

NEURAL COMPUTATION

Prof. Alexander Huth

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LAST TIME

- * methods
 - * lesions
- * cortical maps

TODAY

- * Methods for measuring brain activity (aka neurophysiology) !

SOURCES OF SIGNAL

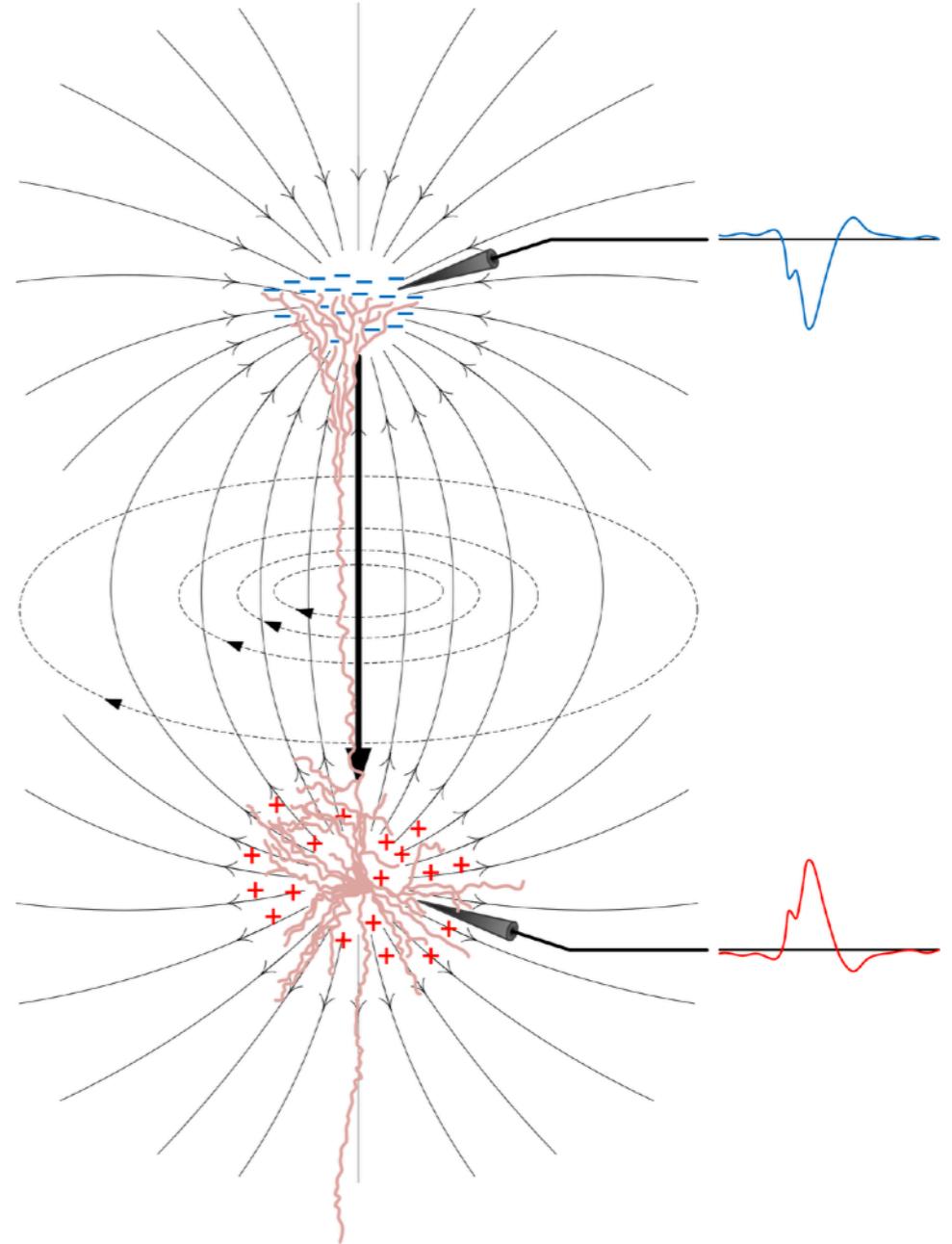
- * Electric fields
- * Calcium concentration
- * Metabolism (e.g. glucose uptake)
- * Blood oxygen level dependent (BOLD)

