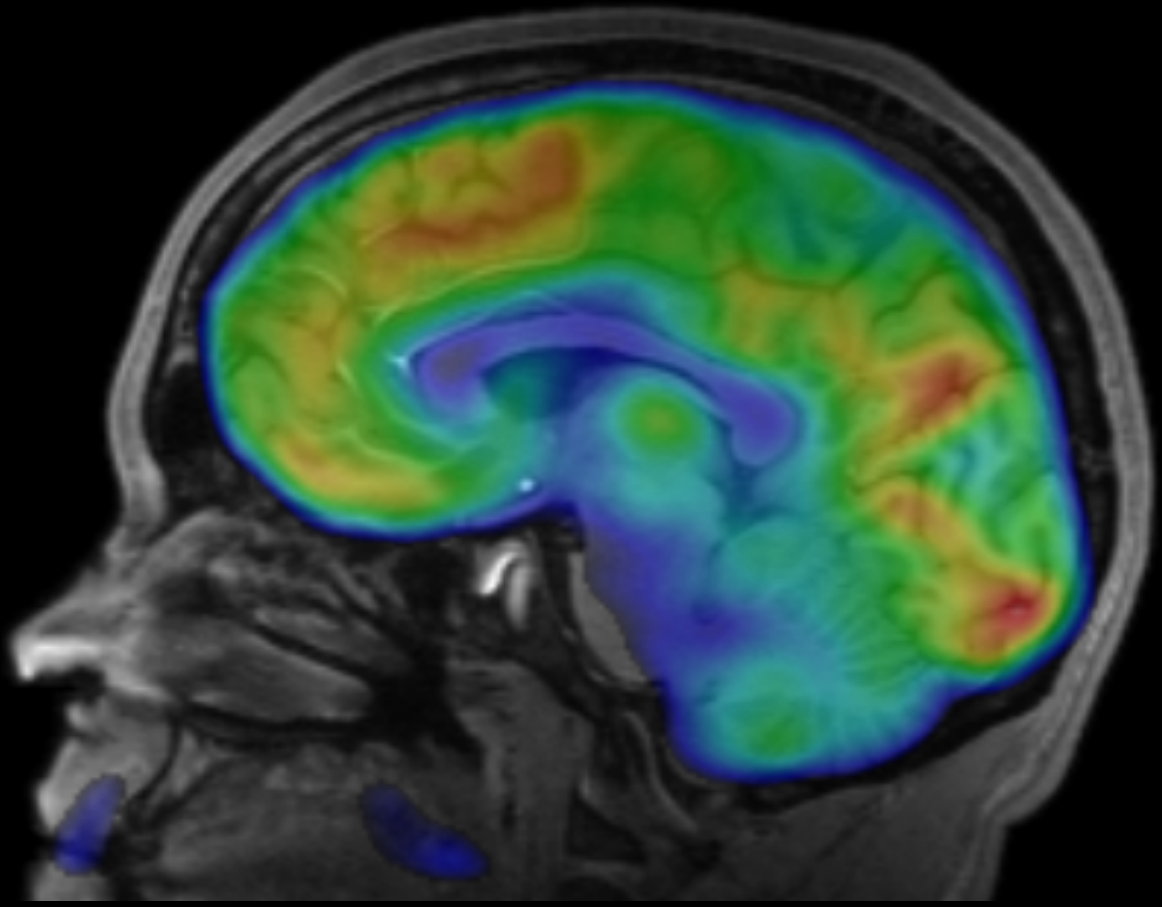
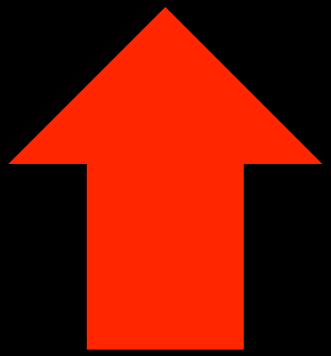
INTRO TO BRAIN IMAGING



Tom Morin

Remember this Association:

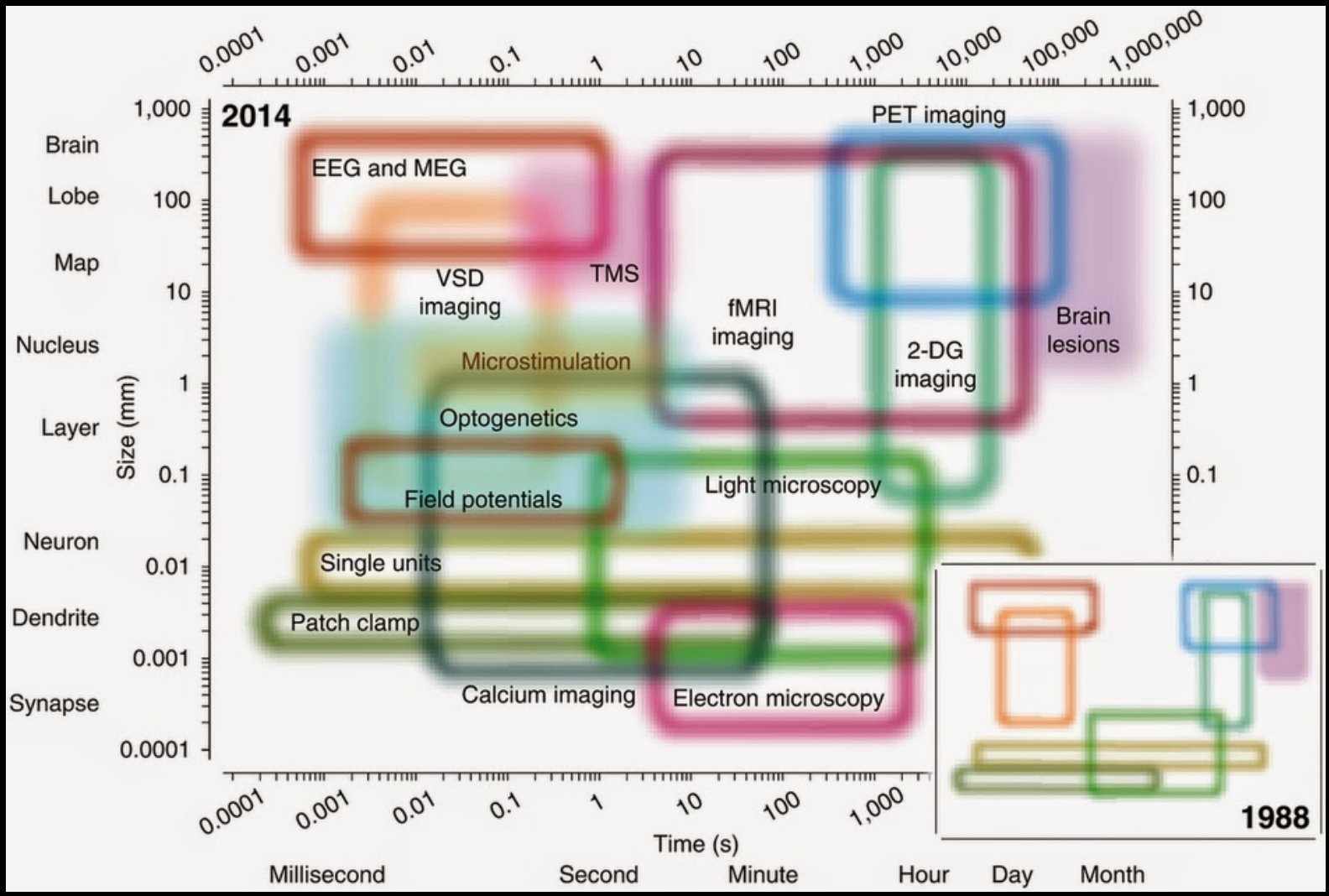
Patel =



Agenda

- What is PET imaging?
- How does MRI work?
- What can we learn with fMRI?
- What is resting-state fMRI?
- My Current Research
- The future…

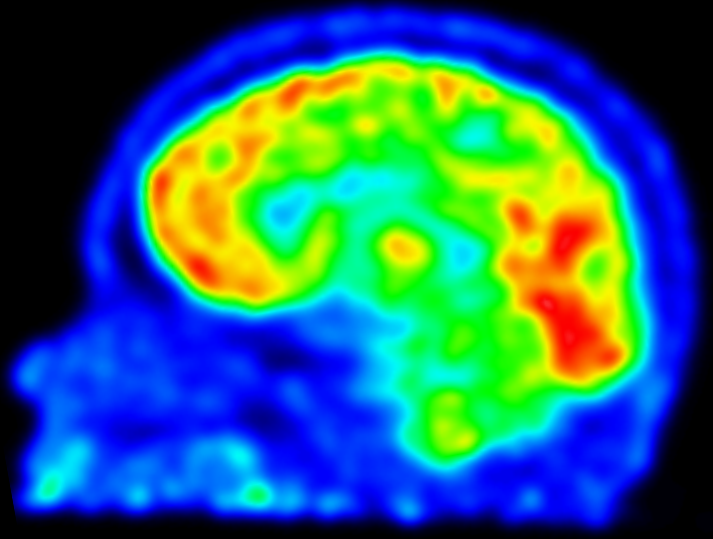
Temporal & Spatial Resolution



Sejnowski, et al. 2014

Positron Emission Tomography (PET)

- Temporal Resolution: Hours to Days (sometimes minutes)
- Spatial Resolution: ~2mm^3 (at best)
- Not just an image, it's **DATA**! ☺



Positron Emission Tomography

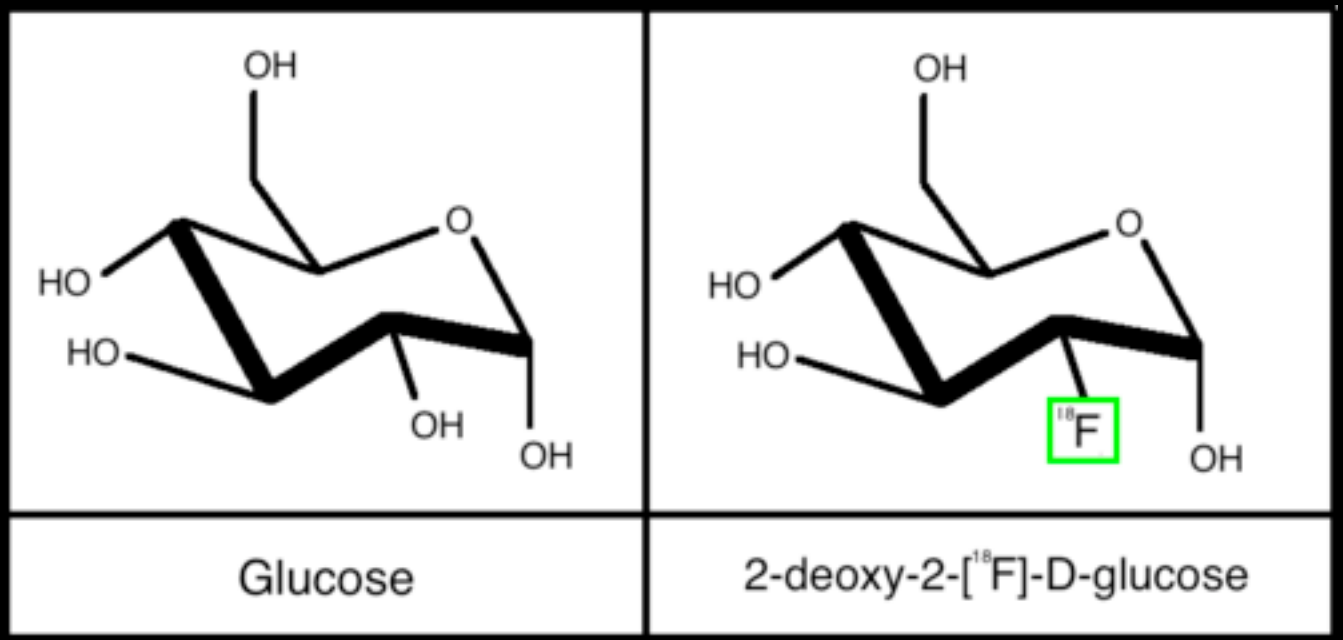
https://www.youtube.com/watch?v=oySvkmezdo0 (1 min video − no sound)

