Are no or yes:
3 questions I have about brain labeling

Works in progress: July 26th, 2010

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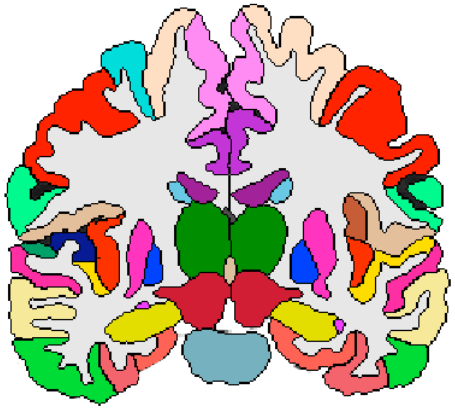
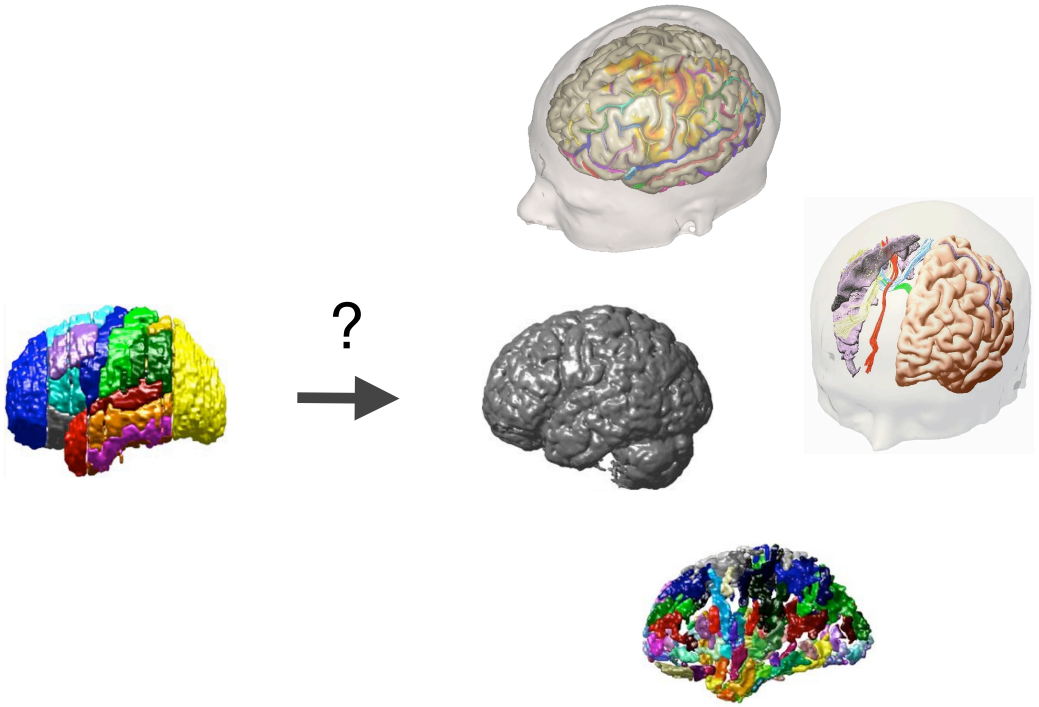
asst. professor of clinical neurobiology



Why label brains?

(This question doesn't count as one of the three.)



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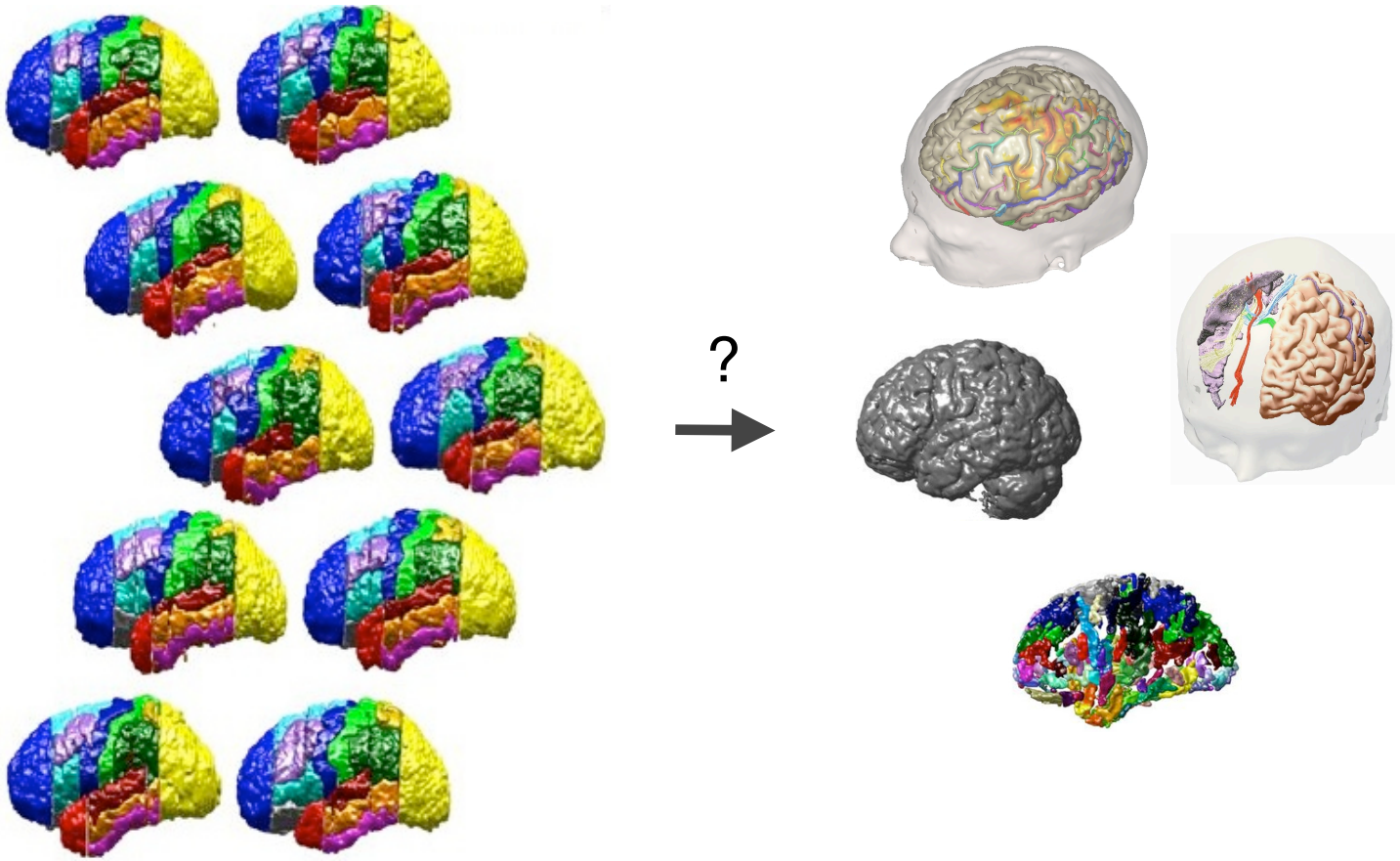
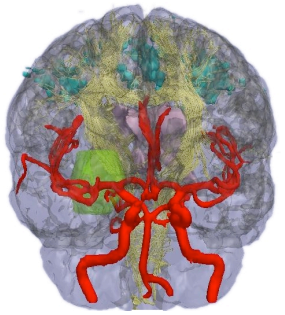


Why label brains?

Labels serve as a visual guide and teaching tool

- teach brain anatomy
- guide neurosurgery



http://www.cbd.ucla.edu/bios/iacoboni.html, http://brainvisa.info/, http://dx.doi.org/10.1126/science.1145876
http://groups.csail.mit.edu/vision/medical-vision/past-projects.html, http://www.spl.harvard.edu/publications/item/view/1265

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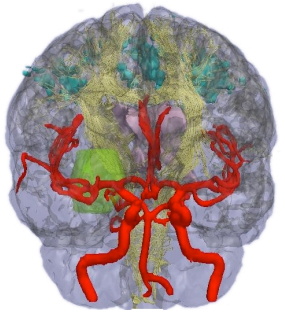
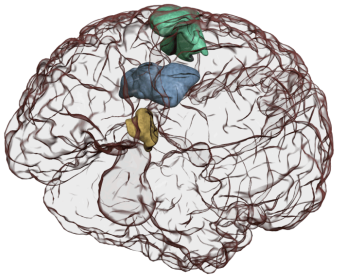


Labels break up data within a brain

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



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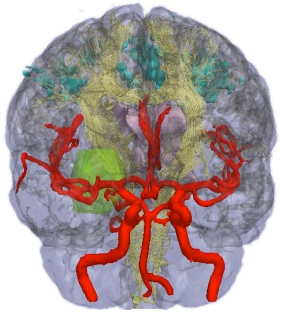

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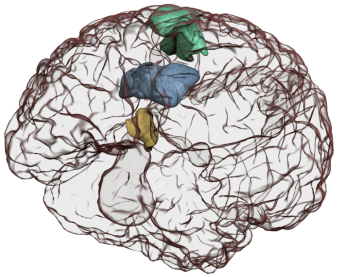
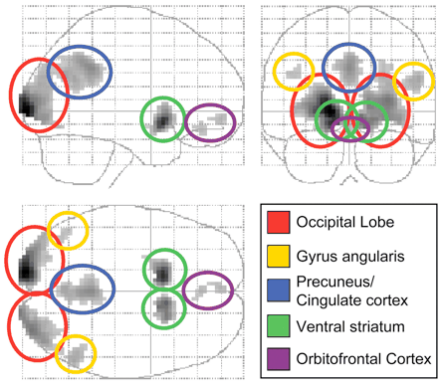


Labels establish correspondences across brains

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



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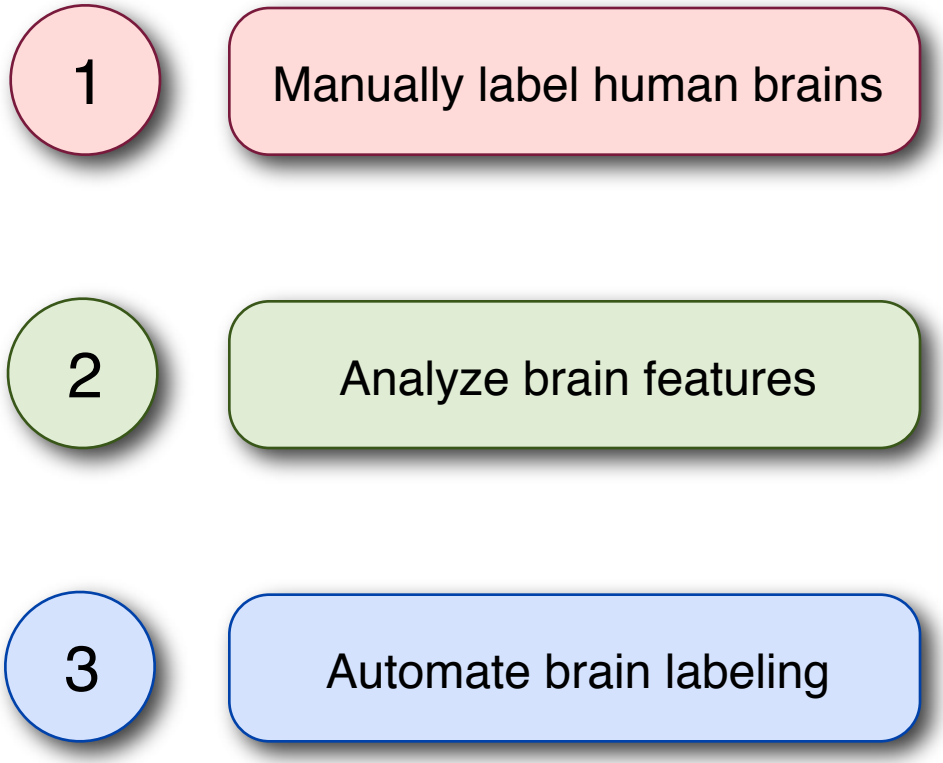
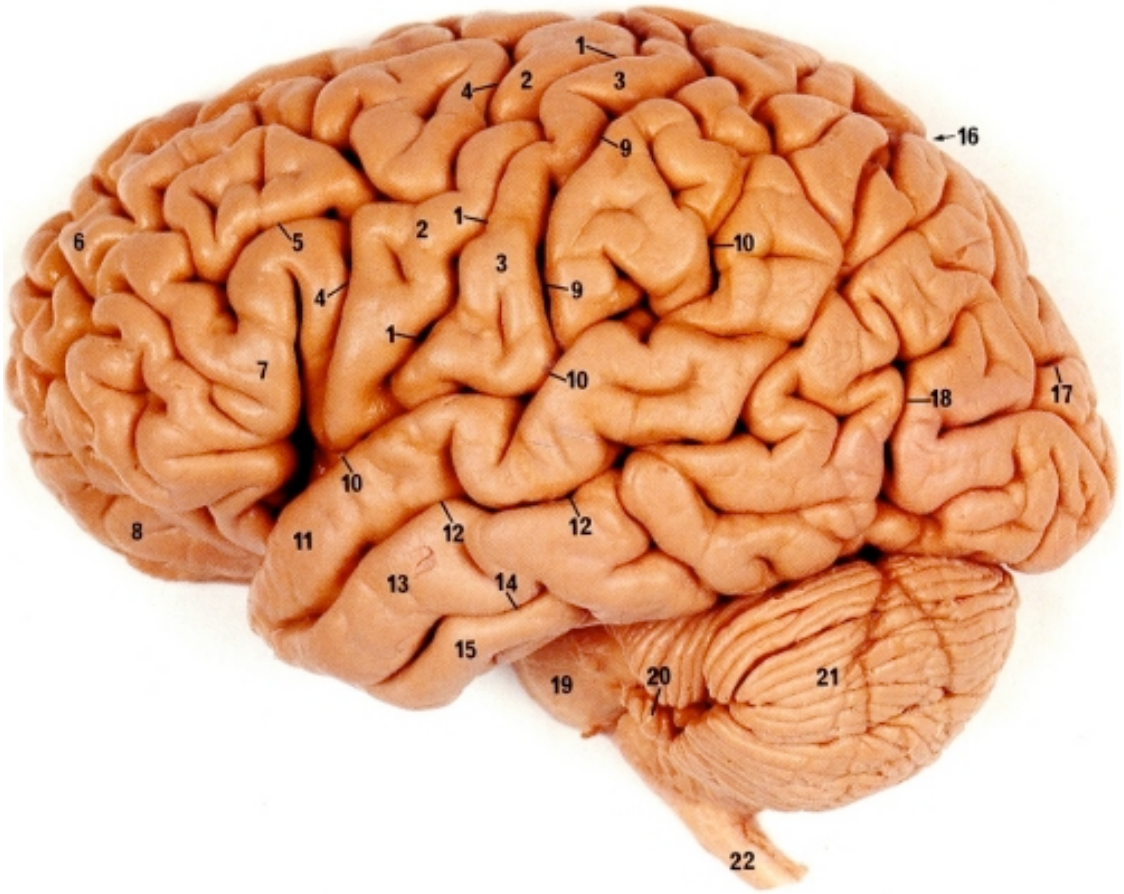
NIMH R01: “Mindboggling Shape Analysis and Identification” has 3 components:

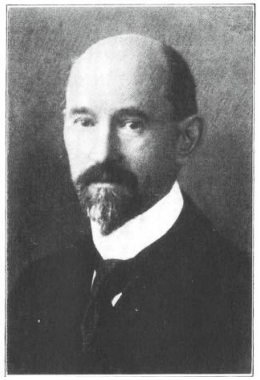


I will pick one pressing question from each component...

1. Manually label human brains
2. Analyze brain features
3. Automate brain labeling

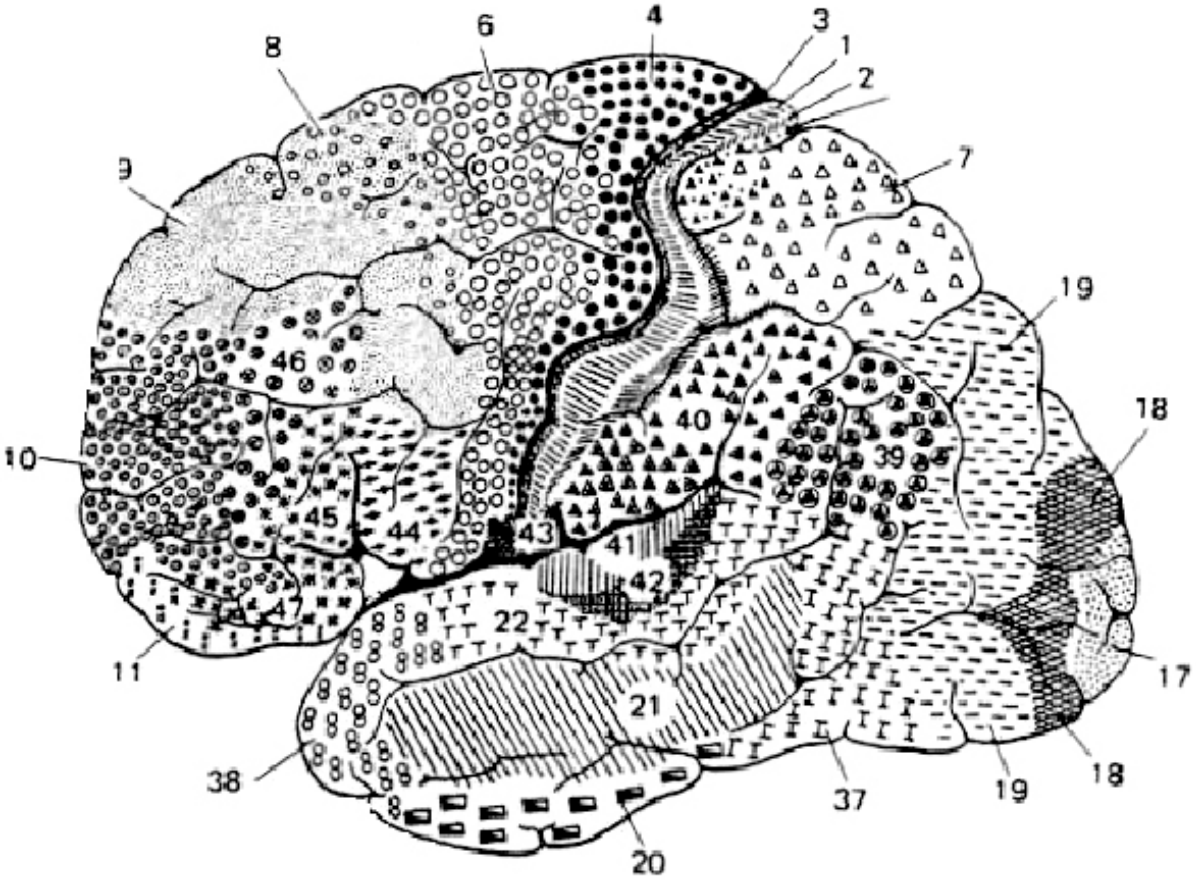
The object of inquiry

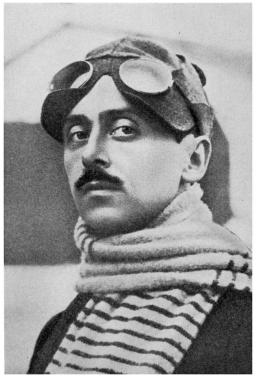




Korbinian Brodmann
(1868-1918)

