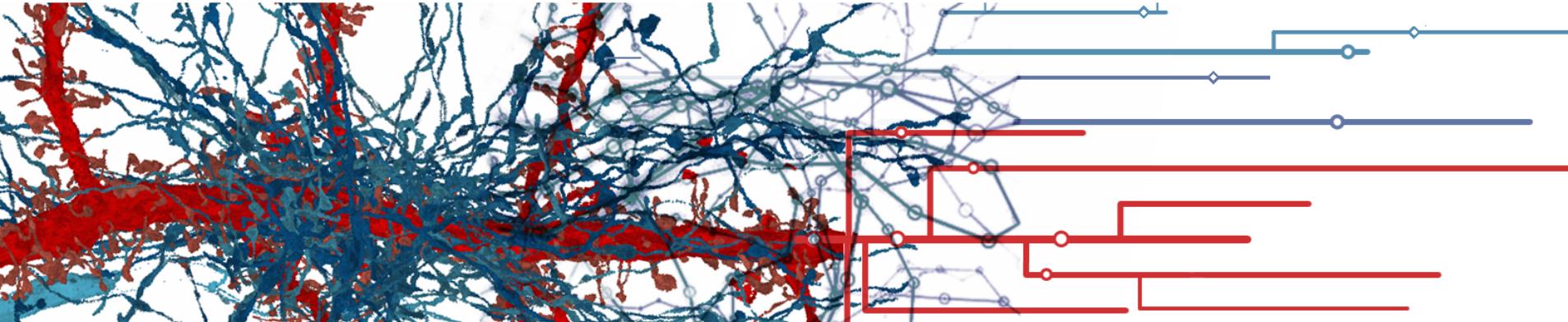


NeuroLines

A Subway Map Metaphor for Visualizing Nanoscale
Neuronal Connectivity

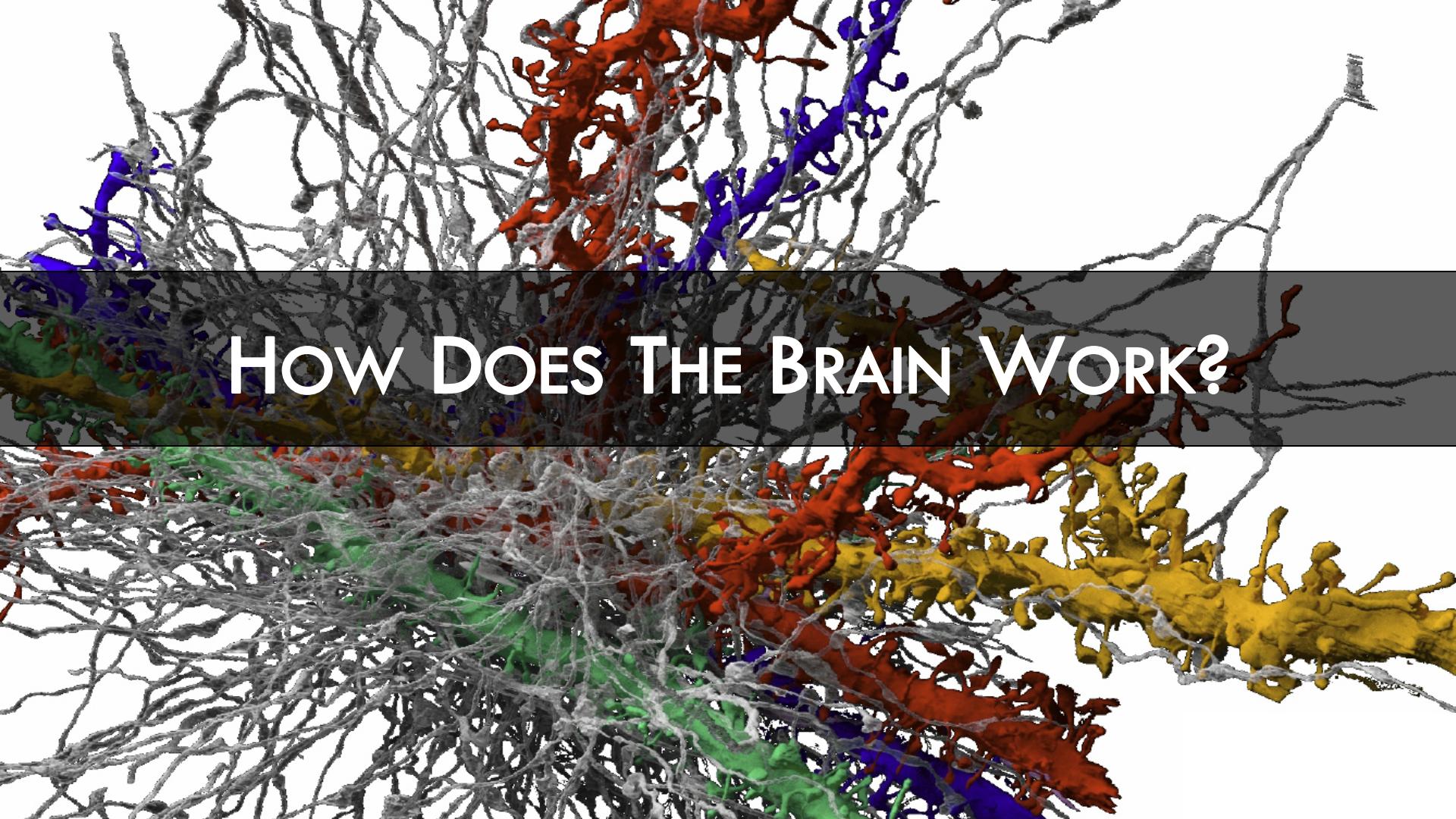


Ali K. Al-Awami, Johanna Beyer, Hendrik Strobelt, Narayanan Kasthuri, Jeff W. Lichtman, Hanspeter Pfister, and Markus Hadwiger



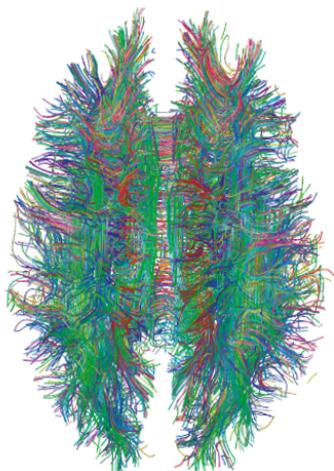
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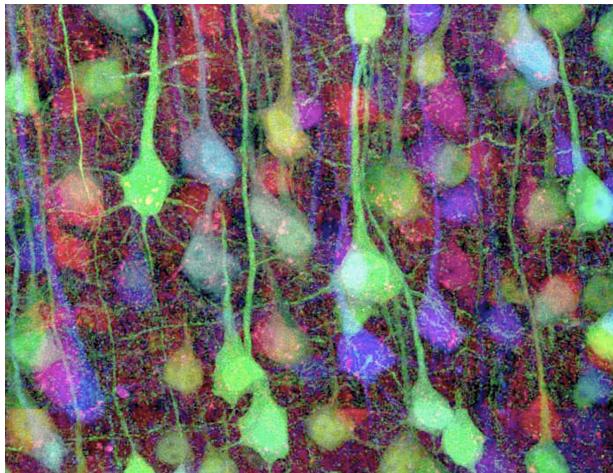
HOW DOES THE BRAIN WORK?

