

Functional  
MRI: Part 1 of  
2

Dr. Alexander  
Mark Weber

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# Understanding and Interpreting Functional Magnetic Resonance Imaging

## Precision Health Boot Camp

Alexander Mark Weber

Department of Pediatrics, Division of Neurology  
University of British Columbia

9:00 - 11:00 AM  
August 9th, 2022

# Preamble

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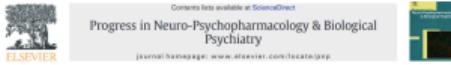
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A preliminary study of functional connectivity of medication naïve children with obsessive-compulsive disorder  
Alexander Mark Weber<sup>a</sup>, Noam Soren<sup>a,b,c\*</sup>, Michael David Noseworthy<sup>a,d,e,f</sup>



Magn Reson Mater Phys (2014) 27:291–301  
DOI 10.1007/s10346-013-0420-5

RESEARCH ARTICLE

Brain Fractal Blood-Oxygen Level Dependent (BOLD) Signals: The Effect of MRI Acquisition Parameters on Temporal Fractal Dimension (FD) Stability  
Volume 2, Issue 1, 2013,  
DOI: 10.1615/VisulitzImageProcComputBiomed.2013006937



Mohamed A. Morsi  
School of Biomedical Engineering, McMaster University, Hamilton; Department of Psychiatry and Behavioural Neuroscience, McMaster, Ontario, Canada

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School of Biomedical Engineering, McMaster University, Hamilton, ON, Canada; Imaging Research Centre, St. Joseph's Healthcare, Hamilton, ON, Canada; Electrical and Computer Engineering, McMaster University, Hamilton, ON, Canada; Department of Radiology, McMaster University, Hamilton, ON, Canada

A preliminary study on the effects of acute ethanol ingestion on default mode network and temporal fractal properties of the brain

Alexander M. Weber · Noam Soren · Michael D. Noseworthy



ORIGINAL RESEARCH  
Published: 11 January 2012  
doi:10.3389/fphys.2012.00001

Cerebrovascular Reactivity Following Spinal Cord Injury

✉ Alexander Mark Weber, Tom E. Nightingale, Michael Jarrett, Amanda H. X. Lee, Olivia Campbell, Mathias Walter, Samuel J.E. Lucas, Aaron Phillips, Alexander Rauscher, Andrei Krassioukov  
doi: https://doi.org/10.1101/2022.06.28.22276567

Fractal-Based Analysis of fMRI BOLD Signal During Naturalistic Viewing Conditions  
Olivia Campbell<sup>1</sup>, Tamara Vanderveldt<sup>1,2,3,4</sup> and Alexander Mark Weber<sup>1,2,3,4,5</sup>

<sup>1</sup> School of Biomedical Engineering, University of British Columbia, Vancouver, BC, Canada; <sup>2</sup> UBC Okanagan, Kelowna, BC, Canada; <sup>3</sup> Department of Psychiatry and Behavioural Neuroscience, St. Joseph's Health Care, Hamilton, ON, Canada; <sup>4</sup> Department of Radiology, McMaster University, Hamilton, ON, Canada; <sup>5</sup> Department of Neuroscience, University of British Columbia, Vancouver, BC, Canada

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- 6 fMRI Analysis**
- 7 Second Section**

# Land Acknowledgement

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I would like to acknowledge that we are gathered today on the traditional, ancestral, and unceded territory of the Musqueam people.



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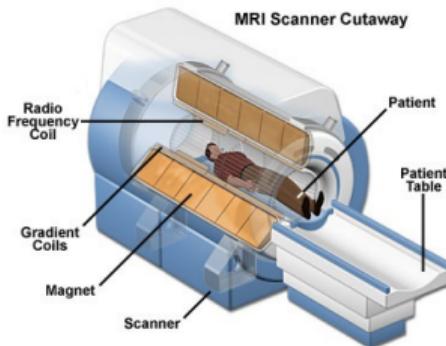
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- **Magnetic:** Large magnet: 1.5 Tesla to 10 Tesla strength
- Earth's magnetic field is 0.00005 Tesla
- Our BCCHR Research MRI is 3T; 60,000x Earth's magnetic field
- **Resonance:** Uses radiowaves with frequencies that resonate with atomic nuclei (hydrogen, usually)
- **Imaging:** Converts spatial frequencies and phase into images

<https://www.northwestradiology.com/blog/page/16/>

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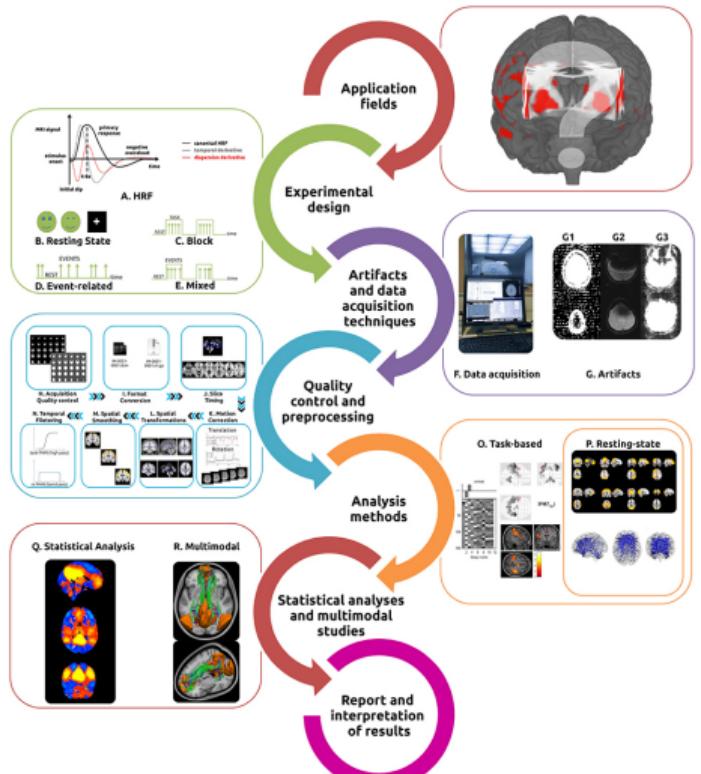
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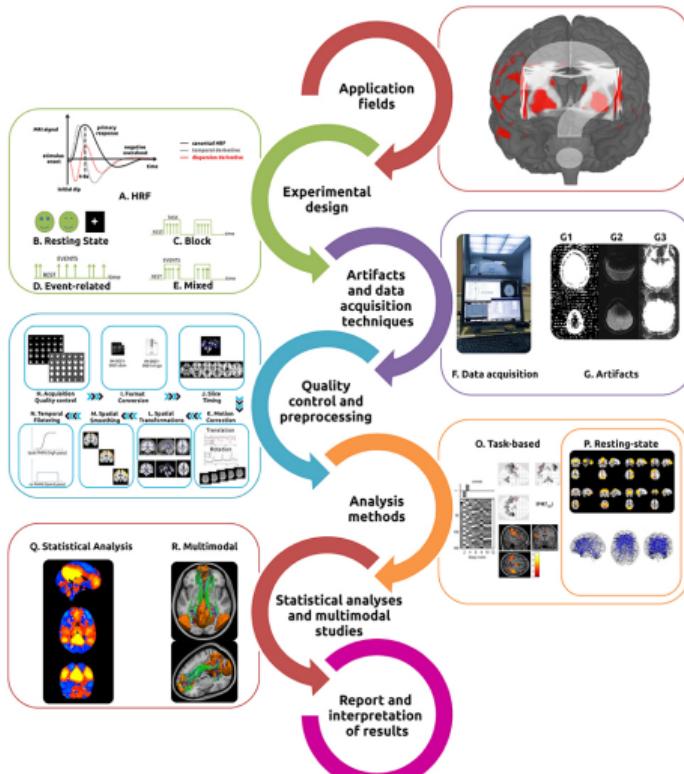
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## Lecture:

- MRI Physics
- Brain physiology
- fMRI acquisition
- Task vs Resting State fMRI

## Tutorial:

- Get data from PACS; Copy over to Sockeye
- Conversion and preprocessing (two ways)
- Task-based analysis
- Resting-state analysis