Cytoarchitectonic boundaries





Constantin von Economo
(1876-1931)

Cytoarchitectonic boundaries

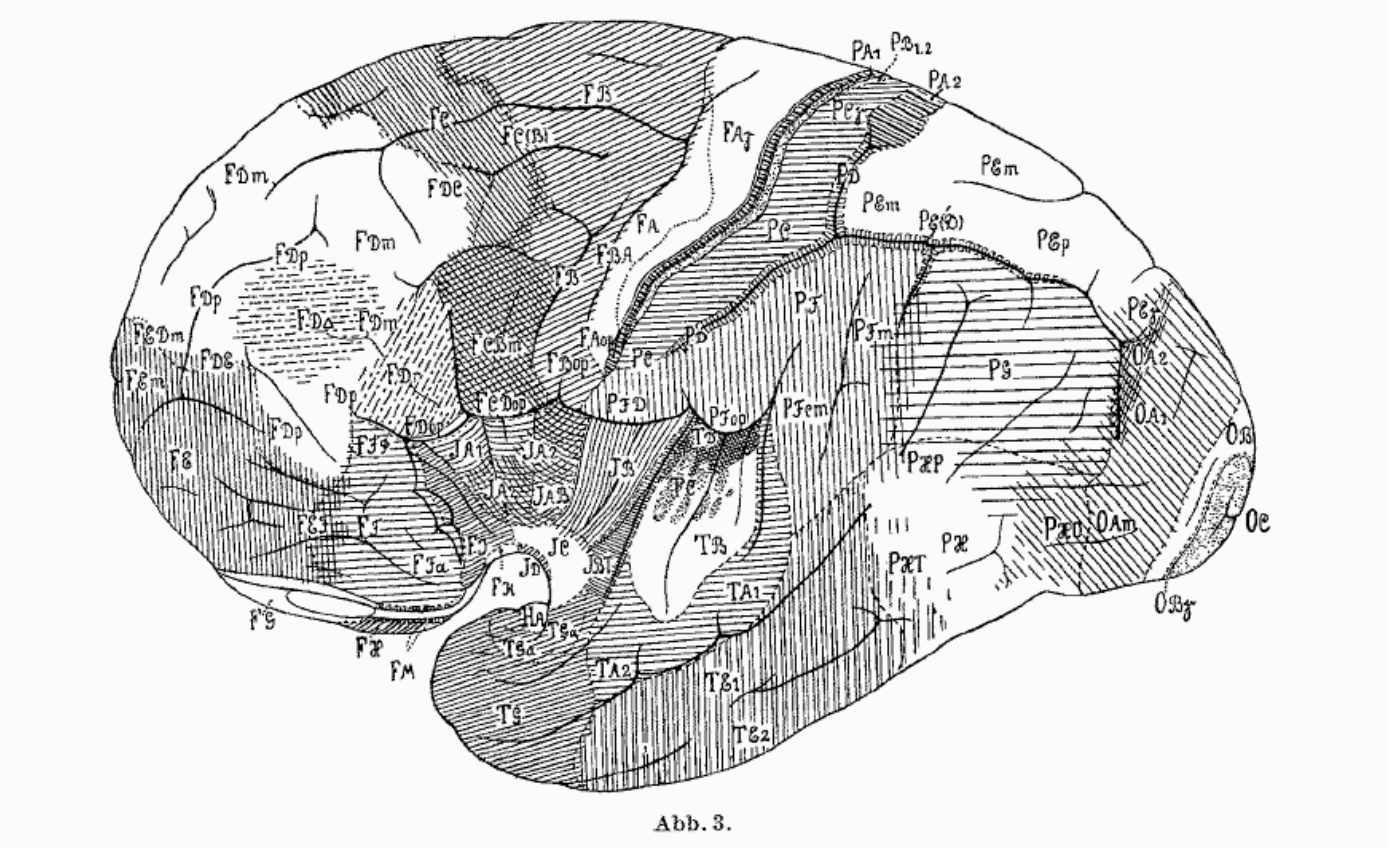
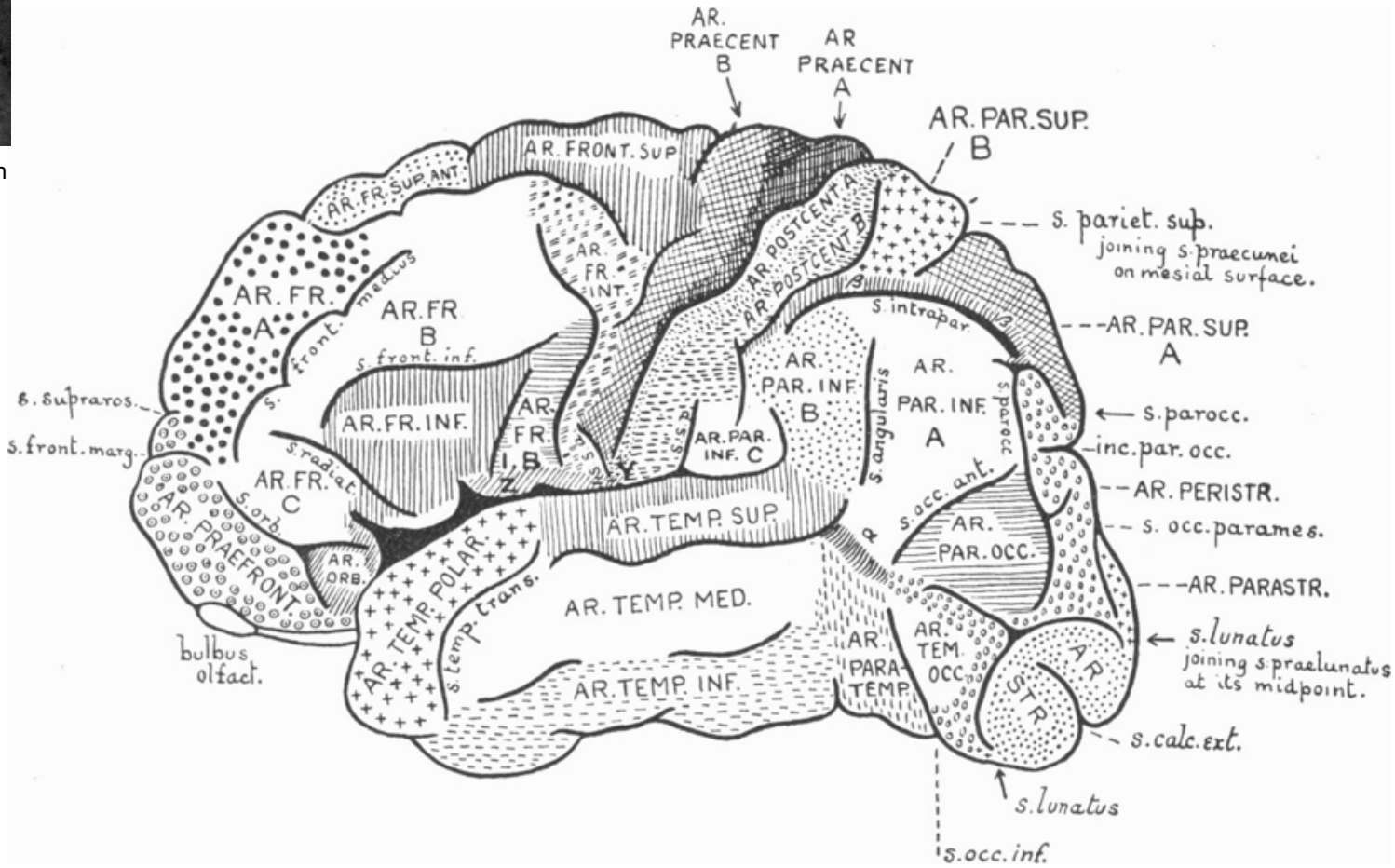


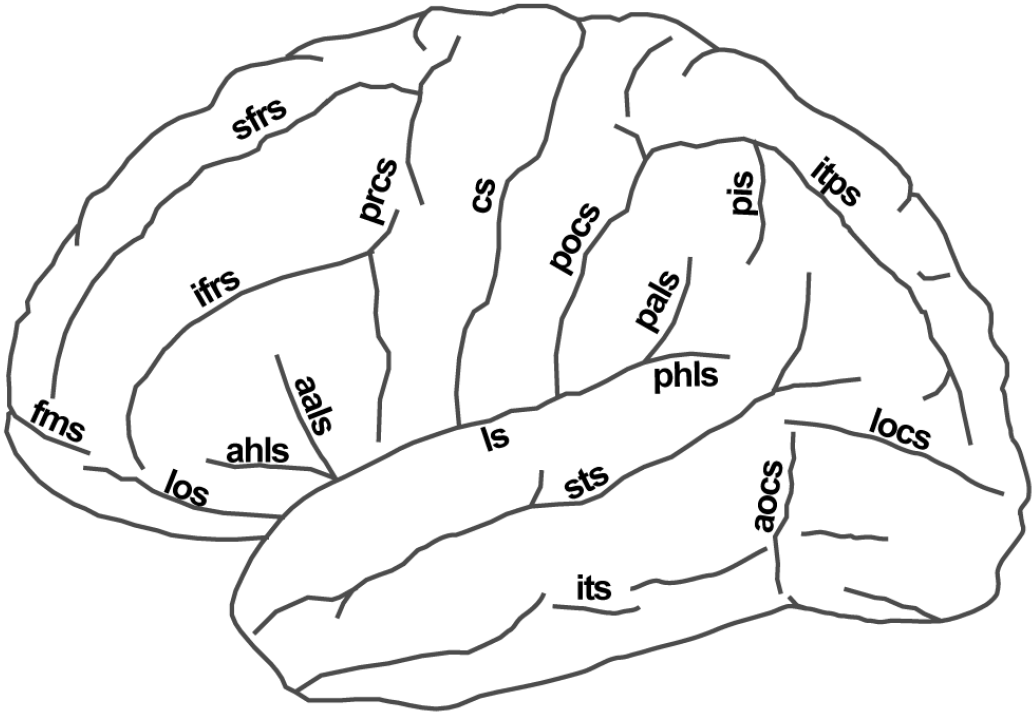
Abb. 3.

Sir Grafton Elliot Smith
(1871-1937)

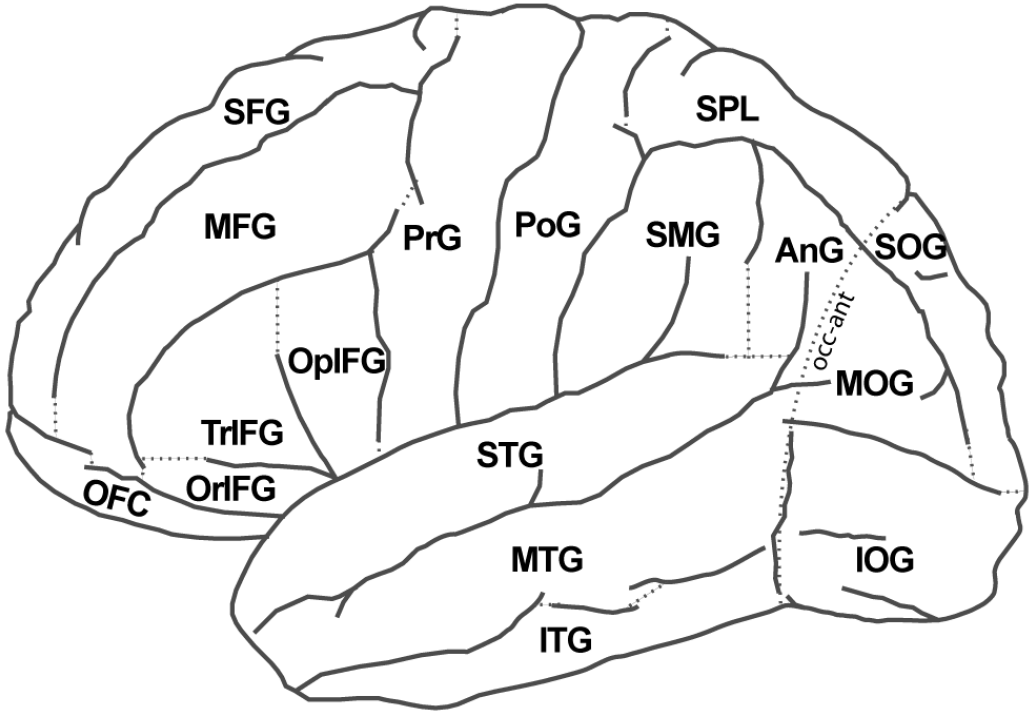
Topographic boundaries

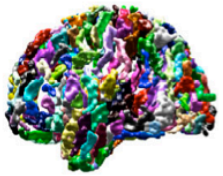


Sulcus definitions



Gyrus definitions





brainCOLOR Collaborative Open Labeling Online Resource

Proposed Cortical Parcellation Protocol: SURVEY 1 SURVEY 2

Neuromorphometrics has developed a cortical parcellation (anatomical labeling) protocol that will be used by trained personnel to manually label an initial set of at least 800 to 1,000 T1-weighted MRI brain volumes as part of three different NIH-funded grants (find out more).

This protocol is derived from some of the best and most frequently used parcellation methods established by other research groups. From a detailed review of these methods, including their anatomic validity and consistency across brains, Jason Tourville and Ruth Carper have extracted the best approaches from each of these research groups and consolidated them into a single parcellation protocol.

The anatomically labeled brain images will be made publicly available online as a free, downloadable resource. In order to ensure that these anatomical labels are meaningful and useful to the neuroscientific community, we urge you to take the following two surveys.

SURVEY 1, below, collects your comments regarding the protocol.
SURVEY 2 takes recommendations for additional datasets you wish to have us manually label.

Instructions
For each survey, please fill in your name and email address, fill in the survey and click the Submit button at the bottom of the survey.

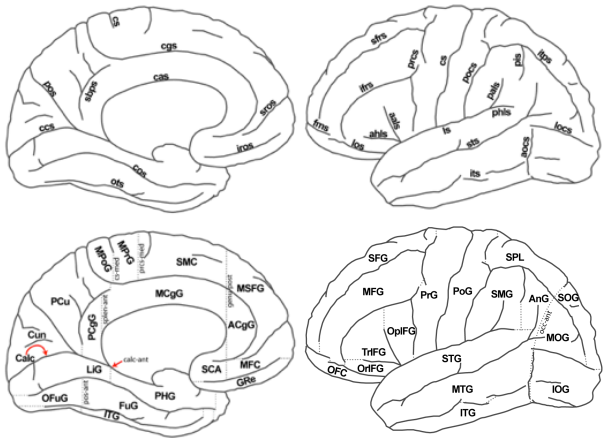


Figure 2. Region-delimiting sulci (top) and proposed regions of interest (bottom) of the medial (left) and lateral (right) cortical surfaces are schematized (see lists above for abbreviation definitions). All regions, including optional regions are shown with the exception of entorhinal cortex. Boundaries not formed by sulci are indicated by dotted lines. Dividing planes are labeled (all lower case; dotted lines that are not labeled represent simple extensions of sulci). The curved arrow from the Calcarine Cortex ROI (Calc) to the calcarine sulcus indicates that the ROI lies within the sulcus.

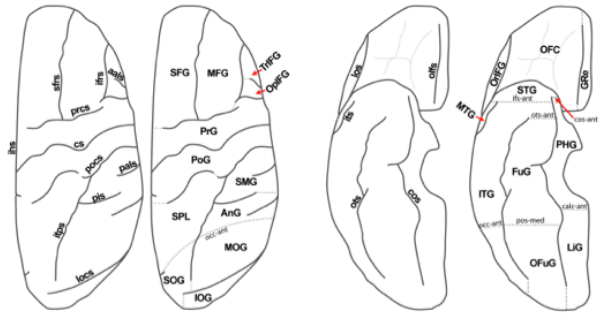
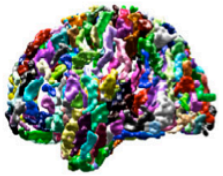


Figure 3. Sulci and ROIs are shown on the dorsal (left group) and ventral (right group) surfaces. Boundaries not formed by sulci are indicated by dotted lines. Dividing planes are labeled (all lower case; dotted lines that are not labeled represent simple extensions of sulci).



brainCOLOR Collaborative Open Labeling Online Resource

Proposed Cortical Parcellation Protocol: SURVEY 1 SURVEY 2

Frontal Lobe (FL): Lateral Surface

Precentral Gyrus (PrG)

Anterior: precentral sulcus --- Posterior: central sulcus --- Superior: superior margin of the interhemispheric fissure --- Inferior: lateral margin of the dorsal bank of the lateral fissure

Superior Frontal Gyrus (SFG)

Anterior: frontomarginal sulcus --- Posterior: precentral sulcus / plane prcs-med --- Medial: superior margin of interhemispheric fissure --- Inferior: anteriorly: lateral orbital sulcus; posteriorly: middle frontal sulcus

Middle Frontal Gyrus (MFG)

Posterior: precentral sulcus --- Superior: superior frontal sulcus --- Inferior: anteriorly: lateral orbital sulcus; posteriorly: inferior frontal sulcus

Inferior Frontal Gyrus (IFG)

Posterior: precentral sulcus --- Superior/anterior: anteriorly: lateral orbital sulcus; posteriorly: inferior frontal sulcus --- Inferior: anteriorly: lateral orbital sulcus; posteriorly: lateral orbital sulcus / posterior projection from the posterior limit of the lateral orbital sulcus to the lateral sulcus

Regions of interest included in the protocol

ACgG	anterior cingulate gyrus
AIns*	anterior insula
AnG	angular gyrus
Calc*	calcarine cortex
CgG	cingulate gyrus
CO	central operculum
Cun	cuneus
Ent	entorhinal area
FO	frontal operculum
FuG	fusiform gyrus
GRe	gyrus rectus
IFG	inferior frontal gyrus
IOG	inferior occipital gyrus
ITG	inferior temporal gyrus
LiG	lingual gyrus
MCgG*	middle cingulate gyrus
MFC*	medial frontal cortex
MFG	middle frontal gyrus
MOG*	middle occipital gyrus
MPoG	postcentral gyrus, medial segment
MPrG	precentral gyrus, medial segment
MSFG	superior frontal gyrus, medial segment
MTG	middle temporal gyrus
OFC*	orbitofrontal cortex
OFuG*	occipital fusiform gyrus
OpIFG	opercular part of the inferior frontal gyrus
OrIFG	orbital part of the inferior frontal gyrus
PCgG	posterior cingulate gyrus
PCu	precuneus
PHG	parahippocampal gyrus
PIns*	posterior insula
PO	parietal operculum
PoG	postcentral gyrus
PP*	planum polare
PrG	precentral gyrus
PT*	planum temporale
SCA	subcallosal area
SFG	supereior frontal gyrus
SMC*	supplementary motor cortex
SMG	supramarginal gyrus
SOG	superior occipital gyrus
SPL	superior parietal lobule
STG	superior temporal gyrus
TriFG	triangular part of the inferior frontal gyrus
TTG	transverse temporal gyrus

