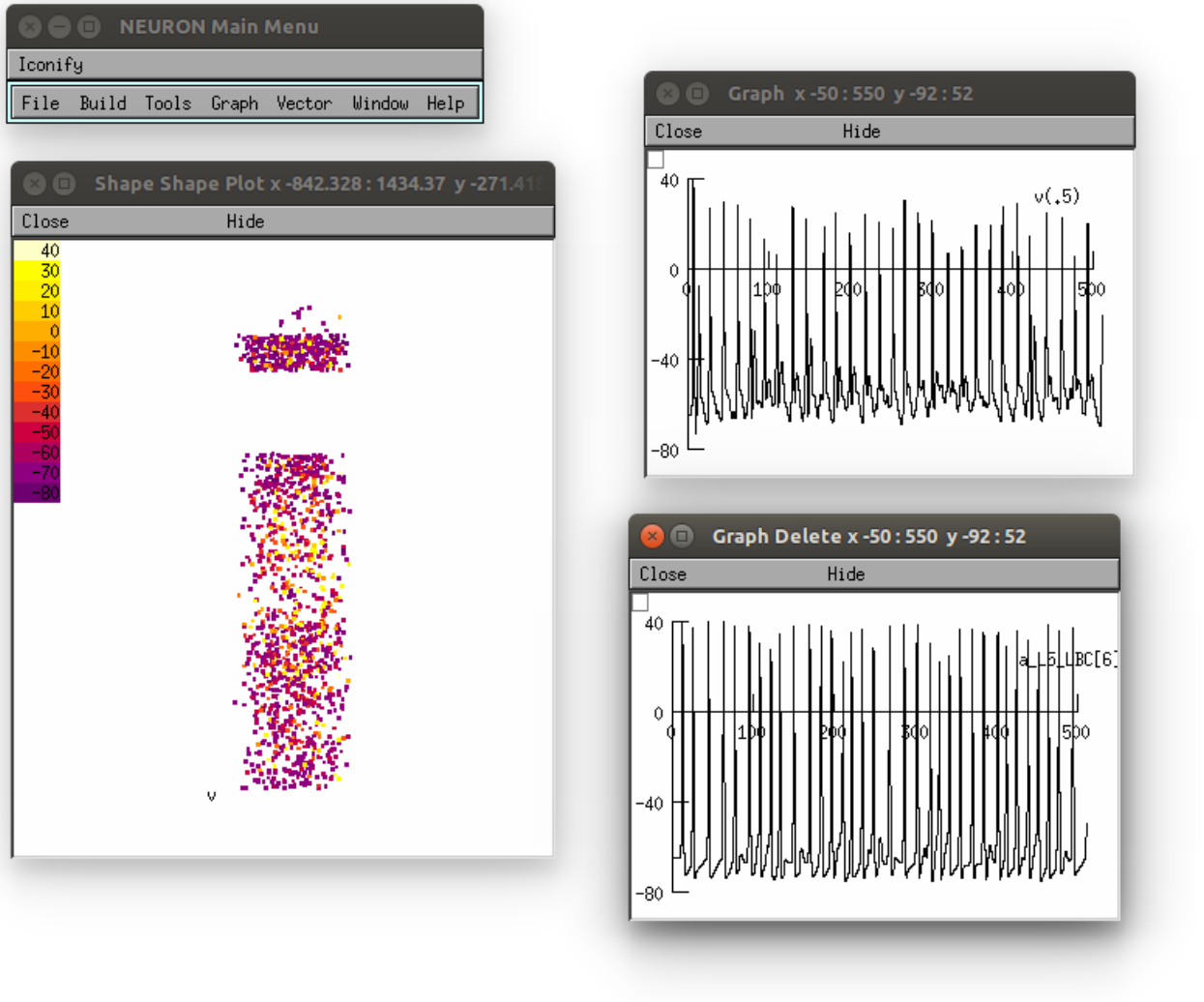
NeuroMLlite example: Blue Brain Project column



