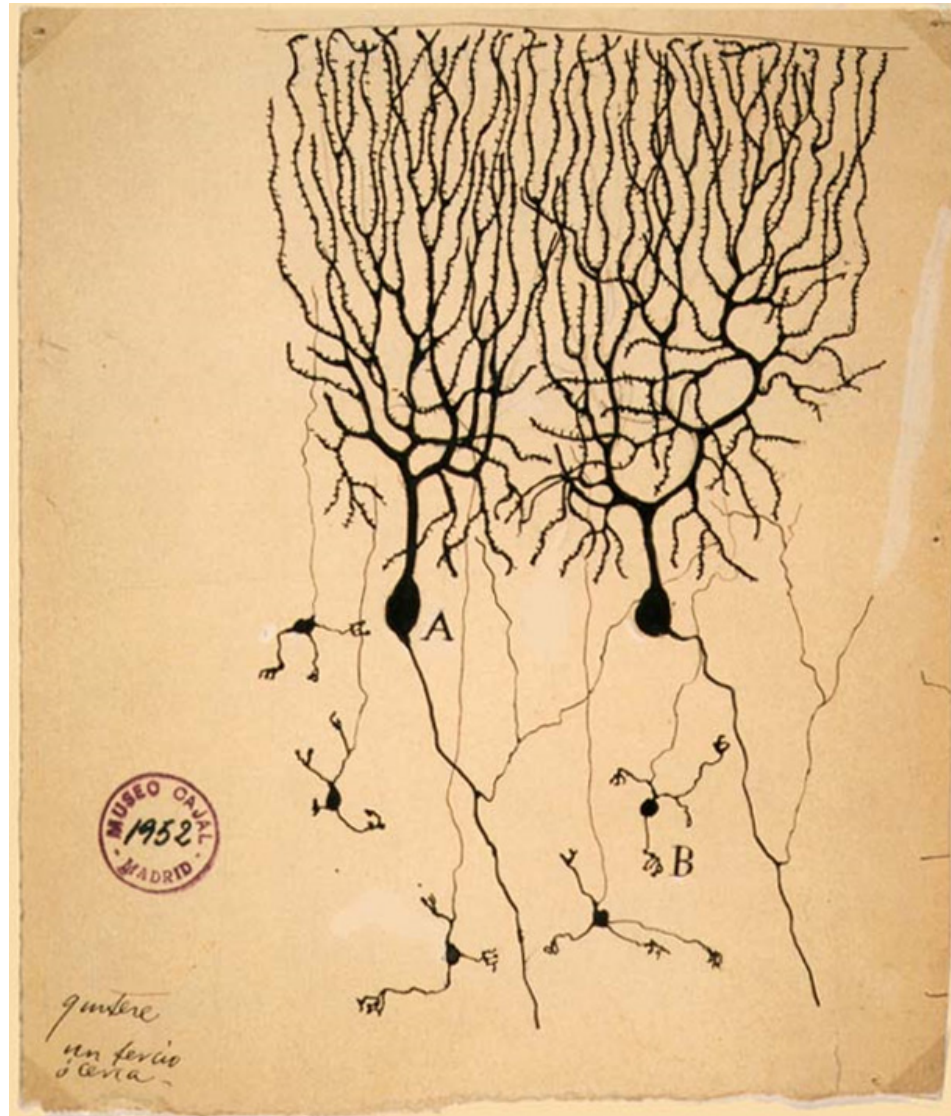


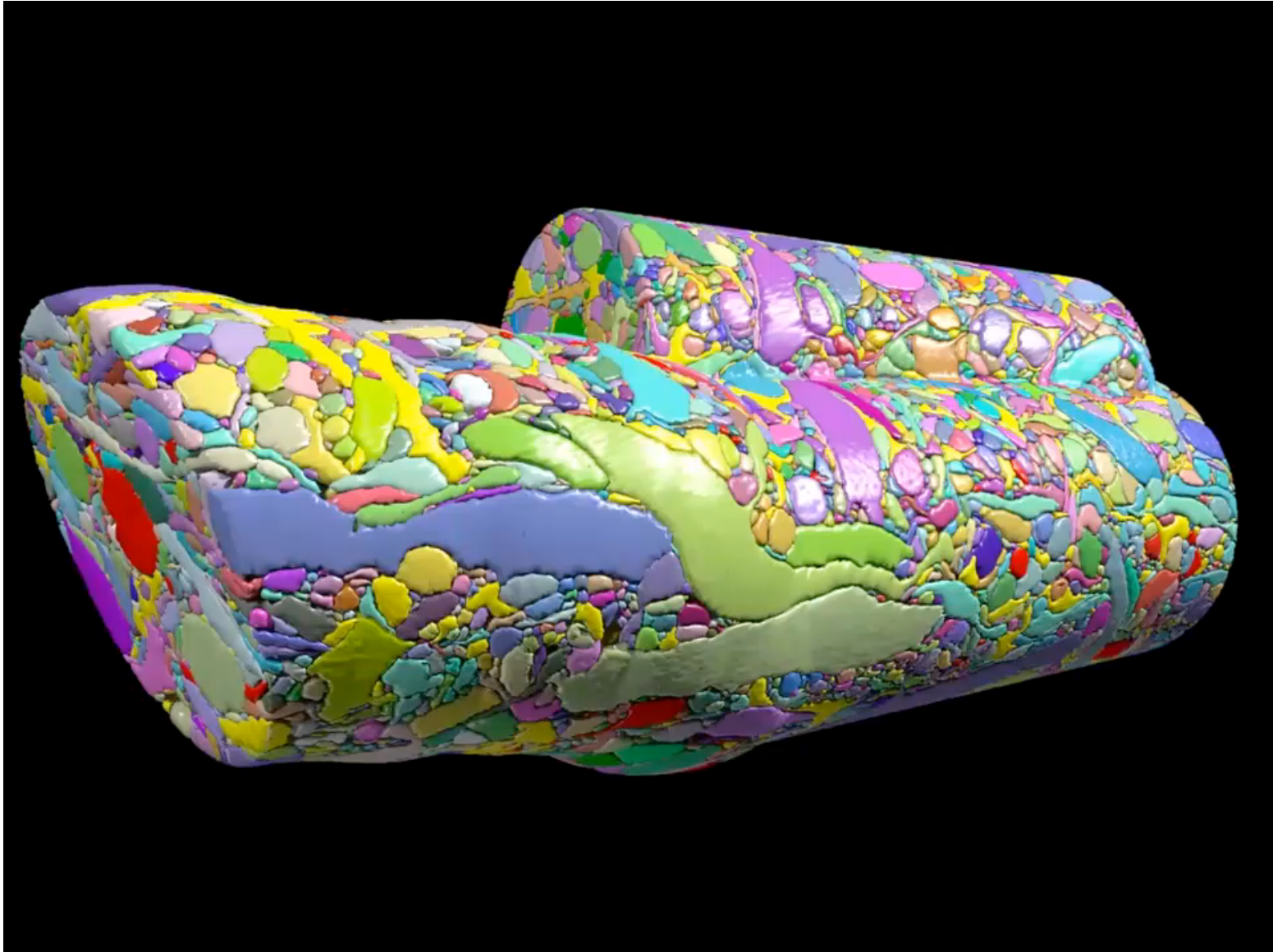
CSE 40171: Artificial Intelligence



The Brain: Neural Computation

