

NeuralEnsemble is a community-based initiative to promote and co-ordinate open-source software development in neuroscience.

# Software

NeuralEnsemble hosts a number of software projects for computational and systems neuroscience, including PyNN, Neo, Elephant, OpenElectrophy and libNeuroML, mostly hosted on GitHub.

NeuralEnsemble

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## Brian

Brian is a simulator for spiking neural networks available on almost all platforms. The main idea behind this project is that a simulator should not only save the time of processing, but also make it easier to work with neural models.



## Elephant

Elephant is a package for the analysis of neurophysiology data, using the Python language.



## Mozaik

An integrated workflow framework for large scale neural simulations.



## NEST

NEST is a simulator for spiking neural network models from small-scale microcircuits to brain-scale networks of the order of  $10^8$  neurons and  $10^{12}$  synapses. The same code can be used on a large range of architectures from laptops and workstations to HPC clusters and supercomputer.



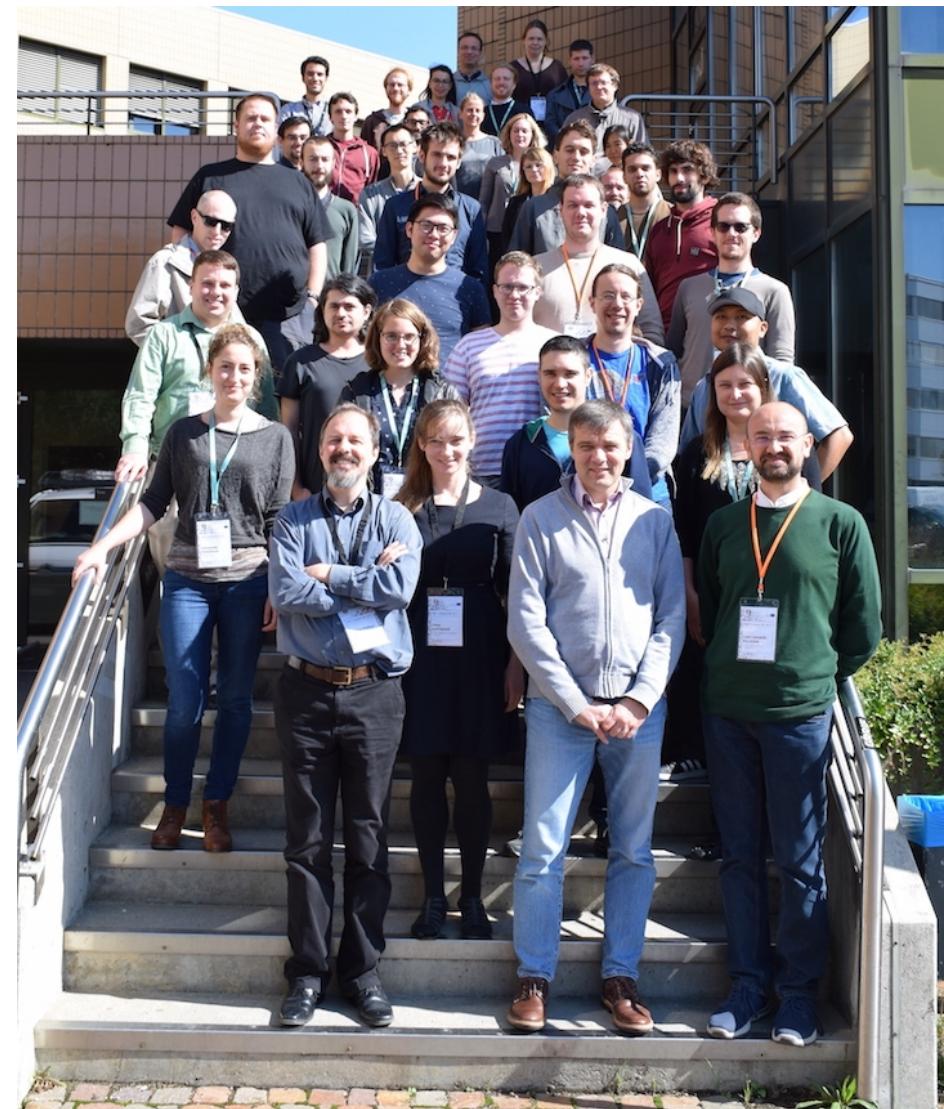
## Neo

Neo is a package for representing electrophysiology data in Python, together with support for reading a

## Workshops

We organize an annual "CodeJam" workshop, bringing together scientists, graduate students, and scientific programmers to share ideas, present their work, and write code together.

These workshops have been hugely effective in catalyzing open-source neuroscience software development.



## **Community**

There is a NeuralEnsemble Google group for discussion of collaborative neuroscience software development (mainly in Python, but users of other languages are welcome!) and to provide software support.

If you have any questions about any of the software hosted by NeuralEnsemble, please join the group and post a message in one of the forums.

**<https://groups.google.com/forum/#!forum/neuralensemble>**

# OpenWorm

<http://www.openworm.org>

OpenWorm aims to build the first comprehensive computational model of the *Caenorhabditis elegans* (*C. elegans*), a microscopic roundworm. With only a thousand cells, it solves basic problems such as feeding, mate-finding and predator avoidance. Despite being extremely well studied in biology, this organism still eludes a deep, principled understanding of its biology.

