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rogilmore

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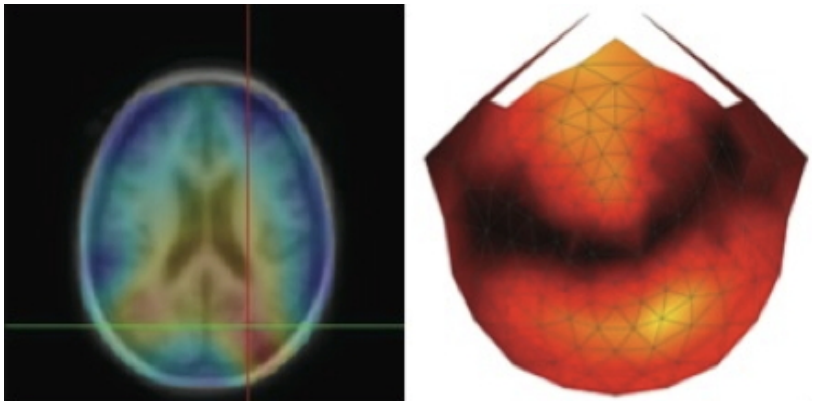
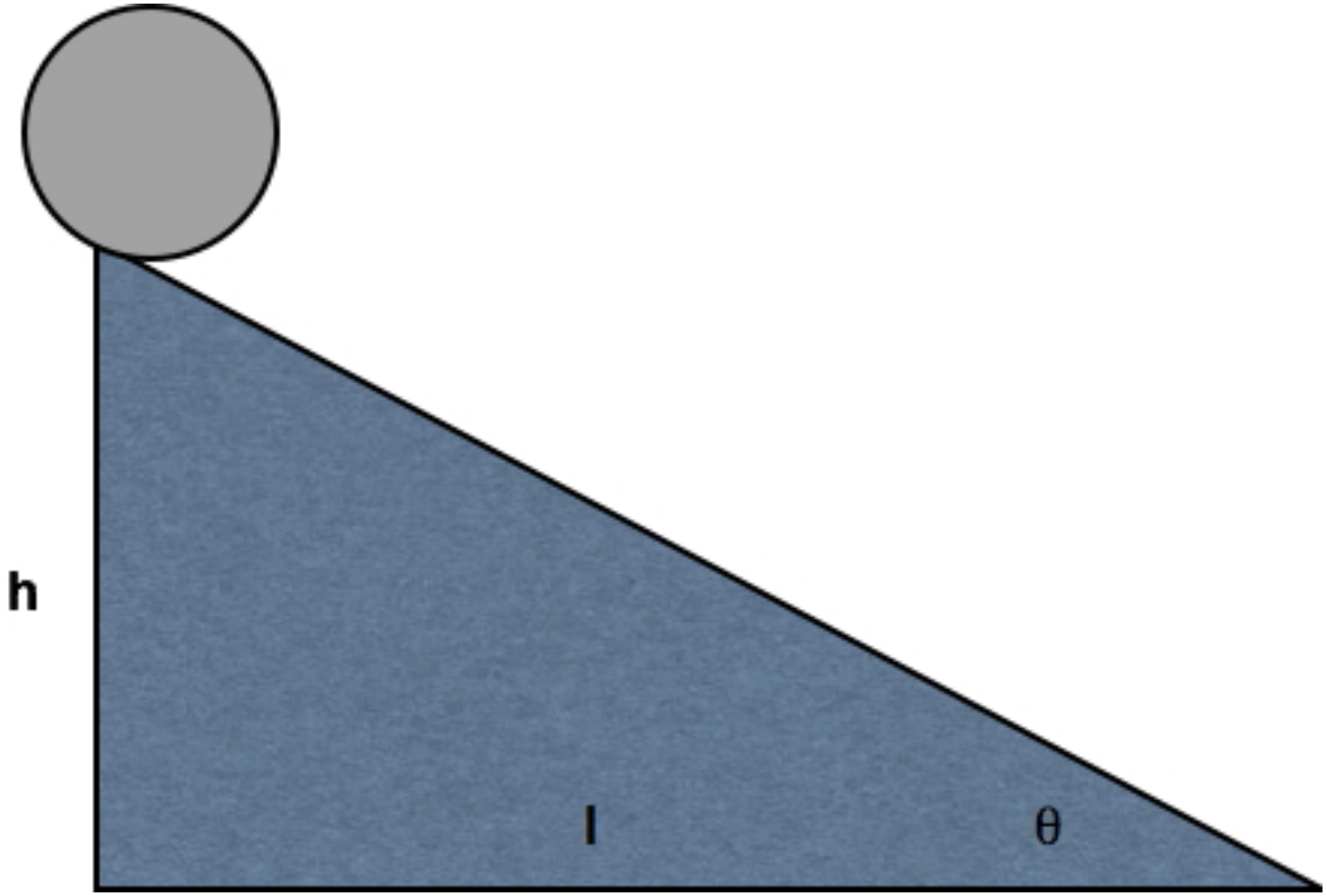
PSY 511

