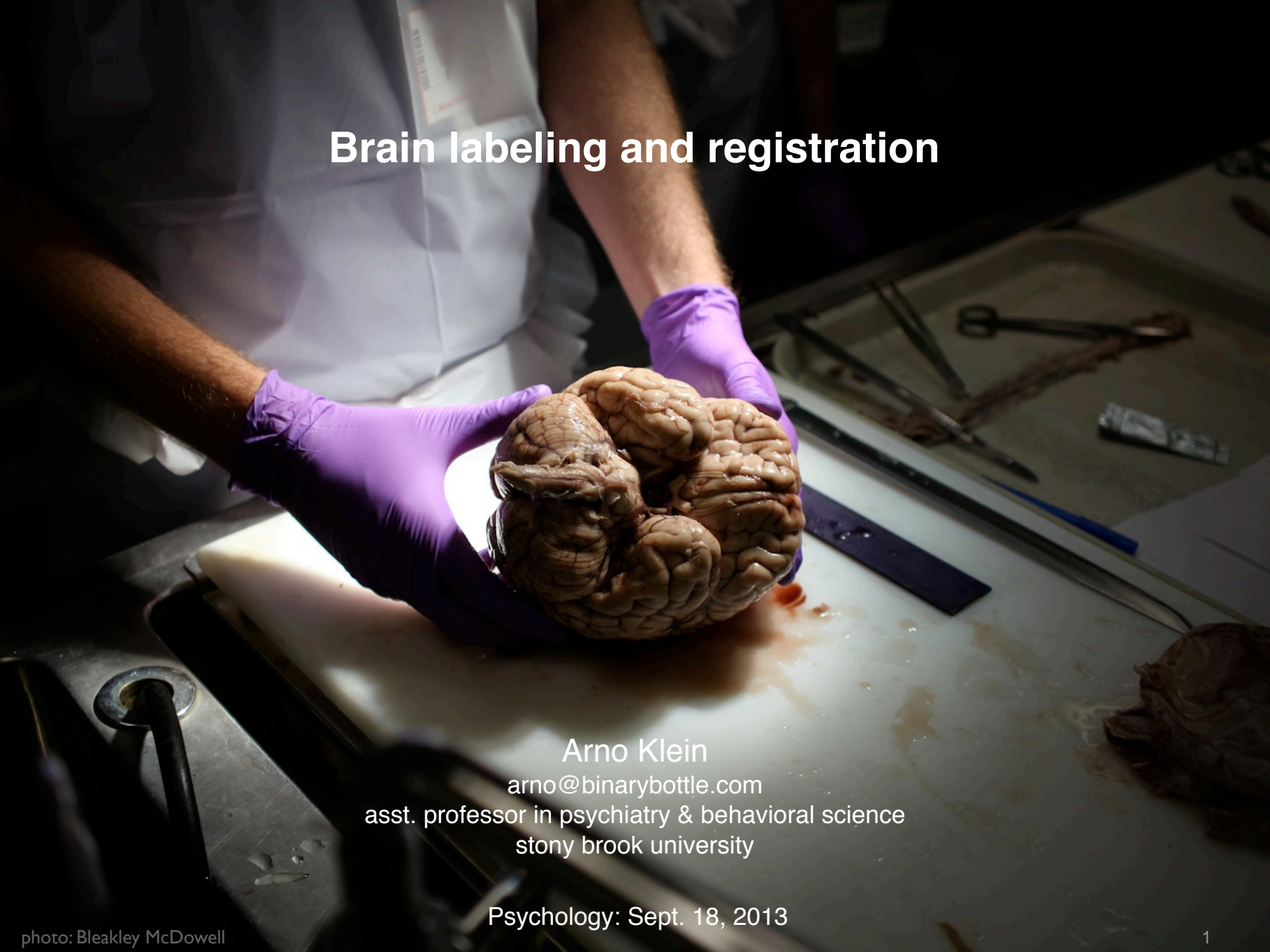
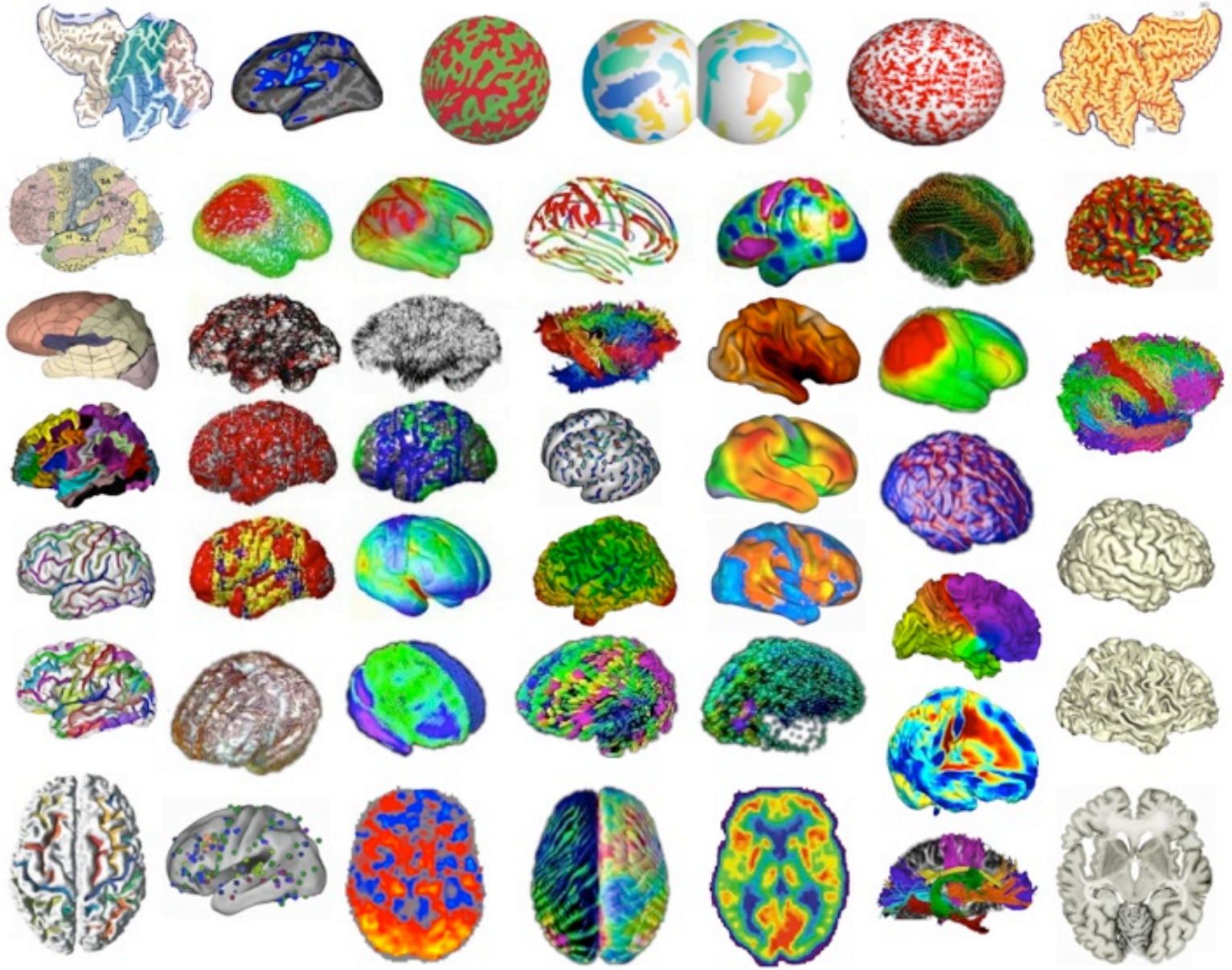


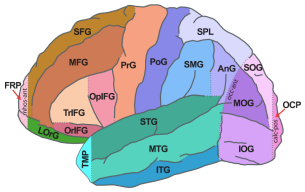
Brain labeling and registration

Arno Klein
arno@binarybottle.com
asst. professor in psychiatry & behavioral science
stony brook university

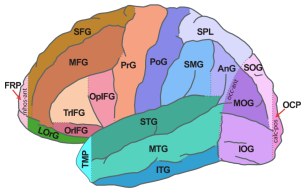
Psychology: Sept. 18, 2013

photo: Bleakley McDowell





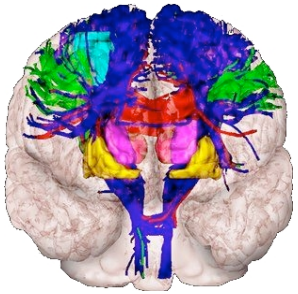
Why label brains?

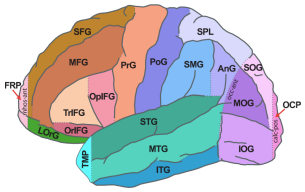


Why label brains?

Labels visually augment anatomy

- teach anatomy
- guide surgery





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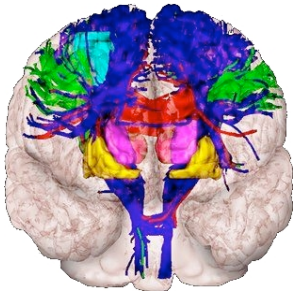
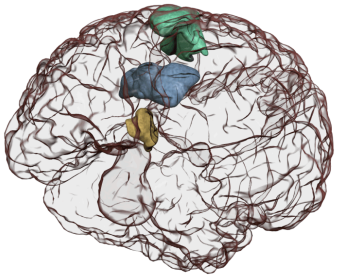
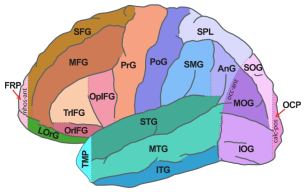


Labels break up data

- process data by region
- quantify and report data by region





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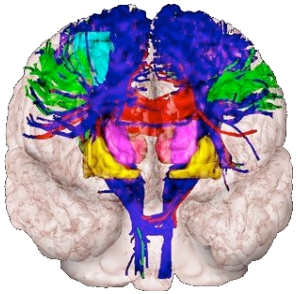

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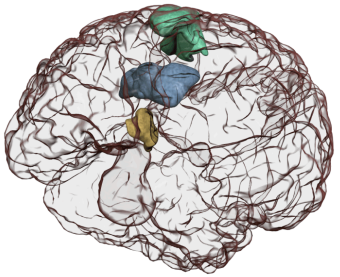
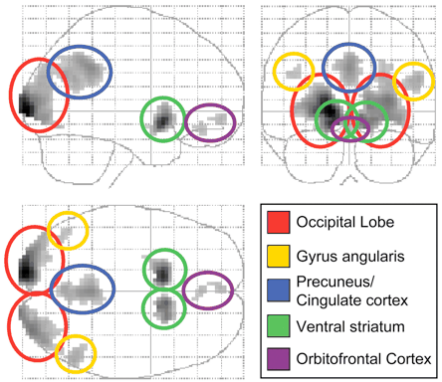
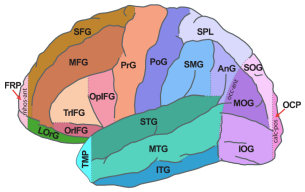


