# PSY 511

## Course intro

Rick Gilmore

2021-09-01 18:36:20

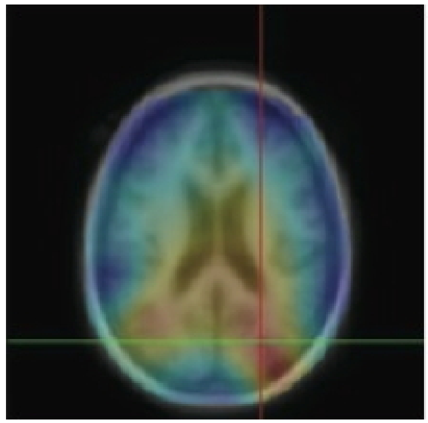
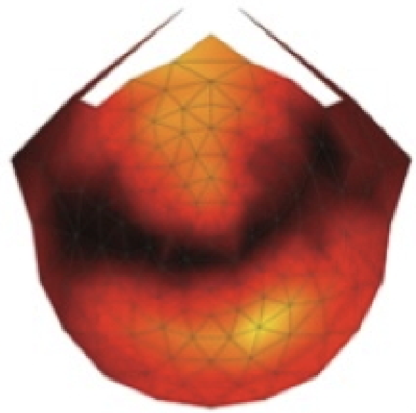
# Prelude

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

– Jeff Lichtman ultra dude

PSY 511

# Foundations of Cognitive and Affective Neuroscience

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BROWN UNIVERSITY

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Databrary

PLAY

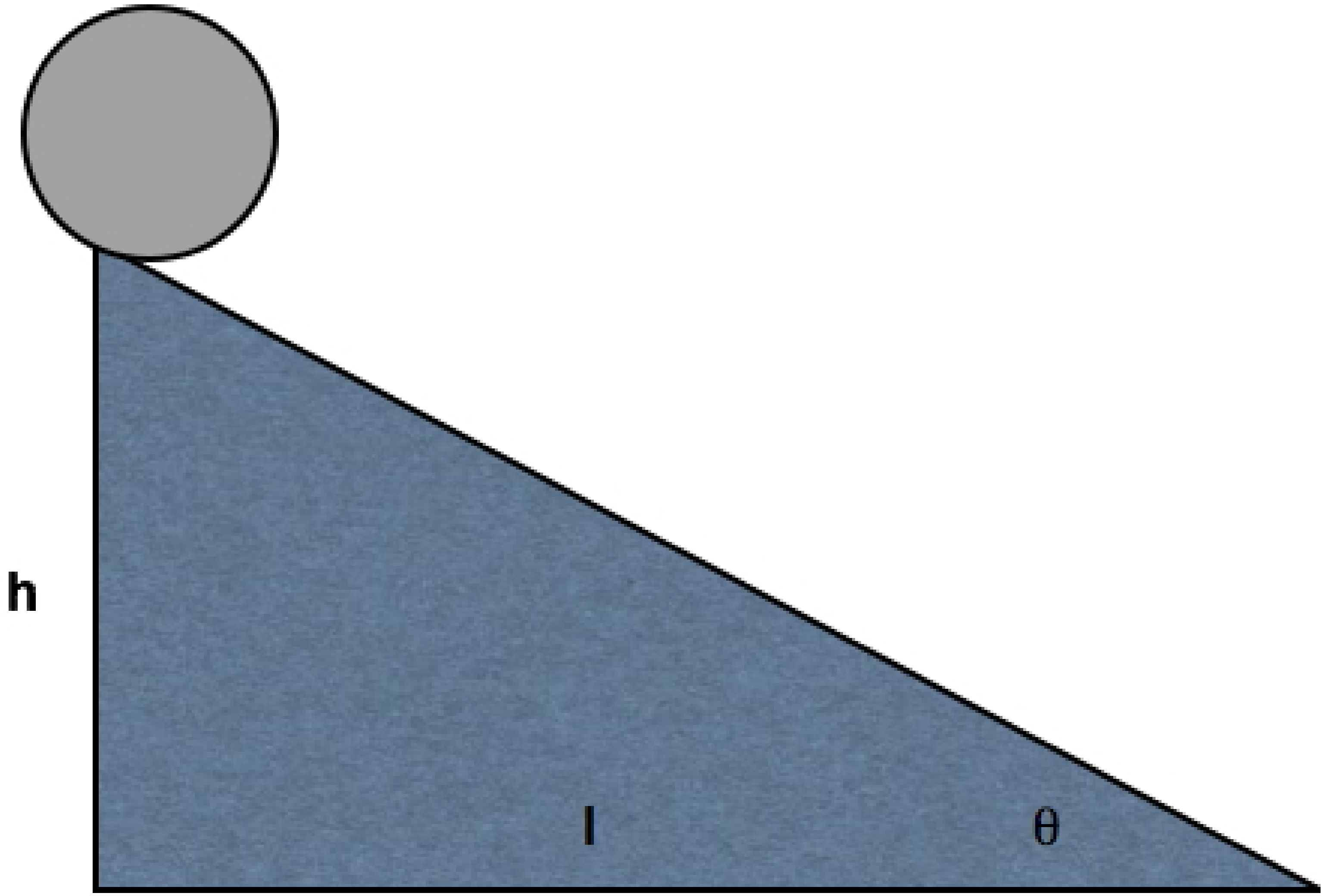
Play & Learning Across a Year

- Hiking, camping/backpacking, cycling, paddling
- Music, theatre
- Activism
- Amateur radio (K3ROG), computing

# Today's topics

- Why neuroscience is harder than physics
- Course overview
- The connectome and beyond
- Does neuroscience need behavior? Does behavioral science need the brain?

