ANATOMICAL NEUROIMAGING

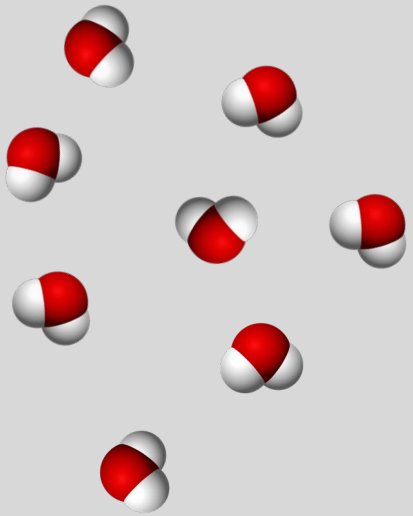
Josh Cochran

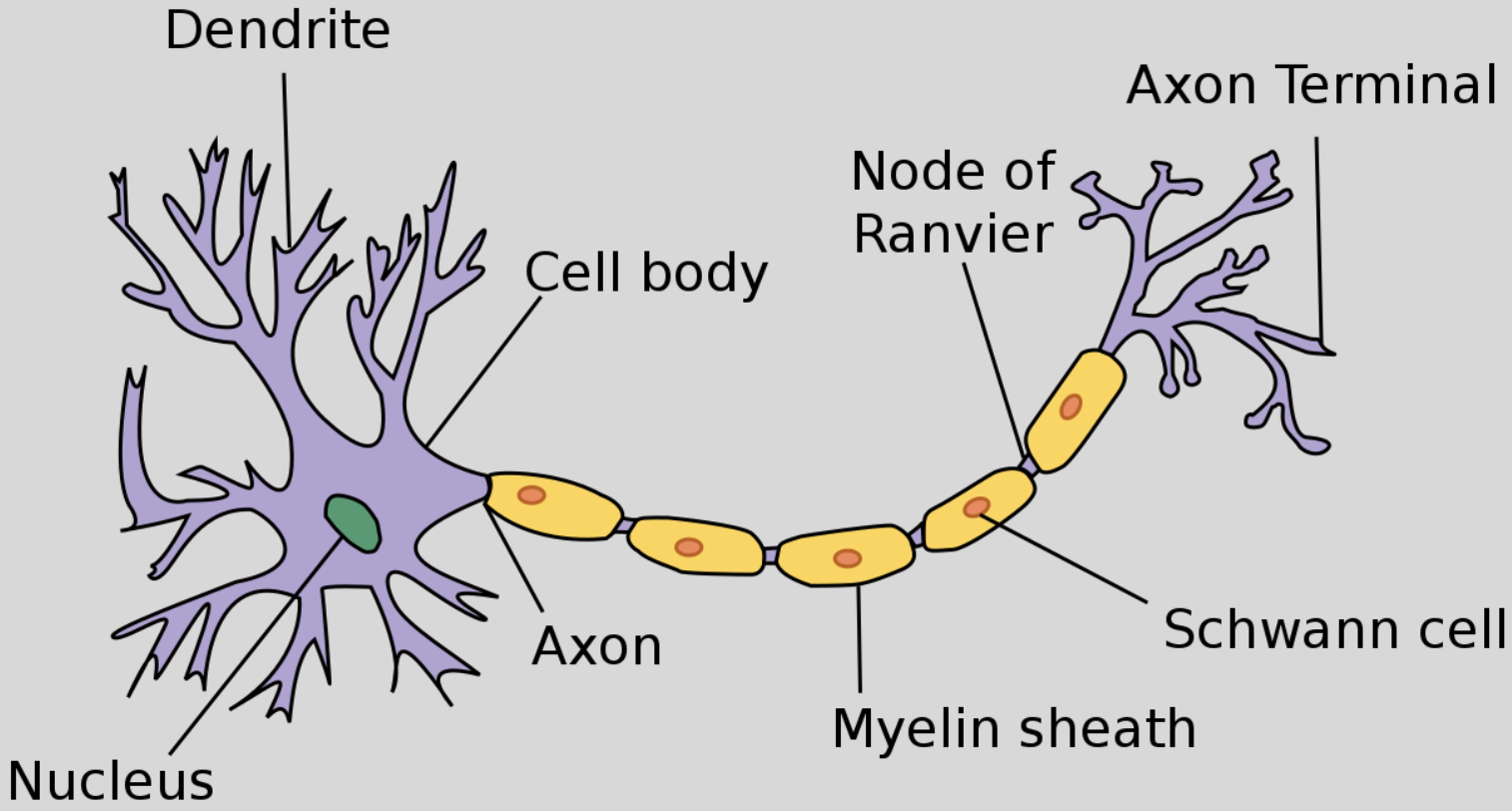
Overview

- Anatomical and physics refresher
- Anatomical scans
  - How to differentiate them and what you can see
- Anatomical image processing
  - What needs to be done and what you get from it

