# Lecture 15

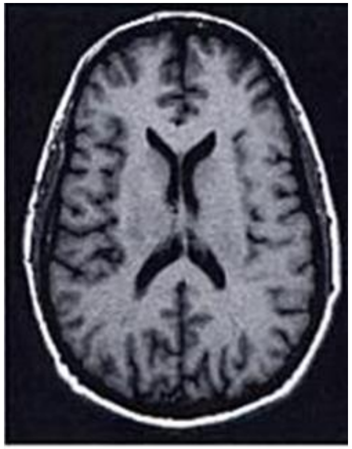
## PD imaging and MRI magnets

Read section 5.14 from Smith and Webb for magnets

# Some facts about $T_1$ and $T_2$ weighing

**$T_1$ weighting:**

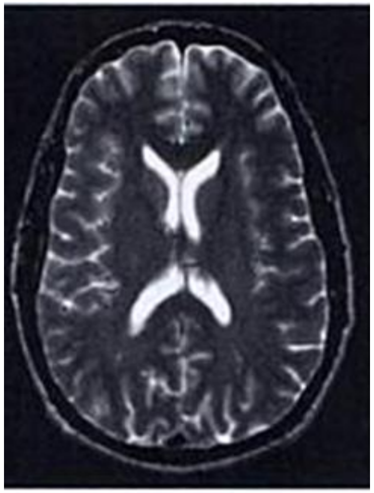
- Fluids are dark (why?- homework), normal tissue is mid-grey or bright.
- Clear boundaries between the different tissues seen. Anatomy scans.



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

**$T_2$ weighting:**

- Fluids are bright, normal tissue is dark.
- Abnormal collections of fluid are also bright. Pathology scans.



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

# Proton density and contrast

# Proton density (PD)

- Proton density: Total number of excitable spins (N) in the imaged volume.

- Decides the maximum signal that can be obtained from a particular tissue. N gives a measure of $M_o$.

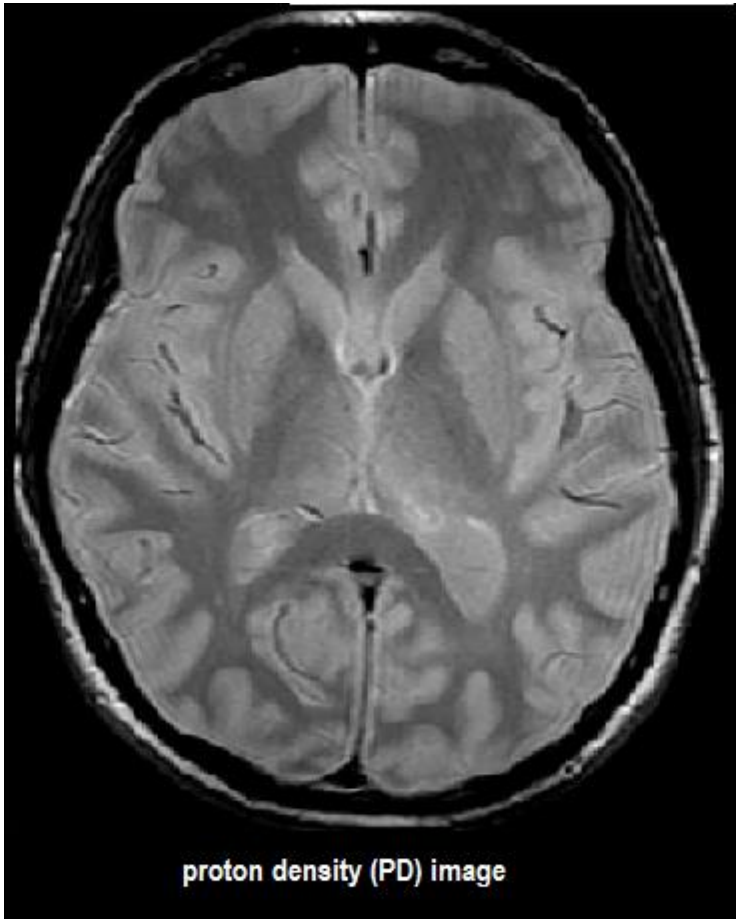
| Tissue | Proton density (a.u.) |
|---|---|
| Grey matter | 85 |
| White matter | 70 |
| CSF | 100 |
| Metastasis | 85 |
| Fat | 100 |

# How will you choose $T_R$ and $T_E$ for proton density weighing?

- Choose very long TR (2500 ms) and very short TE (15 ms) to eliminate $T_1$ and $T_2$ dependency.

