

## Neuro Imaging Data

Diffusion Imaging  
Data

Structural Imaging  
Data

- \* Deals with the Structure of the brain and the diagnosis of gross intracranial disease such as tumor, Strokes and Injury

### \* Convert Between File Formats

Source /org/fsl/fslviz | Pml-Zarvo | Software | bashrc

### \* Computerized Axial Tomography is a form of STRUCTURAL NEUROIMAGING

- Series of x-ray Images of Head
- Images used to Construct overall Image of Brain
- Relatively low resolution
- Can see major structural Problems

## MRI (Magnetic Resonance Imaging)

- \* Structural neuroimaging , uses magnetic fields and radio frequency energy , Hydrogen atoms respond by emitting energy , Machine uses Energy to Construct Image . Better resolution than CAT Scan .

## POSITRON EMISSION TOMOGRAPHY (PET)

- \* Functional Neuroimaging , Patient Injected w/ Radioactive Substance , Substance Emits Positrons , Positrons collide with Tissue , Emit gamma rays , Gamma rays detected by device , gives Image of cerebral blood flow , Shows which areas are most active .

## FUNCTIONAL MAGNETIC RESONANCE IMAGING (fMRI)

- \* Functional Neuroimaging , uses magnetic field and Radio frequency energy , uses different response of oxygenated and un oxygenated blood to detect change in blood flow , Shows which areas are most active shows activity along with High resolution Structural Image .

## RESOLUTION

SPATIAL (How small  
Can we see things happening  
in the brain)

TEMPORAL (How quickly things  
change that we can capture in  
the brain)

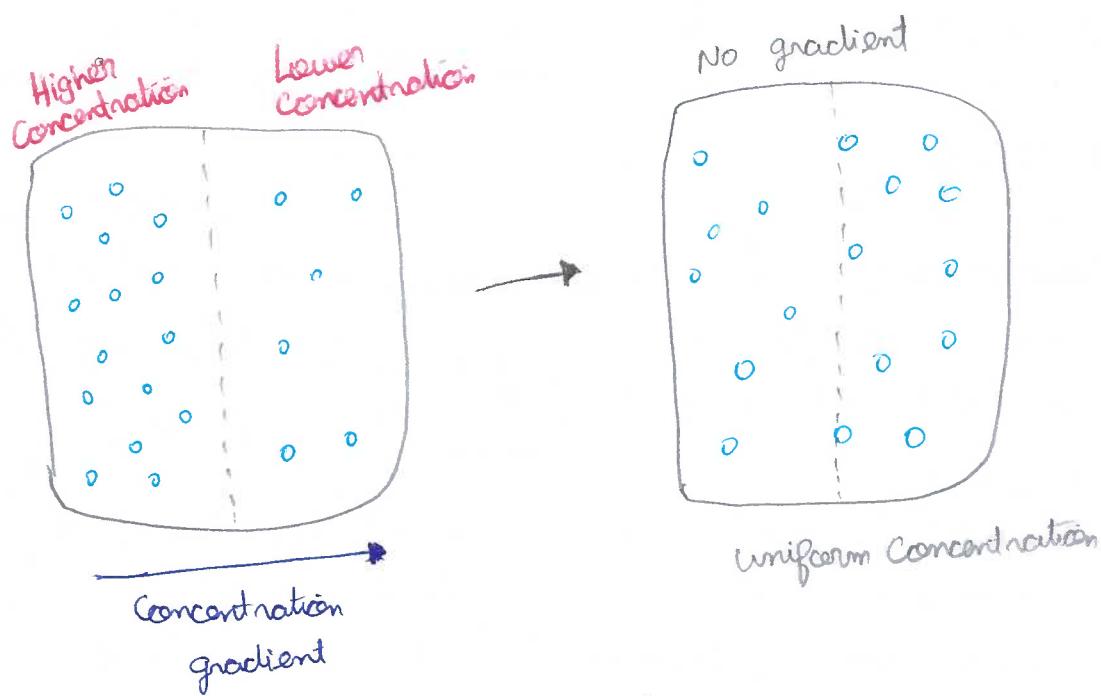
- \* Lot of people when use MRI, they are doing VOLUMETRIC STUDIES
- \* VOLUMETRIC STUDIES are Studies of Volumes (What is the volume of AMIGO when you are 3, 4, 5 and 6). Some people study the Structure & some people study the Volume.

01/29/2019  
TUESDAY

## DIFFUSION IMAGING - BASIC CONCEPTS

- \* MR Images represent displacements of water molecules at the cellular level
- \* Probing motion at the micrometer scale, orders of magnitude smaller than MR resolution

\* Diffusion : Relates flow to Concentration gradient



### CONCENTRATION GRADIENT :-

Concentration of a chemical in a solution refers to how many of the chemical's molecules are sitting in a small volume of the solution. Concentration could be measured in molecules per liter, although molecules are so small compared to a liter that we usually use different units. A GRADIENT is a measurement of how much something changes as you move from one region to another. So a CONCENTRATION gradient is a measurement of how the concentration of something changes from one place to another.

 → Constant Concentration of molecules  
(NO GRADIENT)



→ A concentration gradient, with a higher concentration of molecules on the right than on the left.

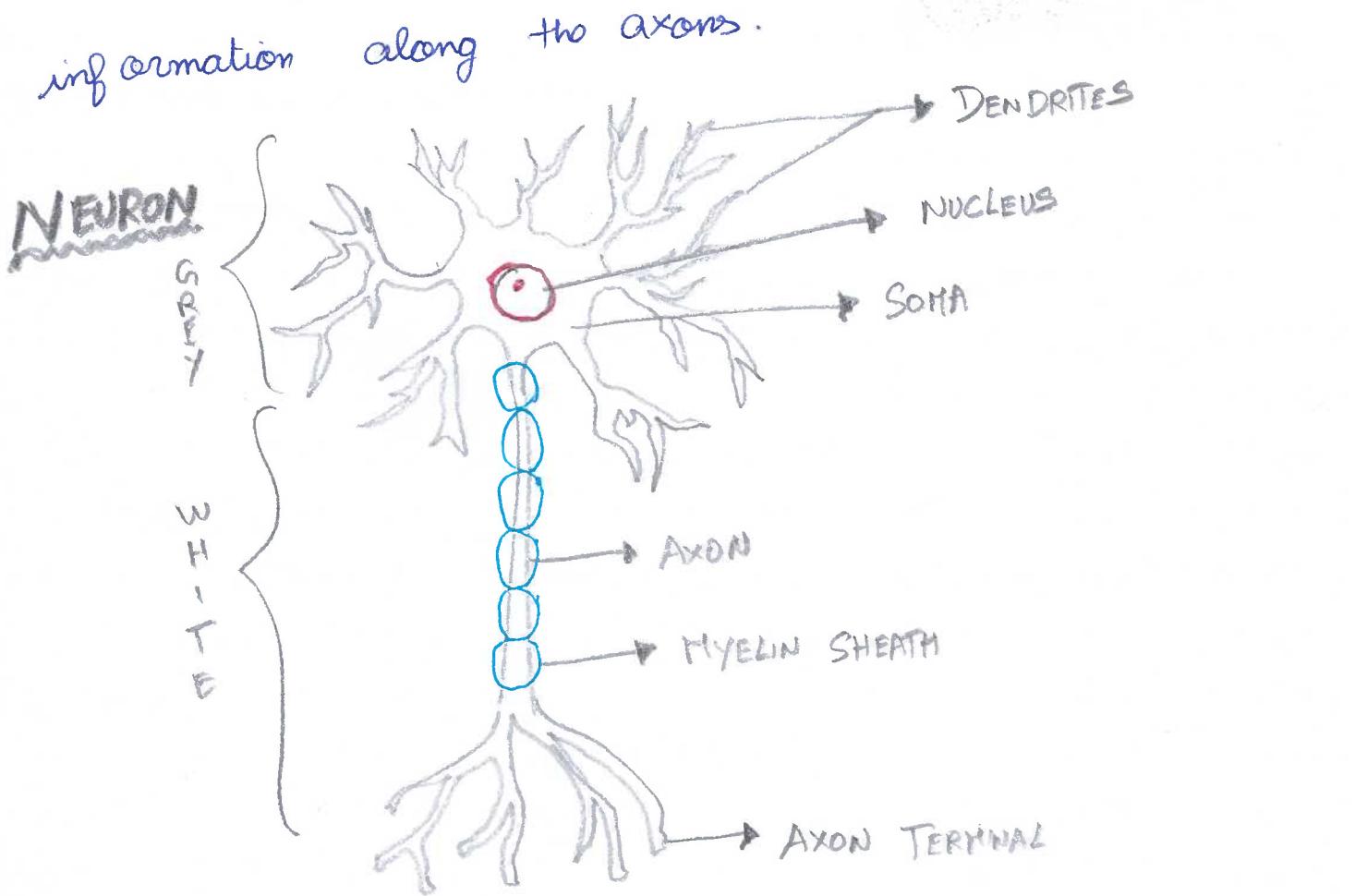
$$\boxed{\text{Flow} = D \frac{dc}{dx}}$$

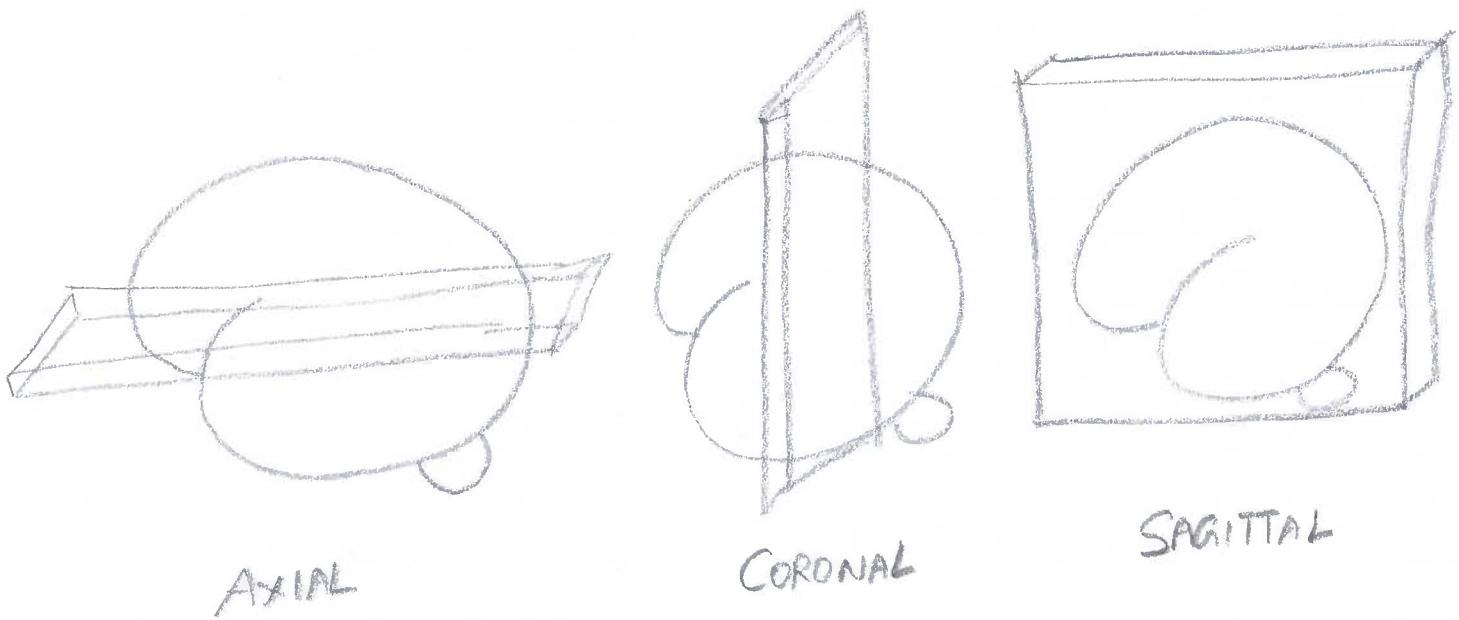
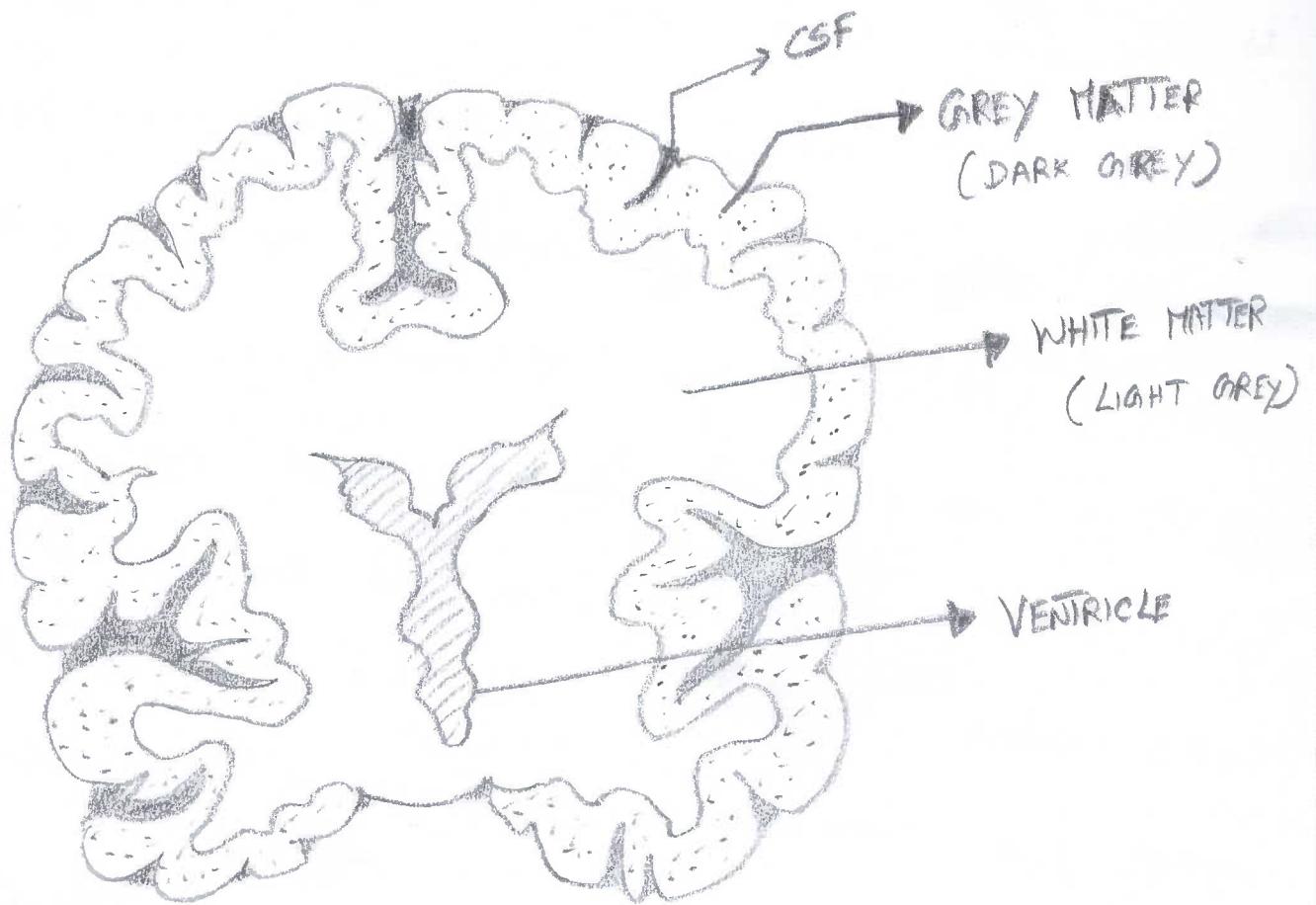
DWI → Diffusion Weighted Image



