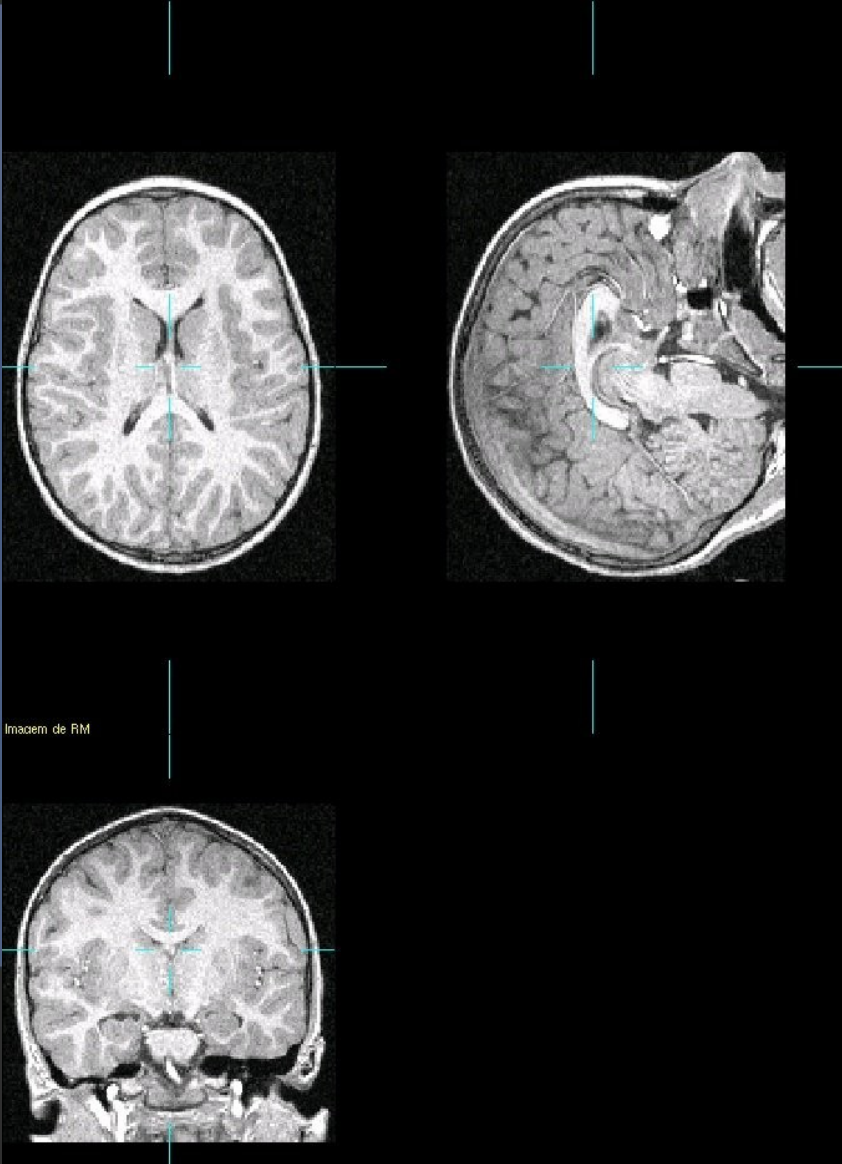


Magnetic Resonance Images (MRI)

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UFPR
Informatics Department

MR Images



[http://www.jpascasereports.com/article/S2213-5766\(13\)00005-5/fulltext](http://www.jpascasereports.com/article/S2213-5766(13)00005-5/fulltext)

MR Images

- History:
 - Described and measured in 1938 by Isidor Rabi;
 - Rabi was awarded the Nobel in Physics for this work;
 - Felix Bloch and Edward M Purcell expanded the technique and shared the Nobel Prize in 1953;
 - First NMR spectra of protein (Ribonuclease) (1956);
 - Fourier Transform spectroscopy (Ernst) (1965).

MR Images

- History:
 - Imaging tomography (Mansfield) (1973)
 - First protein structure (bovine pancreatic trypsin inhibitor) in solution (Wüthrich) (1985).

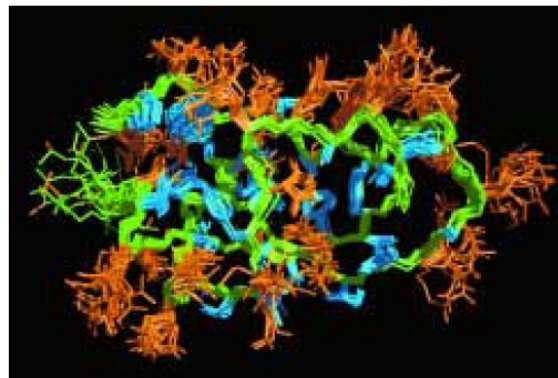


Figure 27. NMR structure of BPTI represented by a bundle of 20 conformers superimposed for best fit of the polypeptide backbone. The polypeptide backbone is green, core side-chains are blue, and solvent-accessible surface side-chains are red.



MR Images

- Nuclear Magnetic Resonance:
 - It is a phenomenon which occurs when the nuclei of certain atoms are immersed in a static magnetic field and exposed to a second oscillating magnetic field;
 - Most of matter you can examine is composed of molecules;
 - Molecules are composed of atoms;
 - Water molecule has one oxygen and two hydrogen atoms.

MR Images

- Nuclear Magnetic Resonance:
 - All nucleons have the quantum property of spin;
 - Overall spin is determined by the spin quantum number S ;
 - **$S = 0$**
 - If number the protons and neutrons is the same;

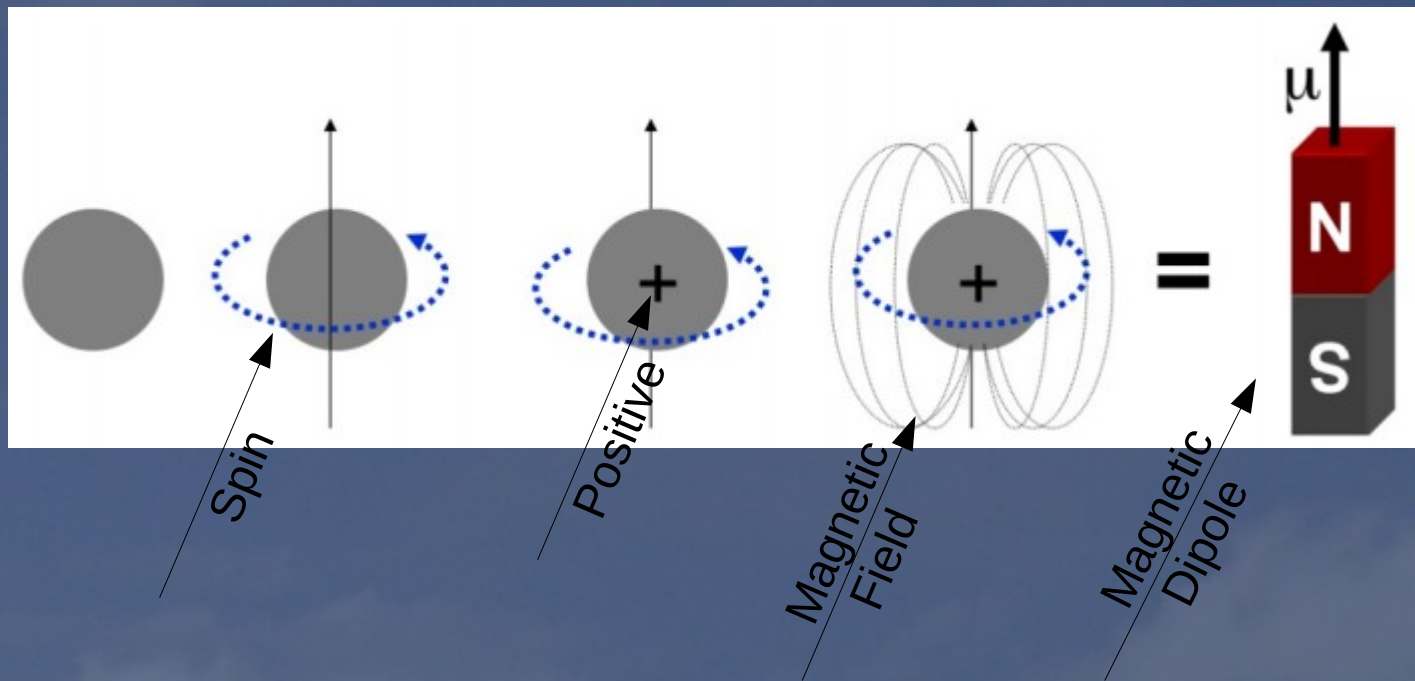
- Spin:
 - Spin is a fundamental property of nature like electrical charge or mass;
 - Spin comes in multiples of $1/2$ and can be + or - ;
 - Protons, electrons, and neutrons possess spin;
 - Individual unpaired electrons, protons, and neutrons each possesses a spin of $1/2$.

MR Images

- H^1 proton:
 - Sensibility;
 - Natural abundance 99,98% ;
 - 10% Body weight is H^1 ;
 - Image is acquired by small mobile molecules (water);
 - Characteristics of H^1 is different to health and unhealthy tissue.

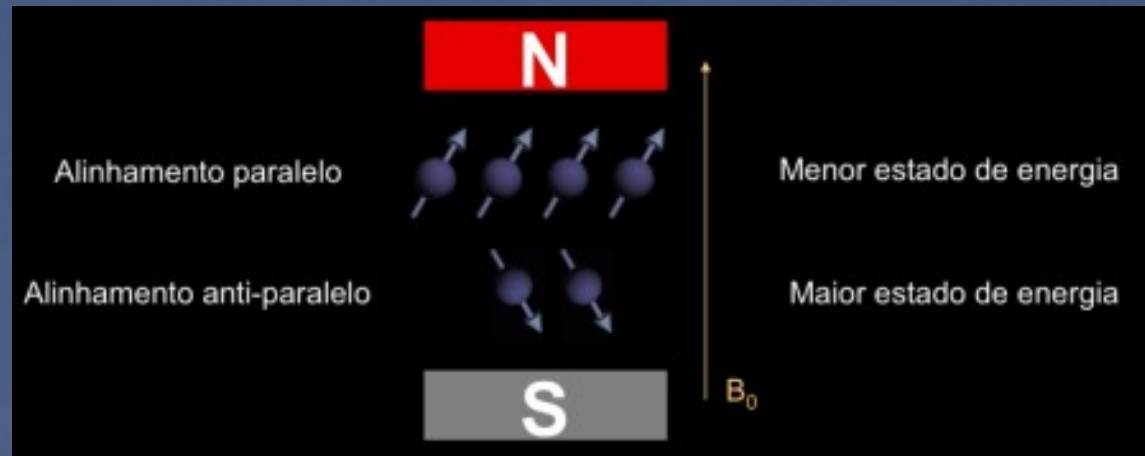
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- Magnetic Moment
 - H^1 proton:



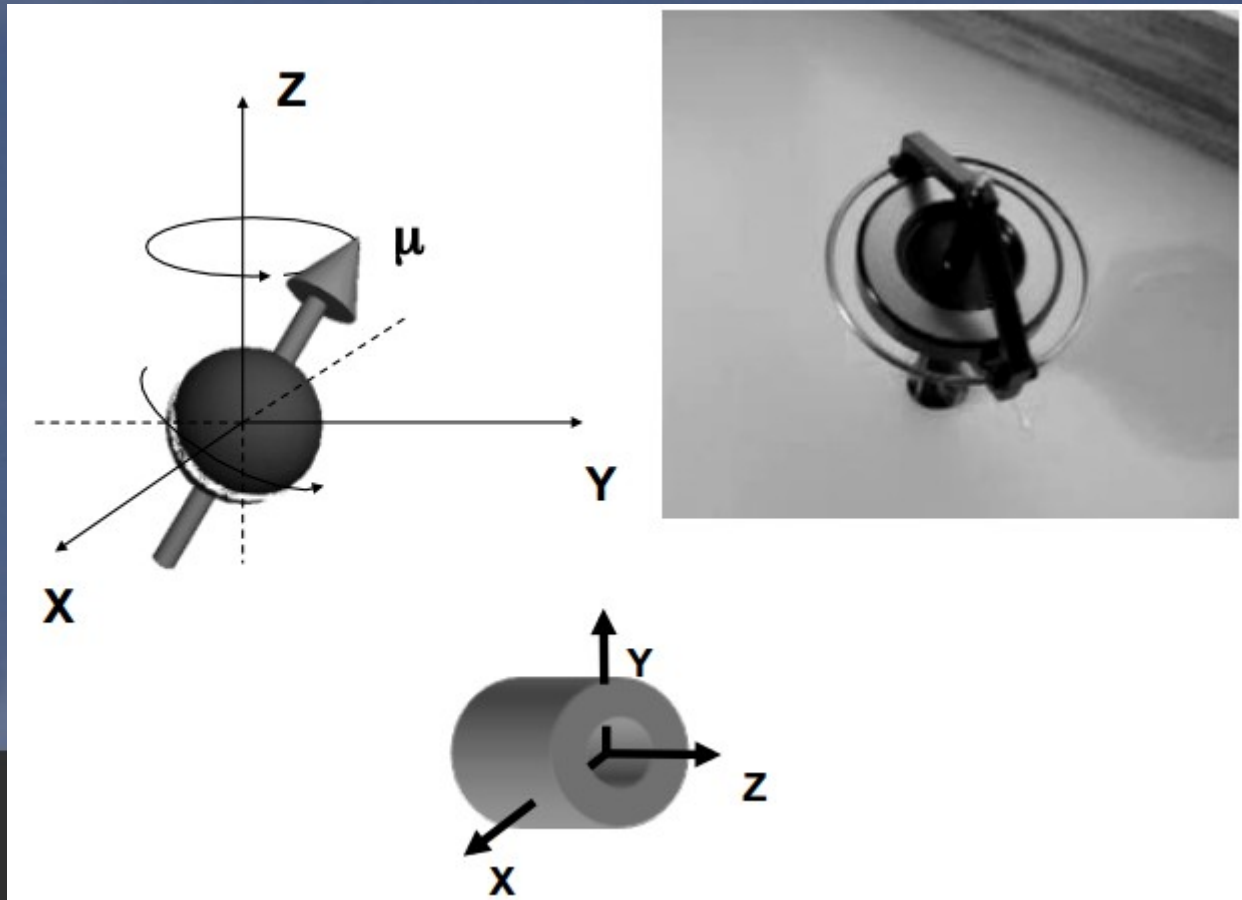
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- Magnetic Alignment:
 - 1.5 T



MR Images

- Precession Frequency:



MR Images

- Precession Frequency:
 - The precession frequency (ω) is determined by external magnetic field (B) and expressed by **Lamor Equation**:
 - γ is Torque.
 - Particular constant for each element.

$$\omega = \frac{\gamma}{2\pi} \cdot B$$

Nuclei	Torque $\gamma / 2\pi$ (MHz/T)
^1H	42,57
^{13}C	10,71
^{23}Na	11,26
^{31}P	17,23

0,35 T - _____ MHz

0,5 T - 21,28 MHz

1,0 T - 42,57 MHz

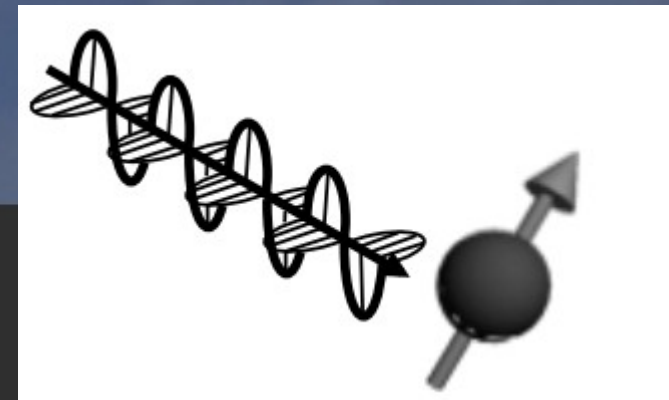
1,5 T - _____ MHz

2,0 T - 85,14 MHz

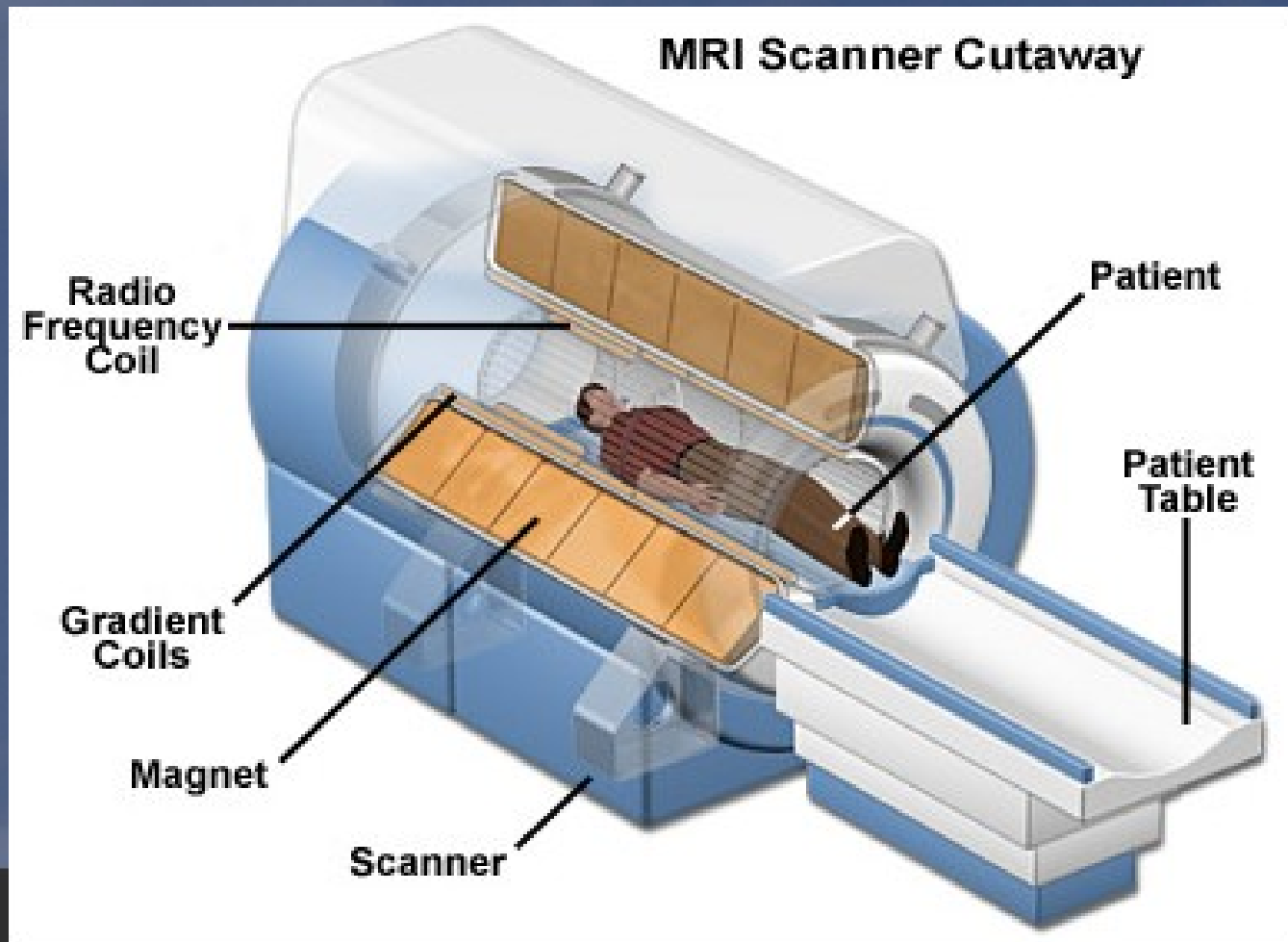
3,0 T - _____ MHz

MR Images

- Resonance:
 - It is a phenomenon which occurs when object exposed an oscillating disturbance in its natural frequency of vibration gains energy;
 - Examples:
 - Diapason;
 - Sound breaking glass crystal.
 - Used radio-frequency (RF).

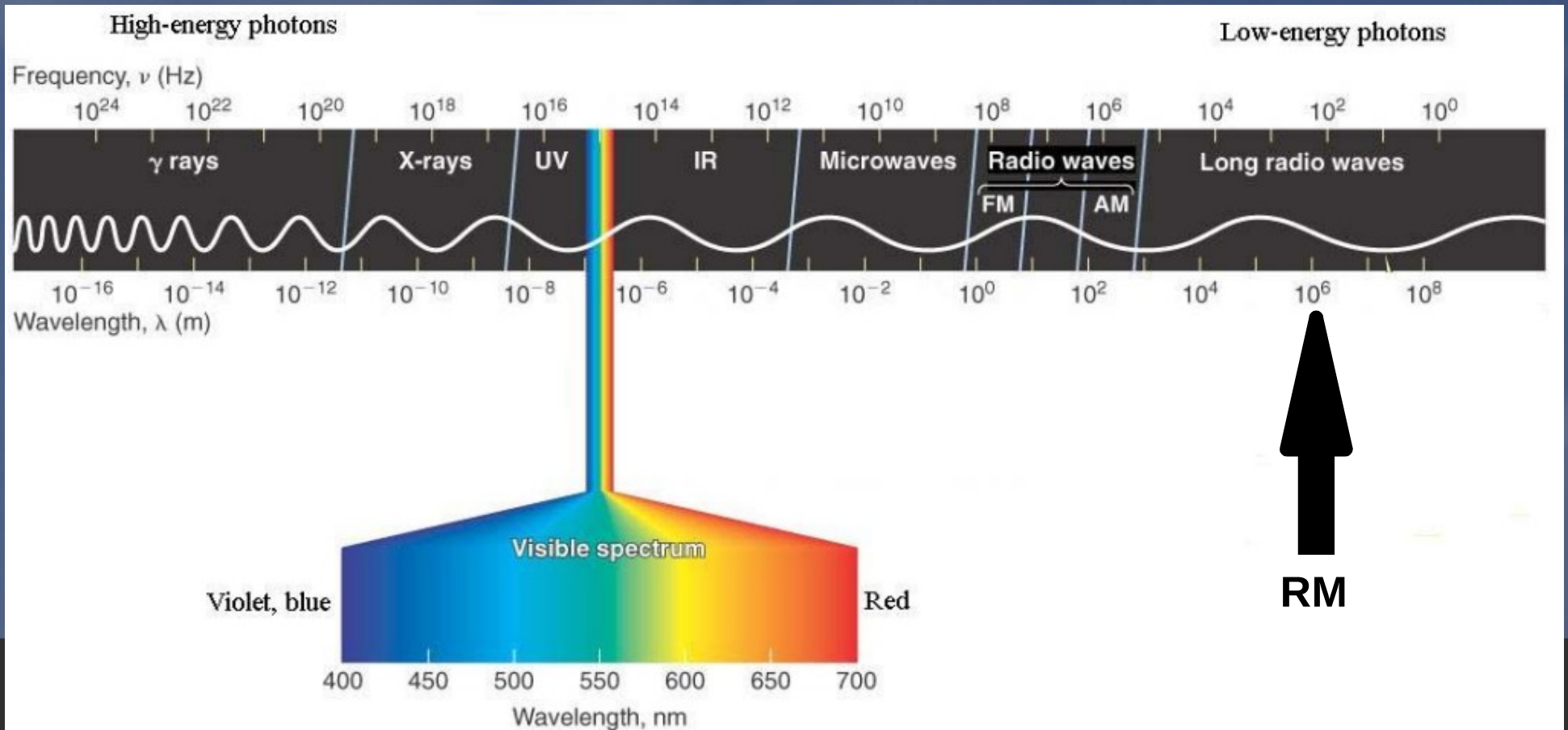


MR Images



MR Images

- Electromagnetic Spectrum:

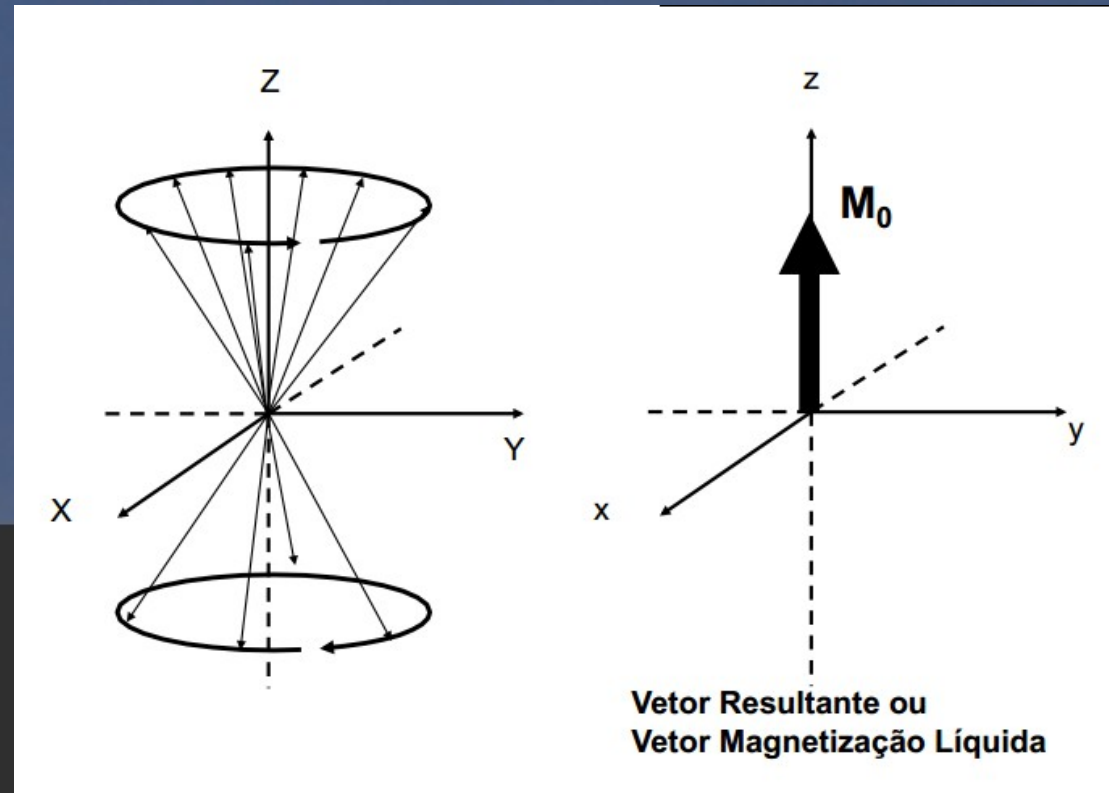


http://ec.europa.eu/health/ph_risk/committees/04_scenihp/docs/scenihp_o_019.pdf

MR Images

- Radio-frequency (RF) effects:
 - Energy transfer, nuclei with low energy change state to high energy;
 - Nuclei precessing in phase.

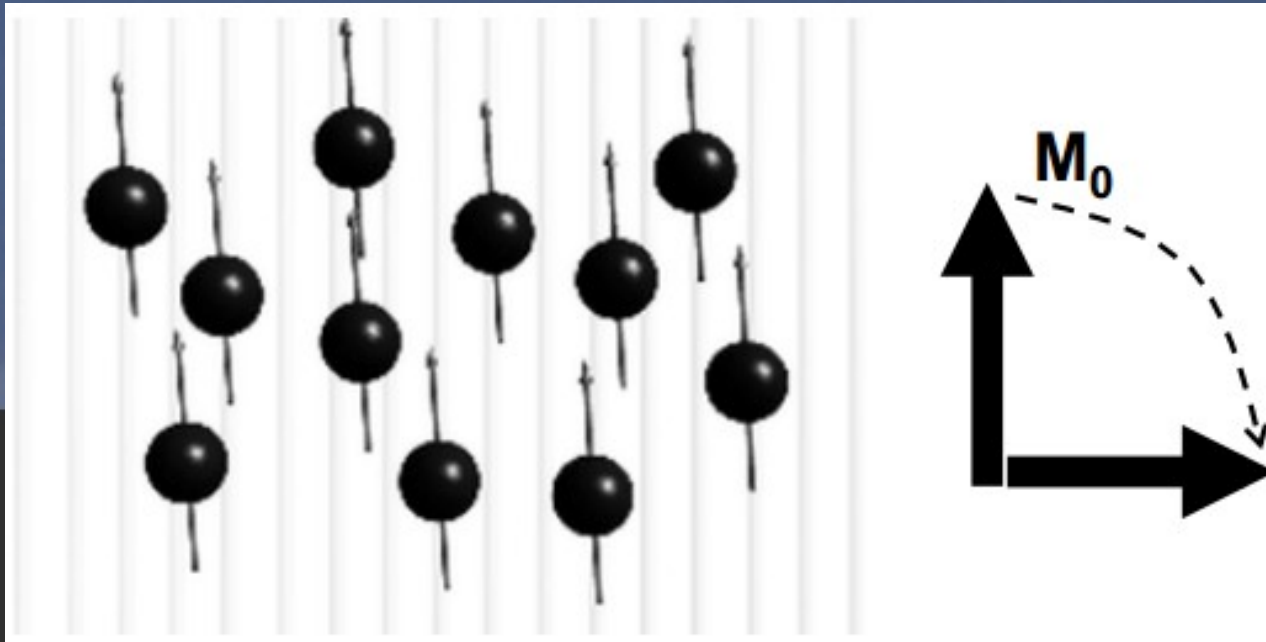
RF could be considered a B_1 field applied in a perpendicular direction to the Z axis (B_0).



MR Images

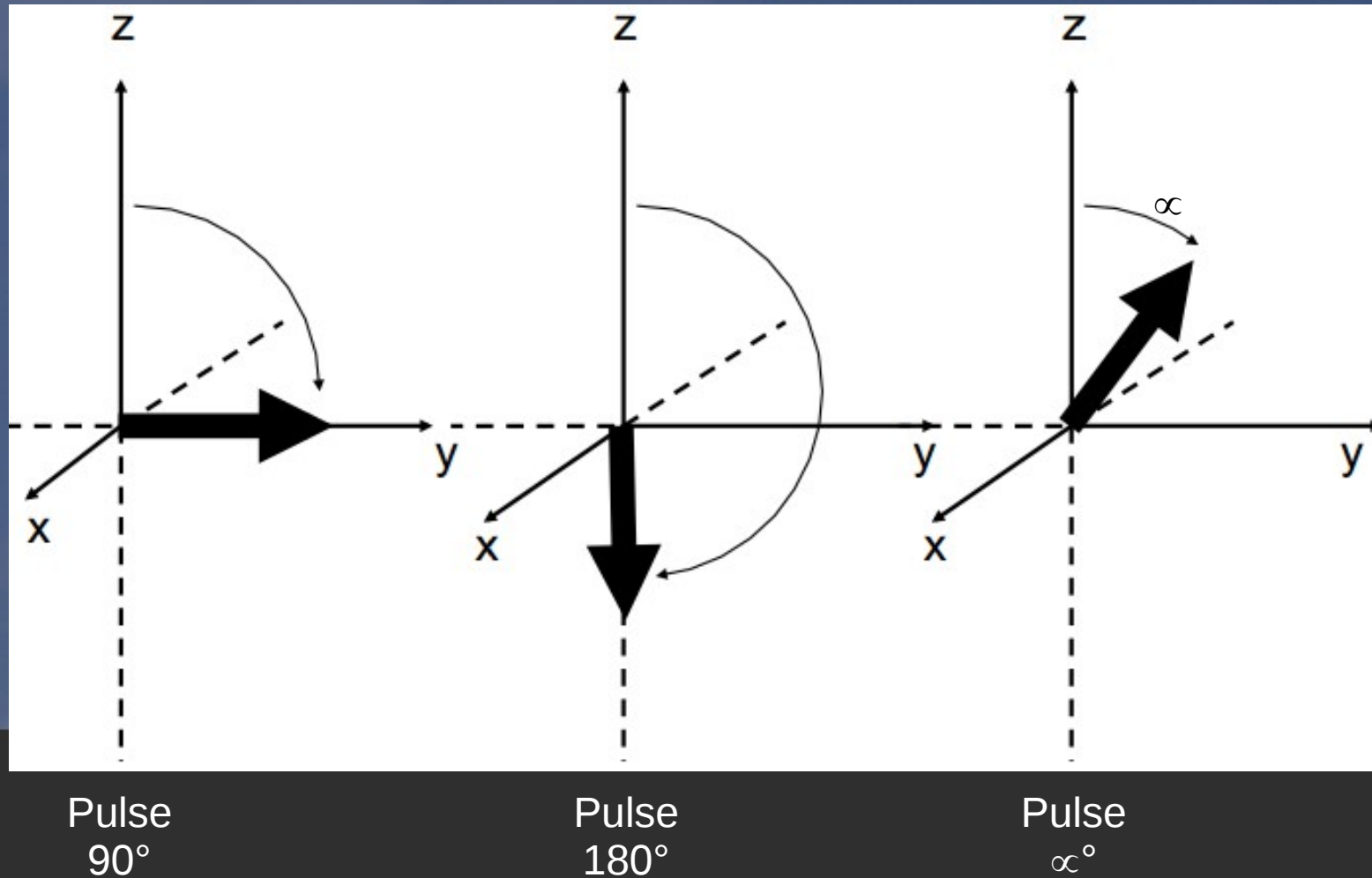
- Apply RF pulse in Resonance with protons of H^1

$$\omega = \frac{\gamma}{2\pi} \cdot B$$



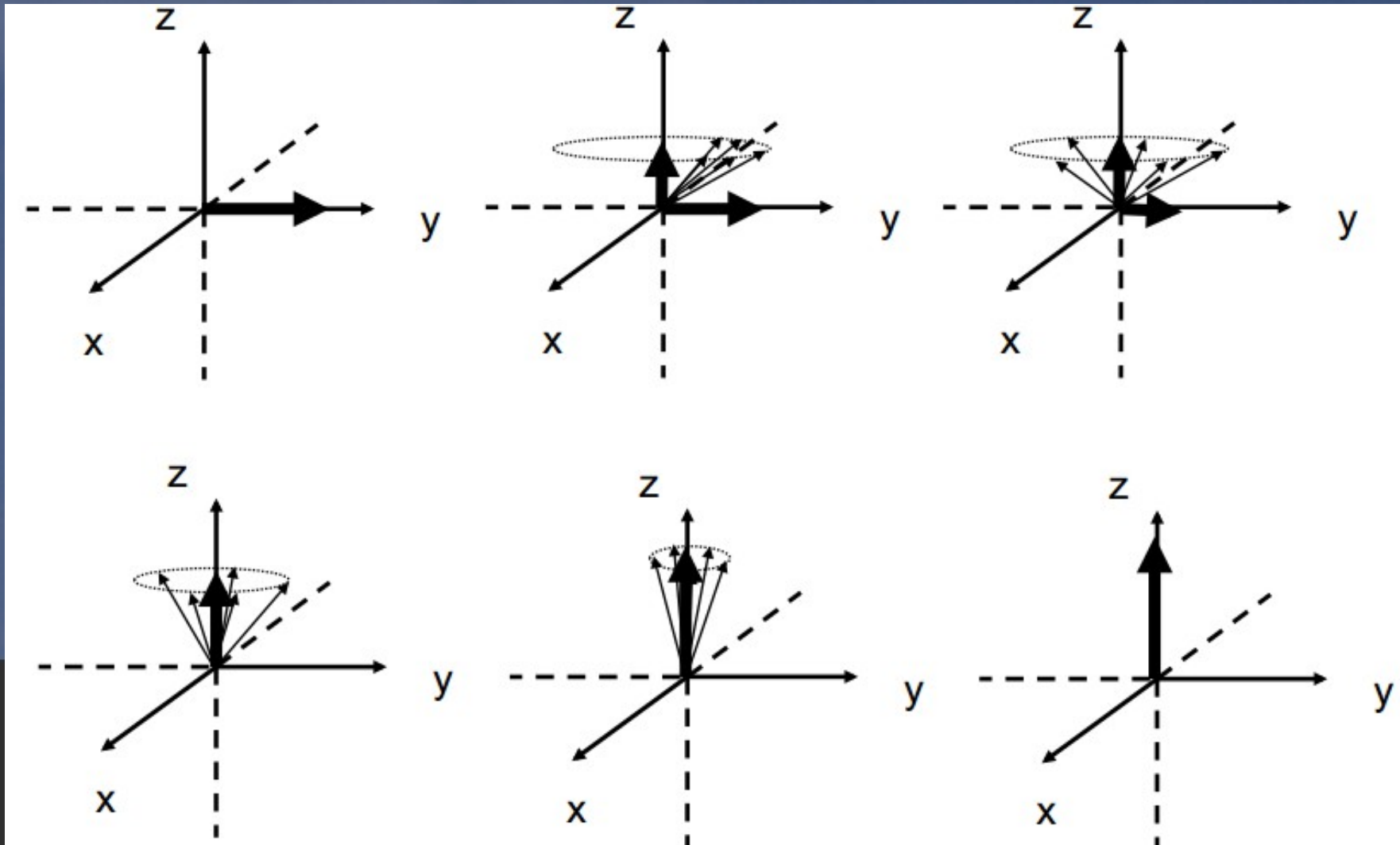
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- RF pulses:



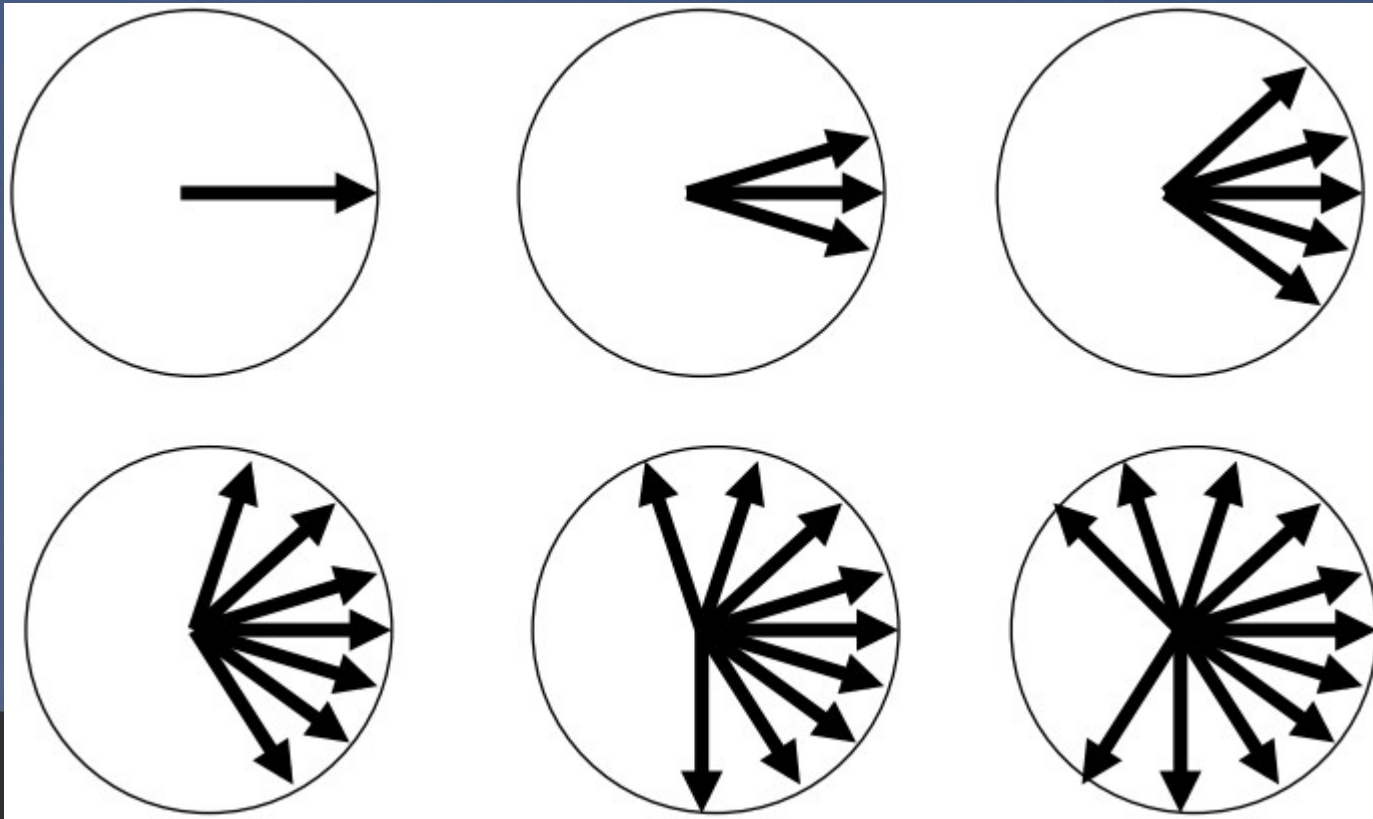
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- T1, T2 and T2*:



MR Images

- Superior Vision:

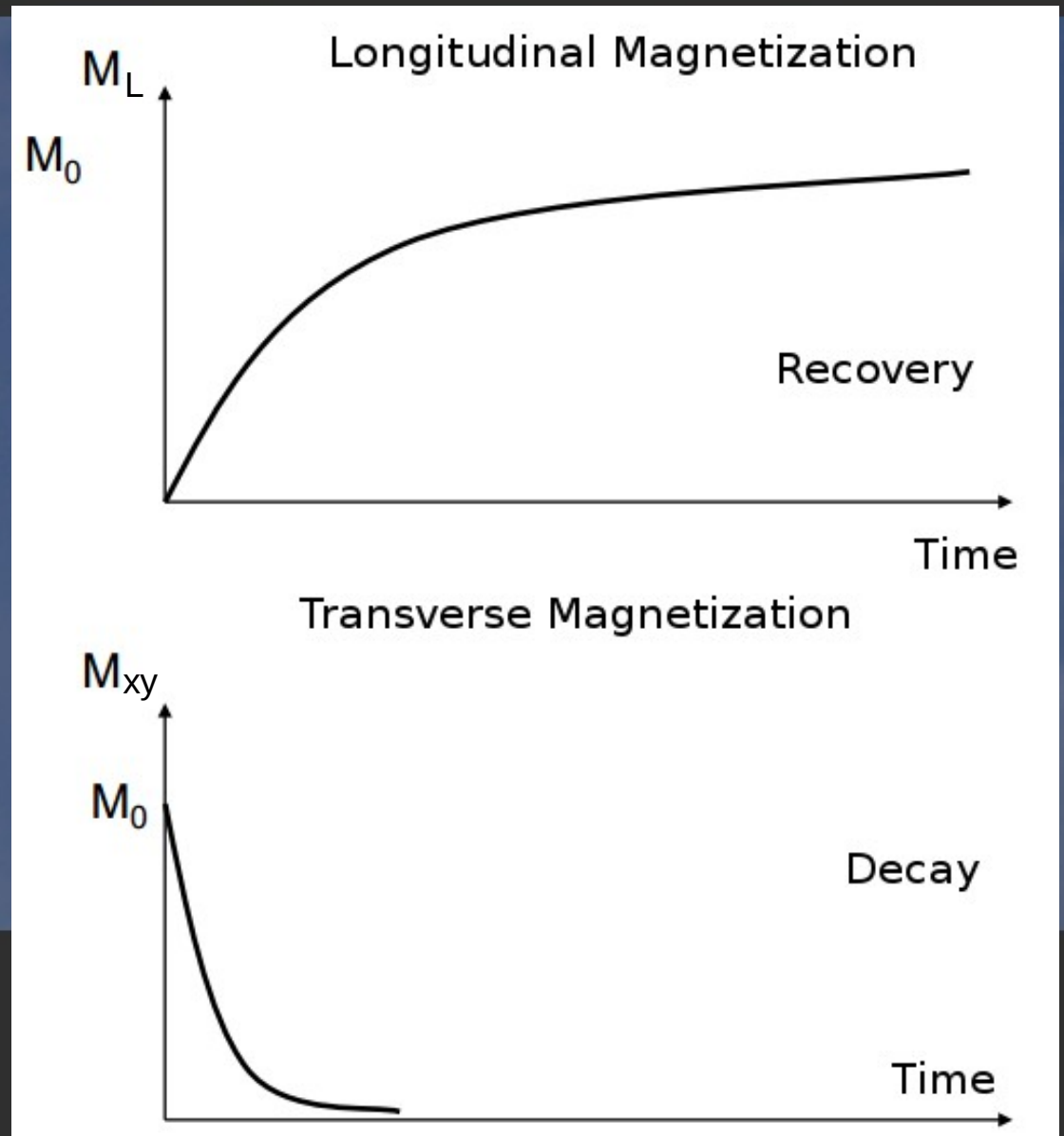
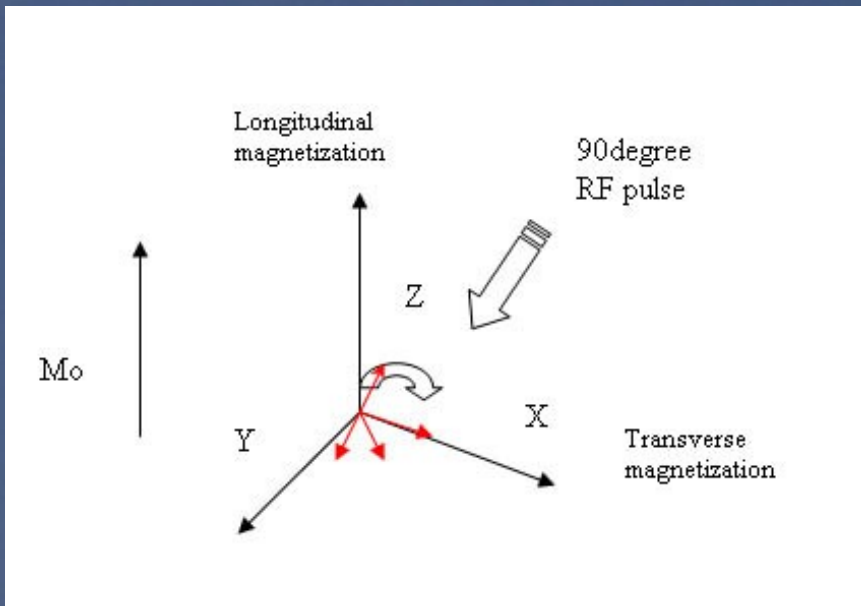


H in water

H in Fat

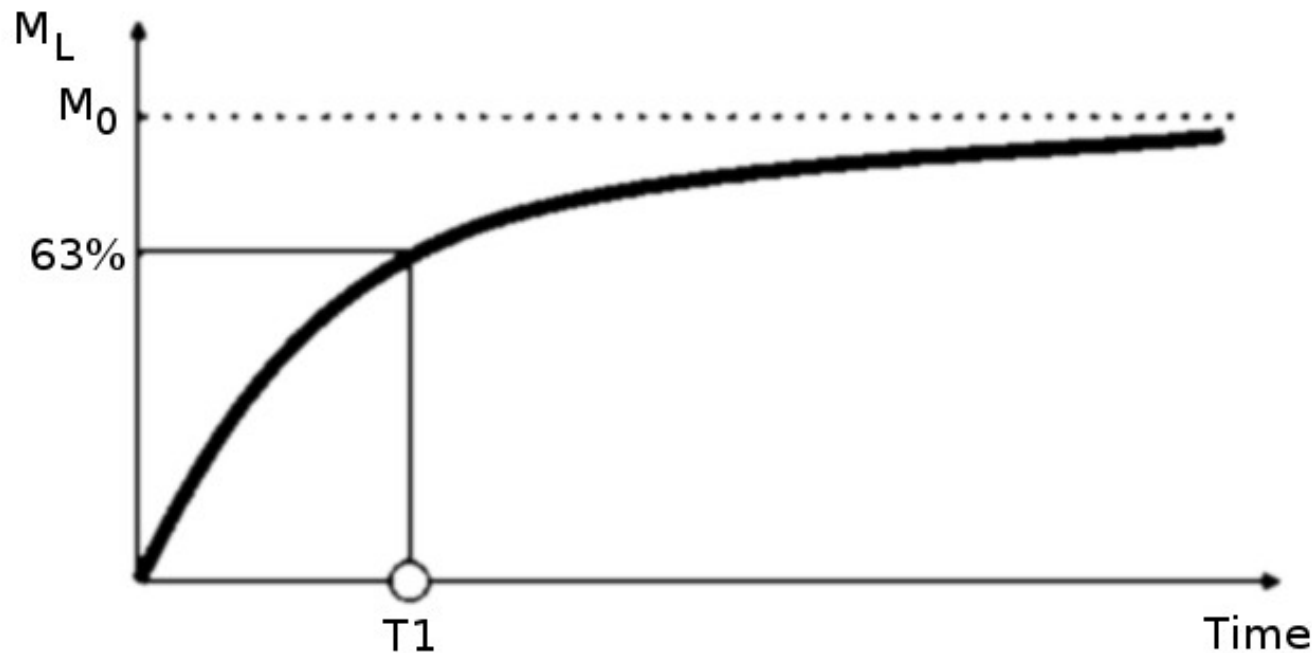
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- Planes:



MR Images

- T1:
 - Longitudinal Recovery or Spin-Net;
 - Necessary time to M_L reach 63% of M_0

