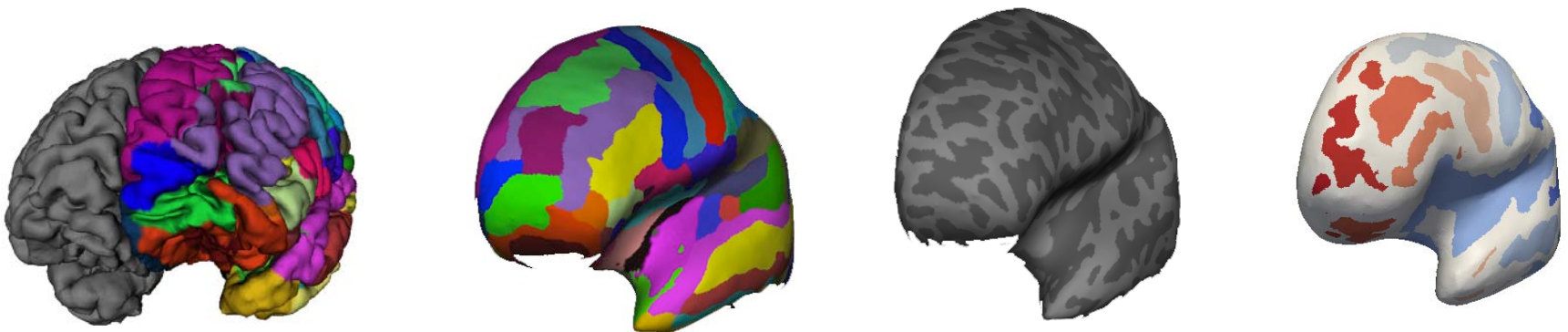


Feature-based brain labeling and query web data integration

Nolan Nichols and Jim Brinkley



Why label brains?

Labels serve as a visual guide and teaching tool

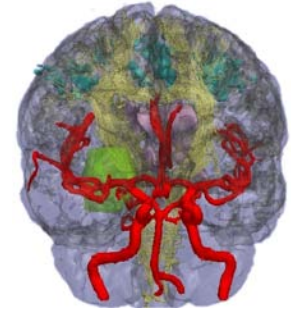
- teach brain anatomy
- guide neurosurgery



Why label brains?

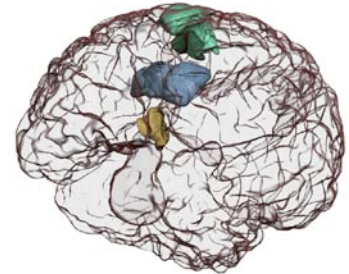
Labels serve as a visual guide and teaching tool

- teach brain anatomy
- guide neurosurgery



Labels break up data within a brain

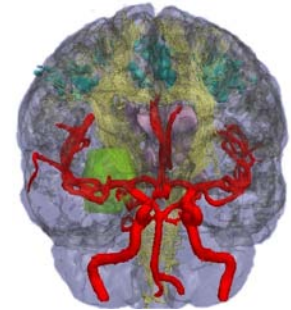
- assign results to brain regions
- quantify data by brain region



Why label brains?

Labels serve as a visual guide and teaching tool

- teach brain anatomy
- guide neurosurgery



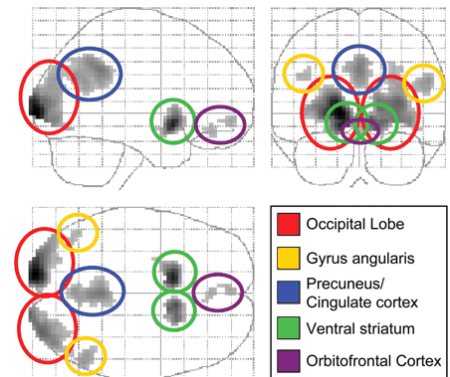
Labels break up data within a brain

- assign results to brain regions
- quantify data by brain region

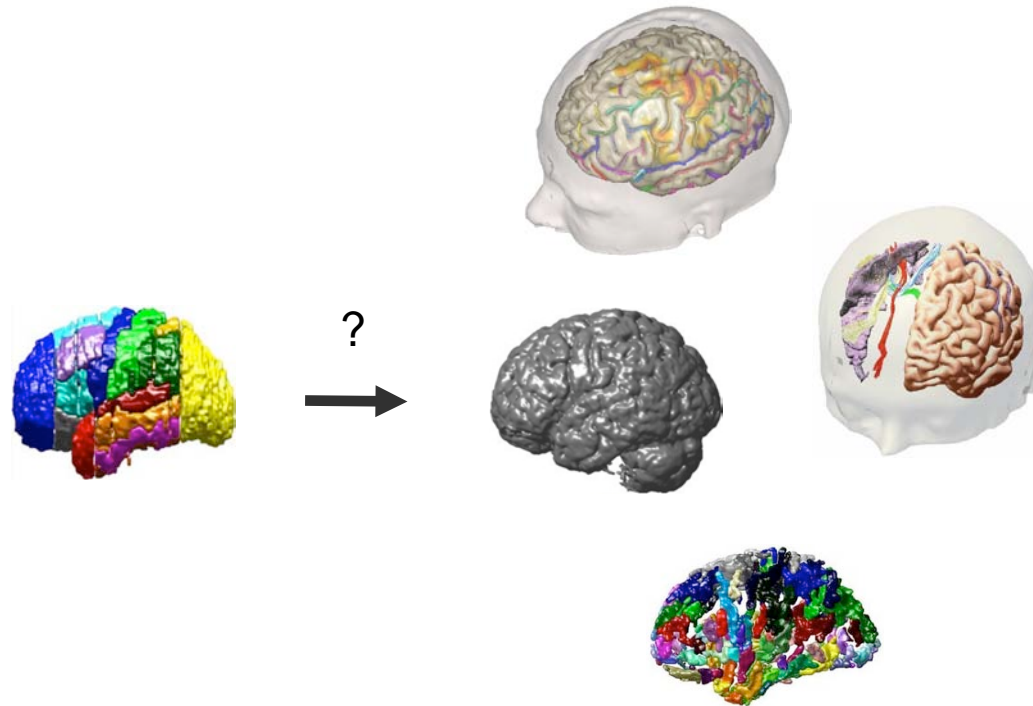


Labels establish correspondences across brains

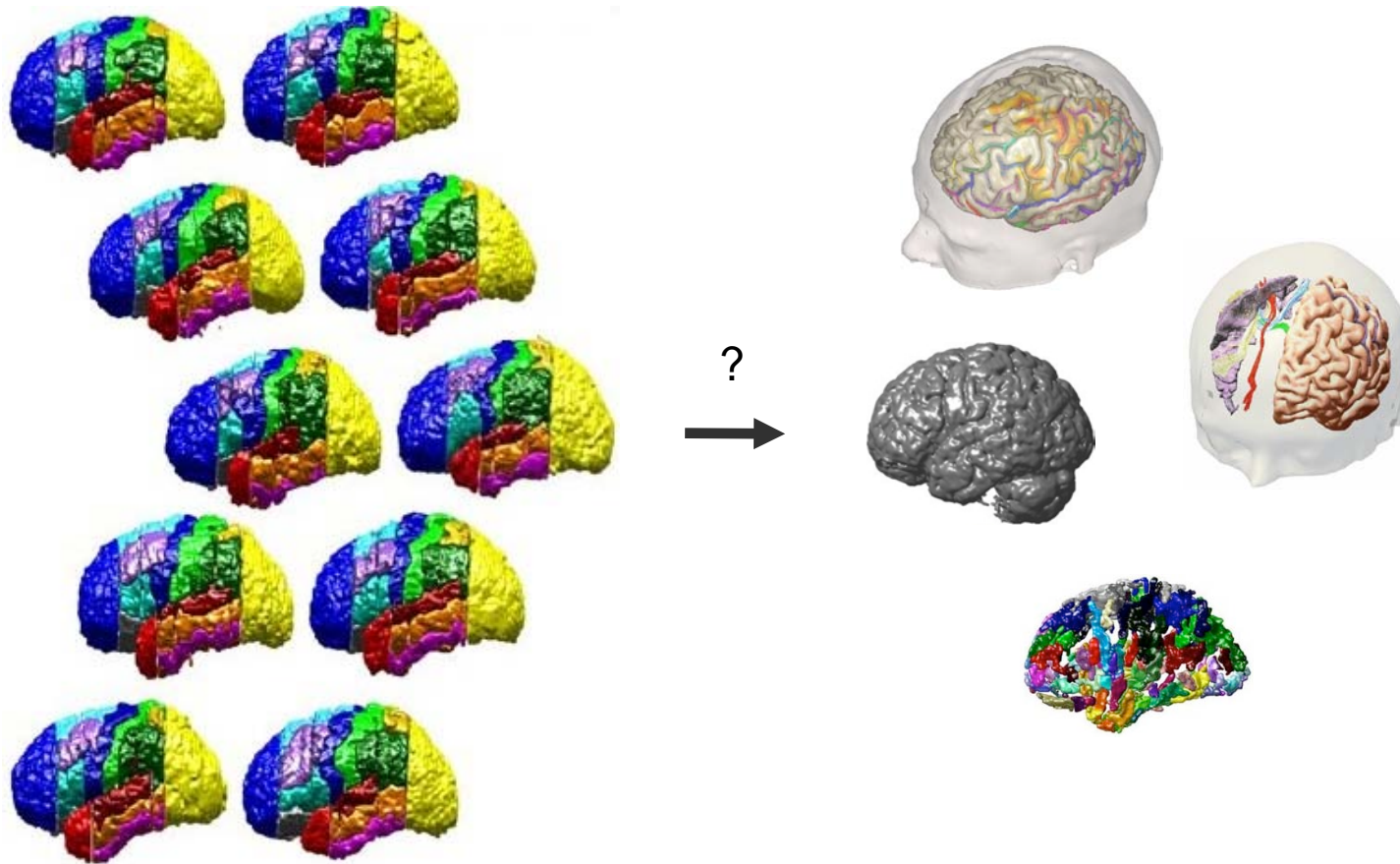
- compare individuals within and across studies
- communicate results with a common language



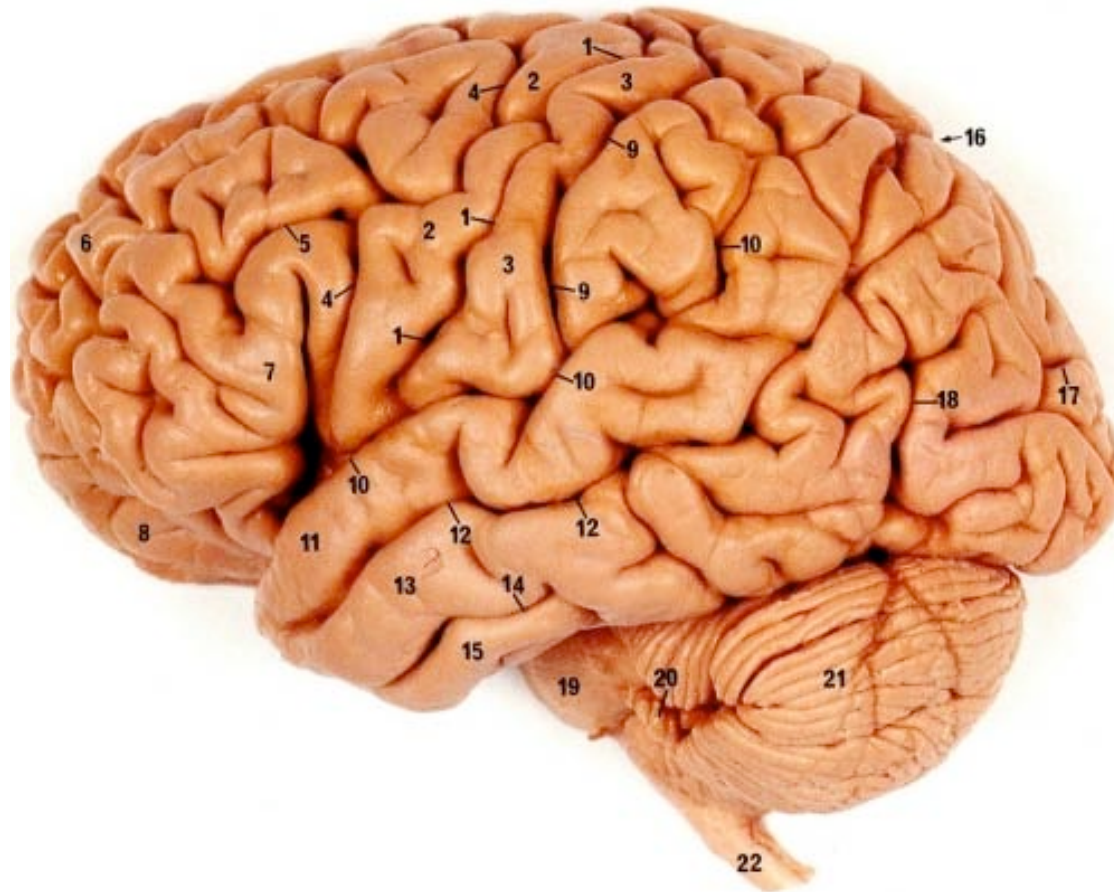
How should we label brains?