CONNECTOMICS

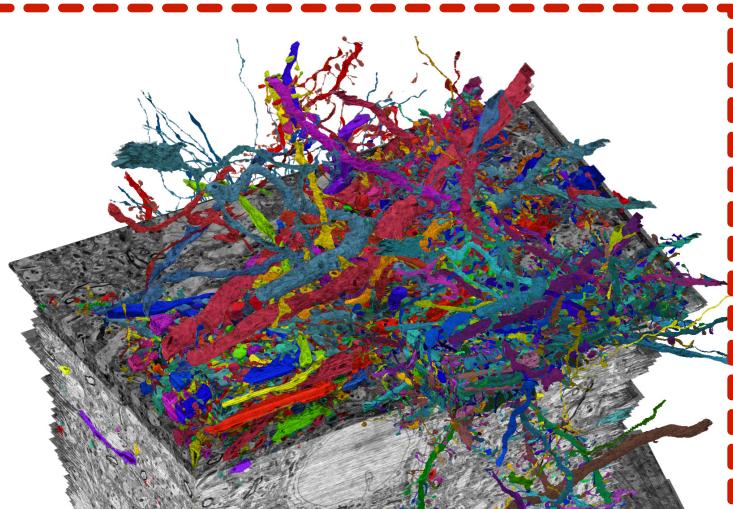


Macro

10^{-2} m



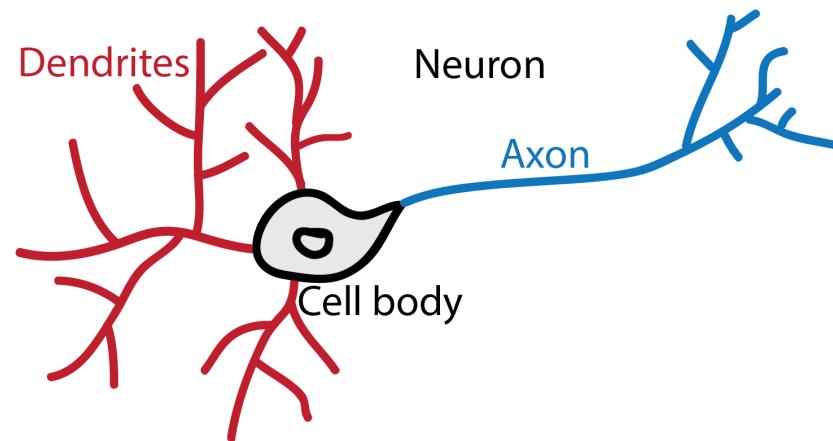
Meso



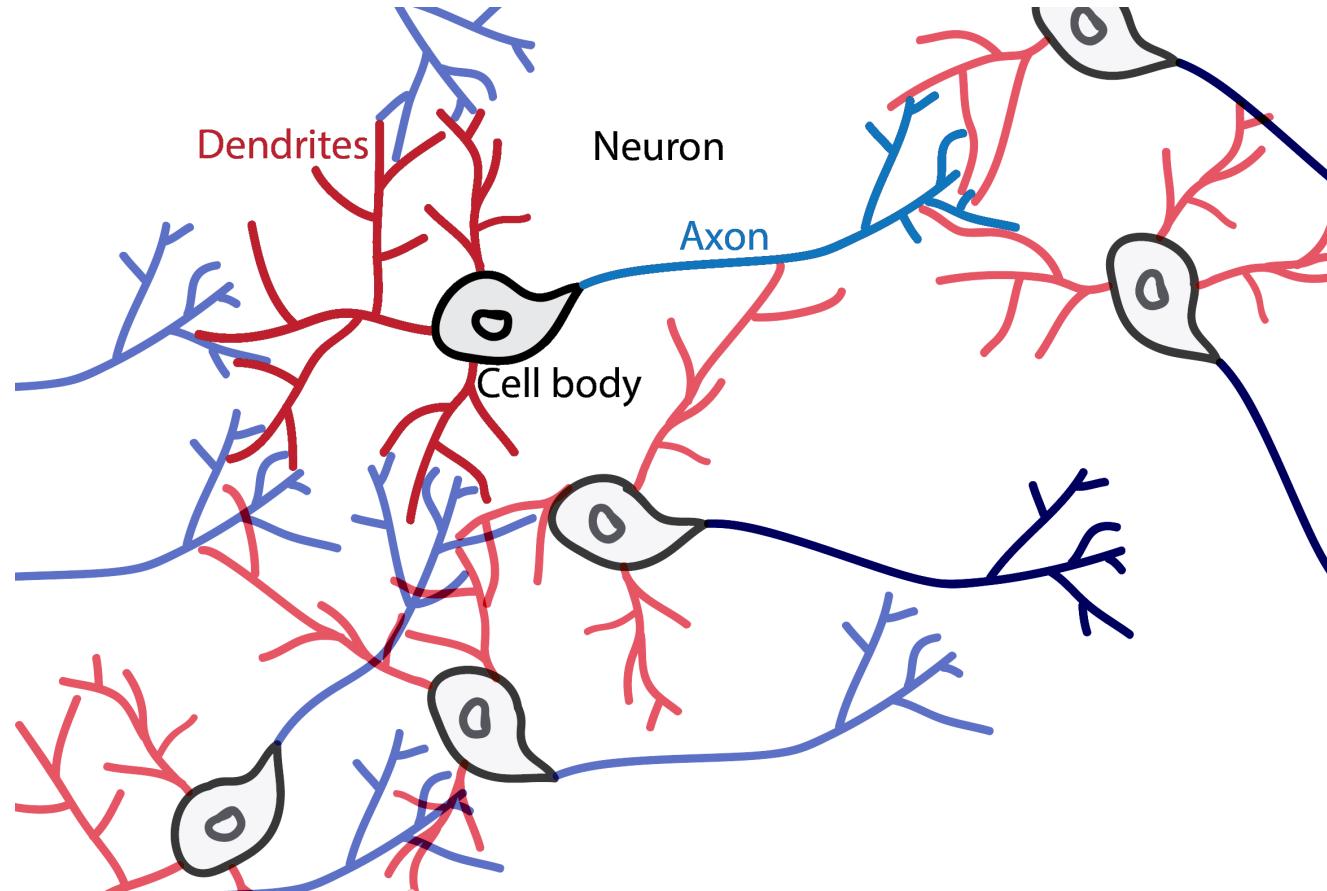
Micro / Nano

10^{-9} m

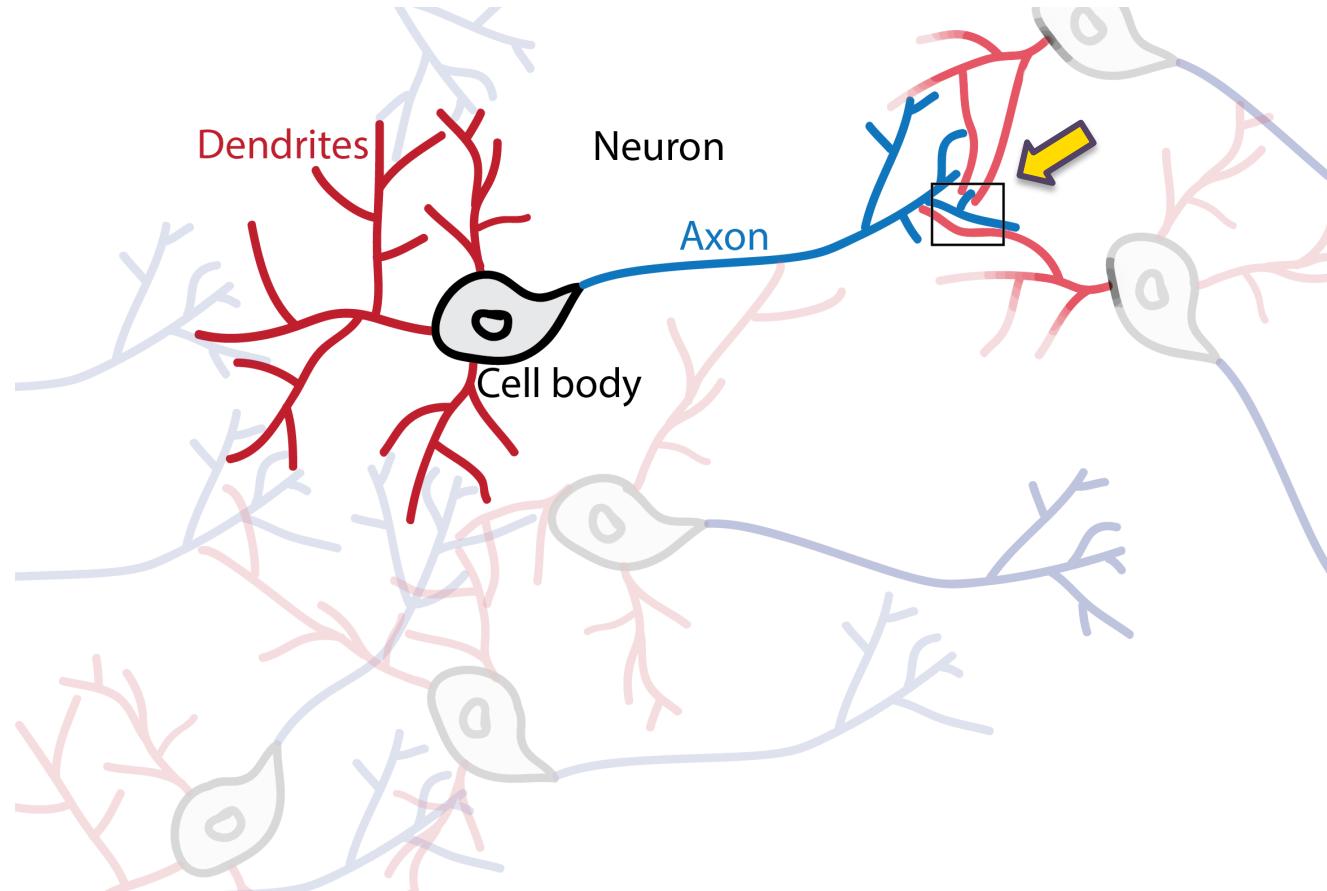
NEURONS



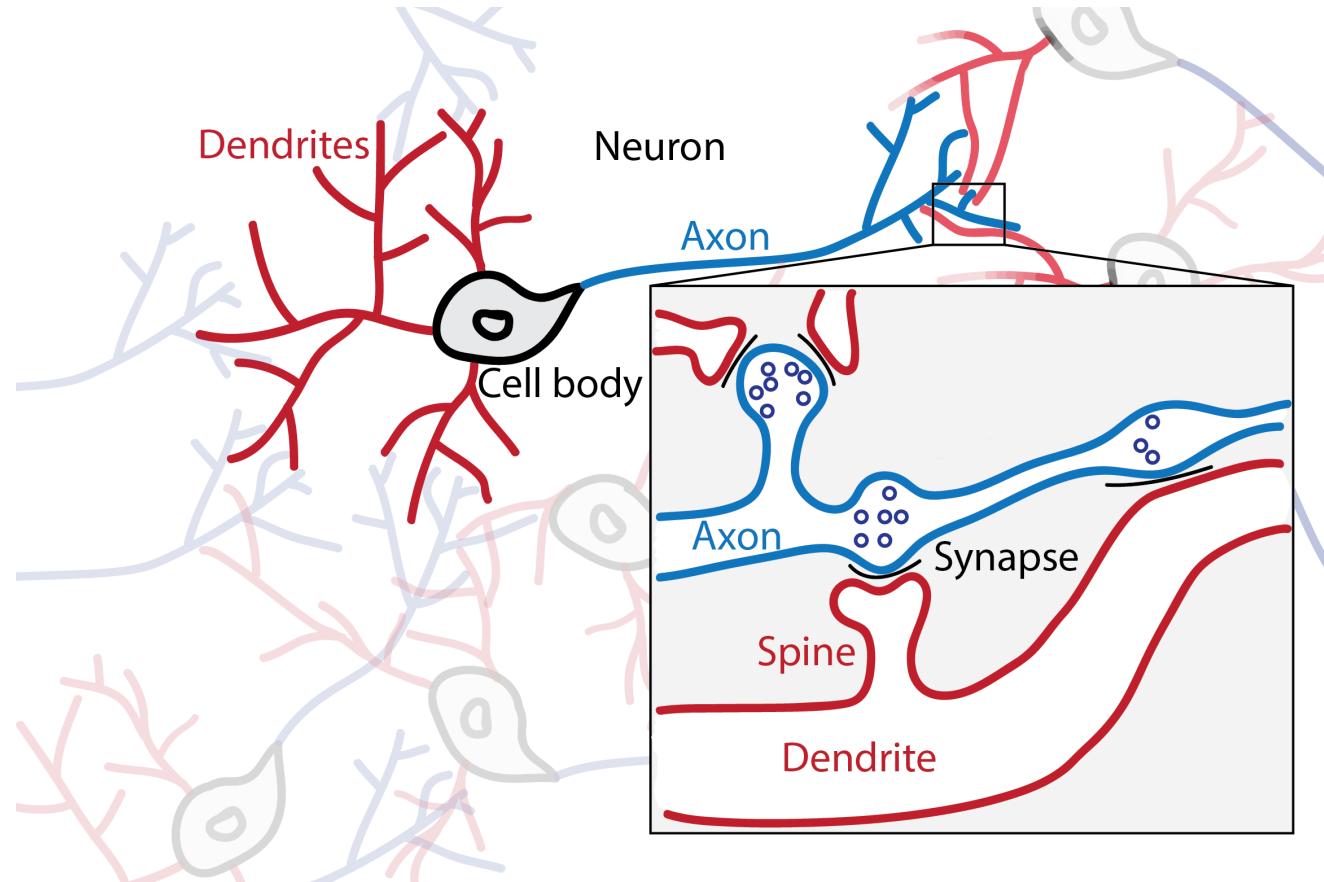
NEURONS



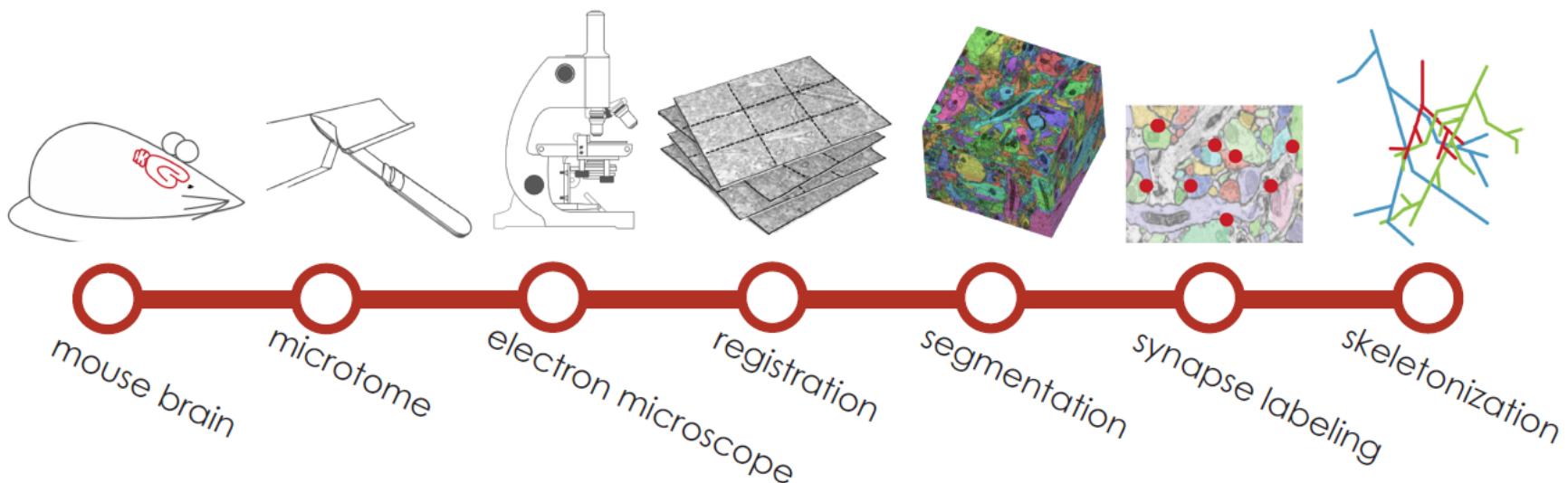
NEURONS



NEURONS AND SYNAPSES

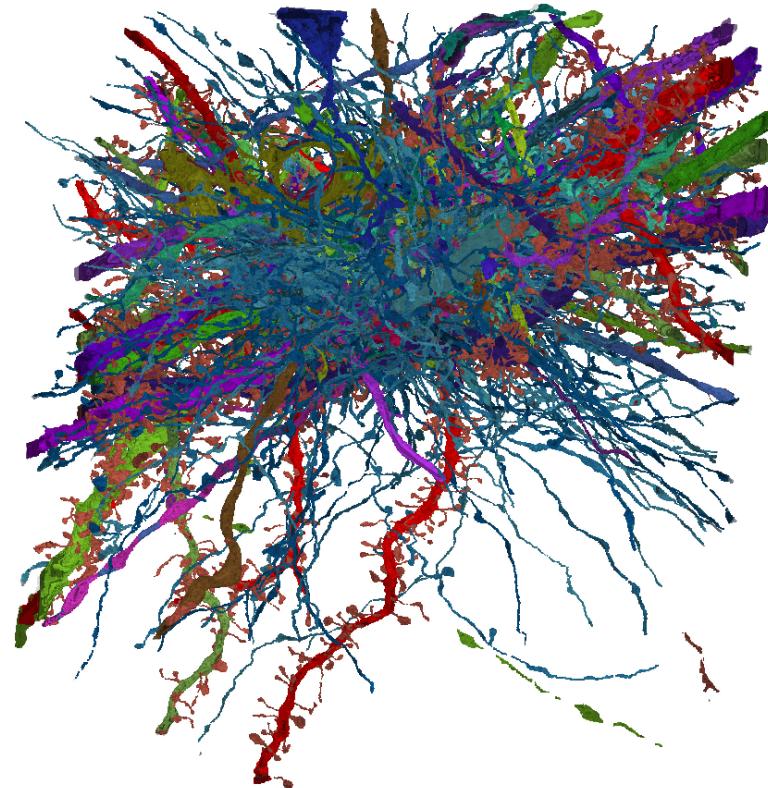


DATA ACQUISITION WORKFLOW



PROBLEM

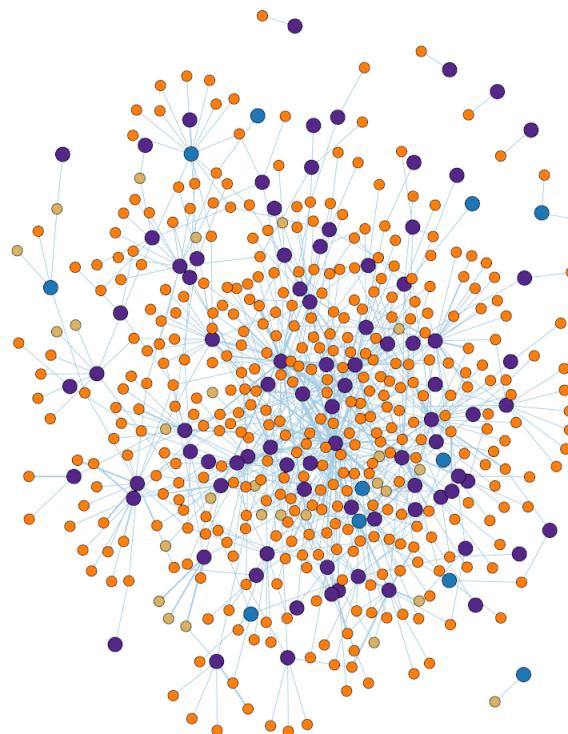
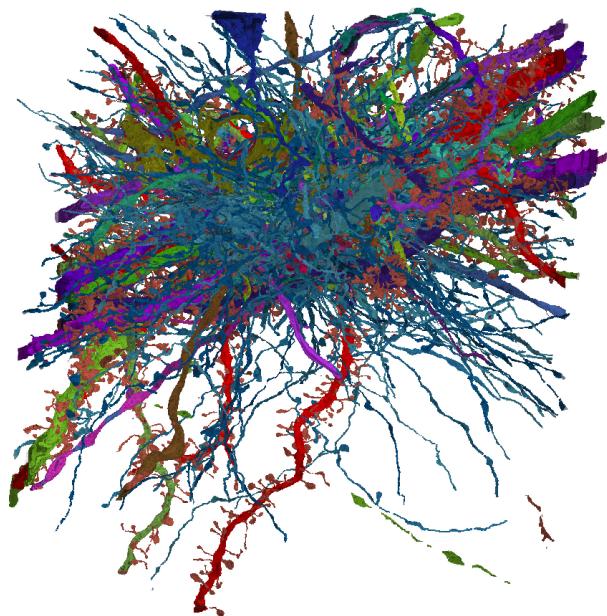
~ 750 Neurites
~4000 Objects
~700GB Seg.
~1.7 TB EM+Seg.
~60 μm^3



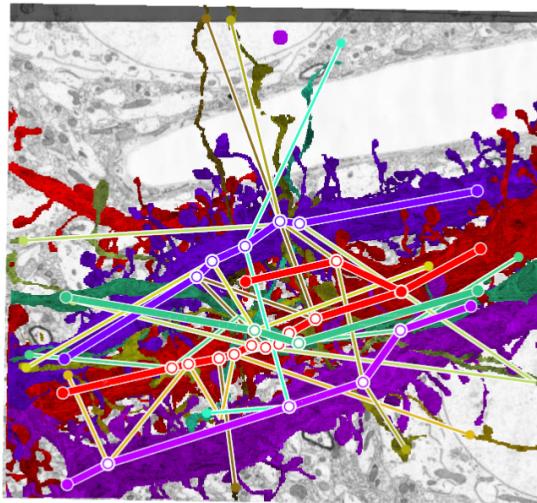
VISUALIZATION GOALS

- Simple
- Scalable
- Clutter Free
- Feature Preserving

CONNECTOME EXPLORER [BEYER ET AL. 2013]



FIRST ATTEMPT: 3D SUBWAY MAP





axon_61 - neuron_4

NEUROLINES



dendrite_174 - neuron_14

dendrite_167 - neuron_13

dendrite_192 - neuron_23

dendrite_193 - neuron_15

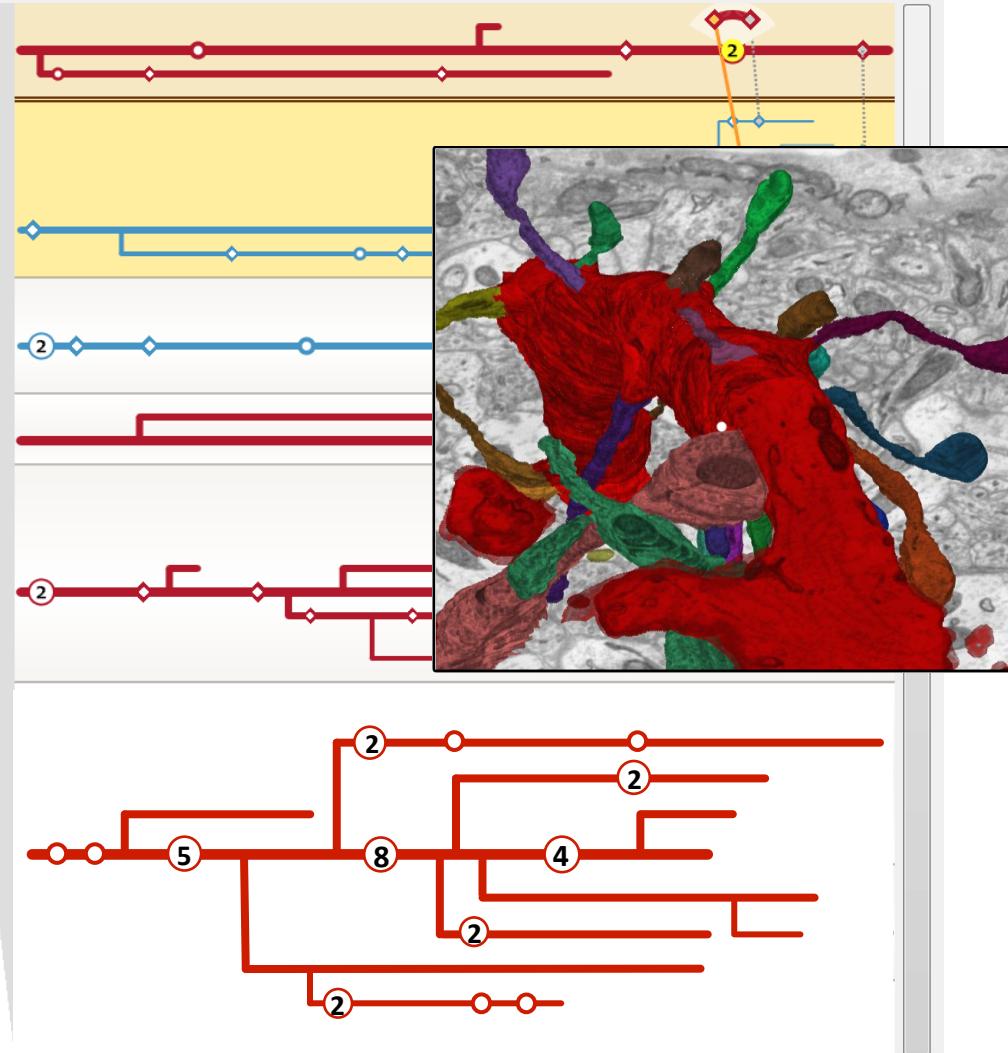
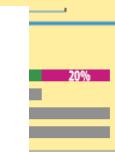
dendrite_149 - neuron_11

