Magnetic Resonance Imaging

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Magnetic Resonance Imaging

A) What is MRI?

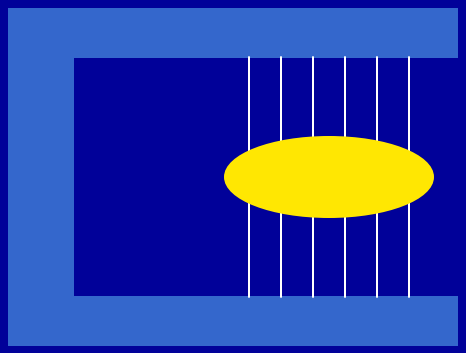
B) Why do MRI?

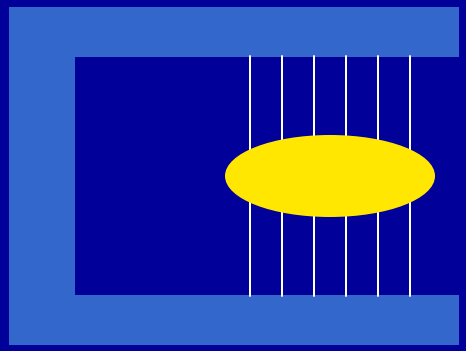
C) What can we do with an MRI scanner?

What is MRI?

Magnetic Resonance Imaging

We place our ‘sample’ in a very large magnetic field ~ 50,000 times larger than the earths field.



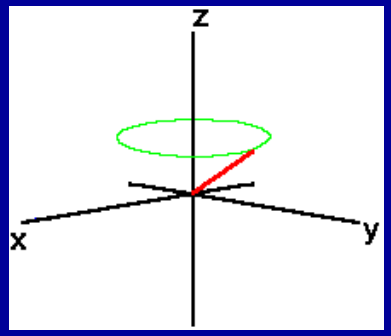


What is MRI?

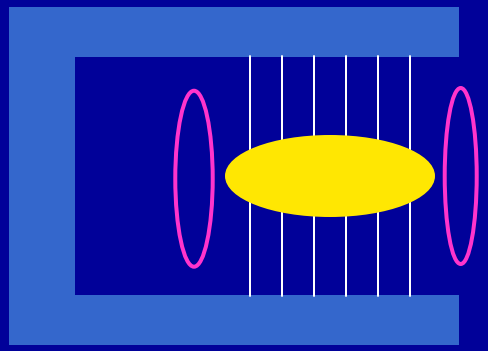
Magnetic **Resonance** Imaging

In a large magnetic field hydrogen nuclei behave like little magnets. They align with the field and precess around the field at a frequency which is proportional to the magnetic field.

$\omega_{precession} = \gamma H$



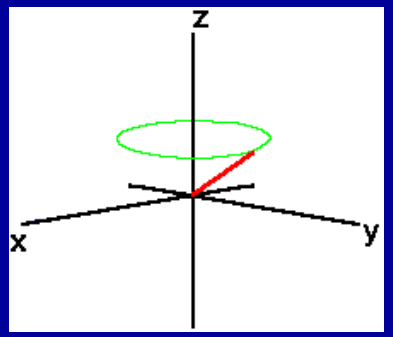
Precession



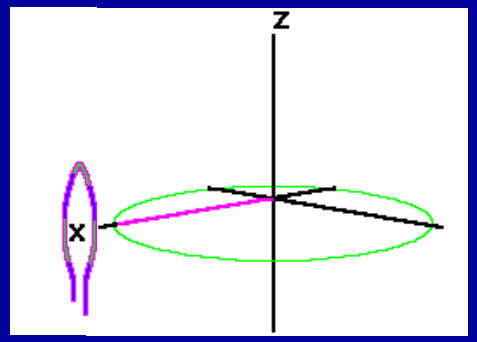
What is MRI?

Magnetic **Resonance** Imaging

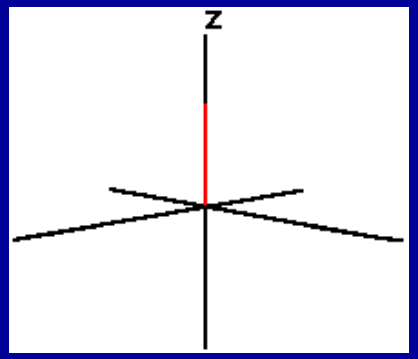
By applying a electromagnetic field which oscillates at the same frequency as the hydrogen nuclei, we can change the angle of precession of the hydrogen nuclei.



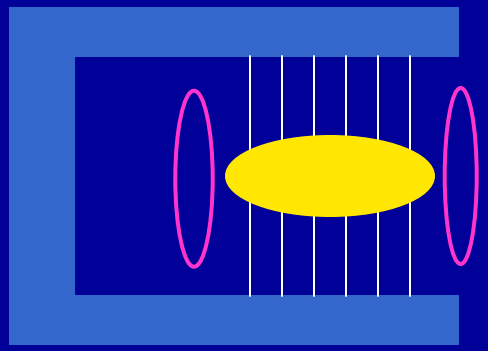
Precession



Resonance with applied radio frequency pulse



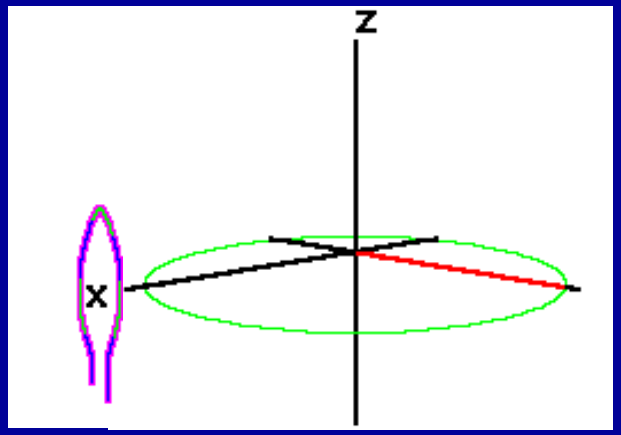
Tilting the magnetization



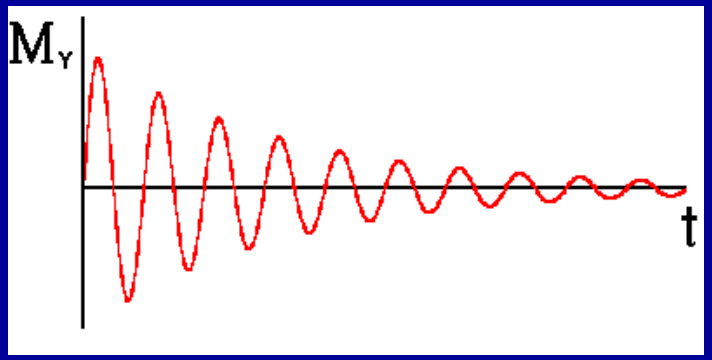
What is MRI?

Magnetic Resonance Imaging

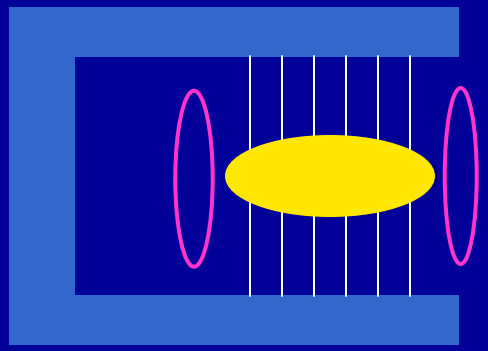
If you rotate a magnet next to a pickup coil, you induce a current which can be registered on a computer.



Pickup coil measures rotating hydrogen nuclei



Signal recorded on computer

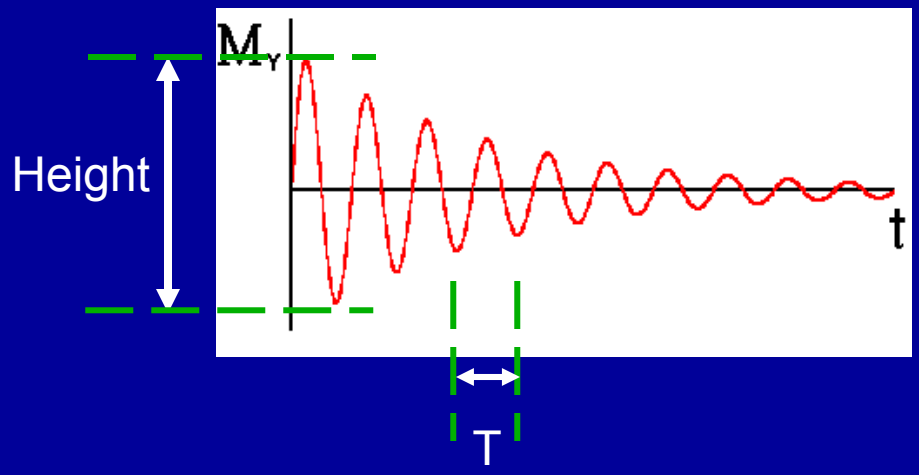


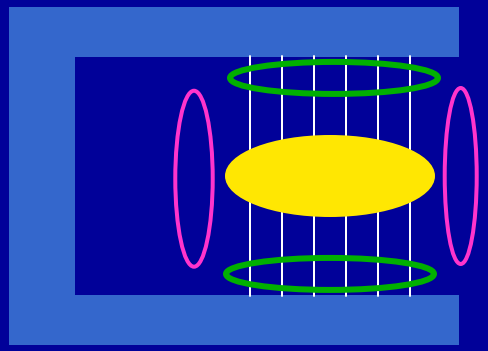
What is MRI?

Magnetic Resonance Imaging

The height of this signal is proportional to the number of hydrogen nuclei.

The frequency (=1/T) is proportional to the magnetic field strength.

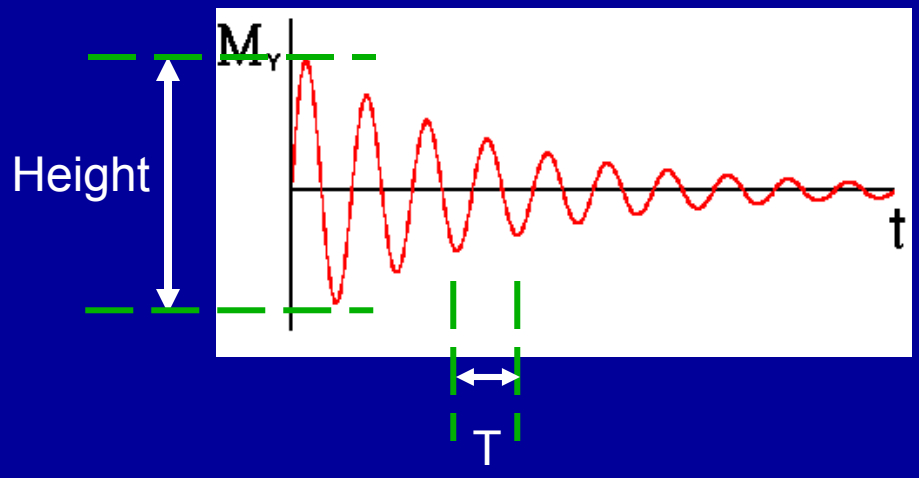


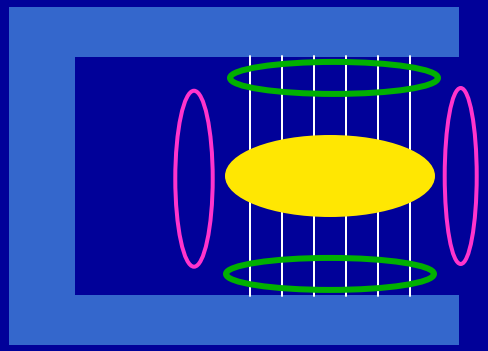


What is MRI?

Magnetic Resonance Imaging

By causing the magnetic field strength to change with position (using magnetic field gradient coils), we can make a magnetic resonance image.



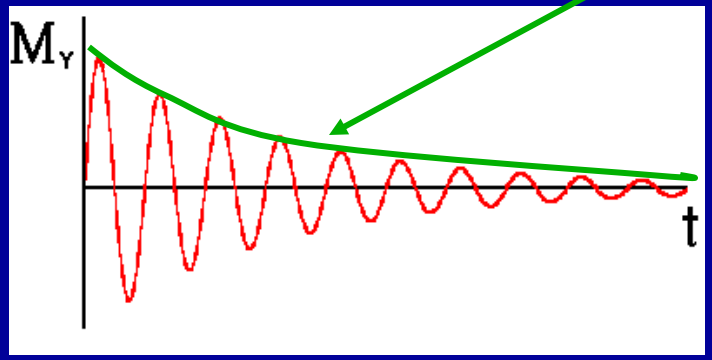


What is MRI?

Magnetic Resonance Imaging

The rate of signal decay with time depends upon the environment of the hydrogen nuclei. This can provide image contrast.

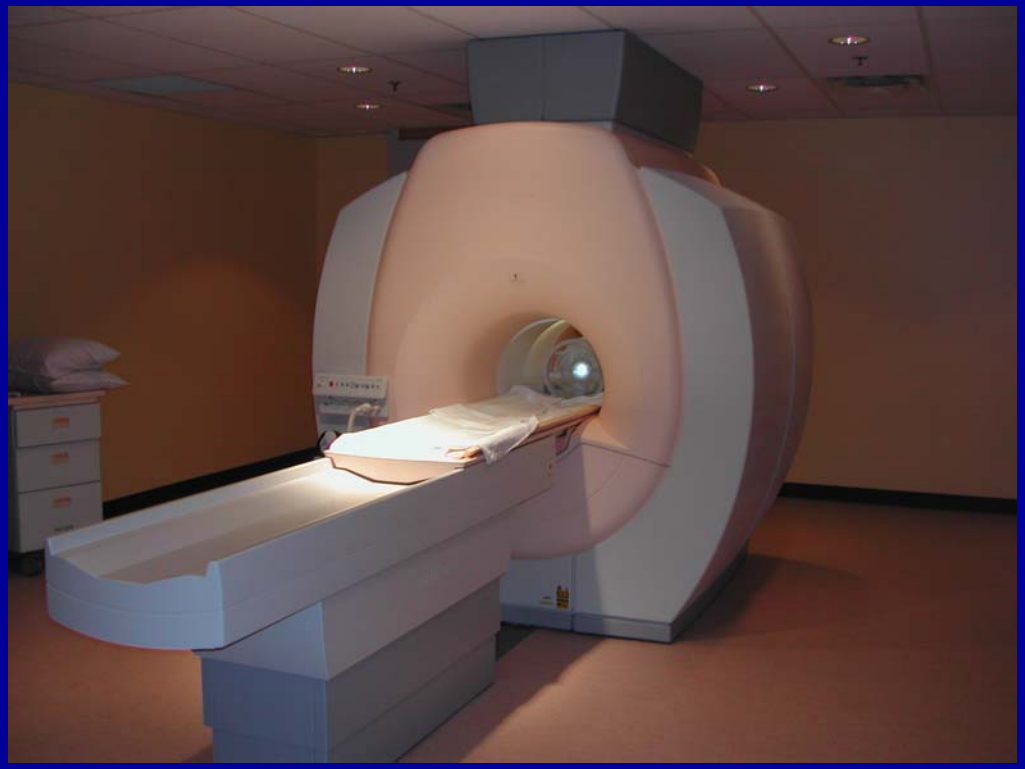
Decay of signal



Detail: When we look at a MR image, we are actually looking at signal largely from hydrogen nuclei on water and fat (lipid) molecules

What is MRI?

