OPEN SOURCE BRAIN

Introduction to OSB & NeuroML

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University College London

Supported by
wellcome trust

Overview

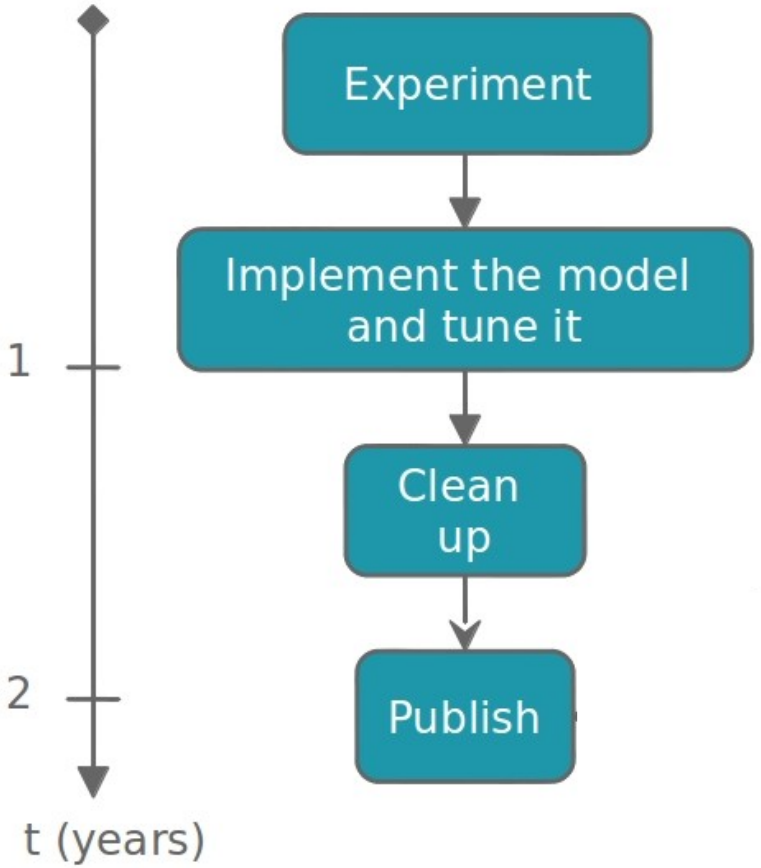
The current state of neuronal model sharing/reuse

The Open Source Brain Initiative

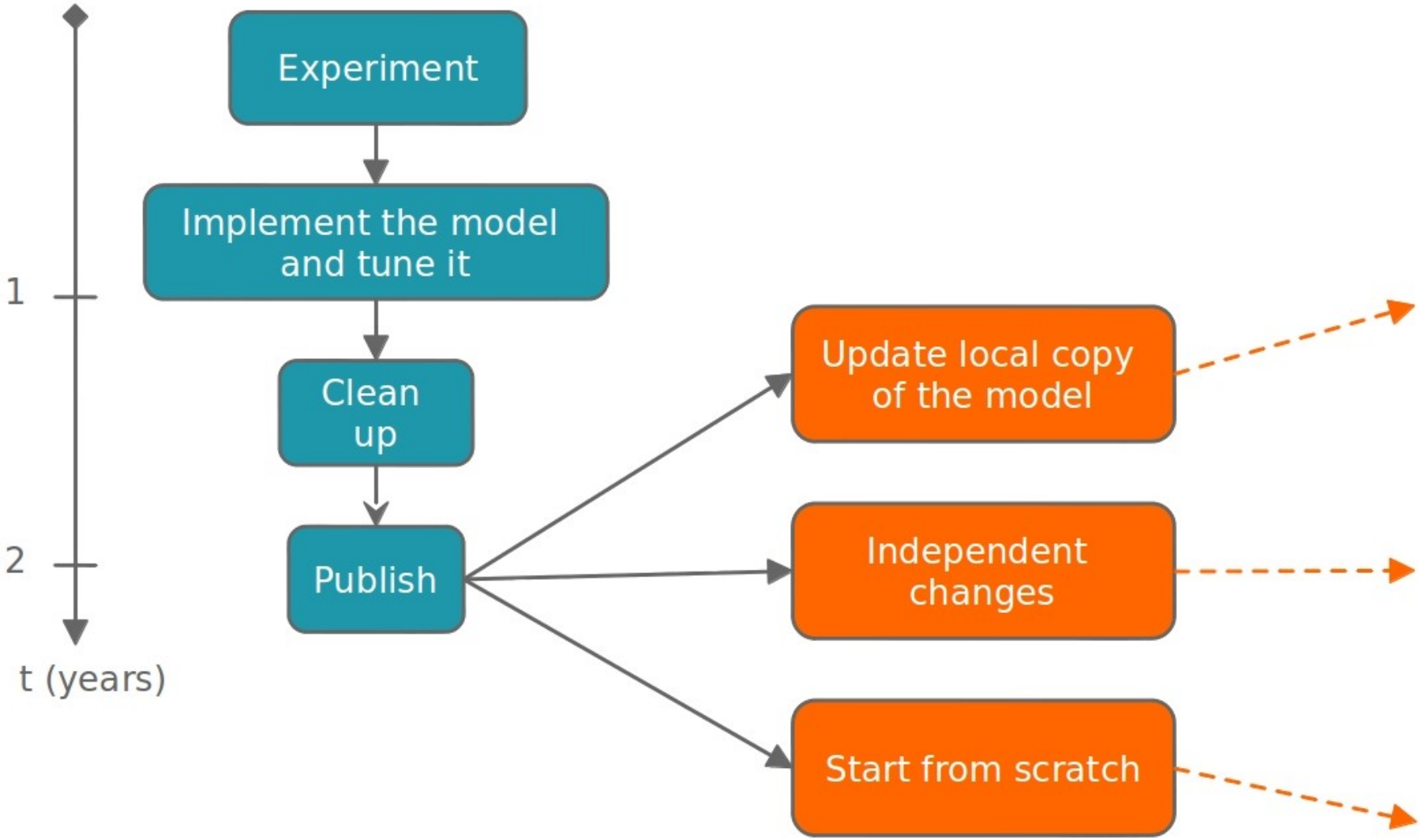
NeuroML

Collaborative modelling

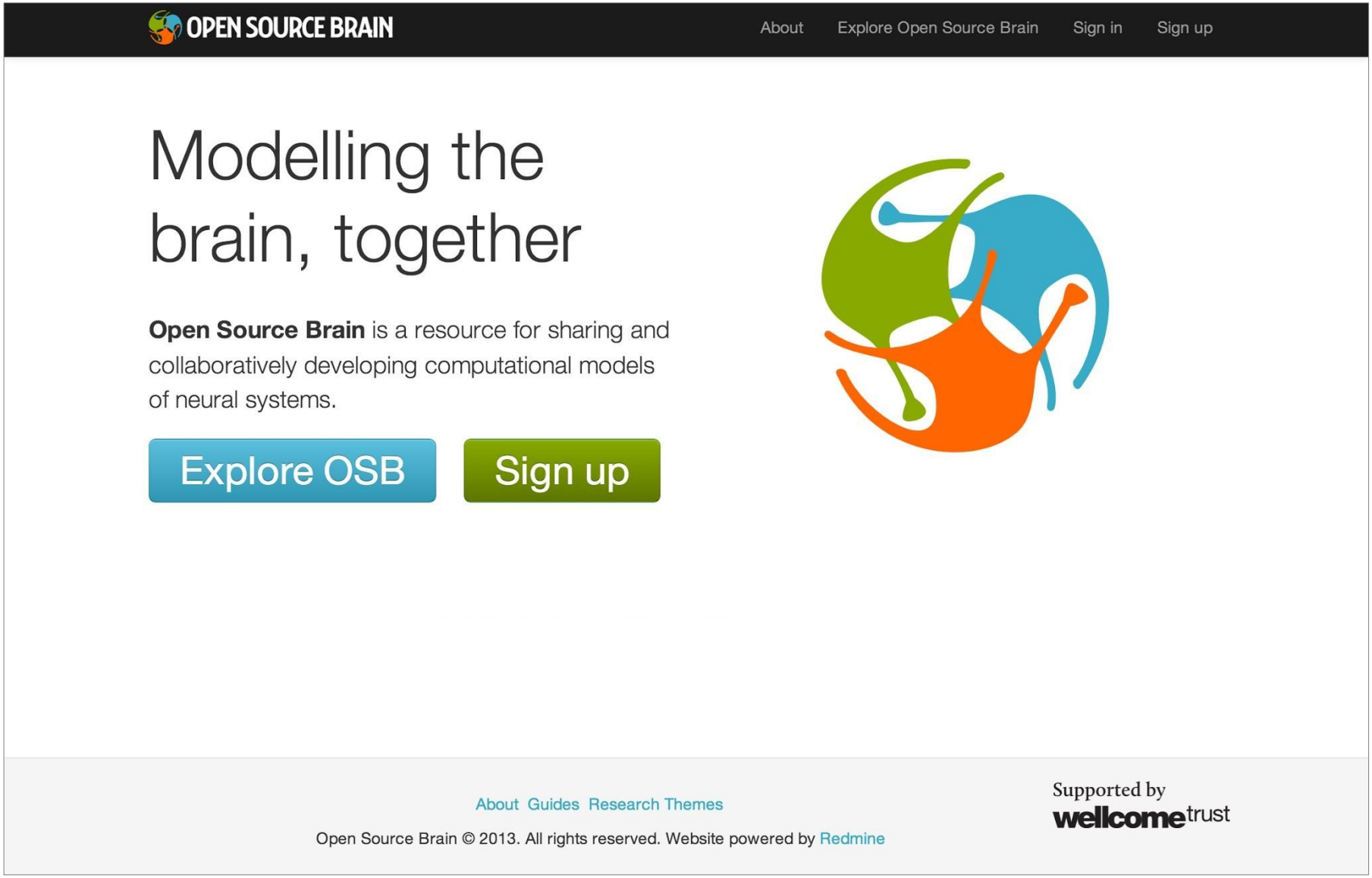
Current neuronal model development life-cycle



