Module 11: Basics of MRI

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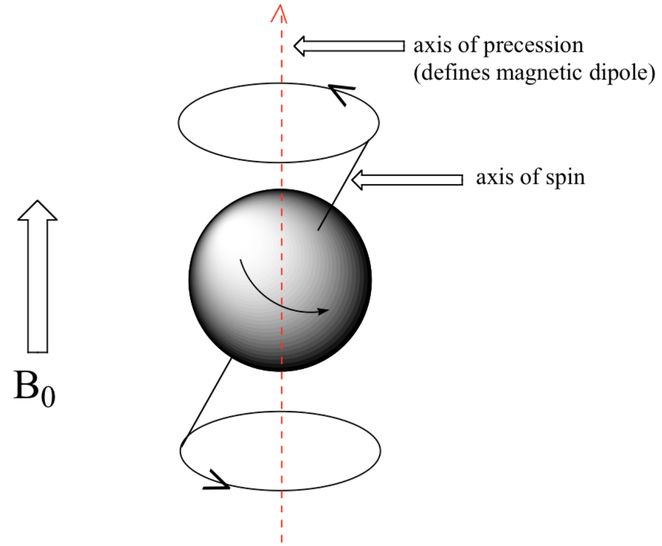
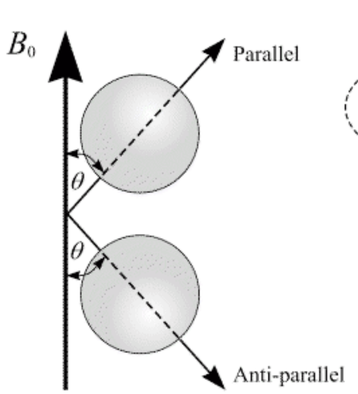
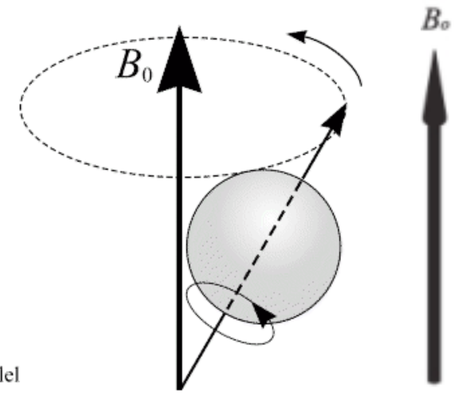
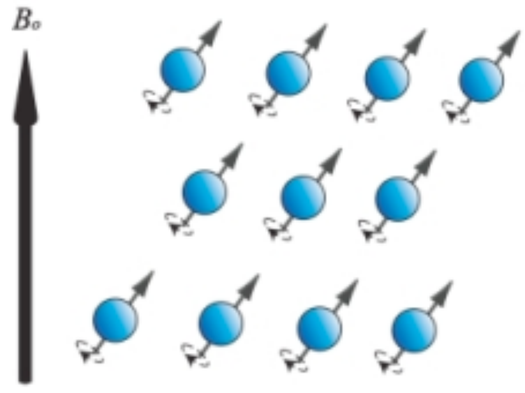
MRI Signal

- Thermal energy causes protons to spin
- In a magnetic field protons assume a state parallel or anti-parallel to direction of magnetic field
- Maintain a gyroscopic motion



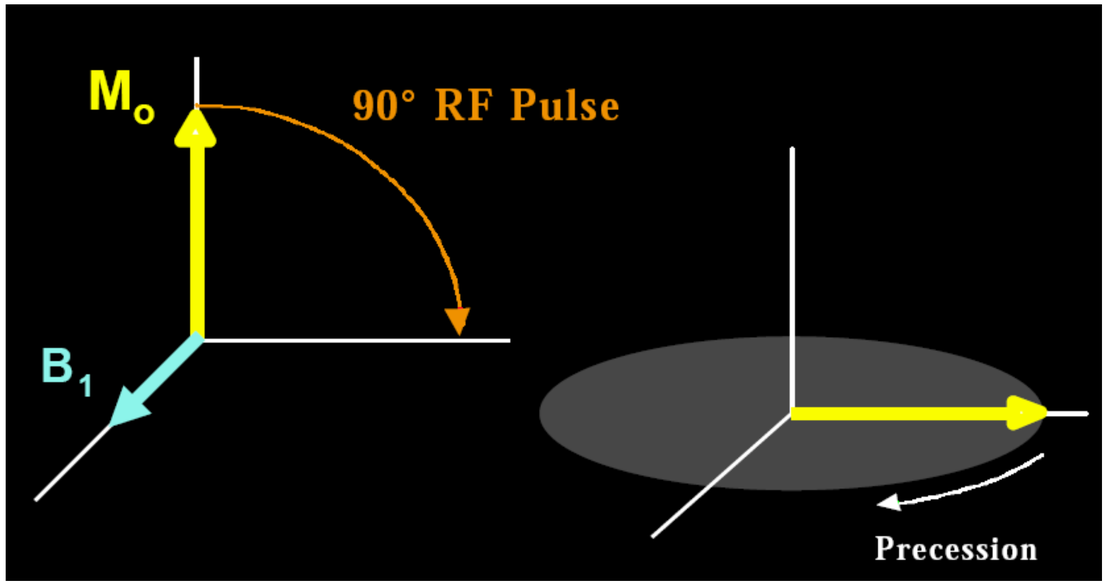




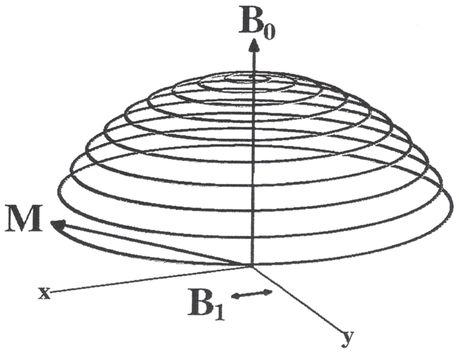


MRI Signal

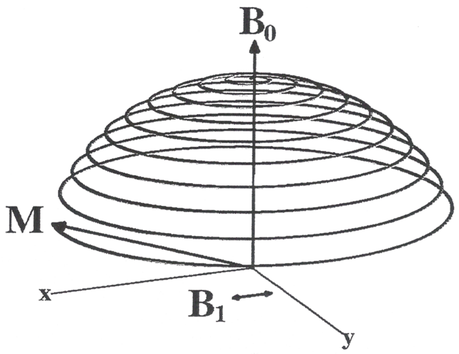
- The introduction of a small magnetic field perpendicular to the direction the main magnetic field (B0) causes the precession to move away from the axis of the magnetic field