Magnetic Resonance Imaging

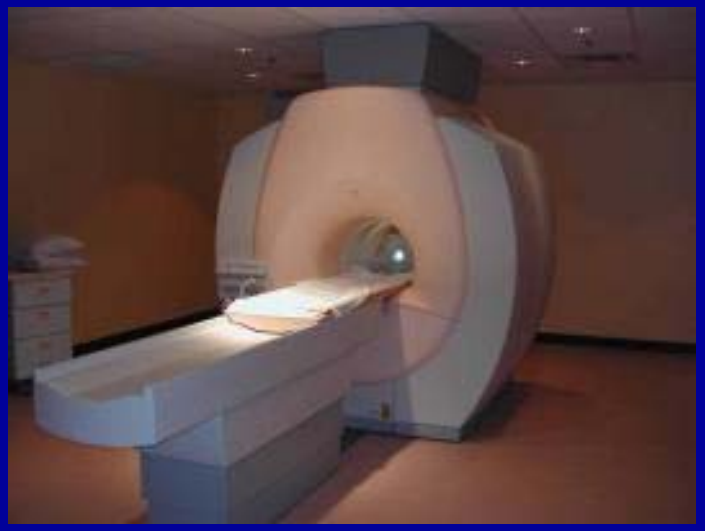


MRI Technology

- Four main parts of an MR Scanner are:
  - Magnet
  - Magnetic field gradients
  - Radio-frequency transceiver
  - Computer

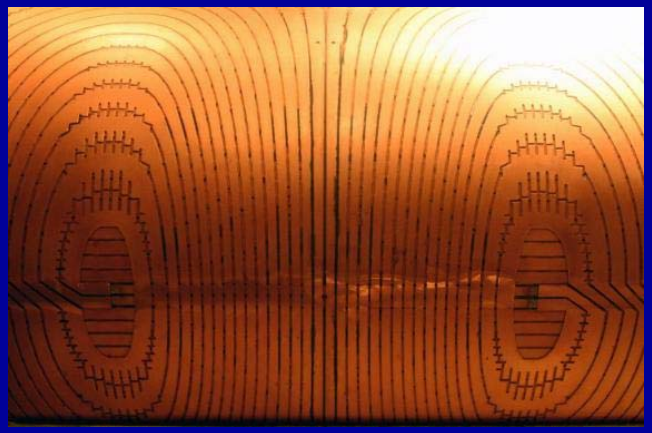
Magnet: 3.0T Philips Achieva

- Shortest bore (1.57m) 3.0T whole body
- Bore 60cm diameter
- Actively shielded (Two concentric magnets)
- 15 km of Niobium-Titanium wire kept at 4.2K
- 1400 litres liquid He, one fill/year
- This is a superconducting magnet
- Nausea experienced when moving in the 3.0T field



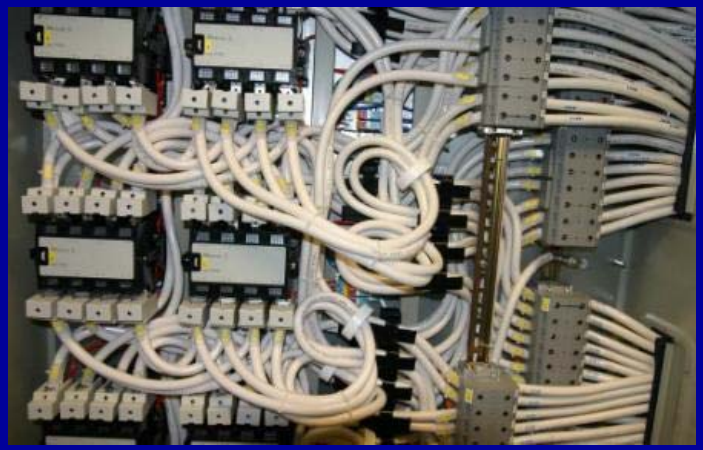
Magnet: 3.0T Philips Achieva

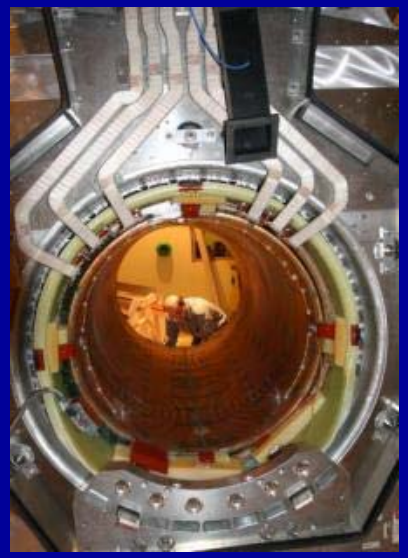
Magnetic Field Gradients



- Gradients spatially encode the MRI frequency
- There are three independent sets of gradient coils: x, y and z
- Not quiet – subjects need ear protection
- Can induce peripheral nerve stimulation

Gradients





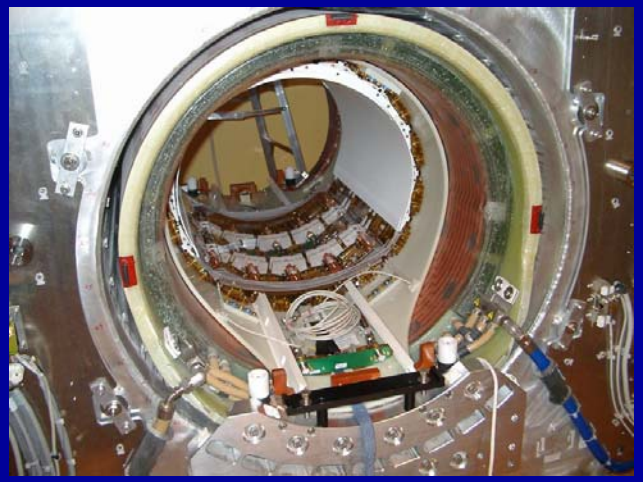
Radio Frequency Transeiver

- At 3.0 T, $\omega_o = \gamma B = 128$ MHz
- 25 kW RF transmitter
- Up to 16 receiver channels
- Coils: Body, Head, Spine array, Cardiac, Torso, Knee, Flex L, M, S.

Radio Frequency Transeiver

Copper room to keep out stray radio waves

Body Coil



MRIs (public) in British Columbia

- UBC
- VGH (2)
- St Pauls (2)
- Children's
- Royal Columbian
- Surrey
- Victoria General (2)
- Royal Jubilee
- Kelowna
- Kamloops
- Nanaimo
- Prince George
- Cranbrook, Penticton, Trail
- *Abbotsford*
- *Burnaby*
- *White Rock*

Why do MRI?

1) MRI involves no ionizing radiation and is, to the best of our knowledge, harmless.

2) MRI gives rise to images with exquisite soft tissue contrast.

3) The contrast of an MR image can be altered by changing how the image is acquired.

4) MRI can detect water content changes, lesions, tumors, flowing blood, beating heart, tissue metabolites, microscopic structure, and much more.

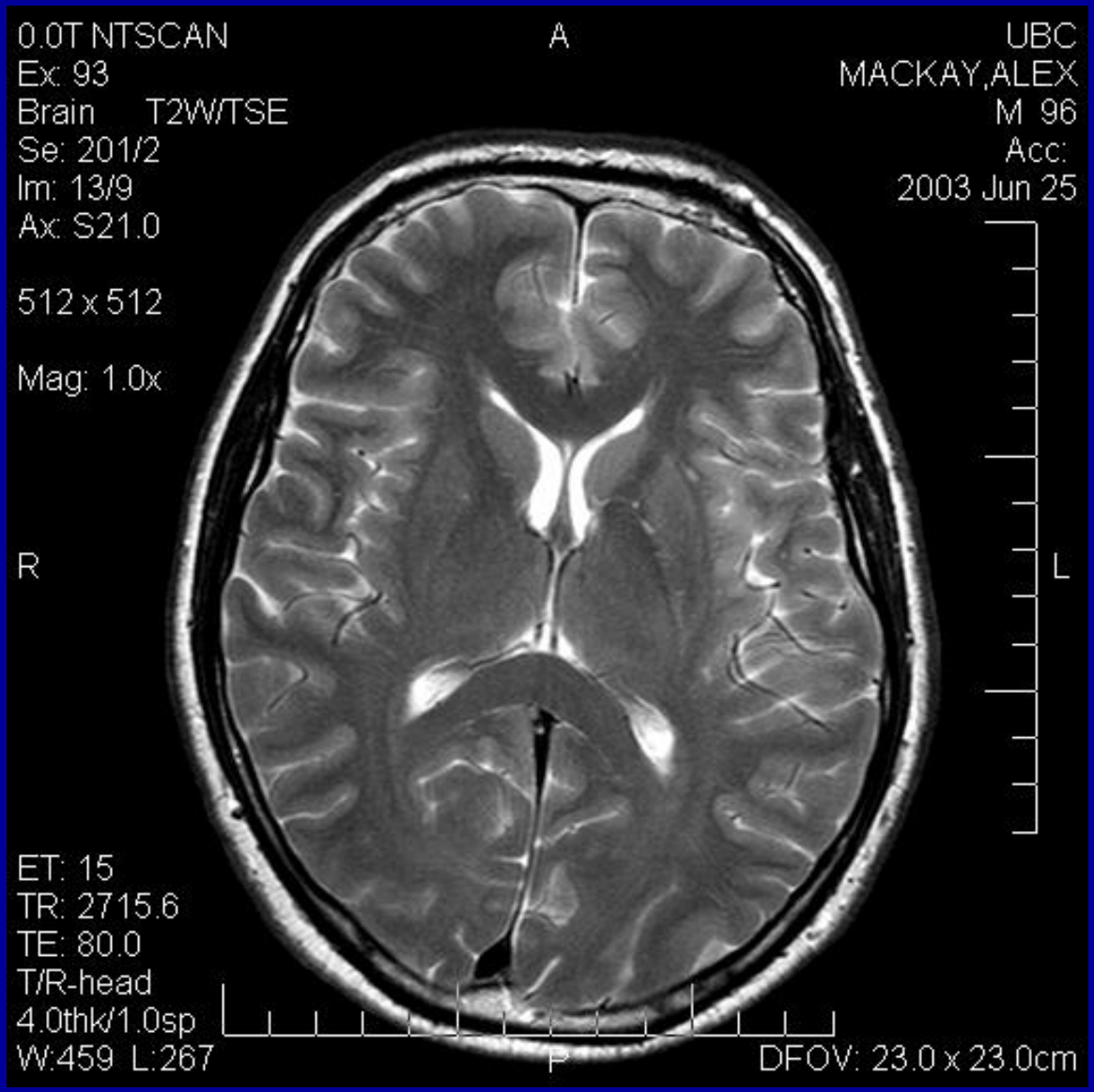
What can we do with an MR Scanner?

1) Radiologists, cardiologists and neurologists use MR to aid in diagnosis and management of human disease.

2) Science and health professionals use MRI to research disease mechanisms and assess potential disease therapies.

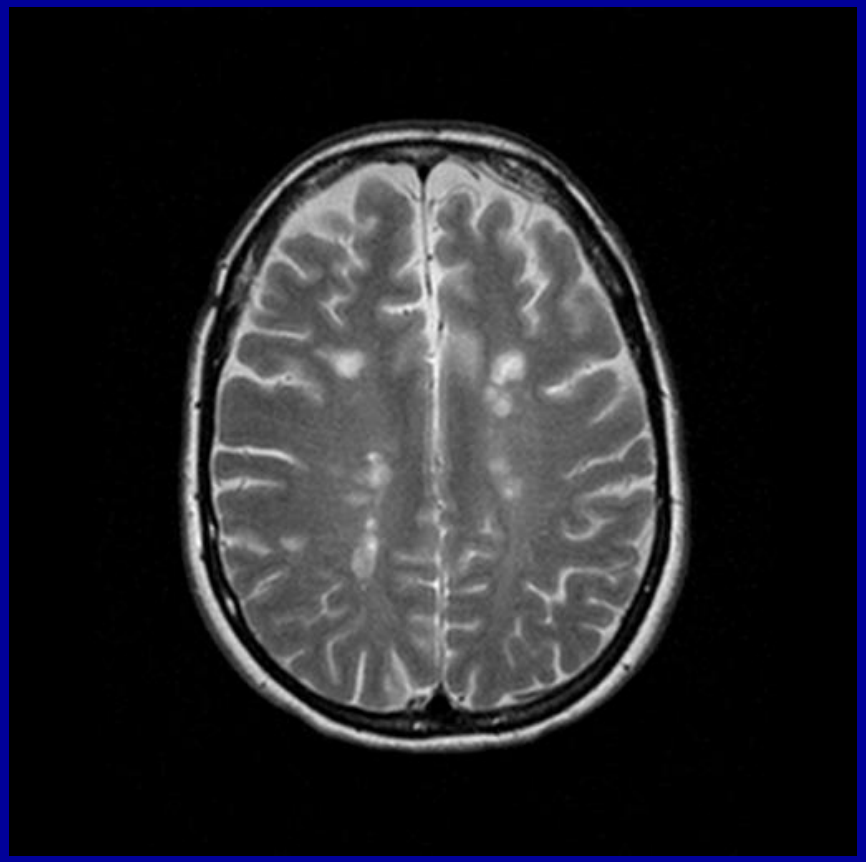
3) Psychologists and psychiatrists use MRI to learn about how the brain works.

