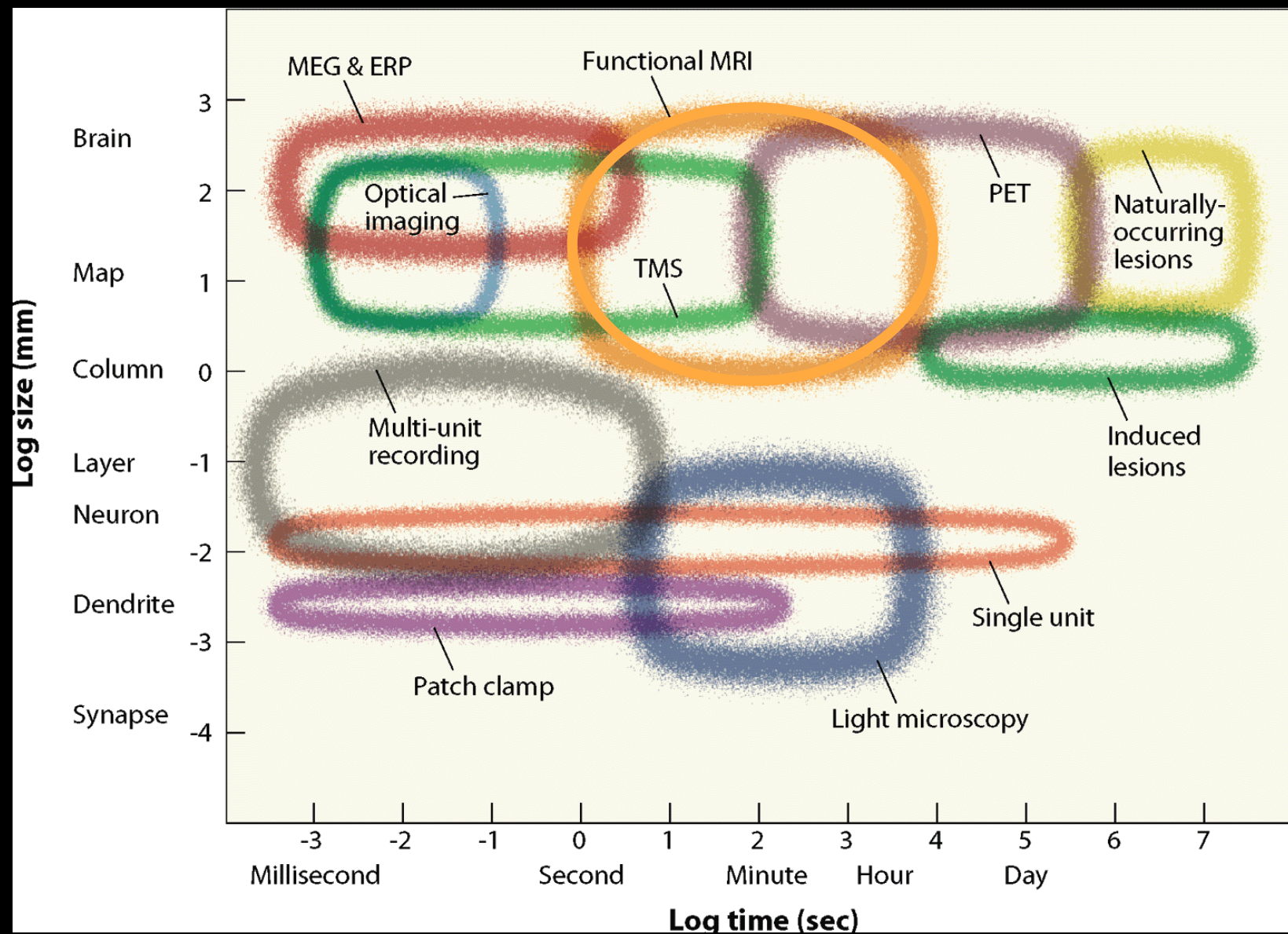


Beyond fMRI...

Joe Kable

Summer Workshop on Decision Neuroscience

August 21, 2009

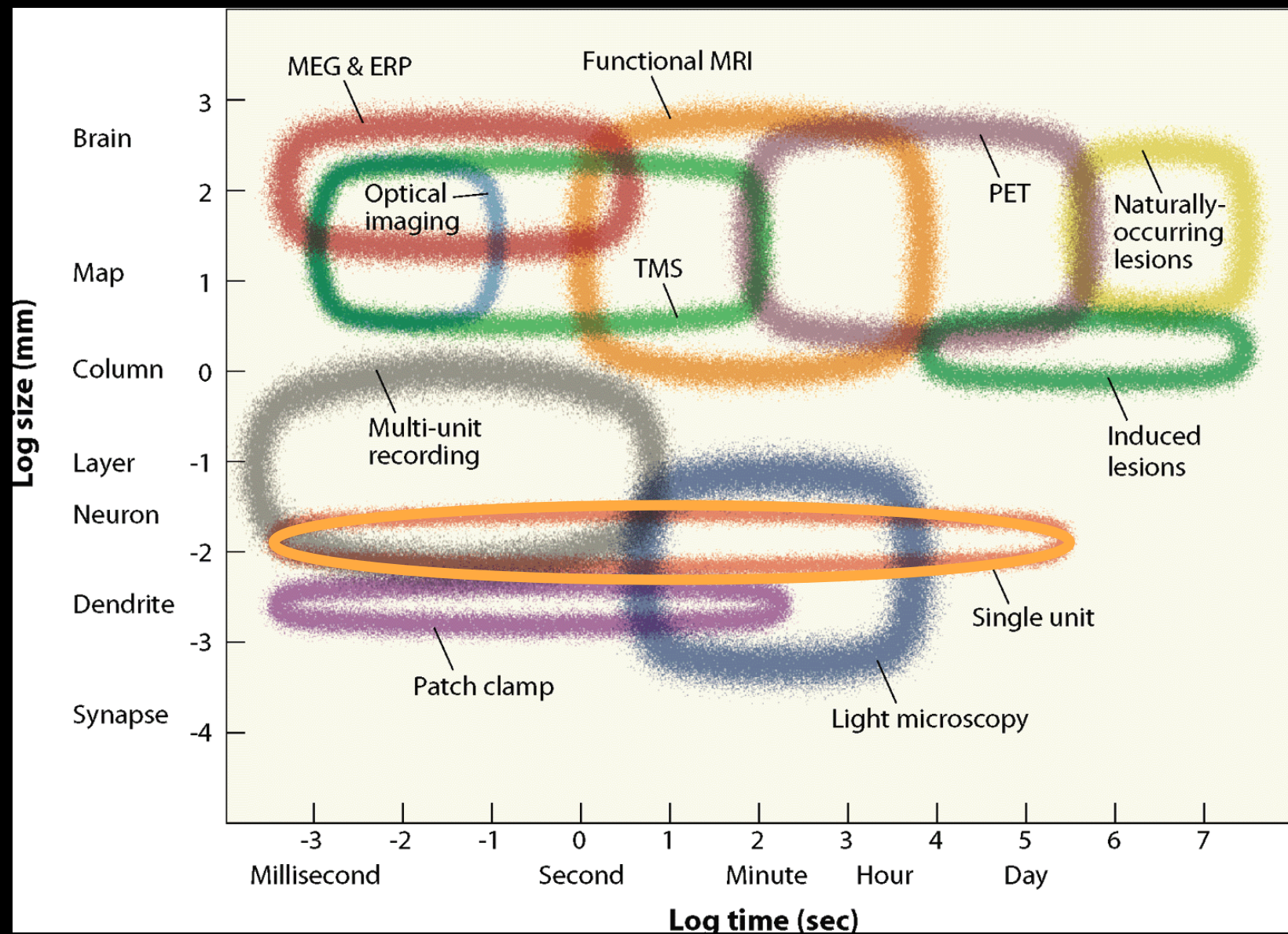


What are the strengths of fMRI?

- Noninvasive, safe
- Can be done in humans
- Verified correlate of neural activity
- Great spatio-temporal resolution
- Widely available
- Relatively easy to get started (compared to other neuroscience techniques)

What are the weakness of fMRI?

- What it measures (i.e., blood flow):
 - » Blood flow is an indirect measure of neural activity
 - » Could measure electrical or chemical activity more directly
 - » Could have better *spatial* or *temporal* resolution
- *Correlation* is not *causation*:
 - » fMRI only tells you that a region is *active* during a process, not that it is *necessary* for a process.
 - » Where possible, would like to have both *necessity* and *sufficiency* studies as well