Foundations of Cognitive and Affective Neuroscience



Rick O. Gilmore, Ph.D.
Associate Professor of Psychology

Why neuroscience is harder than physics



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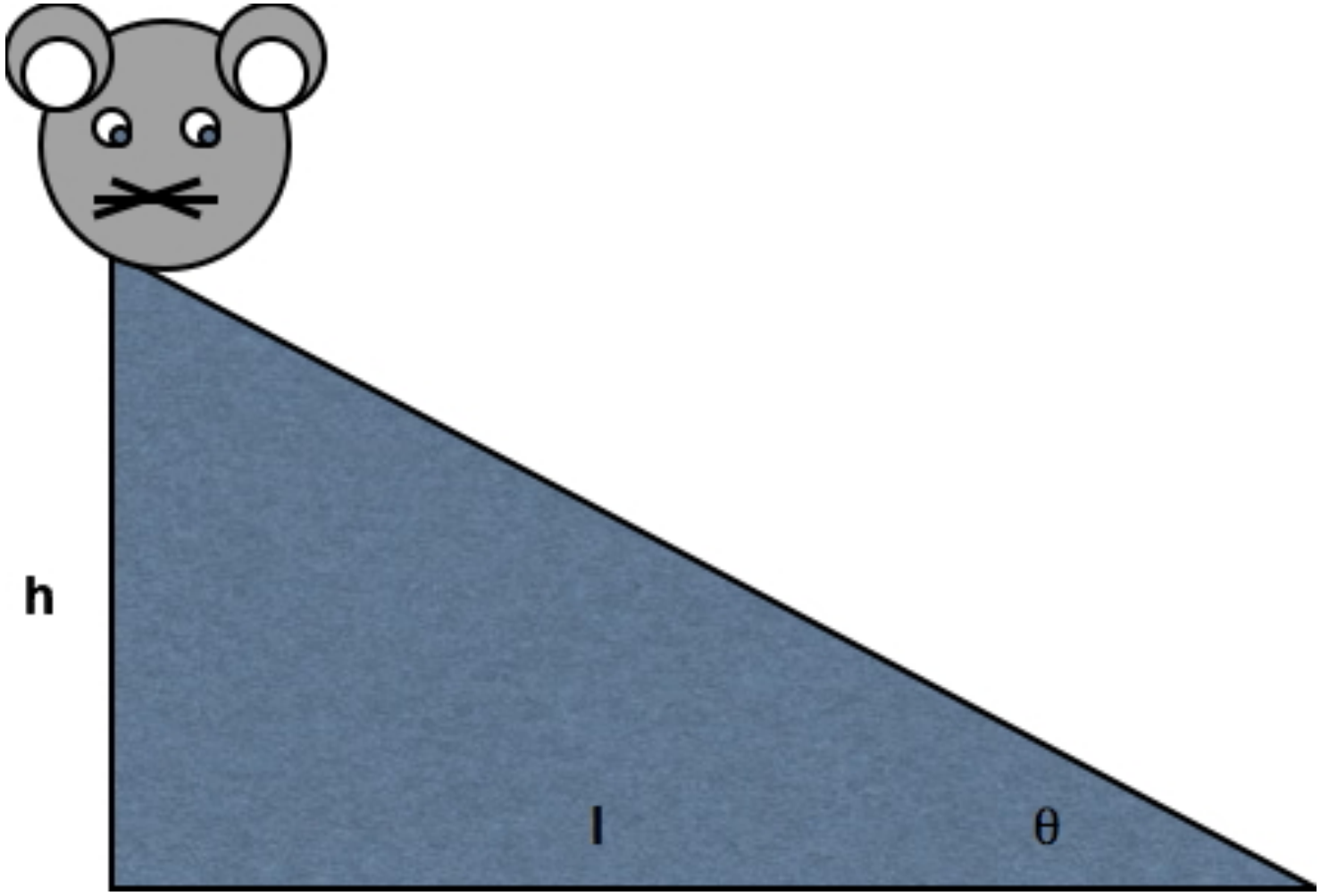
Why neuroscience is harder than physics



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What do we need to know to answer the question?

A. What is the wedge made of?

B. What happened to the mouse recently?

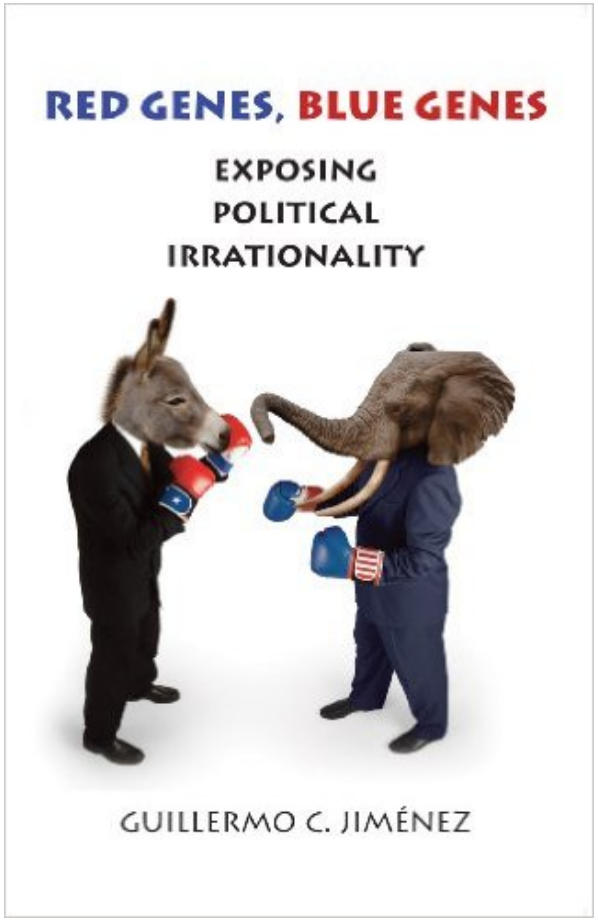
C. The mouse's sex or age?

D. The mouse's state (hungry, horny, asleep)

E. Mouse's genetic strain

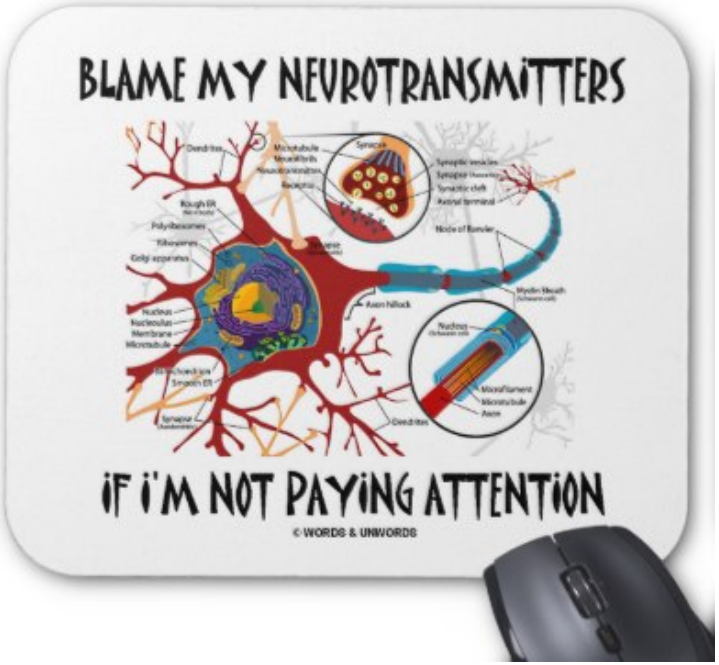
This course is about…

Genes



http://ecx.images-

Neurotransmitters



http://rlv.zcache.com/blame_my_neurotransmitters_if_not_paying_attention_mousepap144383961261005279trak_400.jpg

