Lec 14
(Spin echo and contrast in MRI images)

Recap: Measuring T_2 from FID is difficult

- FID decays with T_2^* time constant.

$$\frac{1}{T_2^*} = \frac{1}{T_2'} + \frac{1}{T_2}$$

Inhomogeneous mag. field (property of MR set-up)

spin-spin interaction

Recap: Dephasing of magnetization ("pure" T_2 effect)

- Each spin sees a slightly different magnetic field.
- Magnetization for each spin packet rotates at its own Larmor frequency.
- Net magnetization starts to dephase.
- Vector sum of transverse component is zero when totally dephased.

"Inhomogeneous" T_2-relaxation

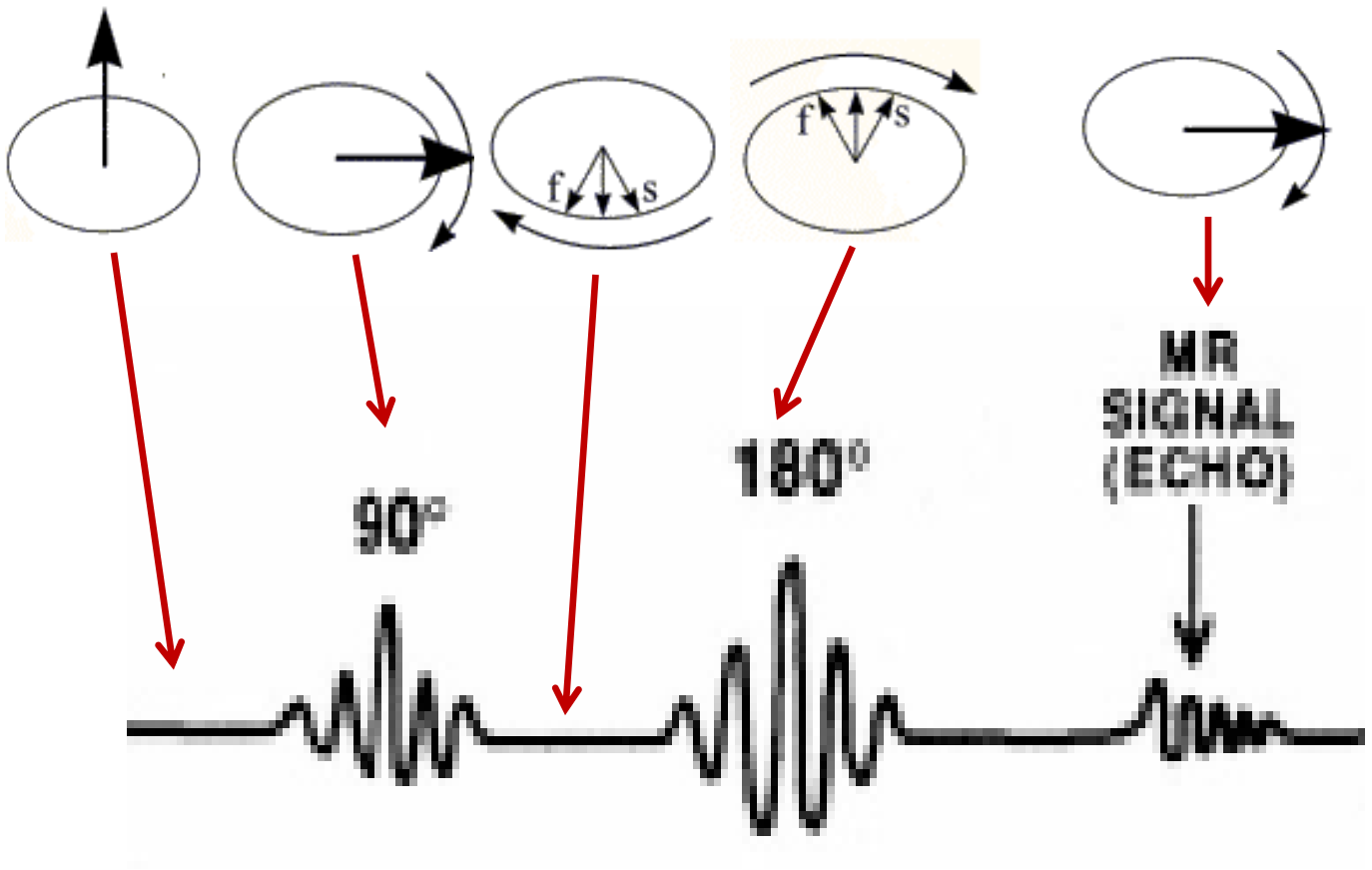
$$\frac{1}{T_2^*} = \frac{1}{T_2'} + \frac{1}{T_2}$$

