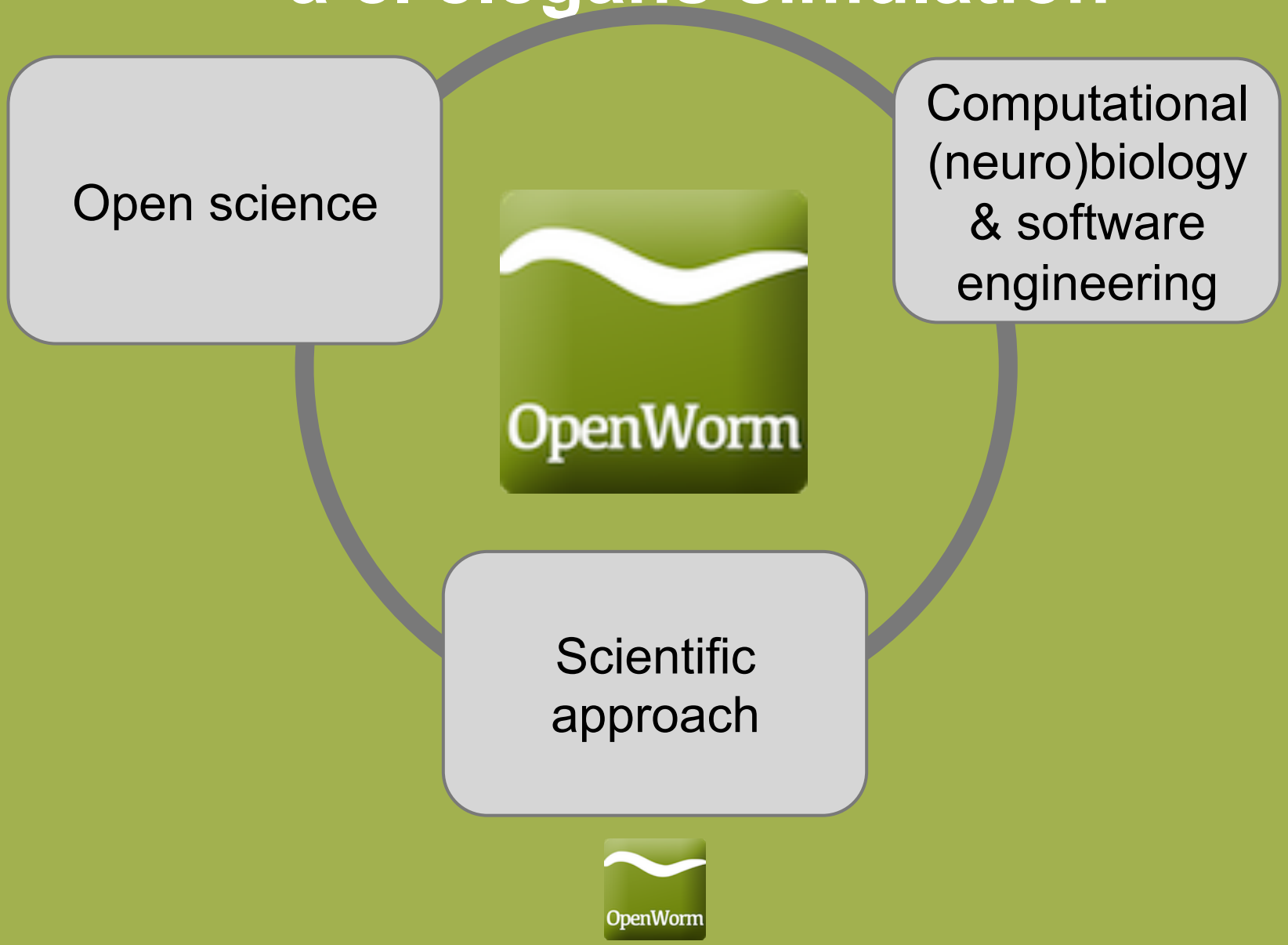
OpenWorm: Aggregating biological simulations in an open science project

Stephen Larson, Ph.D
Project Coordinator
OpenWorm.org

OpenWorm is building a c. elegans simulation

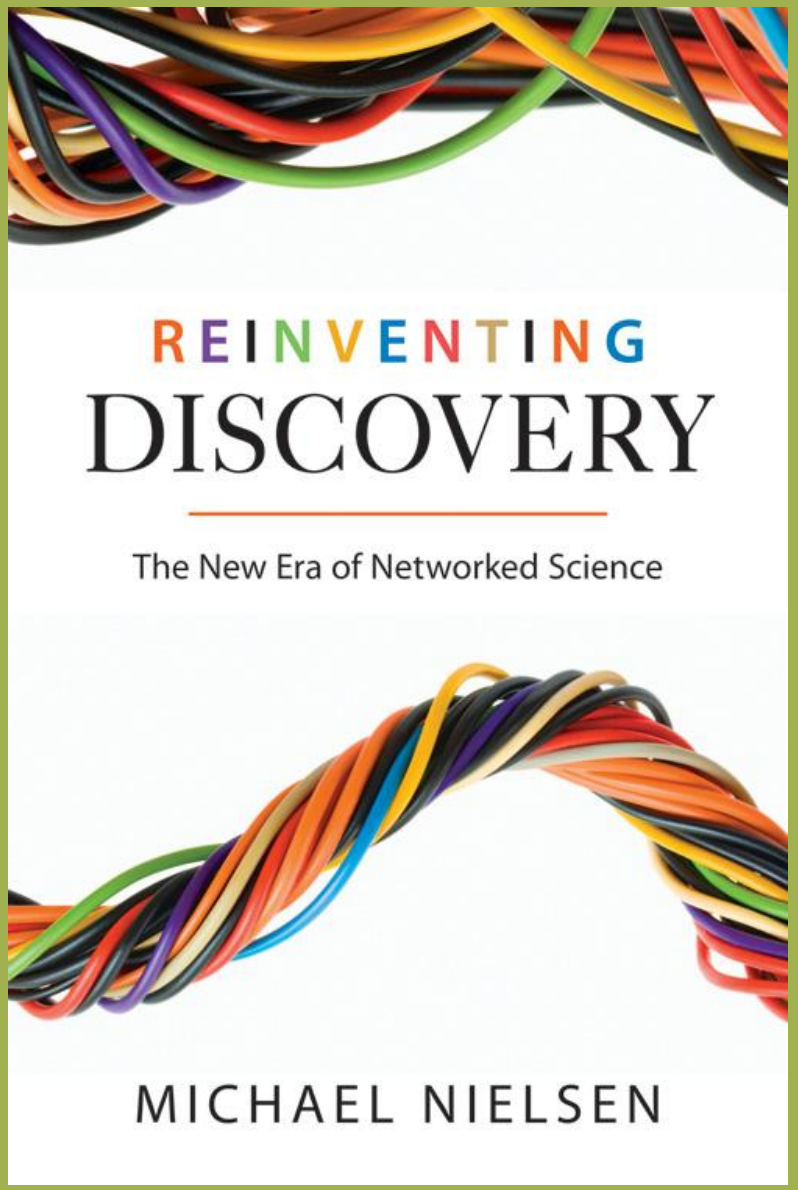


OpenWorm's goal

- Long term: Full scale **simulation** of a **C. elegans**
- Medium term: Accurately predict **WormBehavior** database using **3D neuromechanical model**

OpenWorm

- Independent international **open science** community started in 2011
  - 9 **core** members
  - 36 **contributors** across 12 **countries**
  - 24 **GitHub repos** & 220 **GitHub followers**
  - 300 **mailing list** members
- Community open source construction
  - Every line of code posted on GitHub
- Hosted 40+ online meetings last year
  - Streamed on YouTube



OpenWorm

People

Imagine working with a group of super-motivated wizards coming together for a common goal.
It's amazing what talented people can achieve when their creativity is unleashed.

Core team

Our Superheroes.

Andrey Palyanov	Balazs Szigeti	Giovanni Idili	Jim Hokanson	Matteo Cantarelli	Michael Currie
Padraig Gleeson	Sergey Khayrulin	Stephen Larson			

Contributors

Helping us with amazing support. Thanks!

Alexander Dibert	Andrew Leifer	Andrew Papadopoli	Bóris Marin	Charles Cooper	Christian Grove
Chris Jensen	Crystin Slade	Dan Knudsen	David Dalrymple	Deanne Taylor	Dmitriy Shabanov
Dmitar Shterionov	Eviatar Yemini	Gaston Gentile	Gleb Kuznetsov	Jay Coggan	Jesus Martinez
John Hurliman	John White	Jordan Boyle	Jinze Yu	Marius Buibas	Mariusz Sasinski
Matt Olson	Mike Vella	Mei Zhen	Netta Cohen	Pedro Tabacof	Peter McCluskey
Petr Baudis	Rayner Lucas	Rich Stoner	Steven Cook	Timothy Busbice	Vanessa Adelmann

Posted challenge on GitHub

slarson opened this issue 8 months ago

Create HivePlot data set from connectome

Edit

tabacof is assigned

Milestone: **Data visualization**

A HivePlot is a great way to visualize complex networks. To better understand what these are, check out the general introduction slides.

The c. elegans connectome is the connectivity graph of all of the neurons of its simple "brain". Visualizing this graph has yielded some insight into its structure, but it is still hard to pull patterns out of this graph as it is highly complex.

As far as I can find, HivePlots have not yet been applied to connectomes. This is a great opportunity to start.

- Take the connectivity graph data from our spreadsheet (first sheet only to start)
- Download the java HivePlot program
- Open an example under this program to understand the format:

```
A [attribute1=100 attribute2=1000] # node 'A'
B [attribute1=200 attribute2=2000] # node 'B'
C [attribute1=400 attribute2=4000] # node 'C'
A -> B [atttribute1=100 attribute2=1000 attribute3=positive] # edge from 'A' to 'B'
B -> C [attribute1=200 attribute2=2000 attribute3=negative] # edge from 'B' to 'C'
```

- Write a python script to convert the connectivity graph data into this format.
- Load the data up, play with different ways of creating the hive plot for this data set, generate images & share.

https://github.com/openworm/OpenWorm/issues/39

A volunteer emerges

Personal contribution to the project

Inbox x Boomerang x Forums x

Pedro Tabacof <tabacof@gmail.com> Feb 27

to info

Hello,

I really like the idea of this project and I was wondering how I could contribute. I'm a computer engineer with scientific computing experience (C/C++, Python, Matlab), including work with ODE integrators (Cvode, Lsoda), neural networks (Matlab toolbox), evolutionary computing, nonlinear optimization (Minpack, NLOPT) and system identification/optimal control (CasADi). I have some above average knowledge in neurobiology, though I'm very rusty on this aspect.

How should I start? I must admit I don't have much free time on my week, so I will need some time before I gather enough knowledge to do anything worthwhile.

Thanks,
Pedro Tabacof.
School of Electrical and Computer Engineering,
State University of Campinas, Brazil.

