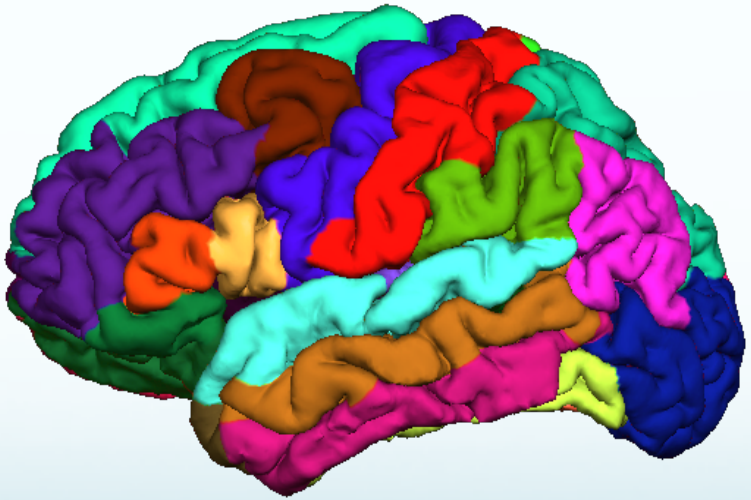
- freesurfer.net

Working with FreeSurfer Regions-of-Interest (ROIs)



Outline

- Subcortical Segmentation
- Cortical Parcellation
- WM Segmentation
- Preparation/Analysis of Stats

FreeSurfer ROI Terminology

ROI = Region Of Interest

Volume/Image (Subcortical):

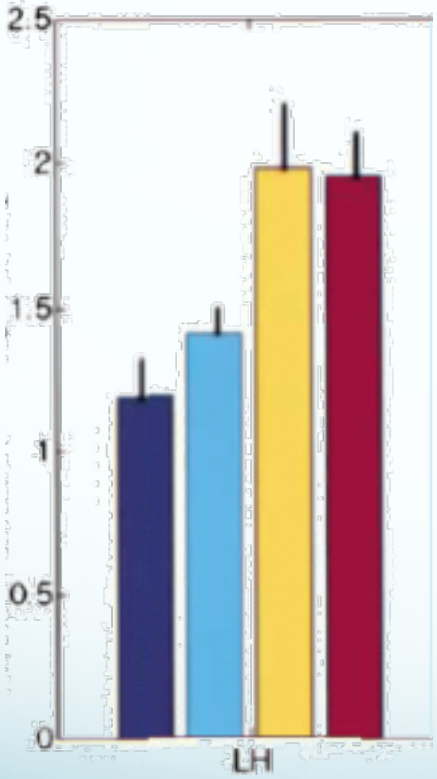
- Segmentation

Surface (Cortical):

- Parcellation/Annotation
- Clusters, Masks (from sig.mgh, fMRI)
- Label you created

SUBCORTICAL AUTOMATIC SEGMENTATION (aseg)

ROI Volume Study



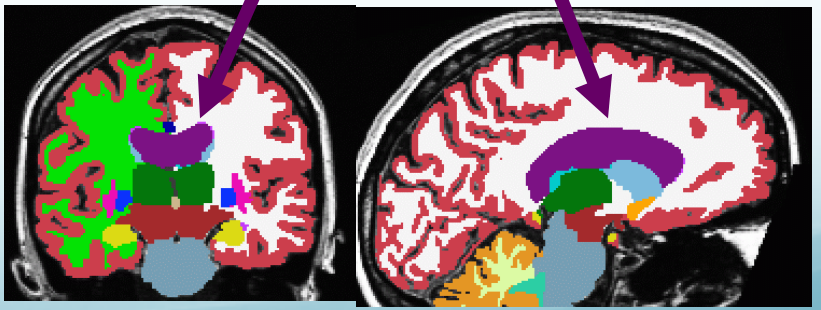
Lateral Ventricular Volume
(left)(Percent of Intracranial Volume)

Healthy

Did NOT convert

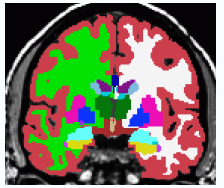
Did convert

Probable AD

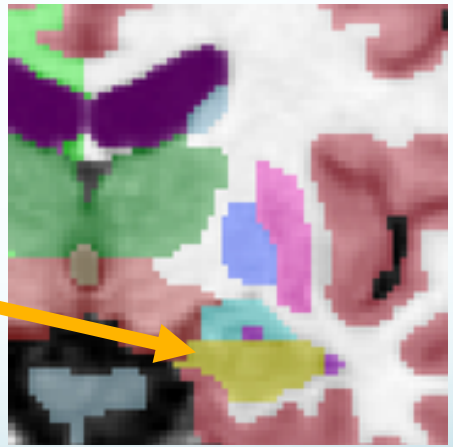


Fischl, et al, 2002, Neuron

Segmentation

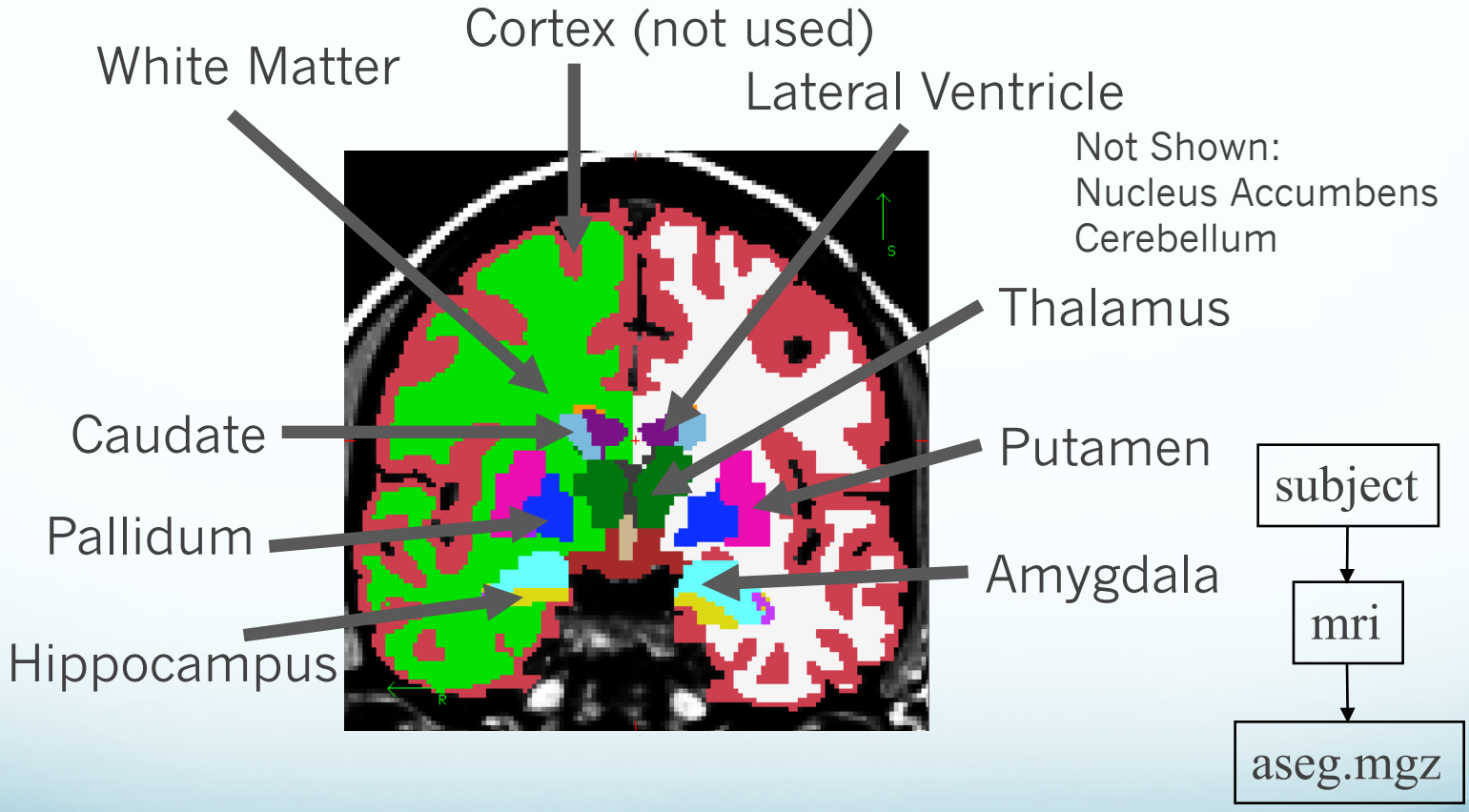


- Volume (for surfaces: “surface segmentation”)
- Volume-style format (mgz, nii, nii.gz)
- Each voxel has one index (number ID)
- Index List found in color lookup table (LUT)
  - $FREESUFER_HOME/FreeSurferColorLUT.txt
    17 Left-Hippocampus 220 216 20 0
    Index = 17
    Name = Left-Hippocampus
    Red=220, Green=216, Blue=20 (out of 255)
    alpha = 0 (not really used)



