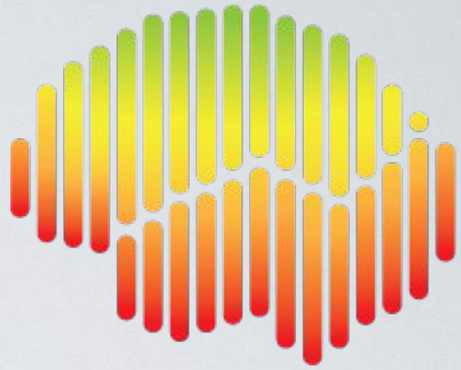


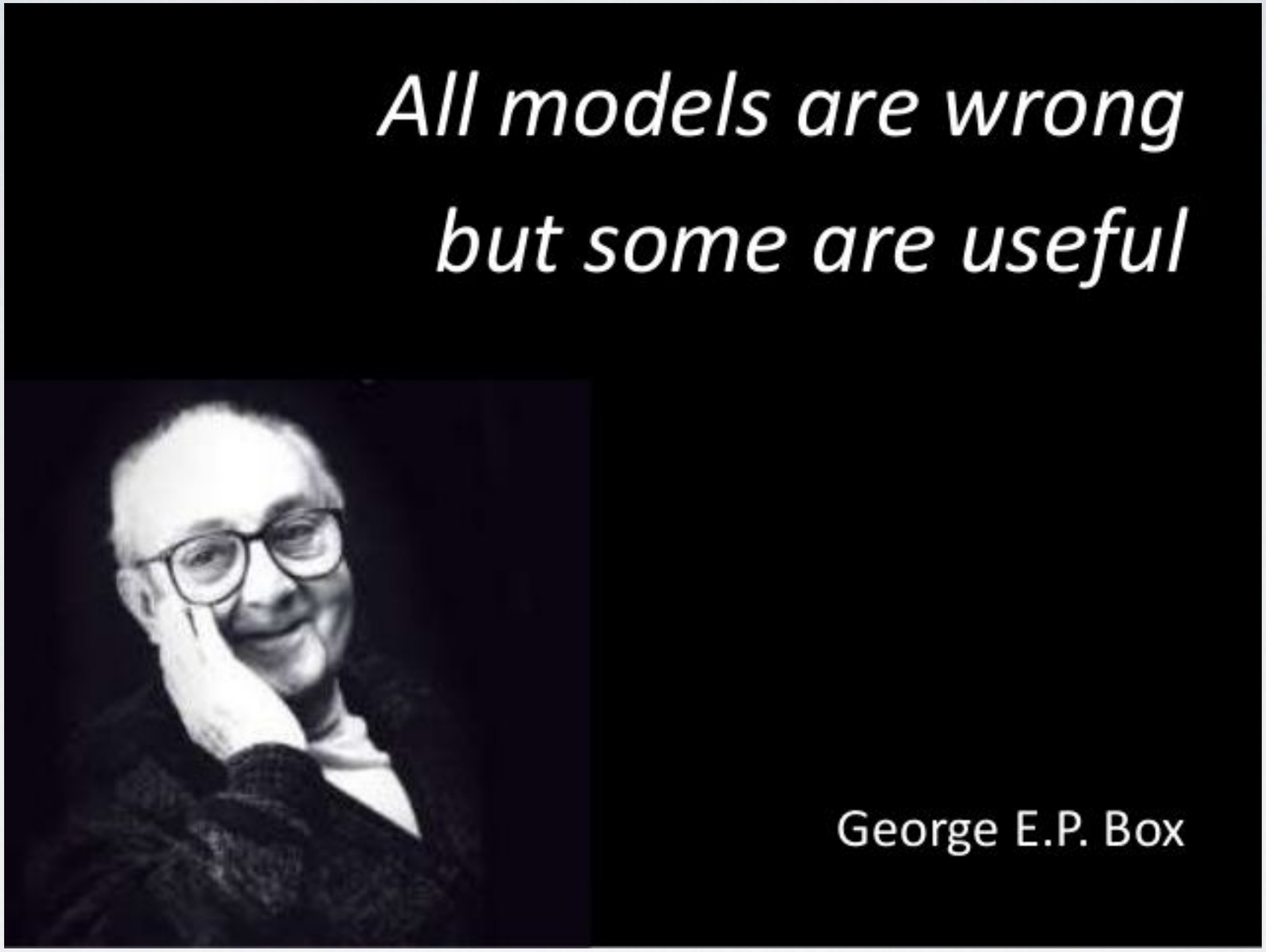
COMPUTER MODELS IN NEUROSCIENCE: ARE THEY ANY GOOD?

Richard C. (Rick) Gerkin, PhD

Laboratory for Informatics and Computation in Open Neuroscience

ASU

Arizona State University



But which ones?

$$\begin{cases} \frac{dV_m}{dt} = \frac{I}{C_m} - \frac{\bar{g}_K n^4}{C_m}(V_m - V_K) - \frac{\bar{g}_{Na} m^3 h}{C_m}(V_m - V_{Na}) - \frac{\bar{g}_l}{C_m}(V_m - V_l) \\ \frac{dn}{dt} = \alpha_n(V_m)(1-n) - \beta_n(V_m)n \\ \frac{dm}{dt} = \alpha_m(V_m)(1-m) - \beta_m(V_m)m \\ \frac{dh}{dt} = \alpha_h(V_m)(1-h) - \beta_h(V_m)h \end{cases}$$