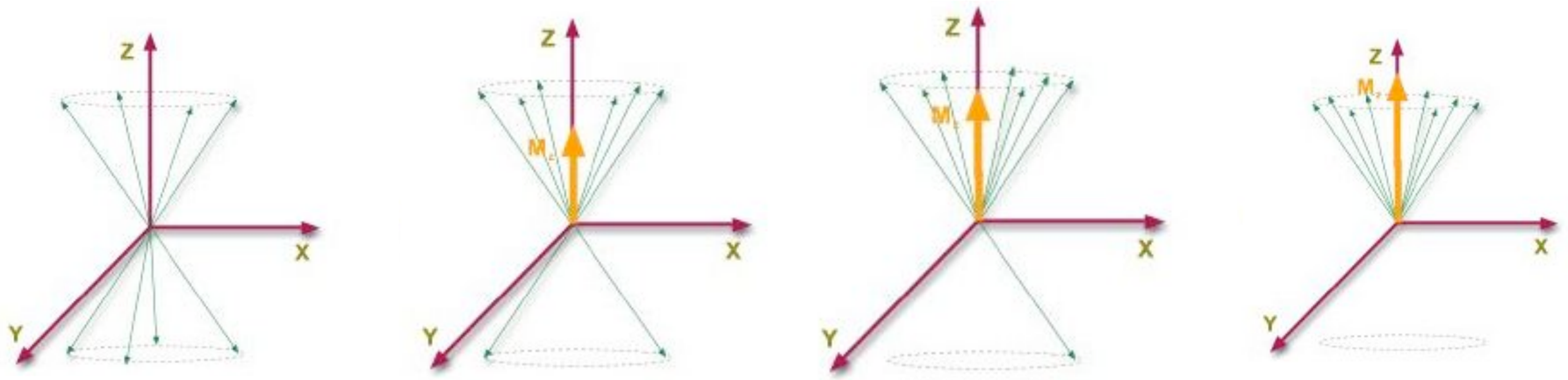


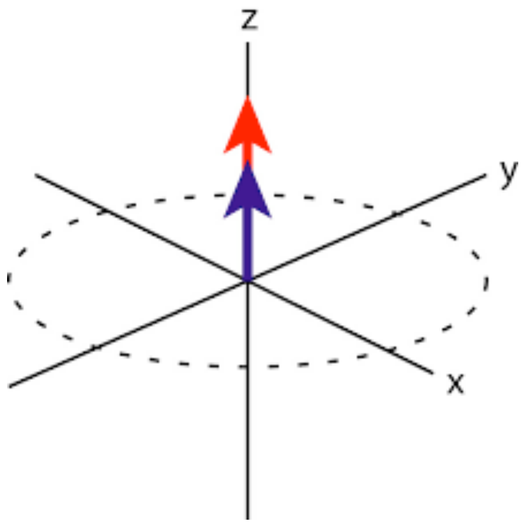
Excitation

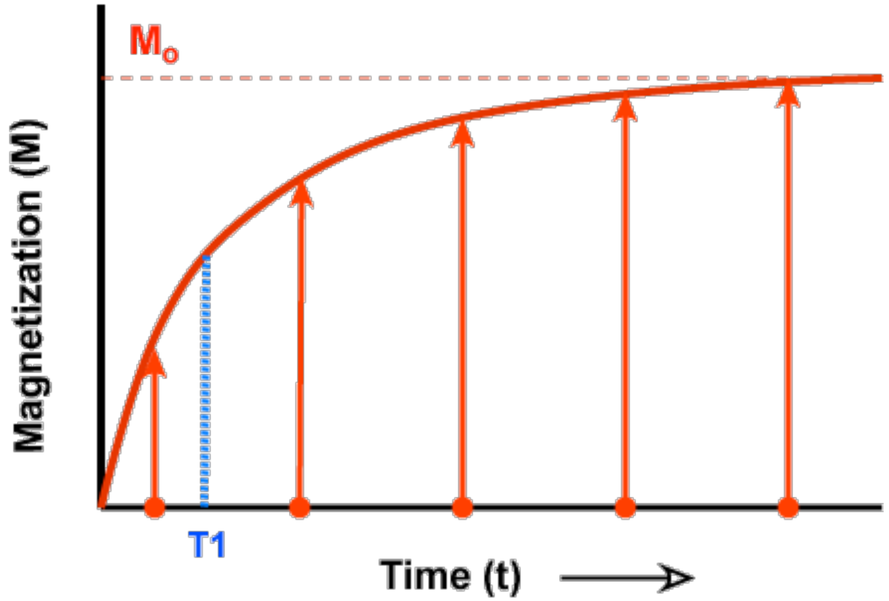


MRI Signal



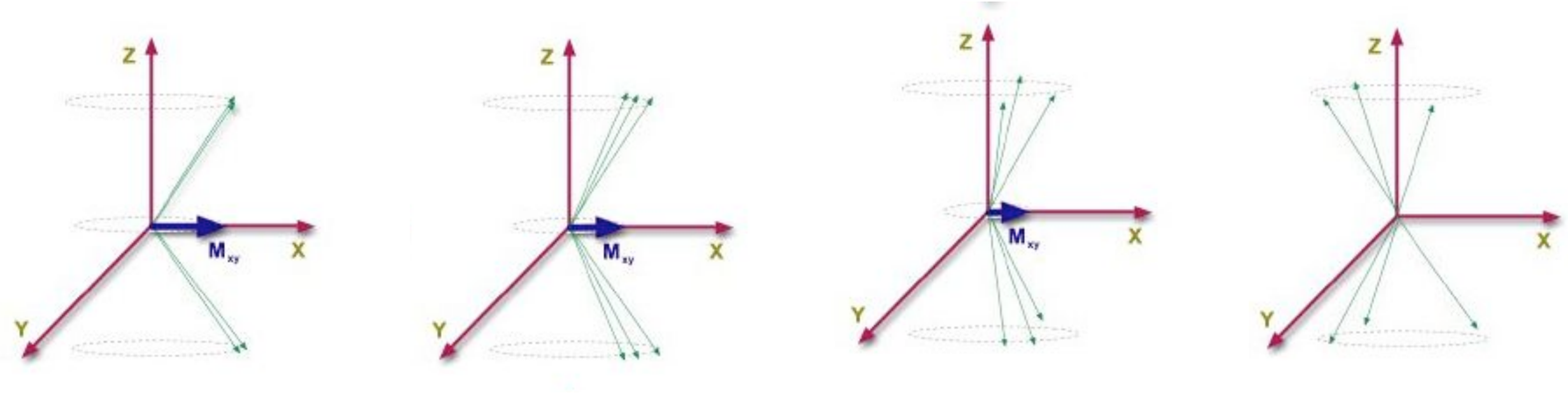


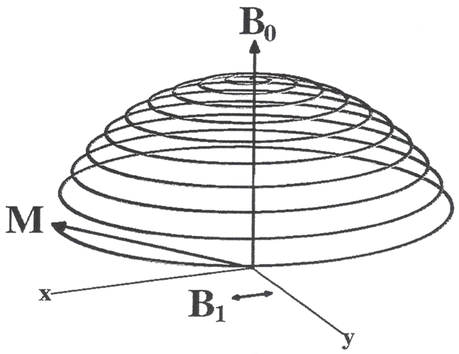


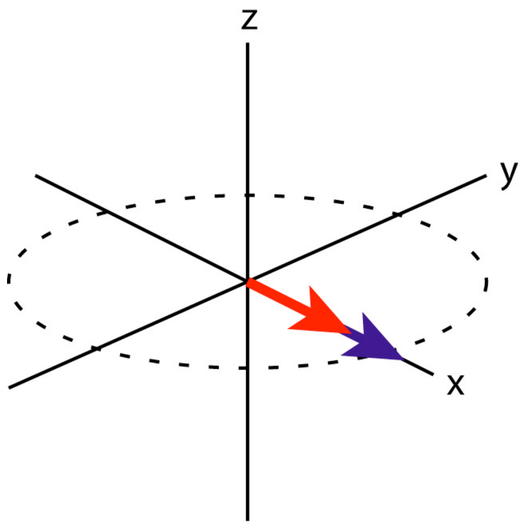


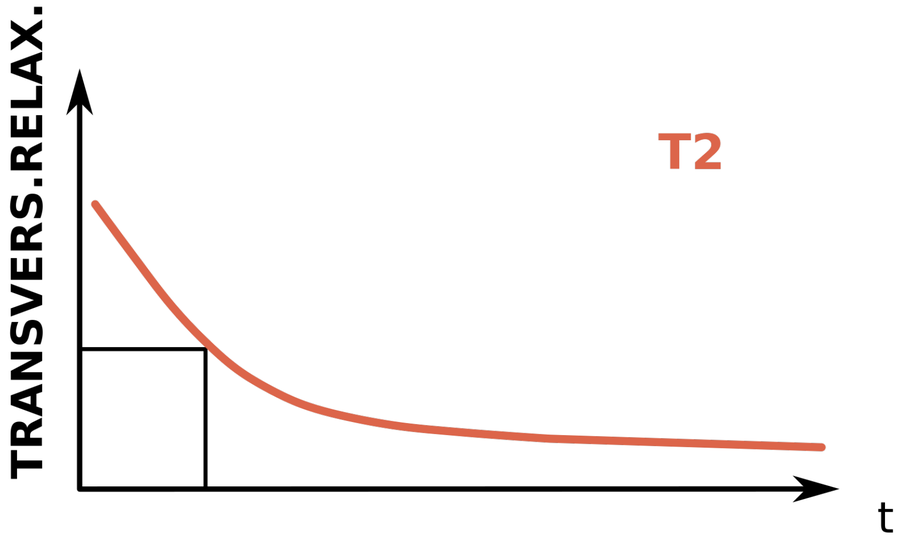
Longitudinal or T1 relaxation

MRI Signal





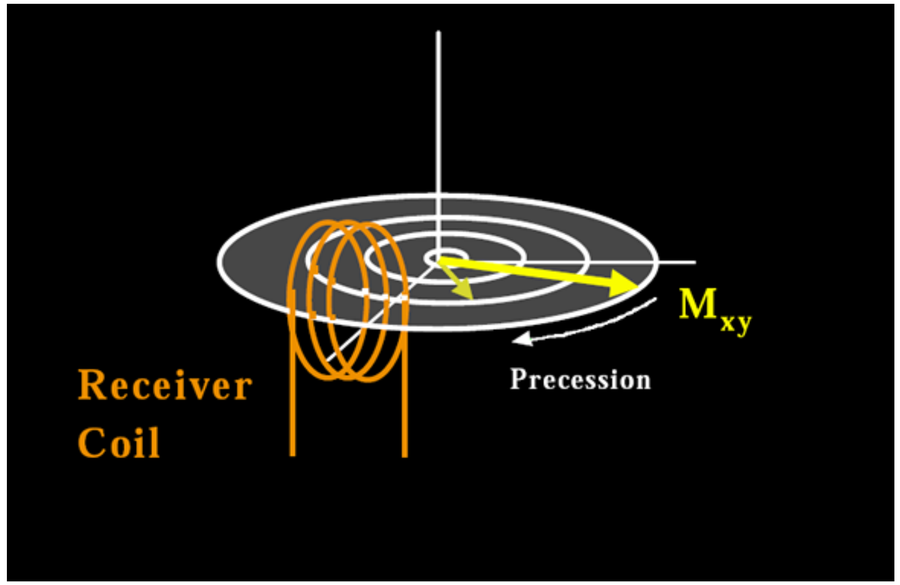