- aseg.mgz, aparc+aseg.mgz, wmparc.mgz

Subcortical Segmentation (aseg)



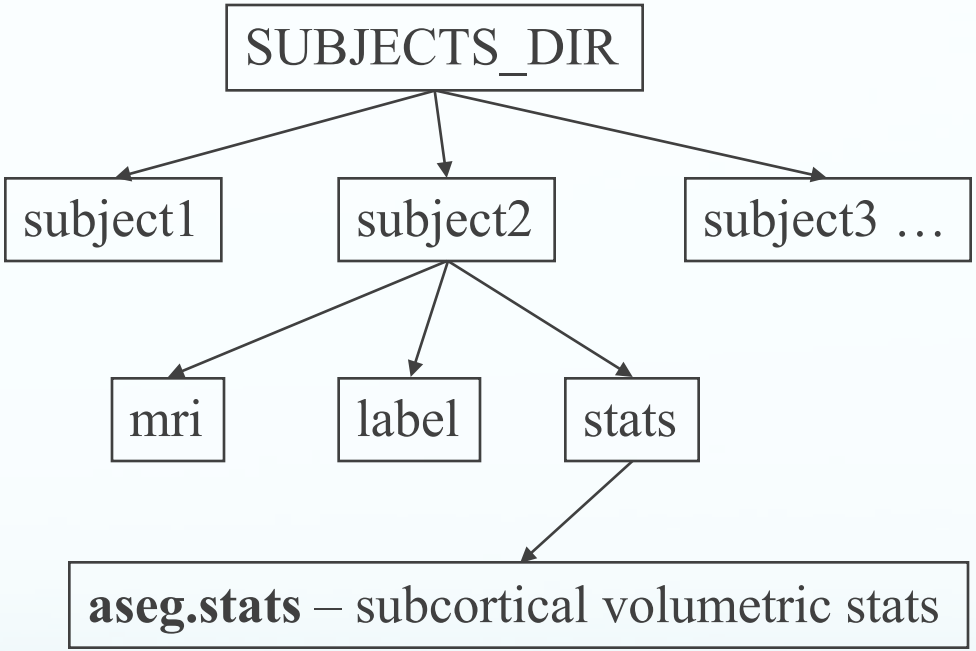
Whole Brain Segmentation: Automated Labeling of Neuroanatomical Structures in the Human Brain, Fischl et al. (2002). Neuron, 33:341-355.

Volumetric Segmentation Atlas Description

- 39 Subjects
- 14 Male, 25 Female
- Ages 18-87
  - Young (18-22): 10
  - Mid (40-60): 10
  - Old Healthy (69+): 8
  - Old Alzheimer's (68+): 11
- Siemens 1.5T Vision (Wash U)

Whole Brain Segmentation: Automated Labeling of Neuroanatomical Structures in the Human Brain, Fischl et al. (2002). Neuron, 33:341-355.

FreeSurfer Stats Outputs



created by *mri_segstats*

aseg.stats

Index	SegId	NVoxels	Volume_mm3	StructName	Mean	StdDev	Min	Max	Range
1	4	5855	5855.0	Left-Lateral-Ventricle	37.7920	10.9705	20.0000	88.0000	68.0000
2	5	245	245.0	Left-Inf-Lat-Vent	56.4091	9.5906	26.0000	79.0000	53.0000
3	7	16357	16357.0	Left-Cerebellum-White-Matter	91.2850	4.8989	49.0000	106.0000	57.0000
4	8	60367	60367.0	Left-Cerebellum-Cortex	76.3620	9.5724	26.0000	135.0000	109.0000
5	10	7460	7460.0	Left-Thalamus-Proper	91.3778	7.4668	43.0000	108.0000	65.0000
6	11	3133	3133.0	Left-Caudate	78.5801	8.2886	42.0000	107.0000	65.0000
7	12	5521	5521.0	Left-Putamen	86.9680	5.5752	66.0000	106.0000	40.0000
8	13	1816	1816.0	Left-Pallidum	97.7162	3.4302	79.0000	106.0000	27.0000
9	14	852	852.0	3rd-Ventricle	41.9007	11.8230	22.0000	69.0000	47.0000
10	15	1820	1820.0	4th-Ventricle	39.7053	10.6407	20.0000	76.0000	56.0000
11	16	25647	25647.0	Brain-Stem	85.2103	8.2819	38.0000	106.0000	68.0000
12	17	4467	4467.0	Left-Hippocampus	77.6346	7.5845	45.0000	107.0000	62.0000
13	18	1668	1668.0	Left-Amygdala	74.5104	5.8320	50.0000	94.0000	44.0000
14	24	1595	1595.0	CSF	52.1348	11.6113	29.0000	87.0000	58.0000

Index: nth Segmentation in stats file
SegId: index into lookup table
NVoxels: number of Voxels in segmentation
StructName: name of structure from LUT
Mean/StdDev/Min/Max/Range: intensity across ROI

aseg.stats Global Measures:
Cortical, Gray, White, Intracranial Volumes

Also in aseg.stats header:

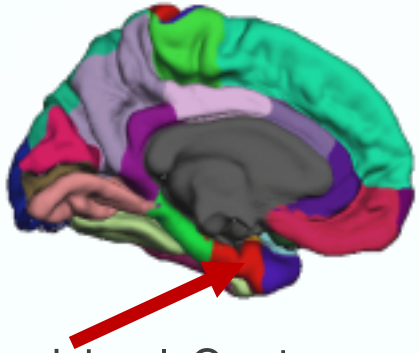
```
# Measure lhCortex, lhCortexVol, Left hemisphere cortical gray matter volume, 192176.447567, mm^3
# Measure rhCortex, rhCortexVol, Right hemisphere cortical gray matter volume, 194153.9526, mm^3
# Measure Cortex, CortexVol, Total cortical gray matter volume, 386330.400185, mm^3
# Measure lhCorticalWhiteMatter, lhCorticalWhiteMatterVol, Left hemisphere cortical white matter volume,
    217372.890625, mm^3
# Measure rhCorticalWhiteMatter, rhCorticalWhiteMatterVol, Right hemisphere cortical white matter volume,
    219048.187500, mm^3
# Measure CorticalWhiteMatter, CorticalWhiteMatterVol, Total cortical white matter volume, 436421.078125, mm^3
# Measure SubCortGray, SubCortGrayVol, Subcortical gray matter volume, 182006.000000, mm^3
# Measure TotalGray, TotalGrayVol, Total gray matter volume, 568336.400185, mm^3
# Measure SupraTentorial, SupraTentorialVol, Supratentorial volume, 939646.861571, mm^3
# Measure IntraCranialVol, ICV, Intracranial Volume, 1495162.656130, mm^3
```

lhCortex, rhCortex, Cortex: surface-based cortical gray matter volume
lhCorticalWhiteMater, ... : surface-based cortical white matter volume
SubCortGray: volume-based measure of subcortical gray matter
TotalGray: Cortex + Subcortical gray
IntraCranialVol: Estimated Total Intracranial vol (eTIV)
http://surfer.nmr.mgh.harvard.edu/fswiki/eTIV

http://freesurfer.net/fswiki/MorphometryStats

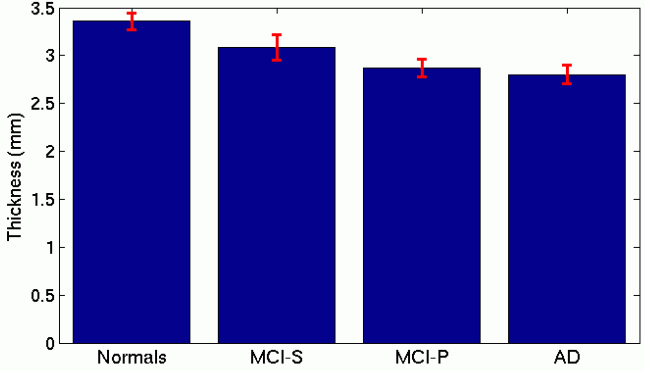
CORTICAL AUTOMATIC PARCELLATION (aparc)

