Anatomical analysis with Freesurfer

31082024

WhatsApp group

https://chat.whatsapp.com/L5qwsHRiBkZ8Z0PfiOhpSb

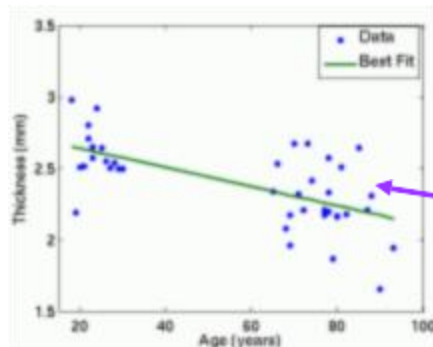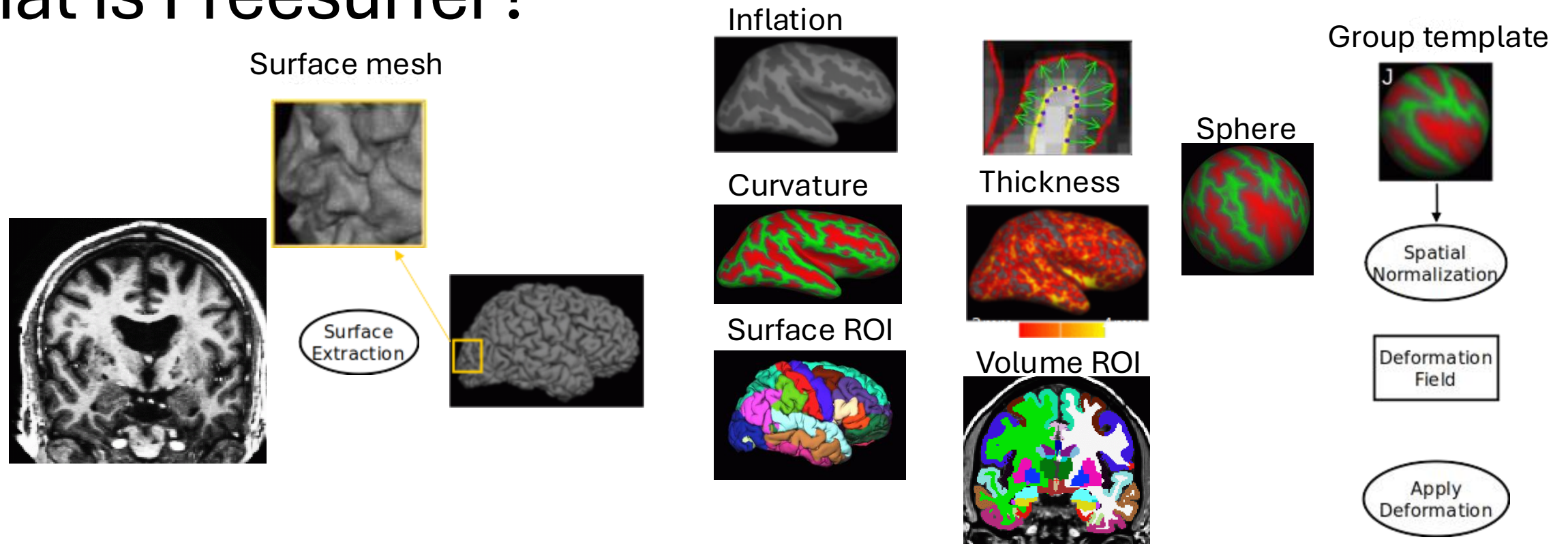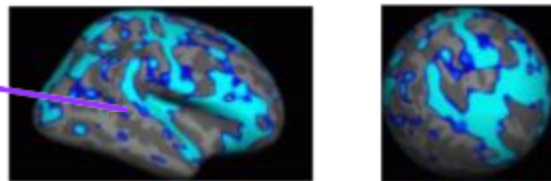NeuroImaging Workshop IIITH BCCL

WhatsApp group

Outline

- What is Freesurfer?

- Recap Freesurfer terms

- Recon-all
  - Components of each step in recon-all and it's output

- Exploring ROI-based summary of cortical thickness or gray matter volumes

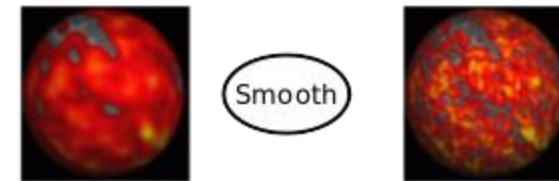- Statistical comparisons between CN vs AD

What is Freesurfer?