Now suppose we zoom out so that instead of seeing discrete little particles, we see a continuous gradient going from left to right (because molecules are so small, you can't see the individual molecules that make up food colouring in water). If we represent high concentrations with dark pink and lower concentrations with white, a continuous gradient would look like above picture.

White Matter: White matter is found in the deeper fissures of the brain (sub cortical). It contains nerve fibers (axons), which are extensions of nerve cells (neurons). Many of these nerve fibers are surrounded by a type of sheath or covering called myelin. Myelin gives the white matter its color. It also protects the nerve fibers from injury. Also, it improves the speed and transmission of electrical nerve signals. Neurons use electro-chemical signals to transfer information along the axons.



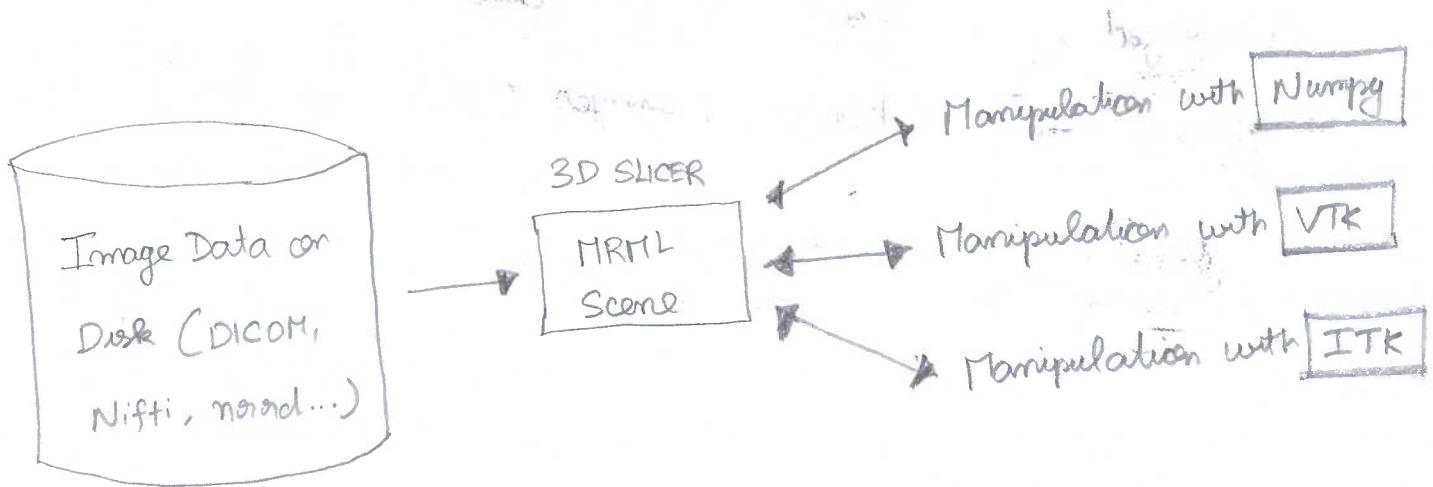


## SLICER MODULES :

Command Line Interface → Standalone executable with limited Input / output arguments

Scripted Modules (Python) → Recommended for fast Prototyping

Loadable Modules (C++ Plugin) → optimized for heavy Computation



**MRML → MEDICAL REALITY MARKUP LANGUAGE**

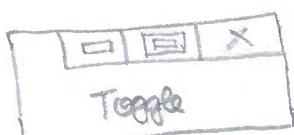
**SLICER LIBRARIES → PYTHON 2.7, NUMPY, VTK, CTK, ITK, PYTHON QT**

QT GUI IN PYTHON

b = qt.QPushButton('Toggle') → creates a button called 'Toggle'

b. connect ('clicked()', toggle) → Function is integrated to the button

b. show()



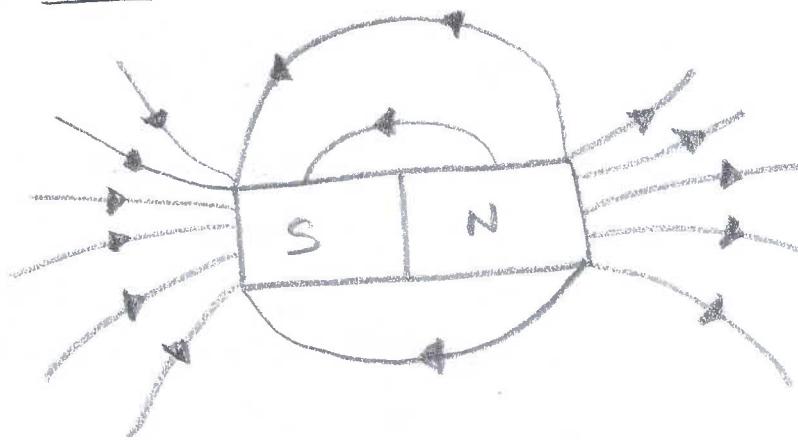
## Module :

- \* Defines User Interface , Processing , Self - tests
- \* Various types : Scripted (Python) , CLI , Loadable (C++)

## Extension :

- \* Collection of modules
- \* Packaged in a single zip file and distributed through the Extension Manager (Slicer app store)

## MAGNETIC FIELD :

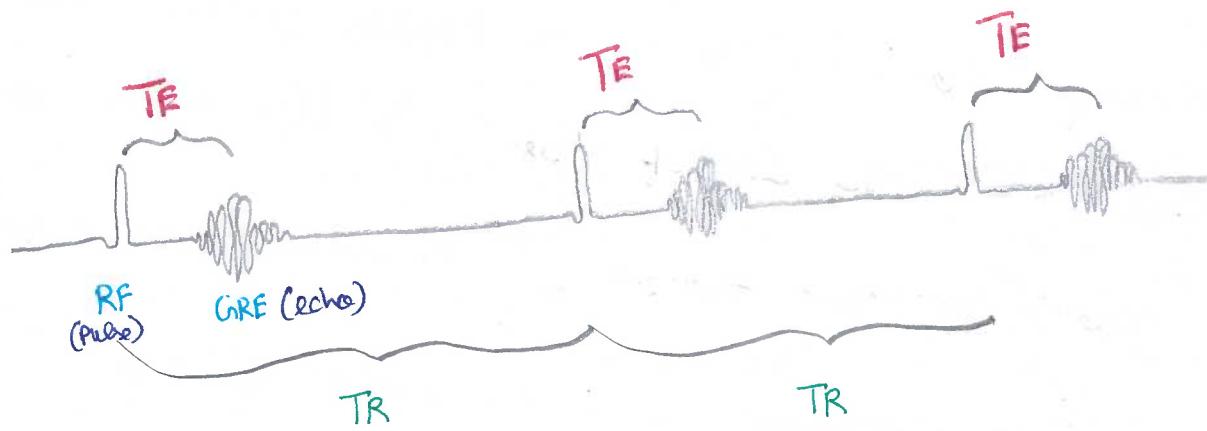


A Magnetic field is formally defined to be an array of Vectors (denoted by the boldfaced letter  $\mathbf{B}$ ) whose magnitude  $B$  and direction at each point in space define how the field will act on a charge moving at that location

## TR and TE

TR and TE are basic pulse sequence parameters and stand for REPETITION TIME and ECHOTIME respectively. They are typically measured in milliseconds (ms).

Echo Time (TE) represents the time from the center of the RF-pulse to the center of the echo. For pulse sequences with multiple echoes between each RF pulse, several echo time may be defined and are commonly noted TE<sub>1</sub>, TE<sub>2</sub>, TE<sub>3</sub> etc.



Repetition Time (TR) is the length of time between corresponding consecutive points on a repeating series of pulses + echoes.

TISSUE can be characterized by two different relaxation times -  $T_1$  and  $T_2$

$T_1$  (Longitudinal relaxation time) is the time constant which determines the rate at which excited protons return to equilibrium. It is a measure of the time taken for the spinning protons to realign with the external magnetic field.

$T_2$  (Transverse relaxation time) is the time constant which determines the rate at which excited protons reach equilibrium or go out of phase with each other. It is a measure of time taken for spinning protons to lose phase coherence among the nuclei spinning perpendicular to the main field.

### MRI Imaging Sequences:-

The most common MRI Sequences are  $T_1$ - weighted and  $T_2$ - weighted scans.  $T_1$ - weighted Images are produced by using short TE and TR times. The Contrast + brightness of the Image

are predominantly determined by T1 properties of tissue.

T2-weighted images are produced using longer TE and TR times.

In these images, the contrast and brightness are predominately determined by the T2 properties of the tissue.

In - general T1 and T2 weighted Images can be

easily differentiated by looking the CSF . CSF is dark on

T1 - weighted imaging and bright on T2 - weighted Imaging

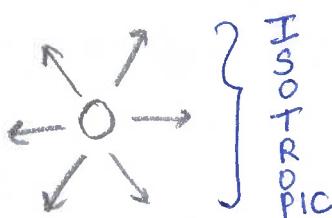
	Short TR	Long TR
Short TE	T1	PD
Long TE	NOT-USED	T2

## DIFFUSION IN BRAIN TISSUE

\* we can differentiate between tissues in the brain based on how water molecules **diffuse** through each type of tissue

### GREY MATTER

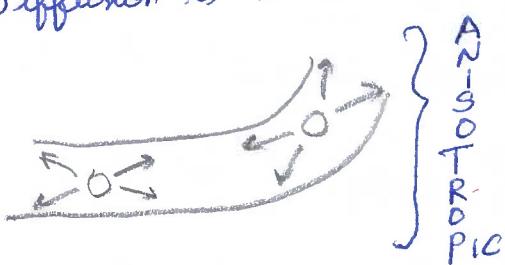
→ Diffusion is unrestricted



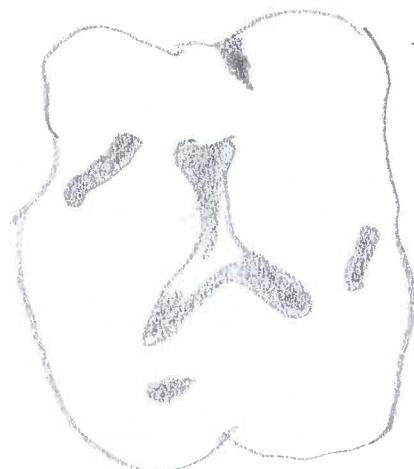
Water molecules are equally likely to move in any possible direction

### WHITE MATTER

Diffusion is Restricted



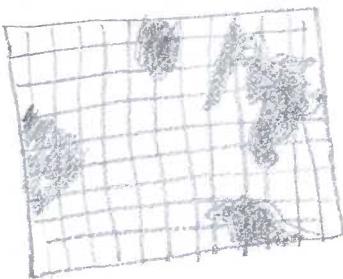
Water molecules move more freely in parallel to the axons than in to axons



→ What this contrast tells us?

At any voxel that's very dark, at that voxel there was a lot of movement parallel to the gradient direction

Lighter voxel, less movement to the gradient direction



At every Voxel we want to know

- Is this in white matter
- What is the orientation of diffusion
- What is the Magnitude of diffusion  
↓  
the speed at which the water molecules are diffusing

For every Voxel in the Brain

I need to capture the above Info

How? For each Voxel what the 3D Trajectory of diffusion is like in that location?

