on Brightspace

<u>Supplemental Readings (on MRI)</u>

Huettel, Song, & McCarthy (2009). *Functional Magnetic Resonance Imaging*. Oxford University Press.

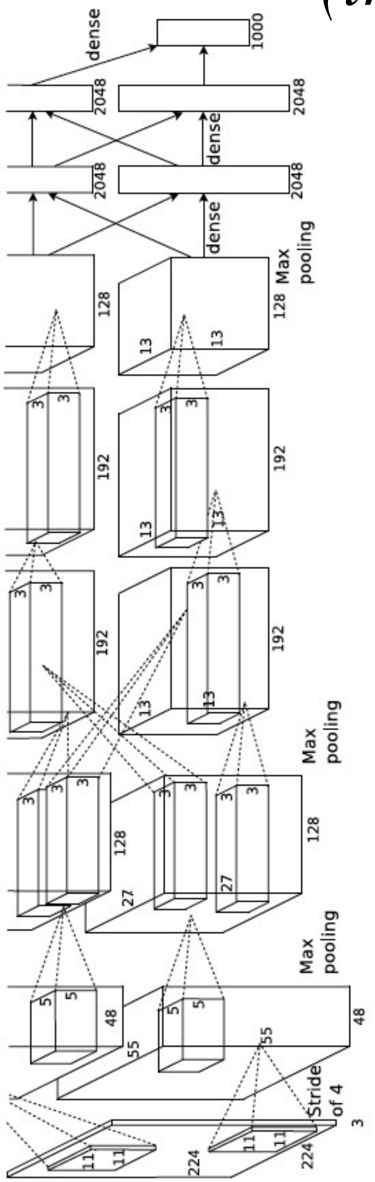
Blink (2004). *MRI Physics for Anyone Who Does Not Have a Degree in Physics* (http://www.mri-physics.net).

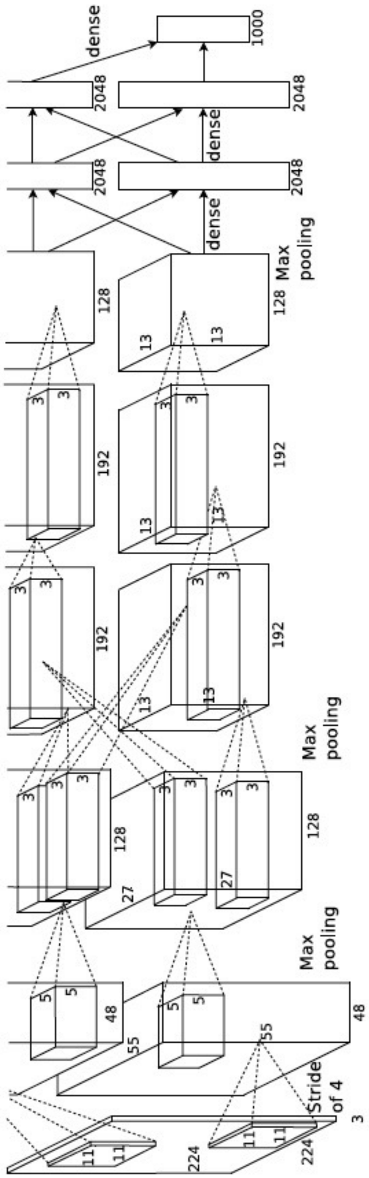
can CNN models explain brain function?

(a question it'll take some time to get to answering)

(the best computer vision models)

modern CNN models are informed by the brain:





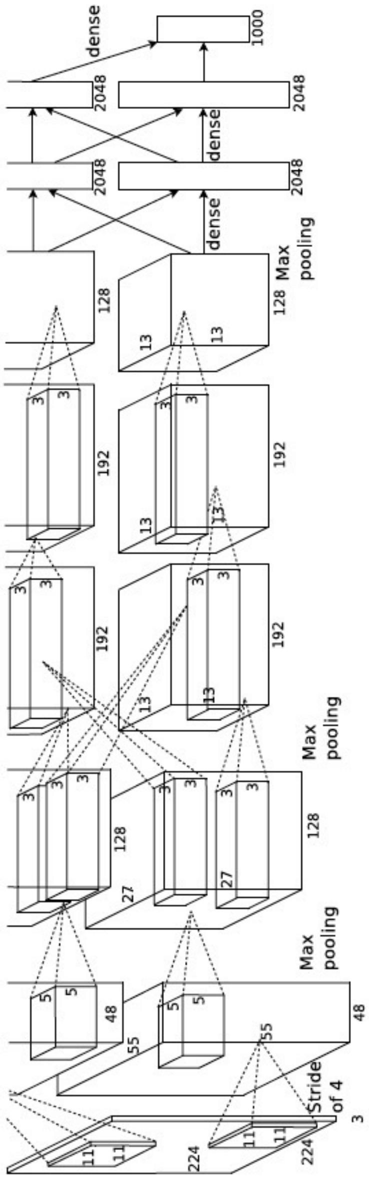
modern CNN models are informed by the brain:

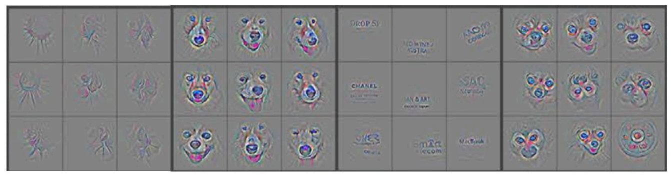
- *composed of neural-like units (like brains)*
- *highly parallel (like brains)*
- *learn (like brains)*
- *with multiplicative weights (like synapses)*
- *with additive net inputs (like dendritic processes)*
- *with nonlinear activations (like action potentials)*
- *with learning via connections (like neurons)*
- *convolutional operations (like brain areas)*
- *multiple feature maps (like brain areas)*
- *hierarchical (like brains)*
- *deep (like brains)*
- *some have recurrent* connections (like brains)*

can these models help explain the brain too?

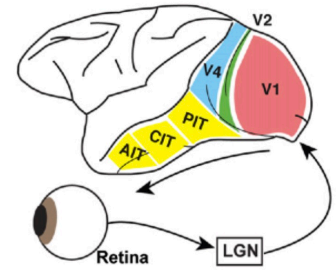
** haven't discussed*

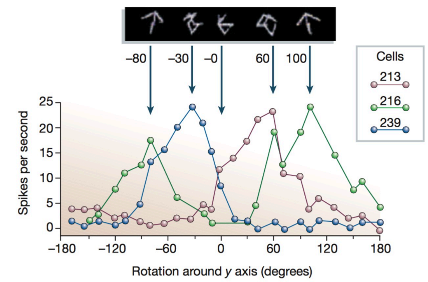
go beyond mere resemblance (descriptive) **to more scientifically rigorous**