Surface mesh

Inflation

Surface Extraction

Curvature

Thickness

Sphere

Group template

Spatial Normalization

Deformation Field

Surface ROI

Volume ROI

Apply Deformation
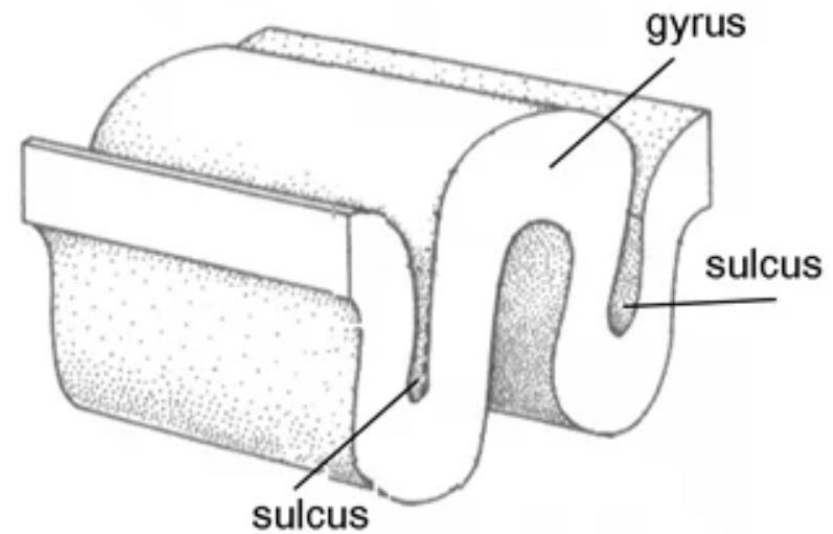
Statistical analysis

Group analysis

Smooth

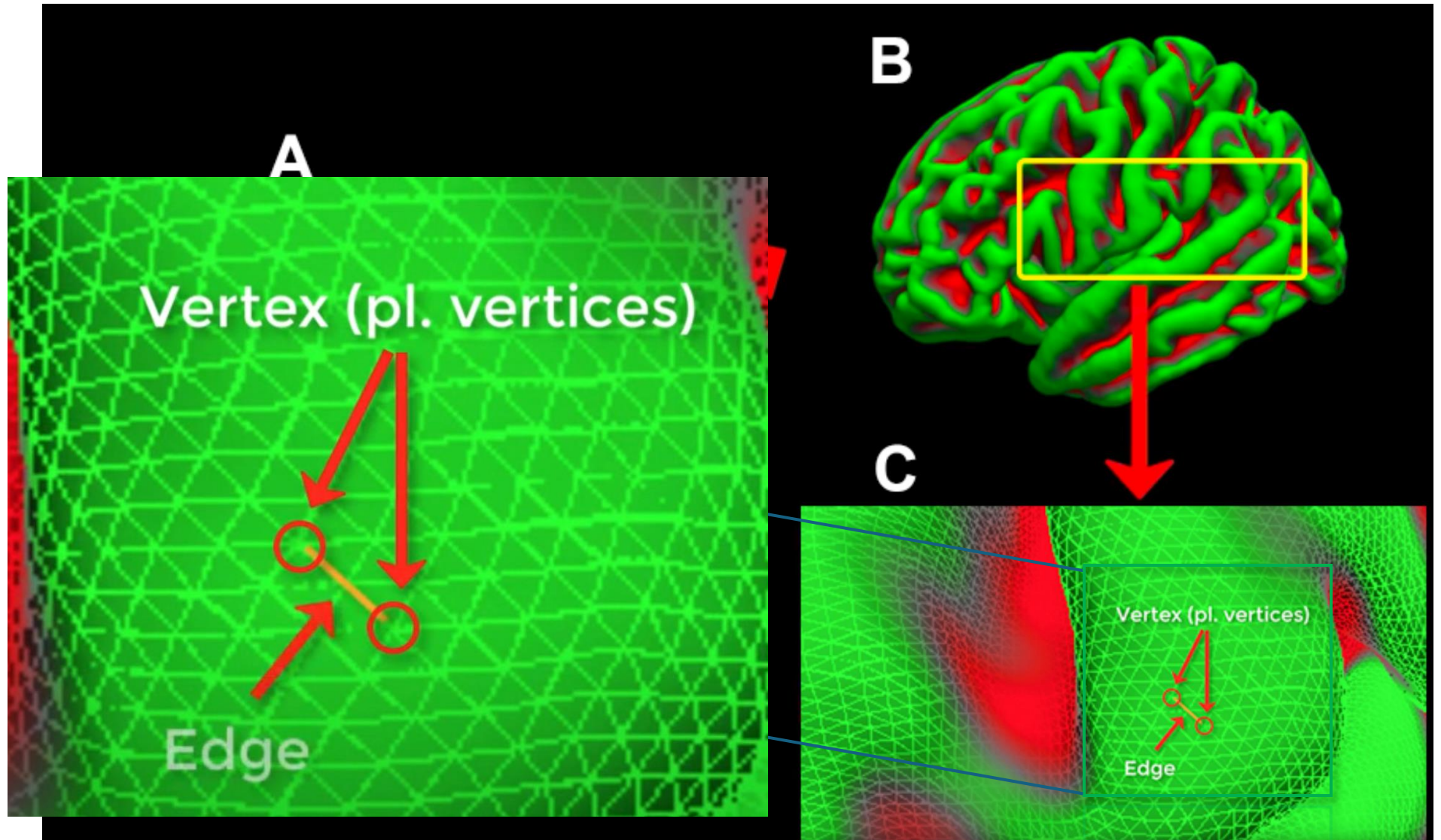P < 0.01

Thickness group space

Cortex

- Gyri and Sulci of the Brain

Reconstructs cortical surface from a 3D volume

recon-all

https://andysbrainbook.readthedocs.io/

Reconstructs cortical surface from a 3D volume

recon-all

https://andysbrainbook.readthedocs.io/
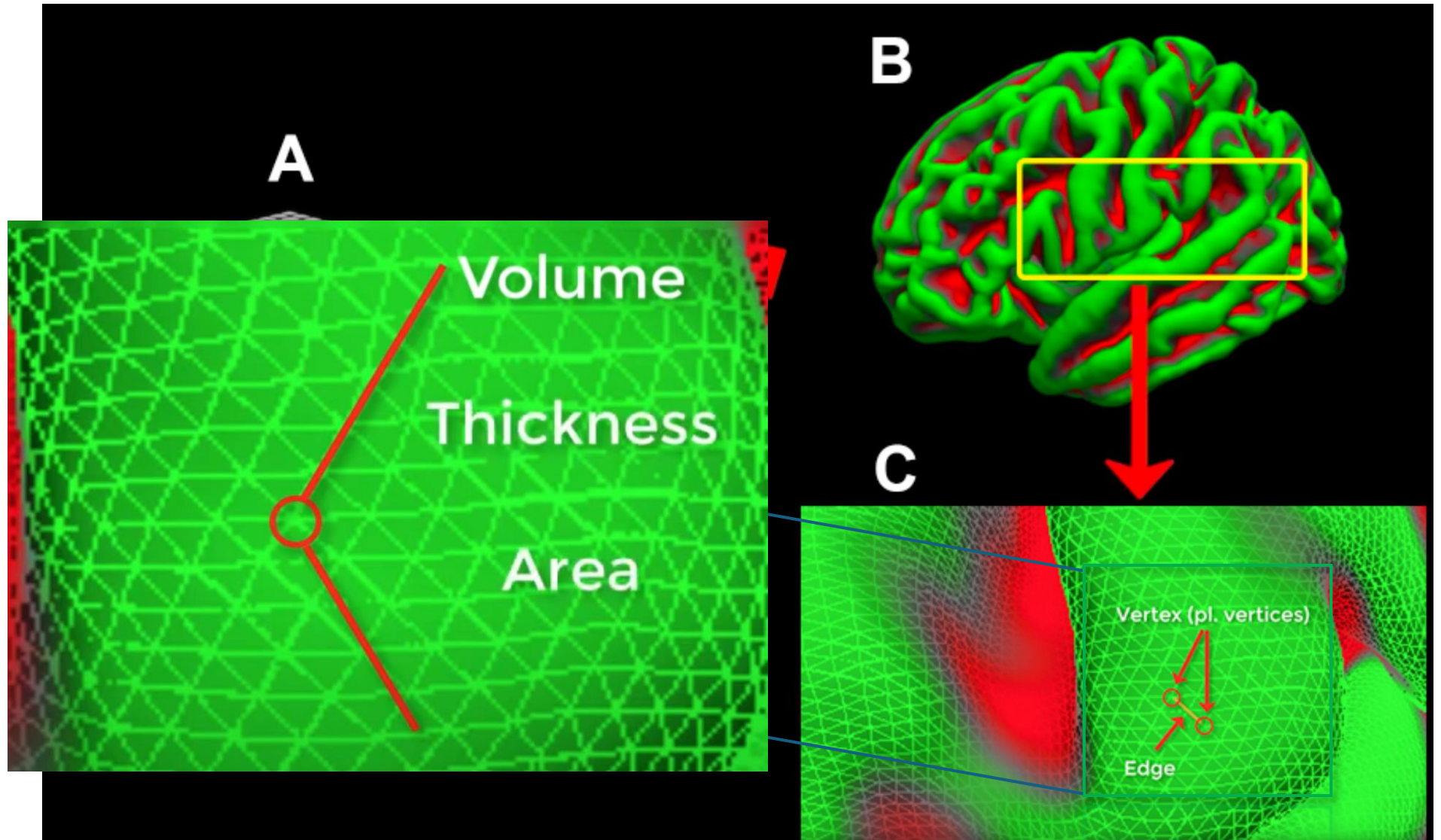
Inflated brain for better visualization

freeview
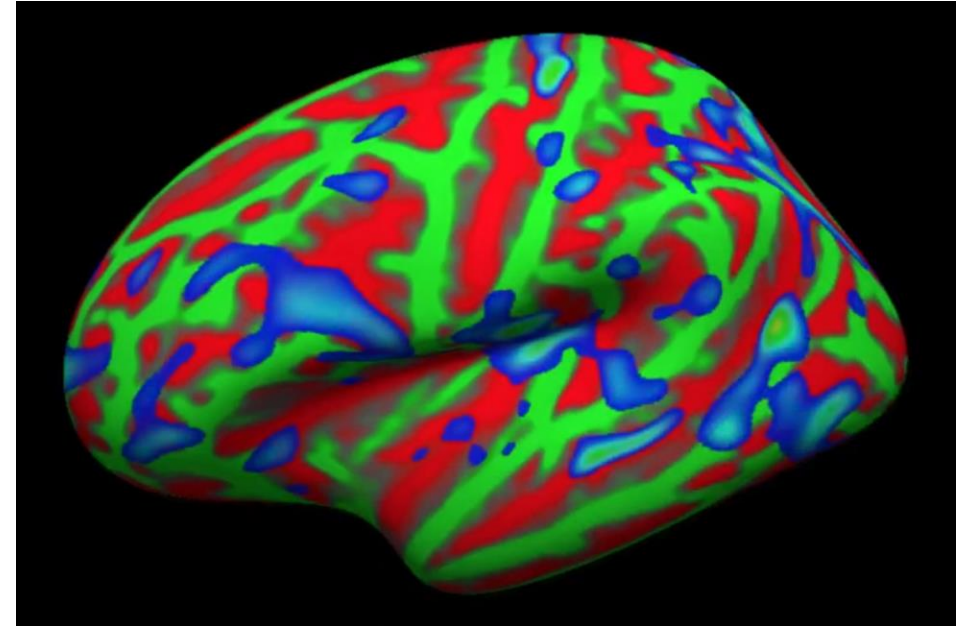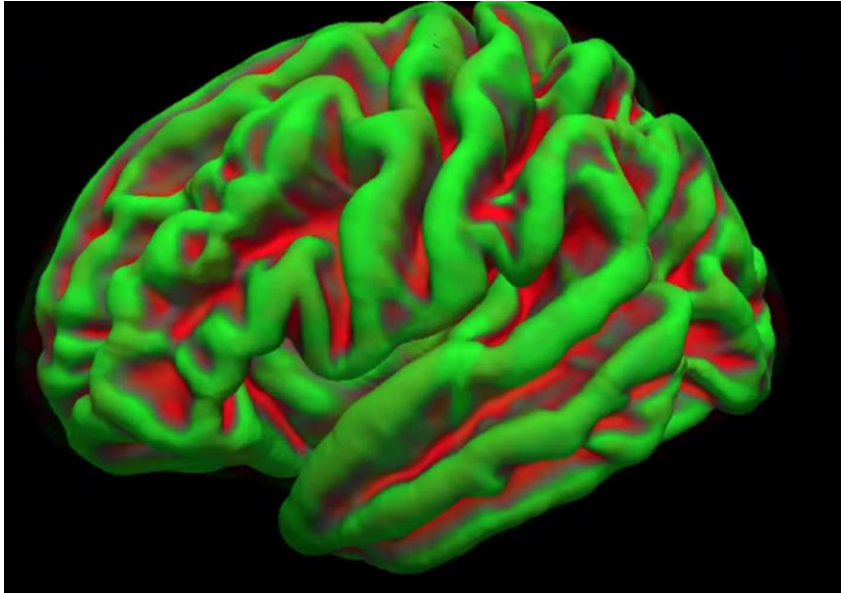
Gyrus – Green
Sulcus - Red

Grey Matter
differences – Blue

https://andysbrainbook.readthedocs.io/

The output files of recon-all

Grey Matter

White Matter
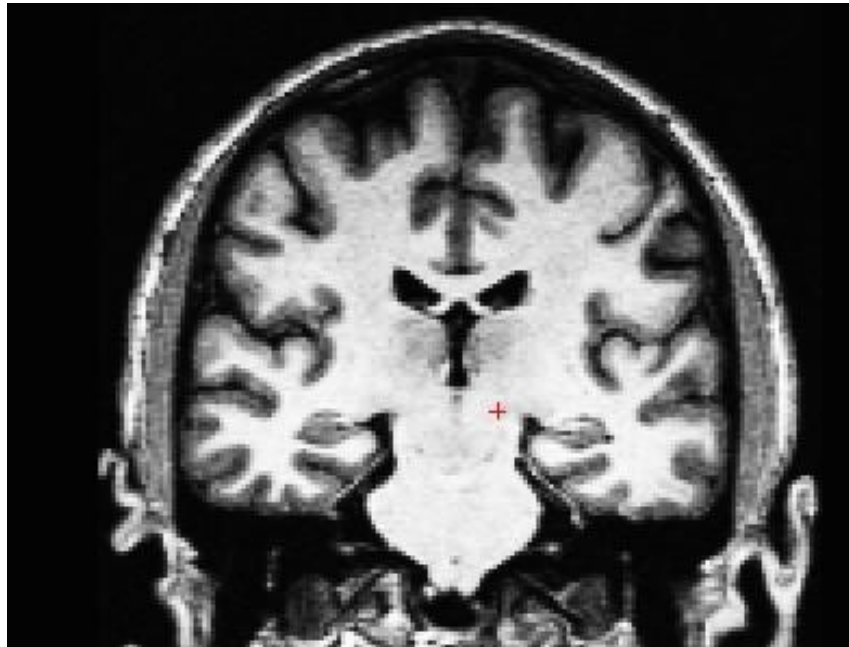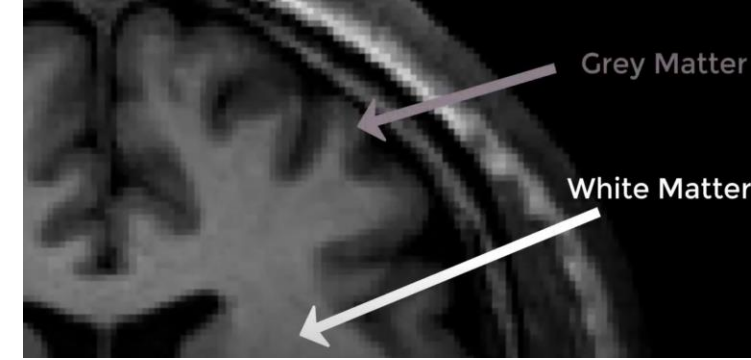
T1 weighted Input
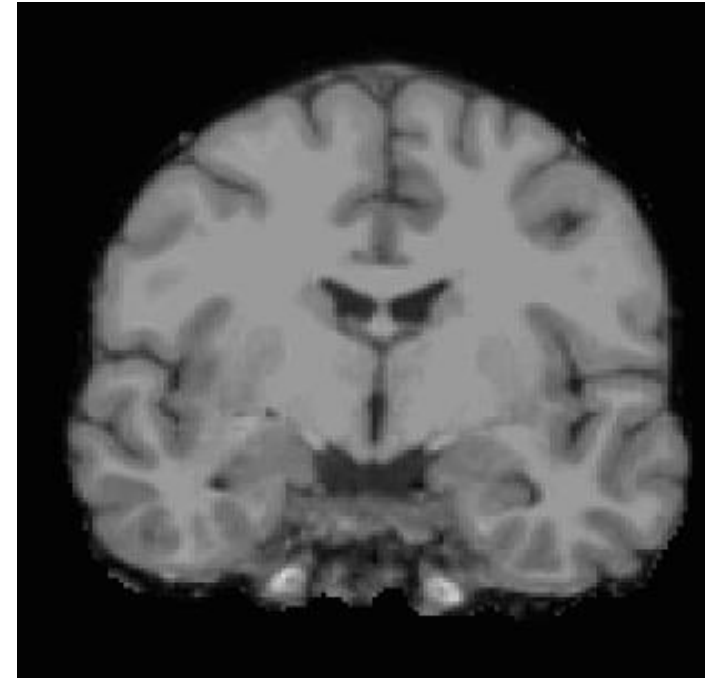
Skull stripping

