Module 12: Basics of fMRI

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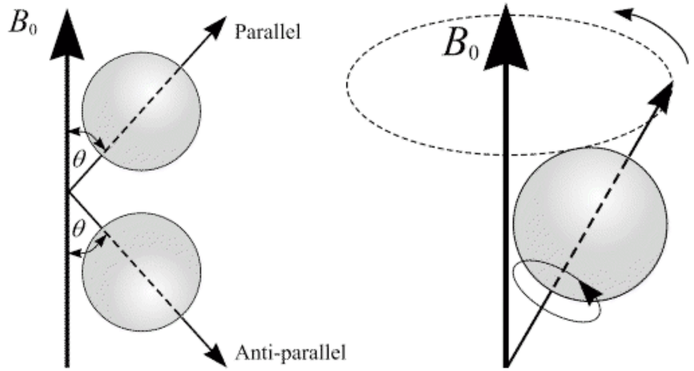
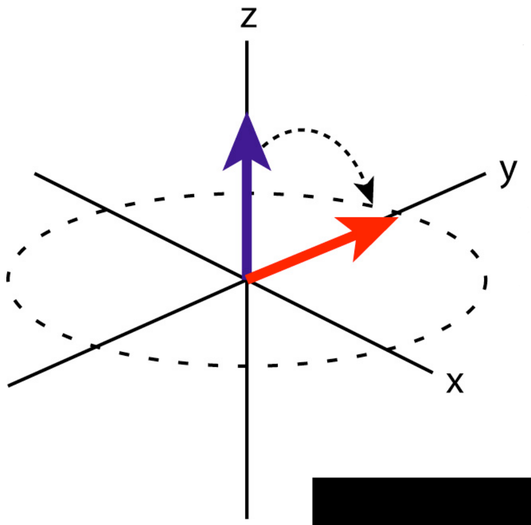
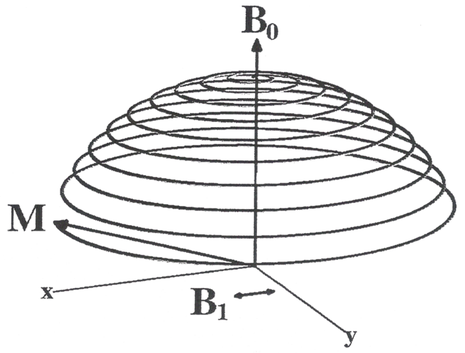
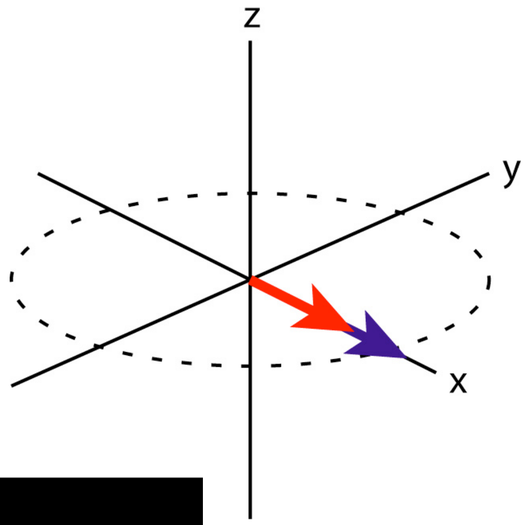
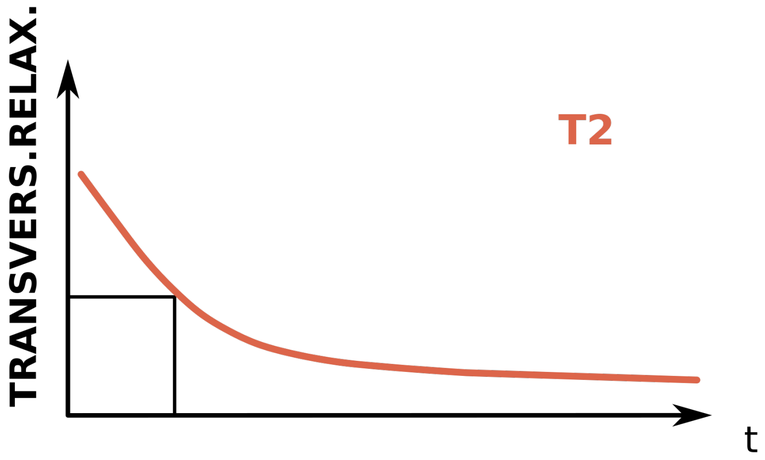
MRI Signal