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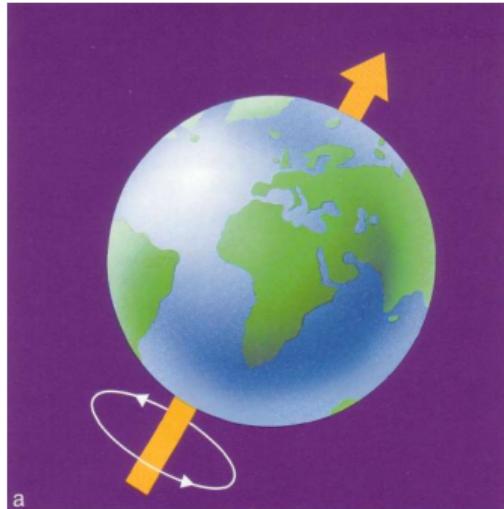
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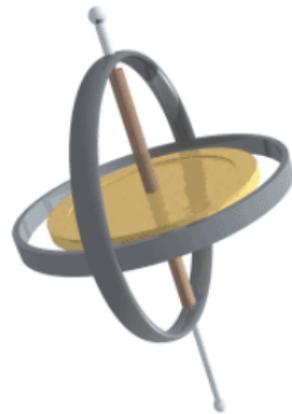
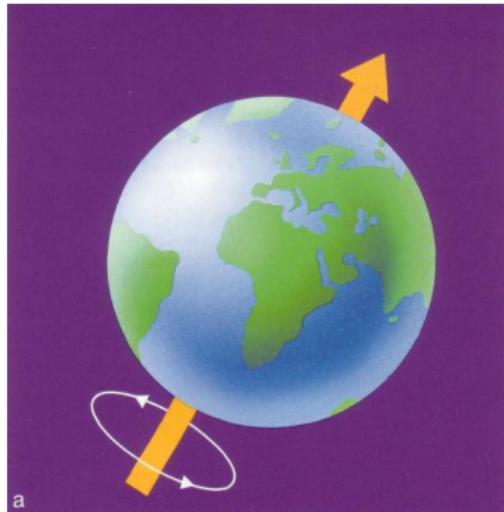
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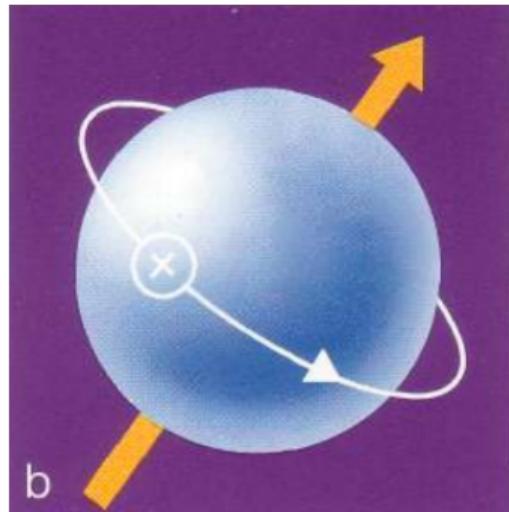
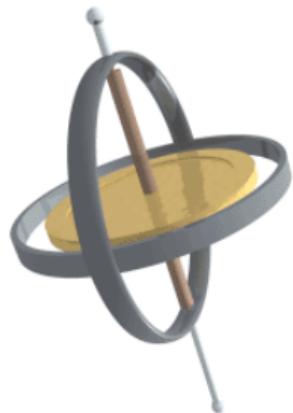
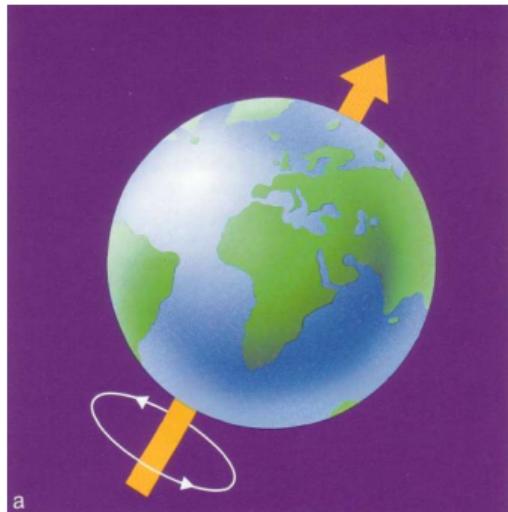
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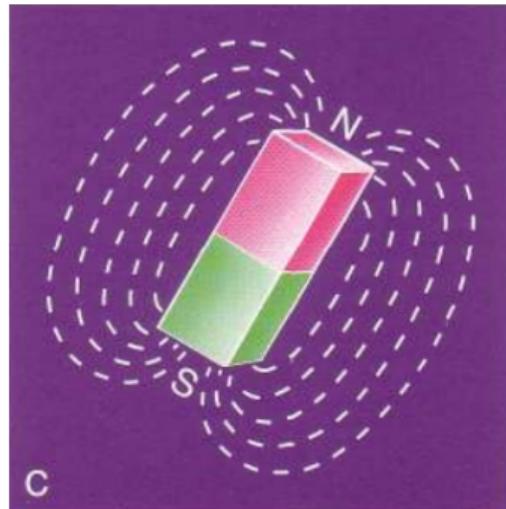
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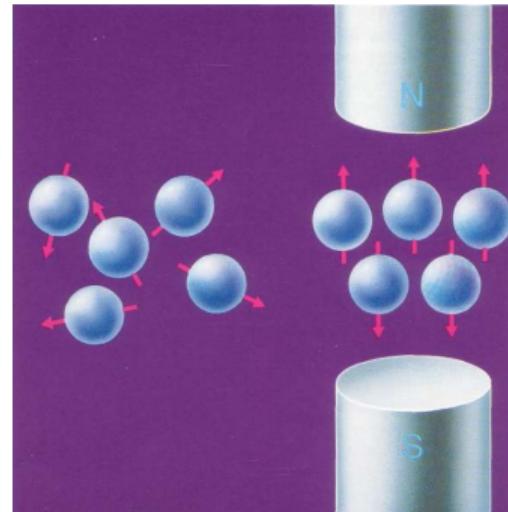
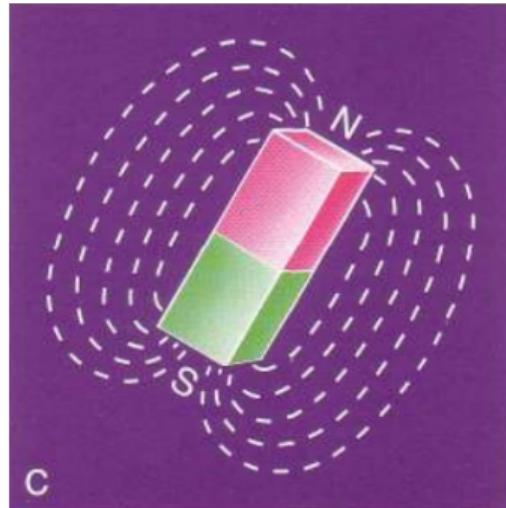
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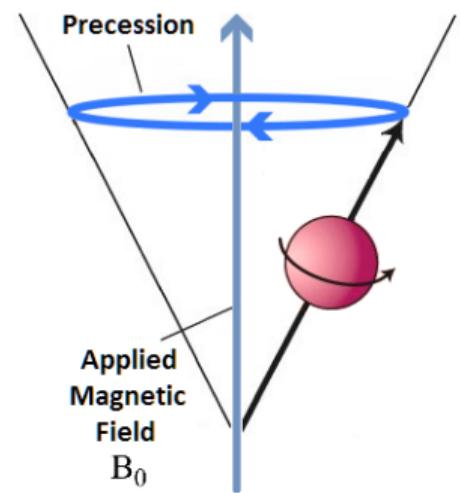
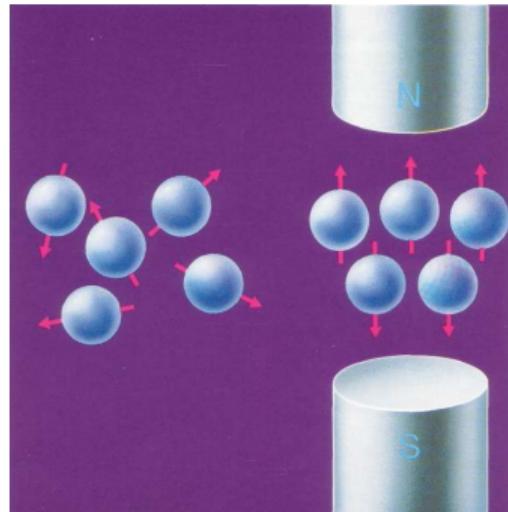
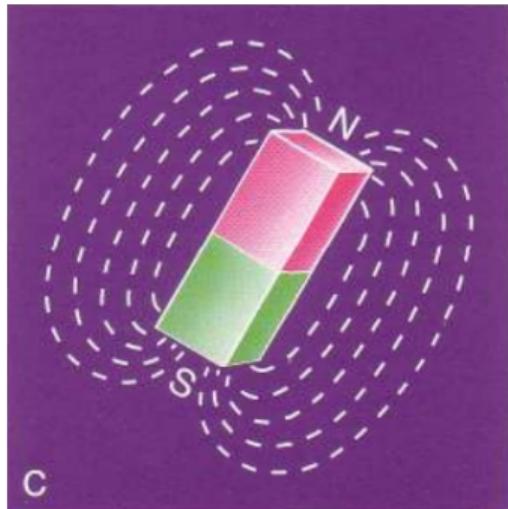
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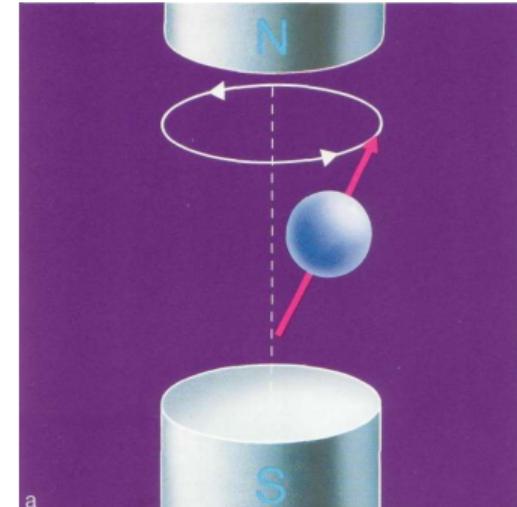
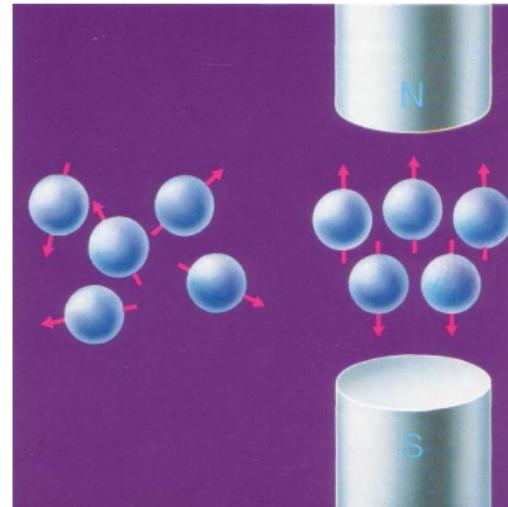
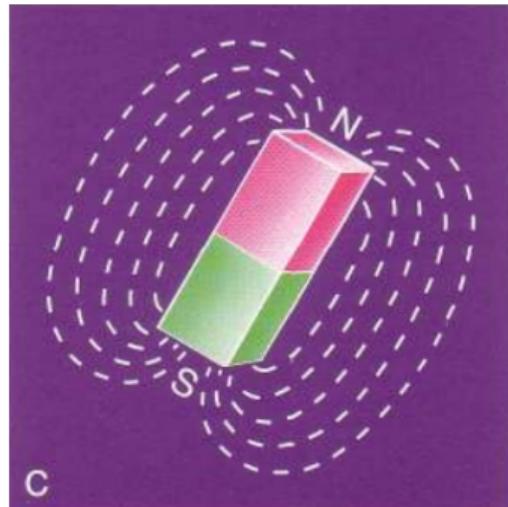
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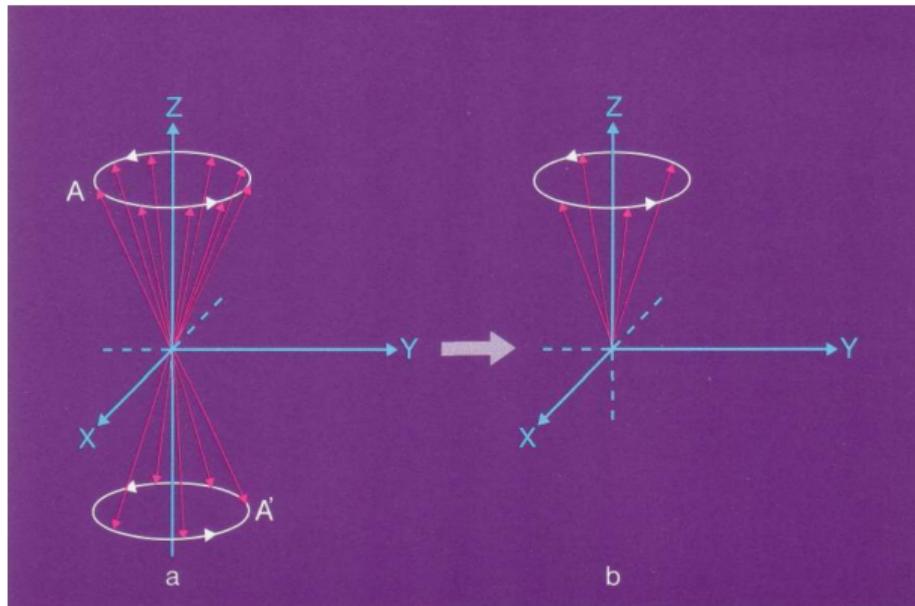
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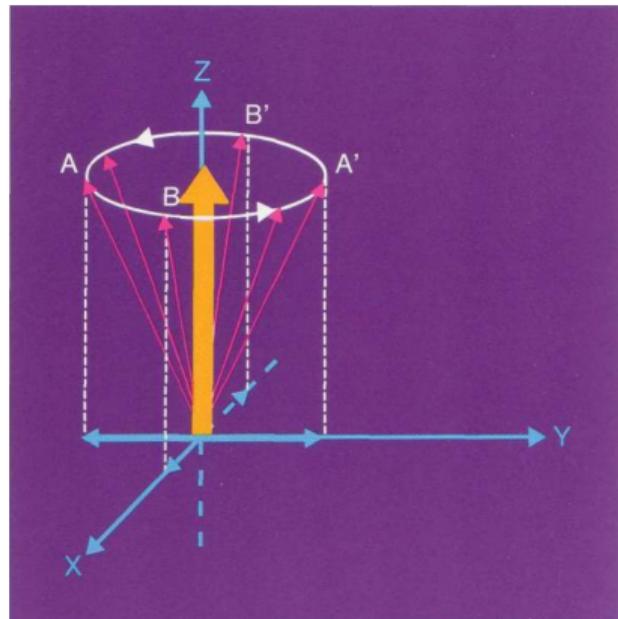
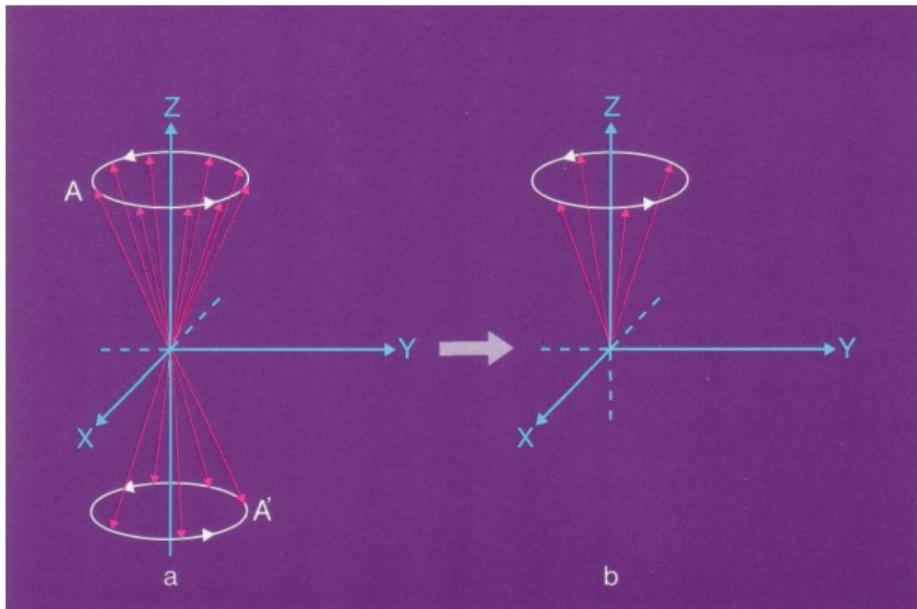
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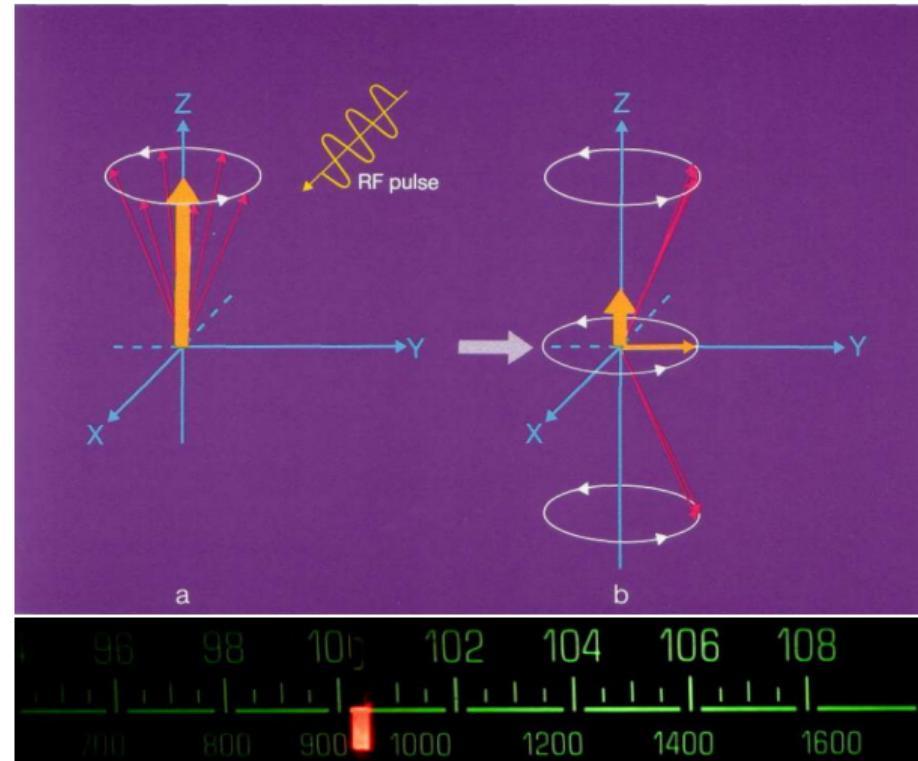
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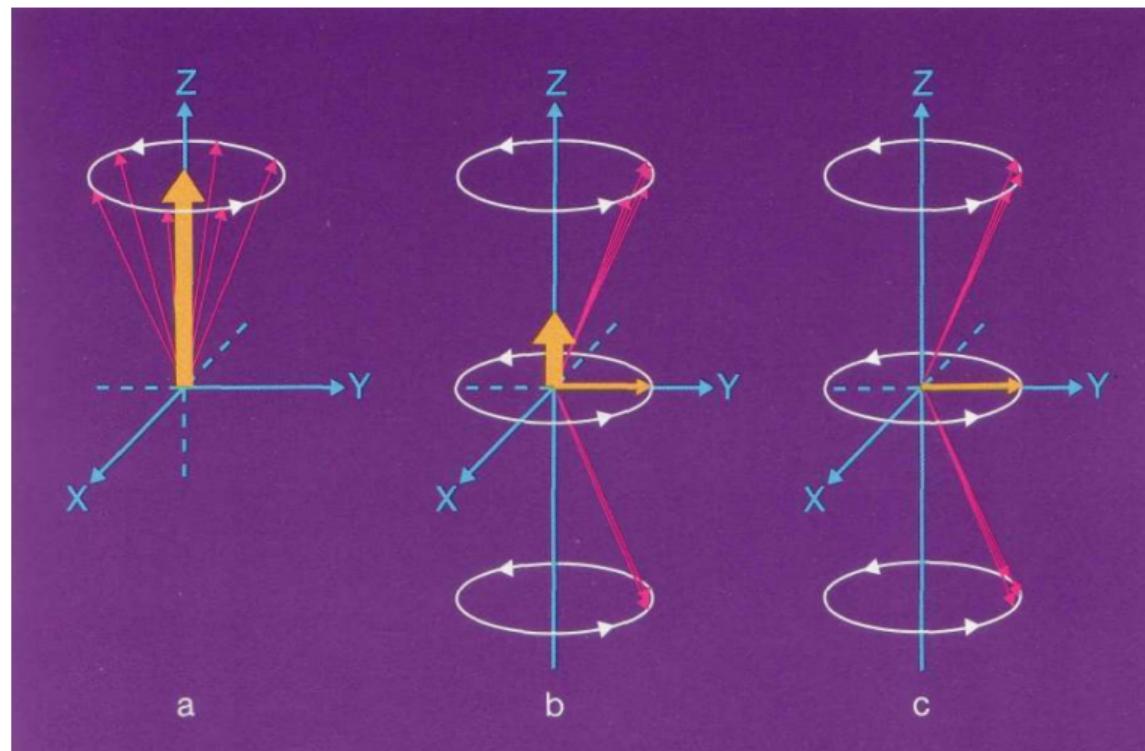
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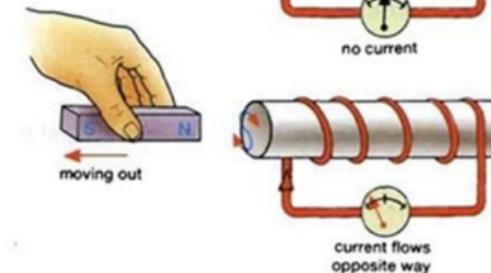
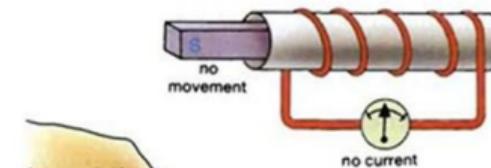
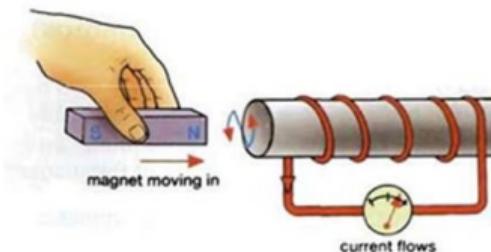
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- Proton's have QM Spin
- When placed in a large magnet (MRI) these protons precess around the main magnetic field
- Some face up and others face down, many cancelling each other out
- If we send a RF pulse at the same precession frequency, we can put these protons in phase: we create a transverse magnetic field, and destroy the longitudinal one
- This transverse magnetic field can be measured thanks to Faraday's Law of Induction