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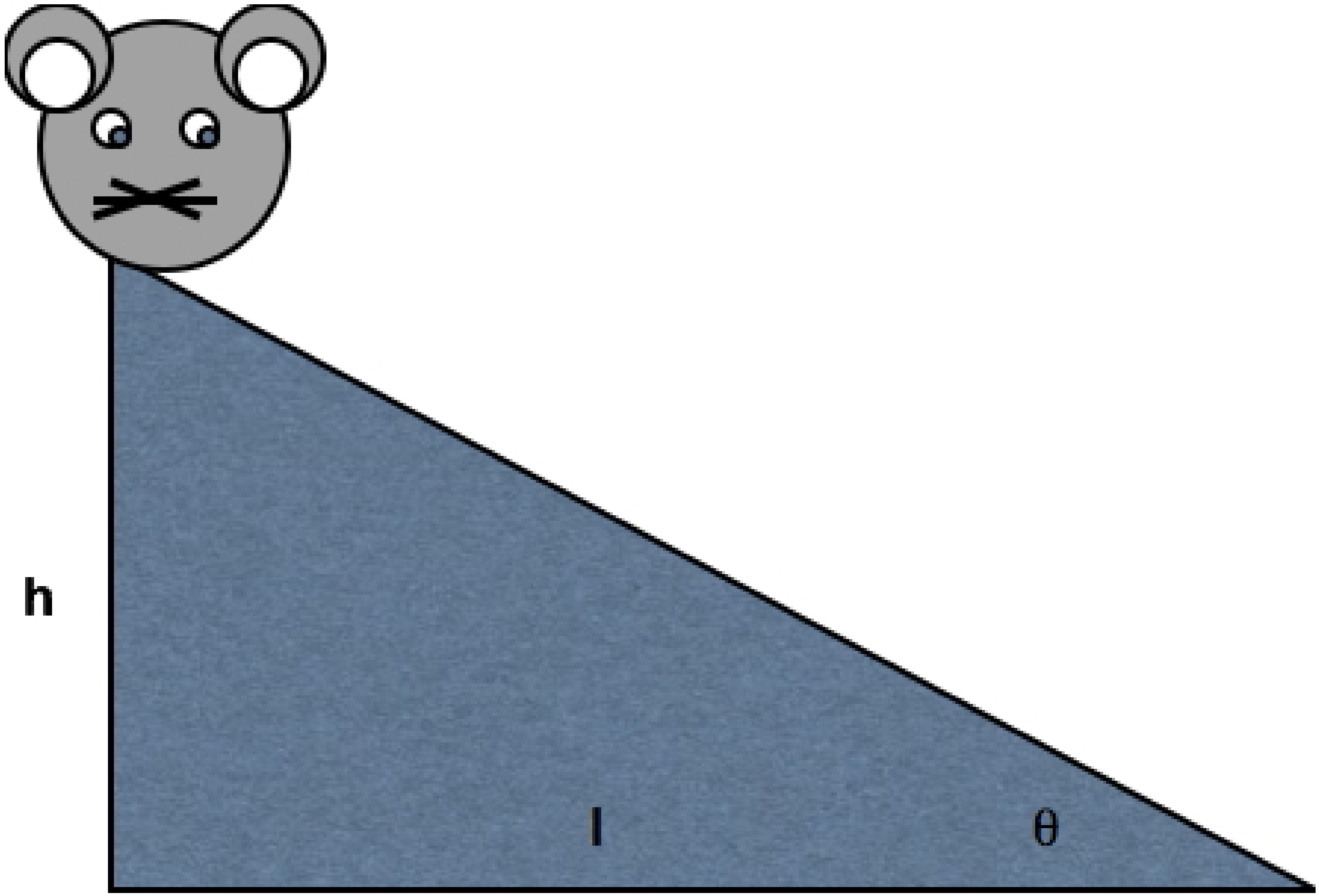
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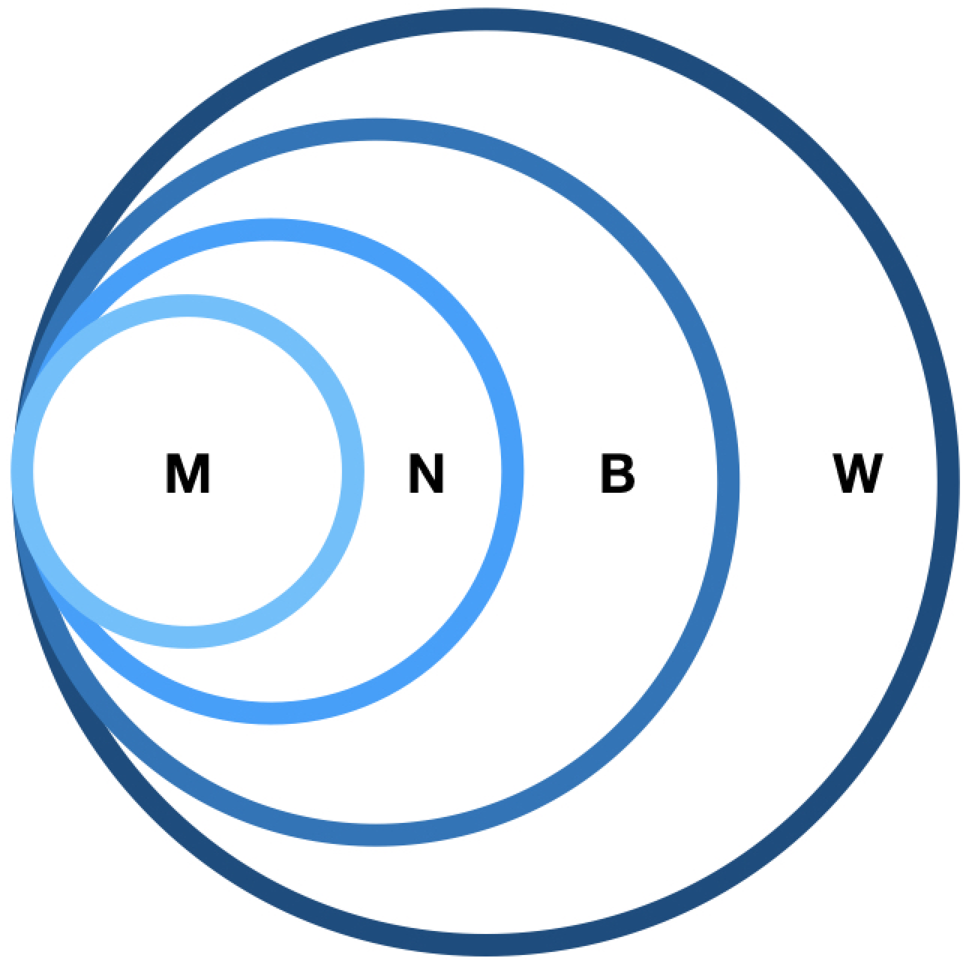
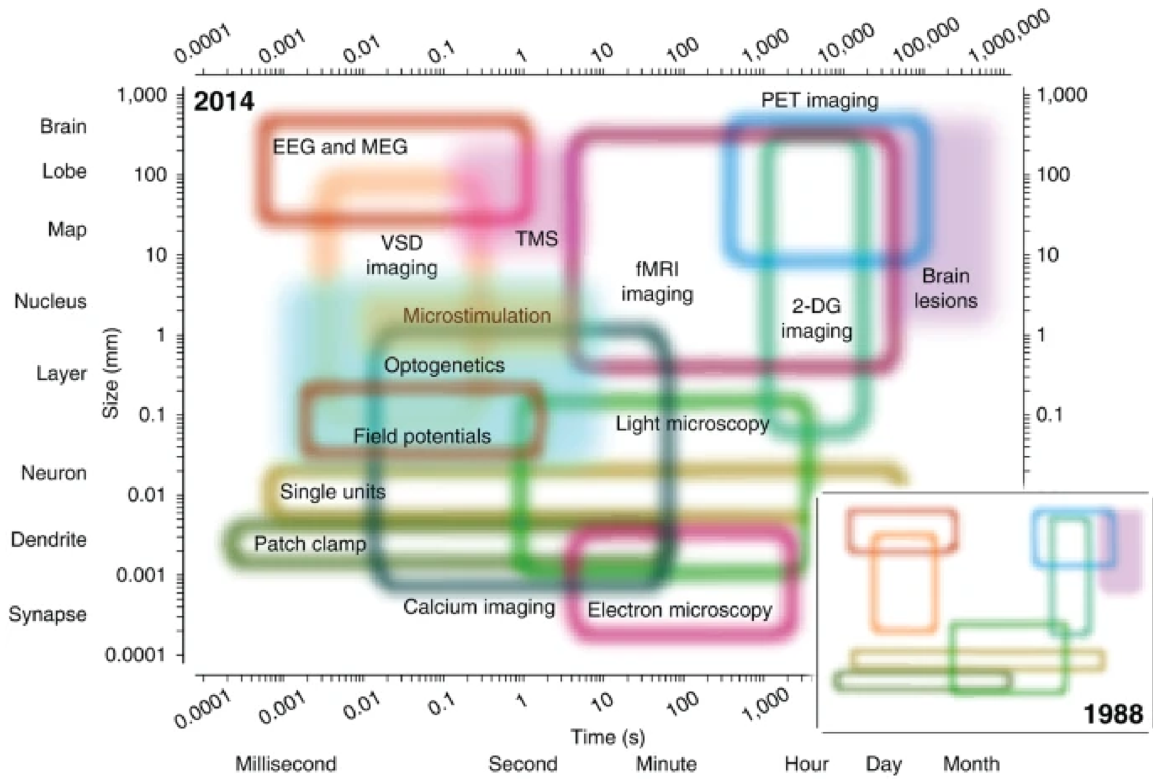
# What do we need to know to answer the question?

