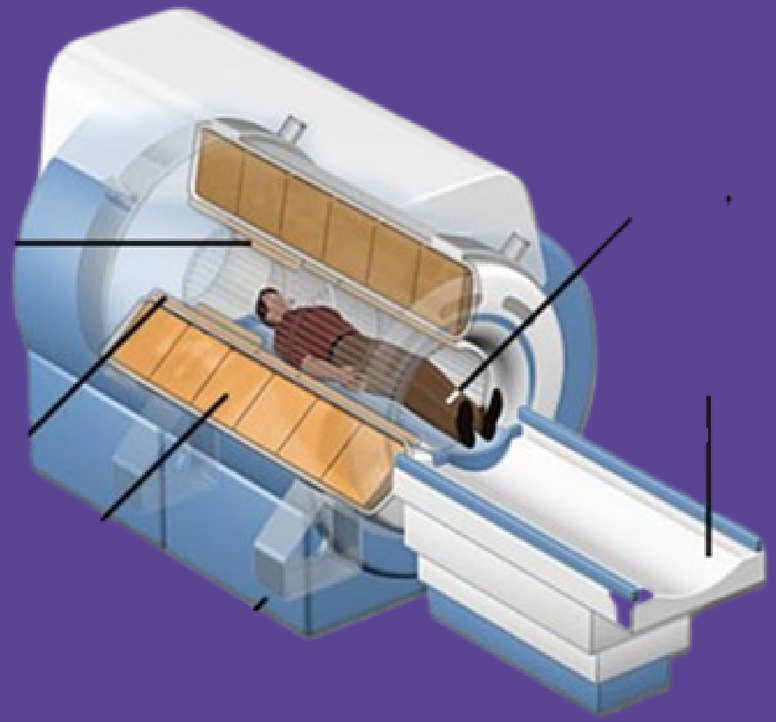
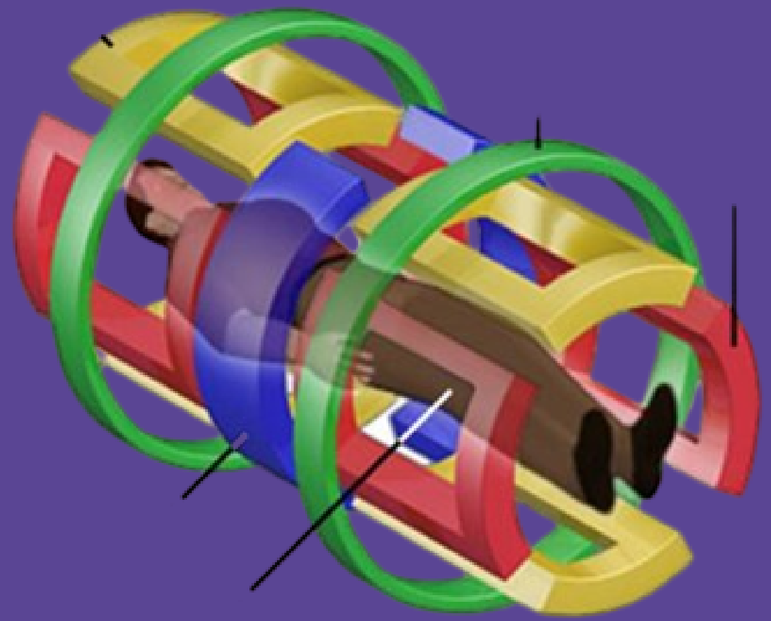
EVERYTHING YOU DIDN'T NEED TO KNOW ABOUT MRI

MAGNETIC *RESONANCE* IMAGING





AS A BROAD OVERVIEW

01

MRI machines are huge superconducting magnets surrounded by transfer- and receive- coils (yay electromagnetism!).