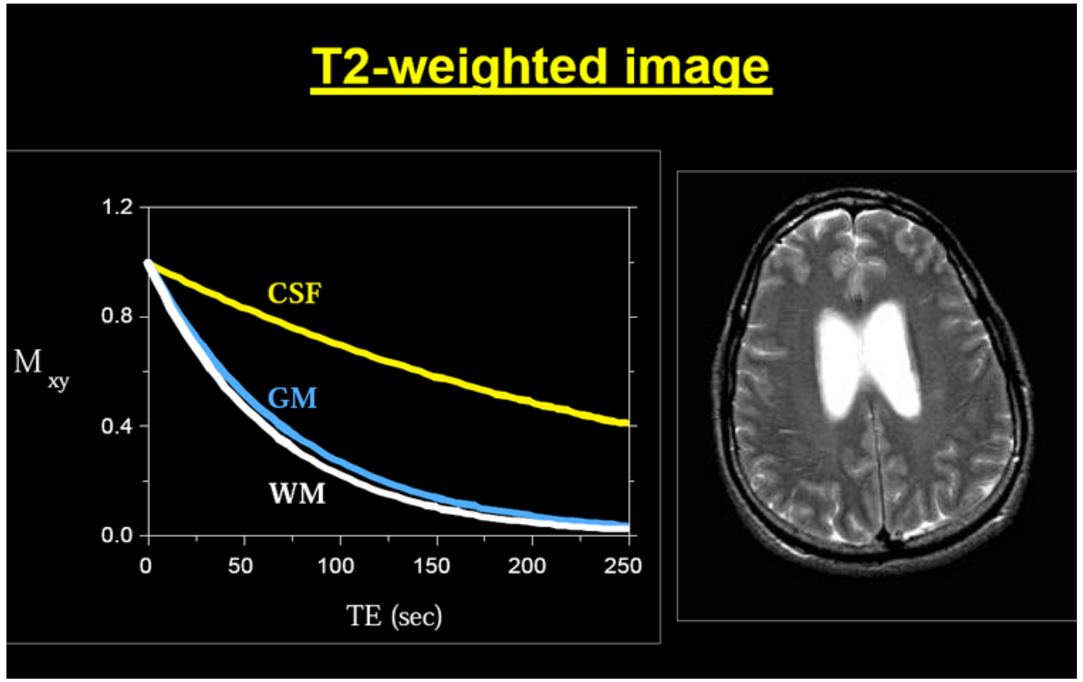

B_0
Parallel
θ
θ
Anti-parallel
B_0


z
y
x

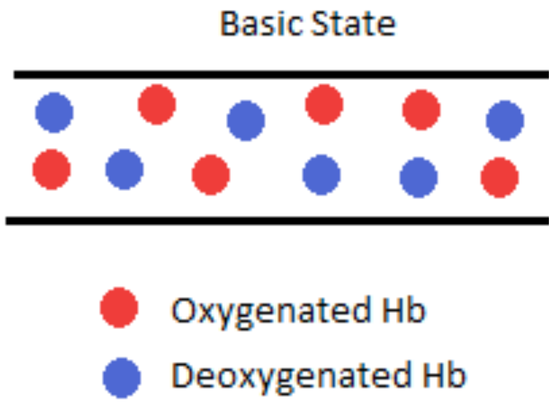

B_0
M
x
B_1
y


z
y
x


TRANSVERS.RELAX.
T2
t

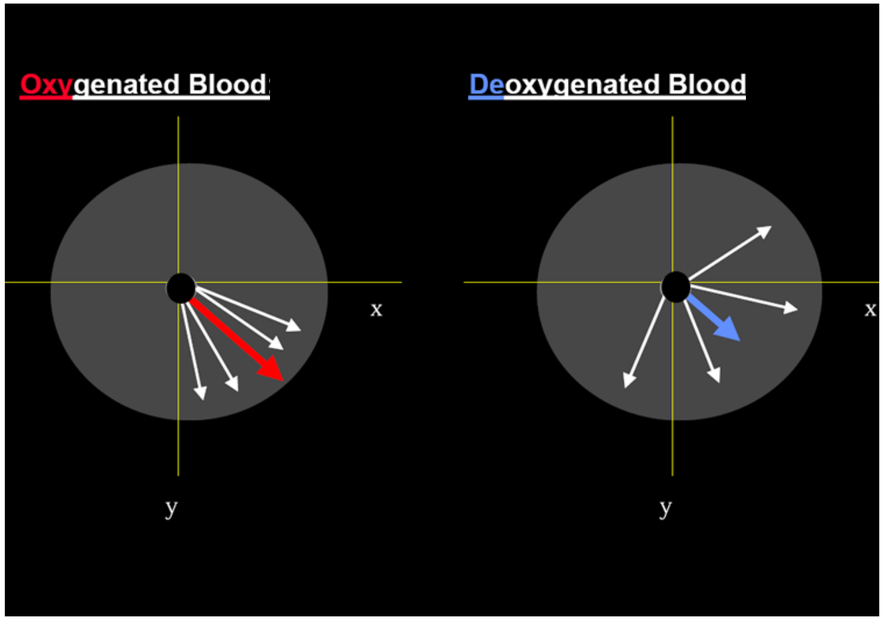

T2-weighted image
1.2
0.8
0.4
0.0
M_{xy}
CSF
GM
WM
0
50
100
150
200
250
TE (sec)

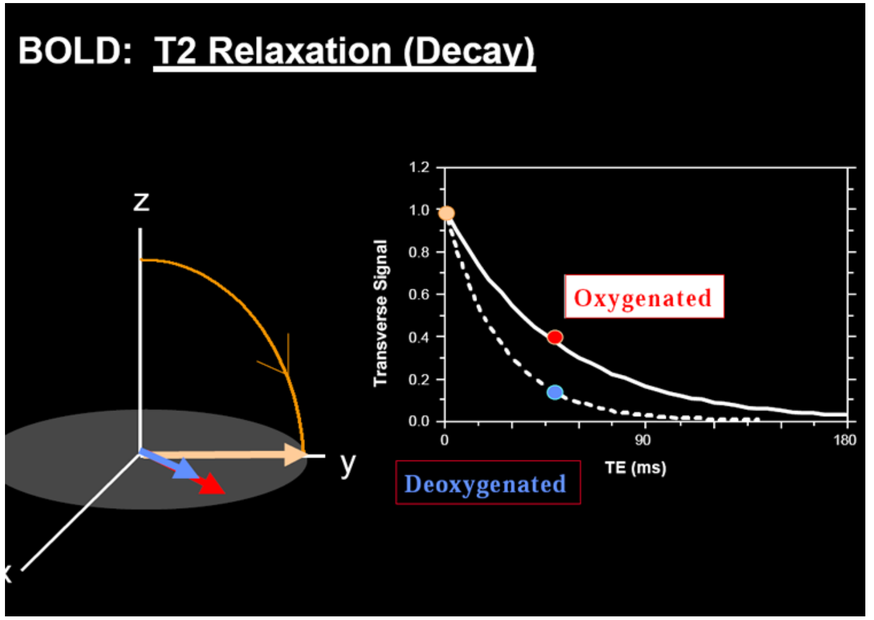
Functional MRI Signal



- During rest blood contains a combination of oxygenated and deoxygenated hemoglobin
- When neurons are active oxygen is consumed increasing the proportion of deoxygenated hemoglobin
- Local blood flow increases to supply more oxygenated hemoglobin

