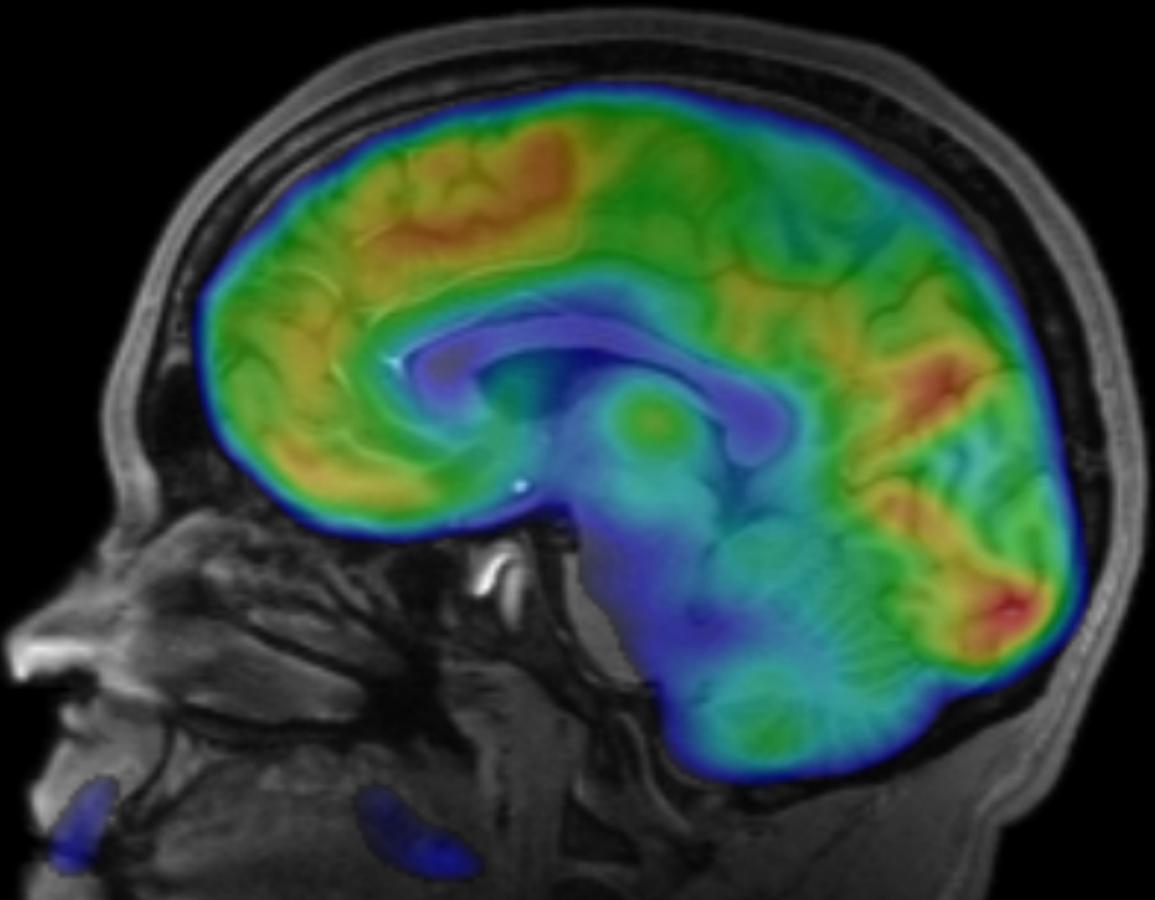


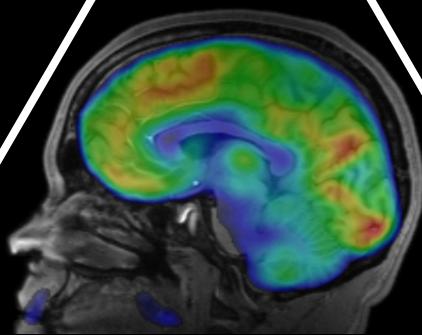
INTRO TO BRAIN IMAGING



Tom Morin

Neuroimaging: A Tool for CBS

Computer Science

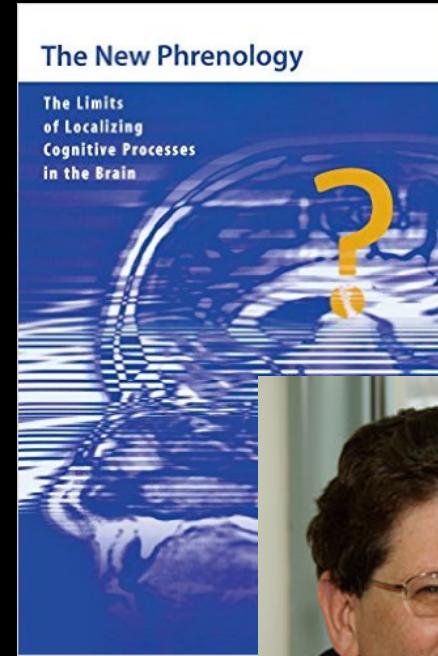
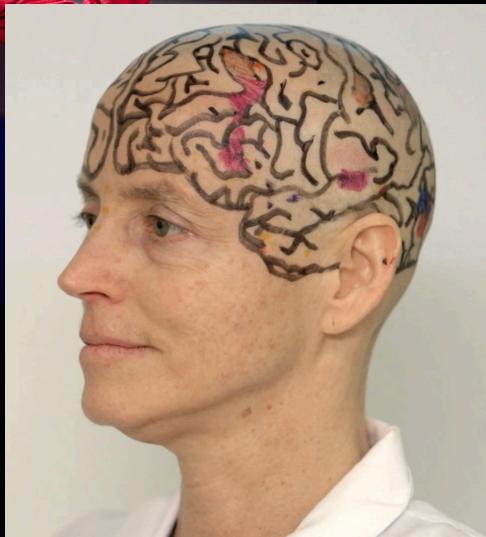


Philosophy

Psychology

From the Homework:

- Can we localize brain function?



Kanwisher's TED Talk

- Believes specific brain regions are responsible for specific cognitive functions
 - The Fusiform Gyrus for Faces
 - The Temporal Parietal Junction for “thinking about what someone else is thinking about”
- Evidence in a Face-viewing study is conclusive
 - Or is it? (*We'll get to this later...*)

Uttal's: The New Phrenology

- Raises the questions:
 - How exactly should we go about defining a cognitive function?
 - Is it even possible to identify/classify all of the different functions the brain has?
- Believes we are making an inappropriate assumption that behavior manifests itself in biology with a one-to-one mapping

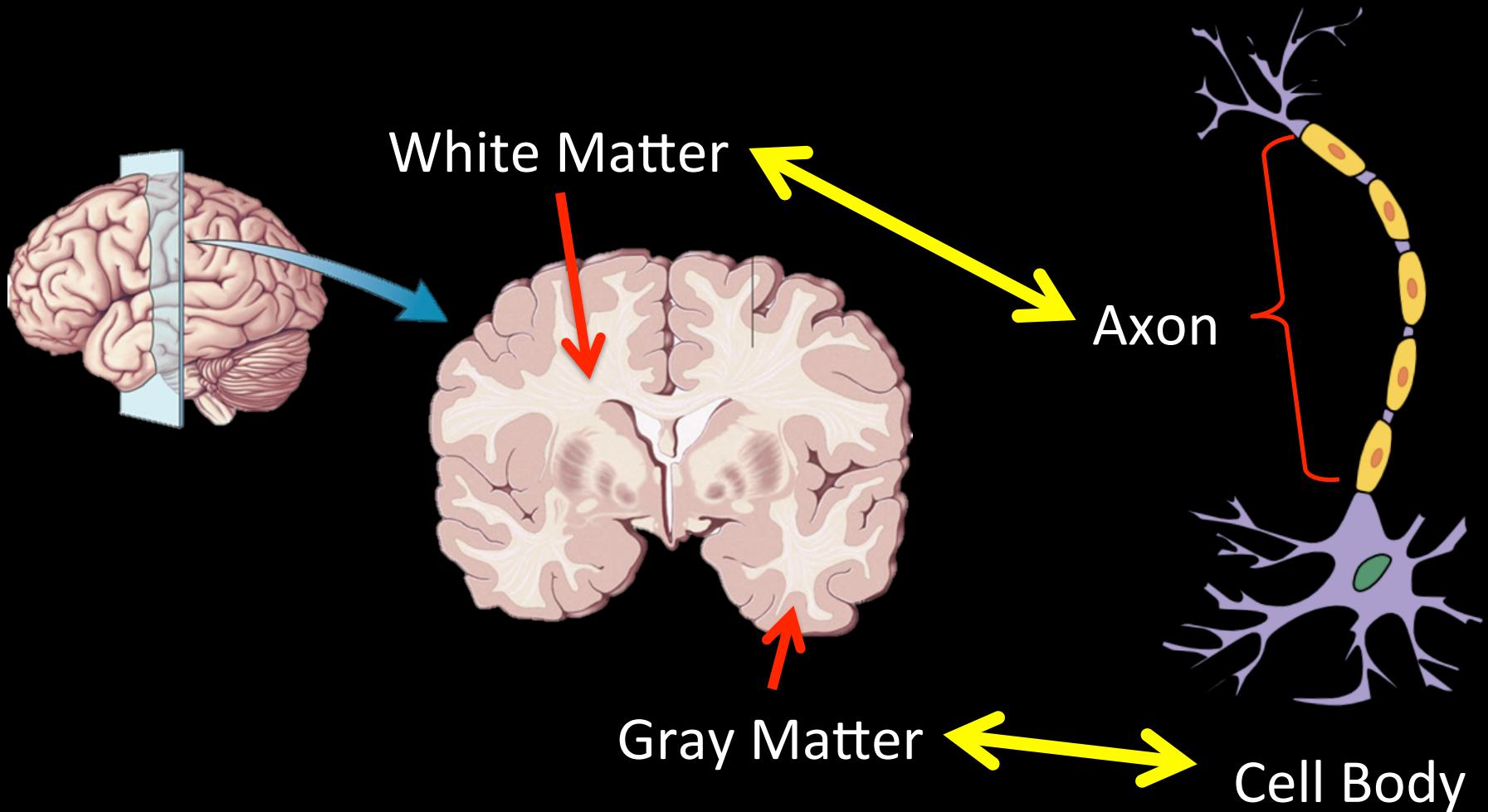
Forum Response: Kate Zheng

- “...one thing that stuck out to me about the Uttal reading was the distinction between a brain region being **sufficient** or simply **necessary** to process information.”
- “It seems that so many parts of our brain are similar, and yet we have some regions that are very specialized. My question would be whether these many areas are, as you say, pieces of a puzzle that is one type of perception. But I would also go further in wondering whether one region is simply necessary, while another region could be sufficient for the mental process to occur.”
- “I read an article comparing the computer to a brain... The authors of the article were investigating the computer in the way that neurologists investigate brain localization in its basest form: analyzing damage to one spot in terms of specific functionality, and they found that while one part of the computer was damaged and prevented a certain function from running smoothly, the damage itself only prevented a different process from being completed, and was not the actual cause of the computer's problem.”
- “Therefore, I do agree with Uttal's idea in that localization should be approached with caution, as a damaged part of the brain may simply stop the brain from connecting in certain ways, and therefore be unable to complete a function, but that area may not be completely responsible for that function.”