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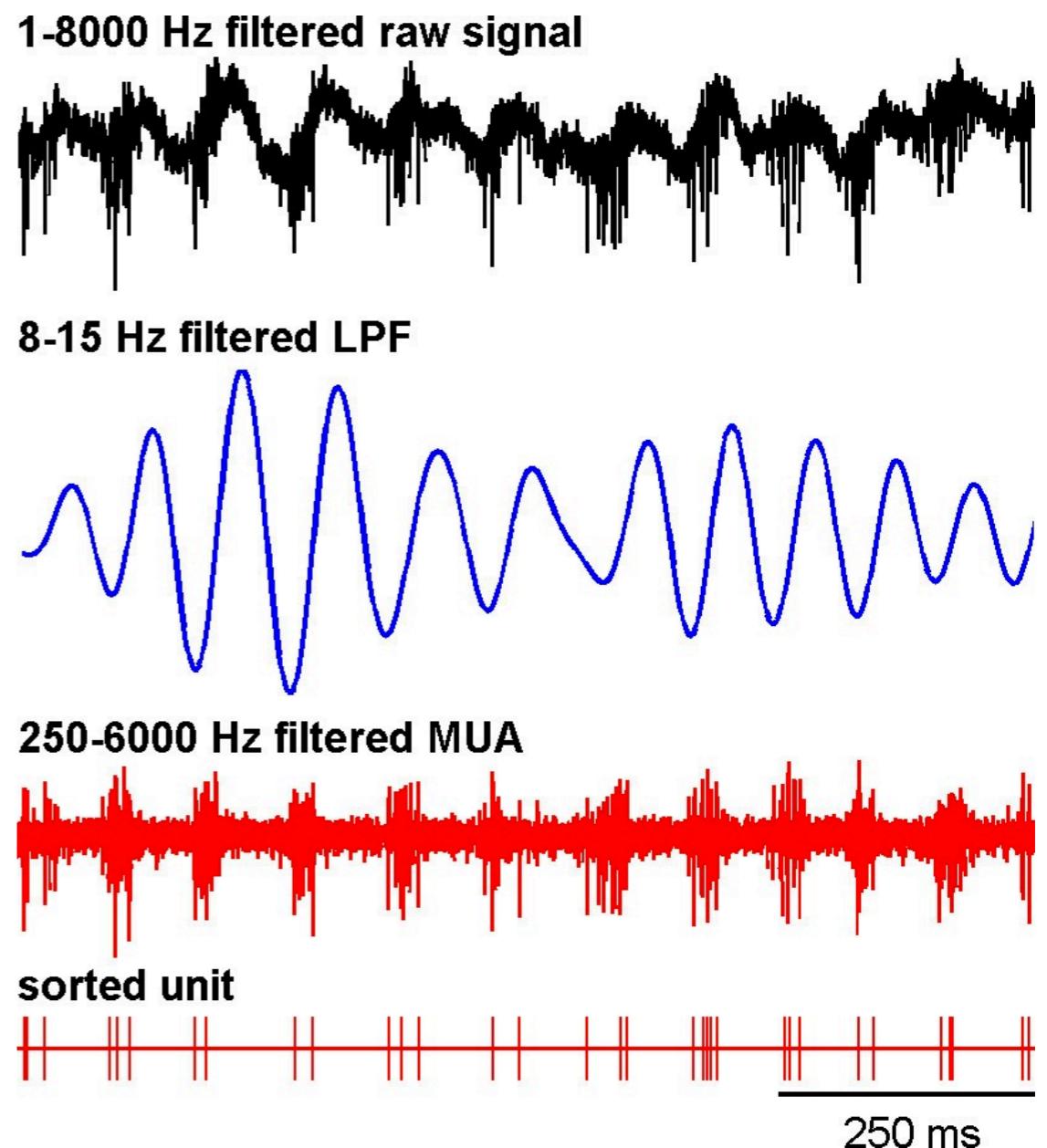
ELECTRIC FIELDS

- * Pyramidal neurons generate **electric fields** when they spike (because current is flowing)
- * These fields are detectable outside the neuron using electrodes

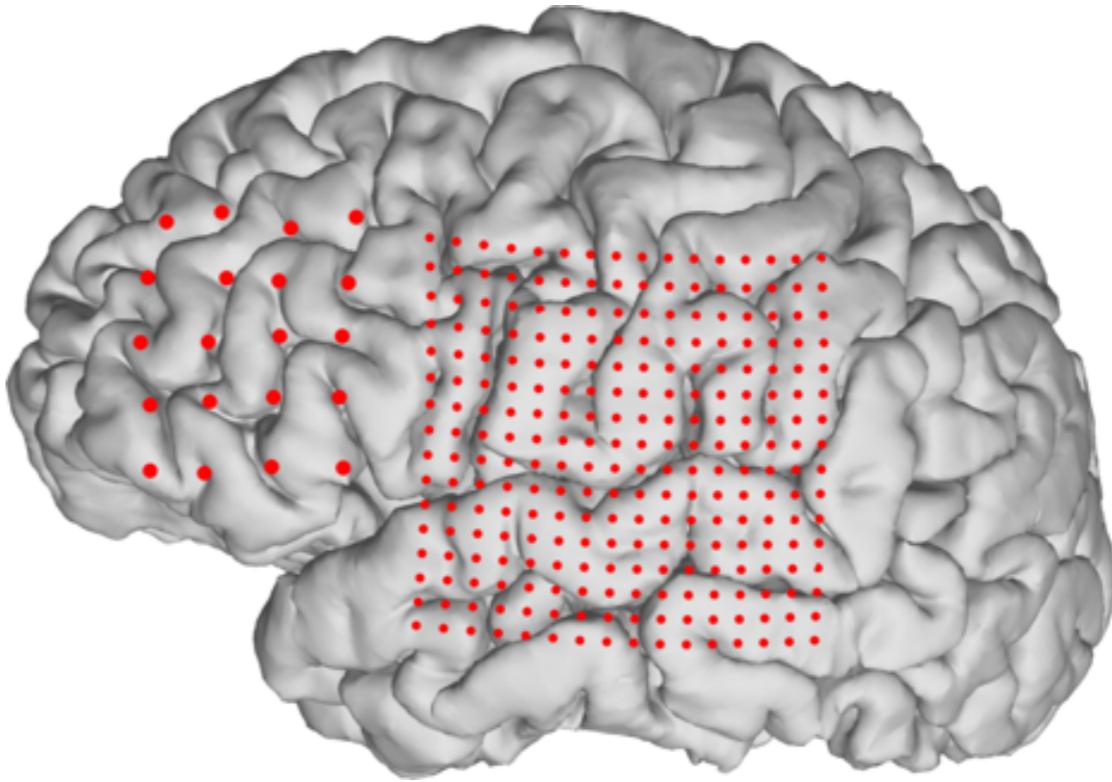
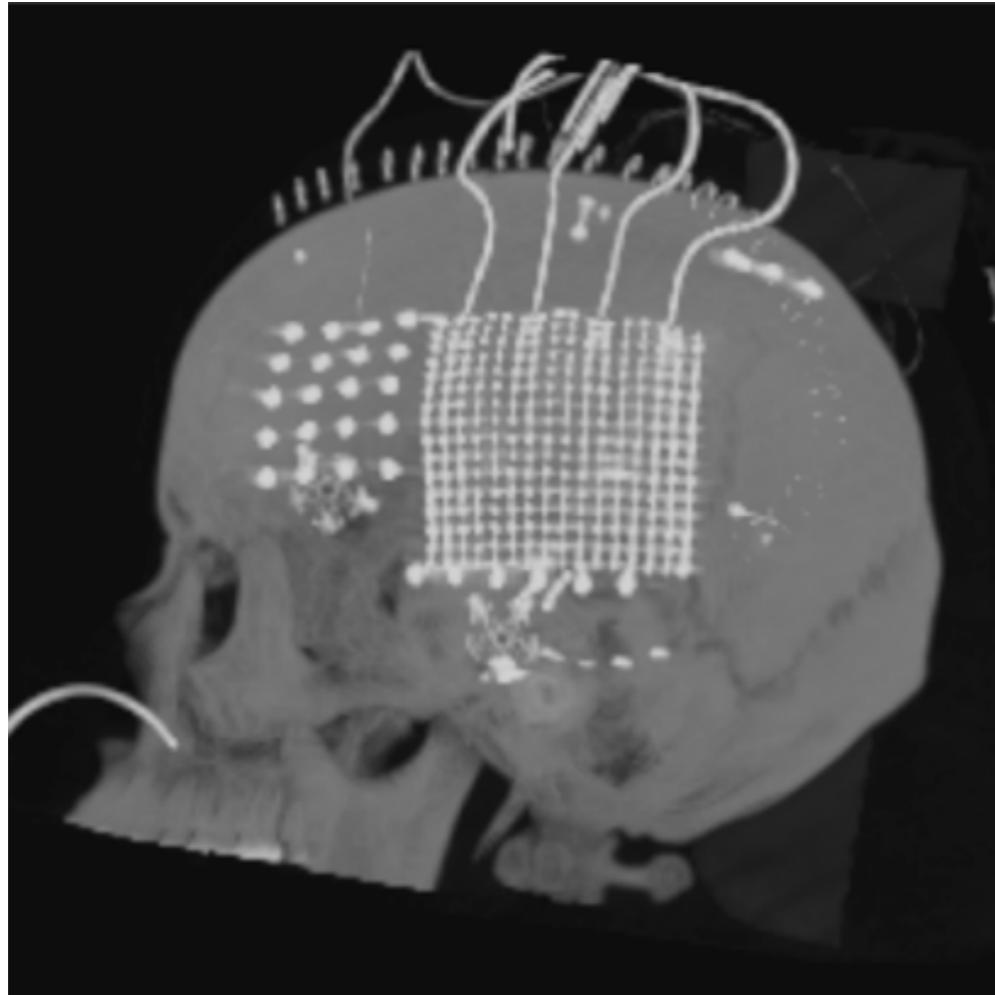