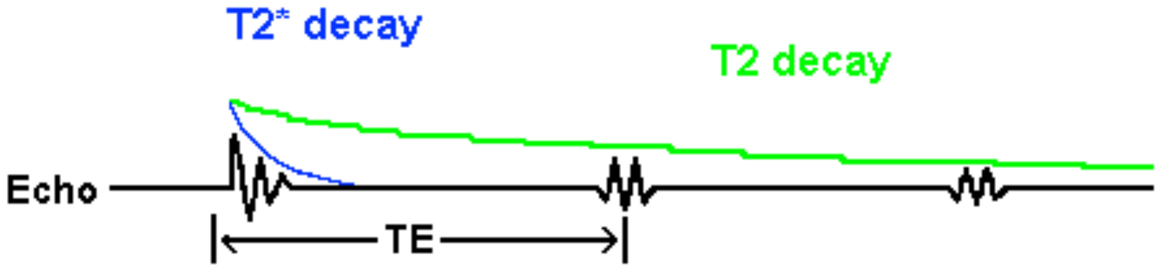
BOLD MRI Signal

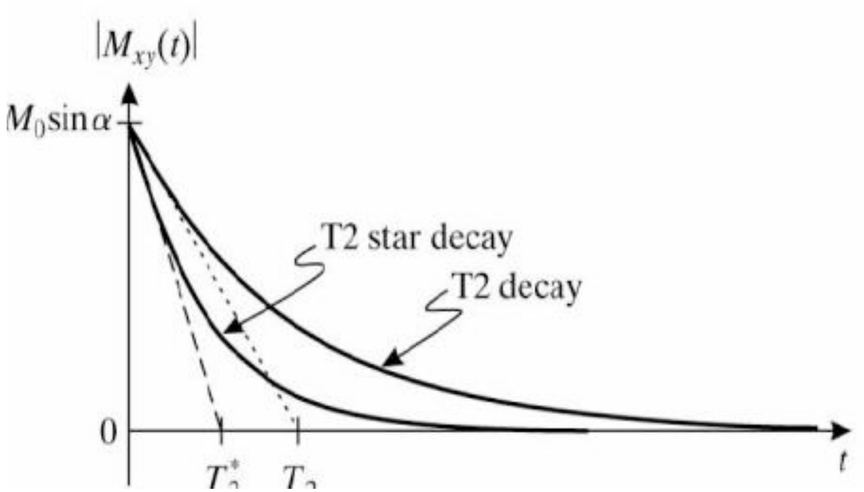




- Oxygenated hemoglobin and deoxygenated hemoglobin have different effects on dephasing with deoxygenated hemoglobin causing more dephasing
- Technique is referred to as **B**lood **O**xygen **L**evel **D**ependent (BOLD) MRI
- Measures changes in homogeneity in the magnetic field in a volume (T2*)