* not included in the NeuroNames database

Sulci included in the protocol and their abbreviations

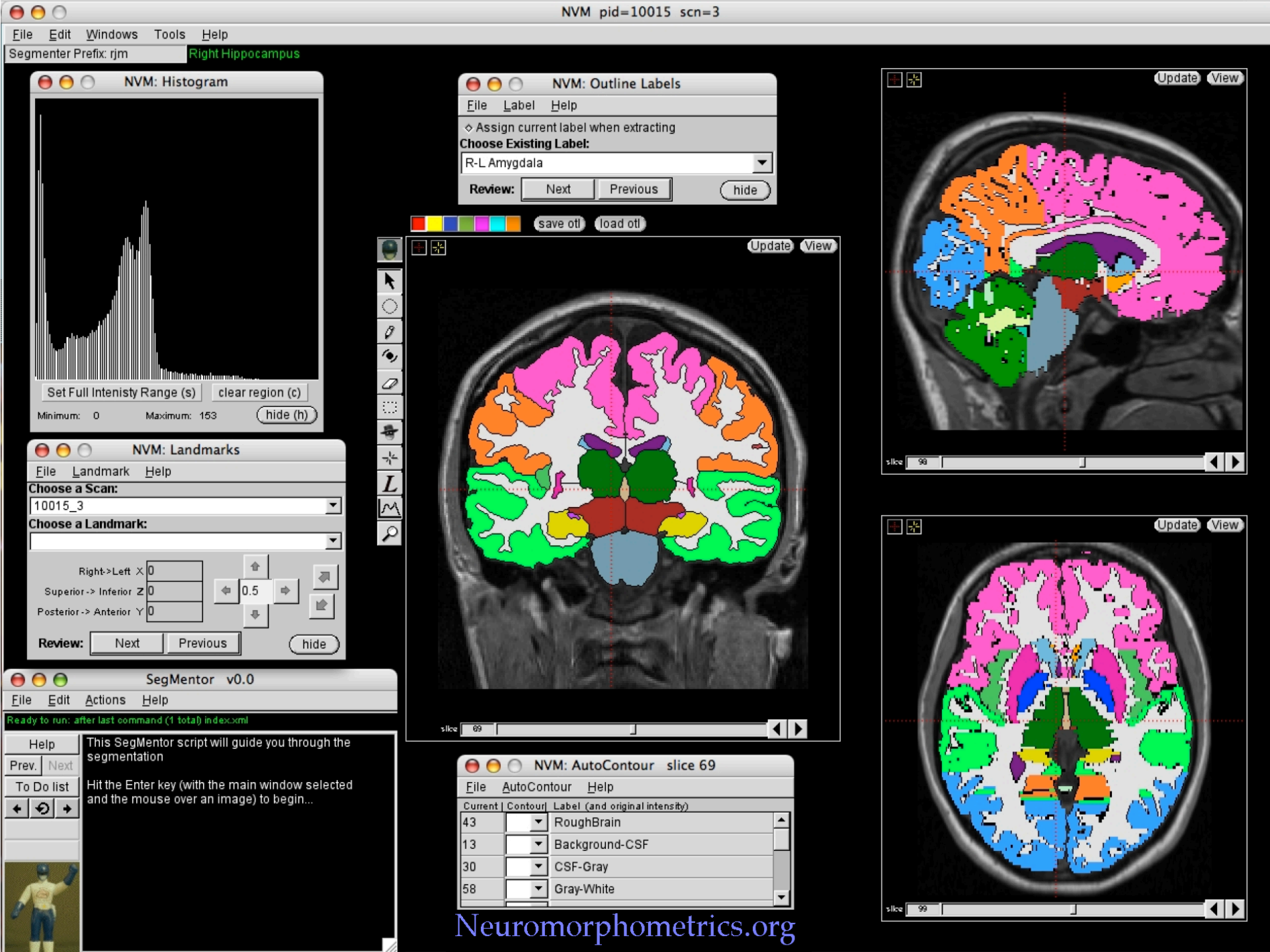
aals	anterior ascending ramus of the lateral sulcus
ahls	anterior horizontal ramus of the lateral sulcus
aocs	anterior occipital sulcus
cas	callosal sulcus
ccs	calcarine sulcus
cgs	cingulate sulcus
cis	central insular sulcus
cos	collateral sulcus
crs	circular insular sulcus
cs	central sulcus
fms*	frontomarginal sulcus
ftts*	first transverse temporal sulcus
hs*	Heschl's sulcus
ifrs	inferior frontal sulcus
ihs*	interhemispheric sulcus
ltts*	intermediate transverse temporal sulcus
iros	inferior rostral sulcus
itps	intraparietal sulcus
its	inferior temporal sulcus
locs	lateral occipital sulcus
los	lateral orbital sulcus
ls	lateral sulcus
olfs	olfactory sulcus
ots	occipitotemporal sulcus
pals	posterior ascending ramus of the lateral sulcus
phls	posterior horizontal ramus of the lateral sulcus
pis*	primary intermediate sulcus
pocs	postcentral sulcus
pos	parietooccipital sulcus
prcs*	precentral sulcus
sbps	subparietal sulcus
sfrs	superior frontal sulcus
sros	superior rostral sulcus
sts	superior temporal sulcus

* not included in the NeuroNames database

Dividing planes included in the protocol and their abbreviations

The following dividing planes are used in the protocol.
Planes are coronal unless specified otherwise:

calc-ant	anterior limit of the calcarine sulcus
cos-ant	anterior limit of the collateral sulcus
cs-med	dorsomedial limit of the central sulcus;
genu-post	marked by the posterior limit of the genu of the corpus callosum
ifs-ant	anterior limit of the inferior temporal sulcus
occ-ant	oblique medial-lateral plane given by a line drawn through points at (i) ventrolateral limit of the anterior occipital sulcus, (ii) jnct of the lateral occipital sulcus and the anterior occipital sulcus, and (iii) the dorsomedial limit of the parietooccipital sulcus
ots-ant	anterior limit of the occipitotemporal sulcus
prcs-med	dorsomedial limit of the precentral sulcus
prcs-lat	ventrolateral limit of the precentral sulcus
pocs-lat	ventrolateral limit of the postcentral sulcus
pos-ant	anterior limit of the ventral bank of the parietooccipital sulcus
tf-jnct	junction of the temporal and frontal lobes
splen-ant	anterior limit of the splenium of the corpus callosum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Right Hippocampus
NVM: Histogram
Set Full Intenisty Range (s)
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Maximum: 153
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NVM: Outline Labels
File Label Help
◇ Assign current label when extracting
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slice 69
slice 98
slice 99
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Superior -> Inferior Z 0
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Help
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Hit the Enter key (with the main window selected and the mouse over an image) to begin...
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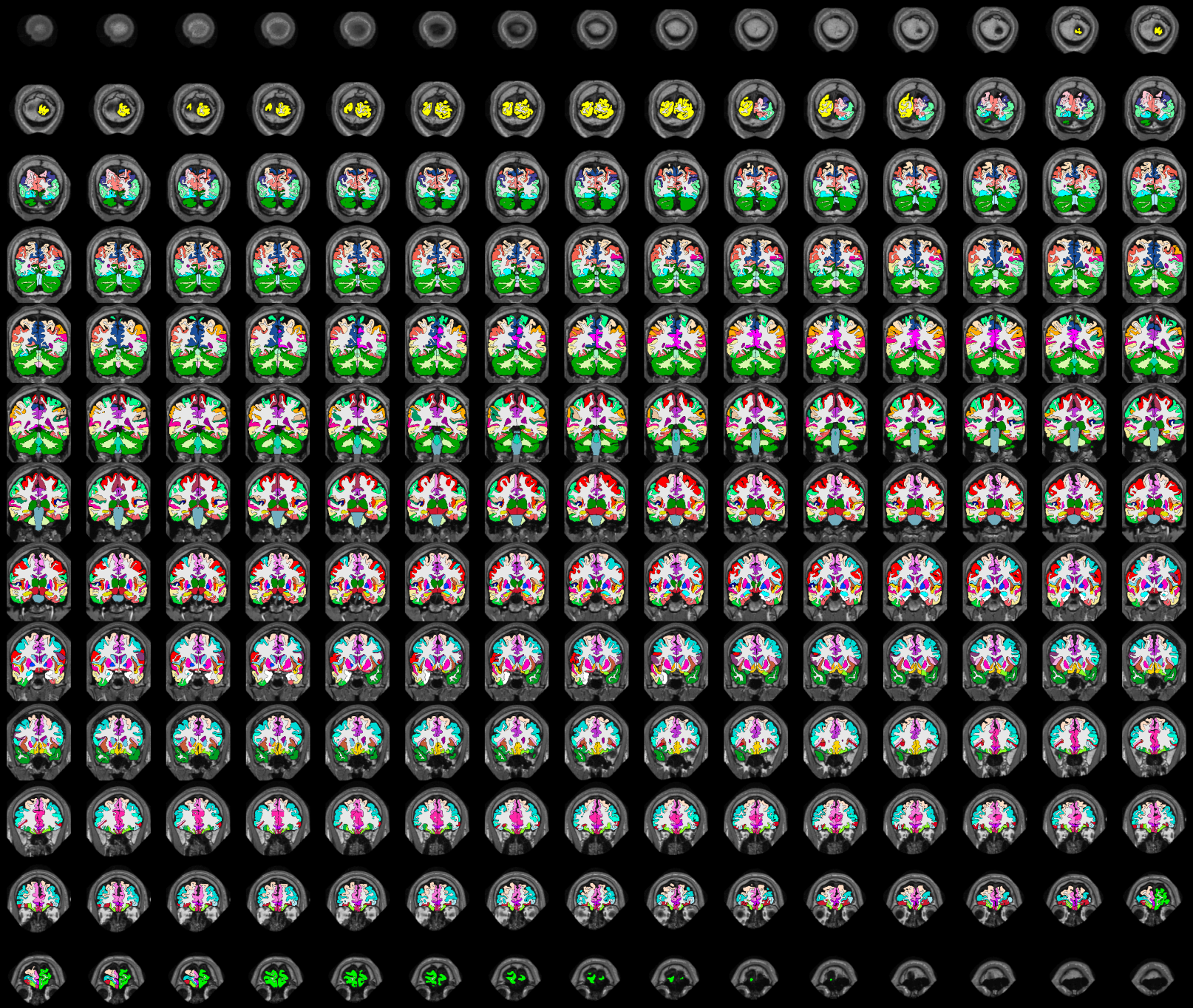
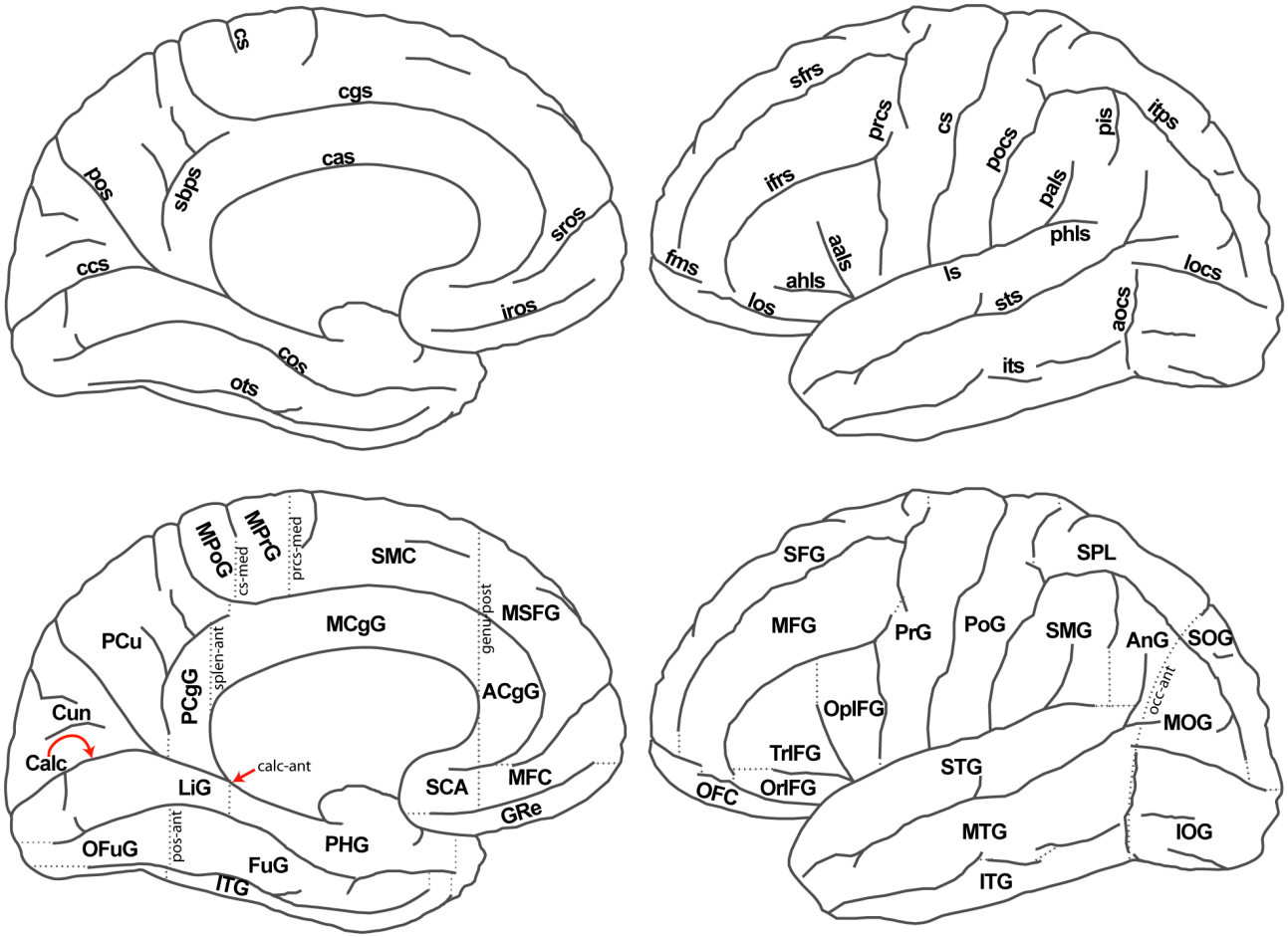
43 RoughBrain
13 Background-CSF
30 CSF-Gray
58 Gray-White
Neuromorphometrics.org



Label boundary planes



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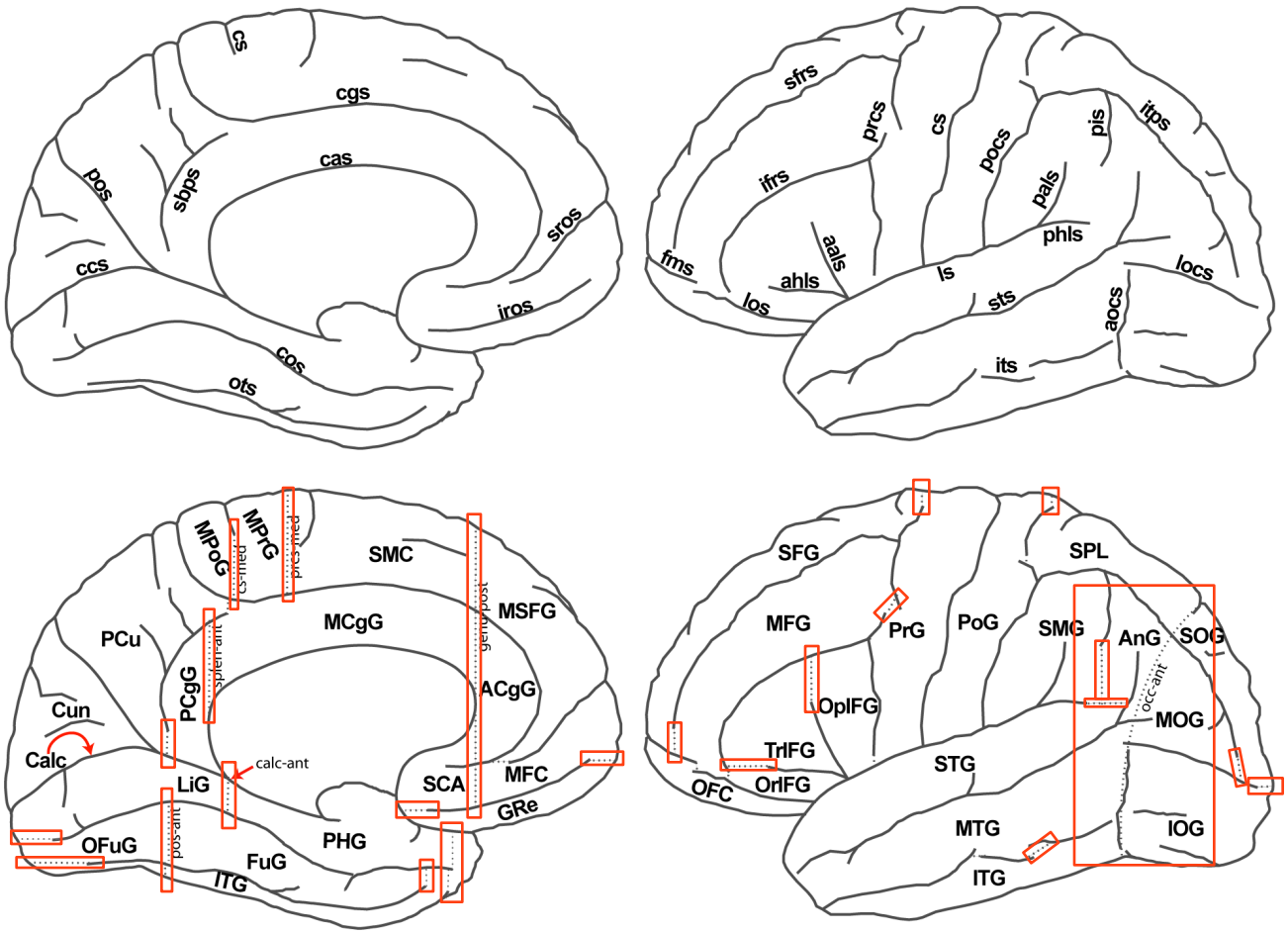
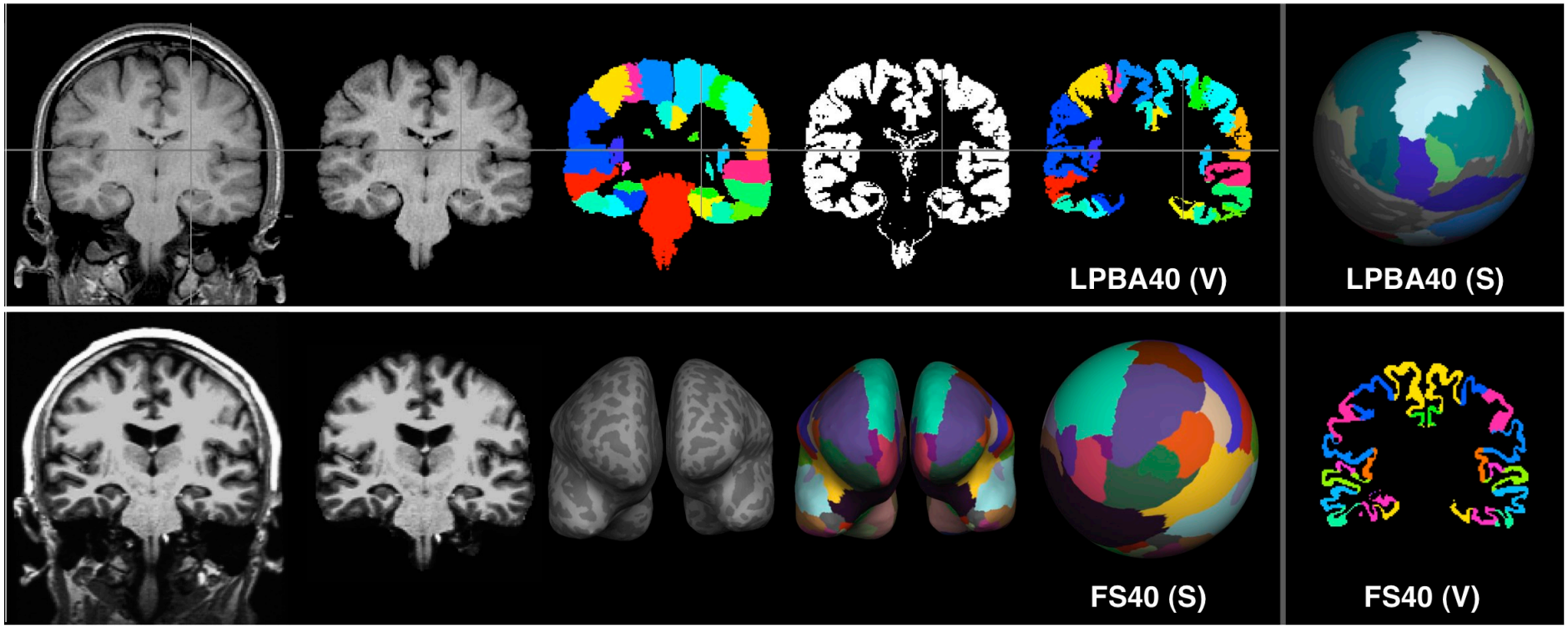