Pedro Tabacof, citizen scientist

Pedro Tabacof
tabacof

Unicamp
Brazil
Joined on Aug 14, 2012

Contributions | Repositories | Public Activity

tabacof starred casadi/casadi 3 months ago

tabacof starred openworm/OpenWorm 3 months ago

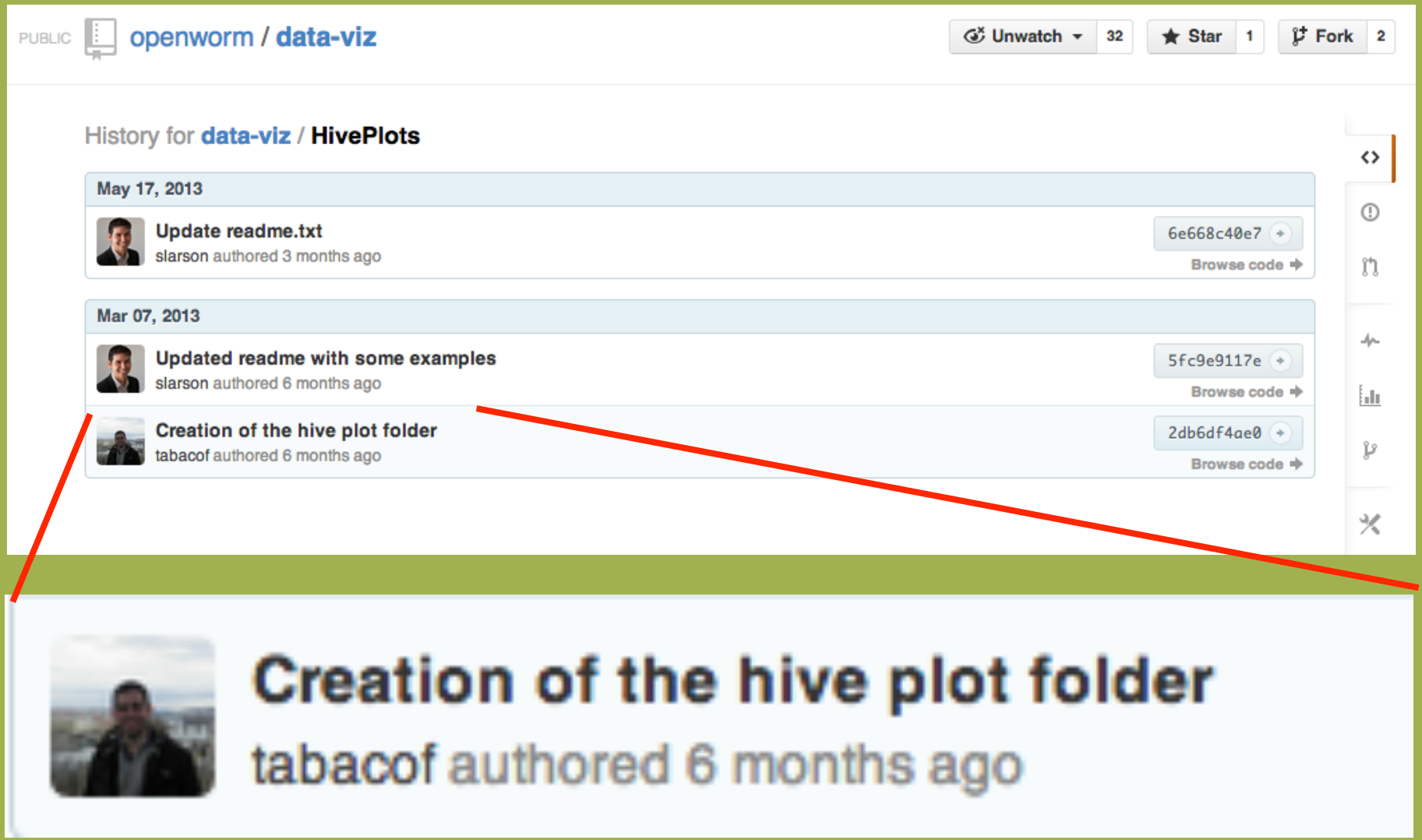
tabacof created repository casadi 5 months ago

6 months ago
tabacof pushed to master at openworm/data-viz
2db6df4 Creation of the hive plot folder

tabacof starred openworm/OpenWorm 6 months ago

https://github.com/tabacof?tab=activity

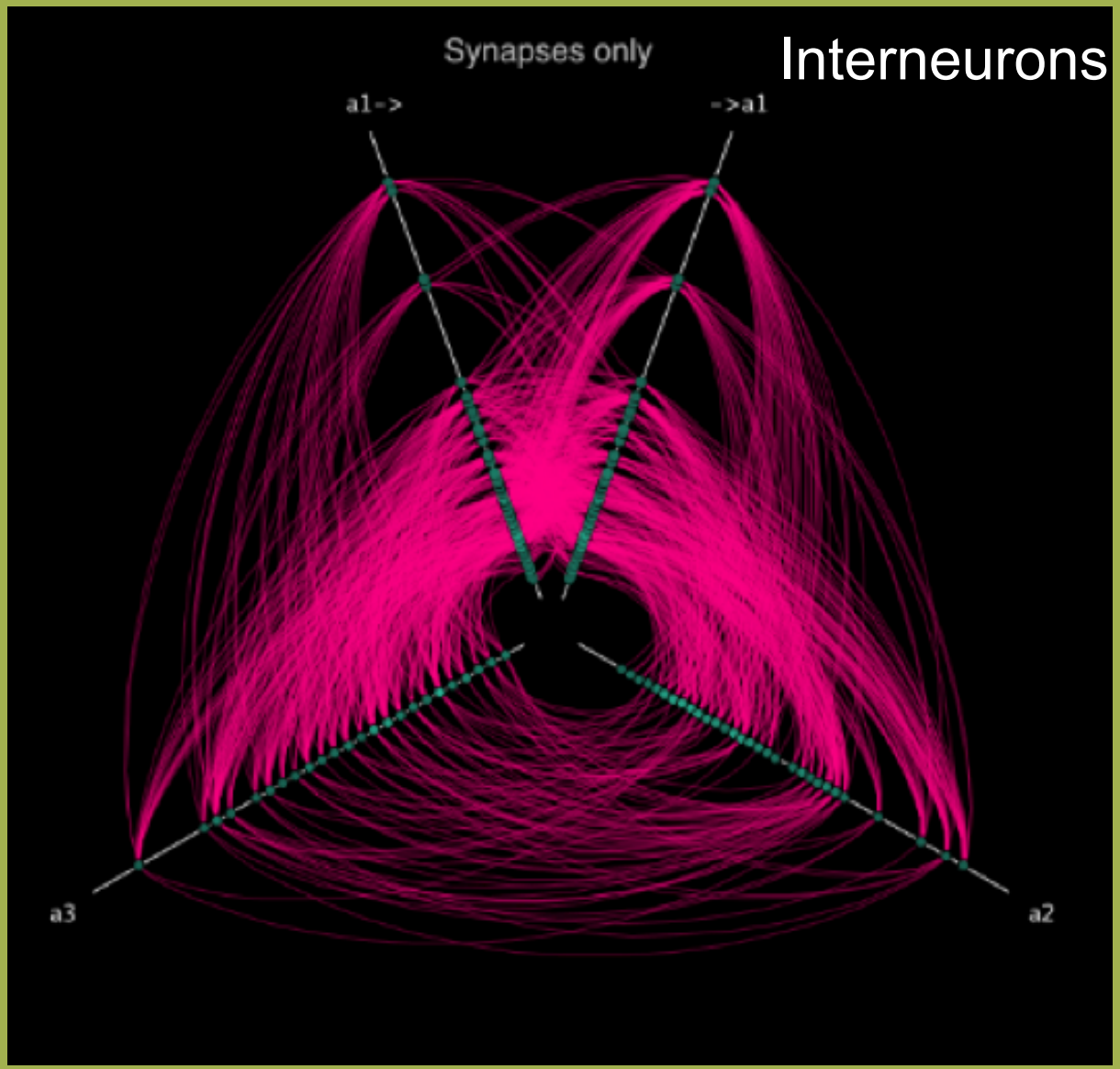
Three weeks later, a result!



https://github.com/openworm/data-viz/commits/master/HivePlots

Chemical synapse connectome

image produced using JHive



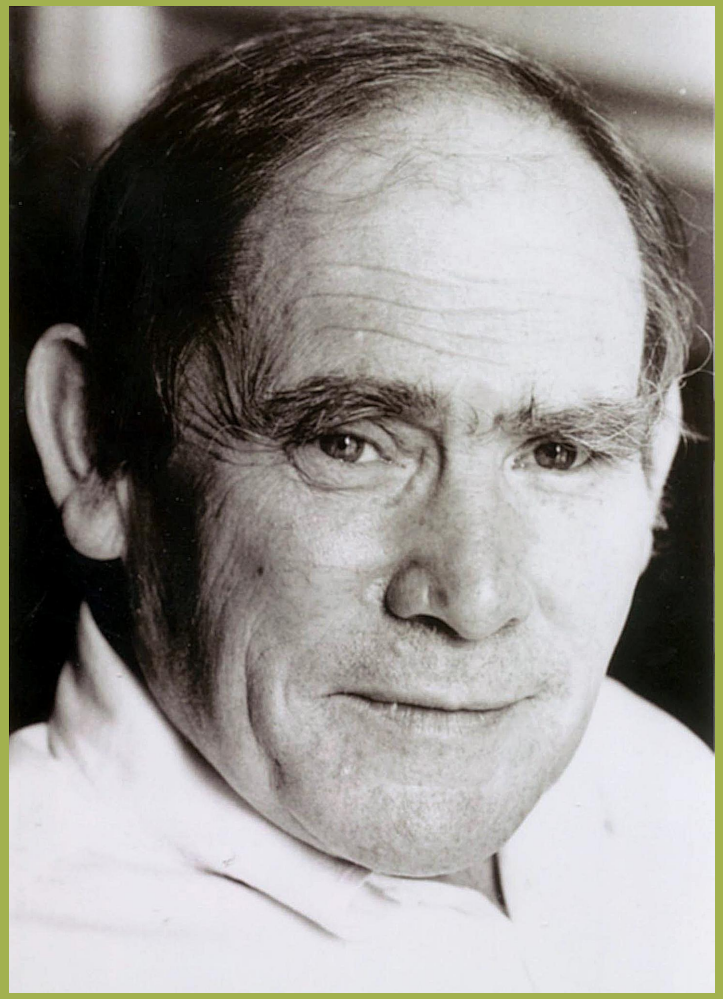
Sensory neurons

Motor neurons

https://github.com/openworm/data-viz/tree/master/HivePlots

Why C. elegans?