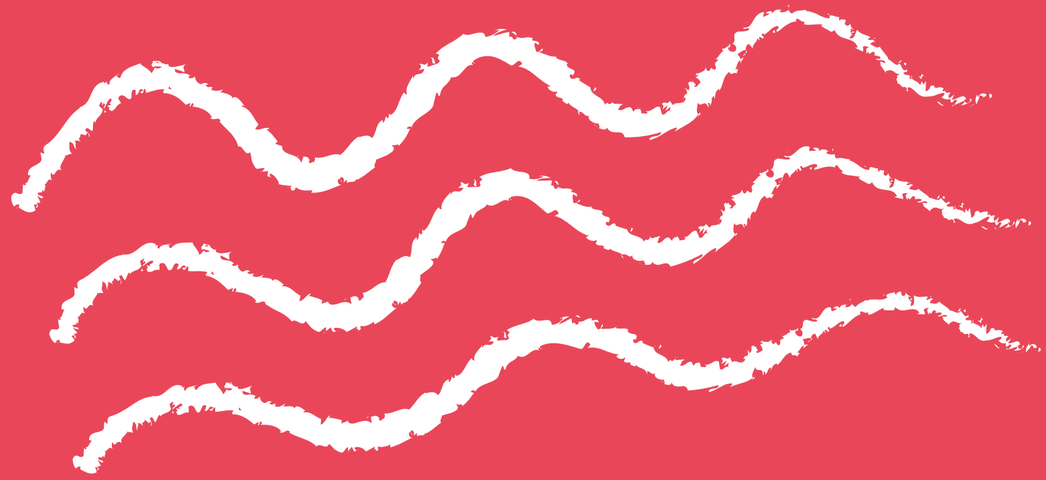
02

More granularly, MRI detects contrast between materials by sending magnetic pulses at the target body part and measuring the response. Responses that differ significantly, when averaged, indicate different material. The contrast between the signals, correlated with the location where it was measured, will create the final image.

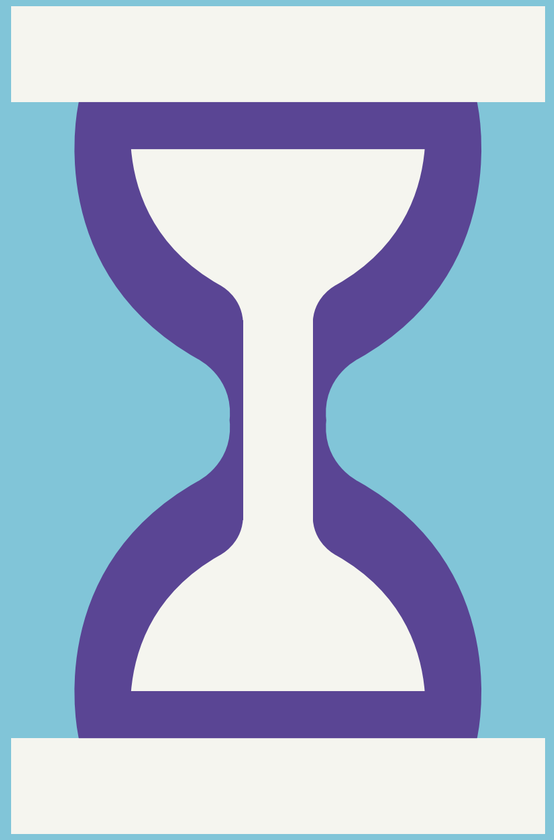
RESONANCE

- PROTONS HAVE "LARMOR FREQUENCIES" AT WHICH THEY "RESONATE" OR ECHO BACK THE GIVEN WAVE. AFTER SENDING A PULSE OF RF ENERGY [WAVES ON THE RADIO FREQUENCY SPECTRUM] AT PROTONS (PRIMARILY FROM HYDROGEN NUCLEI), MRI MACHINES RECEIVE THE ECHOED RESPONSE.