Labels identify corresponding objects

- communicate using the same terms
- compare data across subjects and studies



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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SPL
MFG
PrG
PoG
SMG
AnG
SOG
FRP
OpIFG
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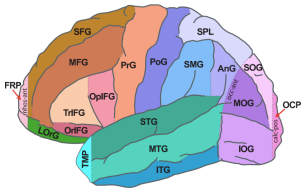
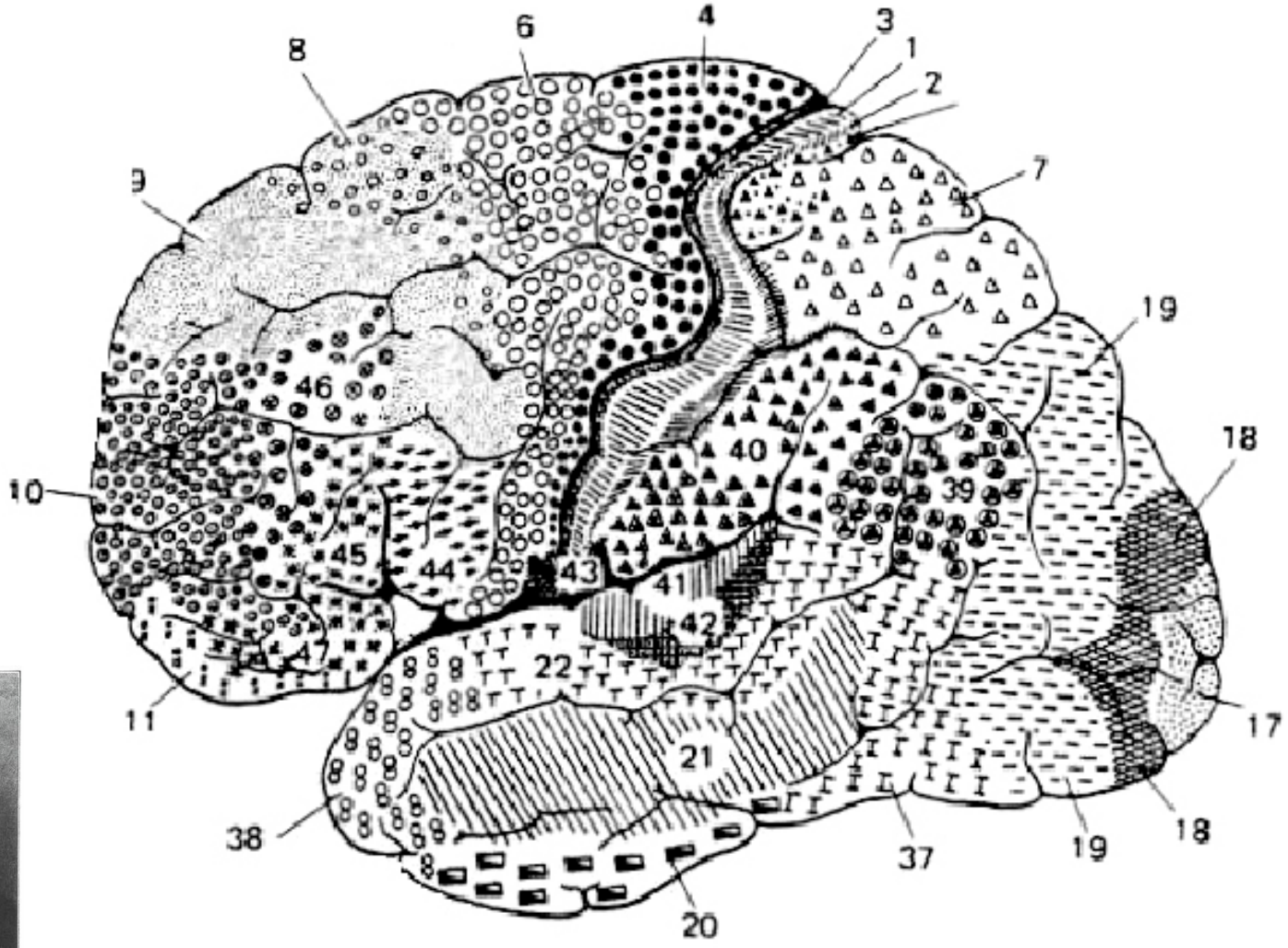
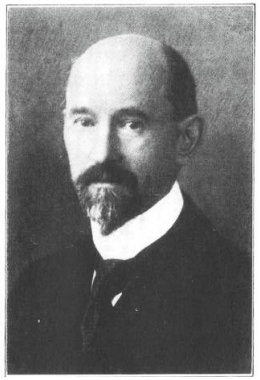
OCP
TriFG
STG
OrIFG
MTG
IOG
TMP
ITG

Anatomy

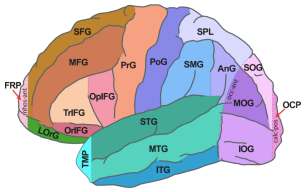


Cytoarchitectonic divisions

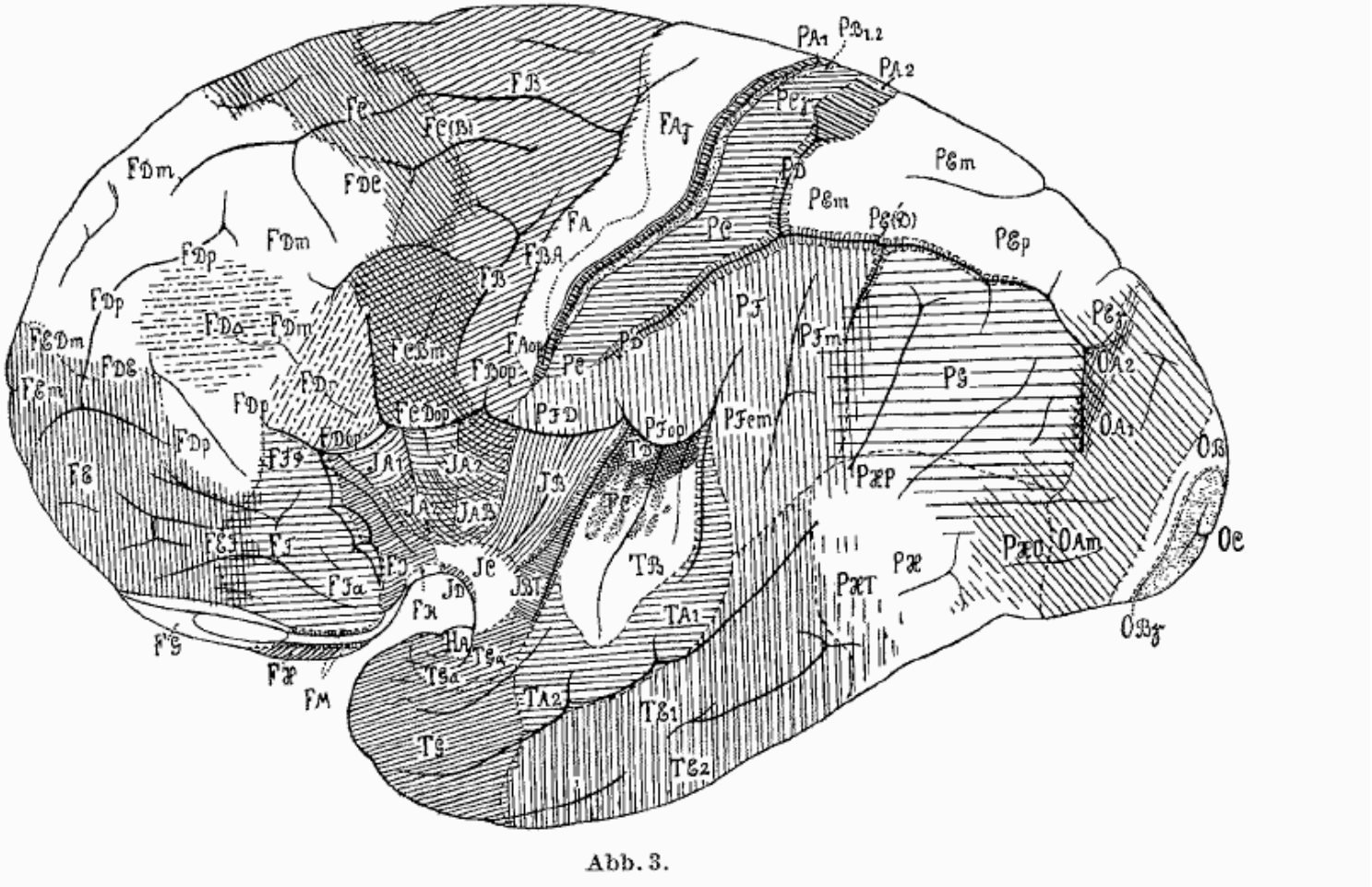


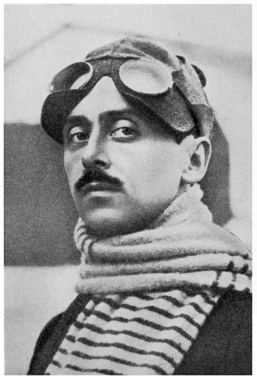


Korbinian Brodmann
(1868-1918)

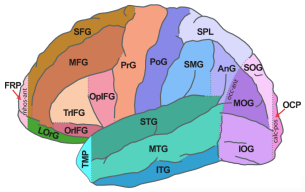


Cytoarchitectonic divisions

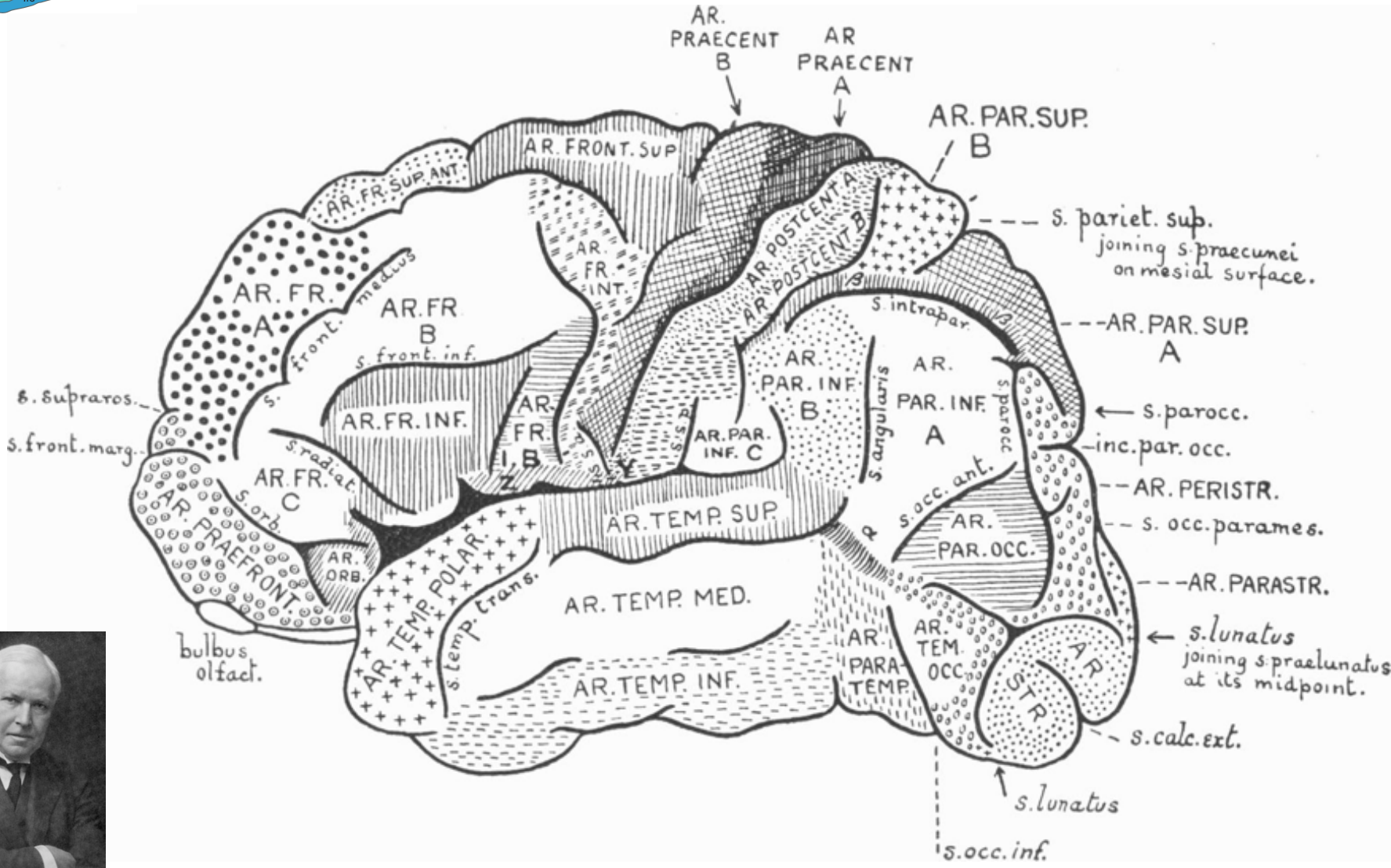




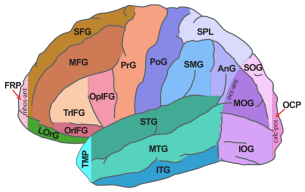
Constantin von Economo
(1876-1931)



