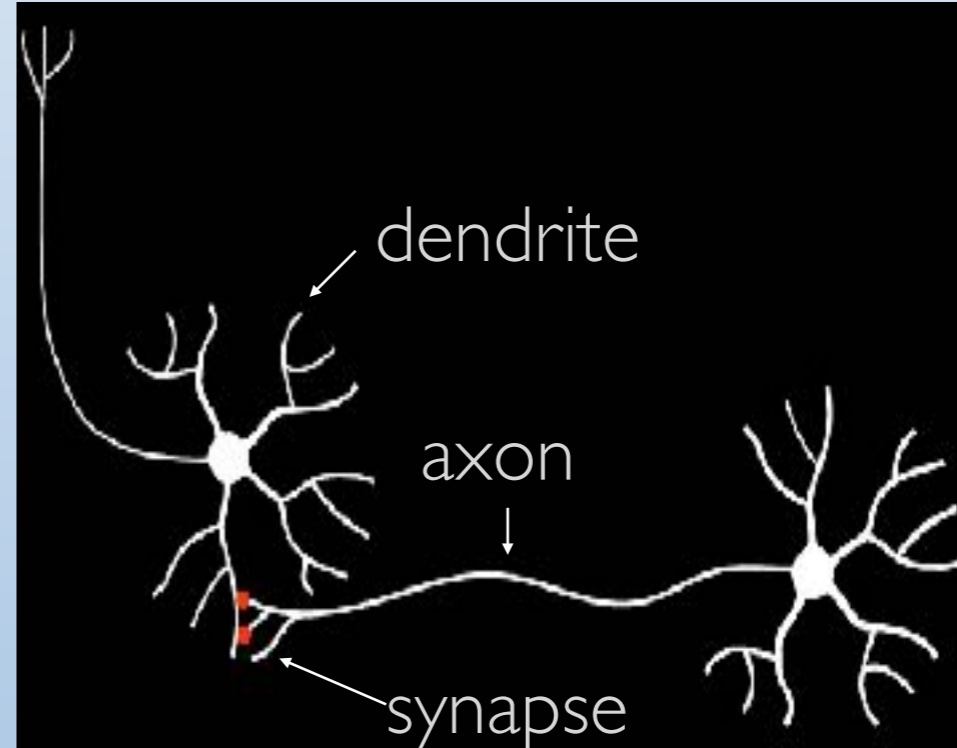
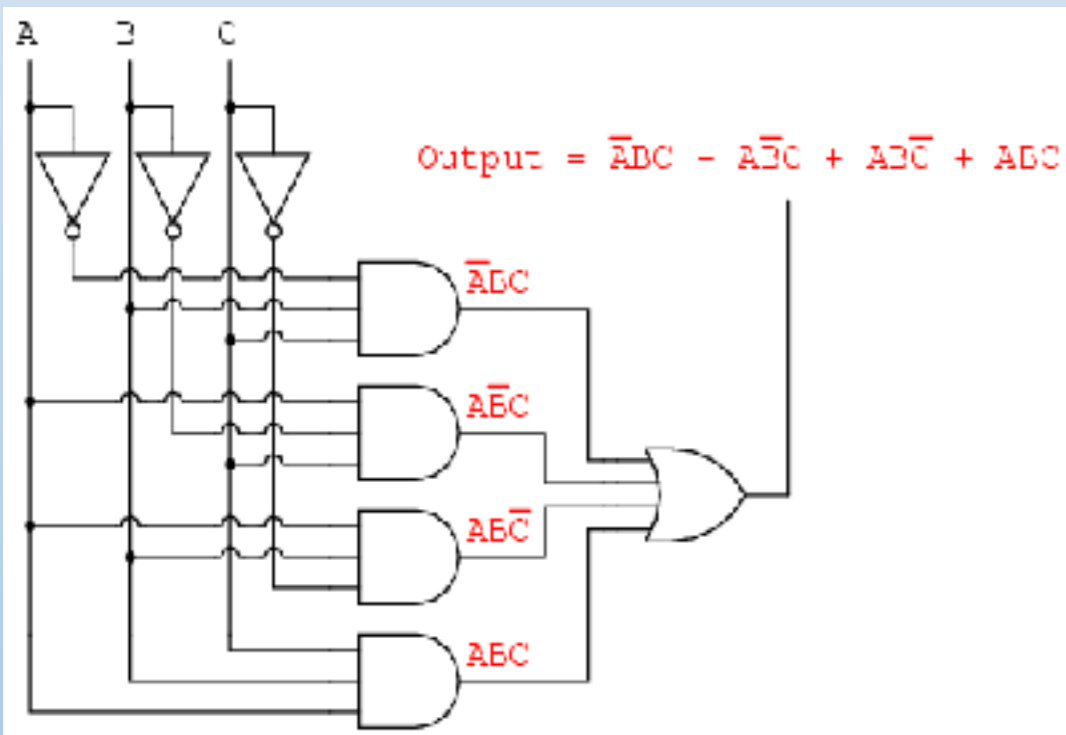
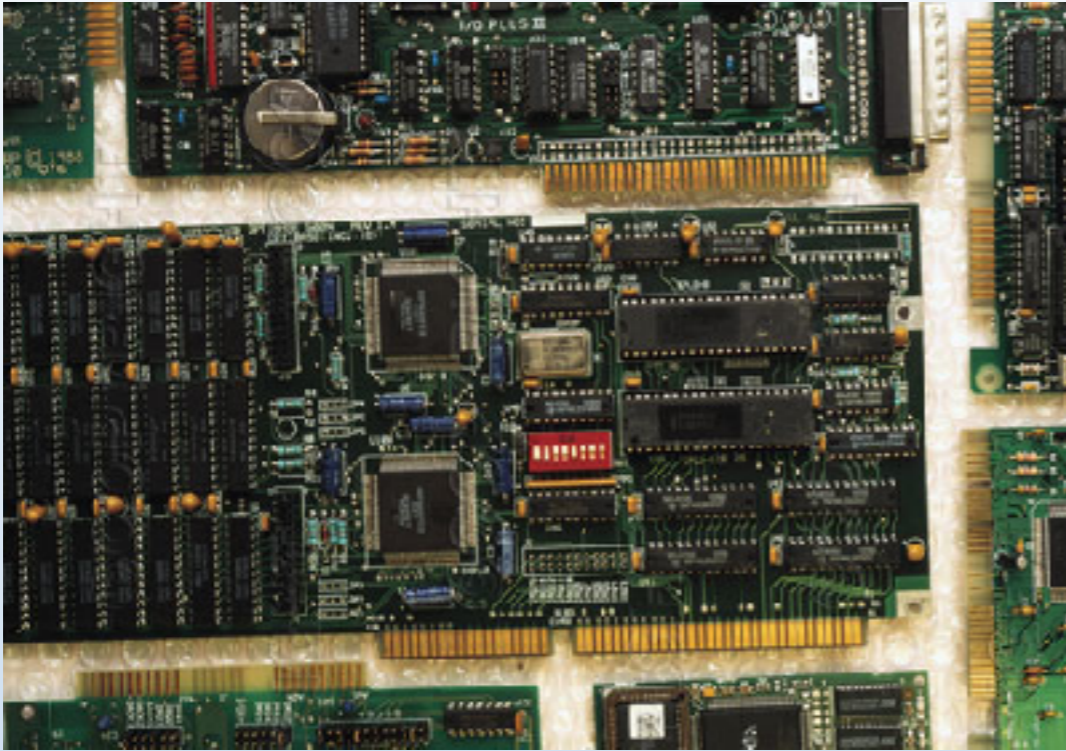