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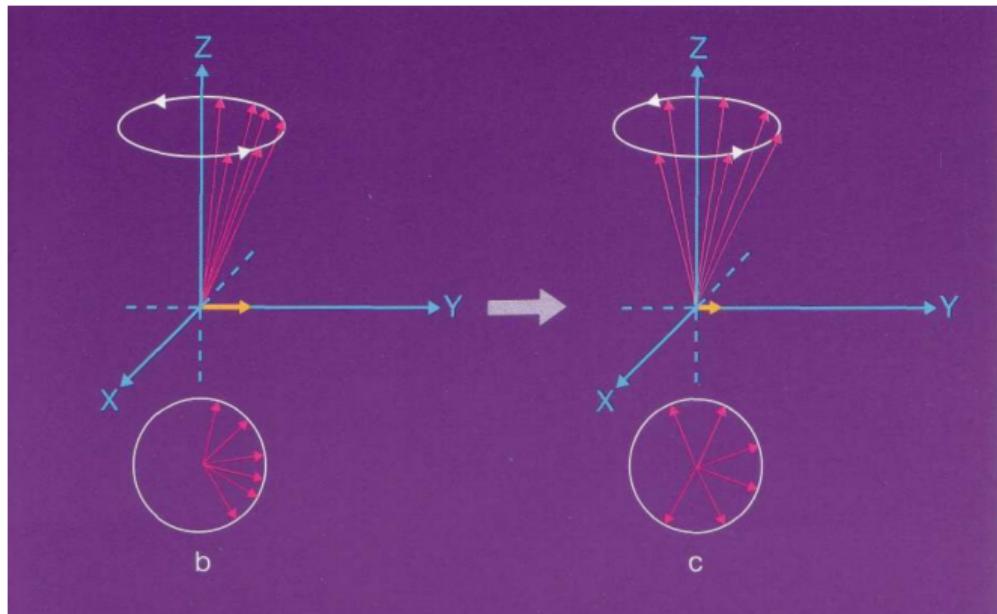
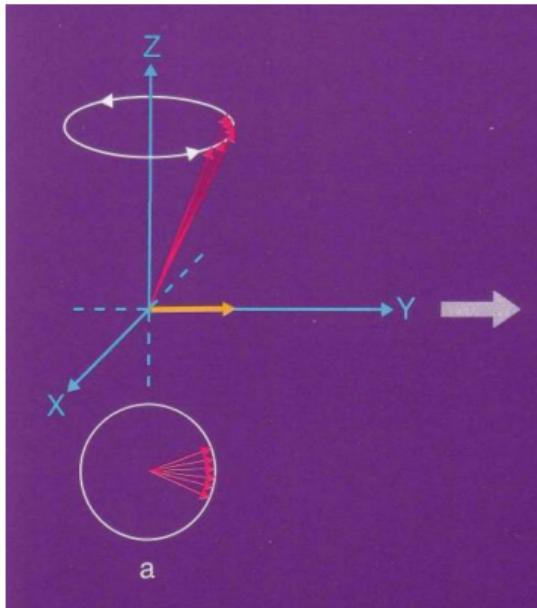
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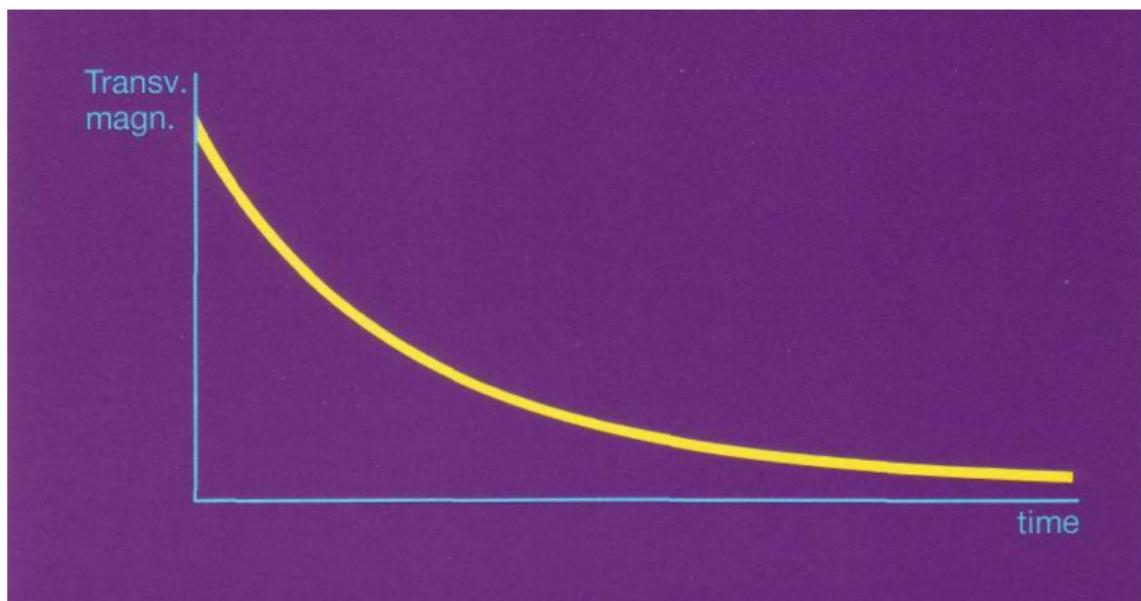
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## T2 relaxation