One way is TENSOR D

A tensor is a  $3 \times 3$  symmetric, Positive -definite matrix

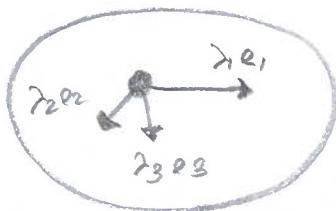
$$D = \begin{bmatrix} d_{11} & d_{12} & d_{13} \\ d_{12} & d_{22} & d_{23} \\ d_{13} & d_{23} & d_{33} \end{bmatrix}$$

D is a Symmetric  $3 \times 3 \Rightarrow$  It has 6 unique elements

The Matrix D is o Positive -definite  $\Rightarrow$

→ It has 3 real, Positive eigen values  $\lambda_1, \lambda_2, \lambda_3 > 0$

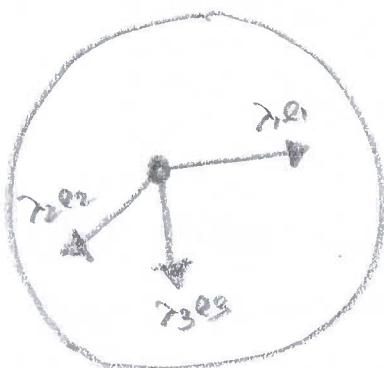
→ It has 3 orthogonal eigen vector  $e_1, e_2, e_3$



- \* Eigen Vectors express diffusion direction
- \* Eigen values express diffusion magnitude

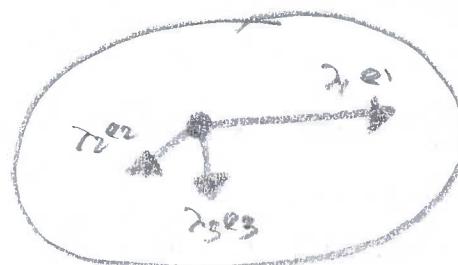
### I SOTROPIC DIFFUSION

$$\lambda_1 \approx \lambda_2 \approx \lambda_3$$

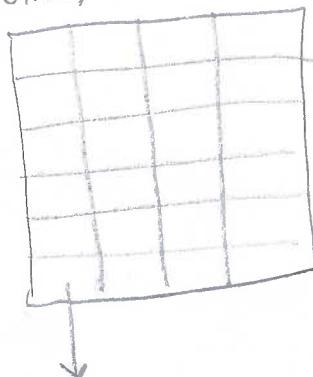


### ANISOTROPIC DIFFUSION

$$\lambda_1 > \lambda_2 \gg \lambda_3$$

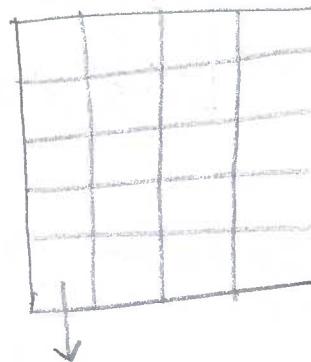


### GREY-SCALE IMAGE



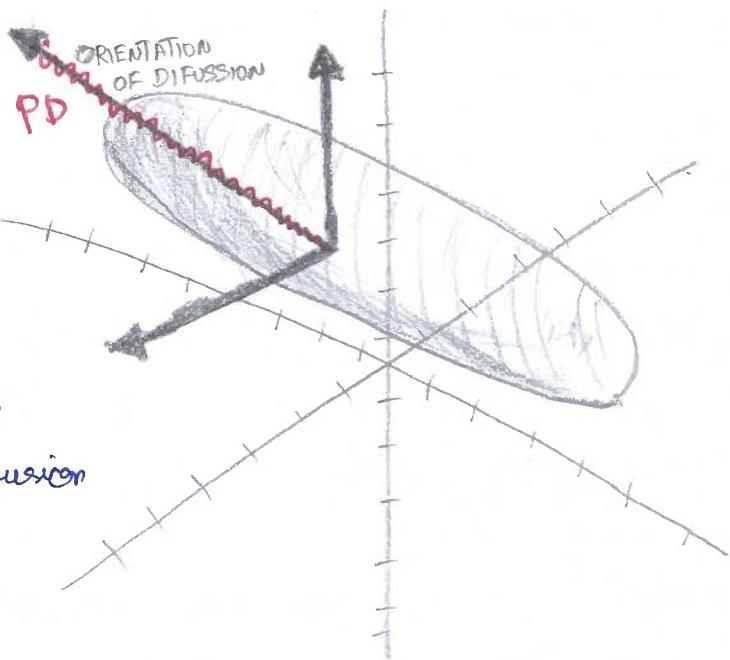
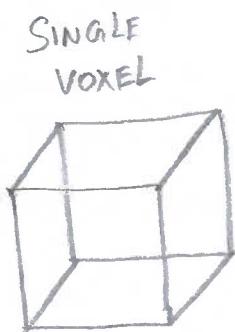
Intensity value at  
each voxel

### TENSOR MAP



A Tensor at each Voxel

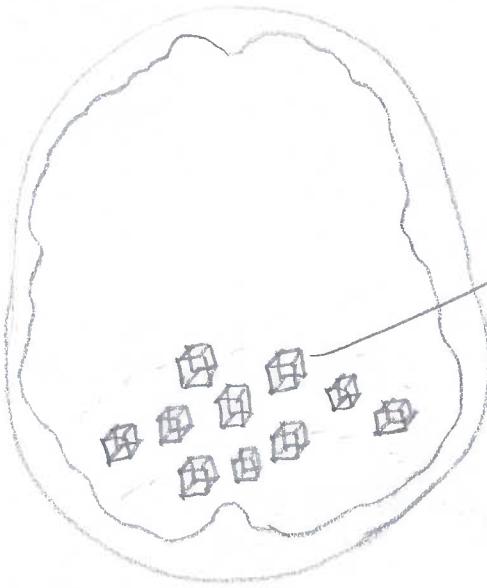
## 3D ELLIPSE



- \* From a Single VOXEL we can calculate, what is the diffusion in the VOXEL looks like
- \* The long axis tells us the overall dominant direction of diffusion at that VOXEL
- \* The thickness of the 3D-Ellipsoid is expressed as FRACTIONAL ANISOTROPY. This is a scalar value between 0 and 1. A value of zero means the diffusion is isotropic. A value of one means that diffusion occurs only along 1 axis and is fully restricted along all other directions. The PRINCIPAL DIRECTION of the diffusion tensor can be used to infer the white-matter connectivity of the brain.

WHITE MATTER	GREY MATTER
FA is HIGH (ellipsoid)	FA is SMALL (sphere)

D → Rate of diffusion (How fast the spins are moving)



what is the Principal diffusion direction at each VOXEL?  
Let's look at the surrounding Voxel and take a look at the orientation of the R<sub>0</sub> diffusion. Do we find a streamlin?

IS THERE A CONTINUOUS PATHWAY OF PRINCIPAL DIFFUSION DIRECTION  
this allows us to re-construct the location and orientation of diffusion by doing TRACTOGRAPHY

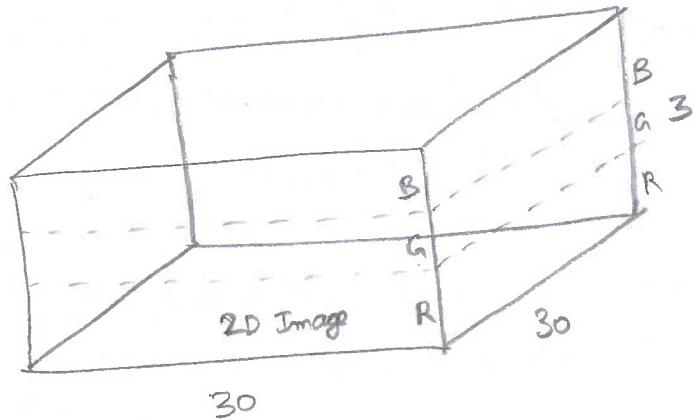
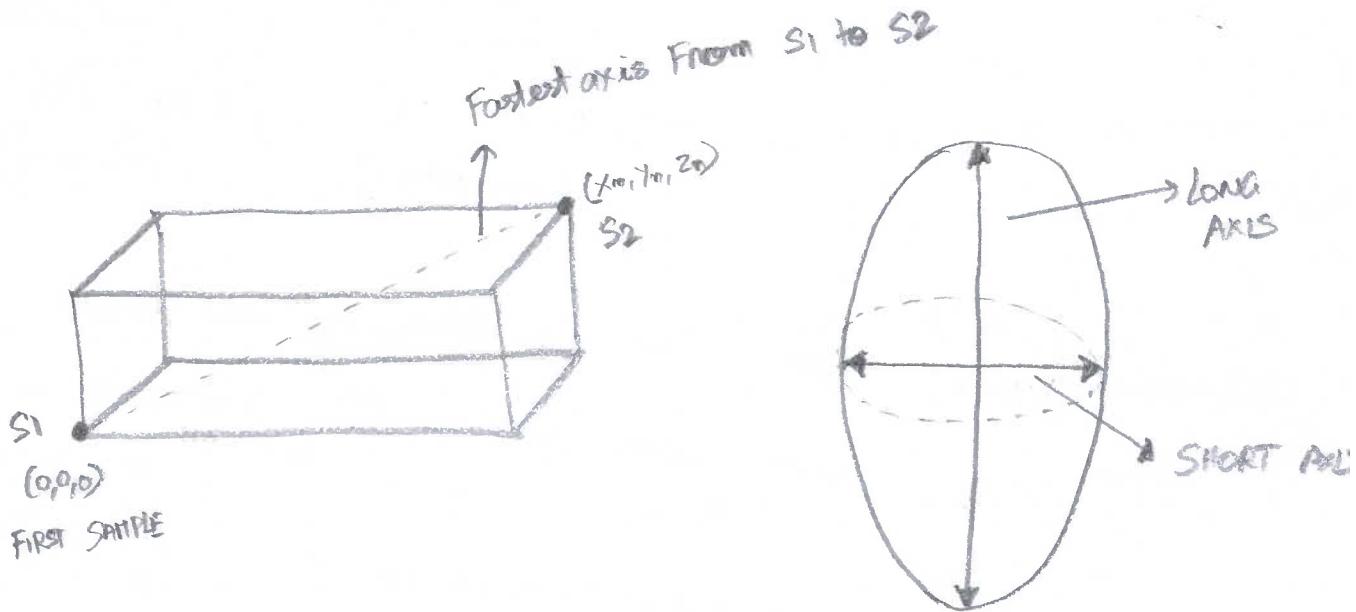
NRRD: Tool for representing and Processing N-dimensional raster data.

4 aspects of Raster data

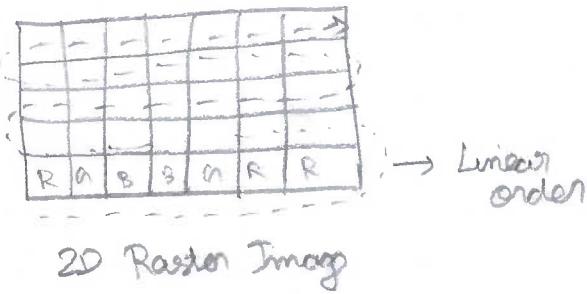
- 1) Dimension of the grid
- 2) Raster order of the samples
- 3) Details about each axis and data associated with each Sample Point

Data dimension:

$$\text{NRRD\_DIM\_MAX} = 16$$



the "Fastest" axis is the one associated with the co-ordinates which increments fastest as the samples are traversed in linear order.



Color axis - Horizontal - Vertical axis

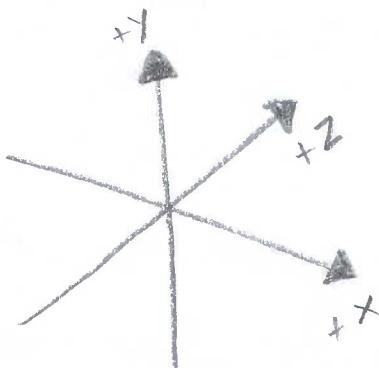
FAST

SLOW

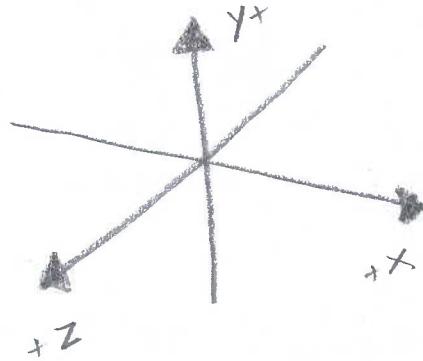
Anterior	Posterior	Superior	Inferior
FRONT VIEW	BACK VIEW		
		Toward the head / upper part of a structure (Bird's view, looking down)	Away from the head / lower part of a structure (Bottom view, looking up)

"Mutually exclusive" refers to two conditions, by their nature cannot both exist at the same time.

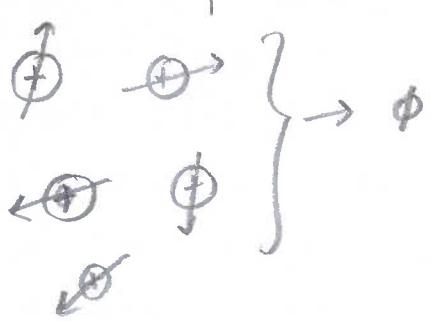
Example: "At any given moment, a certain cat may be alive or it may be dead, but it cannot be both. These conditions are mutually exclusive".



