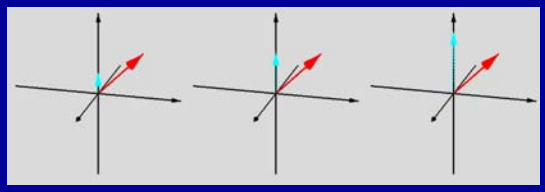
Spins in a Magnetic Field



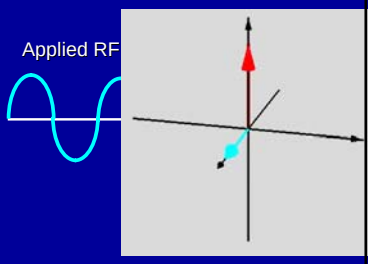
Three “spins” with different applied magnetic fields.

Excitation

Try this: Apply a magnetic field ($\mathbf{B}_1$) rotating at $\omega_0 = \gamma \mathbf{B}_0$ in the plane perpendicular to $\mathbf{B}_0$

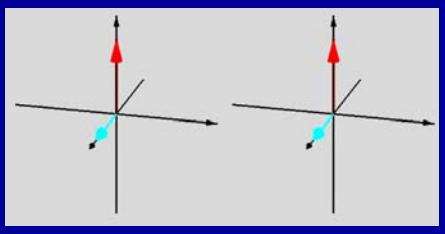
➔

Magnetization will tip into transverse plane



Rotating Frame of Reference

It is much easier to see the rotation of the magnetization around the B1 field by rotating the frame of reference at the rotation rate of the RF pulse



Lab Frame Rotating Frame

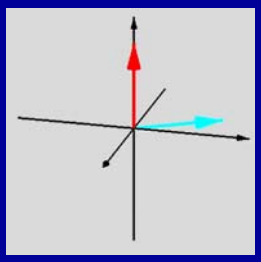
Resonance Phenomena

- Excitation in MRI works when you apply magnetic fields at the “resonance” frequency.

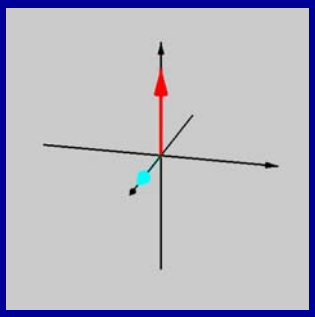
- Conversely, excitation does not work when you excite at the incorrect frequency.

Off-Resonance Excitation

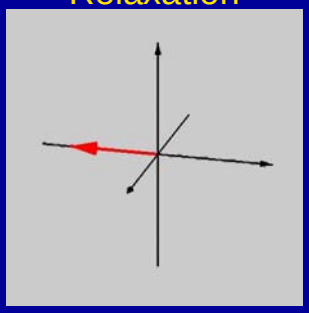
- Excitation only works when $\mathbf{B}_1$ field is applied at $\omega_0 = \gamma \mathbf{B}_0$ (wrong ΔE)
- This will allows us the select particular groups of spins to excite (e.g. slices, water or fat, etc.)



Excitation



Relaxation



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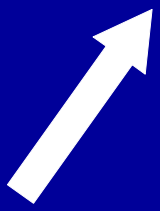
Resting State

U. Michigan - Noll

Excitation

U. Michigan - Noll

Excitation



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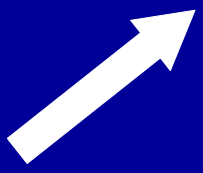
Excitation



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Excitation

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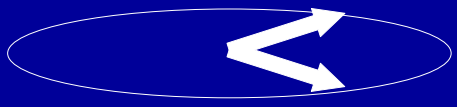
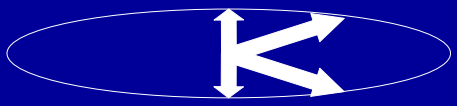
Excitation