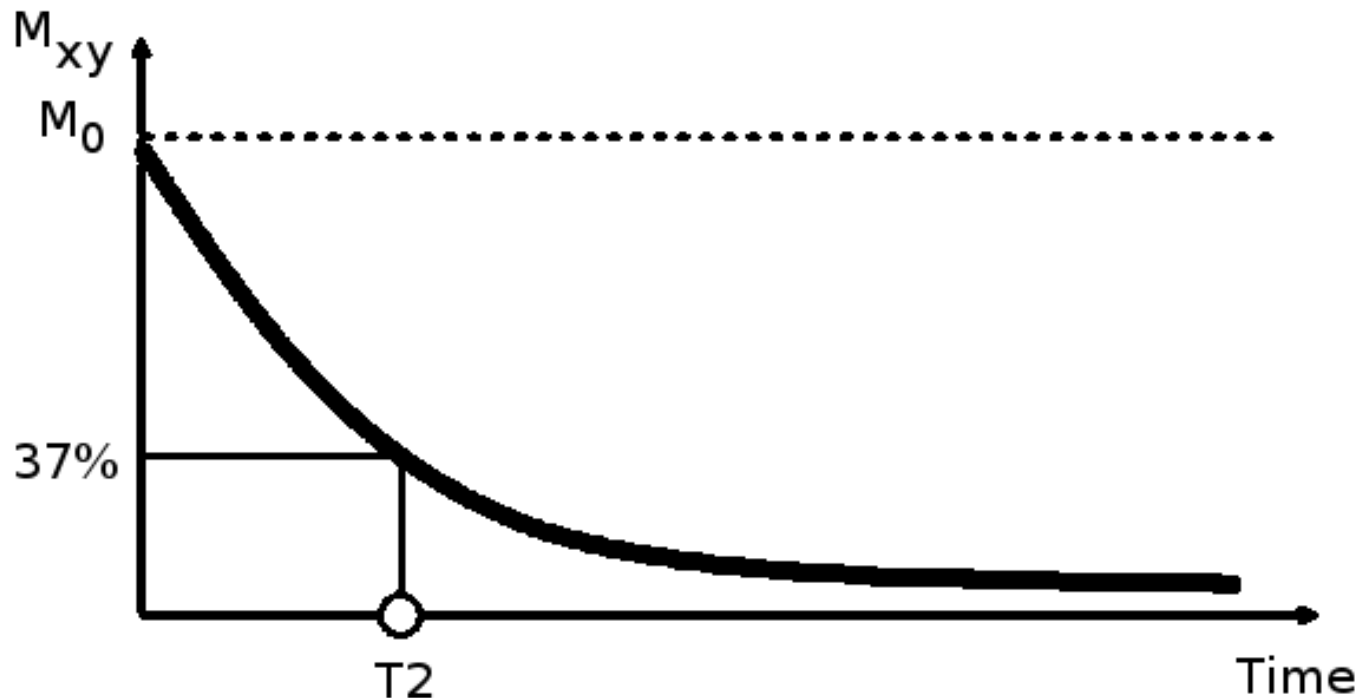


$$M_z = M_L = M_0 \cdot (1 - e^{-\frac{t}{T1}})$$

Relaxation Time $T1 = 1/T1$

MR Images

- T2:
 - Transversal Decay or Spin-Spin;
 - Necessary time to M_T decreases 37% of M_0

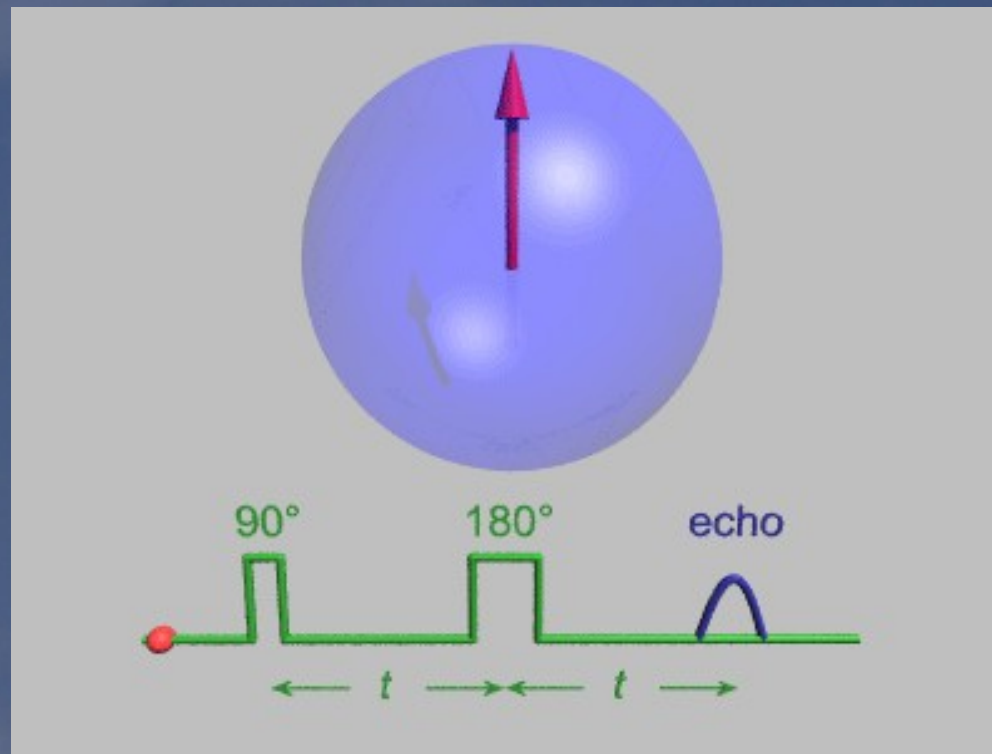


$$M_{xy} = M_T = M_0 \cdot e^{-\frac{t}{T_2}}$$

Relaxation Time $T_2 = 1/T_2$

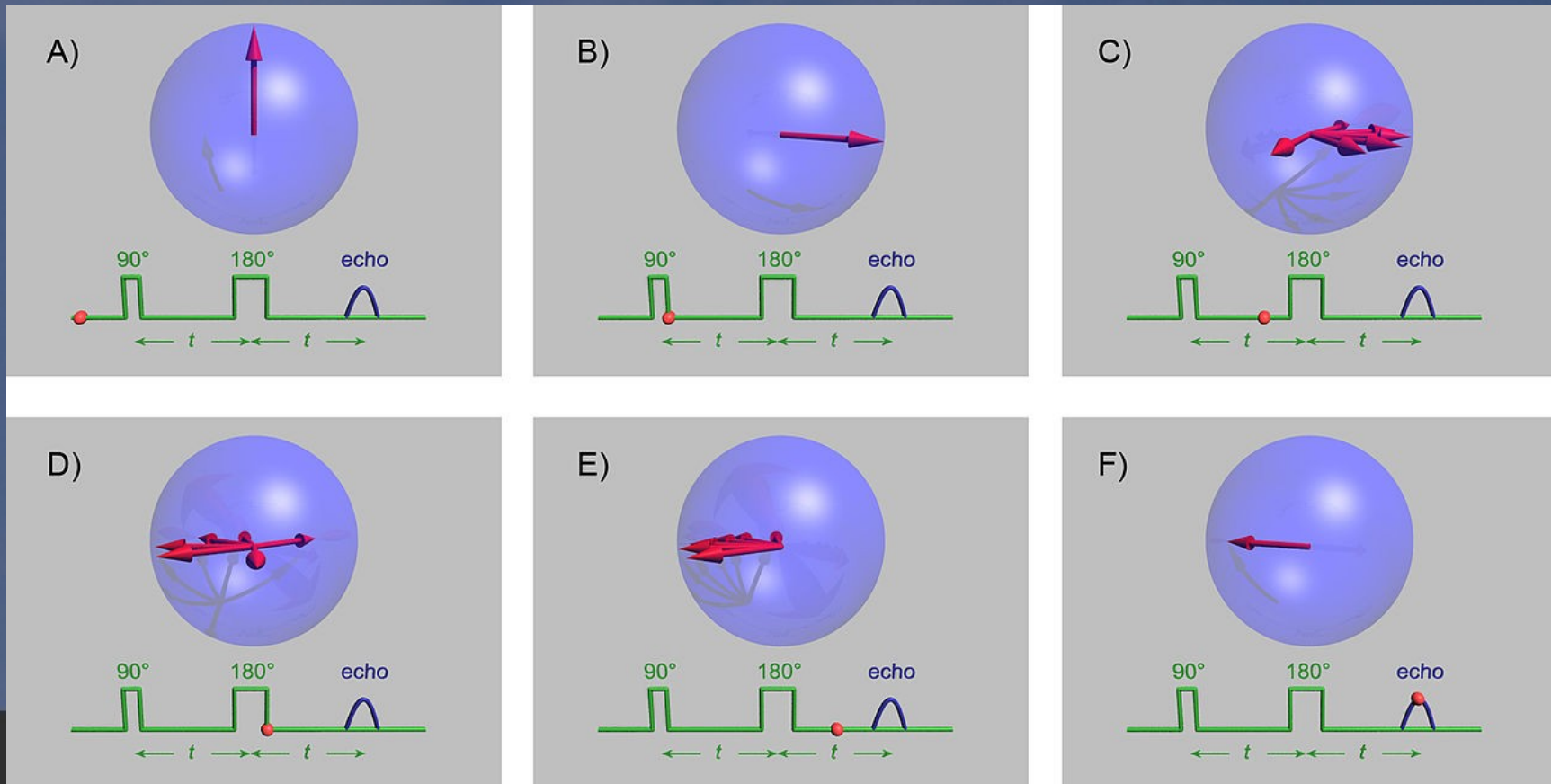
MR Images

- Spin Echo sequence:



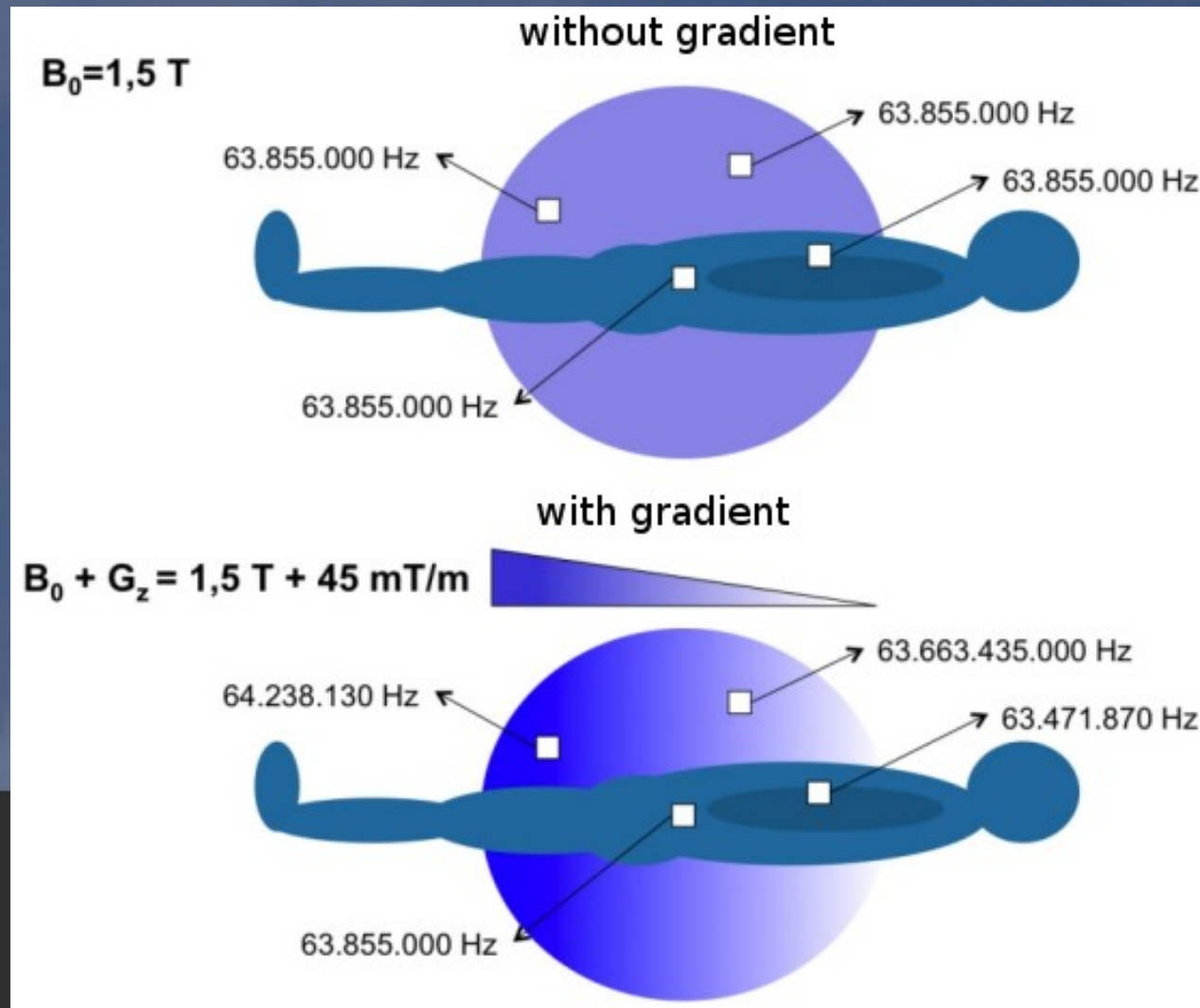
MR Images

- Spin Echo sequence:



MR Images

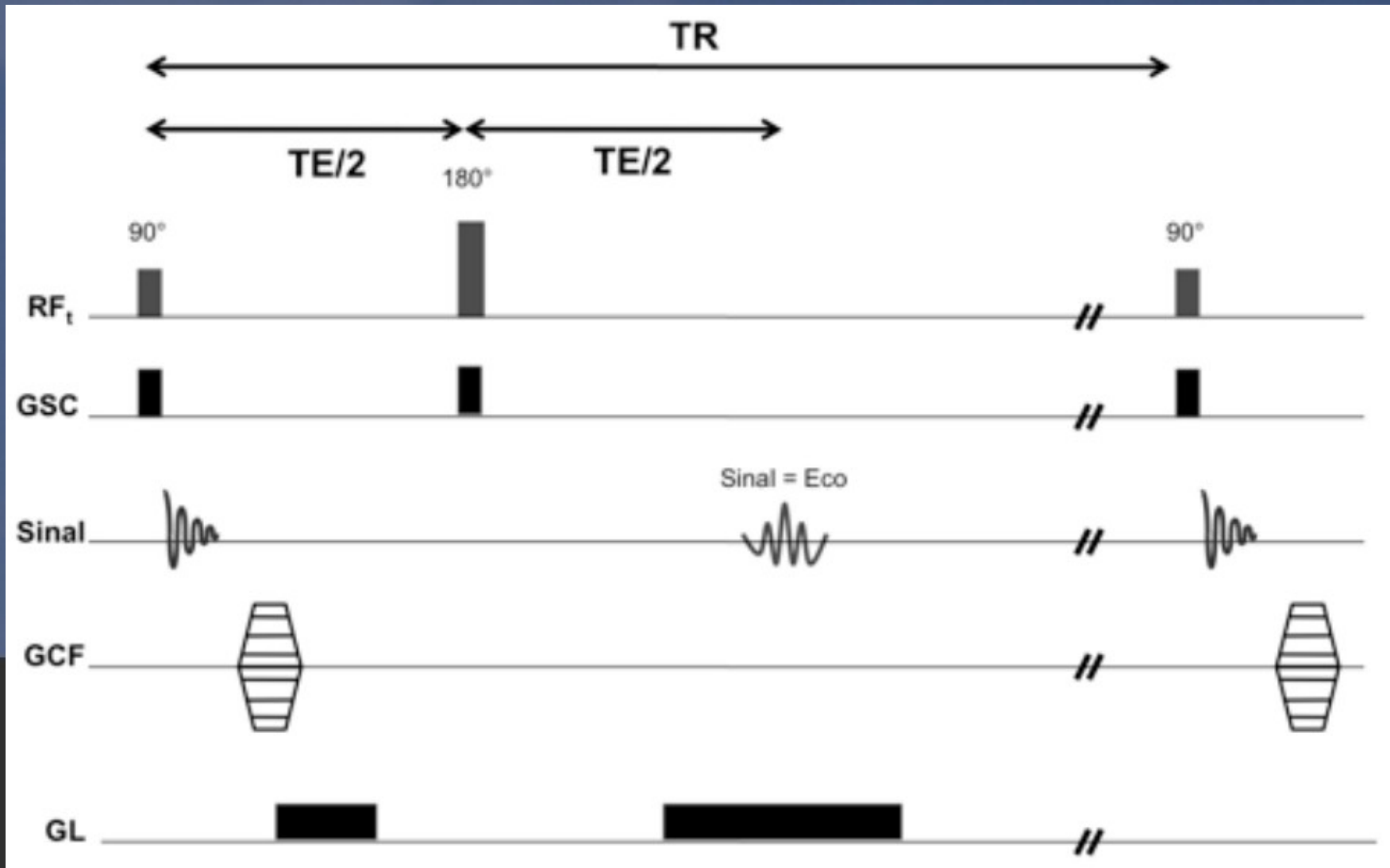
- Gradients:



MR Images

- Spin Echo sequence:

TR = Repetition time
TE = Echo time

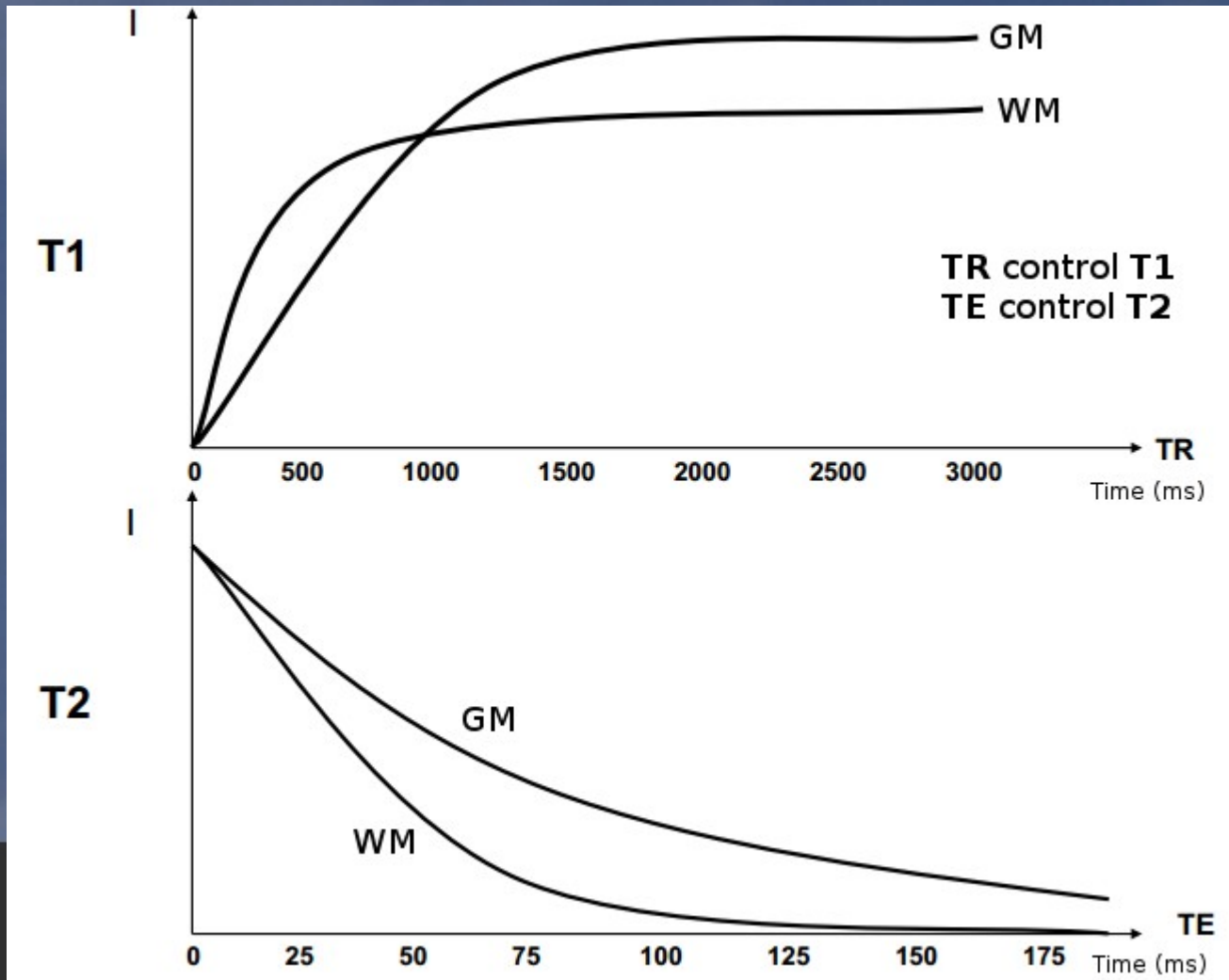


MR Images

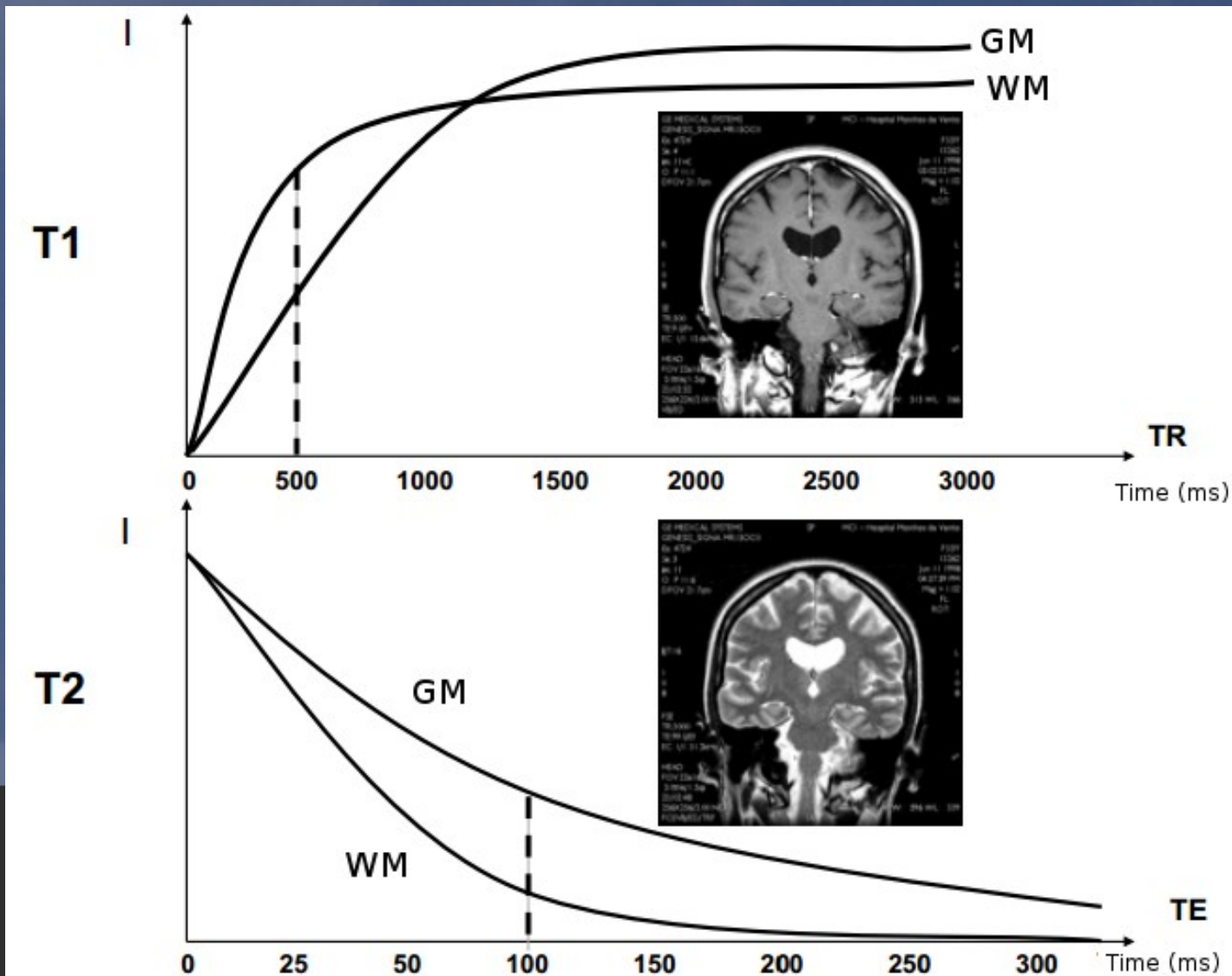
- Relaxation time 1.5T:

Tissue	T1 (ms)	T2(ms)
Gray Matter	1000	70
White Matter	750	60
Fat	260	80
Muscle	850	45
CSF	2500	200
Pure Water	3000	3000

