

# Building the Functional Map of the Fruit Fly Brain

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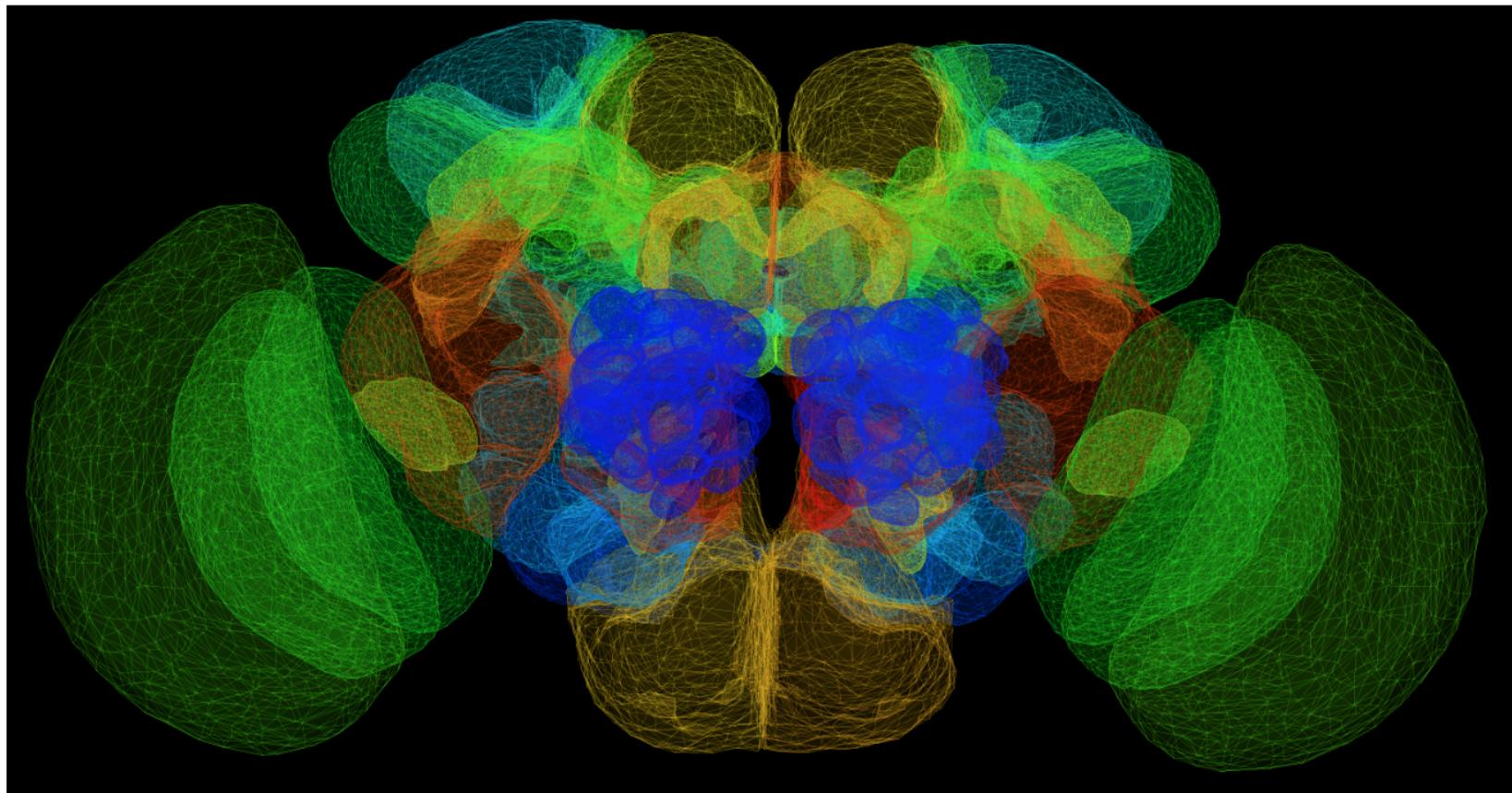
June 22, 2019