Inhomogeneous mag. field (property of MR set-up)

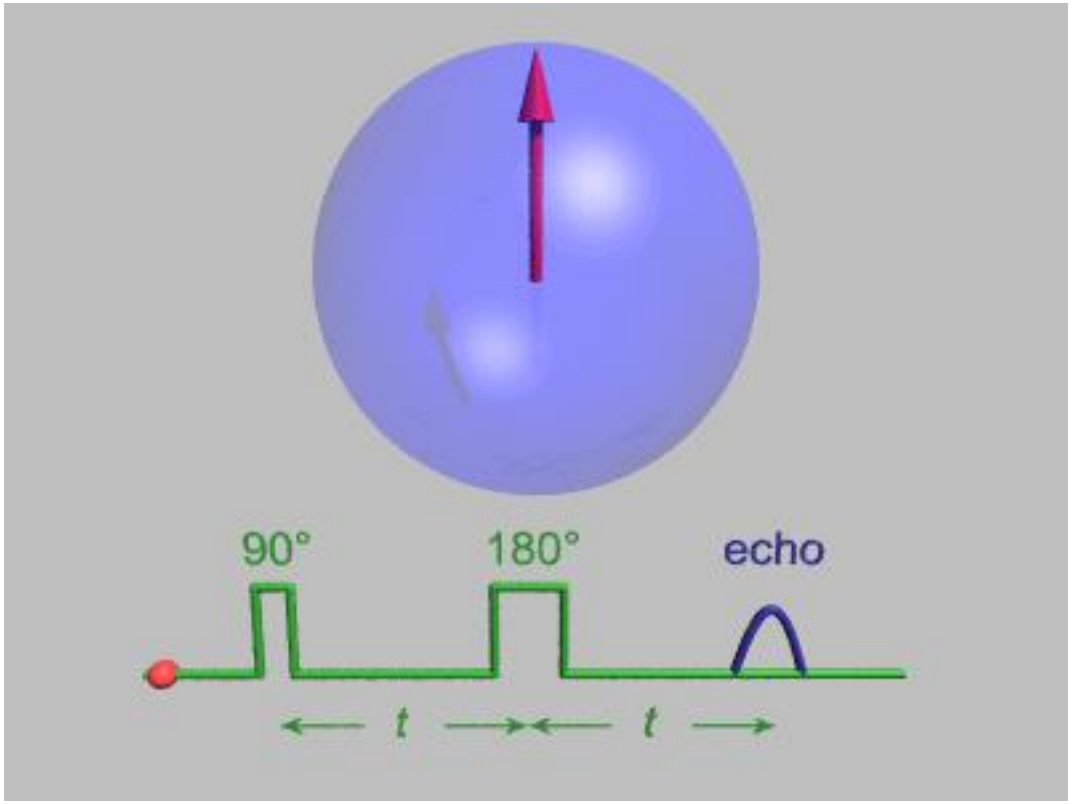
spin-spin interaction

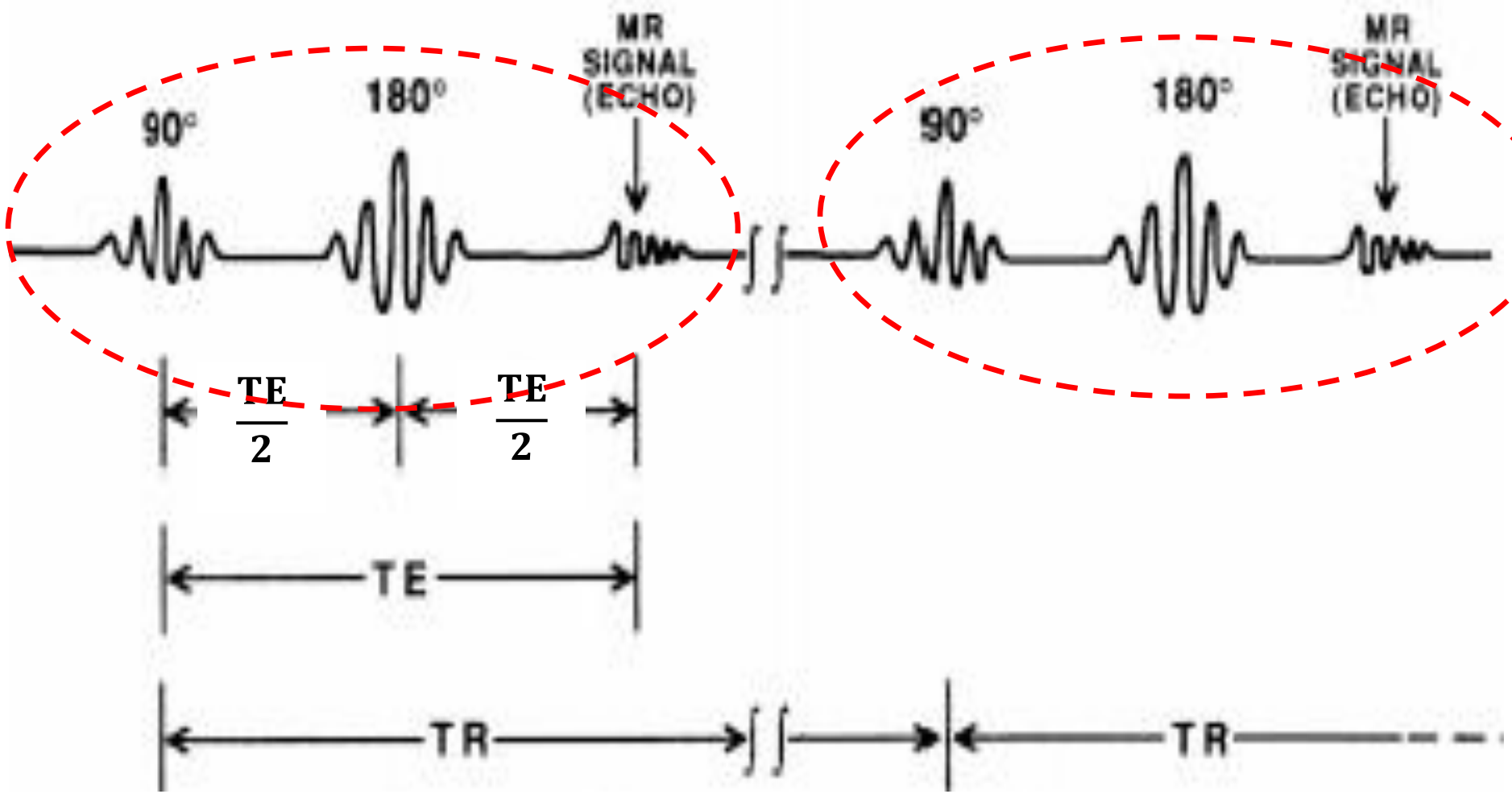
- Magnet design
- Different magnetic susceptibilities (e.g. near surgical implant, at tissue boundaries with different magnetic properties, etc.).