dendrite_91 - neuron_7

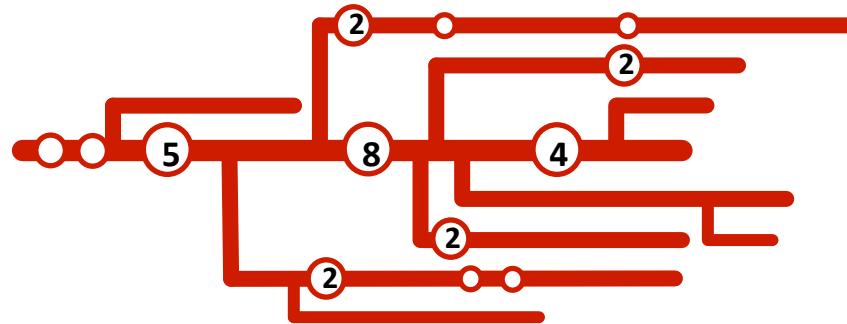
dendrite_55 - neuron_3

dendrite_54 - neuron_3

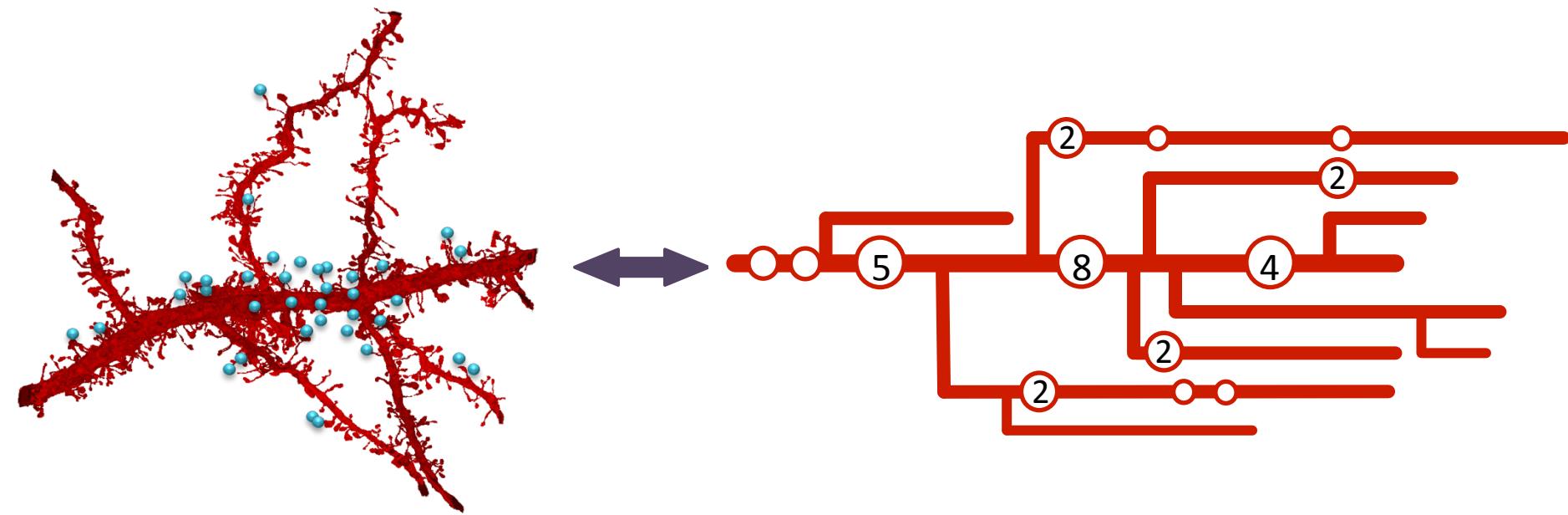
dendrite_157 - neuron_12



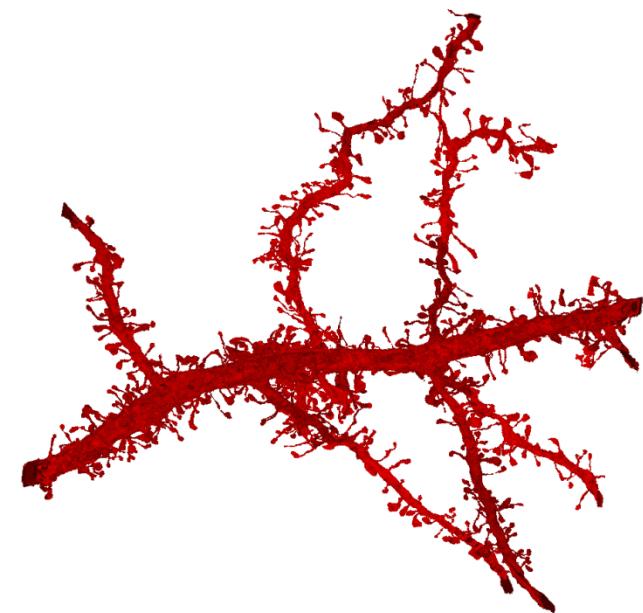
VISUAL ENCODING



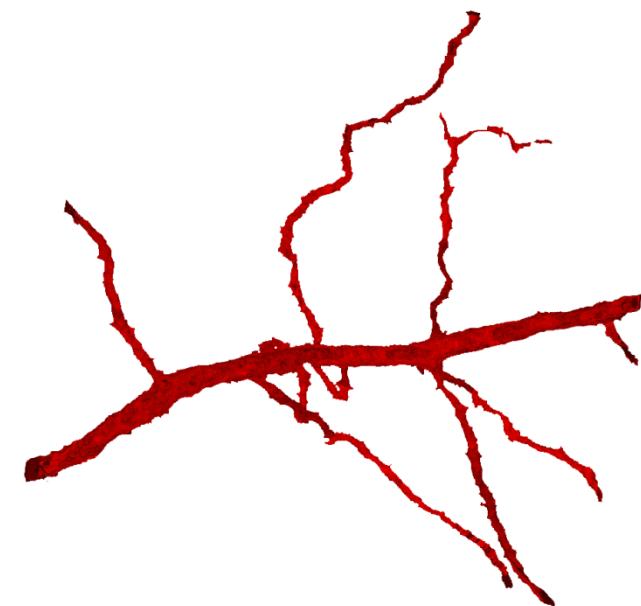
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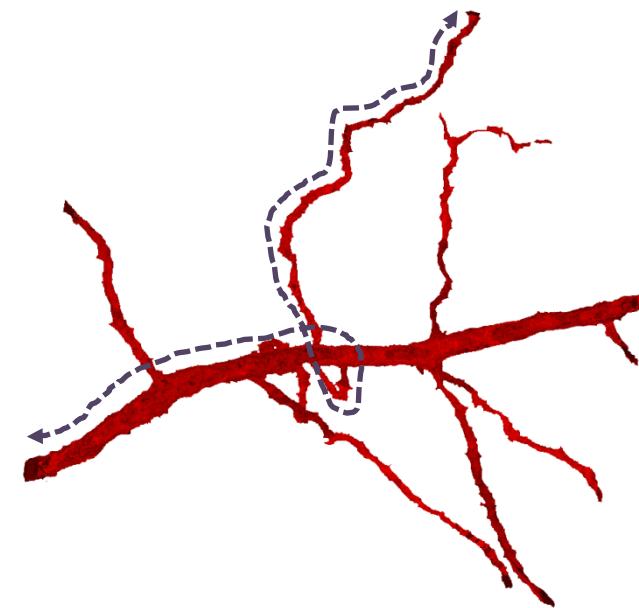
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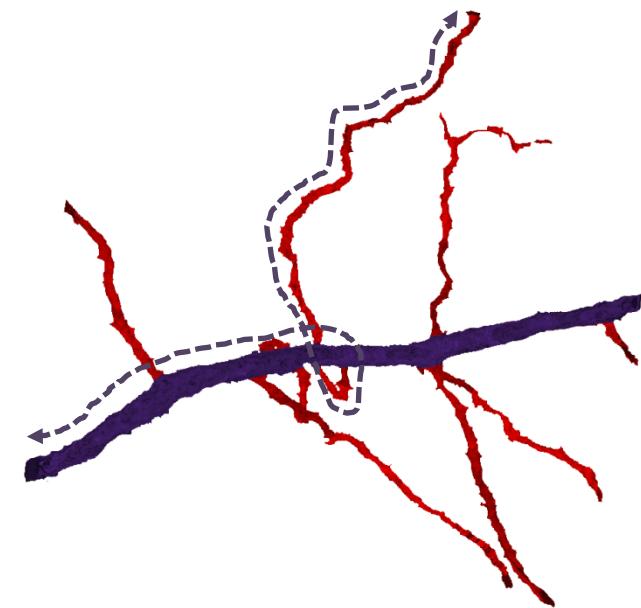
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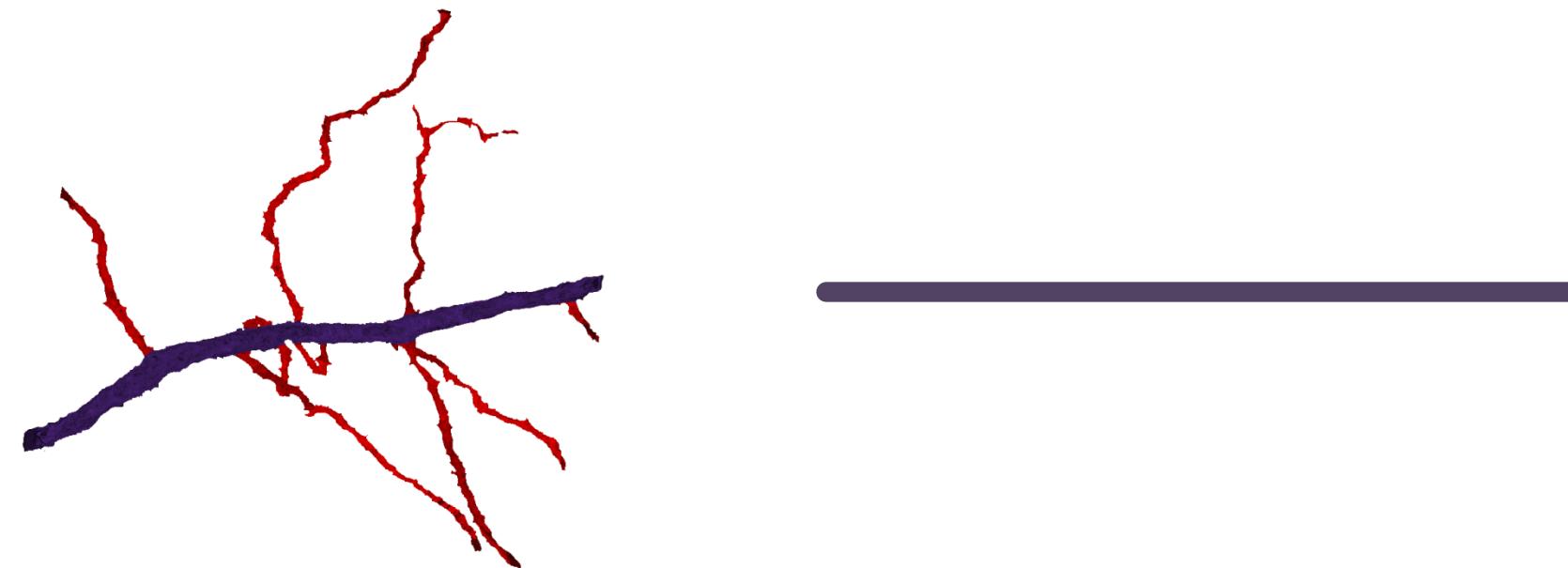
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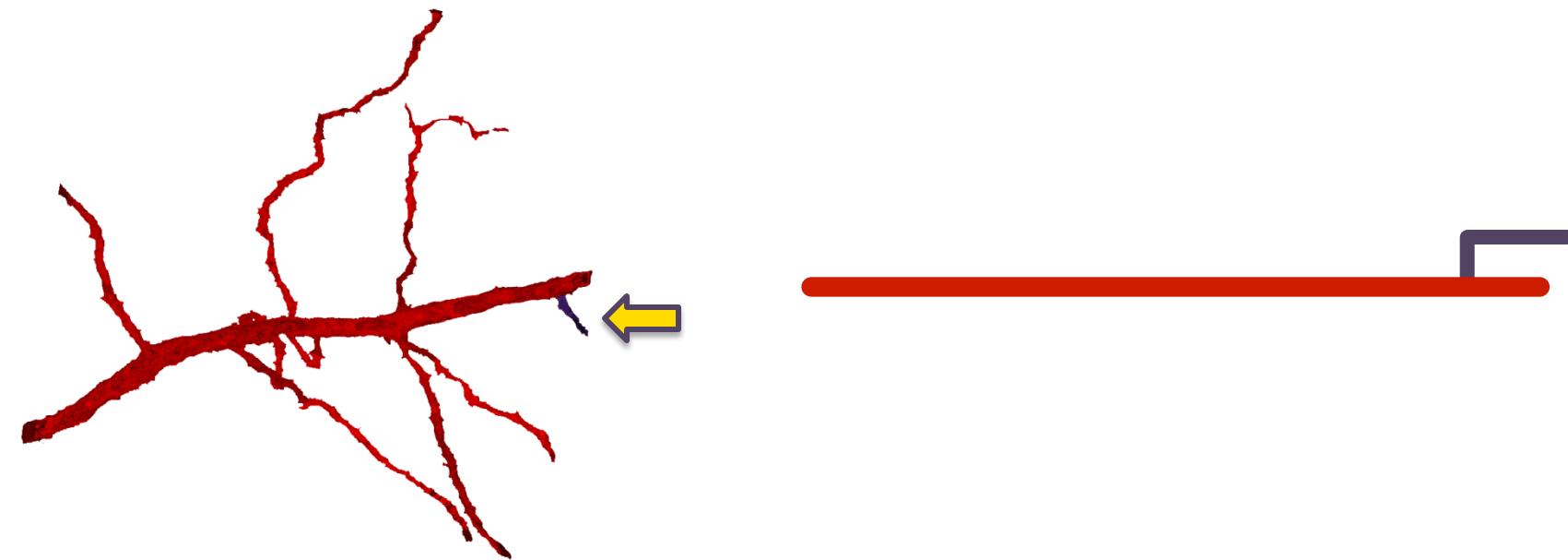
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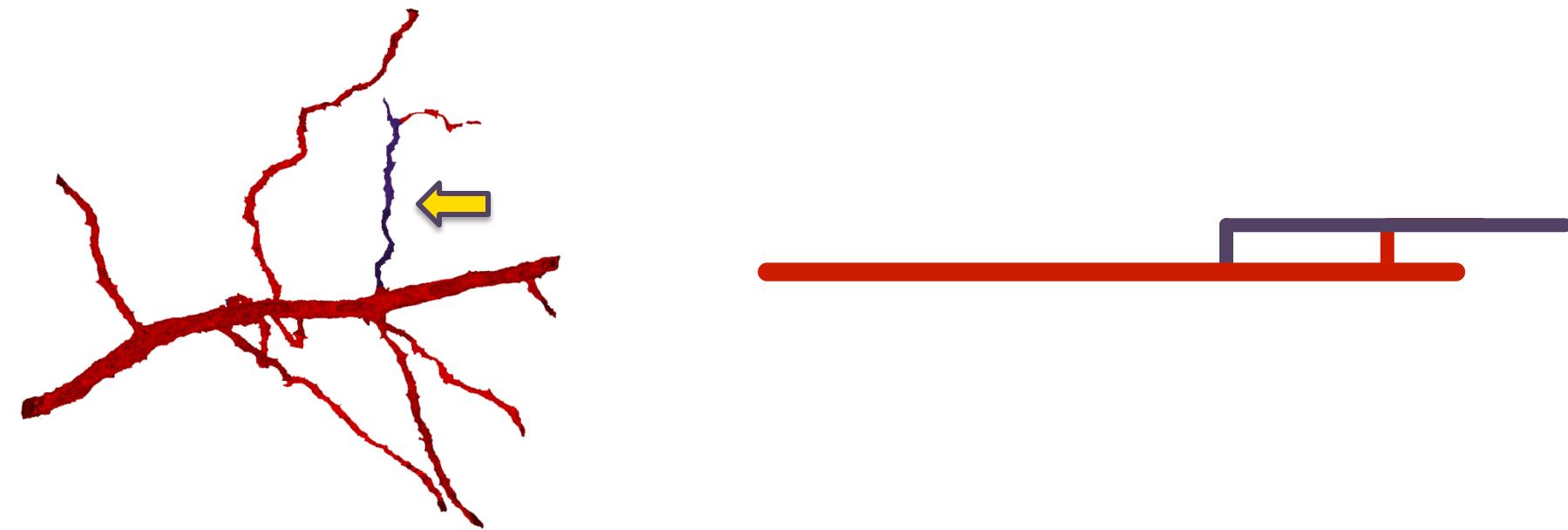
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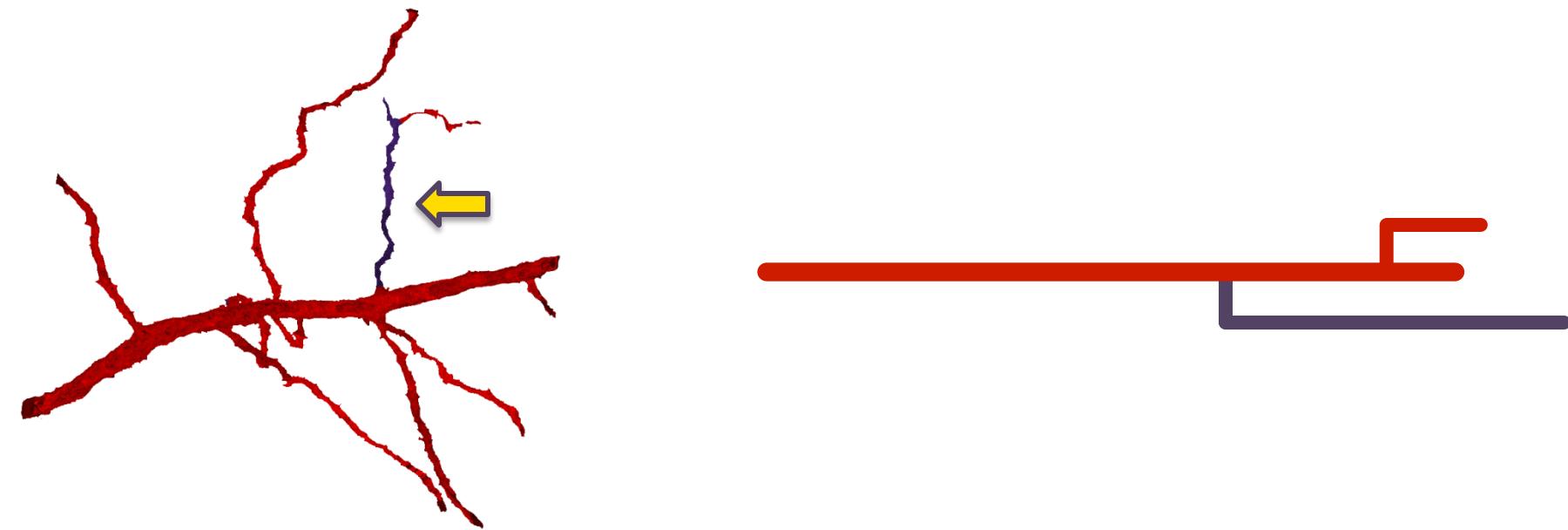
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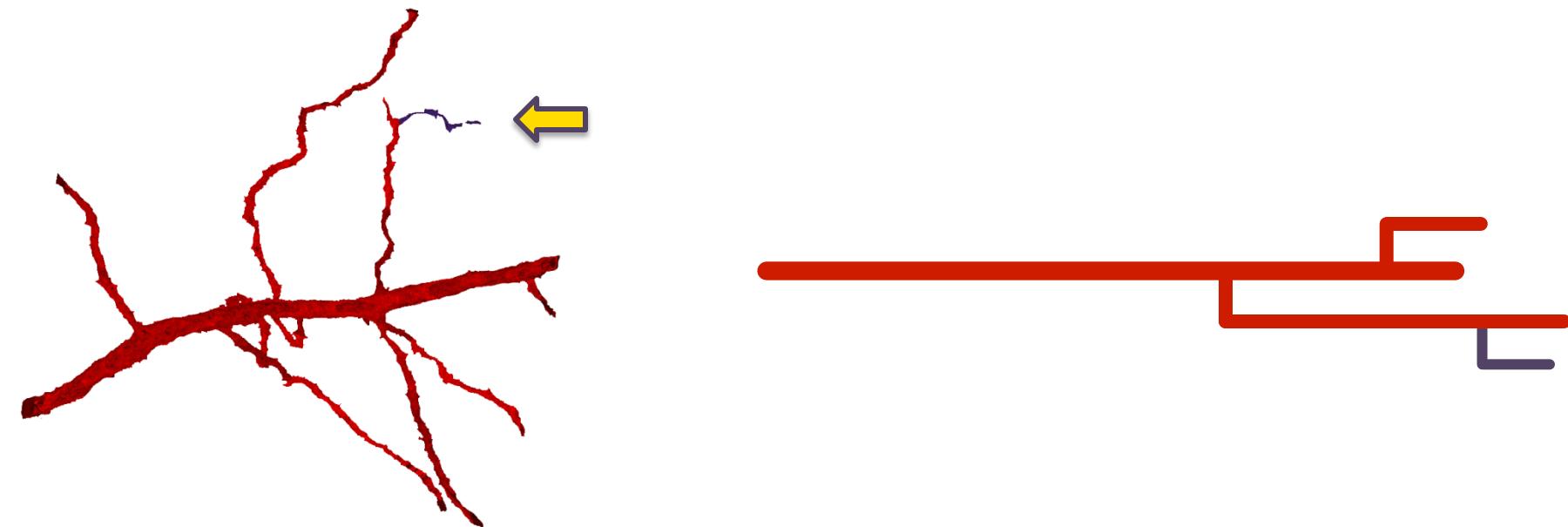