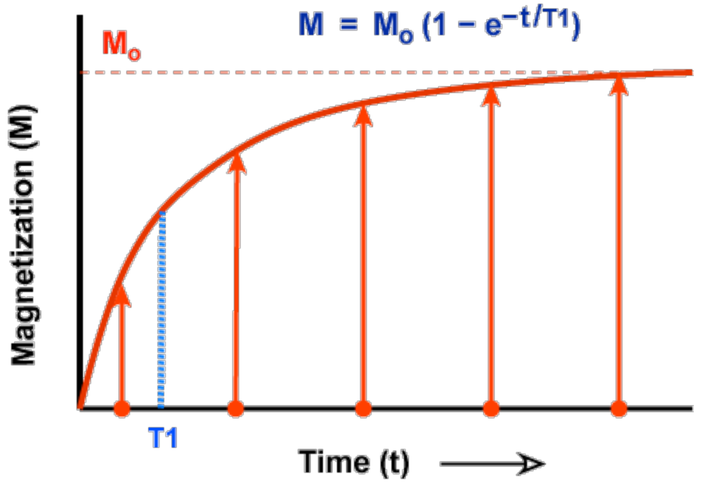


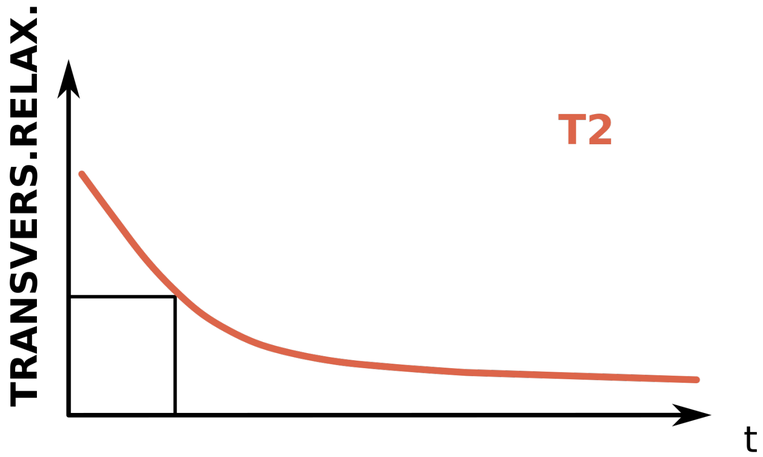
Transverse or T2 relaxation

MRI Signal

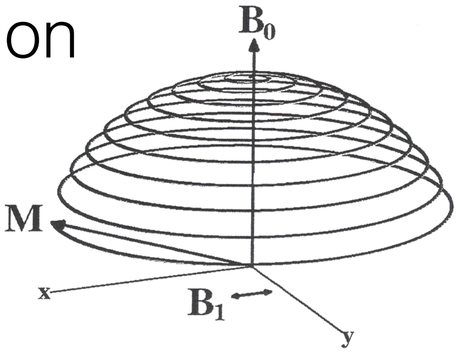
- Free precession of longitudinal or transverse magnetization induces a signal in the receiver coil
- Relaxation time is the characteristic time it takes the spin to recover after being disturbed from equilibrium