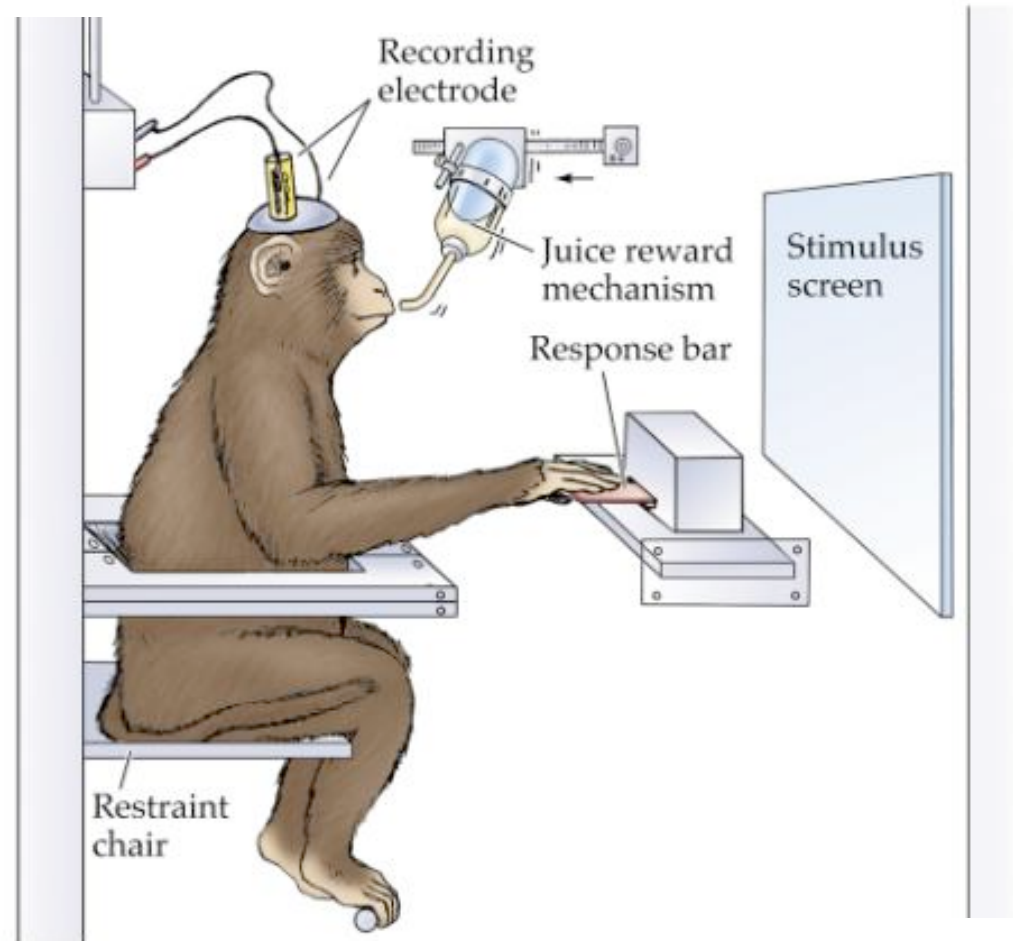


Neurophysiological Experiments

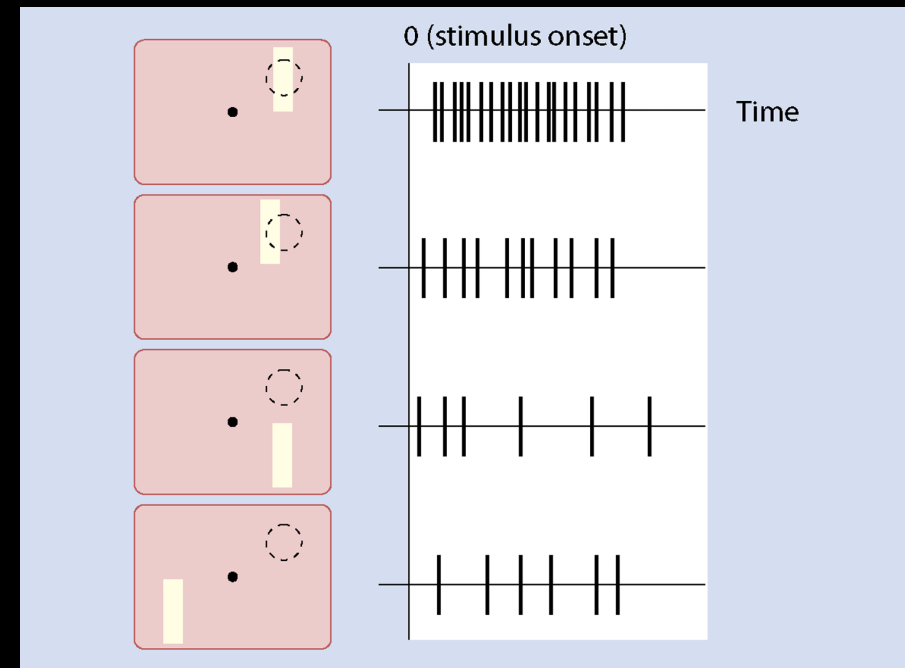
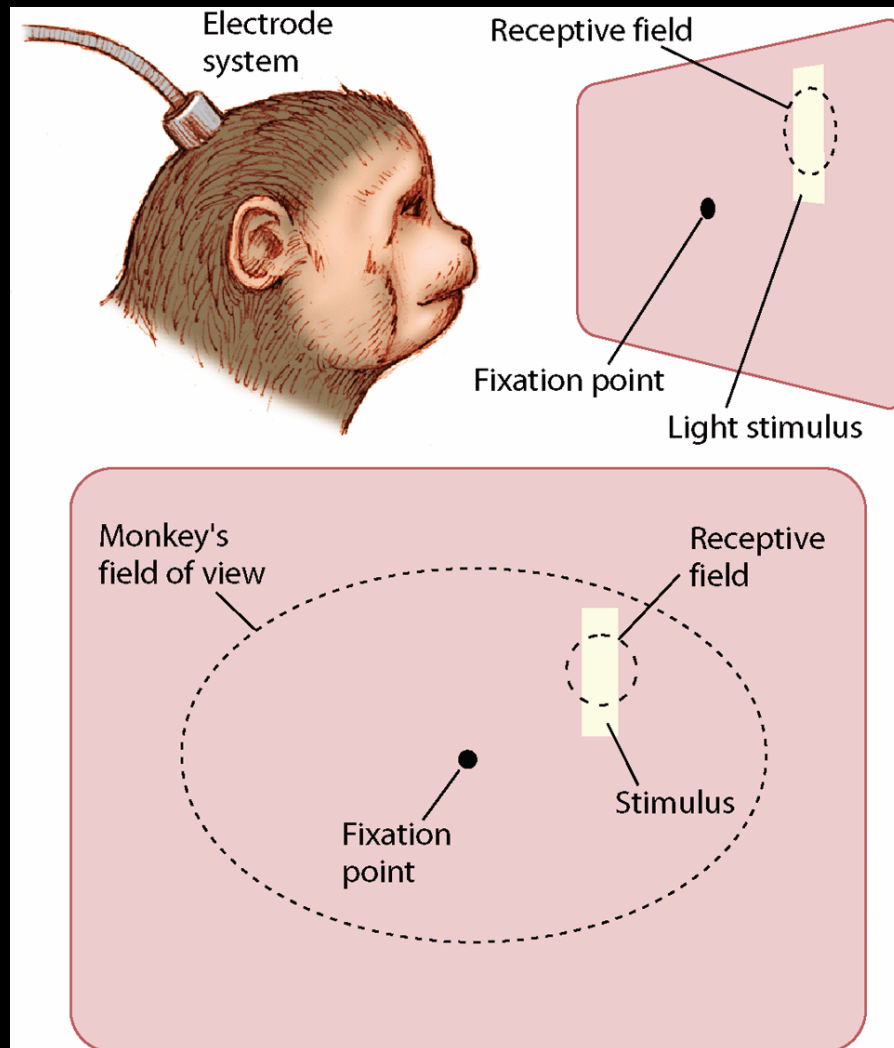
Measures response properties of single cells

- » thin electrode inserted into animal's brain
- » If electrode near neuronal membrane, measure electrical activity
- » Record intracellularly (difficult, can damage cell) or extracellularly (more typical; activity reflects responses of a set of neurons)
- » Determine experimental manipulations that change the cell's response (e.g. increase above baseline firing rate)

