

Freesurfer Applications

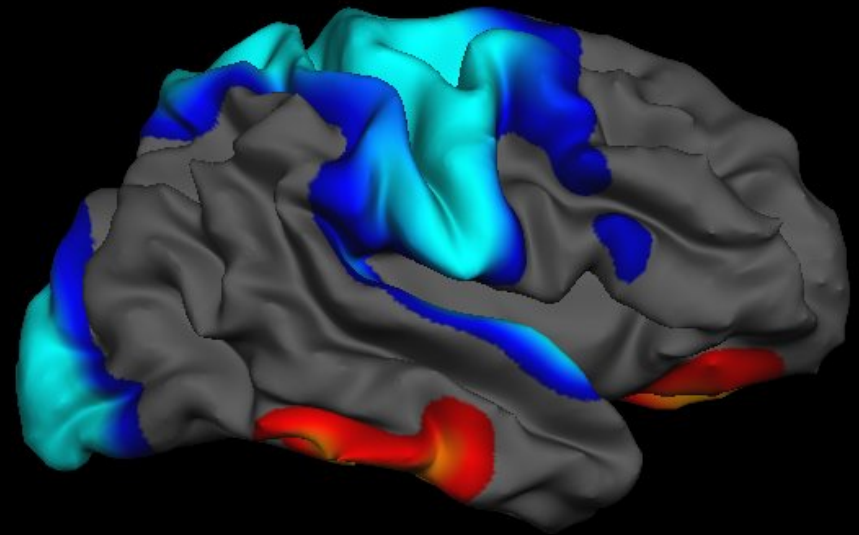
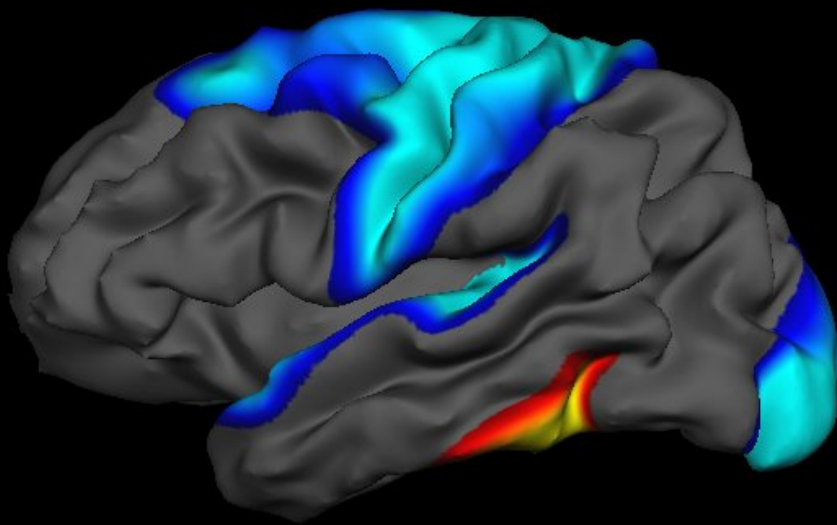


David H. Salat

salat@nmr.mgh.harvard.edu



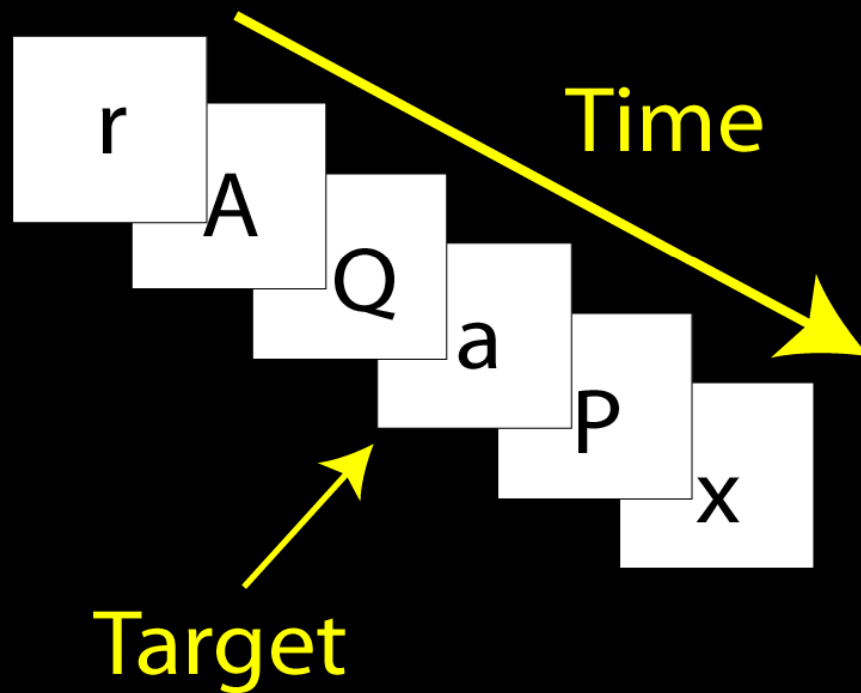
**MGH/MIT/HMS Athinoula A. Martinos Center for
Biomedical Imaging**



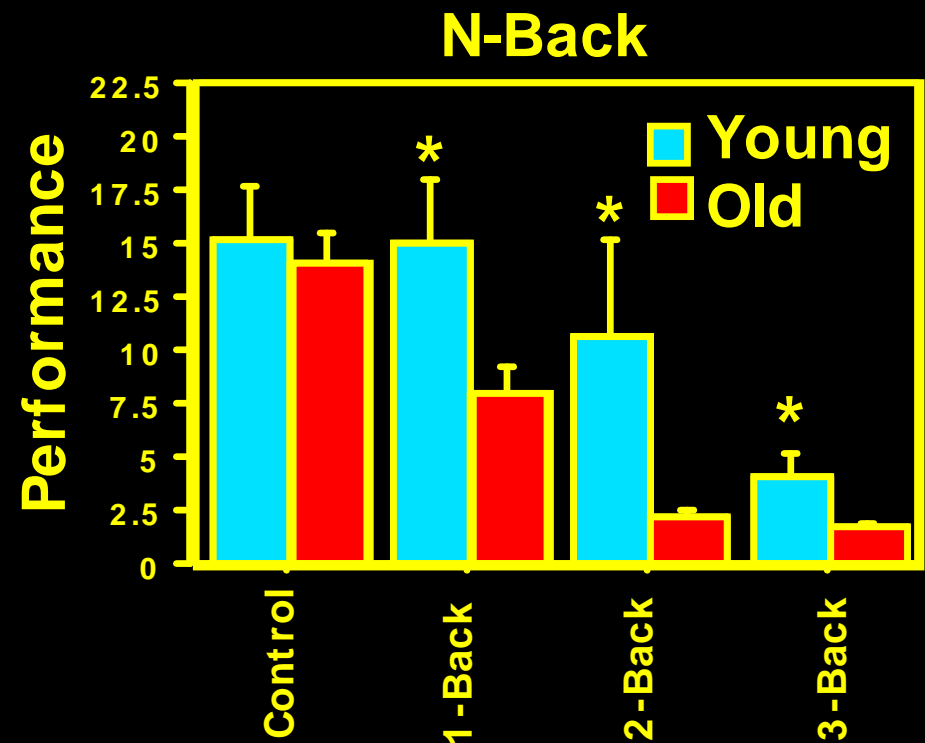
FreeSurfer Resources

- Most items can be found on the FreeSurfer webpage:
 - <http://surfer.nmr.mgh.harvard.edu>
- Journal Articles-
 - Surface reconstruction
 - Coordinate system
 - Thickness
 - Subcortical segmentation
 - White Matter Parcellation
 - Applications
- Documentation: **Freesurfer Wiki**
 - Manuals
 - Tutorials
 - Downloads
 - Software Help Files
 - How to cite Freesurfer
- E-mail List:
 - Majordomo@surfer.nmr.mgh.harvard.edu

fMRI: Working Memory: N-Back

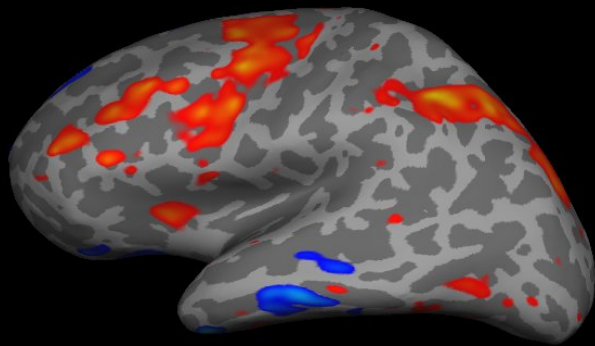


2-Back

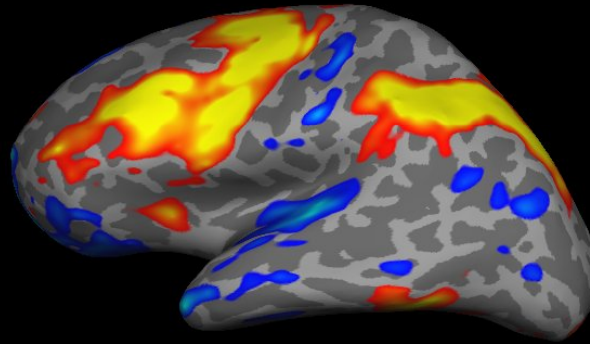


Working Memory: fMRI

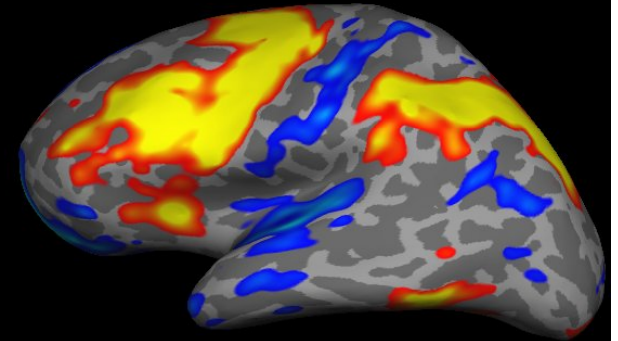
One Back



Two Back

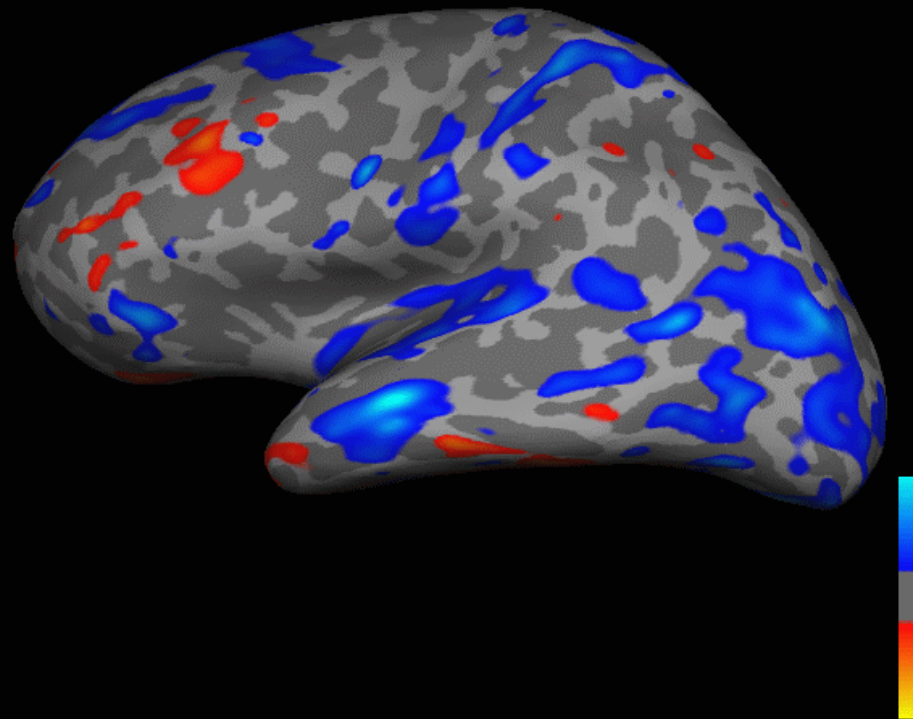


Three Back



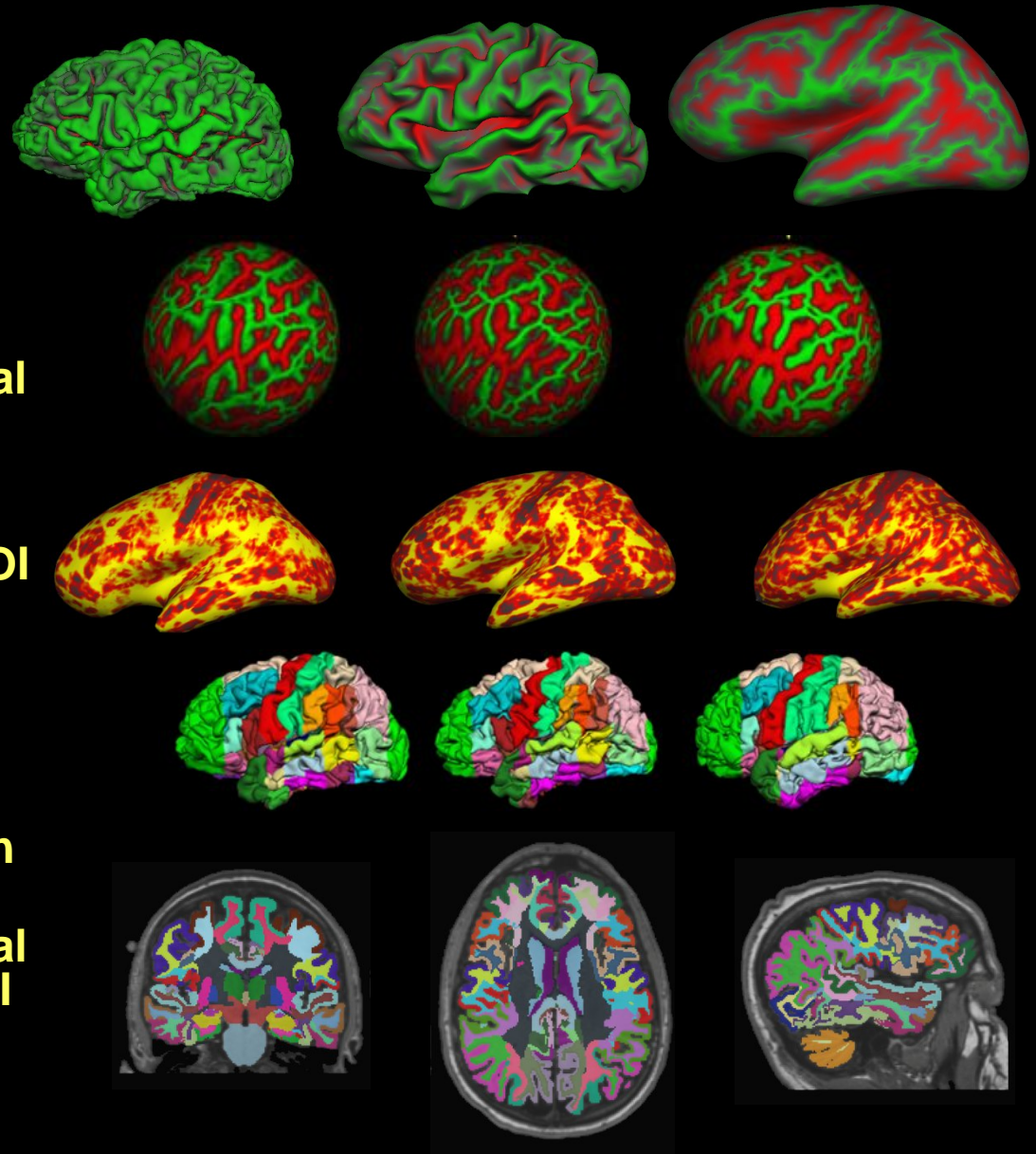
N-Back Working Memory Load

One Back → Two Back → Three Back



What can we do with Freesurfer?