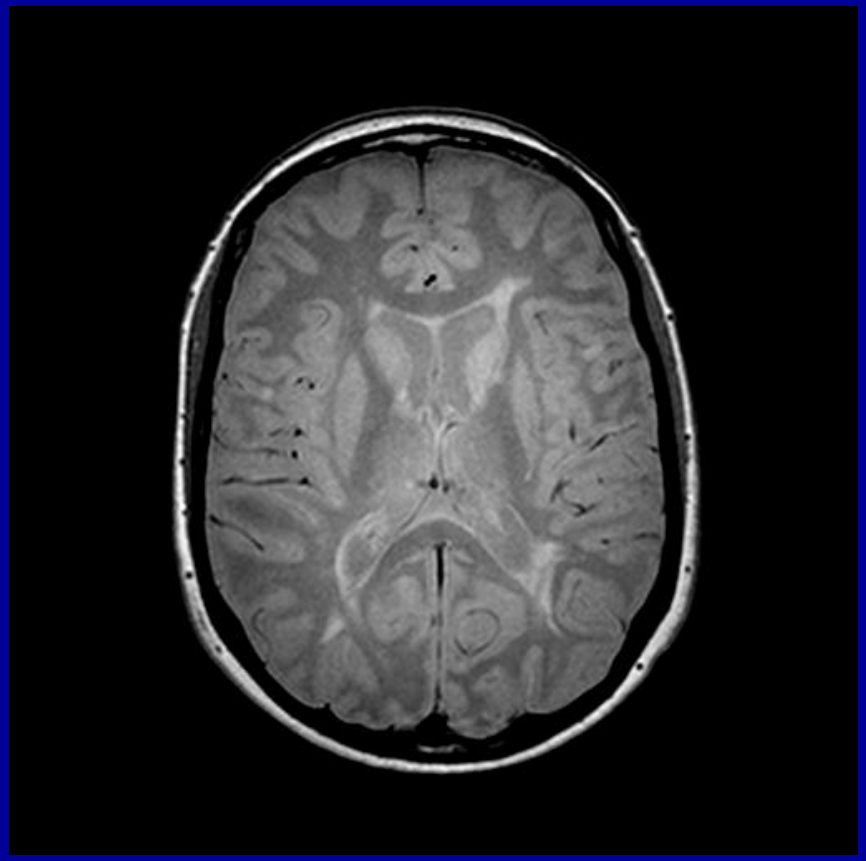
Conventional MRI



Healthy Volunteer

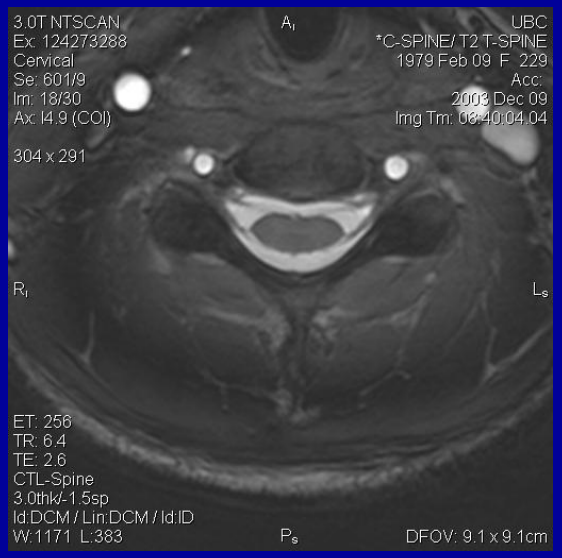
Conventional MRI

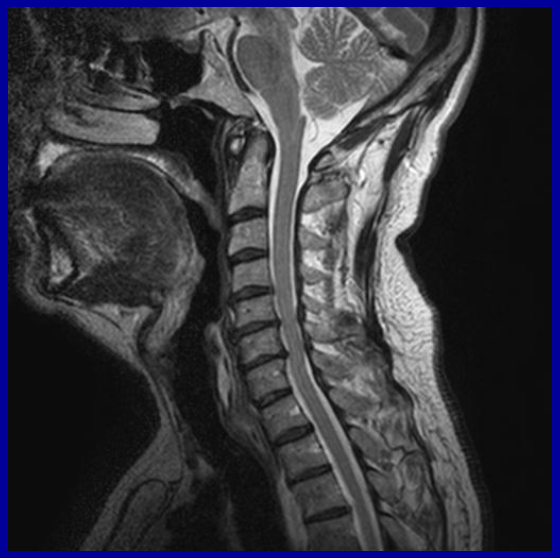


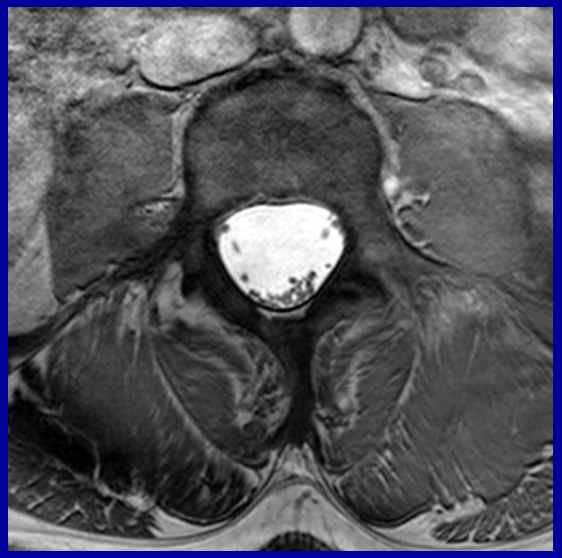


Patients with Multiple Sclerosis

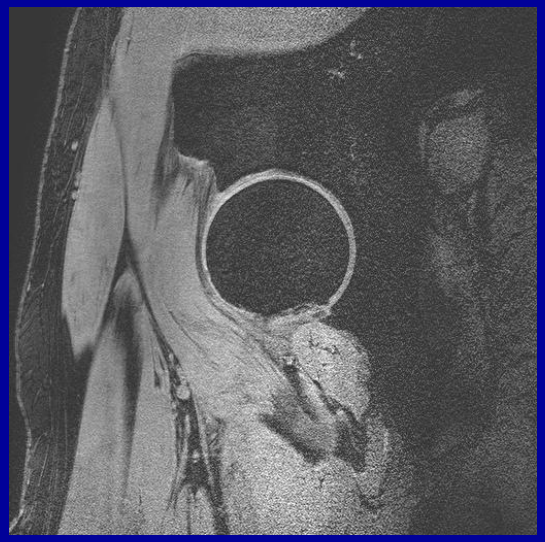
Conventional MRI



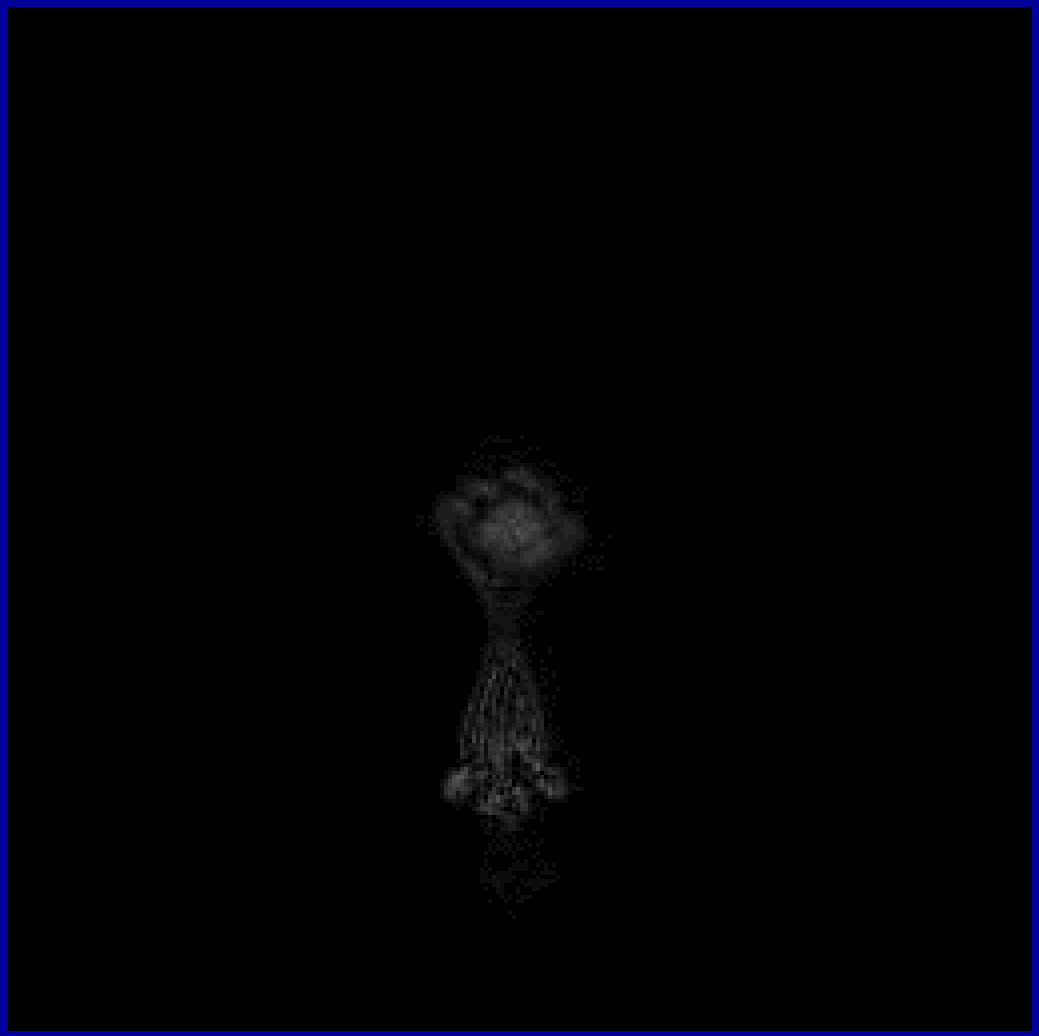




Conventional MRI



Volumetric Imaging

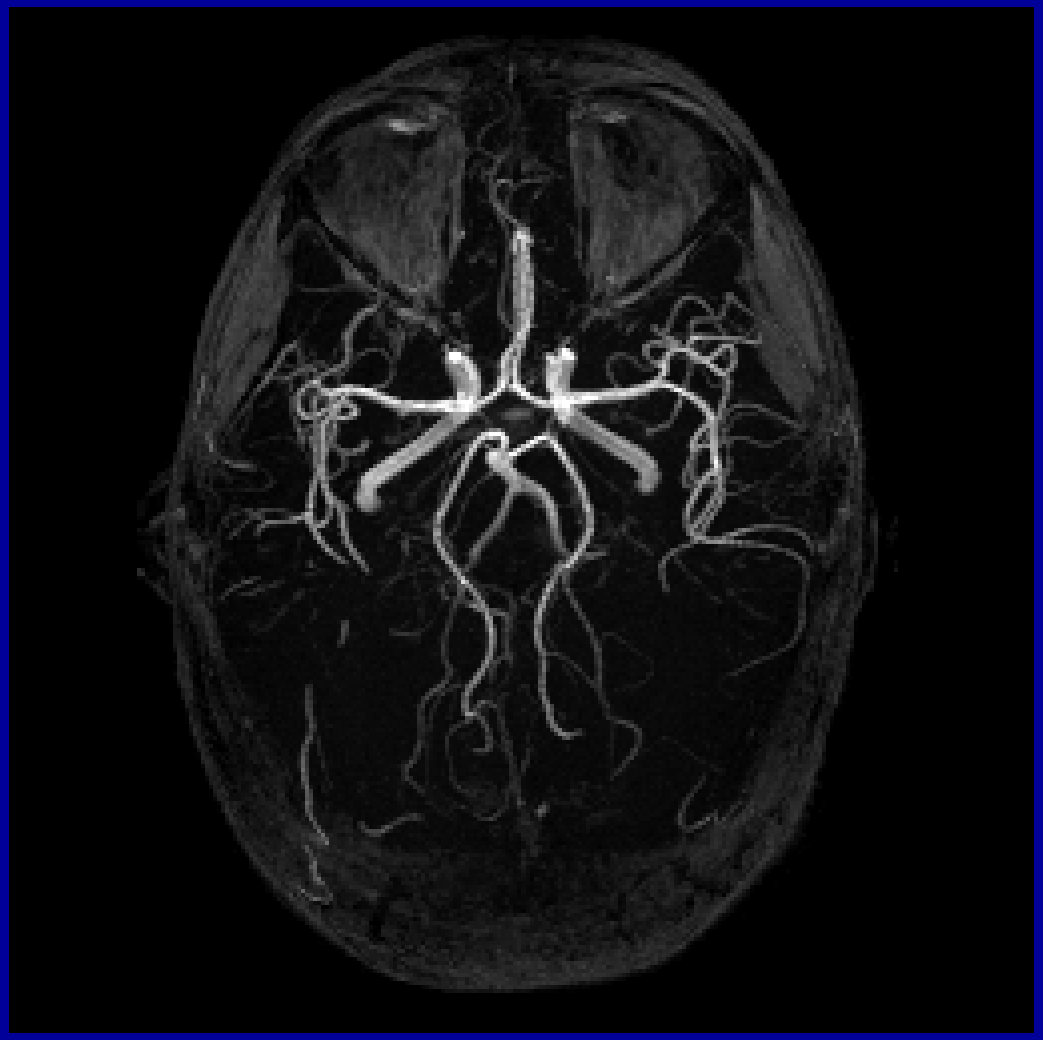


Magnetic Resonance Angiography

$$X = X_o + Vt$$

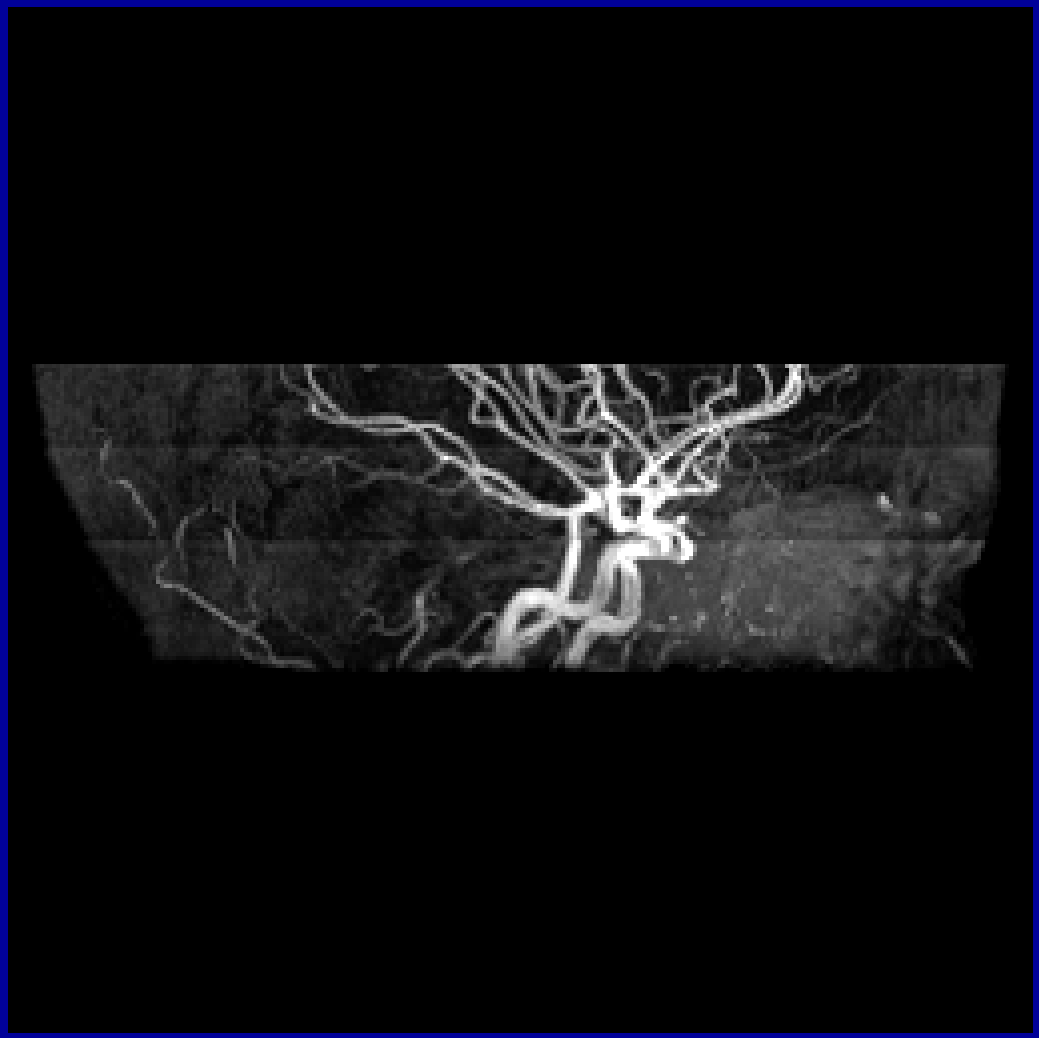
Static tissue **Flowing Blood**

MR Angiogram from Brain

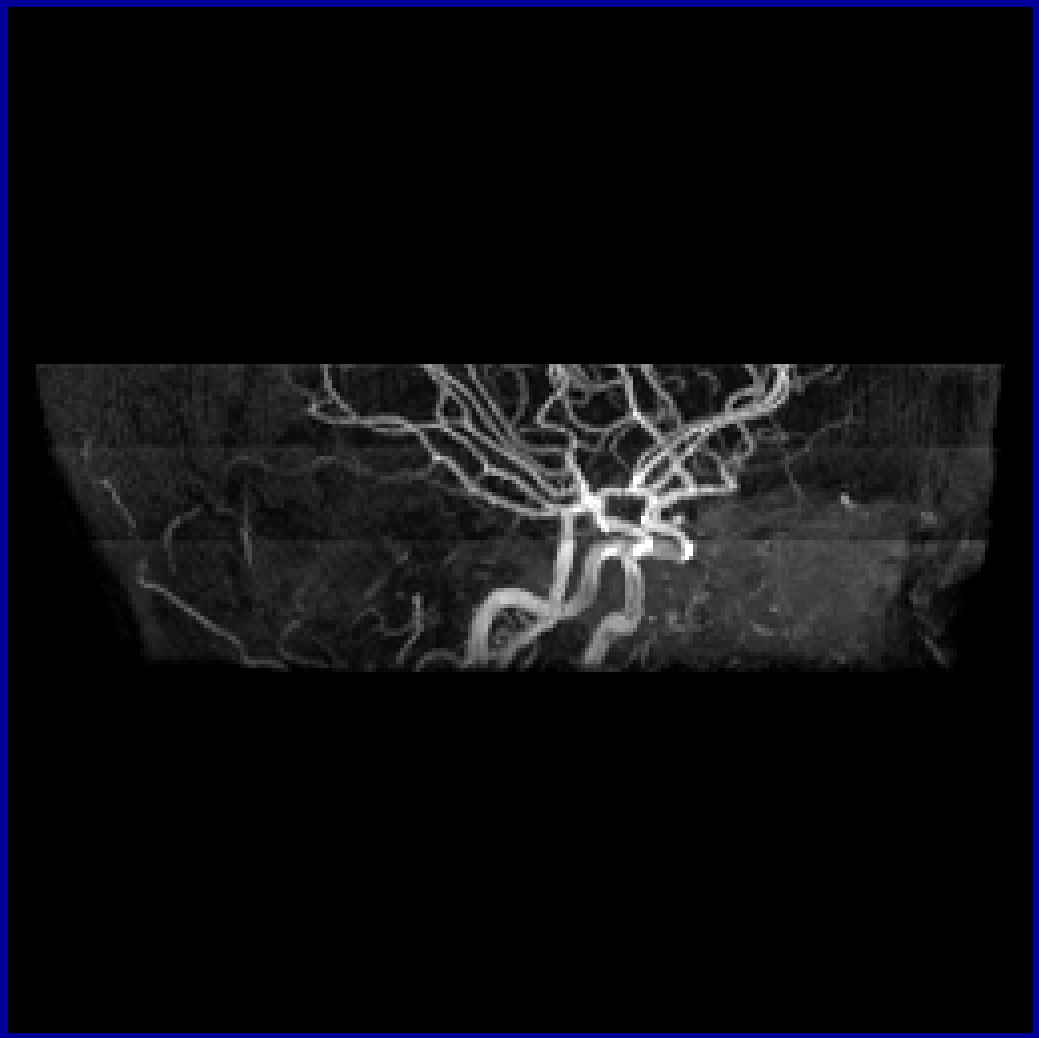


