

# Orientations and Coordinates

Posterior-Anterior

Superior-Inferior

Ipsilateral

Contralateral

Rostral-Caudal

Dorsal-Ventral

Lateral-Medial

Proximal-Distal

Orthogonal/Oblique

Coronal

Sagittal

Axial (Transverse)

$x, y, z$

Canonical view

World Space

Voxel Space

Image origin

Radiological View

Neurological View

Flipping

Rotation

Radians

Fiducial

AC-PC line

# Why do we care about Orientations and Coordinates?

Brains have different shapes & sizes.

Brain volumes have different resolutions.

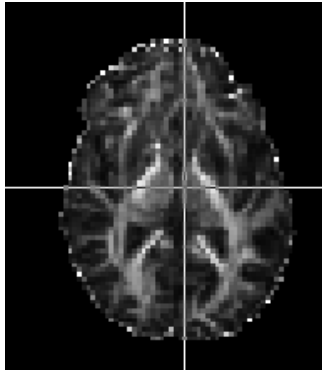
Before we can compare individuals and images, we need clear and consistent

- 1) Relative Anatomical Locations
- 2) MRI Volume Coordinates,
- 3) Reorientation through Flipping and Rotation.

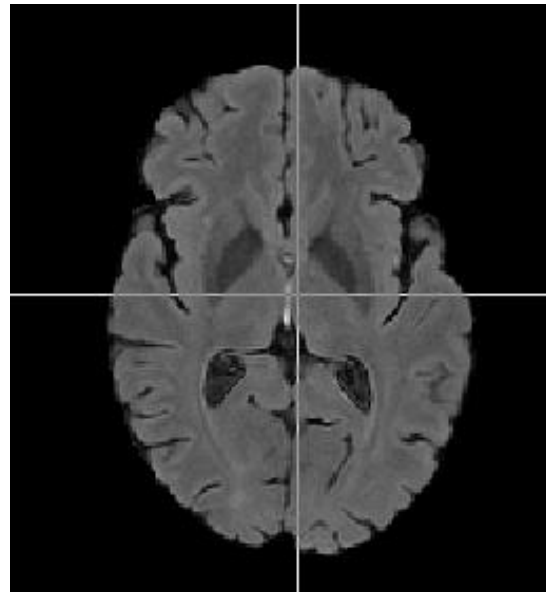
# Brains have Different Shapes and Sizes



# Brain volumes have different resolutions



128x128x57  
FA



256x256x57  
Flair



136x256x256  
SPGR

# 1) Relative Anatomical Locations

We need terminology for talking about anatomy...i.e., the relative positions of one structure and another.

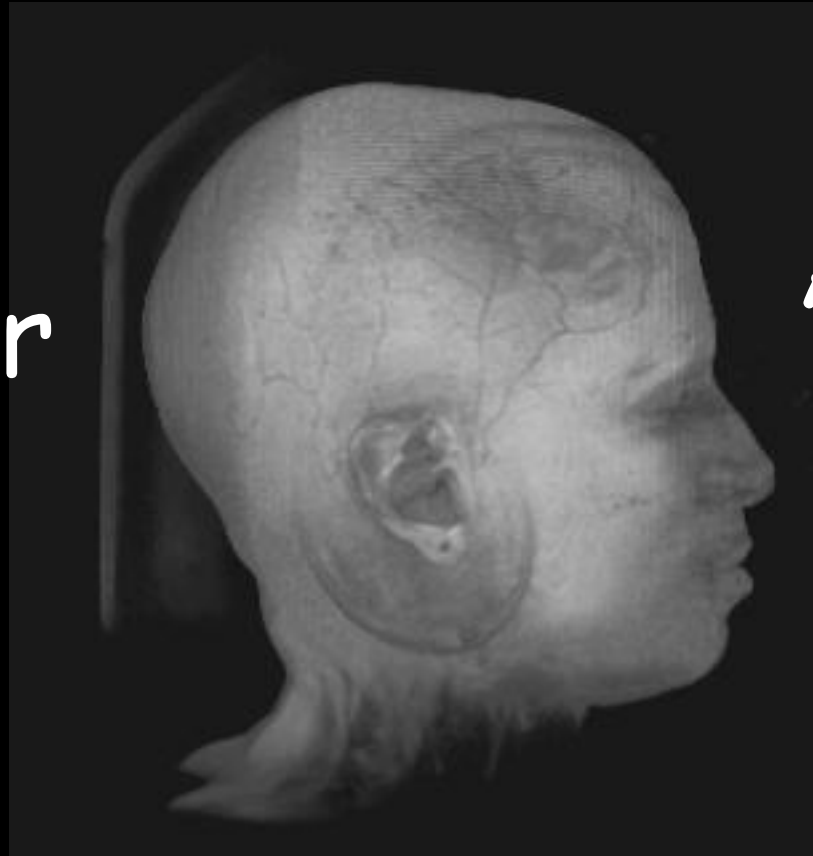
For brain imaging, we prefer some vocabulary.

But you'll occasionally hear other anatomical orientation terms.

Right and left present special problems, so they'll be discussed when we talk about coordinate systems.

Terms you'll hear a lot

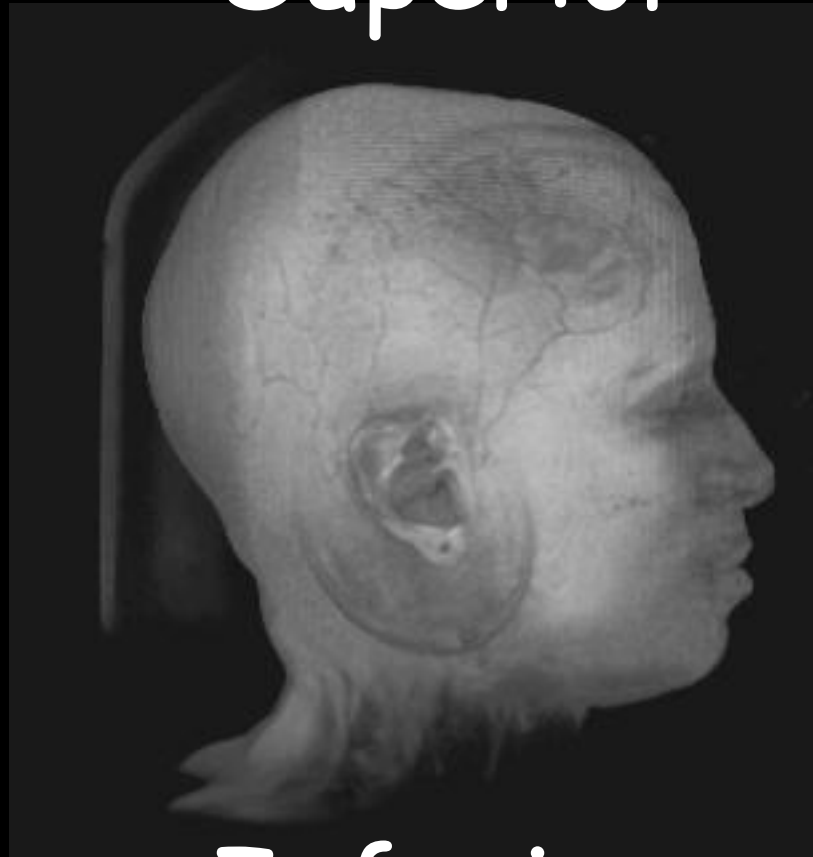
Posterior



Anterior



Superior



Inferior

# Ipsilateral-Contralateral

**Ipsilateral** (Latin *ipse*; self/same): on the same side as another structure. Thus, the left arm is **ipsilateral** to the left leg.

**Contralateral** (Latin *contra*; against): on the opposite side from another structure. Thus, the left arm is **contralateral** to the right arm.

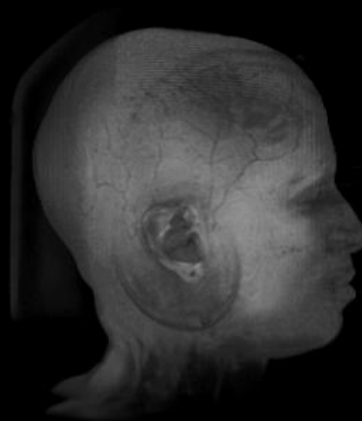
Terms you'll hear occasionally

These terms can be used for brains,  
but were originally meant for 4 legged animals,  
which makes them potentially confusing.



