Lec 7
Introduction to MRI

Discovery of MRI led to Nobel prize in Physiology or Medicine in 2003

Press Release

6 October 2003

The Nobel Assembly at Karolinska Institutet has today decided to award
The Nobel Prize in Physiology or Medicine for 2003 jointly to

Paul C Lauterbur and **Peter Mansfield**

for their discoveries concerning **"magnetic resonance imaging"**

Can you guess how many more Nobel prizes are related to magnetic resonance?

1952 (Physics): Bloch and Purcell (*new methods for nuclear magnetic precision measurements)*

1991 (Chemistry): Ernst (*methodology for high precision nuclear magnetic resonance spectroscopy*)

2002 (Chemistry): Wuthrich (*nuclear magnetic resonance spectroscopy for determining the 3D structure of biological macromolecules in solution)*

Reference material for MRI

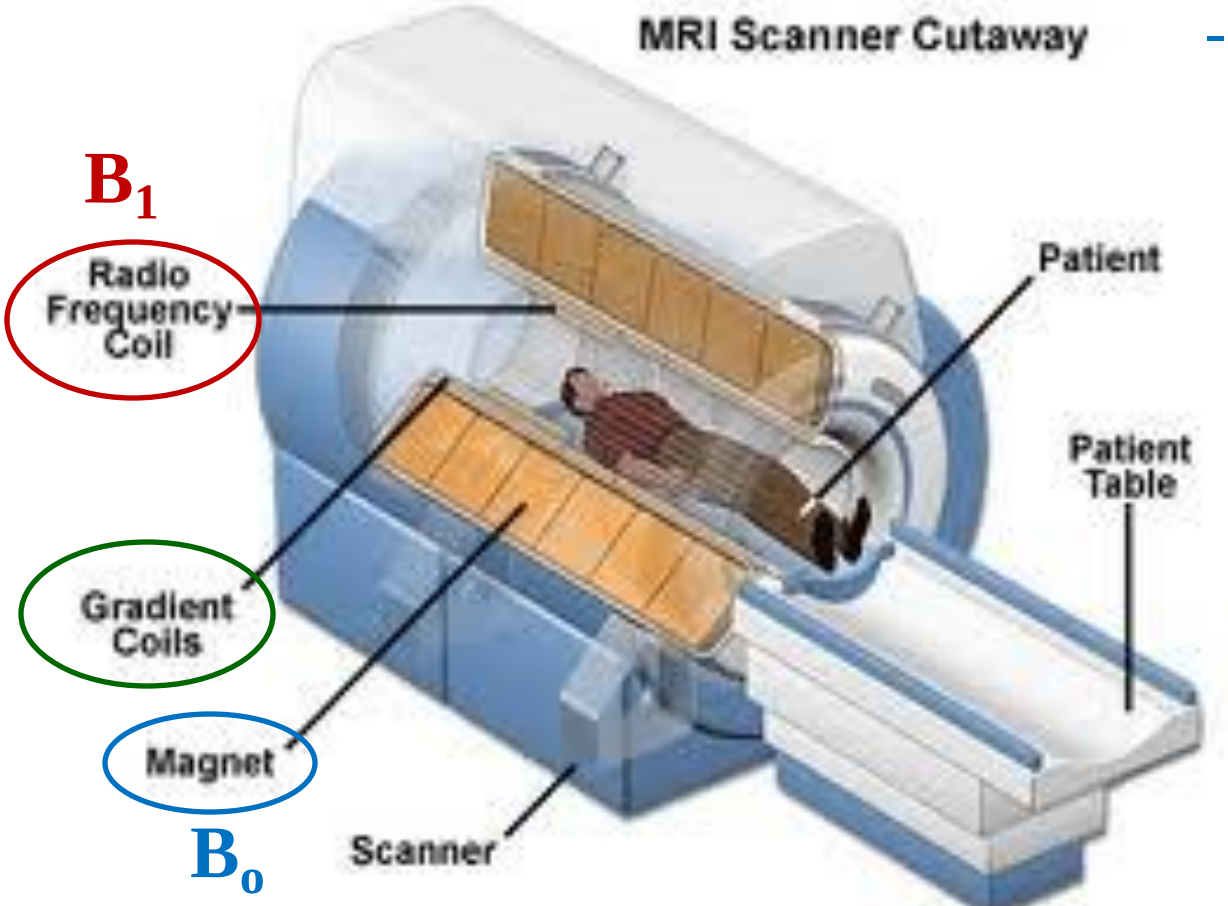
- Hendee: chapters 23 and 24
- Smith and Webb: pages 204 - 222
- There's an online book by Joseph Hornak at *http://www.cis.rit.edu/htbooks/mri/inside.htm*

Interaction between spin magnetic moments in tissue and external magnetic fields.