Mapping the Brain: Machine Learning to the Rescue

P. Fua
IC-CVLab
EPFL

Computers and Brains



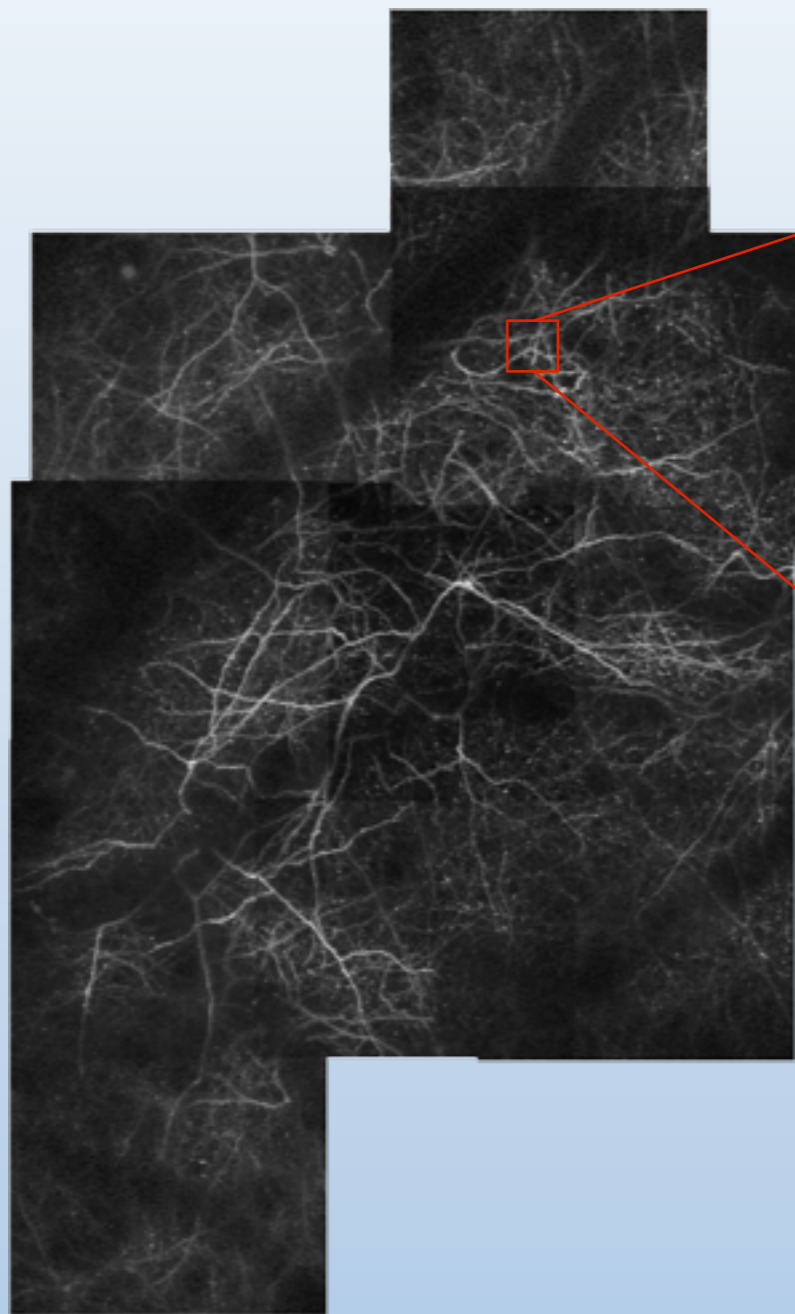
The Promise

Understanding how neurons are connected would help us:

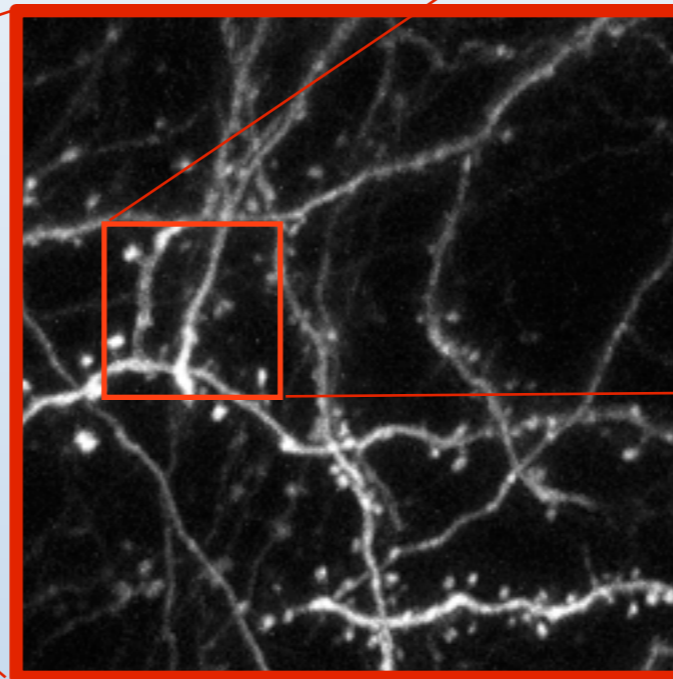
- Build models that we can test, manipulate, and use to simulate different functions;
- Understand how the removal of synapses or demyelinating diseases affect function;
- Develop and test new drugs to reverse the effect of neuro-degenerative diseases.

—> **Major scientific advances.**

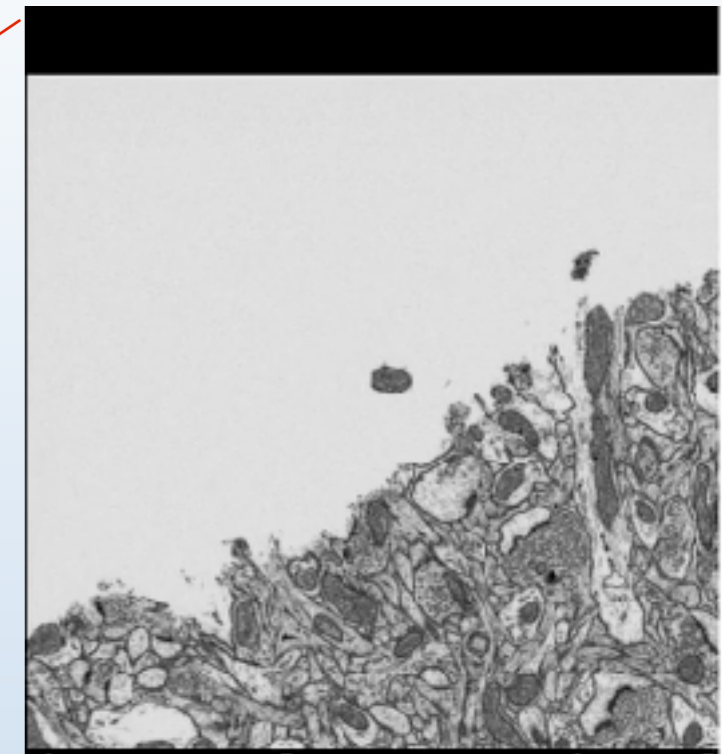
Multi-Scale Imagery



Fluorescent neurons in vivo in the adult mouse brain.

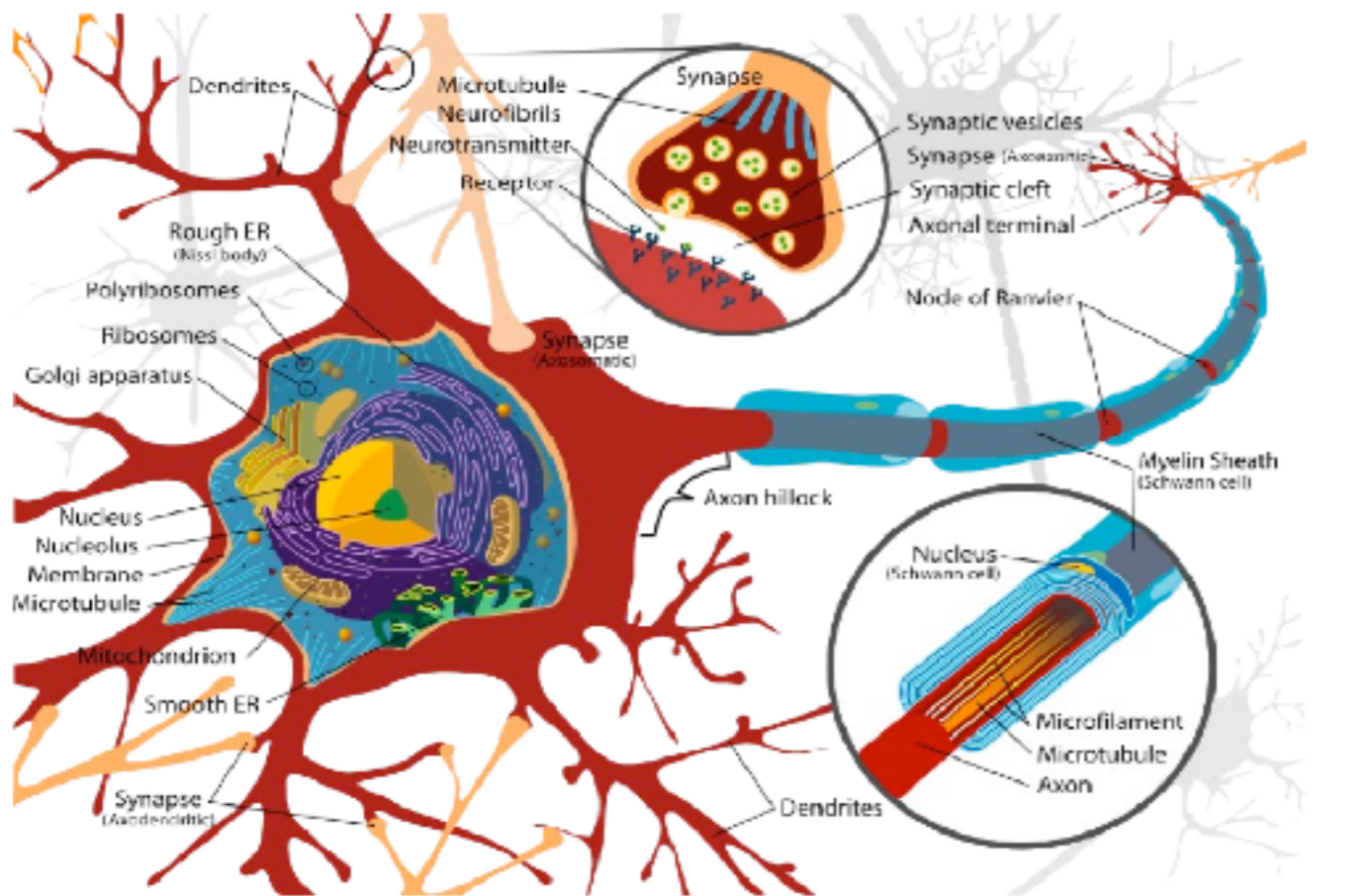


Imaged through a cranial window using a 2-photon microscope.