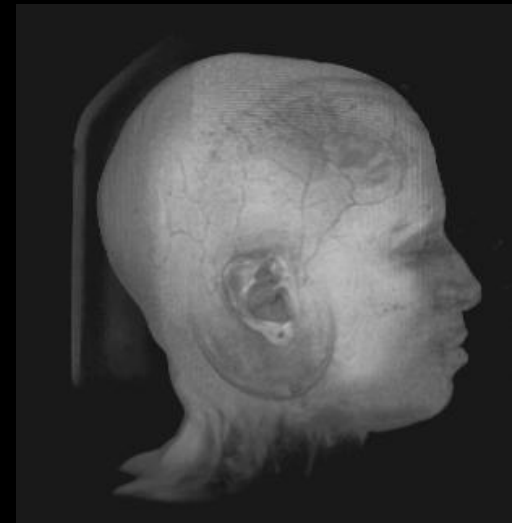
Caudal (L. Tail)

Rostral (L. Snout)



More terms that can be used for brains,  
but were originally meant for 4 legged animals,

Dorsal (L. Back)



Ventral (L. Belly)

# Lateral Medial

**lateral** (Latin *lateralis*, "to the side") (left or right).

**medial** means "towards the median (Latin *medius*, "middle") plane".

# Proximal Distal

**Proximal** (Latin *proximus*, nearest) is used to describe where the appendage joins the body.

**Distal** (Latin *distare*; to stand away from) is used for the point furthest from the point of attachment to the body.

## 2) Coordinate Systems

The MRI volume is a 3D matrix consisting of rows, columns and slices.

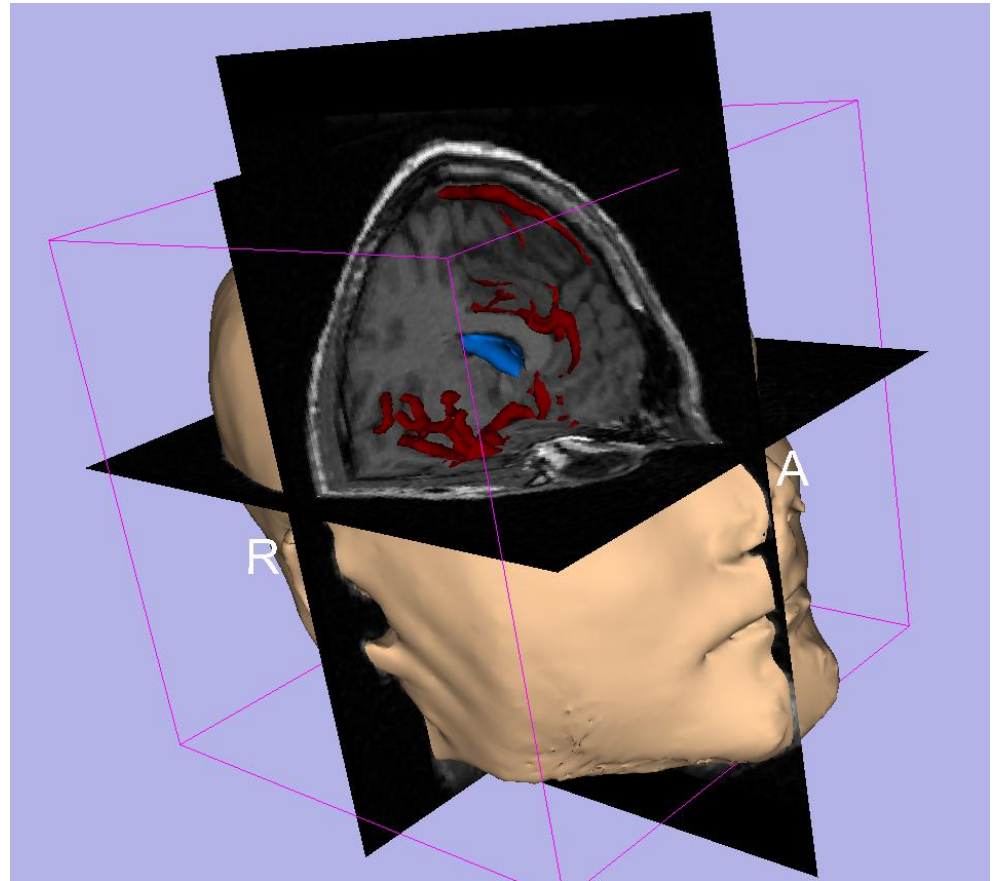
We need a way to talk about locations in the MRI volume.



# The 3 Orthogonal Planes

When we view 3D images of the brain, we view them in slices.

Orthogonal slices are at right angles to each other.

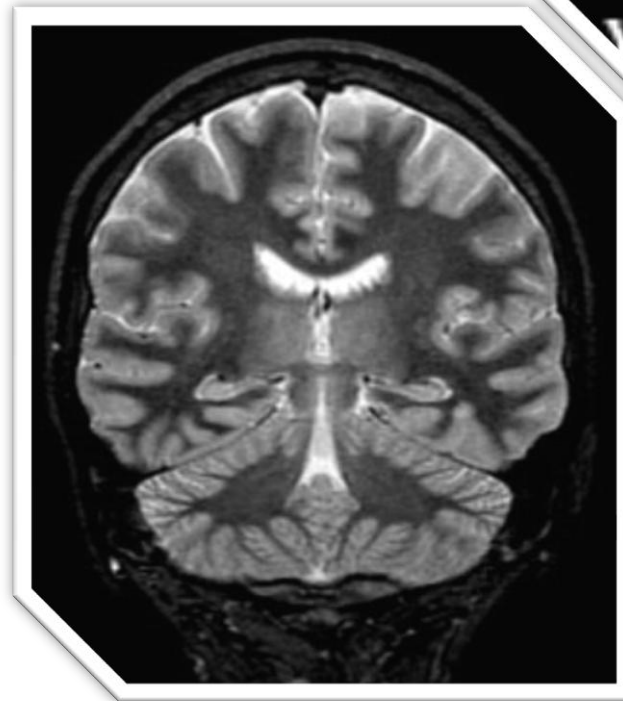


# Coronal

A coronal plane divides front from back.



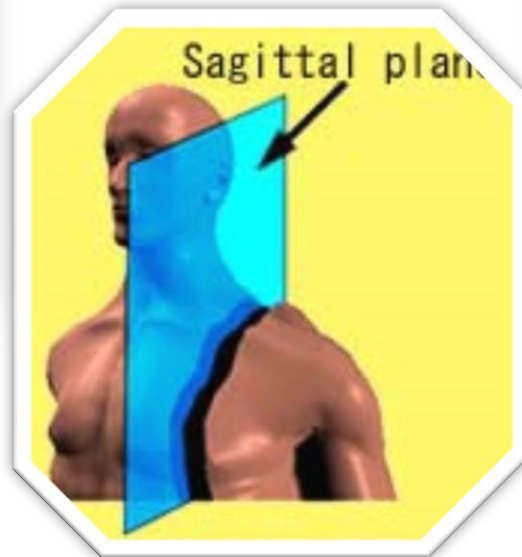
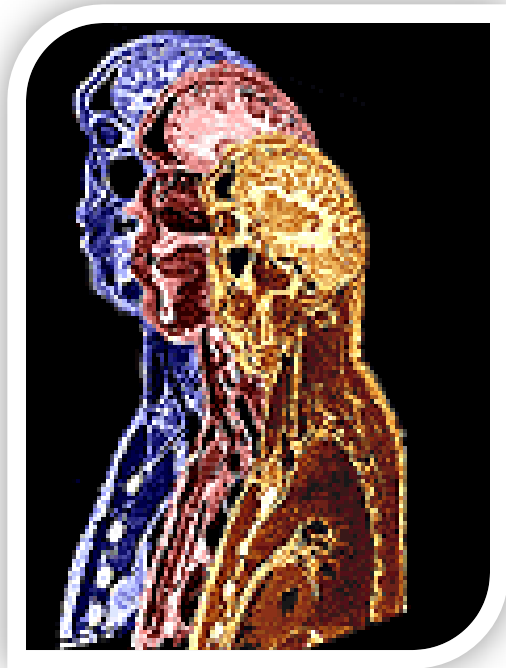
Corona



# Sagittal



- The sagittal (L. *Sagitta*, "arrow") plane divides left from right.



# Axial (Transverse)

A slice perpendicular to the long axis is "axial".  
The axial plane divides top from bottom.



# Oblique Planes

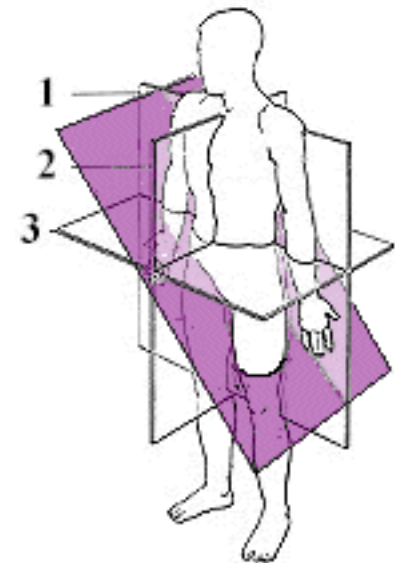
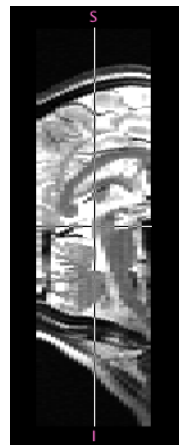
Any plane of section that is not one of the 3 orthogonal planes, is oblique.