- What is the state…
  - Of the world ($W$)
  - Of the organism
    - Body ($B$)
    - Nervous system ($N$)
    - Mind ($M$)


M
N
B
W

# Some states are more easily measured than others

- $W, B, N$ more or less **directly**




[Sejnowski 2014]

# Measure mental states ($M$)

- **indirectly**
- Via $N$, $B$, $W$ (+ prior beliefs/knowledge)
- Examples?

# What are essential components/dimensions of $W$?

# What are essential components/dimensions of $B$?

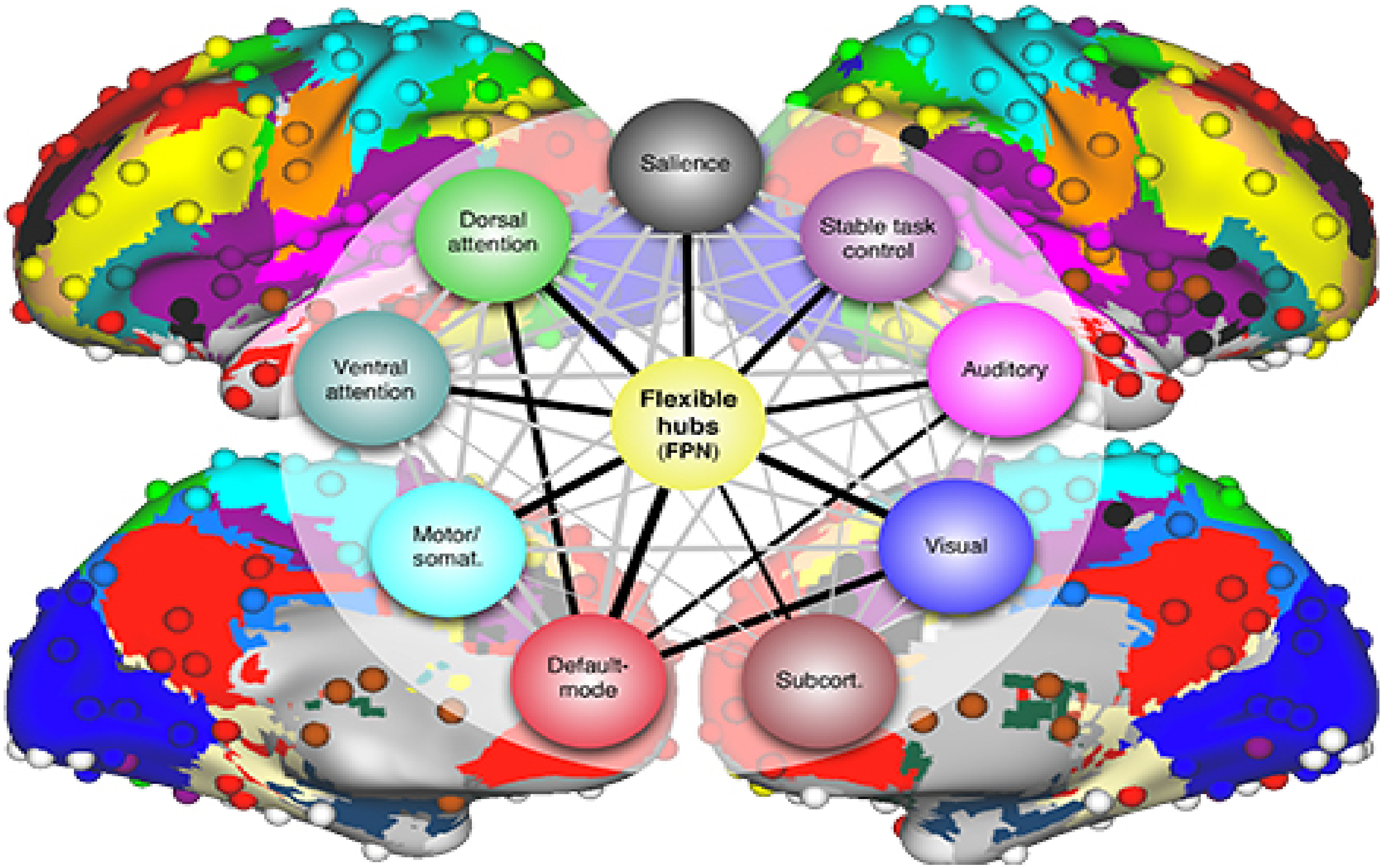
# Brain & behavior are complex, dynamic *systems* with

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

# Systems…

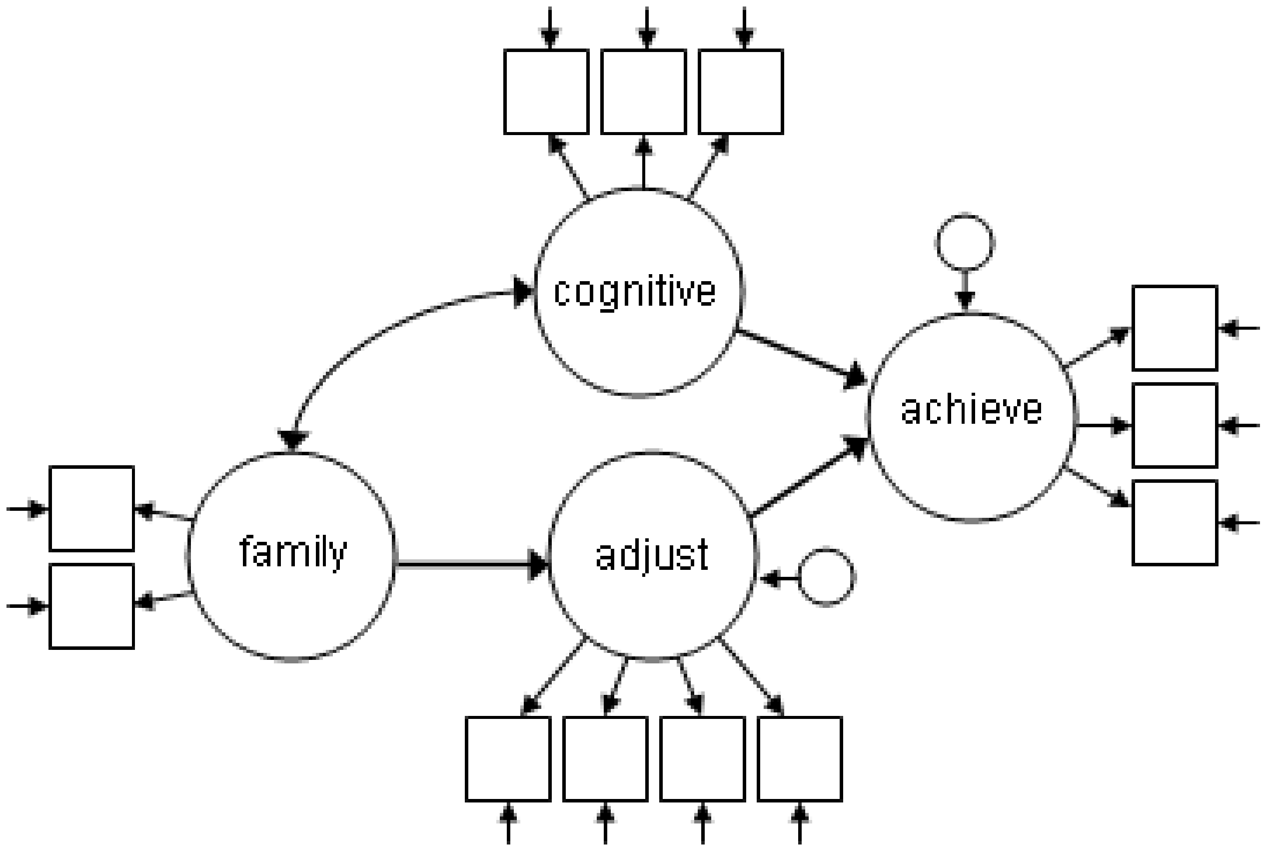
- “Behave” or change state across time
- Return to starting state
- Appear to be regulated, controlled, influenced by feedback loops
- $B(t+1) = f(W(t), B(t), N(t), M(t))$