# Part I

## From Brain Structure to Function

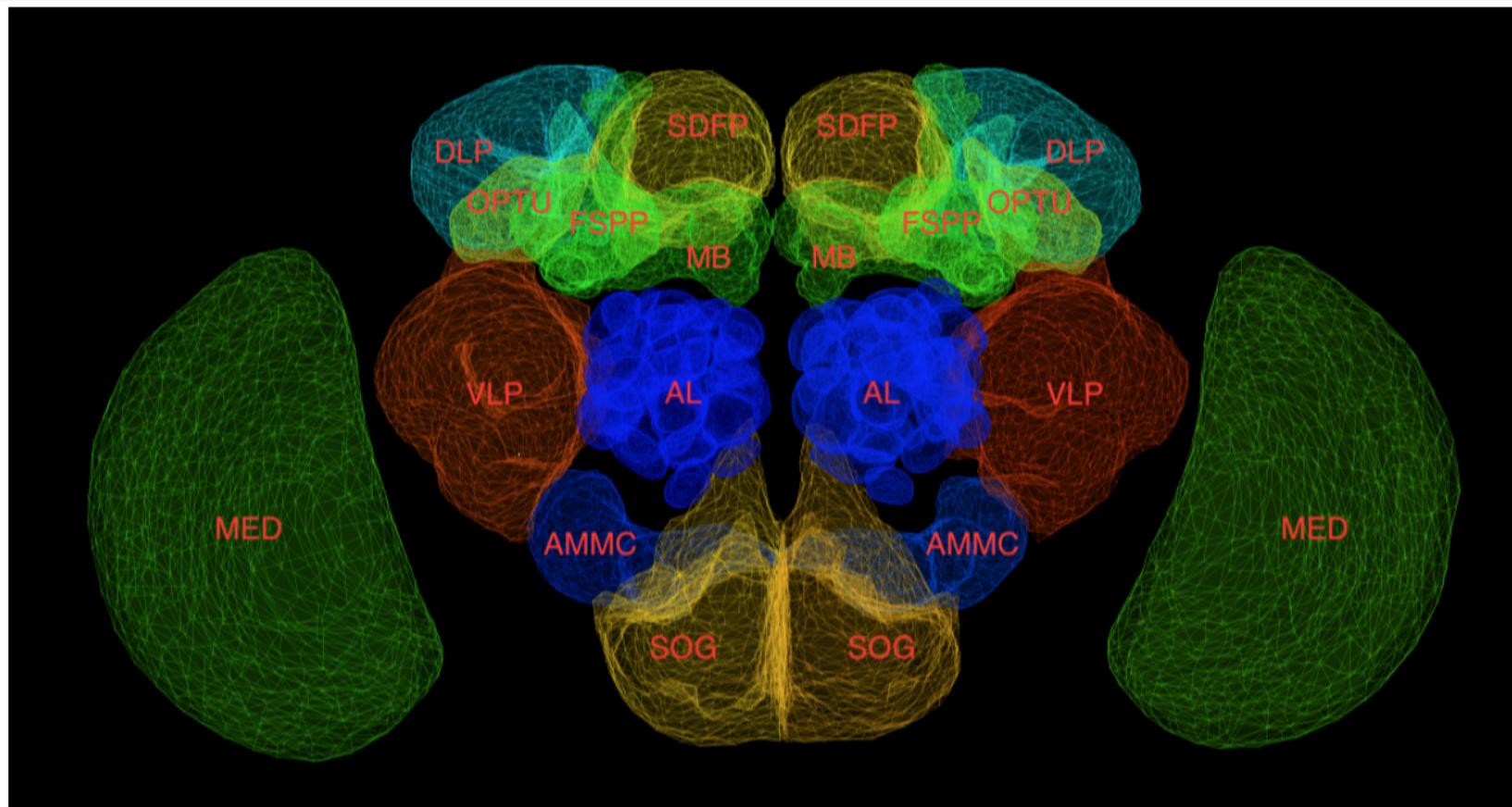
# The Neuropils of the Fruit Fly Brain

3D View



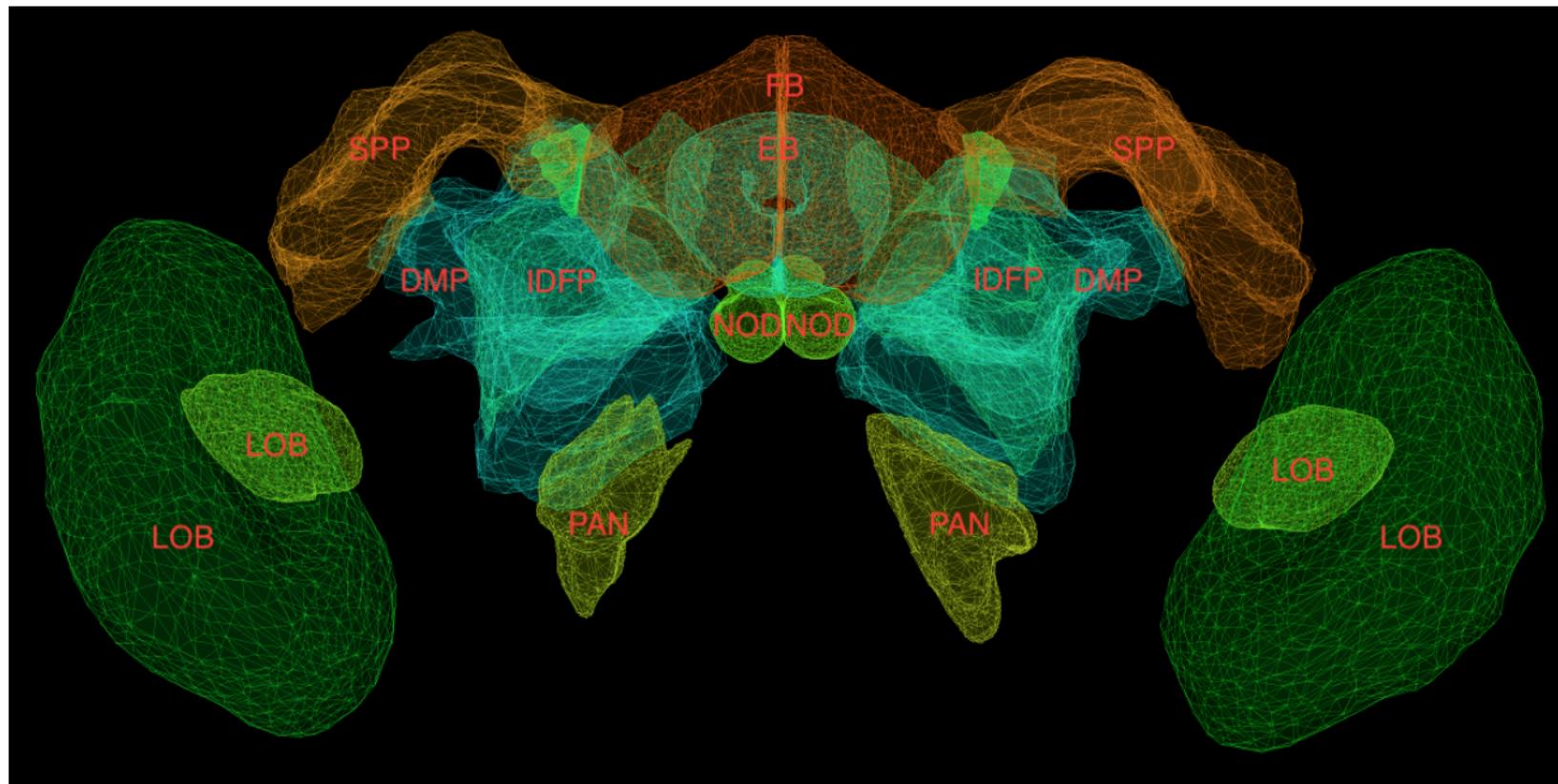
