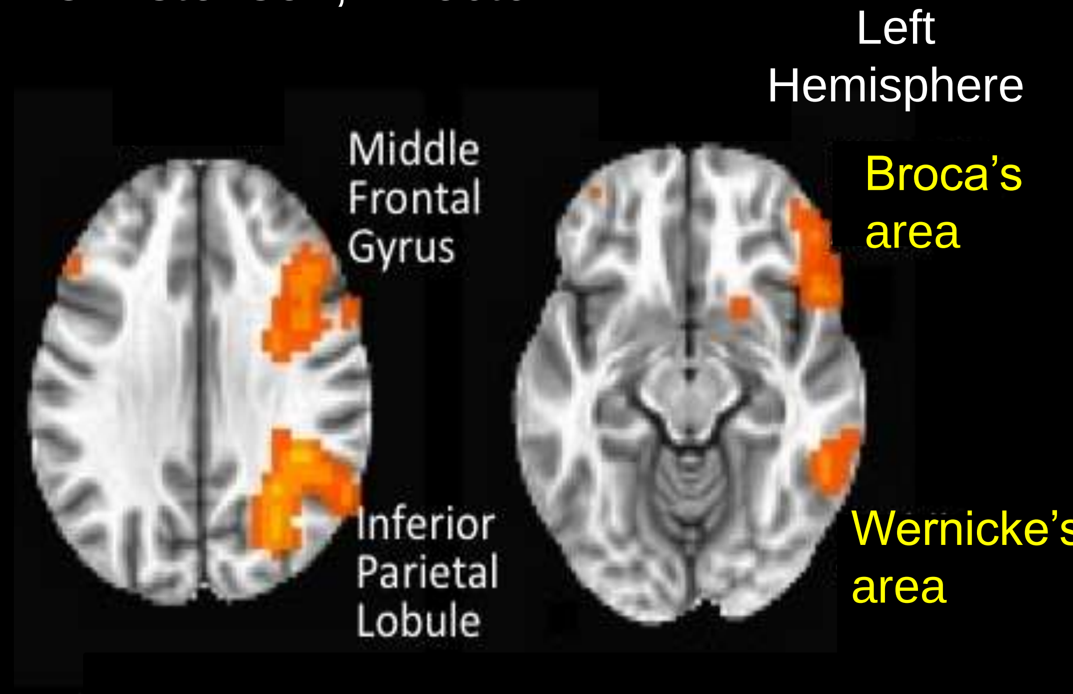
Rethinking How We Listen to Language: Insights from Functional Brain Mapping

BLAMlab

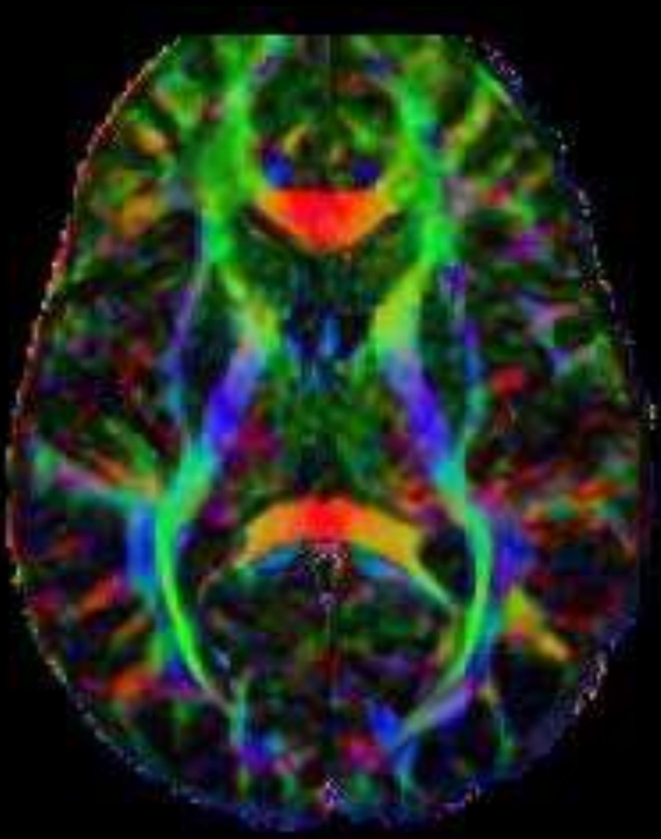
LABORATORY FOR BRAIN IMAGING, LANGUAGE, ATTENTION & MEMORY

Dr. Tom Christensen, Director



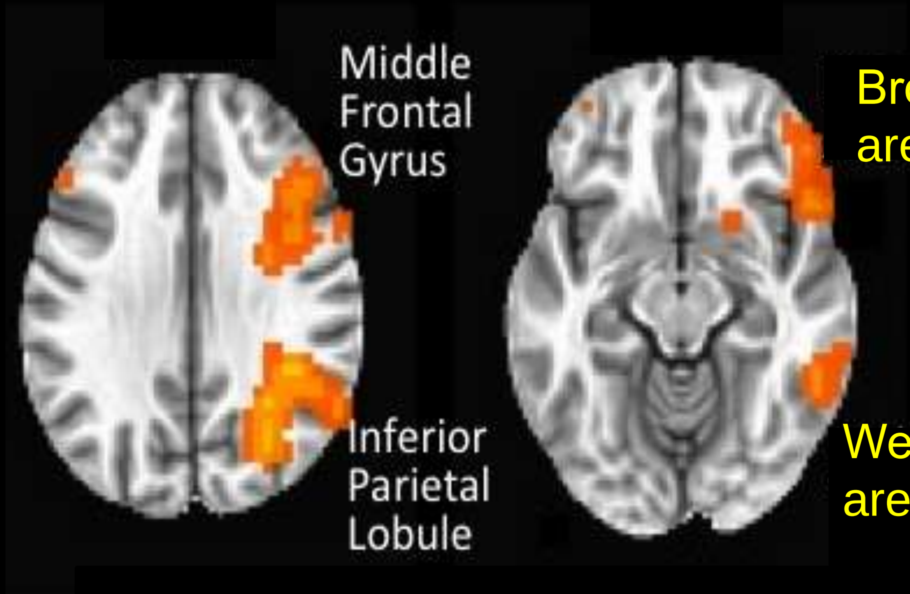
Department of Speech, Language & Hearing Sciences

The Brain is HIGHLY Interconnected!



DIFFUSION TENSOR IMAGING

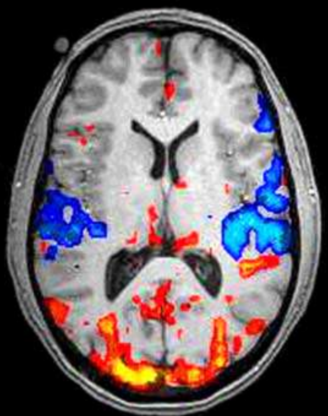
FUNCTIONAL MRI



Broca's area

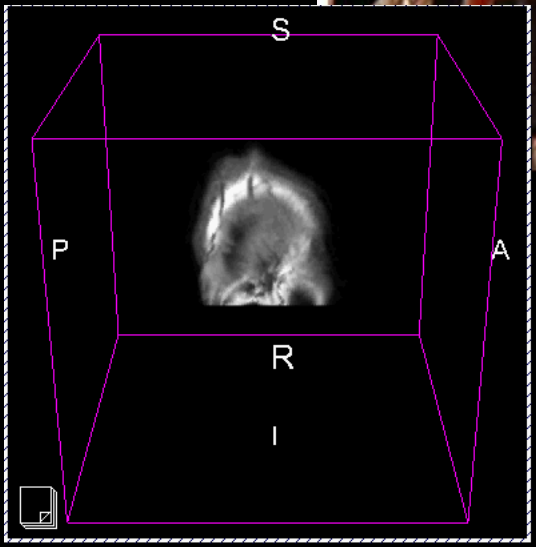
Wernicke's area

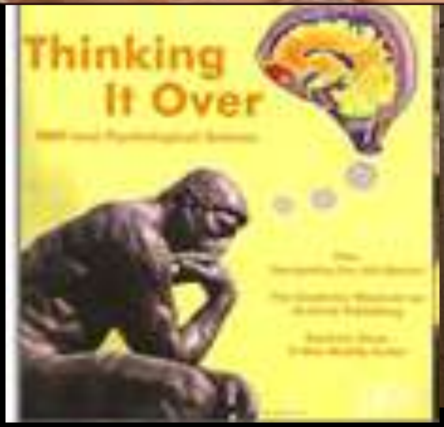
Brain Research in the Press

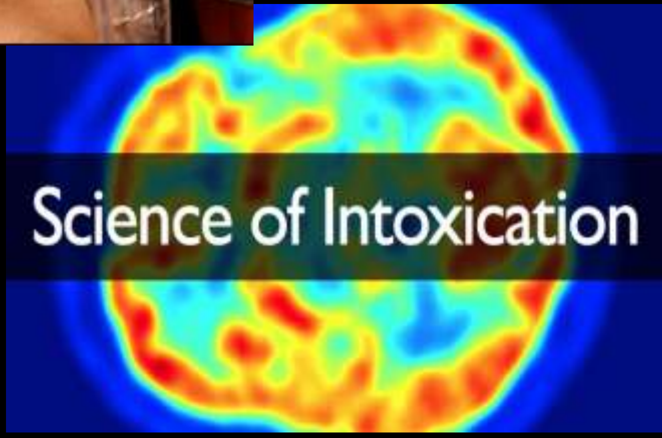



I Was a Neuroscience Guinea Pig: How Scientists Scrambled My Brain

By Lisa Katayama 11.26.07







BRAIN QUIZ

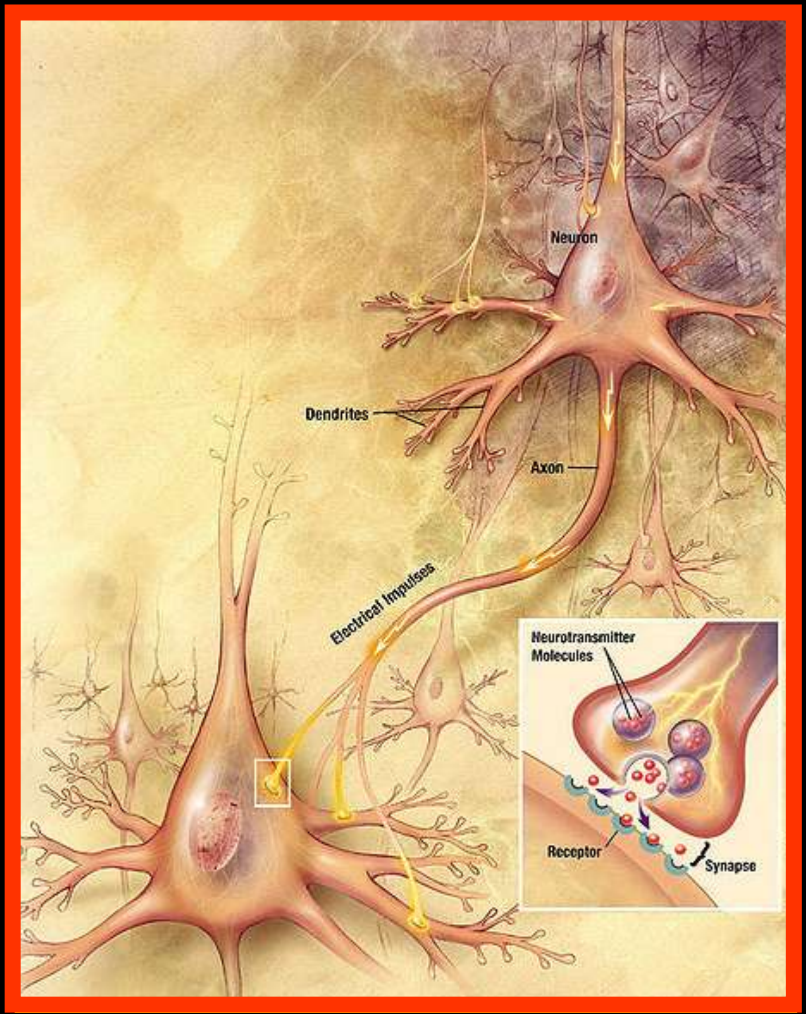
The average human brain contains about how many neurons?

A. one million

B. one billion

C. one-hundred billion

D. one-hundred trillion



BRAIN QUIZ

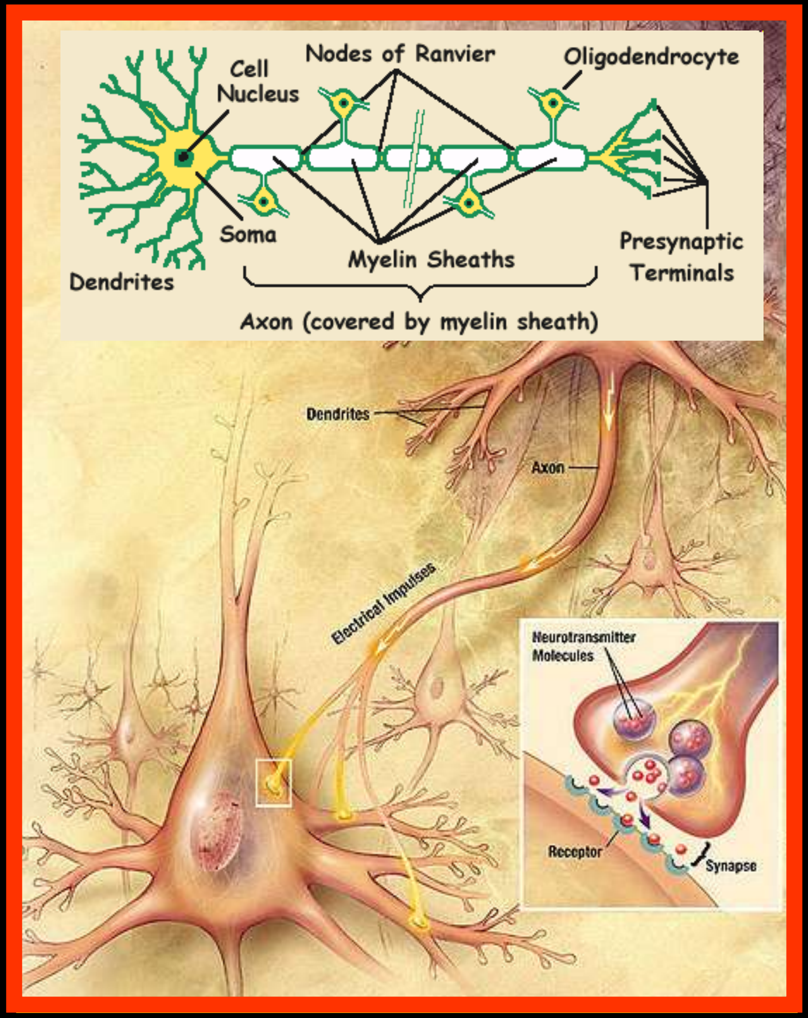
The average human brain contains about how much ***FAT*** ?