FIB stack and reconstructed neural structures.

Really Big Data!



- A human brain contains approximately 100 billion neurons and 100 trillion synapses.
- It would take 1000 Exabytes to store an uncompressed digitization at 5nm resolution.

amazon

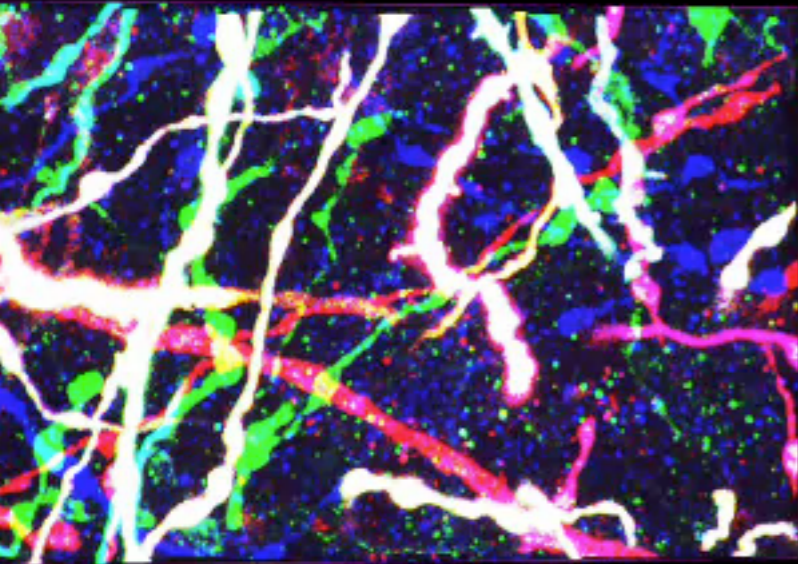
x 500!

Machine learning to the rescue!

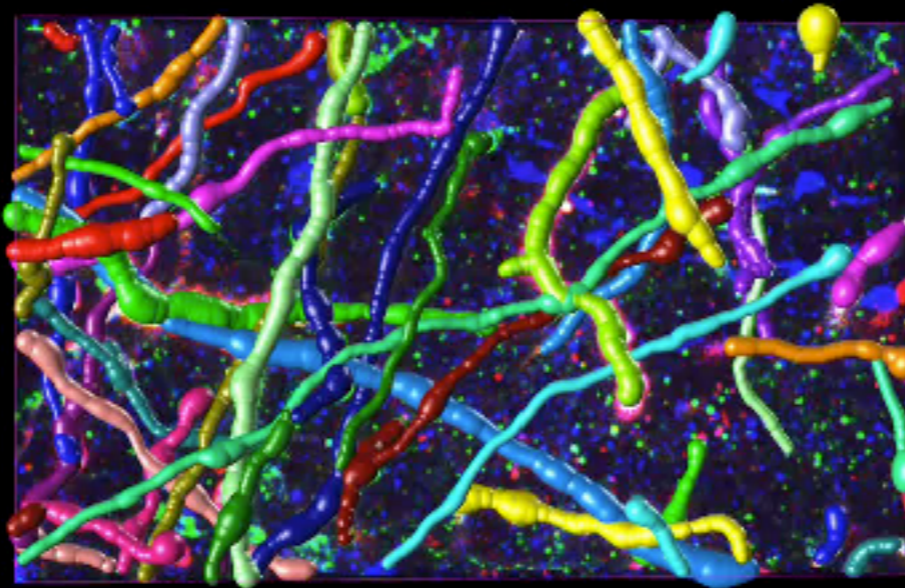
1. Delineate Dendritic Trees in LM Micrographs
2. Find Synapses and Mitochondria in FIBSEM Micrographs