Biophysically-detailed Models

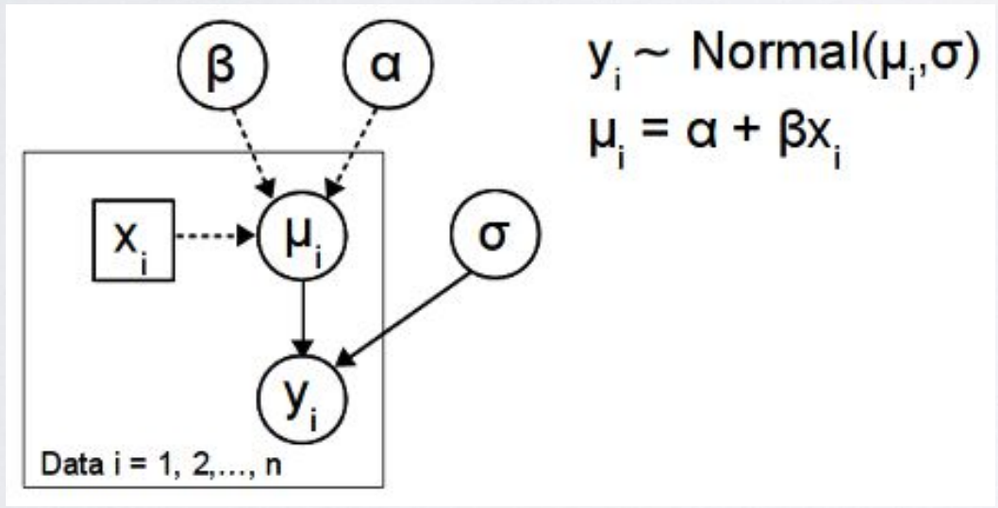
$$C\frac{dV}{dt} = -g_L(V - E_L) + g_L\Delta_T \exp\left(\frac{V - V_T}{\Delta_T}\right) - g_e(t)(V - E_e) - g_i(t)(V - E_i) - w$$

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

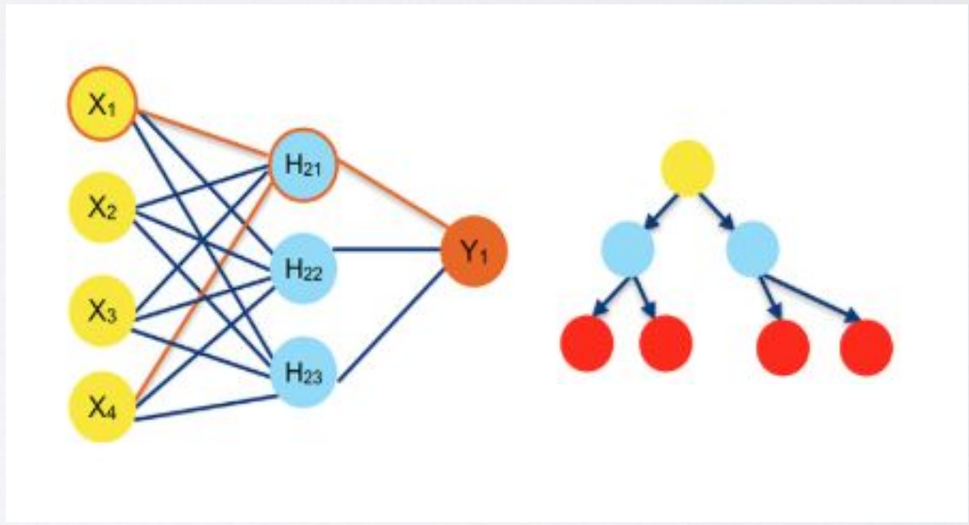
At spike time ($V > 20$ mV): $V \rightarrow EL$