- DIFFERENT TISSUES HAVE DIFFERENT RESONANT FREQUENCIES, SO IF YOU SEND A PULSE TO ONE AREA AT 60MHZ, ONLY SOME OF THE TISSUES WILL ECHO BACK. SENDING ANOTHER PULSE AT 40MHZ WILL CAUSE OTHERS TO ECHO AND *BOOM* YOU CAN DIFFERENTIATE THEM



AN IMAGING METHOD KNOWN AS MR SPECTROSCOPY USES THIS TO DETERMINE THE PRECISE CHEMICAL COMPOSITION OF TISSUES [MRI FOCUSES INSTEAD ON THE STRUCTURE; SPACIAL LOCATIONS OF TISSUES AND HIGH RESOLUTION CONTRAST BETWEEN THEM]



PULSE ANGLES

A pulse of magnetic energy (in the context of MRI) is characterized by the angle it misaligns the proton's magnetic field by. Individual protons have a natural spin and hence magnetic alignment, and hitting them with a stronger field aligns them to *that* field. The rotation from the reference point of the original field can be measured in degrees, so MRI pulses are measured in degrees (which correlate to length and strength of the pulse). 90 and 180 degree pulses are common, and smaller pulses are used in gradient echo imaging.

3 THINGS THAT IMPACT SIGNAL STRENGTH

PD
PROTON DENSITY

The density of the protons in the given tissue has a significant impact on the strength of the echoing signal (more protons -> stronger signal)

T1

T1 values indicate the amount of time it takes for the proton to relax to its natural longitudinal magnetization (given that the pulse sent changed its magnetization angle).

T2

This is a noisy value; the "true" T2 (aka T2* is lower) but that's somewhat out of this scope

T2 values indicate the amount of time it takes for the magnetization of the proton to decay after a (typically 90 degree) pulse excites it.

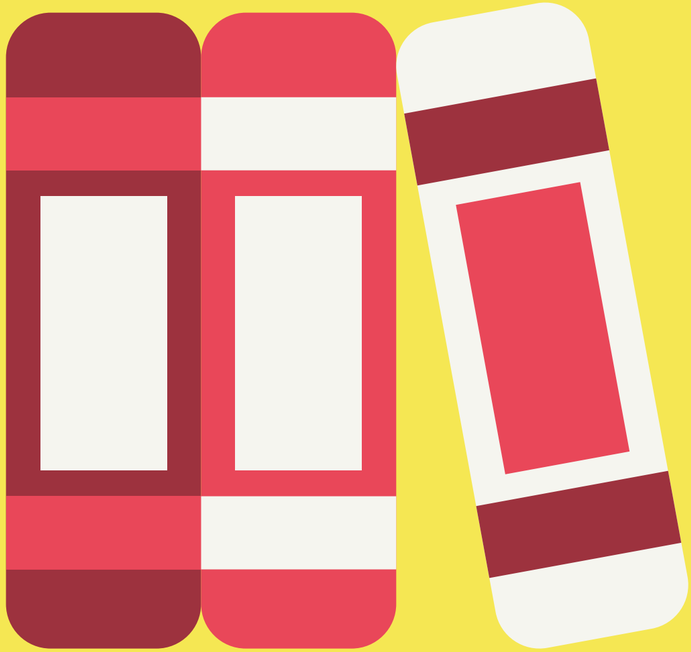
Tissue	T2 (msec)	T1 (0.5 T) (msec)	T1 (1.5 T) (msec)
Adipose (Fat)	80	210	260
Liver	42	350	500
Muscle	45	550	870
White Matter	90	500	780
Gray Matter	100	650	920
CSF	160	1800	2400

I think of T1 as "time to return to phase/magnetization" and T2 as "time to return to signal strength"

WEIGHTS AND PULSES

AN IMAGE CAN BE WEIGHTED TO PRIMARILY DETECT CONTRAST BASED ON ONE OF THOSE VALUES (EG T1-WEIGHTED)

THIS IS DONE THROUGH PULSE SEQUENCES. YOU DIDN'T JUST THINK TISSUES GOT BLASTED WITH A CONTINUOUS MAGNETIC FIELD DID YOU? NOOO THAT WOULD BE TOO EASY. INSTEAD, VERY SPECIFIC TIME INTERVALS AND PULSE STRENGTHS ARE USED TO MAXIMIZE MEASURED CONTRAST IN SIGNAL STRENGTHS WHILE PROTONS ARE IN SPECIFIC STATES (IE WHEN THOSE WITH LOWER T1 VALUES ARE MORE MAGNETIZED)