—> **Sophisticated Multi-Scale Brain Models.**

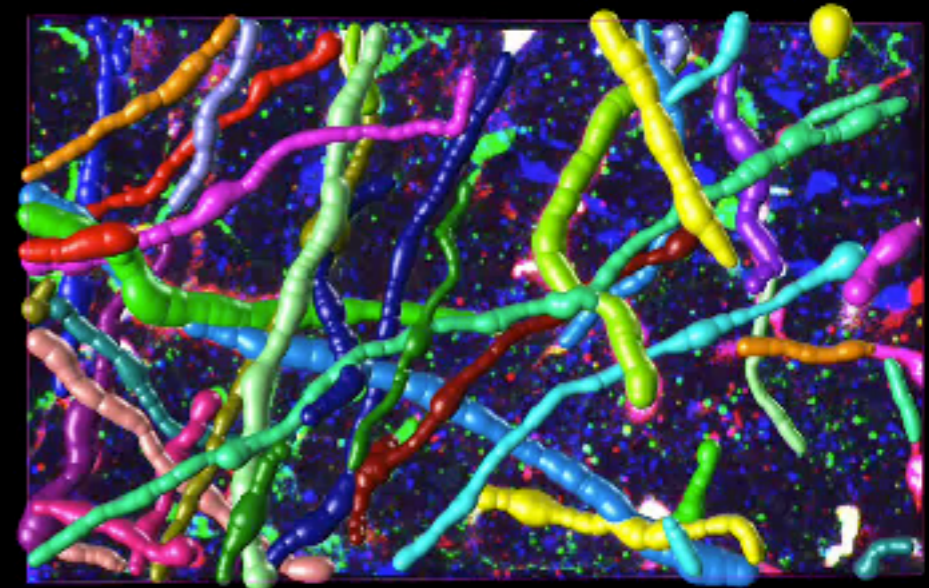
Neural Structures in Light Microscopy



Brainbow Stack

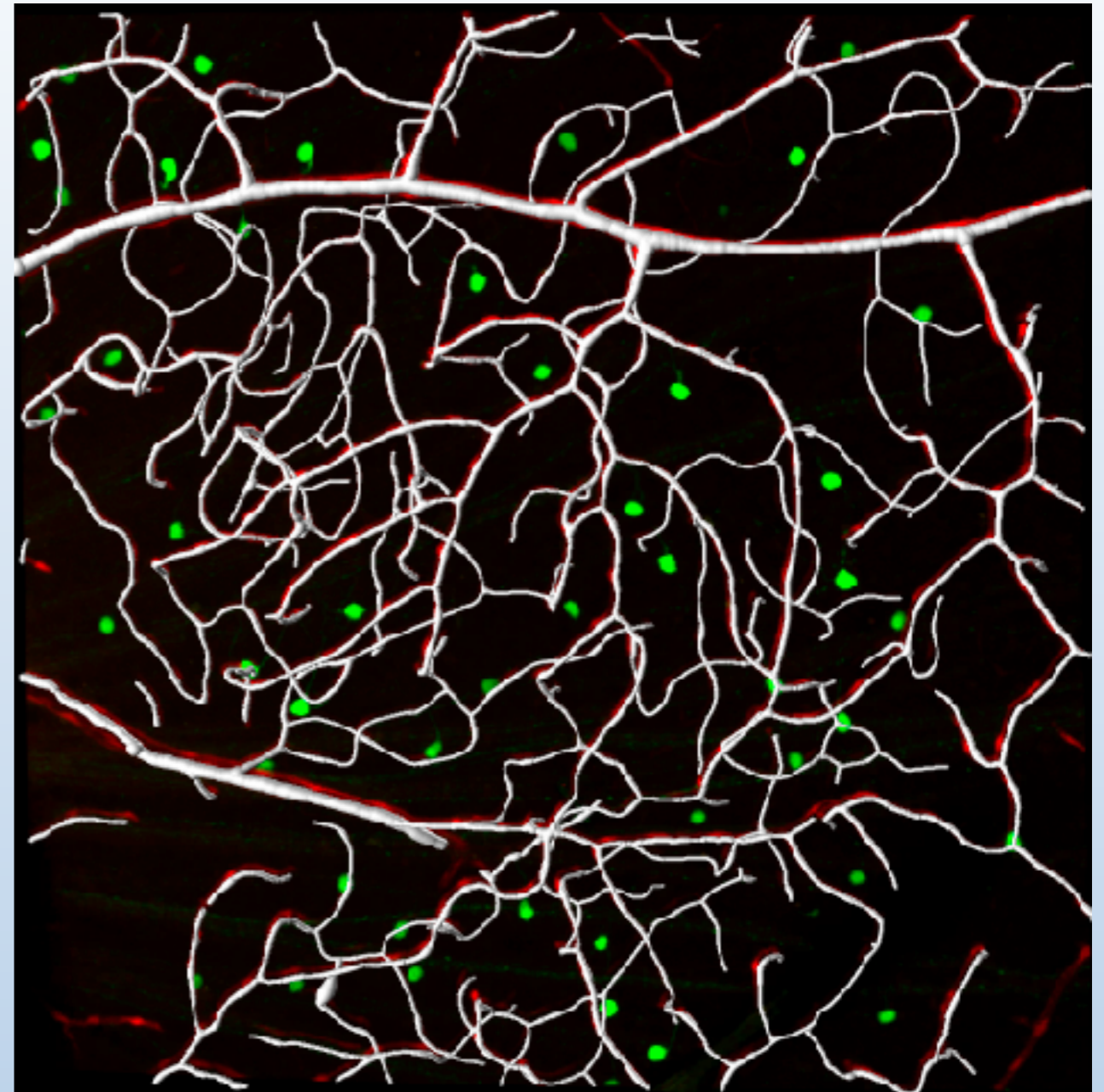
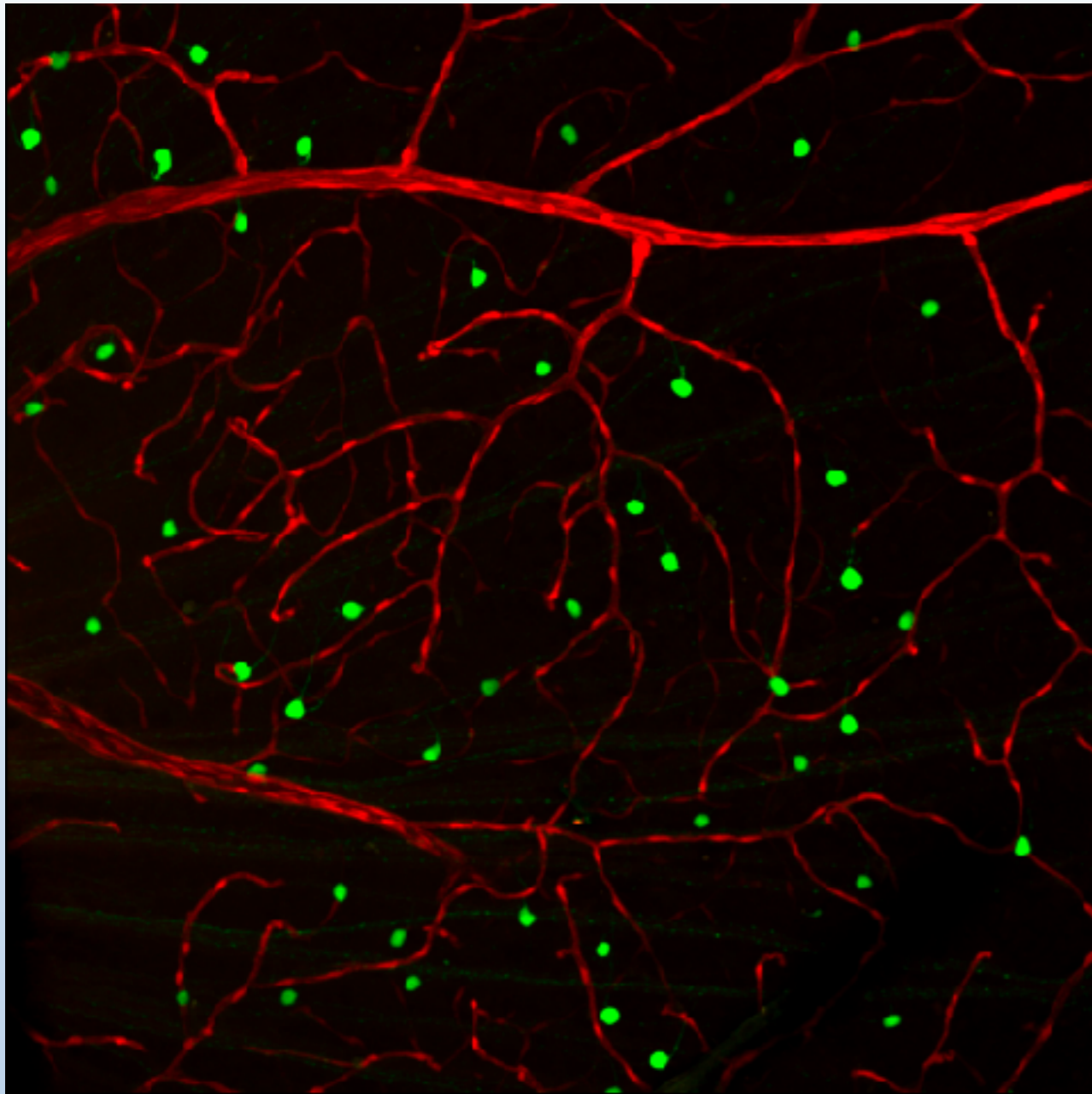


Ground Truth



QMIP reconstruction

Retina Blood Vessels



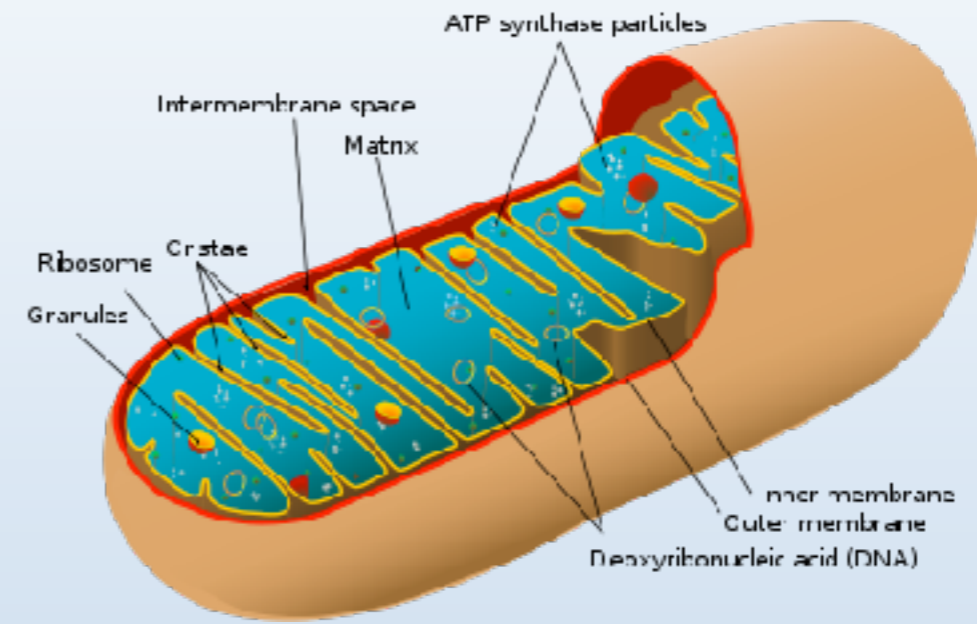
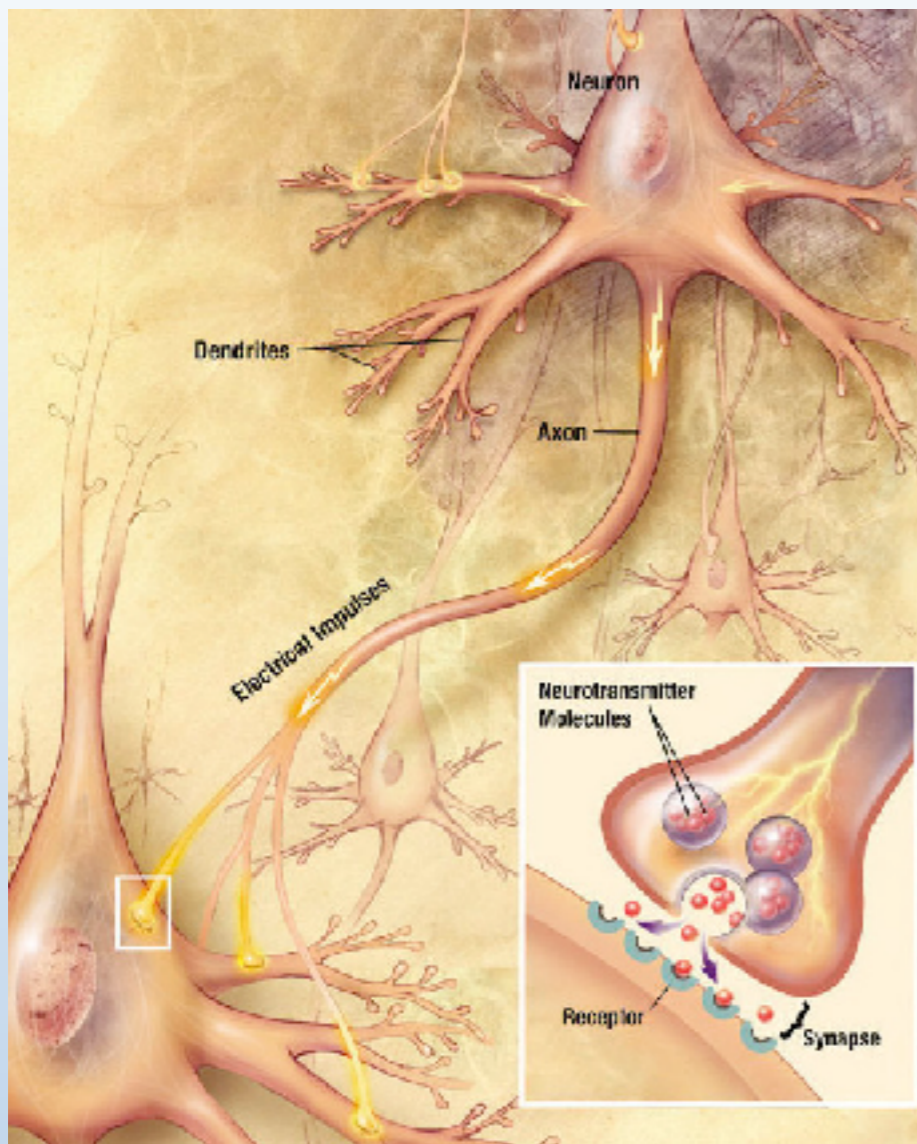
Roads in Aerial Images



