Brain labeling, feature identification and shape analysis

Works in Progress
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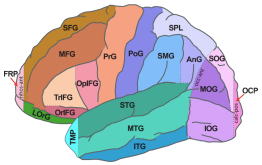
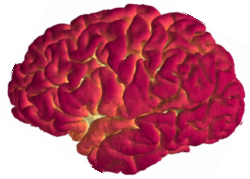
www.mindboggle.info
asst. professor of clinical neurobiology
columbia university

Mindboggle 3-year R01

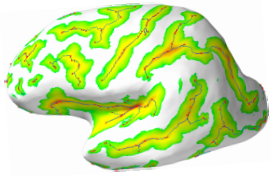


101 manually labeled brain atlases and morphometry database

Mindboggle software:



- shape analysis



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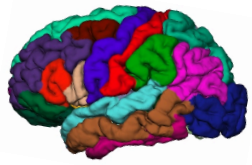
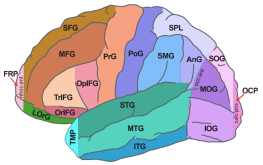
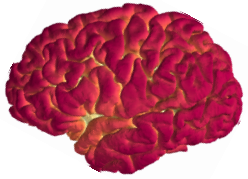


- automated labeling



manual

Mindboggle



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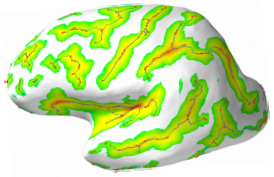

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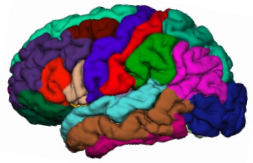

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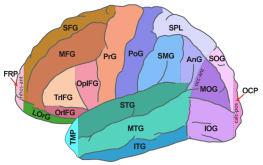

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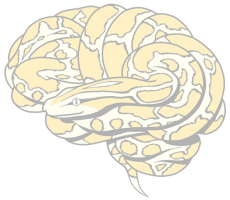

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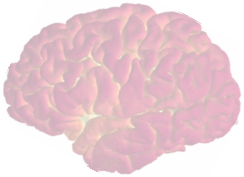
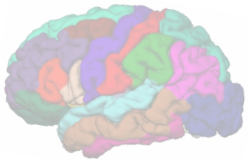


morphometry

features



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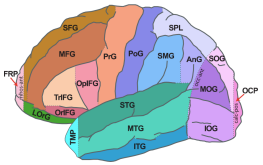

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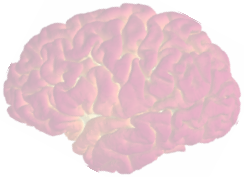

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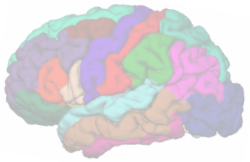

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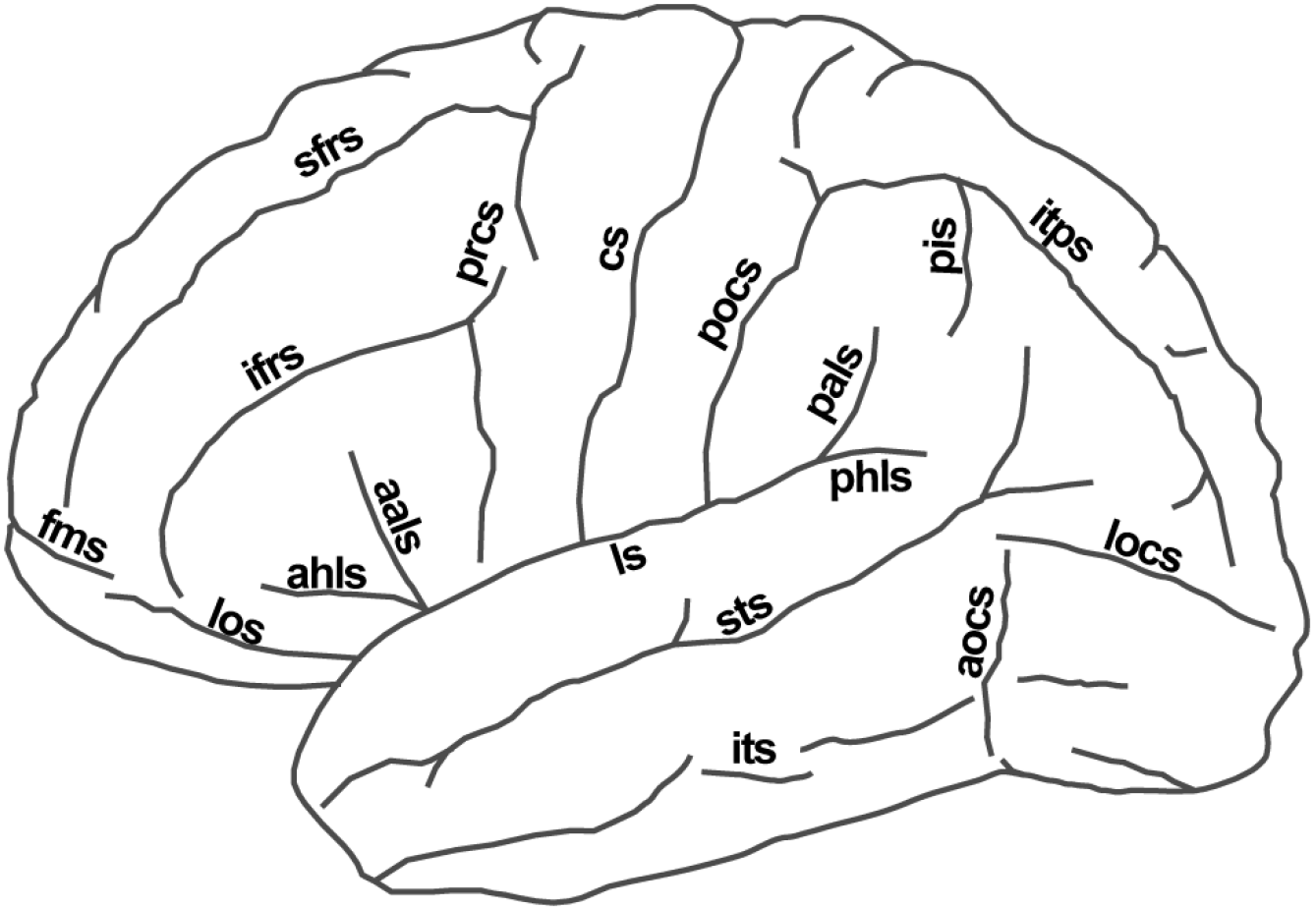
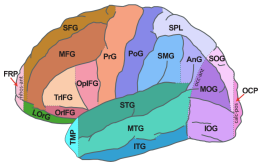


Sulcus definitions



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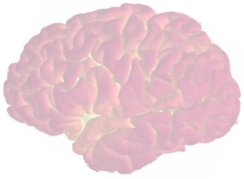
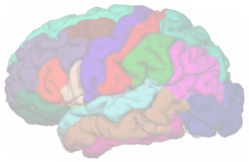


morphometry

features



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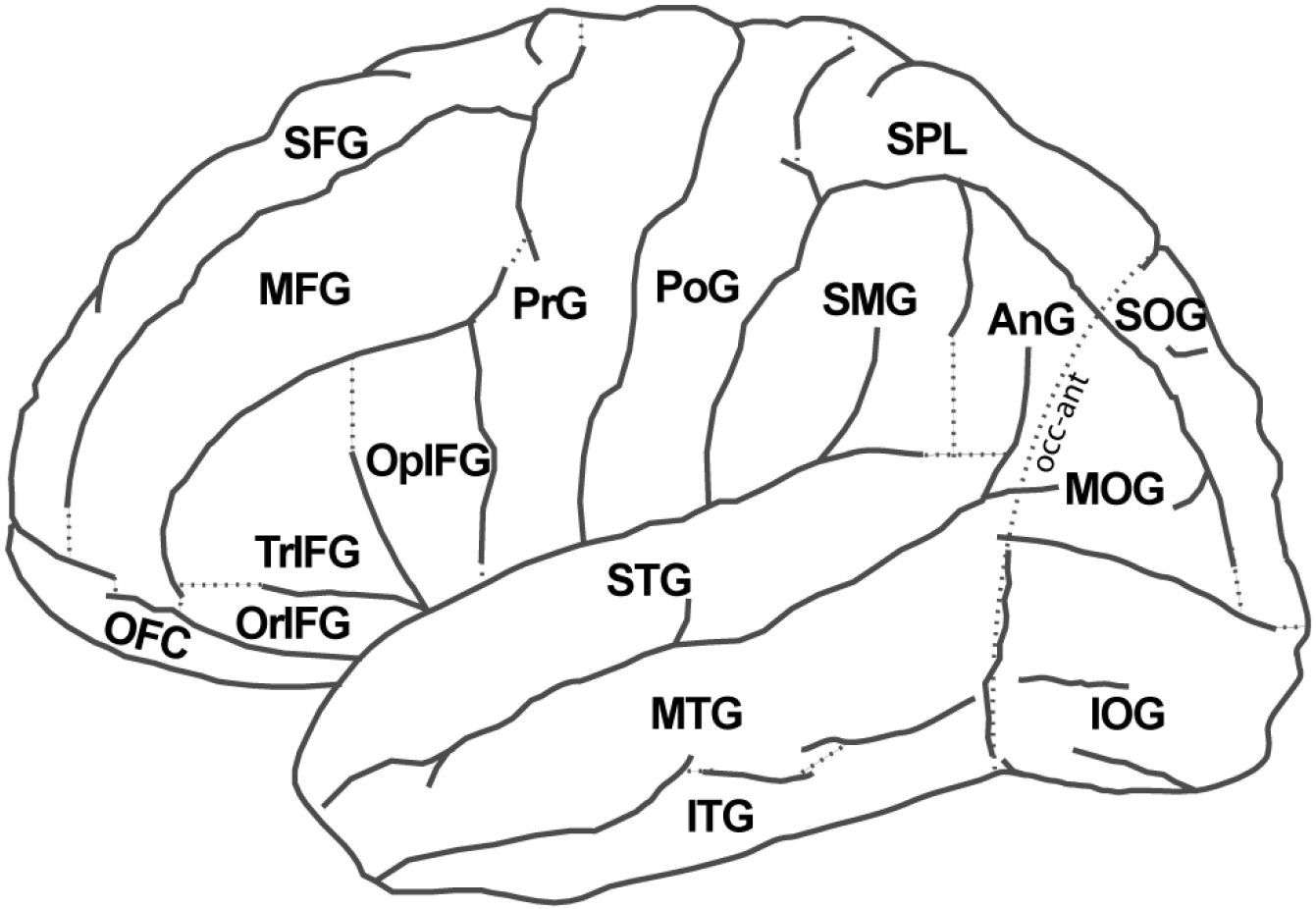
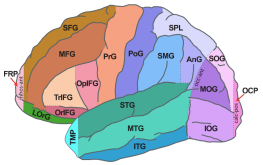


Gyrus definitions



manual

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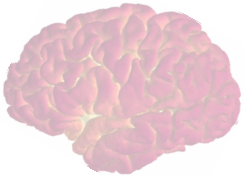
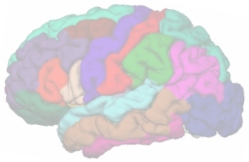


morphometry

features



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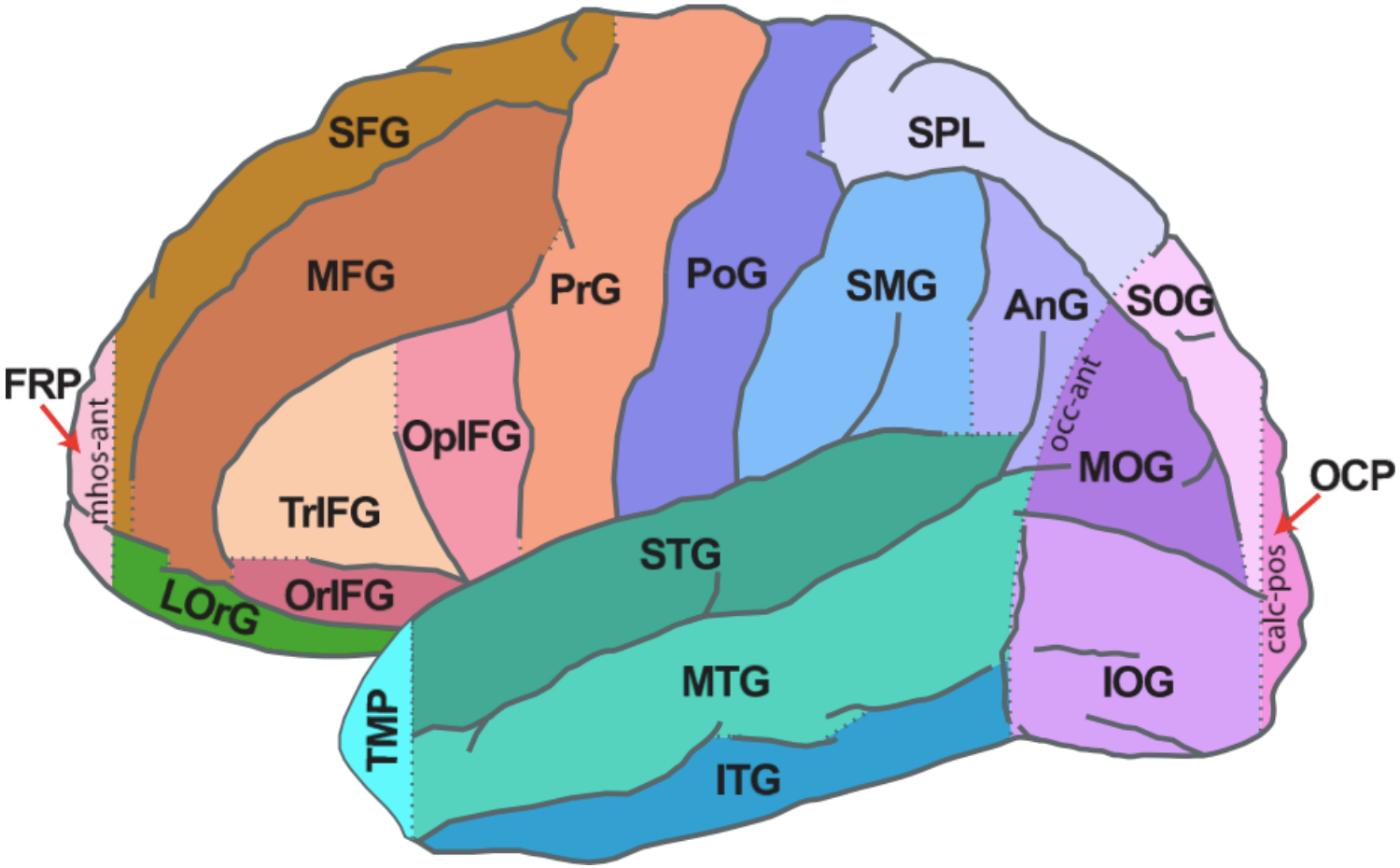

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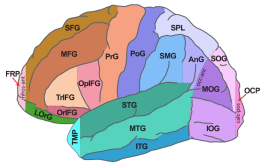

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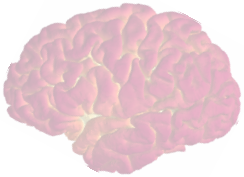

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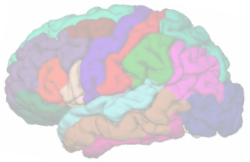

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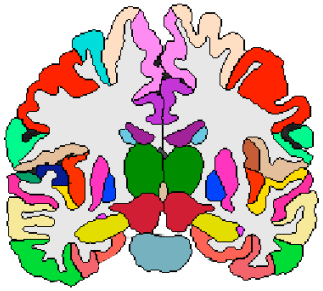
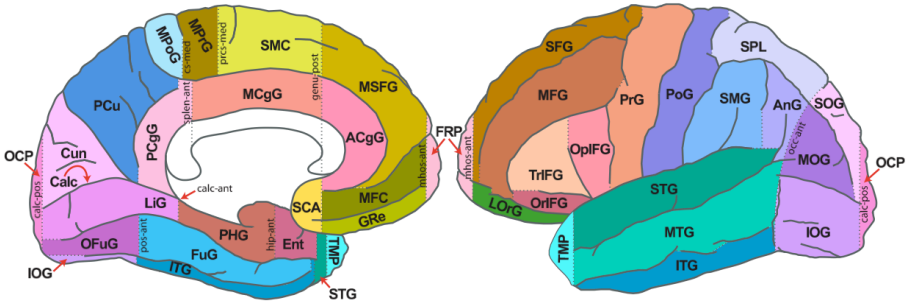
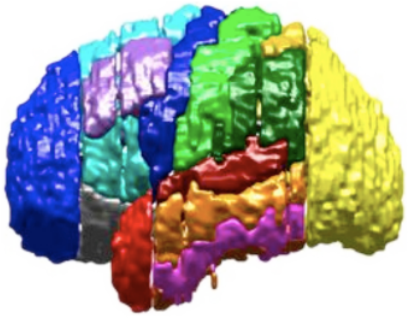
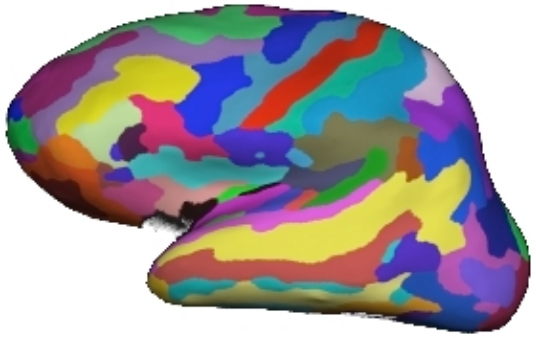
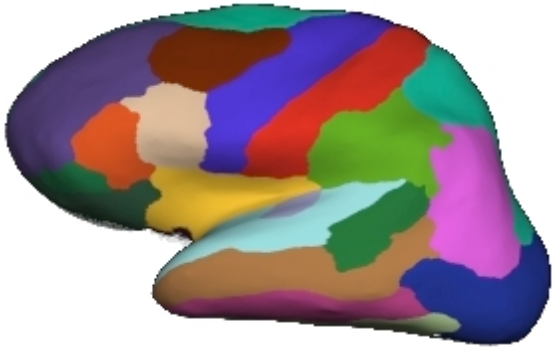
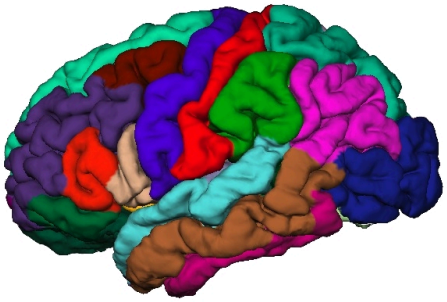




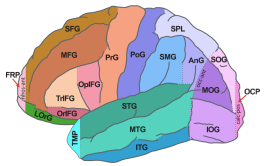






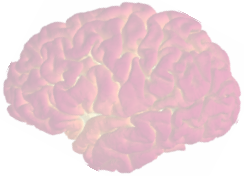


Volume and surface label definitions



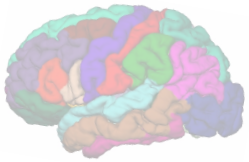
manual

Mindboggle



morphometry

features



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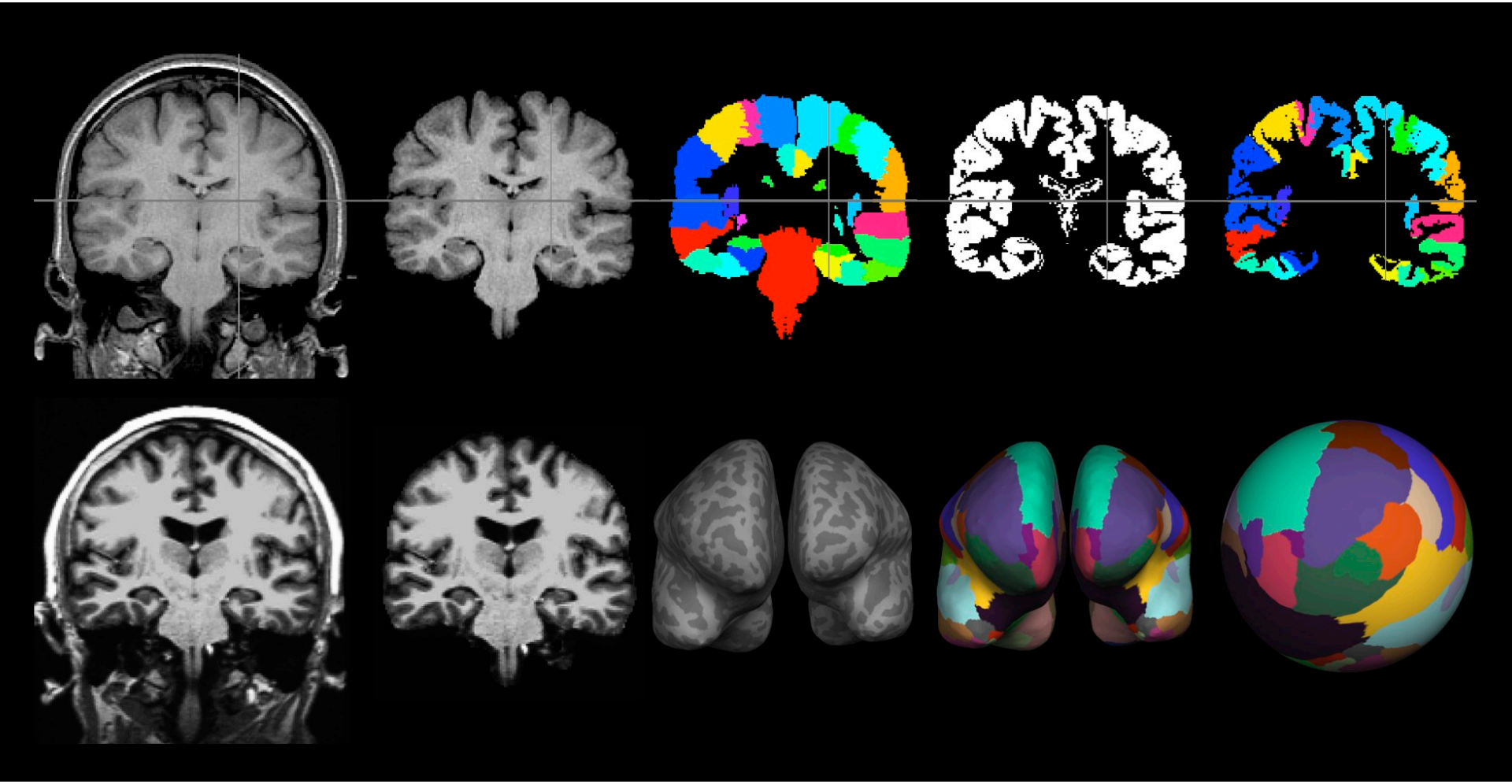
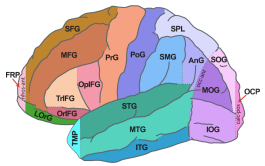