Spin echo measures T_2



Spin debunching happens due to T_2^+ processes (field inhomogeneities)


90°
180°
echo
t
t



- **TE** is echo time and **TR** is repetition time

Repetition time and echo time

These times are chosen by the experimenter.

- **TR** is the length of the relaxation time between two excitation ($\pi/2$) pulses.

- **TE** is the time interval between the excitation pulse ($\pi/2$) and measurement of MR signal.

T_1, T_2 are tissue properties. We do not choose them.

T_1 and T_2 of tissues

- Different tissues have different values of T_1 and T_2.
- Diseased tissues have different T_1 and T_2 compared to healthy tissues.
- T_1 and T_2 are not related.

T_1, T_2 (milliseconds) of tissues

Tissue	T_1 (@ 1.5T)	T_1 (@ 3T)	T_2 (@ 1.5T)	T_2 (@ 3T)
Brain (white)	790	1100	90	60
Brain (grey)	920	1600	100	80
Liver	500	800	50	40
Skeletal muscle	870	1420	60	30
Lipid (subcutaneous)	290	360	160	130
Cartilage	1060	1240	42	37

What can you infer from this table?

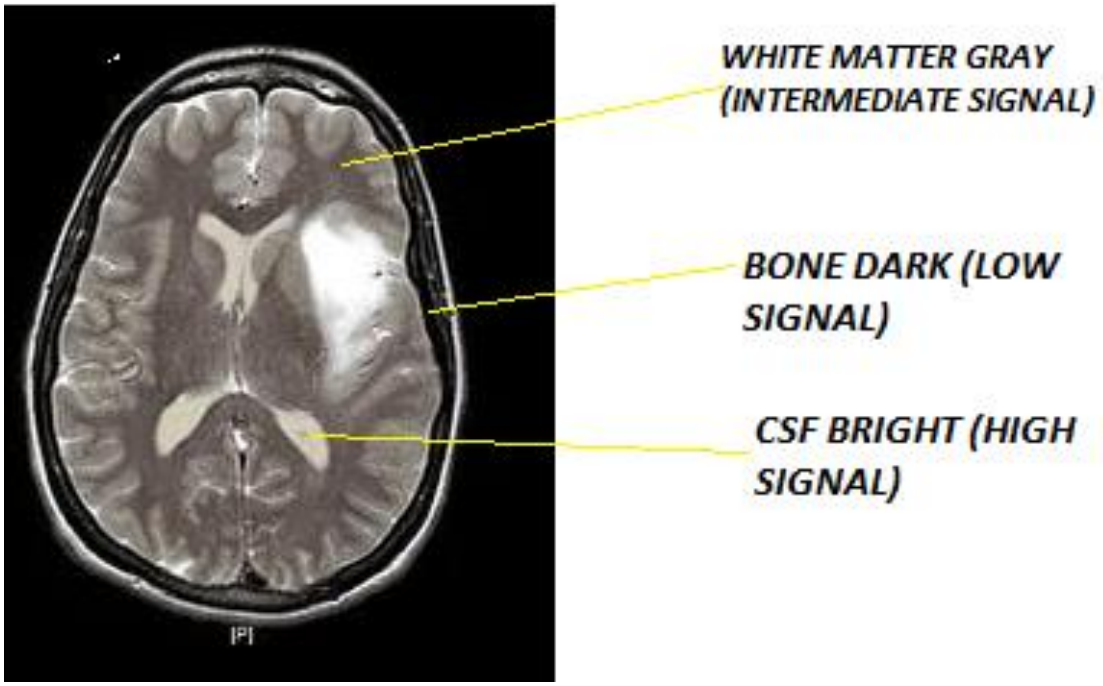
- $T_2 < T_1$. for all tissues
- The values of T_1 and T_2 depend on the magnetic field (B_o).

$$M_0 = \frac{N(\gamma\hbar)^2 B_0}{4kT}$$

T_1, T_2 determine if we can measure signals from a particular tissue

- Can’t measure MRI signals from **bone** .
- Extremely small T_2 (~ 0.01 ms).
- Signal disappears before measurement!