Thickness and Area ROI Studies



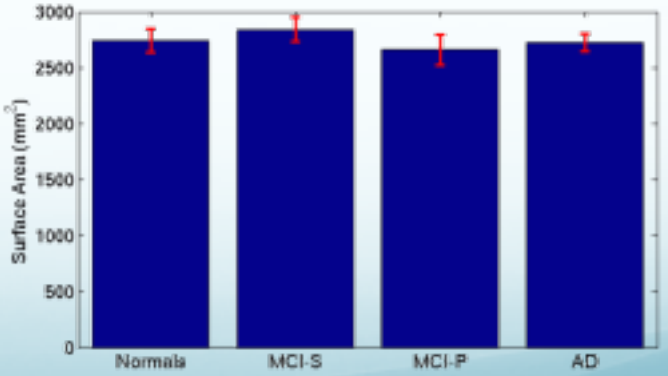
Entorhinal Cortex

Thickness of Entorhinal Cortex



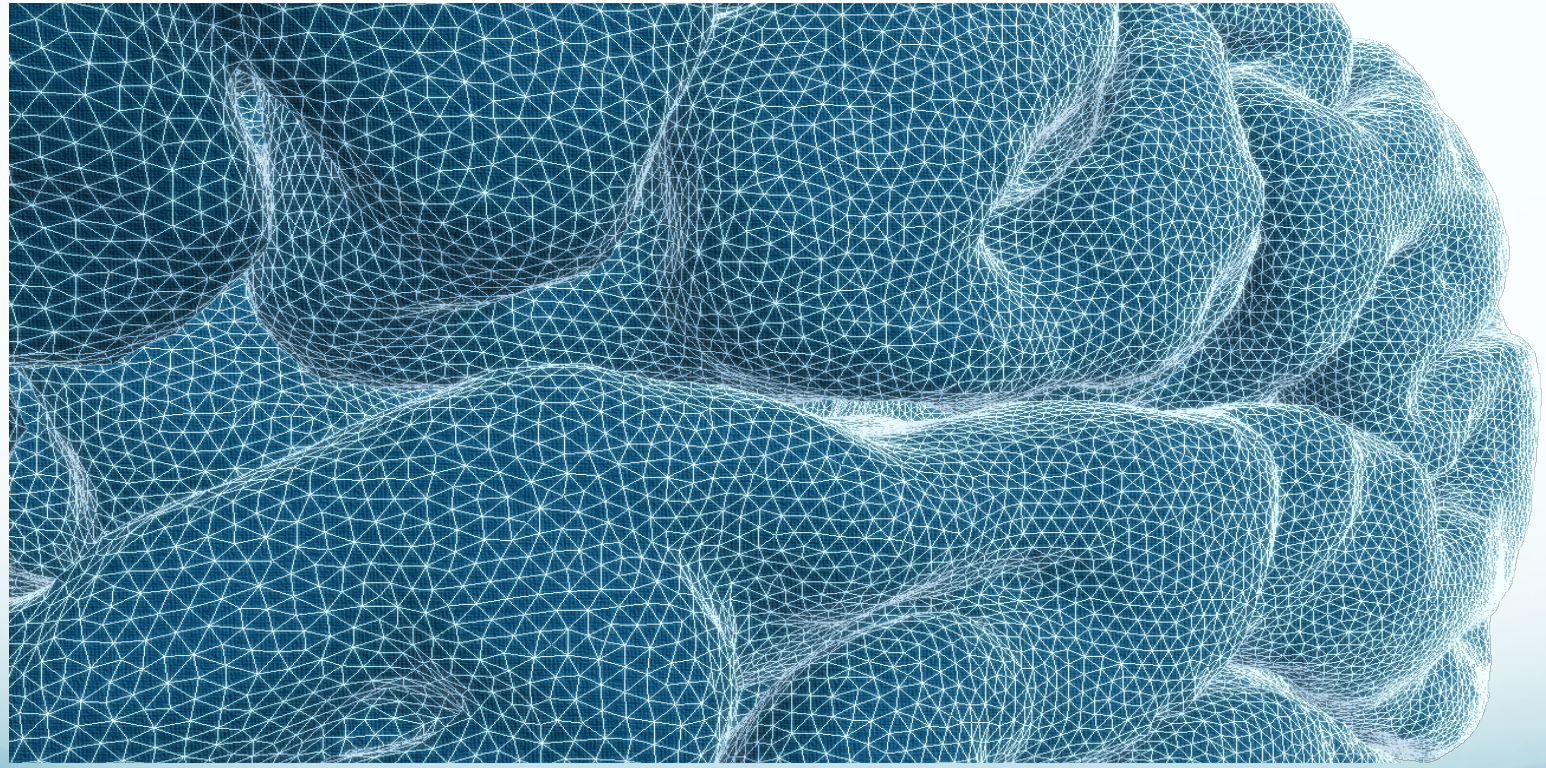
Middle Temporal Gyrus

Surface Area of MTG



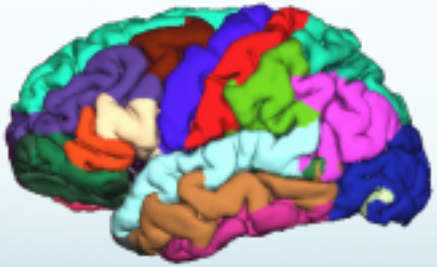
Gray matter volume also possible

Surface Mesh (zoom-in)

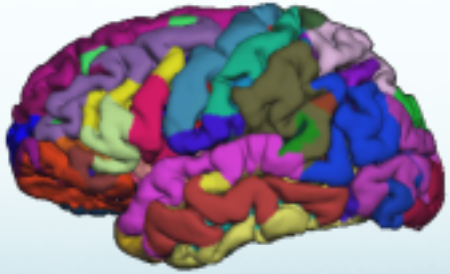


Parcellation/Annotation

- Surface ONLY
- Annotation format (*something.annot*)
- Each vertex has only one label/index
- Index List also found in color lookup table (LUT)
  - $FREESUFER_HOME/FreeSurferColorLUT.txt