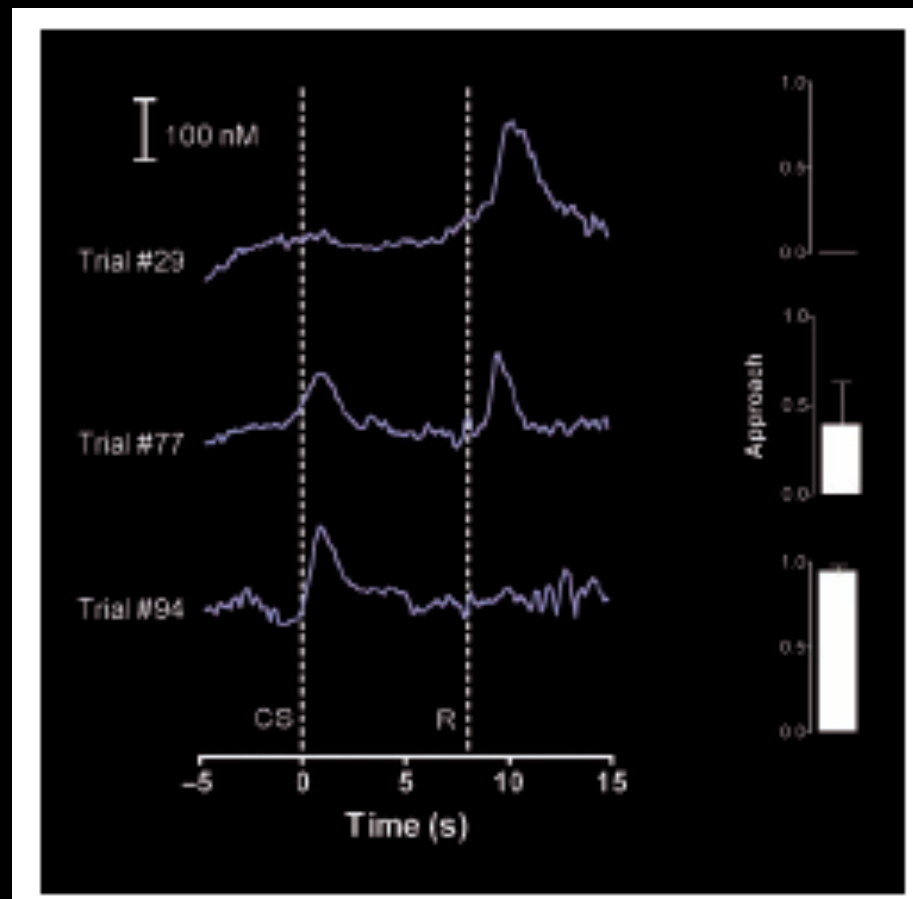




Receptive Field

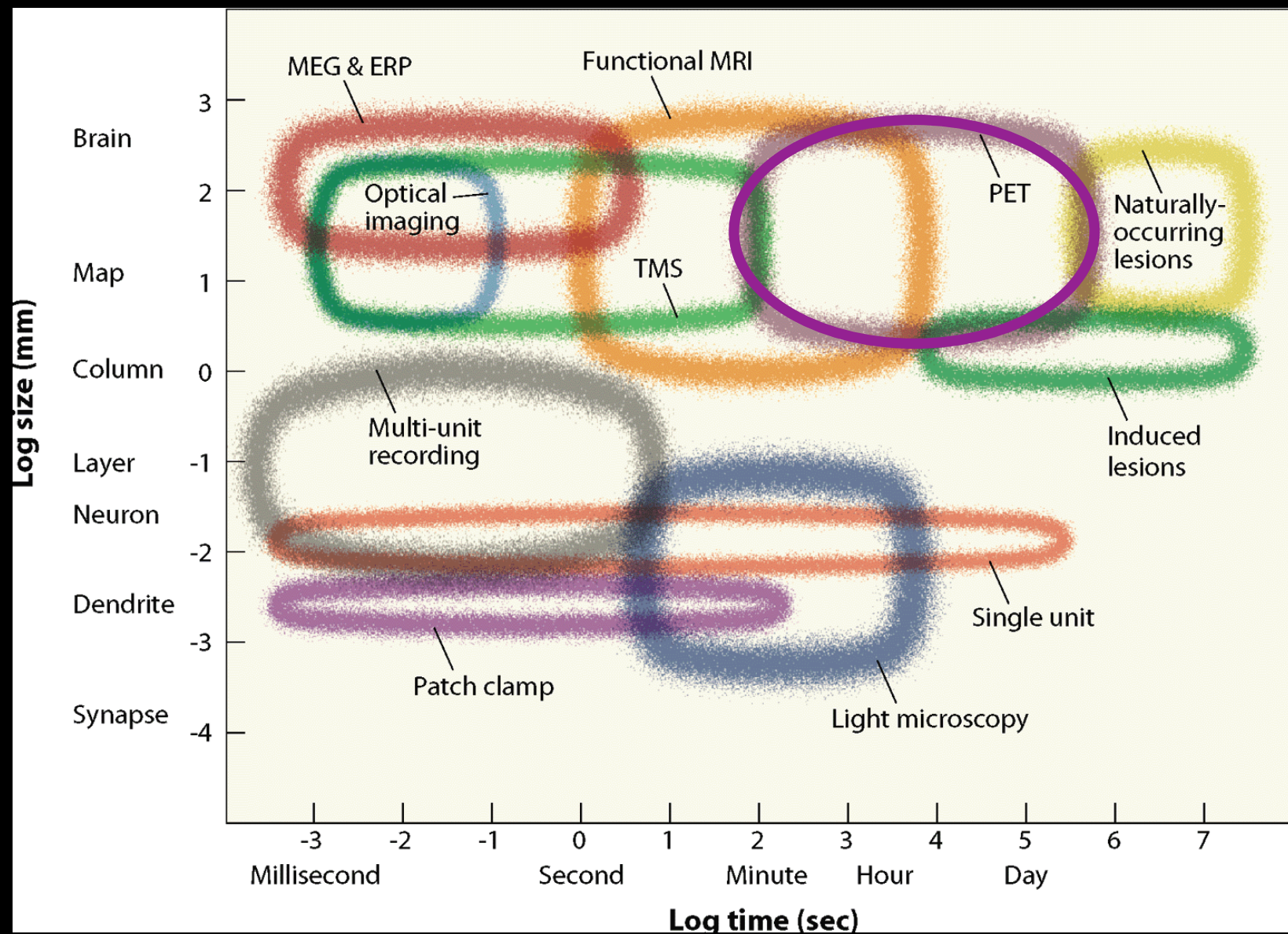


Electrochemical Measurements of Dopamine Release

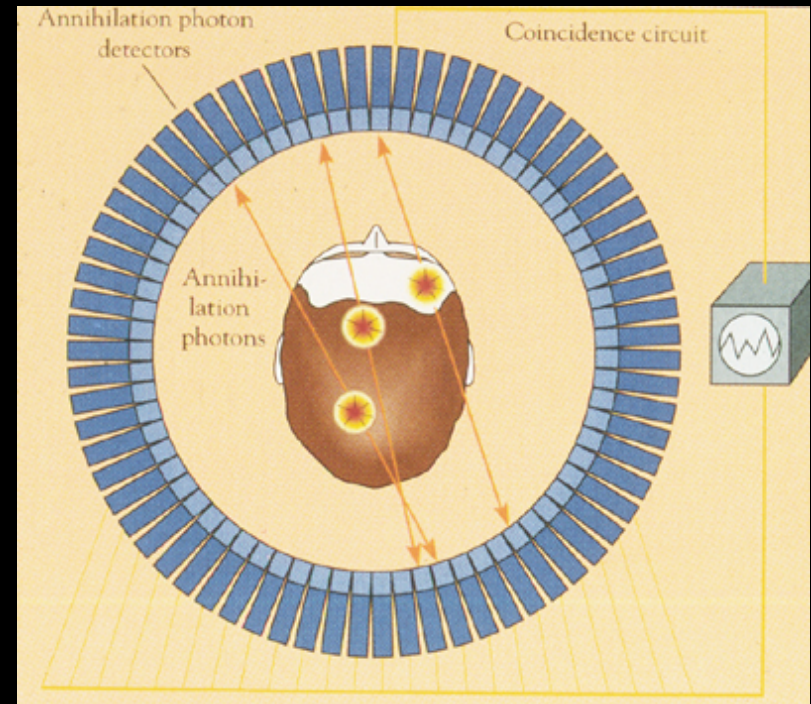


Neurophysiological Experiments:

- Pluses:
 - » Can examine neuronal responses at the level of the single cell – “Gold Standard”
 - » Best spatial and temporal resolution achievable
- Minuses:
 - » Cannot look over large regions – understanding the brain “one cell at a time”
 - » Animals take a long time to train, and they don’t have some abilities that we might want to study (e.g. language).

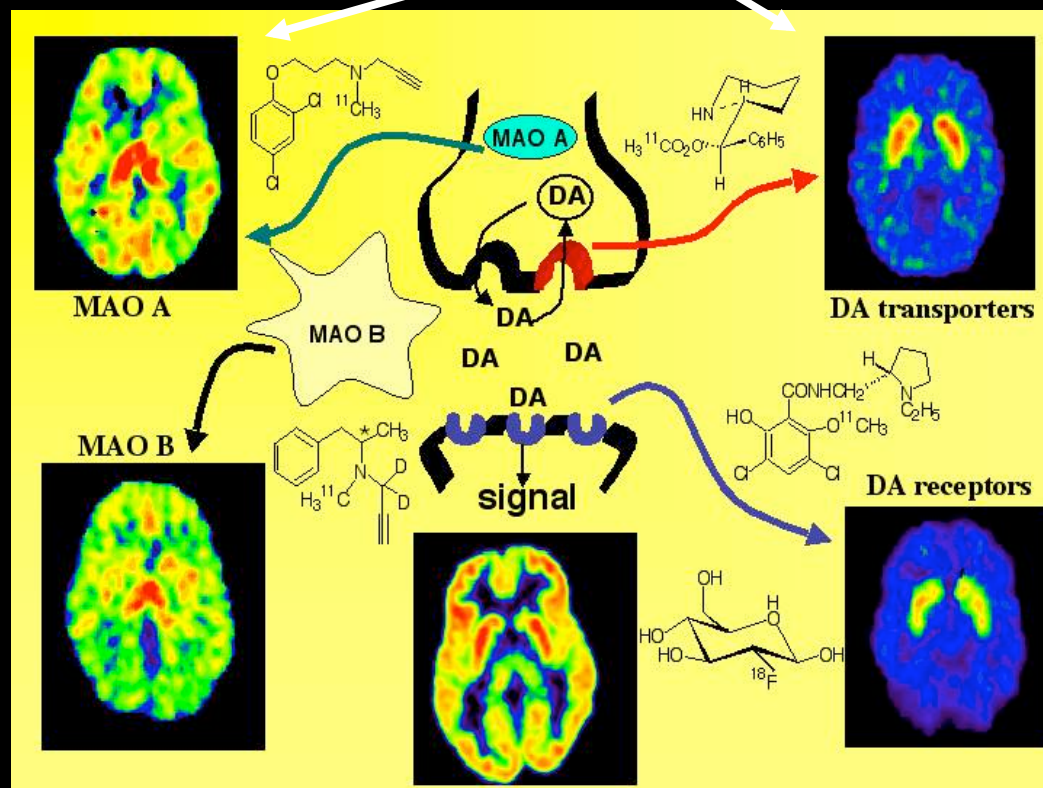


PET (Positron Emission Tomography)



PET: Specific Tracers

Neurotransmitter maps (using ^{11}C)