# The Neuropils of the Fruit Fly Brain (cont'd)

Front View



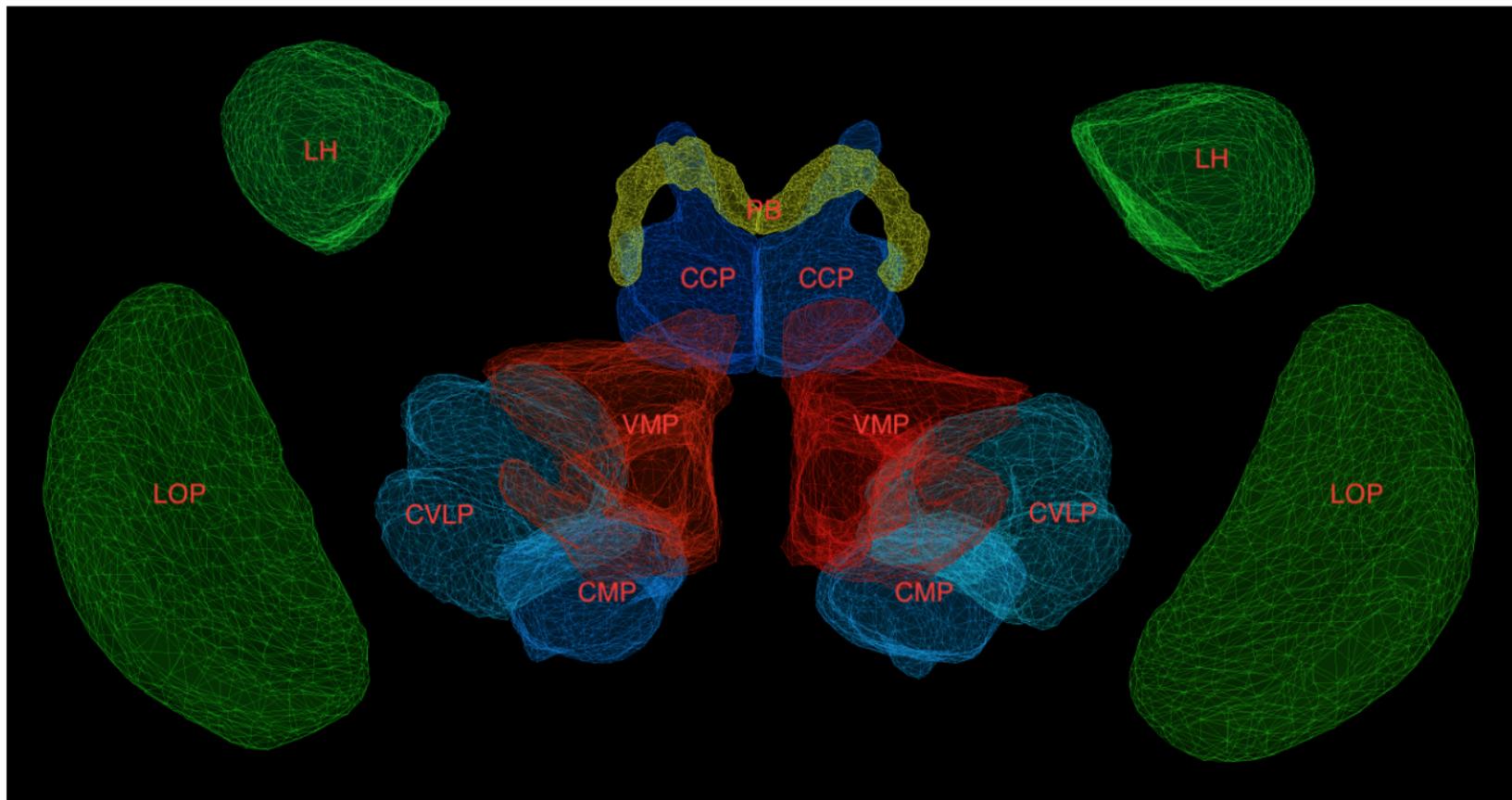
# The Neuropils of the Fruit Fly Brain (cont'd)