Depending on the structure we wish to view, an oblique plane can be helpful.

Orthogonal

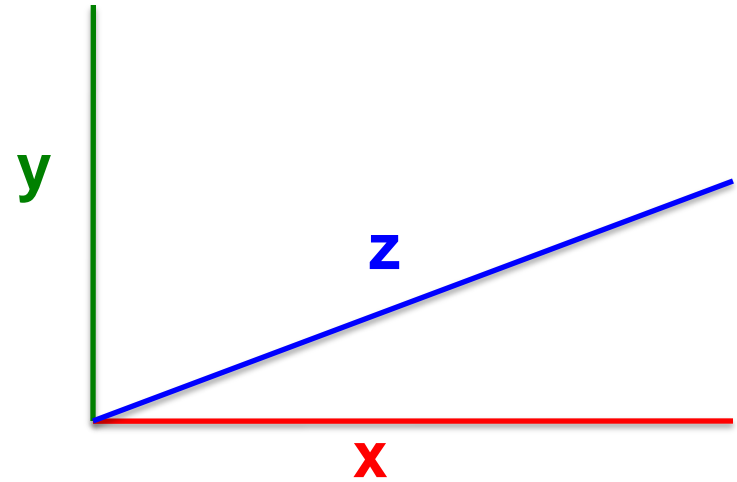


Oblique





# X and Y and Z



x, y and z represent the 3 orthogonal directions in the image:

Most brain imaging programs align the brain with the x,y,z axes in a preferred "canonical" view.

x is Right - Left (R-L)

y is Anterior - Posterior (A-P)

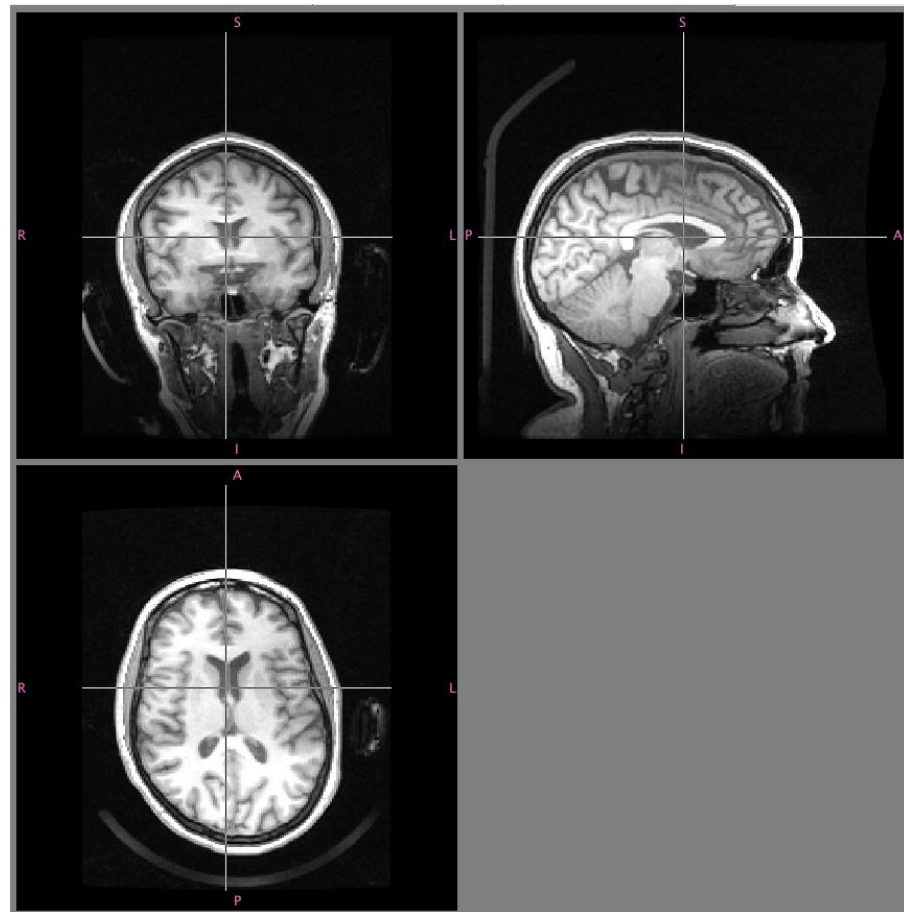
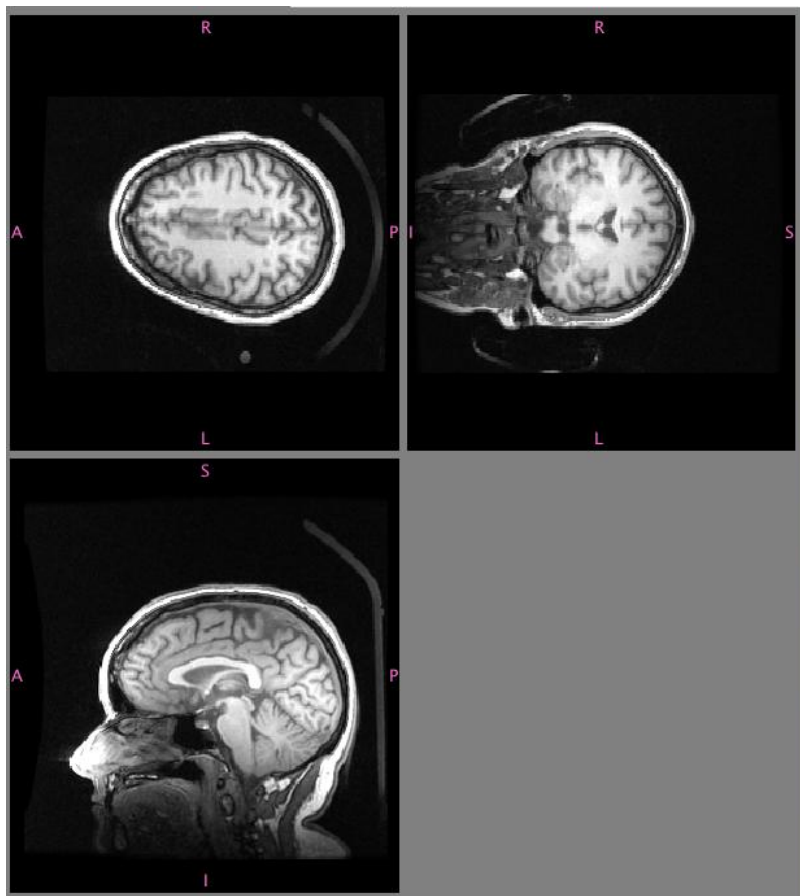
z is Inferior - Superior (I-S)

