

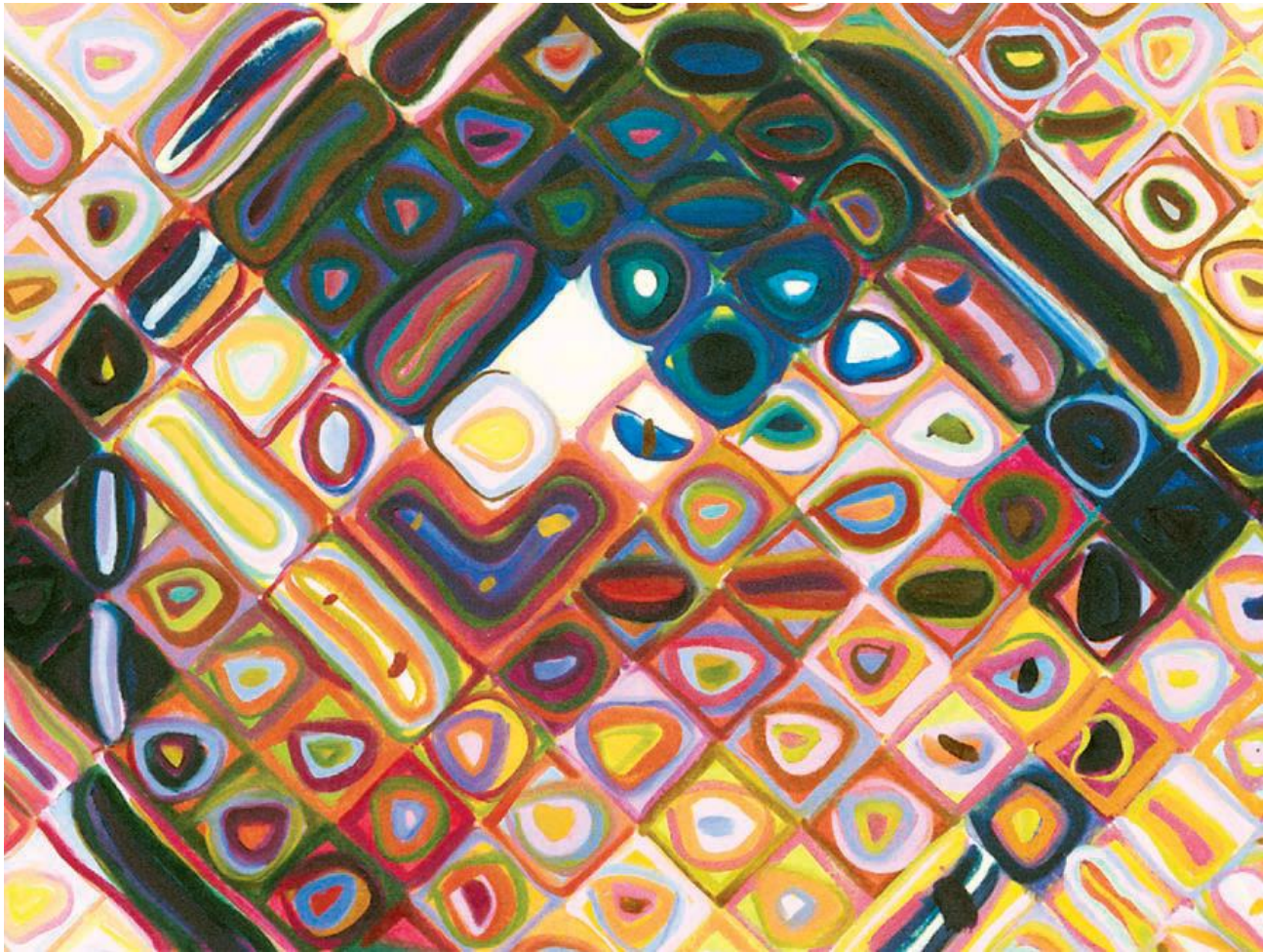


# Introduction to Cognitive Neuroscience

Lecture 00: Introduction

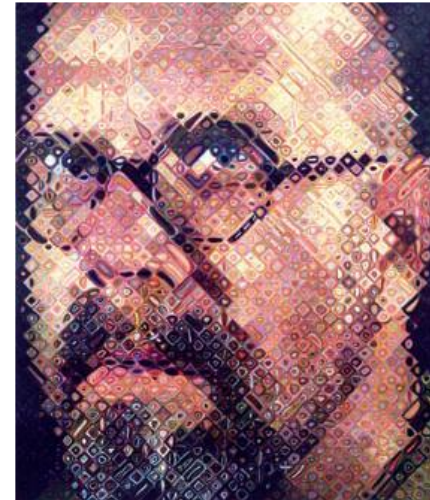
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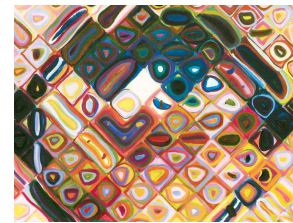
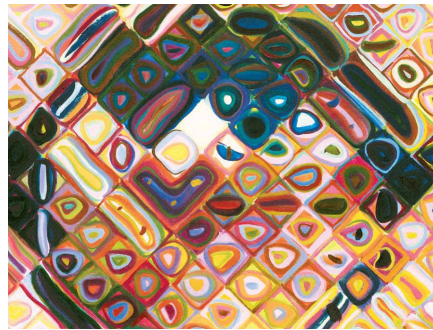
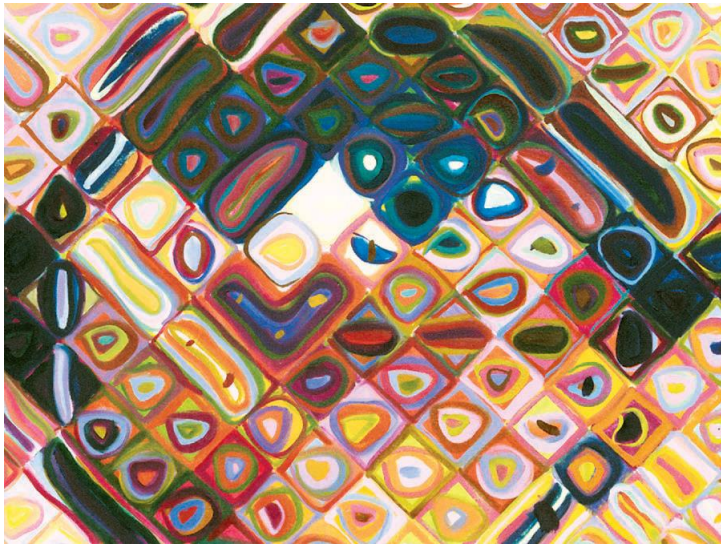


### Detail of a self-portrait by Chuck Close:

- Viewed from a short distance: the painting appears to be an abstract grid of vividly colored squares and ovals (local feature)
- Viewed from farther away: the local color blend and we begin to perceive a framed-eye (global feature)
- **Chuck Close** has prosopagnosia, or difficulty in recognizing faces; his technique of flattening and subdividing an image into manageable elements enhances his ability to both perceive and portray the face.



The **interplay** between these local and global features, which are **conveyed by discrete visual pathways**, gives the portrait its **particular dynamism**





# Topics



- A short history and an introduction to cognitive science
- Different branches and common methods in cognitive neuroscience
- Cellular and molecular structure of neural system
  - Computational neuroscience
  - Models of single neurons and networks
- Structure and function of neural systems, different sensory pathways, and association areas.
- Brain Control of Movement
- Sensory systems including:
  - somatosensory and pain
  - visual
  - auditory

# Workshops + invited lectures



- Cognitive modeling
- Neural data analyses: discrete neural data, spikes.
- Neural data analyses: continues neural data, LFPs and EEG data
- fMRI analyses

# Evaluation



- Midterm : 20%
- Final: 25%
- Quiz: 10%
- Assignments: 30%
  - 5-6 HWs
- Final project: 10%
- The final exam cover all topics with main focus on after midterm sessions.