brainmask.mgz
Unique to
Freesurfer

The Output of Recon-all

Grey Matter

White Matter
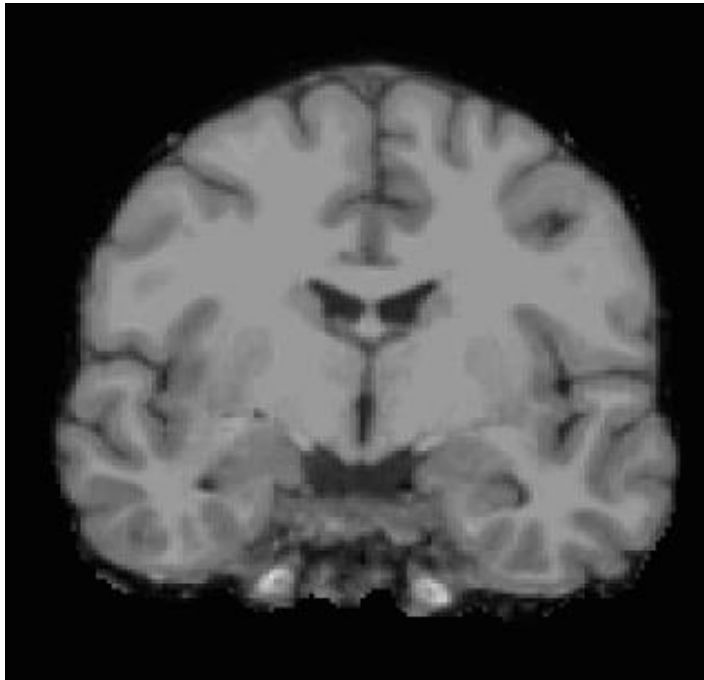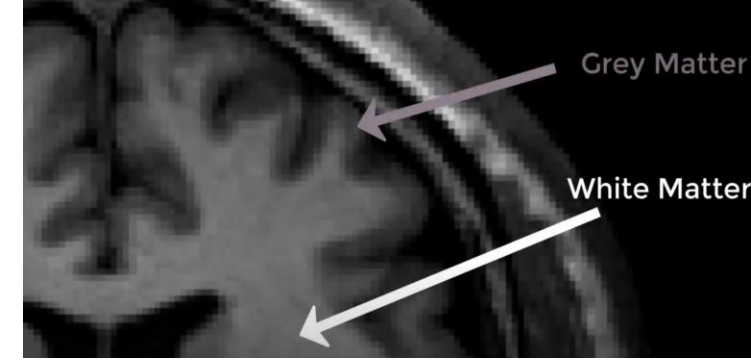
Skull stripping
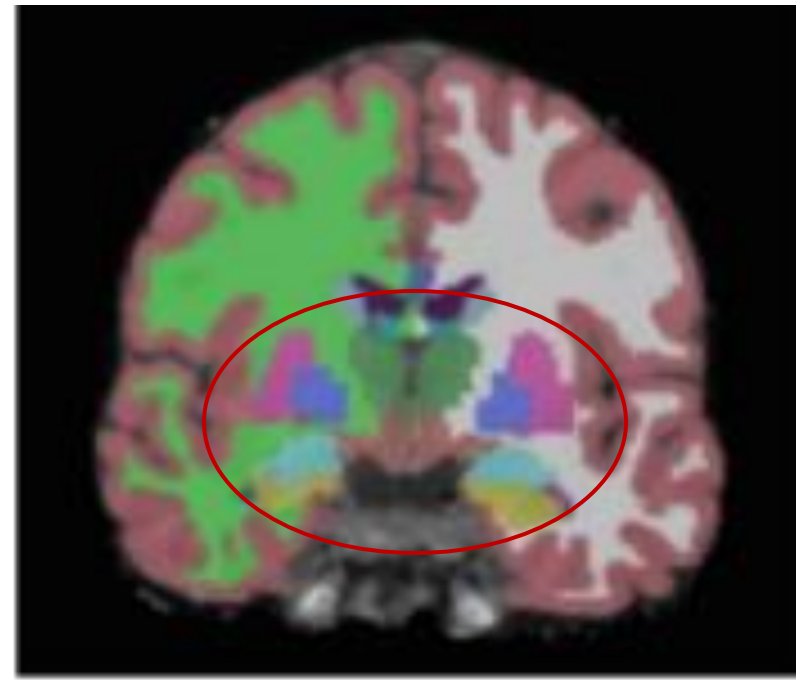
Volume labelling