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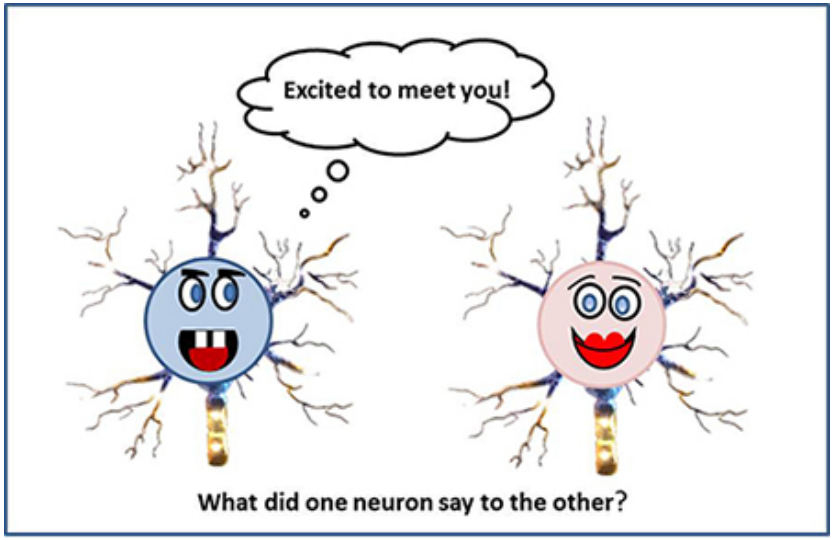
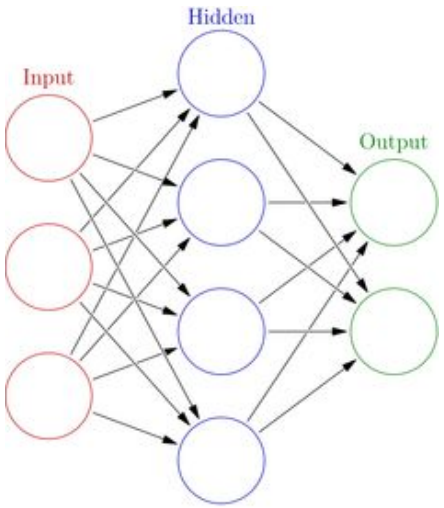
Neurons



http://www.biolegend.com/NewsLegend/032515blog/neuron_cartoon.jpg

Networks



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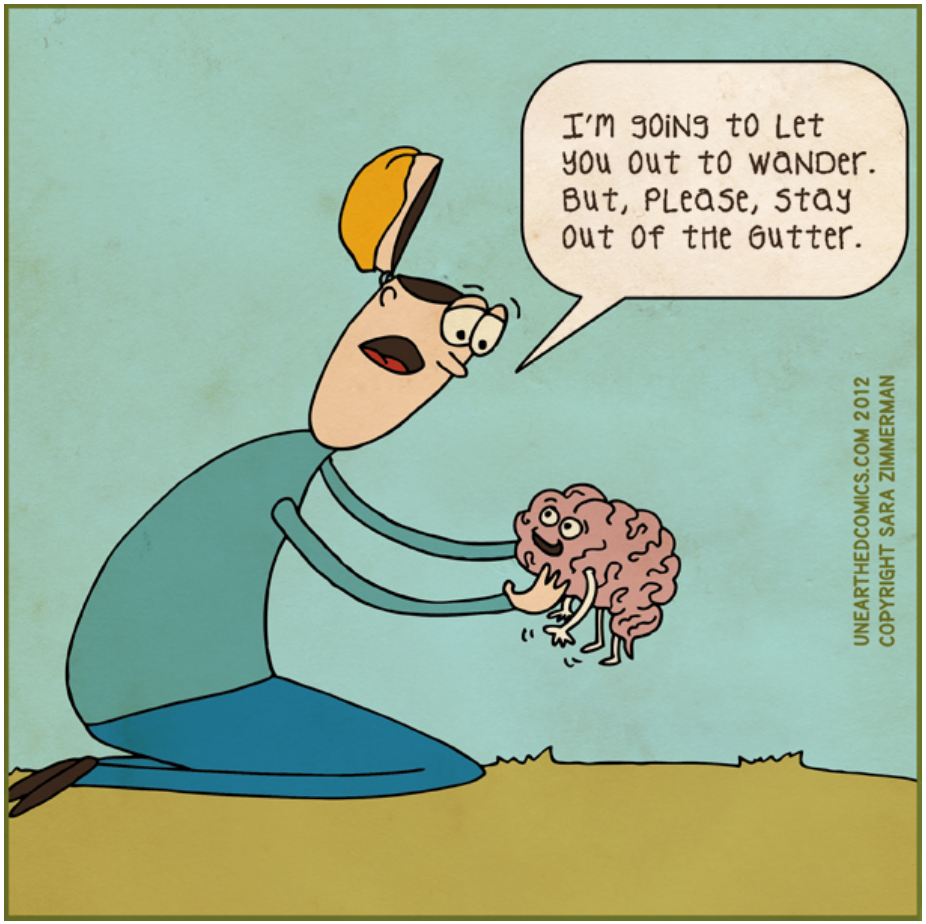
Brains



http://unearthedcomics.com/wp-content/uploads/2012/12/Unearthed- 11/62

Behavior

"I forgot to make a back-up copy of my brain, so everything I learned last semester was lost."

http://www.glasbergen.com/wp-content/gallery/teen/edu01.gif

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Goals

- Master fundamentals of neuroscientific concepts and facts
- Prepare to read primary source literature in behavioral, cognitive, affective, and clinical neuroscience

Course structure

https://github.com/psu-psychology/psy-511-scan-fdns/blob/master/syllabus.md

What is the basic plan of the nervous system?

- Neuroanatomy
- Rooted in behavior, evolution, development

Approach

- How do neurons and networks achieve behavioral goals?
- Information processing or computing

Approach

What do animals (and people) do?

- Have to
- Choose to

What's the information required?

- Input
- Computation/processing
- Output

Approach

Brain architecture (neuroanatomy)

Brain function (neurophysiology)

Brain communication (neurochemistry)

Changes over evolutionary and developmental time

What is neuroscience?

The study of the nervous system

- And the behavior it makes possible

Questions

- What are the parts of the nervous system?
- How do the parts work? What do they do?
- Where did they come from?

Your turn

- What are the main categories of behavior we want to understand?
- Papers you want to read

Your turn, Part II

- How do the behaviors you picked fit with the prior framework?
- Describe the main
- Inputs
- Outputs
- Computations

