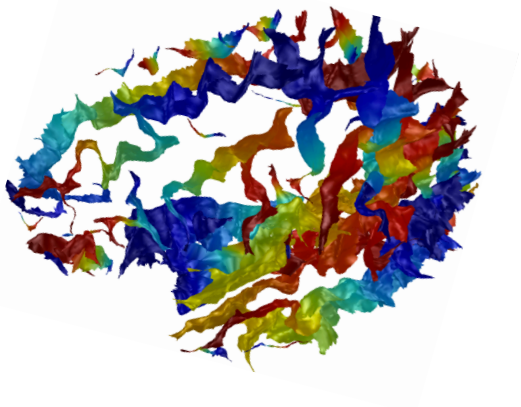
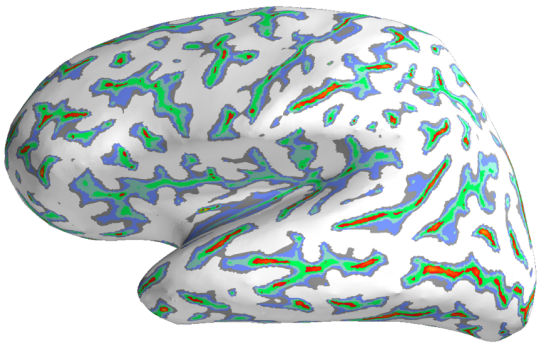
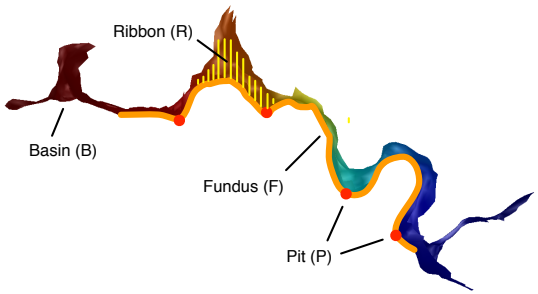
Mindboggle

update / lowdown







Arno Klein
arno@binarybottle.com
asst. professor of clinical neurobiology
columbia university

June 20, 2011
Works in progress talk
NIMH RO1 grant #MH084029-03

www.mindboggle.info/lectures

Forrest Bao
graduate student (Texas Tech)
Anatomical feature extraction

Noah Lee
postdoctoral research scientist
Graph-based feature database

Yrjö Häme
graduate student
Feature matching

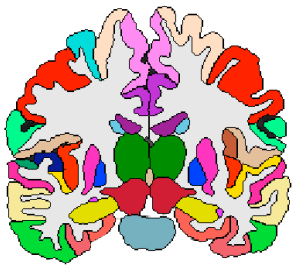
Denis Peruzzo
former postdoc
Feature graph matching

Mireia Montañola
visiting graduate student <u>as of today!</u>
Surface wrangling

Brian Avants
assistant professor (UPenn)
Diffeomorphic registration

Mindboggle project overview

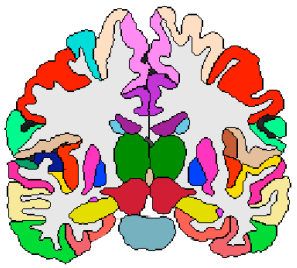
1. Manually label brain images



Mindboggle project overview

1. Manually label brain images

➔ Publicly available labeled data



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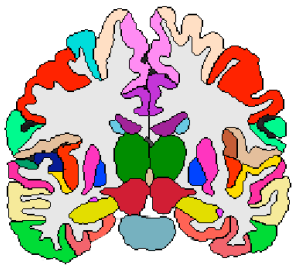
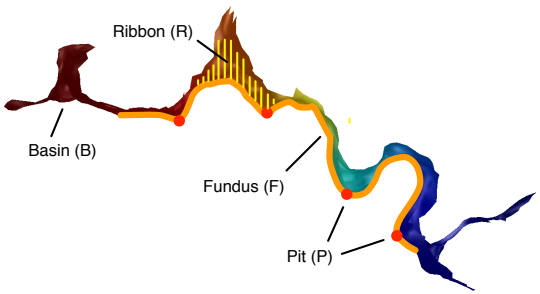


→ Publicly available labeled data

2. Extract brain structures, characterize their shapes



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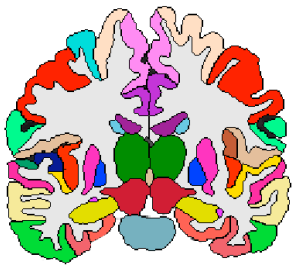

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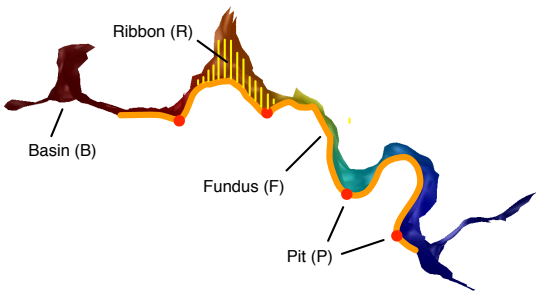

→ Online morphometry database

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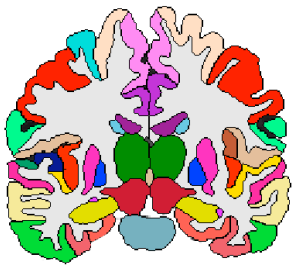

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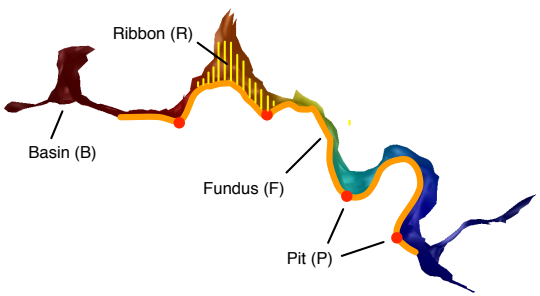
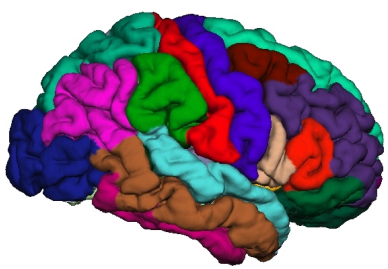


→ Online morphometry database

3. Automate labeling of brain images



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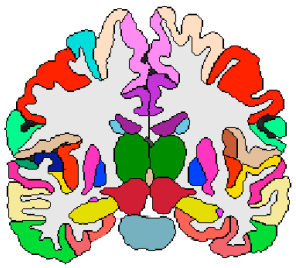

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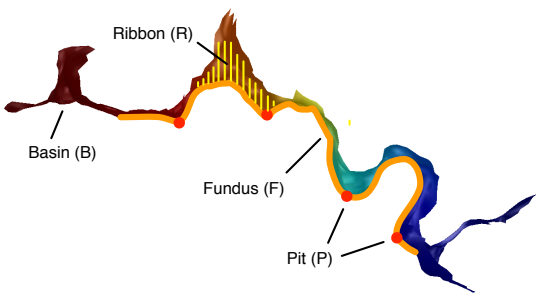

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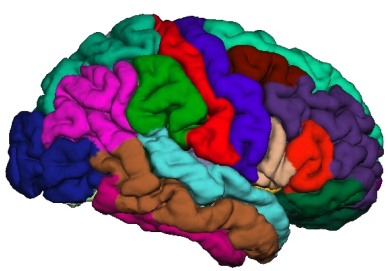

→ Open-source Mindboggle software

Mindboggle project overview

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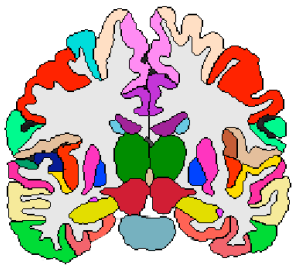

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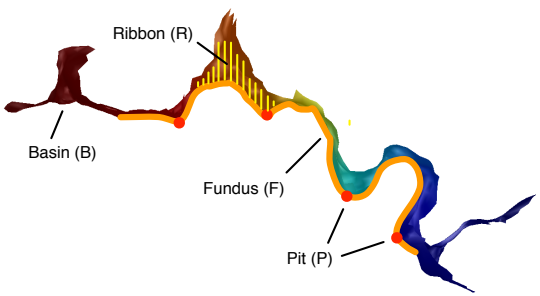

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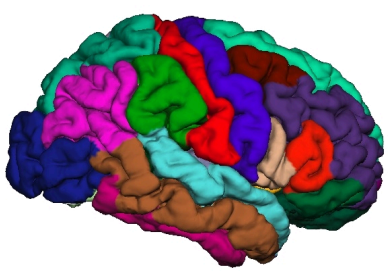
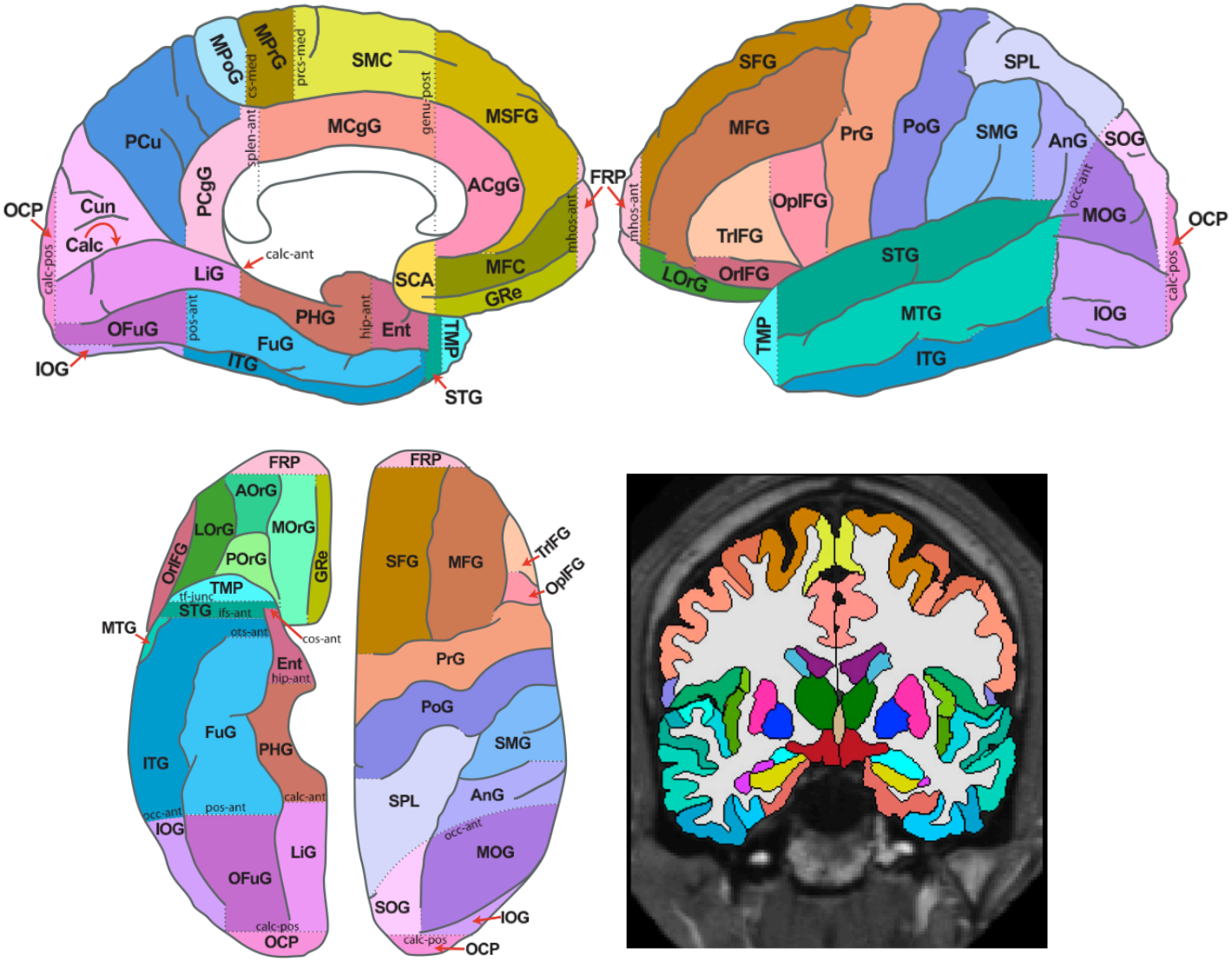
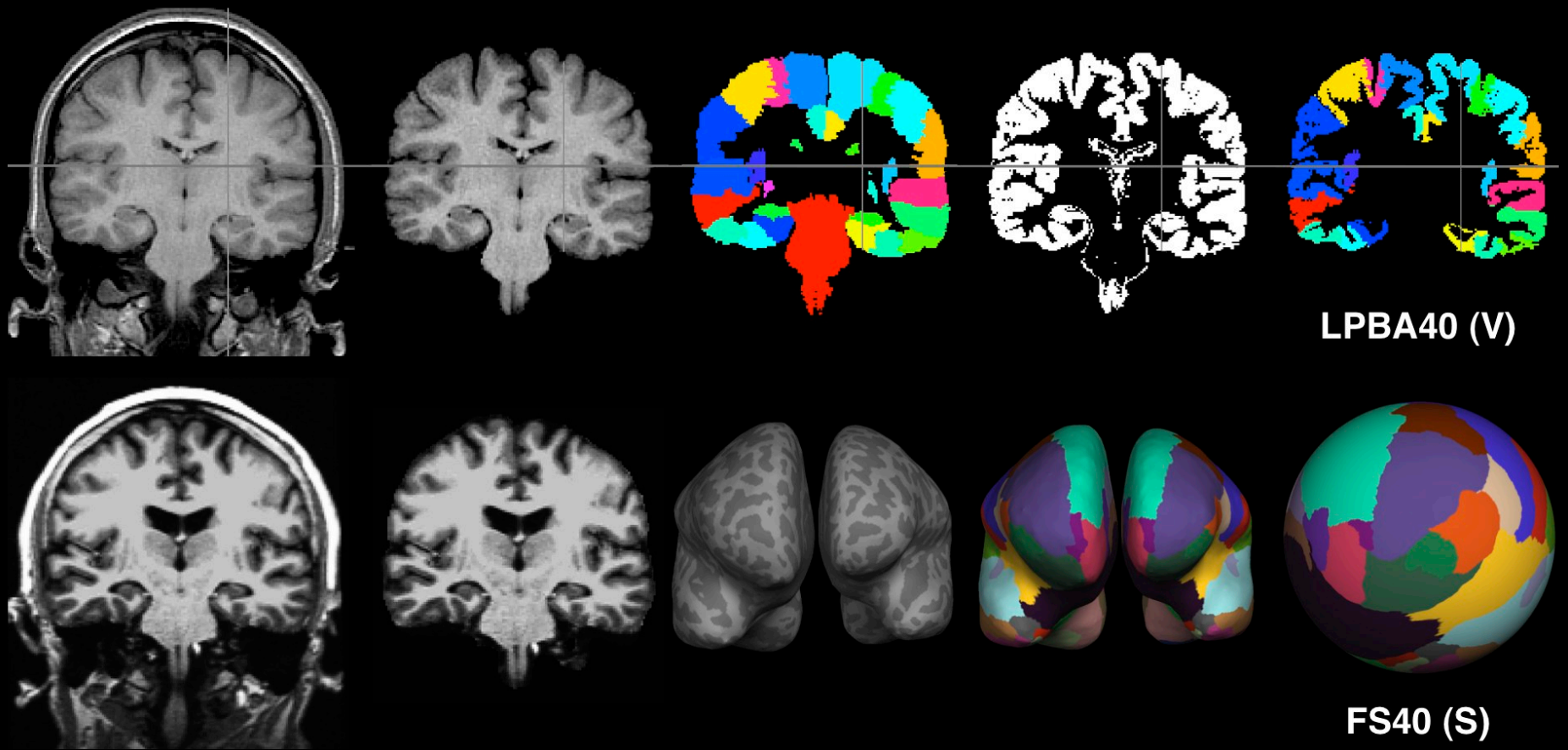