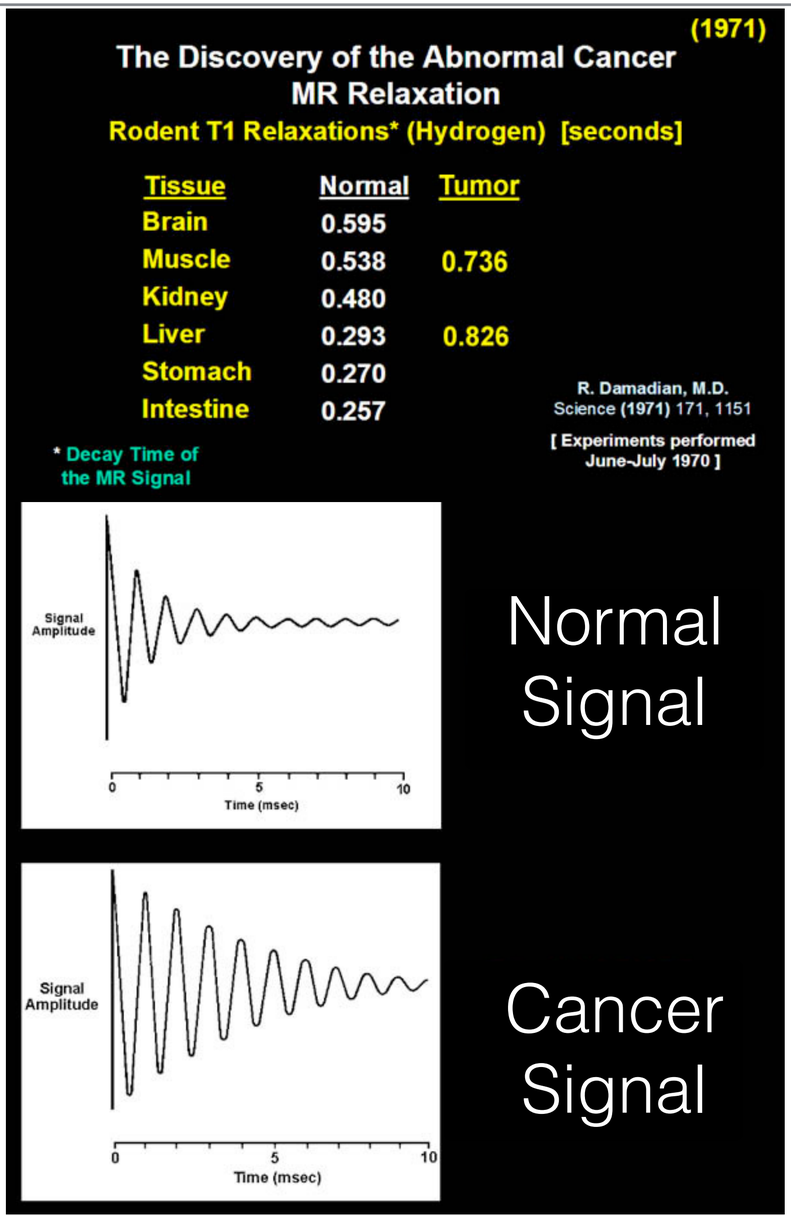
Relaxation



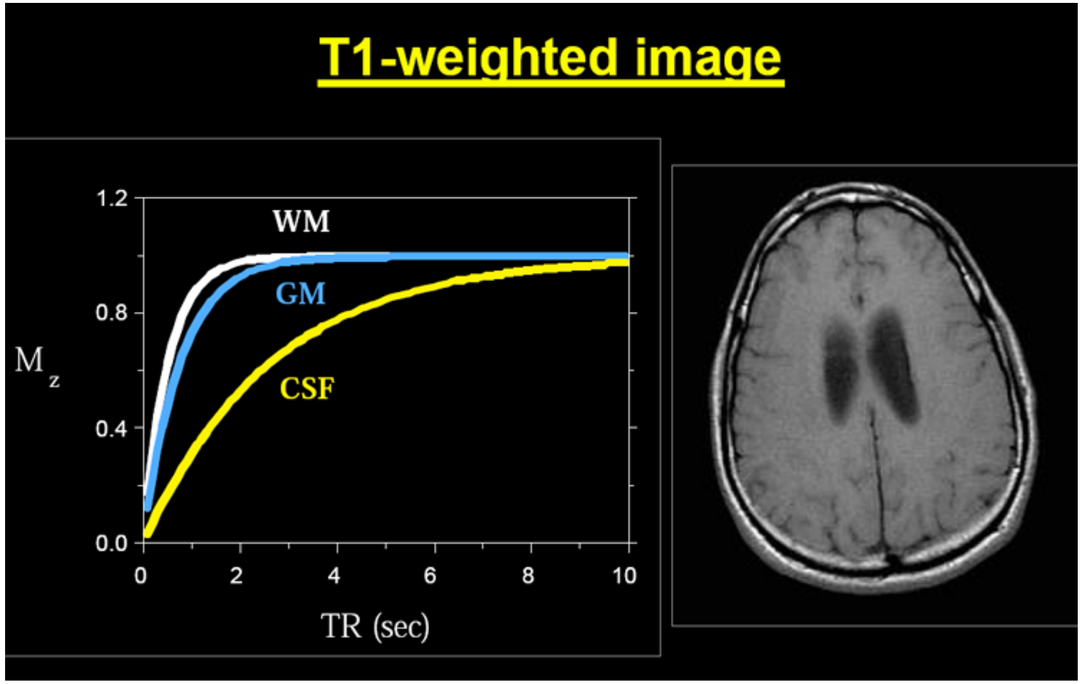
Relaxation Times

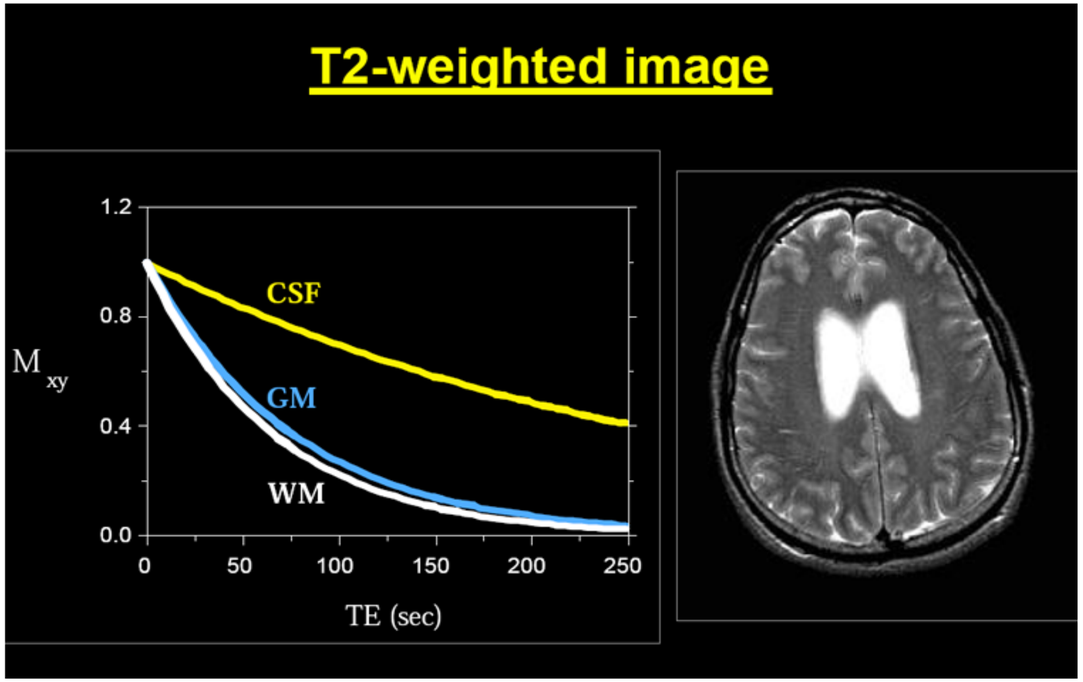
Biological matter has different but consistent T1 and T2 relaxation times depending on its composition

Field strength (T)	Tissue	T1 (ms)	T2 (ms)	$T2^*$ (ms)	Proton density
1.5	White matter	510	67	78	0.61
	Gray matter	760	77	69	0.69
	Arterial blood	1441	290	55	0.72
	CSF	2650	280	n.a.	1.0
3.0	White matter	1080	70	50	0.61
	Gray matter	1820	100	50	0.69
	Arterial blood	1932	275	46	0.72
	CSF	3817	1442	n.a.	1.0