Image contrast



High signal intensity: bright

Low signal intensity: dark

Intermediate signal intensity: gray

Can we exploit T_1 and T_2 of different brain tissues to enhance image contrast?

Tissue	**T_1 (1.5T)**	**T_2 (1.5T)**
White matter	790 ms	90 ms
Grey matter	920 ms	100 ms
CSF	2400 ms	200 ms
Fat	270 ms	80 ms

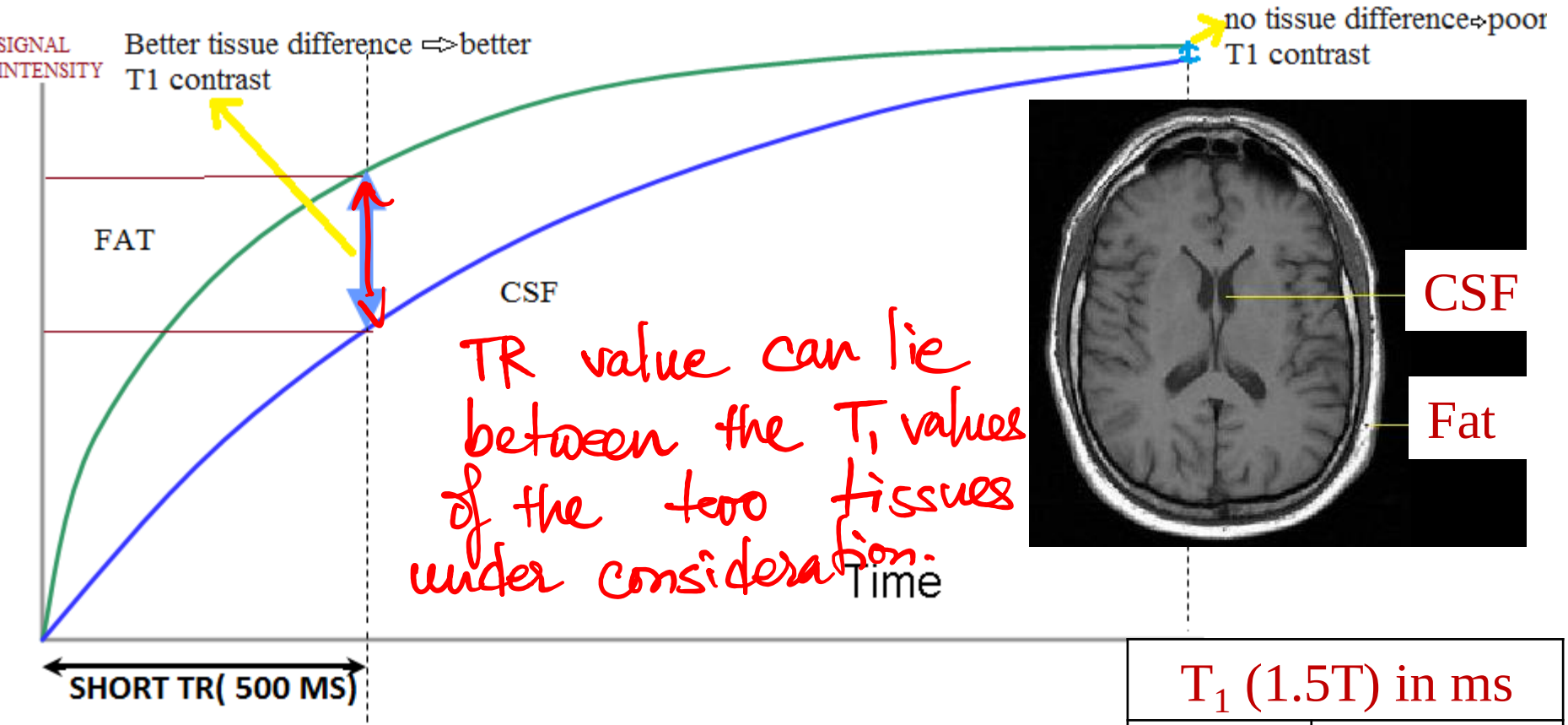
T_1 weighing of MRI images

- Short TR (appropriately chosen) will not allow some tissues to recover equilibrium magnetization (M_o).
- Long TR allows all tissues to recover completely.
- Keep TE short (~ 15ms) to neglect T_2 dependency.

$$M_0 = \frac{N(\gamma\hbar)^2 B_0}{4kT}$$

How "short" should TR be?