Agenda for the Rest of Today

- Quick Brain Anatomy Review
- How Does MRI Work?
 - Structural MRI
 - Functional MRI
- How Does PET Work?
- Looking to the Future

Quick Brain Anatomy Review

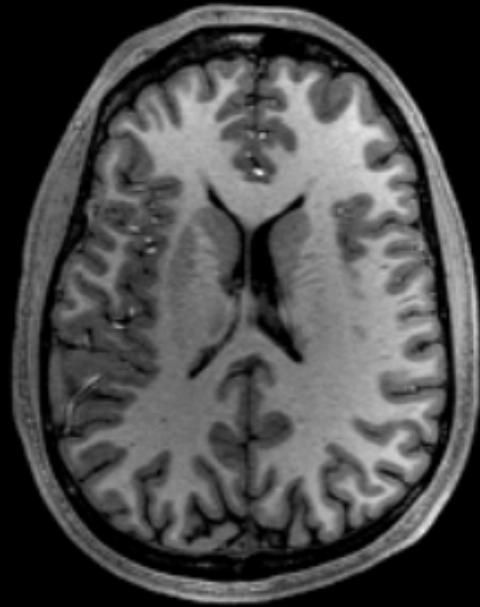
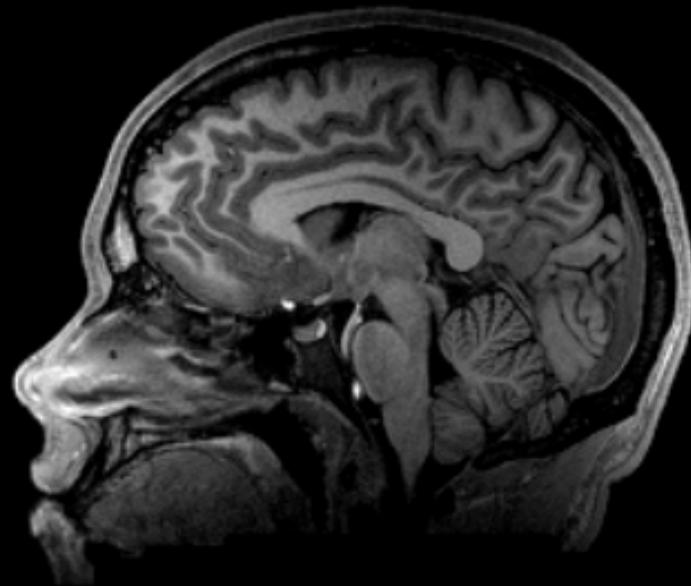
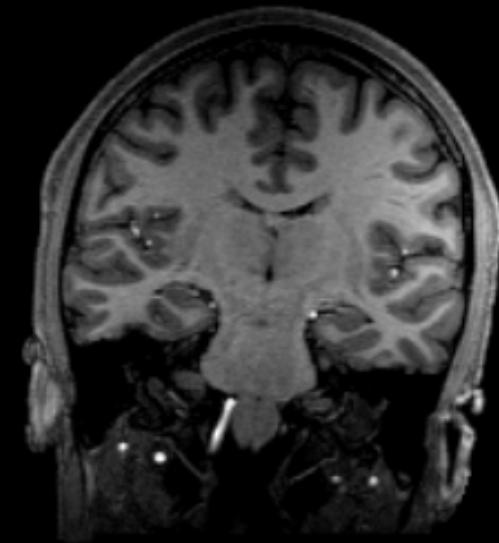


What am I Looking at?

Coronal

Sagittal

Axial



MR Safety

Demonstration of the powerful magnetic field
of a clinical 1.5 Tesla MR scanner

Part II - Oxygen bottle



by
G. Starck, B. Vikhoff-Baaz, K. Lagerstrand,
E. Forssell-Aronsson och S. Ekholm

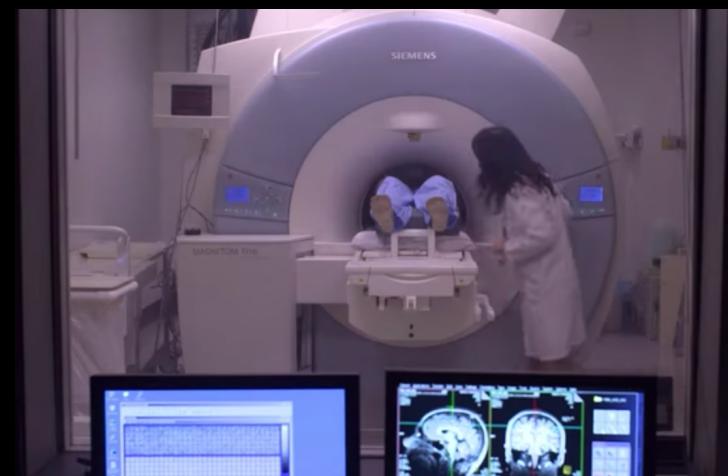
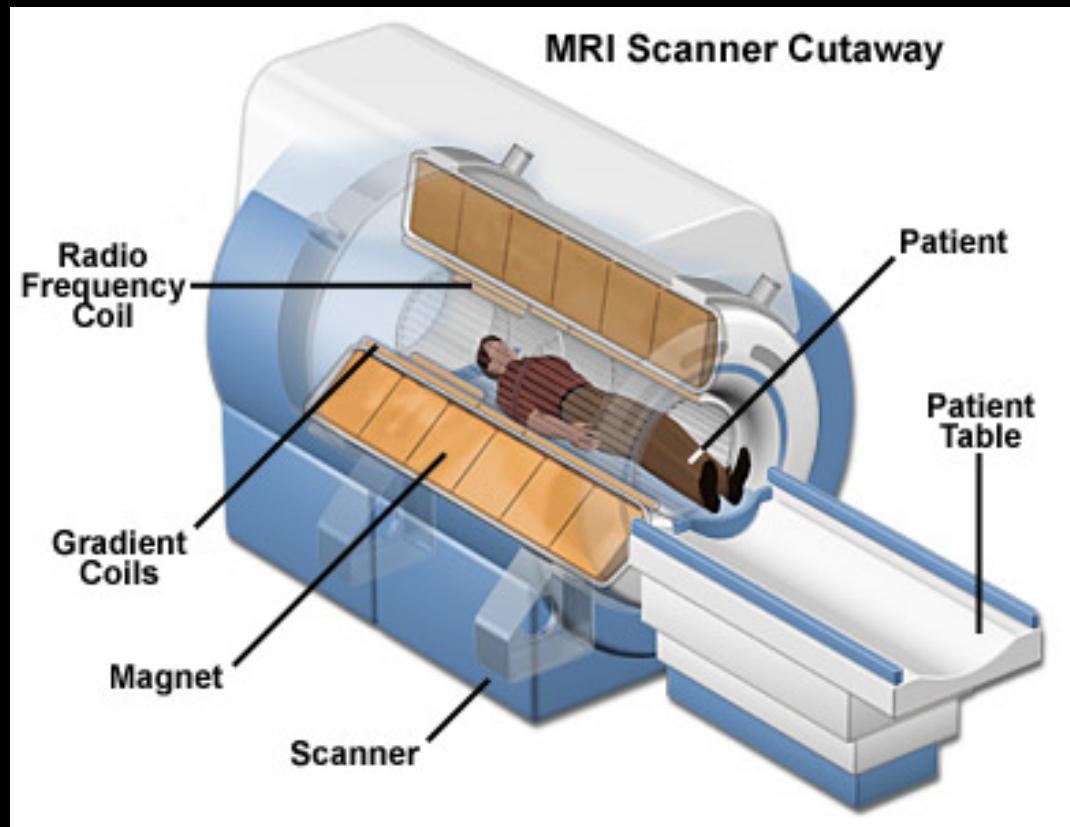


SAHLGRENSKA
UNIVERSITY HOSPITAL

2004

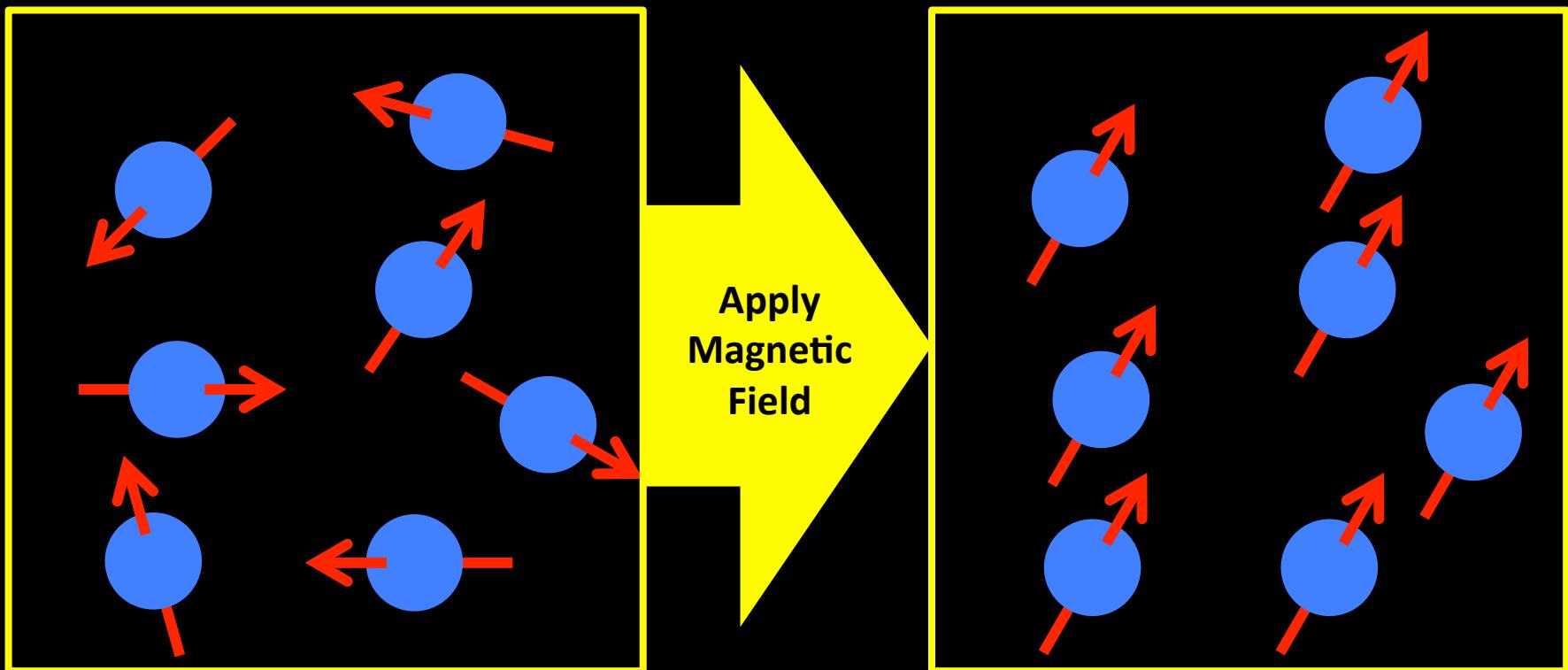
O₂ Tank vs. Watermelon: <https://www.youtube.com/watch?v=plvIEf7JsKo>

How Does MRI Work?