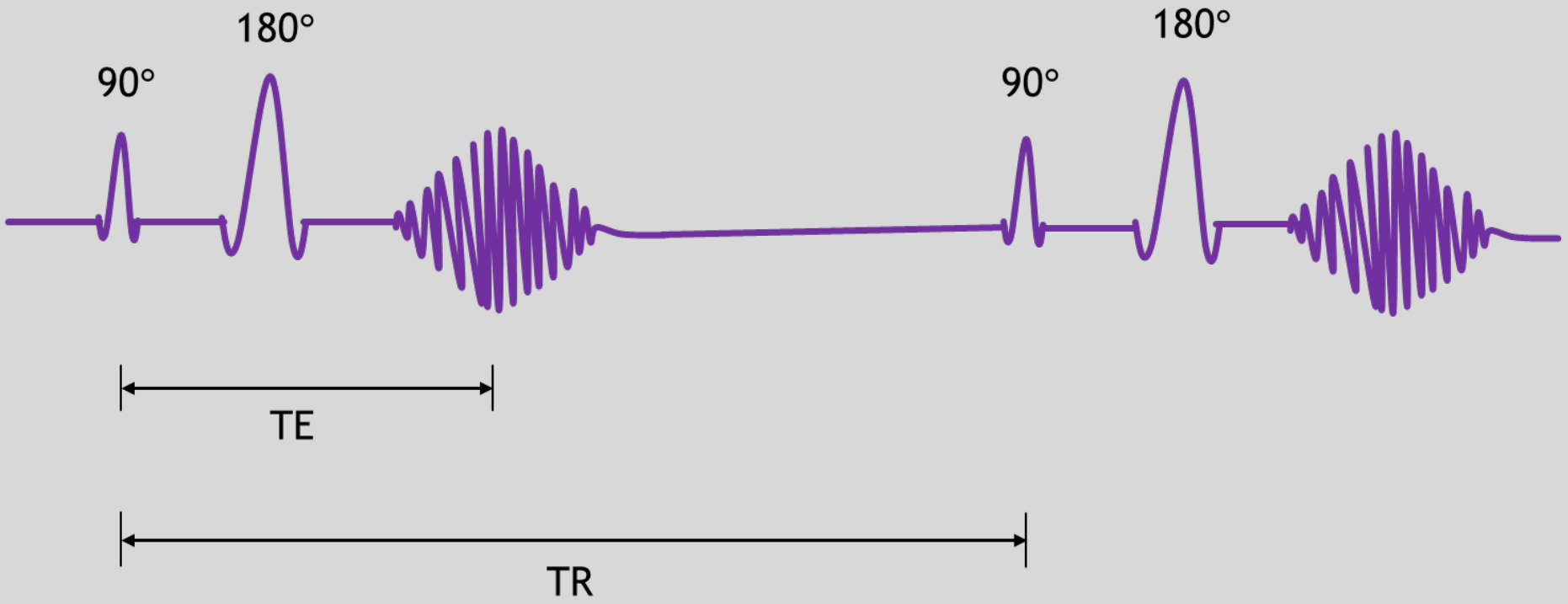
Main Components of the Brain

Water



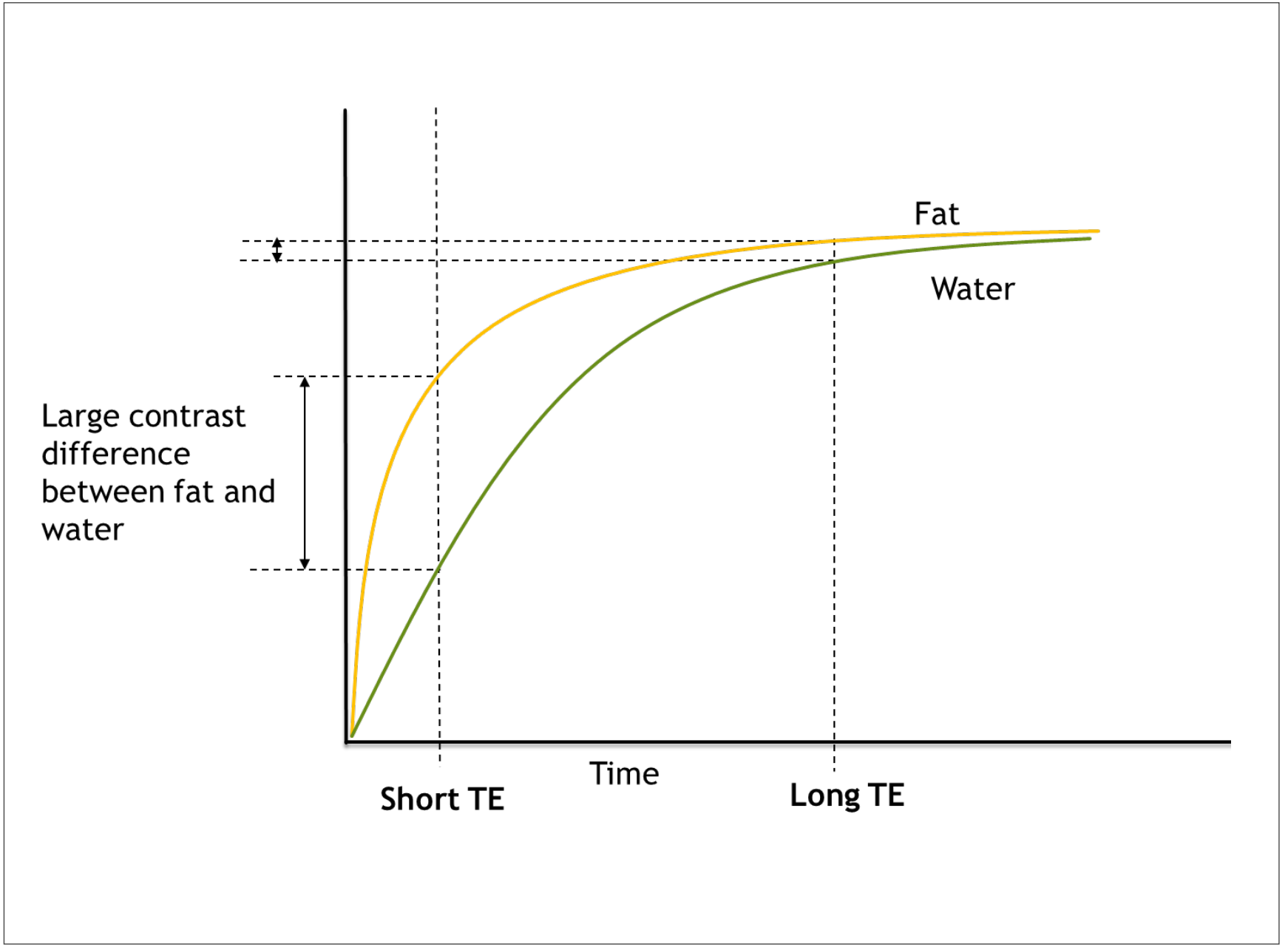


MRI Physics Refresher



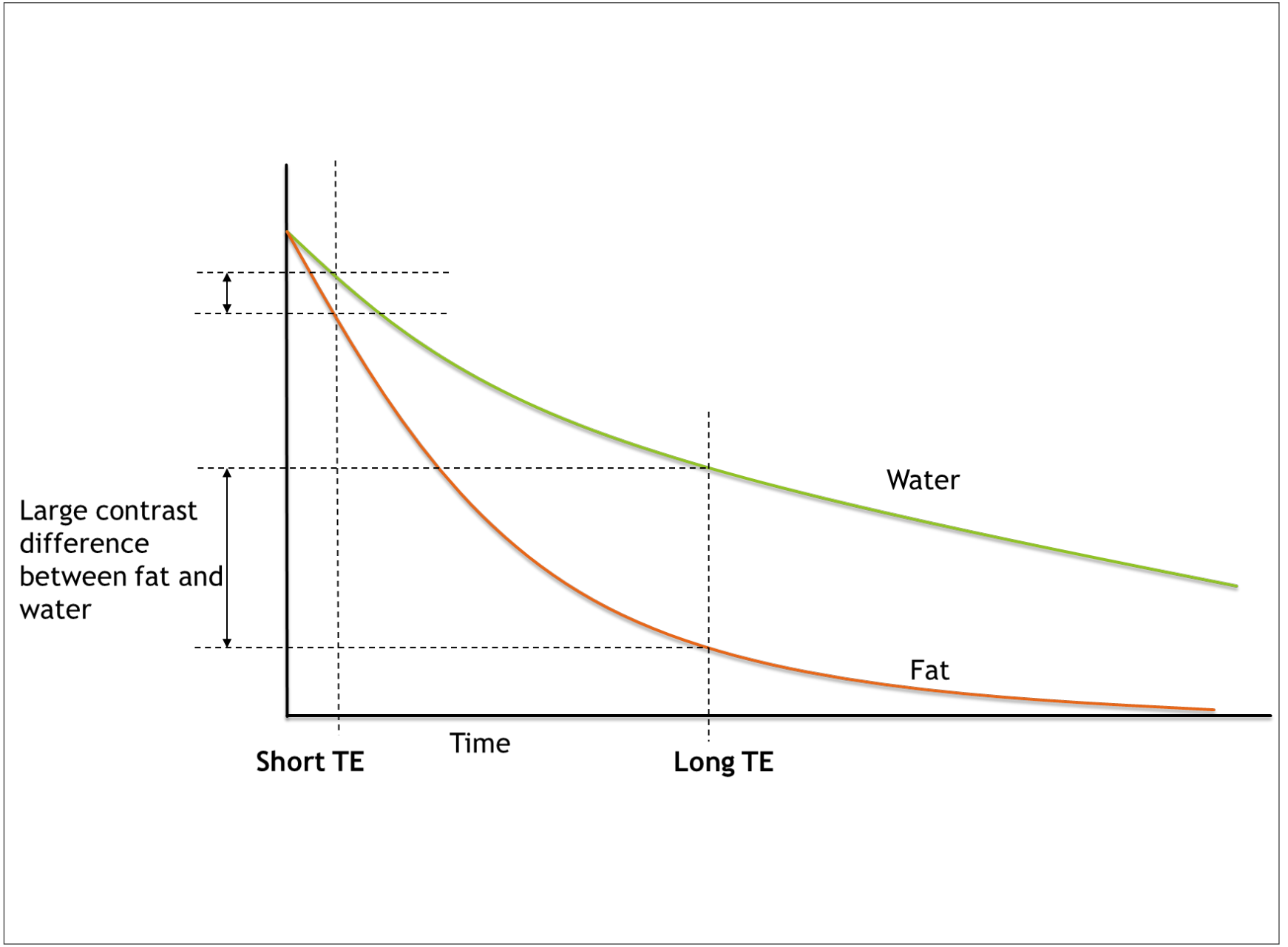
T1w


z=79


Fat
Water
Large contrast difference between fat and water
Time
Short TE
Long TE

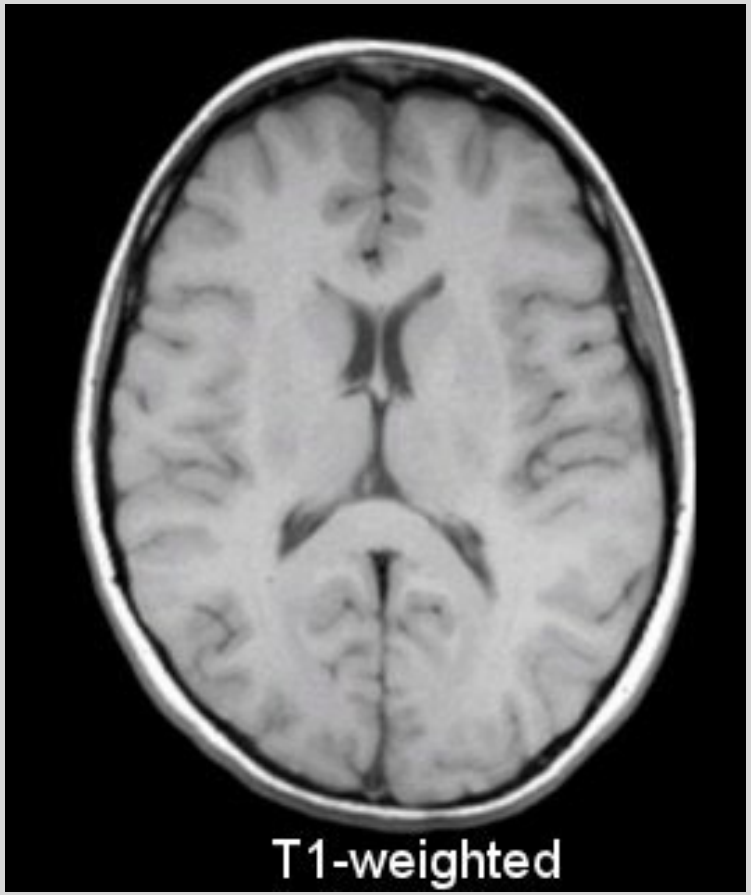
T2w


z=79


Large contrast difference between fat and water
Water
Fat
Time
Short TE
Long TE

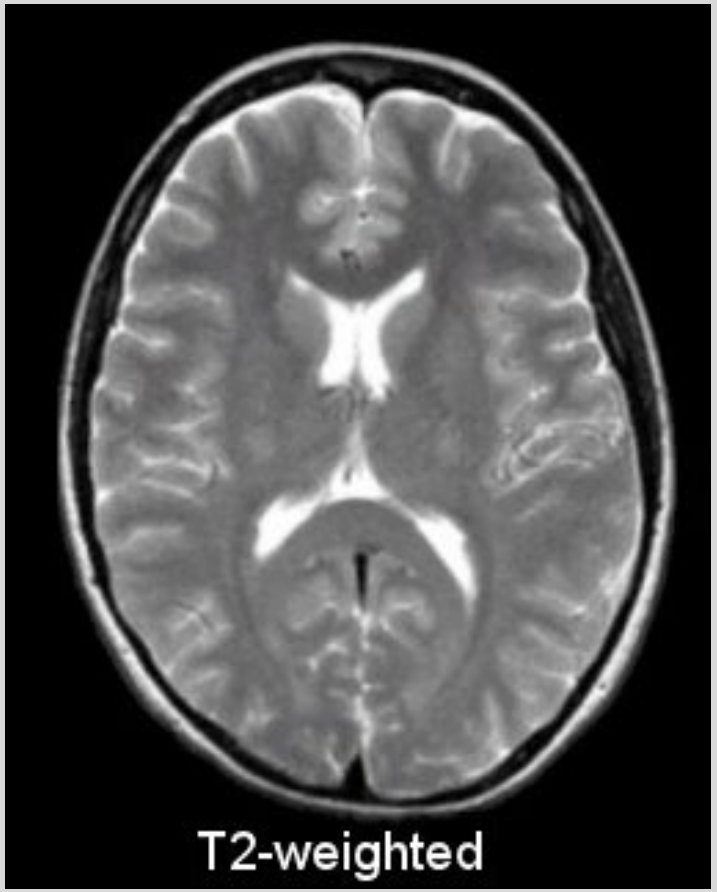
T1w Images

	TR (msec)	TE (msec)
T1-Weighted (short TR and TE)	**500**	**14**
T2-Weighted (long TR and TE)	**4000**	**90**
Flair (very long TR and TE	**9000**	**114**



T2w Images

	TR (msec)	TE (msec)
T1-Weighted (short TR and TE)	**500**	**14**
T2-Weighted (long TR and TE)	**4000**	**90**
Flair (very long TR and TE	**9000**	**114**



Flair Images

	TR (msec)	TE (msec)
T1-Weighted (short TR and TE)	**500**	**14**
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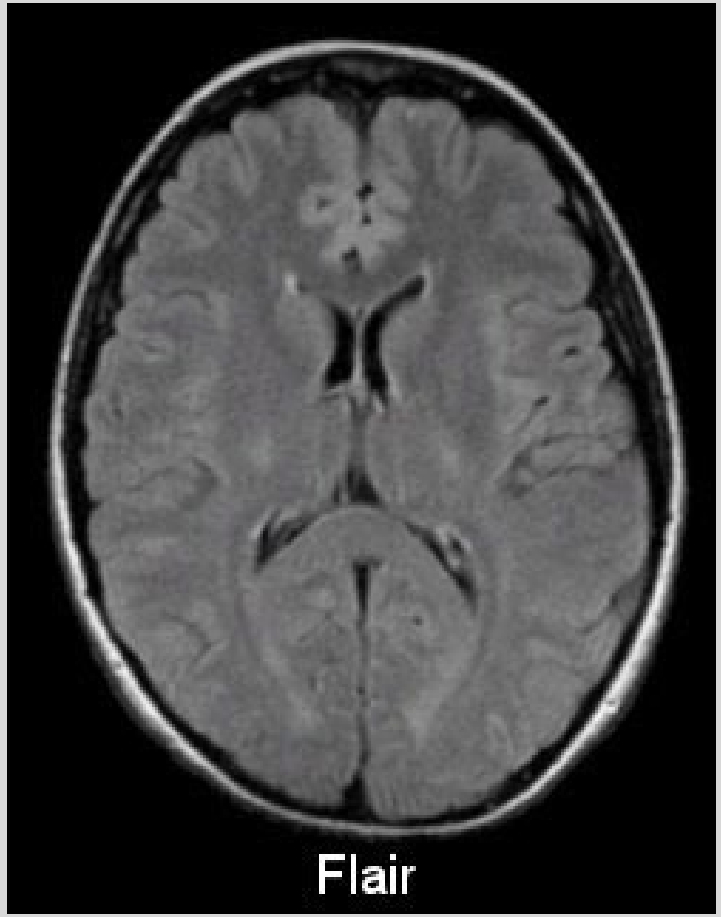
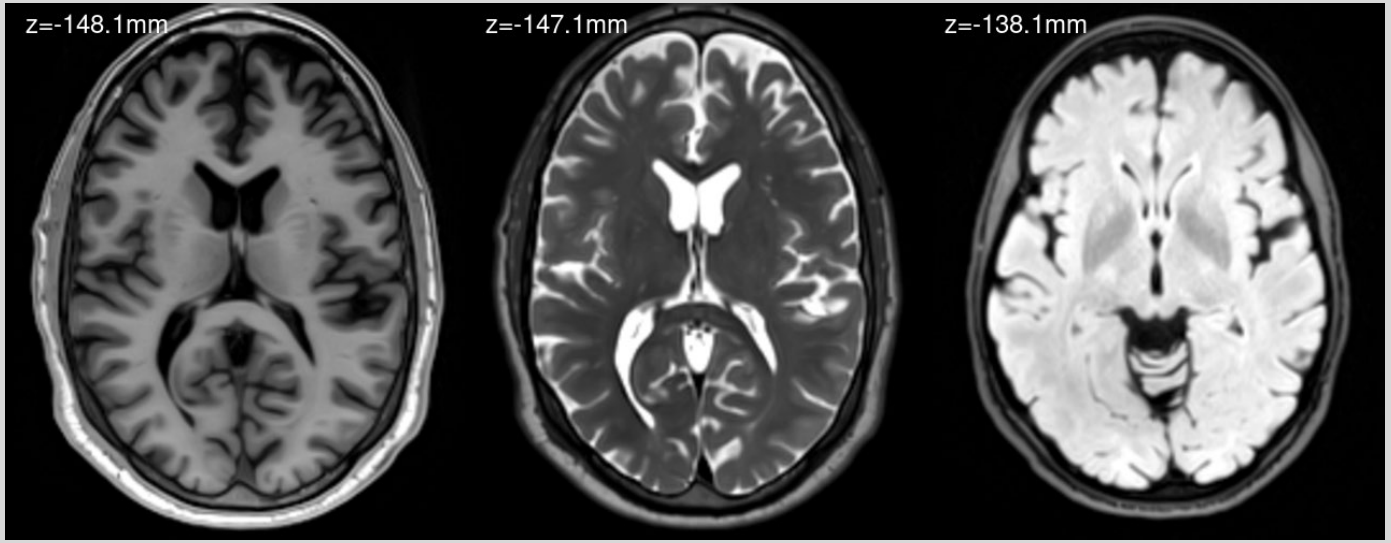
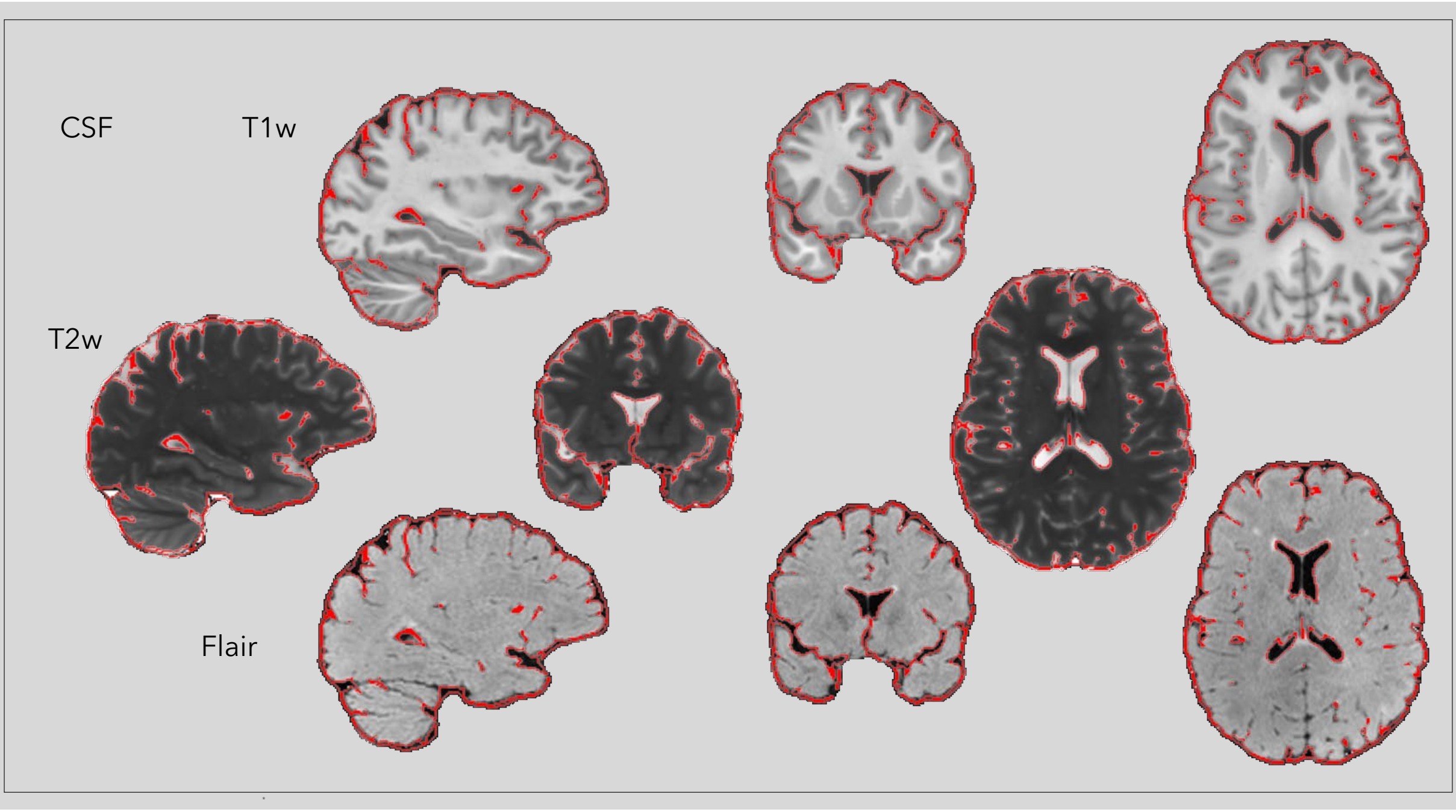
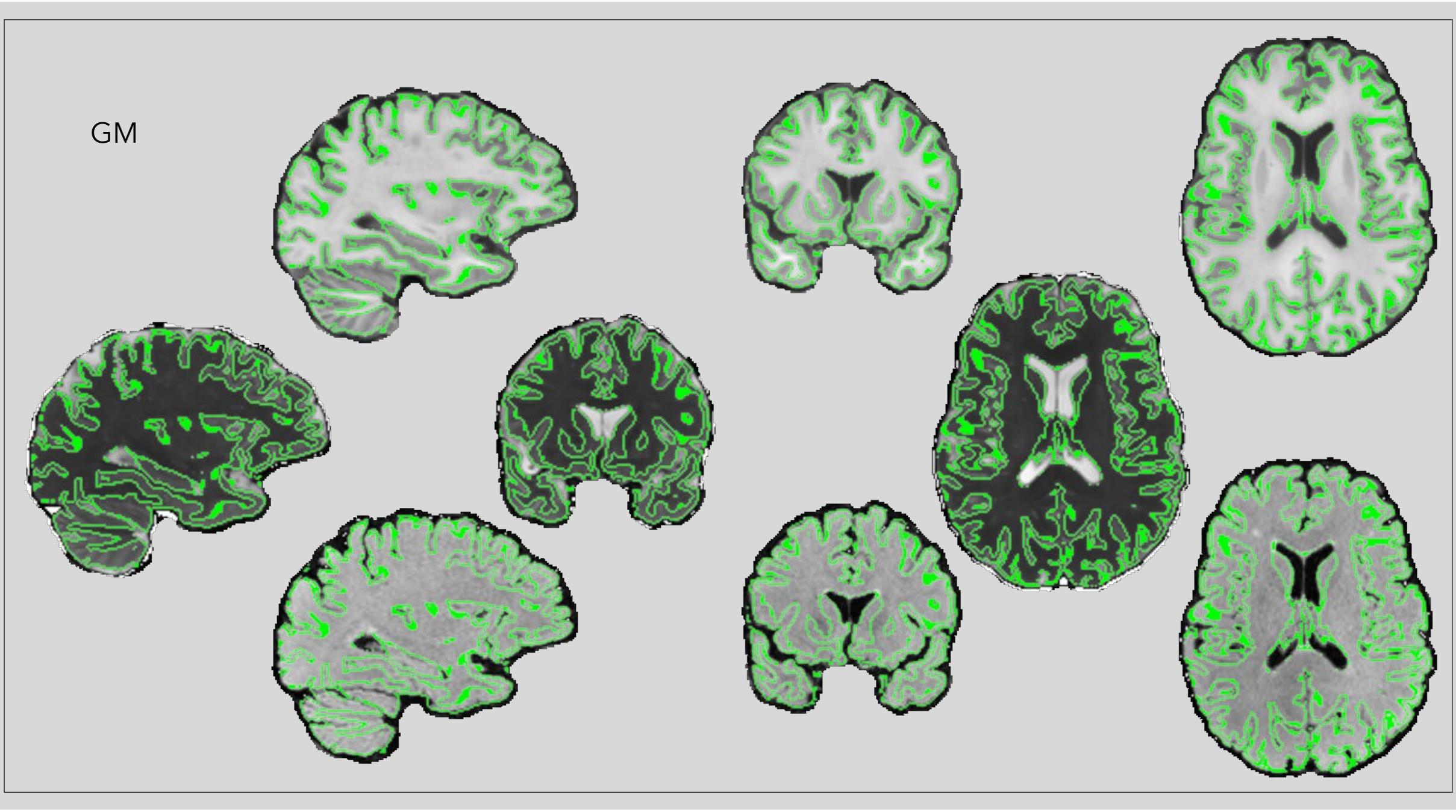
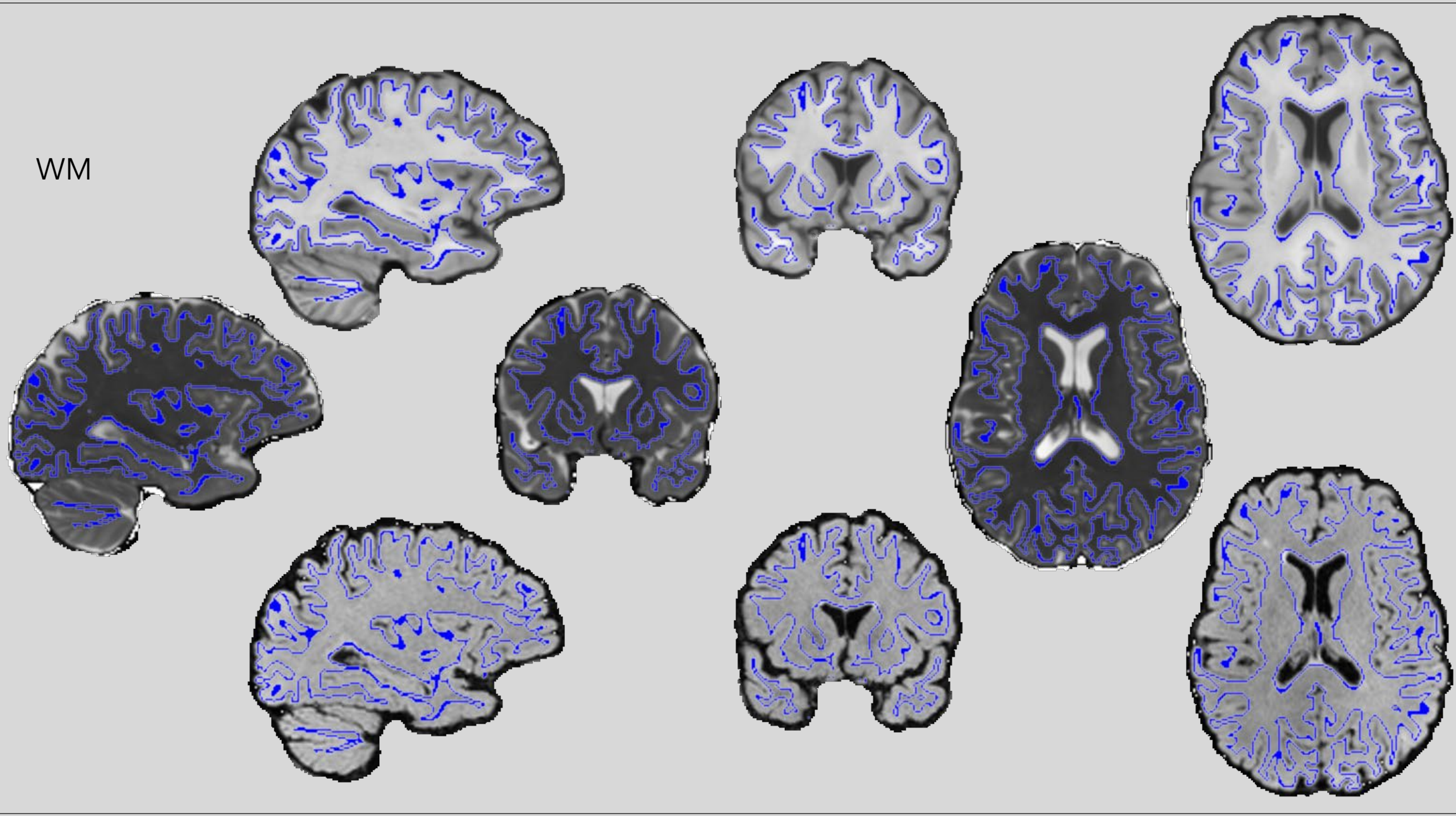