Machine Learning

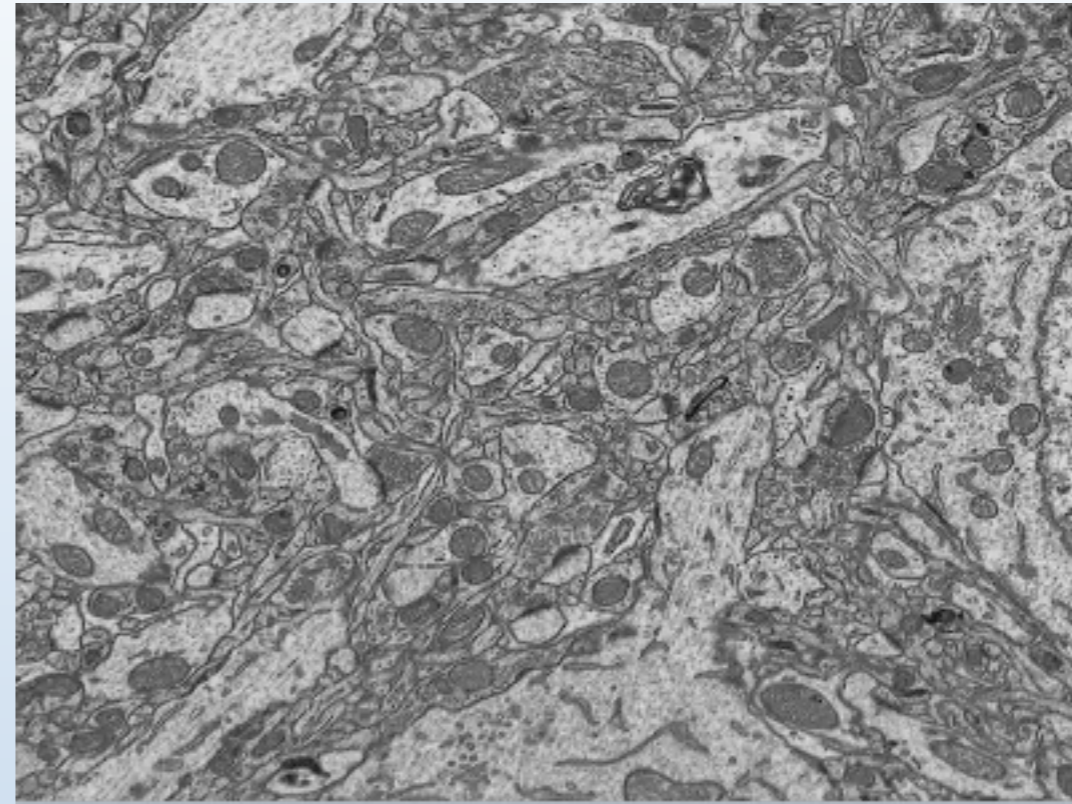
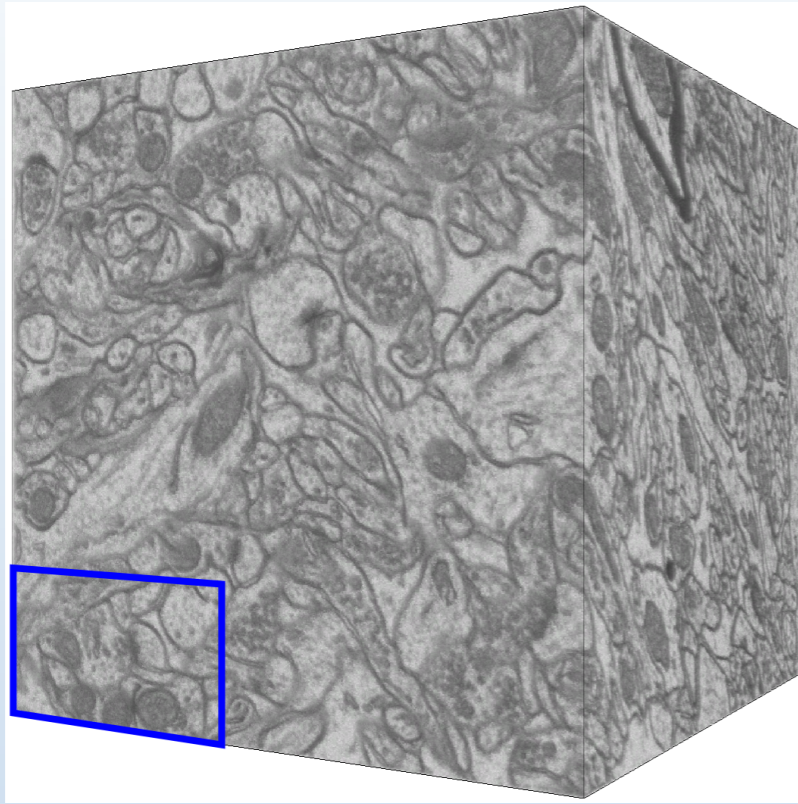
- Enables the **same** algorithm to operate in **many** different context. We simply have to train them using different kind of data.
- Can leverage knowledge about one domain to handle a different one. In other words, you can train on roads and race on dendrites.

Synapses and Mitochondria

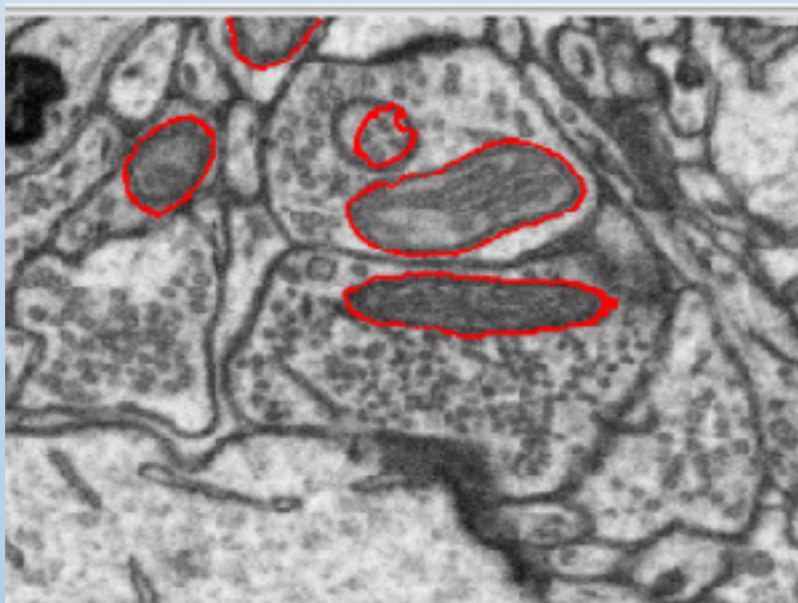


- Synapses transmit signals from neurons to other cells.
- Mitochondria provide cells with the energy they need.
- Neuro-degenerative diseases affect their shapes.

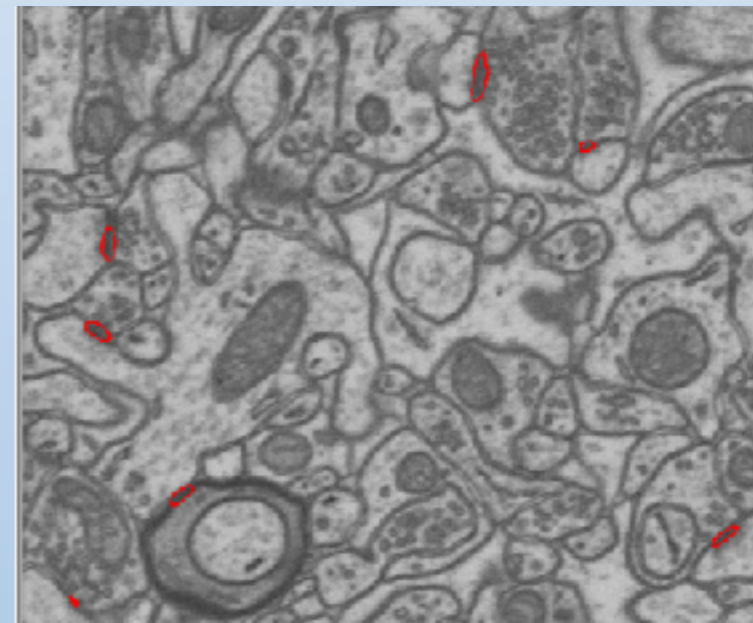
Electron Microscopy



FIBSEM stack at 5 nm resolution.

