PSY 511 2018-08-22 Course Intro

Rick Gilmore

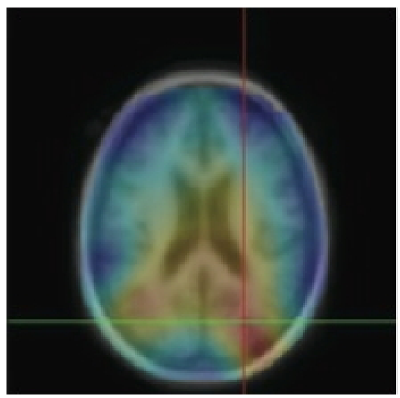
2018-08-22 08:18:50

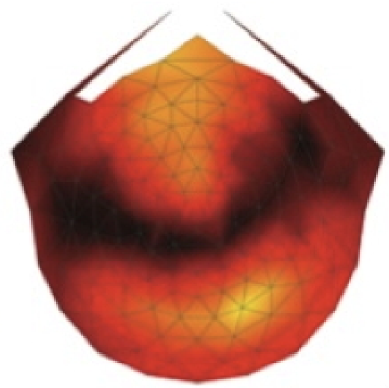
Prelude

"If understanding everything we need to know about the brain is a mile, how far have we walked?"

PSY 511

Foundations of Cognitive and Affective Neuroscience



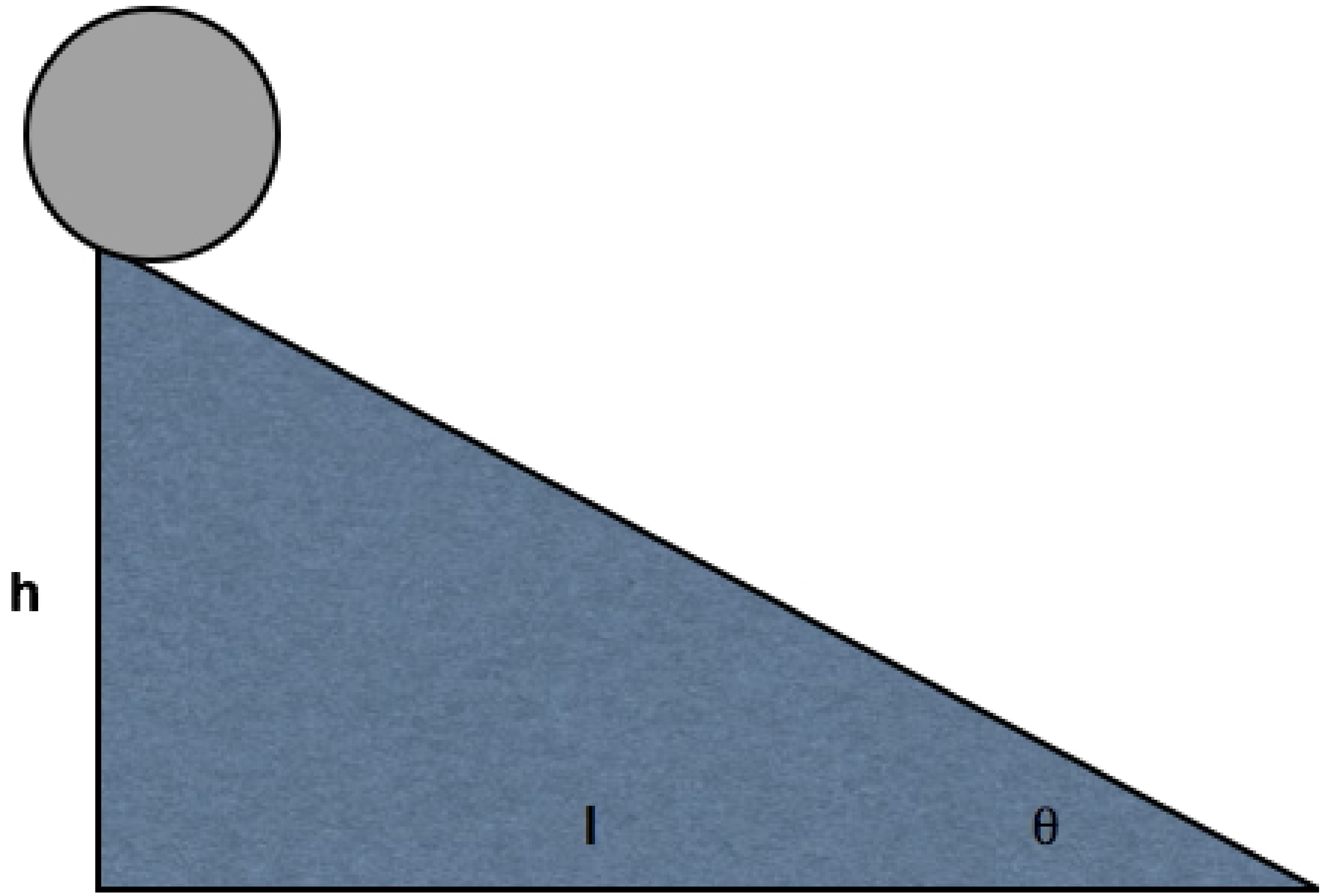


Rick O. Gilmore, Ph.D.
Associate Professor of Psychology

Today's topics

- Why neuroscience is harder than physics
- Course overview
- Methods in neuroscience

Why neuroscience is harder than physics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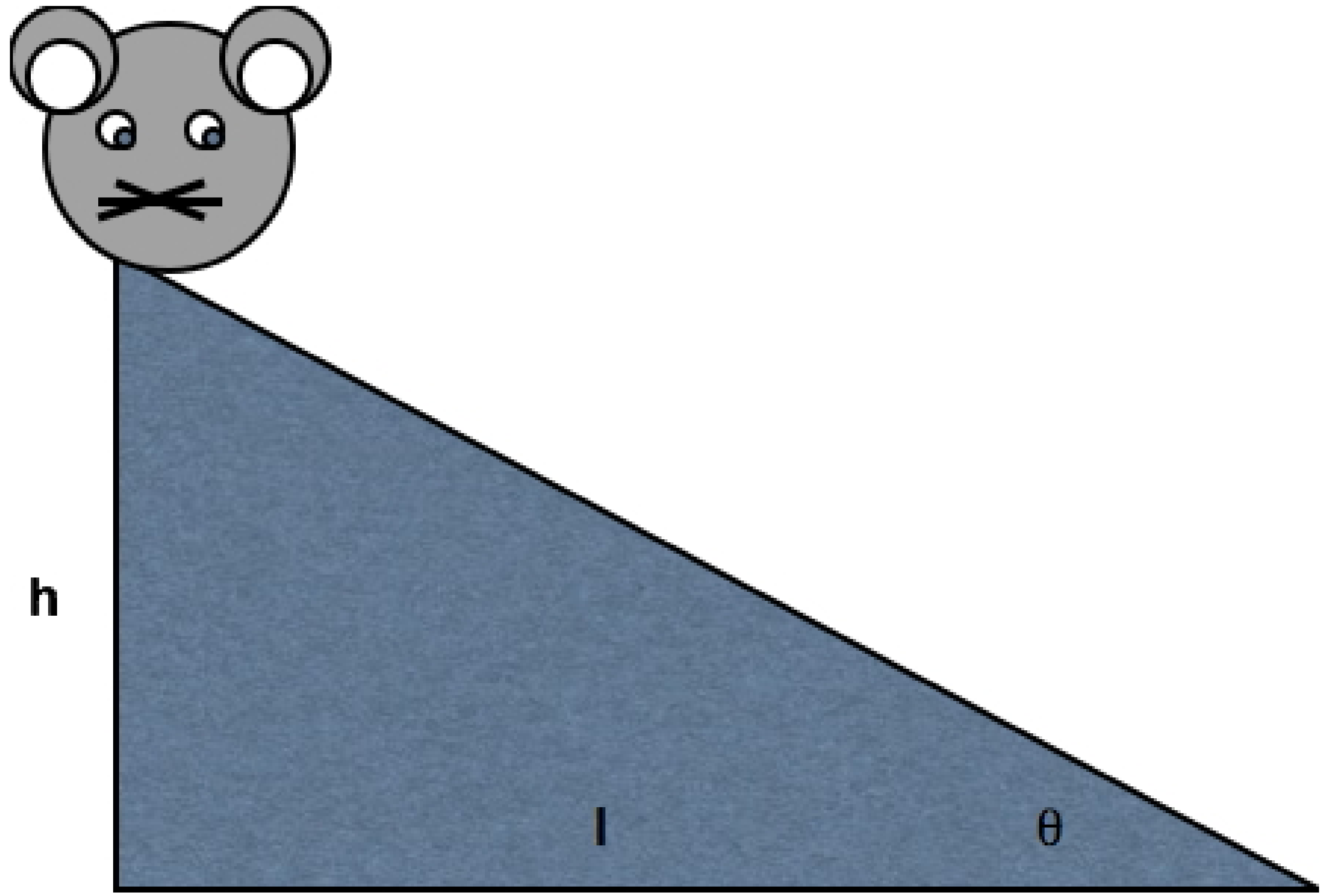
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What do we need to know to answer the question?

- What is the state…
  - Of the world
  - Of the organism
    - Body
    - Brain/mind
- Some states more easily measured than others

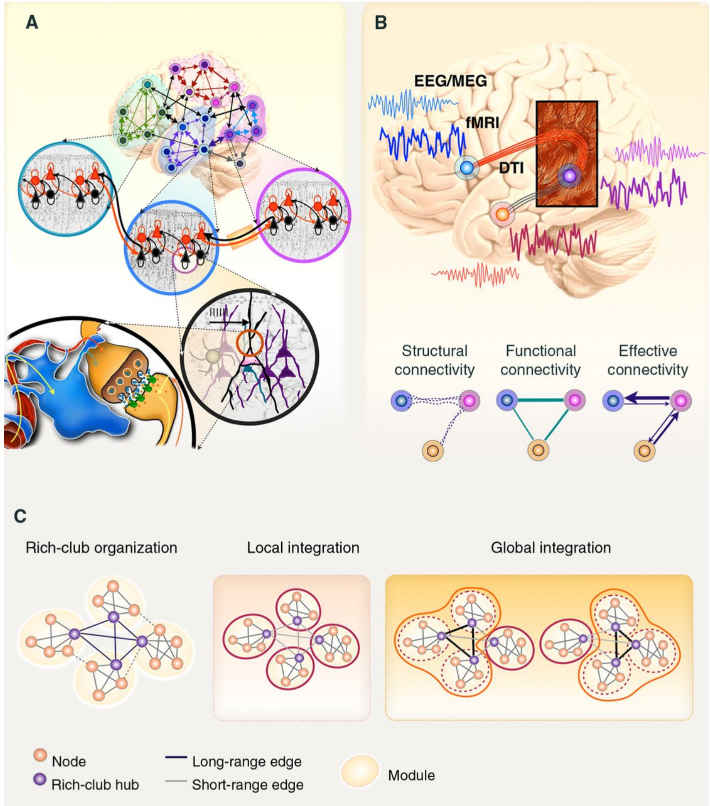
Brain & behavior are complex, dynamic *systems* with