# Some definitions



- **Cognition** - The acquisition, storage, transformation, and use of knowledge.
- **Neuroscience** - Study of the structure and workings of the nervous system.
- **Cognitive neuroscience** - Study of how cognitive processes can be explained by the structure and function of the brain.

The screenshot shows a Google search interface with the query 'neuroscience' entered in the search bar. The search results page displays 'About 41,300,000 results (0.49 seconds)'. The top result is a Wikipedia entry titled 'Neuroscience - Wikipedia, the free encyclopedia', with the URL 'en.wikipedia.org/wiki/Neuroscience'. To the right of the text is a small image of a human brain with a red and green overlay. Below the main result, there is a section titled 'Related topics' which includes two entries: 'Cognitive neuroscience' and 'Nervous system', each with a brief description and a link to explore the topic further. At the bottom of the search results, there is a 'Show less' button and a 'Feedback' link.

# Intro2BrainSci.

## Intro and history

Historical evolution of cognitive science

How can we access brain

## Cellular foundation of brain

Dynamical modeling

## Major techniques and methods

Psychophysics and behavioral modeling

Coding and decoding

Imaging

## Cognition

Sensory systems

Motor controls

High level cognitive functions





# Brief history

# The 19<sup>th</sup> century

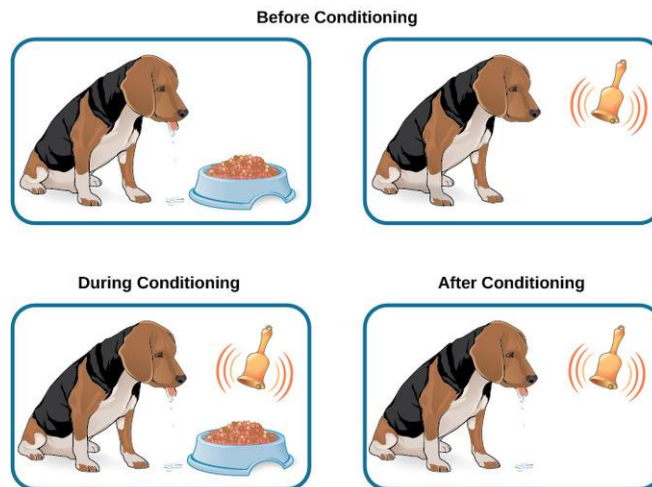


- Until the 19<sup>th</sup> century **introspection** was the main method to understand the mind.
- Mind study was the branch of **philosophy**
- Middle of 19<sup>th</sup> century: the emergence of **experimental psychology**
  - Concerned on the sequence of events by which an external stimulus become internal sensation
- At the end of 19<sup>th</sup>:
  - The interests turned to **how behavior generated**, how it is **modified by learning and attention**, and how it is stored in memory

