Why do we have so many brain coordinate systems?

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WhyNHow seminar 12/04/08

About brain atlases

- What are they?
- What do we use them for?
- Who creates them?
- Which one shall I use?

Brain atlas definition

- Atlas: defines spatial characteristics of the brain; most often integrated from multiple sources (one or more samples, possibly multiple modalities)
  - Where is a given structure / region of functional activation? What are its shape and characteristics and how do we refer to it? How different is this brain compared with a normal database?
- can have many forms
  - descriptions of structure or function of the whole brain
  - map of groups or populations
  - definition may depend on intended application
- properties at construction:
  - Transforms DOF
  - Number of input images
  - Contents of the population

Use for atlases

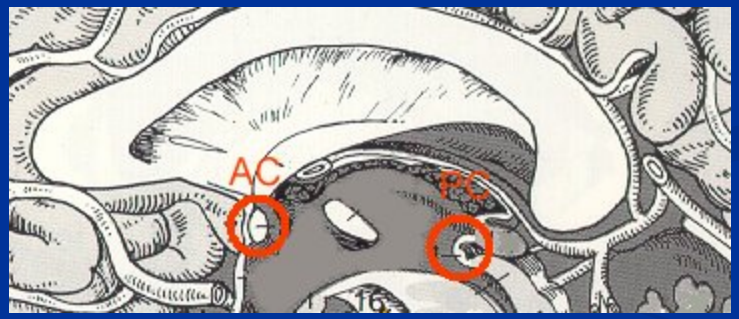
- Comparison of an individual system
- Changes followed over time
  - brain development, neuro-degeneration, …
- Comparison across individuals, modalities or states
- Automatic functional/anatomical labeling
- Shape analysis
- …

Available atlases

- Some pre-defined coordinate systems
  - Talairach
  - MNI atlases
  - FreeSurfer atlases
  - * T. Yeo, ….
- Can be created
  - Careful! – have to have a good reason (for example, pediatric, diseased population, …)

Talairach Coordinate System

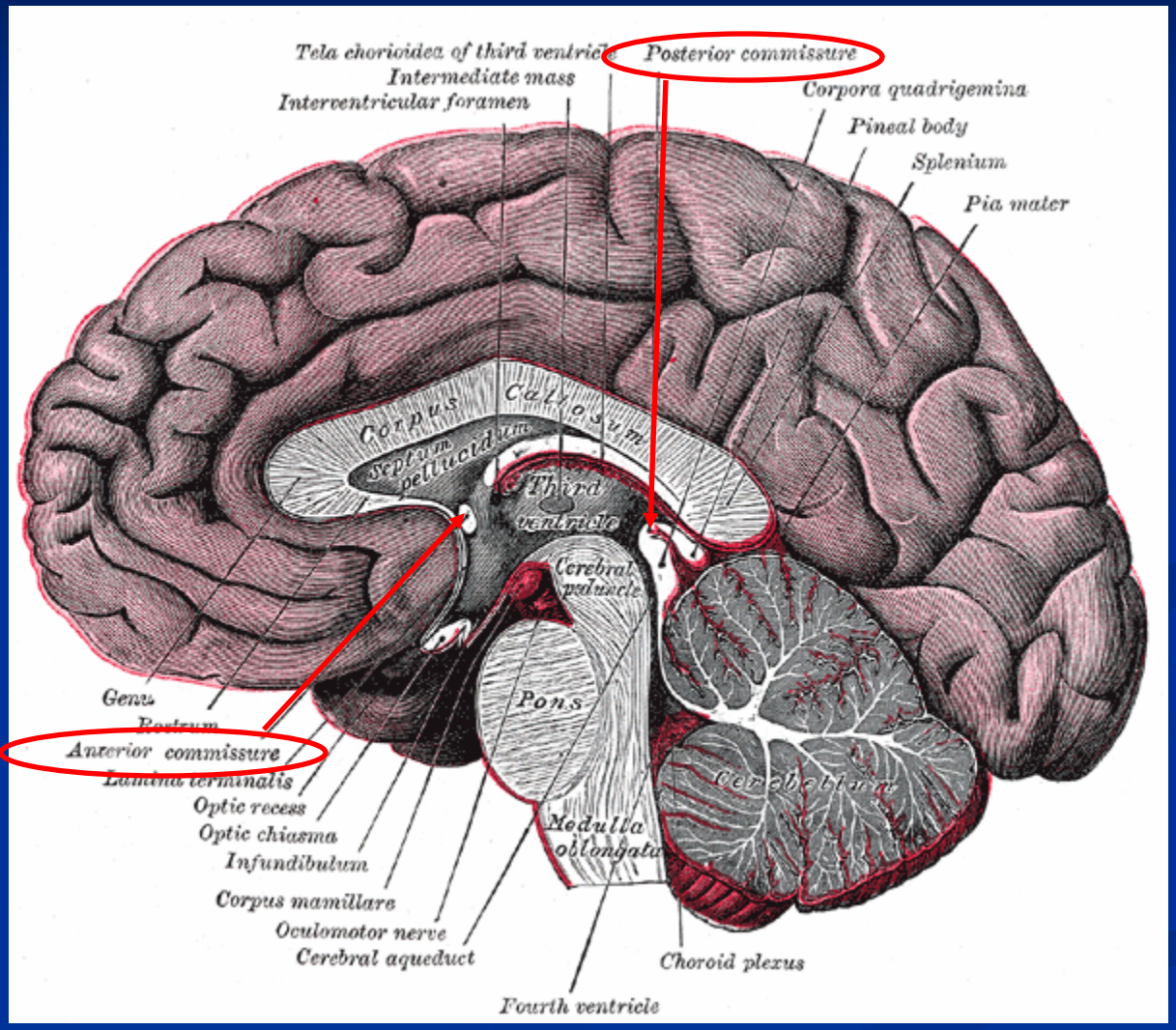
- aka. *stereotaxic* coordinate system
- defined by AC-PC line (midsagittal plane is the vertical)
- distances measured from AC as origin



- J. Talairach and P. Tournoux, "*Co-planar Stereotaxic Atlas of the Human Brain: 3-Dimensional Proportional System - an Approach to Cerebral Imaging*", Thieme Medical Publishers, New York, NY, 1988