	T1-Weighted	T2-Weighted	Flair
CSF	Dark	Bright	Dark
White Matter	Light	Dark Gray	Dark Gray
Gray Matter	Gray	Light Gray	Light Gray

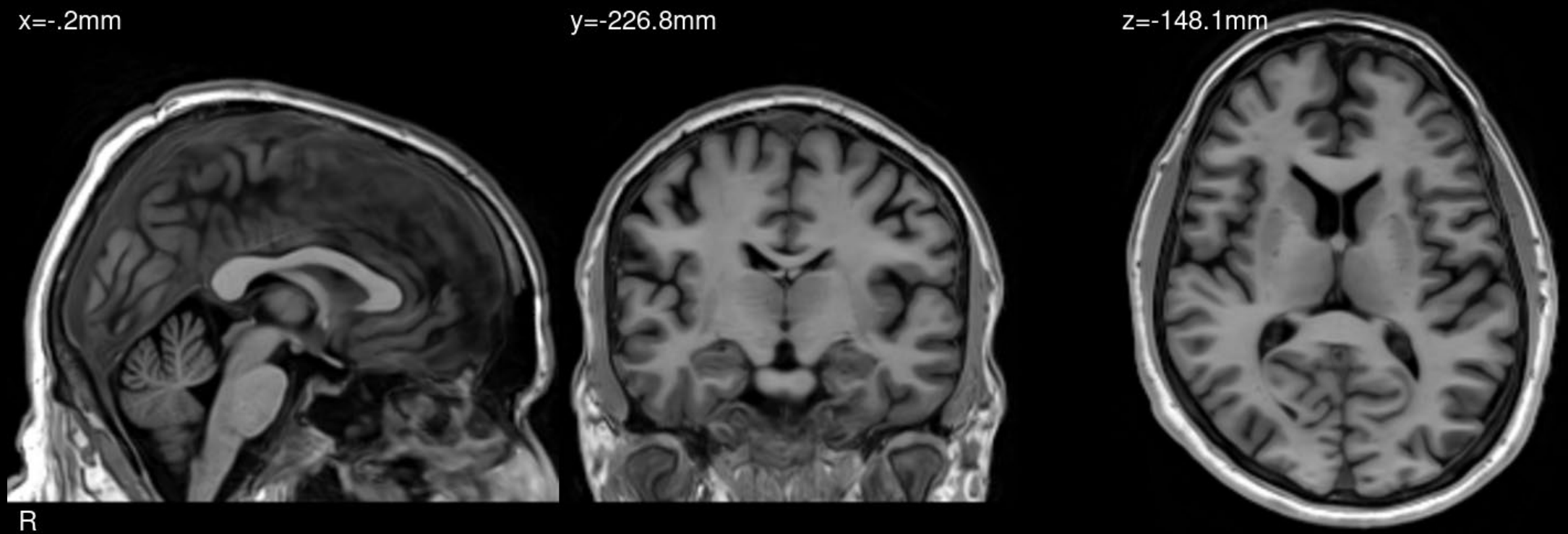



CSF
T1w
T2w
Flair


GM


WM

QUIZ TIME!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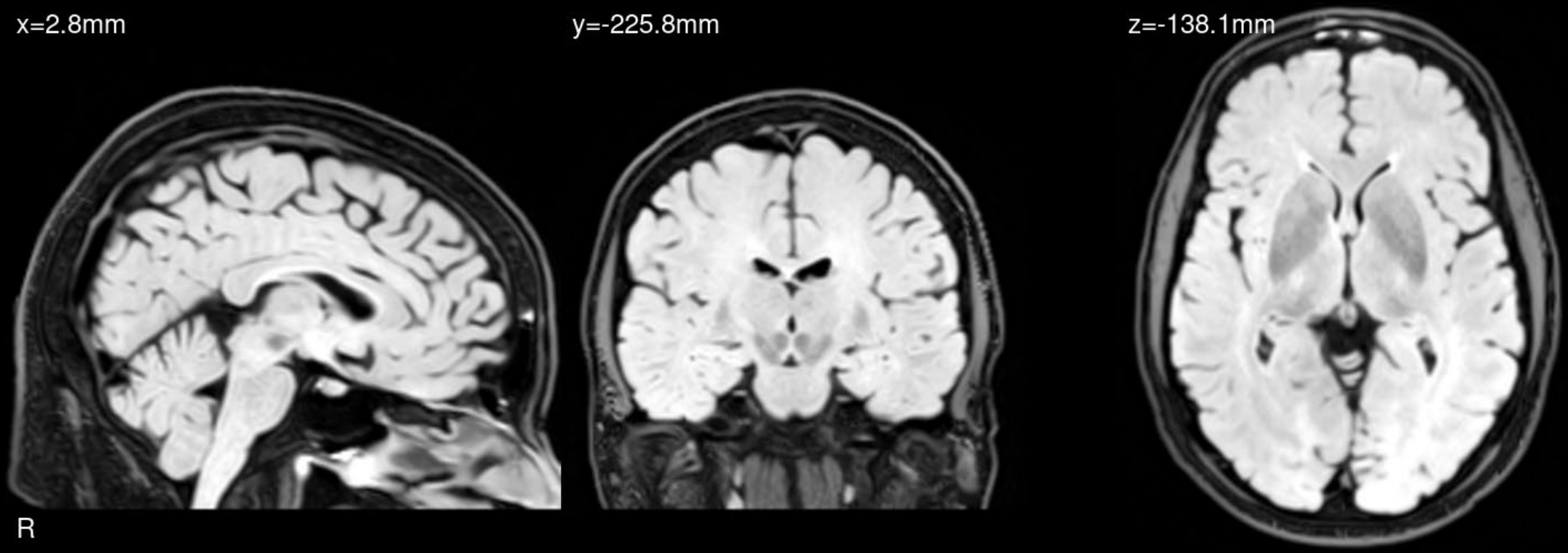
z=-148.1mm
R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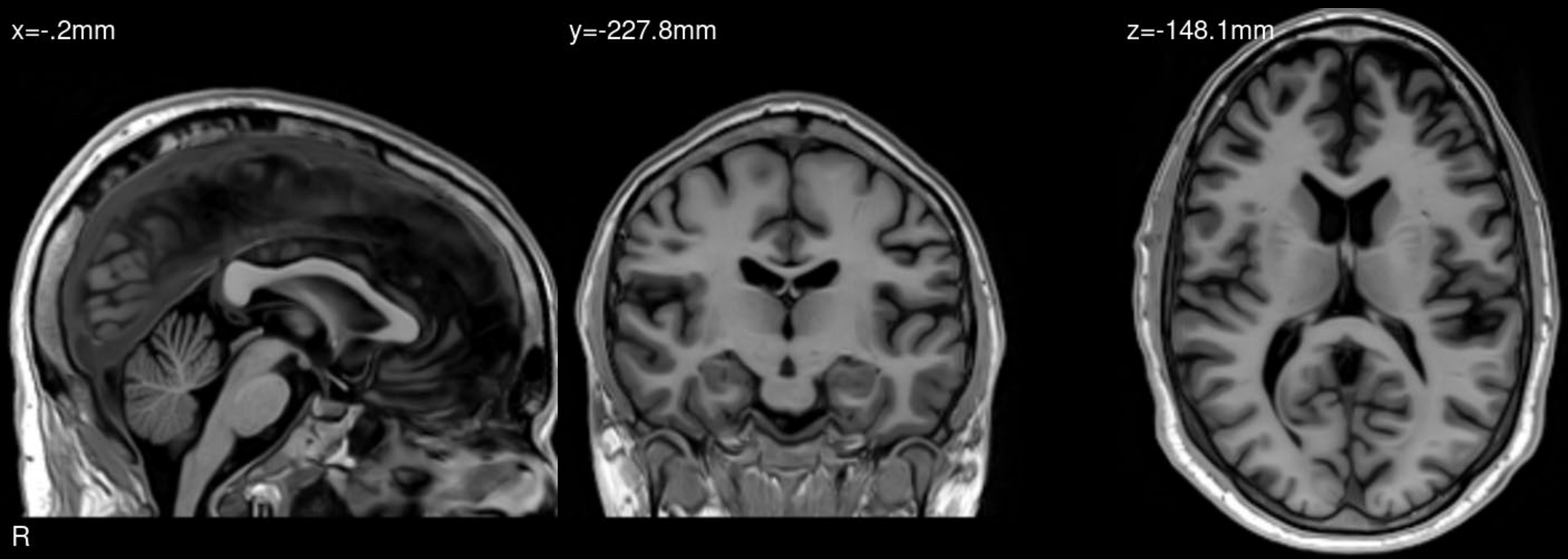
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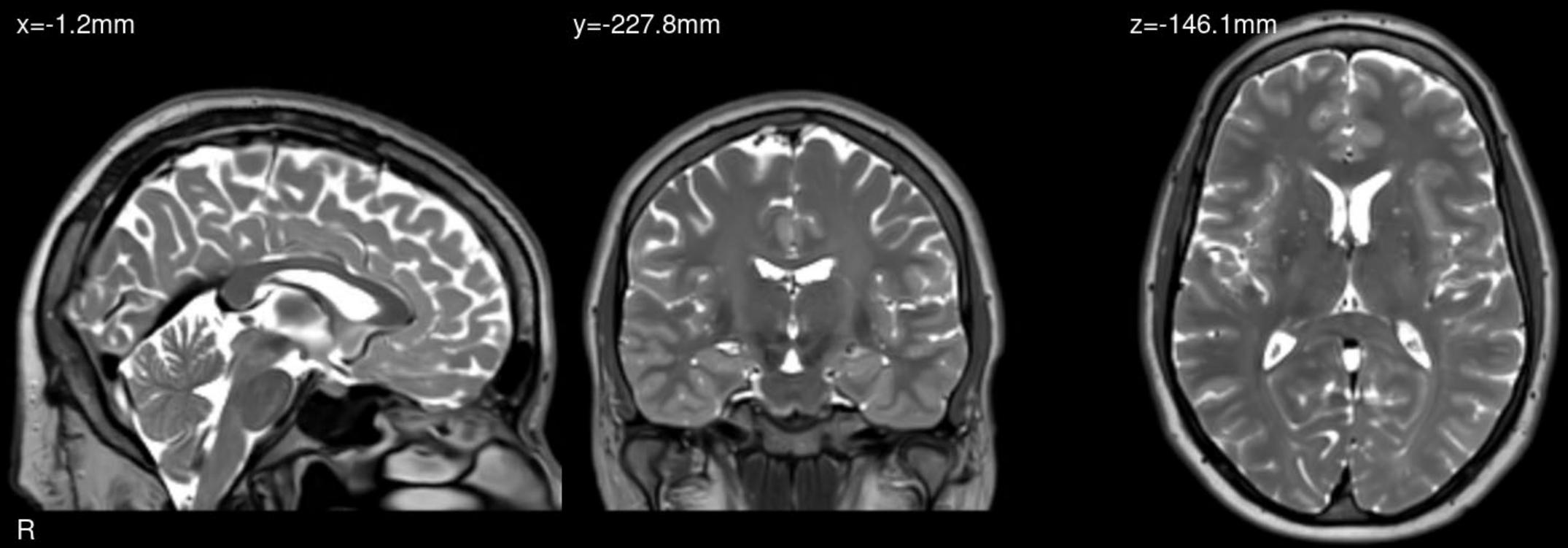
R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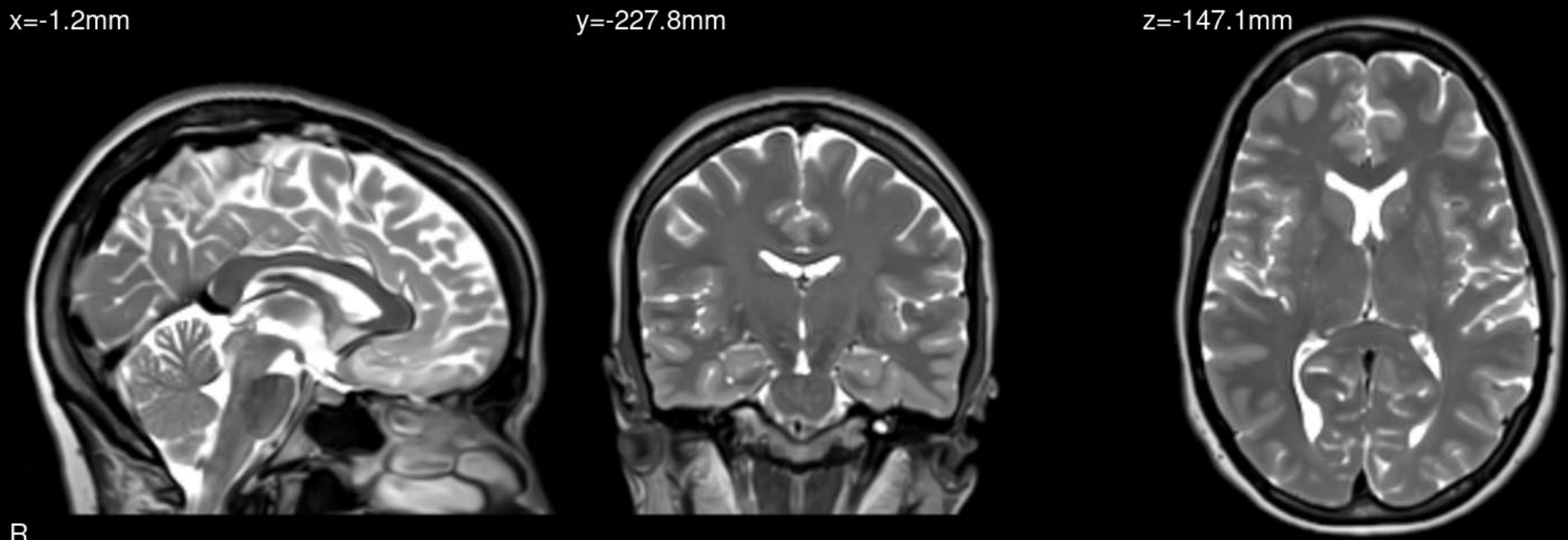
R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z=-147.1mm
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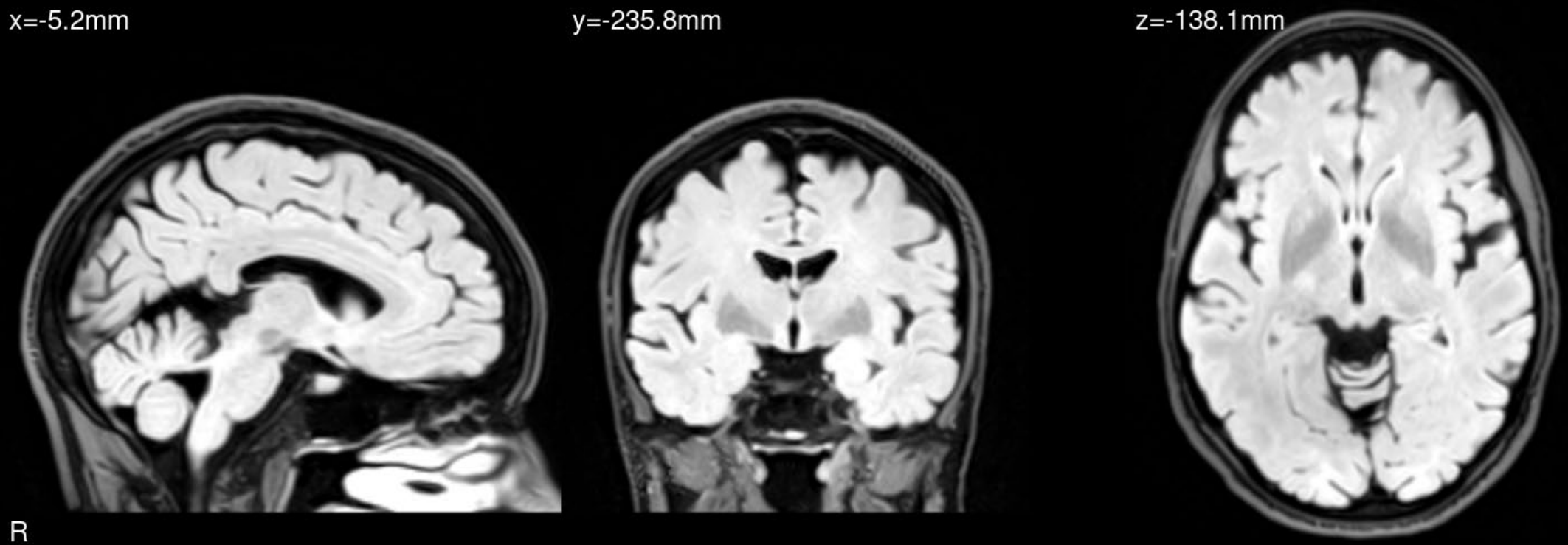
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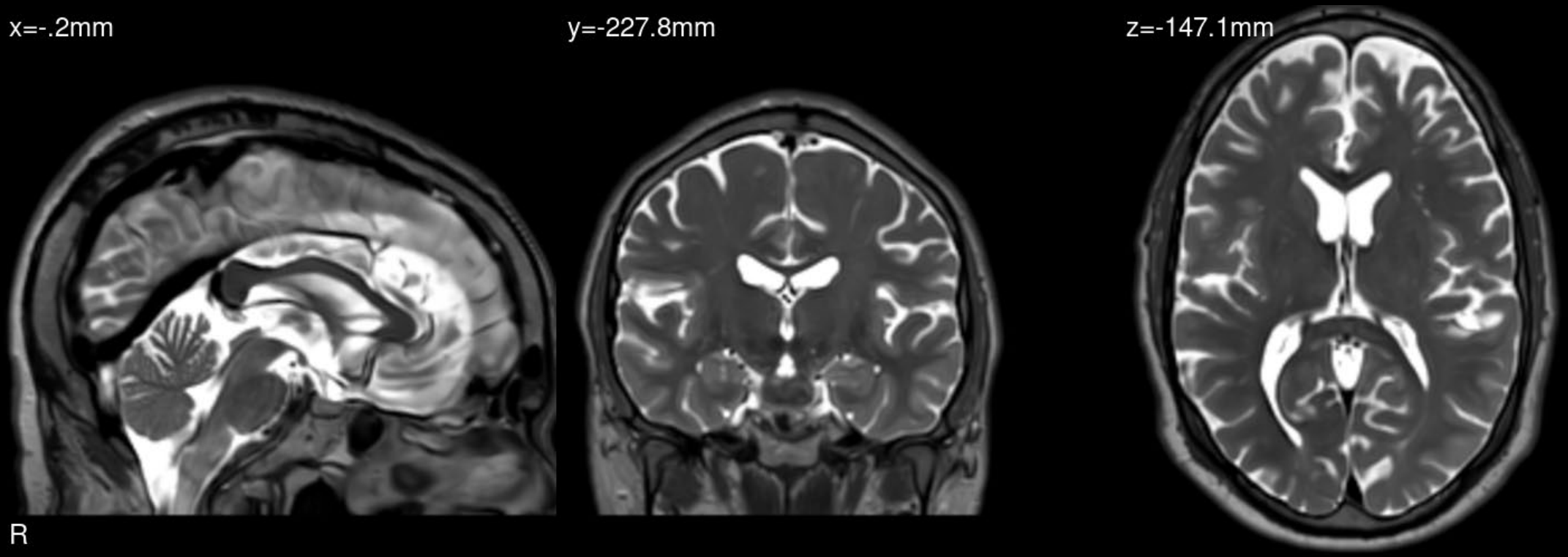
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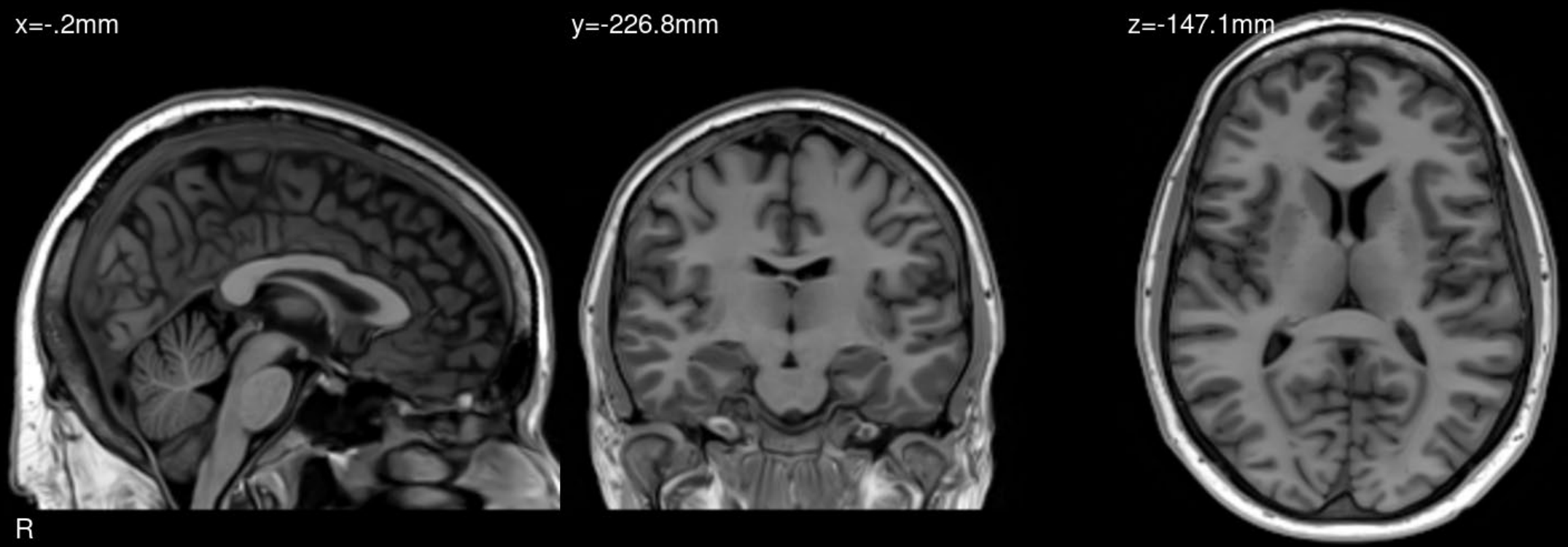
R