How should we label brains?



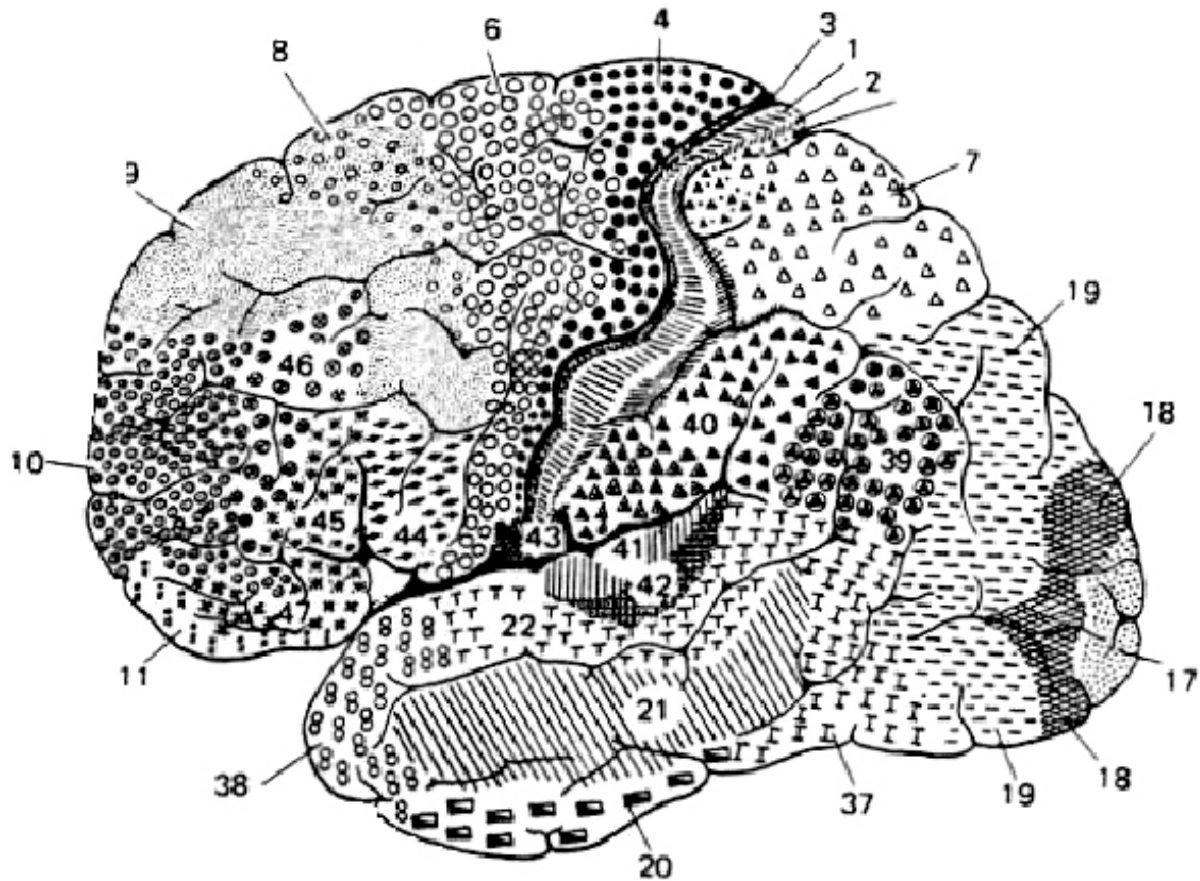
1. Manual labeling





Korbinian Brodmann
(1868-1918)

Cytoarchitectonic boundaries





Cytoarchitectonic boundaries

Constantin von Economo
(1876-1931)

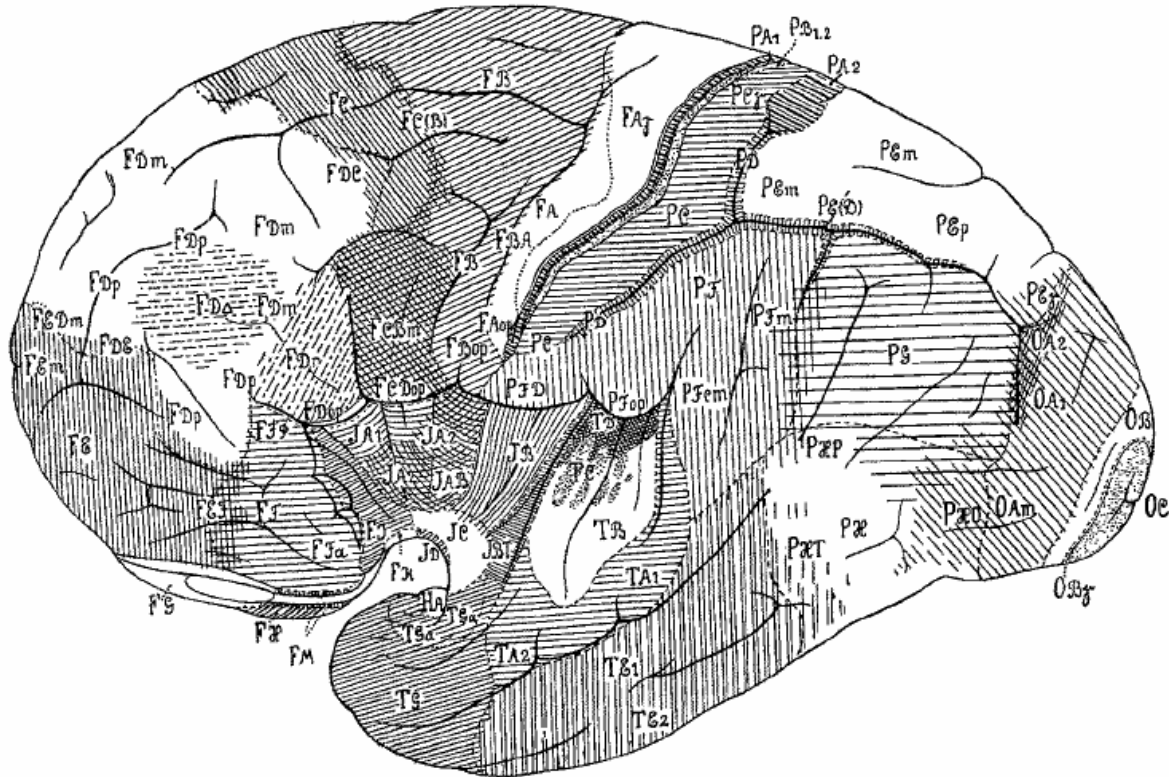
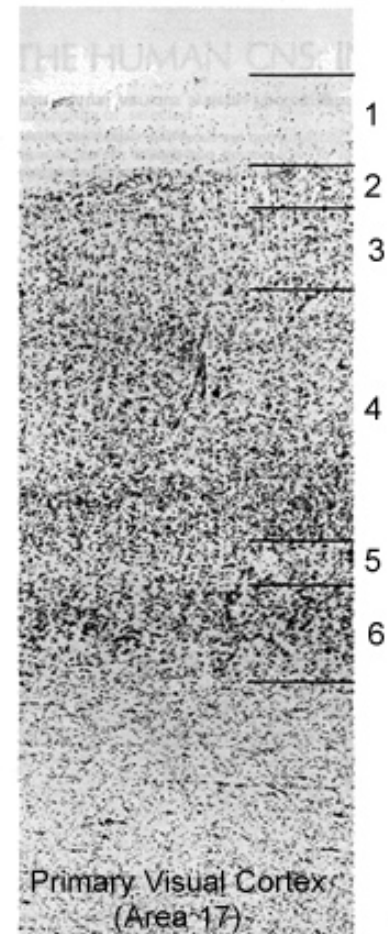
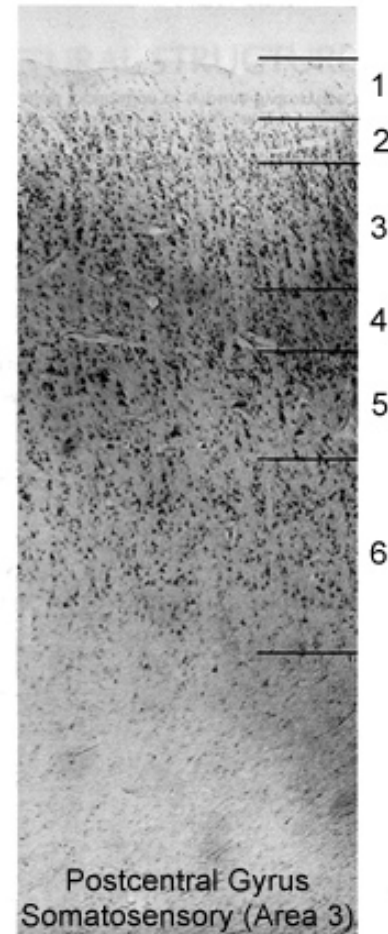
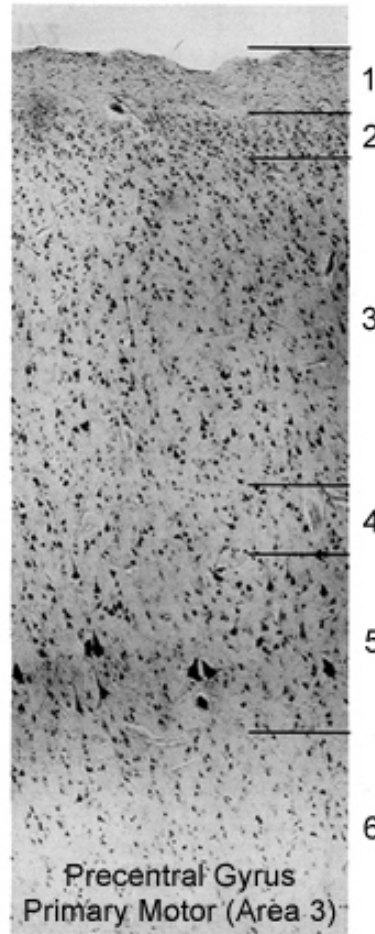
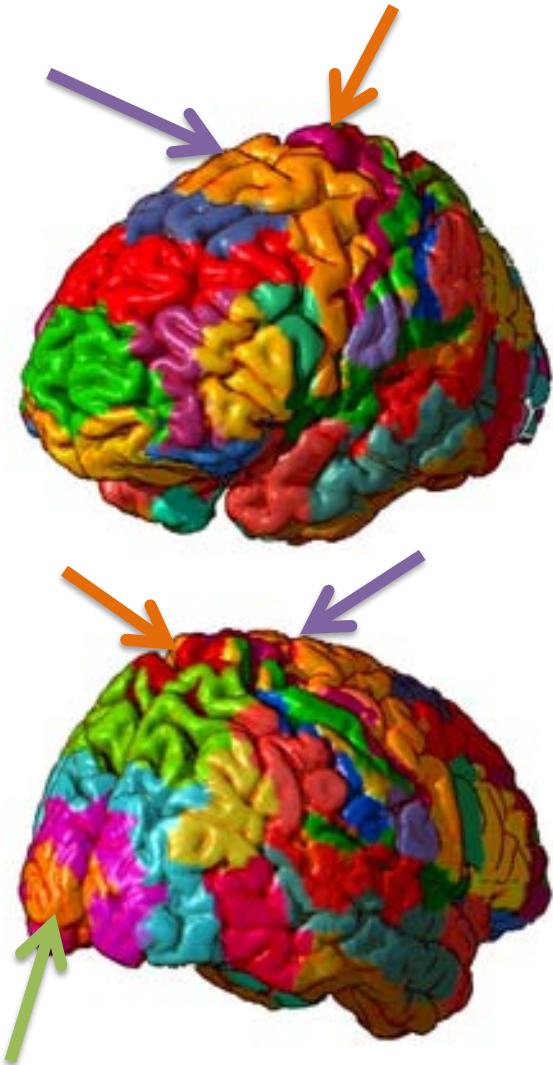
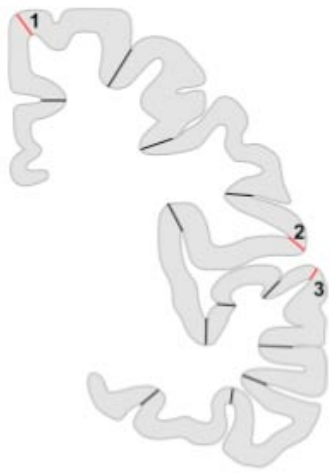


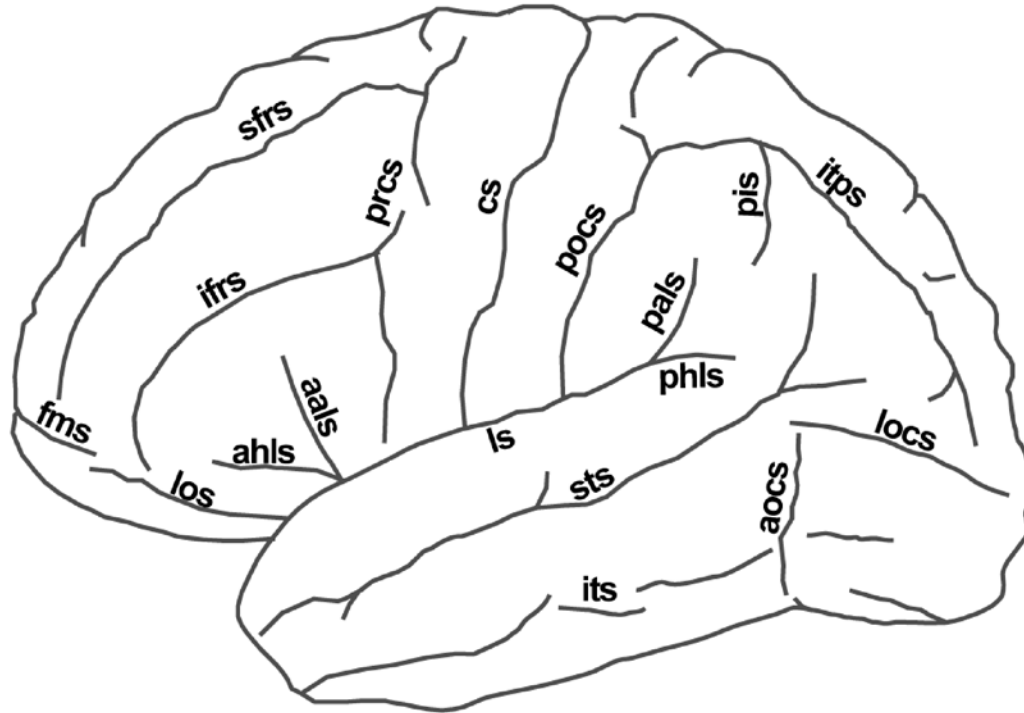
Abb. 3.