- Works comparatively better for fat and CSF (high PD. Why though?)

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



# Compare how CSF and fat look in all three images

$T_1$-weighted (TR = 600, TE = 11) | Density-weighted (TR = 3000, TE = 17) | $T_2$-weighted (TR = 3800, TE = 102)

| | $T_1$ | $T_2$ |
|---|---|---|
| CSF | 2400 | 200 |
| Fat | 270 | 80 |

# Superconducting magnet ($B_o$)

- Must be spatially homogeneous. <u>Why</u>?

- Temporally stable (drift ~ 1ppb) during MRI (~ 40 min)

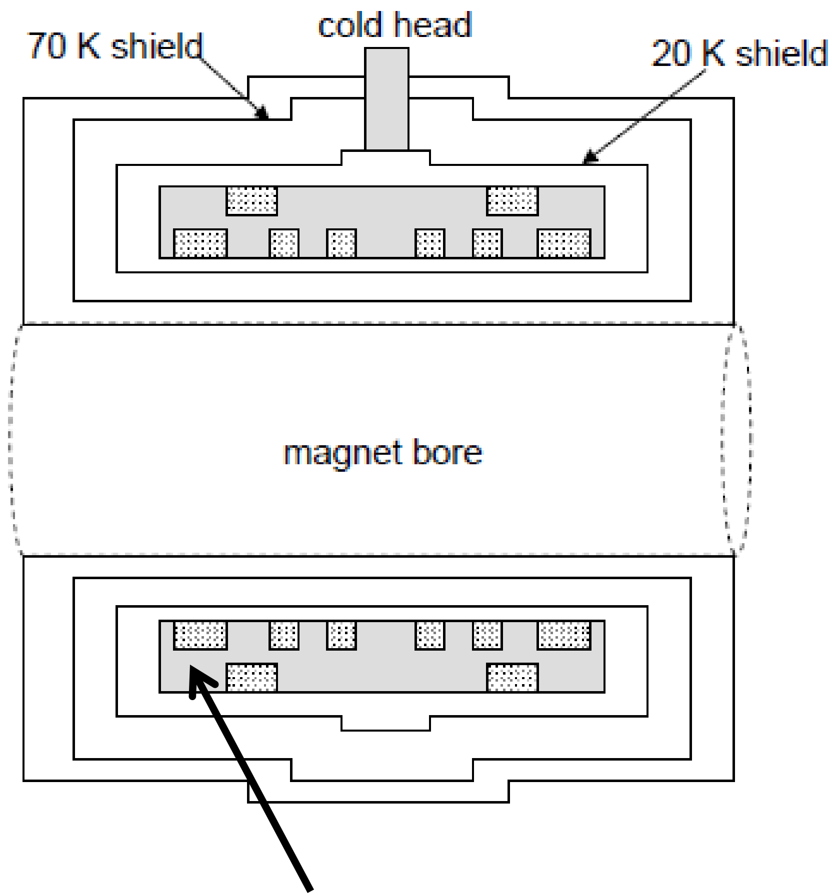

Typically 1.5T - 3T

Solenoid (homogeneous field at the centre)

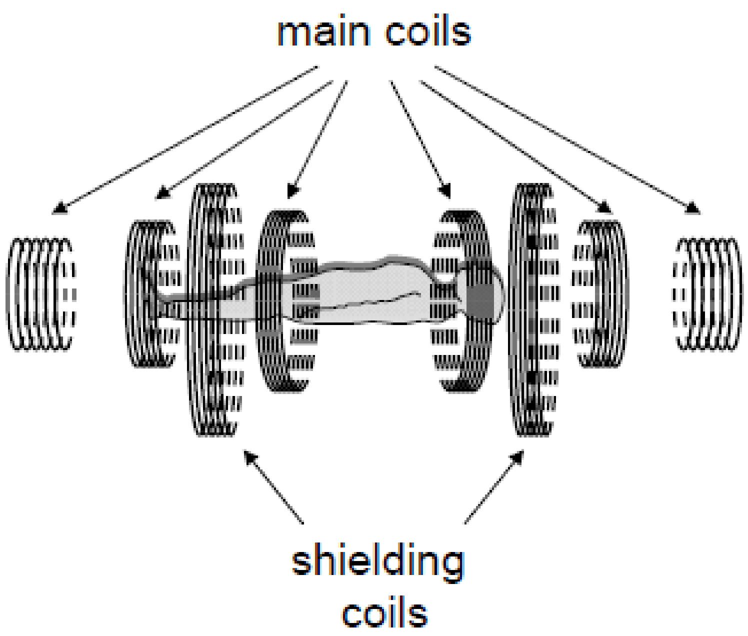
- For $B_o \sim 3T$, $I = 350A$. Could the high current lead to a problem?