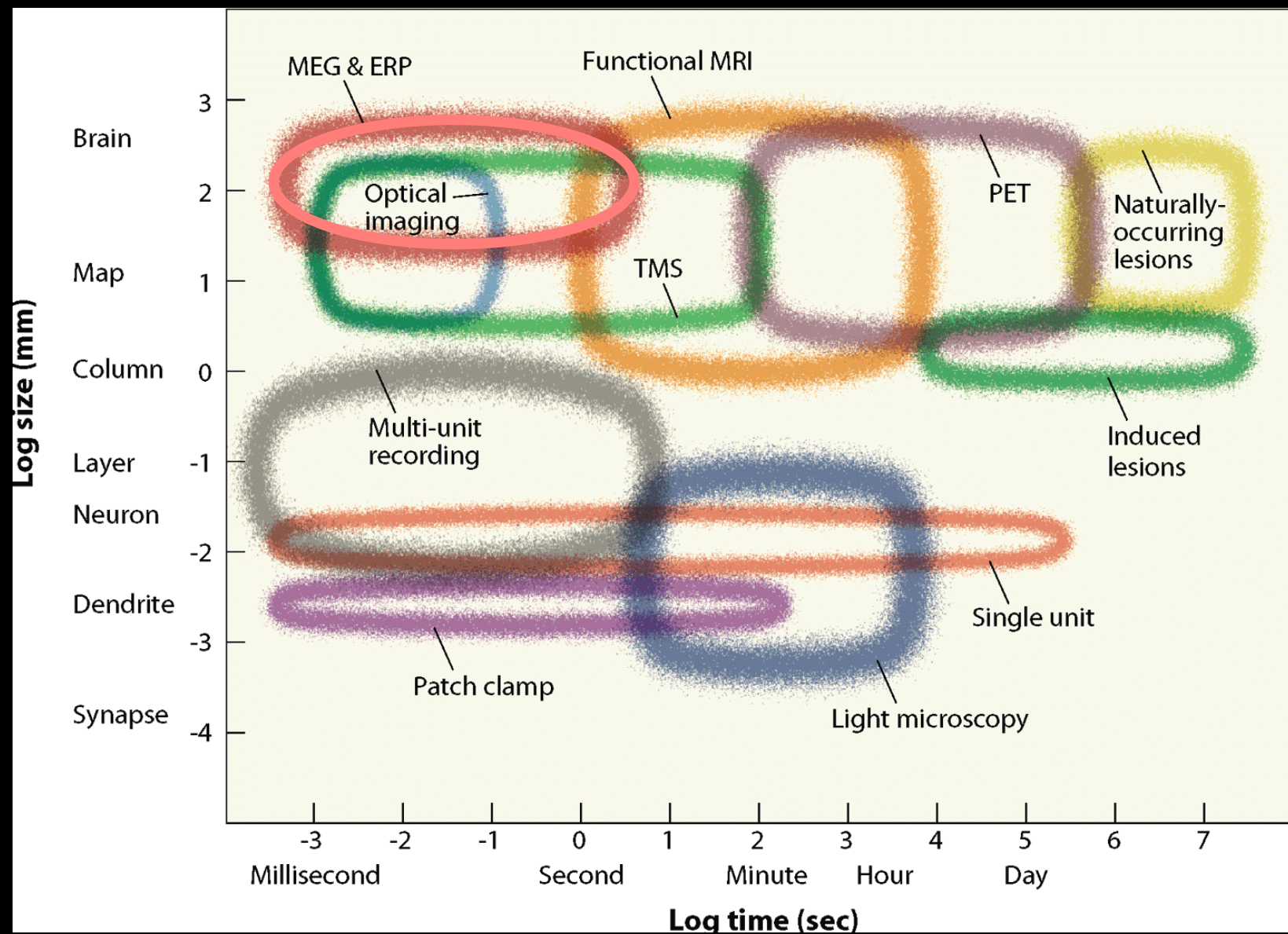


<http://www.bnl.gov/pet/>

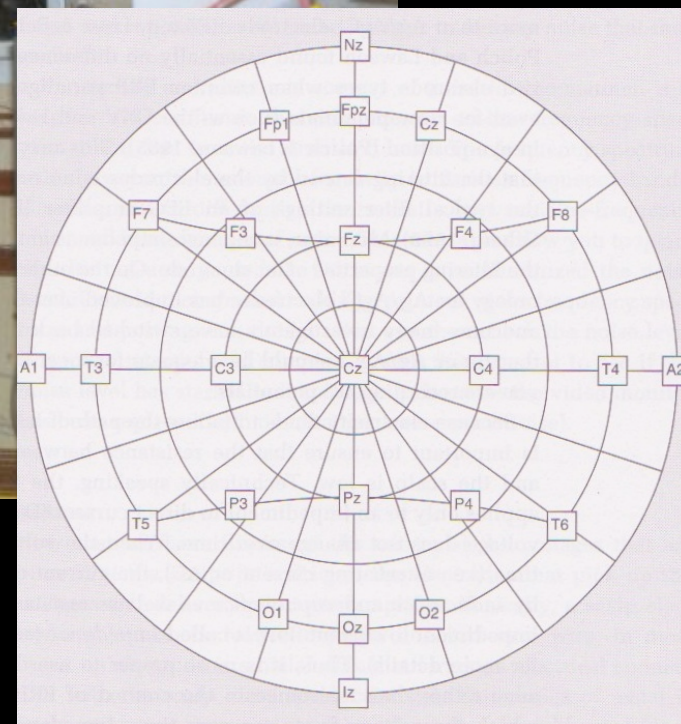
 ^{18}F FDG map (glucose consumption)

PET:

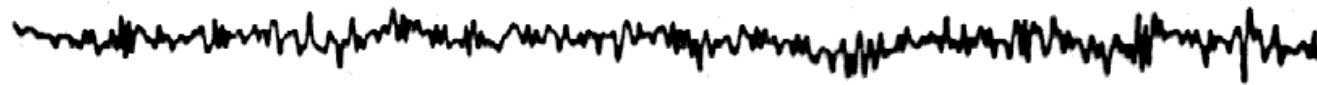
- Pluses:
 - » Can obtain absolute measures of blood flow and cerebral metabolism
 - » Can obtain maps of many other functions (neurotransmitter receptors, transporters, etc.)
- Minuses:
 - » Poorer spatiotemporal resolution compared to fMRI
 - » Involves radioactivity, expensive



Electroencephalograph (EEG)

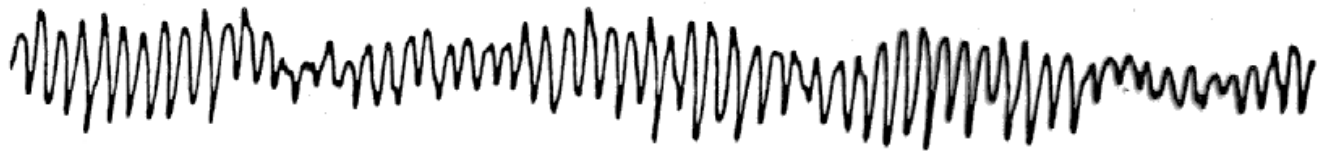


aroused



I

relaxed



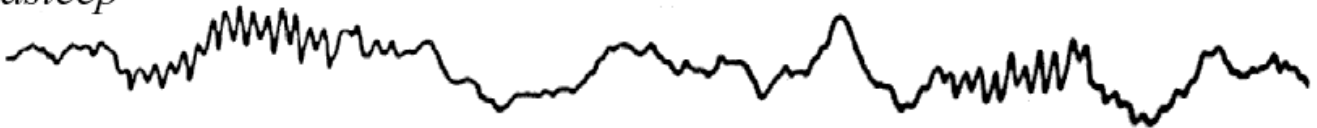
I

sleepy



I

asleep



I

deep sleep

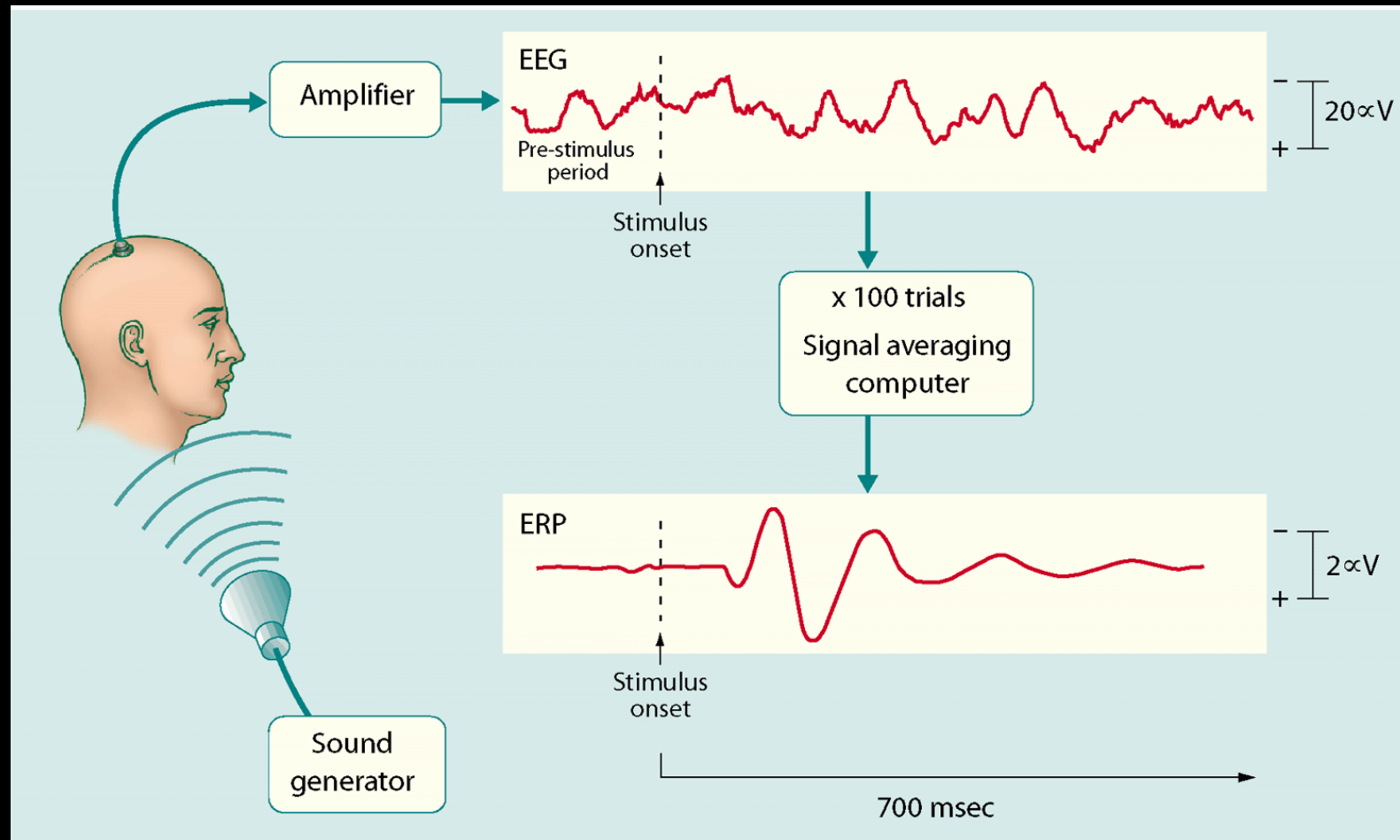


I

50 μ V

1 sec

ERP (Event-Related Potential)