Mid View



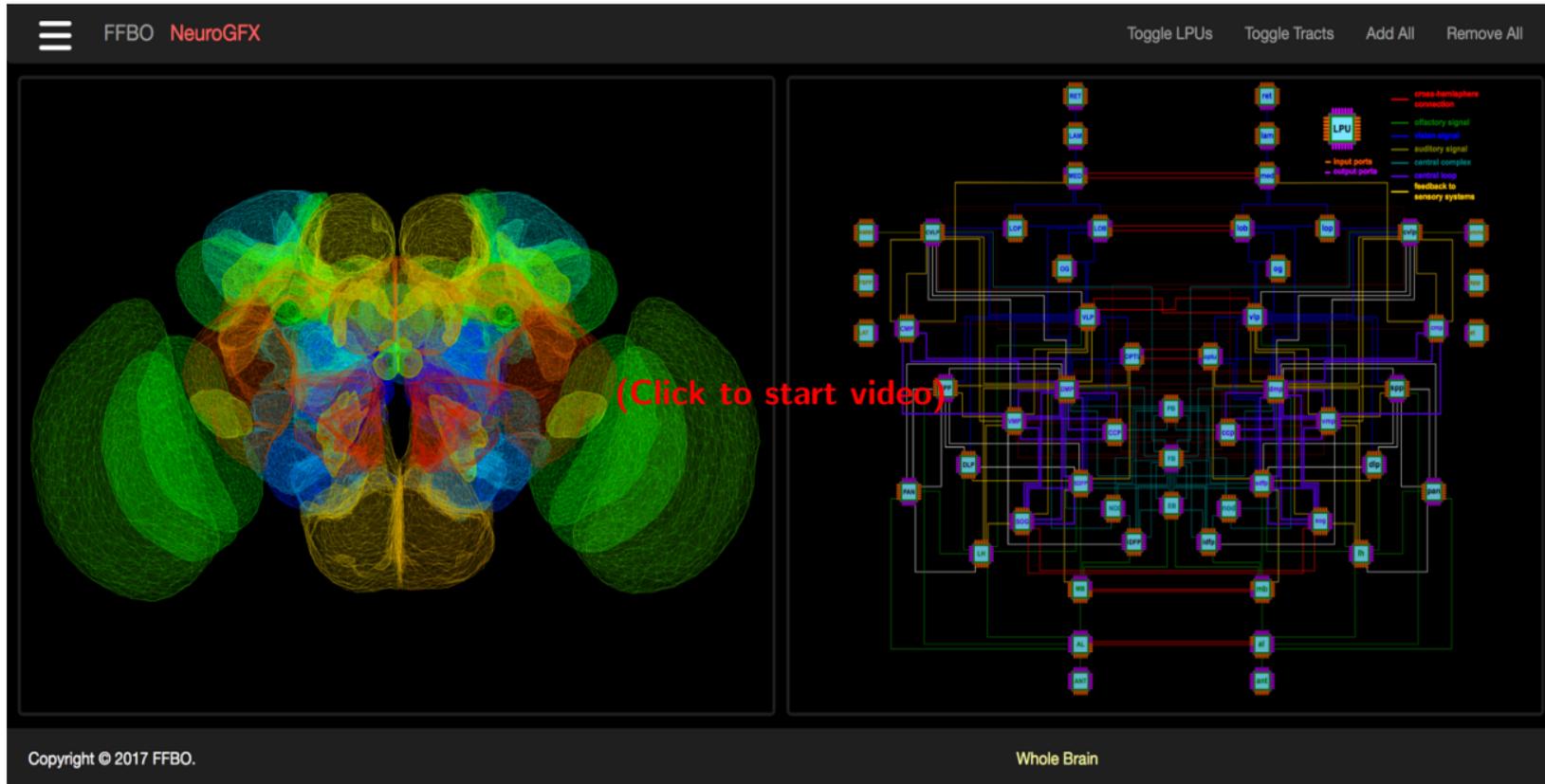
# The Neuropils of the Fruit Fly Brain (cont'd)