# Behaviorism; rigorous empirical school of psychology

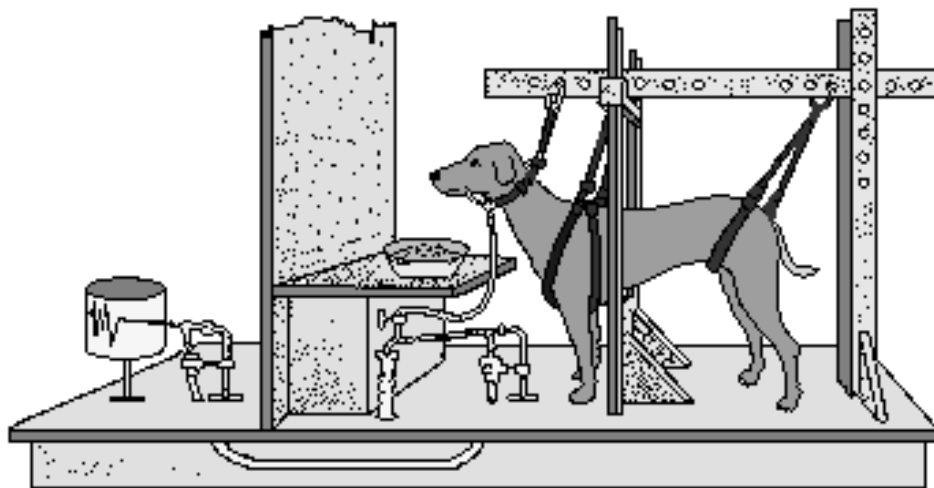


Discovery of simple **experimental ways of studying** learning and memory (Hermann Ebbinghaus in 1885 and Ivan Pavlov and Edgar Thorndik) led to a rigorous empirical school of psychology

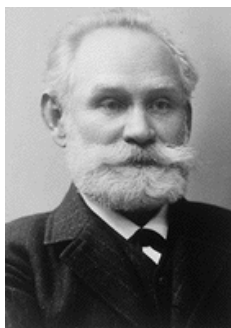


Born: 1849 - 1936, Russia

# Animals learn predictions



very general across species, stimuli, behaviors



Ivan Pavlov



Unconditioned Response  
(Salivation)



Unconditioned Stimulus  
(Food)



No Response



Neutral Stimulus  
(Bell Ringing)



Unconditioned Response  
(Salivation)



Neutral Stimulus  
(Bell Ringing)



Unconditioned Stimulus  
(Food)



Conditioned Response  
(Salivation)



Conditioned Stimulus  
(Bell Ringing)



John B. Watson

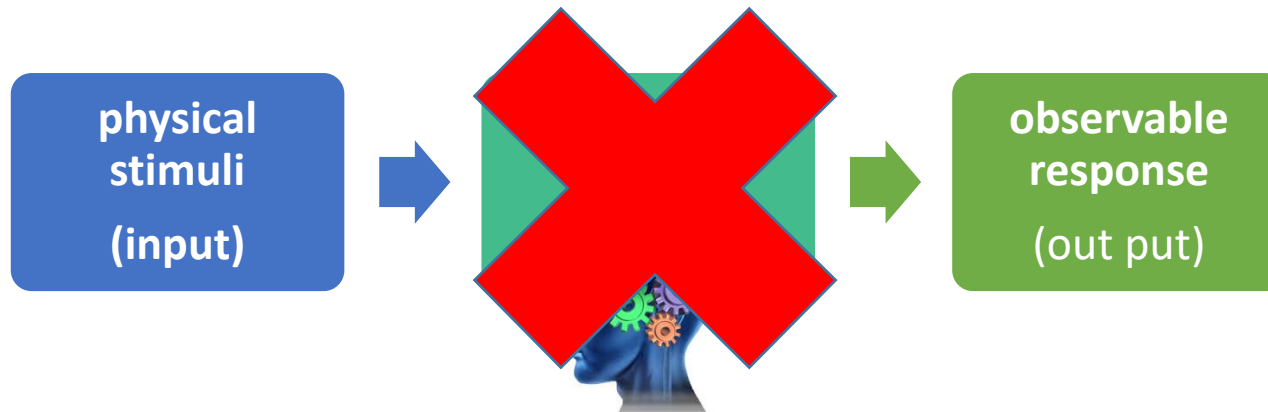


B. F. Skinner

# Behaviorism 1950s

- They argued that behaviour could be studied with the **precision of physical science**, but only if psychologist abandoned **speculation** about what **occures in the mind** and focused exclusively on the **observable aspect of behaviour**.
- All of unobservable mental processes, such as motivation, feeling, conscious awareness, are **inaccessible to scientific study**.