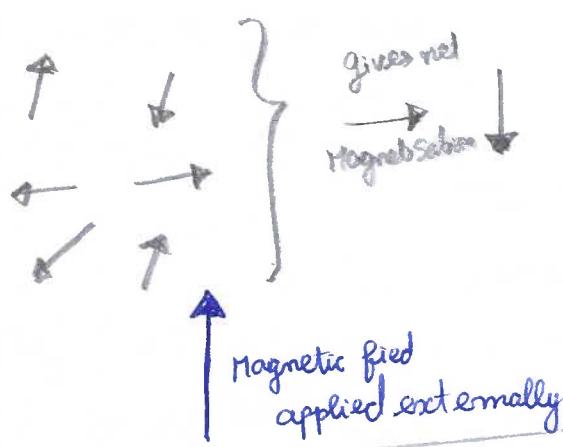
Left-handed



Right-handed

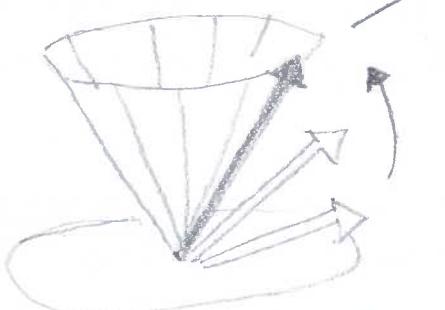


absence of externally applied magnetic field



\* If we take a really large sample of protons and place it under an externally applied magnetic field, all of the billions of protons in that sample are going to take the orientation anti-parallel to externally applied magnetic field.

### SPIN ANGULAR MOMENTUM :-



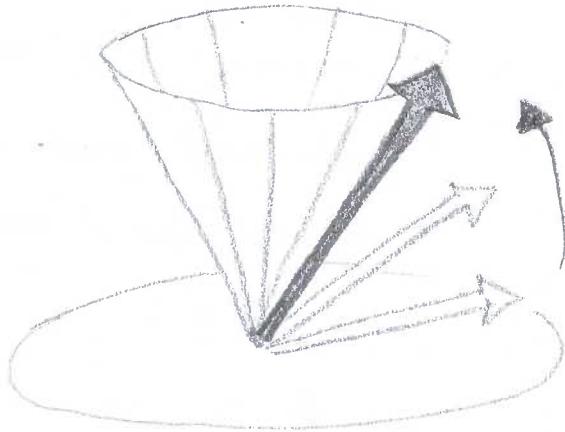
CONE SHAPED TRAJECTORY

$$\omega = \frac{qB}{\gamma m}$$

gyromagnetic ratio  
Precision

### LAHOR EQUATION

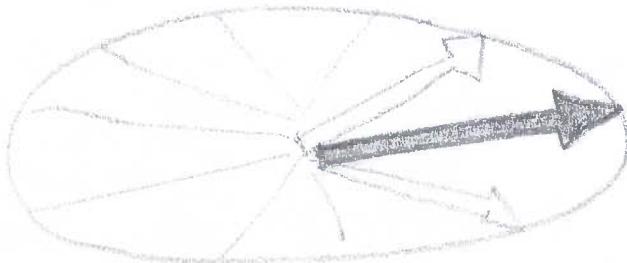
\* The determination of the shape of the trajectory as well as the rate / frequency it spins has to do with the nature of the nucleus.



SPATIAL  
RESOLUTION } Spatial  
resolution

refers to the number of  
pixels utilized in construction  
of the image. Images having  
higher spatial resolution  
are composed with a greater  
number of pixels  
than those of  
lower spatial  
resolution.

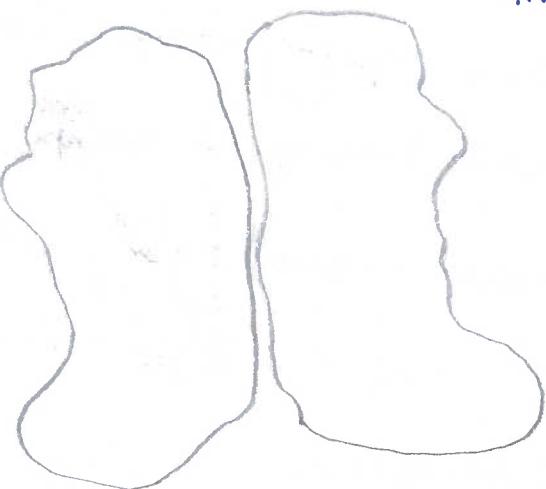
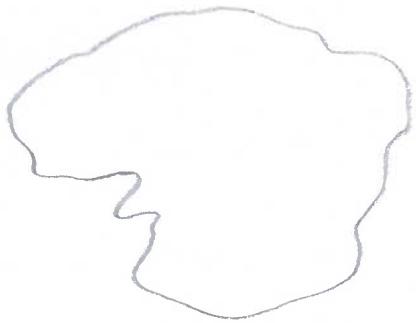
~~Definition of~~  
~~Resolution~~



- 1) brain mask. mgz → skull-stripped volume primarily used for troubleshooting
- 2) Vm. mgz → white matter mask also used for troubleshooting
- 3) aseg. mgz → subcortical segmentation volume

3 - MOST COMMON VOLUMES

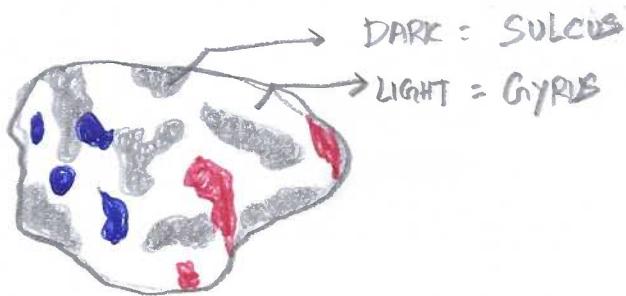
Free Surfer Terms: Most sophisticated and widely - used  
(SURFACE BASED ANALYSIS)



morphometry  
Software  
available

(STRUCTURAL ANALYSIS)

Parcellation: How the cortex  
is labeled



Segmentation: How the subcortical  
structures are labeled

Recon-all (all of the free surfer Pre-Processing)

\* Recon-all refers to RECONSTRUCTION

Command :-

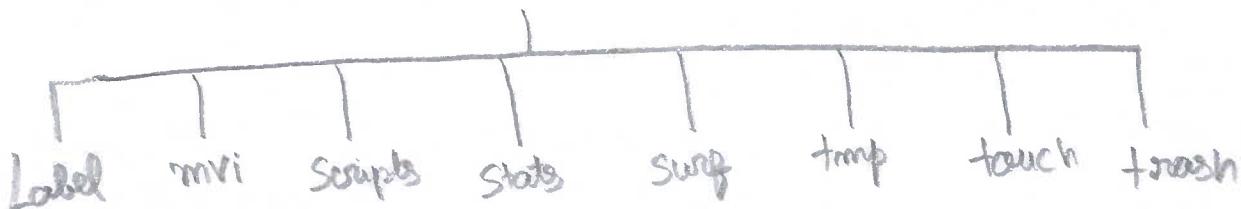
recon-all -s subvol -i subvol\_anat.nii -all

- auto recon 1
- 1) Motion correction and Conform
- 2) NNU (non-uniform intensity normalization)
- 3) Talairach + transform Computation
- 4) Intensity Normalization 1
- 5) Skull Strip
  - auto recon 2
- 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) & Statistics
- 12) Intensity Normalization 2 (start here for Control Points)
- 13) White matter segmentation
- 14) Edit WW with ASeg
- 15) Fill (start here for WM edits)
- 16) Tessellation (begins per-hemisphere operations)
- 17) Smooth1
- 18) Inflate 1

FREE  
SURFER

- 19) QSphere  
 20) Automatic Topology Fixer  
 21) Final Surfs (Start here for brain edits for pial surf.)  
 22) Smooth 2  
 23) Inflate 2  
 - auto\_recon 3  
 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

\$ SUBJECTS\_DIR / subj01



## Inter- Subject Registration :

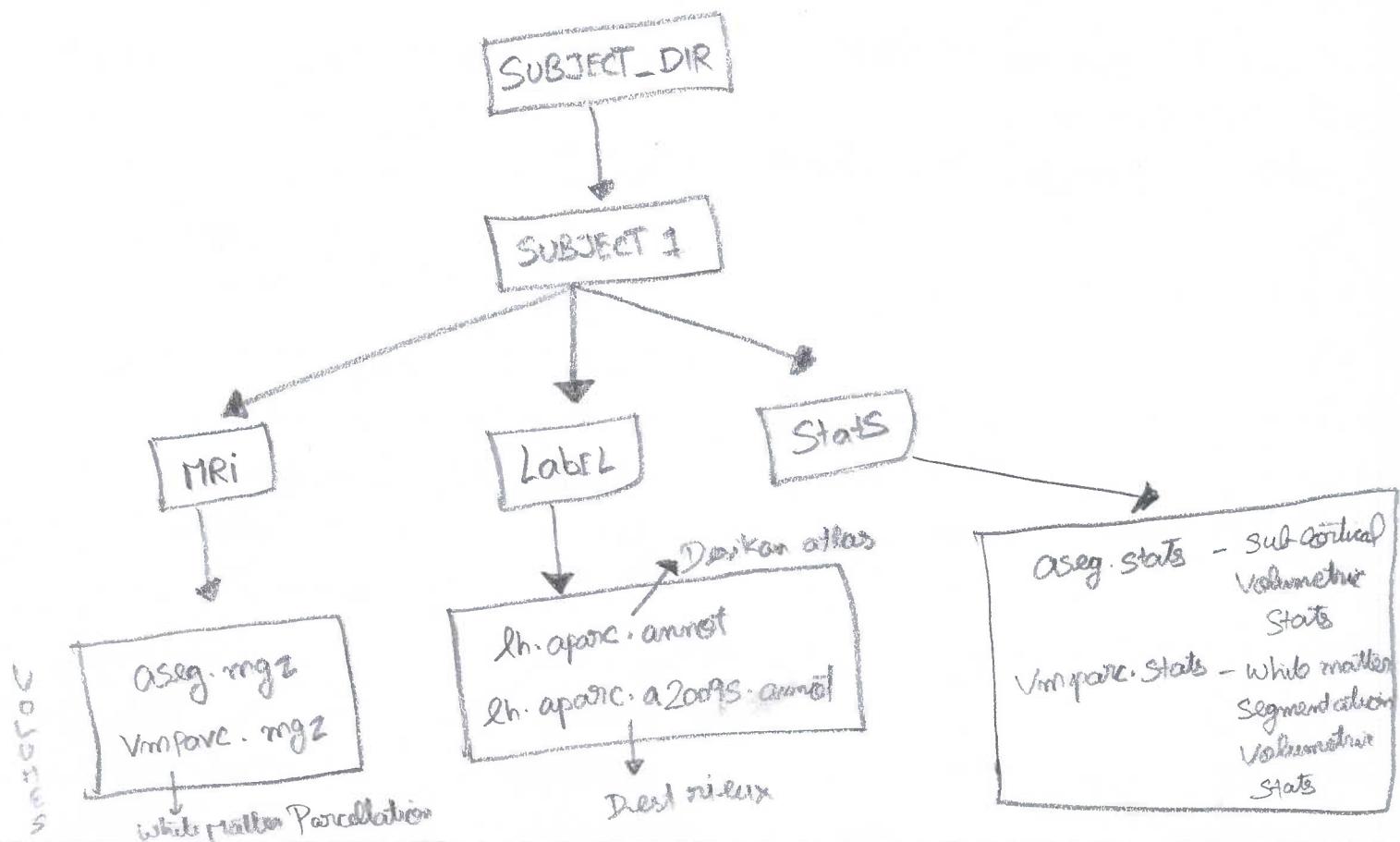
- \* You have a Template Image
- \* You have a Subject Image from Scanner
- \* The whole purpose of registration is to try to match the above (Registering one surface to other)

## 12 Degree of freedom

3 translations, 3 Rotations, 3 Zooms, 3 Shears

- \* Non-Linear transformation

Sub Cortical Segmentation (aseg → automatic segmentation)



Lh. aparc. Stats - Left hemi Desikan / Killiany Surface Stats

Lh. aparc.a2009.stats - Left hemi Destrieux

ASEG - VOLUME OF BRAIN (volume based segmentation)

PARCELLATION - SURFACE SEGMENTATION

\* ROI = REGION OF INTEREST

- Segmentation (ie. Sub cortical)
- Parcellation / Annotation
- clusters, Masks (from Sig. mgh, fMRI)
- Label you created

## SEGMENTATION

- Volume on Surface (usually volume)
- Volume-Style format (eg. mgz, nii, etc)
- Each Voxel / vertex has one Index (number ID)
- Index list found in color lookup table (LUT)  
\$ FREESURFER\_HOME / FreeSurfer Colors LUT.txt

17 Left-Hippocampus 220 216 20 0

Index = 17

Name: Left-Hippocampus

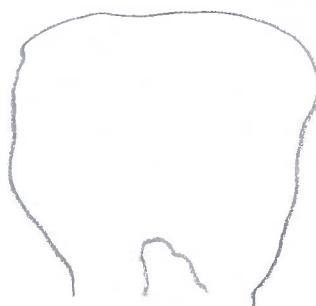
Red = 220, Green = 216, Blue = 20

alpha = 0 (not really used)