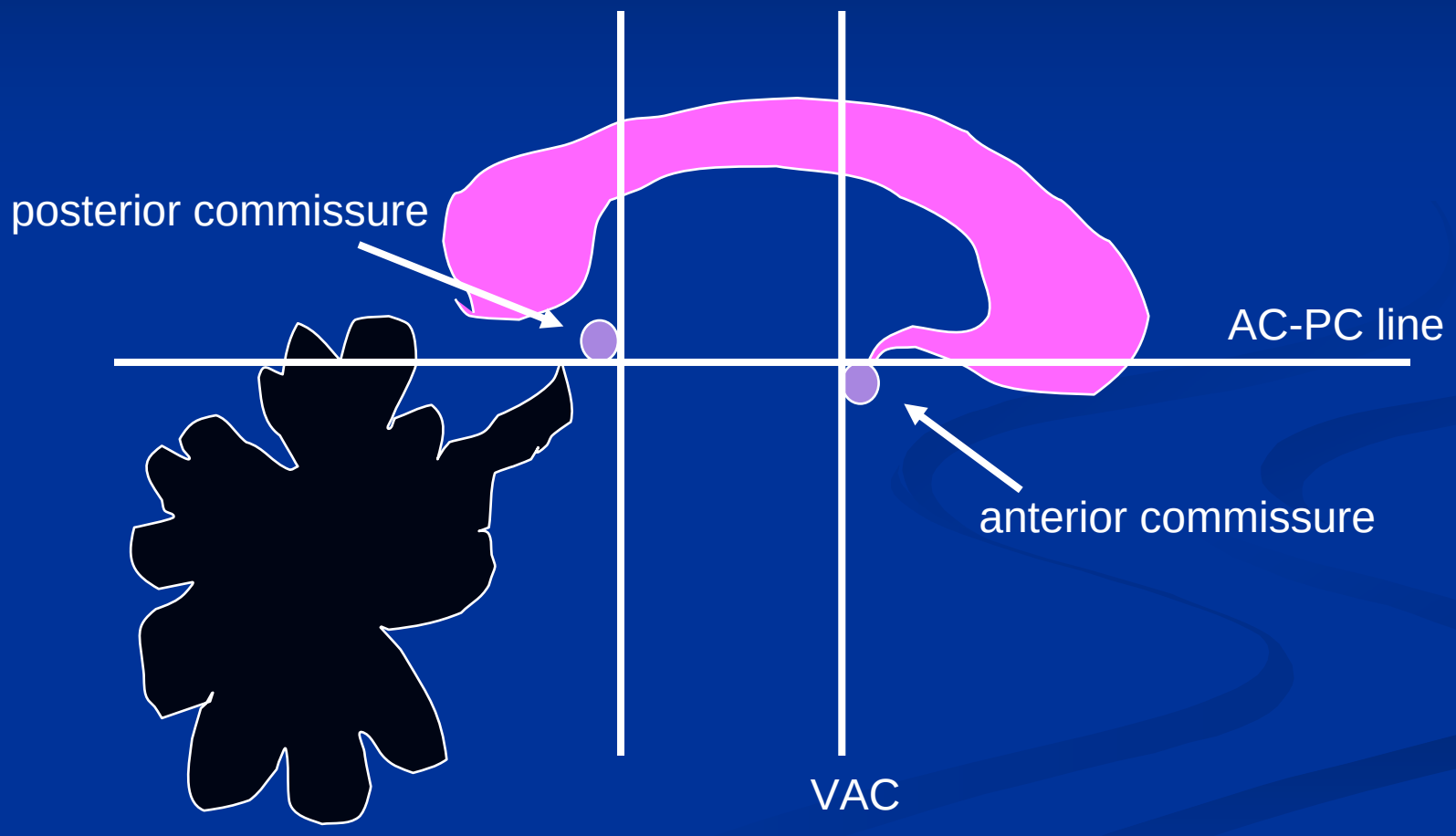
http://www.cns.atr.jp/cbi/vbmeg/img/BrainVoyager/Users1-4-a.png

