Mitochondrial Size Gradients in Cortical Neurons Suggested by 3D Electron Microscopy

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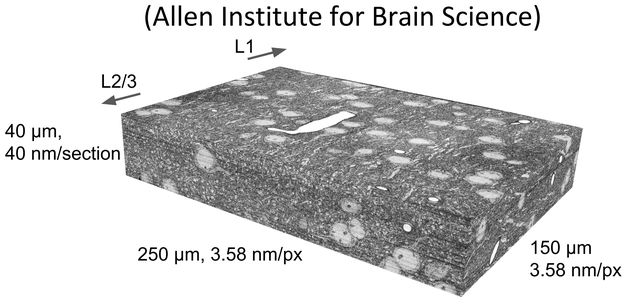
Highlights

- We reconstruct mitochondria within pyramidal neurons already segmented and skeletonized within an electron microscopy volume of mouse V1.
- We associate each mitochondrion with a compartment location (axon, dendrite or soma) by means of a semantic segmentation of the cell's automated skeleton.
- We compare the size and shape of mitochondria of these different compartments, and find that somatic mitochondria are intermediate in size between (smaller) axonal and (larger) dendritic objects.
- Our data also suggest a gradient of mitochondria size at this scale, consistent with mitochondrial size filtering between compartments (Lewis et al., 2018).

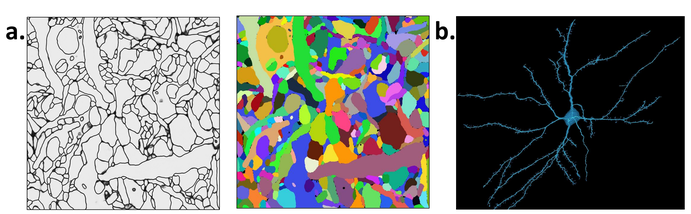
Previous Neuron Segmentation

Serial Section TEM of Mouse V1 - Layer 2/3

(Allen Institute for Brain Science)