Also known as spin-spin decay: it is a time measure of the rate of decay caused by spin-spin interactions



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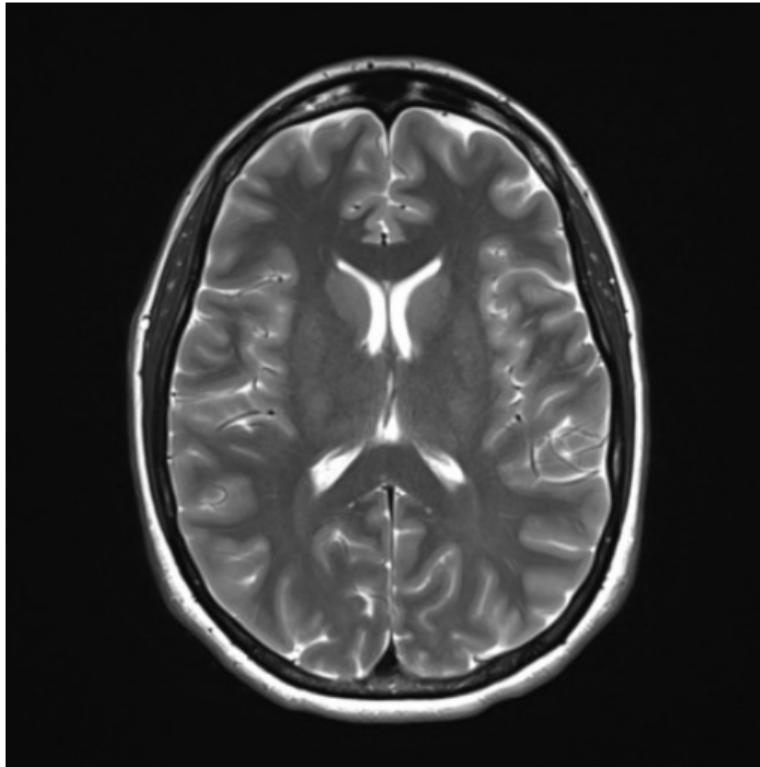
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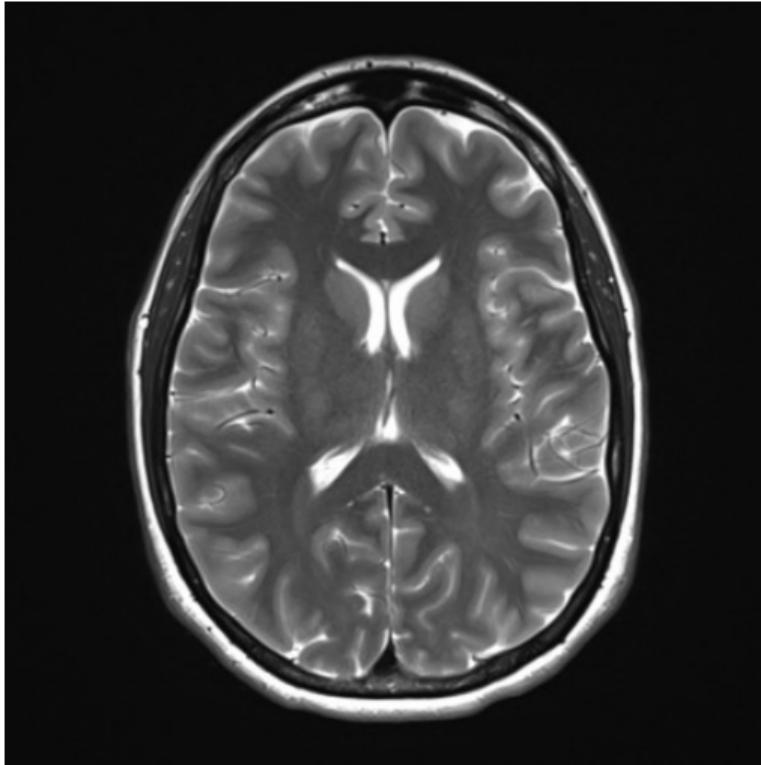
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## $T_2$ -weighted scan

- Water is bright
- A mix of water/tissue is less bright (grey matter)
- Fatty tissue is dark (white matter)