# PARCELLATION / ANNOTATION

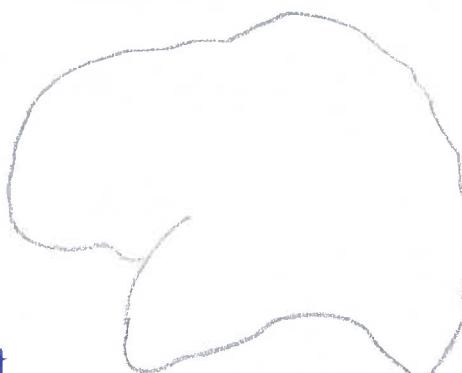
- Surface ONLY
- Annotation format (something.annot)
- Each Vertex has only one label / index
- Index List also found in color lookup table (LOT)

## LABEL FILE

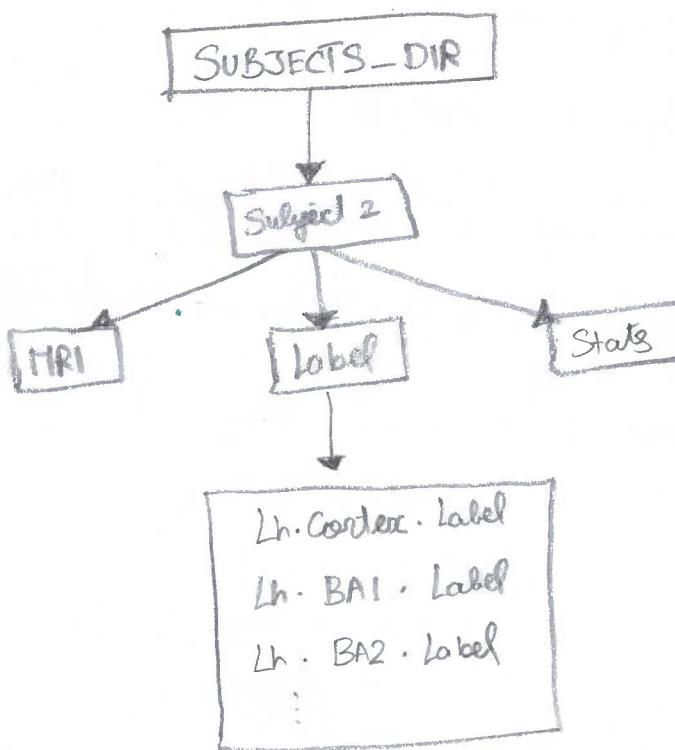


IN VOLUME

- \* EASY TO DRAW
- \* USE 'select voxels' Tool in tkmedit
- \* can use Free View
- \* Simple text format



ON SURFACE



aseg. Stats - SUBCORTICAL VOLUMETRIC STATS

Vmparc. 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

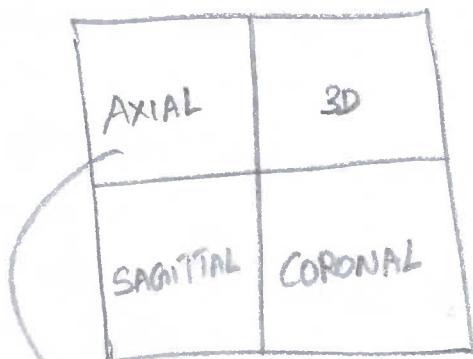
rh. aparc. a2009. Stats - RIGHT DESTRIEUX

### EXTRACT STRUCTURAL MEASUREMENTS

asegstats2 table (segmentations)

aparcstats2 table (parcellations)

### SLICER VIEW



The result of a volumetric acquisition is a 3D volume of data related to Patient. The 3D raster dataset is sampled on a discrete grid with elements called VOXELS which contain the SIGNAL INTENSITY

02/19/2019  
TUESDAY

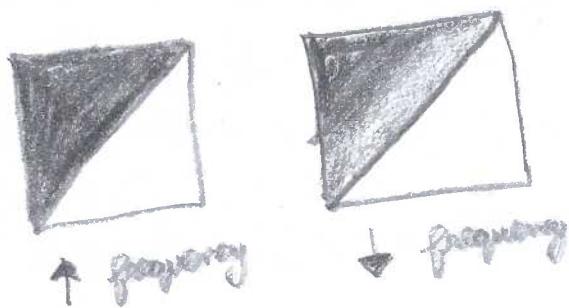
## ANATOMICAL AXES

- 1) Superior = Head
- 2) Inferior = feet
- 3) Anterior = front
- 4) Posterior = back
- 5) Proximal = central
- 6) Distal = Peripherial

## SPATIAL SMOOTHING

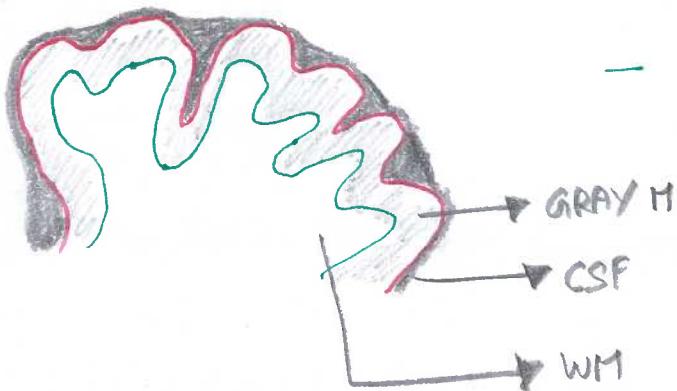
"Smoothing" is generally used to describe spatial smoothing in neuroimaging and that's a nice euphemism for "blurring".  
Spatial Smoothing consists of applying a small blurring kernel across your image, to average part of the intensities from neighboring voxels together. The effect is to blur the image somewhat and make it smoother - softening the hard edges, lowering the overall spatial frequency, and hopefully improving your signal-to-noise ratio.

High frequency = Sharpness



### Free-Surfer Tutorial

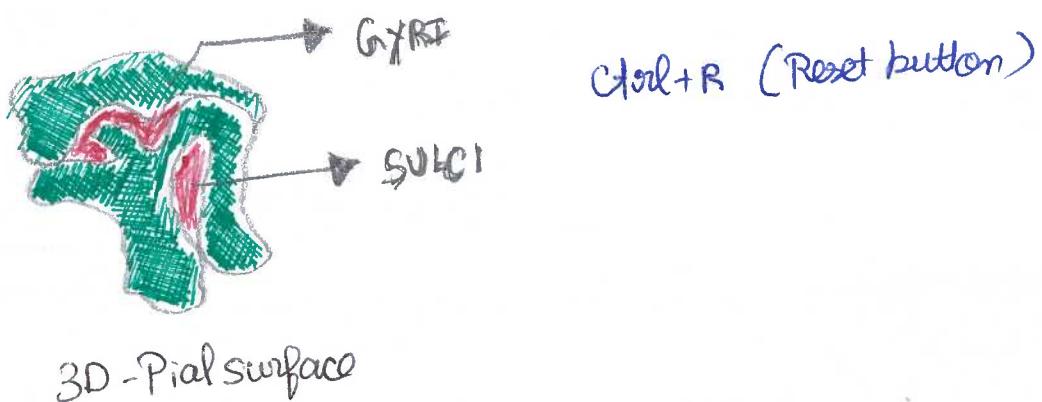
- (Surface between gray and pia)
- (Surface between white and gray)



- 1) brainmask 110 (VH voxels have an Intensity Value of Somewhere between 100 and 110)
- 2) The "heat" setting is used for editing because it allows us to be able to see the underlying anatomy, while still being able to locate inaccuracies in the "WM.mgz"

Lh. pial: annot = apart.annot ( Loads the Desikan - Killiany parcellation on the pial surface)

Lh. pial: annot = afarec.2009s.annot ( Loads the Destrieux cortical parcellation on the pial surface)



By default there are two parcellations that are made when  
recon-all is run.

?h.aparc.annot ( DESIKAN - KILLIANY ATLAS )

?h.aparc.a2009s.annot ( DESTRIEUX ATLAS )

# TENSOR

A Tensor is a Mathematical Representation of

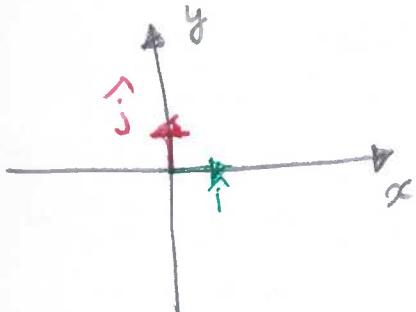
SCALAR = Tensor of Rank 0 → Magnitude **no direction** 1

VECTOR = Tensor of Rank 1 → Magnitude + direction 3

DYAD = Tensor of Rank 2 → Magnitude + IN Each 9

TRIAD = Tensor of Rank 3 → Magnitude + "3x3x3" dim 27

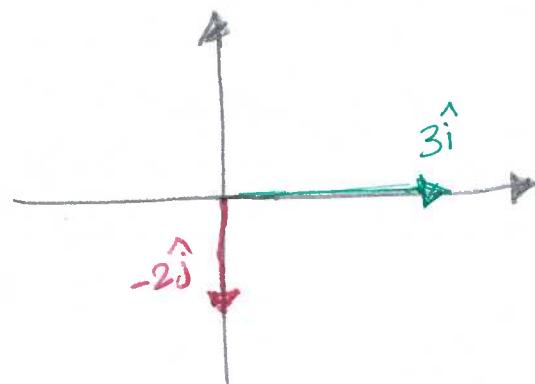
## UNIT VECTOR

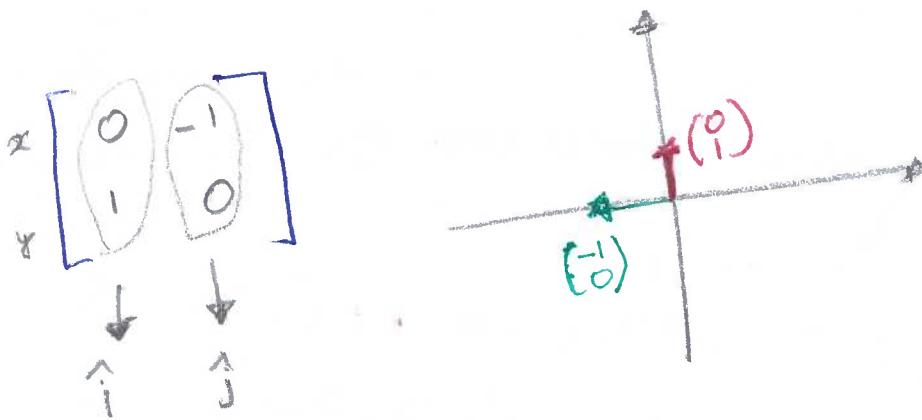


unit vector has length 1

$\hat{i}$  and  $\hat{j}$  are the "basis vectors" of the xy coordinate system

now think of our coordinates  $\begin{bmatrix} 3 \\ -2 \end{bmatrix}$  that scales the unit vector



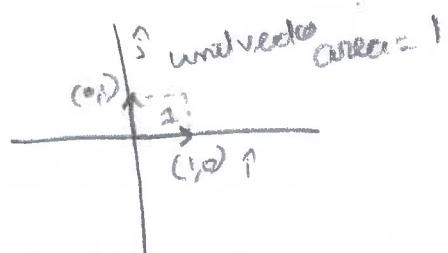


In 3D dimension there are 3 basis vector

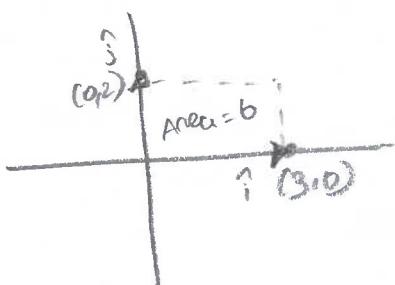
$$\rightarrow \hat{i}, \hat{j}, \hat{k}$$

Determinant:

$$\begin{bmatrix} 3 & 0 \\ 0 & 2 \end{bmatrix} \quad \begin{array}{l} \uparrow \quad \downarrow \\ \hat{i} \quad \hat{j} \end{array}$$



$$\text{Det} \left( \begin{bmatrix} 3 & 0 \\ 0 & 2 \end{bmatrix} \right) = 6$$

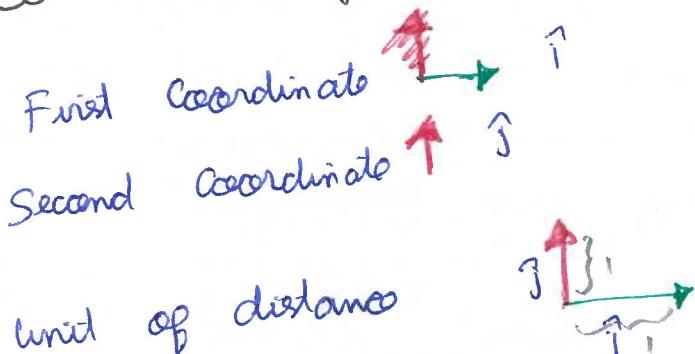


Whenever the orientation of the space is Inverted

the determinant will be NEGATIVE

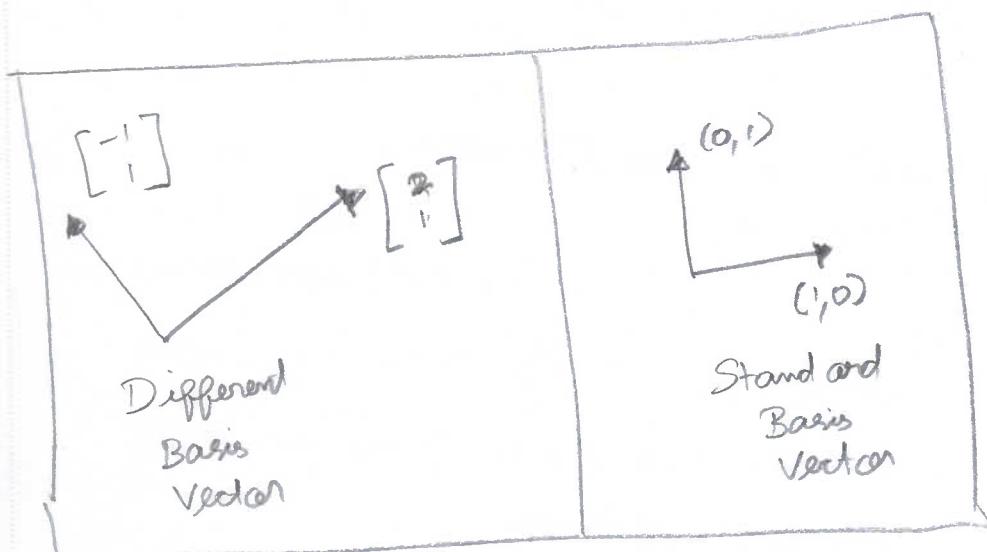
In 3D the determinant gives us the "VOLUME"