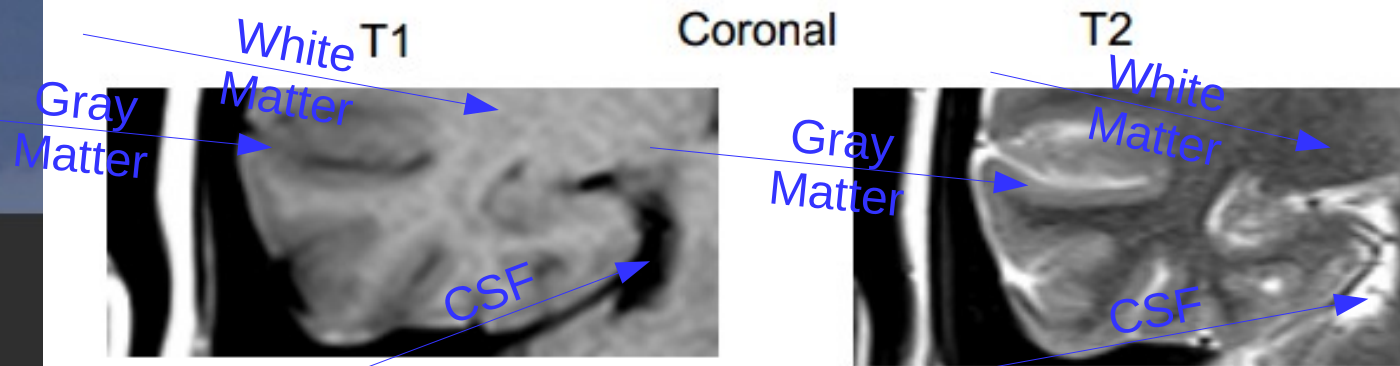
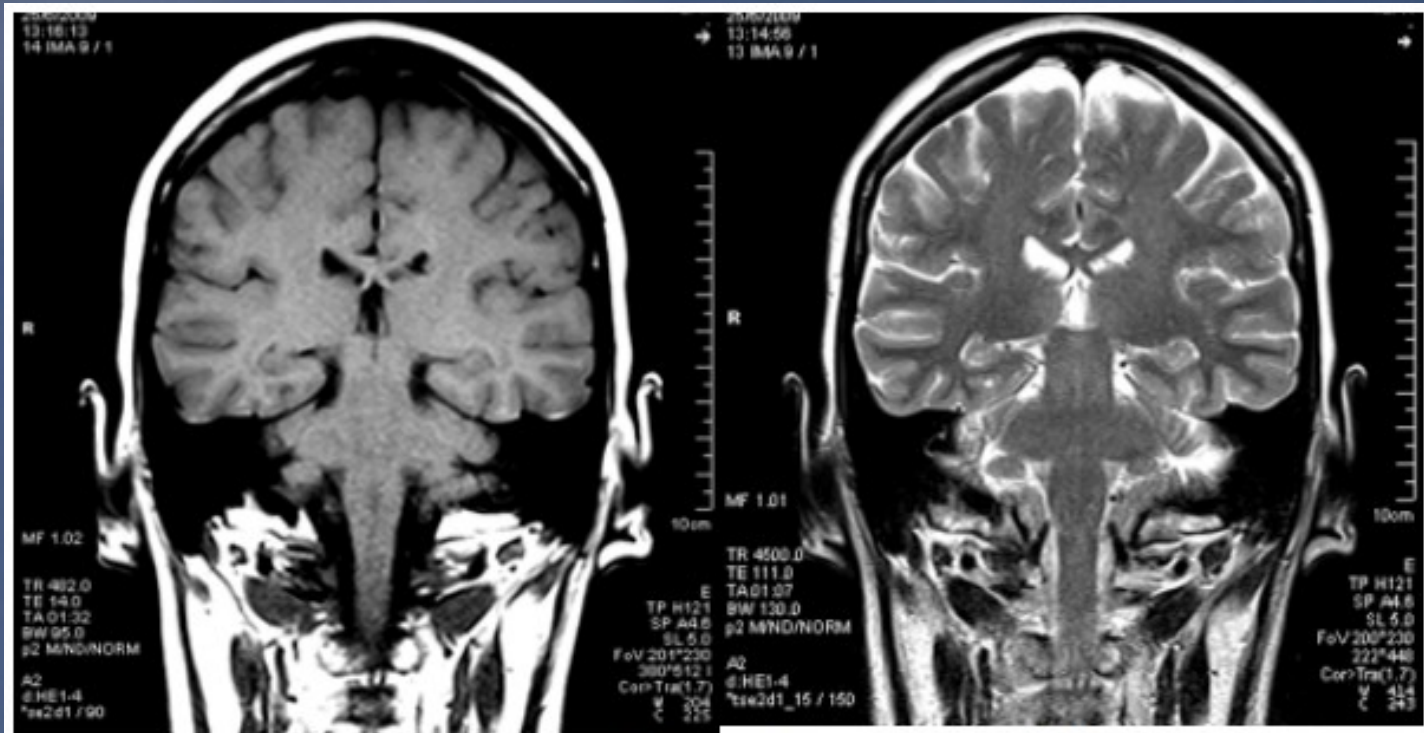
MR Images



MR Images



MR Images

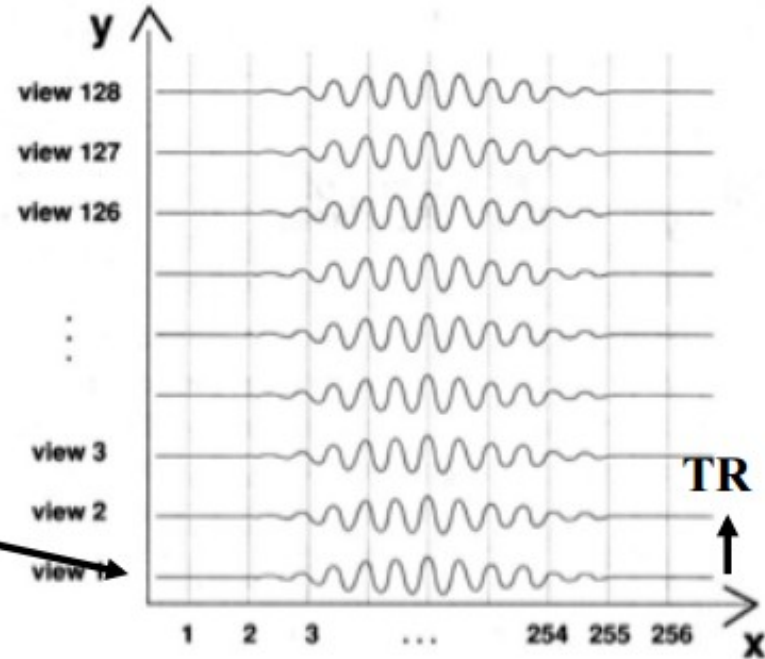
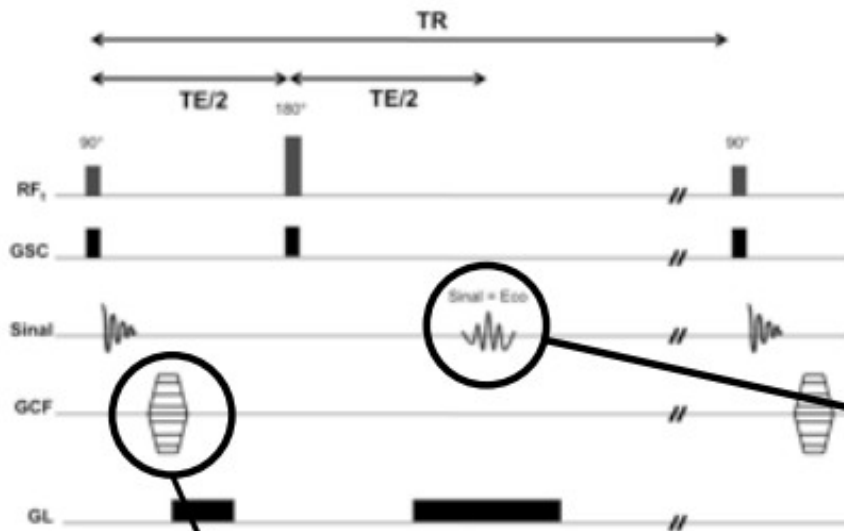


MR Images

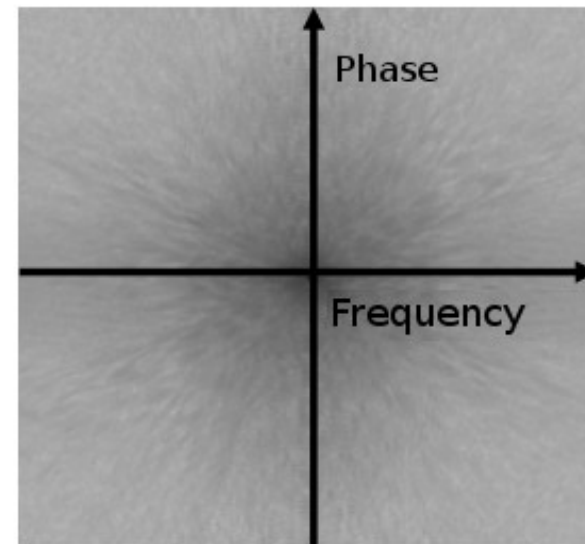
- K-space:
 - Spatial Frequency Domain;
 - Represent spin density distribution in two dimensions;
 - Phase encoding per line;