# May be thought of as networks




https://source.wustl.edu/2013/08/brain-flexible-hub-network-helps-humans-adapt/

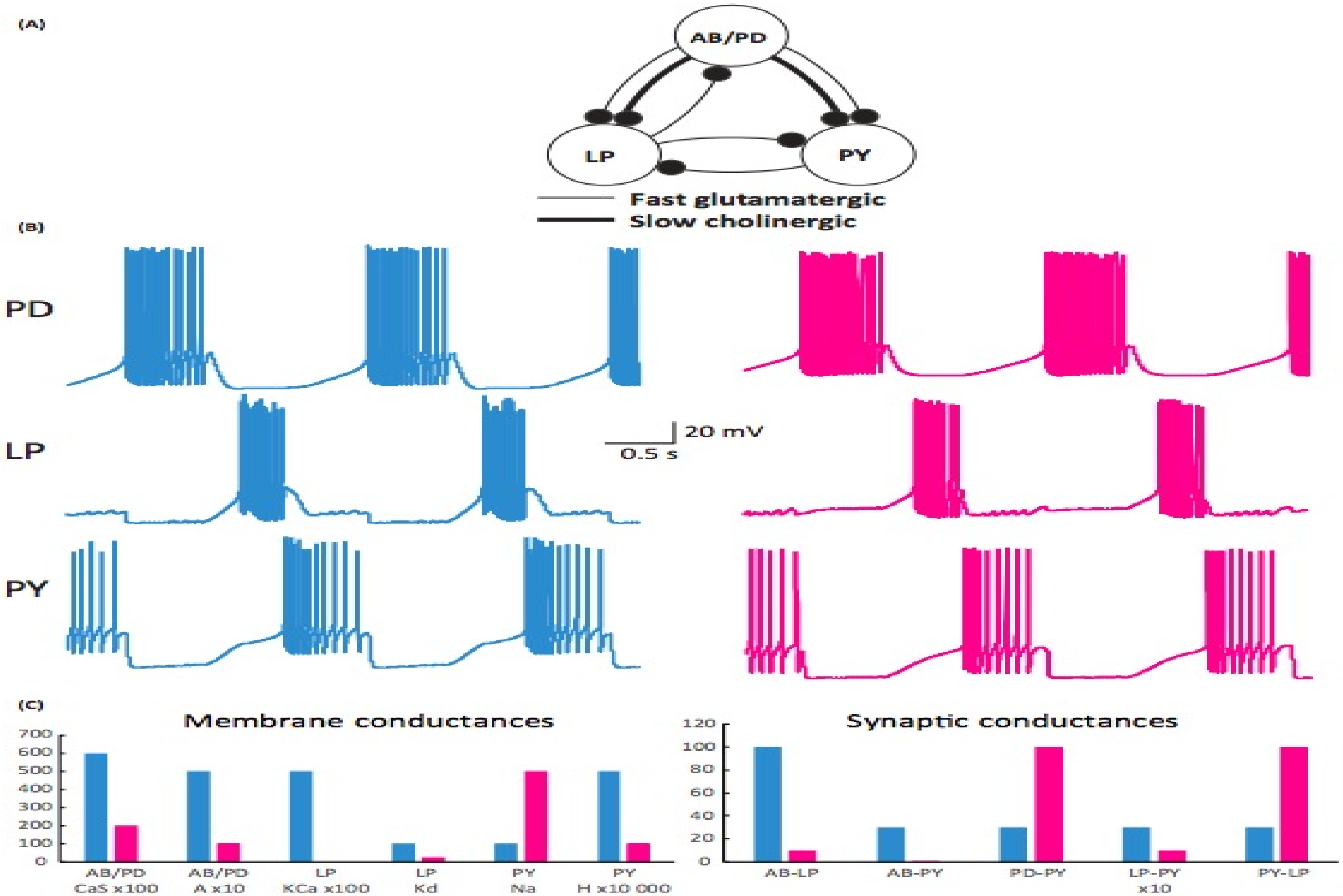
# At multiple levels of organization…



# Studying systems is hard because…

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

# e.g., “equifinality” in micro-circuits




(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-2021/

# Questions

- What is the basic organizational 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 an information processing system

