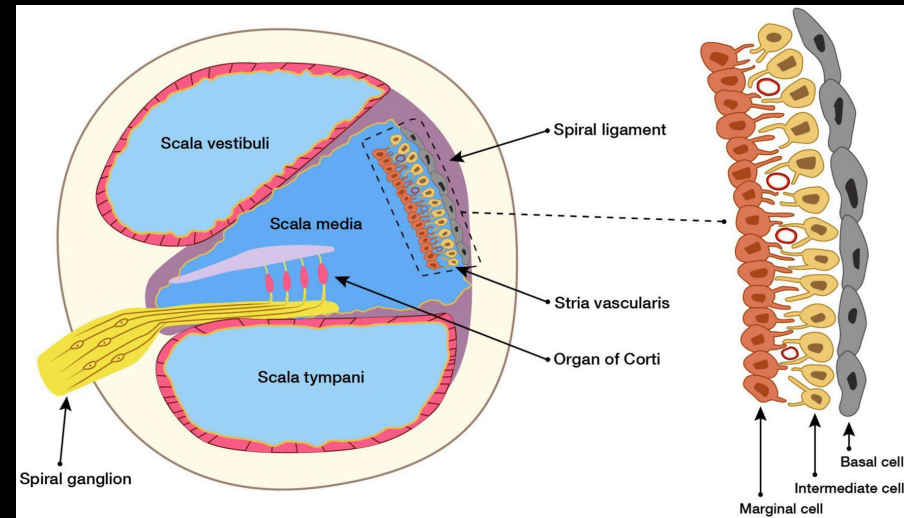


**Automatic
Segmentation
and 3D
Reconstruction
of the Inner Ear
from Histology
slides**

Aseem Jain

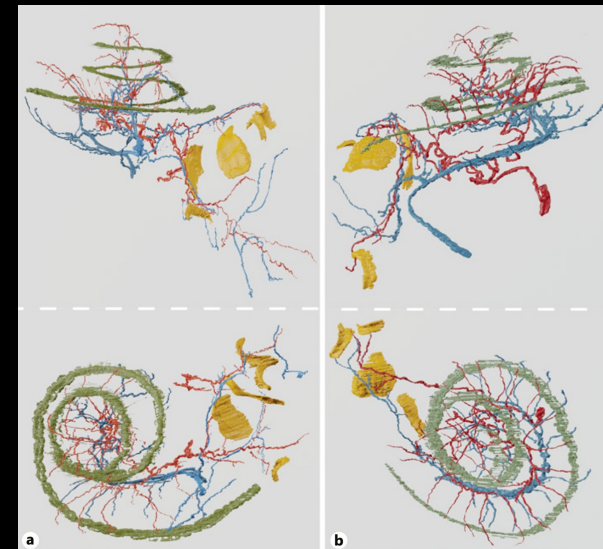
The Project

- We plan to develop an automated method to extract clinically relevant features from histopathology slides and use the segmentations to construct a 3D model of the ear. Such features include relevant vasculature, scala media/vestibuli, and stria vascularis. To do this, we will use deep learning methods to perform semantic segmentation. To reconstruct the inner ear, we will first align adjacent slides and the stack/interpolate between slices to generate a 3D model



Clinical Motivation

- Histopathology is the key to understanding the pathophysiology of various diseases in the inner ear. Such diseases include menieres, vestibular neuritis, etc. Researchers currently manually segment out relevant structures for 2D analysis; few have reconstructed these 2D slices into 3D reconstruction.