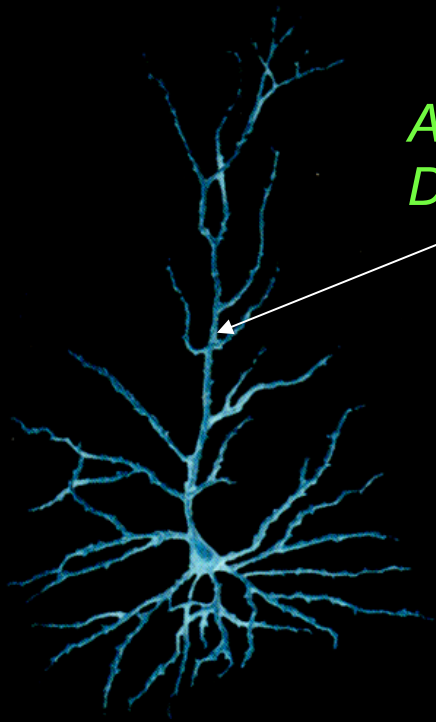


EEG: Raw time course

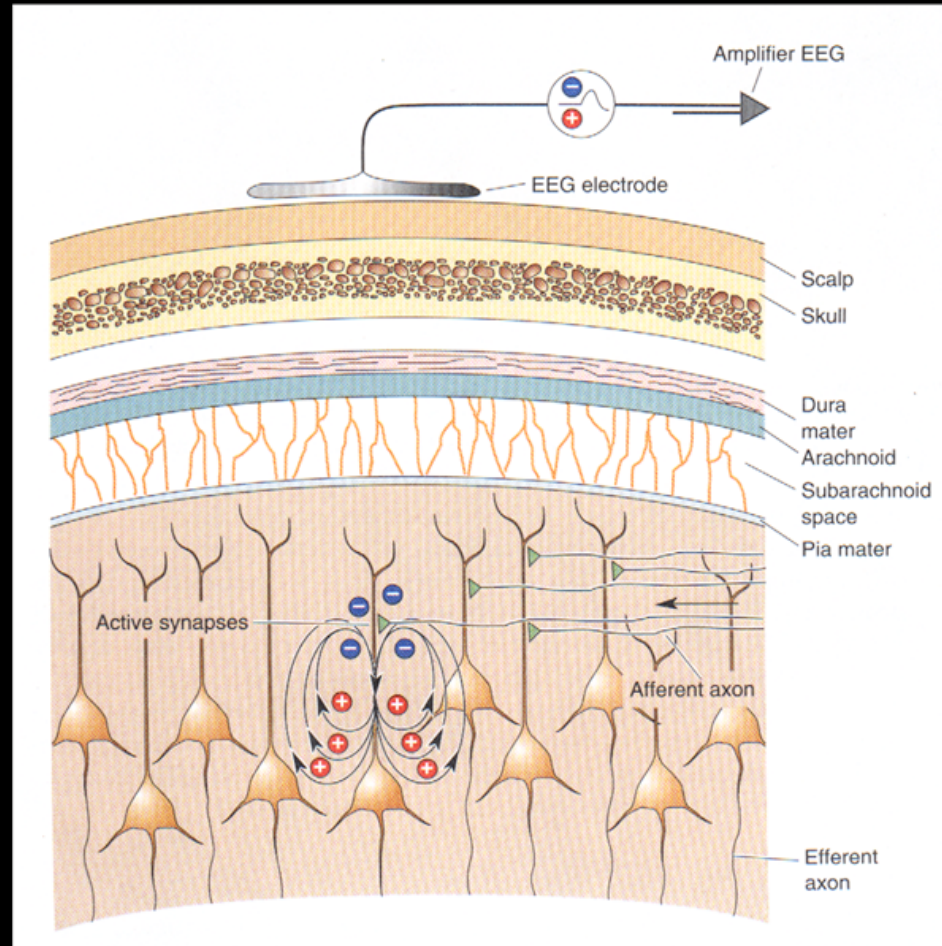
ERP: Average time course of response to an event

What generates the EEG signal?

Pyramidal Cell

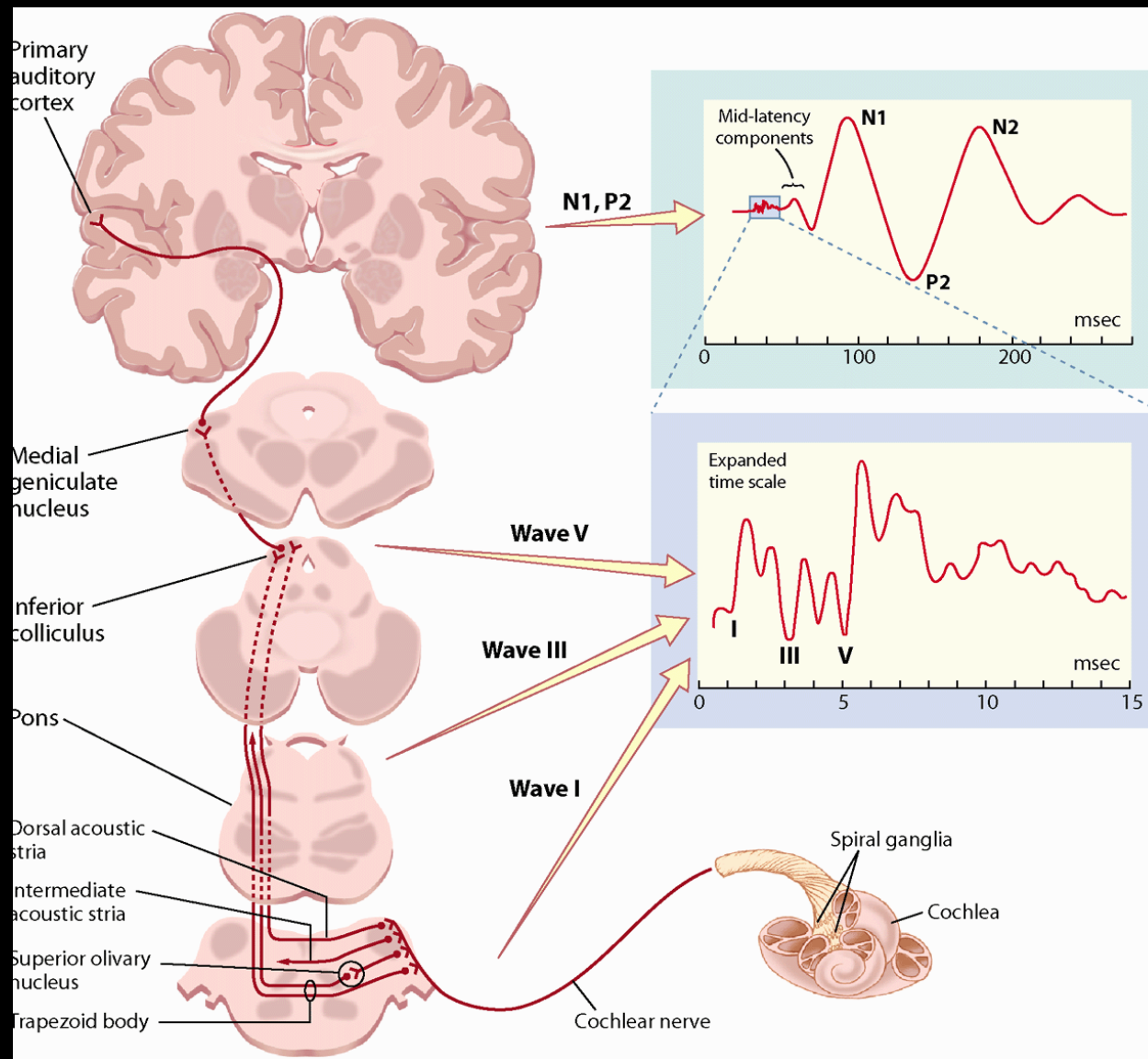


Apical Dendrite

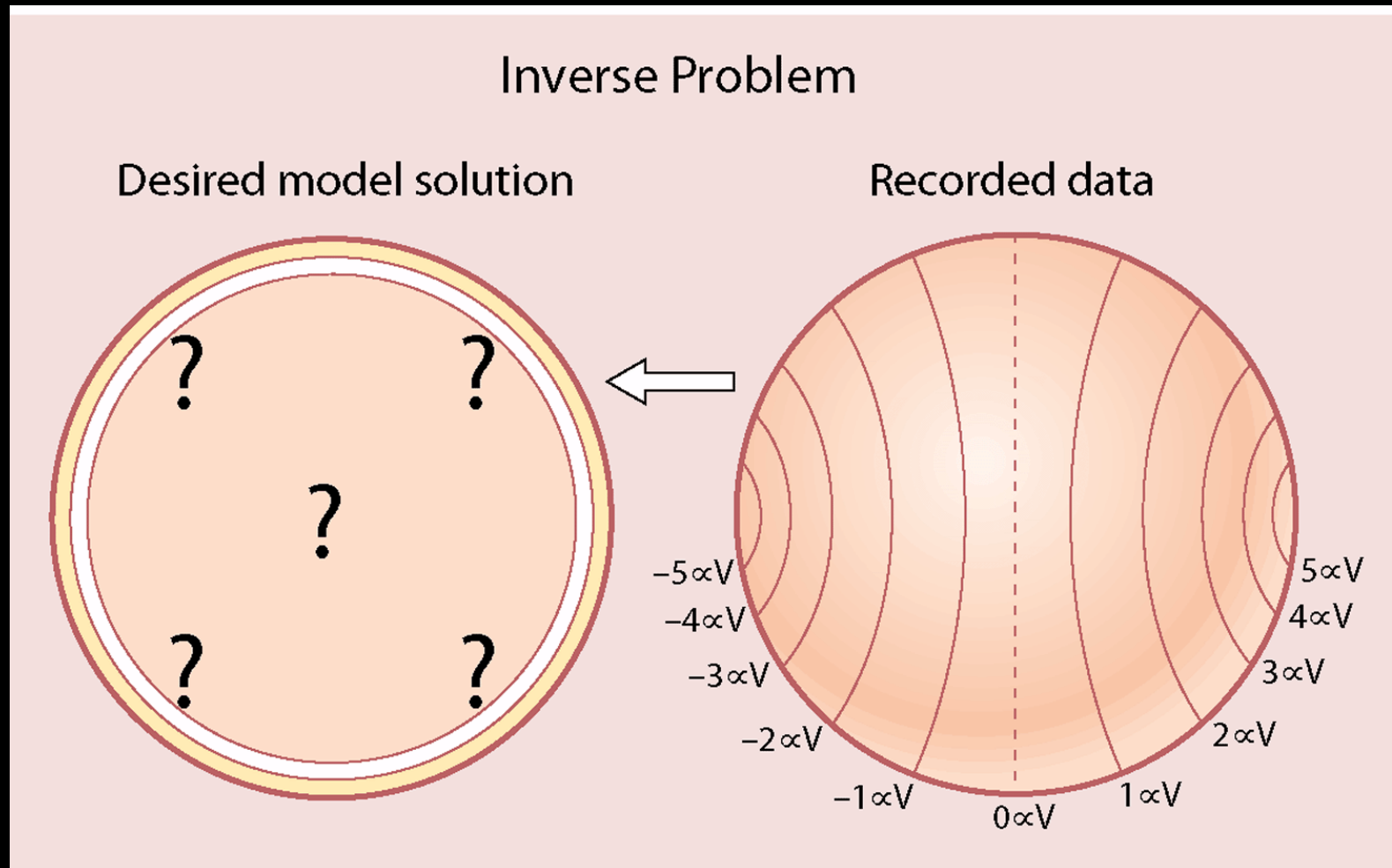


When a sizable number of Pyramidal neurons are oriented parallel to each other and fire in synchrony, they produce a voltage differential known as a dipole, which can be measured on the cortical surface.