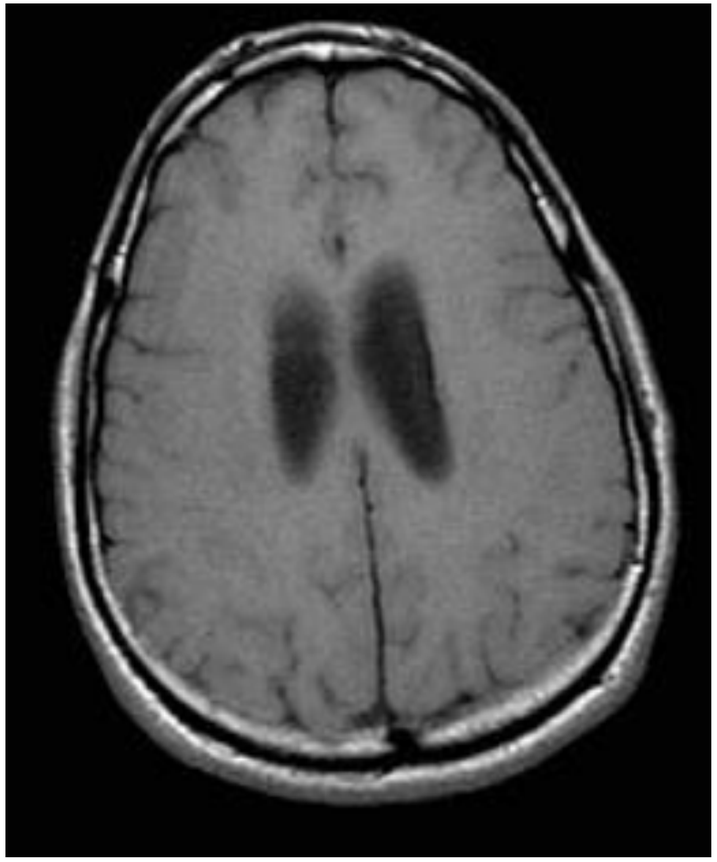
MRI Signal



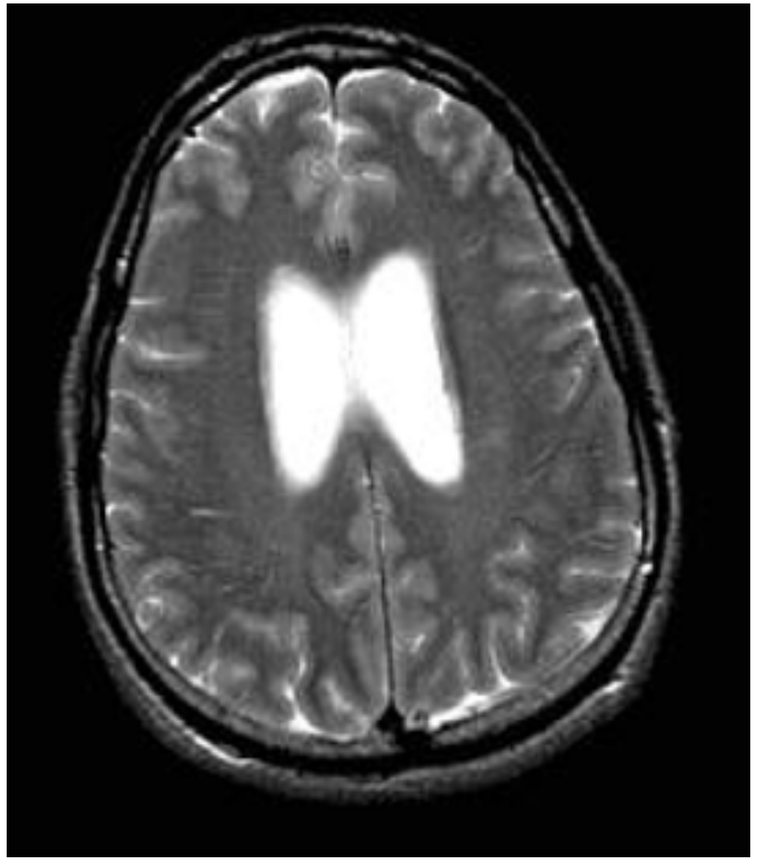


White matter, grey matter and CSF have different T1 and T2 relaxation times

MRI Signal



T1 Weighted Image

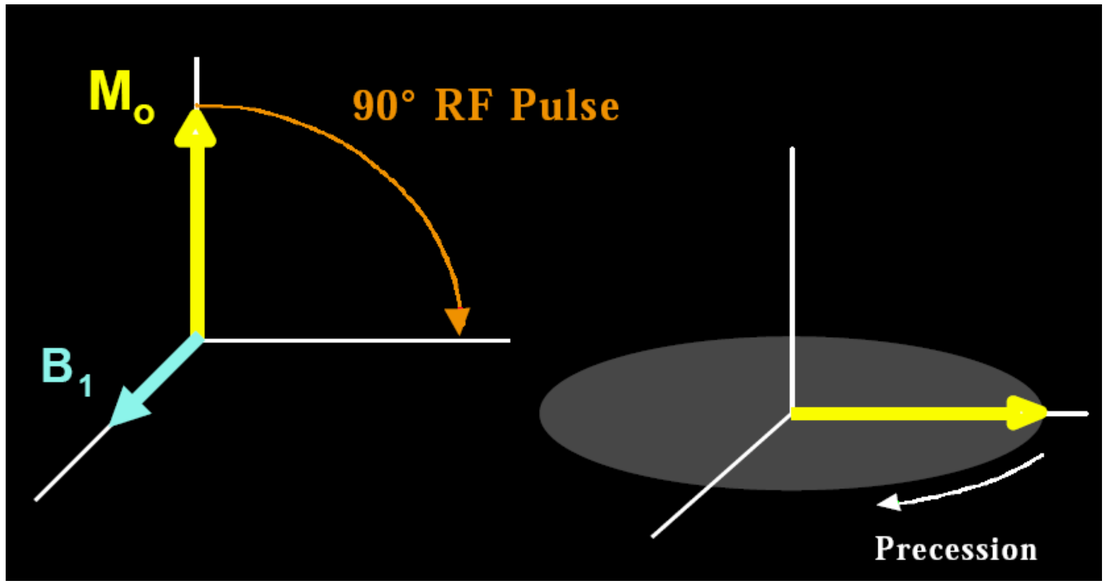


T2 Weighted Image

Spatial Specificity

Introducing Spatial Specificity:

- Precession or spins are in low energy parallel or high energy anti-parallel state.
