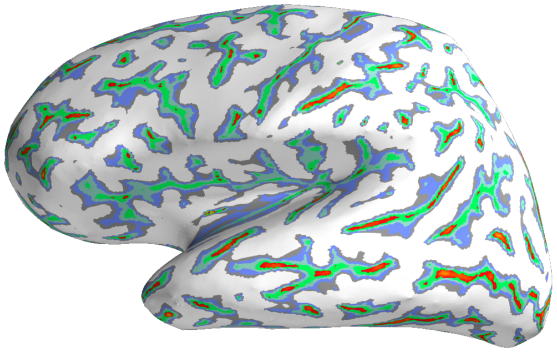
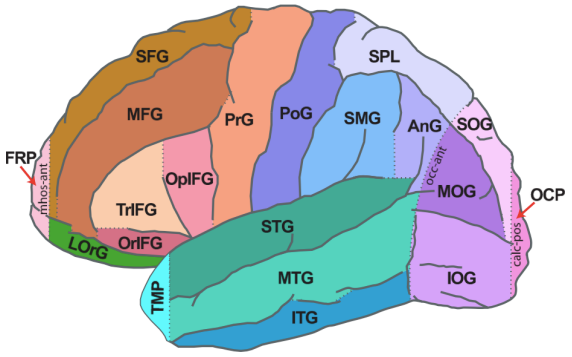
Mindboggle

An informatics framework for open research in quantifying the shape of the human brain





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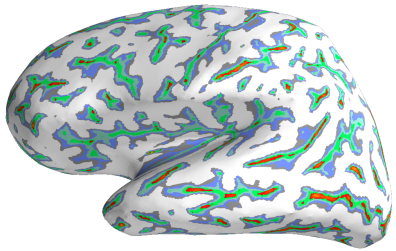
asst. professor of clinical neurobiology
columbia university

September 19, 2011
BioImage Informatics II, Janelia Farm

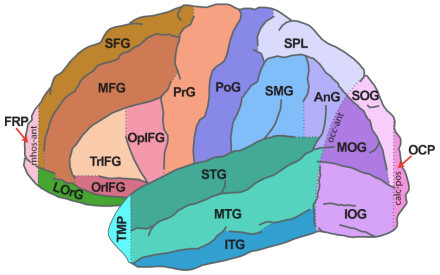
NIMH RO1 grant #MH084029-03

www.mindboggle.info/lectures

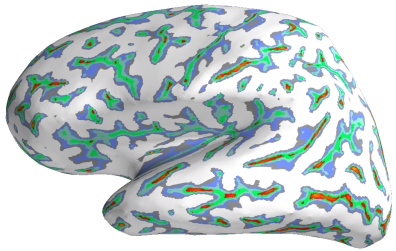


Shape analysis of brains

Informatics framework



Automated brain labeling



Shape analysis of brains

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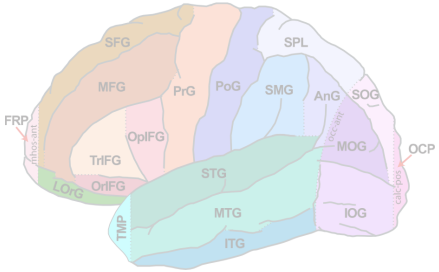
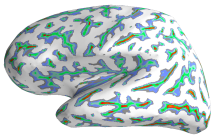
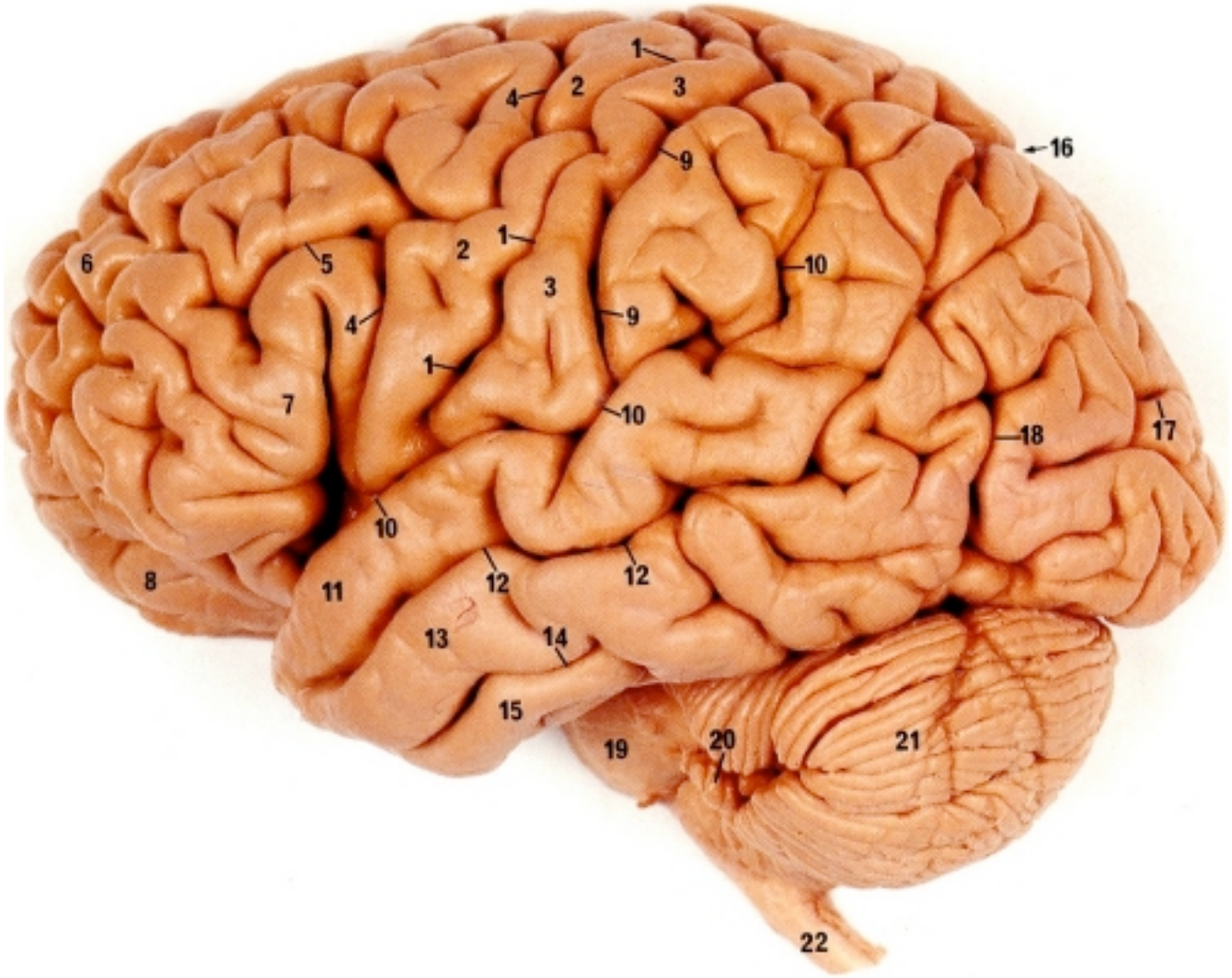


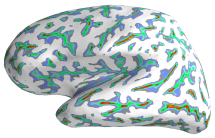
Automated brain labeling



Shape analysis

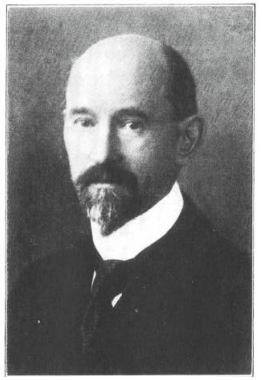
the brain



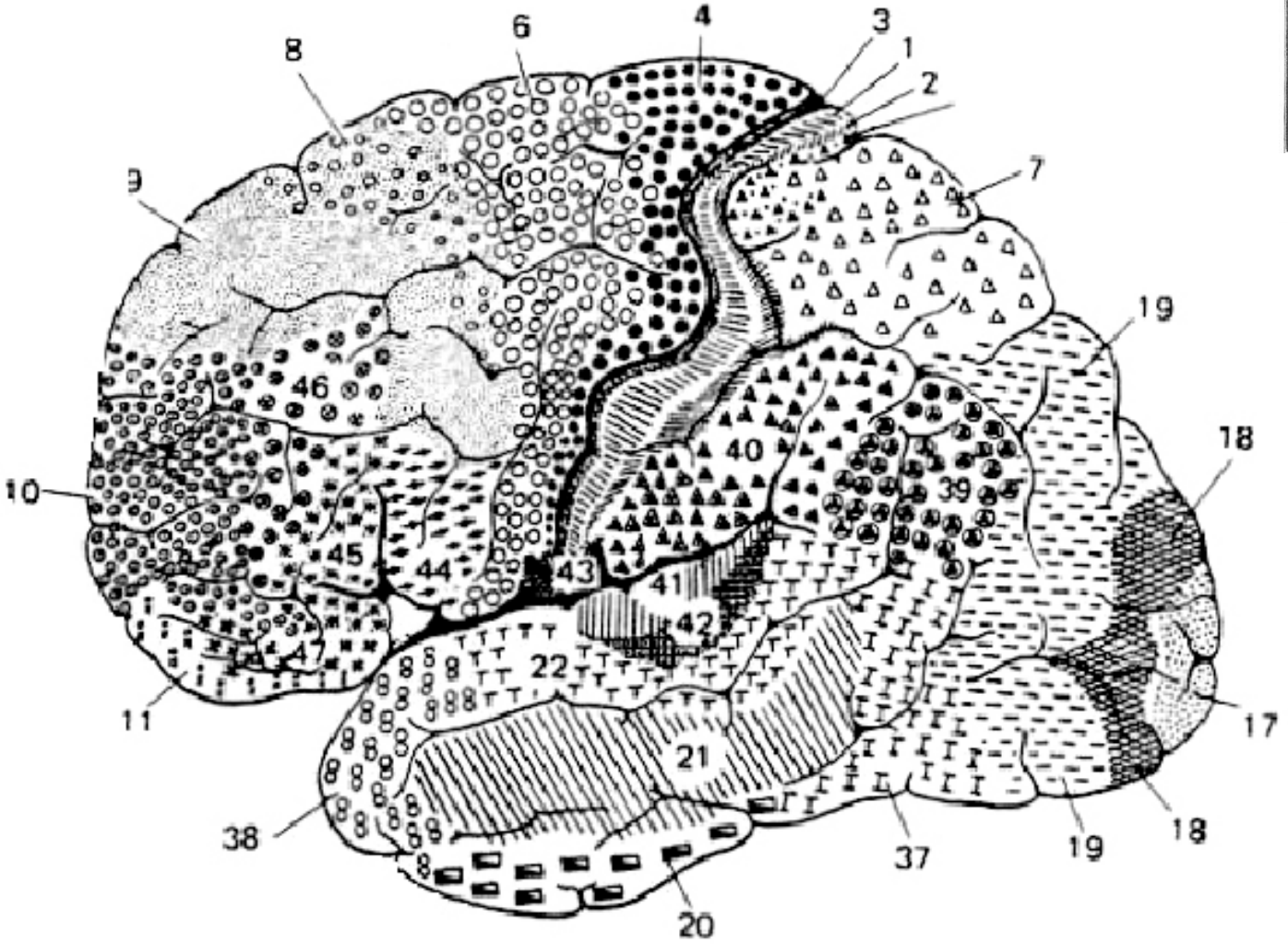


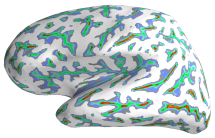
Shape analysis

cytoarchitectonic boundaries



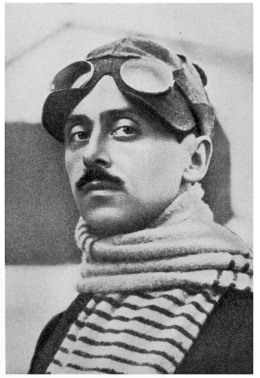
Korbinian Brodmann
(1868-1918)





Shape analysis

cytoarchitectonic boundaries



Constantin von Economo
(1876-1931)