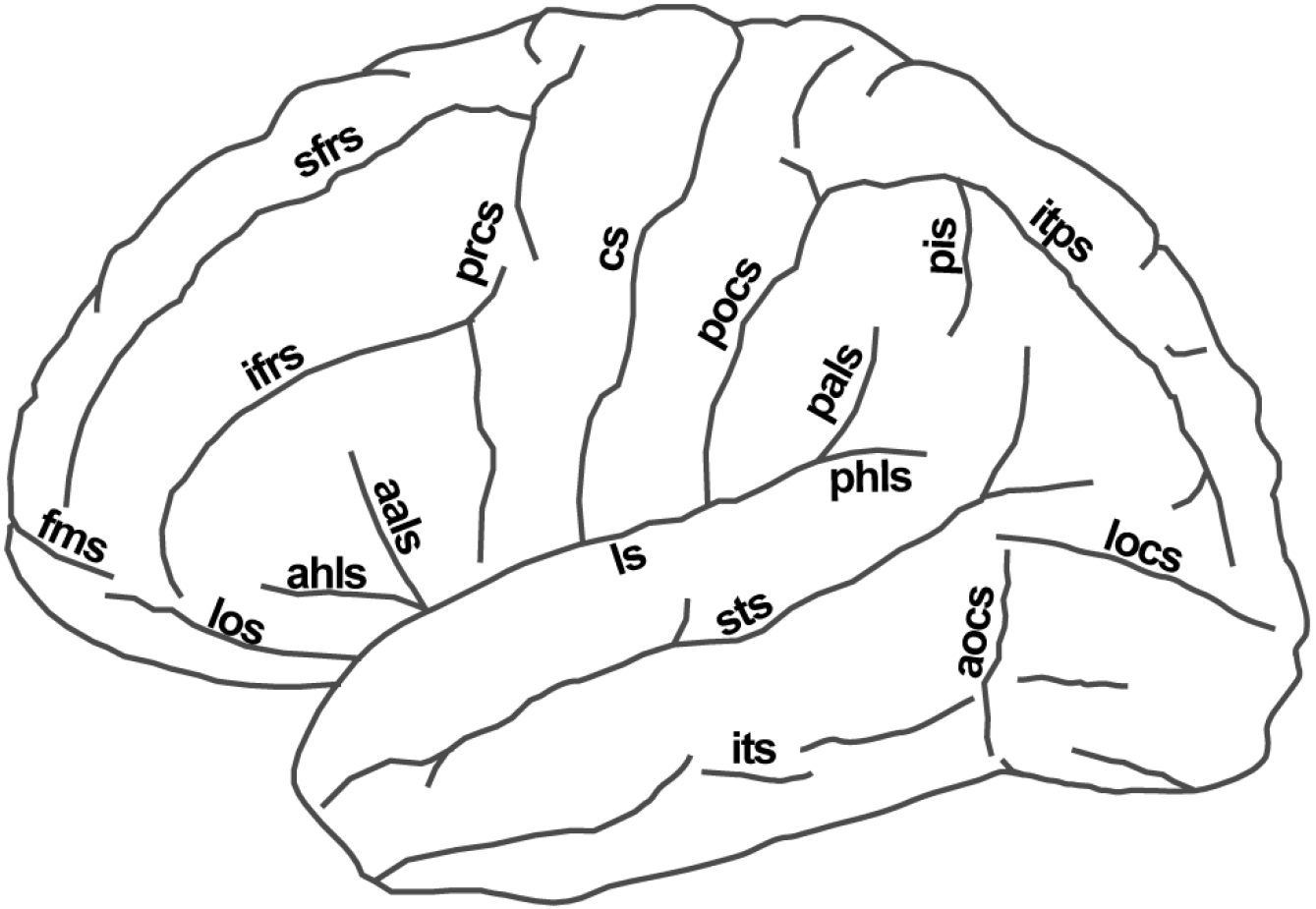
Topographic divisions

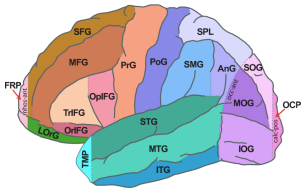


Sir Grafton Elliot Smith
(1871-1937)

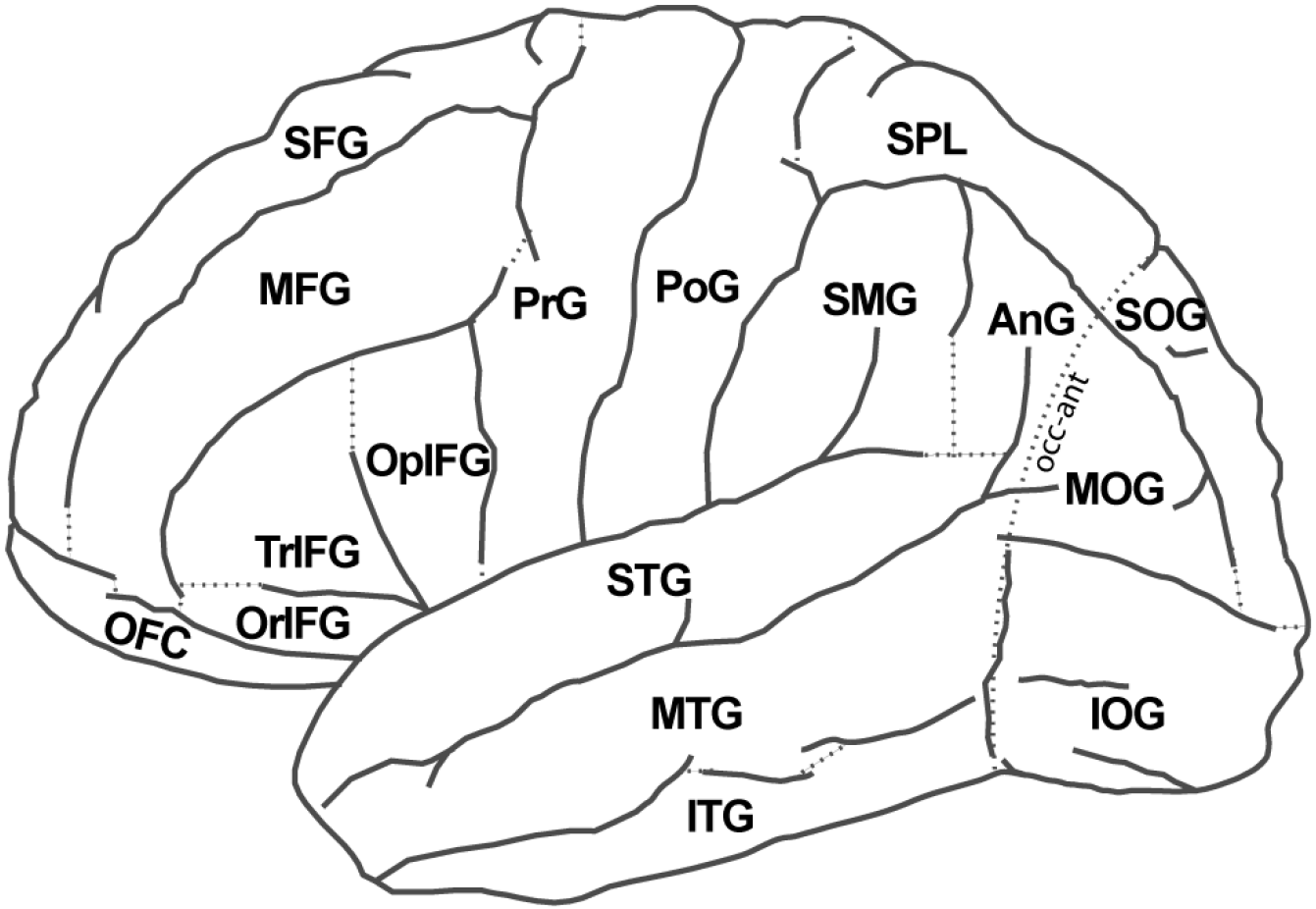


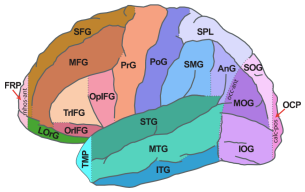
Creases (“sulcus folds”)





Exterior surface (“gyrus regions”)





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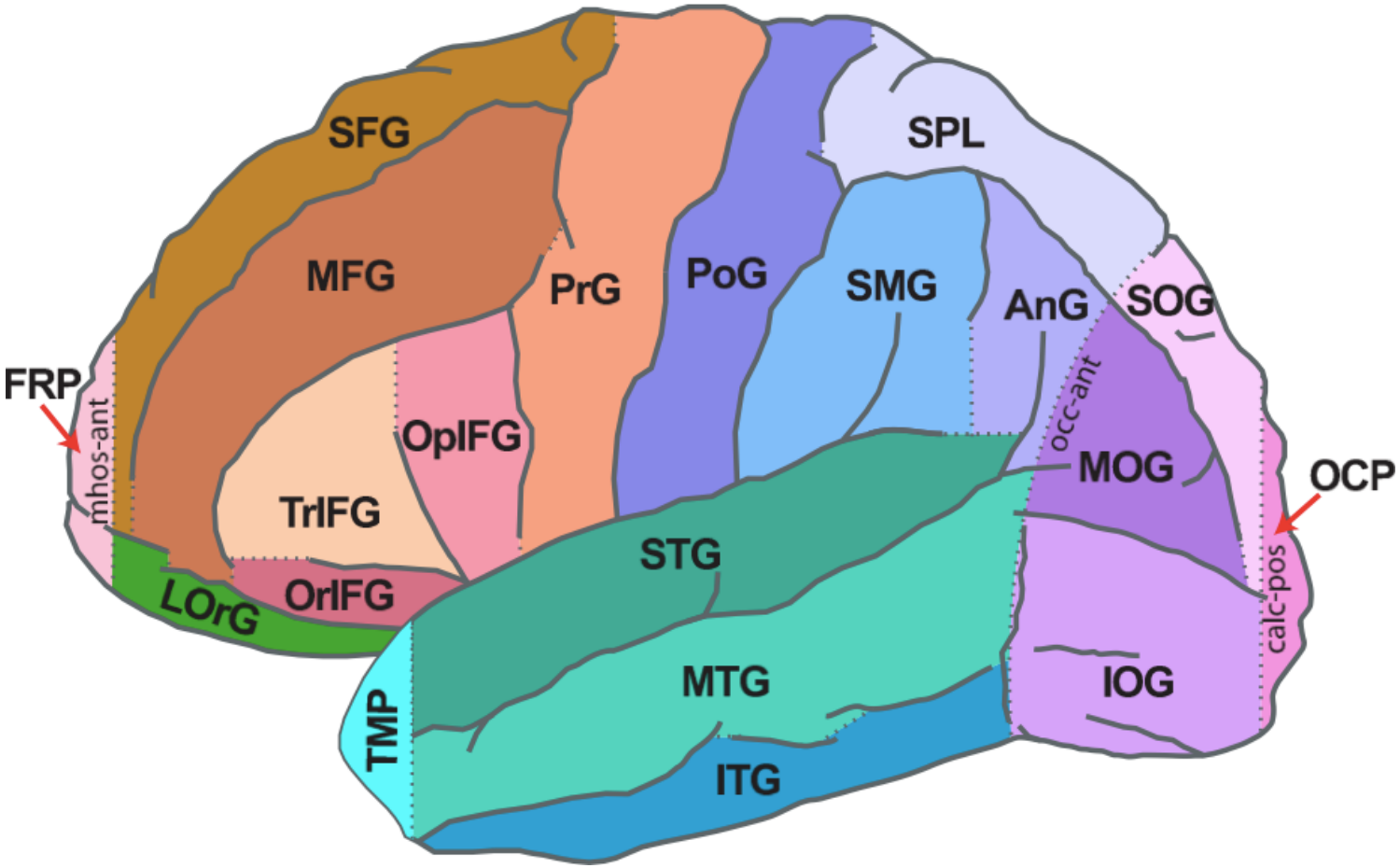
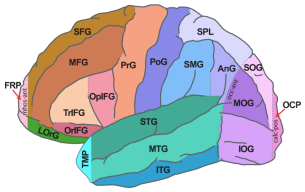
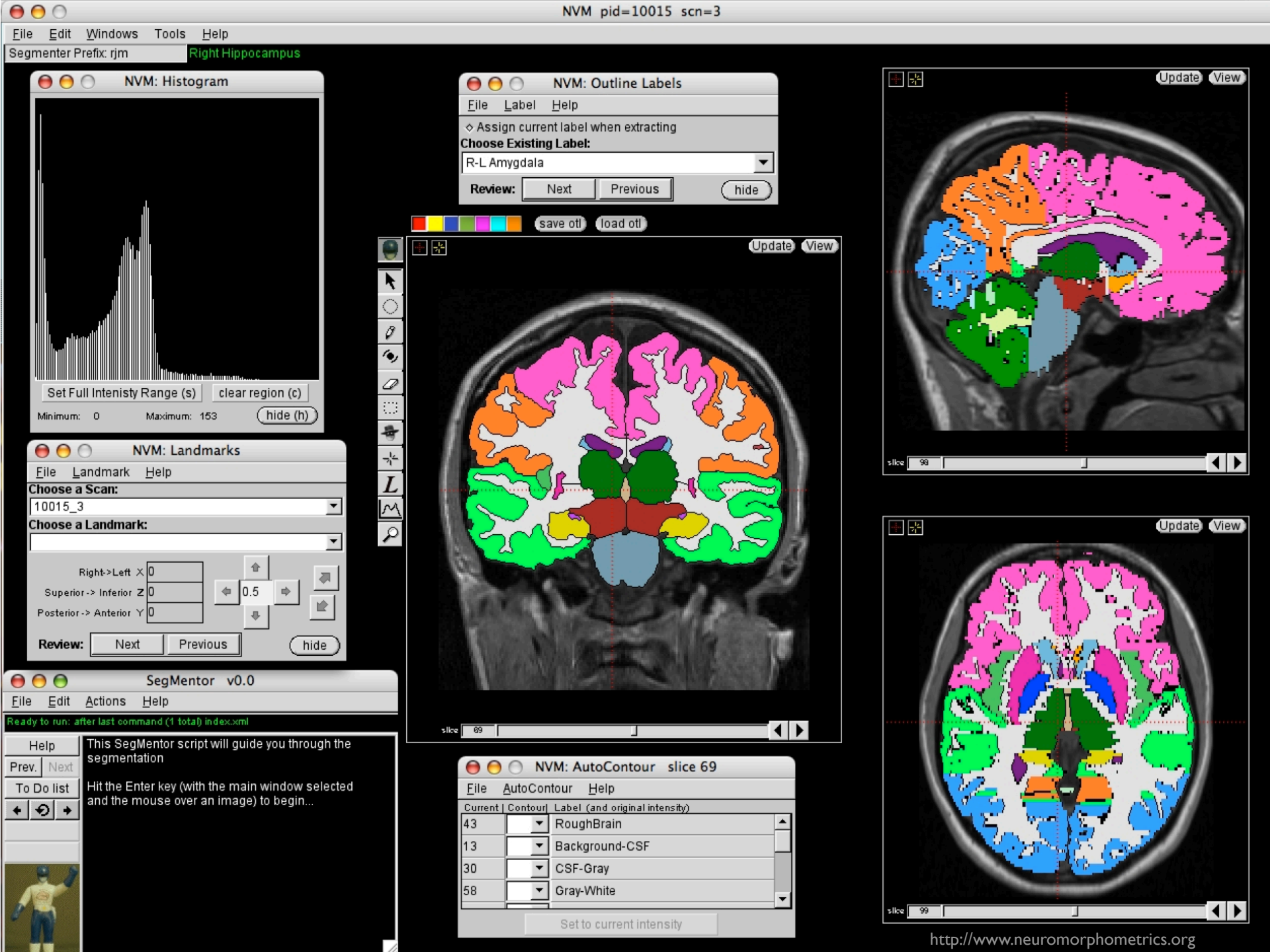