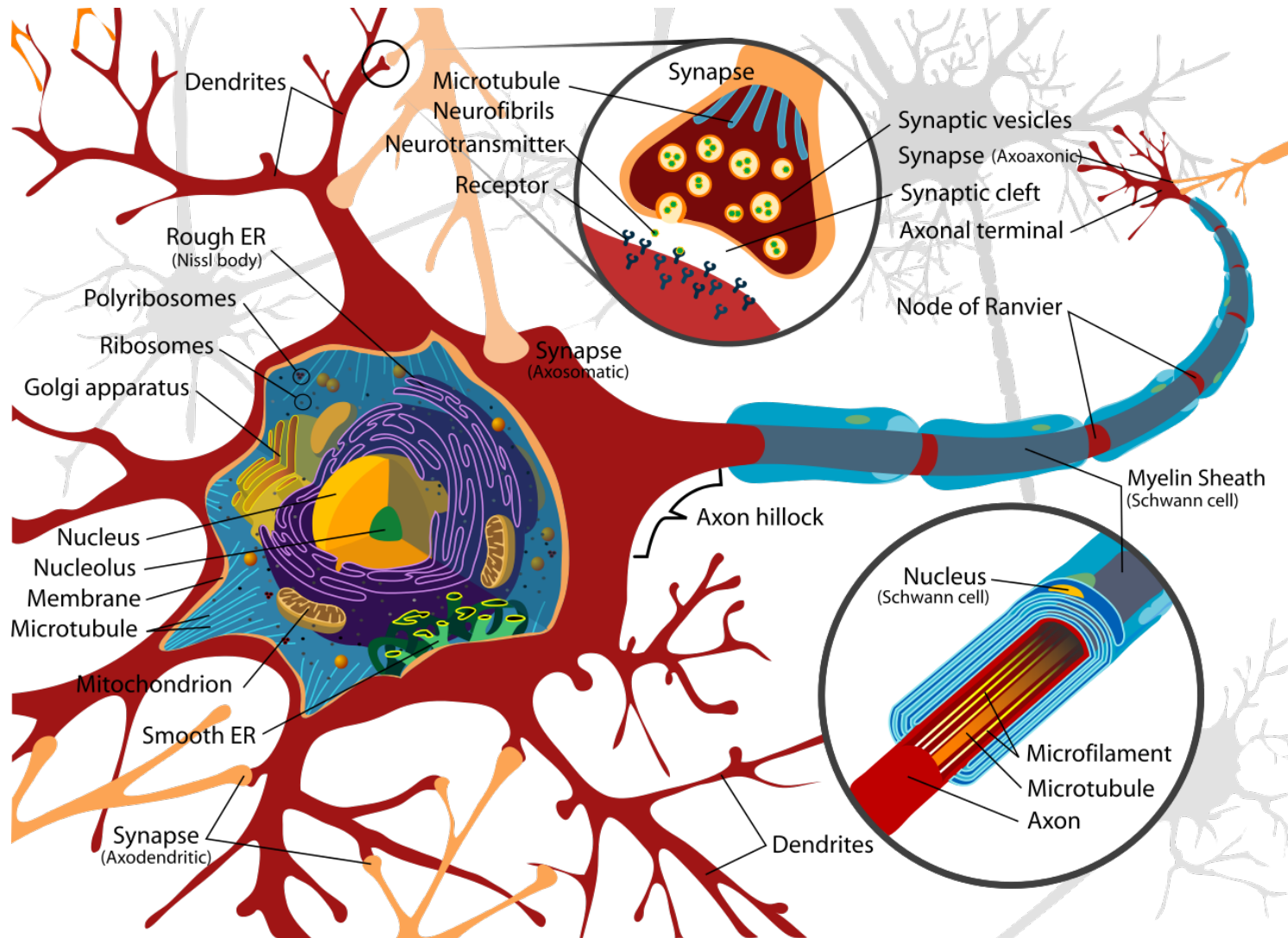
The brain at the circuit level



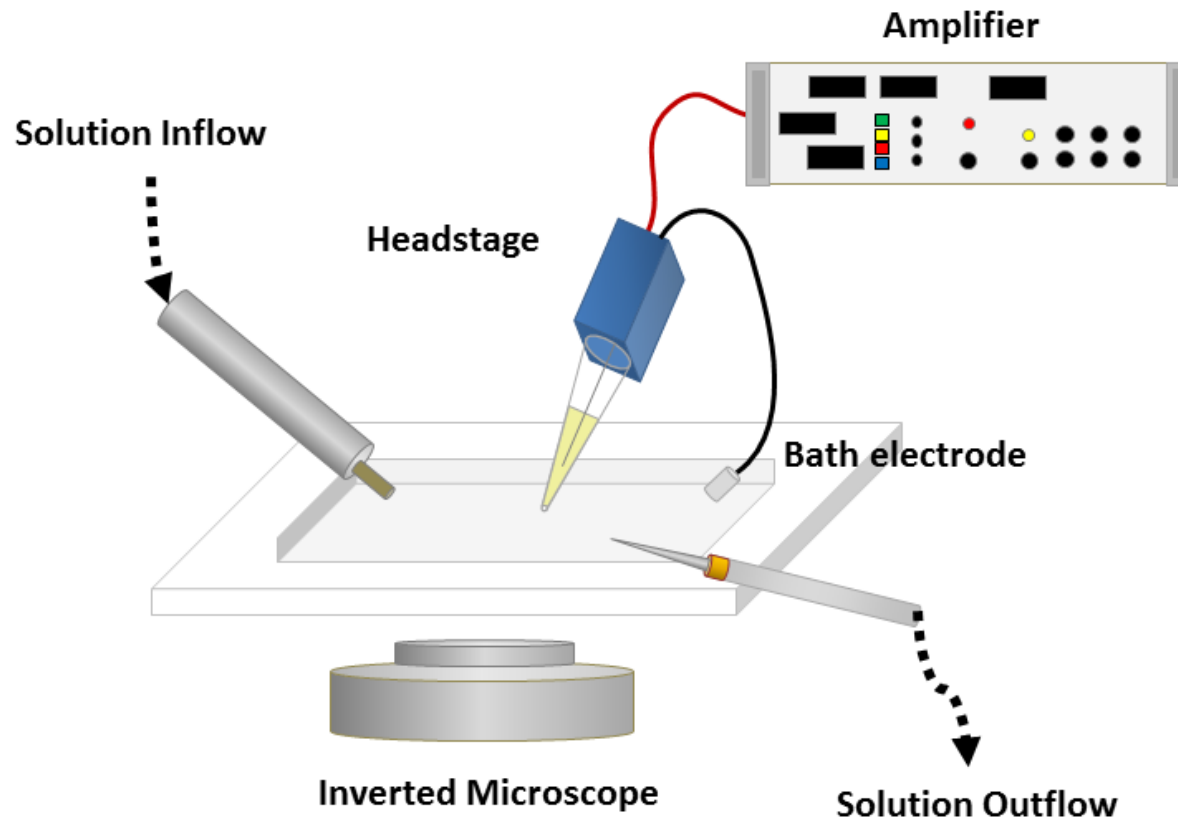


N. Kasthuri et al. Cell 2015

Neuronal Structures