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

Radiotracers

- “Tag” a chemical with a radioactive isotope

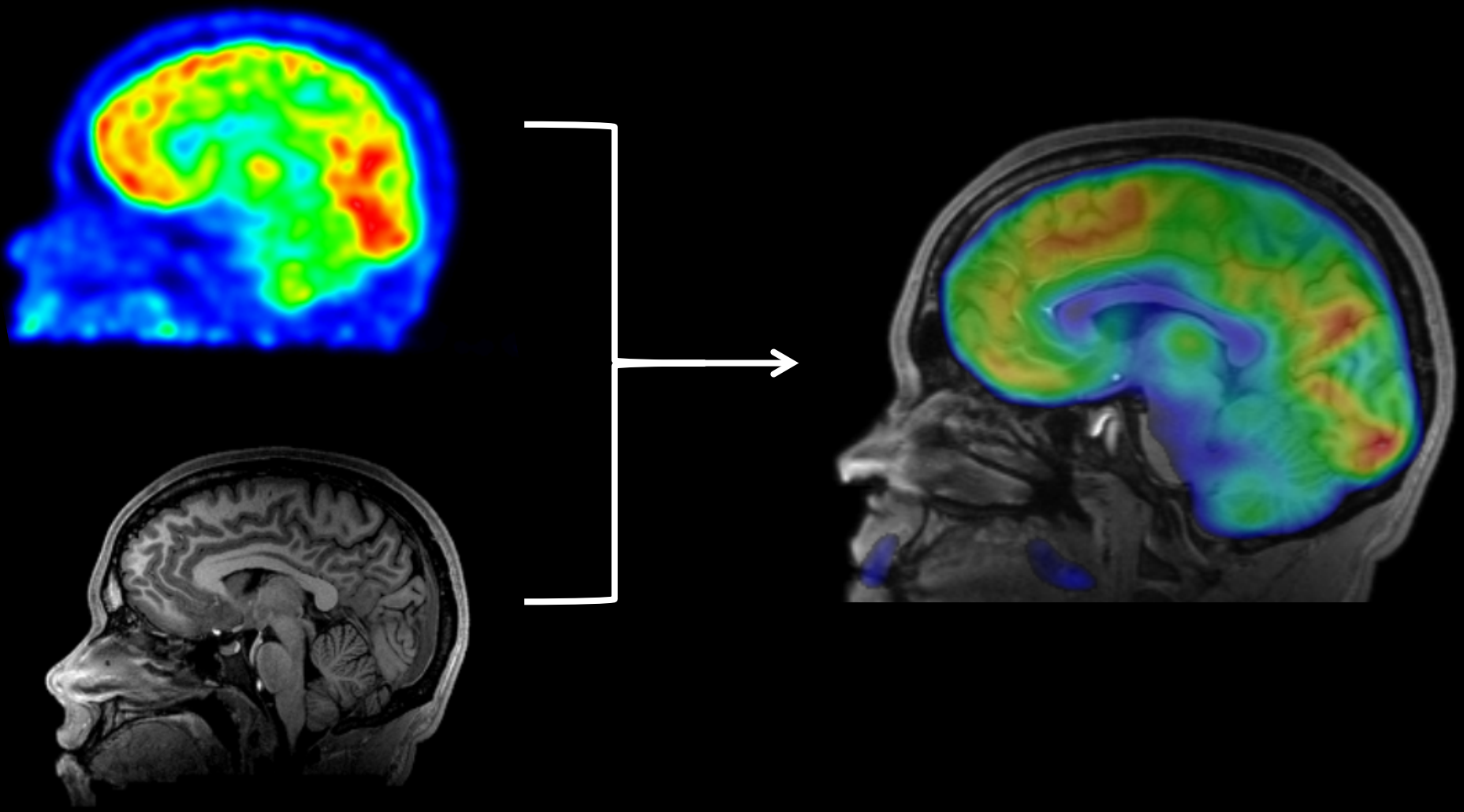
  For example, flourodeoxyglucose or FDG is just glucose (sugar) with an [^{18}F] tag



PET Applications

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

Simultaneous MR/PET



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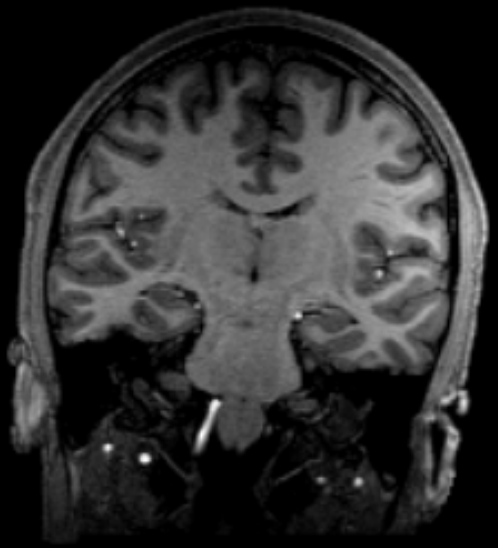
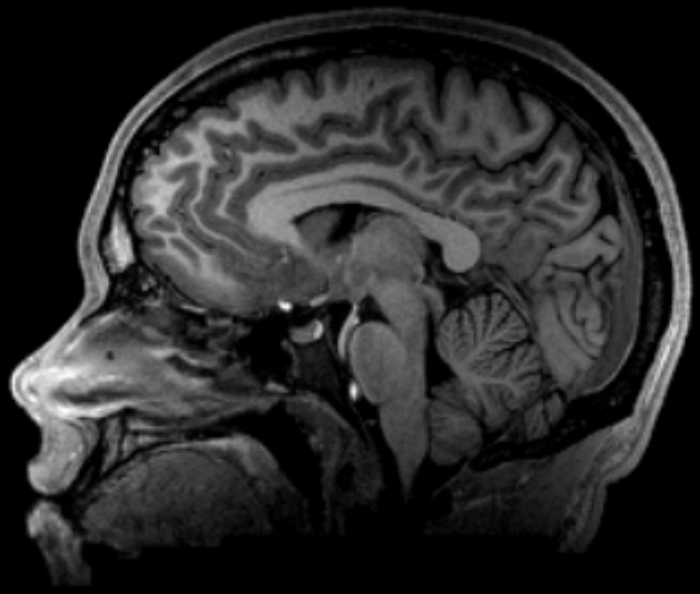
What am I Looking at?