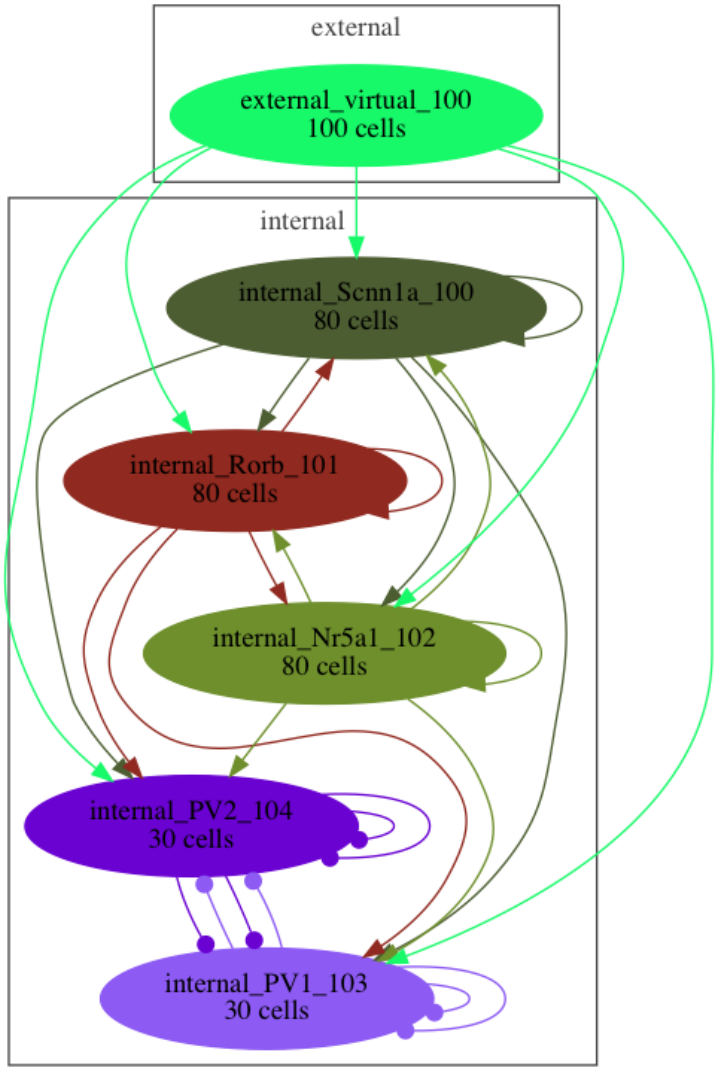


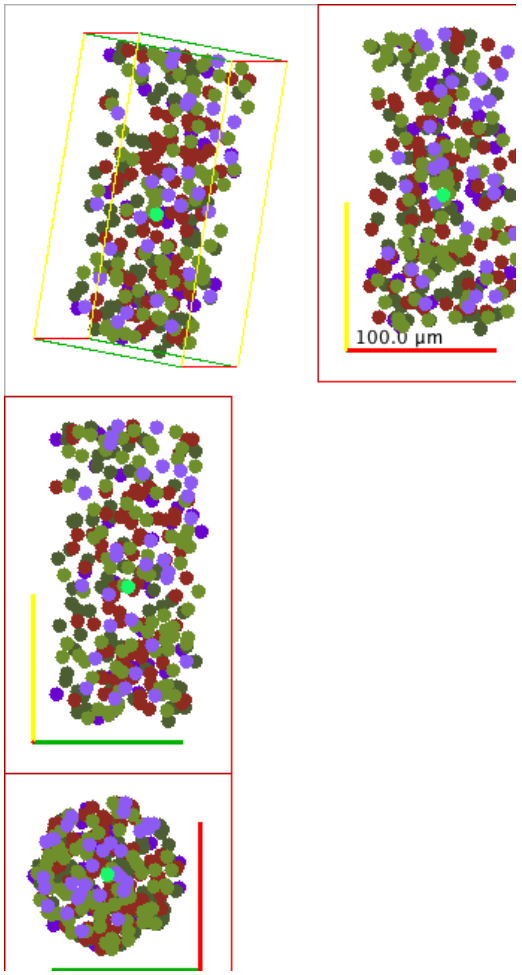


NeuroMLlite example: Blue