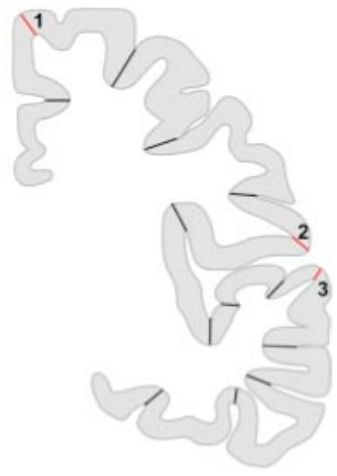
Cytoarchitectural Parcellation



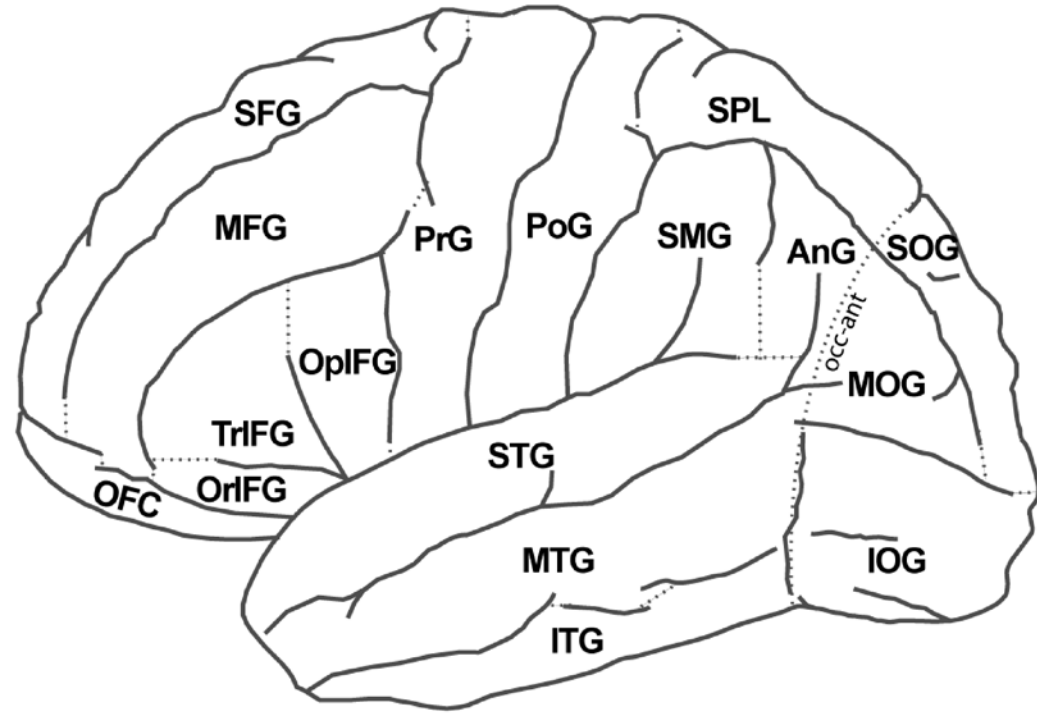


Sulcus definitions





Gyrus definitions



2. Automated labeling

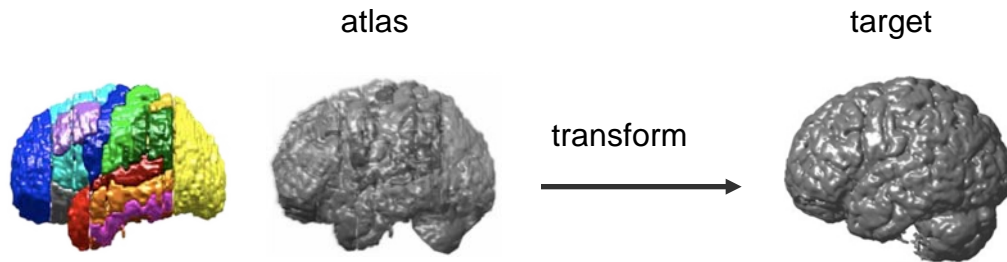


Convention: registration-based labeling



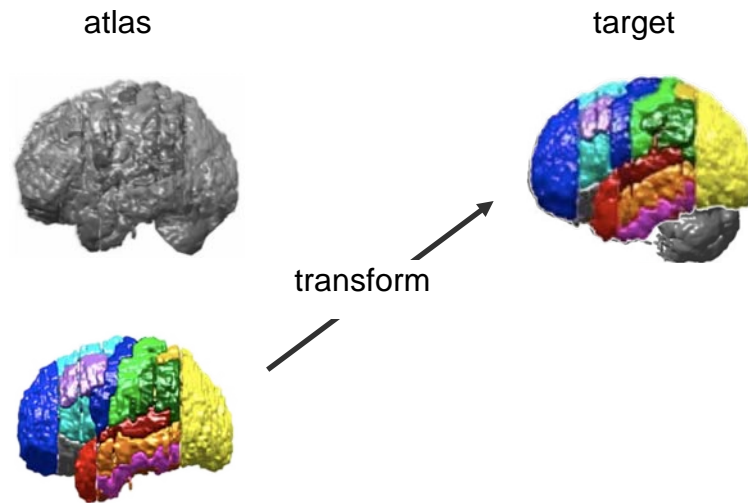
Convention: registration-based labeling

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

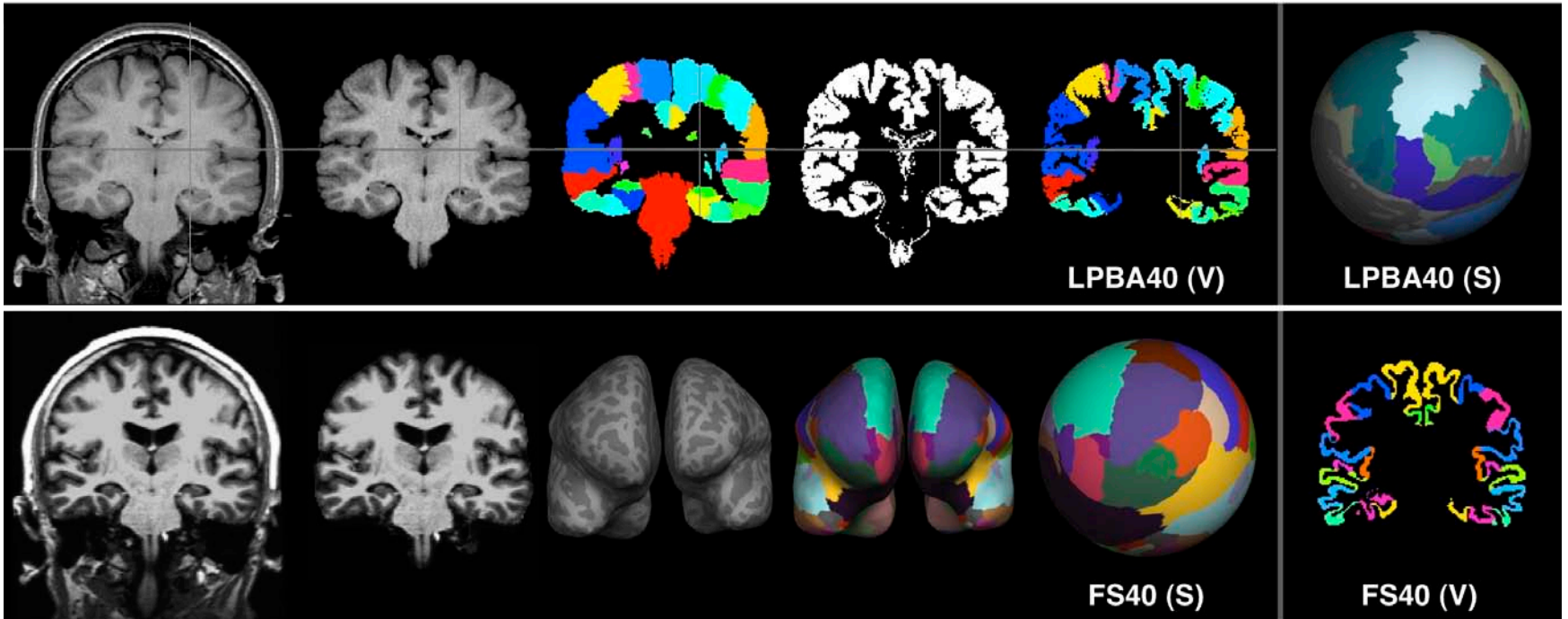


Convention: registration-based labeling

Step 2: apply the transform to the atlas labels



Volume and surface data
(labeled in volumes *and* surfaces)