Excitation

T_2 Relaxation

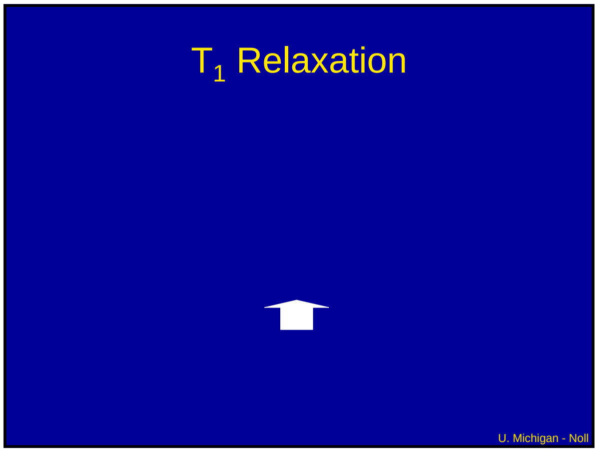


T_2 Relaxation



T_2 Relaxation

T_2 Relaxation


T_1 Relaxation
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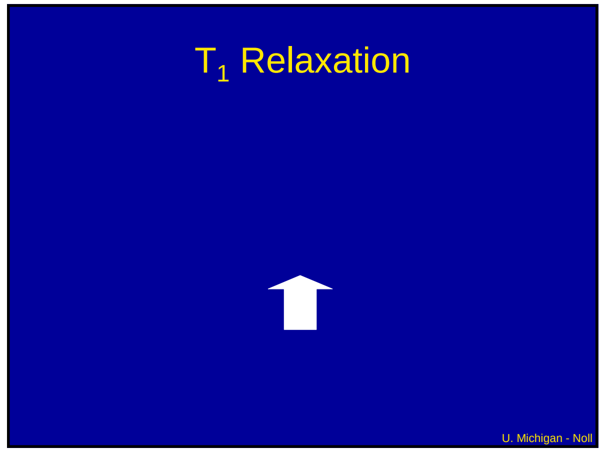
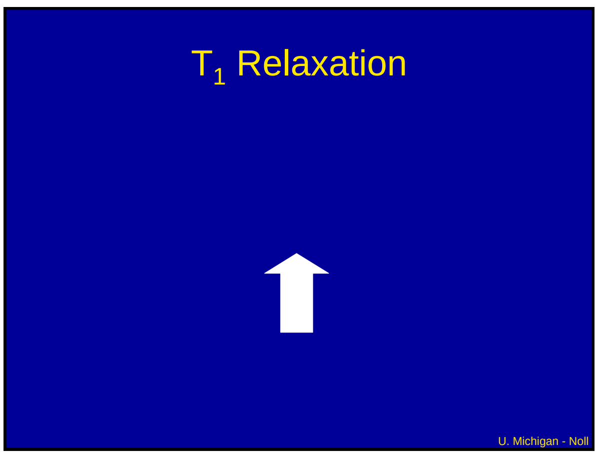