Frequency (RF) of external magnetic field matches with “some” internal frequency in tissue.

Deals with behavior of atomic **nuclei** in magnetic field.

What magnetic fields do we have?



- Steady magnetic field, B_o (initially align spins)
- RF magnetic field, B_1 (excites aligned spins)
- Spatial modulation of B_o for image encoding

https://www.researchgate.net/figure/MRI-scanner-cutaway-thanks-for-the-image-from-34_fig1_280792219

Some pre-MRI checks for patients

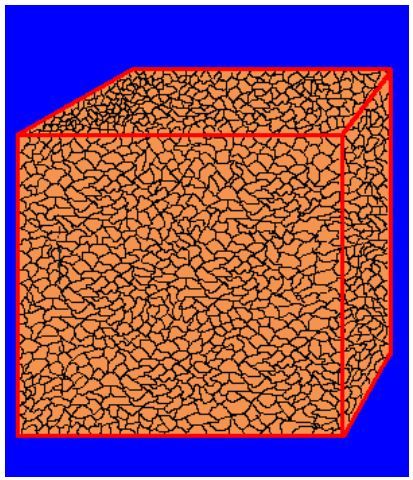
- Ferromagnetic objects
- Non-ferromagnetic objects: local image distortion
- Claustrophobia (~ 45 - 60 min)
- Movement (due to sneeze, cough, etc.)
- Acoustic protection (ear plugs for high noise levels)

Not all patients can undergo an MRI!

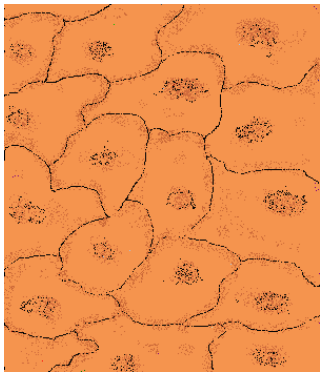
- Steady magnetic field ~ 1.5 - 3T
- Earth's magnetic field ~ 50μT

https://newcastleclinic.co.uk/mri-safety-week-precautions-to-take-before-an-mri-scan/

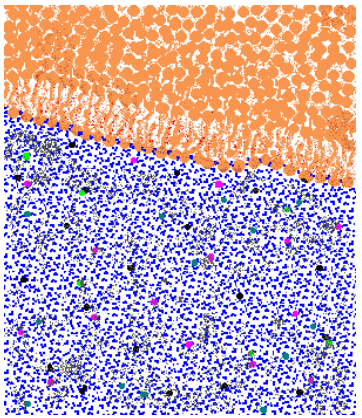
Origin of magnetic moment in tissue



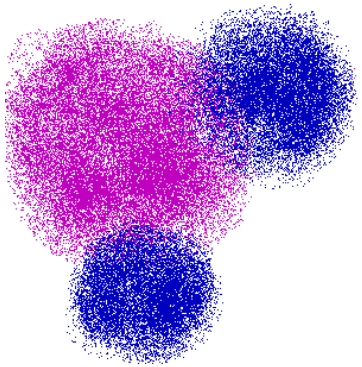
Tissue volume element (voxel)



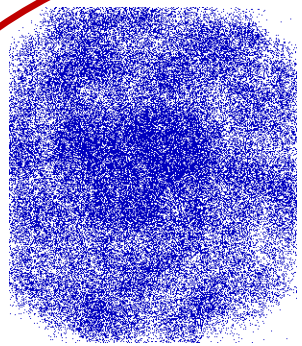
Cells



Water



H_2O molecule



H-nucleus

Tiny magnet

http://www.cis.rit.edu/htbooks/mri/inside.htm

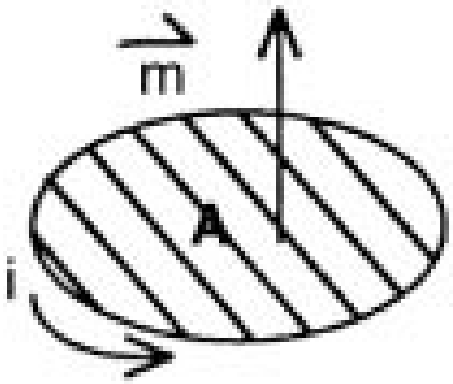
MRI measures signal from hydrogen nuclei

Element	Biological Abundance
Hydrogen	0.63
Carbon	0.094
Nitrogen	0.015
Sodium	0.00041
Phosphorus	0.0024
Calcium	0.0022
Oxygen	0.26

Frequency range

Clinical MRI: between 15 and 80 MHz for hydrogen imaging.