ELECTRIC FIELDS

- * Using surgically implanted electrodes we can detect:
 - * Spikes
 - * Local field potentials (LFP)



ECoG: Electrocorticography



images c/o Liberty Hamilton, Chang Lab UCSF 2016

Advantages

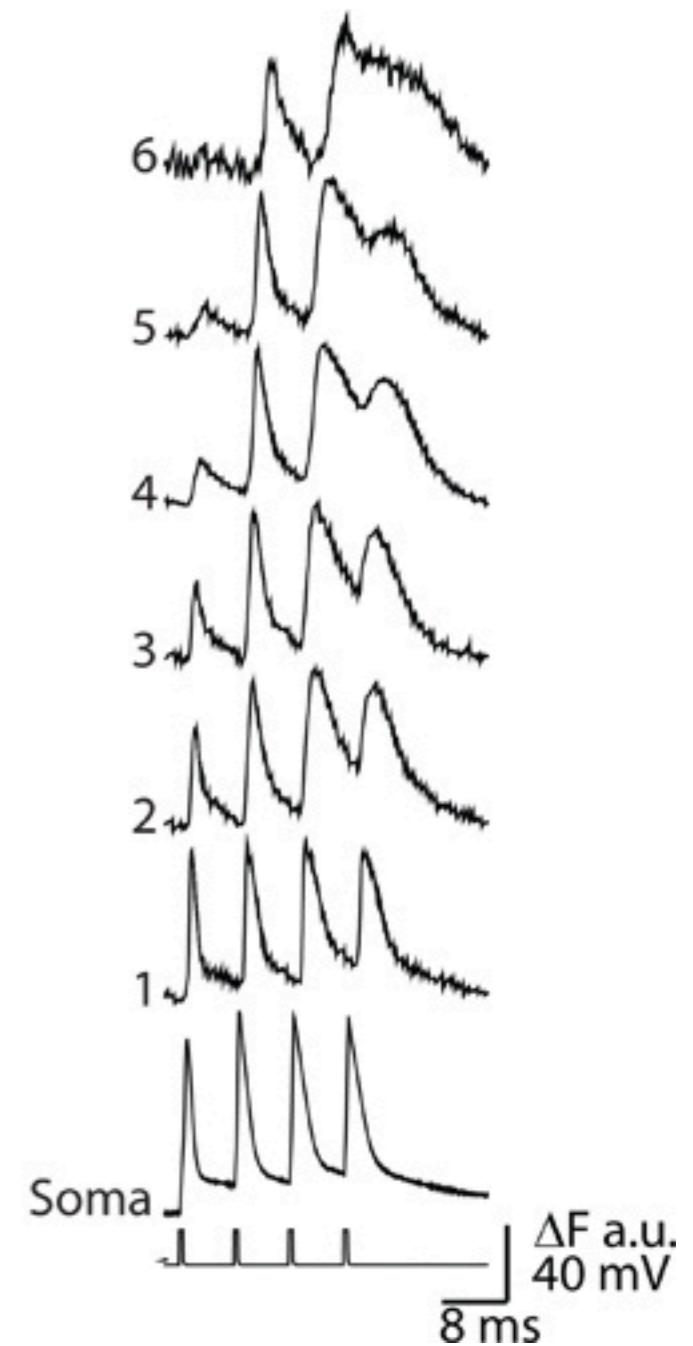
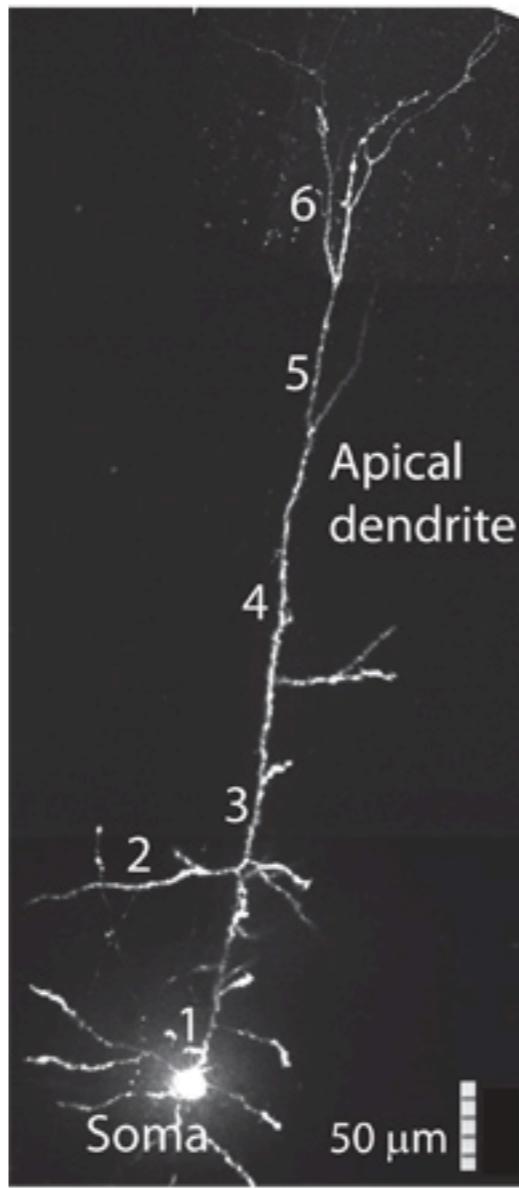
- Relatively good signal quality
- Good temporal resolution
- Measures neural activity
- Inherently 2D

