Breakout Session 6: Track B

Retinal Circuitry - Improving AI Readiness of Existing Retinal Connectomes

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Retinal Circuitry - Improving AI Readiness of Existing Retinal Connectomes

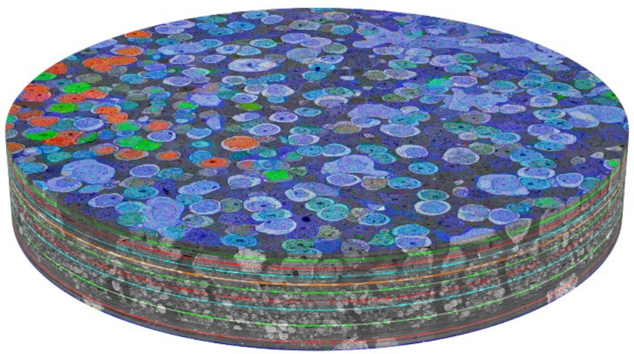
Presenter: James Anderson

PI: Bryan Jones

NOT-OD-22-67

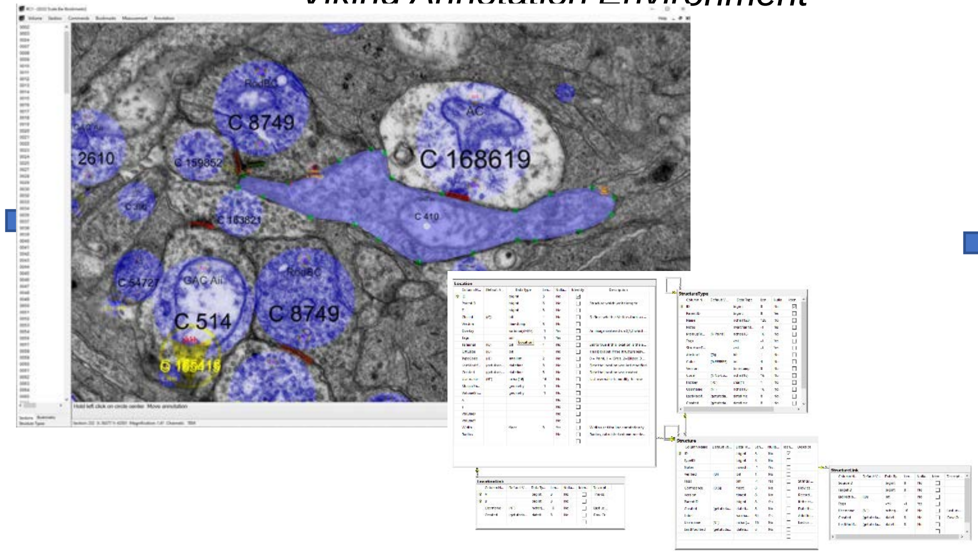
Connectomics Workflow

Volume Construction

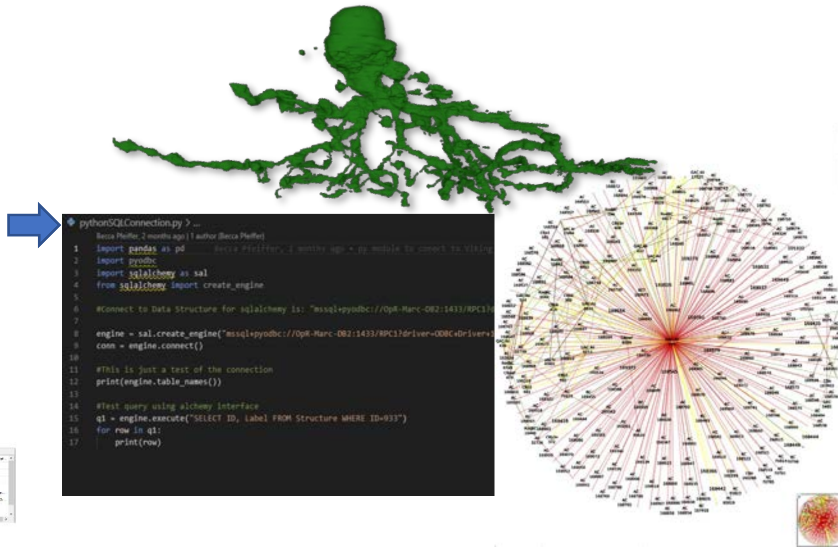


- ssTEM (70-90nm sections)
- 2.18nm/px resolution
- Interleaved small molecule labeling

Viking Annotation Environment



Analysis



Comparative Neuroanatomy

RC1
Rabbit retinal connectome
Status: Open
Database Annotations: ~1.3 million

RC2
Mouse retinal connectome
Status: Active
Database Annotations: ~500k

RC3
Primate (Macaque) retinal connectome
Status: Captured
Database Annotations: N/A