Labeling protocols

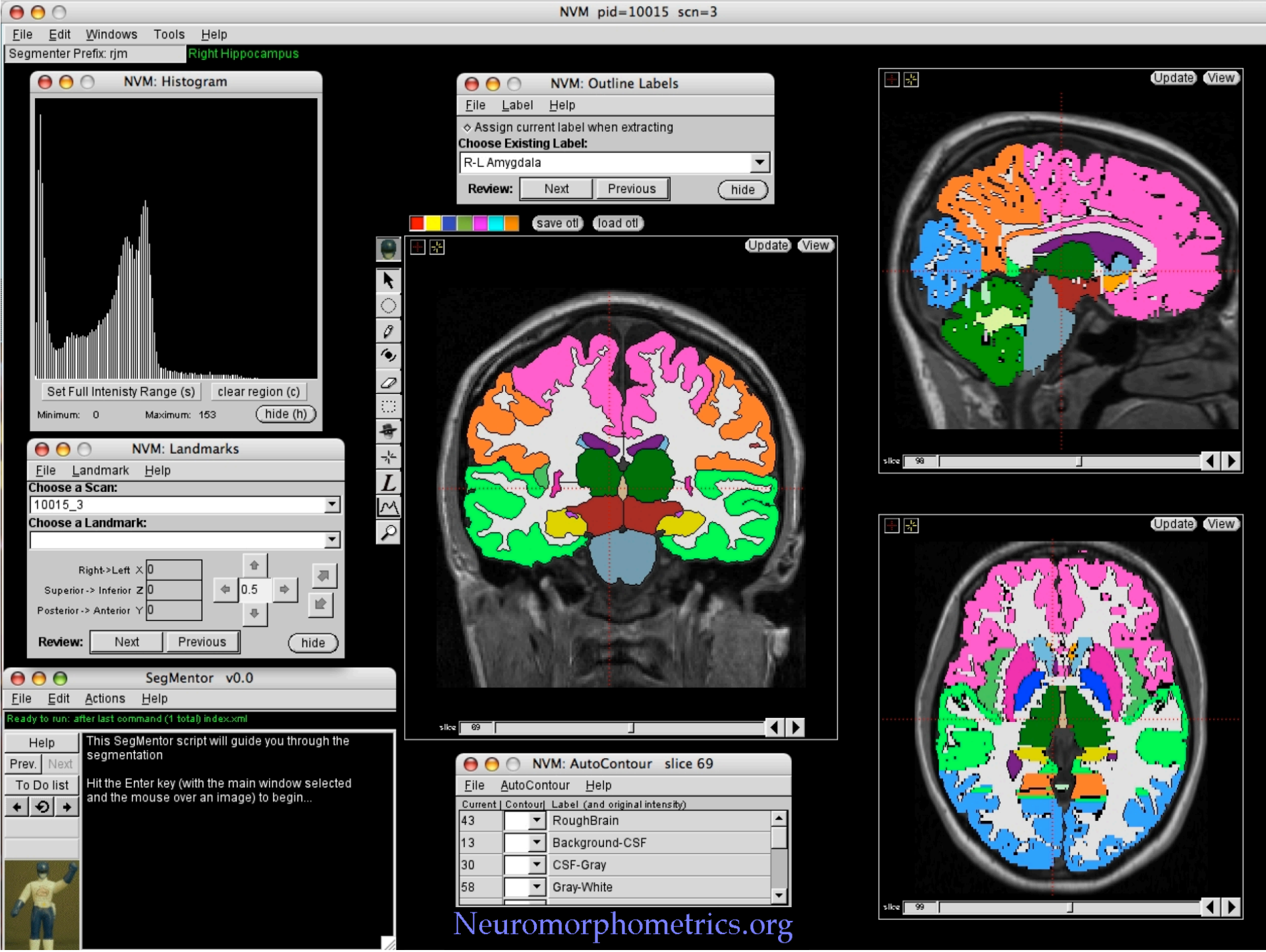
ex: BrainCOLOR

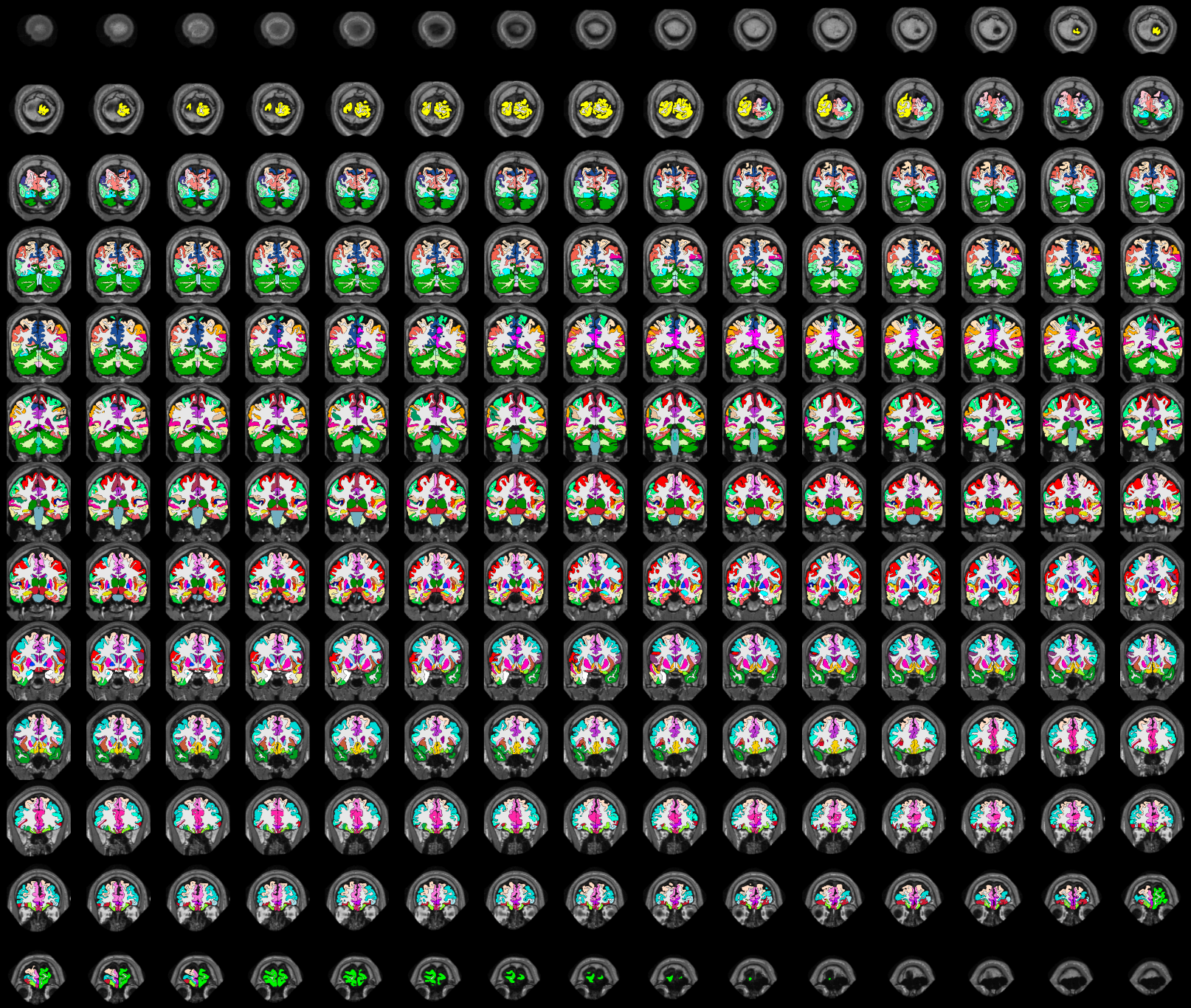


Labeling in volumes vs. surfaces



http://www.mindboggle.info/papers/

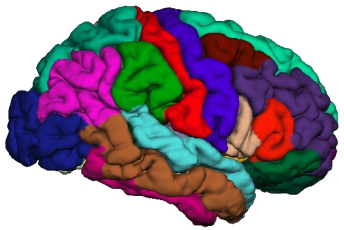

NVM pid=10015 scn=3
File Edit Windows Tools Help
Segmenter Prefix: rjm
Right Hippocampus
NVM: Histogram
Set Full Intenisty Range (s)
clear region (c)
Minimum: 0
Maximum: 153
hide (h)
NVM: Outline Labels
File Label Help
◇ Assign current label when extracting
Choose Existing Label:
R-L Amygdala
Review:
Next
Previous
hide
save otl
load otl
Update
View
slice 69
slice 98
slice 99
NVM: Landmarks
File Landmark Help
Choose a Scan:
10015_3
Choose a Landmark:
Right->Left X 0
Superior -> Inferior Z 0
Posterior -> Anterior Y 0
0.5
Review:
Next
Previous
hide
SegMentor v0.0
File Edit Actions Help
Ready to run: after last command (1 total) index.xml
Help
Prev.
Next
To Do list
This SegMentor script will guide you through the segmentation
Hit the Enter key (with the main window selected and the mouse over an image) to begin...
NVM: AutoContour slice 69
File AutoContour Help
Current
Contour
Label (and original intensity)
43 RoughBrain
13 Background-CSF
30 CSF-Gray
58 Gray-White
Neuromorphometrics.org



Monday, June 20, 2011

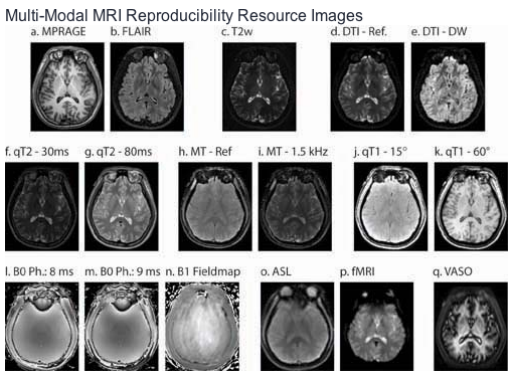
Data to label

N (#scans/subj)	#modalities	Data
20 (2)	1	OASIS
21 (2)	8	MMRR
40 (2)	5	EMBARC
>20 (1)	6	PTBP



OASIS *http://www.oasis-brains.org/* T1

MRI Multimodal Reproducibility Resource
http://www.nitrc.org/projects/multimodal/
MPRAGE, FLAIR,
resting state fMRI,
B0 and B1 field maps,
ASL, VASO, DTI,
quantitative T1 mapping,
quantitative T2 mapping,
magnetization transfer imaging



EMBARC
http://grants.nih.gov/grants/guide/rfa-files/RFA-MH-10-040.html
T1, fMRI and resting state fMRI, DTI, ASL, EEG

Pediatric Template for Brain Perfusion (UCLA)
http://projectreporter.nih.gov/project_info_description.cfm?icde=0&aid=7802848
T1, DTI, MT, perfusion, concurrent ASL/BOLD sequence and resting state fMRI

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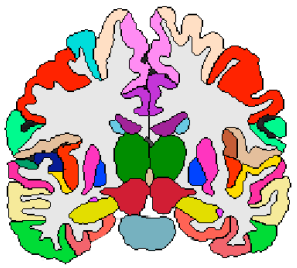

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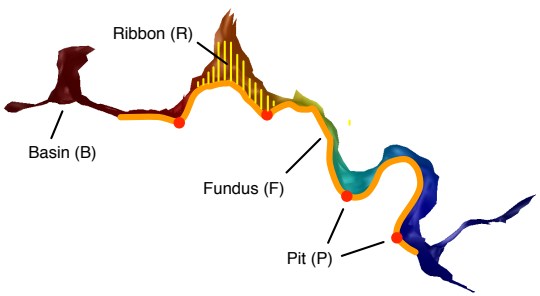

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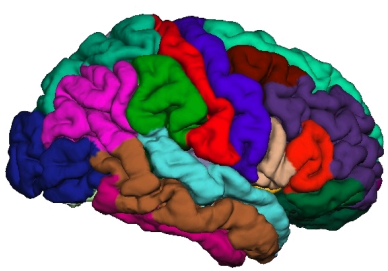
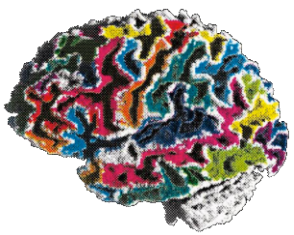
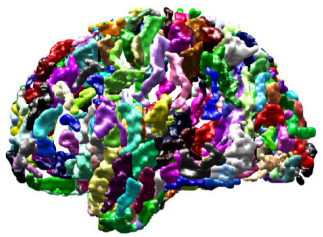