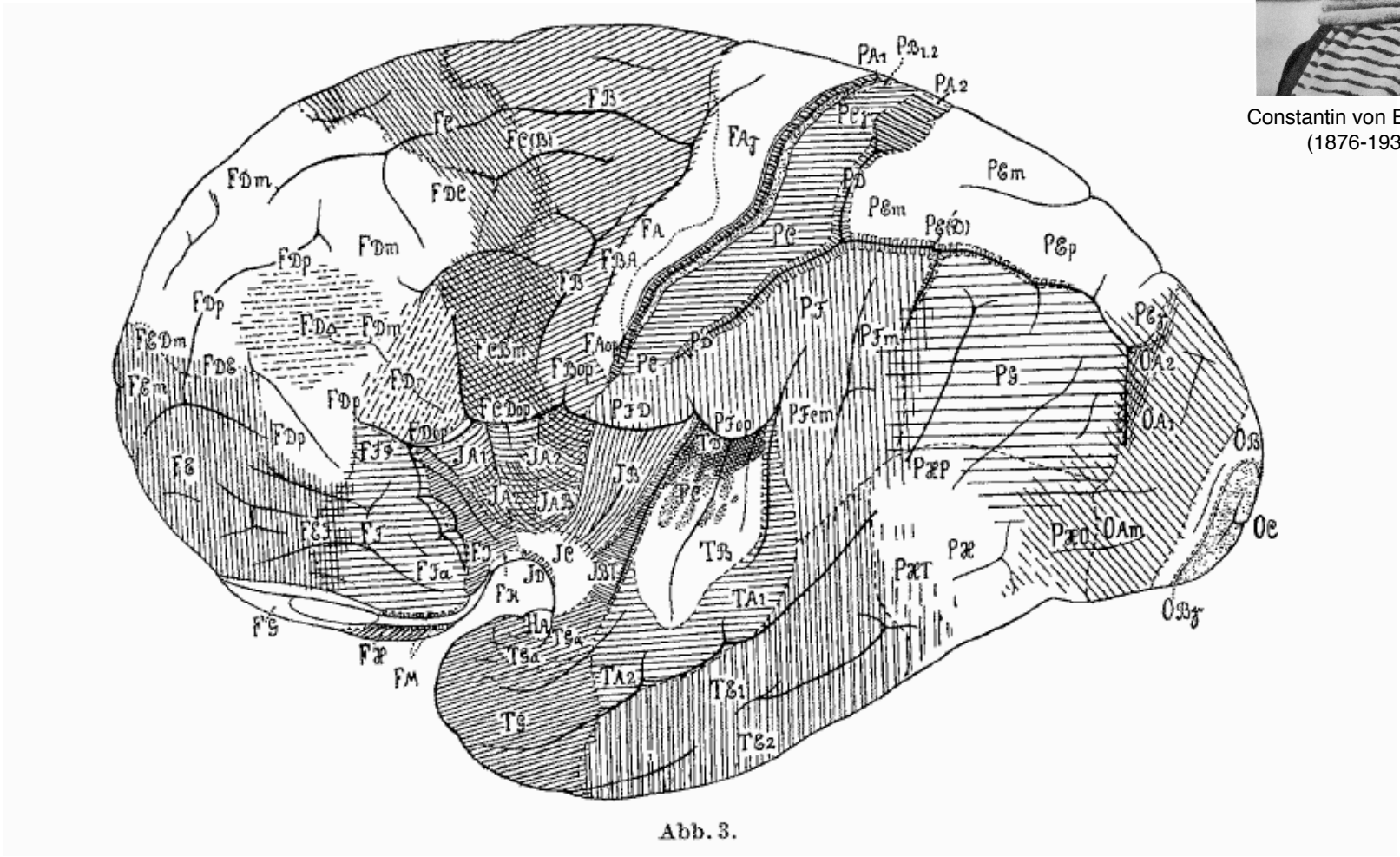
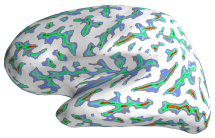


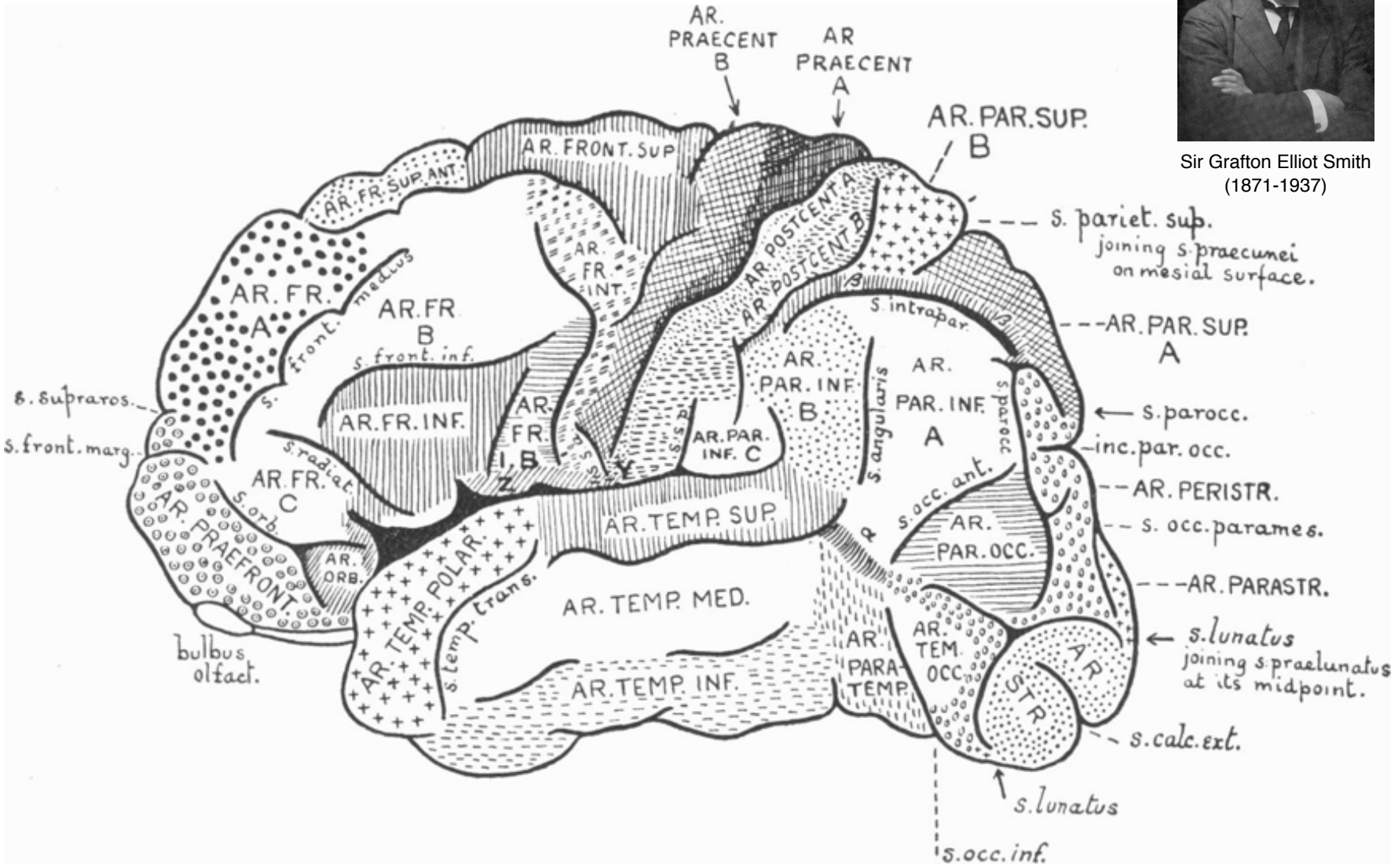
Abb. 3.

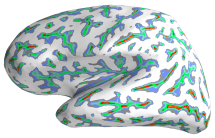


Shape analysis

topographic boundaries

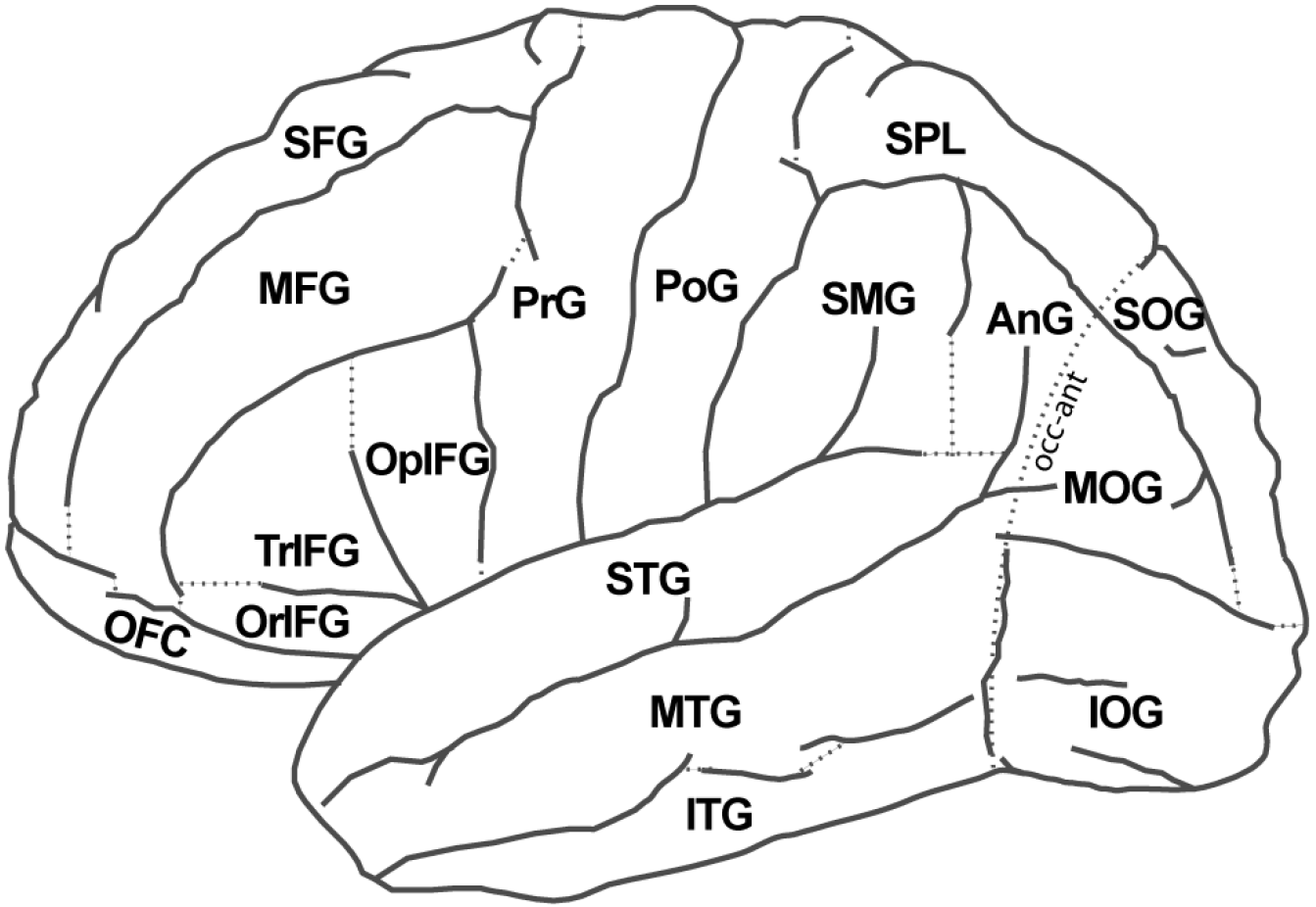
Sir Grafton Elliot Smith
(1871-1937)