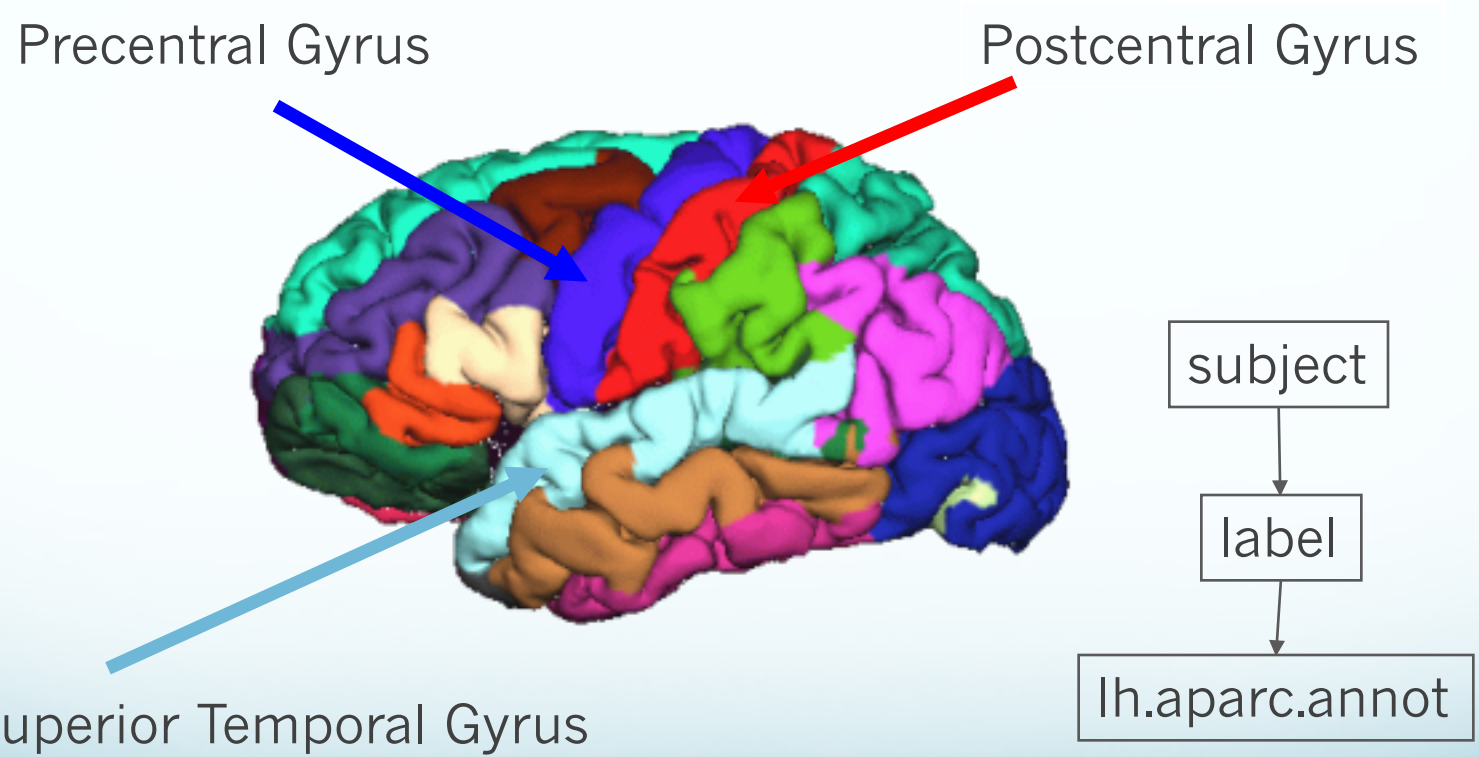


?h.aparc.annot



?h.aparc.a2009.annot

Automatic Surface Parcellation: Desikan/Killiany Atlas (35 ROI's)



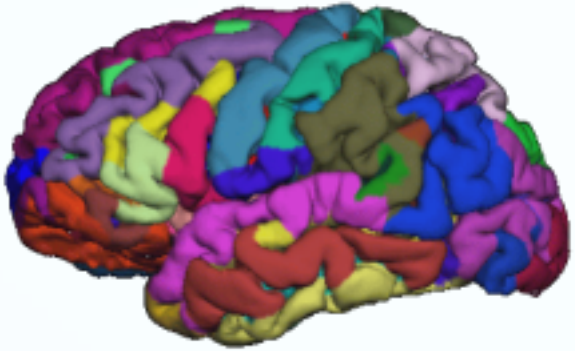
An automated labeling system for subdividing the human cerebral cortex on MRI scans into gyral based regions of interest, Desikan, R.S., F. Segonne, B. Fischl, B.T. Quinn, B.C. Dickerson, D. Blacker, R.L. Buckner, A.M. Dale, R.P. Maguire, B.T. Hyman, M.S. Albert, and R.J. Killiany, (2006). NeuroImage 31(3):968-80.

Desikan/Killiany Atlas

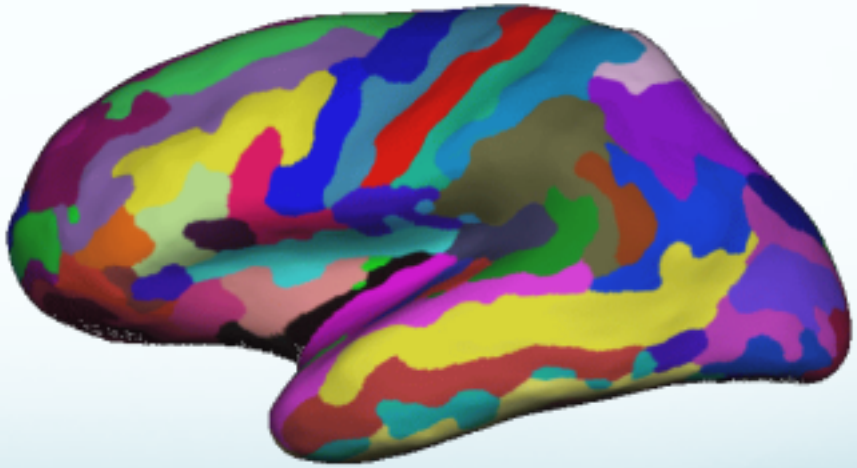
- 40 Subjects
- 14 Male, 26 Female
- Ages 18-87
- 30 Nondemented
- 10 Demented
- Siemens 1.5T Vision (Wash U)

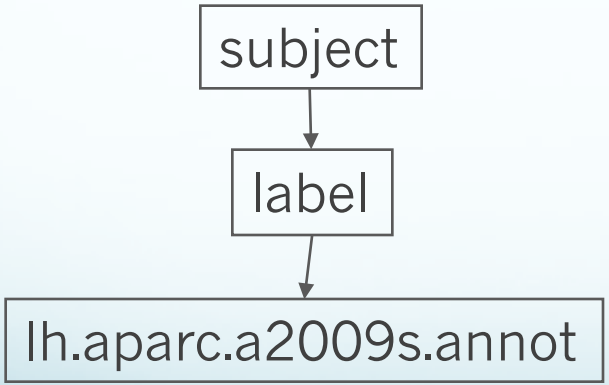
An automated labeling system for subdividing the human cerebral cortex on MRI scans into gyral based regions of interest, Desikan, R.S., F. Segonne, B. Fischl, B.T. Quinn, B.C. Dickerson, D. Blacker, R.L. Buckner, A.M. Dale, R.P. Maguire, B.T. Hyman, M.S. Albert, and R.J. Killiany, (2006). NeuroImage 31(3):968-80.

Automatic Surface Parcellation: Destrieux Atlas



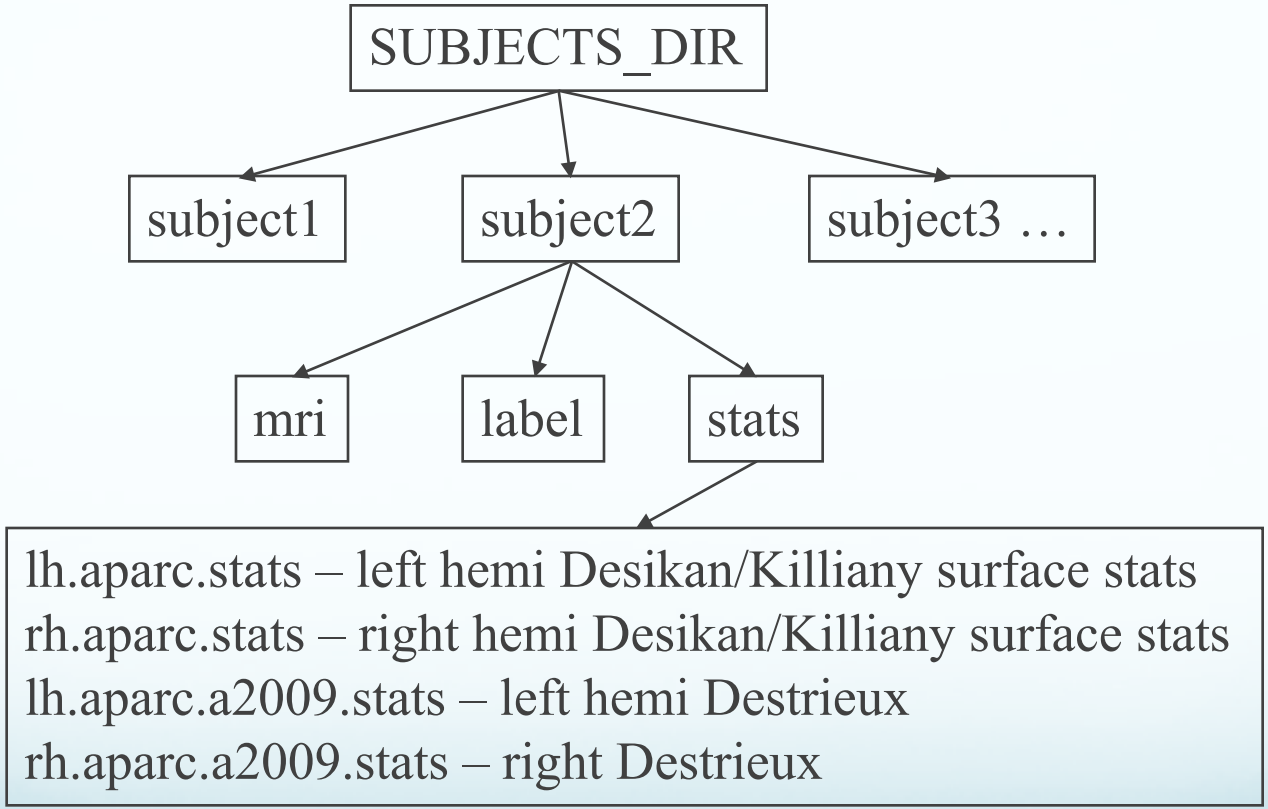
- 58 Parcellation Units
- 12 Subjects





Automatically Parcellating the Human Cerebral Cortex, Fischl, B., A. van der Kouwe, C. Destrieux, E. Halgren, F. Segonne, D. Salat, E. Busa, L. Seidman, J. Goldstein, D. Kennedy, V. Caviness, N. Makris, B. Rosen, and A.M. Dale, (2004). Cerebral Cortex, 14:11-22.