Goals

- **Minimum:** Create software to perform semantic segmentation of Temporal Bone WSI of macaque ears
- **Expected:** Software that can segment and reconstruct a 3D volume of the inner ear
- **Maximum:** Apply this technique to human temporal bone anatomy
 - Extract clinically relevant features of such as volume, density of cells, curvature, etc
 - Assess difference between normal and sickle cell patients

	Activities	Deliverable	Proposed Completion date	New Completion date
Minimum	Scan and Label	Appropriate structure from 1 monkey ear	40 labeled WSI; 81 scanned slides total	3/6 4/6
	Implement U-Net with proposed algorithm		Functional software that segments vasculature from WSI	3/16 4/13
	Validation of U-Net on test data		Internal validation report that analyzes non-labeled slides	3/23 4/15
Expected	Align segmented images**		Software that can align WSI slides; validate against manual alignment	4/4
	Reconstruction in 3D		3D mesh file that can be assessed by neurotologist	4/11 4/6
Maximum	Manuscript writing		Submitted manuscript	4/26
	Analysis of human temporal bone		3D mesh file that can be assessed by neurotologist. Report that includes clinically relevant features such as volume, curvature, etc.	5/1

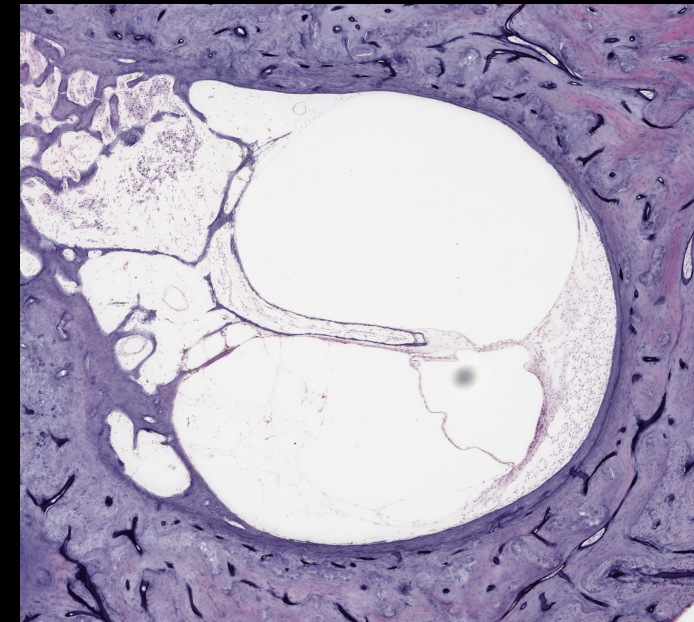
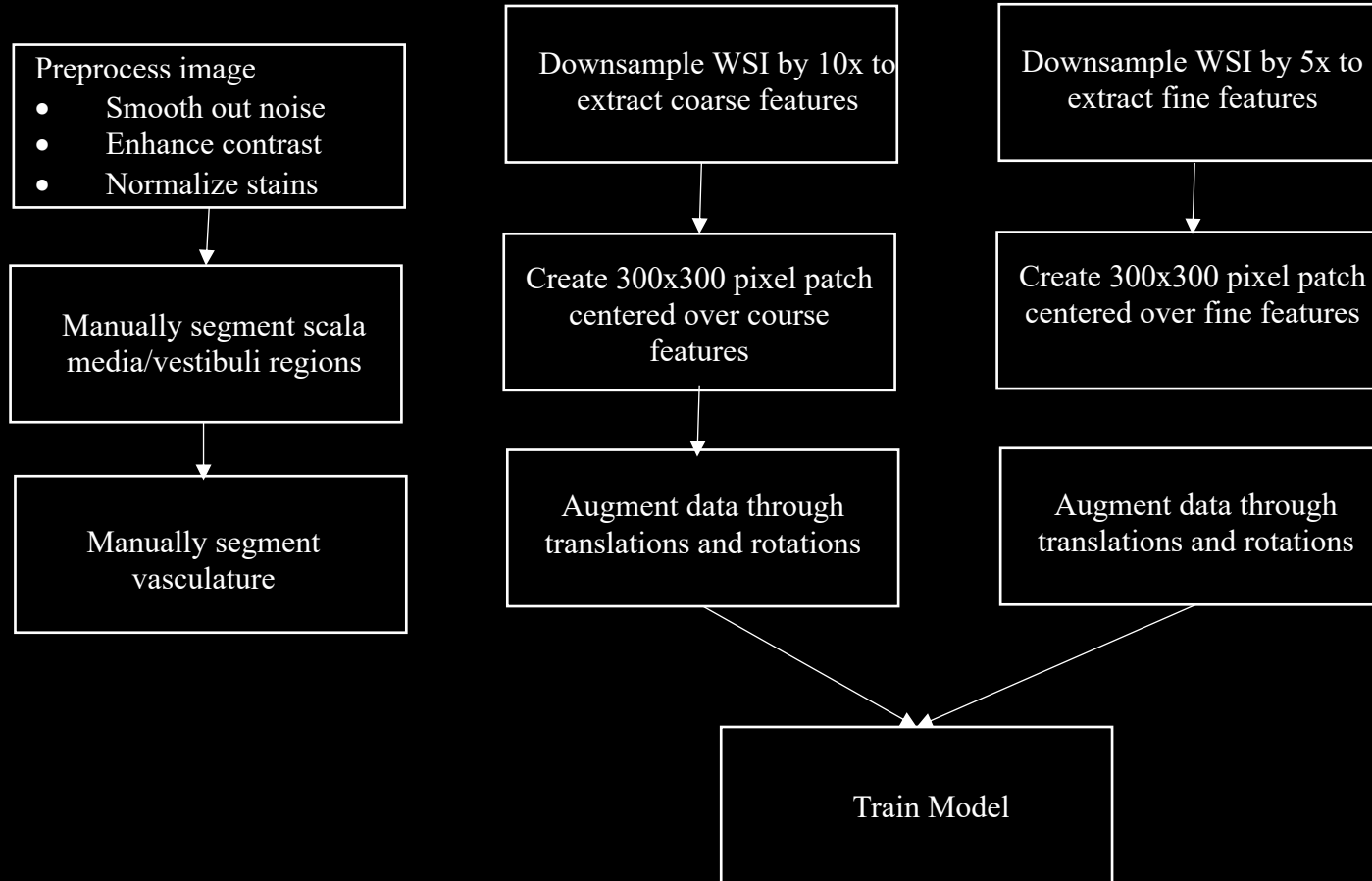
Dependencies	Need	Status	Follow up	Contingency Plan	Planned	Hard
Access to sectioned Macaque Ears	Used to create training	Completed	n/a	Use existing temporal bone scans	2/16	2/23
Access to Olympus Microscope	Need to scan sectioned slices of macaque Ears	Completed	n/a	n/a	2/16	3/14
Label Validation**	Need to have Dr. Lauer/ Dr. Creighton/ Dr. Ward validate accuracy of labeled training data	In progress	n/a	Validate with post-doc in Lauer lab	2/28 4/4	4/13
Access to Virtual GPU	Need access to virtual GPU to create deep learning model	Completed	n/a	Run deep learning framework locally	n/a	n/a