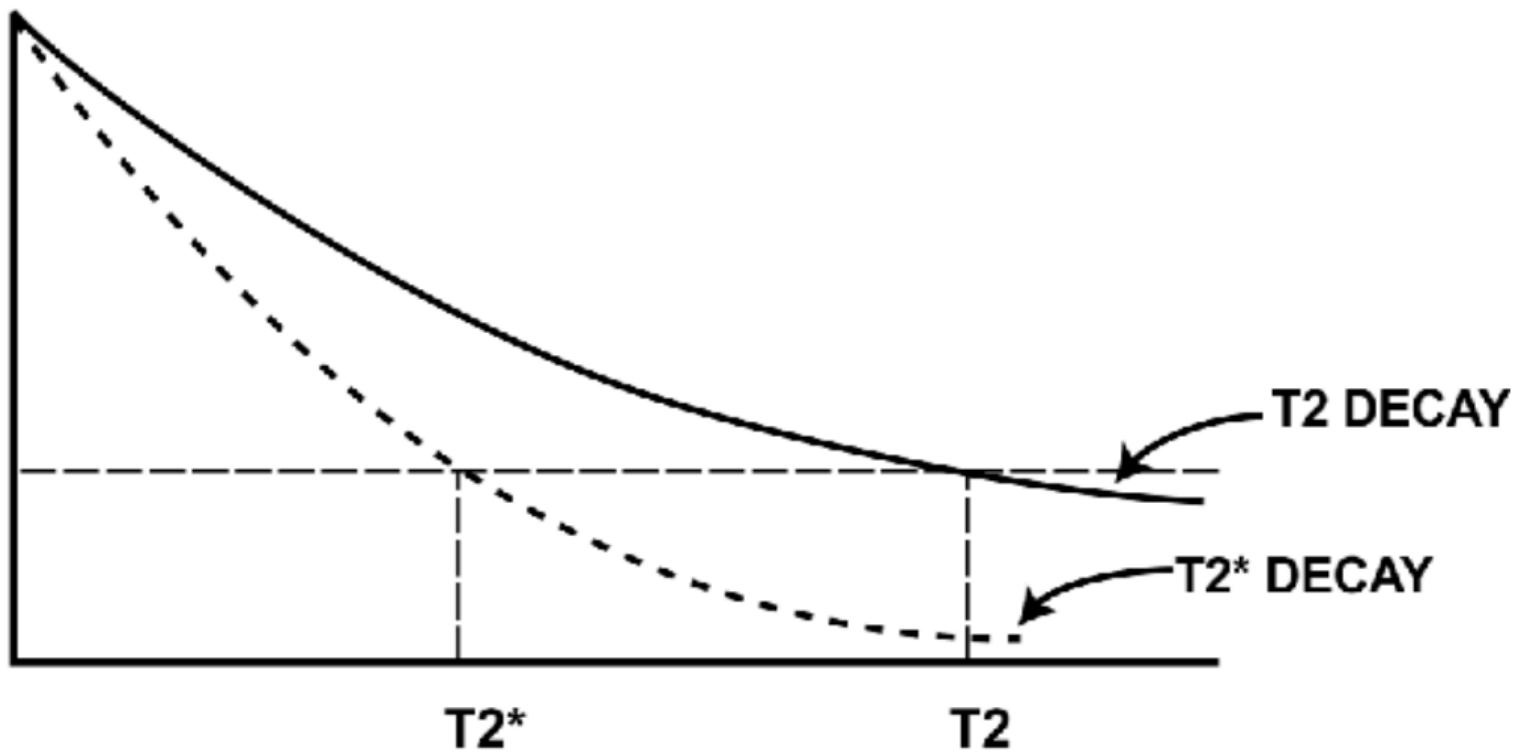
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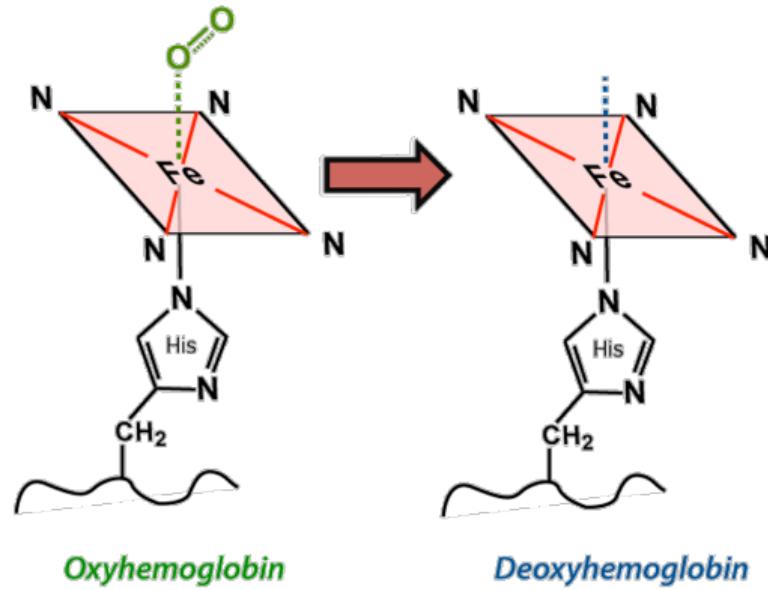
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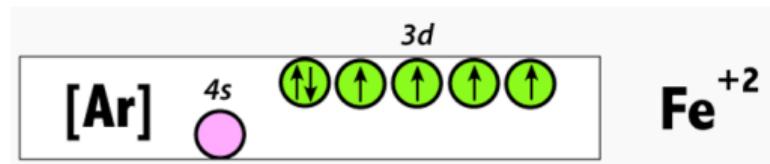
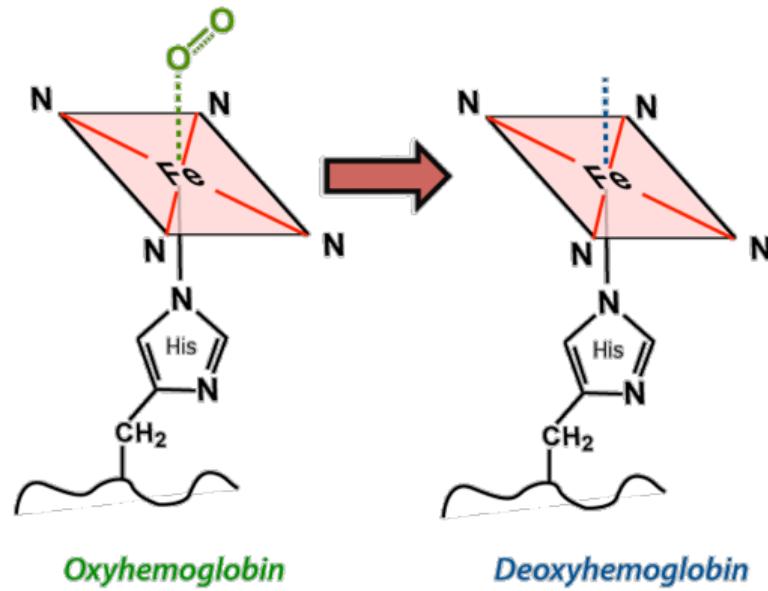
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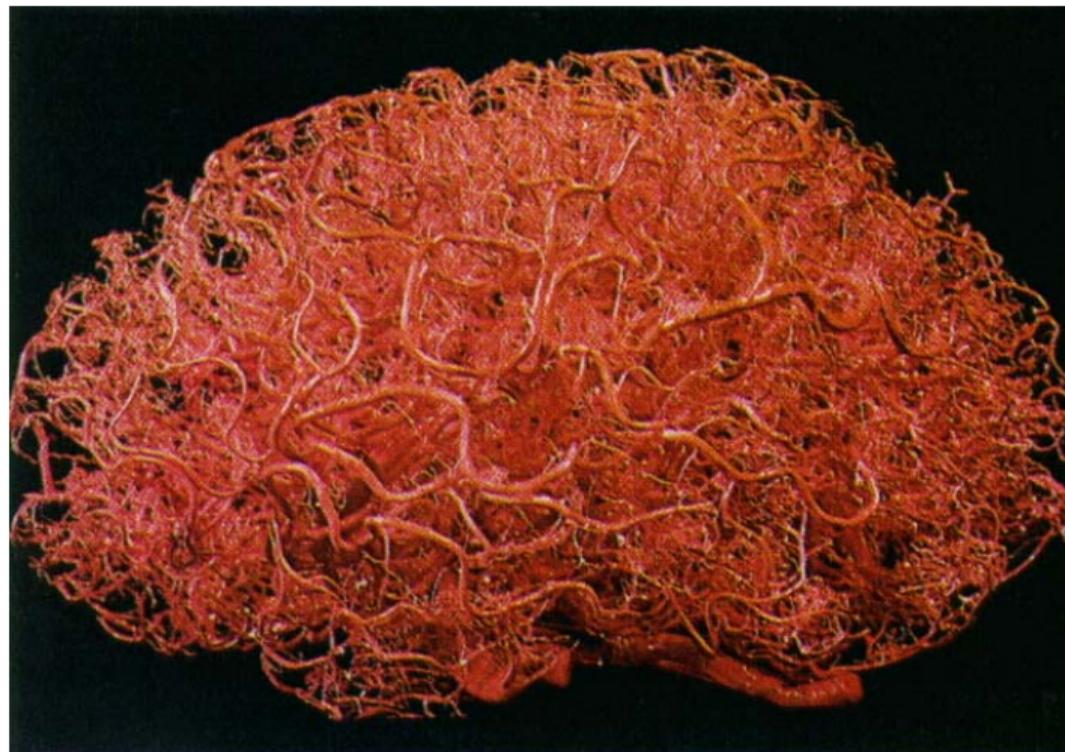
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Zlokovic, B. and Apuzzo, M. (1998). Strategies to Circumvent Vascular Barriers of the Central Nervous System. *Neurosurgery* 43, 877-878.

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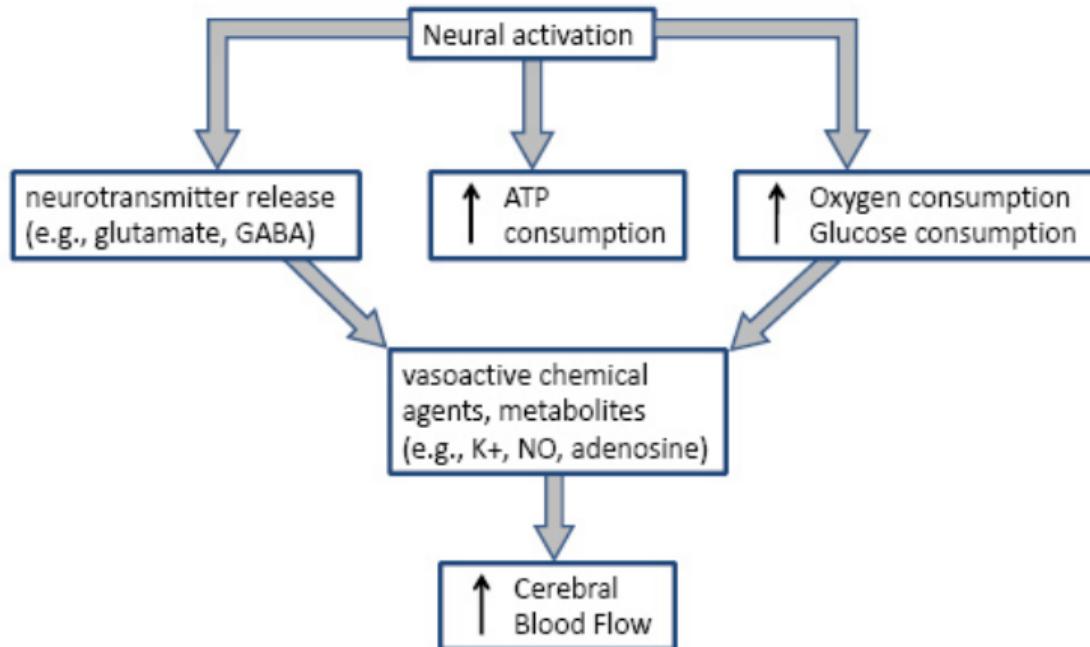
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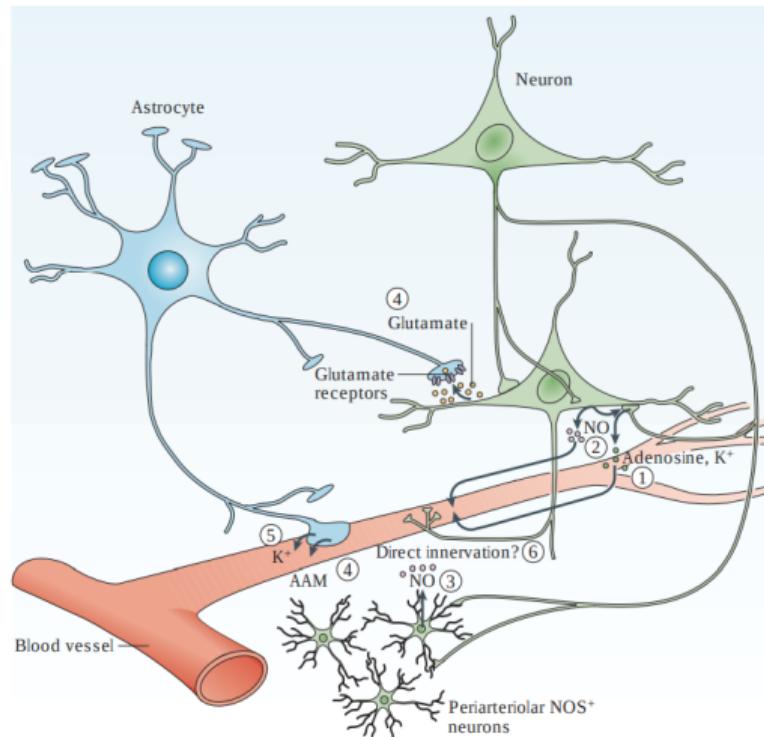
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D'Esposito et al. (2003). Nature Reviews Neuroscience, 4

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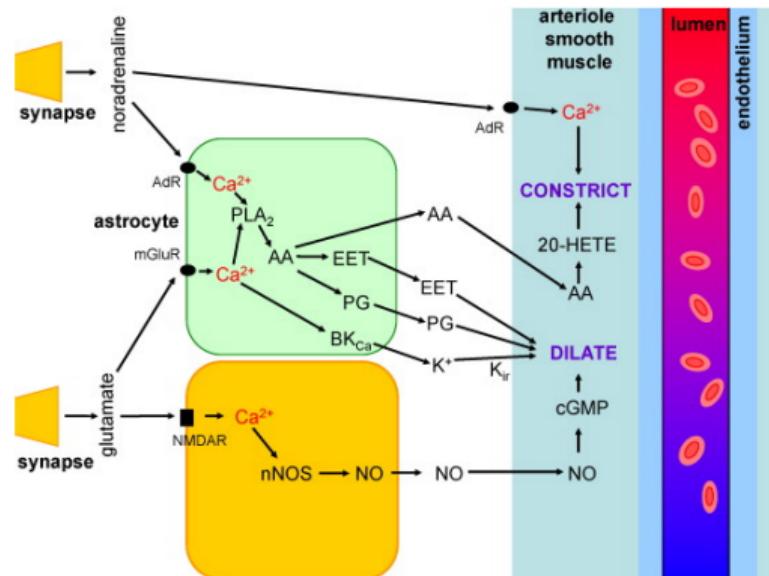
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Harris et al. (2011). Developmental Cognitive Neuroscience, 1, 3