FreeSurfer Stats Outputs



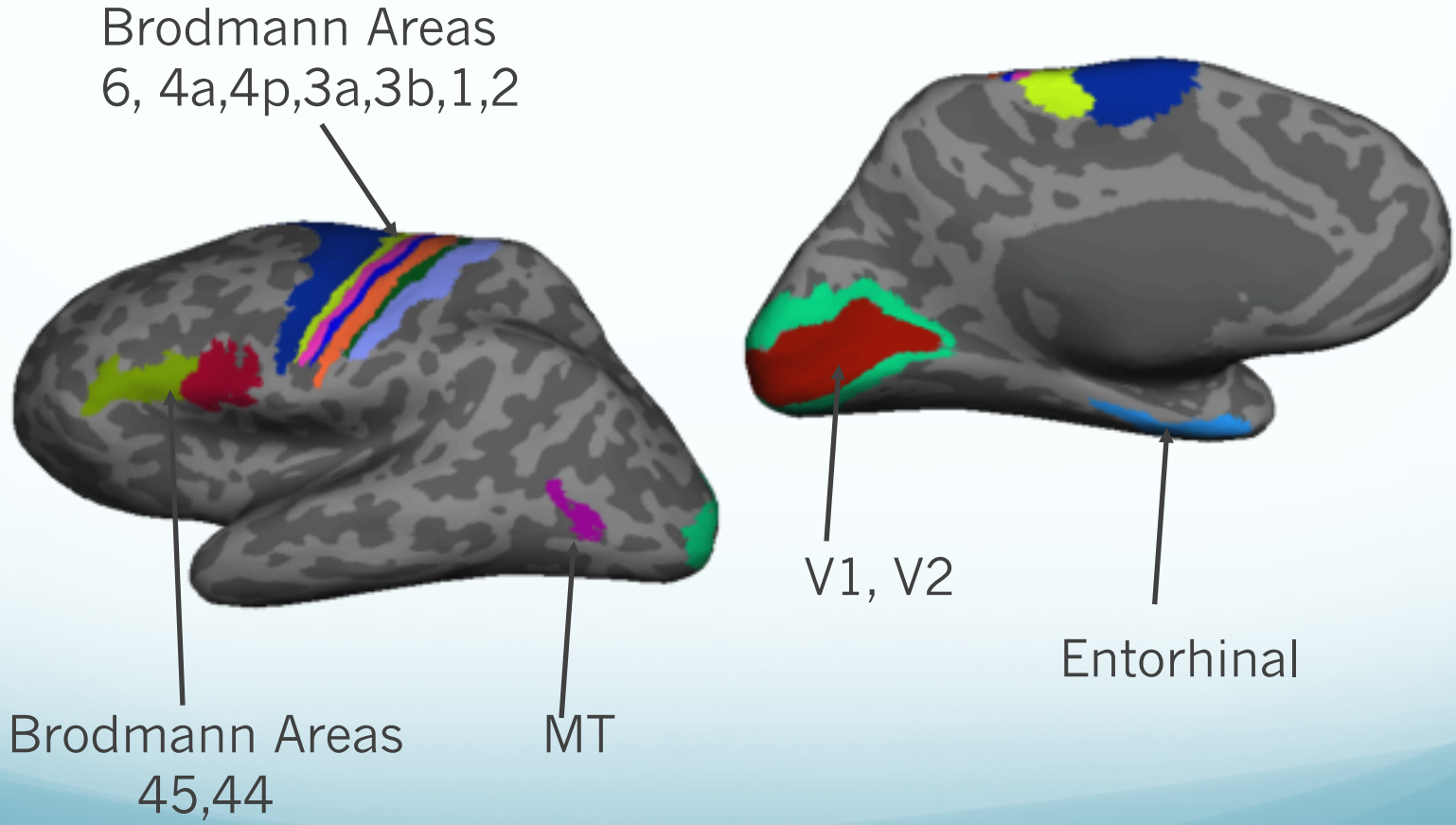
created by mris_anatomical_stats

Parcellation Stats File

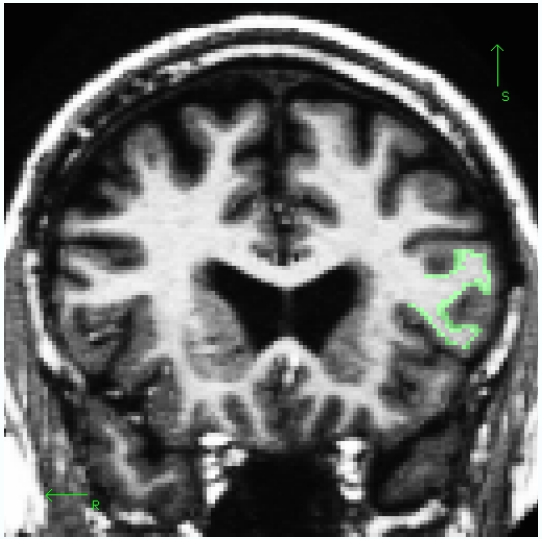
StructName	NumVert	SurfArea	GrayVol	ThickAvg	ThickStd	MeanCurv	GausCurv	FoldInd	CurvInd
bankssts	1157	811	1992	2.303	0.567	0.117	0.031	10	1.6
caudalanteriorcingulate	779	543	1908	3.472	0.676	0.185	0.064	26	1.8
caudalmiddlefrontal	3145	2137	5443	2.311	0.593	0.132	0.041	35	5.3
cuneus	1809	1195	2286	1.672	0.411	0.162	0.067	34	4.6
entorhinal	436	265	1269	2.871	0.881	0.119	0.037	5	0.6
fusiform	3307	2126	5161	2.109	0.689	0.144	0.064	71	8.7
inferiorparietal	5184	3514	8343	2.136	0.552	0.146	0.055	82	11.5
inferiortemporal	3746	2610	8752	2.683	0.748	0.178	0.132	140	18.0

StructName:	Name of structure/ROI
NumVert:	Number of vertices in ROI
SurfArea:	Surface area in mm2
GrayVol:	Volume of gray matter (surface-based)
ThickAvg/ThickStd:	Average and stddev of thickness in ROI
MeanCurv:	Mean curvature
GausCurv:	Mean gaussian curvature
FoldInd:	Folding index
CurvInd:	Curvature index

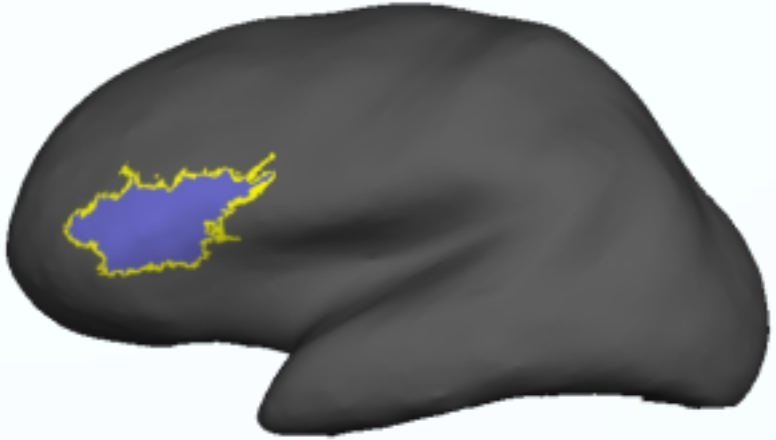
Other ROIs (ex vivo)