T_1 weighed image

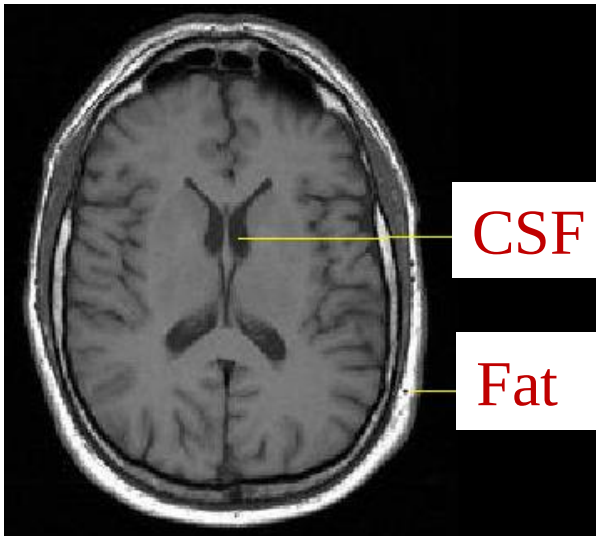


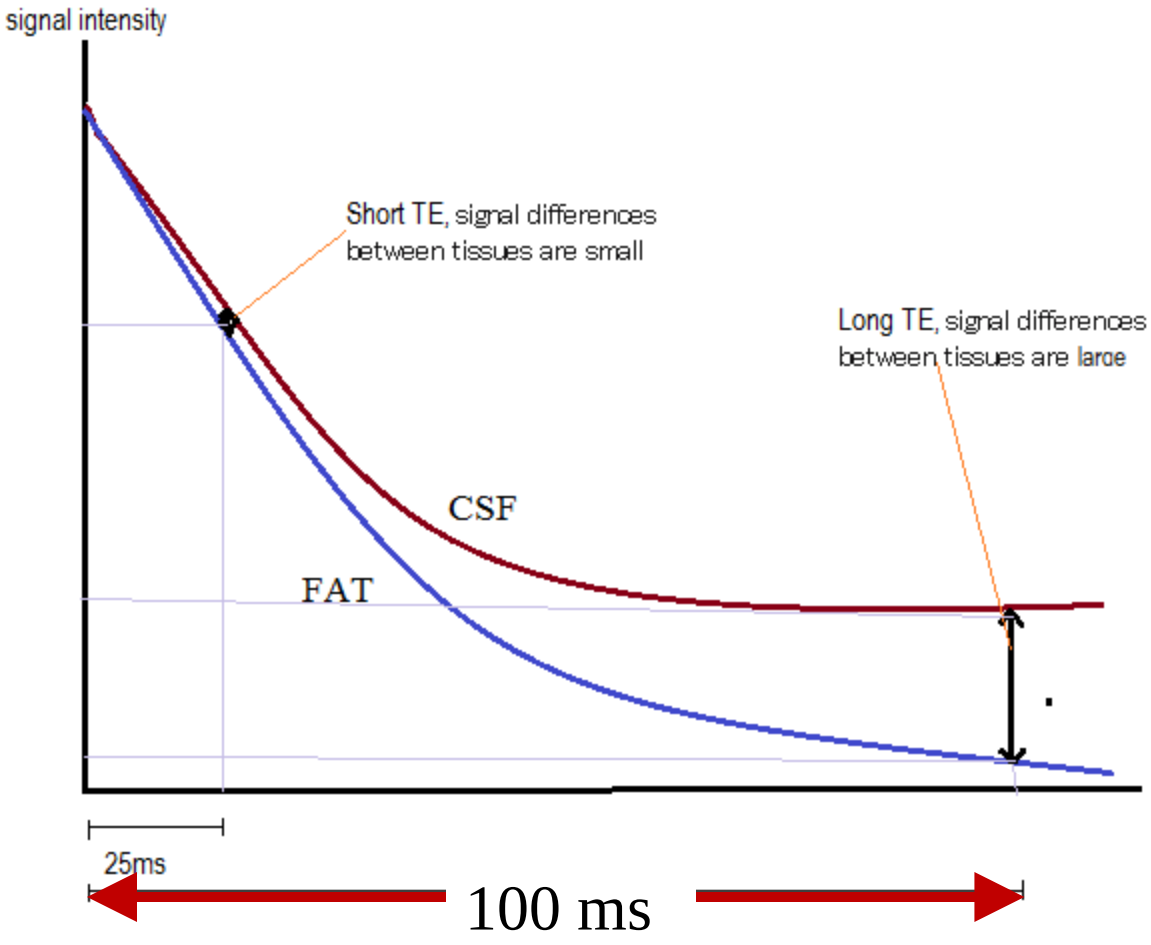
T_1 (1.5T) in ms	
CSF	2400
Fat	270