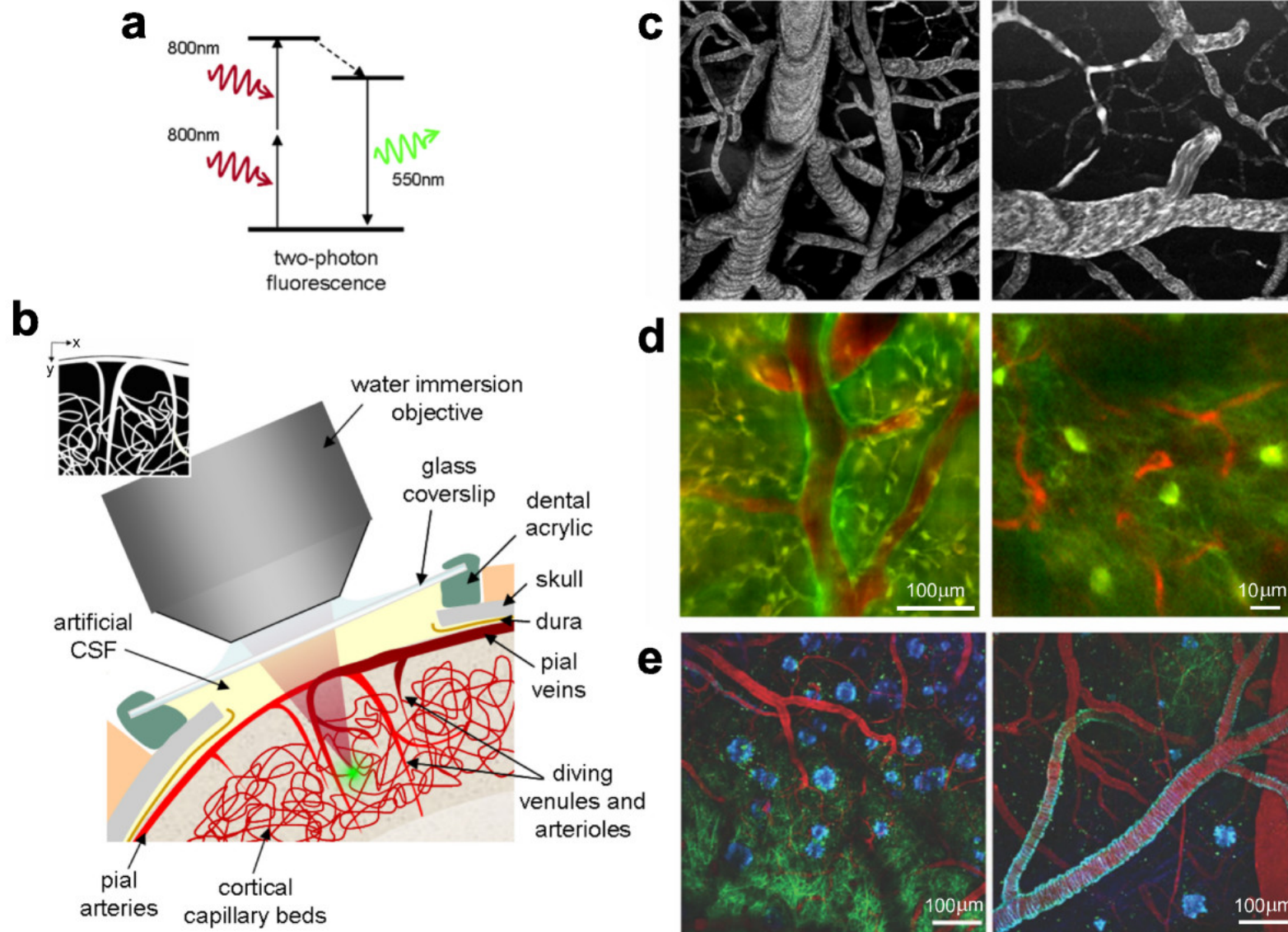


Electrophysiology

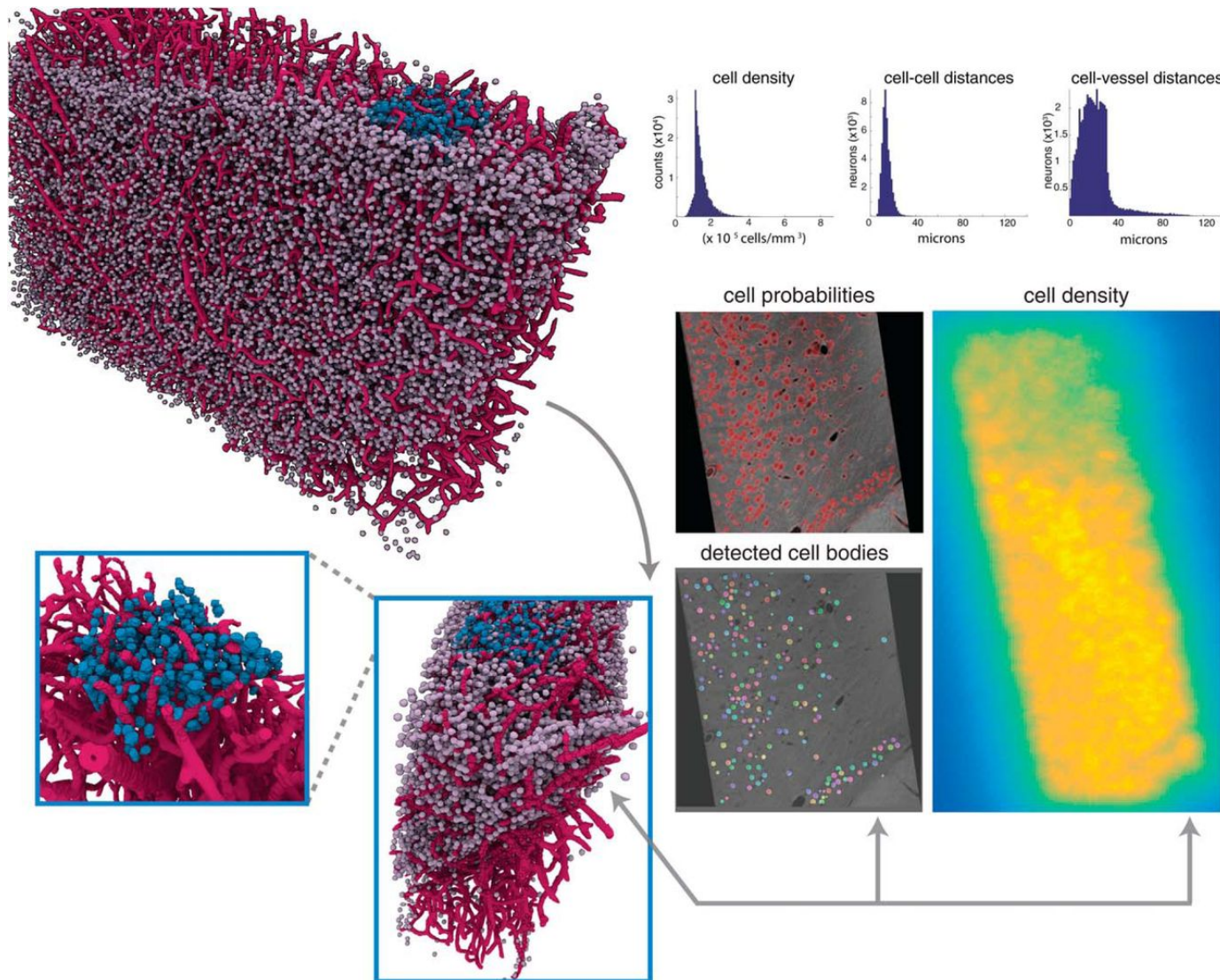


Typical equipment used during classical patch clamp recording © BY-SA 4.0 PeaBrainC