# 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's goals

Long term

Full scale **simulation** of an organism, **C. elegans**

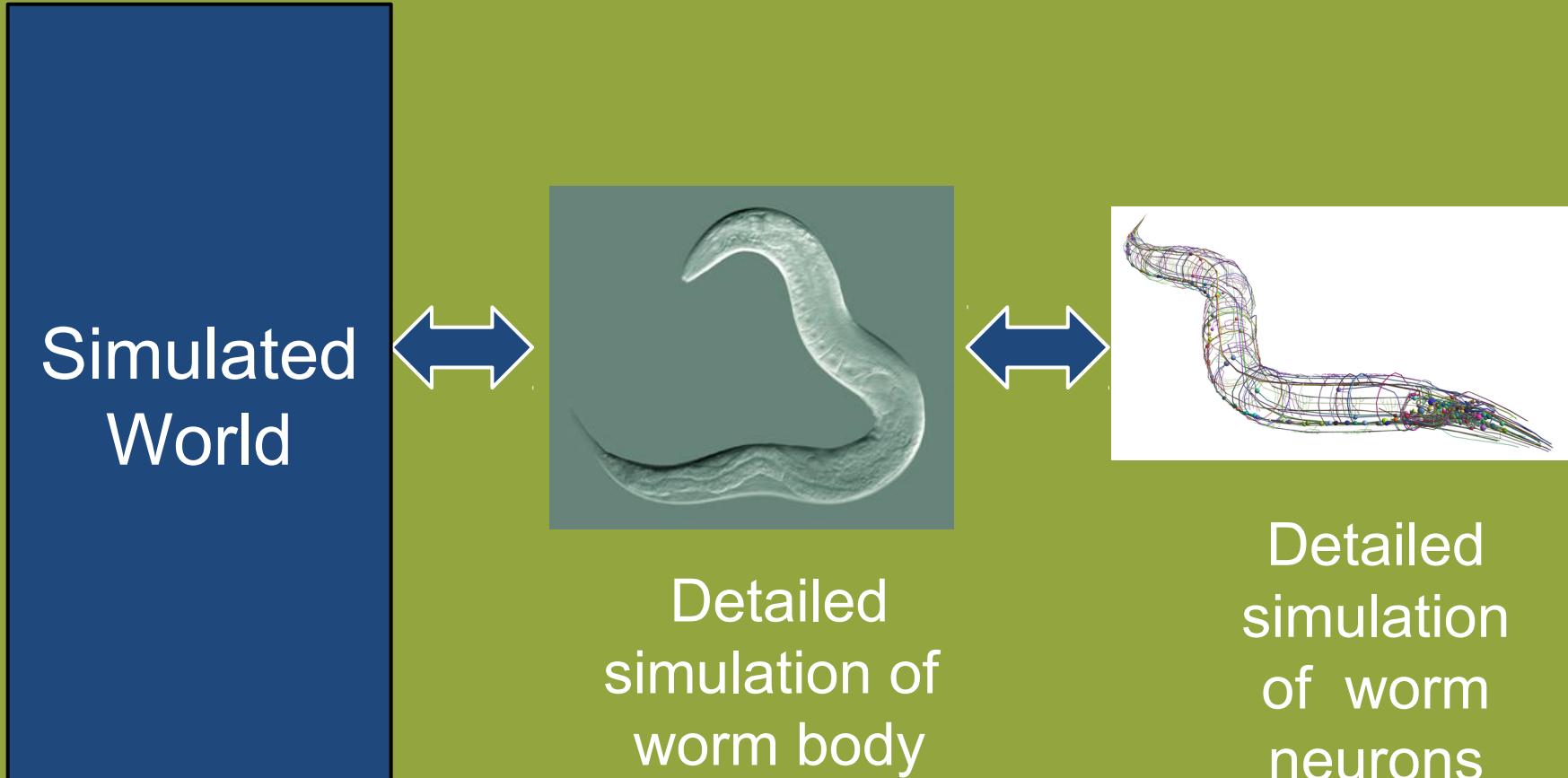
Medium term

Accurately predict simple **animal behavior** using a **computer model.**



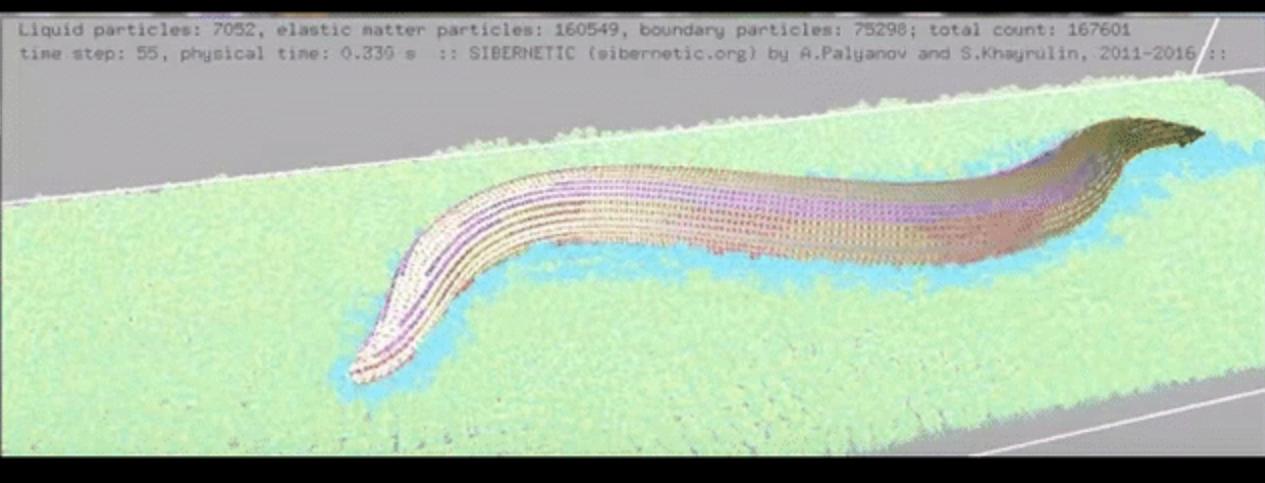
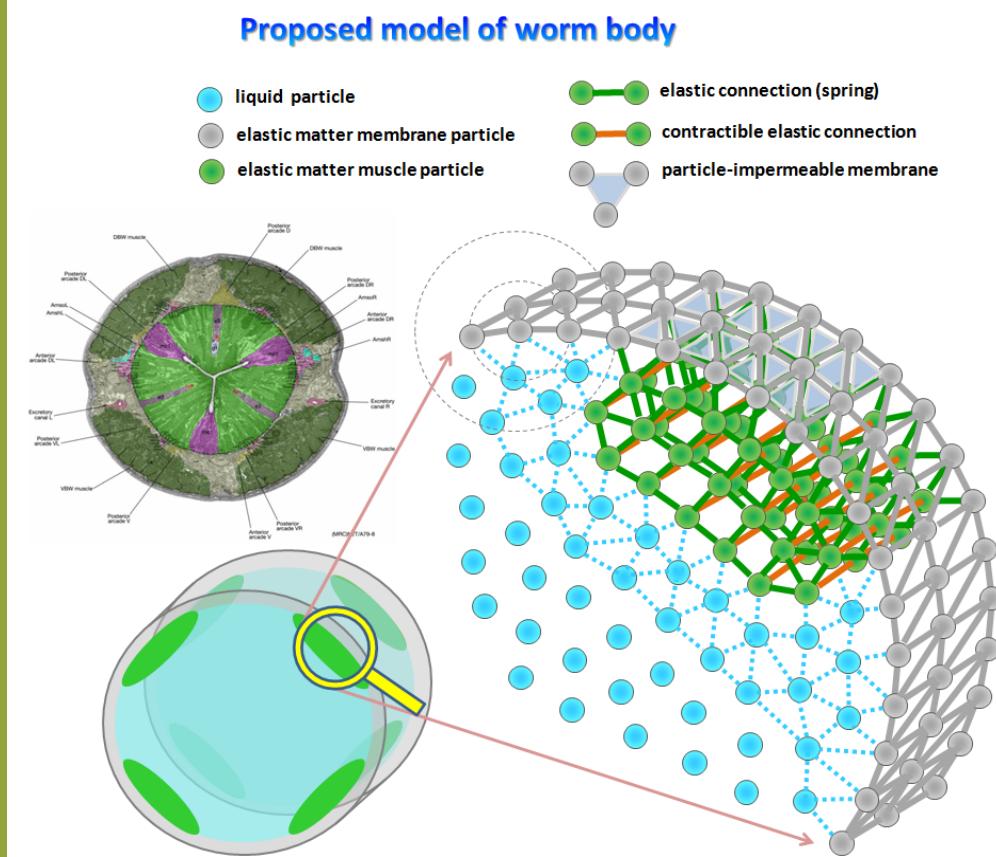
Szigeti et al.  
Front. Comp. Neuro., 2014