Pathoconnectomics

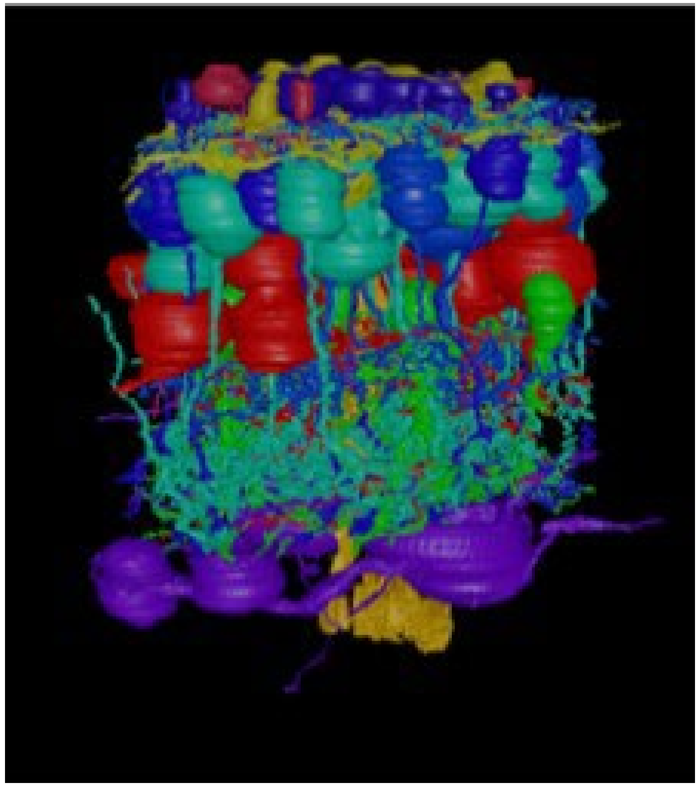
RPC1
Pathoconnectome from 10mo rabbit model of Retinitis Pigmentosa (Phase 1 retinal degeneration)
Status: Open
Database Annotations: ~280k

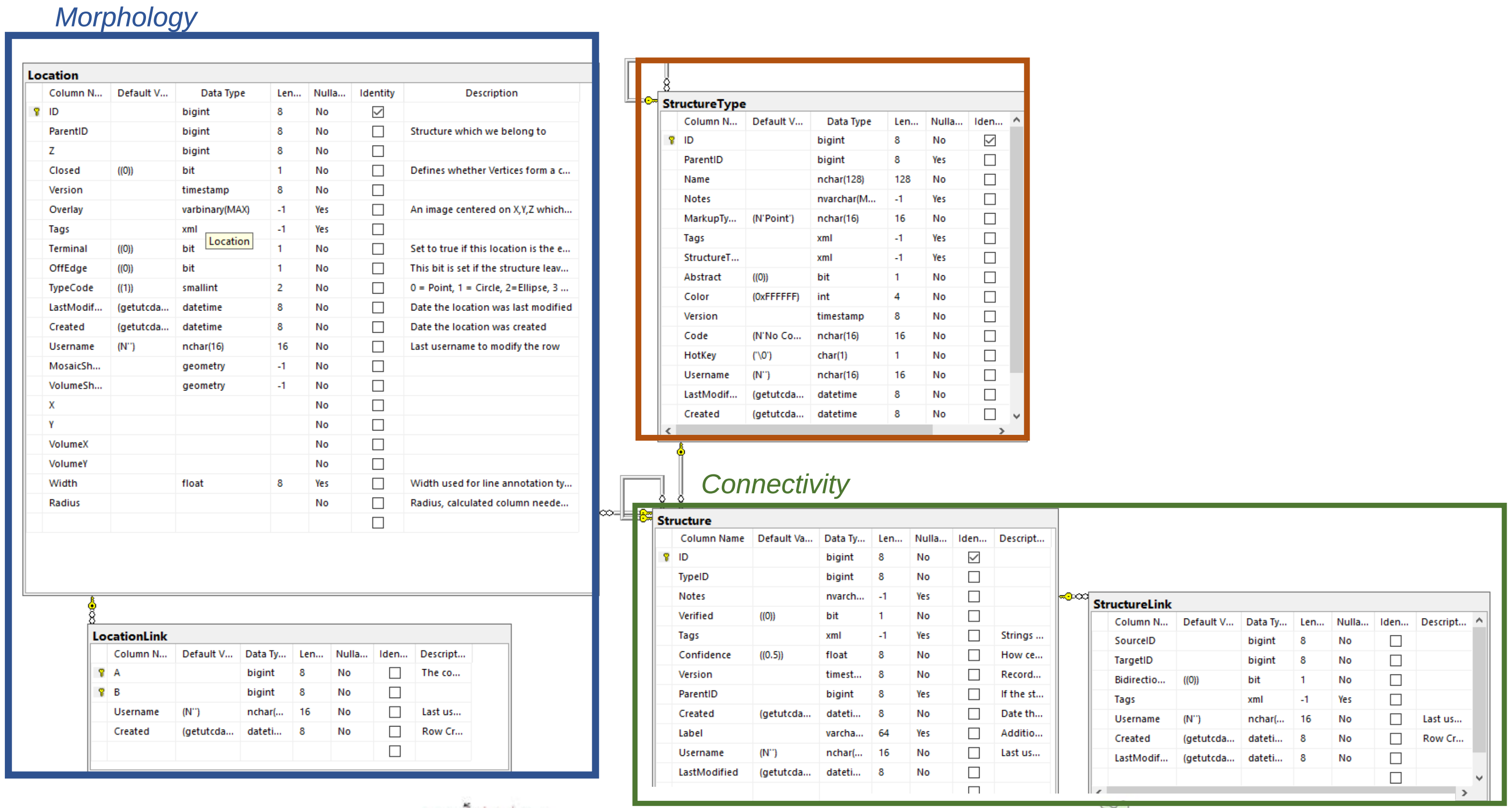
RPC2
Pathoconnectome from 2yo rabbit model of Retinitis Pigmentosa (Phase 2 retinal degeneration)
Status: Active
Database Annotations: ~100k

RPC3
Pathoconnectome from 4yo rabbit model of Retinitis Pigmentosa (Phase 3 retinal degeneration)
Status: Captured
Database Annotations: N/A

Database Features:

- SQL reduces development cost and maintenance. Very mature tools.
- Flexible addition of new structures
- Geometry columns encode annotations. Spatial queries within SQL. Enables encoding any geometric shape.
- Hierarchy describes relationships of biological structures (Parent=Cell, Child=Subcellular structures)
- Size, shape, and position are encoded in every annotation
- Morphology and connectivity are encoded in separate but relatable graphs. Allowing efficient querying.