aseg.mgz

https://andysbrainbook.readthedocs.io/

Surface and thickness estimates
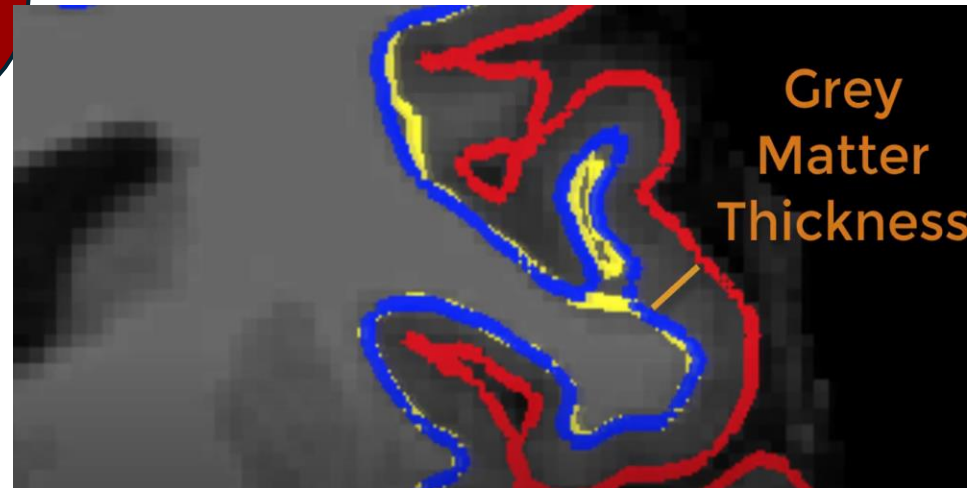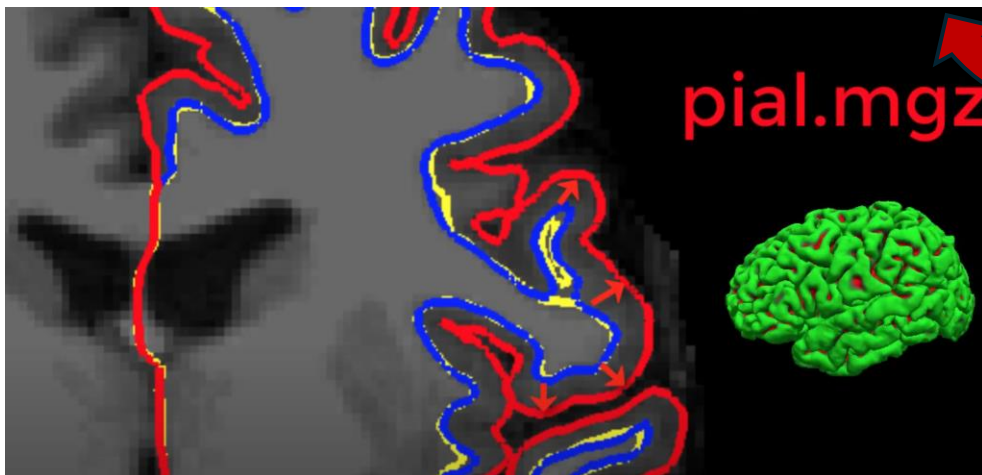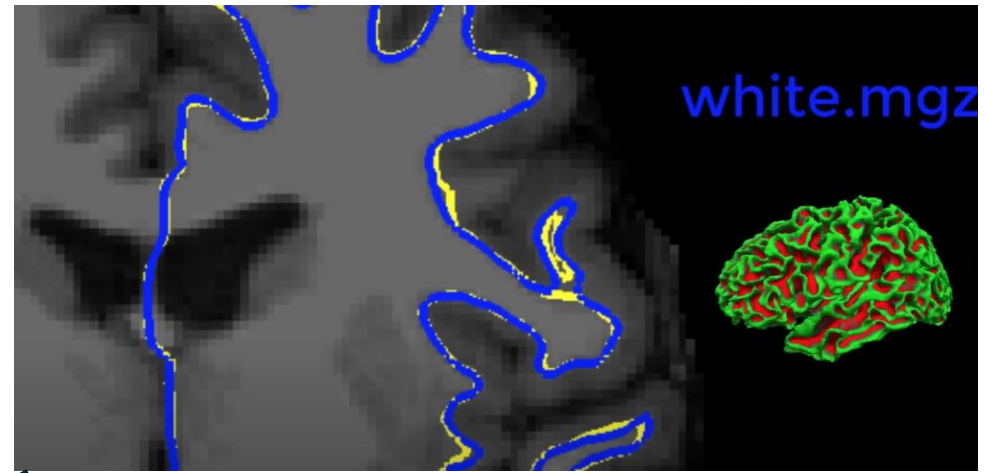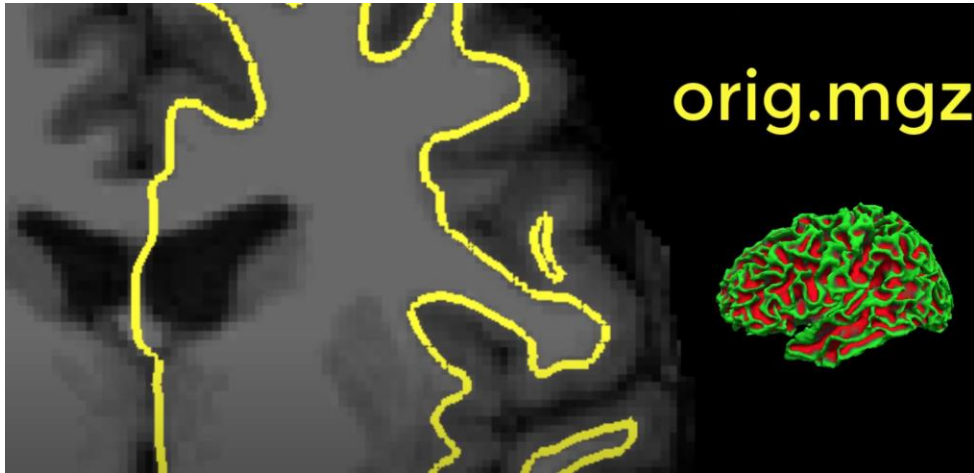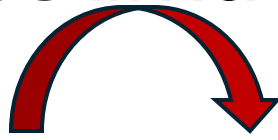
The output of recon-all
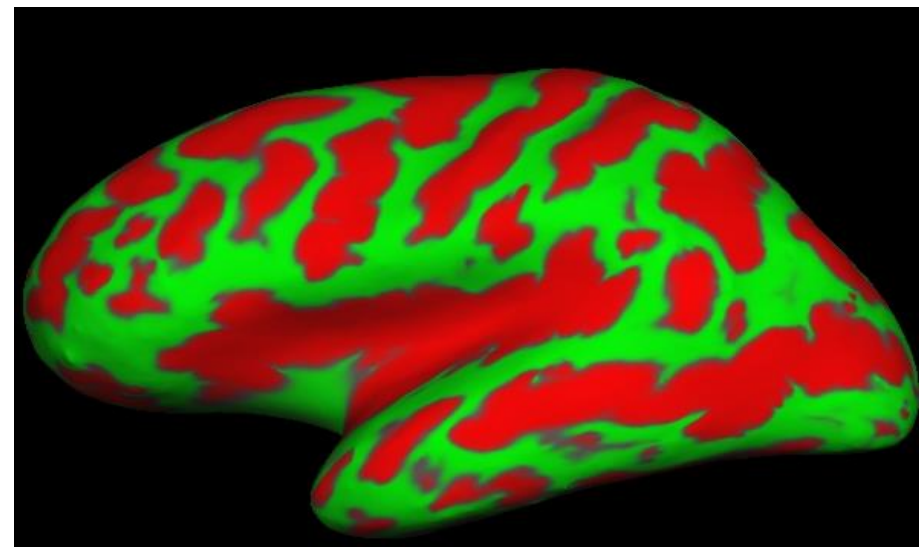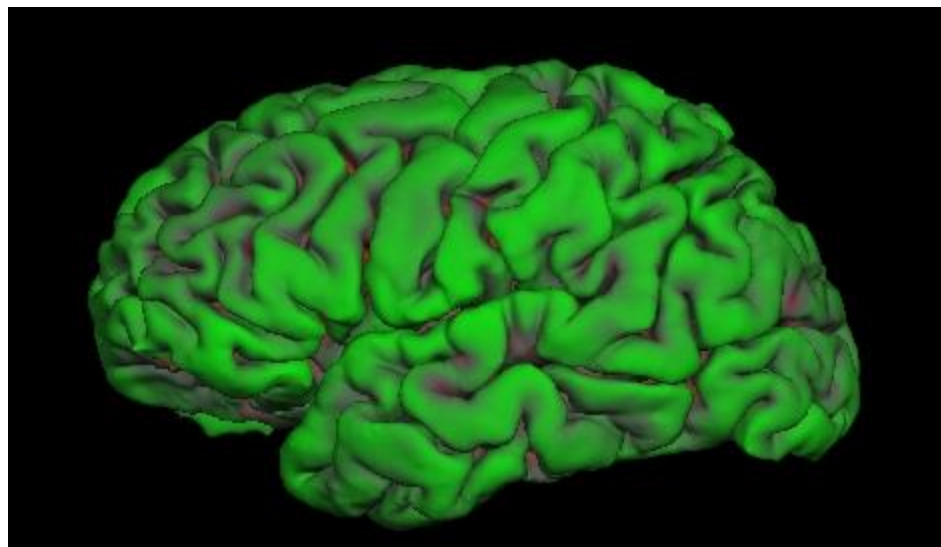
Inflated (lh and rh)

Spherical registration
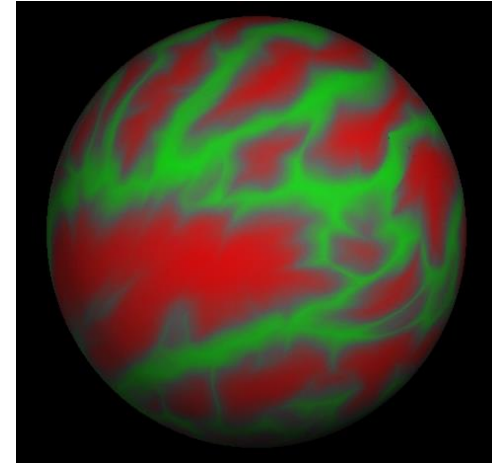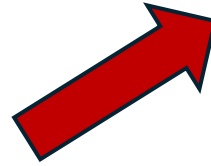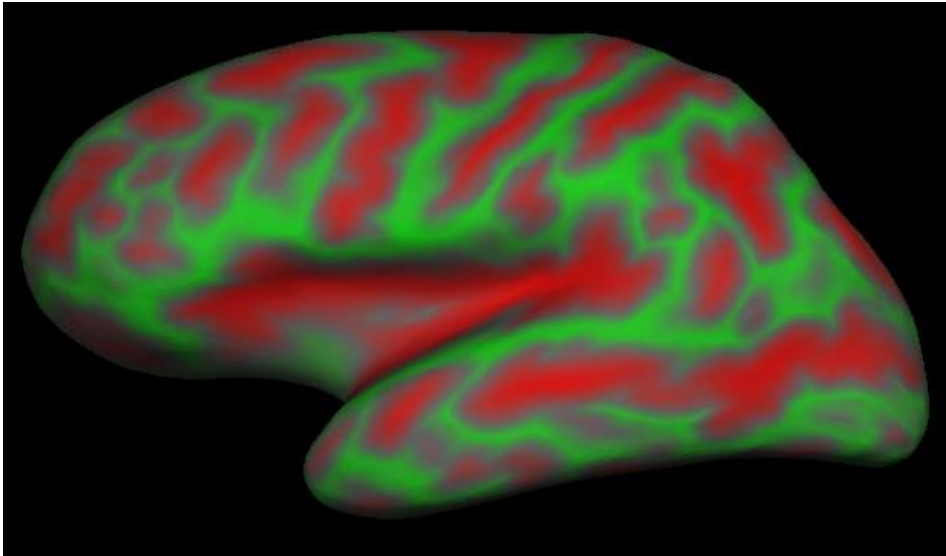
Lh.sphere
Rh.sphere
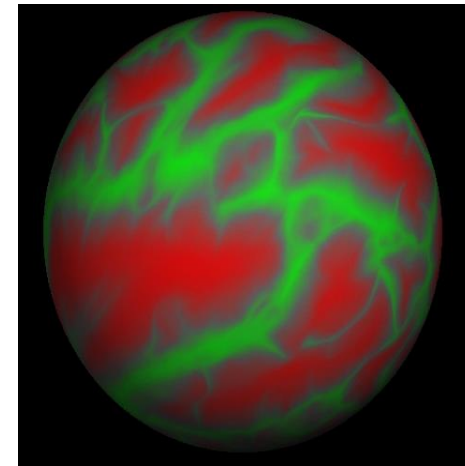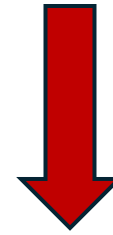
Lh.sphere.reg
Rh.sphere.reg

