An Overview of Magnetic Resonance Imaging (MRI)

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What is MRI?

- A medical imaging technique that records changing magnetic fields
- Also called Nuclear Magnetic Resonance (NMR)
- Can give different kinds of images based on the pulse sequence (will talk about later)
- Capable of complete body scans, but commonly used for brain

An image of the brain obtained using MRI

http://brainfunctionss.com

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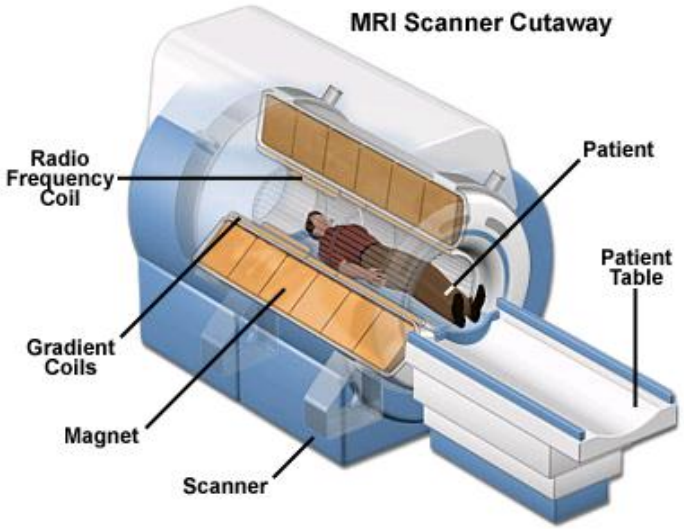
MRI Machine

- The main parts of the machine are:
  - RF Coils
  - Gradient Coils
  - Magnet

*How these work together will be explained later

- Patient is required to lay as still as possible
- One scan can cost from $400 to $3,500
- A machine can cost as much as $1 million



MRI Machine with main parts noted

http://www.magnet.fsu.edu

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Who is it for?

Medtronic's Revo MRI SureScan pacemaker. First FDA approved MRI-compatible pacemaker in Feb. 2011

http://www.comhs.org

- MRI is safe for most patients
- Patients who cannot receive a scan are:
  - People who get nervous in small places (claustrophobic)
  - People with non-MRI-compatible implants
  - People with metal pieces near vital organs

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How does it work?

- MRI stimulates a signal from the object using magnetic fields and radiofrequency pulses
- MRI reads data using magnetic gradients and places it into k-space (frequency domain)
- K-space (frequency domain) is translated into spatial domain giving an image!

- To grasp the idea of the MRI process, it is important to review the following concepts:
  - Understanding the Signal: Magnetization Vector
  - Pinpointing the Signal: Magnetization Gradients
  - Creating the Signal: Pulse Sequence
  - Collecting the Signal: K-Space

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Before continuing…

- The explanation in this presentation briefly goes over some of the key ideas of how MRI data is obtained
  - There are a lot of mathematical equations and physics involved in fully understanding the process
  - If you are interested in the details, refer to the references at the end of this presentation and/or take the following classes to satisfy your curiosity: BME309, BME438, ECE507

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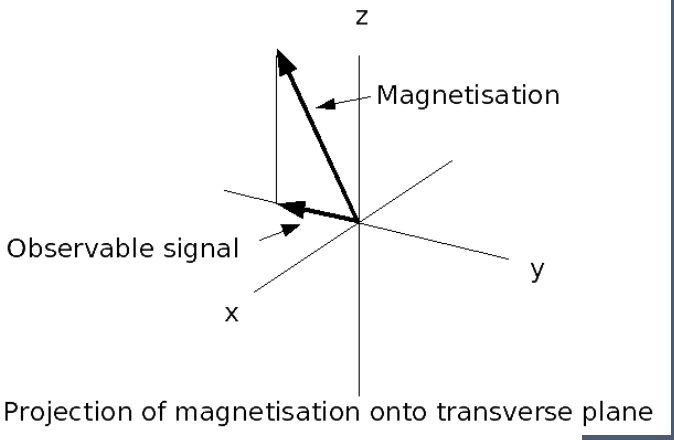
Magnetization Vector