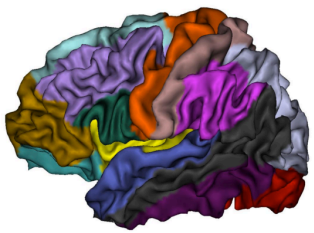
Extract brain structures

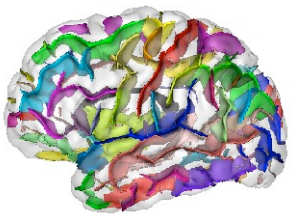
3-D basins



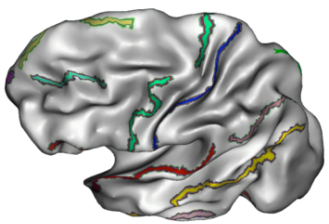


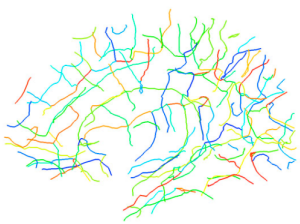
surfaces
ribbons



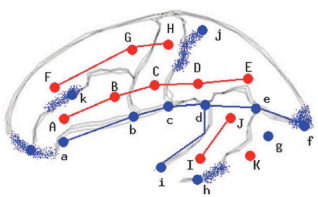


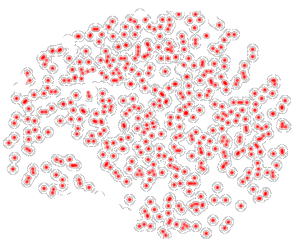
curves

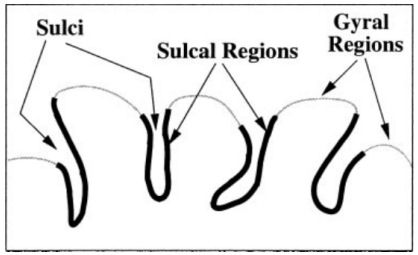




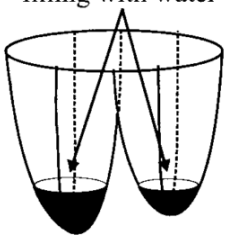
points



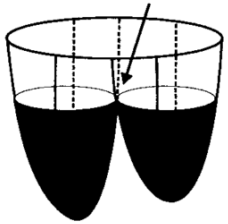




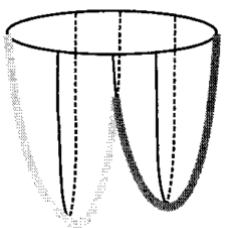
catchment basins begin filling with water



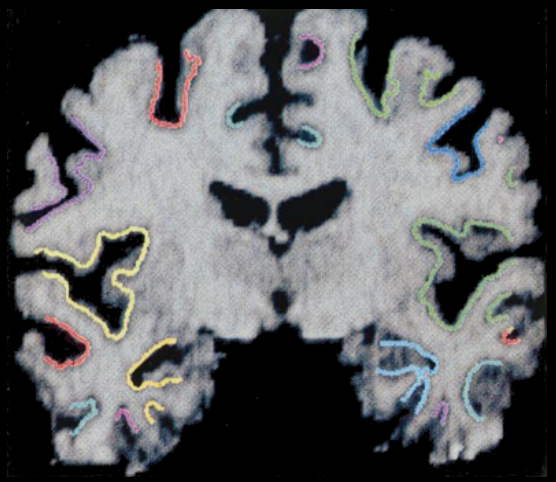
watershed line forms here

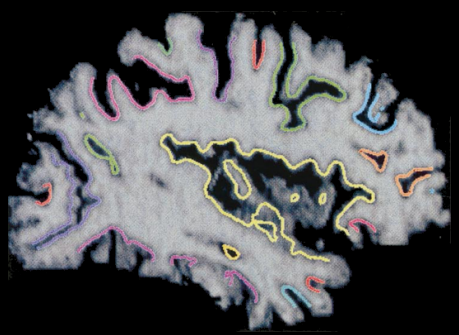


ideal segmentation

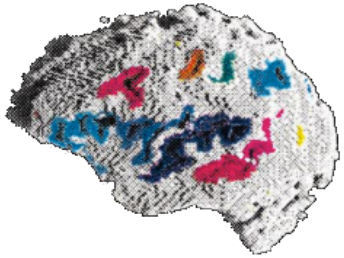


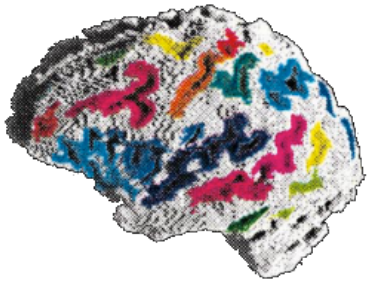
sulcus **basins**

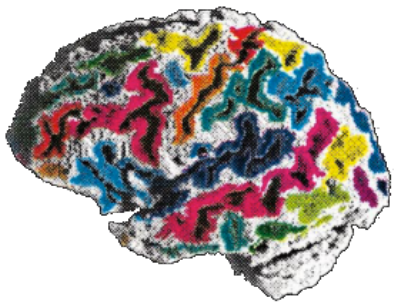




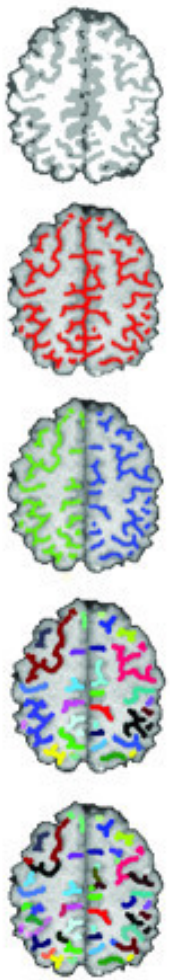
Rettman et al. 2002, Lohmann et al., 2000

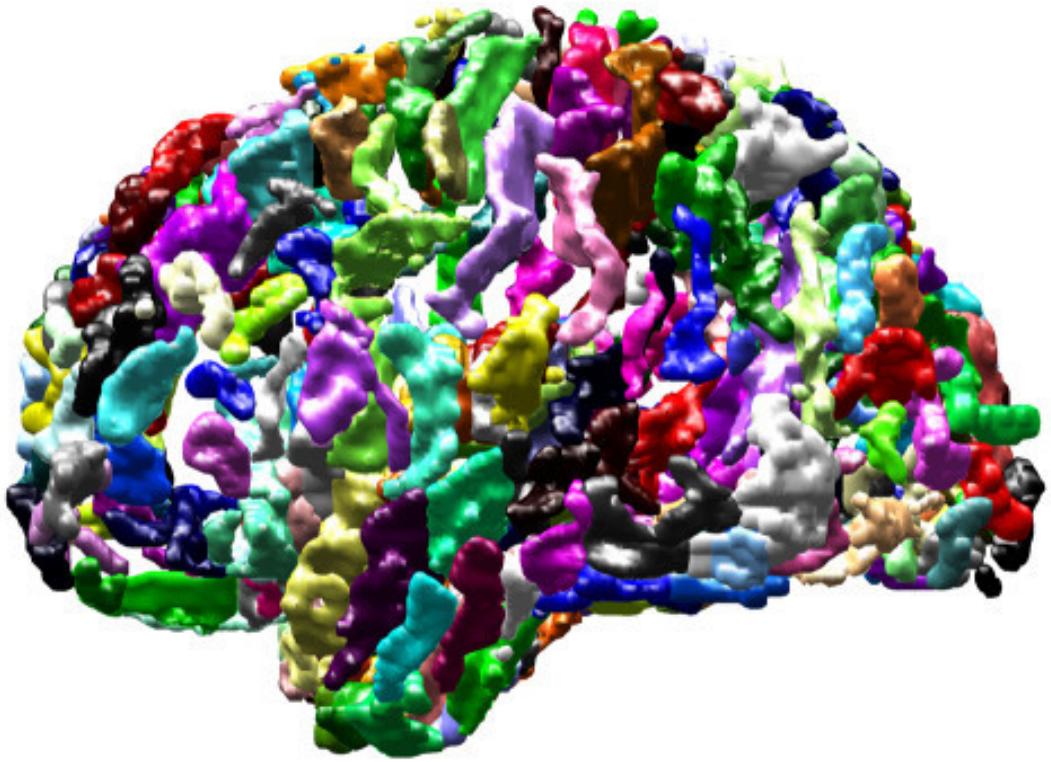




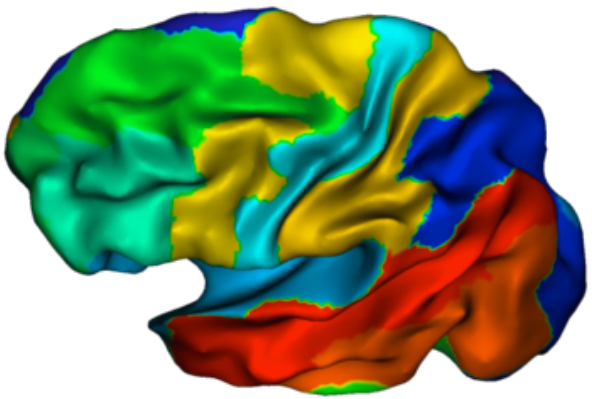


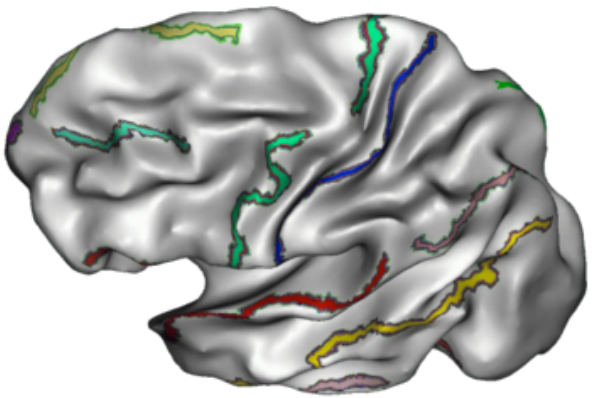
sulcus **skeletons**

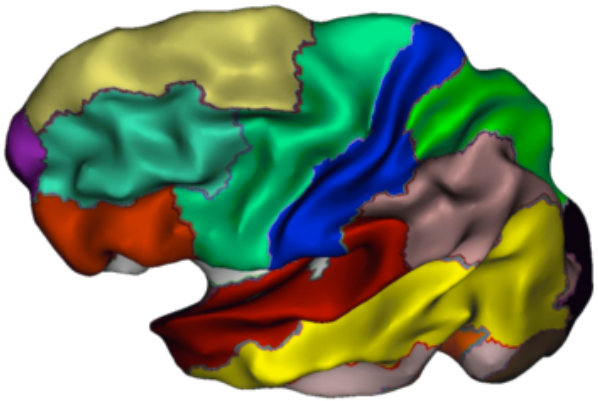


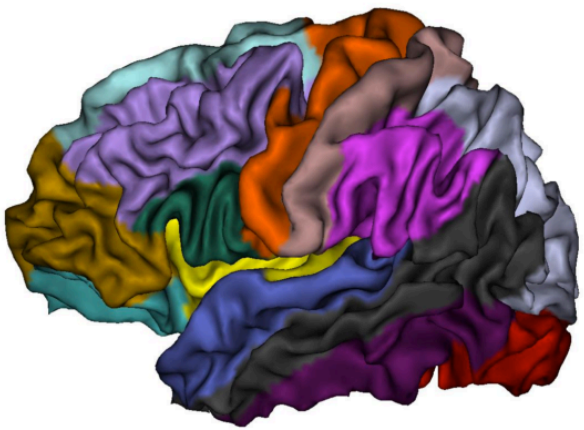


sulcus & gyrus **surfaces**



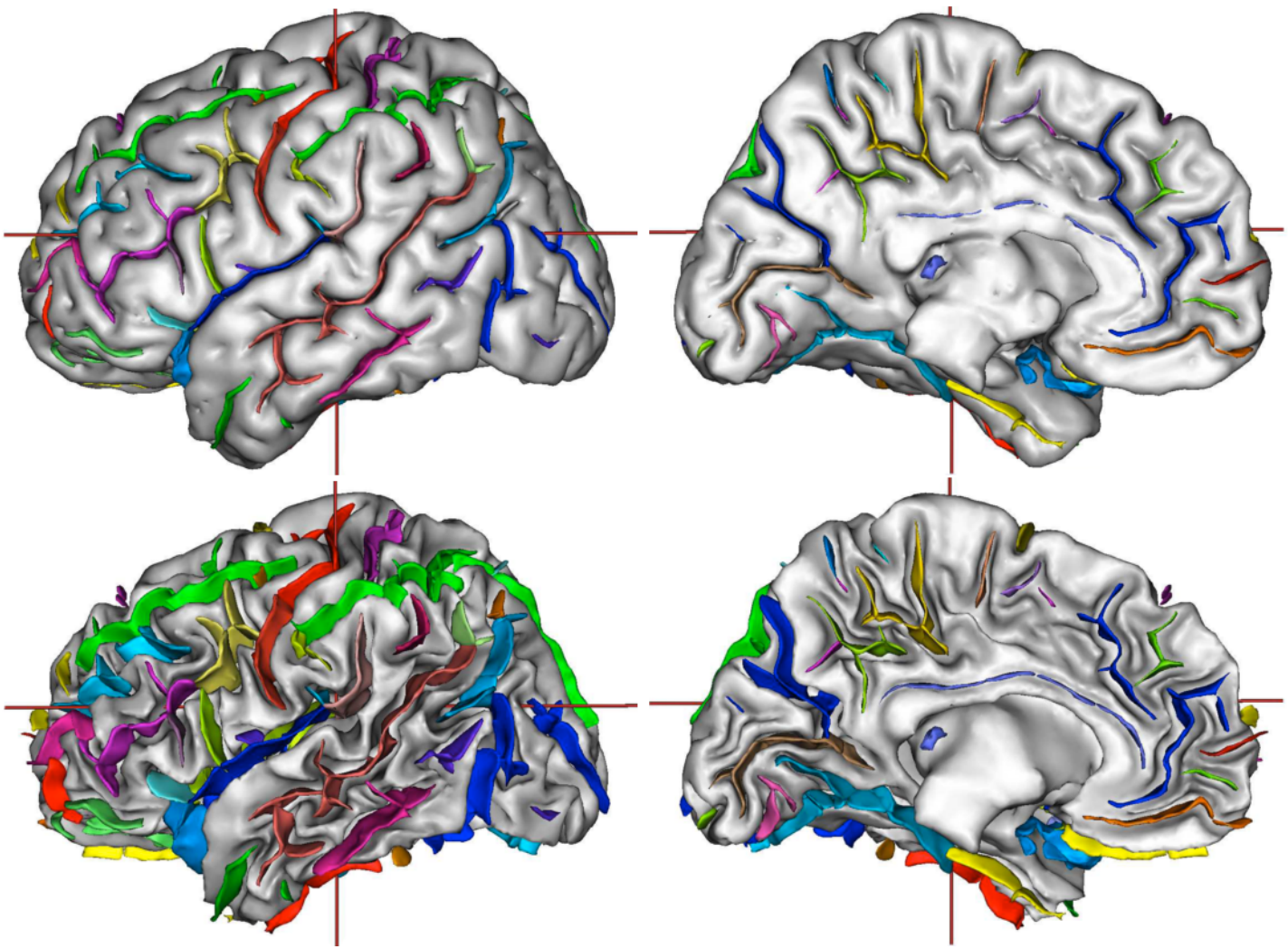






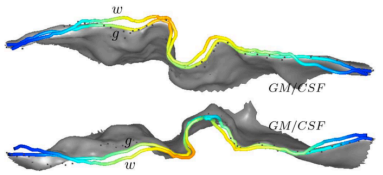
Cachia et al., 2003, Clouchoux et al., 2006