Classical magnetic moment (due to a current)

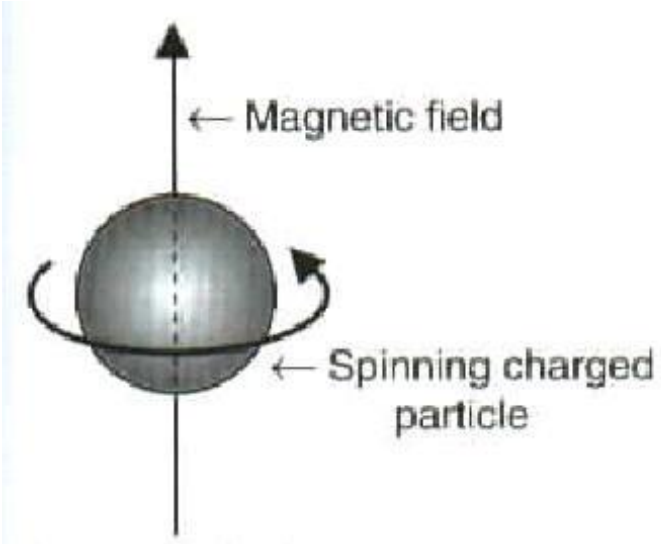


$$\vec{m} = i\vec{A}$$

Magnetic moment = (current) x (area of the current loop)

Magnetic moment of hydrogen nuclei

- Spin is actually a quantum mechanical concept. We give an oversimplified classical analogy in this course!
- Each spinning hydrogen nucleus (positive charge) has a “spin magnetic moment”.

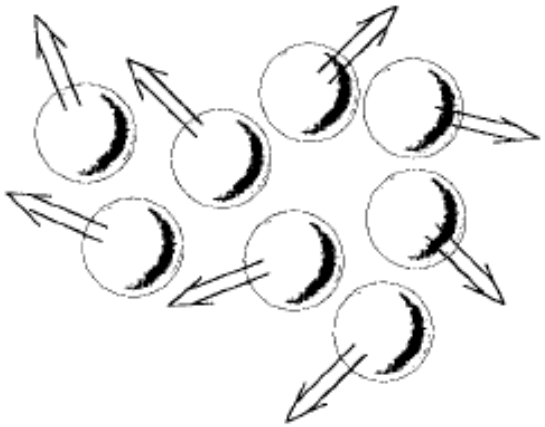


Calculate the number of spins inside a voxel.

- Take a voxel to be a cube of side 1 mm
- Hint: first find the number of water molecules in the voxel.

In absence of B_o

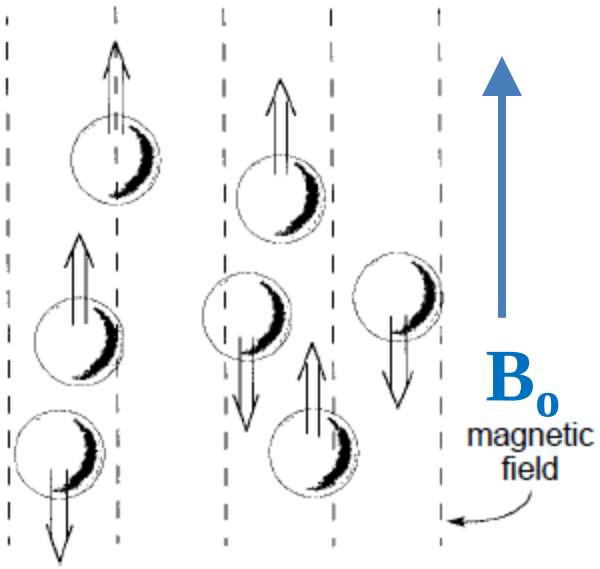
A single voxel (~ mm^3) has ~10^{19} spins.



Randomly oriented spins.
No net magnetization.

What happens in B_o field?

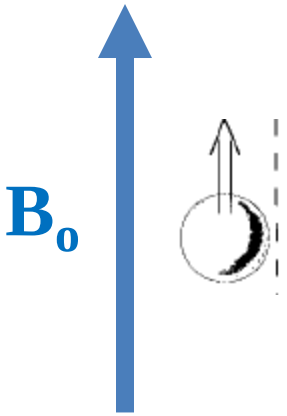
In presence of B_o

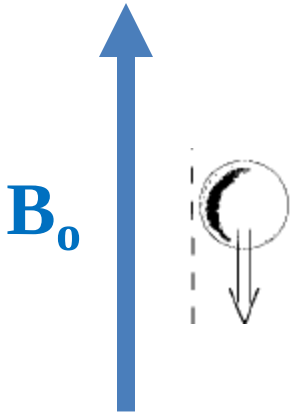


- Spins line up with B_o
- Non-zero net magnetization

Some spins are parallel and
some are anti-parallel to B_o.

Spins are “quantized” in a magnetic field





Low energy

Parallel

High energy

Anti-parallel