"object-like" like IT

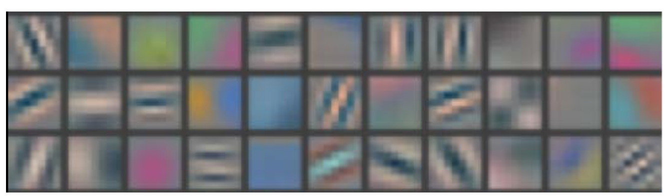


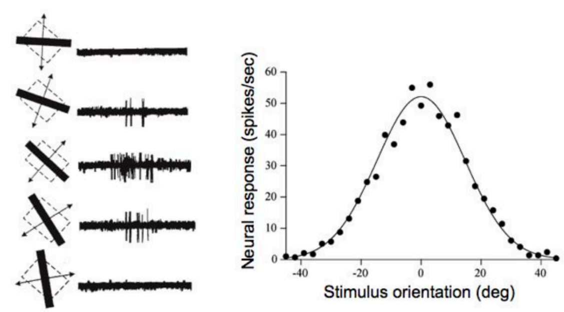


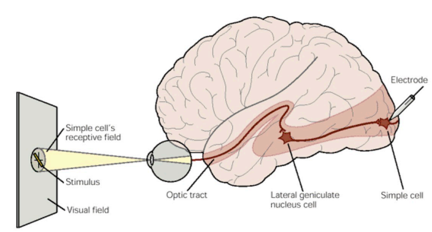
CNN representations

brain representations

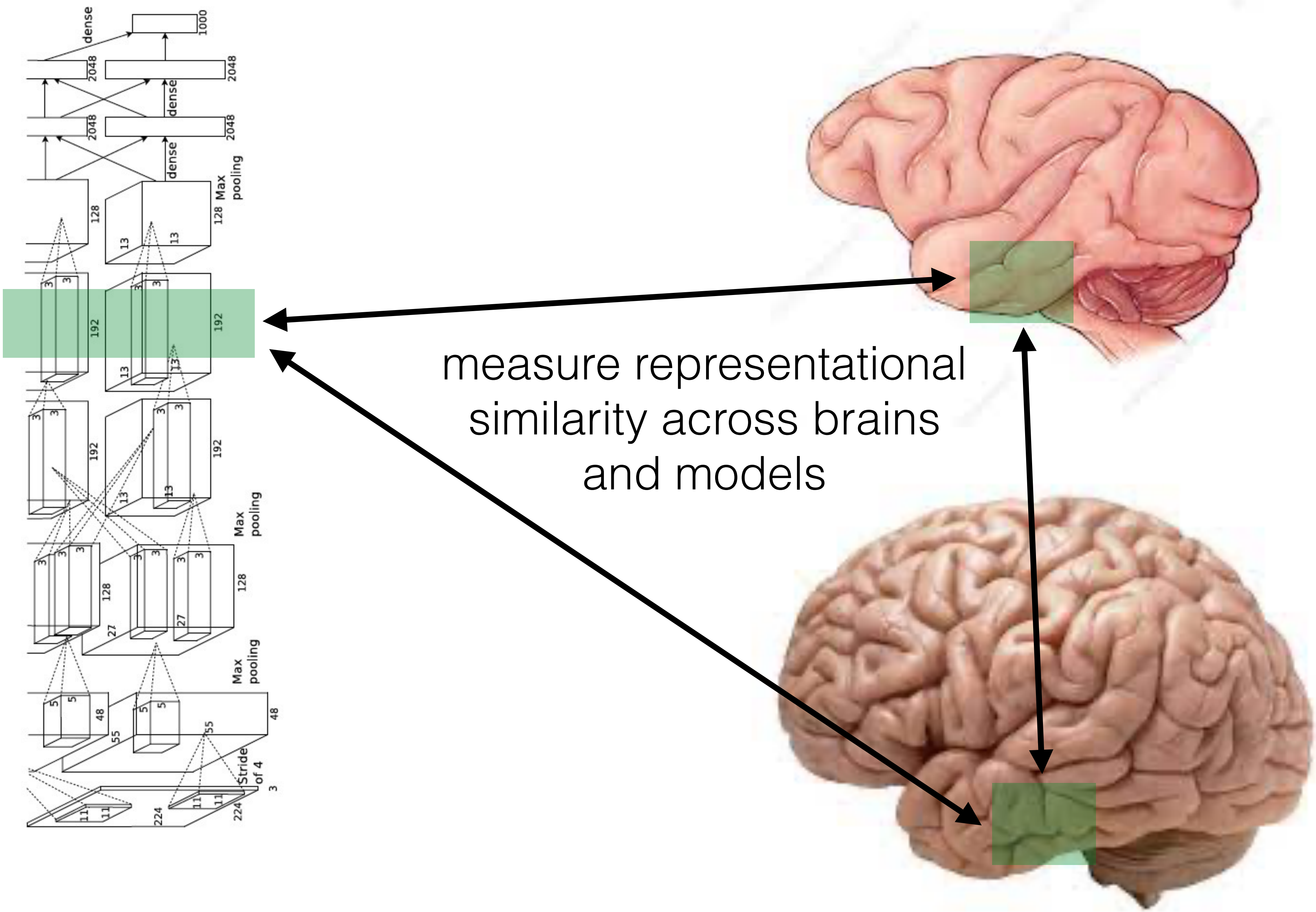
"gabor-like" like V1



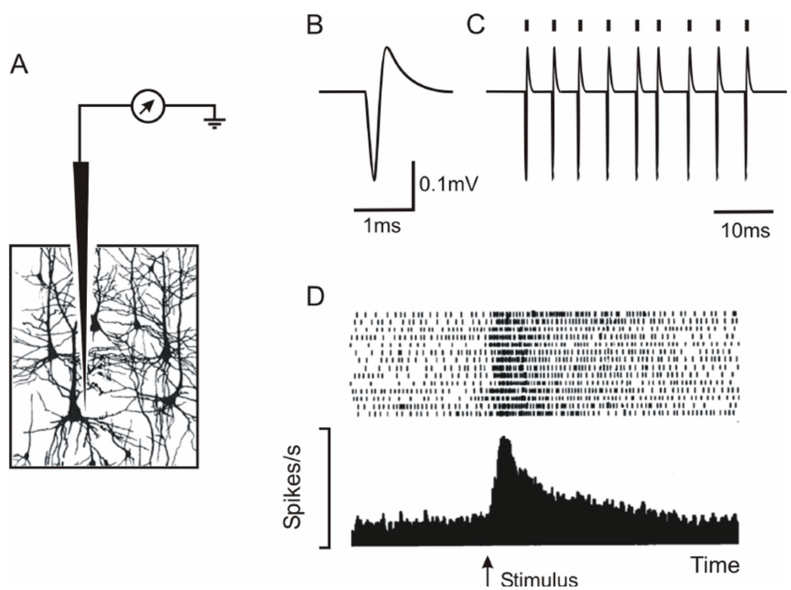




go beyond mere resemblance (descriptive)
to more scientifically rigorous



neurophysiological recordings



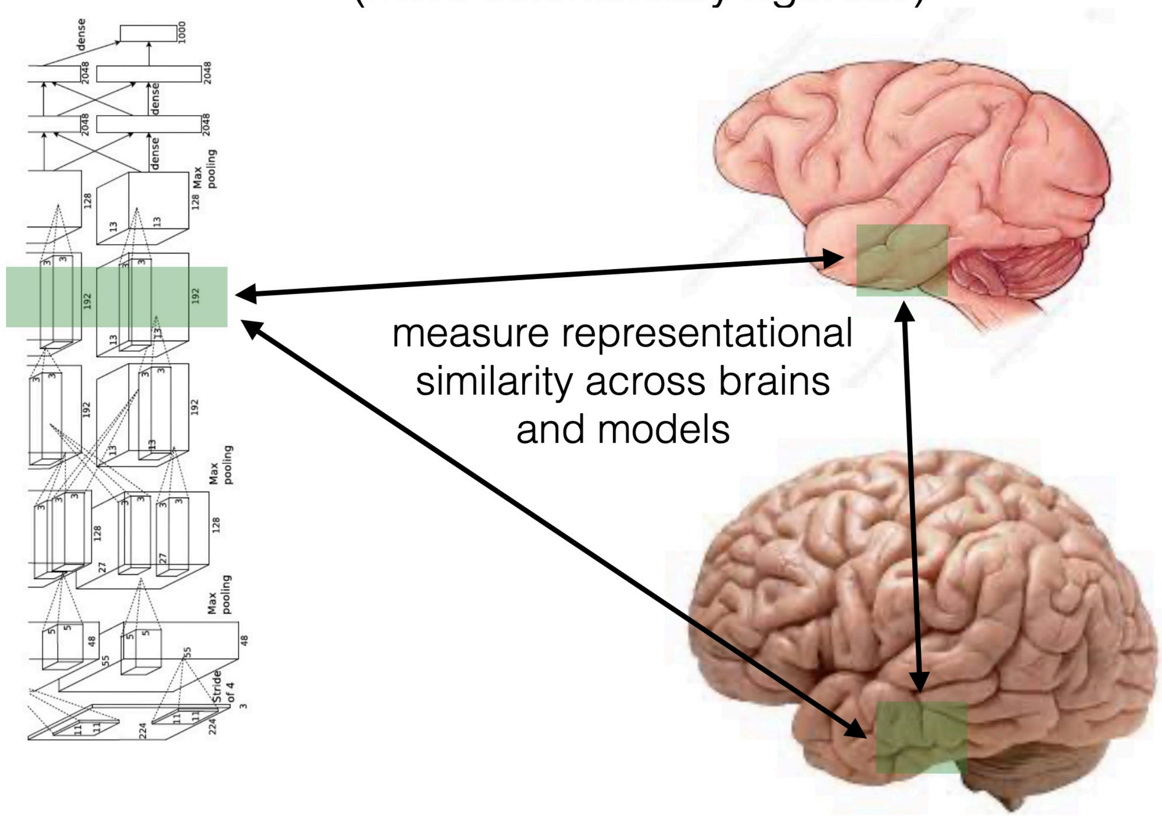
single-unit recordings
(one neuron at a time)

multi-unit recordings
(many at a time)

fMRI

we will go on a bit of a journey talking about fMRI before we get back to this

go beyond mere resemblance
(more scientifically rigorous)



functional magnetic resonance imaging (fMRI)

Magnetic Resonance Imaging (MRI) Scanner

is a huge, powerful magnet that can take structural and functional images of your body

Magnetic Resonance Imaging (MRI) Scanner

huge, powerful magnet

Magnetic Resonance Imaging (MRI) Scanner

huge, powerful magnet

Magnetic Resonance Imaging (MRI) Scanner

huge, powerful magnet

Magnetic Resonance Imaging (MRI) Scanner

huge, powerful magnet

https://www.youtube.com/watch?v=6BBx8BwLhqg

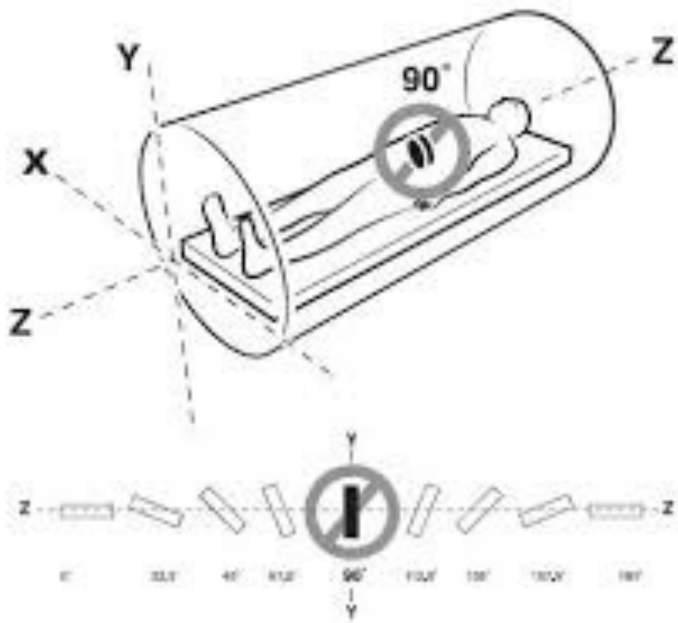
Magnetic Resonance Imaging (MRI) Scanner

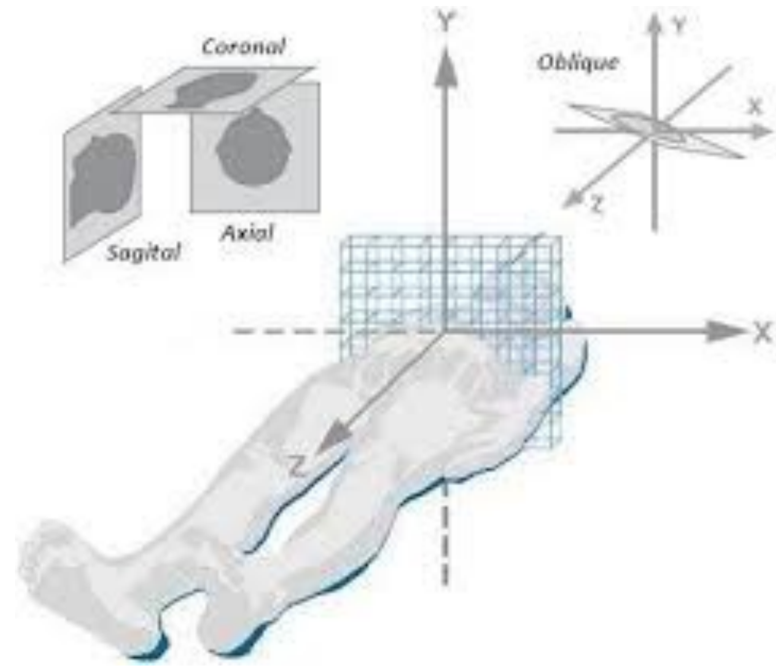
strong magnetic field
3 Tesla (3T), ~60,000x earth's magnetic field

1.5T and 3T used in medical imaging

Vanderbilt has 3T and 7T for research with humans
and 4.7, 7, 9.4, 15.2T for research with rats and mice

Magnetic Resonance Imaging (MRI) Scanner

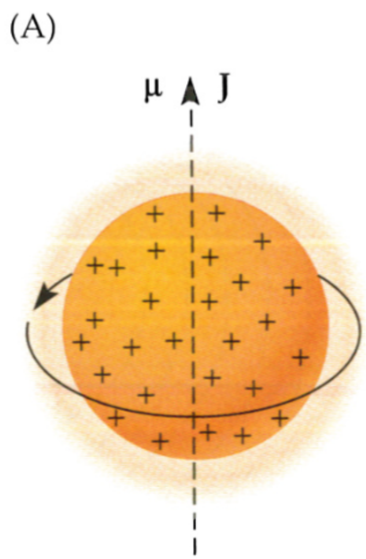


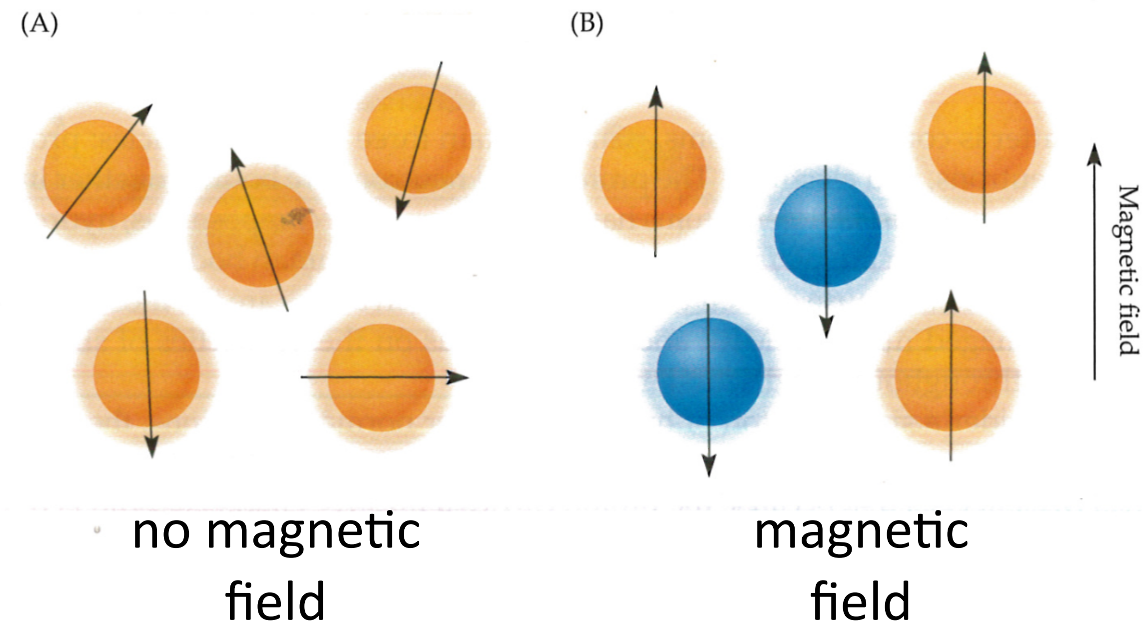


a person is slid into the scanner bore
inside this strong magnetic field

(safety checklists to prevent metals on or inside their bodies)