- They focus on relationship between specific **physical stimuli** and **observable response** in intact animal.
- They treat to all cognitive process that intervene between stimulus (input) and behavior (output) as **irrelevant**



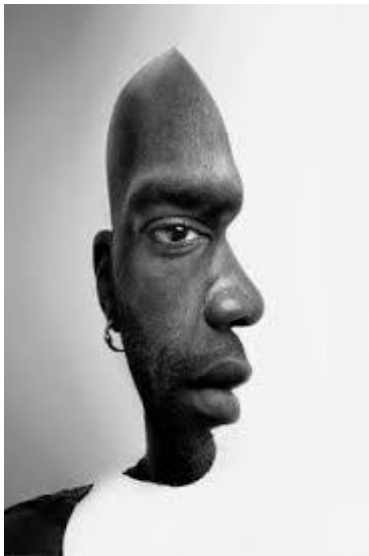
The **observable behavior** is all there is to mental life



# Cognitive psychology 1960s

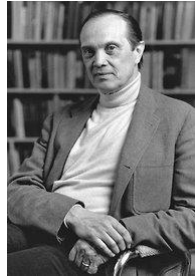


Earlier evidences from **Gestalt** psychology, **psychoanalysis**, and **neurology** make it easy for cognitive psychologists to convince the scientific community that behaviorism **was too limiting**





Frederick Bartlett



George  
Miller



Noam Chomsky



Ulric Neisser



Edwin Tolman

- They demonstrate our **knowledge is based on our biological equipment**
- Perception is a **constructive process** that depend not only on the stimulus but also mental apparatus of perceiver (the organization of sensory and motor system).
- We now realize that this process also involves **emotion, motivation, and reward.**

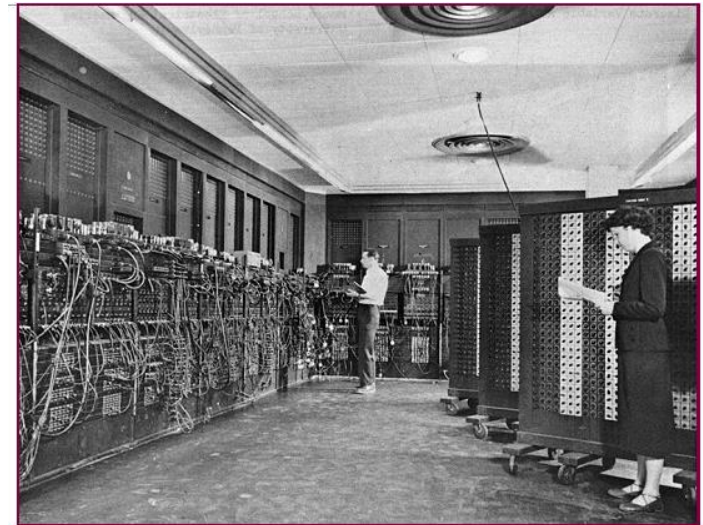
# Cognitivists against the behaviorists



- What distinguished two groups was not only their **conceptual approach to behavior** but also the **complexity of the methods** they used.
- Cognitivists realized that only input–output relationships vary significantly because of **mental states, past history, and expectations** (**fix input and multiple output**)
- These variables must **also be observable in behavior** (or output) but are just **more difficult to identify** than the behavior defined by behaviorists.