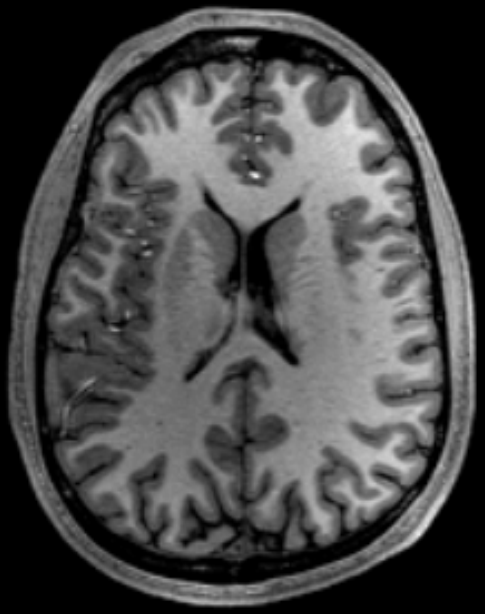
Coronal



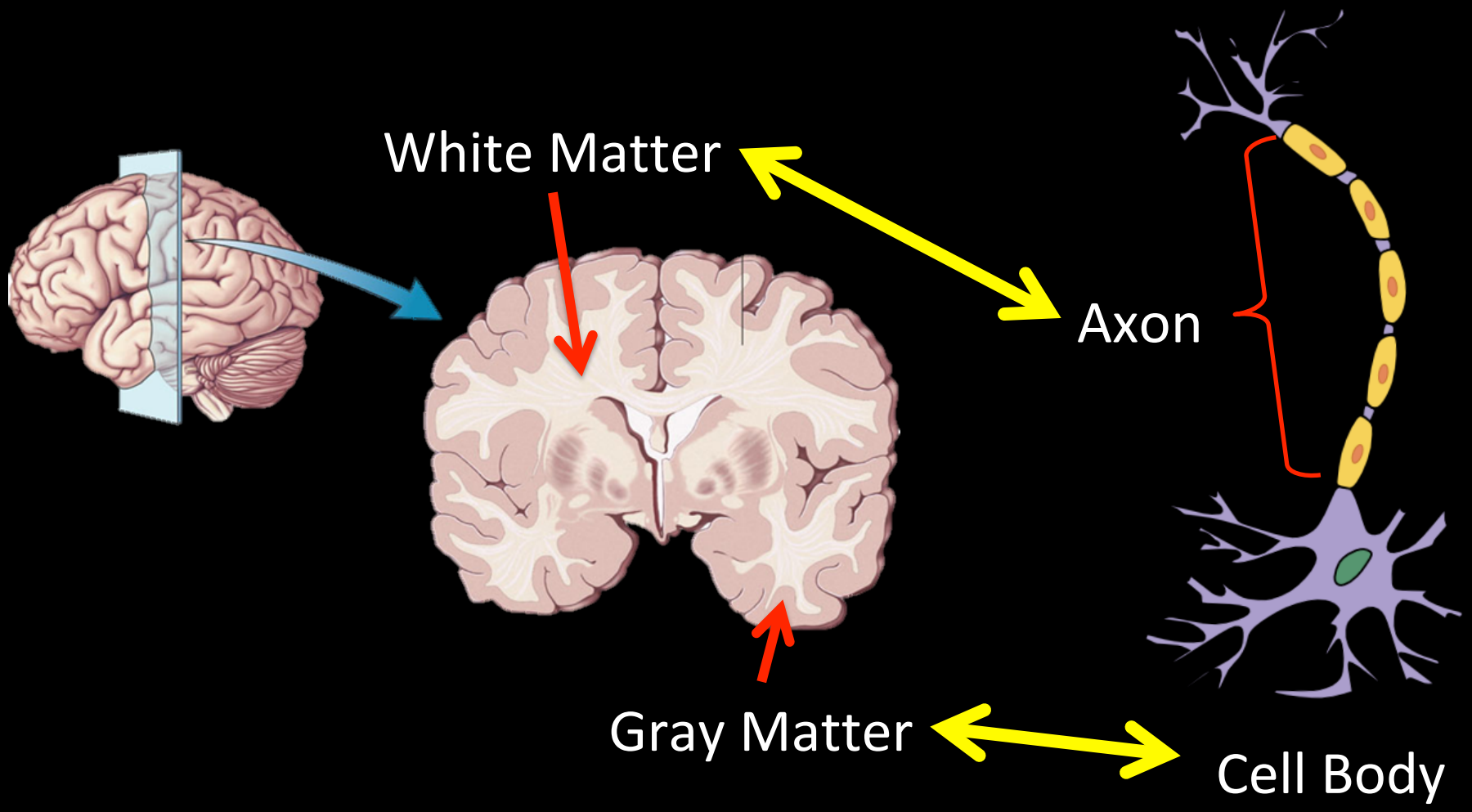
Sagittal



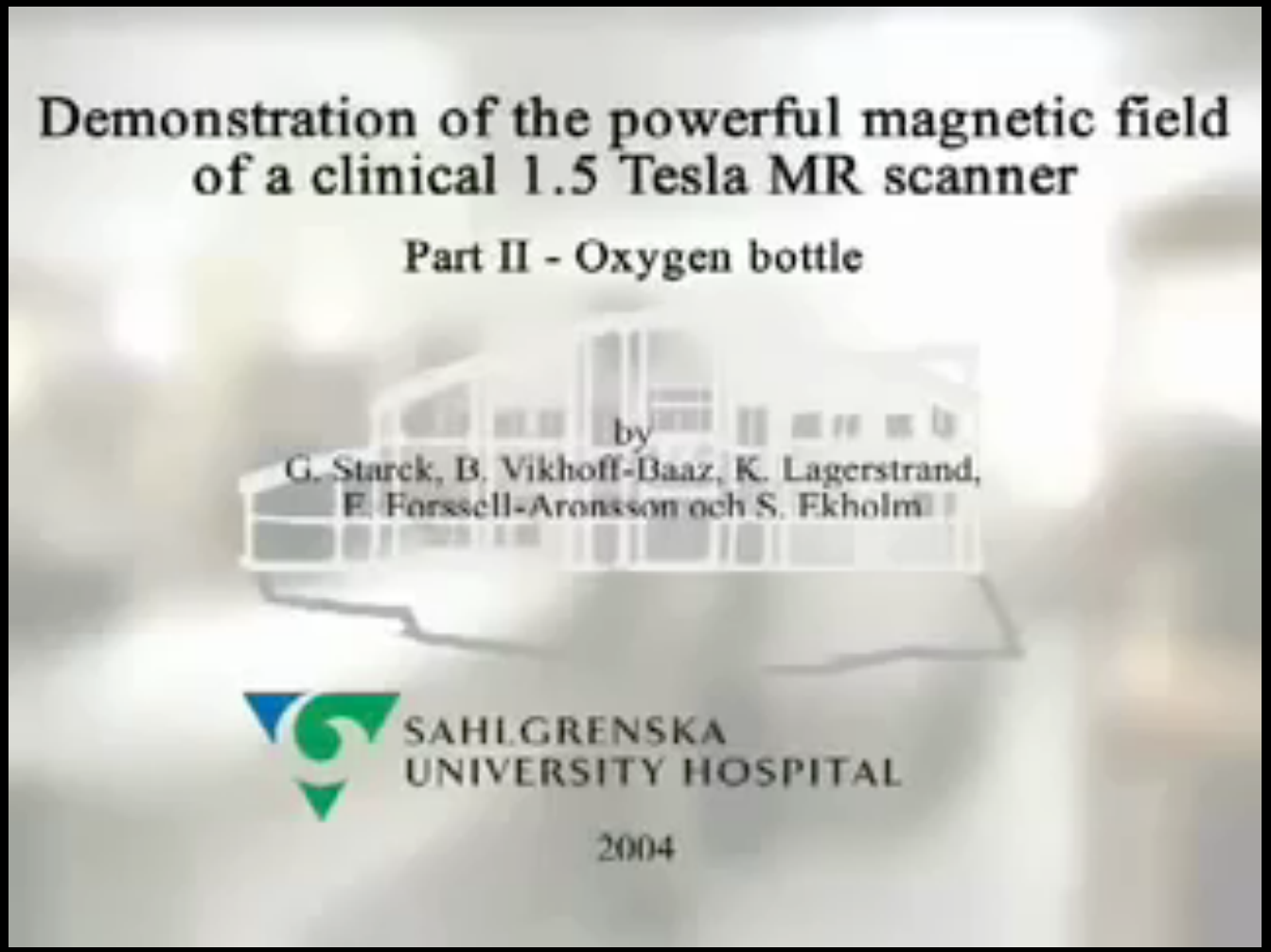
Axial



Quick Brain Anatomy Review

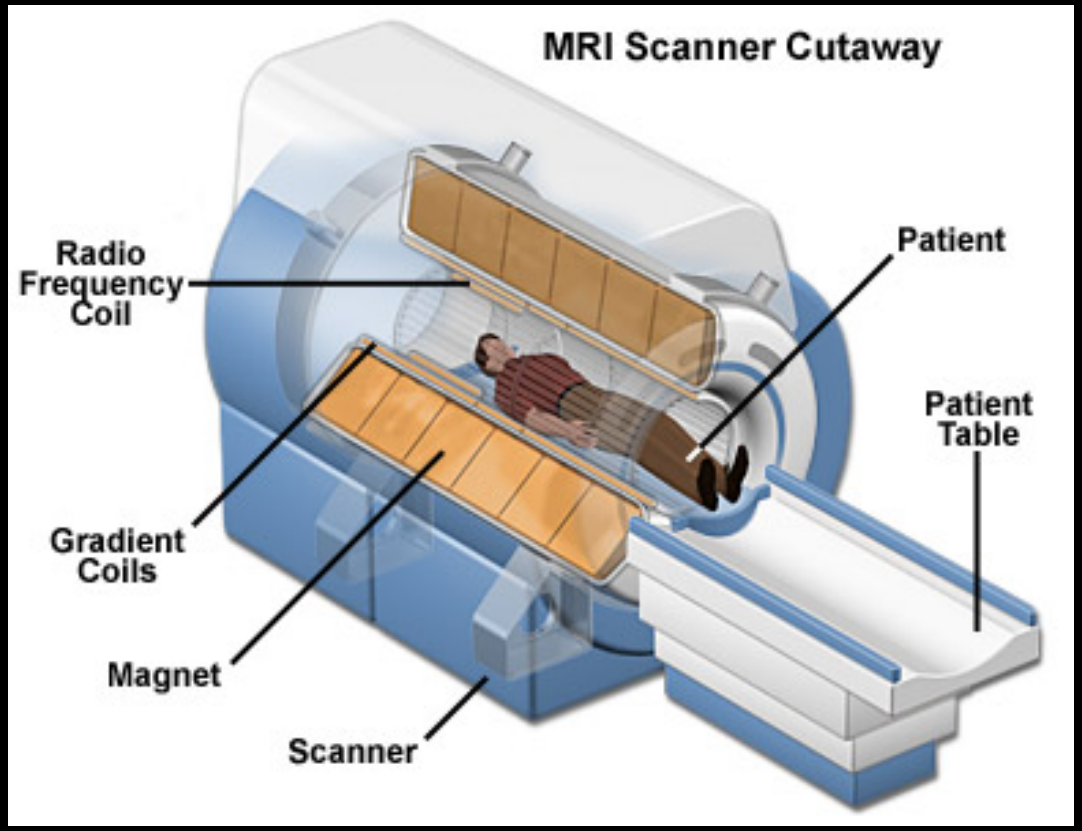


MR Safety



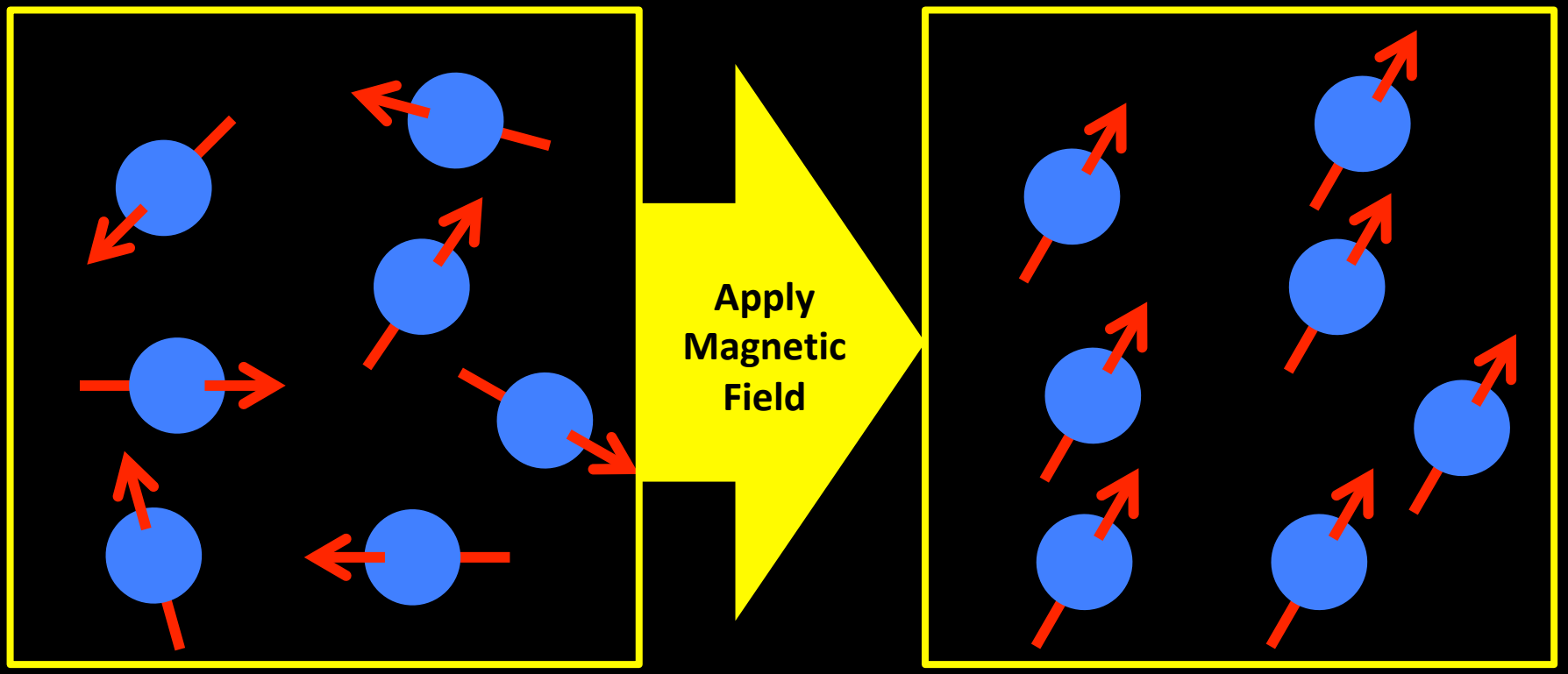
O_2 Tank vs. Watermelon: https://www.youtube.com/watch?v=plvIEf7JsKo

How Does MRI Work?