a little MR physics



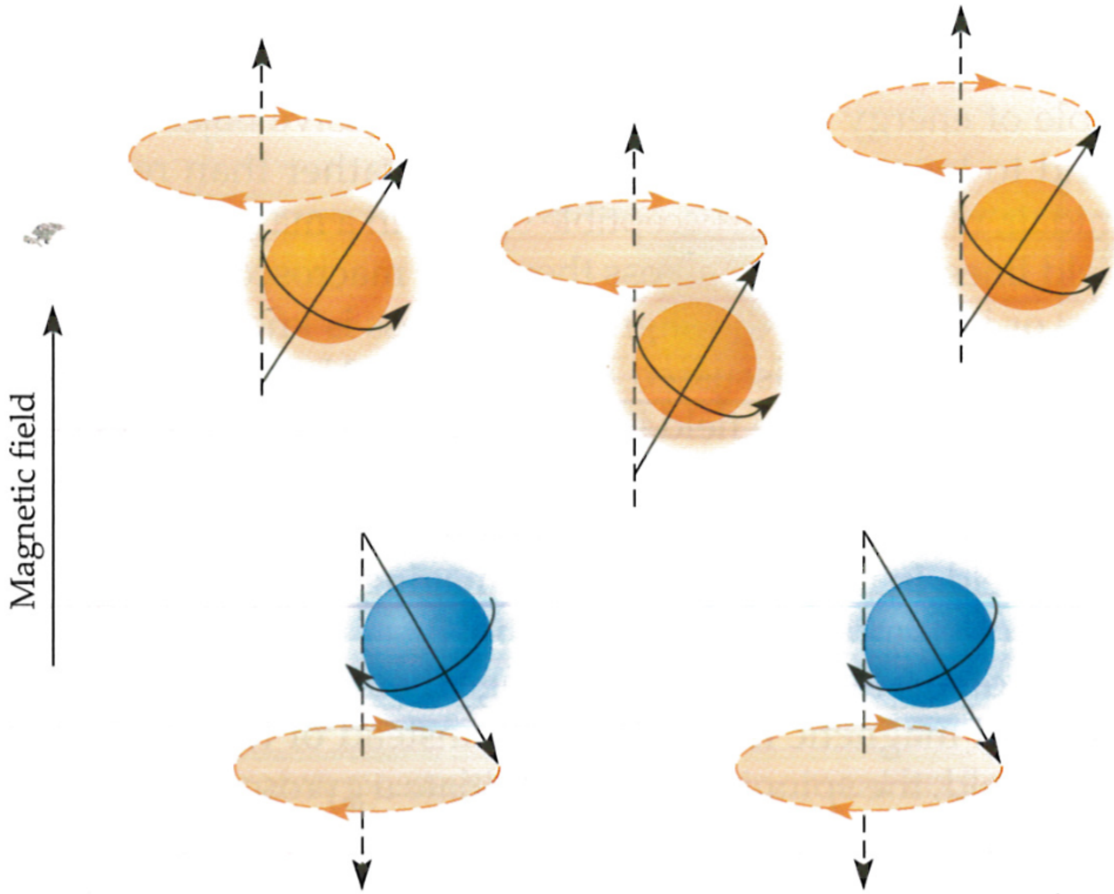


hydrogen atoms are ubiquitous throughout the body

protons of hydrogen atoms are like tiny spinning magnets

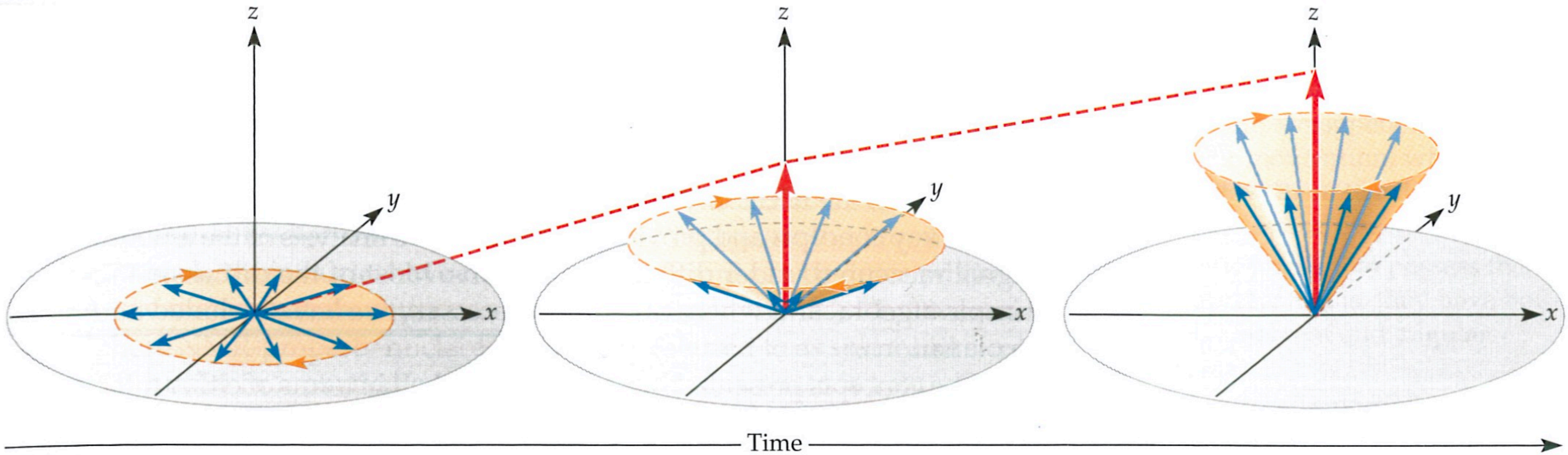
hydrogen protons align (or anti-align) with strong magnetic field

a little MR physics



the protons actually precess (like a spinning top)

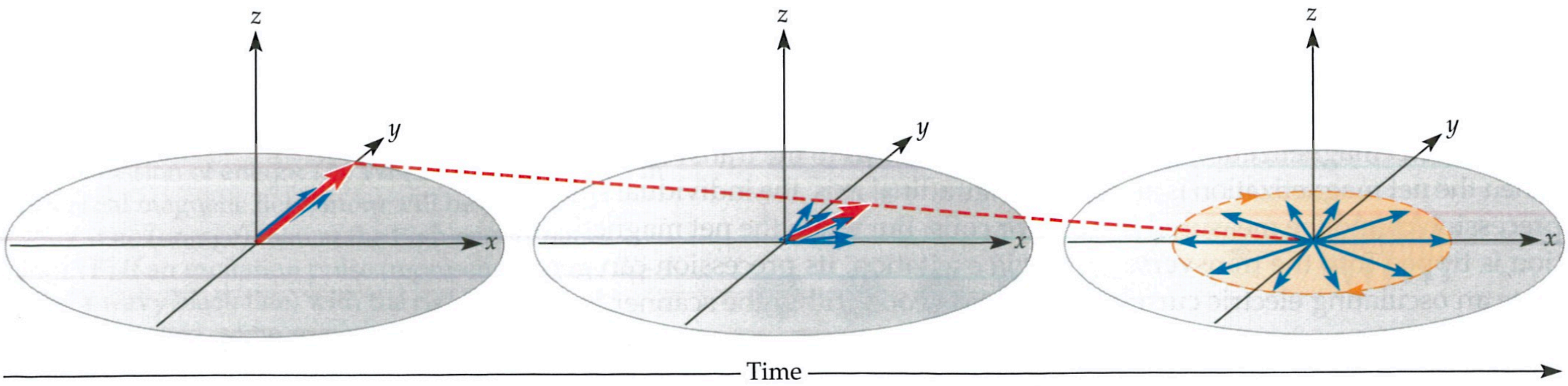
a little MR physics



a carefully-calibrated radio frequency (RF) pulse will knock the hydrogen protons out of alignment with field

as they come back into alignment, they emit energy, which can be read as an RF signal (T1 recovery)

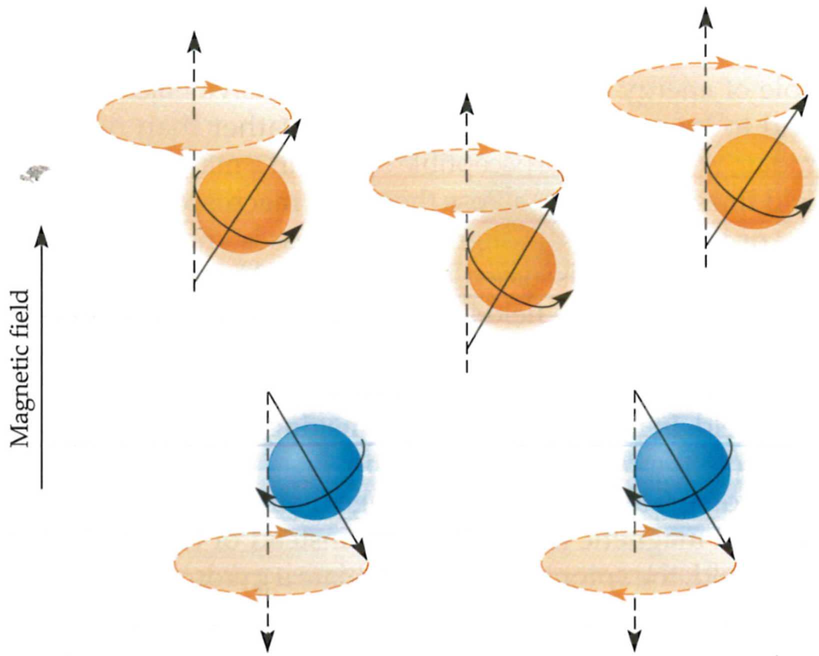
a little MR physics



a carefully-calibrated radio frequency (RF) pulse will also align the protons in their precession angle

as they come go out of phase, they emit energy, which can also be read as an RF signal (T2 decay)

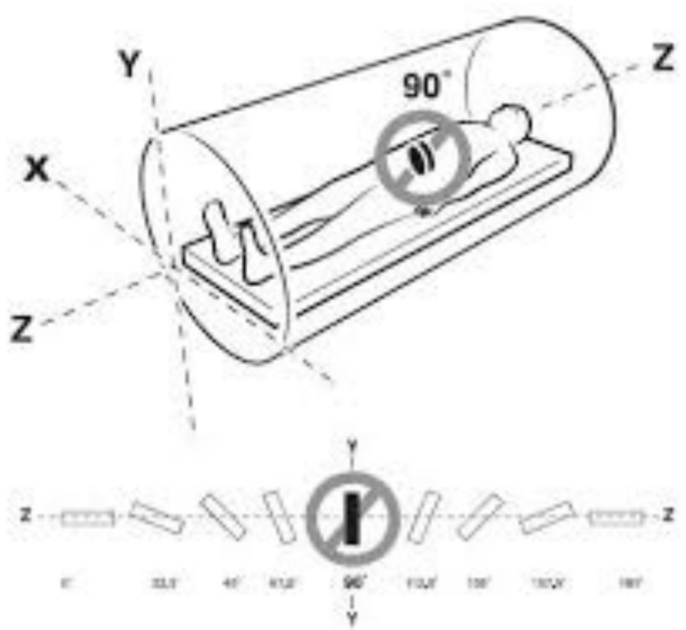
a little MR physics

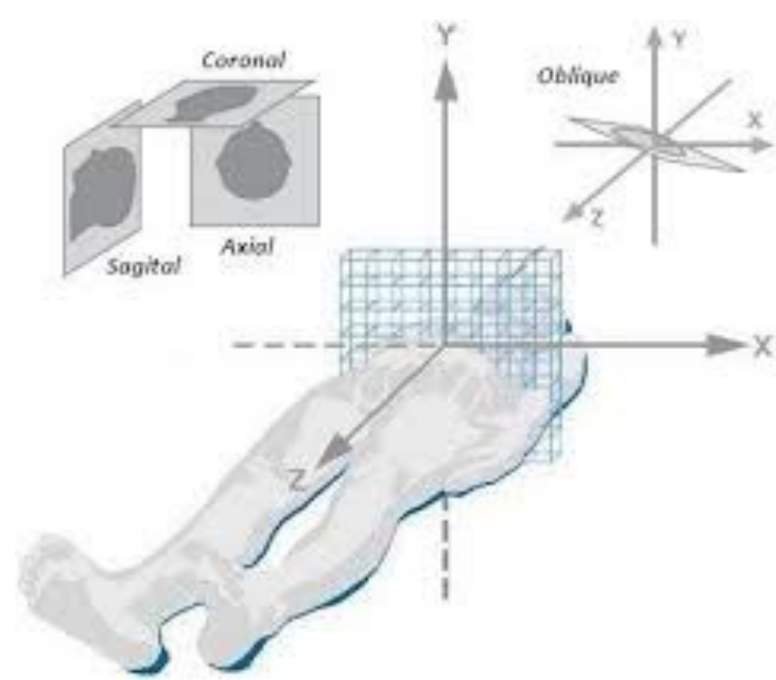


different kinds of body tissue* bind hydrogen to different degrees and there are local magnetic tissue inhomogeneities, causing different relaxation and decay times, causing different temporal properties of RF signals, leading to differences in imaged body tissue