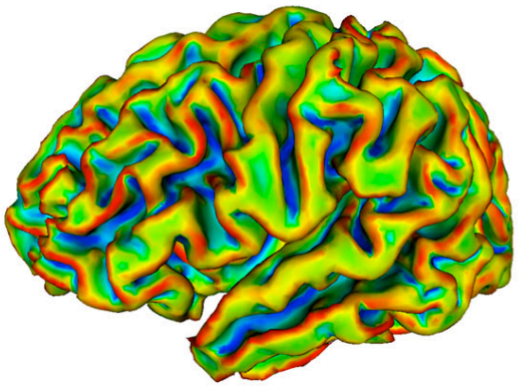
sulcus **ribbons**

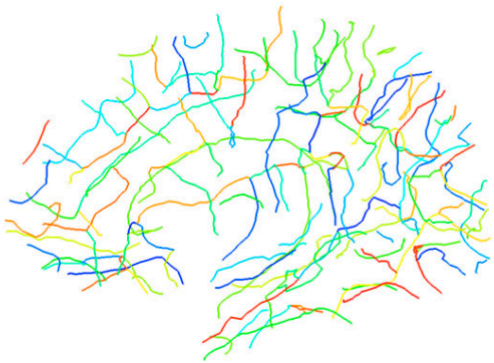


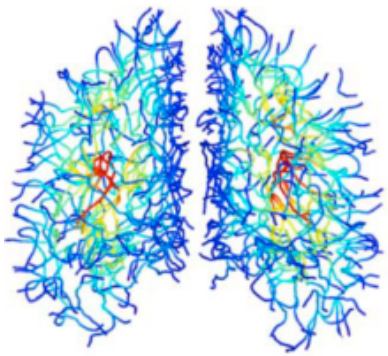
Clouchoux, 2008

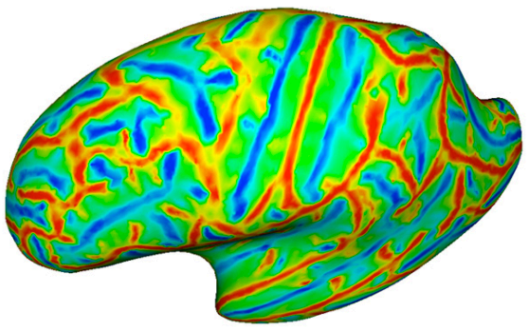
sulcus **curves**

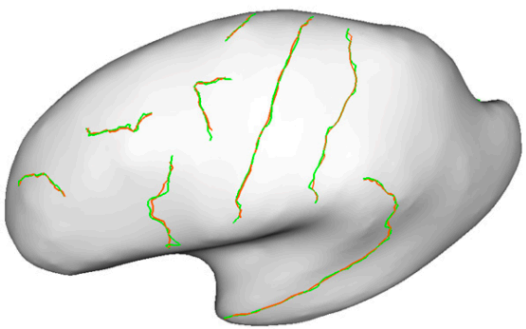


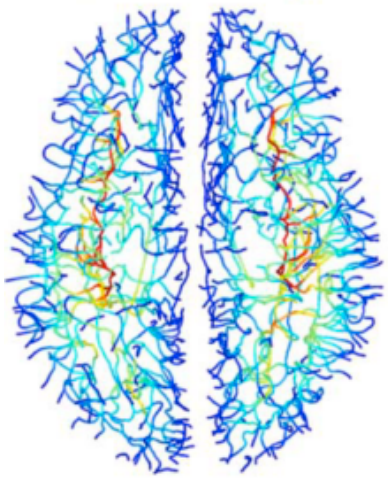






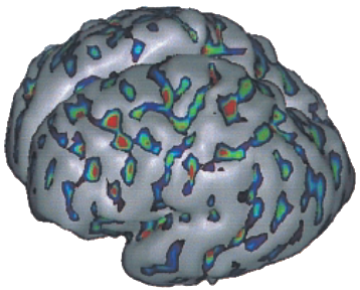


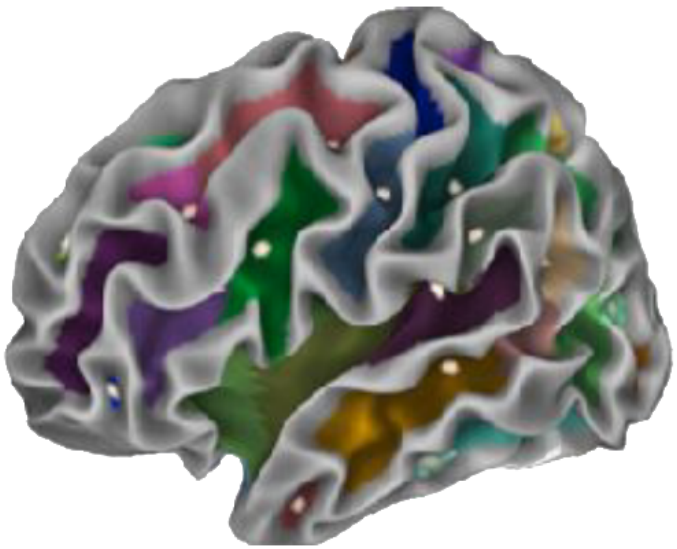


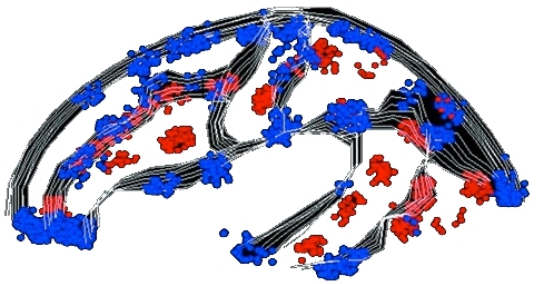


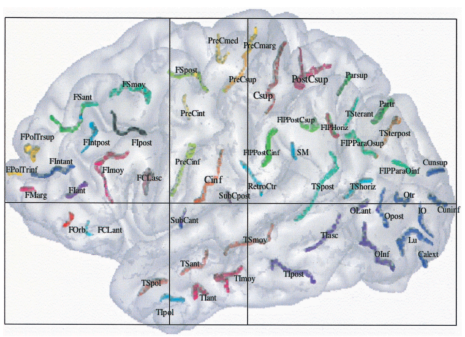
Li et al., 2008, Kao et al., 2007

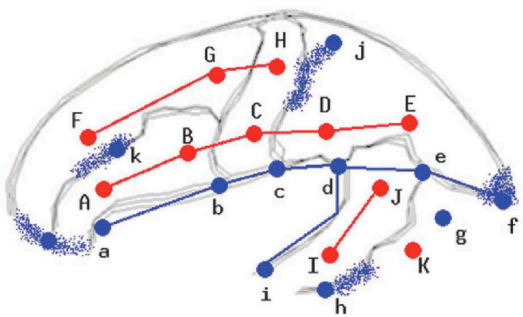
sulcus **pits**







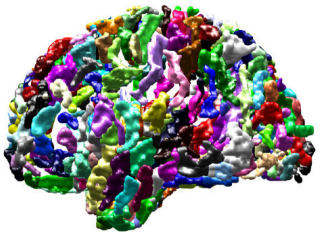


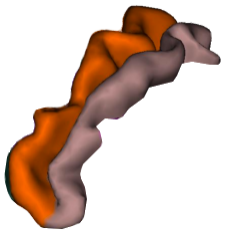


Regis et al., 2005, Im et al., 2010, Lohmann et al., 2007

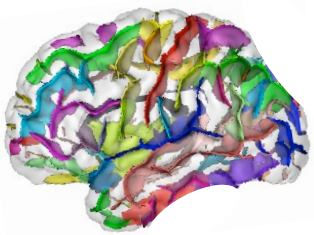
Combine structures in a nested hierarchy?