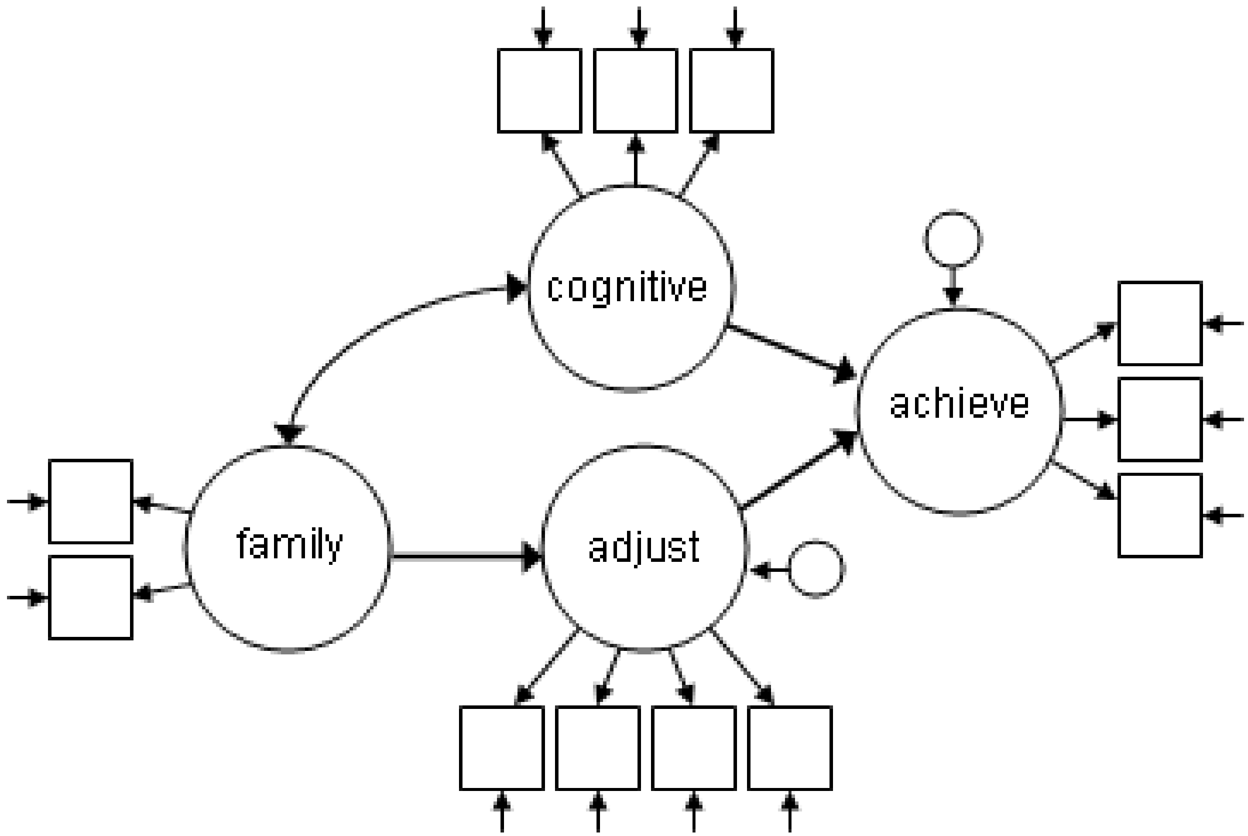
- Components
- Interactions
- Forces/influences
- Boundaries
- Inputs/outputs/processes

Systems…

- "Behave" or change state across time
- Return to starting state
- Appear to be regulated, controlled, influenced by feedback loops

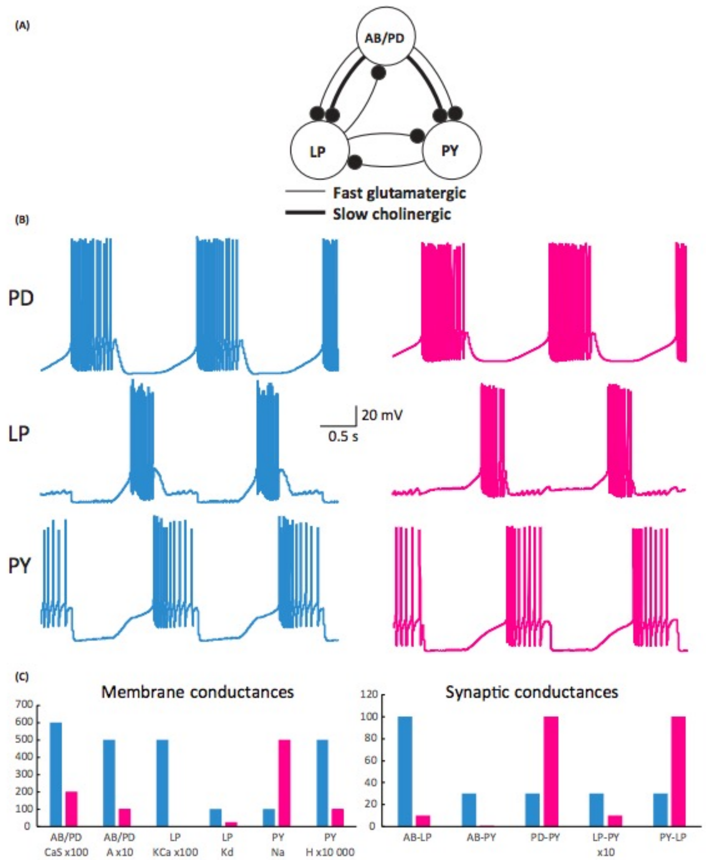
May be thought of as networks




cognitive
achieve
family
adjust

Studying systems is hard because…

- Single parts -> multiple functions
- Single functions -> multiple parts



(Calabrese, 2018)

Studying systems is hard because…

- Change structure/function over time
- Biological systems not "designed" like human-engineered ones
- Hard to measure what is being exchanged, what is being controlled

Course overview

PSY 511.001 Goals

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

Structure

https://psu-psychology.github.io/psy-511-scan-fdns-2018

Questions

- What is the basic plan of the nervous system?
- How do neurons work?
- How do neurons connected in networks achieve behavioral goals?
- How does the nervous system develop? How has it evolved?
- How do disorders of the mind reveal themselves in the nervous system?

Approach

Brain architecture (neuroanatomy)

Brain function (neurophysiology)

Brain communication (neurochemistry)

Changes over evolutionary and developmental time

Approach

The nervous system as information processing system

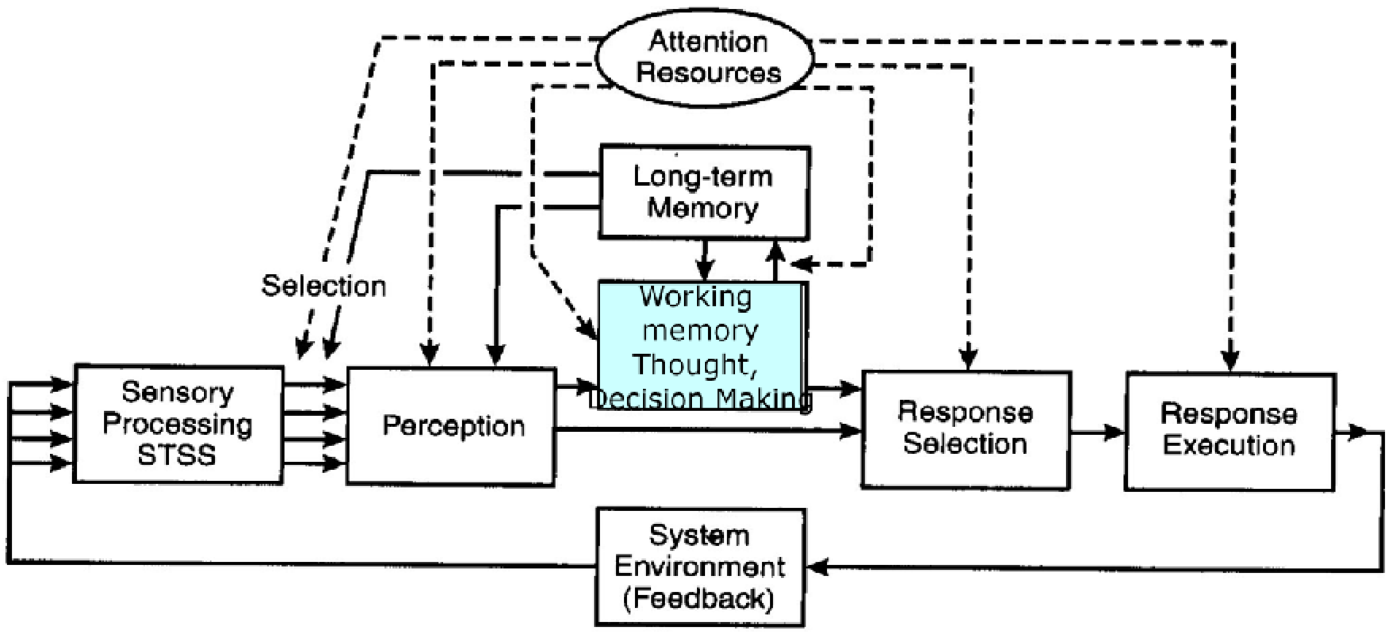


Figure 1.3 A model of human information processing stages.

Inputs

- From environment, body, brain

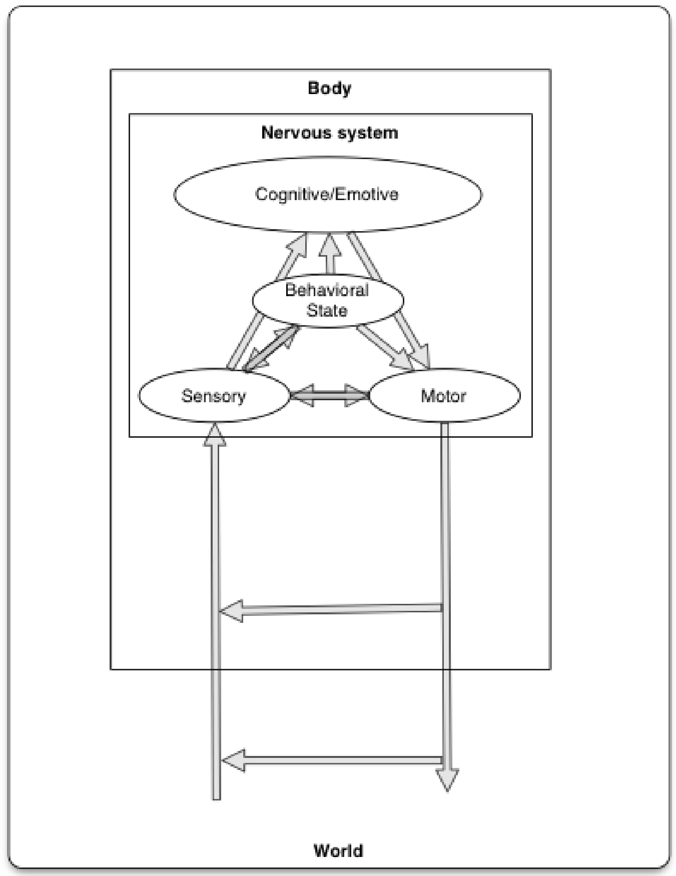
Processing

- Current inputs + brain state + body state + possible future states…
- Stored information
- Physiological & behavioral goals