x=-.2mm
y=-226.8mm
z=-147.1mm
R

T1w with Contrast

- Gadolinium(III) - GAD
- Iron oxide: superparamagnetic
- Iron platinum: superparamagnetic
- Manganese

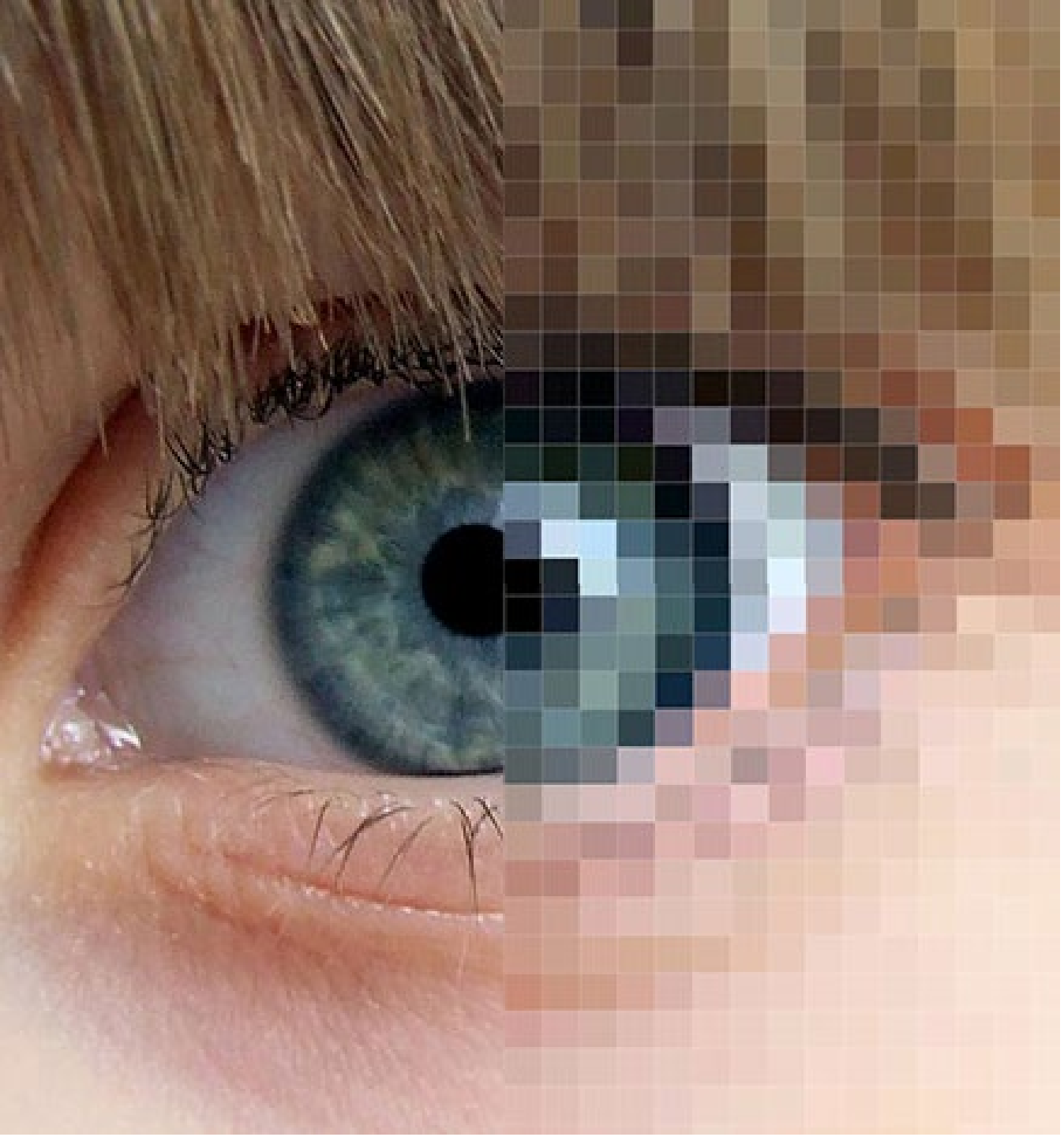


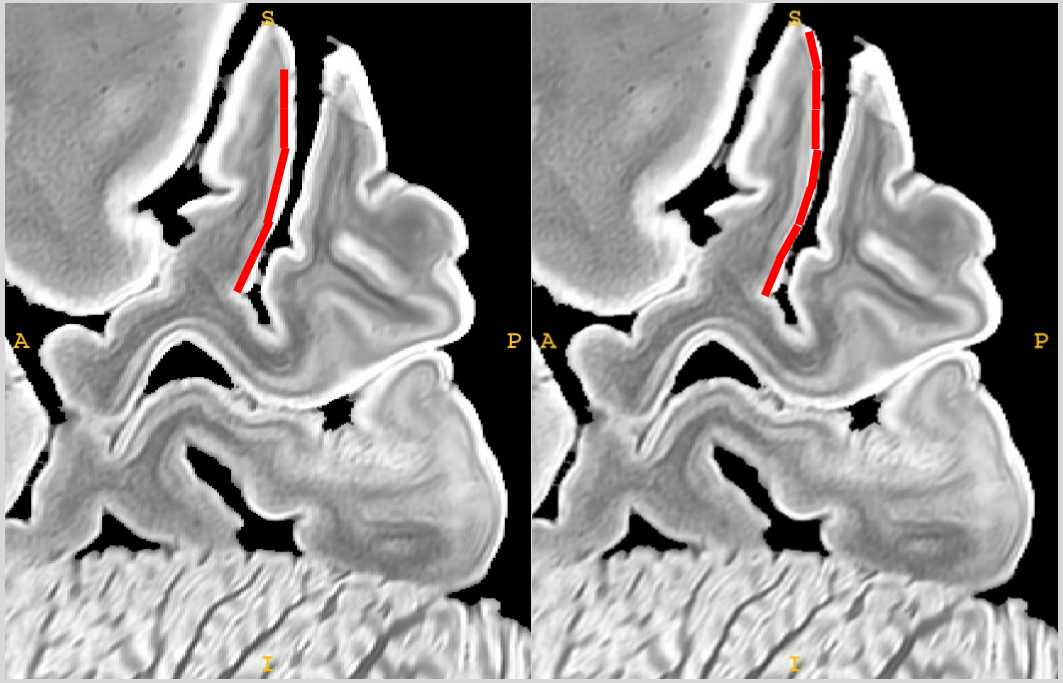
Image resolution

- Resolution can affect how we calculate volumes
- Images that are anisotropic compared to isotropic can also affect volume calculations
  - Geographic Example

Coastline Paradox

- Coastline do not have a well-defined length due to the fractal curve-like properties of the coast