- MRI signals rely on the magnetization vector M
  - Vector M has a M_z and M_{xy} component



- Signal is obtained from the M_{xy} component of the vector M
  - Signal intensity is dependent on M_{xy} magnitude

http://chem4823.usask.ca

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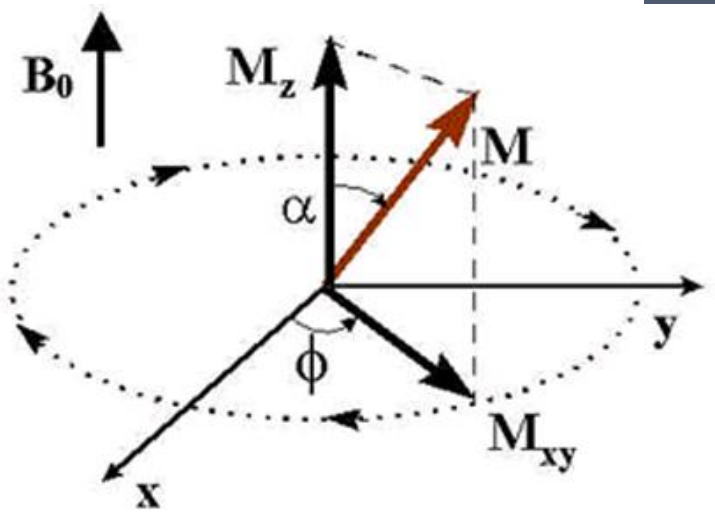
Magnetization Vector

- A strong constant magnetic field B_0 is always present
  - In the direction of M_z^+
  - If M is not in the direction of M_z^+, B_0 forces M to return to M_z^+
- Vector M is affected by Radio Frequency (RF) pulses of different angles
  - 90° angle tips vector M onto the M_{xy} plane



Components of a Magnetization Vector. A tipped vector has both Mz and Mxy component

http://www.spl.harvard.edu

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Magnetization Gradients

Problem: How do we know where the signal is coming from?

Answer: Magnetization Gradients

- Magnetization Gradients allow each point in space to be distinguishable
  - Like placing an xyz coordinate system on the imaged object
  - Without magnetization gradients, there is no way to determine where the data came from in space
  - Called spatial encoding

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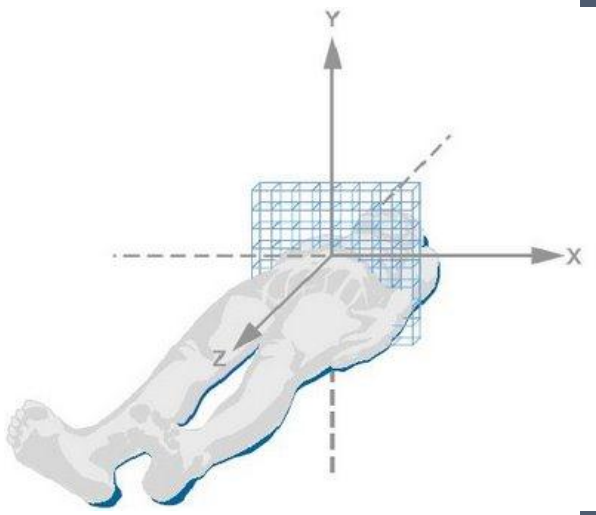
Magnetization Gradients

- Three types of gradients
  - Slice selection – along the z-axis
  - Phase encoding – along x-axis
  - Frequency-encoding – along y-axis



- Amplitude and duration of these gradients determine how information is read in k-space
  - Points in k-space are read by manipulating these gradients