- **Surface inflation and manipulation:** Visualize structural and functional data; reveal data in sulcal depths
- **Intersubject registration:** Alternate spatial normalization
- **Morphometric analysis:** Cortical thickness; analysis of folding patterns
- **Cortical Parcellation:** Analysis of cortical subregions; fMRI ROI analysis
- **Subcortical segmentation:** Volumetric analysis; fMRI ROI analysis
- **White matter parcellation:** Volumetric analysis; DTI region of interest analysis
- **Integrate with FSL tools:** Spatial normalization of fMRI data; ROI analyses



Original T1
Data

Cortical Reconstruction
Subcortical Segmentation

(Recon-all)

Output Data

Surfaces

(computer models)

Volumes

(labeled MRI images)

Thickness, aparc,
curv, sulc, jacobian

Visualization
Tksurfer

Visualization
tkmedit

Segmentation,
parcellation, white
matter parcellation

Individual
subjects

Region of
interest
analysis

Spreadsheet
Stat software

Group comparisons/
statistics

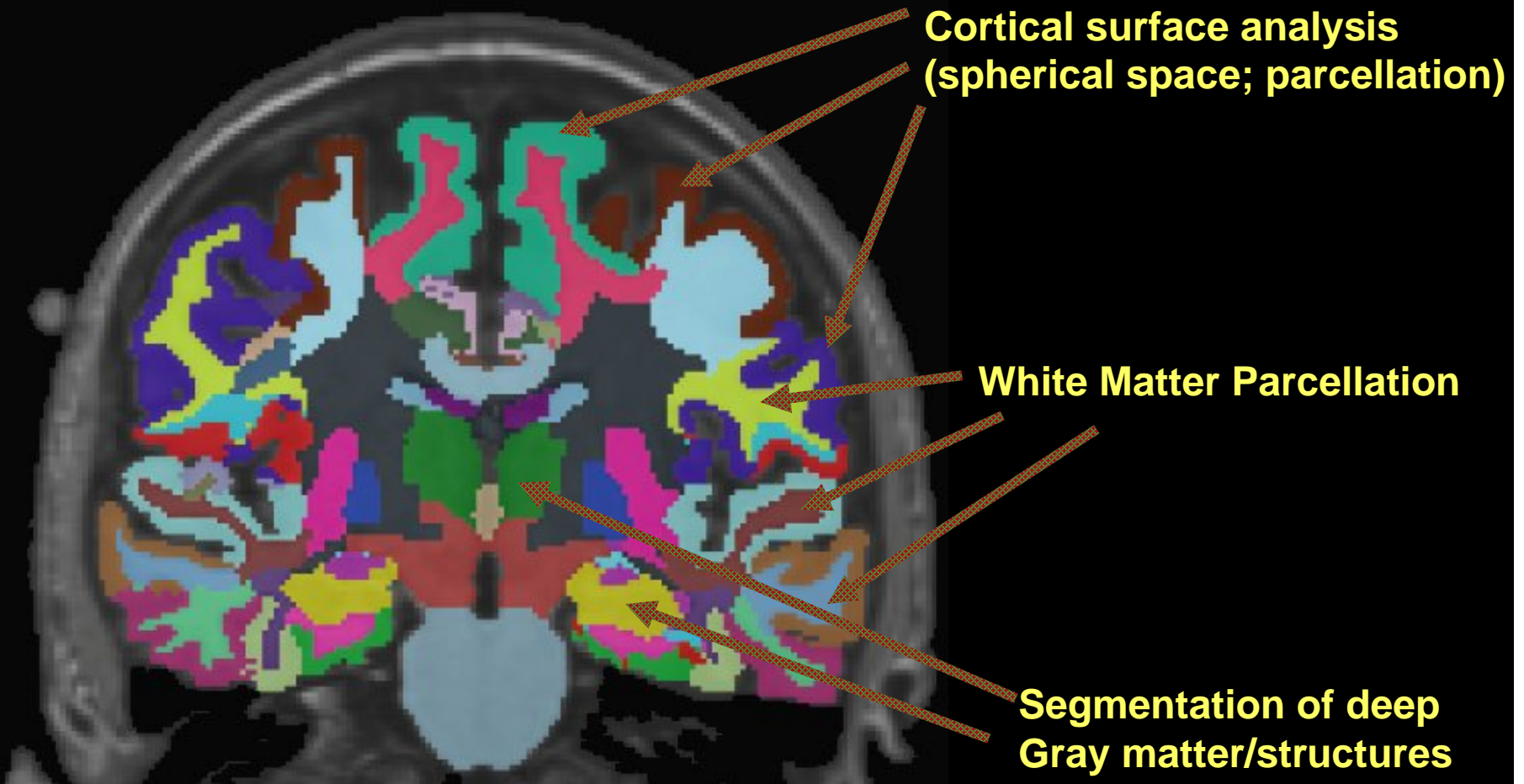
Qdec,
mri_glmfit

Individual
subjects

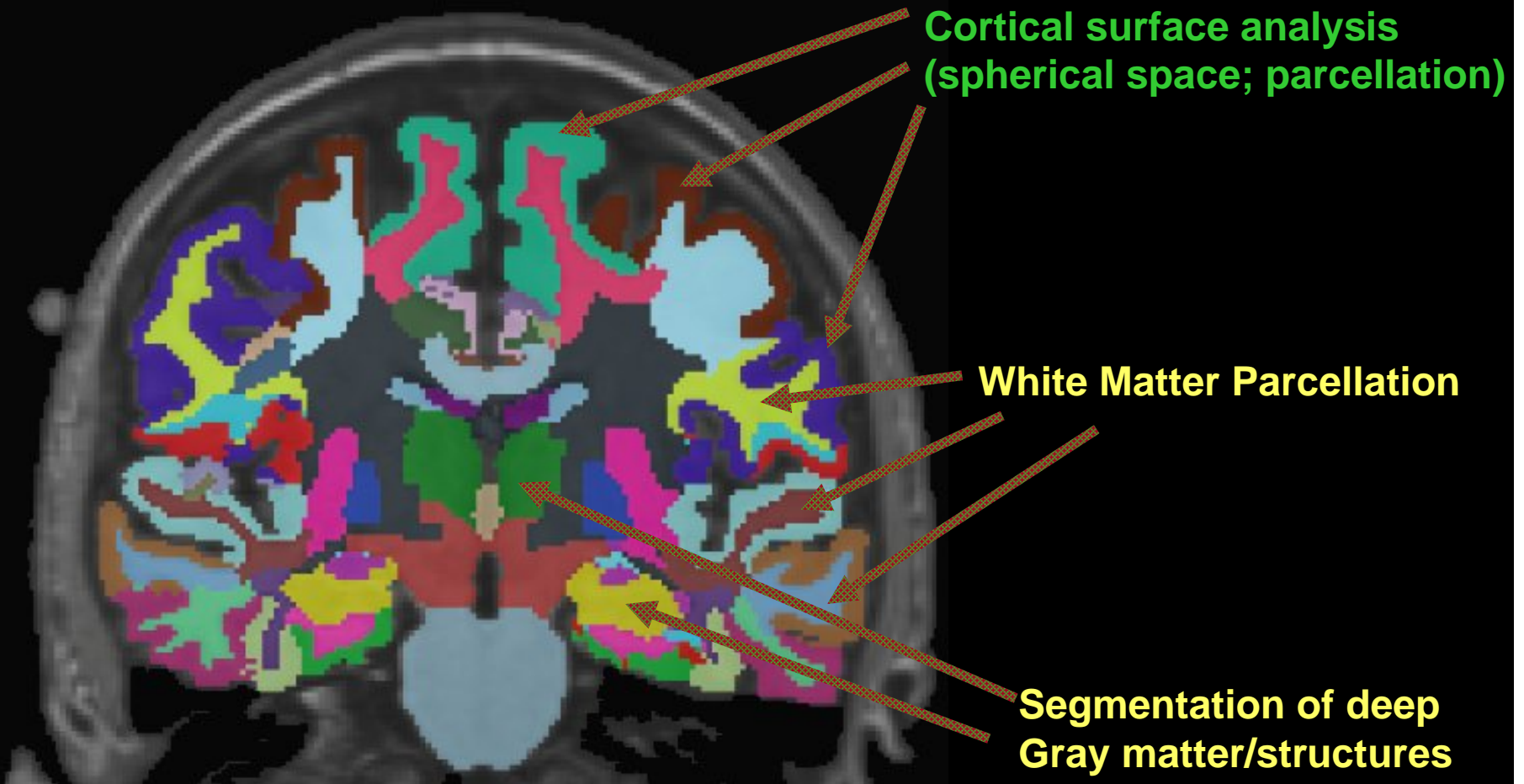
Region of
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Post Reconstruction Levels of Analysis/Anatomy



Post Reconstruction Levels of Analysis/Anatomy



Original T1 Data **Cortical Reconstruction Subcortical Segmentation** (Recon-all)

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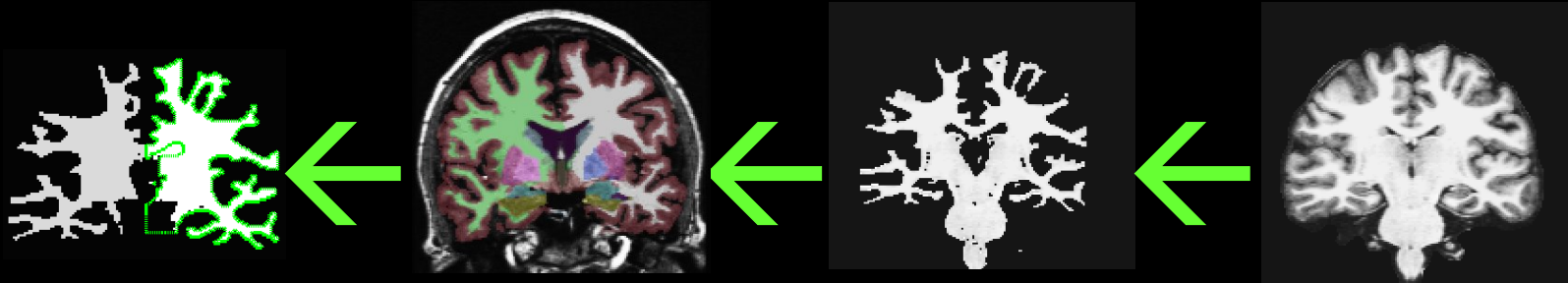
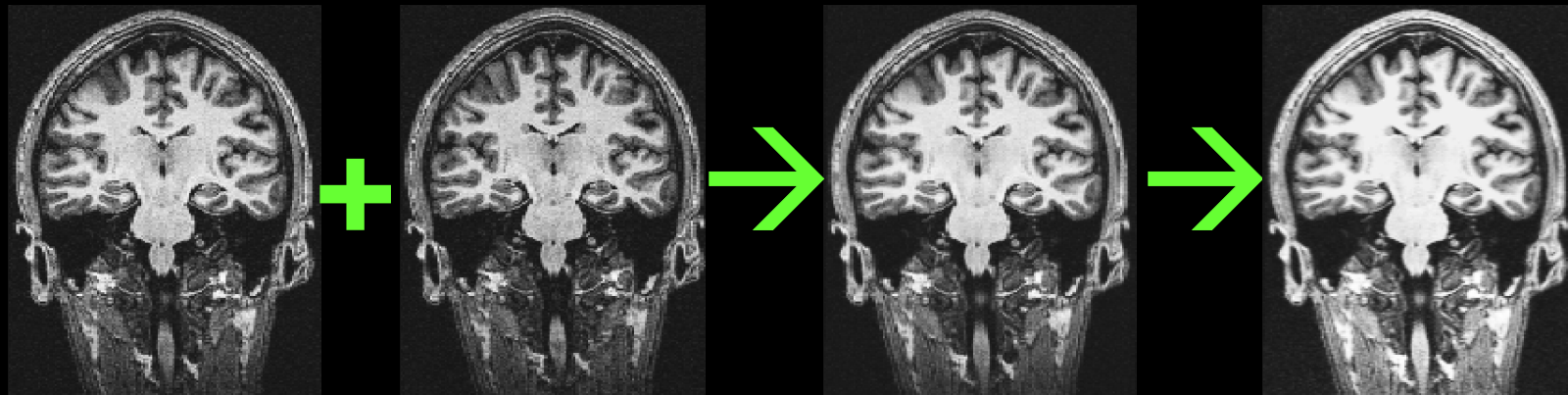
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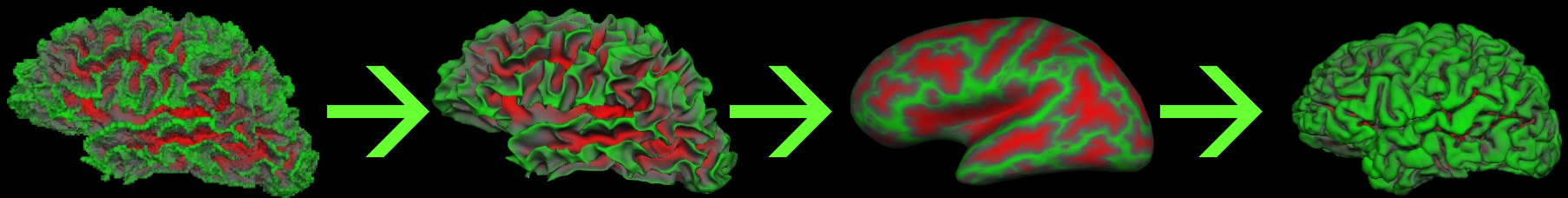
Spreadsheet
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Cortical Reconstruction

Volume Processing



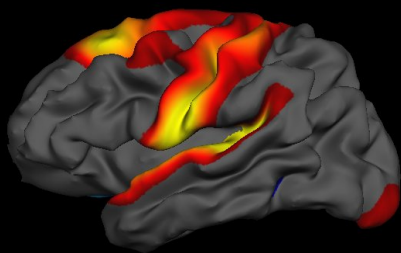
Surface Processing



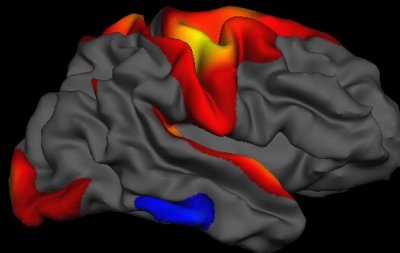
What do we mean by cortical surface?

- Cortical mantle/neocortex
- These surface based procedures can not be used to examine certain structures such as the hippocampus, amygdala, etc. (use volume segmentation for that)

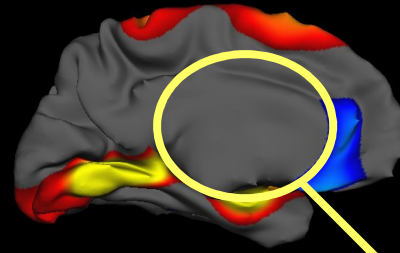
Left-Lateral



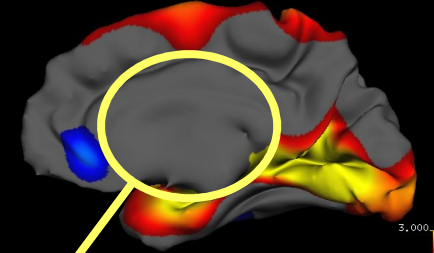
Right-Lateral



Left-Medial



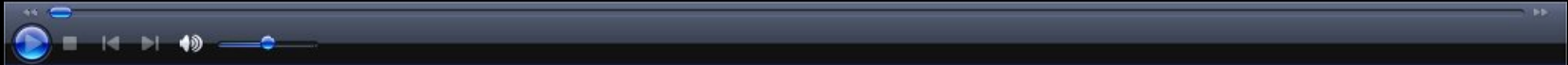
Right-Medial



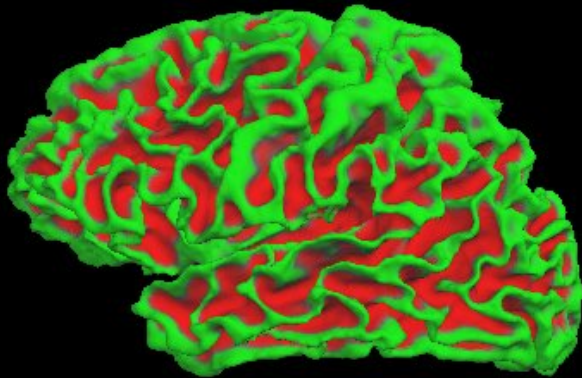
Medial regions that are not part of the cortical mantle are masked from analysis: corpus callosum, thalamus, ventricles



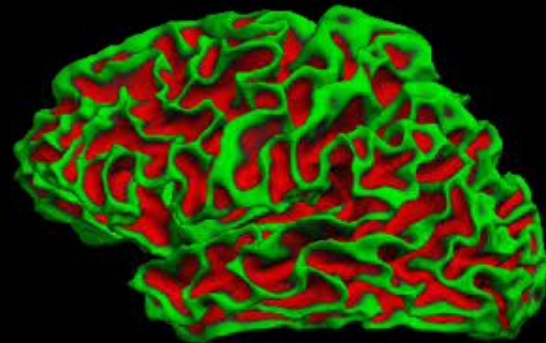
Optimal Surface Placement: Critical for Thickness Accuracy