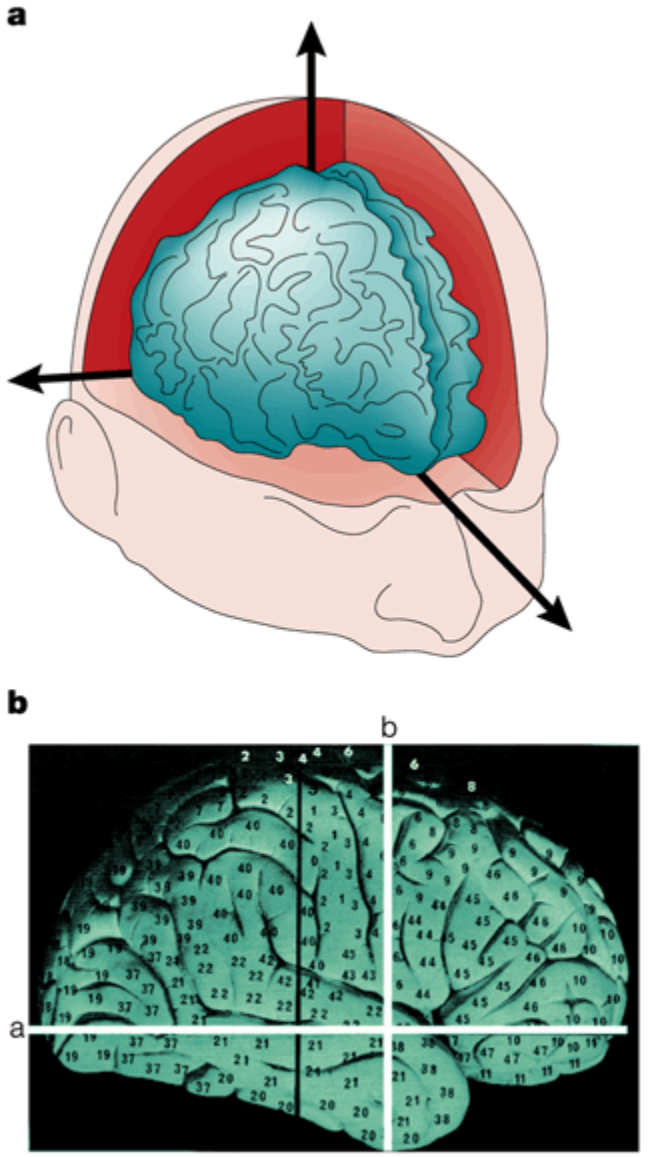
AC-PC line



http://upload.wikimedia.org/wikipedia/commons/2/22/Gray720.png

AC-PC line





Nature Reviews | Neuroscience

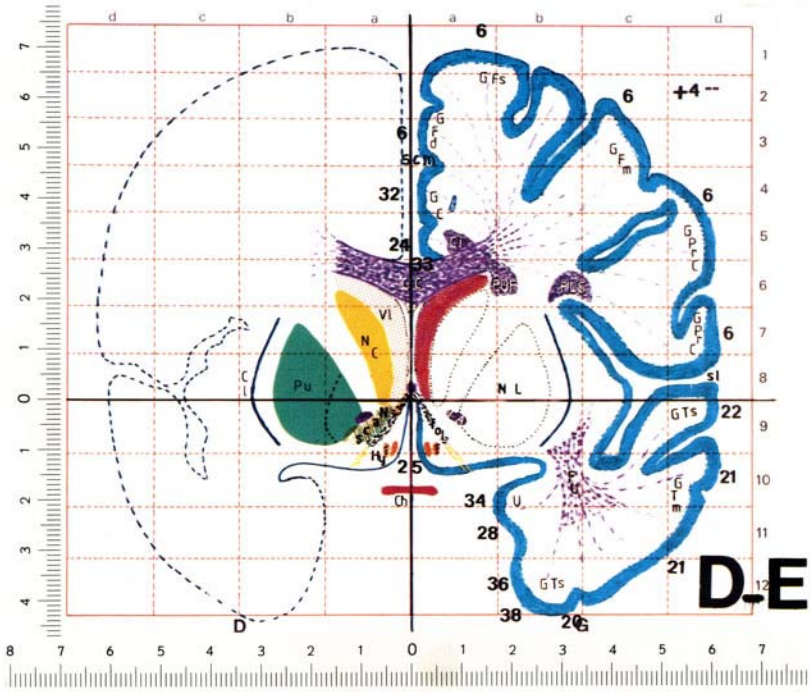


Figure 77

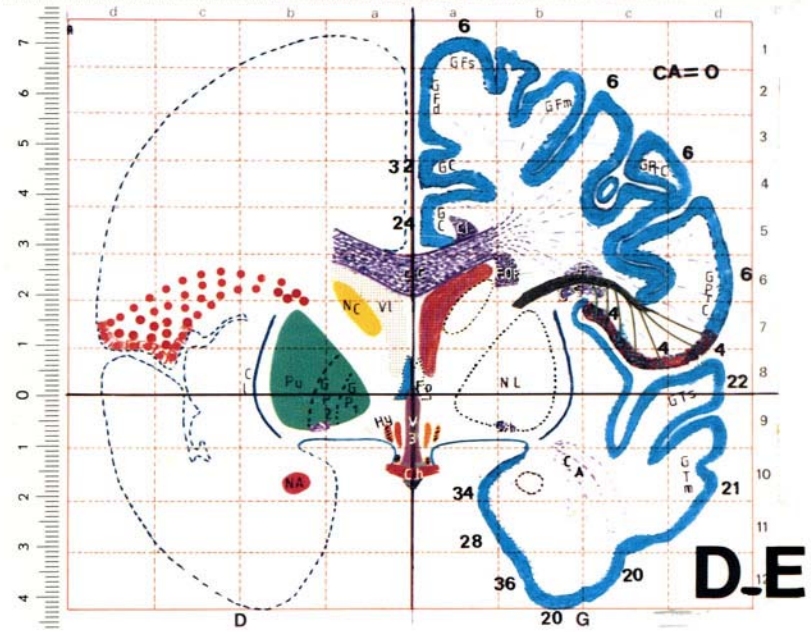


Figure 78

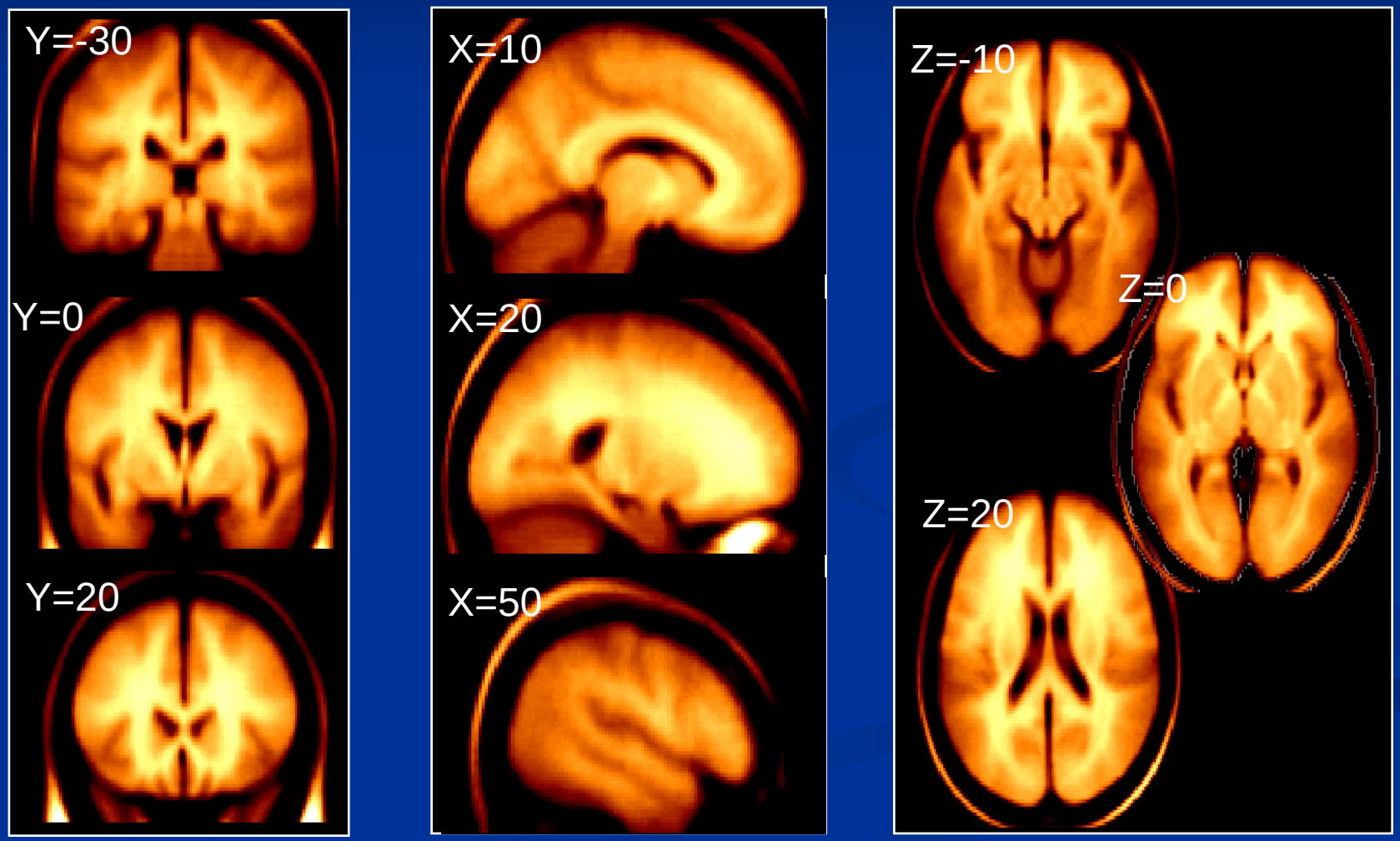
Talairach Coordinate System

- widely used: stereotactic and functional neurosurgery; human brain mapping, neuroradiology, medical image analysis, and neuroscience education
- standard anatomical landmarks → individual brain image to 'standard Talairach space' → inferences about tissue identity at specific locations by referring to the atlas
- disadvantages:
  - approximate method for Brodmann area definition (gross visual inspection rather than histology)
  - created from post-mortem brain (from a woman with a smaller than average cranium) → most individual brains must be considerably warped to fit the small size of the atlas