ERP allows measurement of the timing of neural firing with millisecond precision:

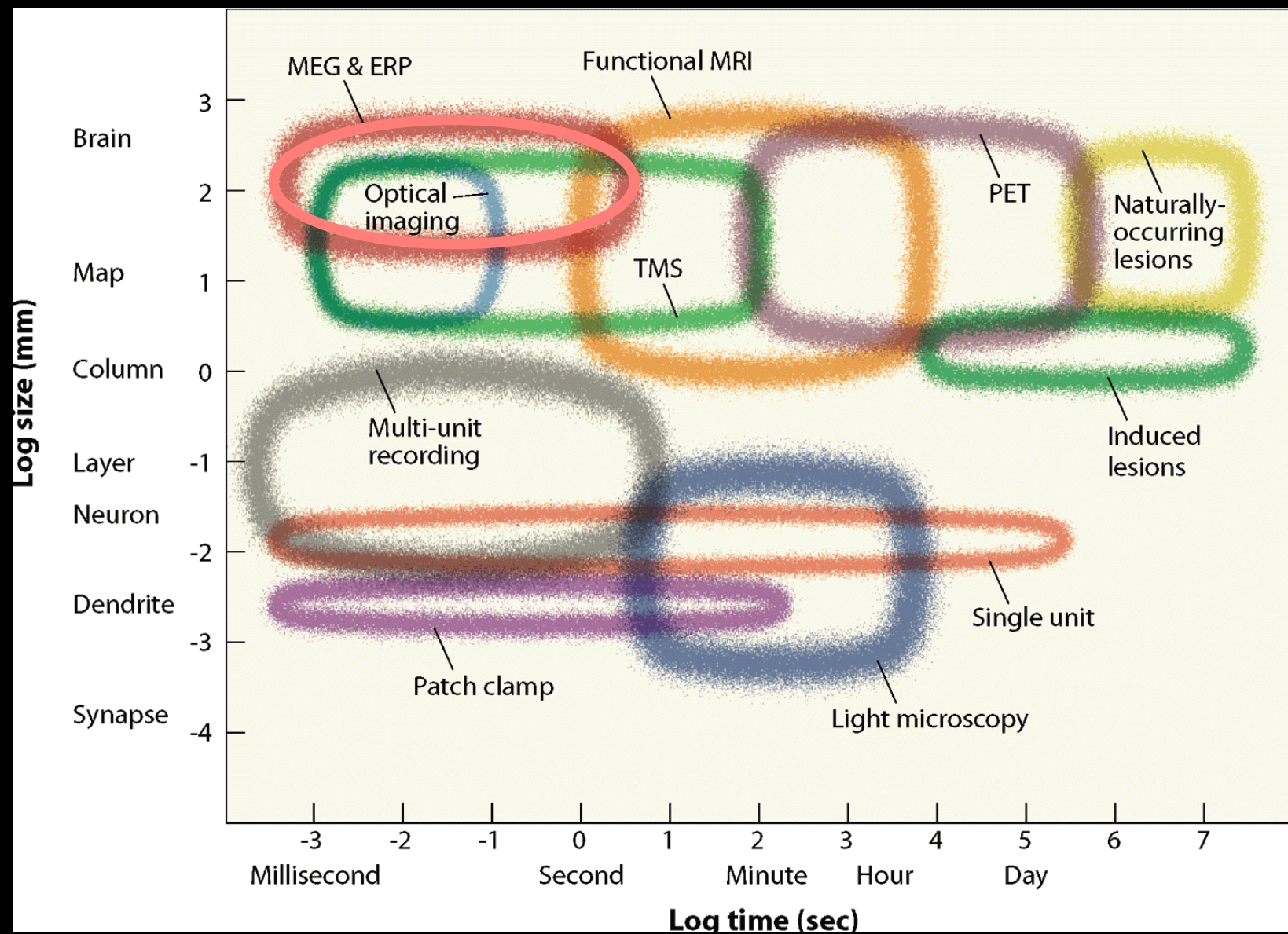


But it is not so great for determining where in the brain that neural firing takes place:

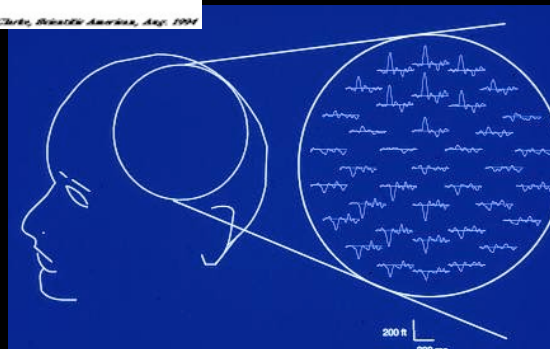
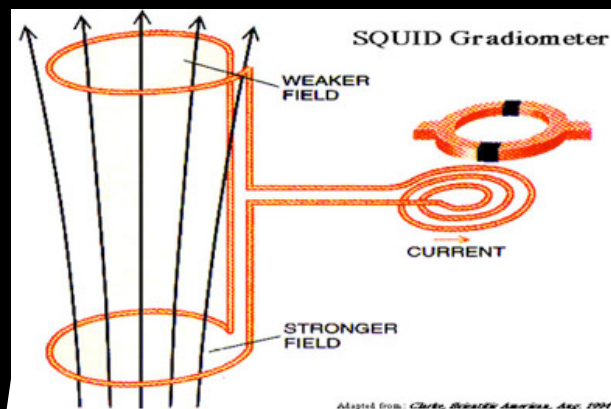


ERPs:

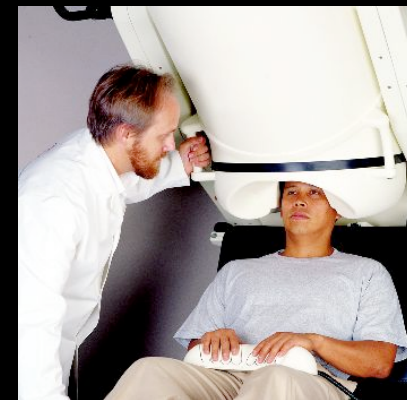
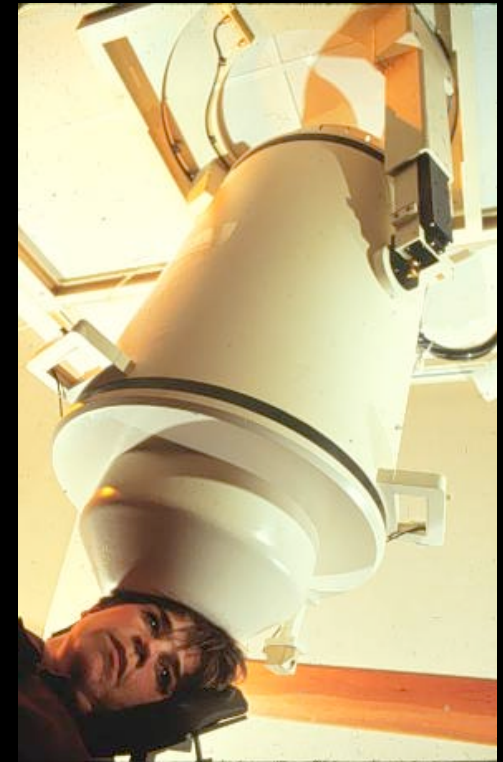
- Pluses:
 - » Great temporal resolution
 - » Direct measure of electrical activity
 - » Less expensive than fMRI
- Minuses:
 - » Poor spatial resolution, inverse problem
 - » Not equally sensitive to all kinds of electrical activity