Brain Project column

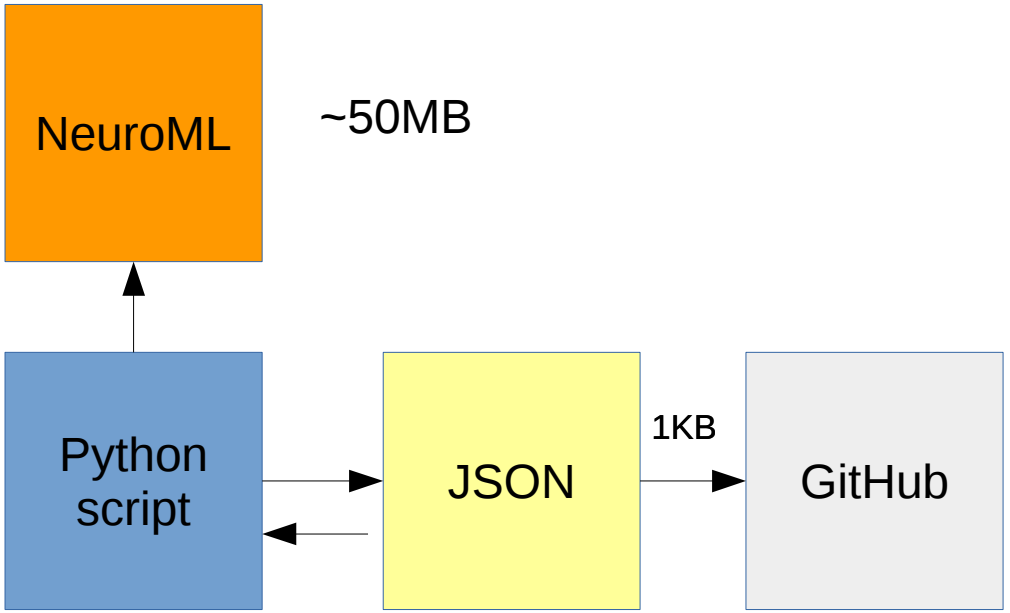


NeuroMLlite example: Sonata import

