Introduction to NeuroML & Open Source Brain

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University College London

How can we improve the model building and sharing process?

Reproducibility

Accessibility

Portability

Transparency

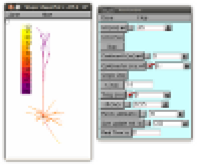
NeuroML

Standardised XML language for computational neuroscience

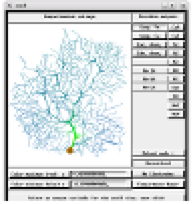
Version 1.x allowed specification of:

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

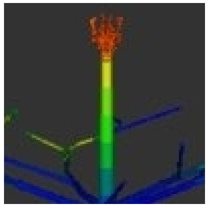
30+ simulators/applications/databases/libraries support NeuroML



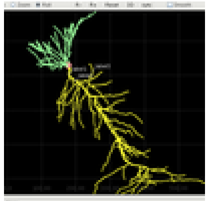
NEURON



GENESIS



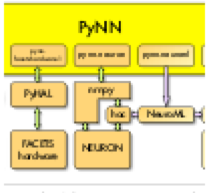
MOOSE



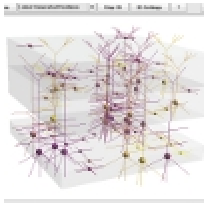
PSICS

neurospaces

NeuroSpaces



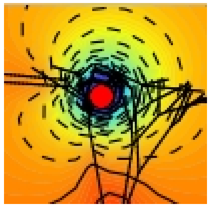
PyNN



neuroConstruct

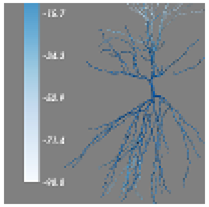
OpenWorm

OpenWorm

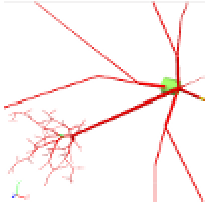


LFPy

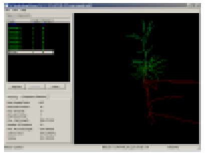
CATMAID



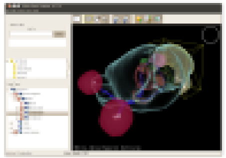
Neuronvisio



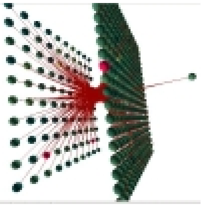
Moogli



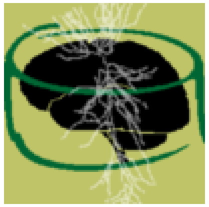
NeuronLand



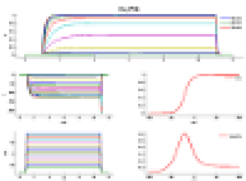
Whole Brain Catalog



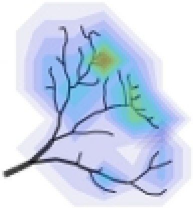
NeurAnim



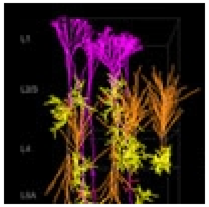
NeuroMorpho



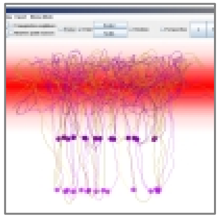
Channelpedia @ BlueBrainProject



TREES toolbox



NeuGen



CX3D

OPEN SOURCE BRAIN [NeuroML] wellcome trust

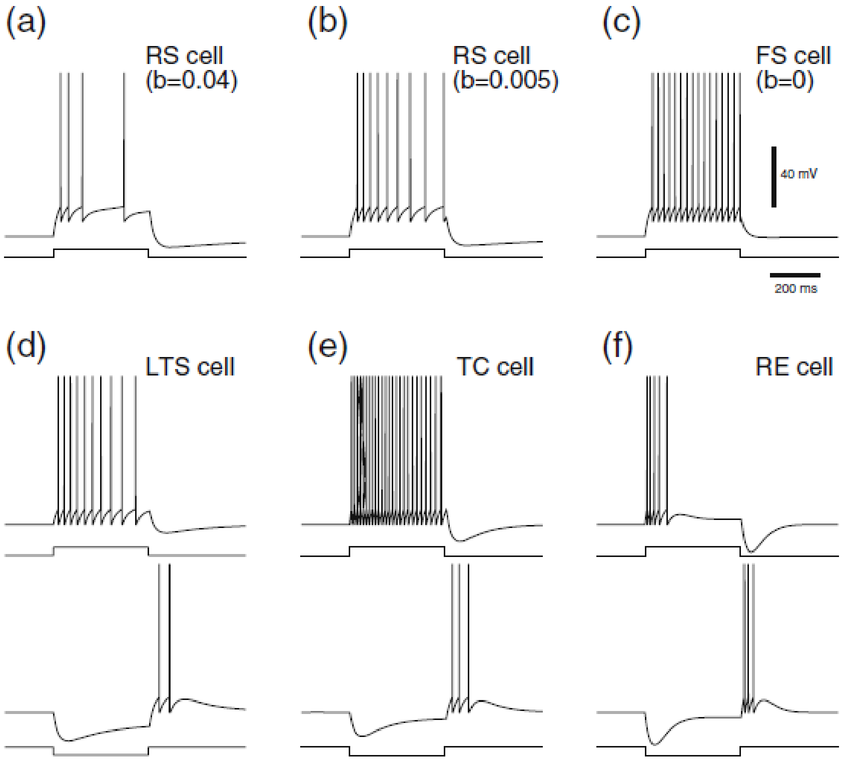
Brette & Gerstner Adaptive Exponential Integrate & Fire neuron model

$$C\frac{dV}{dt} = -g_L(V - E_L) + g_L\Delta_T \exp\left(\frac{V - V_T}{\Delta_T}\right) - g_e(t)(V - E_e) - g_i(t)(V - E_i) - w$$

$$\tau_w \frac{dw}{dt} = a(V - E_L) - w$$

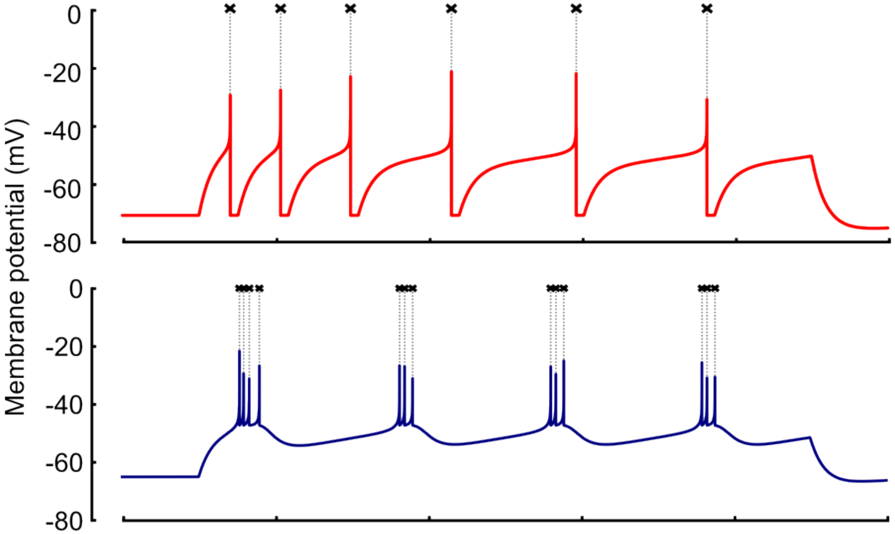
At spike time ($V > 20$ mV): $V \rightarrow EL$