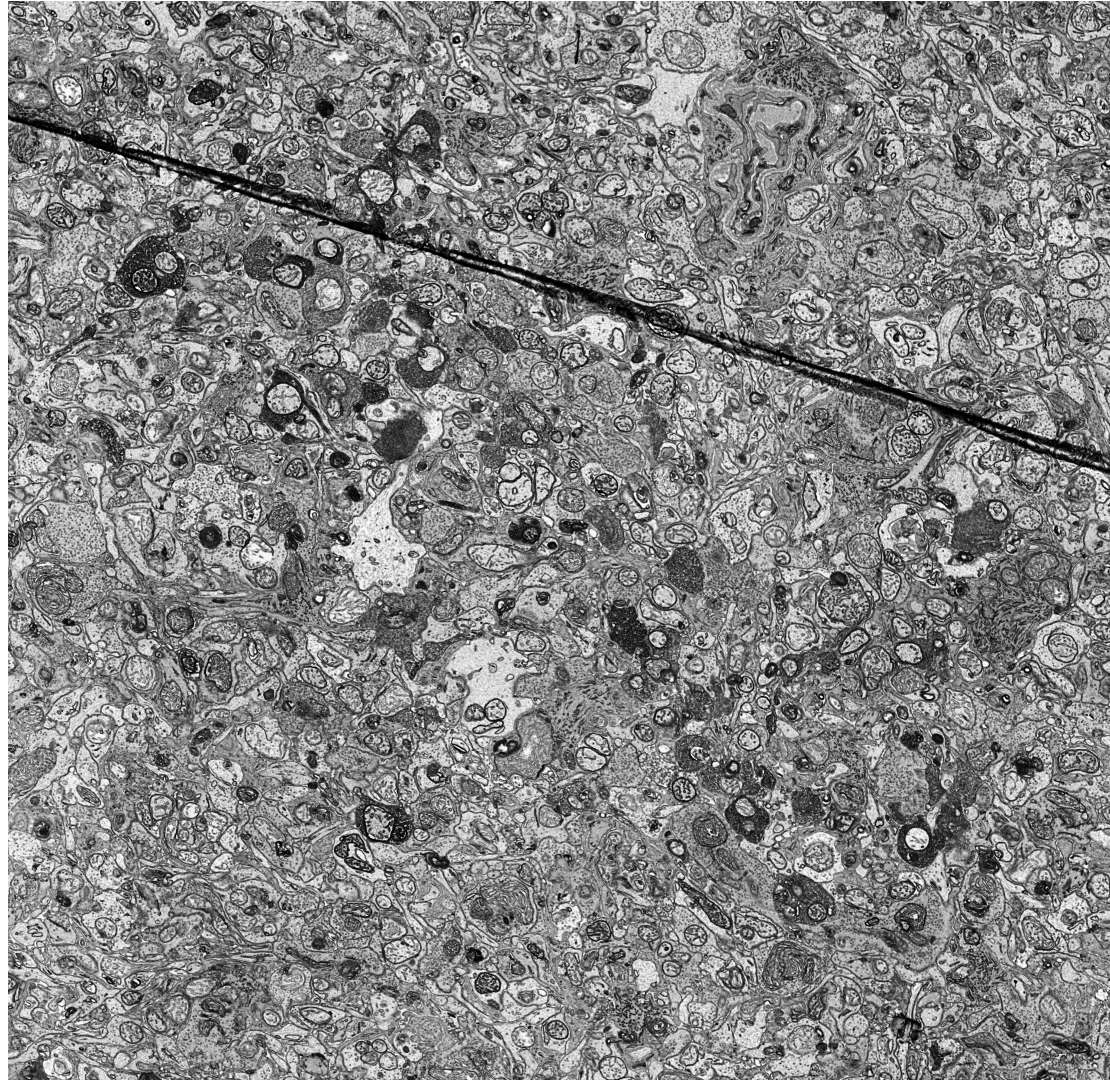
Two-Photon Excitation Microscopy



X-Ray Tomography

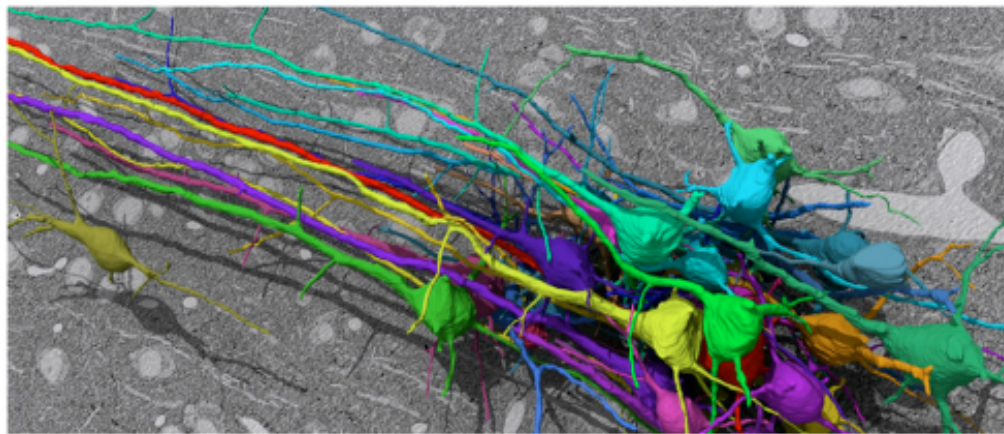


Electron Microscopy



Connectomics

“You are your Connectome”



EM reconstruction of mouse brain cortex. Lichtman Lab, Harvard University

Ambitious Goals

- Map *all* of the connections in a brain, neuron by neuron, synapse by synapse
- Understand the elements of neural computation
 - Vision, Motor Control, Language, Learning
- Understand abstract aspects of the mind
 - Memory, Intelligence, Personality, Identity