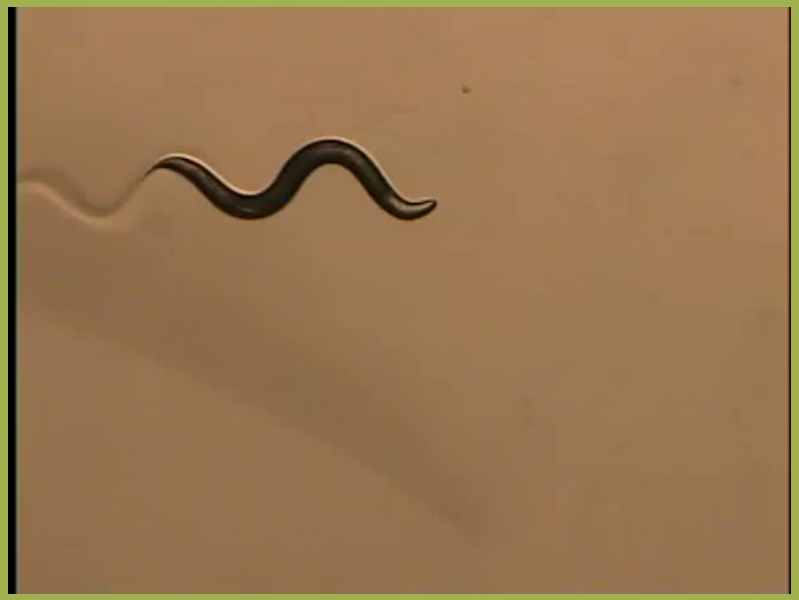
Dr Sydney Brenner



OpenWorm

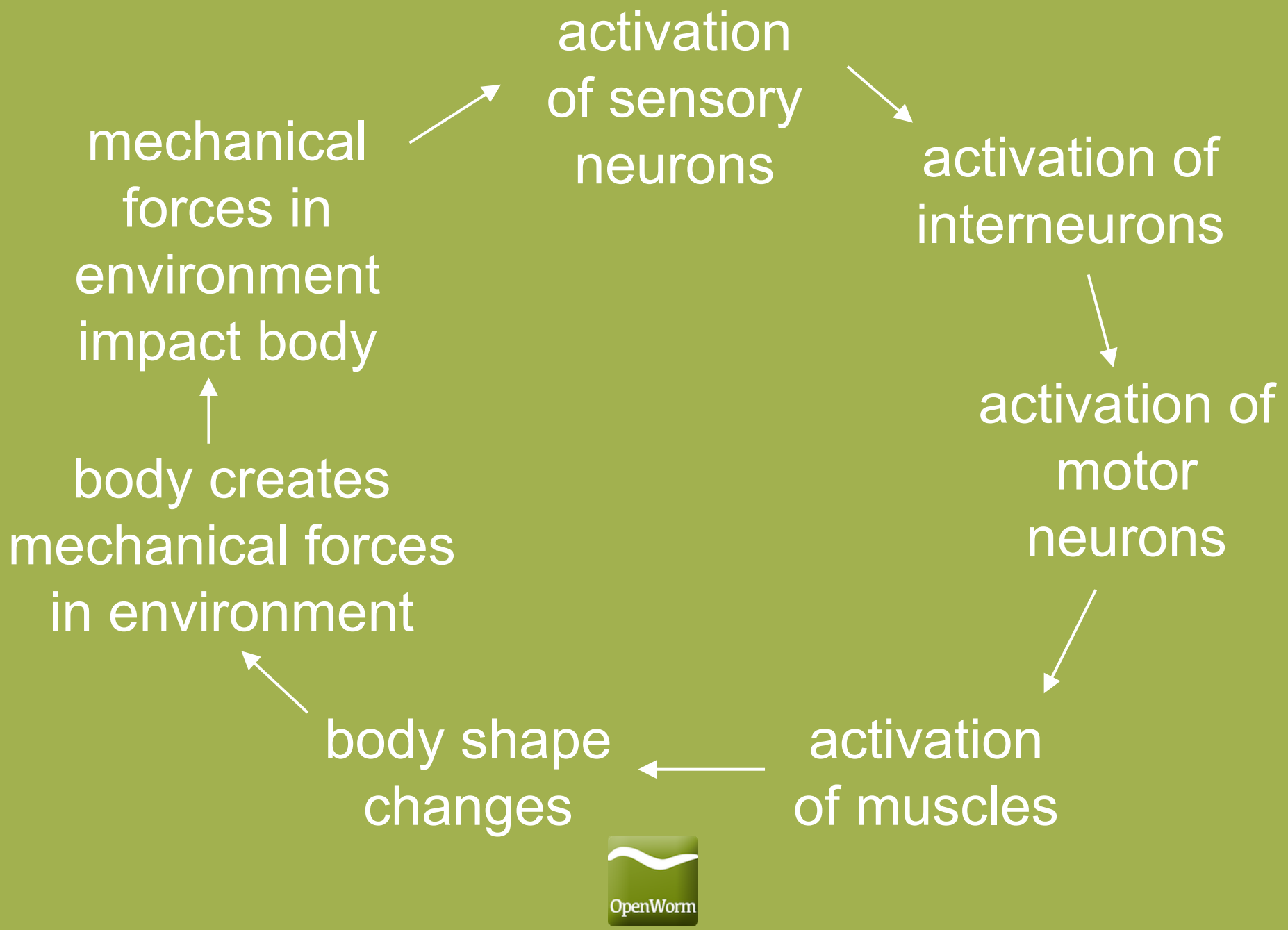
C. elegans background

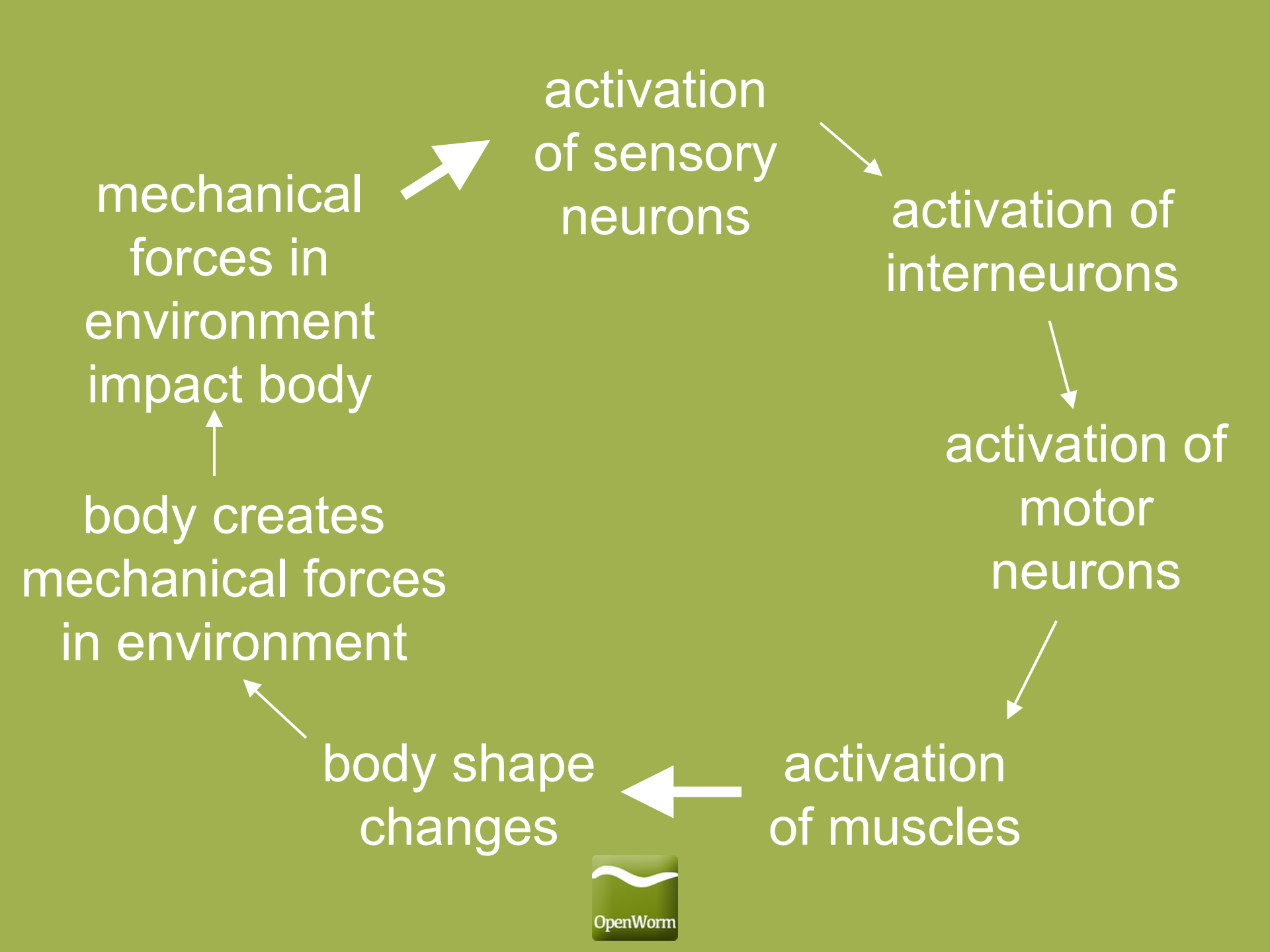
- Behavior
  - Seeks out food & mates
  - Avoids predators & toxins
  - Has social behaviors
- Genomics
  - First fully sequenced organism
- Cellular anatomy
  - 302 neurons, 95 muscle cells, ~1000 total cells
  - Every cell division from fertilized egg to adult is known
- Connectome
  - Only full organism connectome completed to date.