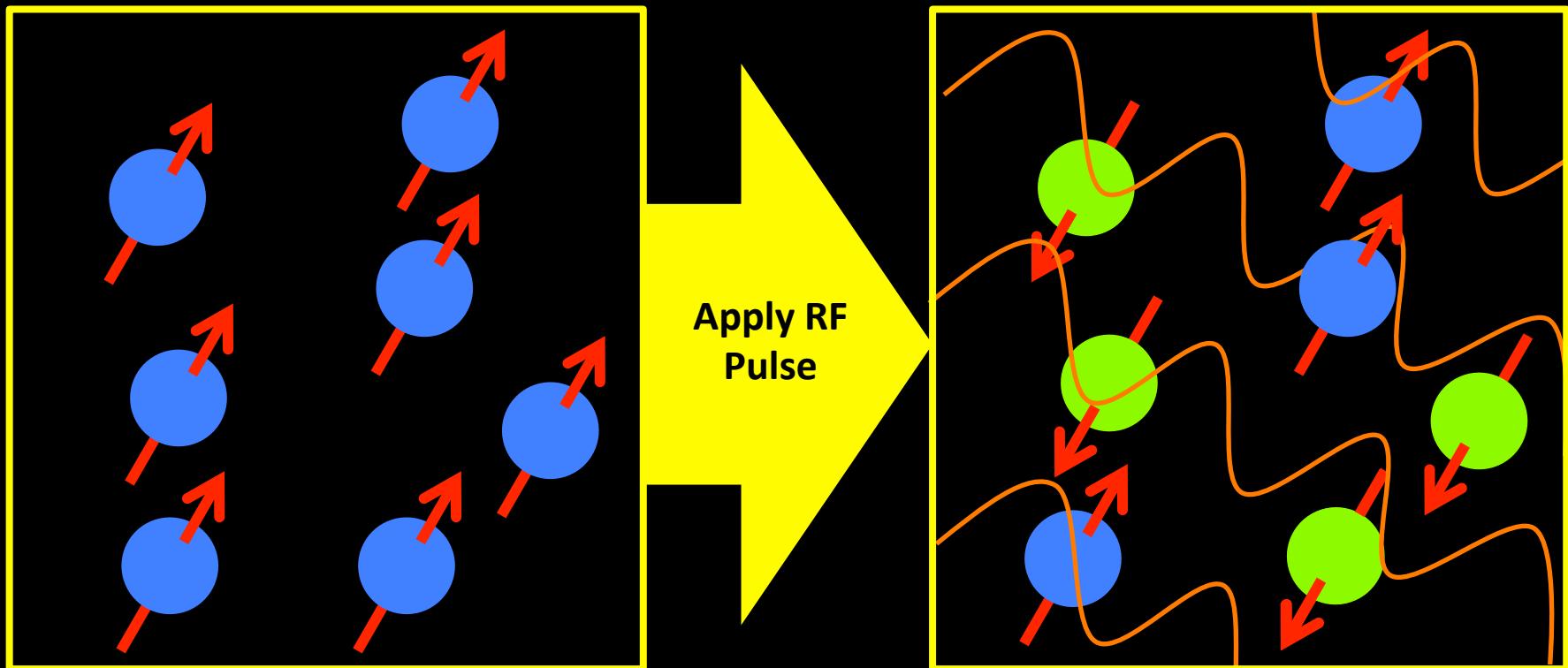
How Does MRI Work?

1. Place subject in a strong magnetic field
 - Protons align to the direction of the field



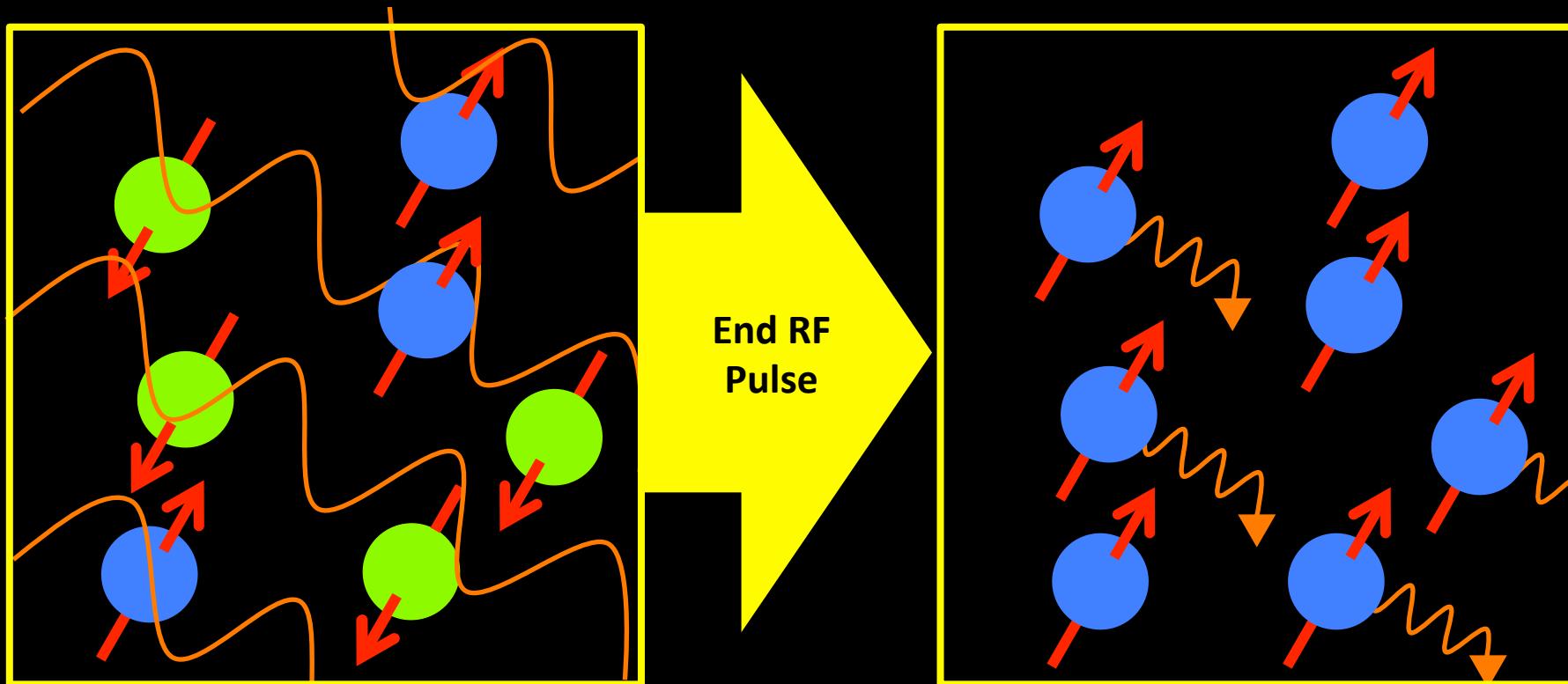
How Does MRI Work?

2. Apply a radiofrequency pulse, temporarily sending some protons into an **excited state**

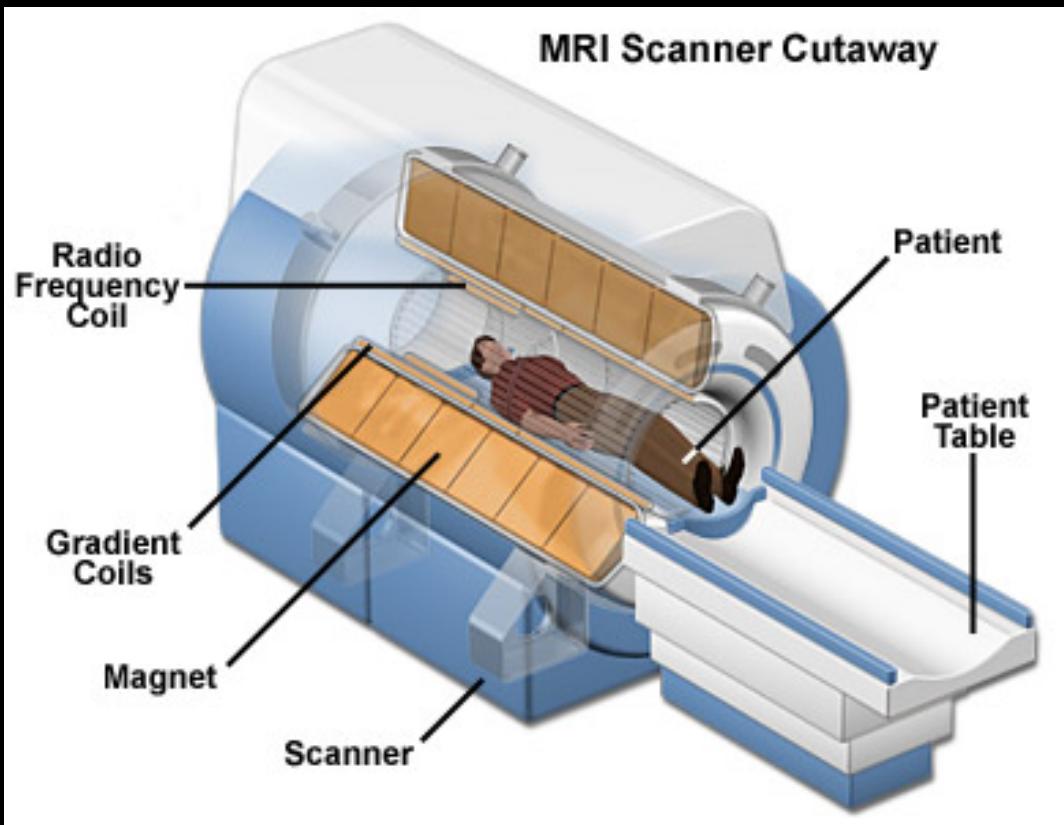


How Does MRI Work?

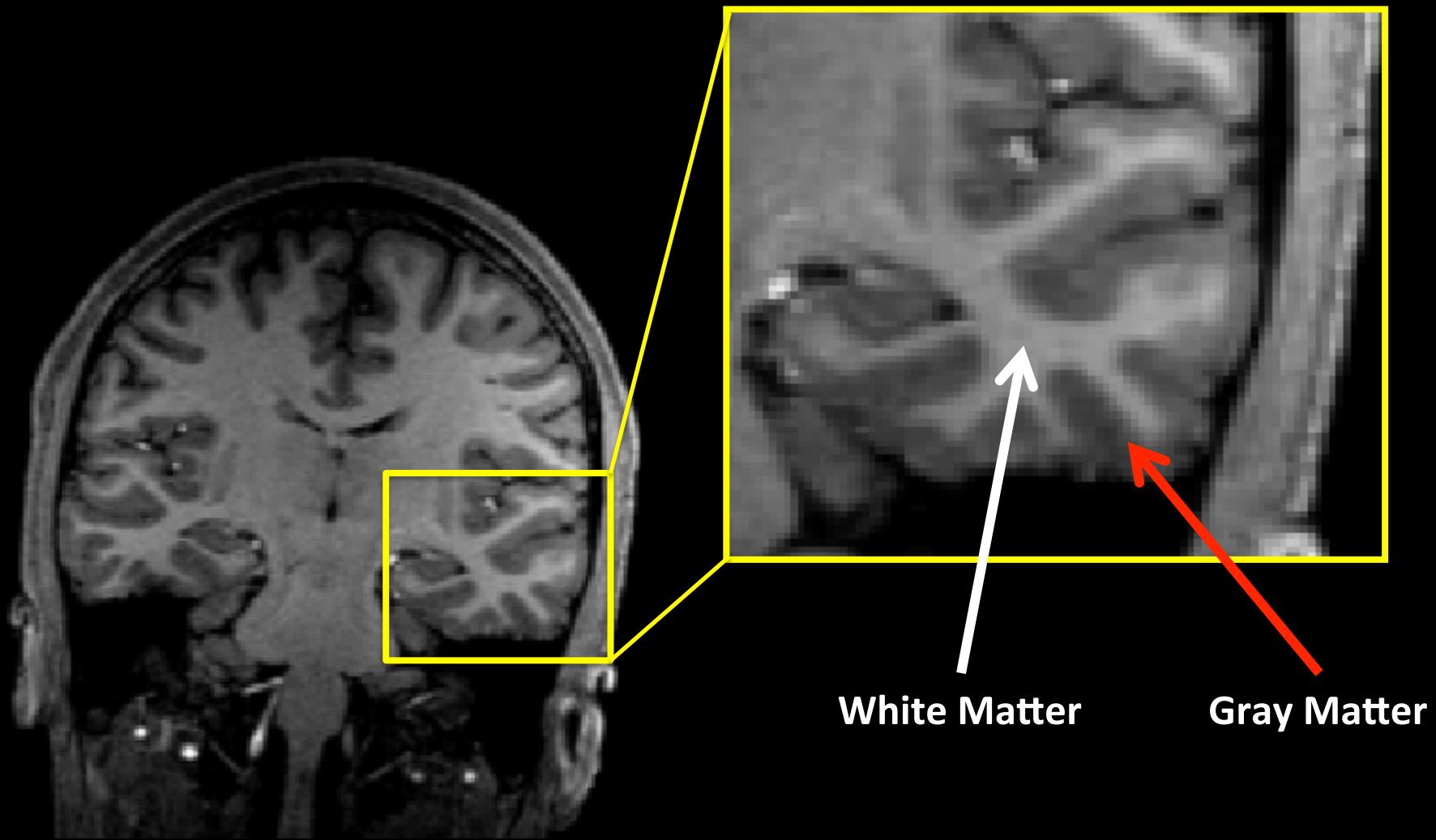
3. End the pulse, allowing protons to relax back
 - As they relax, the protons release energy in the form of radiowaves, that is detected by RF coils