** e.g., neurons, myelin (fat), bone, liquid (ventricles)*

a little MR physics



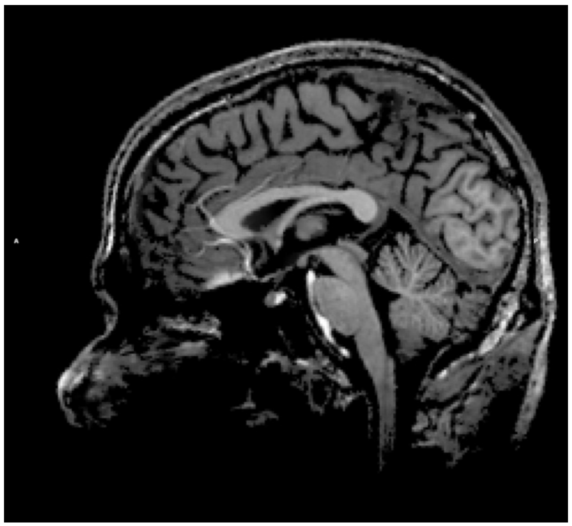


with only the main (z) magnetic field, all the hydrogen atoms in the body in the bore would be knocked together (and RF signals are not positional)

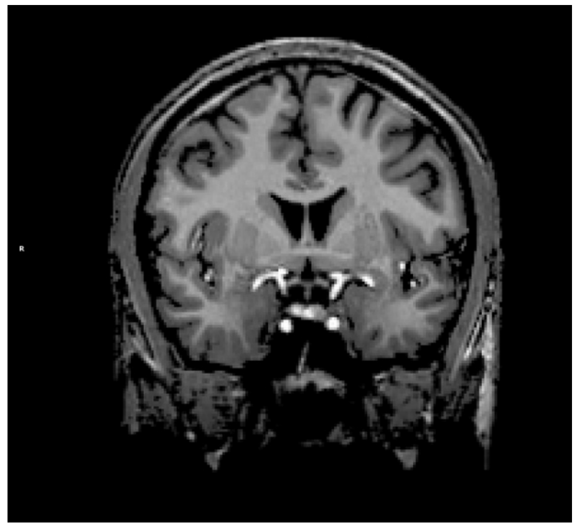
trigger RF pulse depends on precise magnetic field

so there are other x, y, z magnetic field gradients that permit "slices" of the body to be imaged (localized in x, y, z)

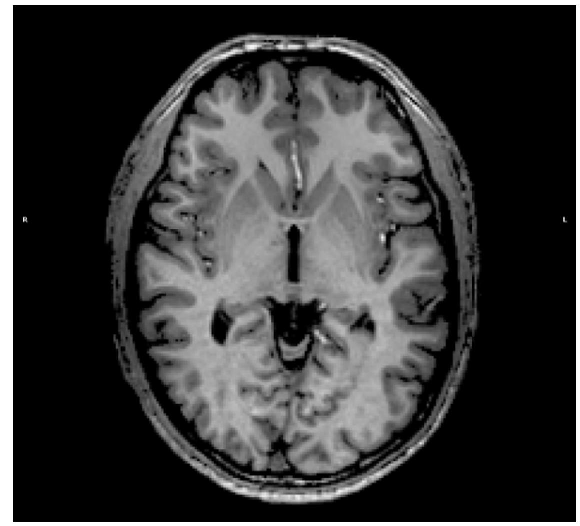
MR images



Sagittal



Coronal

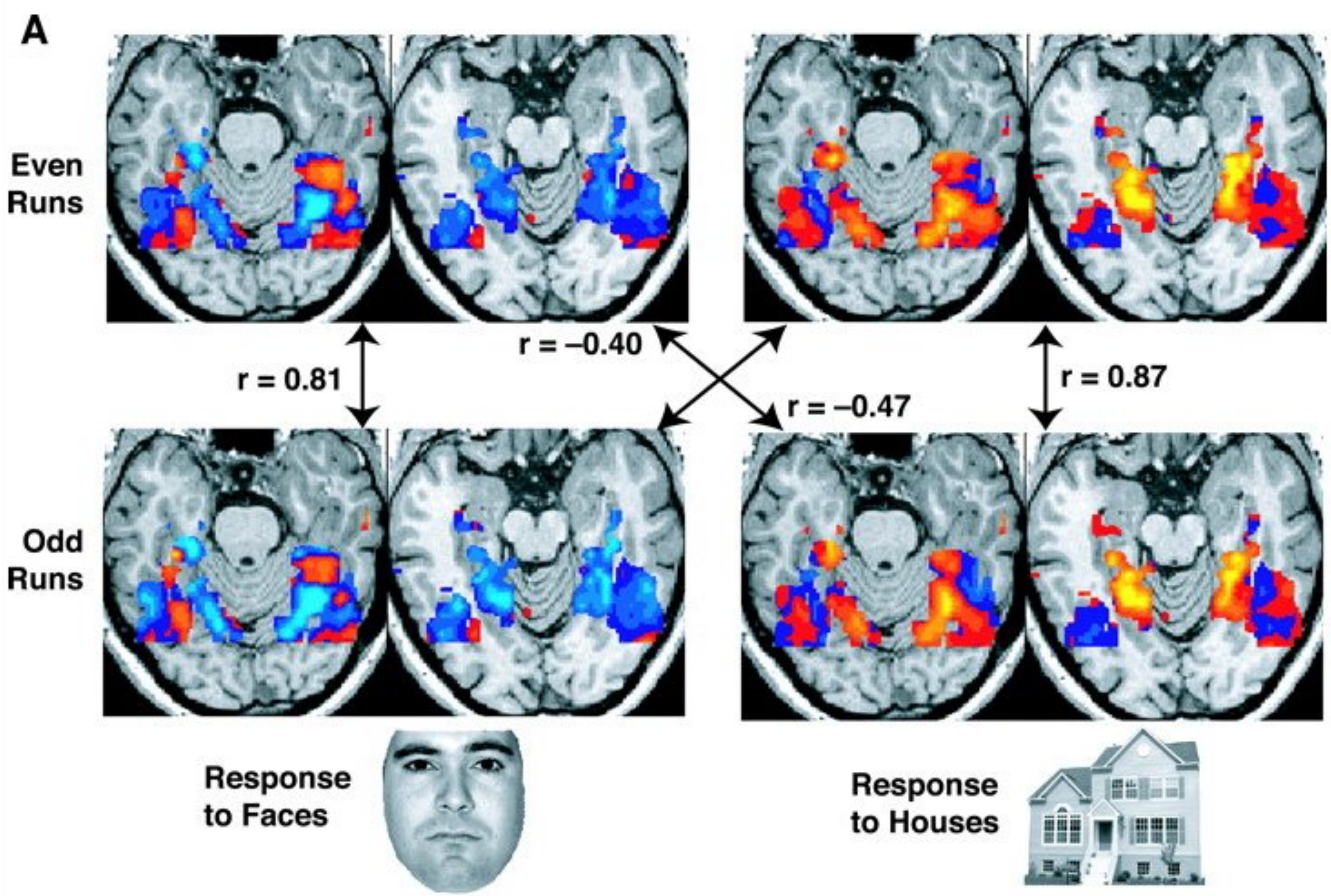


Transverse

T1-weighted
typical anatomical brain image

fMRI (functional MRI) images

functional MR (colors) overlaying anatomical MR (grayscale)



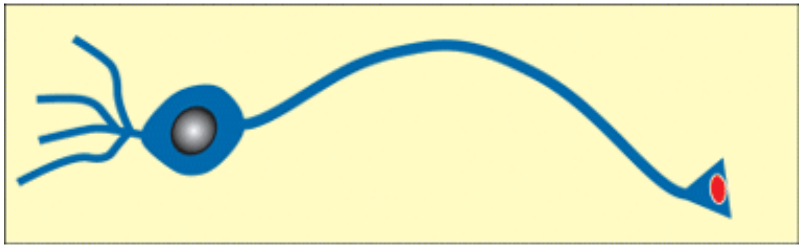
T2-weighted
typical functional brain image

fMRI (functional MRI)

functional = brain activity

fMRI (functional MRI)

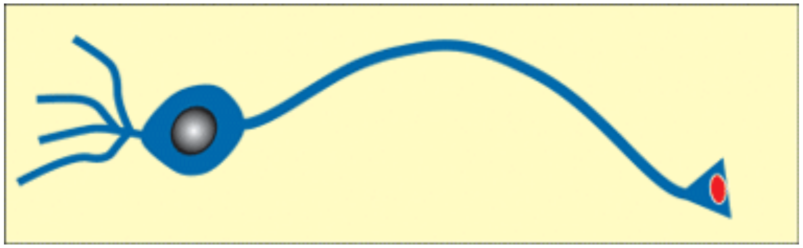
functional = brain activity



neural activity require energy

fMRI (functional MRI)

functional = brain activity

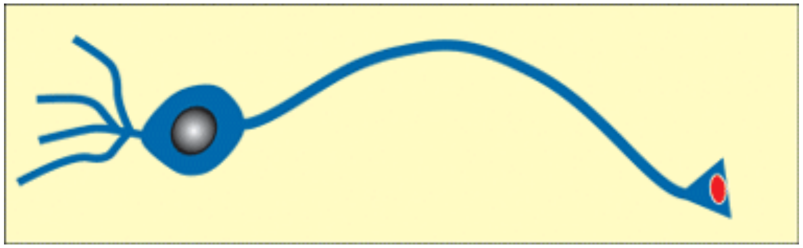


neural activity require energy

Human Brain:
- weighs about 3lbs
- but uses up to 20% of metabolic energy

fMRI (functional MRI)

functional = brain activity



neural activity require energy

47% of energy use in the rodent brain goes towards restoration of ionic concentration gradients following action potentials

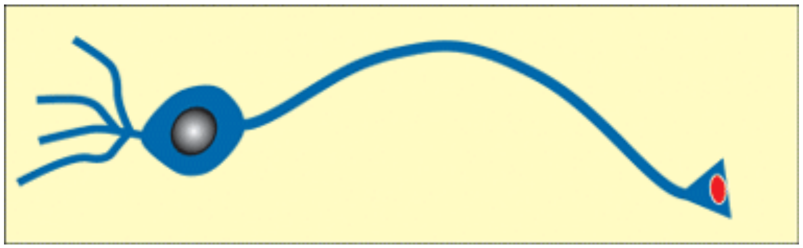
34% to restoration after EPSPs and IPSPs along dendrites