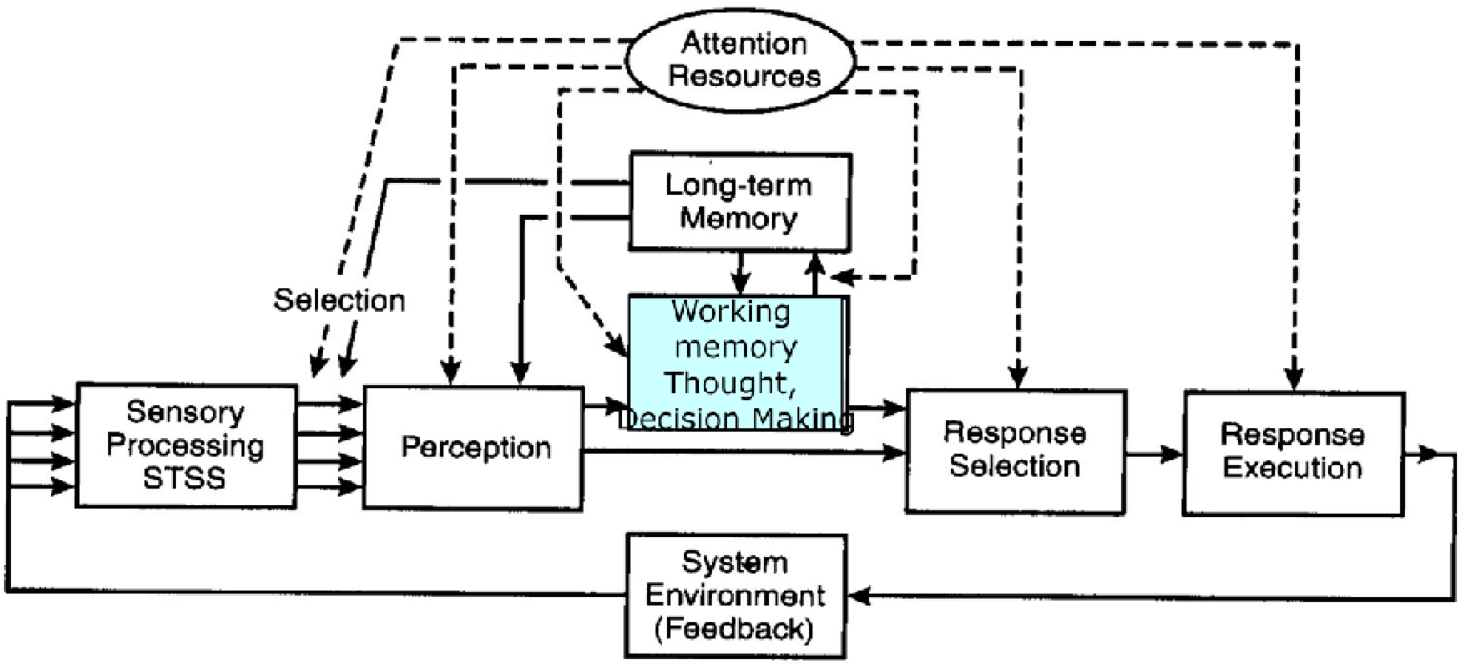


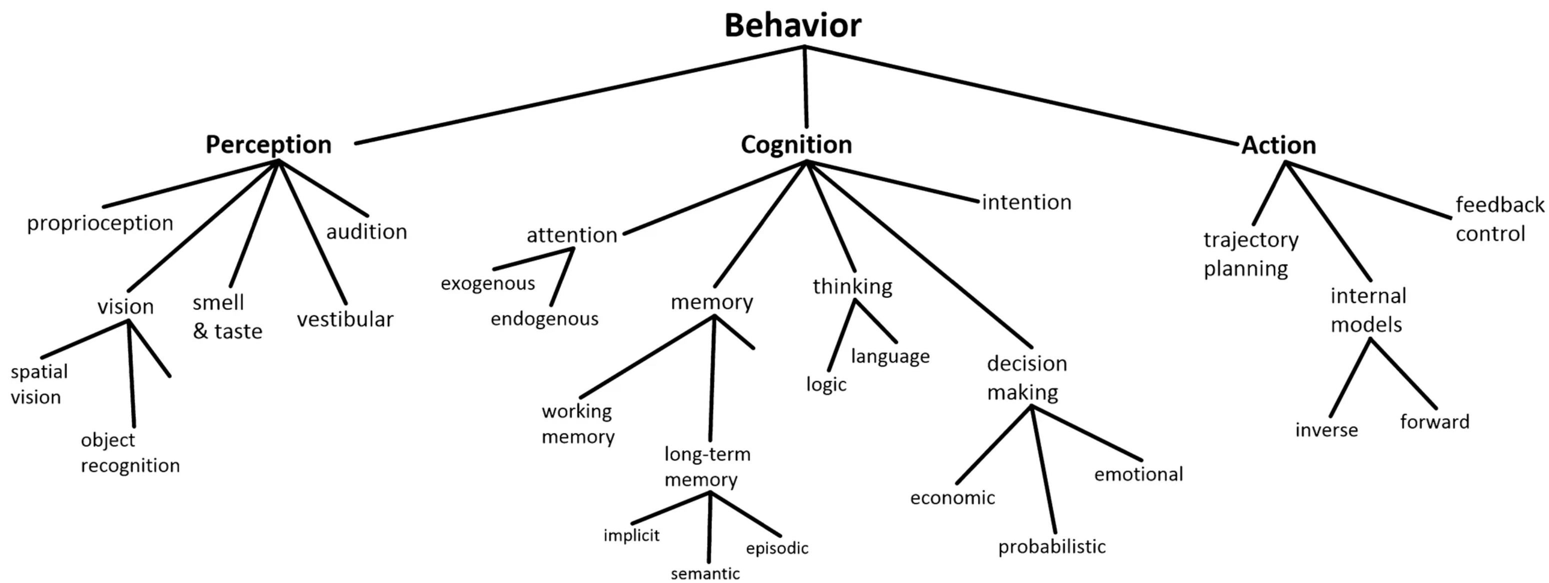

**Figure 1.3** A model of human information processing stages.

## Inputs

- From environment, body, brain

## Processing

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


Behavior
Perception
Cognition
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episodic
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economic
probabilistic
emotional
trajectory
planning
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models
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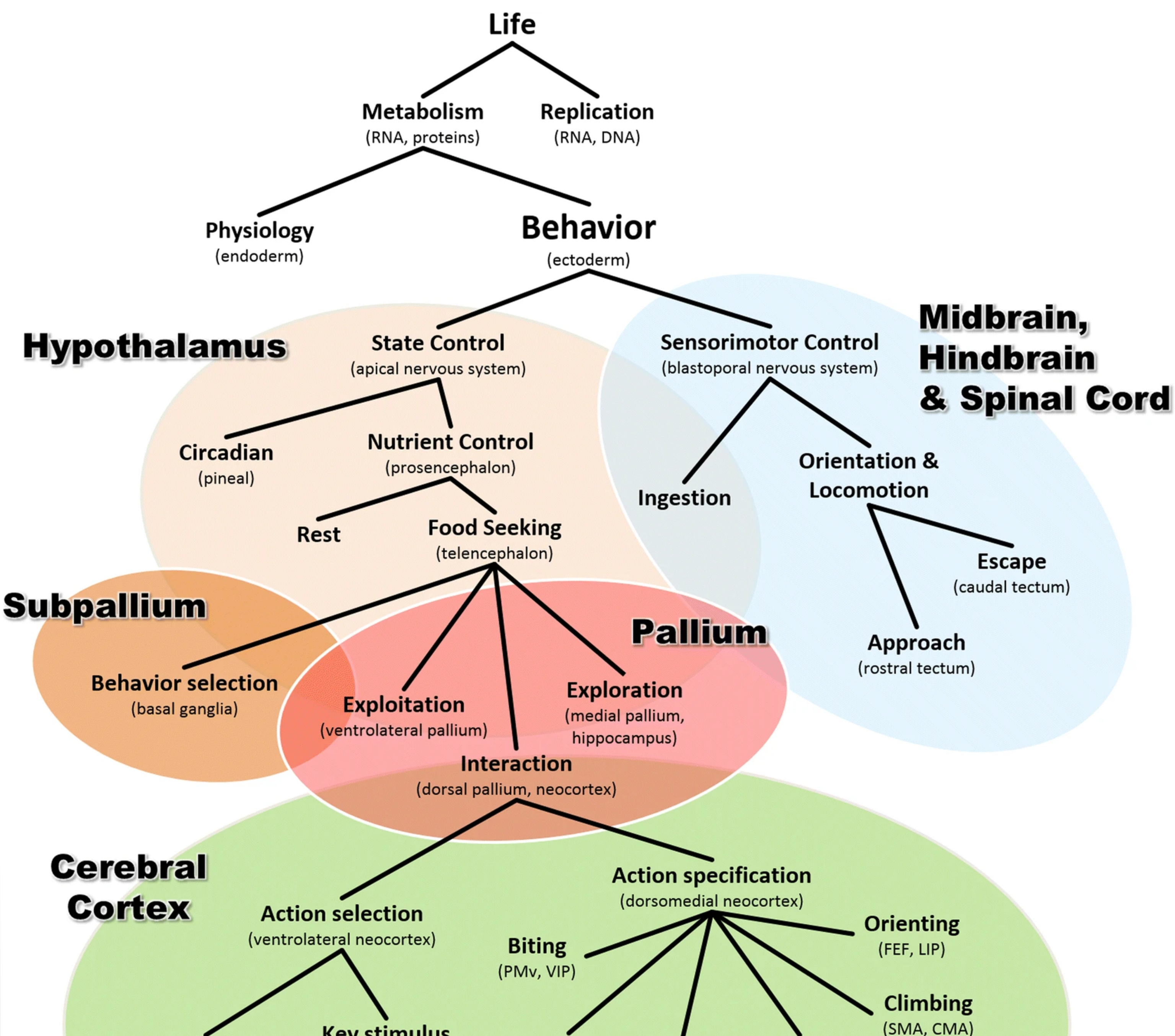
(Cisek, 2019)