# A complete simulation of the worm's brain, body and environment





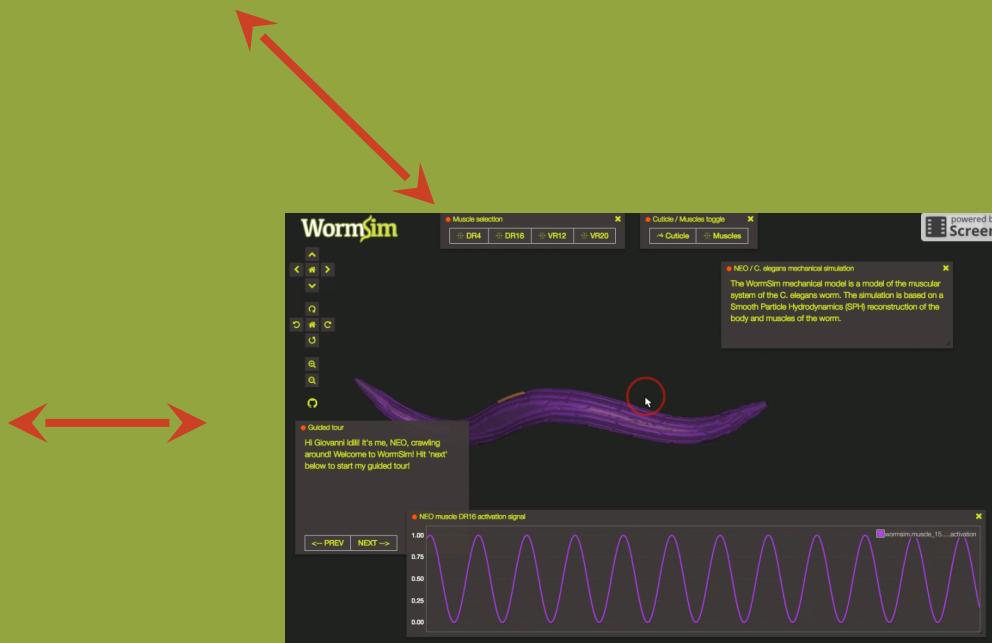
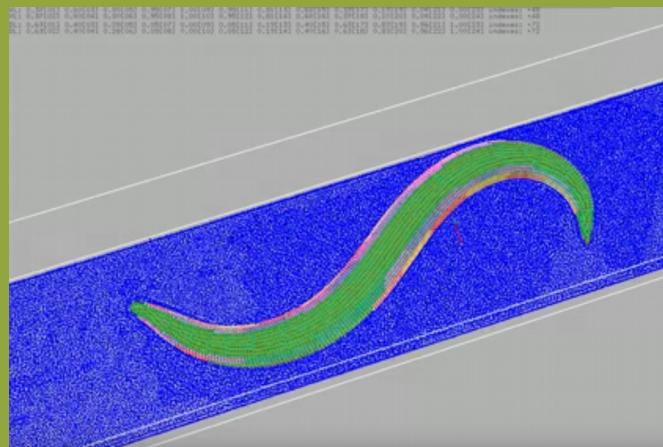
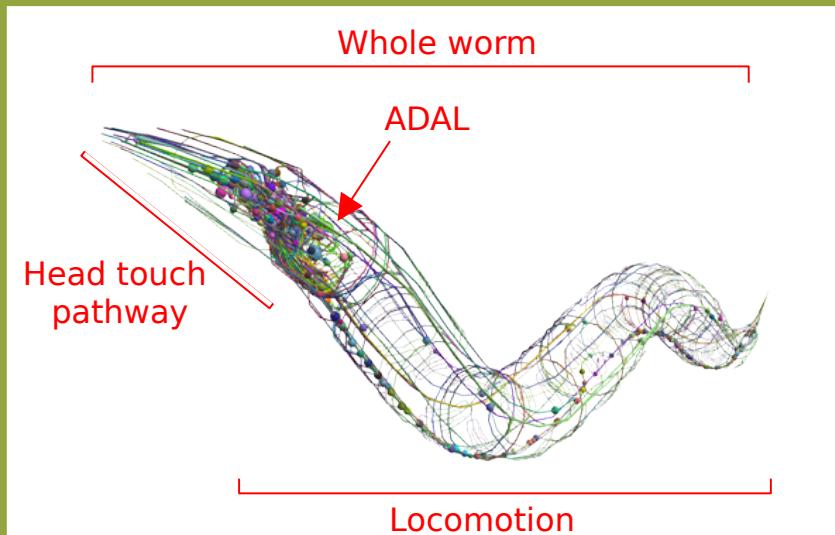
# SIBERNETIC