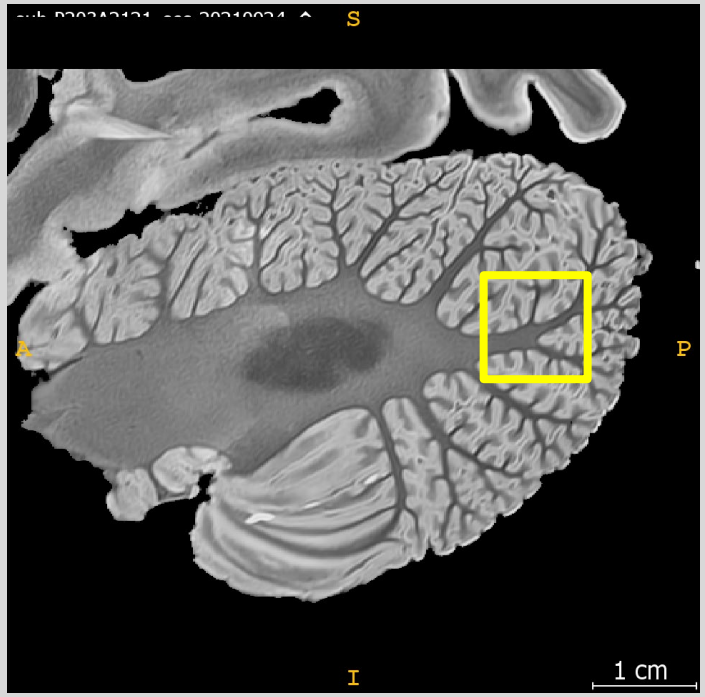
2800 km	3400 km

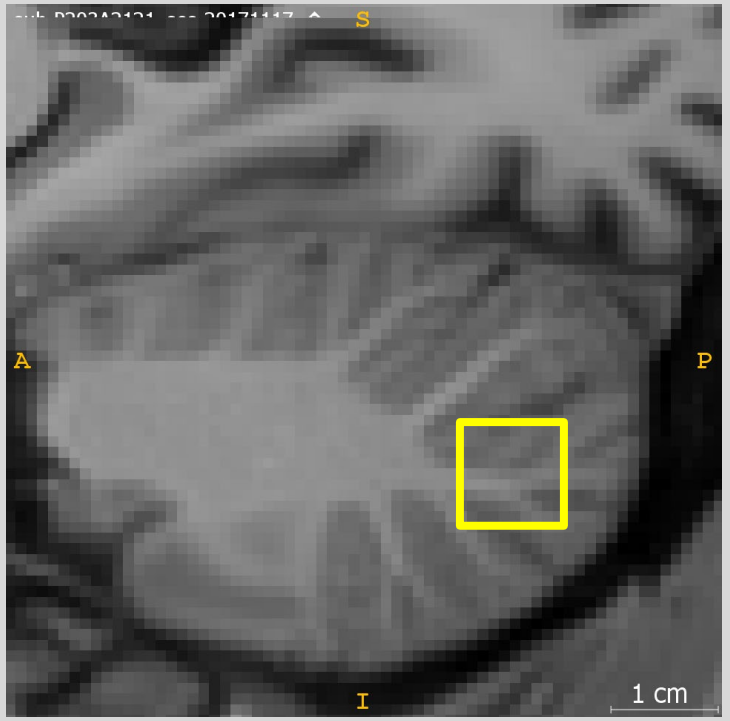


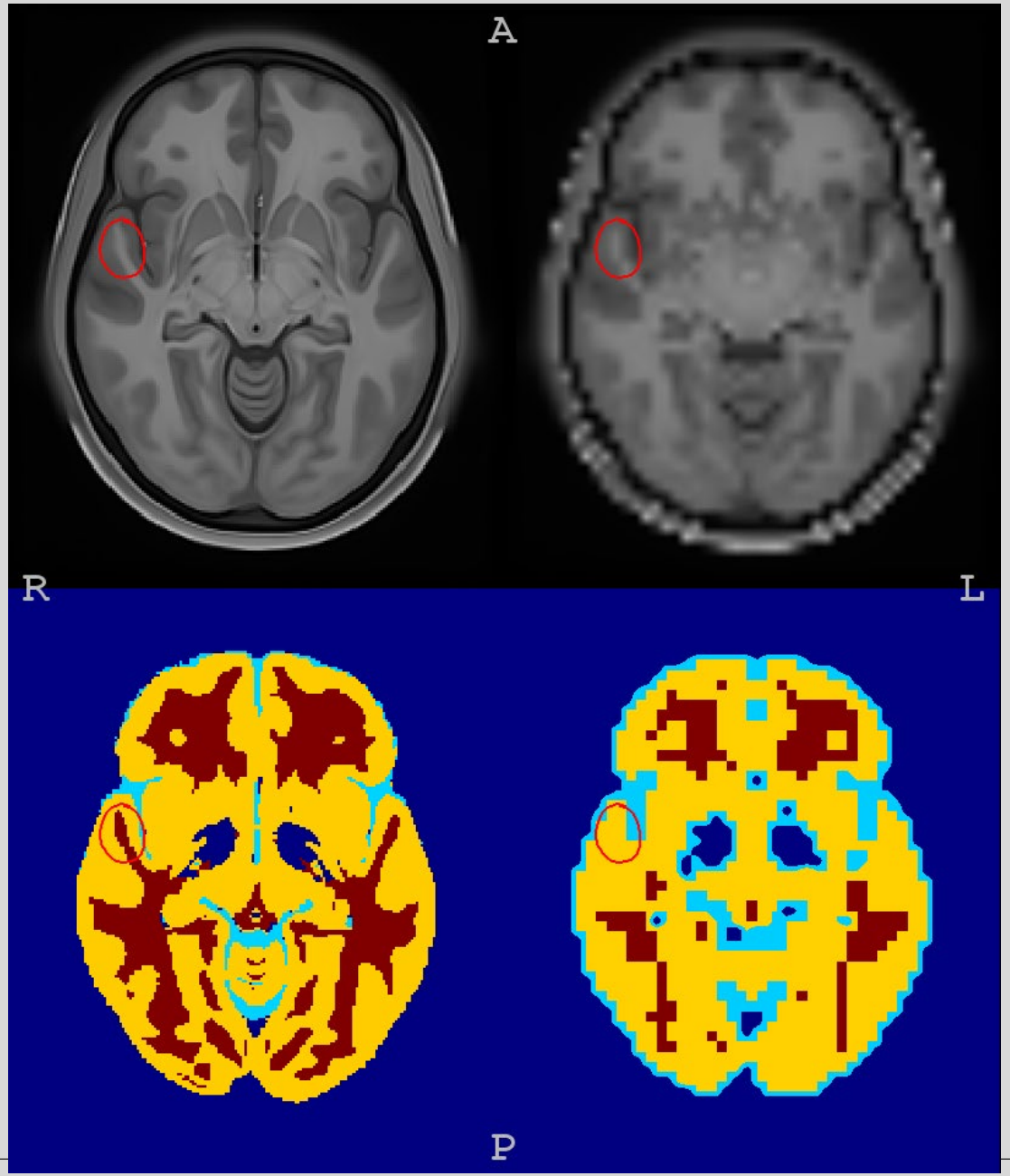
2mm — 3 segments 1mm — 7 segments

Partial Voluming

- Each voxels signal is the sum of **all** the signal within the volume
- The lower the resolution the less confident we can be in boundaries






A
R
L
P

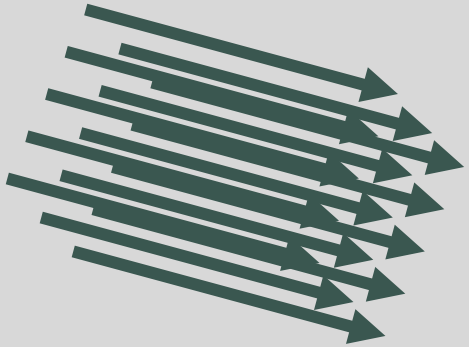
Images directly off the scanner are imperfect

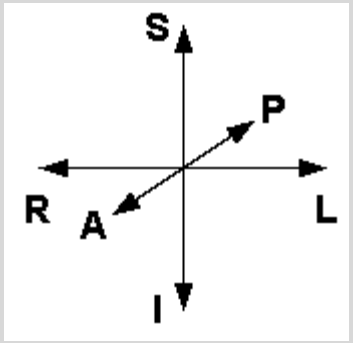
- Noise
- Misalignment
- Anisotropic images

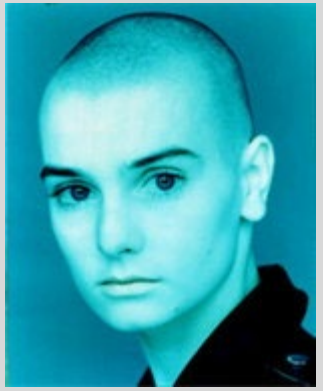
PROCESSING PIPELINE

Reorienting Images

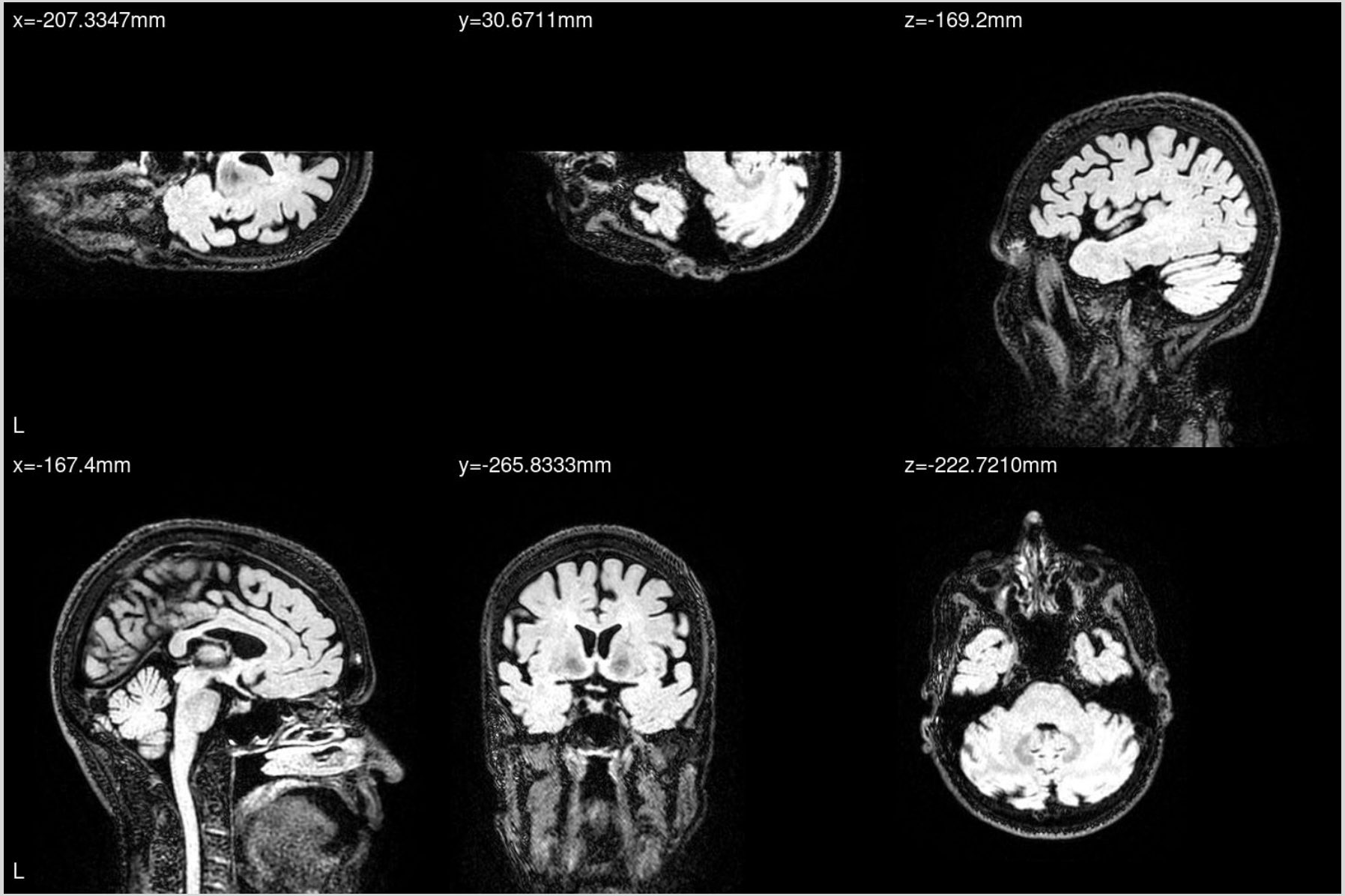
- We want to make sure that all images are oriented the same way for processing
- We use RPI orientation





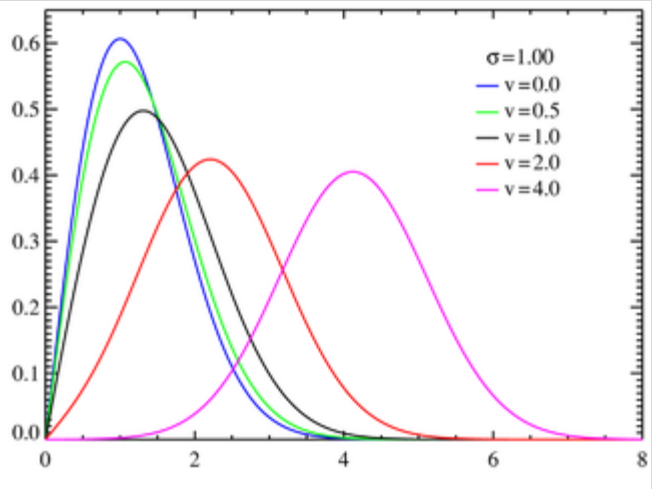


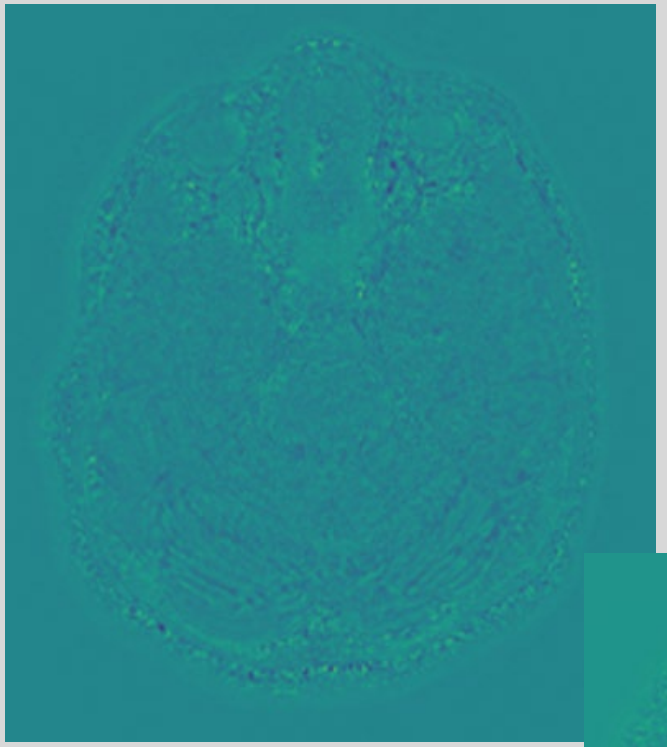
Right	Left
Anterior	Posterior
Inferior	Superior

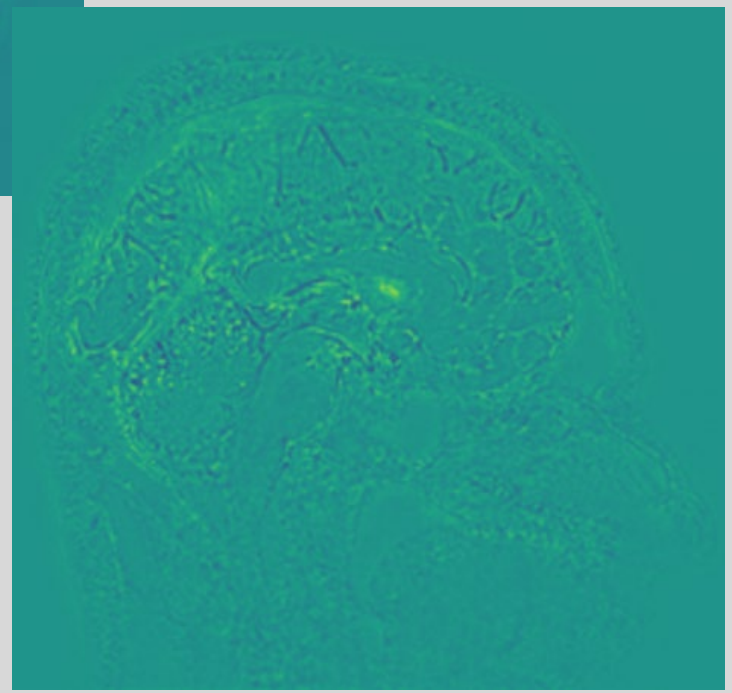

x=-207.3347mm
y=30.6711mm
z=-169.2mm
L
x=-167.4mm
y=-265.8333mm
z=-222.7210mm
L

Denoising Images

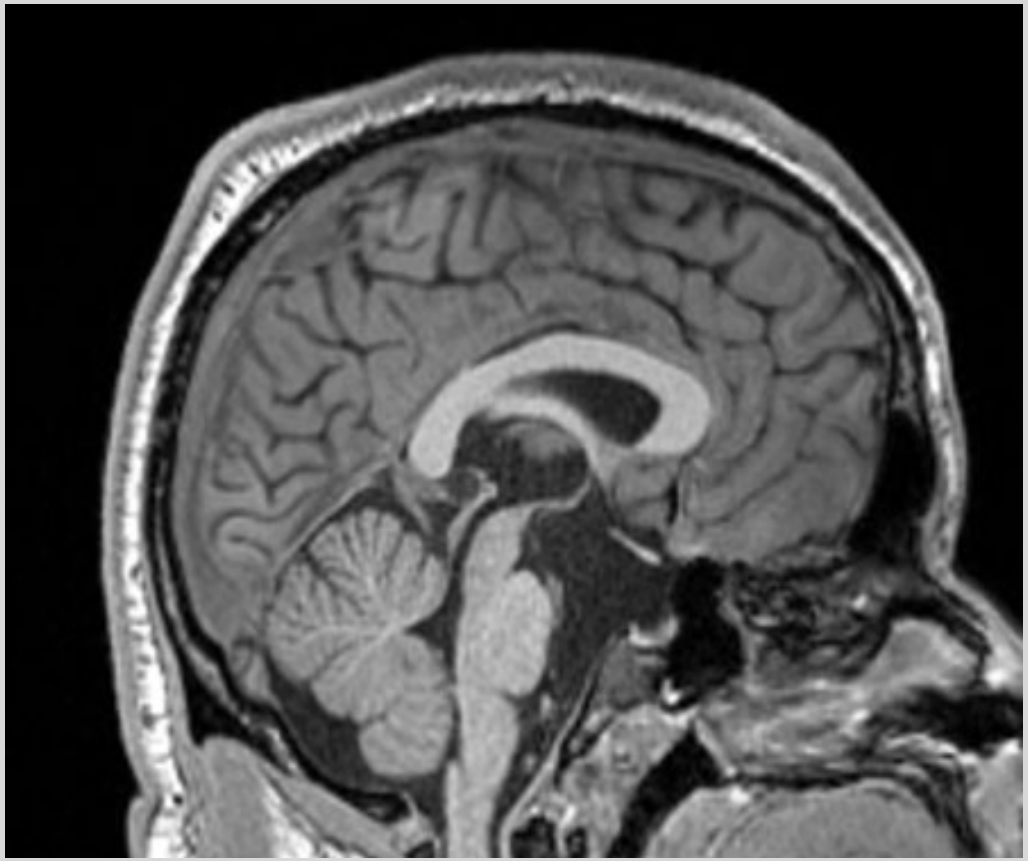
- Noise can affect image processing
- Can employ Rician or Gaussian noise model

