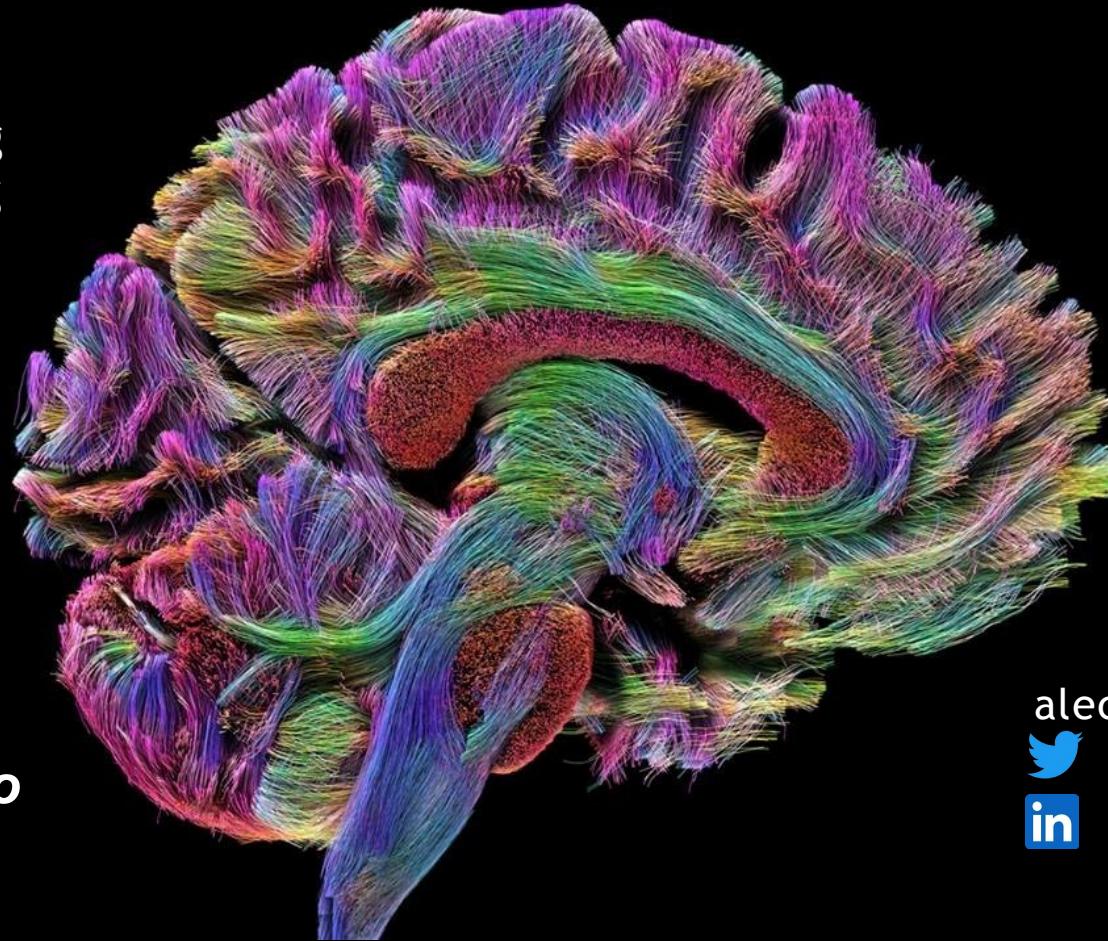


Machine Learning for Neuroimaging and Neuroscience

Lesson 1 *Introduction to data*



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AND TECHNOLOGY

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Alessandro Crimi

Objectives

At the end of this course, you **SHOULD** be able to

1. Master and explain fundamental aspects of data related to neuroimaging.
2. Write programs to perform statistical prediction or pattern recognition on neuroimaging or neuroscience.
3. Be able to design studies using statistics or machine learning in neuroimaging (e.g. diagnose/predict stroke, brain tumor, etc).

Syllabus

14 sessions

- Lectures
- Laboratories
- Projects

Final grades 50% from laboratories and project

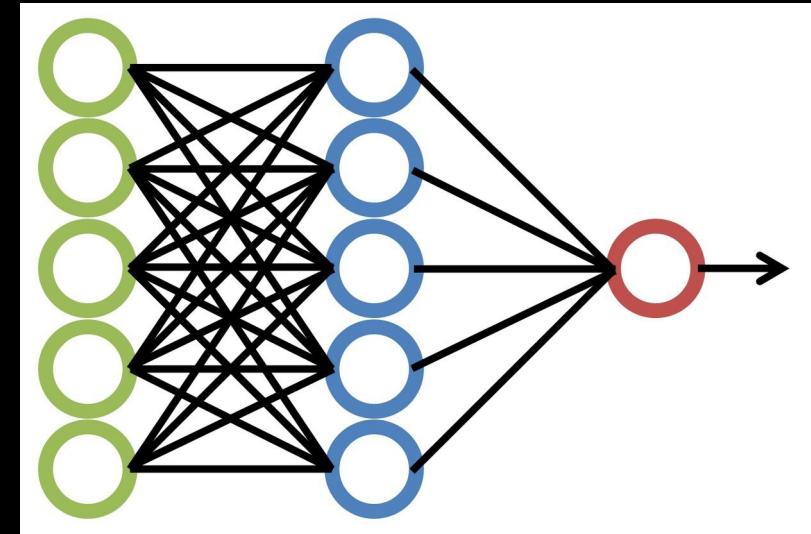
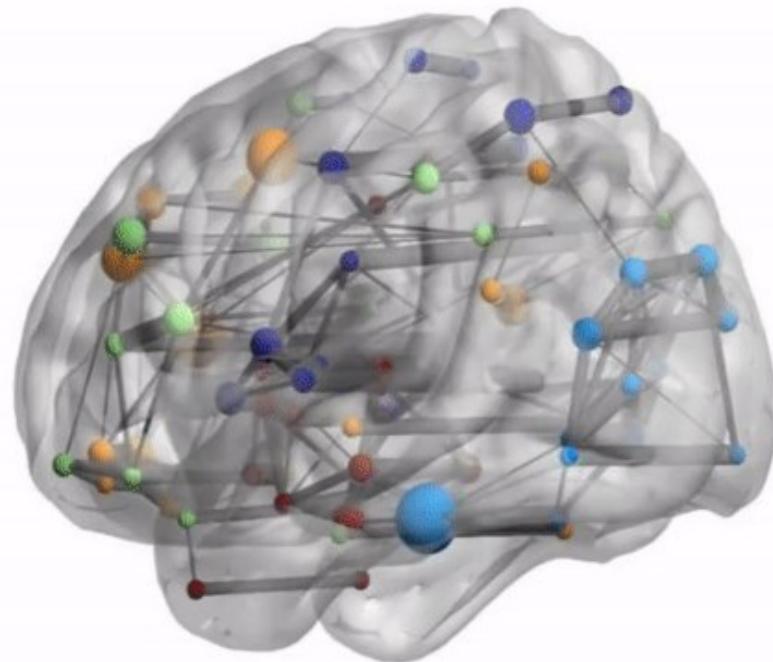
Syllabus

Lectures

1. Introduction to neuroimaging data (date:)
2. Structural connectivity (date:)
3. Functional connectivity (date:)
4. EEG and wearables (date:)
5. Graph connectivity (date:)
6. Causality and effective connectivity (date:)
7. BCI & review (date:)

Lab plans (We alternate sessions of guided lab activities and assigned projects: from October 3rd until January
(see document on Github)

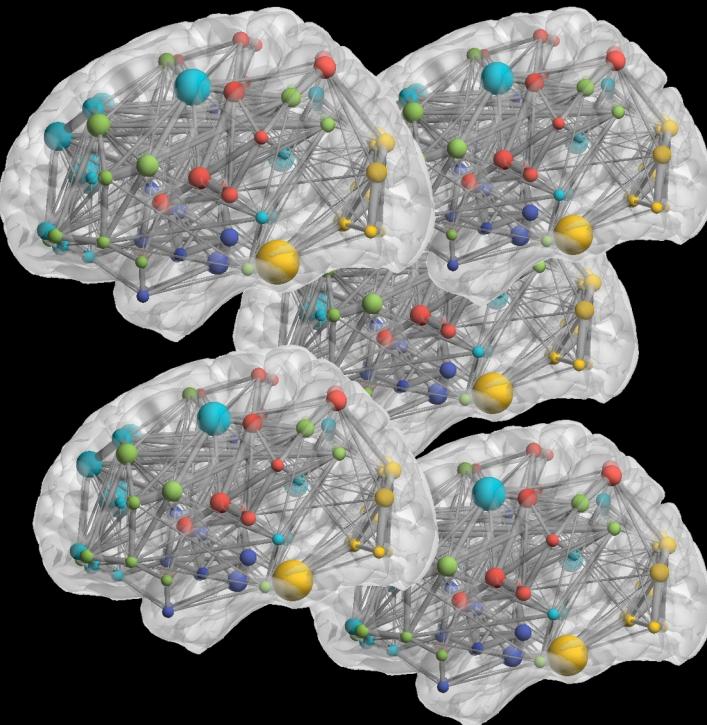
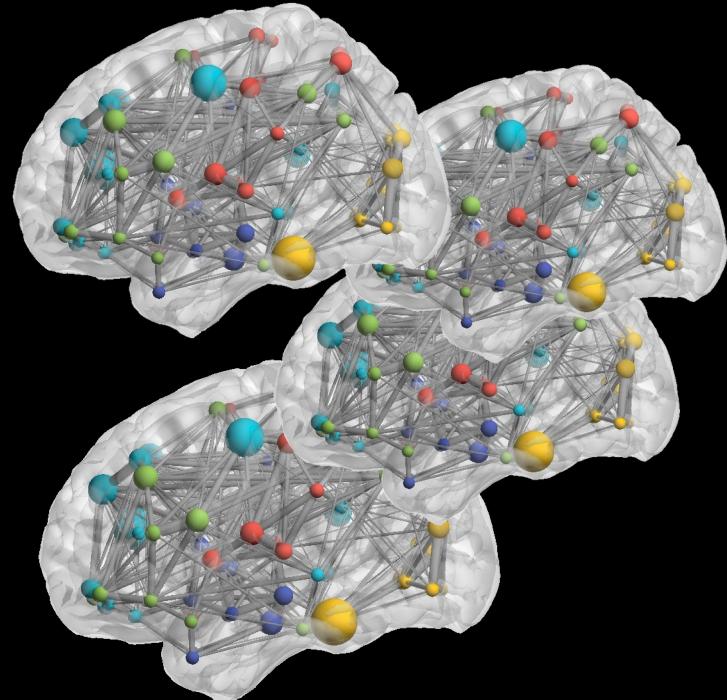
Welcome