Rotating Projection of MR Angiogram

Rotate 10º

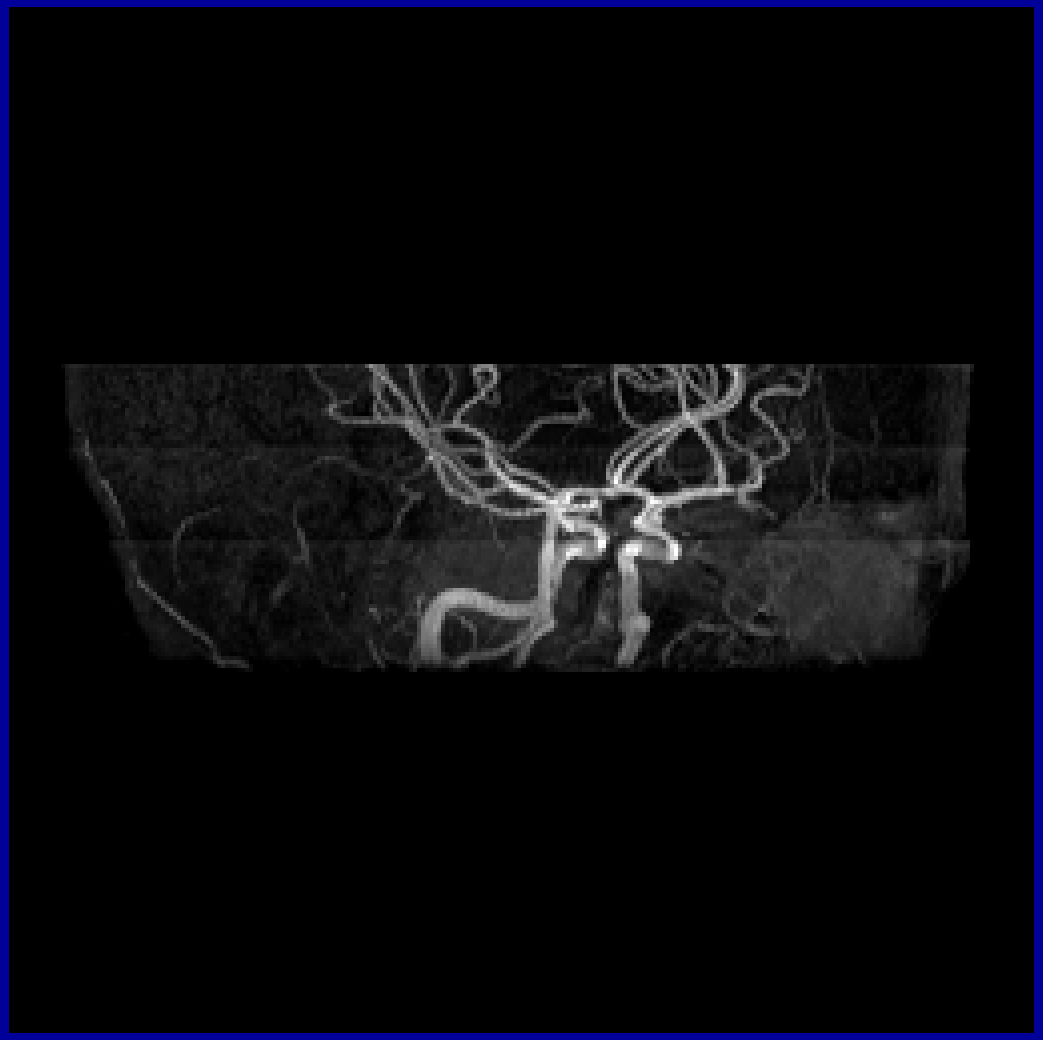


Rotate 10º



Rotate 10º

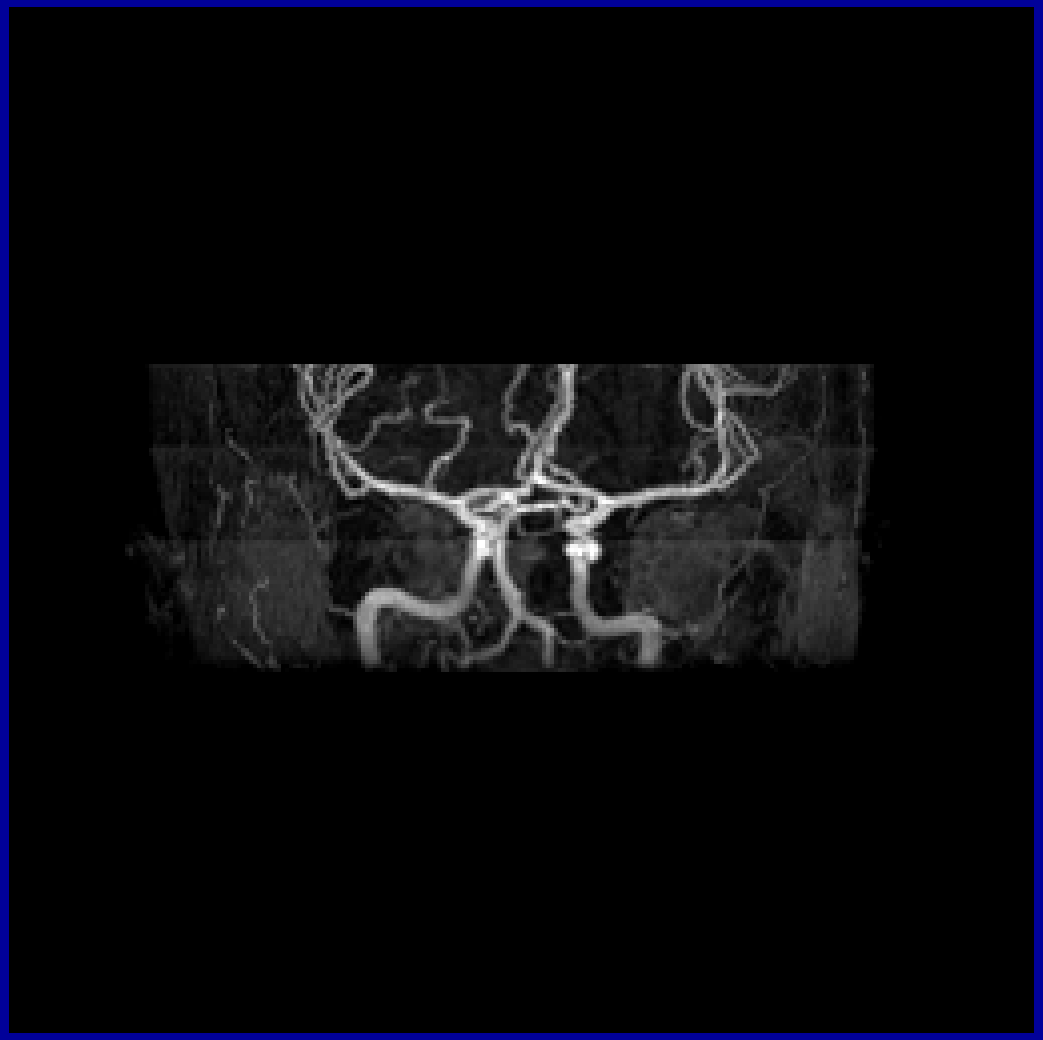
Rotate 10º



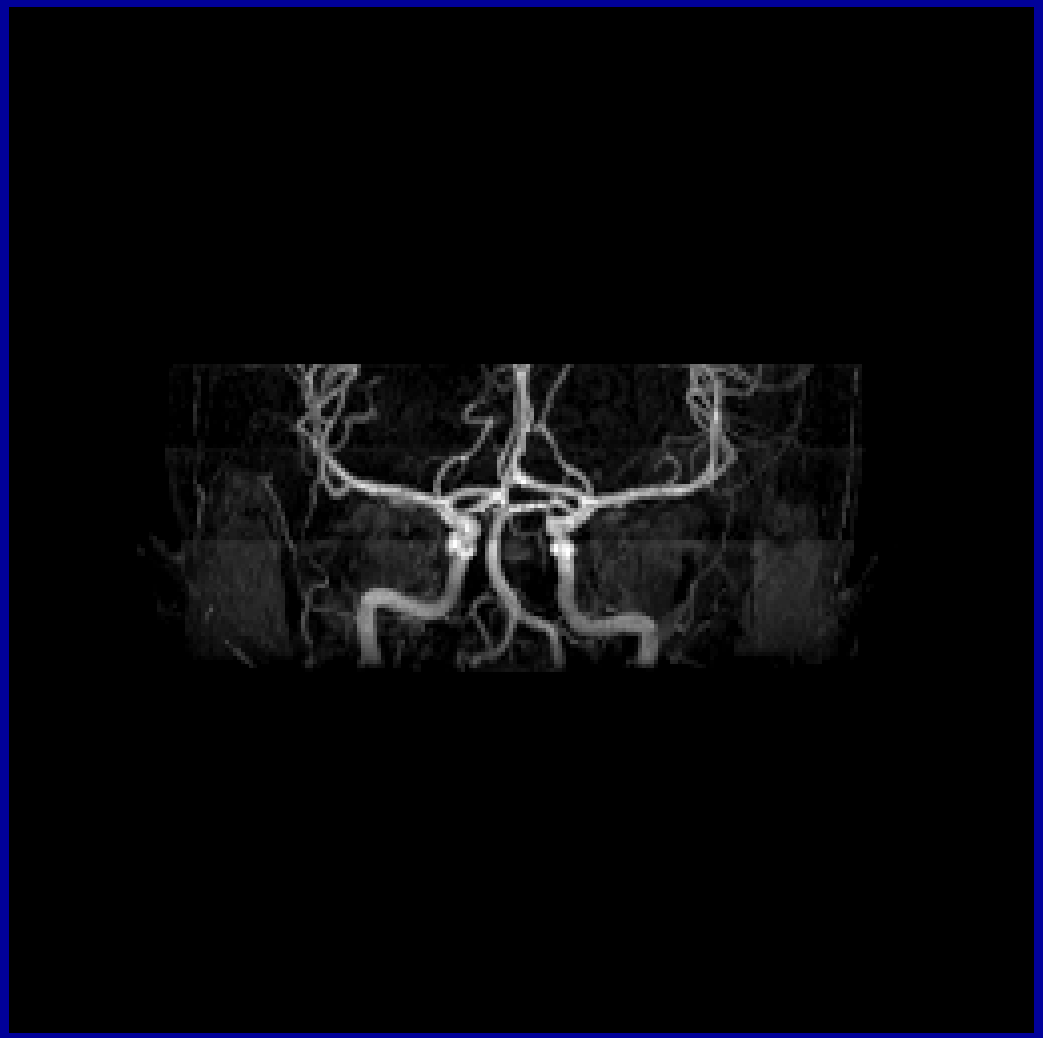
Rotate 10º

Rotate 10º

Rotate 10º



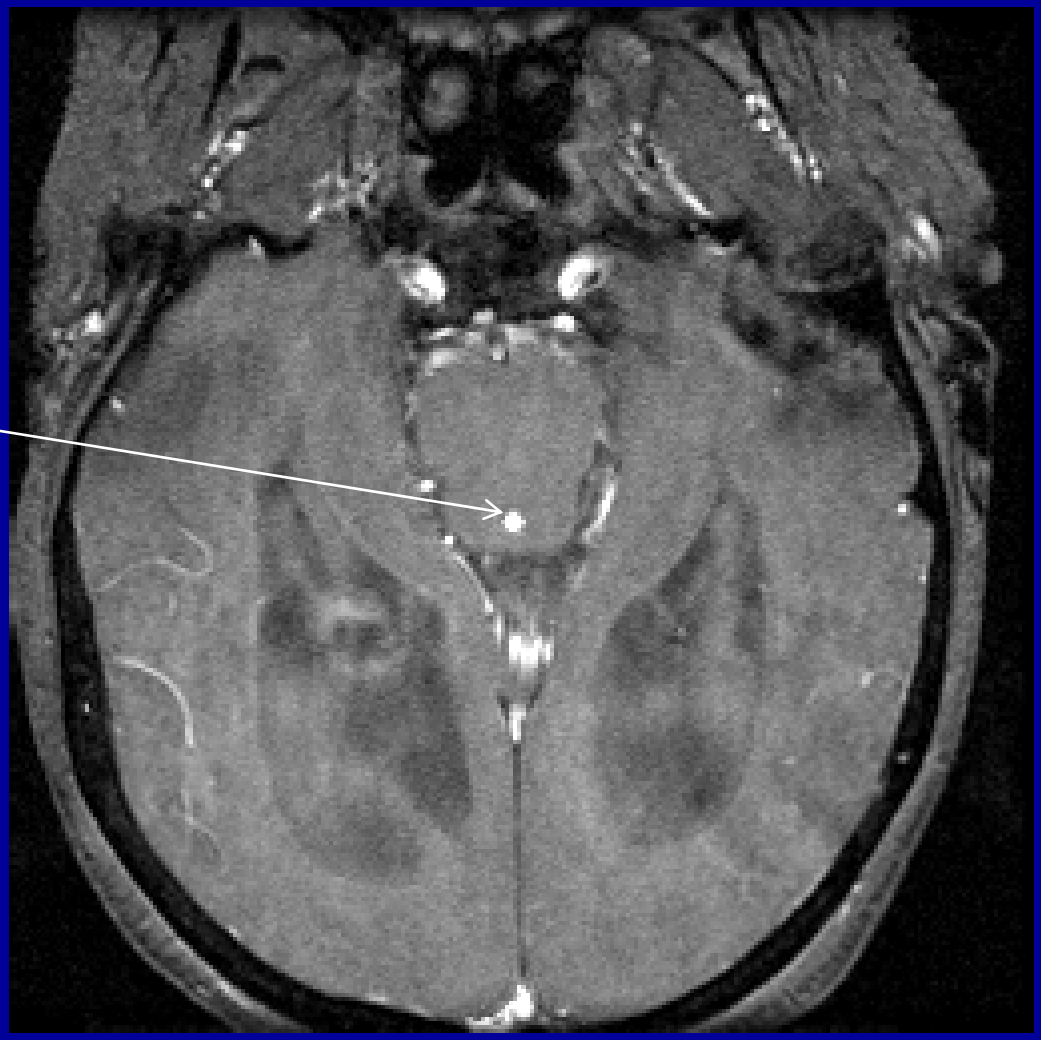
Stop



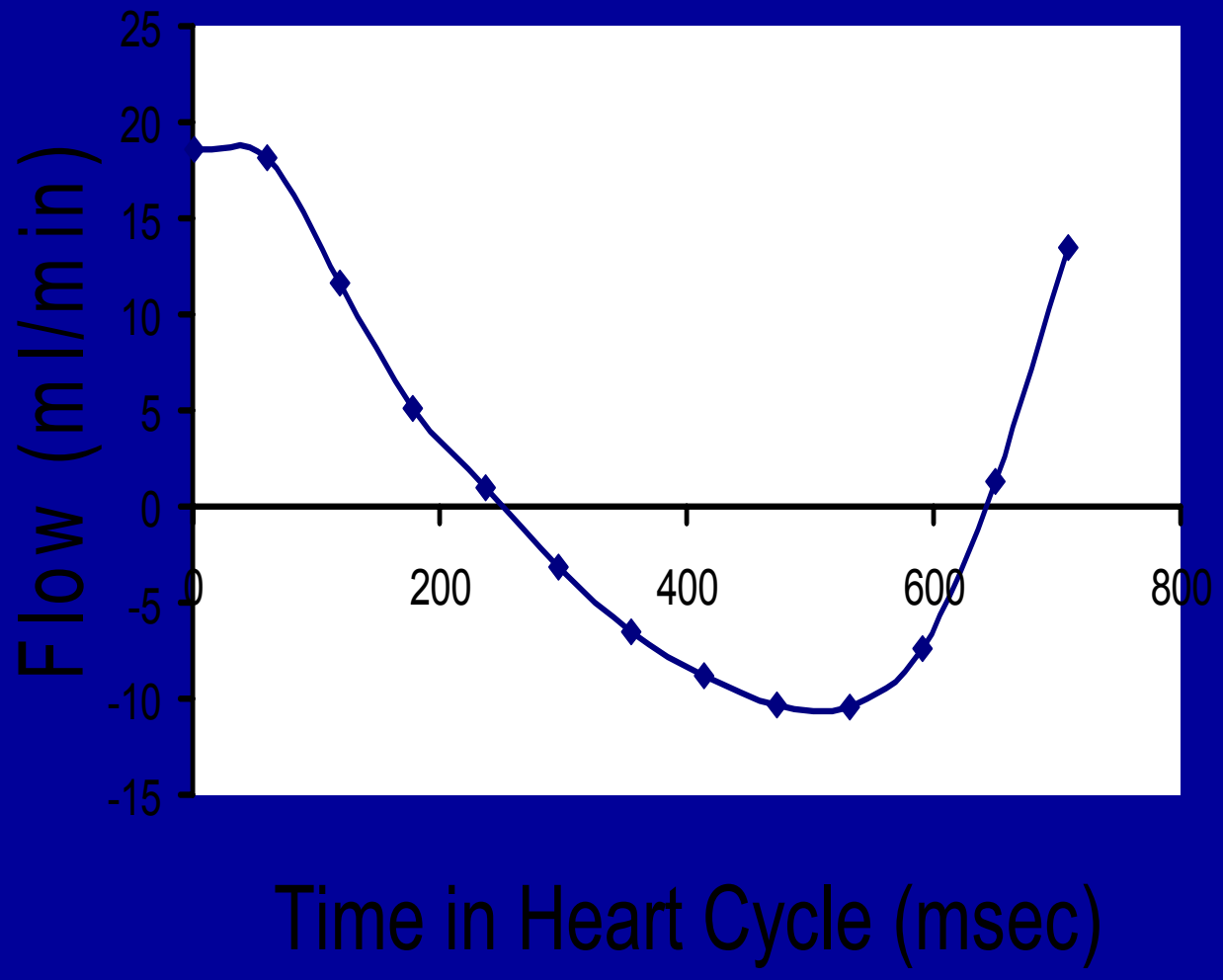
Flow Analysis of the Cerebral Aqueduct

Cerebral aqueduct

Image Across Aqueduct Plane

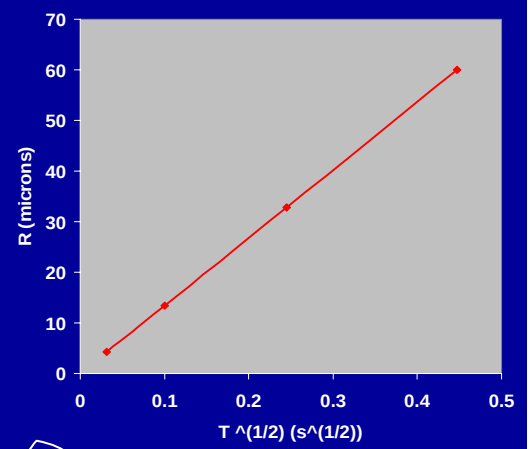


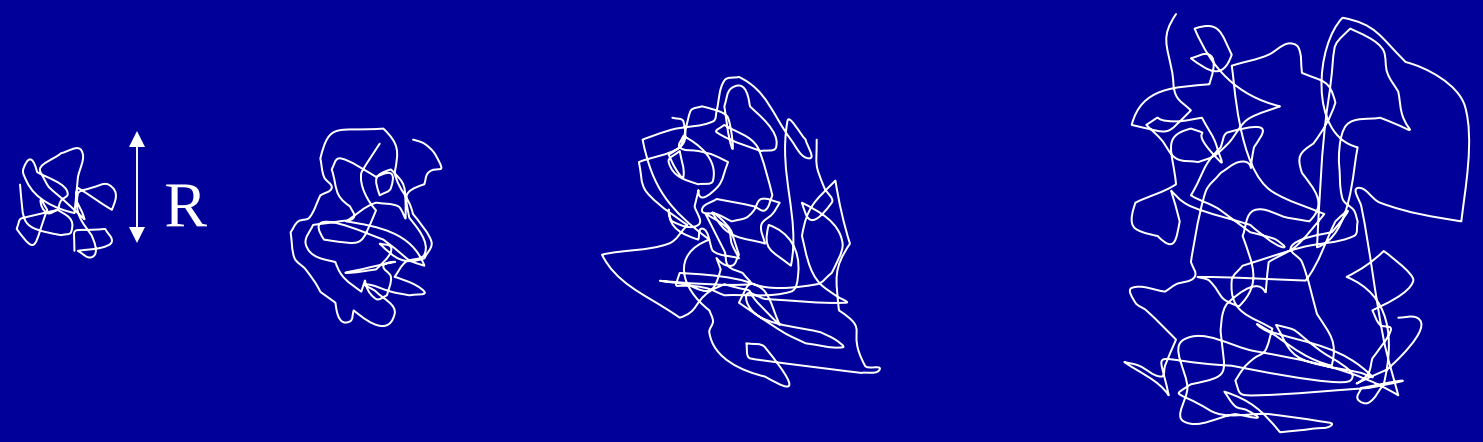
Flow Through the Cerebral Aqueduct



Diffusion

Diffusion is the random motion of water molecules due to their excess kinetic energy.