- To change to a a spin from a low energy state to a high energy state electromagnetic energy is needed
- Frequency needed is known as the ***Larmor Frequency:***

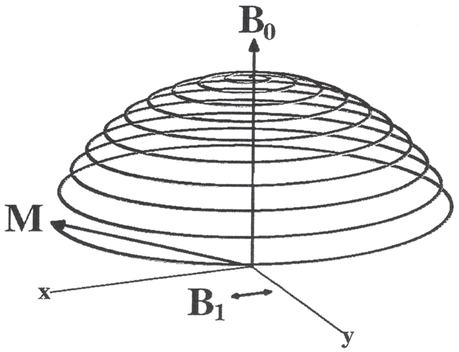


$$\omega_0 = \gamma B_0$$

Larmor Frequency in Mhz

Gyromagnetic ratio

Strength Mag. Field



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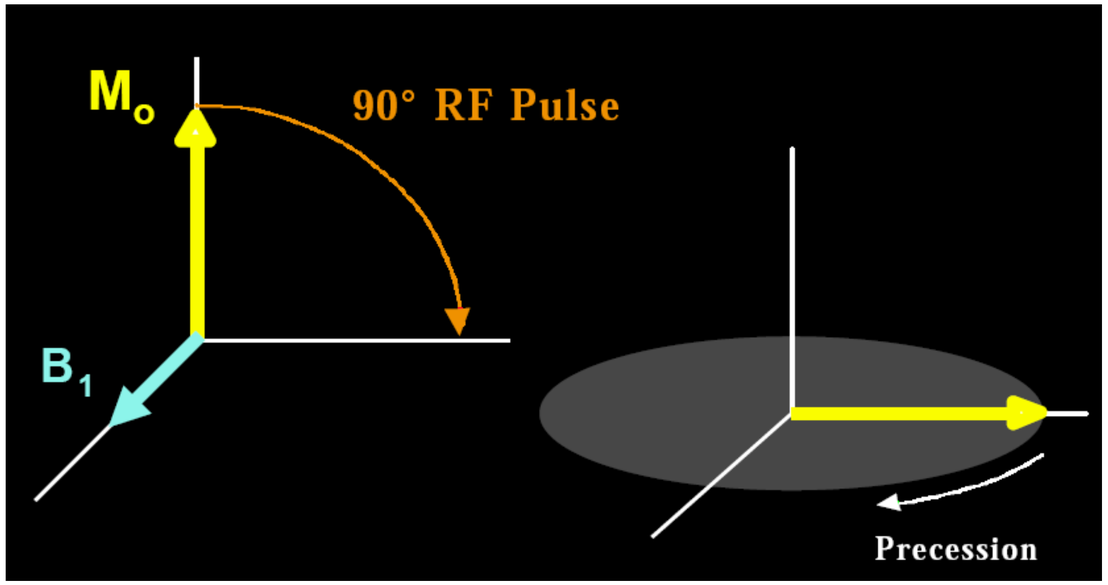