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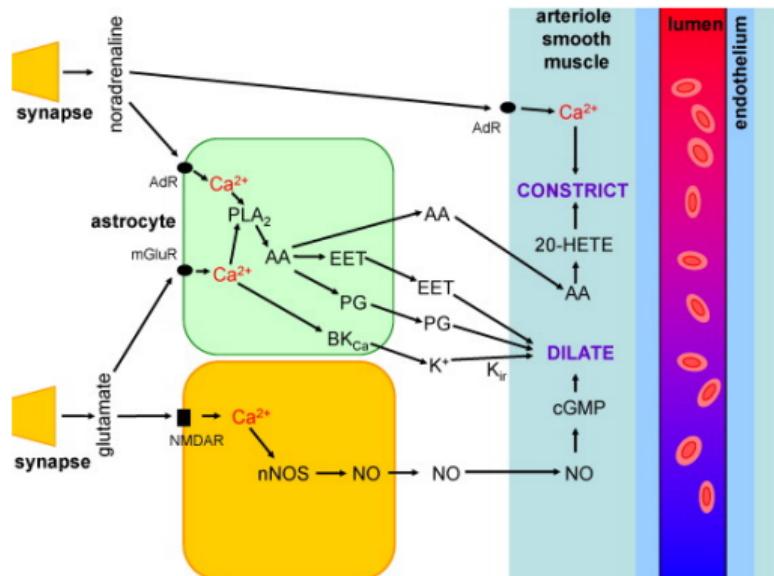
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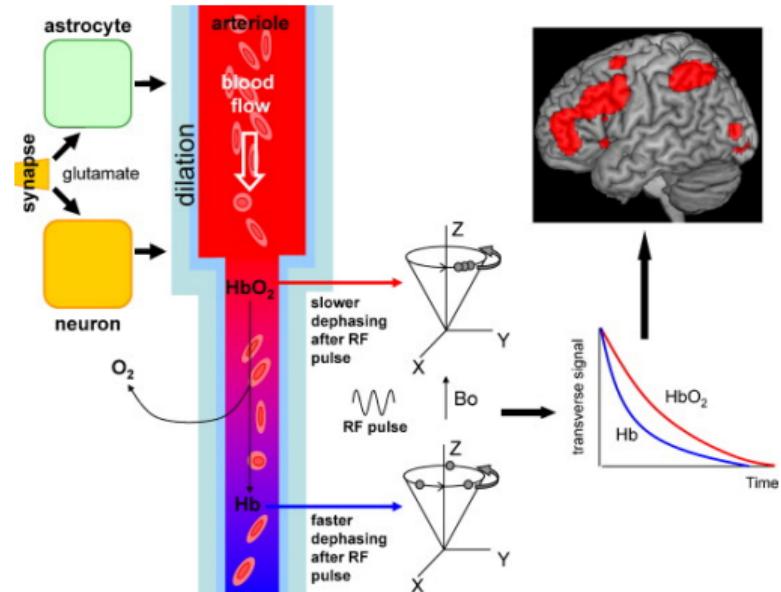
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Harris et al. (2011). Developmental Cognitive Neuroscience, 1, 3



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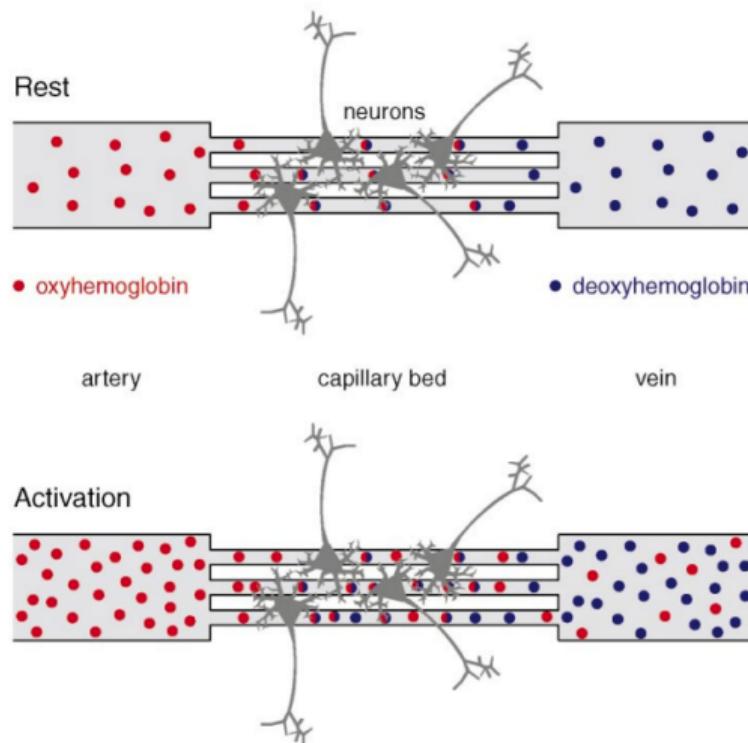
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- Under normal conditions, **oxygenated hemoglobin** is converted to **deoxygenated hemoglobin** within the capillary bed at a constant rate

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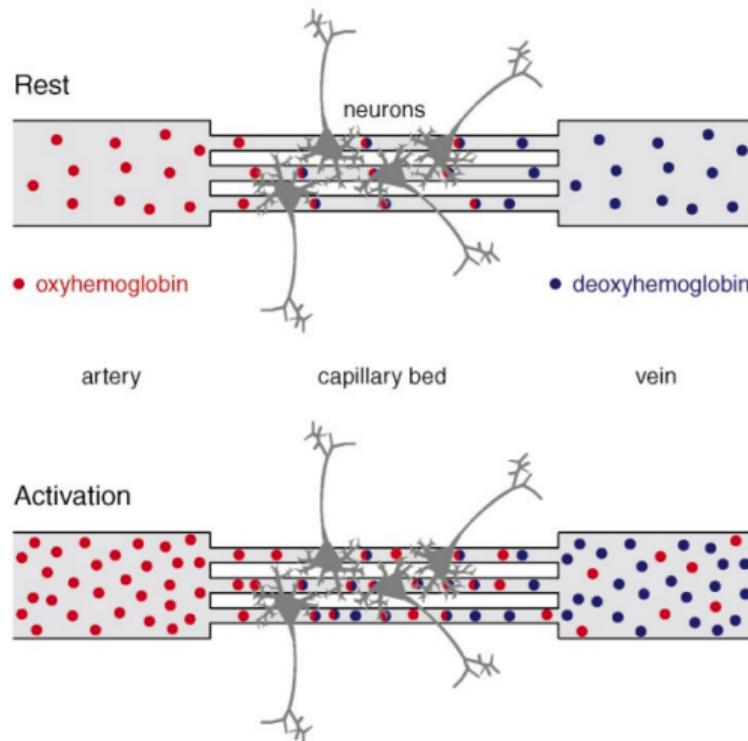
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Dogil et al. (2002). Journal of Neurolinguistics, 15(1), 59-90

- Under normal conditions, **oxygenated hemoglobin** is converted to **deoxygenated hemoglobin** within the capillary bed at a constant rate
- When neurons become **active**, the vascular system supplies more **oxygenated hemoglobin** than is needed via an overcompensatory increase in blood flow.

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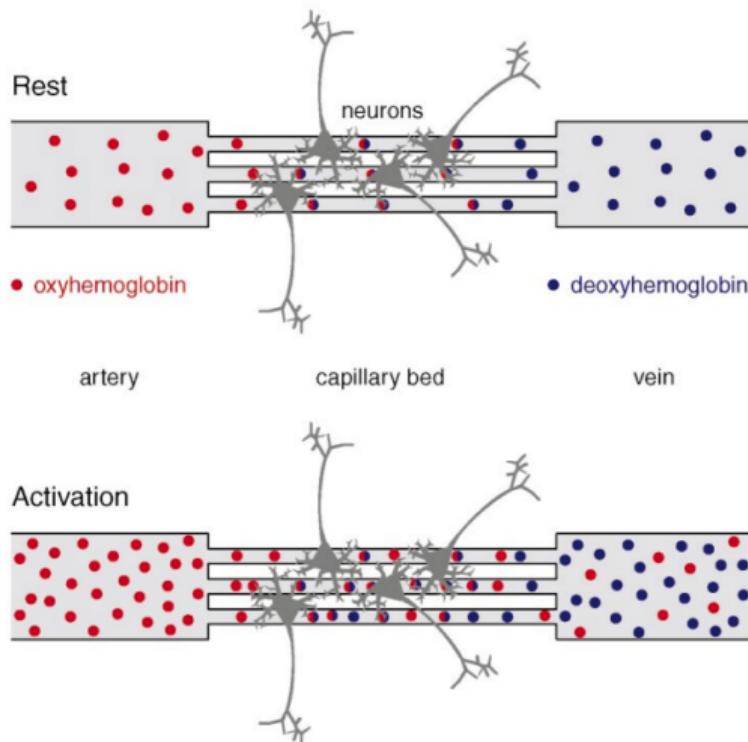
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Dogil et al. (2002). Journal of Neurolinguistics, 15(1), 59-90

- Under normal conditions, **oxygenated hemoglobin** is converted to **deoxygenated hemoglobin** within the capillary bed at a constant rate
- When neurons become **active**, the vascular system supplies more **oxygenated hemoglobin** than is needed via an overcompensatory increase in blood flow.
- The result is a net **decrease in deoxygenated hemoglobin** and a corresponding **decrease in signal loss** due to  $T_2^*$  effects

# Hemodynamic Response Function

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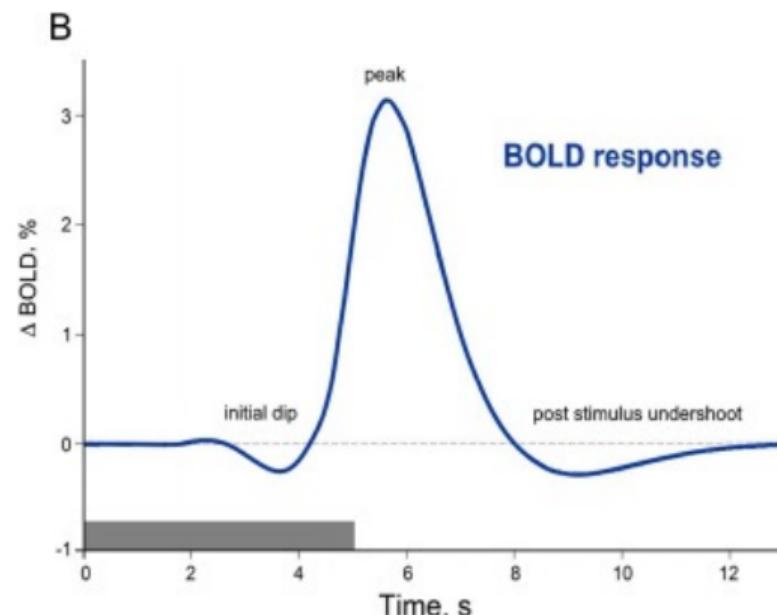
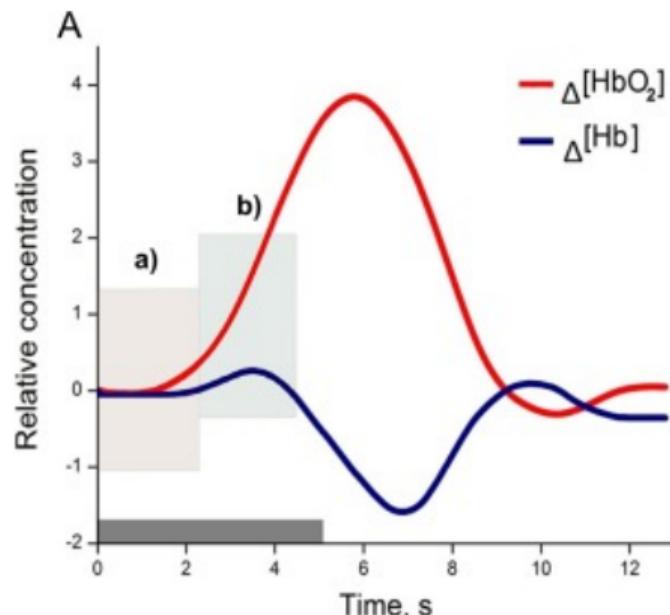
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Sigita Cincicute (2019) PeerJ, Mar 25;7e6621