Location

Column N...	Default V...	Data Type	Len...	Nulla...	Identity	Description
ID		bigint	8	No	☑	
ParentID		bigint	8	No	☐	Structure which we belong to
Z		bigint	8	No	☐	
Closed	((0))	bit	1	No	☐	Defines whether Vertices form a c...
Version		timestamp	8	No	☐	
Overlay		varbinary(MAX)	-1	Yes	☐	An image centered on X,Y,Z which...
Tags		xml	-1	Yes	☐	
Terminal	((0))	bit	1	No	☐	Set to true if this location is the e...
OffEdge	((0))	bit	1	No	☐	This bit is set if the structure leav...
TypeCode	((1))	smallint	2	No	☐	0 = Point, 1 = Circle, 2=Ellipse, 3 ...
LastModif...	(getutcda...	datetime	8	No	☐	Date the location was last modified
Created	(getutcda...	datetime	8	No	☐	Date the location was created
Username	(N'')	nchar(16)	16	No	☐	Last username to modify the row
MosaicSh...		geometry	-1	No	☐	
VolumeSh...		geometry	-1	No	☐	
X				No	☐	
Y				No	☐	
VolumeX				No	☐	
VolumeY				No	☐	
Width		float	8	Yes	☐	Width used for line annotation ty...
Radius				No	☐	Radius, calculated column neede...

Location

LocationLink

Column N...	Default V...	Data Ty...	Len...	Nulla...	Iden...	Descript...
A		bigint	8	No	☐	The co...
B		bigint	8	No	☐	
Username	(N'')	nchar(...	16	No	☐	Last us...
Created	(getutcda...	dateti...	8	No	☐	Row Cr...

StructureType

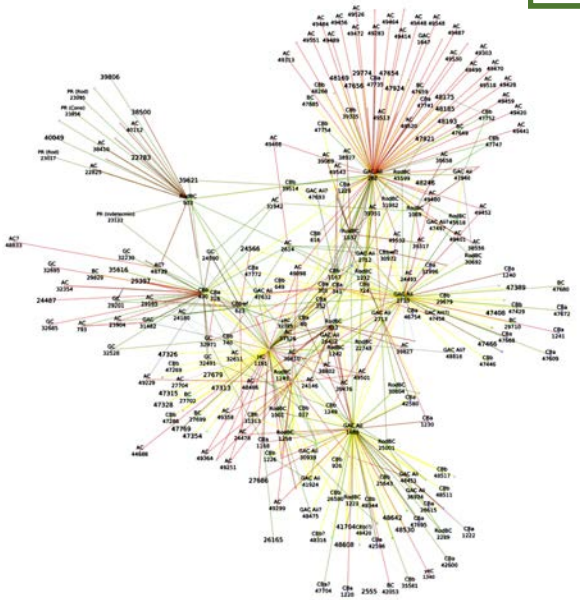
Column N...	Default V...	Data Type	Len...	Nulla...	Iden...
ID		bigint	8	No	☑
ParentID		bigint	8	Yes	☐
Name		nchar(128)	128	No	☐
Notes		nvarchar(M...	-1	Yes	☐
MarkupTy...	(N'Point')	nchar(16)	16	No	☐
Tags		xml	-1	Yes	☐
StructureT...		xml	-1	Yes	☐
Abstract	((0))	bit	1	No	☐
Color	(0xFFFFFF)	int	4	No	☐
Version		timestamp	8	No	☐
Code	(N'No Co...	nchar(16)	16	No	☐
HotKey	('\0')	char(1)	1	No	☐
Username	(N'')	nchar(16)	16	No	☐
LastModif...	(getutcda...	datetime	8	No	☐
Created	(getutcda...	datetime	8	No	☐