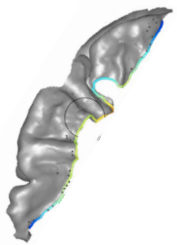
3-D





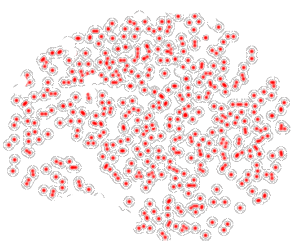
2-D



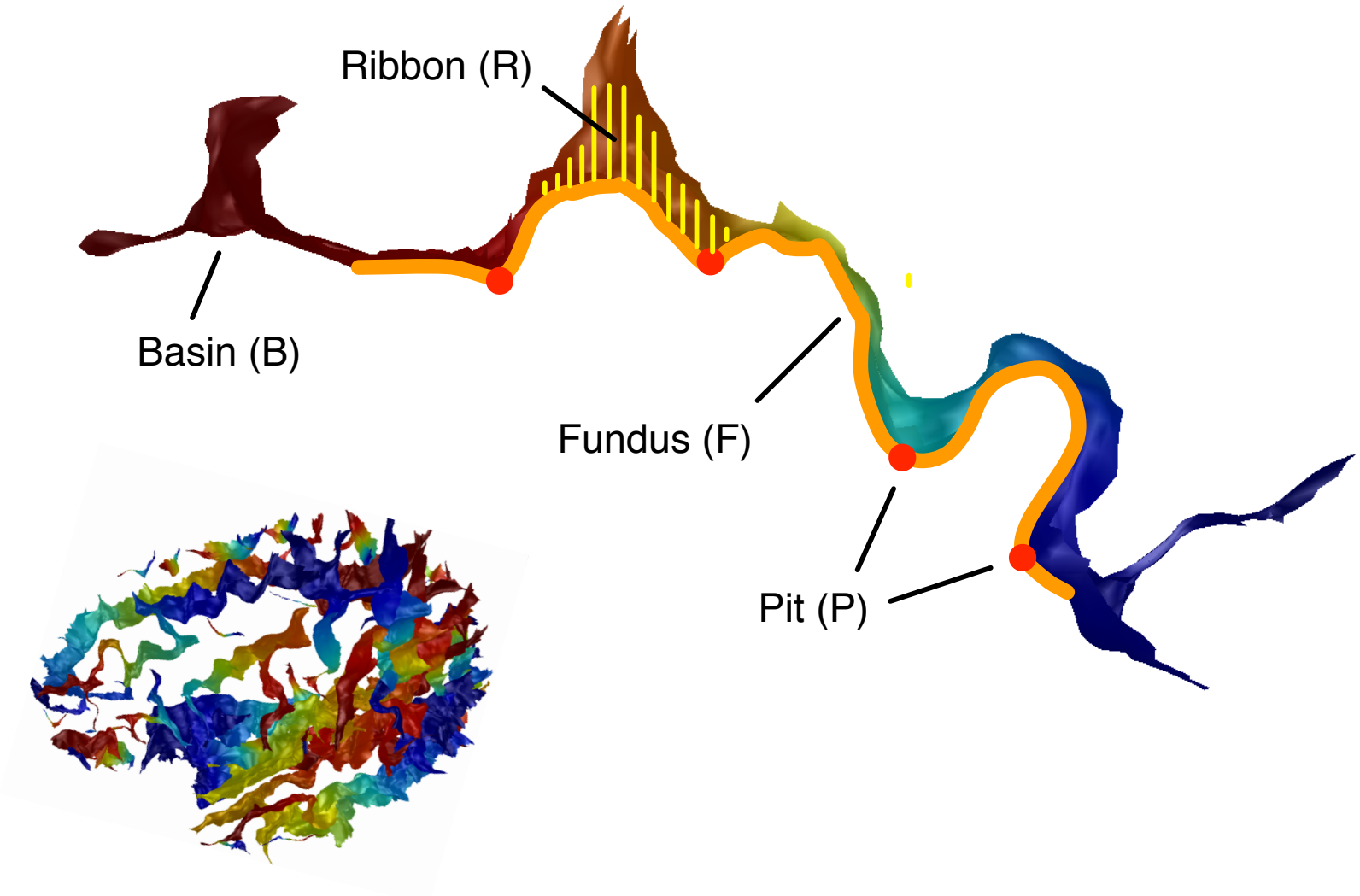


1-D

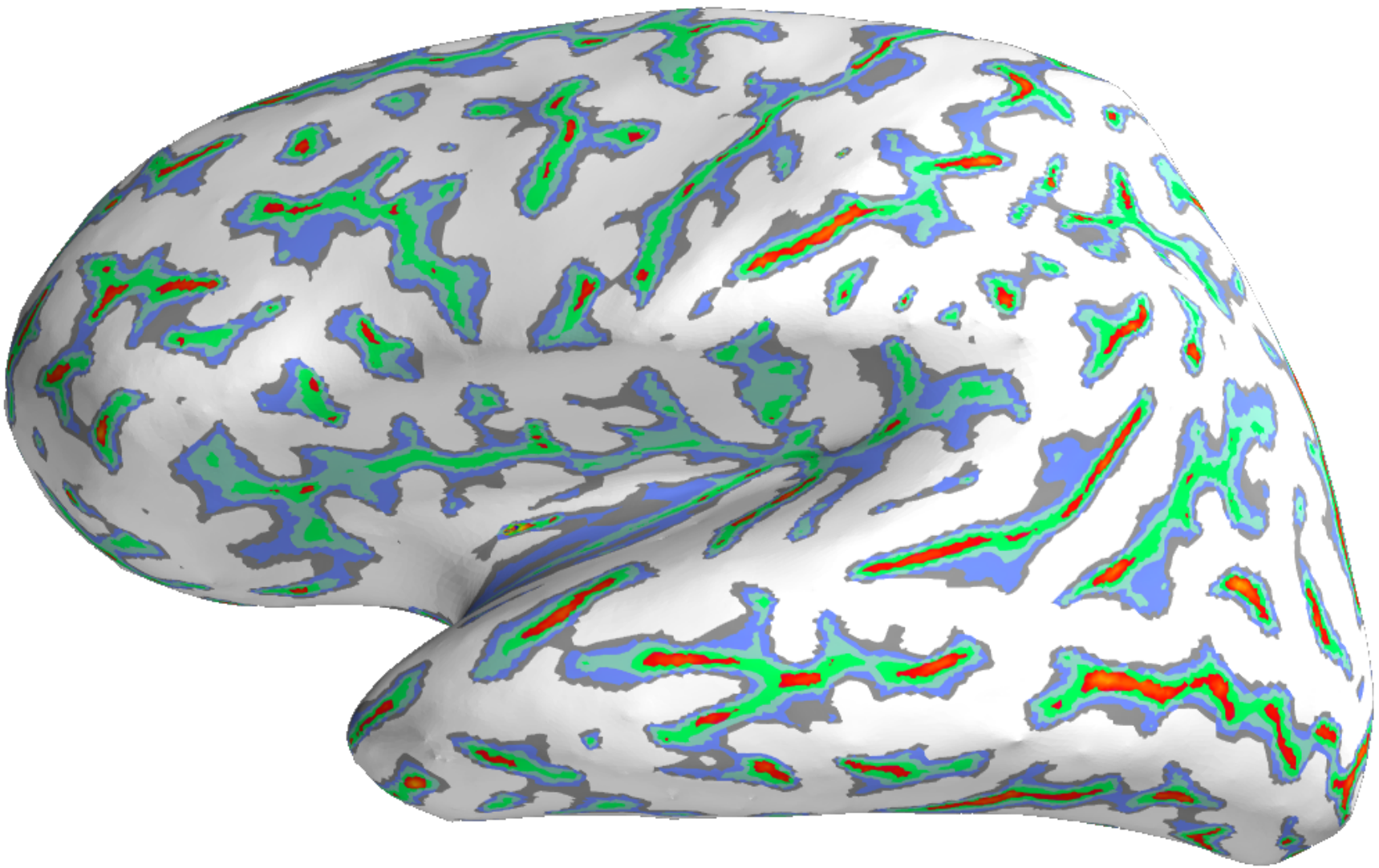
0-D



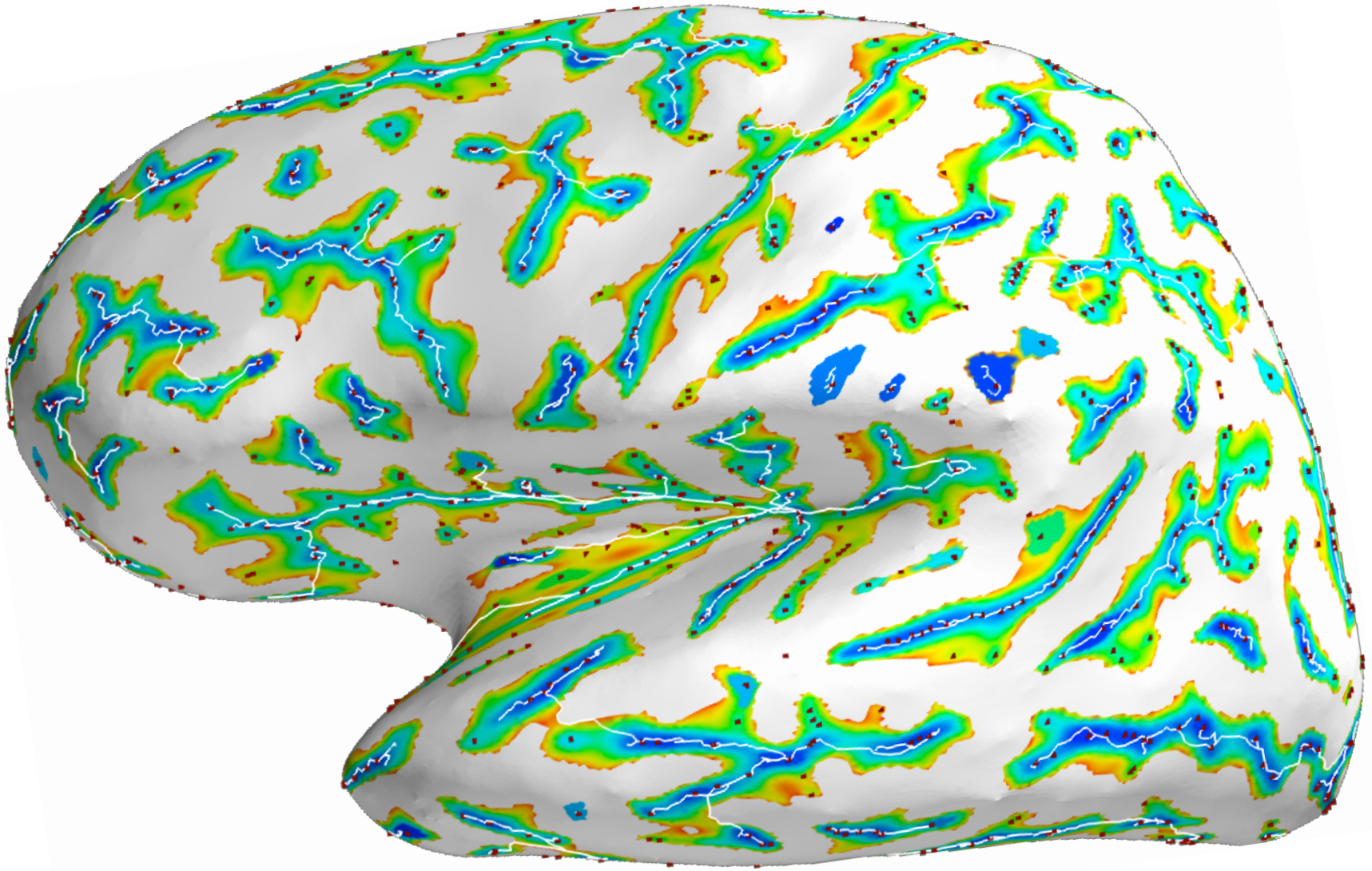
Combine structures in a nested hierarchy?



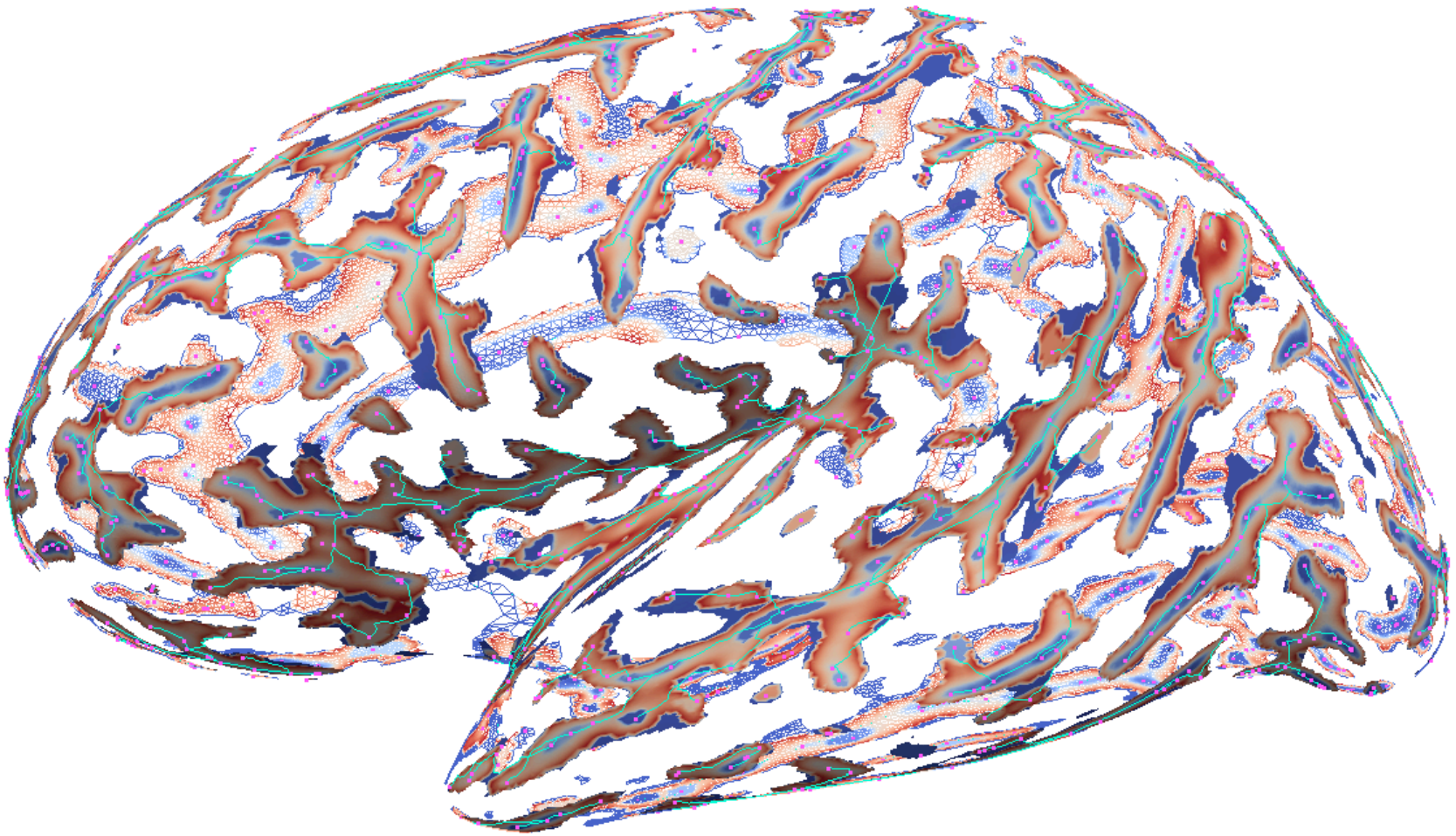
Combine basins, fundi, and pits in a nested hierarchy



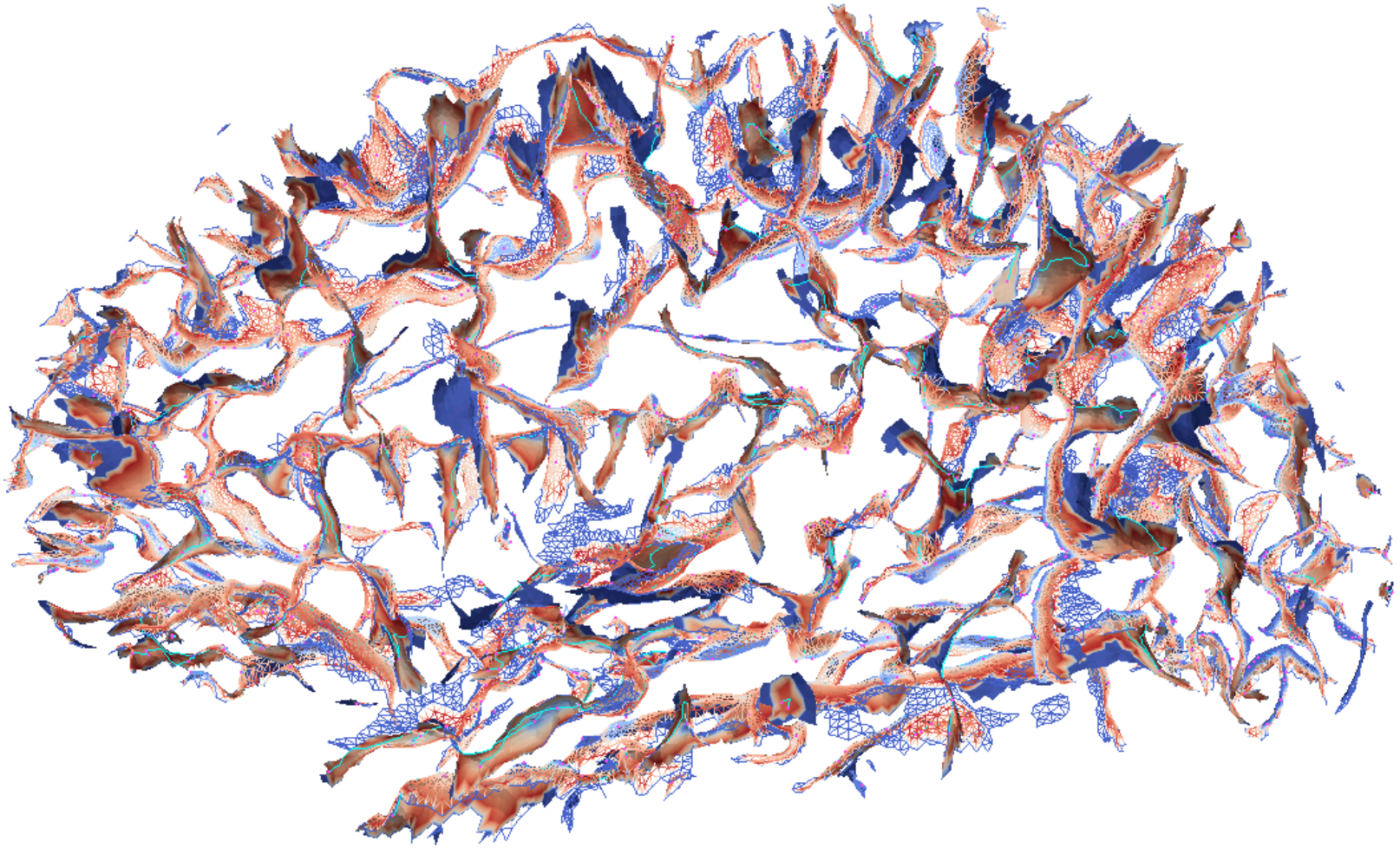
Combine basins, fundi, and pits in a nested hierarchy



Combine basins, fundi, and pits in a nested hierarchy

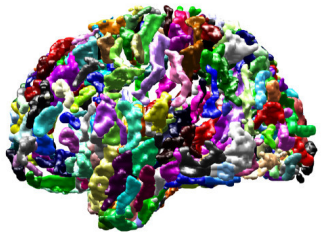


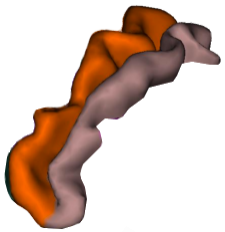
Combine basins, fundi, and pits in a nested hierarchy



Characterize their shapes: **features**

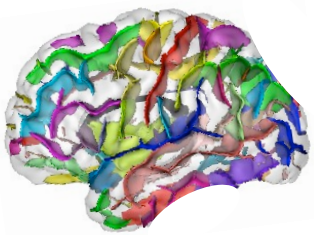
3-D

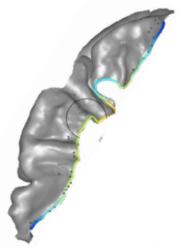




volume
surface area
lengths (thickness)
...

2-D



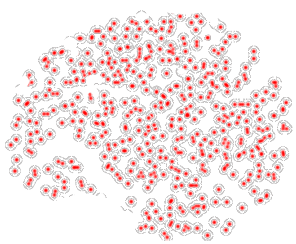


area
curvature
convexity
spectral components
...