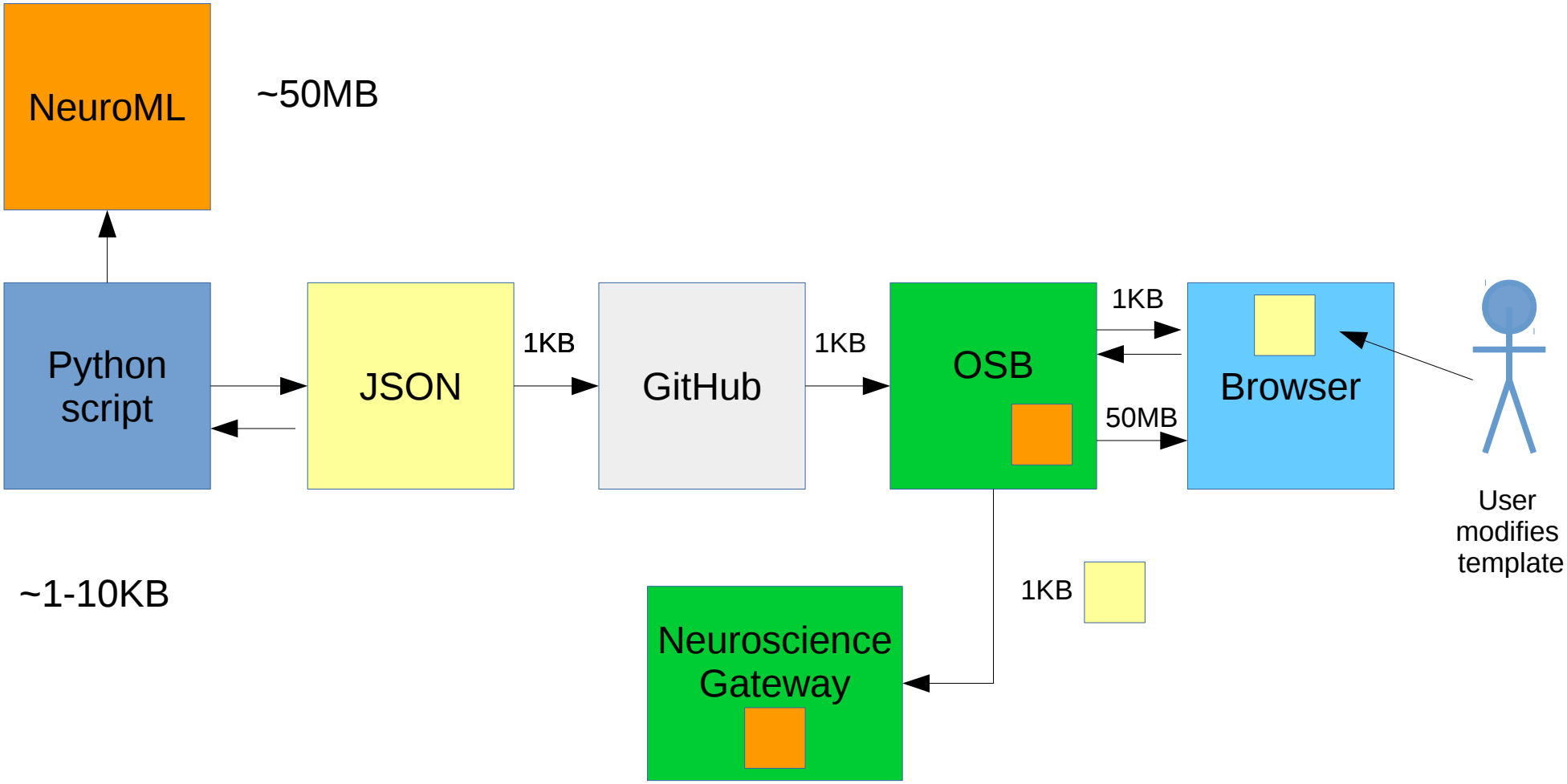




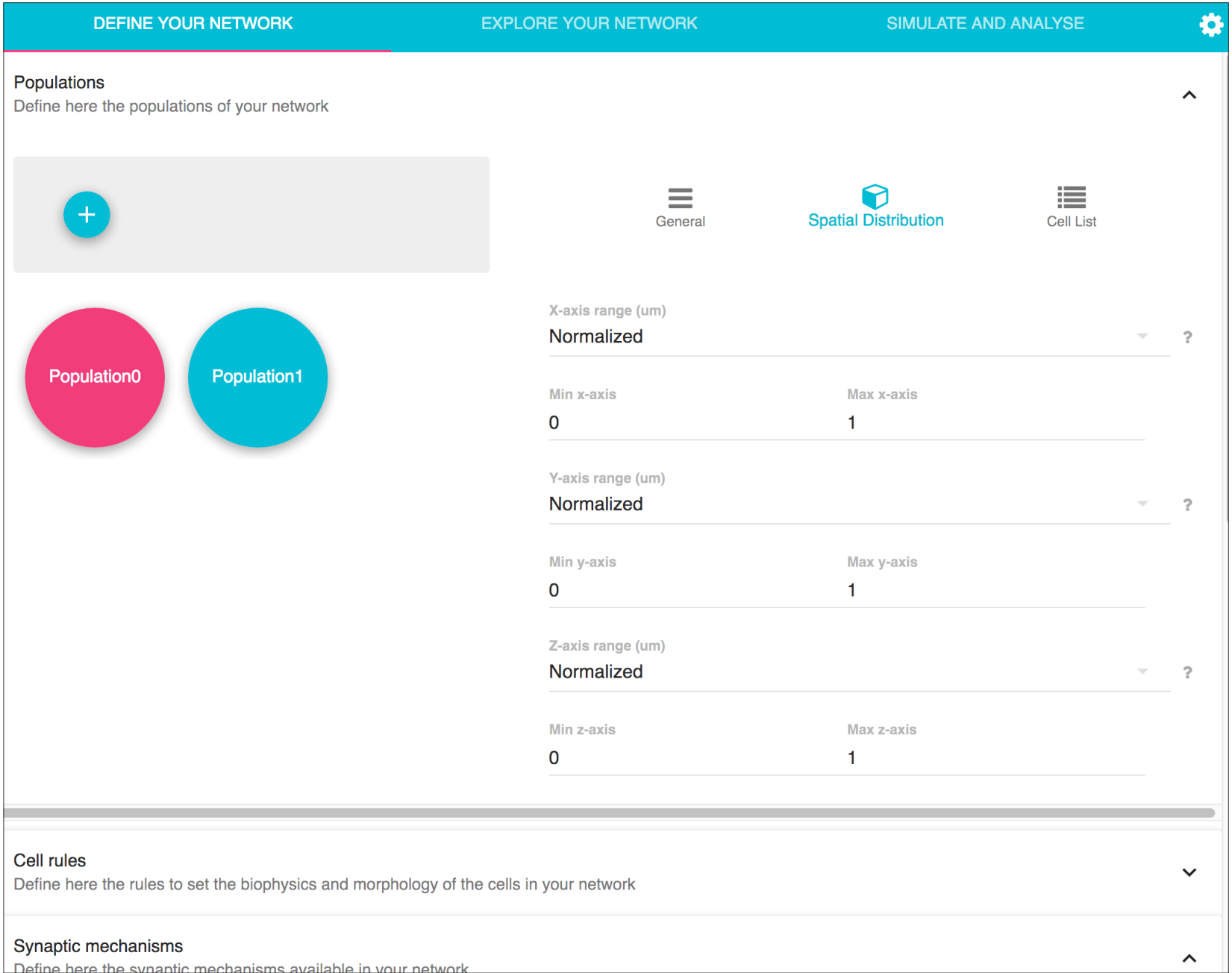
Improved workflow on OSB with NeuroMLlite