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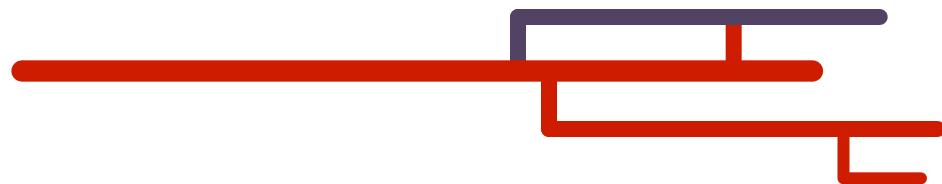
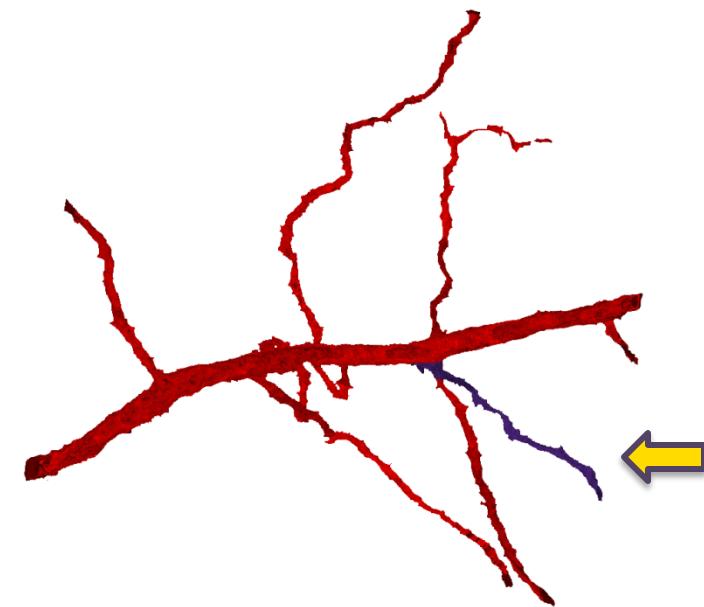
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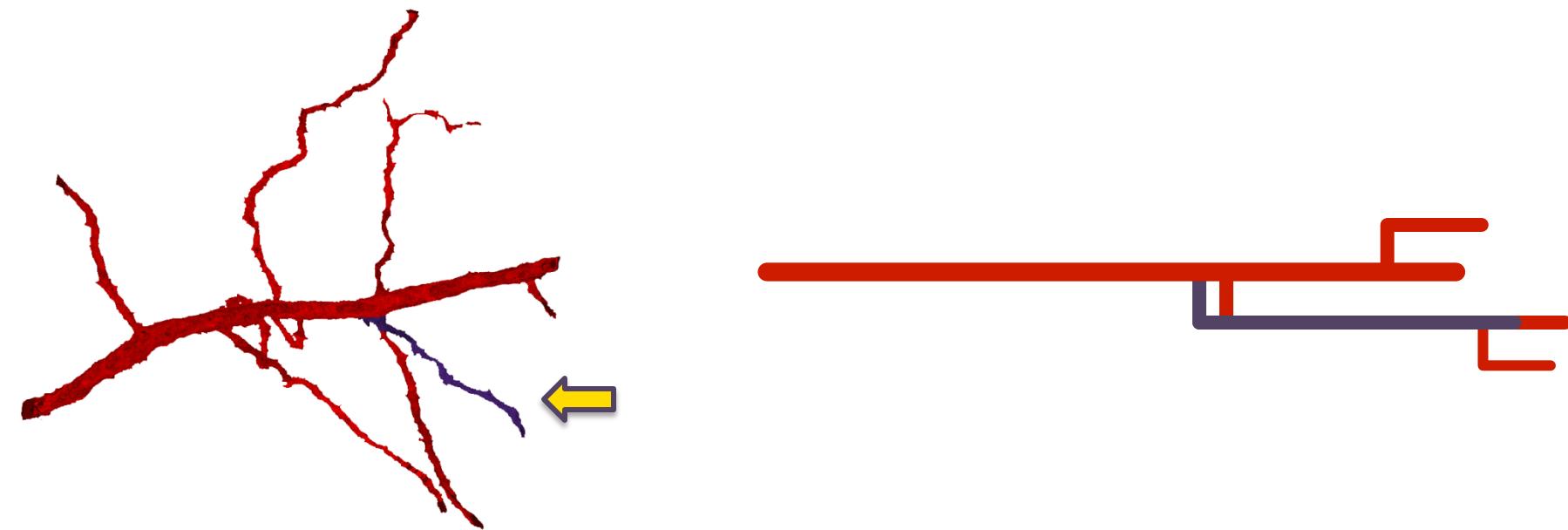
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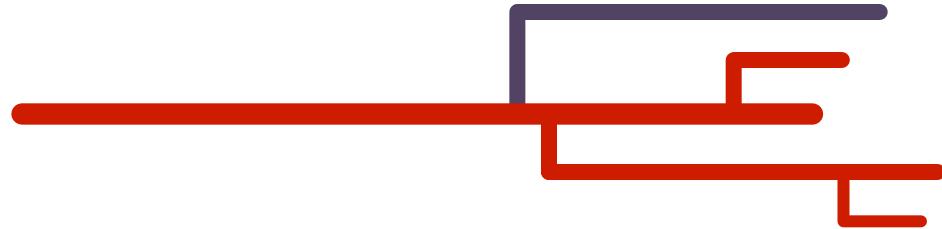
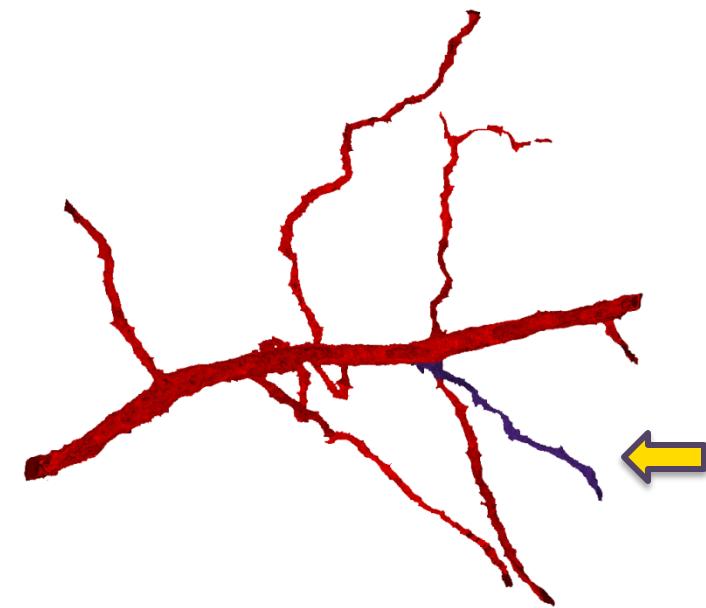
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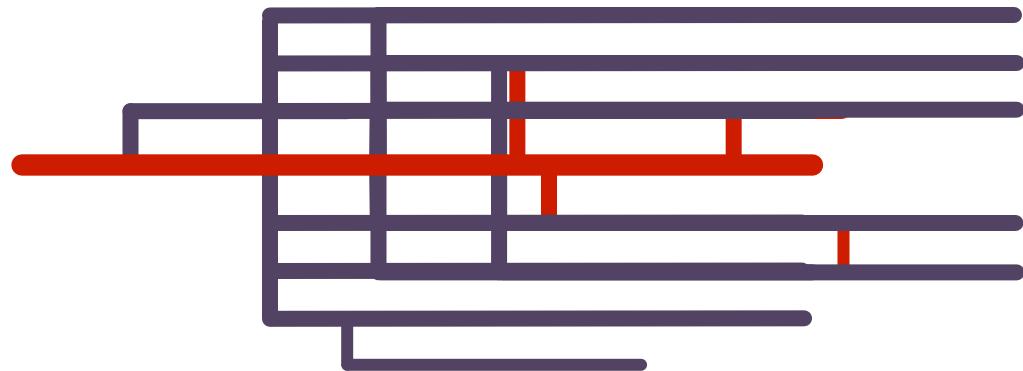
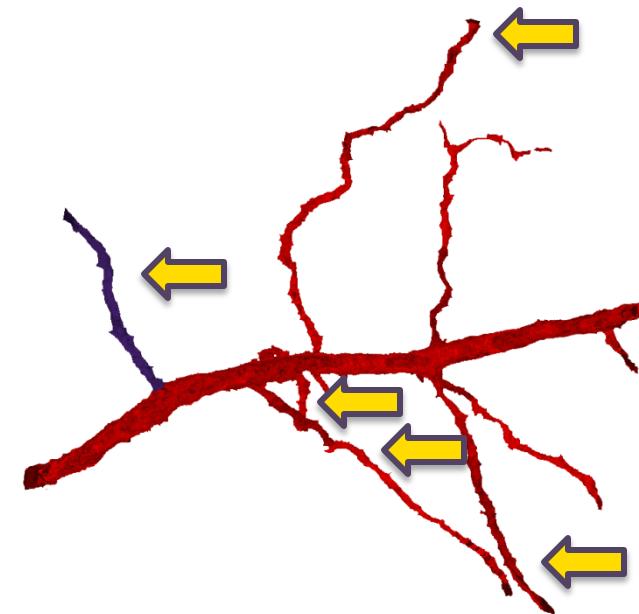
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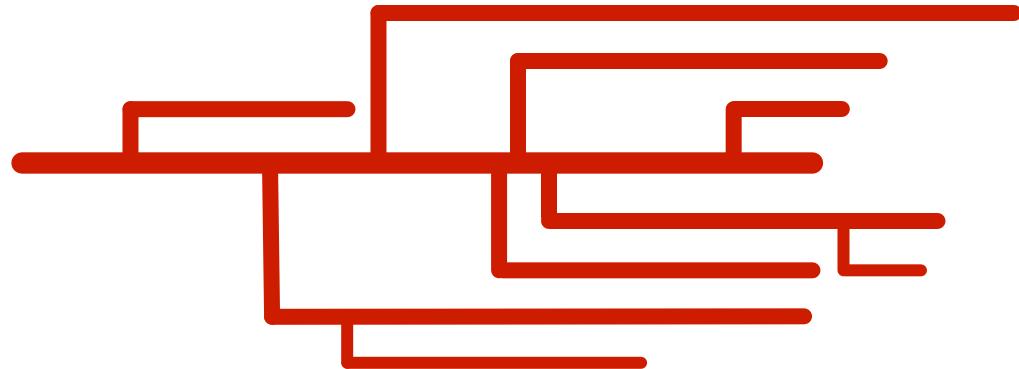
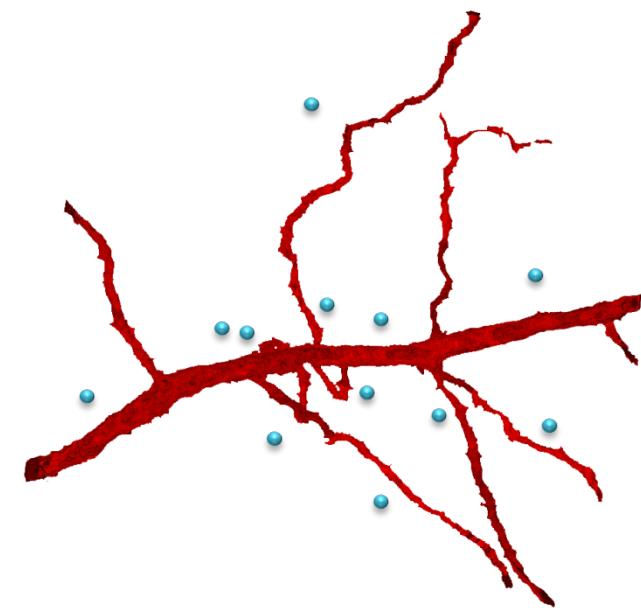
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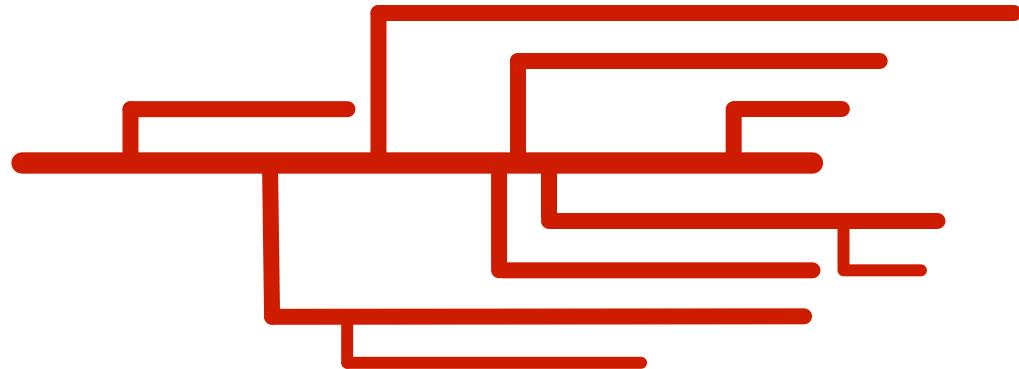
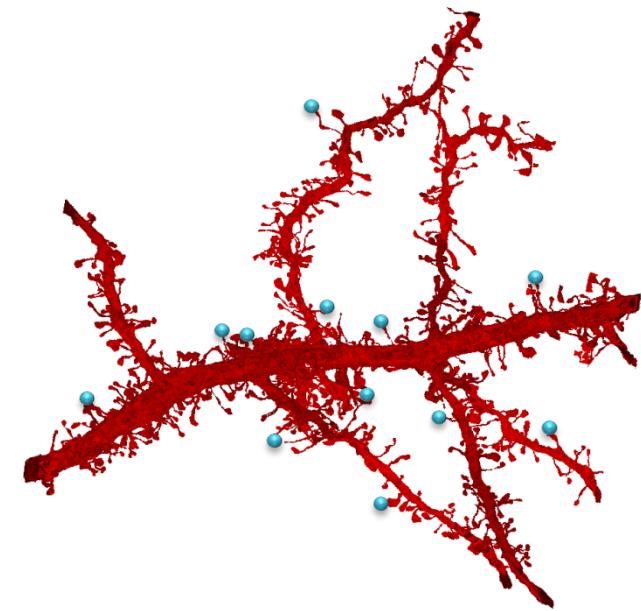
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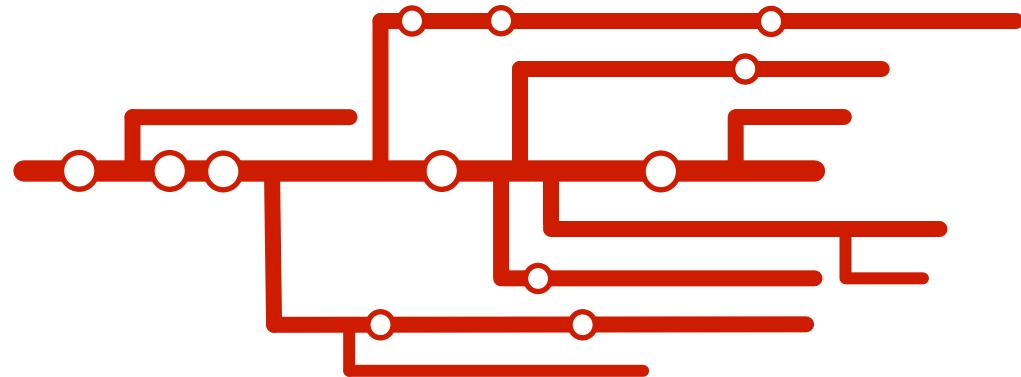
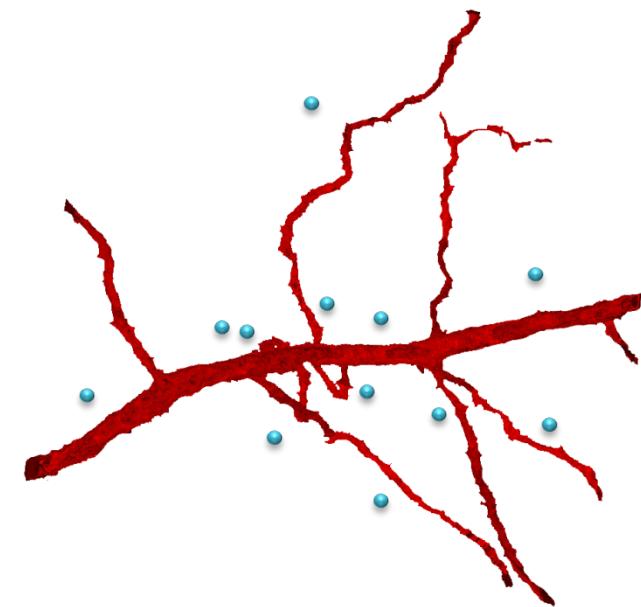
VISUAL ENCODING: SYNAPSES