Volume and surface label definitions



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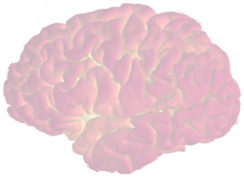

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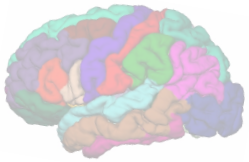

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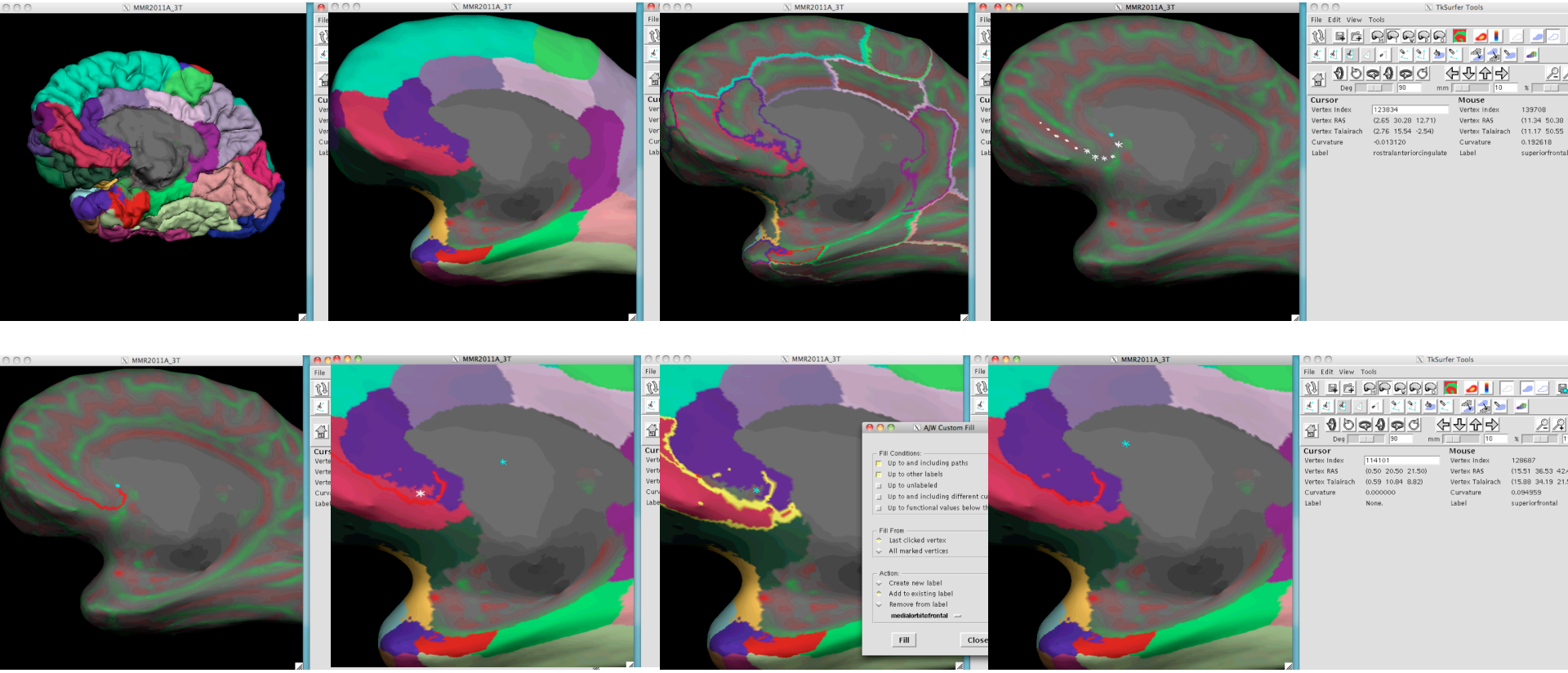
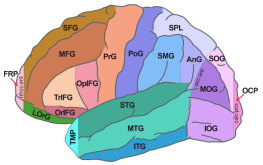
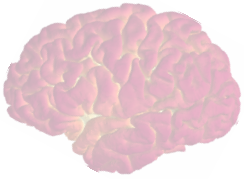


Manual editing of cortical surface labels



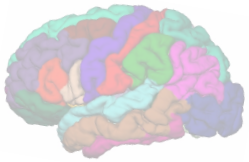
manual

Mindboggle



morphometry

features



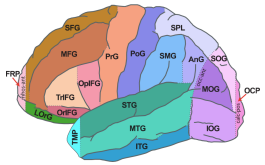
labels

Data sets comprising the Mindboggle-101 labeled data set

Name	Source	N	Age (mean, SD)	Gender		Hand	
				M	F	R	L
NKI-RS-22	"Nathan Kline Institute / Rockland Sample"	22	20-40 (26.0, 5.2)	12	10	21	1
NKI-TRT-24	"Nathan Kline Institute / Test-Retest"	24	21-60 (34.4, 12.6)	18	6	19*	3*
MMRR-21	"Multi-Modal MRI Reproducibility Resource"	21	22-61 (31,8, 9.2)	11	10	18	1
MMRR-3T7T-2	2 3T/7T subjects acquired after the MMRR-21 subjects	2	22, 24	2	0	2	0
HLN-12	"Human Language Network" study subjects	12	23-39 (27.8, 4.6)	6	6	12	0
OASIS-TRT-20	"Open Access Series of Imaging Studies" test-retest ("reliability") sample	20	19-34 (23.4, 3.9)	8	12	20	0

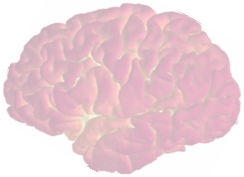
NKI-RS-22	http://fcon_1000.projects.nitrc.org/indi/pro/nki.html
NKI-TRT-24	http://fcon_1000.projects.nitrc.org/indi/pro/eNKI_RS_TRT/FrontPage.html
MMRR-21	http://www.nitrc.org/projects/multimodal
MMRR-3T7T-2	http://www.nitrc.org/projects/multimodal
HLN-12	https://masi.vuse.vanderbilt.edu/public/plos12.tar.bz2
OASIS-TRT-20	http://www.oasis-brains.org/app/action/BundleAction/bundle/OAS1_RELIABILITY

*(2 ambidextrous)



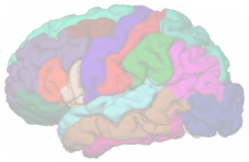
manual

Mindboggle



morphometry

features



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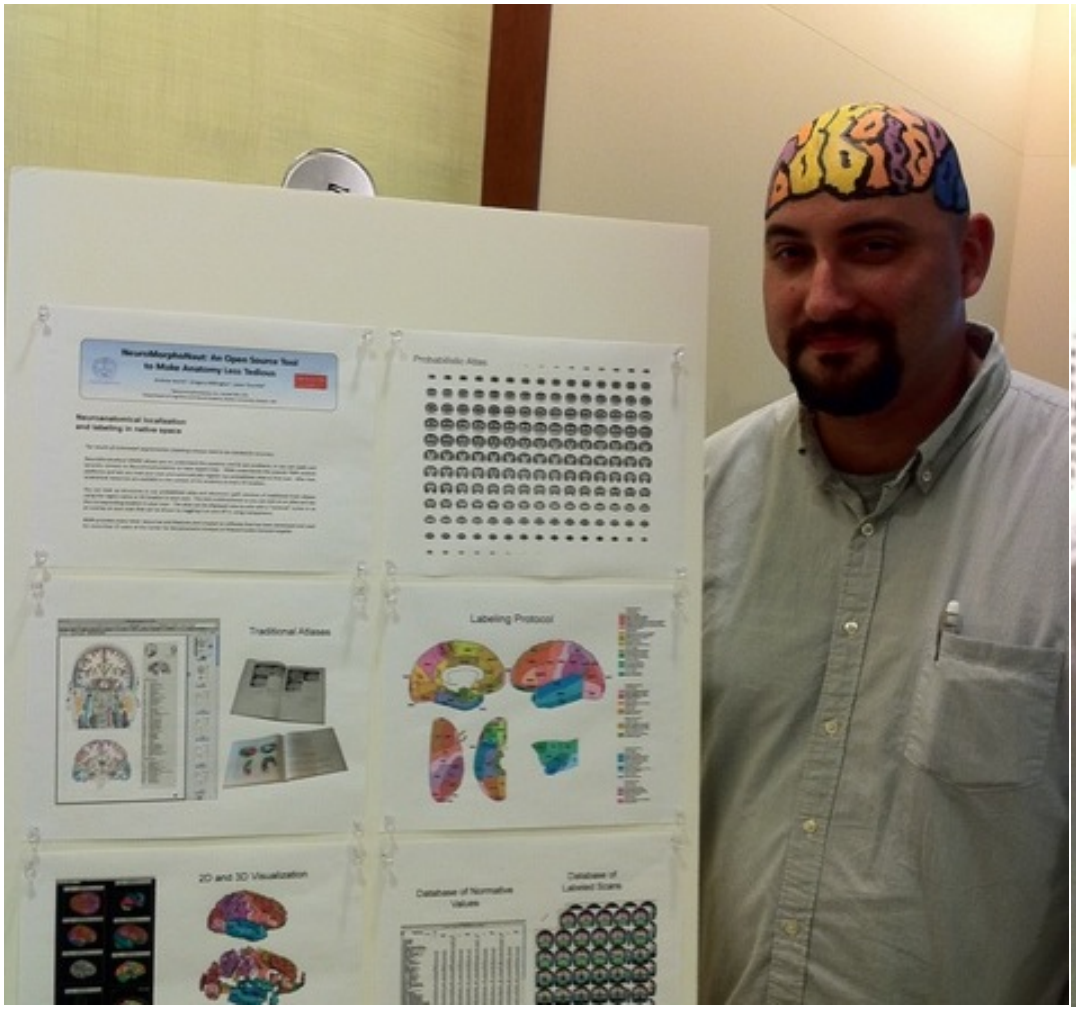
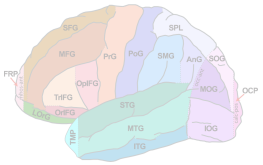
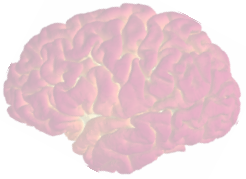


Greg Millington
Neuromorphometrics



manual

Mindboggle



morphometry

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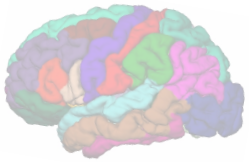
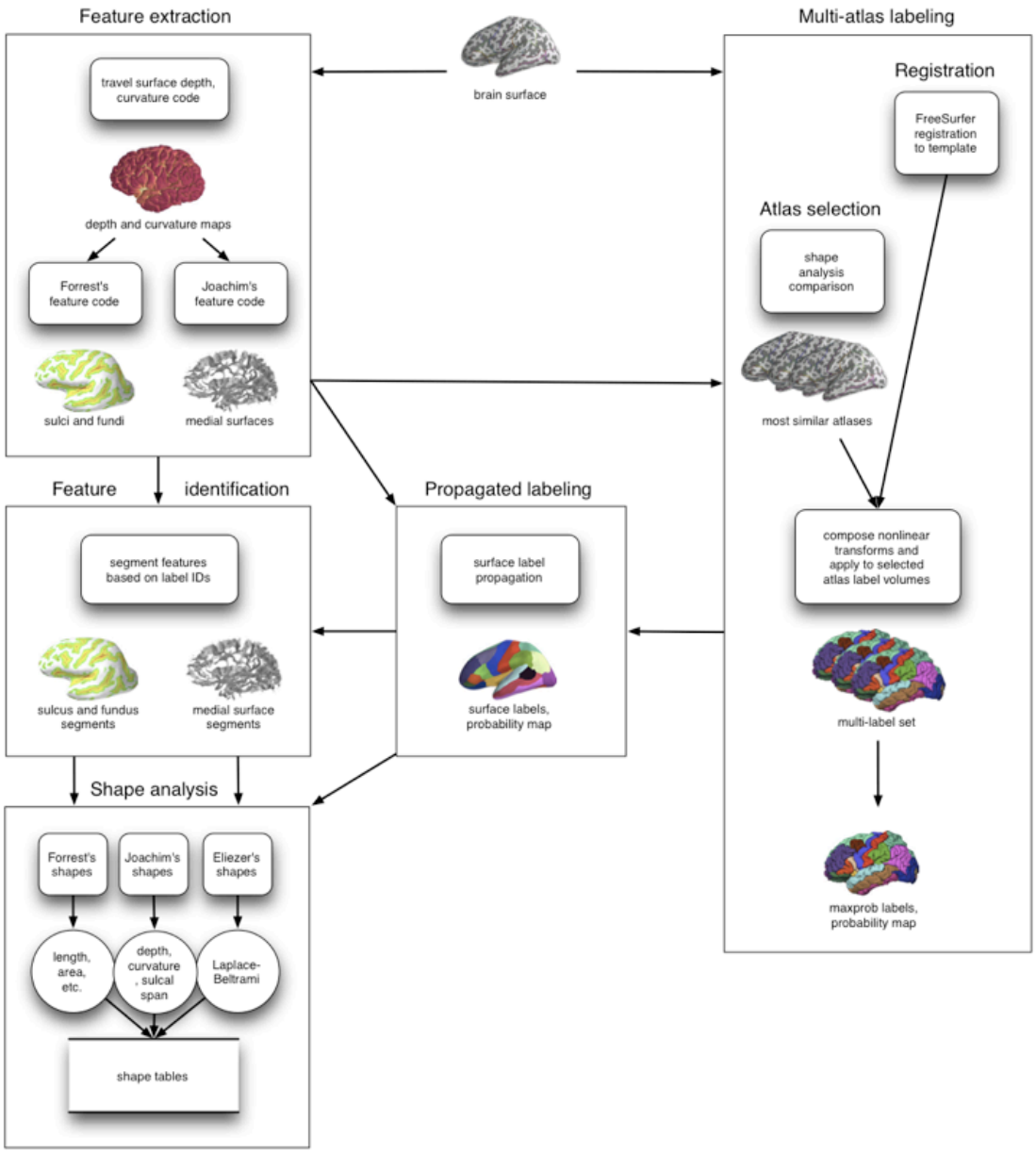


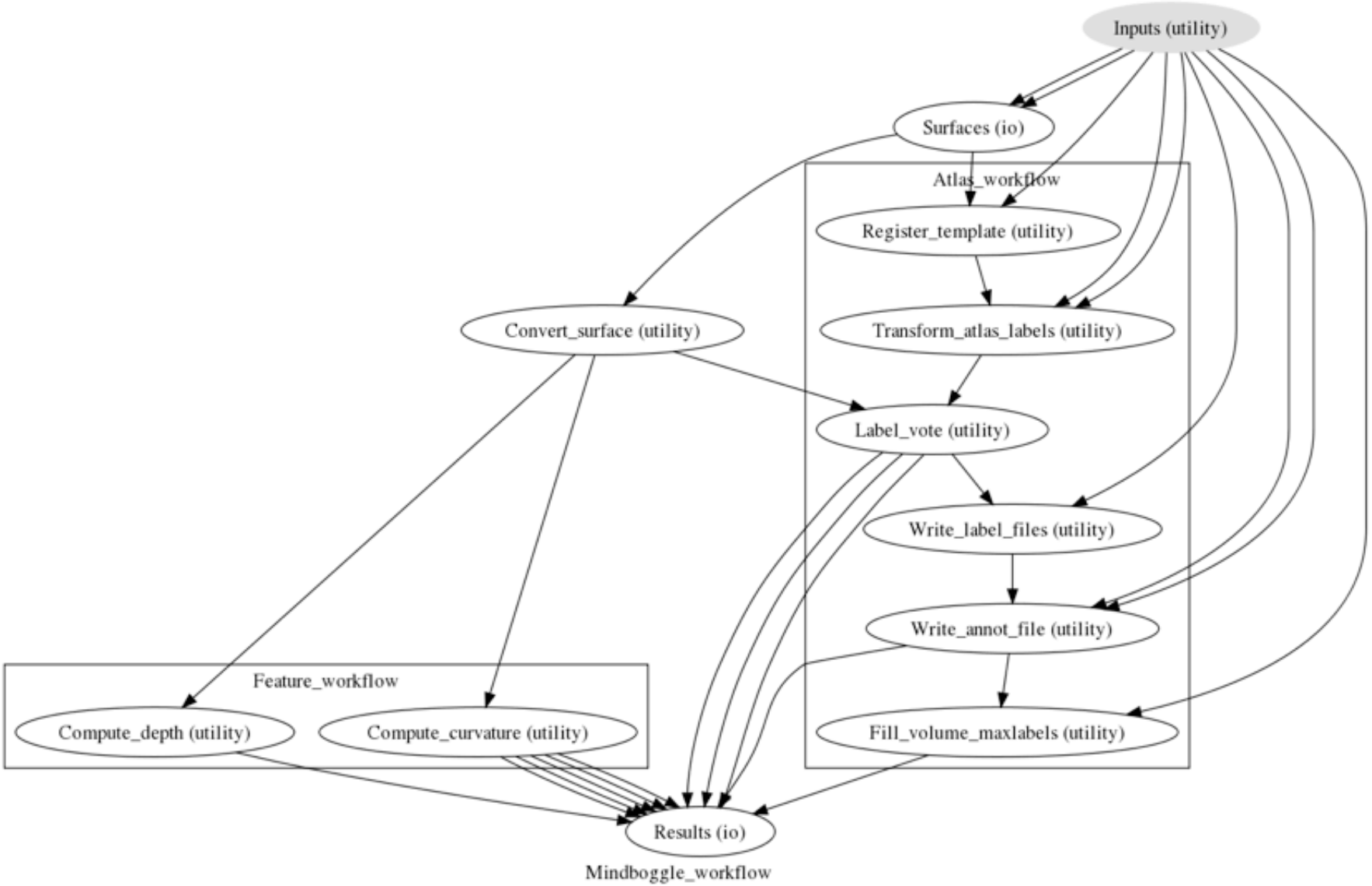
labels

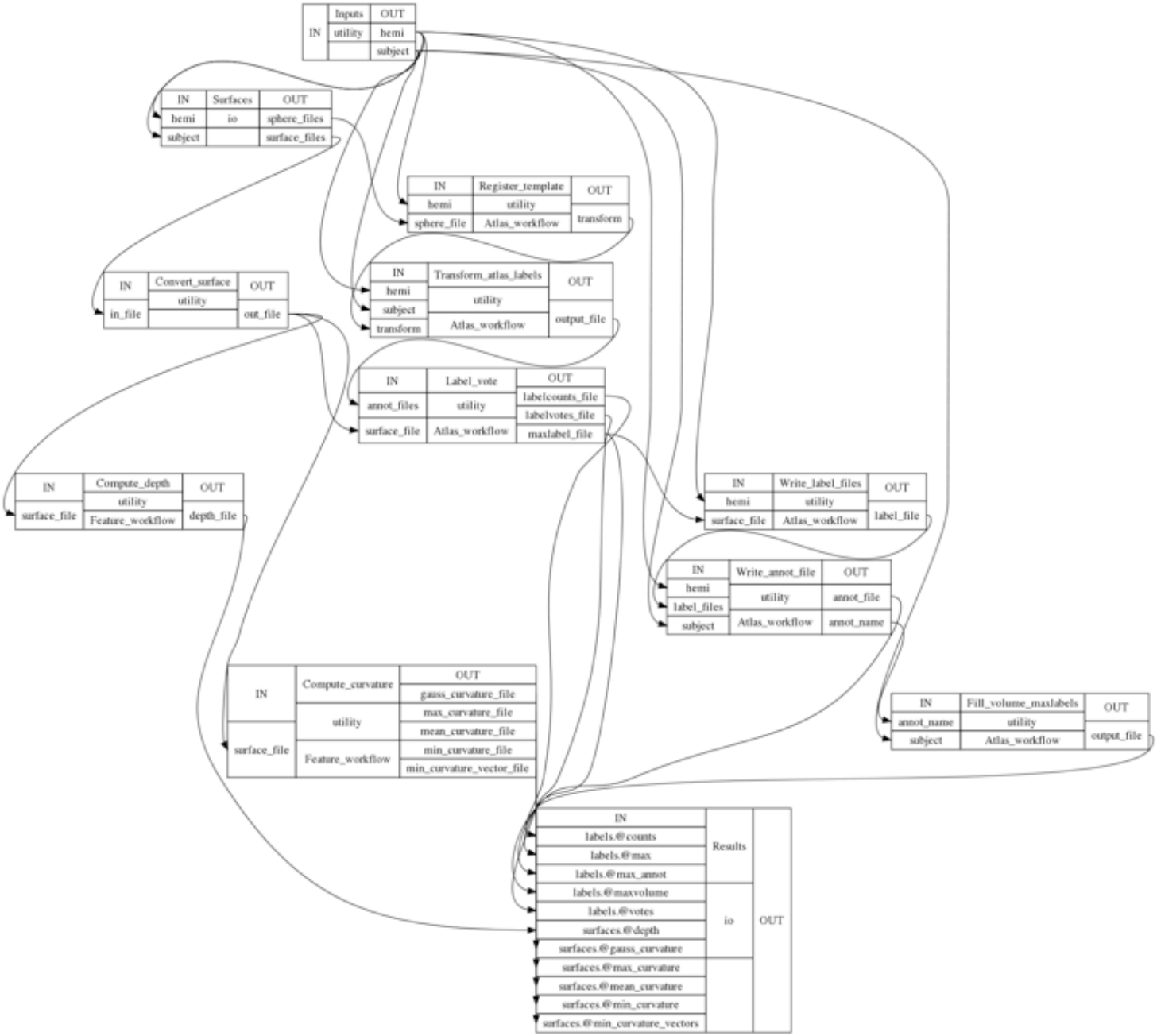
Mindboggle software:

- Python and Python-wrapped C++
- Open source, freely available
- Software pipeline framework
- Upload to a server for processing brain images?