A. 10%

B. 50%

C. 90%

D. 99%

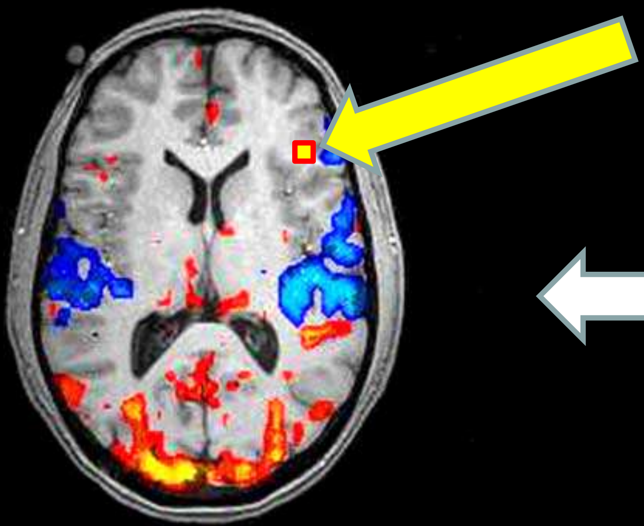


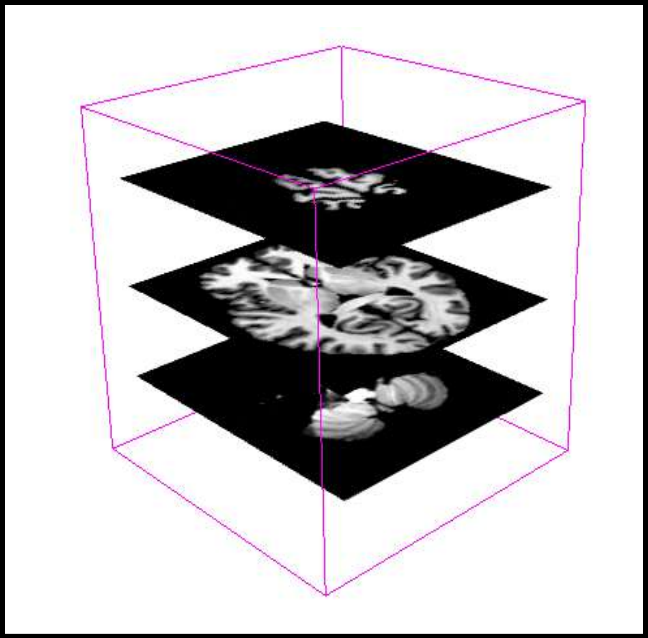
BRAIN QUIZ

ONE fMRI voxel measures the activity of approximately *HOW MANY neurons?*

64 voxels wide

64 voxels tall



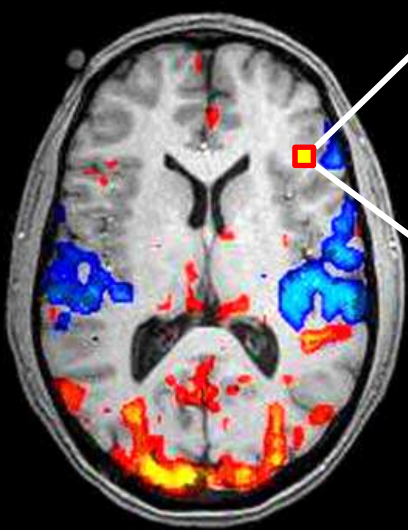


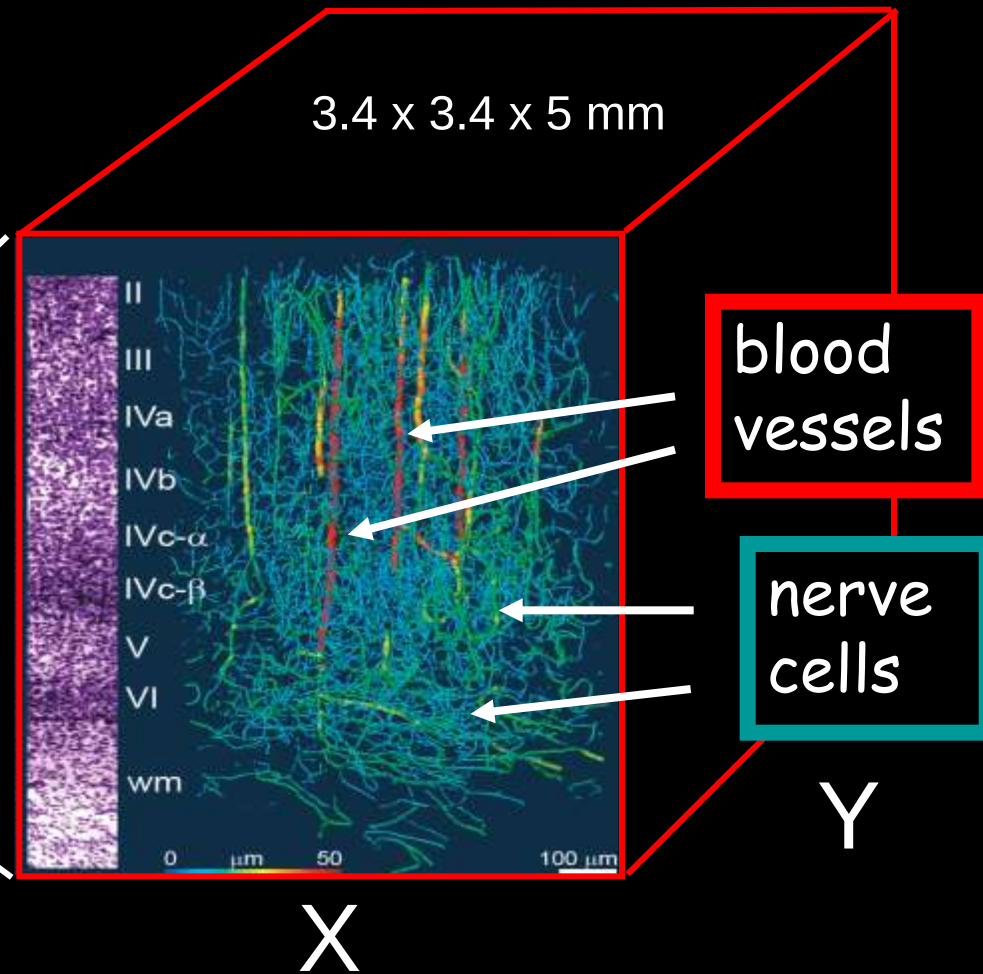
BRAIN QUIZ

ONE fMRI voxel measures the activity of approximately *ONE MILLION neurons!*

X: 64 voxels

Y: 64 voxels





This is ONE VOXEL in the image

BRAIN QUIZ

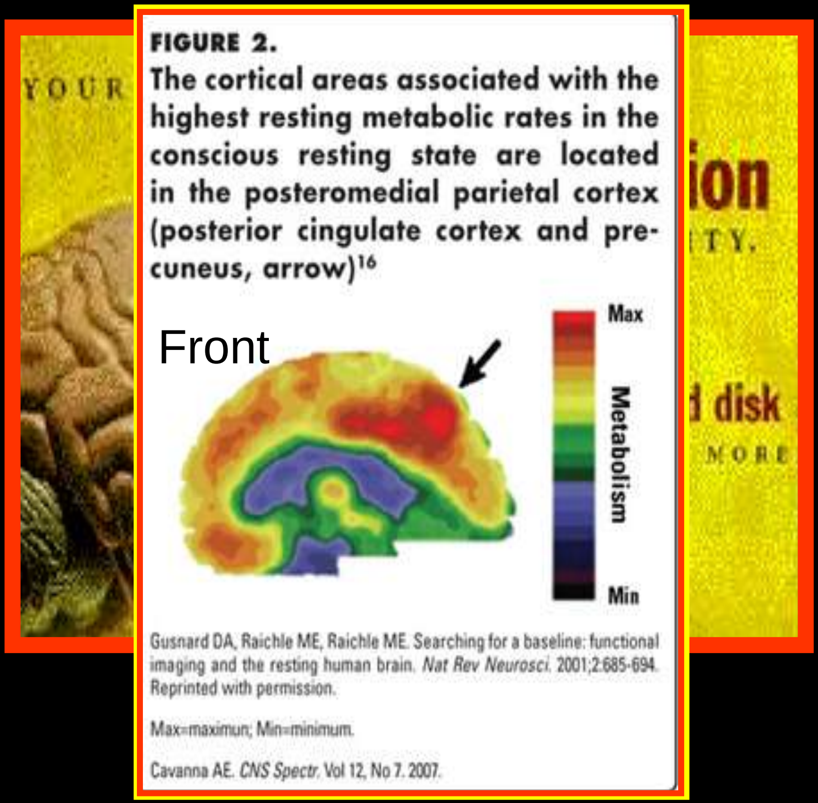
T or F?

You use only 10% of your brain.

FALSE!

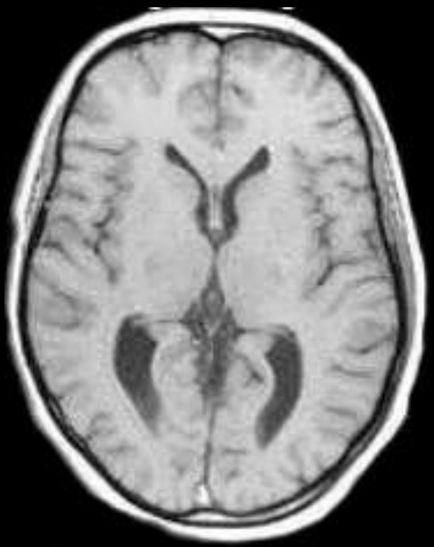
FALSE!!

FALSE!!!



fMRI: What are we imaging?

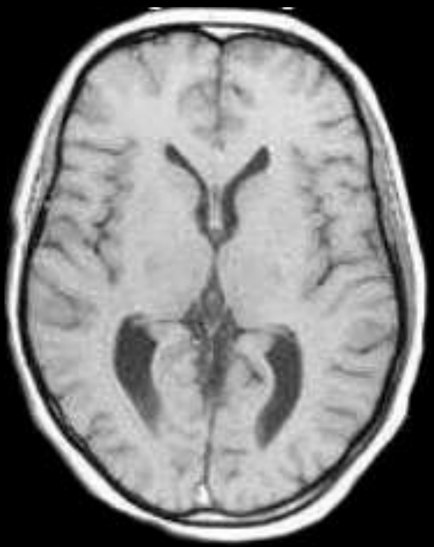
???



UA’s 3-Tesla GE Scanner

fMRI: What are we imaging?

???



What is the physical basis of the image?

Spinning & Wobbling Protons

The “R” in MRI: <u>RESONANCE</u>

For protons of hydrogen:

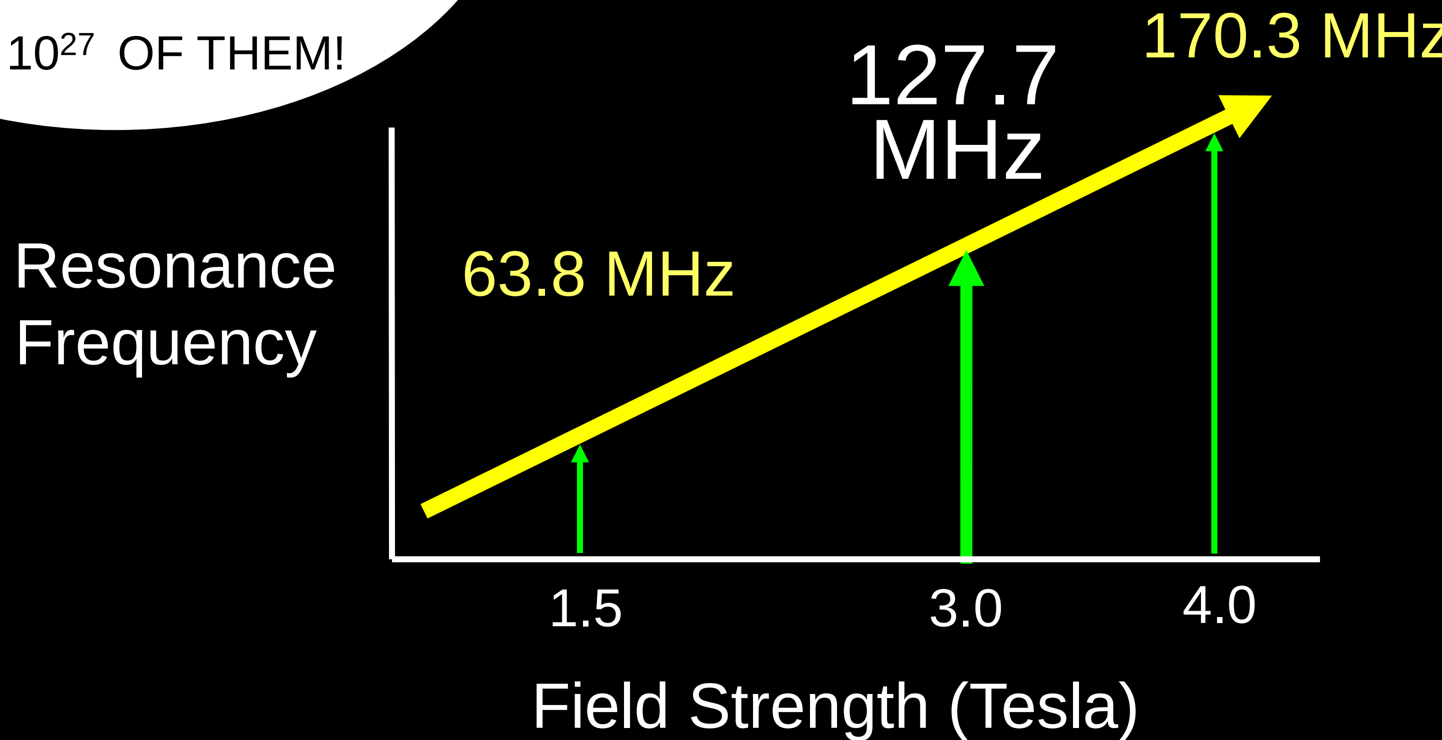
^{1}H

γ = 42.58 MHz / Tesla

5 x 10^{27} OF THEM!