Label File



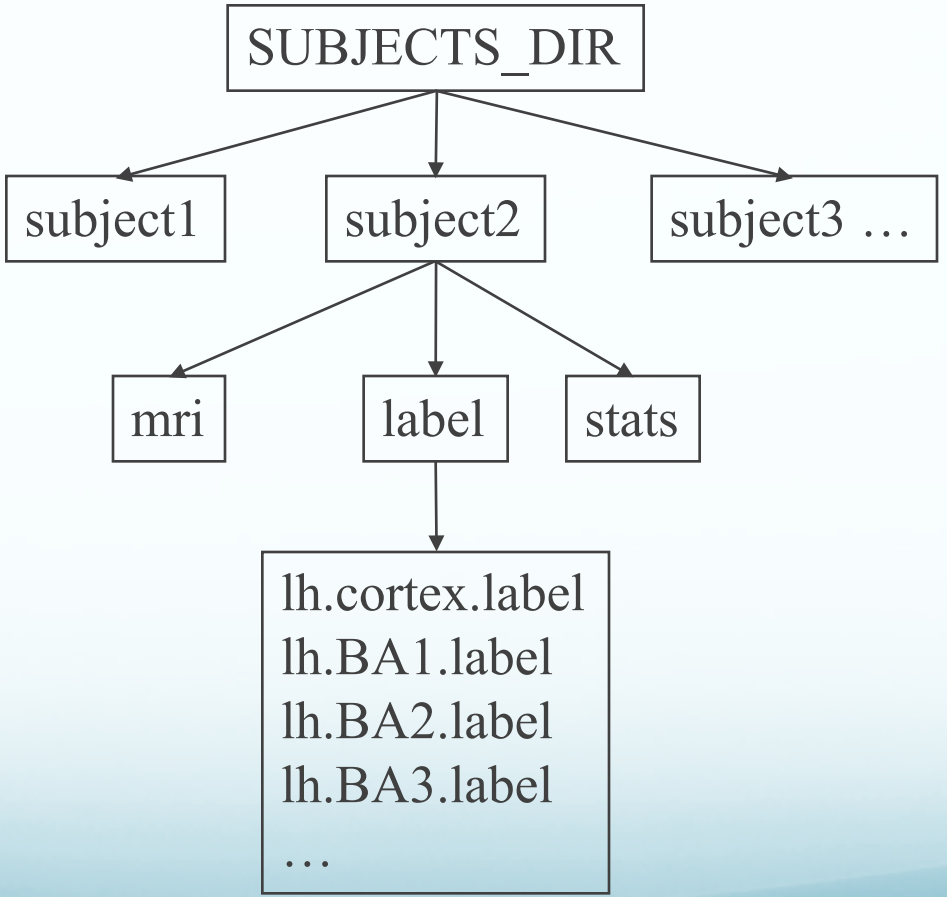
In Volume



On Surface

- Easy to draw
- Use ‘Select Voxels’ Tool in tkmedit
- Or use FreeView
- Simple text format

Example Label Files

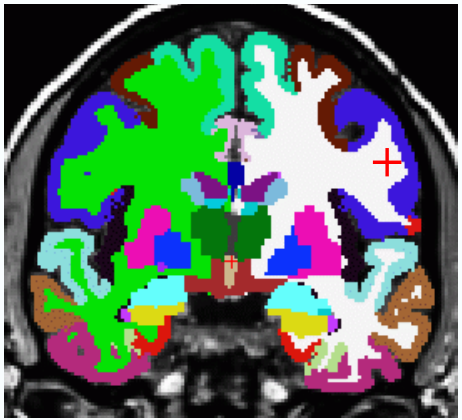


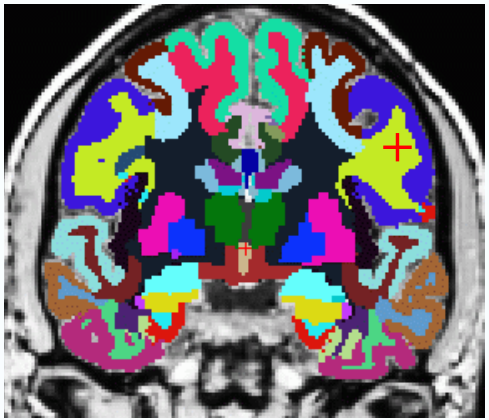
Creating Label Files

- Drawing tools:
  - tkmedit, freeview
  - tksurfer
  - QDEC
- Deriving from other data
  - mris_annotation2label: cortical parcellation broken into units
  - mri_volcluster: a volume made into a cluster
  - mri_surfcluster: a surface made into a cluster
  - mri_vol2label: a volume/segmentation made into a label
  - mri_label2label: label from one space mapped to another

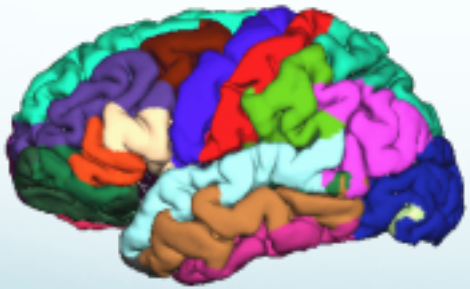
WHITE MATTER SEGMENTATION (wmparc)

Gyral White Matter Segmentation

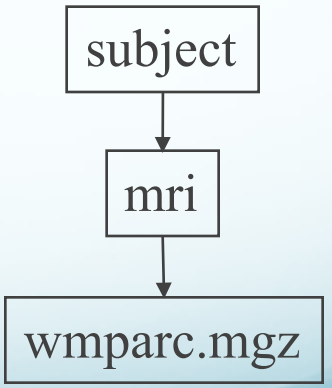




wmparc.mgz

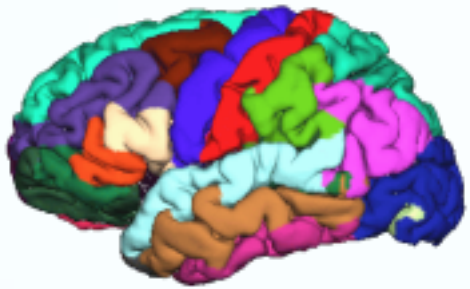


Nearest Cortical Label
to point in White Matter

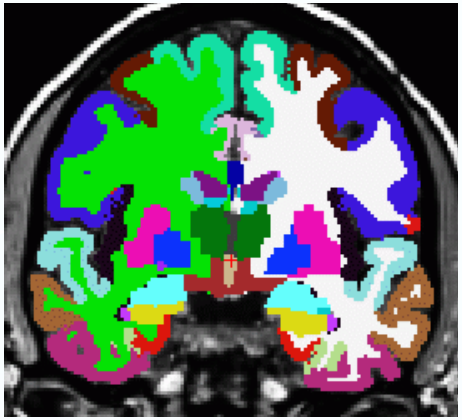


Salat, et al., Age-associated alterations in cortical gray and white matter signal intensity and gray to white matter contrast. *Neuroimage* **2009,** 48, (1), 21-8.