Mindboggle


Feature extraction
travel surface depth, curvature code
depth and curvature maps
Forrest's feature code
Joachim's feature code
sulci and fundi
medial surfaces
brain surface
Multi-atlas labeling
Registration
FreeSurfer registration to template
Atlas selection
shape analysis comparison
most similar atlases
compose nonlinear transforms and apply to selected atlas label volumes
multi-label set
maxprob labels, probability map
Feature identification
segment features based on label IDs
sulcus and fundus segments
medial surface segments
Propagated labeling
surface label propagation
surface labels, probability map
Shape analysis
Forrest's shapes
Joachim's shapes
Eliezer's shapes
length, area, etc.
depth, curvature , sulcal span
Laplace-Beltrami
shape tables


Inputs (utility)
Surfaces (io)
Atlas_workflow
Register_template (utility)
Convert_surface (utility)
Transform_atlas_labels (utility)
Label_vote (utility)
Write_label_files (utility)
Write_annot_file (utility)
Feature_workflow
Compute_depth (utility)
Compute_curvature (utility)
Fill_volume_maxlabels (utility)
Results (io)
Mindboggle_workflow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Surfaces
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surface_files
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Register_template
utility
Atlas_workflow
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transform
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Convert_surface
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out_file
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Transform_atlas_labels
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output_file
hemi
subject
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IN
Label_vote
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Atlas_workflow
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annot_files
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Atlas_workflow
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Results
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OUT
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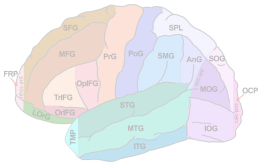
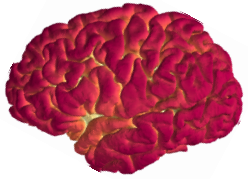


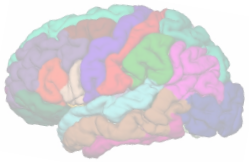
manual

Mindboggle



morphometry

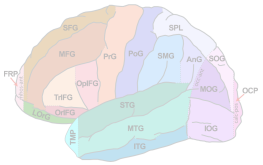
features



labels

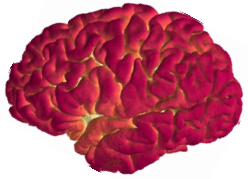
Mindboggle software:

- Morphometry

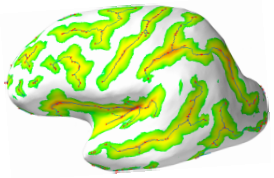


manual

Mindboggle



morphometry



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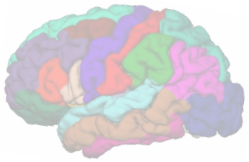
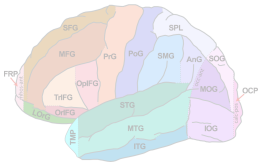


labels

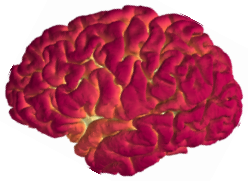
Mindboggle software:

- Morphometry
- Feature extraction and identification

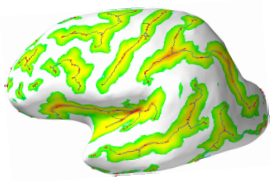


manual

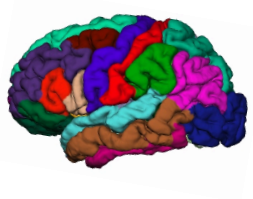
Mindboggle



morphometry



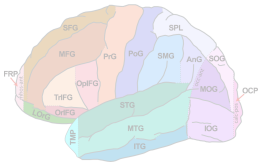
features



labels

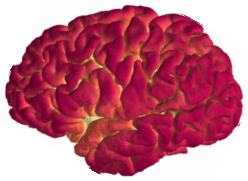
Mindboggle software:

- Morphometry
- Feature extraction and identification
- Labeling



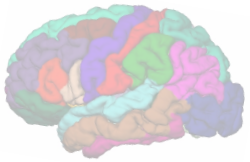
manual

Mindboggle



morphometry

features



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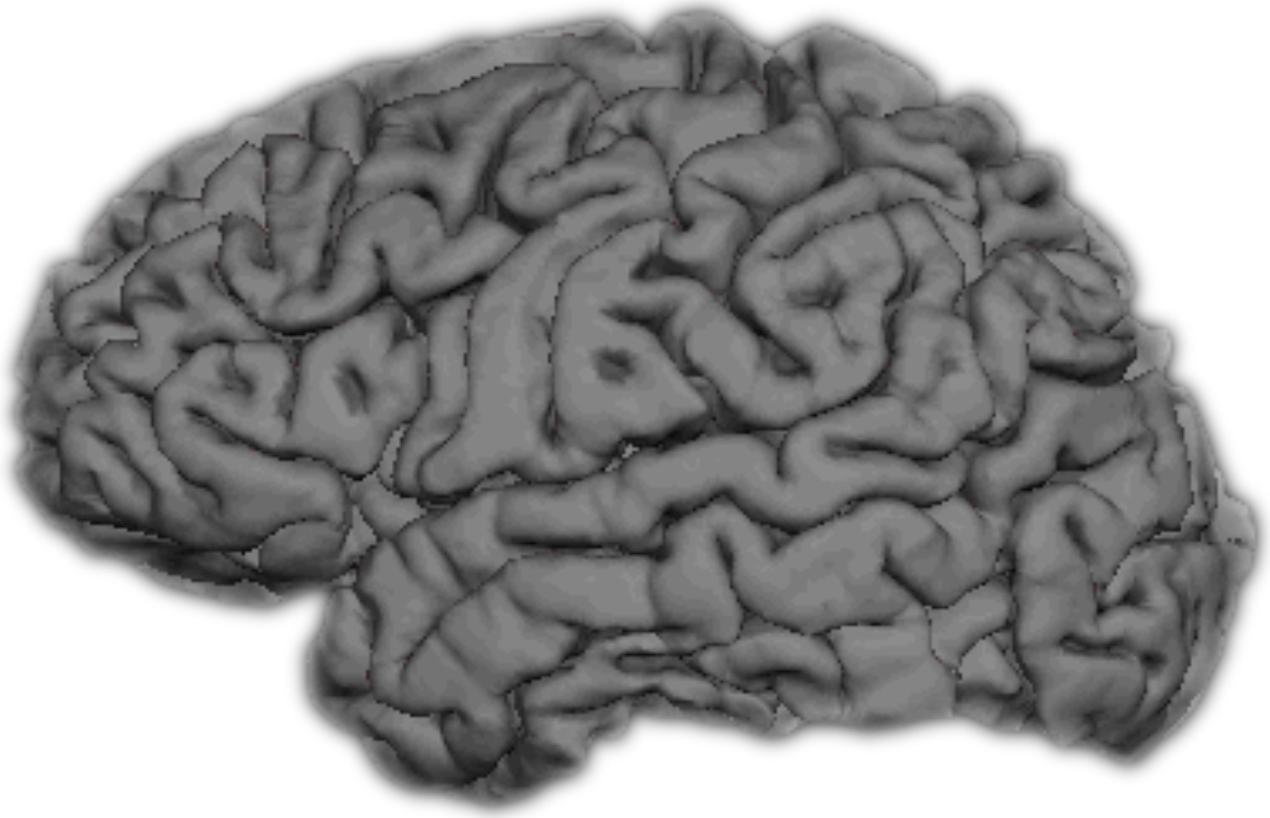
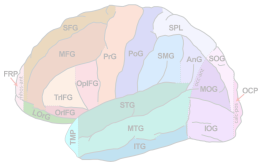
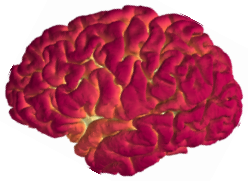




manual

Mindboggle



morphometry

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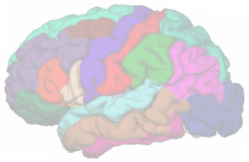

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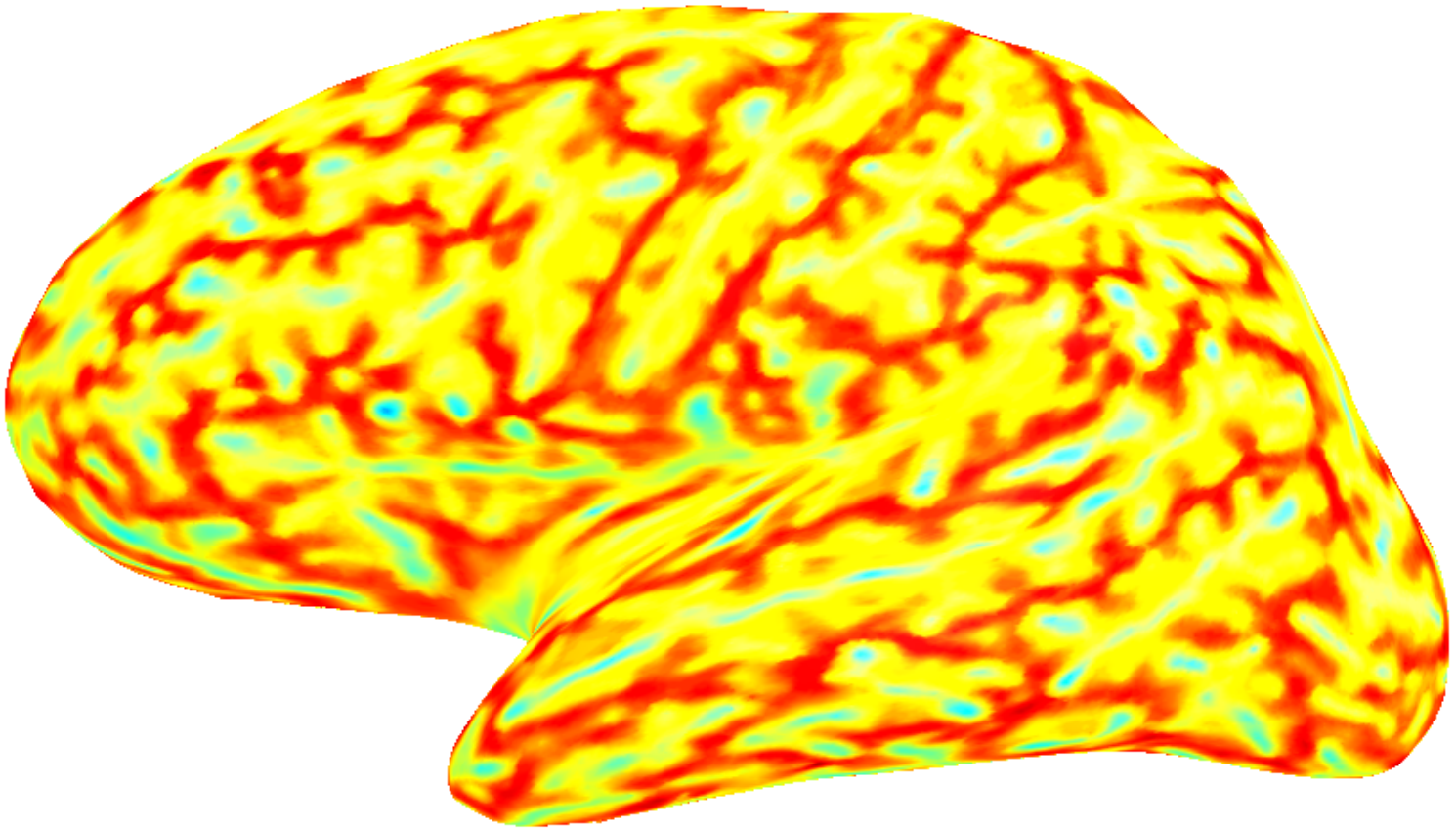
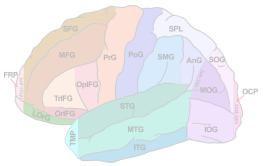
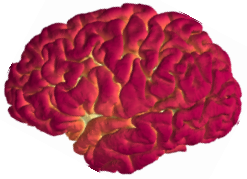


Mean curvature (inflated surface)



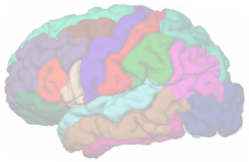
manual

Mindboggle



morphometry

features



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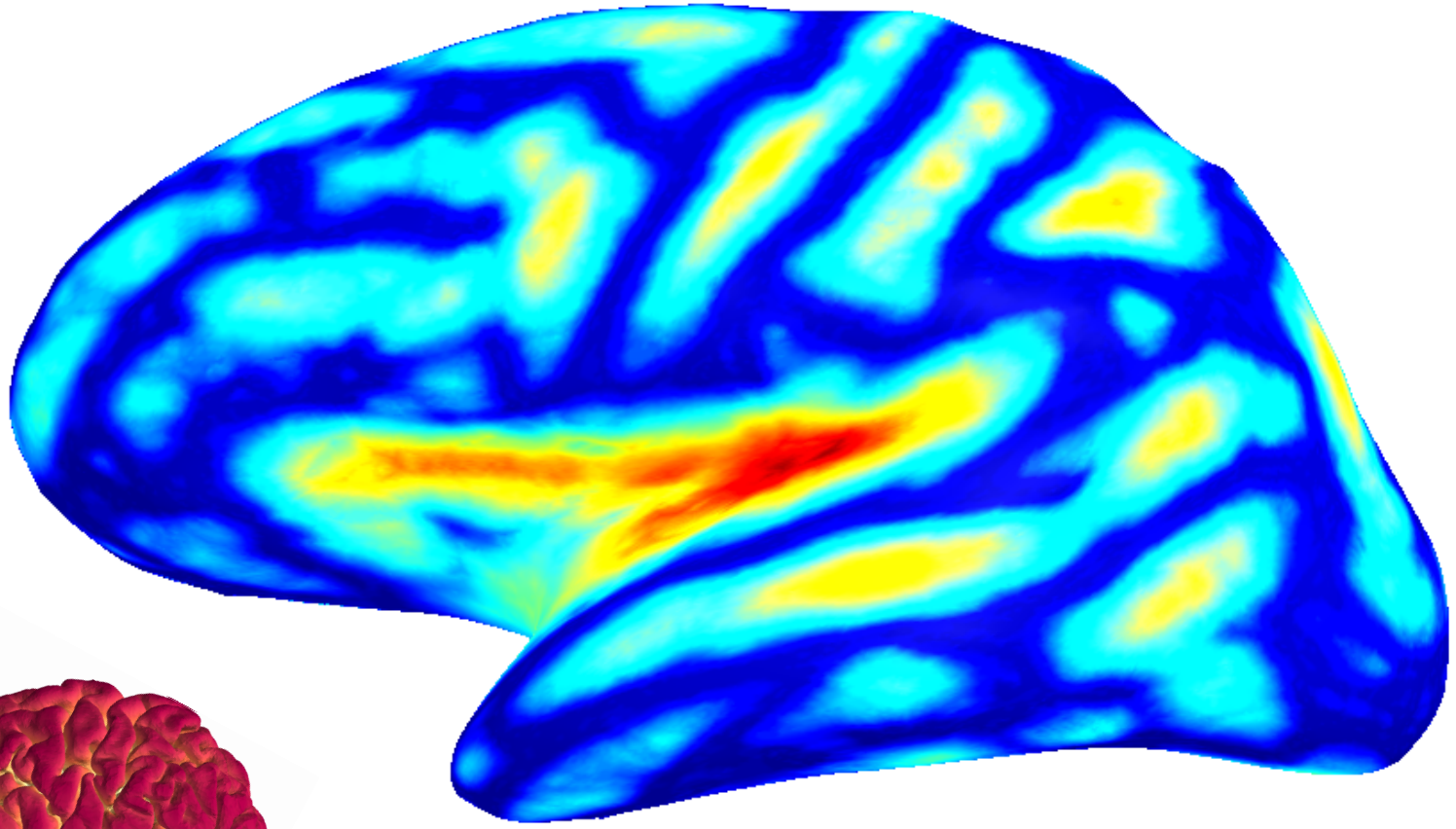
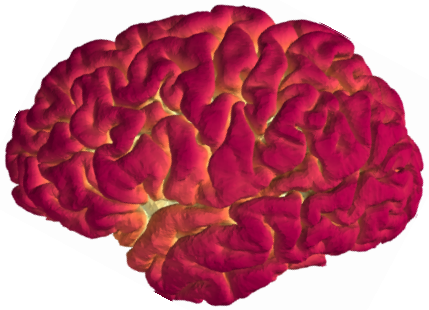
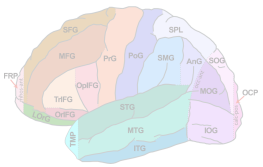


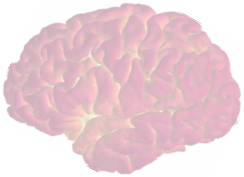


Depth

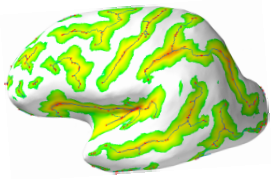


manual

Mindboggle



morphometry



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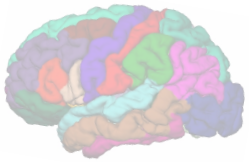

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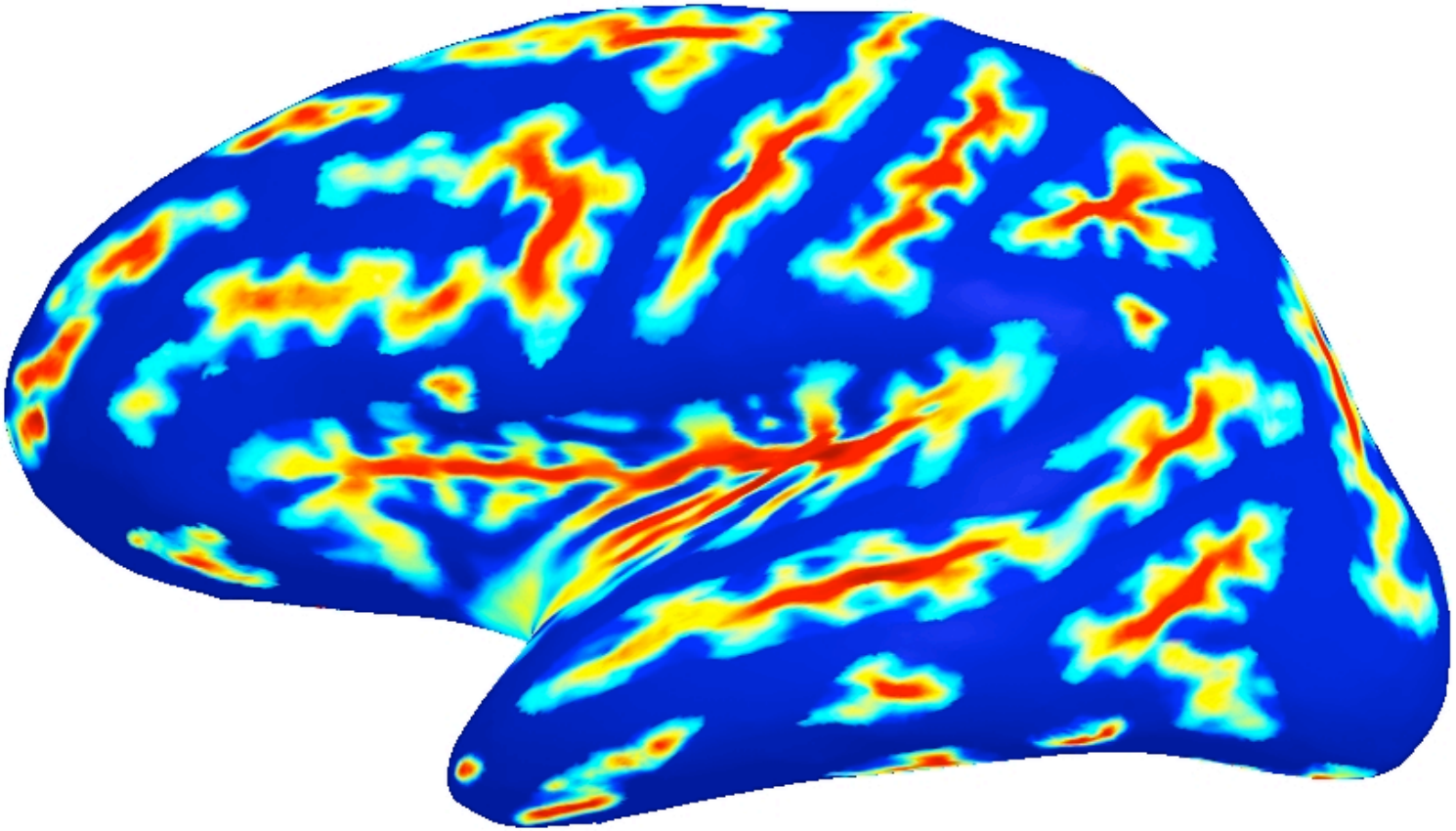
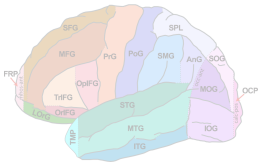
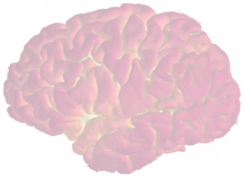


Fundus curves (HMMF)

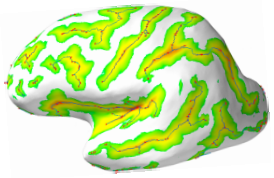


manual

Mindboggle



morphometry



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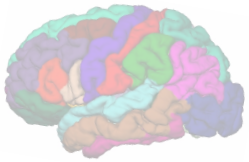

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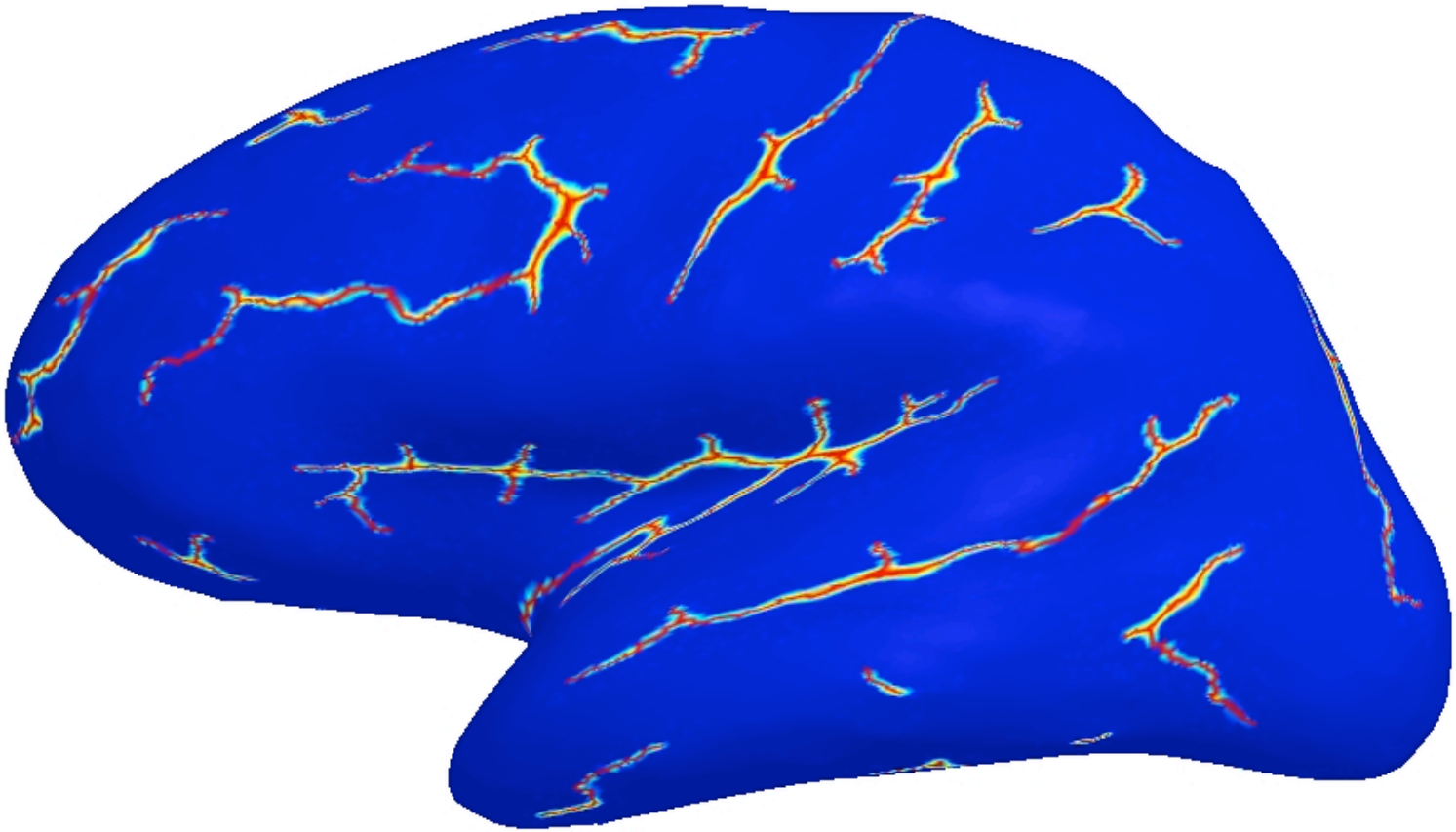
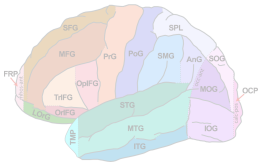
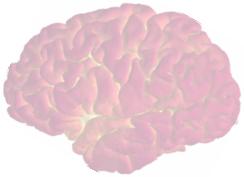