MEG: magnetoencephalography



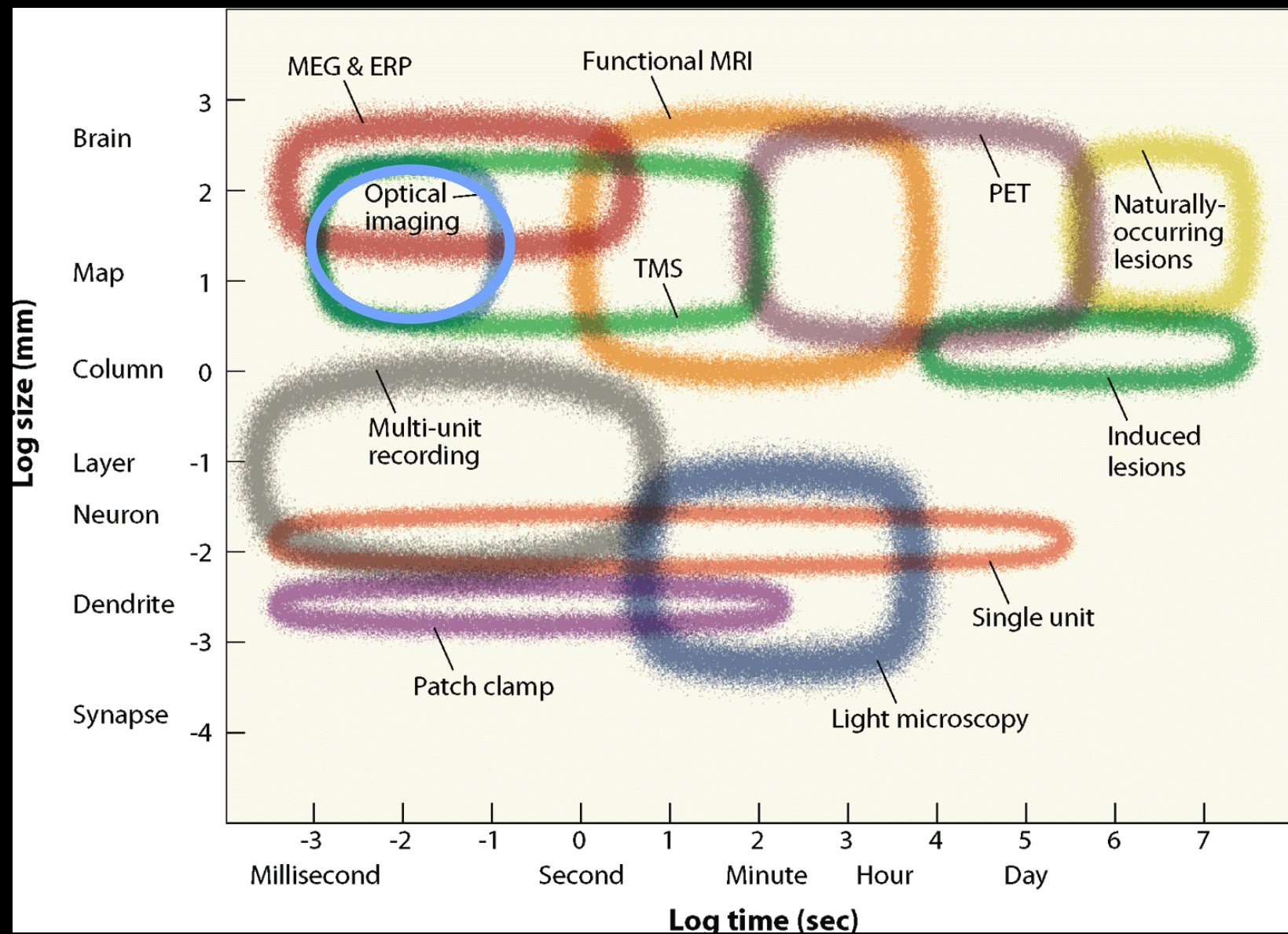
http://mcns10.med.nyu.edu/research/meg_new/meg_new.html



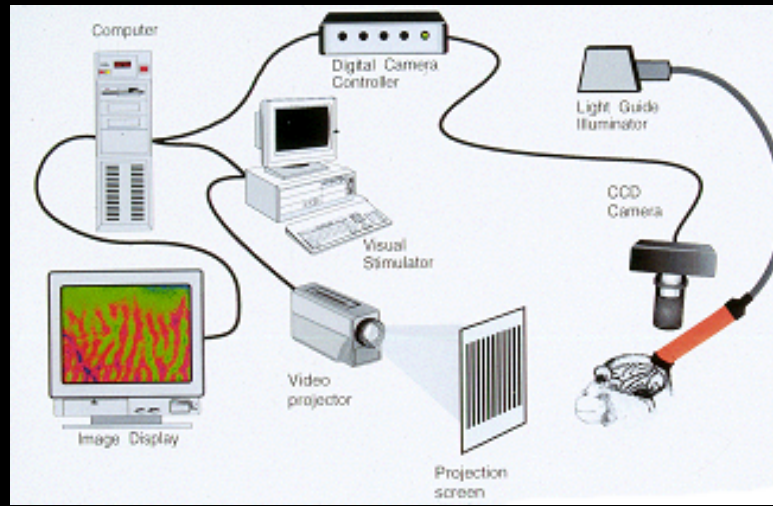
http://www.4dneuroimaging.com/external_english/html/m36spec.html

MEG (similar to ERPs):

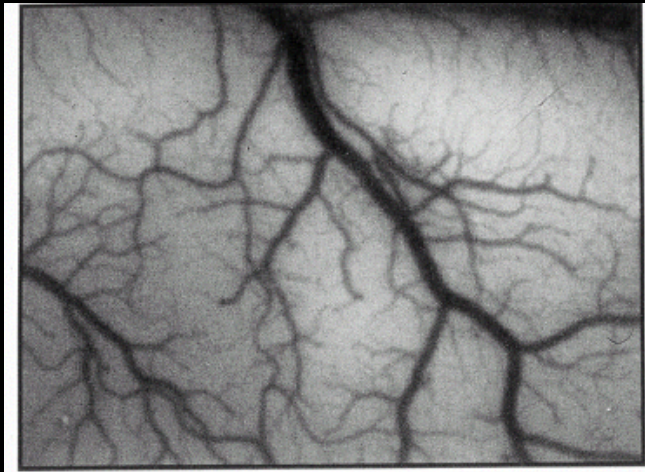
- Pluses:
 - » Great temporal resolution
 - » More direct measure of neural activity
- Minuses:
 - » Poor spatial resolution, inverse problem
 - » Not equally sensitive to all kinds of activity



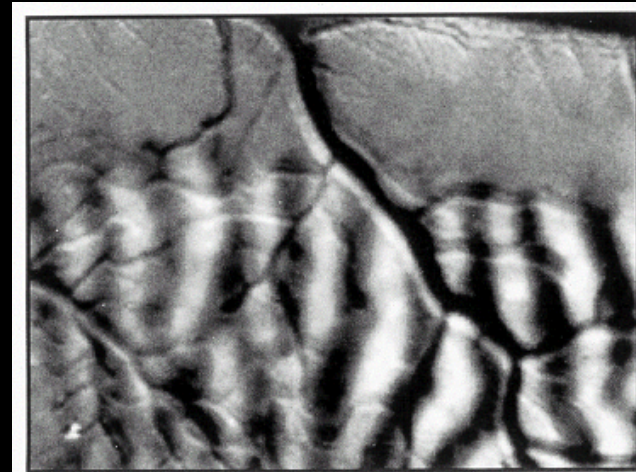
Optical Imaging



Apparatus

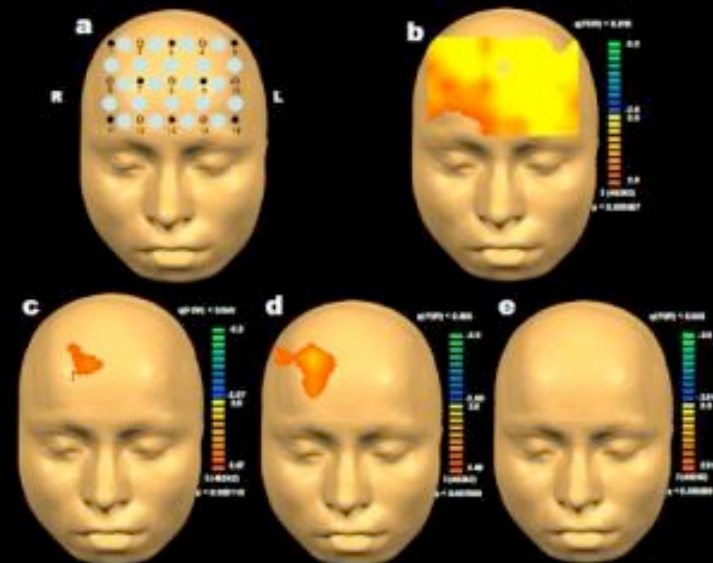
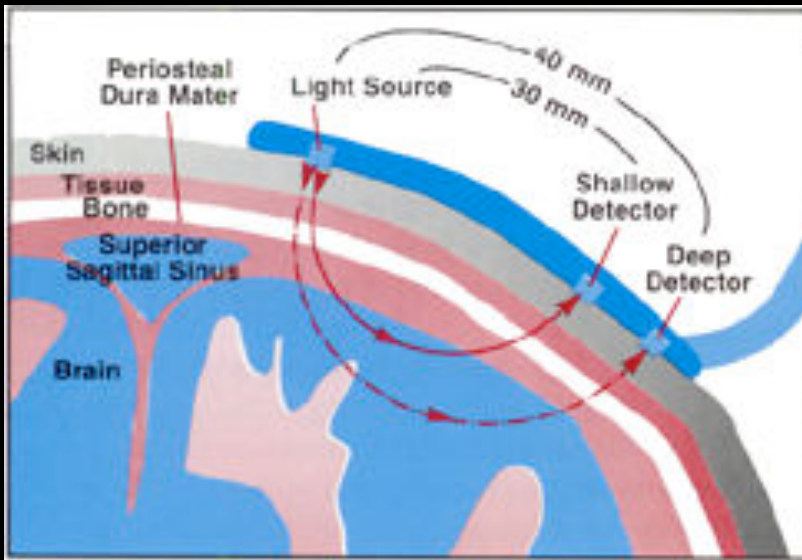