Disadvantages

- Invasive, requires craniotomy
- Poor spatial resolution (~ 8 mm)
- Neural activity measure is biased

ELECTRIC FIELDS

- * A newer method detects electric fields using **voltage-sensitive dyes (VSDs)**
- * VSDs are chemicals that need to be added to the brain



ELECTRIC FIELDS

- * Summed electric fields from many neurons can also be detected **outside the head** (i.e. non-invasively)

EEG: Electroencephalography



Tangemann et al. 2010



Cichocki et al. 2009

Advantages

Relatively simple and cheap
Good temporal resolution
Measures neural activity
Inherently 2D

Disadvantages

Poor signal quality
Poor spatial resolution (> 1 cm)
Neural activity measure is biased

MAGNETIC FIELDS

- * Moving charges generate **magnetic fields** in addition to electric fields
- * Detection is trickier, but measurement is less distorted by skull, etc.

MEG: Magnetoencephalography



Roberts et al., 2008

Joseph Kaczmarek / AP

Advantages

- Better signal quality than EEG
- Good temporal resolution
- Measures neural activity
- Inherently 2D

Disadvantages

- Expensive, requires gnomes
- Poor spatial resolution (~ 8 mm?)
- Neural activity measure is biased

SOURCES OF SIGNAL

- * Electric fields
- * **Calcium concentration**
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CALCIUM

- * When an action potential reaches an axon terminal, it causes a **massive inflow of calcium ions** into the neuron
- * Calcium concentration is actually what triggers **neurotransmitter release**

CALCIUM

- * **Calcium indicators** are molecules that change their fluorescence properties in the presence of calcium
- * People have designed calcium indicator proteins that can be **encoded as genes** and then produced by neurons themselves
- * Most commonly used: GCaMP

CALCIUM

- * Genetically encoded methods like GCaMP have a *huge* advantage because they can **selectively target** specific cells for recording based on **gene expression**
- * But:
 - * Indicators are slow or have low SNR: can't necessarily see single spikes