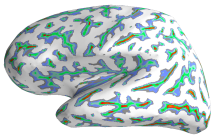




Shape analysis

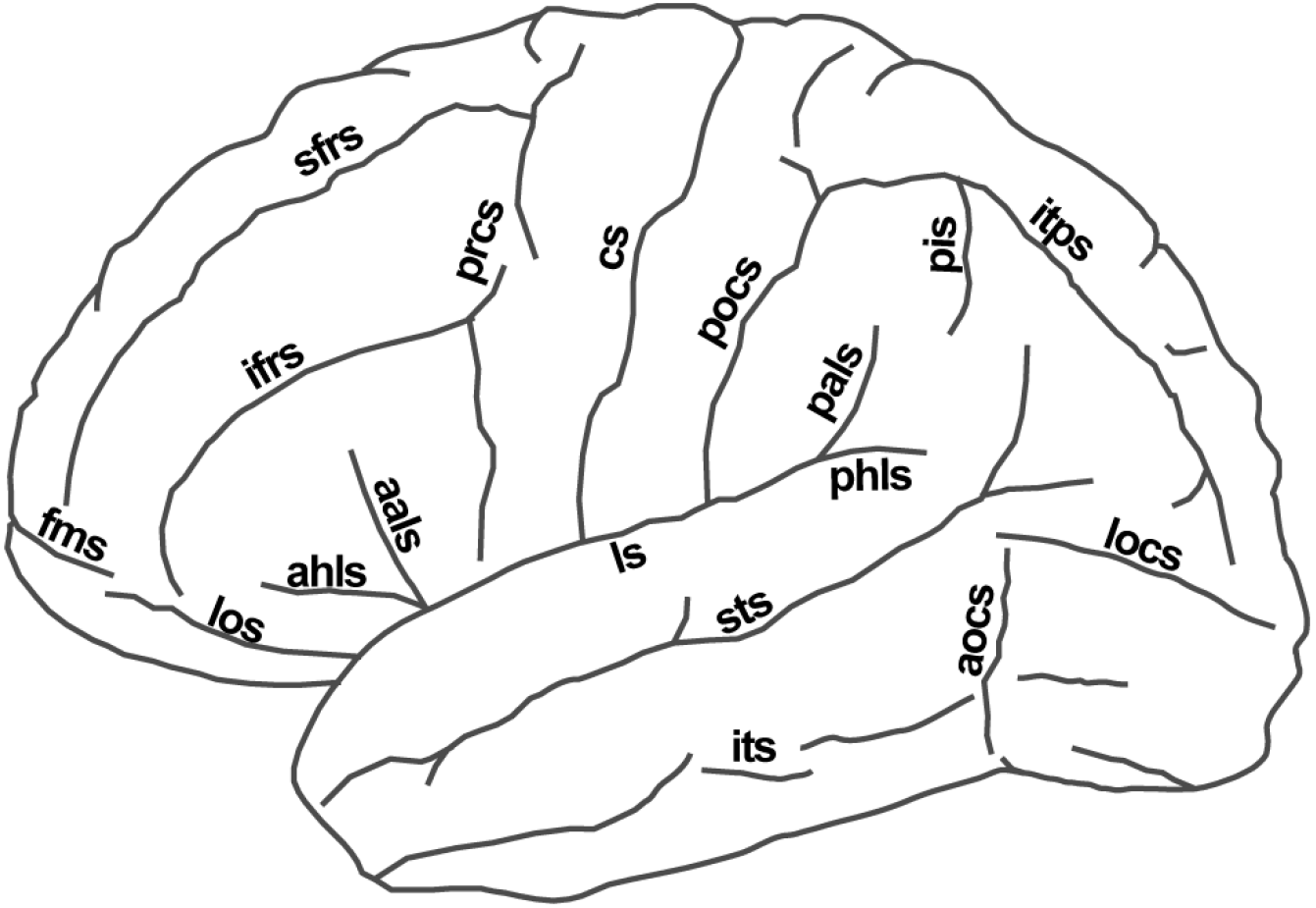
gyrus definitions

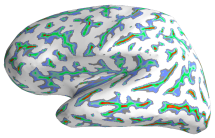




Shape analysis

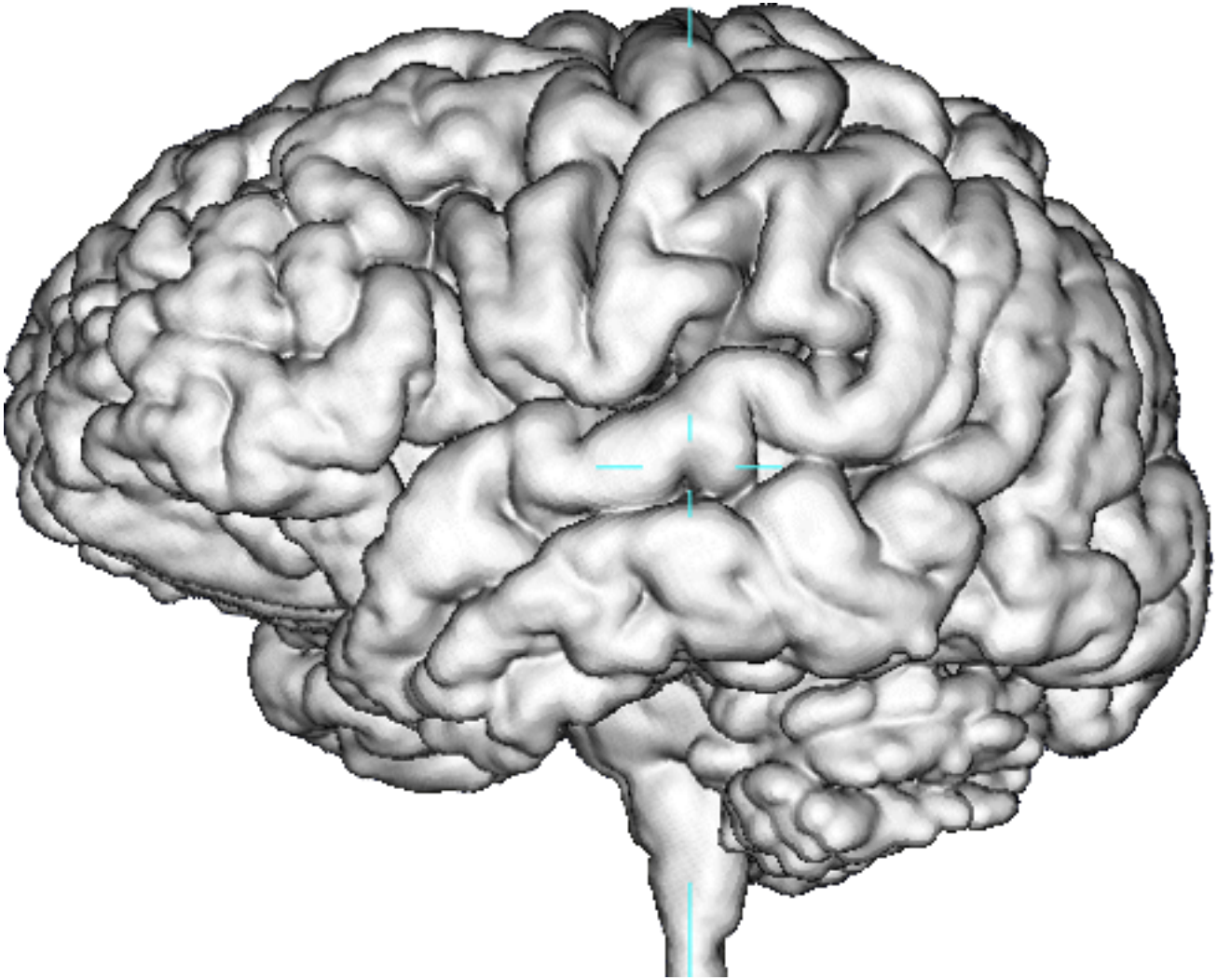
sulcus folds

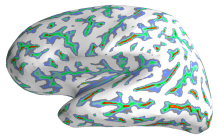




Shape analysis

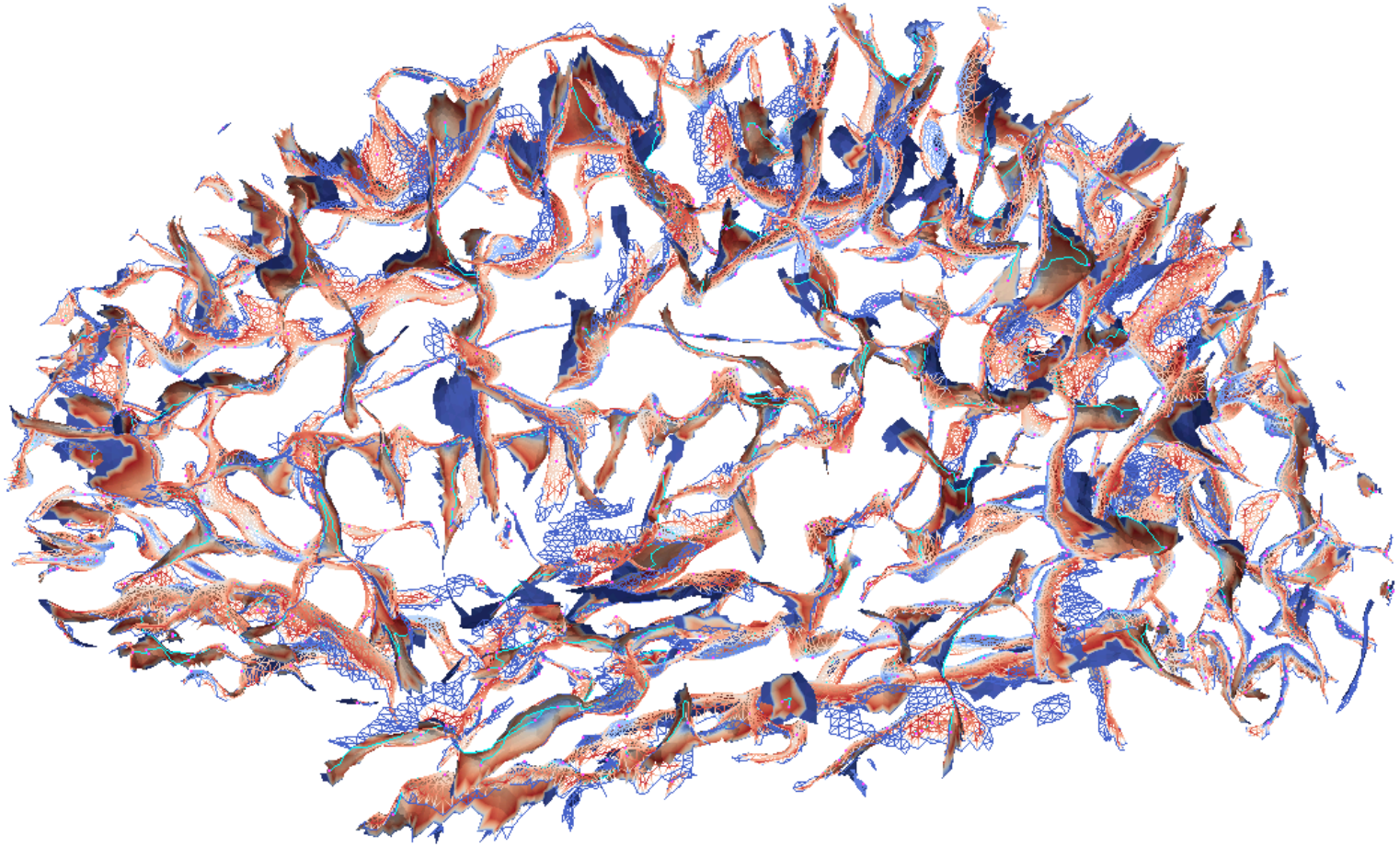
sulcus folds

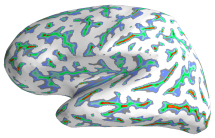




Shape analysis

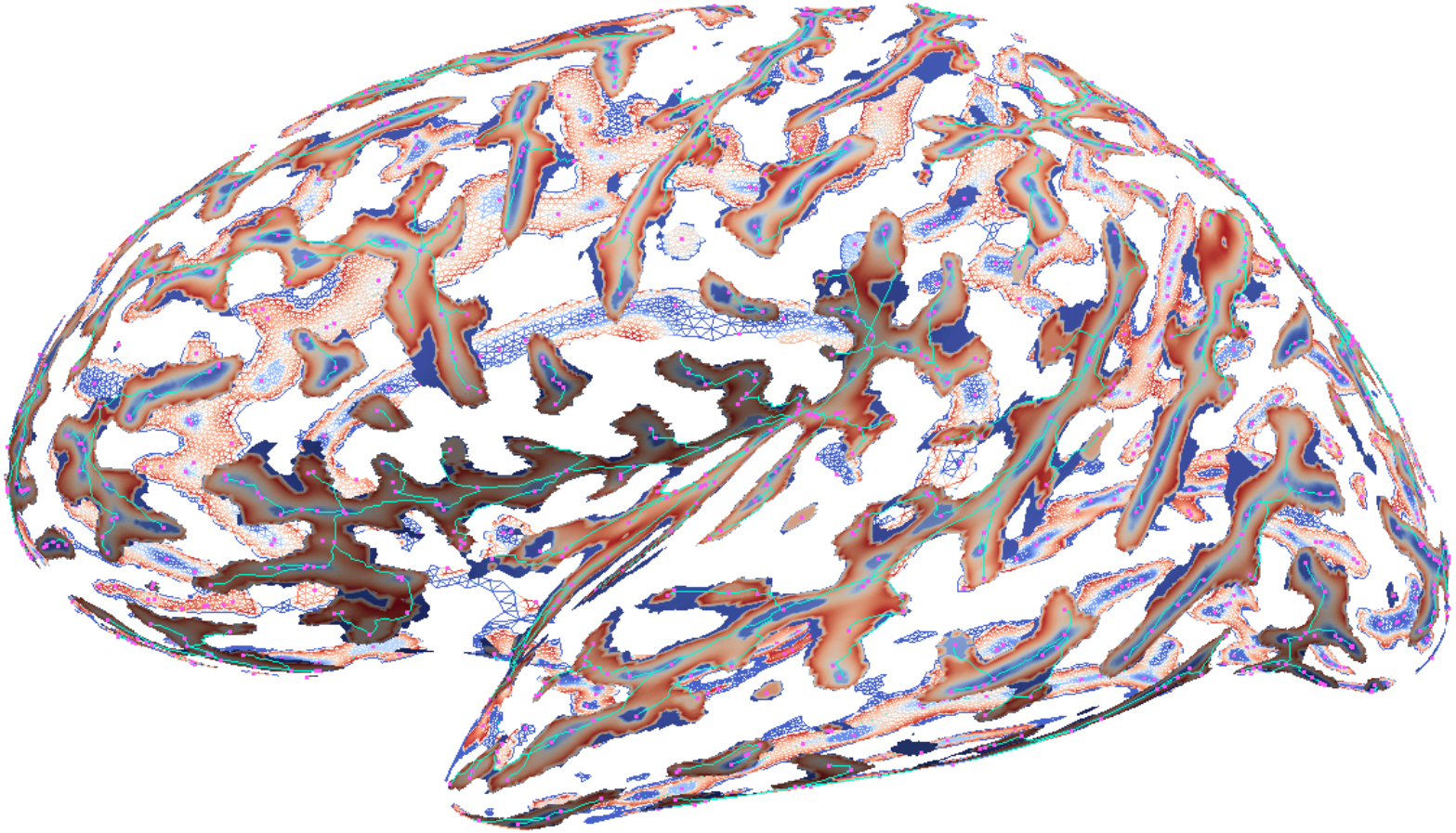
sulcus basins

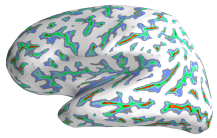




Shape analysis

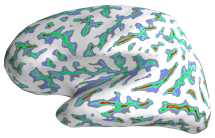
sulcus basins (inflated brain)