Current model development life-cycle



The Open Source Brain repository



The Open Source Brain Repository

Wellcome Trust funded project

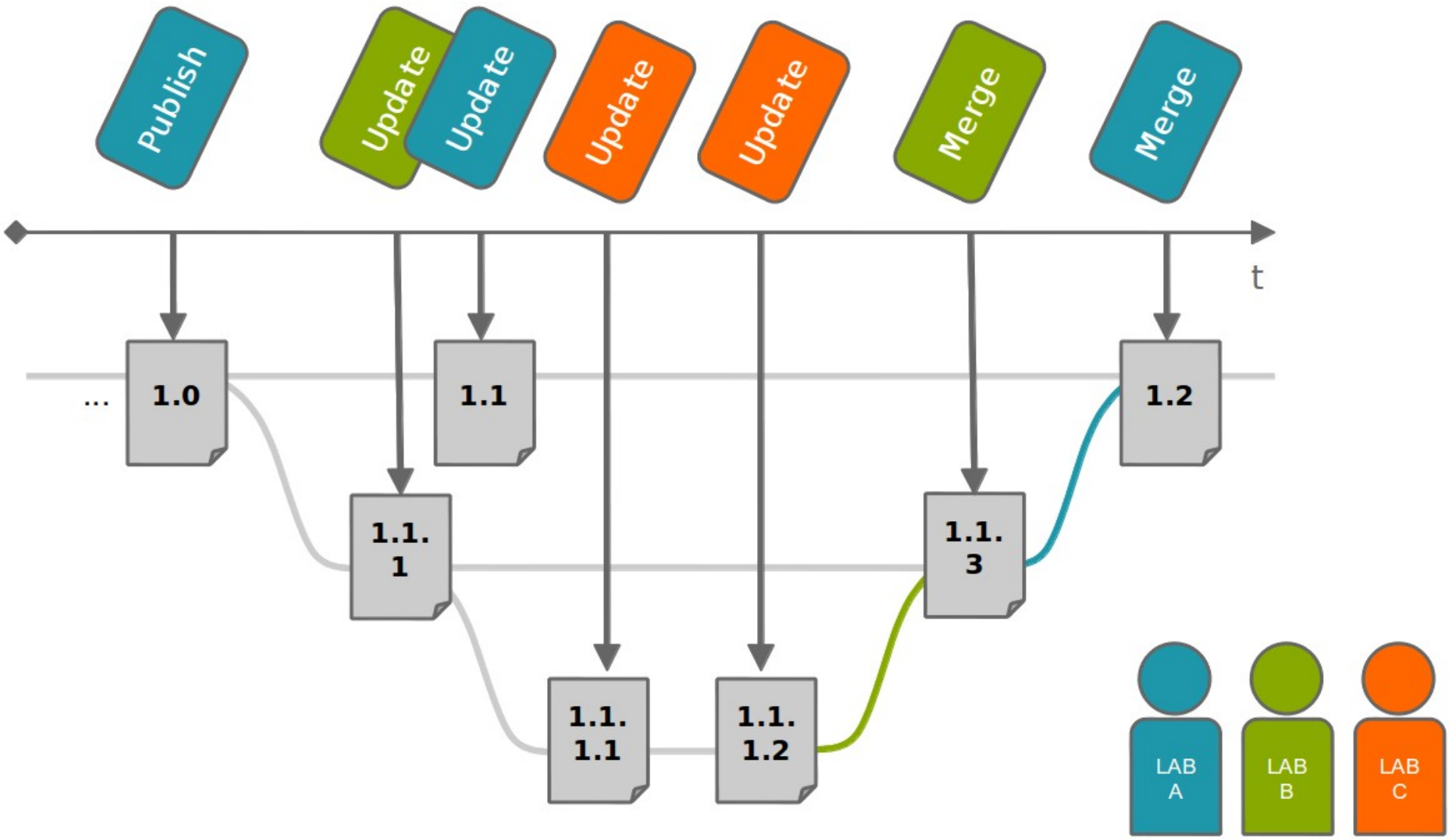
Open source model development repository for computational neuroscience

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

OSB development scenario



Models available on OSB

Neocortex

Mainen et al. (1995)
L5 Pyramidal cell
Rothman et al. (2010)
L5 Pyramidal cell
Hay et al (2011)
L5 Pyramidal cell
Traub et al. (2005)
L2/3 Pyr (FRB/RS), L4SS, L5 Pyr (IB/RS), L6 Pyr, Deep & superficial basket, axo-axonic & LTS interneurons, Cortical column network model

Basal Ganglia

Blackwell et al (in press)
Medium Spiny Neuron

Cerebellum

Maex and Schutter (1998)
Granule cell layer
Steuber and Saviane, based on Berends et al. (2005)
Granule cell
Vervaeke et al. (2010)
Golgi cell network
Solinas et al. (2007a,b)
Granule cell, Golgi cell
De Schutter and Bower (1994)
Purkinje cell
Steuber et al. (2011)
Cerebellar nucleus neuron

Hippocampus

Migliore et al. (2005)
CA1 Pyramidal cell

Abstract neuron models

Izhikevich (2003)
Morris & Lecar (1981)
FitzHugh & Nagumo (1969)

Thalamus

Traub et al. (2005)
Thalamocortical relay cell, Nucleus reticularis thalami cell

C elegans

OpenWorm project
302 cell connectome

Explore Open Source Brain

Cells and Networks
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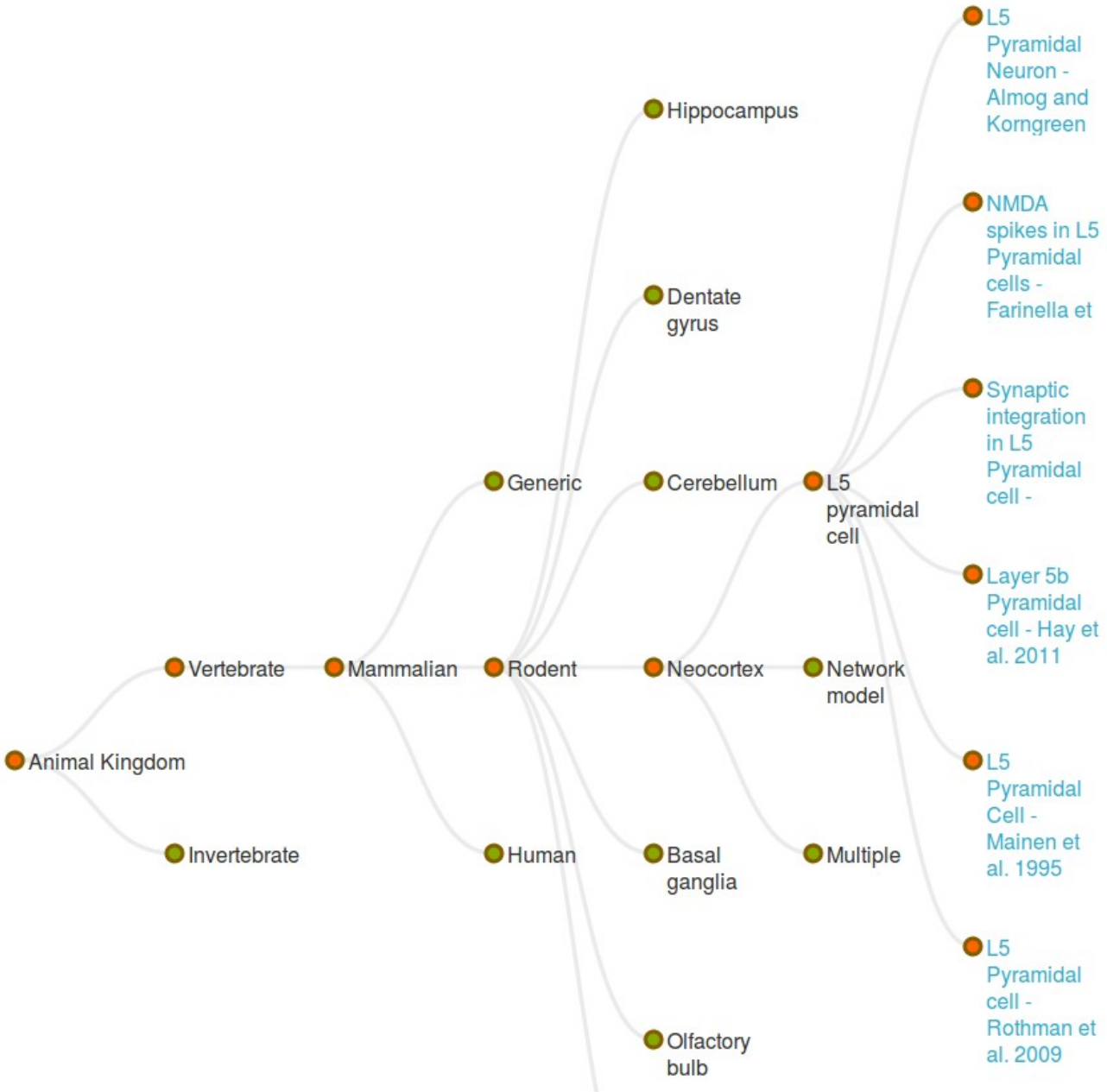
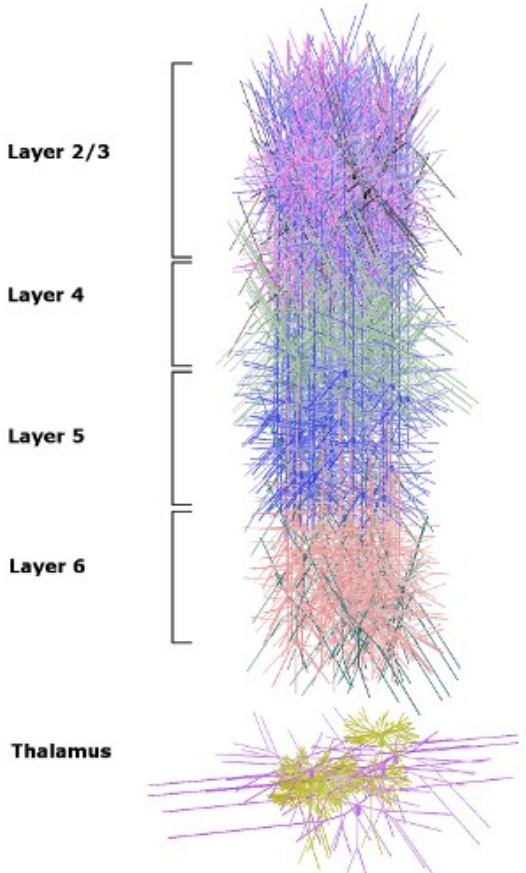


Thalamocortical network Traub et al. 2005

OSB endorsed project

Curation against published models: Medium ★★

Description



Status

Single cell models are stable in NeuroML v1.8.1, NEURON, GENESIS, MOOSE. Mappings to NeuroML v2.0 are being tested.

The large scale networks from Traub et al 2005 are in the process of being ported, see the wiki for more details.

NeuroML v2.x support ★ NeuroML v1.x support ★★★

NEURON support ★★★ GENESIS 2 support ★★★ MOOSE support ★★★

Members

Developer: Chaitanya Chintaluri, Daniel Wójcik, Eugenio Piasini, Helena Głąbska, jacek rogala, Michael Hines, Padraig Gleeson, Subhasis Ray, Tomás Fernández Alfonso, Yates Buckley
Scientific Coordinator: Angus Silver