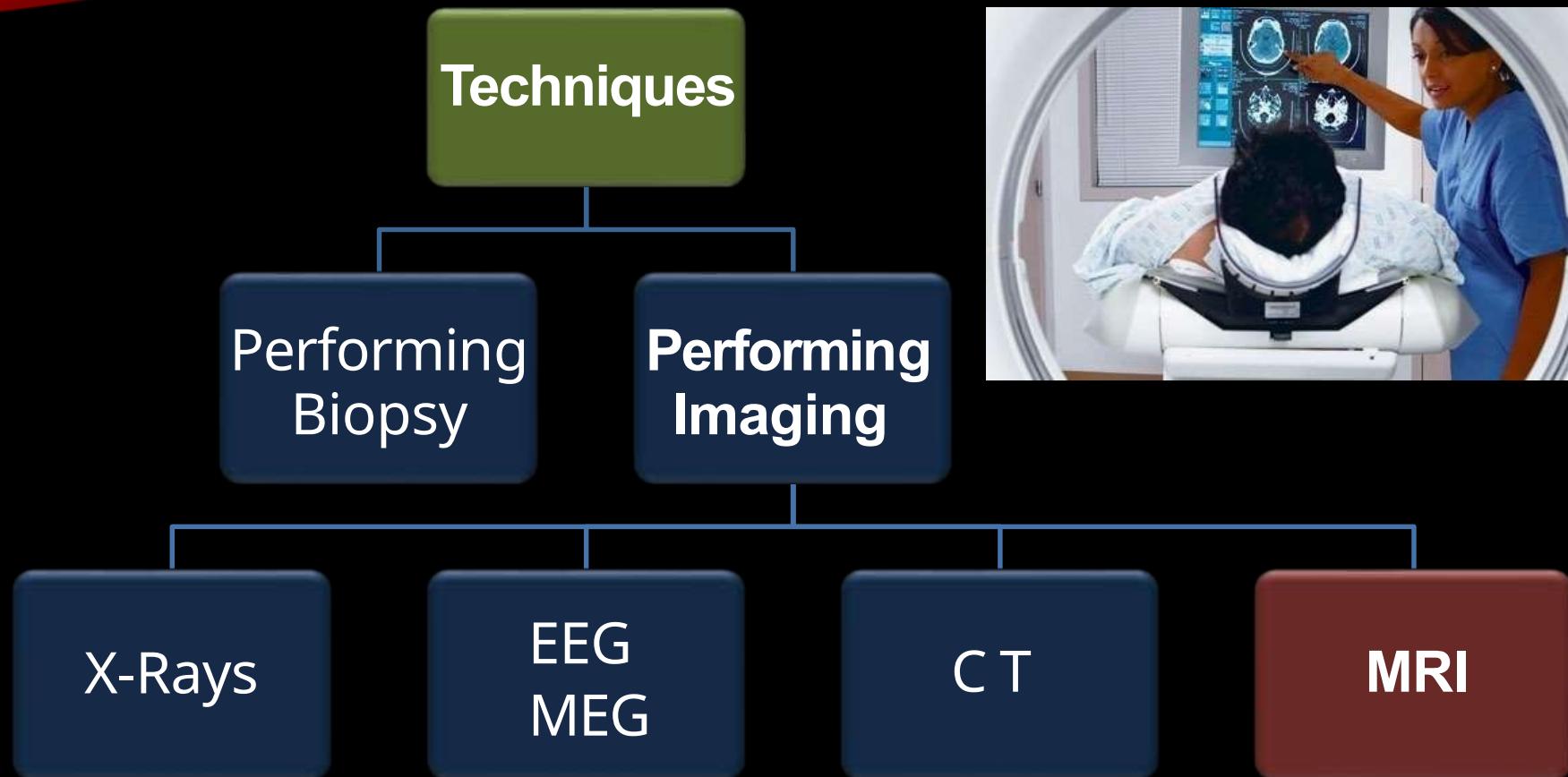
Alzheimer, Schizophrenia,...

Matched healthy control

Alzheimer or Healthy



We can use different technologies and modalities



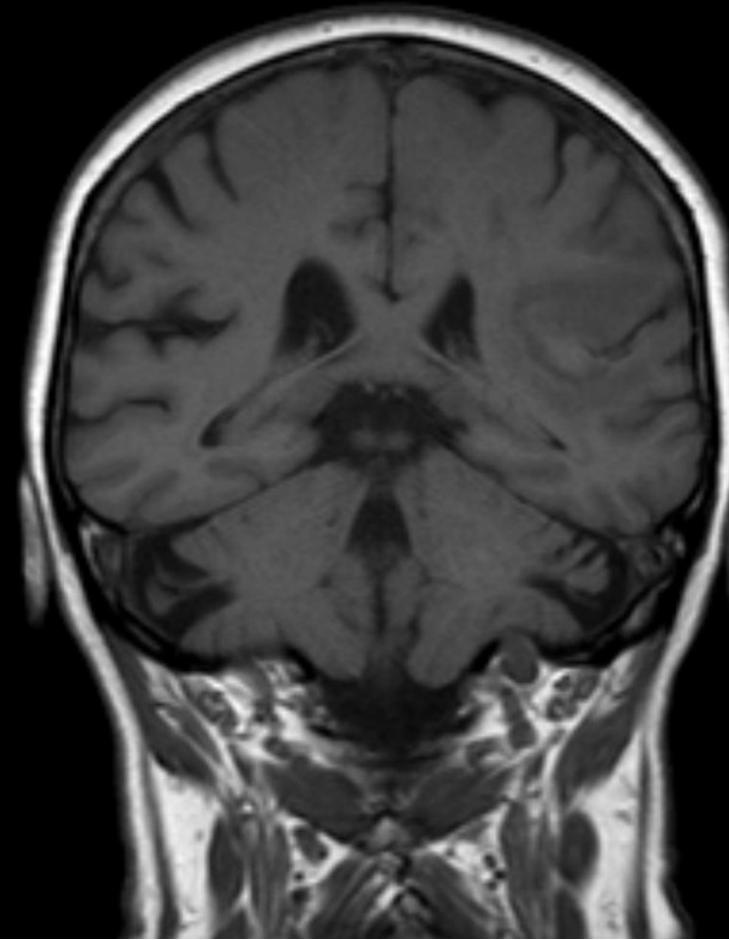
We can use different technologies and modalities

- CT (x-ray, ionizing radiation, with or without contrast)
- MRI (magnetic field and radio pulses, with or without contrast)
- EEG (detecting electrical signal)
- Ultrasound- rarely used
- PET and SPECT imaging (radioactive tracer)

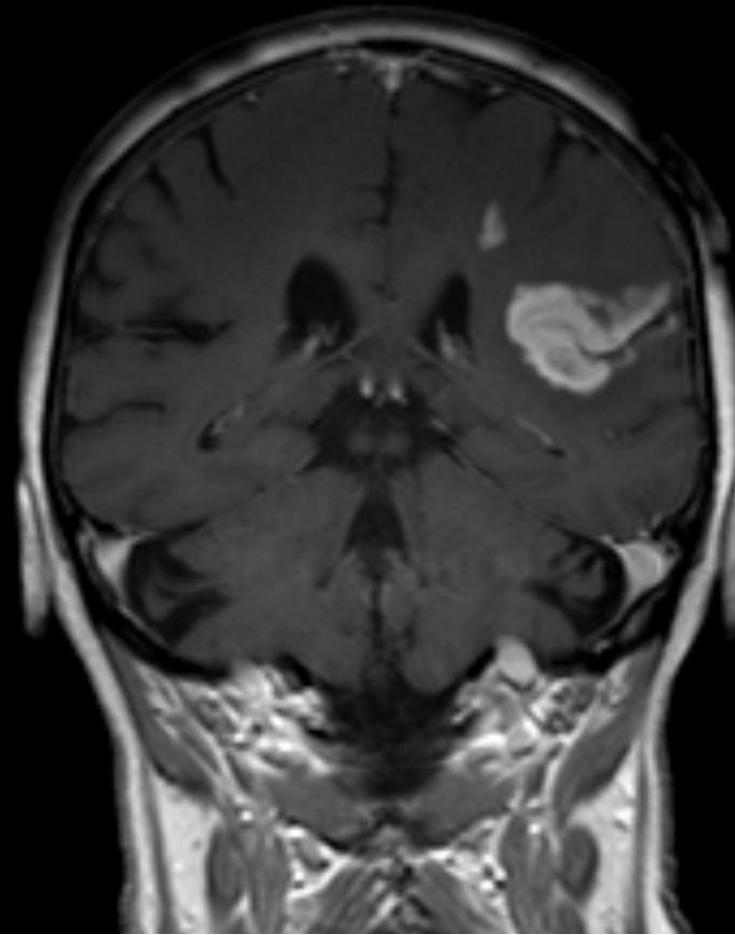
Enhancement

- Patients receive and injections or something
- Implies that contrast is visible
- Can be normal (e.g., blood vessels)
- Often pathologic- implies blood-brain barrier

No Enhancement



No Enhancement



Neuroimaging can take different forms

- CT Pros and Cons

- good for intracranial haemorrhage or calcified lesions

- quick

- Cheap & dirty

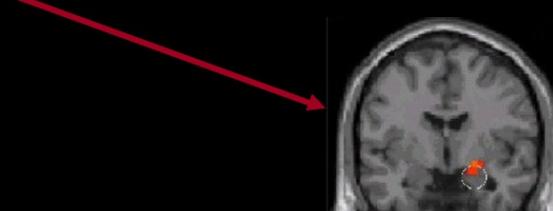
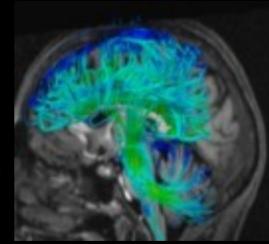
- MRI Pros and Cons

- superior tissue contrast and spatial resolution

- expensive, noisy,



MRI is cool



How does research work?



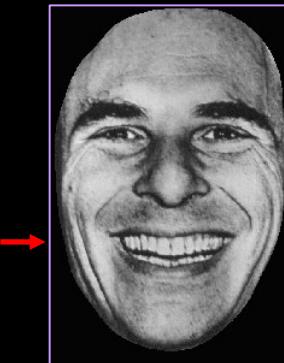
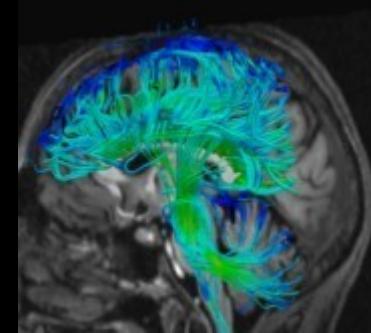
MRI Scanner



MRI Scanner



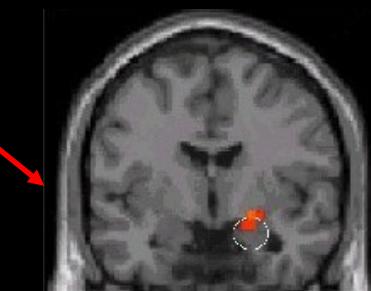
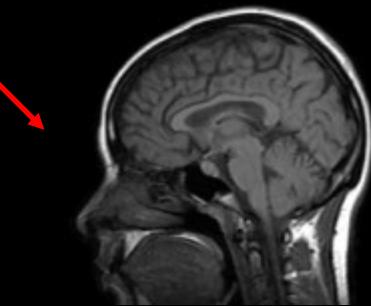
Process Data



Stimulus
(e.g. picture)



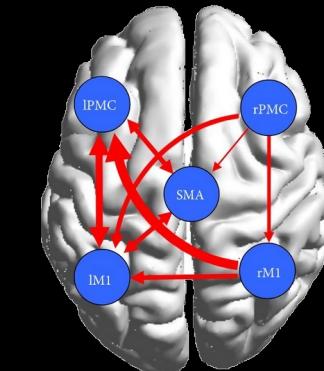
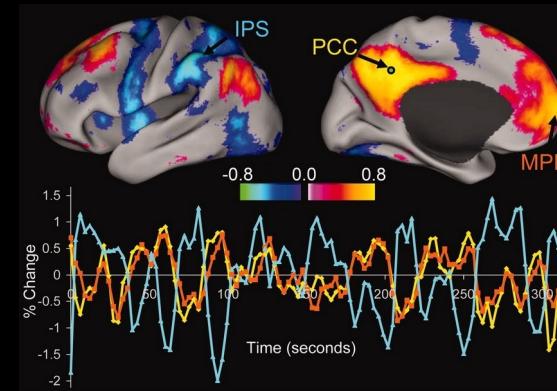
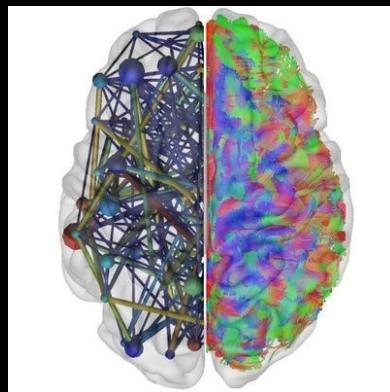
Process Data



There is more(e.g. MRA)



Structural, functional & effective connectivity



Structural/anatomical connectivity

= presence of axonal connections / white matter tracks (eg, DWI, AAV tracers)

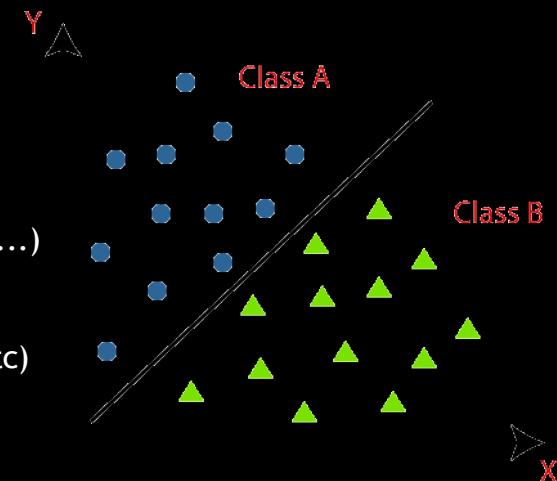
Functional connectivity

= statistical dependencies between regional time series (eg, Pearson correlation, ICA,...)