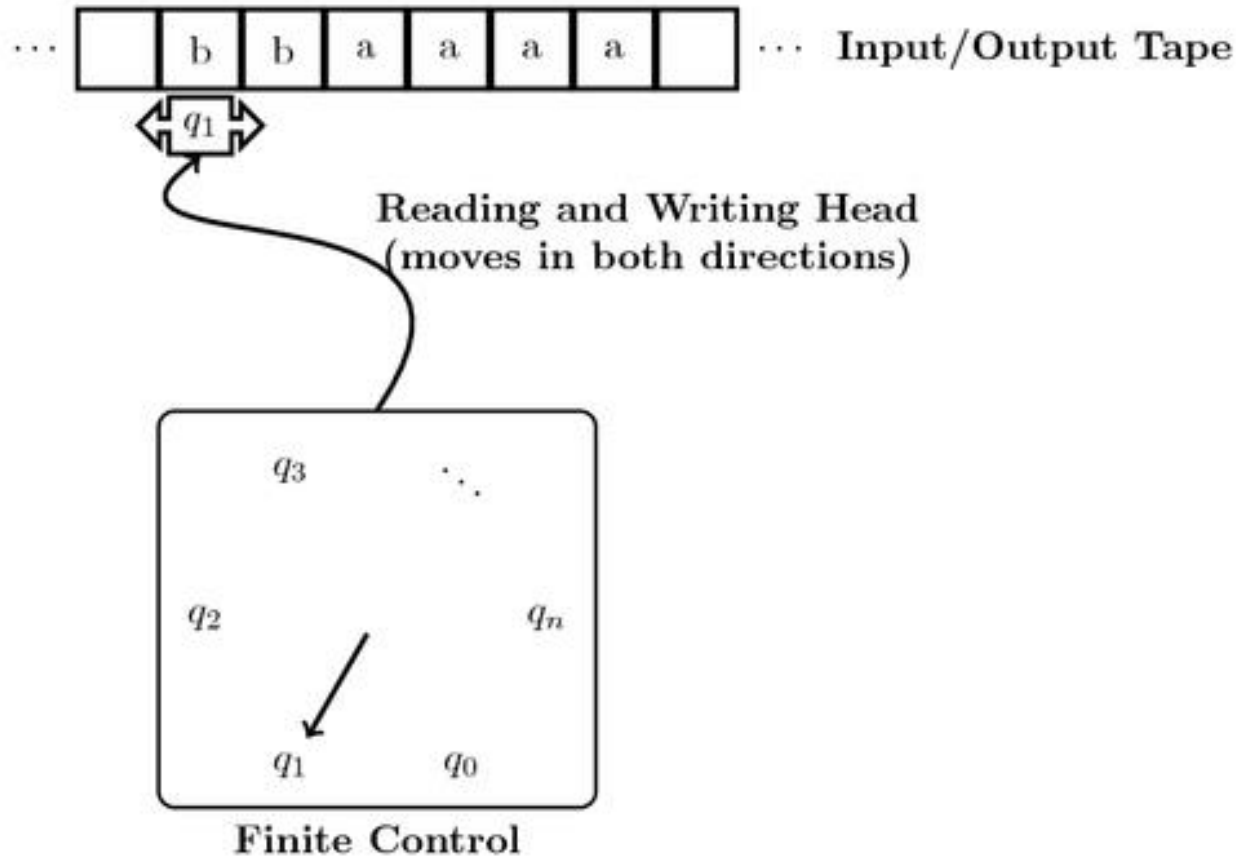
# Coincidence with large scale computer

- Growth of computers contributed to success of **information processing** approach to cognition.
- Respectable context for discussing **mechanisms that produce behavior**. (Like software!)
- large neural networks that in principle are capable of higher mental functions



Glen Beck and Betty Snyder program ENIAC, circa 1947 - 1955. [Image courtesy of the U.S. Army](#).