Gray/CSF Deformation



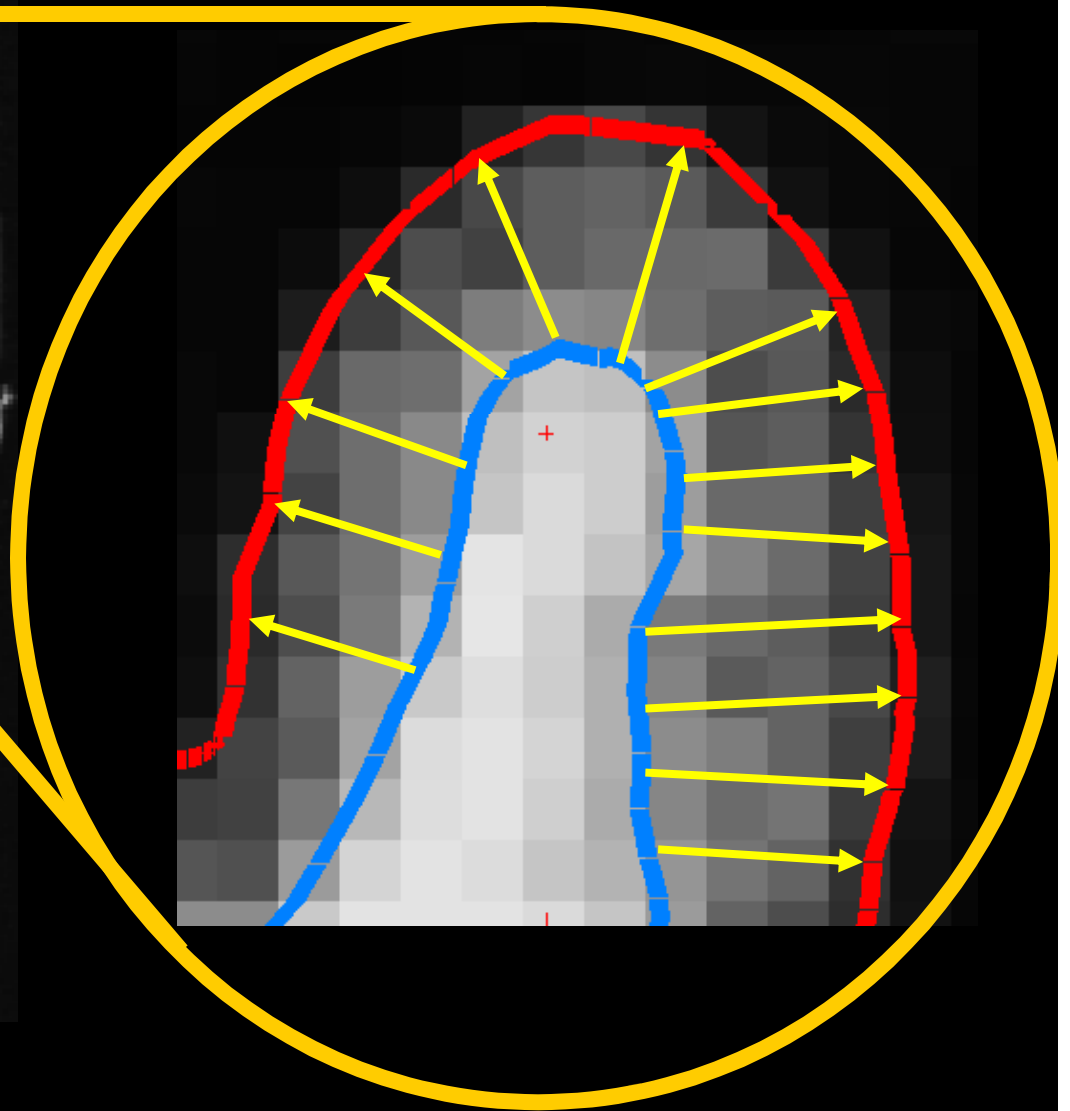
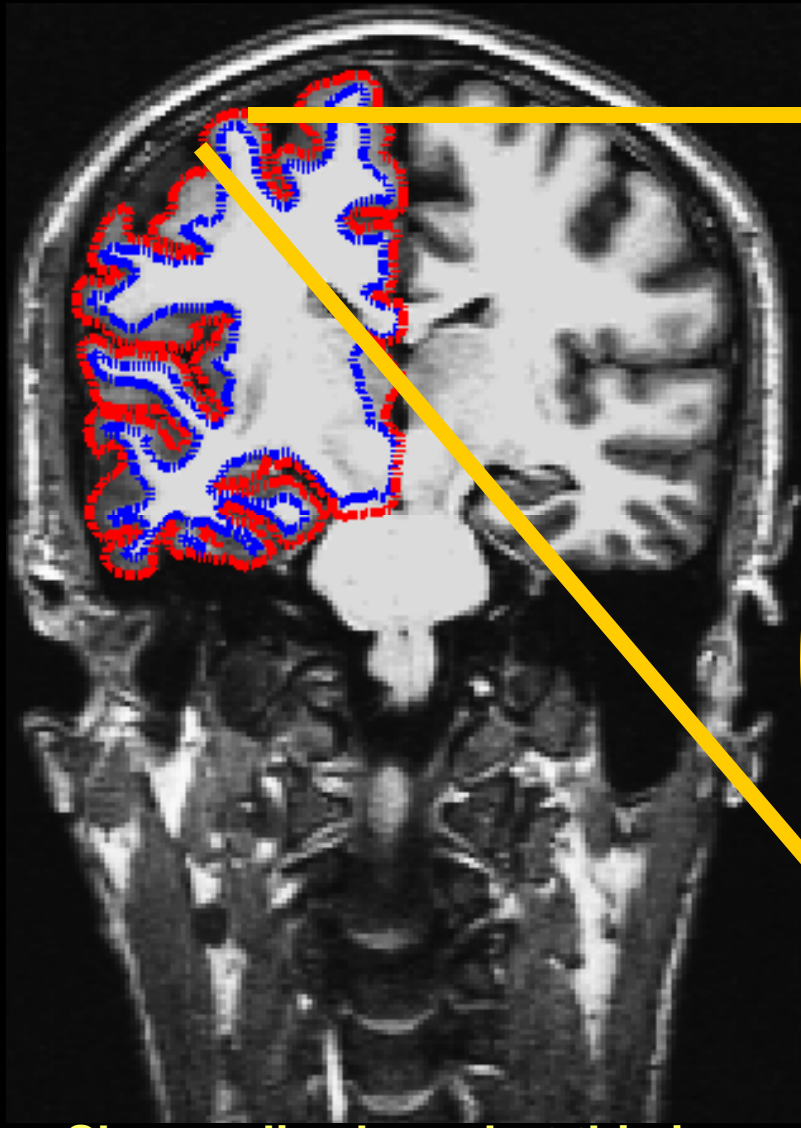
Gray-White Boundary



Outer Cortical Surface

Dale and Sereno, 1993; Dale et al., Dale et al., 1999; Fischl et al., 1999;
Fischl et al., 2000; Fischl et al., 2001

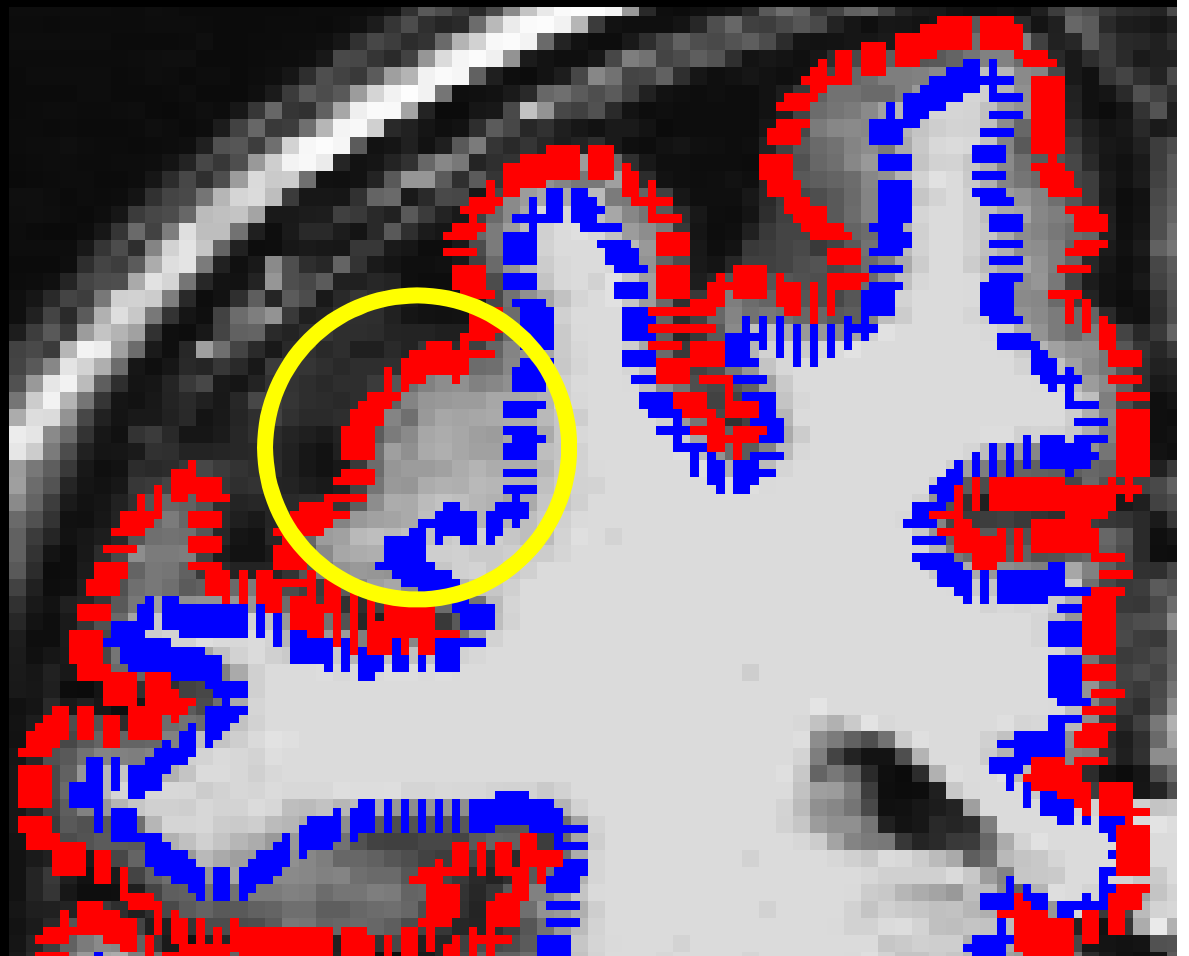
Cortical Thickness



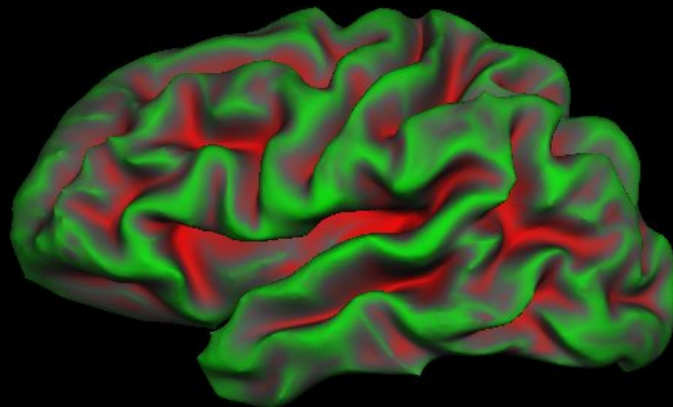
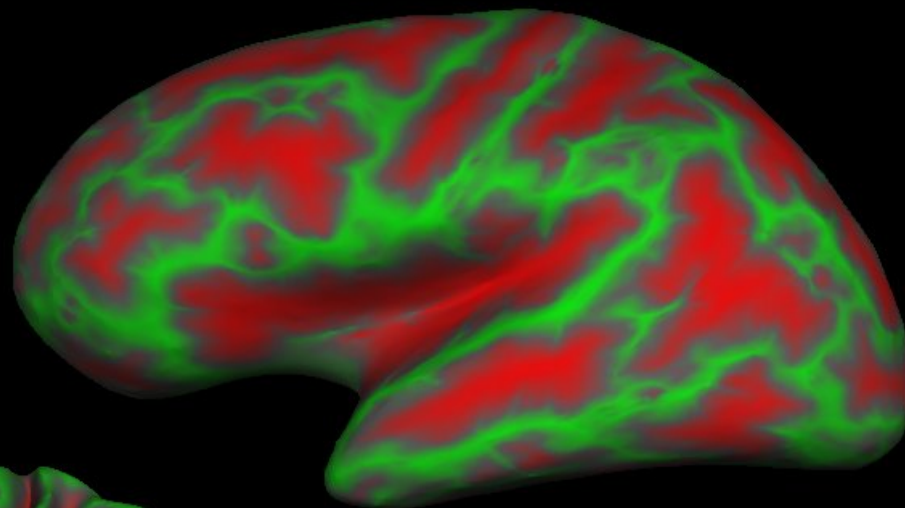
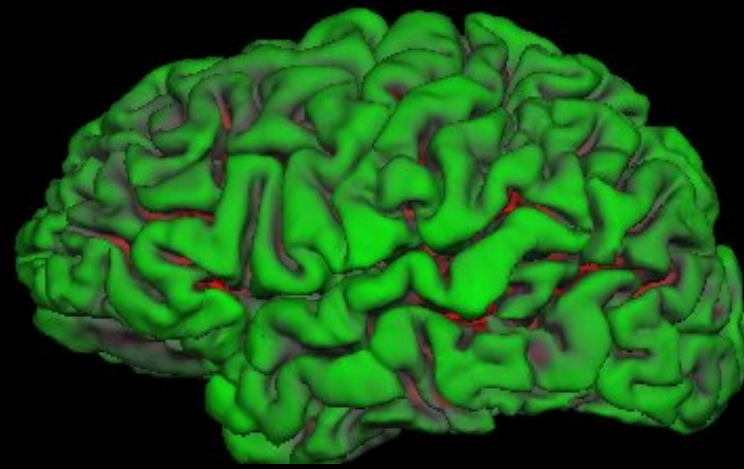
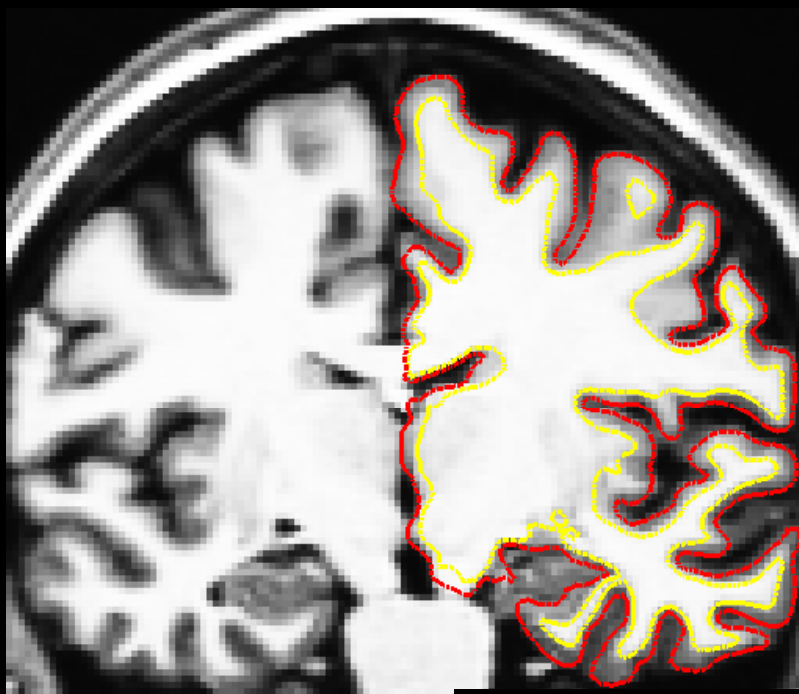
Shown slice here, but this is a whole ribbon process