Establishing compatibility between volume and surface label definitions



1 How should we solicit feedback about our labels?

1

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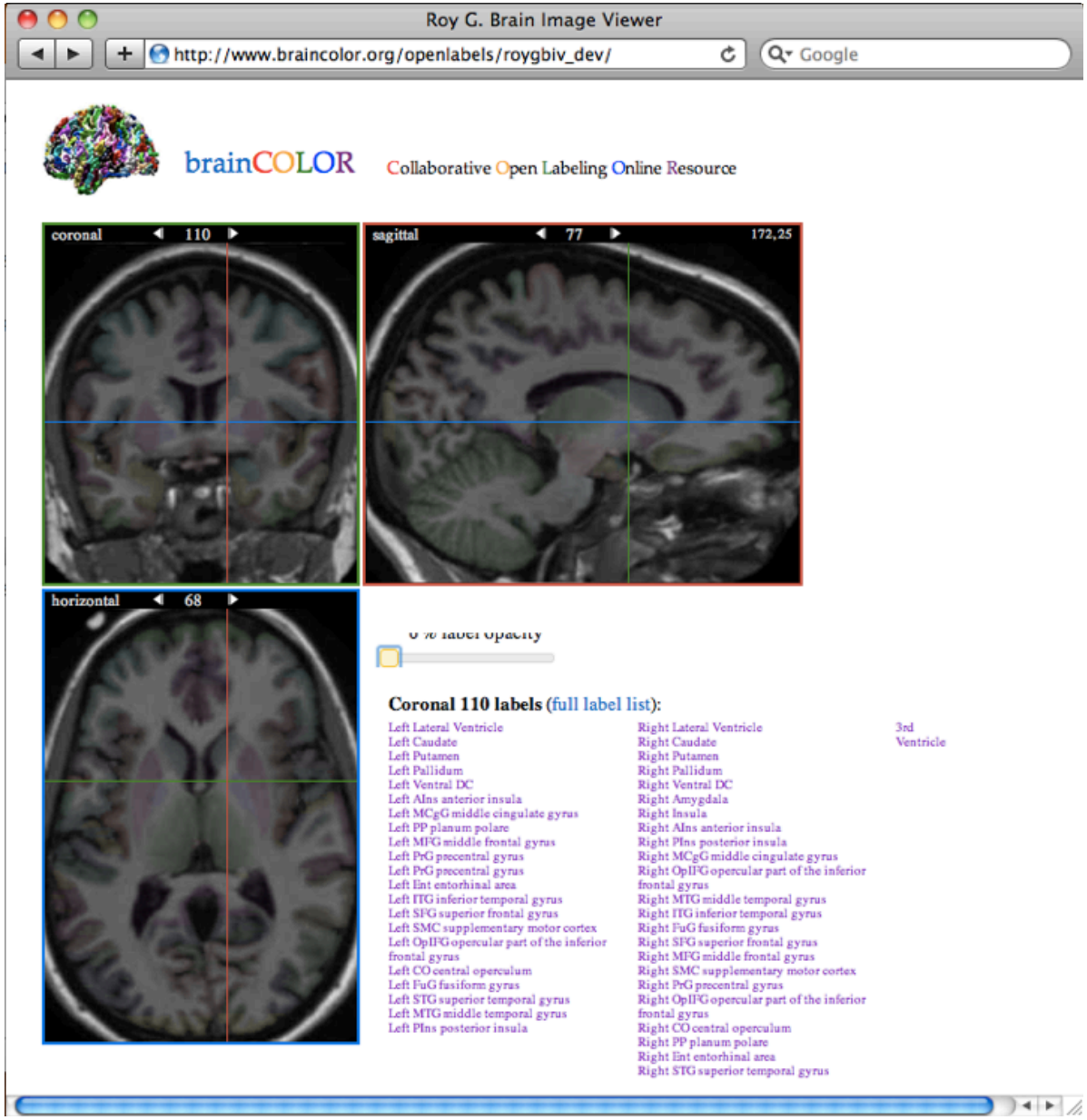

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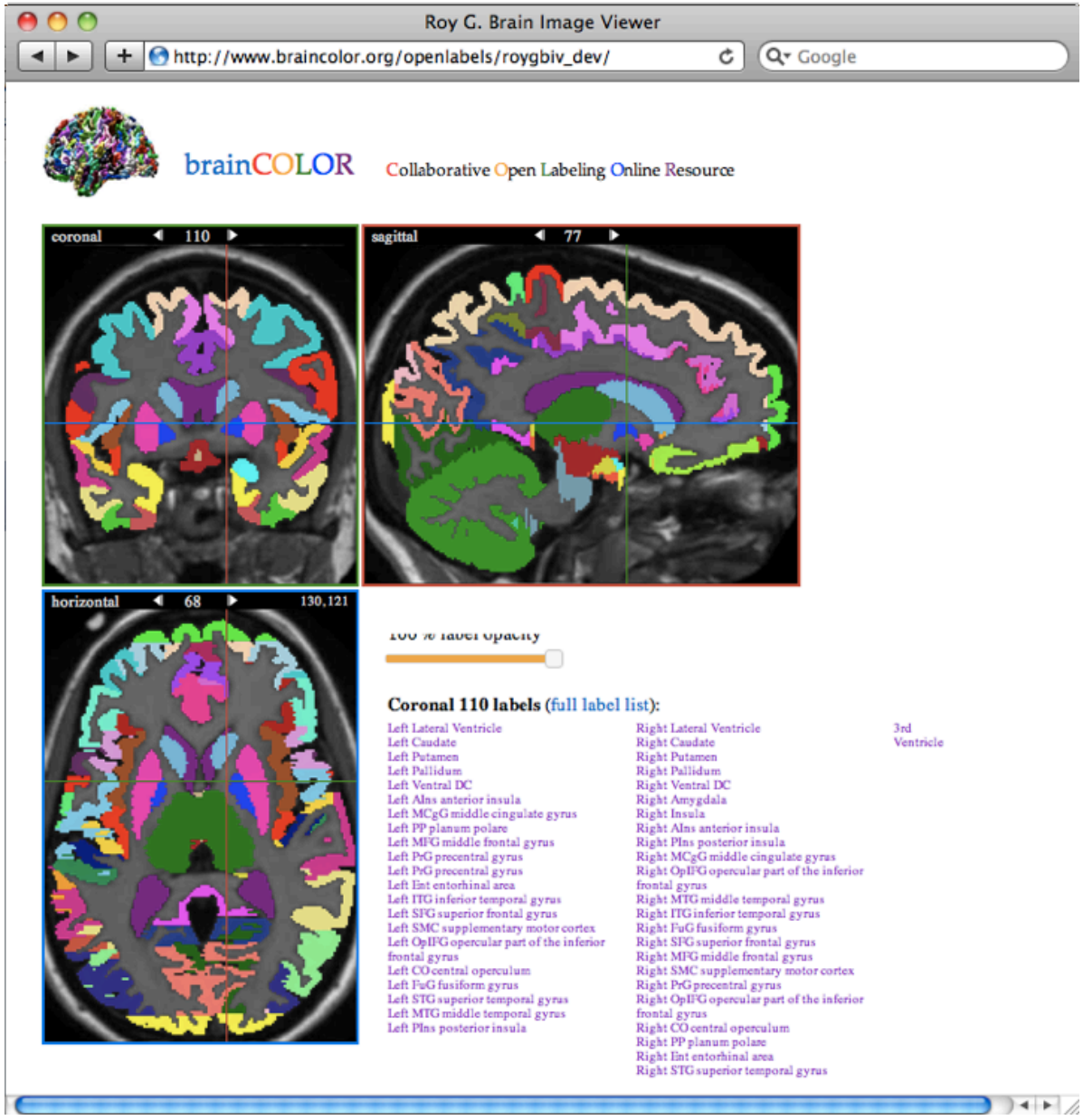

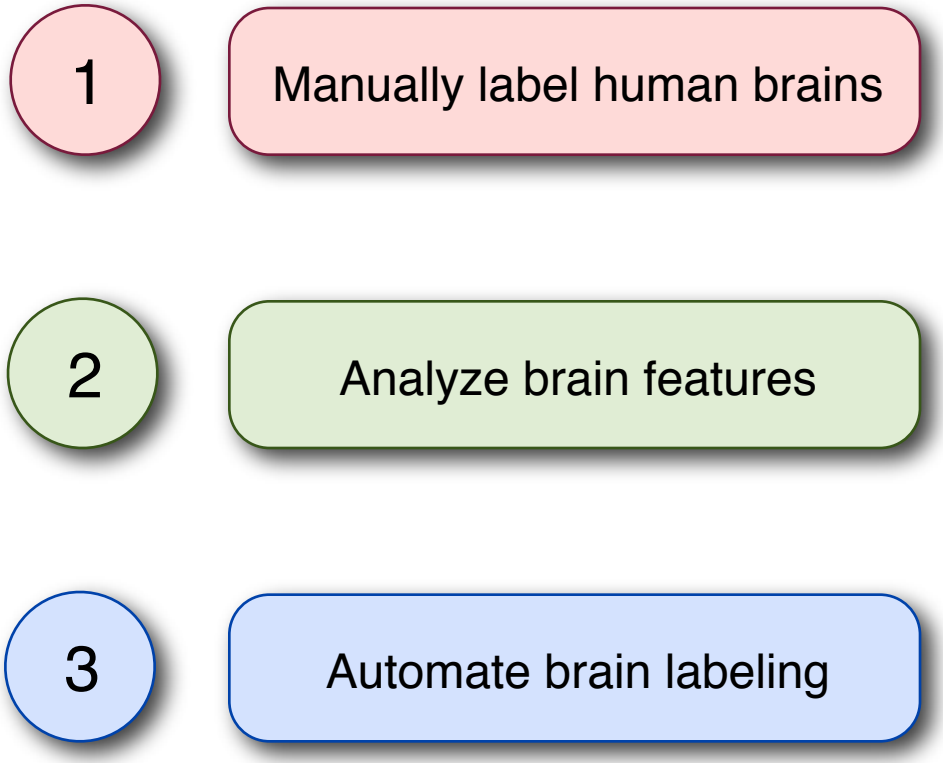
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Analyze brain features
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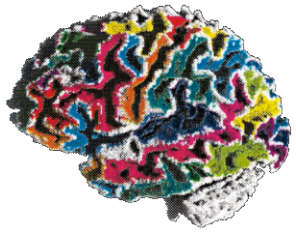
1 Manually label human brains

2 Analyze brain features

3 Automate brain labeling

Candidate features

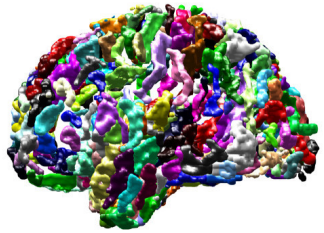


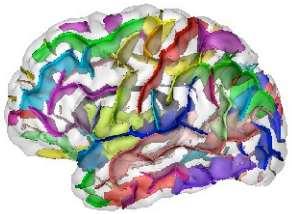
3-D:

labeled **regions** (manual)

sulcal **basins**

sulcal **skeletons**

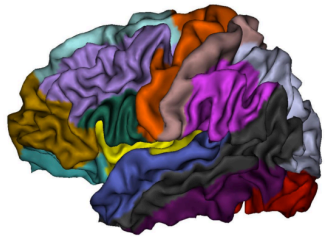


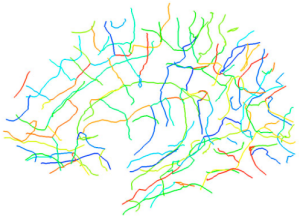


2-D:

sulcal **ribbons**

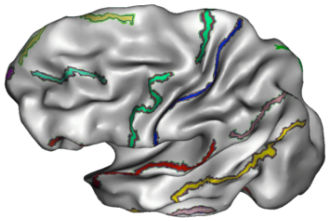
gyral **surfaces**

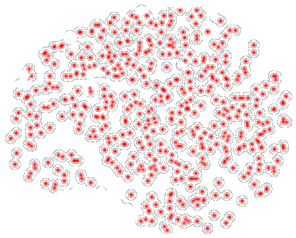




1-D:

sulcal & gyral **curves**

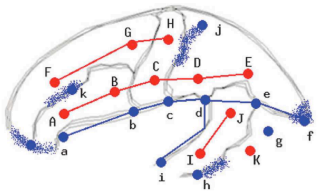




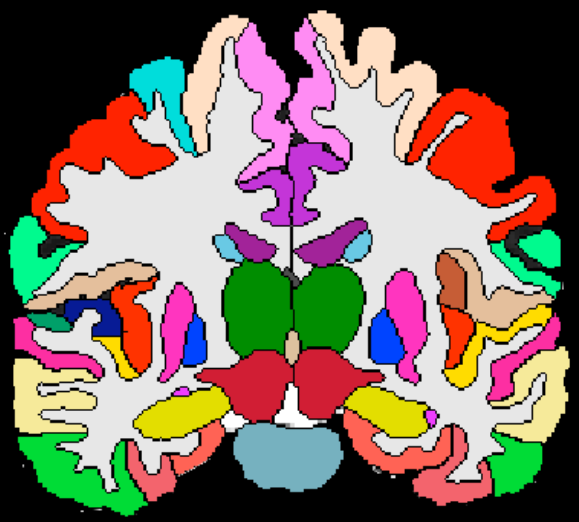
0-D:

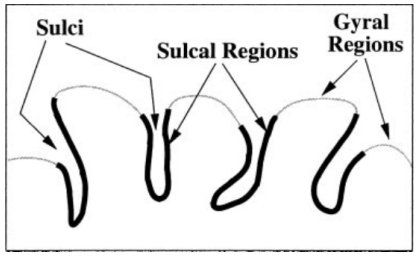
SIFT **points**

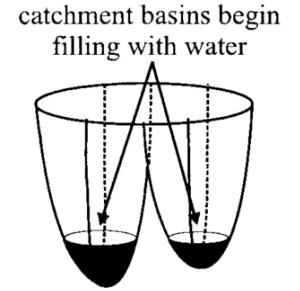
sulcal **pits**

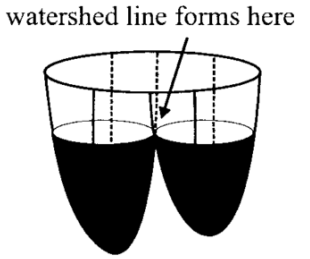


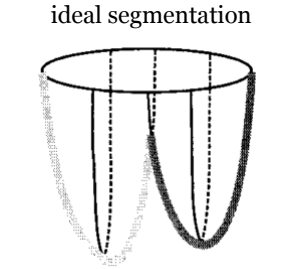
Candidate features in 3-D:
manually labeled **regions**



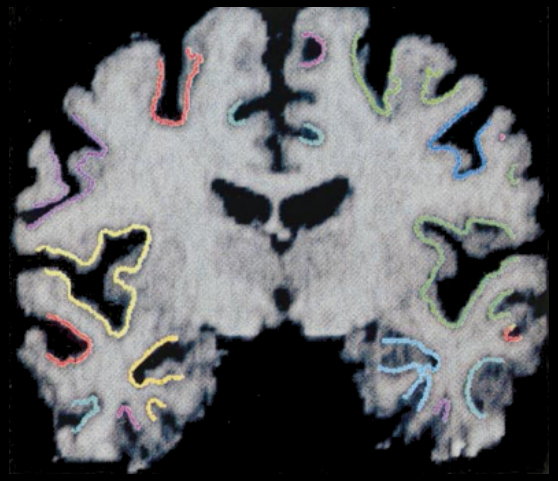


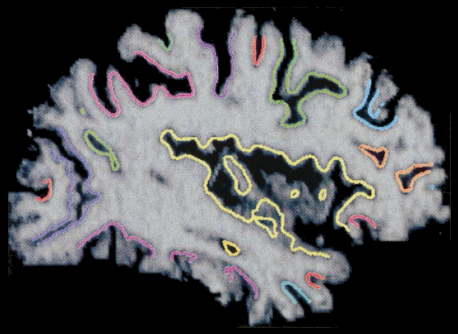




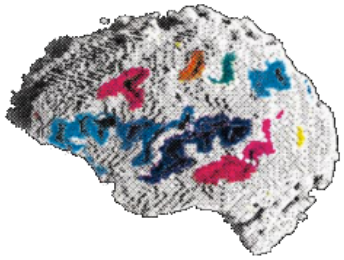


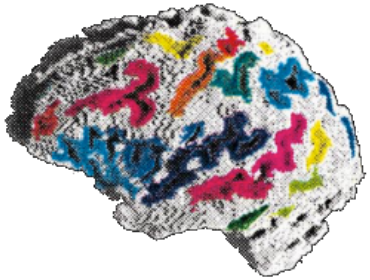
Candidate features in 3-D: sulcal **basins**