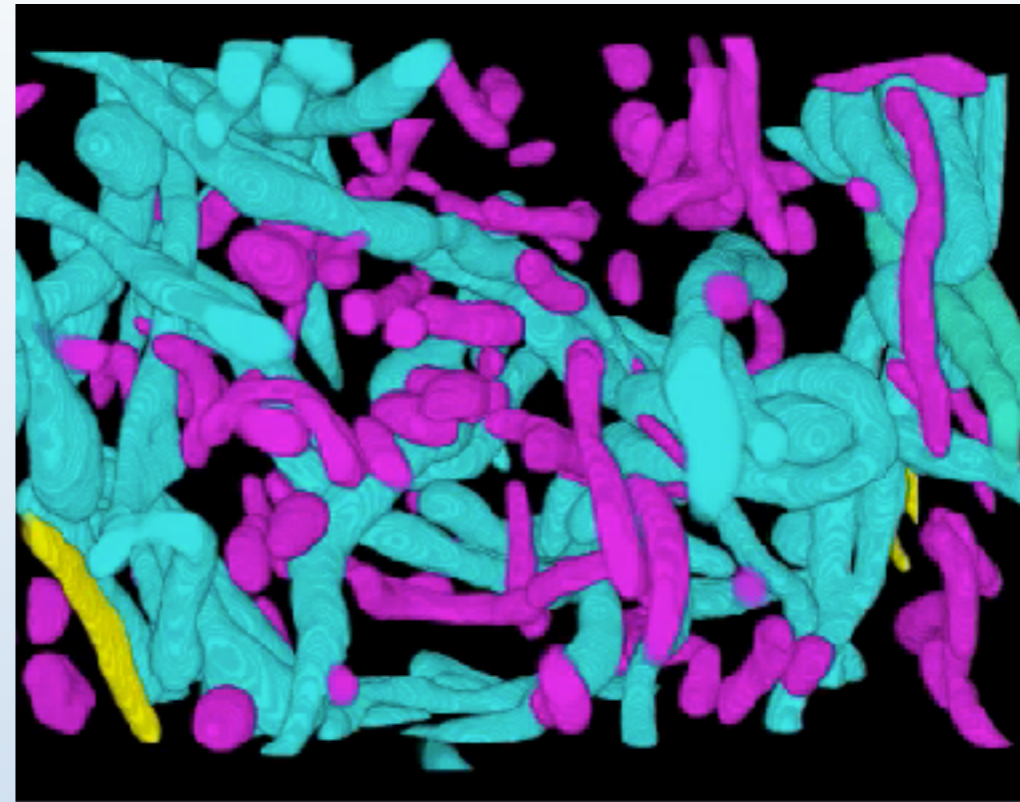
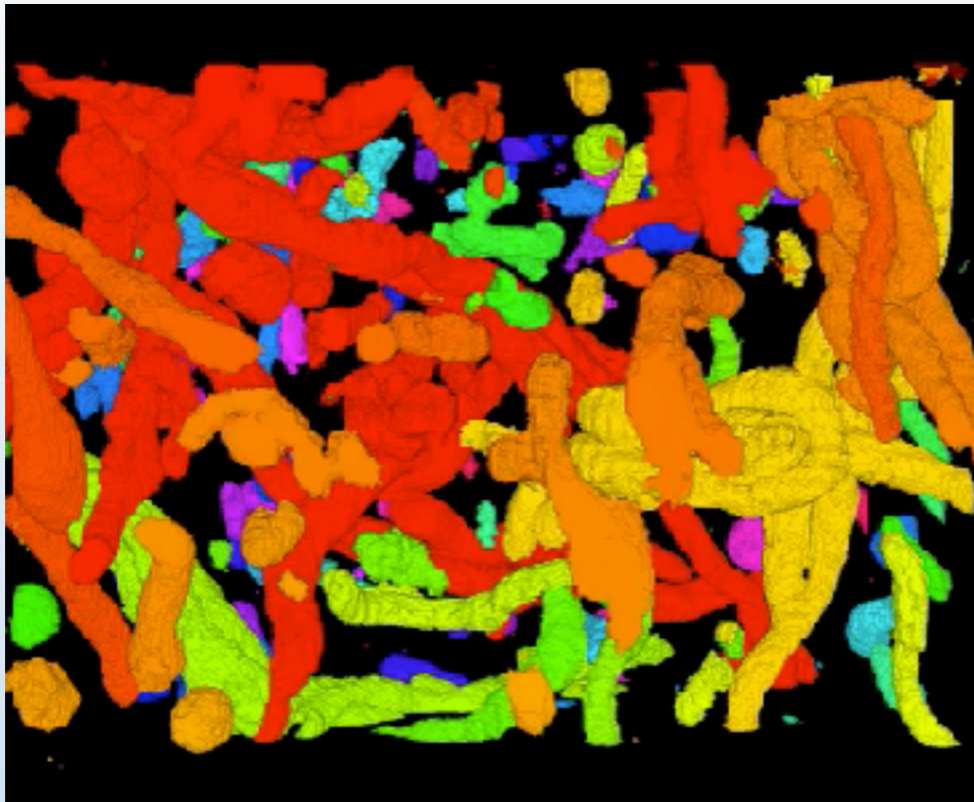