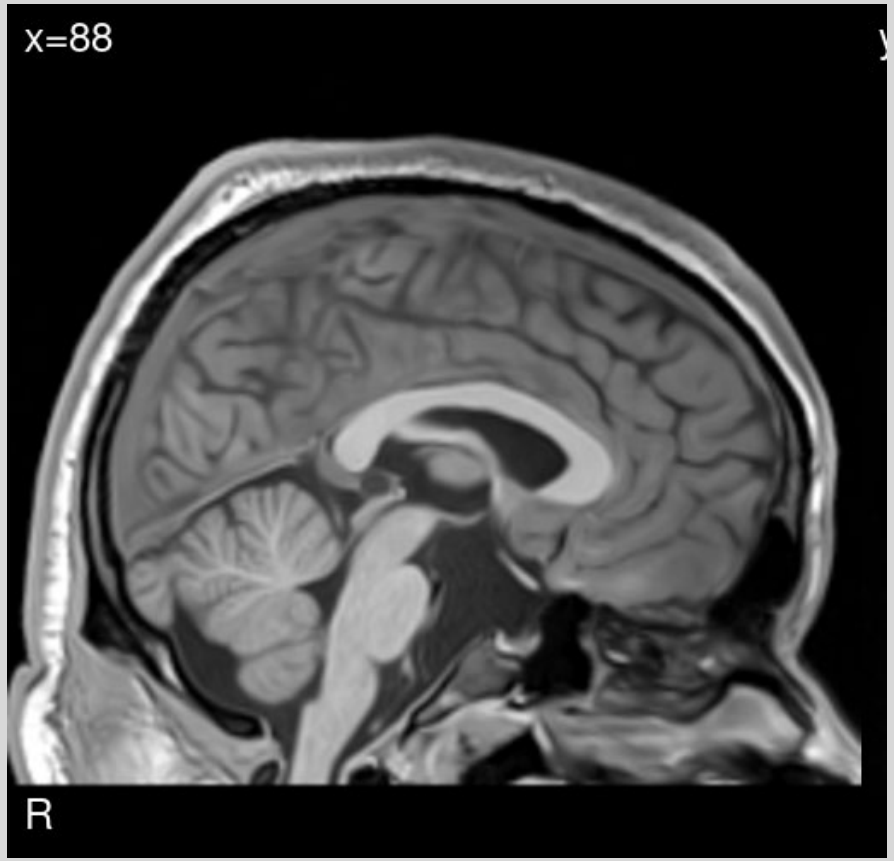






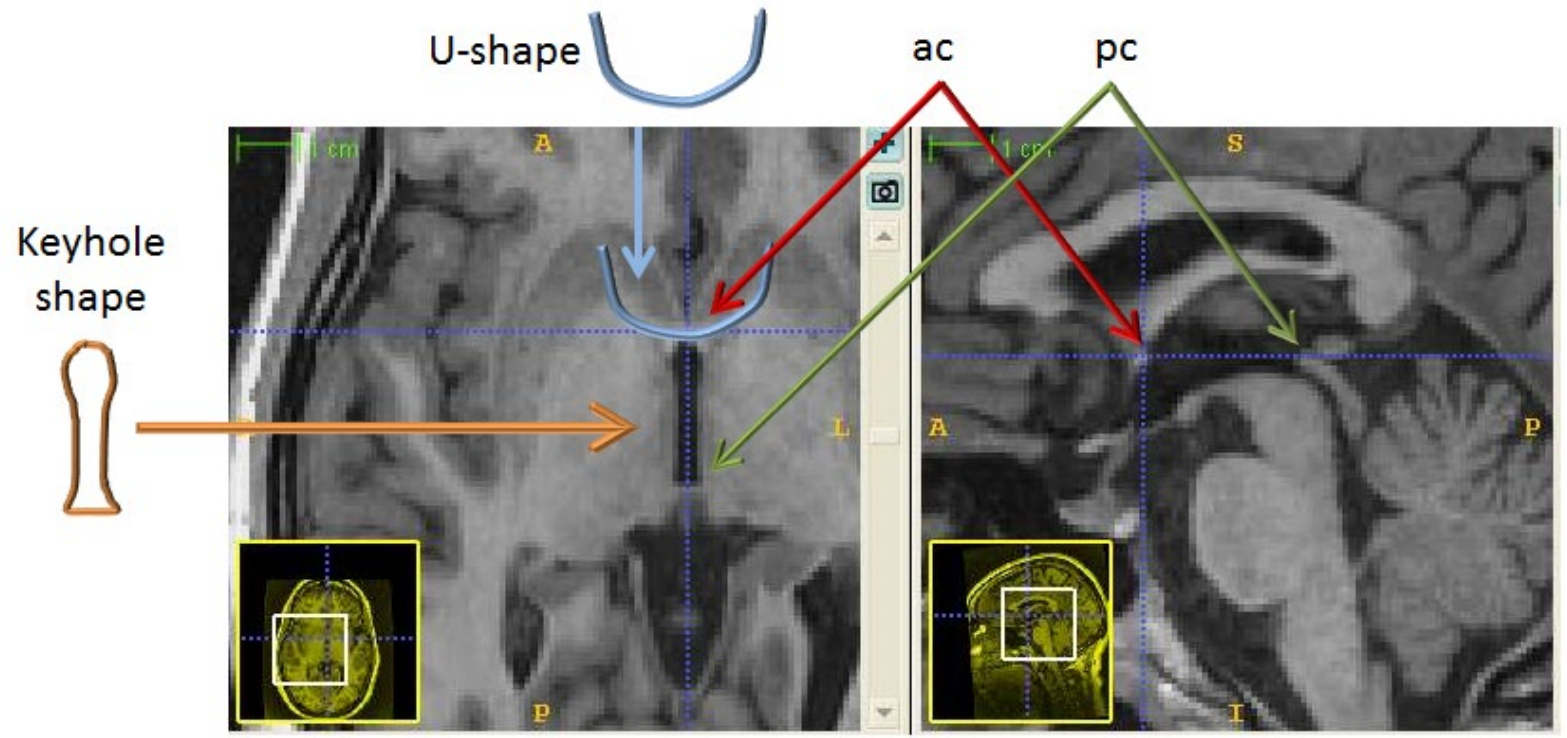
Before & After





Rigid alignment to template

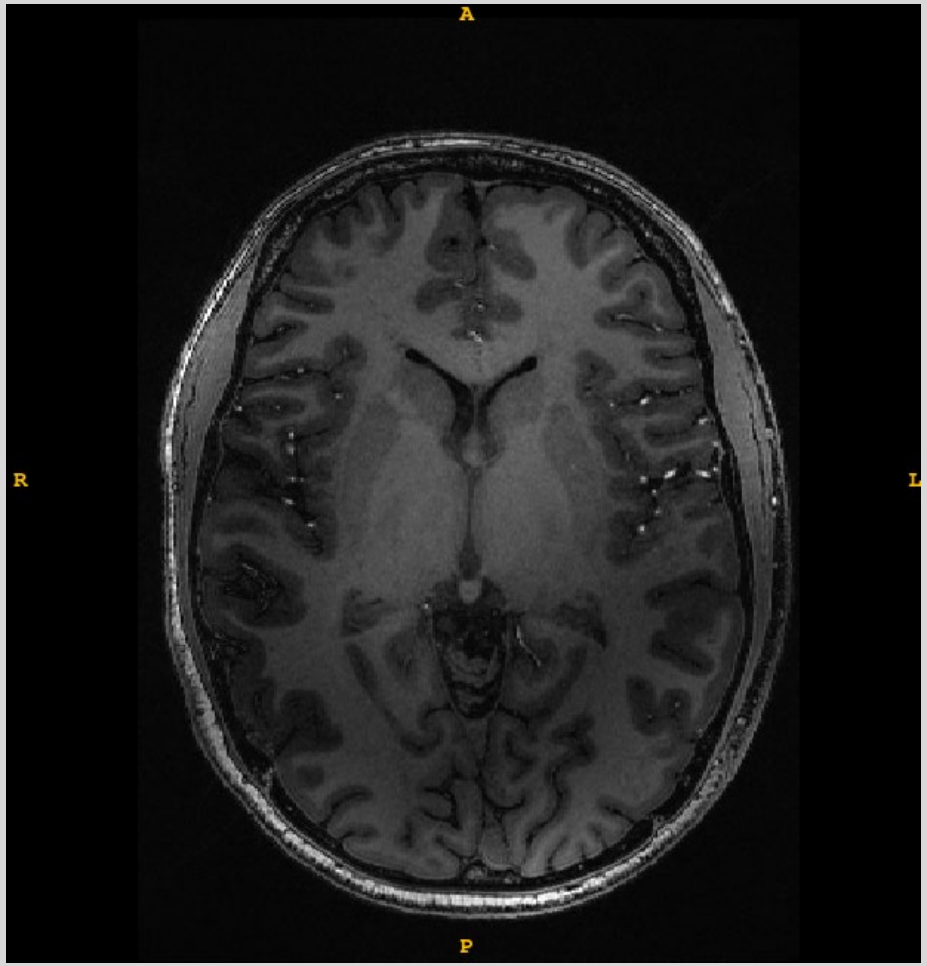
- We want scans to generally aligned to the same place as template brain
- We do this rather than ACPC alignment or feature detection
- Rigid alignment allows scans to be generally aligned and reduces computing work

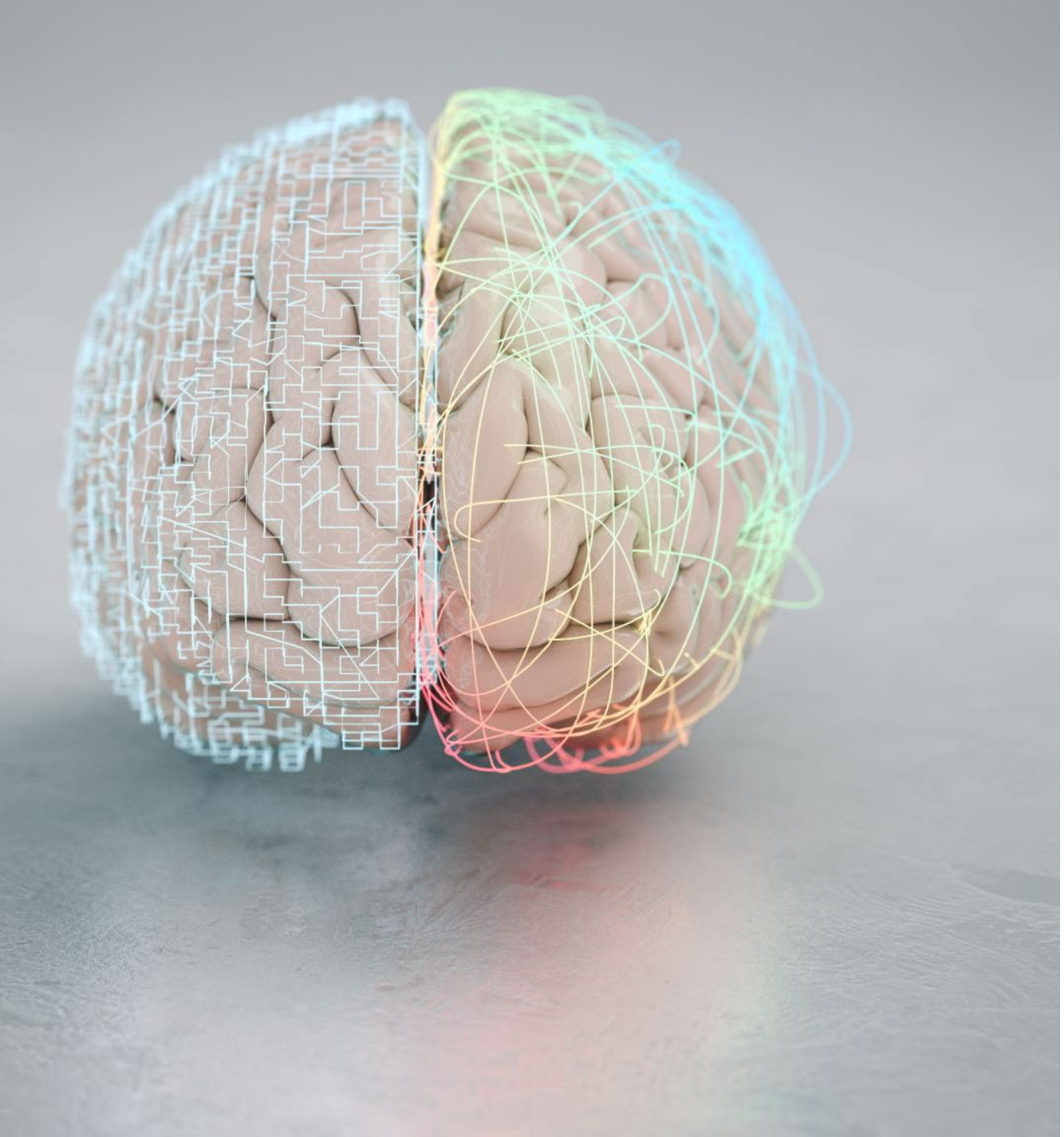


Averaging multiple images

- Scans are just number in space

- Multiple good scans can be averaged together to best represent the participant





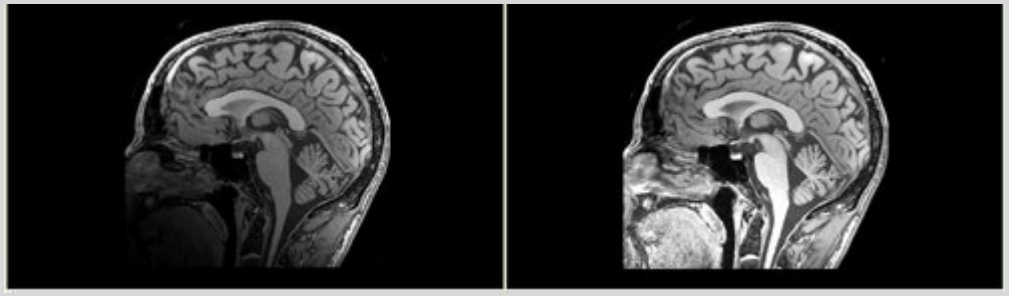
Foreground/Background Masking

- Use AFNI 3dAutomask to focus on the center of the FOV
- This allow for faster and more accurate processing as everything is focused on the brain

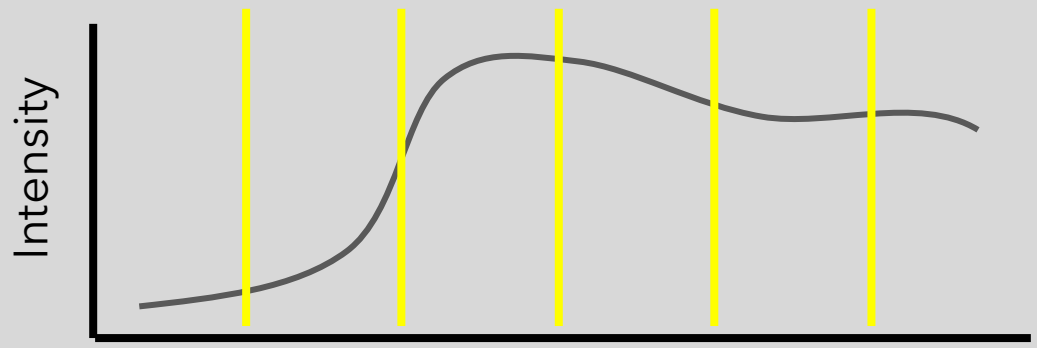
Intensity non-homogeneity correction

- T1/T2 Method

$$\frac{T1w}{T2w} \approx \frac{x * b}{(1/x) * b} = x^2$$

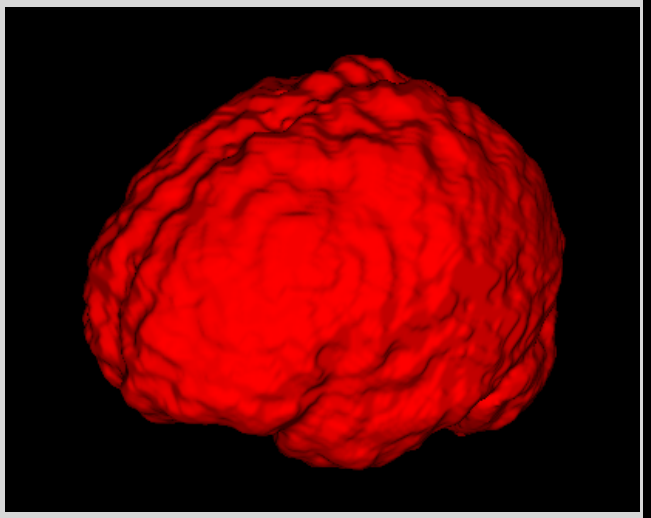


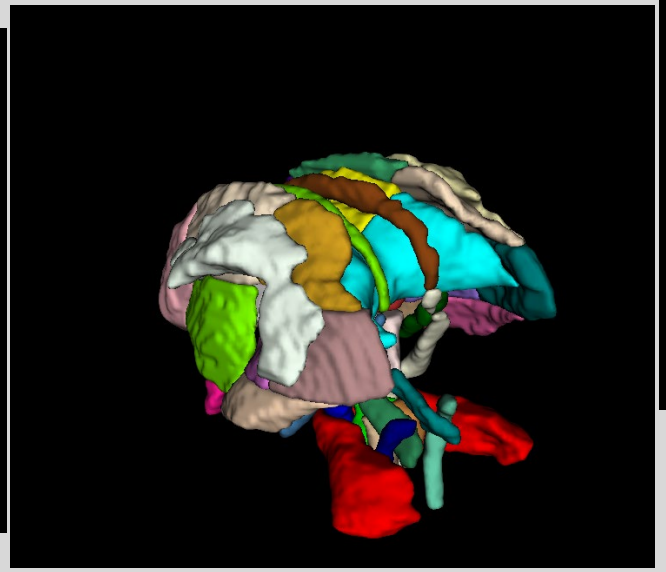
- N4 Method
  - N4 curves are fit to low frequency fluctuations in intensity