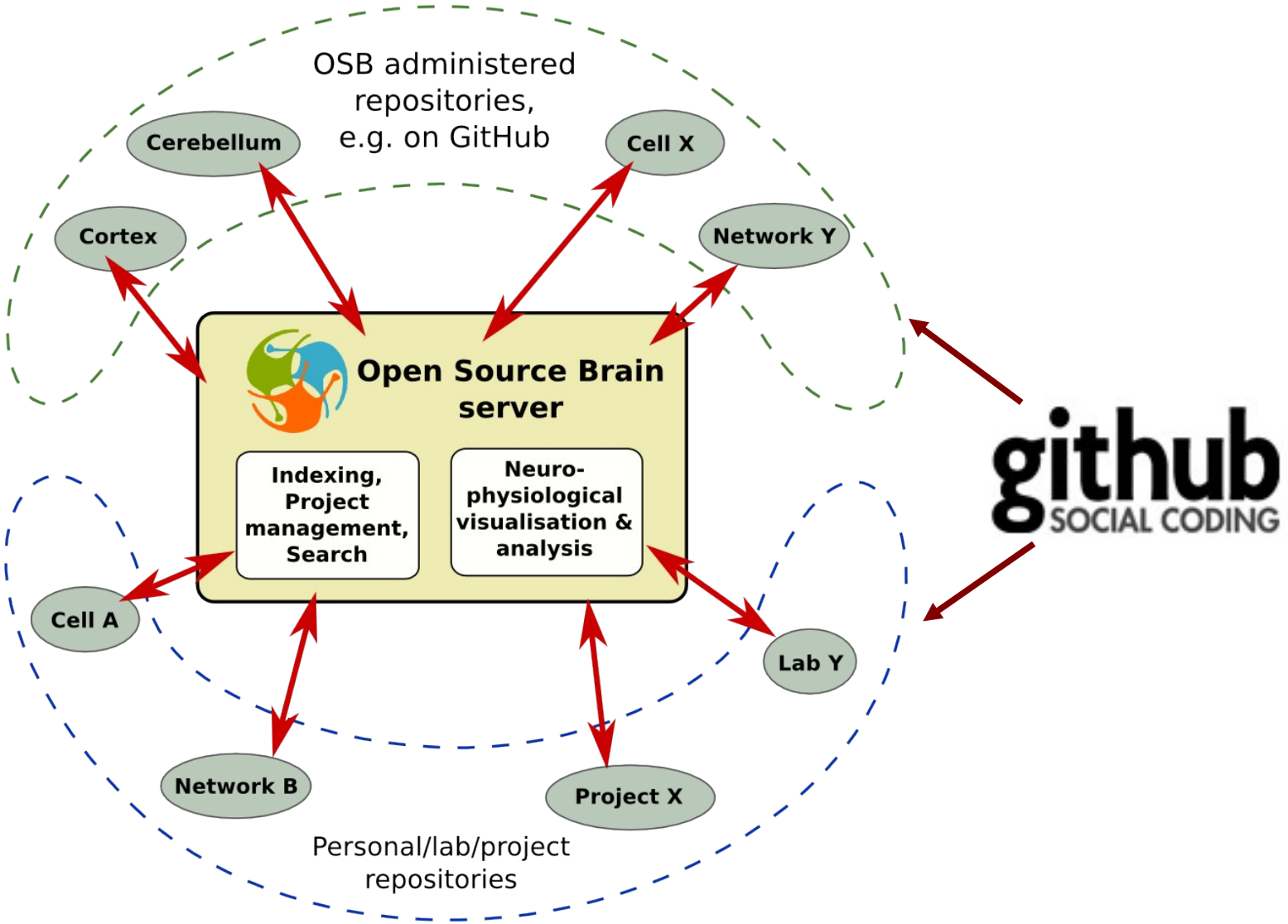
References

The original published version of this model is available on ModelDB

This model was originally developed in: **FORTRAN**

The code for this model is hosted on GitHub: https://github.com/OpenSourceBrain/Thalamocortical

“Hub and Spoke” architecture



UBLIC OpenSourceBrain / **Thalamocortical**

GitHub repository for an OSB project containing a thalamocortical network model based on Traub et al. 2005 — Edit

62 commits | **1** branch | **0** releases | **3** contributors

branch: **master** **Thalamocortical** /

Ignoring object files

pgleeson authored 2 months ago latest commit `2c67b8eeae`

Fortran_g77	Original Fortran g77 code	7 months ago
Fortran_ifc	Fortran version which work	3 months ago
MOOSE	Adding MOOSE version of Traub model from: https://svn.code.sf.net/p/m…	3 months ago
Neuron	original neuron version	7 months ago
neuroConstruct	Ensuring parallel settings are for serial running on local machine	2 months ago
.gitignore	Ignoring object files	2 months ago
README	Update README.	2 years ago

Code
Issues 0
Pull Requests 0
Pulse
Graphs
Network
Settings

SSH clone URL

`git@github.com:Ope`

You can clone with HTTPS, SSH, or Subversion.

Download ZIP

README

This is a project implementing cells from the thalamocortical network model of Traub et al 2005 in NeuroML.

Based on the NEURON implementation from: http://senselab.med.yale.edu/ModelDB/ShowModel.asp?model=45539.

PUBLIC OpenSourceBrain / Thalamocortical

Unwatch 4 | Star 3 | Fork 4

Graph | Members

The Thalamocortical network graph

Keyboard shortcuts available

All branches in the network using OpenSourceBrain/Thalamocortical as the reference point. Read our blog post about how it works.

Show Help

Thalamocortical network Traub et al. 2005

OSB endorsed project

Curation against published models: Medium ★★

Known issues with Traub et al 2005.

This is a quite complex and detailed model and as discussed in the original paper

> Any model, even of a small bit of cortex, is subject to difficulties and hazards: limited data, large numbers of parameters, criticisms that models with complexity comparable to the modeled system cannot be scientifically useful, the expense and slowness of the necessary computations, and serious uncertainties as to how a complex model can be compared with experiment and shown to be predictive.
> The above difficulties and hazards are too real to be dismissed readily. In our opinion, the only way to proceed is through a state of denial that any of the difficulties need be fatal. The reader must then judge whether the results, preliminary as they must be, help our understanding.

Even the published Fortran version of this model was acknowledged to be incomplete. Each conversion of this model will deviate to a small or large extent from this version.

Questions about physiological properties of model

Dependence on Fast Regular Bursting cells for oscillatory behaviour

Prevalence of gap junctions

High current threshold for deep pyramidal firing

Not tested with external synaptic input

Limitations of the conversion of the model to NEURON

It is useful to read the notes on conversion of this model to NEURON from Fortran by Tom Morse and Michael Hines

Slightly different method of running the simulation (e.g. in Neuron information about spike is sent immediately, in Fortran every 0.1 ms)

somatic current 1nA + EPSP

somatic current 0.5 nA + 3*EPSP

Neuron

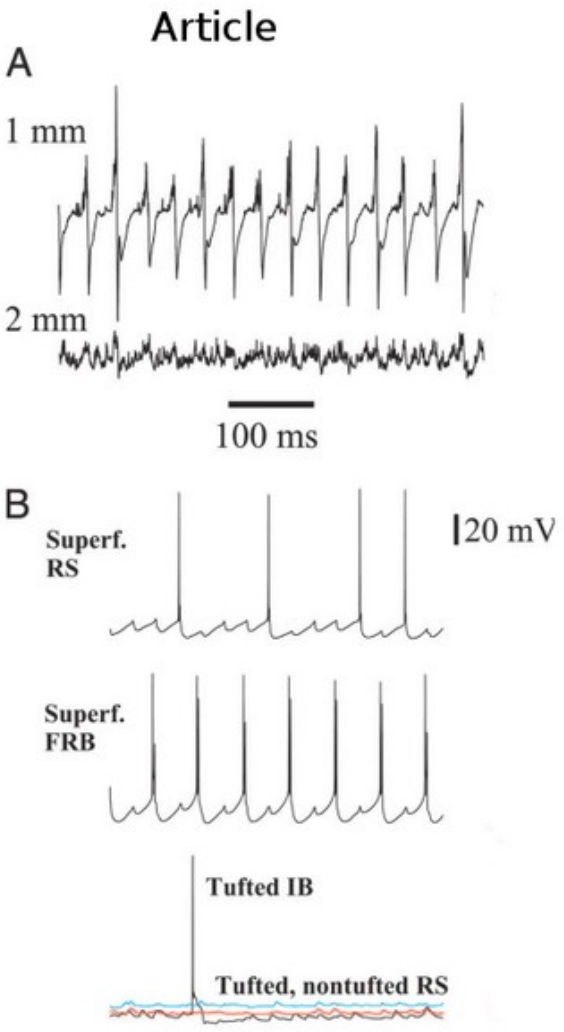
EPSP, 3 * EPSP

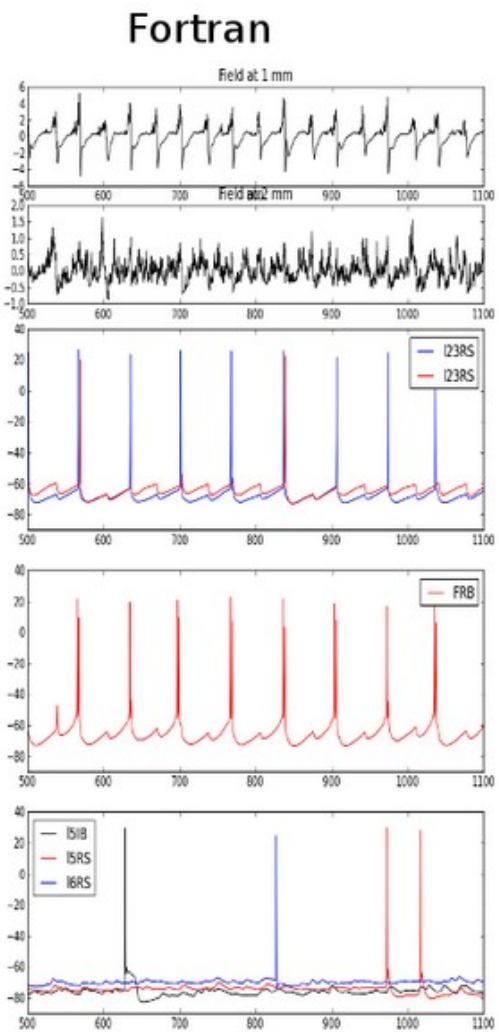
somatic current 1 nA + EPSP, 3*EPSP

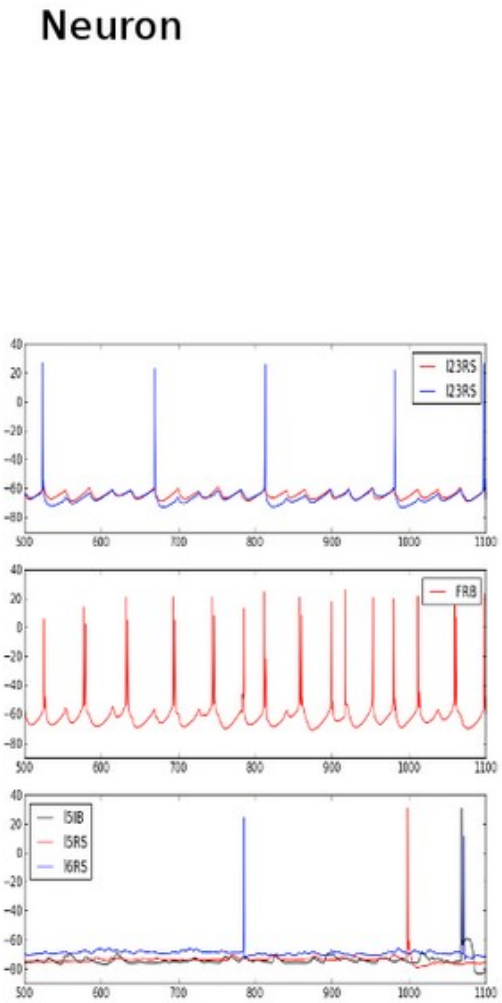
somatic current 0.5 nA + EPSP, 3*EPSP

Figure 2

"Simulation of kainate-induced gamma oscillations"





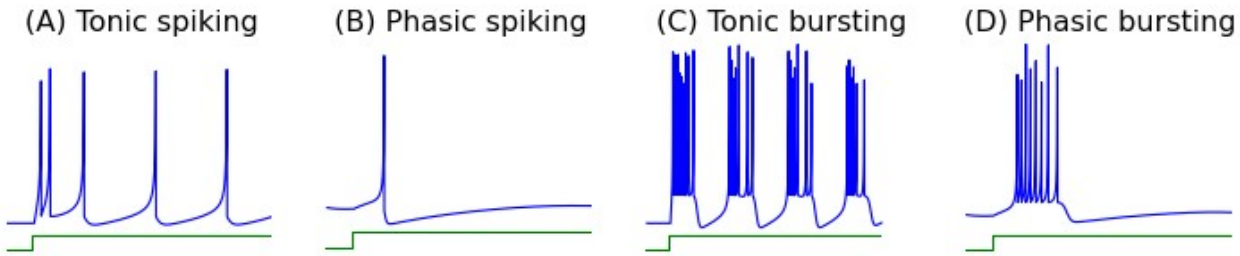


Izhikevich Spiking Neuron Model

OSB endorsed project

Curation against published models: Good ★★★

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**

Watch 2 | Star 1 | Fork 1

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

27 commits | **1** branch | **0** releases | **2** contributors

branch: **master** **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)

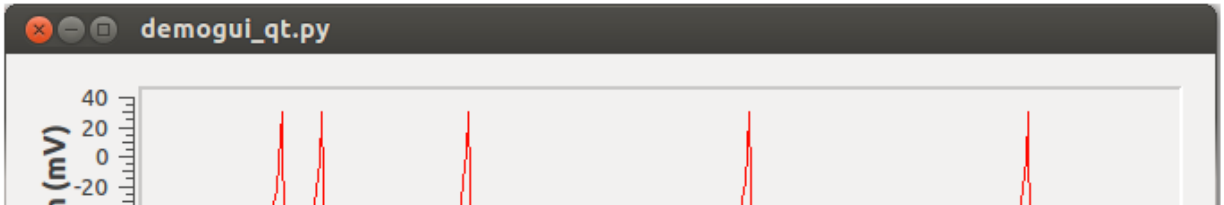
(a) Same behaviour
(b) Similar behaviour when slightly modifying parameters. See the table below.
(c) Similar but not identical behaviour (different number of spikes in the stimulus time frame)
(d) Not yet implemented. Need ramp injected current. See https://github.com/NeuralEnsemble/PyNN/issues/257
(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).