BOLD MRI Signal

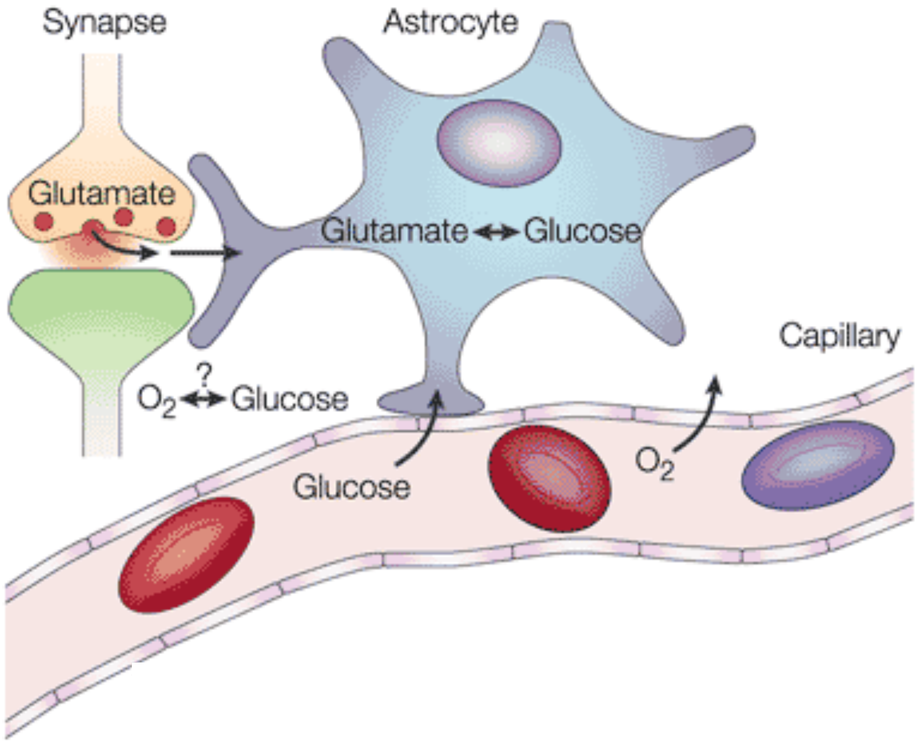


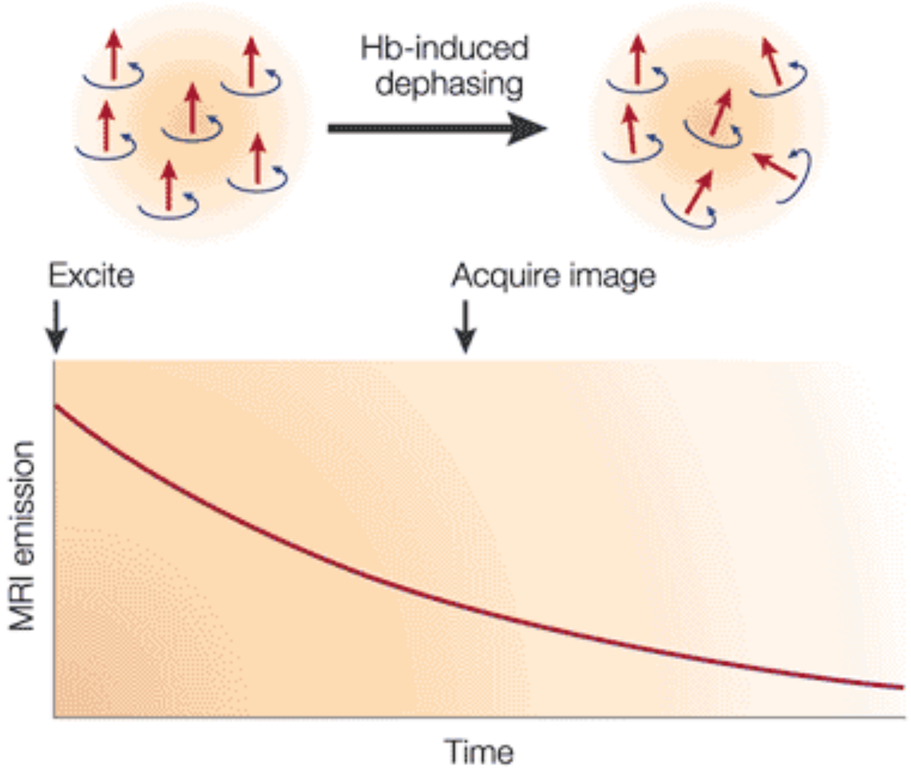


T2: Transverse magnetization decay of a spin after radio frequency pulse

T2*: Transverse magnetization decay from local magnetic field variations

BOLD MRI Signal





- Deoxygenated hemoglobin is paramagnetic and introduces inhomogeneity
- Oxygenated hemoglobin is weakly diamagnetic and has little effect

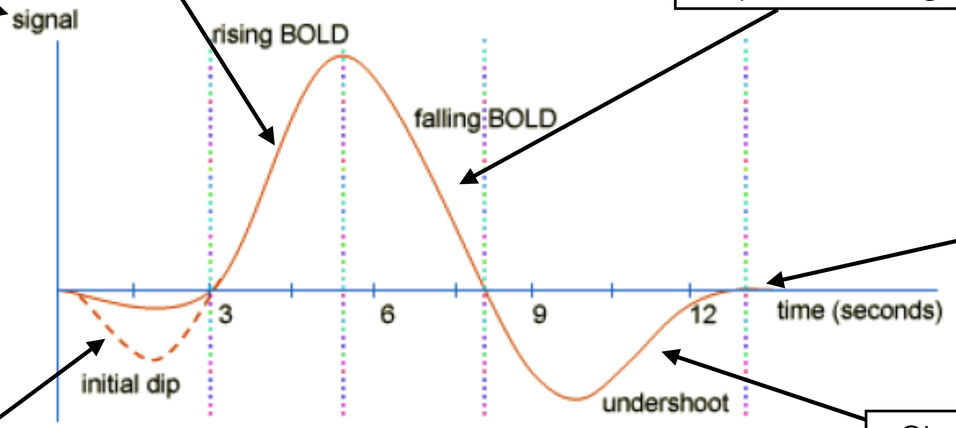
BOLD MRI Signal

Stimulus results in brain activation

Influx of oxygenated blood to support cognitive task quickly increases MRI signal

Oxygenation and MRI signal drops once cognitive task ends

Ratio of oxygenated and deoxygenated blood and MRI signal are back to baseline



Hemodynamic Response Function

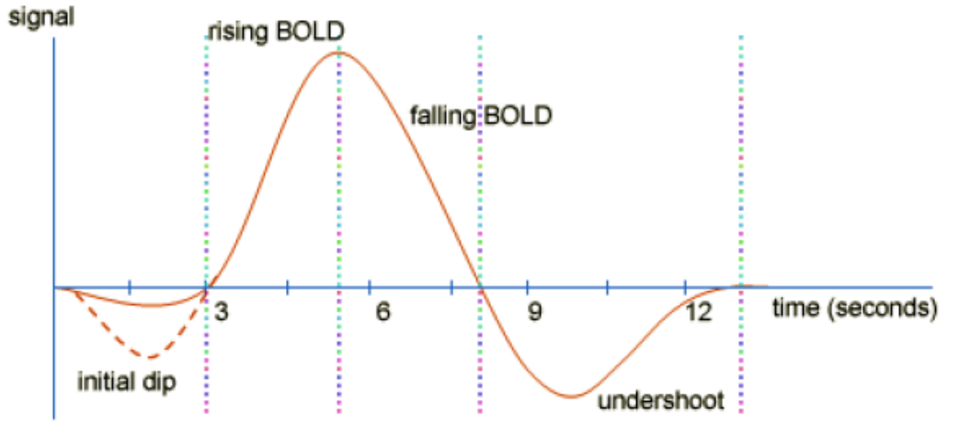
Activity uses available oxygen, increasing local deoxyhemoglobin and causing an initial dip in the MRI signal