Thickness must consider entire ribbon

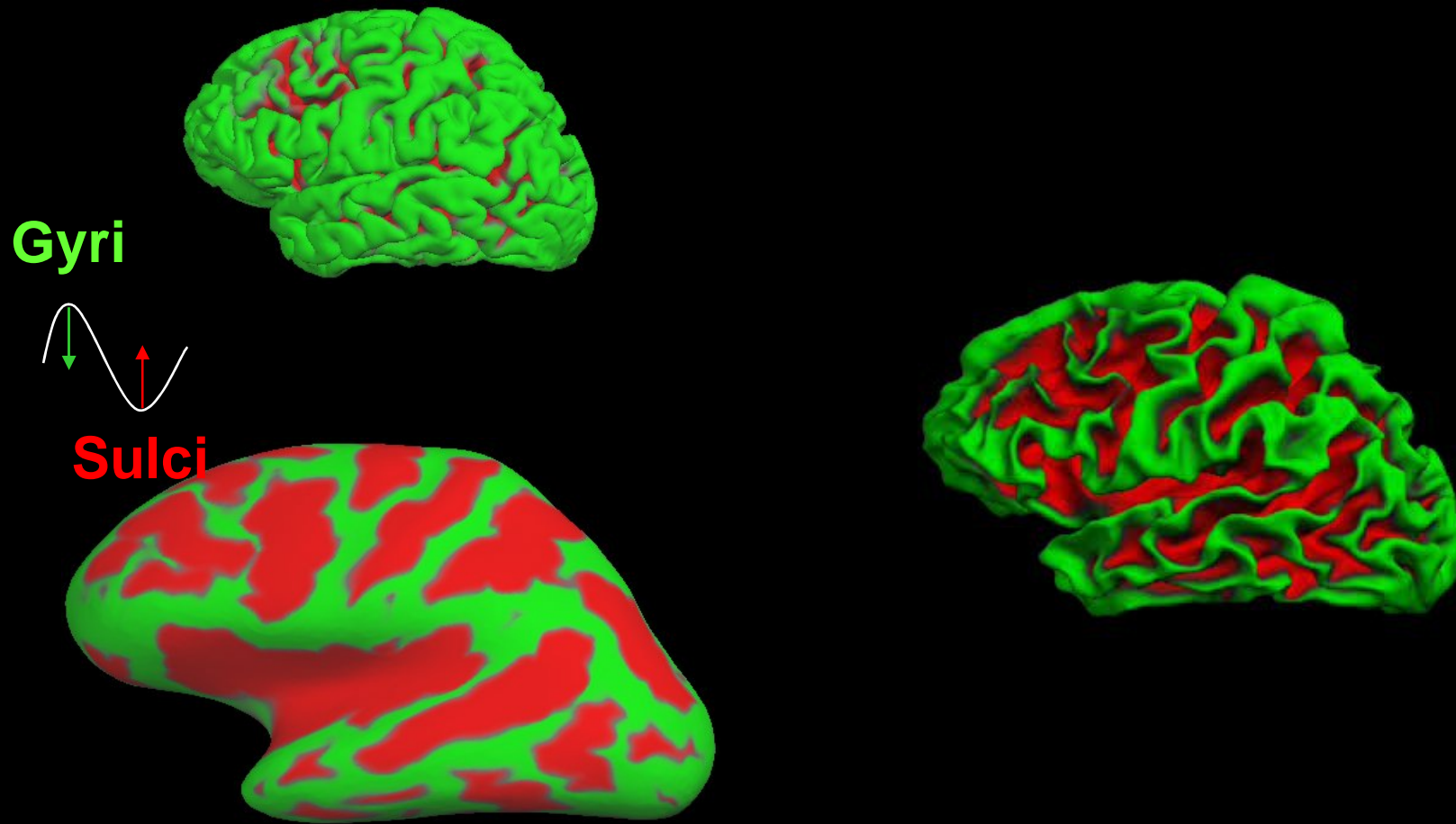
Cortex is not ~10 mm thick



**Models can be
manipulated**



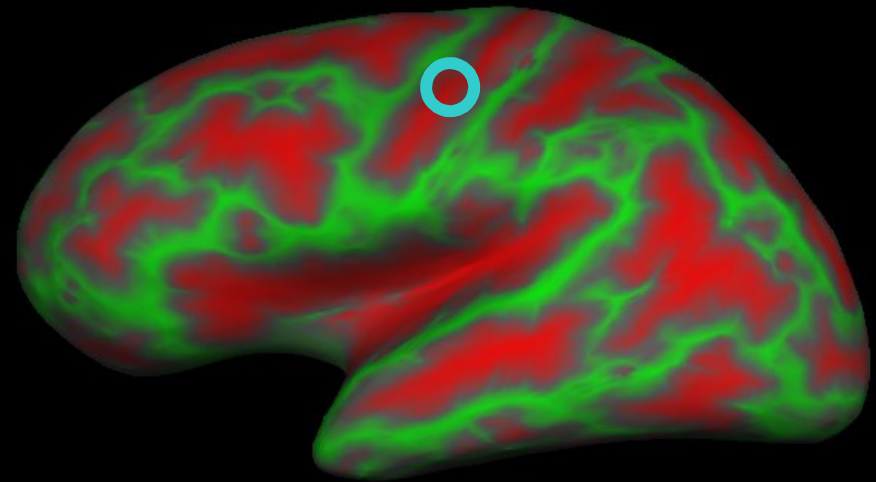
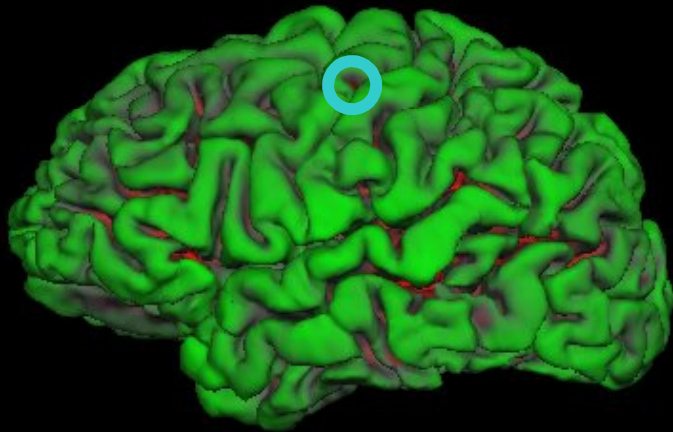
Visualization: Surface Inflation



Dale and Sereno, 1993; Dale et al., Dale et al., 1999; Fischl et al., 1999;
Fischl et al., 2000; Fischl et al., 2001

Surface Smoothing

Limit smoothing to regions close on cortical surface



Cortical thinning in aging and AD

Questions:

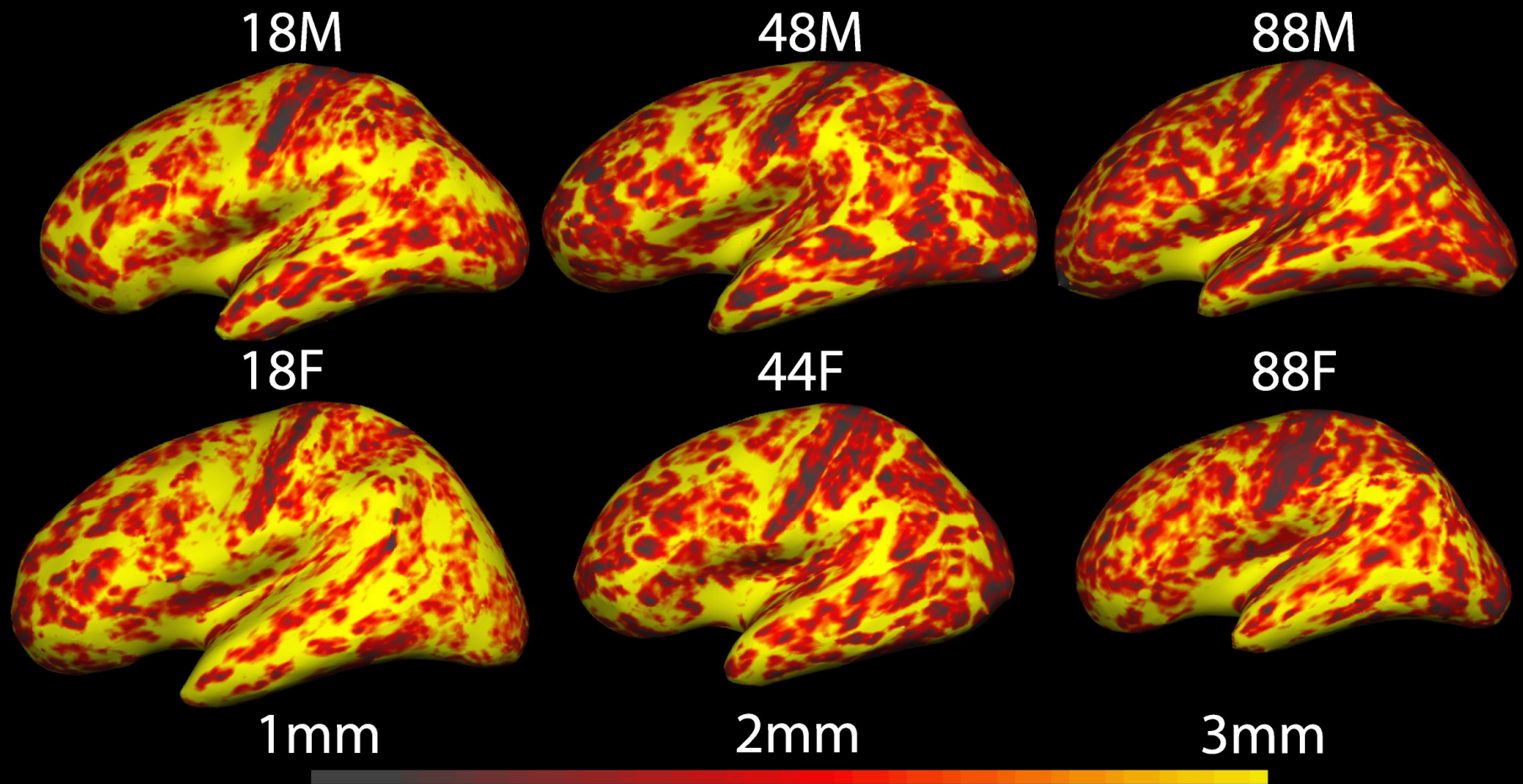
How early can age-related cortical atrophy be detected?

What are the regional patterns of age-related cortical atrophy?

Do patterns of cortical atrophy differ in AD compared to healthy aging?

Inflated Thickness Maps in Six Individuals

- Yellow is thicker cortex, red is thinner cortex
- Thinner cortex in older adults (more red) visible on individual maps



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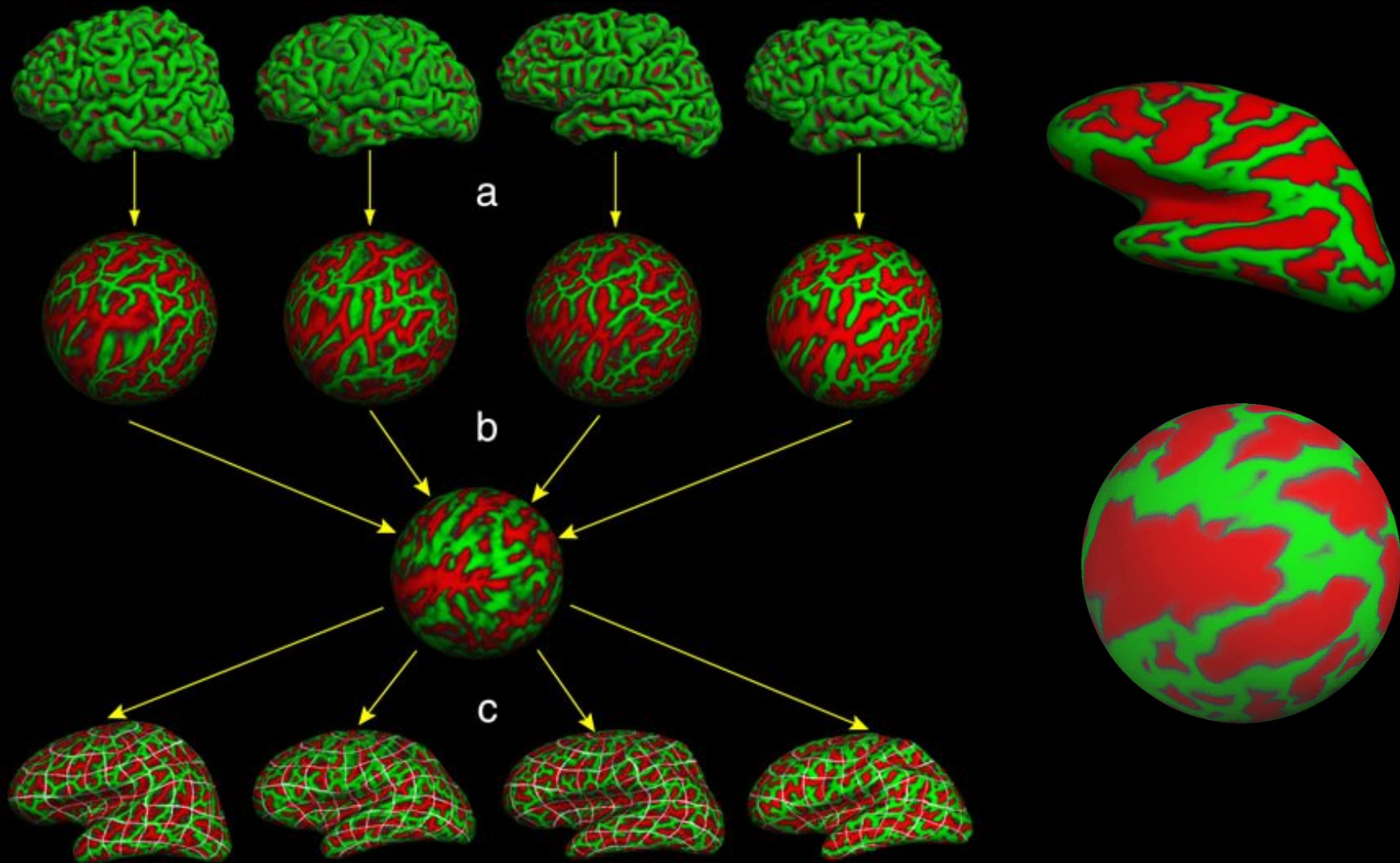
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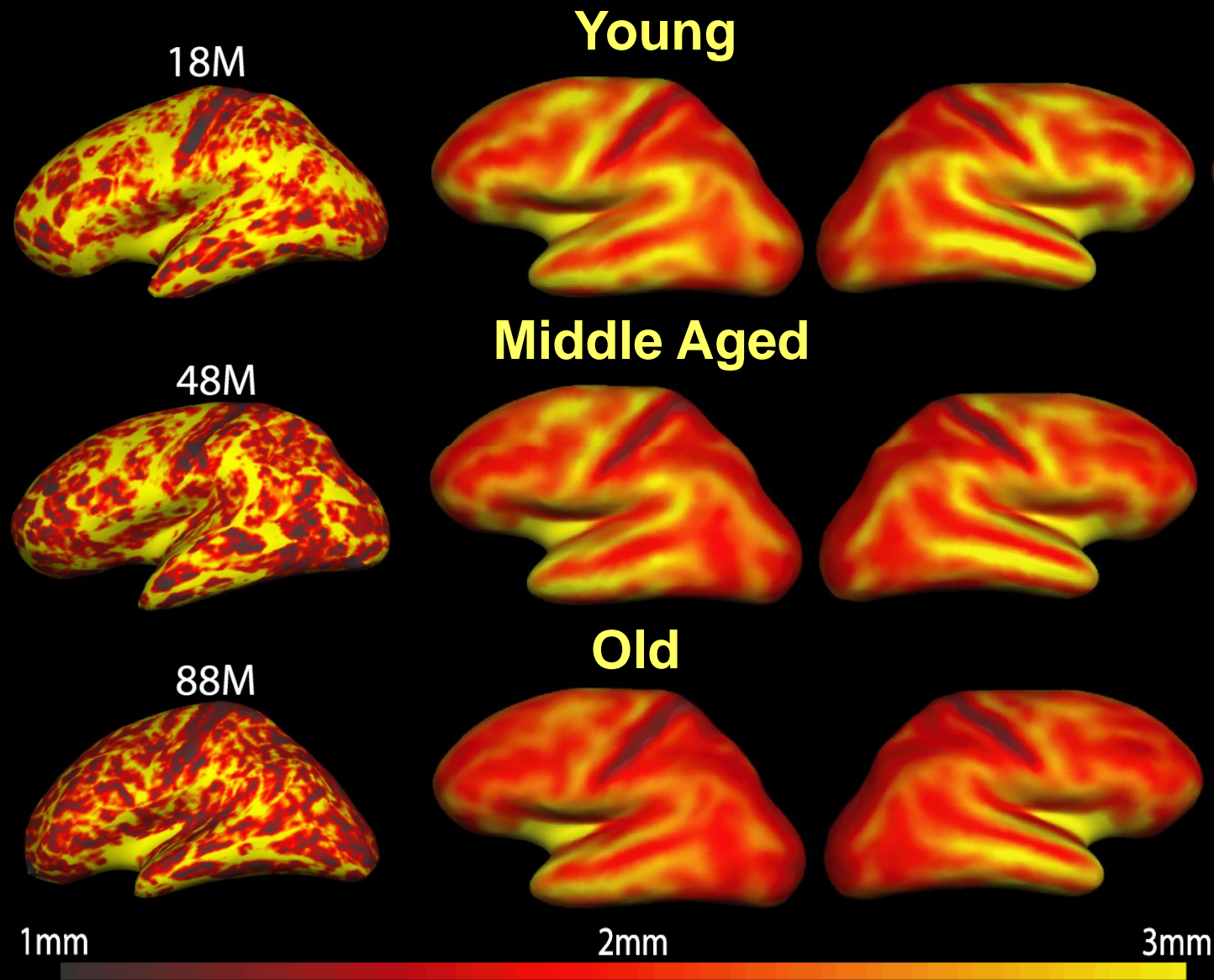
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Inter-Subject Morphing