T = 1 ms
R = 4 μ

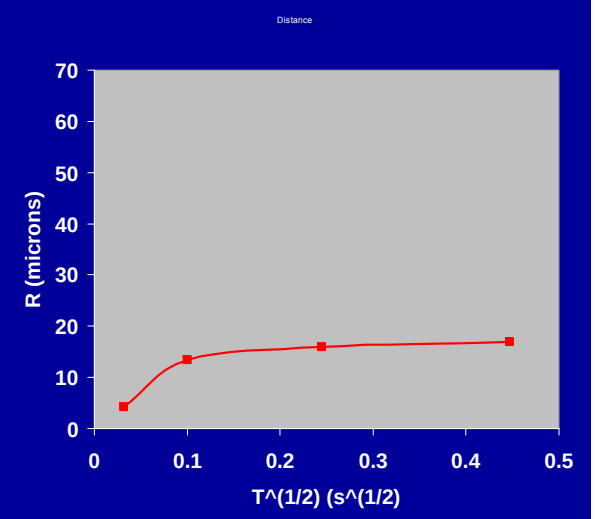
T = 10 ms
R = 13 μ

T = 60 ms
R = 33 μ

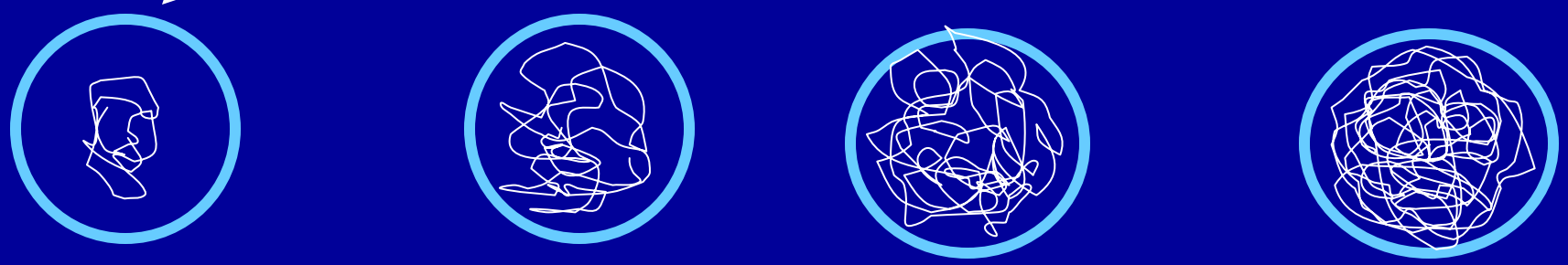
T = 200 ms
R = 60 μ

Restricted Diffusion

The outer membranes of cells act as diffusion barriers.



Cell Membrane



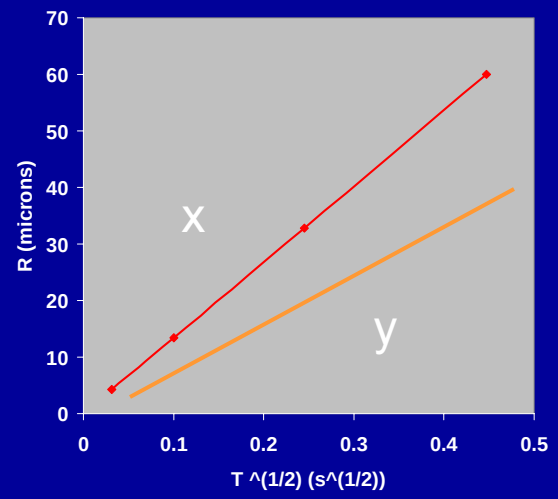
T = 1 ms
R = 4 μ

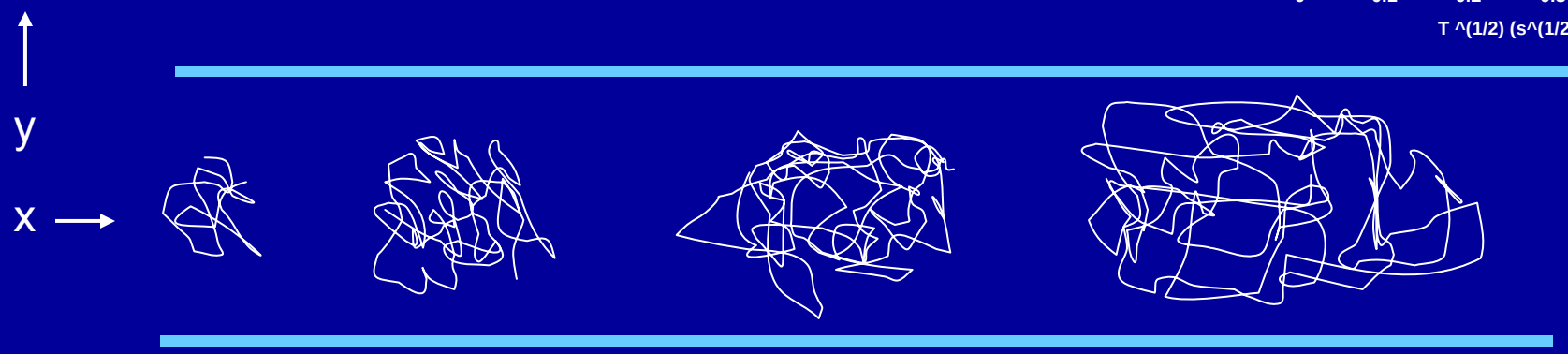
T = 10 ms
R = 13 μ

T = 60 ms
R = 16 μ

T = 200 ms
R = 17 μ

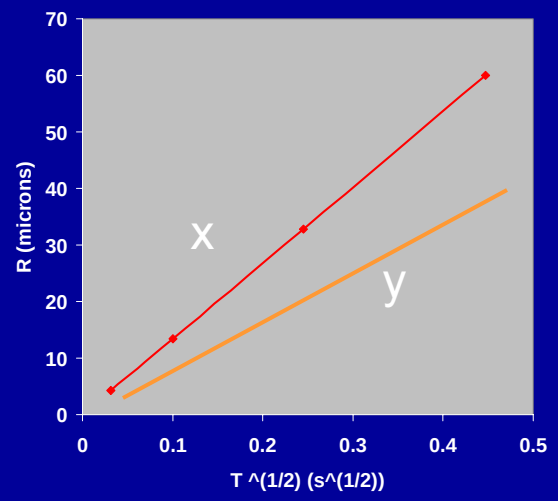
Anisotropic Diffusion





T = 1 ms	T = 10 ms	T = 60 ms	T = 200 ms
$R_y = 2\ \mu$	$R_y = 5\ \mu$	$R_y = 13\mu$	$R_y = 24\ \mu$
$R_x = 2\ \mu$	$R_x = 8\ \mu$	$R_x = 19\ \mu$	$R_x = 35\ \mu$

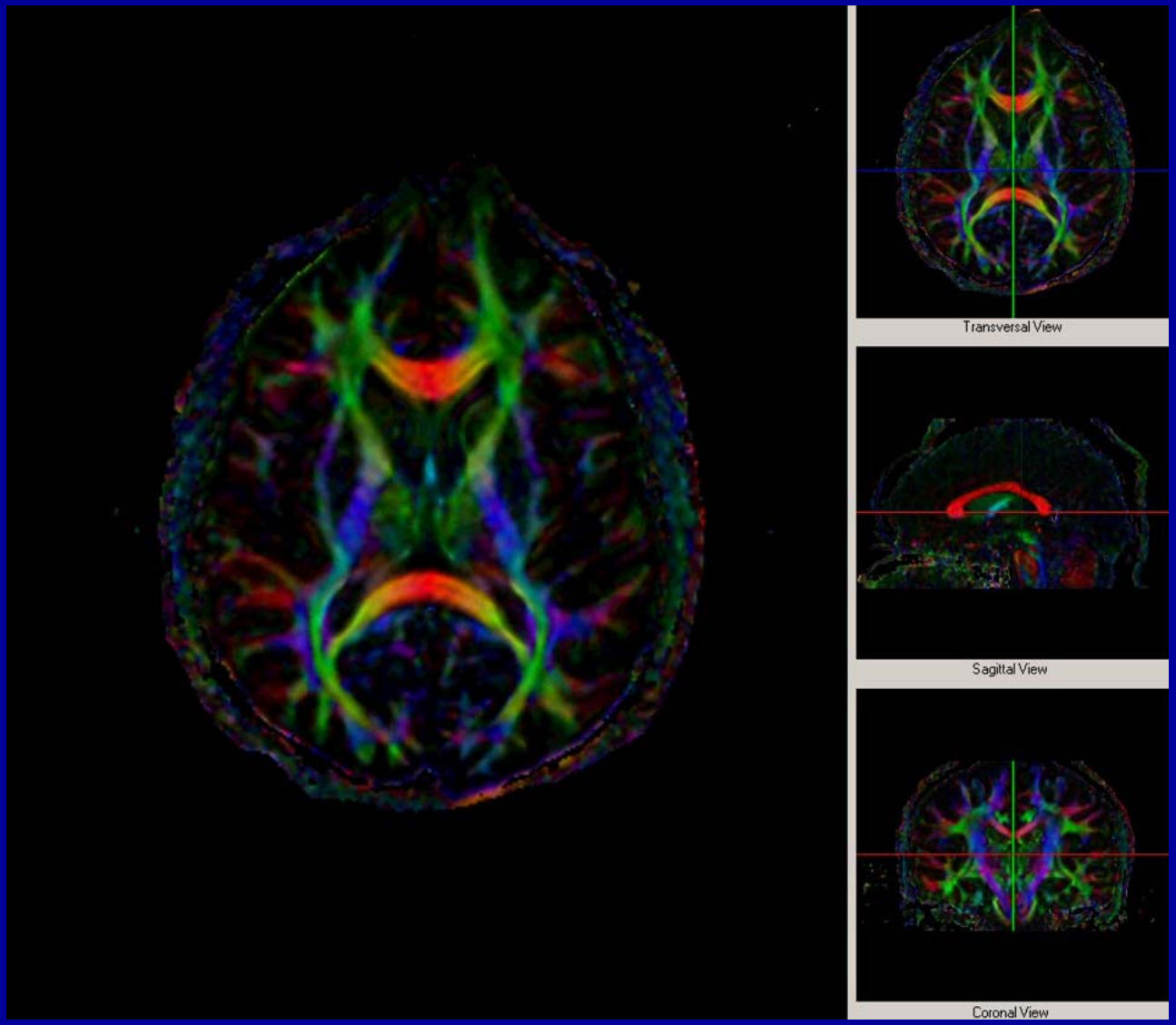
Anisotropic Diffusion



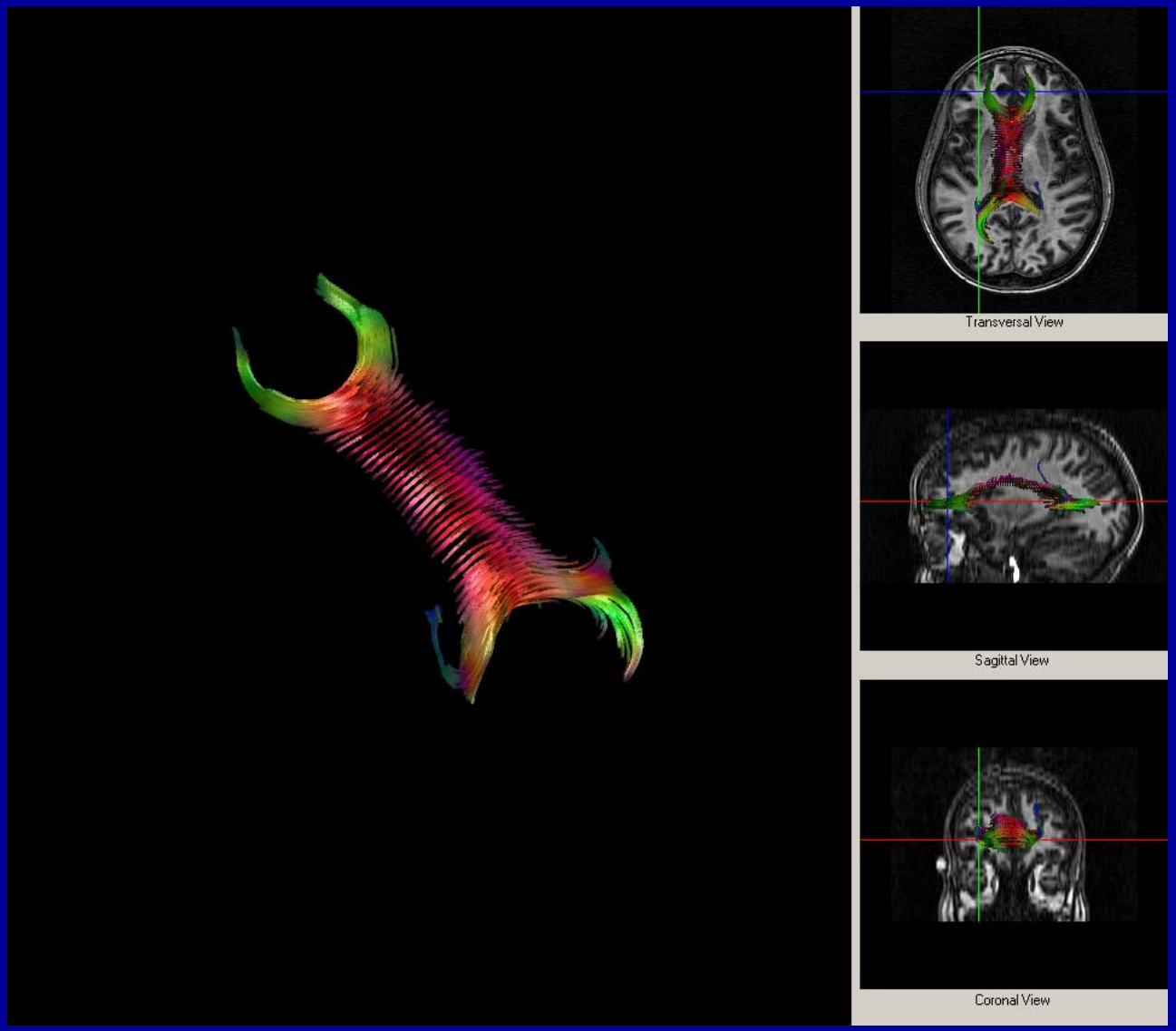
The white matter of brain contains many, many neuronal axons which are long tubes. Neurons cause water diffusion in brain to be anisotropic.

Using <u>diffusion MRI</u>, we can measure the direction of neuronal tracts in the brain.