Back View



# From Brain Structure to Function

## Modeling Computational Units of the Fruit Fly Brain



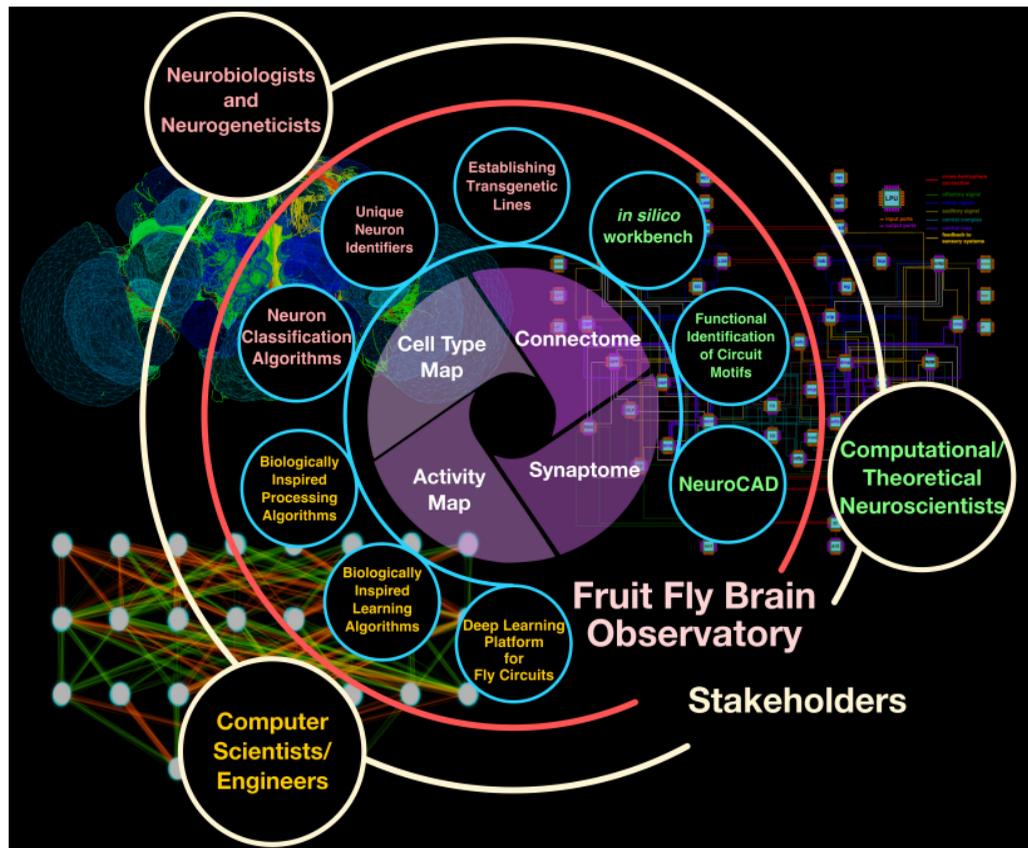
The **functional map** of the fruit fly brain is the collection of canonical circuits and their I/O behavior evaluated at different levels of abstraction.

Characterizing the functional map is a central goal of three key stakeholders:

- **neurogeneticists and neurobiologists** exploring the state of the art of *Drosophila* genetics, anatomical and neurophysiological data as it pertains to classes of neurons, neural circuits, and behavior,
- **computational/theoretical neuroscientists** interested in executable models of neural circuits in health and disease and, more broadly, in the logic of computation with neural circuits, and
- **computer scientists/engineers** interested in using biological networks to improve machine learning and deep learning models and algorithms.