1-D

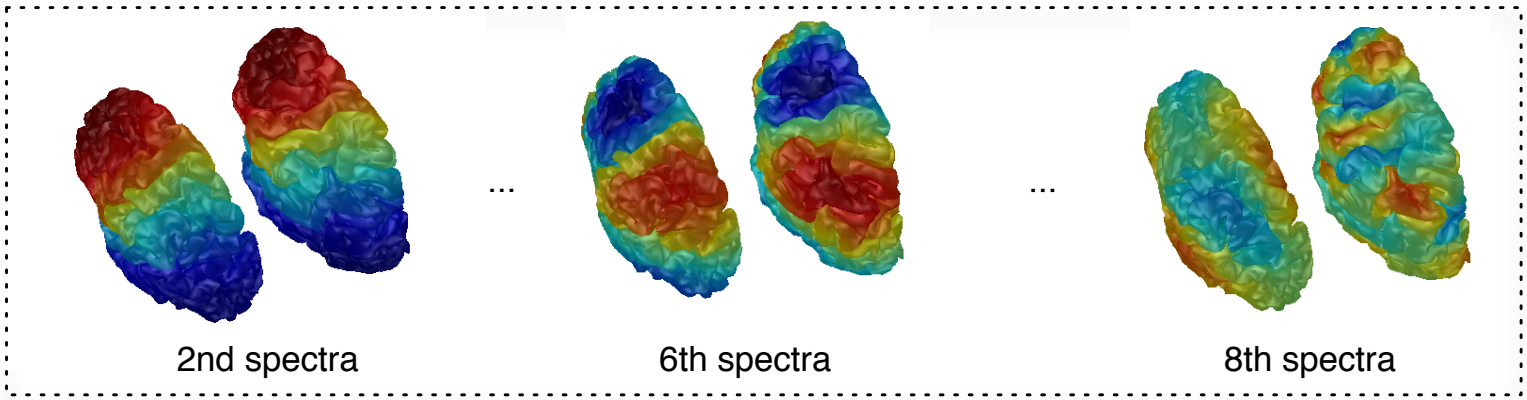
length
curvature
convexity
...

0-D

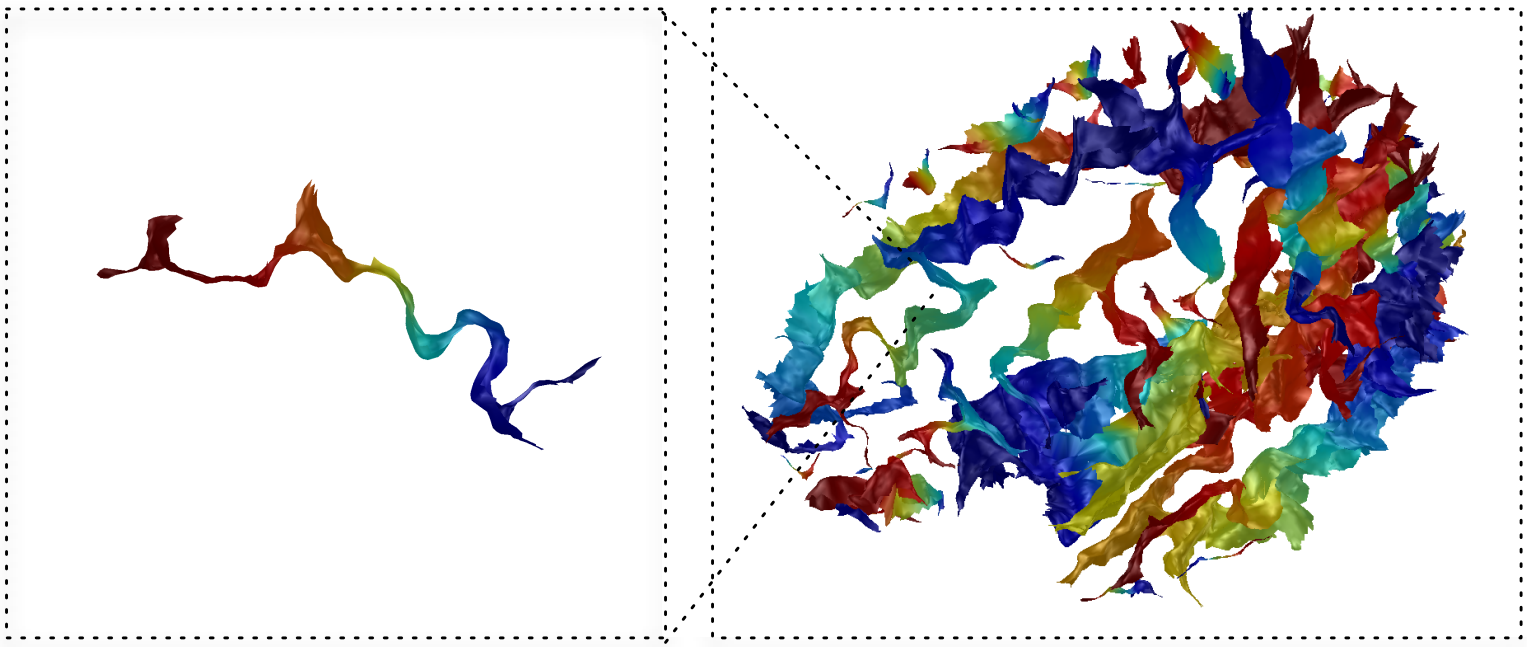


3-D convex hull volume
1-D sequence along a curve
...

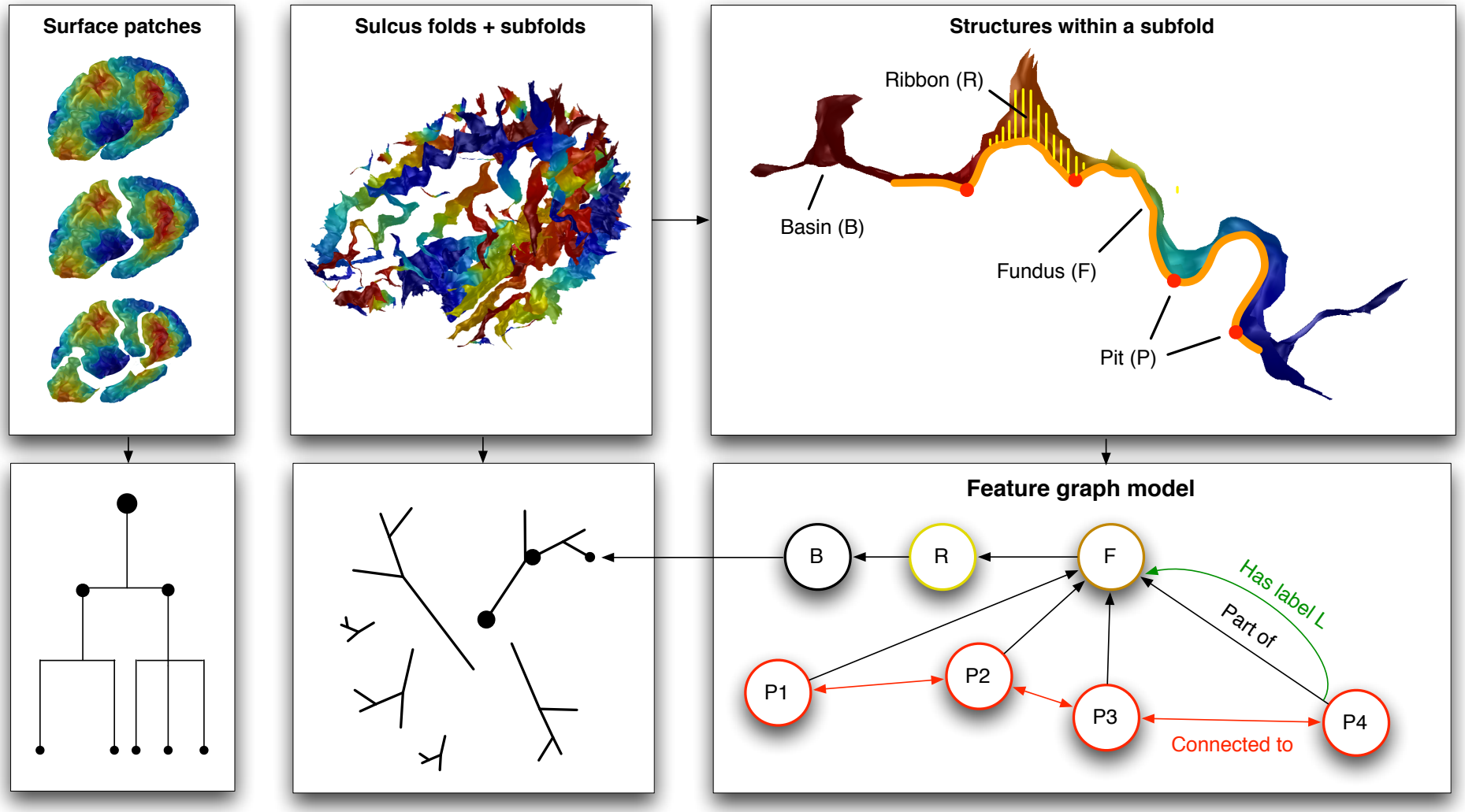
Laplace-Beltrami operator shape characterization



Global to local



Represent nested features within a graph-based data model

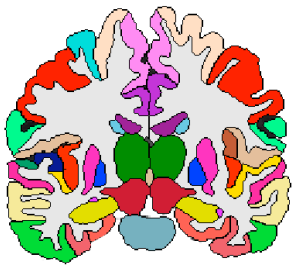


Top: structures: surface patches fragmented by application of the Laplace-Beltrami operator, sulcus folds and subfolds, and structures within a subfold.
Bottom: schematic diagrams representing the hierarchical relationships among nested structures.
Bottom right: features as properties of edges (relationships: Part of, Connected to, Has label) and nodes (geometric, shape, spectral, and connectivity measures).

Mindboggle project overview

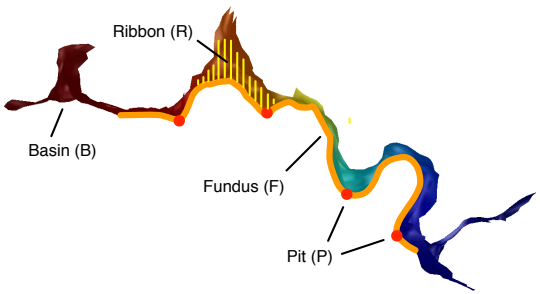
1. Manually label brain images

→ Publicly available labeled data



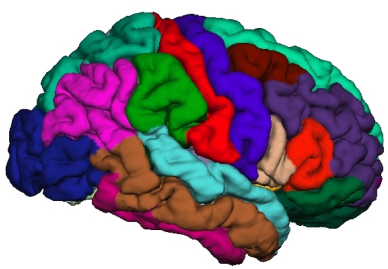
2. Extract brain structures, characterize their shapes