Palyanov, Khayrulin,  
(unpublished)

# c302

(Subsets of)  
302 cell  
neuronal  
network in  
NeuroML



**SIBERNETIC**

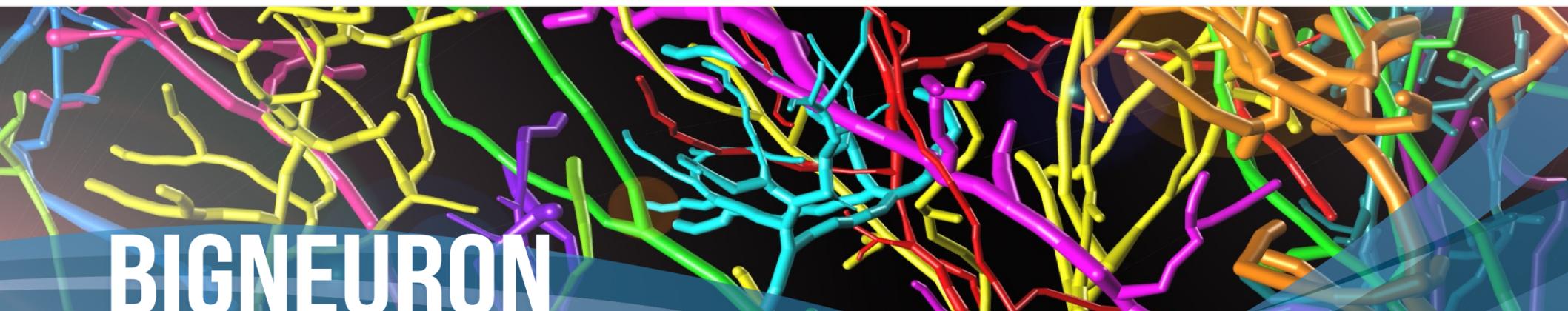


**WormSim**

# BigNeuron

<https://alleninstitute.org/bigneuron>

BigNeuron is a community effort to define and advance state-of-the-art of single neuron reconstruction: an essential unsolved challenge in brain science. The project will both standardize the methods to generate high quality and consistent data, and mobilize the reconstruction community to generate interest in solving these complex and interesting algorithmic problems.



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## OVERVIEW

### WHY DO WE NEED BIGNEURON?

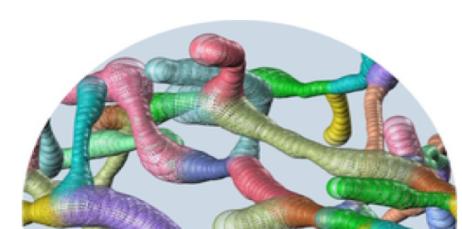
The three-dimensional shape of a neuron plays a major role in determining its connectivity, integration of synaptic inputs and cellular firing properties, and also changes dynamically with its activity and the state of the organism. Analyzing the three-dimensional shape of neurons in an unbiased way is critical to understanding how neurons function and developing applications to model neural circuitry.

### THE PROBLEM

Advances in brain cellular imaging have now yielded thousands of detailed images of neurons from dozens of different organisms stored in personal collections across the globe, comprising many petabytes of data. Dozens of different imaging paradigms and algorithms have now been generated for visualizing the 3D structure of neurons from labs around the world. In order for large data sets to be cross-compared, however, the neuroscience field needs standards – for collecting the data, for determining the acceptable levels of resolution that are most suitable for analysis, and for deciding which analysis approach is the most effective for the most important questions driving the field.