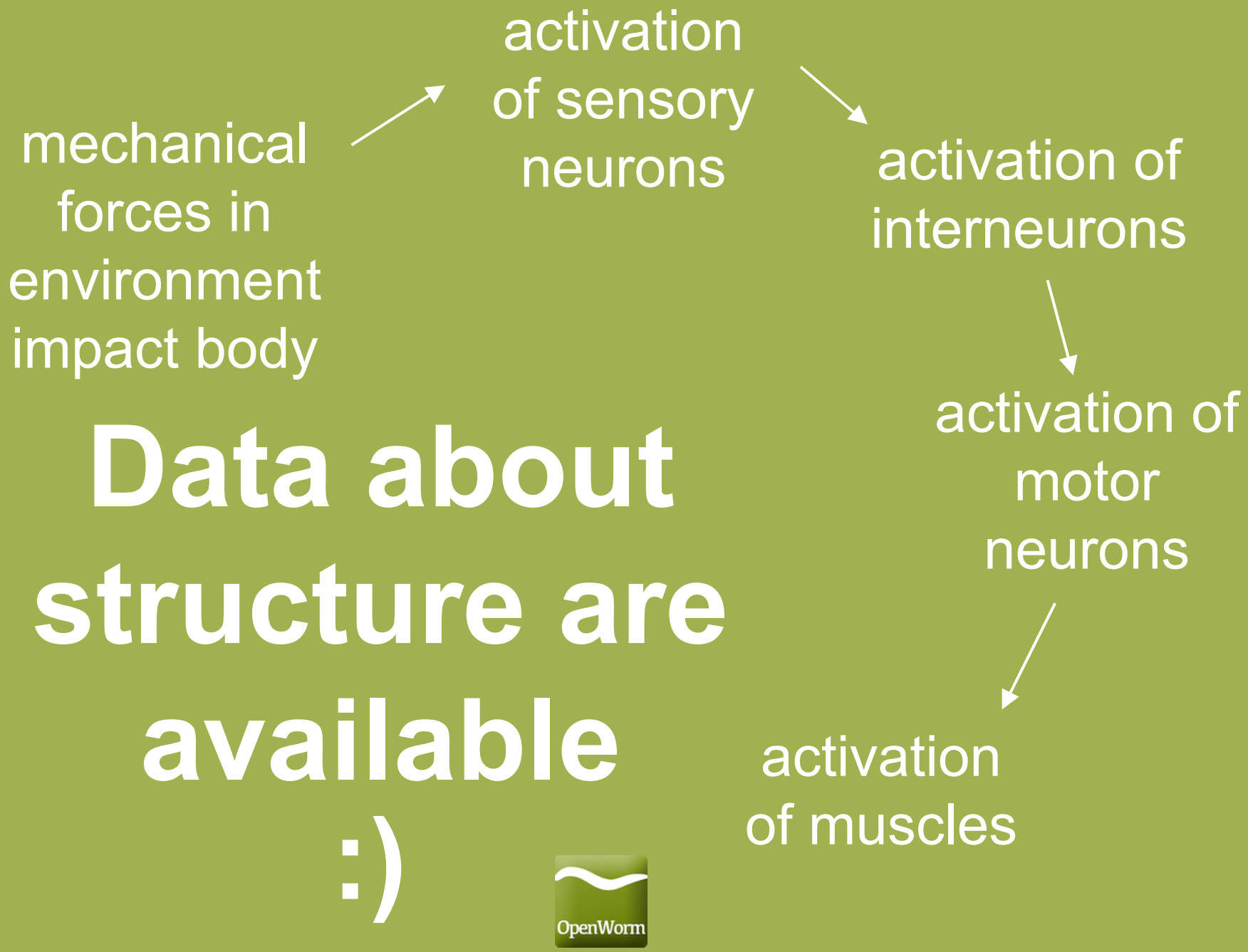


OpenWorm

C. elegans represents a *huge* opportunity for computational biology

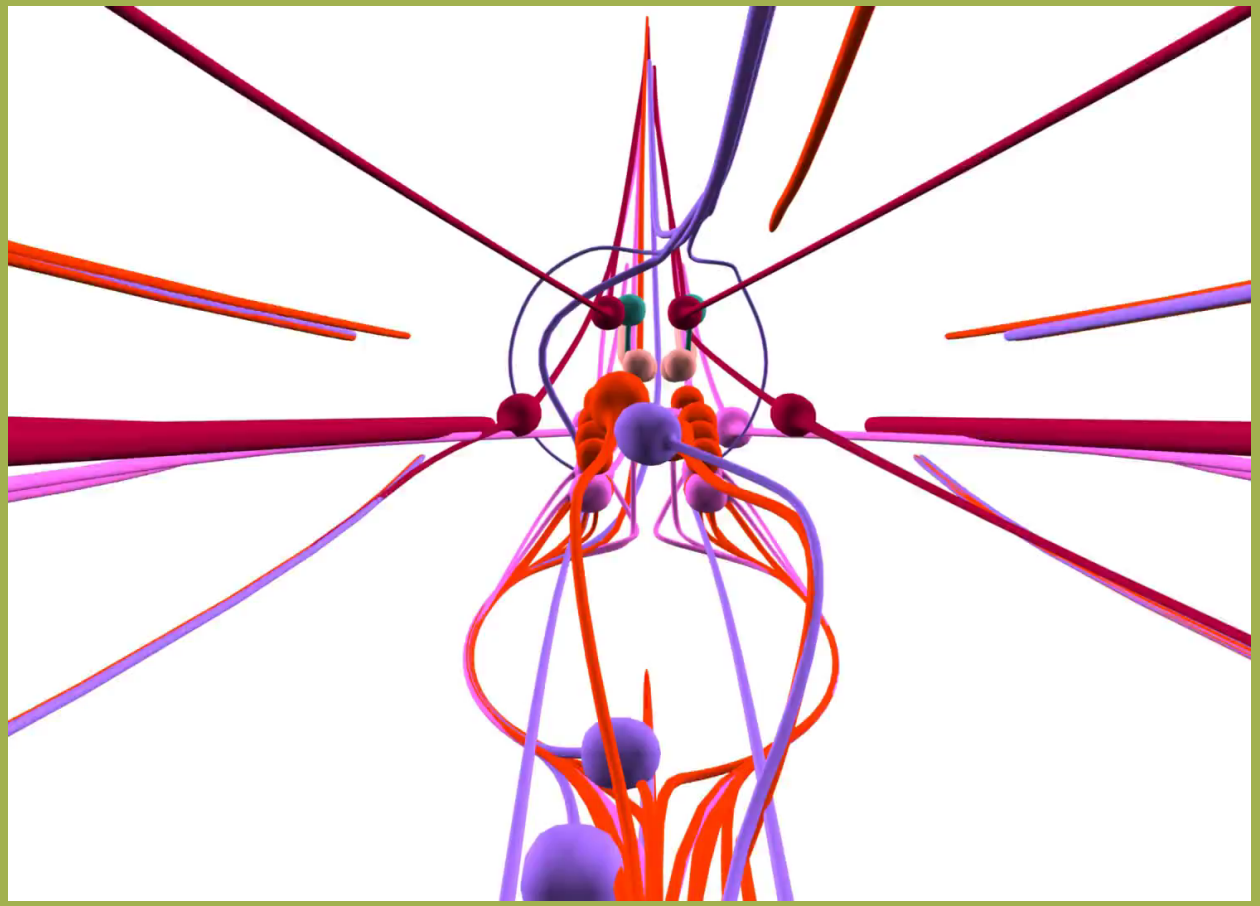

activation of sensory neurons
activation of interneurons
activation of motor neurons
activation of muscles
body shape changes
body creates mechanical forces in environment
mechanical forces in environment impact body
OpenWorm


activation of sensory neurons
activation of interneurons
activation of motor neurons
activation of muscles
body shape changes
body creates mechanical forces in environment
mechanical forces in environment impact body
OpenWorm


activation of sensory neurons
mechanical forces in environment impact body
activation of interneurons
activation of motor neurons
activation of muscles
Data about structure are available :)
OpenWorm

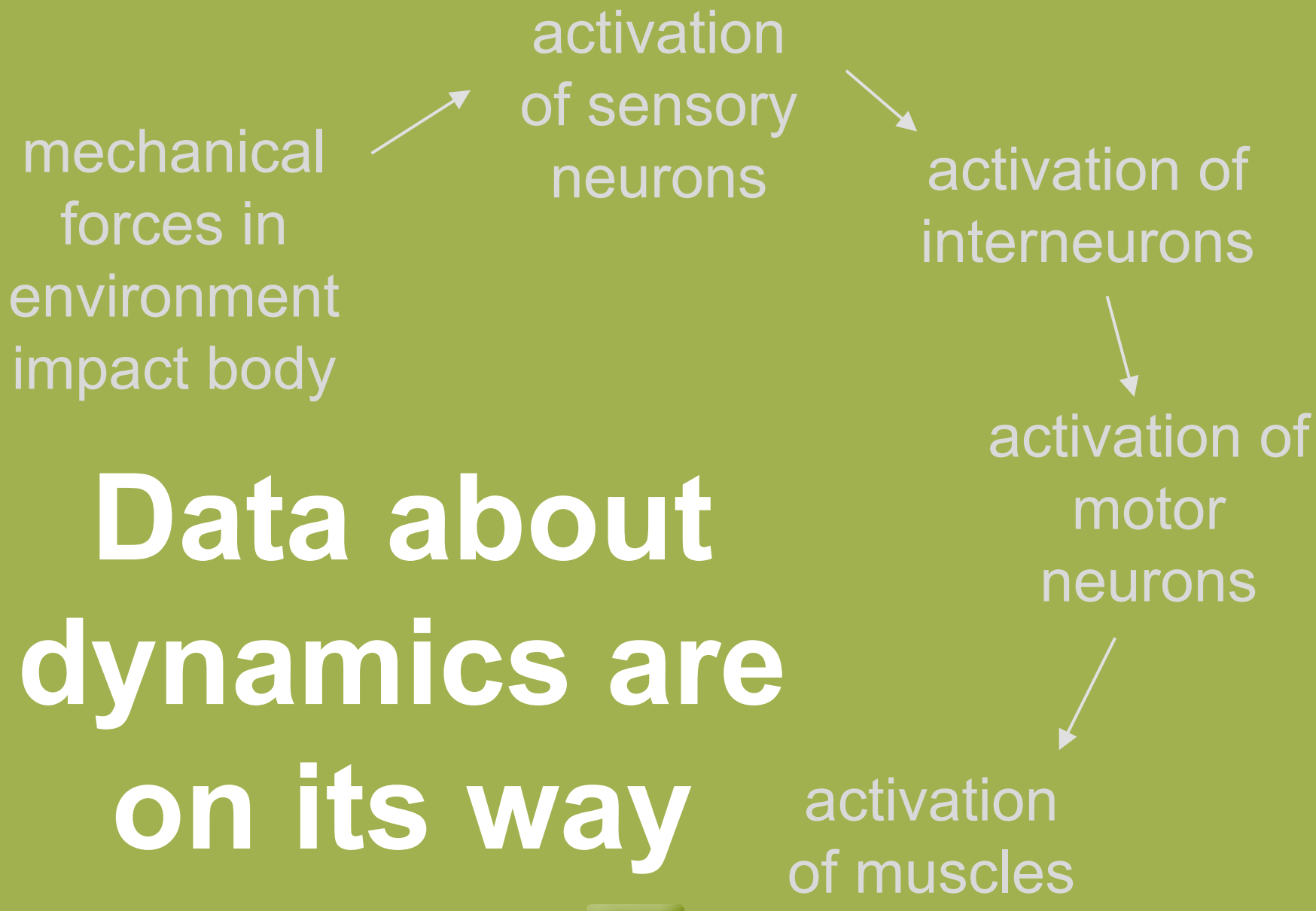
C. elegans connectome 2013

NeuroML represenation of c. elegans conectome on OpenSource Brain

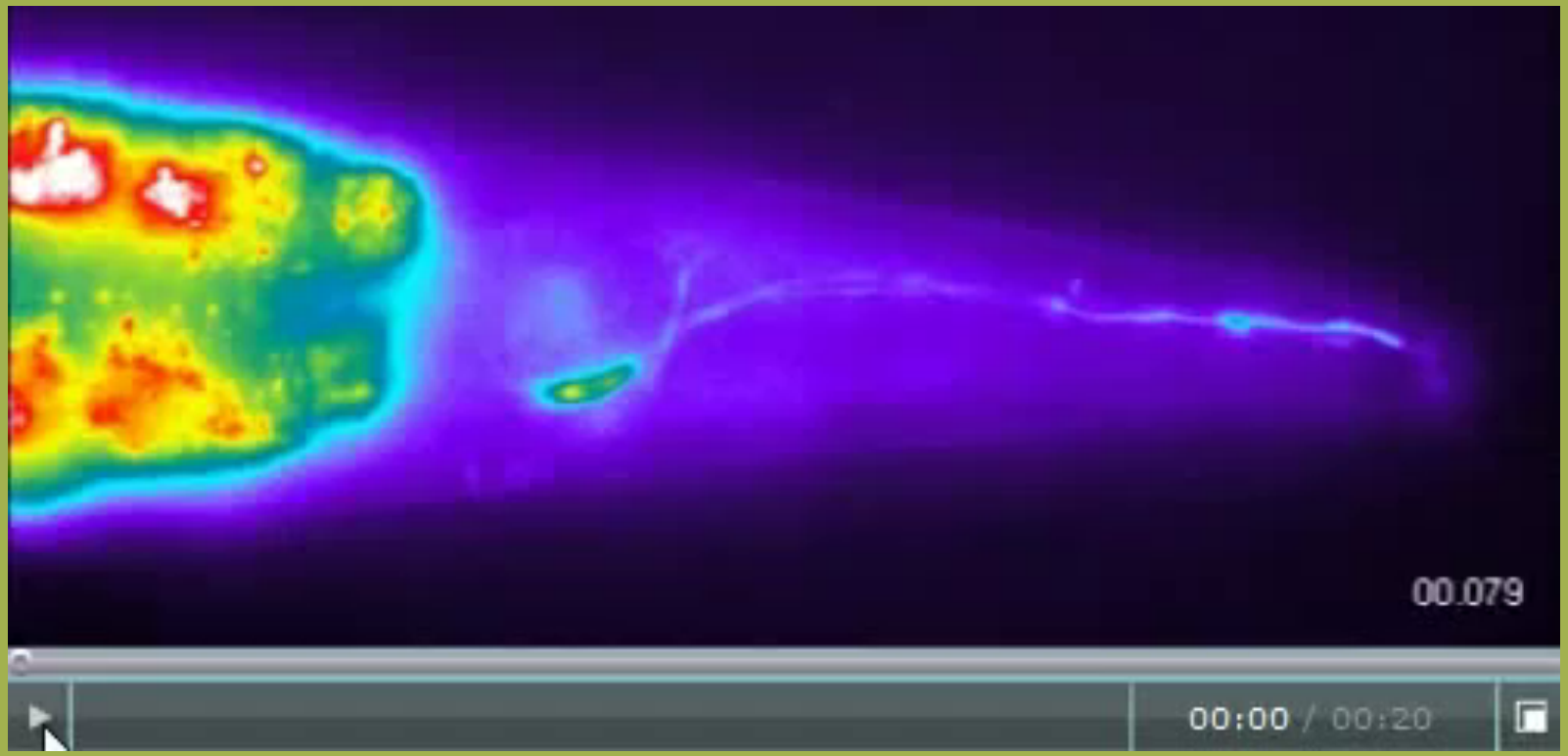


Christian Grove, Wormbase

OpenWorm


activation of sensory neurons
activation of interneurons
activation of motor neurons
activation of muscles
mechanical forces in environment impact body
Data about dynamics are on its way
OpenWorm

Data on dynamics of neurons in c. elegans is being revolutionized by optical imaging