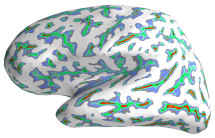
Shape analysis

curvature and depth maps



Shape analysis

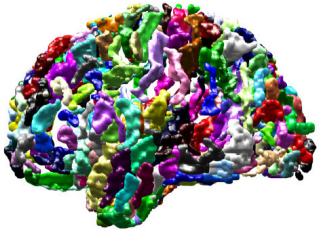
sulcus basins, fundi, and pits

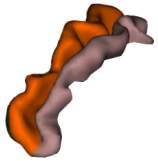


Shape analysis

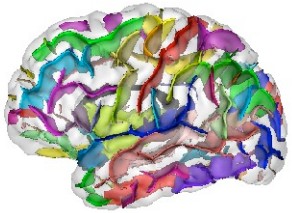
nested structures

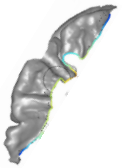
basins



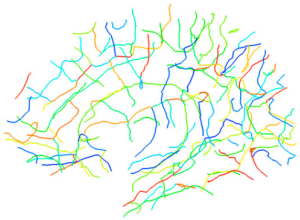


ribbons

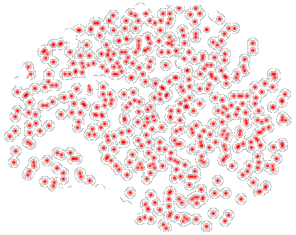


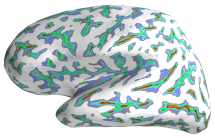


curves



points

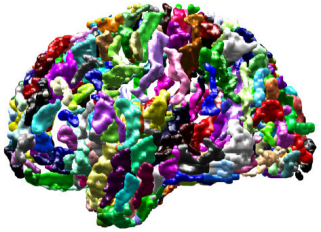


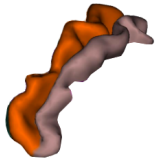


Shape analysis

geometric and shape quantification

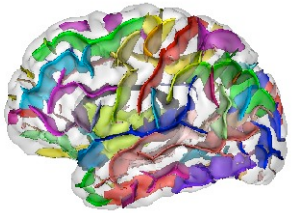
basins

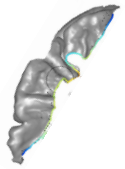




volume
surface area
cortical thickness / sulcal span
...

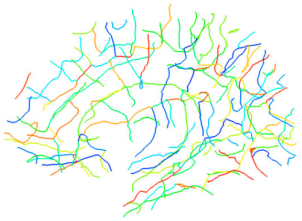
ribbons





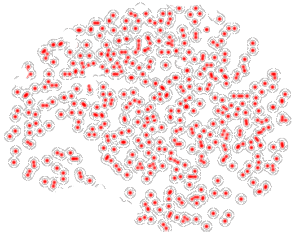
convex hull volume
surface area
depth
curvature
convexity
spectral components
...

curves

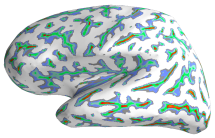


length / tortuosity
depth
curvature
convexity
spectral components
...

points

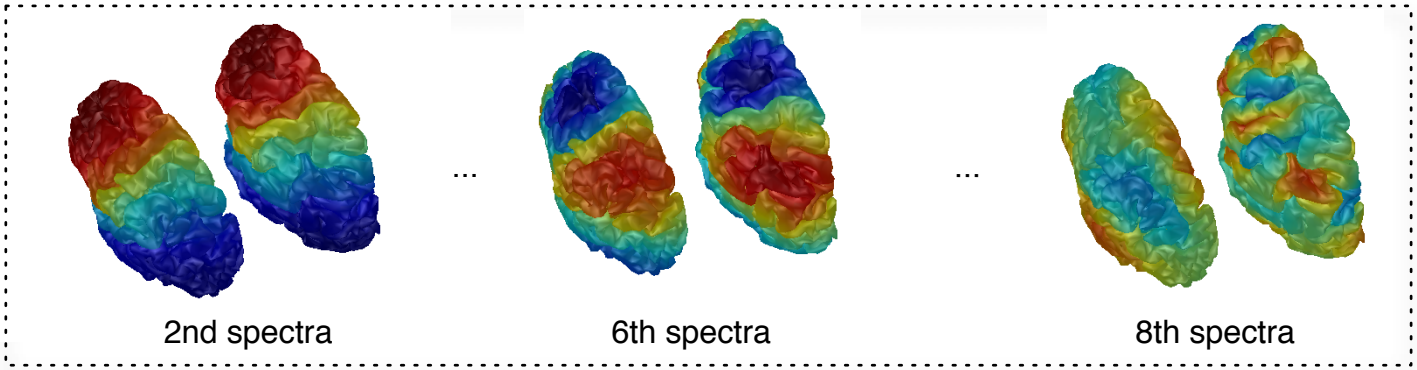


convex hull volume
sequence along a curve
...