# Building the Functional Map of the Fruit Fly Brain: Key Stakeholders (cont'd)

Fruit Fly Brain Observatory (FFBO): An Open Collaborative Ecosystem

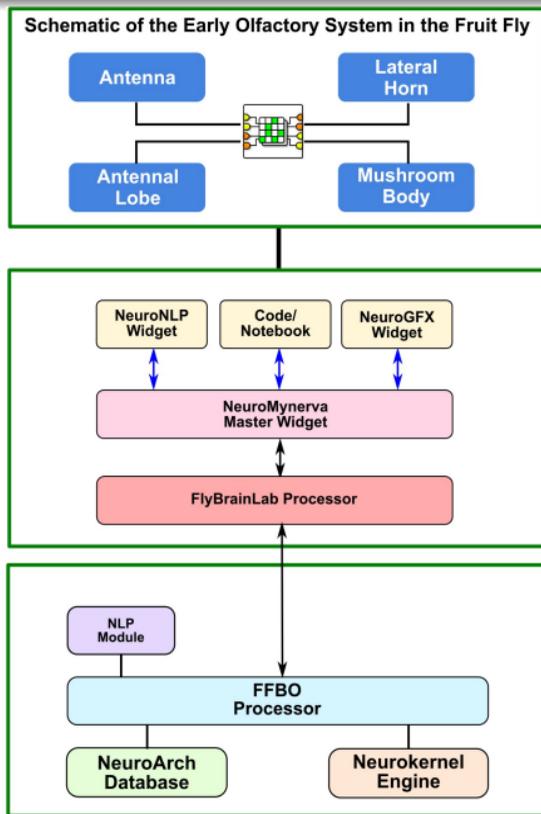


FFBO provides a

- hub for storing & integrating fruit fly brain research data from worldwide data sources,
- unified repository of tools and methods to build, emulate and compare fruit fly brain models in health and disease,
- an open framework for fruit fly brain data processing and model execution.

# FlyBrainLab: Interactive Computing Platform for Evaluating Executable Brain Circuits

Think of “Matlab” for Fruit Fly Brains



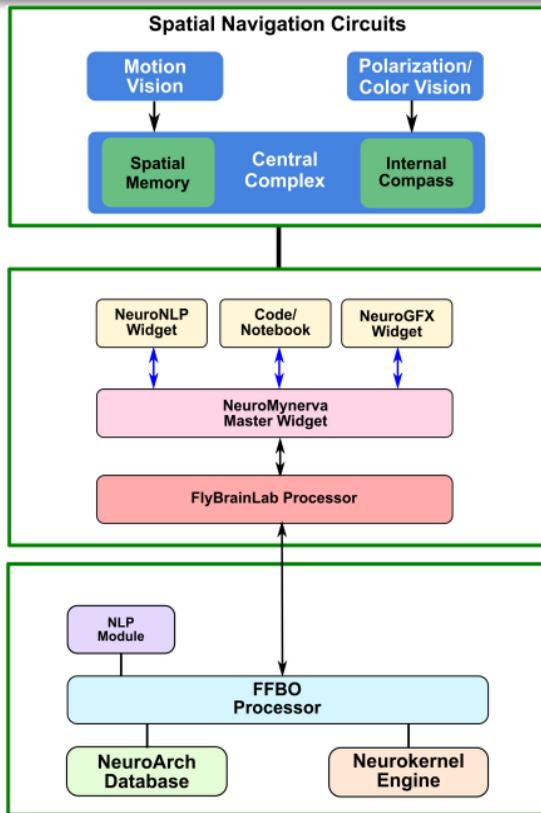
FlyBrainLab (FBL) systems architecture.

Underlying the FBL architecture are 3 key building blocks.

- **NeuroArch Database:** hosts both biological data and computational models of fly brain circuits.
- **Neurokernel Engine:** supports massively parallel execution of fly brain circuits on GPUs.
- **NeuroMinerva:** interactive computing interface based on JupyterLab with a suite of highly integrated applications for data query, visualization and circuit execution.