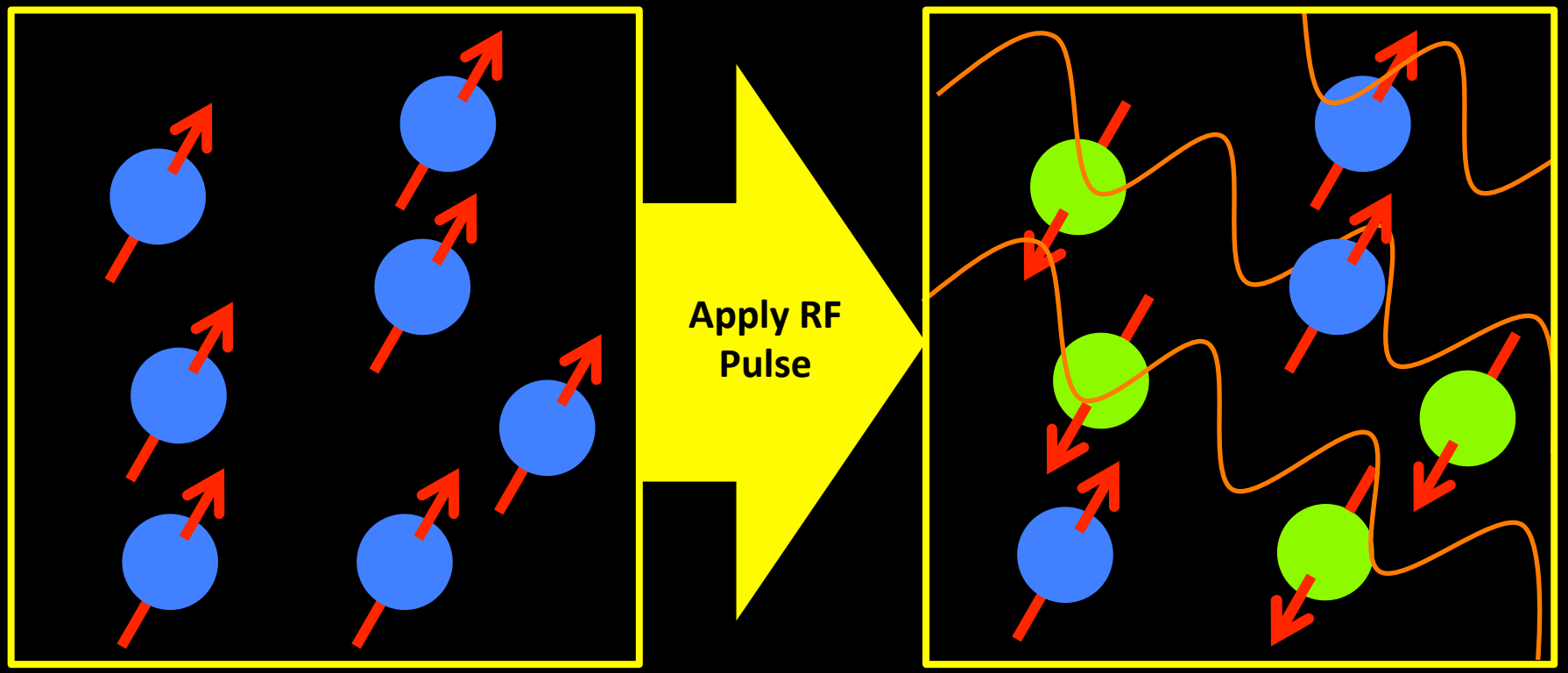
Magnetic Resonance Imaging

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



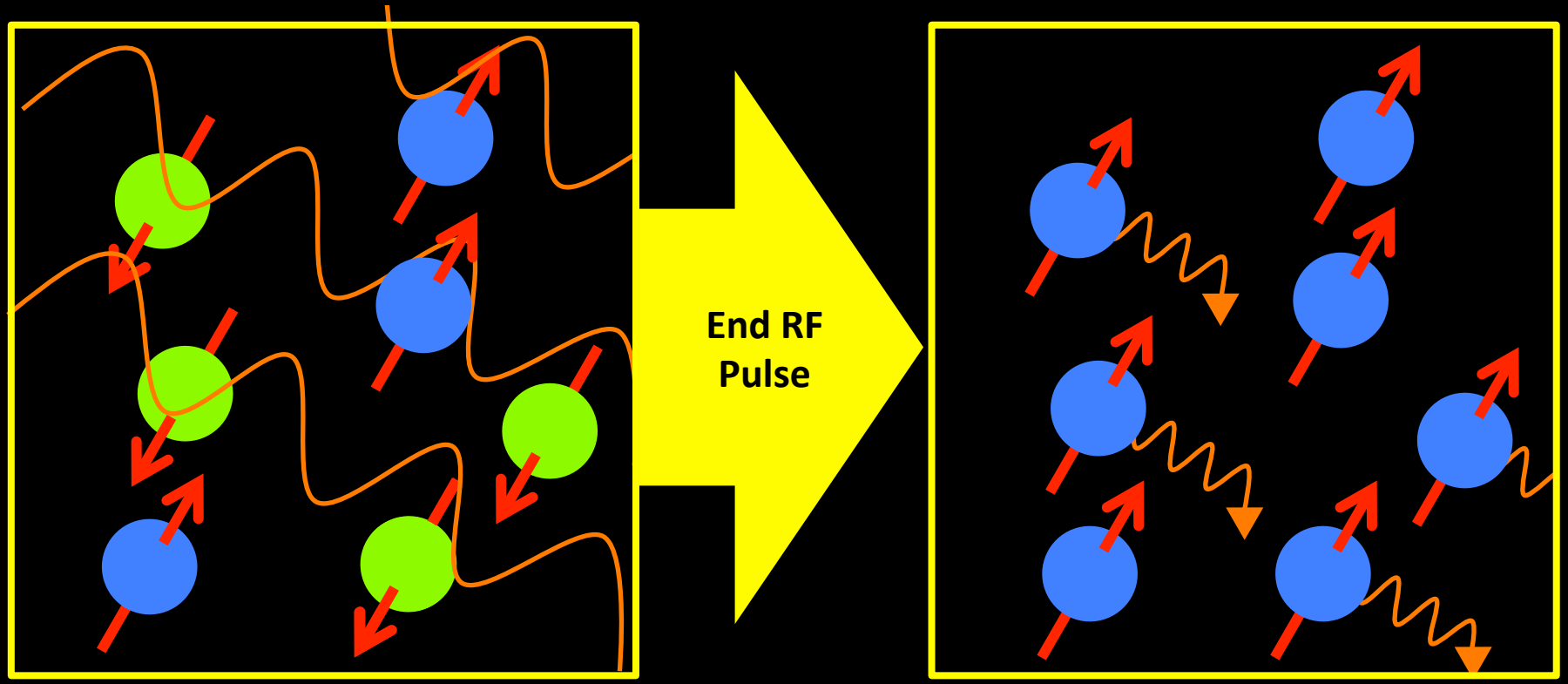
Magnetic Resonance Imaging

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

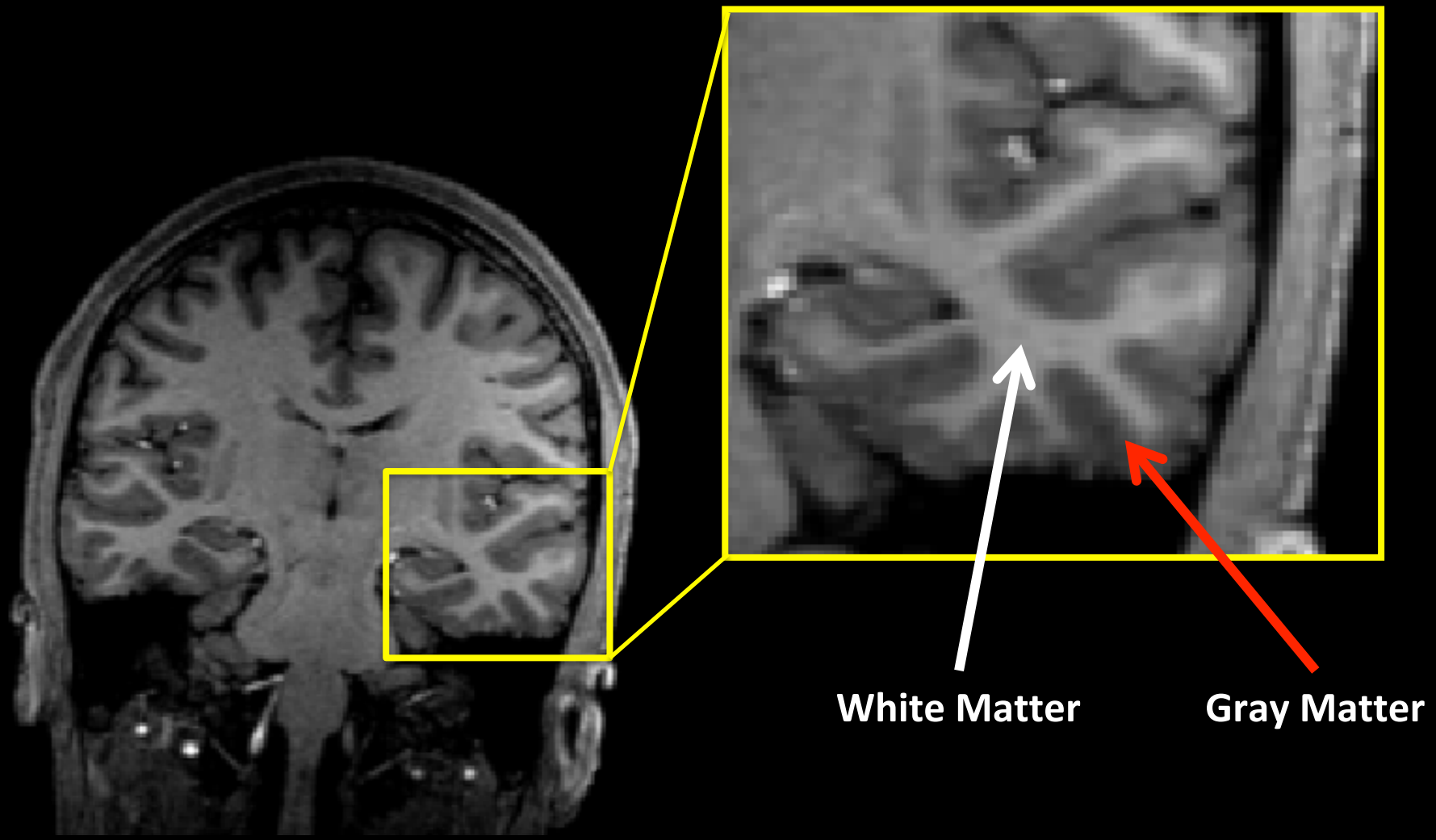


Magnetic Resonance Imaging

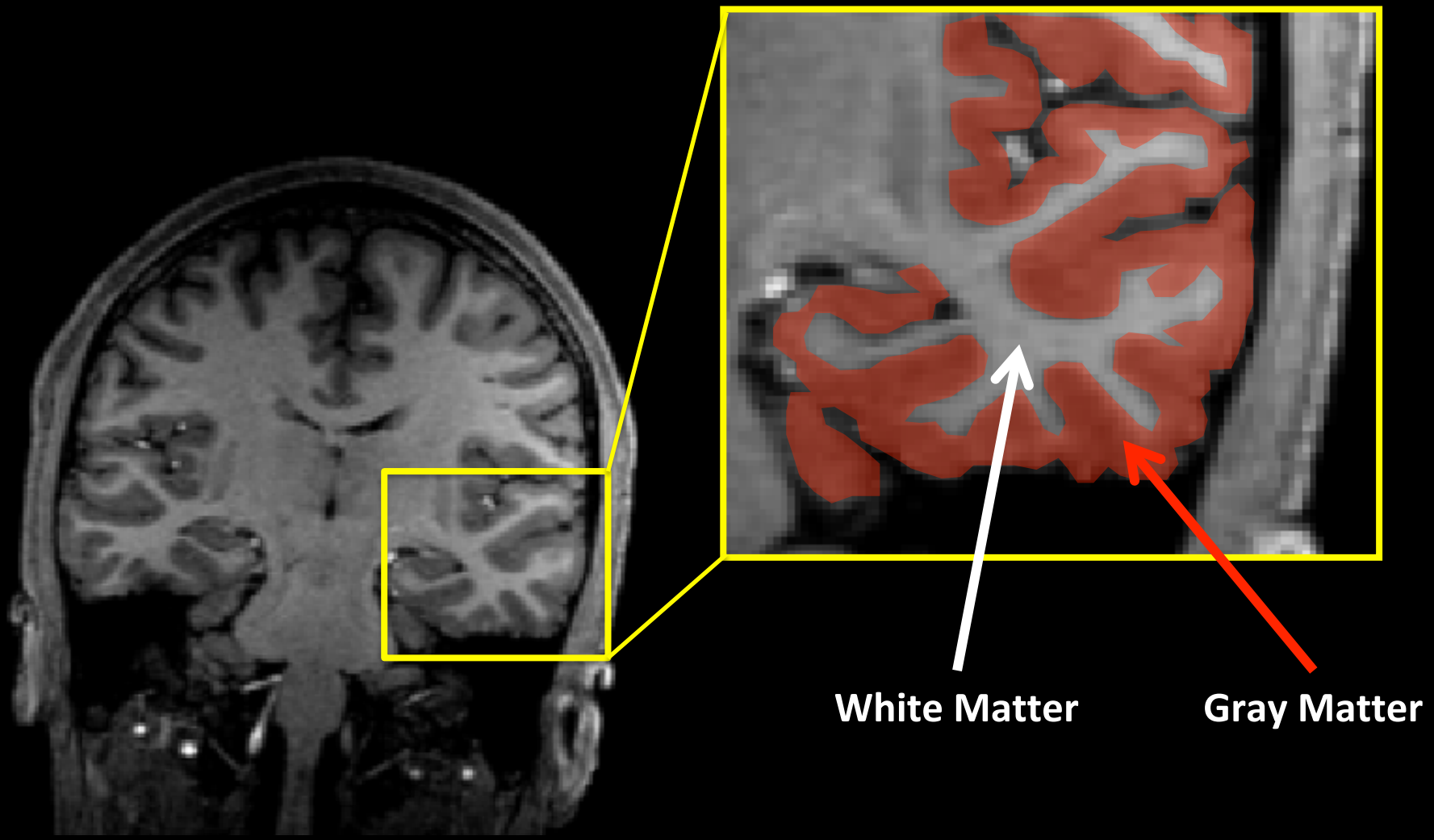
3. End the pulse, allowing protons to relax back
   - As they relax, the protons release energy in the form of radiowaves, that is detected by RF coils