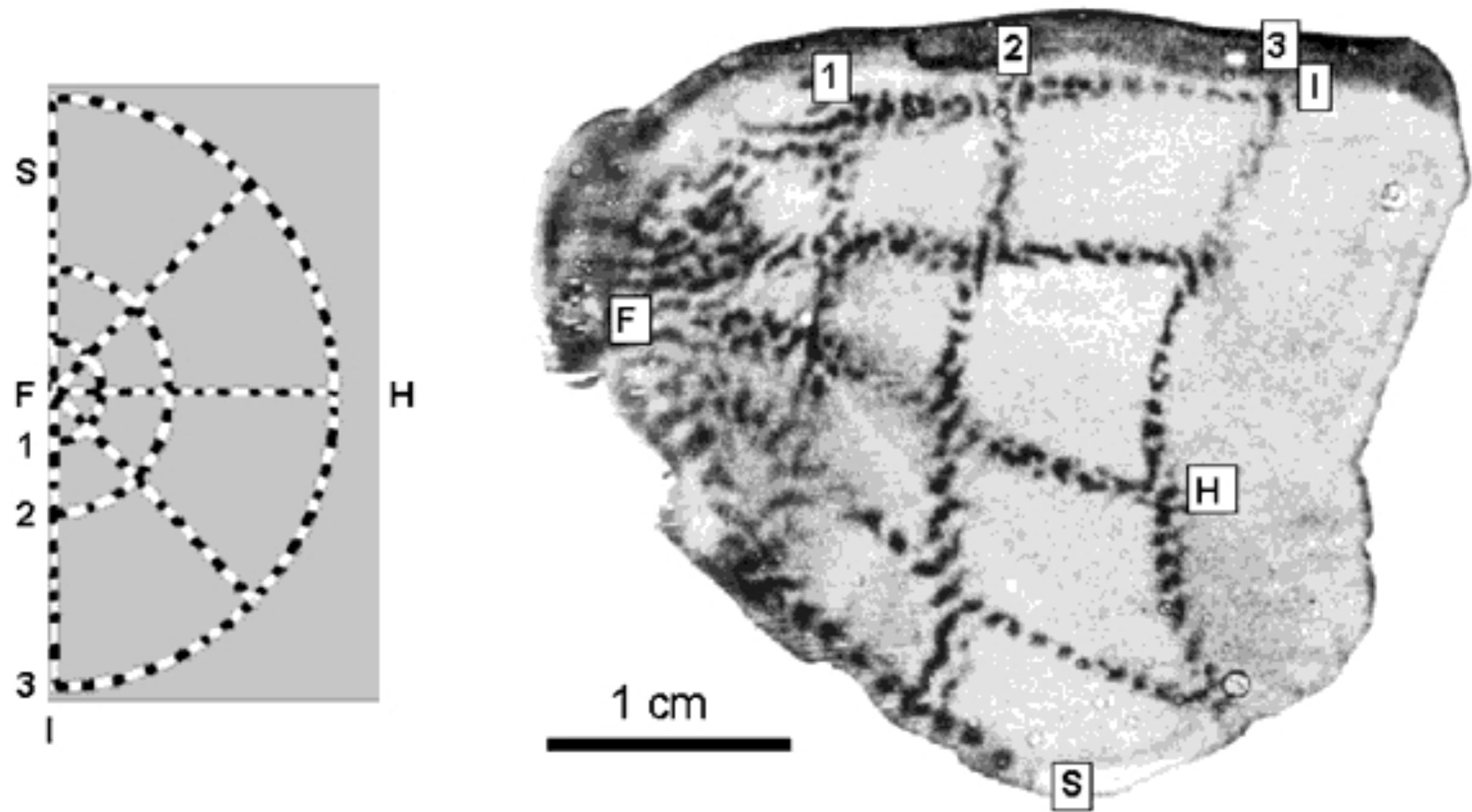
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AUTORADIOGRAPHY

- * Introduce a **radioactive version** of some molecule (e.g. deoxyglucose)
- * Wait for that molecule to accumulate
- * Slice up the brain
- * Lay the slices on a photographic plate

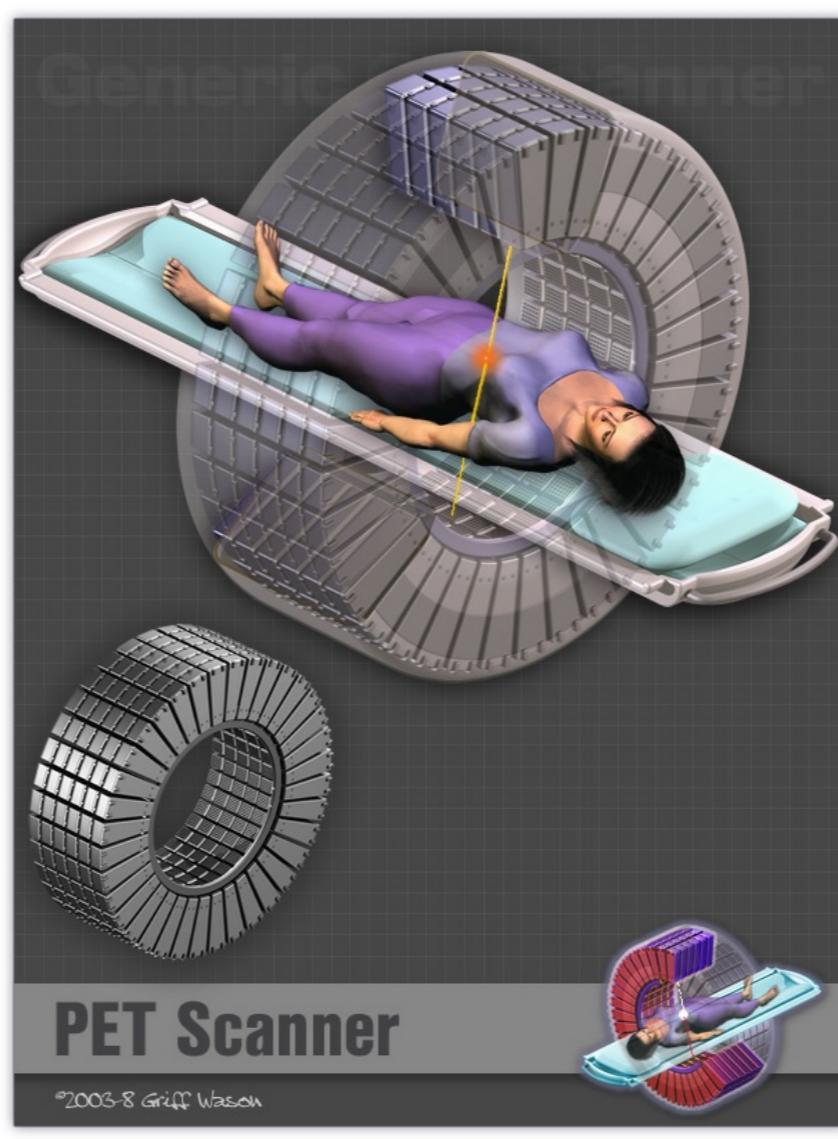
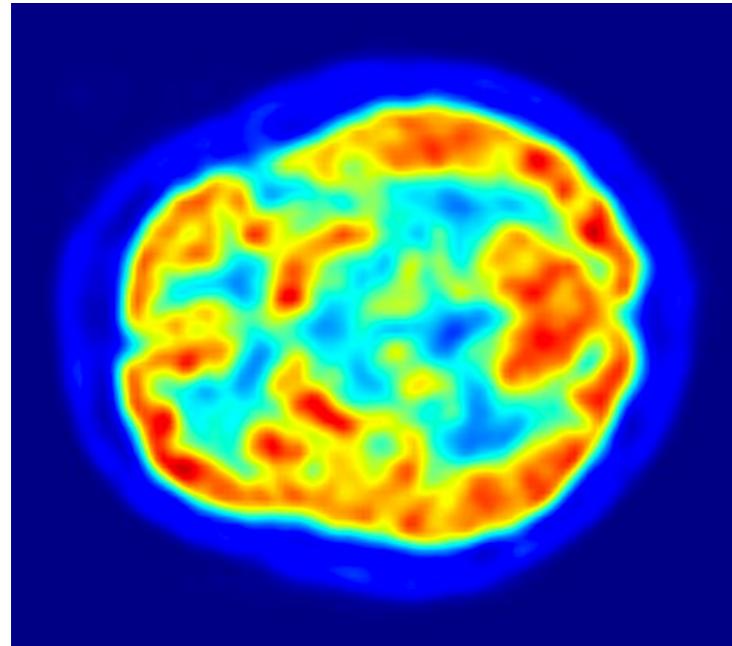
Retinotopic map in primary visual cortex