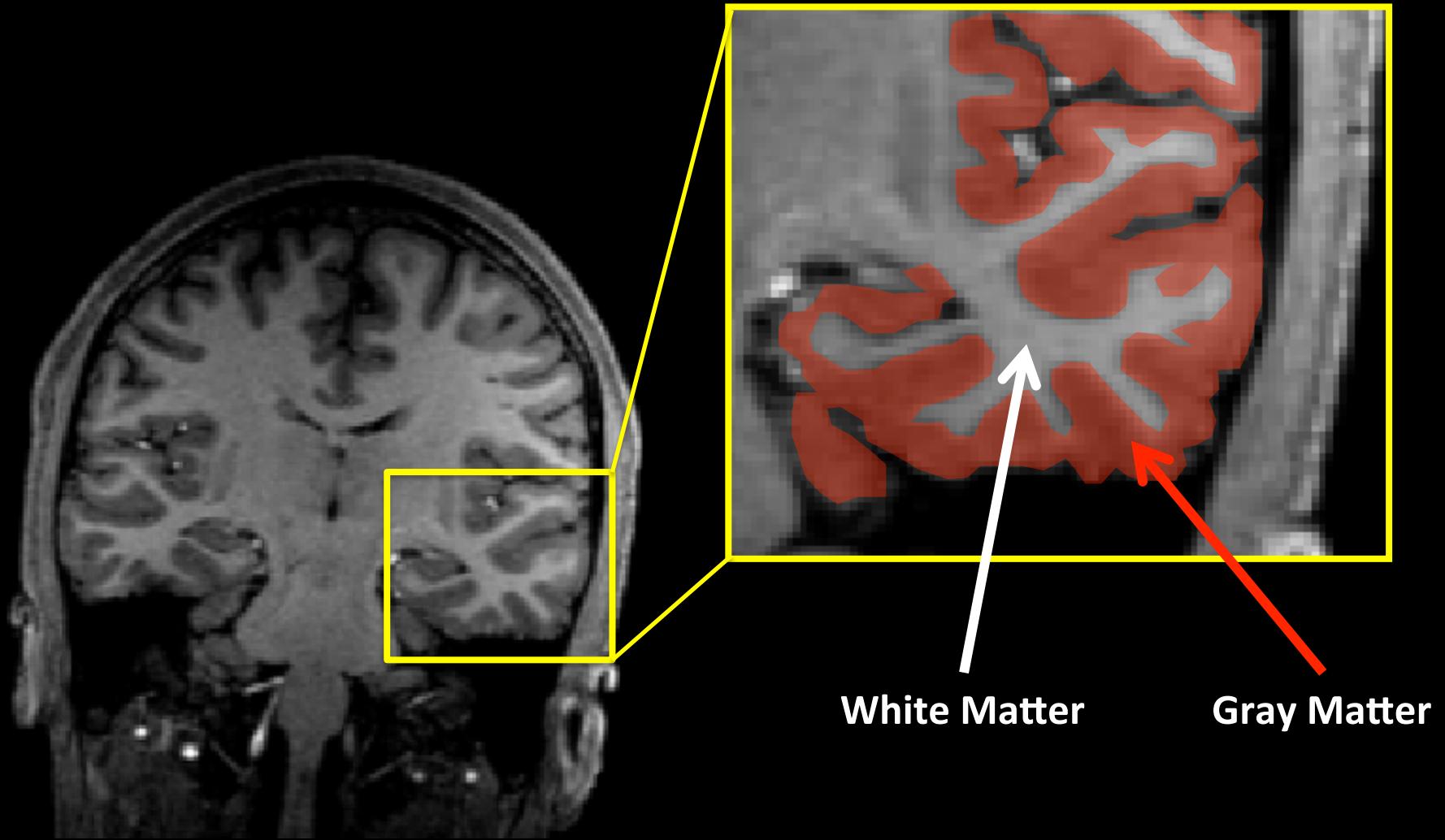
How Does MRI Work?



MR Signal Differs for Each Tissue

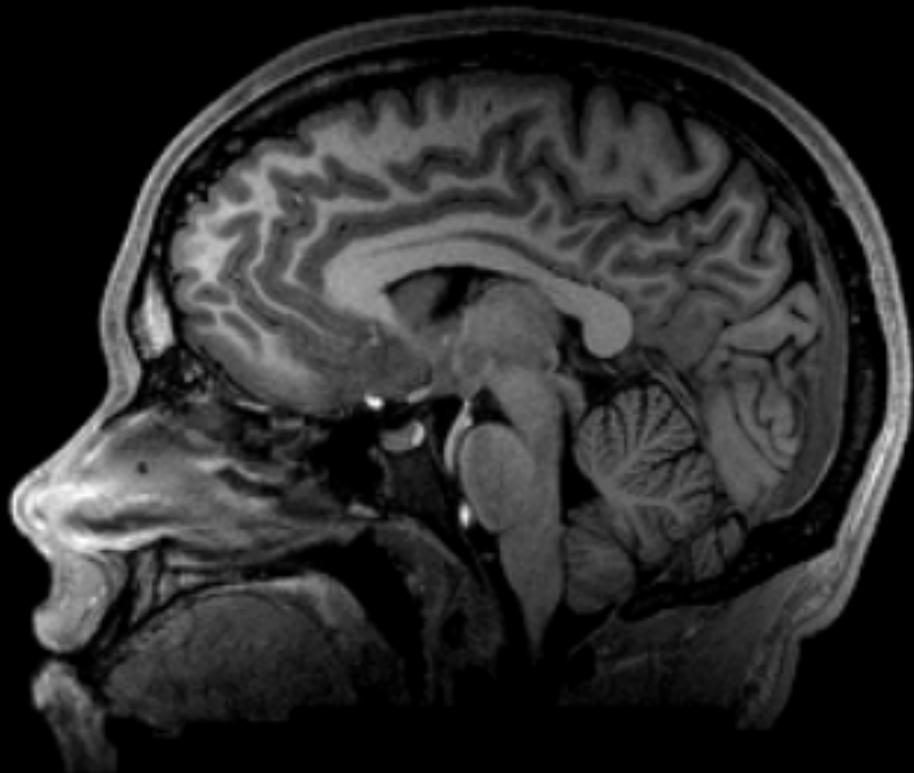


MR Signal Differs for Each Tissue



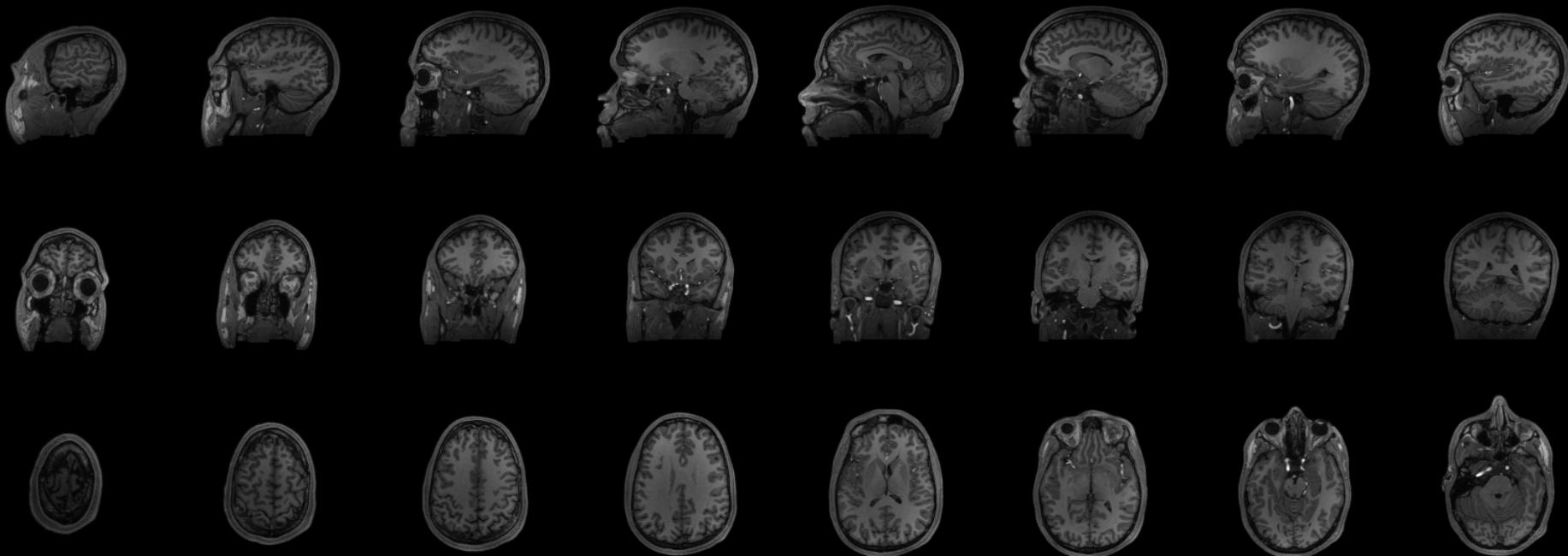
Structural MRI

- 5-10 minutes to acquire
- ~1mm resolution
- 3 Dimensional
- It's not just an image, it's DATA! ☺