$w \rightarrow w + b$

Reduced Models

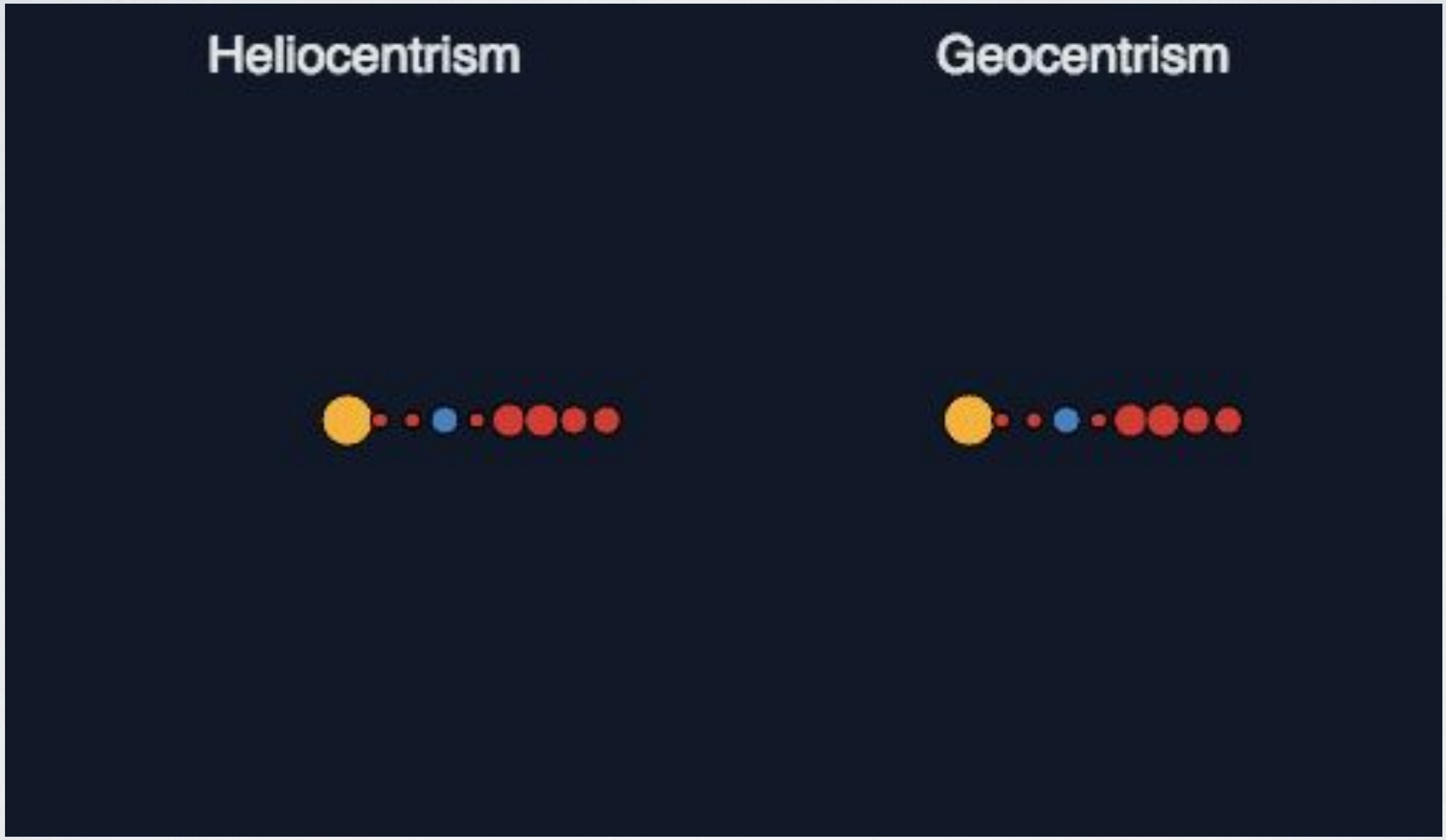


Statistical Models



Machine Learning Models

EXAMPLE: A brief history of cosmology



EXAMPLE: A brief history of cosmology

Experimentalists

Modelers

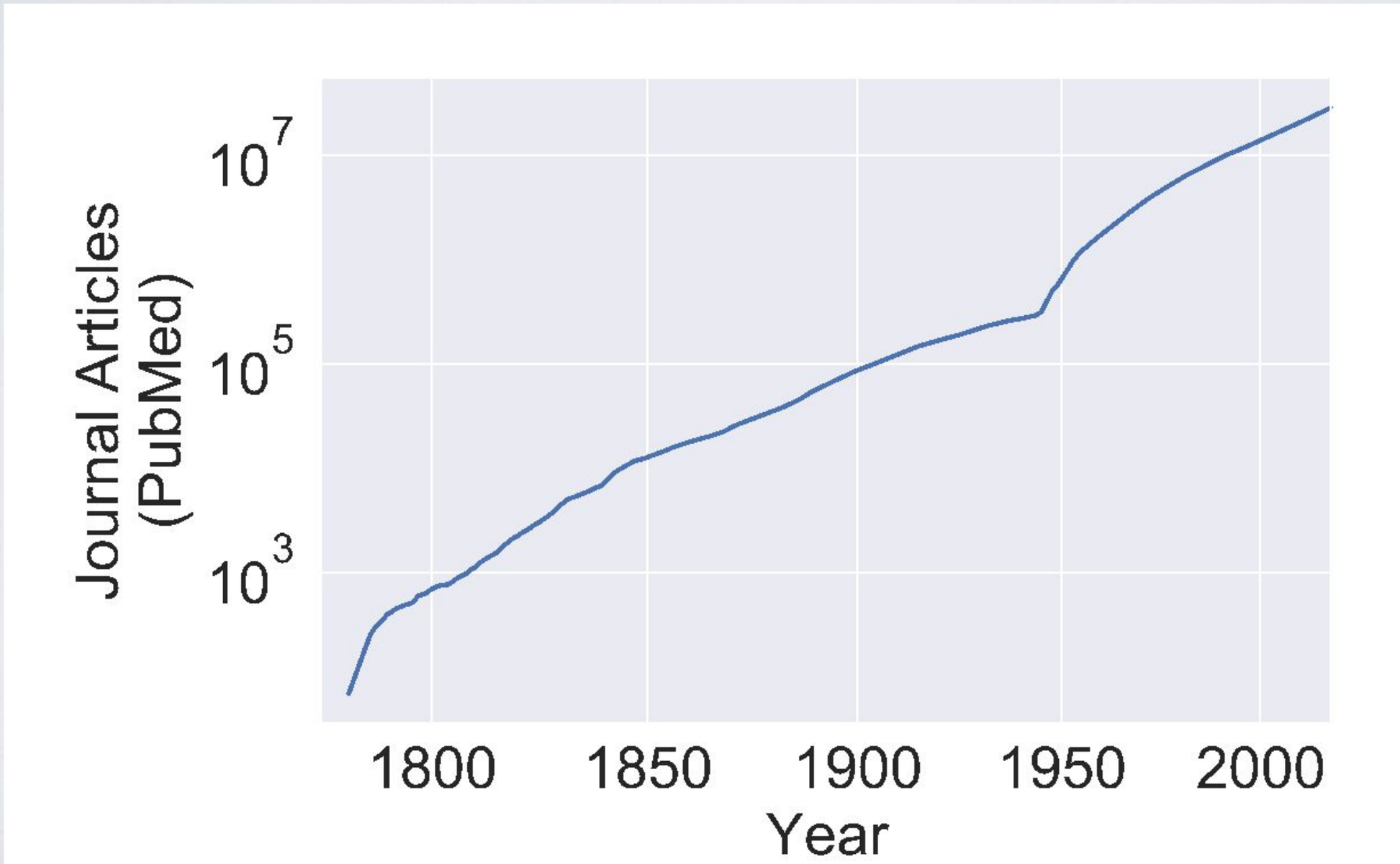
	Babylonians	Brahe	Galileo	Le Verrier
Ptolemy				
Copernicus				
Kepler				
Newton				
Einstein				

Pass Fail Unclear

nature
International journal of science

Bornmann and Muntz, 2014
https://www.ncbi.nlm.nih.gov/pubmed/

Global scientific output doubles every nine years



How can we:

1) evaluate models against *all* relevant data?
2) do it automatically?
3) do it publicly and transparently?