Outputs

- To brain, body, environment

Cajal/Swanson Architecture



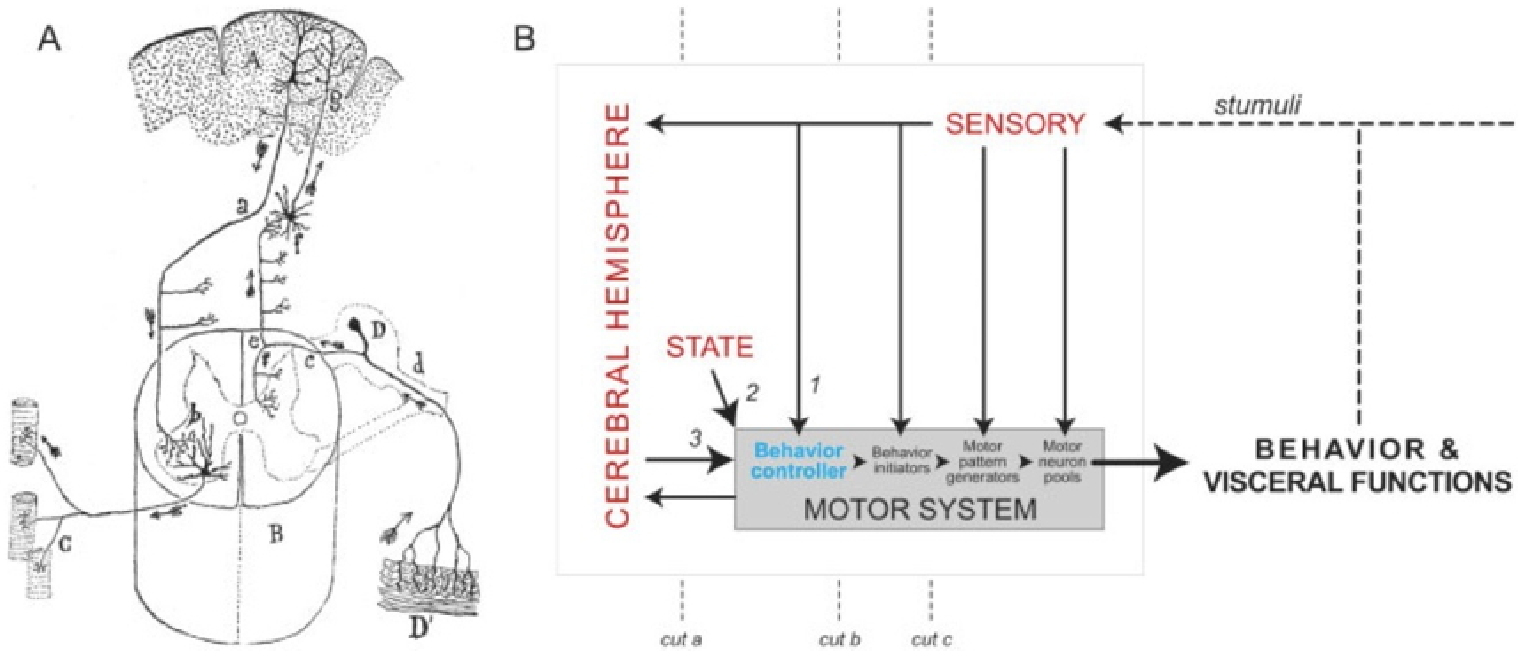


Fig. 1. **A:** Perhaps the first diagram illustrating the cellular organization of a vertebrate spinal reflex, based on the neuron doctrine and law of functional polarity, published by Cajal in 1890 (see Cajal, 1894). Note that he emphasized two interconnected sources of motor neuron (b) control: dorsal root ganglion cells (D) and cerebral cortical pyramidal (or psychomotor) neurons (A). For clarity, he showed sensory input to the right side of the spinal cord, and motor output from the left side. **B:** A modern version of the basic plan of nervous system organization, adding behavioral state inputs (2) to sensory or voluntary (1) and cerebral hemisphere/cognitive or voluntary (3) inputs to the motor system hierarchy; see text for details (adapted from Swanson, 2000a).

Swanson, 2005

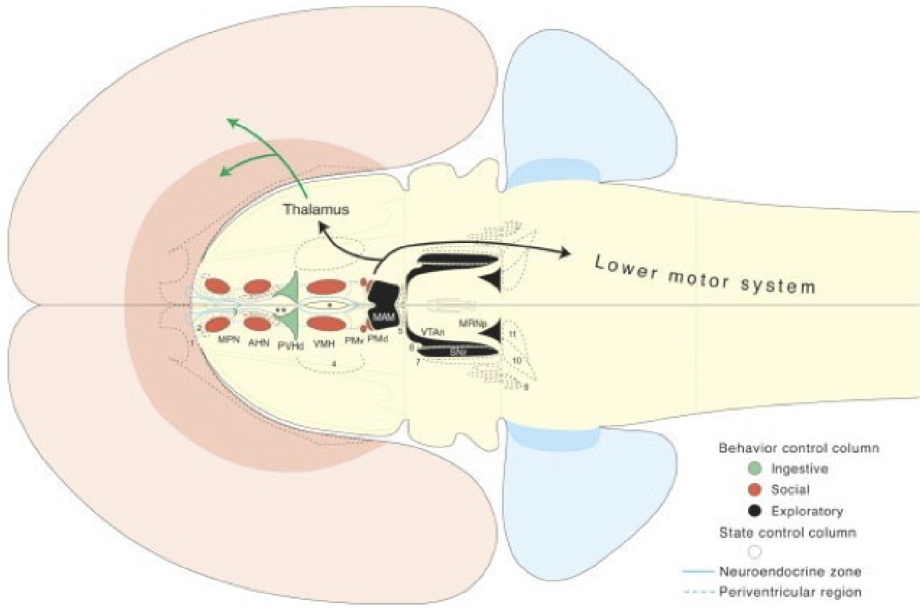
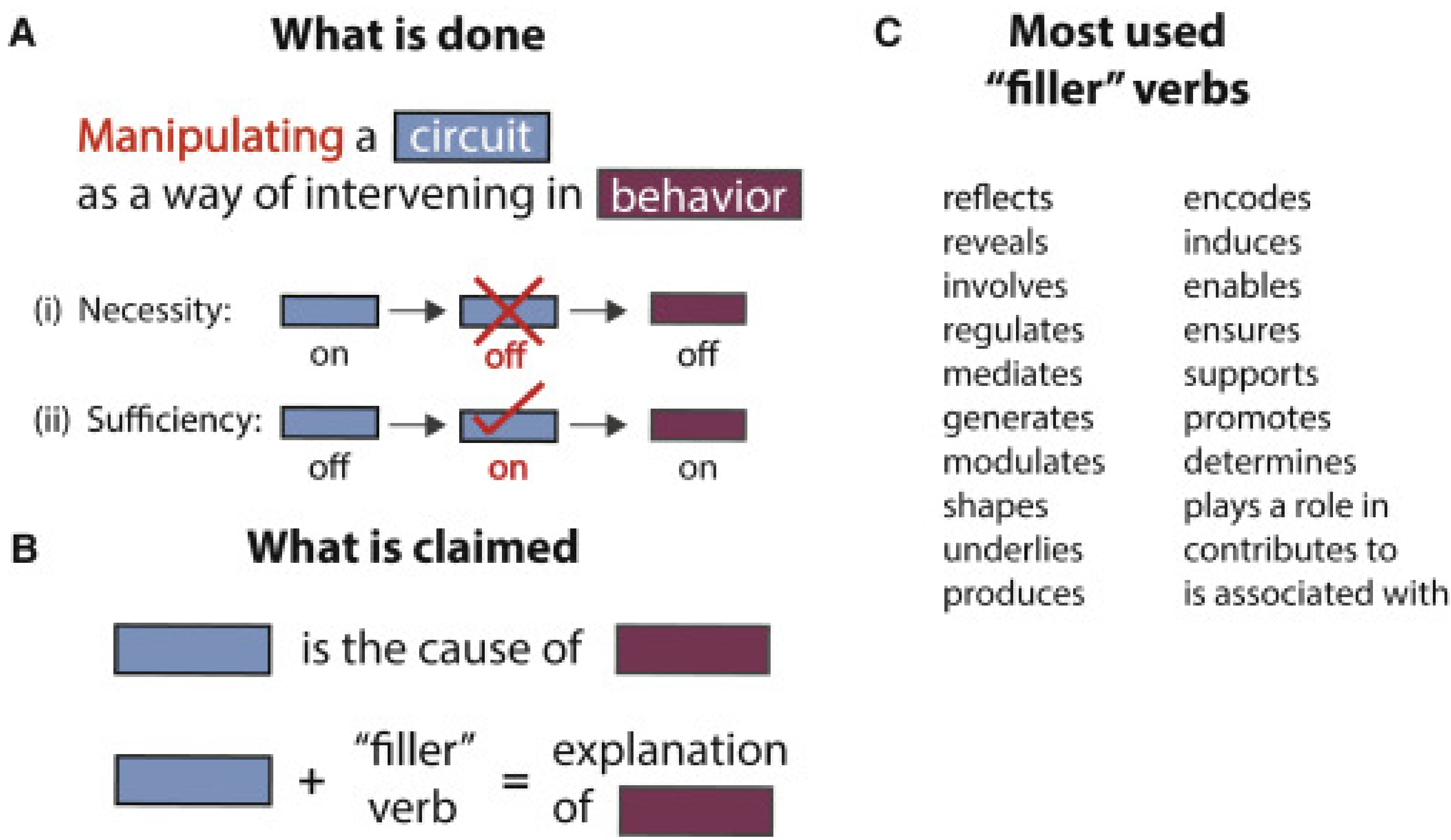


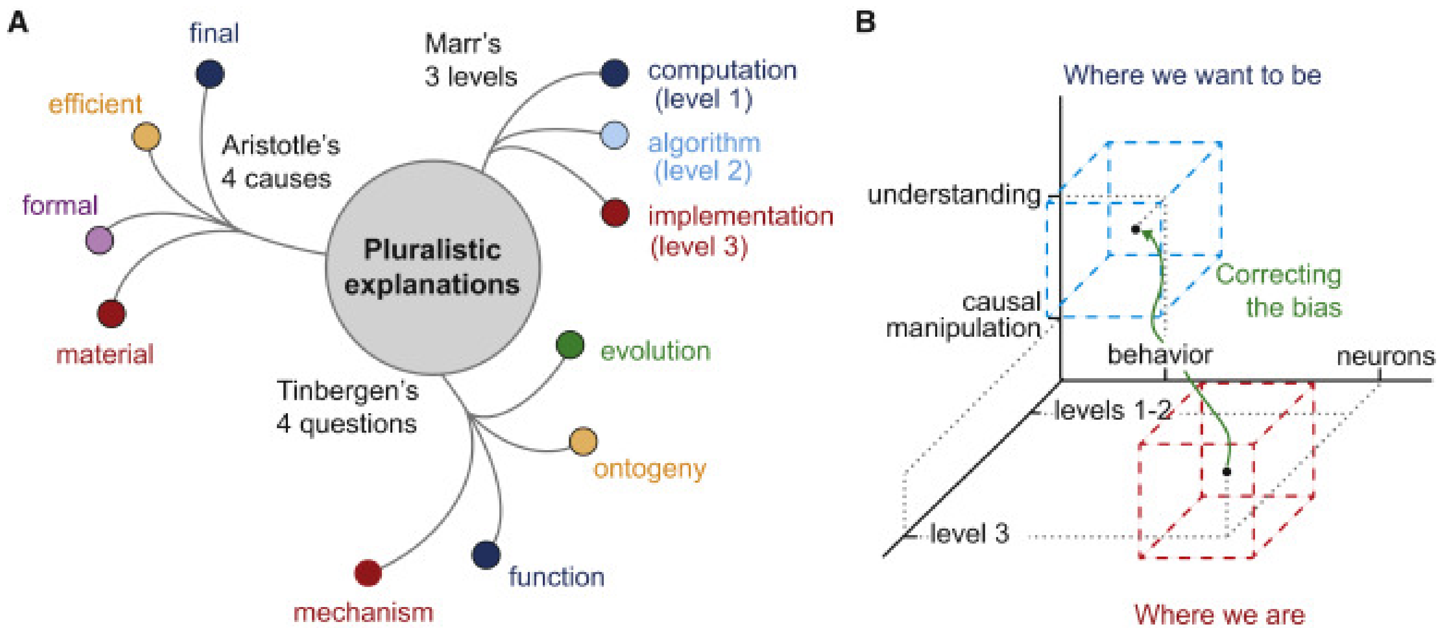
Fig. 3. Basic topography of the behavior control column (BCC) in ventromedial regions of the upper brainstem as viewed on a flatmap of the rat central nervous system. Each component minimally generates a dual projection to the lower motor system (primarily motor pattern generator networks and motoneuron pools) and dorsal thalamus. Where analyzed experimentally (dorsal premammillary nucleus, PMd; mammillary body, MAM; and reticular substantia nigra, SNr), the thalamic projection is a collateral of the descending projection to motor system. This dual projection may be either glutamatergic (e.g., MAM) or GABAergic (e.g., SNr). The BCC caudal segment contains MAM, nondopaminergic ventral tegmental area (VTAn), SNr, and parvicellular midbrain reticular nucleus (MRNp). The BCC rostral segment contains medial preoptic nucleus (MPN), anterior hypothalamic nucleus (AHN), ventromedial nucleus (VMH), ventral premammillary nucleus (PMv), and PMd. Two critical functional regions lie between the BCC rostral segment and third ventricle (midline): the median eminence (*, asterisk) and surrounding neuroendocrine motor zone (solid blue line), and the periventricular region (dashed blue line and **, double asterisks), which contains visceromotor pattern generator and circadian rhythm generator networks. The behavioral state control column, running parallel to the BCC, is indicated by dashed outlines (see text for more information).