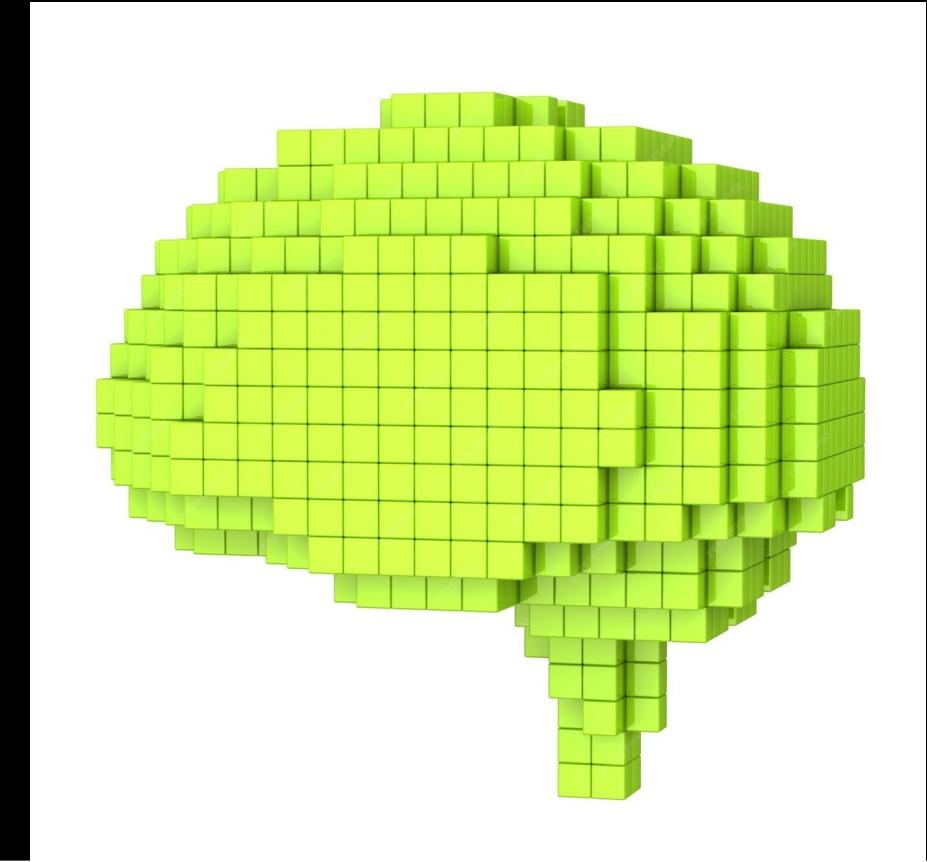
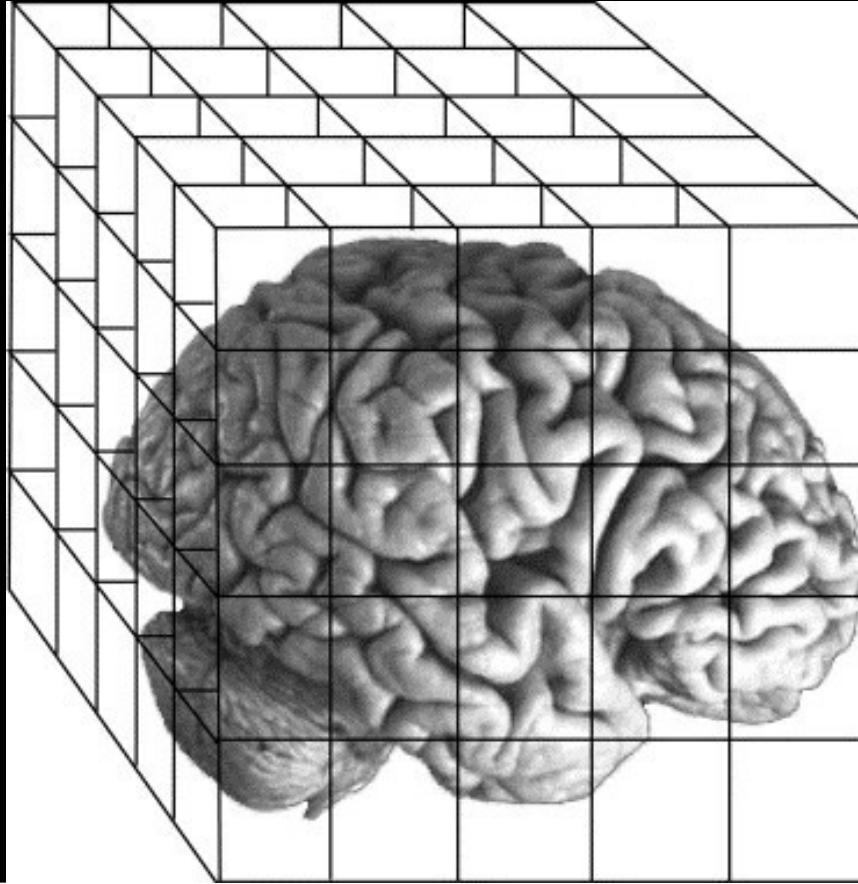
Effective connectivity

= causal (directed) influences between neuronal populations (eg, DCM, Granger C., etc)

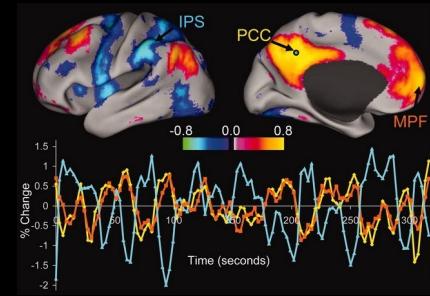
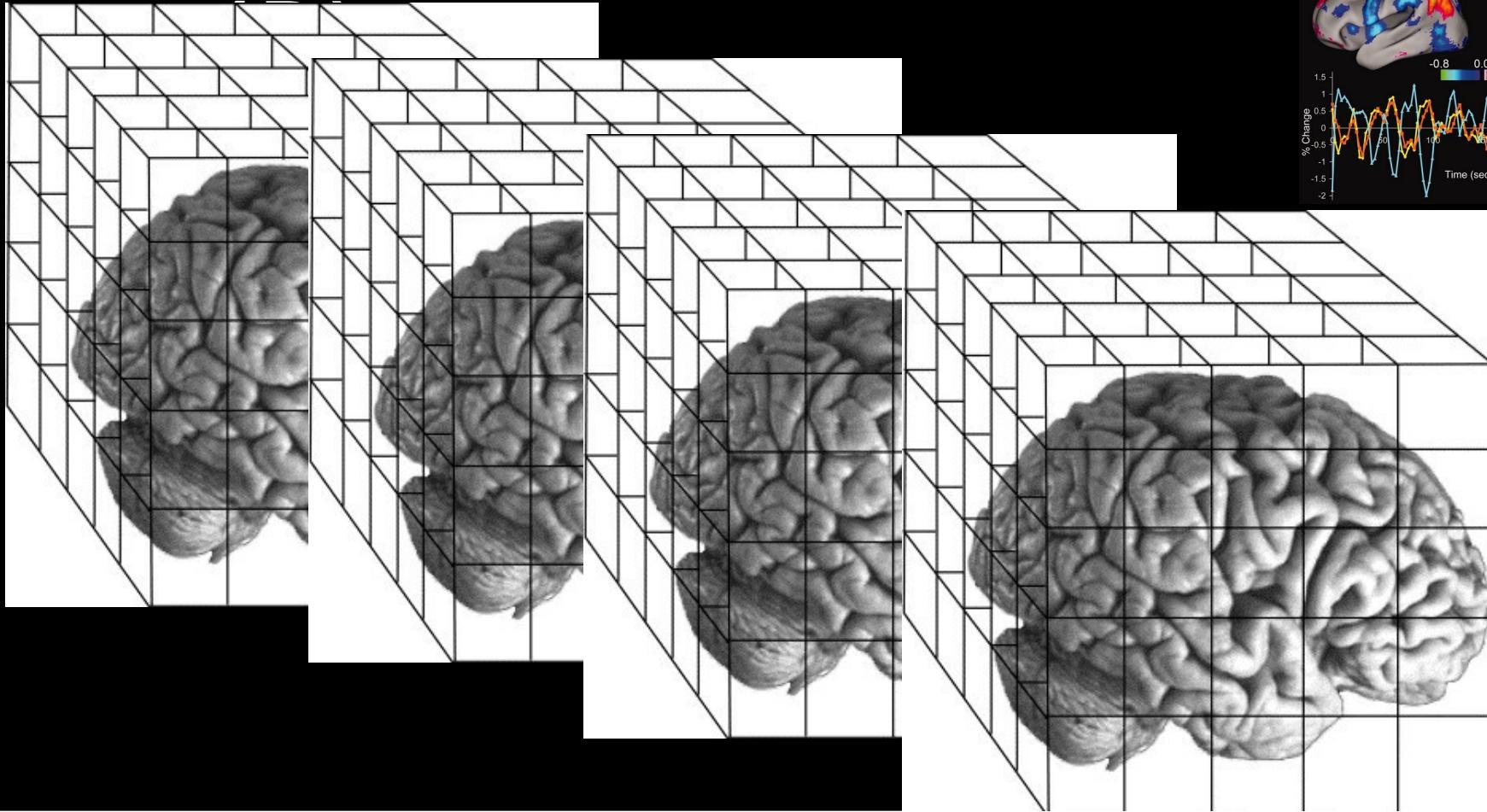
Nobody cares about Morphological connectivity



Voxel (pixel in 3D)



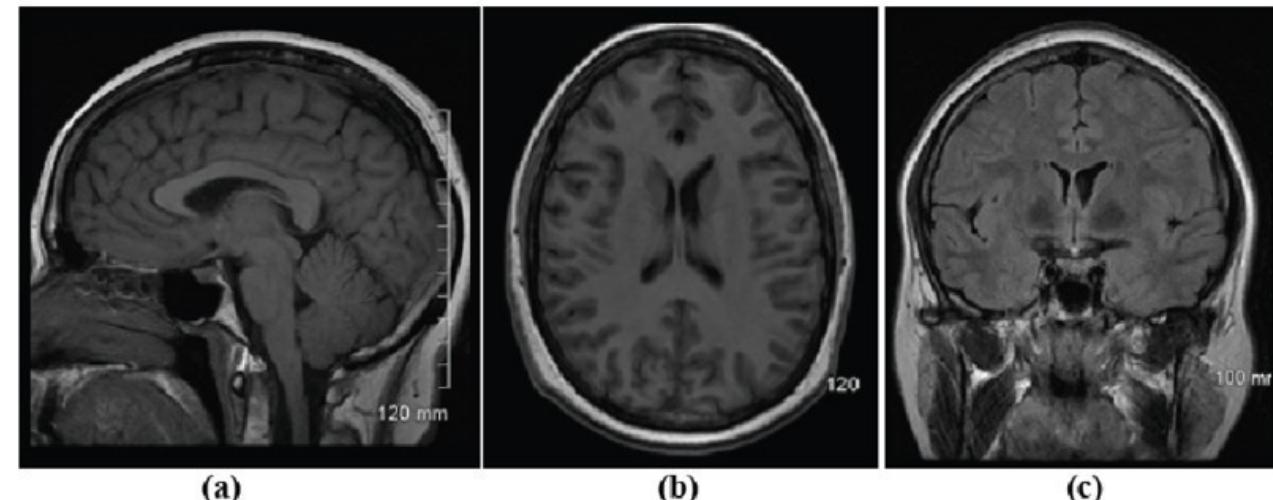
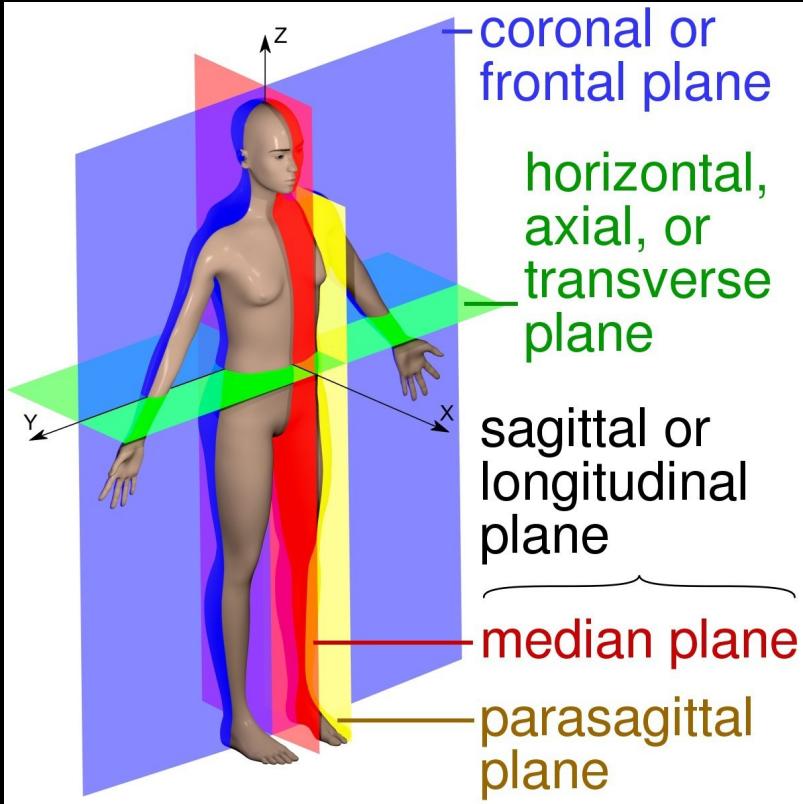
fMRI/DTI Voxel (pixel in