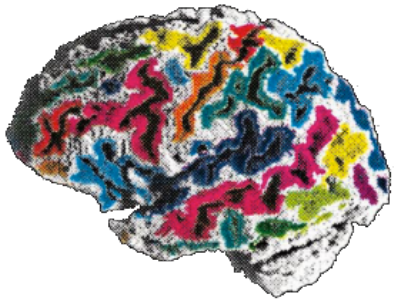


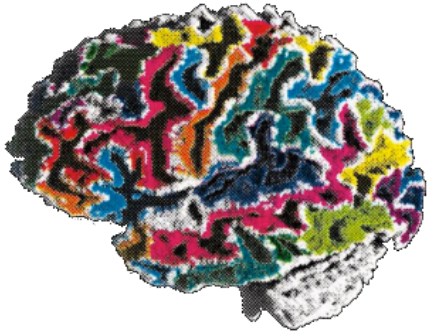


Rettman et al. 2002, Lohmann et al., 2000

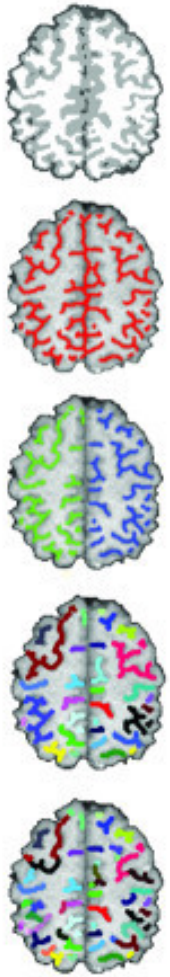


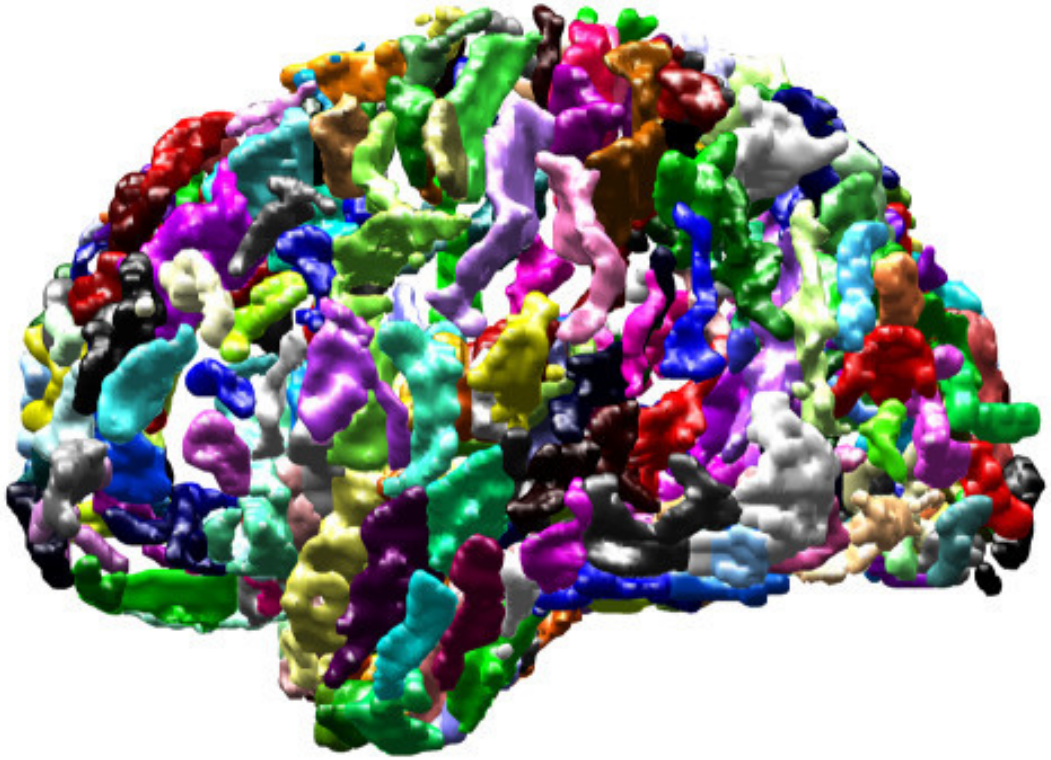




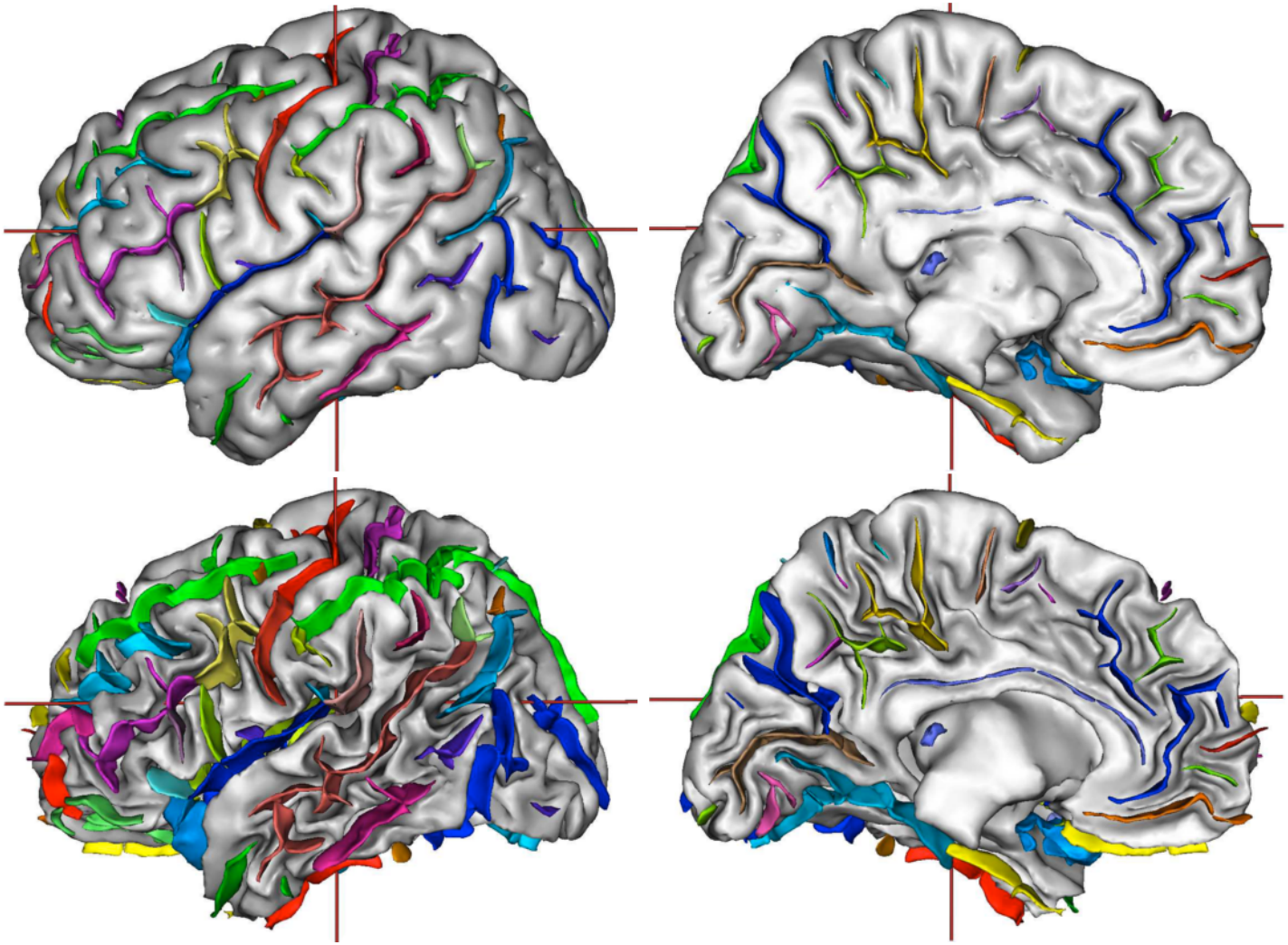


Candidate features in 3-D:
sulcal **skeletons**



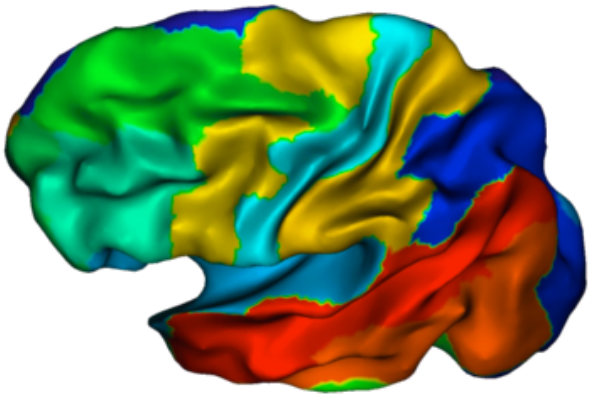


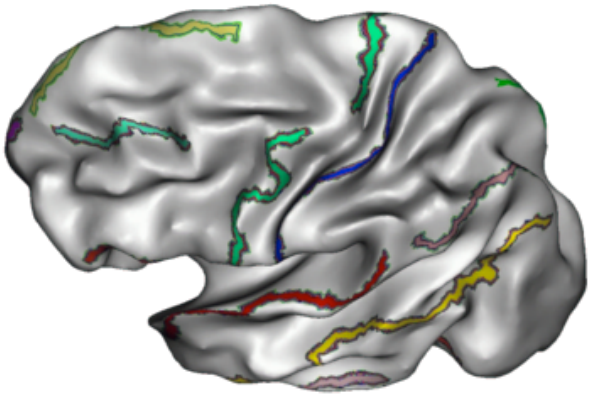
Candidate features in 2-D:
sulcal **ribbons**

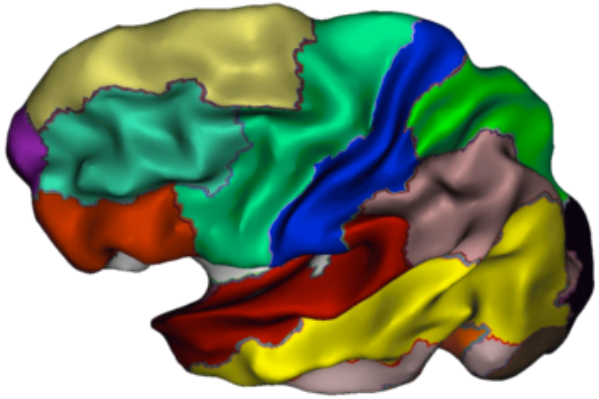


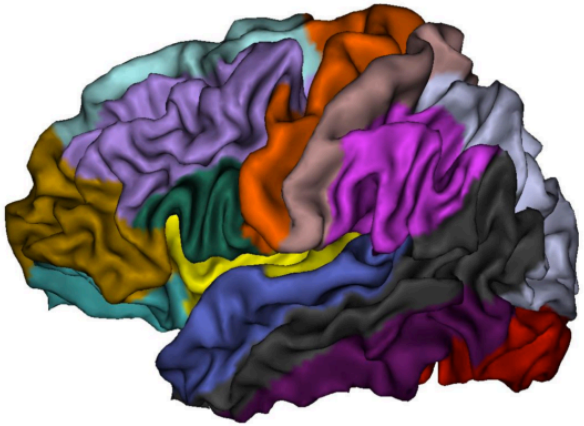
Clouchoux, 2008

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



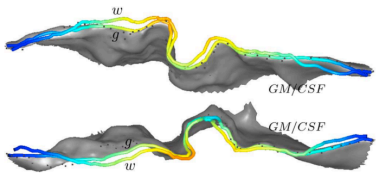


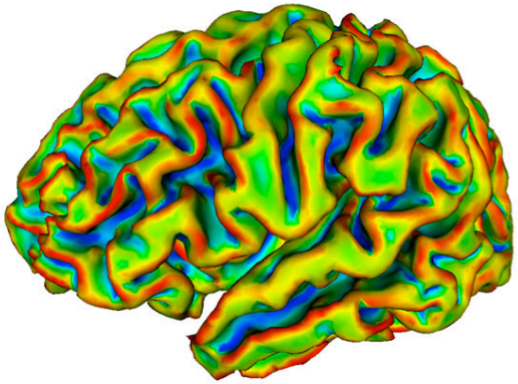


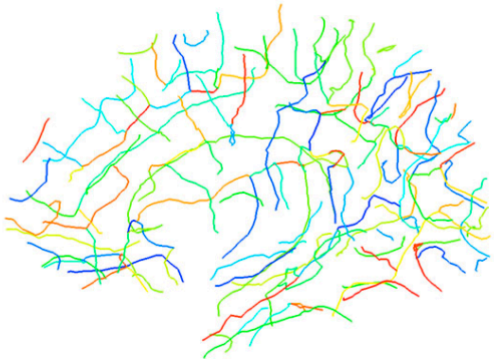


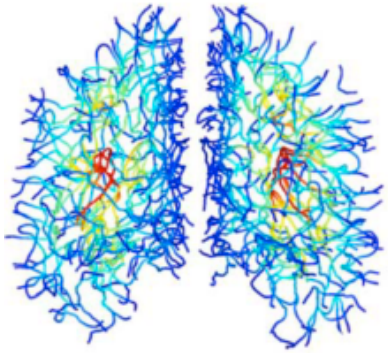
Cachia et al., 2003, Clouchoux et al., 2006

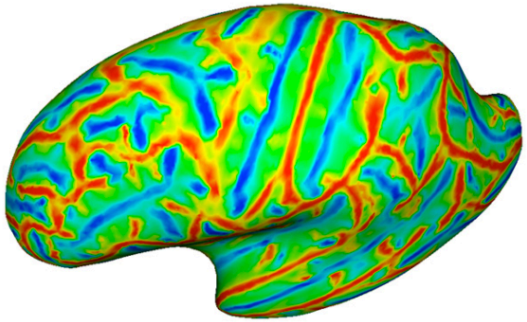
Candidate features in 1-D:
sulcal **curves**

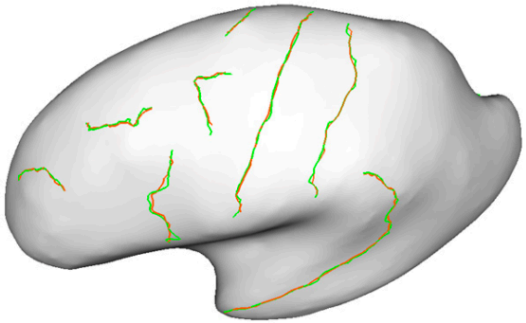


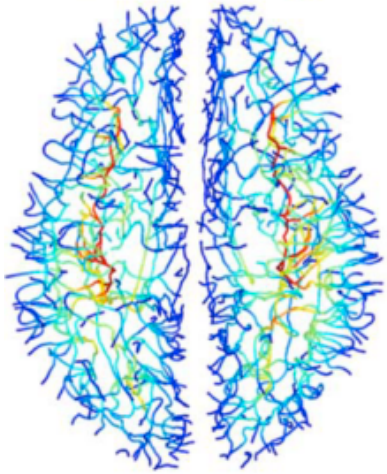






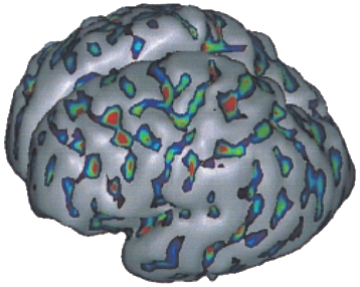


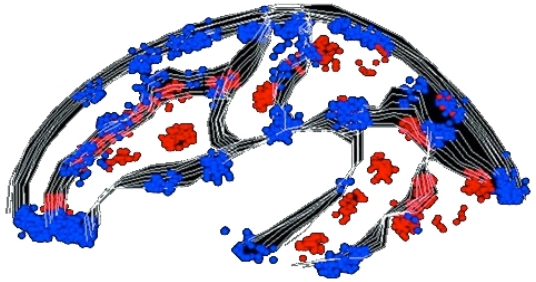


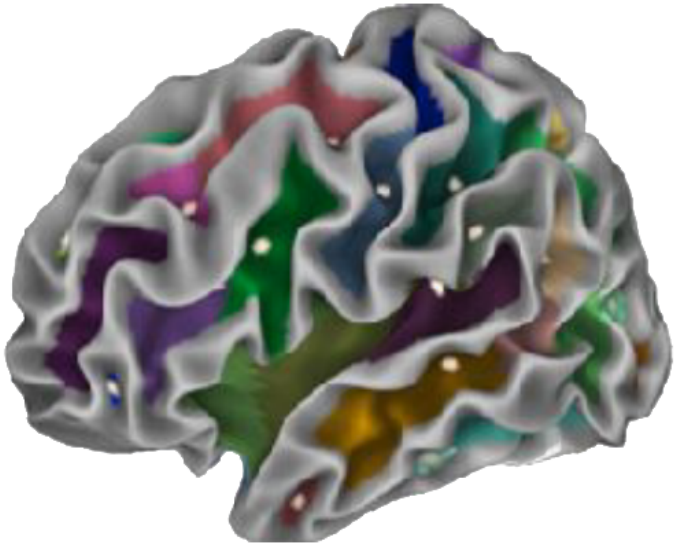


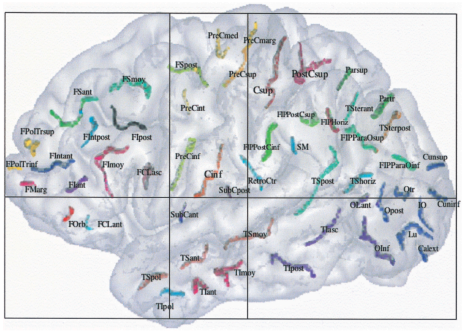
Li et al., 2008, Kao et al., 2007

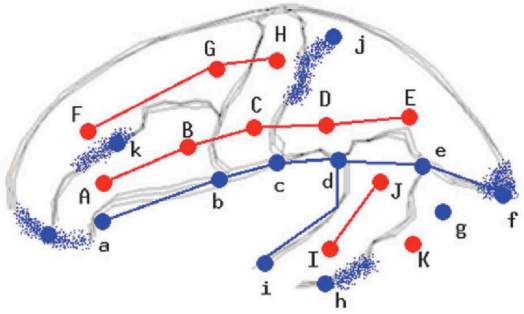
Candidate features in 0-D: sulcal **pits**