SciDash

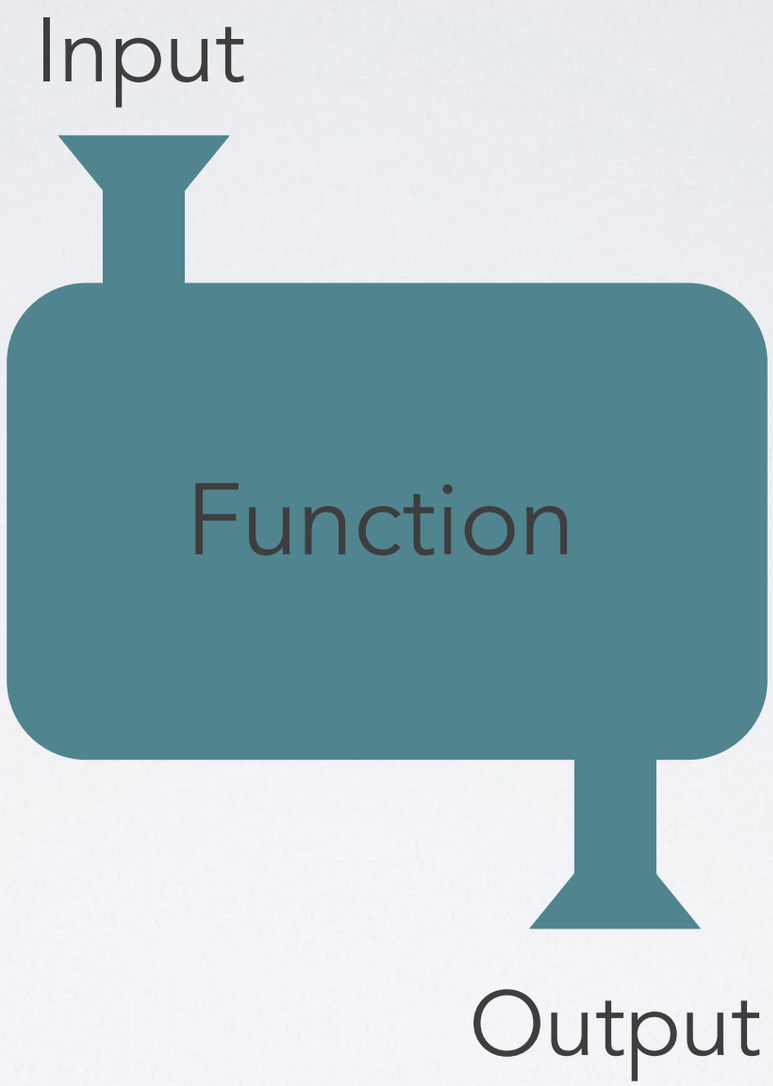
Collections of empirically-informed unit tests.

Evaluate models according to which tests they pass.

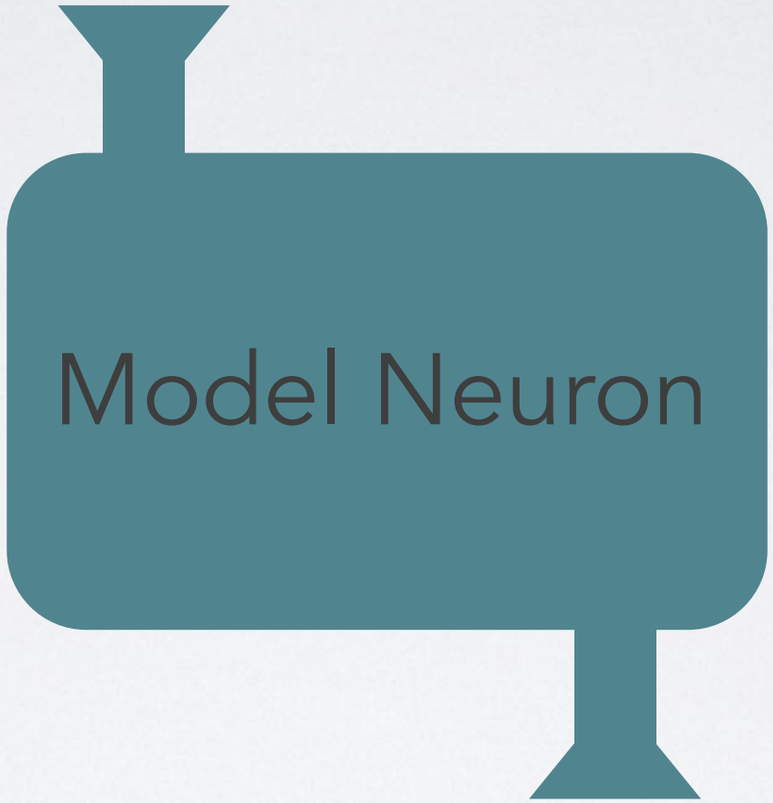
What is a UNIT TEST?

"… a strict, written contract that the piece of code must satisfy."

http://en.wikipedia.org/wiki/unit_testing


Input
Function
Output

Input during Simulation Experiment

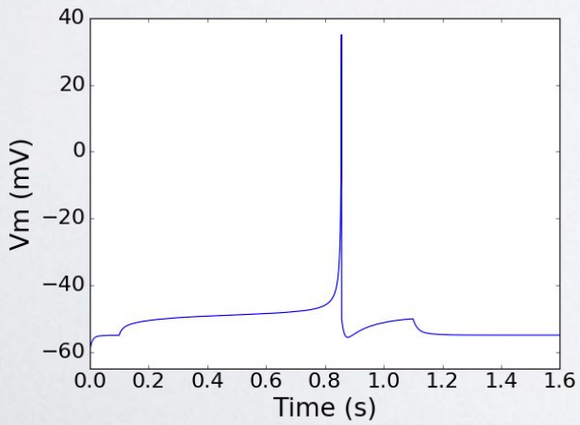


Predicted Observations from Simulated Output

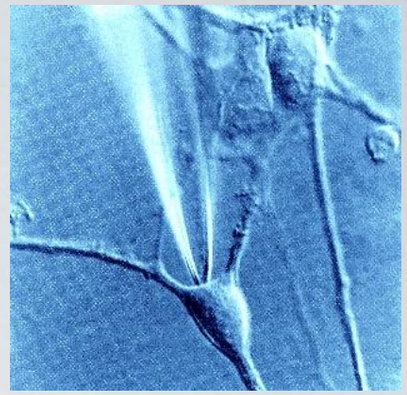
Input: 100 pA current injected to soma for 800 msec

MODEL

cortical pyramidal cell



Output: predicted membrane potential waveform



100 pA current injected
to soma for 800 msec

MODEL
cortical pyramidal cell

100 pA current injected
to soma for 800 msec

REAL
cortical pyramidal cell

predicted membrane
potential waveform

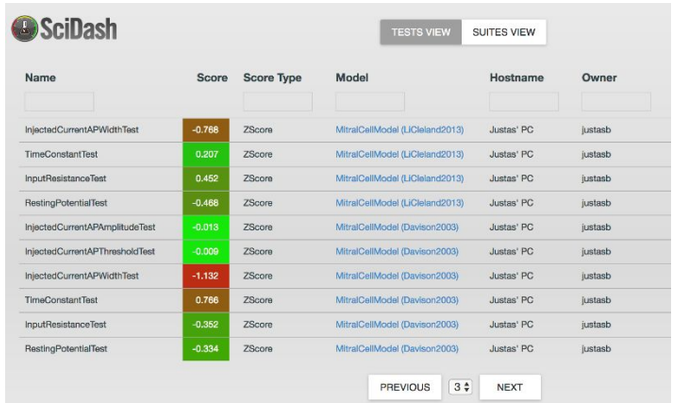
?

recorded membrane
potential waveform

SciDash

SciUnit, a Pythonic framework for data-driven unit testing that separates the interface from the implementation, respecting the diversity of conventions for modeling and data collection.