Fundus curves (HMMF)

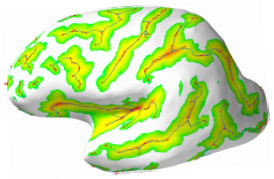


manual

Mindboggle



morphometry



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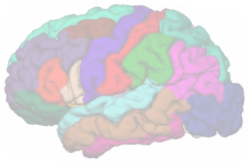

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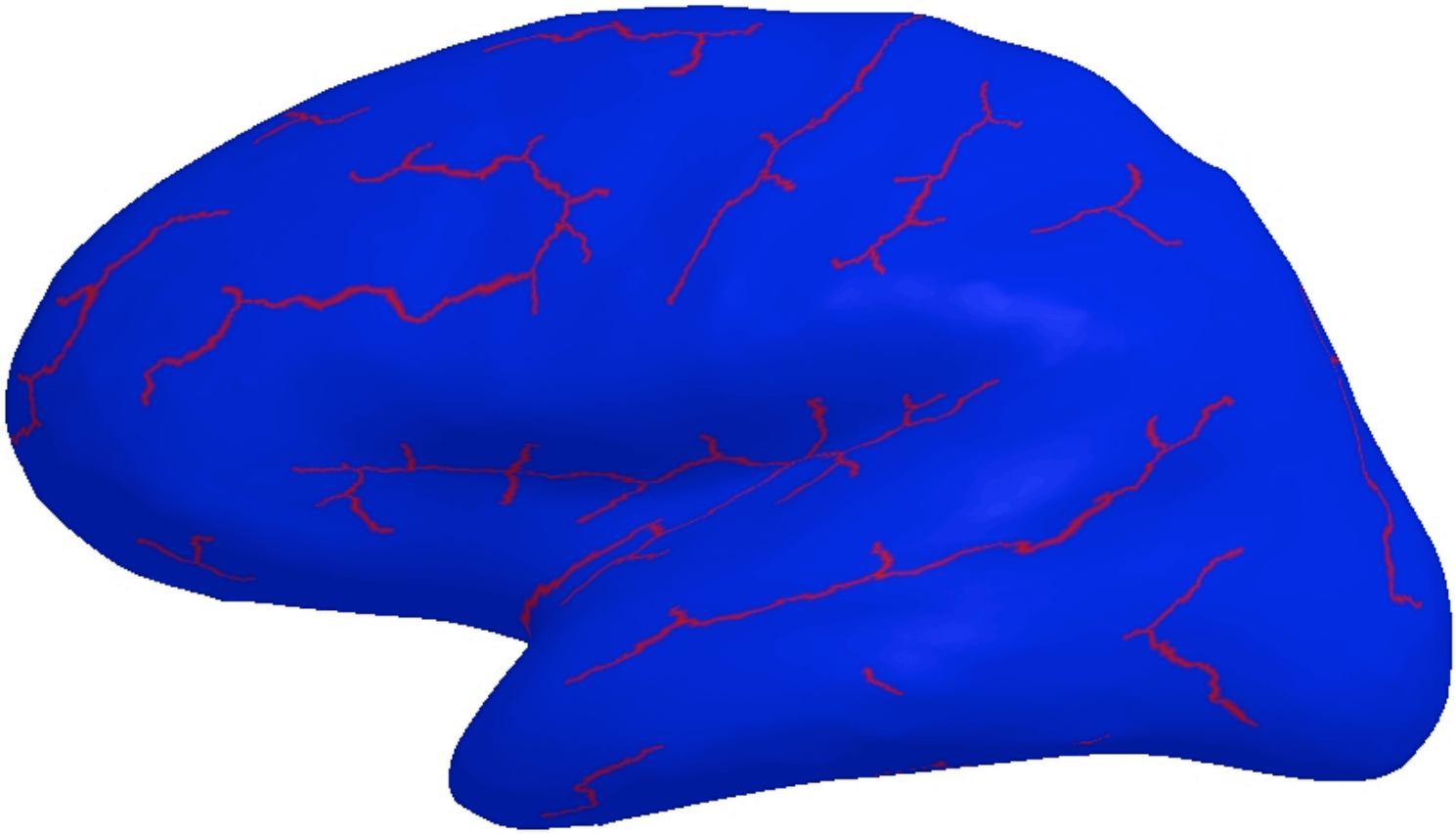
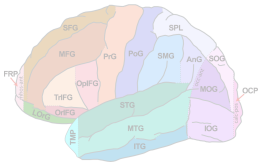
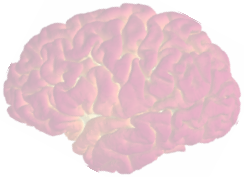


Fundus curves (HMMF)

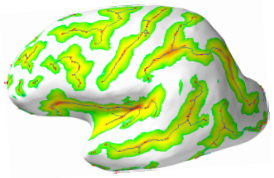


manual

Mindboggle



morphometry



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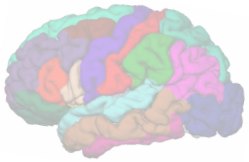

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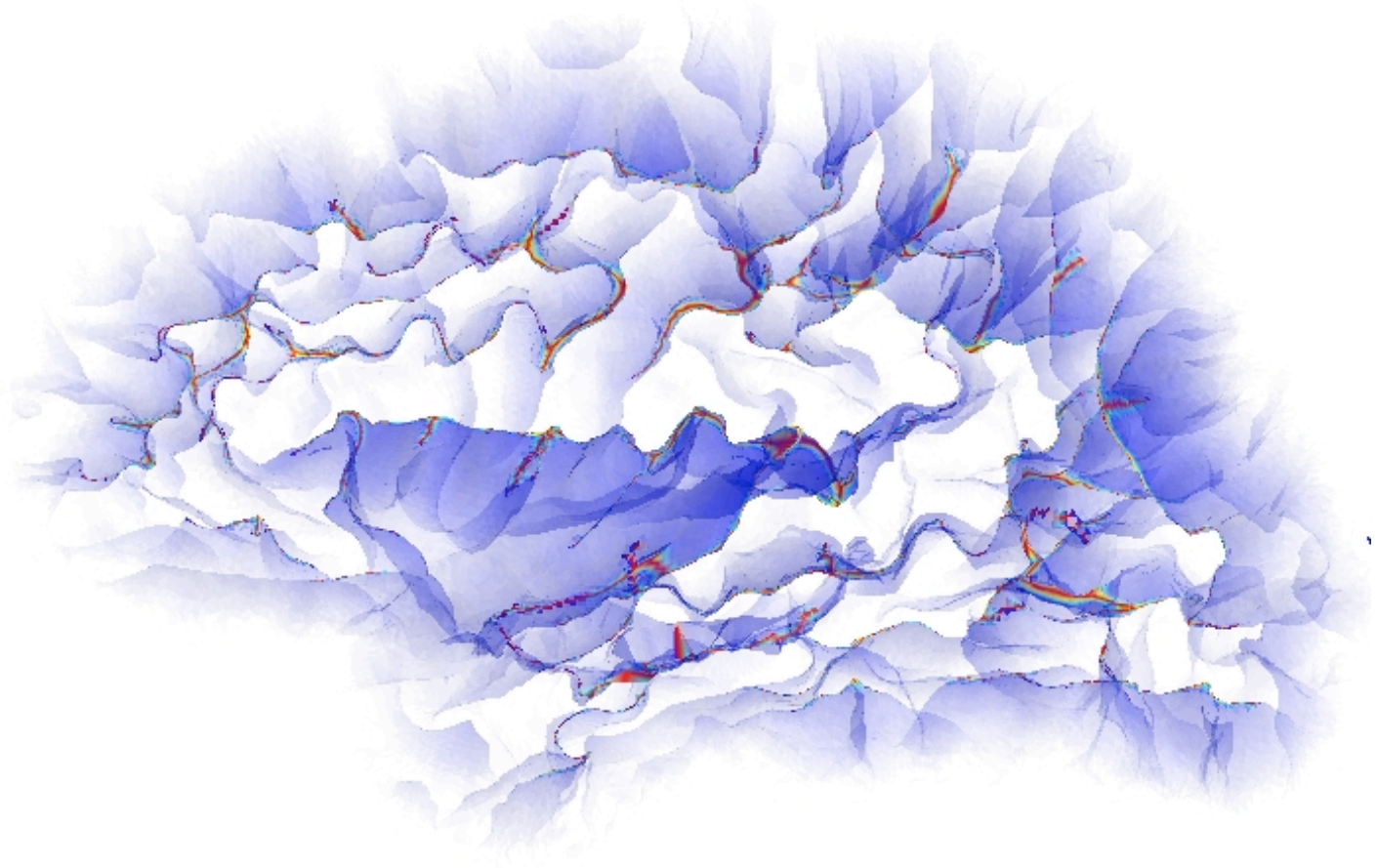
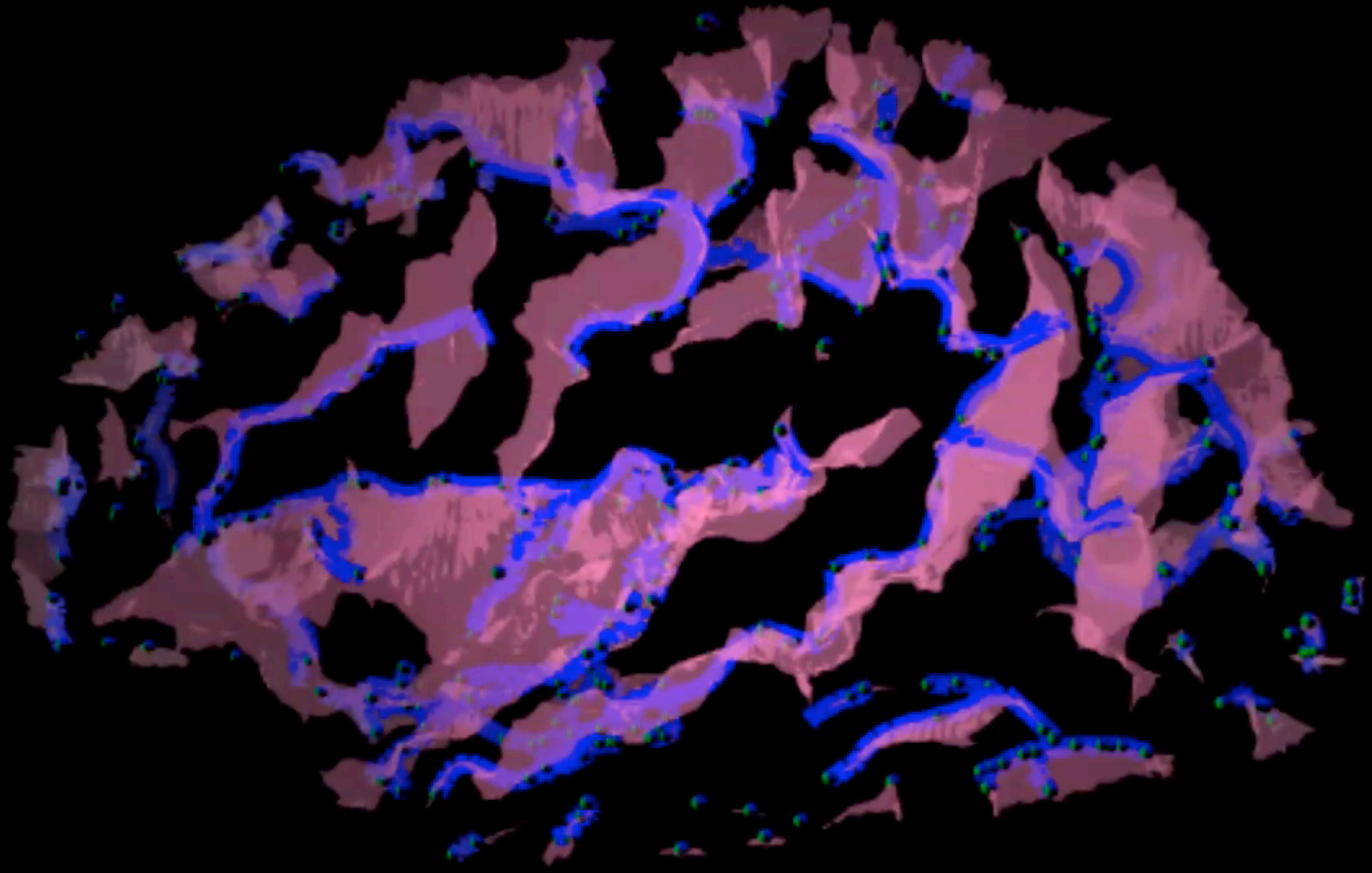
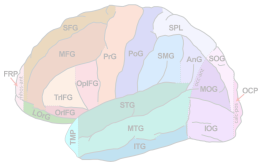


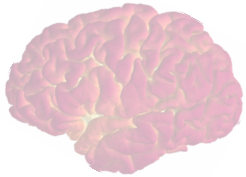
Fundus curves (HMMF)





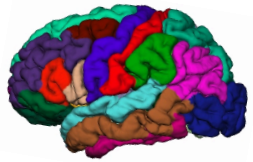
manual

Mindboggle



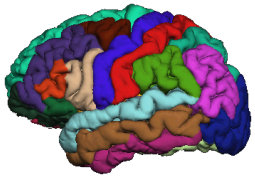
morphometry

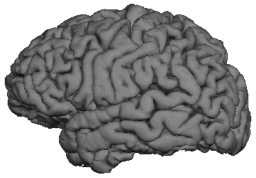
features



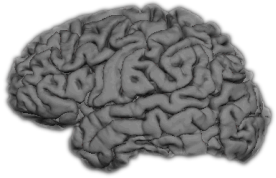
labels

atlas

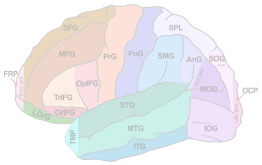




target

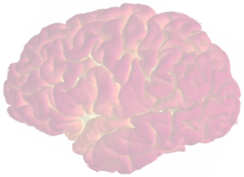


Registration-based labeling



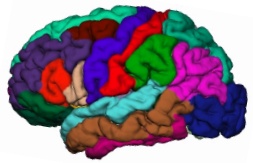
manual

Mindboggle



morphometry

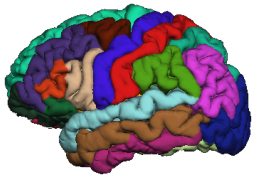
features

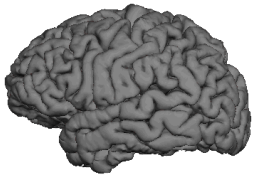


labels

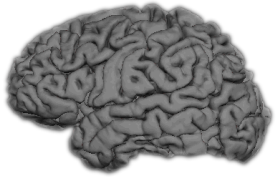
atlas

target



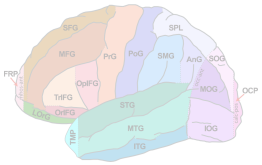


transform



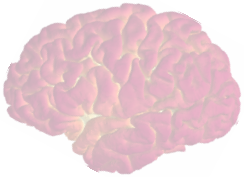
Registration-based labeling:

Step 1: compute registration transform from atlas to target



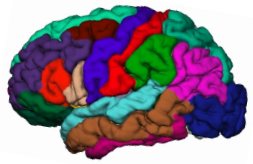
manual

Mindboggle

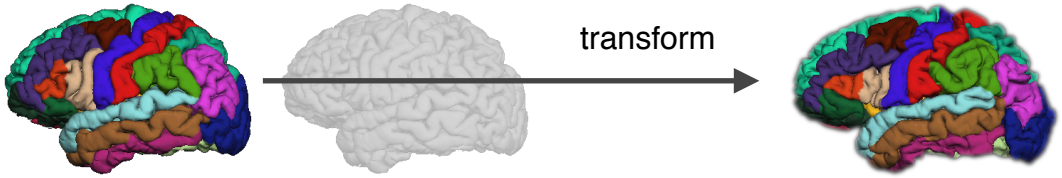


morphometry

features

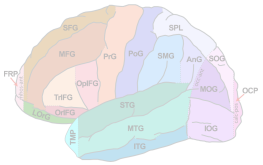


labels



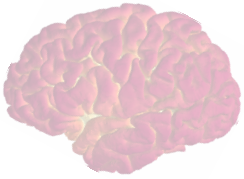
Registration-based labeling:

Step 2: apply transform to atlas labels



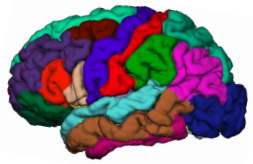
manual

Mindboggle

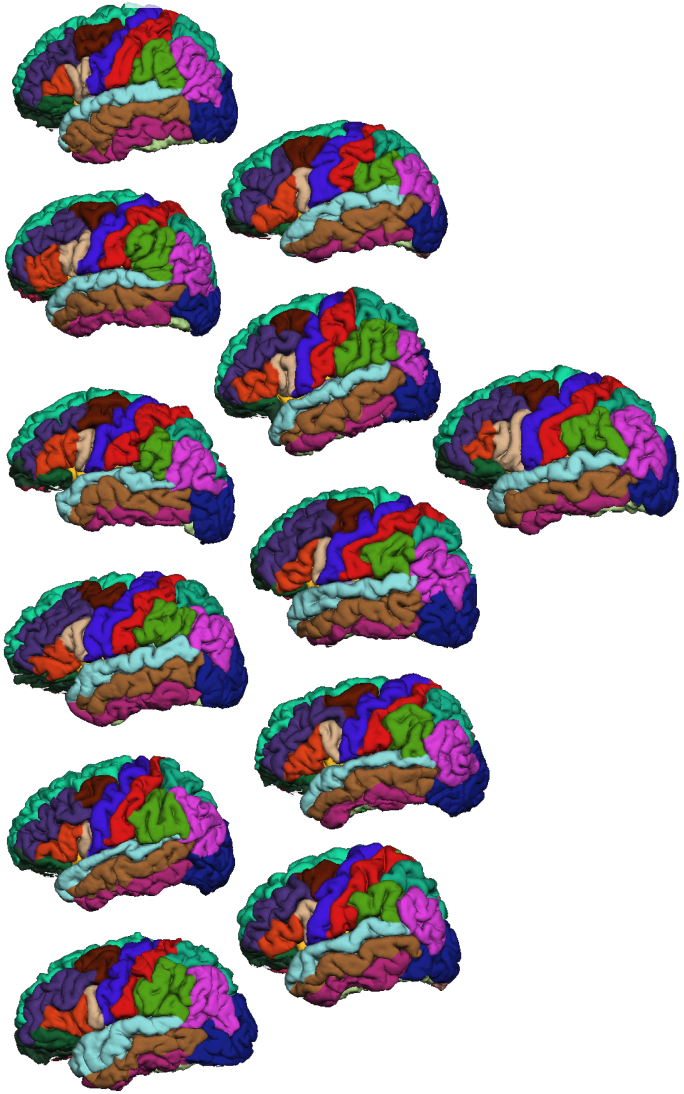


morphometry

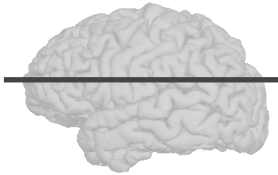
features



labels

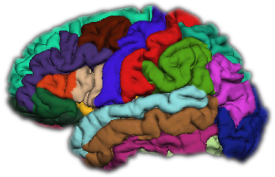


atlases



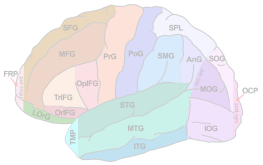
transform

majority-vote
labeled
target



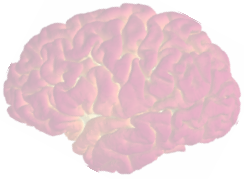
Registration-based labeling:

Step N: repeat for multiple atlases
and choose majority-vote labels



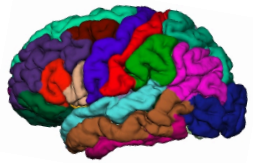
manual

Mindboggle

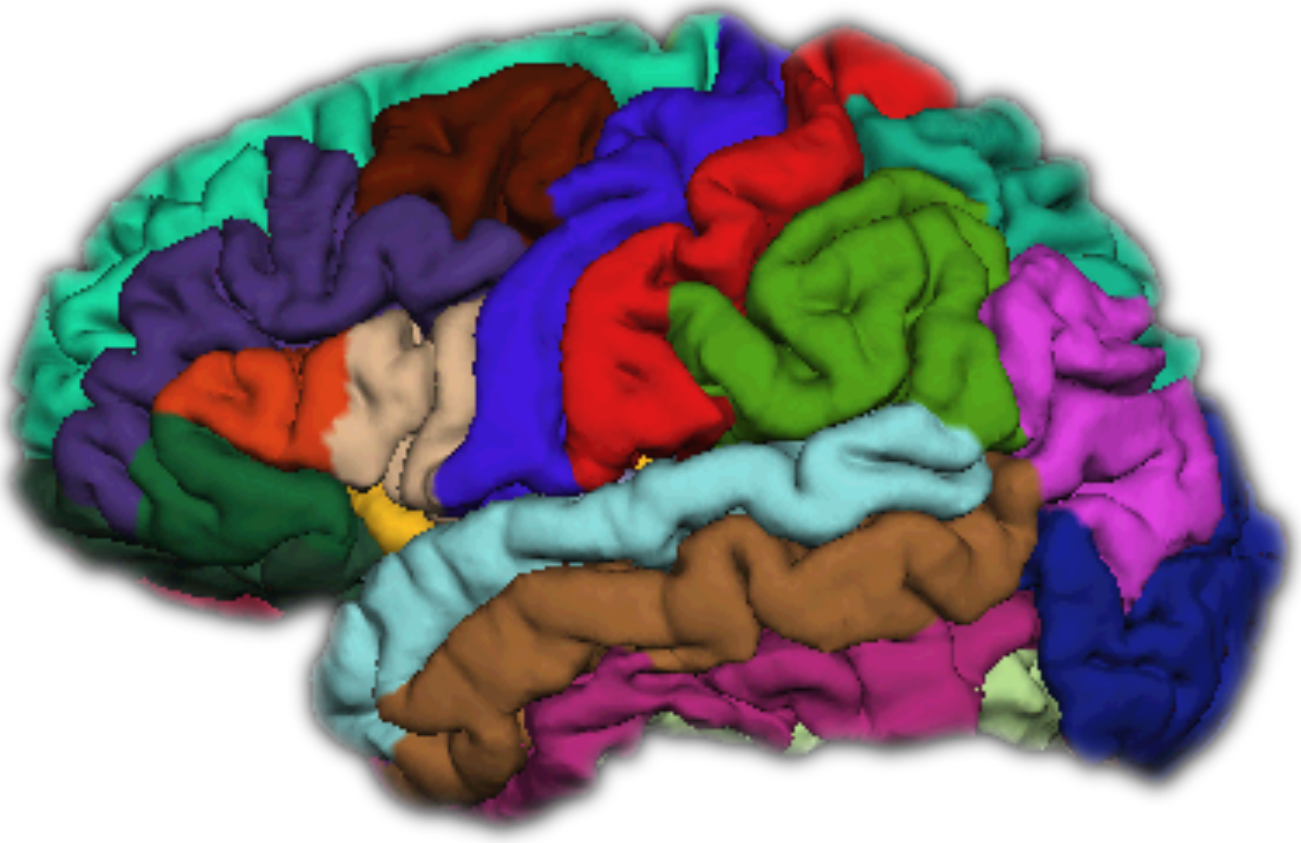


morphometry

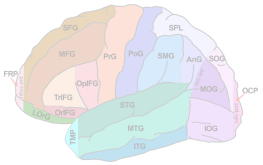
features



labels

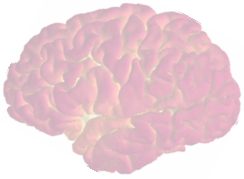


Majority vote labels



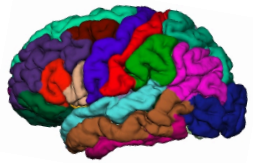
manual

Mindboggle

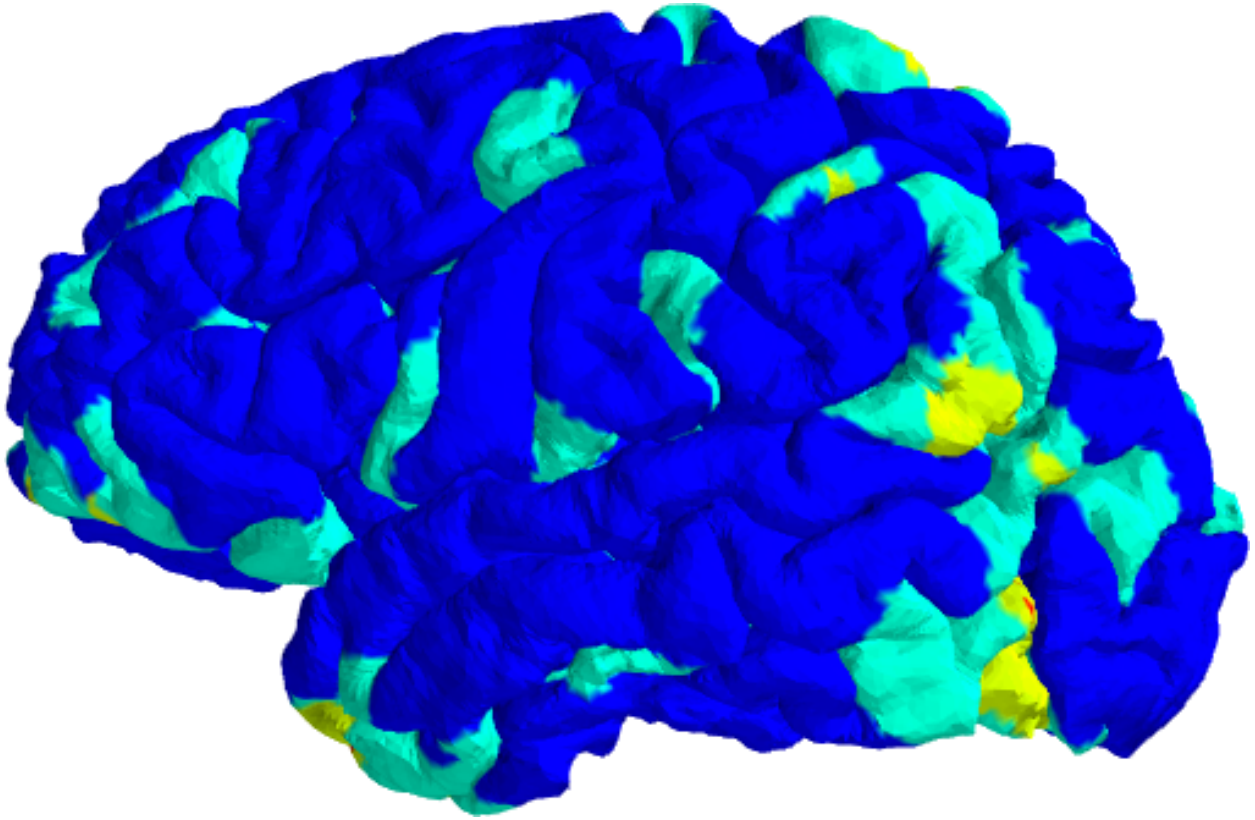


morphometry

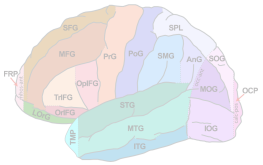
features



labels

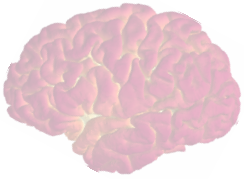


Majority vote labels: #labels/vertex



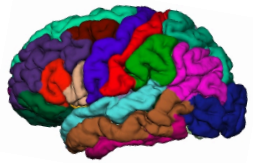
manual

Mindboggle

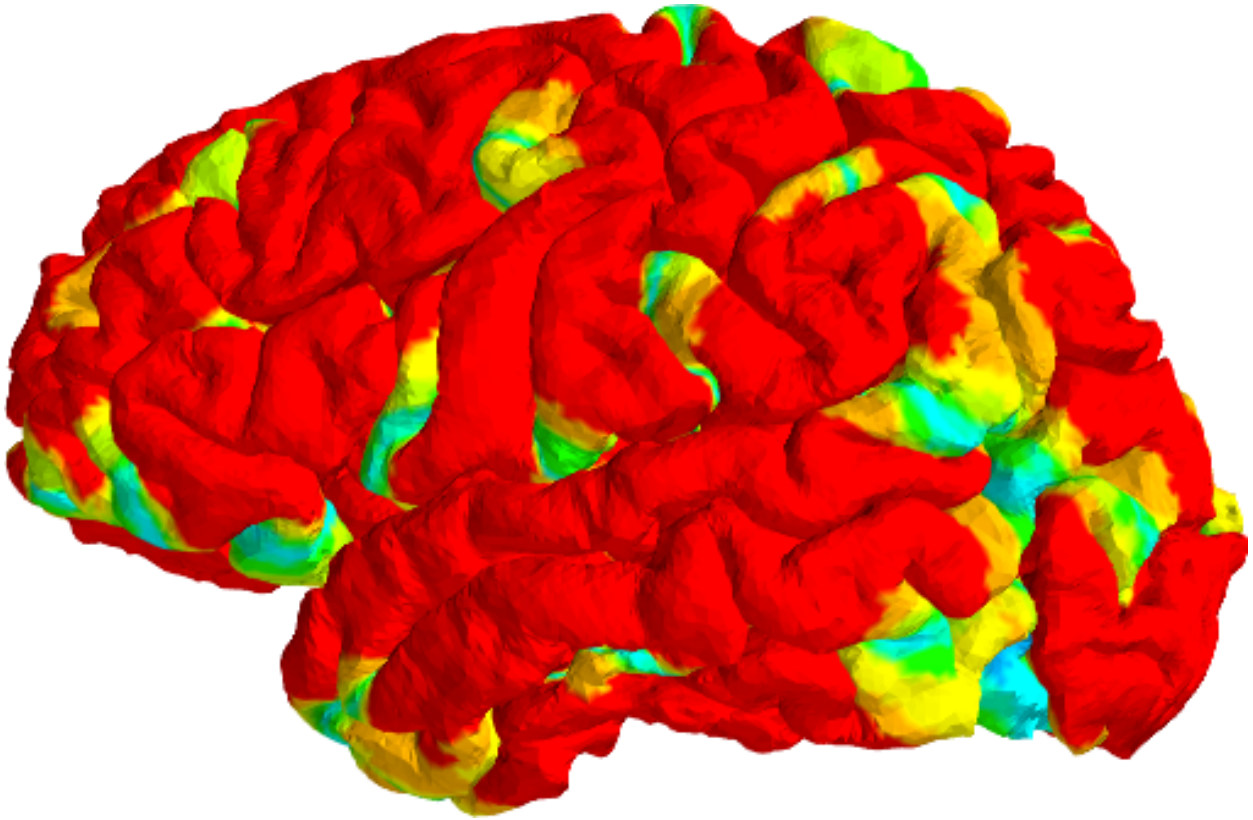


morphometry

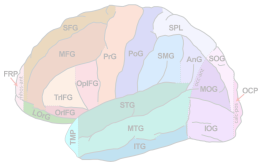
features



labels

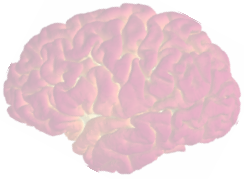


Majority vote labels: #votes/winning label



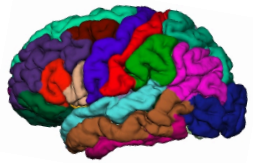
manual

Mindboggle

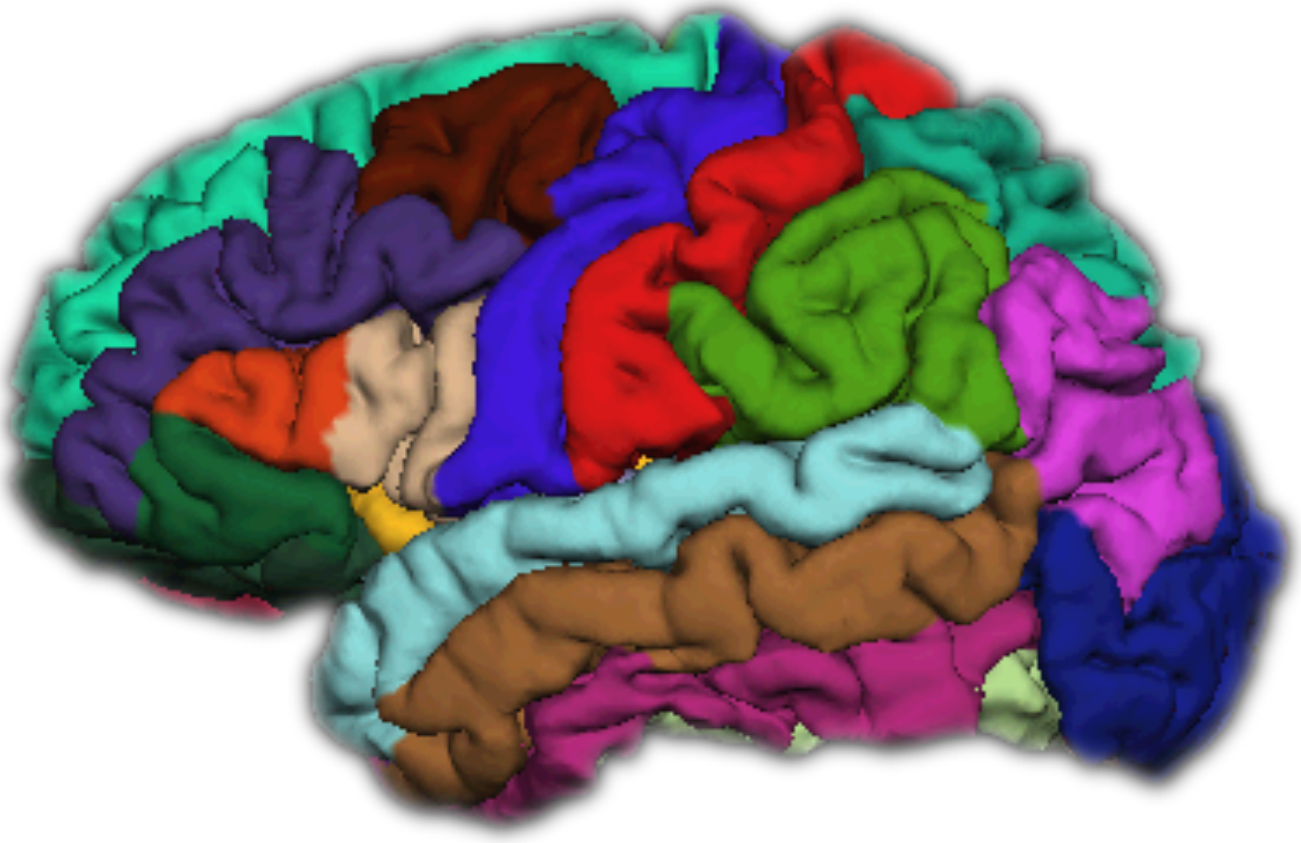


morphometry

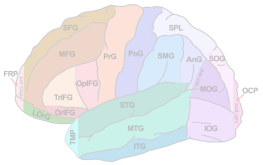
features



labels

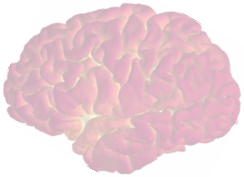


Majority vote labels



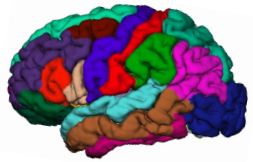
manual

Mindboggle

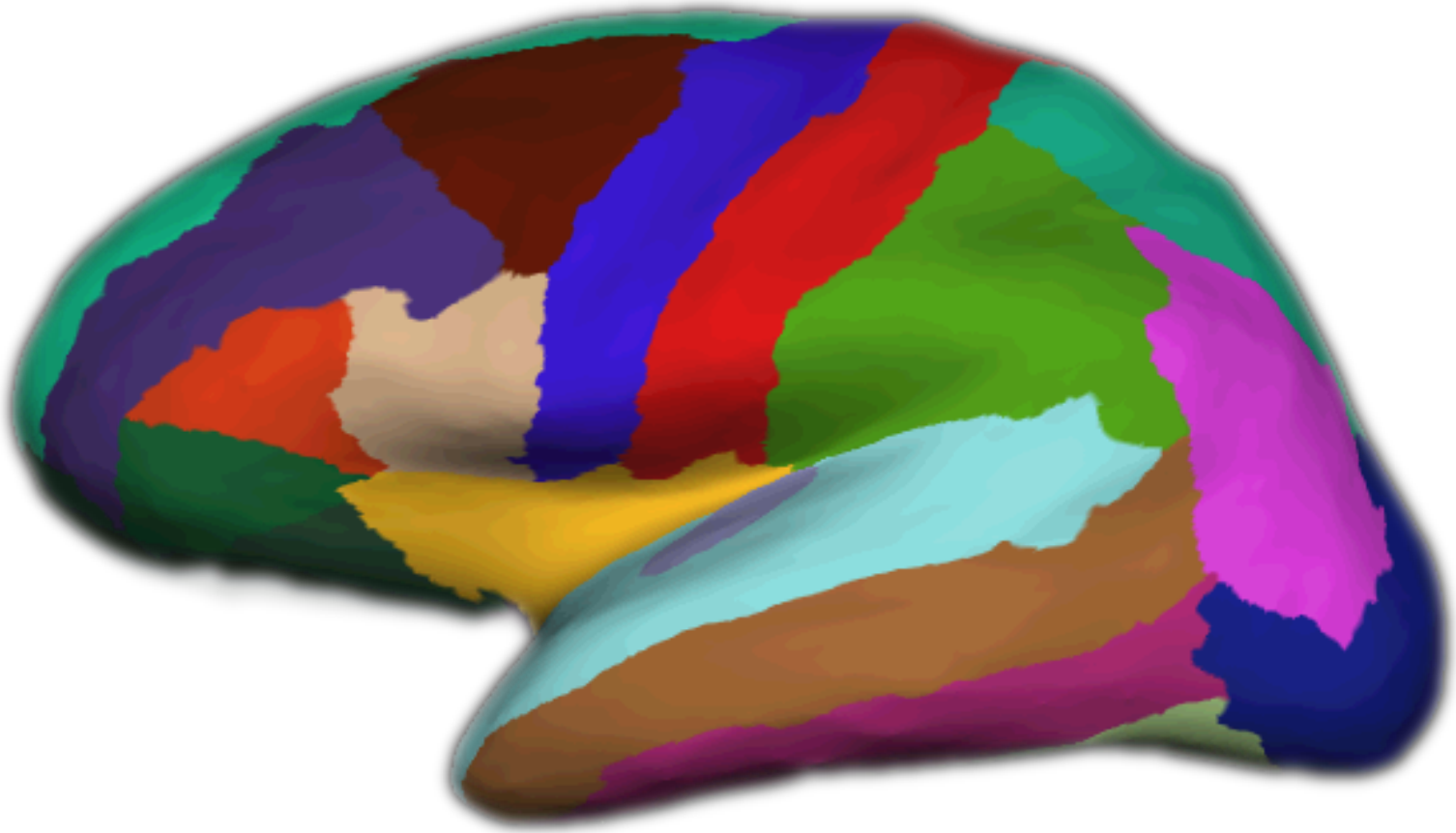


morphometry

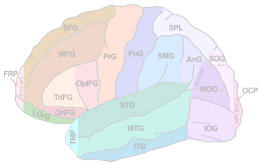
features



labels

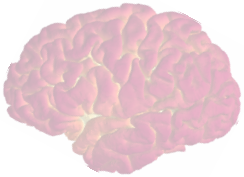


Majority vote labels (inflated)



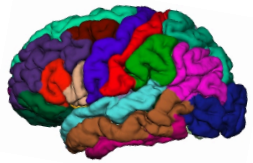
manual

Mindboggle

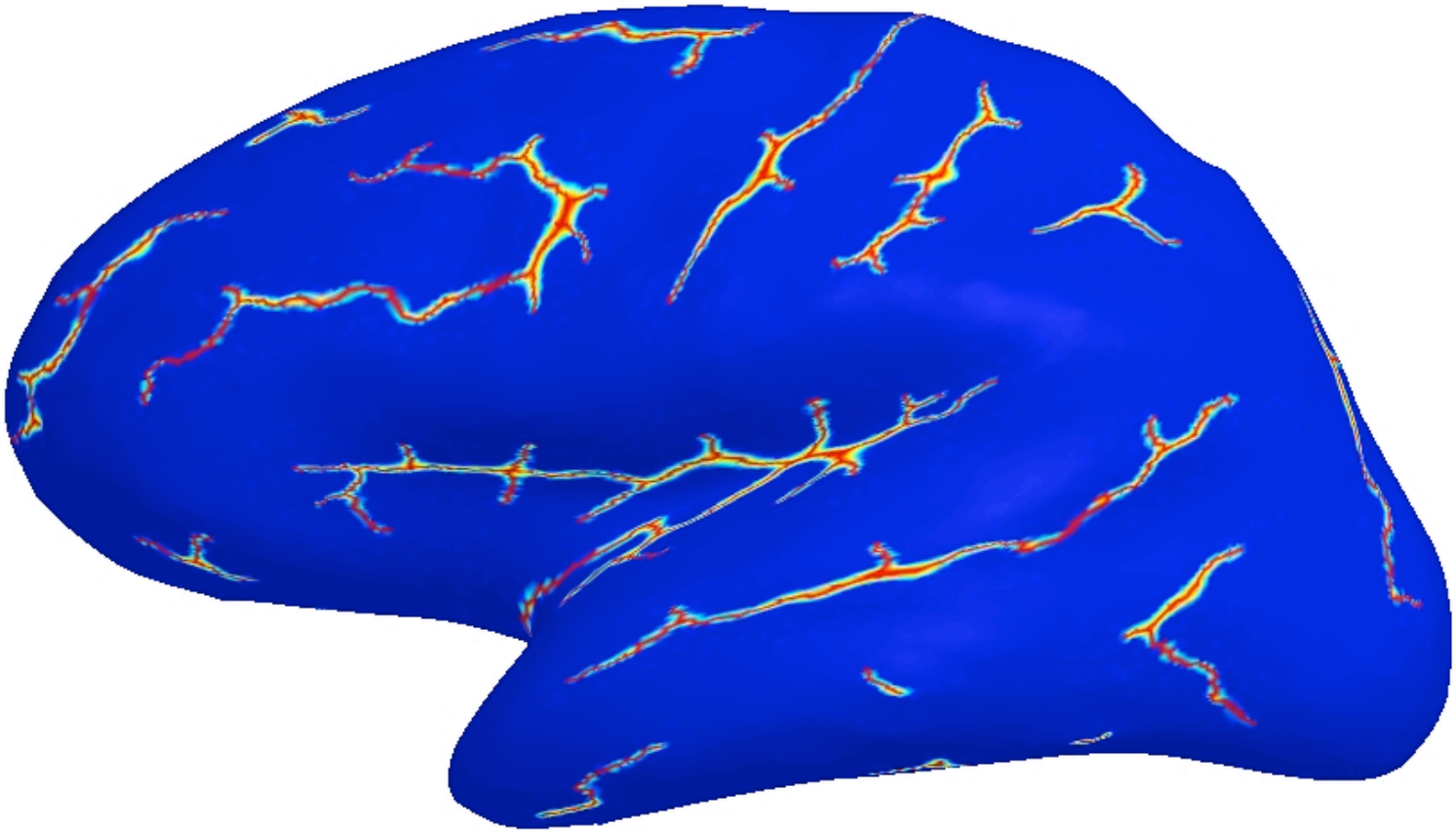


morphometry

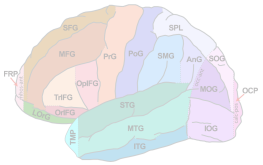
features



labels

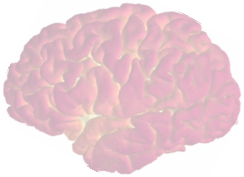


Refine label boundaries using sulcal fundi



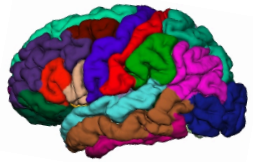
manual

Mindboggle

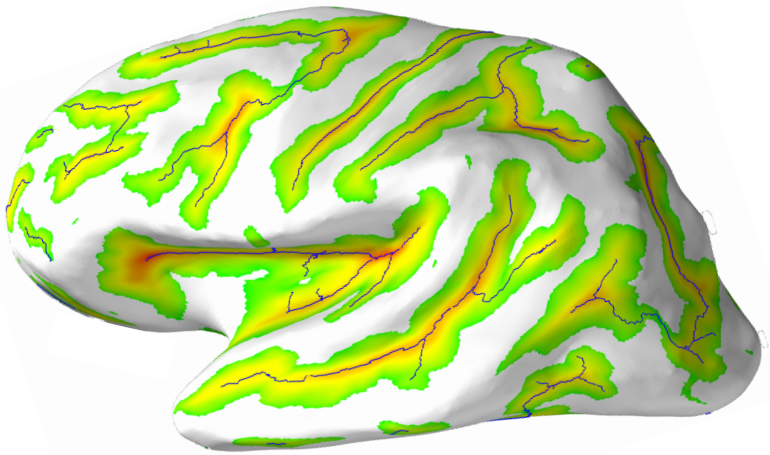


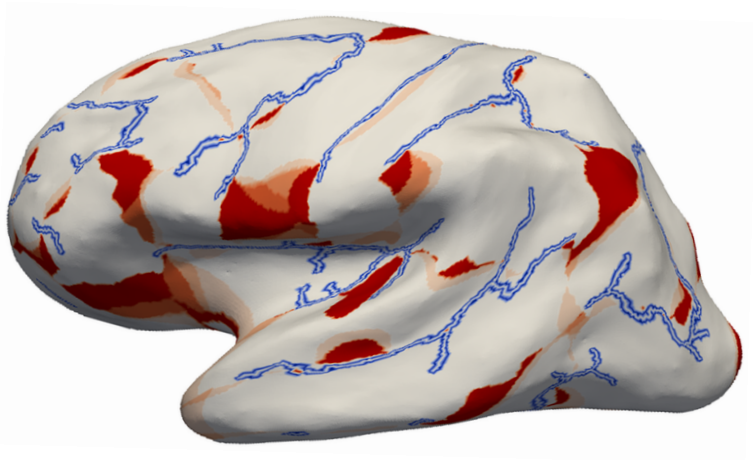
morphometry

features

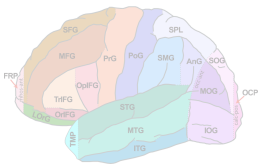


labels



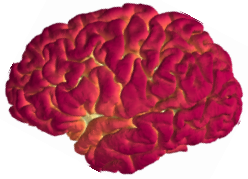


Refine label boundaries using sulcal fundi (rank error test)