$$\omega_0 = \gamma B_0$$

Larmor Frequency in Mhz

Gyromagnetic ratio

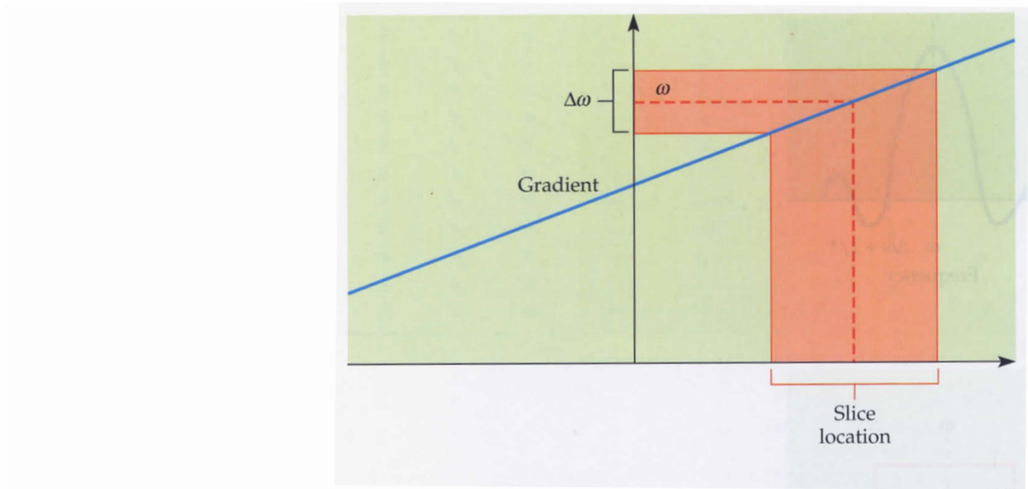
Strength Mag. Field

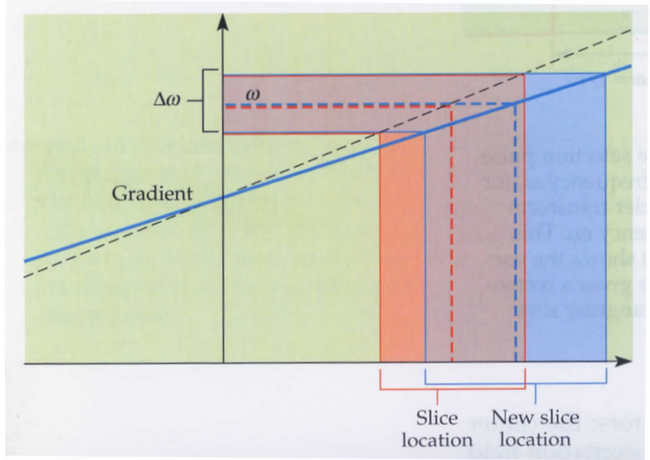
Nucleus or Particle	Gyromagnetic Ratio (γ) in MHz/Tesla
^{1}H	42.58
^{3}He	-32.43
^{13}C	10.71
^{19}F	40.05
^{23}Na	11.26
^{31}P	17.24
electron	-27,204

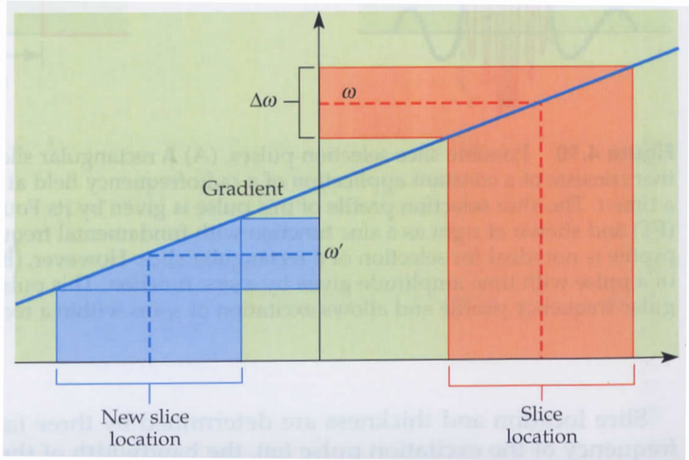
Spatial Specificity

Introducing Spatial Specificity:

- The Larmor frequency depends on local magnetic field strength
- By combining a linear gradient and pulse with a center frequency and a defined bandwidth a slice location can be selected for excitation
- A different slice can be selected by varying the linear gradient or the pulse frequency



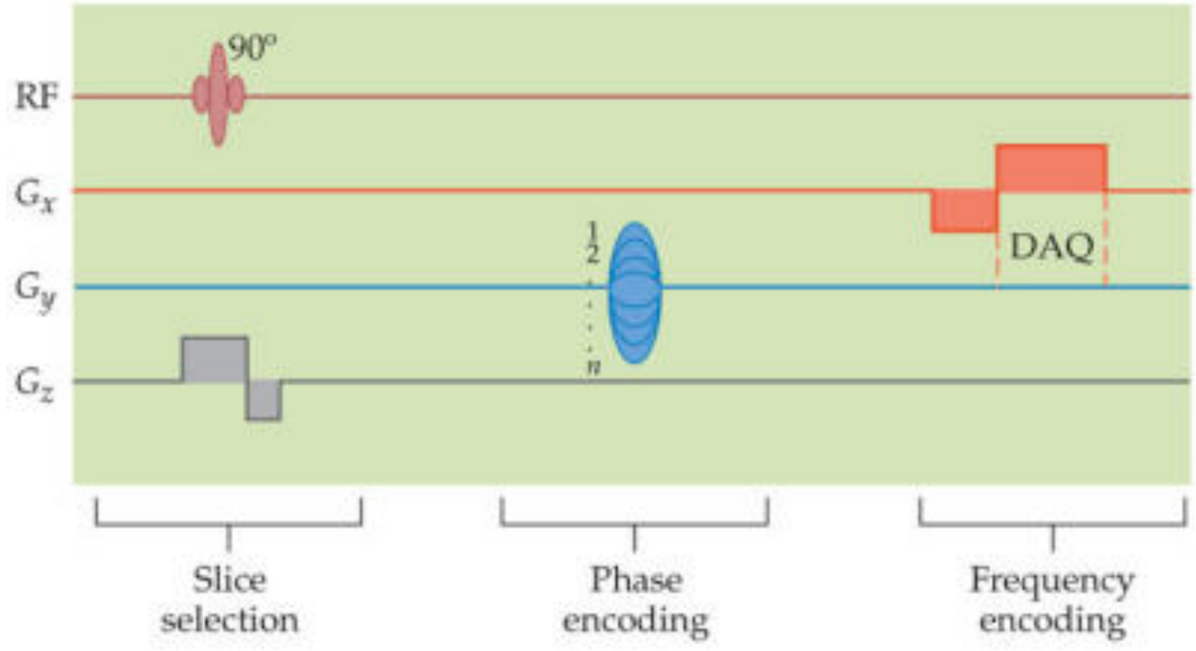




Spatial Specificity

Introducing Spatial Specificity:

- Selective excitation provides one dimension of selection (z)
- Distinguishing signals from different location by applying gradient fields is called frequency encoding (x)
- The gradient field in the third direction perpendicular to both of the other gradients is called phase encoding (y)