Swanson, 2005

Why neuroscience needs behavior



(Krakauer, Ghazanfar, Gomez-Marin, MacIver, & Poeppel, 2017)



(Krakauer et al., 2017)

Neuroscience methods

Evaluating methods

What is the question?

- Structure X -> Structure Y
- Structure X -> Function Y

What are we measuring?

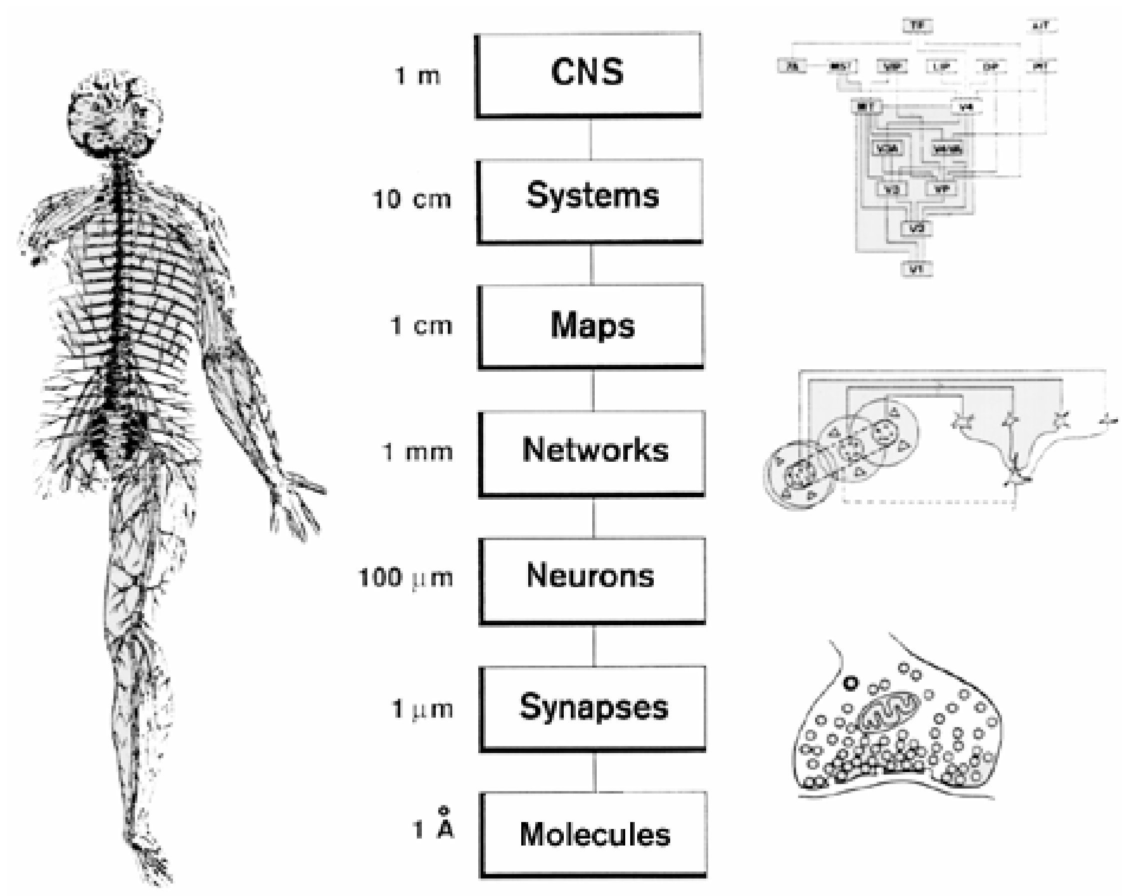
- Structure
- Activity
    - Why not *function*?

Evaluating methods

Strengths & Weaknesses

- Cost
- Invasiveness
- Spatial/temporal resolution

Spatial resolution



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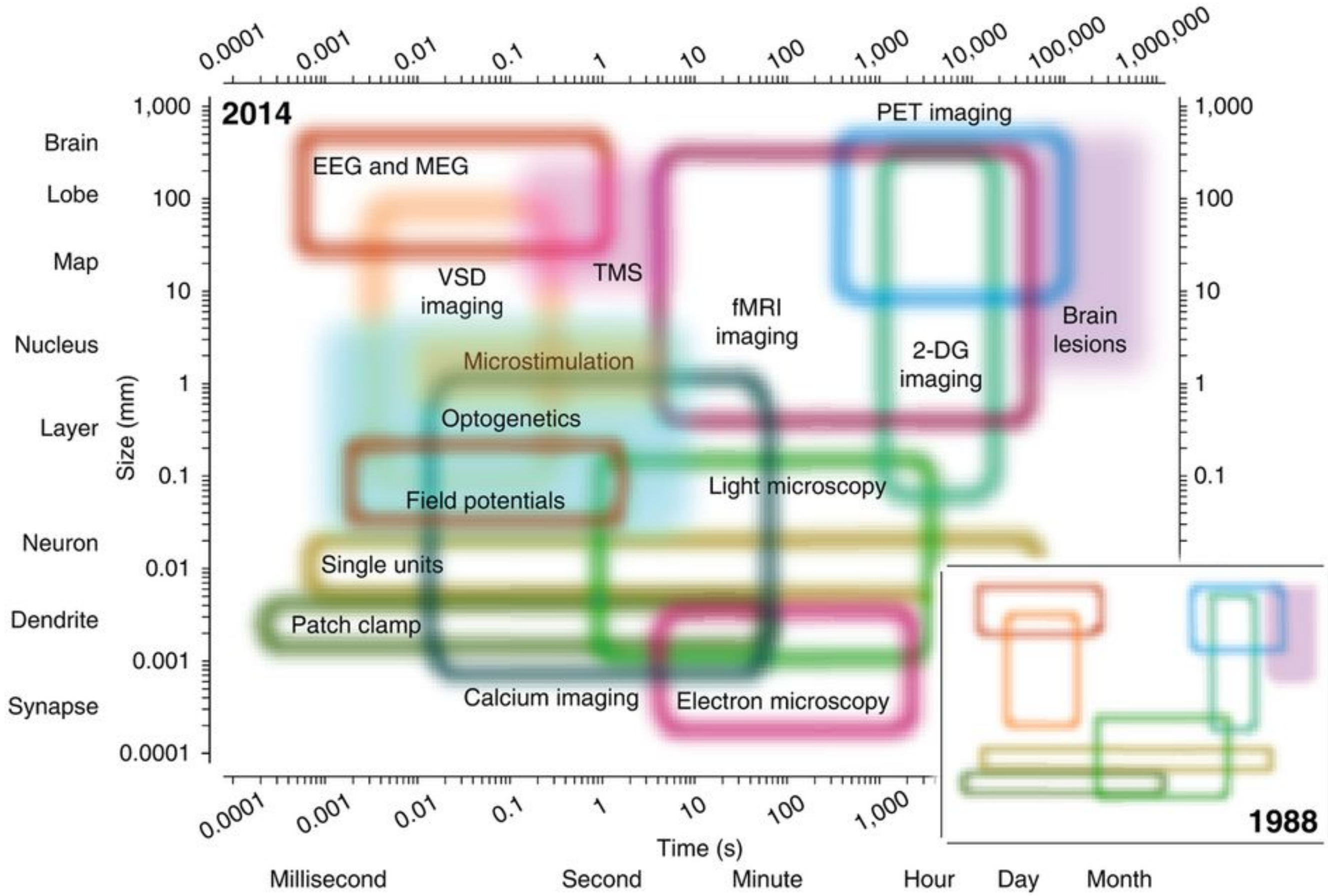
…and temporal Resolution



(Sejnowski, Churchland, & Movshon, 2014)

Types of methods

Structural

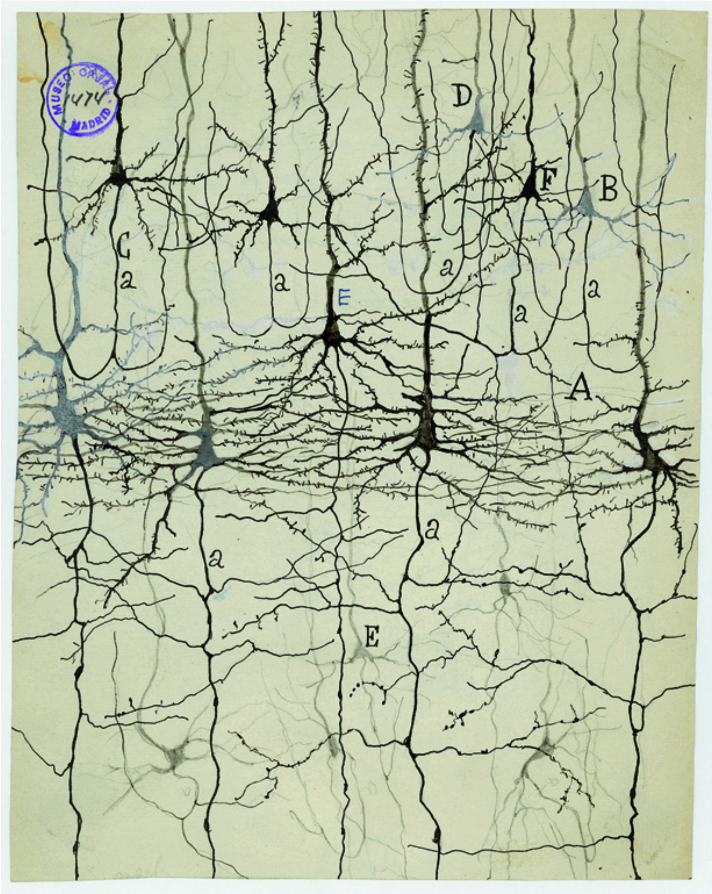
- Anatomy
- Connectivity/connectome

Functional (next time)