MNI atlases

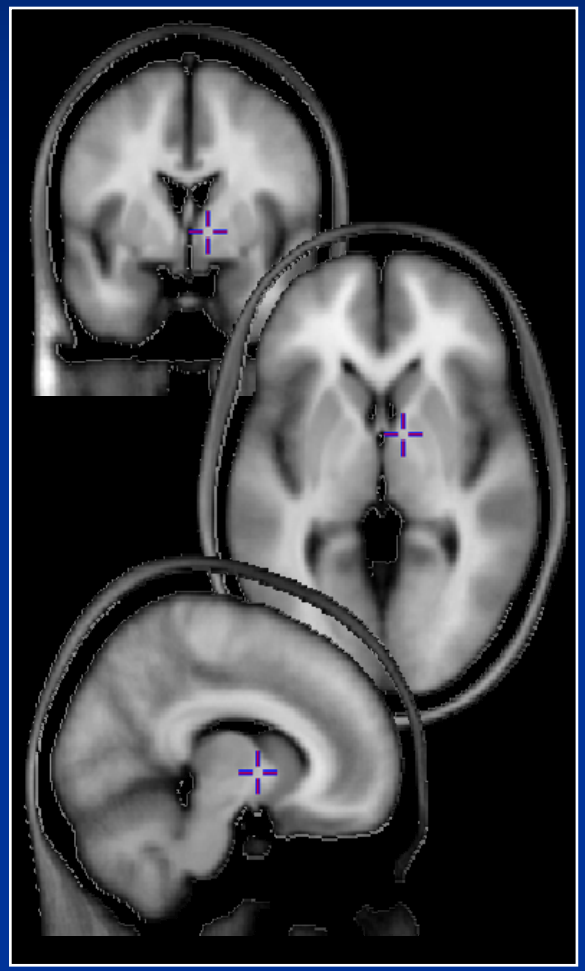
- MNI250
  - 250 normal MRI scans approximately matched to the Talairach brain (using a set of **manual** landmarks; brains scaled to match landmarks in Talairach atlas)
  - rarely used
- MNI305
  - 305 right handed subjects, 239 M, 66 F, age 23.4 +/- 4.1)
  - +55 brains registered automatically (linear transformation)
  - Evans, Collins et al., "*3D statistical neuroanatomical models from 305 MRI volumes*", '93
- ICBM152
  - average of 152 normal MRI scans matched to MNI305 (9 DOF)
  - standard template in SPM99 and later
- ICBM452
  - *air12*: average of 452 brains (12 DOF linear transform to MNI305)
  - *warp5:* average of 452 brains (affine + non-linear warping)
  - not widely used yet
- Colin27
  - C. Holmes scanned 27 times; scans coregistered and averaged; matched to the MNI305
  - SPM96 standard template; MNI brainweb simulator