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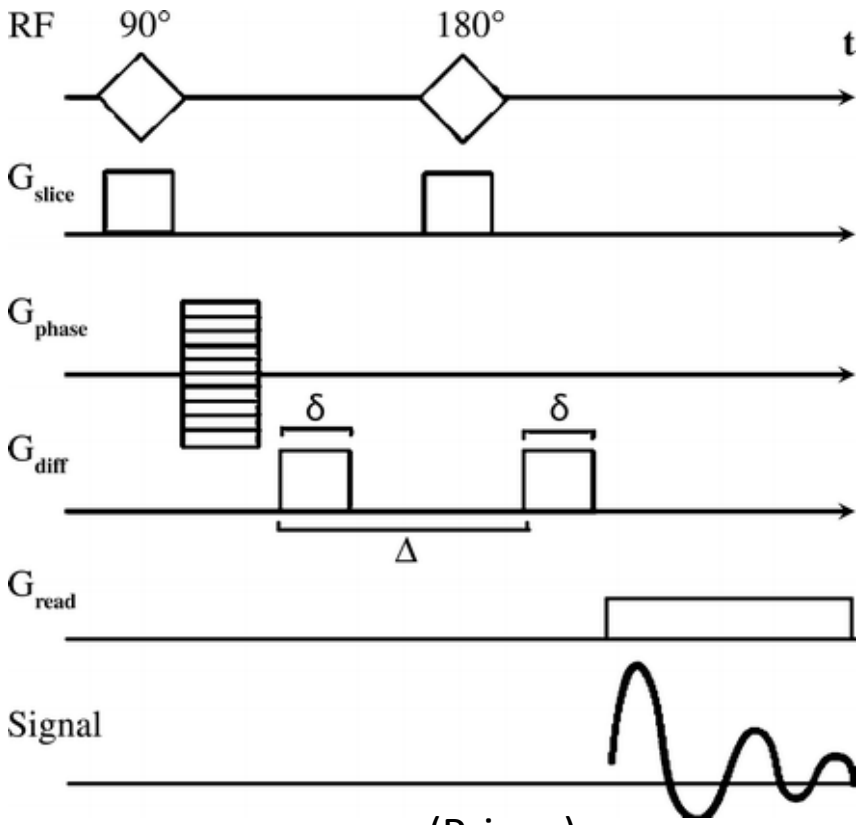
Pulse Sequence

- Pulse sequence shows the timing of RF pulses and gradients
  - Determines the type of image
    - T1, T2, DWI
- Some qualities of pulse sequences have special names
  - Inversion Recovery – 180 pulse before tip pulse
  - Spin Echo – 180 pulse after tip pulse



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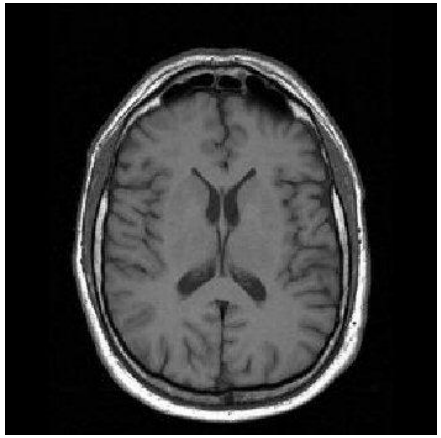
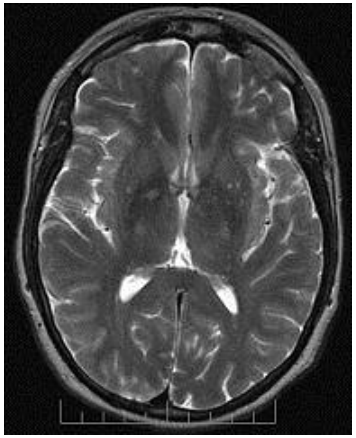
Pulse Sequence

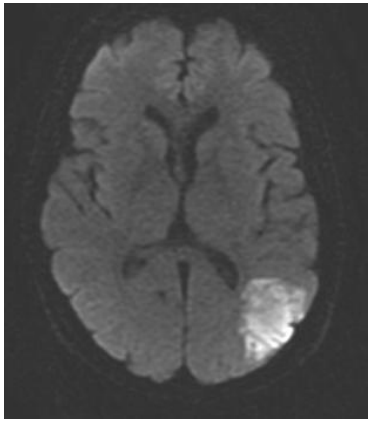
Like mentioned earlier, pulse sequence determines the type of image:



T1 - Weighted



T2 - Weighted



Diffusion Weighted

MRI is capable of obtaining all sorts of information!