Registrations

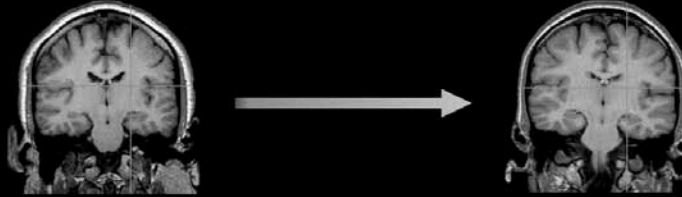
source
image

template
image

target
image

volume-based
registrations

ART, SyN



ART, SyN



SyN



surface-based
registrations

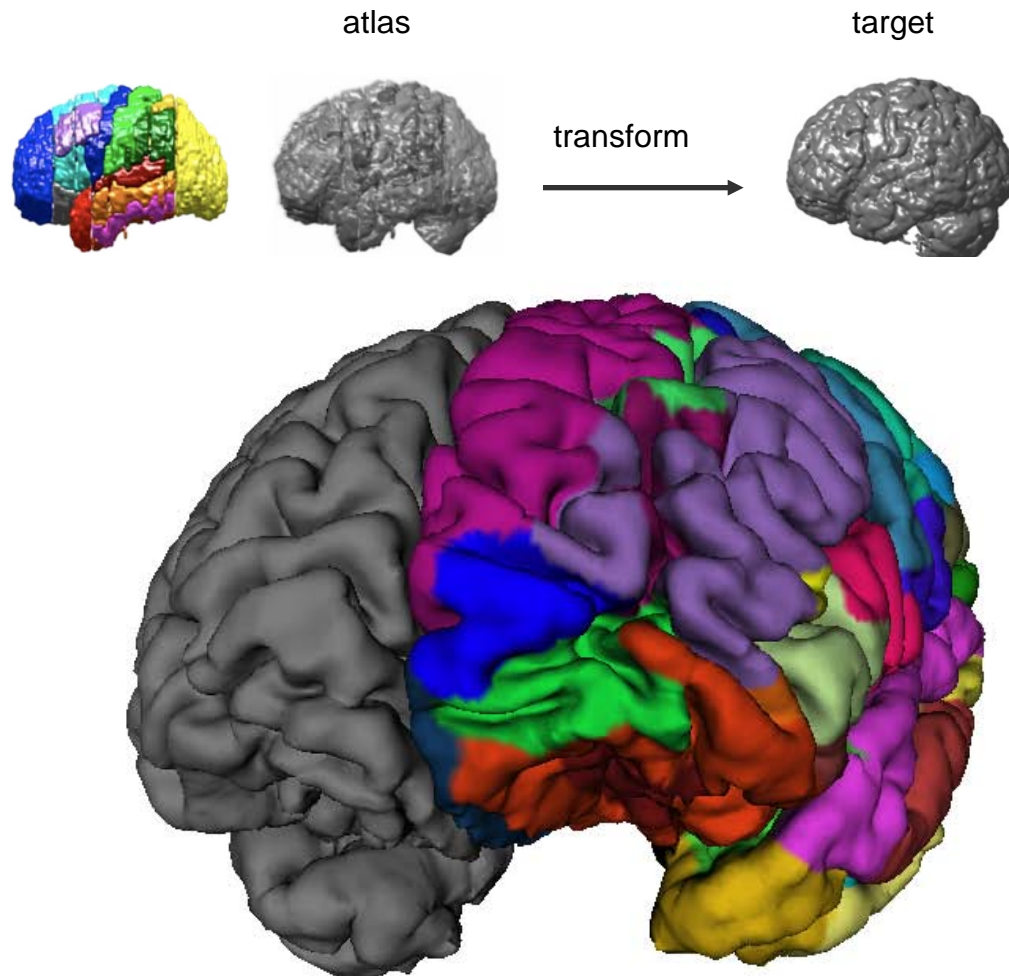
FreeSurfer,
Spherical
Demons



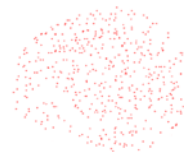
FreeSurfer



Convention: registration-based labeling

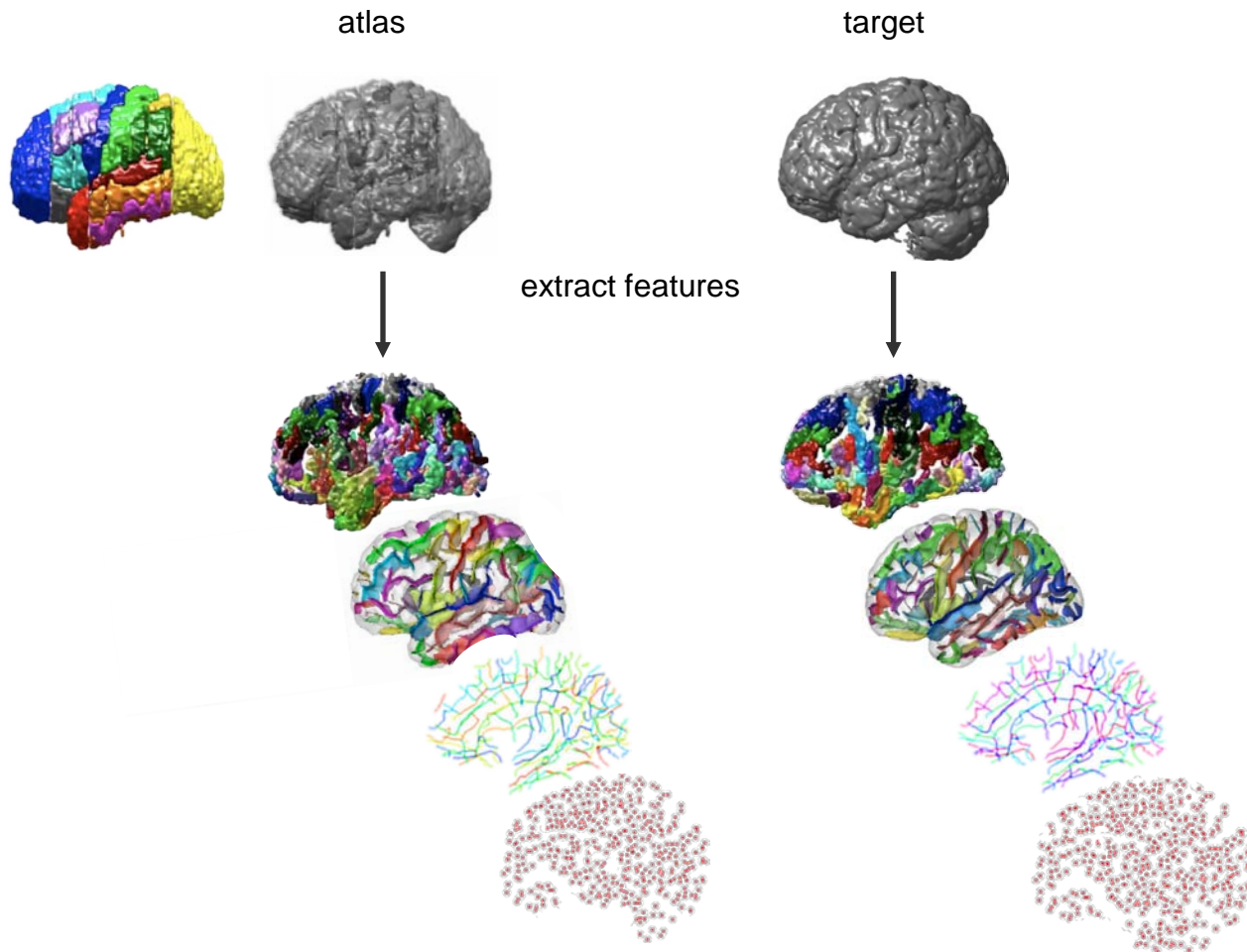


Mindboggle 2: feature-based labeling



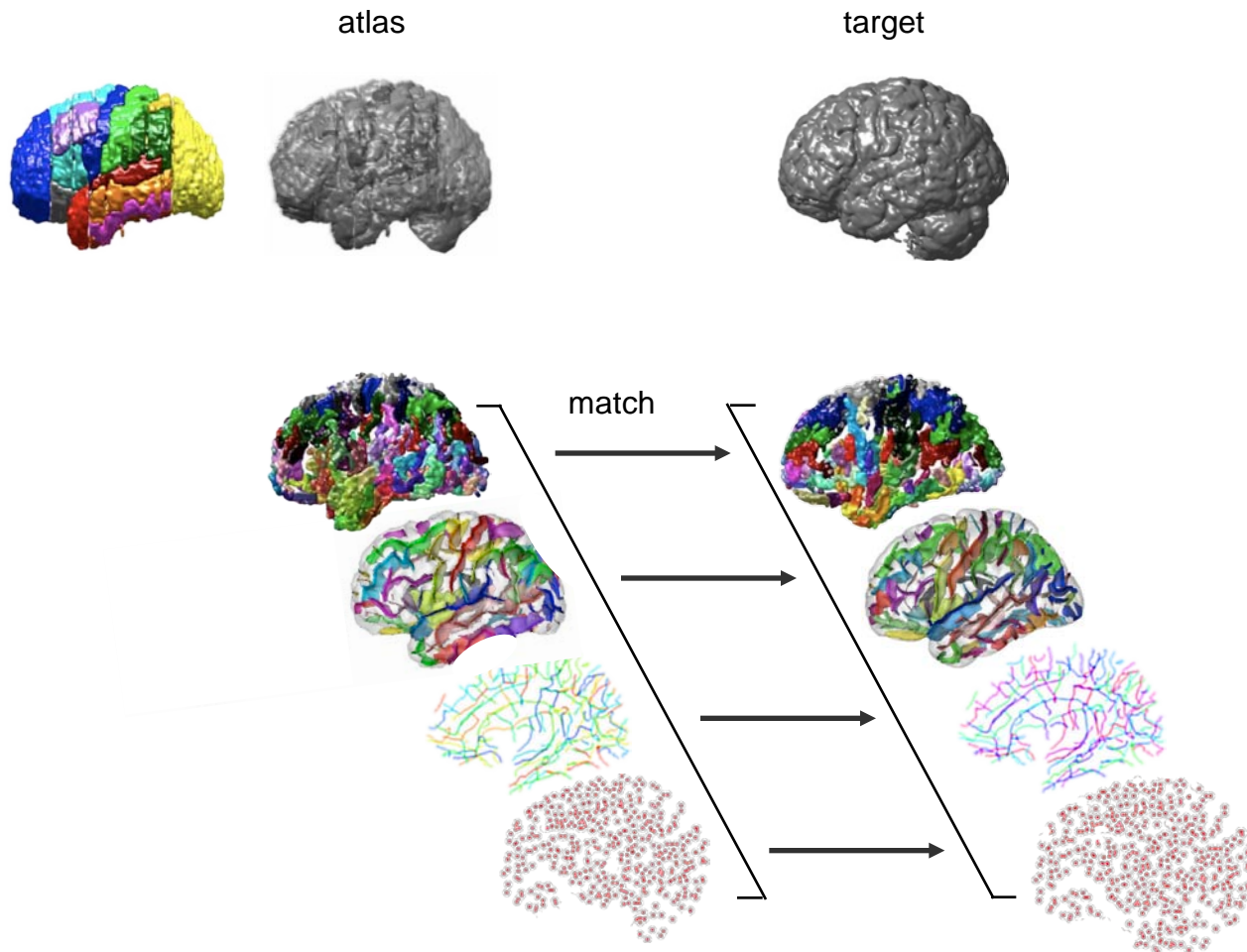
Mindboggle 2: feature-based labeling

Step 1: extract features



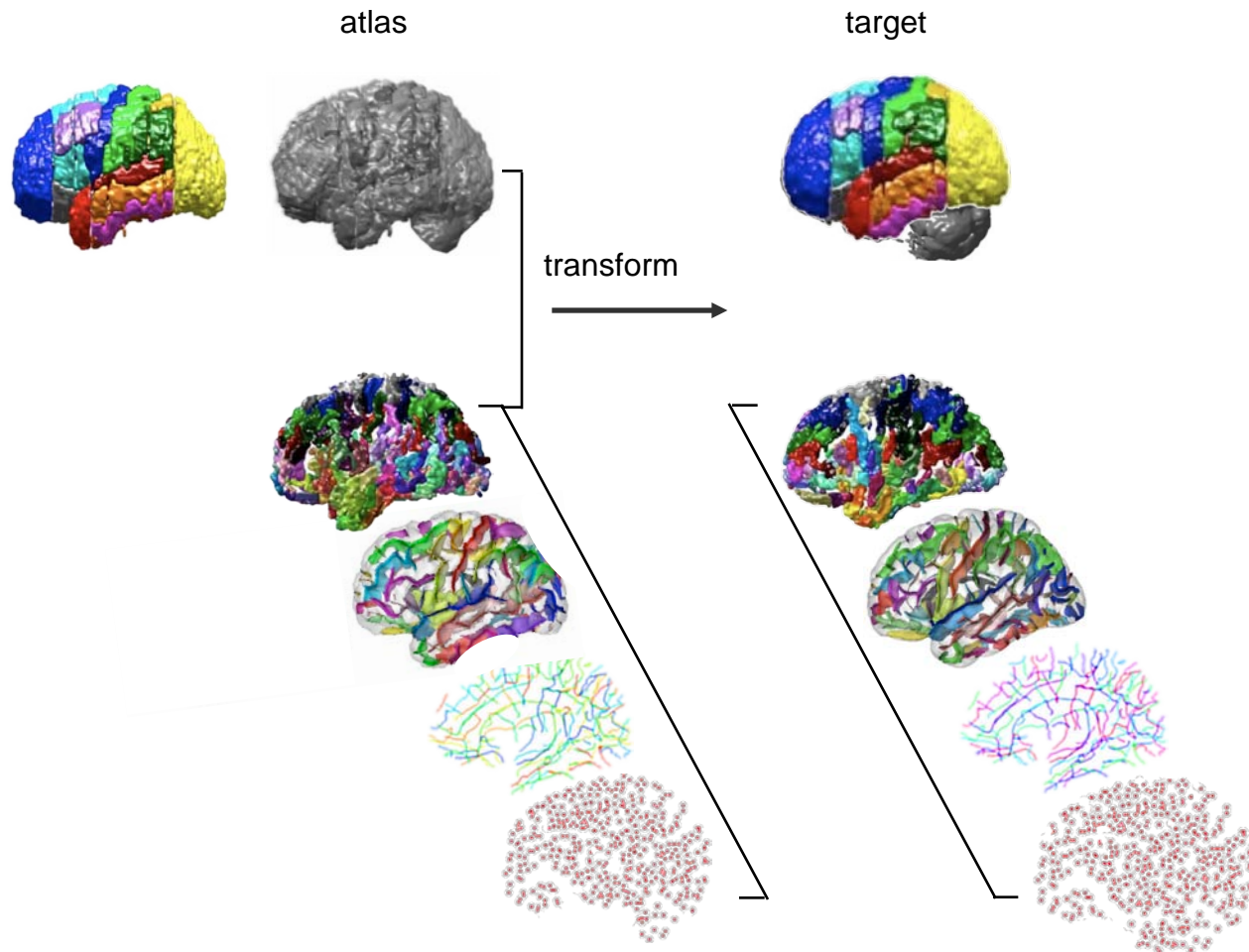
Mindboggle 2: feature-based labeling

Step 2: match atlas and target features



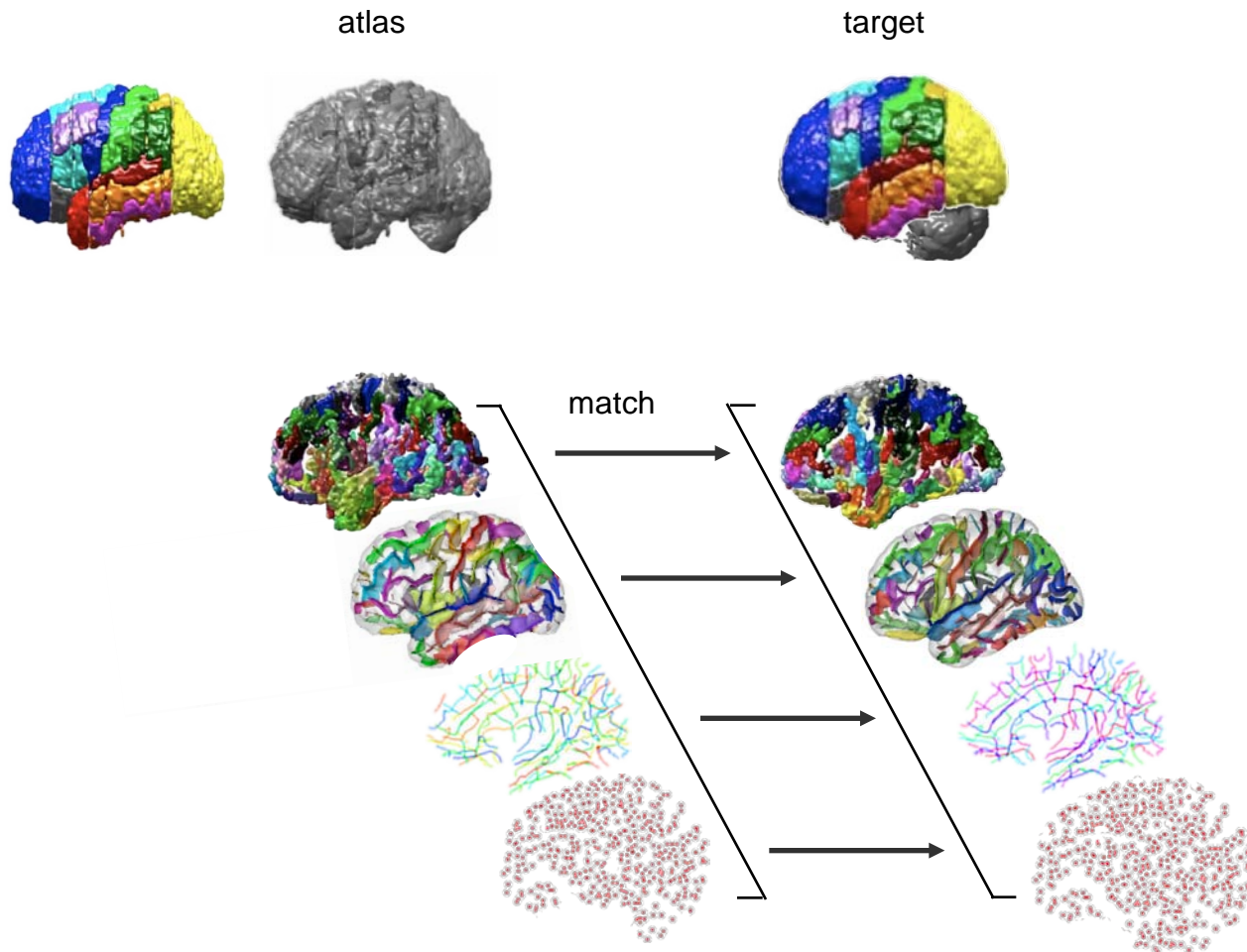
Mindboggle 2: feature-based labeling

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



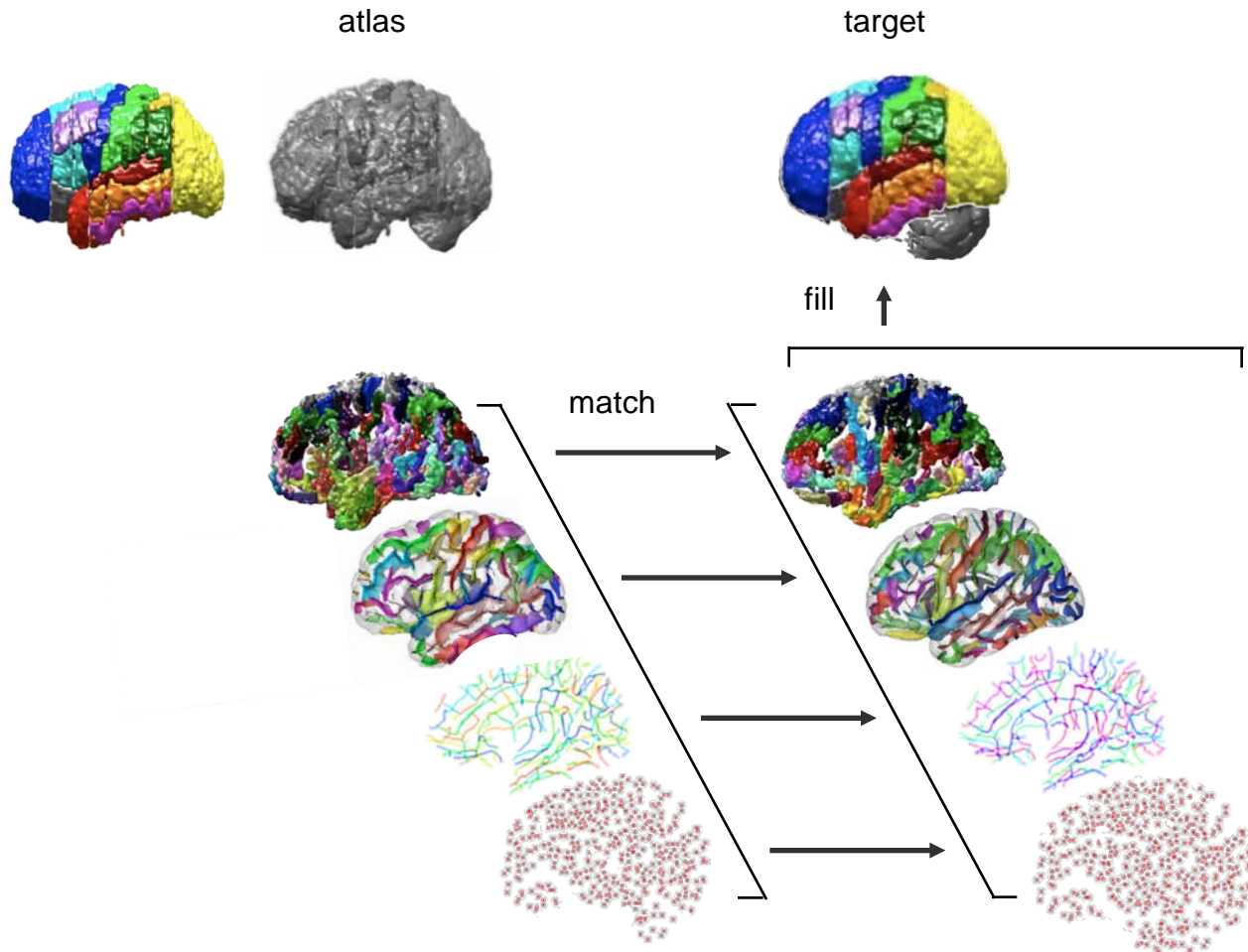
Mindboggle 2: feature-based labeling

Step 2: or match...



Mindboggle 2: feature-based labeling