- What does it do?
- Physiology/Activity

Mapping structures

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



http://connectomethebook.com/wp-content/uploads/2011/11/Brainforest17_1119.jpg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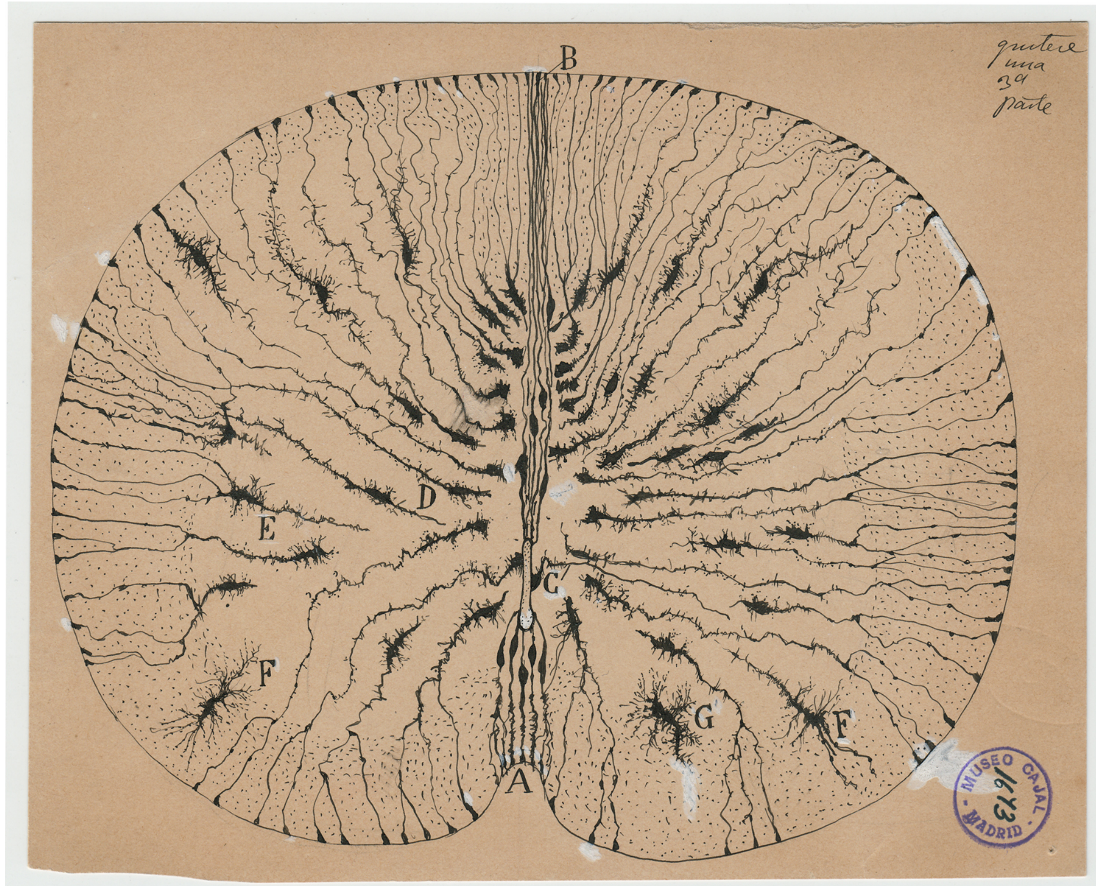
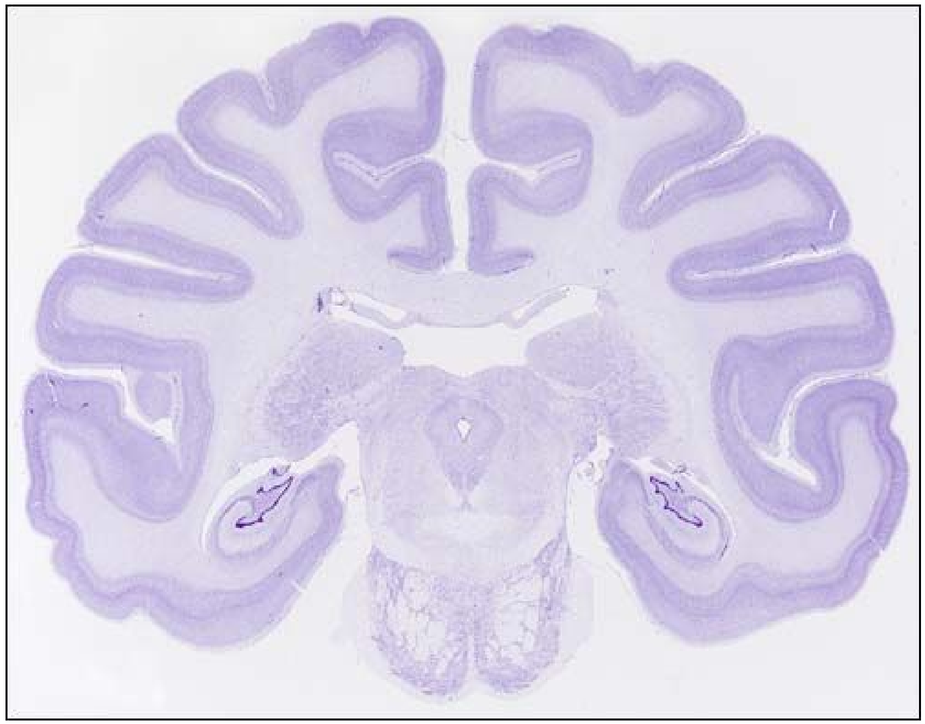


http://wam.umn.edu/calendar/cajal/

Camillo Golgi

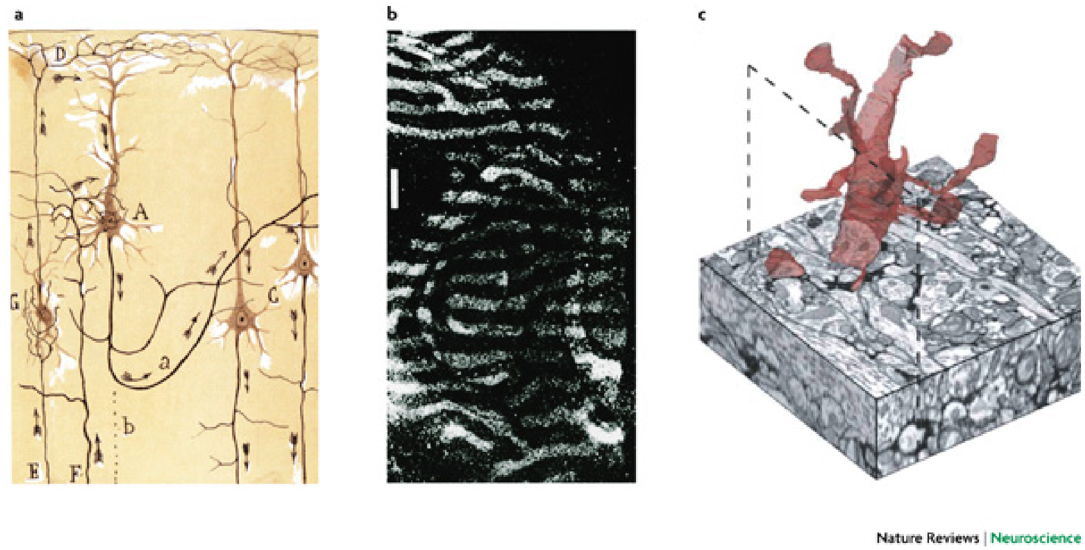
Nissl stain

- Cell bodies



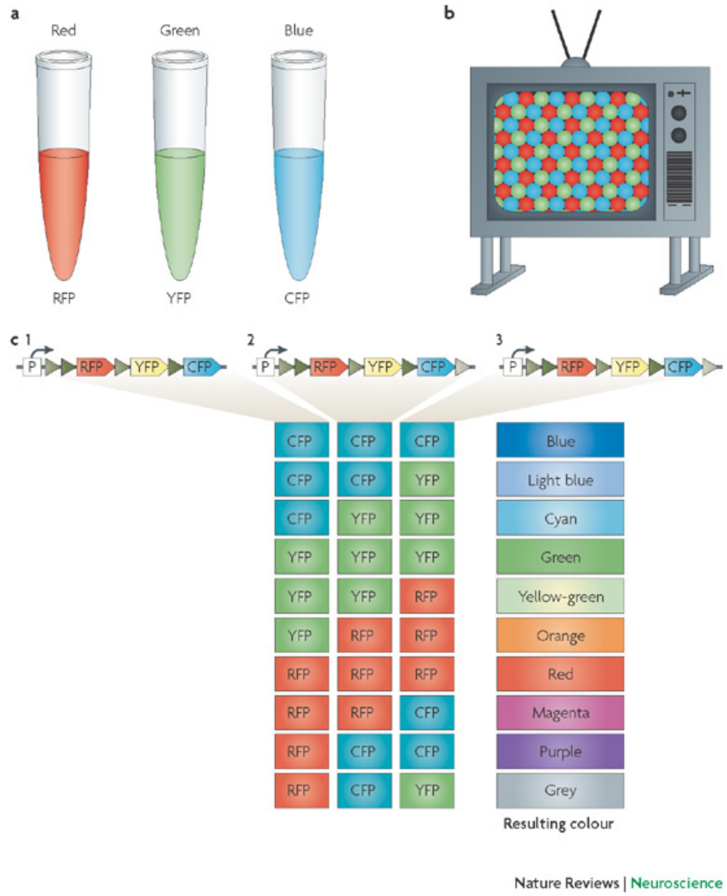
Franz Nissl

Brainbow



(Lichtman, Livet, & Sanes, 2008)

Brainbow



(Lichtman et al., 2008)

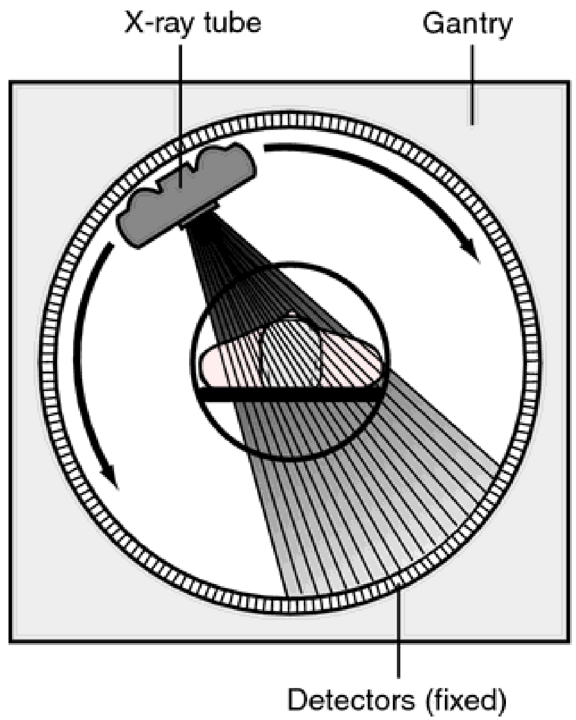
Clarity

Evaluating cellular tracing techniques

- Invasive (in humans post-mortem only)
- High spatial resolution, but poor/coarse temporal
    - Why?