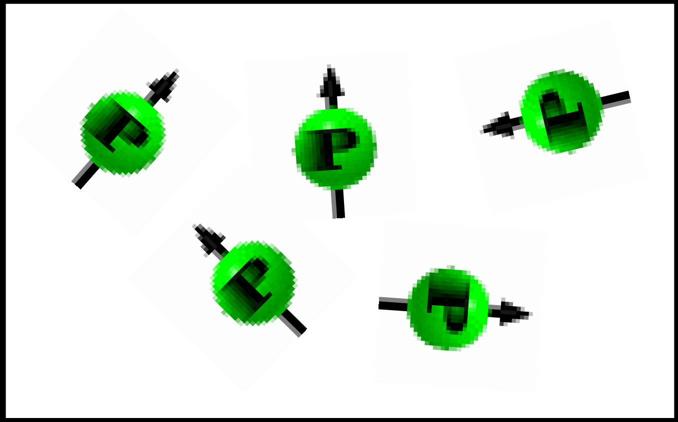
The *Larmor equation:*

Resonance freq. = γ x Main Field



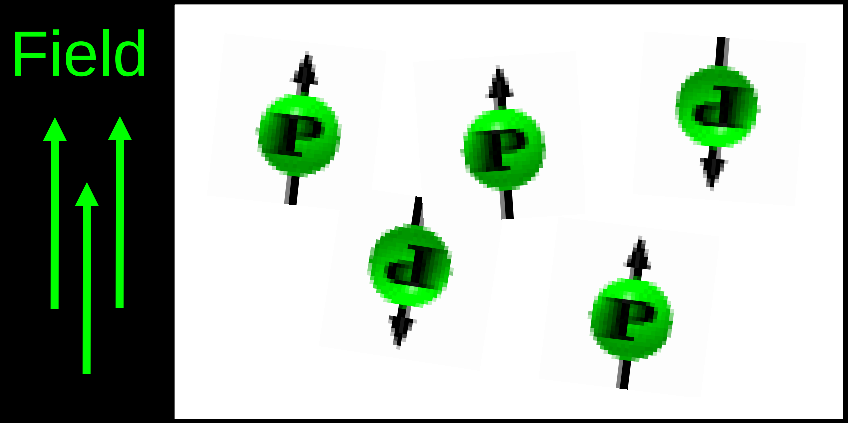
What exactly are we imaging?

Outside magnetic field



Inside magnetic field

Main Field



5×10^{27} in a 150 lb person

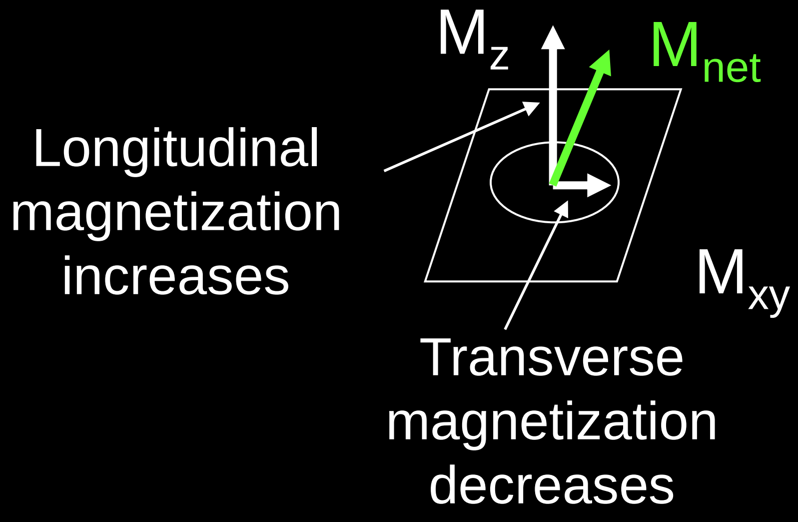
Spinning Protons

Outside the magnetic field:

- protons are randomly oriented

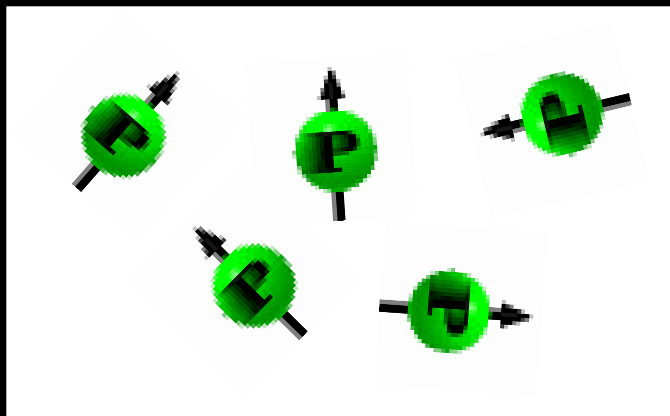
Inside the magnetic field:

- spins align parallel or anti-parallel to main field
- longitudinal component (M_Z) is large
- transverse component (M_{XY}) is small
- only 0.0003% of protons / Tesla align with field



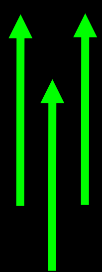
What exactly are we imaging?

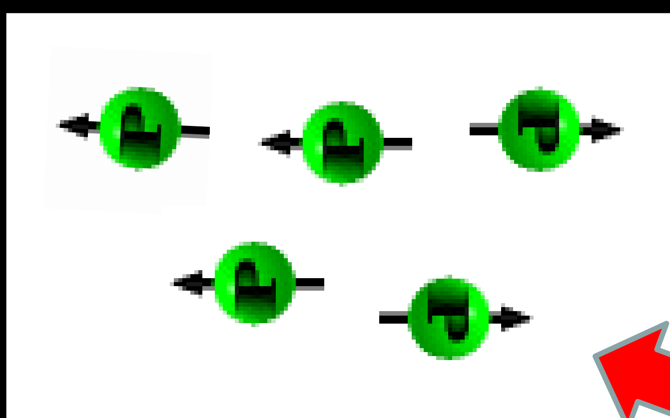
Outside magnetic field



Inside magnetic field

Main Field





5×10^{27} in a 150 lb person

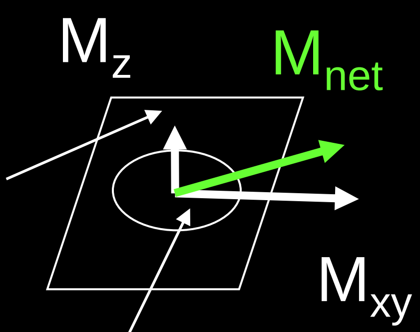
Spinning Protons

Outside the magnetic field:

- protons are randomly oriented

Inside the magnetic field:

- spins align parallel or anti-parallel to main field
- longitudinal component (M_Z) is large
- transverse component (M_{XY}) is small
- only 0.0003% of protons / Tesla align with field



Longitudinal magnetization DEcreases

Transverse magnetization INcreases

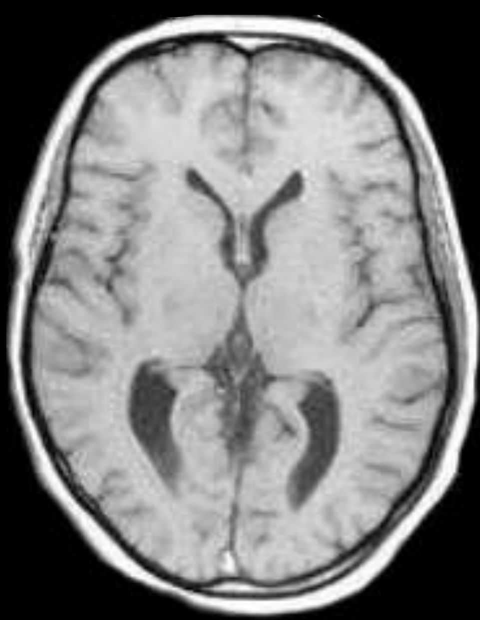
EXCITATION PULSE!!!!