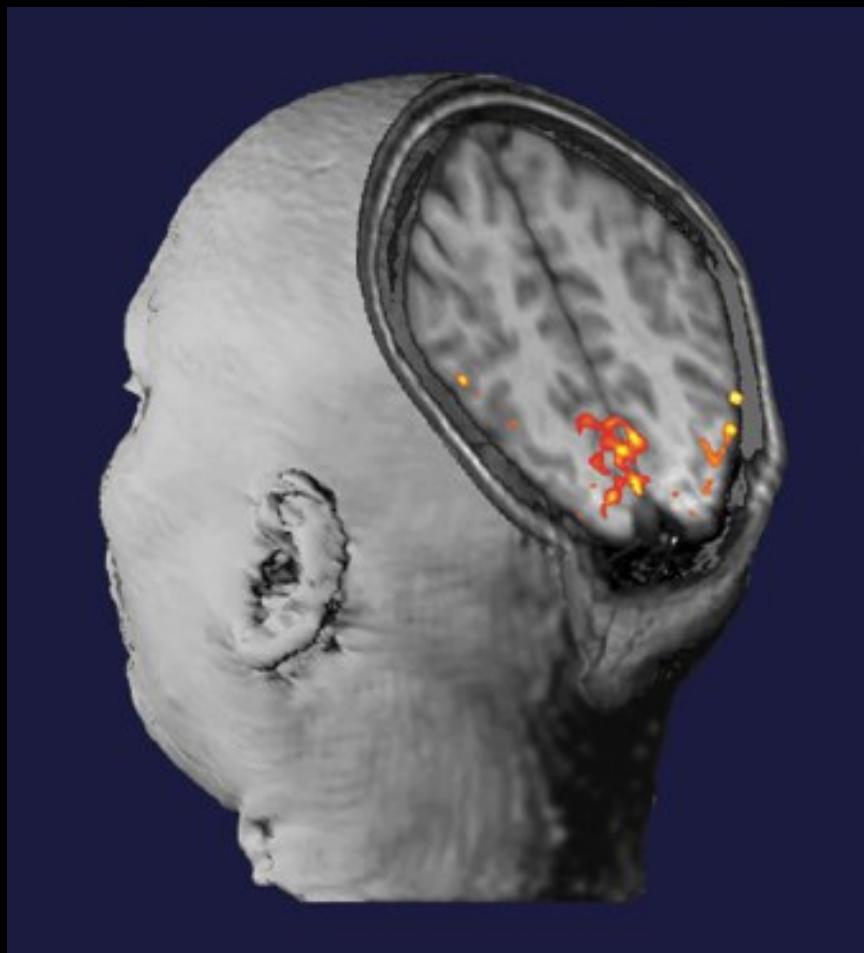
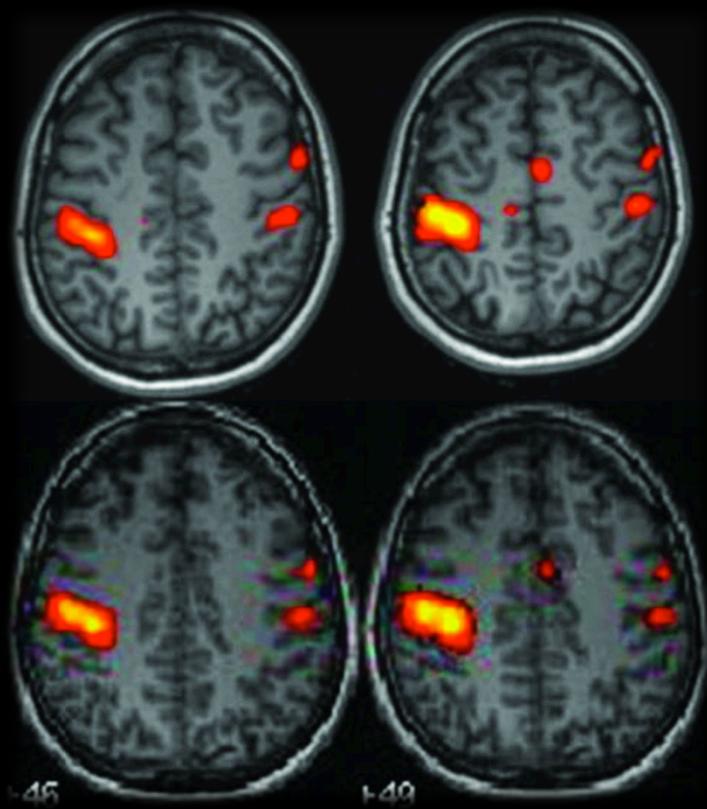


We Acquire One Slice at a Time

- Online Example of Brain Slices:
 - tmmorin.com/Tom.html



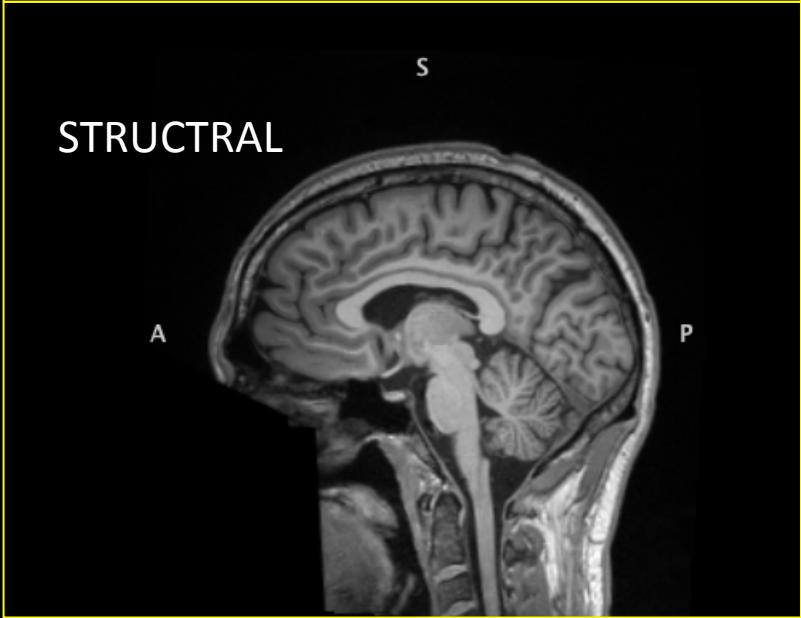
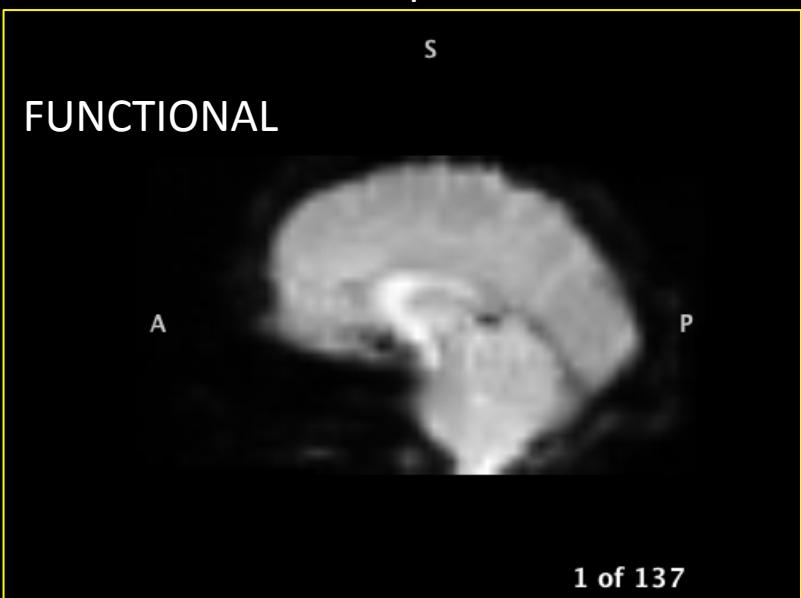
Functional MRI (fMRI)



fMRI

OpenfMRI ds000115

- 4D “Video” of brain activity
- One image every 3 seconds
- Looks blurry because images are acquired quickly
- It’s not just a video, it’s DATA!



What Are We Measuring With fMRI?