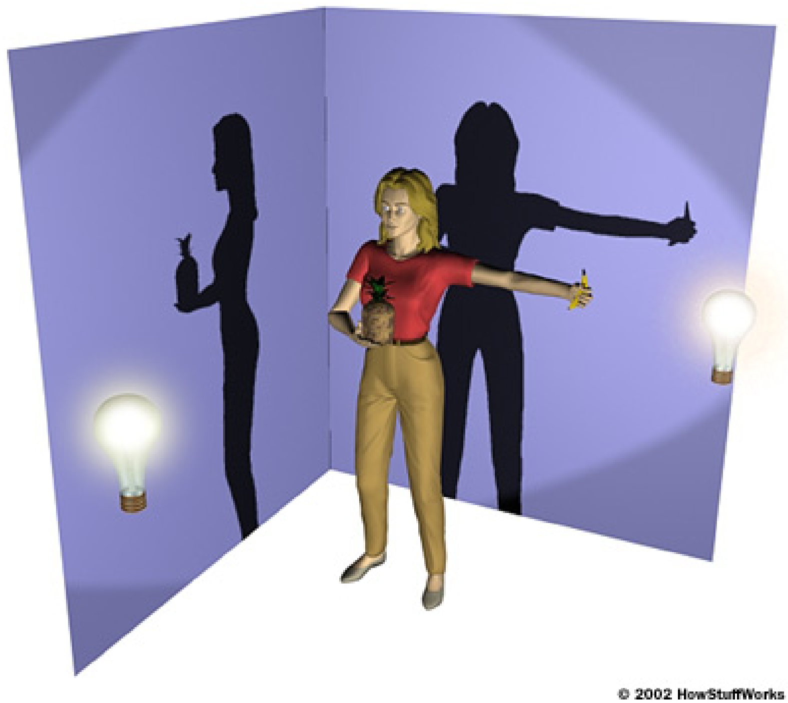
Mapping structures

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

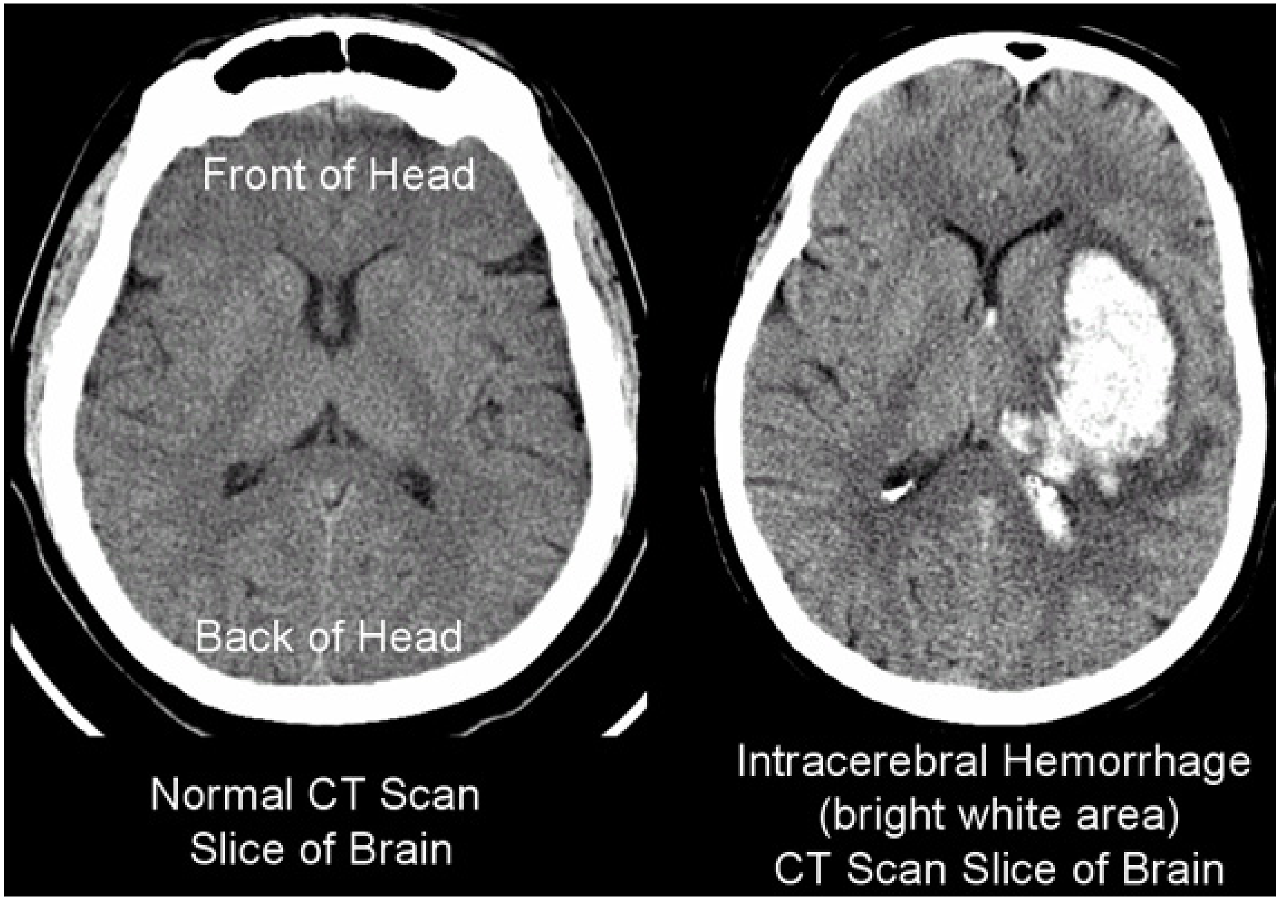


http://img.tfd.com/mk/T/X2604-T-22.png

Tomography



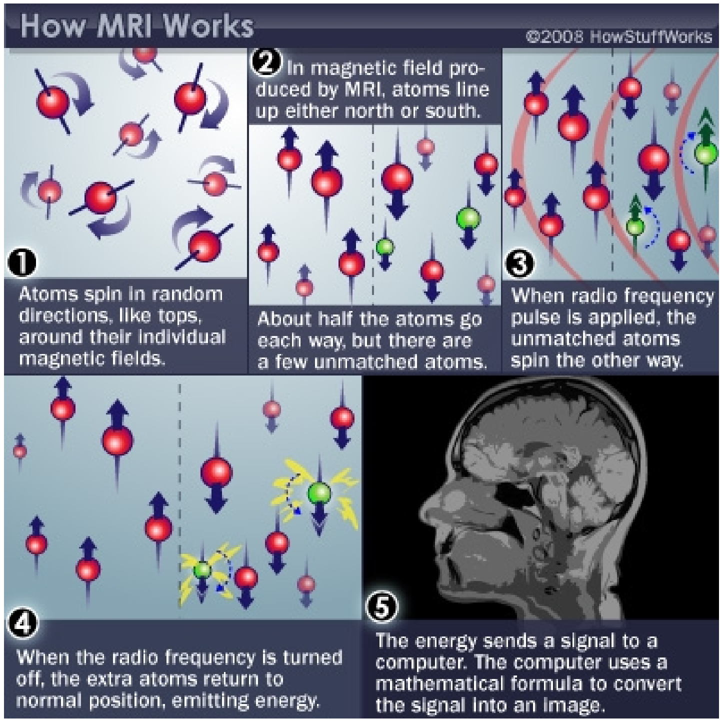
http://static.howstuffworks.com/gif/cat-scan-pineapple.jpg


Front of Head
Back of Head
Normal CT Scan
Slice of Brain
Intracerebral Hemorrhage
(bright white area)
CT Scan Slice of Brain

Magnetic Resonance Imaging (MRI)

- Magnetic resonance a property of some isotopes and complex molecules
- Hydrogen (H), common in water & fat, is one
- In magnetic field, H atoms absorb and release radio frequency (RF) energy
- H atoms align with strong magnetic field
- Applying RF pulse perturbs alignment
- Rate/timing of realignment varies by tissue
- Realignment gives off radio frequency (RF) signals
- Strength of RF ~ density