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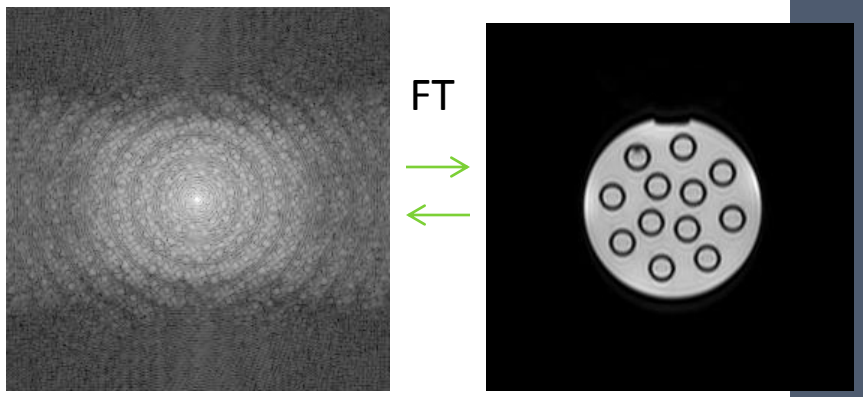
K-Space

- K-Space is a space where MRI data is stored
- The topics reviewed till now are the techniques to fill points in k-space
- By performing a fourier transform, k-space can be translated into an image



K-space Image

http://www.revisemri.com/tools/kspace/

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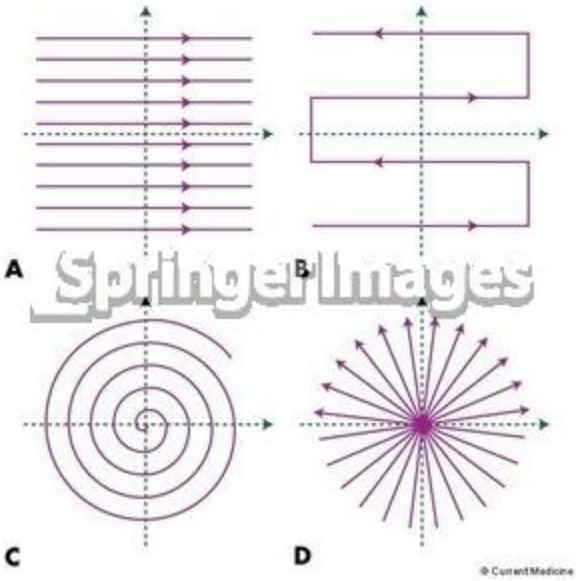
K-Space

- K-space is sampled using magnetic gradients
- Many methods to sample k-space:
  - A)Parallel Lines
  - B)Echo-Planar Imaging
  - C)Spiral
  - D)Radial
- Each method has its own advantages and disadvantages



http://www.springerimages.com

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K-Space

- Data in k-space determines the final image
- Below is an example of how k-space affects the final image:

practicalfmri.blogspot.com

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Uses for MRI

There are two uses for MRI:

- Diagnostic
  - Find unhealthy tissue in the body
  - Locate tumors
  - Bone damage
  - Assess condition of tissue
  - Surgery planning
- Research
  - Neuroscience
  - Determine relationships between images and disorders
  - Cancer
  - Understand how the brain works doing tasks

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References/Further Resources

- http://www.imaios.com/en**
- http://www.revisemri.com/*
- http://www.mr-tip.com/serv1.php?type=db
- www.biac.duke.edu/education/courses/fall05/fmri/handouts/2005_Week2_BasicPhysics.ppt
- Prince, Jerry. *Medical Imaging and systems*. Upper Saddle River, N.J.: Pearson Prentice Hall, 2006.

*-Highly Recommended

**-Highly highly recommended, but requires free sign up

Presentation By: Arnold Evia

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