$w \rightarrow w + b$

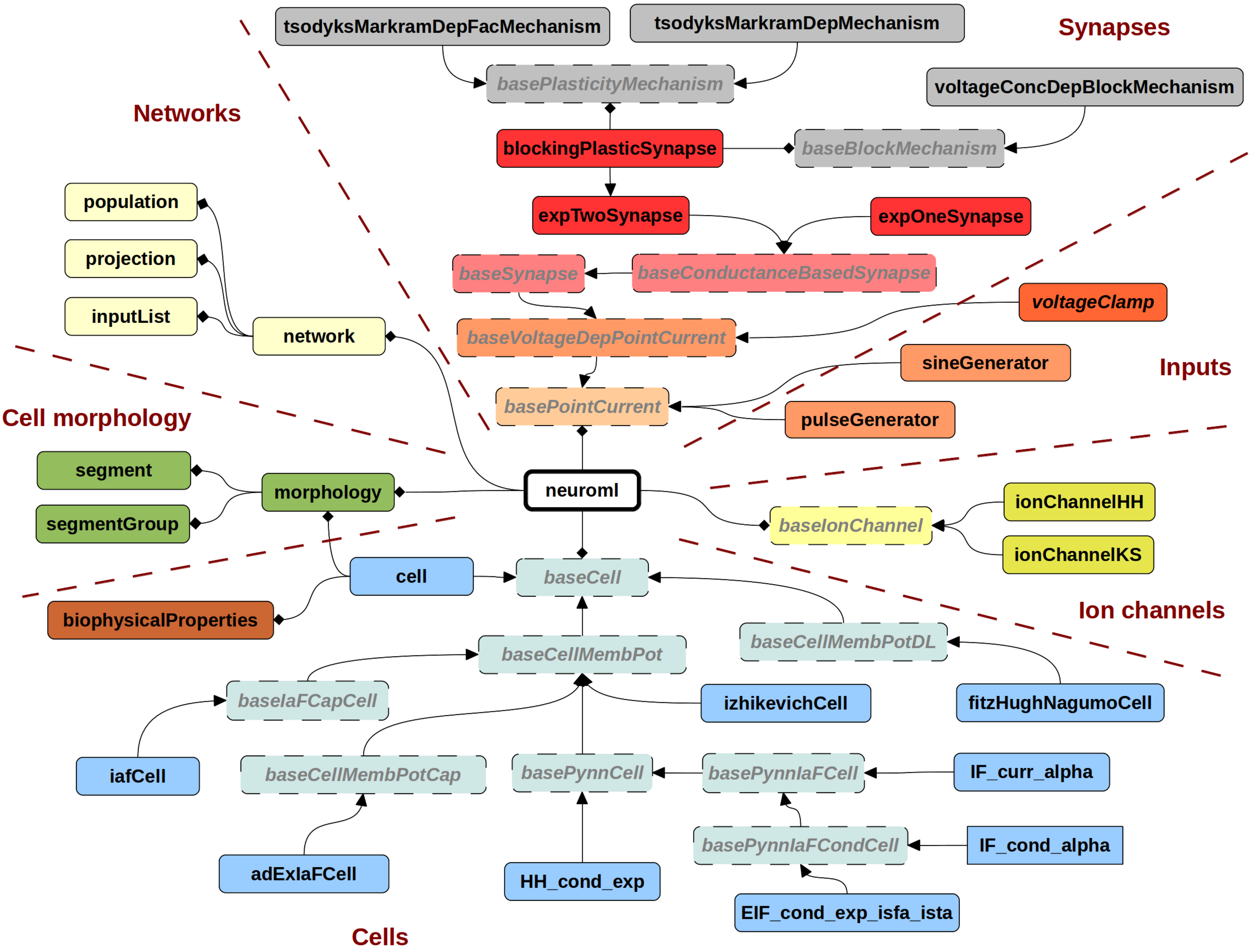


```
<adExIaFCell  id="adEx1" C="281 pF"  gL="30 nS"
   EL="-70.6 mV"      reset="-70.6 mV" VT="-50.4 mV"
   thresh="-20 mV" delT="2 mV"        tauw="144 ms"
   a="4 nS"             b="0.0805 nA"     refract="5 ms"/>
```

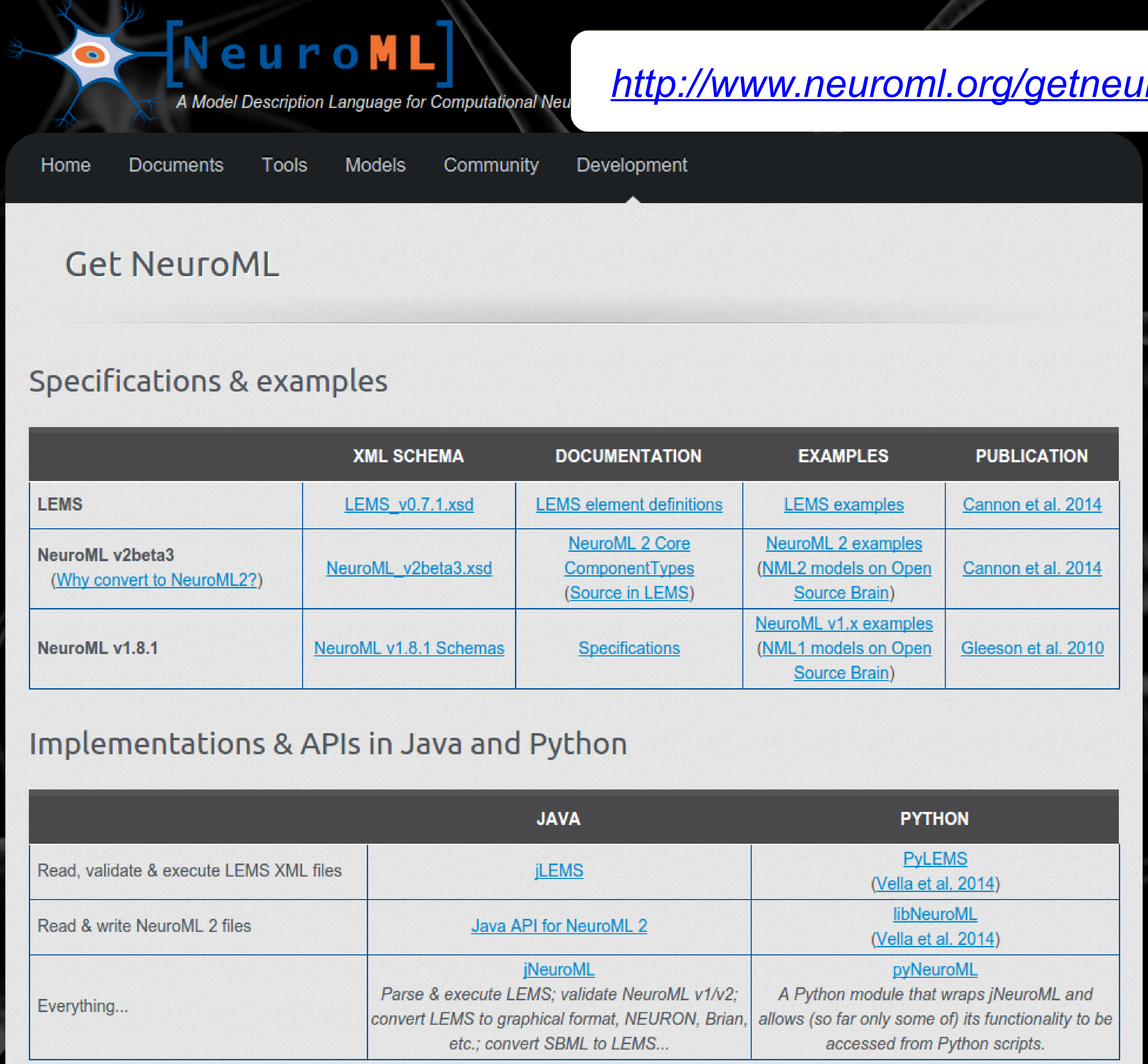
```
<adExIaFCell id="adEx2" C="281 pF"    gL="30 nS"
   EL="-65 mV"       reset="-47.2 mV"  VT="-50.4 mV"
   thresh="-20 mV" delT="2 mV"        tauw="40 ms"
   a="4 nS"             b="0.08 nA"        refract="0 ms"/>
```



NeuroML version 2.0



http://www.neuroml.org/getneuroml



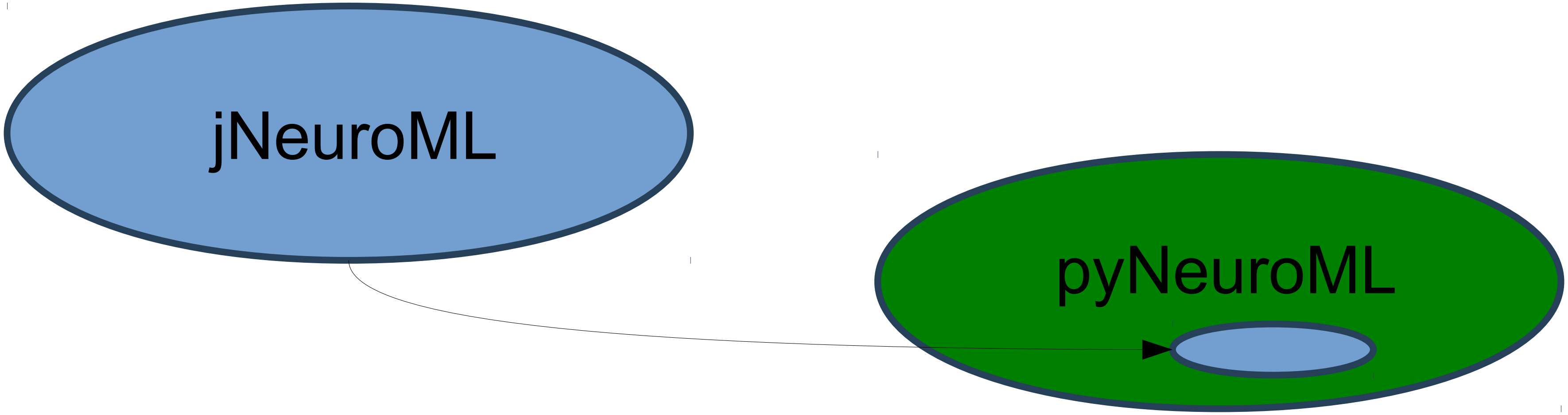
Get NeuroML

Specifications & examples

	XML SCHEMA	DOCUMENTATION	EXAMPLES	PUBLICATION
LEMS	LEMS_v0.7.1.xsd	LEMS element definitions	LEMS examples	Cannon et al. 2014
NeuroML v2beta3 (Why convert to NeuroML2?)	NeuroML_v2beta3.xsd	NeuroML 2 Core ComponentTypes (Source in LEMS)	NeuroML 2 examples (NML2 models on Open Source Brain)	Cannon et al. 2014
NeuroML v1.8.1	NeuroML v1.8.1 Schemas	Specifications	NeuroML v1.x examples (NML1 models on Open Source Brain)	Gleeson et al. 2010