Research Themes

Cerebellar Granule Cell Modelling

Towards community developed cerebellar granule cell models

This project was started following the 2013 OSB kickoff meeting. At that meeting it was decided that the development of individual cell models from the cerebellum would be a good test case for exploring the requirements on technical infrastructure and the social aspects of collaborative model development. Due to the many independent granule cell layer networks being developed by participants at the OSB meeting, the cerebellar granule cell was identified as a good first cell model to focus on.

This wiki is intended to help gather the following information/requirements:

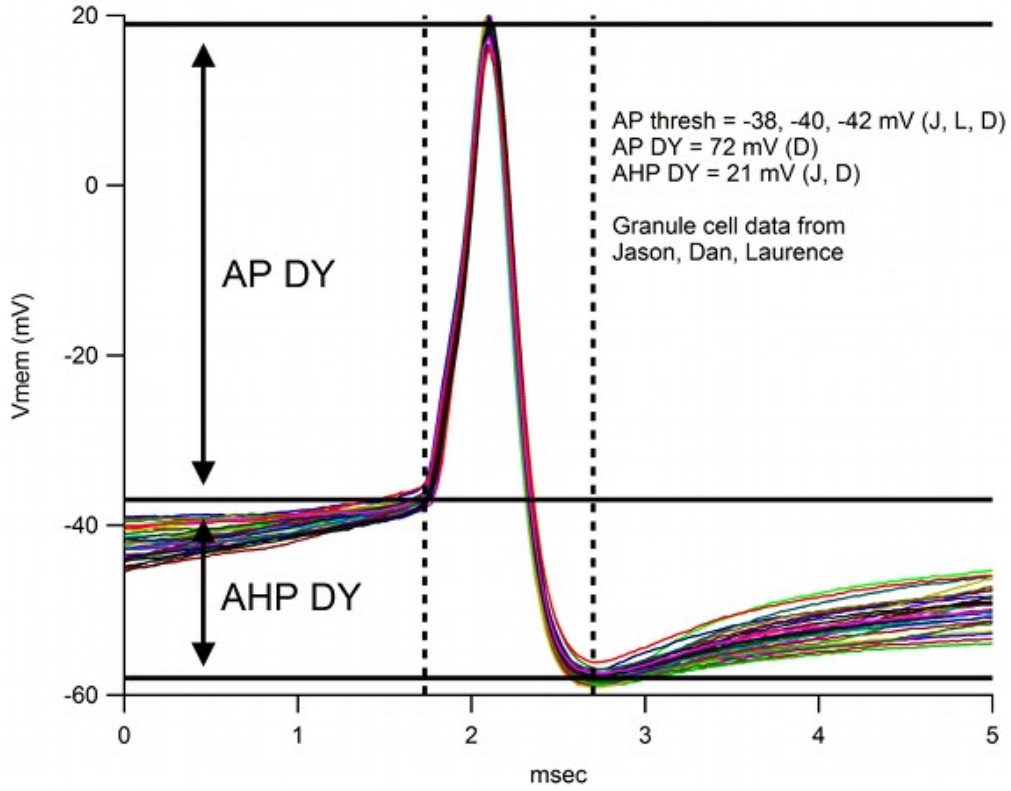
- ***What granule cell models are out there?***
- ***What electrophysiological properties do labs wish to reproduce in their models?***
- ***What experimental data is publicly available on the behaviour of the granule cell?***
- ***How well do existing models reproduce these behaviours?***

Silver lab

These figures are mainly based on data obtained by Jason Rothman for the paper: Synaptic depression enables neuronal gain control Nature 2009.

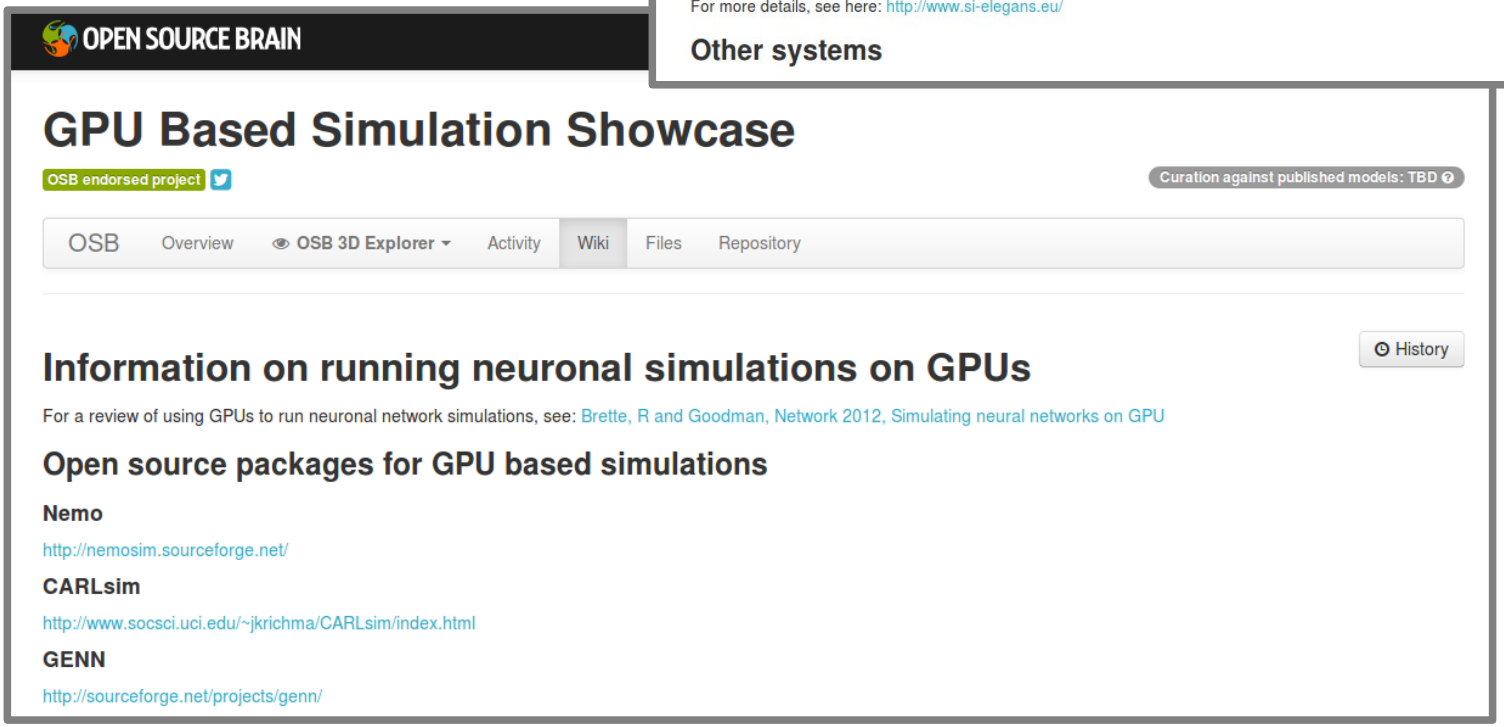
Species: **Sprague-Dawley rats**
Region: **Cerebellar vermis**
Method: **Whole-cell recordings (Note: an Axopatch 200B amplifier was used)**
Full methods here.

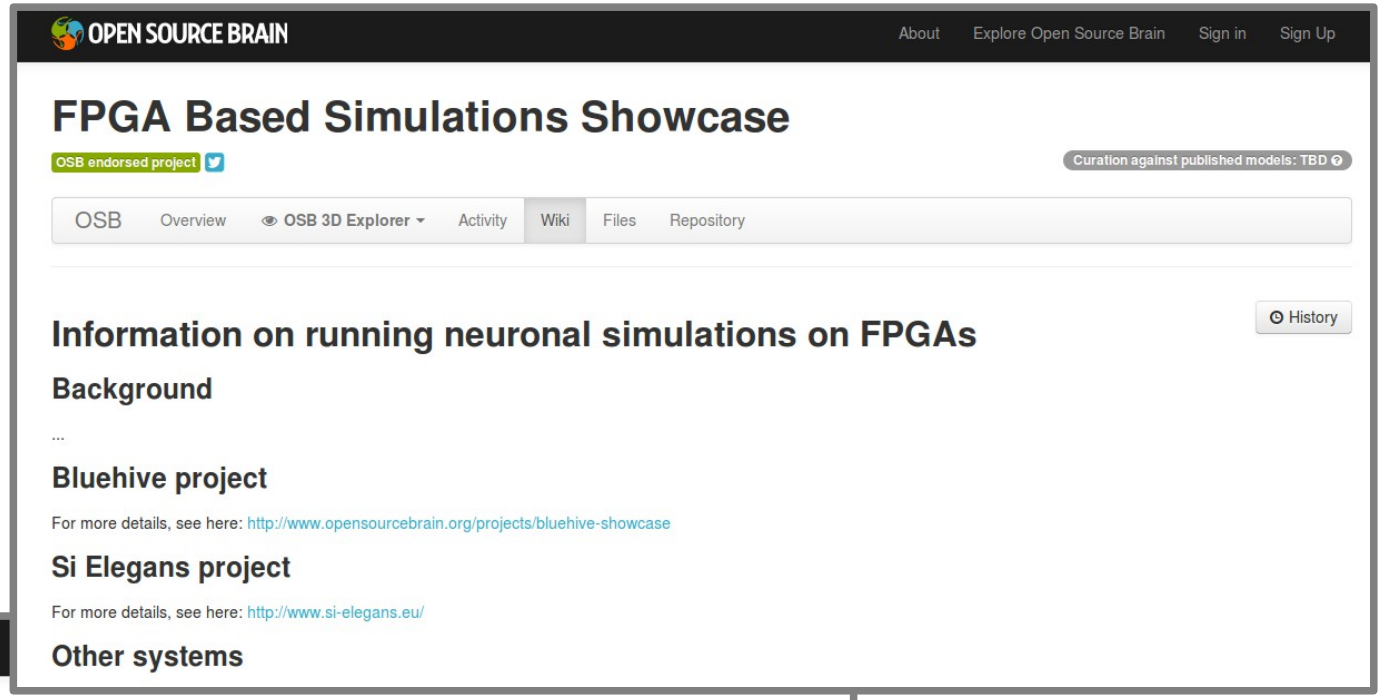
AP threshold: **-38mV to -42 mV**
AP height (from threshold to peak): **72 mV**
AHP depth (from threshold to AHP minimum) **21 mV**
Time of AP threshold to time of AHP minimum: **0.9 ms**



...