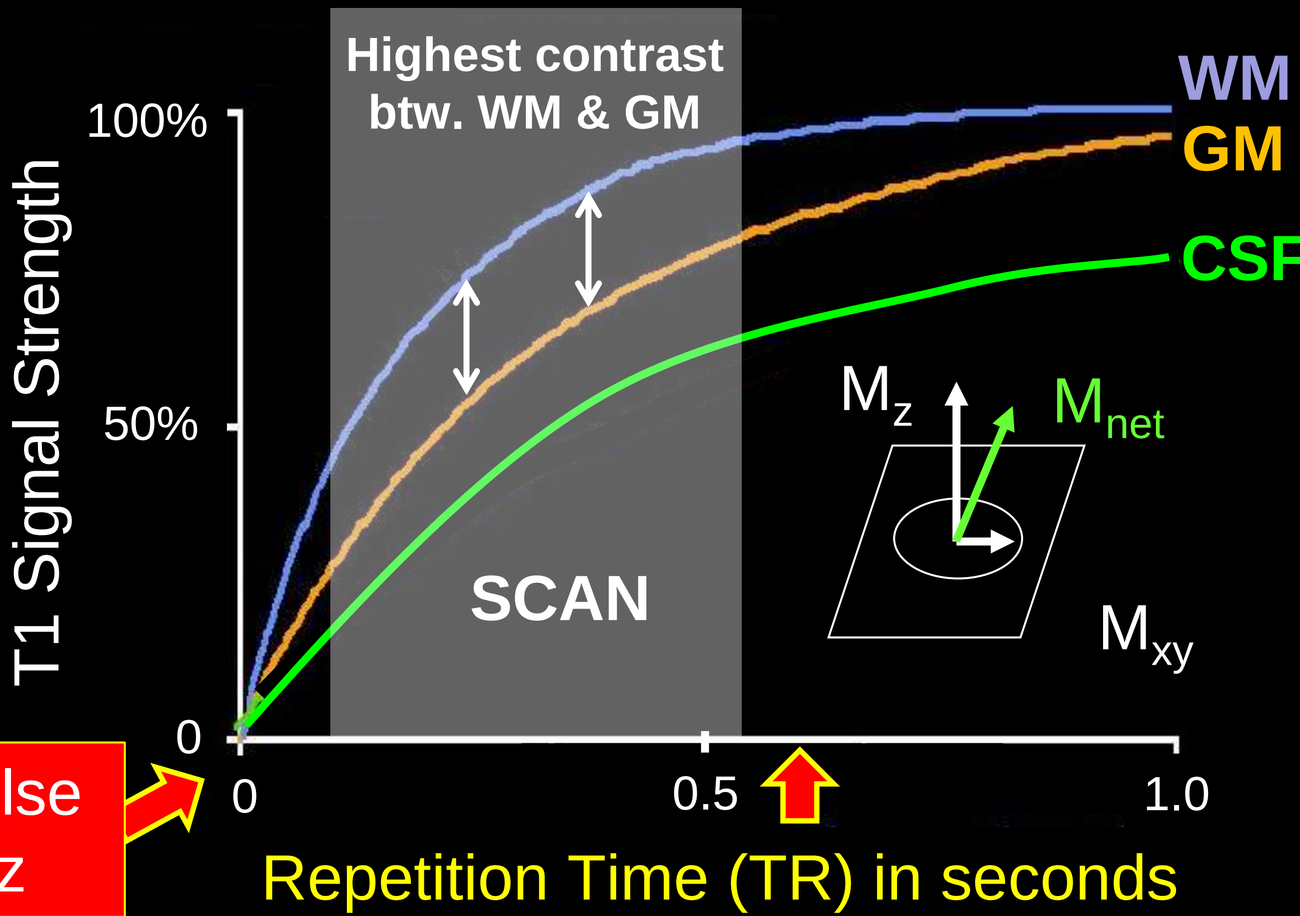
Physics of MRI

T1 = time constant for recovery of longitudinal alignment between spins

TR (time of repetition) = time interval between excitation pulses

TE (time to echo) = time to wait before we measure T1

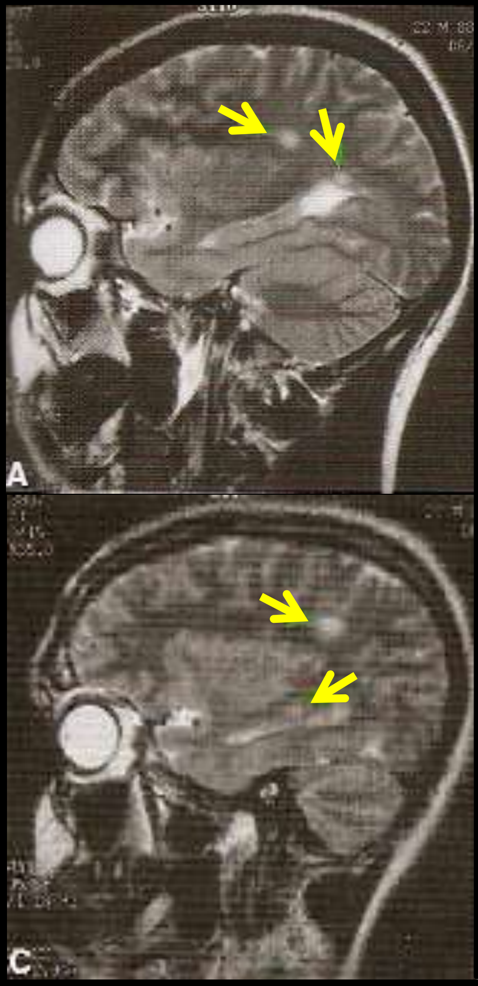


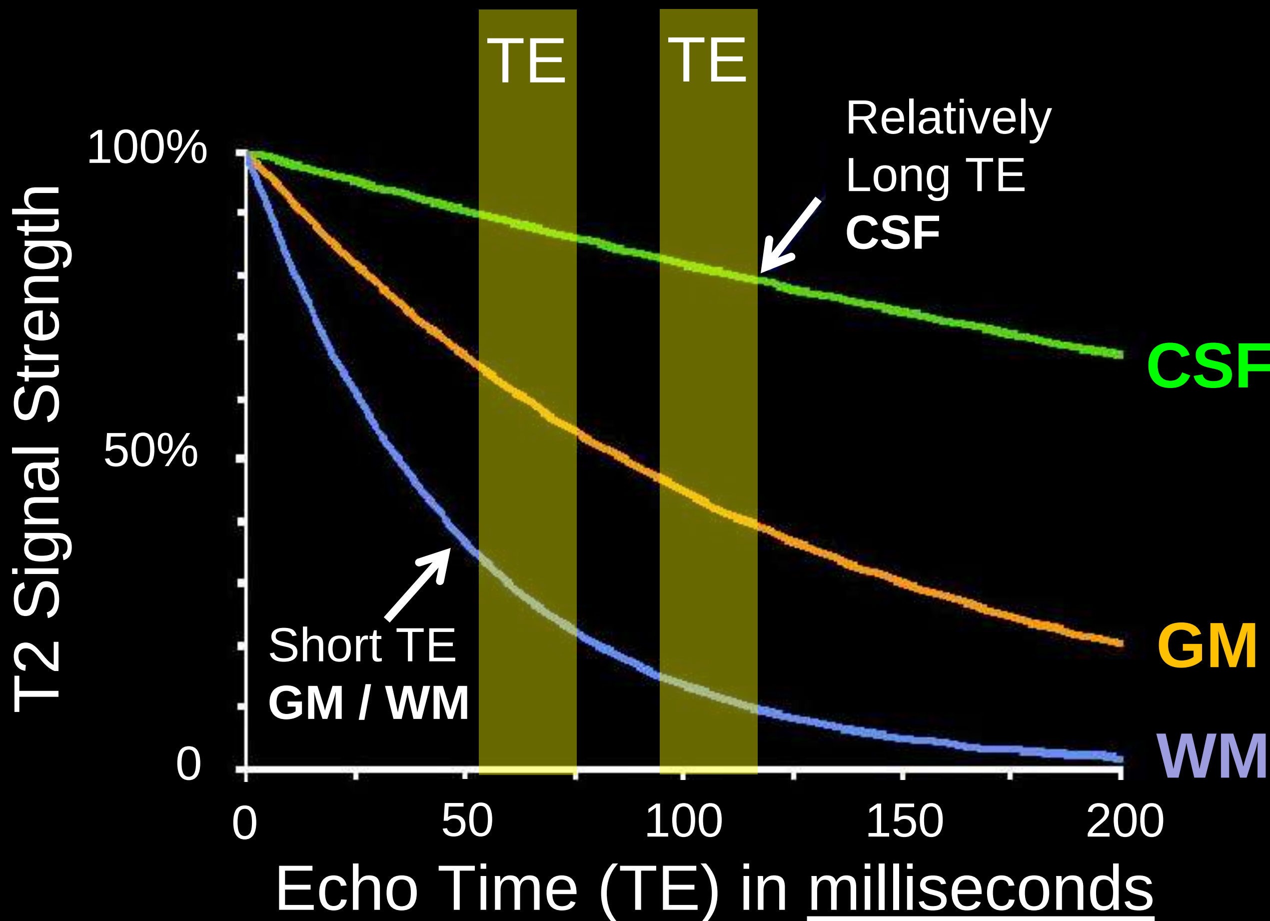


Physics of MRI

T2 = time constant for decay of transverse alignment between spins

TE (time to echo) = time to wait to measure T2



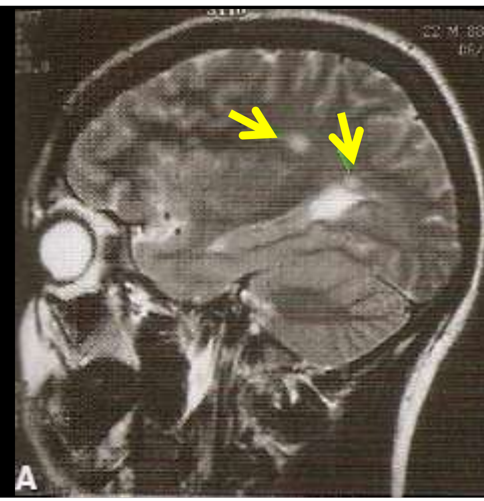


Use T1 and T2 to Fit the Need

T1-weighted Contrast: Conventional MRI
(WM is white)

T2-weighted Contrast:
- tumors
- strokes

(WM is dark)



MRI vs. fMRI

M agnetic
R esonance
I maging

vs.

functional
MRI

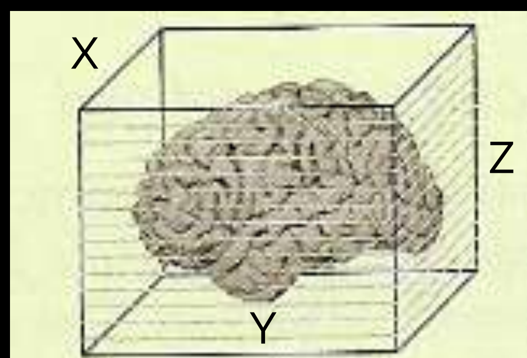
The Typical fMRI Experiment

VICTIMS

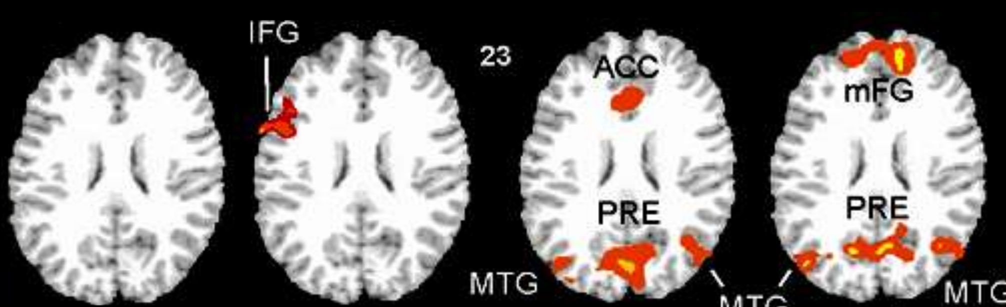
Scanning Sessions

Anatomical
& Functional
Runs

Single 3D Volume



SLICES



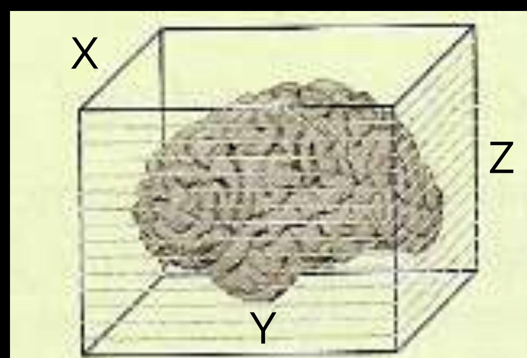
The Typical fMRI Experiment

S
U
B
J
E
C
T
S

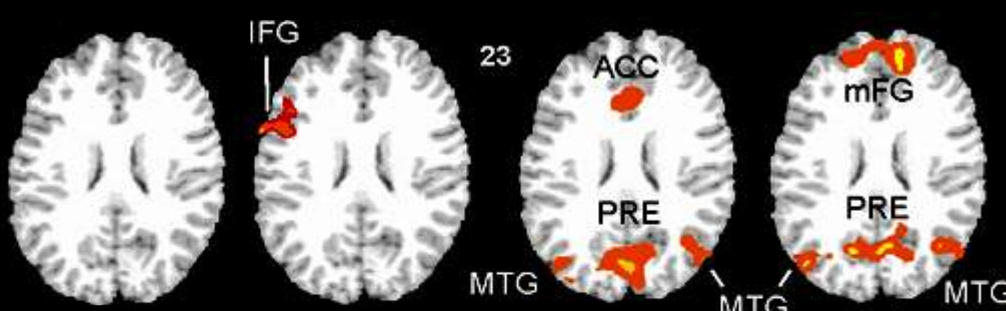
Scanning Sessions

Anatomical
& Functional
Runs

Single 3D Volume



S
L
I
C
E
S

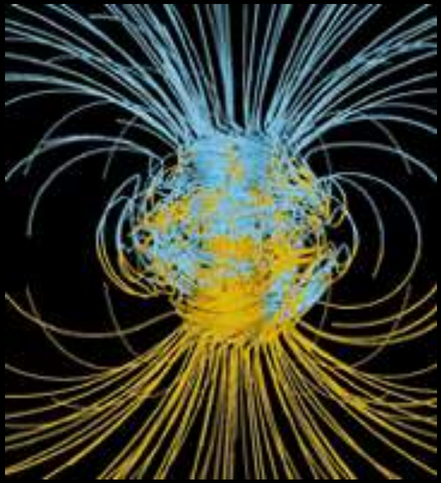


Magnet Safety

Very Powerful Magnet is on constantly!

- 1 Tesla (T) = 10,000 Gauss
- Earth's magnetic field = 0.5 Gauss
- 3 Tesla = 3 x 10,000 ÷ 0.5 = 60,000 x Earth's magnetic field

EARTH



x 60,000 =

UA's SCANNER

Main Magnetic Field

Thanks go to Jody Culham's fMRI website for some of the following slides

Magnet Safety

The whopping strength of the magnet makes safety critically important.

Things can fly – even BIG things!

Source: *http://www.simplyphysics.com/flying_objects.html*

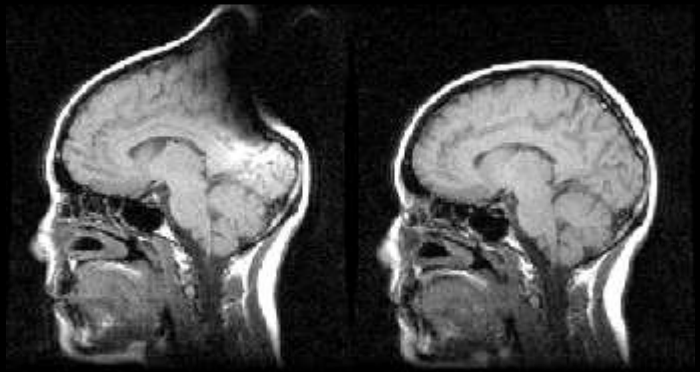
Source: *http://www.simplyphysics.com/flying_objects.html*

- We must screen subjects very carefully
- Always ON - make sure <u>everyone</u> is aware of the hazards
- Must develop a plan for screening <u>every time</u> someone enters the magnet room

Subject Safety

Anyone going near the magnet – subjects, staff and visitors <u>must be thoroughly screened</u>:

Subjects must have **no metal** *inside* the body:
• pacemakers
• aneurysm clips
• metal implants (e.g., cochlear implants)
• intrauterine devices (IUDs)
• some dental work (fillings okay)



Left: with hair band
Right: without it

Subjects must remove metal outside the body:
• jewelry, watches, piercings, even some tattoos!
• coins, etc.
• wallet
• any metal that may distort the field

Subjects must be given ear plugs or headphones (acoustic noise can reach 120 dB!)

Spinning & Wobbling Protons

The "R" in MRI: <u>RESONANCE</u>

For protons of hydrogen:

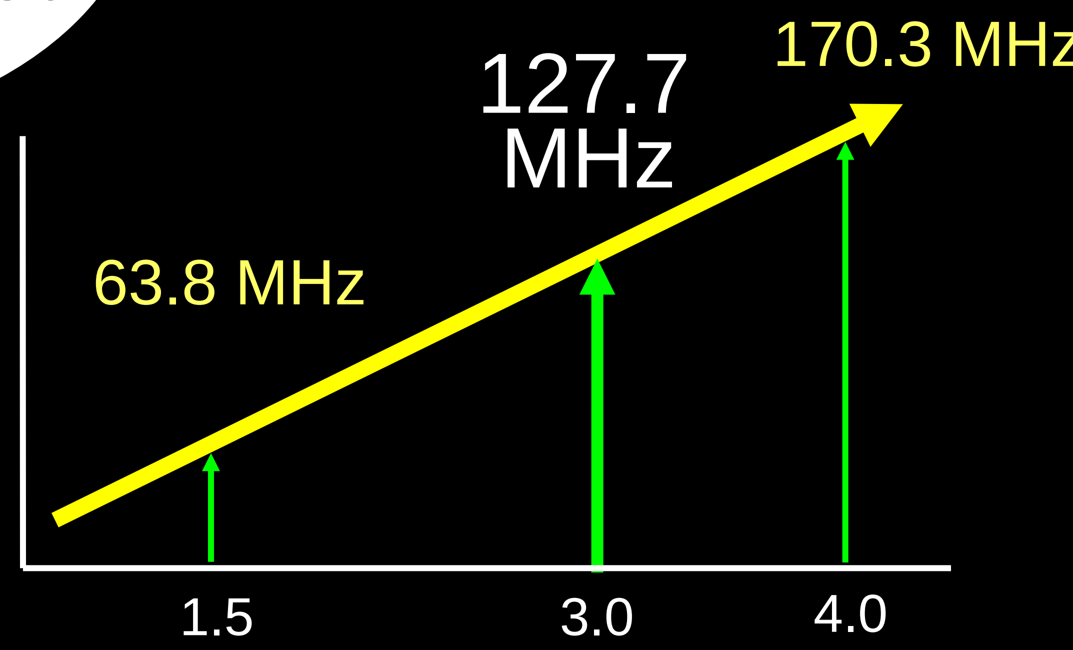
^{1}H

γ = 42.58 MHz / Tesla

5 x 10^{27} OF THEM!