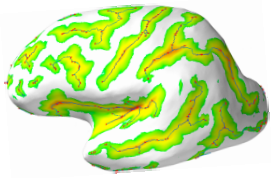


manual

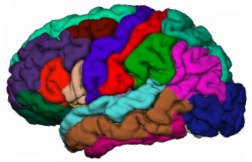
Mindboggle



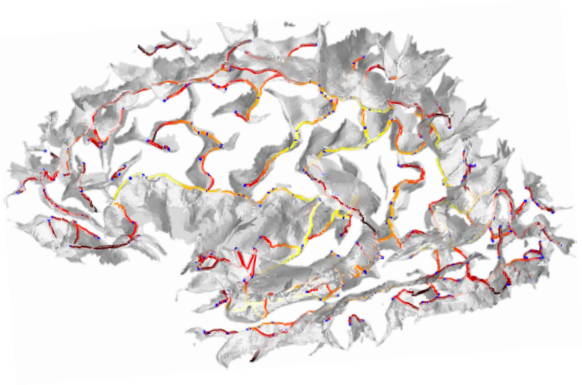
morphometry

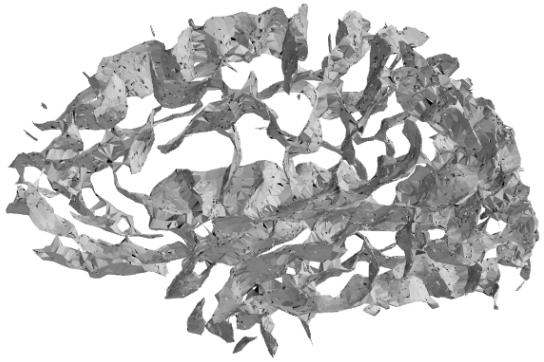


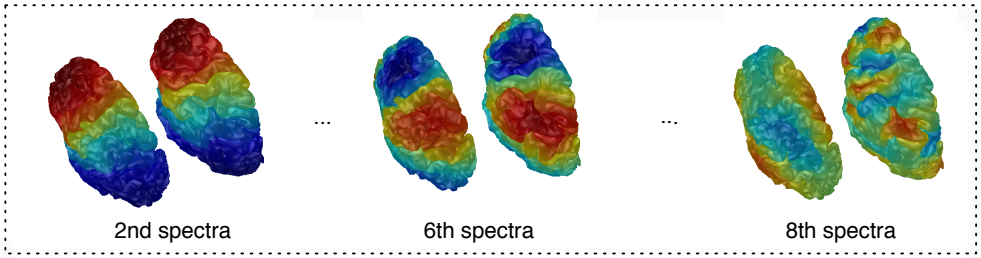
features



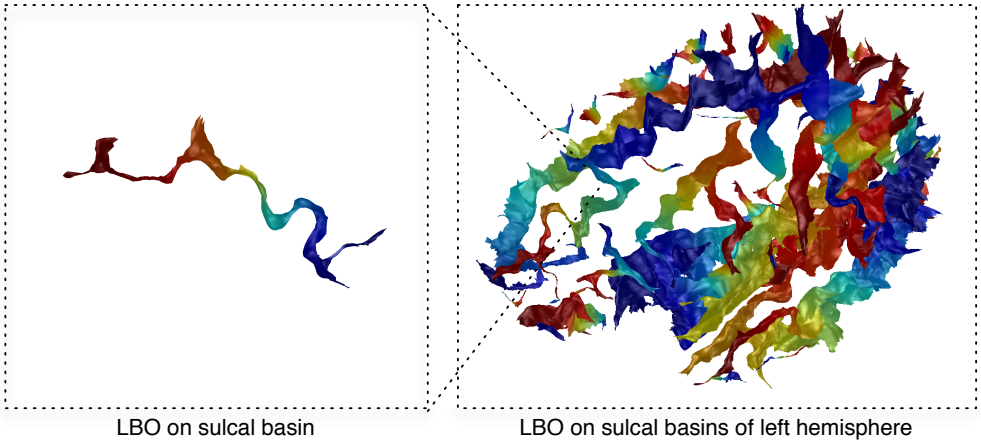
labels







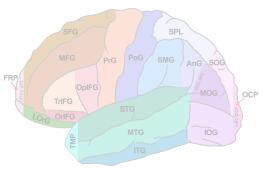
Global to local



LBO on sulcal basin

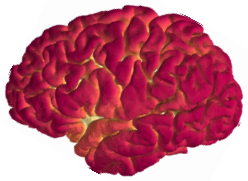
LBO on sulcal basins of left hemisphere

Morphometry of folds, fundi, medial surfaces, and labeled regions

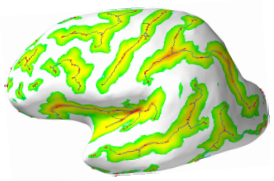


manual

Mindboggle



morphometry



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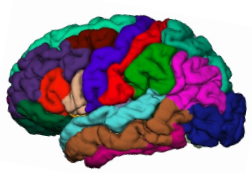

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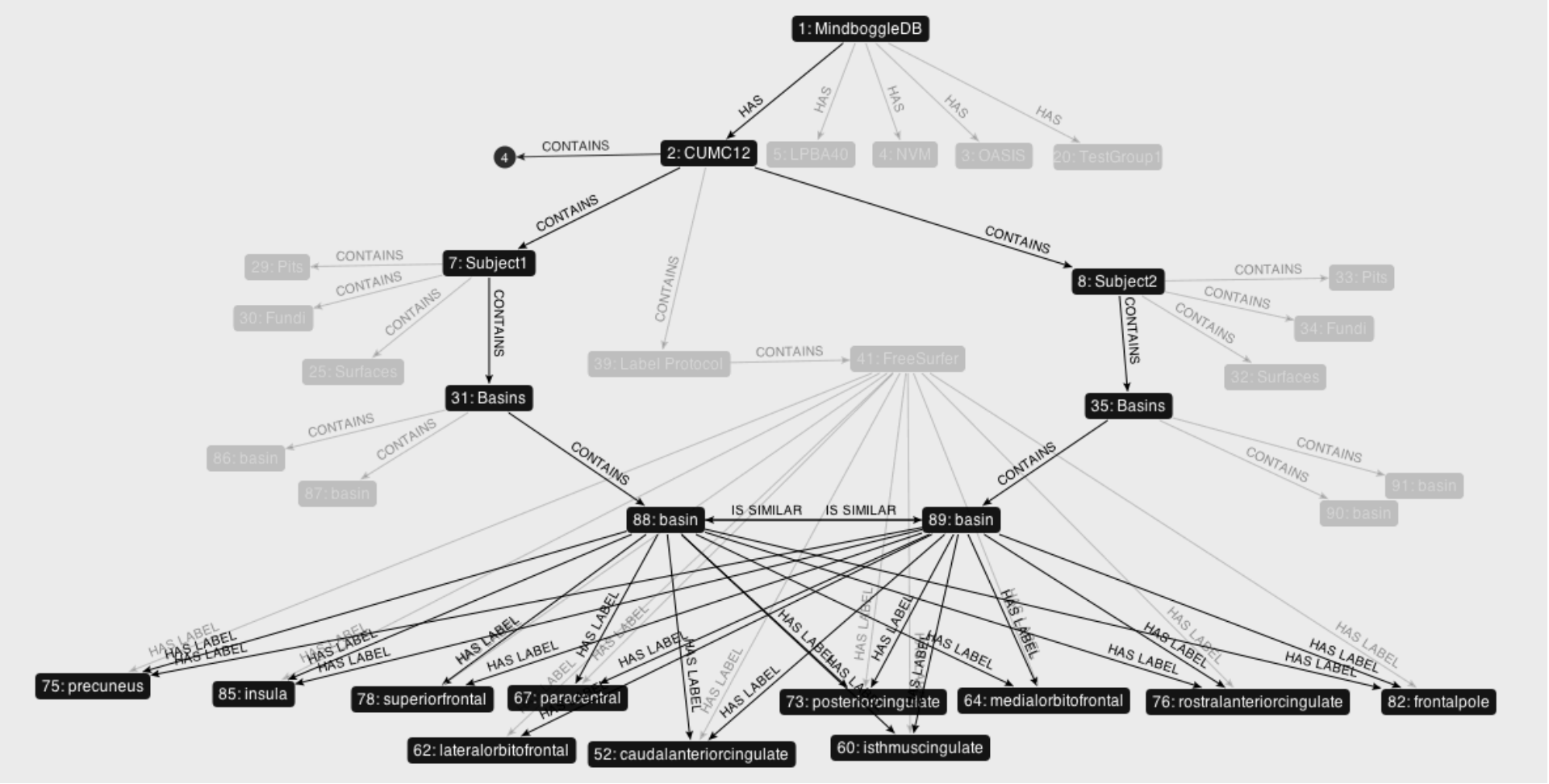
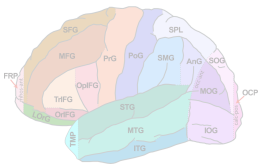


Graph-based database of features and labels



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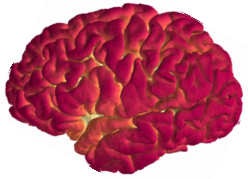

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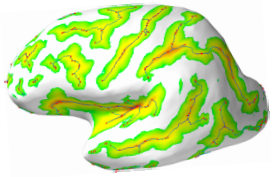

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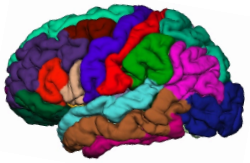

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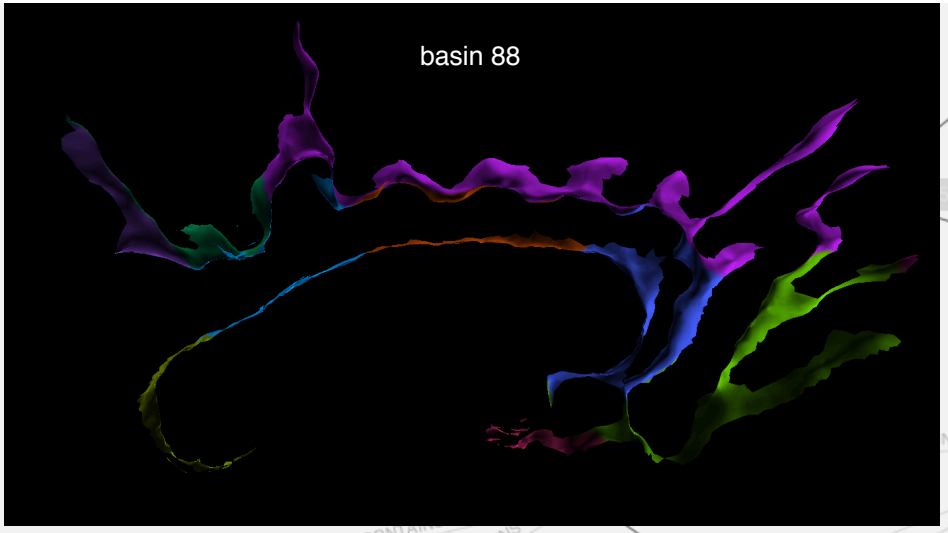
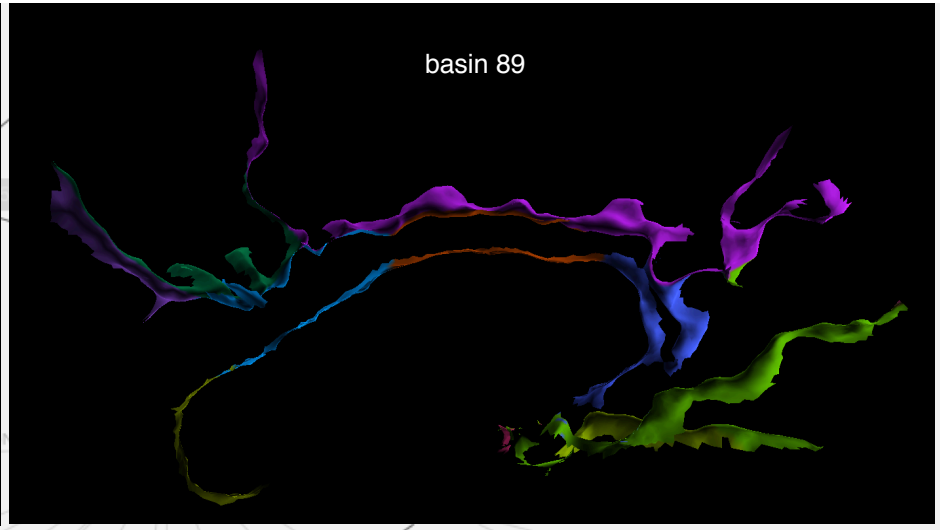
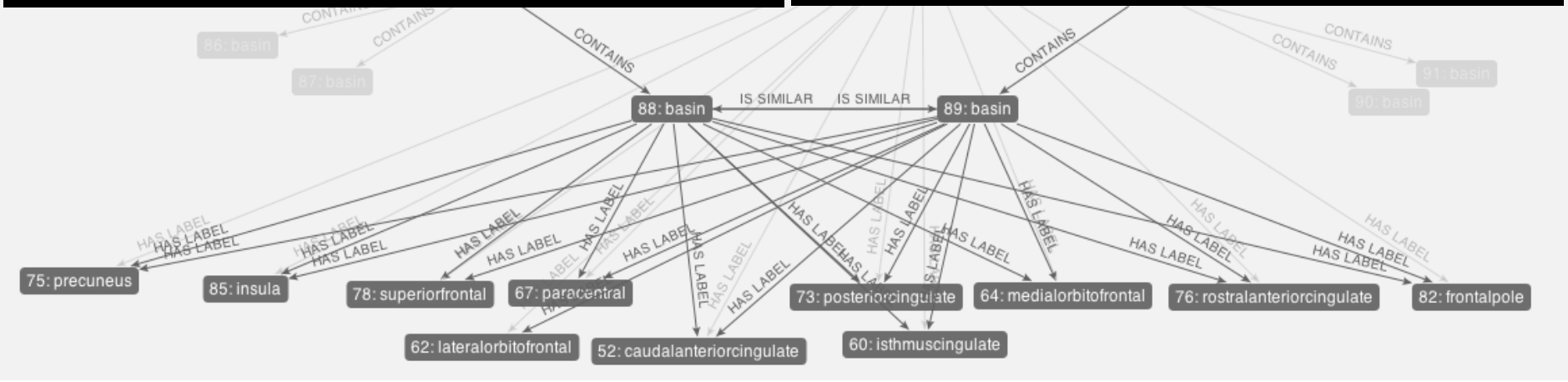
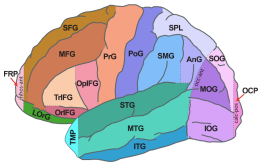






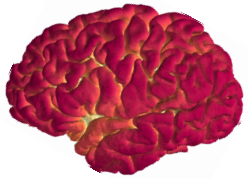
Example database query

Mindboggle 3-year R01

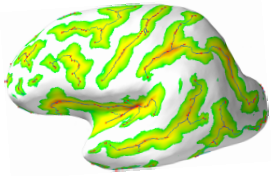


101 manually labeled brain atlases and morphometry database

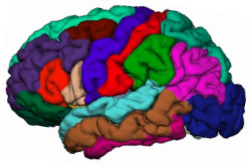
Mindboggle software:



- shape analysis



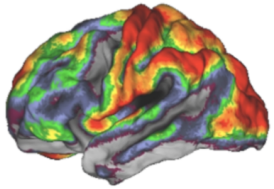
- feature identification



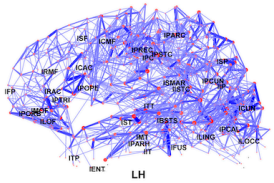
- automated labeling

Mindboggle 1-year U01 supplement

Mindboggle software:

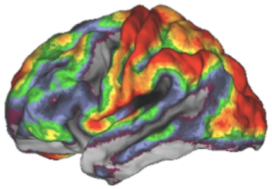


- fMRI features

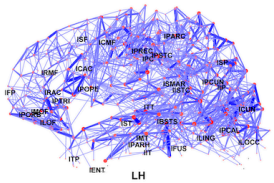


- dMRI features

Mindboggle

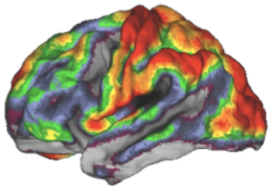


fMRI features



dMRI features

Mindboggle



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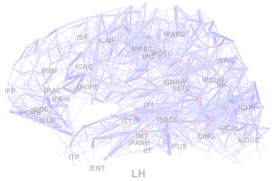

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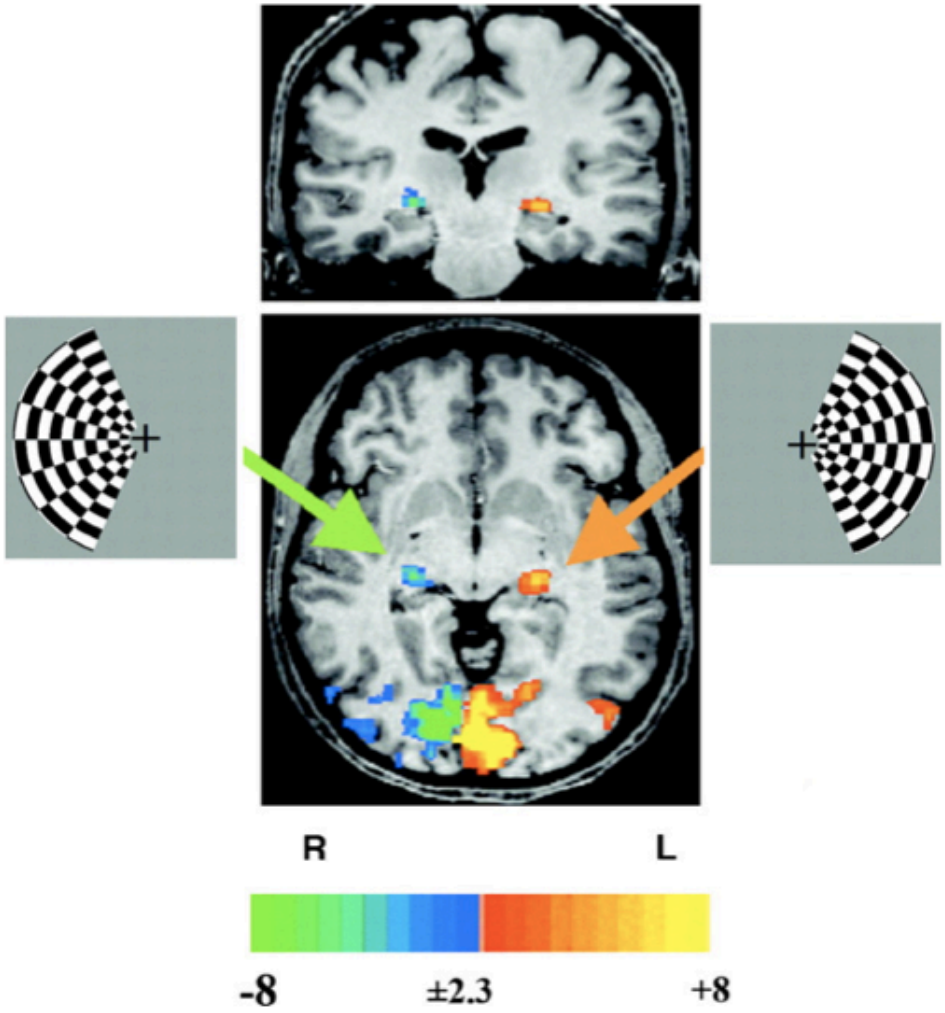
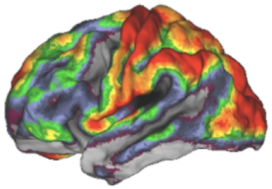


Kastner, et al., 2004

Mindboggle



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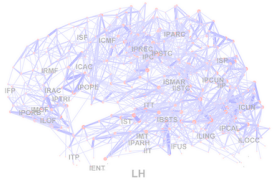