Publicly accessible data on granule cell behaviour





OPEN SOURCE BRAIN [NeuroML]

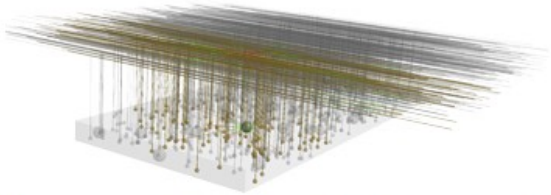
wellcome trust

Granule Cell Layer Maex and De Schutter 1998

OSB endorsed project

Curation against published models: Good ★★★

Description



An extension in 3D of the Granule Cell Layer model from: Maex, R and De Schutter, E. Synchronization of Golgi and Granule Cell Firing in a Detailed Network Model of the Cerebellar Granule Cell Layer J Neurophysiol, Nov 1998; 80: 2521 - 2537.

More...

Status

Stable implementation on NEURON and GENESIS

NeuroML v2.x support ★ | NeuroML v1.x support ★★★ | PyNN support

NEURON support ★★★ | GENESIS 2 support ★★★ | MOOSE support ★ | Brian support

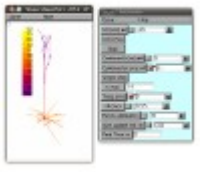
NeuroML

Standardised XML language for computational neuroscience

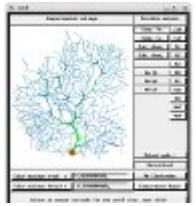
Version 1.x allowed specification of:

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

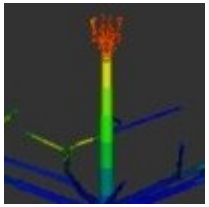
30+ simulators/applications/databases/libraries support NeuroML



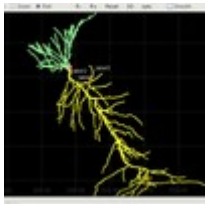
NEURON



GENESIS

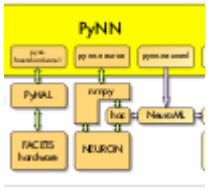


MOOSE



PSICS

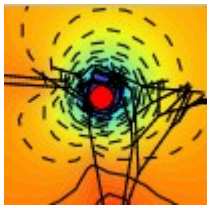
NeuroSpaces



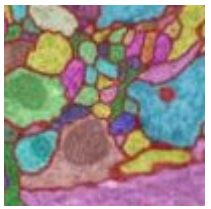
PyNN

neuroConstruct

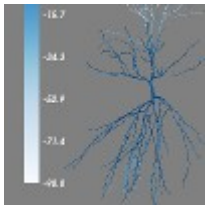
OpenWorm



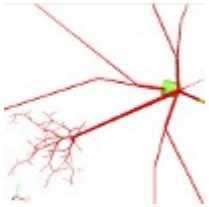
LFPy



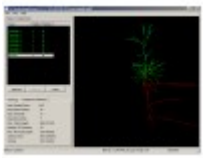
CATMAID



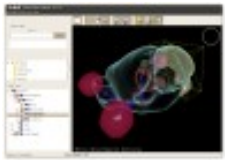
Neuronvisio



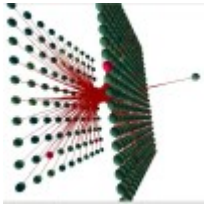
Moogli



NeuronLand

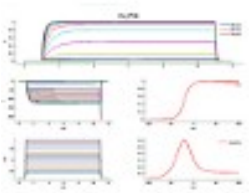


Whole Brain Catalog



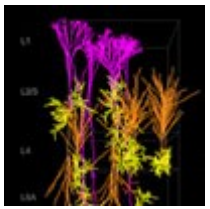
NeurAnim

NeuroMorpho

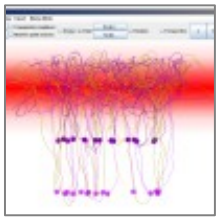


Channelpedia @ BlueBrainProject

TREES toolbox



NeuGen



CX3D

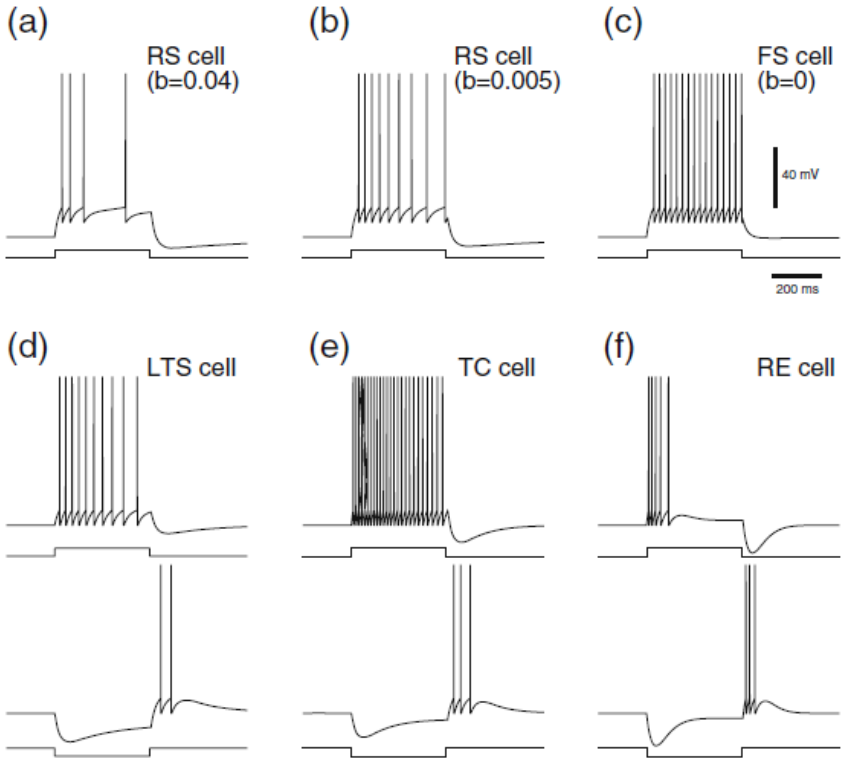
Brette & Gerstner Adaptive Exponential Integrate & Fire neuron model

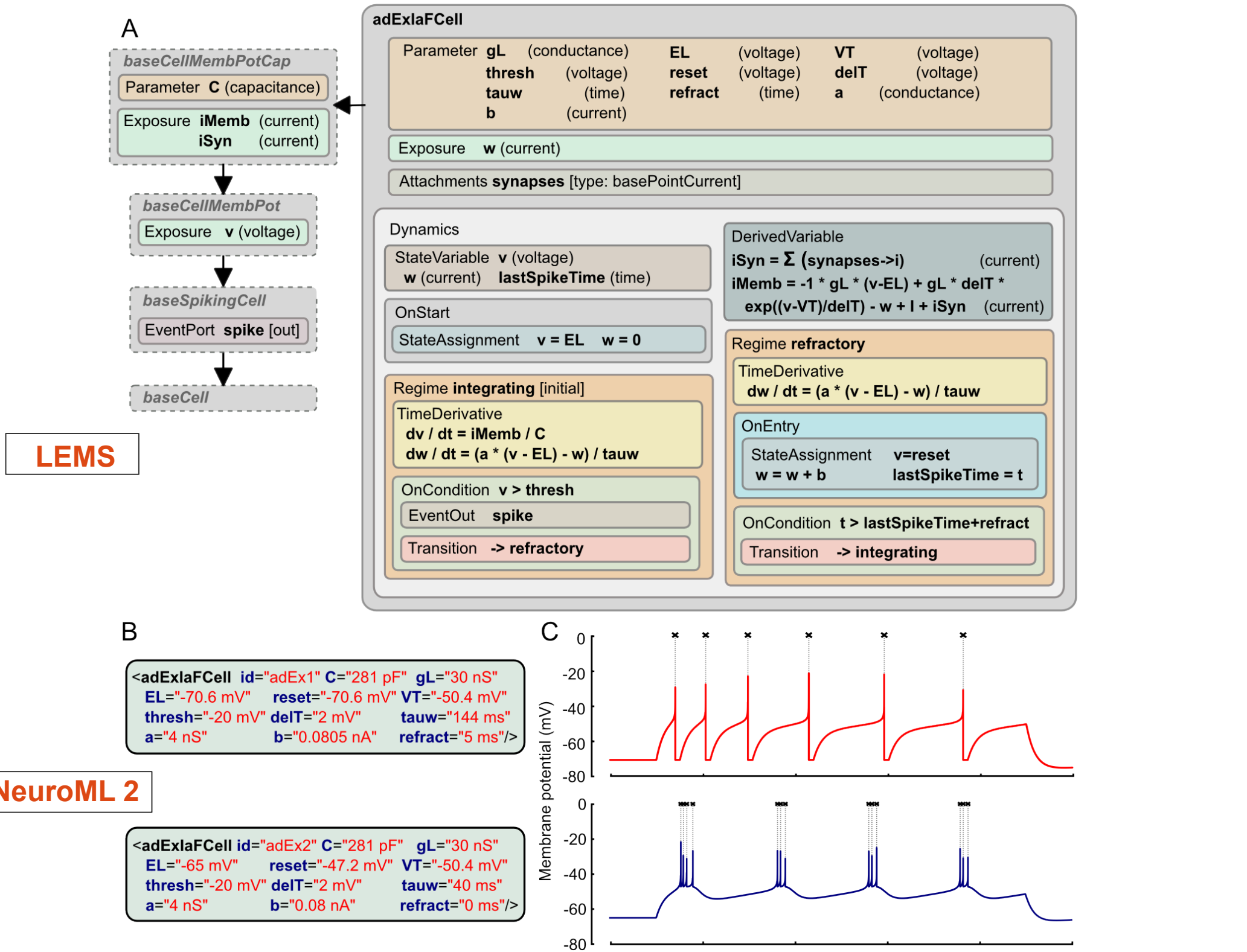
$$C\frac{dV}{dt} = -g_L(V - E_L) + g_L\Delta_T \exp\left(\frac{V - V_T}{\Delta_T}\right) - g_e(t)(V - E_e) - g_i(t)(V - E_i) - w$$