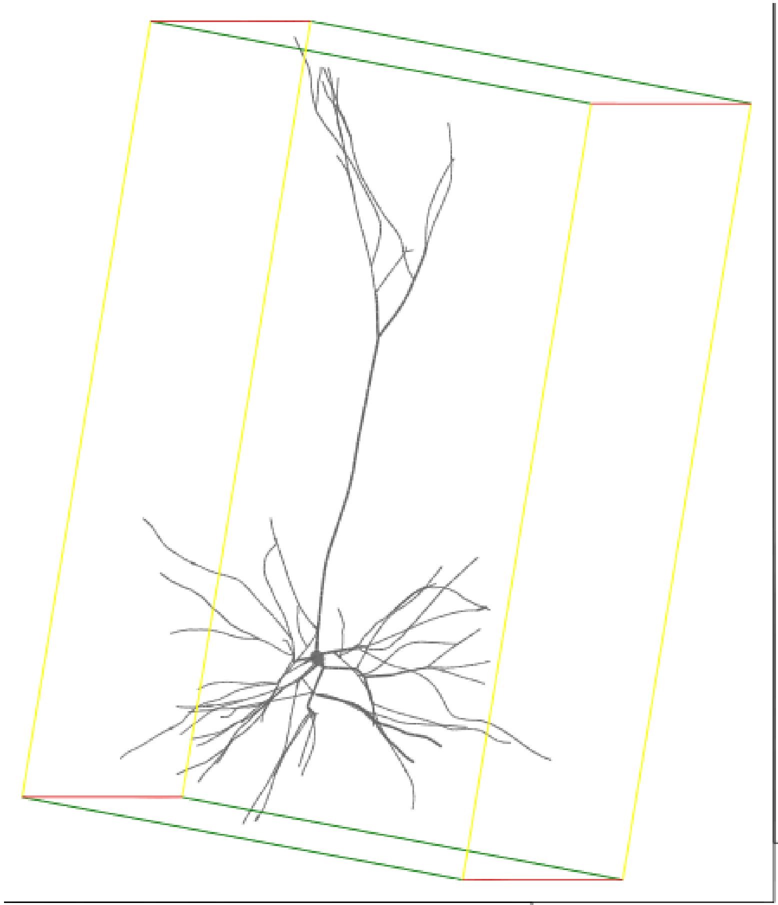
Implementations & APIs in Java and Python

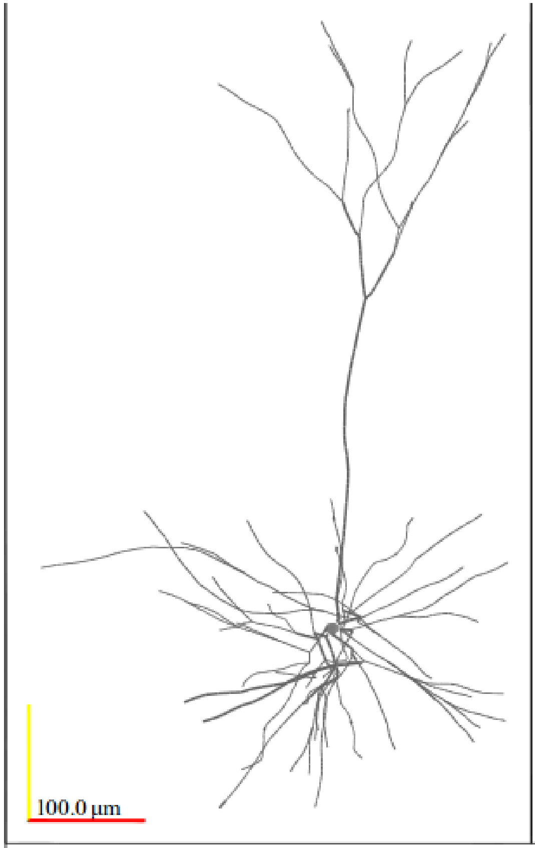
	JAVA	PYTHON
Read, validate & execute LEMS XML files	jLEMS	PyLEMS (Vella et al. 2014)
Read & write NeuroML 2 files	Java API for NeuroML 2	libNeuroML (Vella et al. 2014)
Everything...	jNeuroML *Parse & execute LEMS; validate NeuroML v1/v2; convert LEMS to graphical format, NEURON, Brian, etc.; convert SBML to LEMS...*	pyNeuroML *A Python module that wraps jNeuroML and allows (so far only some of) its functionality to be accessed from Python scripts.*