# Canonical Views

Non-canonical



Canonical



Example is FSL 4.1

# World space vs Voxel Space

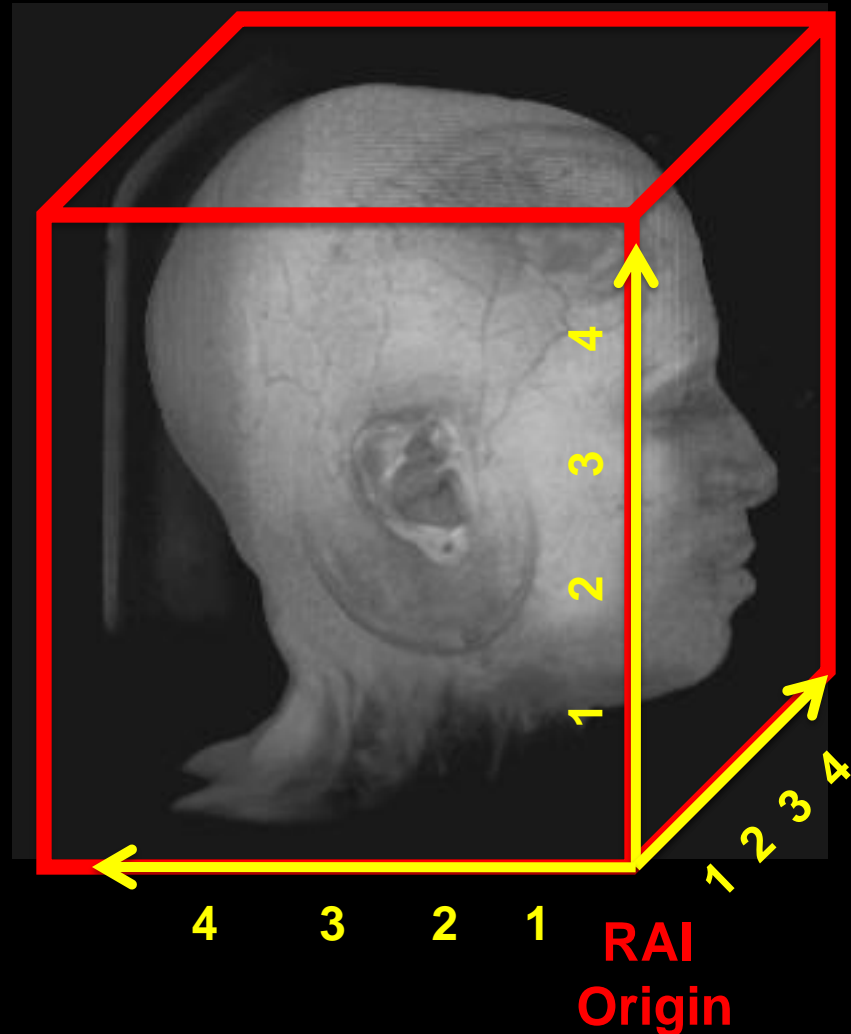
- **World space** corresponds to the real world. Brain positions are described in mm, relative to some physical origin (either the scanner isocenter or some anatomical structure).
- **Voxel space** corresponds to column, row, and slice indices (so a location is described in voxel counts from some outer corner).



# Image Origin: Voxel Space

Image origin in **voxel space** = "first voxel", i.e., the voxel whose coordinates are 0,0,0 (or in some systems 1,1,1). This is usually in one corner of the volume.

- Afni: RAI: 0,0,0
- FSL: RPI: 0,0,0
- SPM: RPI: 1,1,1



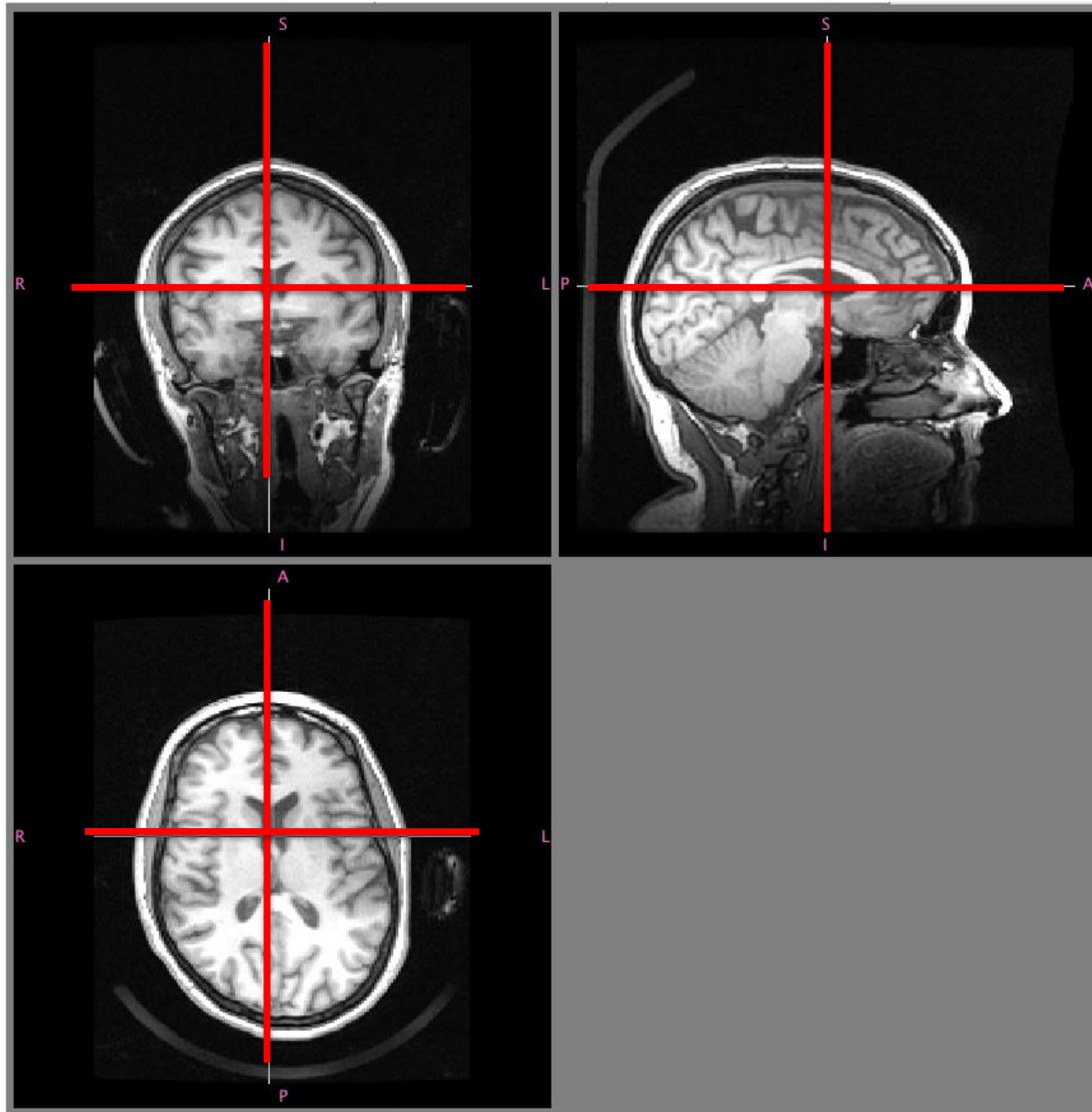
# Image Origin

Image origin in **world space** corresponds roughly to volume center (e.g., the magnet isocenter).

Default crosshair position typically starts at the image origin in world coordinates.

# Default Crosshair: Image Origin (World Coordinates)

Example is FSL 4.1



# Radiological-Neurological Conventions

**Radiological convention:** left is right. A "left-handed coordinate system".

**Neurological convention:** left is left. A "right handed coordinate system".

The conventions are used at 4 different interacting (conflicting?) levels.

# Radiological-Neurological Conventions

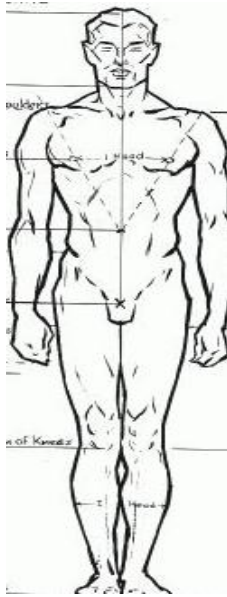
1) MRI scanners can collect images in either convention (depending on slice order).

2) Image analysis programs may assume one convention or the other.

3) The image can be displayed in either convention (regardless of how it was collected).

4) The new image format NIFTI, encodes L and R in the header.