Fischl, Sereno, Dale, Neuroimage, 1999
Fischl et al., Human Brain Mapping, 1999

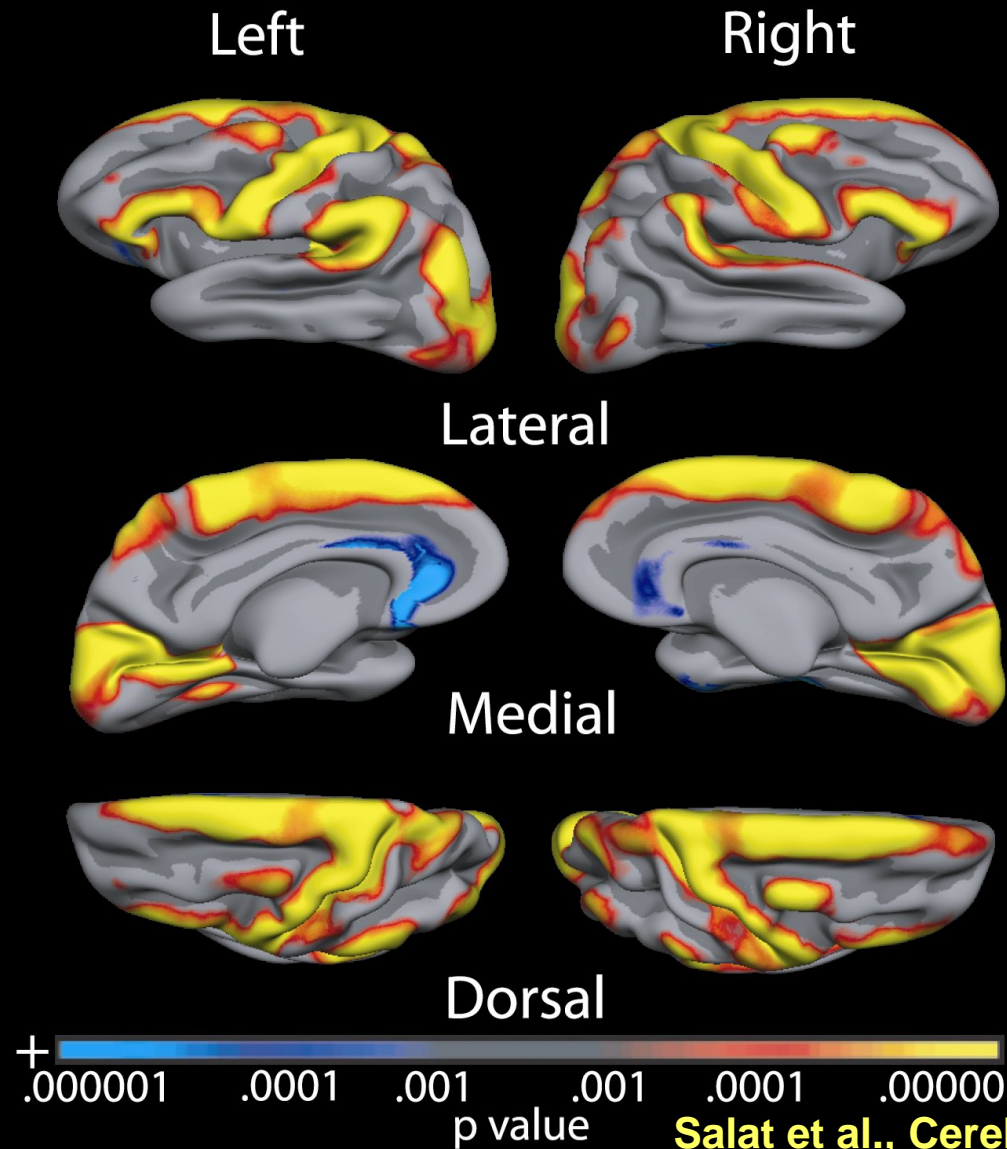
Group Mean Thickness



Salat et al., Cerebral Cortex, 2004

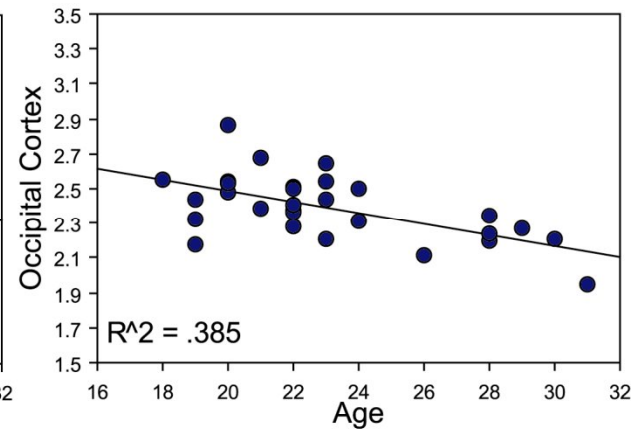
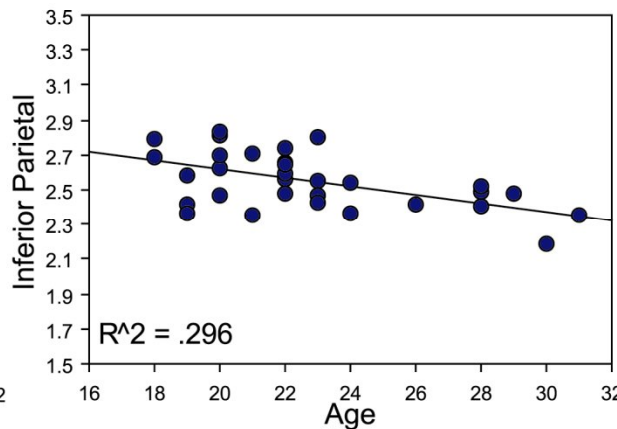
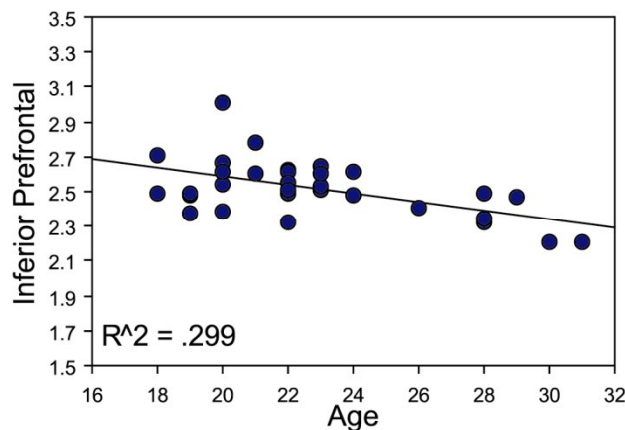
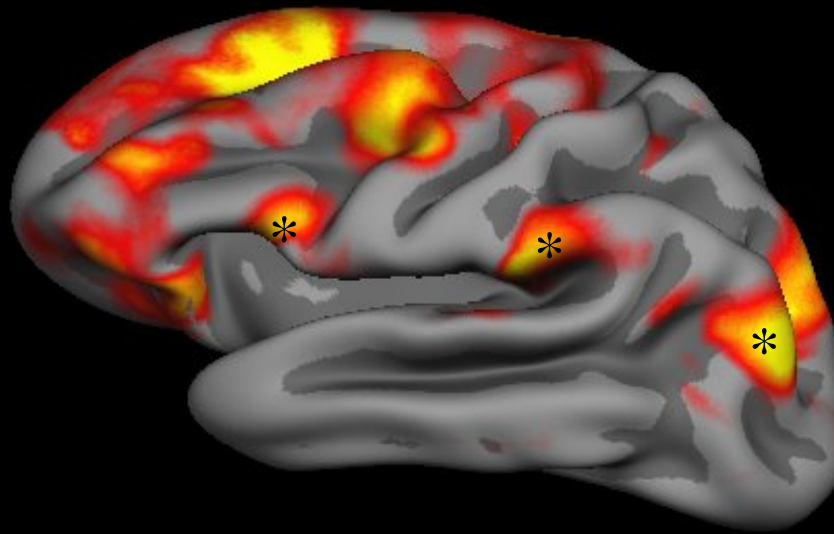
Thinning from Young to Old Age

Thinning in primary as well as association areas



Salat et al., Cerebral Cortex, 2004

Thinning in Young Adults



Confidence for whole sample analysis: e.g. motion, wm damage in OA; Development?

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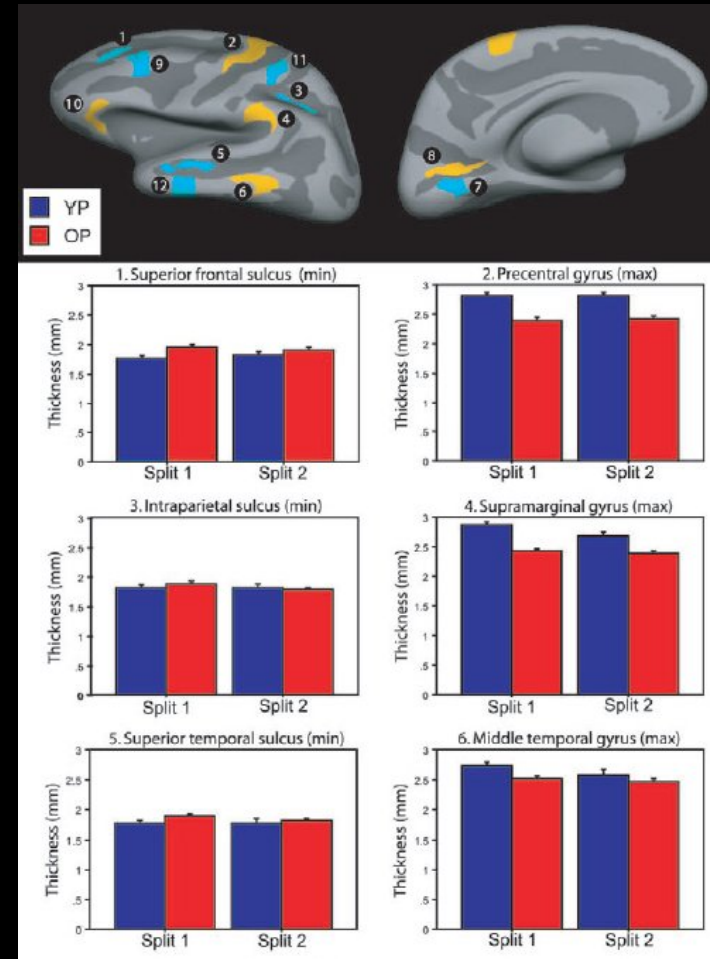
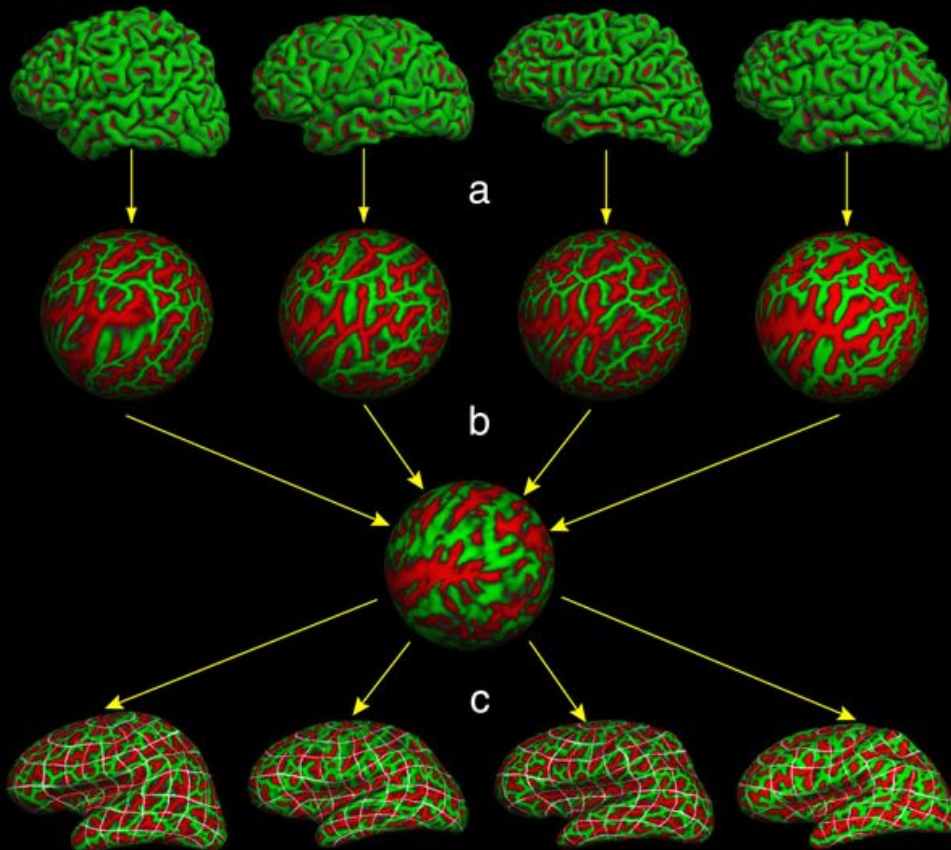
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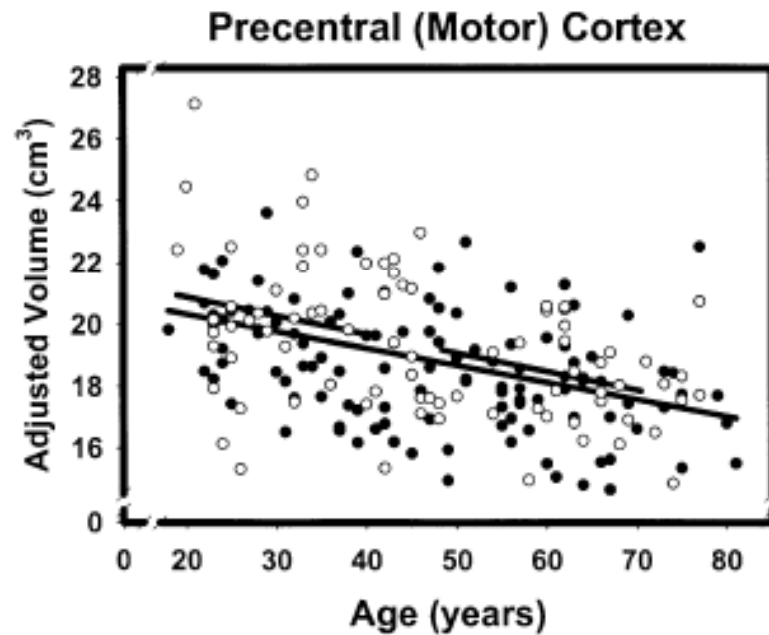
Region of
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Replication of Effects: Label Mapping

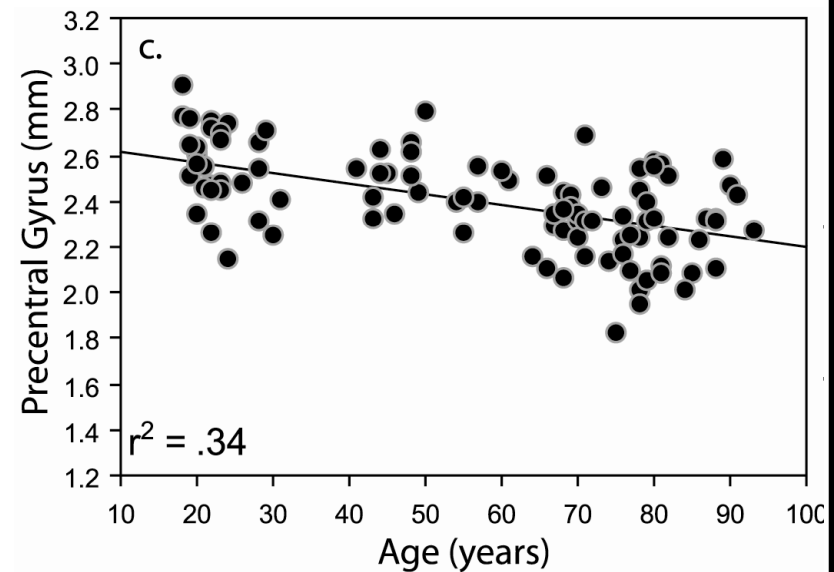


Salat et al., Cerebral Cortex, 2004

Converging Data

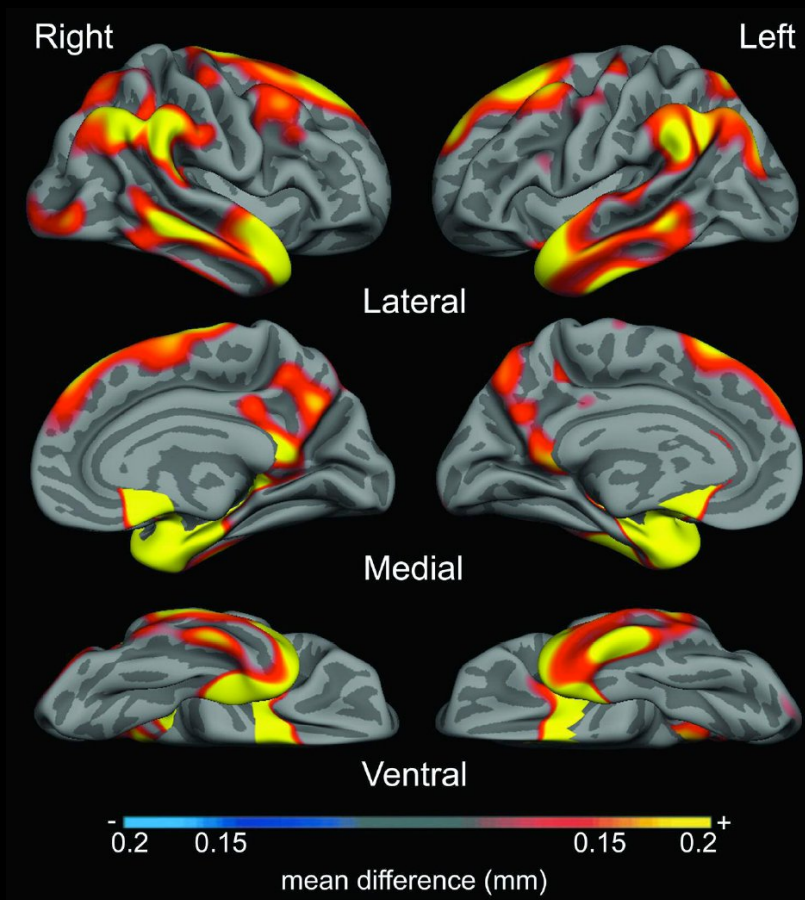


Raz et al., 2004

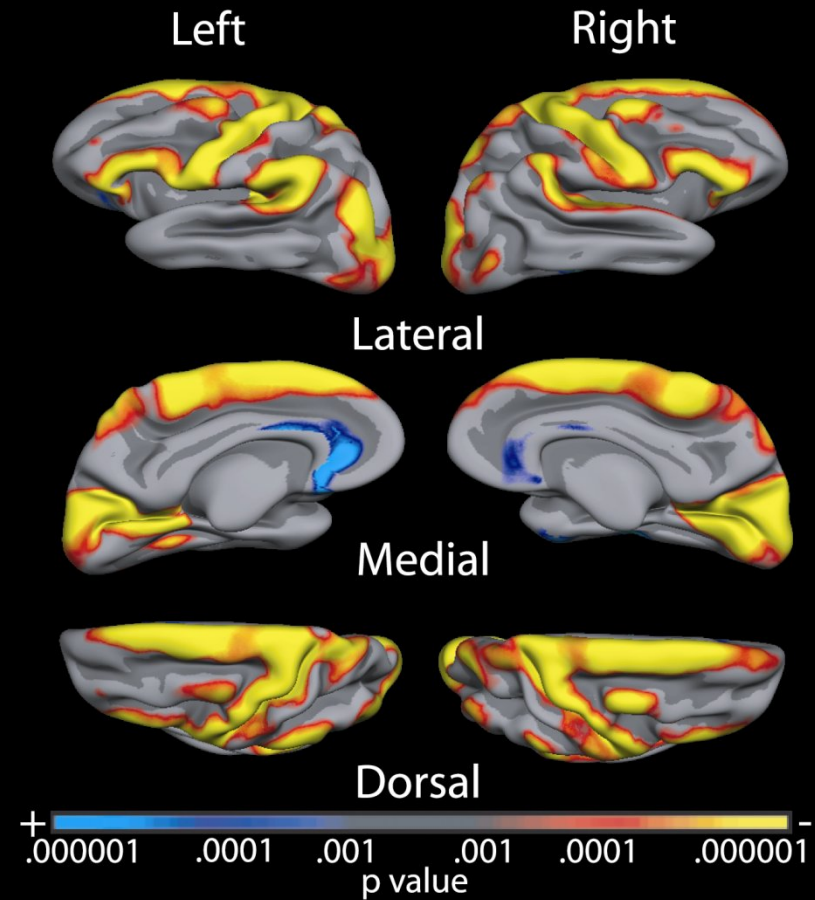


Salat et al., 2004

'Cortical Signature of AD'