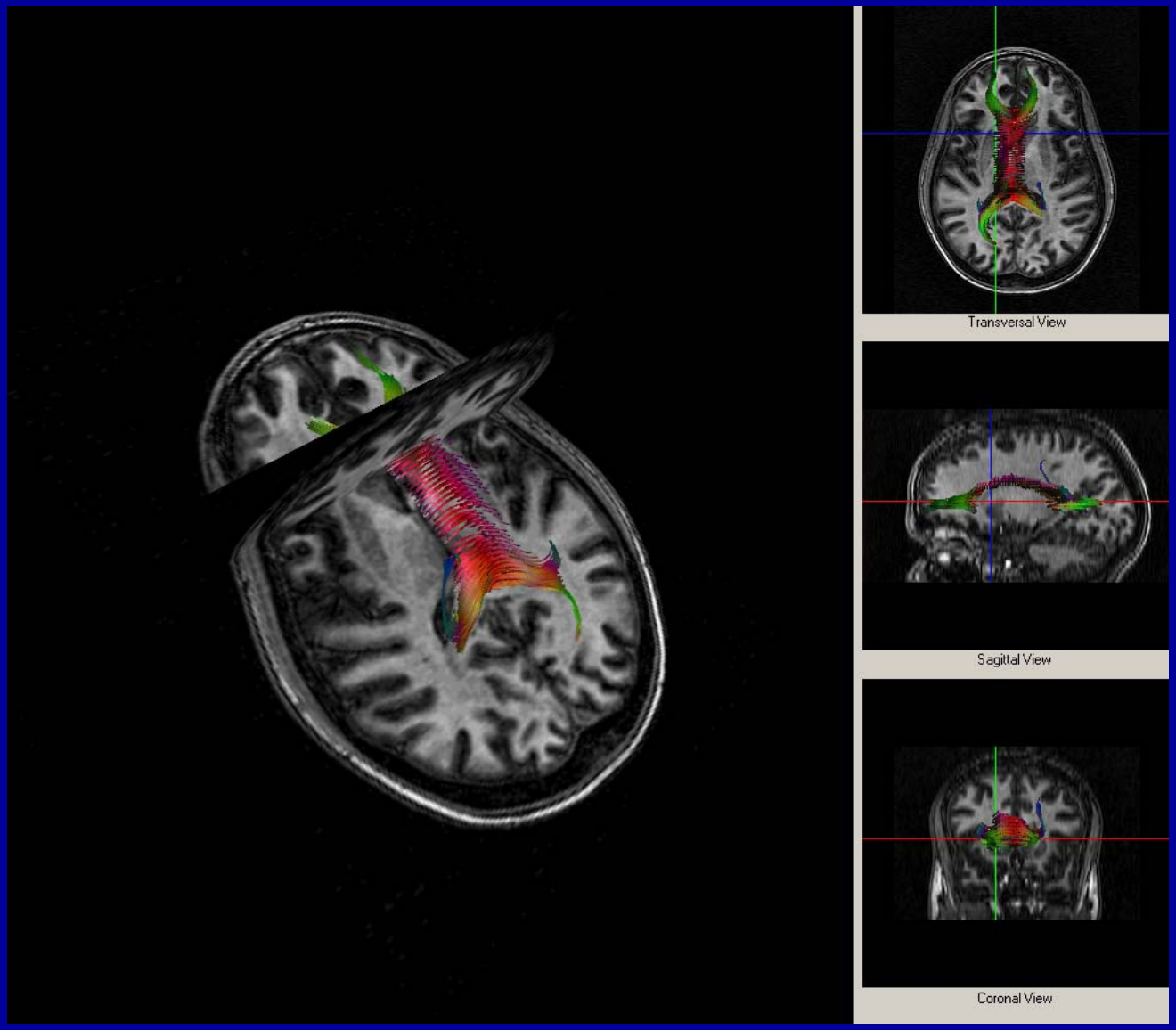
Diffusion Tensor Imaging



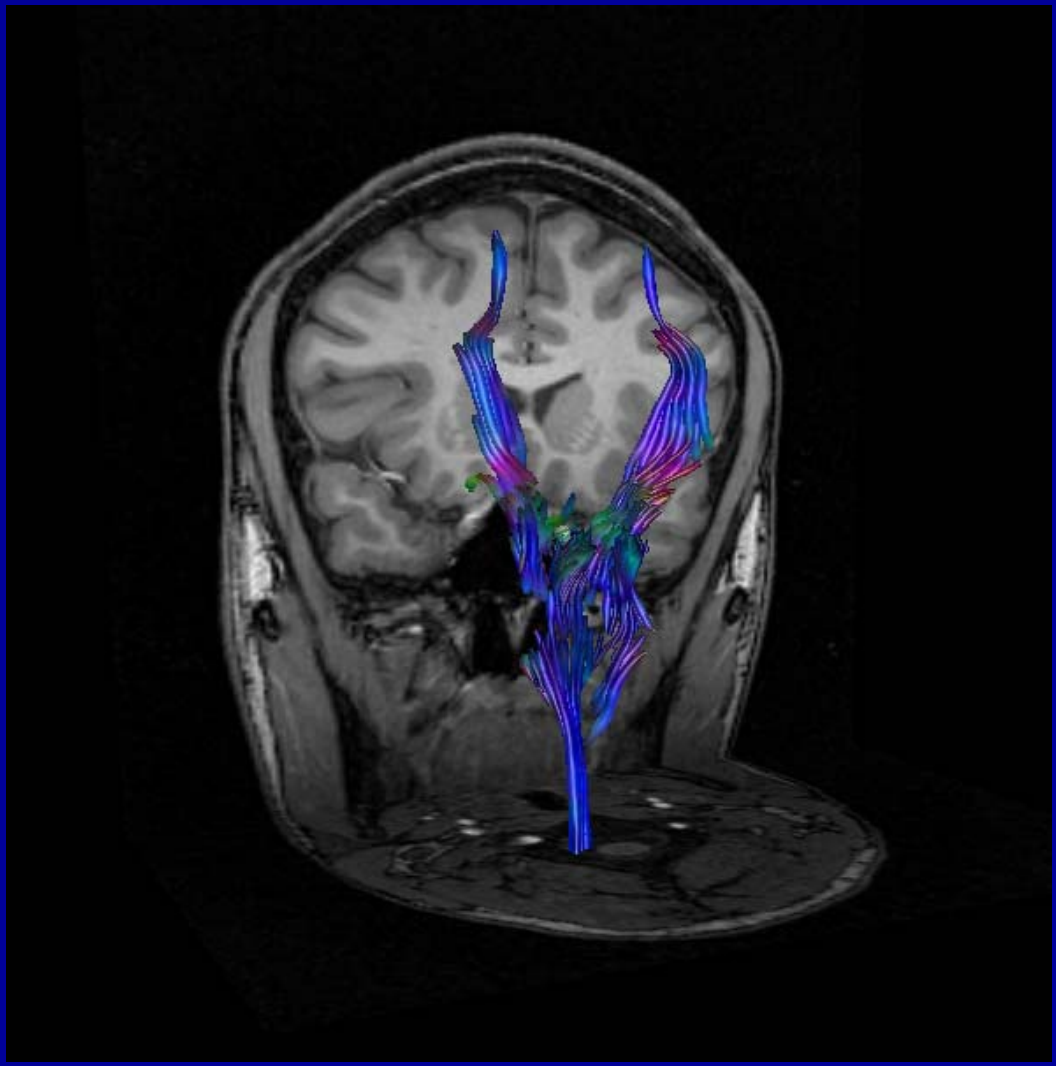
Fibre Tractography



Fibre Tractography



Fibre Tractography



Functional MRI (fMRI)

When a region of brain is activated by some task:

1) Local metabolism uses some oxygen.

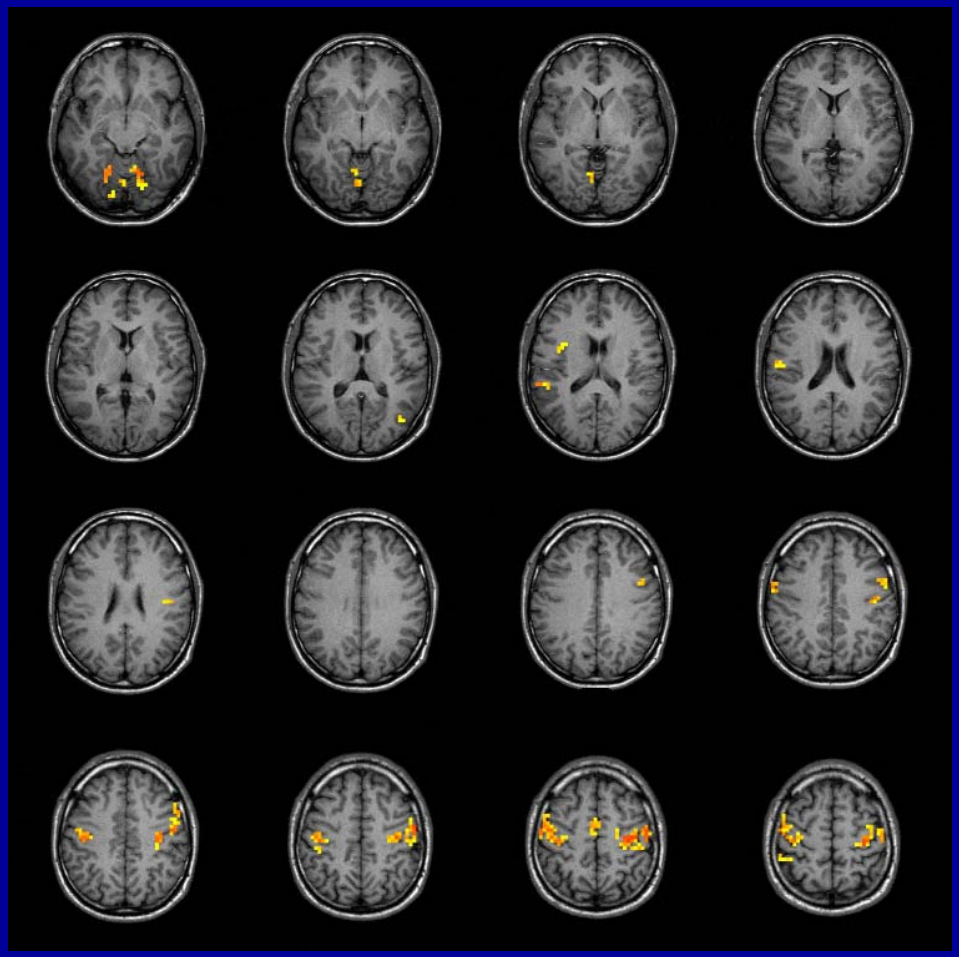
2) This causes an instantaneous drop in local O_2 concentration and also initiates increased blood flow to the region.

3) The result is a period of increased oxyhemoglobin to deoxyhemoglobin ratio.

4) fMRI produces images sensitive to this change in oxygen content.

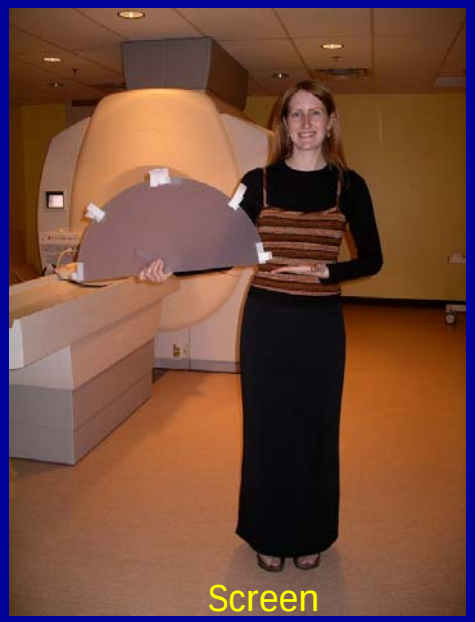
Functional MRI (fMRI)

Finger tapping experiment



fMRI Equipment

Projector



Screen

Sense Head Coil

Presentation Computer

Response Devices

fMRI Research at UBC 3T

There are 22 fMRI research projects underway on the UBC 3T magnet.

Most involve identification of brain regions used for various complex tasks.

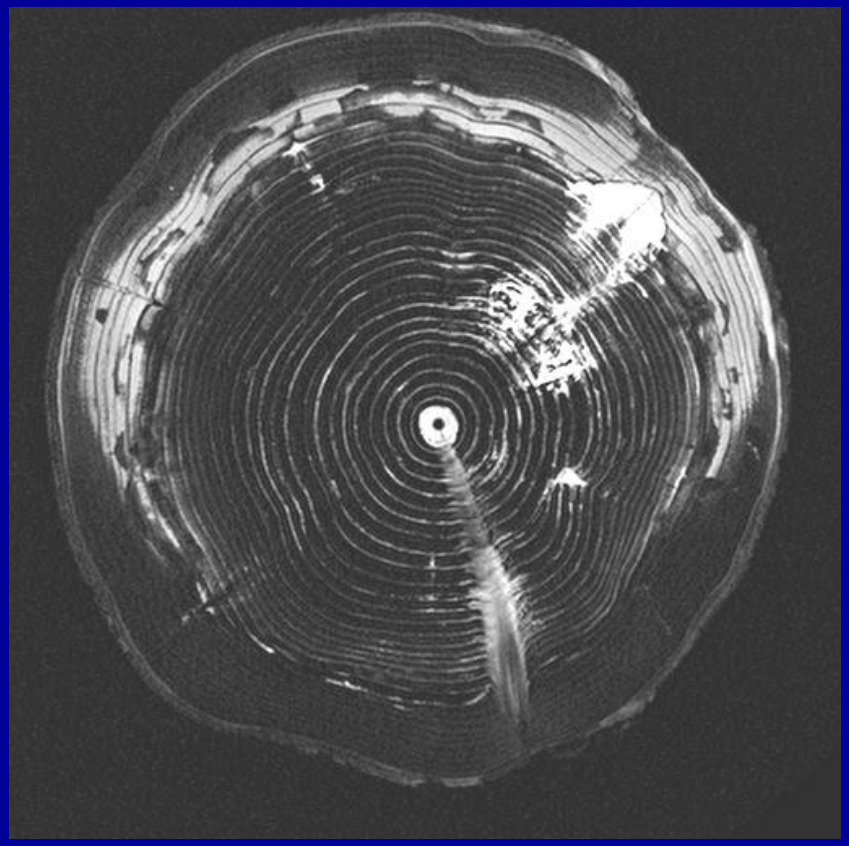
Most of the investigators are from the Psychology, Psychiatry, Neurology and Opthalmology departments at UBC and SFU.

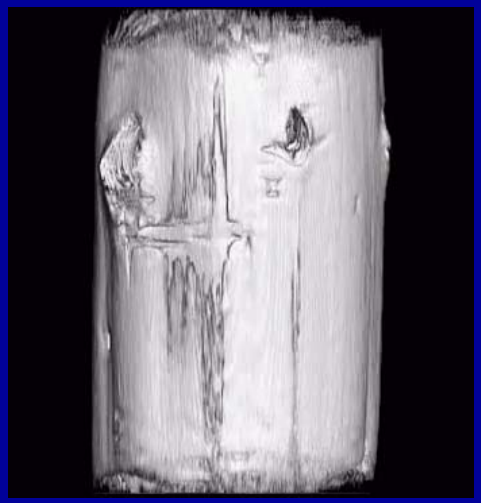
fMRI Research at UBC 3.0T

Functional Neuroimaging of Negative Effect in Elite Swimmers
Elton Ngan, Psychiatry

Abstract versus concrete thought during anagram completion: an fMRI investigation
Kalina Christoff, Psychology

Spatial and Temporal Aspects of Force Production in Parkinson's Disease: Functional Magnetic Resonance Imaging Study
Martin McKeown, Neurology





Magnetic Resonance Spectroscopy

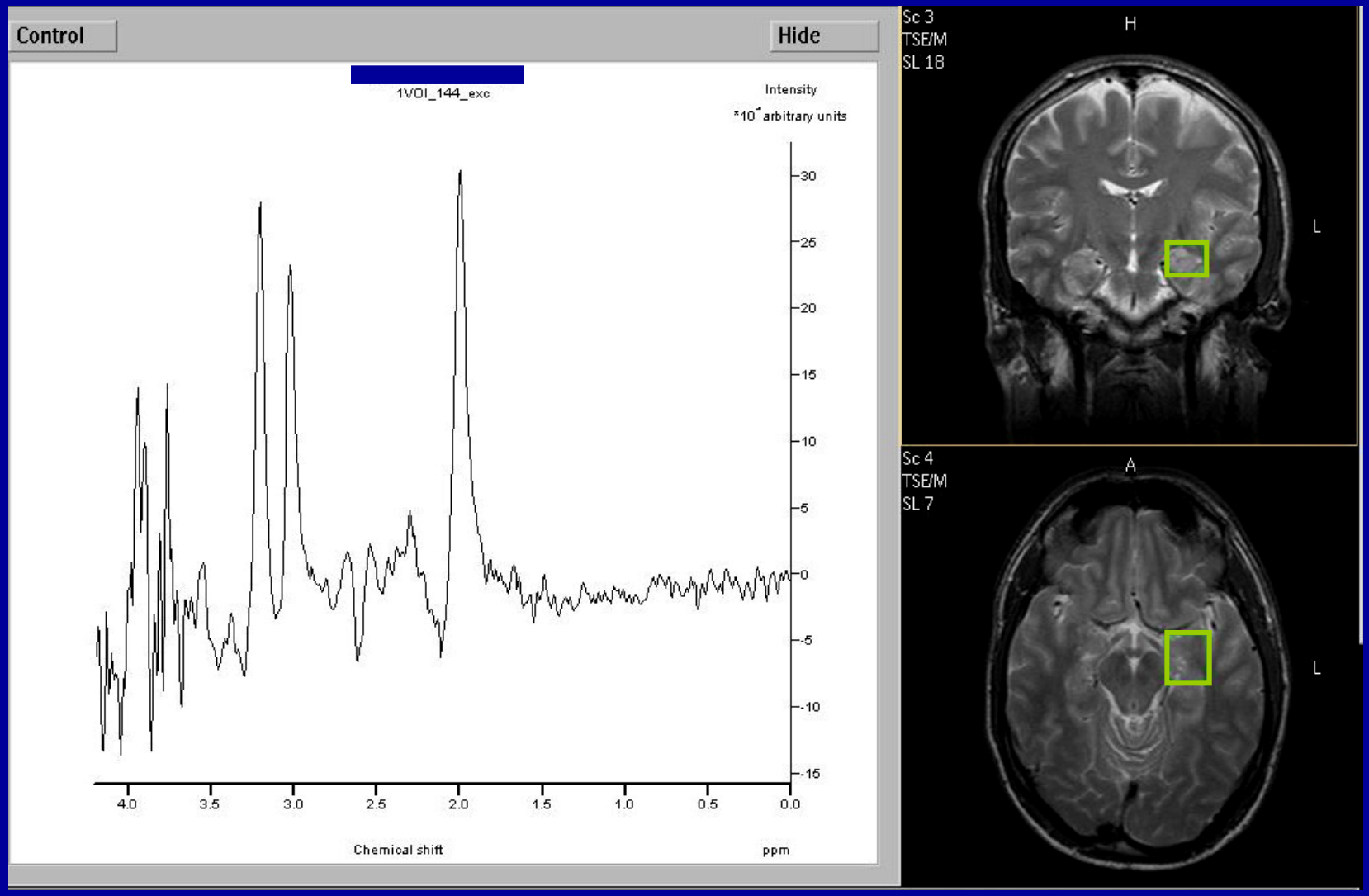
MRS measures signals from proton sites on several brain metabolites including:

N-acetyl-aspartate, phosphocreatine/creatine, choline, myo-inositoyl, glutamate/glutamine.