Solution: Ti-Nb in a Cu matrix

# Cooling needed




Liquid He
(~ 4 Kelvin)

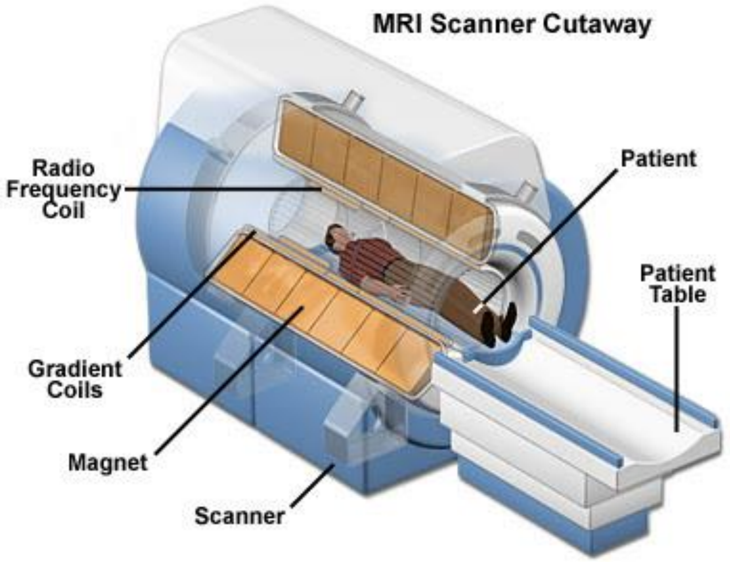


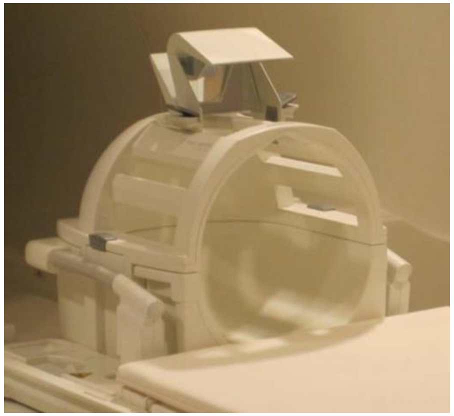

- Shielding: reduce effect of ‘stray field’ outside magnet.
- Passive: put magnet in carbon-steel enclosure
- Active: shim coils

# RF coil ($B_1$)

- Same coil transmits and receives the signal.
- Highest efficiency by matching the size of the coil to the body part being imaged.