$SUBJECTS_DIR/fsaverage; 40 subjects

Cortical Surface Segmentation

Spherical Atlas based on Manual Labeling

$SUBJECTS_DIR/label/ {lh,rh}.aparc.annot

Map to Individual Thru Spherical Reg
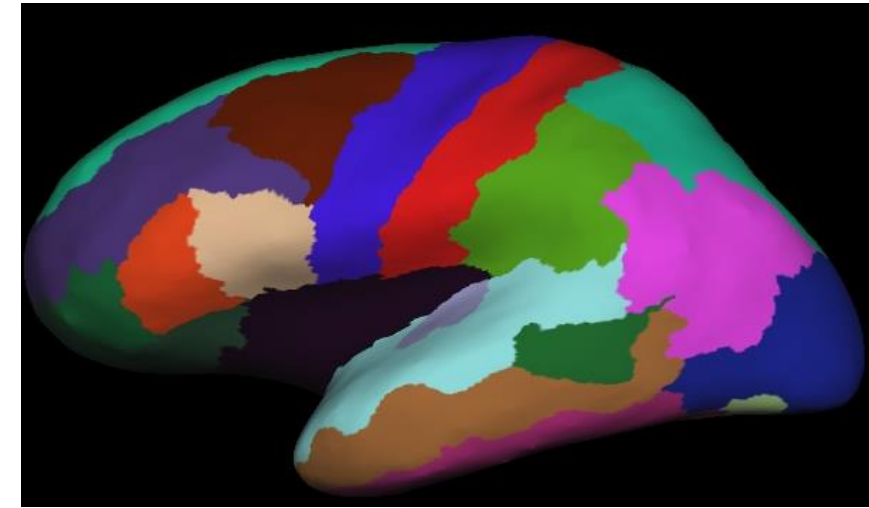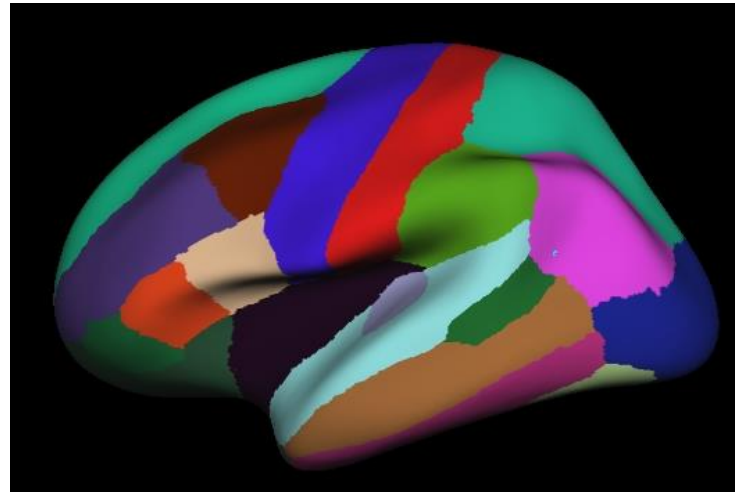
Fine-tune based on individual anatomy

Surface parcellations and Segmentations
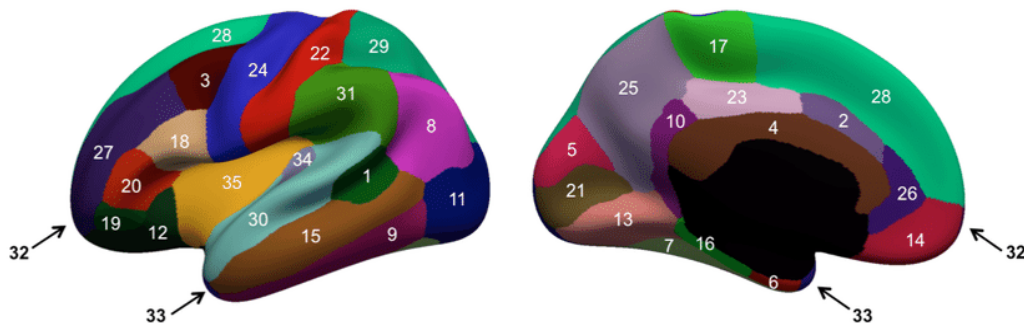
1. Bank of the Superior Temporal Sulcus	2. Caudal Anterior-cingulate Cortex
3. Caudal Middle Frontal Gyrus	4. Unmeasured Corpus Callosum
5. Cuneus Cortex	6. Entorhinal Cortex
7. Fusiform Gyrus	8. Inferior Parietal Cortex
9. Inferior Temporal Gyrus	10. Isthmus-cingulate Cortex
11. Lateral occipital cortex	12. Lateral orbital frontal cortex
13. Lingual gyrus	14. Medial orbital frontal cortex
15. Middle temporal gyrus	16. Parahippocampal gyrus
17. Paracentral lobule	18. Pars opercularis
19. Pars orbitalis	20. Pars triangularis
21. Pericalcarine cortex	22. Postcentral gyrus
23. Posterior-cingulate cortex	24. Precentral gyrus
25. Precuneus cortex	26. Rostral anterior cingulate cortex
27. Rostral middle frontal gyrus	28. Superior frontal gyrus
29. Superior parietal cortex	30. Superior temporal gyrus
31. Supramarginal gyrus	32. Frontal pole
33. Temporal pole	34. Transverse temporal cortex
35. Insula cortex	
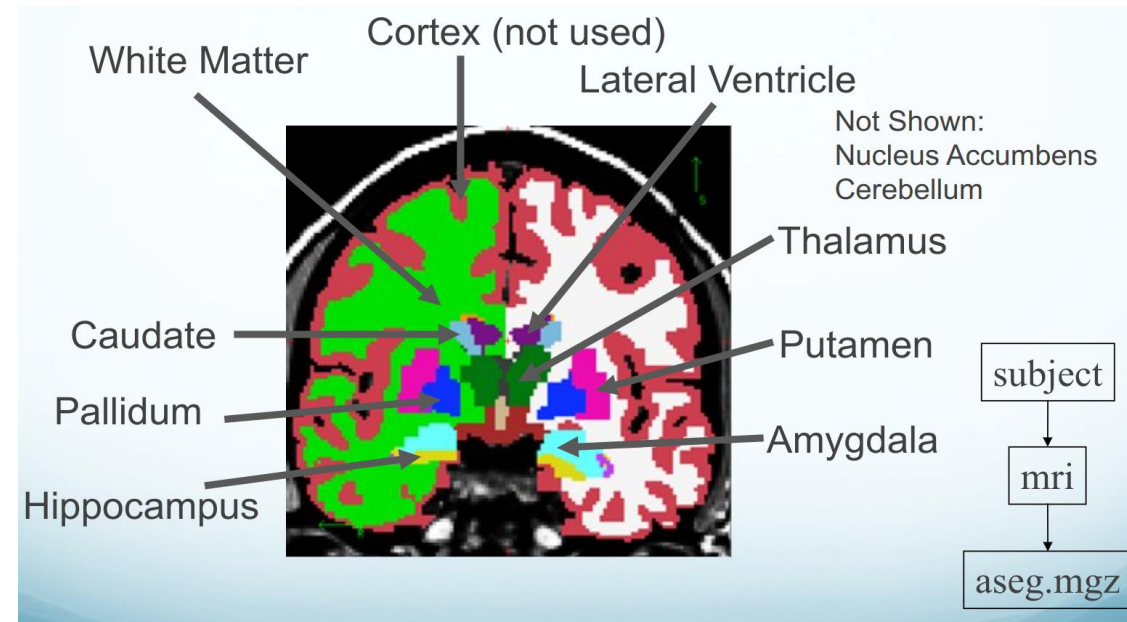
Desikan RS, ..., Killiany RJ. An automated labeling system for subdividing the human cerebral cortex on MRI scans into gyral based regions of interest. Neuroimage. 2006

Individual Processing Stream Overview

T1 Weighted Input → Skull Stripping → Intensity Normalization → Volumetric Labeling → Subcortical Mass → Surface Extraction → Surface Atlas Registration → Gyral Labeling → Stats
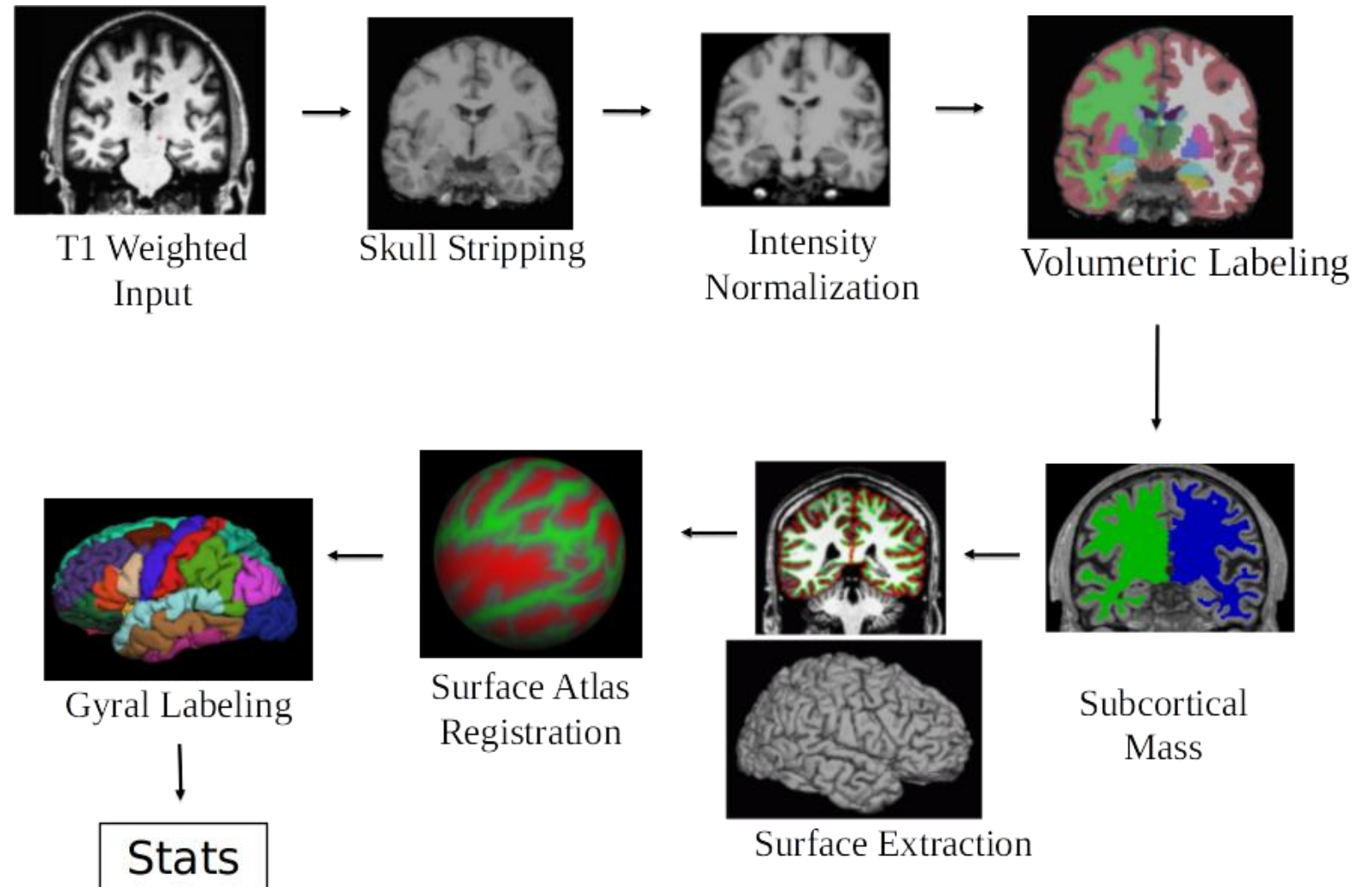
Freesurfer anatomical processing command