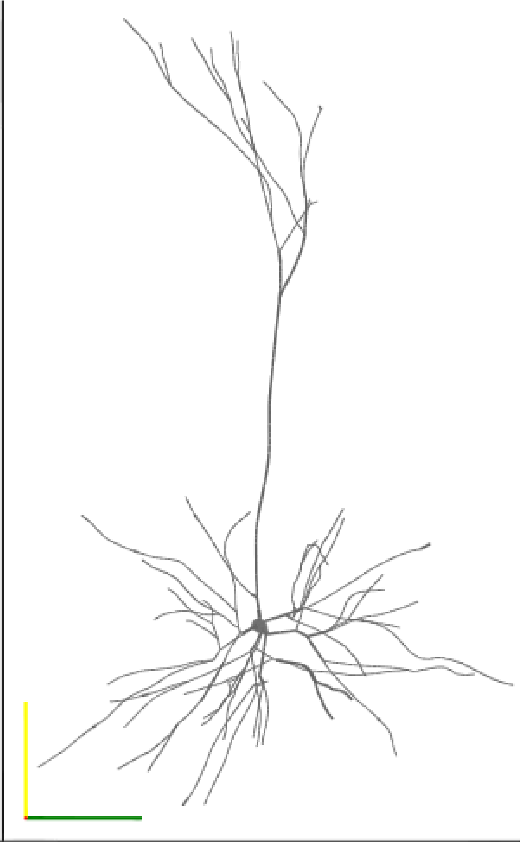


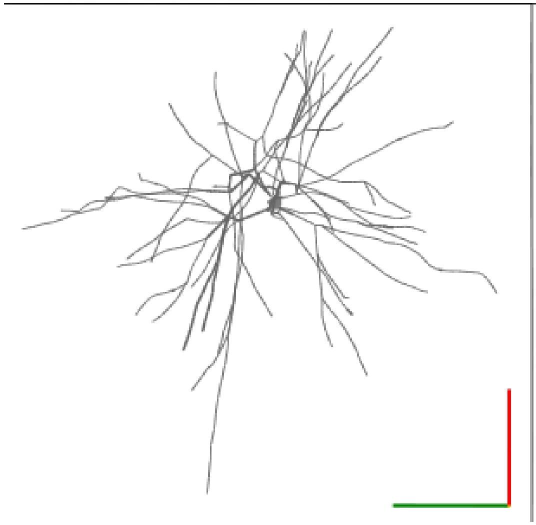
jnml

pynml







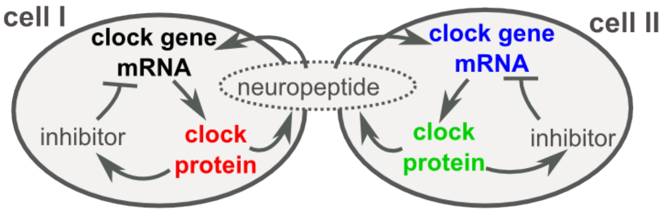


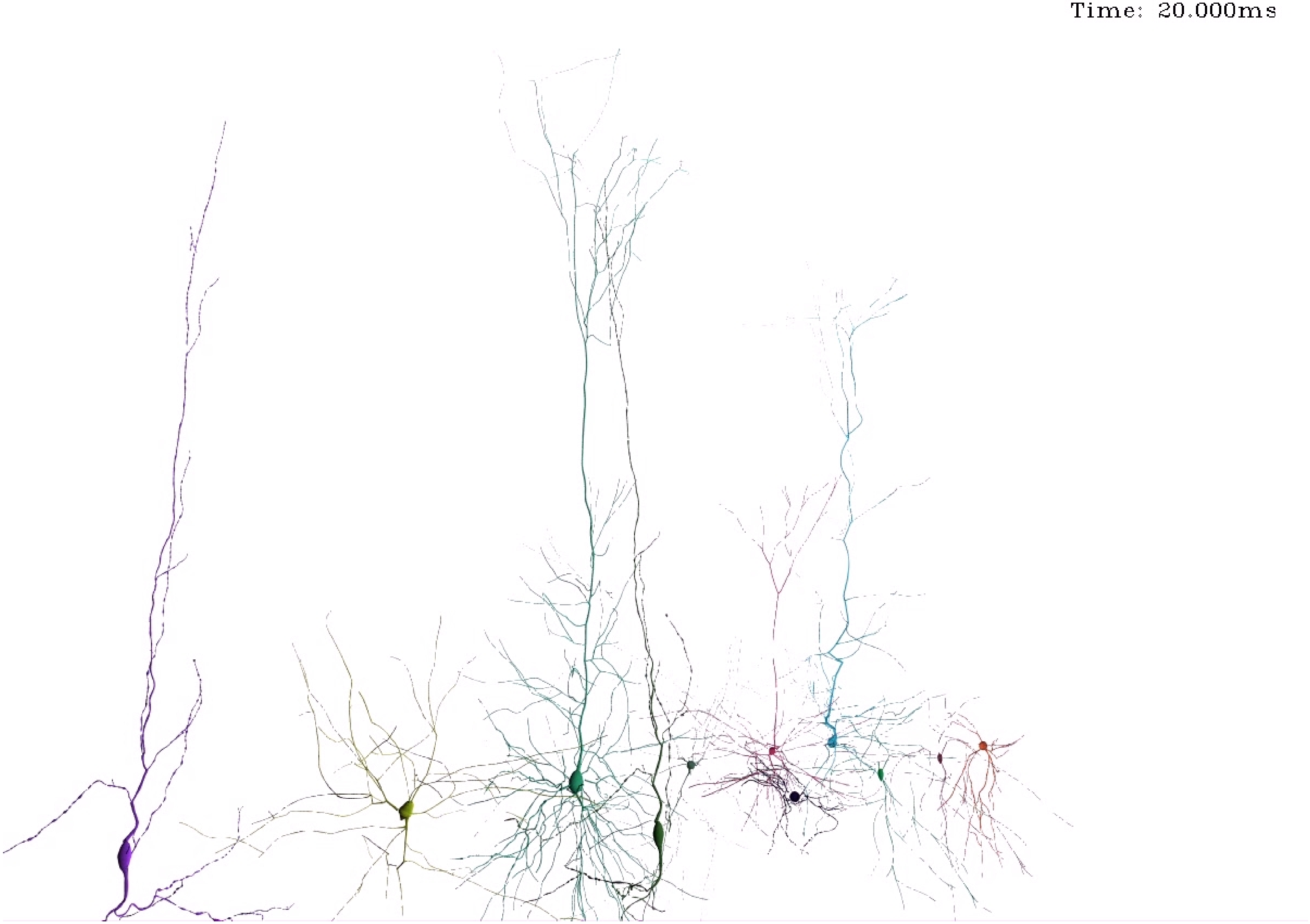
```
jnml  MyCell.nml  -svg

pynml  MyCell.nml  -svg
```

```
jnml -sbml-import Model.sbml 50 0.01
```

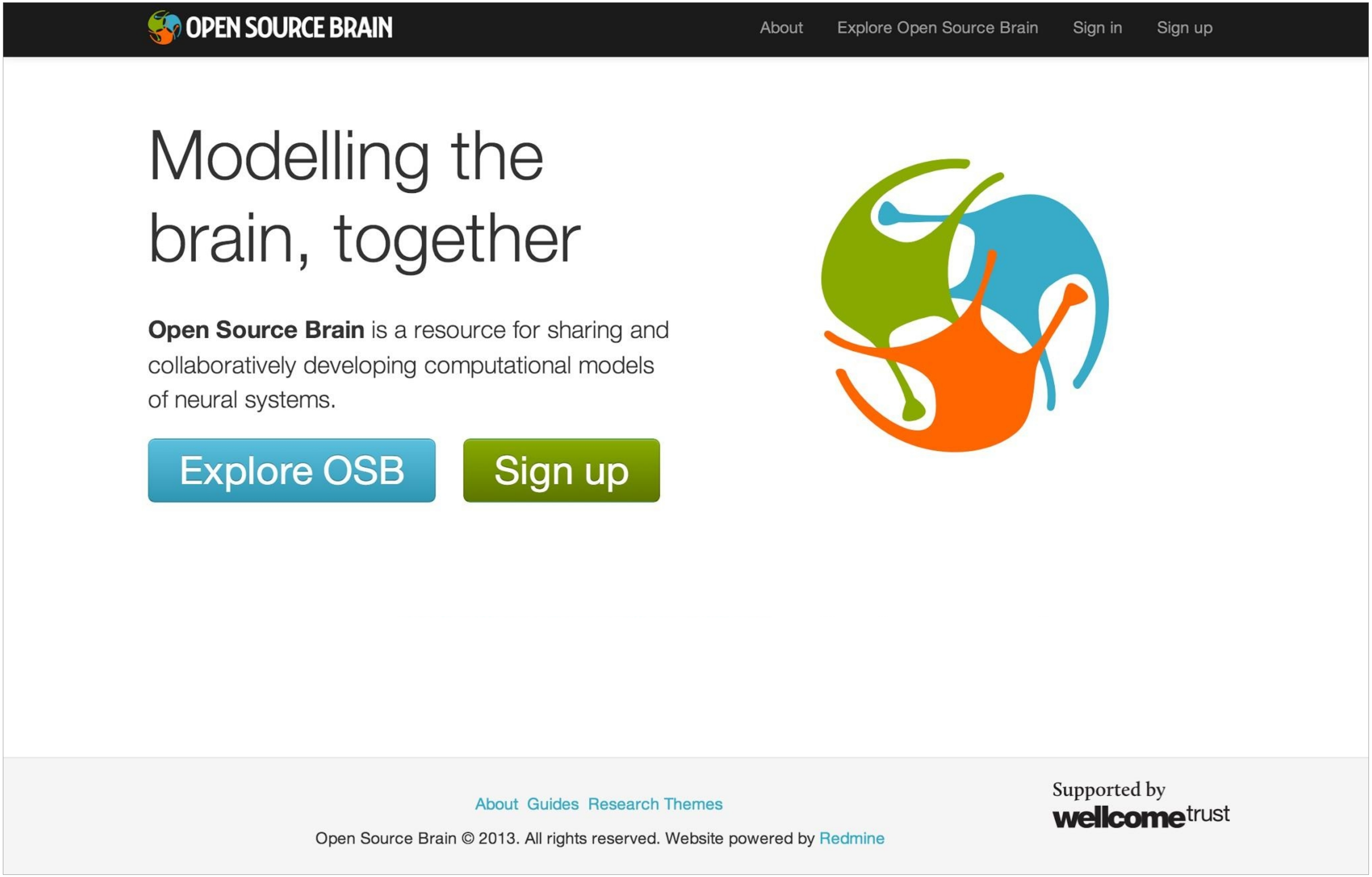
Original SBML model




Time: 20.000ms

Time: 20.000ms

The Open Source Brain repository



OPEN SOURCE BRAIN

Modelling the brain, together

Open Source Brain is a resource for sharing and collaboratively developing computational models of neural systems.