Mitochondria



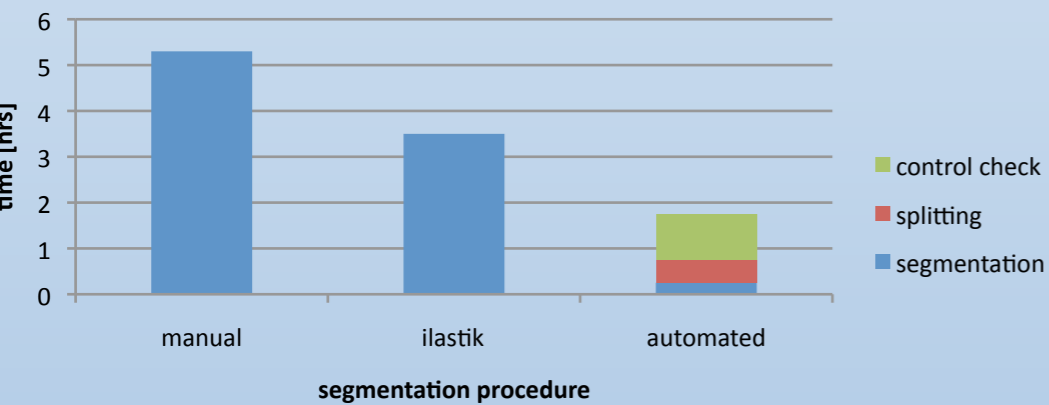
Synapses

3D Mitochondria

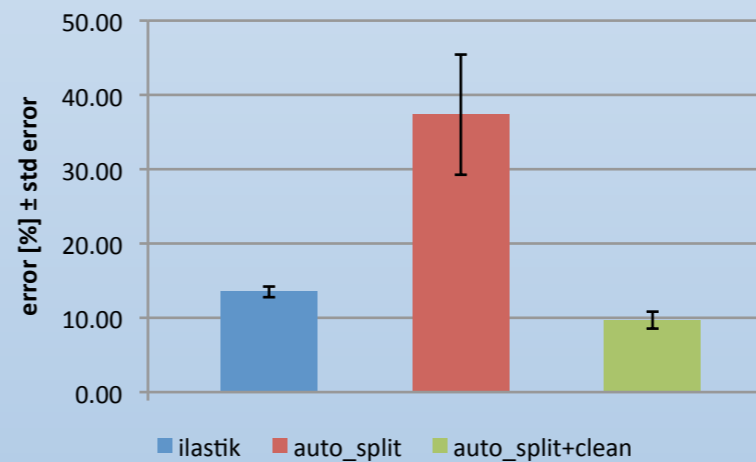


3.21 μm \times 3.21 μm \times 1.08 μm : 53 mitochondria

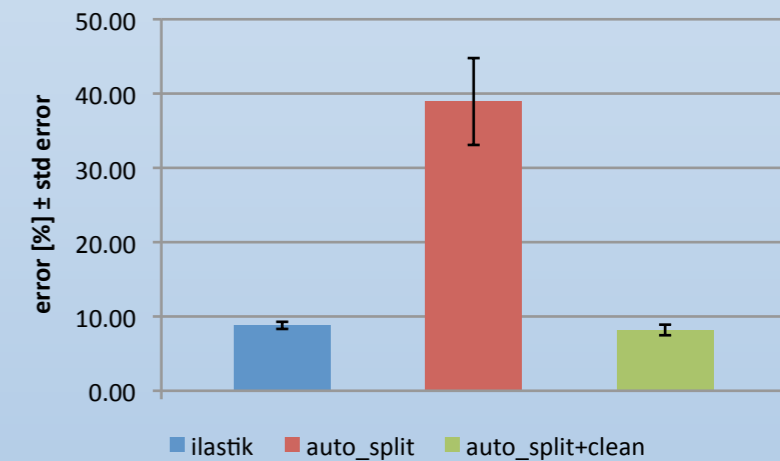
Mitochondria detection



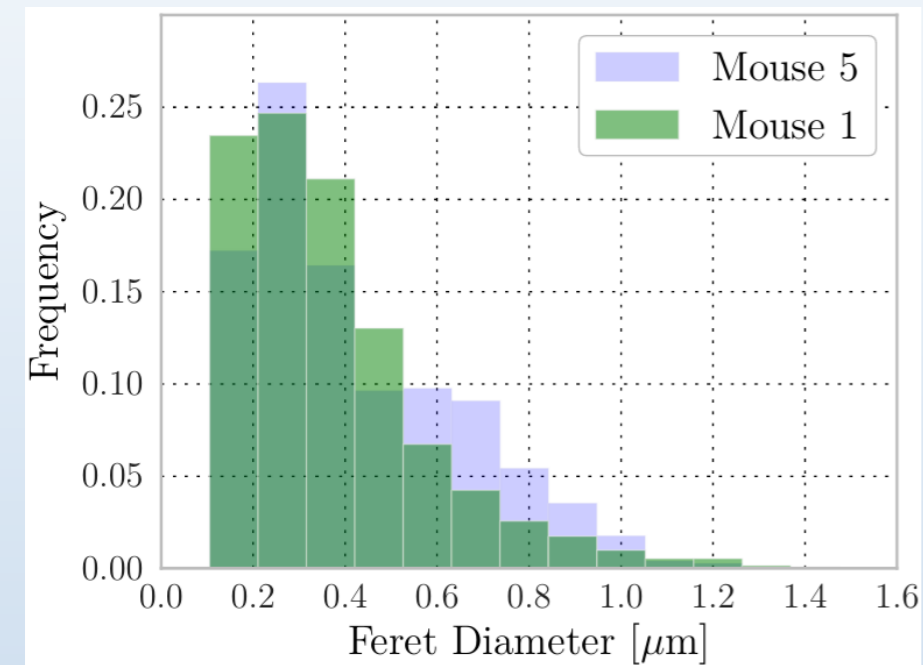
Volume average error



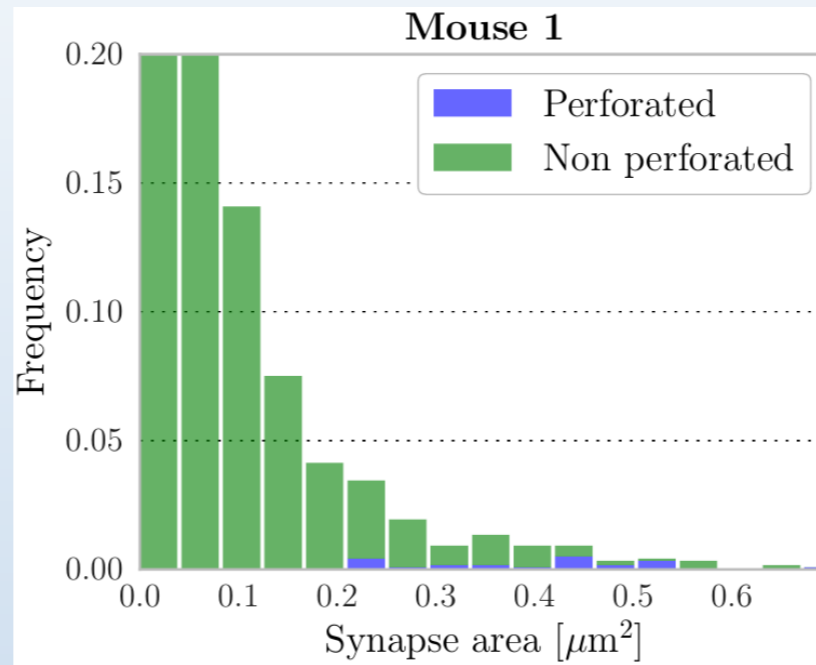
Surface average error



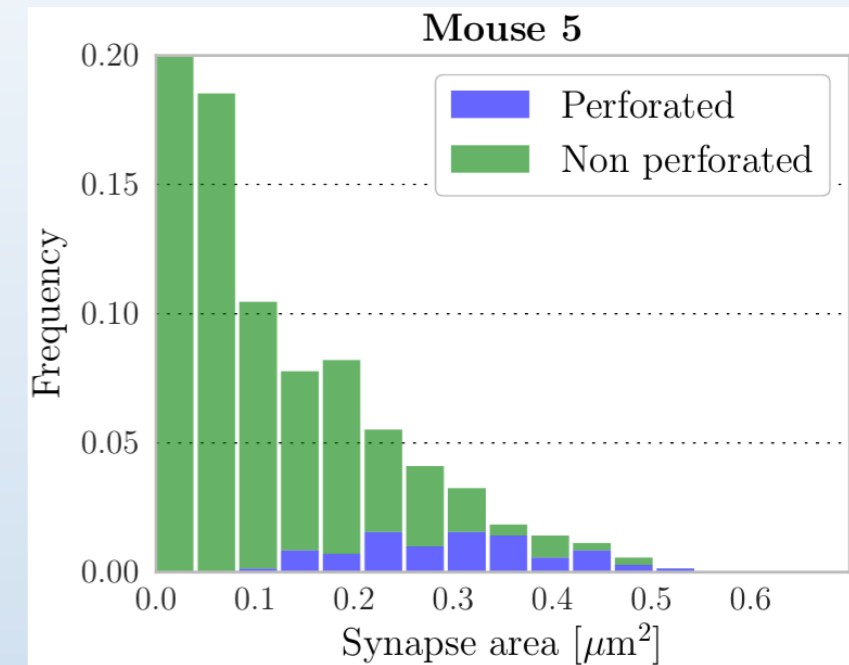
Synapses in Young and Old Mice



PSD diameter



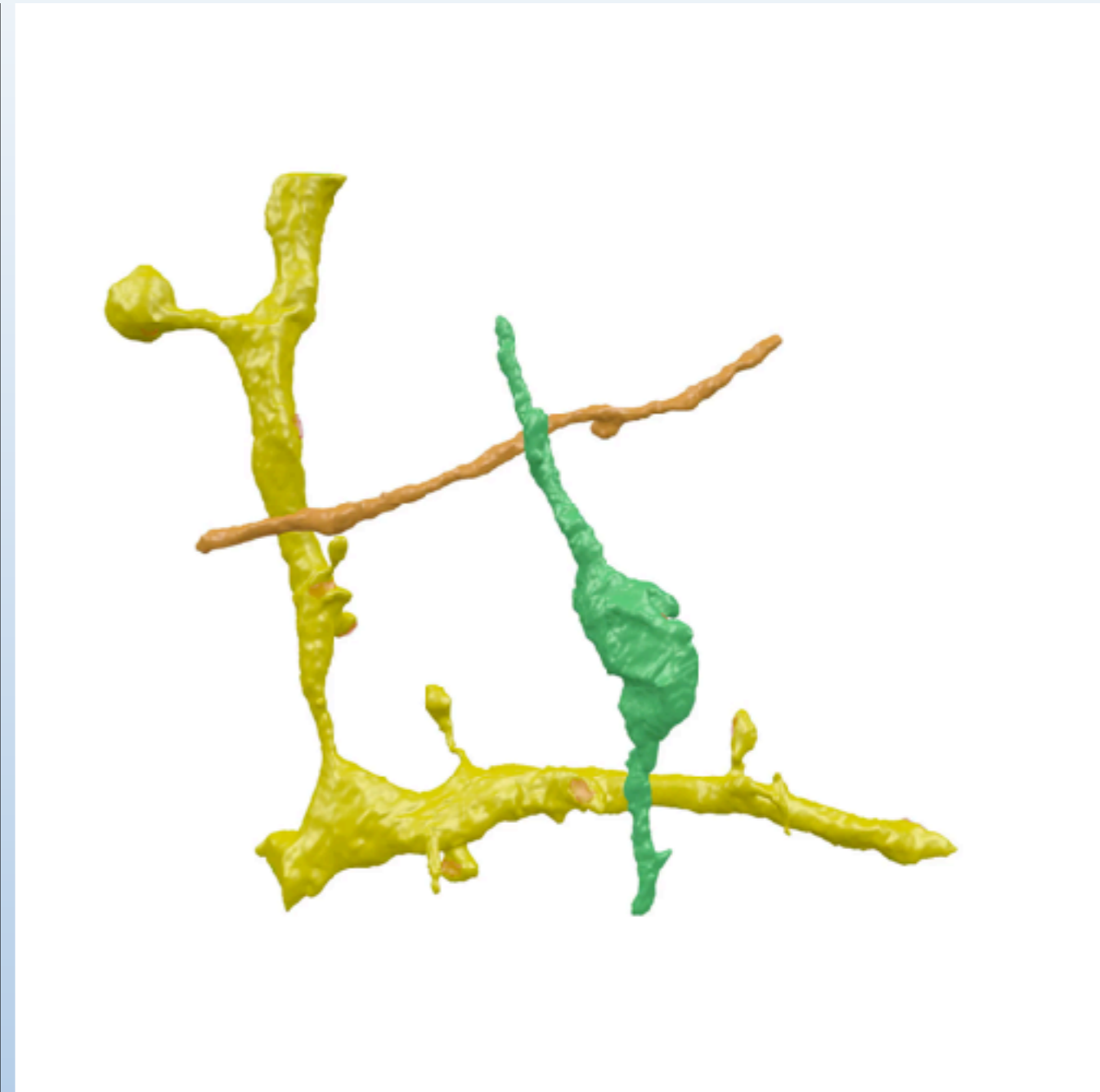
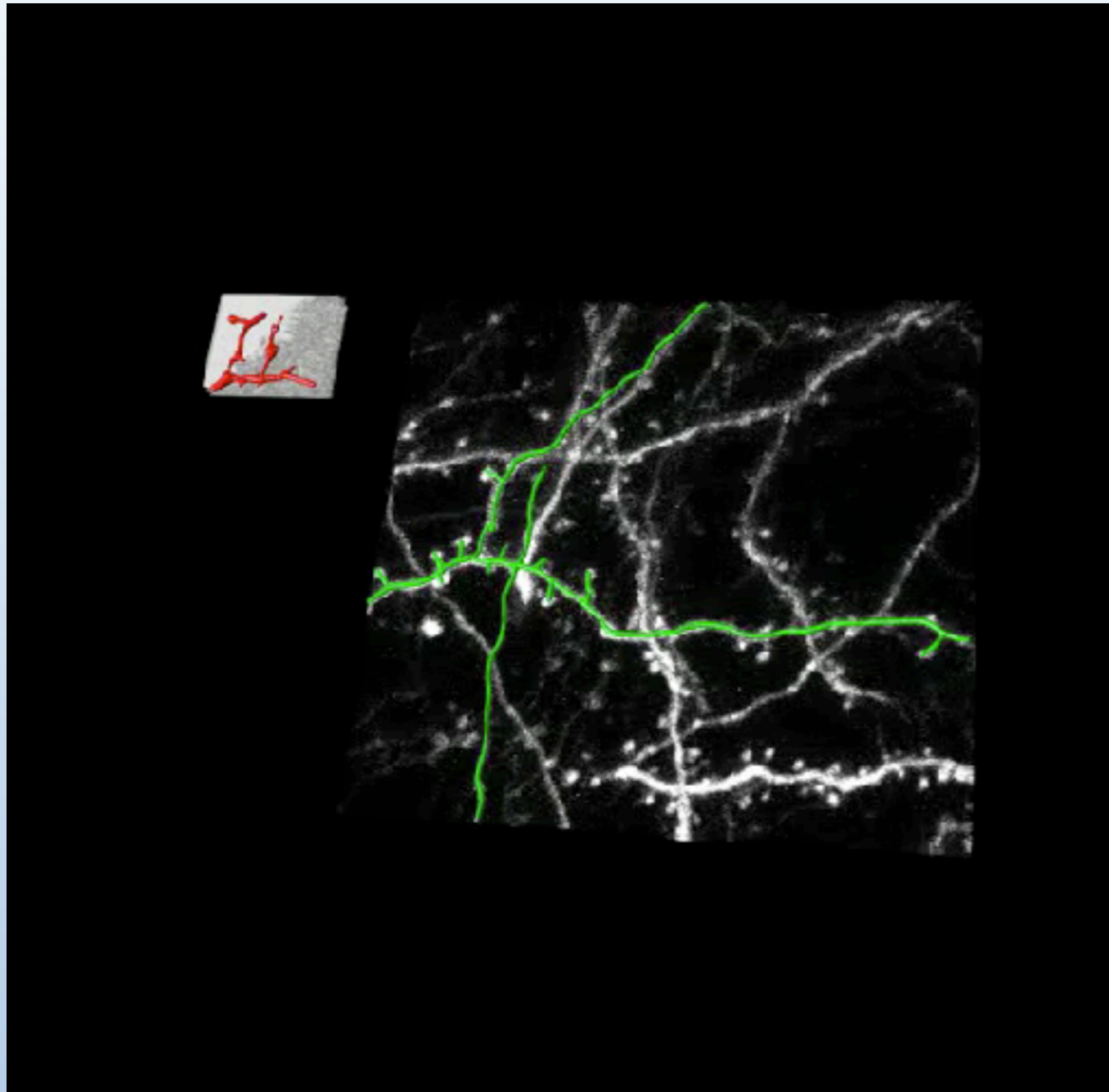