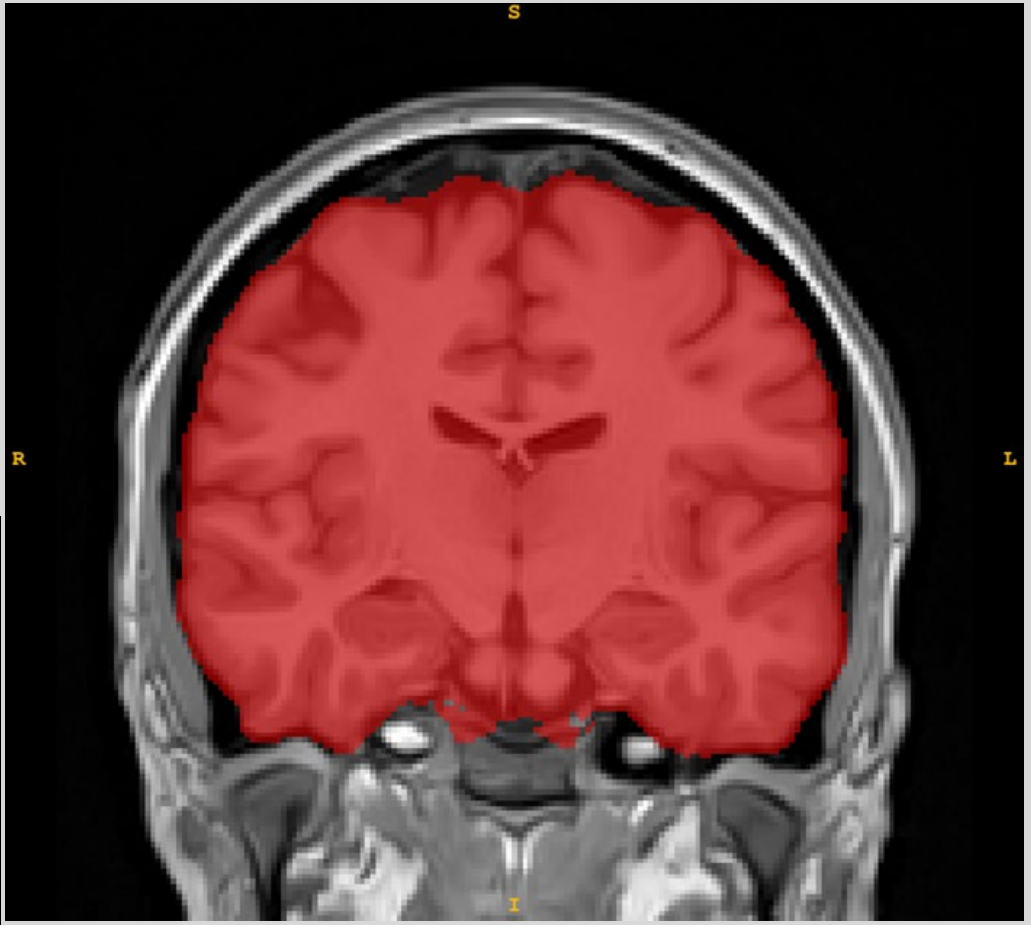


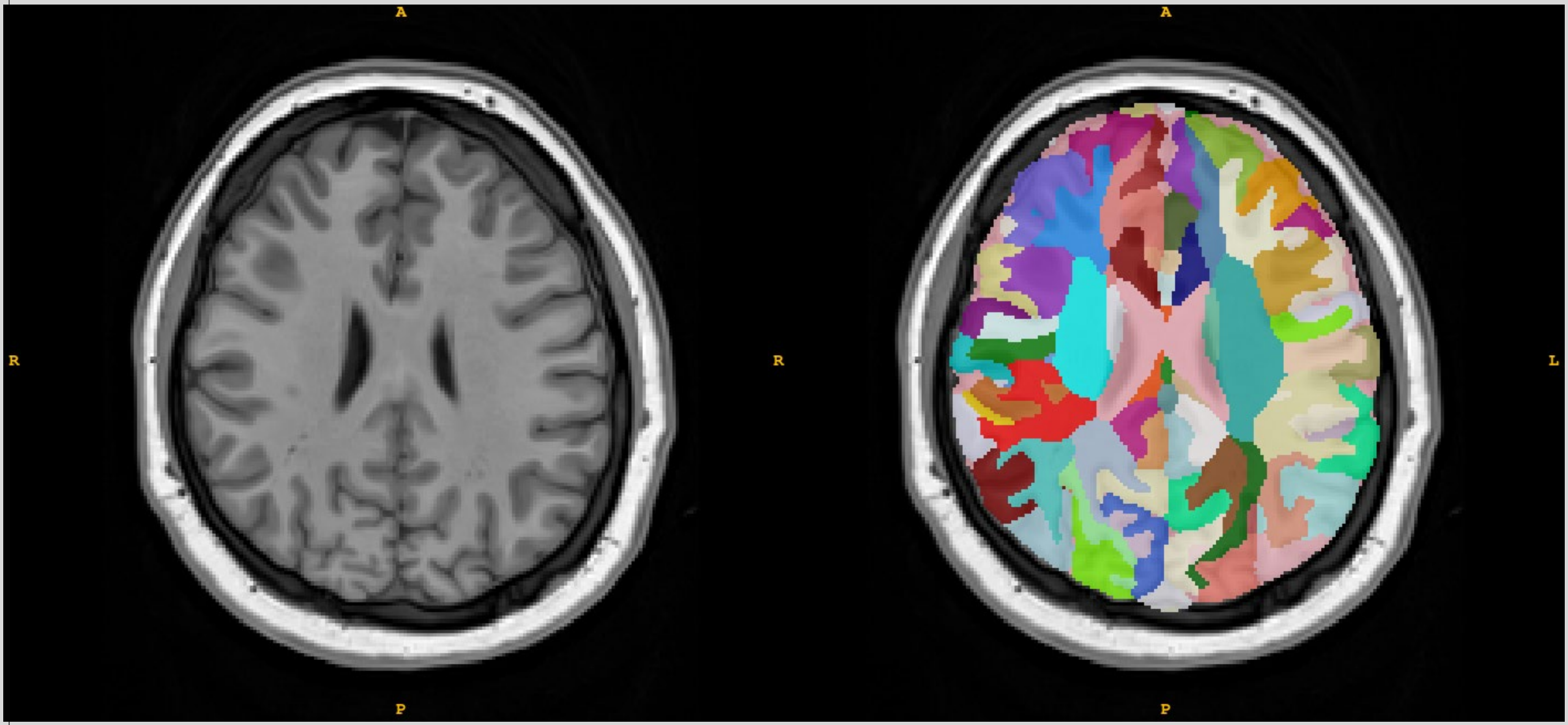
Brain Extraction

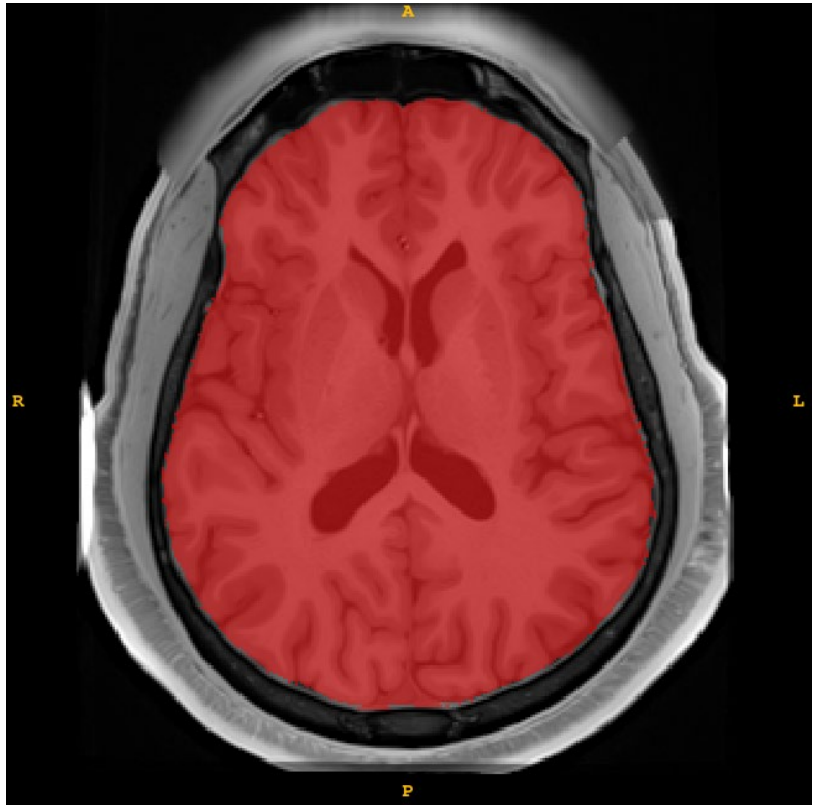
- Masks are just numbers in space
- They can be used to represent any part of the brain

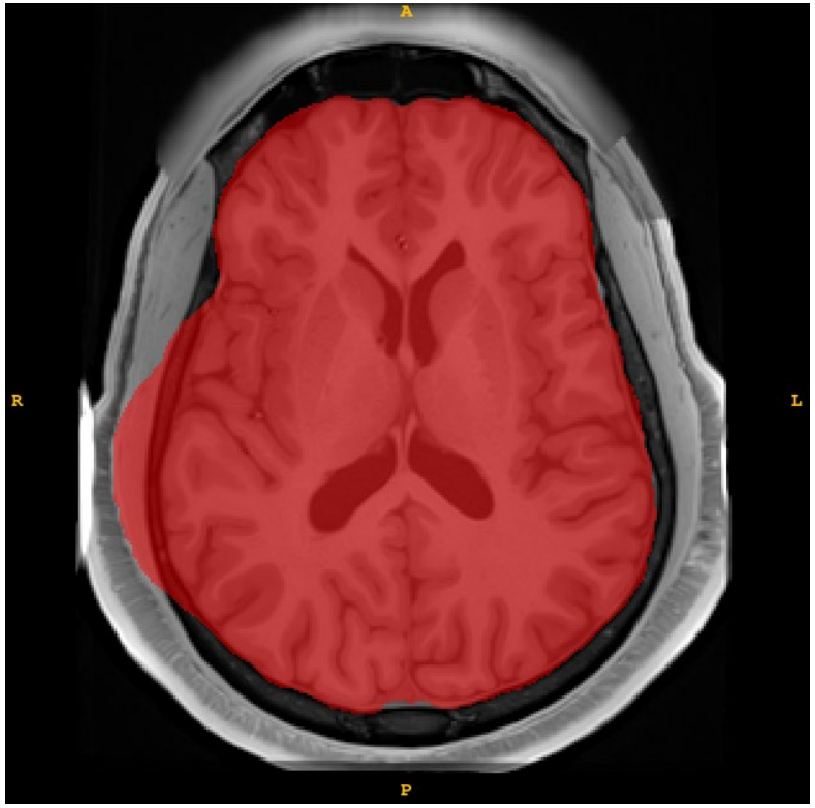


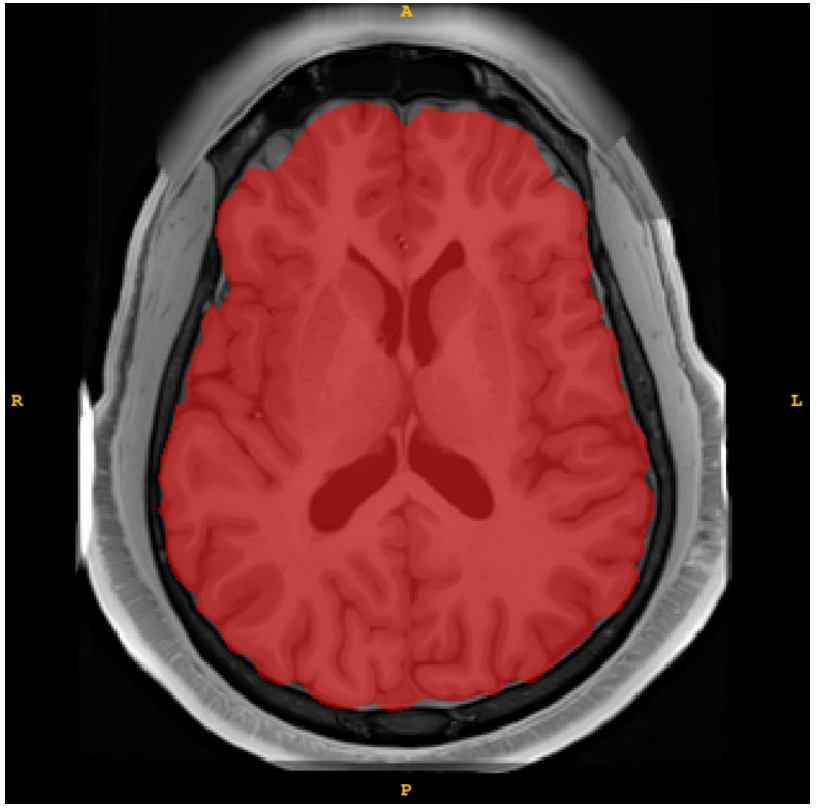





A
R
P
A
R
L
P



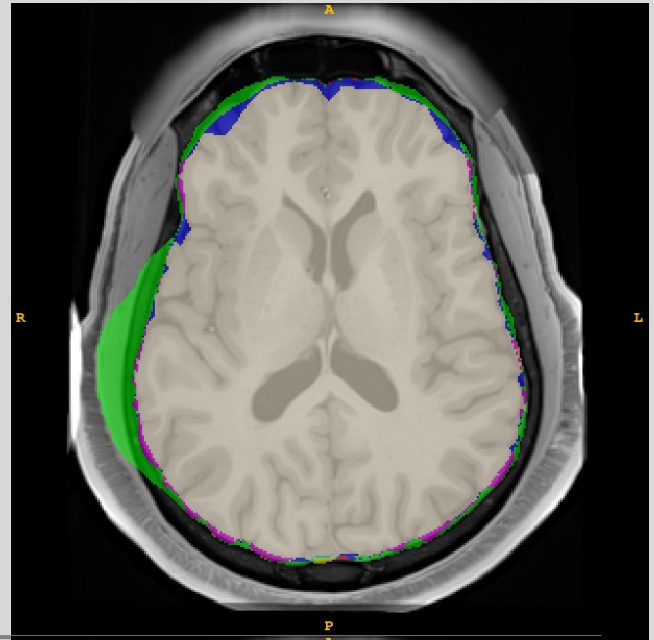




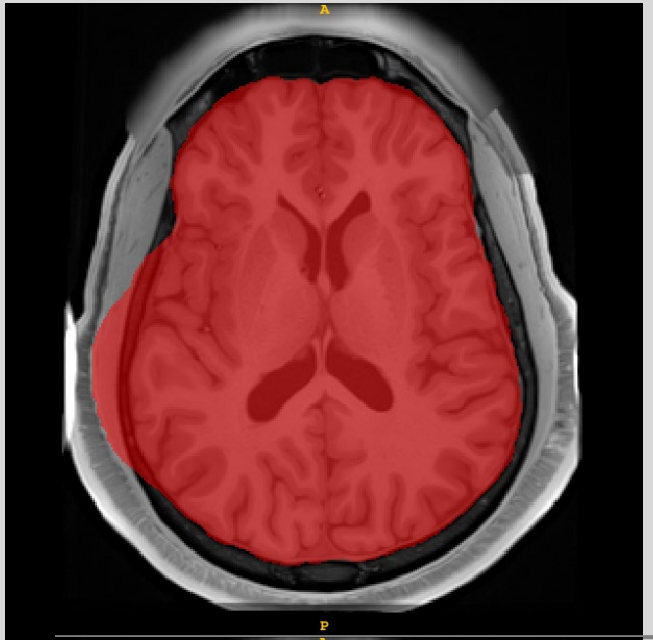
All Masking Programs Have Problems

- 3dskullstrip, BET2, ANTs Brain Extraction can all misidentify brain boundaries
- Multi-Atlas Label Fusion (MALF), Venn, Union, Intersection