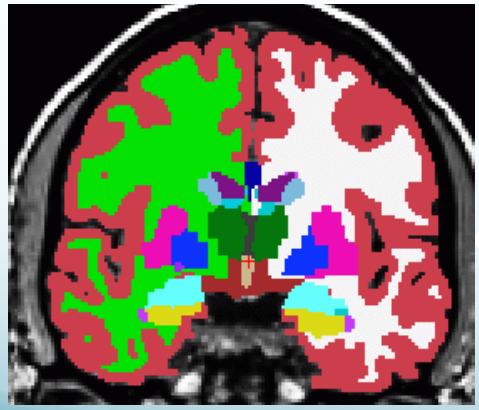
Merged Cortical + Subcortical



aparc

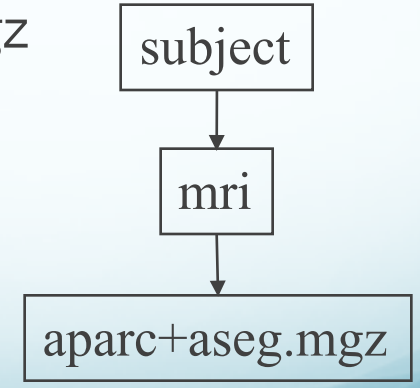


aparc+aseg.mgz



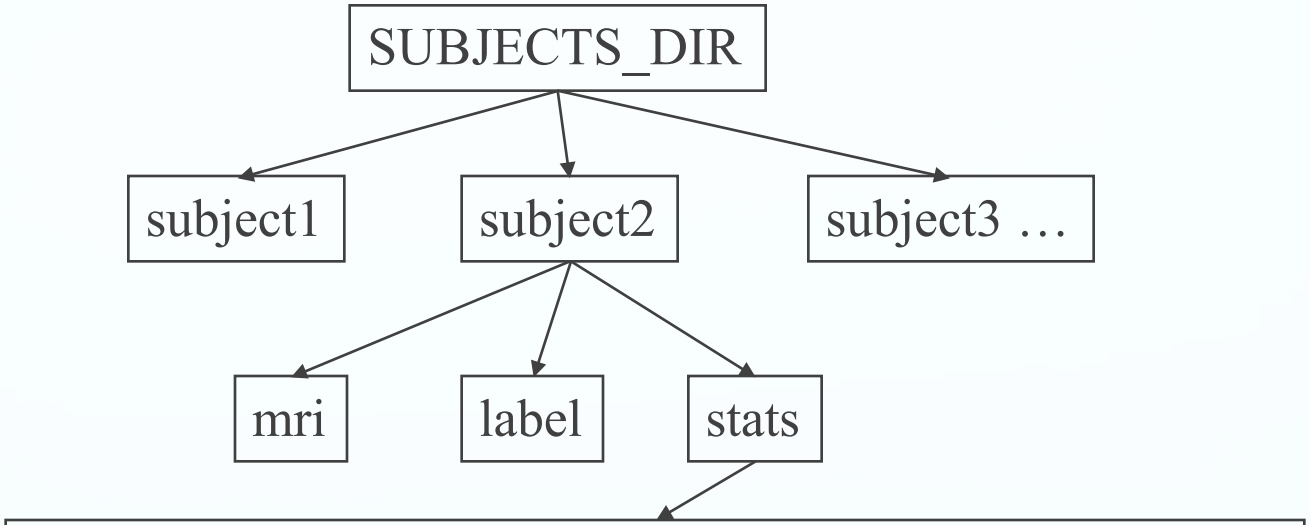
aseg.mgz

No new information
For visualization only



ANALYSIS of STATS

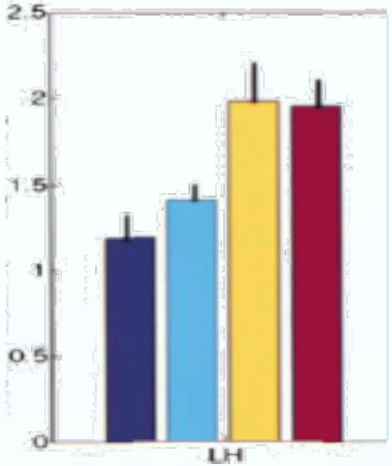
FreeSurfer Stats Outputs

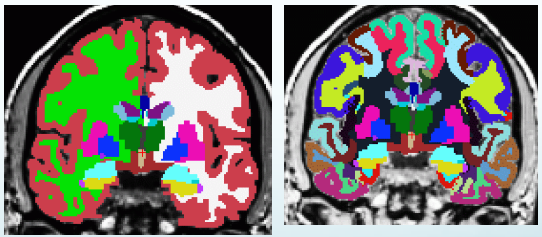


aseg.stats – subcortical volumetric stats
wmparc.stats – white matter segmentation volumetric stats
lh.aparc.stats – left hemi Desikan/Killiany surface stats
rh.aparc.stats – right hemi Desikan/Killiany surface stats
lh.aparc.a2009.stats – left hemi Destrieux
rh.aparc.a2009.stats – right Destrieux

Extract table of subcortical volumes of all structures for all subjects

asegstats2table
--subjects 001 002 003 004 005
--meas volume
--stats aseg.stats
--tablefile aseg.table.txt



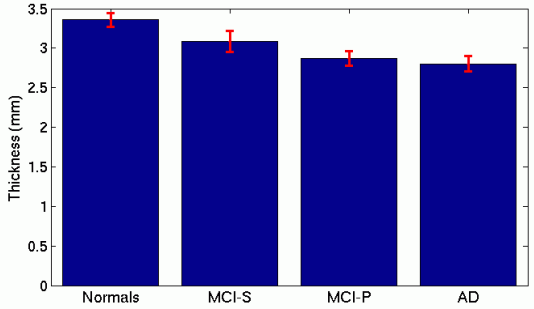


Applies to wmparc.stats too:
(--stats wmparc.stats)

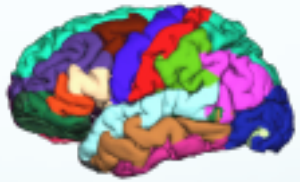
Output is a simple ASCII text file

Extract table of average thickness of all cortical structures for all subjects

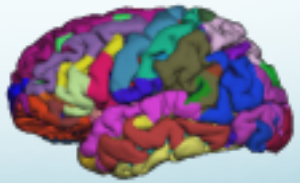
```
aparcstats2table
   --subjects 001 002 003
   --hemi lh
   --meas thickness
   --parc aparc
   --tablefile  aparc_lh_thickness_table.txt
```



Desikan/Killiany Atlas: --parc aparc

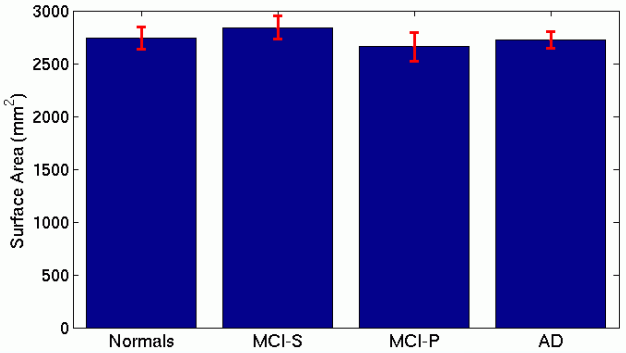


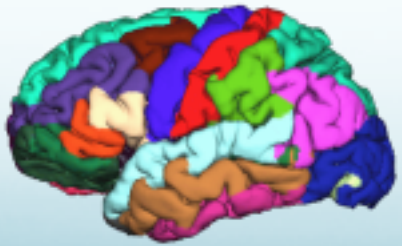
Destrieux Atlas: --parc aparc.a2009s

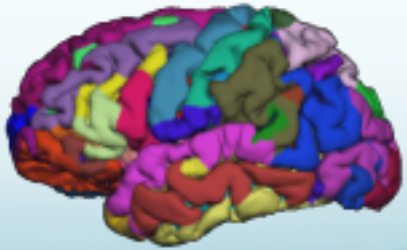


Extract table of surface area of all cortical structures for all subjects

```
aparcstats2table
   --subjects 001 002 003
   --hemi lh
   --meas area
   --parc=aparc
   --tablefile  aparc_lh_area_table.txt
```

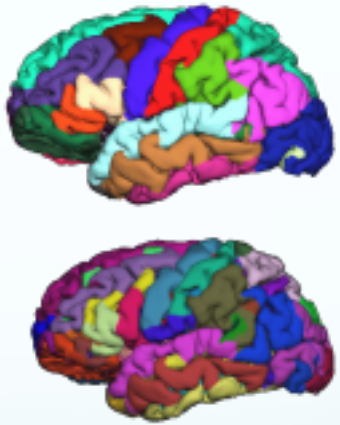






Extract table of GM volume of cortical structures for all subjects

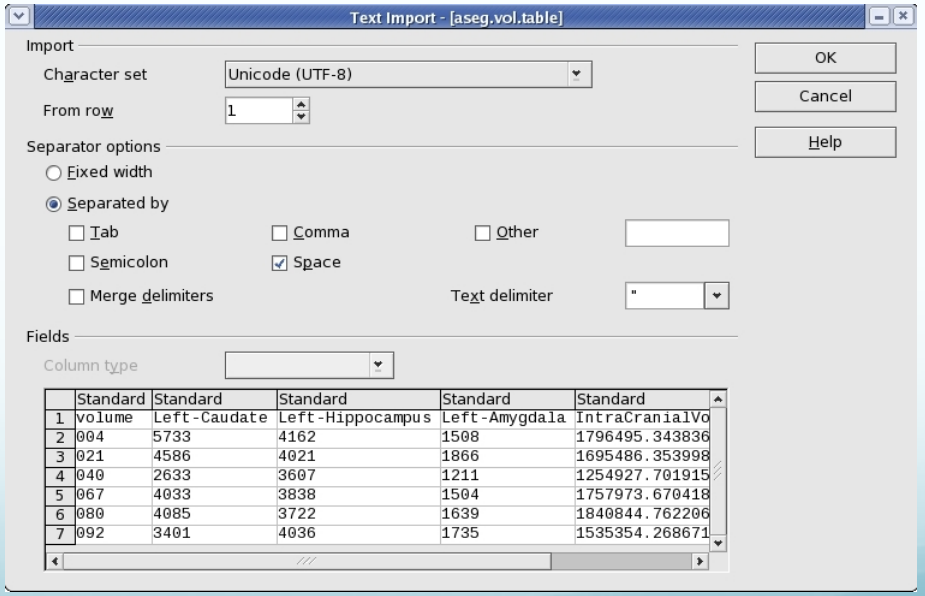
```
aparcstats2table
   --subjects 001 002 003
   --hemi lh
   --meas volume
   --parc=aparc
   --tablefile  aparc_lh_volume_table.txt
```



Note that the volume of cortical structures is extracted with aparcstats2table whereas the volume of subcortical structures is extracted with asegstats2table.