Volume and surface labels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File Edit Windows Tools Help
Segmenter Prefix: rjm
Right Hippocampus
NVM: Histogram
Set Full Intensity Range (s)
clear region (c)
Minimum: 0
Maximum: 153
hide (h)
NVM: Landmarks
File Landmark Help
Choose a Scan:
10015_3
Choose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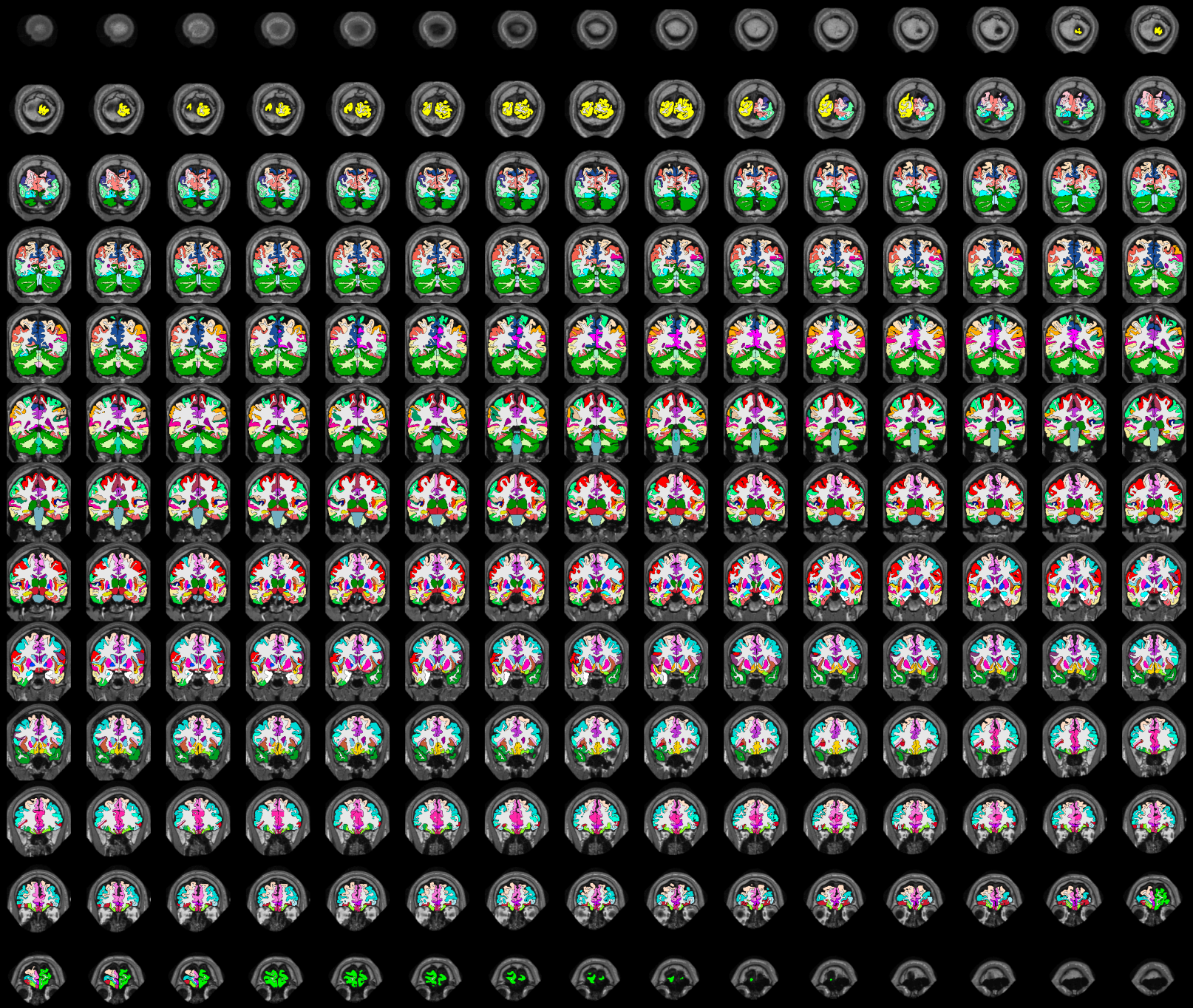
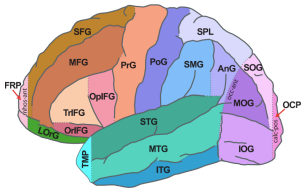
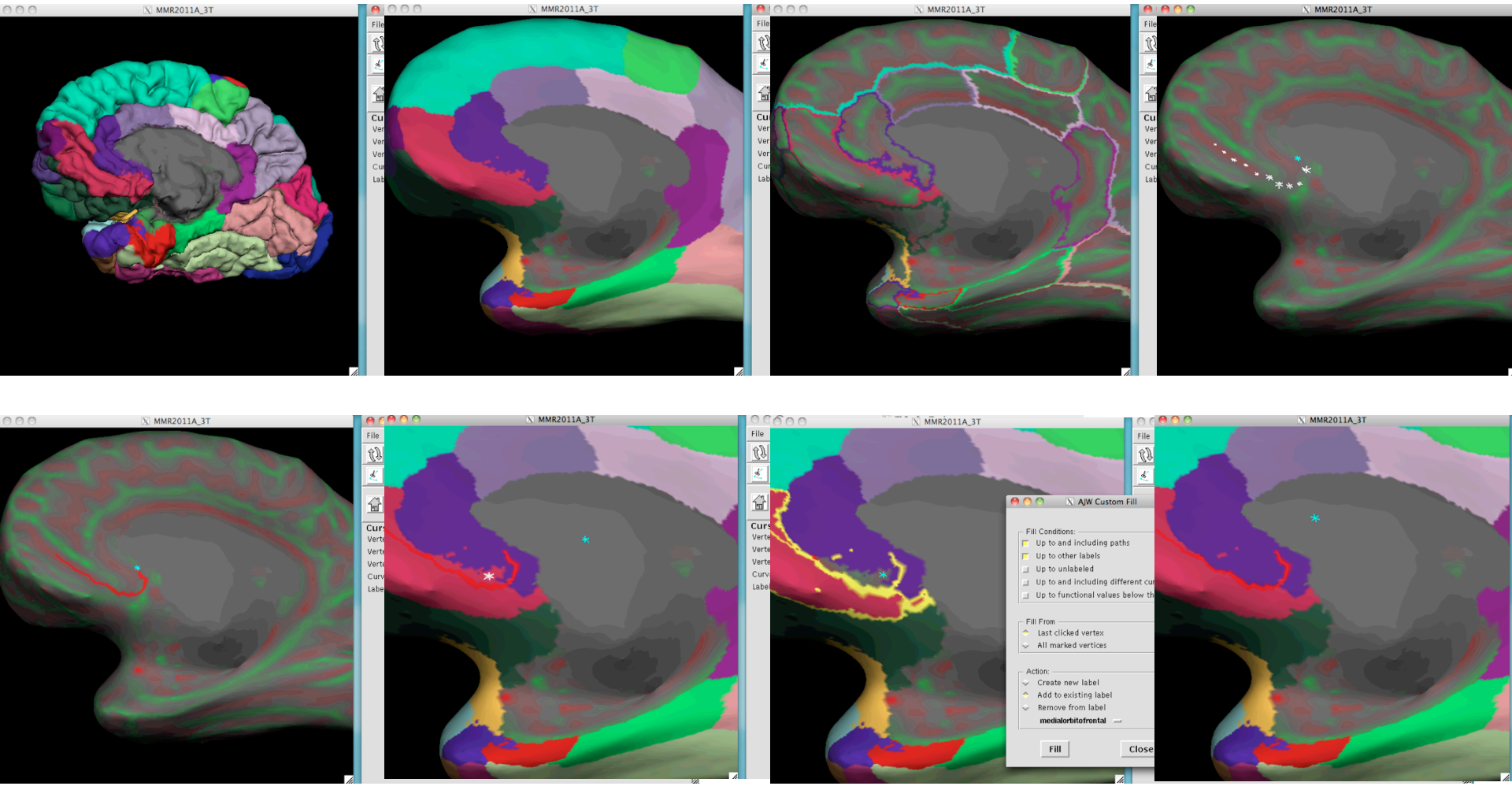
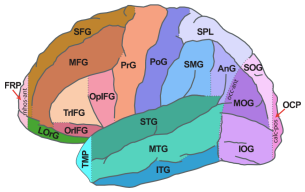
58 Gray-White
Set to current intensity
Update
View
slice 98
Update
View
slice 99
http://www.neuromorphometrics.org



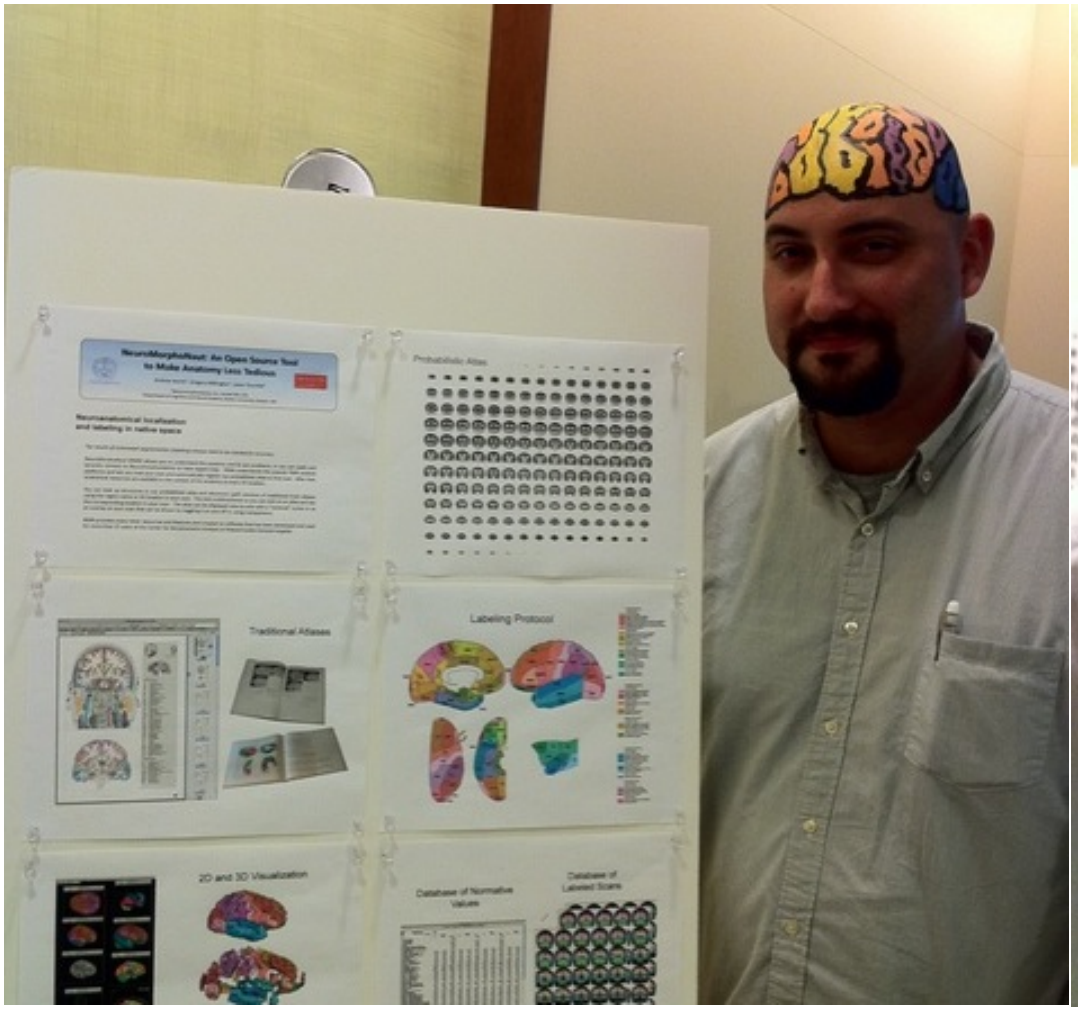


Manual labeling of surfaces





A dedicated human labeler



Greg Millington
Neuromorphometrics

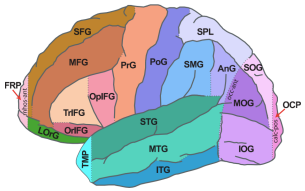
Mindboggle

Software Data Papers People

Data

Welcome to the largest collection of publicly available, manually labeled human brain image data in the world!
Please cite the following article and this website when making use of Mindboggle-101 data:
101 labeled brain images and a consistent human cortical labeling protocol
Arno Klein, Jason Tourville. Frontiers in Brain Imaging Methods. 6:171. DOI: 10.3389/fnins.2012.00171