Knee coil



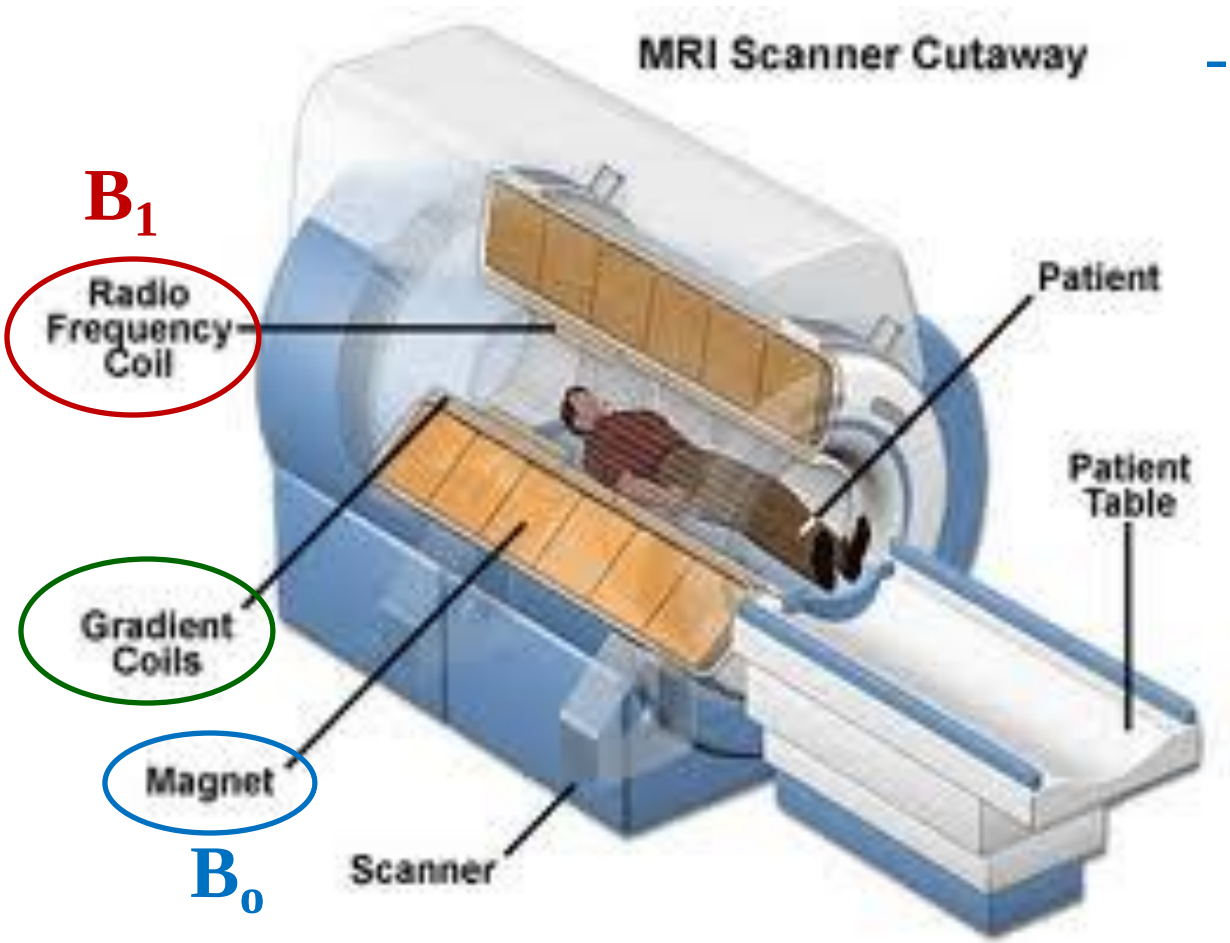
Head coil with mirror (for fMRI)

- Body coil: abdominal imaging

- We now understand why the steady (1.5T) and the RF magnets (~ mT) are there.

- But why do we need the third magnet in the MRI set-up?

# What magnetic fields do we have?



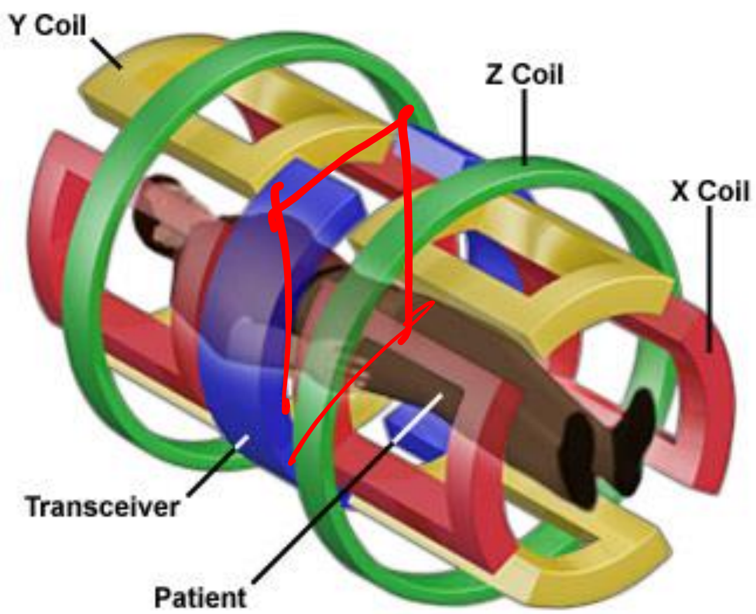

- Steady magnetic field, $B_o$ (initially aligns spins)
- RF magnetic field, $B_1$ (excites aligned spins)
- Spatial information

# Gradient coils

Sections 5.8 and 5.9 from Smith and Webb

# Localizing the signal

We still don’t have a way to distinguish the magnetic resonance signals coming from protons in different locations in the body. We need to localize the signal.




- Pulsed gradients (~ milliseconds)

- G (~10 mT/m) << $B_o$ (~ 1.5 T)
- Over 30 cm, total field variation is ~ 3mT (0.2% of $B_o$)

- Expressed in units of change in resonant frequency per cm (Hz/cm). For protons 10 mT/m = 4,258 Hz/cm.