MR Images

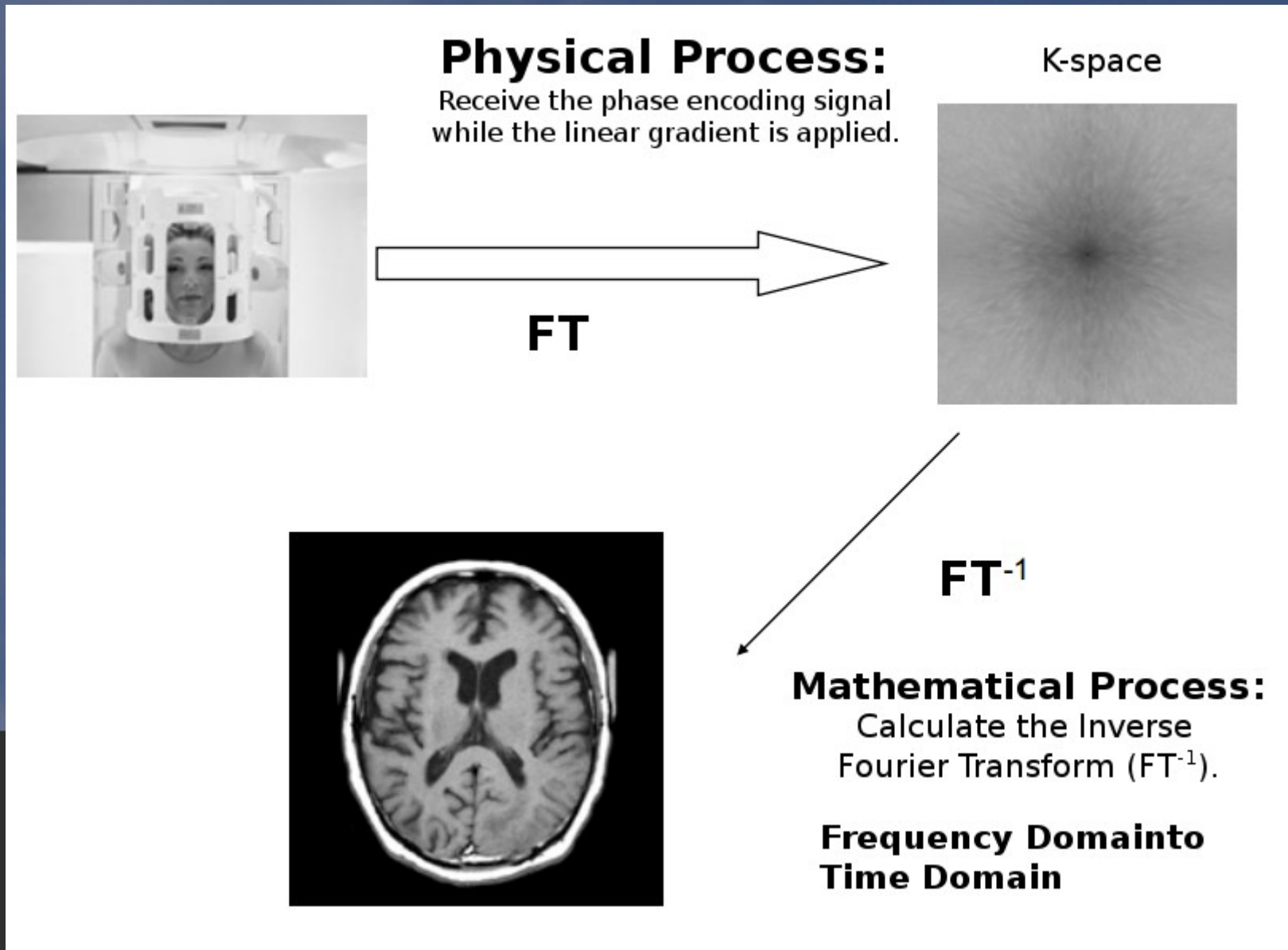
K-space



To each phase encoding is filled one line of K-space

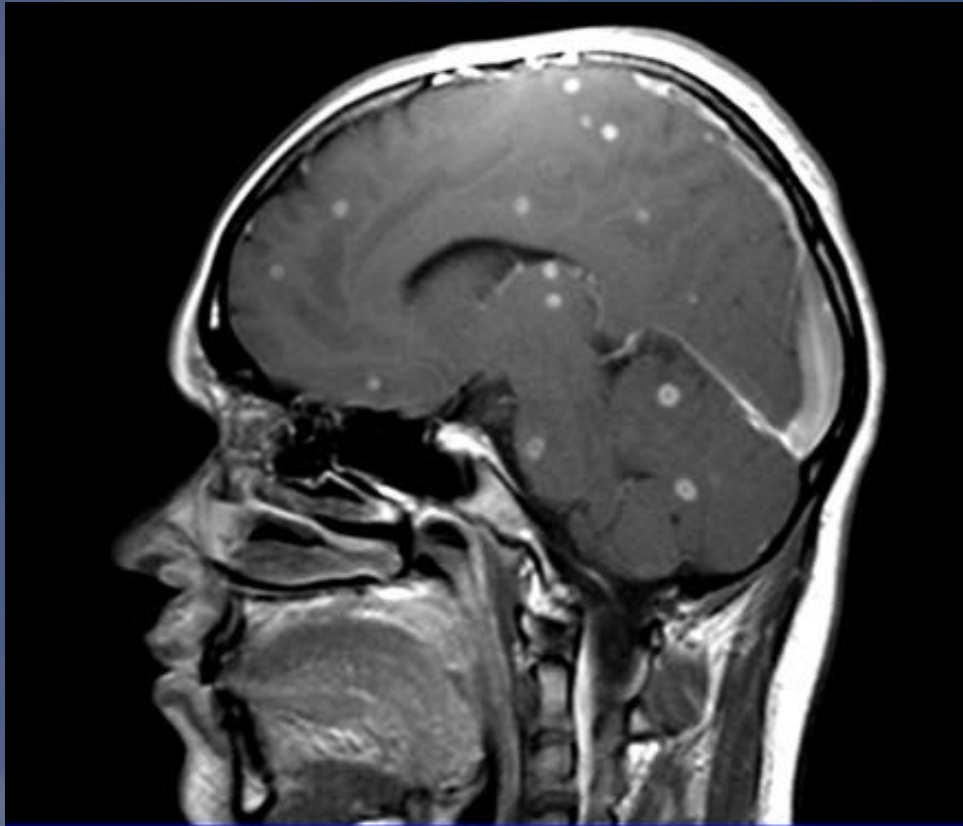


MR Images



MR Images

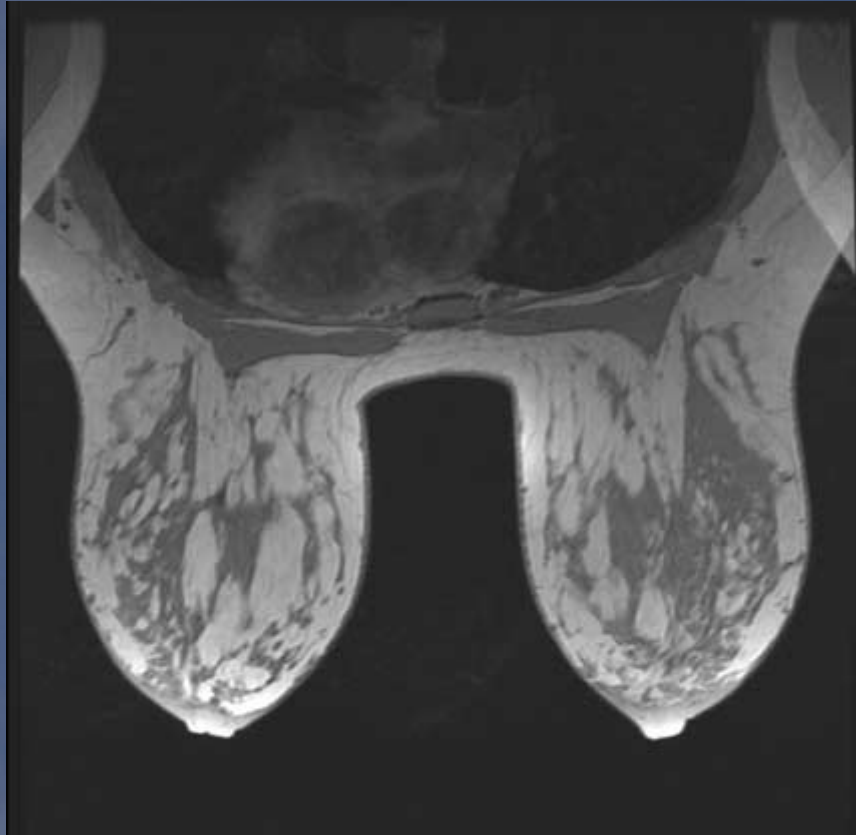
- Examples:



Tuberculomas VS Coccidioidomycosis: a 23-year old patient suffers from severe headache with no other signs or symptoms. An MRI scan of the brain with gadolinium enhancement was performed. The longstanding nature of the complaint argues against a diagnosis of metastatic cancer.

MR Images

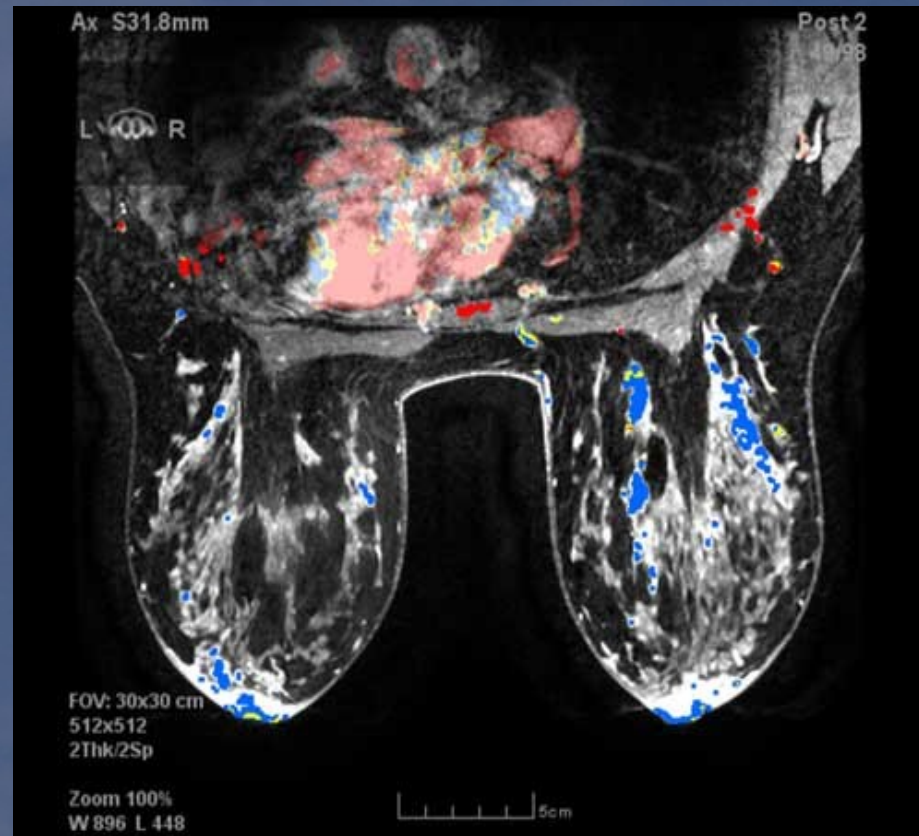
- Examples:



High-resolution MR image of both breasts provides anatomic detail.

MR Images

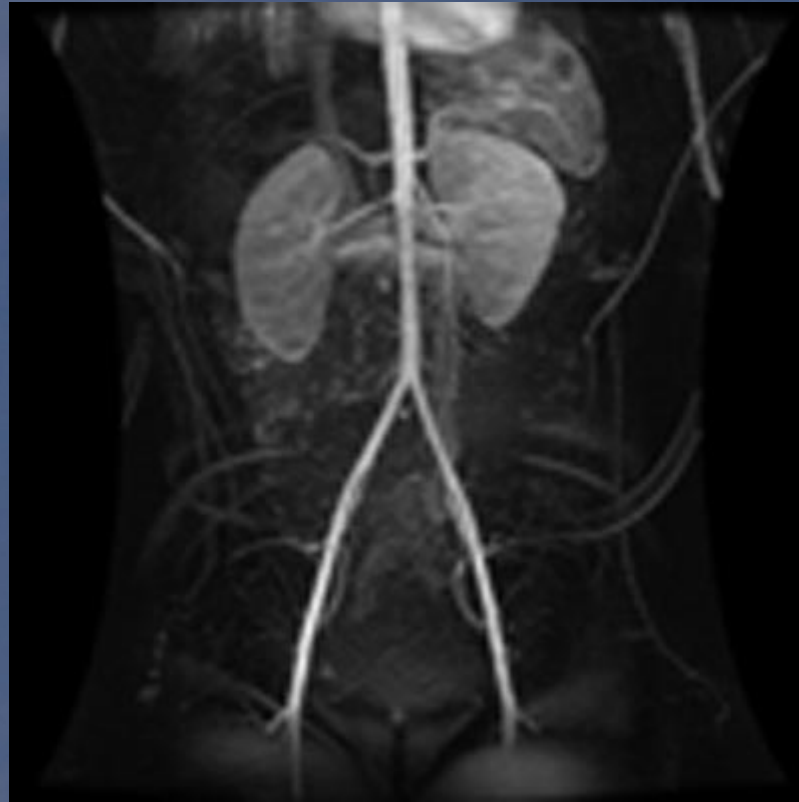
- Examples:



An MR image of two breasts demonstrating vascular supply.

MR Images

- Examples:



This image shows a magnetic resonance angiogram of the abdominal and pelvic vessels of a child.

MR Images

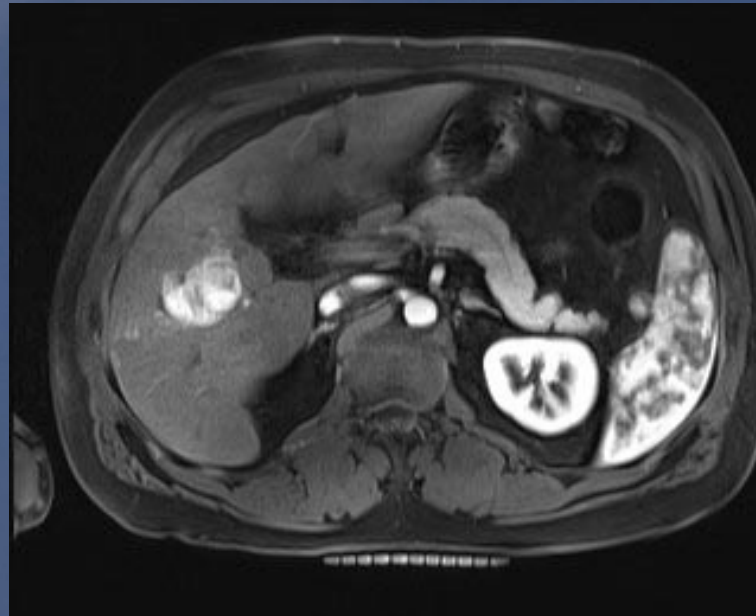
- Examples:



A horizontal tear of the posterior part of the meniscus of the knee.

MR Images

- Examples:



An MRI scan of the abdomen shows a brightly enhanced lesion in the liver which is a hepatocellular carcinoma.

MR Images

- References:

- <http://www.radiologyinfo.org/>
- http://rle.dainf.ct.utfpr.edu.br/hipermidia/images/documentos/Principios_fisicos_da_ressonancia_magnetica.pdf
- <http://rle.dainf.ct.utfpr.edu.br/hipermidia/index.php/ressonancia-magnetica/principios-fisicos-resso>
- Google.com