# Outputs

- To brain, body, environment

# How do Ψ functions map to structures?



# And *vice versa*? (Cepelewicz, 2021)

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AGREE

NEUROSCIENCE

**The Brain Doesn't Think the Way You Think It Does**

24

*Familiar categories of mental functions such as perception, memory and attention reflect our experience of ourselves, but they are misleading about how the brain works. More revealing approaches are emerging.*

*"The brainwide representation of behavioral variables suggests that information encoded nearly anywhere in the forebrain is combined with behavioral state variables into a mixed representation…Our data indicate that it happens as early as primary sensory cortex."*

– (Stringer et al., 2019)

# And do we have the right "psychological" structures?

"Psychological sciences have identified a wealth of cognitive processes and behavioral phenomena, yet struggle to produce cumulative knowledge. Progress is hamstrung by siloed scientific traditions and a focus on explanation over prediction, two issues that are particularly damaging for the study of **multifaceted constructs like self-regulation**…We conclude that self-regulation lacks coherence as a construct…"

– (Eisenberg et al., 2019)

# The connectome and beyond

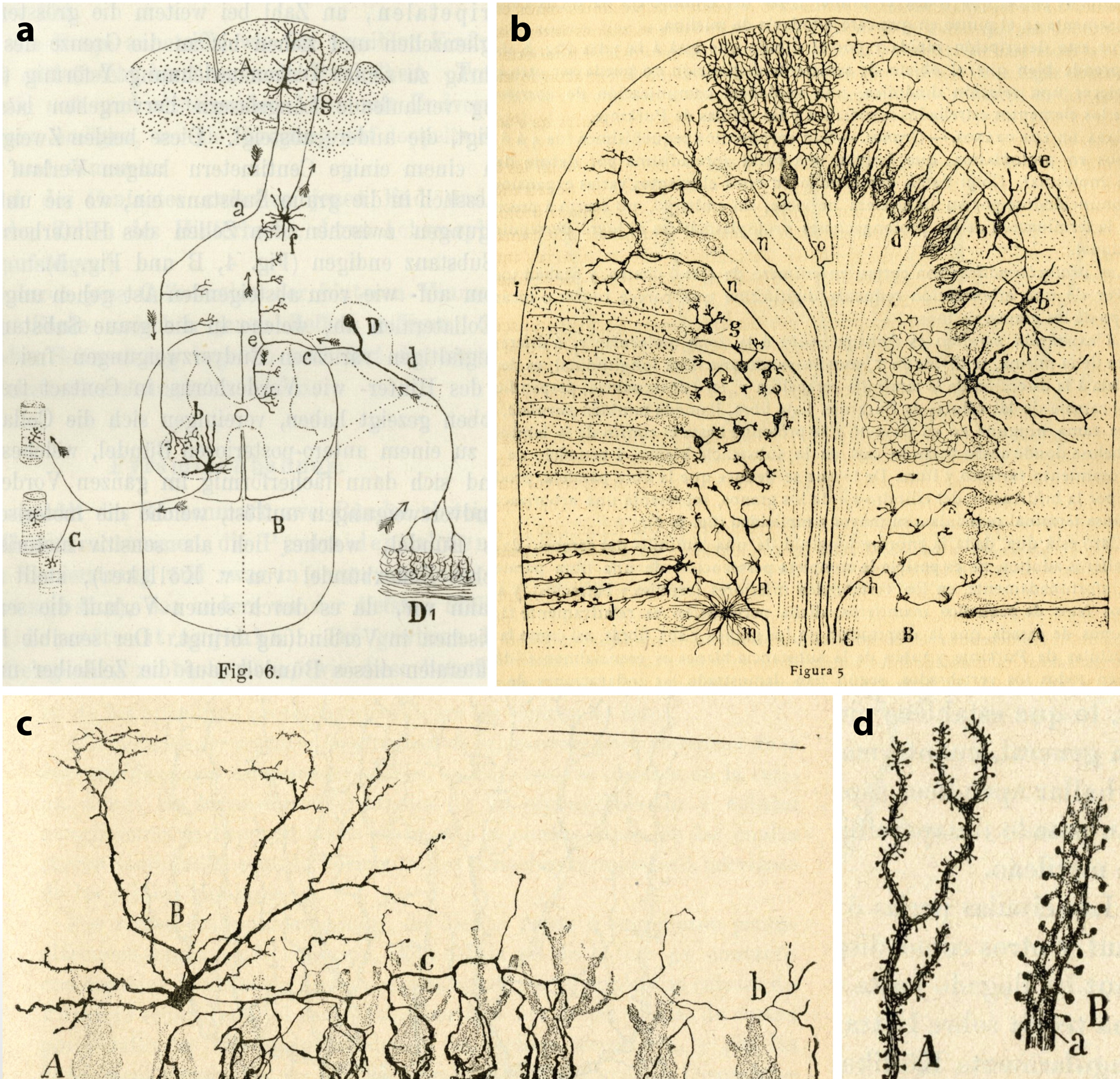
# Discussion of…

Swanson, L. W., & Lichtman, J. W. (2016). From Cajal to Connectome and Beyond. *Annual Review of Neuroscience*, *39*, 197–216.

http://doi.org/10.1146/annurev-neuro-071714-033954

# Key ideas

- Form <> function
- “*What differs between species is the architecture of nervous systems….*”
- Connectomes at different levels of analysis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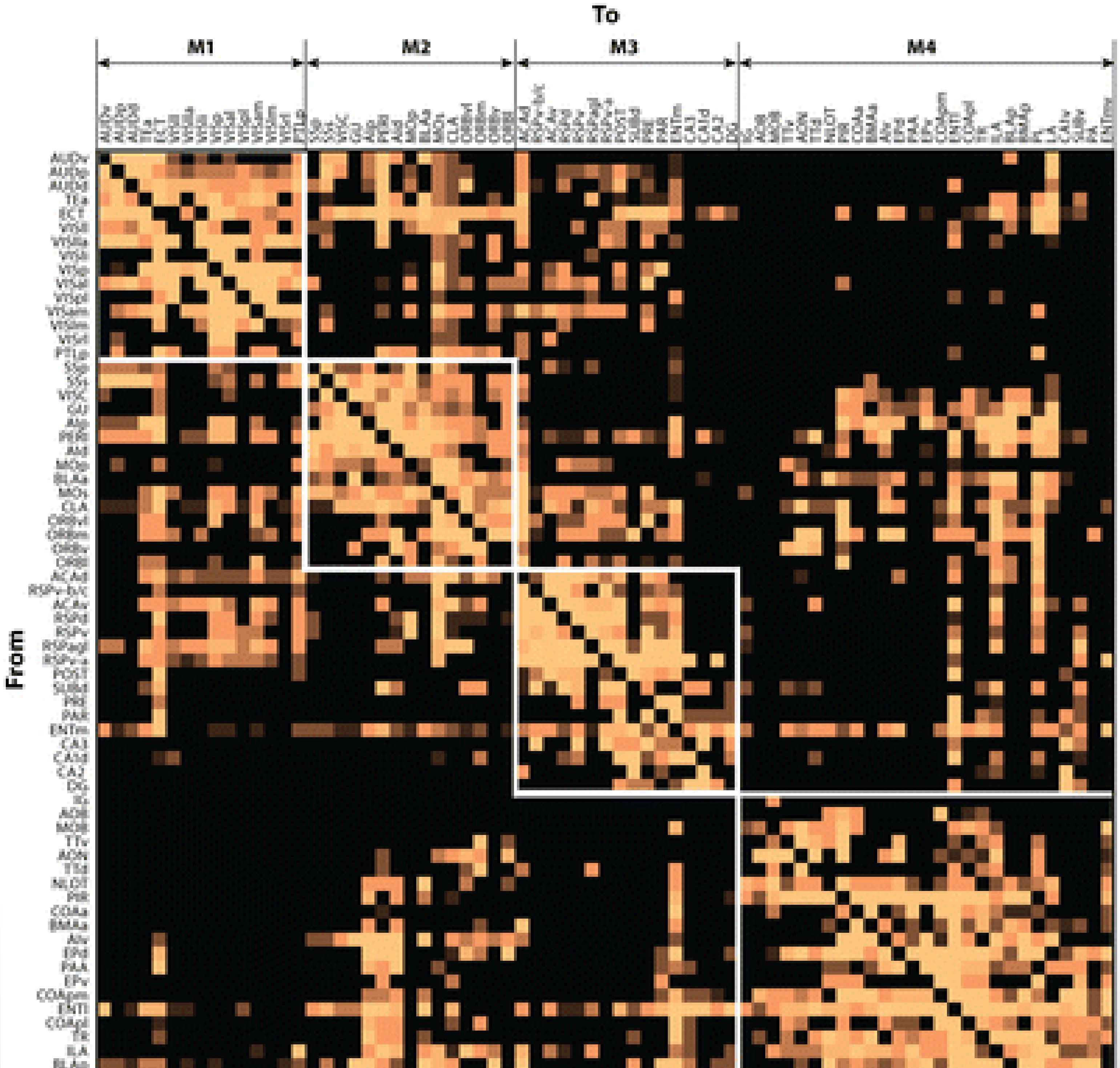