[Note: Please see work by Todd Woodward and others about how this shape should **NOT** be assumed]

# fMRI Acquisition

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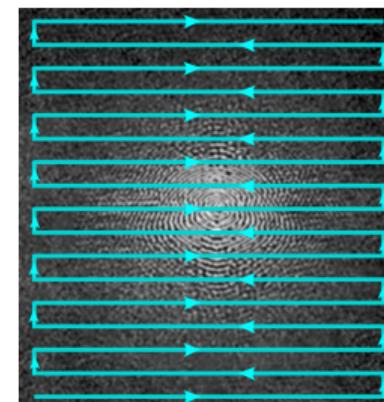
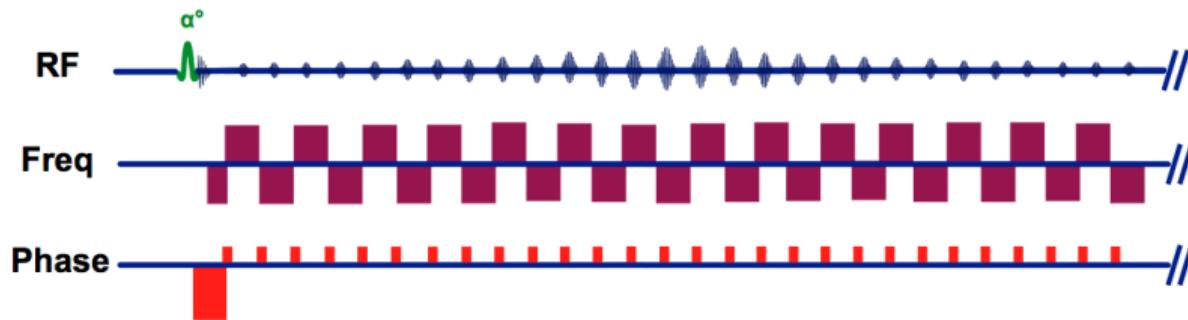
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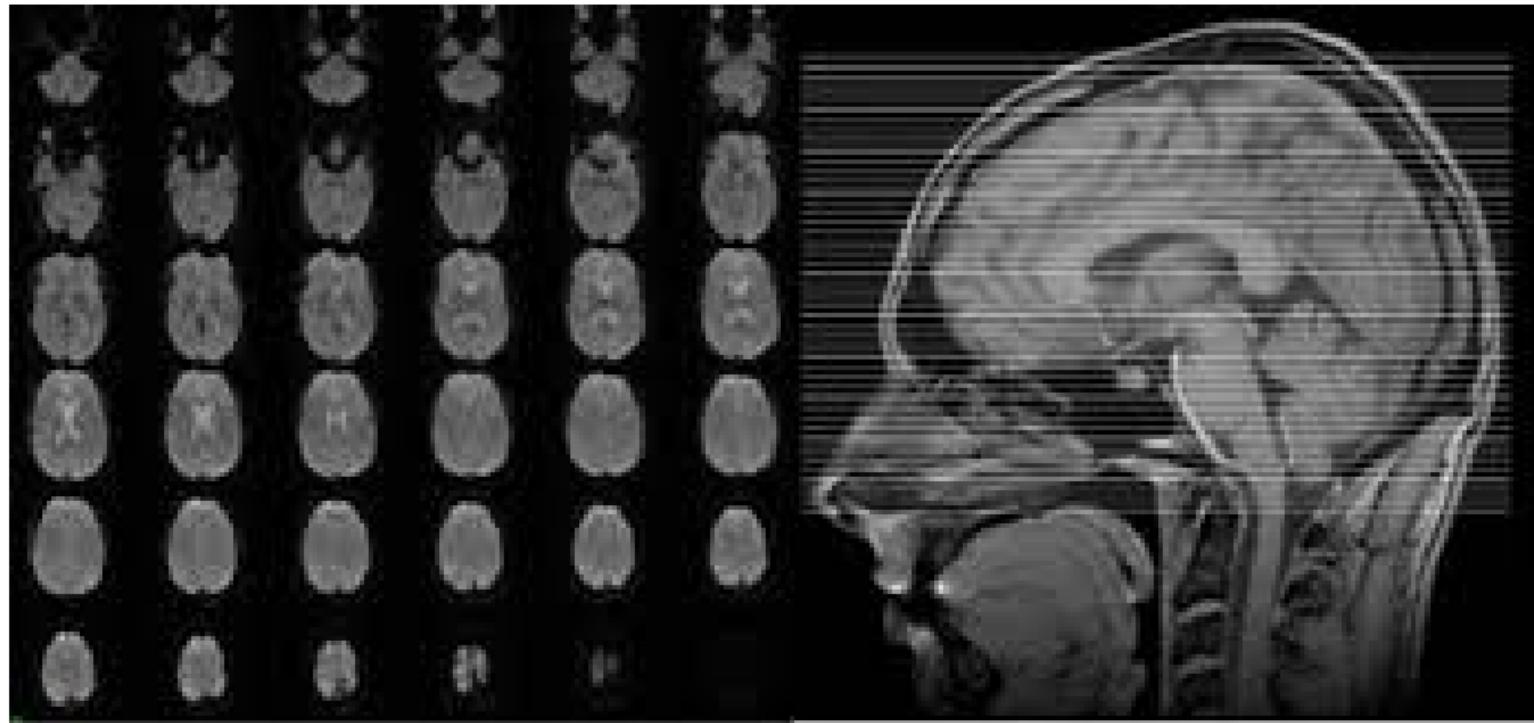
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# fMRI Acquisition

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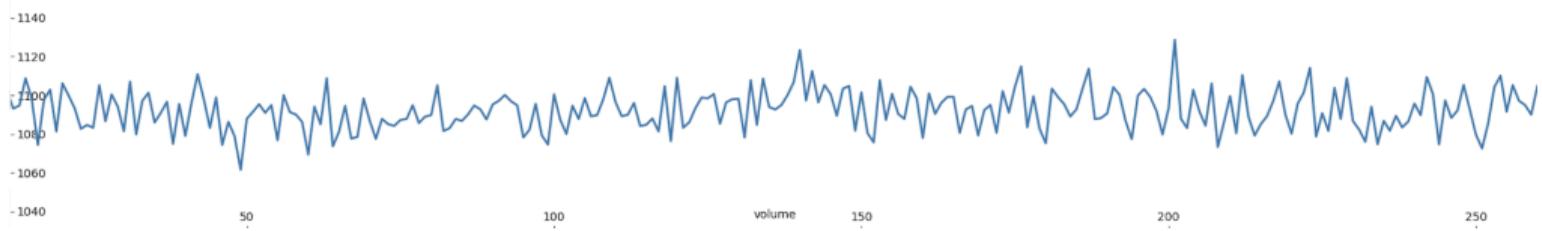
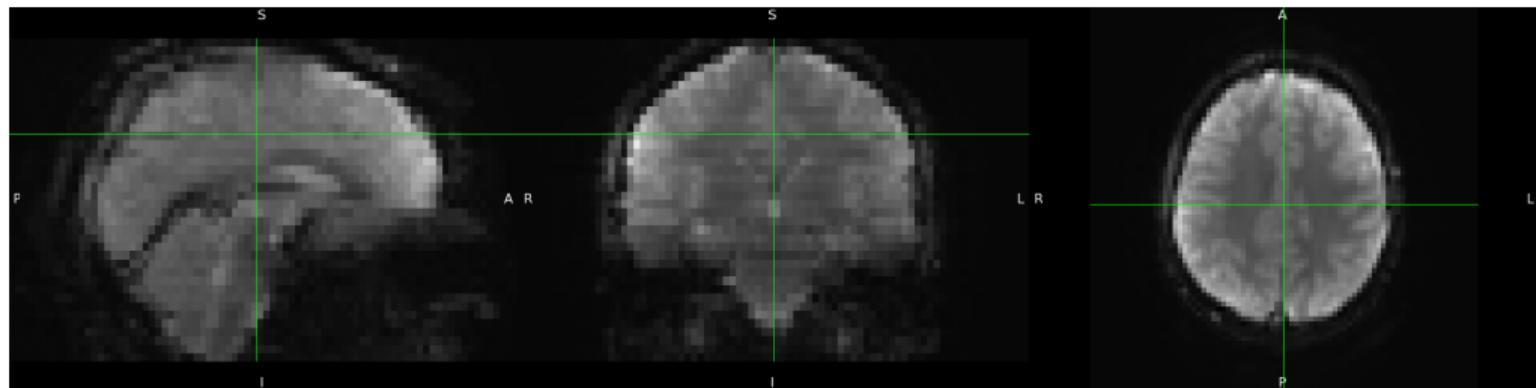
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# fMRI Acquisition: Task-based

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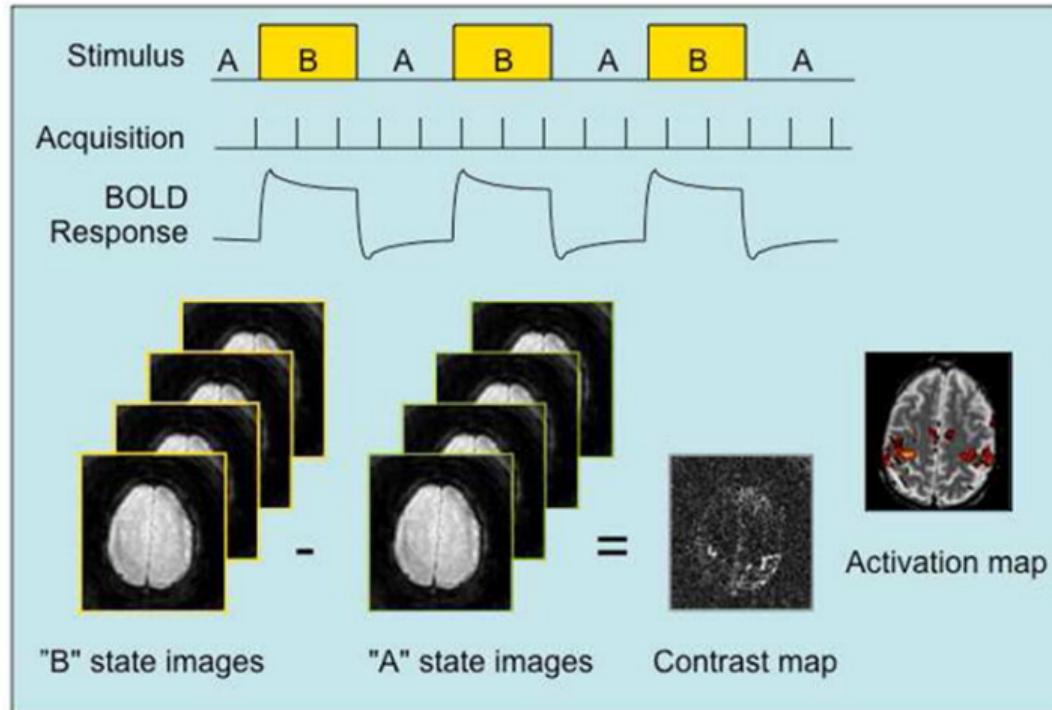
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Gary Glover. (2011). Neurosurg Clin N Am, 22(2): 133-139