- Blood oxygenation level dependency (BOLD) Signal

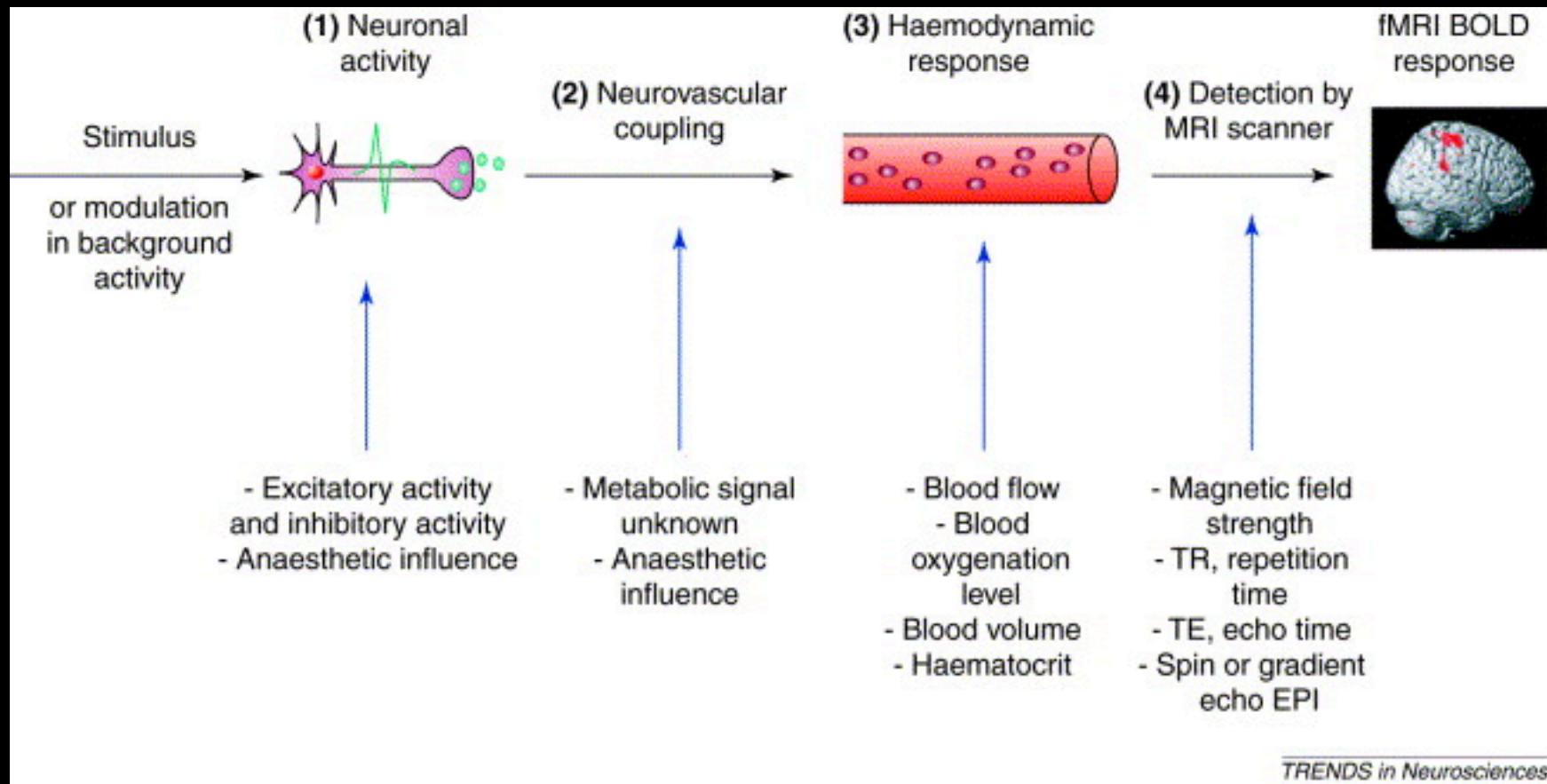


Image Subtraction

- To find areas of “activation,” subtract a control image from a task image

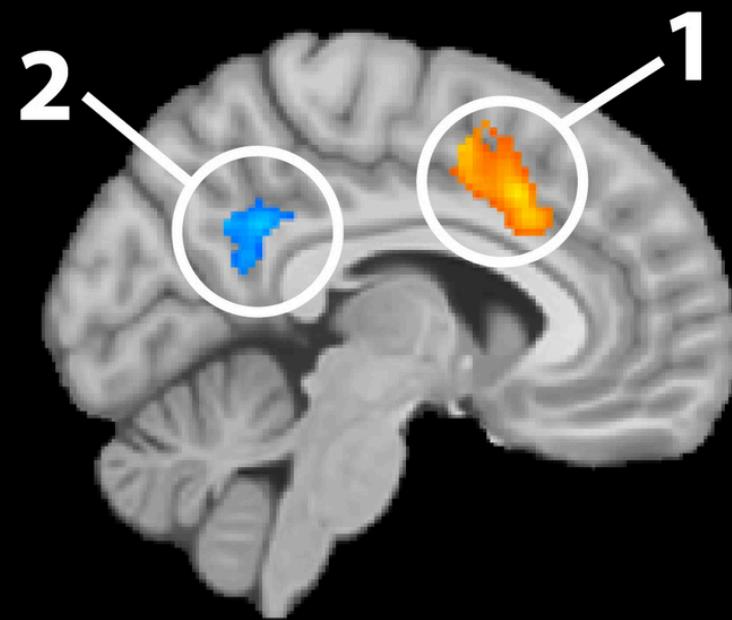


Image Subtraction

1. Yellow/Orange areas show increased activation

2. Blue areas show decreased activation

“A > B” notation says we subtracted condition B from condition A



Task > Control

Aside: fMRI History

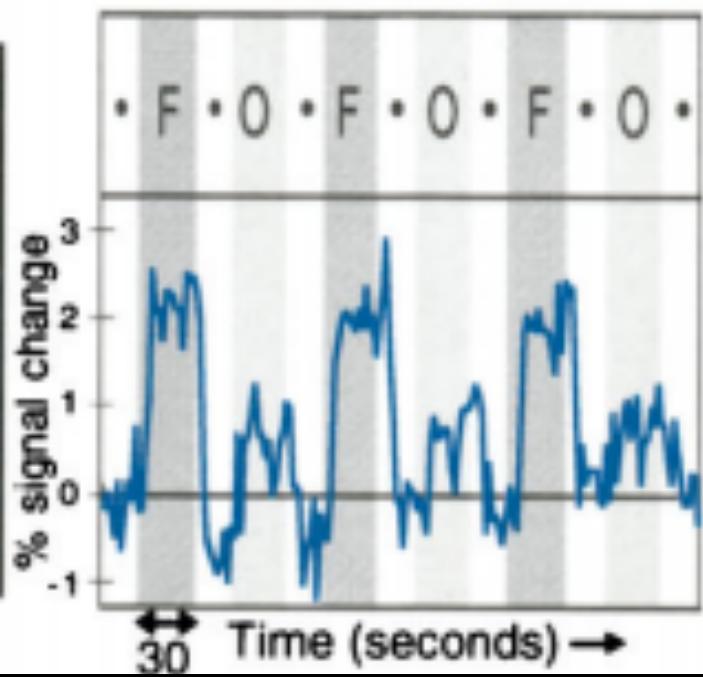
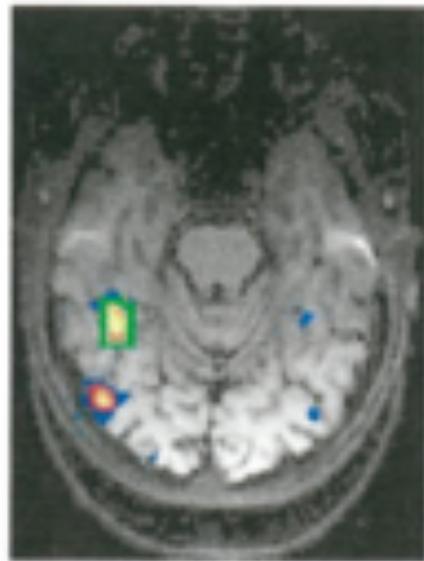
- The first fMRI image was taken at the MGH Martinos Center here in Boston.
- Published on the cover of *Science* in 1991



Finding Functional Brain Regions

- Design a Task/Control Paradigm

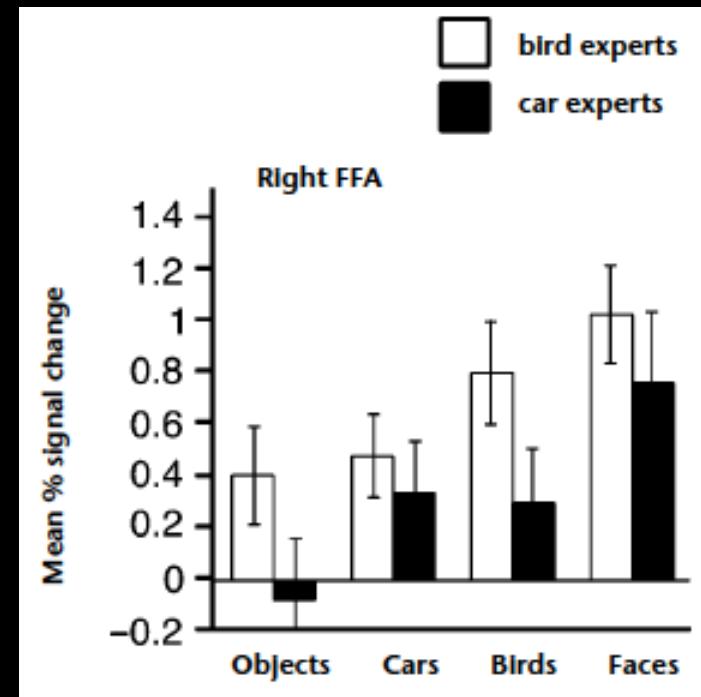
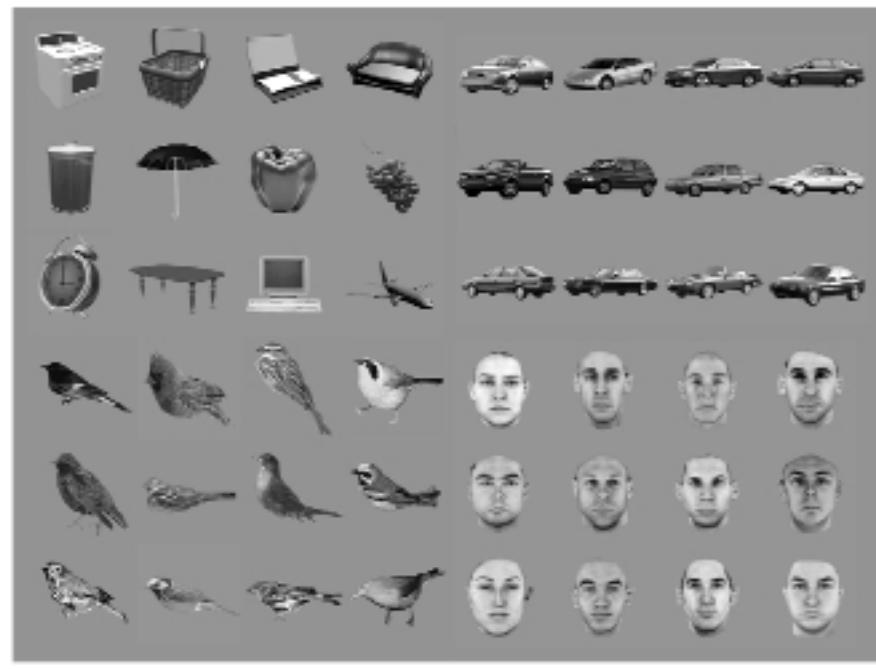
3a. Faces > Objects



Kanwisher, et al. (1997)

Is the FFA Face-Specific?

- Car Experts & Bird Experts show increased FFA activation when viewing cars/birds compared to viewing objects



fMRI Examples

- Cognitive Functions:
 - Working Memory Tasks
 - Attention Tasks
 - Executive Function
 - Decision-Making & Reward
- Surgical Planning

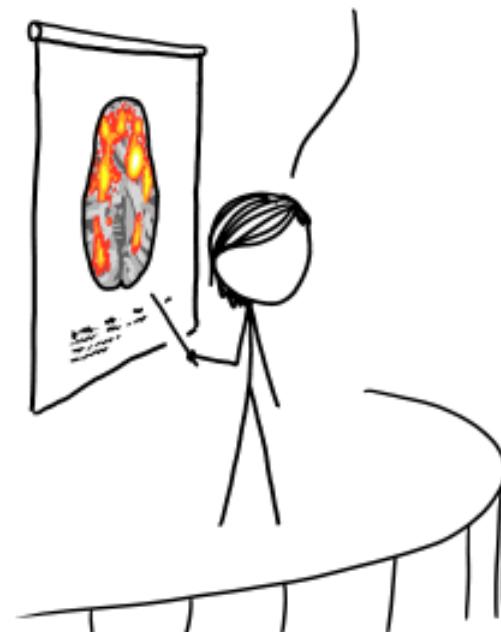
Limitations and Controversy

- This is “macro” imaging
 - Our best resolution is about 1mm³
 - About half a billion synapses per voxel
- The “frame-rate” with fMRI is in seconds
 - EEG can measure brain activity in milliseconds
 - Neurons can fire hundreds of times per second
- Participants are lying down in a dark, loud, crammed tunnel

Forum Responses

- Natalie Clark: “While I've never had a MRI before I've heard that they're both incredibly loud and time consuming. The TED talks discusses MRI's and that Kanwisher had to sit in an MRI machine for a study for multiple hours. I'm wondering if her studies take into account the distractions of the noise of the MRI and the overall feeling of being in an MRI machine. These could possibly be confounding variables that affect her study.”

OUR FMRI STUDY FOUND THAT SUBJECTS PERFORMING SIMPLE MEMORY TASKS SHOWED ACTIVITY IN THE PARTS OF THE BRAIN ASSOCIATED WITH LOUD NOISES, CLAUSTROPHOBIA, AND THE REMOVAL OF JEWELRY.



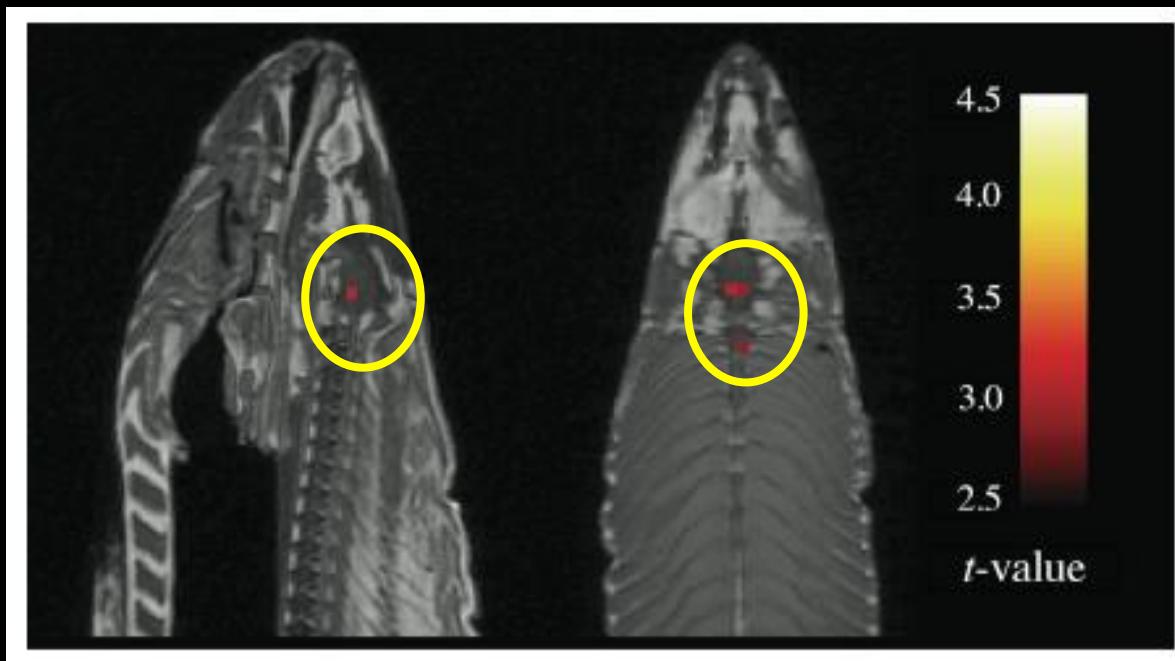
What Does MRI Sound Like?