- New therapies for mental illnesses that present without an obvious pathology
 - Autism and Schizophrenia

C. elegans Connectome

Start Small: 302 neurons

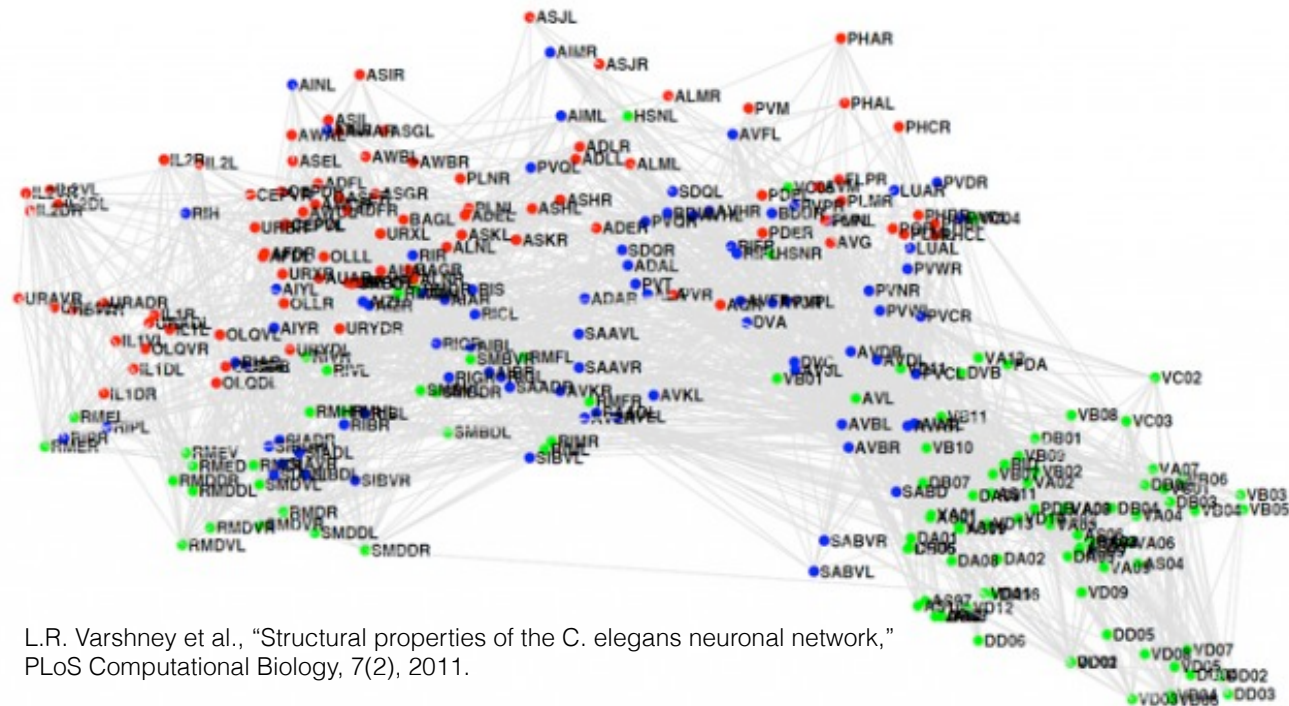


Cut 50nm cross-sections of the worm, and trace the synapses

C. elegans Connectome

12+ year manual effort (1970s - 1980s)

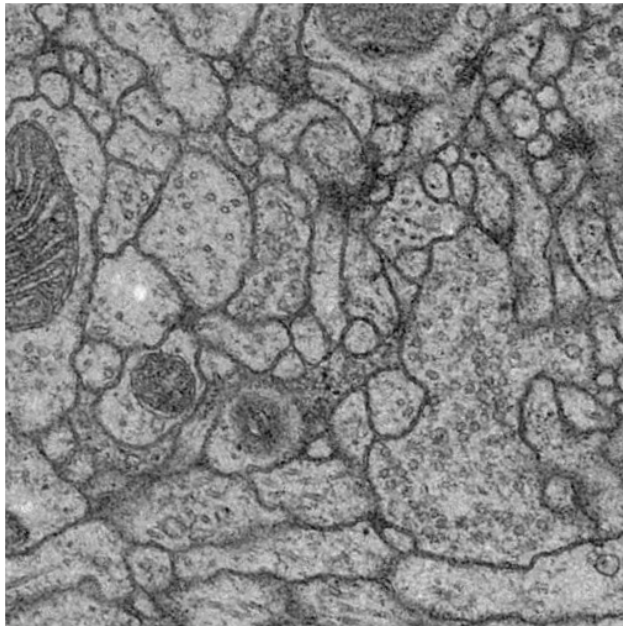
*Computer Vision was in its infancy



L.R. Varshney et al., "Structural properties of the *C. elegans* neuronal network," PLoS Computational Biology, 7(2), 2011.