T_1 Relaxation
U. Michigan - Noll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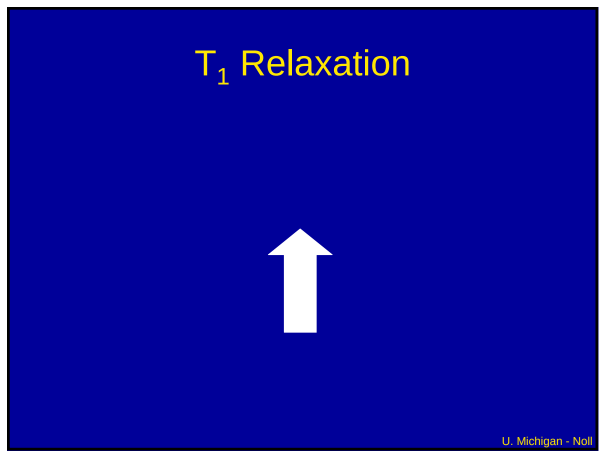
U. Michigan - Noll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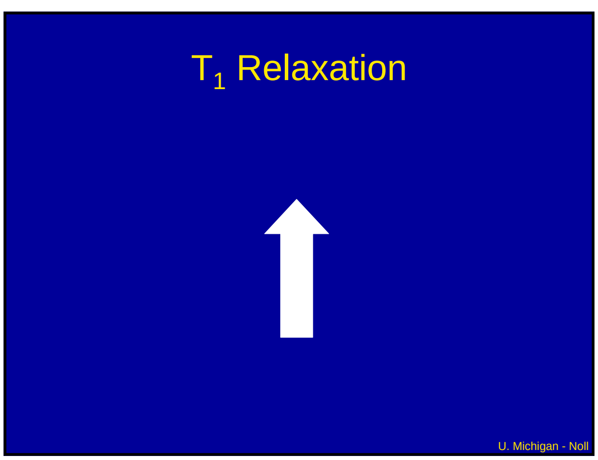
U. Michigan - Noll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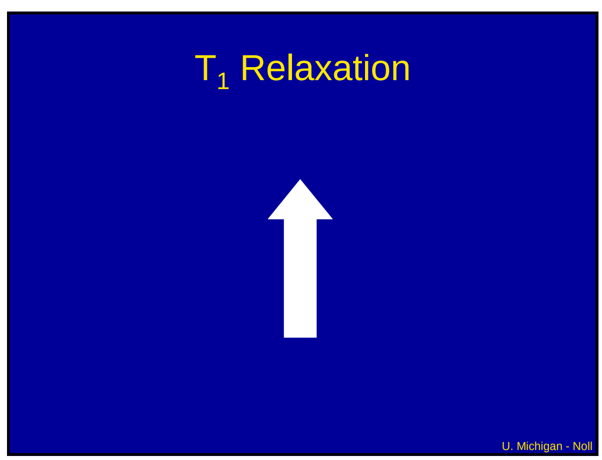
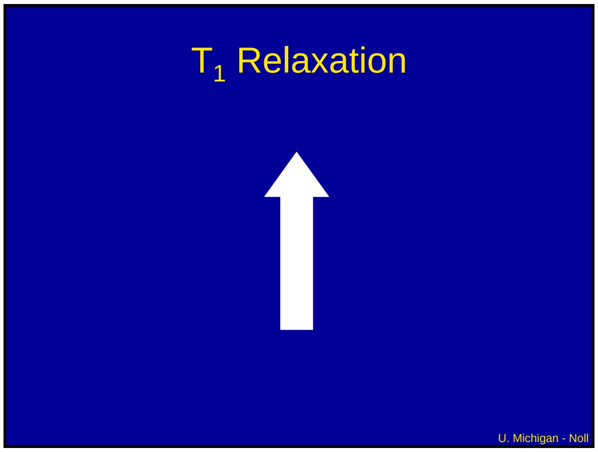
U. Michigan - Noll