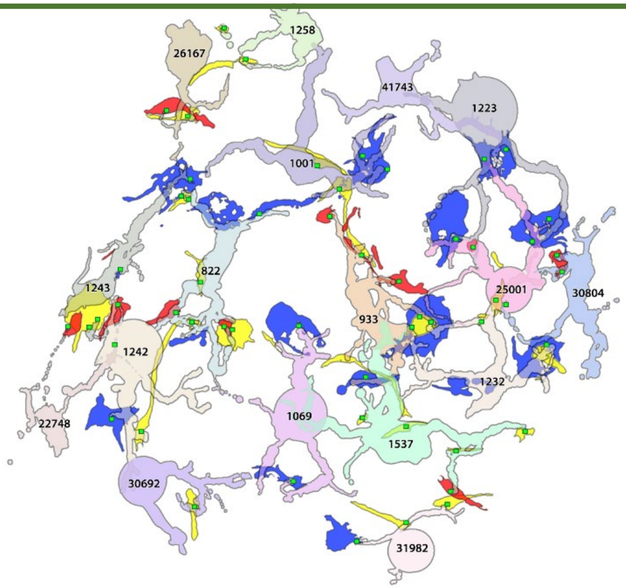
Structure

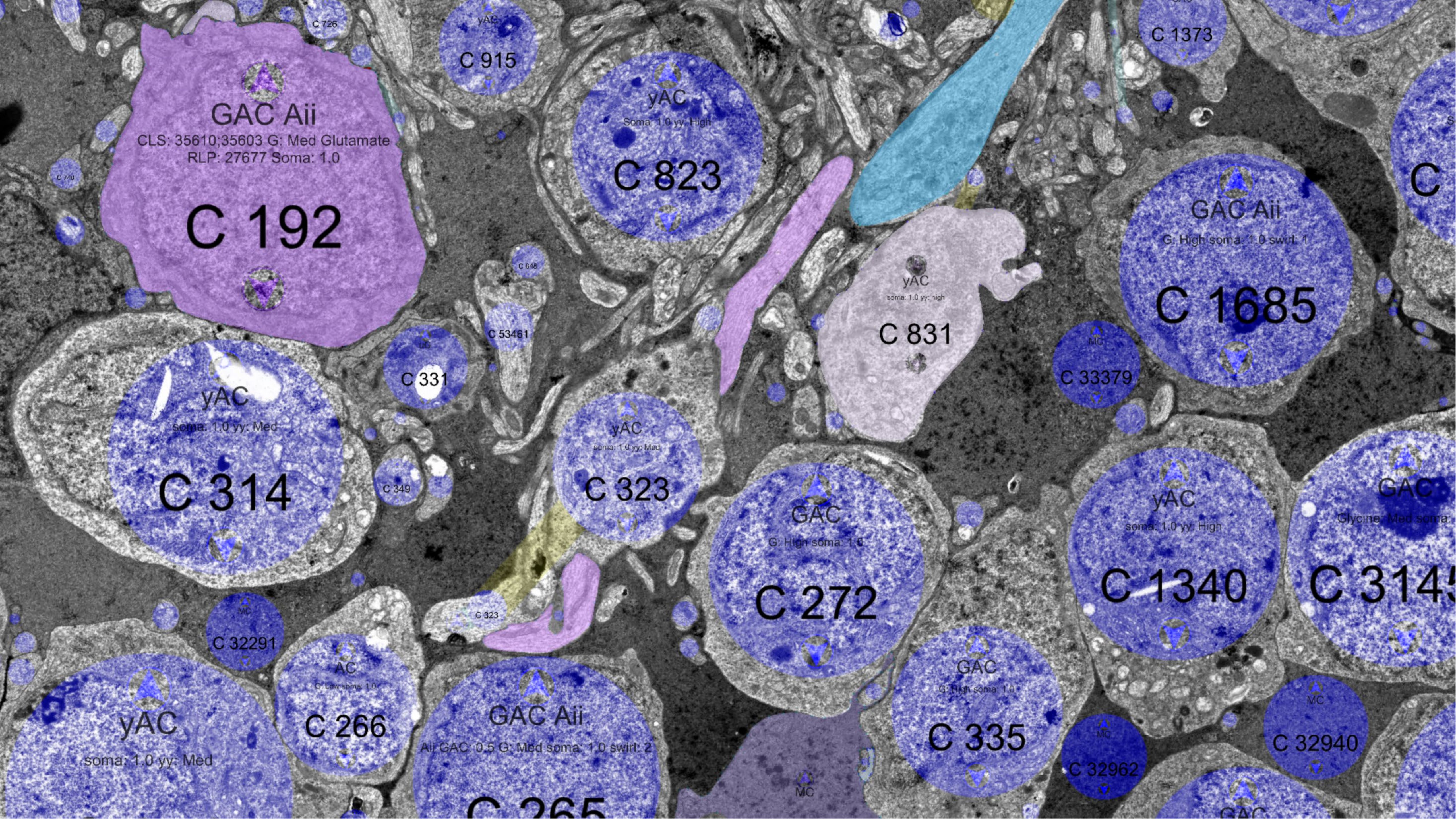
Column Name	Default Va...	Data Ty...	Len...	Nulla...	Iden...	Descript...
ID		bigint	8	No	☑	
TypeID		bigint	8	No	☐	
Notes		nvarch...	-1	Yes	☐	
Verified	((0))	bit	1	No	☐	
Tags		xml	-1	Yes	☐	Strings ...
Confidence	((0.5))	float	8	No	☐	How ce...
Version		timest...	8	No	☐	Record...
ParentID		bigint	8	Yes	☐	If the st...
Created	(getutcda...	dateti...	8	No	☐	Date th...
Label		varcha...	64	Yes	☐	Additio...
Username	(N'')	nchar(...	16	No	☐	Last us...
LastModified	(getutcda...	dateti...	8	No	☐	

StructureLink

Column N...	Default V...	Data Ty...	Len...	Nulla...	Iden...	Descript...
SourceID		bigint	8	No	☐	
TargetID		bigint	8	No	☐	
Bidirectio...	((0))	bit	1	No	☐	
Tags		xml	-1	Yes	☐	
Username	(N'')	nchar(...	16	No	☐	Last us...
Created	(getutcda...	dateti...	8	No	☐	Row Cr...
LastModif...	(getutcda...	dateti...	8	No	☐	