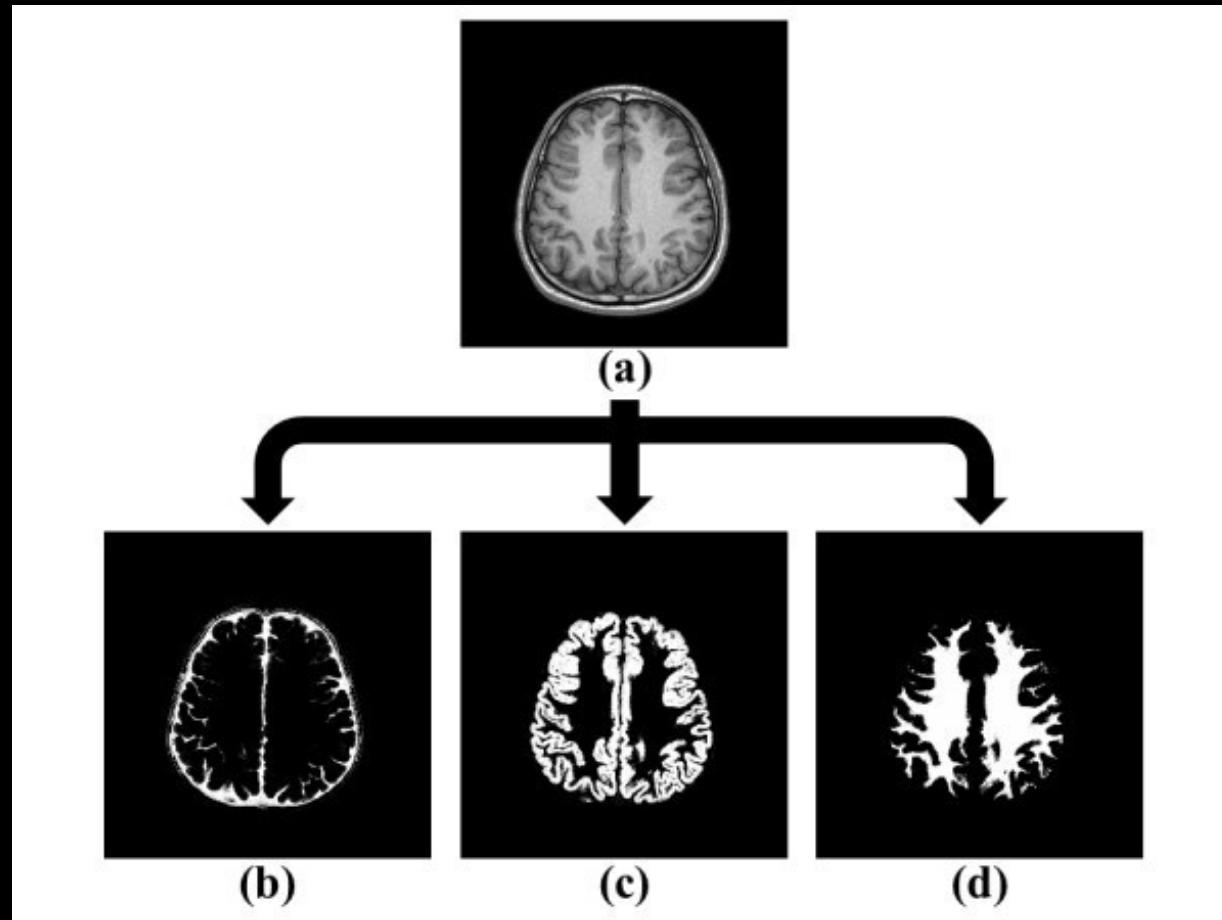
Data format

1. Digital Imaging and Communications in Medicine (**DICOM**) 2D
2. Neuroimaging Informatics Technology Initiative (NIFTI) 2D, 3D or 4D

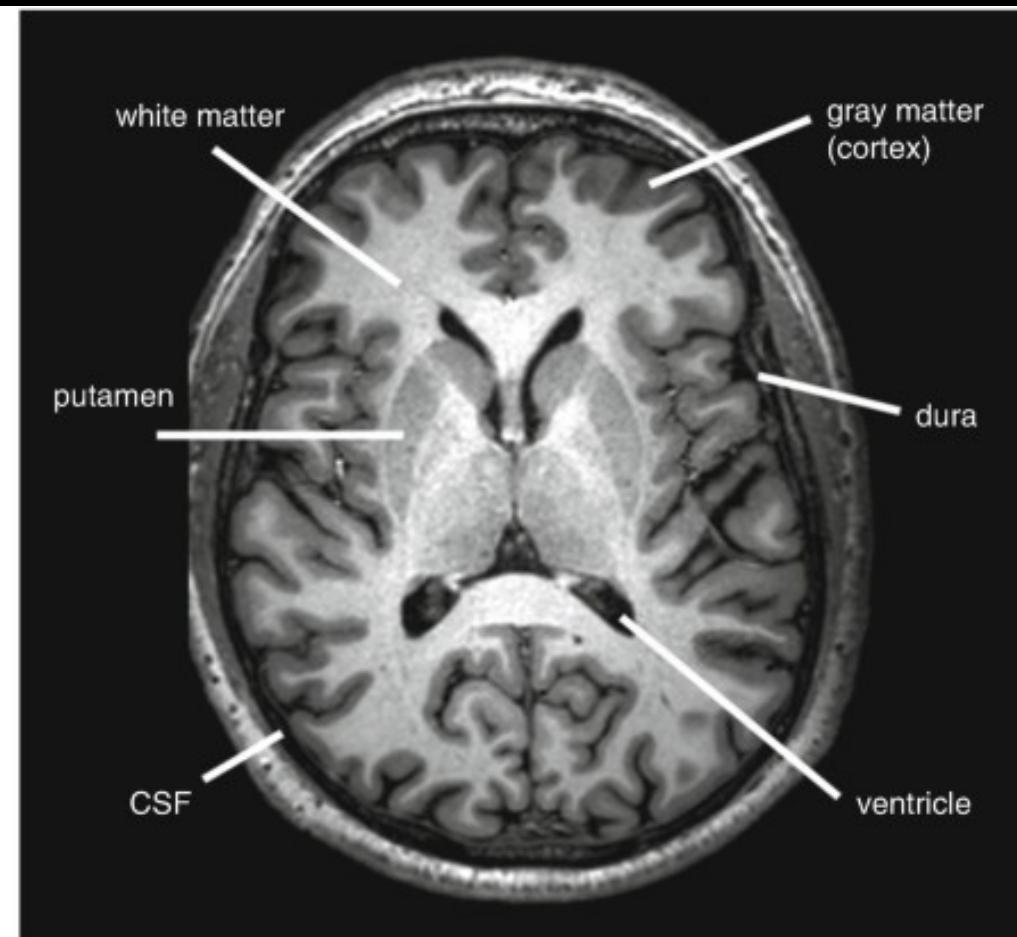
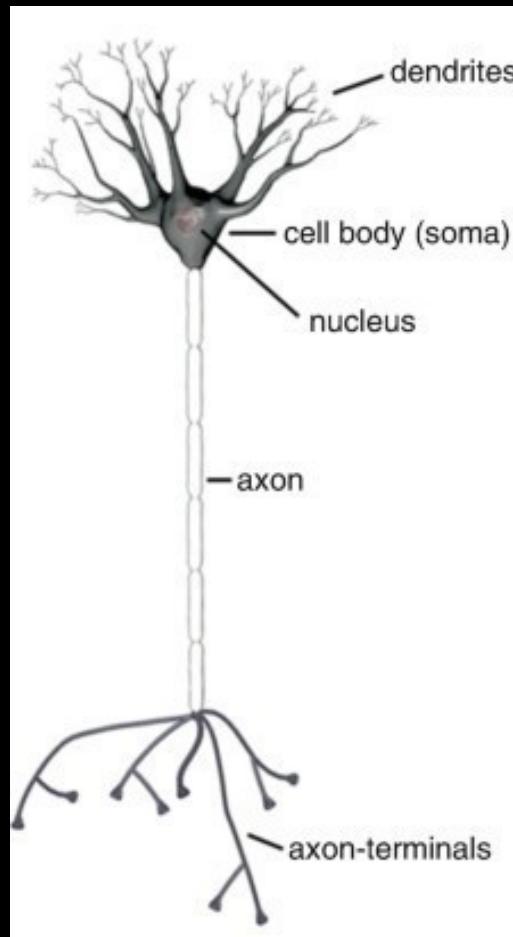
Planes



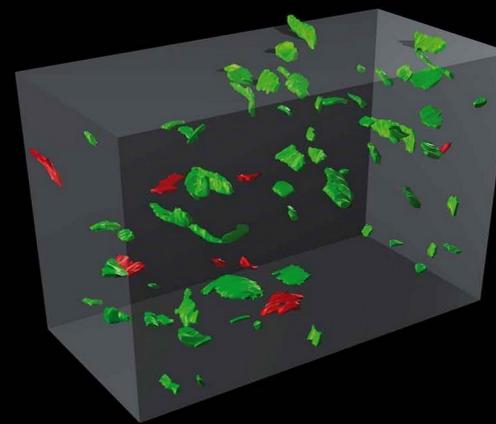
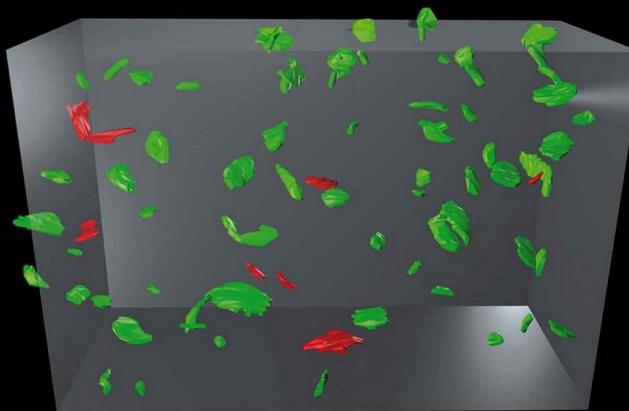
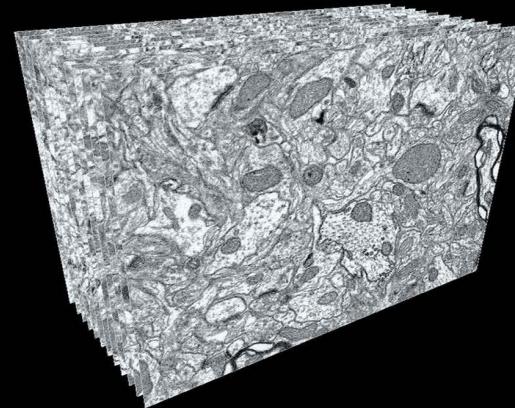
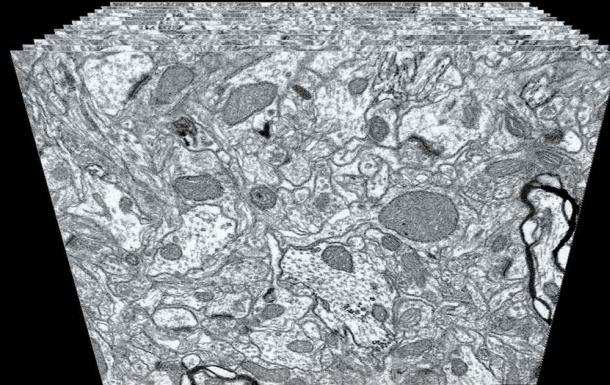
What we usually see in an MRI