T_1 Relaxation
U. Michigan - Noll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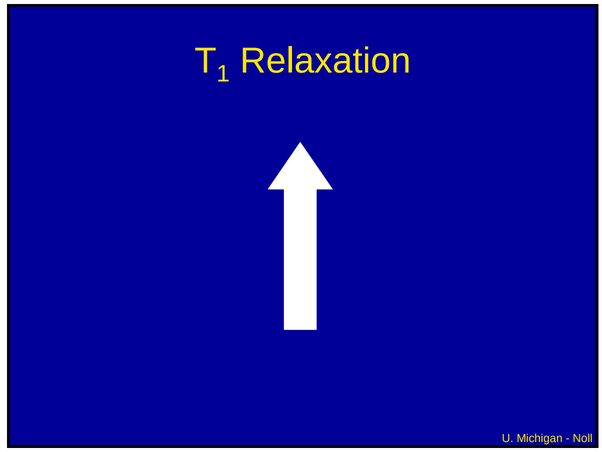
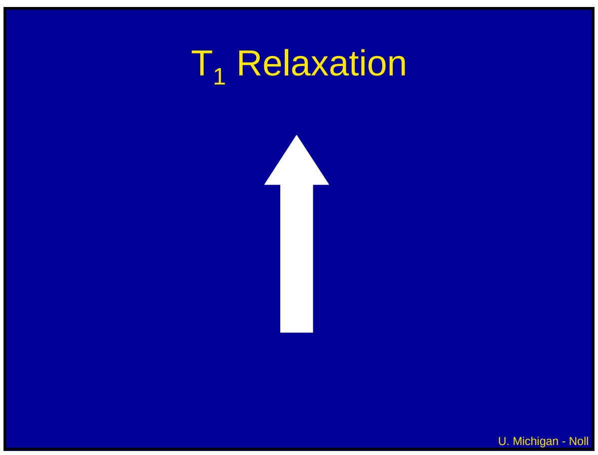
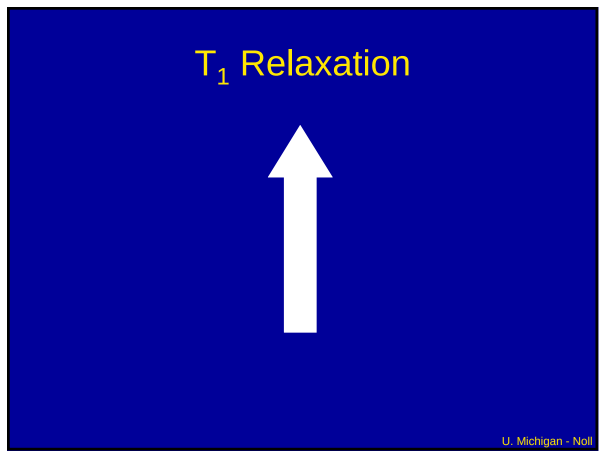
U. Michigan - Noll


T_1 Relaxation
U. Michigan - Noll


T_1 Relaxation
U. Michigan - Noll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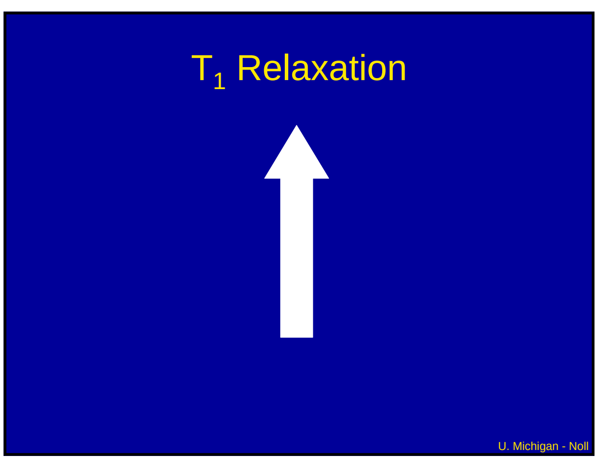
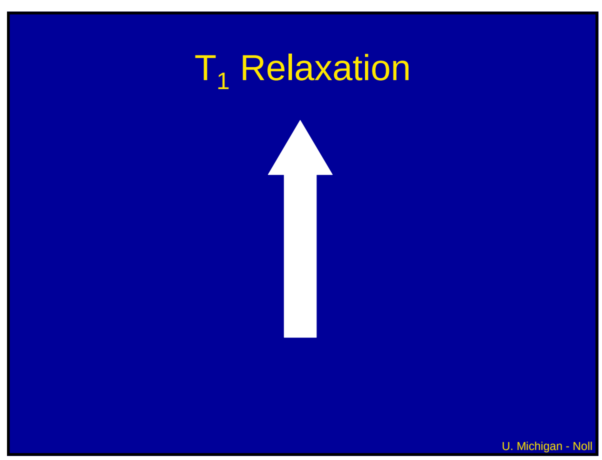
U. Michigan - Noll