MR Signal Differs for Each Tissue

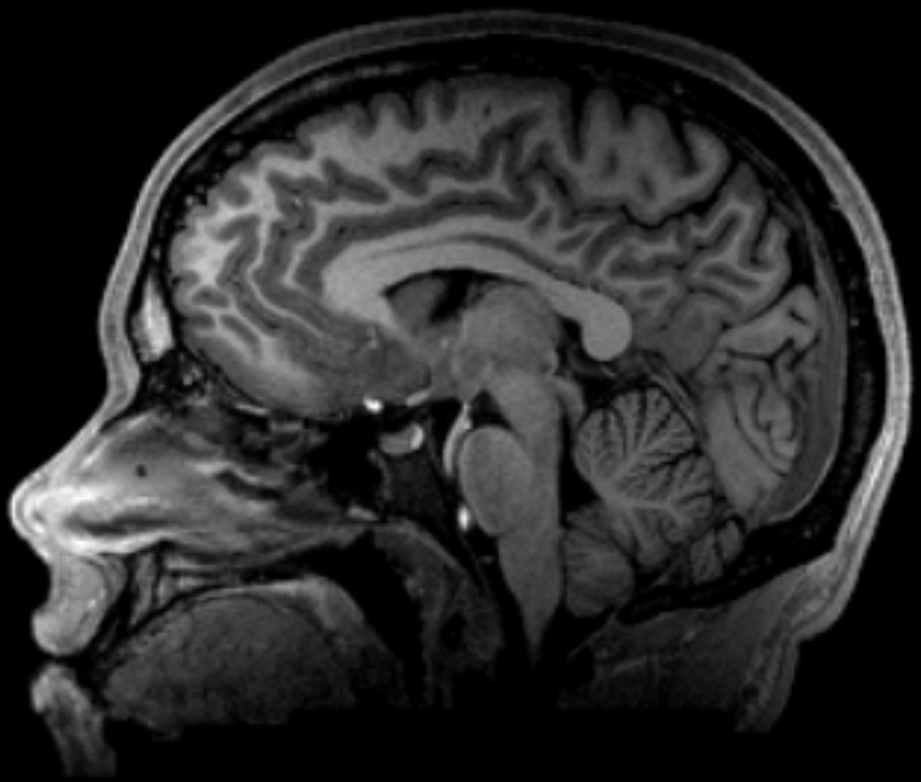


MR Signal Differs for Each Tissue



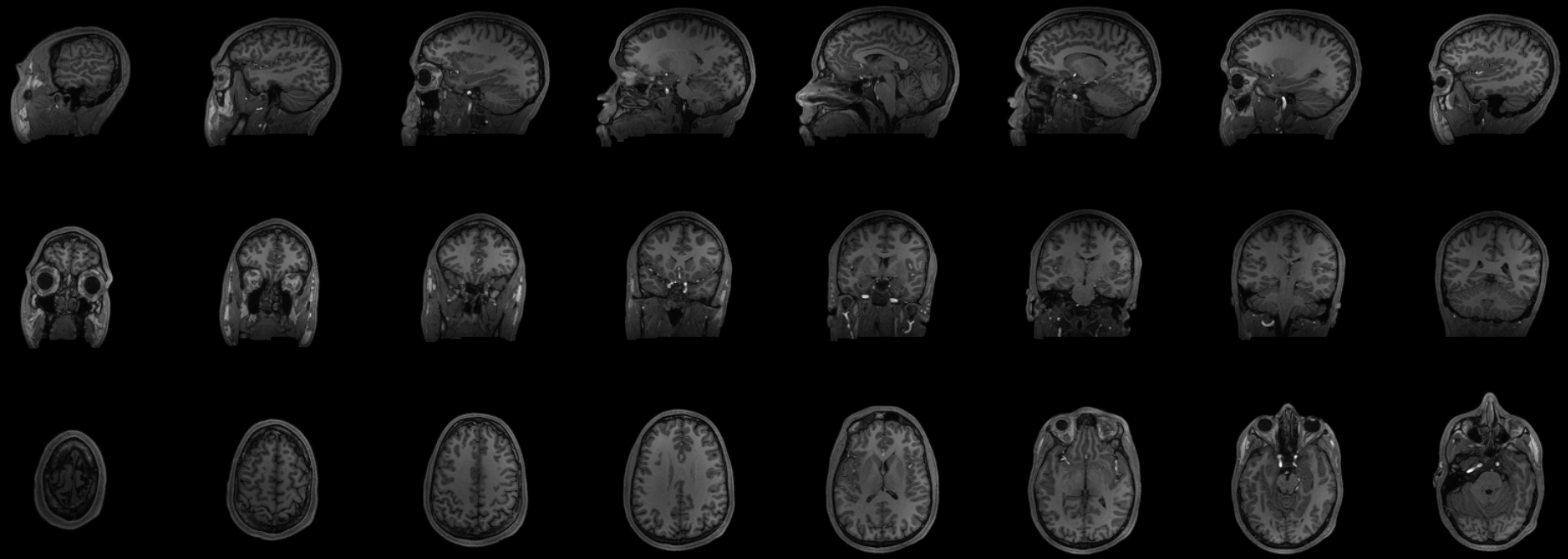
Structural MRI

- 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



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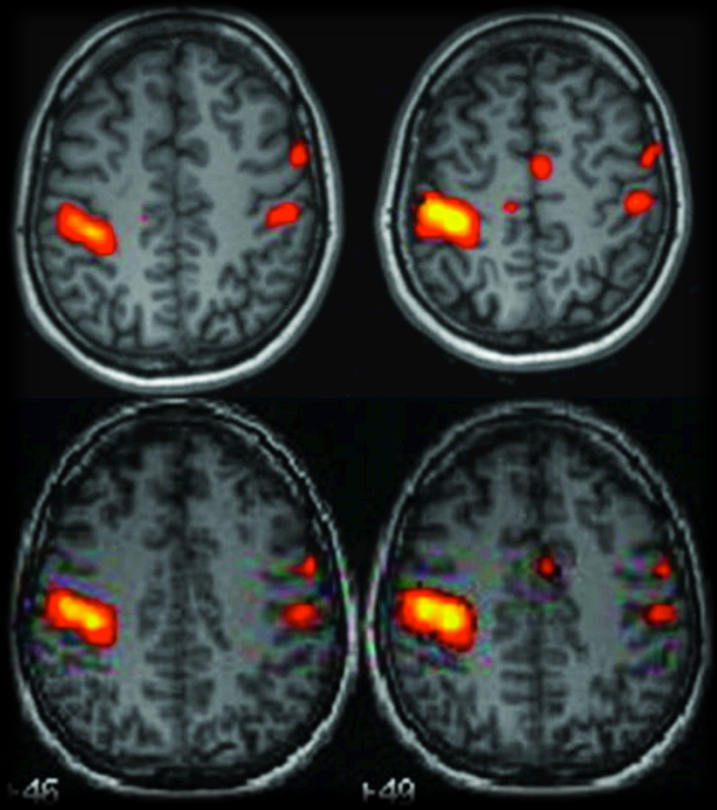
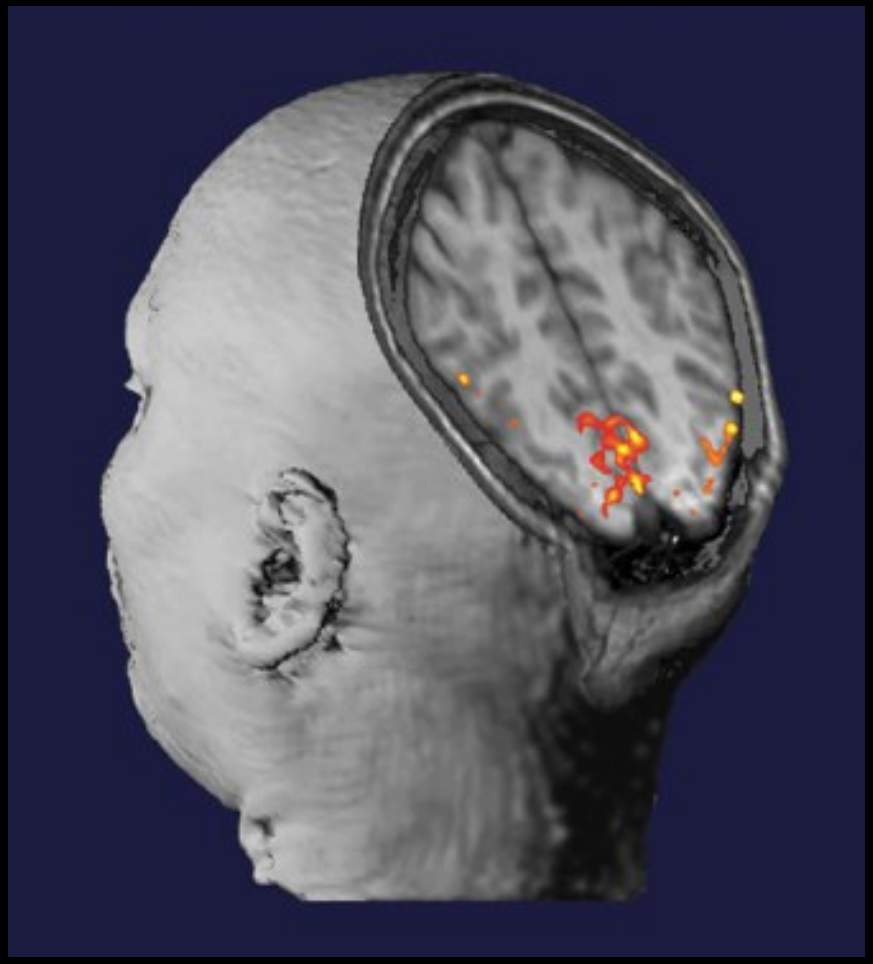
Functional MRI (fMRI)

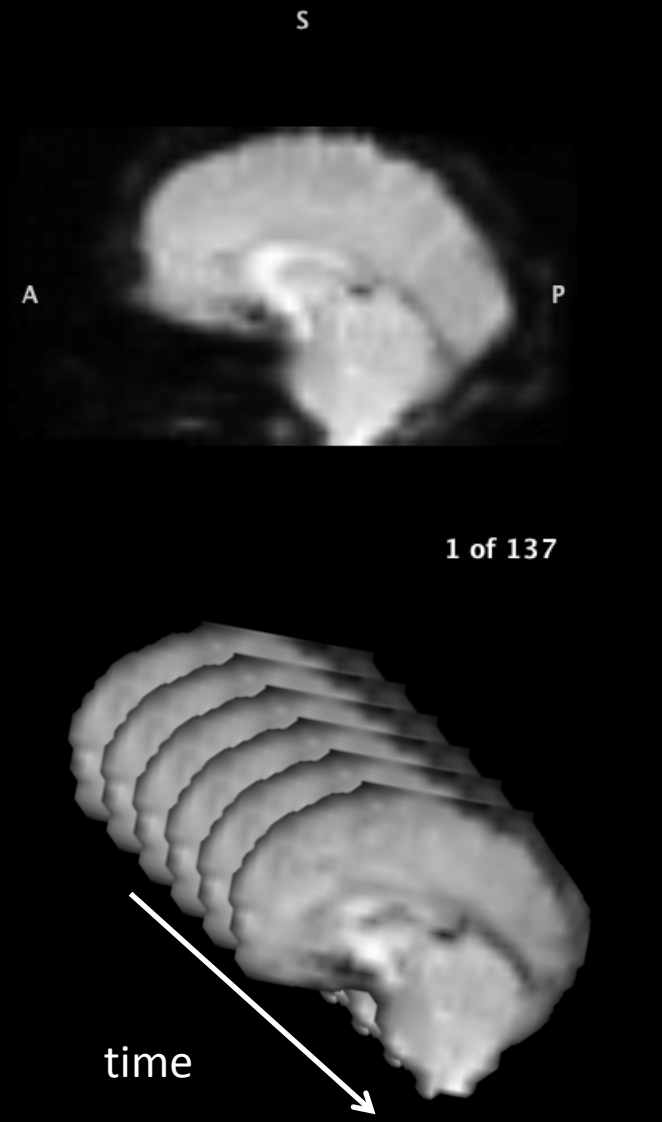




fMRI

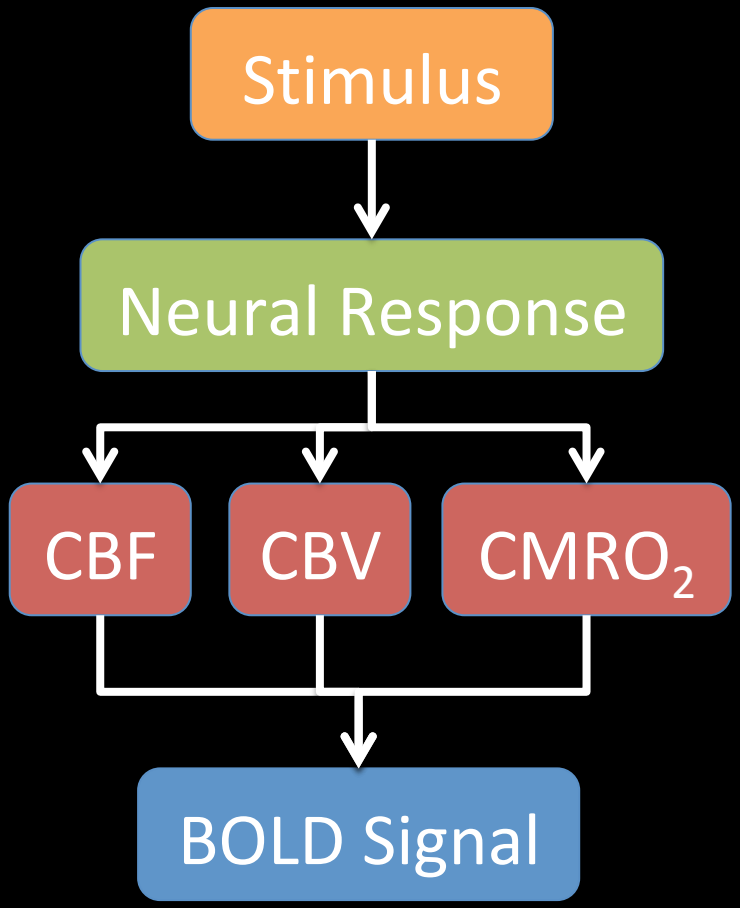
- 4D “Video” of BOLD signal
- Temporal Resolution: 2-3 seconds
- Spatial resolution: ~1mm^3 (with structural scan)
- Remember, this is **DATA**!

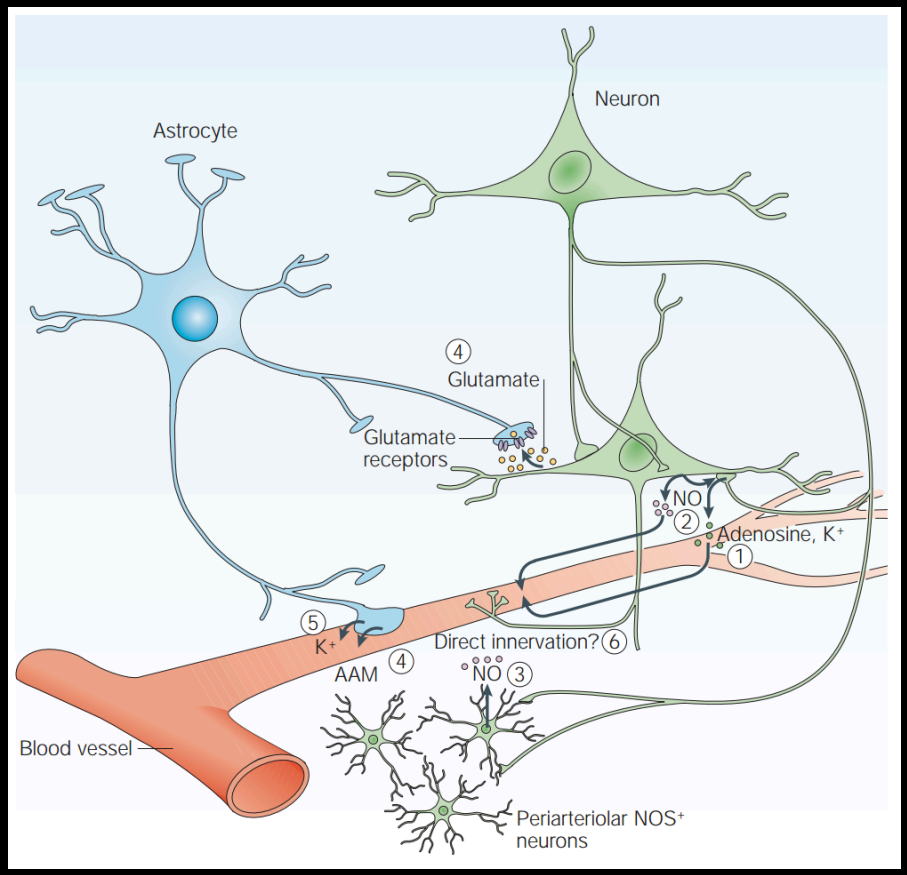
OpenfMRI ds000115



What Are We Measuring With fMRI?