Challenges so far

- Microscope availability/protocol change
- Labeling vasculature

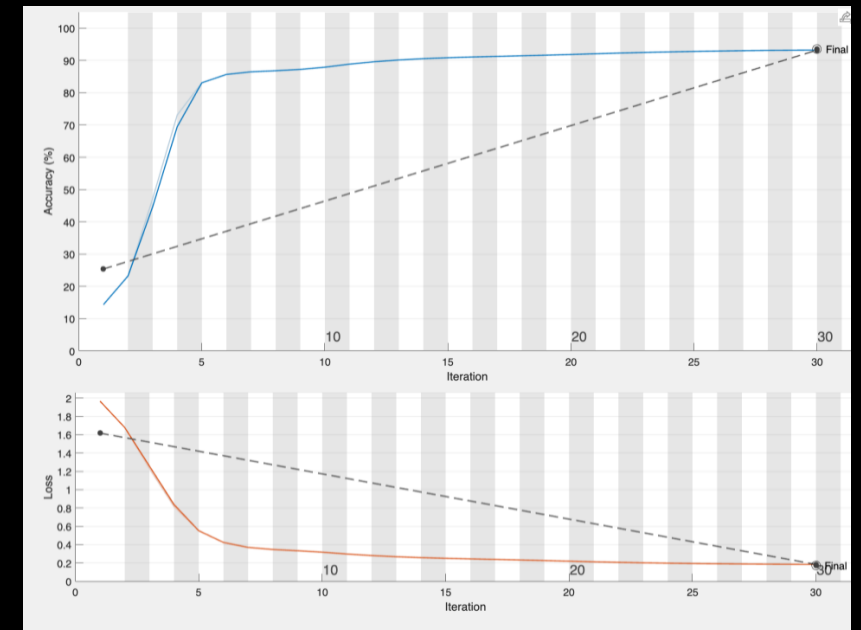
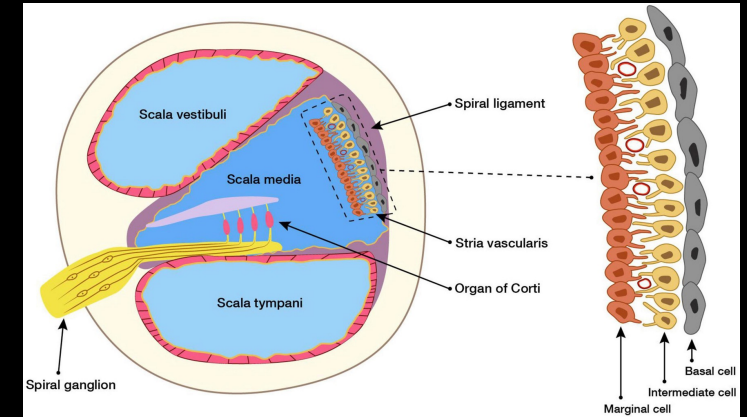


Technical Approach: Semantic Segmentation



Coarse Feature Training and Results

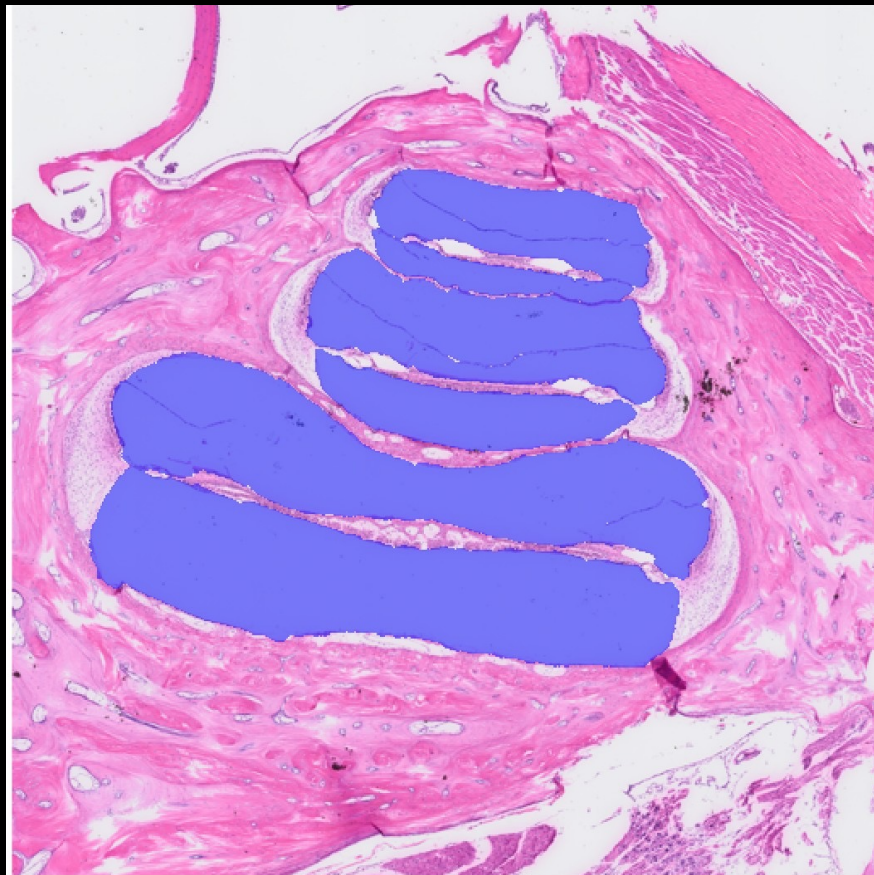
- 20 labeled images
 - Labeled with Scala media, vestibuli, and tympani
- Augmented data with X,Y translation
 - 400 total 512x512 scans
- Training results
 - Accuracy: 93.15%
 - Loss: 0.18