Reference image



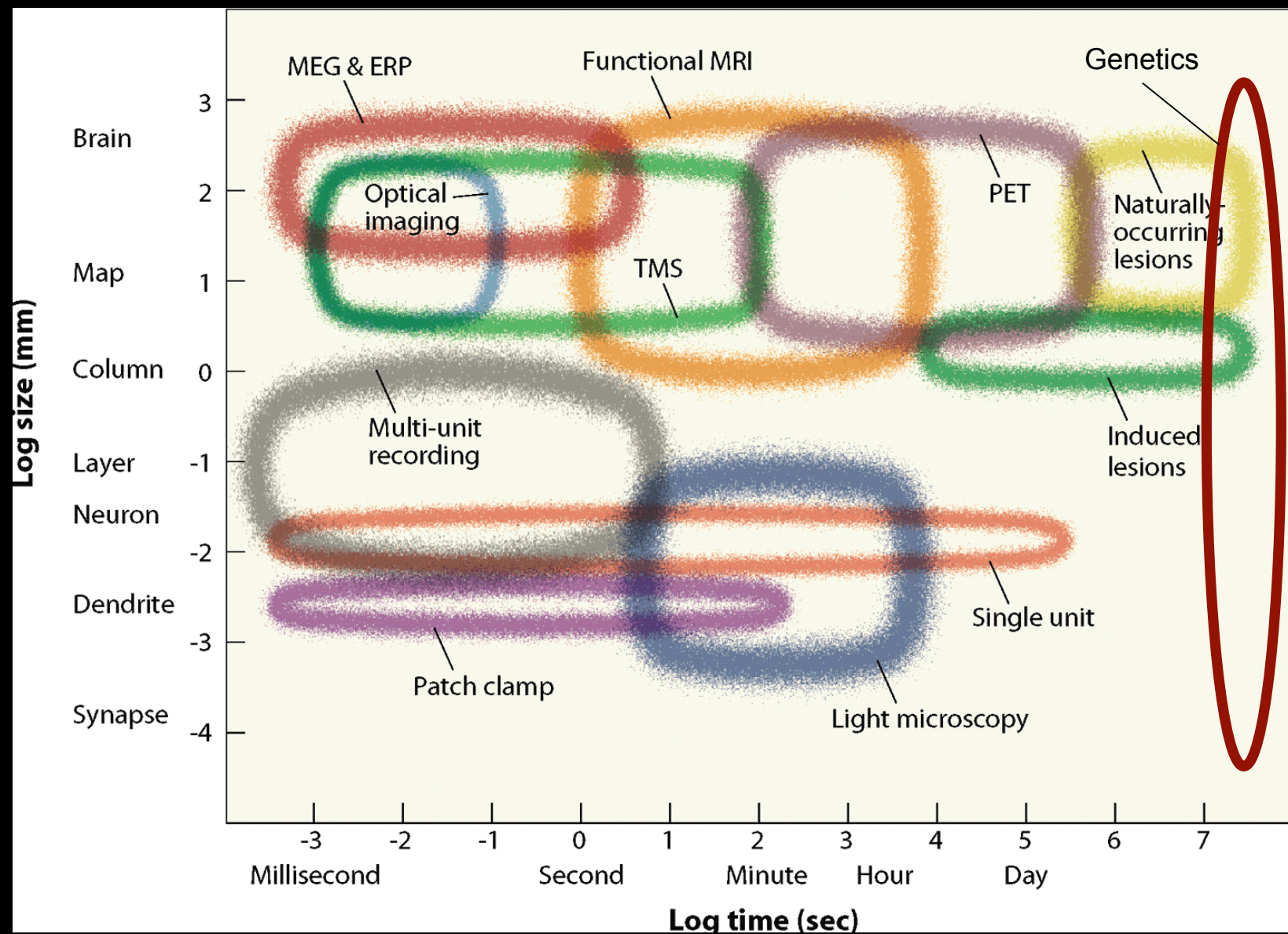
Functional difference image

Near-infrared Spectroscopy (NIRS)

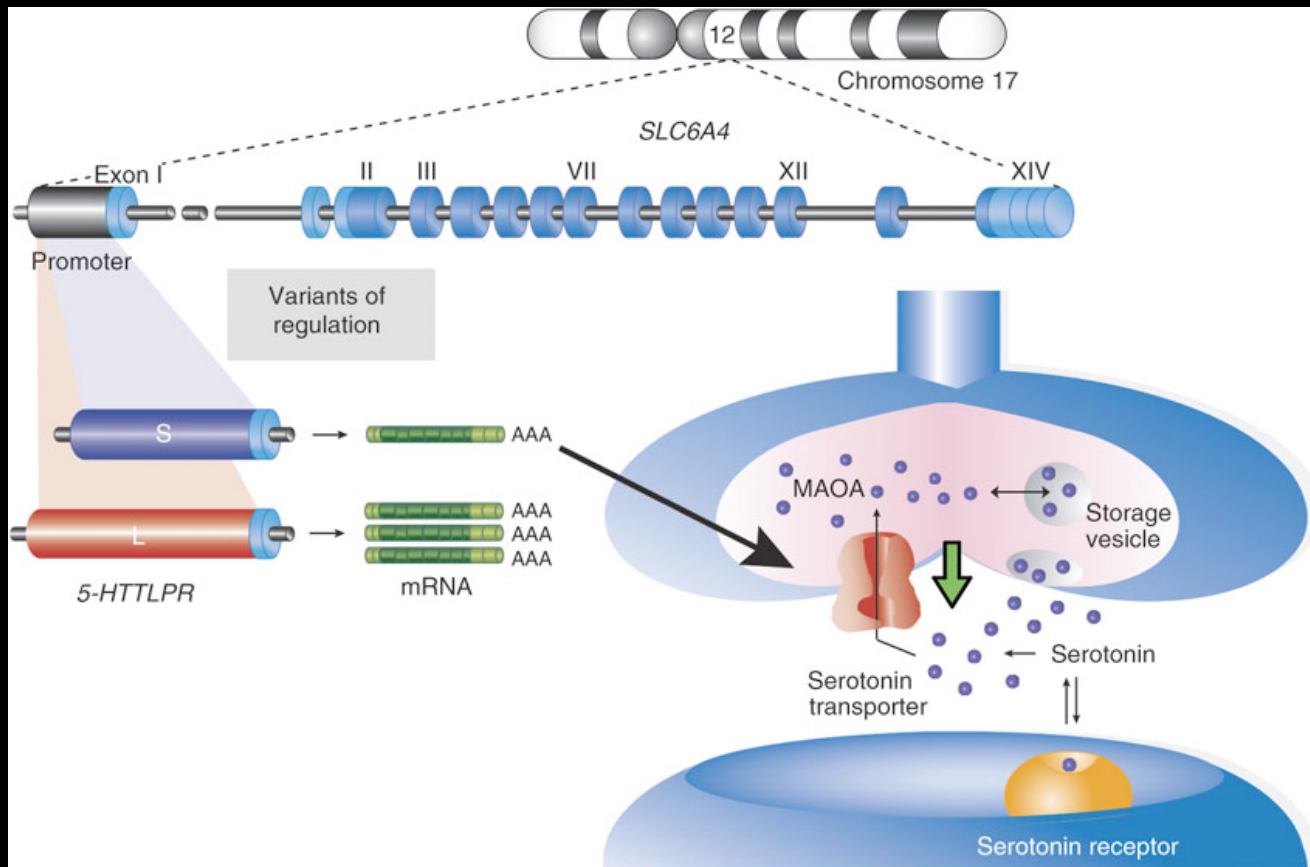


Optical imaging:

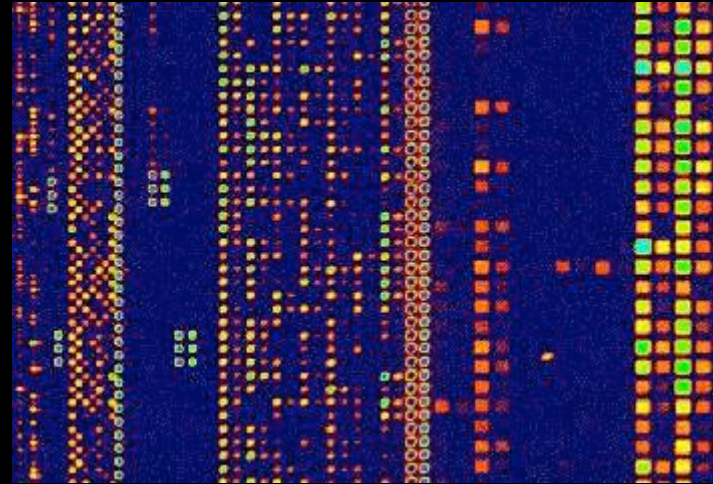
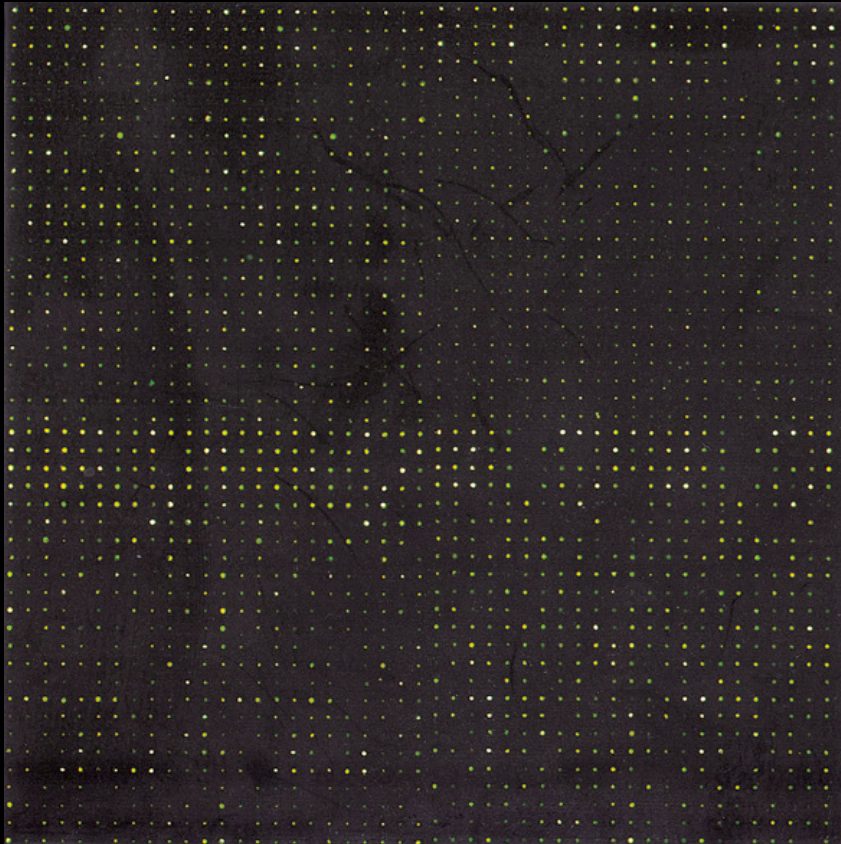
- Pluses:
 - » Portable (compared to other techniques)
 - » Sensitive to the same factors fMRI is
- Minuses:
 - » Only get better spatiotemporal resolution in invasive experiments
 - » Can only measure cortical surface



Candidate Gene Approach



Genome-Wide Association Studies



Genetics:

- Pluses:
 - » Allows you to infer function based on genetically-determined individual differences in neural systems
 - » Completely complementary to other techniques
- Minuses:
 - » Functional differences are likely complex, susceptible to gene-gene and gene-environment interactions (could be plus)
 - » Effects of any one gene on the processes we are interested in is likely to be very small