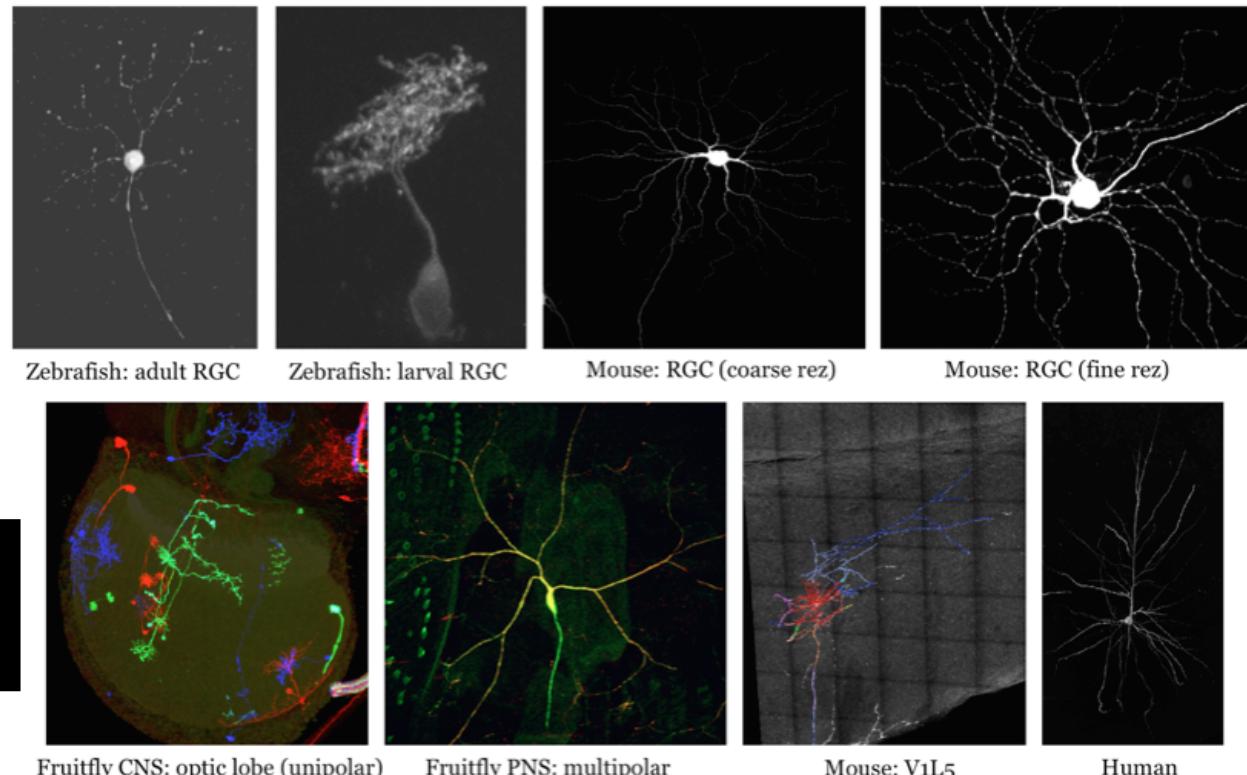
### THE SOLUTION

BigNeuron is a community effort to define and advance the state-of-the-art of single neuron reconstruction and analysis, and to create a common platform for analyzing 3D neuronal structures. The major goal of BigNeuron is to bench-test on a common open platform as many open-source, automated neuron reconstruction algorithms as possible with very large scale, publicly available single 3D neuron image data sets acquired by several light



# BigNeuron Initiative

- A community effort to find out what is exactly the state-of-the-art of single neuron reconstruction, standardize the protocols, and establish a Big Data resource for neuroscience.
- Phase 1 will be 1~1.5 year establishing the technical platforms (3 week-long algorithm-porting hackathons @Asia/Europe/USA, 1 week-long ground truth annotation workshop @ USA, bench-test on 3 fastest supercomputers in US and Europe based on 20k+ single neuron datasets, Open release and analysis of reconstructions).
- 29+ algorithms ported, 30,000+ neurons collected, 166 gold standard neuron reconstructions produced (6~7 annotators per neuron), ~140 silver standard annotations
- Sample images (see right)



Maebashi Institute of Technology

前橋工科大学



THE UNIVERSITY OF  
GEORGIA

Georgia



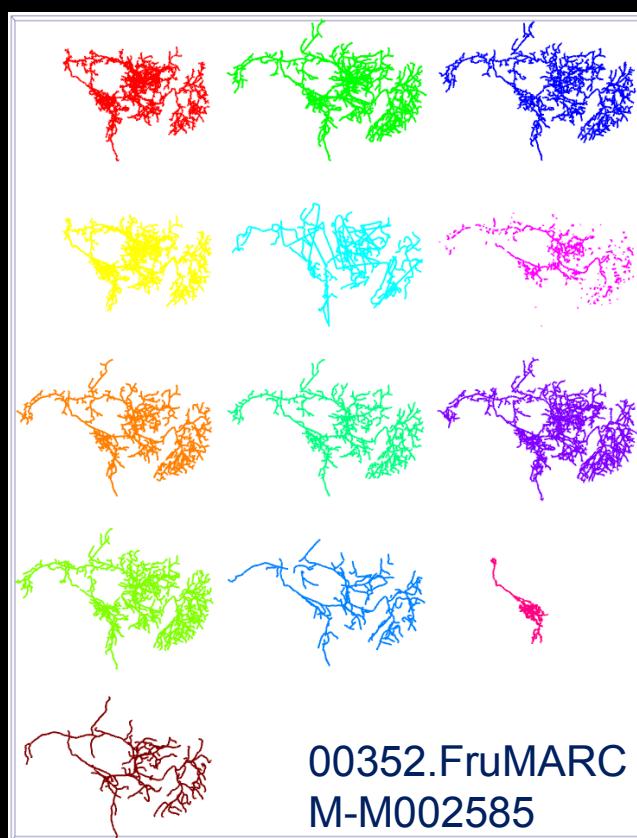
HUAZHONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

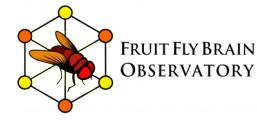


# ~50 Ported Neuron Tracing Algorithms and Implementations

- [https://docs.google.com/spreadsheets/d/1eU0QYomvs4SQVfFbnnnIdAYh0g-u\\_2ozqG6rFzW3isQ/edit#gid=1009169397](https://docs.google.com/spreadsheets/d/1eU0QYomvs4SQVfFbnnnIdAYh0g-u_2ozqG6rFzW3isQ/edit#gid=1009169397)
- Algorithms developed from different perspectives
- Other neuron preprocessing, utility, search, post-processing, visualization methods also ported

Snapshot of bench testing results





# Fruit Fly Brain Observatory

<http://fruitflybrain.org>

<https://github.com/fruitflybrain>

An open-source collaborative research platform that integrates biological data with computational models, and serves as a meeting ground for researchers to interactively explore fruit fly brain function in health and disease.



## Goals

- create an open platform for the emulation and biological validation of fruit fly brain models in health and disease,
- standardize tools for representation of fruit fly brain data and its abstractions,
- create a focus for the neuroscience community with interests in the fruit fly brain and encourage the sharing of fruit fly brain structural data and executable code worldwide.