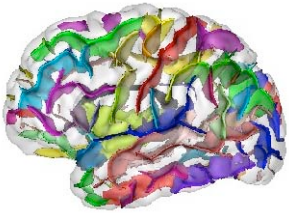
Step 3: then propagate labels within inferred label boundaries?



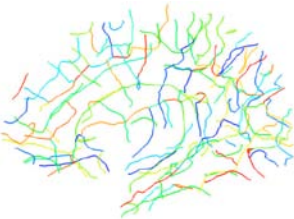
Mindboggle 2: feature-based labeling



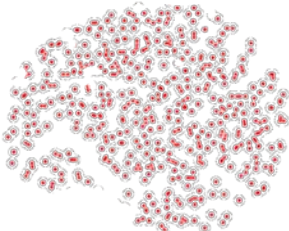
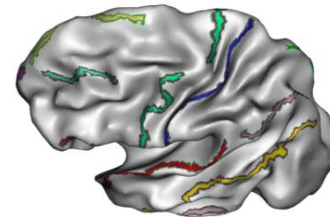
3-D:
labeled **regions** (manual)
sulcal **basins**
sulcal **skeletons**



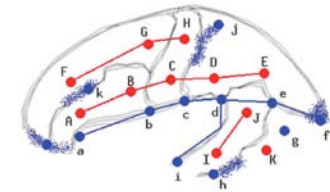
2-D:
sulcal **ribbons**
gyral **surfaces**

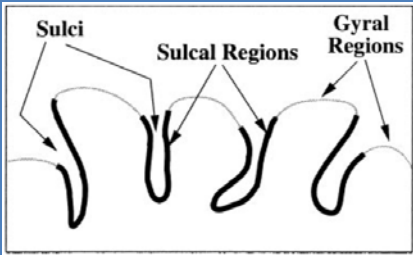


1-D:
sulcal
& gyral **curves**



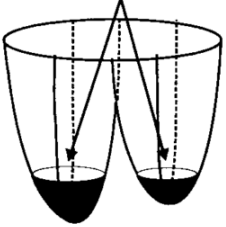
0-D:
SIFT **points**
sulcal **pits**



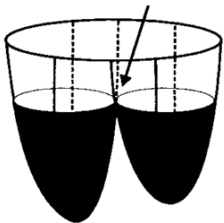


Candidate features in 3-D: sulcal basins

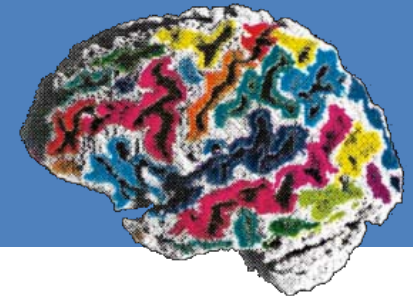
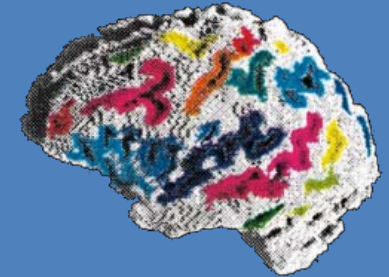
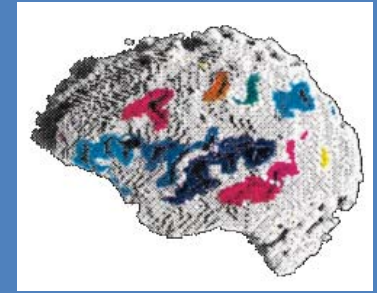
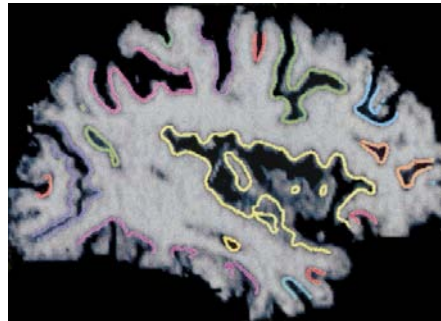
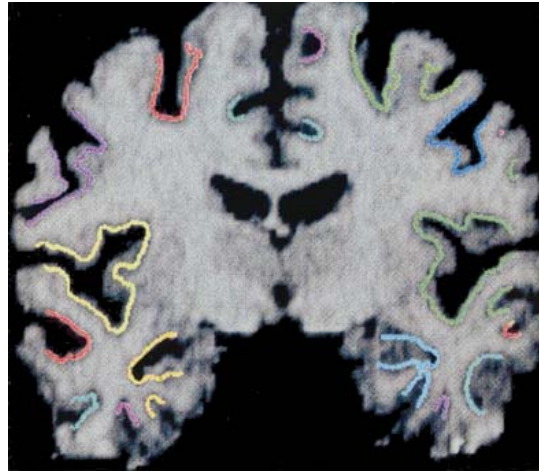
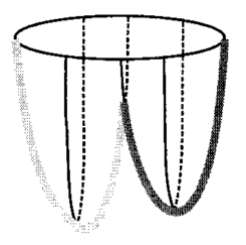
catchment basins begin
filling with water