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

Candidate features in 0-D:
SIFT **points**

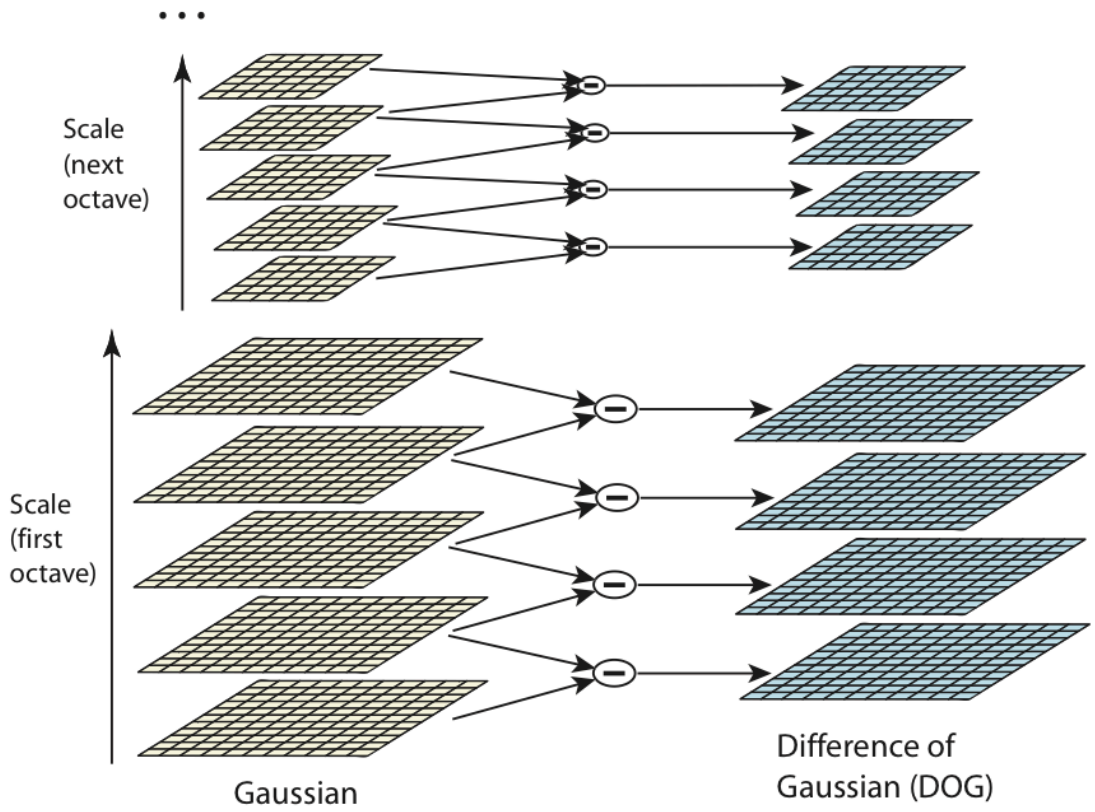
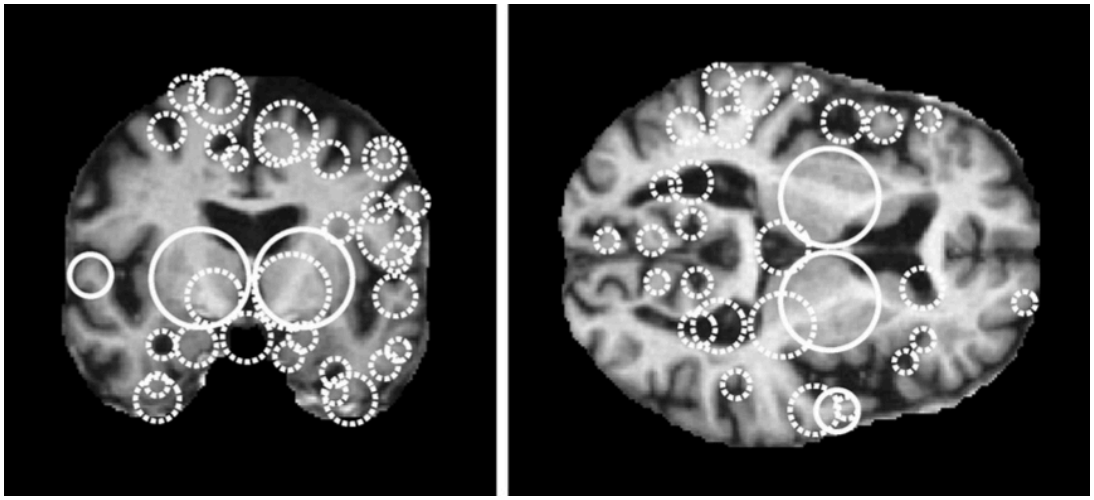


Figure 1: For each octave of scale space, the initial image is repeatedly convolved with Gaussians to produce the set of scale space images shown on the left. Adjacent Gaussian images are subtracted to produce the difference-of-Gaussian images on the right. After each octave, the Gaussian image is down-sampled by a factor of 2, and the process repeated.

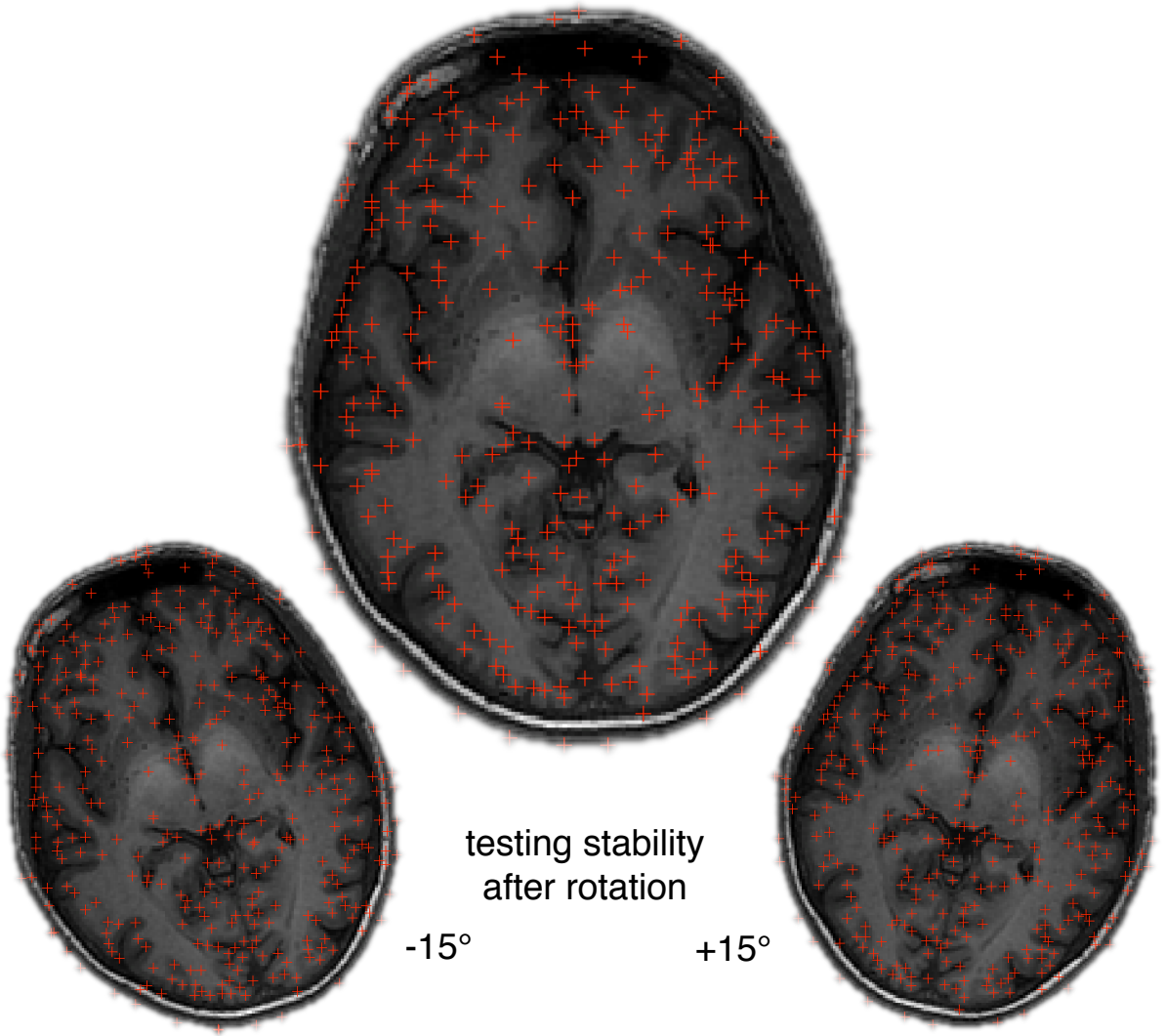
Lowe 2004

Candidate features in 0-D:
SIFT **points**



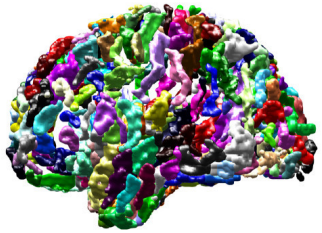
Toews 2008, 2010

Candidate features in 0-D:
SIFT **points**

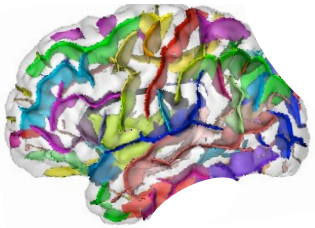


Feature hierarchy

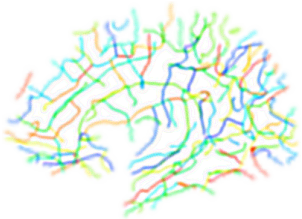
3-D



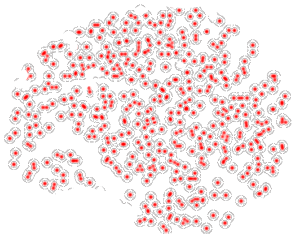
2-D

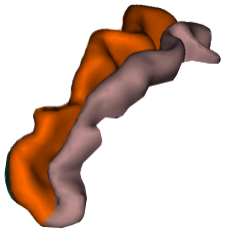


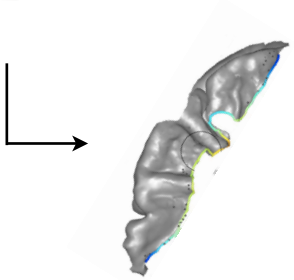
1-D

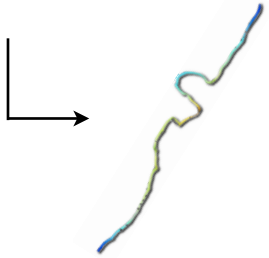


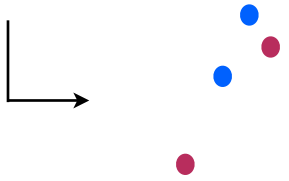
0-D







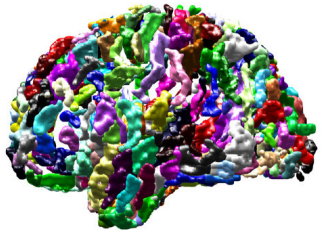


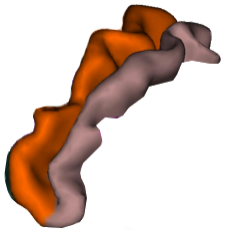


2 What quantities shall we assign to the features?

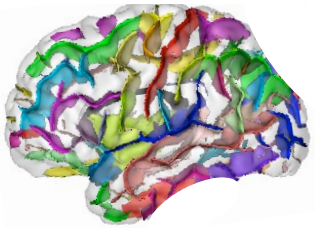
2 What quantities shall we assign to the features?

3-D

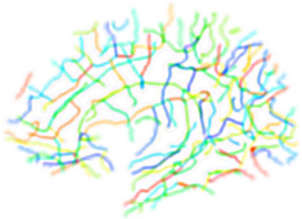




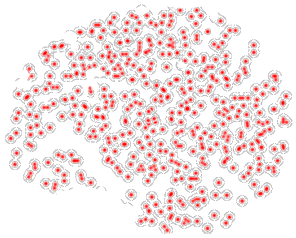
2-D



1-D



0-D



Candidate measures:

volume
surface area
lengths (thickness)
?

area
curvature
convexity
?

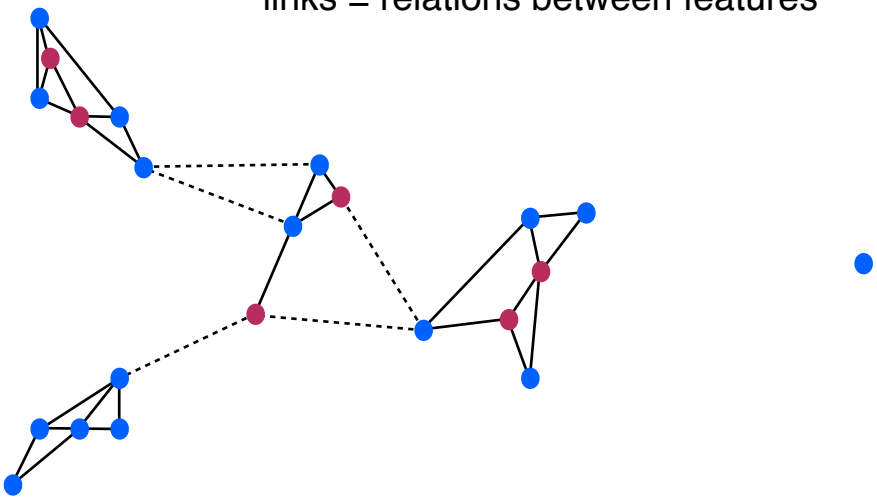
length
curvature
convexity
?

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

2 What quantities shall we assign to the features?

Network analysis measures:

nodes = features
links = relations between features

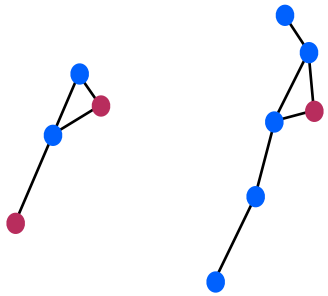


- centrality
- betweenness
- modularity

...

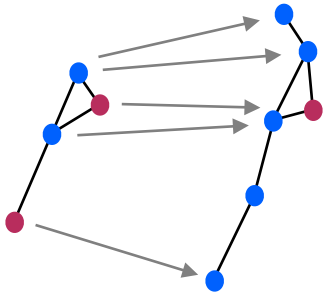
2 What quantities shall we assign to the features?

Deformation-based morphometry

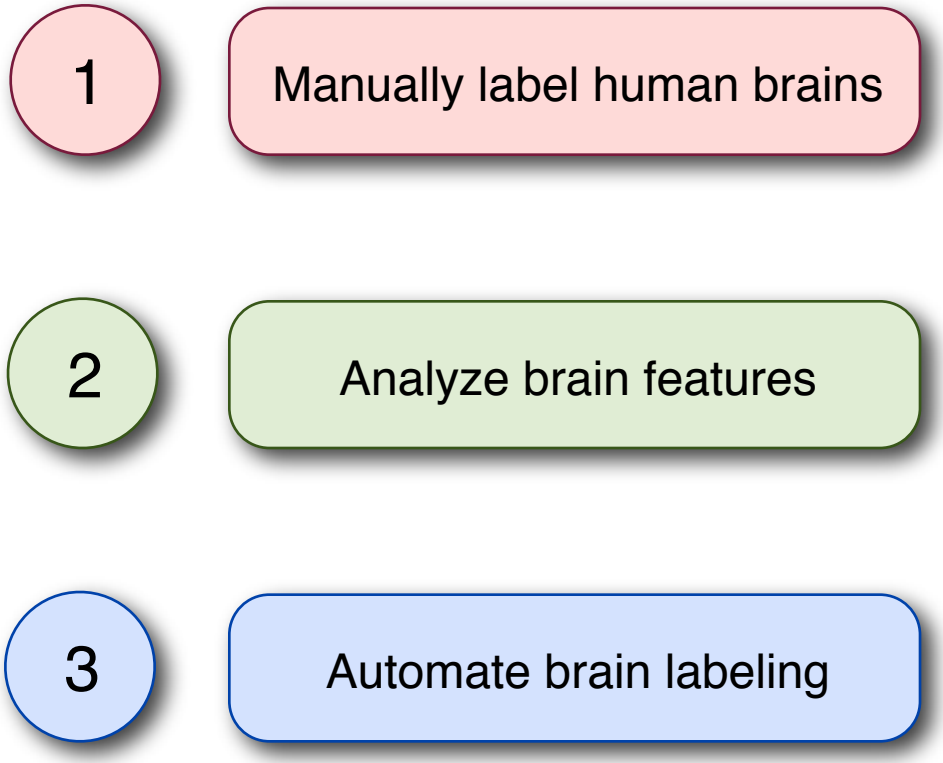


2 What quantities shall we assign to the features?

Deformation-based morphometry measures:



- warp field
- Jacobian
- Haussdorf distance


1
Manually label human brains
2
Analyze brain features
3
Automate brain labeling

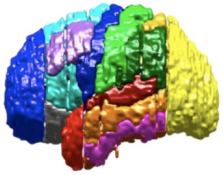
1 Manually label human brains

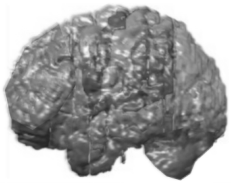
2 Analyze brain features

3 Automate brain labeling

Convention: registration-based labeling

atlas

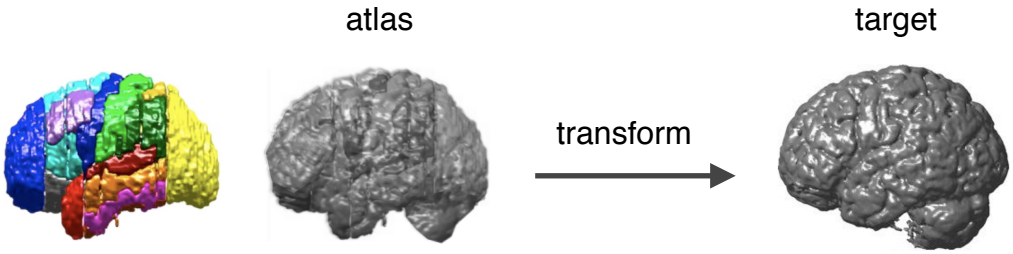




target

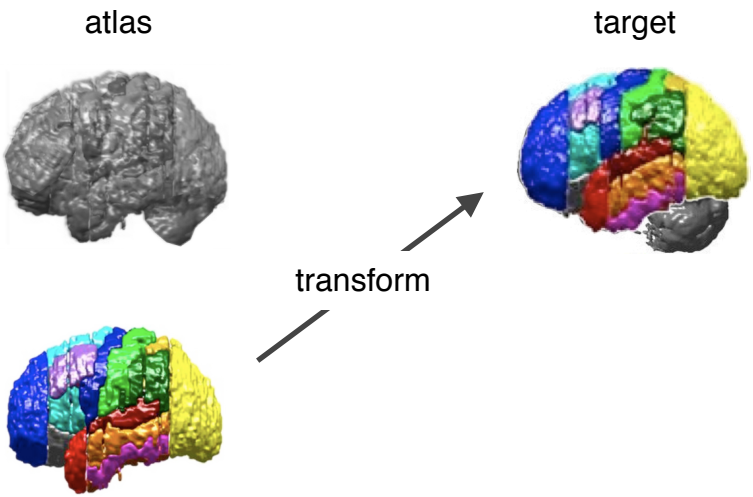
Convention: registration-based labeling

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



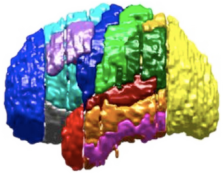
Convention: registration-based labeling

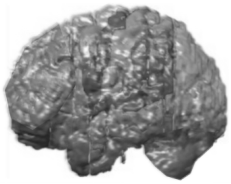
Step 2: apply the transform to the atlas labels