MRI Sounds: https://www.youtube.com/watch?v=xS_V_OgeX-U

Limitations and Controversy

- fMRI is noisy! (you can have false positives)
- Dead salmon shows neural activity



Bennett, et al. (2009)

Limitations and Controversy

- Last summer a study was published claiming that as many as 40,000 fMRI studies may be invalid due to statistical errors found in fMRI analysis software
- “40,000” claim has been redacted, but many studies may still be affected
- Most studies are fine

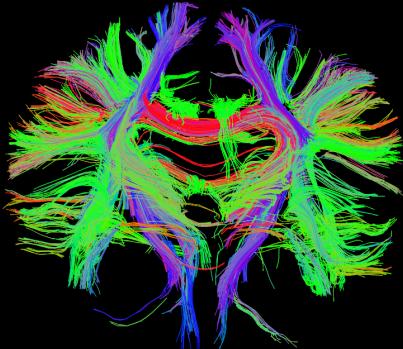


Other Kinds of MRI

- Radiologists and Physicists can tune the MRI machine to look at lots of different physiological features
- Quantitative MRI
 - Perfusion Imaging
 - pH Imaging
 - Sodium Imaging
 - And More!

Other Kinds of MRI

- Diffusion Tensor Imaging (DTI)



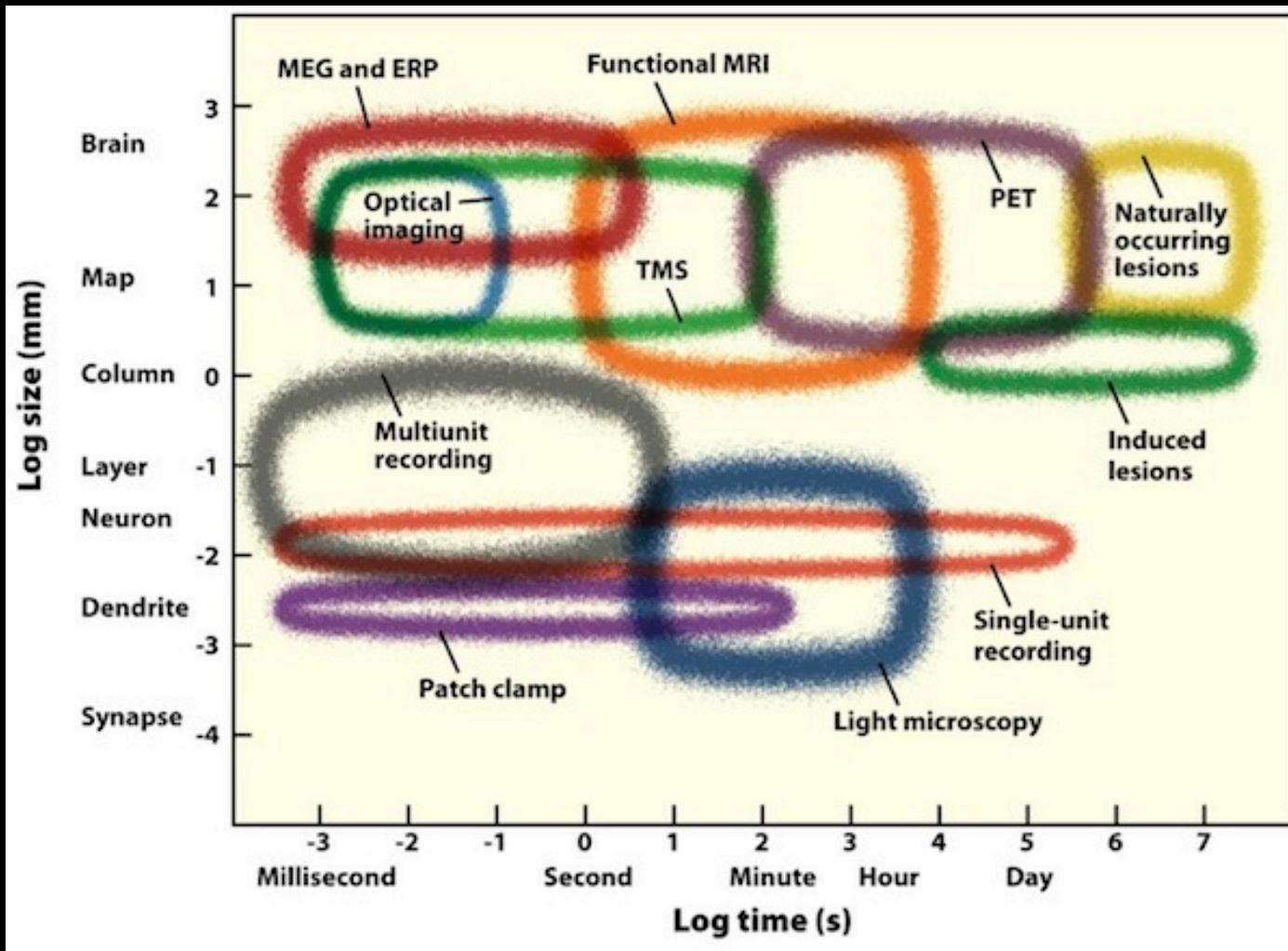
- Image white matter fiber tracts in the brain
- Look at the direction that water is travelling
- Map structural connections

- Resting State fMRI (rs-fMRI) (Coming Up Wednesday!)



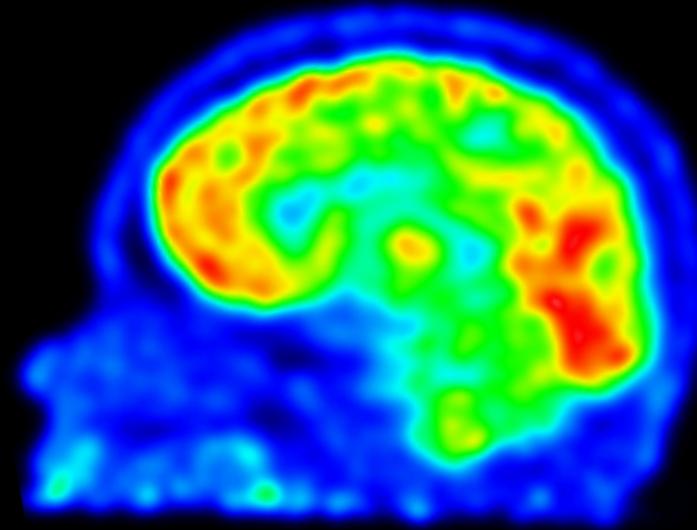
- The brain is always “buzzing” with activity
- Measures the low-frequency signals associated with “background” (not task-related) activity
- Map functional connections

MRI is “Macro” Imaging



Positron Emission Tomography (PET)

- Still-Images or “Videos” are possible
- A single image takes 1-10 minutes to acquire
- Similar spatial resolution to MRI ($\sim 2\text{mm}^3$)
- Not just an image, it's **DATA!** ☺



Positron Emission Tomography

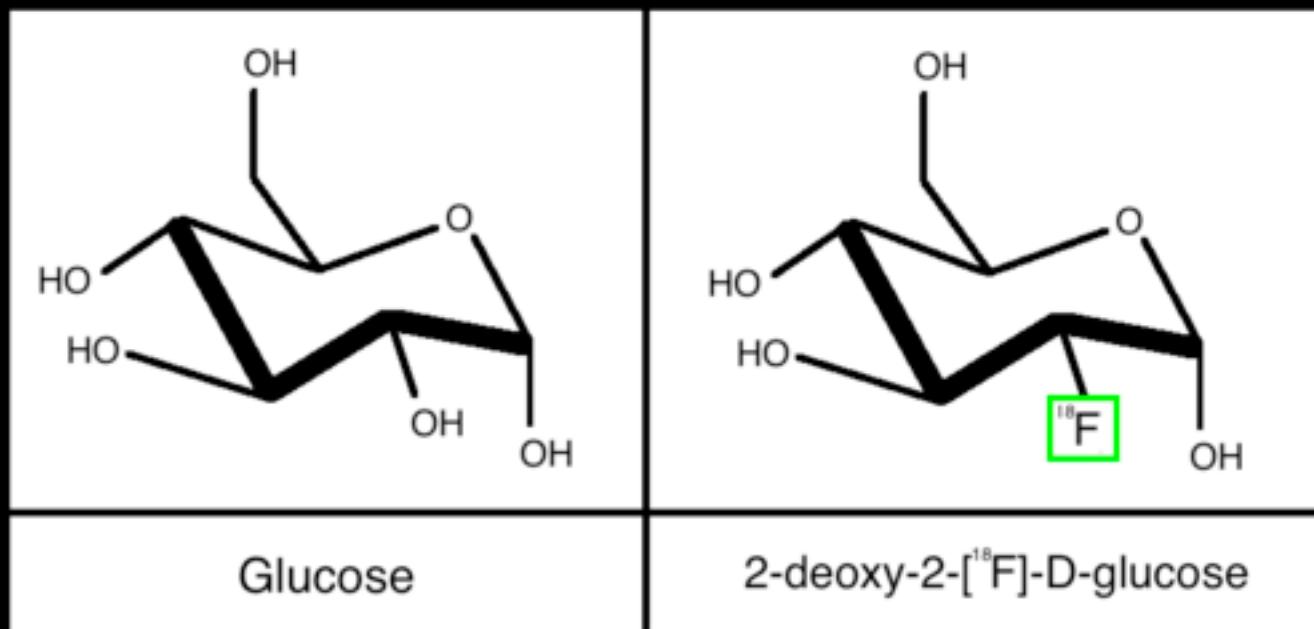


[https://www.youtube.com/watch?
v=oySvkmezdo0](https://www.youtube.com/watch?v=oySvkmezdo0) (1 min video – no sound)

[https://www.youtube.com/watch?
v=yrTy03O0gWw](https://www.youtube.com/watch?v=yrTy03O0gWw) (4 min video - UCL)

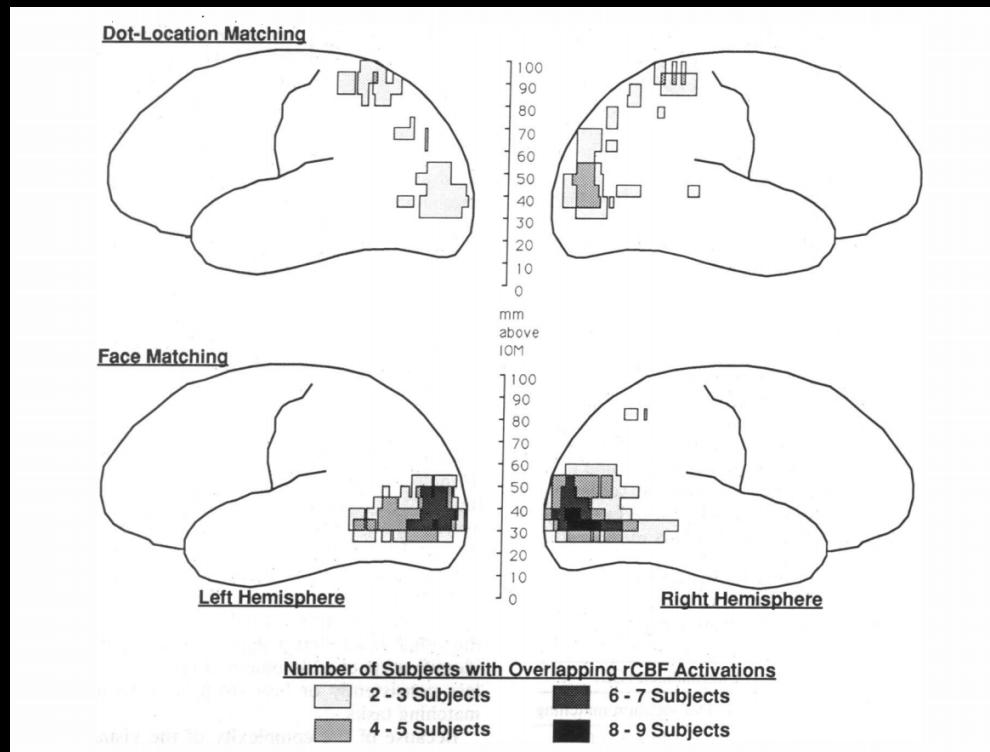
Radiotracers

- “Tag” a chemical with a radioactive isotope
For example, flurodeoxyglucose or FDG is just glucose (sugar) with an [^{18}F] tag