NeuronUnit, an extensible SciUnit-driven library for the testing of neuron, neural circuit, and ion channel models using common simulators against multiple data sources.



A SciDash portal to identify test repositories on GitHub, make it easy to locate them, execute suites of unit tests locally or in the cloud, and visualize results online with rich markup.

SciDash

Interoperable: Repositories of unit tests.

Rigorous: Evaluate models based on tests they pass.

Transparent: Share model evaluations on the web.

Reproducible: Models/data/tests are linked and public.

Experiment Data Discovery

Experiment Data Format

Experiment Data Analysis

Data Summary

Test Instantiation

Test Adjudication

Test Score Visualization

Model Discovery

Model Description

Model Capabilities

Simulation Description

Model Interpreter

Model Execution

Model Output Format

Model Output Analysis

Associated Resources & Standards

Experiment Data Discovery CRCNS.org		**Model Discovery** Open Source Brain / NeuroML-DB
Experiment Data Format Neurodata Without Borders		**Model Description** NeuroML
Experiment Data Analysis NEO / ElePhanT		**Model Capabilities** PyNN / Comp. Neuro. Ontology
Data Summary NeuroElectro / Allen Cell Types		**Simulation Description** SED-ML
Test Instantiation NeuronUnit		**Model Interpreter** jNeuroML
Test Adjudication NumPy / SciPy		**Model Execution** NEURON
Test Score Visualization SciDash	**Model Output Analysis** NEO / ElePhanT	**Model Output Format** NWB / Sonata

[NeuroML] Database

Visual Cortex Layer 2/3 Pyramidal Cell (Stimulated) Network

Model Type: Network

Neurolex IDs: Neocortex primary visual area pyramidal layer 2-3 cell

Keywords: Mouse

Publication: Smith, et. al. (2013) Dendritic spikes enhance stimulus selectivity in cortical neurons in vivo.

Authors: Spencer L Smith Ikuko T Smith Tiago Branco Michael Häusser

Translators: Michael Hausser Tiago Branco

Sources:

View OpenSourceBrain Model View GitHub Model

View OpenSourceBrain on SciCrunch View GitHub on SciCrunch

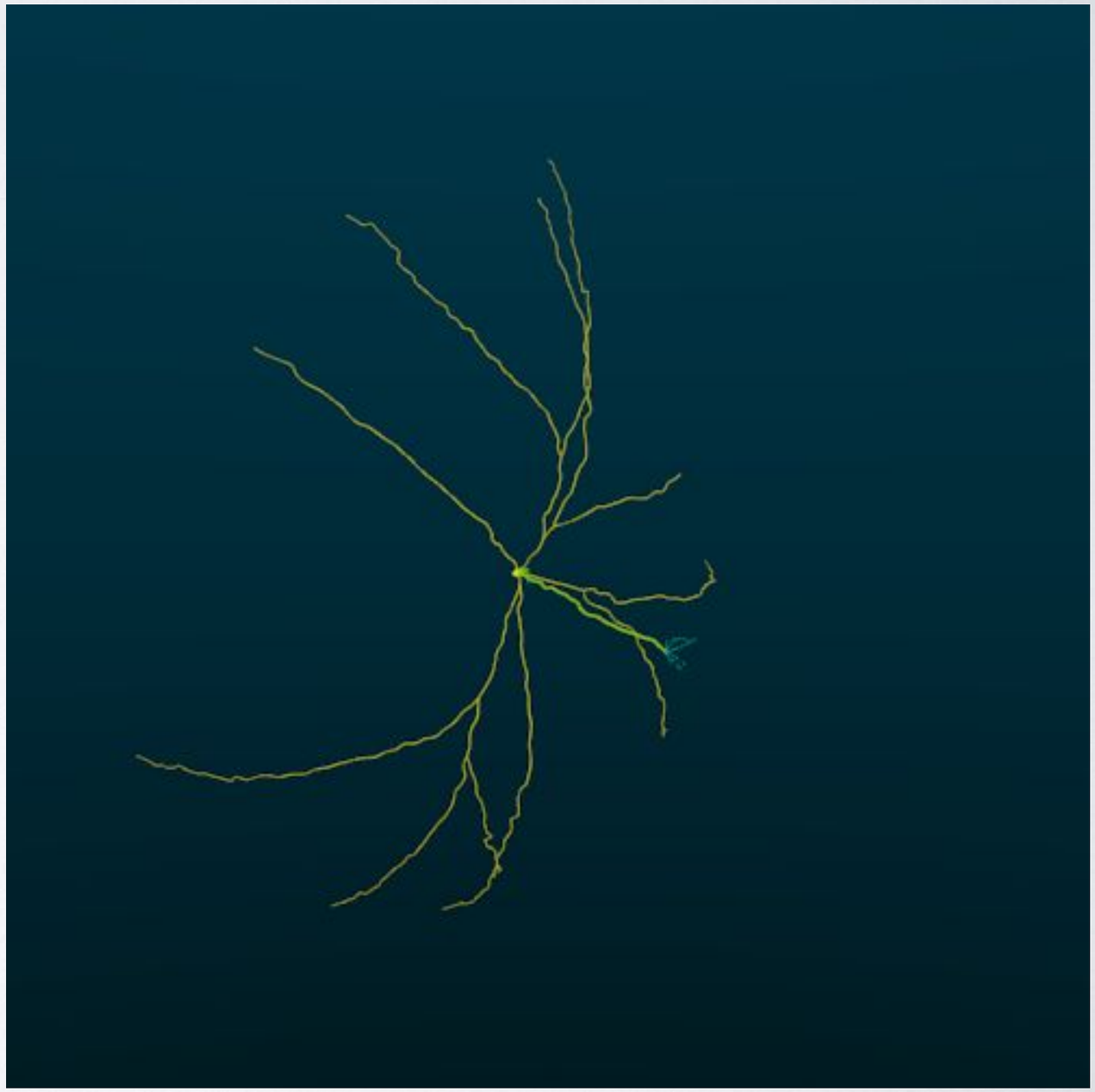
Files:

Download NeuroML Version

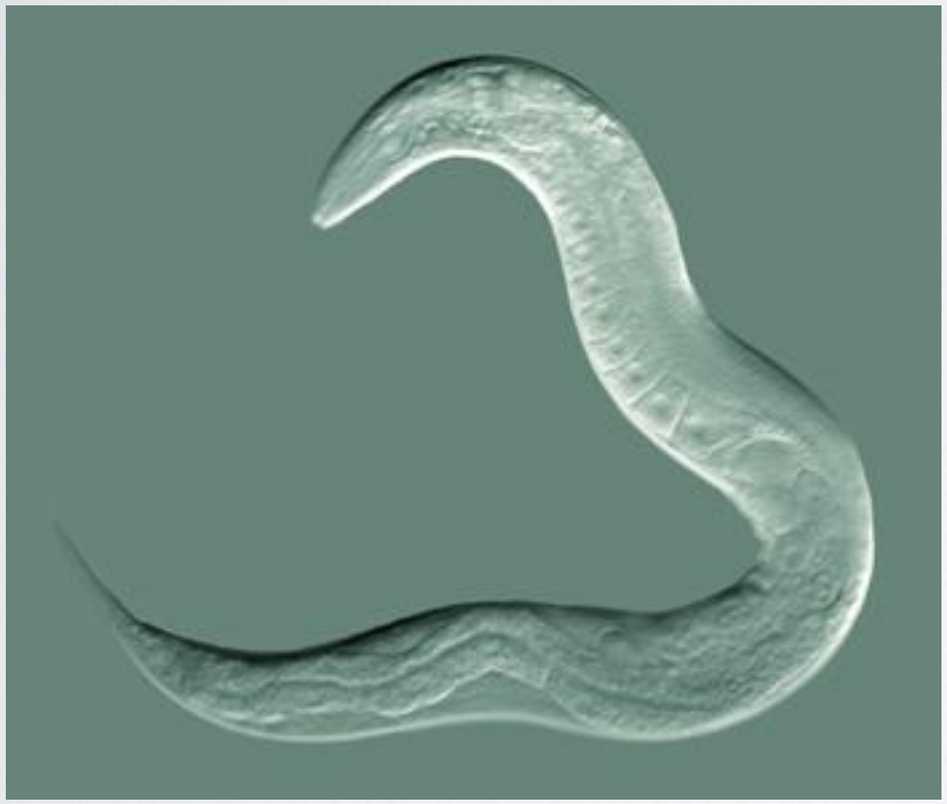
Model ID	NeuroML File	
NMLNT001592	L23_Stim.net.nml	(view NeuroML)
NMLCL001594	L23_NoHotSpot.cell.nml	(view NeuroML)
NMLCH001591	ca.channel.nml	(view NeuroML)

[NeuroML] Database

L-Measure Metric	Value
Soma Surface	14744.5 μm^2
Number of Stems	6.0
Number of Bifurcations	15.0
Number of Branches	34.0
Overall Width	1195.43 µm
Overall Height	1618.8 µm
Overall Depth	738.53 µm
Average Diameter	2.71858 µm
Total Length	9804.39 µm



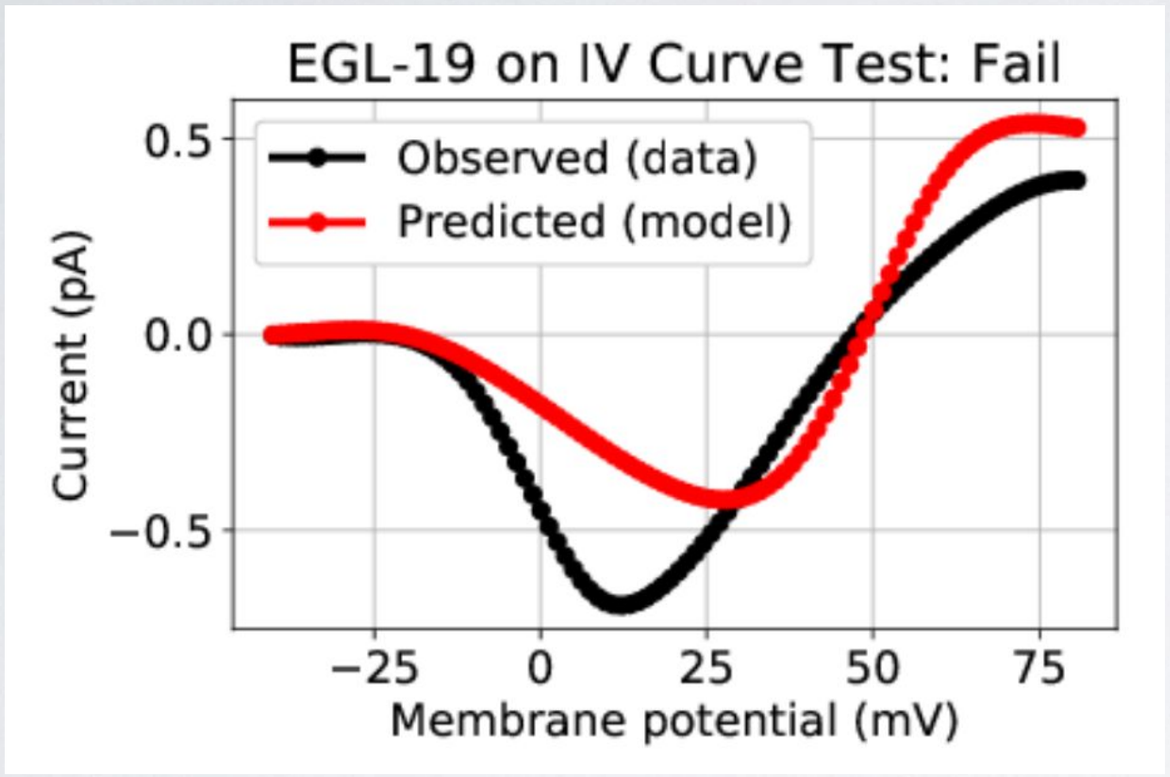
APPLICATION: Simulation of *C. elegans*



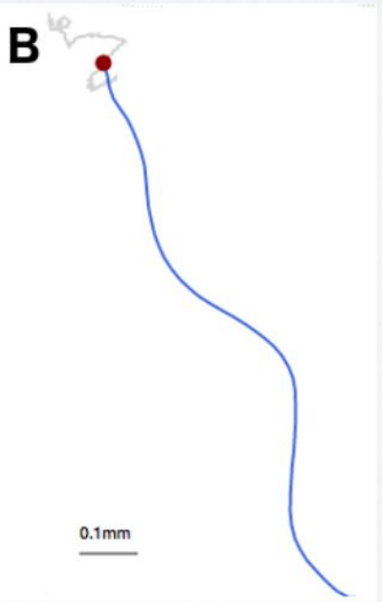
https://en.wikipedia.org/wiki/Caenorhabditis_elegans