→ Online morphometry database



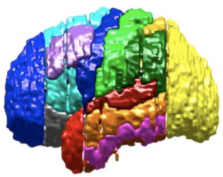
3. Automate labeling of brain images

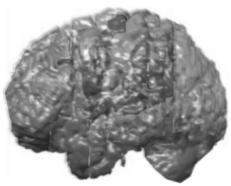
→ Open-source Mindboggle software



Mindboggle 2: feature-based labeling

atlas

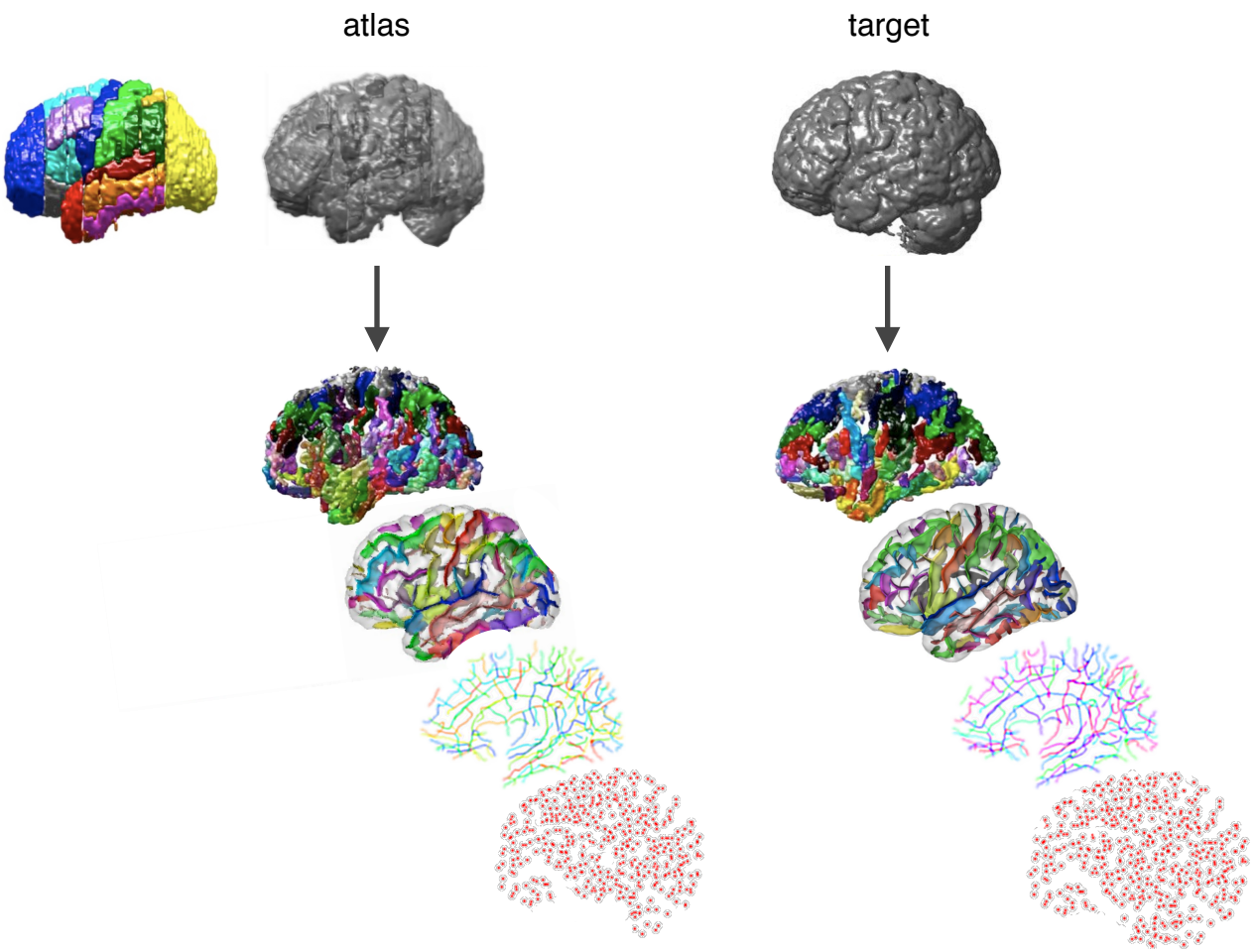




target

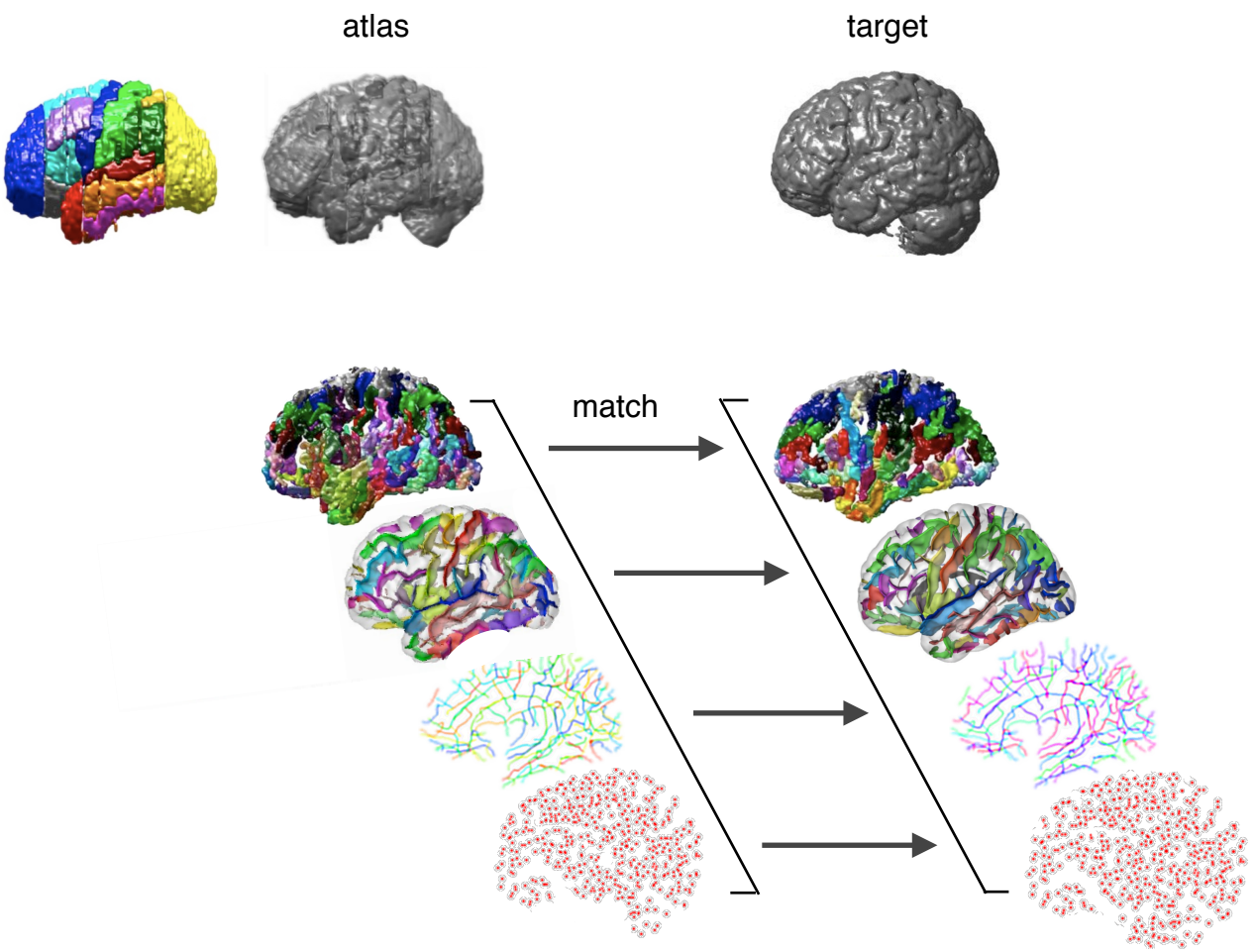
Mindboggle 2: feature-based labeling

Step 1: extract structures, compute their features



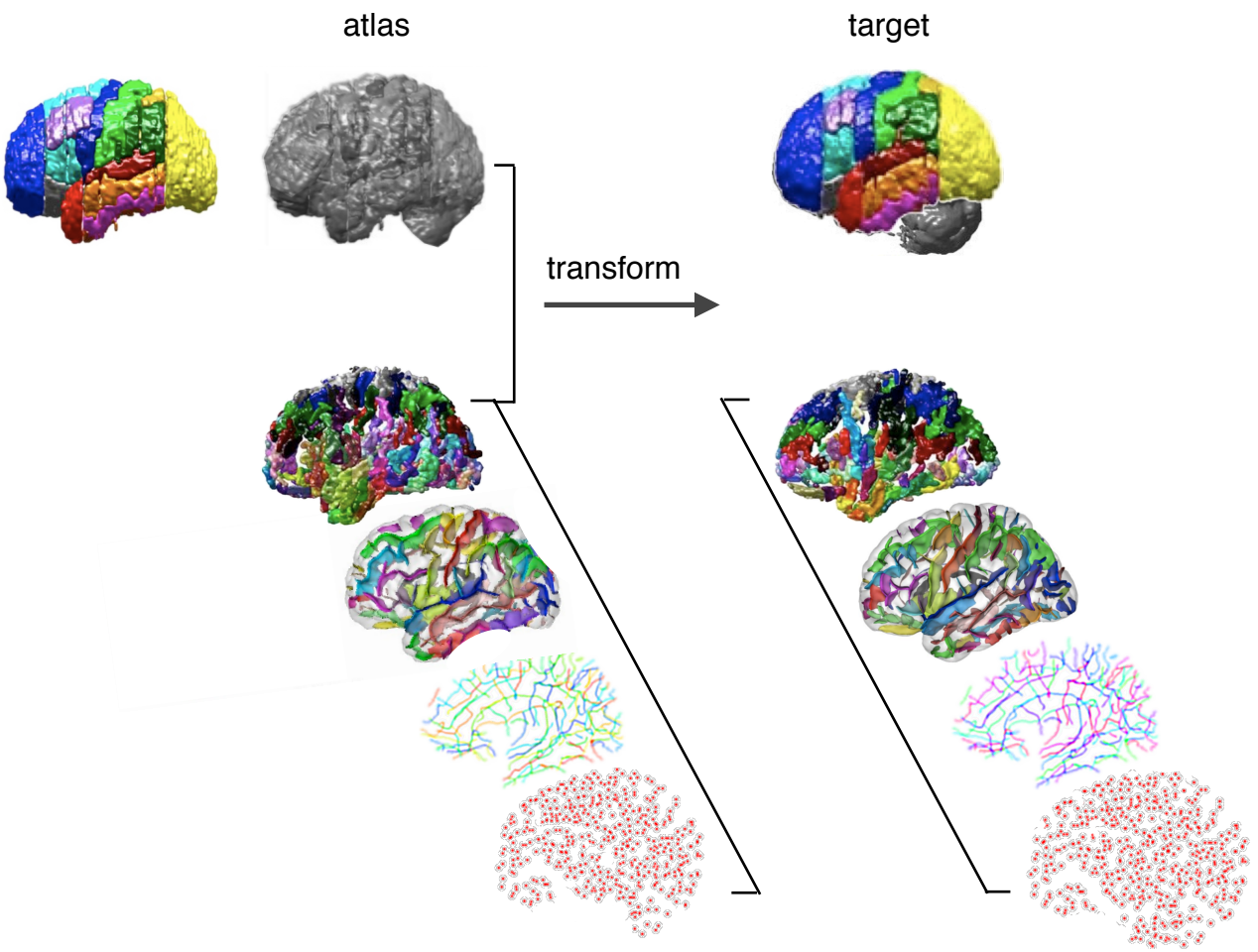
Mindboggle 2: feature-based labeling

Step 2: match atlas and target features



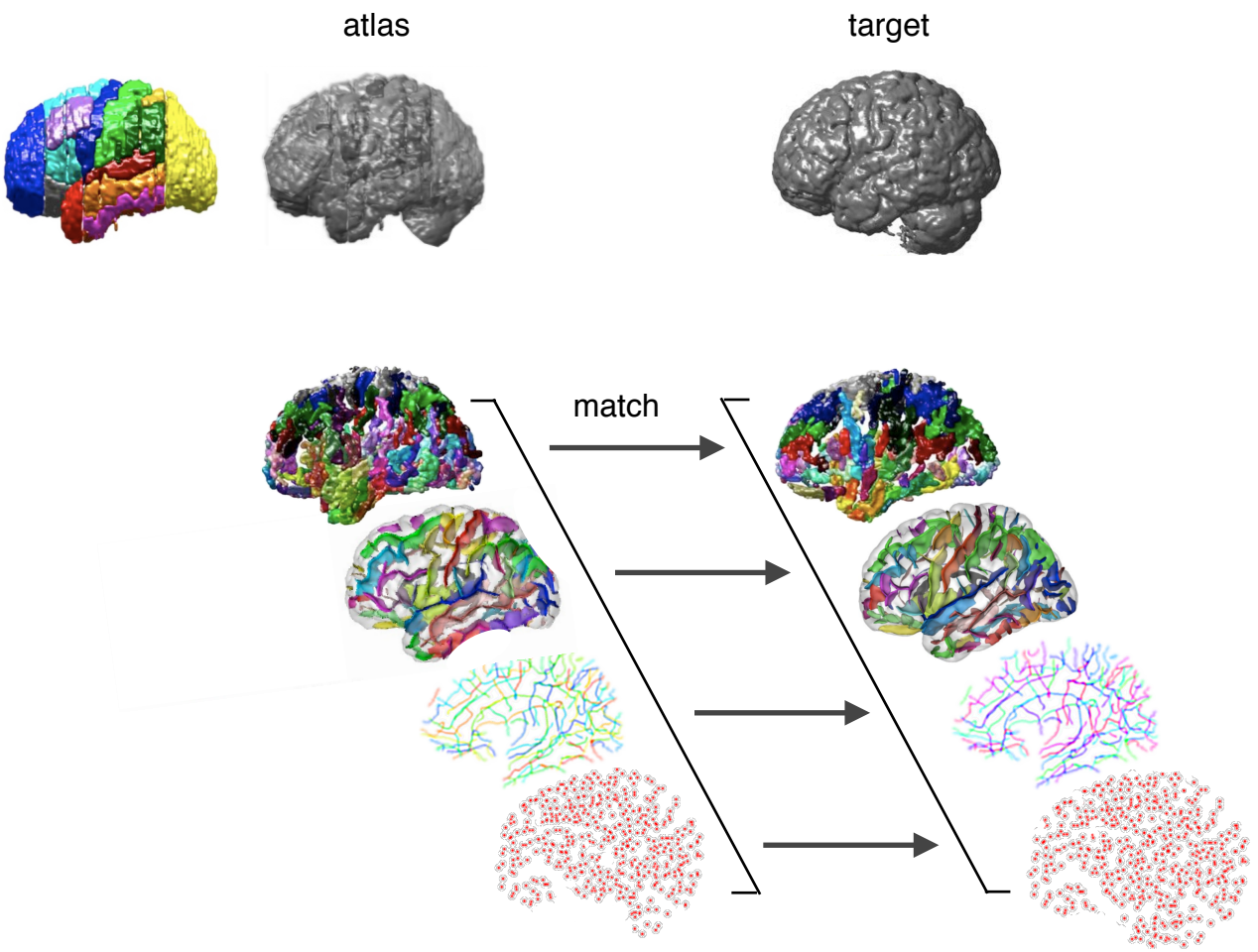
Mindboggle 2: feature-based labeling

Step 3: register atlas and target structures



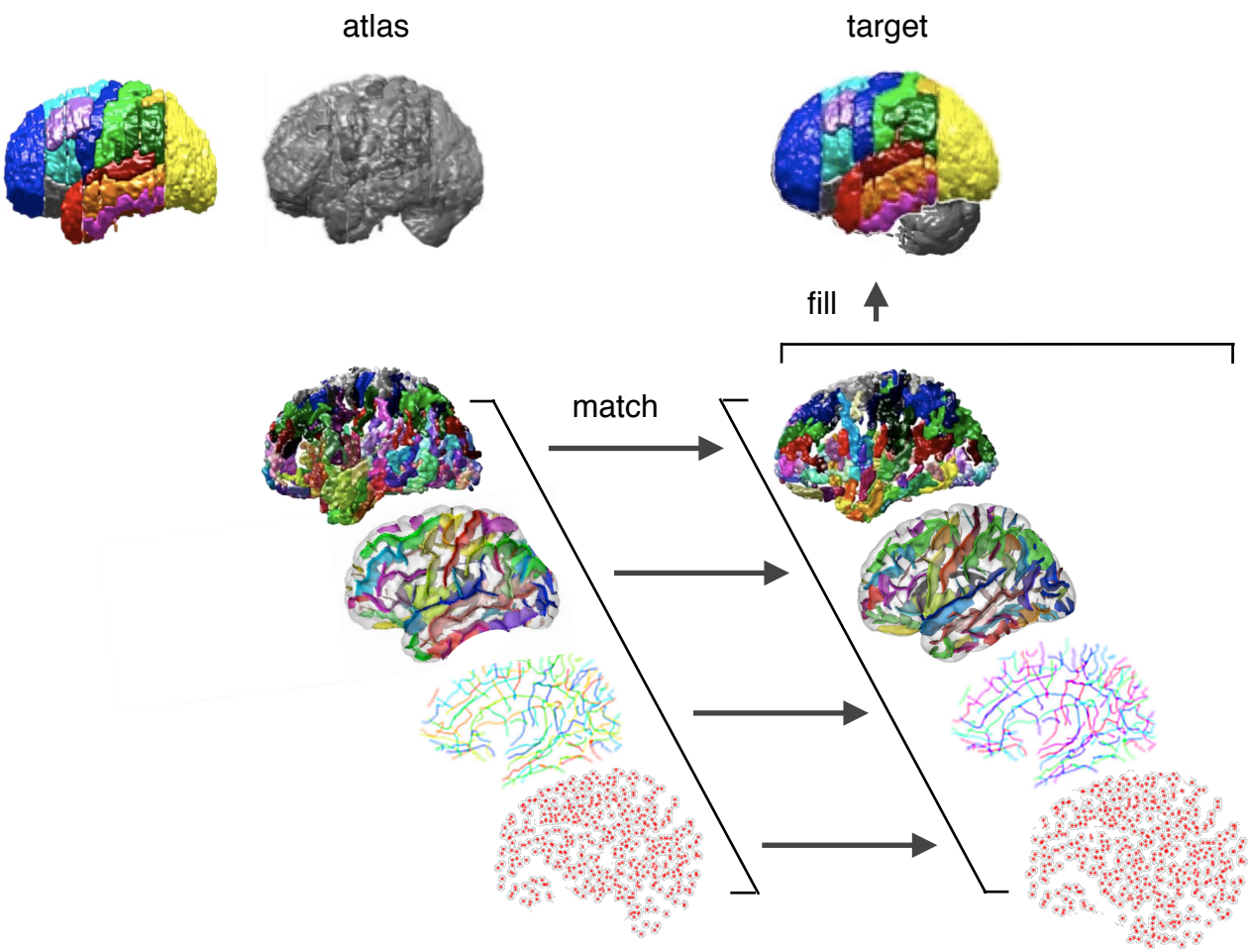
Mindboggle 2: feature-based labeling

Step 2: or match features...