Co-ordinate System



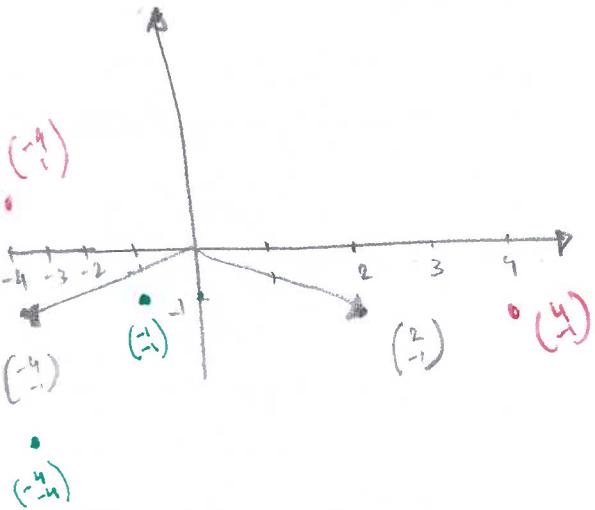
- \* Any way to translate between vectors and sets of numbers is called a Co-ordinate System and the two special vectors  $i$  and  $j$  are called the "basis vector" of our standard co-ordinate system.

What if we used different basis vector?



$$\begin{aligned}\frac{5+3}{3} &= \frac{1}{3} \\ \frac{5 \times 3}{3} &= 2 \\ i = \frac{3 \times 3}{3} &= 2 \times 6 \\ i = \frac{9}{3} &= 12 \\ i = 2 &= 12\end{aligned}$$

$$A: \begin{pmatrix} 2 & -4 \\ -1 & -1 \end{pmatrix}$$

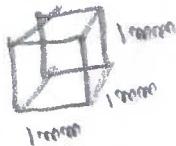


$$\begin{pmatrix} 2-3 & -4 \\ -1 & -1-3 \end{pmatrix} = \begin{pmatrix} -1 & -4 \\ -1 & -4 \end{pmatrix} \begin{pmatrix} -4 \\ 1 \end{pmatrix} : \begin{pmatrix} 4-4 \\ -1-4 \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \end{pmatrix}$$

$$\begin{pmatrix} 2+2 & -4 \\ -1 & -1+2 \end{pmatrix} = \begin{pmatrix} 4 & -4 \\ -1 & 1 \end{pmatrix} \begin{pmatrix} 1 \\ 1 \end{pmatrix} : \begin{pmatrix} 4-4 \\ -1+1 \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \end{pmatrix}$$

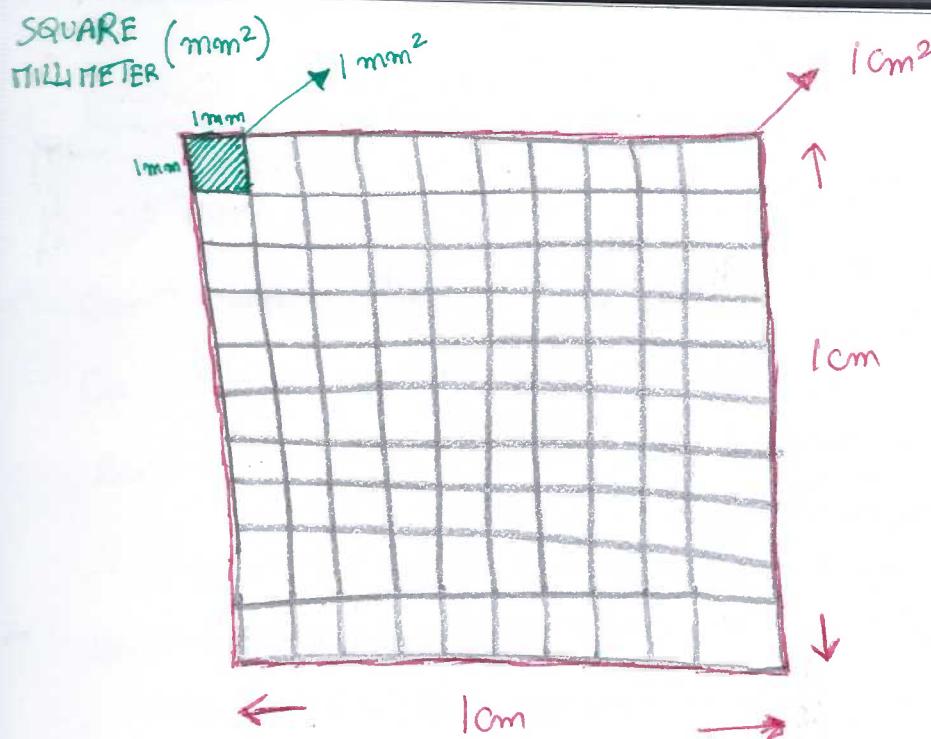
## BRAIN SEGMENTATION MANUAL

- 1) Sub-Cortical Structures (Lateral ventricles, basal ganglia, thalamus/VOC, Inferior lateral ventricles, hippocampus, amygdala)

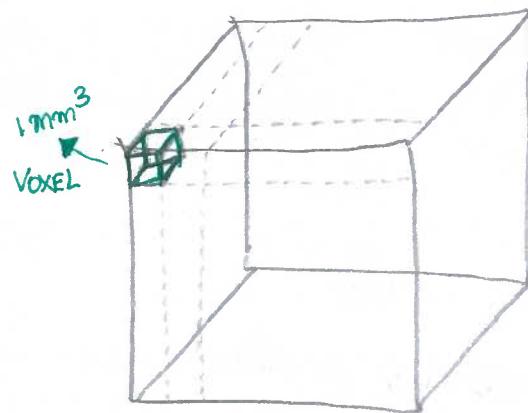


⇒  $\text{mm}^2 \rightarrow \text{Square Millimeter}$

(Voxel Resolution) → Lower the Voxel resolution, higher file size  
 Greater details of depth & Information  
 Smaller the Voxel size, greater the Image spatial resolution

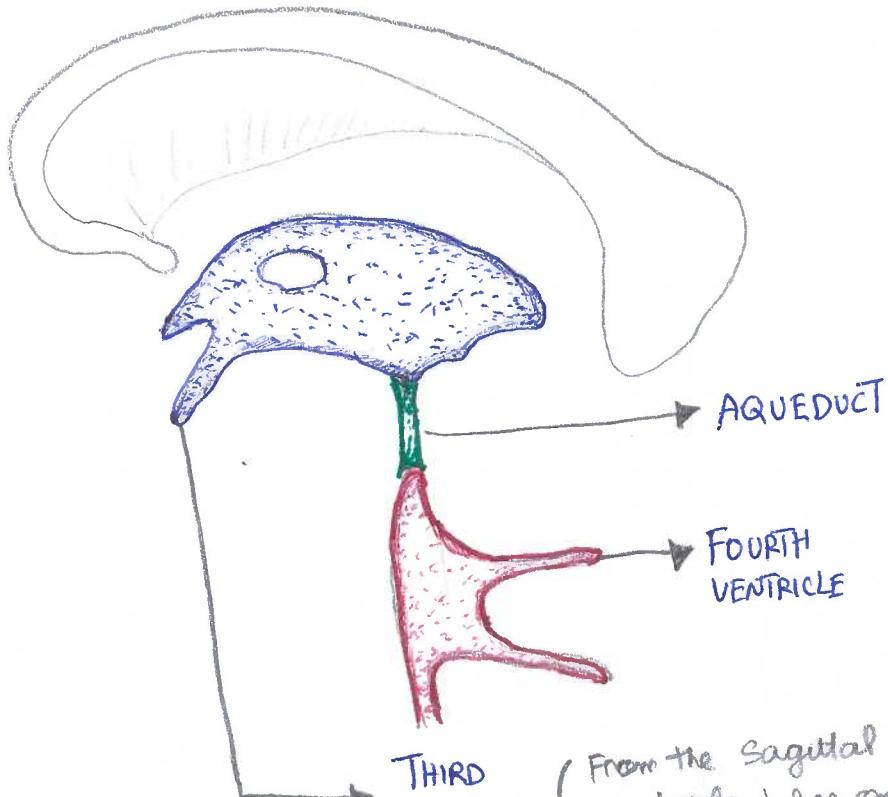


CUBIC MILLIMETER ( $\text{mm}^3$ )



Wmparc → Free Surface label map creates "181" Labels out of the T1 Image. But this Label is not in the same space as the diffusion "bo", so we have to ~~do~~ register the freesurfer label map to the diffusion Image by "fs2dwi-T2.sh"

SAGITTAL VIEW

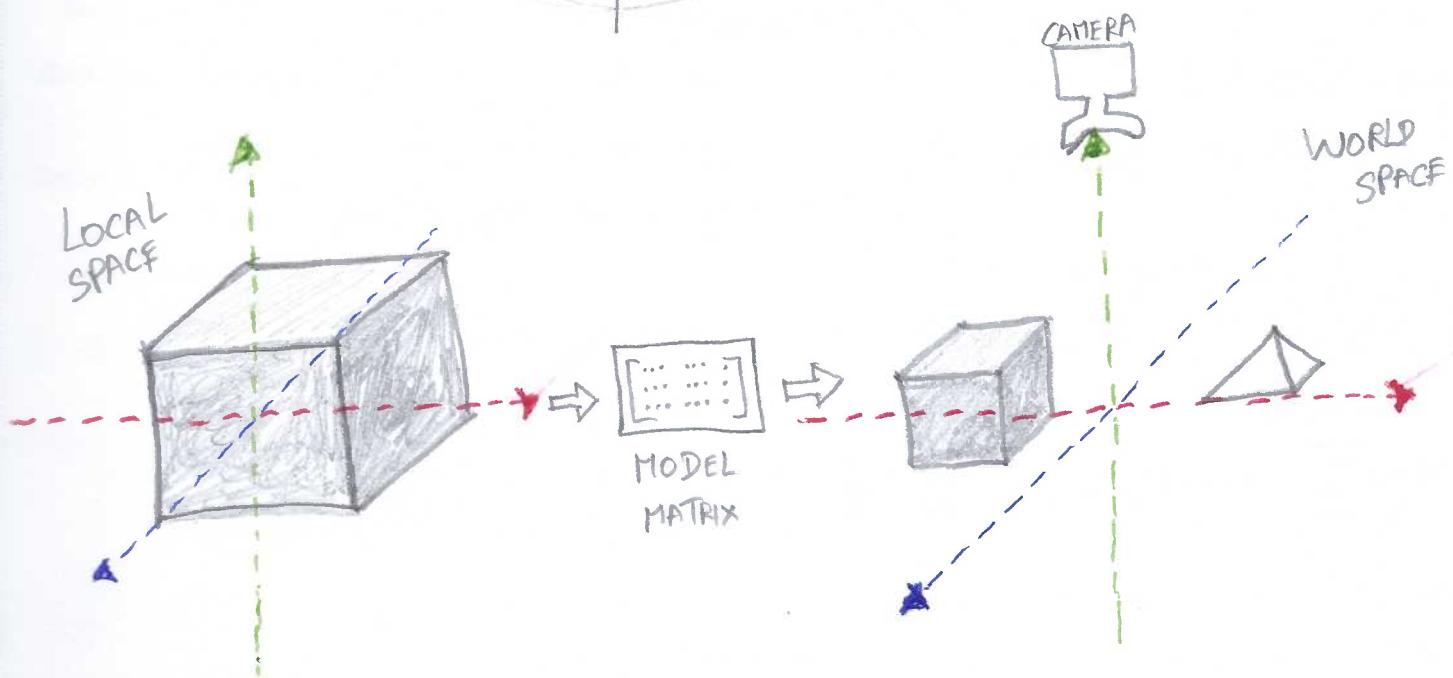
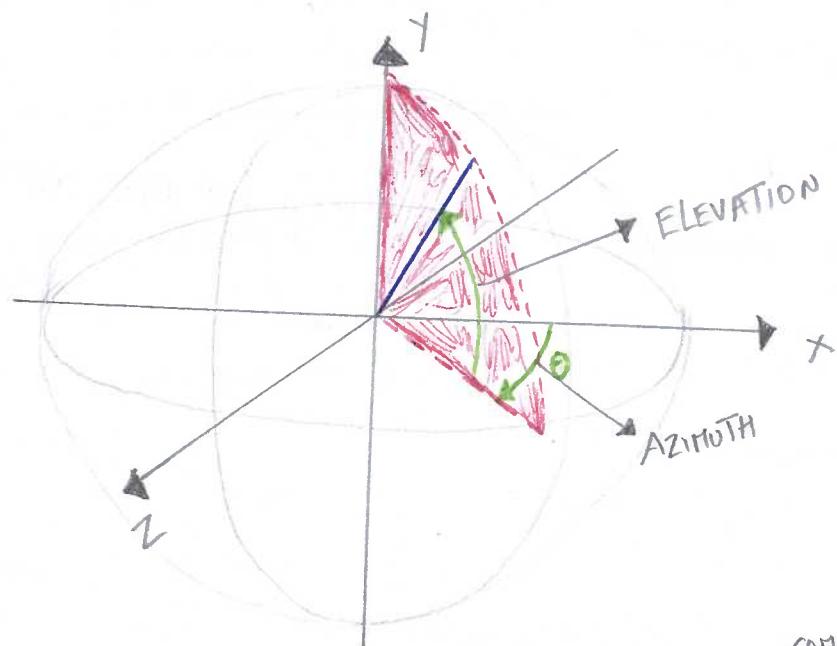


THIRD VENTRICLE (From the Sagittal view, the third ventricle takes on a DONUT SHAPE in most brain)

- \* 3<sup>rd</sup> ventricle is Connected to 4<sup>th</sup> ventricle Via Aqueduct
- \* 3<sup>rd</sup> ventricle is filled with CSF which appears as black on MRI Scan
- \* 3<sup>rd</sup> ventricle is Connected to the lateral ventricles Via the Foramen of Monroes

## WORLD CO-ORDINATE SYSTEM

Two distinct model, each with their own coordinate system can't interact with each other. There needs to be a universal coordinate system that allows each model to interact with each other. This universal system is called **WORLD COORDINATE SYSTEM**. For interaction to occur, the co-ordinate system of each model is transformed into the World Coordinate System. This is the base reference system for the overall model, to which all other model co-ordinates relate.