13% to maintenance of the resting membrane potential

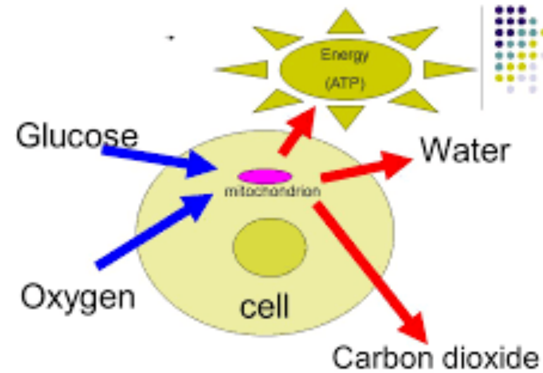
leaves 6% left for all other brain functions

fMRI (functional MRI)

functional = brain activity



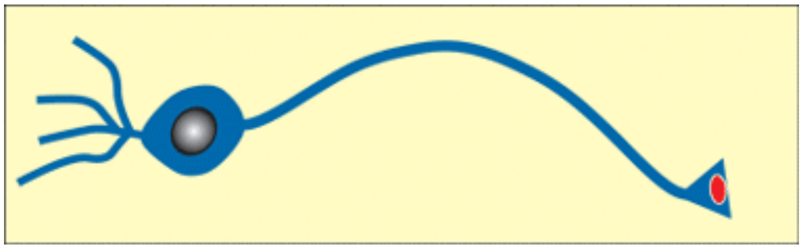
neural activity require energy



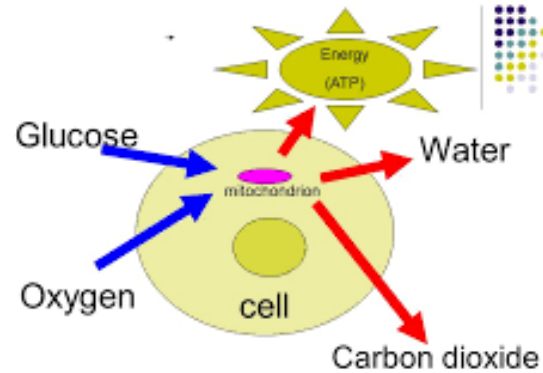
energy from glucose and oxygen

fMRI (functional MRI)

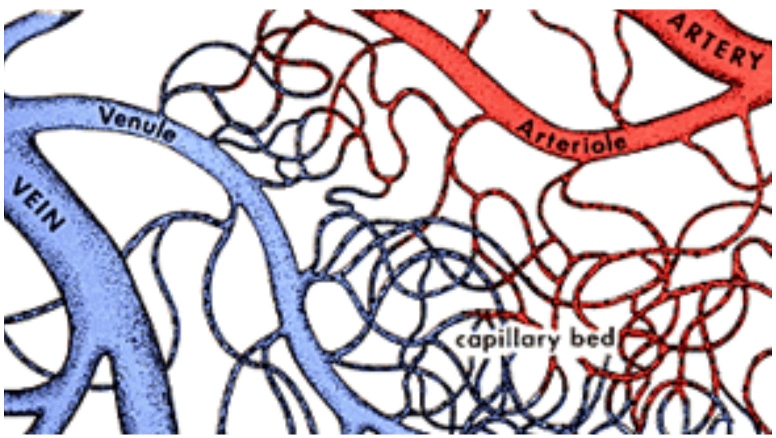
functional = brain activity



neural activity require energy



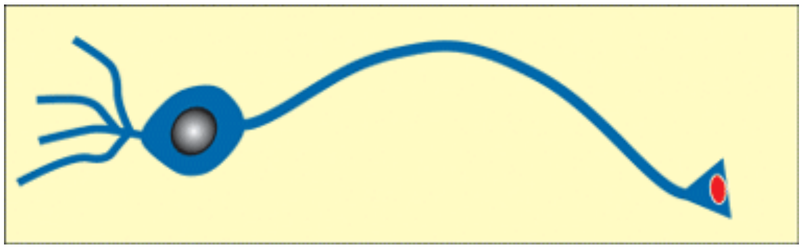
energy from glucose and oxygen



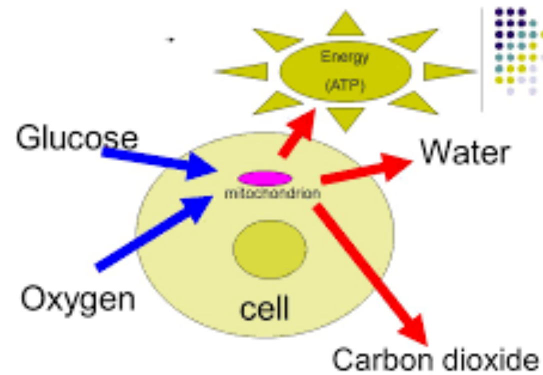
capillaries provide glucose and oxygen to neurons

fMRI (functional MRI)

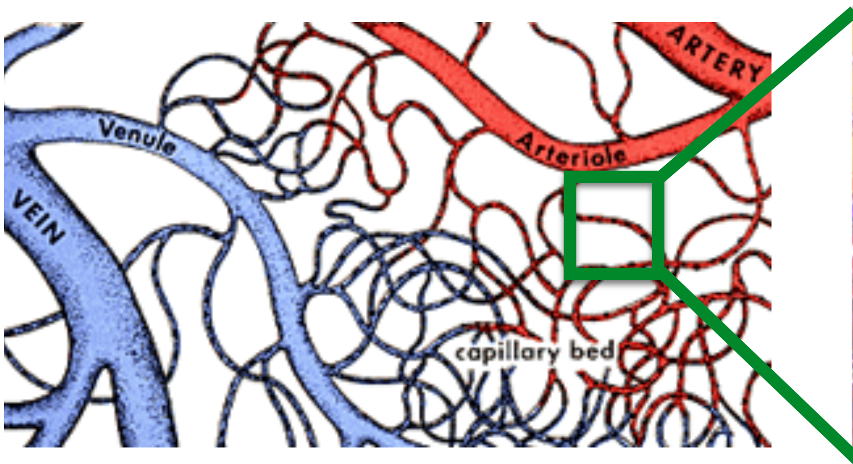
functional = brain activity



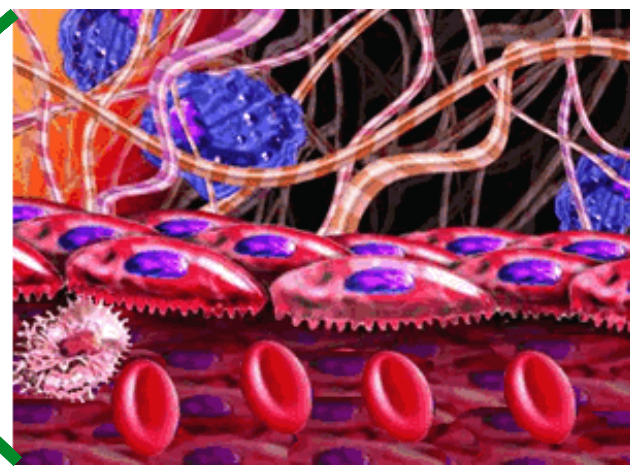
neural activity require energy



energy from glucose and oxygen



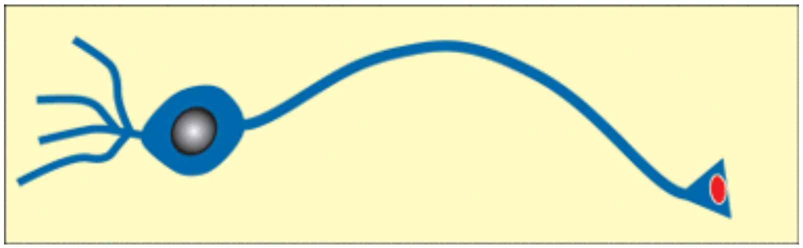
capillaries provide glucose and oxygen to neurons



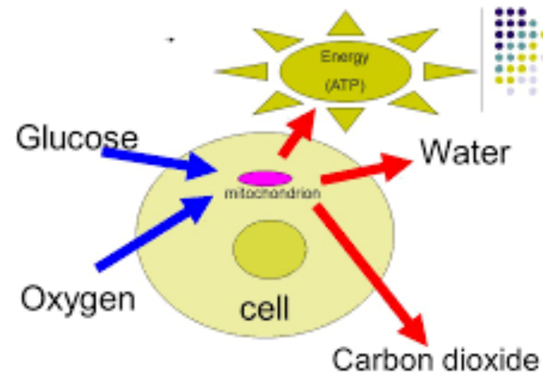
oxygen is carried by red blood cells

fMRI (functional MRI)

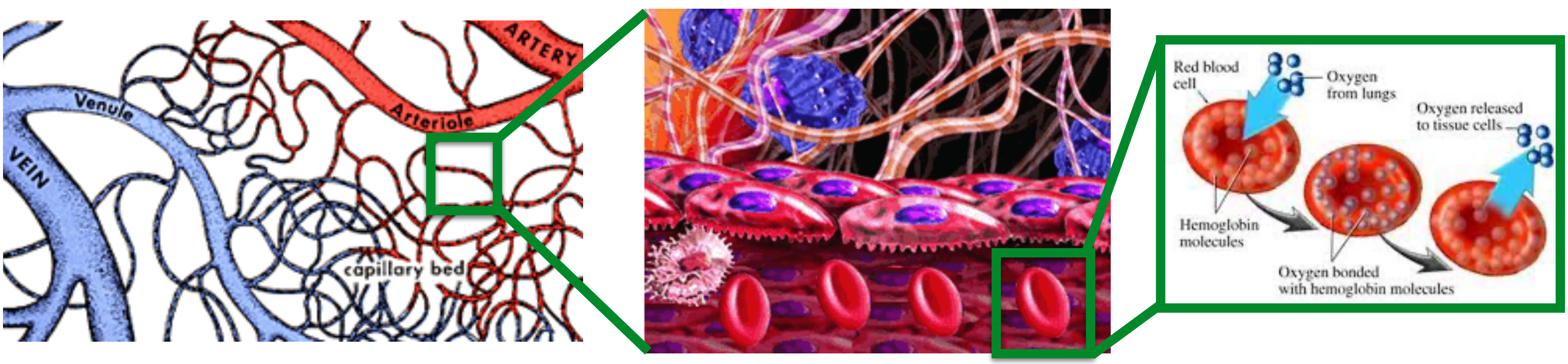
functional = brain activity



neural activity require energy



energy from glucose and oxygen

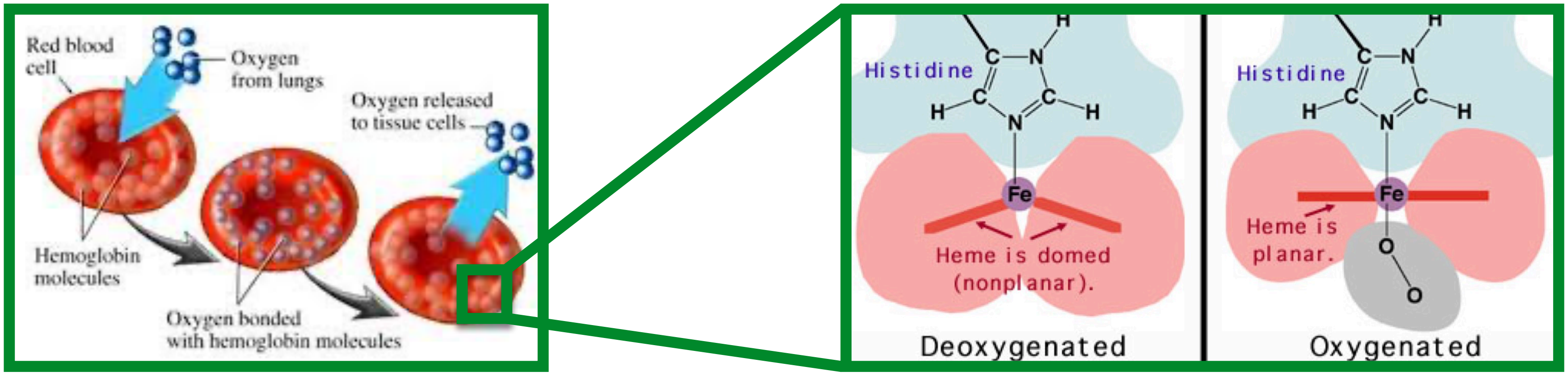


capillaries provide glucose and oxygen to neurons

oxygen is carried by red blood cells

oxygen is bound to hemoglobin

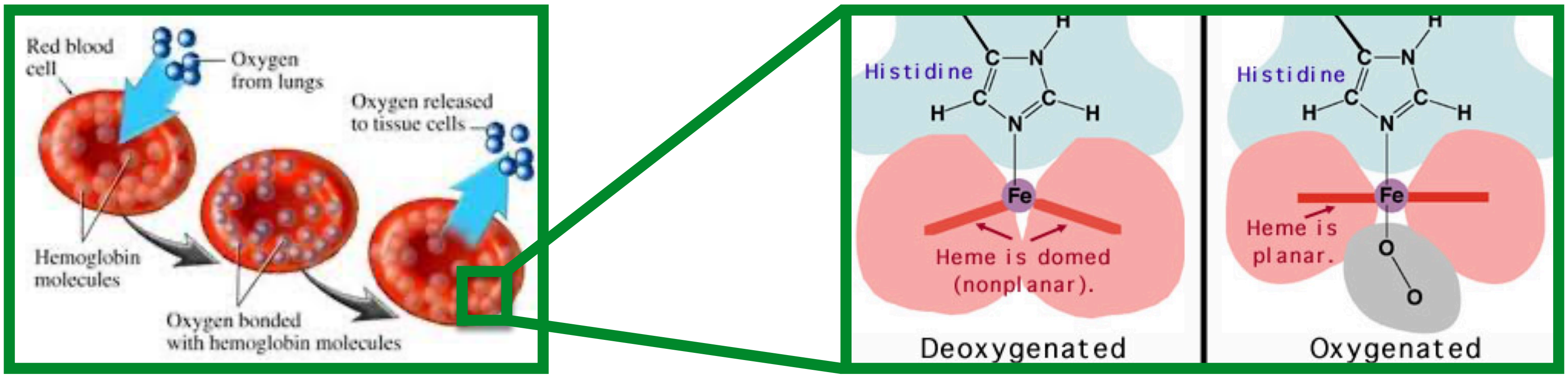
fMRI (functional MRI)