Drosophila Connectome

- Approximately 100,000 Neurons
- Approximately 10,000,000 Synapses



serial section Transmission Electron
Microscopy (ssTEM) data set of the Drosophila
first instar larva ventral nerve cord (VNC)

Albert Cardona, Stephan Saalfeld, Stephan Preibisch, Benjamin Schmid, Anchi Cheng, Jim Pulokas, Pavel Tomancak and Volker Hartenstein (10, 2010), "[An Integrated Micro- and Macroarchitectural Analysis of the Drosophila Brain by Computer-Assisted Serial Section Electron Microscopy](#)", PLoS Biol (Public Library of Science) 8 (10)

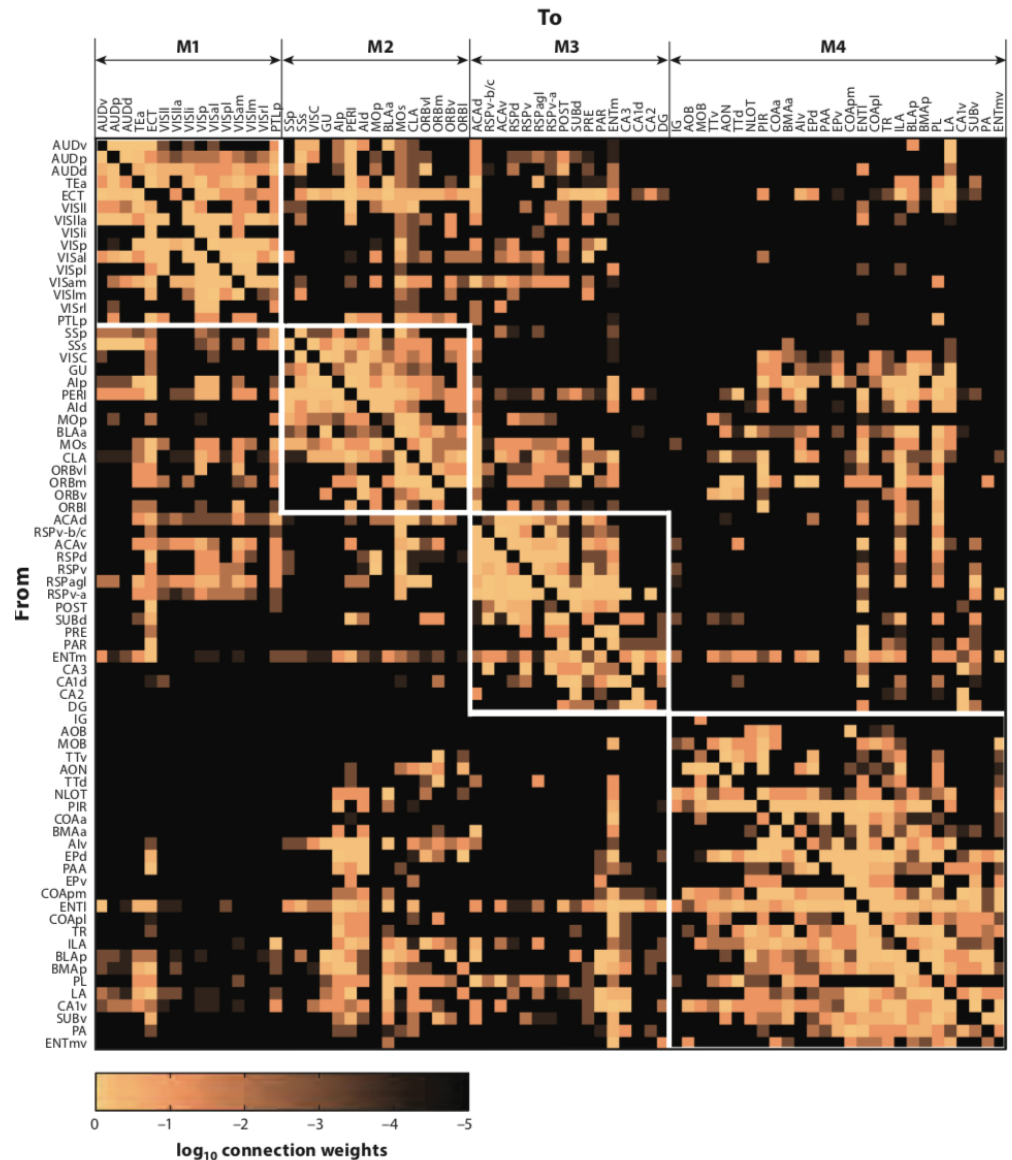
Rat Connectome

- Tens of millions of neurons and billions of connections between them
- Petabytes of data for even small volumes of tissue
- Cannot do this by hand: we need computer vision