## FlyBrainLab: An Interactive Computing Platform

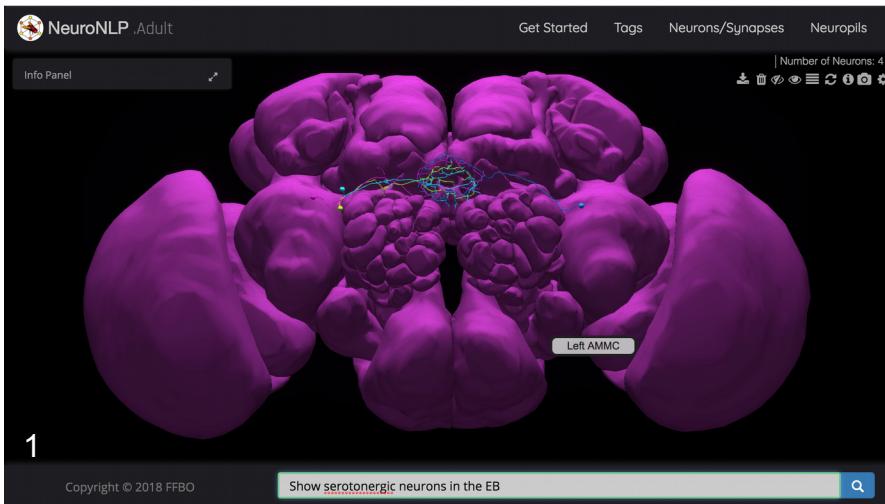
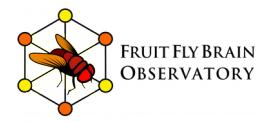
- an one-stop interactive computing platform for studying the function of executable circuits constructed from fly brain data. The **FlyBrainLab** is build upon
  - **NeuroArch**: a single database that integrates anatomical, genetic, neurophysiological data with computational models, providing location, morphology, connectivity and biophysical models of every neuron.
  - **Neurokernel**: a platform for the emulation of fruit fly brain circuits and their execution on GPUs.
  - **NeuroMynerva**: an interactive computing interface based on JupyterLab with a suite of highly integrated, user-friendly applications for data query, visualization and circuit execution.

## FFBO Standalone Tools/Applications

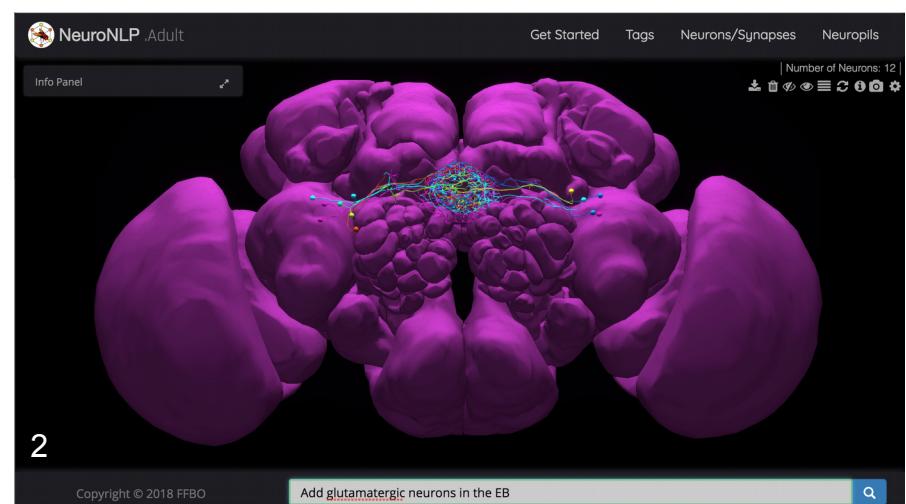
- **NeuroNLP**: seamlessly integrates structural and genetic data from multiple sources that can be intuitively queried, effectively visualized and extensively manipulated.
- **NeuroGFX**: creates executable brain circuit models anchored in structural data for understanding and developing novel hypotheses about brain function.

# NeuroNLP: Querying Fly Brain Data

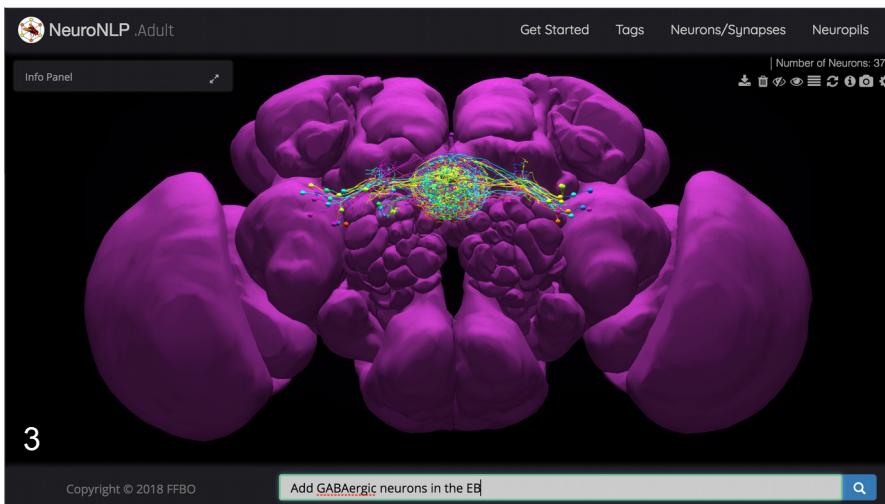
<https://neuronlp.fruitflybrain.org>



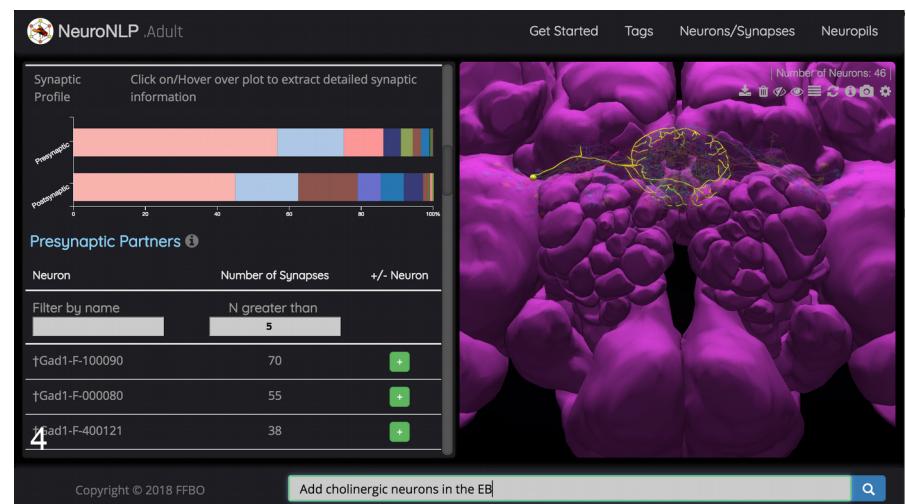
[Show serotonergic neurons in the EB](#)