The *Larmor equation:*

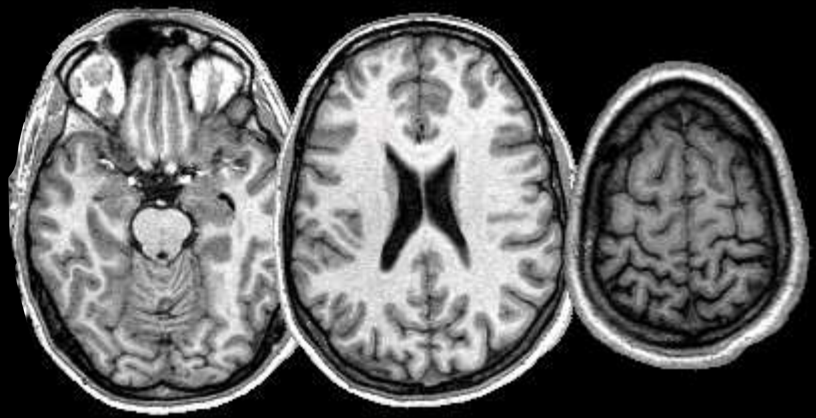
Resonance freq. = γ x Main Field



In the big magnet, ALL protons spin at their resonant frequency

Steps in 3D Localization

Step 1. Slice Selection in Z-plane

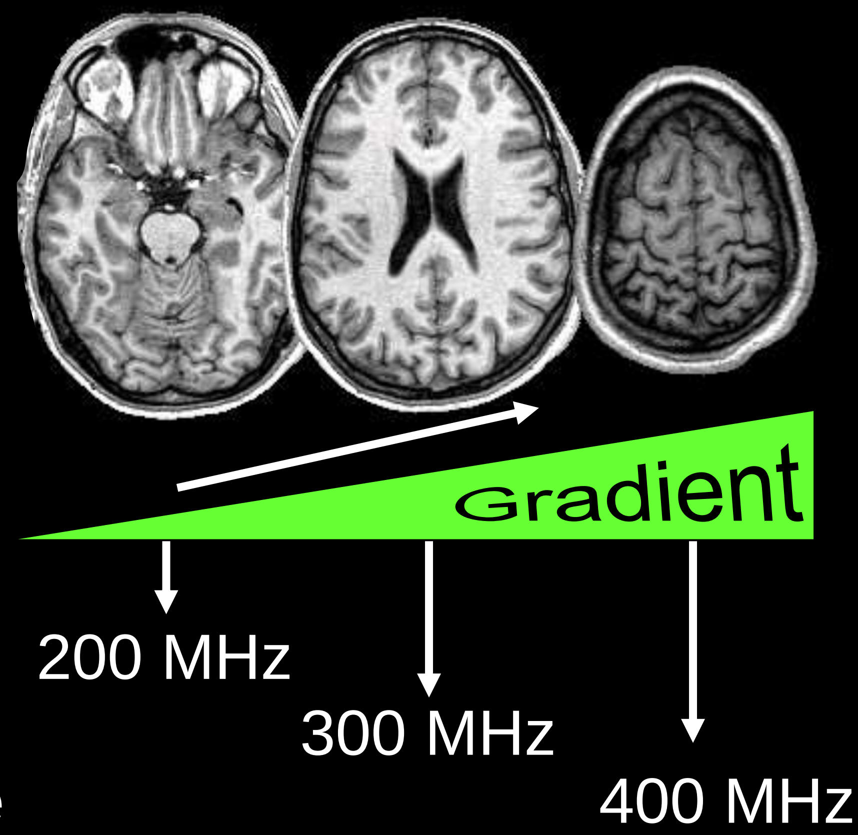


How do we separate one slice from another?

Steps in 3D Localization

Central Innovation: *Sequential* Gradients in the Field

1. Slice Selection in Z-plane



Add *another* magnetic field.
Now, the protons in each slice spin at a **DIFFERENT FREQUENCY…**

Excitation & Radio-Emission

The **EXCITATION PULSE** is set to the SAME RESONANT FREQUENCY as the protons spinning in the first slice.

(200 MHz)

When the pulse & gradient are shut off, the protons ***emit*** radio signals that are then recorded.

The Head Coil ("Birdcage")

The **EXCITATION PULSE** is set to the SAME RESONANT FREQUENCY as the protons spinning in the first slice.

(200 MHz)

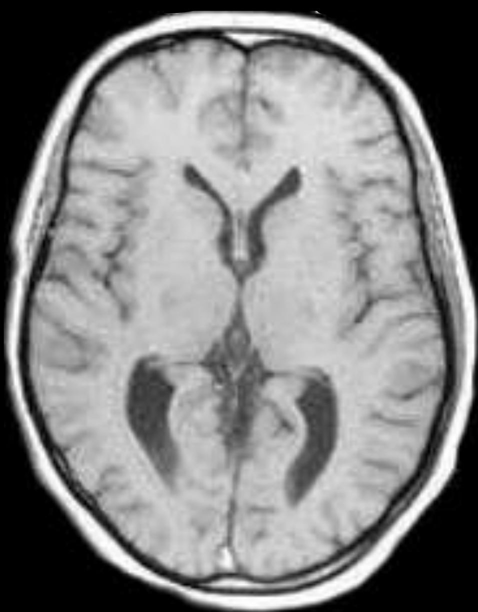
Emitted radio signals are then recorded by the "birdcage" around the head.

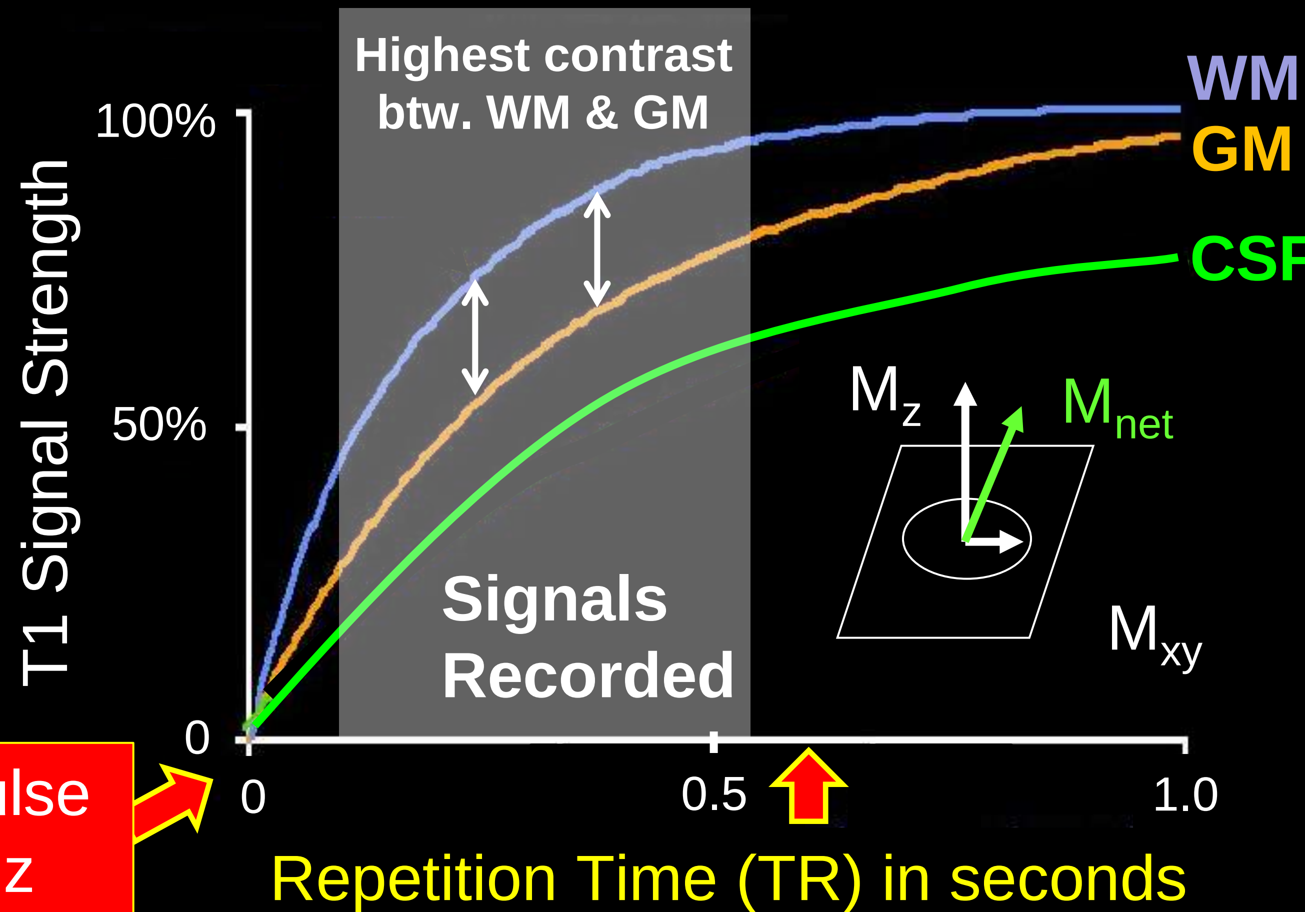
Physics of MRI

T1 = time constant for recovery of longitudinal alignment between spins

TR (repetition time) = time interval between excitation pulses

TE (time to echo) = time between excit. and data acquisition

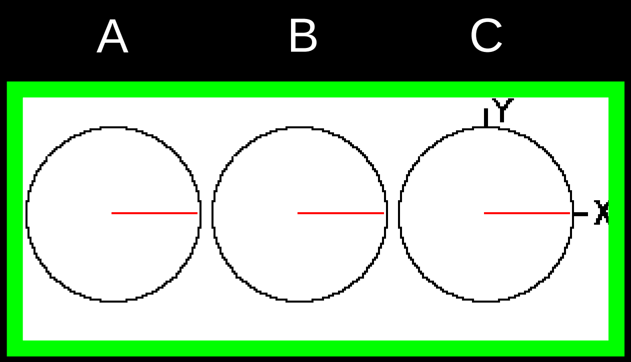




Excitation pulse @ 127.7 MHz

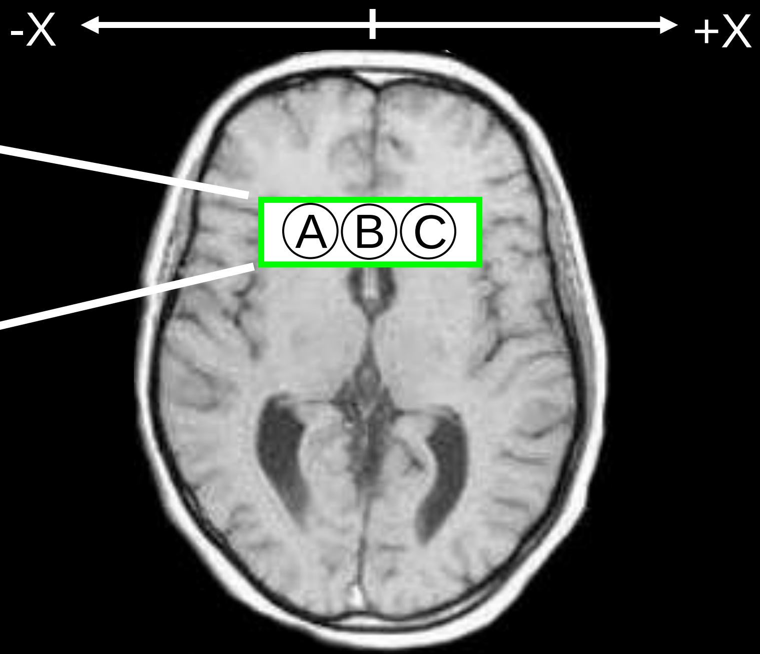
Steps in 3D Localization

Position in the slice



200 MHz

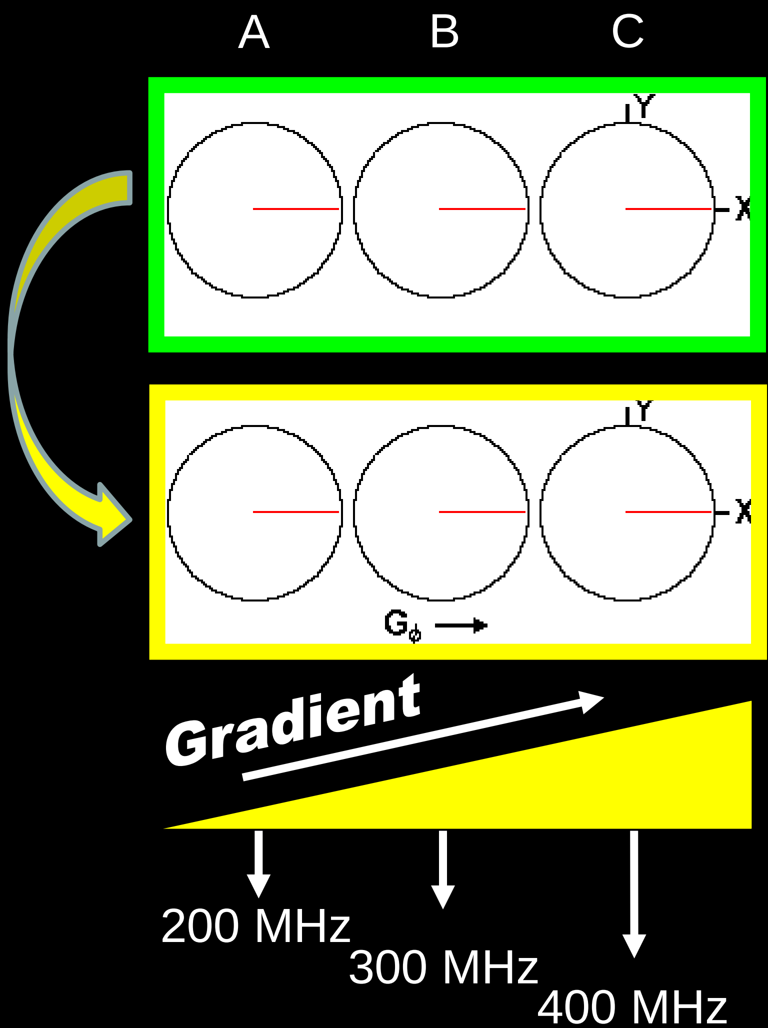
Position in the X-plane



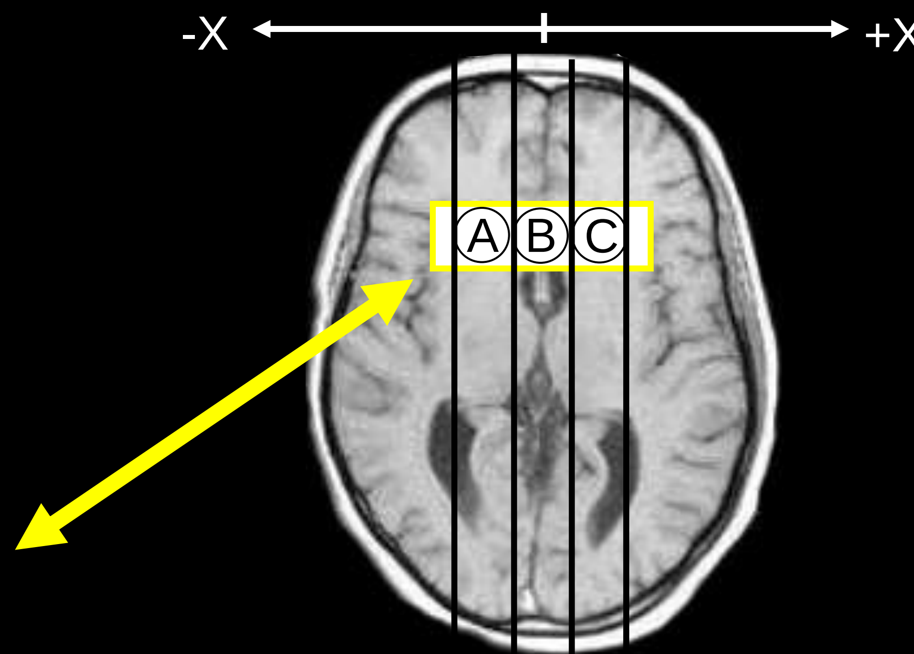
Step 2: How do we separate signals across the Z-slice?