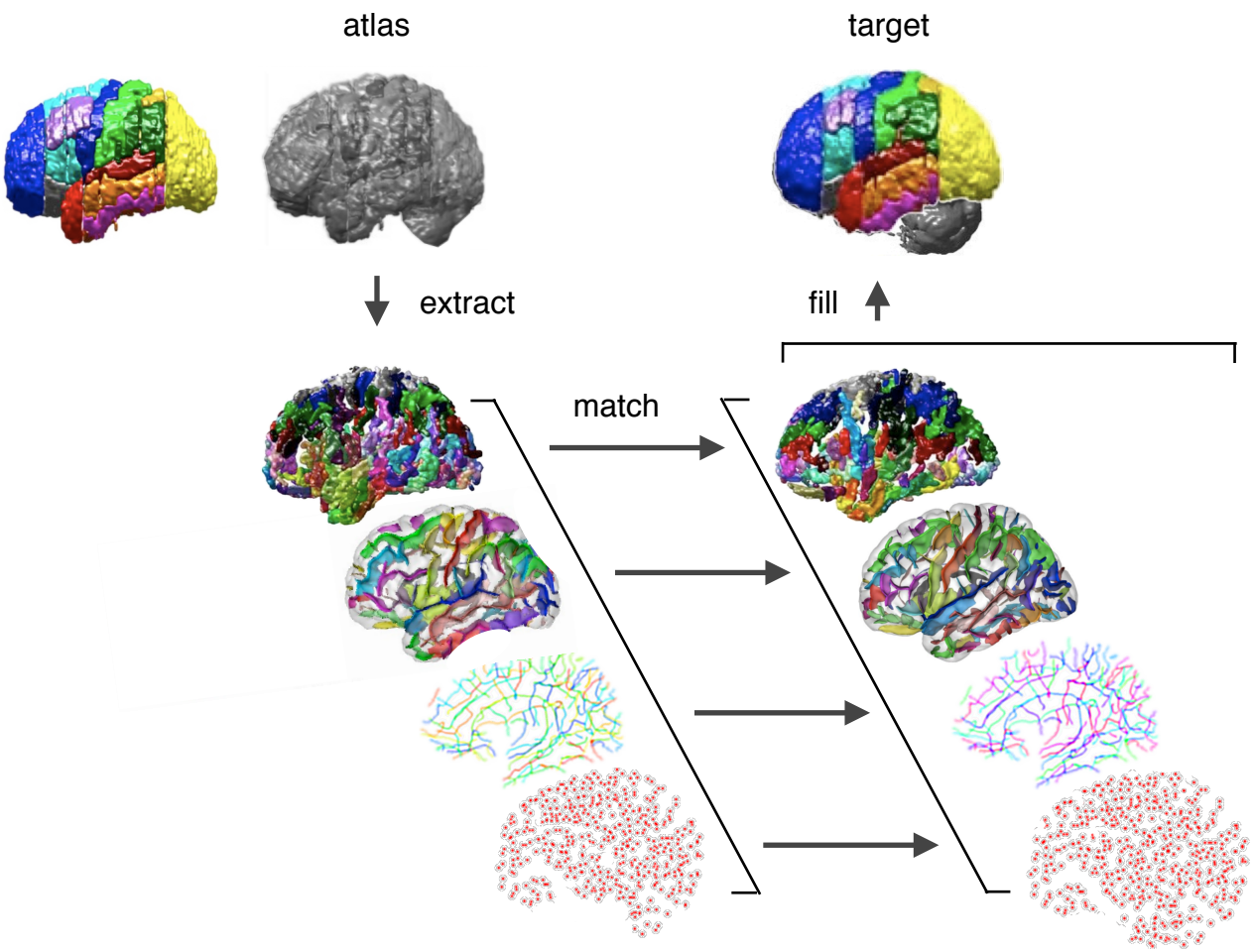


Mindboggle 2: feature-based labeling

Step 3: then propagate labels within inferred label boundaries



Mindboggle 2: feature extraction
feature matching
feature-based labeling



Feature matching

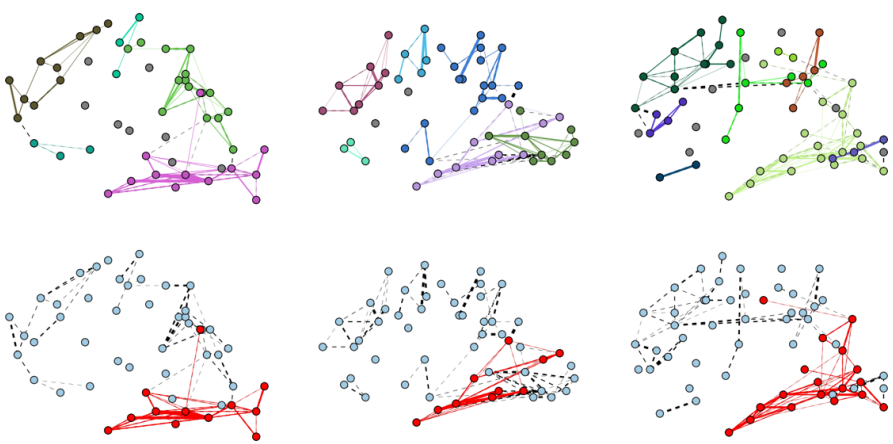
Matching strategies include:

1. MAP Bayesian framework used in face recognition (Moghaddam, 1999)

2. Graph matching:

- graph analysis measures (NetworkX, Brain Connectivity Toolbox)

- queries in the graph-based database (Neo4J)



Early attempt at subgraph extraction (upper row) and matching (lower row).
These graphs were constructed from (left to right) a remitter, non-remitter, and control subject.
The subgraphs in red in the lower row have the highest small-worldness ratio.

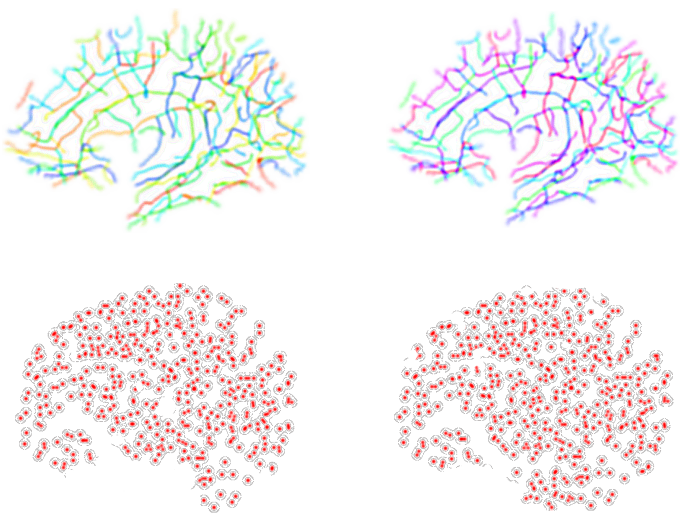
Evaluation of structures

TEST 1: Consistency across subjects:

Measure average distance between landmarks in one subject and landmarks in another co-registered subject

Result: very similar results across 3 fundus extraction algorithms

Problem: bias in favor of greater number of voxels



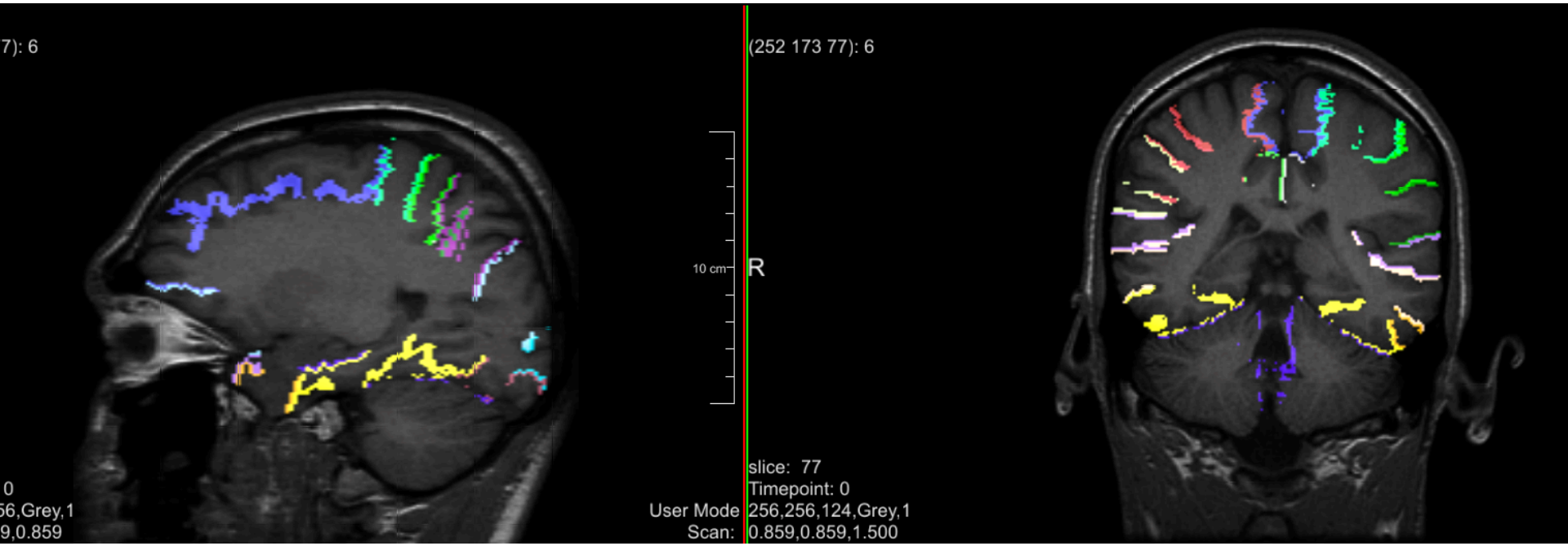
Evaluation of structures

TEST 2: Consistency between structures and label boundaries:

Measure average distance between landmarks and label borders

Result: very similar results across 3 fundus extraction algorithms

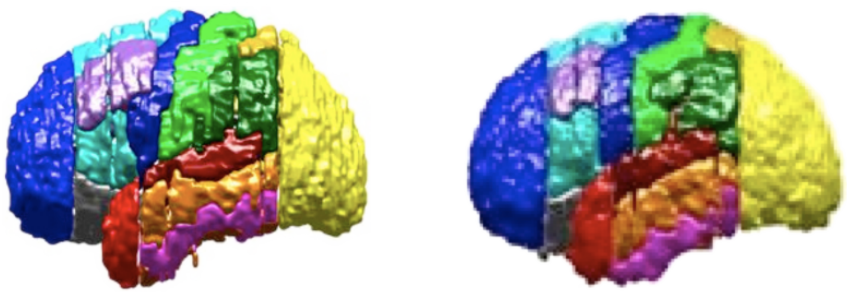
Problem: bias against fundi in lesser folds, where there may not be label borders



Evaluation of structures

TEST 3: Impact of registration accuracy:
Measure overlap between manual target labels and landmark-driven manual source labels

Results: Preliminary results suggest that fundus-driven registrations improve registration accuracy, but results between algorithms are very similar to one another.

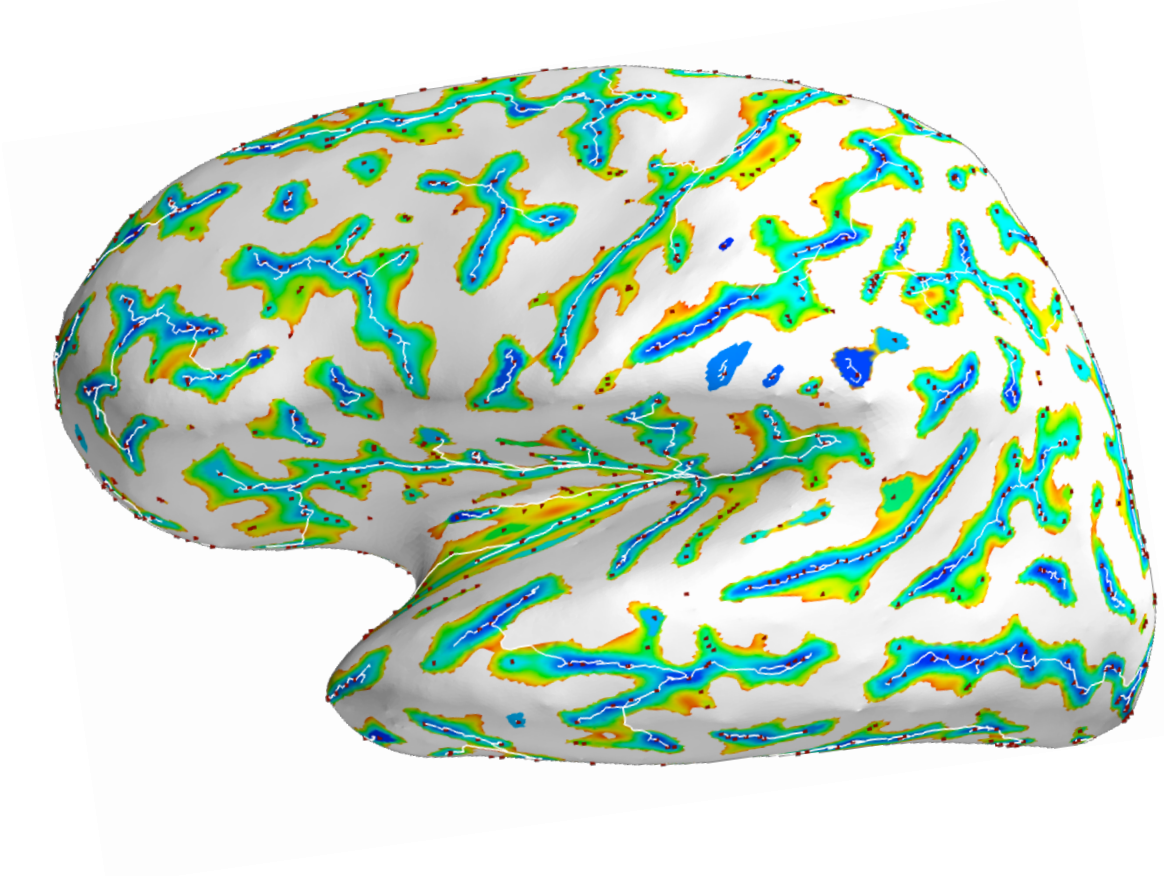


Evaluation of structures

TEST 4: Consistency between different types of structures:

Measure average minimum distance from pits to fundi

Results: Mindboggle pits used to generate fundi, so clearly the winner



Forrest Bao
graduate student (Texas Tech)
Anatomical feature extraction

Noah Lee
postdoctoral research scientist
Graph-based feature database

Yrjö Häme
graduate student
Feature matching

Denis Peruzzo
former postdoc
Feature graph matching

Mireia Montañola
visiting graduate student <u>as of today!</u>
Surface wrangling

Brian Avants
assistant professor (UPenn)
Diffeomorphic registration