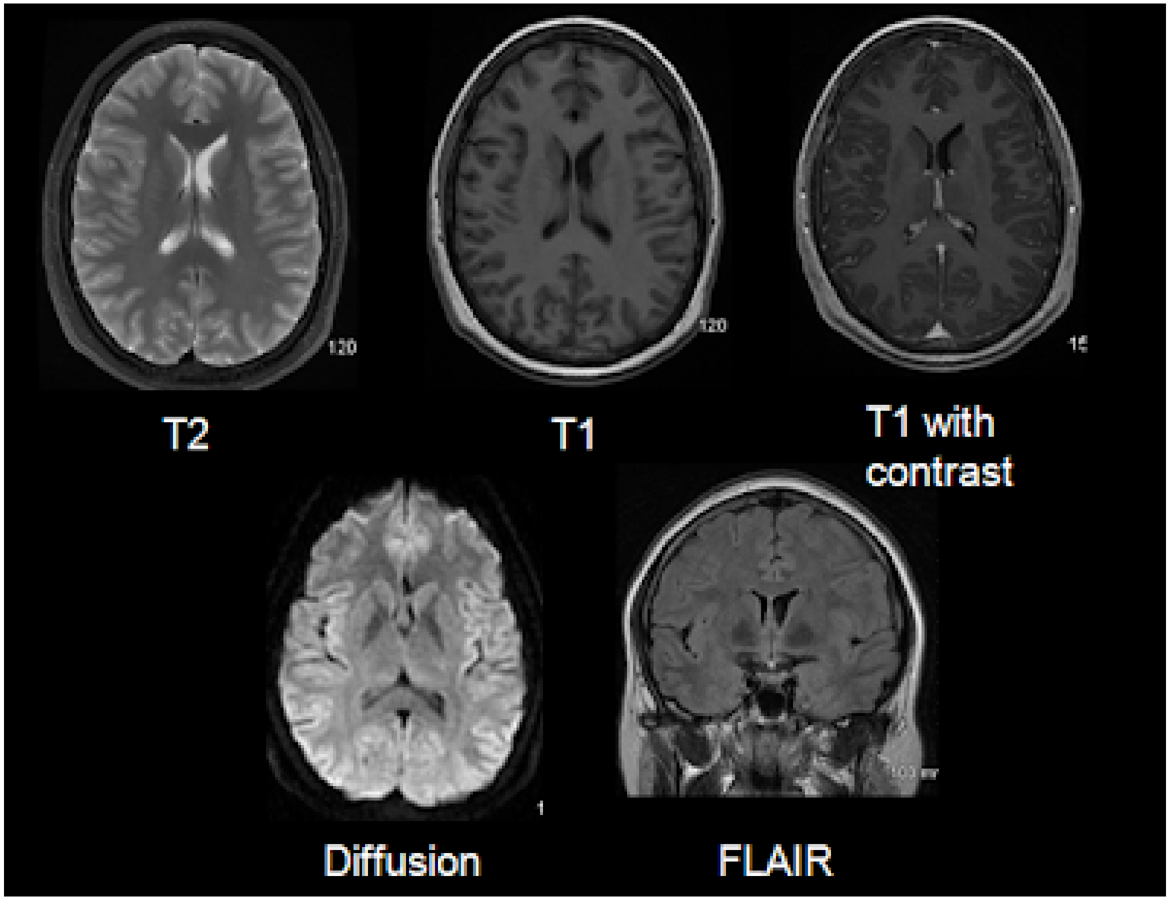
MRI

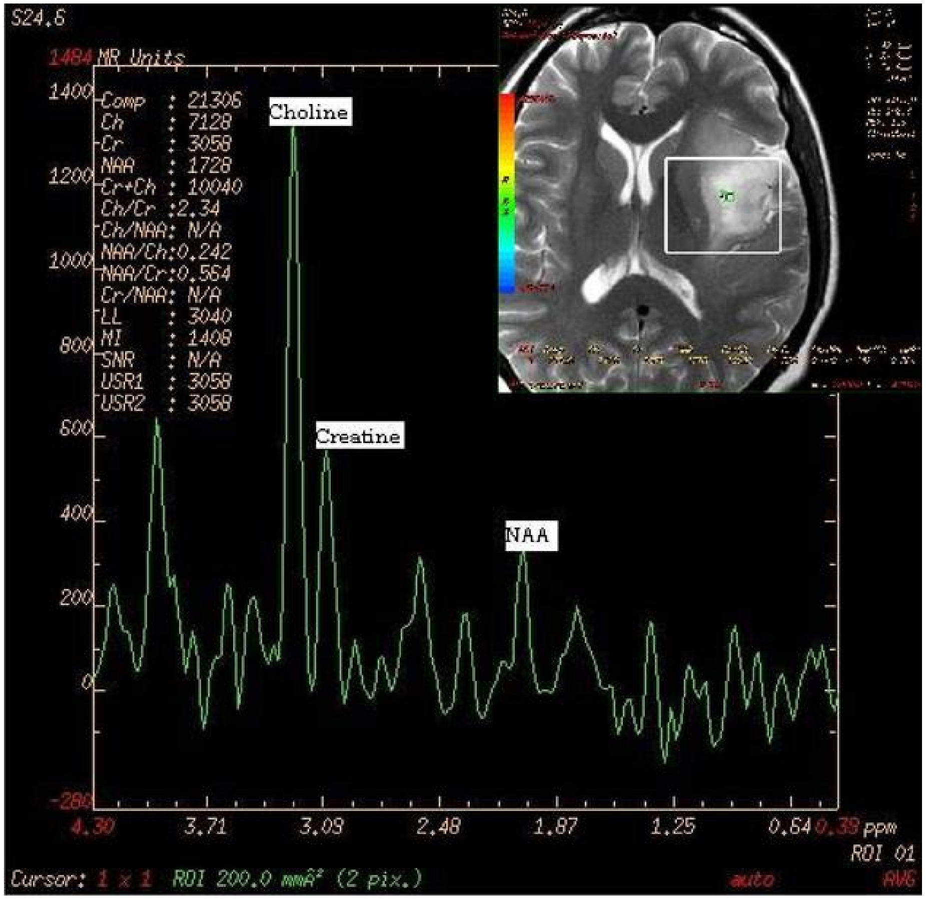


http://s.hswstatic.com/gif/mri-steps.jpg

Structural MRI

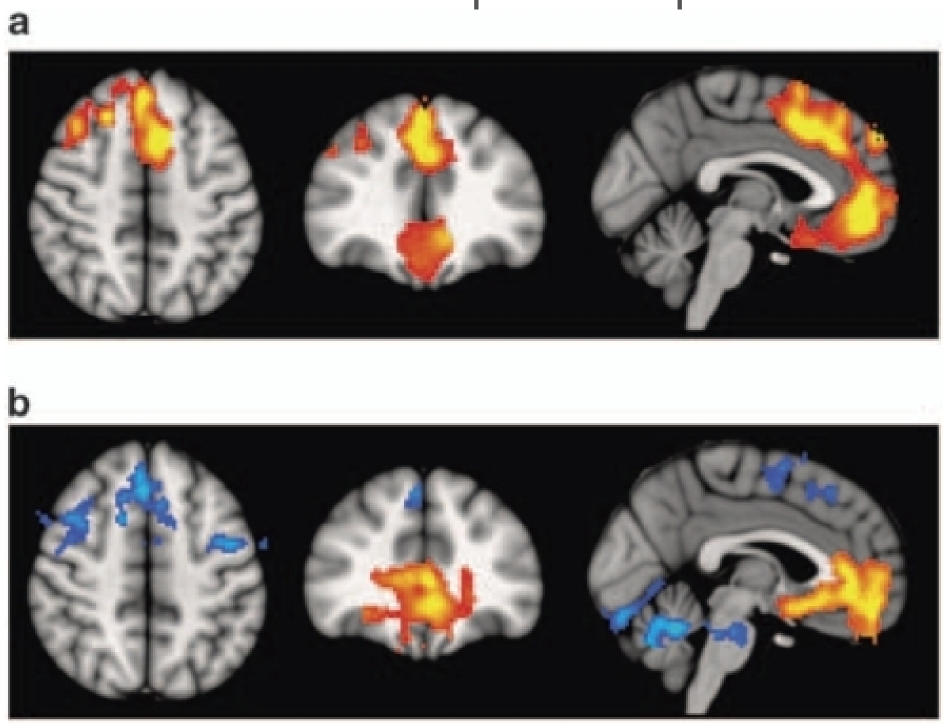
- Tissue density/type differences
- **Gray matter** (nerve cells & **dendrites**) vs. **white matter (axon fibers**)
- **Spectroscopy** (specific metabolites)
- Region sizes/volumes


T2
T1
T1 with contrast
Diffusion
FLAIR


S24.6
1484 MR Units
Comp : 21306
Ch : 7128
Cr : 3058
NAA : 1728
Cr+Ch : 10040
Ch/Cr :2.34
Ch/NAA: N/A
NAA/Ch:0.242
NAA/Cr:0.564
Cr/NAA: N/A
LL : 3040
MI : 1408
SNR : N/A
USR1 : 3058
USR2 : 3058
Choline
Creatine
NAA
1400
1200
1000
800
600
400
200
0
-200
4.30
3.71
3.09
2.48
1.87
1.25
0.64
0.39
ppm
ROI 01
Cursor: 1 x 1 ROI 200.0 mmÂ² (2 pix.)
auto
AVG

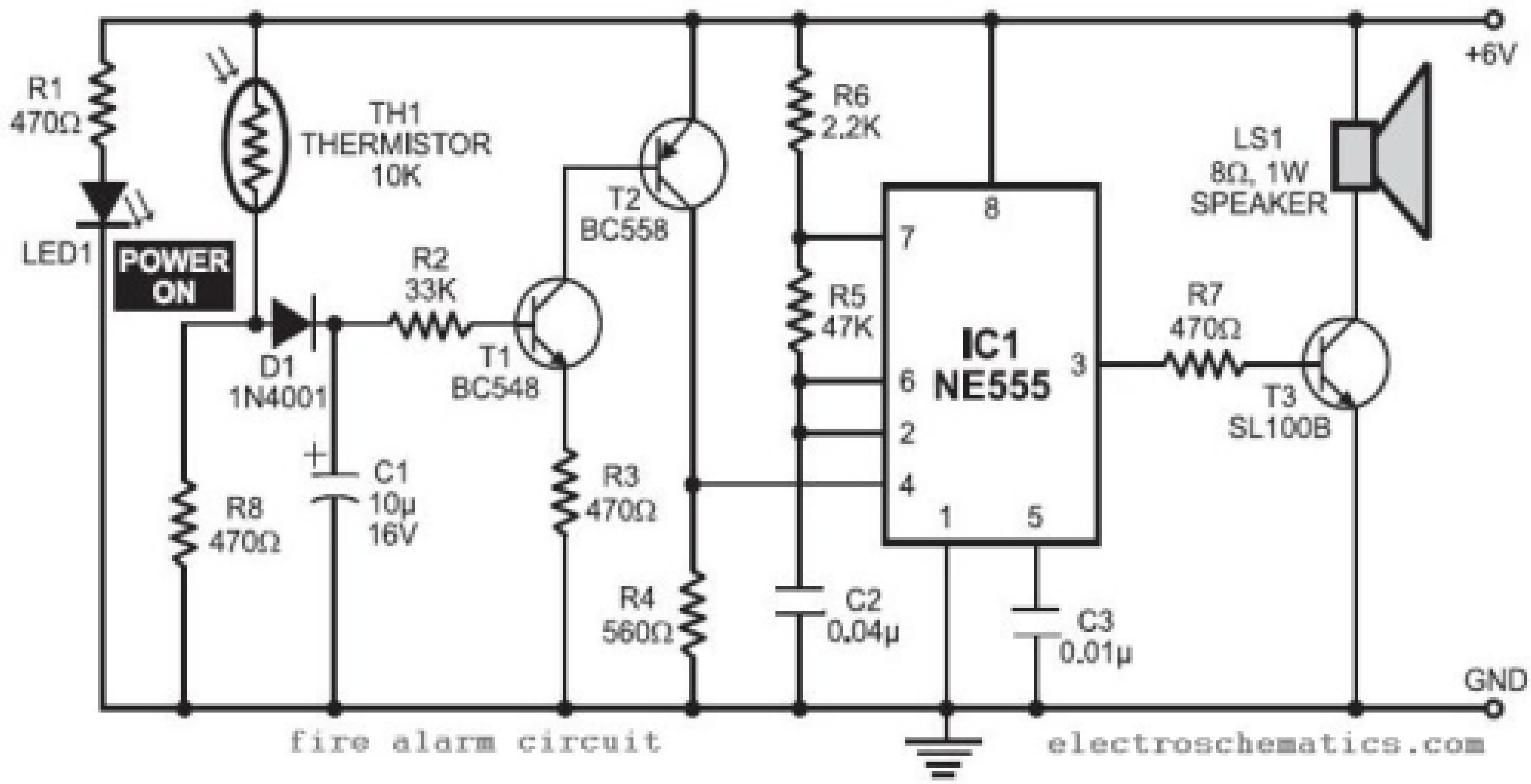
Voxel-based morphometry (VBM)

Volume differences in schizophrenic patients vs. controls



(Pomarol-Clotet et al., 2010)

What is the wiring diagram ("connectome")?



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RESEARCH ARTICLE

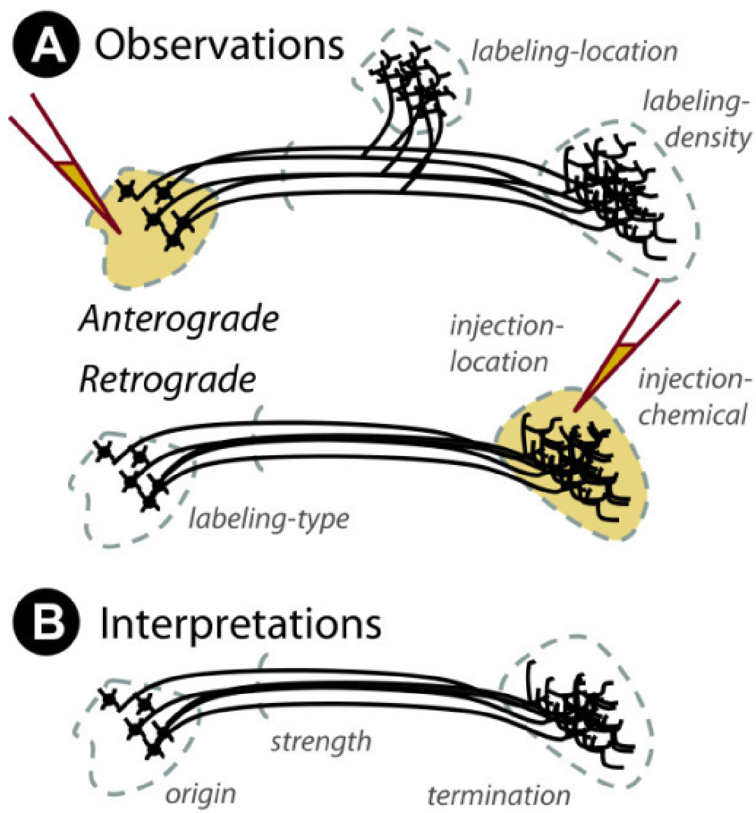
Could a Neuroscientist Understand a Microprocessor?