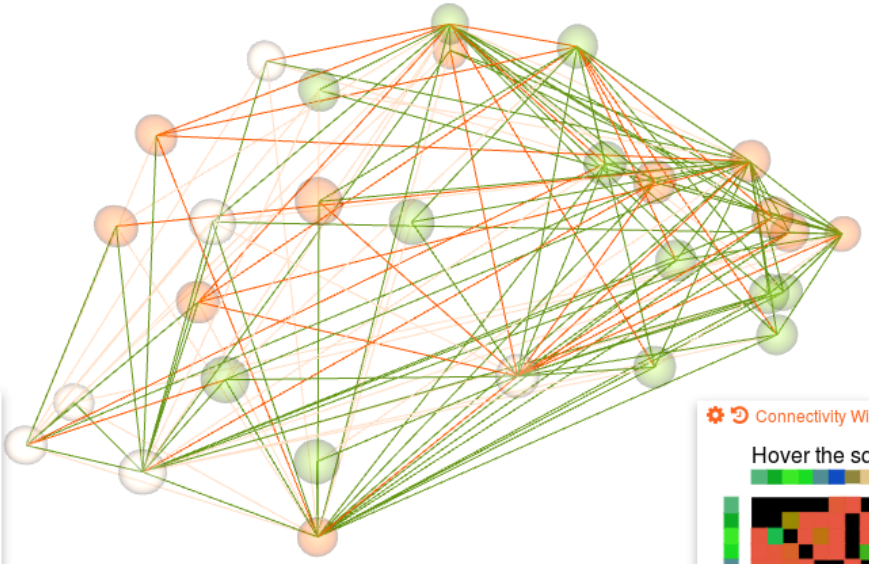
Improved workflow on OSB with NeuroMLlite

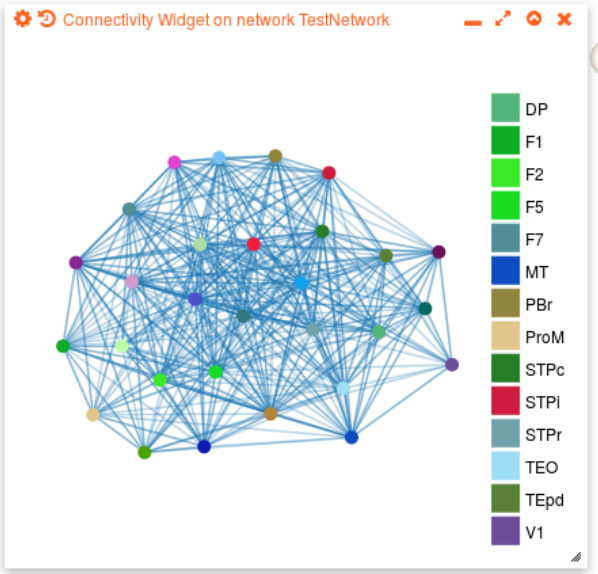


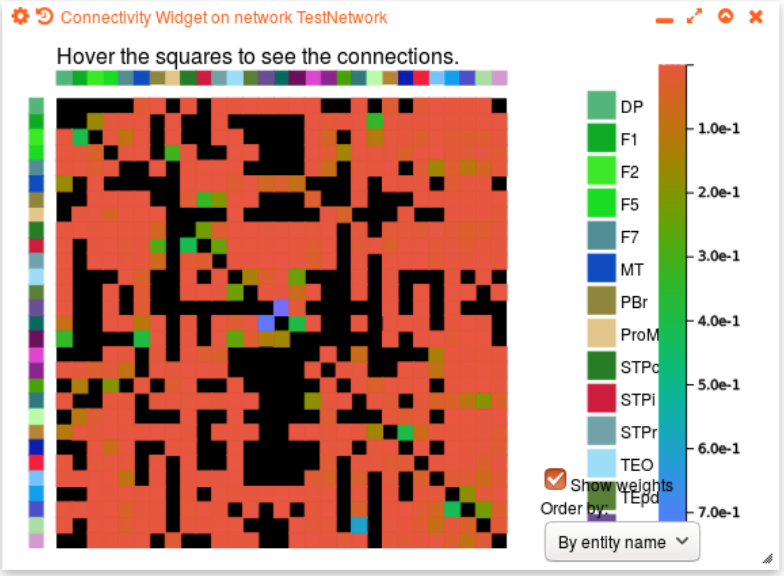
NetPyNE like interface on OSB?