Set path to freesurfer installation

Then try "recon-all"

Fully Automated Reconstruction

recon-all   –i file.nii   –subject bert   –all
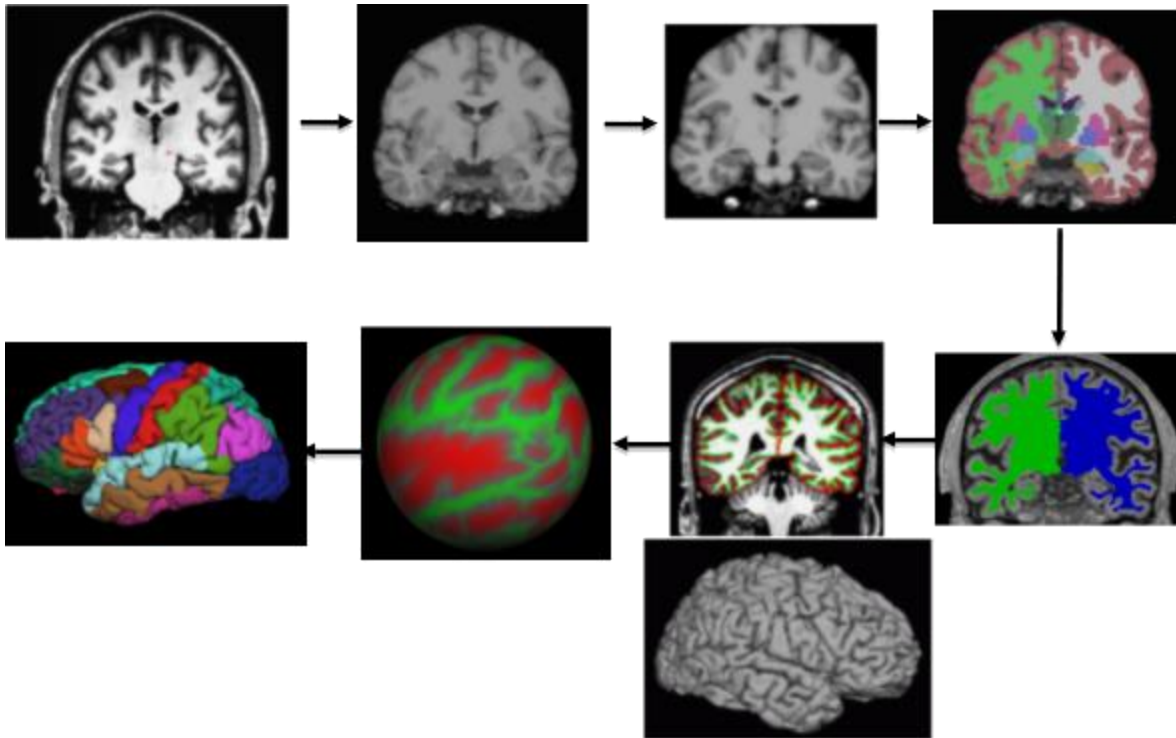
"file.nii" is a single NiFTI file pointing to the T1 MRI image

Freesurfer output variable

"$SUBJECTS_DIR"

Fully Automated Reconstruction

recon-all –i file.nii –subject bert –all
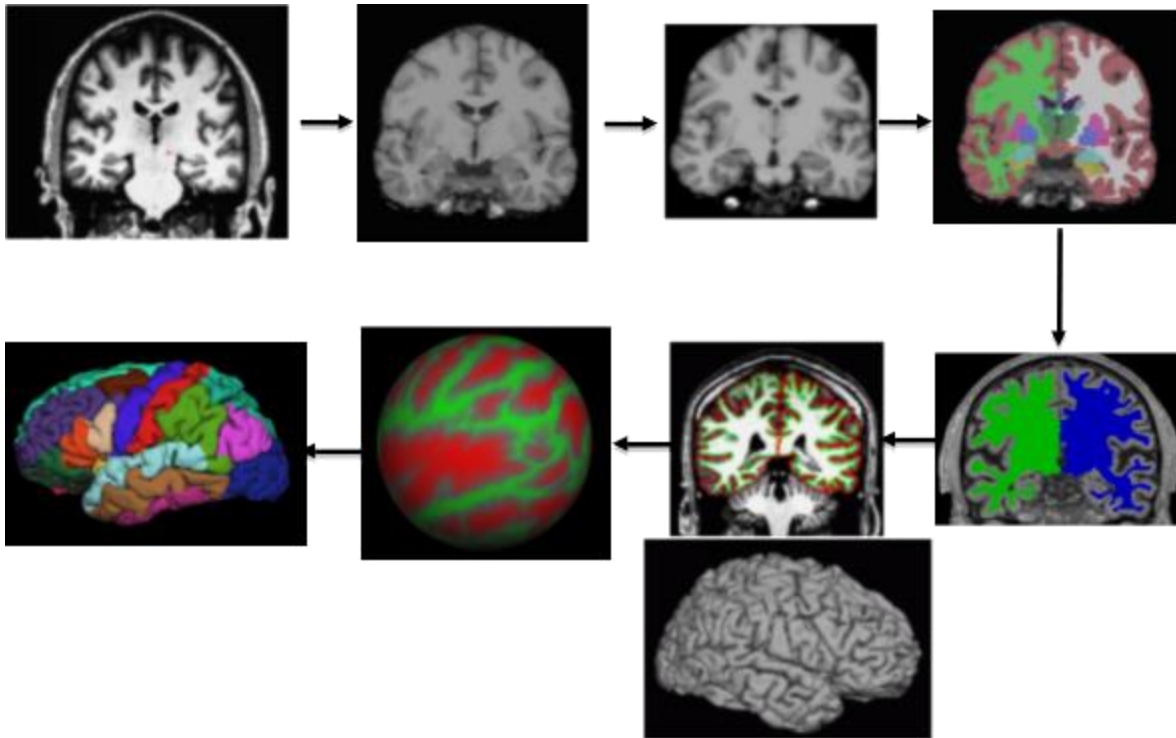
"bert" is the "name" of the subject

Creates a folder in $SUBJECTS_DIR

Fully Automated Reconstruction

recon-all –i file.nii –subject bert –all
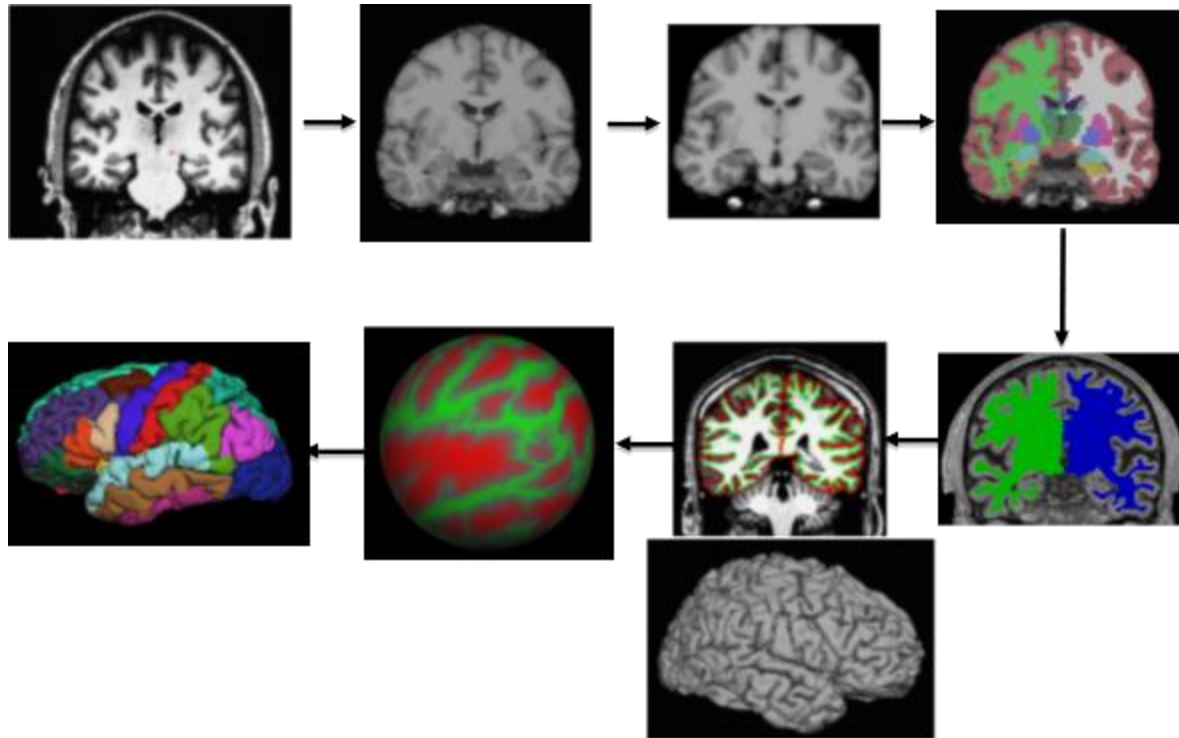
"-all" means do everything

5-10 hours on single CPU

Copyright: Freesurfer https://surfer.nmr.mgh.harvard.edu/fswiki/FreeSurferMethodsCitation

Fully-Automated Directive

-autorecon1	process steps 1-5 (see below)
-autorecon2	process steps 6-23
	after autorecon2, check final surfaces:
	a. if wm edit was required, then run -autorecon2-wm
	b. if control points added, then run -autorecon2-cp
	c. if edits made to correct pial, then run -autorecon2-pial
	d. proceed to run -autorecon3
-autorecon2-cp	process stages 12-23 (uses -f w/ mri_normalize, -keep w/ mri_seg
-autorecon2-wm	process stages 15-23
-autorecon2-pial	process stages 21-23
-autorecon3	process stages 24-31
-hemi ?h	just do lh or rh (default is to do both)