See the README, labeling protocol, the CHANGELOG, and MD5SUMS,
which describe the labeled nifti volumes (nii), vtk surfaces (vtk), and FreeSurfer files (mgh, etc.).
Except where noted, all data are licensed under a Creative Commons License: (cc) BY-NC-SA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SPL
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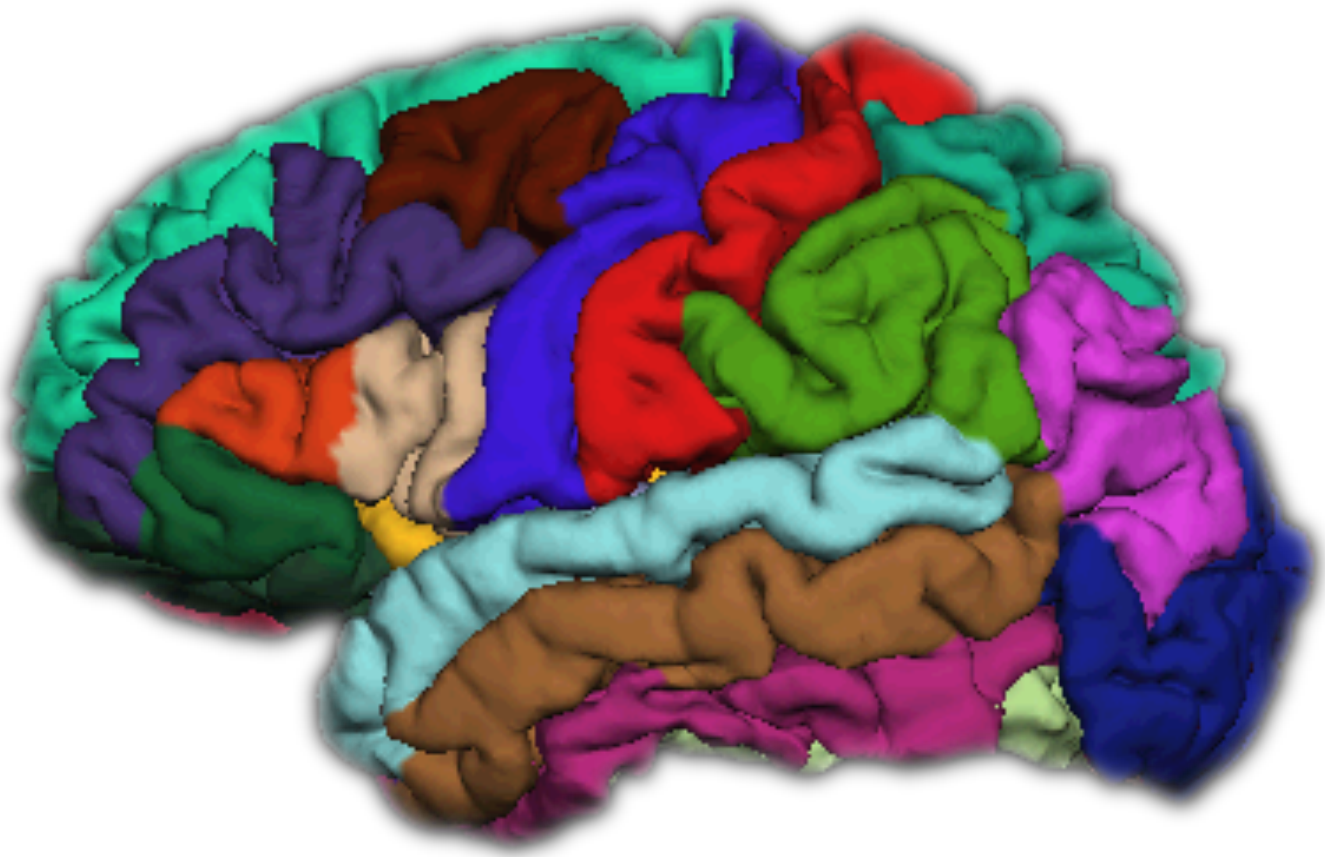
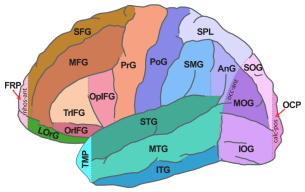
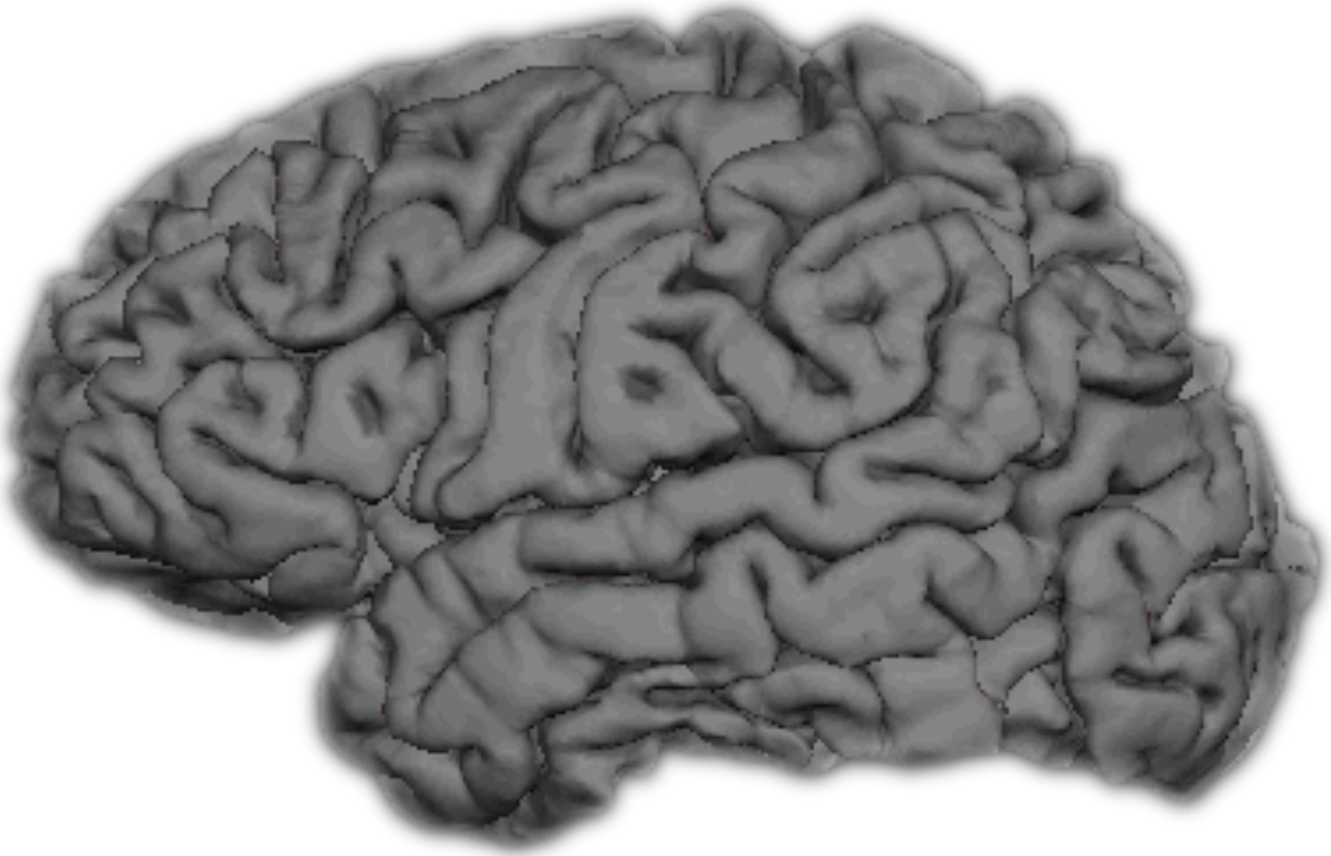
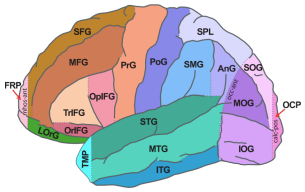
Labels