GAC Aii
CLS: 35610;35603 G: Med Glutamate
RLP: 27677 Soma: 1.0
C 192
C 915
yAC
C 823
C 1373
GAC Aii
C 1685
yAC
C 831
C 33379
C 53461
C 331
yAC
soma: 1.0 yy: Med
C 314
yAC
C 323
C 349
GAC
G: High soma: 1.0
C 272
yAC
soma: 1.0 yy: High
C 1340
GAC
C 32291
AC
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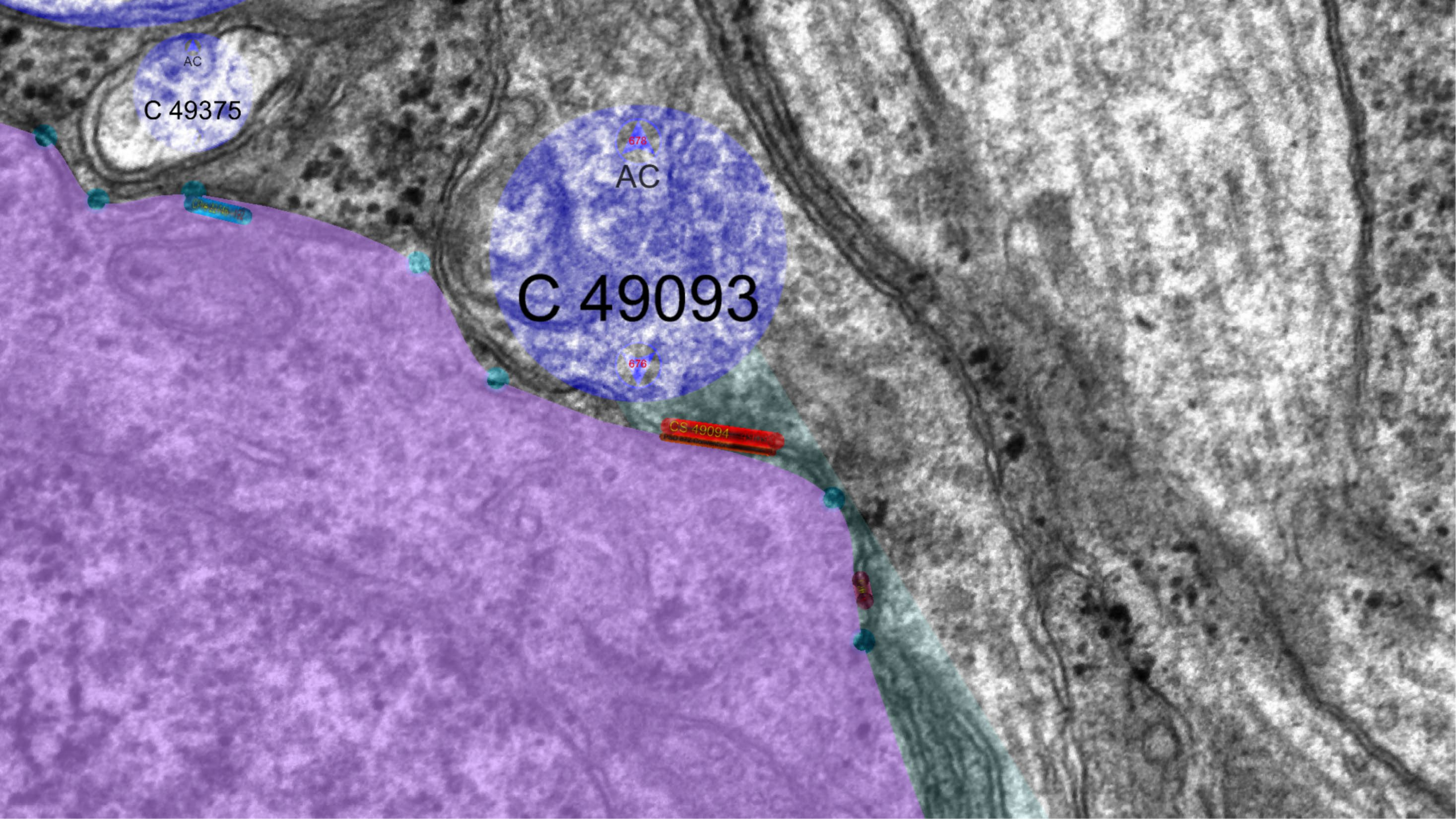
C 32940
yAC
soma: 1.0 yy: Med
MC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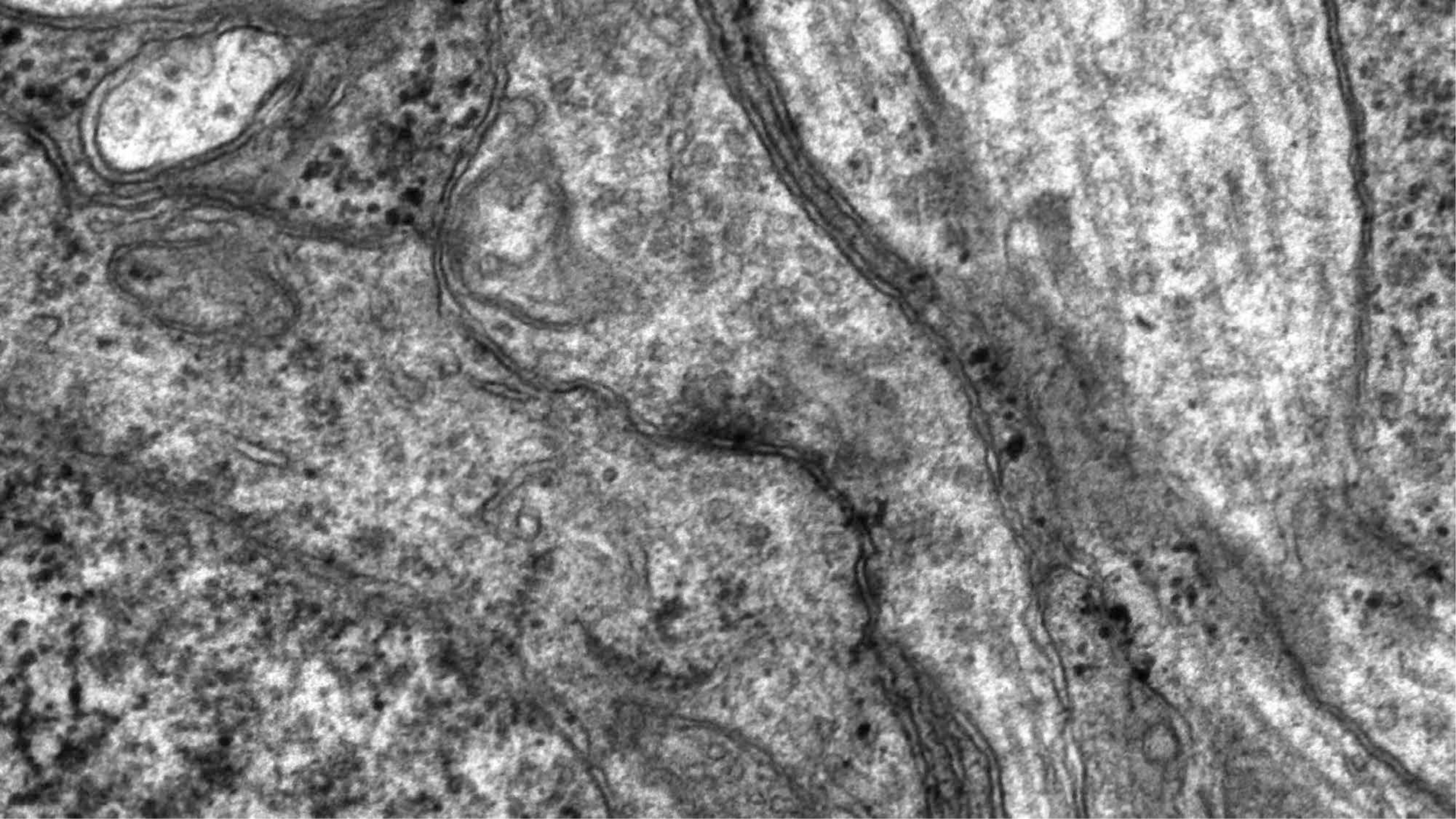
CS 49094