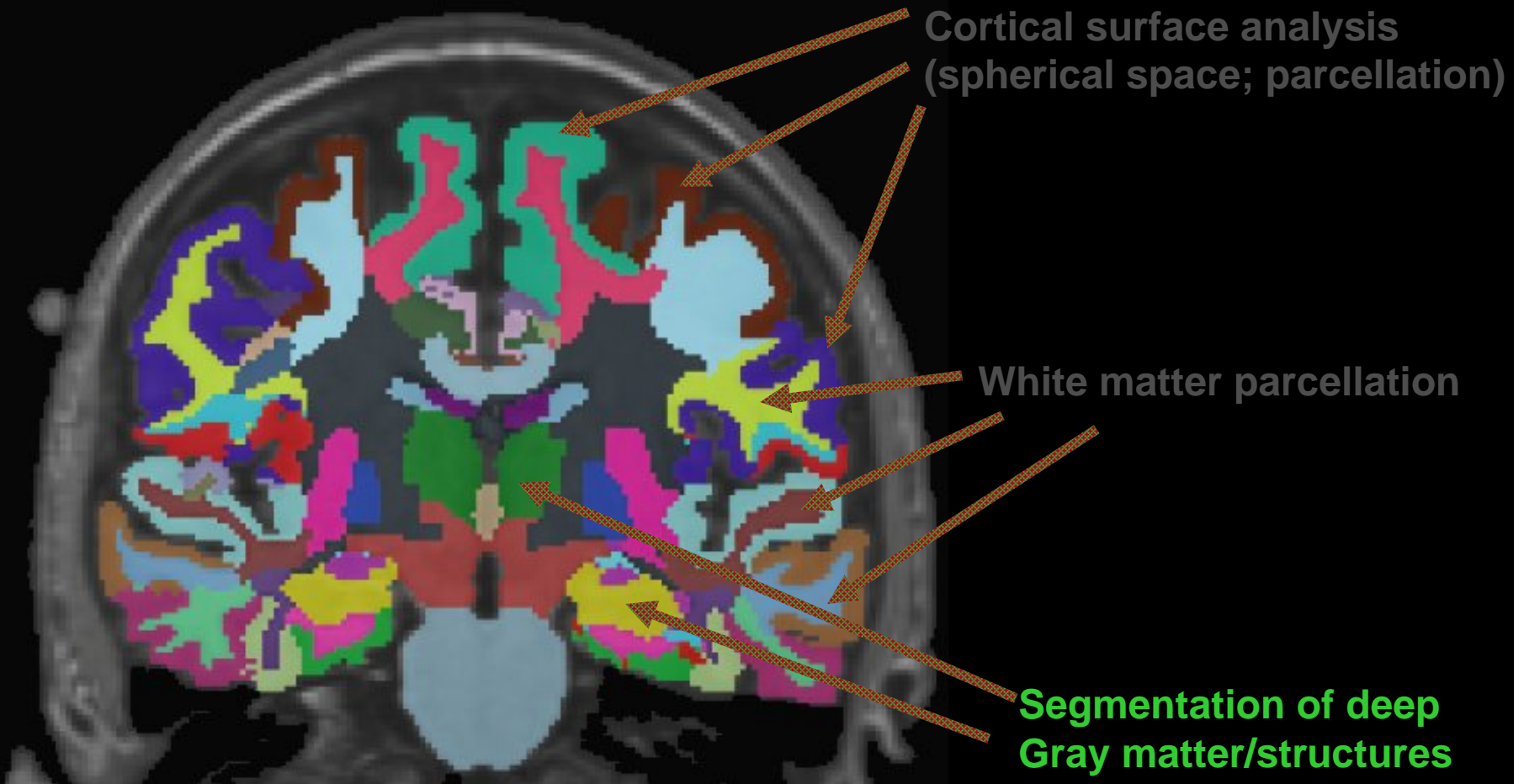


Dickerson et al., Cerebral Cortex, 2008



Salat et al., Cerebral Cortex, 2004

Post Reconstruction Levels of Analysis/Anatomy



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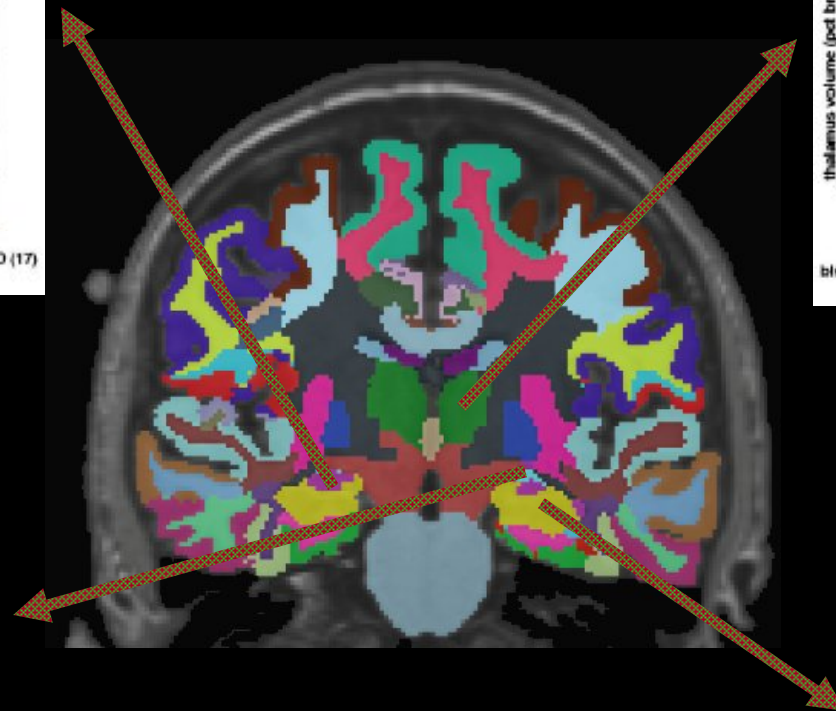
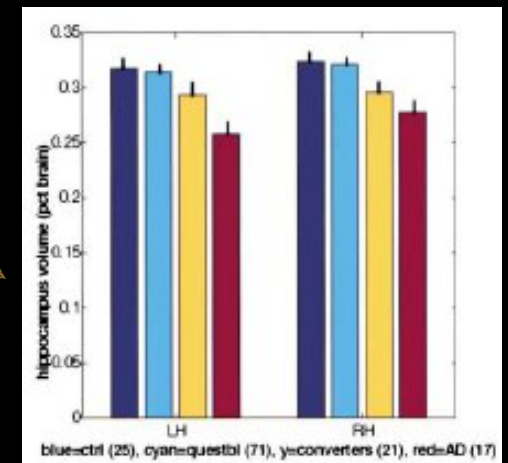
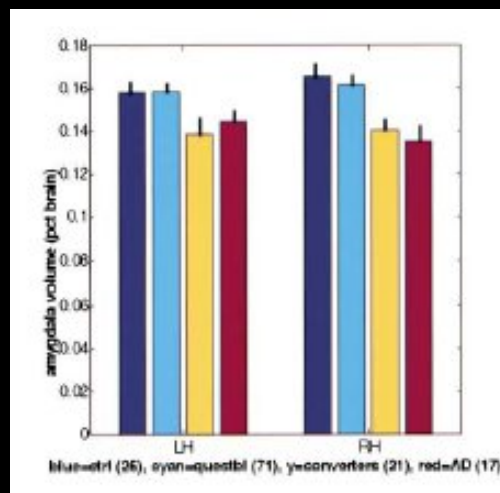
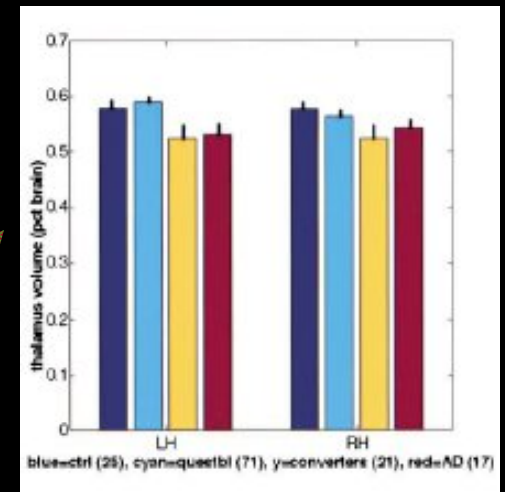
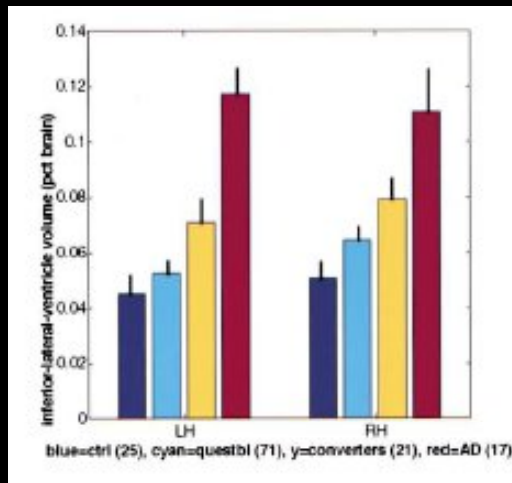
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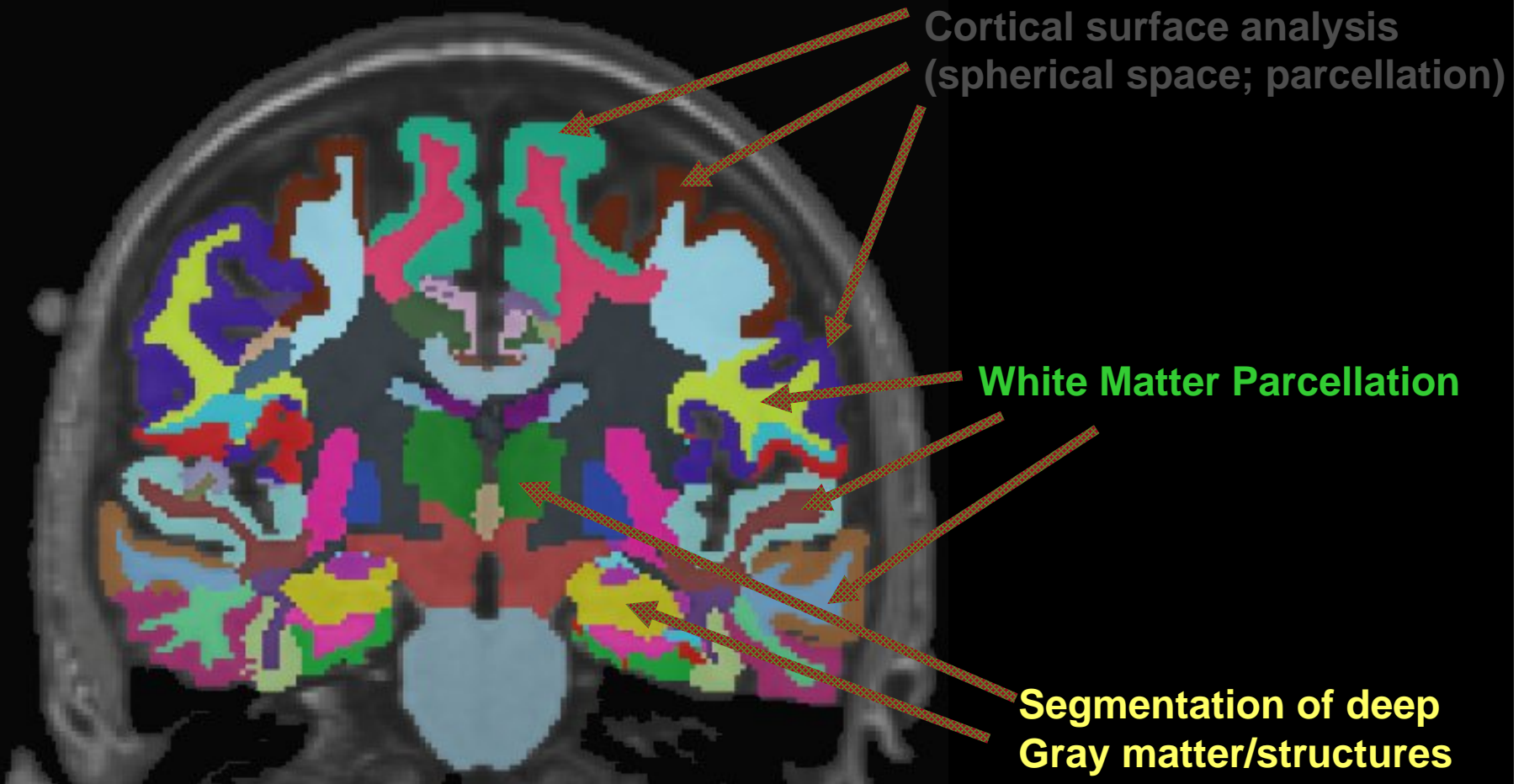
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Volumetric Differences in Individuals Prior to Conversion to AD



Fischl et al., Neuron, 2004

Post Reconstruction Levels of Analysis/Anatomy



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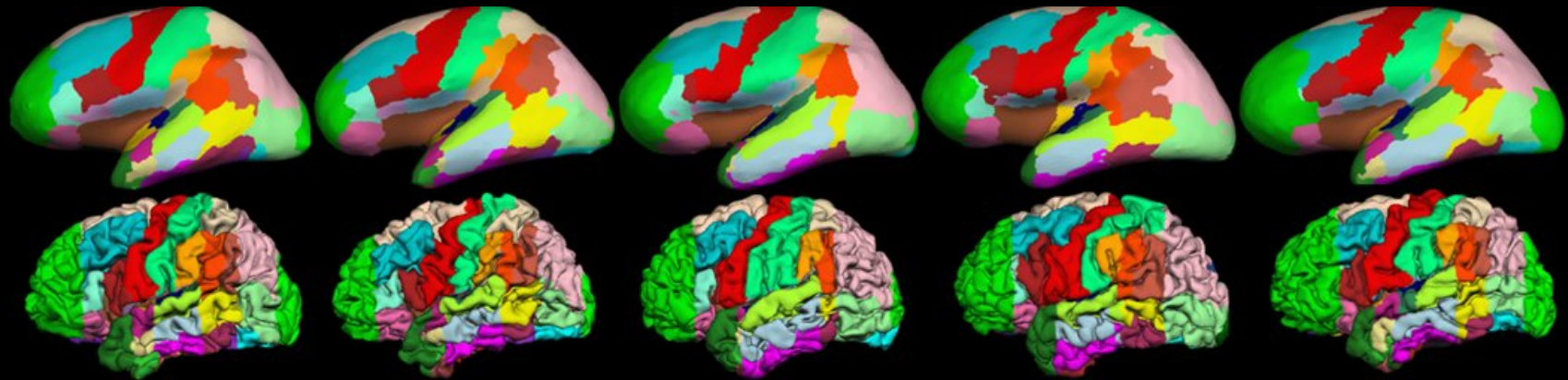
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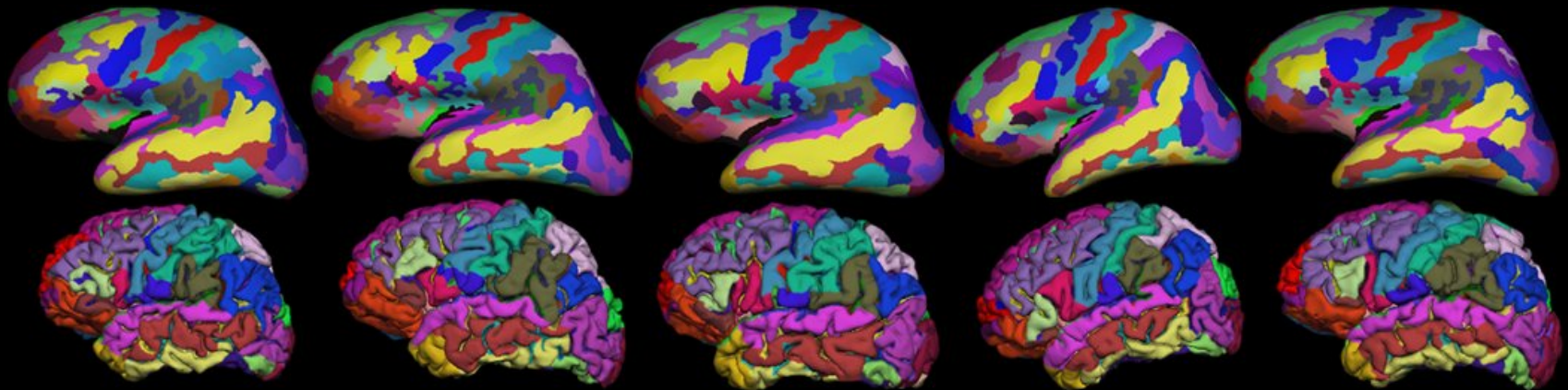
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Cortical Labeling