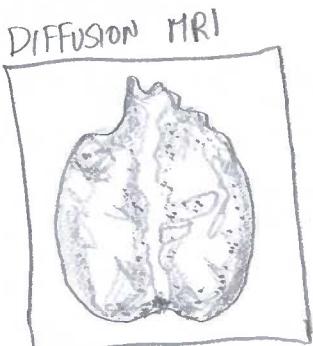


## WORLD CO-ORDINATES:

World co-ordinates are at the bedrock of your game world. The 3D position of all objects are ultimately specified in world space either directly or through a node hierarchy. The ground, buildings, trees and other stationary thing will be fixed in world space. Gameplay calculations and Physics will be done in world space. The axes of world co-ordinates are often taken to represent compass direction such as  $x = \text{east}$ ,  $y = \text{north}$ ,  $z = \text{up}$ .

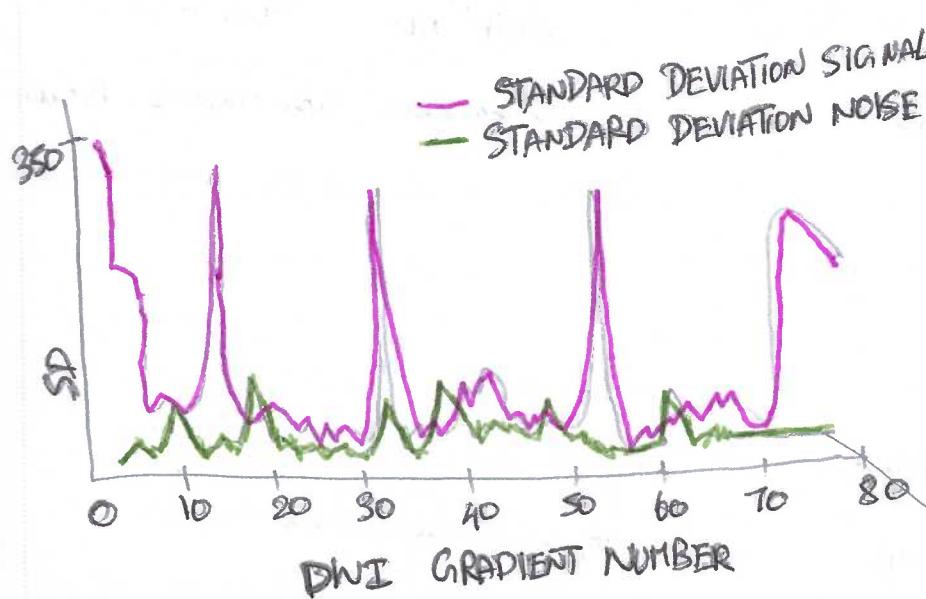
## LOCAL CO-ORDINATES:

Local coordinates are attached to an object (there is one local coordinate for each object). The axes may represent something meaningful to the object, for instance  $x = \text{forward}$ ,  $y = \text{left}$ ,  $z = \text{up}$  for an object such as character, vehicle, gun etc. that has an inherent orientation. As the object moves around, the relationship between Local and world space (as expressed by a transformation matrix) will change. For instance if you flip your car upside down, its Local Z axis ("up in Local space") will now be pointing down in world space.

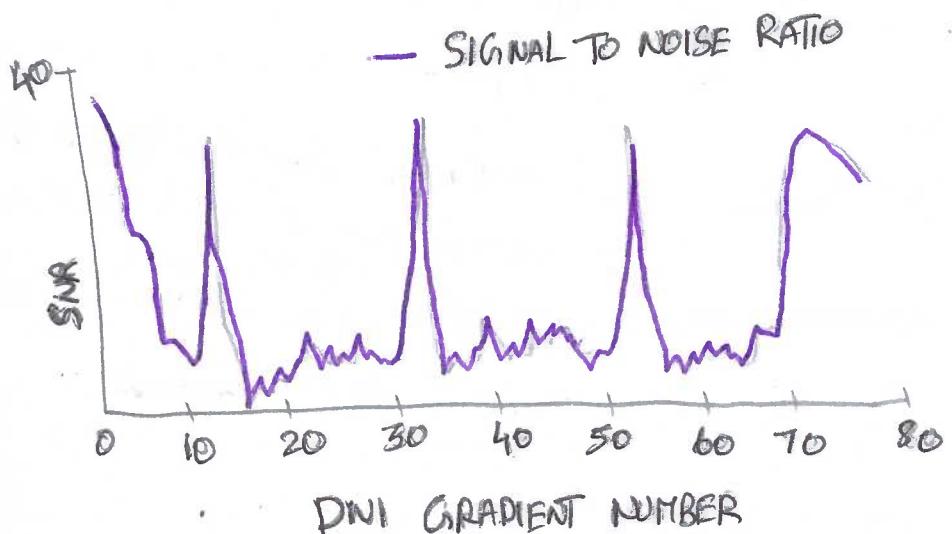


128 128 73 80 → gradients

SNR :- A signal-to-noise ratio compares a level of signal power to a level of noise power. It is often expressed as a measurement of decibels. Higher number generally means a better specification, since there is more useful information (the signal) than there is unwanted data (the noise).



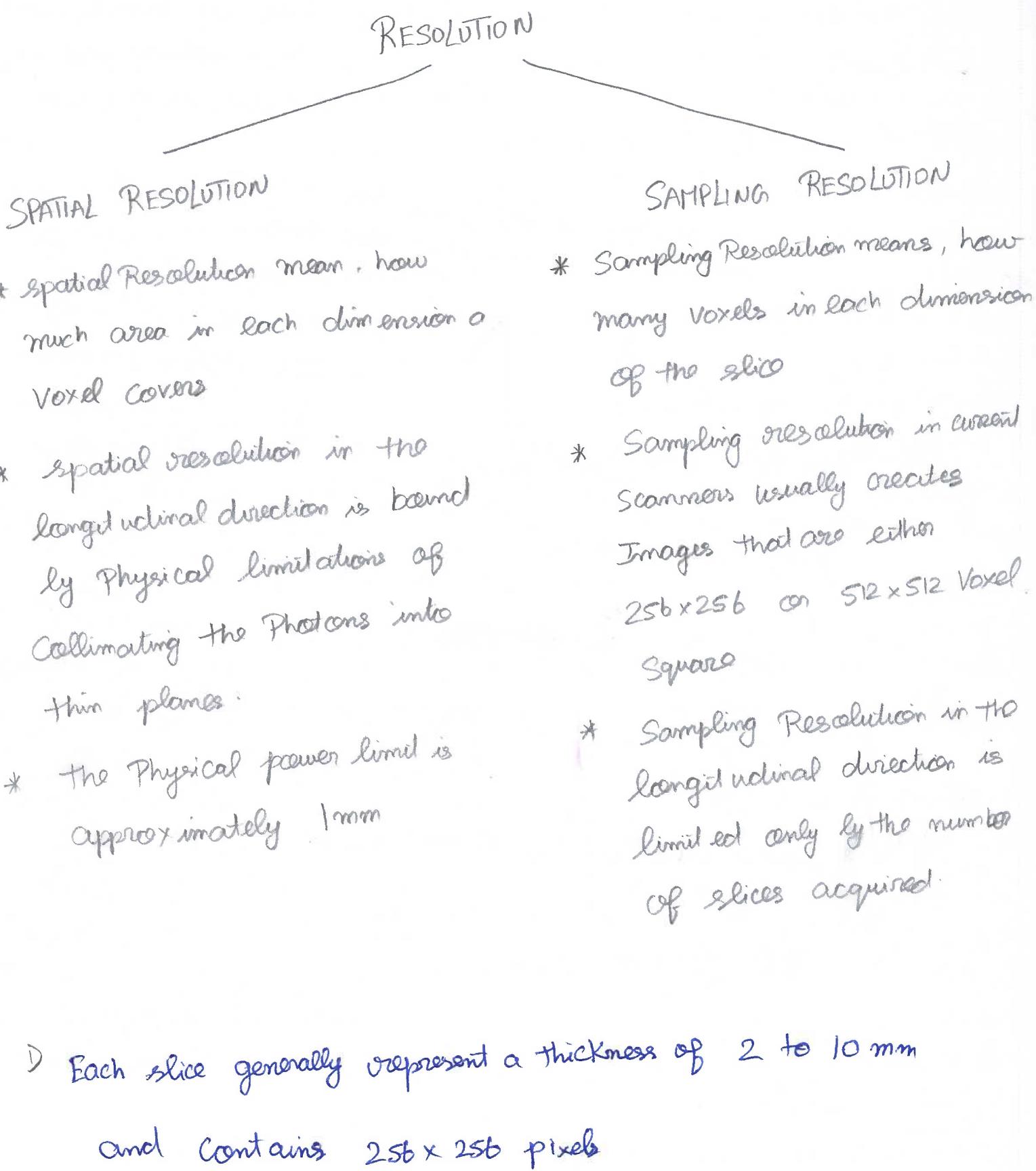
The Standard deviation is a measure of how far the signal fluctuates from the mean. The Variance represents the Power of this fluctuation.



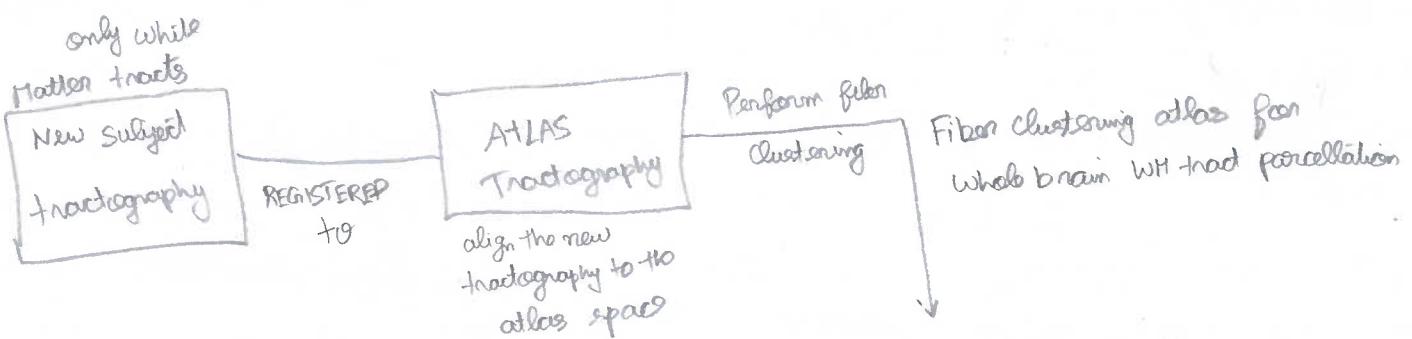
As you can see, there is lot of NOISE in the data.

B-Value is a factor that reflects the strength and timing of the gradients used to generate diffusion-weighted Images. The higher the b-value, the stronger the diffusion effects.

# IMAGE RESOLUTION

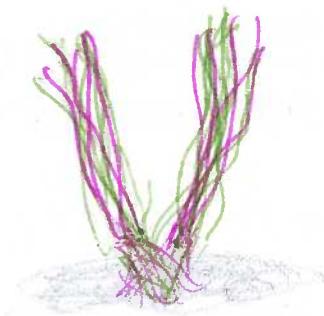


D) The complex pulse sequences of Diffusion Tensor Imaging are beginning to reveal the direction and the course of nerve bundles deep within the white matter of the brain, providing new research area of TRACTOGRAPHY and patient specific anatomical analysis.

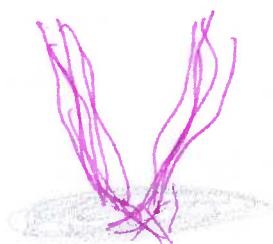


WMQL → Provides anatomical definition of "FIBER TRACTS" based on their intersected Freesurfer regions, to initially identify fiber clusters potentially belonging to common association, commissural  
 ↓  
 and Projection tracts.