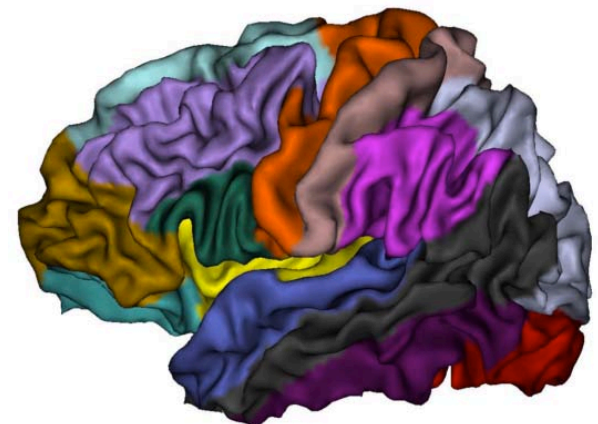
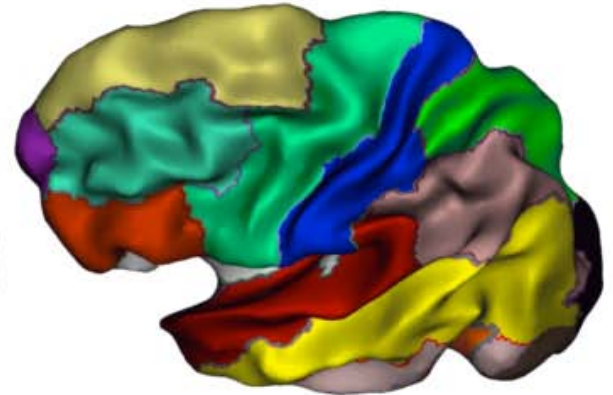
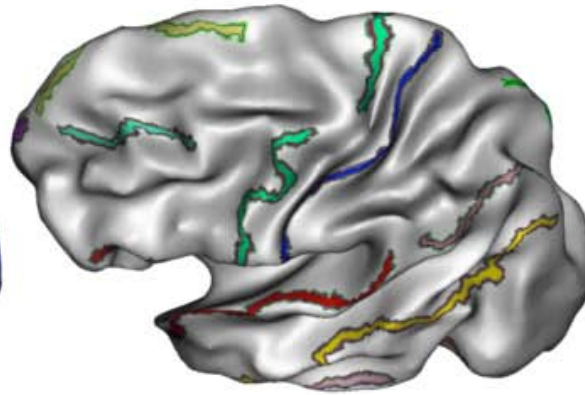
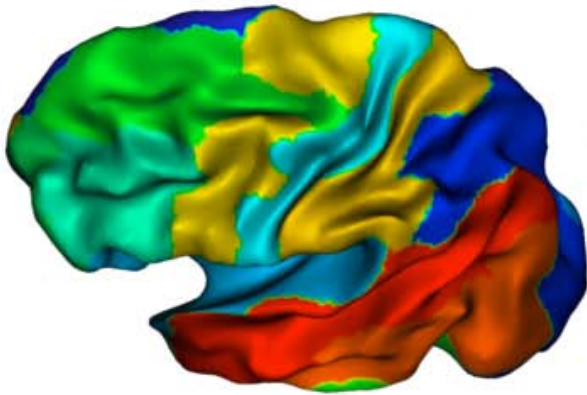
watershed line forms here



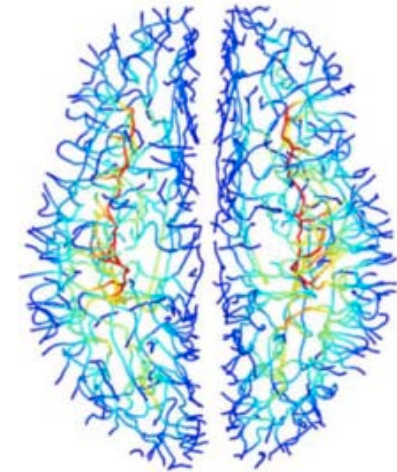
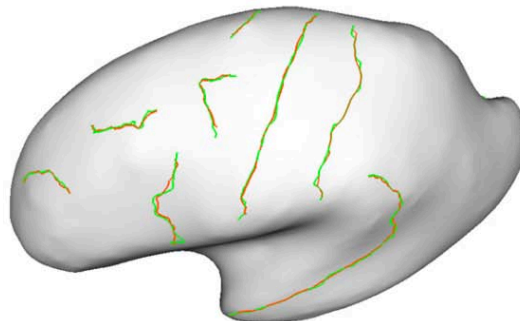
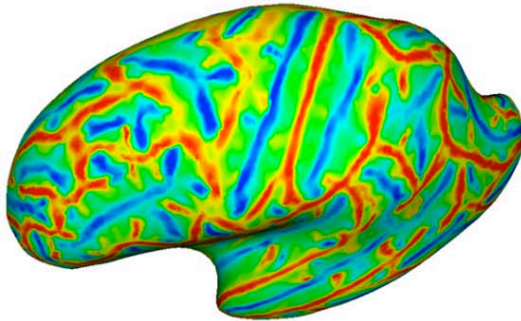
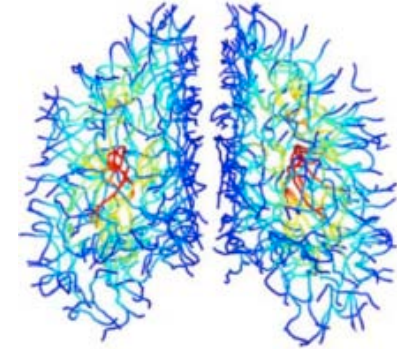
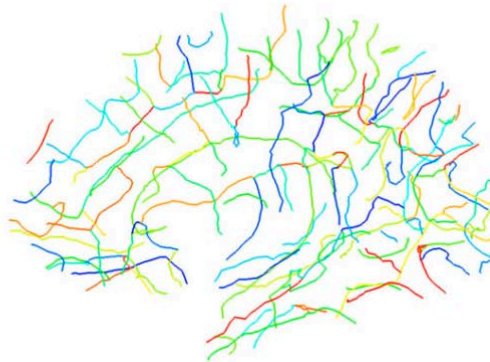
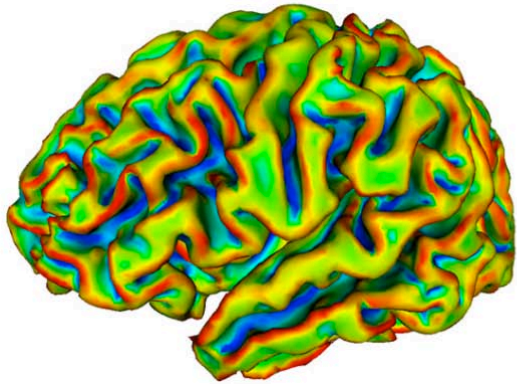
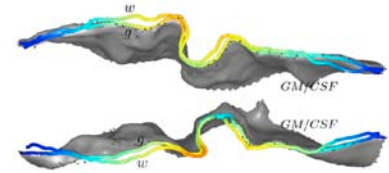
ideal segmentation



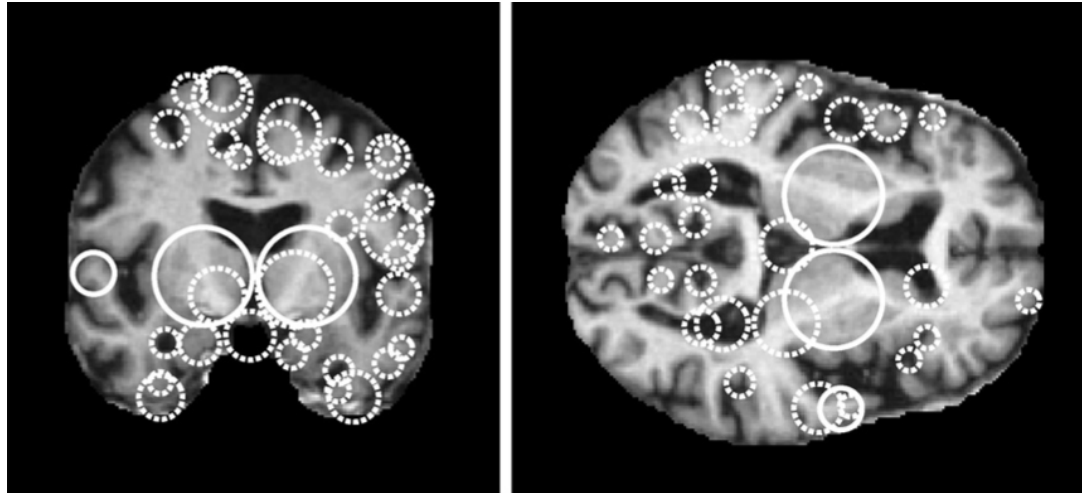
Candidate features in 2-D:
sulcal & gyral **surfaces**



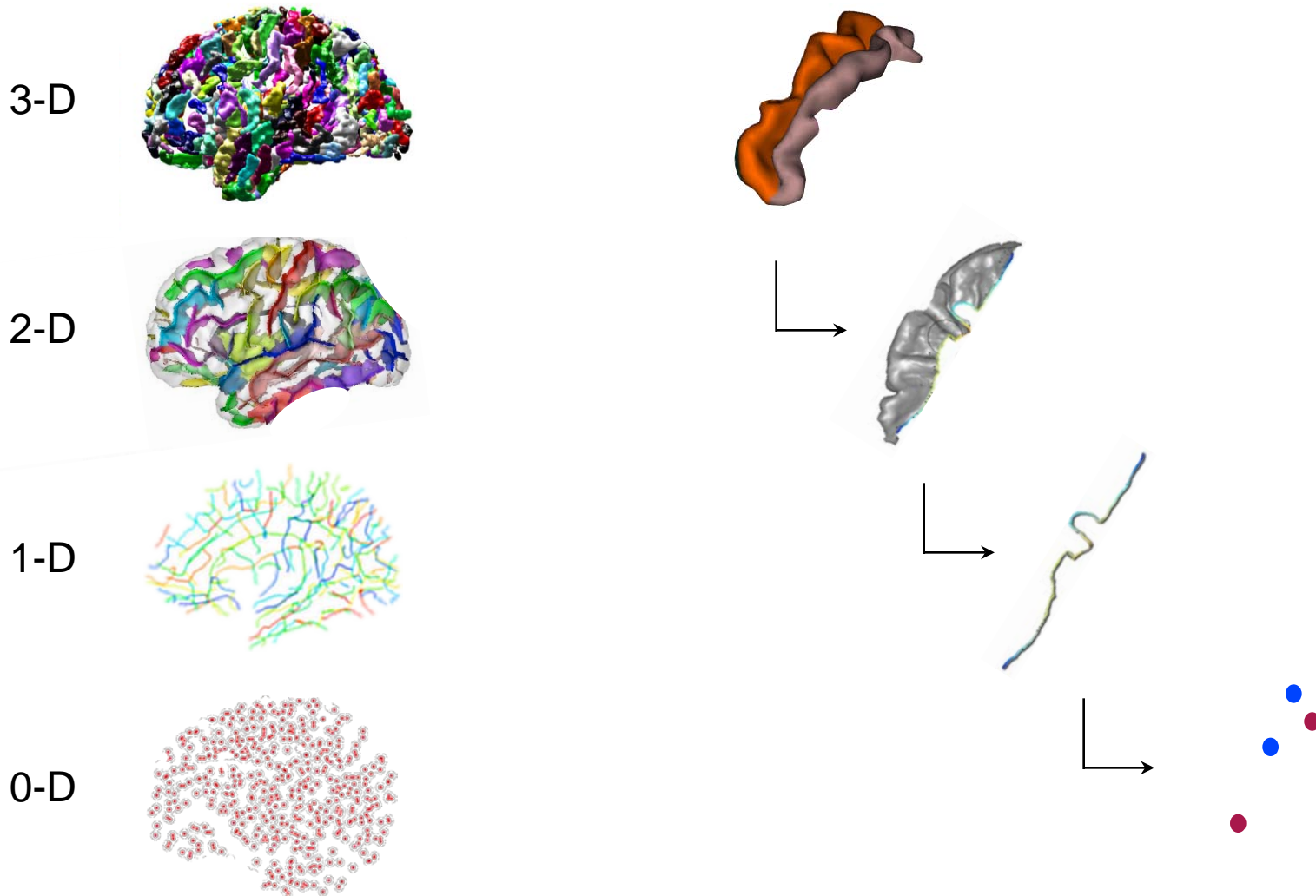
Candidate features in 1-D: sulcal **curves**



Candidate features in 0-D: SIFT points

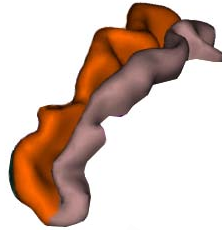


Proposed nested feature hierarchy



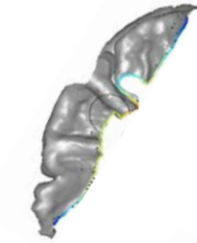
Candidate shape measures

3-D



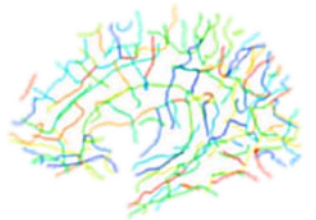
volume
surface area
lengths (thickness)
?

2-D



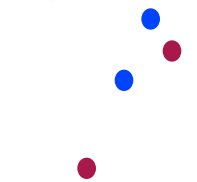
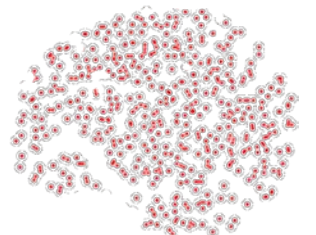
area
curvature
convexity
?