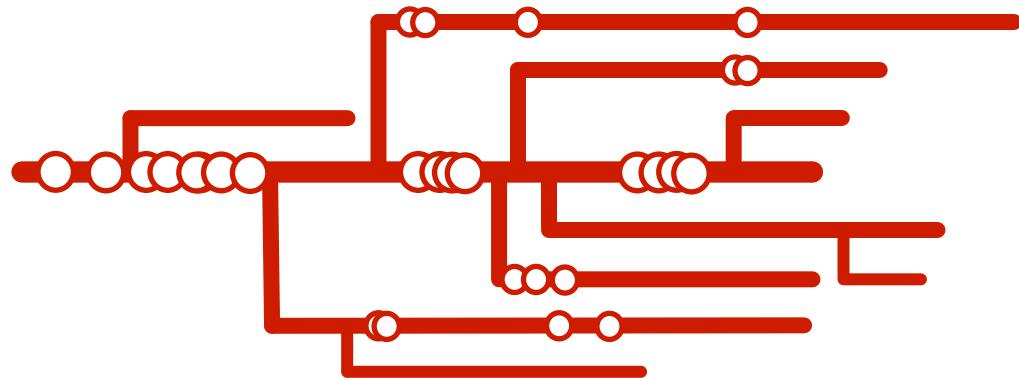
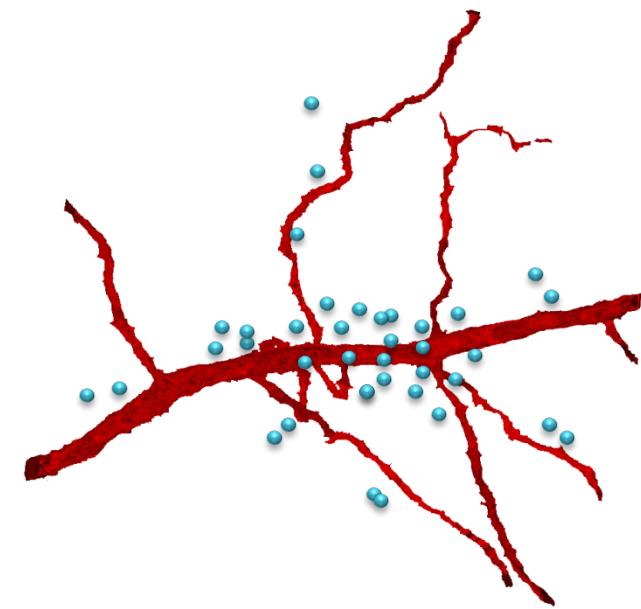
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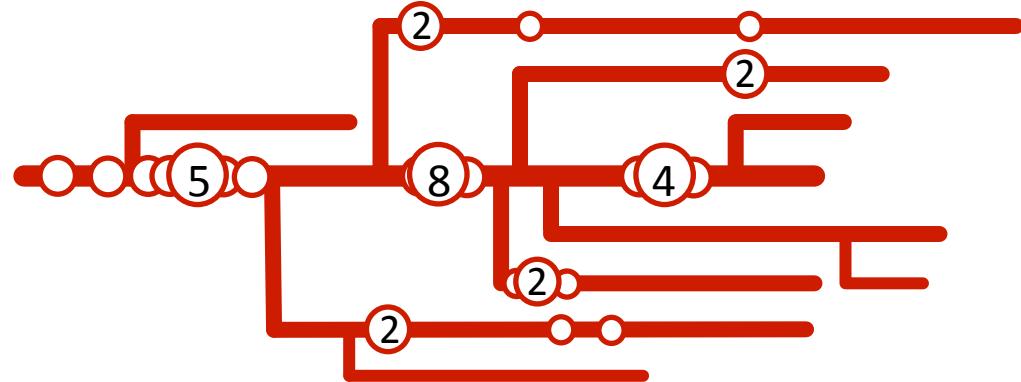
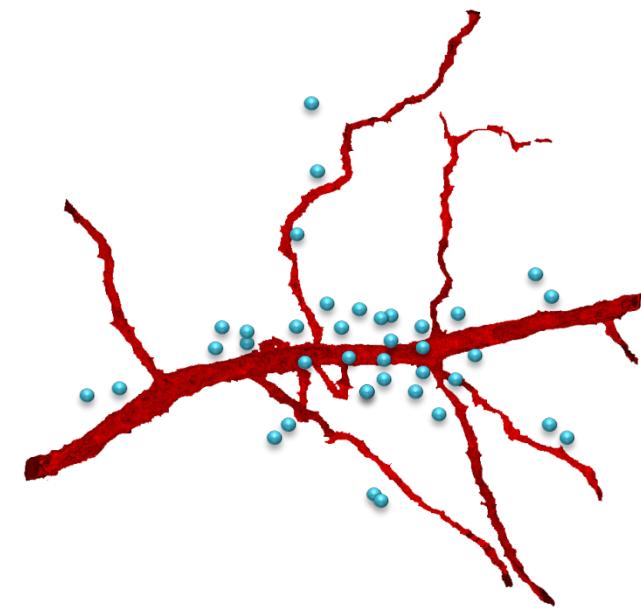
VISUAL ENCODING: SYNAPSES



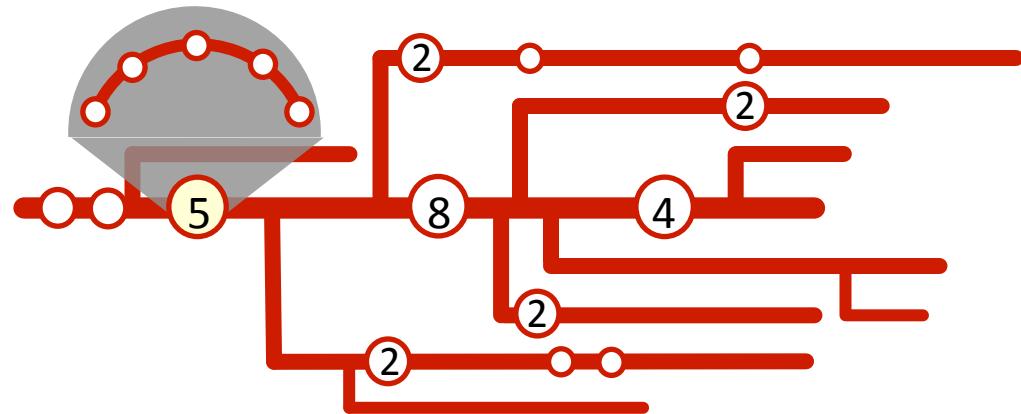
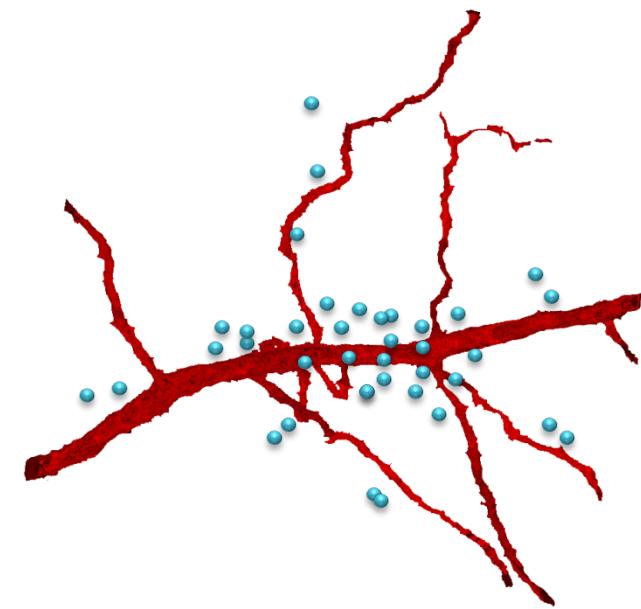
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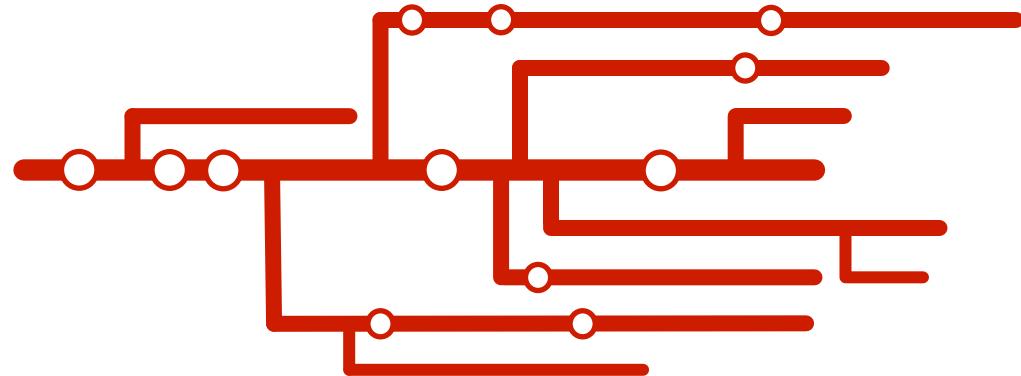
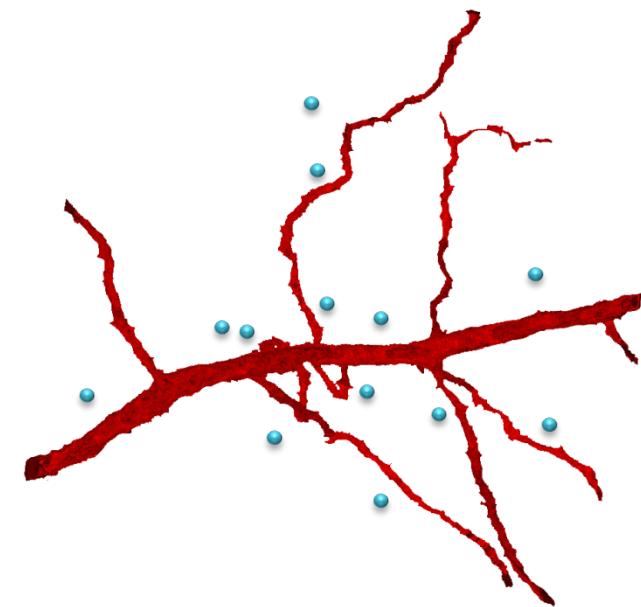
VISUAL ENCODING: CLUSTERING



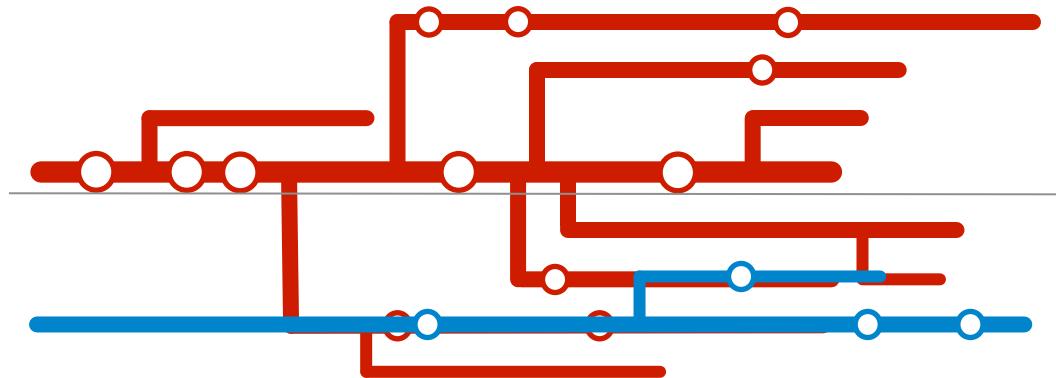
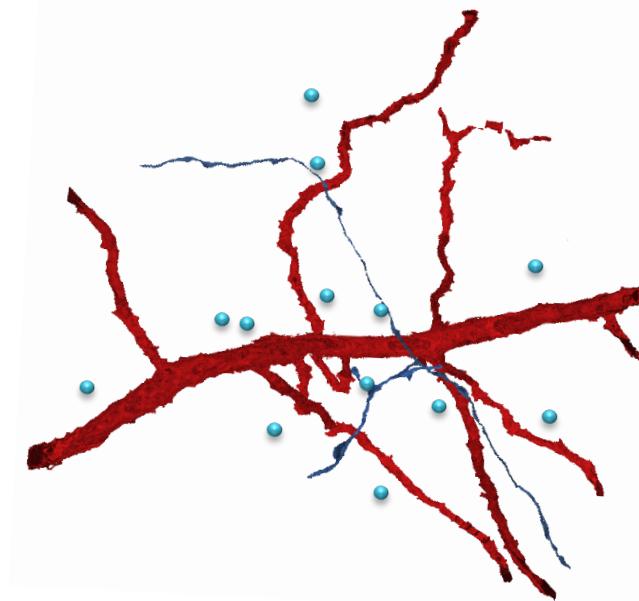
VISUAL ENCODING: CLUSTERING



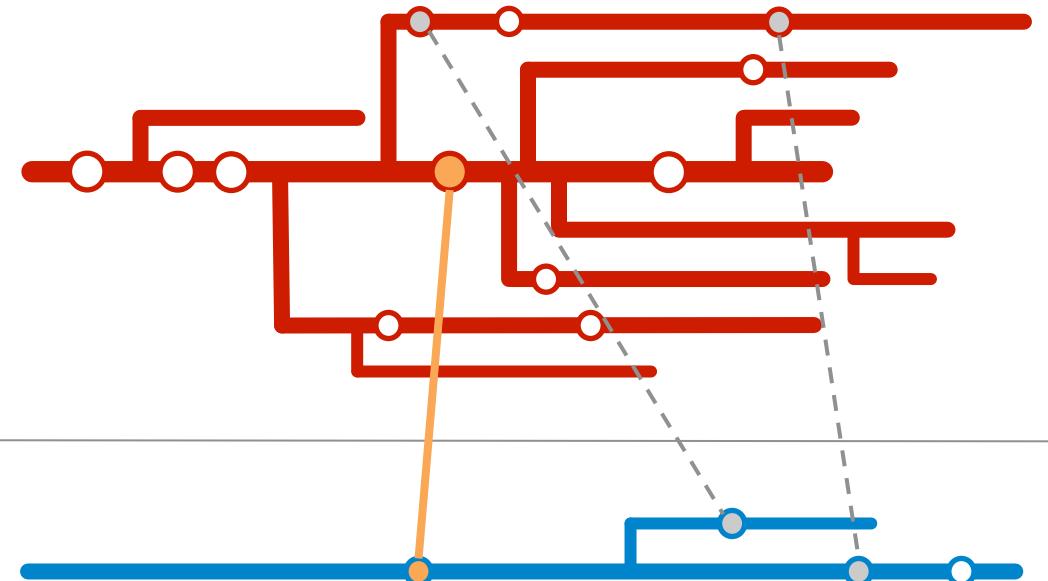
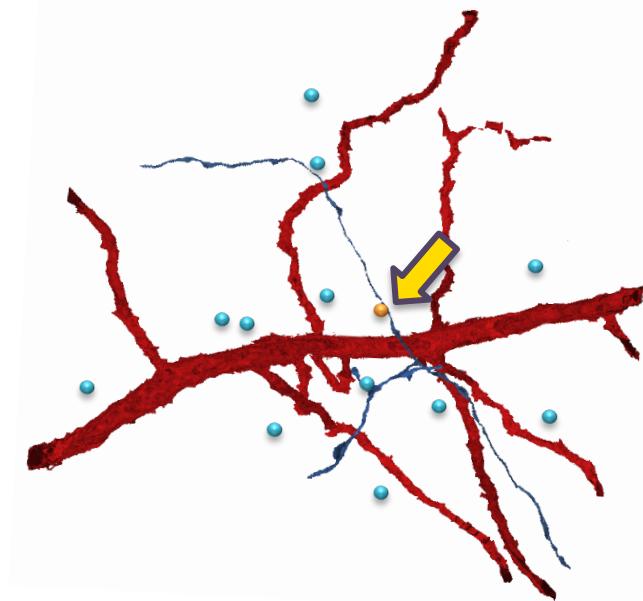
VISUAL ENCODING: SYNAPSES