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

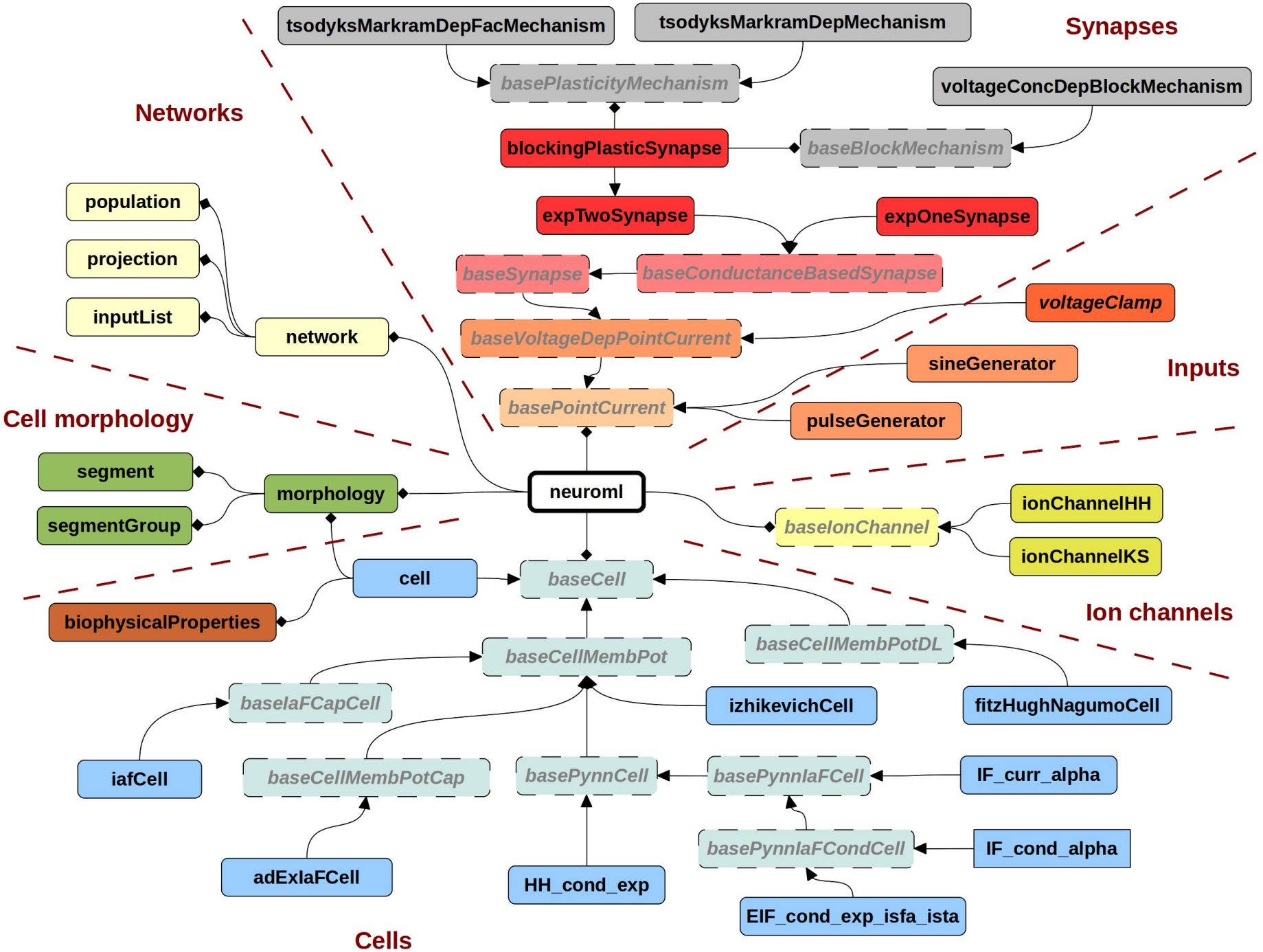
At spike time ($V > 20$ mV): $V \rightarrow EL$

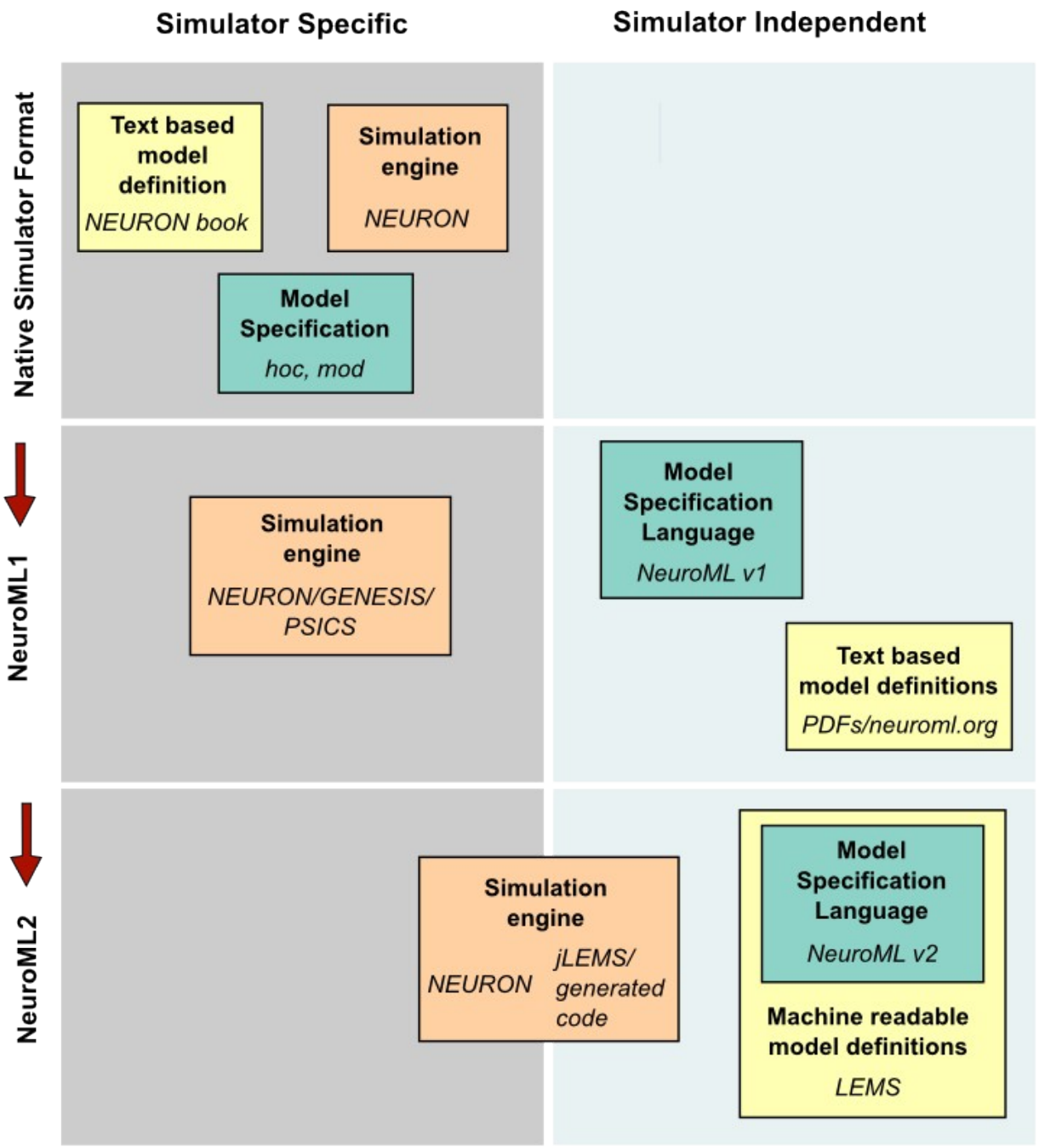
$w \rightarrow w + b$



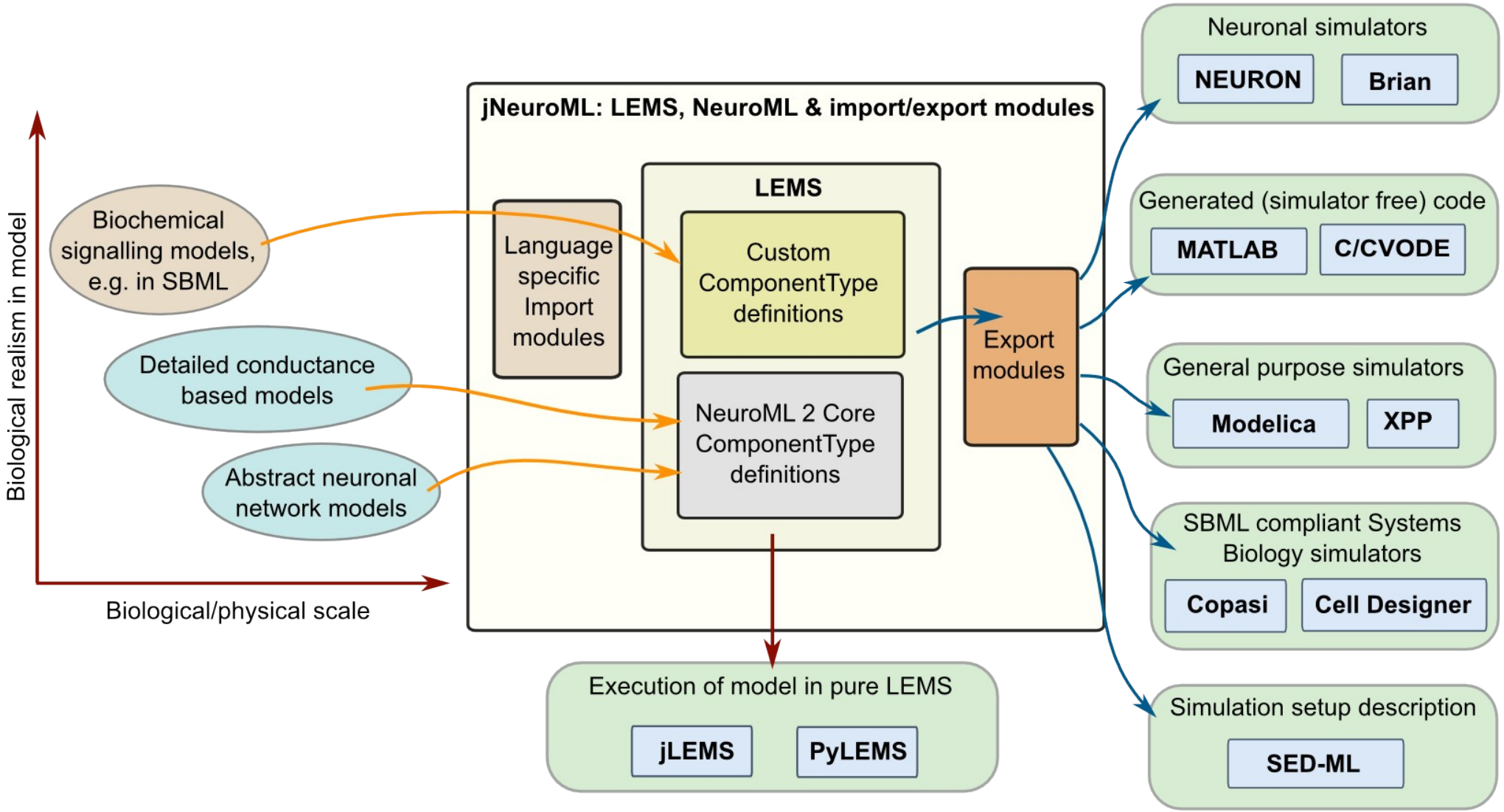

A
baseCellMembPotCap
Parameter C (capacitance)
Exposure iMemb (current)
iSyn (current)
baseCellMembPot
Exposure v (voltage)
baseSpikingCell
EventPort spike [out]
baseCell
LEMS
adExIaFCell
Parameter gL (conductance) EL (voltage) VT (voltage)
thresh (voltage) reset (voltage) delT (voltage)
tauw (time) refract (time) a (conductance)
b (current)
Exposure w (current)
Attachments synapses [type: basePointCurrent]
Dynamics
StateVariable v (voltage)
w (current) lastSpikeTime (time)
OnStart
StateAssignment v = EL w = 0
Regime integrating [initial]
TimeDerivative
dv / dt = iMemb / C
dw / dt = (a * (v - EL) - w) / tauw
OnCondition v > thresh
EventOut spike
Transition -> refractory
DerivedVariable
iSyn = Σ (synapses->i) (current)
iMemb = -1 * gL * (v-EL) + gL * delT *
exp((v-VT)/delT) - w + I + iSyn (current)
Regime refractory
TimeDerivative
dw / dt = (a * (v - EL) - w) / tauw
OnEntry
StateAssignment v=reset
w = w + b lastSpikeTime = t
OnCondition t > lastSpikeTime+refract
Transition -> integrating
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"/>
NeuroML 2
<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"/>
C
Membrane potential (mV)
0
-20
-40
-60
-80
0
-20
-40
-60
-80