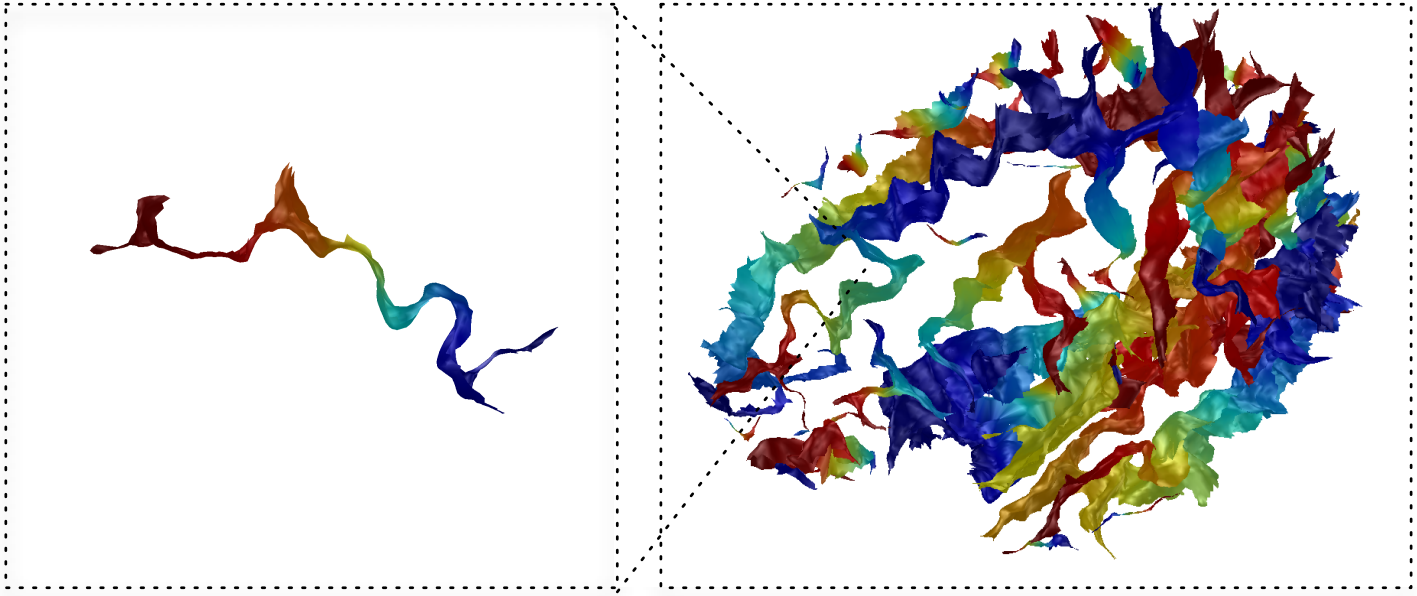


Shape analysis

spectral quantification: Laplace-Beltrami operator

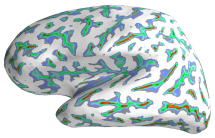


Global to local



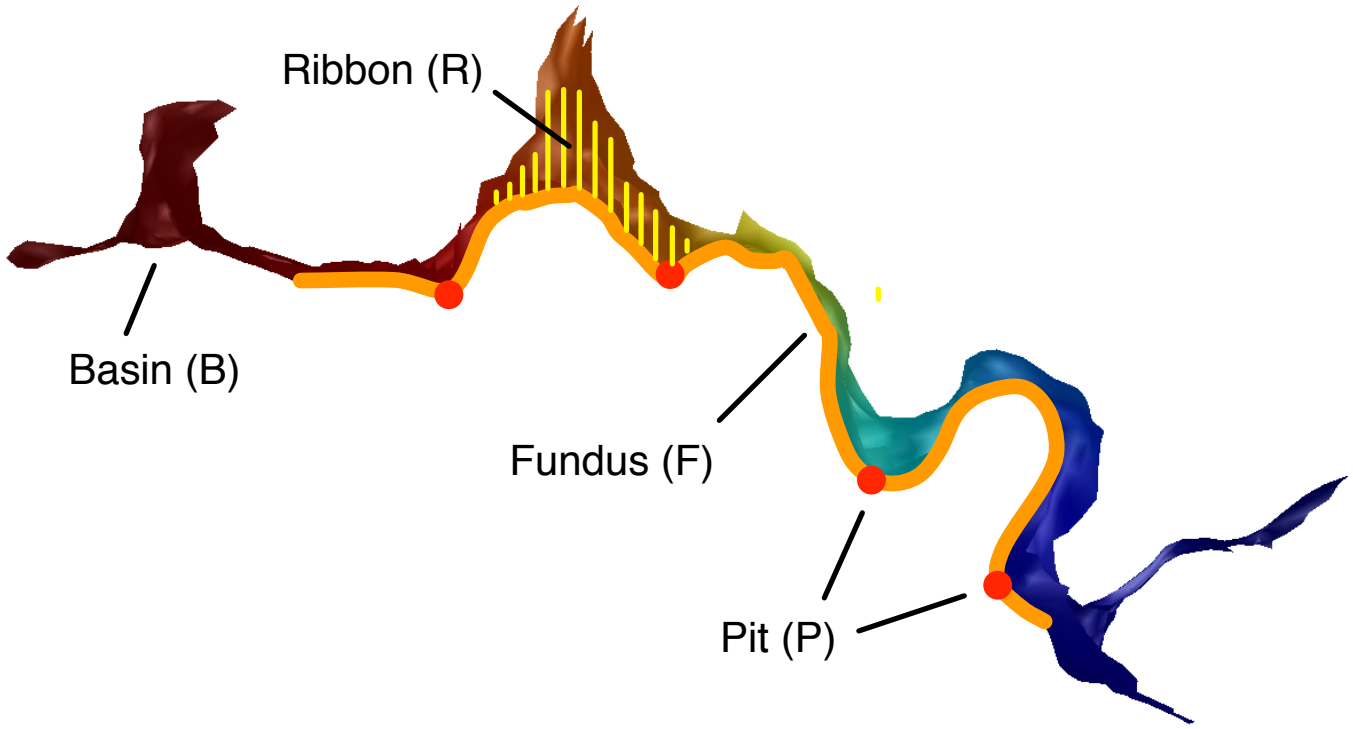
LBO on sulcal basin

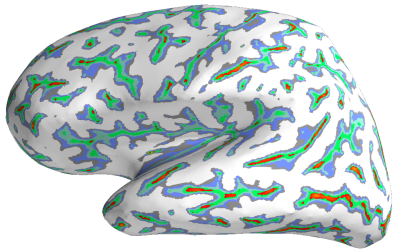
LBO on sulcal basins of left hemisphere



Shape analysis

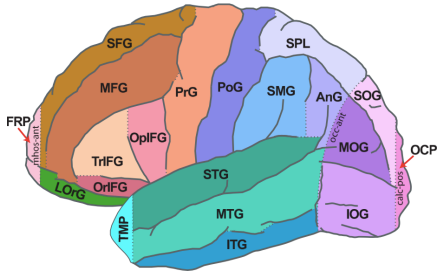
nested structures example



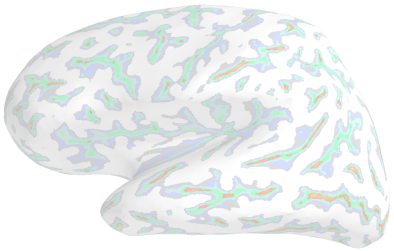


Shape analysis of brains

Informatics framework

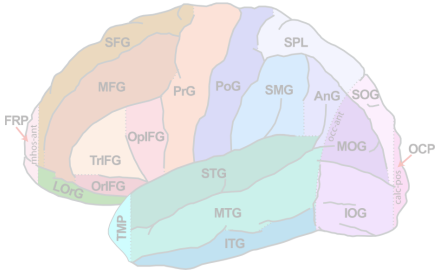


Automated brain labeling



Shape analysis of brains

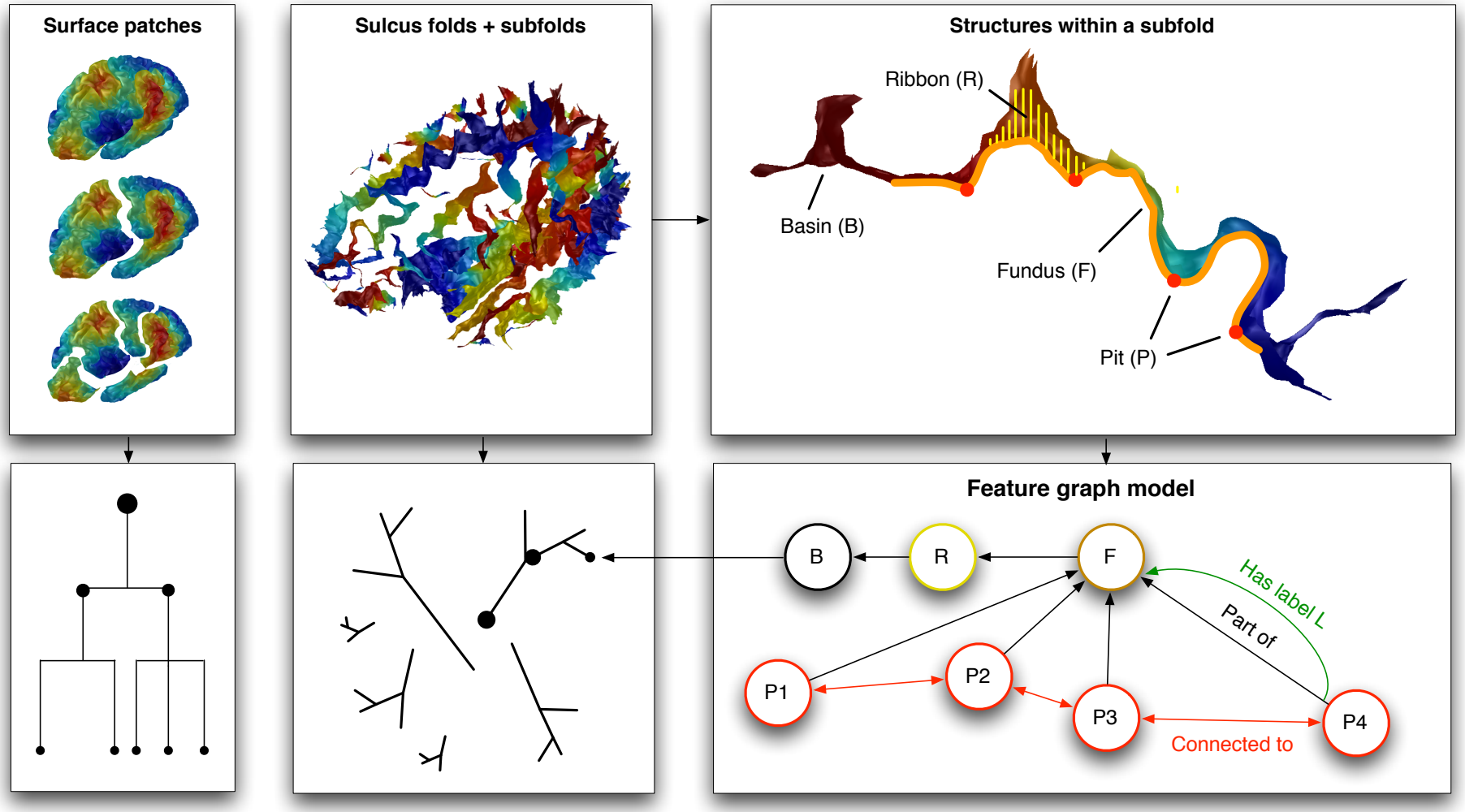
Informatics framework



Automated brain labeling

Informatics framework

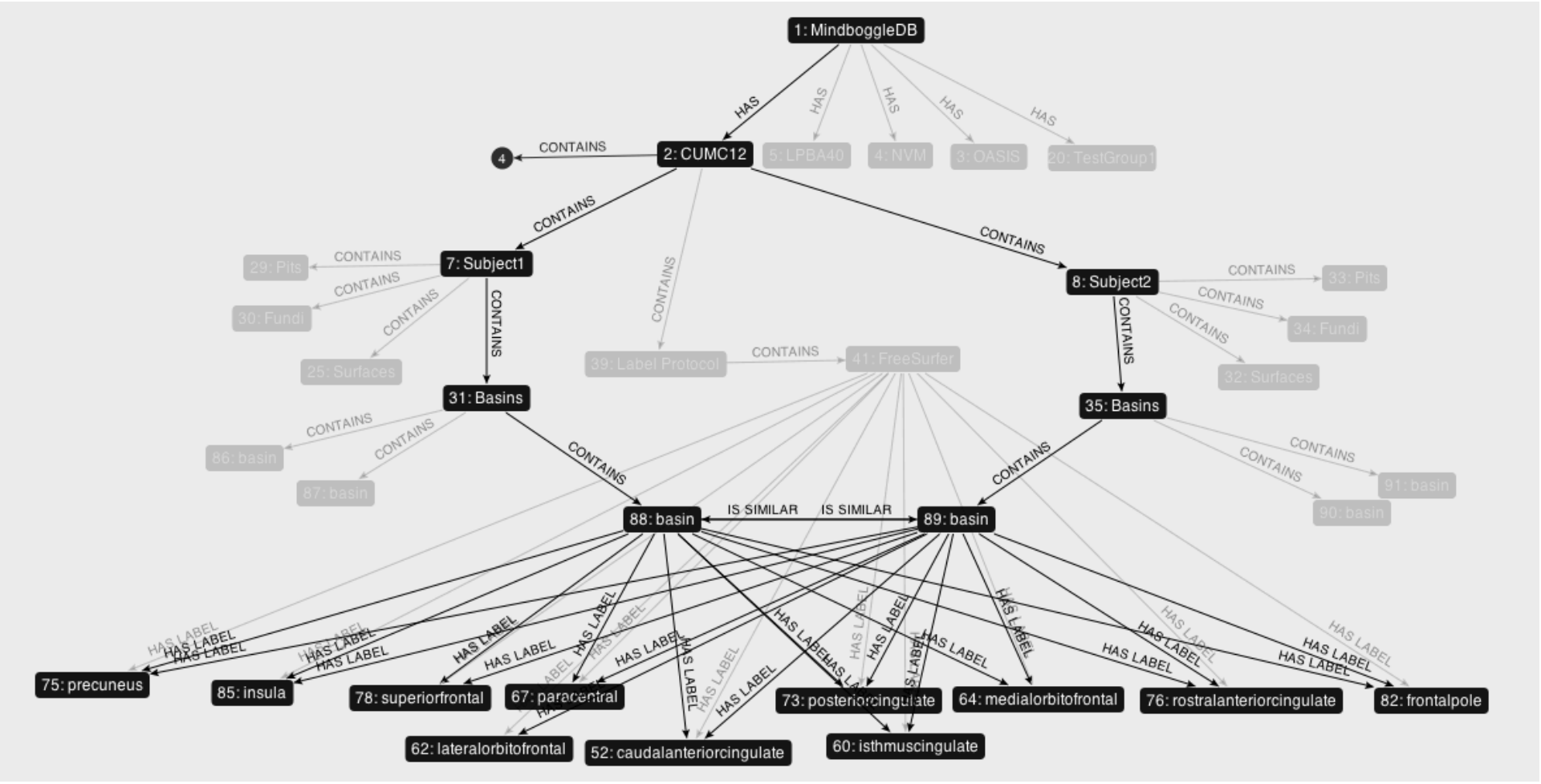
nested structures within a graph-based data model



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).

Informatics framework

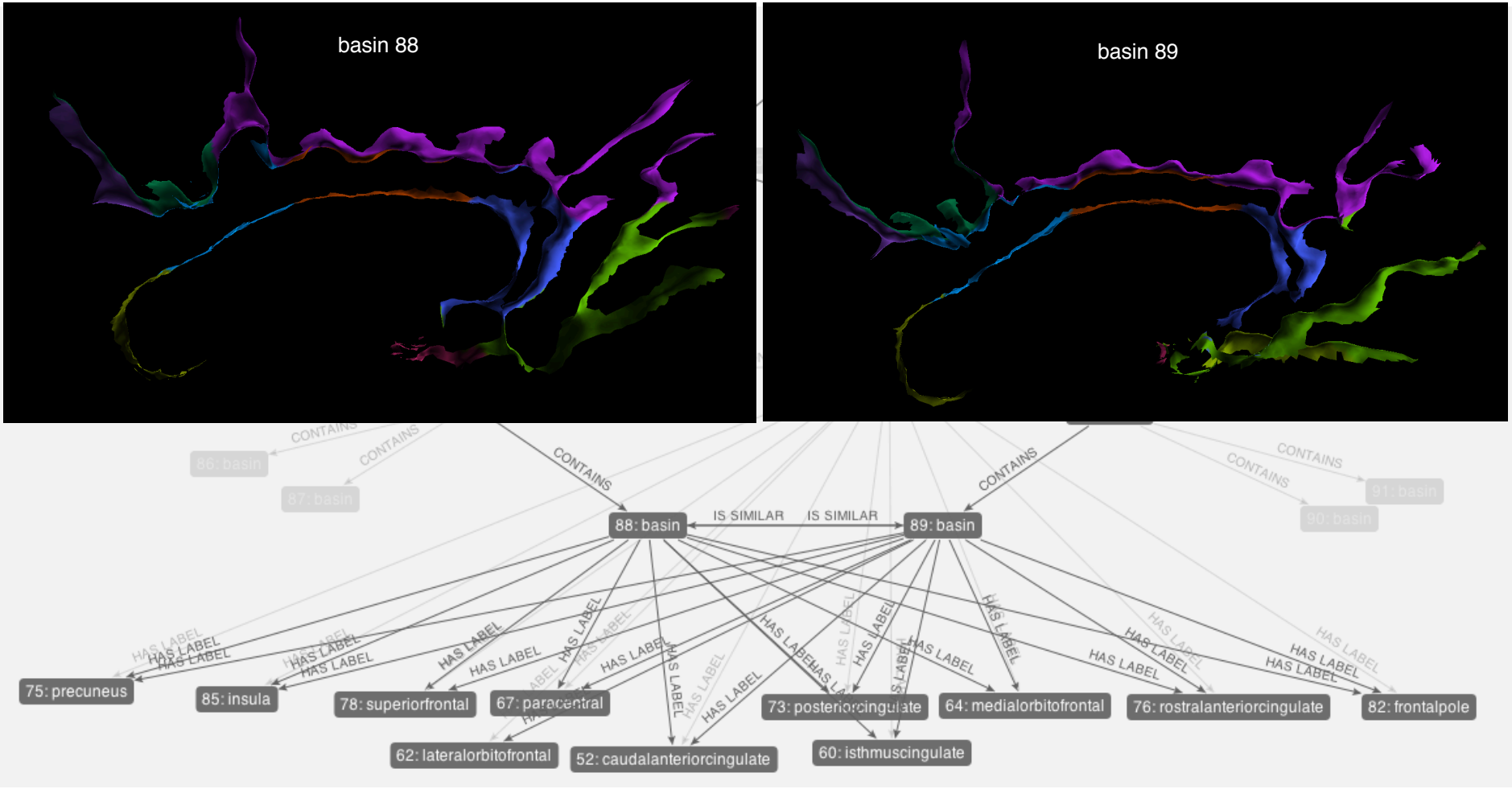
graph-based database of hierarchical brain features



This graph model shows an example of how relations between basins and their labeled regions are represented for two (CUMC12) subjects. Note that basin 88 and 89 share similar labels.

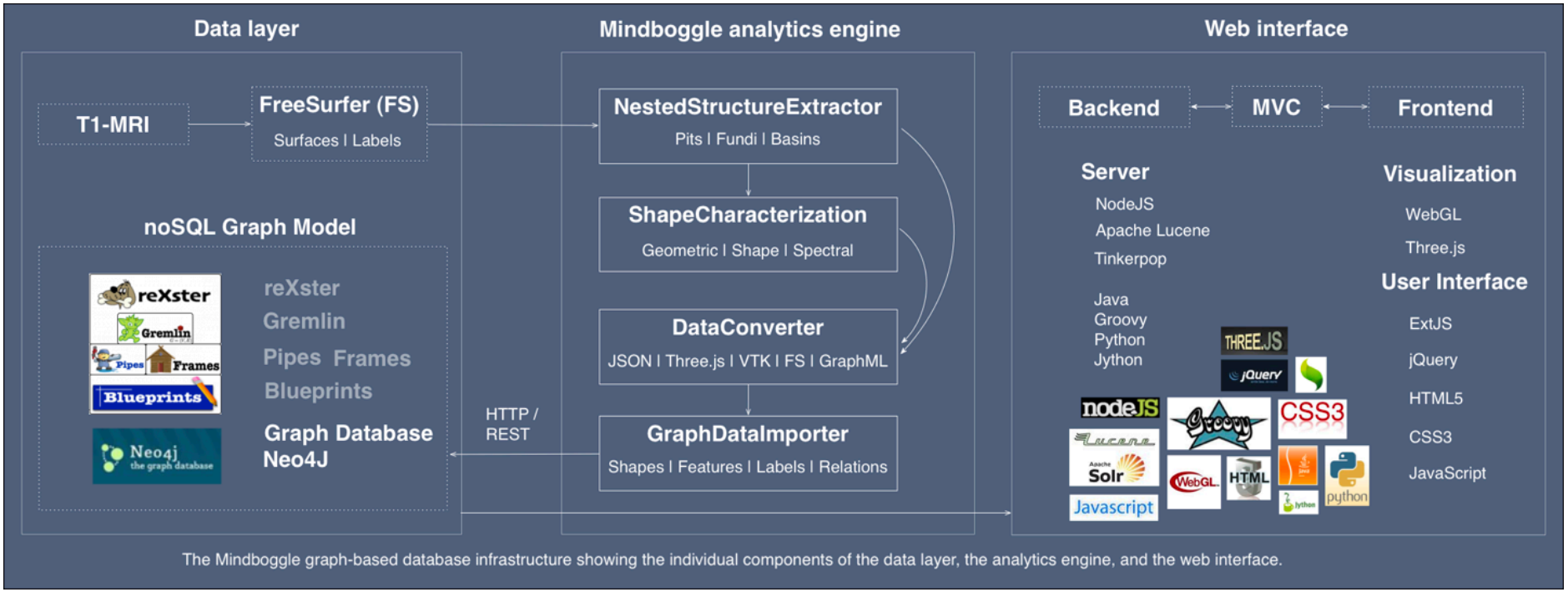
Informatics framework

graph-based database: example query



Informatics framework

graph-based database: infrastructure and example query



The Mindboggle graph-based database infrastructure showing the individual components of the data layer, the analytics engine, and the web interface.