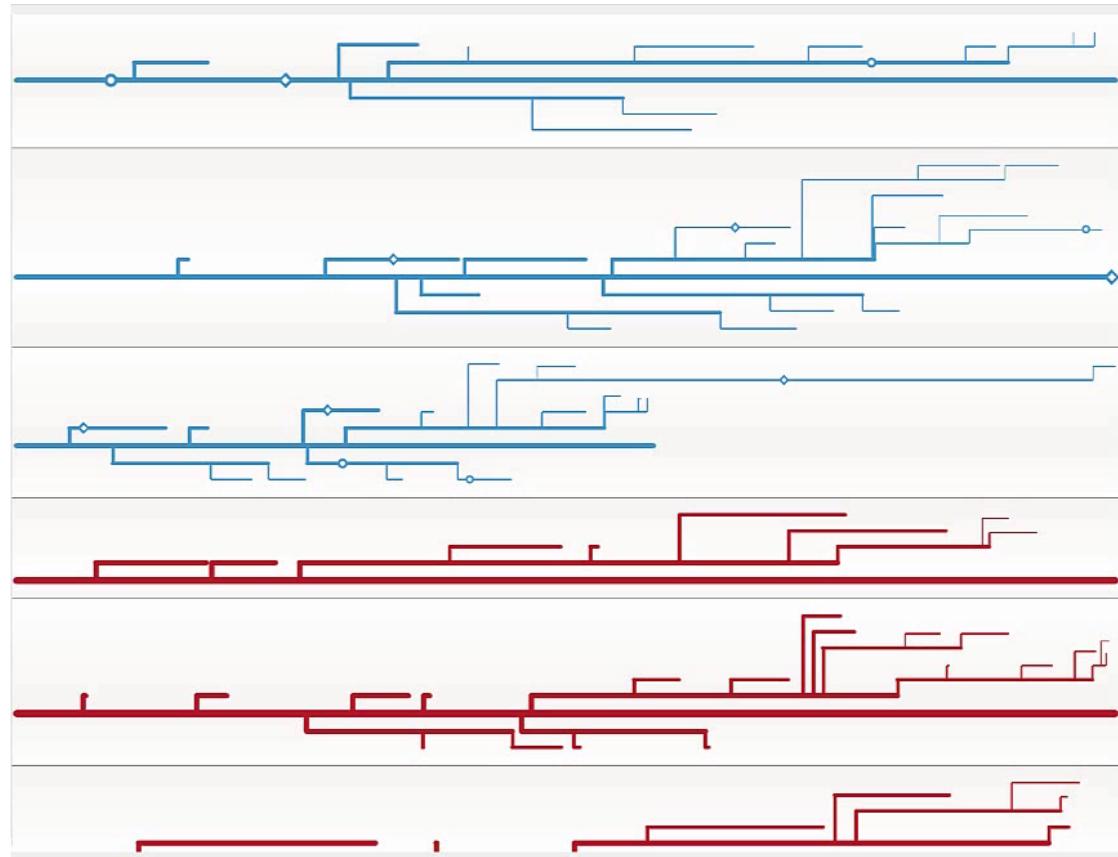
VISUAL ENCODING: SYNAPSES



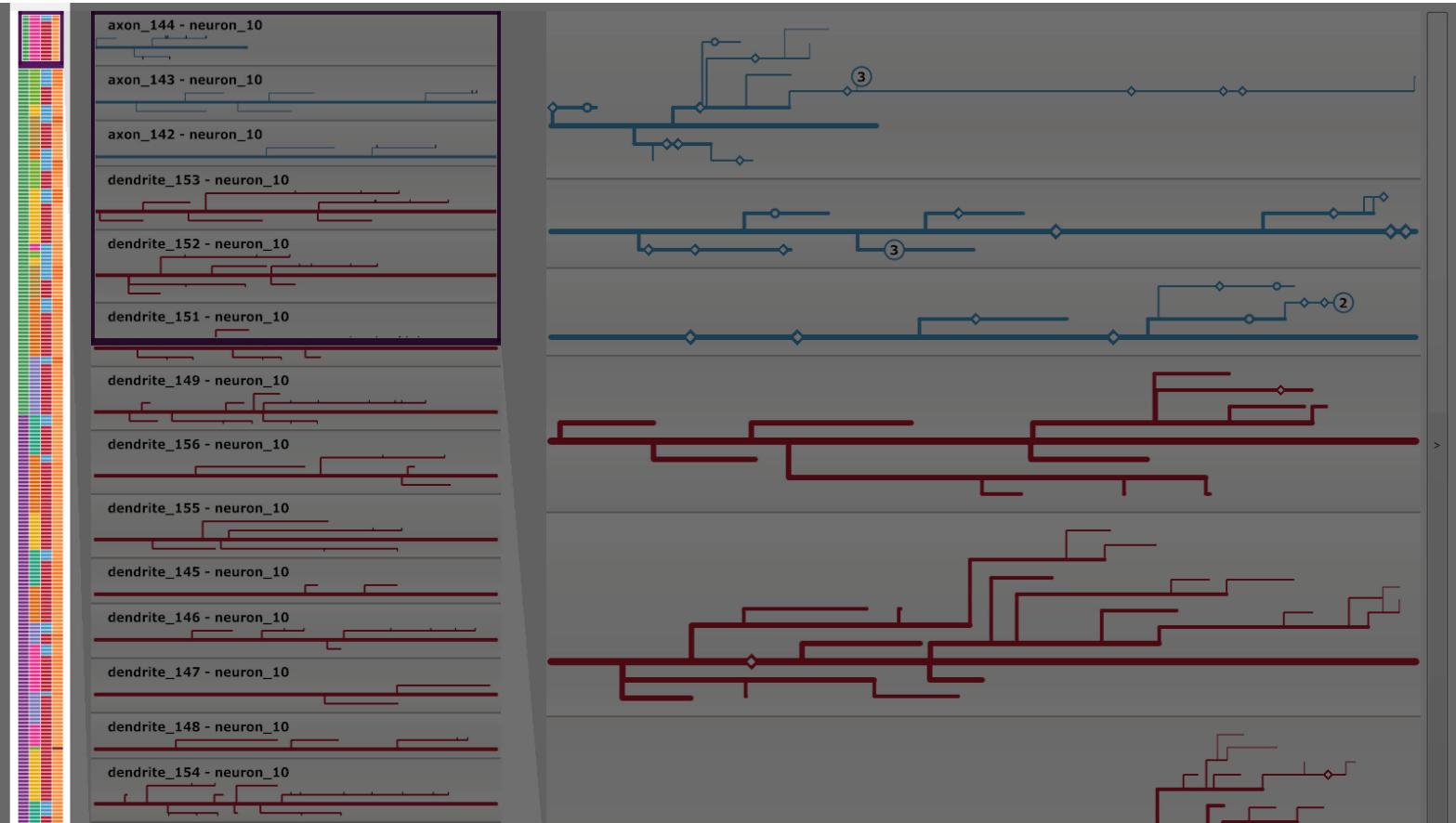
VISUAL ENCODING: SYNAPSE LINKS



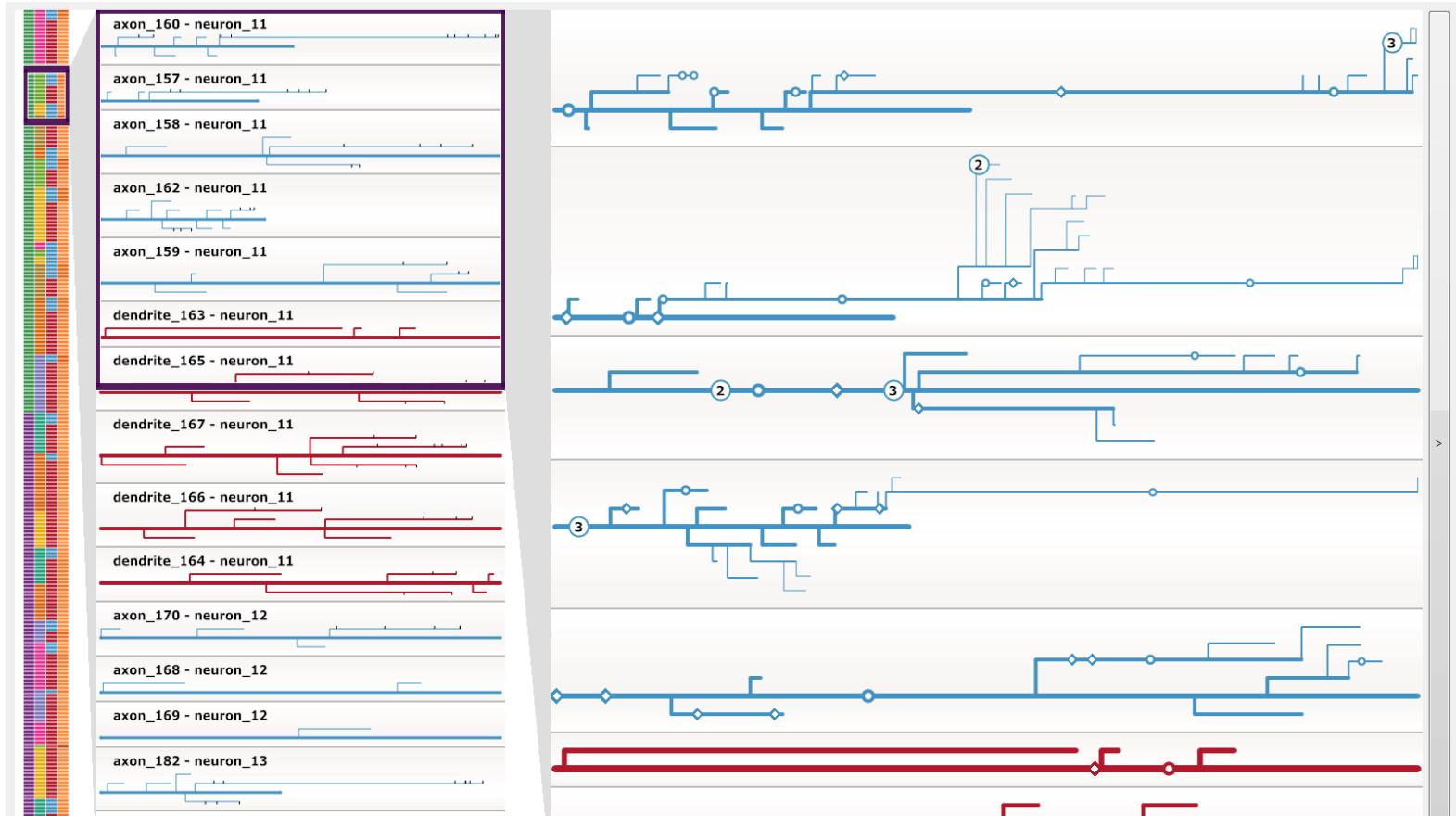
NEUROLINES



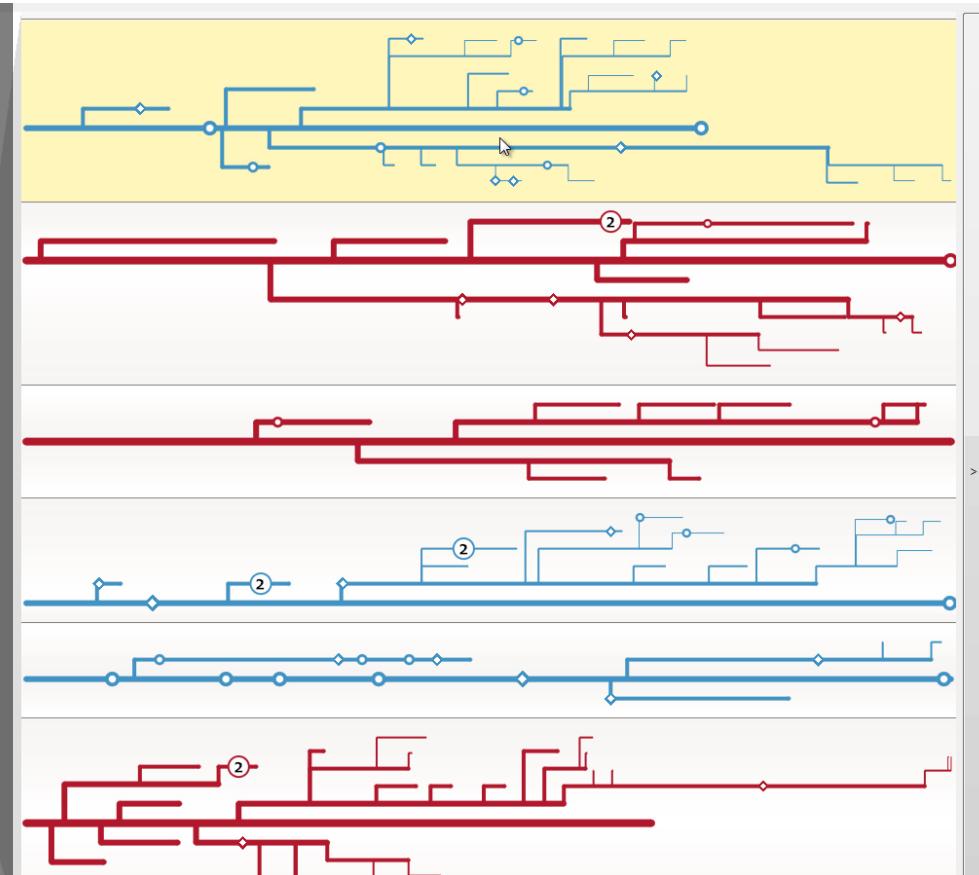
NEUROLINES: NAVIGATION BAR



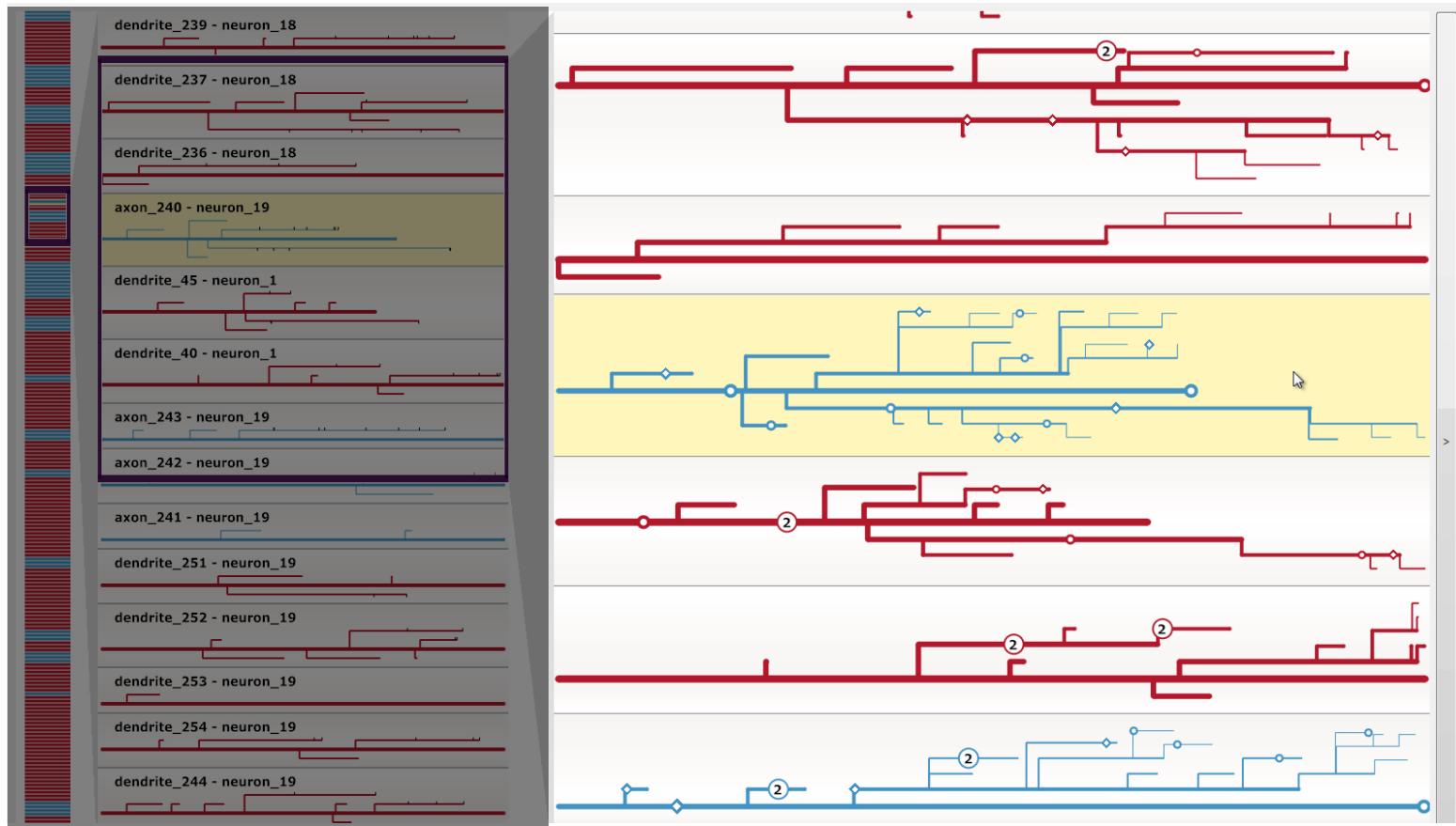
NEUROLINES: NEURITE OVERVIEW



NEUROLINES: WORKSPACE



NEUROLINES: WORKSPACE



NEUROLINES: SYNAPSE DETAILS

346

Bouton: 357 Spine: BD Spine 64 -S

Vesicles: 36 Apparatus: No

Volume: - Volume: -

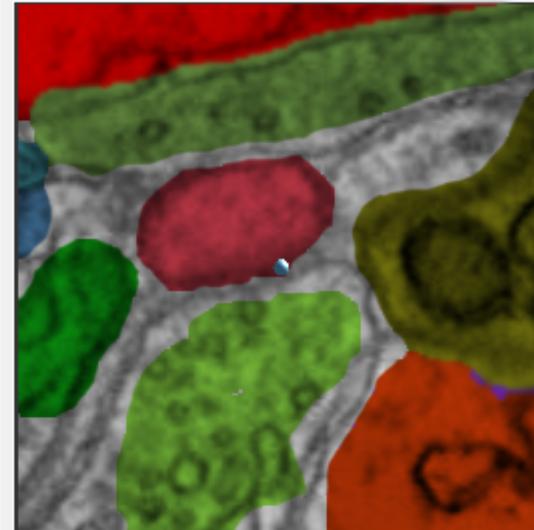
Terminal Branch: Yes

Mitochondrion: -

Axon: Segment 135_AE Dendrite: Bobbys Dendrite (Red)_DE

Neuron: - Neuron: -

Function: Excitatory Function: Excitatory

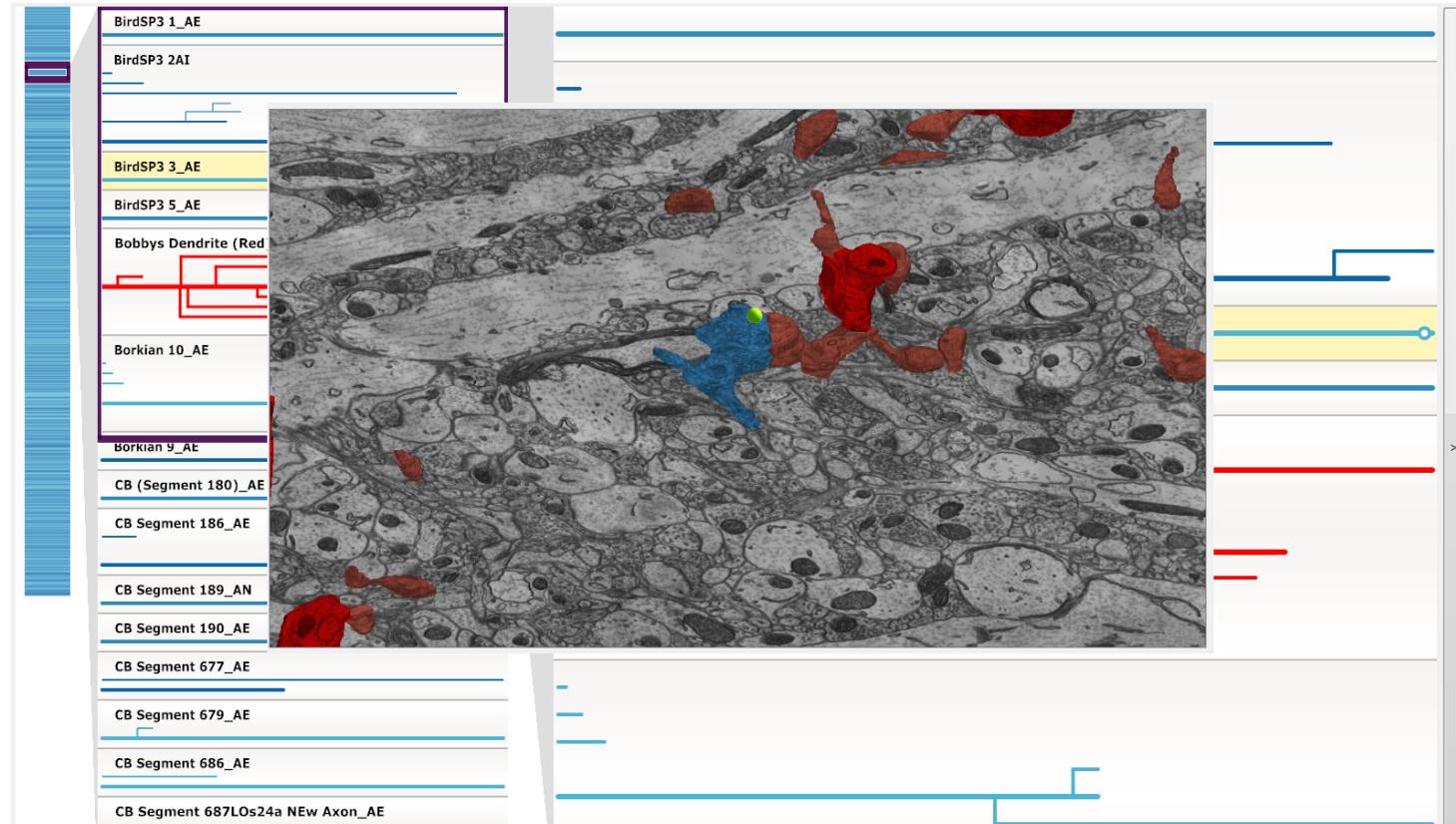


→ Go to synapse (Axon)