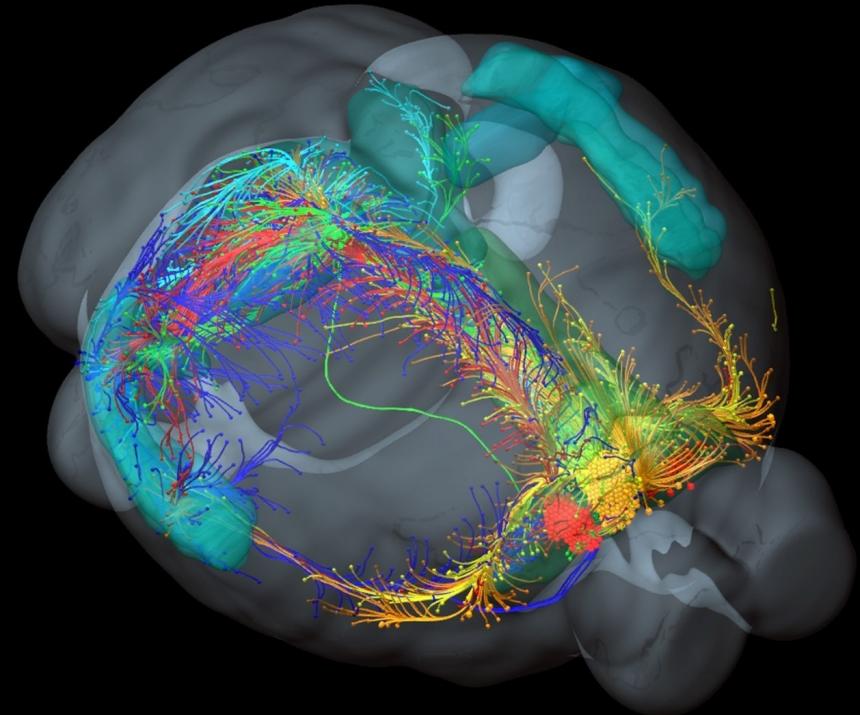
What we usually see in an MRI



Electron microscopy



Adeno-associated virus tractography

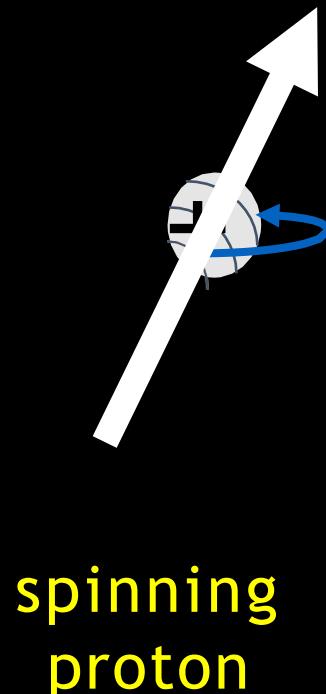


Oh et al. Nature
2014

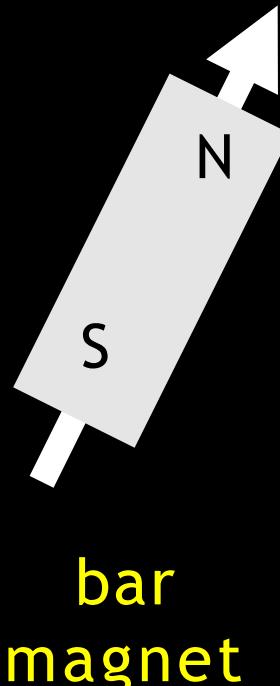


Break

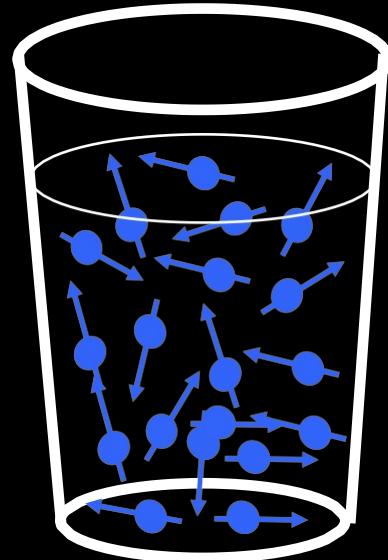
Magnetic Resonance Imaging



- Hydrogen protons spin producing a magnetic field
- A magnetic field creates an electrical charge when it rotates past a coil of wire

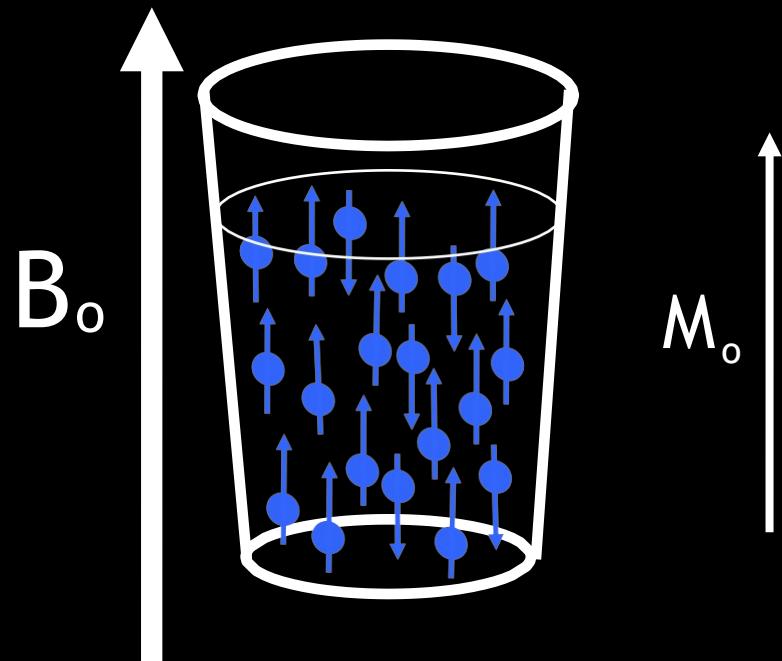


Randomly oriented
protons



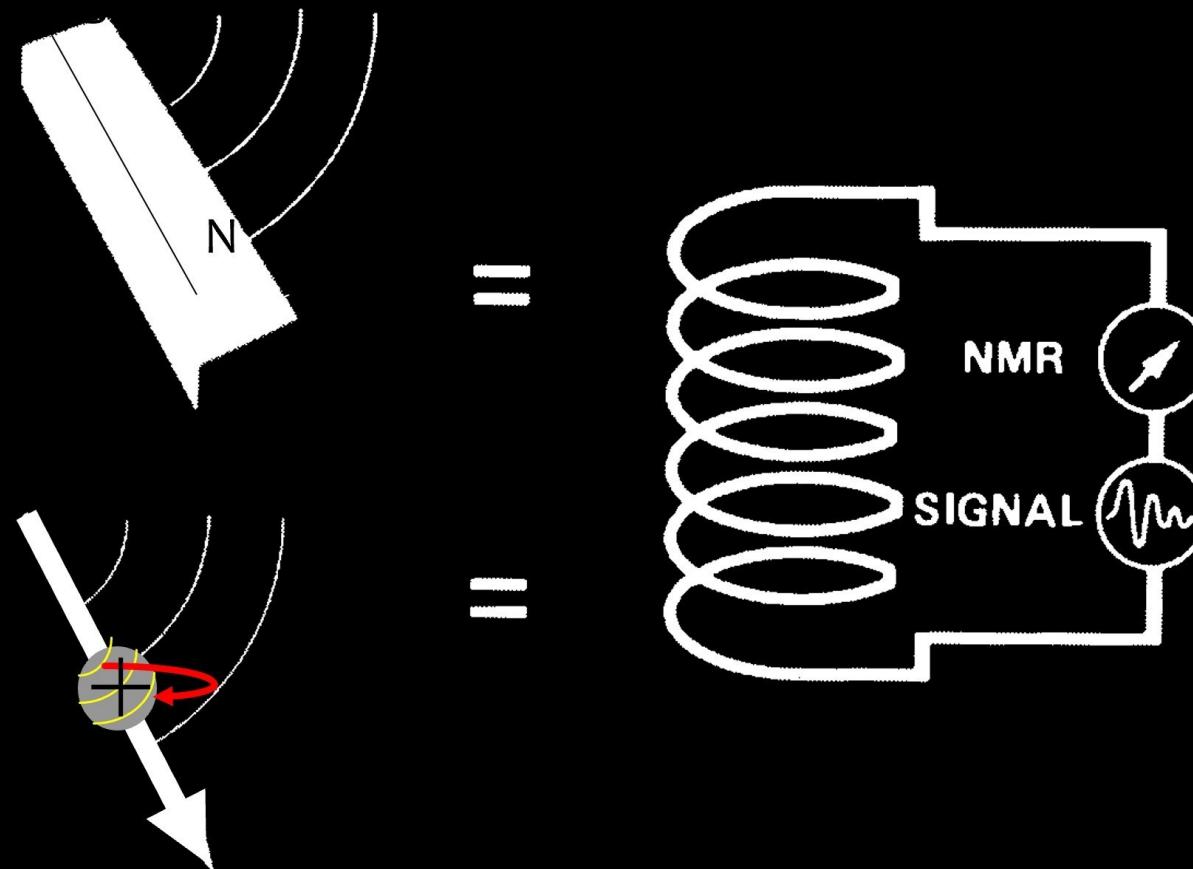
net magnetic
moment is *zero*

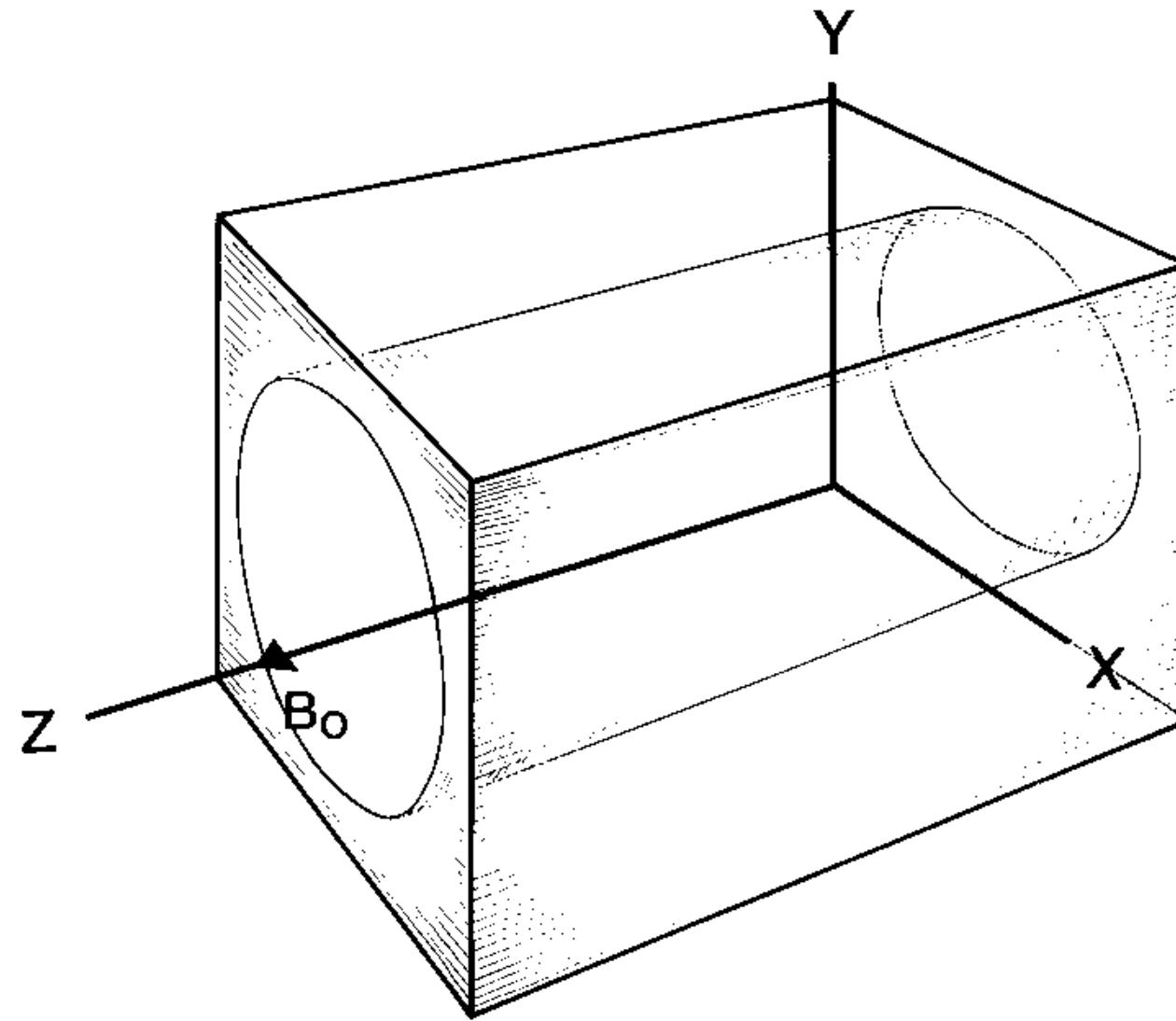
Protons aligned with a
strong magnetic field