Volume Based Atlas

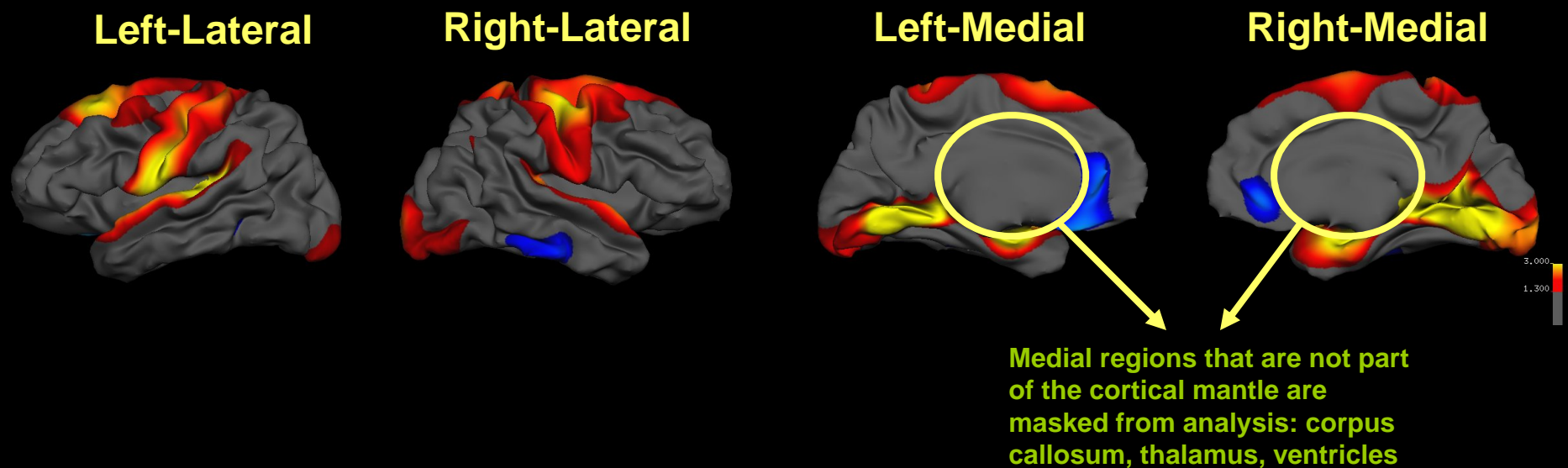


Surface Based Atlas

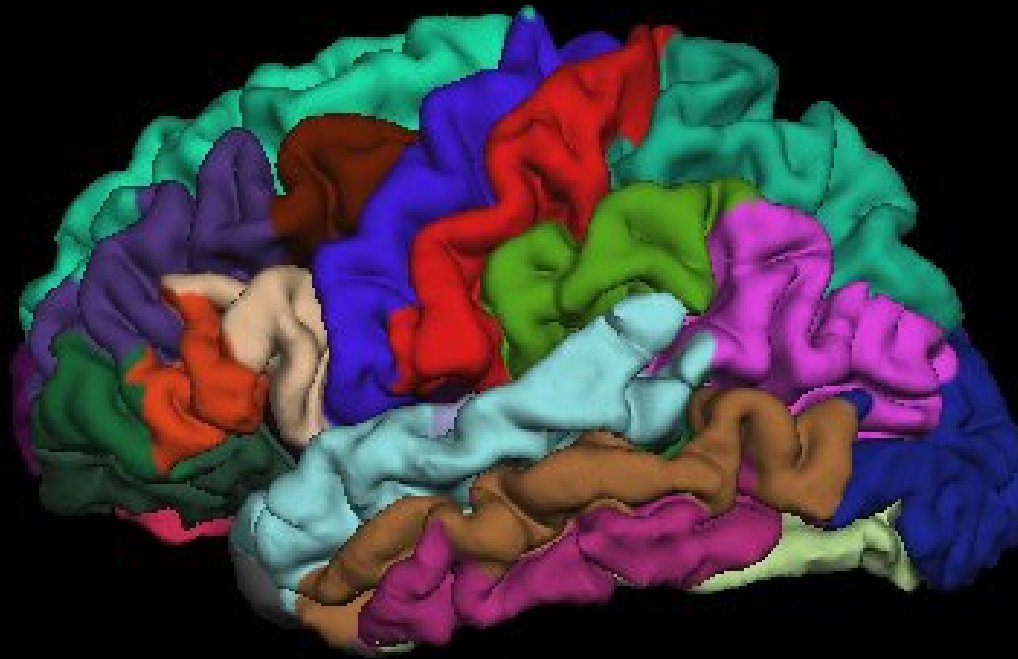


What do we mean by cortical surface?

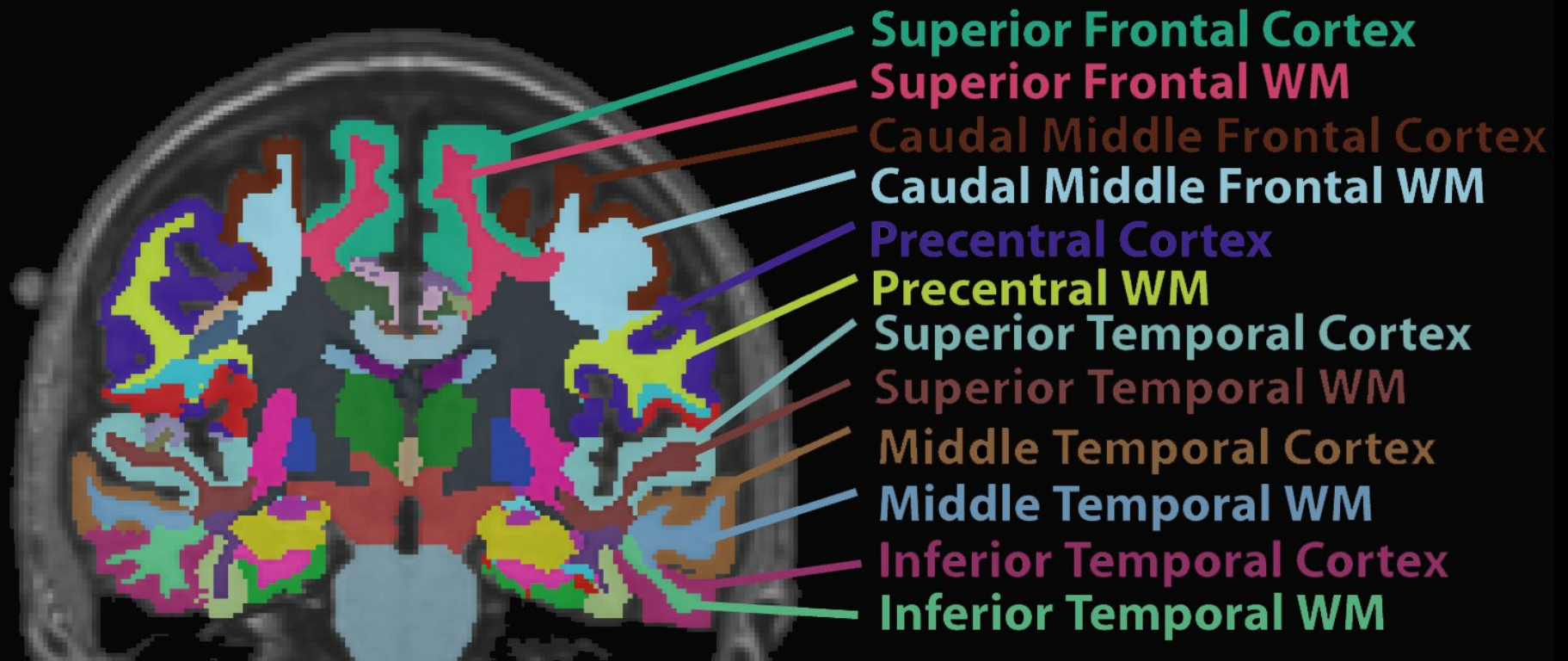
- Cortical mantle/neocortex
- Not white matter



Cortex → White matter



White Matter Parcellation

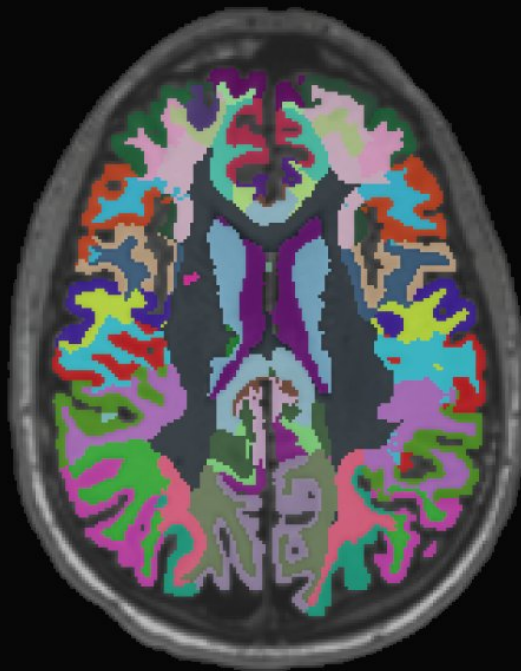


Volumetric Analysis/DTI ROI Analysis

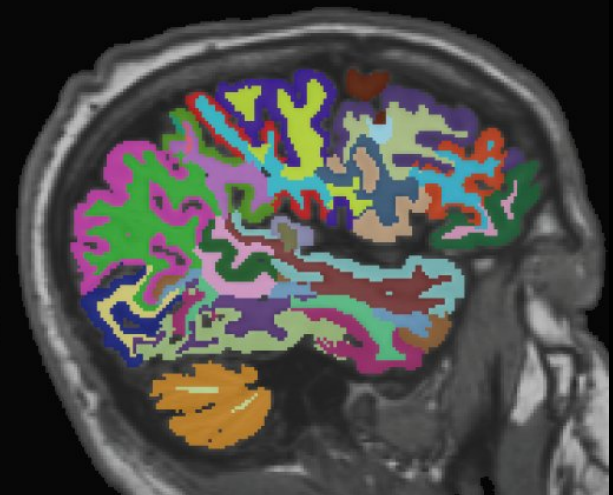
Coronal



Axial



Sagittal



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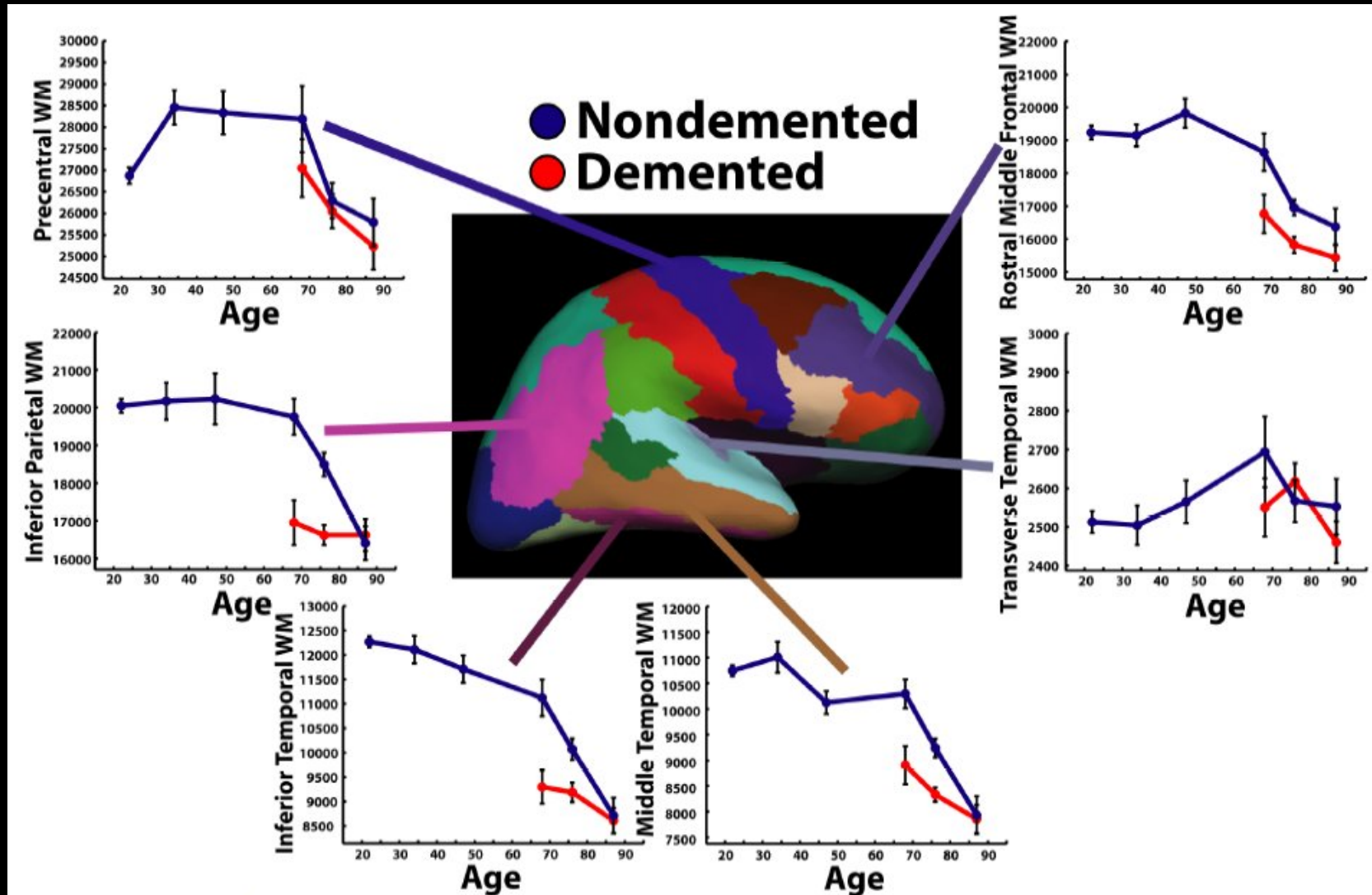
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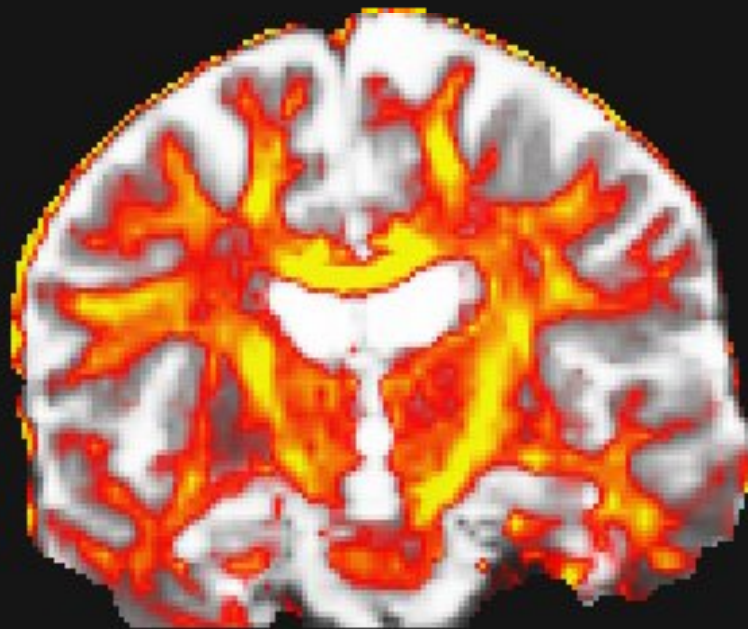
Effects of Age and AD on Regional White Matter