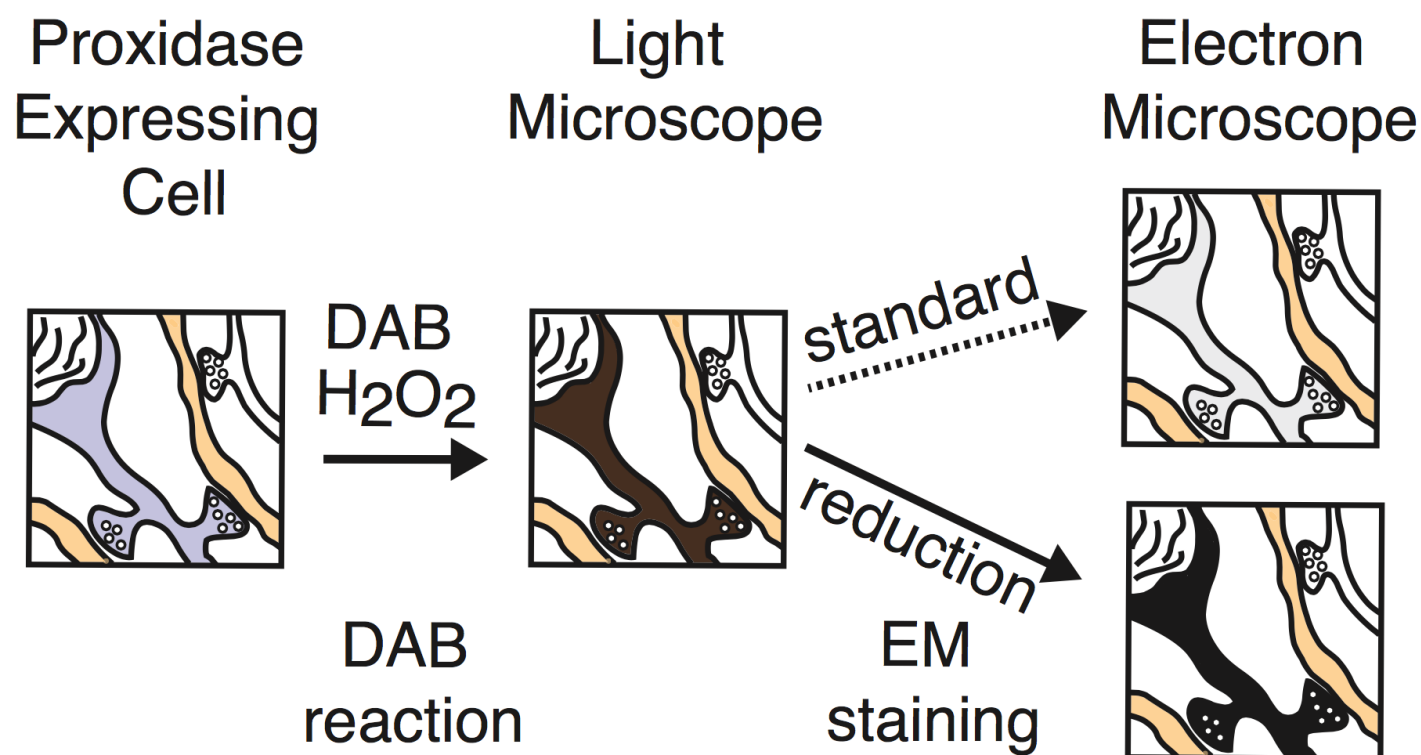
Macroconnectomes

The mammalian brain has on the order of 500 – 1,000 gray matter regions and 25,000–100,000 macroconnections between them.



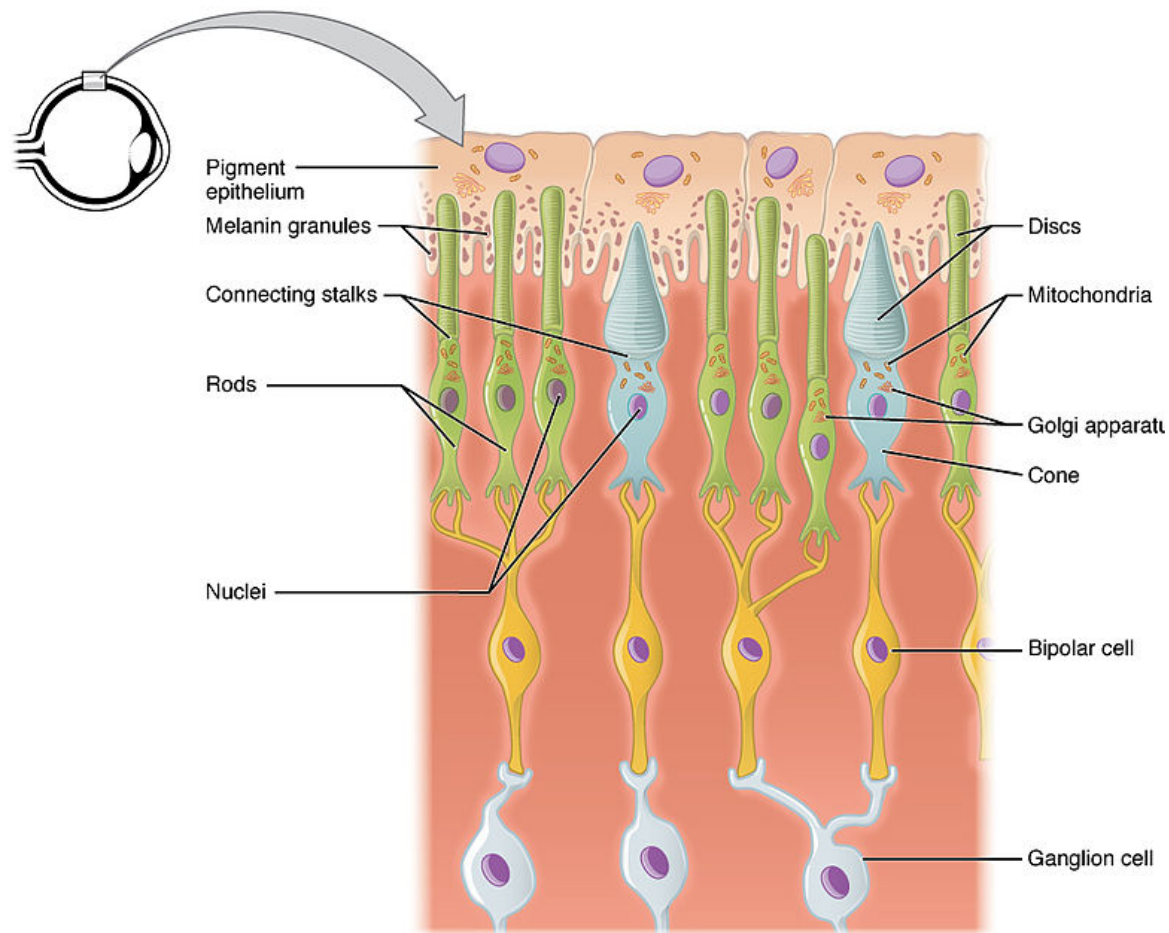
Mesconnectomes

Global mesoconnectomes are the sets of axonal connections between *specific neuron types* within and between gray matter regions of a gender, age, or disease state of a species.