The graph model can be queried via REST, Cypher, reXster, or Gremlin. This example shows how to query all outgoing relations from basin 88:

Gremlin query:

```
{
"script": "g.v(88).outE"
}
```

JSON response:

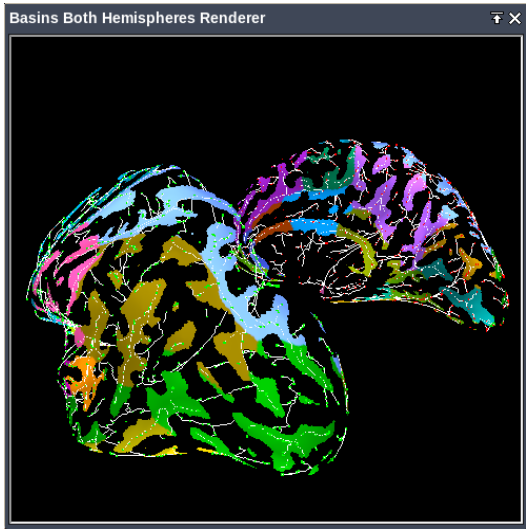
```
[ {
  "start" : "http://192.168.23.219:7474/db/data/node/88",
  "data" : {
  },
  "type" : "IS SIMILAR",
  "extensions" : {
  },
  "end" : "http://192.168.23.219:7474/db/data/node/89"
}, {
  "start" : "http://192.168.23.219:7474/db/data/node/88",
  "data" : {
  },
   "type" : "HAS LABEL",
  "extensions" : {
  },
  "end" : "http://192.168.23.219:7474/db/data/node/60"
},
```

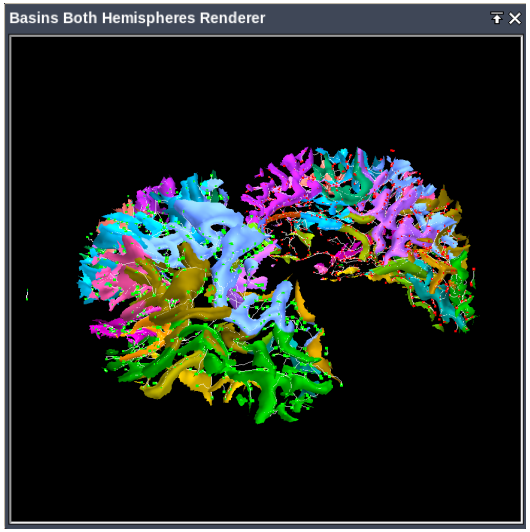
Informatics framework

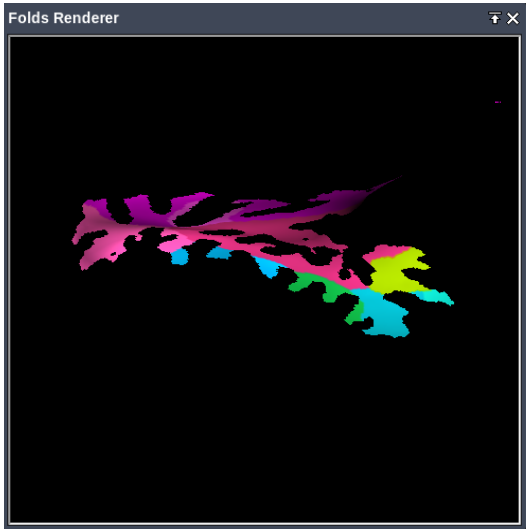
graph-based database: hierarchical structures view

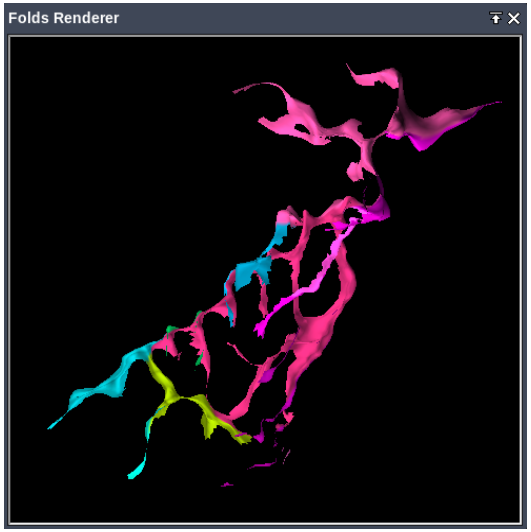
whole brain

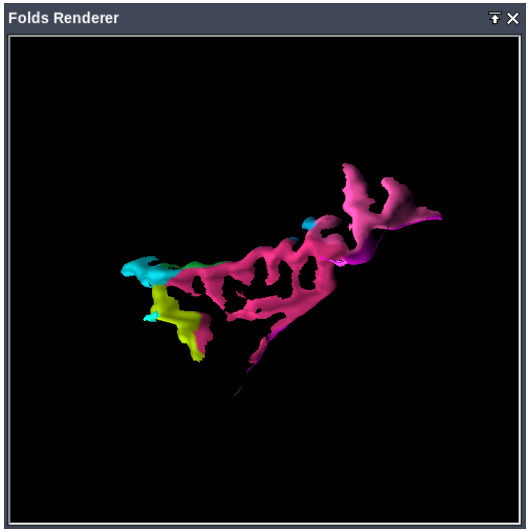
single folds











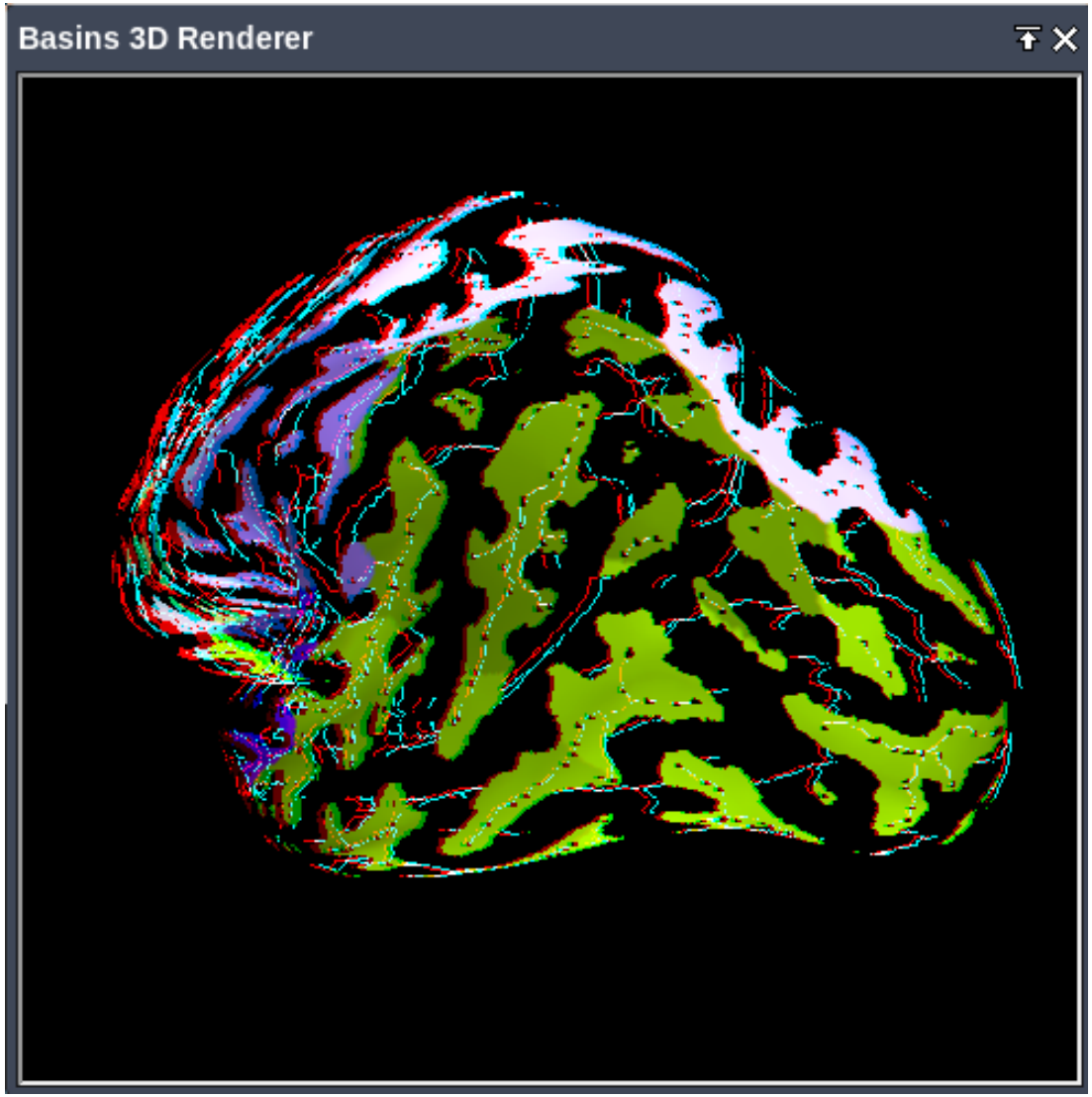
inflated

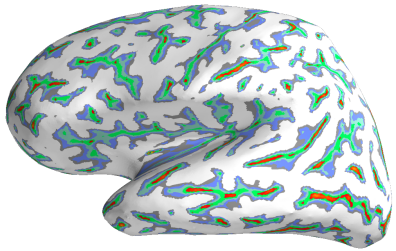
pial

white matter

Informatics framework

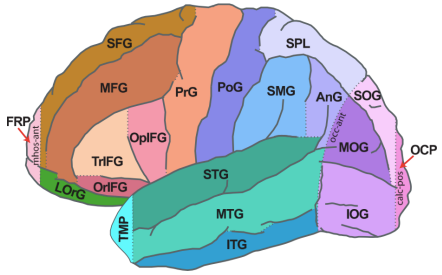
graph-based database: anaglyphic 3-D structures view