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## Part II

# Exploring Fruit Fly Brain Circuits with NeuroNLP

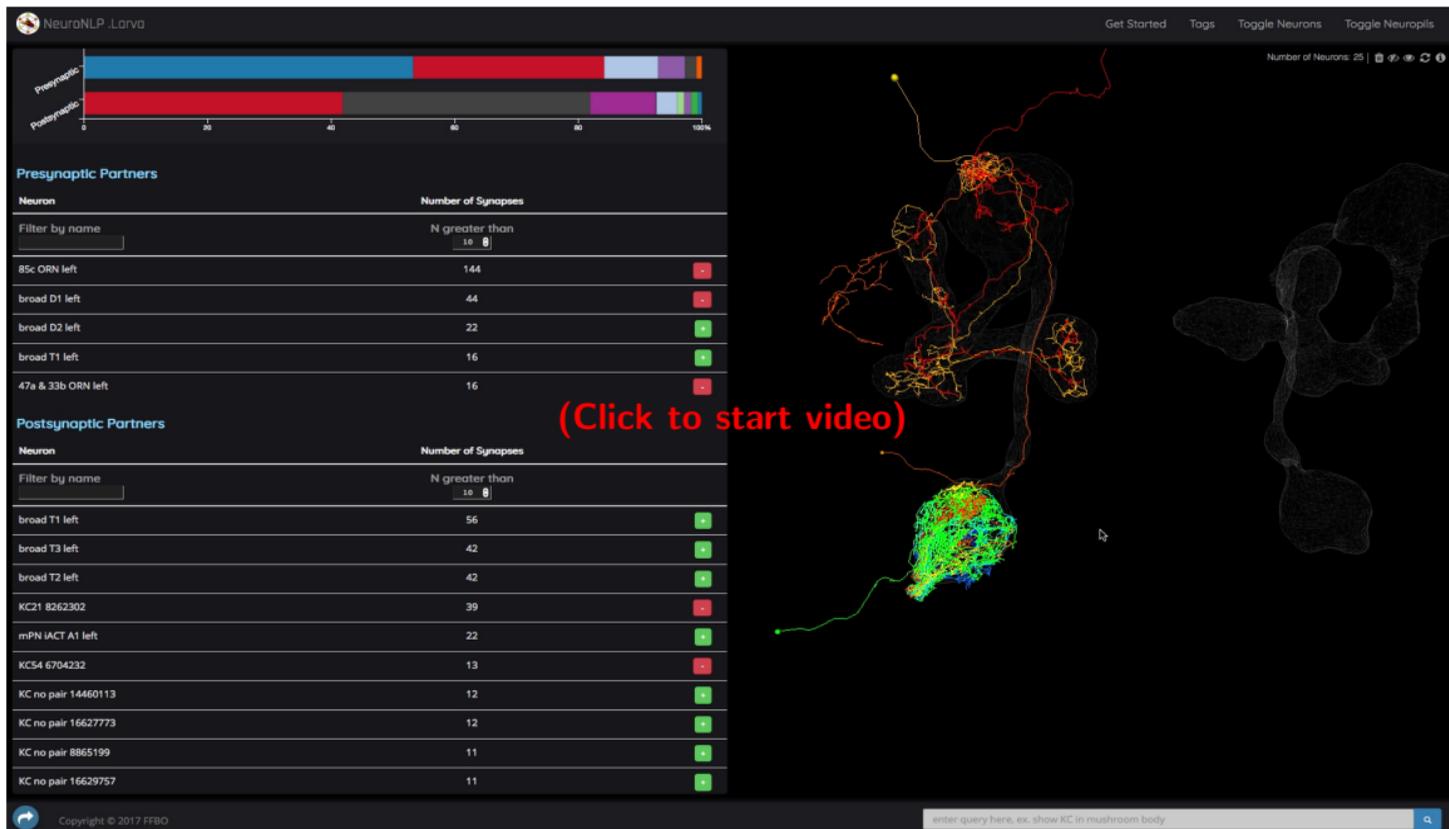
NeuroNLP is a **unique natural language user interface** for querying the NeuroArch fly brain database that

- enables in-depth exploration and investigation of brain structure, using intuitive **plain English queries**,
- provides powerful interactive visualization of neural circuits functionality,
- integrates neural circuits data from multiple sources,
- provides a modern web-based portal for navigating fruit fly brain circuit data,
- **can be accessed from any browser supporting WebGL on laptops and smartphones (<https://neuronlp.fruitflybrain.org>).**

Here, we provide examples outlining capabilities of NeuroNLP to:

- Visualize the **early olfactory system** of *Drosophila* larvae, showing OSNs, PNs, MBONs and DANs;
- Display the early visual system of adult *Drosophila* and focus on the **motion detection pathway**, starting with the L1 neurons and following up to Mi1 and T4 neurons;