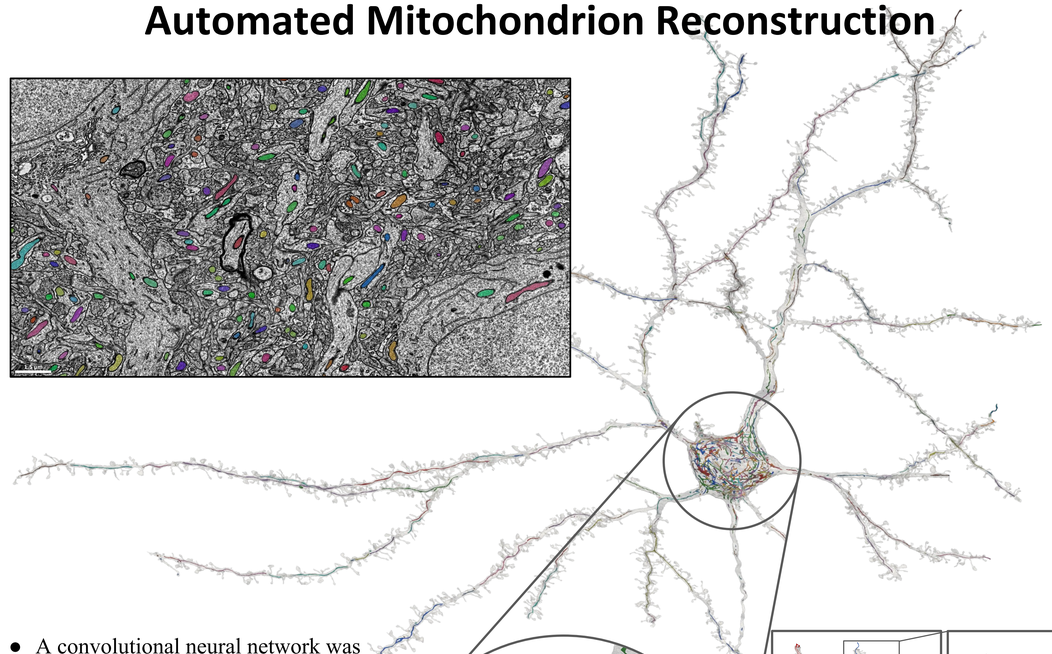


Neuron Segmentation & Skeletonization

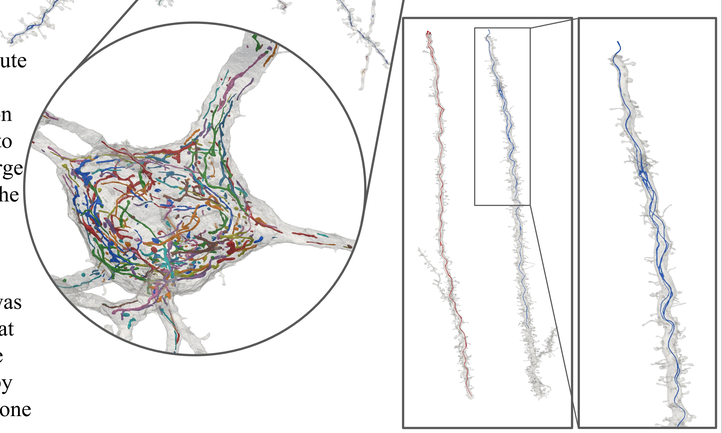


(a) A convolutional neural network was trained to predict cell boundaries in the aligned 3D image. After applying the cell boundary detector over the entire dataset, the image was over-segmented using a modified watershed algorithm (Zlateski & Seung, 2015). These initial regions were then agglomerated by mean affinity agglomeration. **(b)** The segments of pyramidal cells in the volume were processed by a modified version of the TEASAR algorithm (Sato et al., 2000).

Automated Mitochondrion Reconstruction



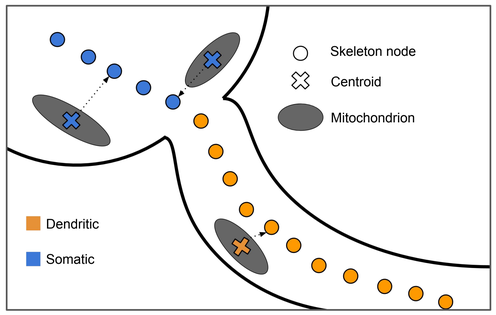
- A convolutional neural network was trained to detect voxels which constitute mitochondria throughout the entire reconstruction volume. Mitochondrion candidates were also filtered by size to remove noise components. Some merge and split errors each affect ~10% of the predicted objects.
- The volume of each mitochondrion was estimated by the number of voxels that constitutes each predicted object. The length of each object was estimated by taking the longest shortest path from one mesh node to another.



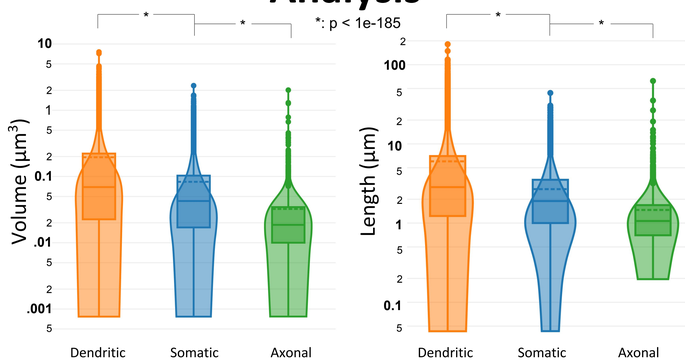
Long mitochondria within apical dendrites

Compartment Association

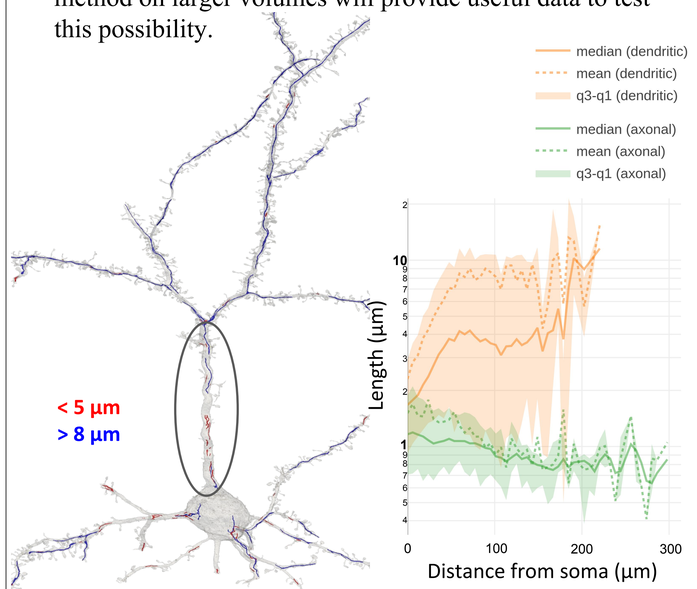
- Features were extracted within a window of 8 µm along the skeleton nodes of each cell based on synapses, contacts, and cell volume. A random forest classifier predicted whether a region belongs to axon, dendrite, or soma. The final prediction was improved by applying a majority voting on cell parts branching proximal to the soma.
- Mitochondria were associated to the semantic class of the skeleton node closest to its centroid coordinate.



Analysis



- **(above)** We find that somatic mitochondria are intermediate in size between dendritic and axonal mitochondria.
- **(below)** Dendritic mitochondria seem to increase in length as distance from the soma increases at this scale, while axonal length decreases. This is consistent with mitochondrial size filtering (Lewis et al., 2018). Using this method on larger volumes will provide useful data to test this possibility.



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