oxygen is bound to hemoglobin

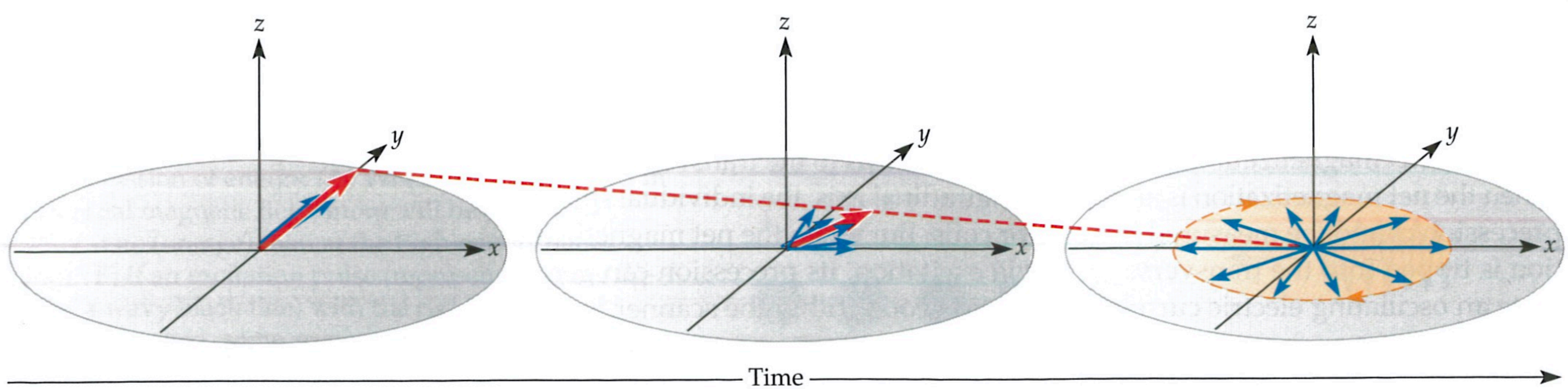
paramagnetic (magnetic properties)

fMRI (functional MRI)



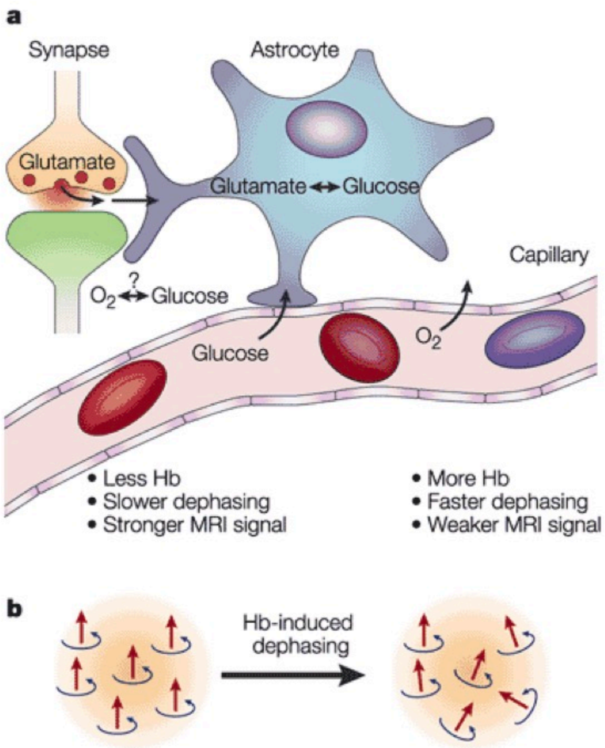
oxygen is bound to hemoglobin

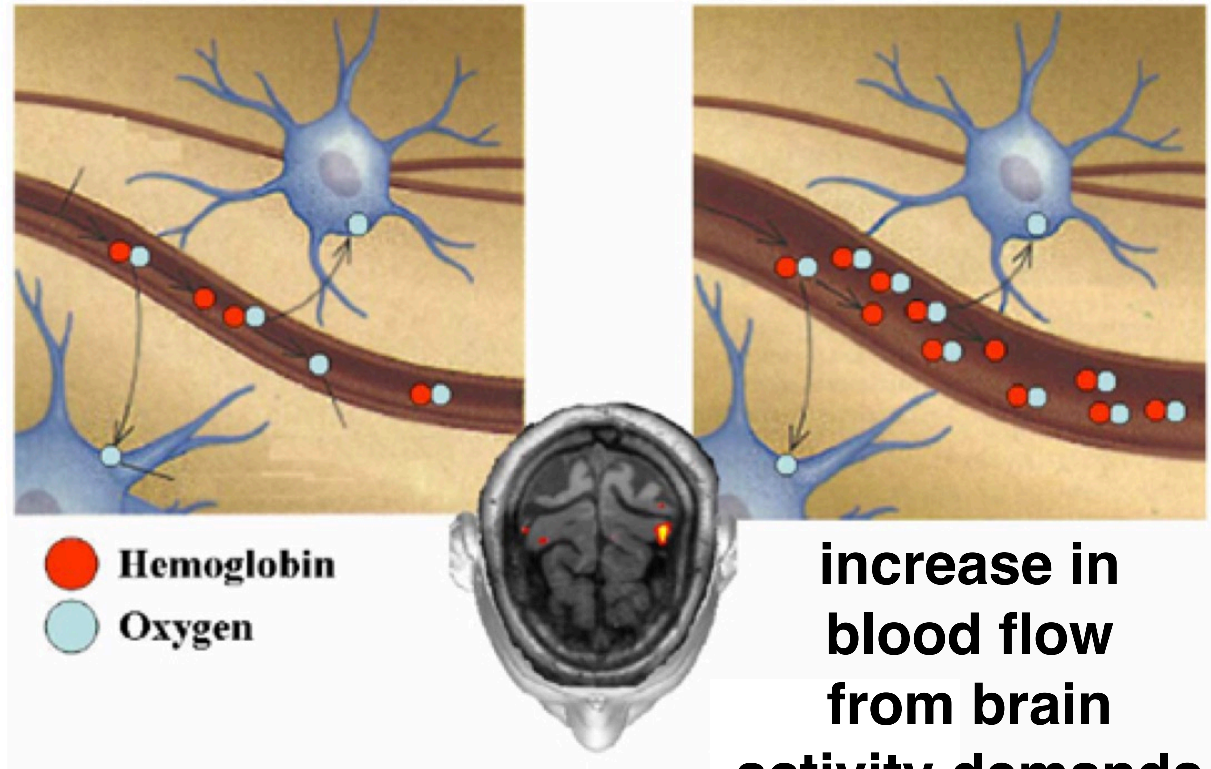
paramagnetic (magnetic properties)



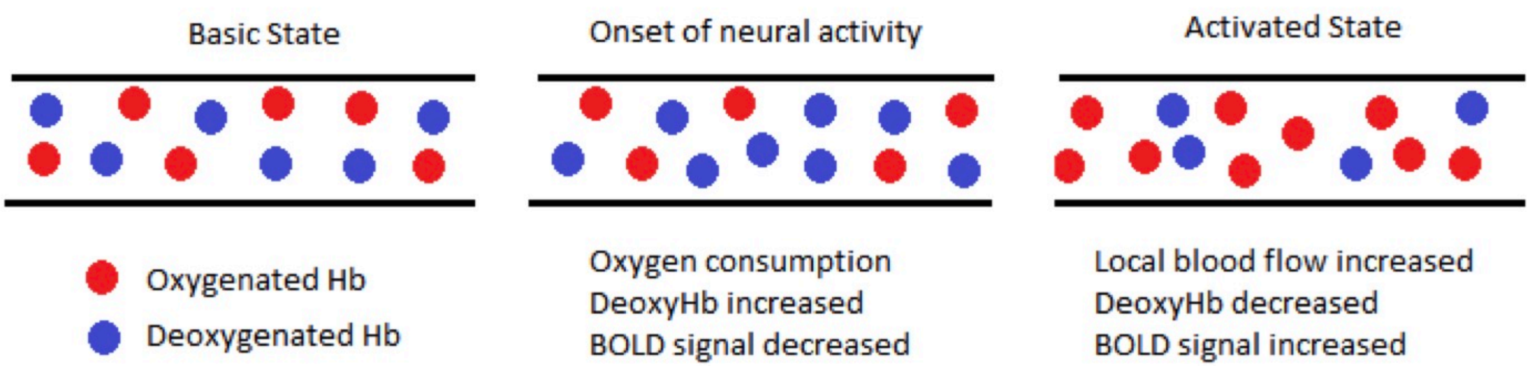
presence of deoxygenated hemoglobin affects local magnetic fields causing a more rapid T2 relaxation after an RF pulse

BOLD (Blood Oxygen Level Dependent) Response





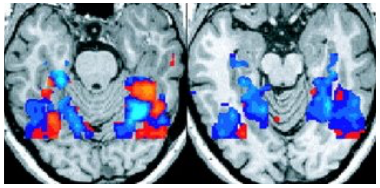
increase in blood flow from brain activity demands



initial increase in deoxy

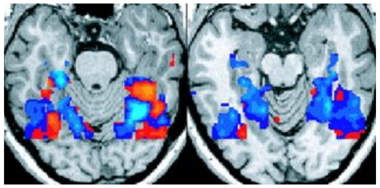
blood flow causes less deoxy

fMRI (functional MRI)

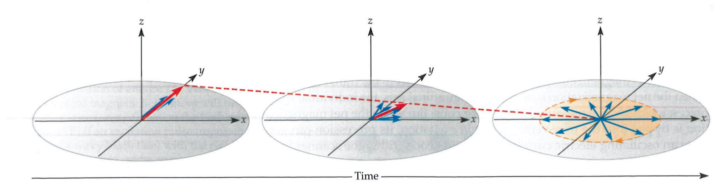


what does fMRI measure?

fMRI (functional MRI)

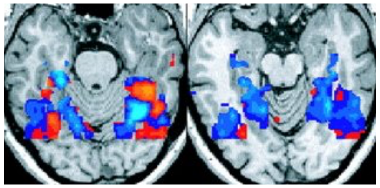


what does fMRI measure?

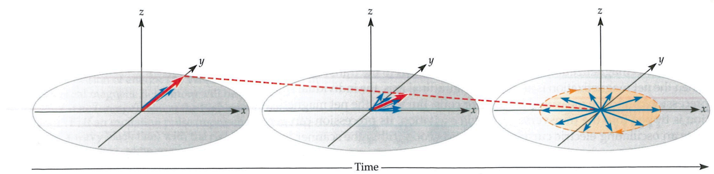


change in T2 relaxation of hydrogen protons

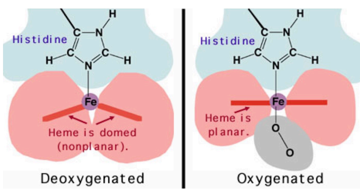
fMRI (functional MRI)



what does fMRI measure?