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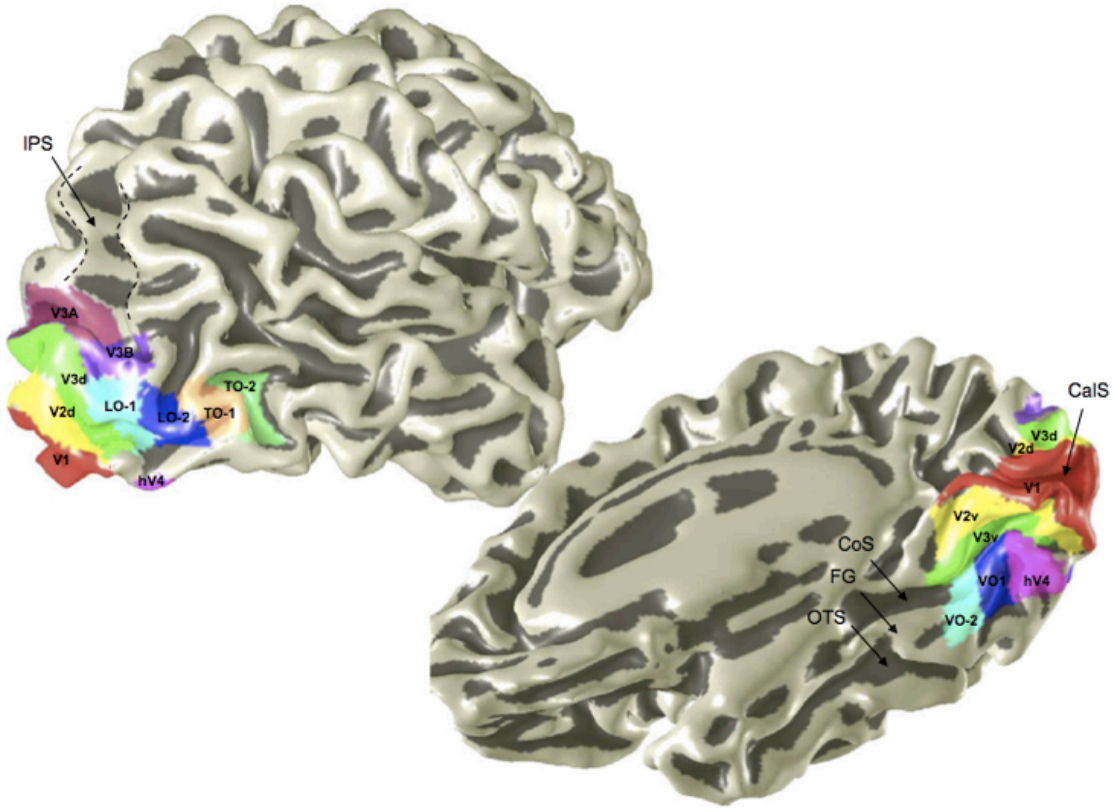

Visuotopic mapping

Wandell and Winawer, 2011

le.com - Calendar | Mindboggle labels and label | Mindboggle on the cloud - C | Mindboggle Roadmap - Goo | Yeo_etal_JNeurophysiol_201
TvKnFaA&feature=player_detailpage

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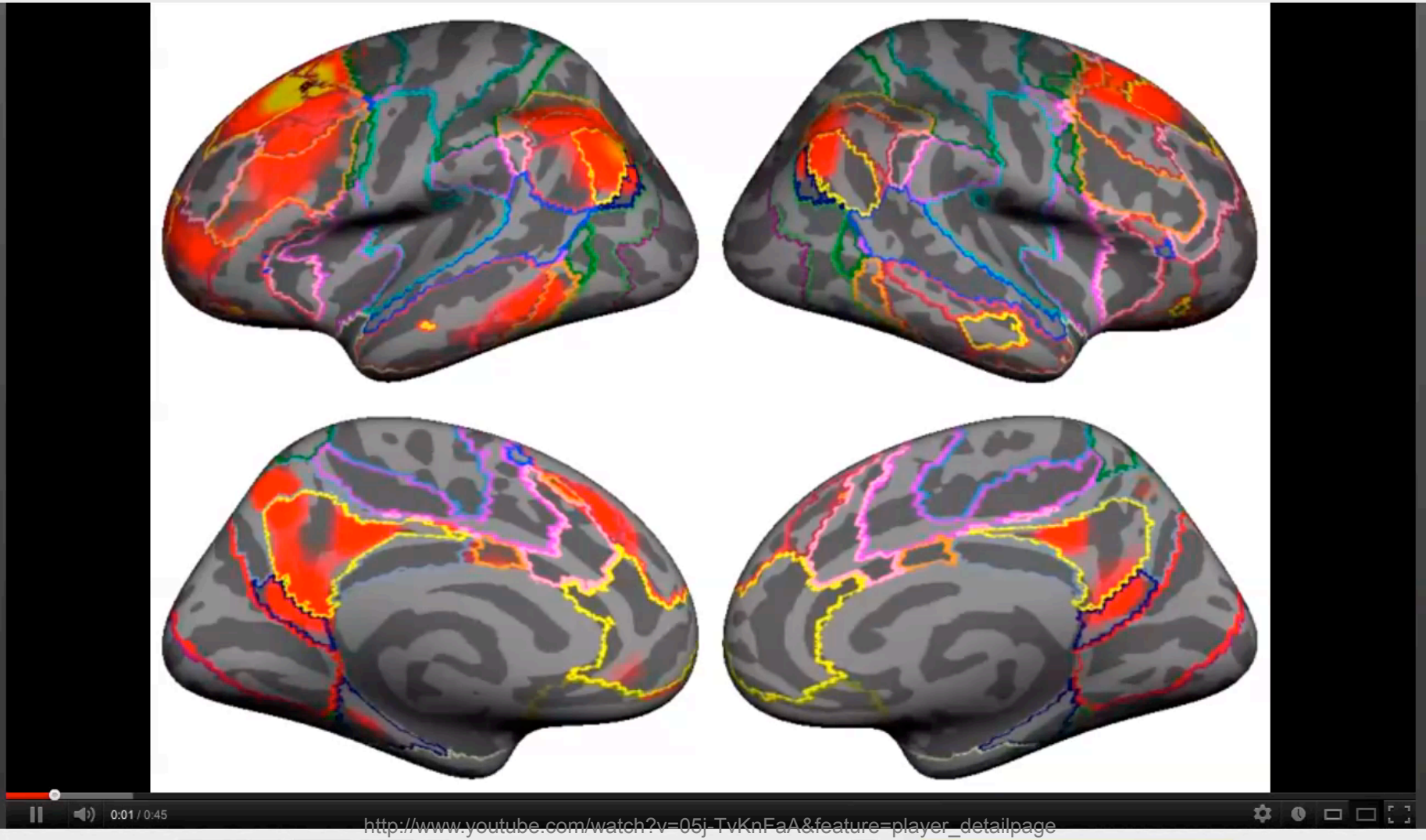

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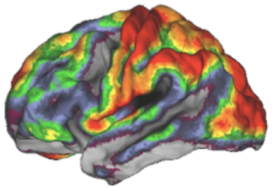

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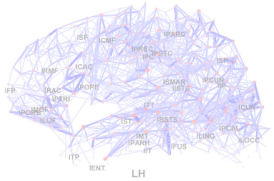

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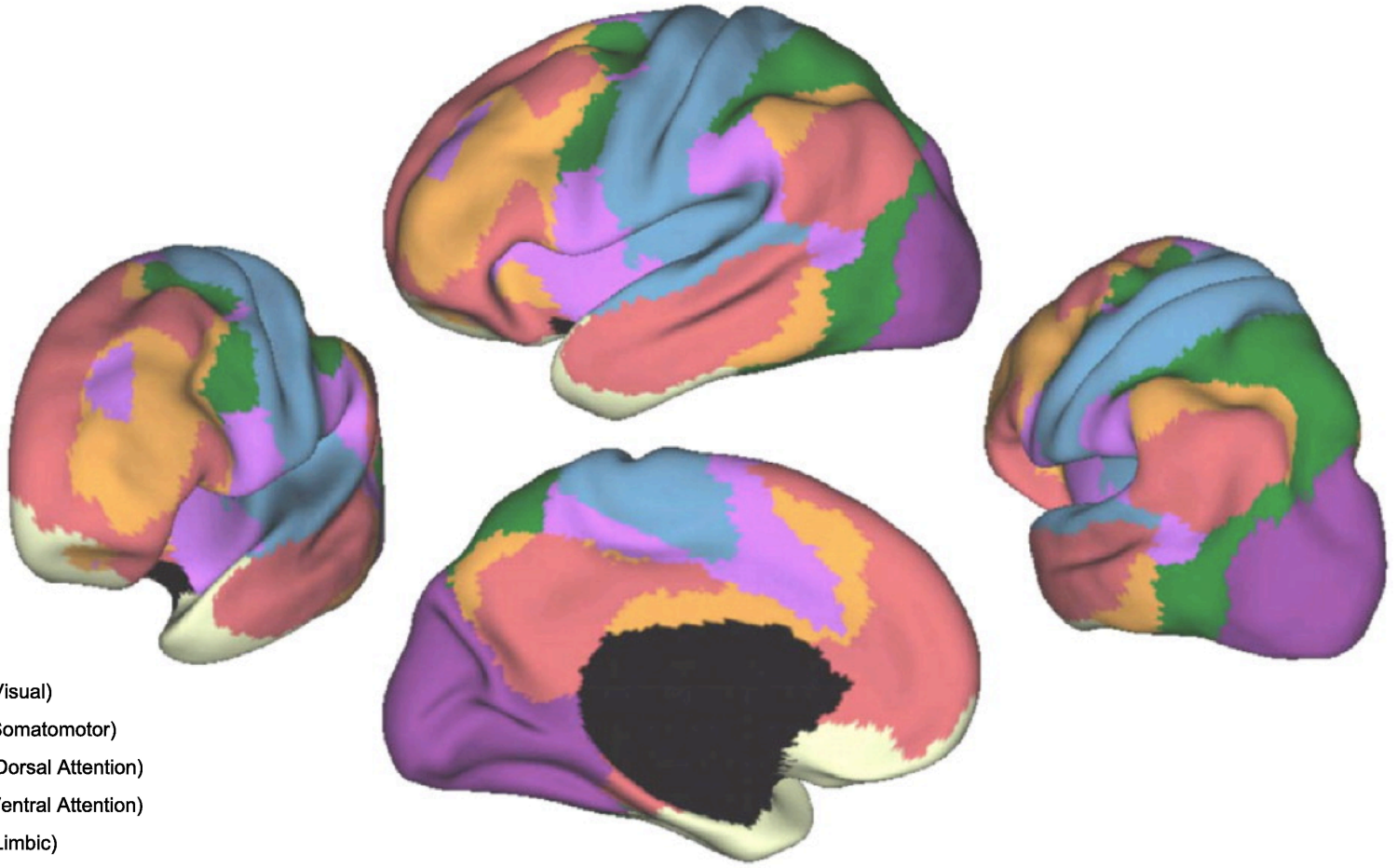
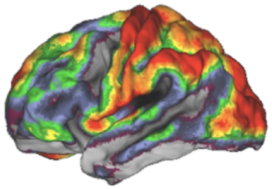


Functional “connectivity”

7-network (N=1000)

Yeo, et al., JNeurophysiology, 2011

Mindboggle



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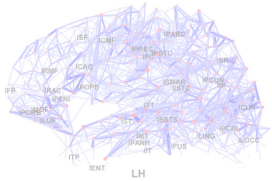

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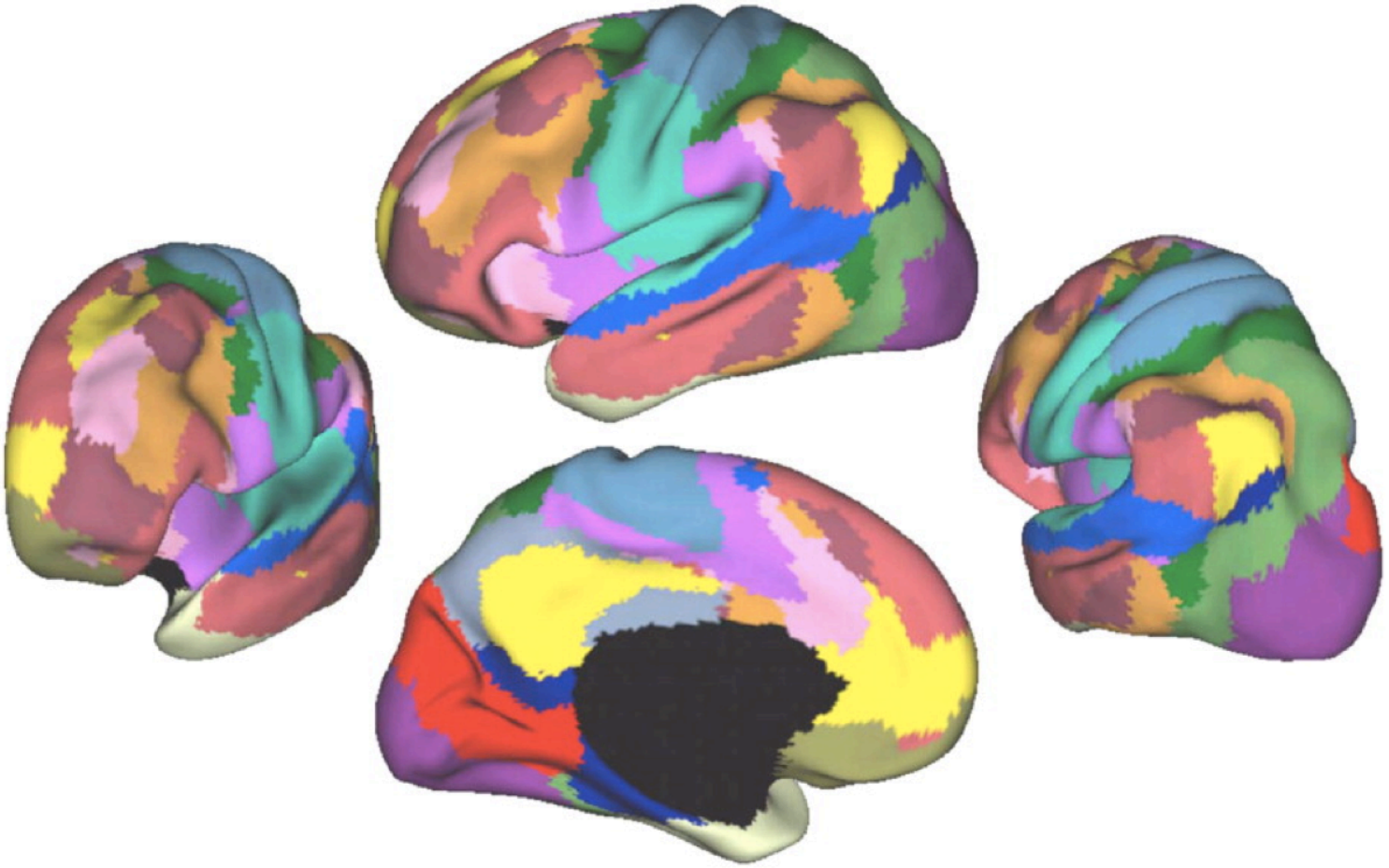
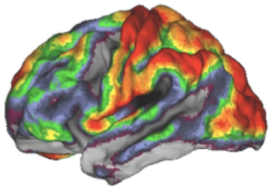


Functional “connectivity”

17-network (N=1000)

Yeo, et al., JNeurophysiology, 2011

Mindboggle



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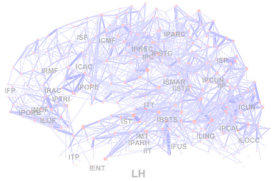

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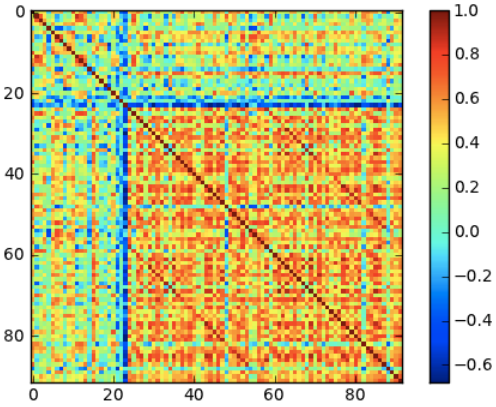
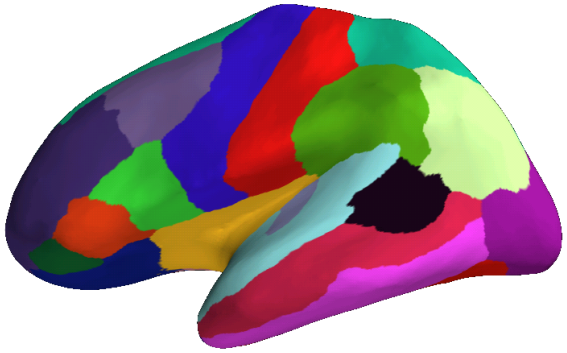
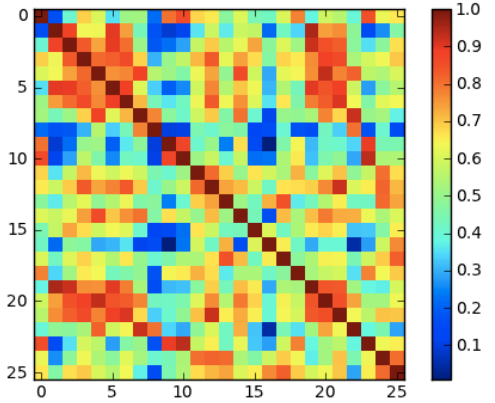
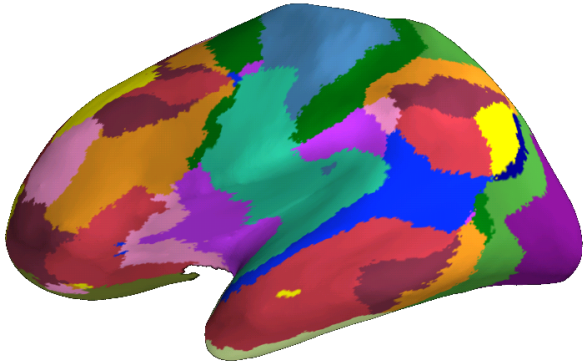


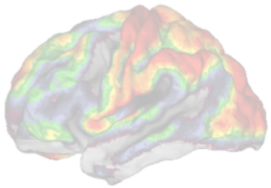






fMRI-connected features

Mindboggle



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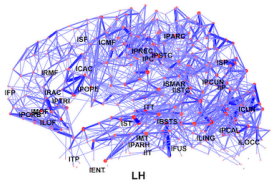

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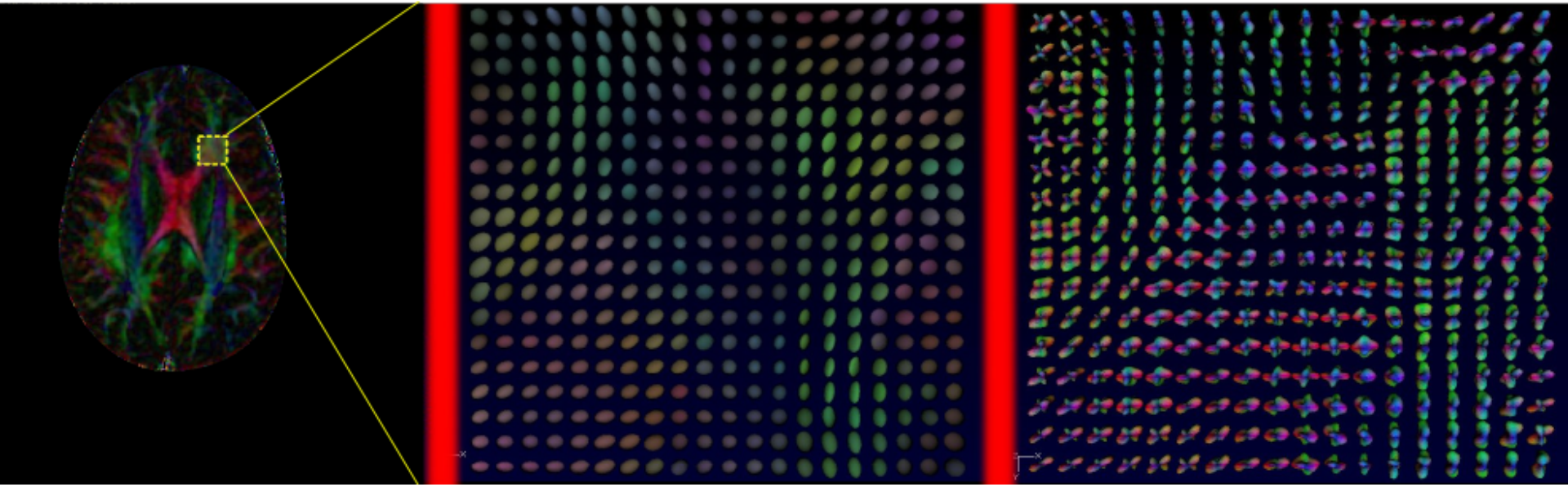

Diffusion MRI

http://www.cim.mcgill.ca/~assemlal/spip.php?