Examples: MNI305 average brain

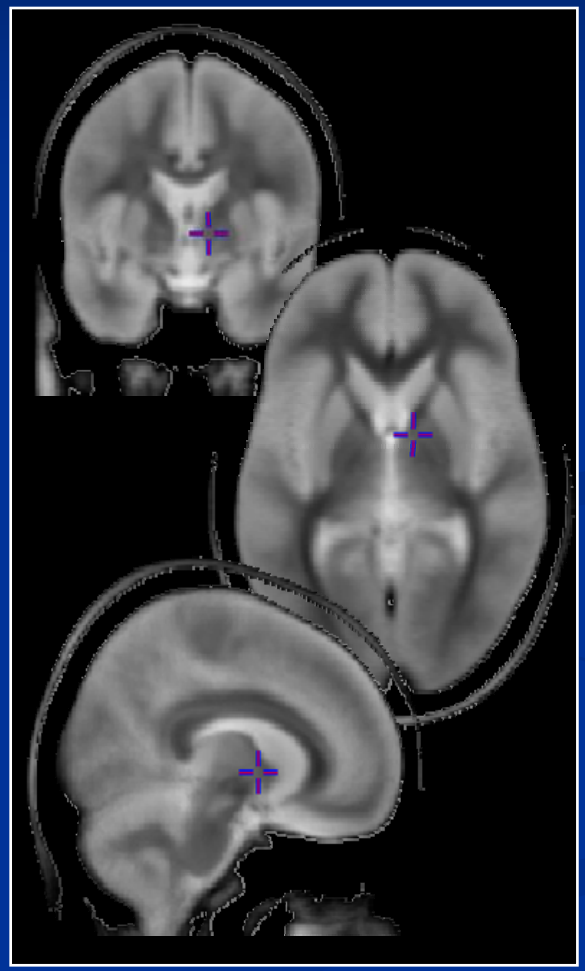


A.C. Evans et al, 1992

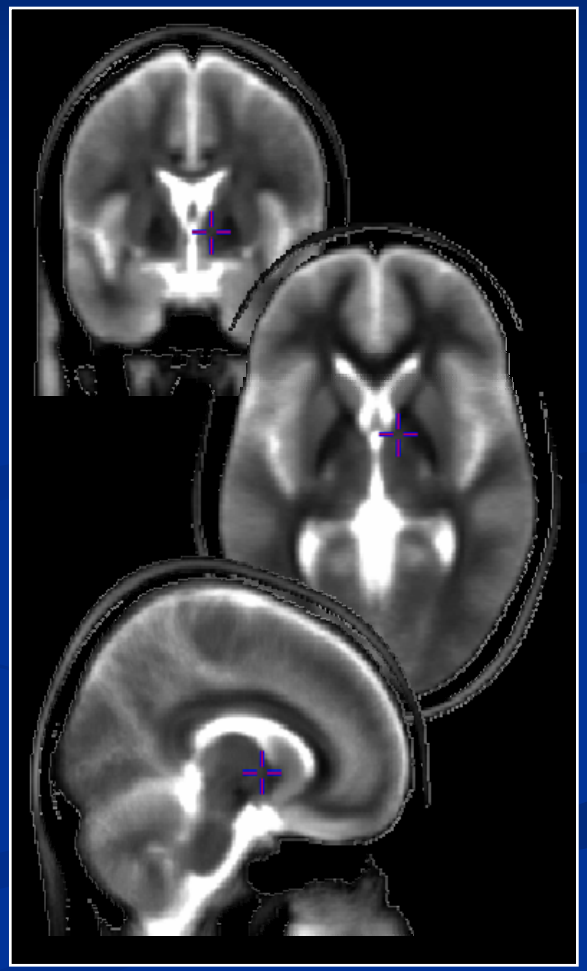
Examples: ICBM152 averages



Average T1

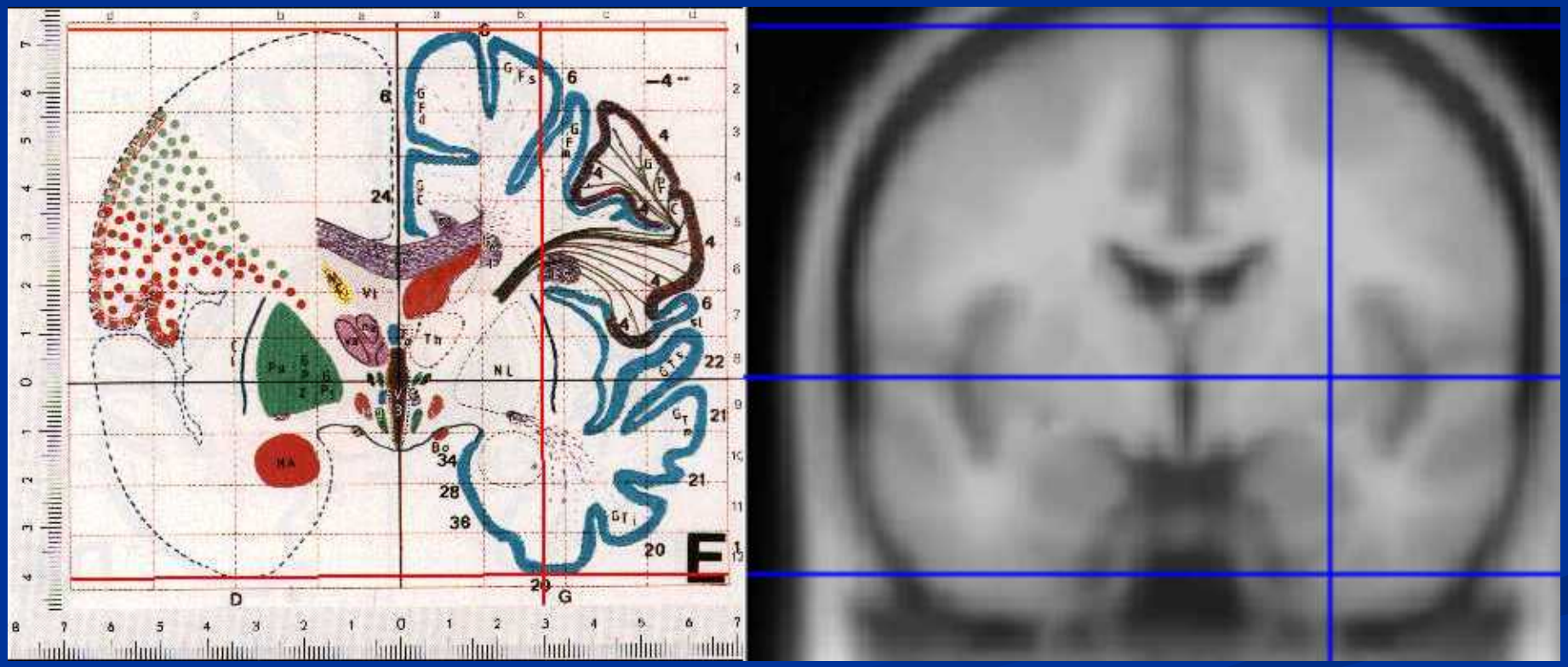


Average PD



Average T2

Talairach vs MNI



http://imaging.mrc-cbu.cam.ac.uk/imaging/MniTalairach

FreeSurfer atlases

- 39 subjects (Buckner data set)
  - Subcortical atlases
  - Cortical atlases

- http://surfer.nmr.mgh.harvard.edu/fswiki/AtlasSubjects?highlight=(atlas)
- http://surfer.nmr.mgh.harvard.edu/fswiki/SurfaceRegAndTemplates