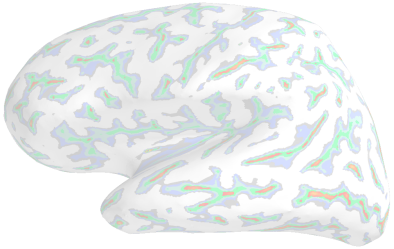


Shape analysis of brains

Informatics framework

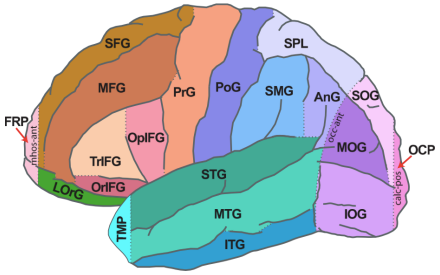


Automated brain labeling

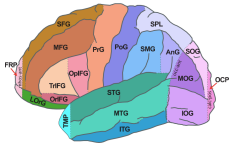


Shape analysis of brains

Informatics framework



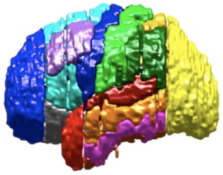
Automated brain labeling

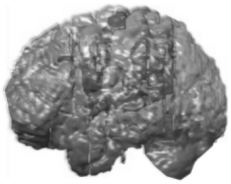


Automated labeling

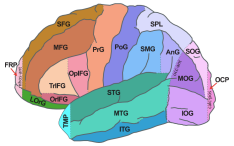
convention: registration-based labeling

atlas





target



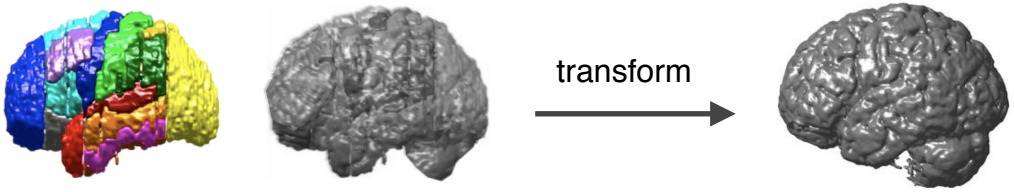
Automated labeling

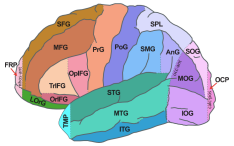
convention: registration-based labeling

Step 1: compute the registration transform from the atlas to the target

atlas

target

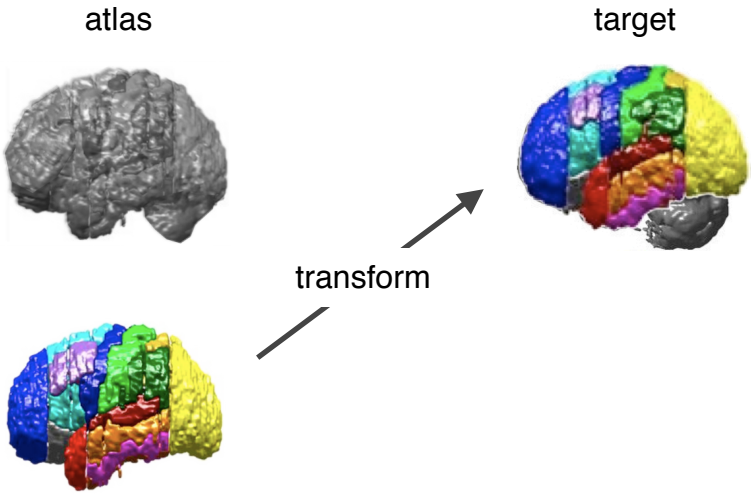


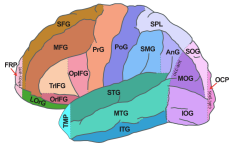


Automated labeling

convention: registration-based labeling

Step 2: apply the transform to the atlas labels

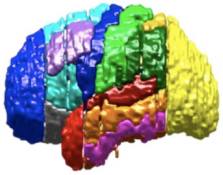


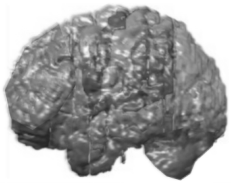


Automated labeling

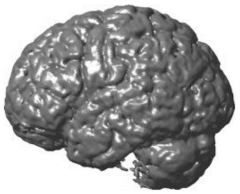
Mindboggle: feature-based labeling

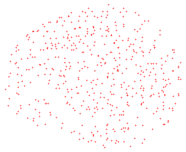
atlas

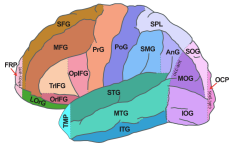




target



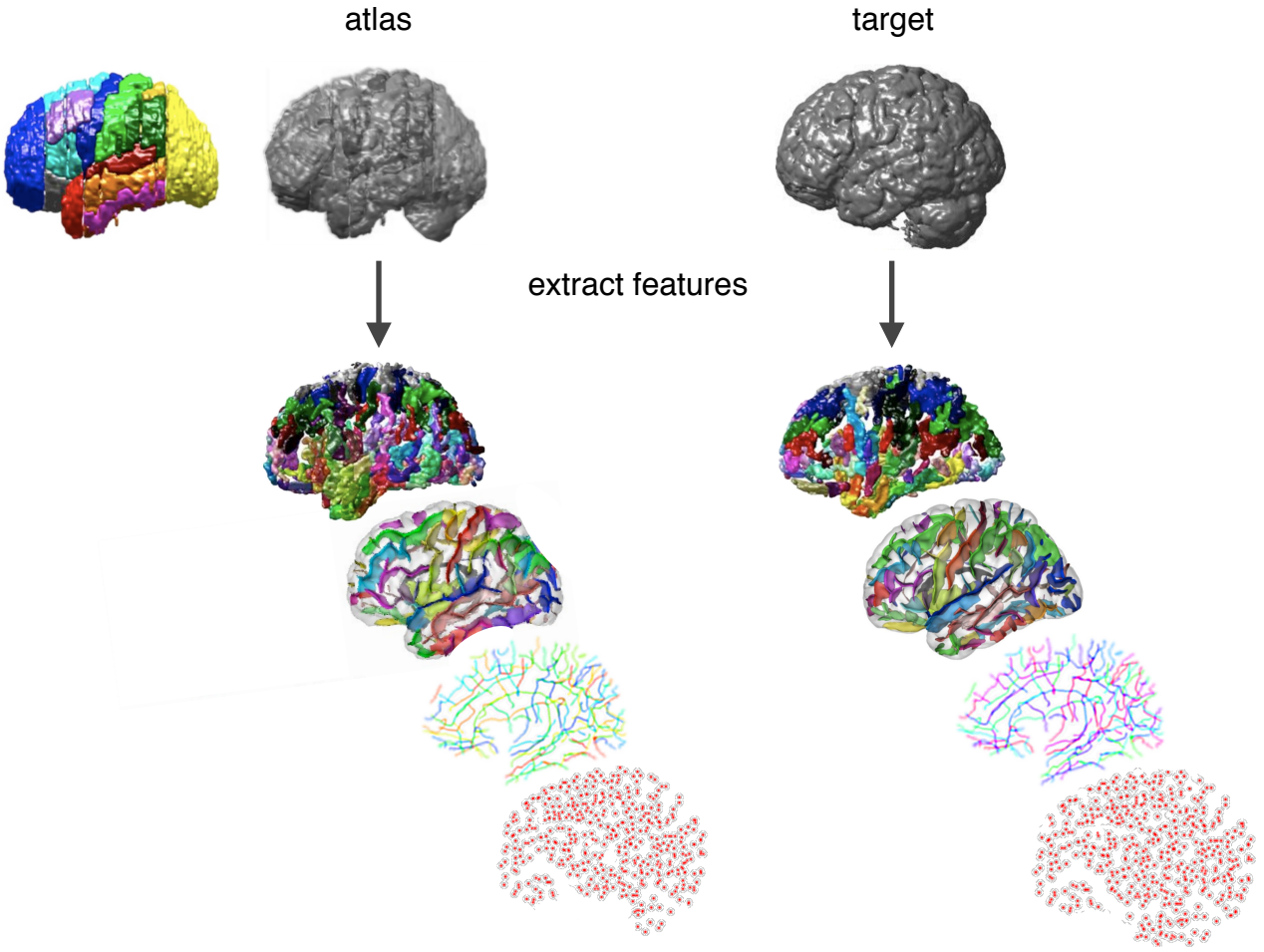


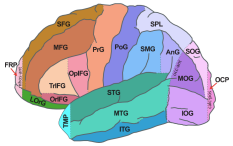


Automated labeling

Mindboggle: feature-based labeling

Step 1: extract features

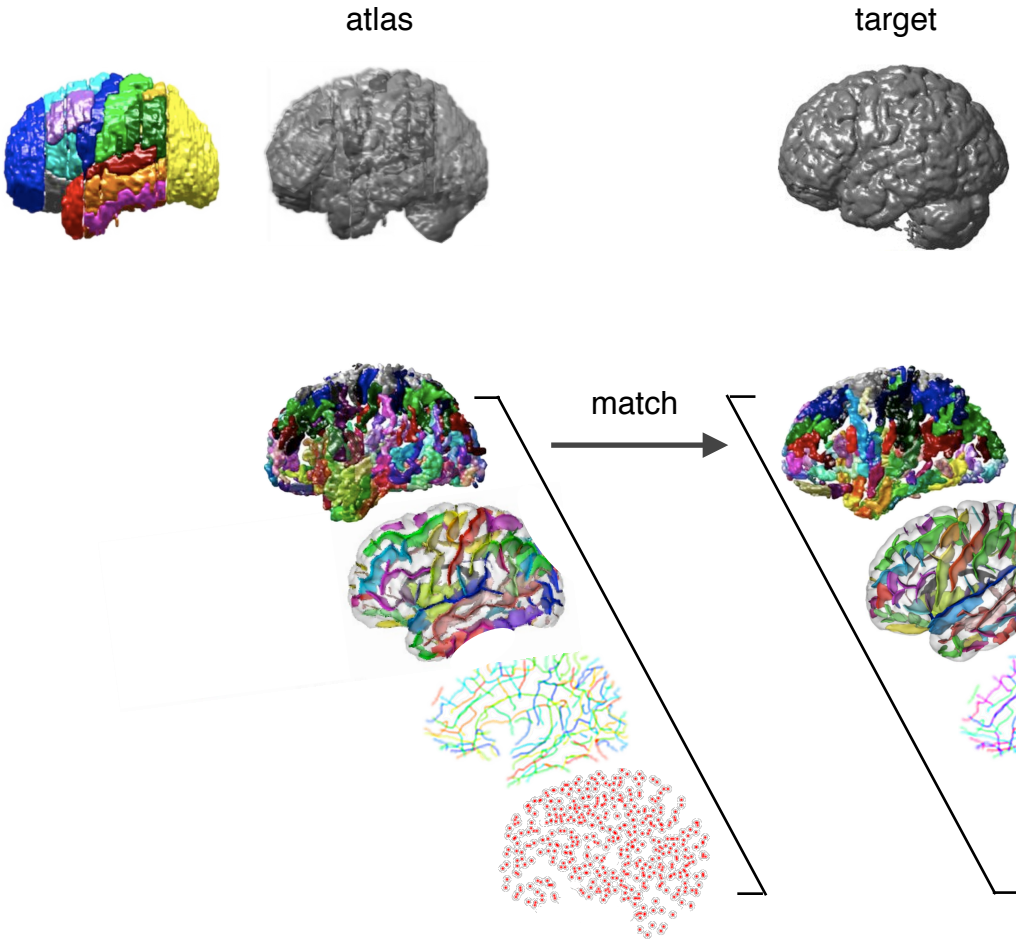


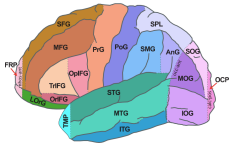


Automated labeling

Mindboggle: feature-based labeling

Step 2: match atlas and target features

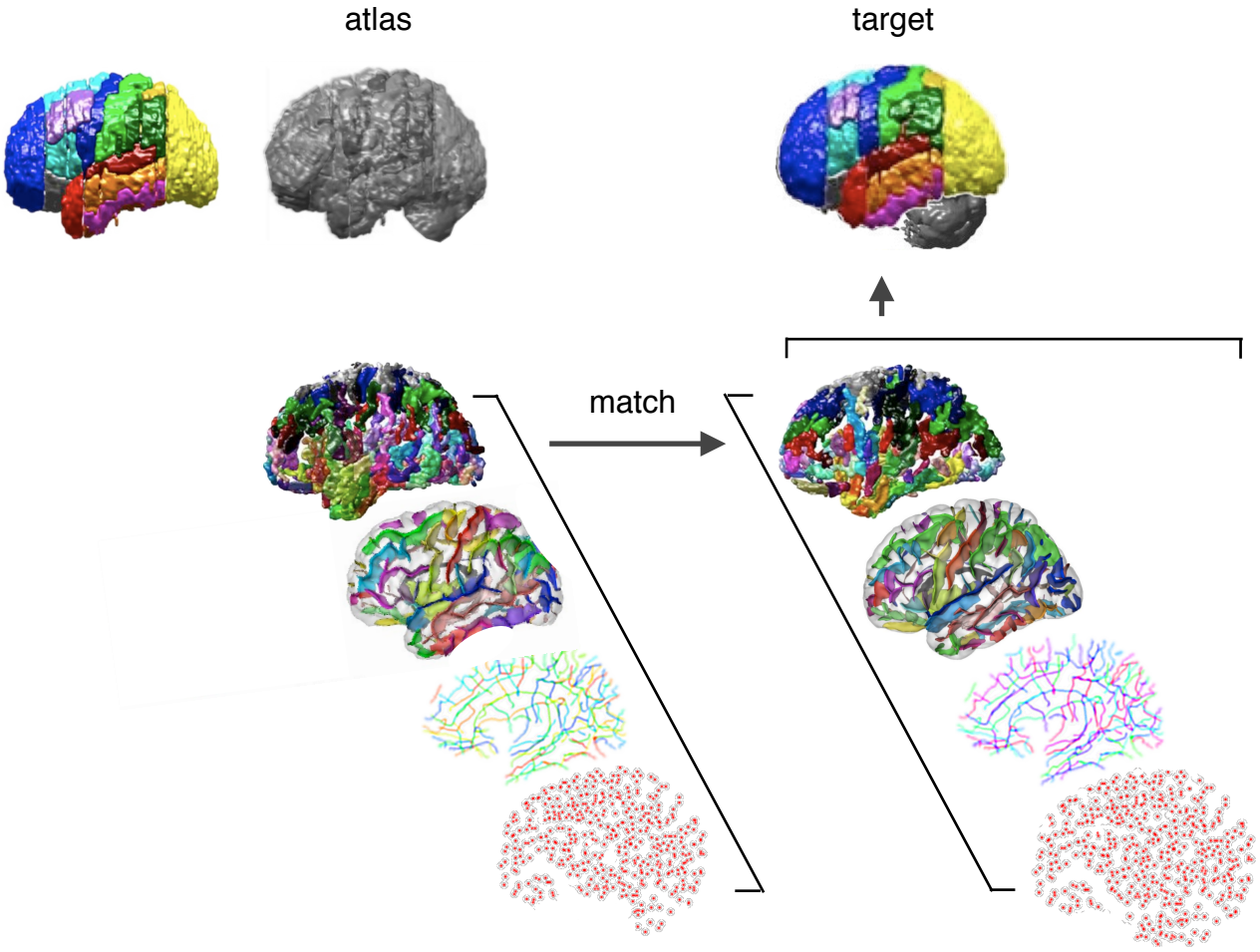


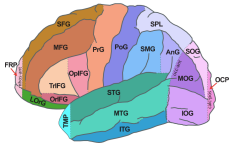


Automated labeling

Mindboggle: feature-based labeling

Step 3: propagate labels within inferred label boundaries?