Open Source Brain © 2013. All rights reserved. Website powered by Redmine

Supported by wellcome trust

The Open Source Brain Repository

Wellcome Trust funded project

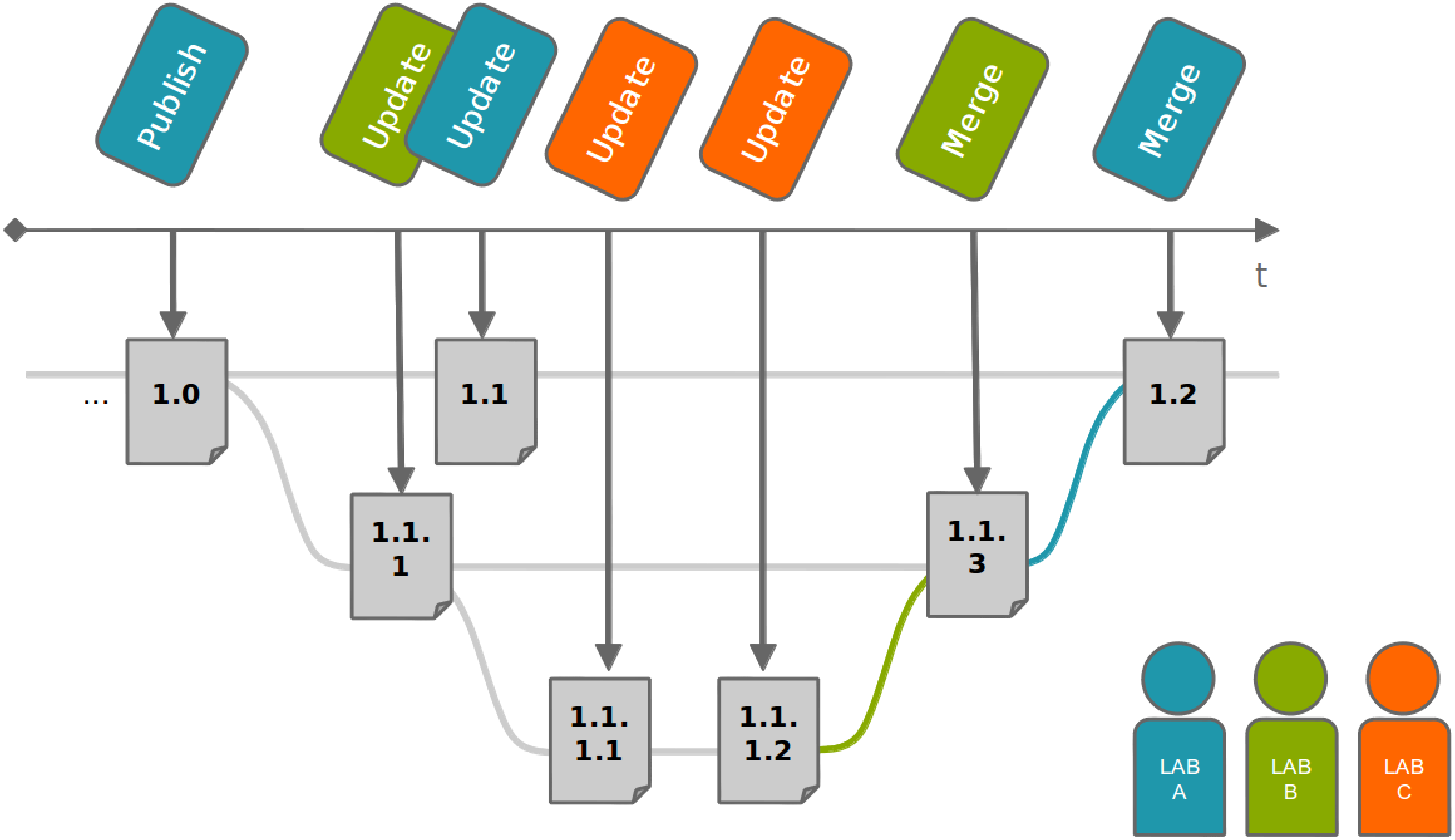
Open source model development repository for computational neuroscience

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

OSB development scenario



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Izhikevich Spiking Neuron Model

OSB endorsed project

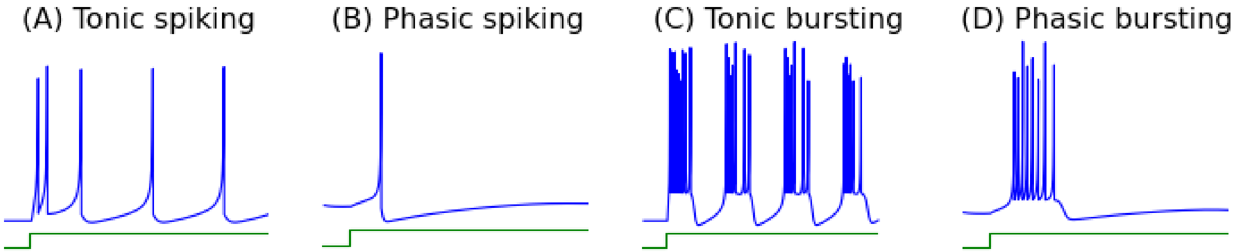
Curation against published models: Good ★★★

Vertebrate / Mammalian / Generic / Neocortex / Multiple / Izhikevich Spiking Neuron Model

OSB | Overview | OSB 3D Explorer | Activity | Issues | Wiki | Files | Repository

- Description
- Status
- Members
- References

Description

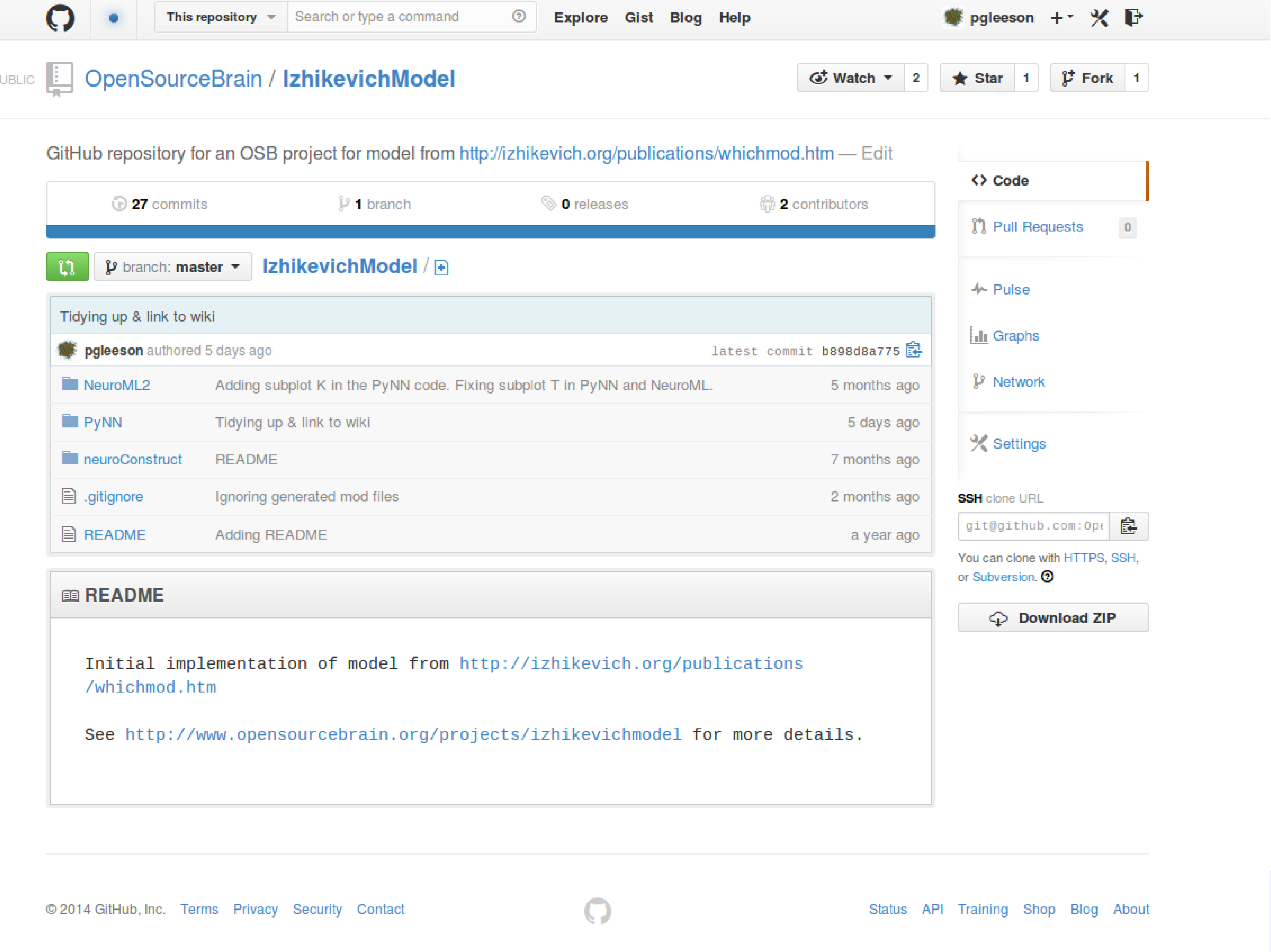


Implementation of model from http://izhikevich.org/publications/whichmod.htm in NeuroML and PyNN.

For more details see the Wiki.

Status

The Izhikevich model is supported by NeuroML v2.0 and PyNN 0.8. This project will demonstrate all of the main firing behaviours of this cell model.



UBLIC OpenSourceBrain / IzhikevichModel

GitHub repository for an OSB project for model from http://izhikevich.org/publications/whichmod.htm — Edit

27 commits | 1 branch | 0 releases | 2 contributors

IzhikevichModel / +

Tidying up & link to wiki

pgleeson authored 5 days ago latest commit b898d8a775

NeuroML2	Adding subplot K in the PyNN code. Fixing subplot T in PyNN and NeuroML.	5 months ago
PyNN	Tidying up & link to wiki	5 days ago
neuroConstruct	README	7 months ago
.gitignore	Ignoring generated mod files	2 months ago
README	Adding README	a year ago

README

```
Initial implementation of model from http://izhikevich.org/publications
/whichmod.htm

See http://www.opensourcebrain.org/projects/izhikevichmodel for more details.
```

SSH clone URL

git@github.com:Ope

You can clone with HTTPS, SSH, or Subversion.