ON PULSE SEQUENCES

THESE DETERMINE T1/T2 WEIGHTINGS

TR

TR: Time to repeat

The interval between each pulse sequence

Shorter TR -> T1 weighted image, since there is less time for protons to recover their phase so differences are more pronounced. Ideally TR will also be timed to coincide with the predicted time when the tissue is 67% magnetized, maximizing contrast

TE

TE: Time to echo

The interval between each individual pulse in a sequence

Longer TE -> T2 weighted image as T2 only shows up near the end of the sequence and longer TE maximizes the amount of time T2-magnetized tissue data is collected

SPEEEED AND GRADIENTS

HOW MRI IS DONE MORE EFFICIENTLY

TR IS SLOW

It takes up the most time in imaging, but we can minimize it by using smaller pulse angles (aka gradient echo imaging - the previously laid out method, 90-TE-180-TR-[repeat] is spin echo imaging). The effects of smaller pulse angles are T2-weighting the image (because the protons are barely dephased and the time it takes to get back to their "normal state is low) and higher signal noise.

ON AN RF LEVEL

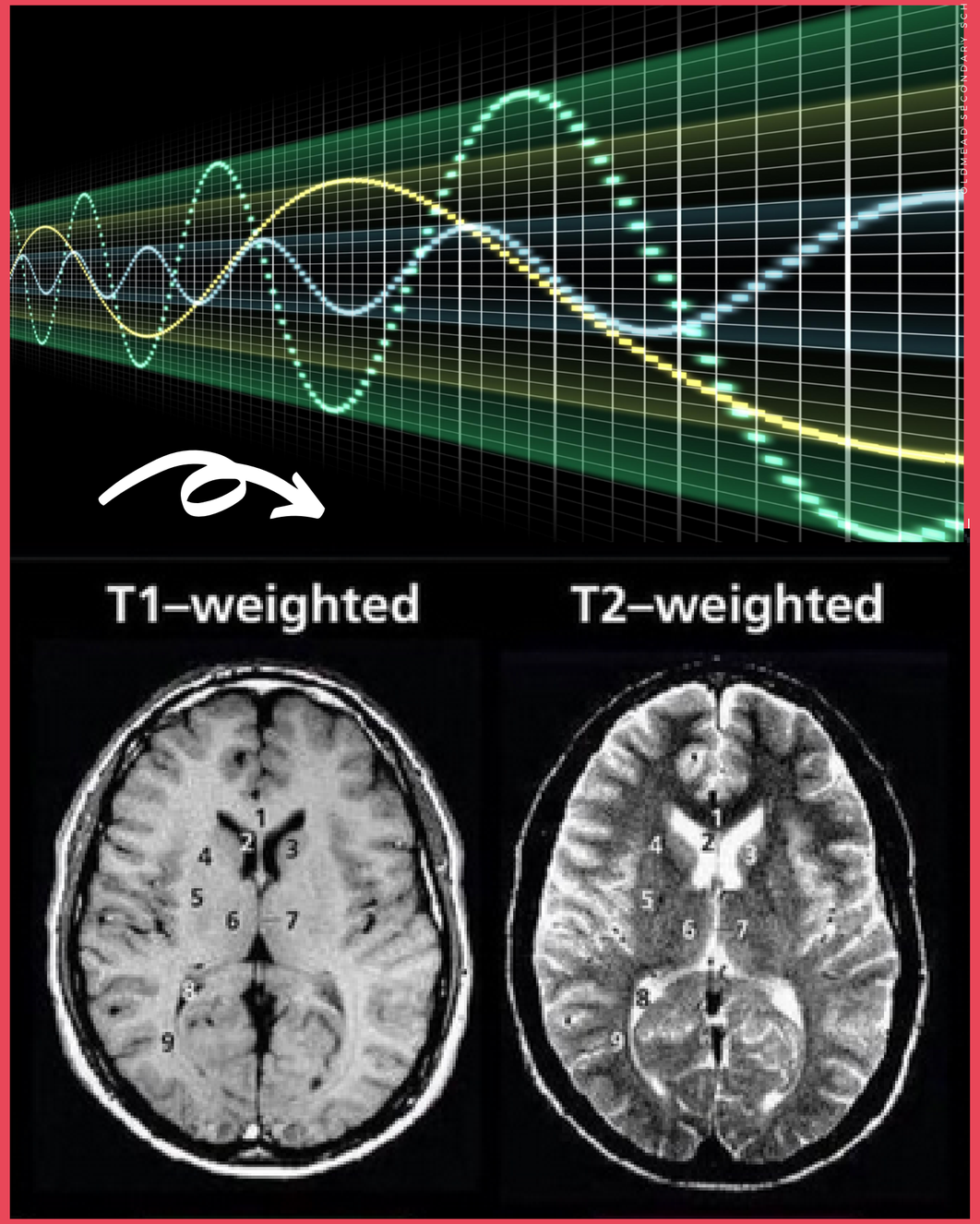
- 1MHz to 300MHz signals are used
- More tissues can be imaged more efficiently by using a range of frequencies (higher bandwidth signal) at the loss of some precision