Steps in 3D Localization

Position in the slice



Position in the X-plane



Step 2:

Add a gradient in the X-plane

Excitation & Radio-Emission

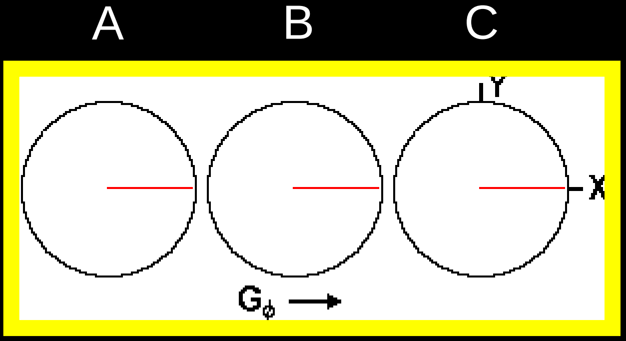
The **EXCITATION PULSE** is set to the SAME RESONANT FREQUENCY as the protons spinning in each X-slice.

(200, 300 MHz…)

Emitted radio signals are then recorded by the “birdcage” around the head.

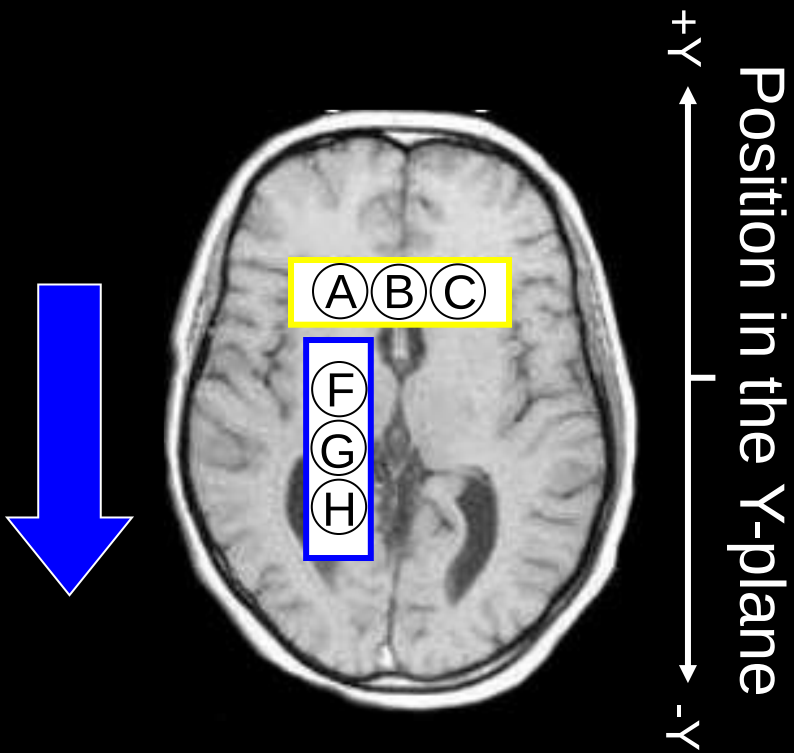
Steps in 3D Localization

Position in the slice



X-GRADIENT

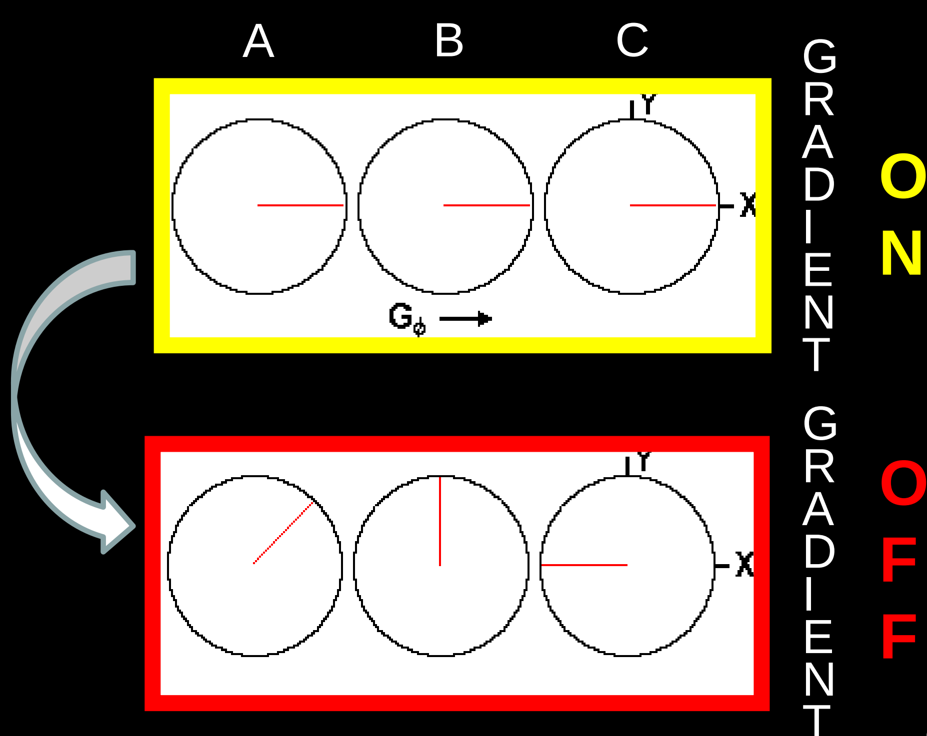
ON



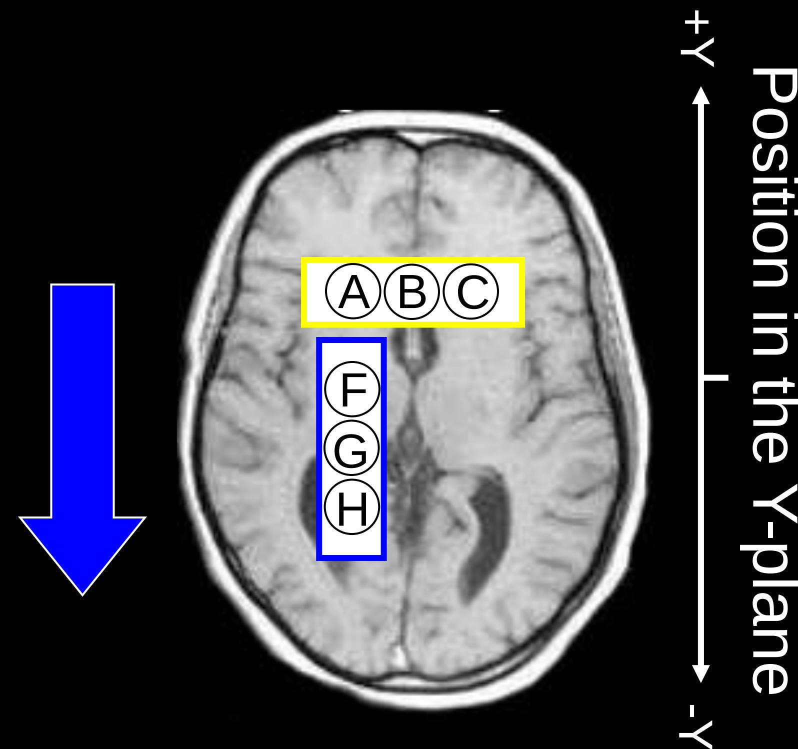
Step 3. How do we get spatial information DOWN the slice?

Steps in 3D Localization

Position in the slice



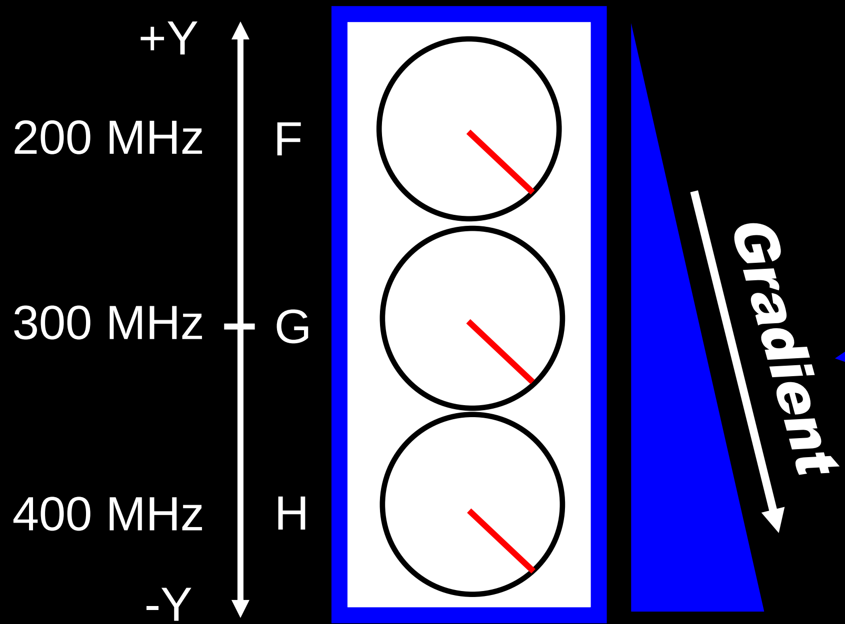
200 MHz

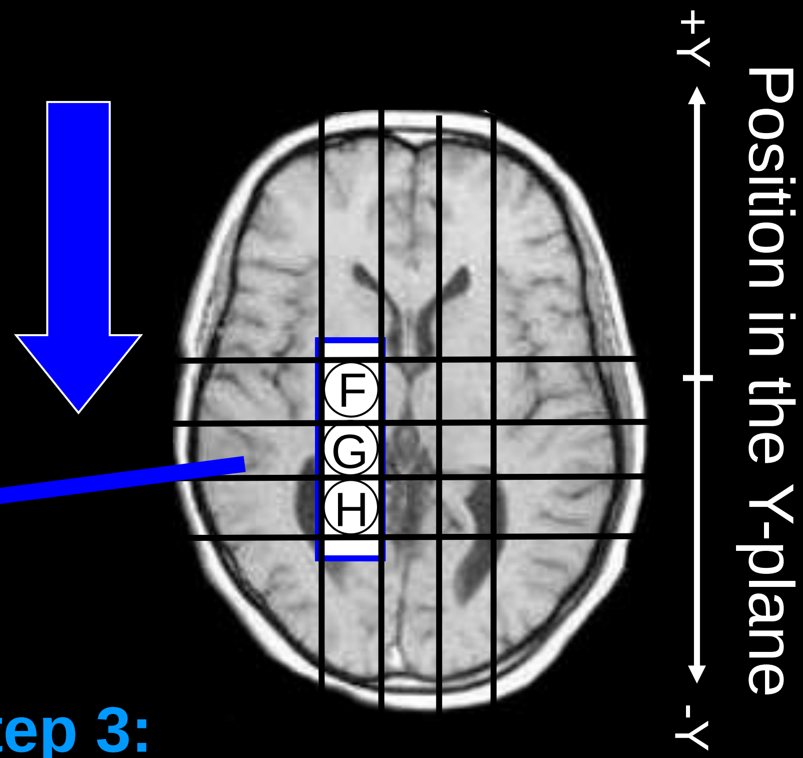


Step 3. How do we get spatial information DOWN the slice?

Steps in 3D Localization

Position in the slice





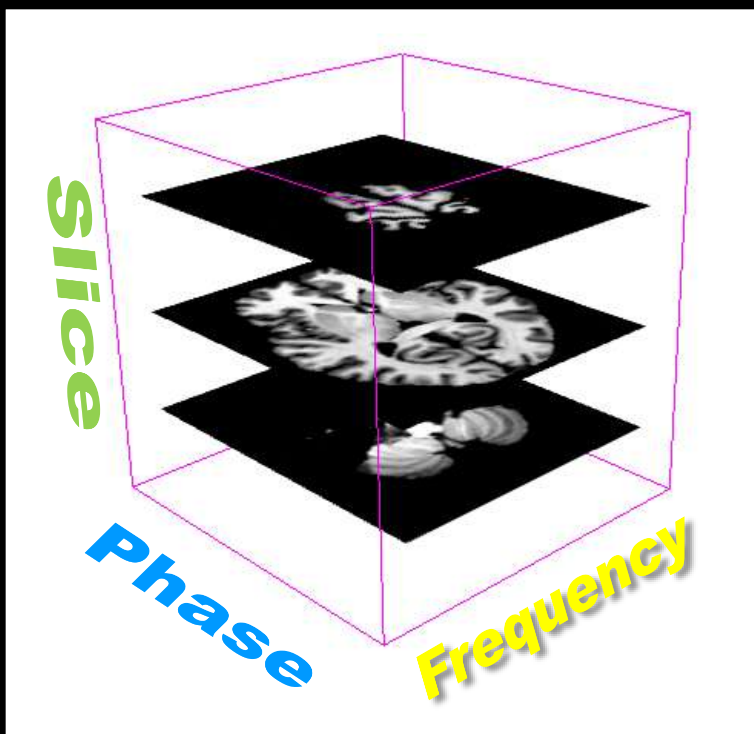
Step 3:

Add ANOTHER gradient

NOW, also record the **phase** information in each column.