# Radiological

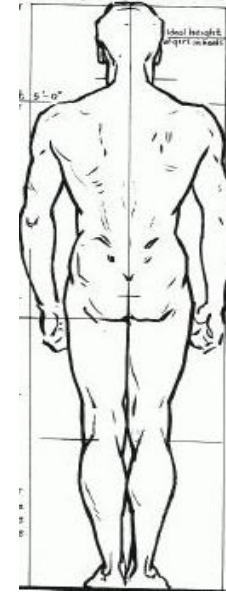


R

L

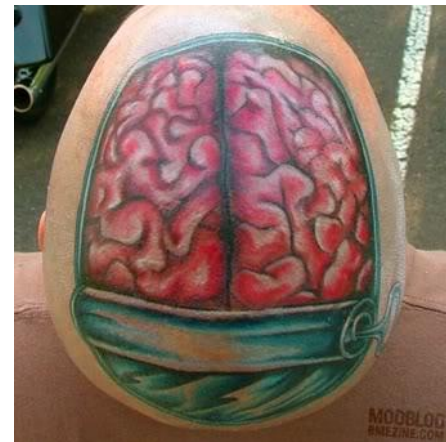


# Neurological

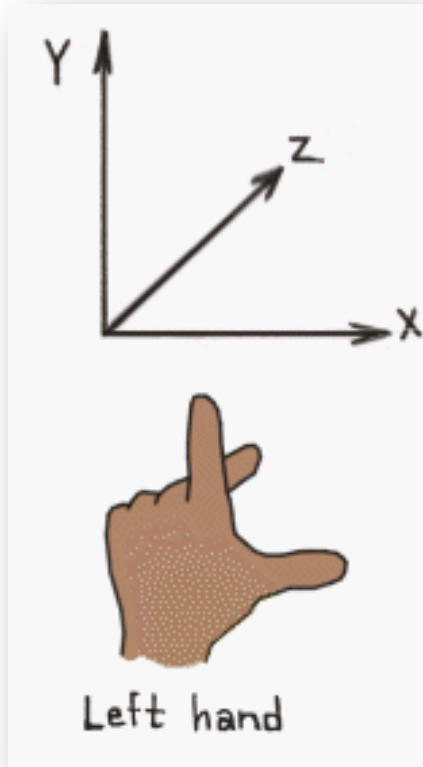


L

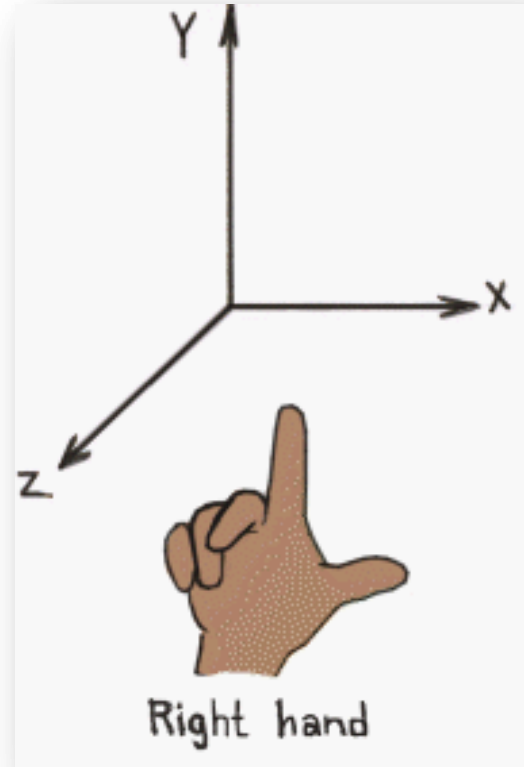
R



Radiological:  
(Left-handed)

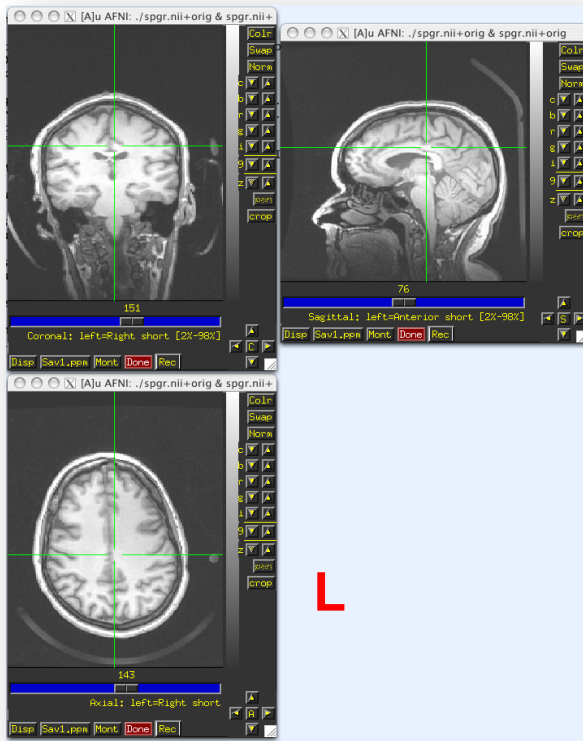


Neurological:  
(Right Handed)



Thumb = pos x,  
Index up = pos y,  
Middle out = pos z

# Interactions between image origin and radiological vs neurological conventions produce different canonical views.



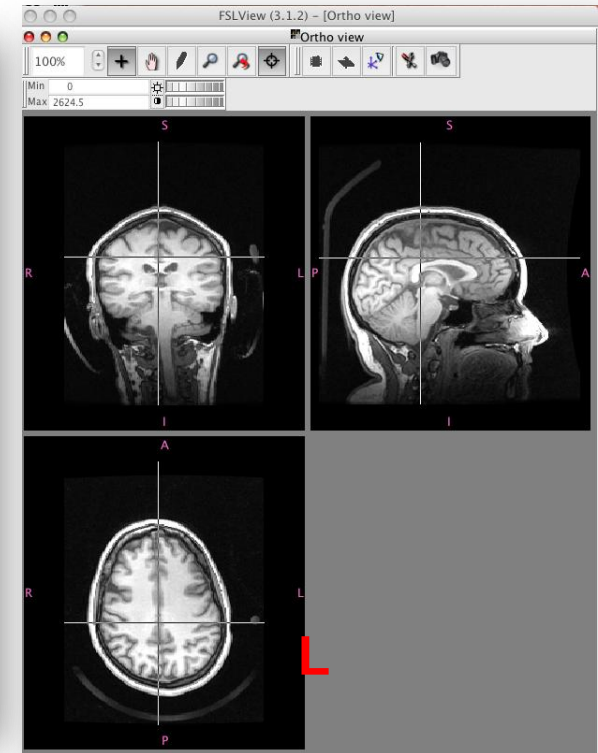
Afni

Radiological  
 $RAI=0,0,0$



SPM

Neurological  
 $RPI=1,1,1$



FSL

Radiological  
 $RPI=0,0,0$



### 3) Flipping and Rotation

Flipping

To get brains into canonical orientations, we may have to flip them several times.

Flipping is always 180° and preserves the orthogonal axes.

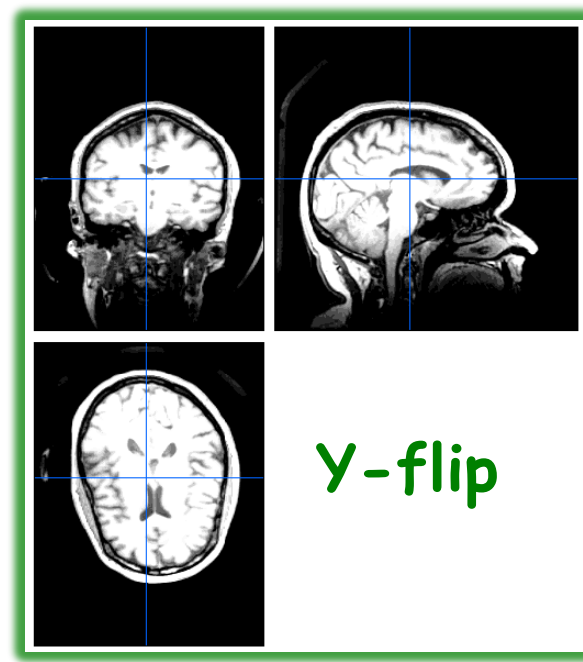
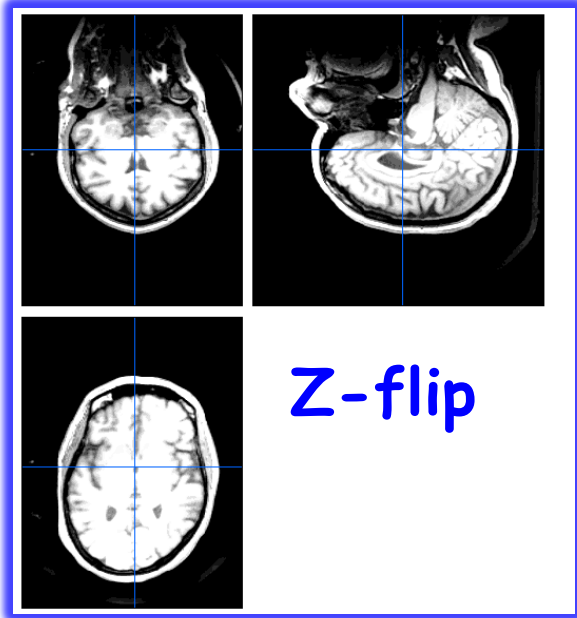
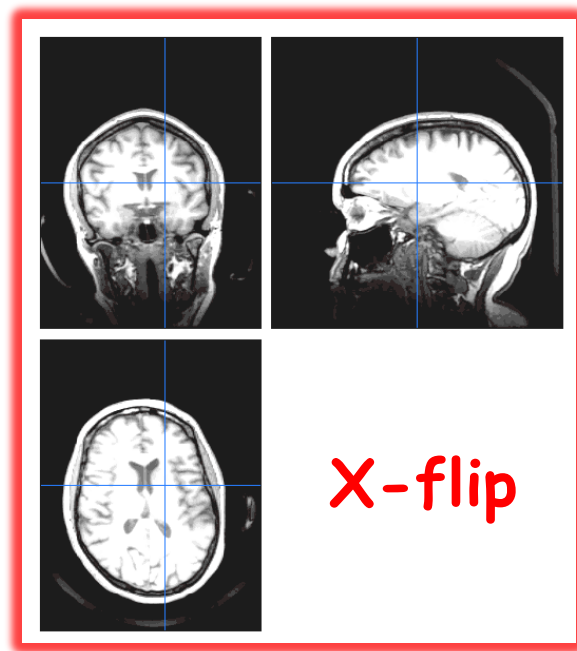
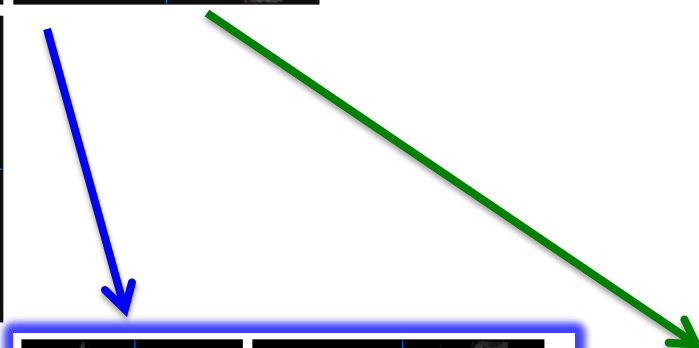
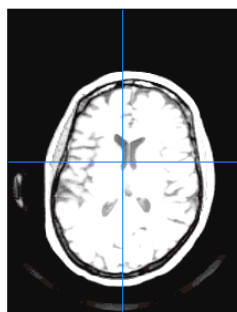
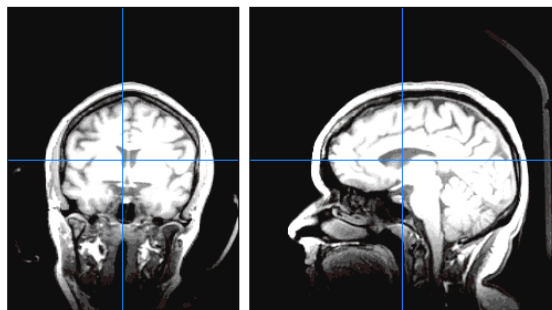
Rotation