- Blood-oxygenation-level-dependent (BOLD) Signal





D'Esposito, et al. (2003)

Image Subtraction

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

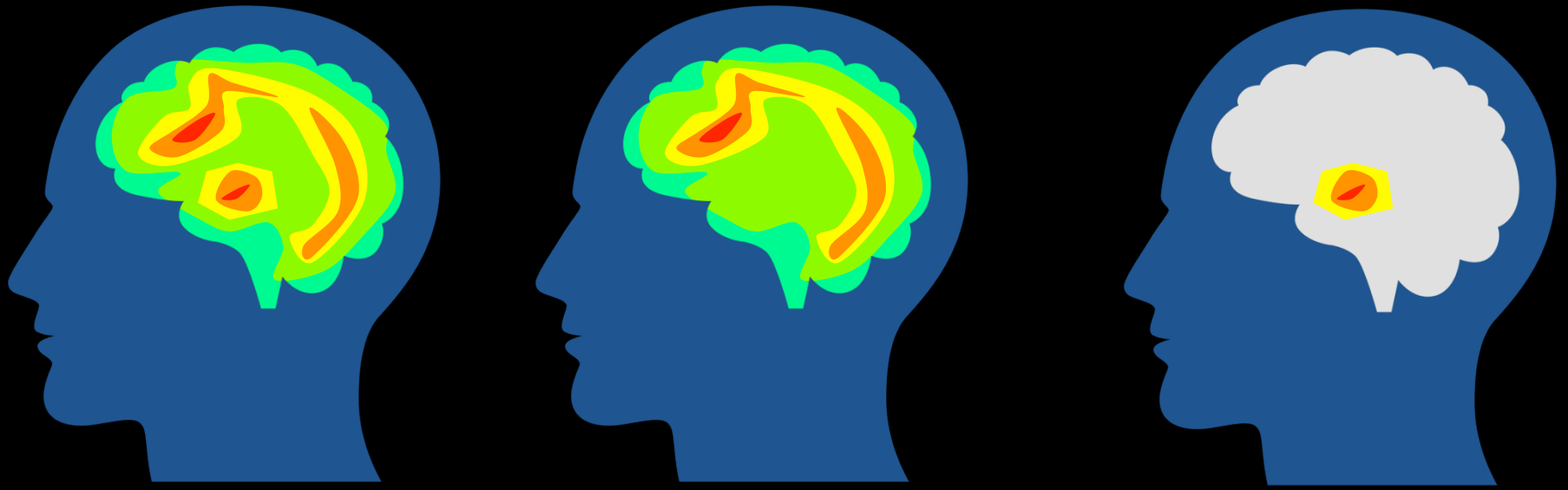
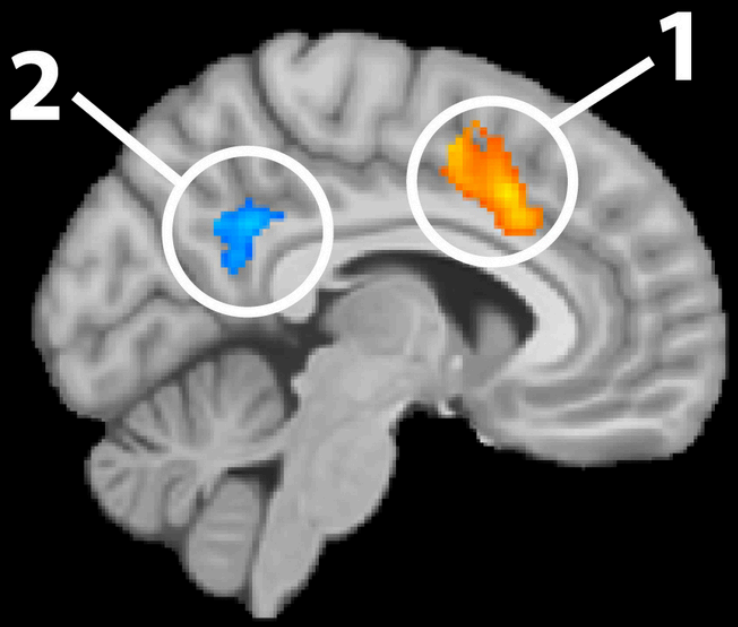


Image Subtraction

1. Yellow/Orange areas show increased activation in the task
2. Blue areas show increased activation in the control

"A > B" notation says we subtracted condition B from condition A



Task > Control

Aside: fMRI History

- fMRI as we know it was developed here in Boston at MGH
- Published on the cover of *Science* in 1991

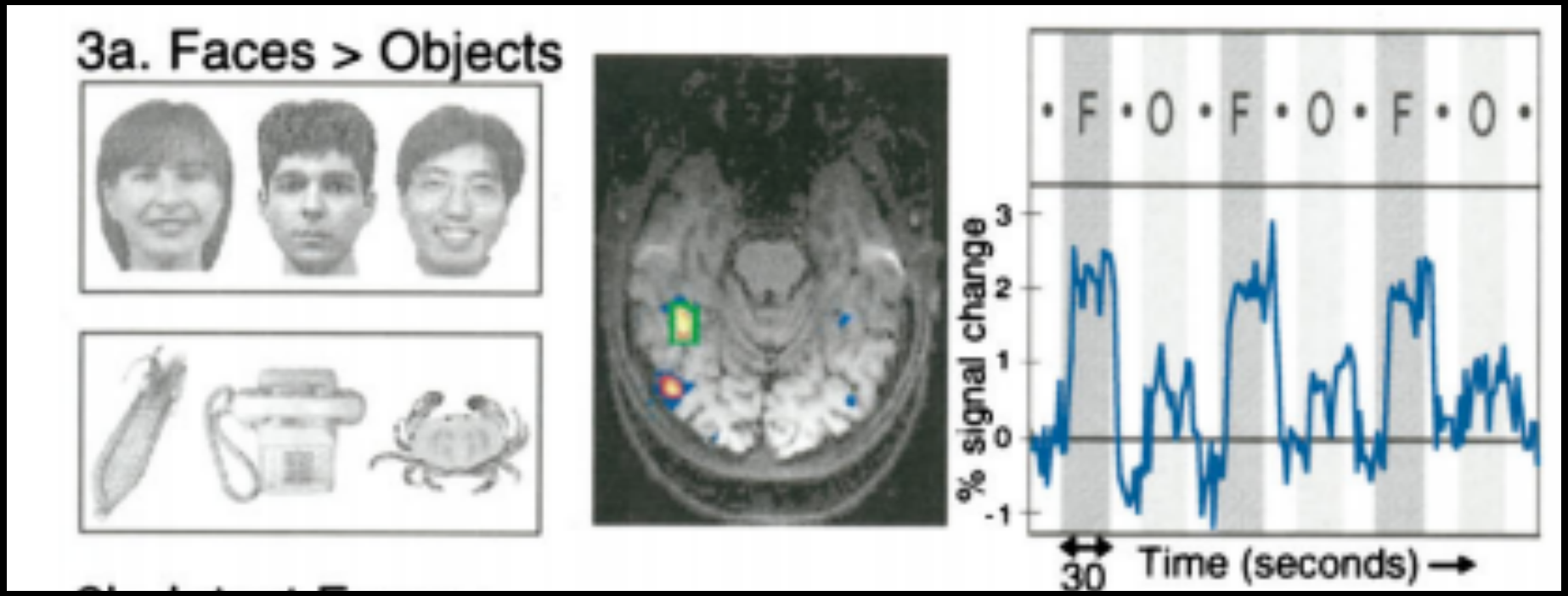
http://www.fmri25.org/behind-the-cover/

Finding Functional Brain Regions

- Nancy Kanwisher, pioneering researcher in fMRI
- Showed we can localize brain regions that show increased activation associated with a cognitive task

Finding Functional Brain Regions

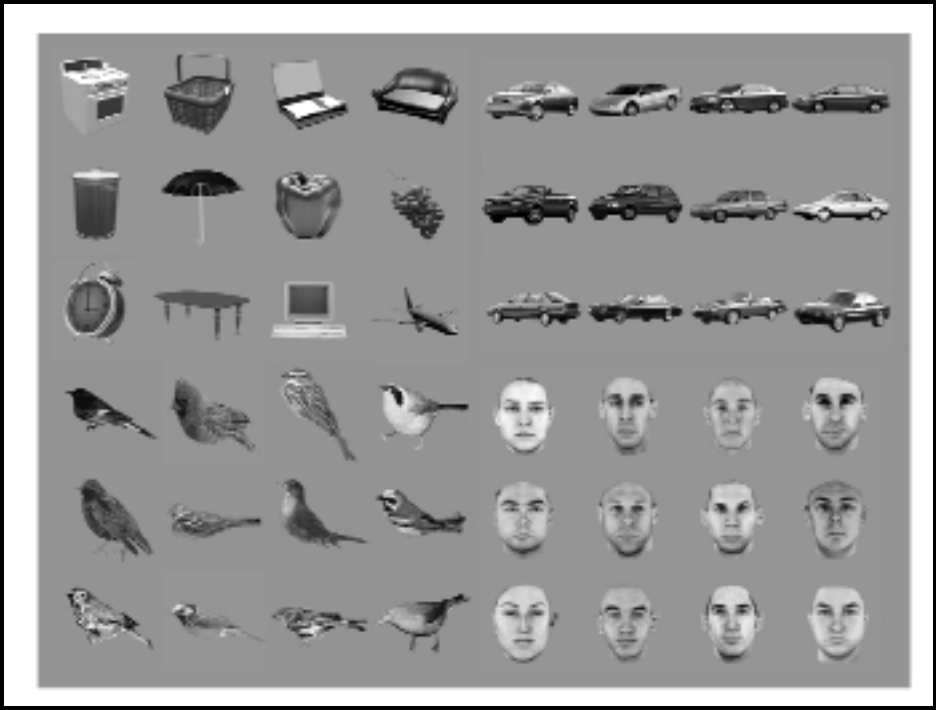
- Design a Task/Control Paradigm

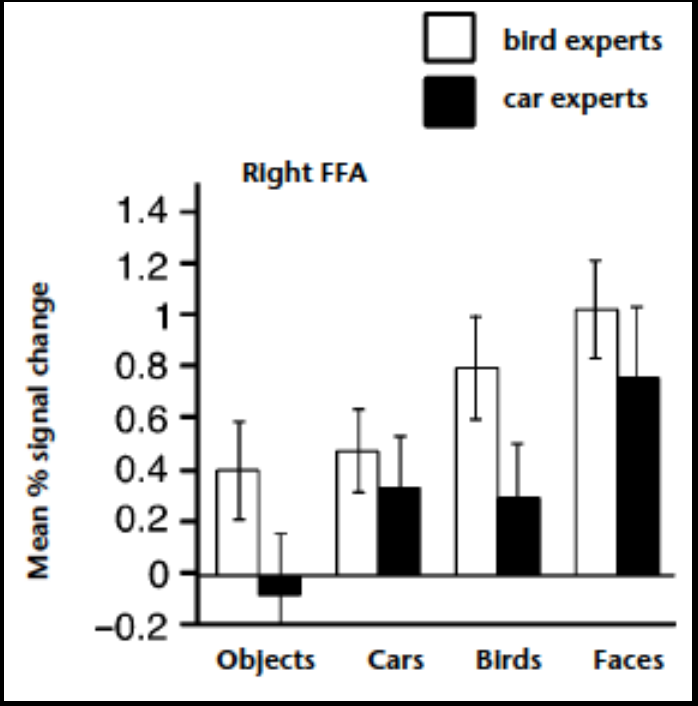


Kanwisher, et al. (1997)

Is the FFA Face-Specific?

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

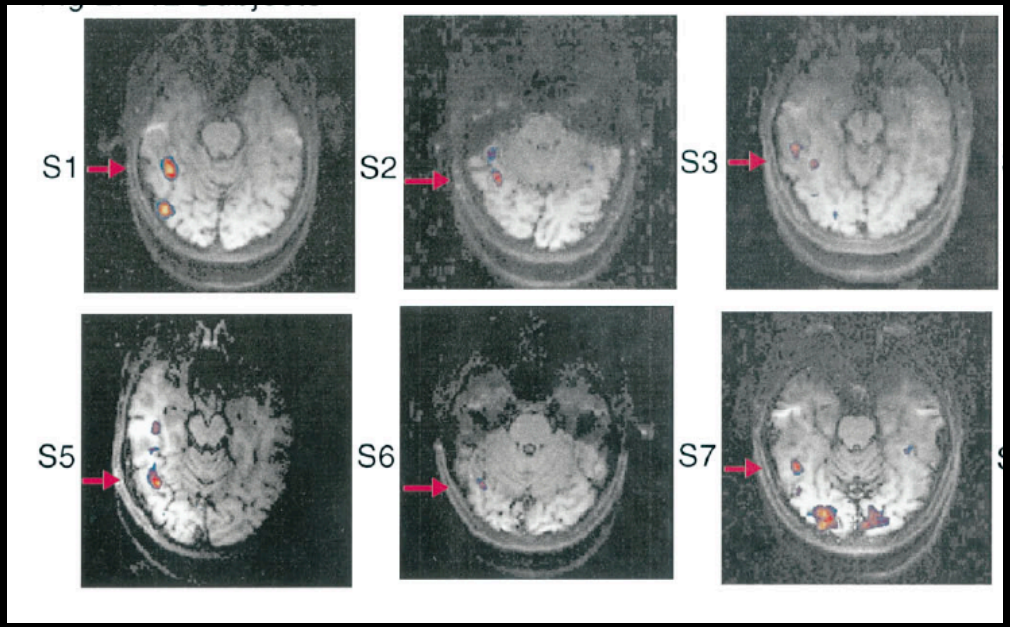




Gauthier, et al. (2000)