[Add glutamatergic neurons in the EB](#)



[Add GABAergic neurons in the EB](#)



[Add cholinergic neurons in the EB](#)

NeuroNLP is a standalone tool for navigating fruit fly brain circuit data using **natural language queries**. A series of example queries are given above, and the final result can be tagged with a unique name (e.g., "EB\_v3\_step4"):

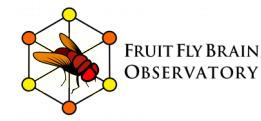
[https://neuronlp.fruitflybrain.org/index.html?tag=EB\\_v3\\_step4](https://neuronlp.fruitflybrain.org/index.html?tag=EB_v3_step4)

Additional Demos are available in the Exercises and on the NeuroNLP webpage (larva or adult)

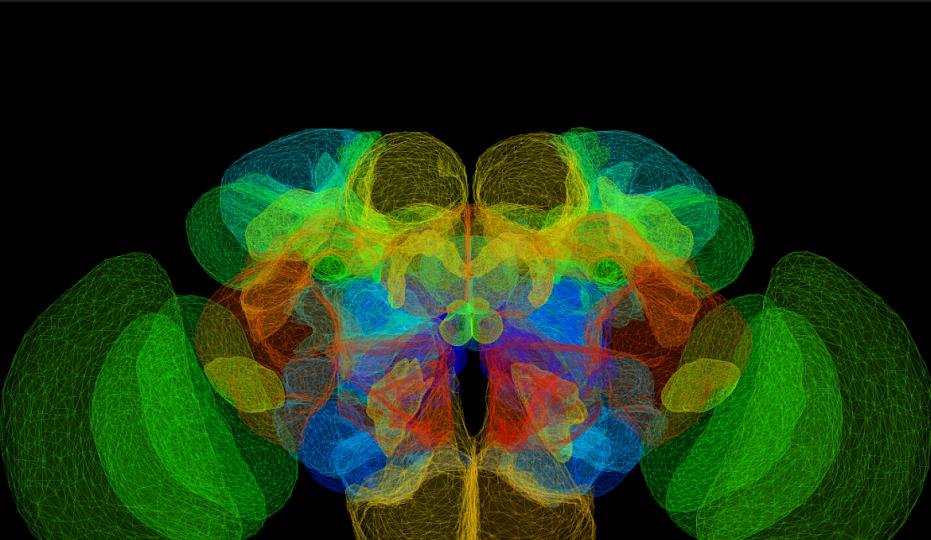
[NeuroNLP.adult](#) or [NeuroNLP.larva](#) >>> [Demos](#)

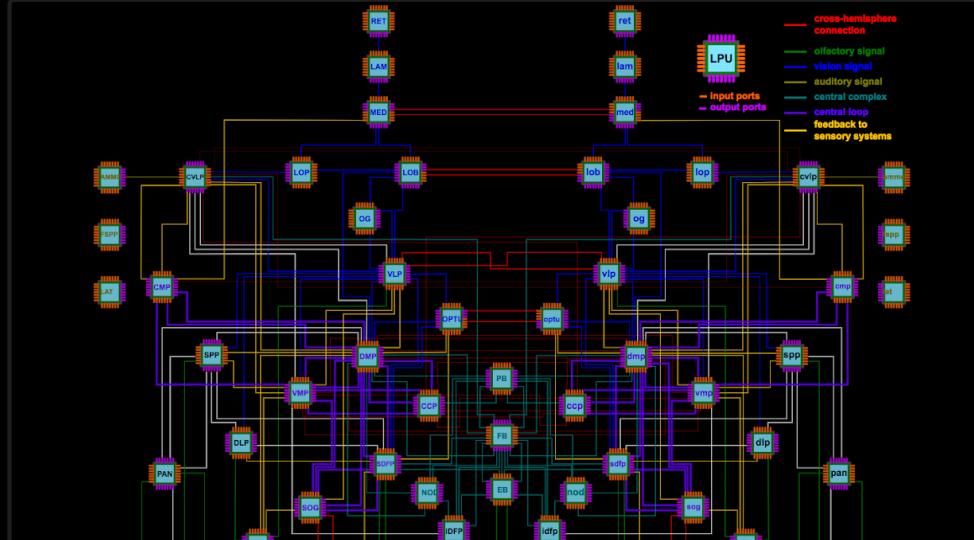
# NeuroGFX: Generating Executable Fly Circuit Models

<https://neurogfx.fruitflybrain.org>



FFBO NeuroGFXToggle LPUs Toggle Tracts Add All Remove All





The diagram illustrates the network of Local Processing Units (LPUs) in the fruit fly brain. Each LPU is represented by a small circuit board icon with various components and connection points. The connections between LPUs are color-coded according to the legend:

- Cross-hemisphere connection (red)
- Olfactory signal (green)
- Vision signal (blue)
- Auditory signal (yellow)
- Central complex (cyan)
- Input ports (orange dashed line)
- Output ports (purple dashed line)
- Central loop (purple line)
- Feedback to sensory systems (purple line)

The diagram shows a complex web of connections between various brain regions, including the RET, LAN, MED, LOB, LOP, DE, PFL, vlg, vlp, vmp, CCP, PFL, SPP, DLP, VMF, COG, NOD, IDP, EBD, dlp, mb, al, and ant.