Rotation is more flexible than flipping.

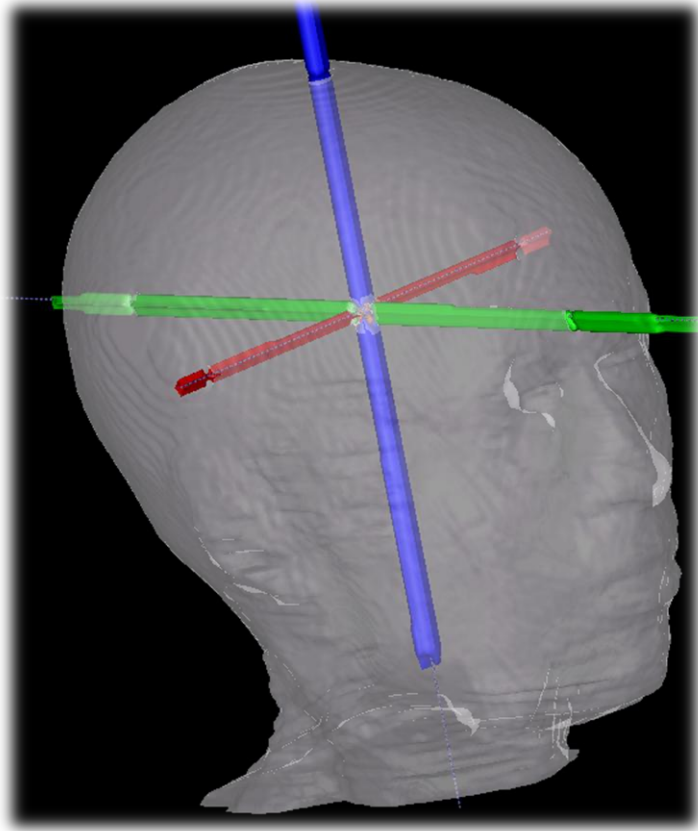
Rotation can be positive or negative.

# Flipping

Canonical SPM



# Rotation



- Rotation around the **x-axis** is **pitch**.
- Rotation around the **y-axis** is **yaw**.
- Rotation around the **z-axis** is **roll**.

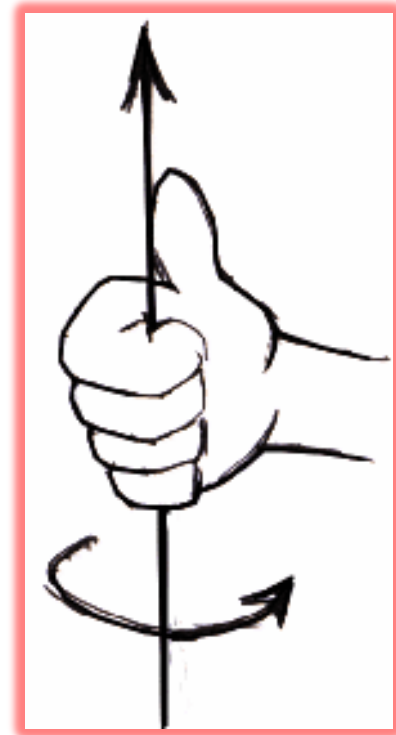
# Rotation

Grasp axis with thumb oriented in positive direction, fingers will then curl in direction of positive rotation for that axis.

Left Handed:  
Clockwise

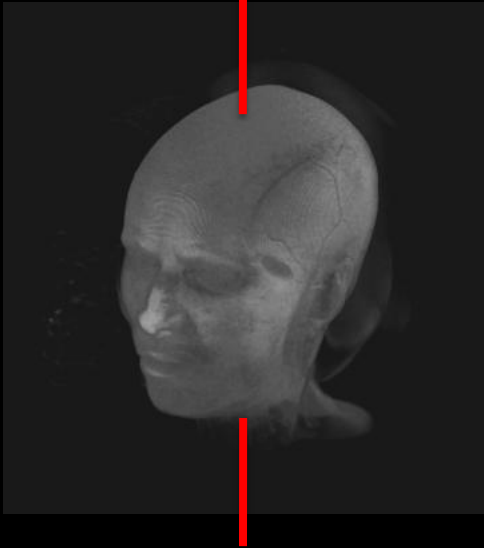


Right Handed:  
Counter-Clockwise



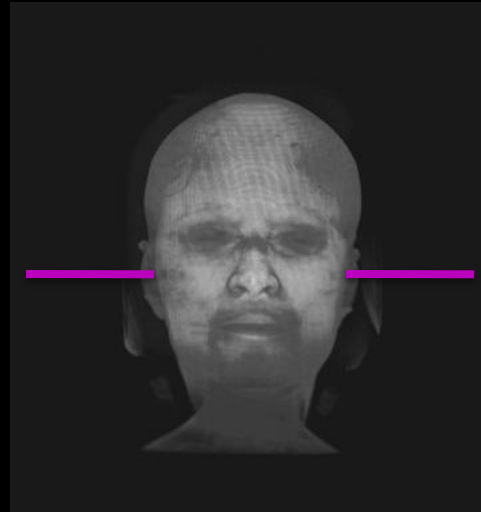
# Positive and Negative Rotation

**ROLL:**  
Rotation  
around the  
z-axis.  
("no")



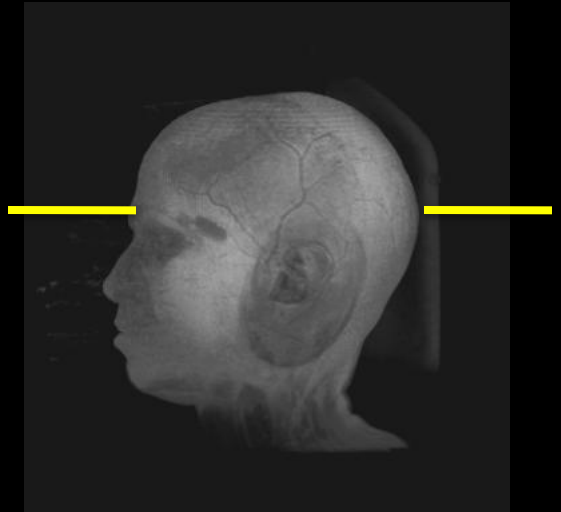
Clockwise:  
+ rotation, FSL;  
-rotation, SPM.

**PITCH:**  
Rotation  
around the  
x-axis.  
("yes")



Forward  
(Clockwise)  
+rotation, FSL;  
-rotation SPM.