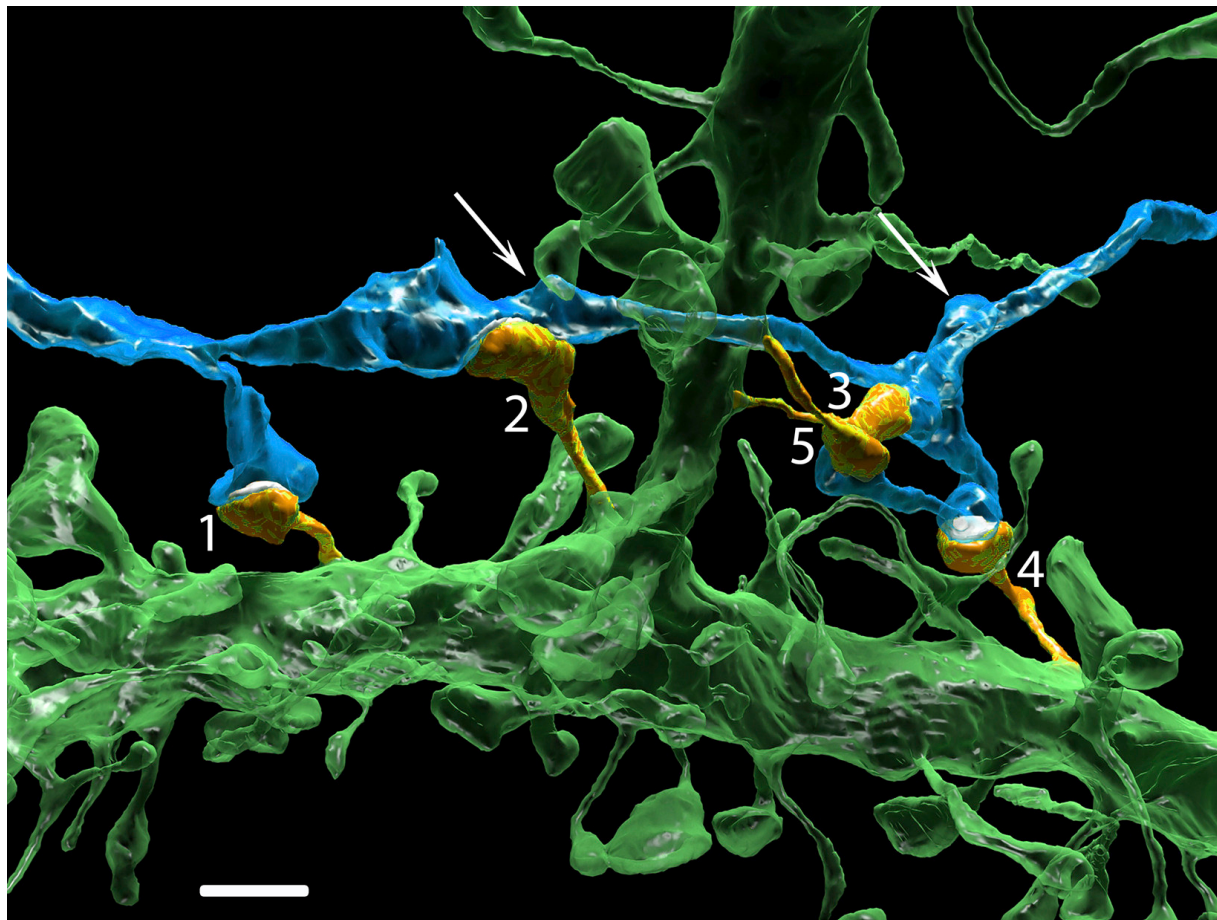
Microconnectomes

Establish canonical synaptic connectivity matrix that interconnects neurons of different types



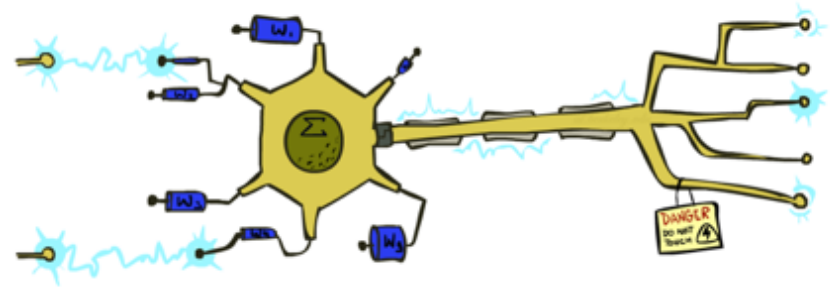
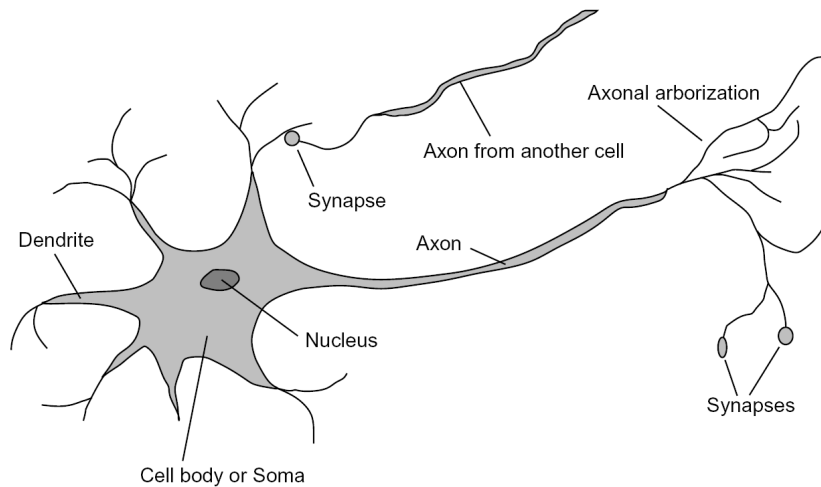
Nanoconnectomes

Nanoconnections are at the most fine-grained level, where the two nodes are pre- and postsynaptic elements of a synapse



How do neurons perform computation?

Perceptrons are a (very) simplified model of biological neurons



McCulloch-Pitts Model

For a given artificial neuron, assume:

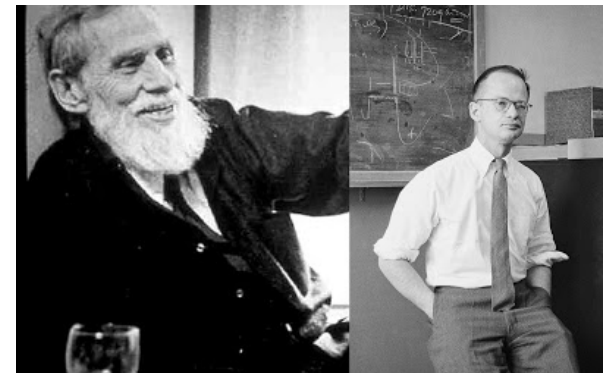
$m + 1$ inputs with

signals x_0 through x_m

weights w_0 through w_m

x_0 is a bias term assigned to +1 ($w_{k0} = b_k$)

m actual inputs to the neuron (x_1 to x_m)



Hebbian Learning

“Let us assume that the persistence or repetition of a reverberatory activity (or "trace") tends to induce lasting cellular changes that add to its stability.[...] When an axon of cell A is near enough to excite a cell B and repeatedly or persistently takes part in firing it, some growth process or metabolic change takes place in one or both cells such that A's efficiency, as one of the cells firing B, is increased.”

Artificial Neural Networks

Add gradient-based learning