Biological imperatives

Sustenance

- Eating & drinking

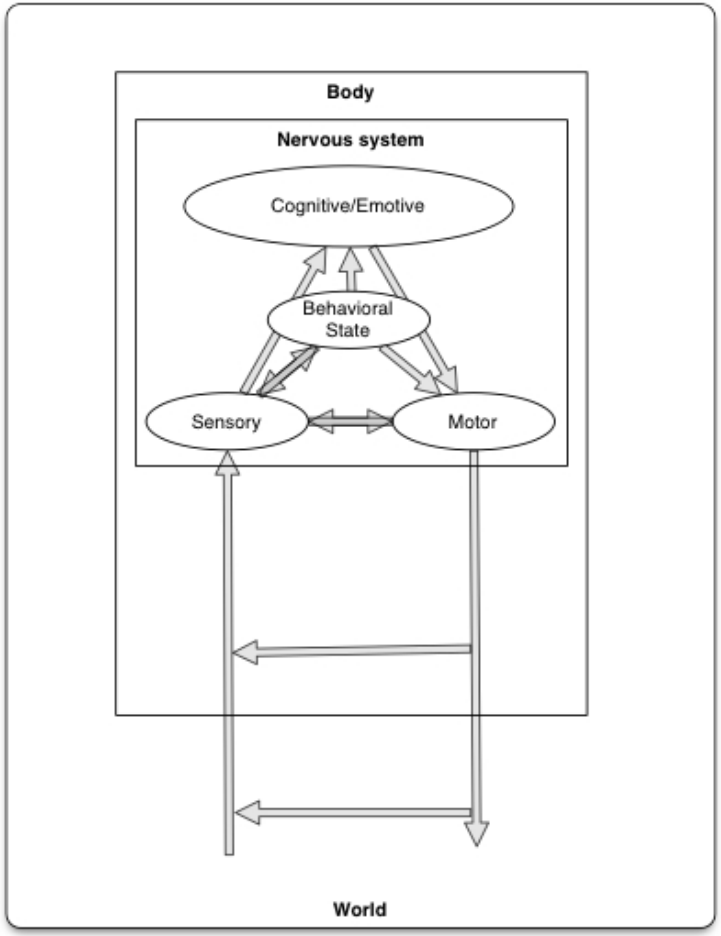
Protection

- Act or rest
- Fight, flee, hide, freeze

Reproduction

- Mate seeking
- Territory protection, nest-building
- Mating
- Caregiving

Brain architecture for enacting biological imperatives



Neuroscience methods

- Methods to the madness
- Tools in the neuroscientist's toolkit
- What they tell us, and what they don't

Evaluating methods

What is the question?

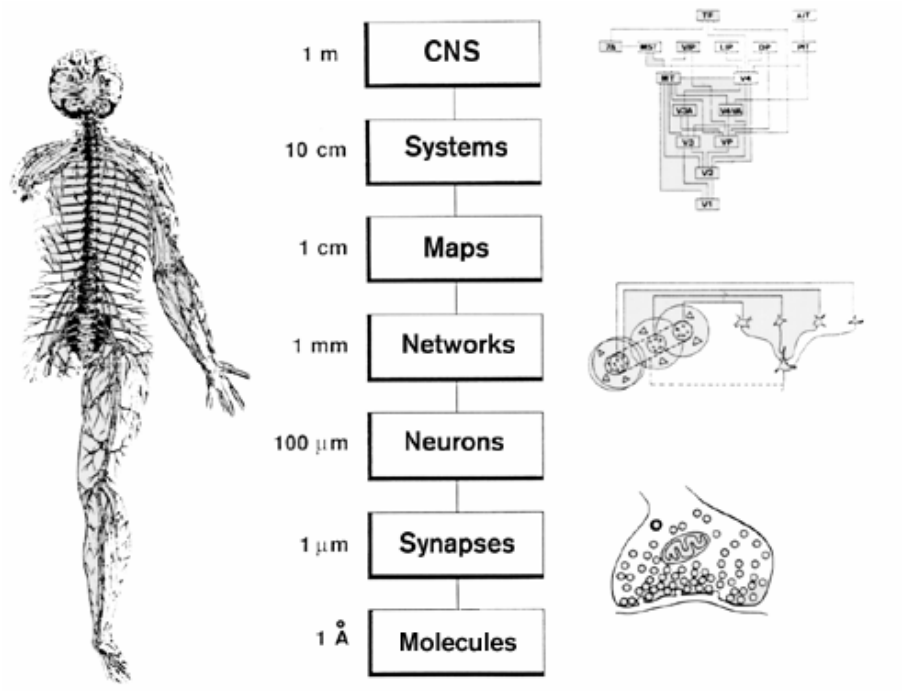
What are we measuring?

- Structure
- Activity

Strengths & Weaknesses

- Cost
- Invasiveness
- Spatial/temporal resolution

Spatial resolution



http://ai.ato.ms/MITECS/Images/churchland.figure1.gif

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Types of methods

Structural

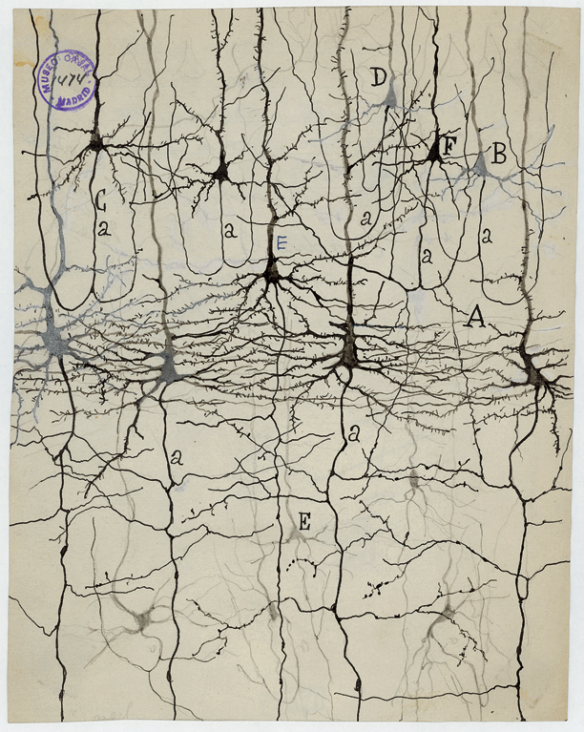
- Mapping the circuitry
- Anatomy

Functional

- What does it do?
- Physiology/Activity

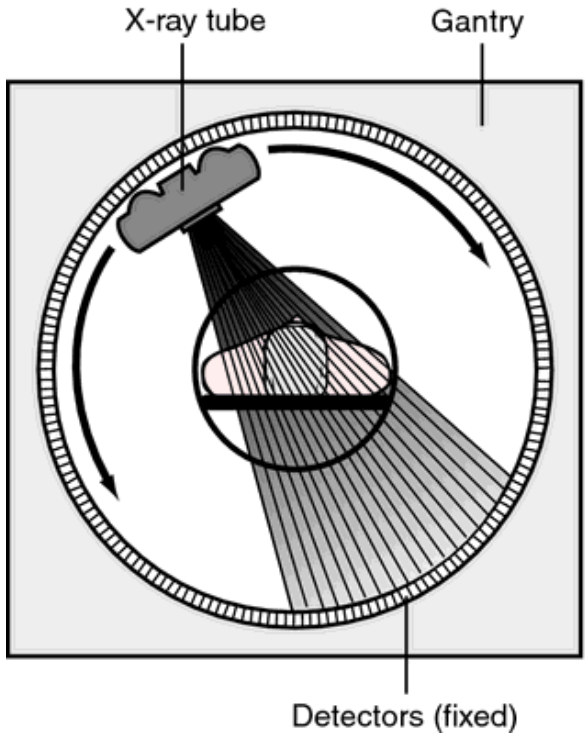
Mapping structures

- Cell/axon stains
- Golgi stain – whole cells
- Cellular distribution, concentration, microanatomy