PET

- * **Positron emission tomography (PET)**
- * Inject a radioactive substance into the subject
- * Wait for positrons to annihilate
- * Record simultaneous gamma ray events
- * Reconstruct image

PET: Positron emission tomography



Advantages

Relatively simple and cheap
Good temporal resolution
Tomographic (2D slice)

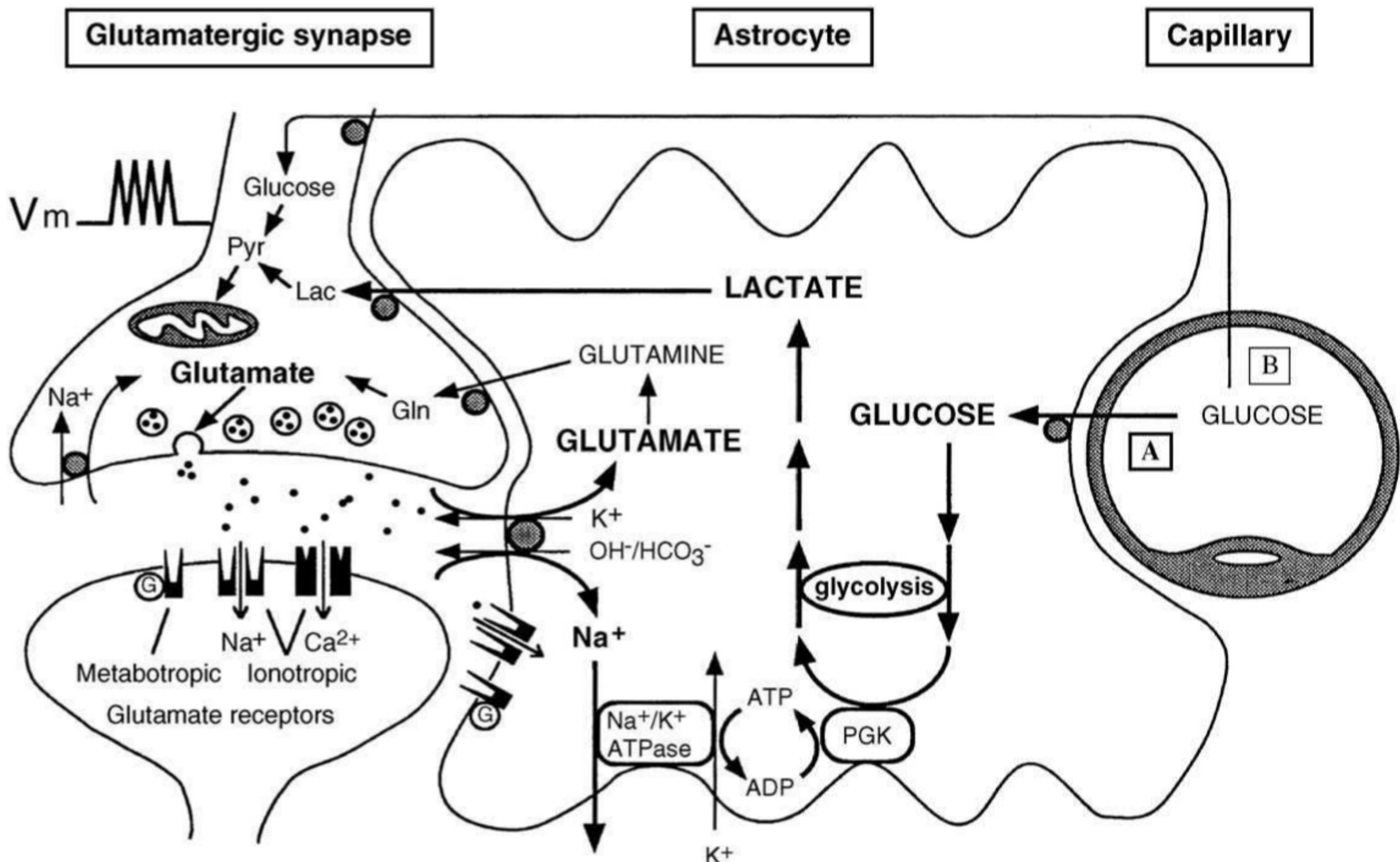
Disadvantages

Poor signal quality
Poor spatial resolution ($> 1 \text{ cm}$)
Probably really bad for you