OpenWorm

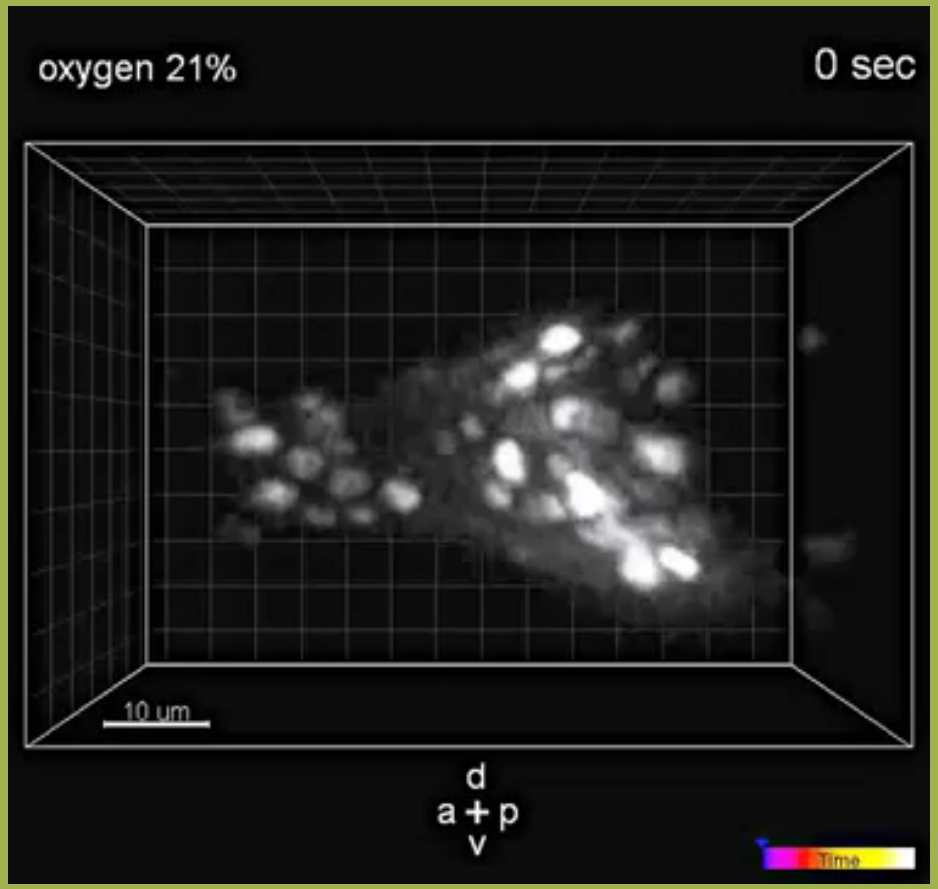
Dr. Sreekanth Chalasani,
Salk Institute

Data on dynamics of neurons in c. elegans is being revolutionized by optical imaging

OpenWorm

Dr. Andrew Liefer,
Princeton University

Data on dynamics of neurons in c. elegans is being revolutionized by optical imaging



OpenWorm

Shrodel et al,
Nat. Methods 2013

Data about structure & dynamics are available :) :)

body creates mechanical forces in environment

body shape changes

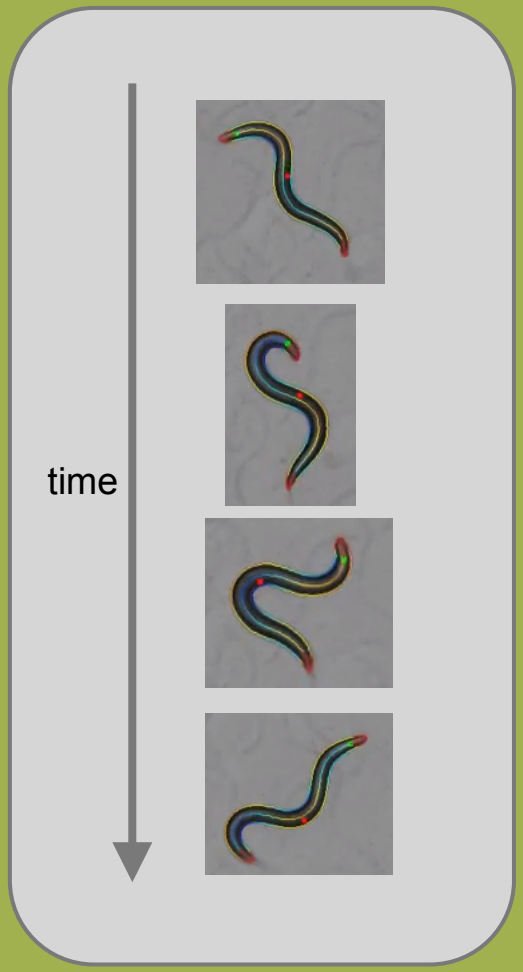
OpenWorm

Worm Behavior Database training data

OpenWorm

Yemini et al.,
Nat. Methods 2013

Worm behavior classifier



Simulated worm snapshots

Behavioral Classifier

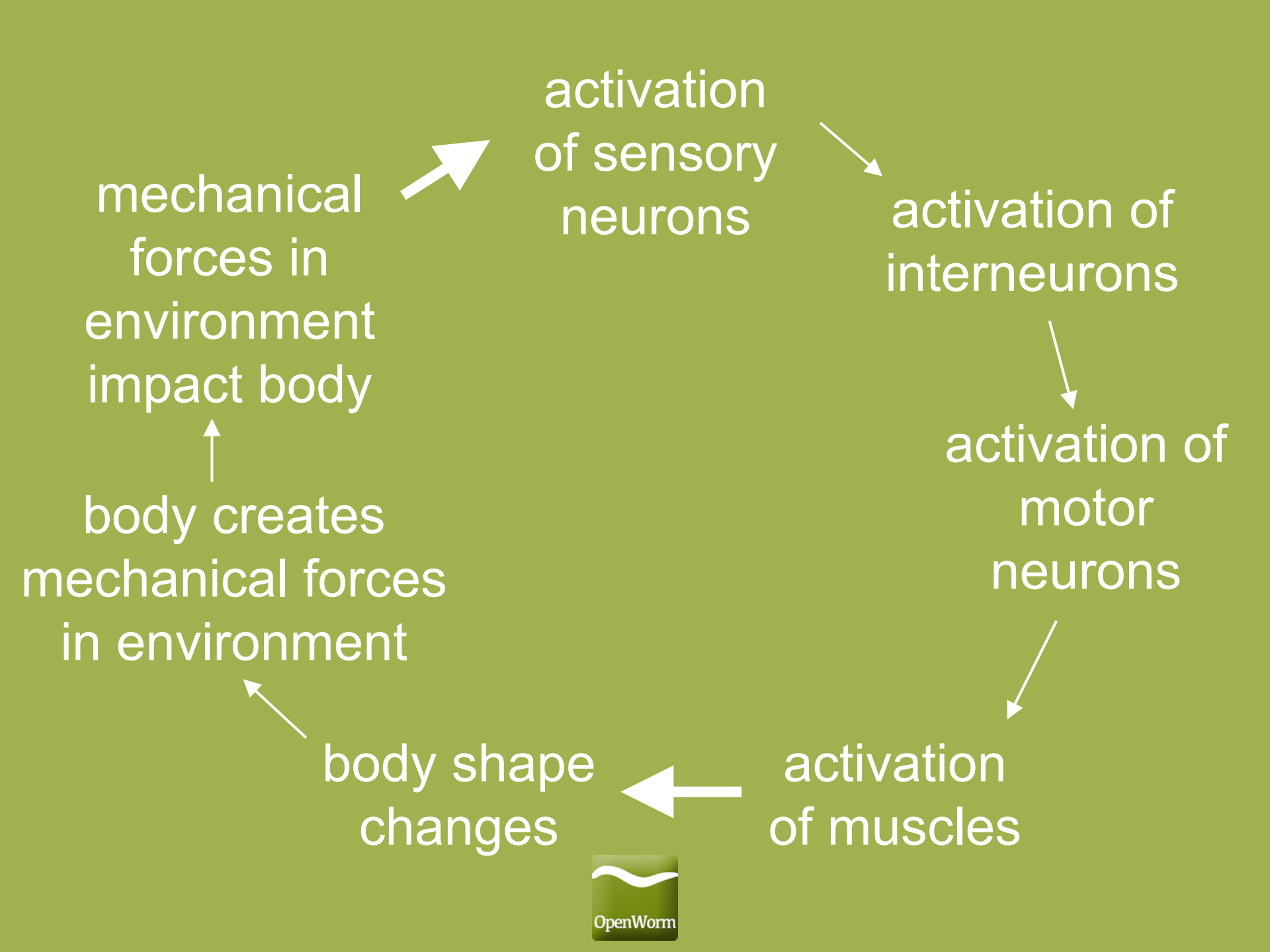
Derived from observations of real worms

#

Quantification of behavioral accuracy

Jim Hokanson
Michael Currie

OpenWorm


activation of sensory neurons
activation of interneurons
activation of motor neurons
activation of muscles
body shape changes
body creates mechanical forces in environment
mechanical forces in environment impact body
OpenWorm