Autorecon Processing Stages (see -autorecon# flags above):
1. Motion Correction and Conform
2. NU (Non-Uniform intensity normalization)
3. Talairach transform computation
4. Intensity Normalization 1
5. Skull Strip

6. EM Register (linear volumetric registration)
7. CA Intensity Normalization
8. CA Non-linear Volumetric Registration
9. Remove Neck
10. LTA with Skull
11. CA Label (Volumetric Labeling, ie Aseg) and Statistics

12. Intensity Normalization 2 (start here for control points)
13. White matter segmentation
14. Edit WM With ASeg
15. Fill (start here for wm edits)
16. Tessellation (begins per-hemisphere operations)
17. Smooth1
18. Inflate1
19. QSphere
20. Automatic Topology Fixer
21. Final Surfs (start here for brain edits for pial surf)
22. Smooth2
23. Inflate2

24. Spherical Mapping
25. Spherical Registration
26. Spherical Registration, Contralateral hemisphere
27. Map average curvature to subject
28. Cortical Parcellation - Desikan_Killiany and Christophe (Labeling)
29. Cortical Parcellation Statistics
30. Cortical Ribbon Mask
31. Cortical Parcellation mapping to Aseg

recon-all –i file.nii –subject bert –all

Upon successful completion of recon-all

$SUBJECTS_DIR/bert

scripts   mri   surf
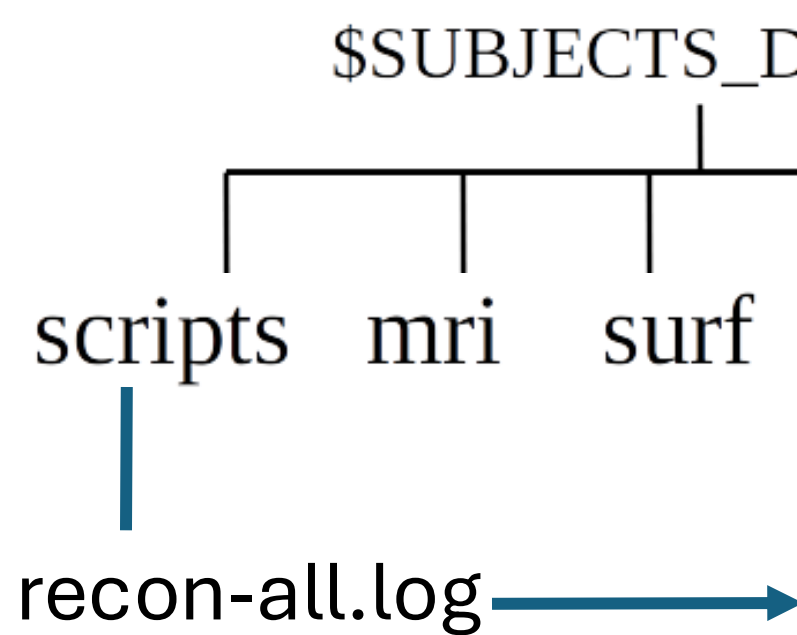
recon-all.log

```
Thu Aug  5 14:11:38 IST 2021
/media/cogsci/SeagateBackupPlusDrive/madhukar/ADNI/processed/011_S_4075_tp0
/home/cogsci/AJP/freesurfer/bin/recon-all
-all -s 011_S_4075_tp0 -i 011_S_4075_tp0_T1w.nii.gz -cw256
subjid 011_S_4075_tp0
setenv SUBJECTS_DIR /media/cogsci/SeagateBackupPlusDrive/madhukar/ADNI/processed
FREESURFER_HOME /home/cogsci/AJP/freesurfer
Actual FREESURFER_HOME /home/cogsci/AJP/freesurfer
build-stamp.txt: freesurfer-Linux-centos6_x86_64-stable-pub-v6.0.0-2beb96c
Linux cogsci-server 4.15.0-142-generic #146~16.04.1-Ubuntu SMP Tue Apr 13 09:27:15 UTC 2021 x86_64 x86_64 x86_64 GNU/Linux
cputime         unlimited
filesize        unlimited
datasize        unlimited
stacksize       8192 kbytes
coredumpsize 0 kbytes
memoryuse       unlimited
vmemoryuse      unlimited
descriptors  1024
memorylocked 64 kbytes
maxproc         192534
maxlocks        unlimited
maxsignal       192534
maxmessage   819200
maxnice         0
maxrtprio       0
maxrttime       unlimited

                total        used        free    shared  buff/cache    available
Mem:        49360620    11573968     1712488    218268    36074164    36764268
Swap:       16678908      339968    16338940

#######################################
program versions used
$Id: recon-all,v 1.580.2.16 2017/01/18 14:11:24 zkaufman Exp $
$Id: mri_motion_correct.fsl,v 1.15 2016/02/16 17:17:20 zkaufman Exp $
mri_convert.bin -all-info
ProgramName: mri_convert.bin  ProgramArguments: -all-info  ProgramVersion: $Name: stable6 $  TimeStamp: 2021/08/05-08:41:38-GMT  BuildTimeStamp: Jan 18 2
3732    2252    4770  1.950 0.500     0.128     0.230     95      5.7  V1_exvivo
4505    2659    5723  1.980 0.457     0.136     0.039     68      7.2  V2_exvivo
 315     203     703  2.726 0.322     0.127     0.029      4      0.4  MT_exvivo
 355     237    1469  4.212 0.737     0.087     0.018      2      0.3  perirhinal_exvivo
 224     157     611  3.152 0.634     0.122     0.023      2      0.2  entorhinal_exvivo

Started at Thu Aug 5 14:11:38 IST 2021
Ended   at Fri Aug 6 00:43:21 IST 2021
#@#%# recon-all-run-time-hours 10.529
recon-all -s 011_S_4075_tp0 finished without error at Fri Aug  6 00:43:21 IST 2021
```

Upon successful completion of recon-all

Viewing volumes with Freeview

set $SUBJECTS_DIR"

freeview -v \
011_S_4075_tp0/mri/T1.mgz \
011_S_4075_tp0/mri/wm.mgz \
011_S_4075_tp0/mri/brainmask.mgz \
011_S_4075_tp0/mri/aseg.mgz:colormap=lut:opacity=0.2 \
-f 011_S_4075_tp0/surf/lh.white:edgecolor=blue \
011_S_4075_tp0/surf/lh.pial:edgecolor=red \
011_S_4075_tp0/surf/rh.white:edgecolor=blue \
011_S_4075_tp0/surf/rh.pial:edgecolor=red

Upon successful completion of recon-all

Upon successful completion of recon-all

$SUBJECTS_DIR/bert

scripts   mri   surf   label   stats

lh.aparc.annot

lh.aparc.a2009s.annot

rh.aparc.annot

rh.aparc.a2009s.annot

Desikan/Killiany Atlas

Destrieux Atlas
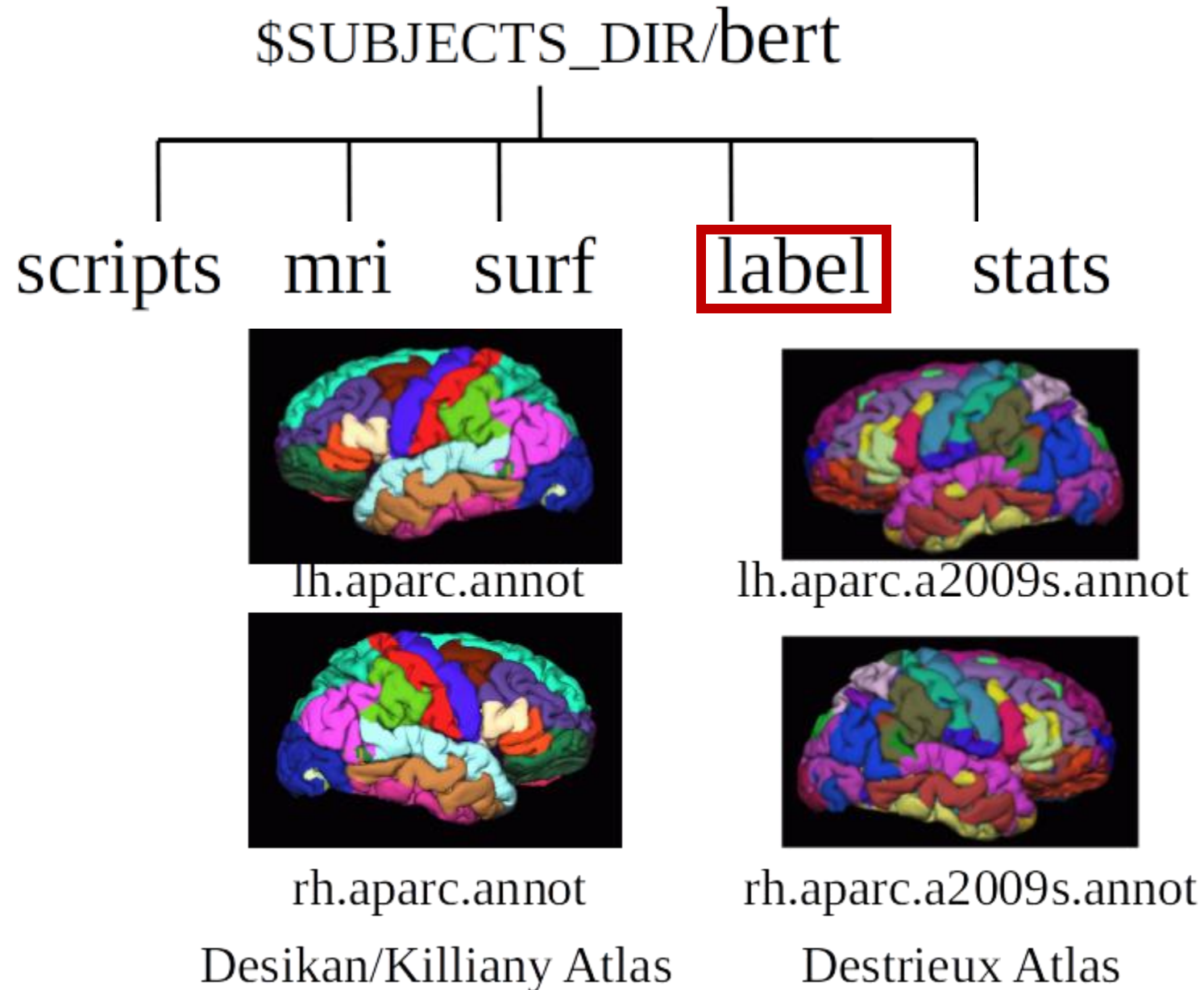
Viewing surface atlases with freeview

set $SUBJECTS_DIR"

freeview -f
011_S_4075_tp0/surf/lh.pial:annot=aparc.annot:name=pial_a
parc:visible=0 \
011_S_4075_tp0/surf/lh.pial:annot=aparc.a2009s.annot:nam
e=pial_aparc_des:visible=0 \
011_S_4075_tp0/surf/lh.inflated:overlay=lh.thickness:overlay
_threshold=0.1,3::name=inflated_thickness:visible=0 \
011_S_4075_tp0/surf/lh.inflated:visible=0 \
011_S_4075_tp0/surf/lh.white:visible=0 \
011_S_4075_tp0/surf/lh.pial \
--viewport 3d