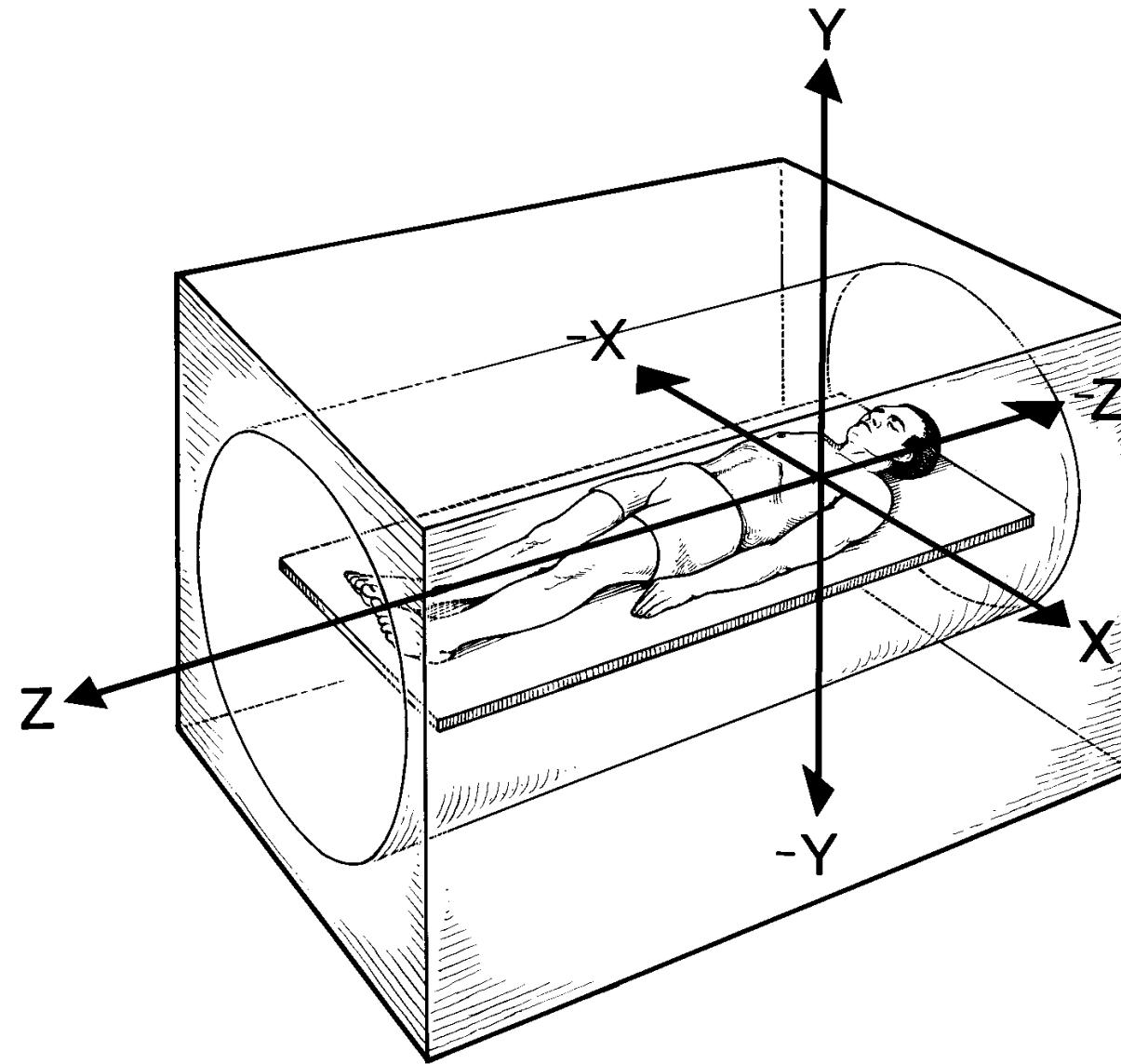


net magnetic moment
is positive

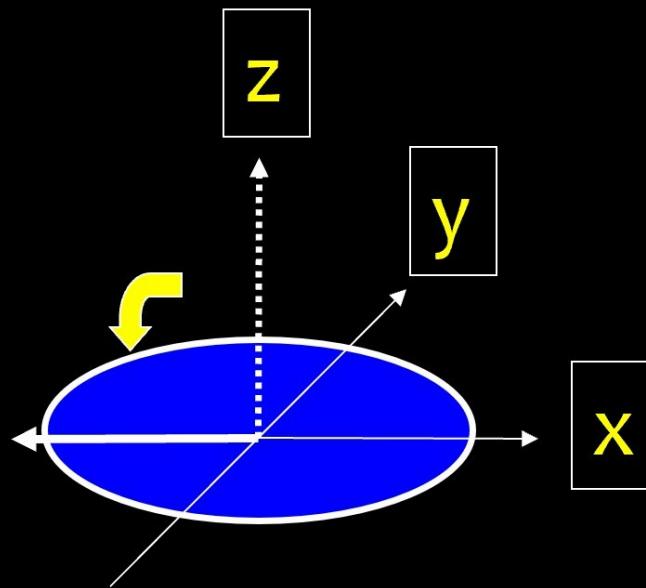
MRI measurement







Flip Angle - Degree of Deflection from Z-axis



90° Radiofrequency Pulse used to “tip” protons into X-Y plane.

The MRI Measurement (Up to this point)

In the presence of the static magnetic field

- Protons align with the field
- Protons precess about the magnetic

Briefly turn on RF pulse

- Provides energy to tip the protons at least partially into the imaging plane

What happens to the protons next?

Relaxations

Longitudinal - precessing protons are pulled back into alignment with main magnetic field of the scanner (B_0) reducing size of the magnetic moment vector in the x-y plane

Transverse - precessing protons become out of phase leading to a drop in the net magnetic moment vector (M_0)

Transverse relaxation occurs much faster than Longitudinal relaxation

Tissue contrast is determined by differences in these two types of relaxation

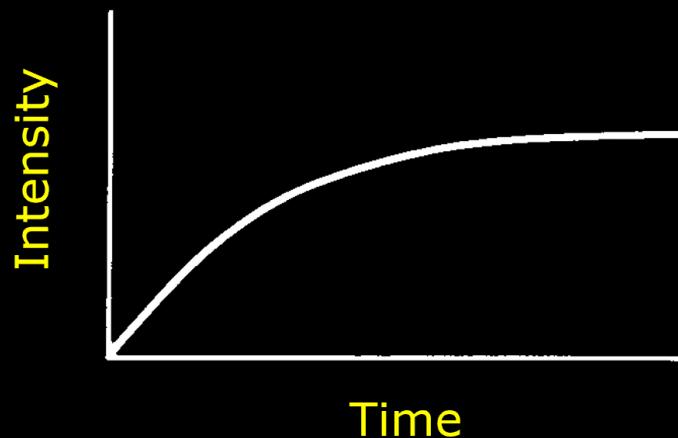
Main Tissue Contrast Controls

Echo Time (TE) - time after 90° RF pulse until readout.
Determines how much transverse relaxation will occur before reading one row of the image.

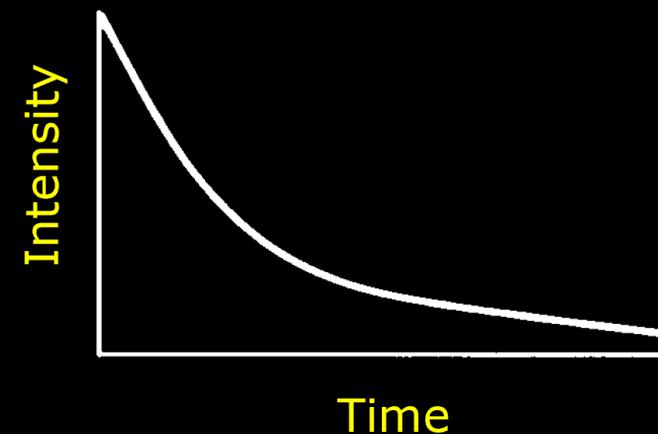
Repetition Time (TR) - time between successive 90° RF pulses. Determines how much longitudinal relaxation will occur before constructing the next row of the image.

Main Tissue Contrast Controls

Every tissue has a different affect on longitudinal (T1) and transverse (T2) relaxation.