Cyber Elegans

OpenWorm

Palyanov et al.,
In Silico Biology, 2012

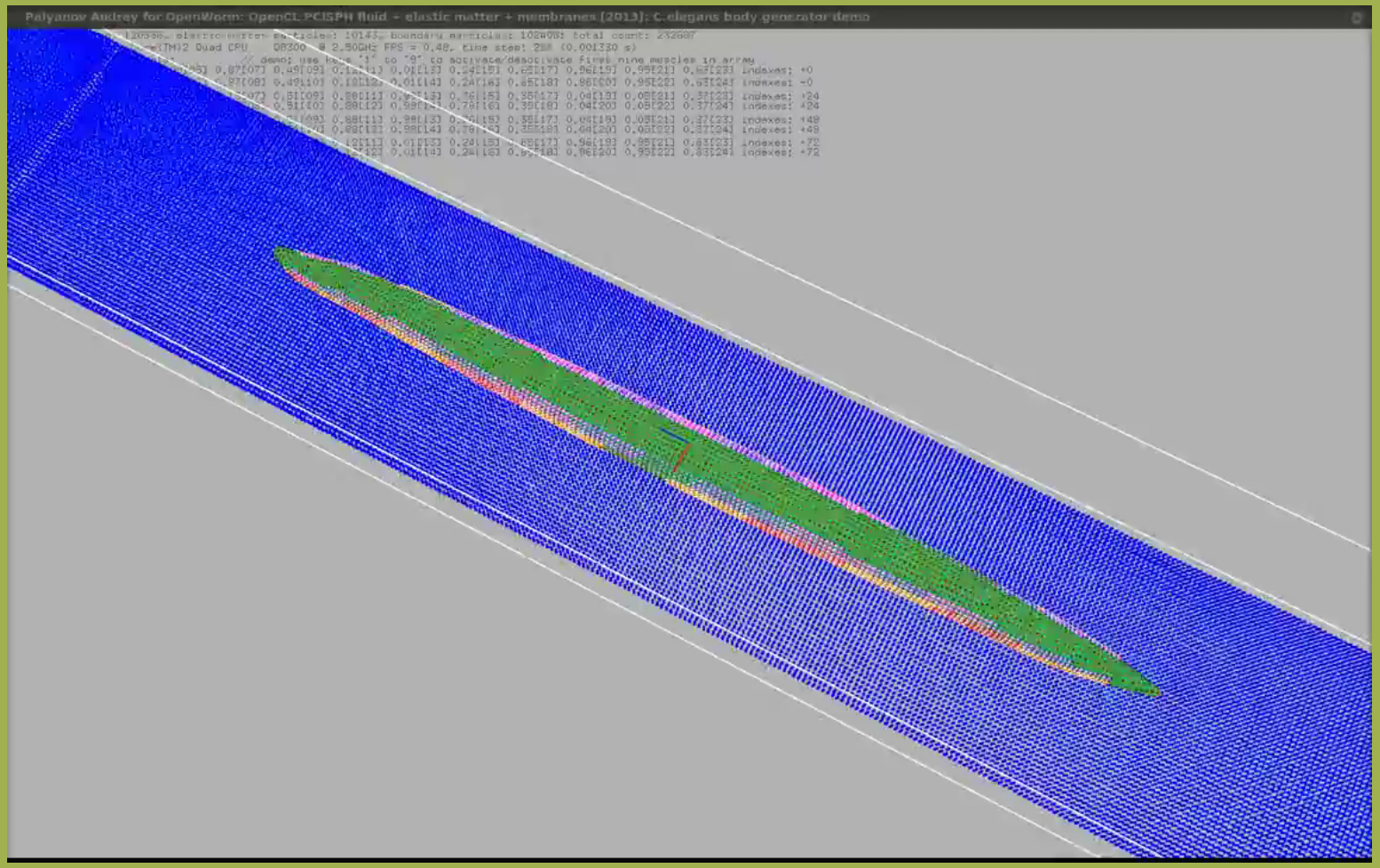
C. elegans connectome 2013

NeuroML represenation of c. elegans conectome on OpenSource Brain

OpenWorm

Padraig Gleeson
Tim Busbice
Matteo Cantarelli

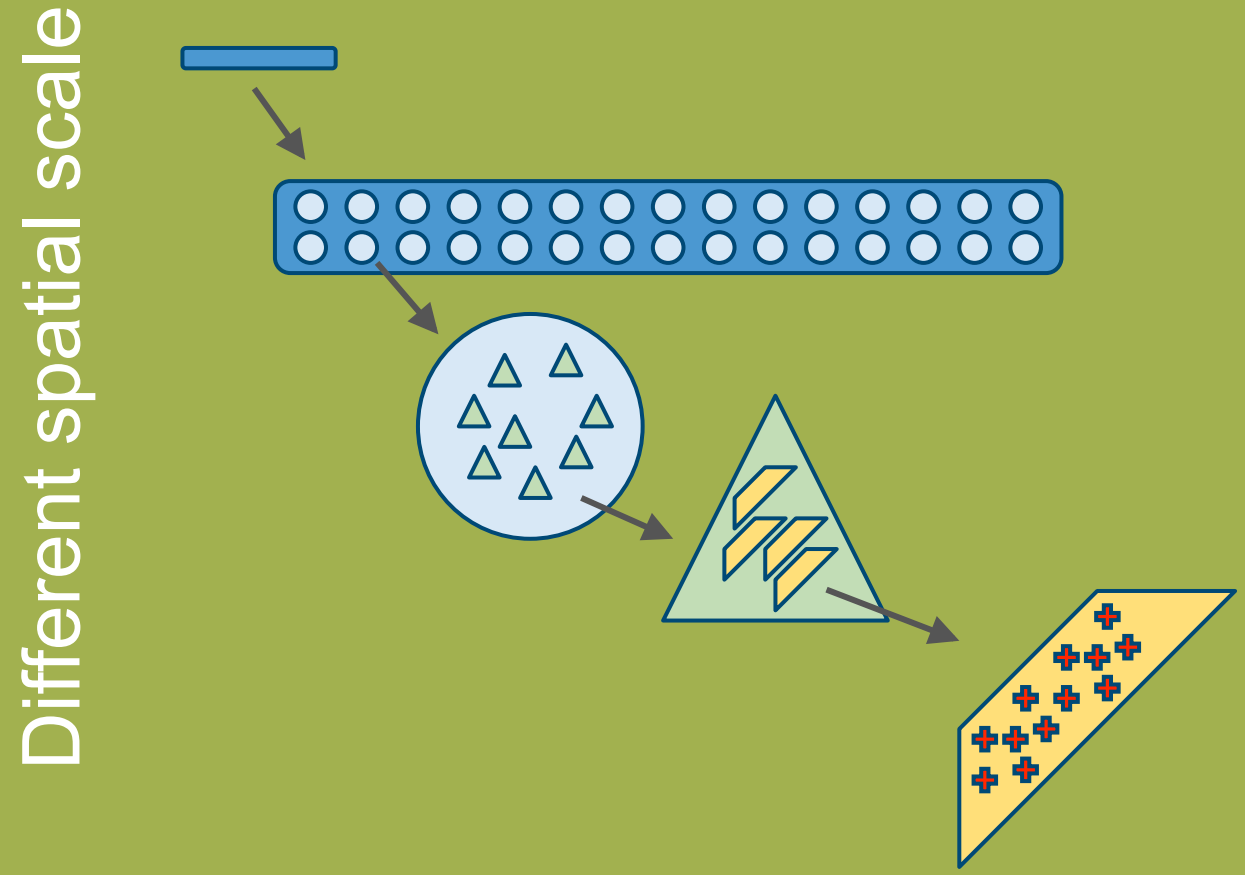
Mechanical prototype: “Sibernetic”



Andrey Palyanov
Sergey Khayrulin
Mike Vella

OpenWorm

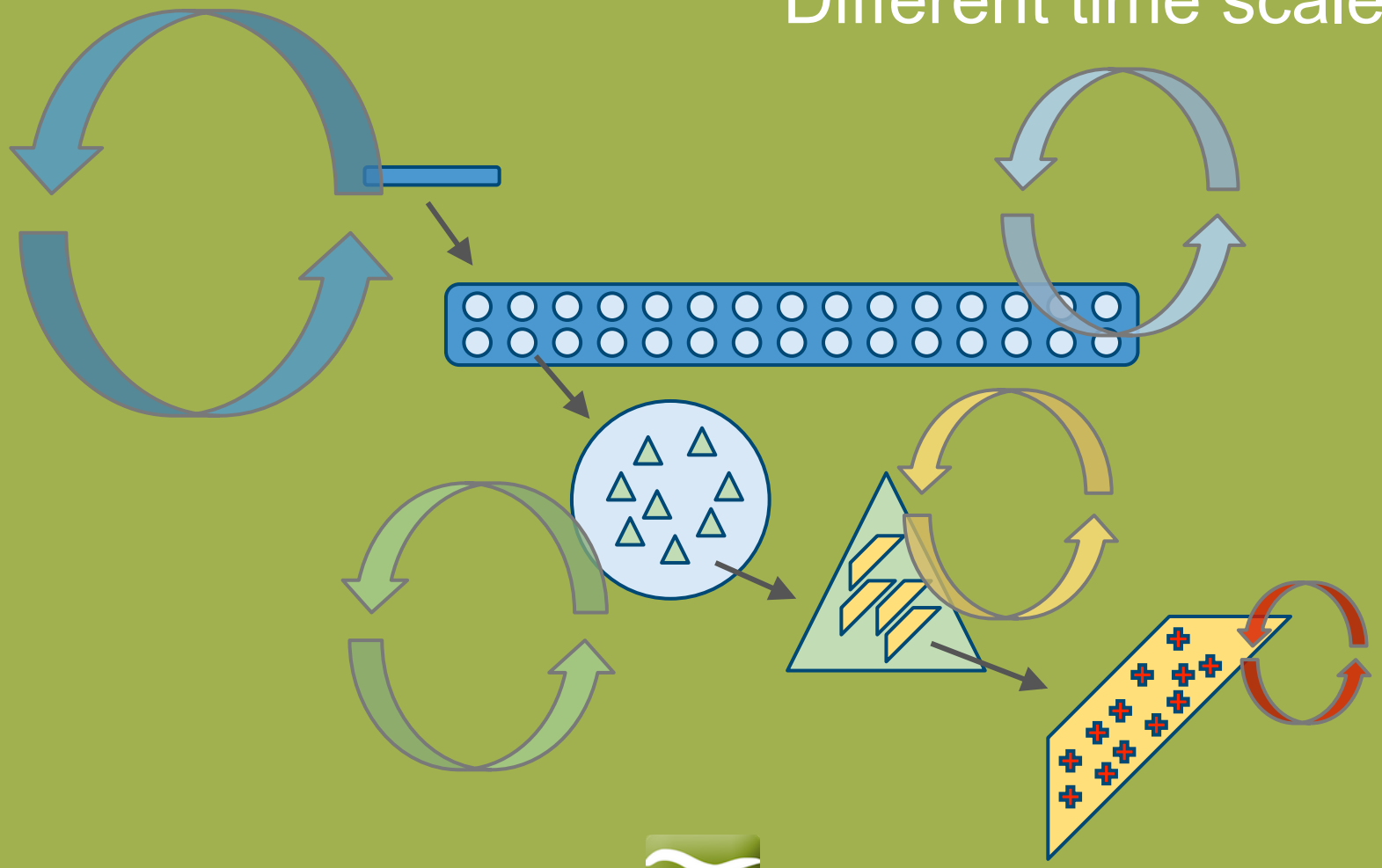
Bridging multi-scale models via software engineering



OpenWorm

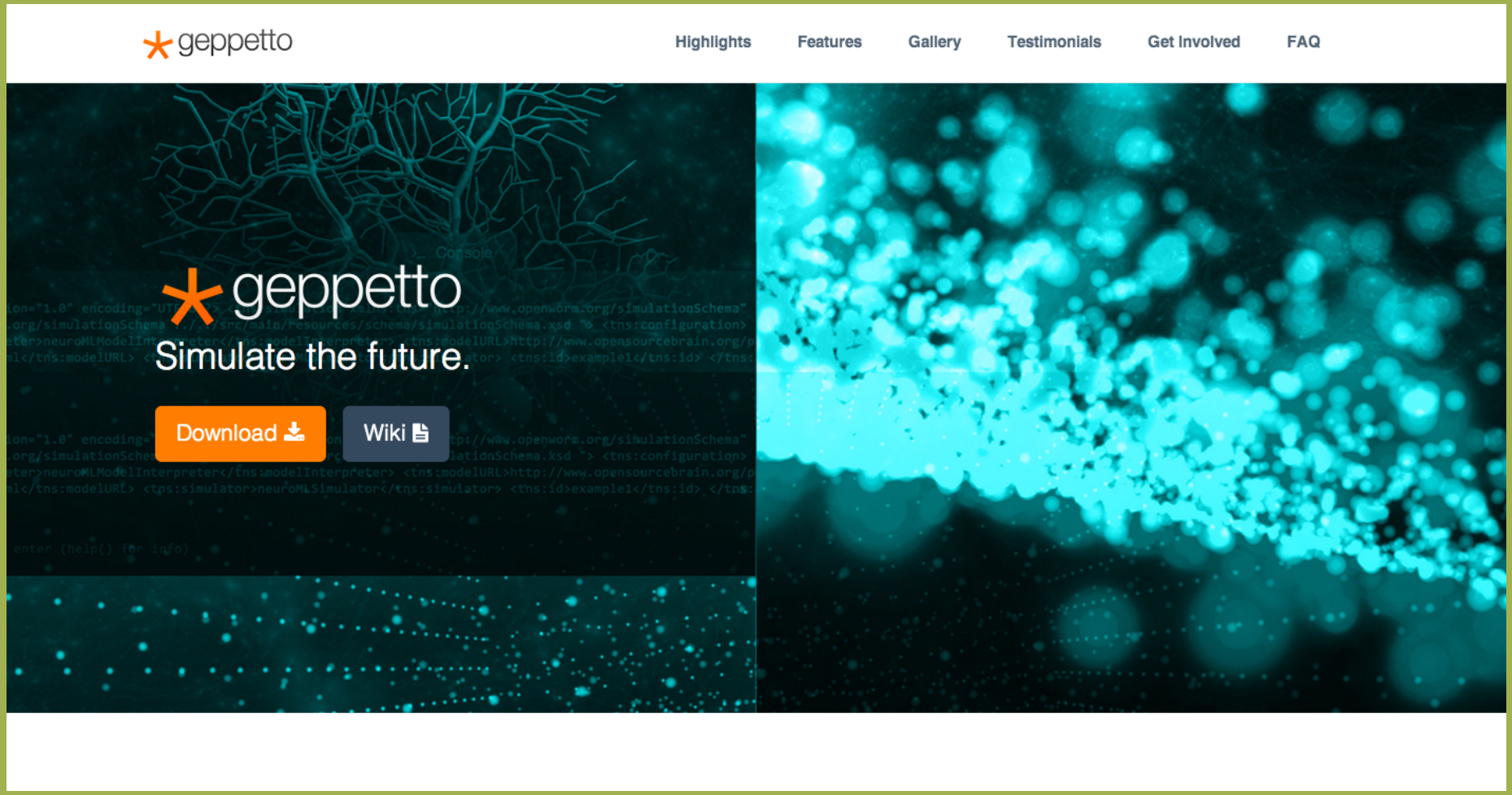
Bridging multi-scale models via software engineering