T_1 Relaxation
U. Michigan - Noll


T_1 Relaxation
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T_1 Relaxation

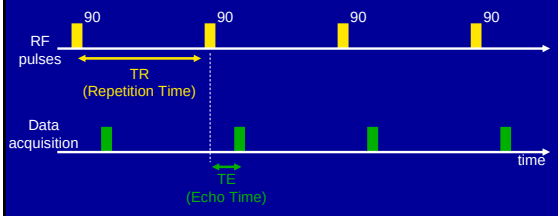
T_1 Relaxation

Typical T_1's, T_2's, and Relative "Spin Density" for Brain Tissue at 3.0 T

	T_1 (ms)	T_2 (ms)	ρ_R
Distilled Water	3000	3000	1
CSF	3000	300	1
Gray matter	1330	110	0.95
White matter	830	80	0.8
Fat	150	35	1

The Pulsed MR Experiment

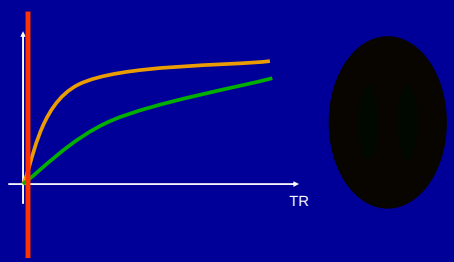
- MRI uses a repeated excitation pulse experimental strategy



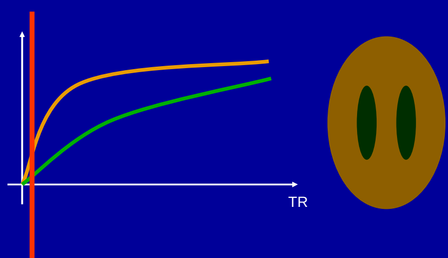
Contrast

- TR mainly controls T1 contrast
  - Excitation or flip angle also contributes
- TE mainly controls T2 contrast