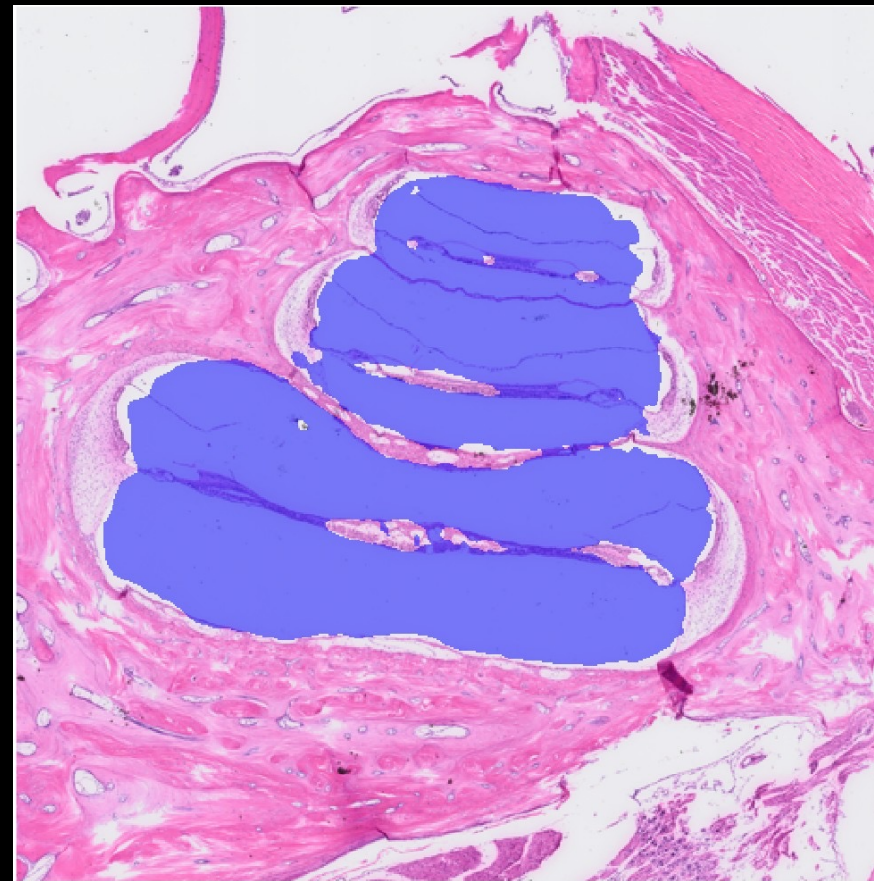
Further analysis

Feature	Dice Score
Scala media	0.46
Scala vestibuli	0.72
Scala tympani	0.63
Total scala*	0.92