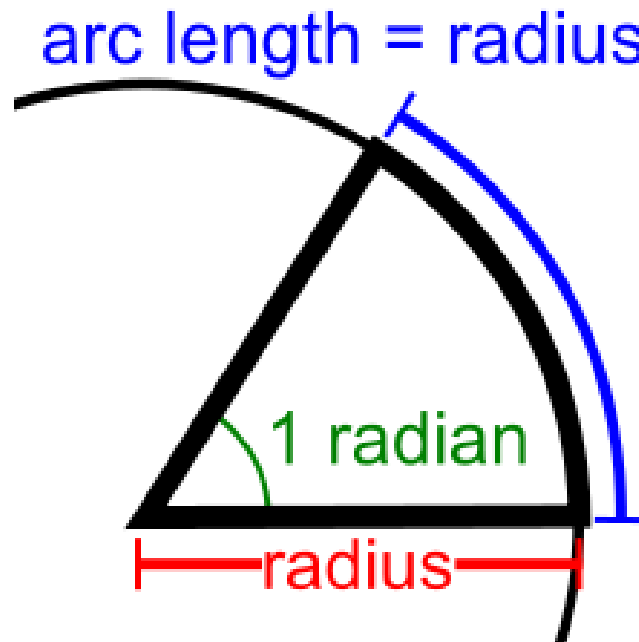
**YAW:**  
Rotation  
around the  
y-axis.  
("maybe")



Rightward  
(Clockwise)  
+rotation, FSL;  
-rotation SPM.

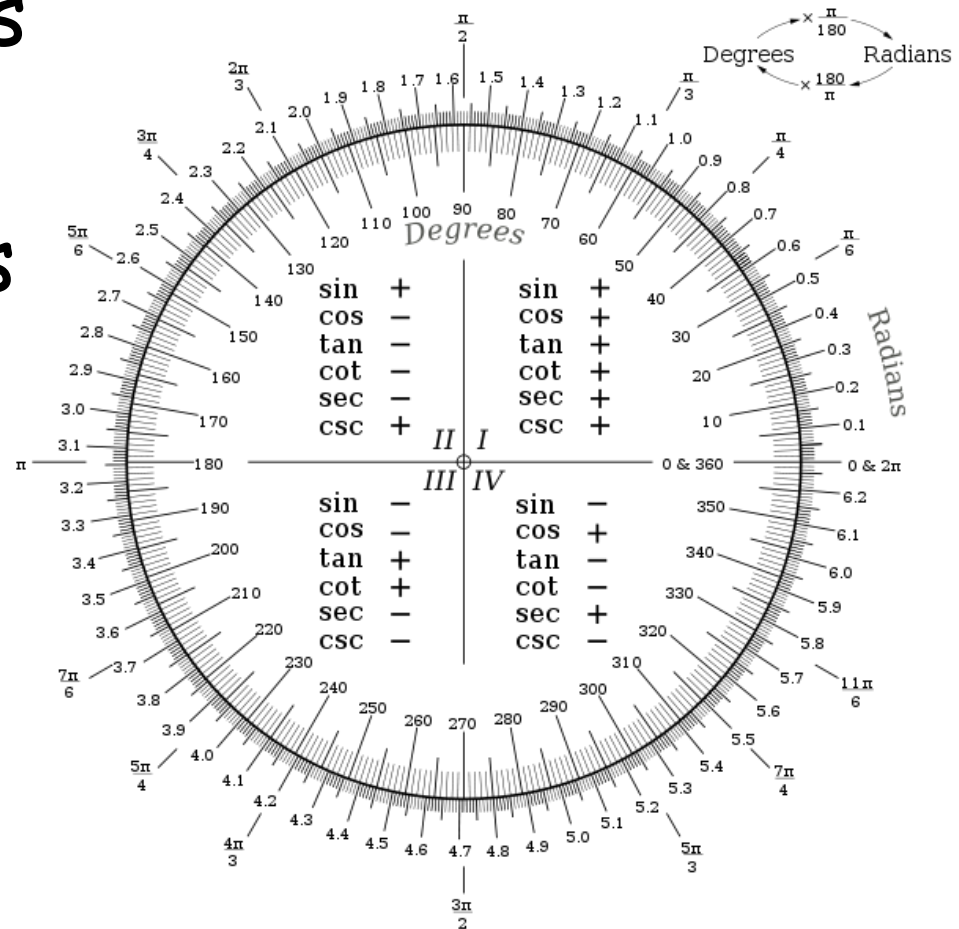
# Degrees and Radians

- FSL measures rotation in degrees.
- SPM measures rotation in radians.
- 1 radian = # of degrees in an angle for which the arc and radius are equal.



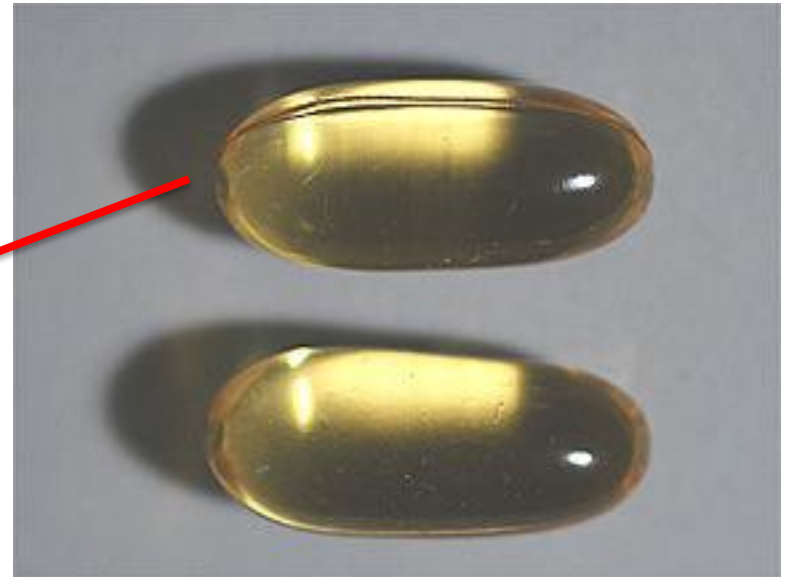
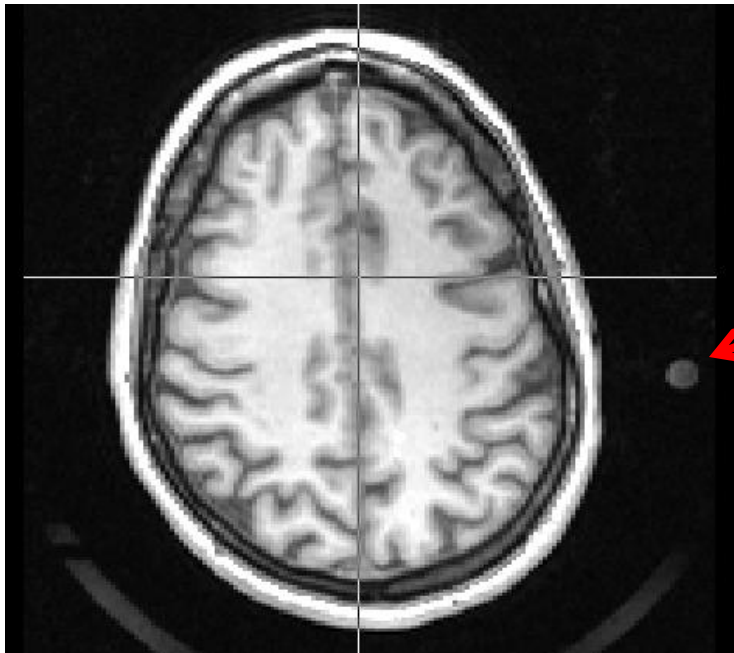
# Radians

- $\text{radians} = \text{degrees}(\pi/180)$ .
- $1 \text{ degree} = \pi/180 = 0.0175 \text{ radians}$ .
- $180 = 3.1416 \text{ radians}$
- $90 = 1.5708 \text{ radians}$
- $45 = 0.7854 \text{ radians}$