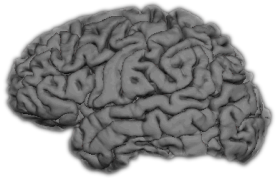


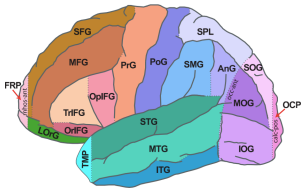
Registration-based labeling





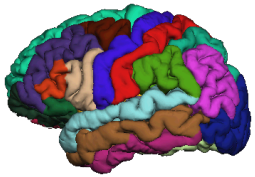
Registration-based labeling

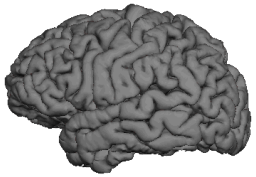




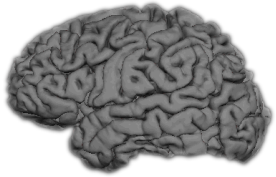
Registration-based labeling

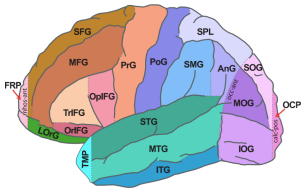
atlas



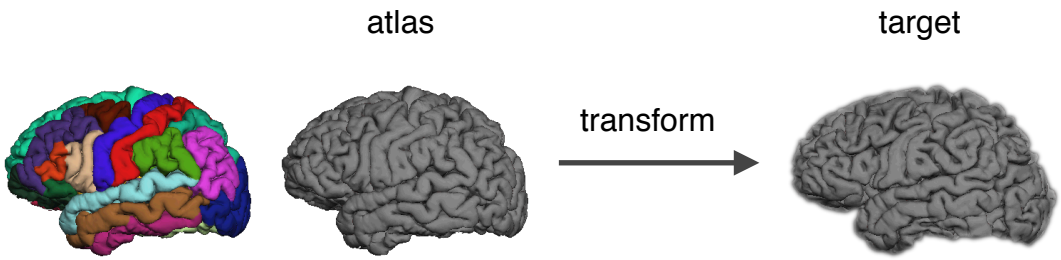


target

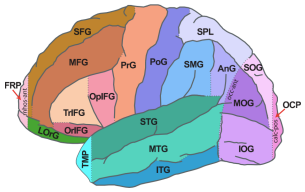




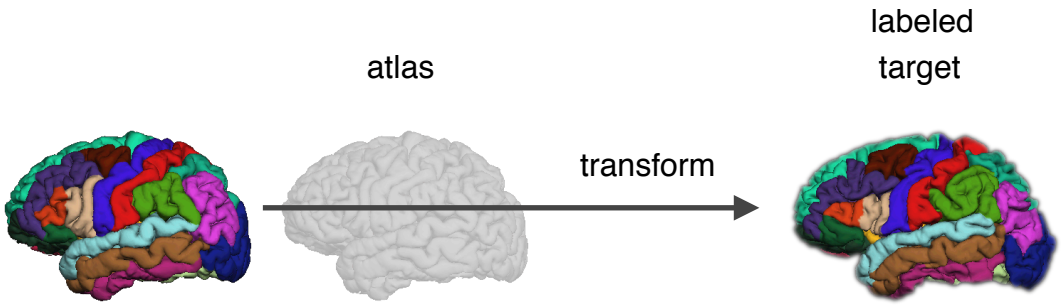
Registration-based labeling



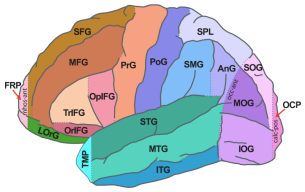
Step 1: compute registration transform



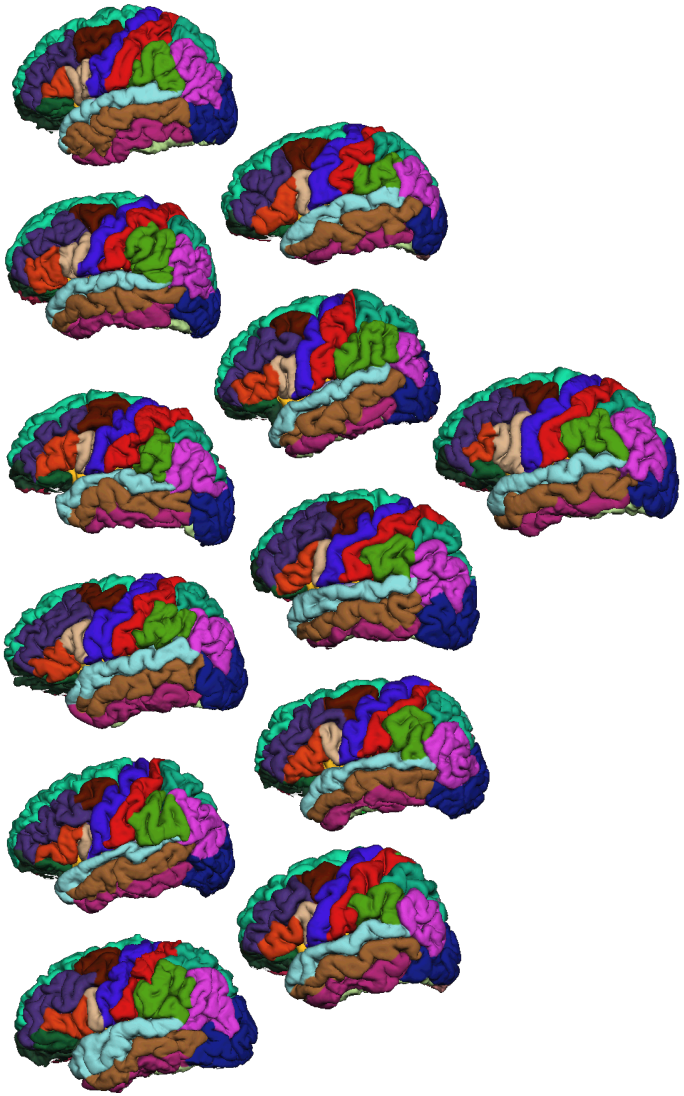
Registration-based labeling



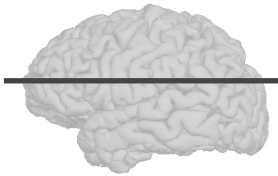
Step 2: apply transform



Registration-based labeling

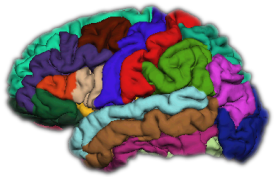


atlases



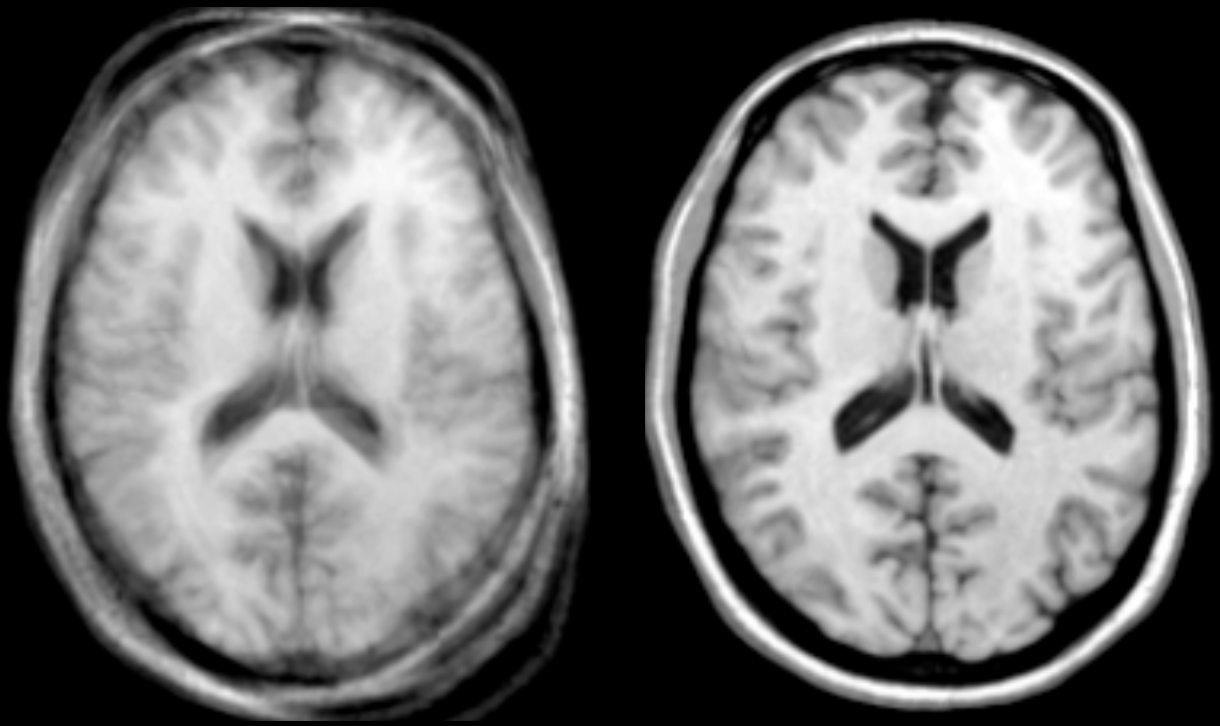
transform

multi-atlas
labeled
target



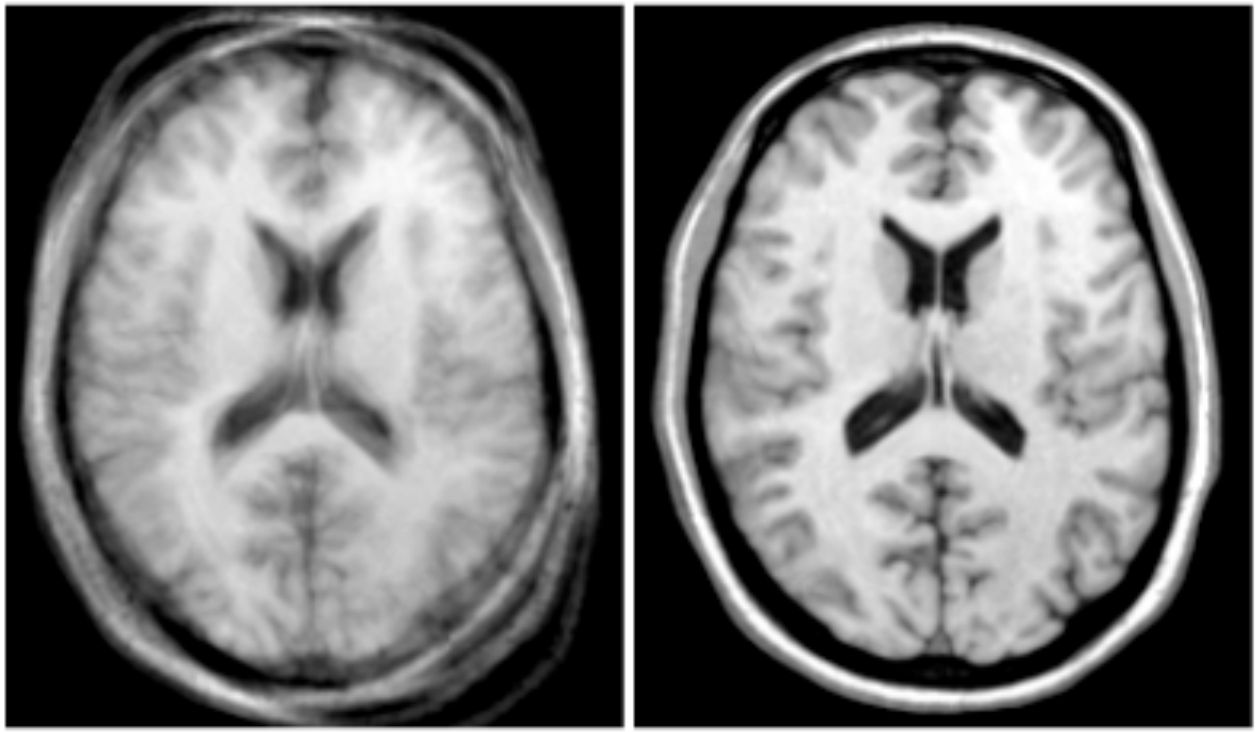
Step N: repeat for multiple atlases

What types of registration are there?



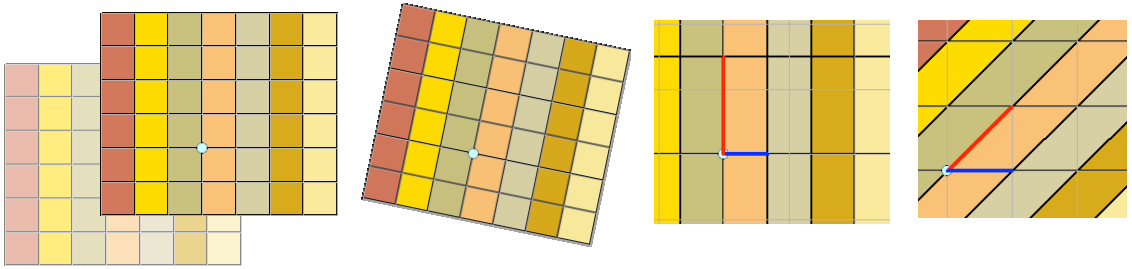
http://dx.doi.org/10.1002/hbm.460030304

Classify by number of degrees of freedom (dof)



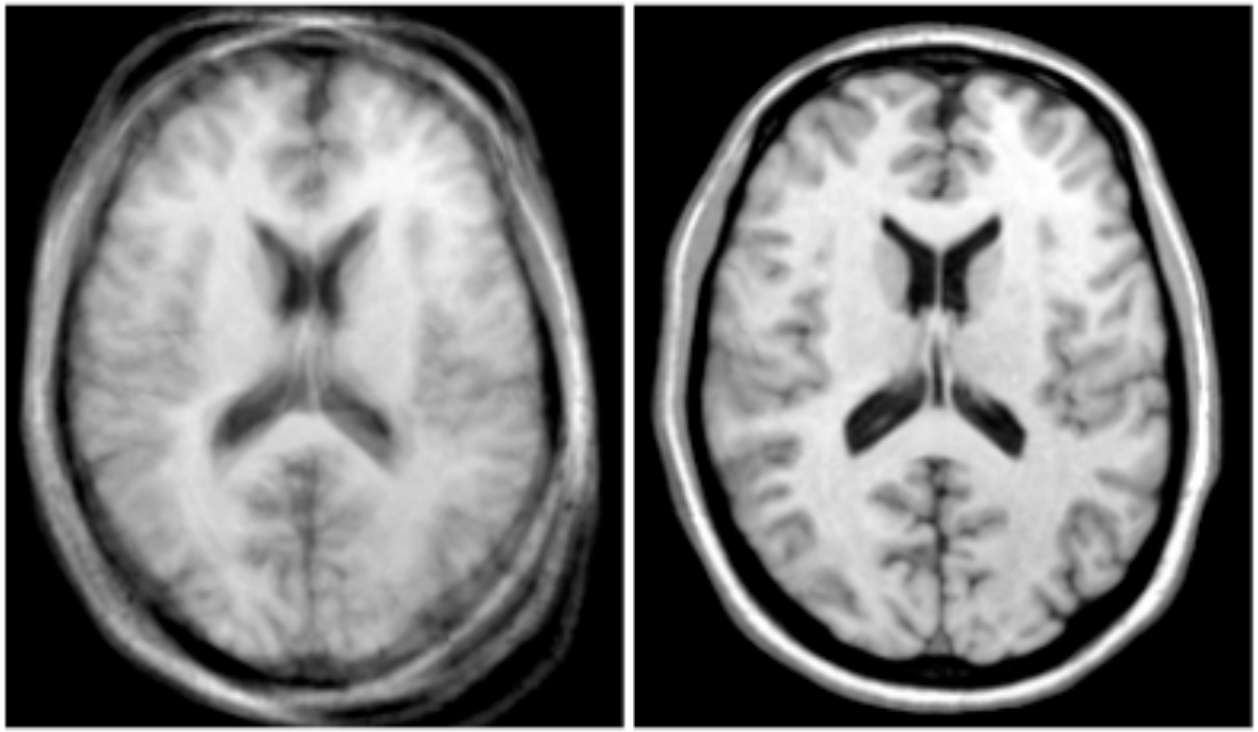
affine (12 dof) nonlinear (>12 dof)