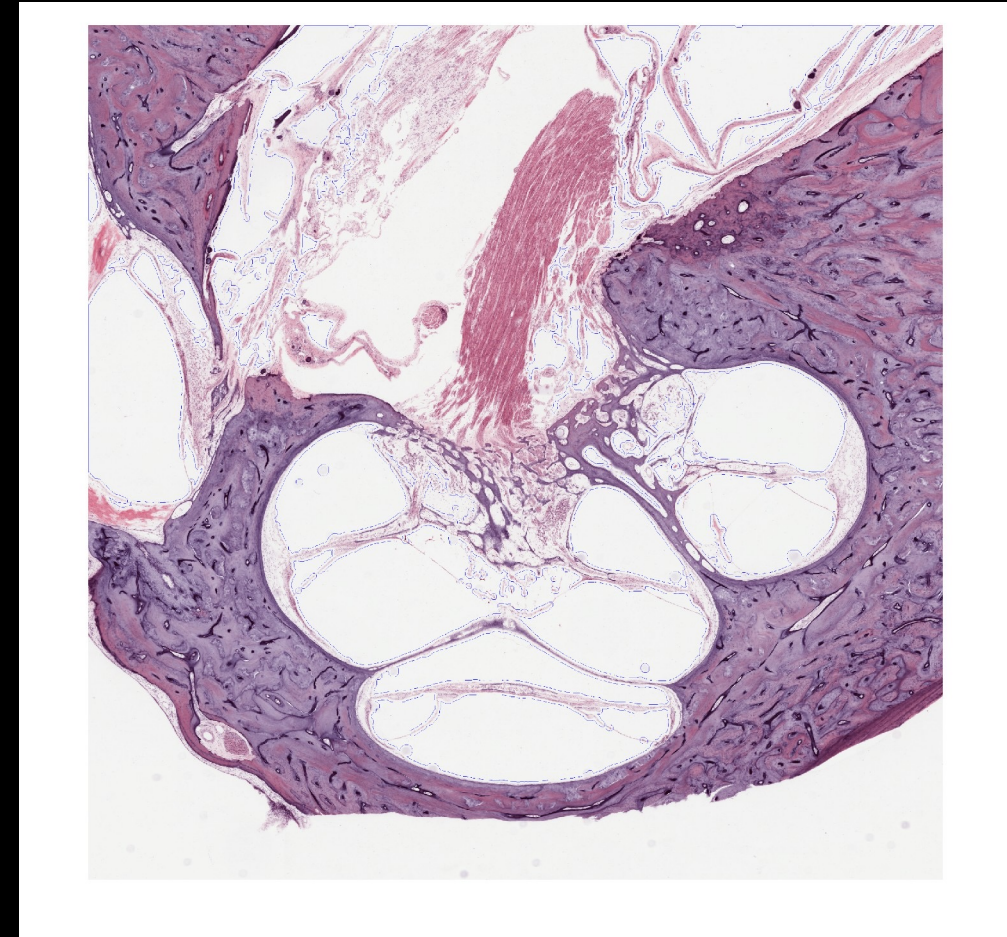
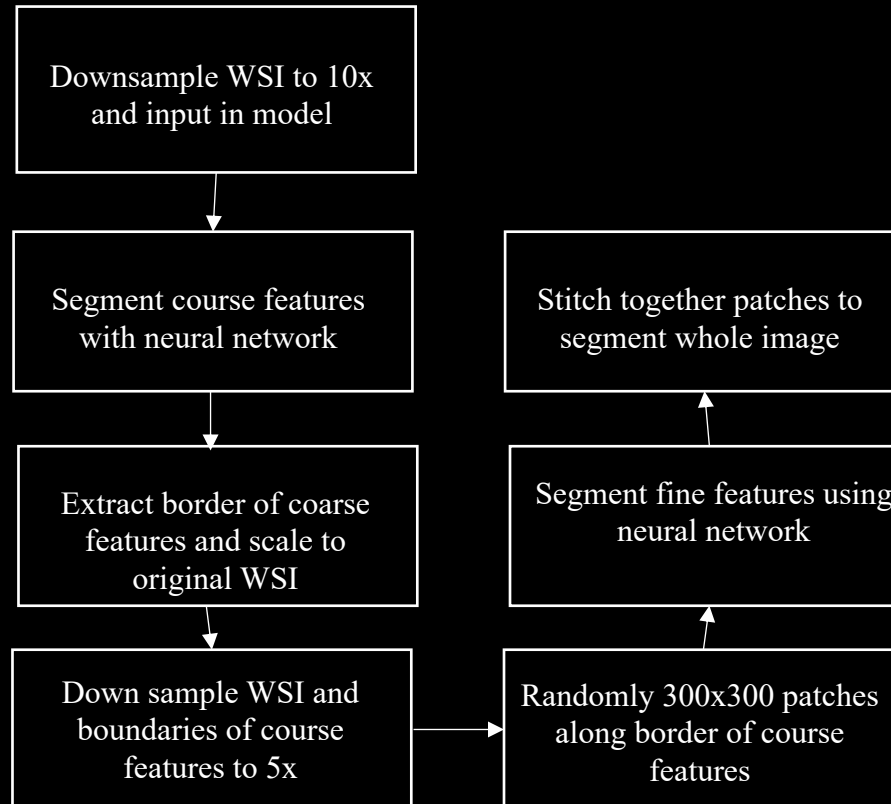
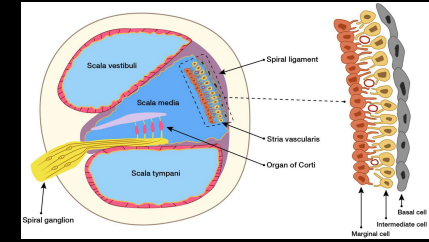
Ground Truth