PET Example: Haxby, et al. (1991)

- Haxby (1991) used H_2^{15}O (radioactive water) to map blood-flow in the brain
- Looked at activity associated with face-matching or dot-location-matching (faces vs. places) in the visual cortex
- Studies like this were the inspiration for fMRI

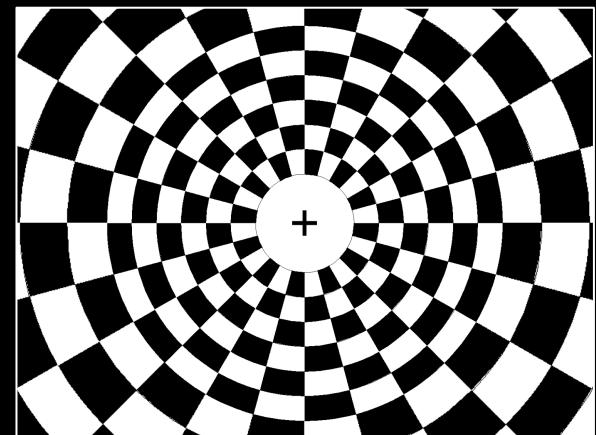
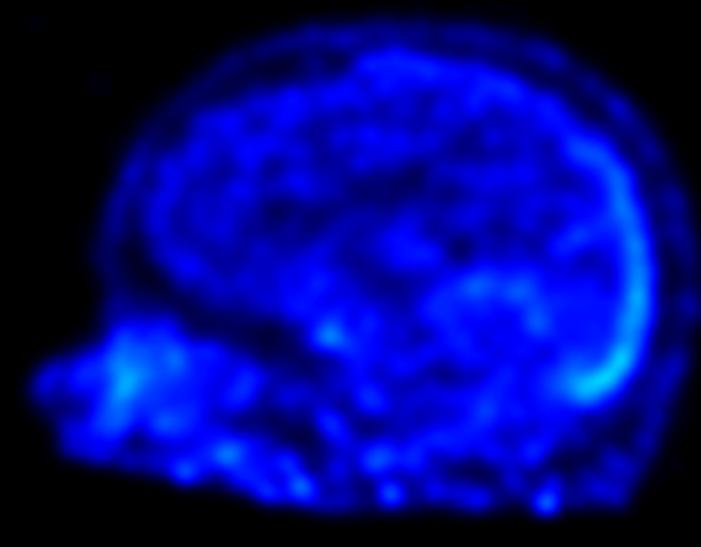


PET Examples

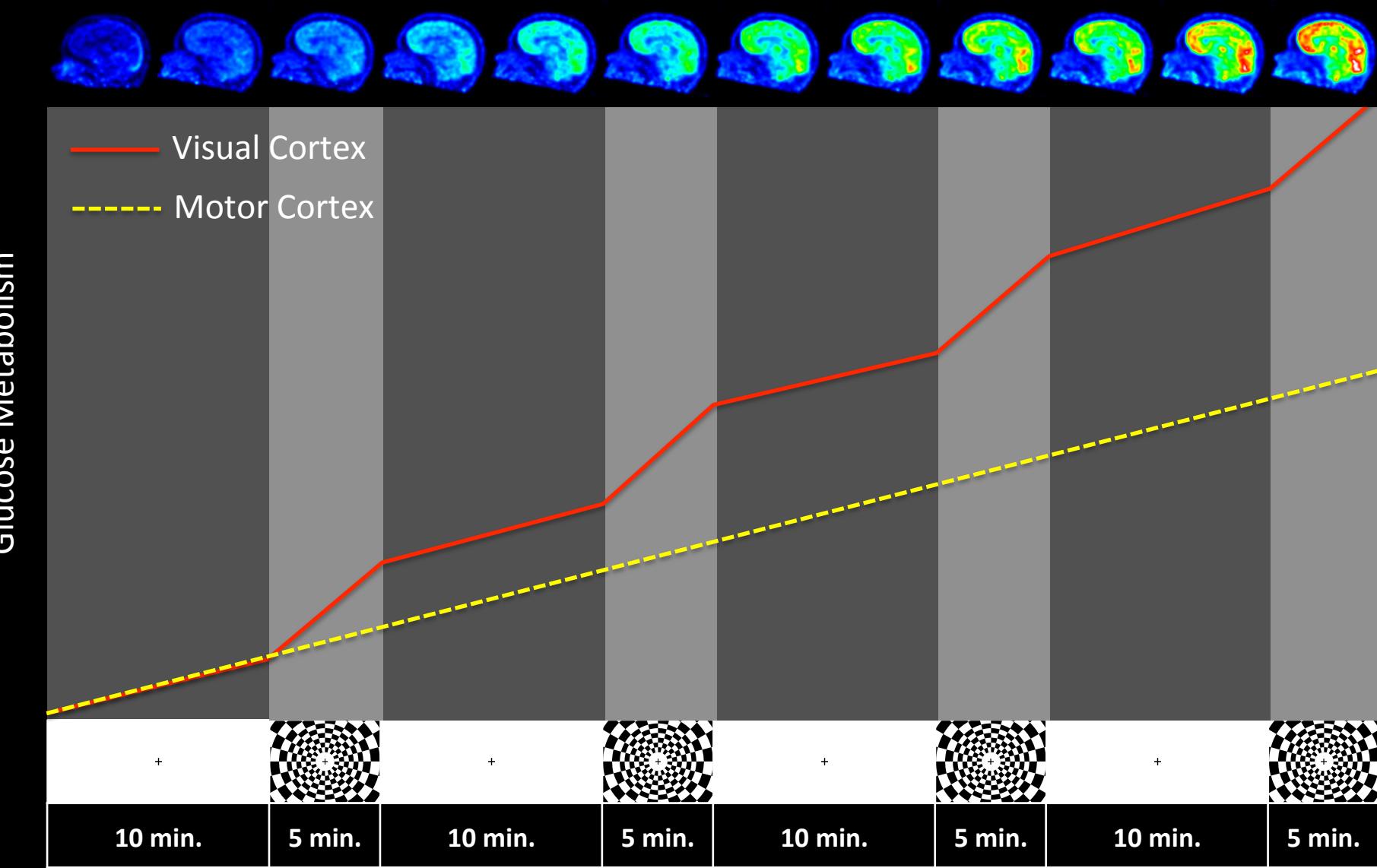
- FDG Imaging (Cancer & Neurology)
- Dopamine Imaging
- Opioid Imaging
- Amyloid Imaging (Alzheimer's)
- Imaging Neuroinflammation & Microglia
- HDAC (epigenetic) imaging
- And Many More!

Functional PET with FDG (fPET-FDG)

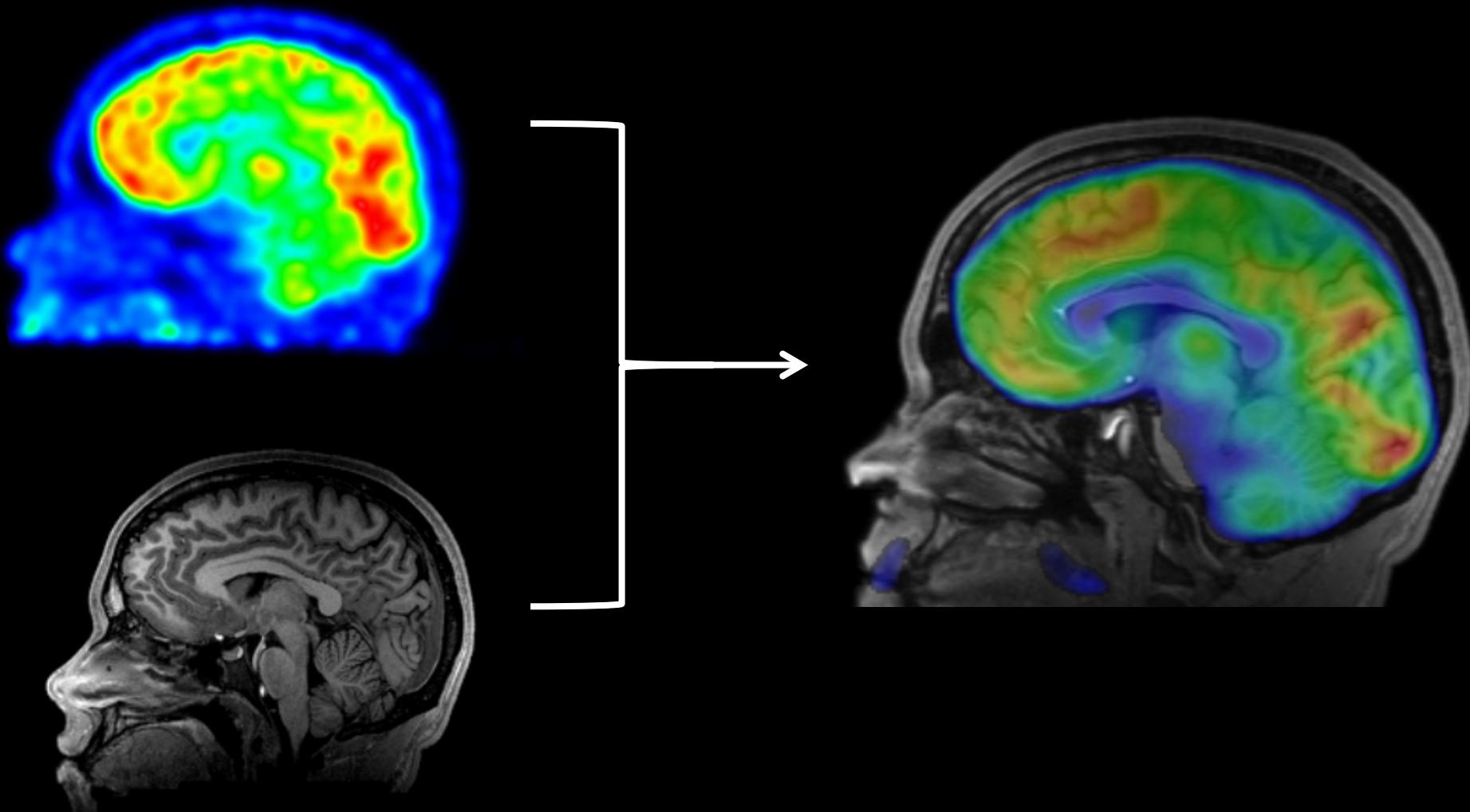
- Instead of injecting it all at once, we constantly infuse the radiotracer
- FDG radiotracer builds up in the brain
- Take a 1-hour PET “video” and pair it with a visual stimulus



fPET-FDG

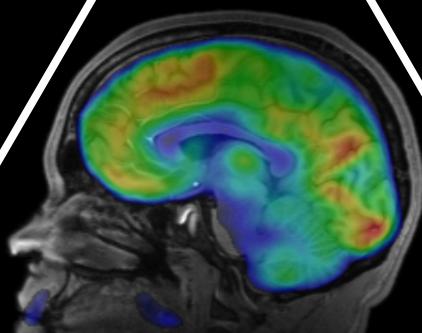


Simultaneous MR/PET



Neuroimaging: A Tool for CBS

Computer Science



Philosophy

Psychology

Questions?

Acknowledgements



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Dr. Jacob Hooker