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Whole Brain

NeuroGFX is a standalone tool for exploring the function of neural circuit models at three levels of abstraction: whole brain level, neuropil level and local circuit level.

The fruit fly brain shown on whole brain level on the left is typically decomposed into some 50 neuropils. The circuit diagram shown on the right depicts the network of Local Processing Units, each modeling a neuropil.

## Additional Links:

- [Neural Circuit Function at Neuropil Level: Antennal Lobe](#)
- [Neural Circuit Function at Local Circuit Level: A cartridge in the Lamina](#)

# Interactive Computing with FlyBrainLab



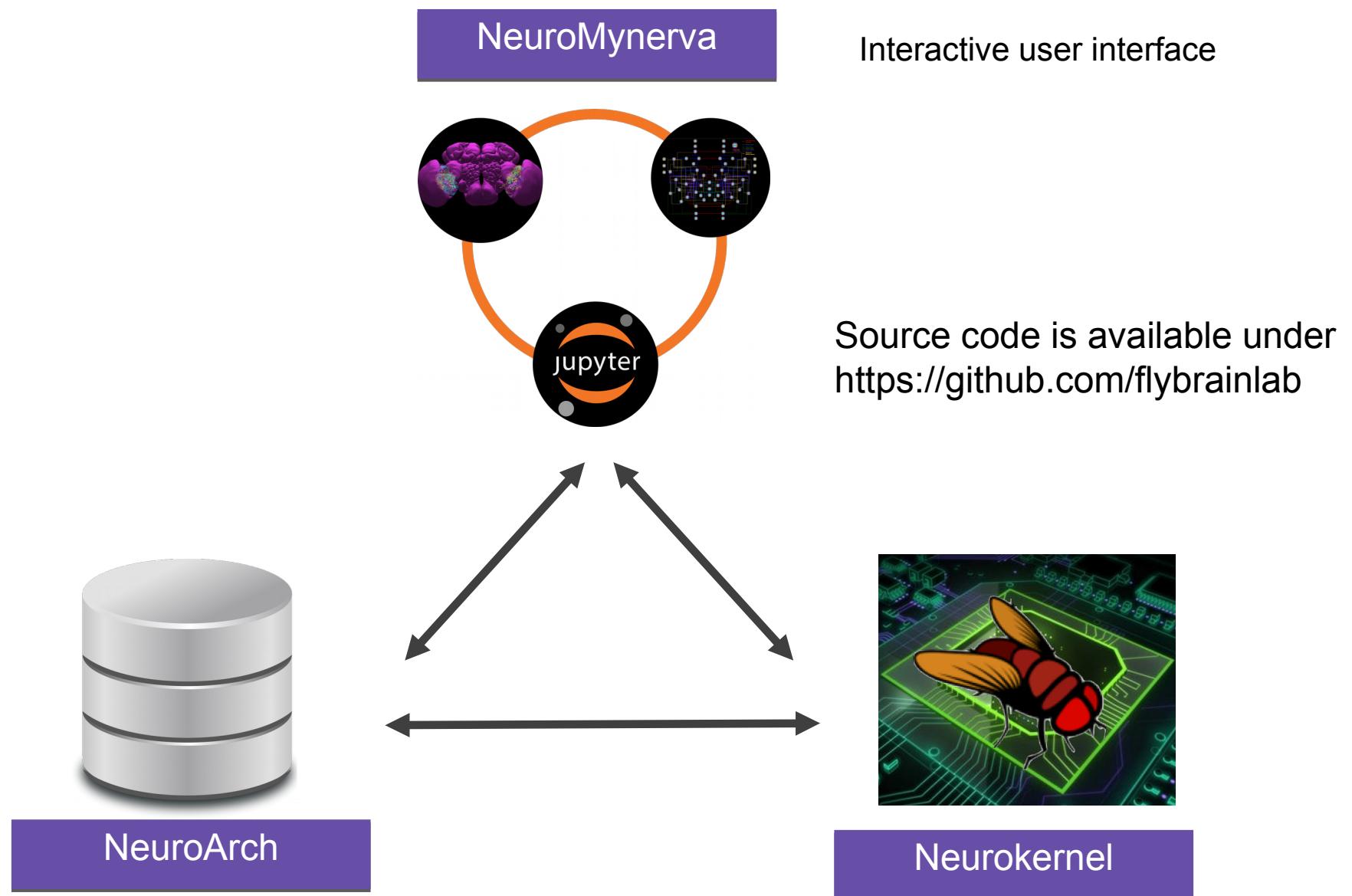
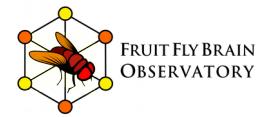
The screenshot displays the FlyBrainLab interface within a JupyterLab environment. On the left, a sidebar provides access to various tools and documentation. The main area features several panels: a central search bar with the placeholder "show neurons that connect lobula to optic glomeruli"; a "Select a node..." dropdown menu listing biological entities like "array [285]", "Cha-F-600012", "VGlut-F-700020", "fru-F-100081", and "Gad1-F-900055"; a "Notebook" panel titled "Untitled4.ipynb" containing code cells; and two visualization panels: "Neu3D" showing a 3D brain model with highlighted neural pathways, and "GFX" showing a detailed circuit diagram with various components and connections.

FlyBrainLab is an *in silico* workbench that enables the exploration of fly brain function directly from biological data. It integrates the NeuroArch database and the Neurokernel emulation platform with a JupyterLab-based interface, and allow users to query biological data, construct executable circuits and analyze execution results interactively.

Users have full access to all commands and data in workspace both by using graphical interface and by executing code in Jupyter Notebooks.

***If desired, all panels interactively respond to commands from another panel.***

# FlyBrainLab: Under The Hood



Representation and manipulation  
of neural circuits

Massively parallel execution of neural  
circuits on GPUs