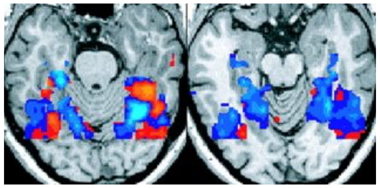


change in T2 relaxation of hydrogen protons

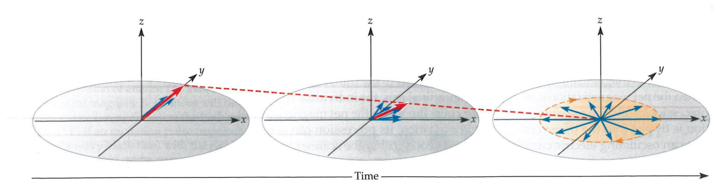


change in proportion of deoxy hemoglobin

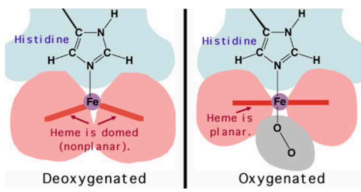
fMRI (functional MRI)



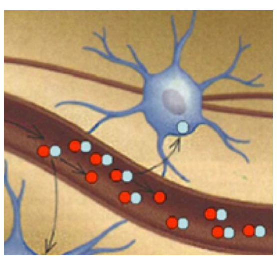
what does fMRI measure?



change in T2 relaxation of hydrogen protons

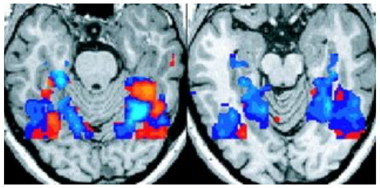


change in proportion of deoxy hemoglobin

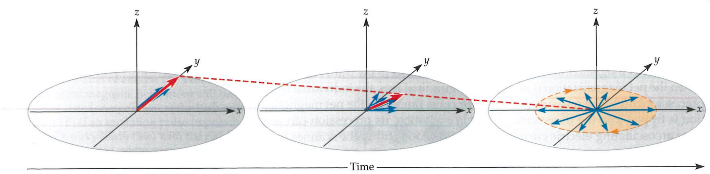


local change in blood flow

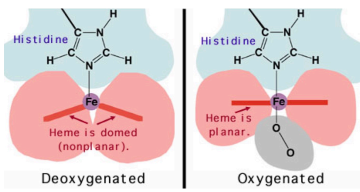
fMRI (functional MRI)



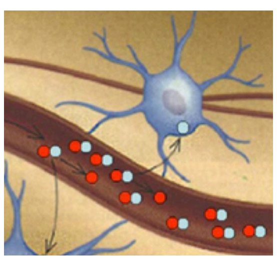
what does fMRI measure?



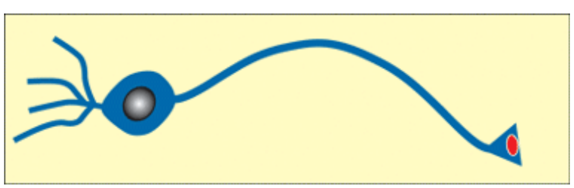
change in T2 relaxation of hydrogen protons



change in proportion of deoxy hemoglobin



local change in blood flow



local change neural activity

fMRI (functional MRI)

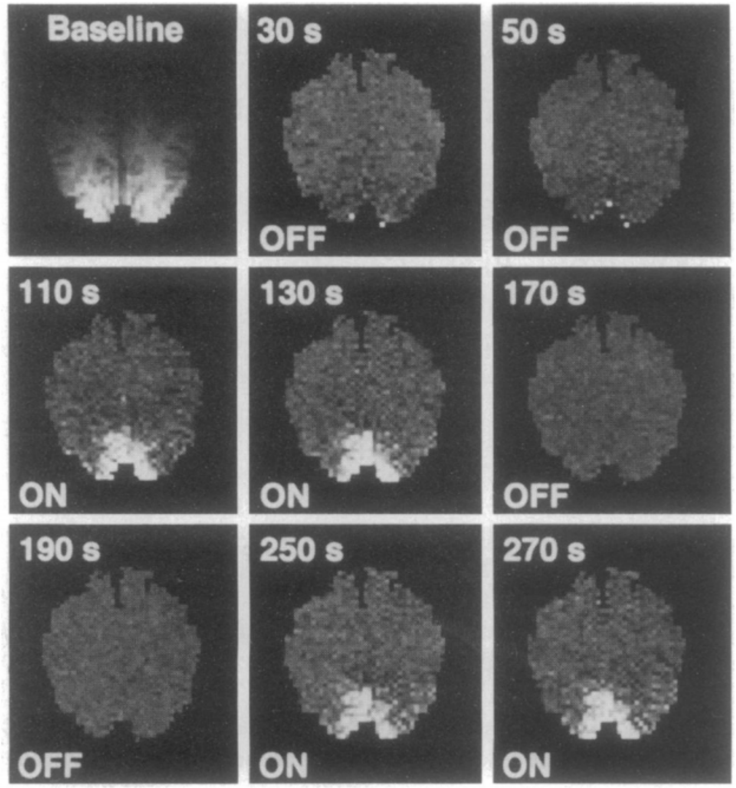
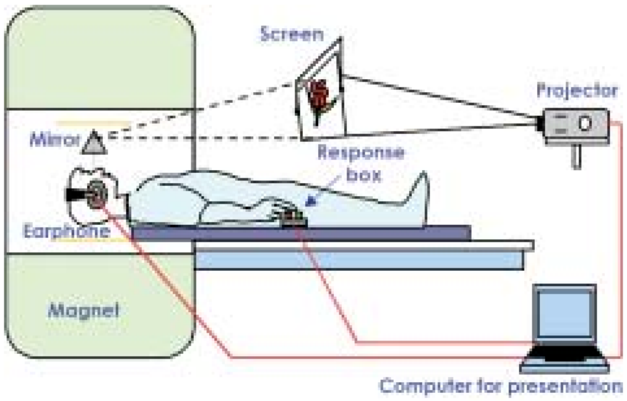


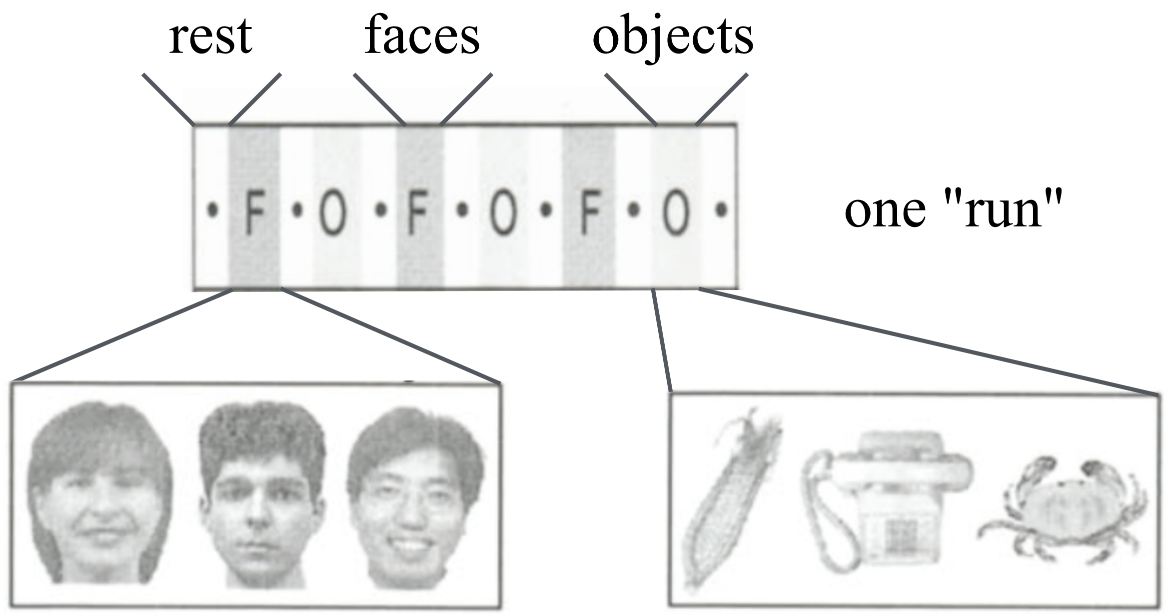
FIG. 1. Noninvasive, real-time MRI mapping of V1 activation during visual stimulation. Images are obliquely aligned along the calcarine fissures with the occipital pole at the bottom. Images were acquired at 3.5-s intervals using an IR sequence (80 images total). A baseline image acquired during darkness (*Upper Left*) was subtracted from subsequent images. Eight of these subtraction images are displayed, chosen when the image intensities (see Fig. 2) reached a steady-state signal level, during darkness (OFF) and during 8-Hz photic stimulation (ON). During stimulation, local increases in signal intensity are detected in the medial–posterior regions of the occipital lobes along the calcarine fissures.

first functional brain image without use of injected contrast agents, Kwong et al. 1992, PNAS*

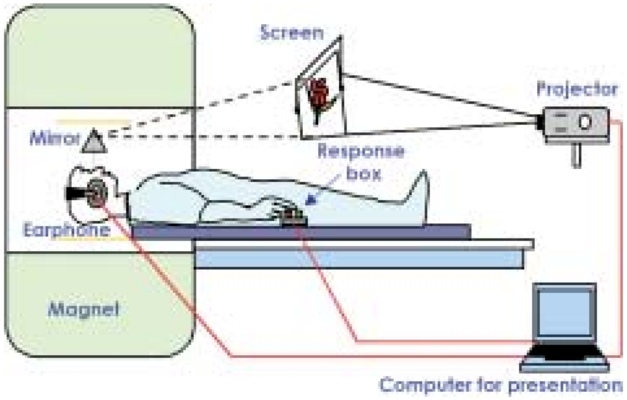
*rejected by *Nature* because a paper with fMRI with injected contrast agents had just appeared in *Science*

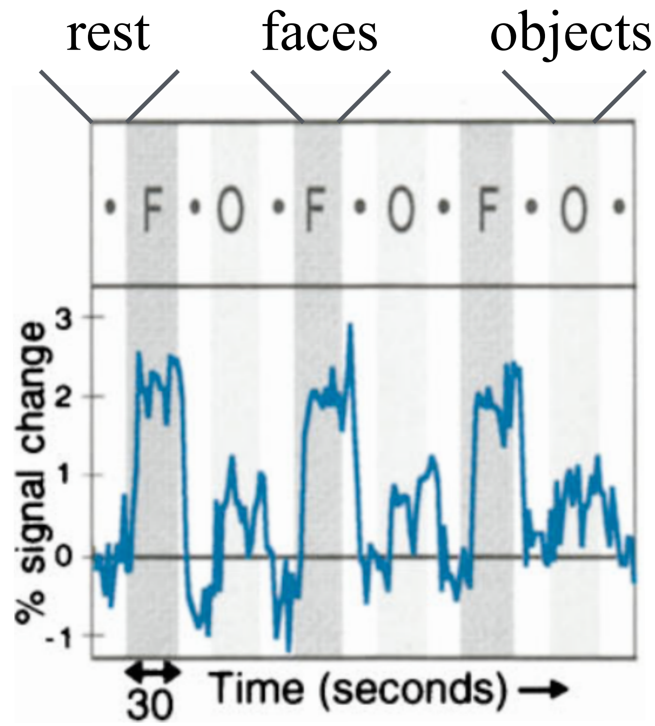
"blocked design" with fMRI



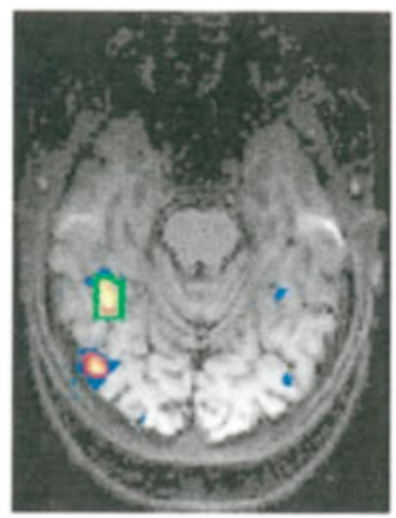


"blocked design" with fMRI





one "run"