Mapping structures

- Computed axial tomography (CAT), CT - X-ray based



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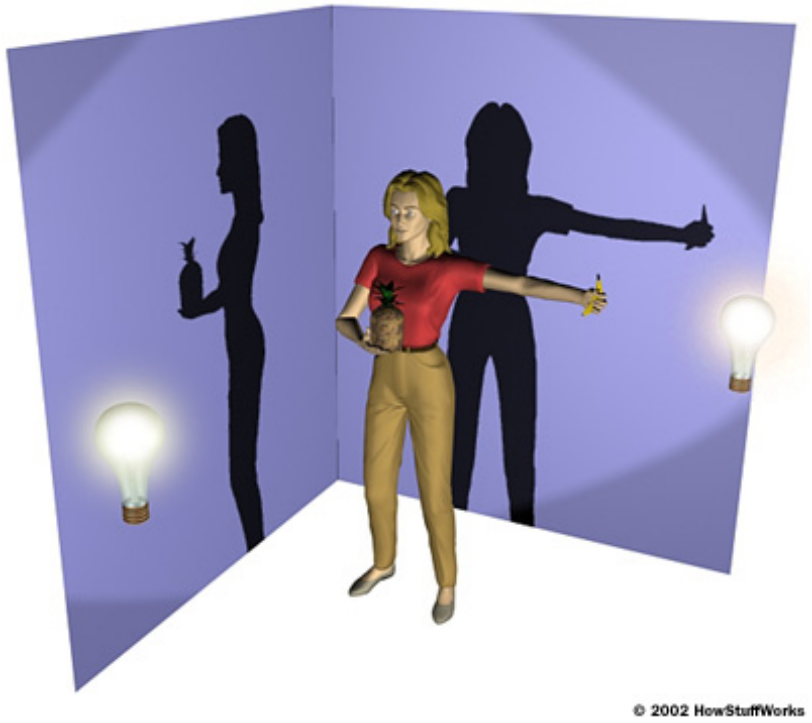
Tomography



http://static.howstuffworks.com/gif/cat-scan-pineapple.jpg

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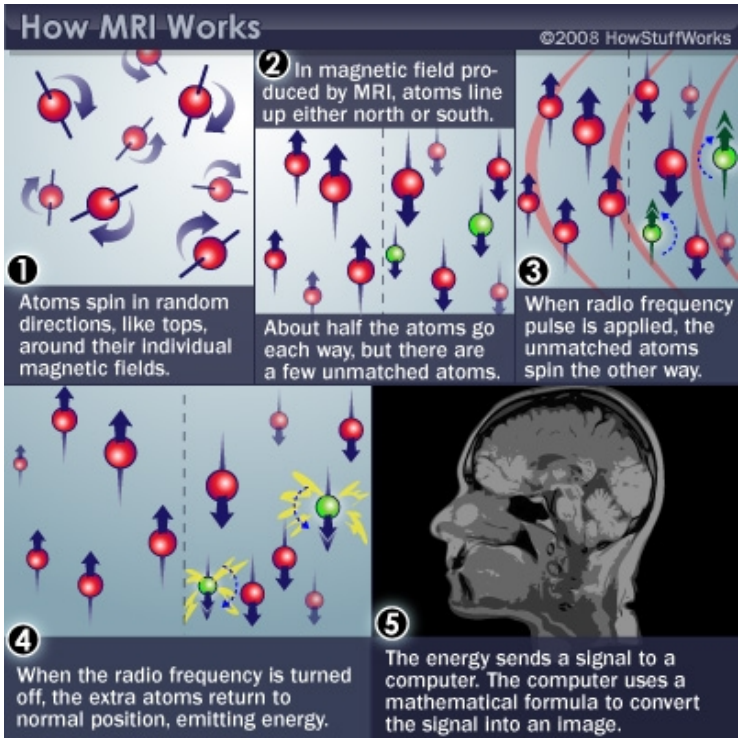
Magnetic Resonance Imaging

- Magnetic resonance
- Protons have spin (magnetic dipole)
- Align with strong magnetic field
- When perturbed, speed of realignment varies by tissue
- Realignment gives off radio frequency signals

MRI



http://s.hswstatic.com/gif/mri-steps.jpg

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Structural MRI

- Tissue density/type differences
- Gray vs. white - Axon fibers
- Spectroscopy
- Region sizes/volumes