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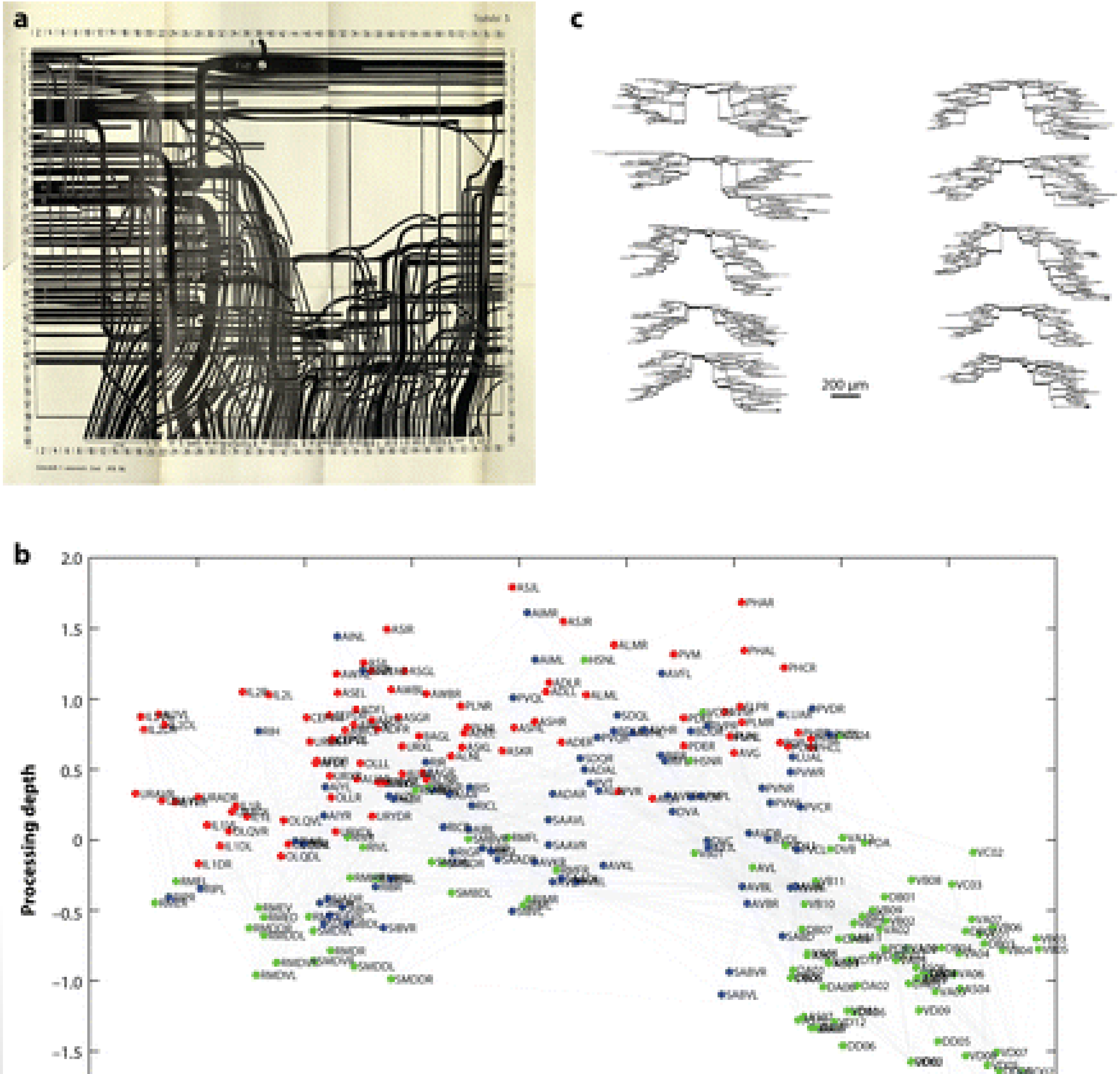
M2
M3
M4
From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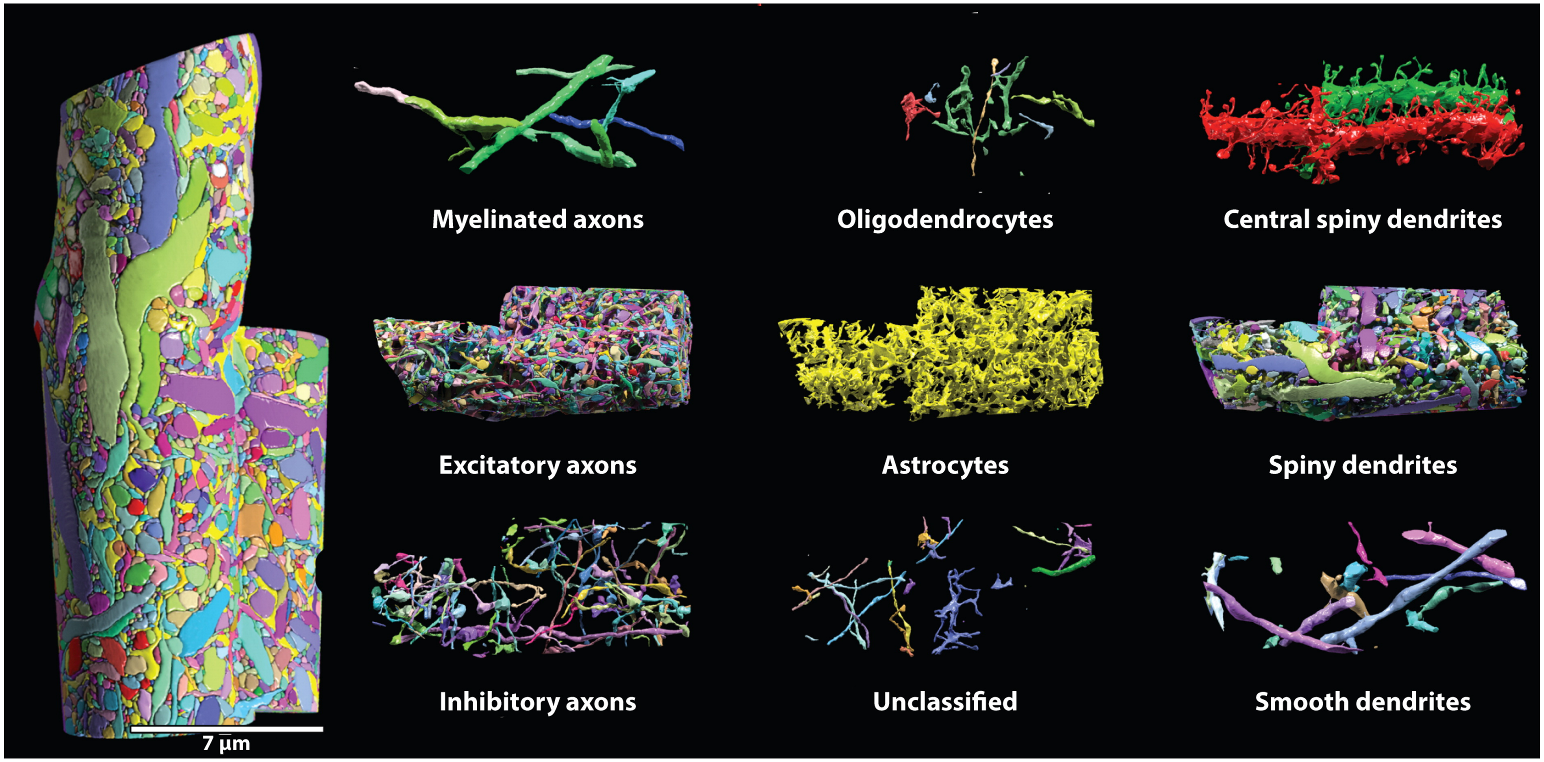
200 μm