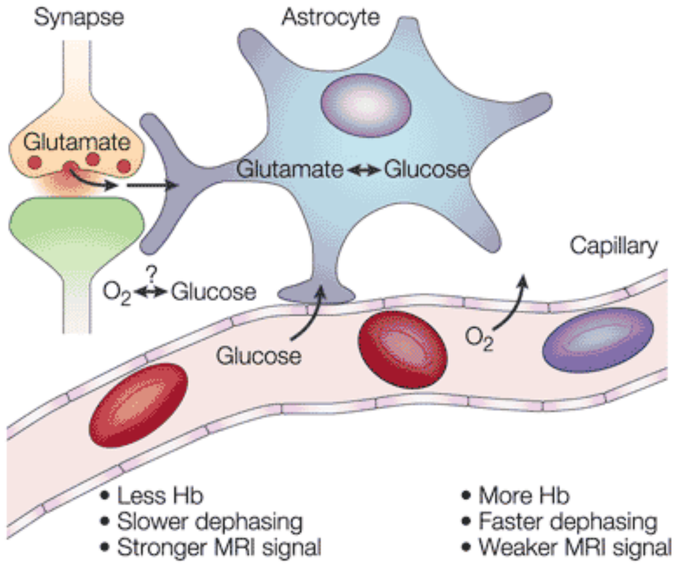
Signal drops below baseline (undershoot) for a few seconds

BOLD MRI Signal

- Important to note that BOLD fMRI does not measure neural activity directly. Rather is measures metabolic demands (oxygen consumption) of active neurons

- The Hemodynamic response function (HRF) represents changes in the fMRI signal triggered by neural activity

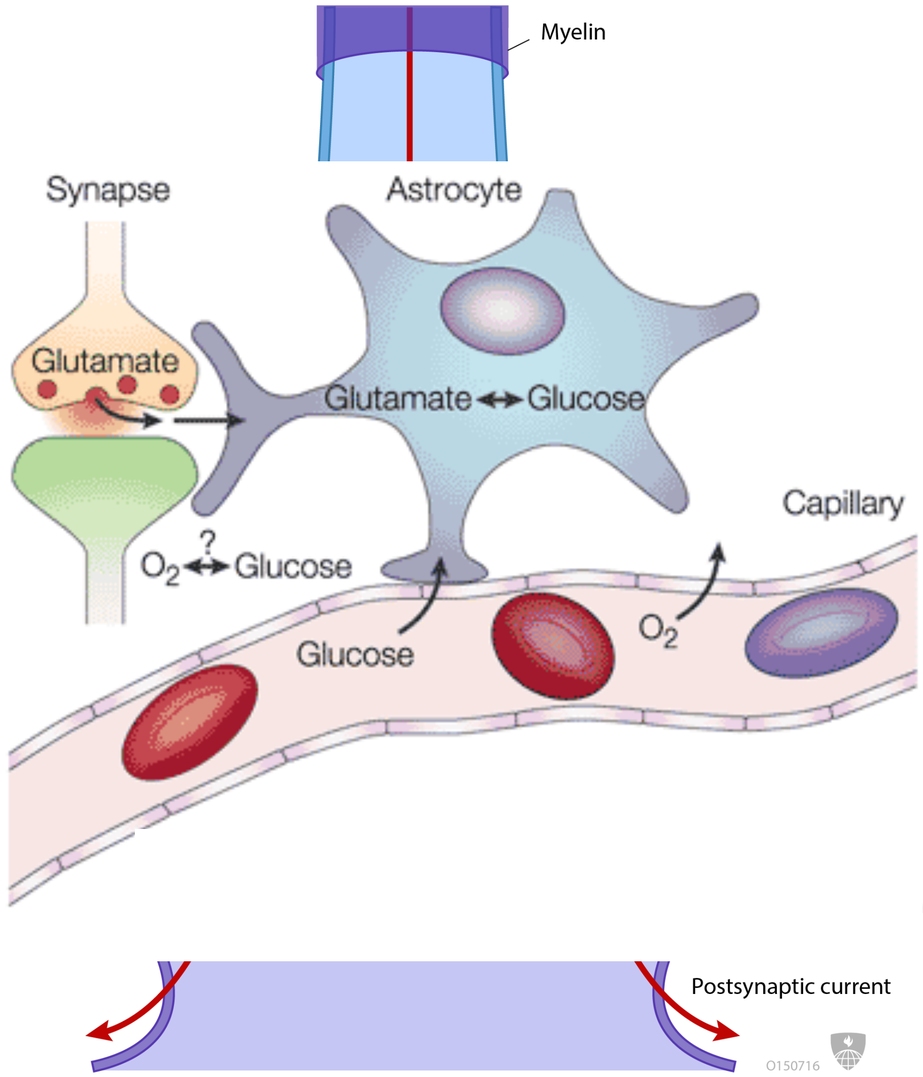




Basis of fMRI Signal

What is the physiological basis of the BOLD signal?