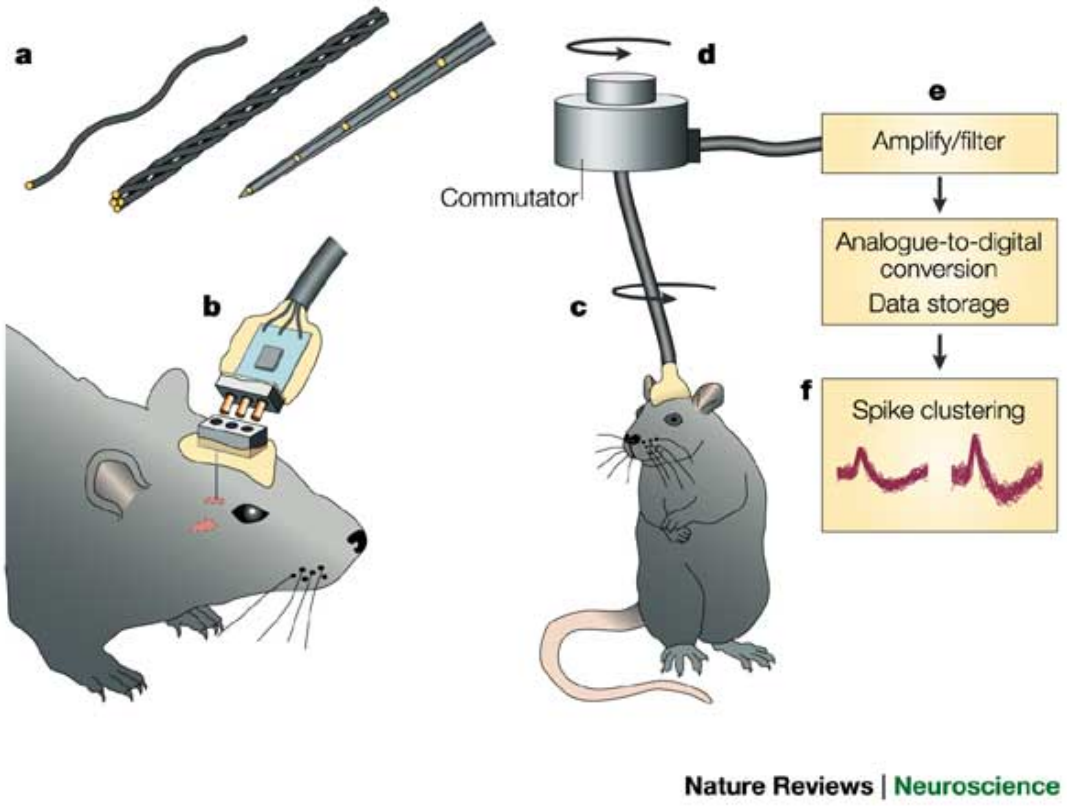
Functional methods

- Recording from the brain
- Interfering with the brain
- Stimulating the brain

Recording from the brain

- Single/multi unit recording
- Microelectrodes
- Small numbers of nerve cells

Single/multi-unit Recording



http://www.nature.com/nrn/journal/v5/n11/images/nrn1535-i1.jpg

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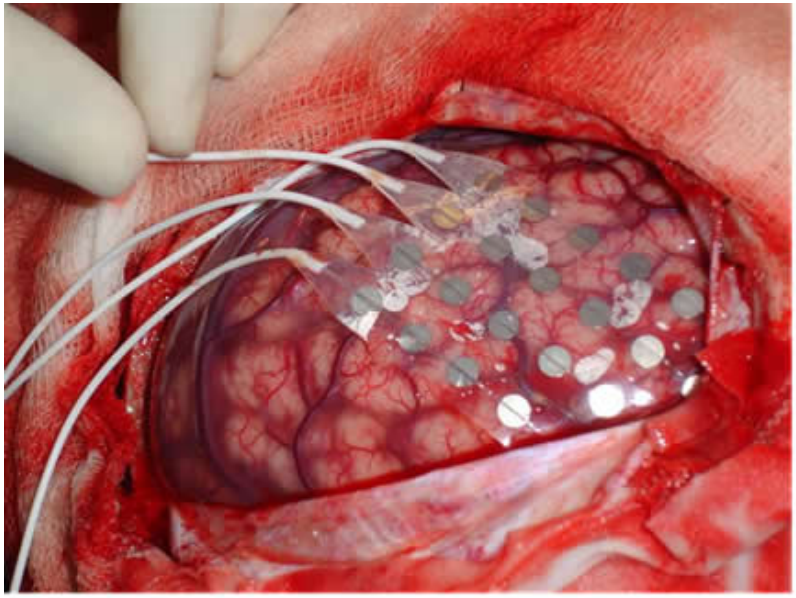
Single/multi-unit recording

- What does neuron X respond to?
- Great temporal (ms), spatial resolution (um)
- Invasive
- Rarely suitable for humans, but…

Electrocorticography



http://www.neurofisiologia.net/wp-content/uploads/2009/07/corticografia.jpg

Single-cell studies ask…

- How does firing frequency, timing vary with behavior?

Positron Emission Tomography (PET)

- Radioactive tracers (glucose, oxygen)
- Positron decay
- Experimental condition - control
- Average across individuals

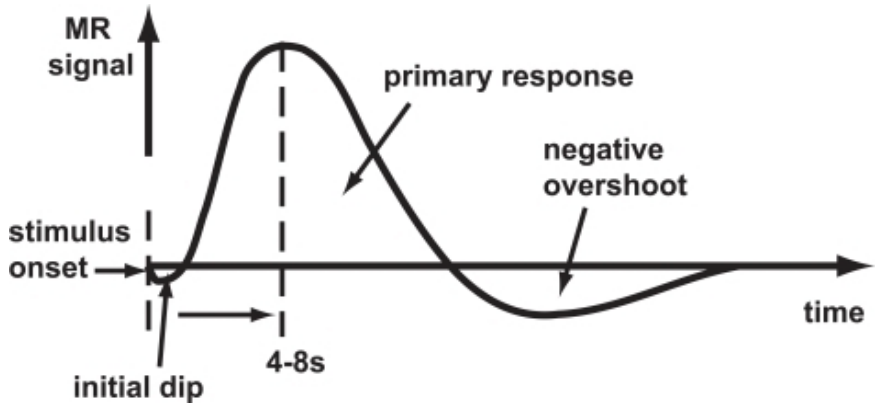
More on PET

- Temporal (~ s) and spatial (mm-cm) resolution worse than fMRI
- Radioactive exposures + mildly invasive
- Dose < airline crew exposure in 1 yr

Functional Magnetic Resonance Imaging (fMRI)

- Neural activity -> local O2 consumption increase
- Blood Oxygen Level Dependent (BOLD) response
- Oxygenated vs. deoxygenated hemoglobin
- Do regional blood O2 levels (and flow) vary with behavior X?
- Non-invasive, but expensive
- Moderate but improving (mm) spatial, temporal (~sec) resolution
- Hemodynamic Response Function
- 1s delay plus 3-6 s ramp-up

Hemodynamic Response Function (HRF)



http://openi.nlm.nih.gov/imgs/512/236/3109590/3109590_TONIJ-5-24_F1.png

Electroencephalography (EEG)

- How does it work?
- Electrodes on scalp or brain surface
- What do we measure?
- Combined activity of huge # of neurons

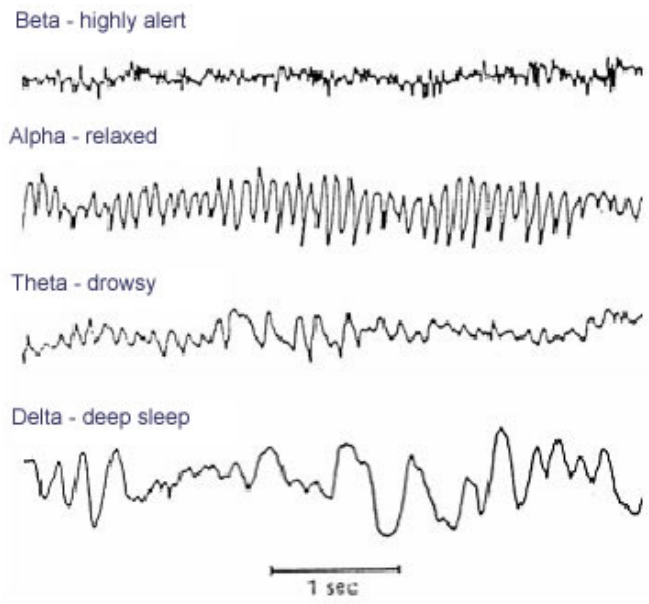
Collecting EEG

http://sfari.org/images/images-2013-folder/images-sfn-2013/20131110sfneeg

EEG

- High temporal, poor spatial resolution
- Analyze frequency bands
- LOW: deep sleep
- MIDDLE: Quiet, alert state
- HIGH:“Binding” information across senses