Different time scales



OpenWorm

Geppetto.org is open source and online



METACELL

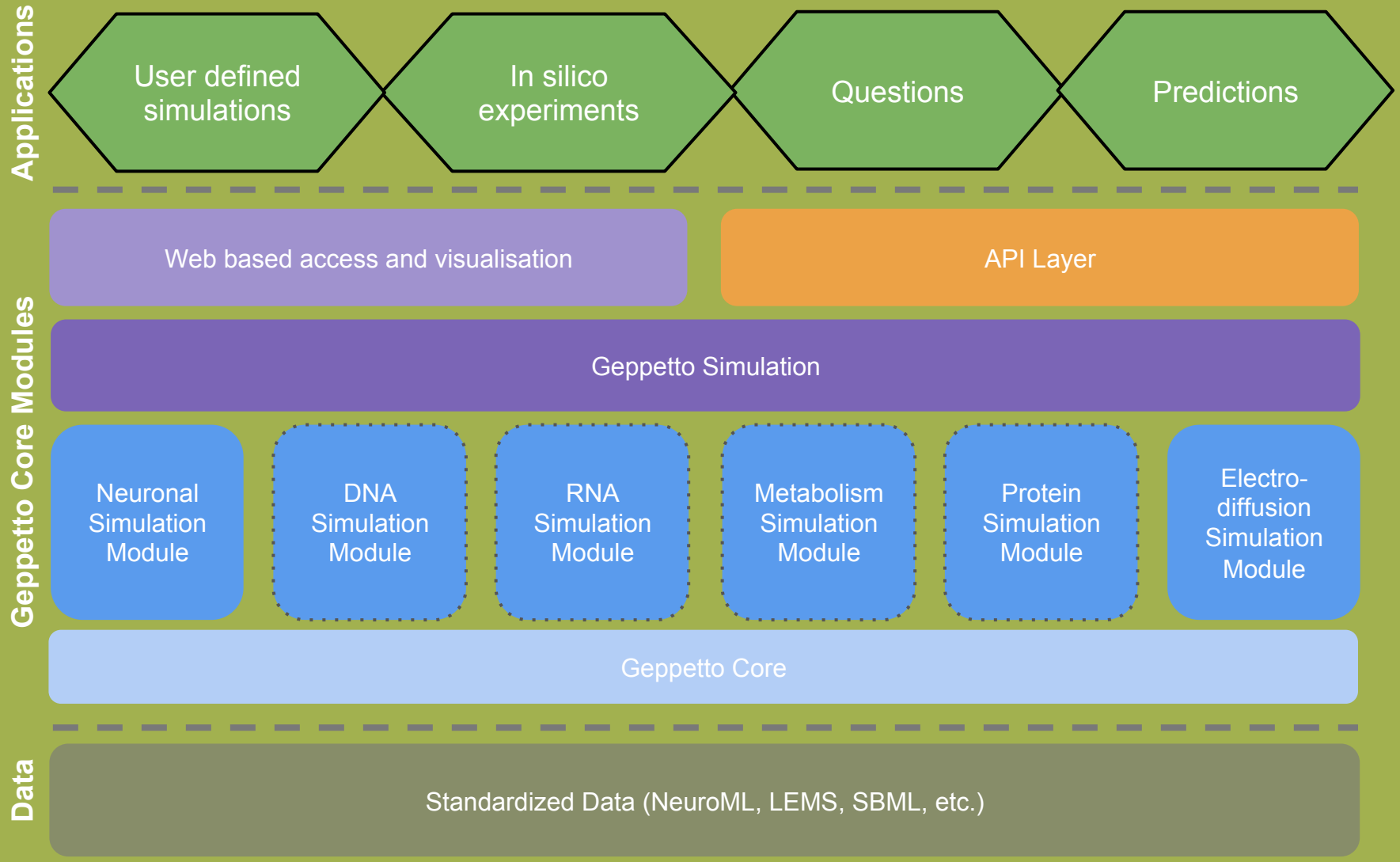
ORION BIONETWORKS

OpenWorm

Open Source Brain

Giovanni Idili
Matteo Cantarelli
Jesus Martinez

Geppetto architecture



In Progress

- Past
  - Palyanov et al. 2012
  - OpenWorm Browser - WebGL & iOS
  - Spatial Connectome in NeuroML
- Present
  - Sibernetic integration
    - First step towards "virtual embodiment"
    - C. elegans motor system & muscle cells
  - Plugging the nervous system into the body model
    - More serious inference around ion channels
  - Building the worm classifier
  - Geppetto
    - Web-Based Service Oriented Architecture
    - Fluid mechanics Solver (PCI-SPH, OpenCL)
    - Single compartment Ne[illegible] Solver (HH, OpenCL)

OpenWorm

New initiative in EU: Si Elegans

- FP7 funded
- Aims to reproduce c. elegans behavior using FPGA models, one per neuron
- More info: http://www.si-elegans.eu

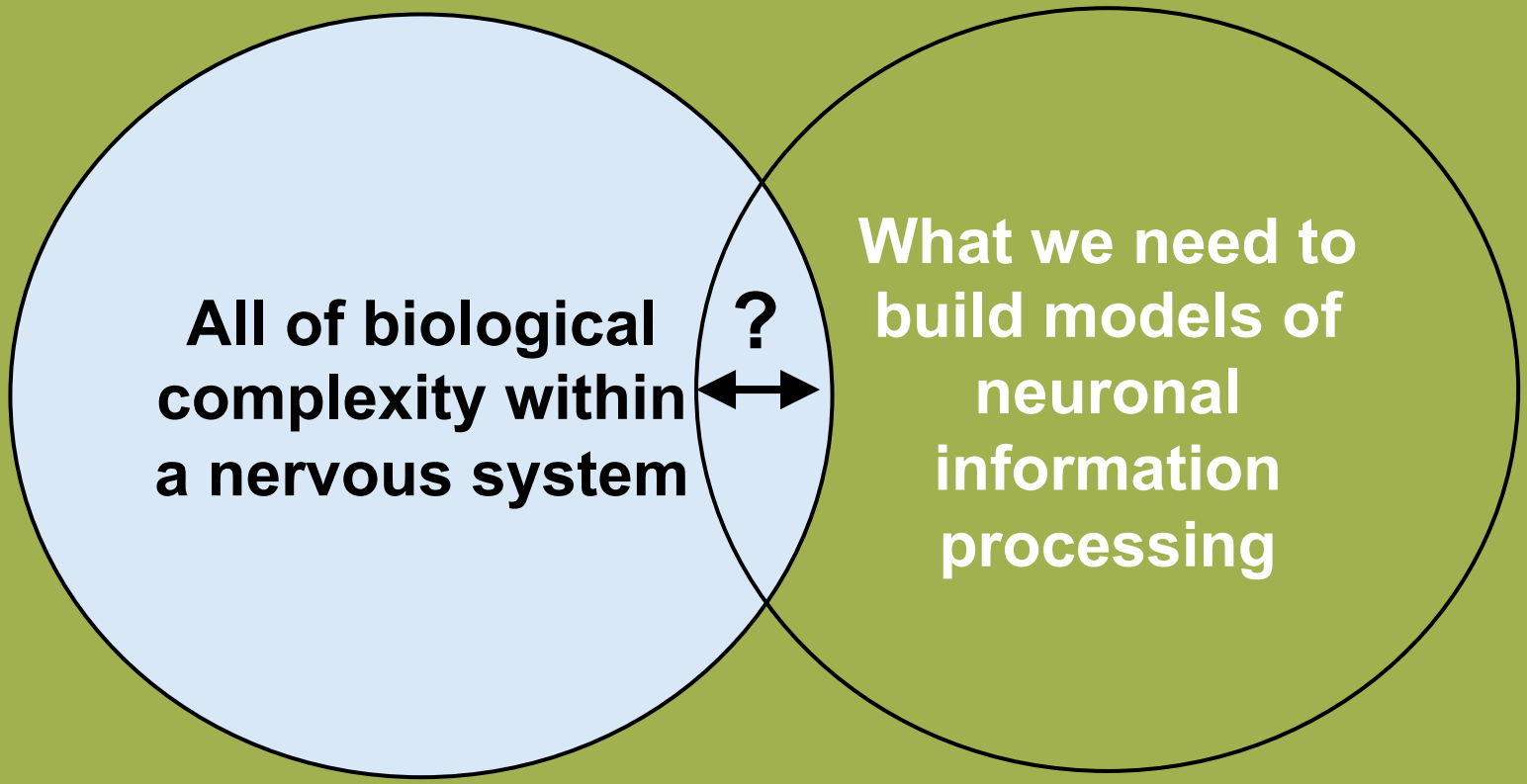
Other c. elegans modeling initatives

- Lab of Netta Cohen, Leeds University
- Lab of Cori Bargmann & Larry Abbott, Columbia University
- Lab of Shawn Lockery, Univ. of Oregon
- Nemaload project, David Dalrymple

The **transistor** is the **fundamental information processing unit** of the computer

The neuron is the **transistor of the brain**, but we don't have a model of a neuron that **predicts all known biophysical data**

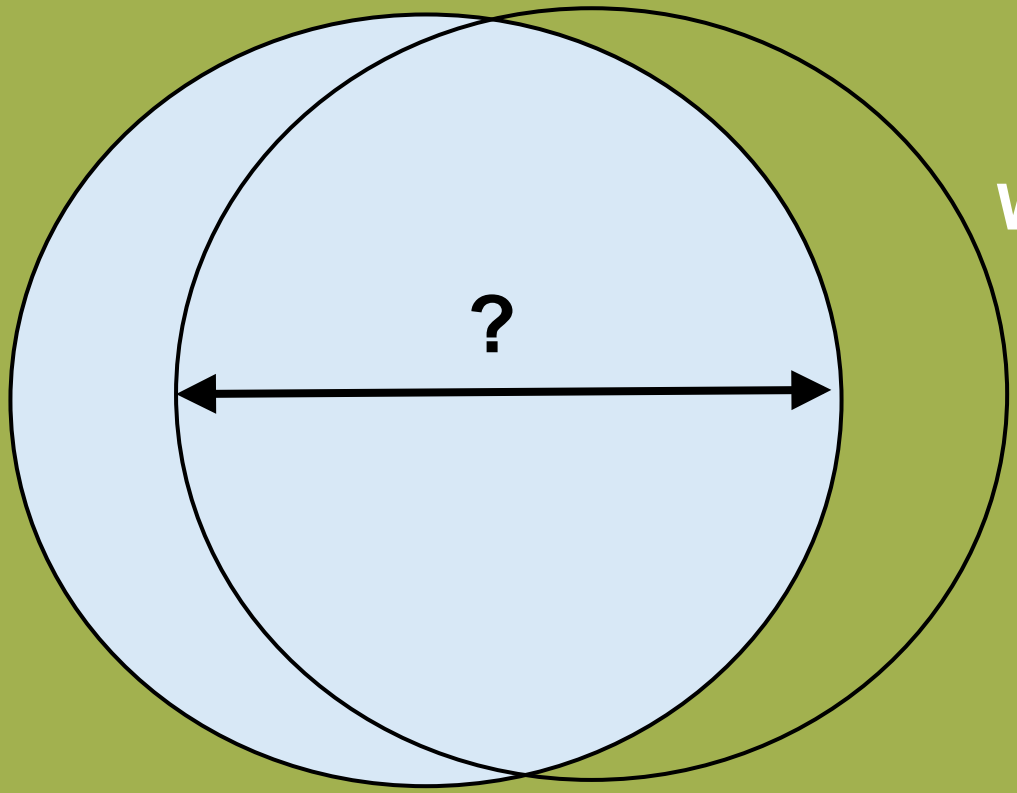
Principal challenge



OpenWorm

Principal challenge

All of biological complexity within a nervous system



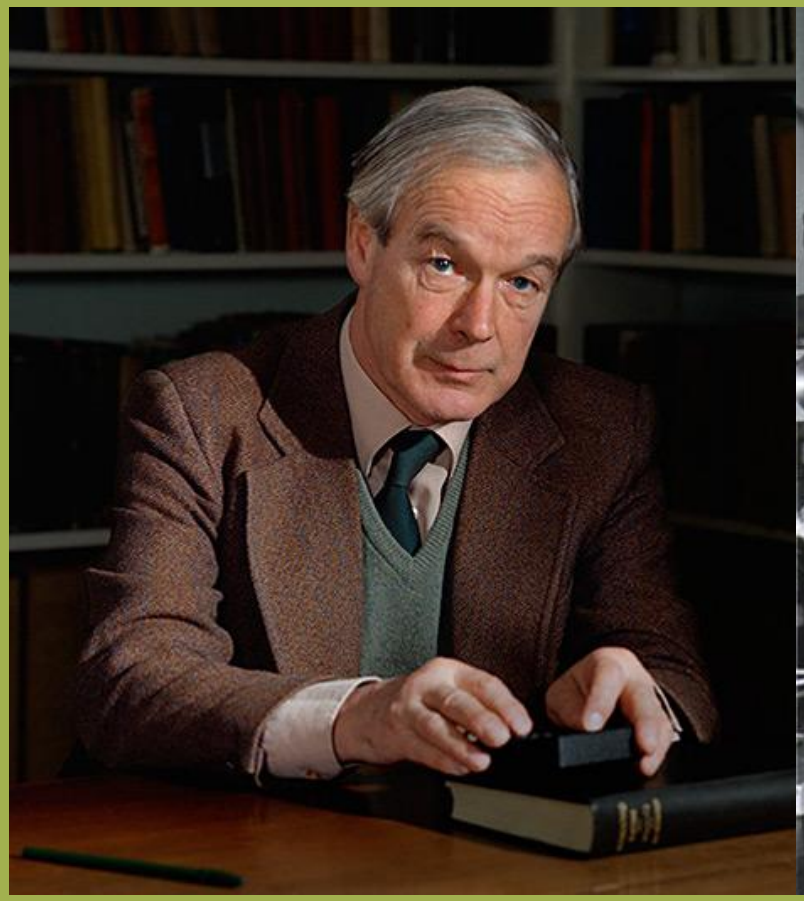
What we need to build models of neuronal information processing