Result

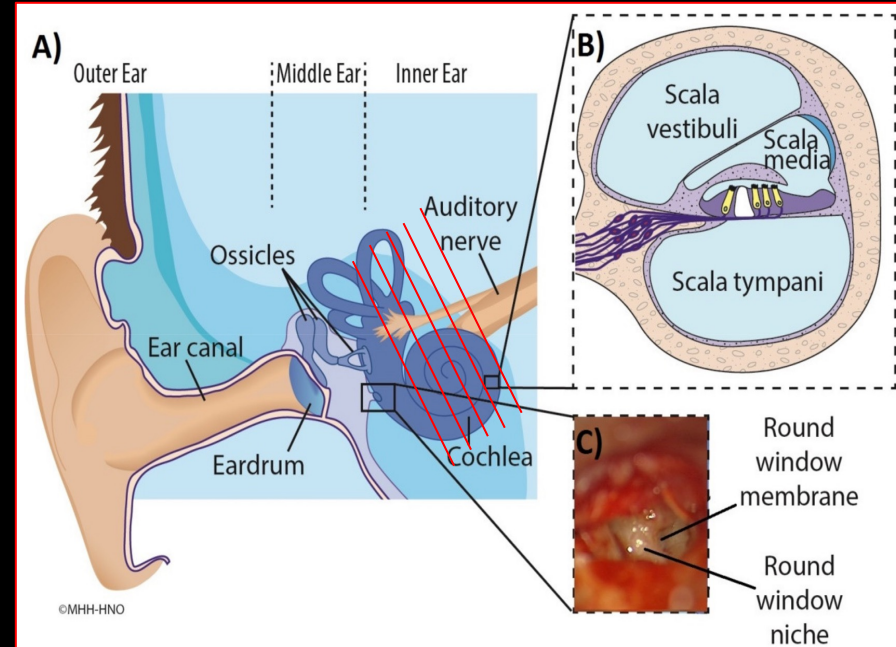


Technical Approach: Semantic Segmentation



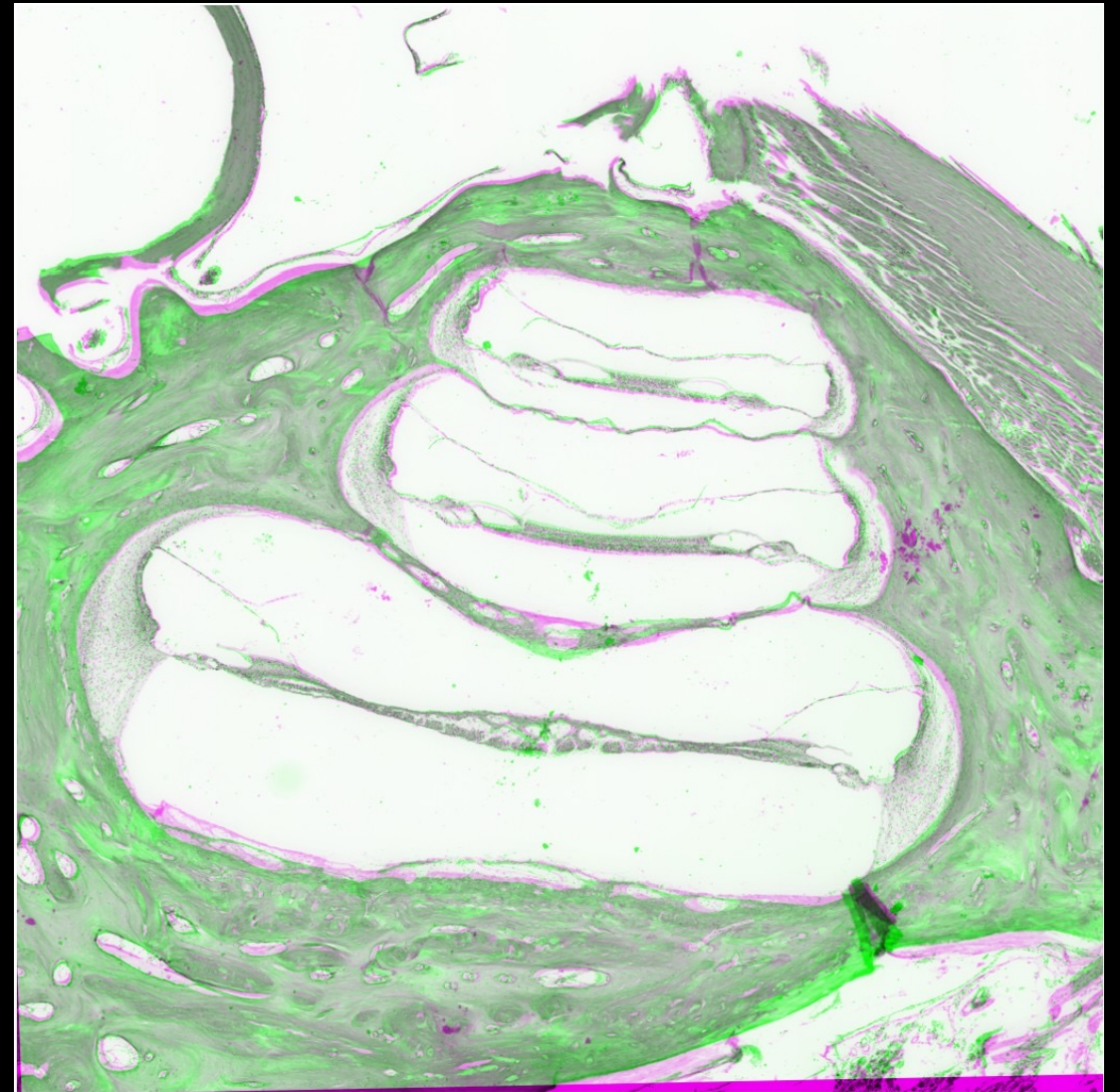
Technical Approach: Align/Register image

- 92 slices in each inner ear (approximately 10micron thickness)
- Align slides to each other
 - Start with middle slices and work out
 - Simple ITK->python implementation of elastix toolbox
- Input aligned 2D segmented slices into Slicer
 - Use interpolation feature in slicer to generate 3D volume



Sample Alignment Results

- Initial Approach
 - Compress images → convert to gray scale
 - Intensity based rigid registration
 - Gradient descent to minimize mean square error



Testing plan

- 3 ears with 91 slides each
- Semantic segmentation
 - 5 fold cross validation of model; accuracy
 - IoU/Jaccard Similarity Coefficient
- 3D reconstruction: validate against a manual alignment and reconstruction.

Next steps

- Semantic Segmentation
 - Correctly label vasculature
 - Train model on vasculature
- Alignment and Reconstruction
 - Apply alignment transforms to segmentations
 - Stack 2D images and view 3D in slicer
- Documentation
 - Continue manuscript writing
 - Maintain git repository

Management Plan

- Meetings: Biweekly meetings with med students until scans are completely segmented
 - Relay progress to sponsors via email/text
- Documentation
 - Github for code repository
 - Google Drive/doc for manuscript writeup