EEG Frequency

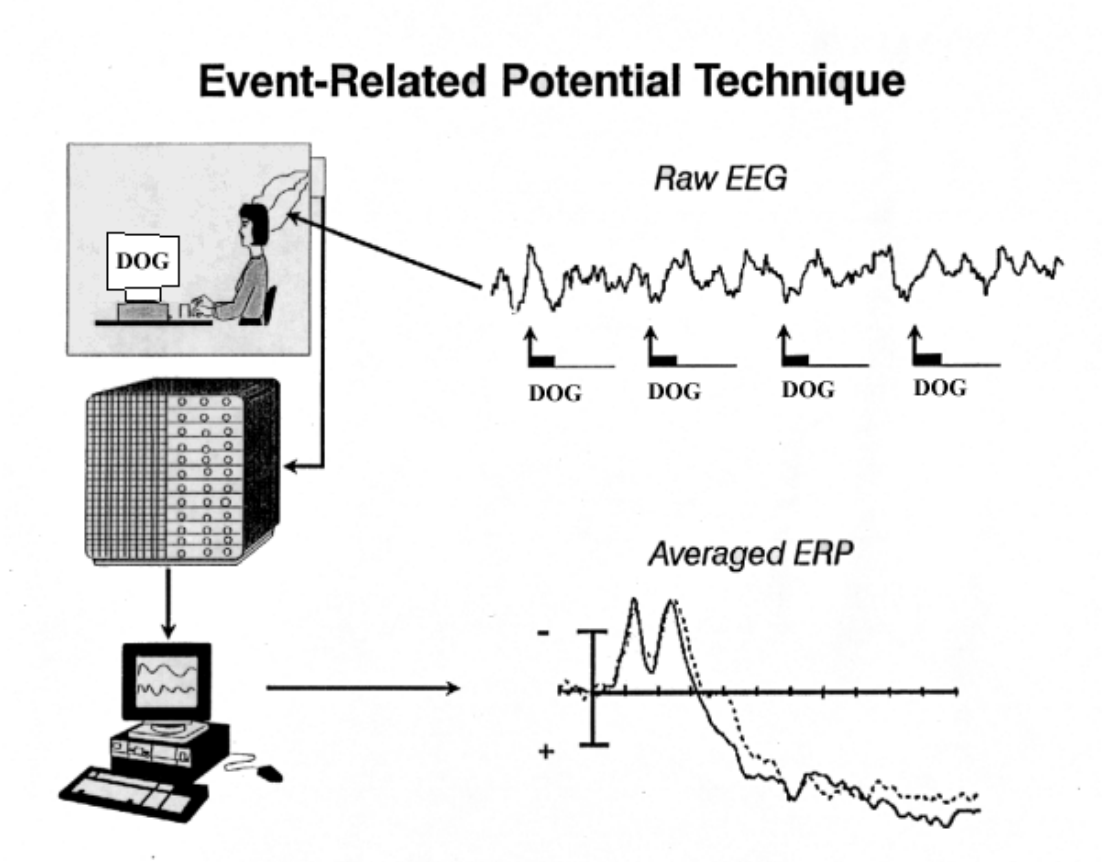


http://www.peakmind.co.uk/images/frequency.jpg

Event-related potentials (ERPs)

- EEGs time-locked to some event - Averaged over many trials

ERP



http://2.bp.blogspot.com/_2ob-1_LsjJs/TAUjw9i_dYI/AAAAAAAAAQQ/9AfiHsnD-P8/s1600/ERP_technique.gif

Magneto-encephalography (MEG)

- Like EEG, but measuring magnetic fields
- High temporal resolution
- Magnetic field propagates w/o distortion

MEG

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How do EEG and fMRI relate?

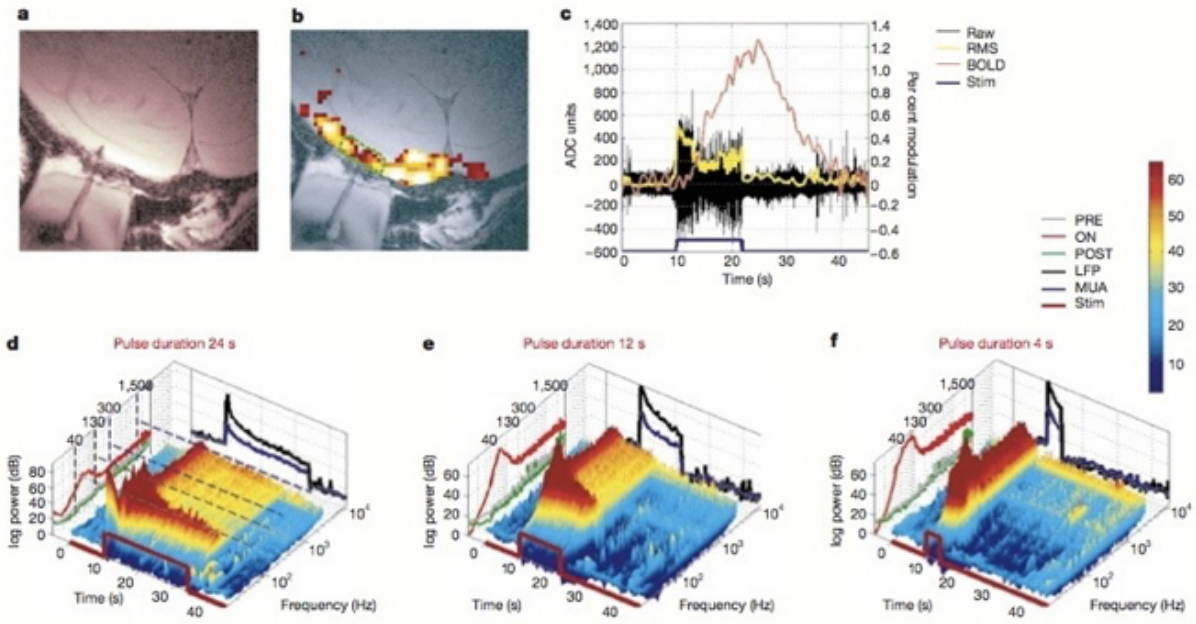


Figure 1 Neural and BOLD responses to pulse stimuli. **a**, FLASH scan (see Methods) showing the location of the electrode tip in primary visual cortex. **b**, BOLD response to rotating chequerboard patterns in striate cortex. Activation can be measured around the electrode tip. **c**, Haemodynamic response (red) superimposed on the de-noised raw neural signal (black). The term 'de-noised raw' denotes that no other signal processing beyond the removal of gradient interference (see Methods) was done. The r.m.s. of the signal is indicated by a thick yellow line. **d**–**f**, Spectrograms for data collected over 24, 12 and 4 s. In each three-dimensional plot, the vertical panel along the time axis shows the average LFP and MUA responses, namely the mean vector of the time series between black and blue dashed lines, respectively. The vertical panel along the frequency axis shows the average spectra for the pre-stimulus, stimulation, and post-stimulus periods. Colour bar shows the logarithm of power. ADC, Analogue to digital converter; STIM, time course of the visual stimulus; PRE, pre-stimulus period; ON, stimulus presentation period; POST, post-stimulus period.