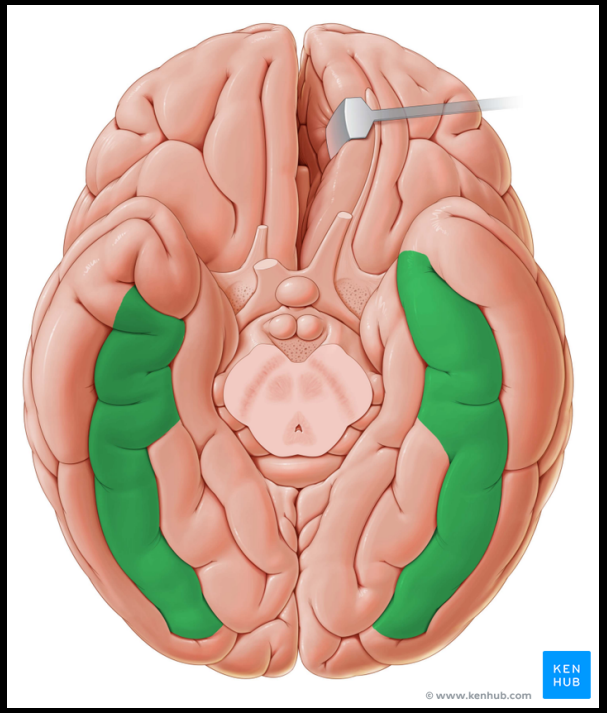
Functional vs. Anatomical Regions

Functional: Fusiform Face Area



Kanwisher, et al. (1997)

Anatomical:
Fusiform Gyrus



kenhub.com

Forum Responses

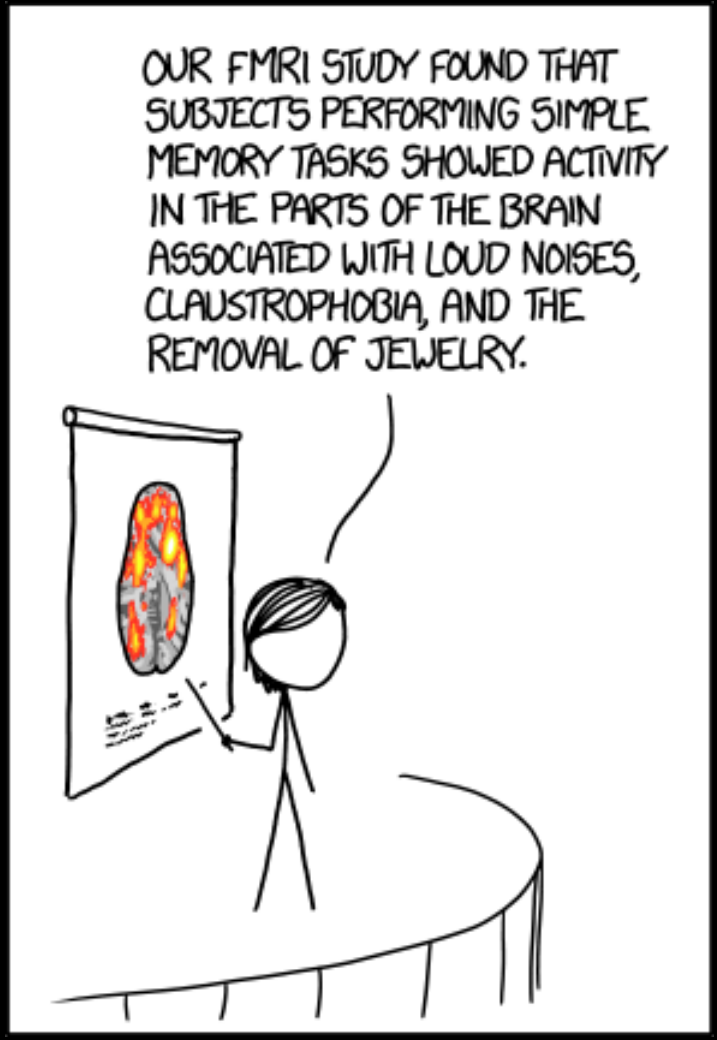
- Great ideas!
- Exercise
  - Avigail Bond, Samuel Strohbehn, Brittany Regas
- Meditation
  - Jordan Gans, Grace Yuh

Limitations and Controversy

- This is “macro” imaging
  - Our best resolution is about $1mm^3$
  - About half a billion synapses per voxel
- The temporal resolution 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

- **<u>Response from Last Year</u>**: "While I've never had a MRI before I've heard that they're both incredibly loud and time consuming. … I'm wondering if [Kanwisher's] 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."

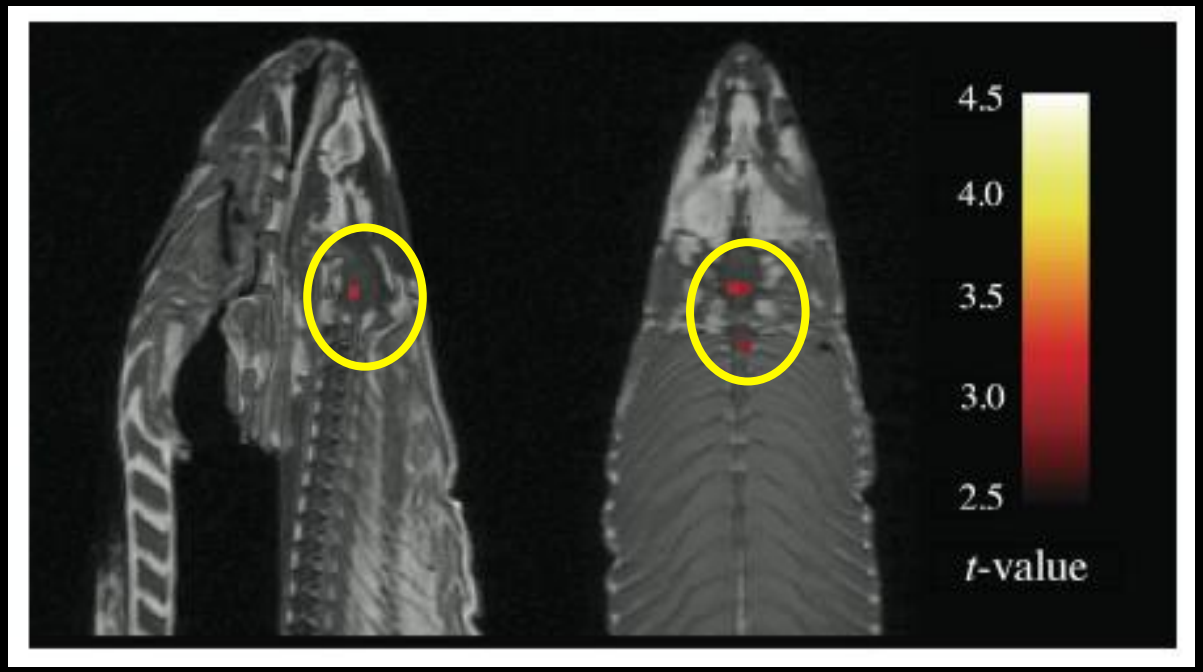


What Does MRI Sound Like?

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)

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Aside: Cortical Surface

https://www.youtube.com/watch?v=aj-d8PZMXt8

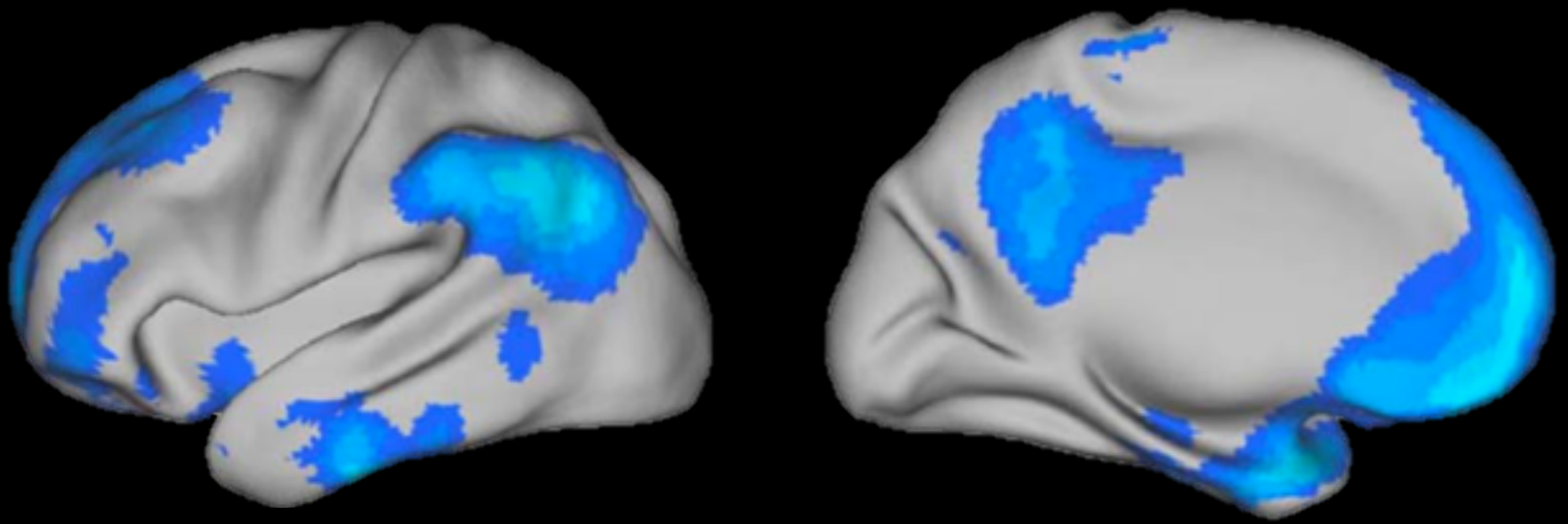
Resting State fMRI

- Data: spontaneous changes in BOLD signal
  - No task… just lie in the scanner and don't fall asleep
- Use the data to map the brain's functional (intrinsic) connectivity

The Origins of Resting State fMRI

- Is our brain ever “at rest?”
- Certain regions tend to be LESS active during all tasks (more active at rest)

<u>The Default Mode Network</u>



Lateral

Medial

Buckner, et al. 2008

DMN is Disrupted in Alzheimer's

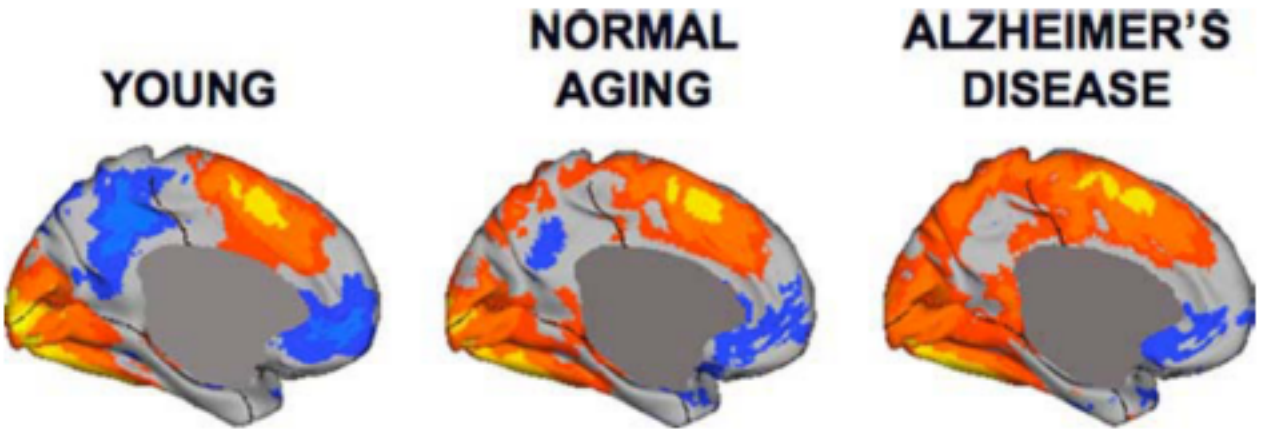
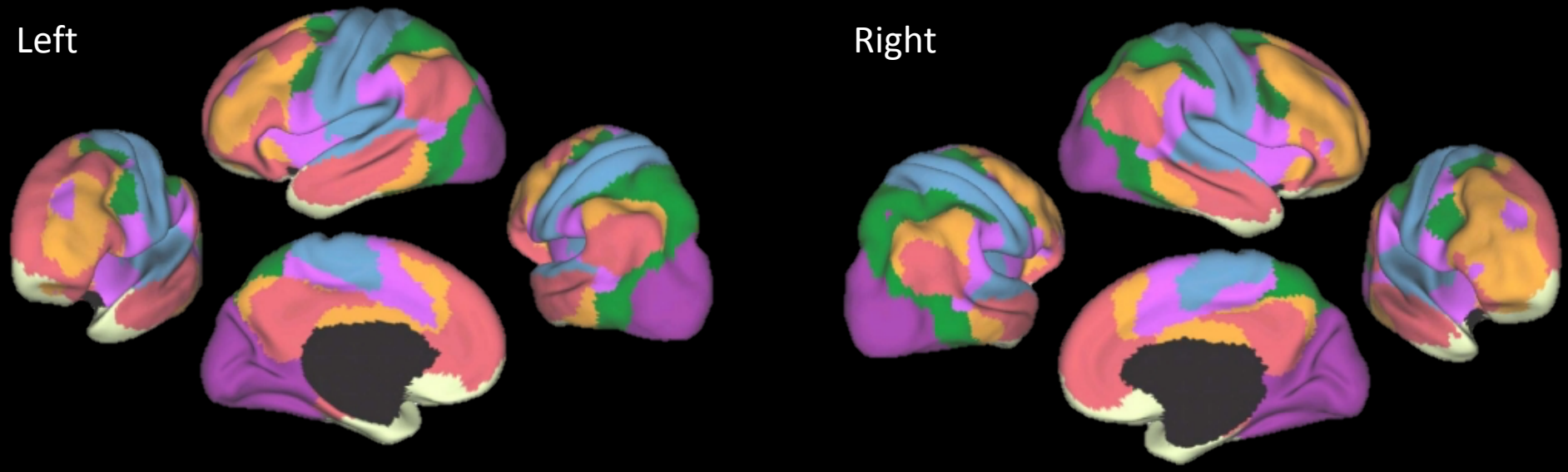


FIGURE 18. Activity within the default network is disrupted in Alzheimer's disease. Task increases (red) and decreases (blue) from a simple word classification task referenced to a passive baseline task are plotted for young adults (left panel), normal older adults (middle panel), and demented older adults with AD (right panel). The young adults show the classic pattern of task-induced deactivation within PCC/Rsp and MPFC. The effect attenuates significantly in AD. Adapted from Lustig et al. (2003, see also Greicius et al. 2004).