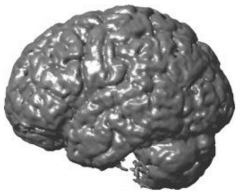
Mindboggle 2: feature-based labeling

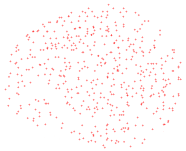
atlas





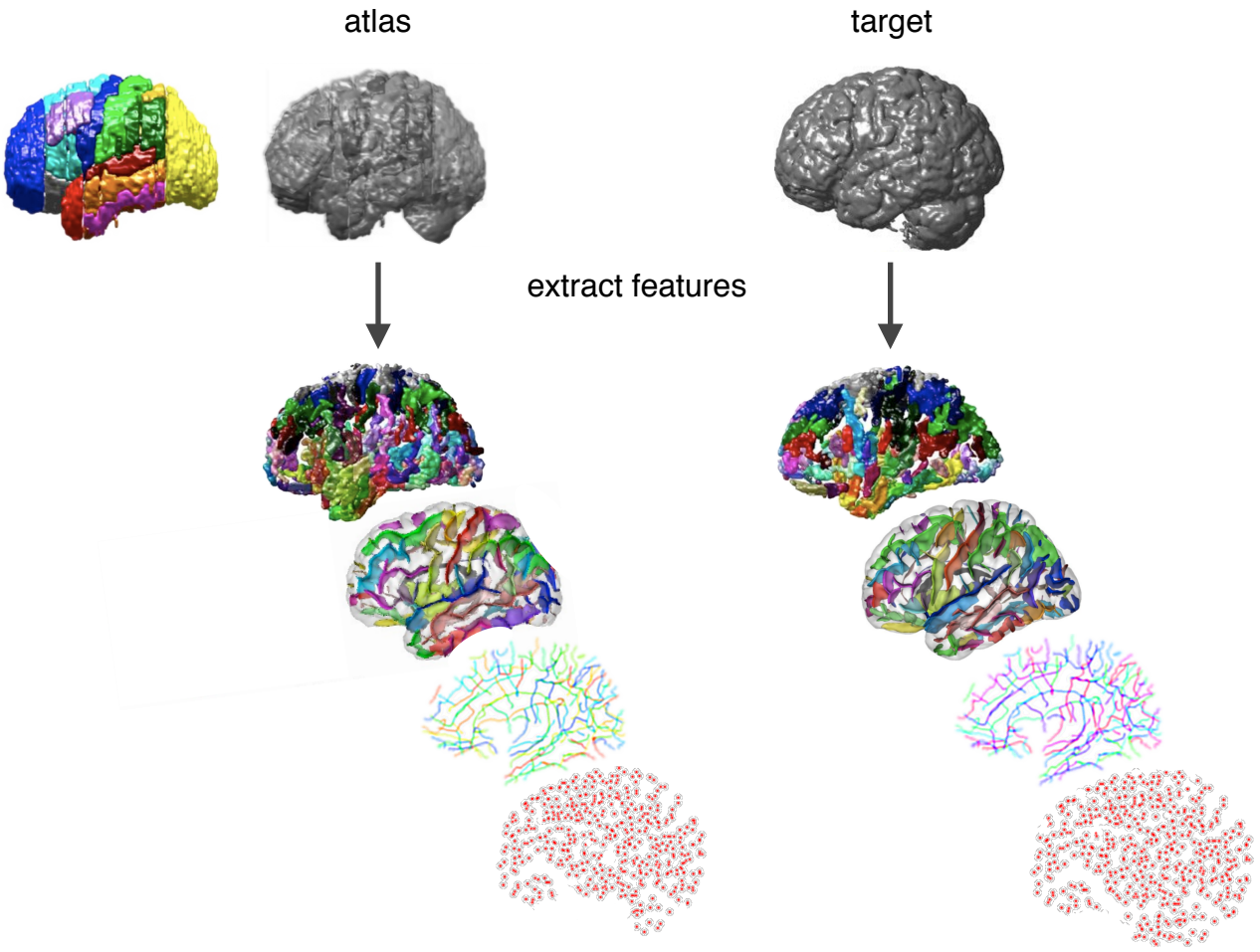
target





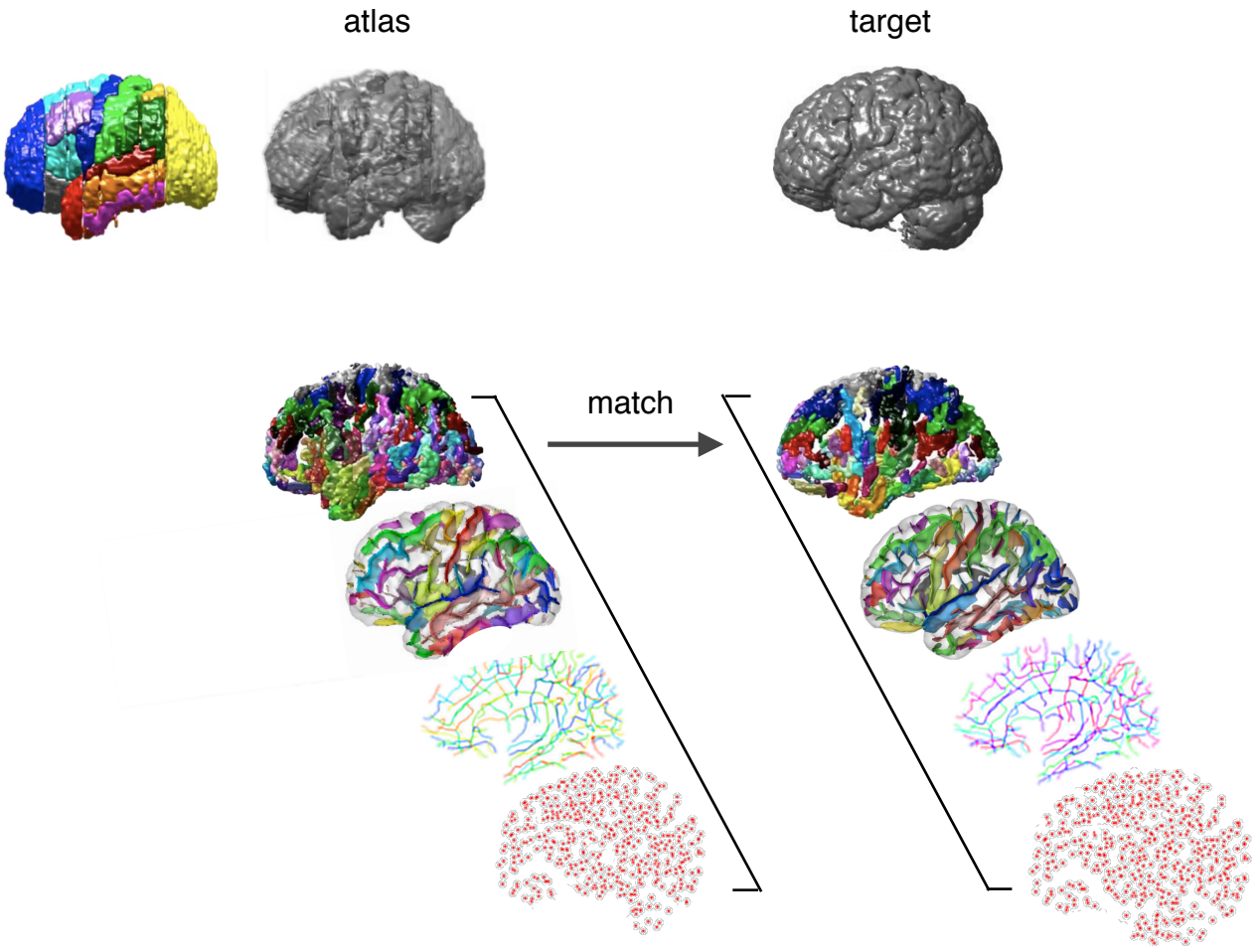
Mindboggle 2: feature-based labeling

Step 1: extract features



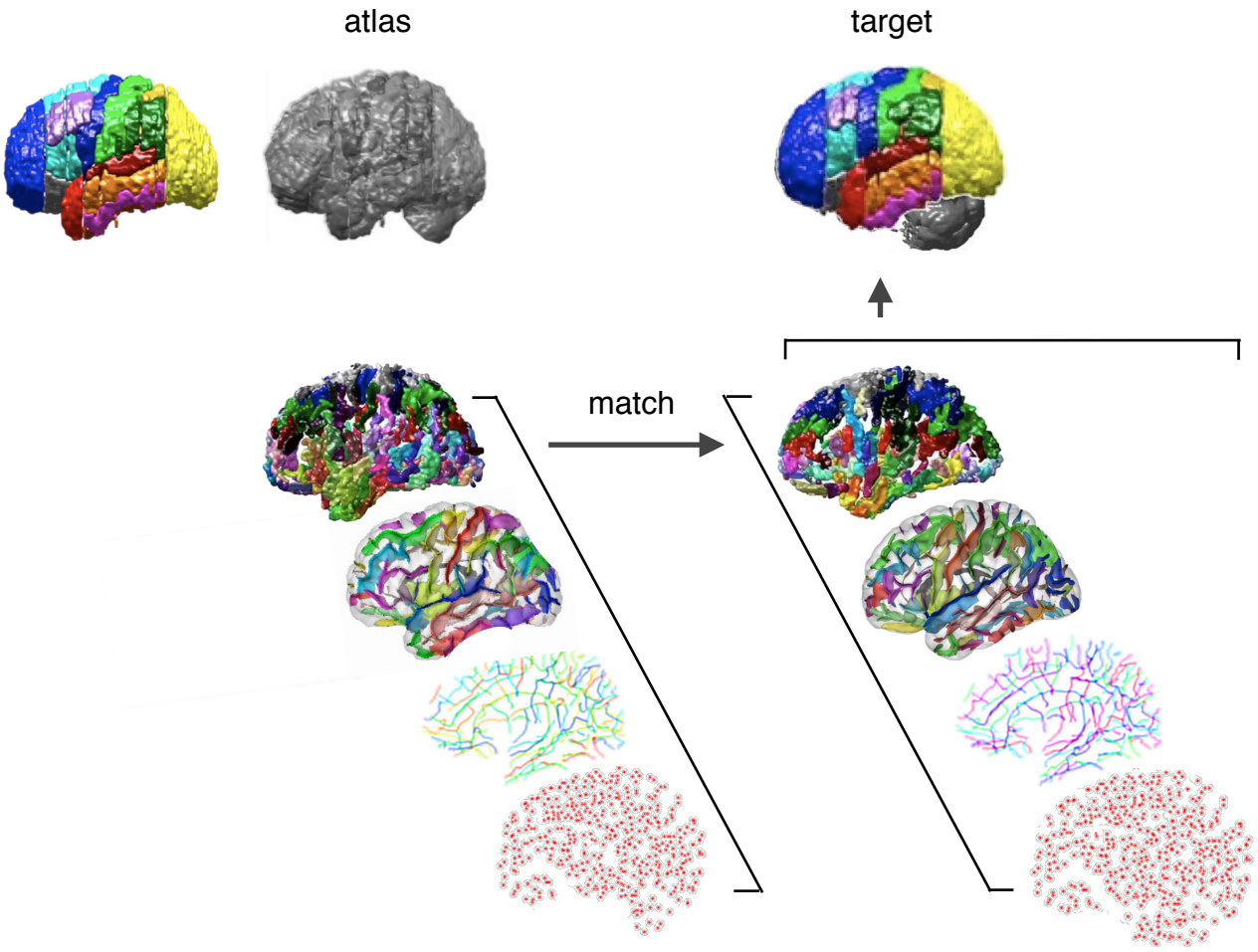
Mindboggle 2: feature-based labeling

Step 2: match atlas and target features



Mindboggle 2: feature-based labeling

Step 3: propagate labels within inferred label boundaries?



Mindboggle 2: feature-based labeling

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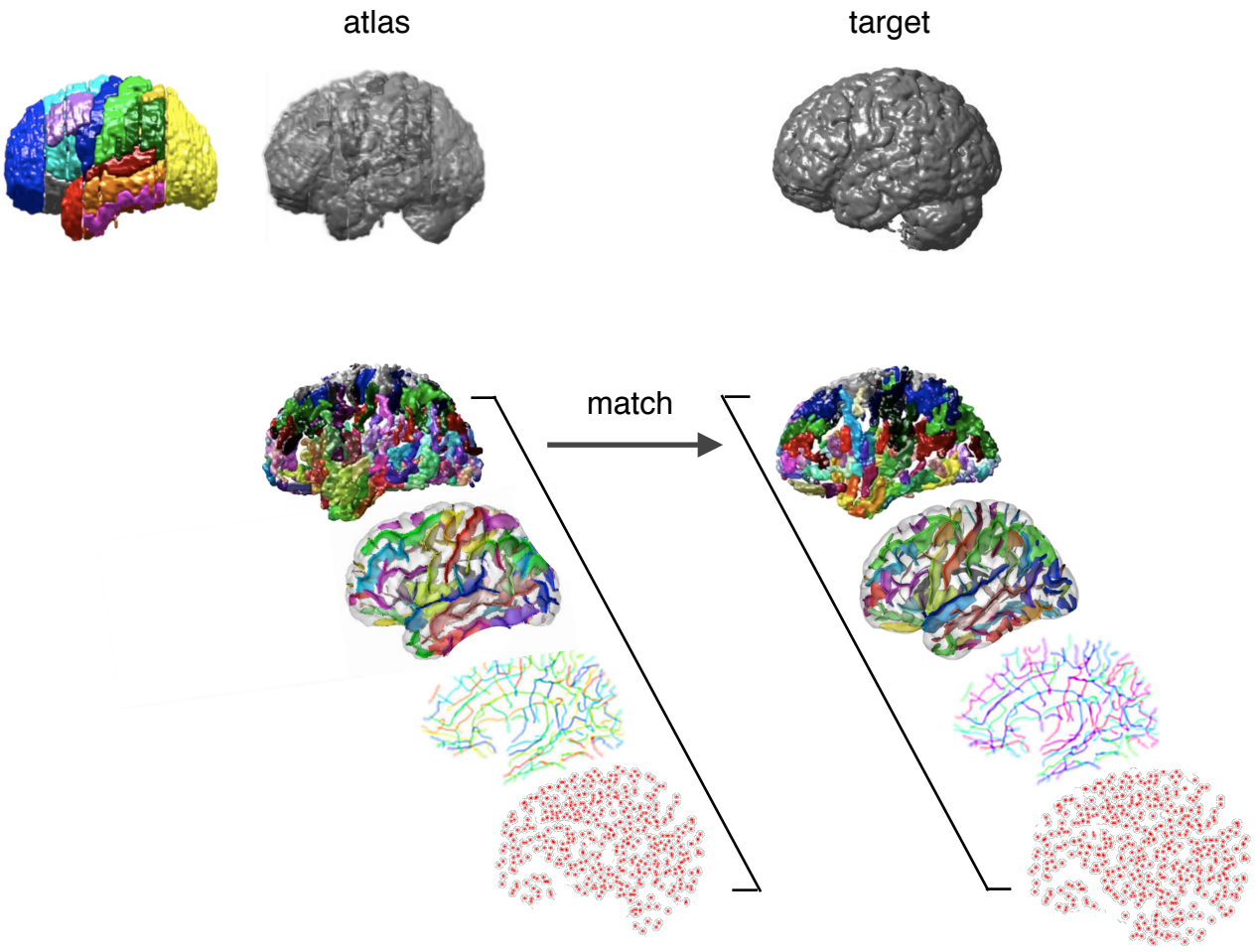
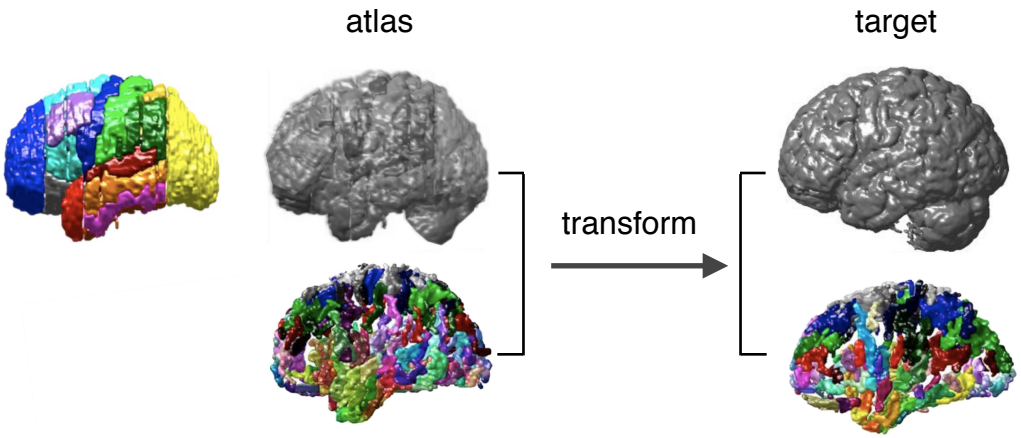


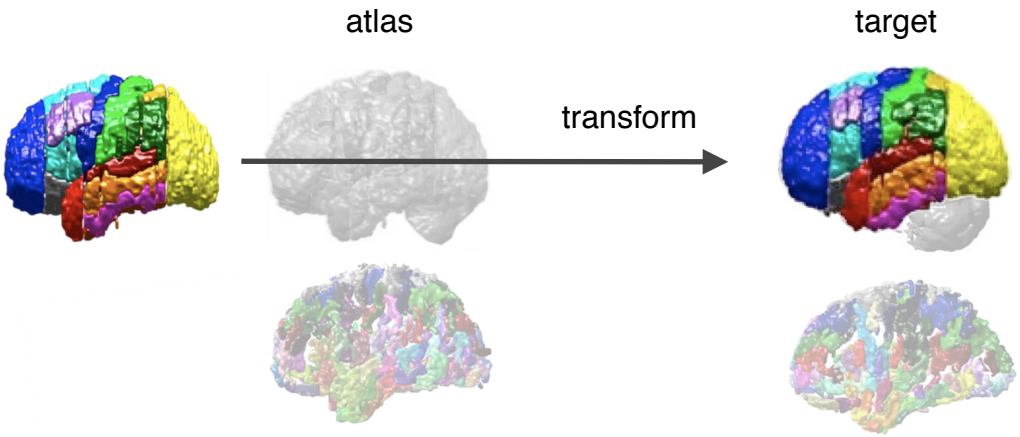
Mindboggle 2: feature-based labeling

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



Mindboggle 2: feature-based labeling

Step 4: apply registration transform to atlas labels



3 What is the best way to match features across brains?

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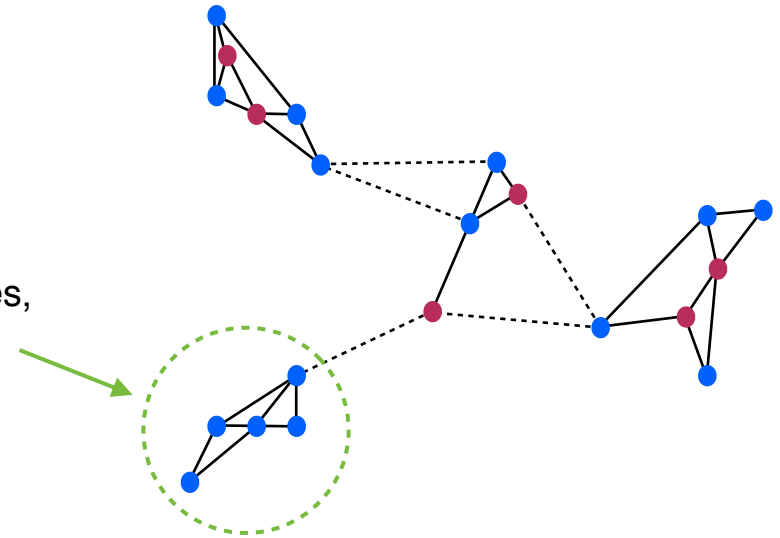
Subgraph matching?