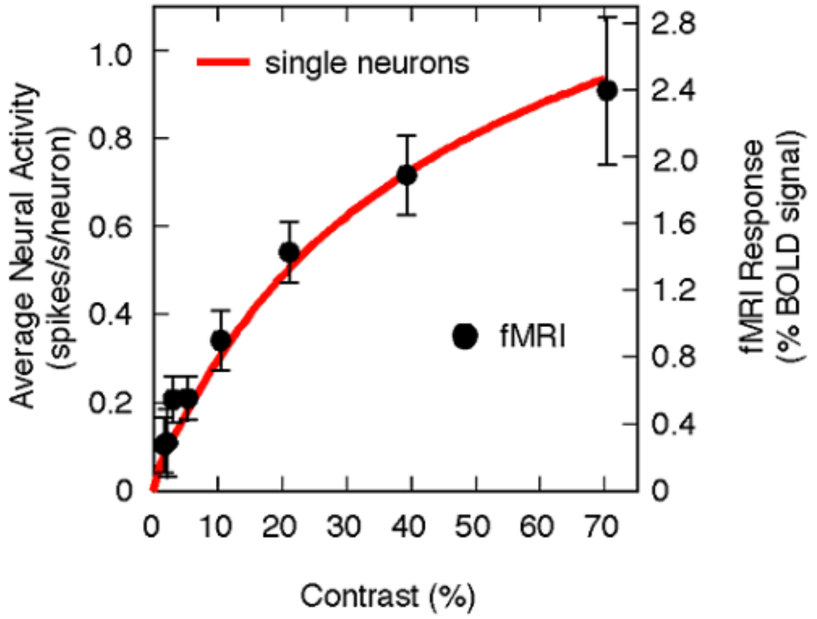
- Presynaptic action potential causes release of glutamate
- Open post-synaptic ion channels
- Re-uptake of glutamate by astrocytes triggers glucose metabolism
- Astrocytes pump out ions out of cell to restore ionic gradients
- Process uses glucose and oxygen



Basis of fMRI Signal

What is the physiological basis of the BOLD signal?

- Initially BOLD signal was thought to be correlated with action potentials



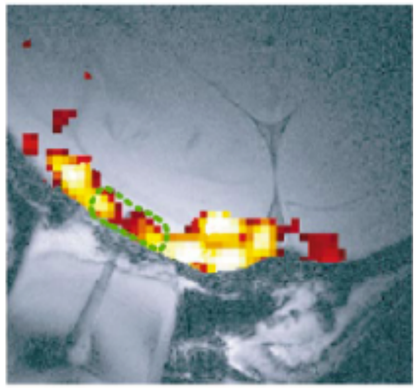
Heeger et al., 2000, *Nat. Neurosci*

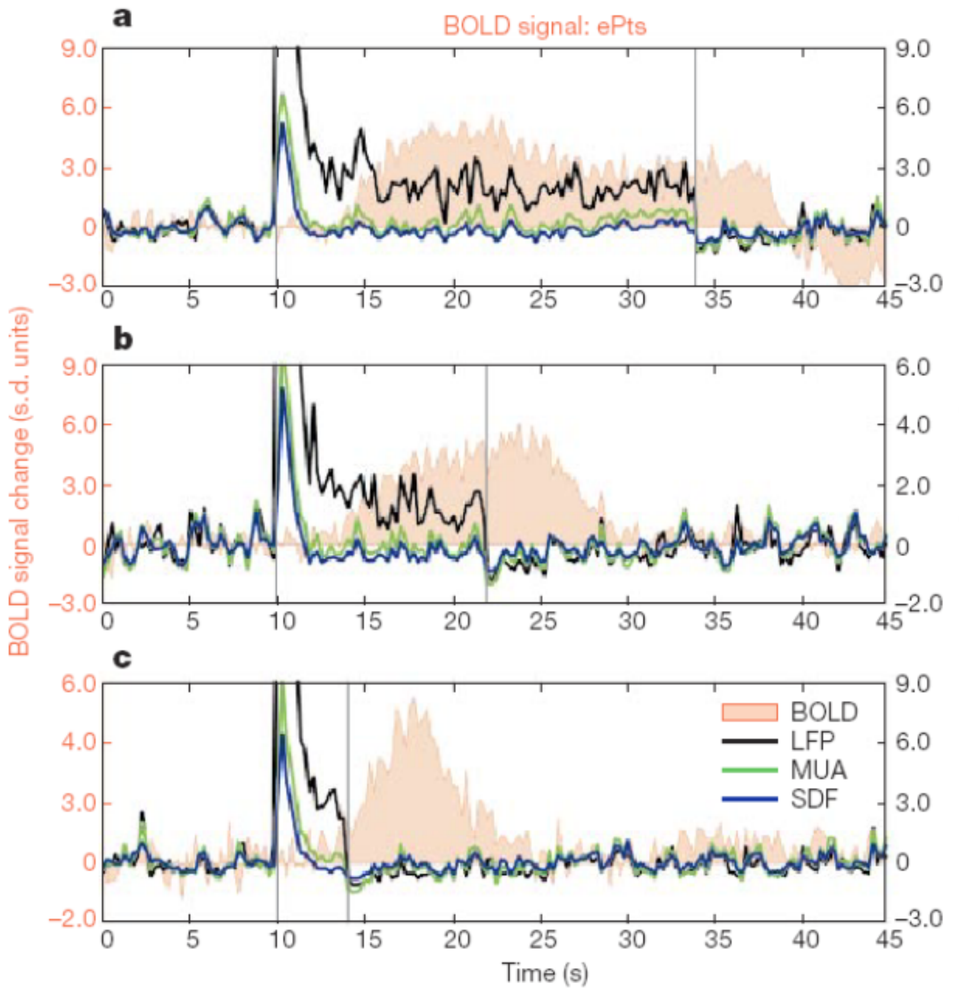
Rees et al., 2000, *Nat. Neurosci*

Basis of fMRI Signal

What is the physiological basis of the BOLD signal?