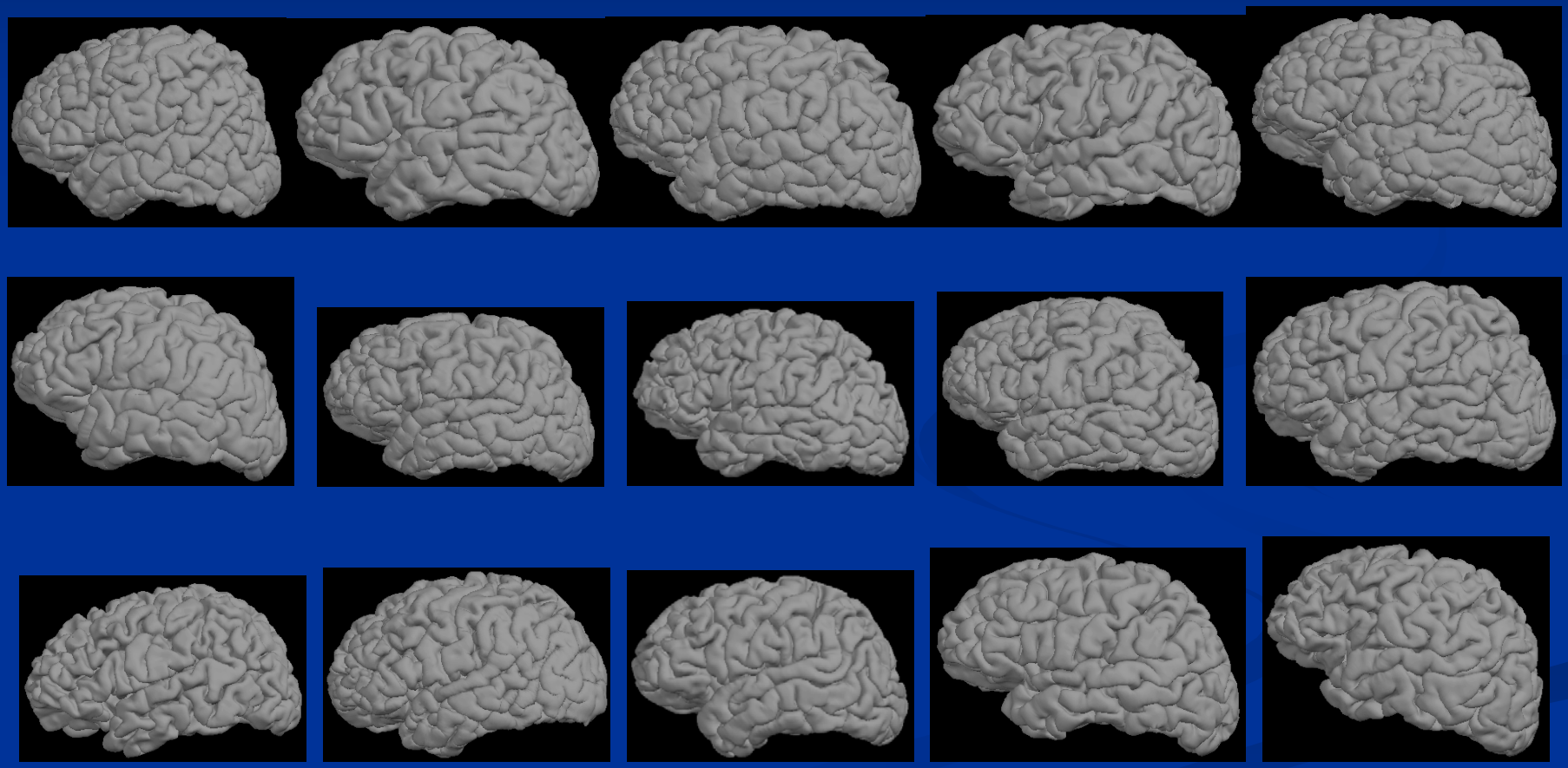
Research directions

- *Effects of Registration Regularization and Atlas Sharpness on Segmentation Accuracy*. Yeo et al. MIA, 12(5):603:615, 2008
- *What Data to Co-register for Computing Atlases*. Yeo et al. MMBIA, ICCV, 2007
- *The Impact of Atlas Formation Methods on Atlas-Guided Brain Segmentation*. Zöllei et al. Statistical Registration: Pair-wise and Group-wise Alignment and Atlas Formation, MICCAI 2007
- ….

Which ones shall I use?

- Will probably depend on application and the goal of the analysis

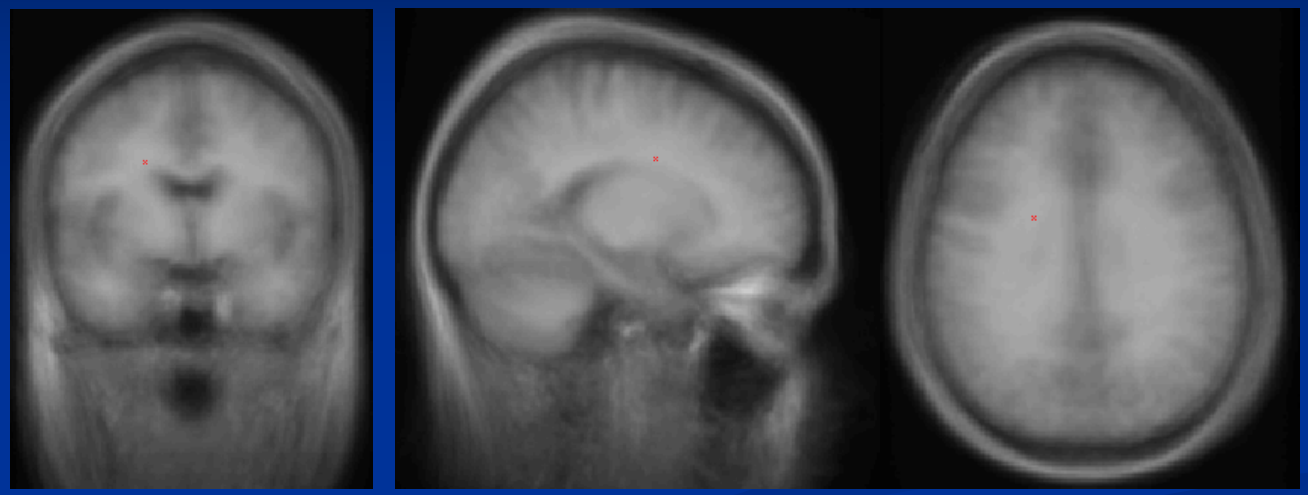
How to align different cortical surfaces?