# fMRI Acquisition: Task-based

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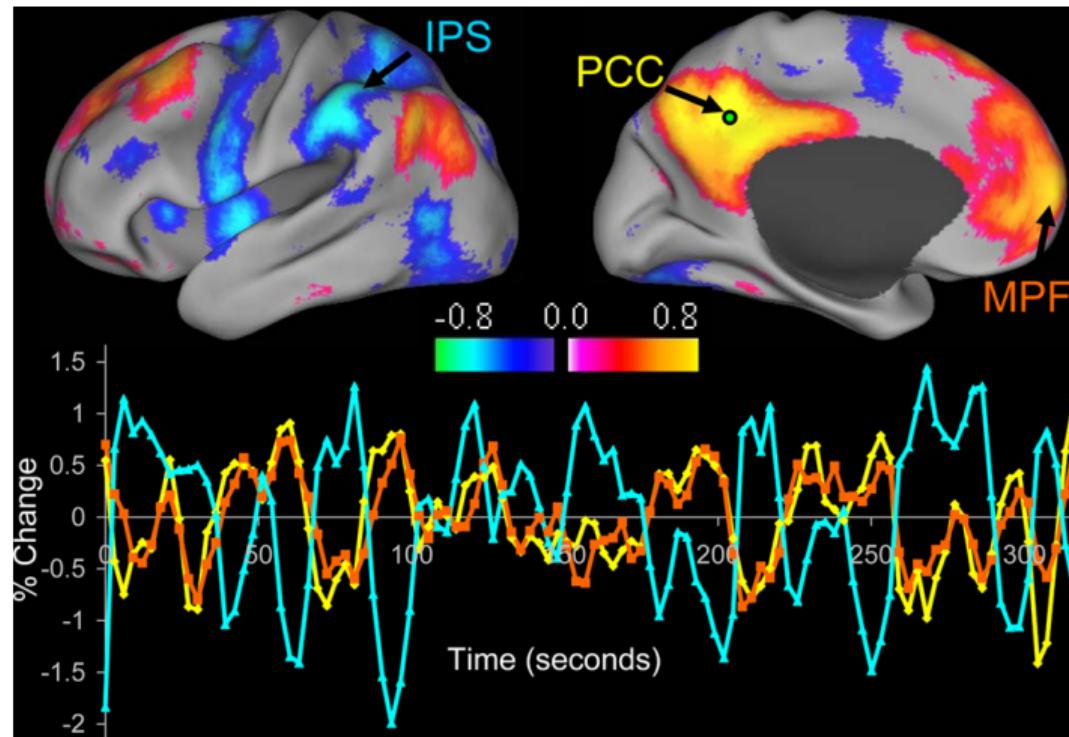
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Fox and Greicius. (2010). Front Syst Neurosci, 4(19)

# fMRI Analysis: Preprocessing

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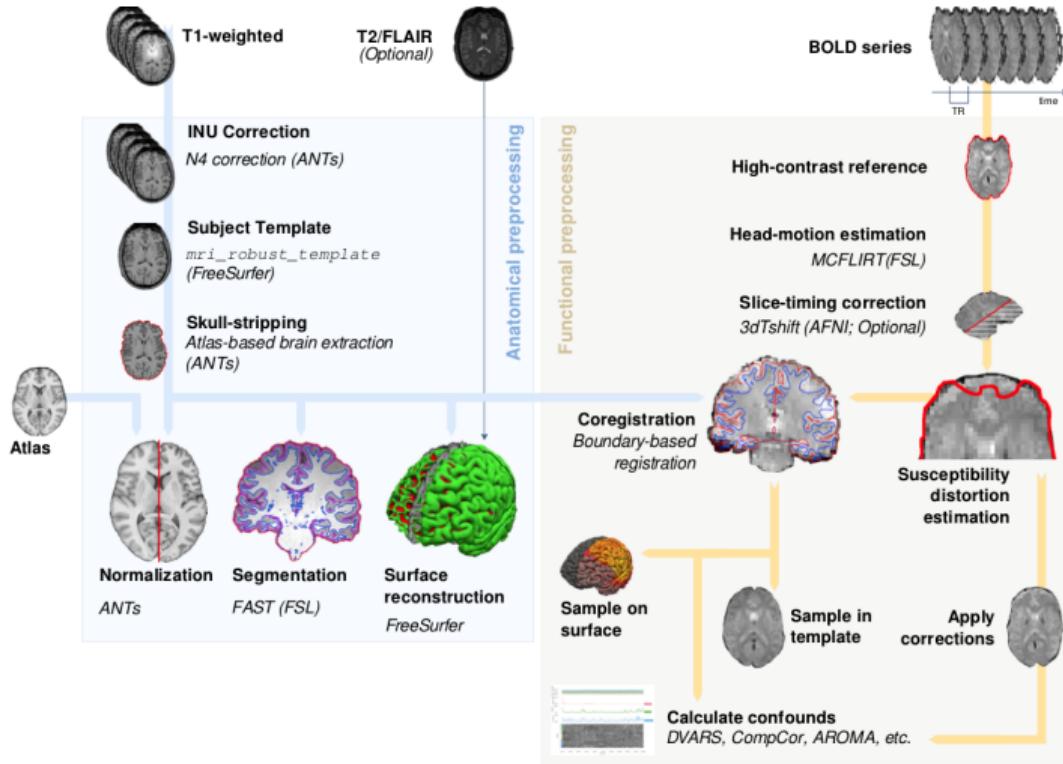
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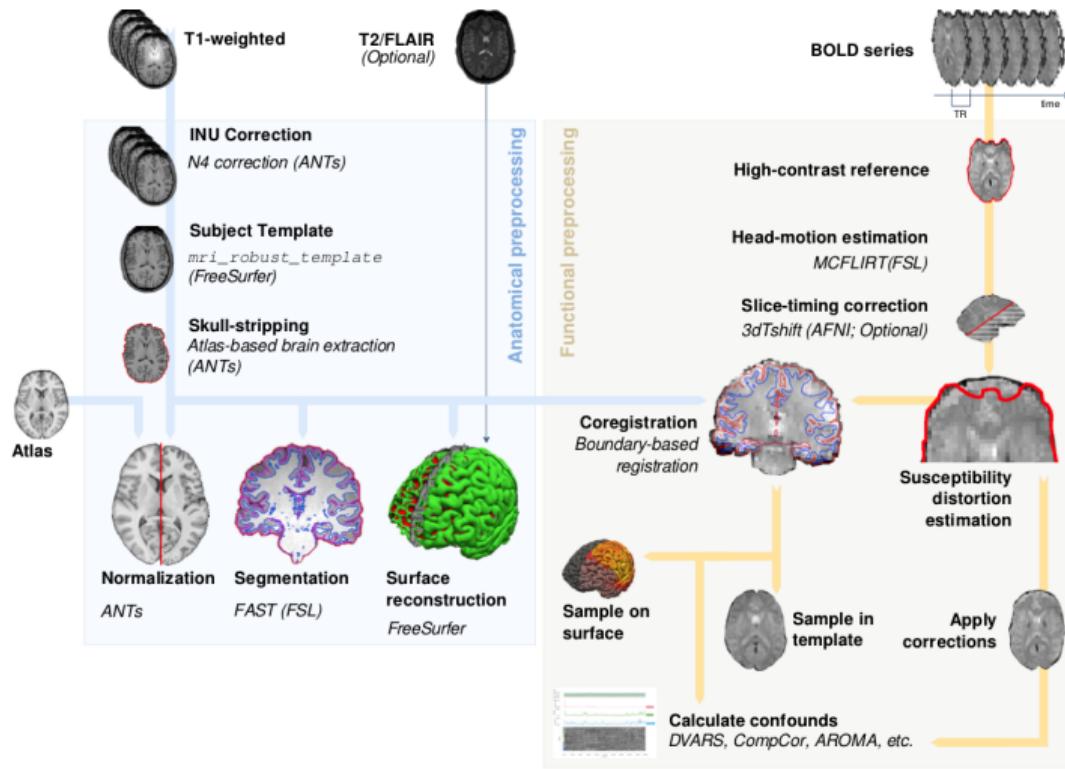
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# fMRI Analysis: Preprocessing



- Brain extraction
- Motion correction
- Slice-timing correction
- Susceptibility distortion correction
- Registration and Normalization
- Estimate noise/confounds
- Data quality check

# fMRI Analysis: Preprocessing

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<https://openneuro.org/>

The screenshot shows the homepage of the OpenNEURO platform. At the top, there is a navigation bar with links for "SEARCH", "SUPPORT", and "FAQ". On the right side of the header is a "Sign in" button. The main content area features a teal background with several large, colorful 3D cubes arranged in a cluster. Each cube represents a different neuroimaging modality: MRI (purple), PET (blue), MEG (orange), EEG (red), and iEEG (green). To the left of the cubes, there is a summary of the platform's resources: "27,542 Participants" and "719 Public Datasets". Below this summary are two search/filtering options: a dropdown menu labeled "Browse by Modalities" and a search bar with a magnifying glass icon. At the bottom of the page, there are social media and account integration links for "SIGN IN" (with Google and ORCID icons), and a footer with standard presentation navigation icons.

# Blocks of Highlighted Text

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In this slide, some important text will be **highlighted** because it's important.  
Please, don't abuse it.

## Block

Sample text

## Alertblock

Sample text in red box

## Examples

Sample text in green box. The title of the block is “Examples”.

# Multiple Columns

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## Heading

- 1 Statement
- 2 Explanation
- 3 Example

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Integer lectus nisl, ultricies in feugiat rutrum, porttitor sit amet augue. Aliquam ut tortor mauris. Sed volutpat ante purus, quis accumsan dolor.

# Table

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<b>Treatments</b>	<b>Response 1</b>	<b>Response 2</b>
Treatment 1	0.0003262	0.562
Treatment 2	0.0015681	0.910
Treatment 3	0.0009271	0.296

Table: Table caption

# Theorem

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## Theorem (Mass–energy equivalence)

$$E = mc^2$$

# Figure

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Uncomment the code on this slide to include your own image from the same directory as the template .TeX file.

# Citation

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An example of the \cite command to cite within the presentation:

This statement requires citation [Smith, 2012].

# References

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John Smith (2012)

Title of the publication

*Journal Name* 12(3), 45 – 678.

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# The End