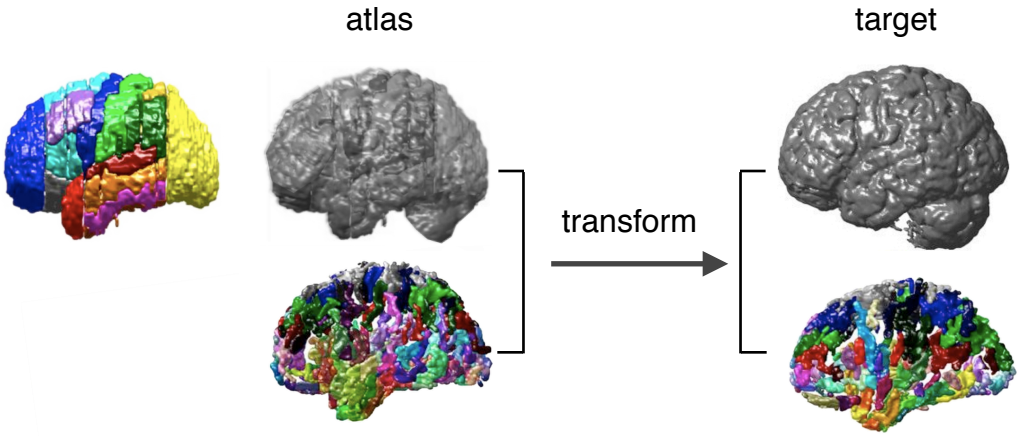


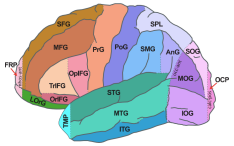


Automated labeling

Mindboggle: feature-based labeling

Alternative Step 3: compute image + landmark-based registration transform from atlas to target

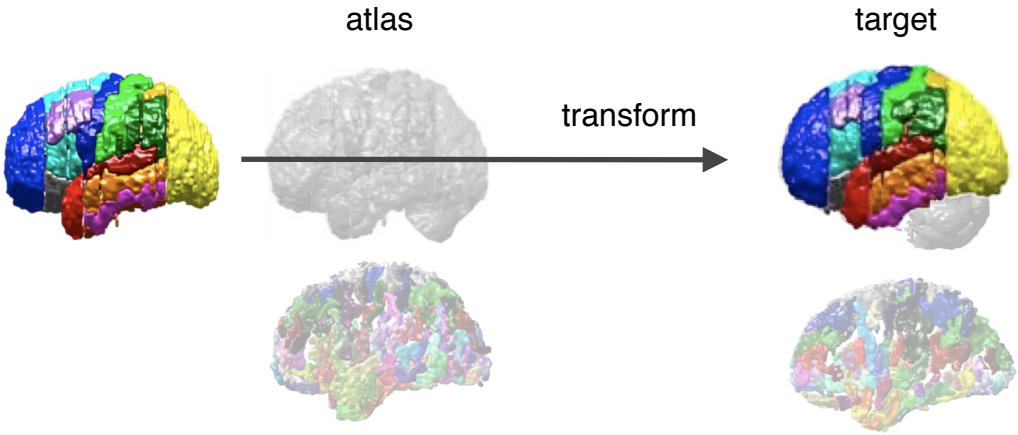




Automated labeling

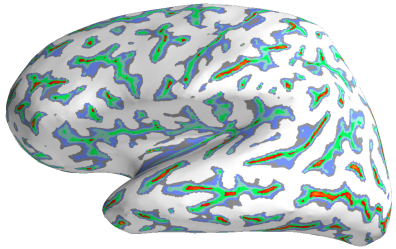
Mindboggle: feature-based labeling

Step 4: apply registration transform to atlas labels



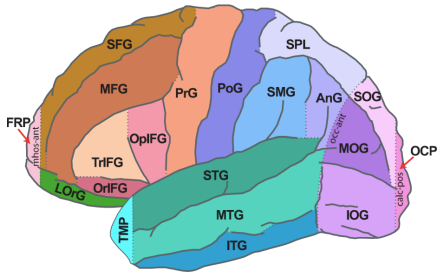
Mindboggle open source software:

shape analysis
querying the graph-based database
interactive visualization
automated anatomical labeling



Shape analysis of brains

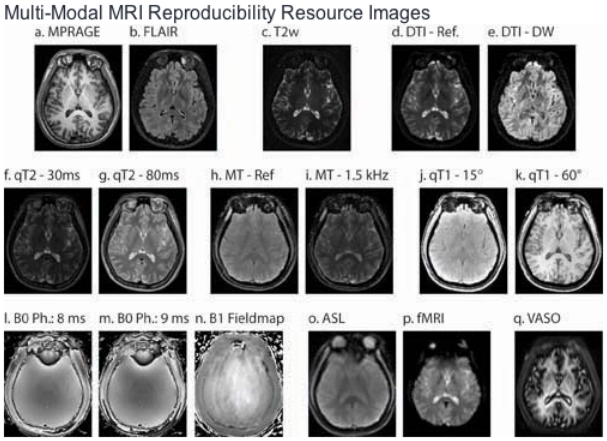
Informatics framework



Automated brain labeling

Mindboggle data:

>100 freely available manually labeled brain images



OASIS

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

MRI Multimodal Reproducibility Resource

http://www.nitrc.org/projects/multimodal/

MPRAGE T1, FLAIR, resting state fMRI,
B0 and B1 field maps, ASL, VASO, DTI,
quantitative T1 and T2 mapping,
magnetization transfer imaging
MMRR2 includes a 7T T1-weighted scan

PLoS 12

http://www.plosone.org/article/info:doi%2F10.1371%2Fjournal.pone.0006660

MPRAGE T1, fMRI, resting state fMRI

Nathan Kline Institute / Rockland Sample

http://fcon_1000.projects.nitrc.org/indi/pro/nki.html

MPRAGE T1, T2, resting state fMRI, DSI,...

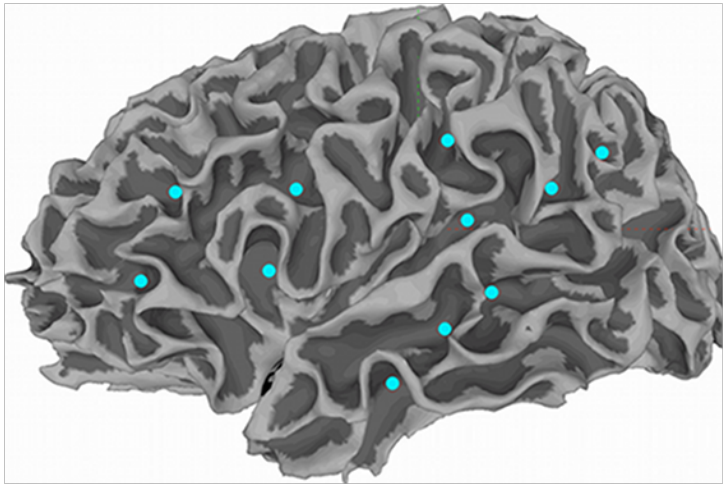
EMBARC

http://grants.nih.gov/grants/guide/rfa-files/RFA-MH-10-040.html

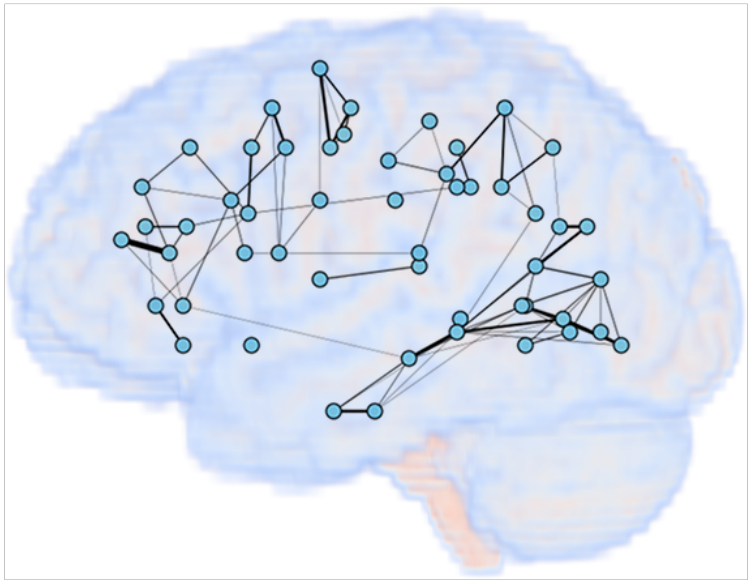
T1, fMRI and resting state fMRI, DTI, ASL, EEG

Multimodal Mindboggle

combine structures across modalities



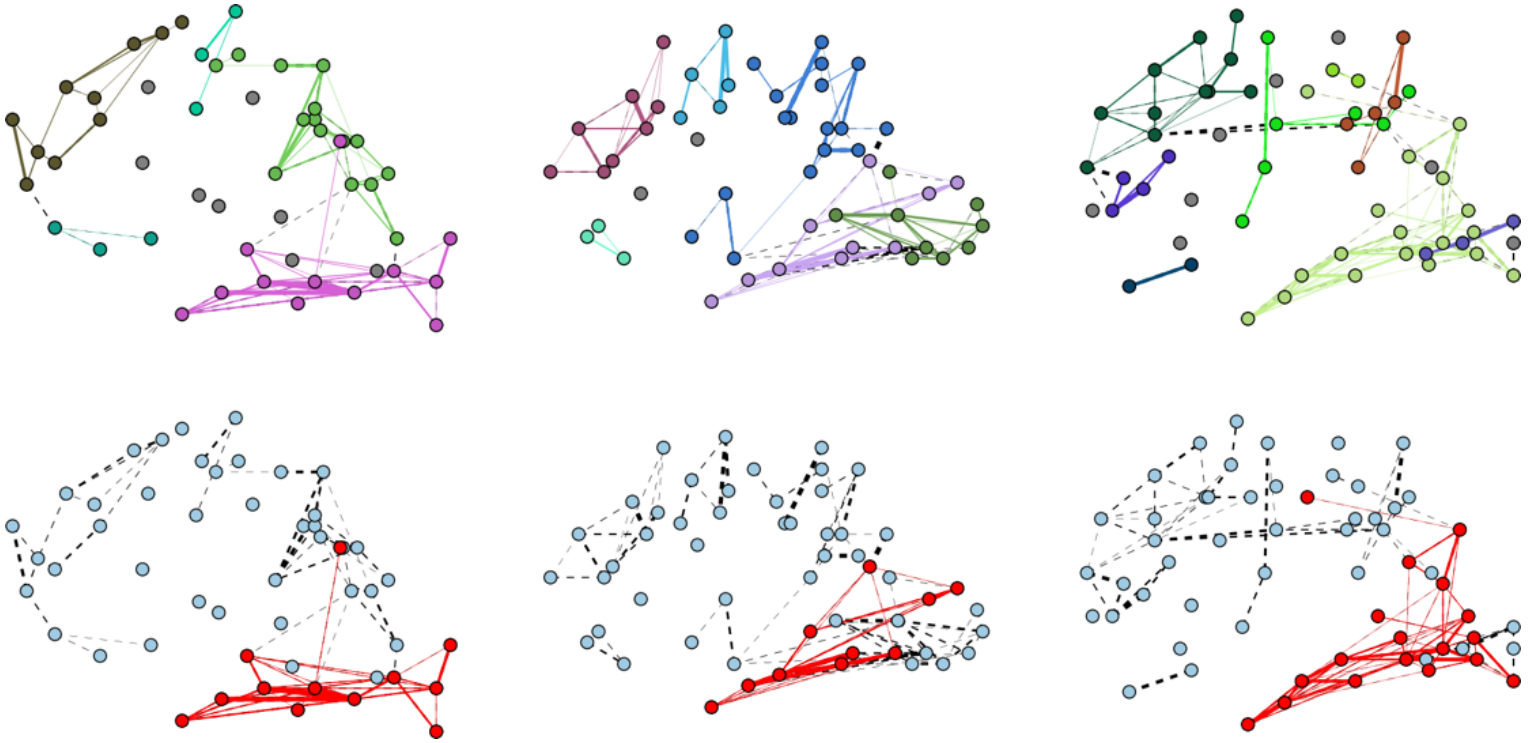
A gray/white matter surface (left lateral view) with visible sulcal pits highlighted (cyan circles). These features go by different names (sulcal roots, buried or annectant gyrii, plis de passage) and may be well conserved structures formed early in development.



DTI connectivity graph (same subject). Vertices represent all extracted sulcal pits and each edge width indicates a connection probability greater than 0.01 between two vertices (and does not follow a tractography path).

Multimodal Mindboggle

clinical example



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.

Feature extraction

Forrest Bao
graduate student (Texas Tech)

Feature matching

Yrjö Häme
graduate student

Database and visualization

Noah Lee
postdoctoral research scientist

Depth features

Mireia Montañola
graduate student
U. Catholique de Louvain, Belgium

Registration

Brian Avants
assistant professor
Univ. of Pennsylvania

Machine learning

Satrajit Ghosh
research scientist
MIT