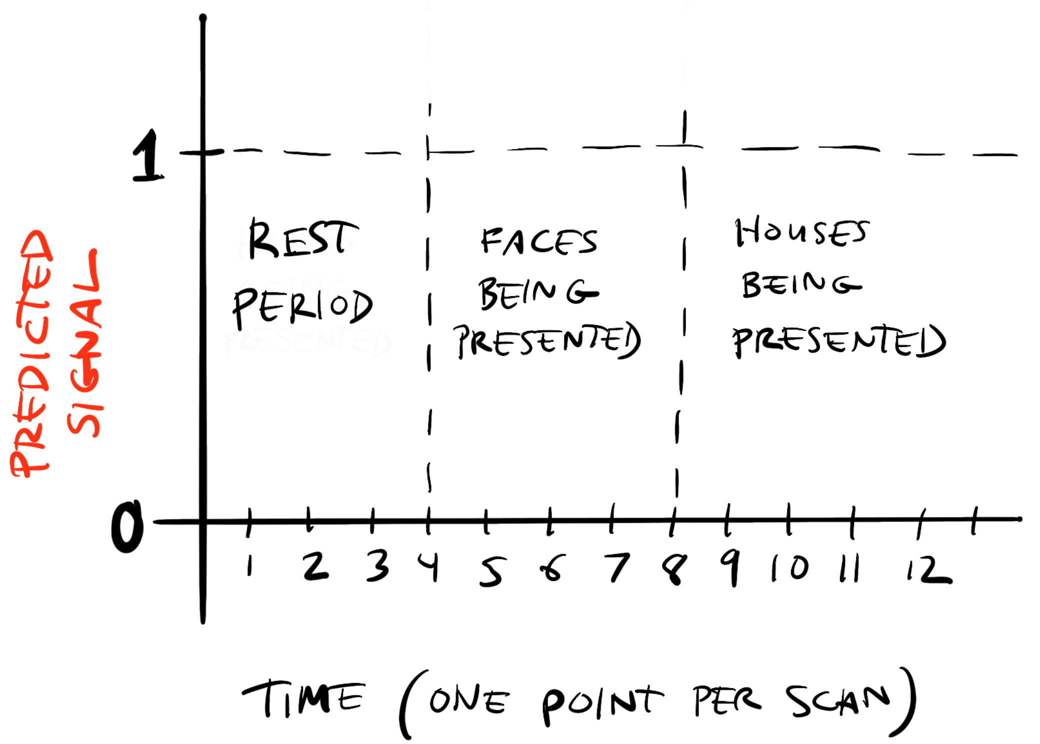


FFA (fusiform face area)

Kanwisher et al. 1997

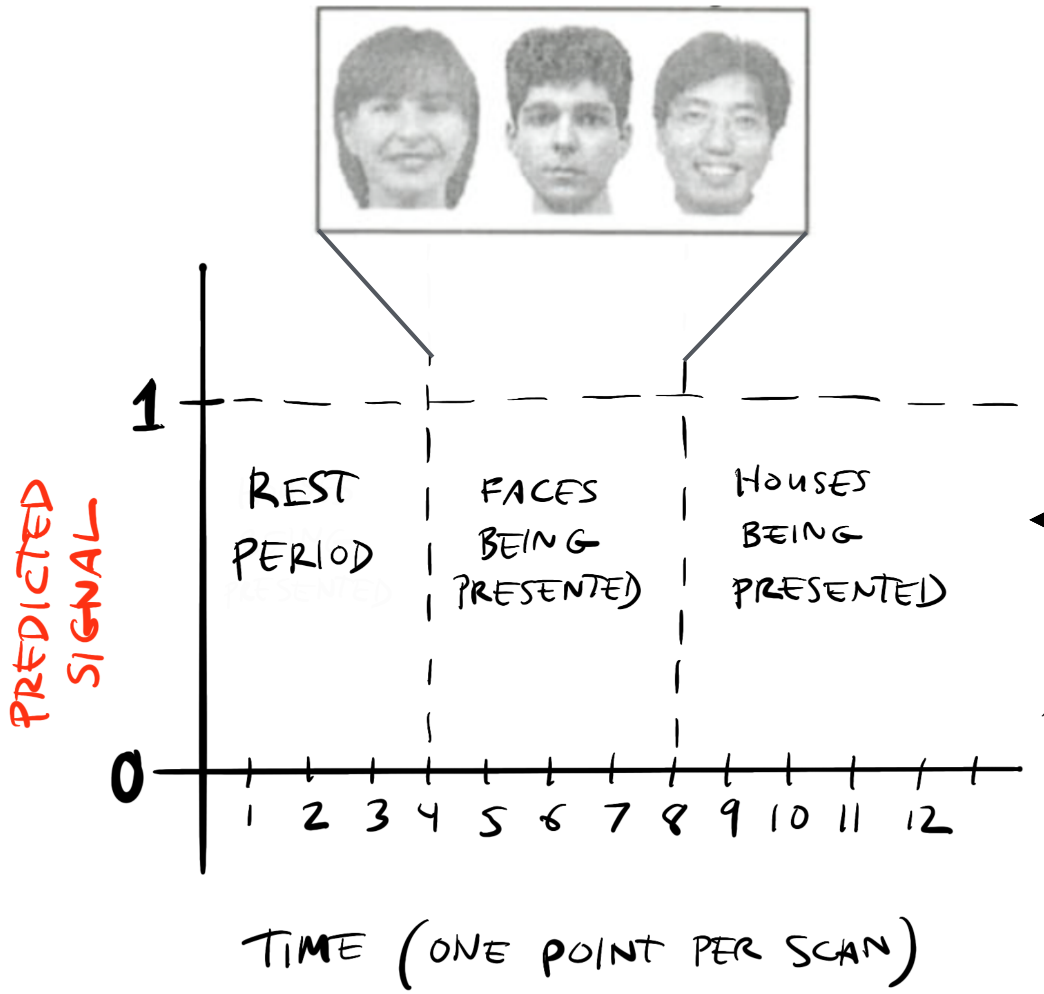
"blocked design" with fMRI

how are data typically analyzed?



"blocked design" with fMRI

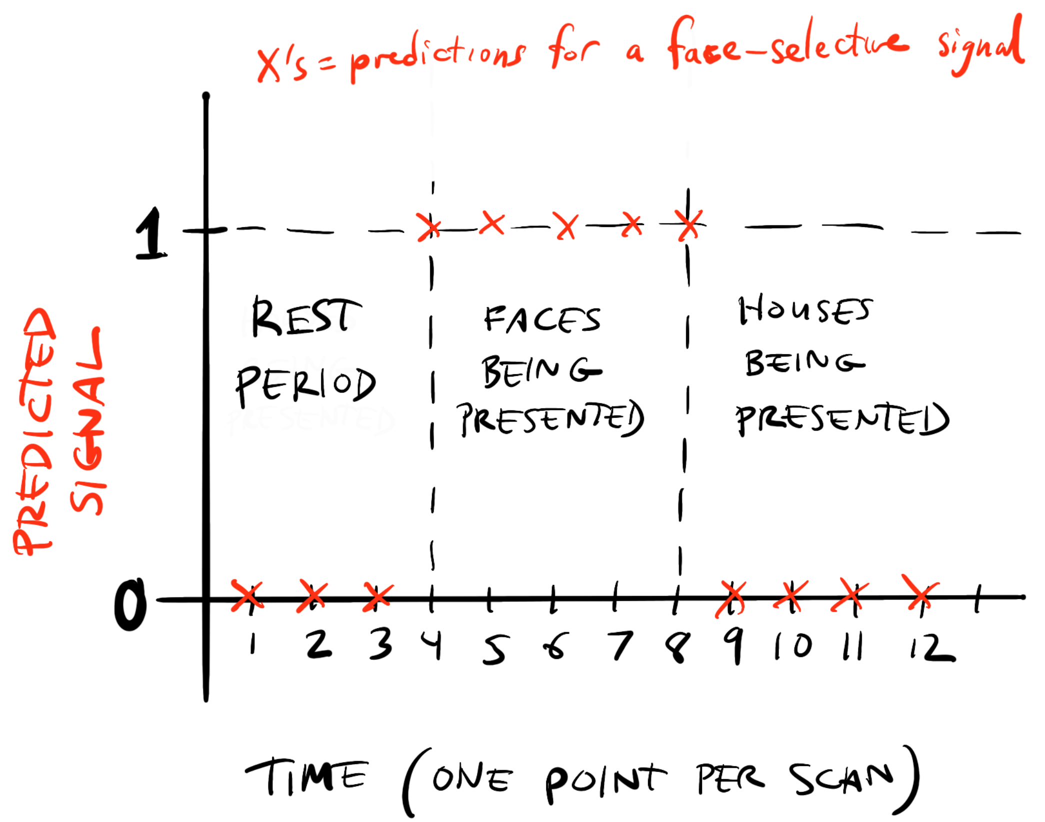
how are data typically analyzed?



this example used houses instead of objects

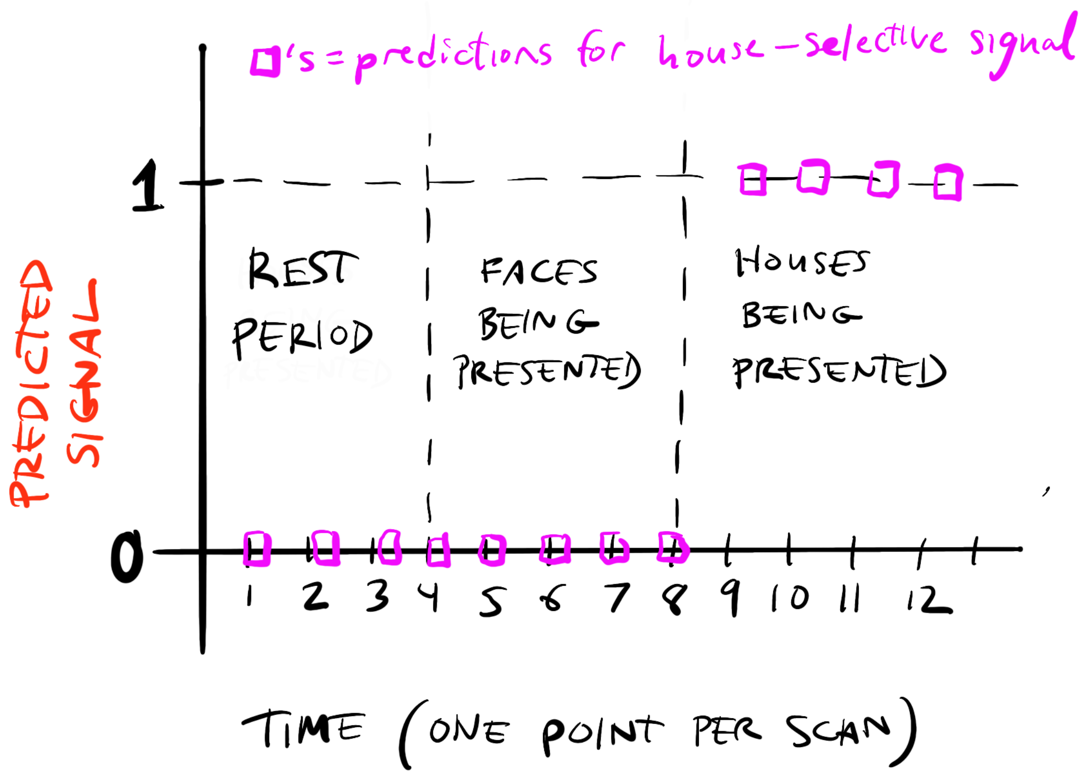
"blocked design" with fMRI

how are data typically analyzed?



"blocked design" with fMRI

how are data typically analyzed?



"blocked design" with fMRI

how are data typically analyzed?

y *is predicted fMRI response*

```
y = β0 + β1*face + β2*house + noise
```