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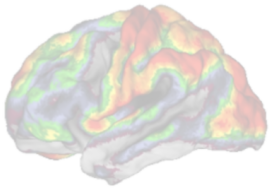

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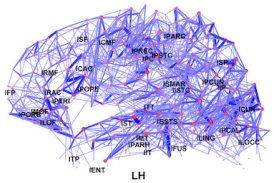

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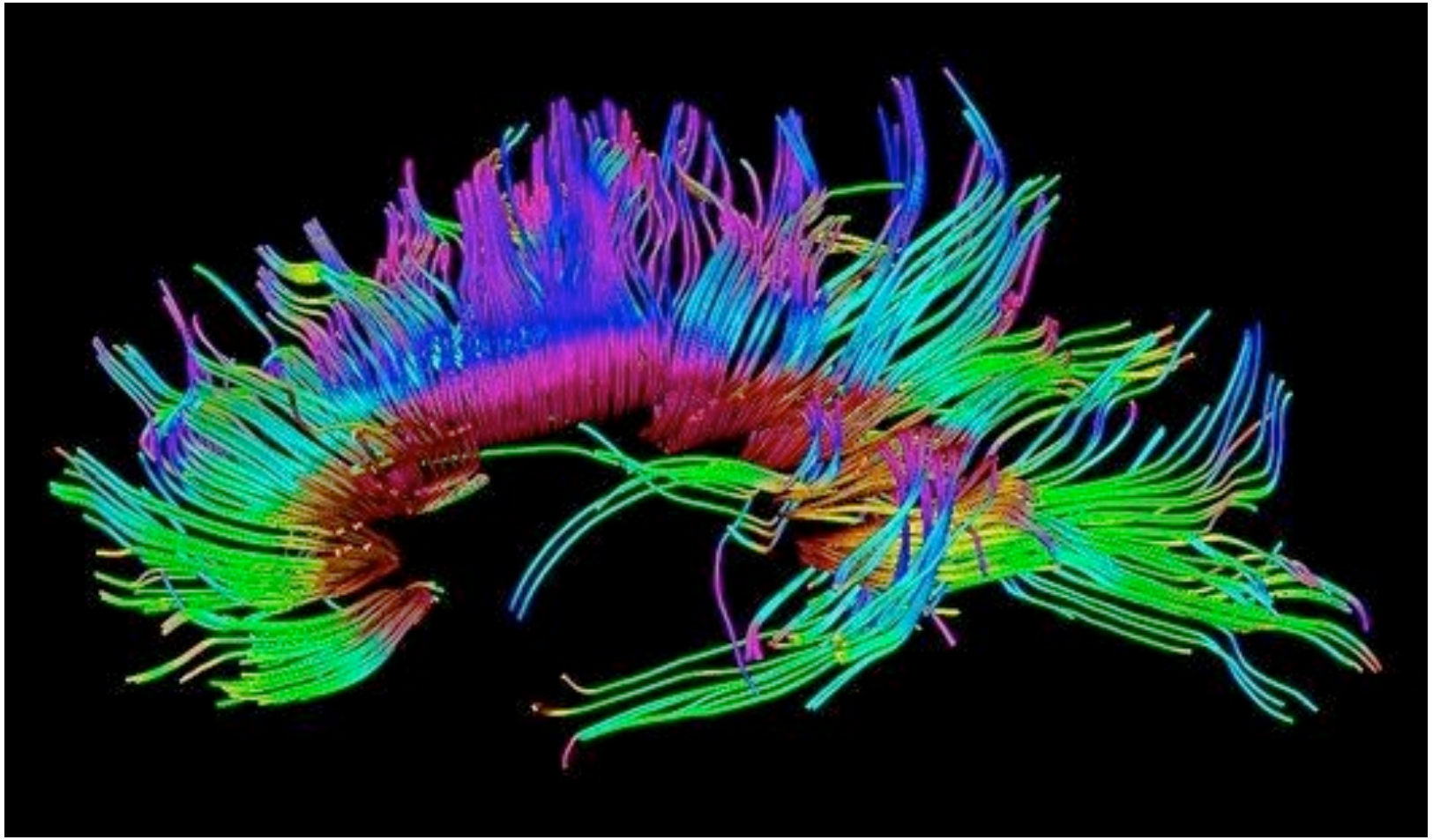
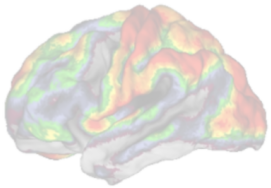


Diffusion tractography

Wiegall et al., 2003, Kirby

Mindboggle



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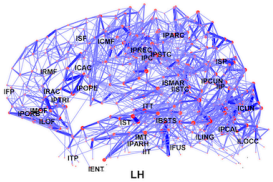

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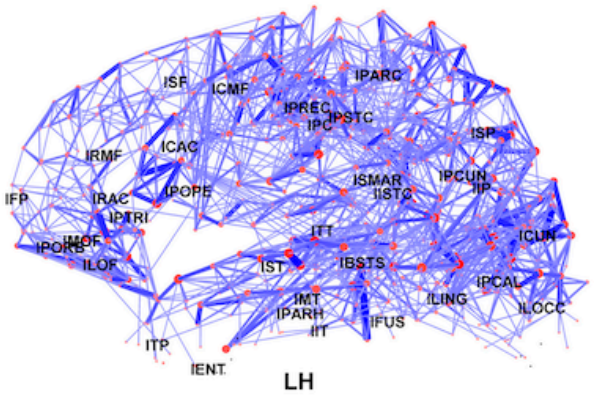
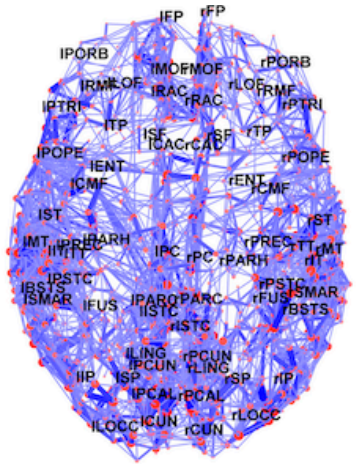
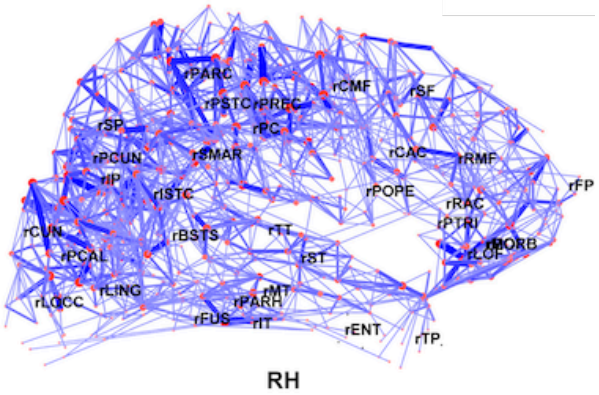
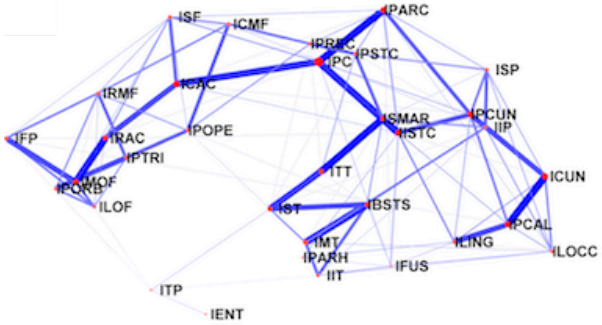
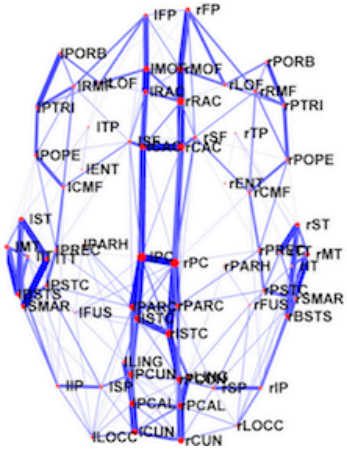
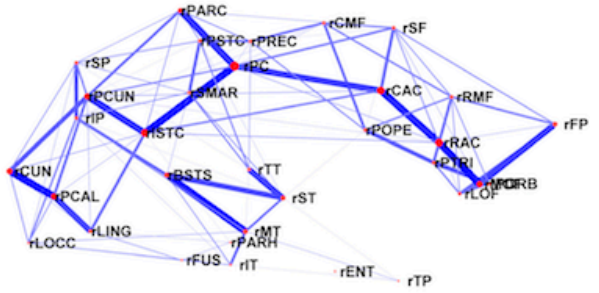








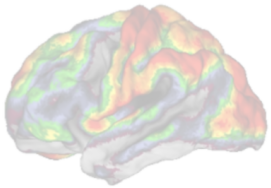




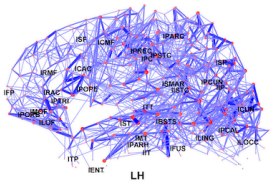
Tractography networks

Hagmann, et al., 2008

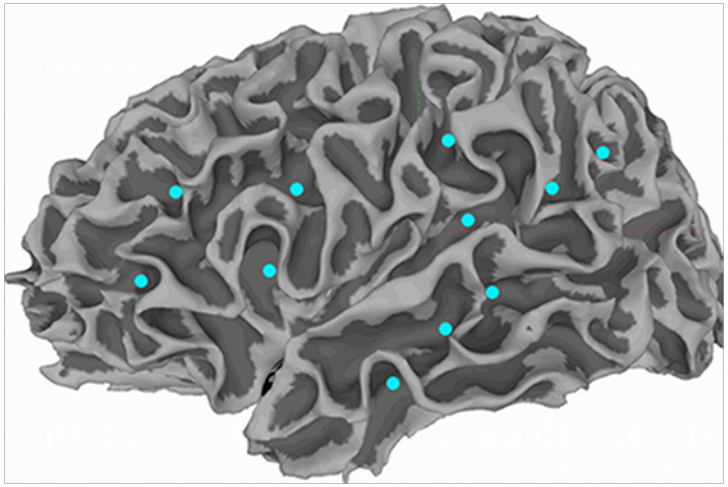
Mindboggle

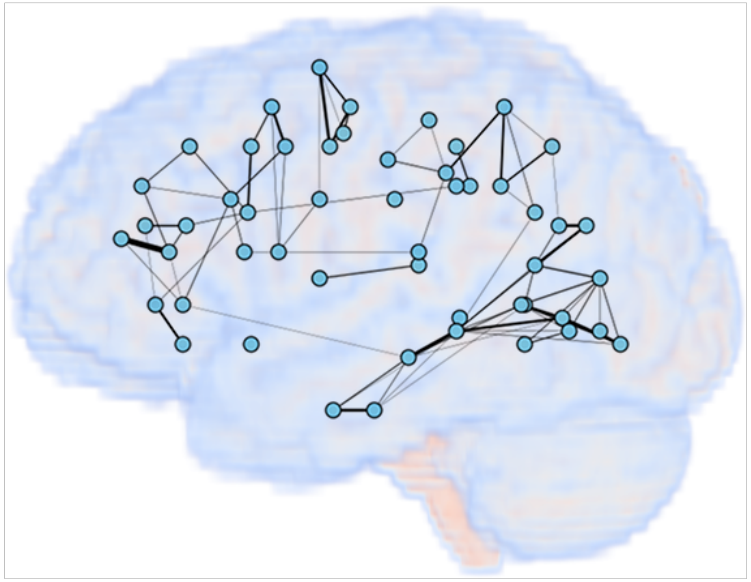


fMRI features



dMRI features

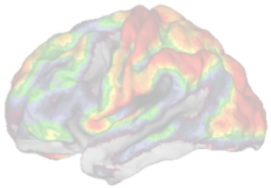




Tractography-connected features

work with Denis Peruzzo

Mindboggle



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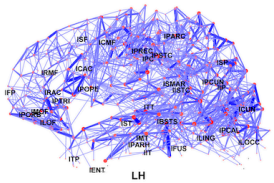

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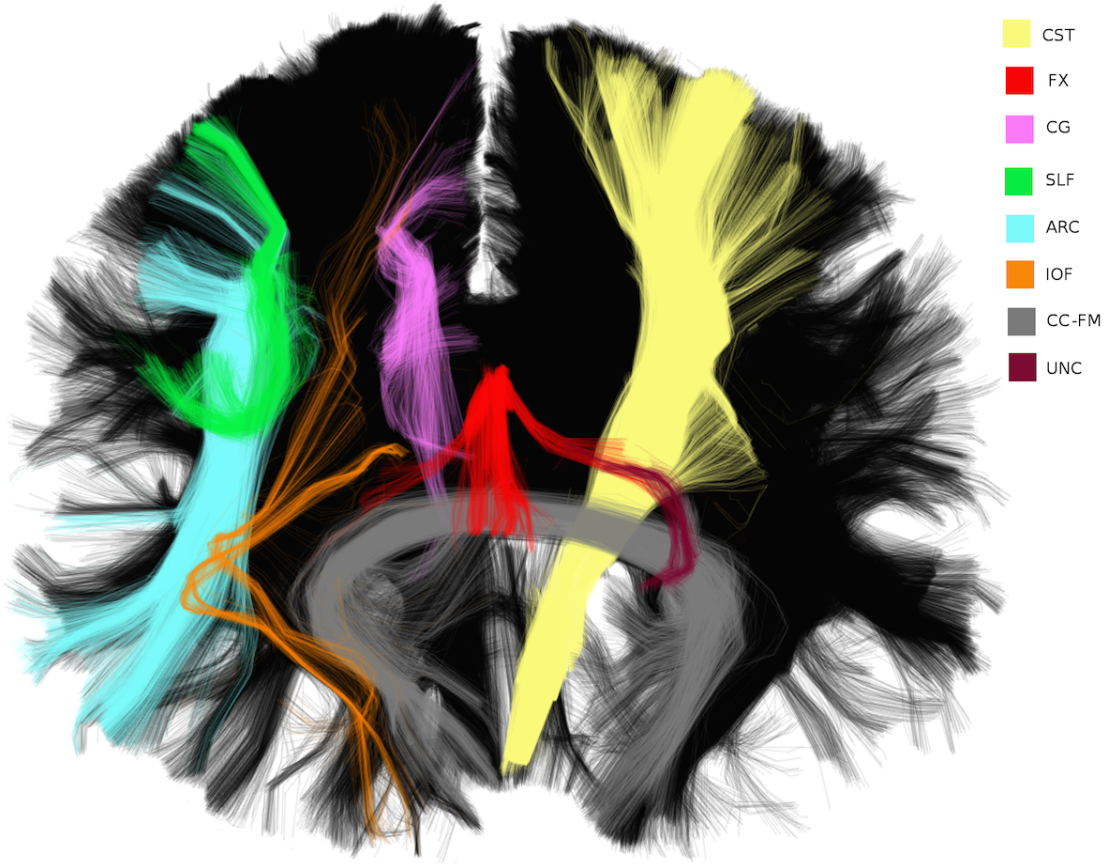
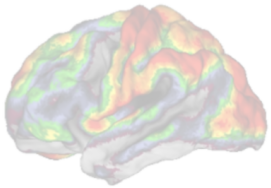


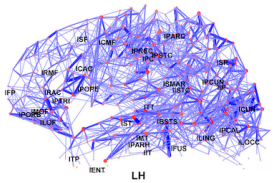
Tractography features

Eleftherios Garyfallidis, 2011

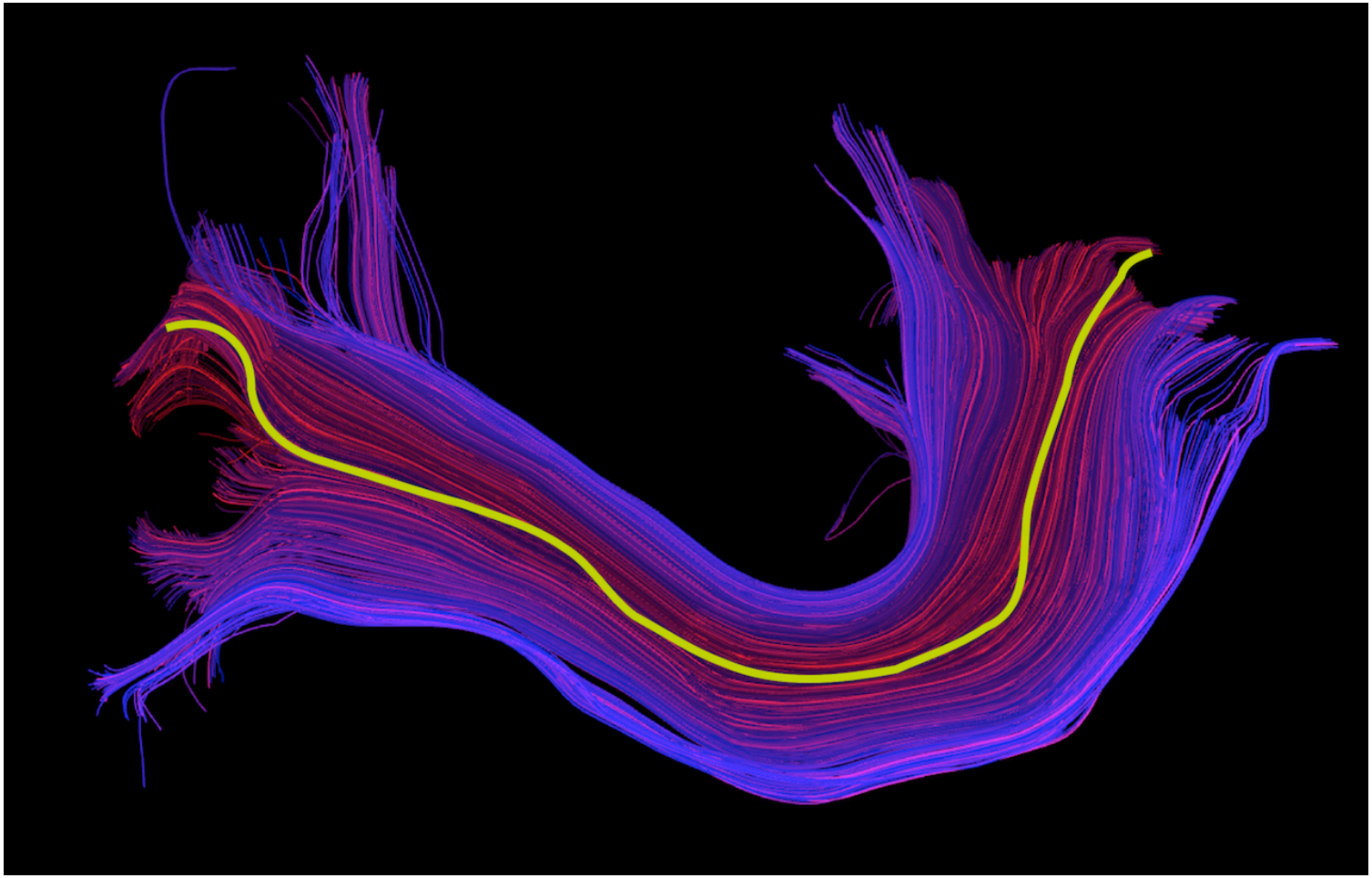
Mindboggle



fMRI features



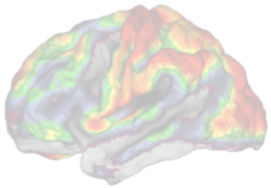
dMRI features



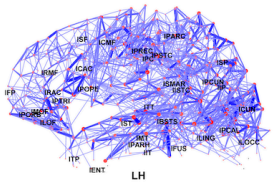
Tractography features

Eleftherios Garyfallidis, 2011

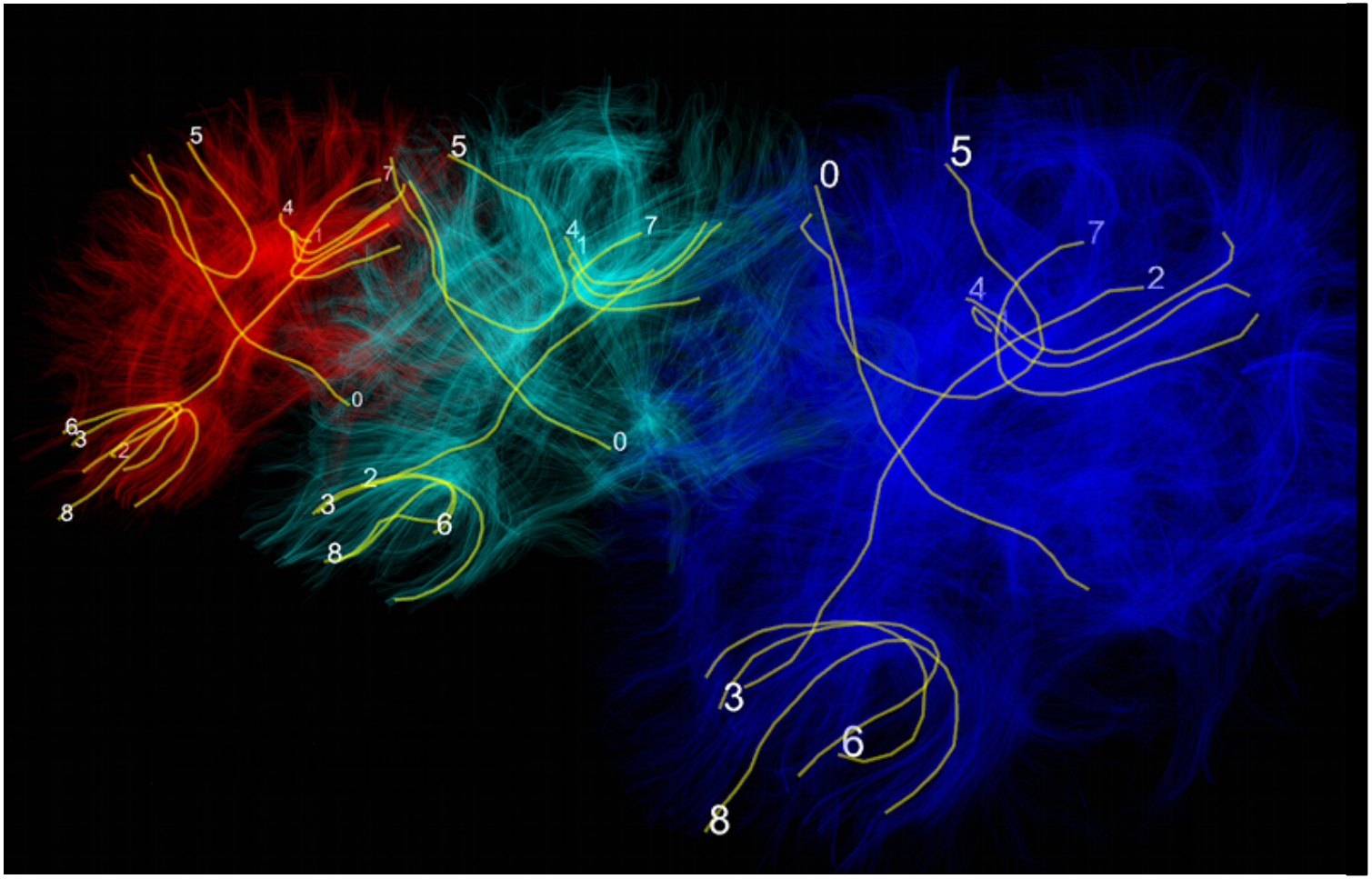
Mindboggle



fMRI features



dMRI features



Tractography features

Eleftherios Garyfallidis, 2011

Mindboggle team

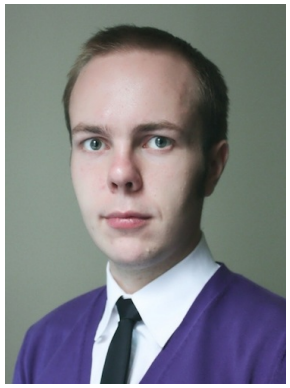
Depth and curvature

Joachim Giard
Univ. Catholique de Louvain, Belgium

Nested features

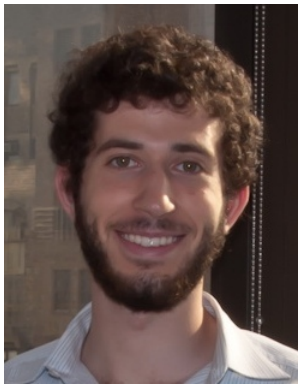
Forrest Bao
Texas Tech

Probabilistic features



Yrjö Häme
Columbia PhD student

Label propagation



Eliezer Stavsky
Columbia PhD student

Anatomical labeling

Greg Millington
Neuromorphometrics, Inc.

Jason Tourville
Boston U.

dMRI features

Eleftherios Garyfallidis
Cambridge University

Machine learning

Satrajit Ghosh
MIT