# Visualization of the Larva Early Olfactory System



# Visualization of the Lamina Cartridge > Medulla Column L1 > Mi1 > T4 Neurons

NeuroNLP .Adult

Get Started Tags Neurons/Synapses Neuropils

Number of Neurons: 7

### Postsynaptic Partners ⓘ

| Neuron         | Number of Synapses | +/- Neuron | +/- Synapses |
|----------------|--------------------|------------|--------------|
| Filter by name | N greater than     |            |              |
| T4             | 5                  |            |              |
| T4b-home       | 41                 | -          | +            |
| T4c-A          | 37                 | -          | +            |
| T4a-home       | 36                 | -          | +            |
| T4d-home       | 31                 | +          | +            |
| T4a-A          | 20                 | +          | +            |
| T4c-E          | 16                 | +          | +            |
| T4d-F          | 13                 | +          | +            |
| T4c-B          | 11                 | +          | +            |
| T4d-B          | 9                  | +          | +            |

(Click + to start video)

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enter query here, ex. show gabaergic local neurons in ellipsoid body

## Part III

# FlyBrainLab: Building the Functional Map One Circuit at a Time

# FlyBrainLab

Think of "Matlab" for Fruit Fly Brains

The screenshot displays the FlyBrainLab interface with several key components:

- Local File I/O:** A file explorer on the left showing a directory structure with files like 'lib', 'node\_modules', 'src', 'style', 'package-lock.json', 'package.json', 'README.md', and 'tsconfig.json'.
- Database Query:** A central window with a search bar and a table of results. The table lists nodes with IDs and names, such as 'E0585-F', 'Tdc2-F-1', 'Cha-F-16', 'E0585-F', 'VGLut-F-900051', 'E0585-F-100007', 'VGLut-F-200478', 'Cha-F-600136', and 'F049C-F-300000'.
- Model emulation & Output Evaluation:** A code editor window showing Python code for interacting with the FlyBrainLab client, including comments and import statements.
- Morphology:** A 3D visualization of a fruit fly brain with neurons highlighted in purple and green.
- Executable Circuit:** A network diagram showing connections between neurons, labeled as 'Whole Brain'.
- Connectomics & Genetic:** A table listing neurons and their connections, including columns for Name, Direct., and Number.

| Name          | Direct. | Number |
|---------------|---------|--------|
| fru-F-500296  | pre     | 1      |
| fru-F-400056  | pre     | 1      |
| fru-F-800010  | pre     | 1      |
| fru-F-600052  | pre     | 1      |
| Cho-F-7000... | pre     | 1      |
| VGLut-F-60... | pre     | 1      |
| VGLut-F-60... | pre     | 1      |
| Cho-F-6000... | pre     | 1      |
| God1-F-600... | pre     | 1      |
| God1-F-500... | pre     | 1      |

# Exploring the Functionality of the Central Complex

The screenshot displays the FlyBrainLab software interface, which is divided into several panels. At the top left, there is a search bar labeled "Enter NLP query...". Below it, a "Select a node" section shows a list of nodes, including "object [0]" and "(empty object)". To the right of the search bar is a code editor window titled "Untitled98.ipynb" with a Python 3 kernel, containing a single line of code: "In [ ]:". The bottom left panel shows a 3D model of a fruit fly brain, rendered in a purple color, with a "Default" dropdown menu and a "Number of Neurons: 0" indicator. The bottom right panel shows a complex neural circuit diagram with numerous nodes and connections, labeled "Whole Brain". A red text overlay "(Click to start video)" is positioned in the center of the interface.

# Exploring the Functionality of the Central Complex (cont'd)

The screenshot displays the FlyBrainLab software interface, which is used for exploring the functionality of the Central Complex in a fruit fly brain. The interface is divided into several panels:

- Top Left:** A search bar labeled "Enter NLP query..." and a list of nodes to select. The list includes:
  - array [66]
  - 0 : TH-F-300013
  - 1 : Gad1-F-700099
  - 2 : Tdc2-F-100014
  - 3 : VG1ut-F-200478
  - 4 : Gad1-F-200210
  - 5 : VG1ut-F-300342
  - 6 : Trh-F-500196
  - 7 : 5HT1A-F-300018
  - 8 : 5-HT1B-F-400007
- Top Right:** A Python code editor window with the following code:

```
In [27]: from cxditor import *
neuron = '/PB/l1/g-l1/LHB/b'
generate_svg((neuron, fout='cx_ex_LHB.svg'))
nm[8].sendSVG('cx_ex_LHB', 'cx_ex_LHB.svg')
nm[8].loadSVG('cx_ex_LHB_v1sual')
```
- Bottom Left:** A 3D visualization of the fruit fly brain, showing the Central Complex (CC) in a purple color. The CC is a complex structure with many neurons, and the visualization shows the connections between them. A tooltip indicates "Number of Neurons: 66".
- Bottom Right:** A schematic diagram of the Central Complex, showing the various neurons and their connections. The diagram is labeled "Whole Brain >> Central Complex".

**(Click to start video)**

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