NeuroML version 2.0



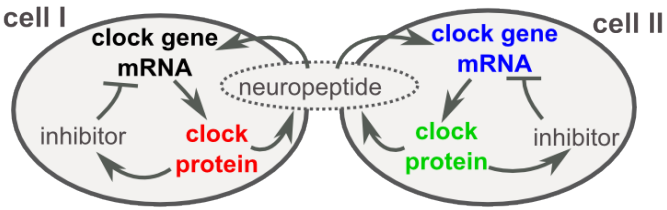

Simulator Specific
Simulator Independent
Native Simulator Format
Text based model definition
NEURON book
Simulation engine
NEURON
Model Specification
hoc, mod
NeuroML1
Simulation engine
NEURON/GENESIS/ PSICS
Model Specification Language
NeuroML v1
Text based model definitions
PDFs/neuroml.org
NeuroML2
Simulation engine
NEURON
jLEMS/ generated code
Model Specification Language
NeuroML v2
Machine readable model definitions
LEMS

Mapping NeuroML to other formats



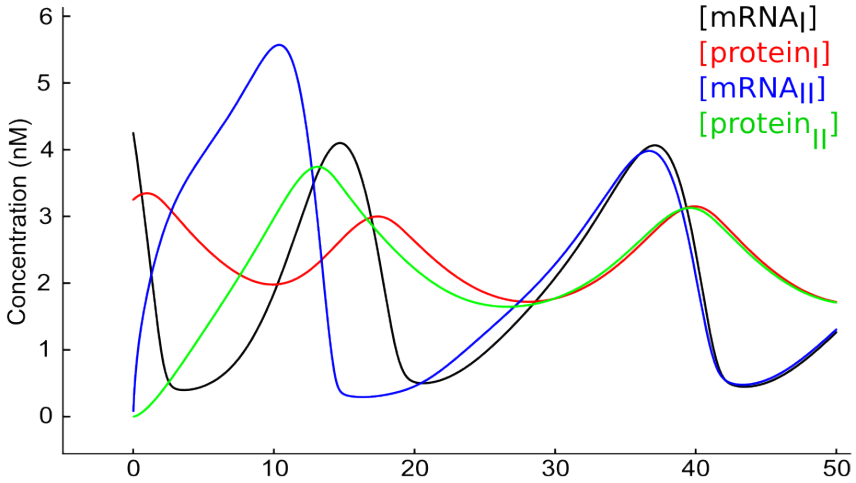
Original SBML model

A



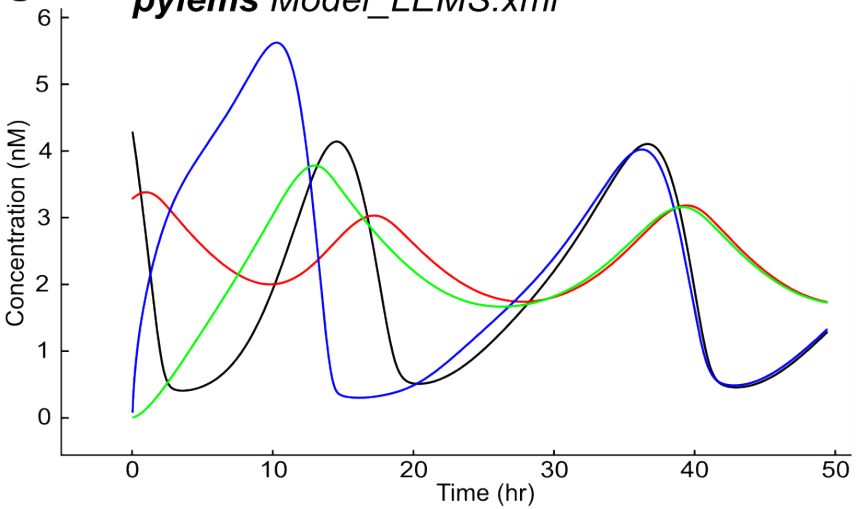
B *jnml* ***-sbml-import*** *Model.sbml 50 0.01*
jnml *Model_LEMS.xml*

jLEMS

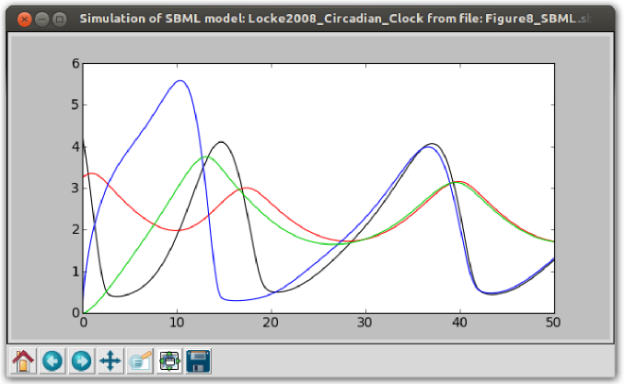


C ***pylems*** *Model_LEMS.xml*

PyLEMS

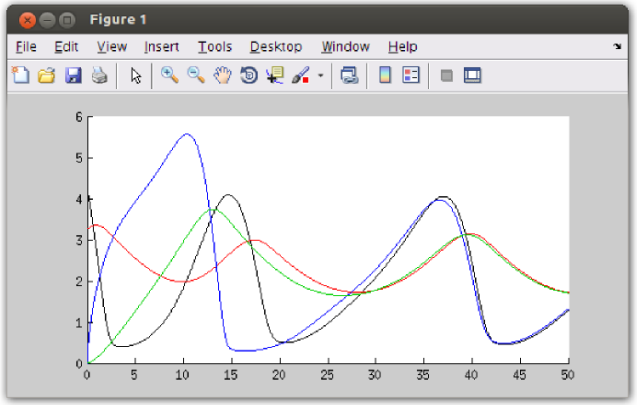


D *jnml Model_LEMS.xml* ***-brian***



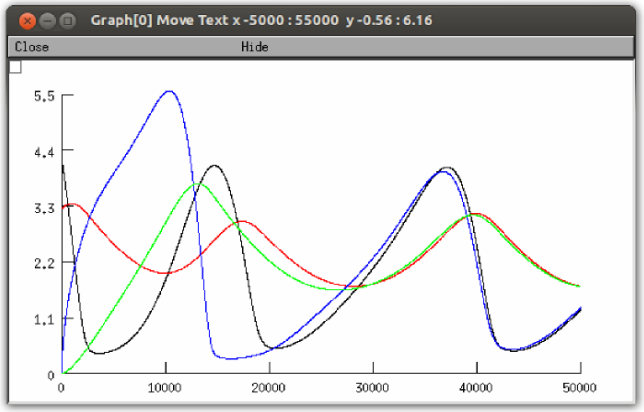
Brian

E *jnml Model_LEMS.xml* ***-matlab***



MATLAB

F *jnml Model_LEMS.xml* ***-neuron***



NEURON

OPEN SOURCE BRAIN [NeuroML]

wellcome trust

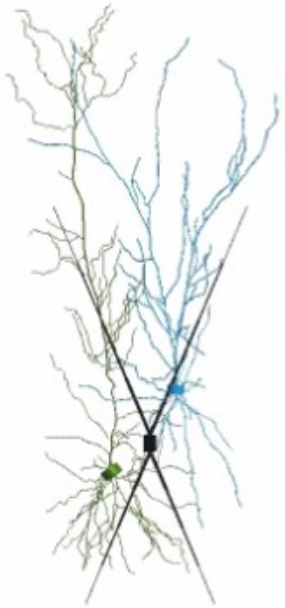
	Curation	NeuroML v1.x	NeuroML v2.x	PyNN	NEURON	GENESIS 2	MOOSE	PSICS	NEST	Brian	OSB Model Validation
OSB l5bpyrcellhayetal2011	★★	★★	★★		★★	★	★				build passing
OSB pospischiletal2008	★	★★	★	?	★★	★	★	?	?	?	
OSB muscle_model	★★		★★								build passing
OSB ca1pyramidalcell	★★	★★★	★		★★★	★★★	★★★	★★★			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	★		★★		★★					★★	