12 dof: 3 translations, 3 rotations, 3 scales, 3 shears



http://dx.doi.org/10.1002/hbm.460030304

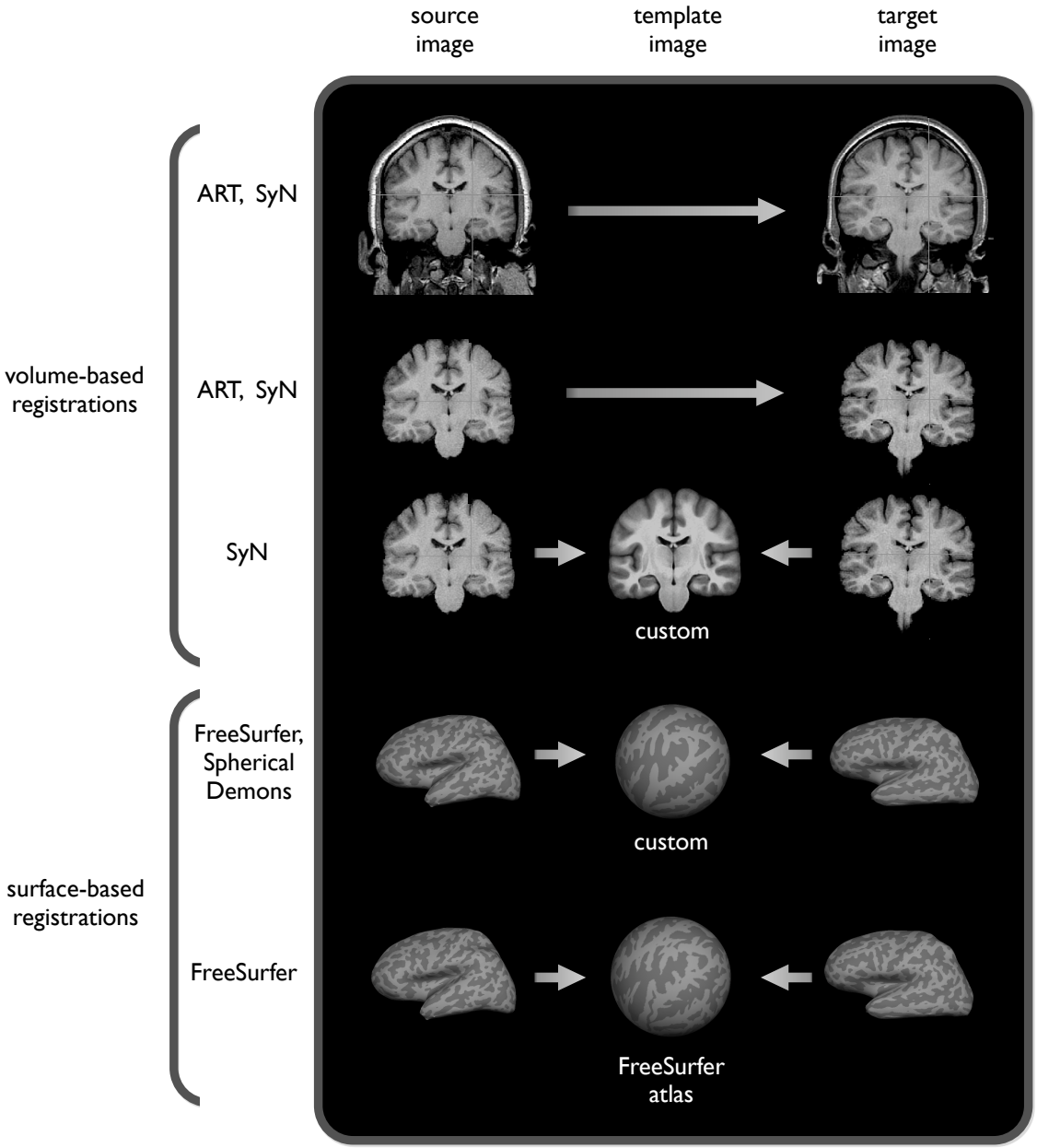
Classify by registration steps



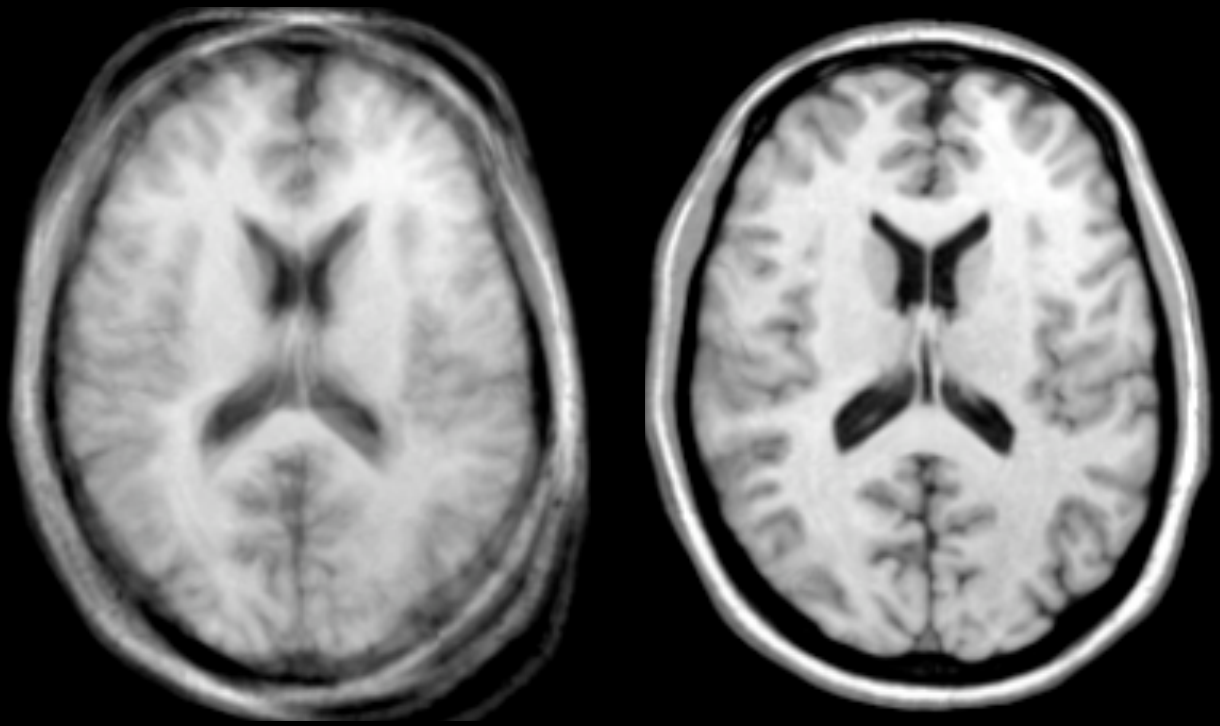
1. Similarity metric: (n)CR, SSD, MSD, (n)CC, MI,...
2. Transformation model: affine, piecewise linear, nonlinear,...
3. Regularization method: multi-resolution/scale, Gaussian blur,...
4. Optimization strategy: simplex, gradient descent,...
5. Interpolation type: nearest-neighbor, trilinear, cubic, sinc,...

http://dx.doi.org/10.1002/hbm.460030304

Classify by space registering in/to

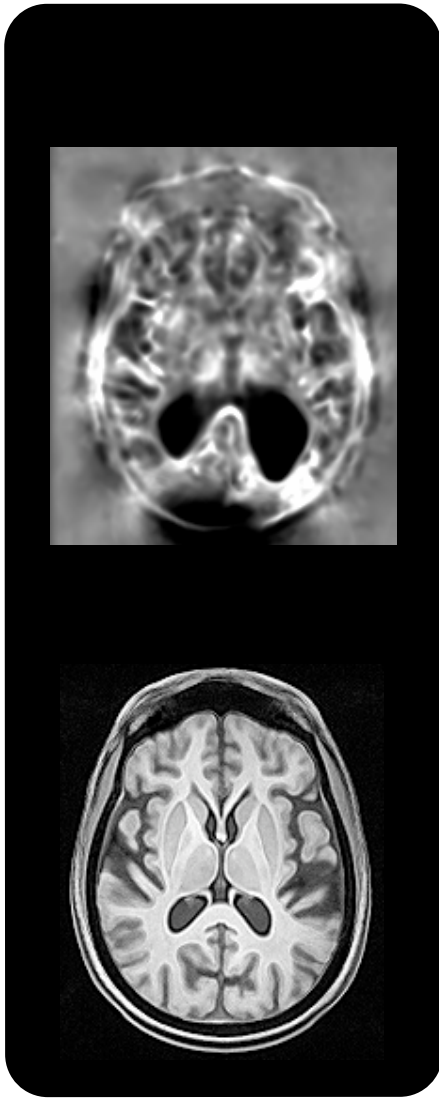


What other applications are there for registration?