Data Sharing

Primary Goal: Make it simple for collaborators to access our combined annotation and image data to create machine learning algorithms to augment volume annotation efforts.

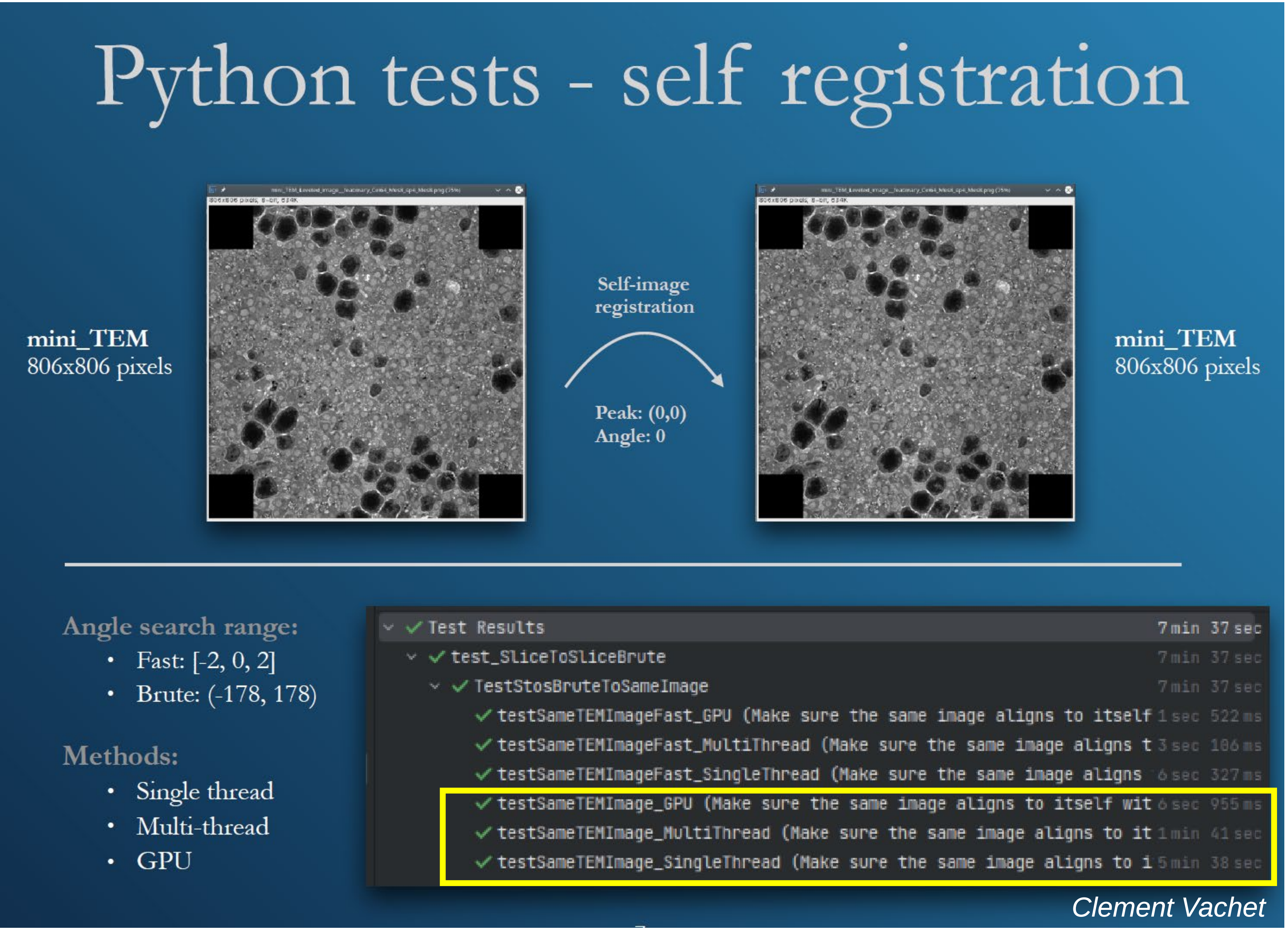
Annotations:

- OData works great for sharing annotations:
  - http://websvc1.connectomes.utah.edu/RC1/OData/
- Queryable, Readable directly into a Browser, Spreadsheet, or programming API
- Spatial data is plain text Open Geospatial Consortium format. Libraries exist to interpret it

Images:

- The goal is to ease accessibility for the image processing lab.
- Viking uses client GPU to perform transforms. Moving processing from client to server simplifies the client experience.
- Real-time transformation has been an advantage for adjusting volume registration during annotation phase.
- Attempts to share images:
  - 1st Approach : Client exports region-of-interest to disk
  - 2nd Approach : Cached RC1 volume available via HTTP, ex: http://storage1.connectomes.utah.edu/RC1VolumeRegisteredV2/RC1/234/Tiles/001/X160_Y049.png
  - 3rd Approach : Web API (Stopped at prototype due to performance issues)
  - 4th Approach : A stack of numpy arrays, either shipped in the mail or a long download

Progress Towards Goal: CuPy proof-of-concept



Registration requirements:
- FFT
- Random Number Generation
- Image Labeling
- Arithmetic
- Convolution

Assembly Requirements:
- Delaunay triangulation
- Texture mapping

Registration Speed

GPU	< 7 sec
Multi-core	101 sec

GPU is 14x faster at Registration!

Progress Towards Goal: GPU Implementation with CuPy

CuPy

CuPy is a NumPy/SciPy open-source array library for GPU-accelerated computing with Python

Transforms	single CPU	multi CPU	partial GPU	full GPU
Rigid_NoRotation	✓	✓		✓
Rigid	✓	✓		✓
Centered Similary	✓	✓		✓
MeshWithRBFFallback	✓	✓	✓	
GridWithRBFFallback	✓	✓	✓	

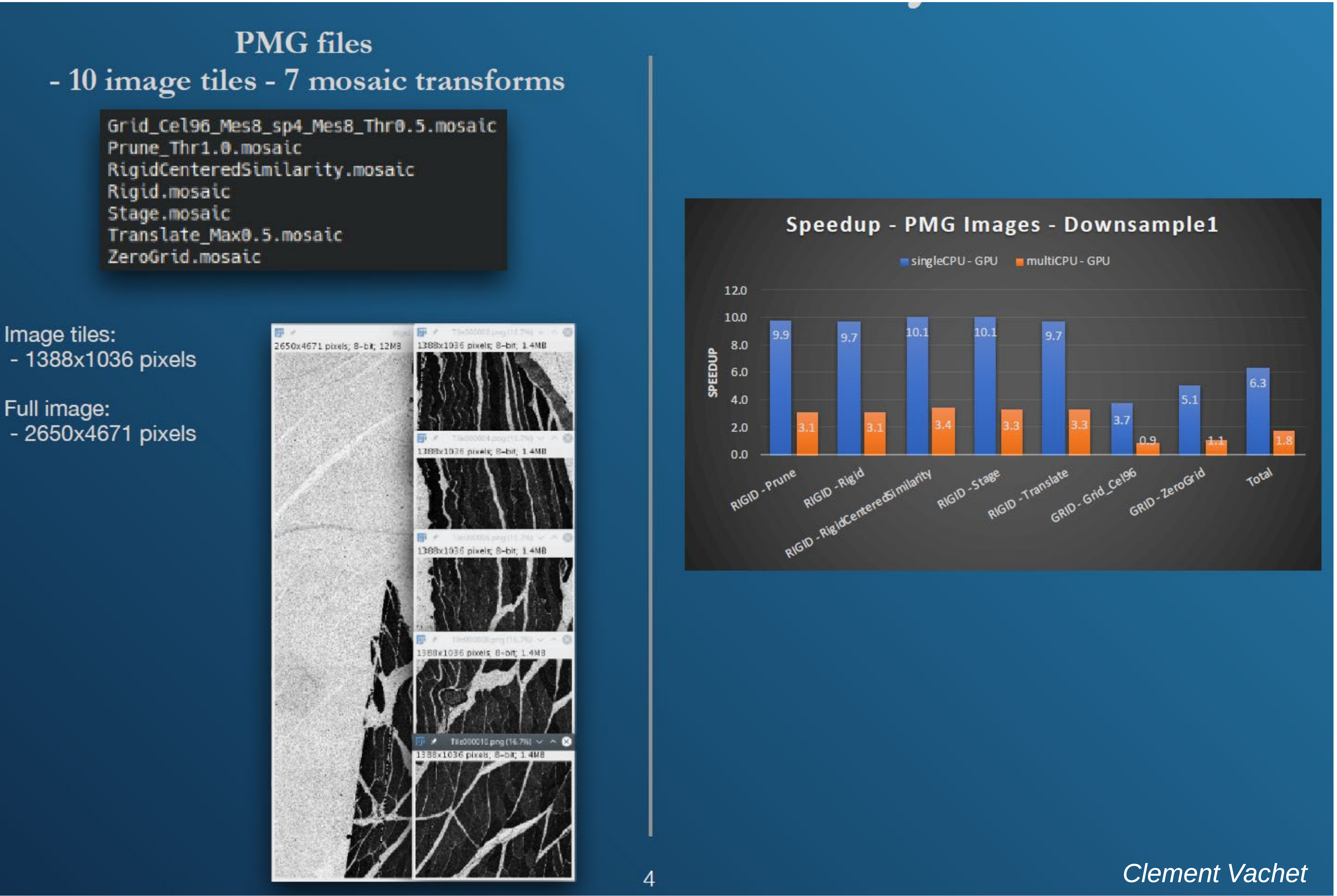
Implementation for assembly transforms

Note: some transform components (e.g. triangulation) haven't yet been implemented in CuPy

Clement Vachet

- CuPy lacked the LinearNDInterpolator function necessary for a full GPU implementation.
- The function was pulled into the next CuPy release two weeks ago
- Our CuPy version will be fully implemented upon next official cupy release

Progress Towards Goal: Tile Assembly



- Ignore the blue bar results.
- Yellow multi-core comparison ran on an 8-core desktop system.
- Beyond missing LinearNDInterpolate I suspect moving memory between CPU and GPU is a significant time cost. Most likely optimizable.