Example: network representation
with nodes for features,
links for relations between features,
and clusters of nodes as modules
(Newman, 2006)



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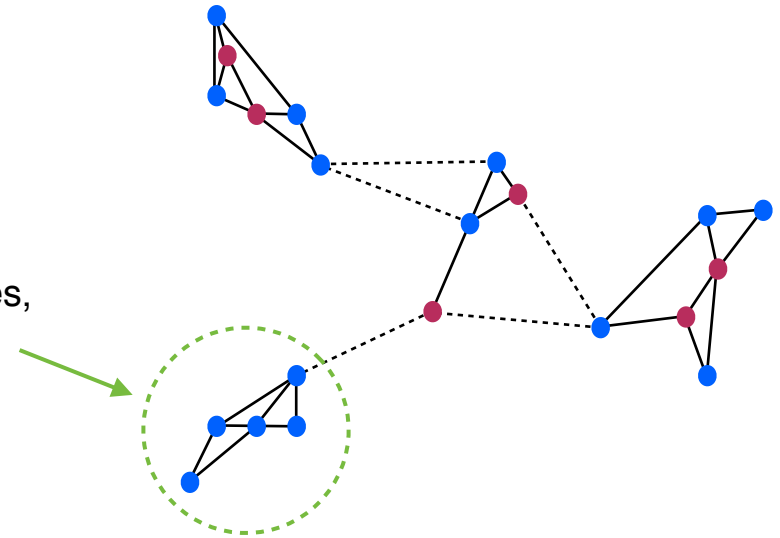

Evolutionary algorithm?

Example: PRSA hybrid of
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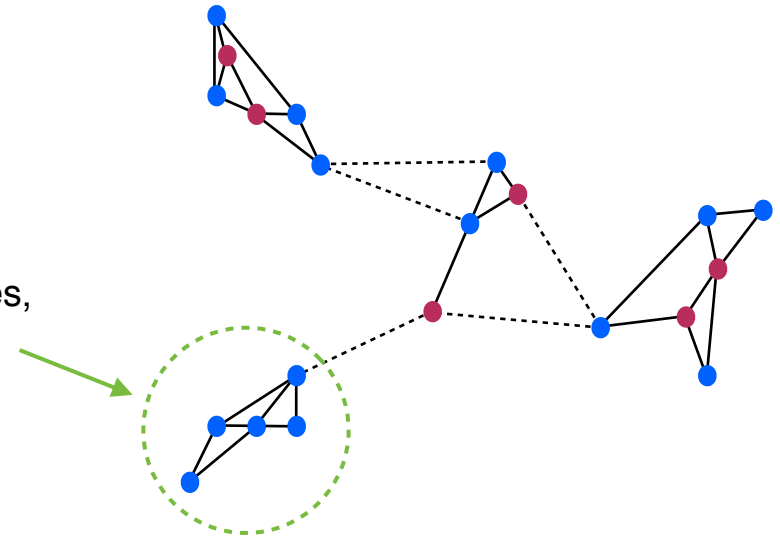

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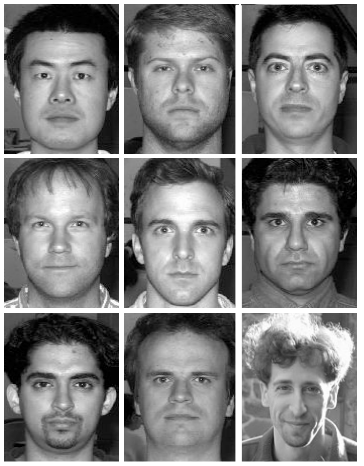
Bayesian face recognition algorithm?

Example: MAP binary classification
(Moghaddam et al., 1998)



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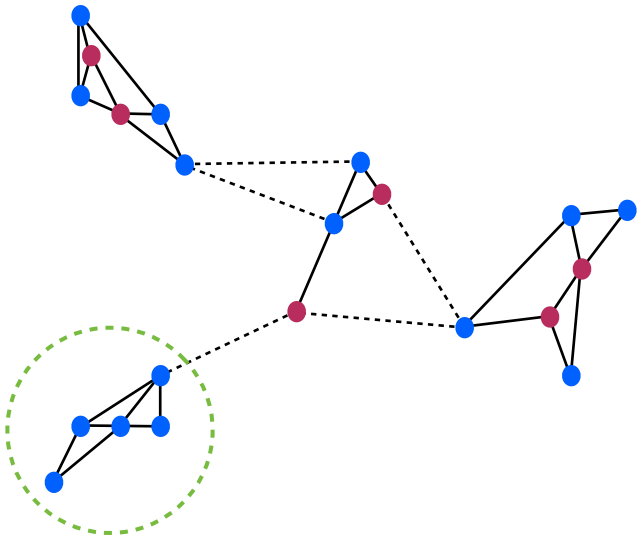

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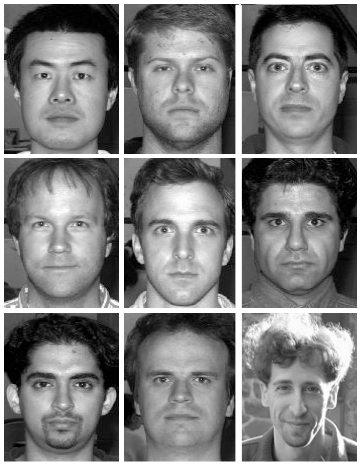
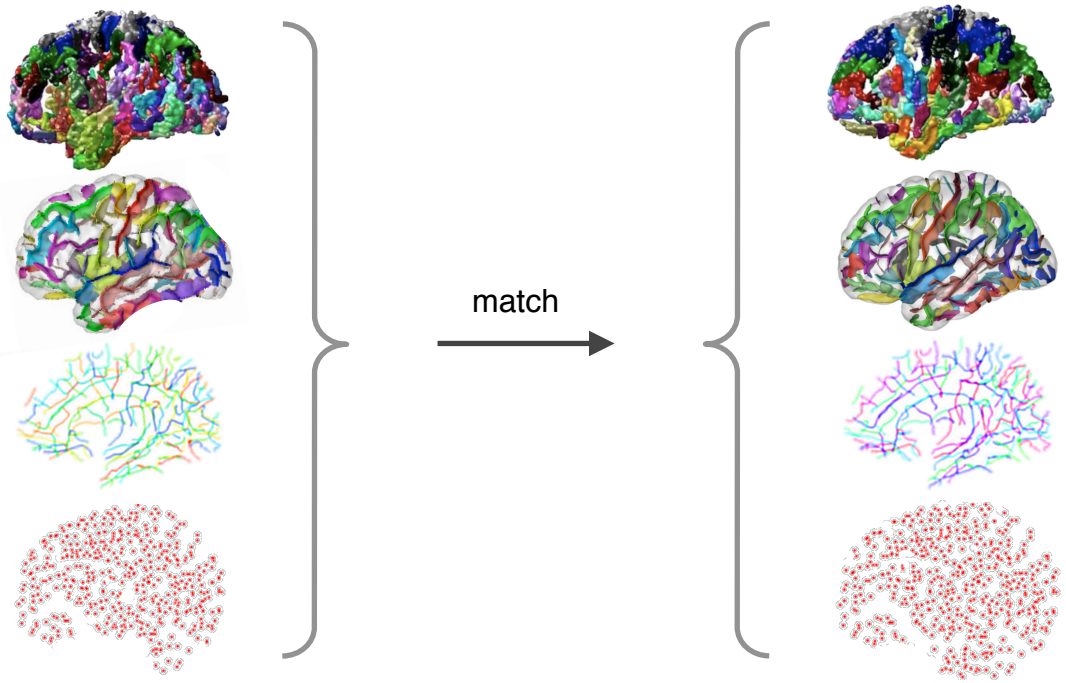


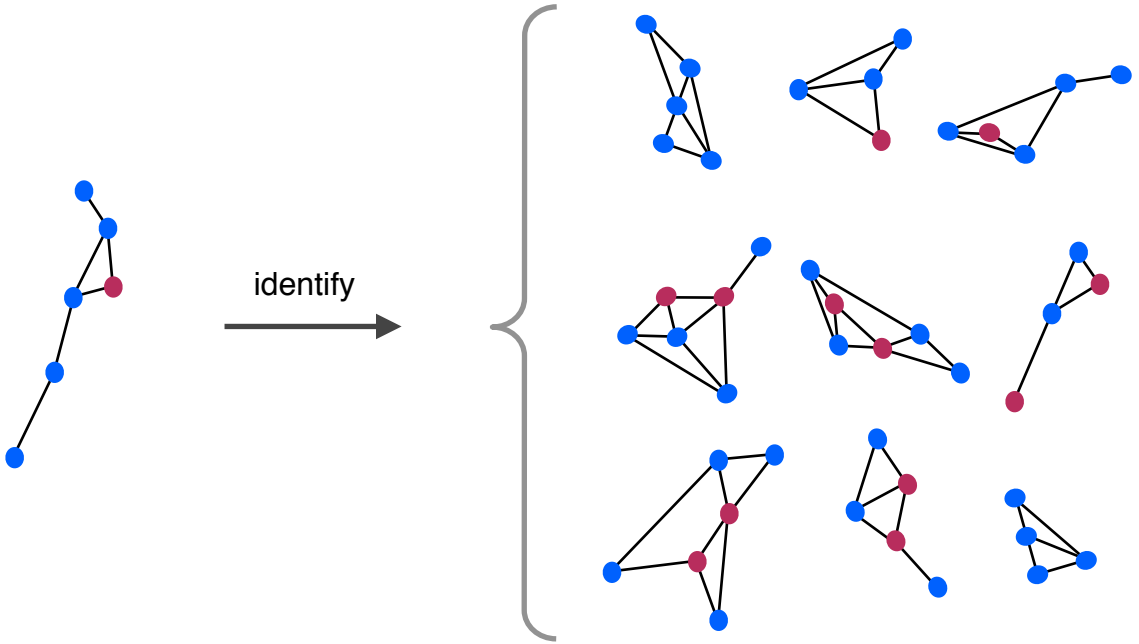
3 What is the best way to match features across brains?

Instead of matching the entire set
of features across whole brains ...



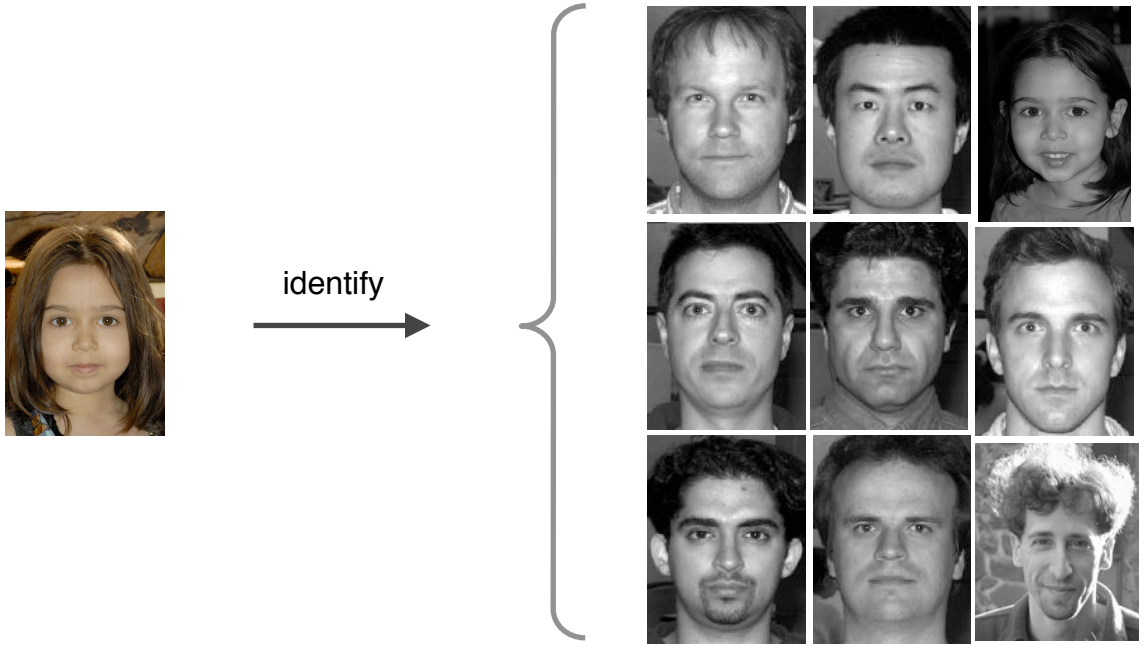
3 What is the best way to match features across brains?

... we can try to identify a group of features within a brain.



3 What is the best way to match features across brains?

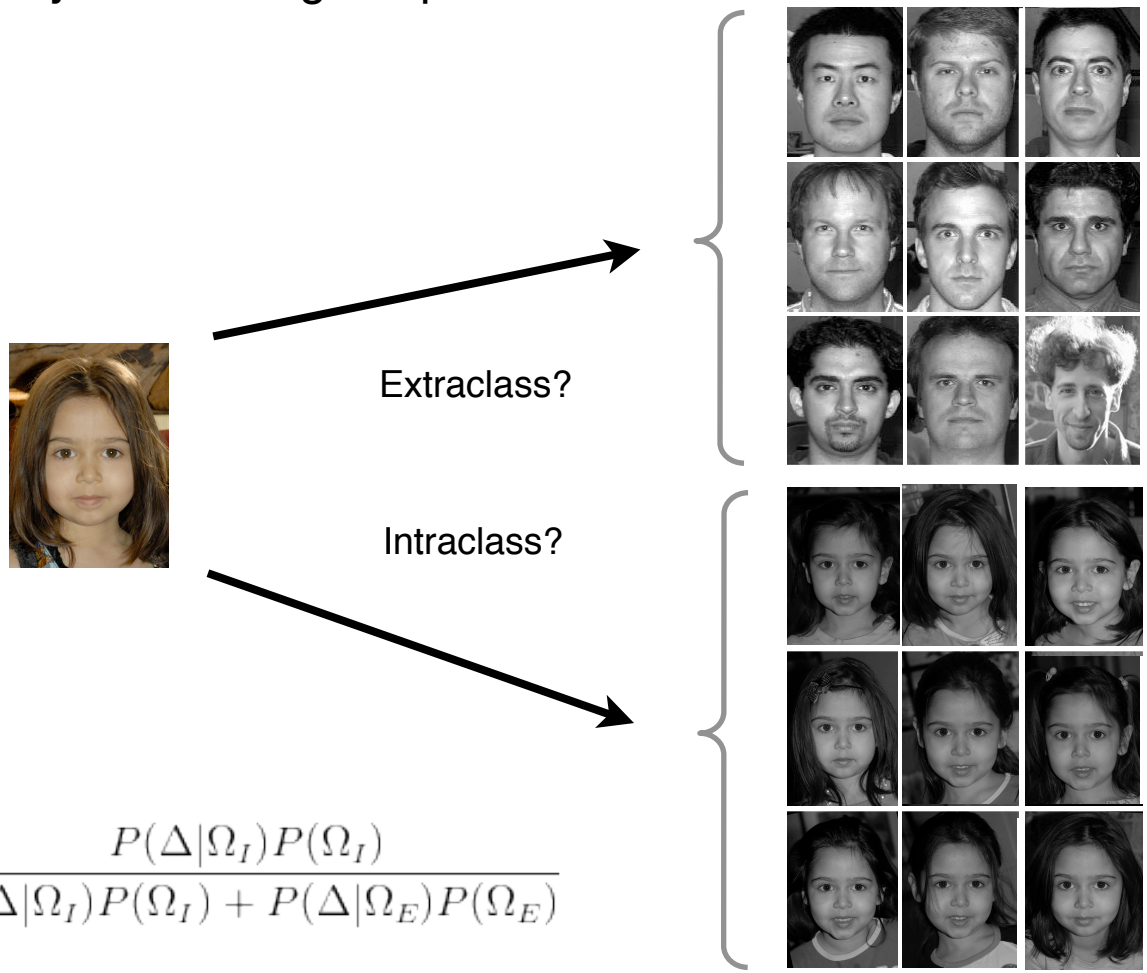
To adapt Bayesian face recognition to this problem, we can think about a set of facial features instead of a group of brain features ...



male faces c/o Brian Avants

3 What is the best way to match features across brains?

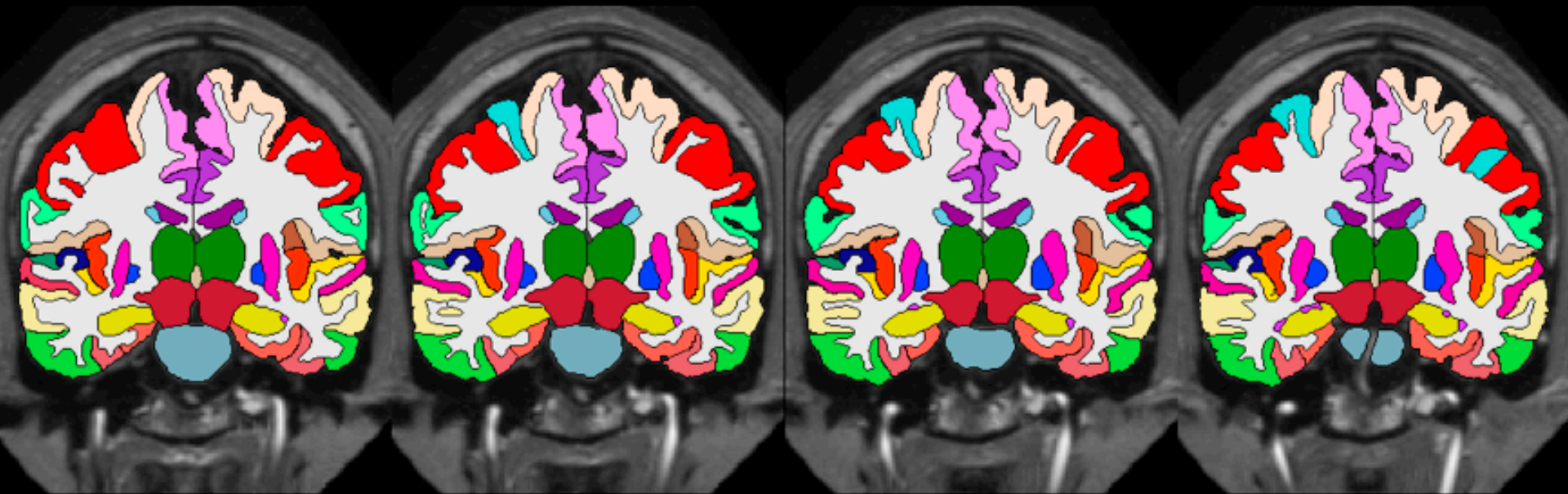
... and perform Bayesian binary classification,
by maximizing the posterior:



$$P(\Omega_I|\Delta) = \frac{P(\Delta|\Omega_I)P(\Omega_I)}{P(\Delta|\Omega_I)P(\Omega_I) + P(\Delta|\Omega_E)P(\Omega_E)}$$

Acknowledgments:

Ray Razlighi - SIFTing for gold
Steve Ellis - persisting in homology
Tito Dal Canton - gravitating waves
Brian Avants - driving landmarks into register (UPenn)
colleagues at MIND

Questions? arno@mindboggle.info

Website: http://www.mindboggle.info