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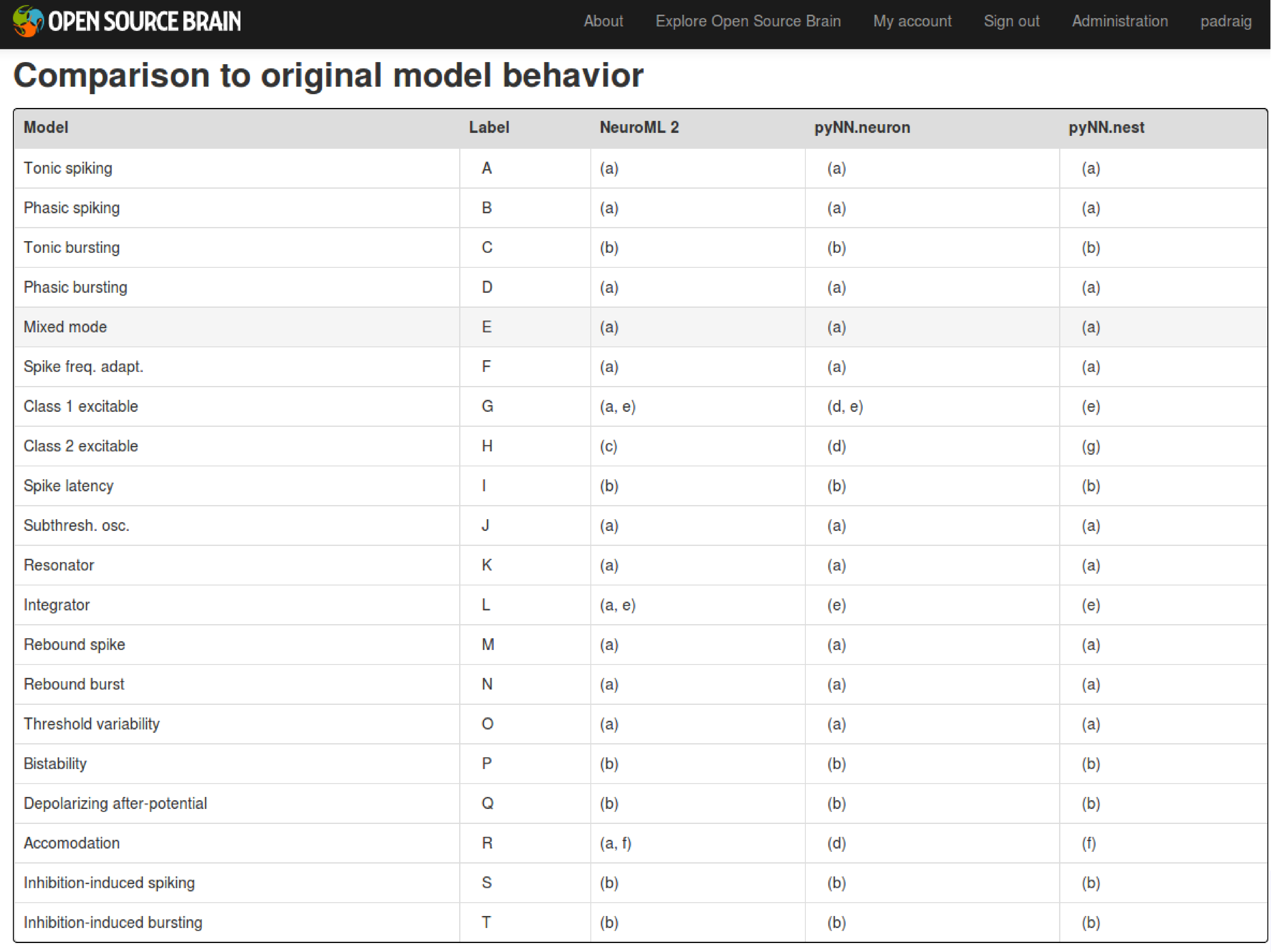


Comparison to original model behavior

Model	Label	NeuroML 2	pyNN.neuron	pyNN.nest
Tonic spiking	A	(a)	(a)	(a)
Phasic spiking	B	(a)	(a)	(a)
Tonic bursting	C	(b)	(b)	(b)
Phasic bursting	D	(a)	(a)	(a)
Mixed mode	E	(a)	(a)	(a)
Spike freq. adapt.	F	(a)	(a)	(a)
Class 1 excitable	G	(a, e)	(d, e)	(e)
Class 2 excitable	H	(c)	(d)	(g)
Spike latency	I	(b)	(b)	(b)
Subthresh. osc.	J	(a)	(a)	(a)
Resonator	K	(a)	(a)	(a)
Integrator	L	(a, e)	(e)	(e)
Rebound spike	M	(a)	(a)	(a)
Rebound burst	N	(a)	(a)	(a)
Threshold variability	O	(a)	(a)	(a)
Bistability	P	(b)	(b)	(b)
Depolarizing after-potential	Q	(b)	(b)	(b)
Accomodation	R	(a, f)	(d)	(f)
Inhibition-induced spiking	S	(b)	(b)	(b)
Inhibition-induced bursting	T	(b)	(b)	(b)

Inhibition-induced spiking	S	(b)	(b)	(b)
Inhibition-induced bursting	T	(b)	(b)	(b)

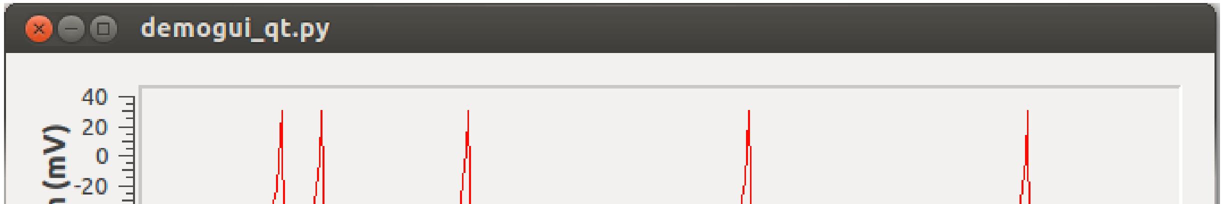
(a) Same behaviour
(b) Similar behaviour when slightly modifying parameters. See the table below.
(c) Similar but not identical behaviour (different number of spikes in the stimulus time frame)
(d) Not yet implemented. Need ramp injected current. See https://github.com/NeuralEnsemble/PyNN/issues/257
(e) Requires an alternative model implementation since the model parameterization is different in the original Matlab code. In NeuroML new ComponentType generalizedIzhikevichCell was created.
(f) Requires an alternative model implementation since the model parameterization is different in the original Matlab code. In NeuroML new ComponentType accomodationIzhikevichCell was created.
(g) Could not reproduce model behavior

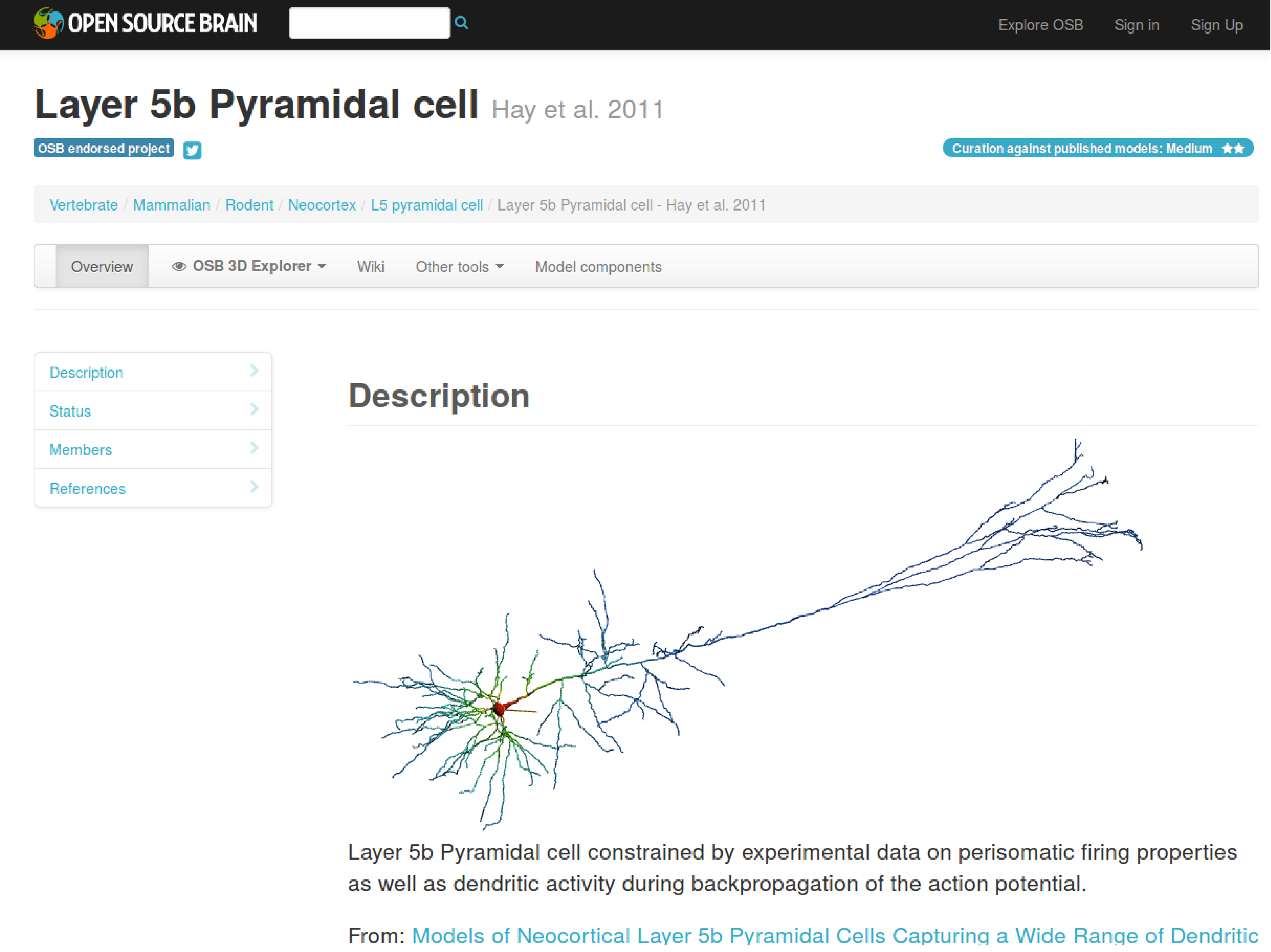
Parameter changes to adequate model behaviour