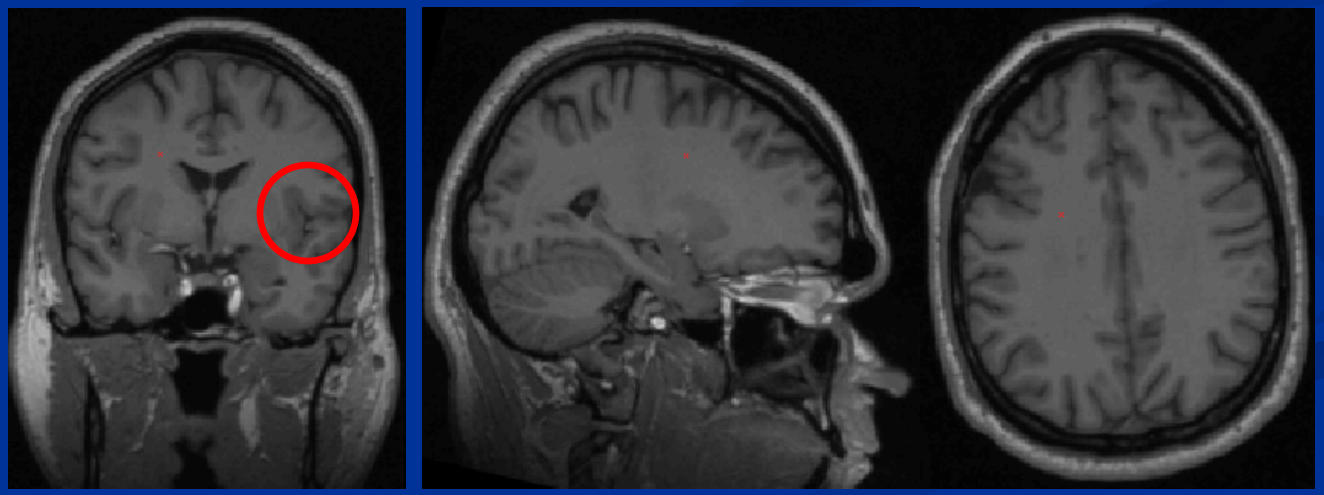
Slide: courtesy of B. Fischl

Talairach averaging

Average of 40

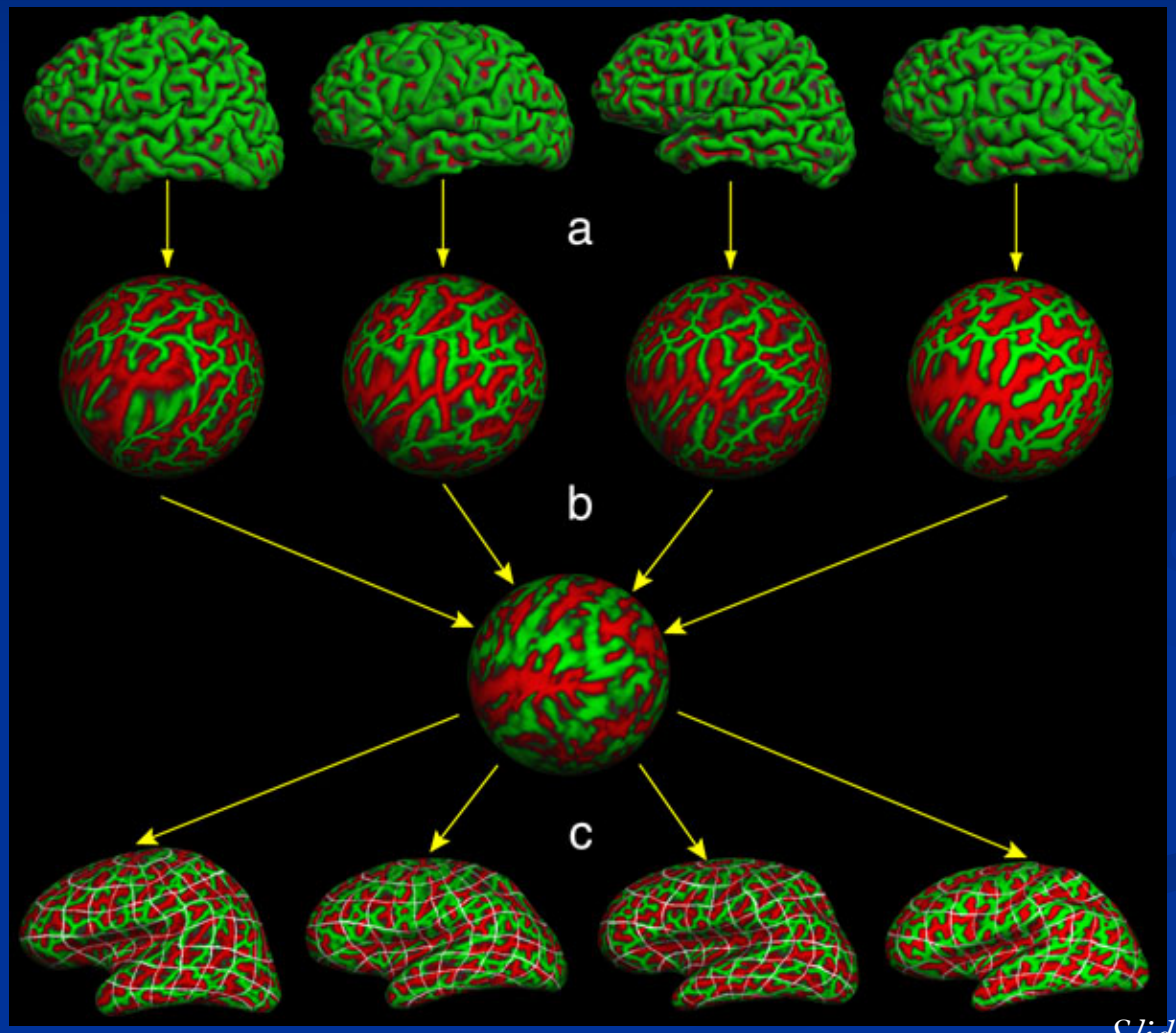


Single subject



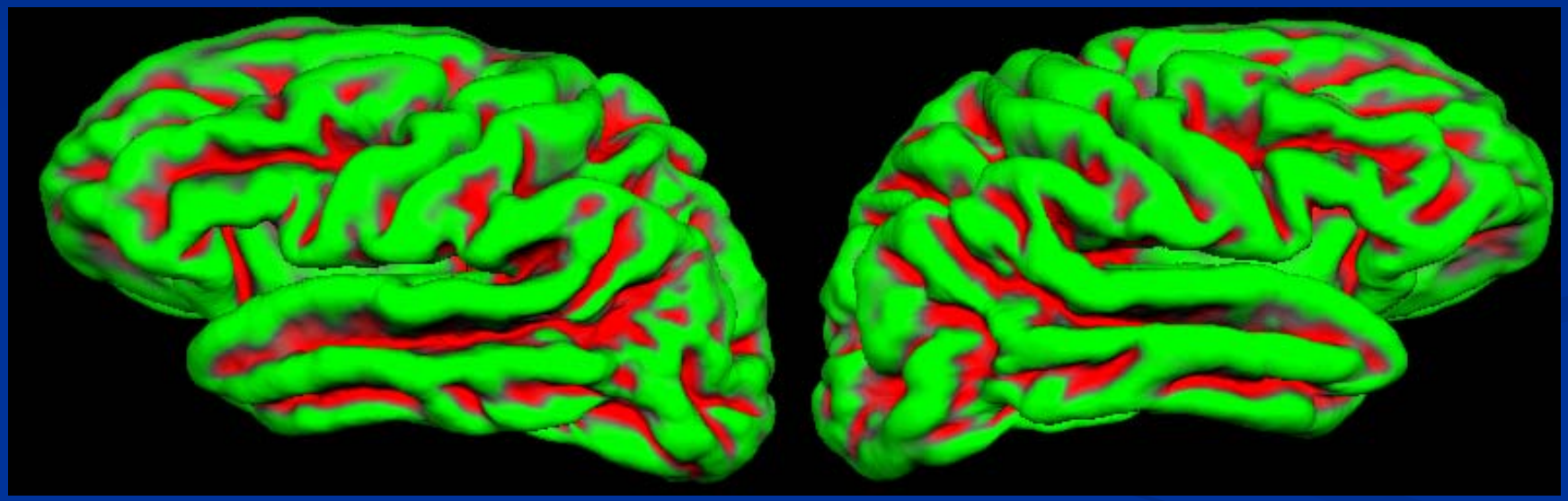
Slide: courtesy of B. Fischl

A Surface-Based Coordinate System



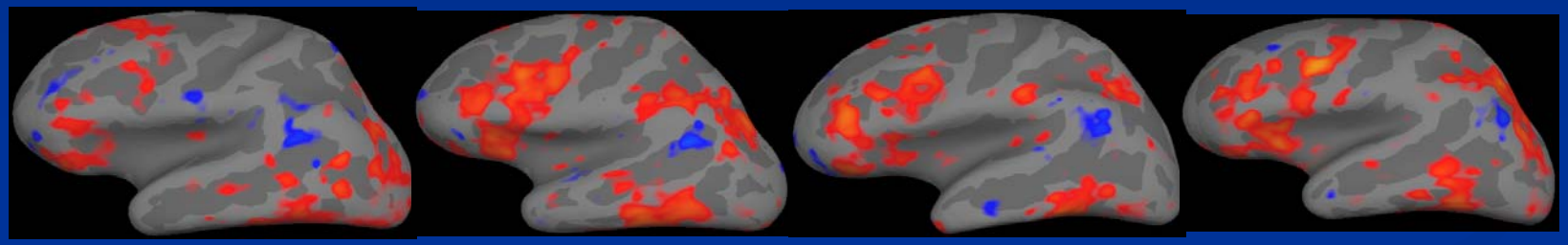
Slide: courtesy of B. Fischl

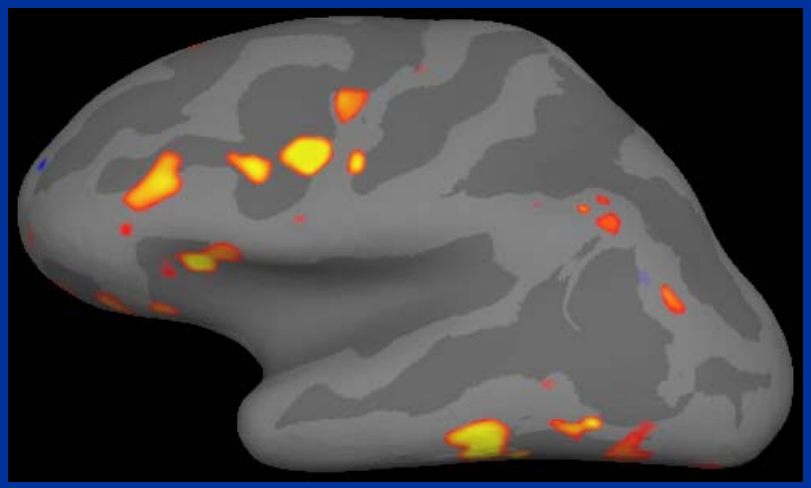
Surface-Based Averaging



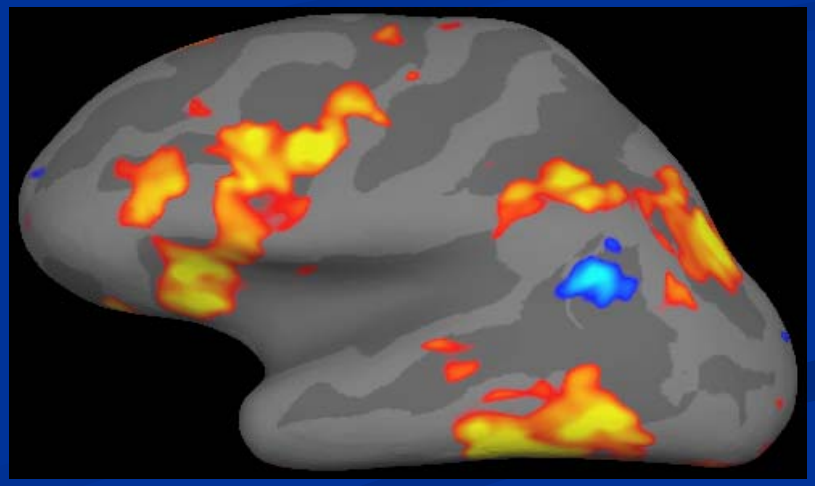
Slide: courtesy of B. Fischl

Inter-Subject Averaging of Functional Activations





Talairach Average



Spherical Average

Slide: courtesy of B. Fischl

Sources

- http://www.loni.ucla.edu/Atlases/
- http://en.wikipedia.org/wiki/Talairach_atlas
- http://www-sop.inria.fr/asclepios/projects/hec/content/brain/ComputationalAnatomy1_aims.html
- http://imaging.mrc-cbu.cam.ac.uk/imaging/MniTalairach

- Also see:
  - http://www.neurovia.umn.edu/webservice/tal_atlas.html
  - www.bic.mni.mcgill.ca/icbmview

End

Registration to Talairach space

- identify AC/PC on mid-sagittal
- define vertical, lateral and anterior-posterior extents
- define 12 piecewise linear transformations:
  - left / right
  - above / below AC-PC
  - anterior-AC / AC-PC / PC-posterior