→ Go to synapse (Dendrite)

→ Go to synapse (Volume View)

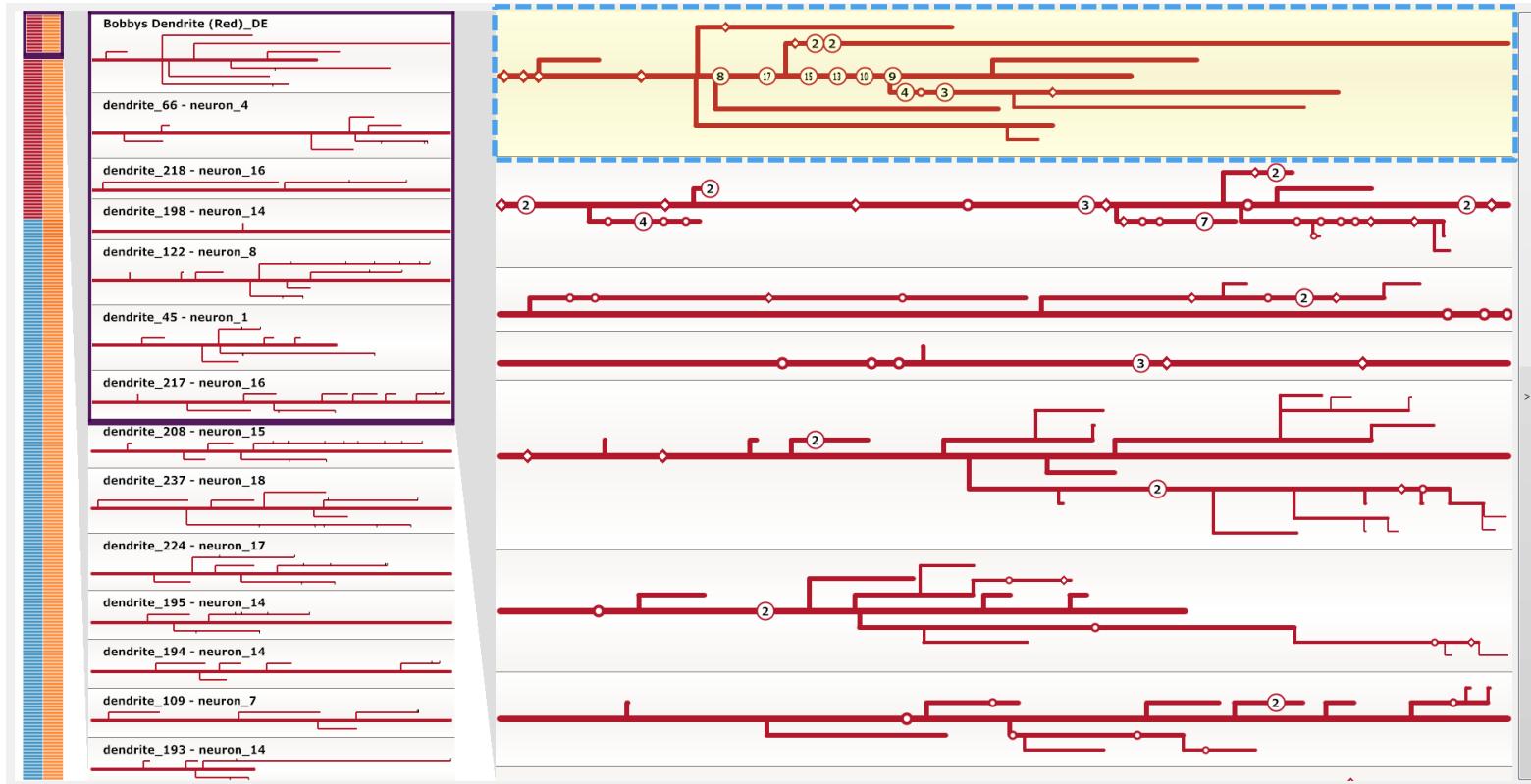
NEUROLINES: VOLUME RENDERING



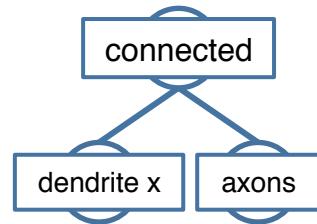
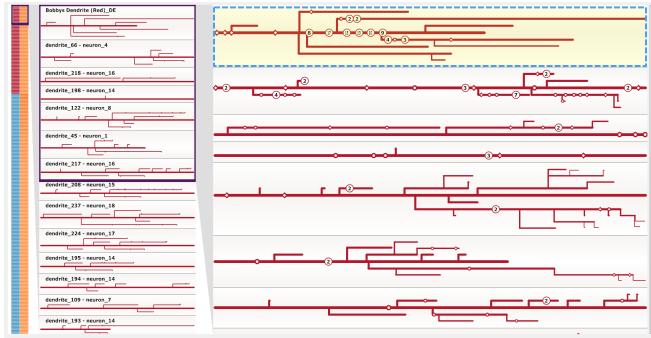
CASE STUDY

How much of the variance in the structure of synapses can be explained by the connectivity of neurons?

CASE STUDY



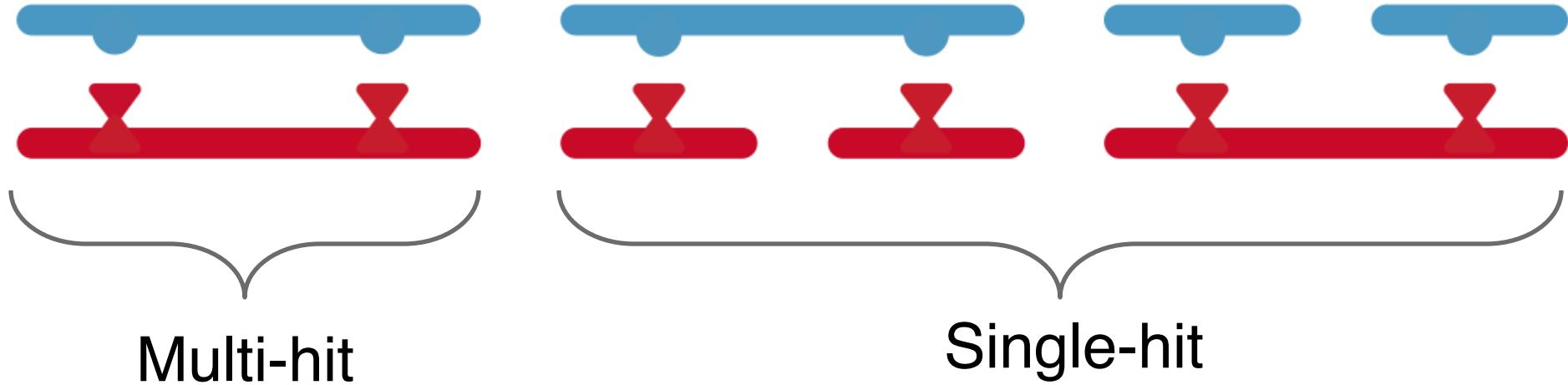
CASE STUDY



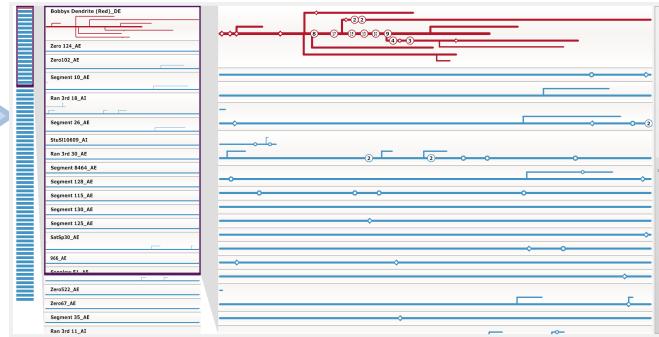
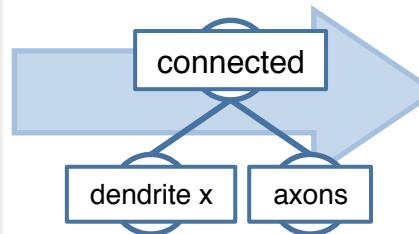
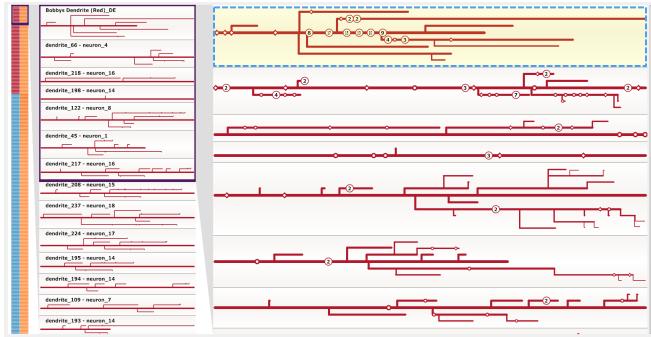
CASE STUDY



CASE STUDY

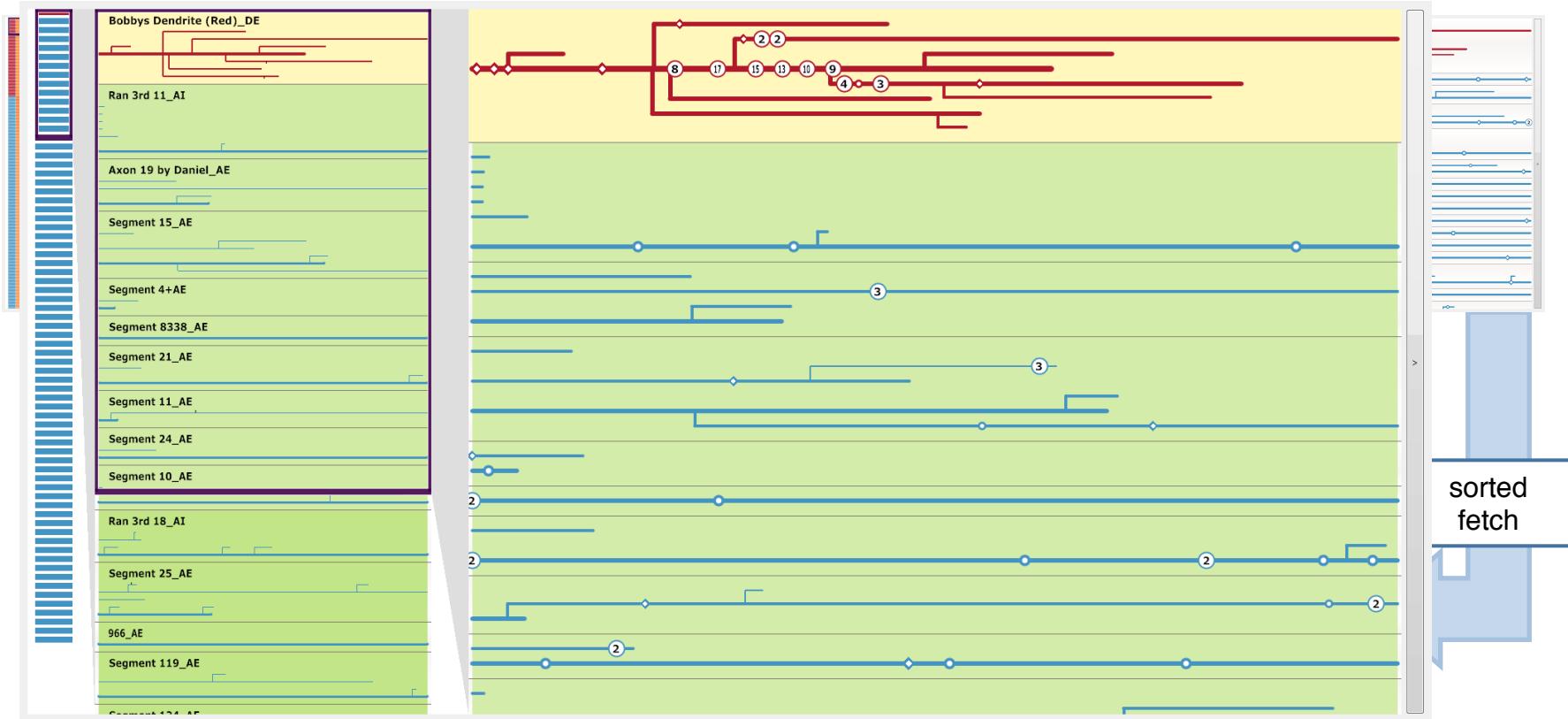


CASE STUDY

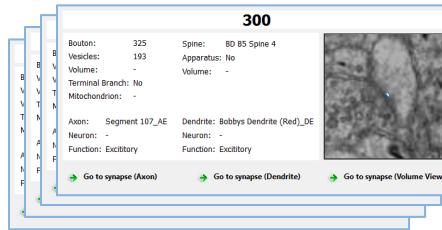
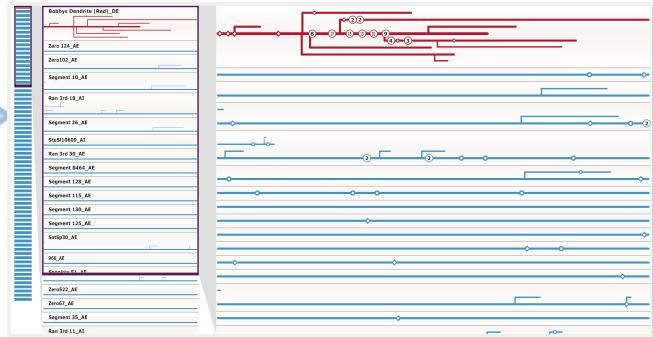
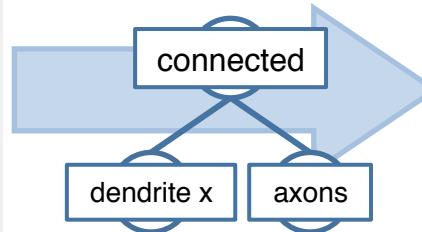
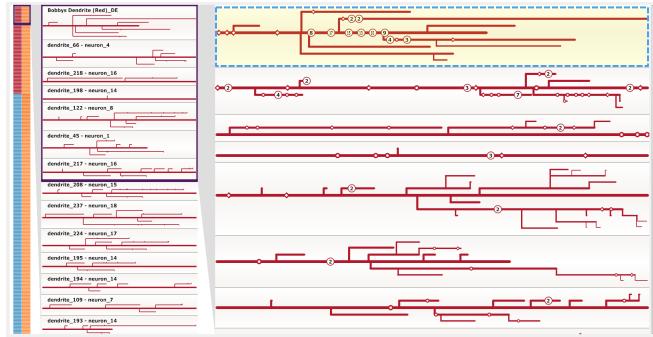