1-D



length
curvature
convexity
?

0-D



number of points
3-D convex hull volume
1-D sequence
?

Proposed Graph Data Model

noSQL graph model of the Mindboggle database



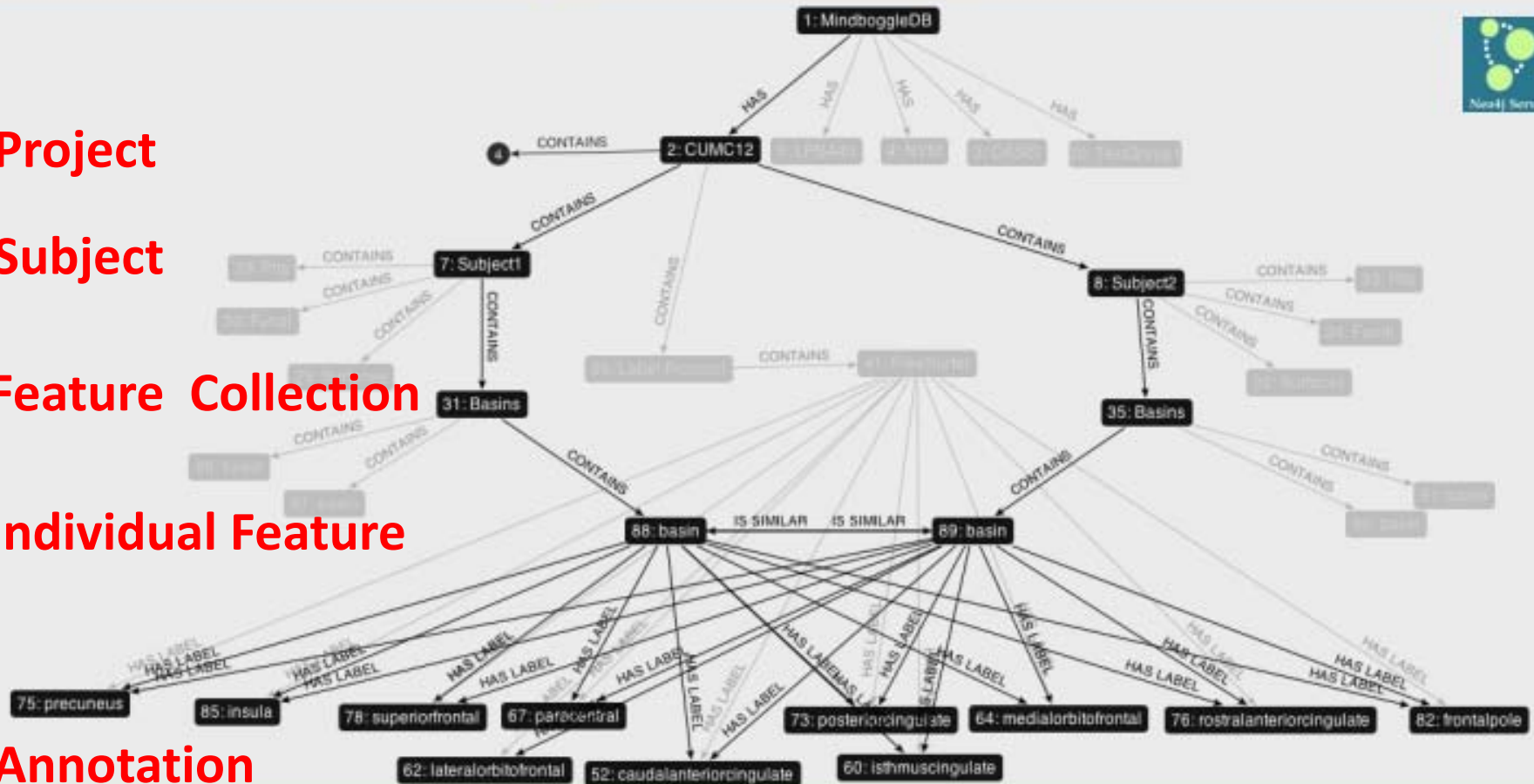
Project

Subject

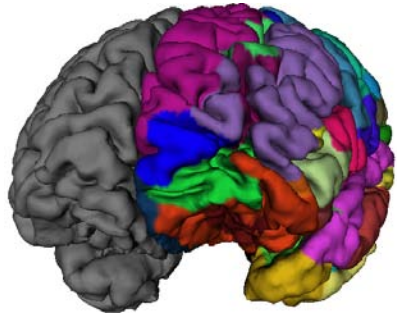
Feature Collection

Individual Feature

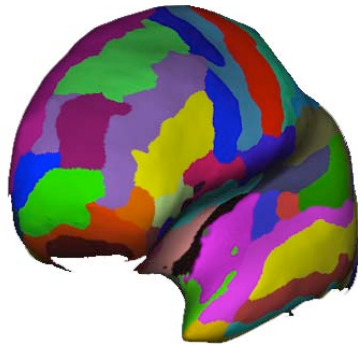
Annotation



What are the relationships between labels?



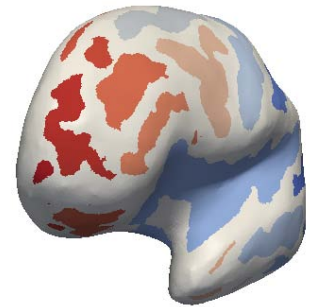
Pial a2009s



Inflated a2009s



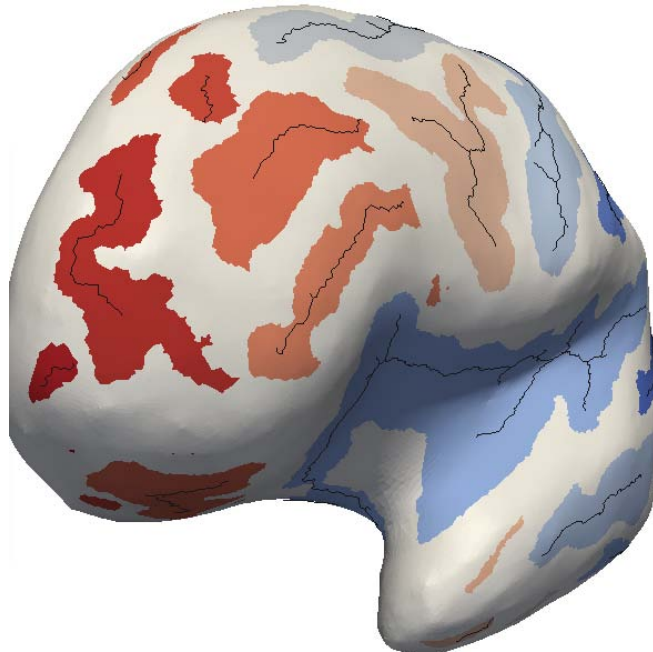
Inflated Gray



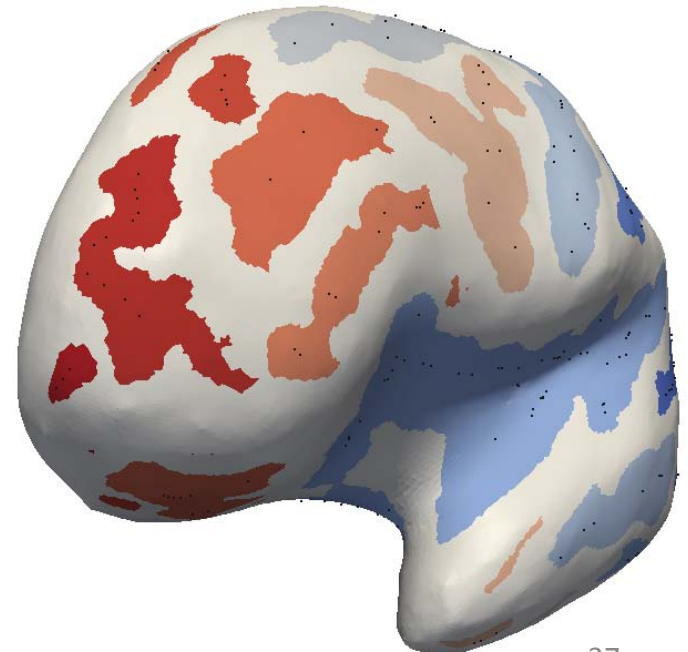
Inflated Basin



Inflated Basin
Hierarchy



Inflated Sulcal Fundi



Inflated Sulcal Pits

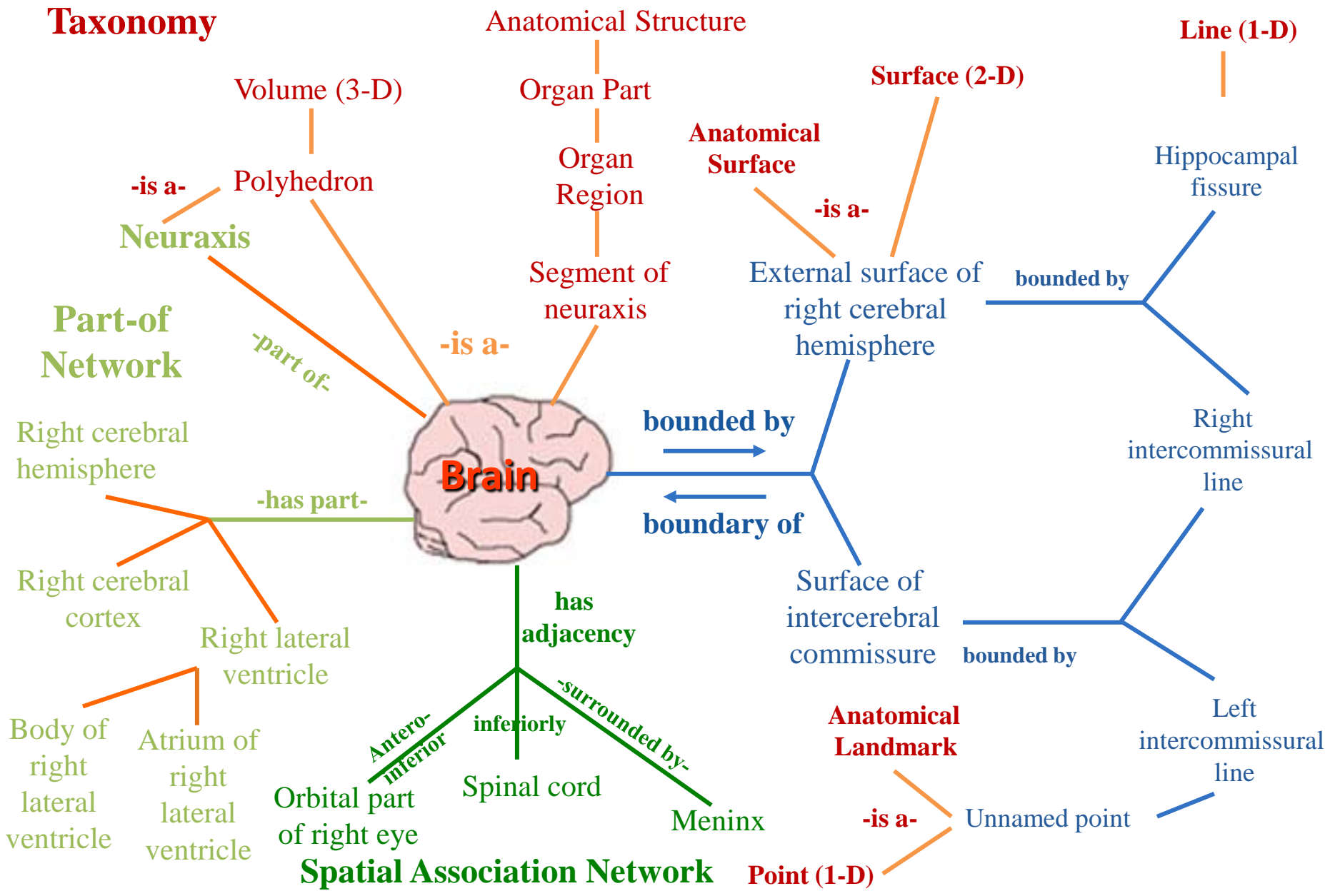
FMA Overview

- Created by Dr. Cornelius Rosse (1995)
- Ontology for the domain of human anatomy
- Theory of anatomy: structural context
- Reference ontology
- A source of computable anatomical knowledge for data annotation, organization, integration, and interoperability

Dimensional Taxonomy

Anatomy Taxonomy

Boundary Network



Topological Parcellation

CLASS BROWSER For Project: ● NeuroFMAv7.28.2010

CLASS EDITOR For Class: 🍷 Left frontal lobe (instance of Lobe of cerebral hemisphere)