Eric Jonas, Konrad Paul Kording

Published: January 12, 2017 • https://doi.org/10.1371/journal.pcbi.1005268

Article | Authors | Metrics | Comments | Related Content

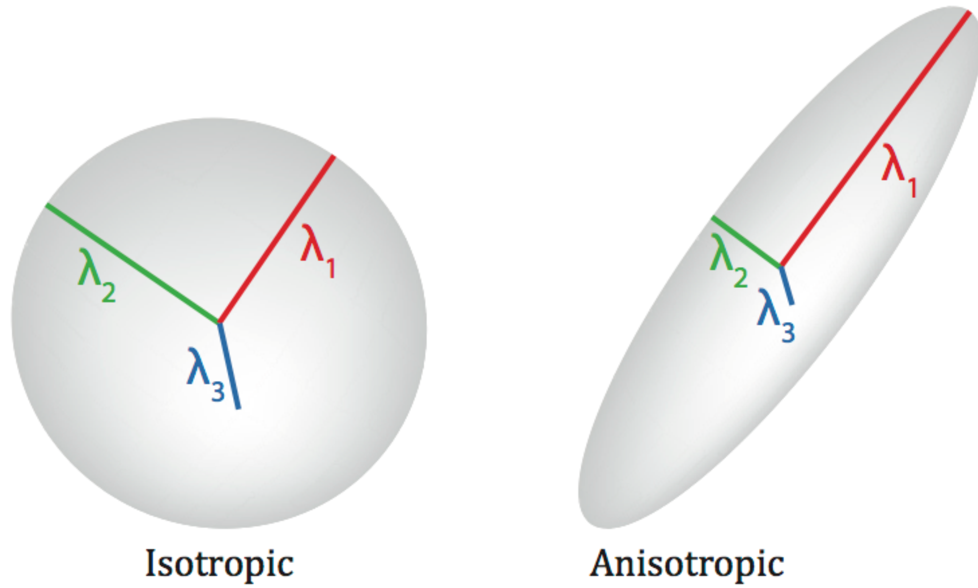
Retrograde (output -> input) vs. anterograde (input -> output) tracers



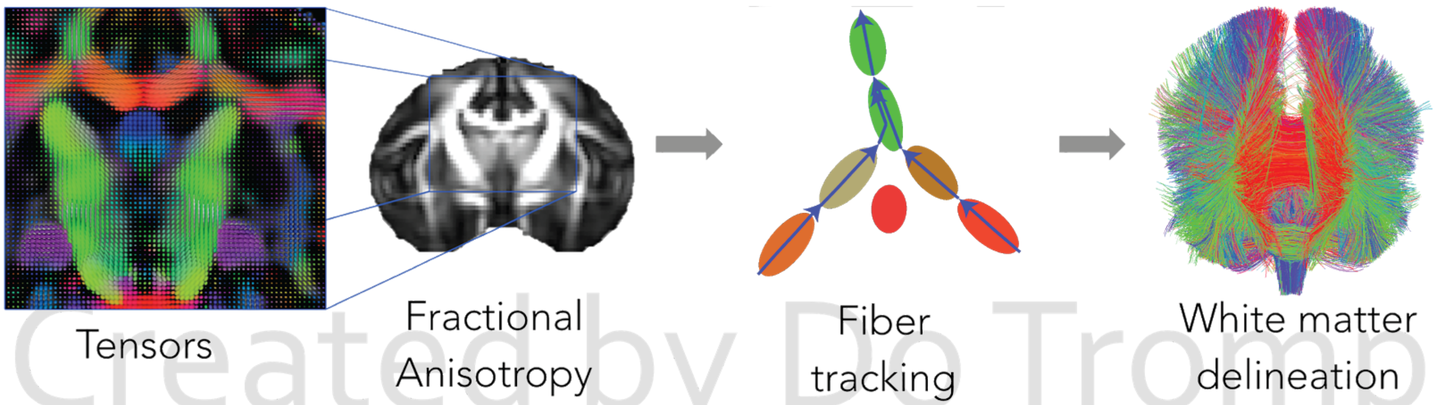
http://openi.nlm.nih.gov/imgs/512/348/3176268/3176268_1471-2105-12-351-2.png

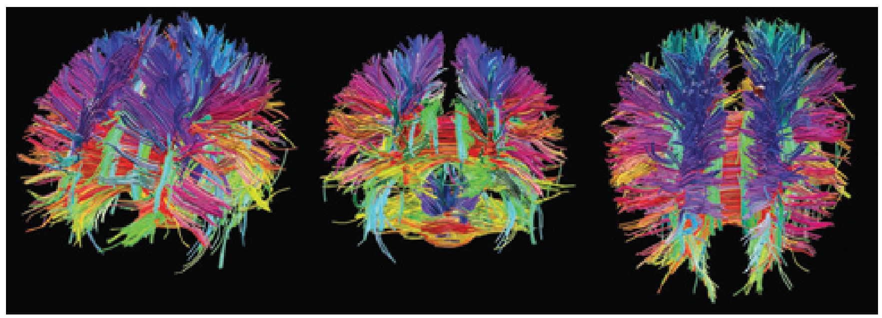
Diffusion Tensor Imaging (DTI)

- Structural MRI technique
- Diffusion tensor: measurement of spatial pattern of H_2O diffusion in small volume
- Uniform ("isotropic") vs. non-uniform ("anisotropic")
- Strong anisotropy suggests large # of axons with similar orientations (fiber tracts)

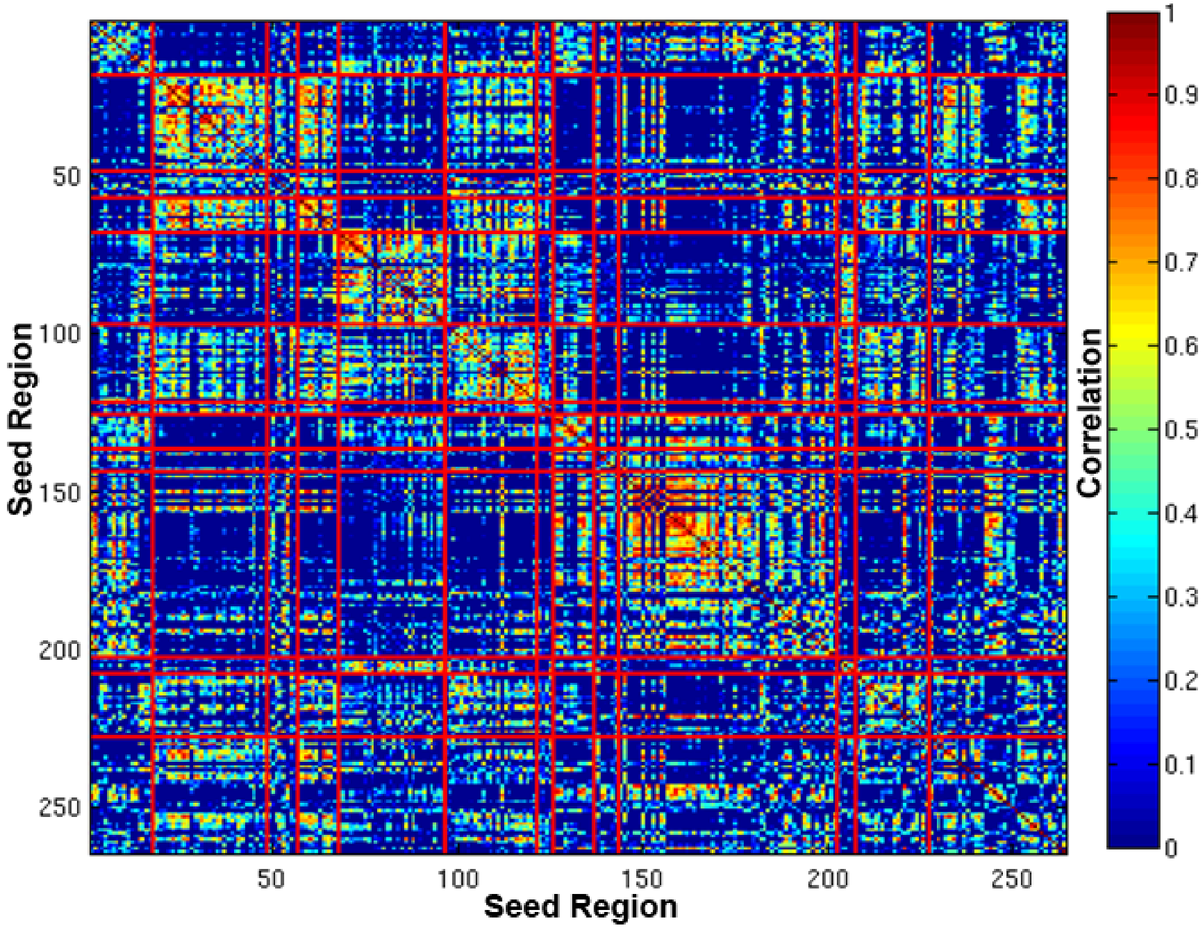


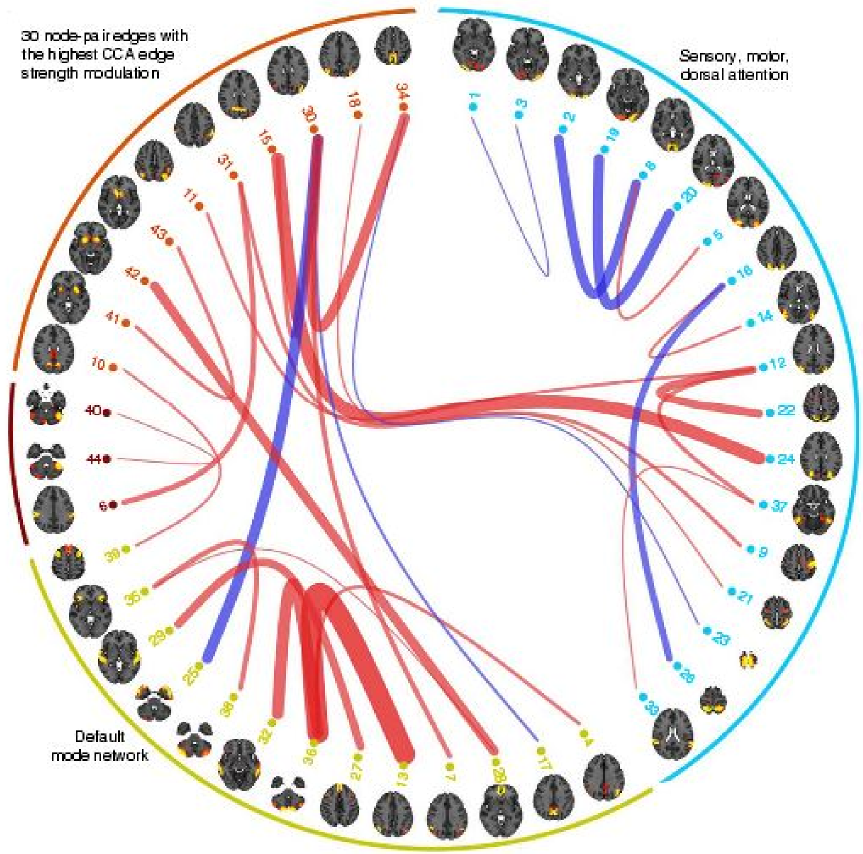
λ_1 = longitudinal (axial) diffusivity(AD)
$(\lambda_2 + \lambda_3)/2$ = radial diffusivity (RD)
$(\lambda_1 + \lambda_2 + \lambda_3)/3$ = mean diffusivity (MD)


Tensors
Fractional
Anisotropy
Fiber
tracking
White matter
delineation



Connectome as matrix




30 node-pair edges with the highest CCA edge strength modulation
Sensory, motor, dorsal attention
Default mode network

Main points

- Psychology is harder than physics
- Understanding brain/behavior relations requires a diverse toolkit
    - Structural vs. functional methods
    - Spatial and temporal resolution
    - Invasive vs. non-

Your turn

1. Pick two papers you want to read and (better) understand

- Email me APA formatted citation (with DOIs)
- Indicate three concepts/terms you are especially interested in understanding

2. Choose a behavior or mental state you want to (better) understand

- Take an information processing perspective and briefly sketch out (in no more than a short paragraph) the main inputs, outputs, and computations involved.
- When thinking about *outputs* make sure to distinguish between *behaviors* (e.g., movements, facial expressions, vocalizations) and *physiological states* (e.g., changes in heart rate, hormone concentrations in the blood, etc.)

References

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Pomarol-Clotet, E., Canales-Rodríguez, E. J., Salvador, R., Sarró, S., Gomar, J. J., Vila, F., … McKenna, P. J. (2010). Medial prefrontal cortex pathology in schizophrenia as revealed by convergent findings from multimodal imaging. *Mol. Psychiatry*, *15*(8), 823–830. https://doi.org/10.1038/mp.2009.146

Sejnowski, T. J., Churchland, P. S., & Movshon, J. A. (2014). Putting big data to good use in neuroscience. *Nature Neuroscience*, *17*(11), 1440–1441. https://doi.org/10.1038/nn.3839