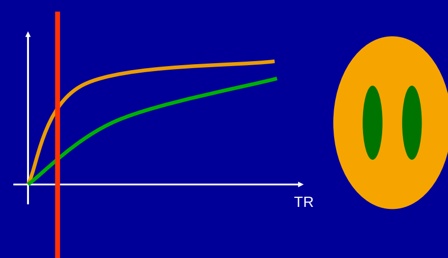
T1 Contrast and TR



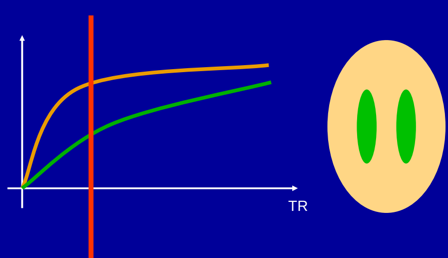
T1 Contrast and TR



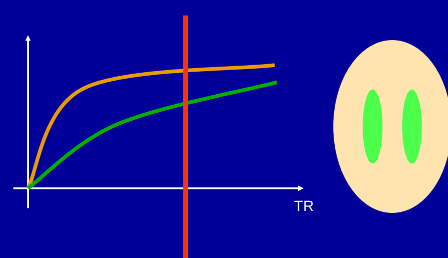
T1 Contrast and TR



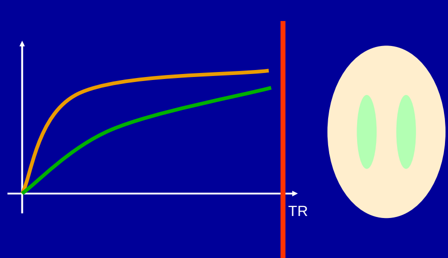
T1 Contrast and TR



T1 Contrast and TR

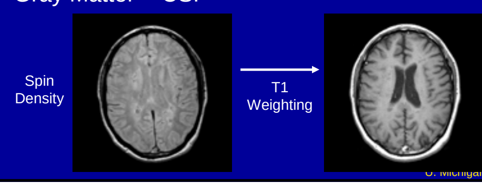


T1 Contrast and TR

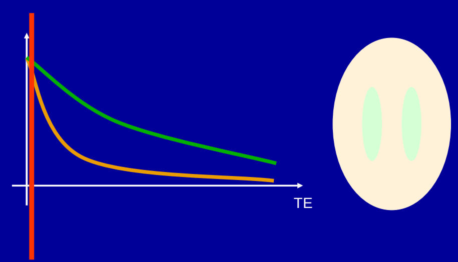


T1 Contrast

- For short TR imaging, tissues with short T1's (rapidly recovering) are brightest
  - Fat > brain tissue
  - White Matter > Grey Matter
  - Gray Matter > CSF



T2 Contrast and TE



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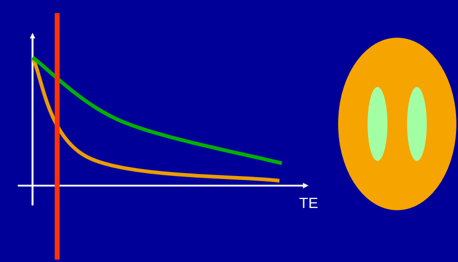
T2 Contrast and TE



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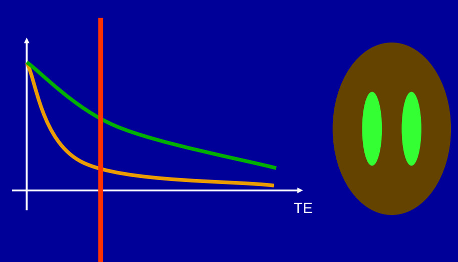
T2 Contrast and TE



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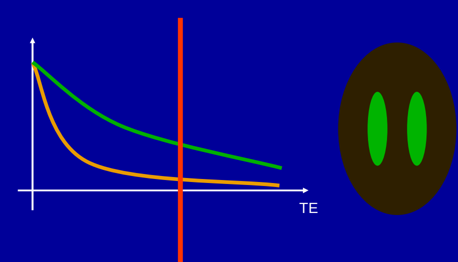
T2 Contrast and TE



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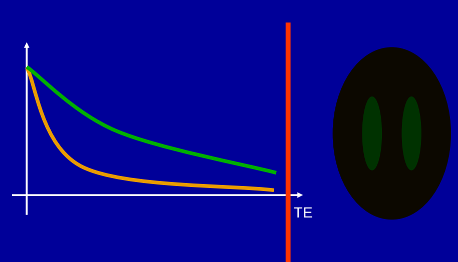
T2 Contrast and TE



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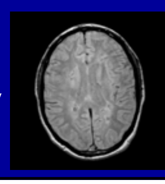
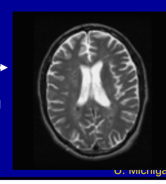
T2 Contrast

- For long TE imaging, tissues with short T2's (rapidly recovering) are darkest
  - Fat < brain tissue
  - White Matter < Grey Matter
  - Gray Matter < CSF

Spin Density



T2 Weighting



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Contrast Equation

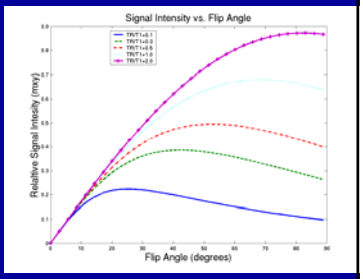
- For a 90 degree flip angle, the contrast equation is:

$$\text{Signal} \propto \rho(1 - e^{-TR/T1})e^{-TE/T2}$$

Can the flip angle be less than 90?