Exporting Table Files

- SPSS, oocalc, matlab
- Choose: Delimited by spaces



GLM Analysis on Stats Files

- mri_glmfit (used for image-based group analysis)
- Use “--table table.txt” instead of “--y” to specify the input
- Eg, “mri_glmfit --table aparc_lh_vol_stats.txt …”
- The rest of the command-line is the same as you would use for a group study (eg, FSGD file and contrasts).
- Output is text file sig.table.dat that lists the significances (-log10(p)) for each ROI and contrast.

Summary

- ROIs are Individualized
- Subcortical and WM ROIs (Volume)
- Surface ROIs (Volume, Area, Thickness)
- http://freesurfer.net/fswiki/MorphometryStats
- Segmentation vs. Annotation vs. Label File
- Extract to table (asegstats2table, aparcstats2table)
- Multimodal Applications

Tutorial

- Simultaneously load:
  - aparc+aseg.mgz (freeview or tkmedit)
  - aparc.annot (tksurfer)
  - FreeSurferColorLUT.txt
- View Individual Stats Files
- Group Table
  - Create
  - Load into spreadsheet

End of Presentation

Label File

- Surface or Volume
- Simple Text format (usually something.label)
  - Each row as 5 Columns: Vertex X Y Z Statistic
    - Vertex – 0-based vertex number
      - only applies to surfaces, ignored for volumes
    - XYZ – coordinates (in one of many systems)
    - Statistic – often ignored
- Eg, lh.cortex.label

Indicates 4 "points" in label →

```
#label , from subject fsaverage
4
 88  -42.261  -81.724  -13.242 0.000000
445  -28.781  -85.827  -16.289 0.000000
446  -39.862  -74.518  -14.432 0.000000
616  -42.856  -74.239   -5.499 0.000000
```

ROI Statistic Files

- Simple text files
- Volume and Surface ROIs (different formats)
- Automatically generated: aseg.stats, lh.aparc.stats, etc
- Combine multiple subjects into one table with asegstats2table or aparcstats2table (then import into excel).
- You can generate your own with either
  - mri_segstats (volume)
  - mris_anatomical_stats (surface)

ROI Studies

- Volumetric/Area
  - size; number of units that make up the ROI
- “Intensity”
  - average values at point measures (voxels or vertices) that make up the ROI

ROI Mean “Intensity” Analysis

- Average vertex/voxel values or “point measures” over ROI
  - MR Intensity (T1)
  - Thickness, Sulcal Depth
- Multimodal
  - fMRI intensity
  - FA values (diffusion data)

ROI Atlas Creation

- Hand label N data sets
  - Volumetric: CMA
  - Surface Based:
    - Desikan/Killiany
    - Destrieux
- Map labels to common coordinate system
- Probabilistic Atlas
  - Probability of a label at a vertex/voxel
    - Maximum Likelihood (ML) Atlas Labels
  - Curvature/Intensity means and stddevs
  - Neighborhood relationships

Automatic Labeling

- Transform ML labels to individual subject*
- Adjust boundaries based on
  - Curvature/Intensity statistics
  - Neighborhood relationships
- Result: labels are customized to each individual.
- You can create your own atlases**

* Formally, we compute maximum a posteriori estimate of the labels given the input data

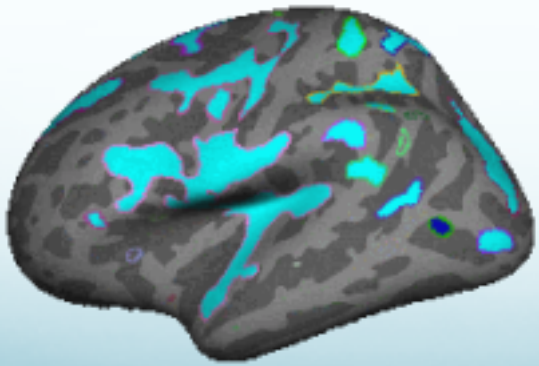
** Time consuming; first check if necessary

Validation -- Jackknife

- Hand label N Data Sets
- Create atlas from (N-1) Data Sets
- Automatically label the left out Data Set
- Compare to Hand-Labeled
- Repeat, Leaving out a different data set each time

Clusters

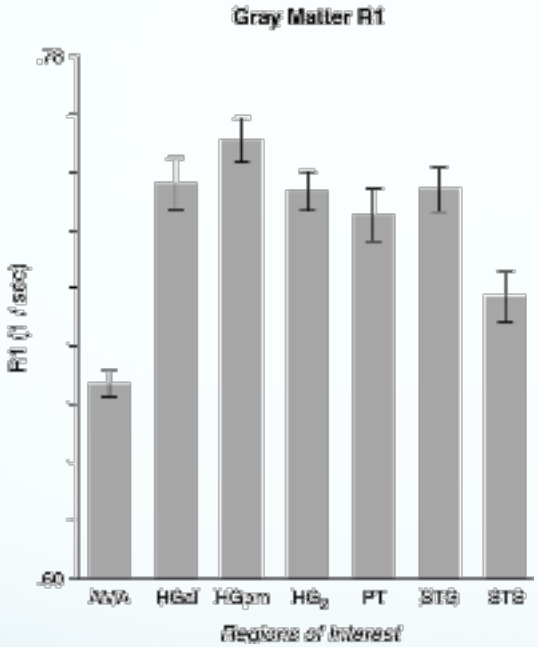
- Clusters (significance map; functional activation)
  - One output of mri_volcluster and mri_surfcluster
  - are segmentations or annotation (volume vs. surface)
  - Each cluster gets its own number/index
  - Masks (another type of segmentation)
    - Binary: 0, 1
    - Can be derived by thresholding statistical maps



Thresholded Activity

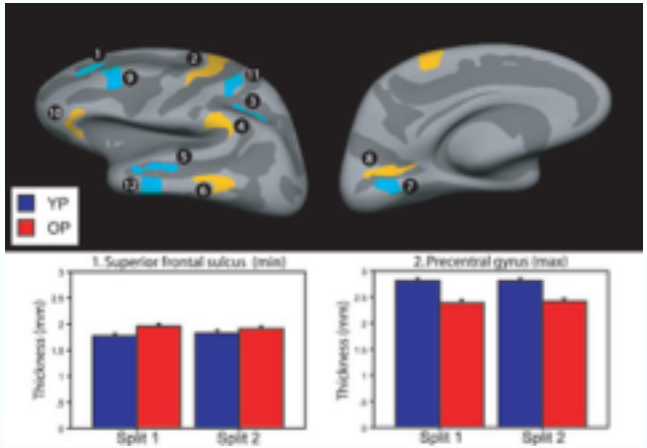
Activation Clusters

ROI Mean “Intensity” Studies



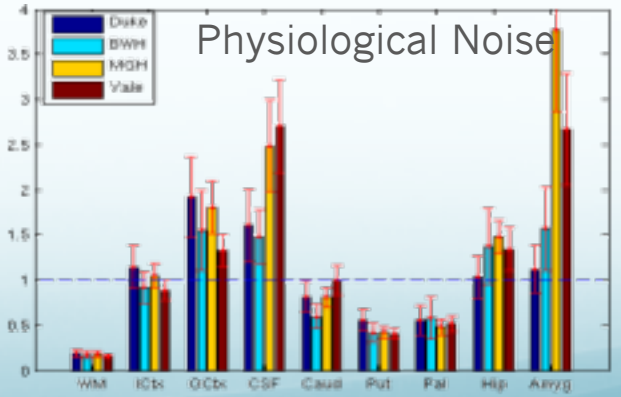
Sigalovsky, et al, 2006

R1 Intensity



Salat, et al, 2004.

Thickness



Greve, et al, 2008.

fMRI