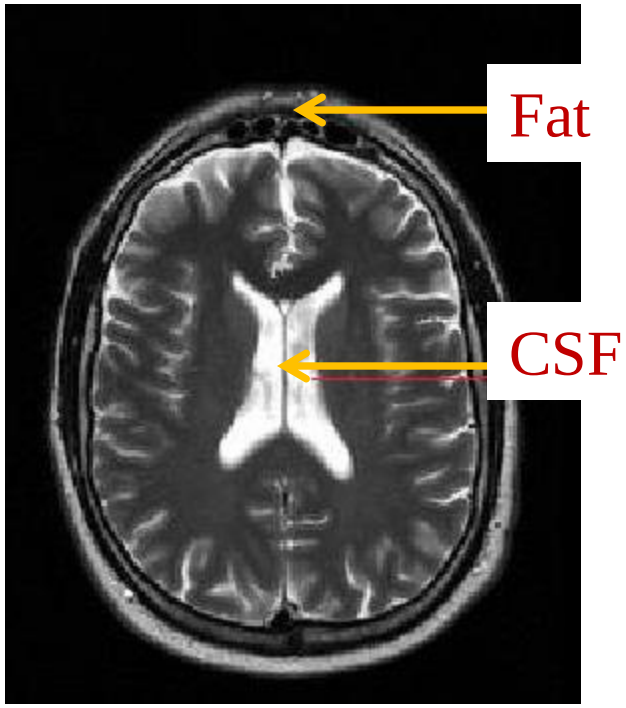
TR ~ 500 ms, TE ~ 15 ms

T_1- weighting gives strong signal for tissues with short relaxation times.