- Of course, but the contrast equation is more complicated.
- Flip angle can be chose to maximize signal strength:

  Ernst Angle

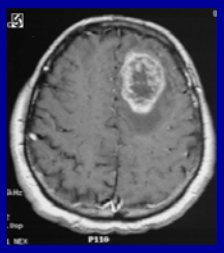


Next Step

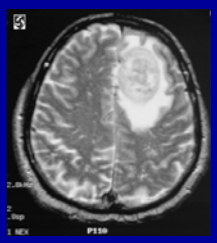
Making an image!!

First – some examples of MR Images and Contrast

Supratentorial Brain Neoplasm



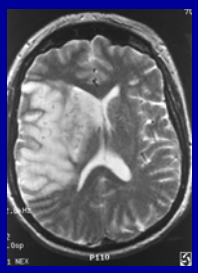
T1-weighted image with contrast



T2-weighted image

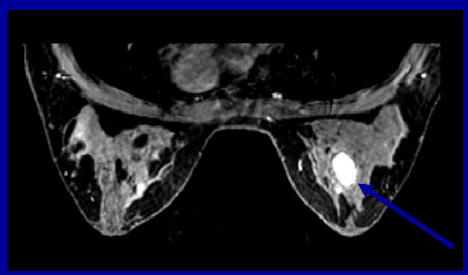
Cerebral Infarction

MR Angiogram

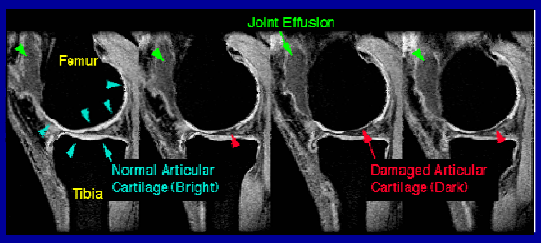


T2-weighted image

Imaging Breast Cancer



Imaging Joints



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Imaging Air Passages

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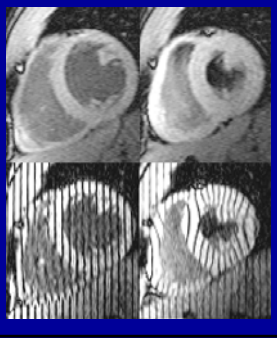
Tagging Cardiac Motion



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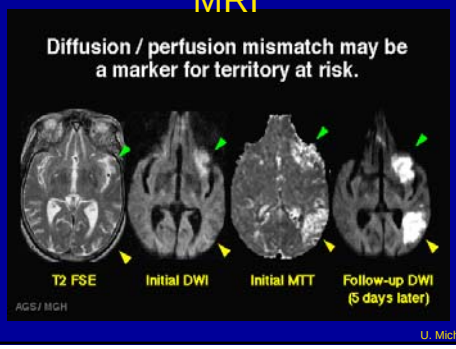
Diffusion and Perfusion Weighted MRI



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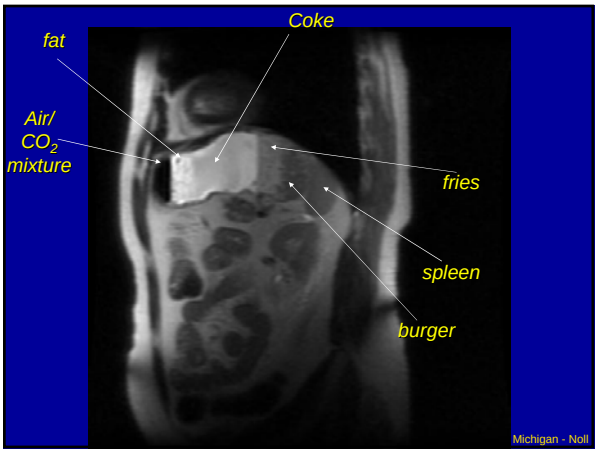

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