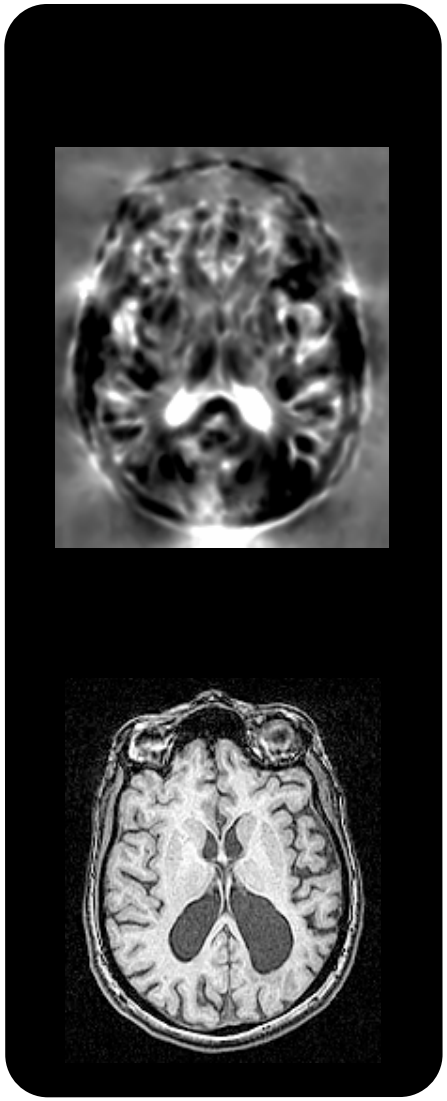


http://dx.doi.org/10.1002/hbm.460030304

1. morphometry

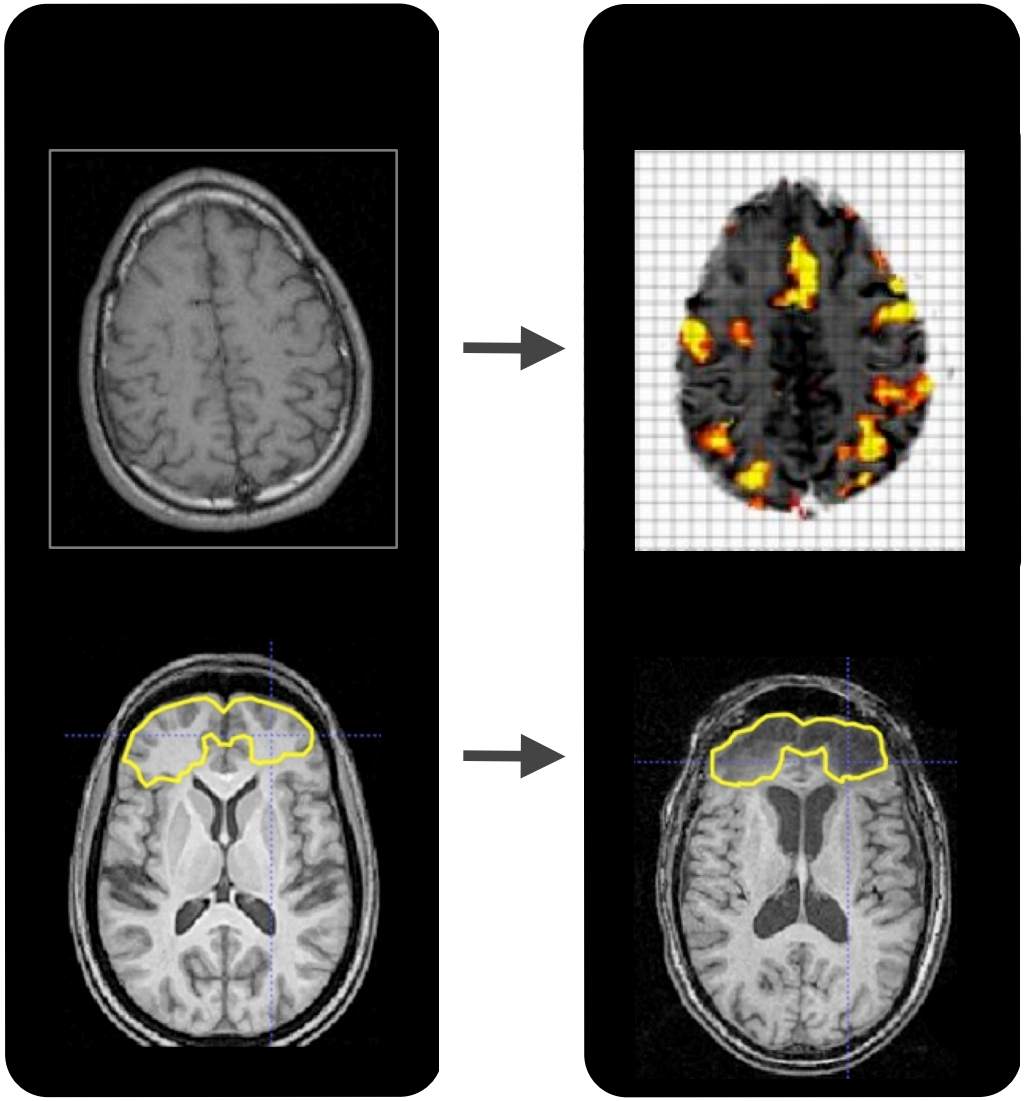


template

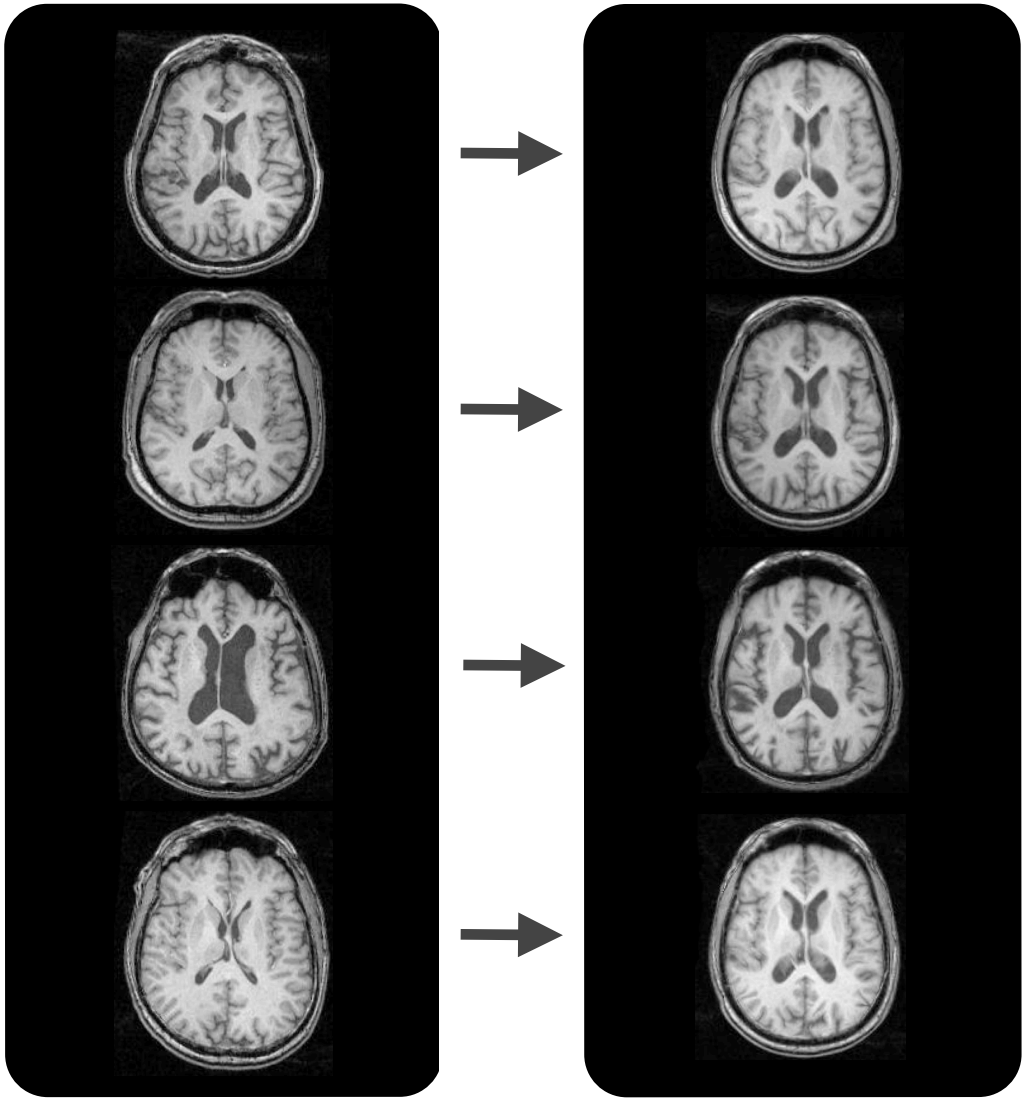


target

2. anatomical localization

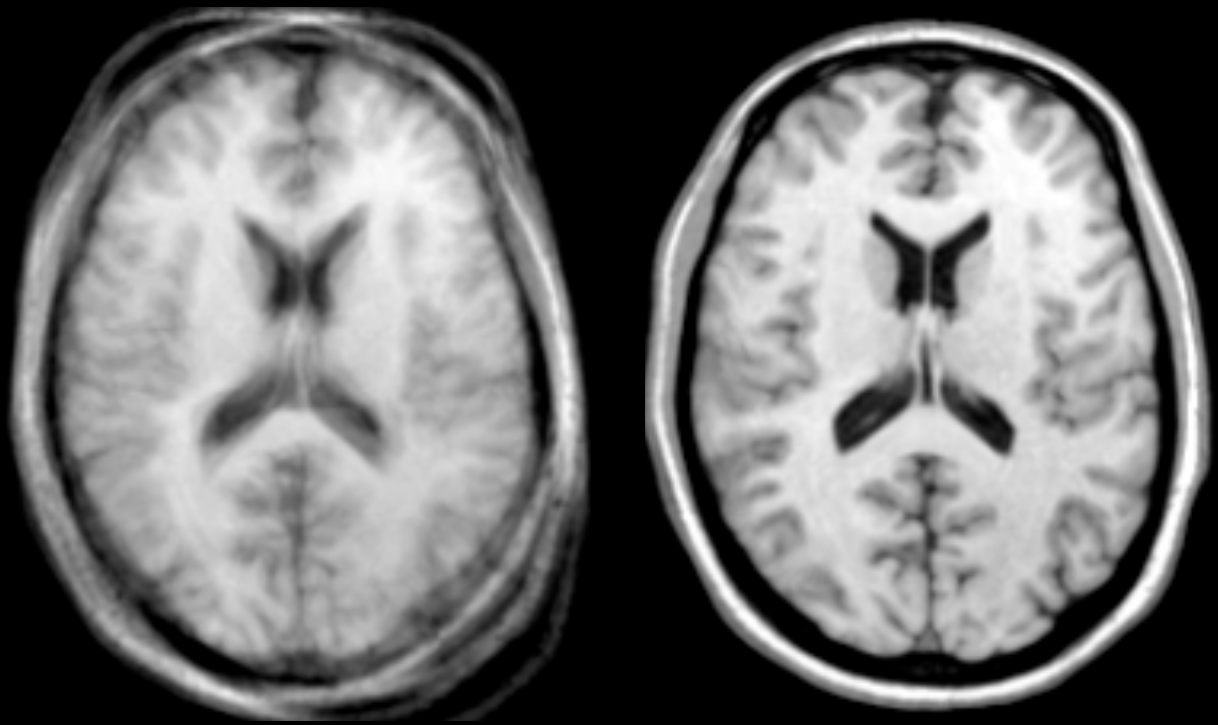


3. “spatial normalization” for group analysis



How accurate is a registration?

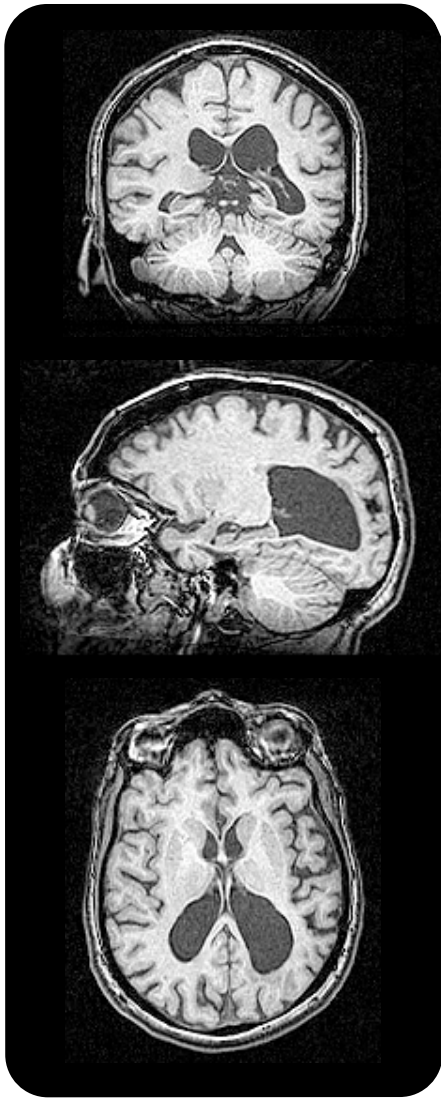
How accurate is the *anatomical* correspondence?



http://dx.doi.org/10.1002/hbm.460030304

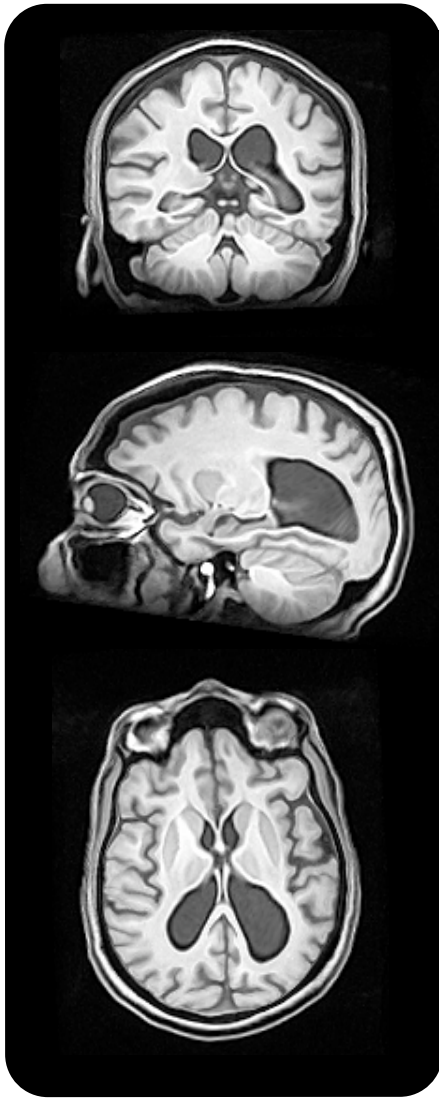
Challenging example

template

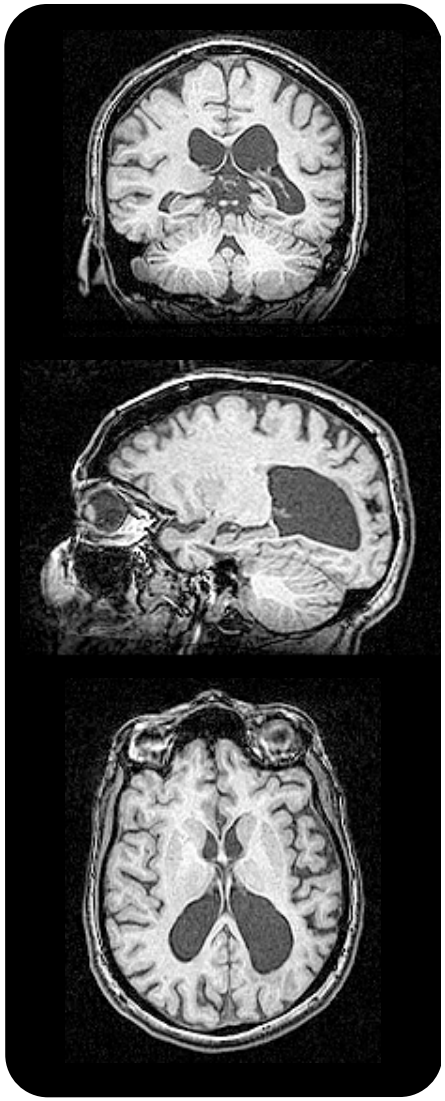


target

Challenging example



template
to target



target

“Evaluation of 14 nonlinear deformation algorithms applied to human brain MRI registration”

NeuroImage (2009)
http://www.mindboggle.info/papers/

Software	Similarity metric	Transformation
SyN	CC	bi-directional diffeomorphism (D)
ART	nCC	FFD based on cubic splines (H, np)
IRTK	nMI	cubic B-splines
SPM5 DARTEL	multinomial model: congealing	FDM of viscosity field (Dc)
JRD-fluid	Jensen-Rényi divergence	viscous fluid; variational calculus (D)
Diffeomorphic Demons	SSD	displacement field (D, np)
FNIRT	SSD	cubic B-splines
ROMEO	displaced frame difference	local affine
ANIMAL	CC	local translations
SICLE	SSD	3-D Fourier series (D)
SPM5 Unified Segment	generative segmentation	discrete cosine transforms
SPM5 “SPM2-type”	MSD	discrete cosine transforms
SPM5 Normalize	MSD	discrete cosine transforms
AIR	MSD	5th-order polynomial warps
FLIRT (linear)	nCR	linear, rigid-body

n = normalized
CC = cross-correlation
CR = correlation ratio
MI = mutual information
MSD = mean of squared differences
SSD = sum of squared differences

D = diffeomorphic
Dc = diffeomorphic, constant over time
FDM = finite difference model
FFD = free-form deformation
H = homeomorphic
np = nonparametric