Swanson LW, Lichtman JW. 2016.
Annu. Rev. Neurosci. 39:197–216

Fig 3. Swanson & Lichtman, 2016

*“The so-called explanatory gap (Horgan 1999) between what we can know and what we want to understand is not necessarily made smaller by more information. Rather, such omics information pushes neuroscience into a different realm where information rather than ideas is the currency.”*

(Swanson & Lichtman, 2016)

*“In this realm, a detailed, bottom-up description of a biological system is mined for whatever conceptual insights might be revealed rather than top-down concepts of what we care about being used as a setup for experiments. In this sense, the data give us a more accurate view of the way things are and, at the same time, push us away from intelligible, albeit facile, answers to the enduring puzzles of the brain."*

(Swanson & Lichtman, 2016)

# Cajal/Swanson Architecture

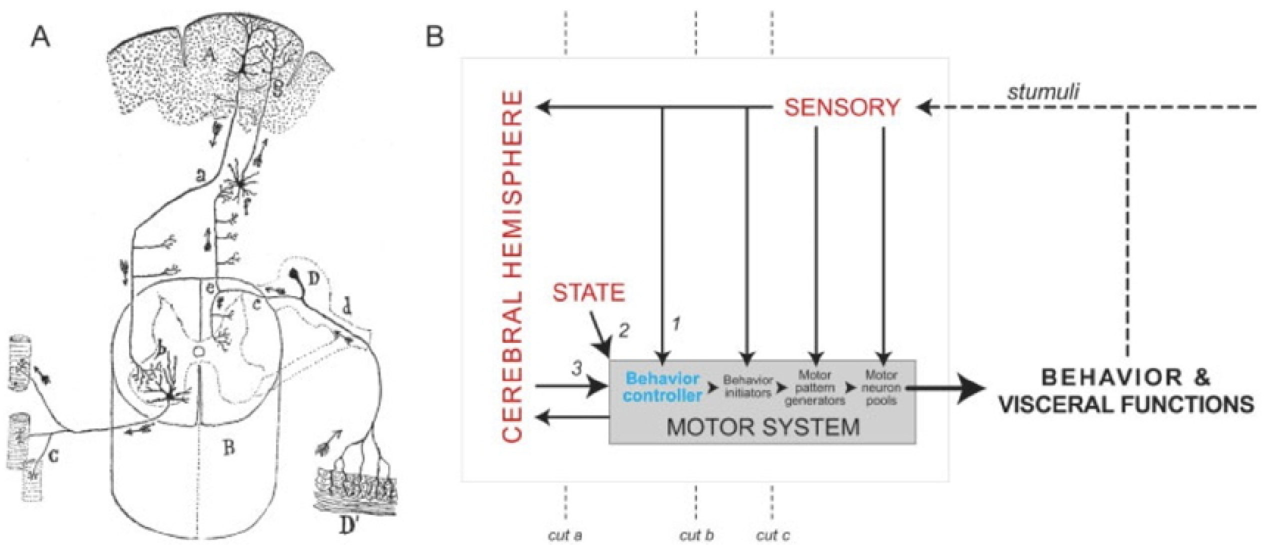



Fig. 1. **A:** Perhaps the first diagram illustrating the cellular organization of a vertebrate spinal reflex, based on the neuron doctrine and law of functional polarity, published by Cajal in 1890 (see Cajal, 1894). Note that he emphasized two interconnected sources of motor neuron (b) control: dorsal 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]

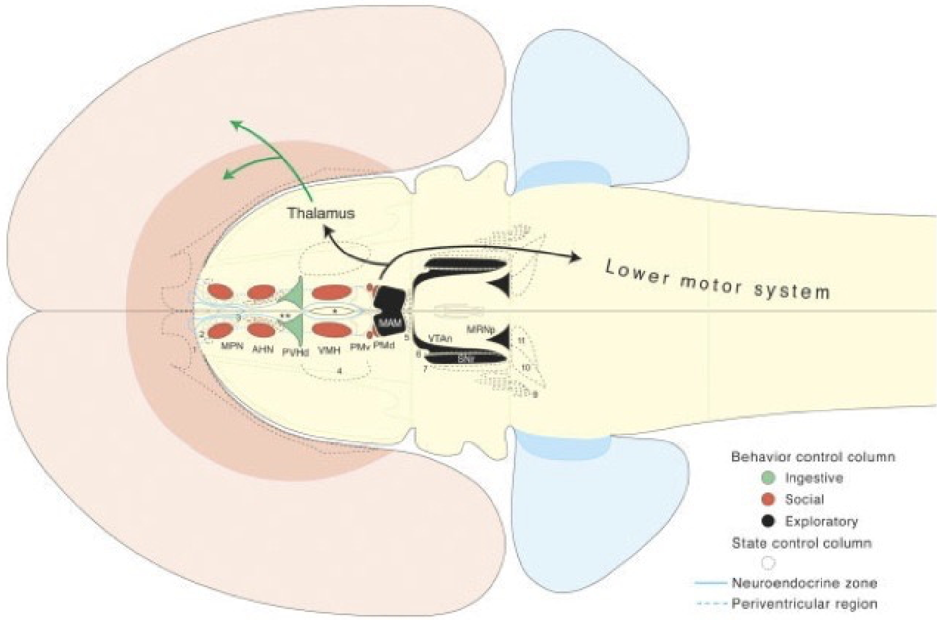



Fig. 3. Basic topography of the behavior control column (BCC) in ventromedial regions of the upper brainstem as viewed on a flatmap of the rat central nervous system. Each component minimally generates a dual projection to the lower motor system (primarily motor pattern generator networks and motoneuron 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

# Main points

- Psychology is harder than physics
- Connectomics and beyond

# 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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Swanson, L. W., & Lichtman, J. W. (2016). From cajal to connectome and beyond. *Annual Review of Neuroscience*, *39*, 197–216. https://doi.org/10.1146/annurev-neuro-071714-033954