Buckner, et al. 2008

Are There Other Functional Networks?

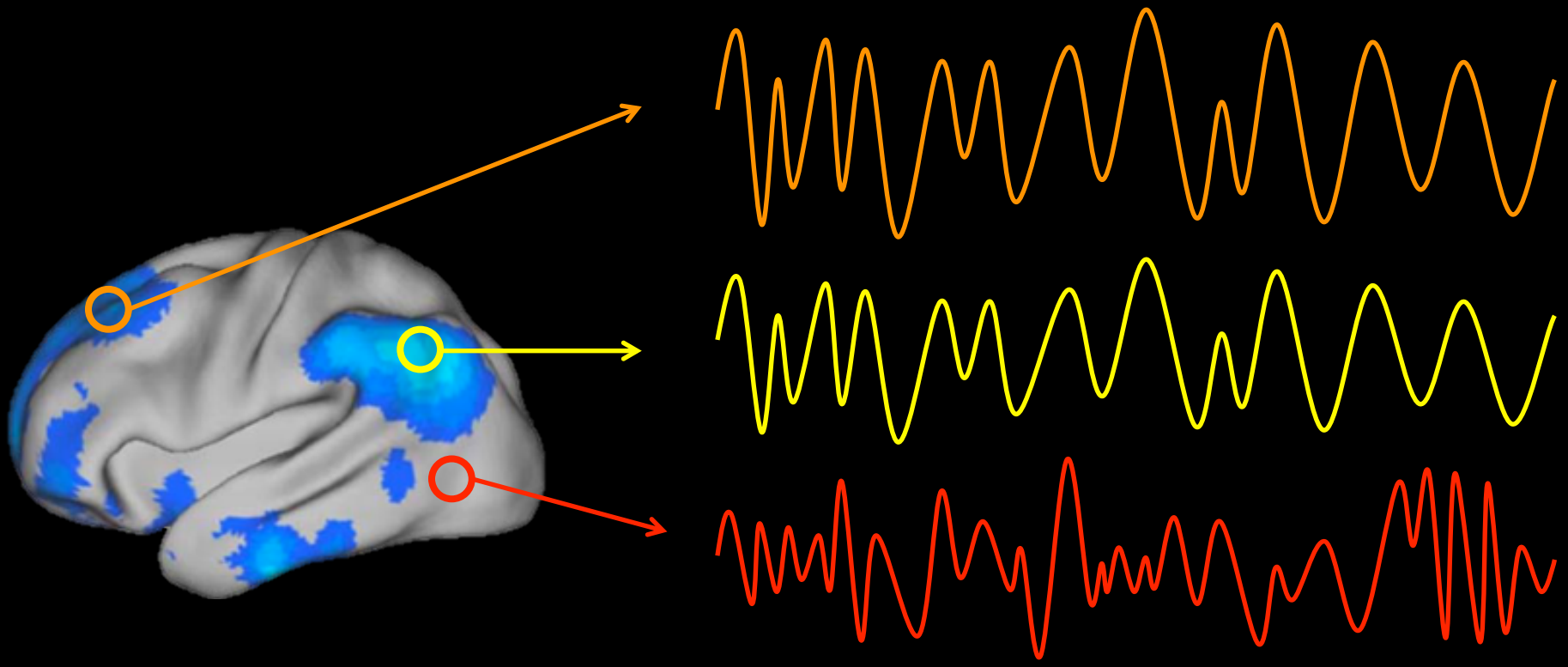
Yeo 7 Network Parcellation



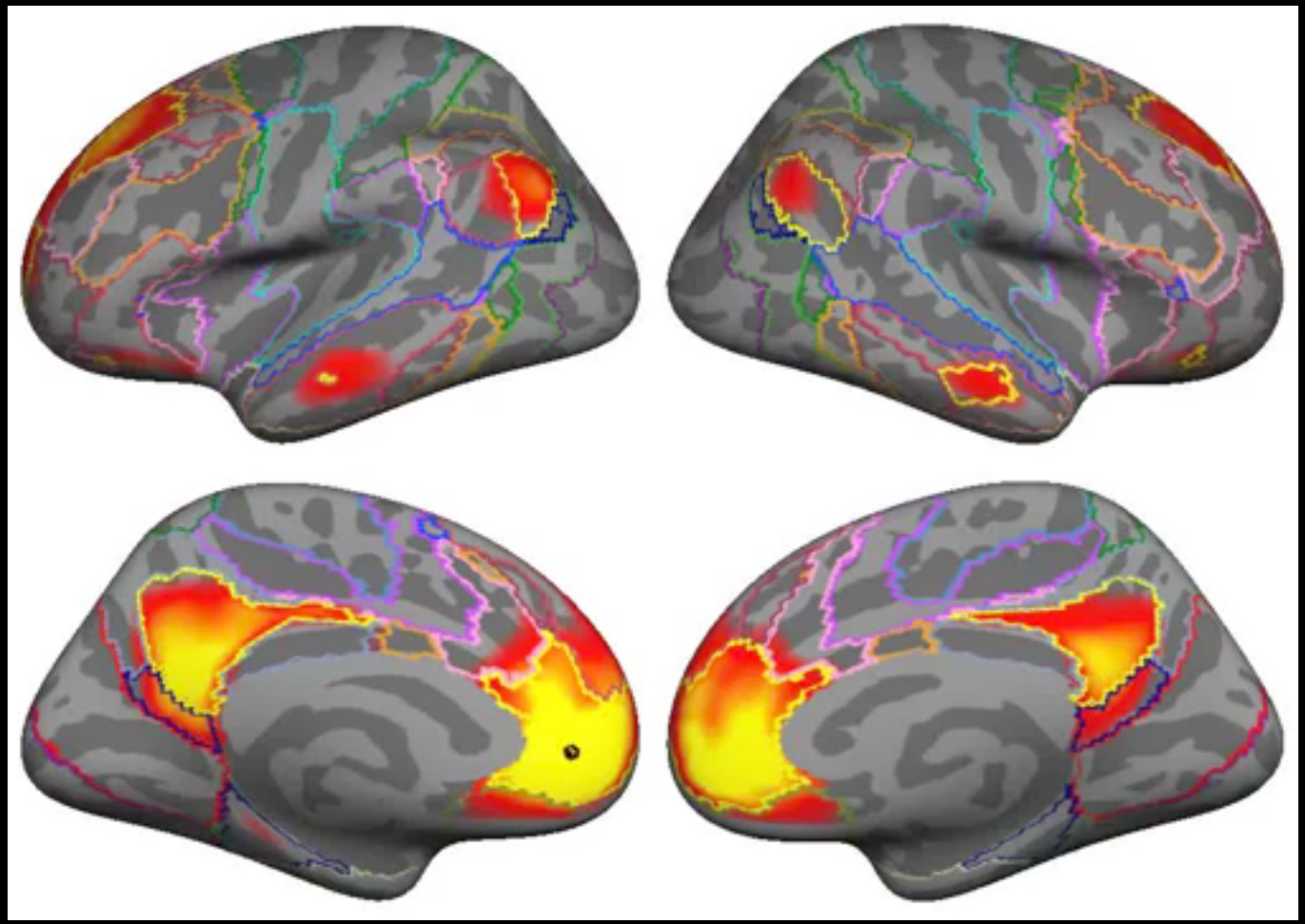
Yeo, et al. 2011

Functional (Intrinsic) Connectivity

- How do spontaneous fluctuations in BOLD signal correlate between brain regions?



Functional (Intrinsic) Connectivity



Yeo, et al. 2011

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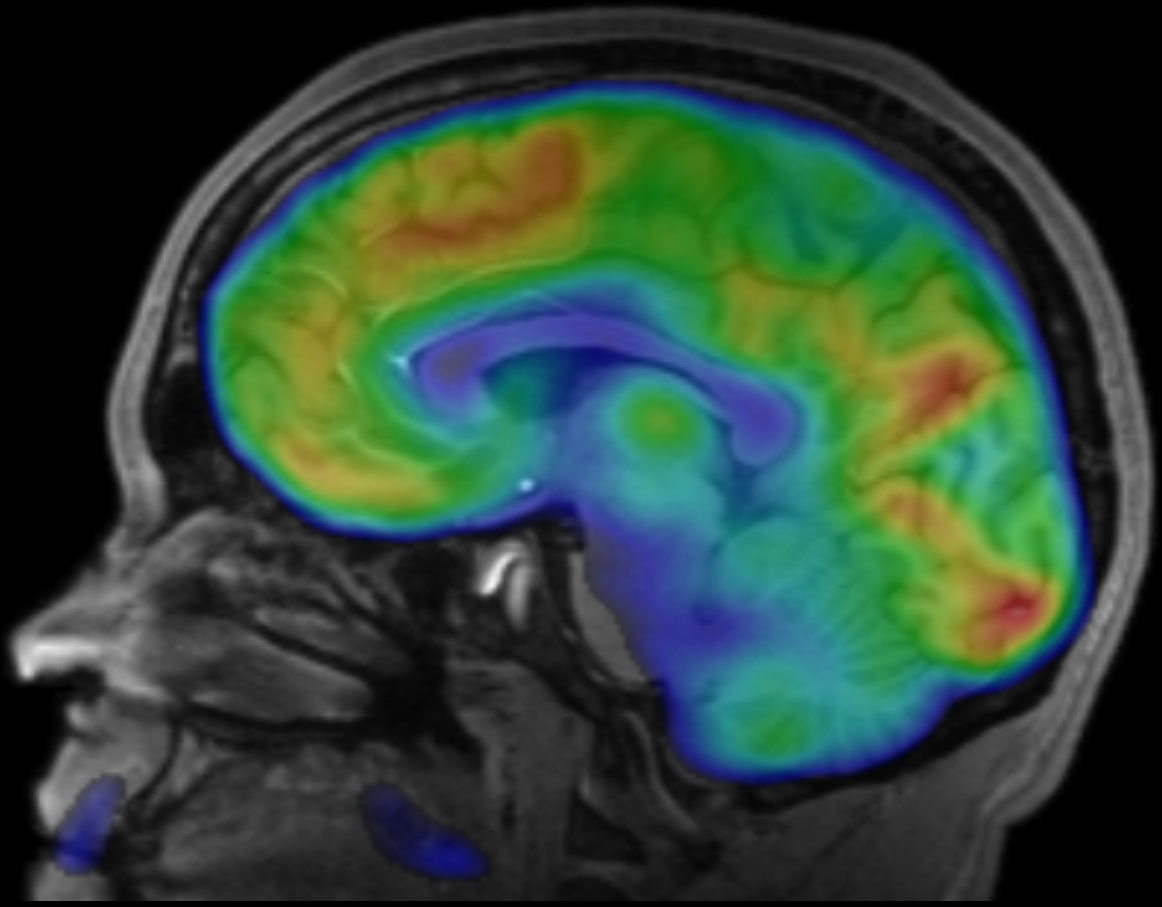
The Future is Now

- Dylan Williams, 21 year-old student at Tufts in 2012 when he was hit by a car
- Deemed “minimally conscious” by physicians at MGH
- Dr. Brian Edlow was conducting research at the time imaging unconscious individuals with fMRI
- Brain responded to music and language sounds
- Dylan regained consciousness a few days later

https://giving.massgeneral.org/fmri-reveals-brains-secrets/



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Dr. Martin Strebl
Dr. Tonya Gilbert
Christine Wu
Baleigh Hightower

Tufts University

Dr. Aniruddh Patel
Dr. Ayanna Thomas
Dr. Ben Hescott
Dr. Elizabeth Race
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Questions?

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