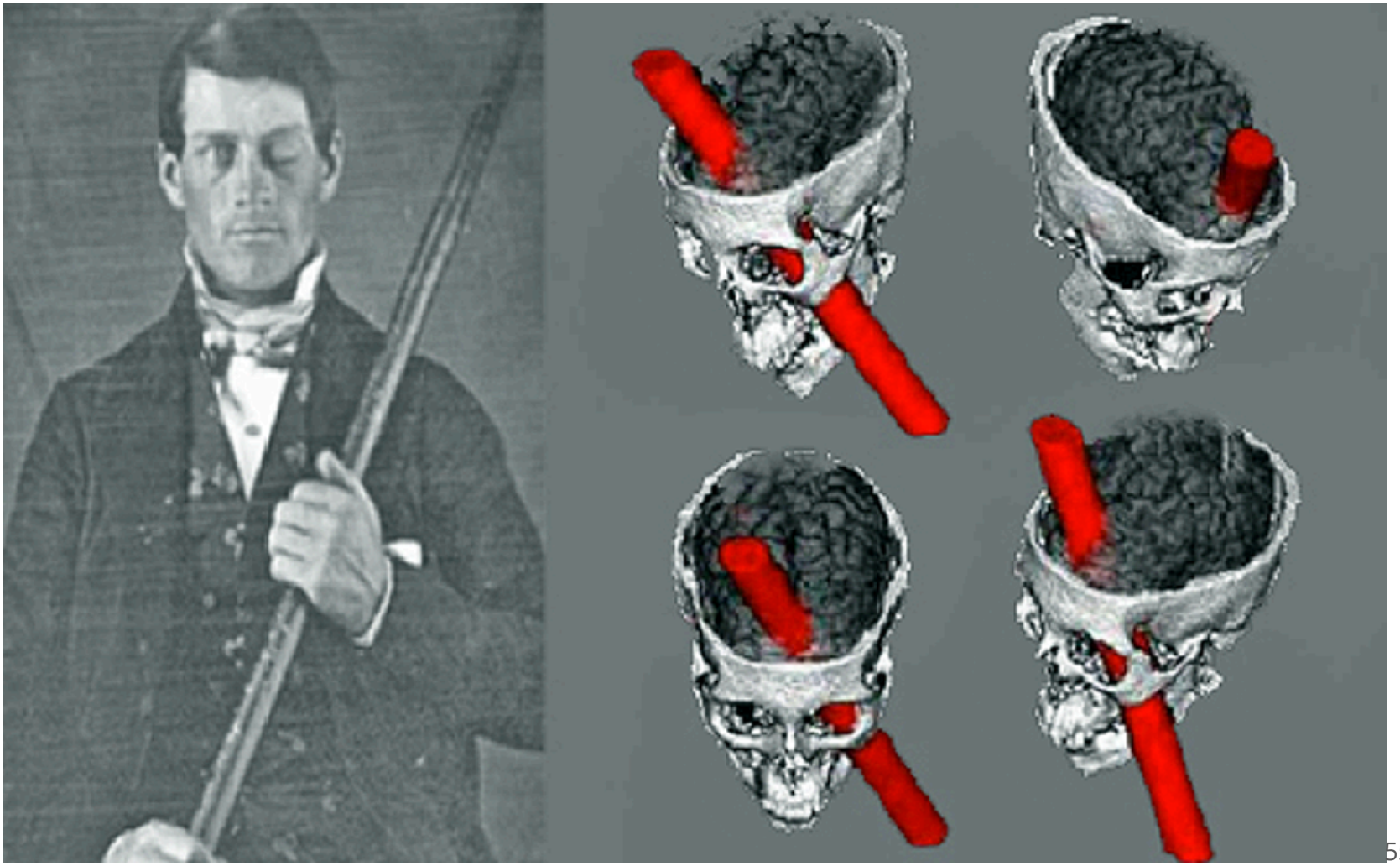
Manipulating the brain

- Interfering with it
- Stimulating it

Interfering with the brain

- Nature's"experiments"
- Stroke, head injury, tumor
- Neuropsychology

Phineas Gage



Evaluating neuropsychological methods

- Logic: damage impairs performance = region critical for behavior
- Poor spatial/temporal resolution, limited control

Stimulating the brain

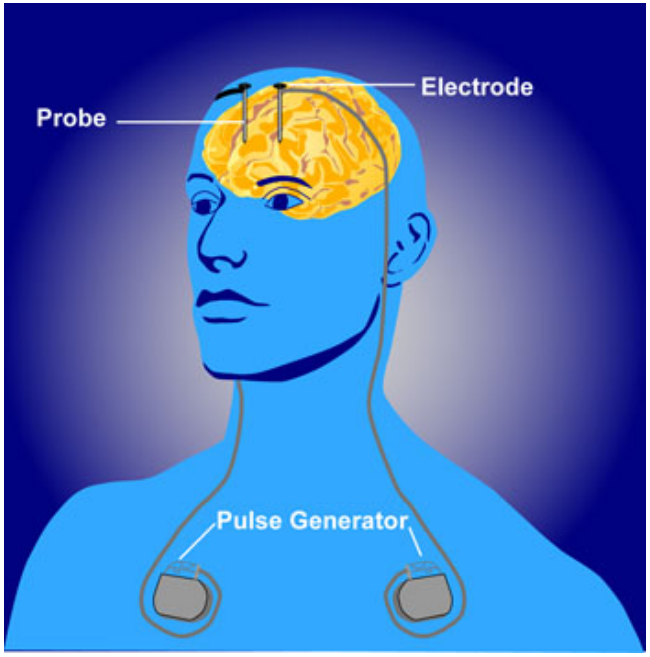
- Electrical (Direct Current Stimulation - DCS)
- Pharmacological
- Magnetic (Transcranial magnetic stimulation-TMS)

Stimulating the brain

- Spatial/temporal resolution?
- Assume stimulation mimics natural activity?

Deep brain stimulation as therapy

- Parkinson's Disease
- Depression
- Epilepsy



http://www.nimh.nih.gov/images/health-and-outreach/mental-health-topic-brain-stimulation-therapies/dbs_60715_3.jpg which

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Simulating the brain

- Computer/mathematical models of brain function
- Example: neural networks
- Cheap, noninvasive, can be stimulated or “lesioned”

Main points

- Multiple structural, functional methods
- Different levels of spatia