- Experiment measuring both BOLD signals and electrophysiological data:
  - Multi-unit activity (MUA) reflecting action potentials
  - Local Field Potentials reflecting summation of post-synaptic potentials (LFP)





Logothetis et al., 2001, *Nat. Neurosci*

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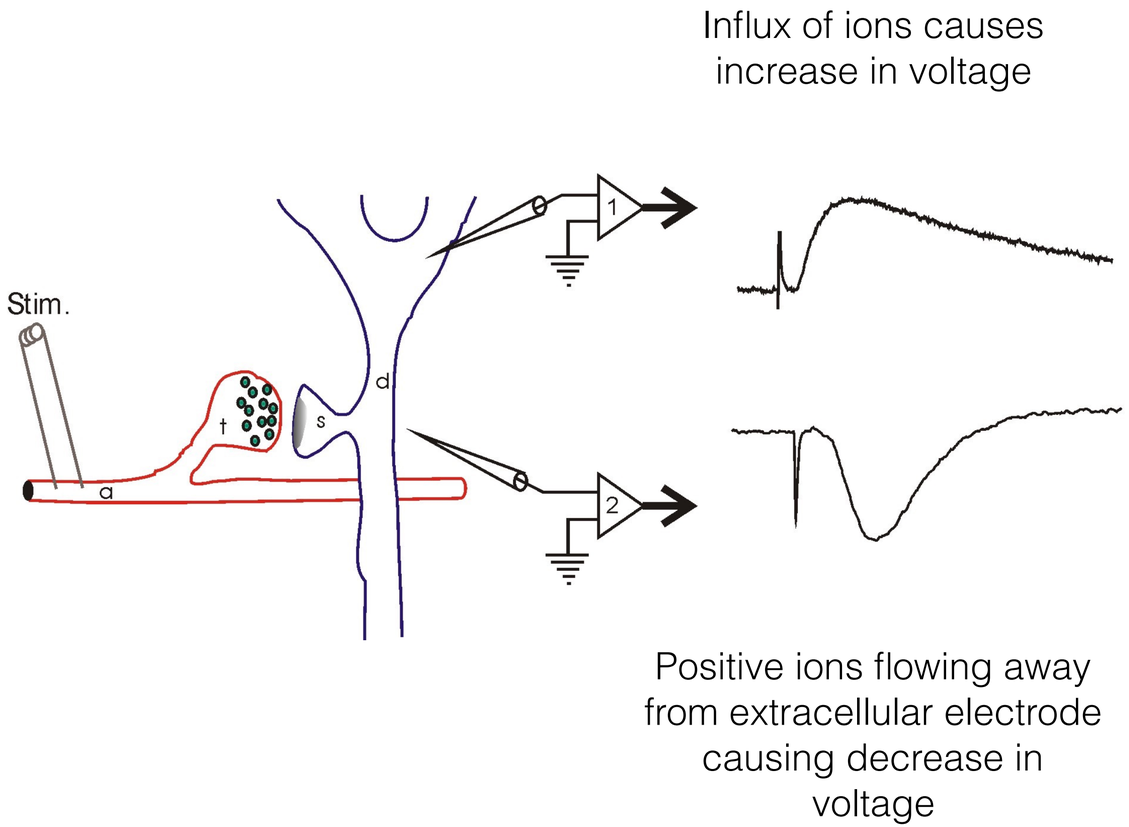

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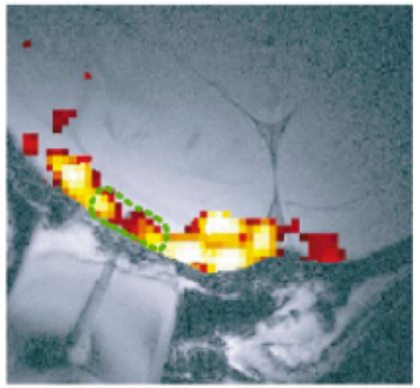
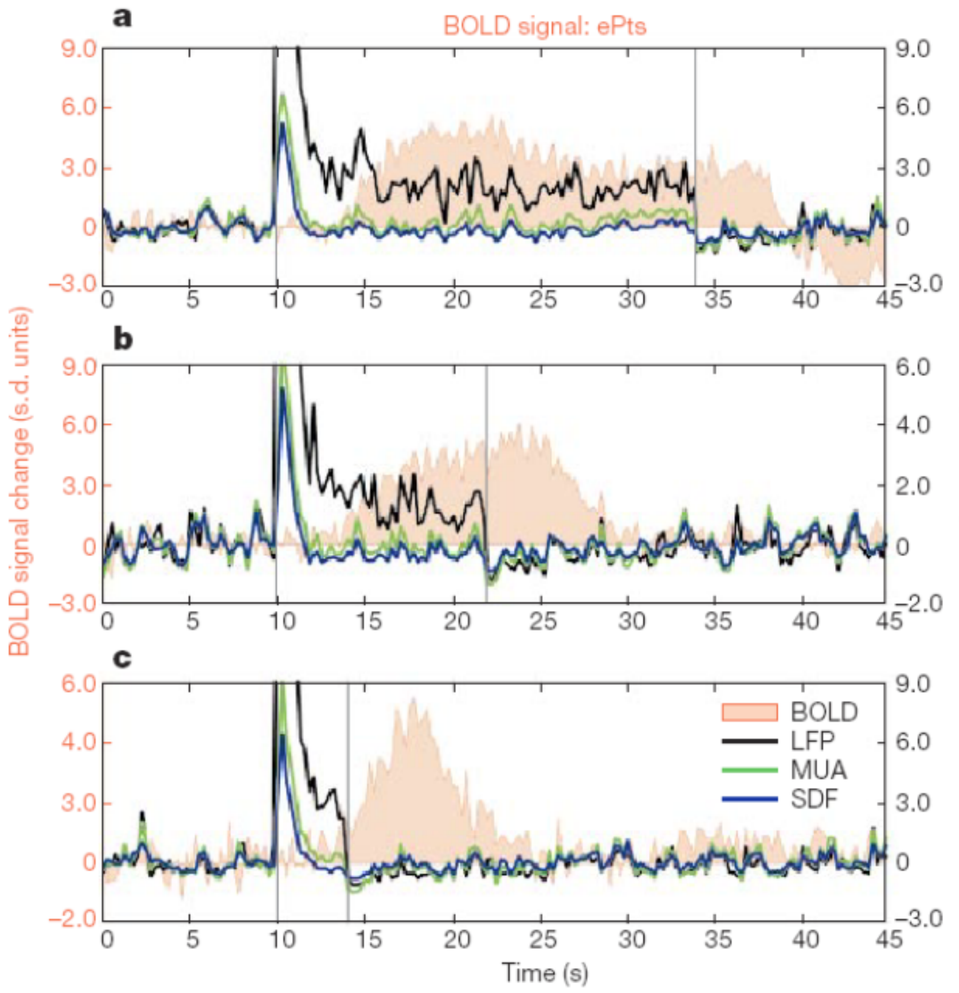