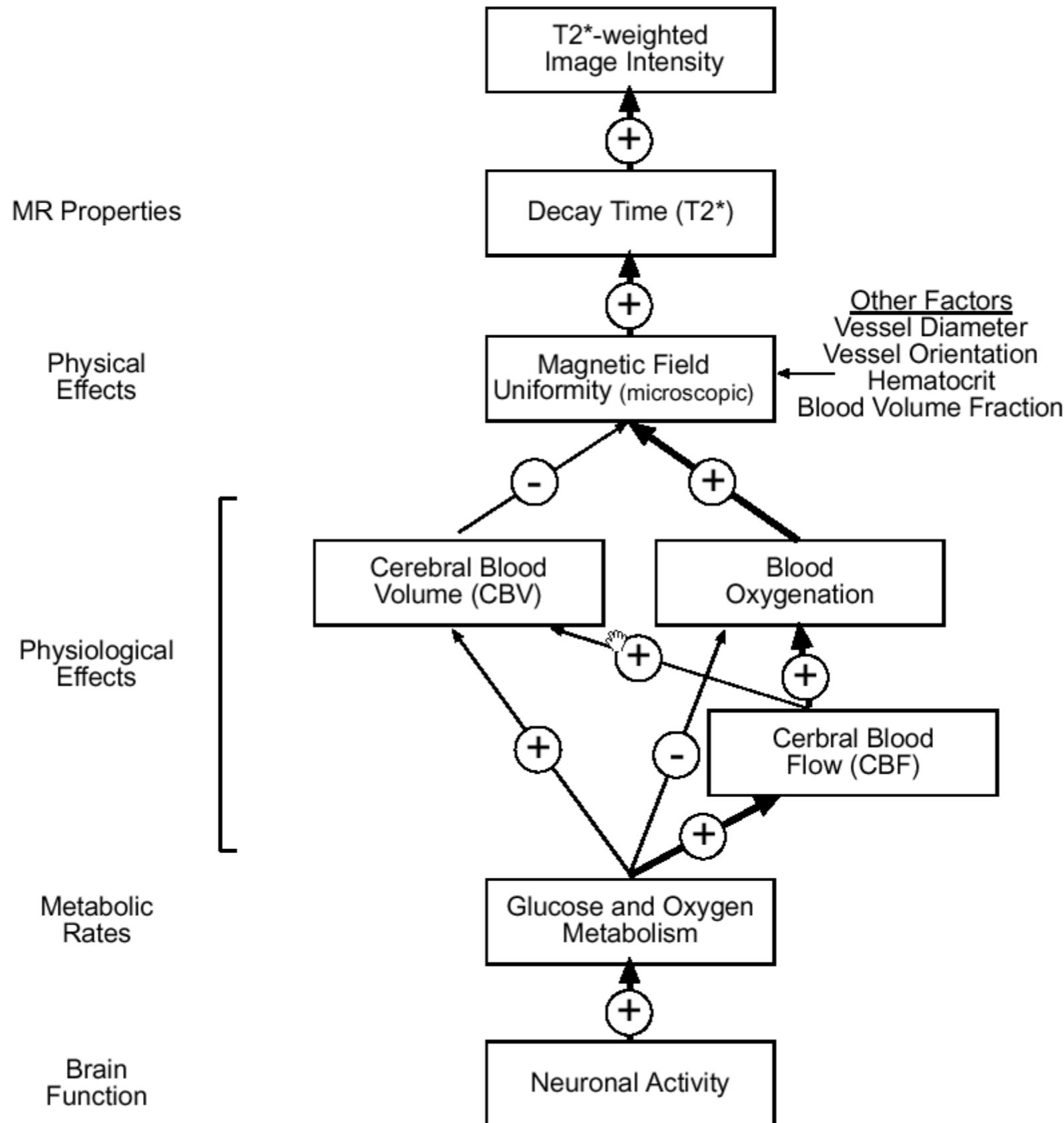
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BOLD SIGNAL



FMRI signals



HOW DOES BOLD WORK?

(the simple version)

- * **Oxyhemoglobin** (HbO_+) and **deoxyhemoglobin** (HbO_-) have different magnetic properties
- * Mixtures of different magnetic properties produce **LOW** signals in MRI (“ T_{2^*} effect” or “dephasing”)