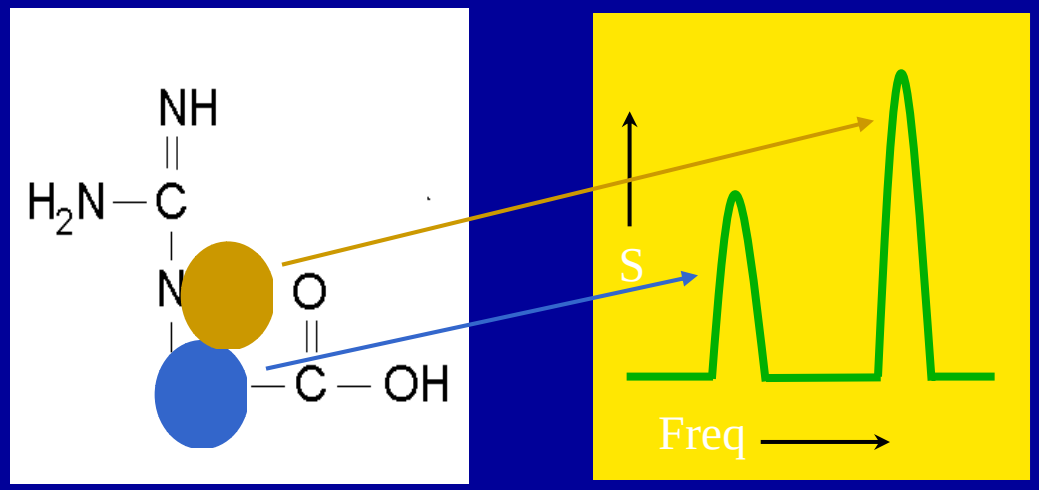
From the proton spectrum we can derive the concentrations of these metabolites.

This enables us to learn about the biochemistry of the brain.

Magnetic Resonance Spectroscopy



MR spectrum from creatine

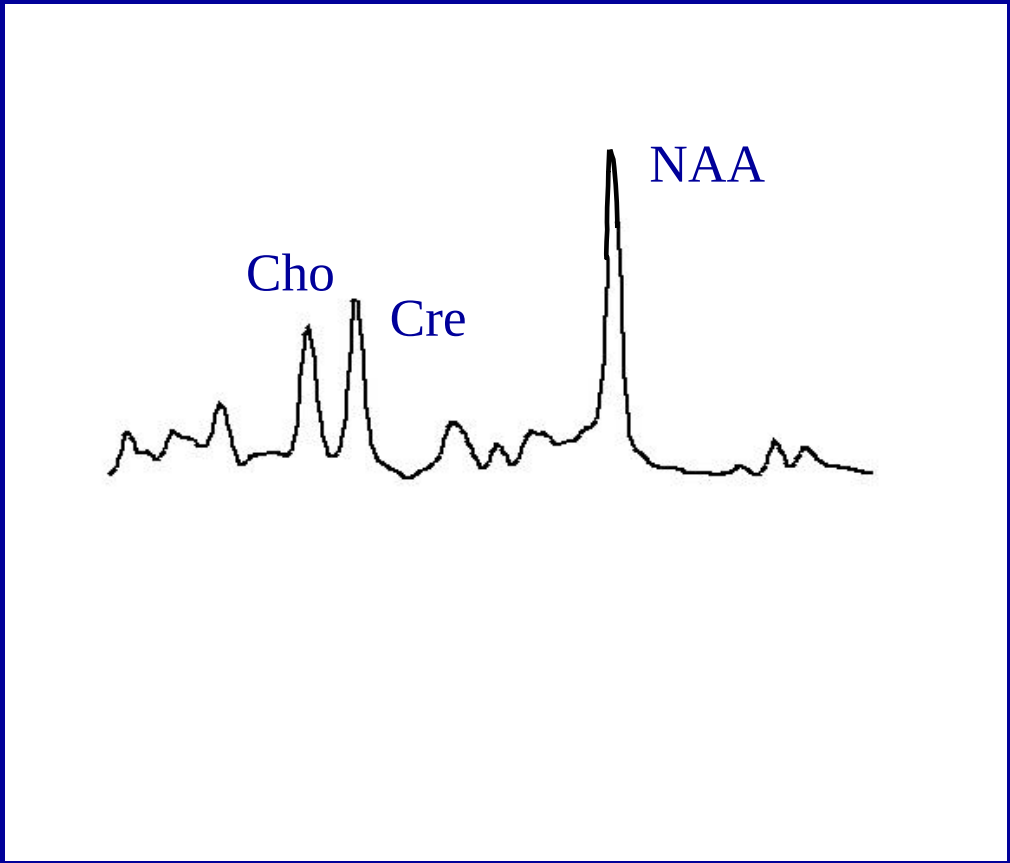


creatine MR spectrum

Peak frequency is determined by the ‘chemical shift’ of the molecular subunit (i.e. CH_3 or CH_2).

Peak area is determined by the concentration of contributing protons.

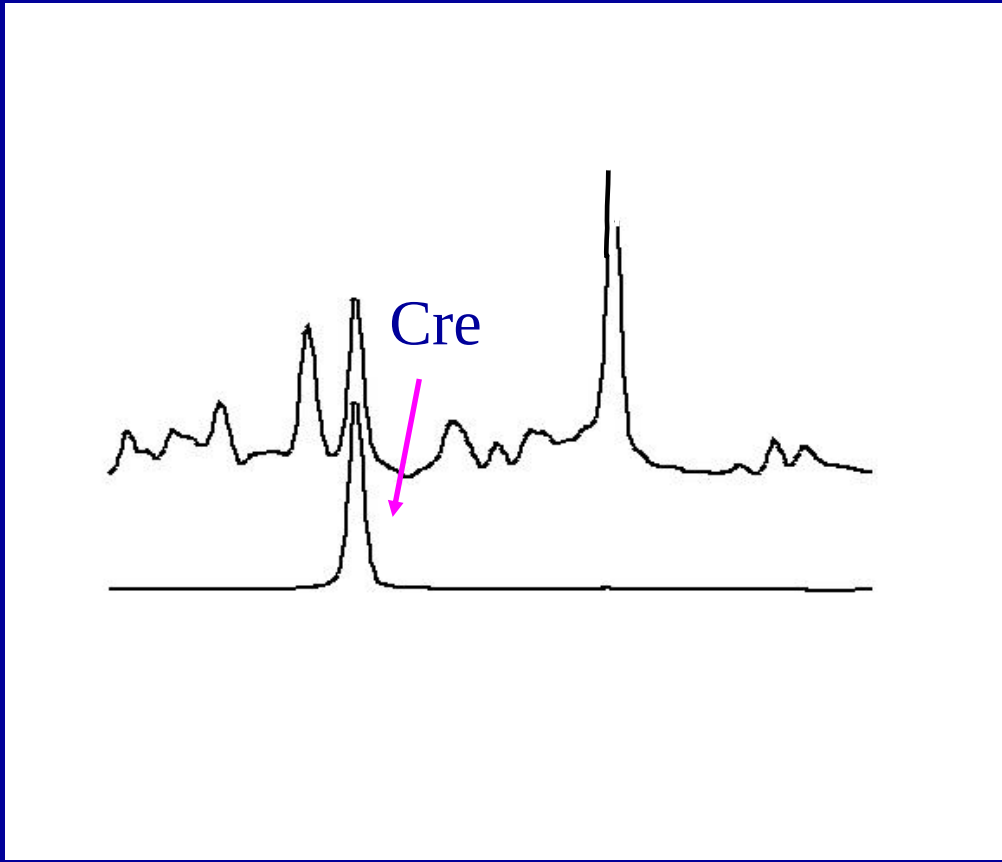
Information in the Brain Spectrum



Spectrum composed of overlapping chemicals.

Signal area related to concentration of chemical.

Information in the Brain Spectrum

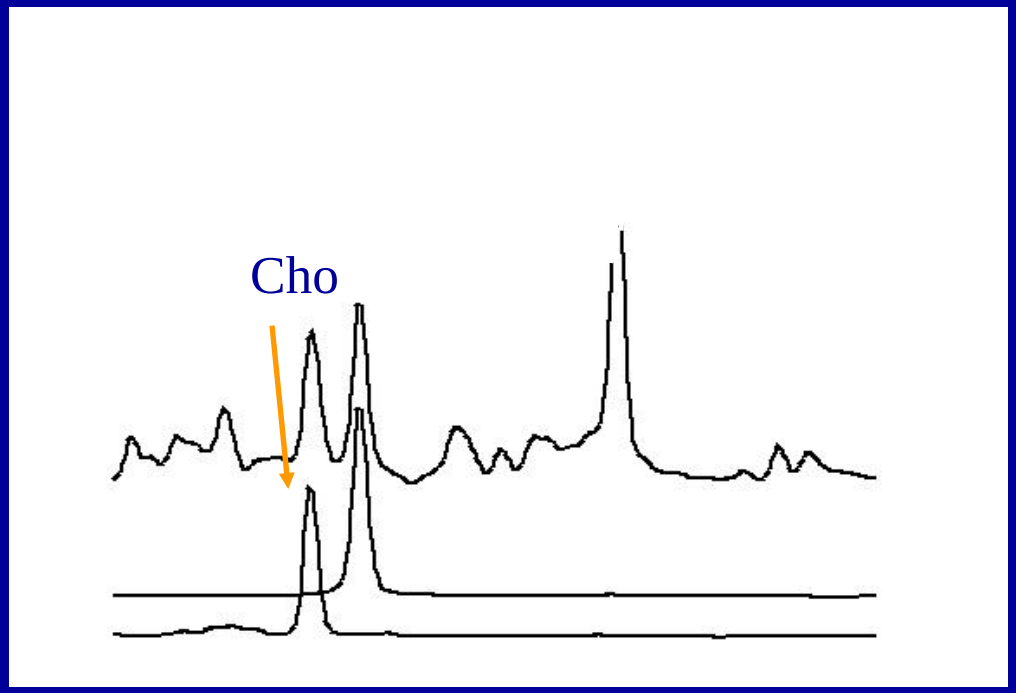


Creatine (Cre)

Cre is involved in energy production in cell mitochondria.

Cre is in neurons and glia.

Information in the Brain Spectrum

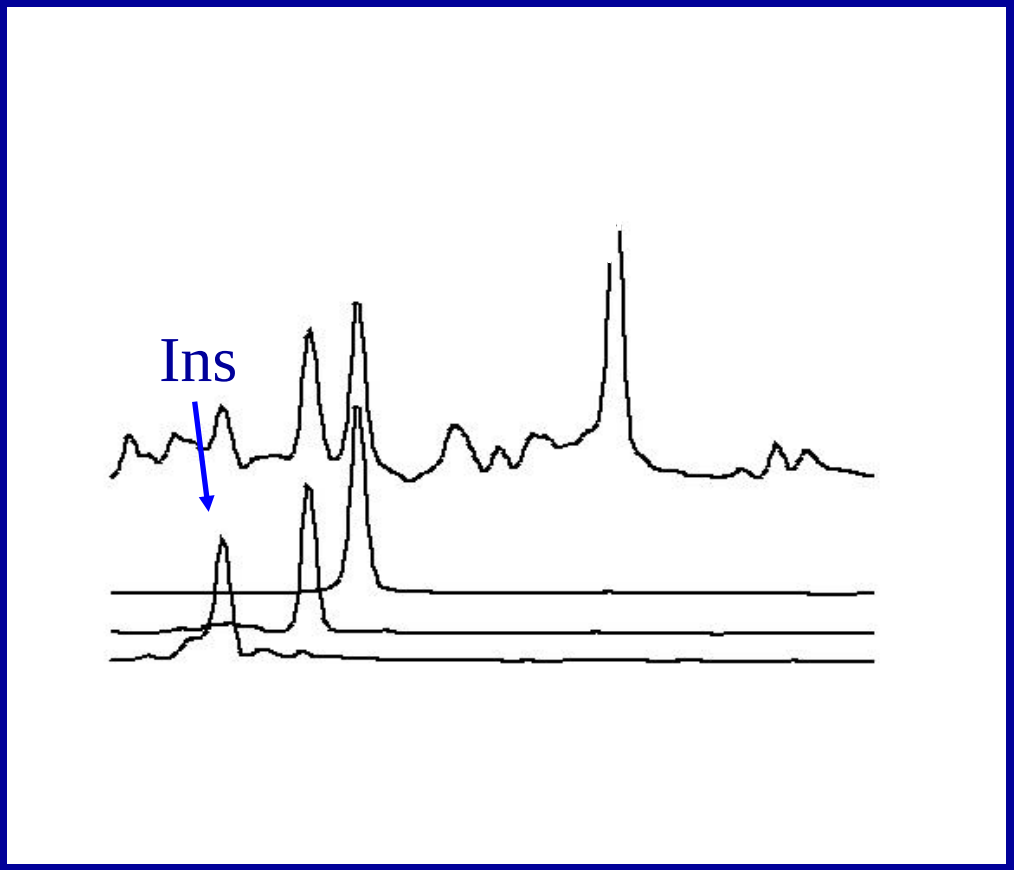


Choline (Cho)

Cho takes part in membrane and neurotransmitter synthesis.

It is elevated in some tumors

Information in the Brain Spectrum



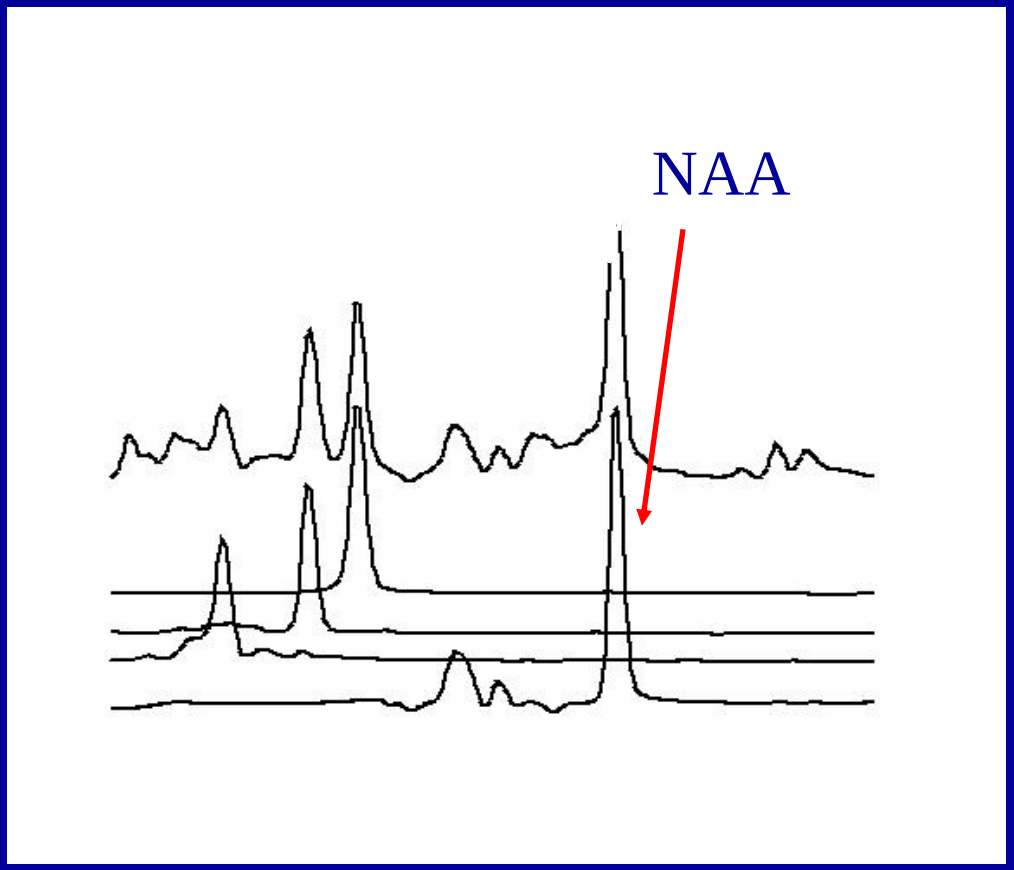
Inositol (Ins)

Ins is a simple sugar.

It is considered an ‘astrocyte’ marker.

Astrocytes are cells involved in scarring (gliosis).