Upon successful completion of recon-all

$SUBJECTS_DIR/bert

scripts mri surf label stats
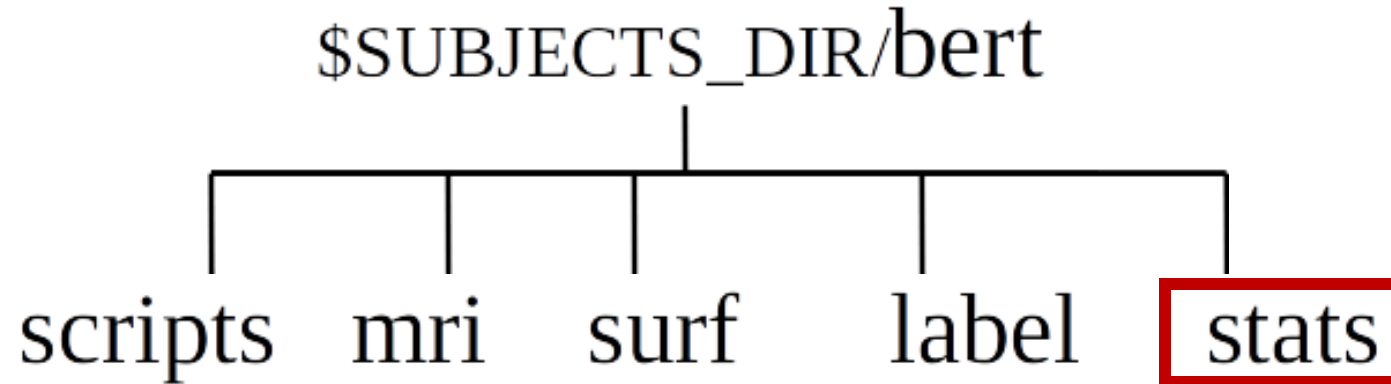
- aseg.stats -- subcortical volumetric stats
- wmparc.stats -- white matter segmentation volumetric stats
- lh/rh.aparc.stats -- left/right hemi Desikan Killiany surface atlas
- lh/rh.aparc.a2009.stats -- left/right hemi Destrieux

ROI summaries – stats folder

Index	SegId	NVoxels	Volume_mm3	StructName	Mean	StdDev	Min	Max	Range
1	4	7230	7553.6	Left-Lateral-Ventricle	29.2	12.5	11.0	91.0	80.0
2	5	267	311.1	Left-Inf-Lat-Vent	51.3	11.5	14.0	84.0	70.0
3	7	10858	11506.0	Left-Cerebellum-White-Matter	86.8	6.7	24.0	106.0	82.0
4	8	50468	50270.0	Left-Cerebellum-Cortex	63.6	11.0	5.0	95.0	90.0
5	10	6625	6379.0	Left-Thalamus-Proper	91.6	8.8	40.0	111.0	71.0
6	11	3335	3407.1	Left-Caudate	81.2	7.1	50.0	100.0	50.0
7	12	4369	4385.7	Left-Putamen	87.2	5.2	57.0	106.0	49.0
8	13	1943	1923.6	Left-Pallidum	98.7	3.9	65.0	112.0	47.0
11	16	17918	17745.1	Brain-Stem	85.7	10.5	25.0	108.0	83.0
12	17	4014	3842.1	Left-Hippocampus	71.1	7.7	26.0	101.0	75.0
13	18	1598	1559.4	Left-Amygdala	72.8	6.4	27.0	97.0	70.0

Routines to generate spread sheets for multiple subjects
- asegstats2table --help
- aparcstats2table --help

Alzheimer's Disease Neuroimaging Initiative

- ADNI
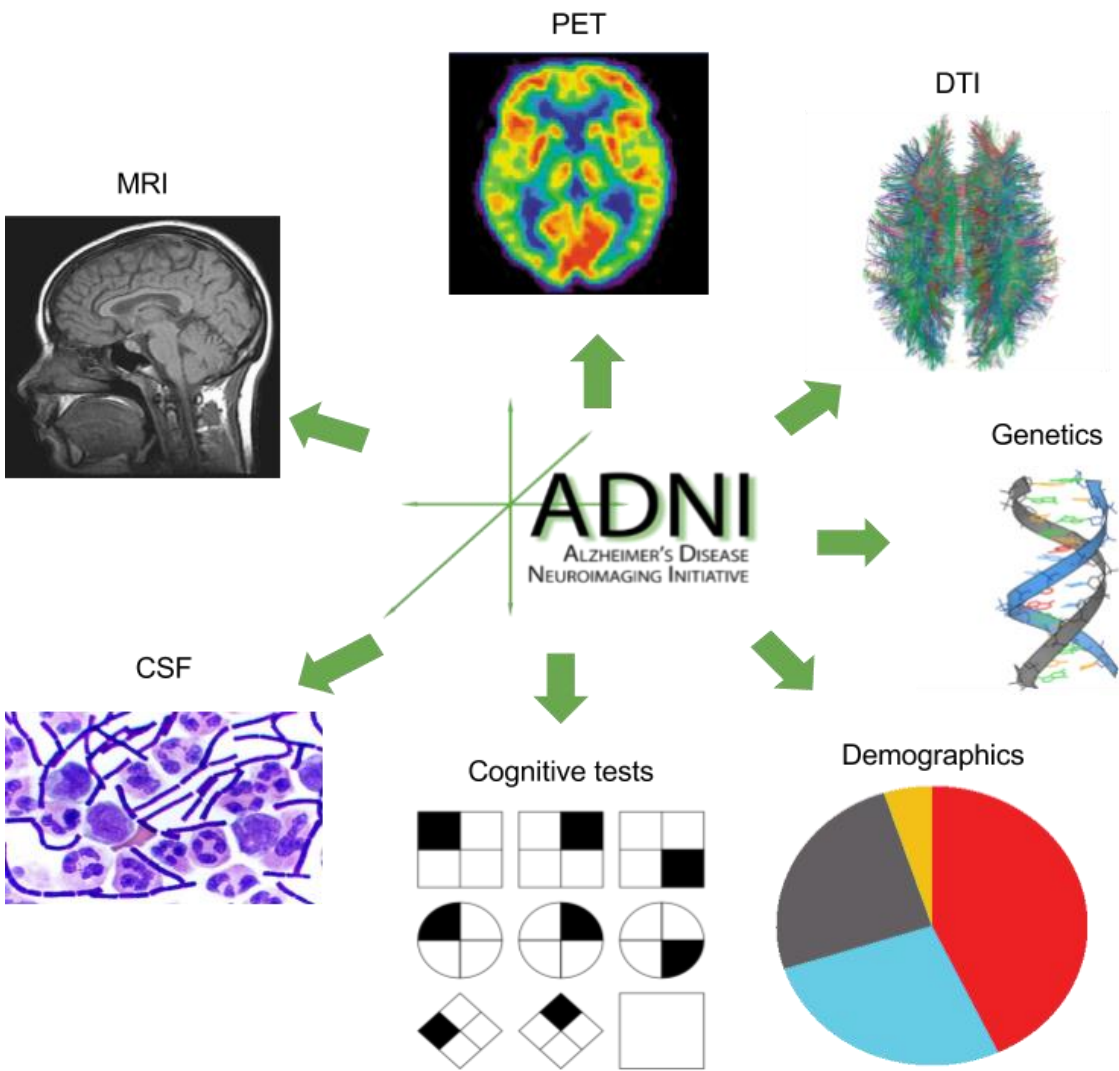
Table 1	Schedule of evaluations for normal subjects, subjects with mild cognitive impairment, and subjects with Alzheimer disease						
	Screening/ baseline visit	Month 6	Month 12	Month 18	Month 24	Month 30	Month 36
Normal							
Clinical	X	X	X		X		X
MRI 1.5	X	X	X		X		X
MRI 3	X		X	X			X
PET							
CSF							
Blood							
Telephone							
Mild cognitive impairment							
Clinical							
MRI 1.5							
MRI 3							
PET	X	X	X	X	X		X
CSF	X		X				
Blood	X	X			X	X	X
Telephone	X		X		X		X
Alzheimer disease							
Clinical	X	X	X		X		
MRI 1.5	X	X	X		X		
PET	X	X	X		X		
CSF	X		X				
Blood	X	X	X		X		
Telephone			X				

Ø 2000 subjects
➢ 8000 scans

Petersen RC, ..,Toga AW, Trojanowski JQ, Weiner MW. Alzheimer's Disease Neuroimaging Initiative (ADNI): clinical characterization. Neurology. 2010 Jan 19;74(3):201-9.

This session

- ADNI
  - Baseline visit
  - Number of subjects: 98
  - Age matched: 75/73 (CN/AD)
  - Gender: M/F (45/53)
  - Cognitively Normal : 51 --   M/F (21/30)
  - Alzheimer's Disease : 47 – M/F (24/23)
  - MMSE : 19-30
    - Severe cognitive impairment: 0-17
    - Mild cognitive impairment: 18-23
    - No cognitive impairment: 24-30

MMSE