PSD area in a young mouse



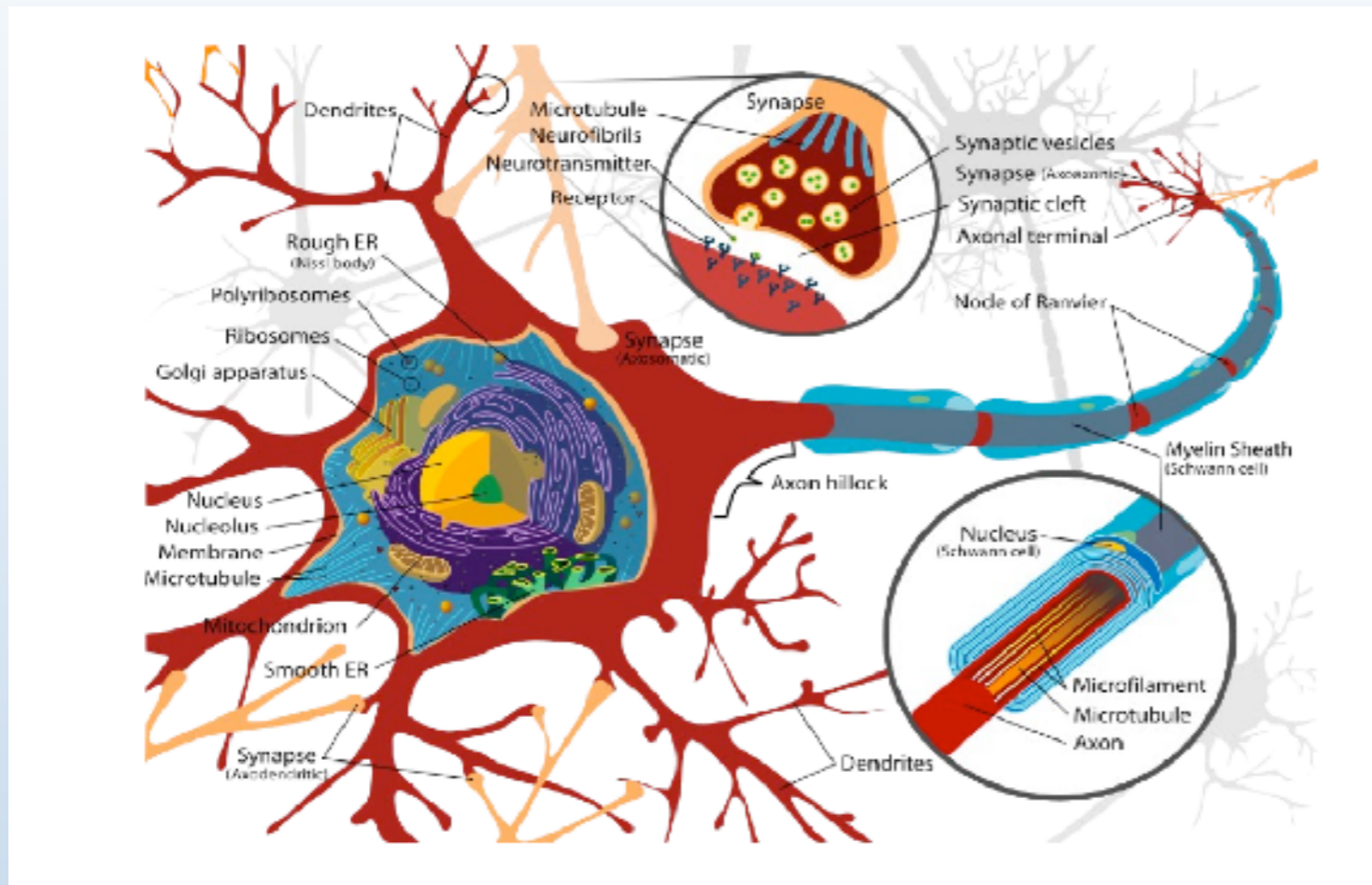
PSD area in an old mouse

—> Fewer but apparently stronger synaptic connections in old mice than in young ones.

Bringing it Together



Conclusion



- A human brain contains approximately 100 billion neurons and 100 trillion synapses.
- It would take 1000 Exabytes to store an uncompressed digitization at 5nm resolution.

- Techniques that rely on Machine Learning can already deliver useful results but not yet on a truly large scale.
- Scaling them up is going to be our challenge for the coming years.