Information in the Brain Spectrum

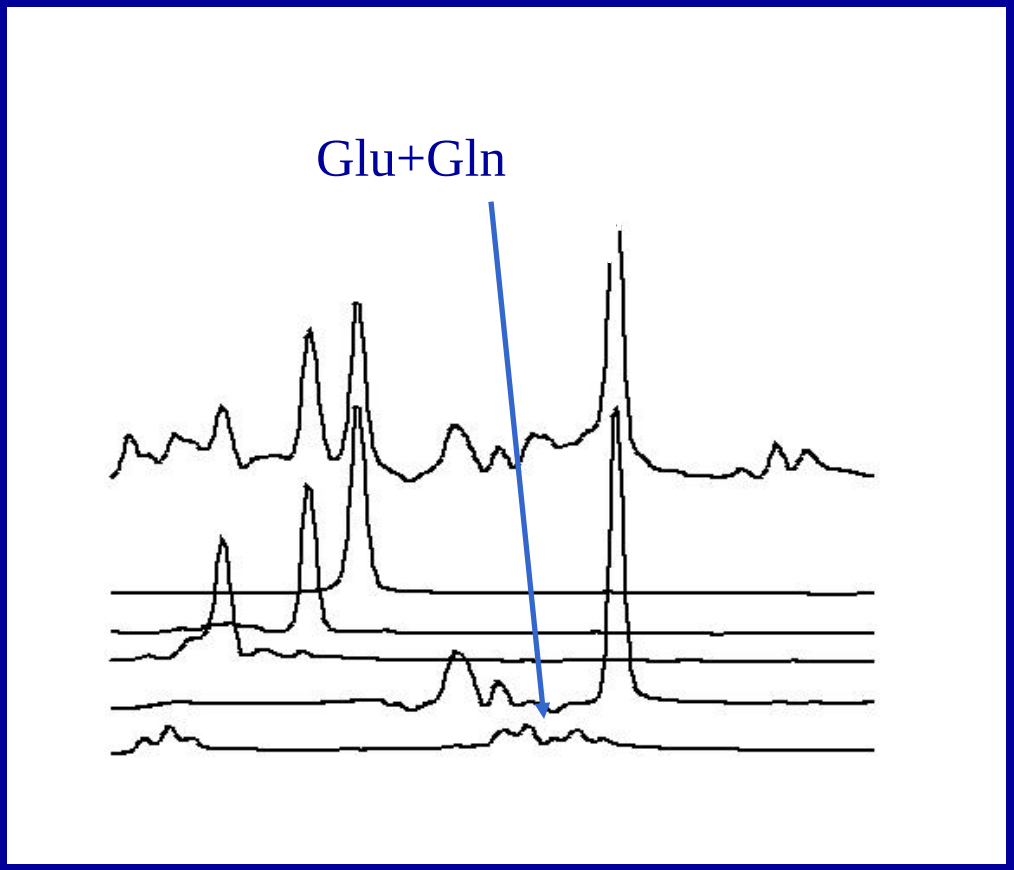


N-Acetyl-Aspartate (NAA)

NAA is thought to be contained only in neurons.

"Neuronal Marker"

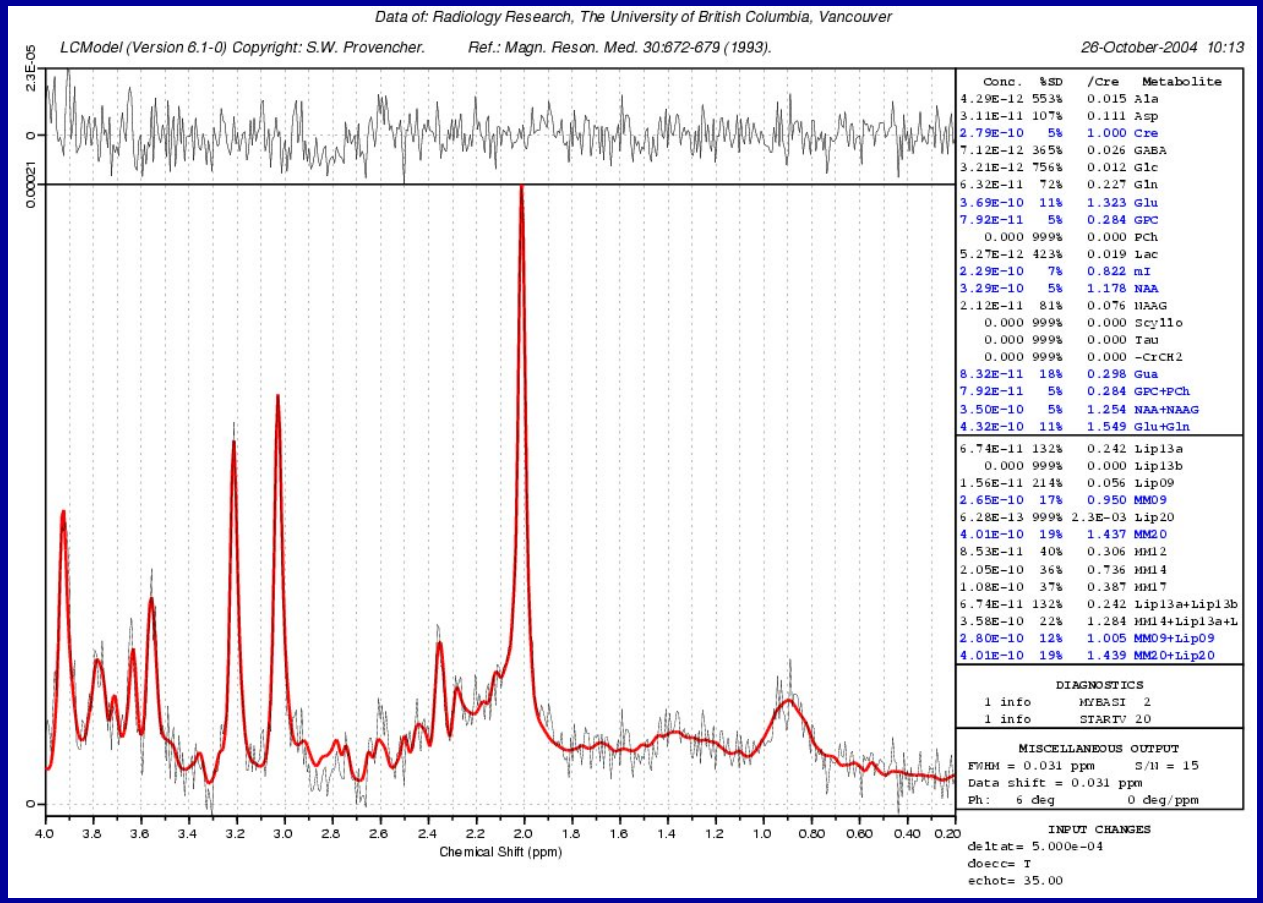
Information in the Brain Spectrum



Glutamate + Glutamine (Glu+Gln)

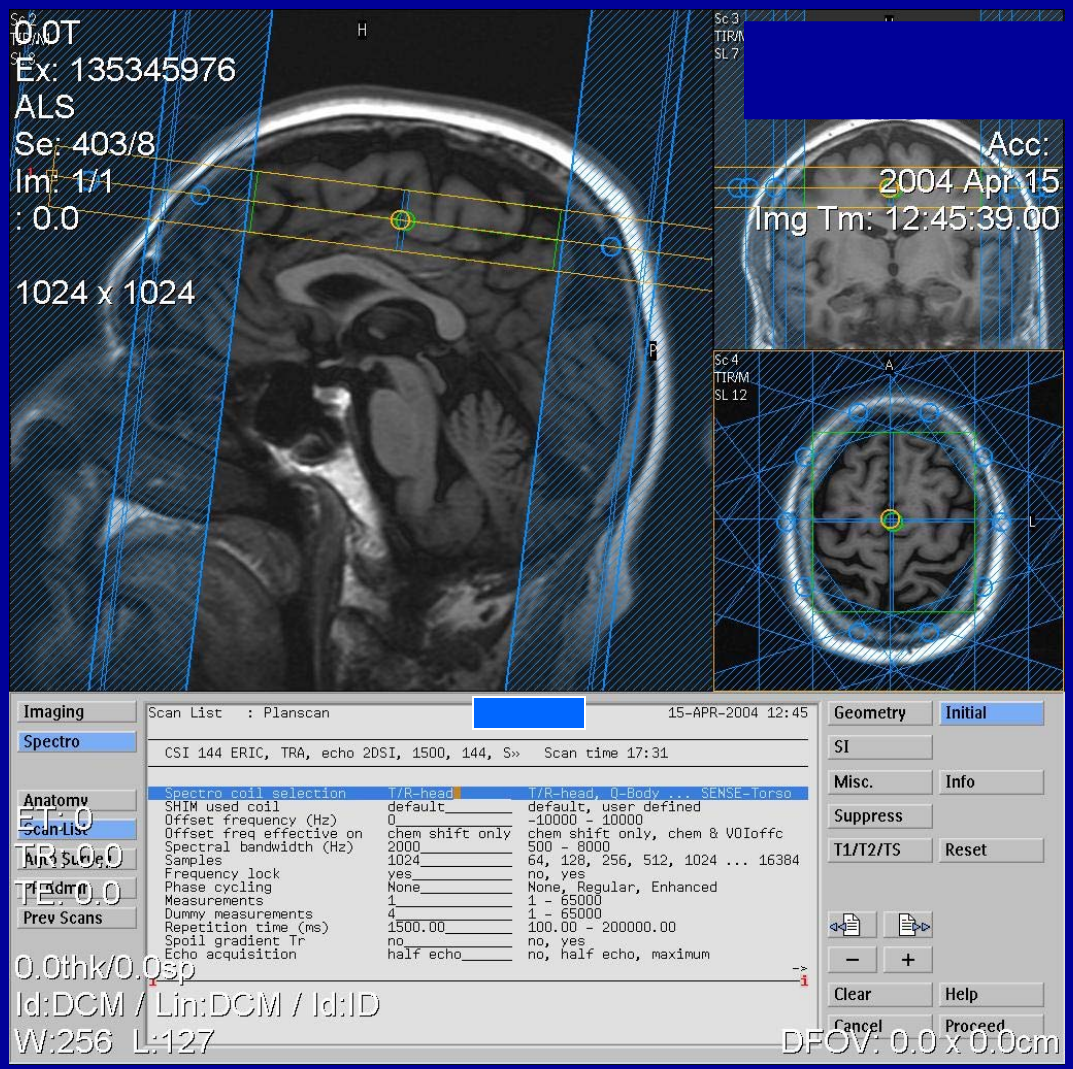
Glu is a neurotransmitter and Gln is involved in neurotransmitter synthesis.

Single Voxel Spectroscopy at 3T

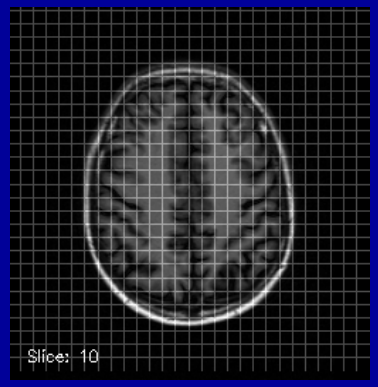


LCModel Spectroscopy Analysis

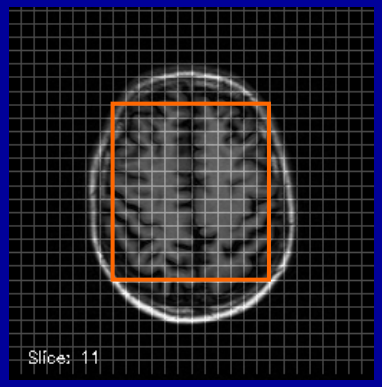
Multi-voxel Spectroscopy (2D CSI)



Multi-voxel Spectroscopy (2D CSI)

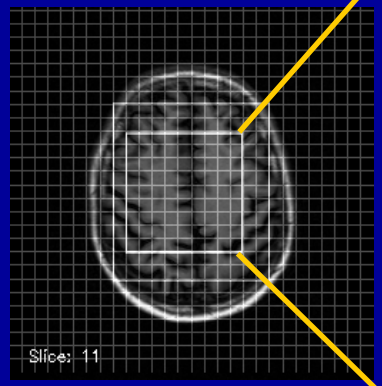


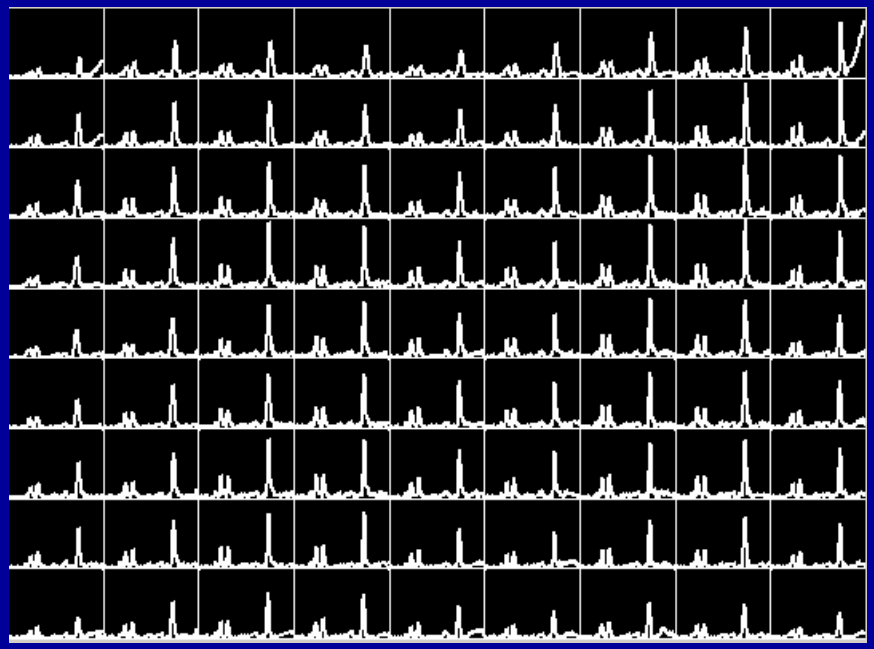
2D-SI Grid
(FOV)



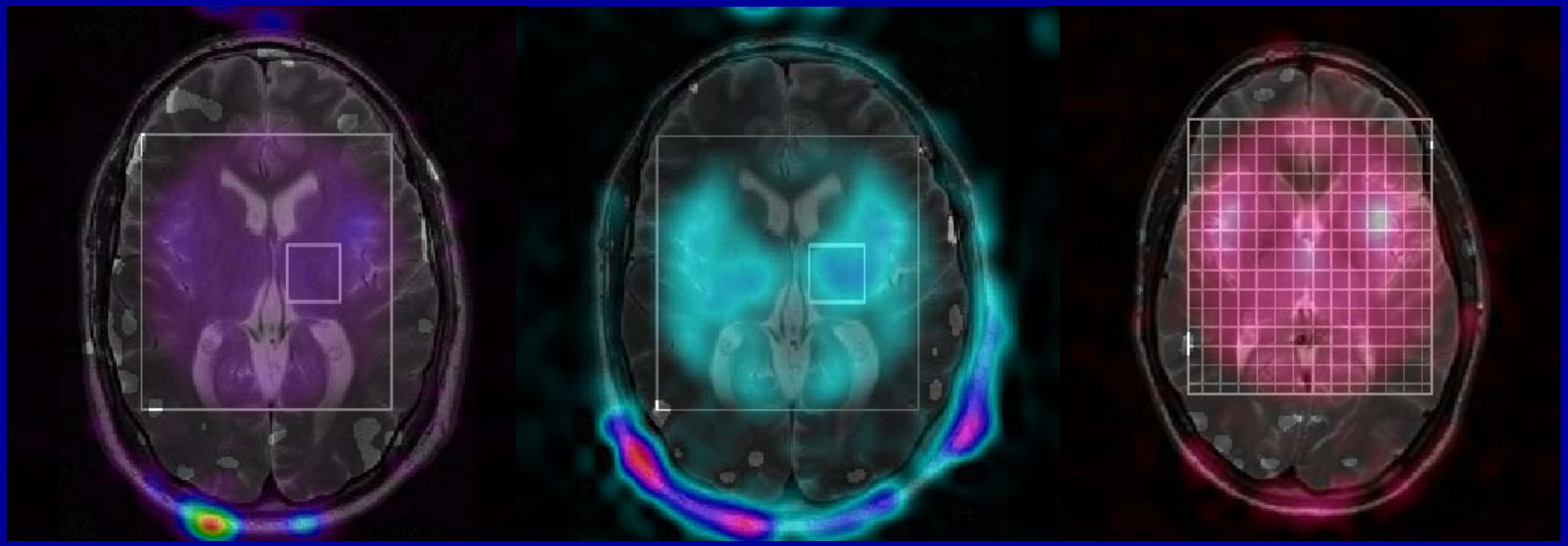
2D-SI Volume
of
Interest

Spectra Display from ROI





Multi-voxel Spectroscopy (2D CSI)



Creatine NAA Choline

Spectroscopy Research at UBC 3T

Early Response in Psychosis

- **SVS placed over the thalamus and anterior cingulate.**

ALS Phase 1 Clinical Trial

- **2DCSI positioned to include the motor cortex.**

MS Clinical Trials

- **SVS positioned over the body of the corpus callosum.**

First Episode of Mania

- **SVS positioned to include the hippocampus and prefrontal cortex.**

Magnetic Resonance Imaging

- There are many 10's of 1000's of MRI's worldwide.
- There are over 10,000 scientists worldwide using MRI for research.
- The technology of MRI is advancing very rapidly. A new MRI scanner is obsolete after 5 years
- It is a very exciting field to work in!

Who works with MRI?

- Physicists
- Engineers
- Chemists
- Mathematicians
- Biologists

- Radiologists
- Neurologists
- Cardiologists
- Pathologists
- Psychiatrists
- Psychologists

The future of MRI is very bright!