# Fiducial

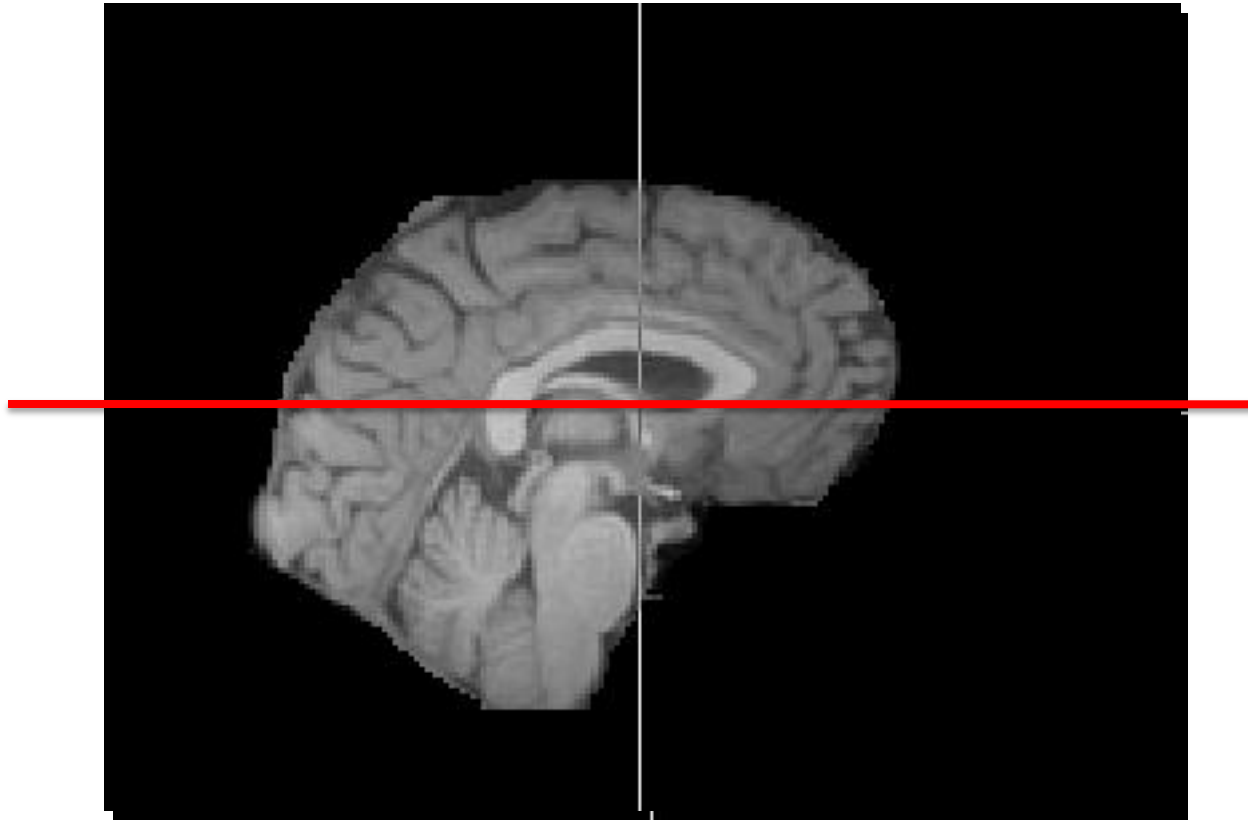
- Use a fiducial (L."to trust"), like a fish oil capsule taped to the left side of the head.
- This way you always know right from left in resulting images, no matter what transformations you apply to the image.





# Fiducials in the brain

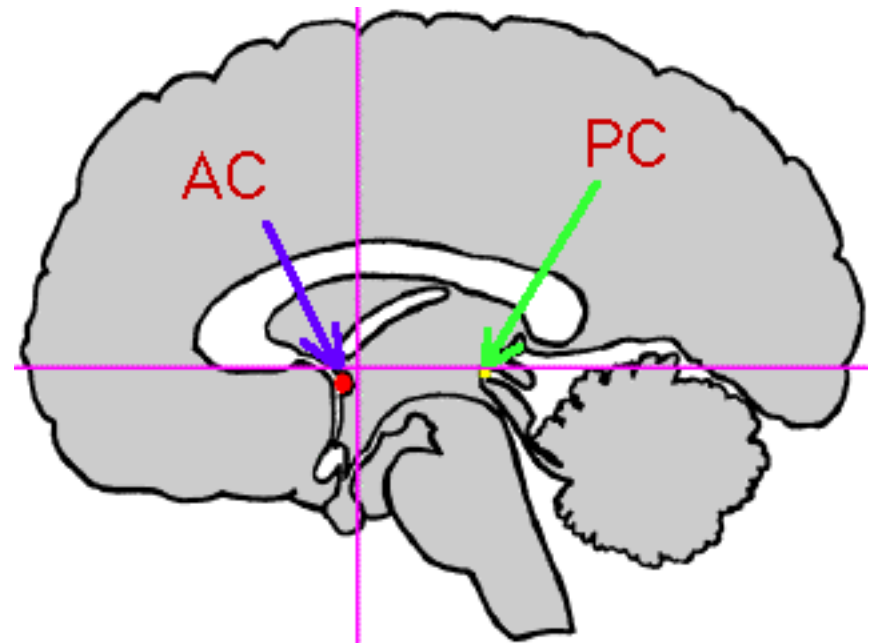
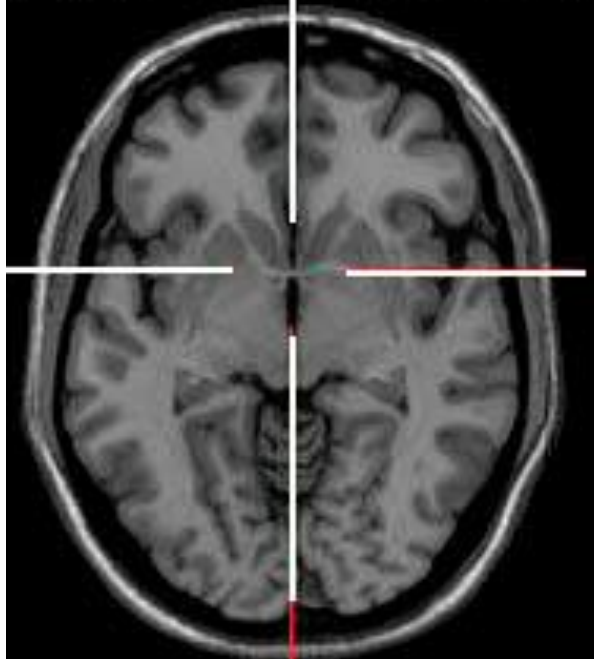
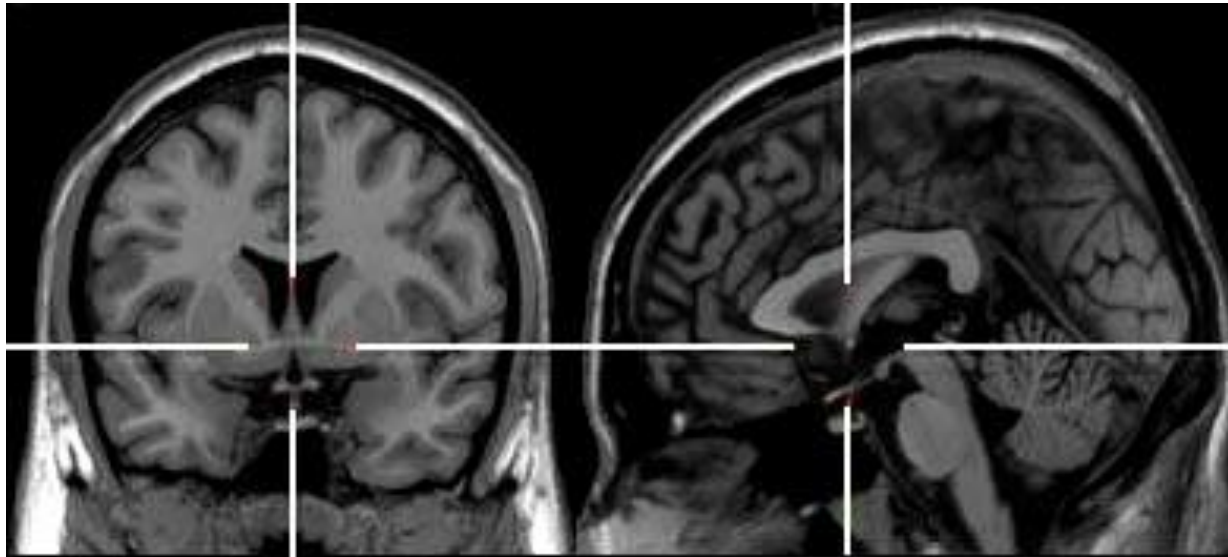
- Not only do the shapes and sizes of peoples' brains differ, but how the orientation of the brain varies inside the skull.



# Fiducials in the Brain

- To maximize slice angle similarity, researchers sometimes align the brain slices to internal fiducials, like the AC-PC line (Anterior to Posterior Commissure).

# AC-PC Line (Anterior to Posterior Commissure)



# Summary

- To do brain imaging, you must discuss the relative positions of structures in the brain.
- In addition, you must understand the coordinate systems used to describe 3D volumes, and how easy Left-Right confusion is.
- Finally, it can be VERY useful to understand fiducials and how to use them.

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