Announcements

• Final exam will be Thursday, May 1st, from 9-12AM.
• Makeup times
  - Thursday May 1st from 2-5, room 120
  - Friday May 2nd from 9-12, room 120
  - Monday May 5th from 2-5, room 120
• Now posted are:
  - Final study guide
  - Lectures 34-37.
  - Last years final.
• Will be posted by Saturday evening:
  - Problem set #6 - strictly multiple choice - will act as study guide.
How does magnetic resonance (MR) work?

STEP #1:

- A large magnetic field aligns the “spins” or magnetic moments of the protons (in hydrogen atoms) in our bodies.

(Actually, only a few per million are lined up, but that turns out to be enough!)
How does MR work?

STEP #2:

- Radio waves are transmitted into our bodies at just the right frequency.
- The spins in our body are then tipped and begin precessing.
How does MR work?

STEP #3:

- Radio waves are then re-emitted from our bodies and detected by receivers.
How 2-D MRI might work - step 1

- A magnetic field gradient is applied in the vertical direction during the pulse of radio waves.
- Only a specific slice (here in the middle) has its spins tipped.
A magnetic field gradient is applied in the horizontal direction.
The emitted radio waves have different frequencies depending on their left/right position.
Completing the 2D image.

- Successive slices are tipped in the vertical direction.
- After each slice is tipped, a left/right gradient ensures that position information is encoded in the frequency of the emitted radio waves.
- In this way every pixel on the person can be measured.
MRI images of a human head
Question

Which of the following facts is most central to How MRI Works?

A. X-rays are more readily absorbed by heavier elements.
B. X-rays and radio waves are both forms of electromagnetic radiation.
C. The speed at which nuclei precess can be altered using magnetic field gradients.
D. The spin of the proton nucleus, 1/2, is the same as the electron spin of 1/2.
What are the strengths and weaknesses of CT and MRI?

**CT**
- Uses X-rays, which are a form of ionizing radiation.
- Imaging is based on the degree to which different tissues absorb X-rays. Particularly good sensitivity to heavier elements.

**MRI**
- Based on “tipping” or exciting spins in the body using radio waves, which are not a form of ionizing radiation.
- Must be done in a large magnetic field, which is not possible for people with pacemakers and some other devices.
- Tends to be most sensitive to “soft tissues” that contain a great deal of water.
But how can you make good images of the air space of lungs?

- The lungs are mostly light fluffy tissue, with (hopefully) very little water and mostly light elements.
- The attenuation of X-rays should be minimal.
- Conventional MRI looks mostly at protons in water.
What if the patient inhaled a spin-polarized gas?

- A He-3 nucleus has two protons with their spins pointing in opposite directions, and one unpaired neutron.
- It is thus a spin-1/2 nucleus just like the proton.
Laser-polarized noble gases enhance MR

**Conventional MR**
- Signal comes from proton spins in water
- Protons are polarized by large magnetic field.
- The polarization $\approx 10^{-6}$ is due to the thermal Boltzmann distribution

**MR using laser-polarized noble gases:**
- The signal comes from laser-polarized noble gases such as $^3$He or $^{129}$Xe
- Polarizations are 5-50%
  (up to 100,000 bigger!)
- Great for imaging lungs
Polarized noble gases can stay polarized for hours making them useful as an inhalable "contrast agents".
Why bother?

Current state of the art is a nuclear medicine scan using a radioactive isotope such as $^{133}\text{Xe}$.
MRI using laser-polarized noble gas greatly improves resolution
Real-time movie of person inhaling He-3

Dynamic Spiral $^3$He MRI in a normal subject

University of Virginia Department of Radiology

Salerno and Mugler et al.
Sagittal slice (side view) dynamic studies enable visualization of the order in which the lung lobes ventilate.
Routine polarization of noble gases make serious clinical studies a practical reality.
N.Y.U. referral of two World Trade Center rescue workers to UVA for He-3 testing

NY City Fire Fighters

March 2002

FEV₁ 80%

FEV₁ 100%