Steps in 3D Localization

1. Slice encoding (bottom to top)
2. Frequency encoding (left to right)
3. Phase encoding (front to back)

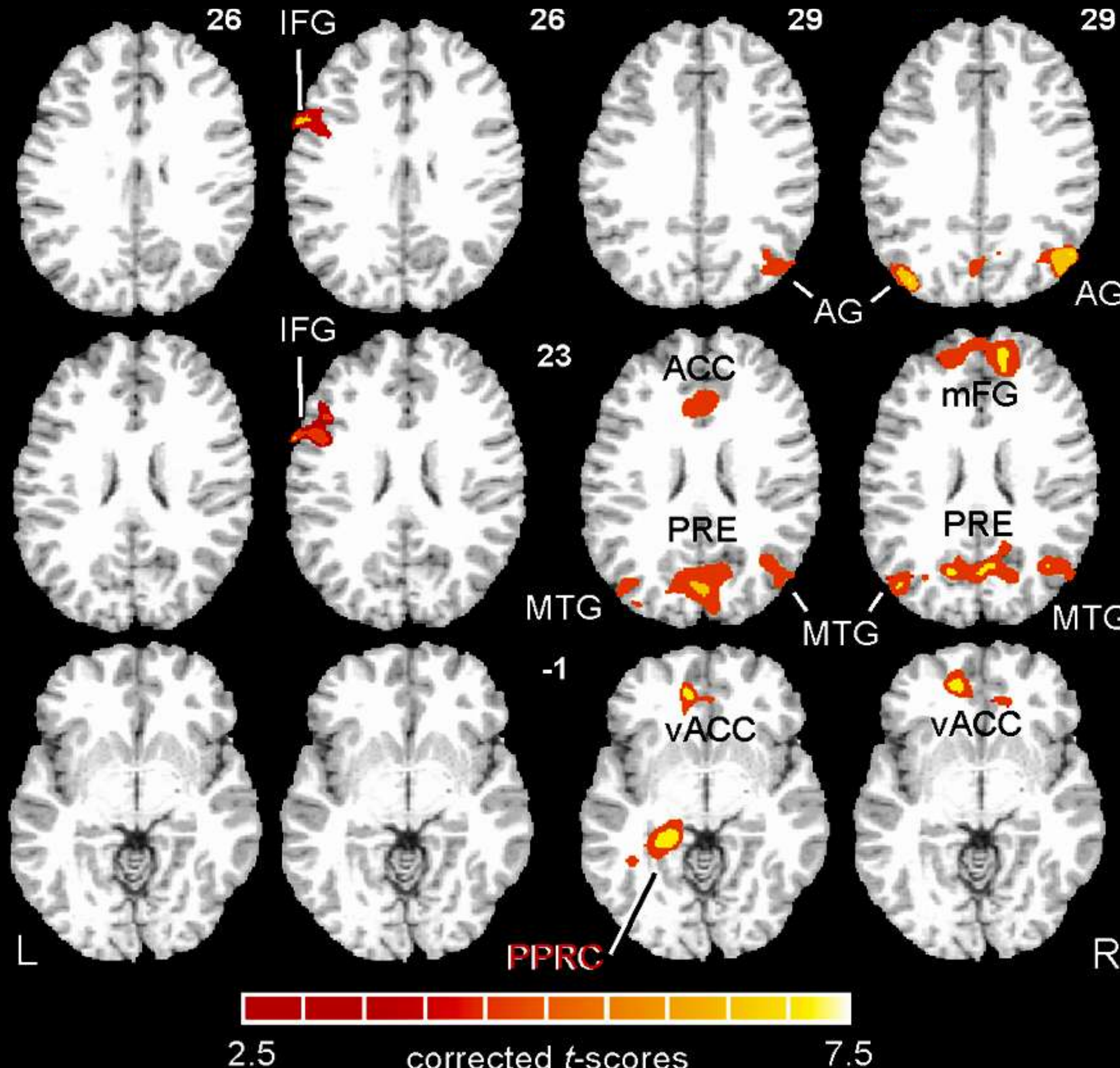


A high-res 3D MRI dataset takes about 7 minutes to collect

Where does the *f*-MRI signal come from?

The colors simply show the MAGNITUDE of activity across the entire brain.

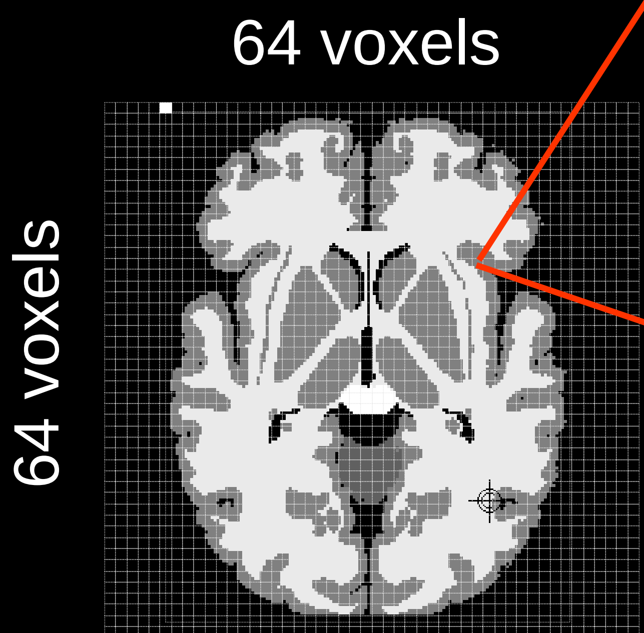
But where does the activity come from?

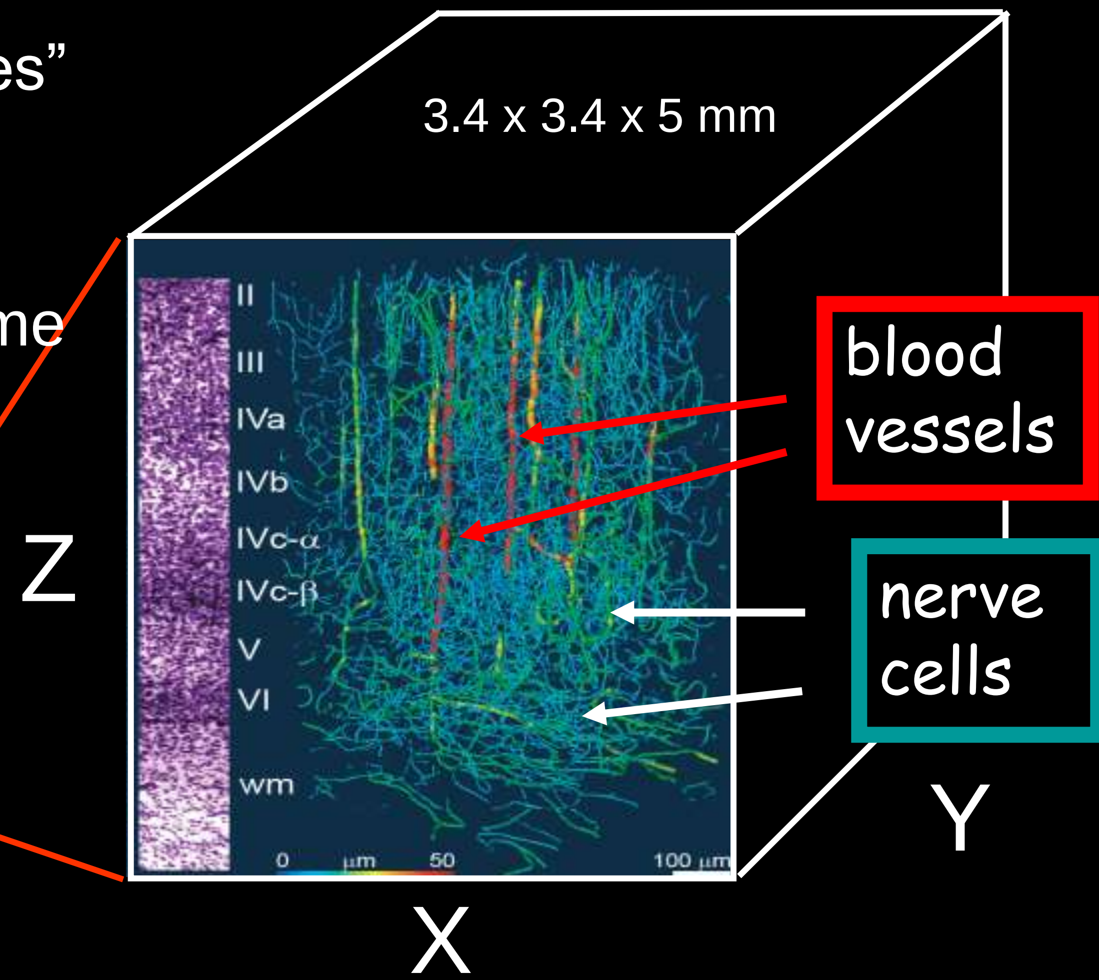


Where does the fMRI signal come from?

ONE fMRI voxel "images" approximately
1 million nerve cells!

These neurons consume LOTS of ENERGY!





This is ONE VOXEL
in the image

fMRI : an indirect measure of neural activity

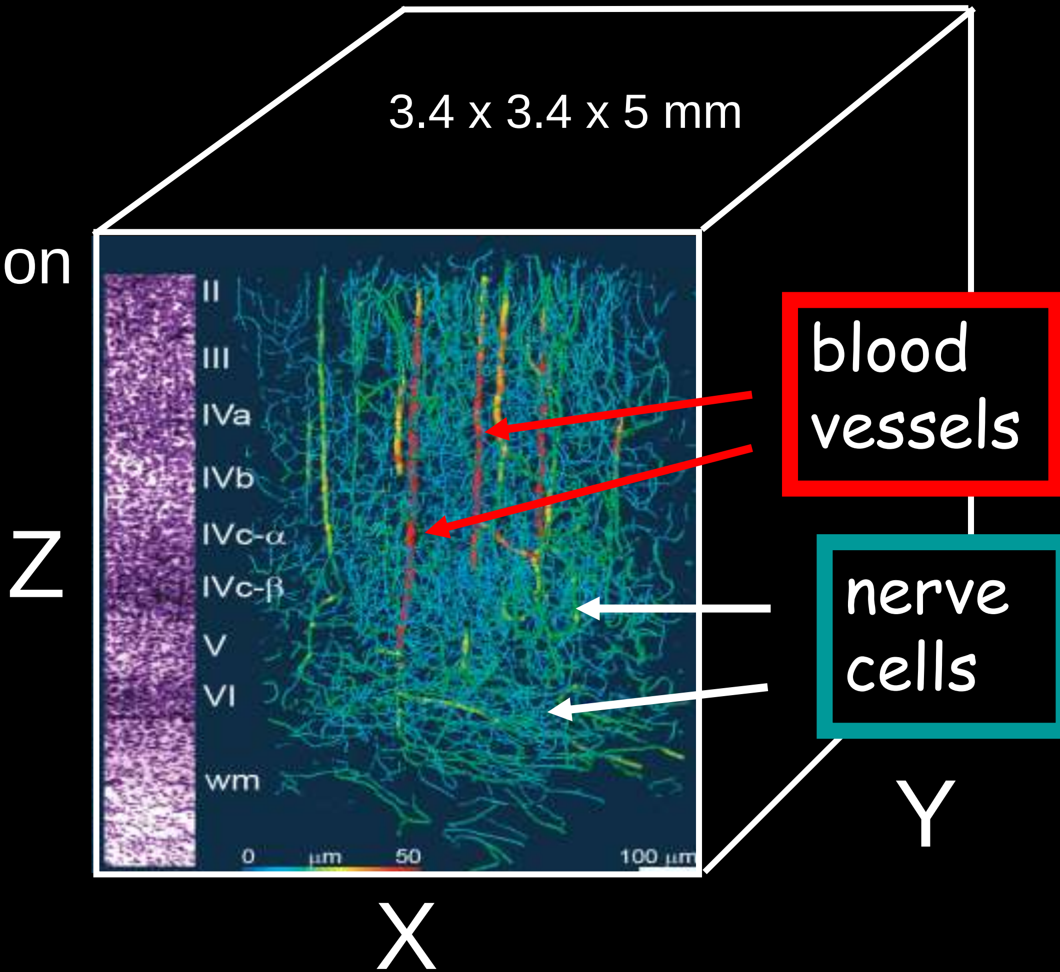
↑ in neural activity
↑ in local blood flow
↑ rate of O_2 consumption