OpenWorm

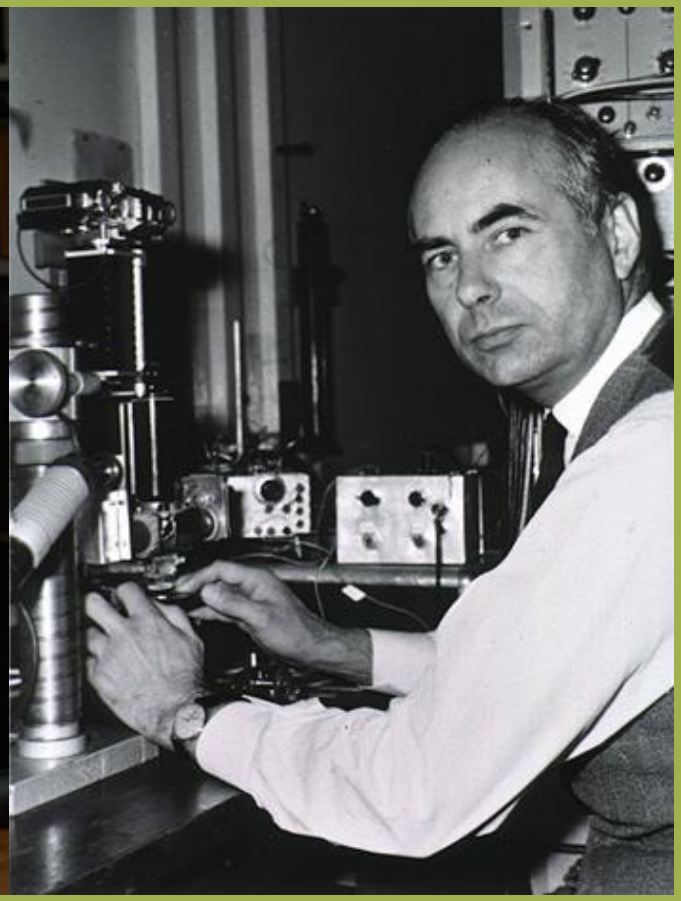
Why not C. elegans?

- Does it have neurons? Yes.
- Do the neurons have action potentials? No.
- Do the neurons still operate using similar biophysical processes? Yes.

Sir Alan Lloyd Hodgkin

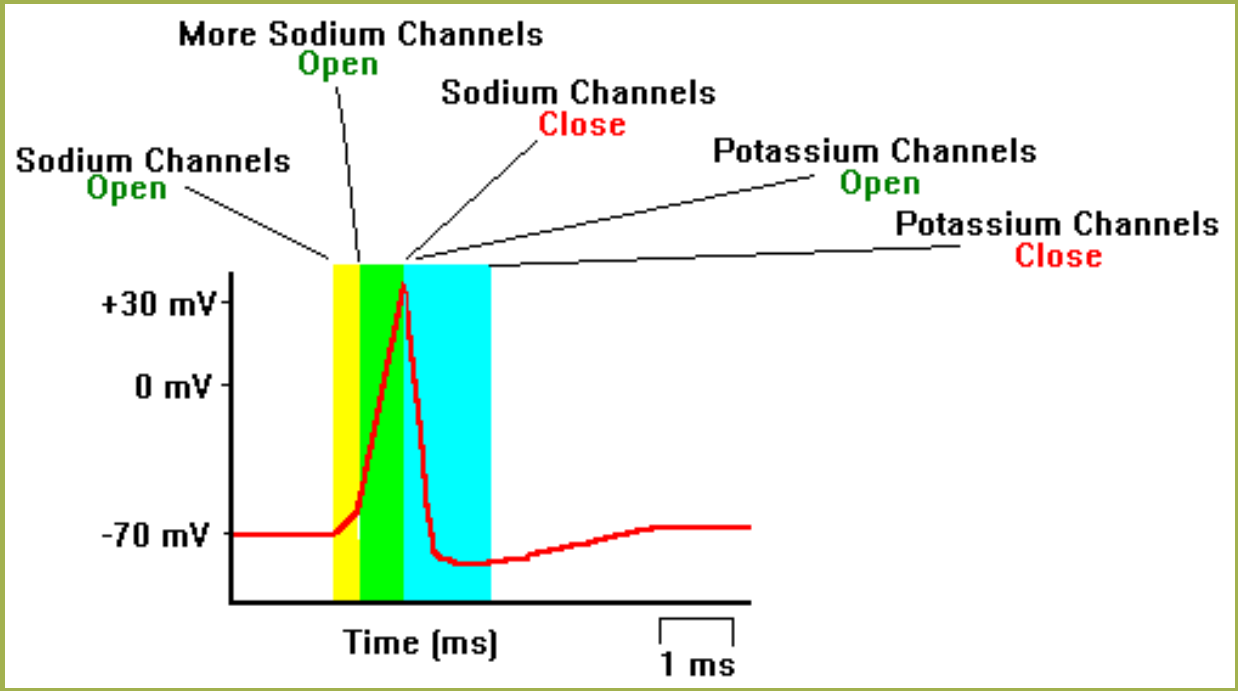


Sir Andrew Fielding Huxley



OpenWorm

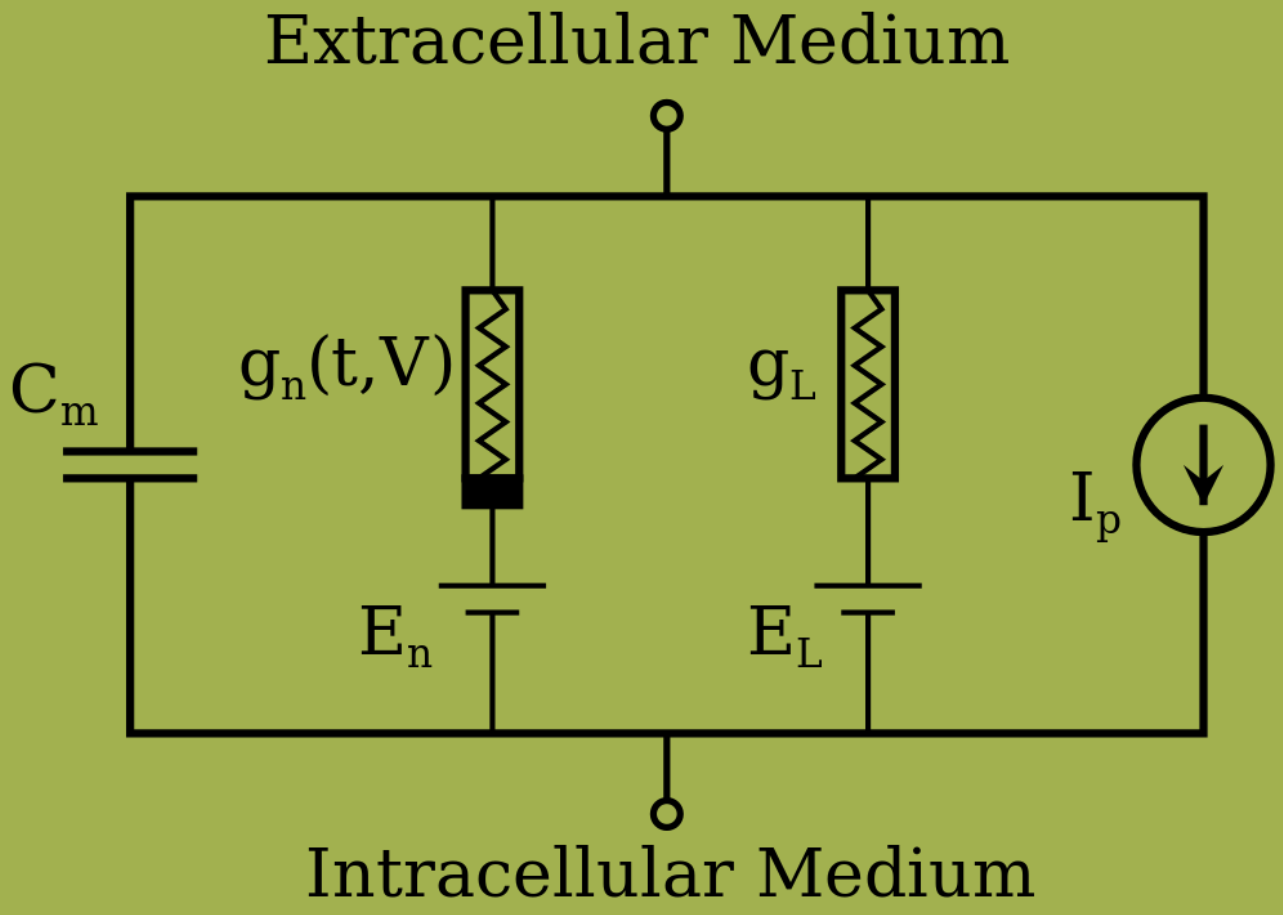
Hodgkin–Huxley model



- 1952 work by two British physiologists
- Awarded the 1963 Nobel Prize in Physiology / Medicine
- Describes how action potentials in neurons are initiated and propagated
- A set of nonlinear ODEs that approximates the electrical characteristics of excitable cells

OpenWorm

Hodgkin–Huxley model



OpenWorm

The functional atom of a neuronal signal is **not a "spike"**, it is a **change in membrane potential**

The structural atom of a neuron is **not** a **node in a graph**, it is an **ion channel**

Dynamics in HH-based models

- Signalling more complex than excitation and inhibition
- Action potentials with different widths
- Neuropeptide signalling
- Re-bound inhibition
- Calcium dynamics
- Dendritic spikes
- Back-propagating action potentials
- …also lends itself better to multiple-compartments

With an accurate biophysical model of a neuron, we could discard details **based on principles** rather than **pragmatism**

Tradeoffs in neuromorphic computing

Partial models of complex neuronal systems

vs

Holistic models of simpler neuronal systems

Response to the charge

- Why would one invest in neuro-inspired / neuromorphic computing over other alternative computing technologies?
  - Efficient computing architectures are embodied within neurons
  - Biological information processing is the result of billions of years of evolution -- tapping into a lot of valuable solutions to problems of information processing
- What are the big wins?
  - Building neuronal models that do what physics models do: accurately predict reality
- How long will it take to get there?
  - ?
- What are the critical path objectives?
  - Better data, more detailed modeling, more validation of detailed models against real data

Contributions

- Introduced the open science initiative of OpenWorm
- Explained the value of c. elegans as a model organism
- Described the target of closing the brain – body loop in c. elegans
- Showed past progress of the OpenWorm project
- Described over-arching ideas behind the pursuit of neuronal models that reproduce real behavioral output

Contact Info

http://openworm.org
@openworm

info@openworm.org