Work in progress: Google Summer of Code





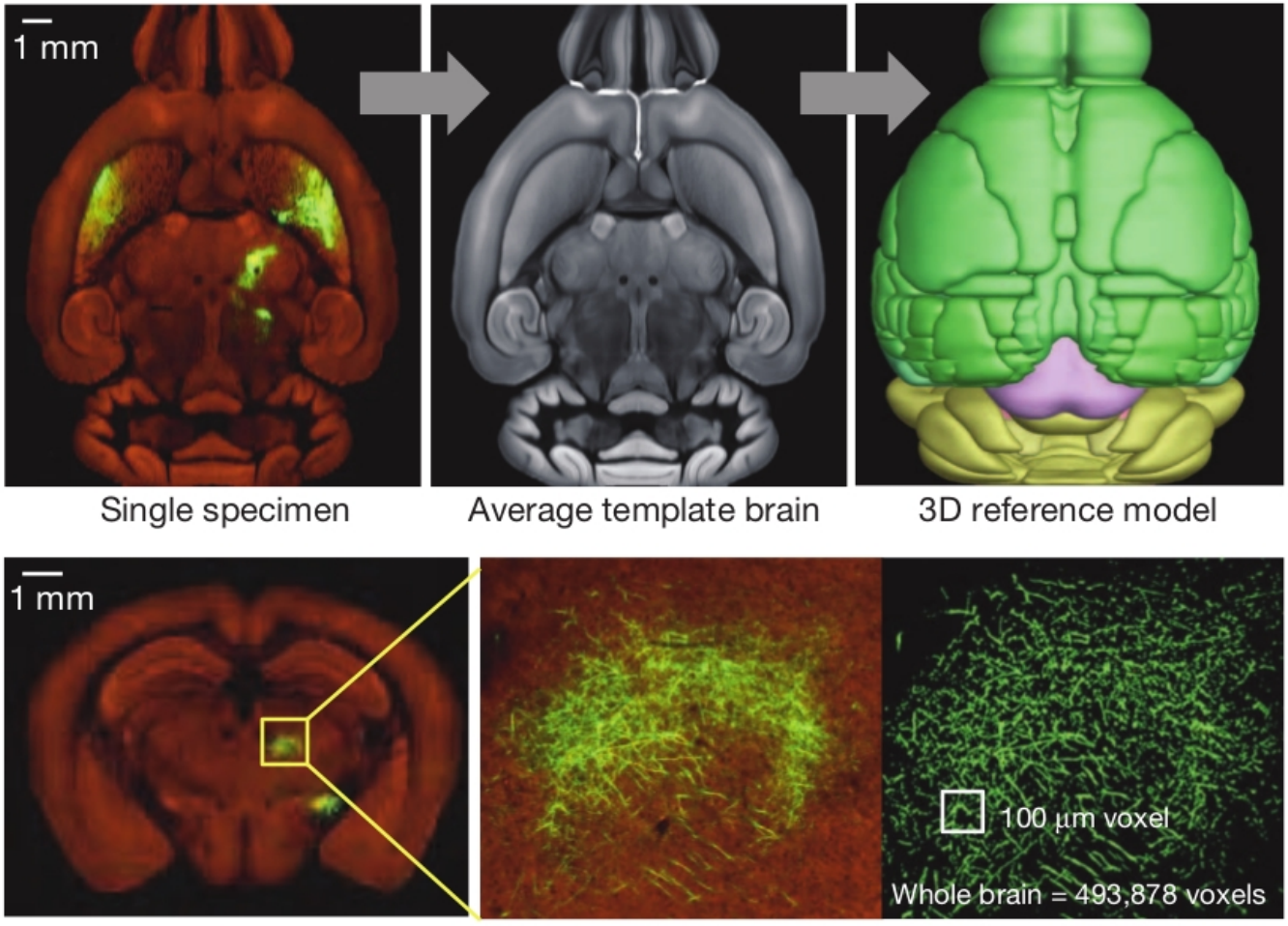


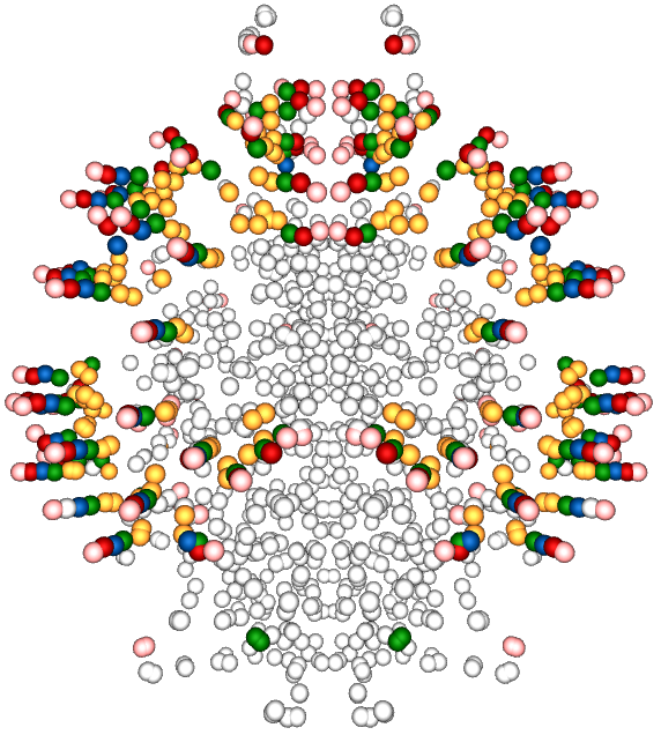
NeuroML

OPEN SOURCE BRAIN

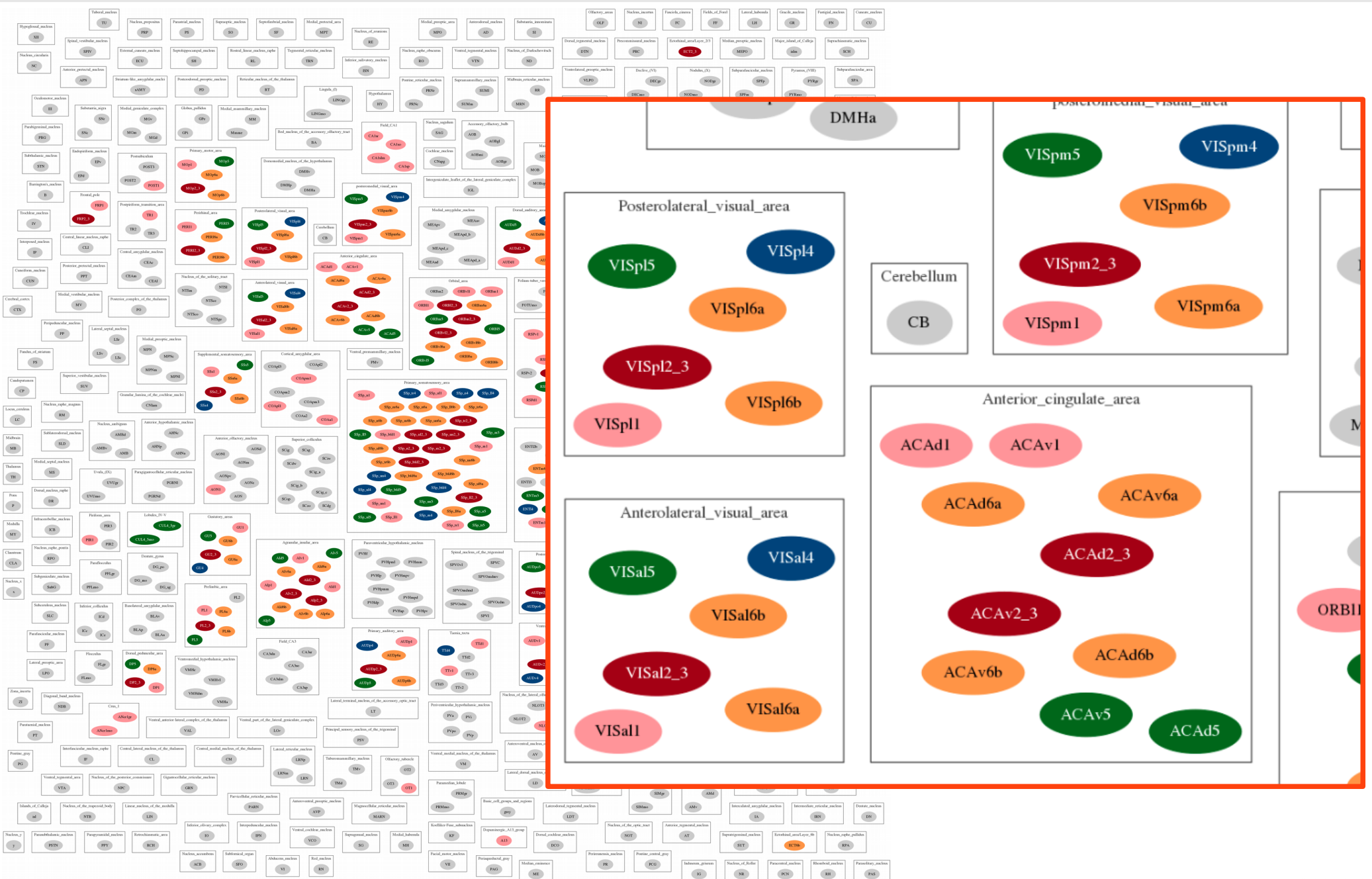
wellcome

In progress: Allen Institute mesoscale connectome





In progress: Allen Institute mesoscale connectome



INCF SIG on Standardised Representations of Network Structures

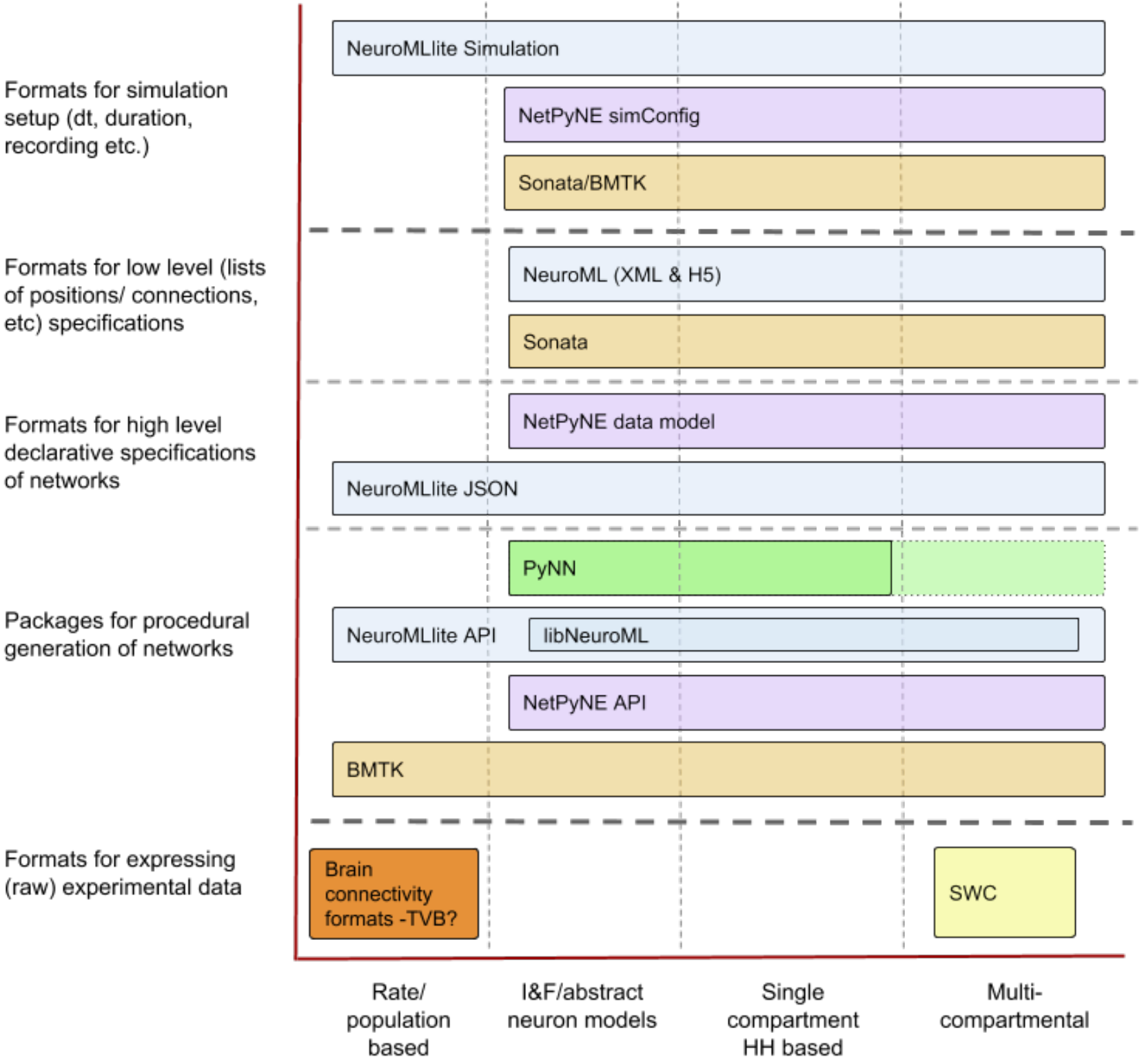
> This SIG deals with the various tools and formats for creating and sharing representations of biological neuronal networks, and will work towards ensuring these are as interoperable and usable as possible for computational neuroscientists.

Contact info

Email: p.gleeson@uc.ac.uk

Current members

- Anton Arkhipov, Allen Institute, USA
- Tom Close, Monash University, Australia
- Sharon Crook, Arizona State University, USA
- Kael Dai, Allen Institute, USA
- Andrew Davison, UNIC, CNRS, France
- Lia Domide, Codemart, Romania & Aix-Marseille Université, France
- Salvador Dura-Bernal, SUNY Downstate Medical Center, USA


Formats for simulation setup (dt, duration, recording etc.)
Formats for low level (lists of positions/ connections, etc) specifications
Formats for high level declarative specifications of networks
Packages for procedural generation of networks
Formats for expressing (raw) experimental data
NeuroMLlite Simulation
NetPyNE simConfig
Sonata/BMTK
NeuroML (XML & H5)
Sonata
NetPyNE data model
NeuroMLlite JSON
PyNN
NeuroMLlite API
libNeuroML
NetPyNE API
BMTK
Brain connectivity formats -TVB?
SWC
Rate/ population based
I&F/abstract neuron models
Single compartment HH based
Multi-compartmental