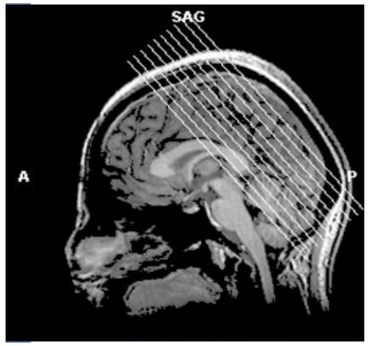


DAQ: Data acquisition

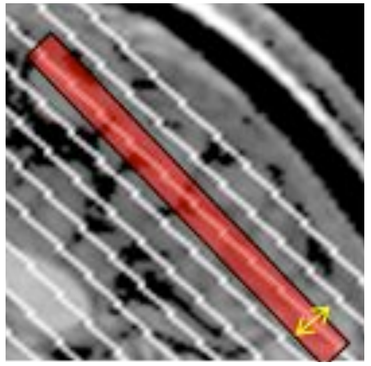
Image Construction

Magnetic Resonance Imaging

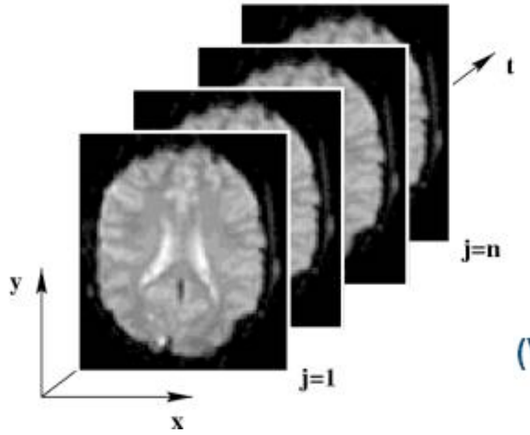
- Static magnetic field creates precession in a spin system
- Linear gradients create spatial specificity
- Larmor radio frequency pulse selectively excites slices
- Combination of gradients and frequency pulse allows for the imaging of any voxel in any direction



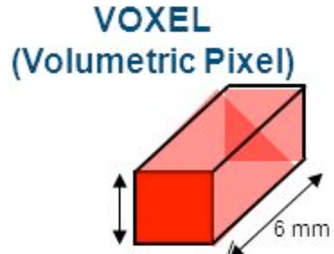
Slice selection



Slice Thickness



Slice Series



Single Slice

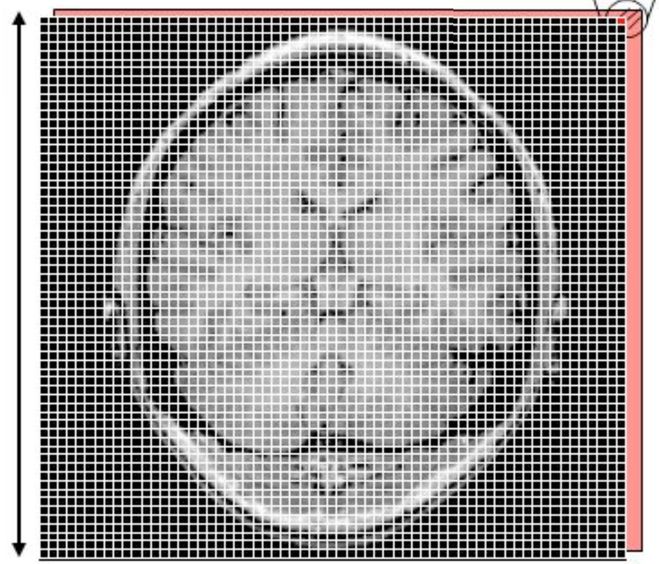
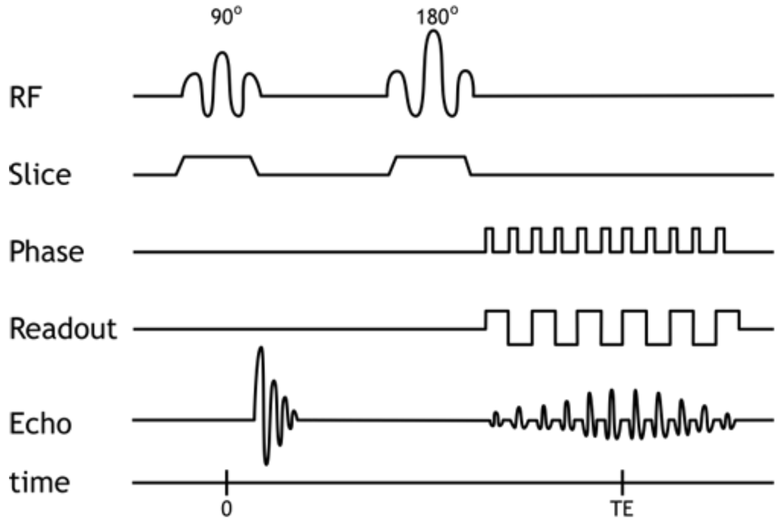
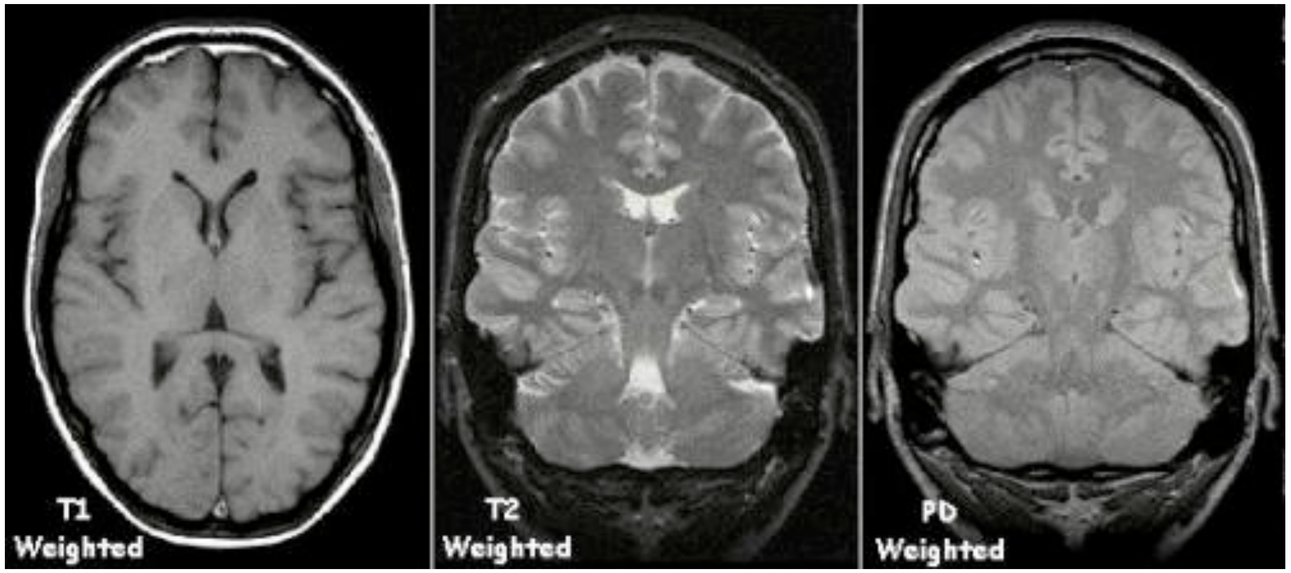


Image Construction

By varying the gradients, excitation and relaxation time readout many different pulse sequences can be created focussing on different properties of the volume of interest.





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