when LBF **>** O_2 cons,

oxyHb **>** deoxyHb

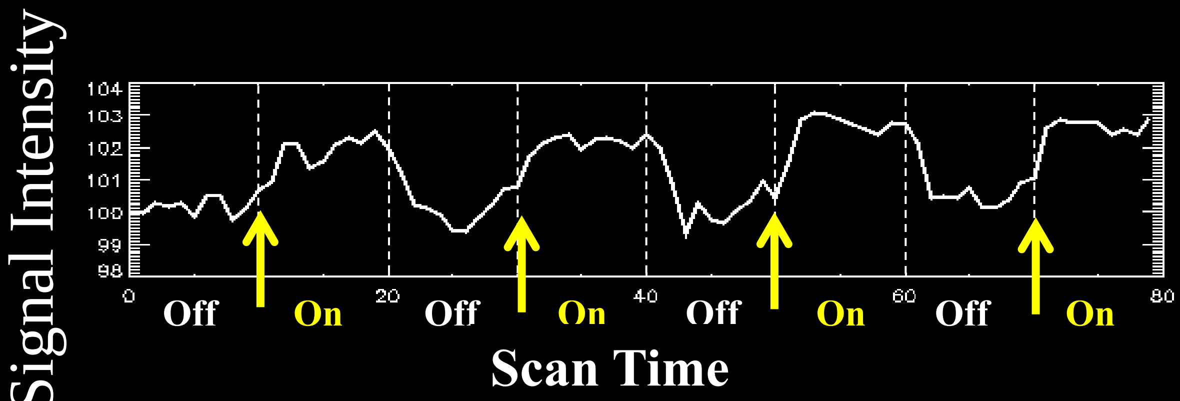
↑ **BOLD** signal

= **B**lood
Oxygen
Level
Dependent
contrast



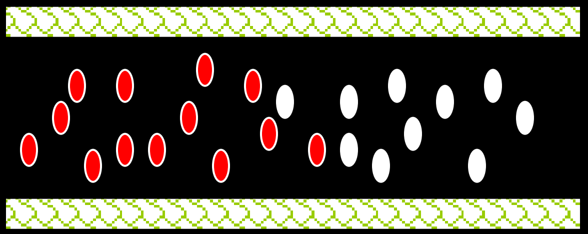
This is ONE VOXEL in the image

Deoxy-Hb and BOLD Contrast



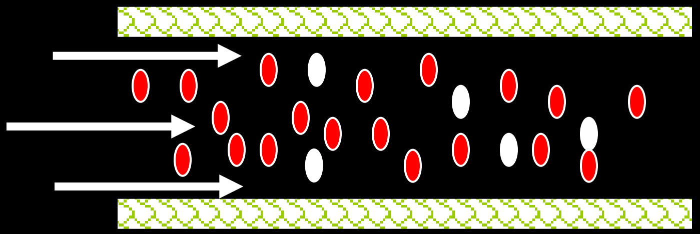
AT REST

Normal blood flow



ACTIVATED

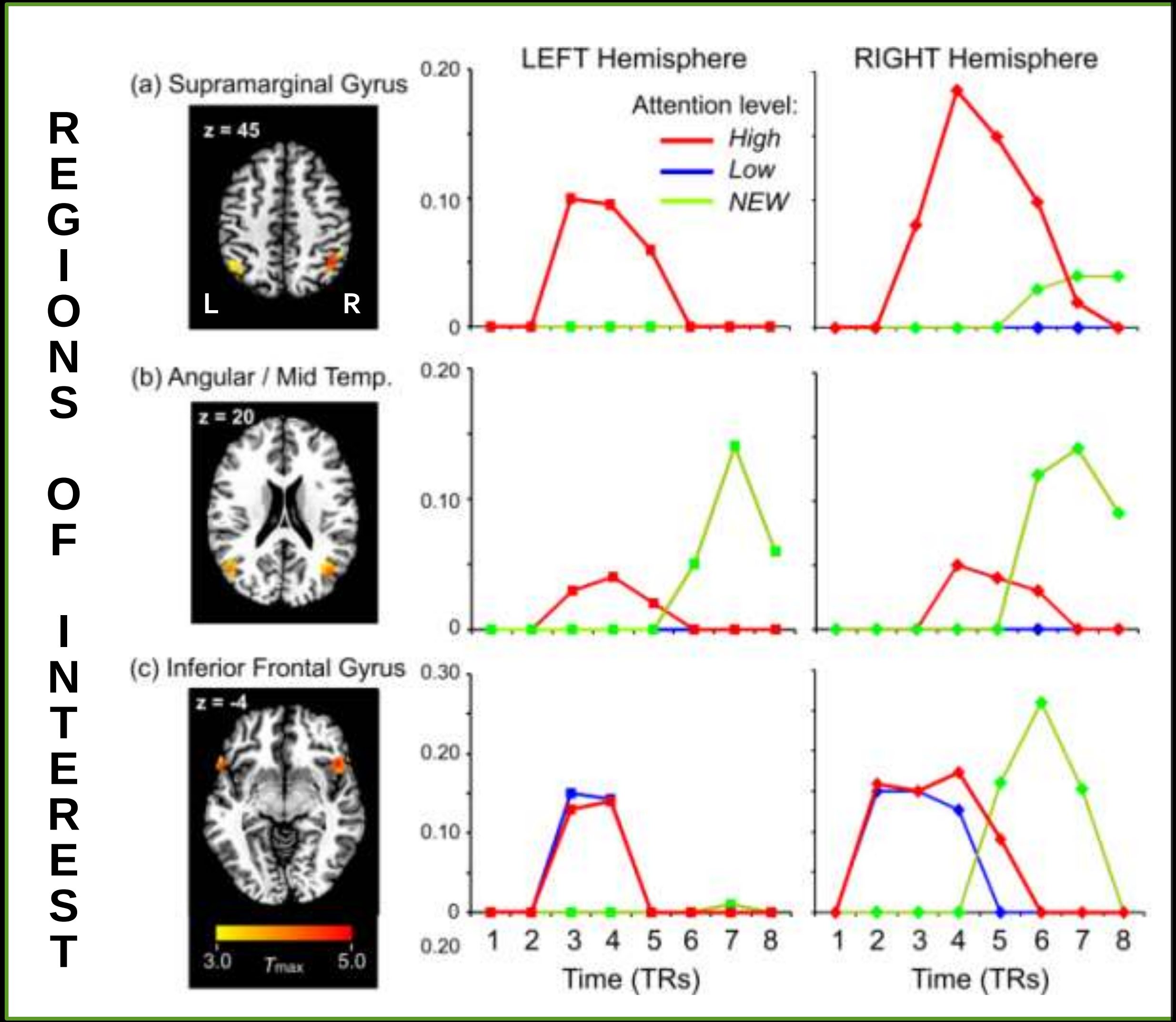
Increased blood flow



Oxyhemoglobin   Deoxyhemoglobin (reduces BOLD)

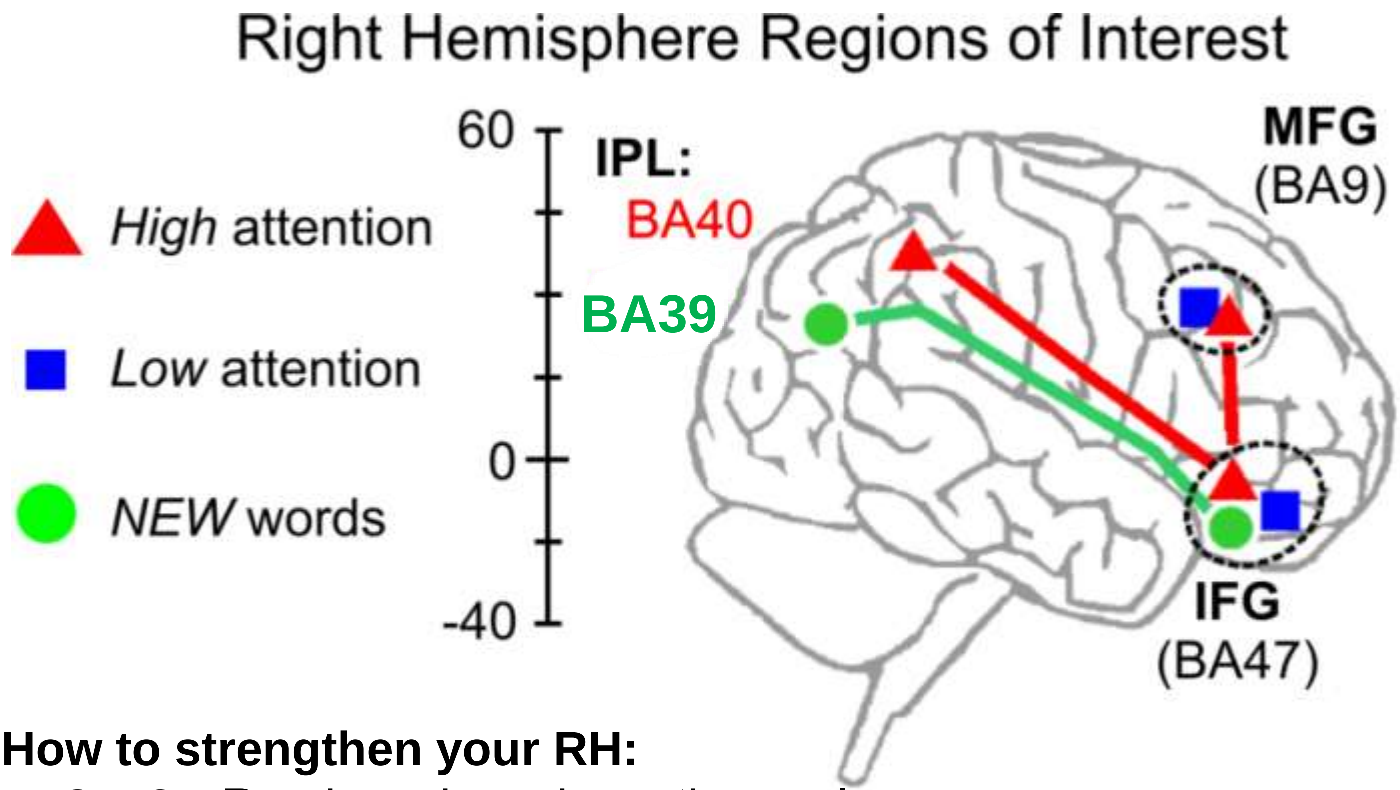
[LESS Deoxyhemoglobin INCREASES the BOLD signal]

fMRI Imaging in my Language Research



From: Christensen et al., 2011

Pathways for ATTENTIVE LISTENING



How to strengthen your RH:

- **SING!** Read music and practice scales…
- **HIKE!** Read trail maps…
- **PAINT** or **DRAW!** Exercise your spatial localization skills…

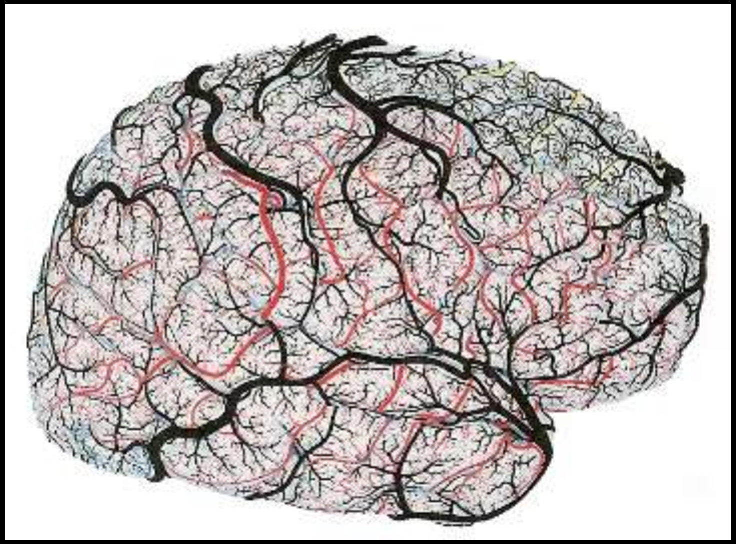
EEG vs. Brain Imaging (MRI, fMRI, DTI)

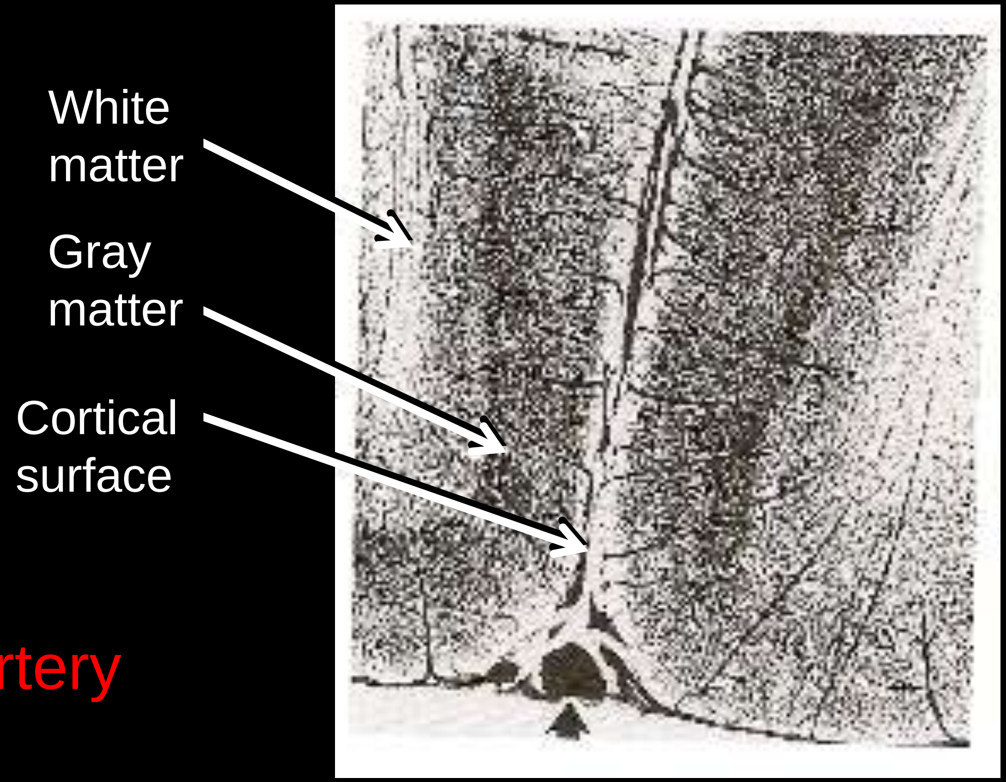
	EEG	MRI	fMRI	DTI
Spatial Resolution	Poor	Excellent	Excellent	Excellent
Temporal Resolution	Excellent	Poor	Poor	Poor
Type of Tissue	Gray	All	Gray	White
Brain Function?	YES	NO	YES	NO

Where does the fMRI signal come from?

"The moment emotional or intellectual activity began, down went the balance at the head end, in consequence of the redistribution of blood in his system."

Where does the fMRI signal come from?





Red: middle cerebral artery

Veins are in black