PARALLELIZATION:

MRIS AREN'T DONE ONE SMALL PIECE OF TISSUE AT A TIME; THAT WOULD BE INEFFICIENT. INSTEAD, EACH PULSE IS DONE IN PARALLEL AND IS GIVEN 2 RF IDENTIFIERS (CALLED FREQUENCY AND PHASE ENCODING GRADIENTS - USED SO EACH PULSE "LAYER" CAN BE IDENTIFIED WHEN POST PROCESSING THE SIGNALS WITH MATHEMATICAL SORCERY AND FFTS). THE PULSES ARE APPLIED IN SPACIAL "SLICES" (AND PULSE SEQUENCES ARE STAGGERED, NOT EXACTLY AT THE SAME TIME)

IN SUMMARY

- ELECTROMAGNETIC PULSES ARE SENT WITH SPECIFIC FREQUENCY RANGES AT AN AREA OF TISSUE AND THE STRENGTH OF THE RESONATING SIGNAL IS MEASURED
- THE PULSES ARE SENT WITH LENGTHS OF TIME AND TIME INTERVALS THAT MAXIMIZE CONTRAST (AT MEASUREMENT TIME) BY EITHER THE TISSUE'S RATE OF SIGNAL DECAY (T2) OR REPHASING (T1)
- ALL OF THE SIGNAL PHASE, FREQUENCY, LOCATION, AND TIMING DATA IS FED INTO *SOFTWARE* THAT DETERMINES DIFFERENCES BETWEEN TYPES OF TISSUE BASED ON HOW THEY RESPONDED TO THE RF AND SPACIALLY ORGANIZES IT INTO AN IMAGE



OTHER INTERESTING THINGS

MAGNET STRENGTH

The MRIs used in hospitals tend to be 3 Tesla, while those in research labs are 5T-7T. The strongest MRI machine ever manufactured was 11.7T

PERSONAL ANECDOTE

(Not sure if I'll have time for this)
TL;DR it's difficult to get a free MRI

COSTS

MRI operating costs are around $400 an hour in cooling and electricity.

NOISE

The clicky sound MRIs make is due to vibration of the RF coils as electricity is sent through them

RADIATION

Electromagnetic energy is non-ionizing, so shouldn't have any negative side effects. As the fields get stronger, people may experience balance issues and vertigo immediately after or during their scan. Also, apparently females are more susceptible to negative effects.

CONTRAST

MRI contrast agents (typically paramagnetic gadolinium ion complexes) may be administered to improve material contrast in T2 weighted images (paramagnetic materials increase T2* because they are less susceptible to proton dephasing). The idea that paramagnetic materials can provide such contrast is used in functional MRI imaging (measures activity in parts of the brain), as deoxygenated blood is paramagnetic while oxygenated is not.

DO YOU HAVE ANY QUESTIONS?

I'M NOT SURE HOW MUCH TIME I'LL HAVE LEFT BUT IF THERE ARE ANY BURNING QUESTIONS ON YOUR MIND I CAN TRY TO ANSWER THEM.