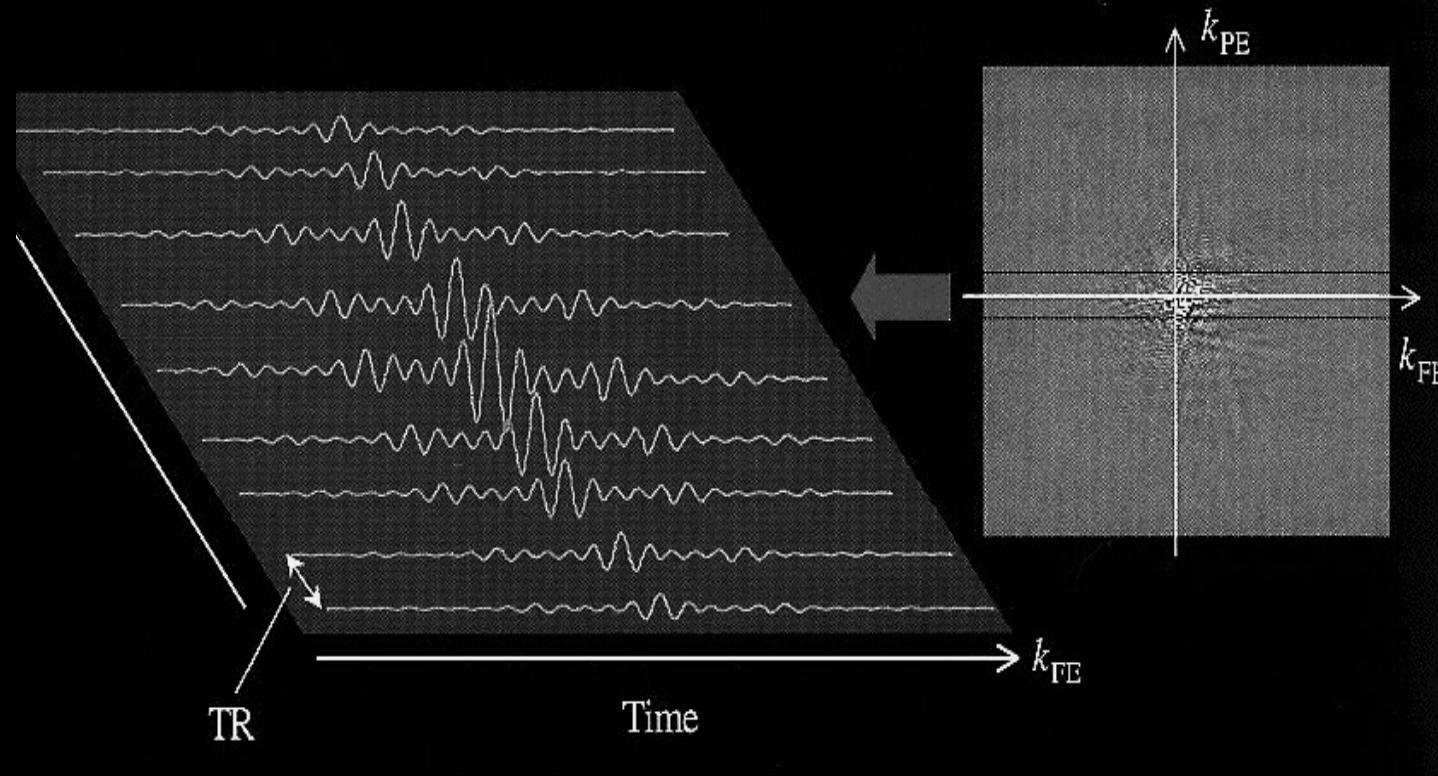
T1 Curve



T2 Curve

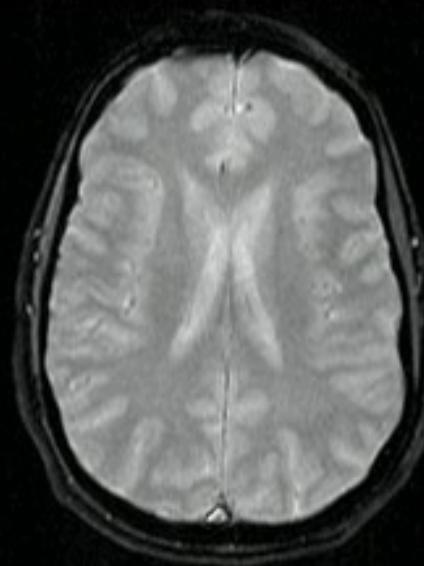
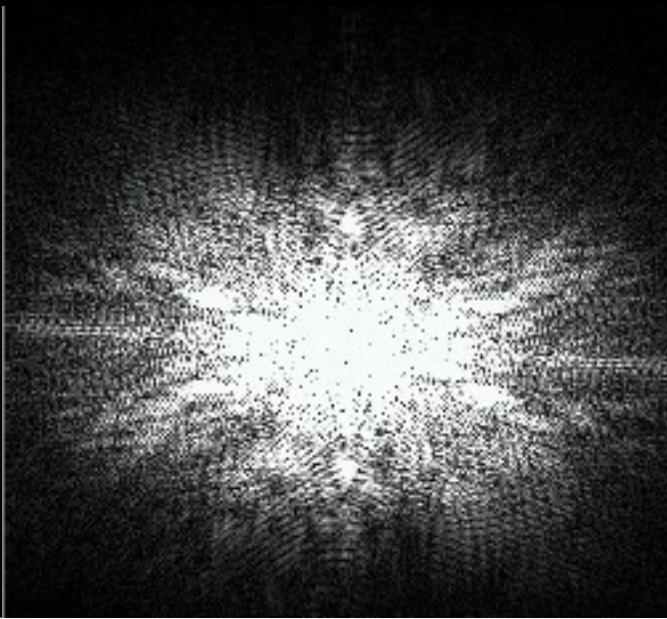
k-space

Signal

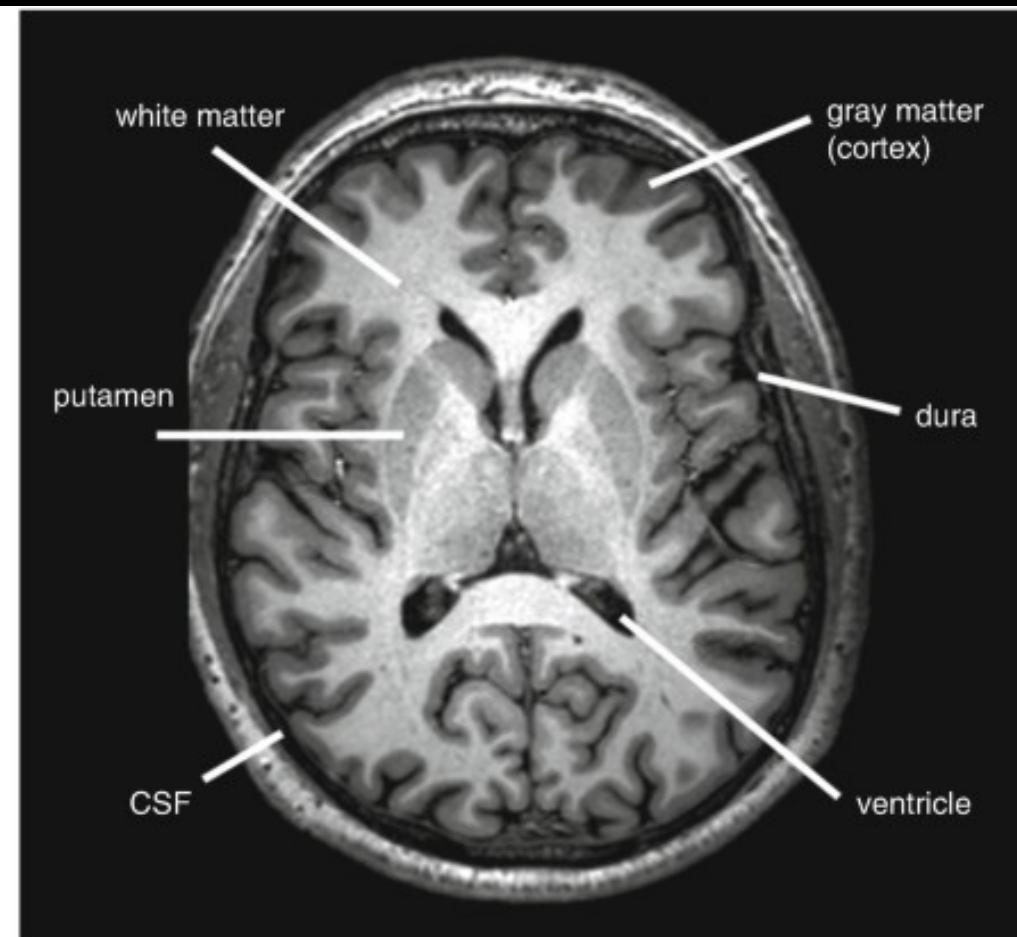
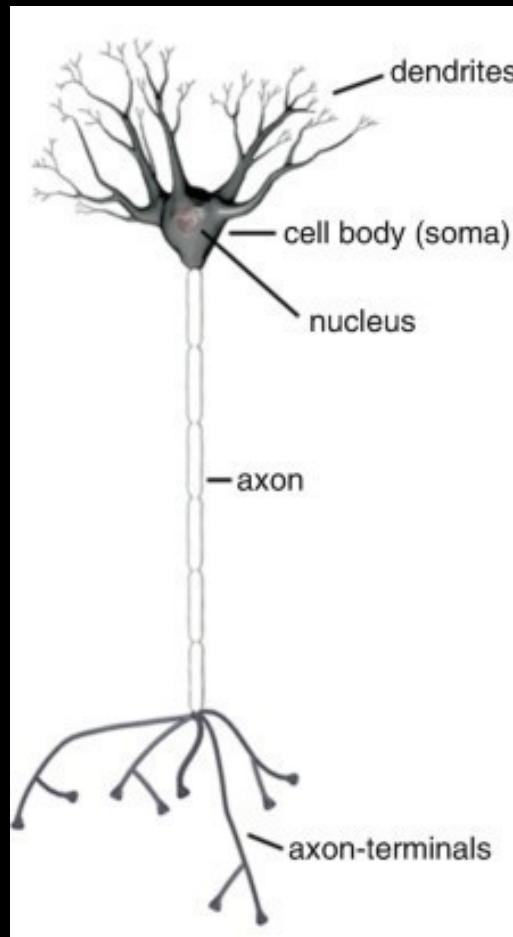


Images From k-space

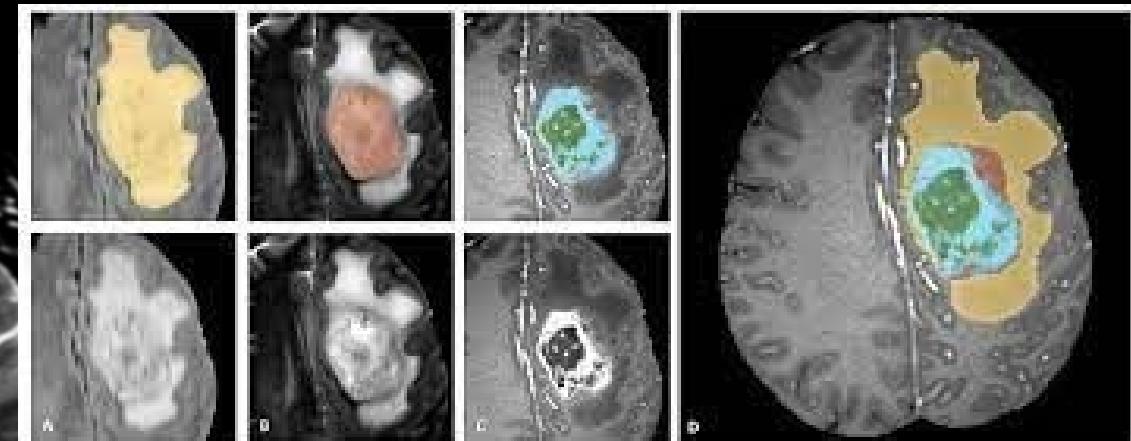
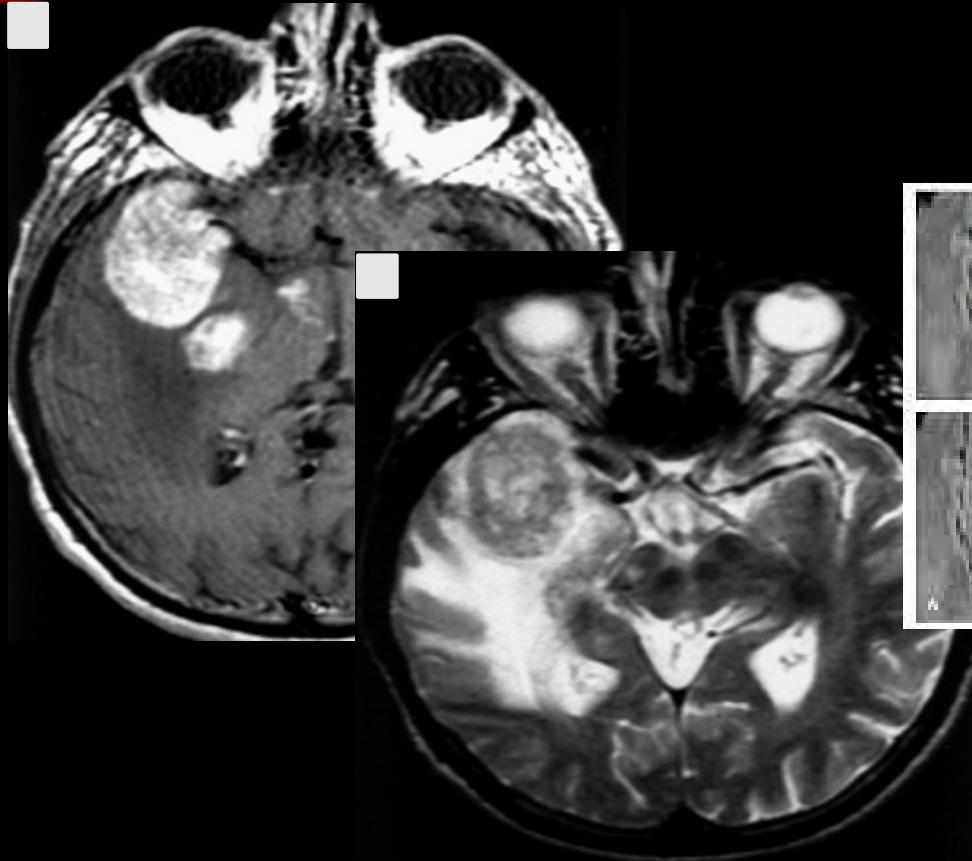
K-space is turned into an image using
a Fourier Transformation