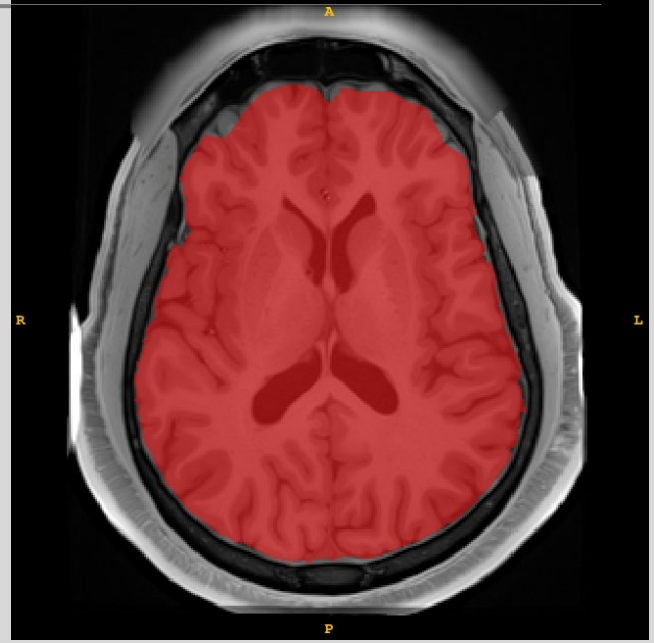
VENN



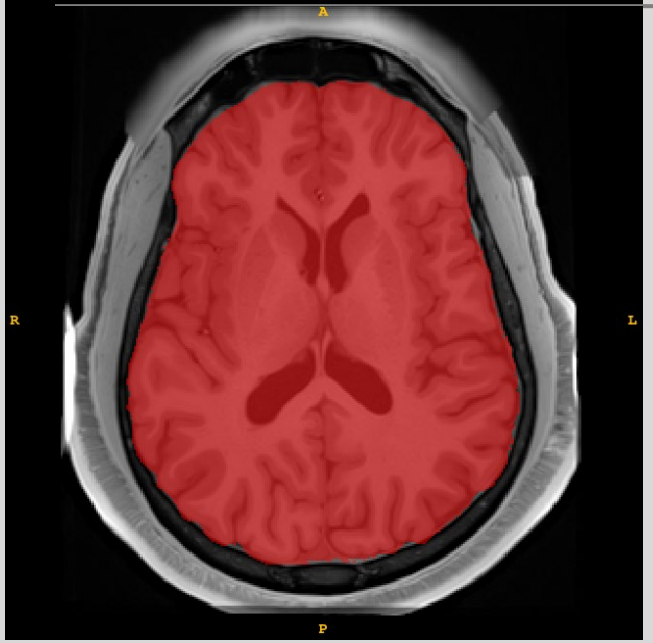
UNION



Intersect

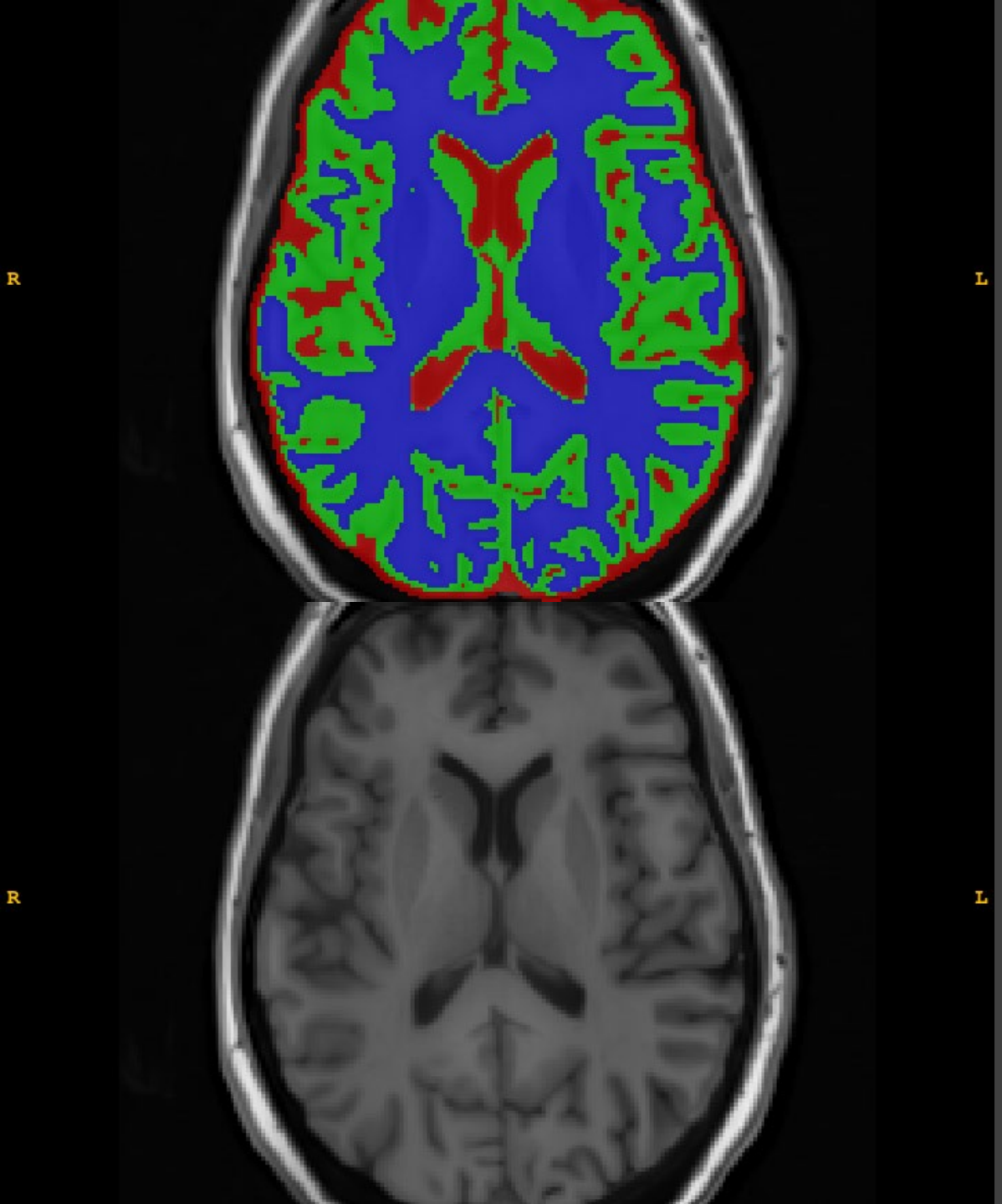


Majority Vote



Rescale Intensity

- Want to create separation of the GM and WM peaks in an intensity histogram
- We must be careful here if the magnitude of intensity is an important measure



Native space

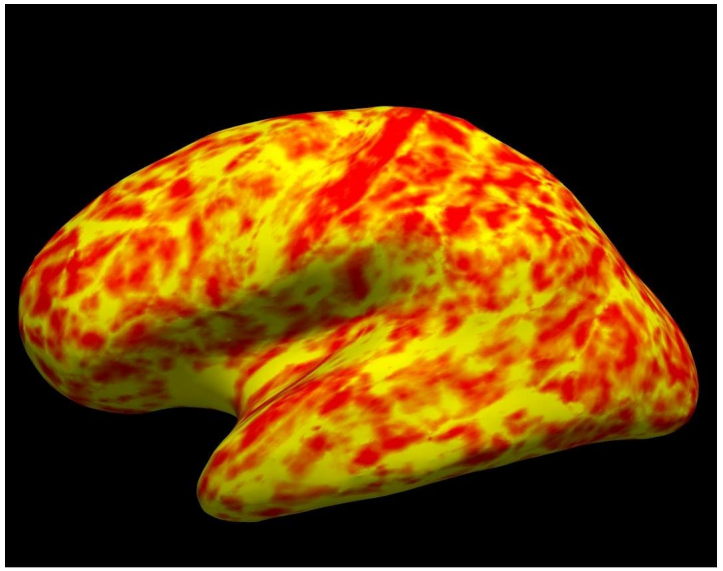
- After all this the images are now in their native
- We can do Atropos tissue classification to mask GM, WM, and CSF

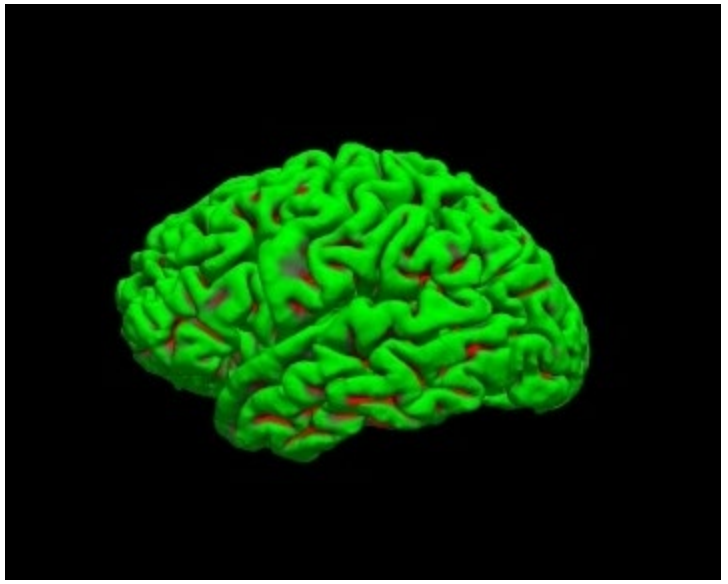
Normalization to template space

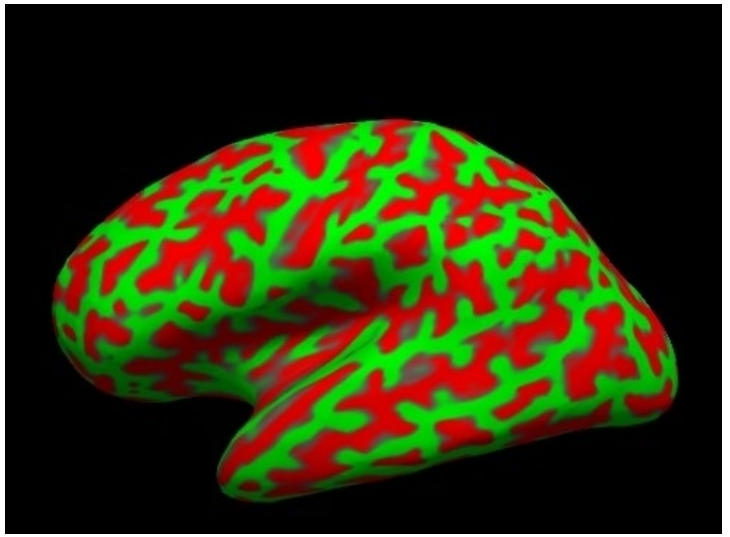
- Common spaces are MNI, HCP, Talairach
- MNI is good for fMRI scan
- HCP is better for Jacobians

Freesurfer

- Created by Bruce Fischl, Anders Dale, Martin Sereno, and Doug Greve
- Best used for measuring cortical structure
- Has capabilities to do functional and diffusion images as well

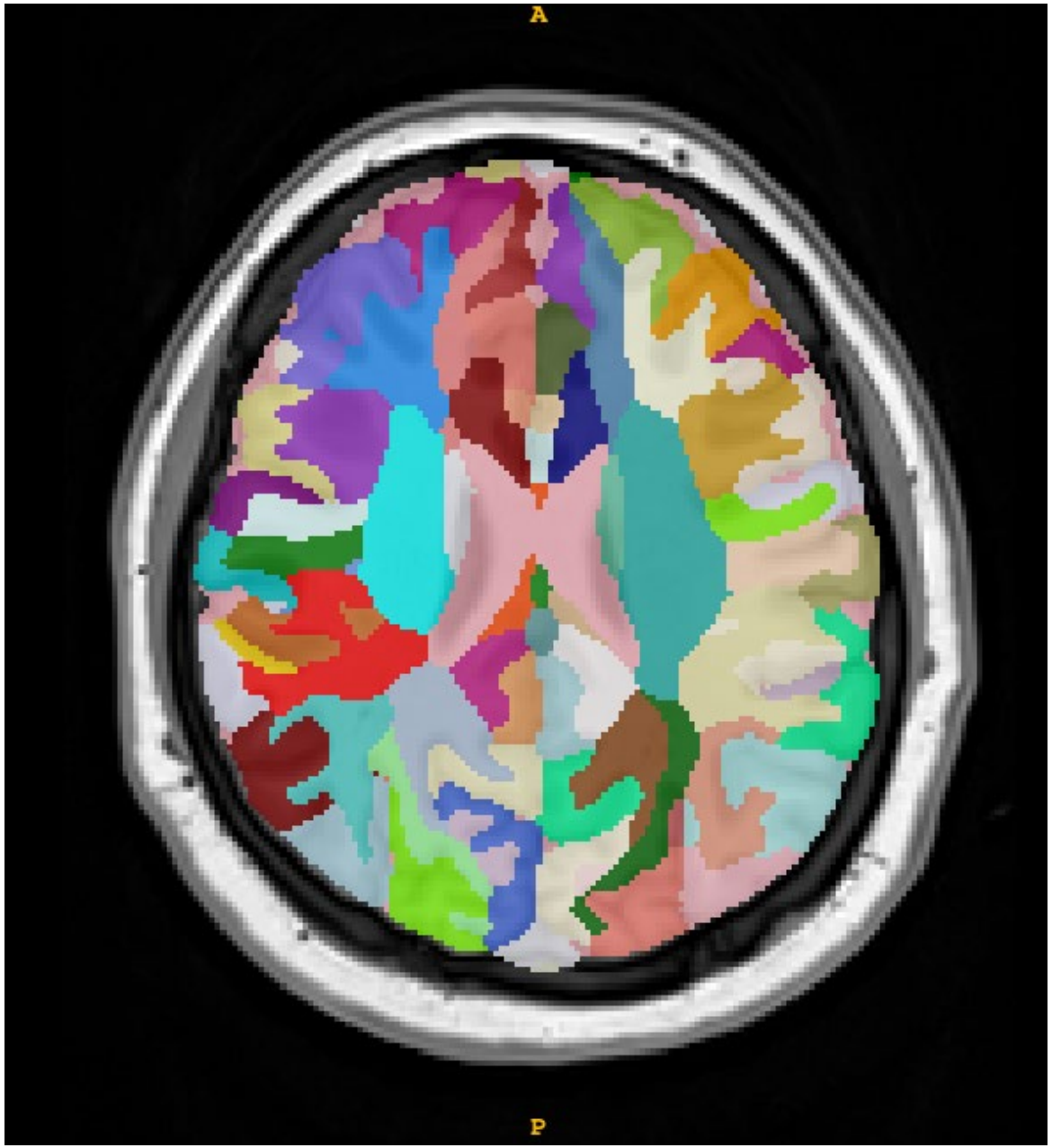






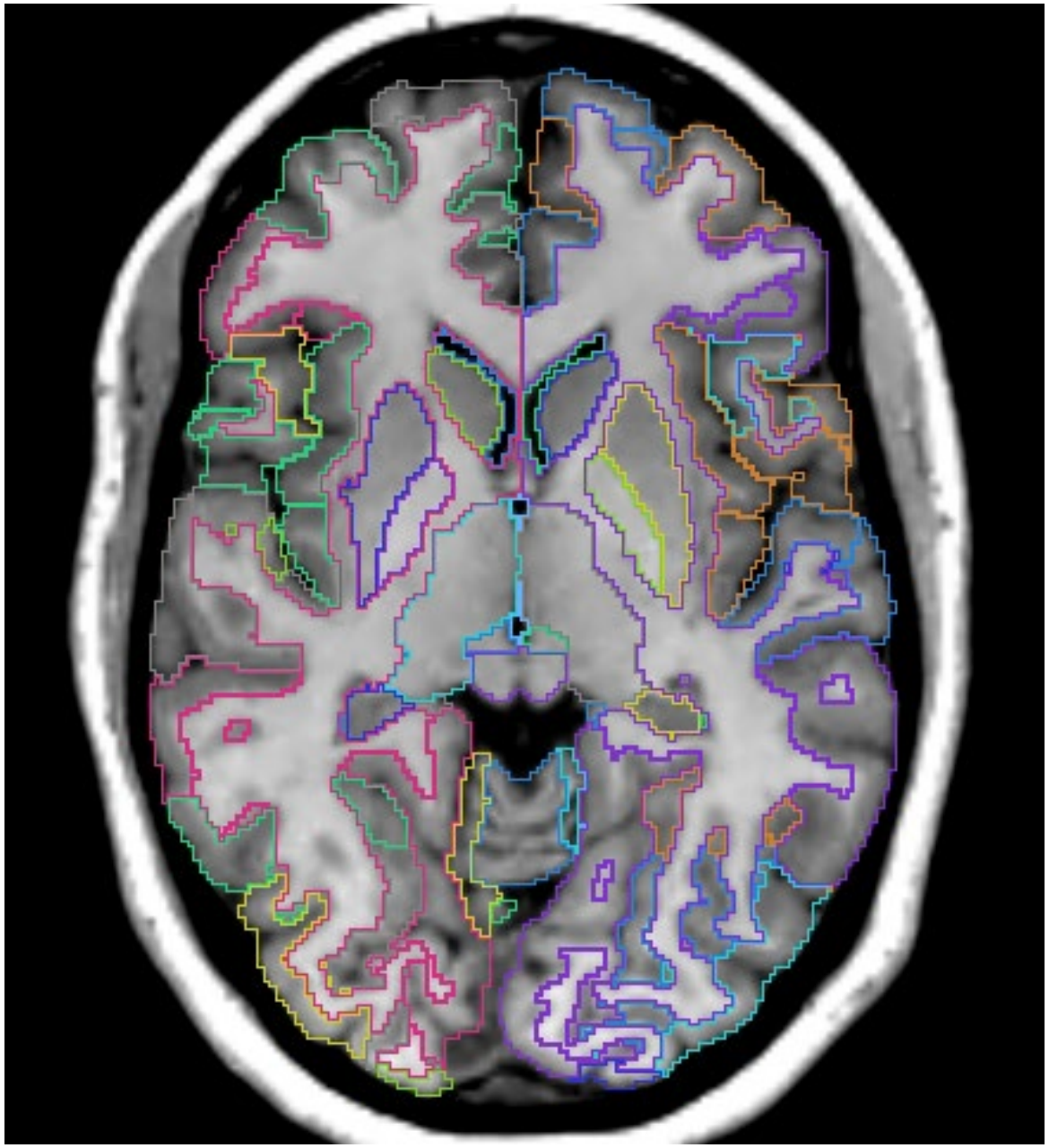
Freesurfer Outputs

- pial, white and inflated surface
- sulcal and curvature maps
- thickness maps
- cortical parcellation



BRAINSAutoworkup

- Developed by Hans Johnson
- We use it to quantify volumetric data for regions throughout the brain



BRAINSAutoworkup Outputs

- Tissue labels
- Average cleaned images
- Probability masks
- Tissue segmentations

Reference

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QUESTIONS?