Progress and Ongoing Efforts

Tools

- Every critical path now utilizes CuPy (with the one exception discussed). Passes unit tests.
- Have support to export a stack of full resolution numpy files
- Waiting for next cupy version to fully test with GPU at scale

Docker Distribution

- Docker is simple to deploy and gives us easy access to our university high-performance computing center. This provides easier access to the command-line tool that can export registered volumes and will allow clients to run the Web Service locally for performance.
- All but one tool required to take images from capture to a 3D numpy array now run in a single docker image.
- We have contracted Kitware to port the remaining legacy C++ ITK-based tool to a web image to complete the docker image.

Web Service

- In progress.
- GPU performance determines if we revisit the original on-the-fly web service prototype or rely upon pre-generated images.

Legacy Data

- Original registered RC1 images available via HTTP are being copied into a stack of numpy arrays.
- RC1 raw data is now compatible with the latest code. Going from imported data to a registered volume is a great stress test for the new GPU code.

MarcLab for Connectomics:

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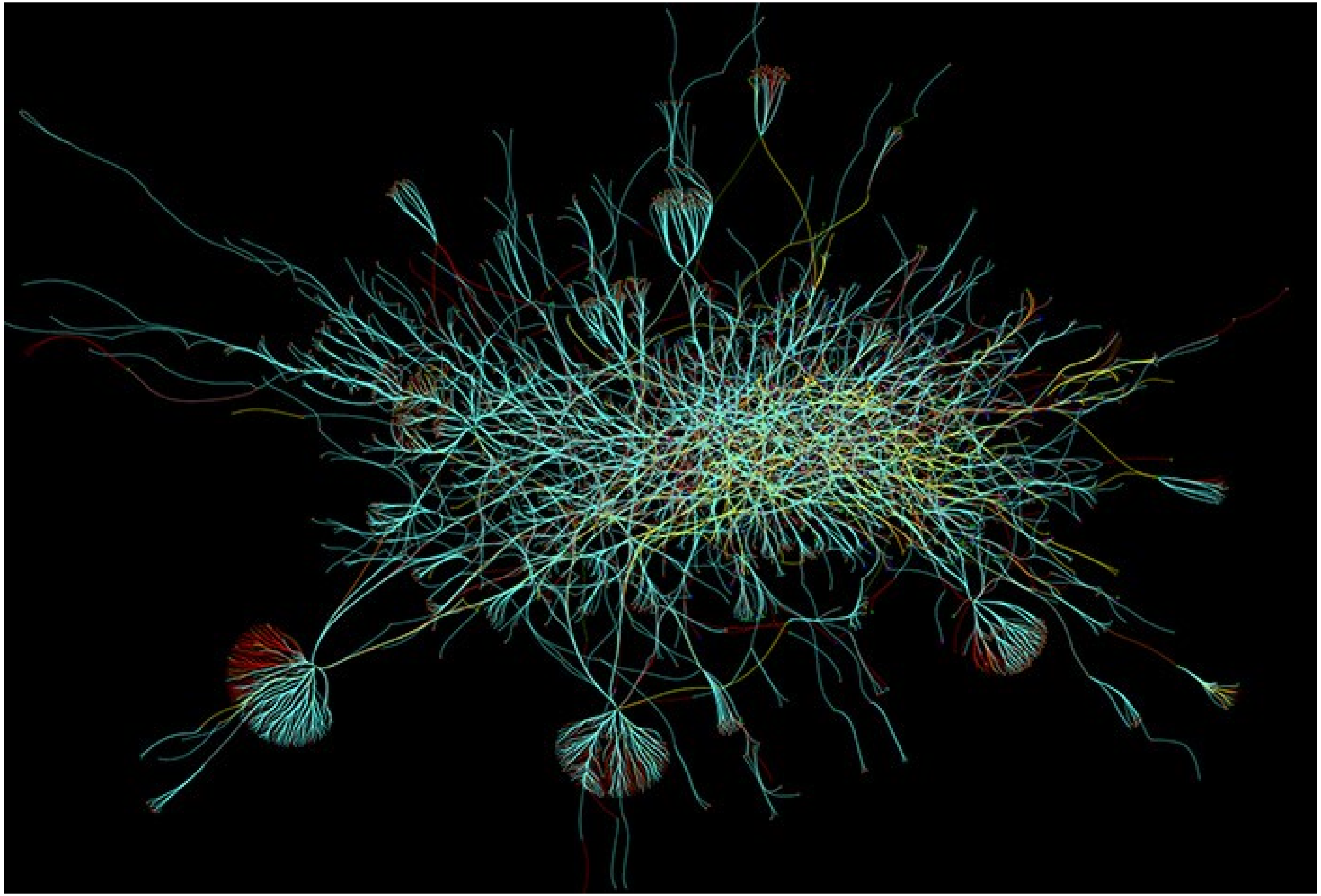
Unmet CuPy Contributor:
Edgar Andrés Margffoy Tuay (LinearNDInterpolator Author)



National Eye Institute

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