Model	Label	Parameter	Original value	New value
Spike latency	I	Amplitude of pulse current	7.04	6.71
Bistability	P	Initial time of 2nd pulse	216	208
Depolarizing after-potential	Q	b	0.2	0.18
Inhibition-induced spiking	S	Inhibition ending	250	220
Inhibition-induced bursting	T	d	-2.0	-0.7

Alternative implementations

An alternative implementation of the Izhikevich model was created using Moose. The code can be found here. There is a GUI in which the user chooses the model parameterization an visualizes the simulation results (see the figure below).





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Layer 5b Pyramidal cell Hay et al. 2011

OSB endorsed project
Curation against published models: Medium ★★

Vertebrate / Mammalian / Rodent / Neocortex / L5 pyramidal cell / Layer 5b Pyramidal cell - Hay et al. 2011

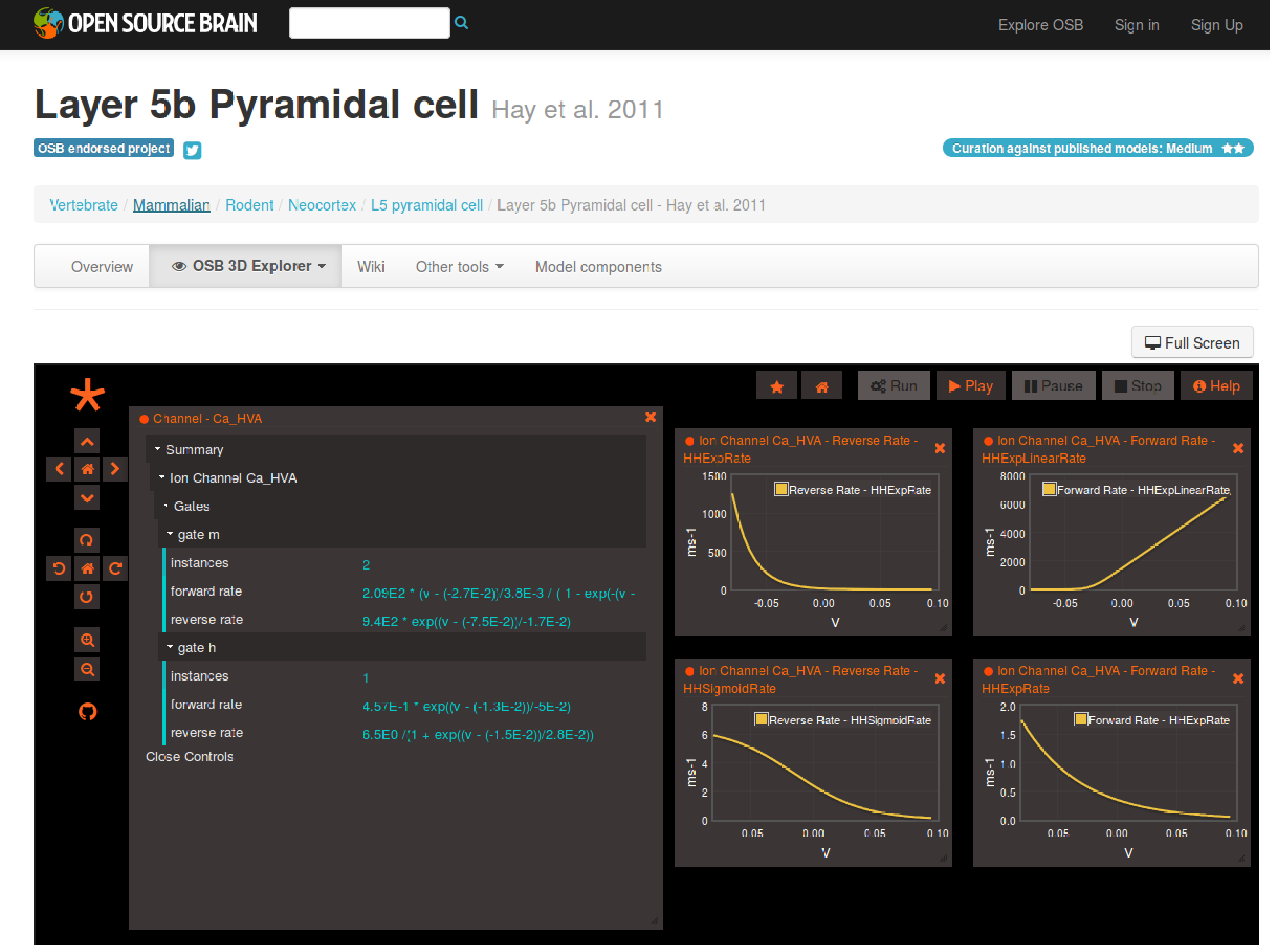
Overview
OSB 3D Explorer
Wiki
Other tools
Model components

Description
Status
Members
References

Description

Layer 5b Pyramidal cell constrained by experimental data on perisomatic firing properties as well as dendritic activity during backpropagation of the action potential.

From: Models of Neocortical Layer 5b Pyramidal Cells Capturing a Wide Range of Dendritic



Layer 5b Pyramidal cell Hay et al. 2011

Vertebrate / Mammalian / Rodent / Neocortex / L5 pyramidal cell / Layer 5b Pyramidal cell - Hay et al. 2011

Channel - Ca_HVA

- Summary
  - Ion Channel Ca_HVA
    - Gates
      - gate m

instances	2
forward rate	2.09E2 * (v - (-2.7E-2))/3.8E-3 / (1 - exp(-(v -
reverse rate	9.4E2 * exp((v - (-7.5E-2))/-1.7E-2)

      - gate h

instances	1
forward rate	4.57E-1 * exp((v - (-1.3E-2))/-5E-2)
reverse rate	6.5E0 /(1 + exp((v - (-1.5E-2))/2.8E-2))