https://openworm.org

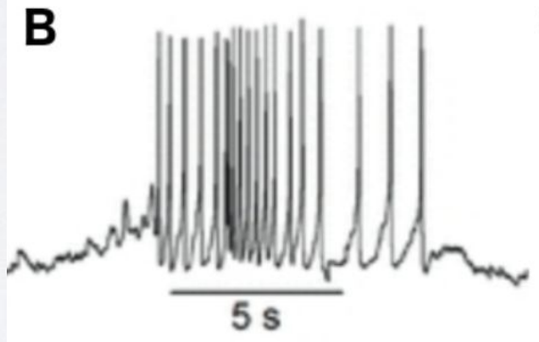
APPLICATION: Simulation of *C. elegans*

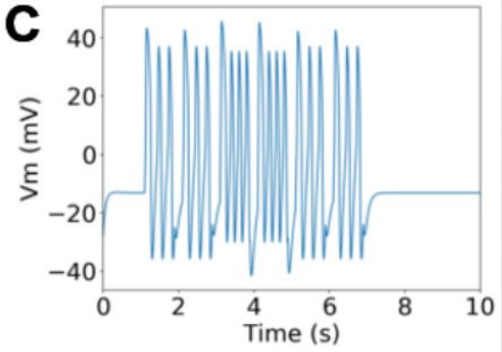


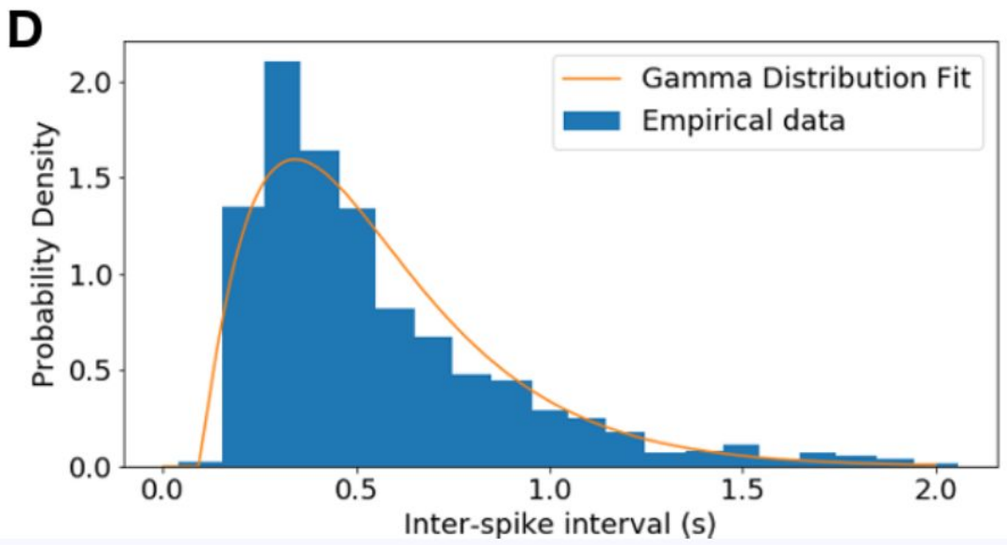
A	sibernetic_c302_short
lengthTest	Z = -0.03
backward_frequencyTest	Insufficient Data
head_tip_speed_absTest	Z = 1.88
max_amplitudeTest	Z = -0.60
midbody_speed_absTest	Z = 0.68
midbody_bend_mean_absTest	Z = 0.48
paused_frequencyTest	Insufficient Data
forward_frequencyTest	Insufficient Data