ATLAS → Contains Probabilistic Information on the location of structures



→ this cluster has "2" ANATOMICAL TRACTS

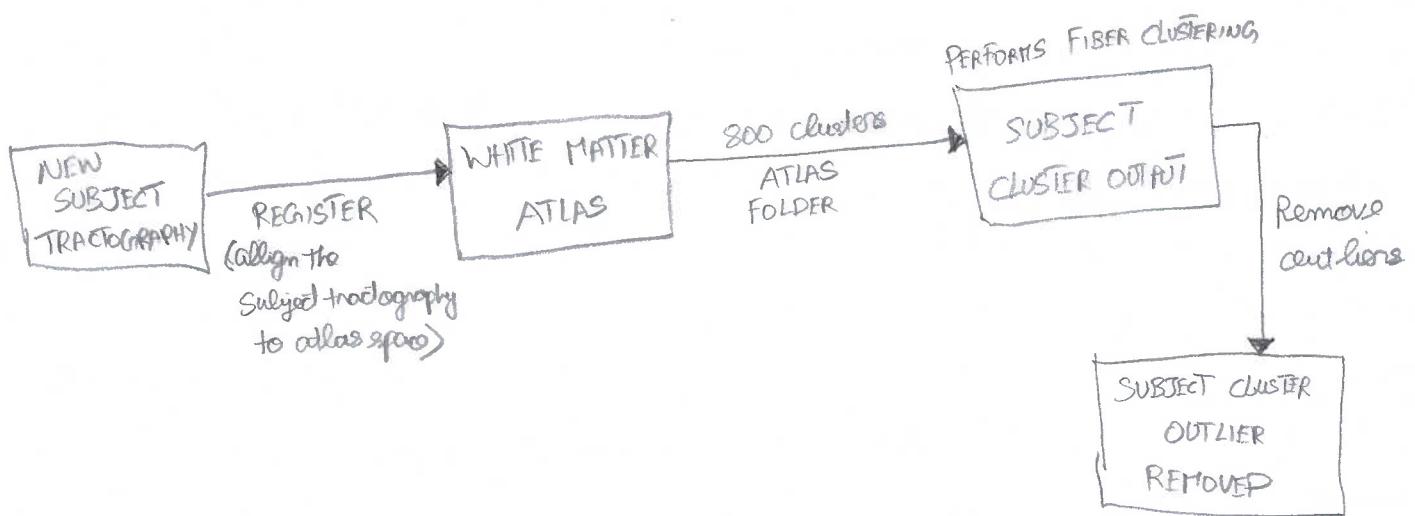


→ CEREBRAL CTX



→ CEREBRAL WM

- i) White matter analysis Software Produces 800 fiber clusters
- ii) SUBJECT - SPECIFIC - WHOLE - BRAIN - WHITE MATTER - PARCELLATION



## SPATIAL TRANSFORMATION

A registration problem is also classified by the type of the SPATIAL TRANSFORMATION used to map points from the space of one image to the space of the second image. A TRANSFORM is typically defined by a set of parameters. The GOAL of registration is to find the optimal parameter with respect to the registration criterion used. Typically, the more parameters or degree of freedom a TRANSFORMATION has, the more difficult it is to solve the optimization problem.

For 2D/2D or 3D/3D registration problem, the spatial transformation can be rigid, affine or deformable.

RIGID  $\rightarrow$  ROTATION + TRANSLATION

AFFINE  $\rightarrow$  RIGID + SCALE + SHEAR

DEFORMABLE  $\rightarrow$  FREE - FORM MAPPINGS

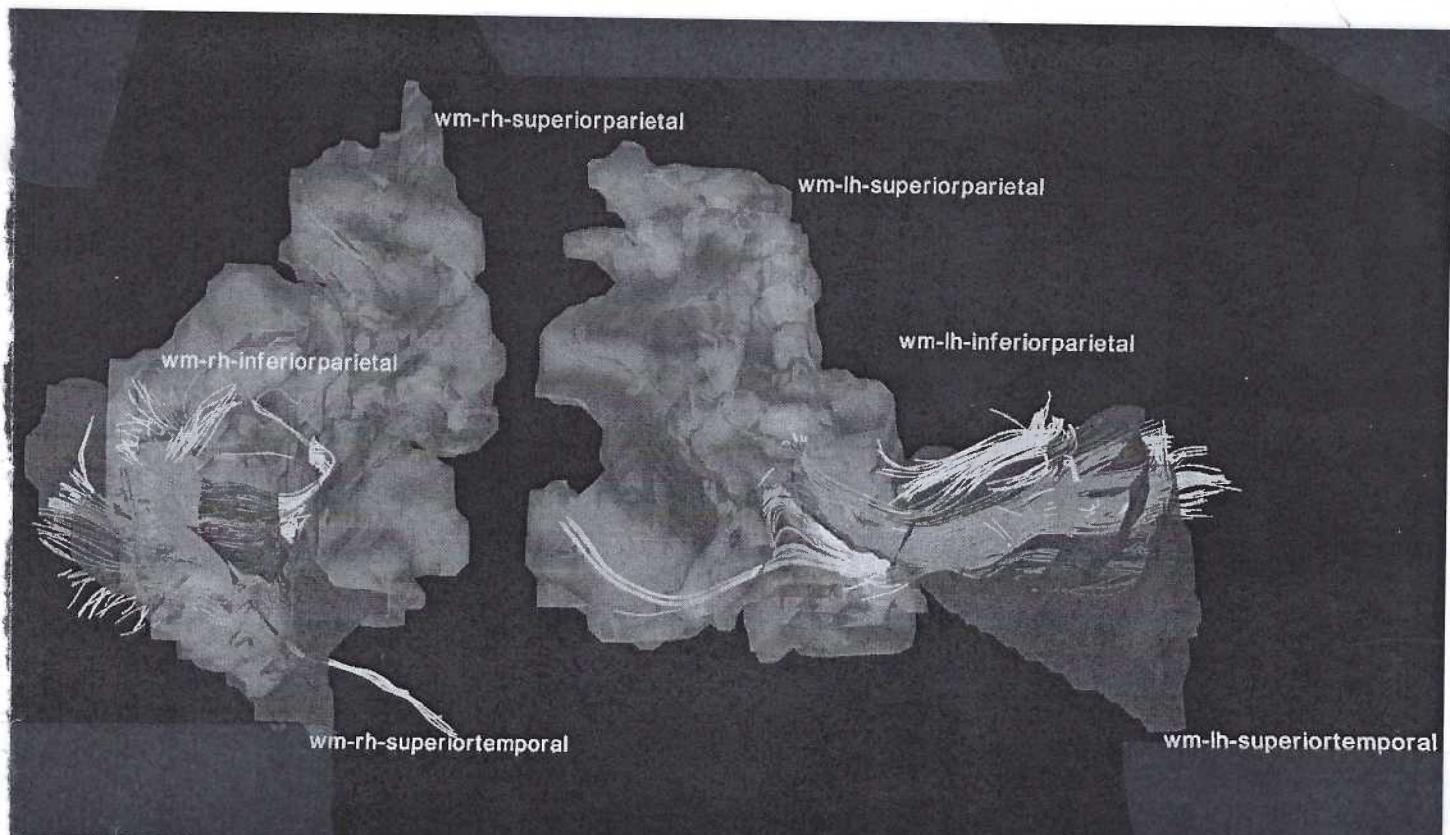
## FREE-SURFER LABEL

- 1) 2029 Ctx-vh-Superior parietal ]
- 2) 2030 Ctx - vh - Superior temporal ]
- 3) 4008 Wm - vh - Inferior parietal
- 4) 4029 Wm - vh - Superior Parietal ]
- 5) 4030 Wm - vh - Superior temporal ]
- 6) 4031 Wm - vh - Supramarginal

MEDIAL LONGITUDINAL FASCICULUS ( A gross grossaudal pathway

Connecting the TEMPORAL and PARIETAL lobes ) MdLF . This

Fiber penetrate the white matter of the Superior temporal gyrus.



MdLF Carries information about the direction that the EYES move.

FSL

anisotropic → Voxels with different size in each direction

$$\text{Eg:- } 1.0 \times 1.0 \times 3.0 \text{ mm}$$

isotropic → Voxels with equal side length in all directions

$$\text{Eg:- } 1.0 \times 1.0 \times 1.0 \text{ mm}$$

Fov (Field of View):

$$(\text{Voxel Size}) \times (\text{no of Voxels in Image})$$

$$(0.8 \times 0.8 \times 1.2 \text{ mm}) \times (320 \times 288 \times 256) = (256.0 \times 230.4 \times 307.2 \text{ mm}^3)$$

Varieties of Acquisition

T<sub>1</sub>, T<sub>2</sub>, PD and FLAIR all show the **GROSS ANATOMY** but are not sensitive to neuronal activity, blood flow or direction of axonal bundles. Thus these kind of Images are all referred to as "**STRUCTURAL IMAGES**".

SNR (Signal to Noise ratio):

SNR is proportional to the Voxel volume, and hence strongly impacted by changes in resolution. This is because the number of hydrogen nuclei in a voxel is proportional to its volume and therefore reducing the size of a voxel reduces the available signal.

## DIFFUSION TENSOR IMAGING

DTI is a Mathematical description of the diffusion process

A large proportion of the diffusion MRI literature is based on quantities that are derived from this Model

The 2 most commonly used quantities that are derived from DTI model

1) Mean Diffusivity (MD)

2) Fractional Anisotropy (FA)

\* FA is a measure of how different the diffusion is in different direction

$\downarrow$  FA  $\iff$  Equal diffusion in all directions  
ISOTROPIC

$\uparrow$  FA  $\iff$  Preferential diffusion in some directions  
but not in others

In addition, the diffusion can be divided into diffusion along the STRONGEST direction (axial diffusivity AD) and diffusion  $\perp$  to the strongest direction (radial diffusivity RD)

### LINEAR TRANSFORMATION

6 DOF  $\rightarrow$  RIGID - BODY TRANSFORMATION

12 DOF  $\rightarrow$  AFFINE TRANSFORMATION

- \* one useful property to know about linear transformation is that they apply equally to the whole Image and **cannot** do different things in different part of the Image; for instance, if you want to scale one part of the Image with a linear transformation, then you must scale the whole Image by the same amount. NON-LINEAR transformations are more flexible and do not follow this constraint

\* Non Linear transformation require too many DOF to be stored in text files, so they are typically stored as Images (called warp field or deformation fields) where the value in the voxel represents the transformation.

## ATLASES:

Many atlases exist in the MNI 152 space and therefore require registration to the MNI 152 template in order for the information from that **ATLAS** to be used in a particular subject or study.

## CMAKE

Cmake is a Make file generator

- 1) When you call Cmake [Path], you ask it to generate a Makefile in the current directory following instructions given in [Path]/CMakeLists.txt
- 2) Usually Cmake output some messages while it is working and after it is done without errors, you can type make to execute your newly created Makefile
- 3) CMakeLists.txt files can reference other CMakeLists.txt in sub-directories, so you are usually only interested by the CMakeLists.txt of the "Top" directory.
- 4) Using an empty build directory is a technique called out-of-source-build, in which all your generated files (.o, executables, Makefile, anything) are generated in the separate "build" directory and not mixed with source files. If you want to clean all, you can delete all the content of the build directory.

variables | o-o-s | Pre-reqs | prerequisites | jnd | oop

- 5) In fact, you can put your "build" directory in any place, as long as you give Cmake the correct path of the Top MakeLists.txt. You can even have several build directories. It is very useful if you need several different build at the same time.
- 6) In old programs, you generate the Makefile too, but using `./configure` (this is called auto-tools). Cmake is considered a successor of the auto-tools
- 7) Cmake .. generates makefiles in the current directory using `.. / MakeLists.txt` file as starting point. make command, executed after this, builds the program, using generated makefile(s) as an input. This is convenient to keep a source code and build results in different folder.
- 8) Cmake automatically generates the Makefiles for your Project
- 9) Cmake is a cross-Platform Makefile generator

## DATASET ATTRIBUTE FORMAT

- 1) scalars
- 2) vectors
- 3) normals
- 4) texture co-ordinates
- 5) 3x3 tensors
- 6) Field data

} Dataset attributes are supported for both points & cells.

SCALARS <dataName> <dataType> <num Comp>

LOOKUP\_TABLE table Name

↳ this is associated with the RGB color specification with the scalar data

1) [sq,sb@Piper] Cmake

↳ searches for **MakeLists.txt** in the current directory & generates the **Makefile**

make

→ Searches the **Makefile** and builds the project (Means compile your program). make execute Commands in makefile to update one or more target names, where name is typically a program

\* BUILD directory contains the final binary library and any temporary files that are required from the build.

\* .SO → This is a Shared Library ( If you wish to make them available system wide you can add them to /usr/lib directory )

An .SO file is a Compiled library file. It stands for "SHARED OBJECT"

## LIBRARIES IN LINUX

libc → STANDARD "C" LIBRARY

glibc → GNU VERSION OF THE STANDARD "C" LIBRARY

curl → MULTIPROTocol FILE TRANSFER LIBRARY

crypt → LIBRARY USED FOR ENCRYPTION , HASHING ,  
ENCODING IN "C"

- 1) Yuhua Chen et al., 2018 ( DCSRN ) + ( EDSRN ) Bee Lim
- 2) PSNR + SSIM ( Testing Structural ) like DICE Score