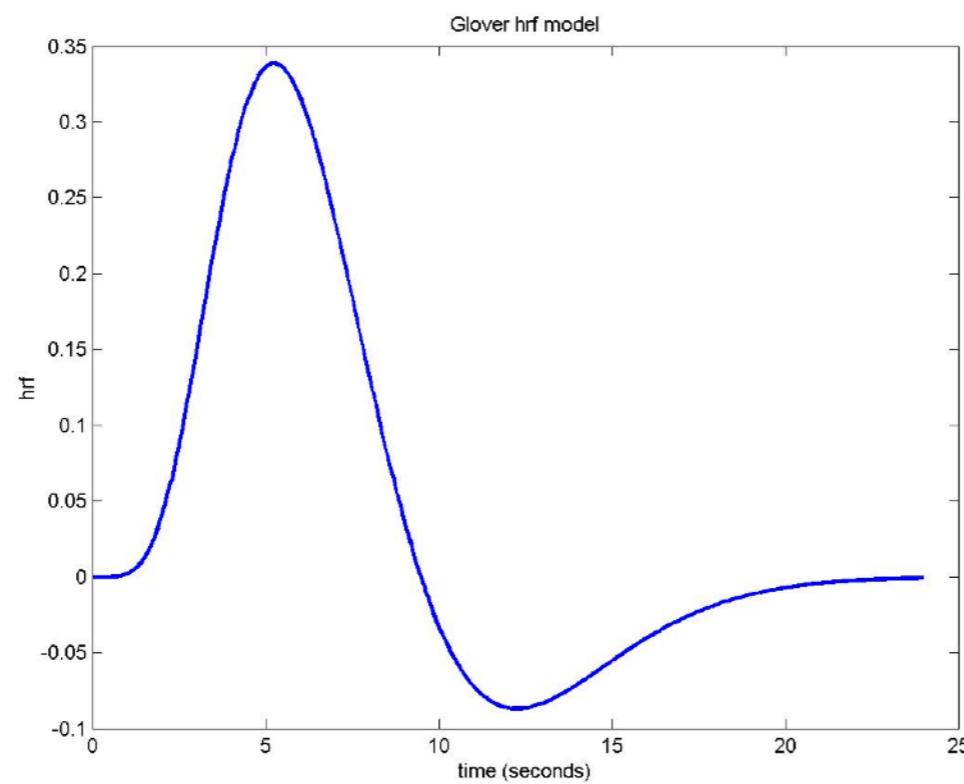
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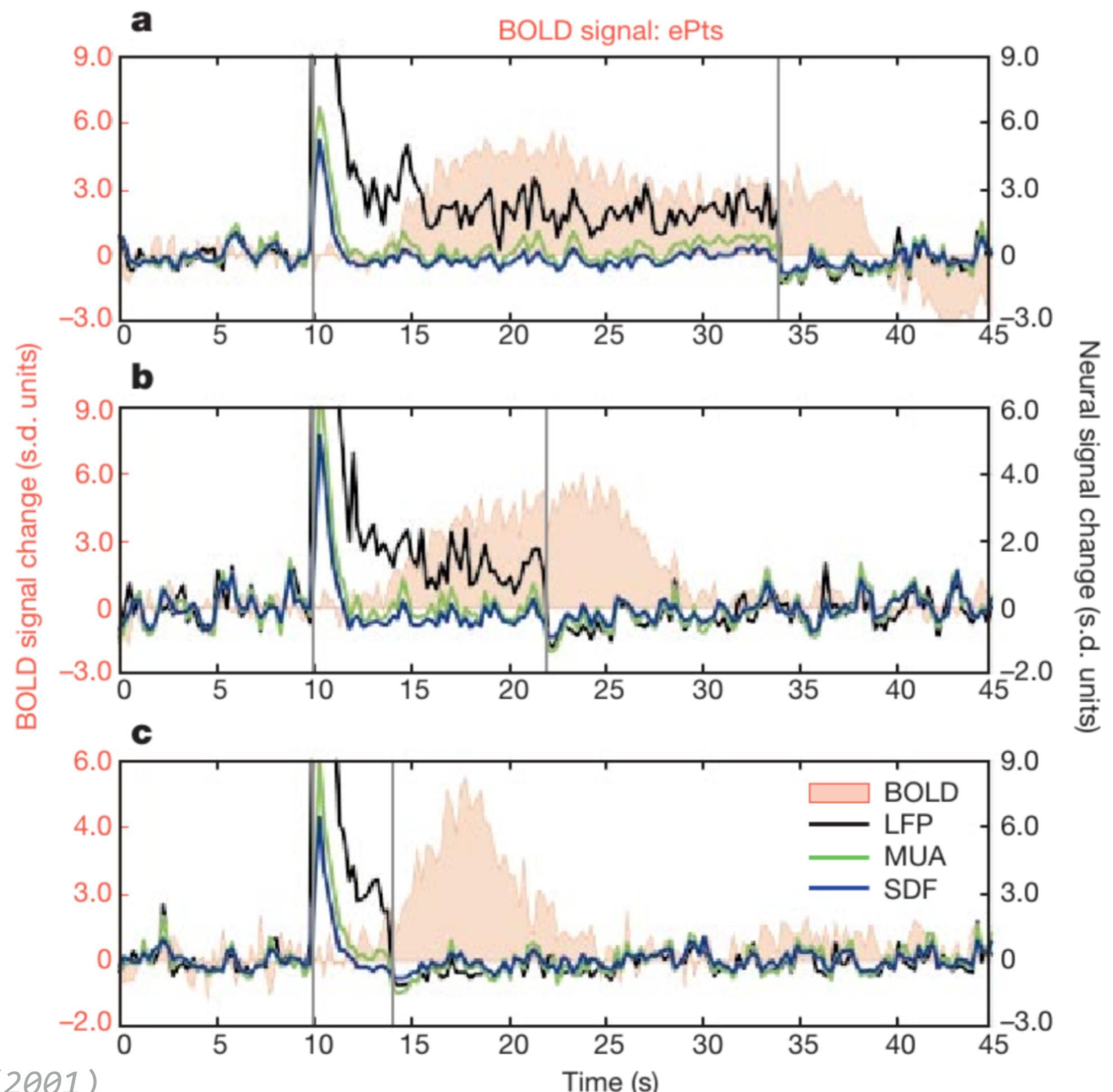
- * **Resting brain tissue:** normal mixture of HbO₊ and HbO₋
 - * **LOW** signal in MRI
- * **Active brain tissue:** calls for extra blood causing big rush of HbO₊, upsets ratio of HbO₊ and HbO₋
 - * **HIGH** signal in MRI

BOLD & HRF

- * BOLD = blood-oxygen level dependent
- * HRF = hemodynamic response function



typical model HRF



FMRI: Functional Magnetic Resonance Imaging



Advantages

Good spatial resolution (~ 3 mm)

Inherently 3D

Disadvantages

Very expensive & complicated

Poor temporal resolution (> 1 s)

Does not measure neural activity