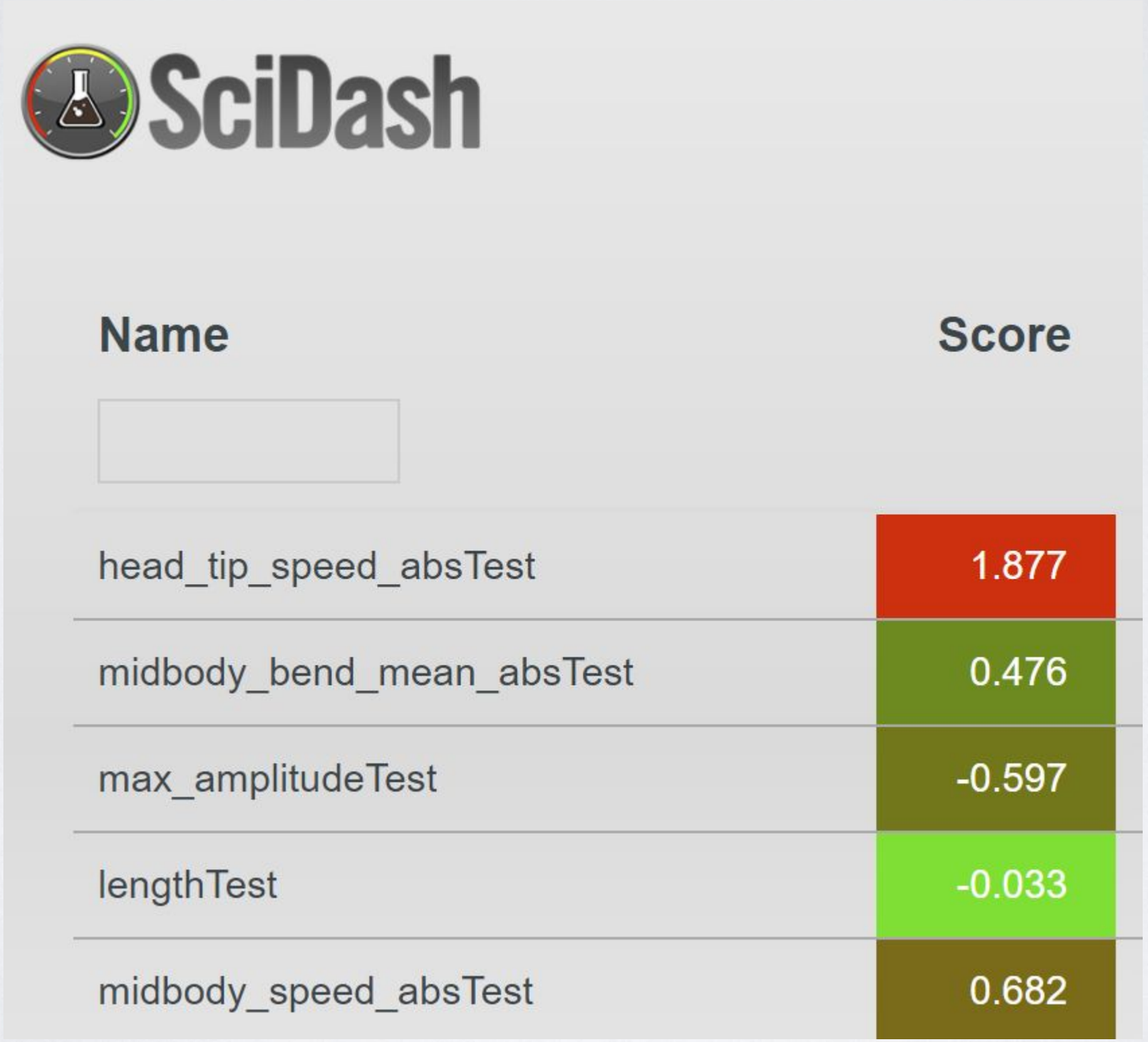
A	LEMS_c302_C2_IClampBWM
APWidthTest	Z = -3.06
APAmplitudeTest	Z = -11.38
ISITest	Z = -0.83
ISICVTest	Ratio = 0.73



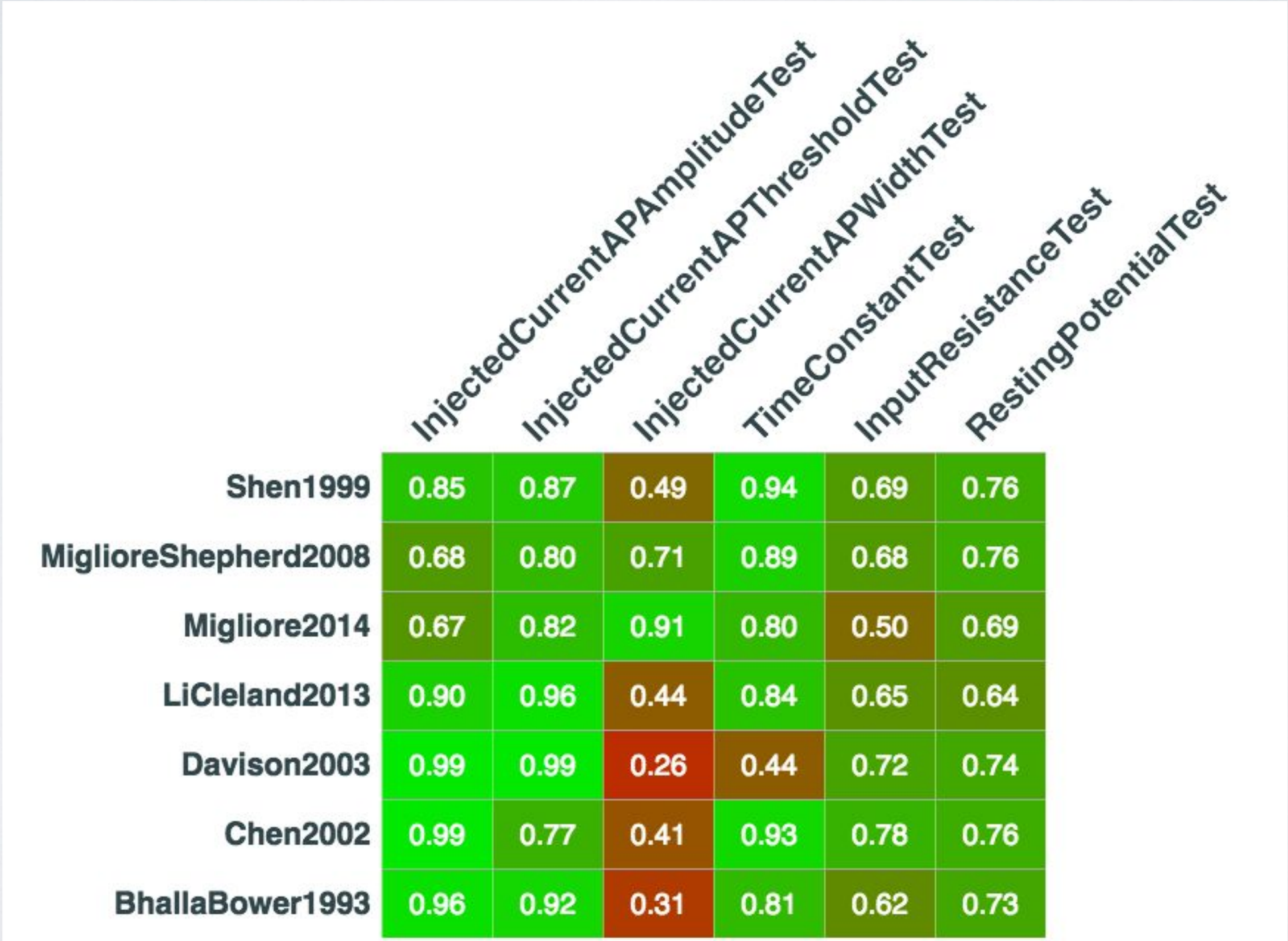




Visualization Portal



Visualization Portal



Project Partners

OPEN SOURCE BRAIN

[NeuroML]

Human Brain Project

OpenWorm

incf

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NIBIB (R01EB021711)

Google
Human Brain Project
Mayo Clinic
INCF