CA1 Pyramidal Sublayer Microcircuit Lee et al 2014

OSB endorsed project

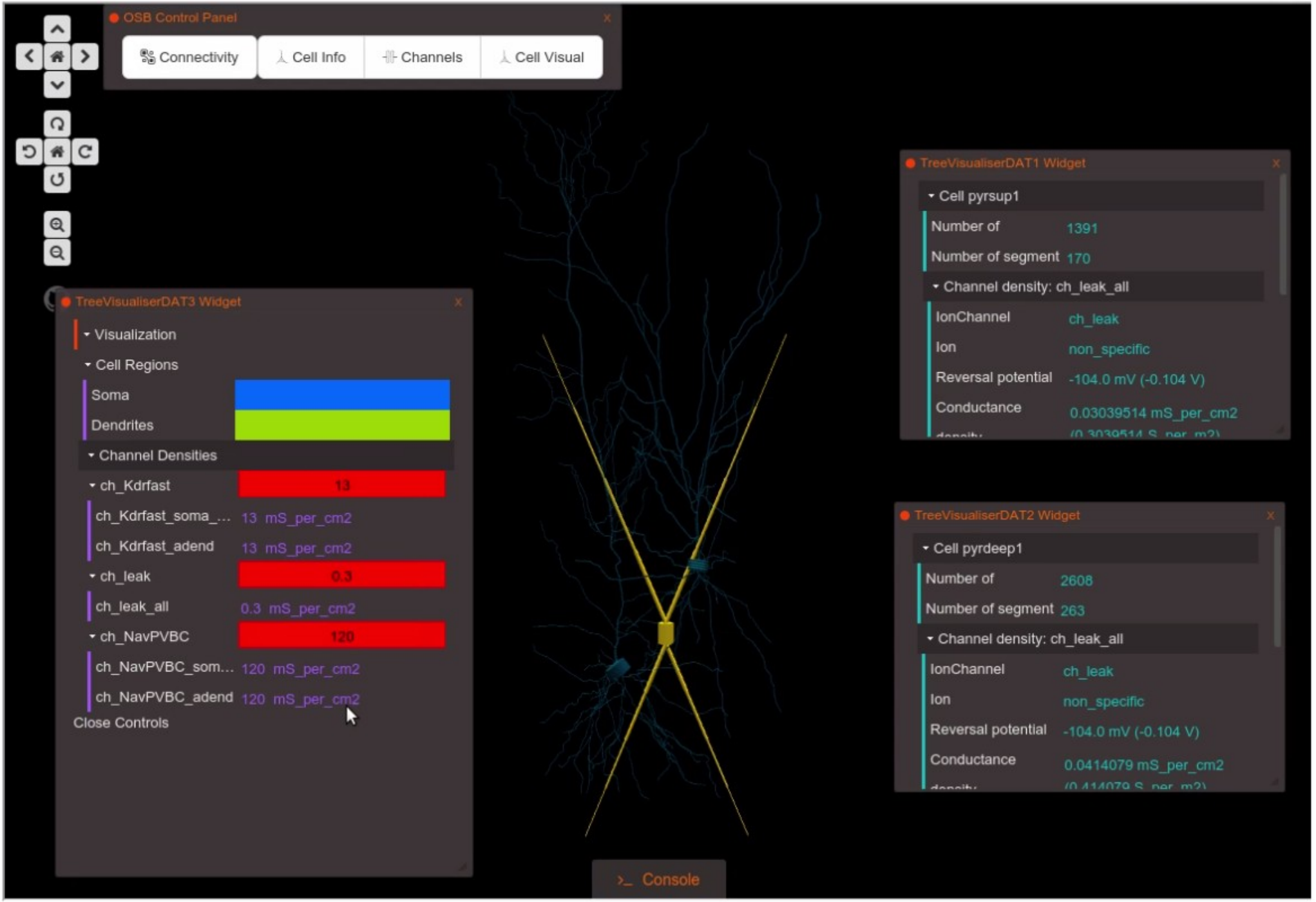
Curation against published models: Low

Description

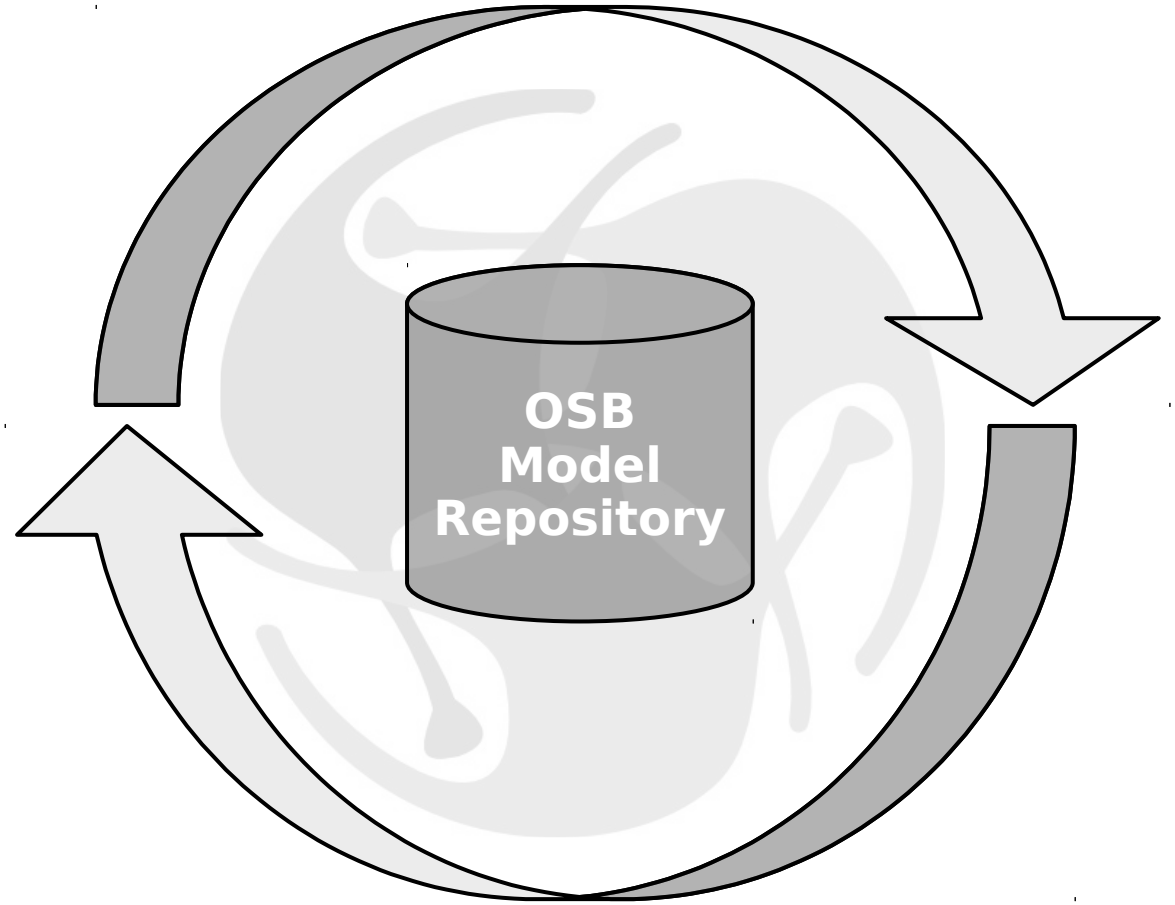


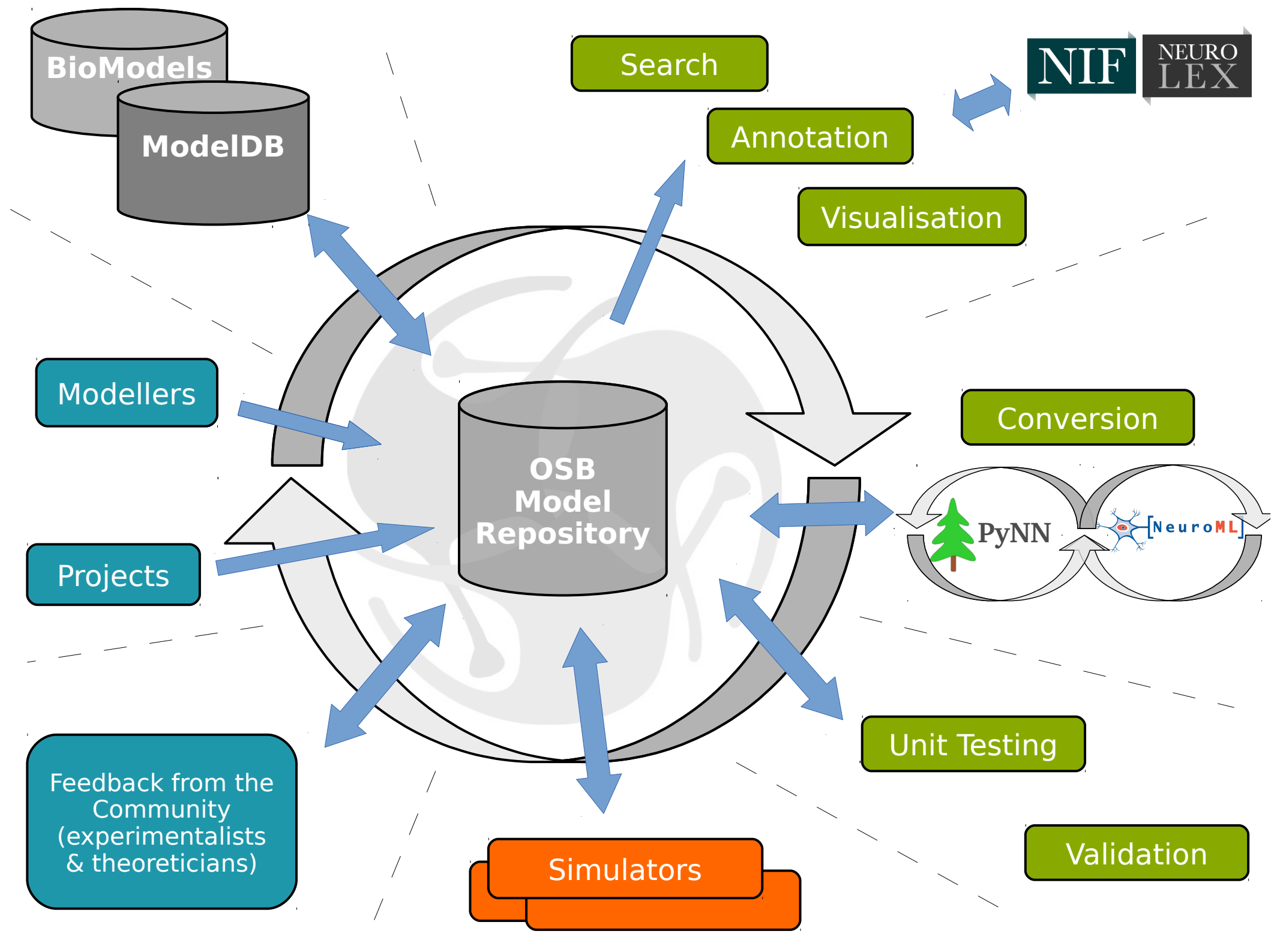
This model examines the interactions between the pyramidal cells of the superficial and deep layers of CA1. It is featured in: Lee et al., 2014. Specifically, this model shows how the experimentally observed differences in synapse strength and number between PV+ basket cells and either superficial and deep pyramidal cells could have significant effects at the network level


OSB Control Panel
Connectivity
Cell Info
Channels
Cell Visual
>_ Console


OSB Control Panel
Connectivity
Cell Info
Channels
Cell Visual
TreeVisualiserDAT3 Widget
Visualization
Cell Regions
Soma
Dendrites
Channel Densities
ch_Kdrfast 13
ch_Kdrfast_soma_... 13 mS_per_cm2
ch_Kdrfast_adend 13 mS_per_cm2
ch_leak 0.3
ch_leak_all 0.3 mS_per_cm2
ch_NavPVBC 120
ch_NavPVBC_som... 120 mS_per_cm2
ch_NavPVBC_adend 120 mS_per_cm2
Close Controls
TreeVisualiserDAT1 Widget
Cell pyrsup1
Number of 1391
Number of segment 170
Channel density: ch_leak_all
IonChannel ch_leak
Ion non_specific
Reversal potential -104.0 mV (-0.104 V)
Conductance 0.03039514 mS_per_cm2
TreeVisualiserDAT2 Widget
Cell pyrdeep1
Number of 2608
Number of segment 263
Channel density: ch_leak_all
IonChannel ch_leak
Ion non_specific
Reversal potential -104.0 mV (-0.104 V)
Conductance 0.0414079 mS_per_cm2
Console

Collaborative development




BioModels
ModelDB
Search
Annotation
Visualisation
NIF
NEURO LEX
Modellers
Projects
OSB Model Repository
Conversion
PyNN
NeuroML
Unit Testing
Validation
Simulators
Feedback from the Community (experimentalists & theoreticians)

How can we make computational neuroscience more scientific?

Reproducibility

Accessibility

Portability

Transparency

Help

Contribute to OSB

Want to contribute to Open Source Brain?

There is a central repository for issues listing OSB projects looking for contributors. A number of other programming tasks (e.g. further development of NeuroML based tools) are also listed, which would be of benefit to OSB projects.

See https://github.com/OpenSourceBrain/Contribute/issues for the current issues/project suggestions.

A template for new issues/project suggestions can be found here.

This is also a place for **labs who have a specific, well defined model building/conversion project** (or tool development task), related to the aims of Open Source Brain, to advertise the project with the understanding that they would be willing to help the developer complete the task, and that the model/code will be open to all.

OpenSourceBrain / Contribute

Issues | Pull requests | Labels | Milestones

Filters | is:issue is:open | New Issue

7 Open ✔ 0 Closed — Author | Labels | Milestones | Assignee | Sort

- **Core set of (multicompartmental) cell models in NeuroML2 for use in detailed model of cerebellar cortex** — Comp neuro experience, Difficulty: Hard, Duration: >3 months
  #7 opened 19 days ago by pgleeson
- **Convert more single compartment cell models of Pospischil et al. 2008** — Comp neuro experience, Difficulty: Medium, Duration: 1 month
  #6 opened 21 days ago by pgleeson
- **Improve SVG/PNG export for detailed morphologies in NeuroML2** — Difficulty: Easy, Duration: 1 week, Java
  #5 opened 21 days ago by pgleeson 0 of 5
- **Improve jLEMS GUI interface** — Difficulty: Easy, Duration: 1 week, Java
  #4 opened 21 days ago by pgleeson
- **Introductory guide to modelling in computational neuroscience** — Comp neuro experience, Difficulty: Medium, Duration: 1 week
  #3 opened on 23 Feb by pgleeson
- **Update reduced CA3 model of Pinsky and Rinzel 1994** — Comp neuro experience, Difficulty: Easy, Duration: 1 week
  #2 opened on 26 Jan by pgleeson
- **Convert Drosophila motoneuron model to NeuroML2** — Comp neuro experience, Difficulty: Medium, Duration: 1 week — 1
  #1 opened on 11 Dec 2014 by pgleeson

ProTip! Adding no:label will show everything without a label.

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Egidio D'Angelo
Volker Steuber
Dieter Jaeger
Andrew Davison
Stephen Larson
Avrama Blackwell
Nicolas Le Novere

Members of the NeuroML community

OpenWorm project

UK INCF Node

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