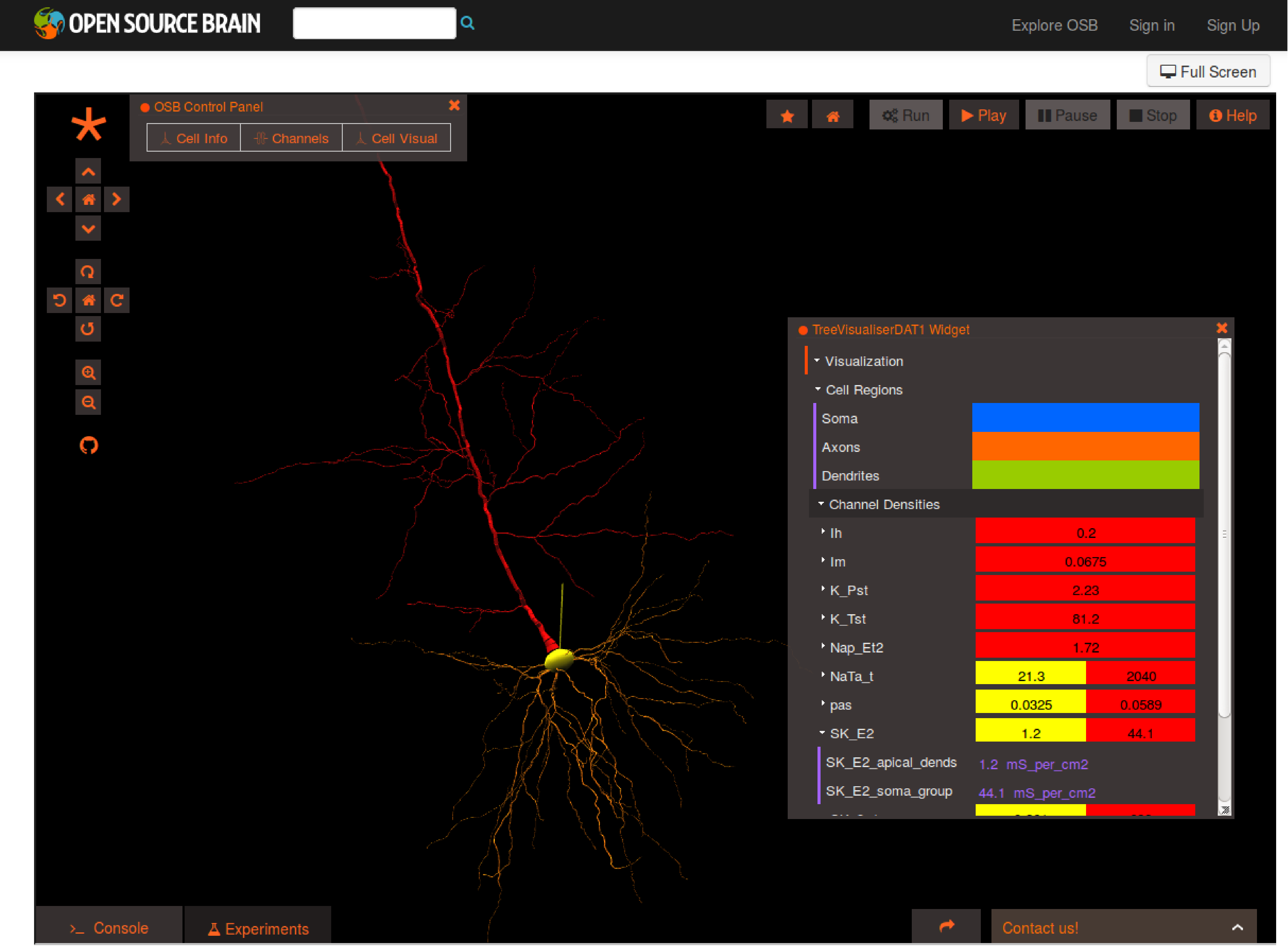
Close Controls

Ion Channel Ca_HVA - Reverse Rate - HHExpRate

Ion Channel Ca_HVA - Forward Rate - HHExpLinearRate

Ion Channel Ca_HVA - Reverse Rate - HHSigmoidRate

Ion Channel Ca_HVA - Forward Rate - HHExpRate



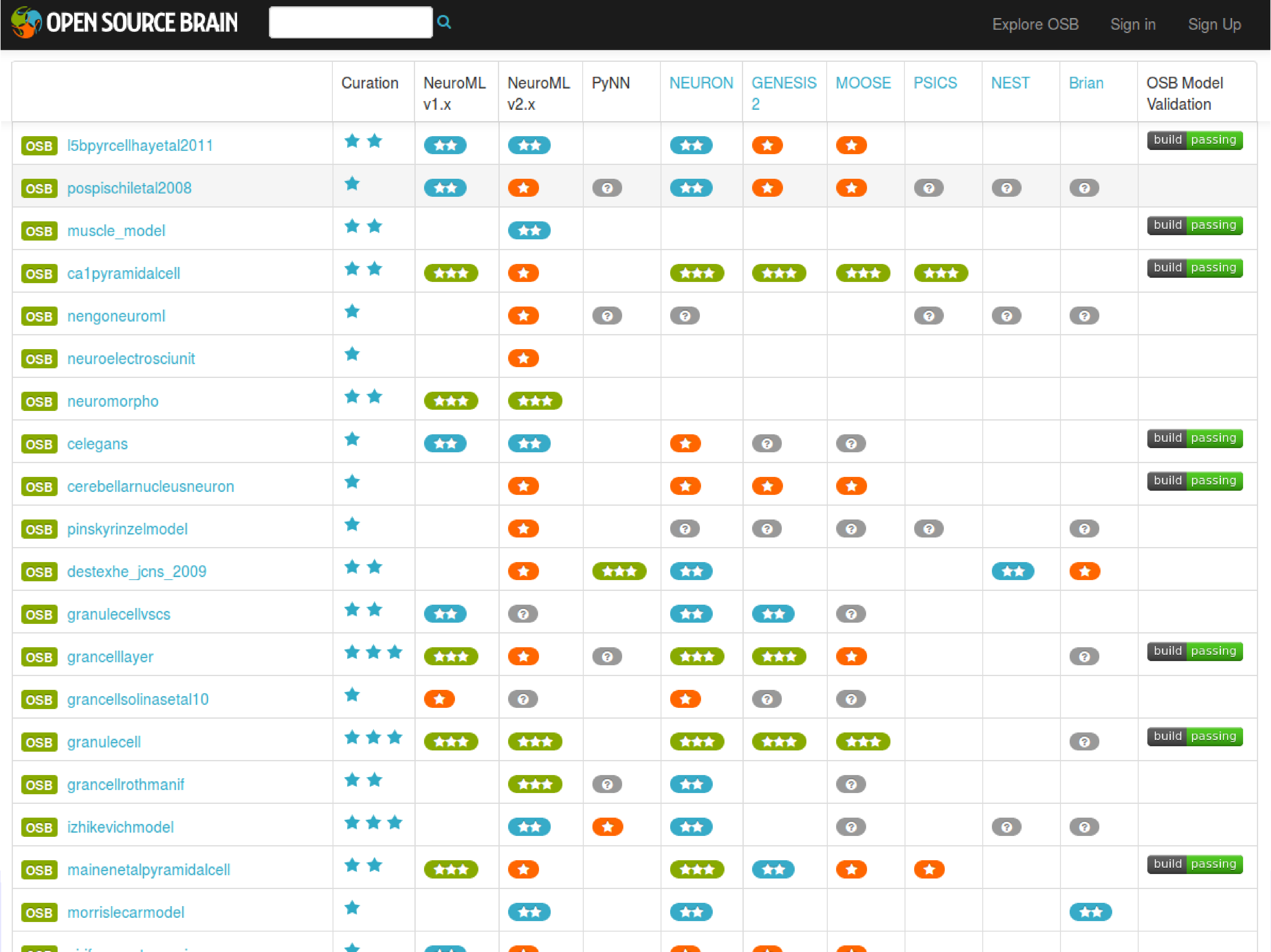
TreeVisualiserDAT1 Widget

- Visualization
  - Cell Regions

Soma	🟦
Axons	🟧
Dendrites	🟩

  - Channel Densities

Ih	0.2	
Im	0.0675	
K_Pst	2.23	
K_Tst	81.2	
Nap_Et2	1.72	
NaTa_t	21.3	2040
pas	0.0325	0.0589
SK_E2	1.2	44.1
SK_E2_apical_dends	1.2 mS_per_cm2	
SK_E2_soma_group	44.1 mS_per_cm2	



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	Curation	NeuroML v1.x	NeuroML v2.x	PyNN	NEURON	GENESIS 2	MOOSE	PSICS	NEST	Brian	OSB Model Validation
OSB l5bpyrcellhayetal2011	★★	★★	★★		★★	★	★				build passing
OSB pospischiletal2008	★	★★	★	?	★★	★	★	?	?	?	
OSB muscle_model	★★		★★								build passing
OSB ca1pyramidalcell	★★	★★★	★		★★★	★★★	★★★	★★★			build passing
OSB nengoneuroml	★		★	?	?			?	?	?	
OSB neuroelectrosciunit	★		★								
OSB neuromorpho	★★	★★★	★★★								
OSB celegans	★	★★	★★		★	?	?				build passing
OSB cerebellarnucleusneuron	★		★		★	★	★				build passing
OSB pinskyrinzelmodel	★		★		?	?	?	?		?	
OSB destexhe_jcns_2009	★★		★	★★★	★★				★★	★	
OSB granulecellvscs	★★	★★	?		★★	★★	?				
OSB grancelllayer	★★★	★★★	★	?	★★★	★★★	★			?	build passing
OSB grancellsolinasetal10	★	★	?		★	?	?				
OSB granulecell	★★★	★★★	★★★		★★★	★★★	★★★			?	build passing
OSB grancellrothmanif	★★		★★★	?	★★		?				
OSB izhikevichmodel	★★★		★★	★	★★		?		?	?	
OSB mainenetalpyramidalcell	★★	★★★	★		★★★	★★	★	★			build passing
OSB morrislecarmodel	★		★★		★★					★★	

How can we improve the model building and sharing process?

Reproducibility

Accessibility

Portability

Transparency

Acknowledgements

Silver Lab @ UCL

Angus Silver

Eugenio Piasini

Boris Marin

Adrian Quintana

Matteo Farinella

Yates Buckley

Matteo Cantarelli

Main Collaborators

Robert Cannon

Sharon Crook

Mike Vella

Early Adopters

Sergio Solinas

Egidio D'Angelo

Volker Steuber

Dieter Jaeger

Andrew Davison

Stephen Larson

Avrama Blackwell

Nicolas Le Novere

Members of the NeuroML community

[NeuroML]

OpenWorm project

OpenWorm

UK INCF Node

The UK
Neuroinformatics Node
● ● ● www.neuroinformatics.org.uk

Funding source:

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