Logothetis et al., 2001, *Nat. Neurosci*

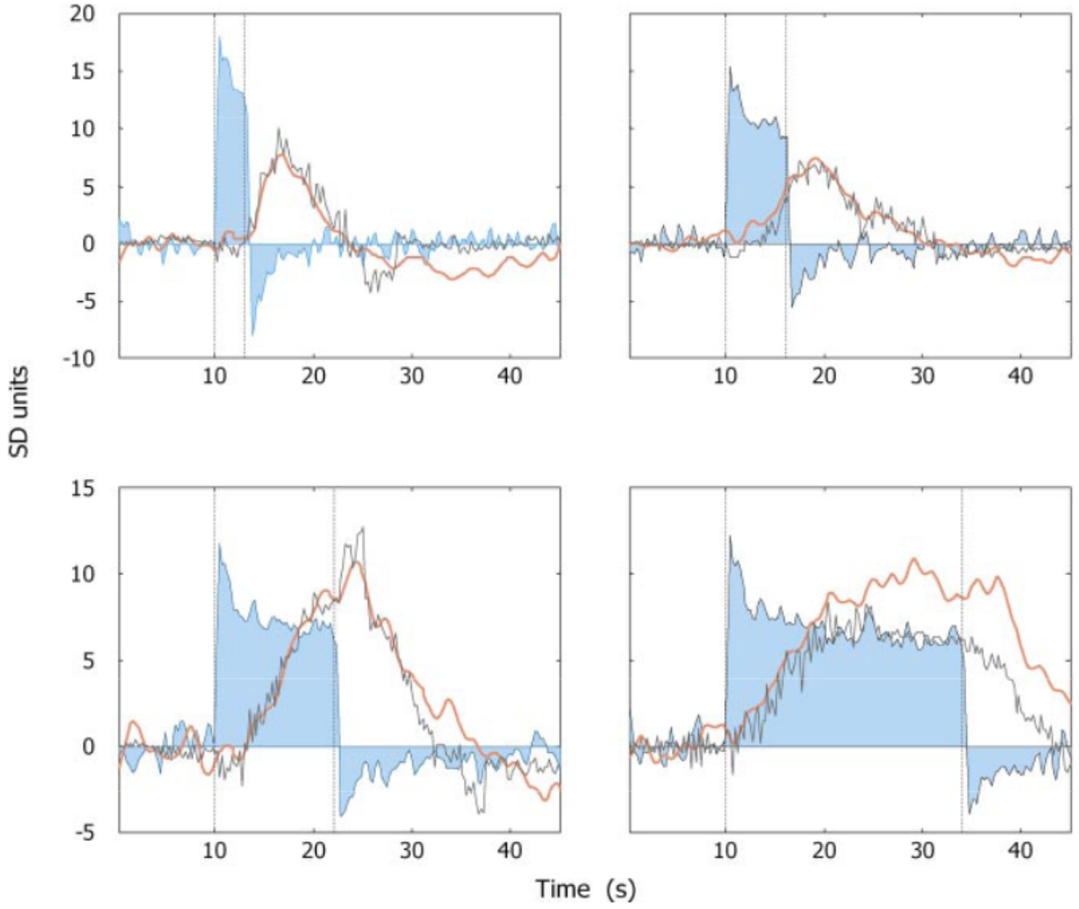
Basis of fMRI Signal

What is the physiological basis of the BOLD signal?

Blue: LFP
Red: BOLD
Grey: Predicted BOLD

BOLD activity is more correlated with Local Field Potentials than Multi-unit activity

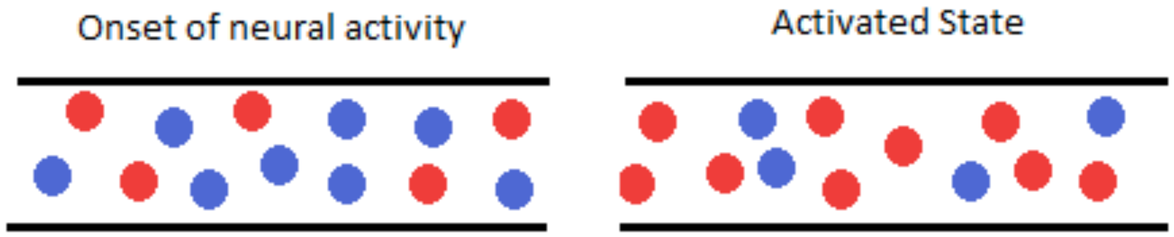
BOLD activity is thought to reflect input to a neural population and information processing within that neural population



Logothetis and Wandell, 2004, *Ann. Rev. Physiol.*

Basis of fMRI Signal

Basis of the BOLD MRI signal?



Oxygen consumption
DeoxyHb increased
BOLD signal decreased

Local blood flow increased
DeoxyHb decreased
BOLD signal increased