T_1 (1.5T) in ms	
CSF	2400
Fat	270



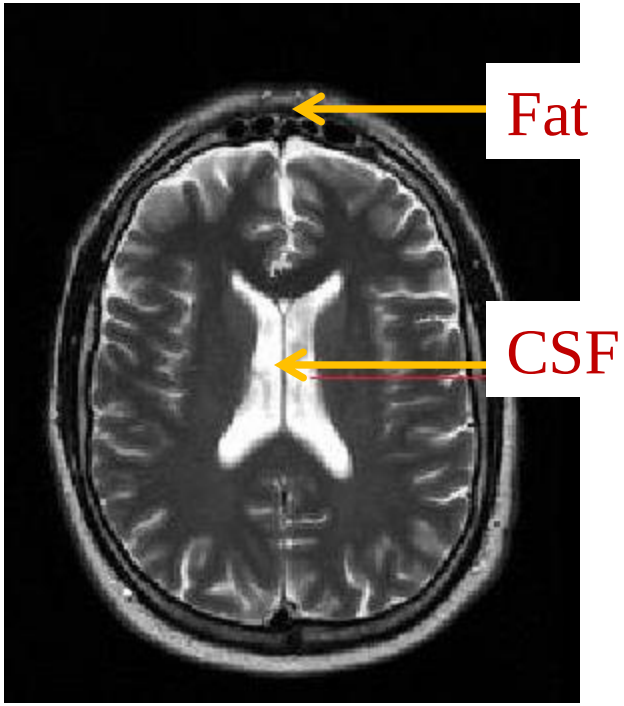




	T_1	T_2
CSF	2400	200
Fat	270	80

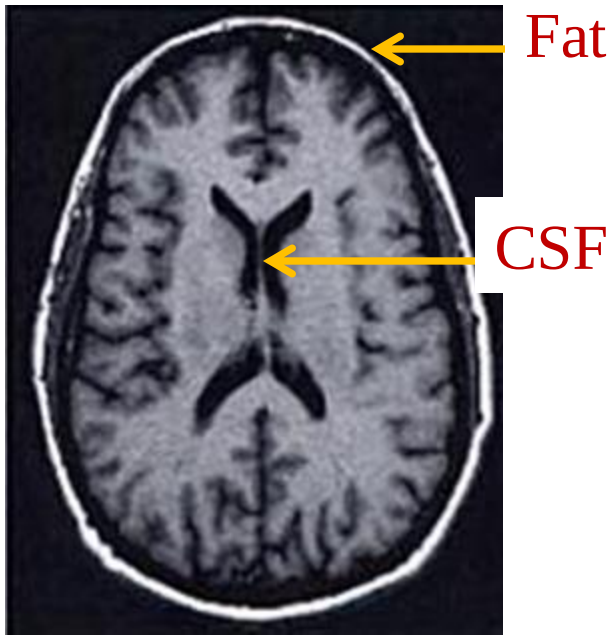
TR ~ 3000 ms, TE ~ 100 ms

T_2- weighting gives strong signal for tissues with long relaxation times.

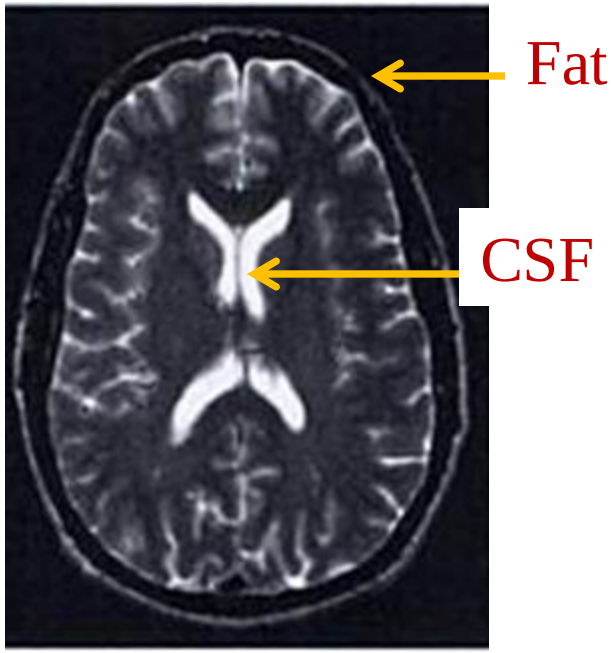


	T_1	T_2
CSF	2400	200
Fat	270	80

Are these images T_1 or T_2 weighed?



T_1-weighted
(TR = 600, TE = 11)



T_2-weighted
(TR = 3800, TE = 102)

	T_1	T_2
CSF	2400	200
Fat	270	80

Is it a good idea to exploit both T_1 and T_2 dependencies simultaneously to enhance the image contrast in MRI? Why or why not?

— No! T_1-weighing & T_2 weighing give opposite effects on the tissues. This would degrade the contrast.