sorted
fetch

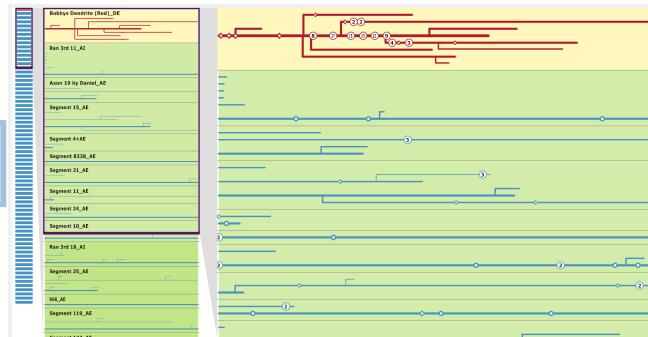
CASE STUDY



CASE STUDY

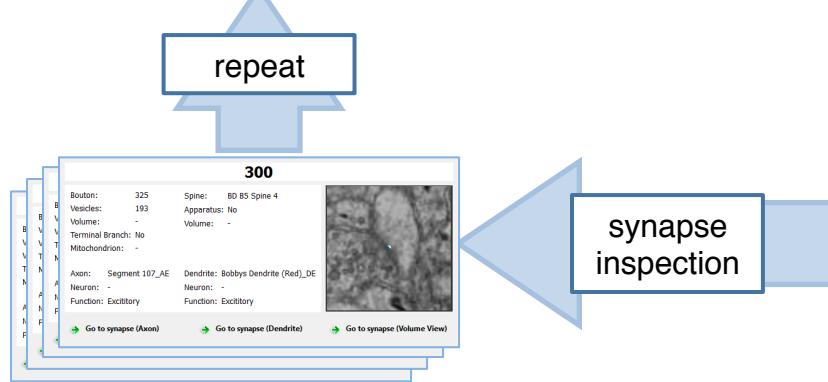
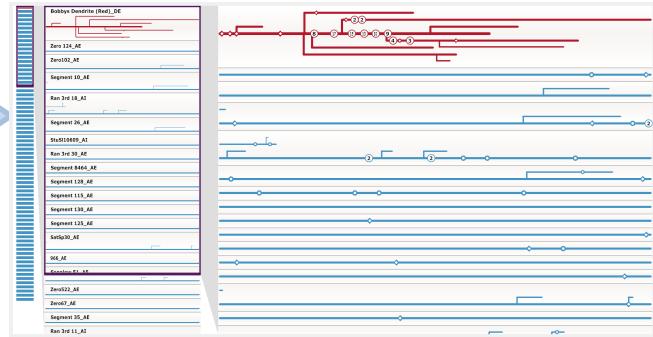
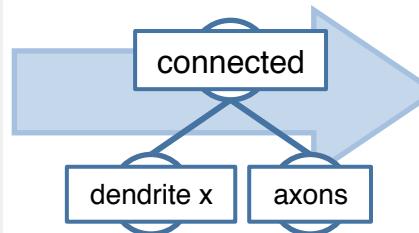
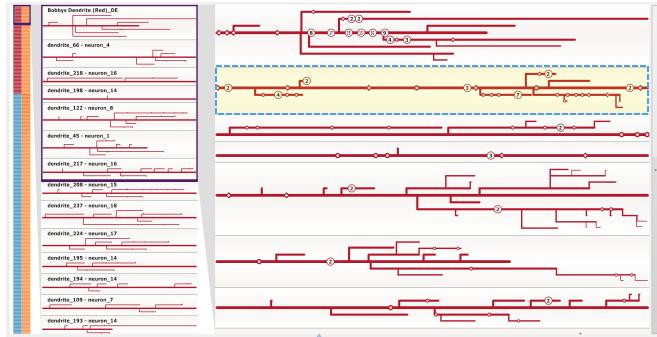


synapse
inspection

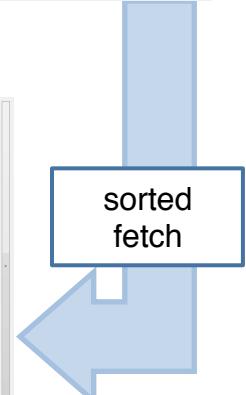
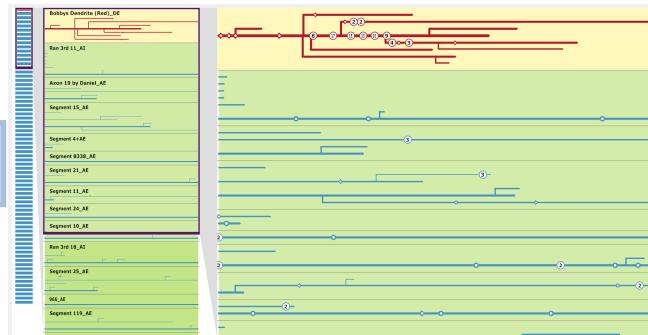


sorted
fetch

CASE STUDY

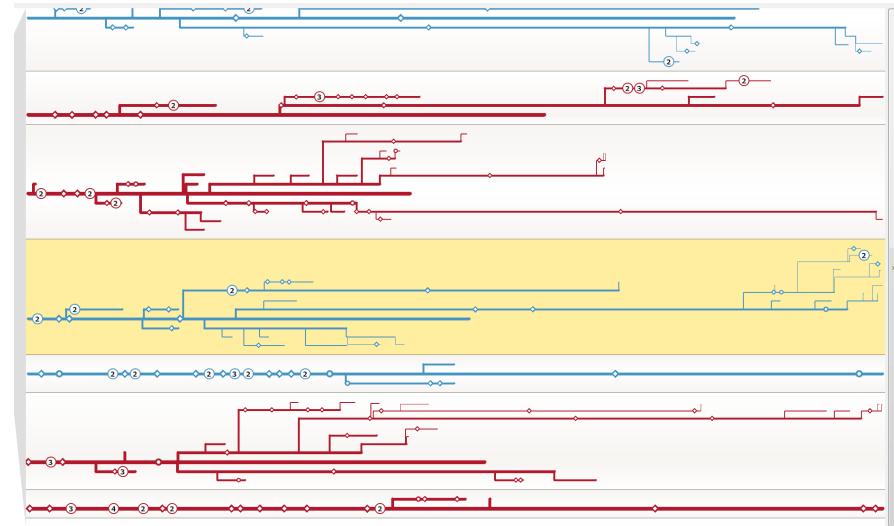


synapse
inspection



SCALABILITY EVALUATION

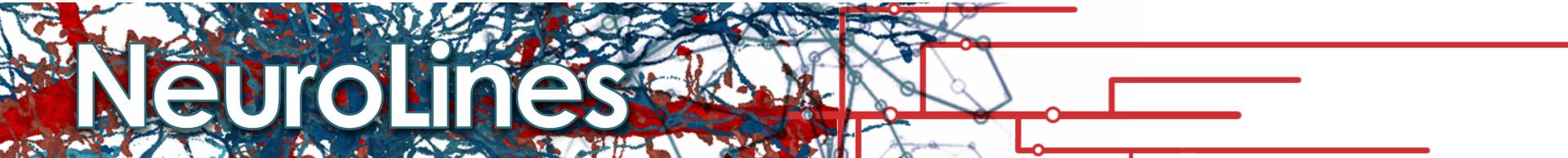
- Real data
 - 100 – 140 fps
- Synthesized data
 - Domain knowledge
 - Neurites ~ 50,000
 - Branches ~ 700,000
 - Activity tests: 28 – 87 fps
 - Stress test: 5 – 79 fps



CONCLUSION

- NeuroLines improves the analysis workflow
- Reduce visual clutter
- Focus on structure and connectivity
- Preserves the topological structure
- Scales in number of neurites, branches, synapses

THANK You



NeuroLines

Ali K. Al-Awami, Johanna Beyer, Hendrik Strobelt, Narayanan Kasthuri,
Jeff W. Lichtman, Hanspeter Pfister and Markus Hadwiger

<http://www.rhoana.org/neurolines/>

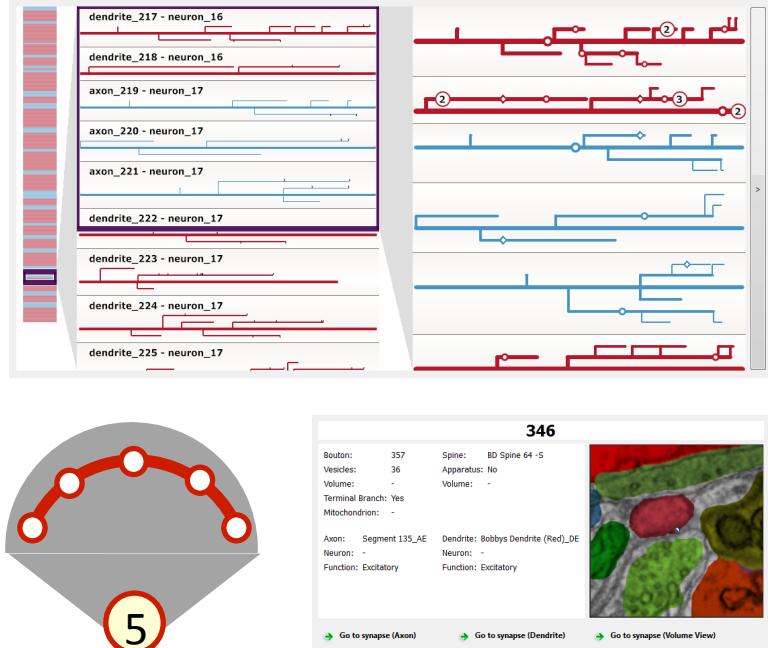


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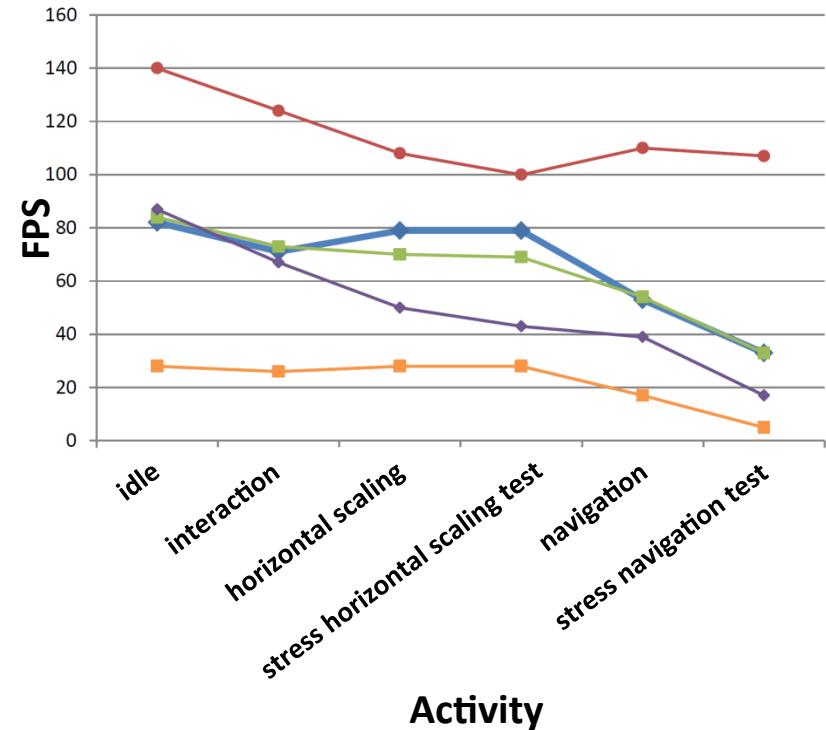
SCALABILITY EVALUATION

- 2D abstraction
- Multi-level views
- Dynamic level of detail
 - Synapse clustering
 - branch collapsing
- Details on demand

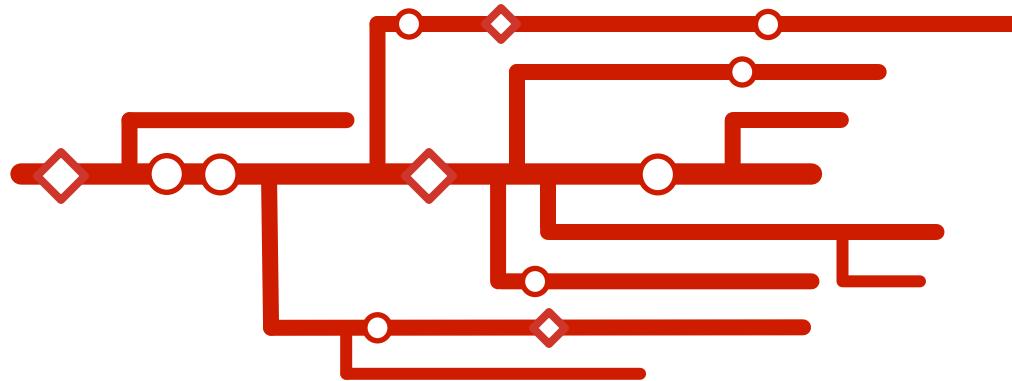


SCALABILITY EVALUATION

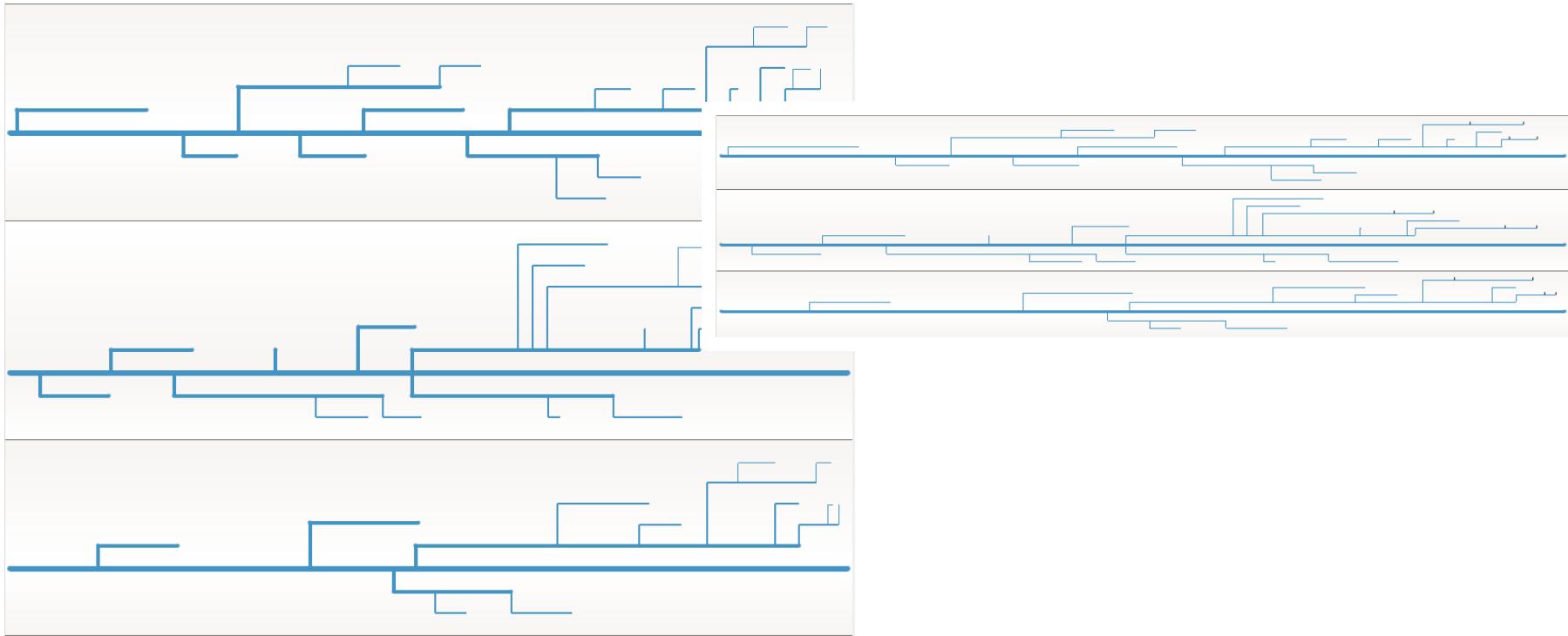
Dataset	Number of Neurites	Total Branches	Total Synapses
Dataset 1	50,000	695,000	9,000
Dataset 2	9,730	134,274	27,244
Dataset 3	2,020	424,806	15,716
Dataset 4	1,040	14,664	23,816
Real Dataset	646	1,421	776



SYNAPSES: SHAFT VS SPINAL



ZOOMING



FUTUREWORK

- Flexibility in adding views representing different levels of abstraction.
- Comparative analysis between different datasets.