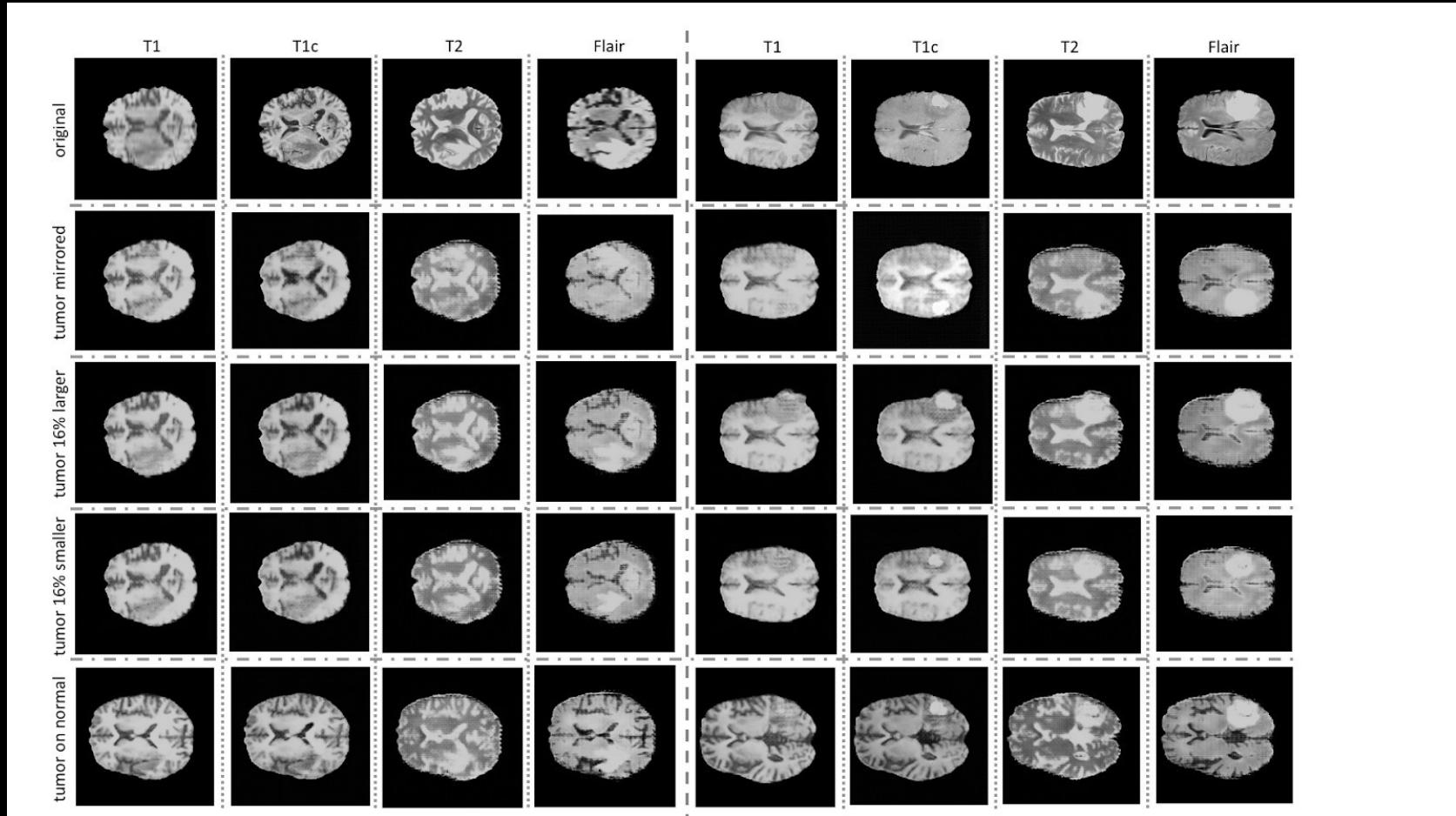
What we usually see in an MRI



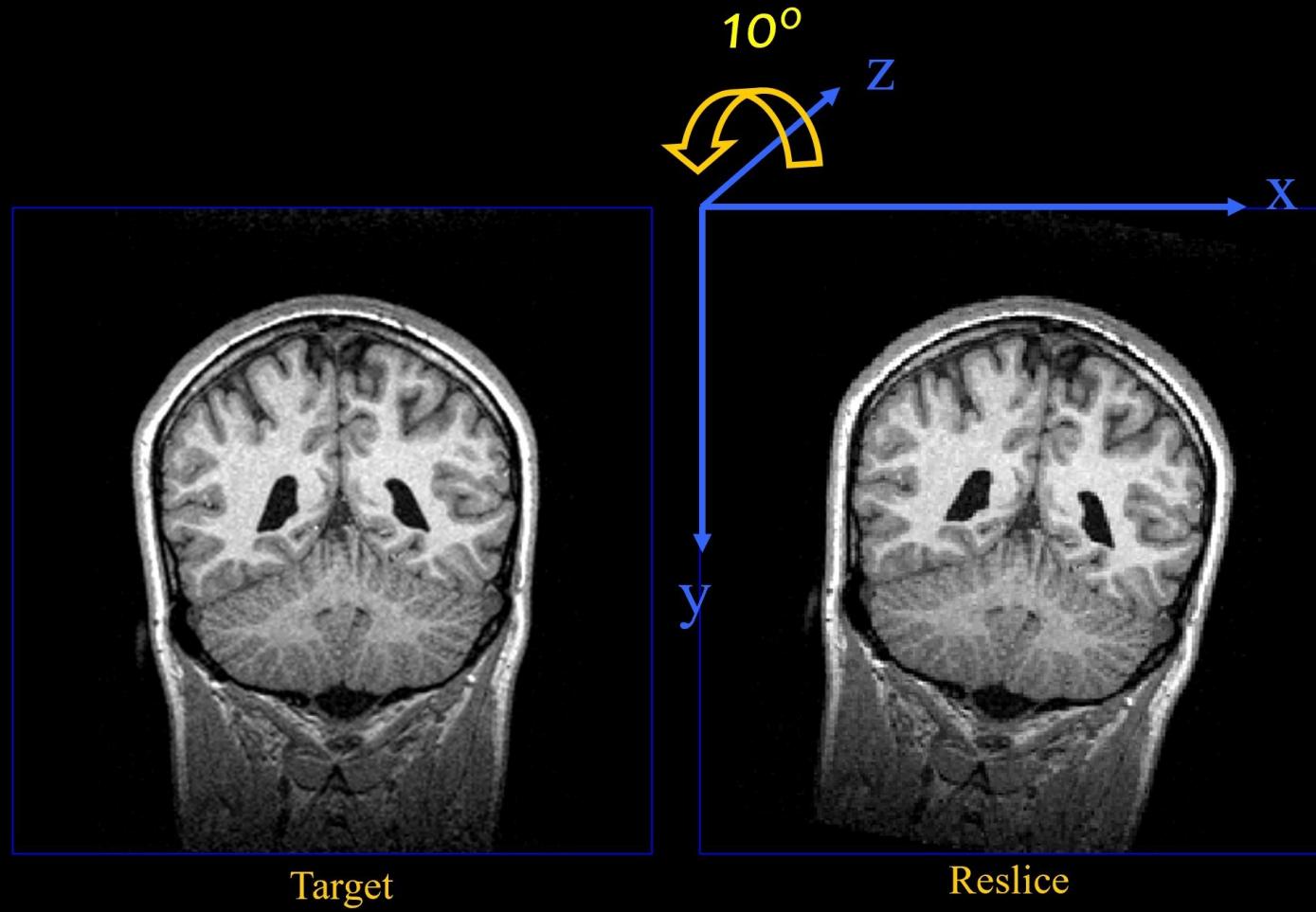
Just structural



GAN TUMOR



Registration

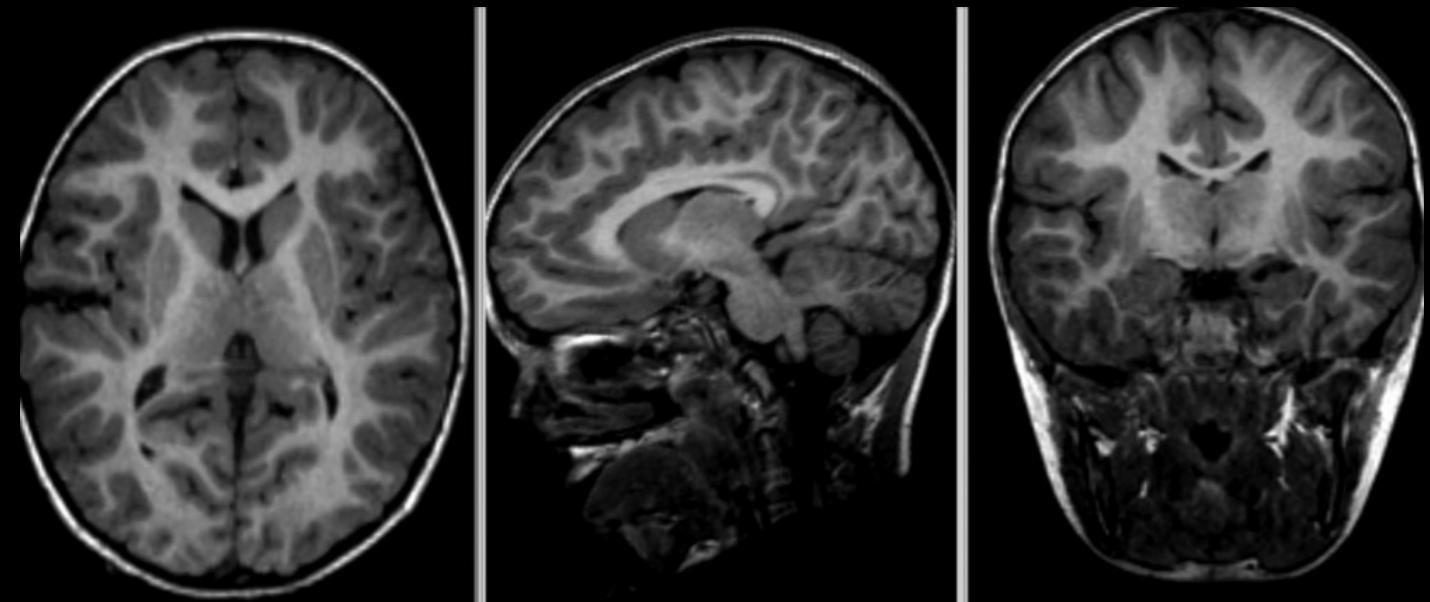


Registration

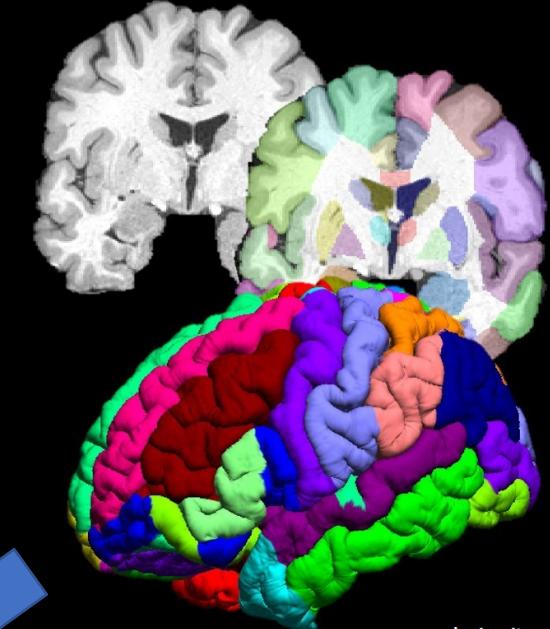
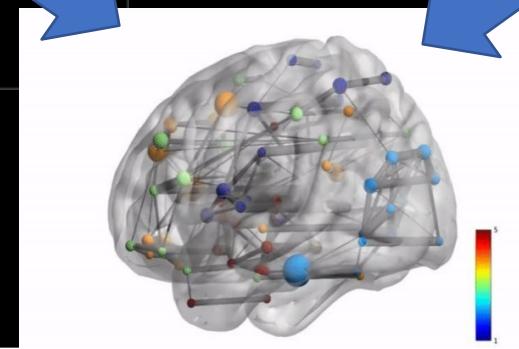
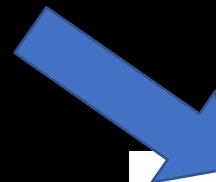
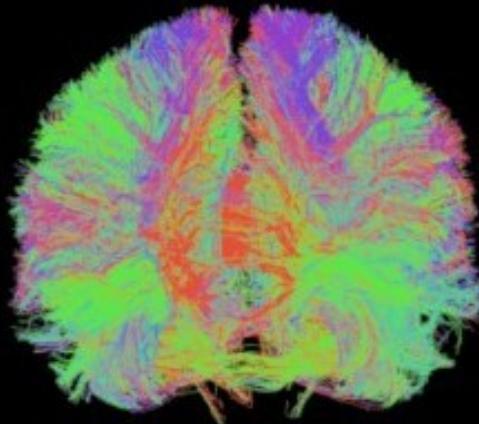
Reasons:

- To have consistent data
- in fMRI people move, breath or have cardiac pulsation (those will be micro-registrations called motion corrections)

Non-linear registration



Structural Connectivity



Summary



1. Neuroimaging uses different types of modalities (CT, MRI, microscopy, etc)
2. Those are often 3D or 4D data types
3. We can use structural MRI as 3D images
4. fMRI works more like signals in time
5. Diffusion MRIs are more complicate types of data, and they allow to create graph networks representations