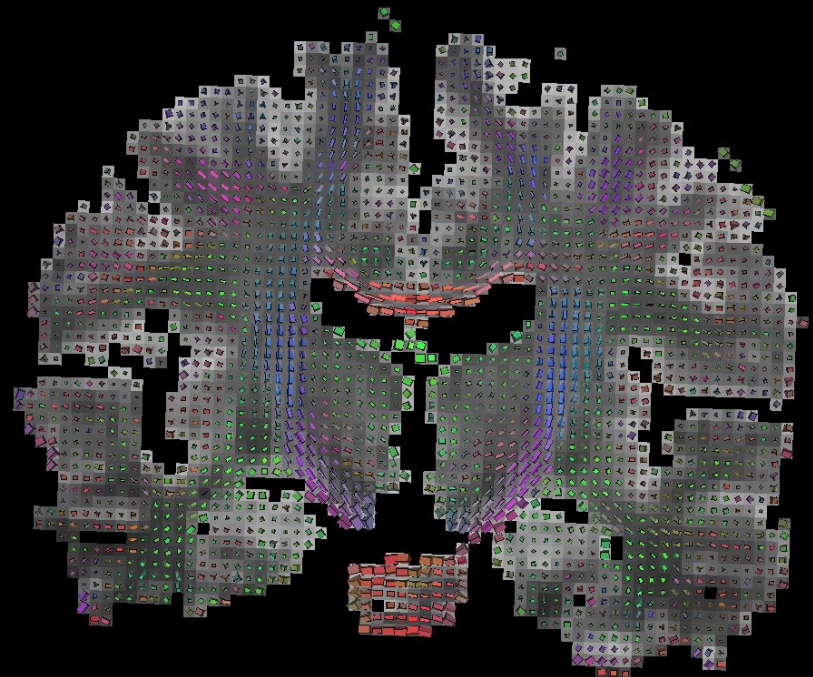
Multi-Spectral/Stream Analysis (combining Freesurfer morphometry with other tools/data types)

- Segmentation of the Corpus Callosum
- Combined DTI/Freesurfer Analysis

Tissue Integrity:
Fractional Anisotropy (FA); Diffusivity



Tissue anatomy:
Tensormap; Tractography



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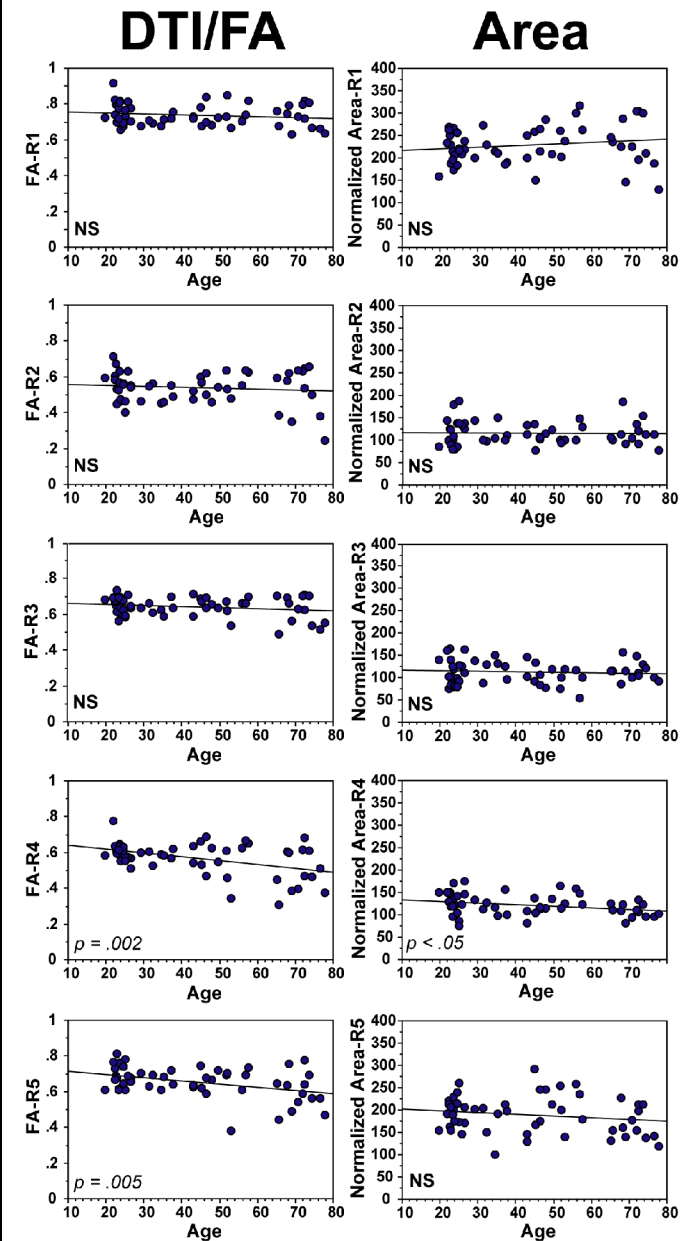
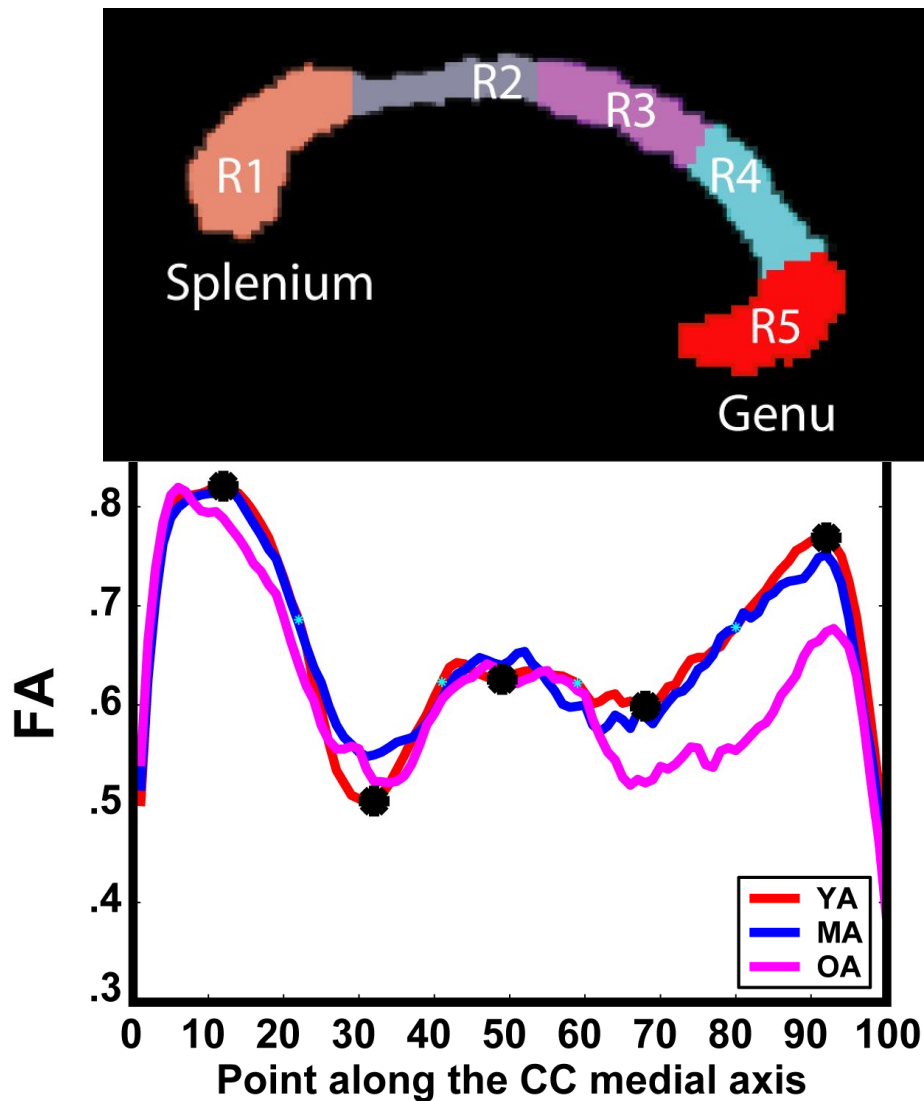
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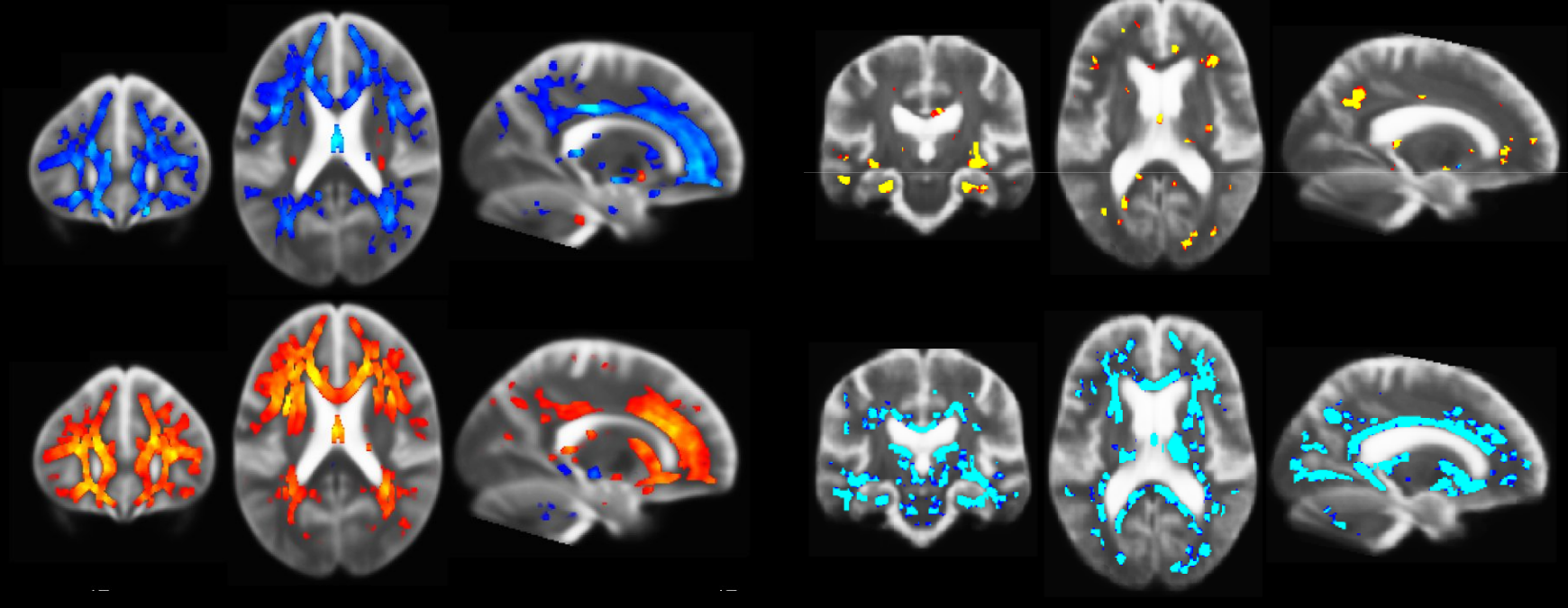
Callosal Segmentation



Diffusion Changes in Aging and Alzheimer's Disease

Aging

AD

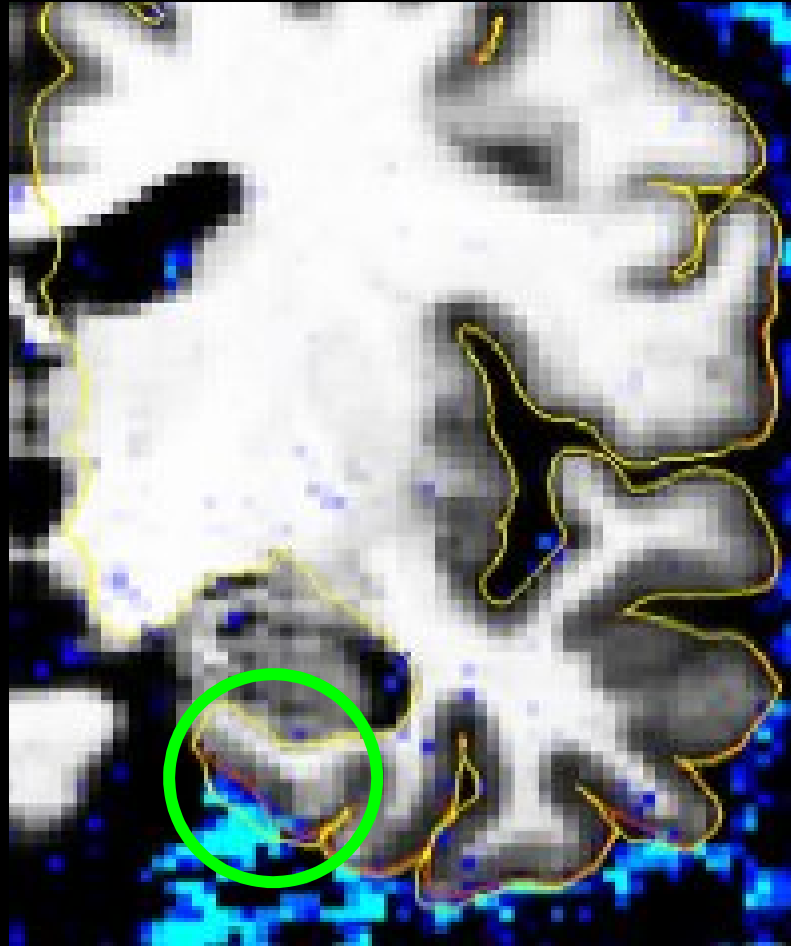


Salat et al., Neurobiol Aging 2005; 2008

MR Anatomy Caveats

- **Reliability and validity of measures/effects dependent on several factors:**
 - **Data quality**
 - **Contrast to noise**
 - **Signal to noise**
 - **Voxel resolution**
 - **MR Artifacts**
 - **MR susceptibility**
 - **MR distortions**
 - **Variations in MR tissue parameters across regions of the brain and are altered in different populations**
 - **Relevant Publications: Fischl et al., 2002; Rosas et al., 2002; Kuperberg et al., 2002; Salat et al., 2004; Han et al., 2004; Fischl et al., 2004; Jovicich et al., 2006; Dickerson et al., 2007**
 - **Most problems with decent data can be fixed through interactive options**
- **What are the biological bases of MR changes?**

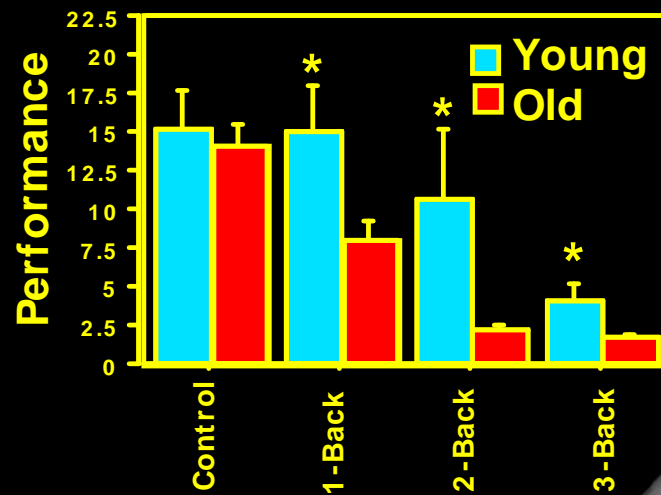
Multispectral Imaging



Van der Kouwe et al., Neuroimage, 2008

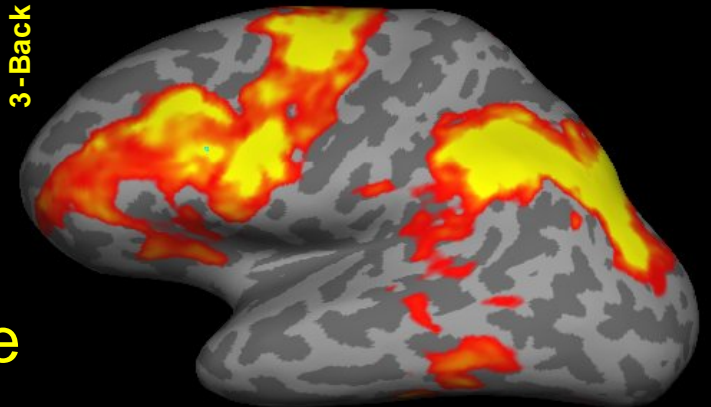
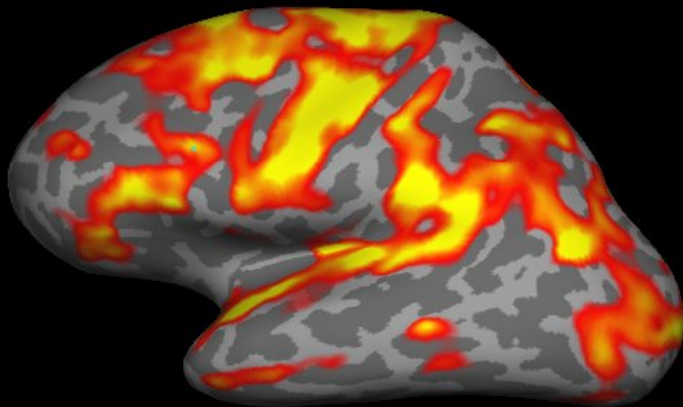
Performance

N-Back

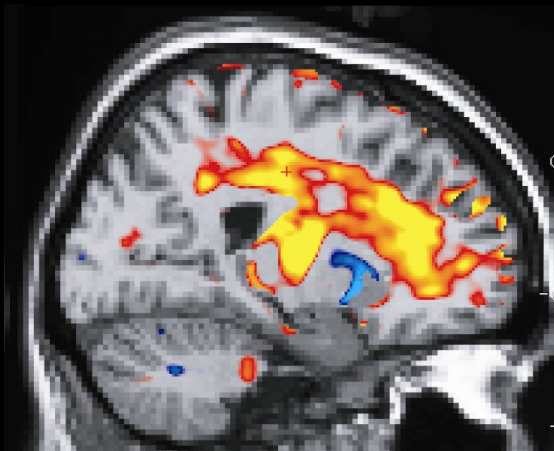


GM Structure

Brain Function



WM Structure



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