Class Hierarchy

- 🍷 Lobe of cerebral hemisphere
 - 🍷 Frontal lobe
 - 🍷 **Left frontal lobe**
 - 🍷 Right frontal lobe
 - ▶ 🍷 Insula
 - ▶ 🍷 Limbic lobe
 - ▶ 🍷 Occipital lobe
 - ▶ 🍷 Parietal lobe
 - ▶ 🍷 Temporal lobe
 - ▶ 🍷 Medial segment of cerebral hemis
 - ▶ 🍷 Segment of cerebral lobe
 - ▶ 🍷 Segment of gyrus of brain

Left frontal lobe

Superclasses

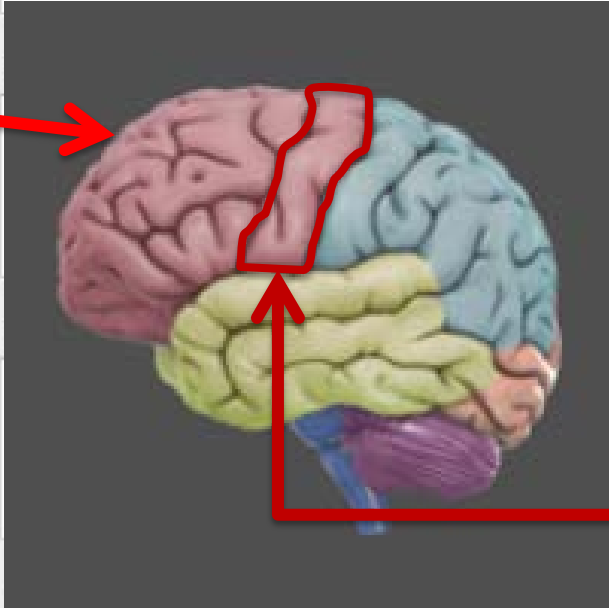
- 🍷 Frontal lobe

Receives Input From

Receives Projection From

Regional Part

- 🍷 **Left precentral gyrus**
- 🍷 Left superior frontal gyrus
- 🍷 Left middle frontal gyrus
- 🍷 Left inferior frontal gyrus
- 🍷 Left frontal pole
- 🍷 Orbitobasal segment of left frontal lobe



Mapping Brain Atlas Labels to the FMA

The image displays the NeuroFMA V1.3 interface, illustrating the mapping of brain atlas labels to the FMA. On the left, a 3D brain model is shown with a red outline highlighting the precentral gyrus. The 'SUBCLASS EXPLORER' window on the left shows the 'Asserted Hierarchy' for the project 'NeuroFMA_V1.3'. The hierarchy is as follows:

- Segment_of_cerebral_hemisphere
 - Gyrus_of_brain
 - Anterior_paracentral_gyrus
 - Gyrus_of_frontal_lobe
 - Frontomarginal_gyrus
 - Inferior_frontal_gyrus
 - Intermediate_orbital_gyrus
 - Medial_frontal_gyrus
 - Middle_frontal_gyrus
 - Orbital_gyrus
 - Precentral_gyrus
 - Left_precentral_gyrus**
 - Right_precentral_gyrus
 - Straight_gyrus

Red arrows indicate the mapping process: from the 'Left_precentral_gyrus' in the hierarchy to the 'ONARD_Instance_2370025' in the 'AAL' list, and from the 'ONARD_Instance_2370025' to the 'name' field in the 'INDIVIDUAL EDITOR' window. The 'INDIVIDUAL EDITOR' window shows the following data:

| Property | Value |
|----------|-----------------|
| FMAID | 271975 |
| name | Precentral_LEFT |

The 'AAL_ID' field is set to '1'. The 'ONARD_Instance_2370025' is listed under the 'AAL' section.

Representing Connectivity in the FMN

CLASS BROWSER For Project: ● NeuroFMAv7.28.2010

CLASS EDITOR For Class: 🍯 Superior longitudinal fasciculus proper (instance of Long cerebral association nerve fasciculus)

Class Hierarchy

- 🍯 Cerebral nerve fasciculus
 - 🍯 Cerebral association nerve fasciculus
 - 🍯 Long cerebral association nerve fasciculus
 - ▶ 🍯 Anterior branch of superior longitudinal fasciculus
 - ▶ 🍯 Arcuate fasciculus
 - ▶ 🍯 Cerebral cingulum
 - ▶ 🍯 Dorsal segment of superior longitudinal fasciculus
 - ▶ 🍯 Inferior longitudinal fasciculus
 - ▶ 🍯 Inferior occipitofrontal fasciculus
 - ▶ 🍯 Posterior branch of superior longitudinal fasciculus
 - ▶ 🍯 Subcallosal fasciculus
 - ▶ 🍯 Superior longitudinal fasciculus
 - ▶ 🍯 Left superior longitudinal fasciculus proper
 - ▶ 🍯 Right superior longitudinal fasciculus proper
 - ▶ 🍯 Superior occipitofrontal fasciculus

Talairach

Arterial Supply

Bounded By

Part Of

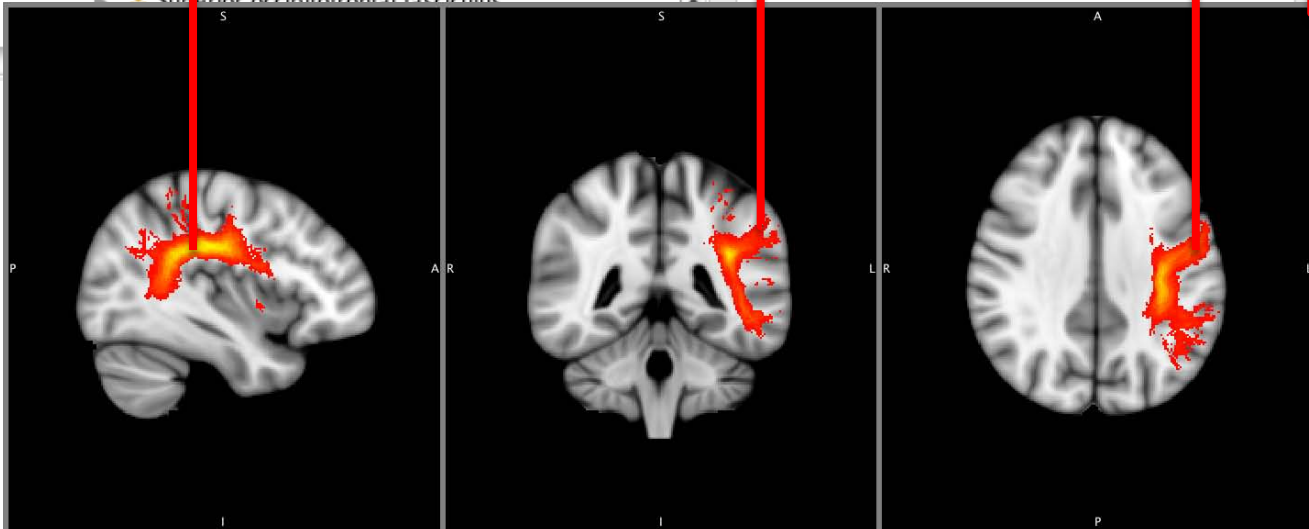
- 🍯 Superior longitudinal fasciculus

Projects From

- 🍯 Brodmann area 39 of inferior parietal lobule

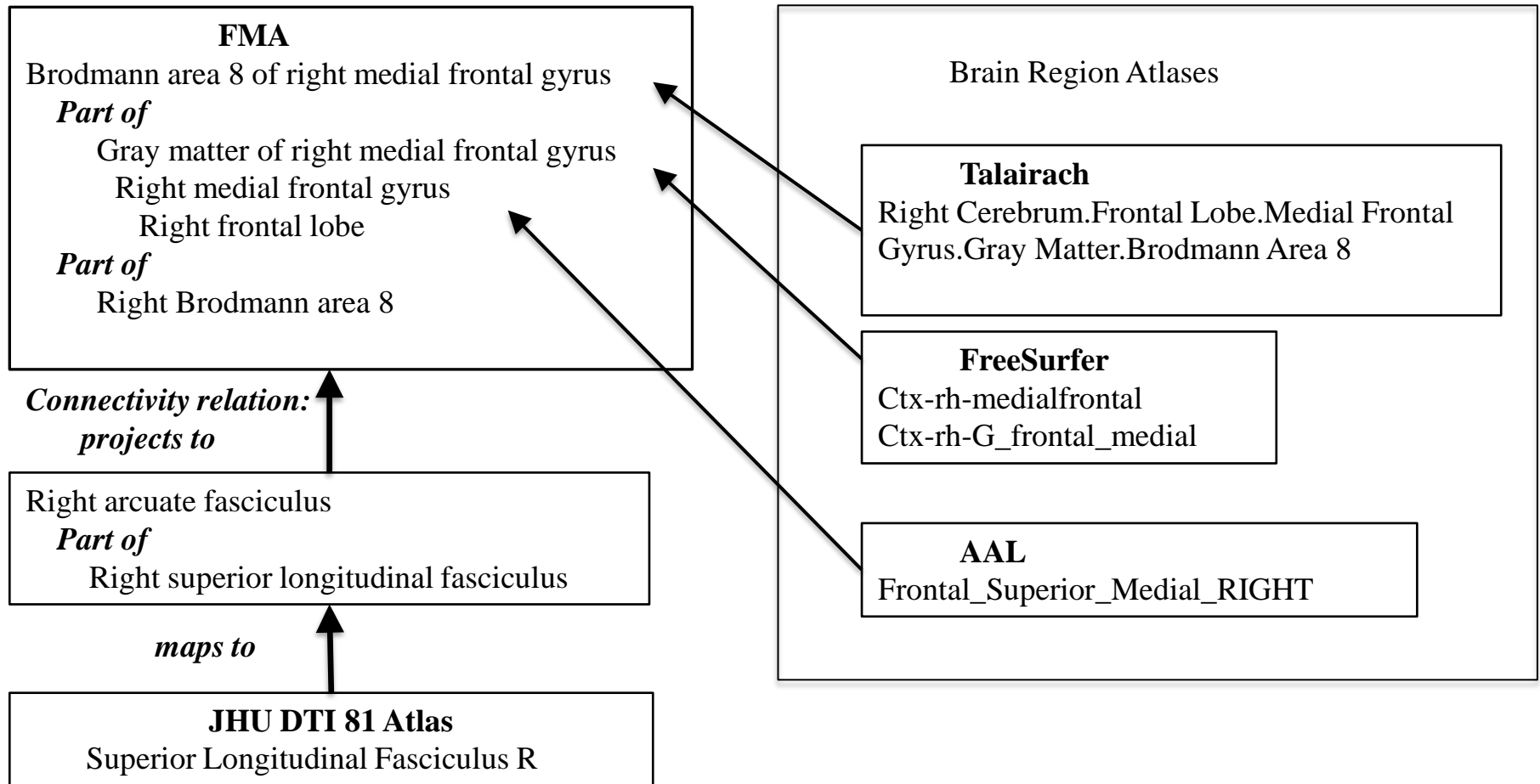
Projects To

- 🍯 Brodmann area 6
- 🍯 Brodmann area 8
- 🍯 Brodmann area 46



JHU DTI 81 Atlas

Cross-correlation of white matter tract with the different gray matter regions



Query Integrator



The screenshot shows the 'Query Manager' interface. At the top left is the 'Structural Informatics Group' logo. The title 'Query Manager' is centered, with the user 'Hello Nolan Nichols' and a 'Logout' button on the right. Below the title is a navigation bar with 'Manage', 'Search', 'Edit', 'User', and 'Help'. The main content area is divided into sections: 'Title' (Image Annotation Service Connectivity Query), 'Description' (Find the AAL IDs of Gray Matter regions connected by the right SLF, then use the AAL IDs to call the AIS webservice that takes the IDs and an fMRI file as arguments, then returns the mean activation for all included), and 'Query' (a SPARQL query). At the bottom, there is a 'Language' dropdown set to 'DXQuery' and an 'Execute' button.

```
declare namespace fma="http://sig.uw.edu/fma#";
declare namespace result="http://sig.uw.edu/result#";
declare namespace rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#";

(: execute a saved query via the QES to find GM regions connected via the left SLF and corresponding AAL IDs :)
let $slfProjectsTo := doc("http://xiphoid.biostr.washington.edu:8080/QueryService/QueryResults?qid=97")

(: brain regions to use as parameters in AIM web service from connectivity query above :)
let $regions := $slfProjectsTo//result:aal_id

(: fMRI file location :)
let $fMRIFile := "/home/bnniii/aim-webservice/images/000640456777zstat1.nii"

(: AIM web service url for an AIM xml file at the label level :)
let $aal2aimMeanByLabel := "http://suralis.biostr.washington.edu:8080/aal2aimMeanByLabel?"

(: call AIM web service using the aalID and fMRI file parameters for the all connected regions :)
let $result := for $aalID in $regions/text()
  return
  doc(concat($aal2aimMeanByLabel, "aalID=", $aalID, ";fMRIFile=", $fMRIFile))

return
<results>
  { $result }
</results>
```

- Create, edit, save, and run web-based queries
- Data must be URL accessible and return XML
- Saved queries can be run via URL, and thus called by other queries
- Supports SPARQL, XQuery, and more...

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