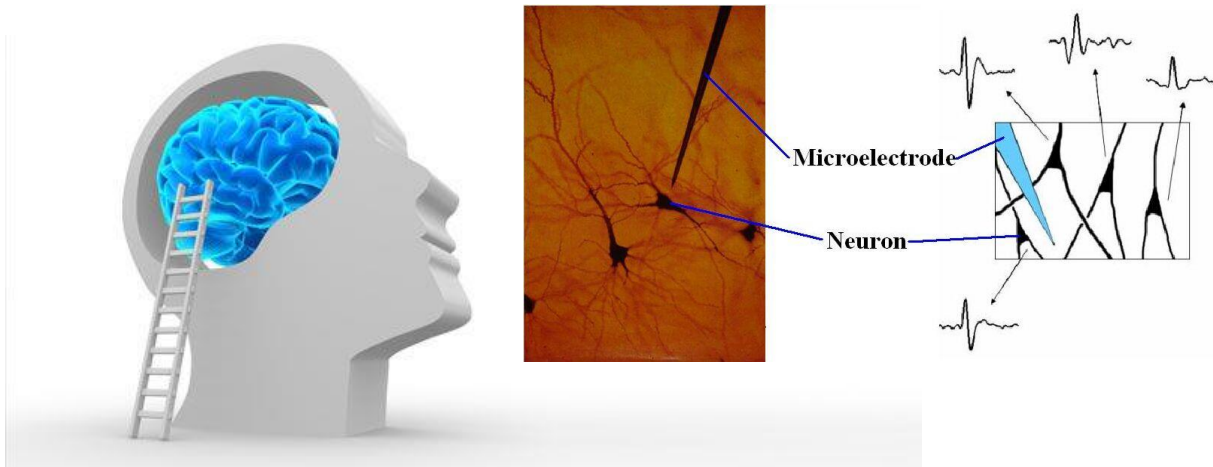
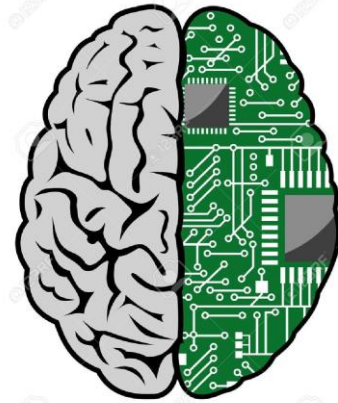
# Turing Machine



# Mental activity as computational processes in the brain



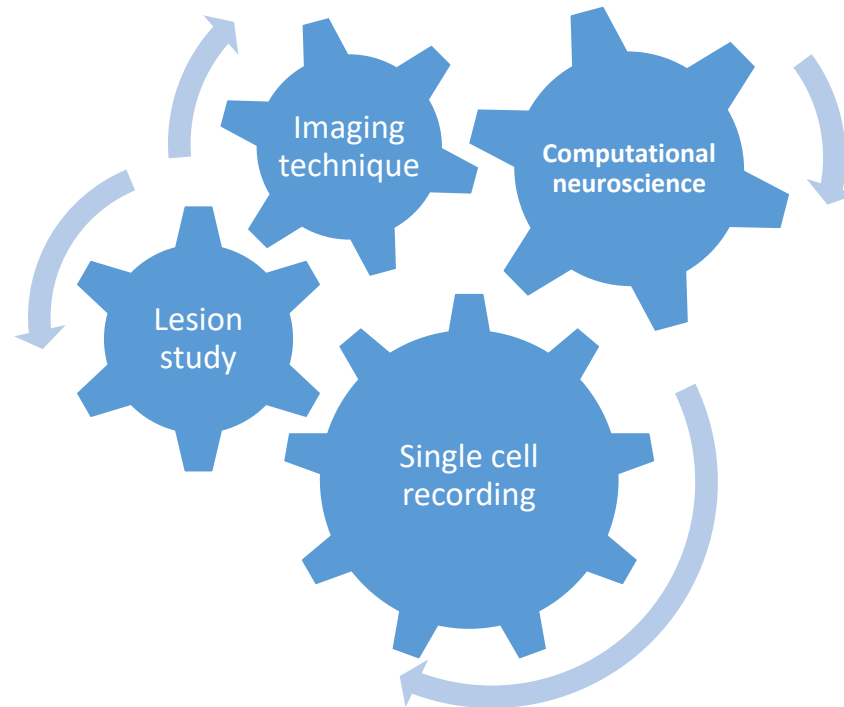
- This view made a lot of **theories for mental process**
- Without direct **access to the brain**, it would be difficult if not impossible to choose between various **rival theories**.



**Singleneuron recording** and **noninvasive imaging** recording techniques have allowed researchers **to access the brain**.



# Cognitive neural science, four major technical and conceptual developments.



# First, Single cell recording in the 1960s and 1970s



Robert Wurtz

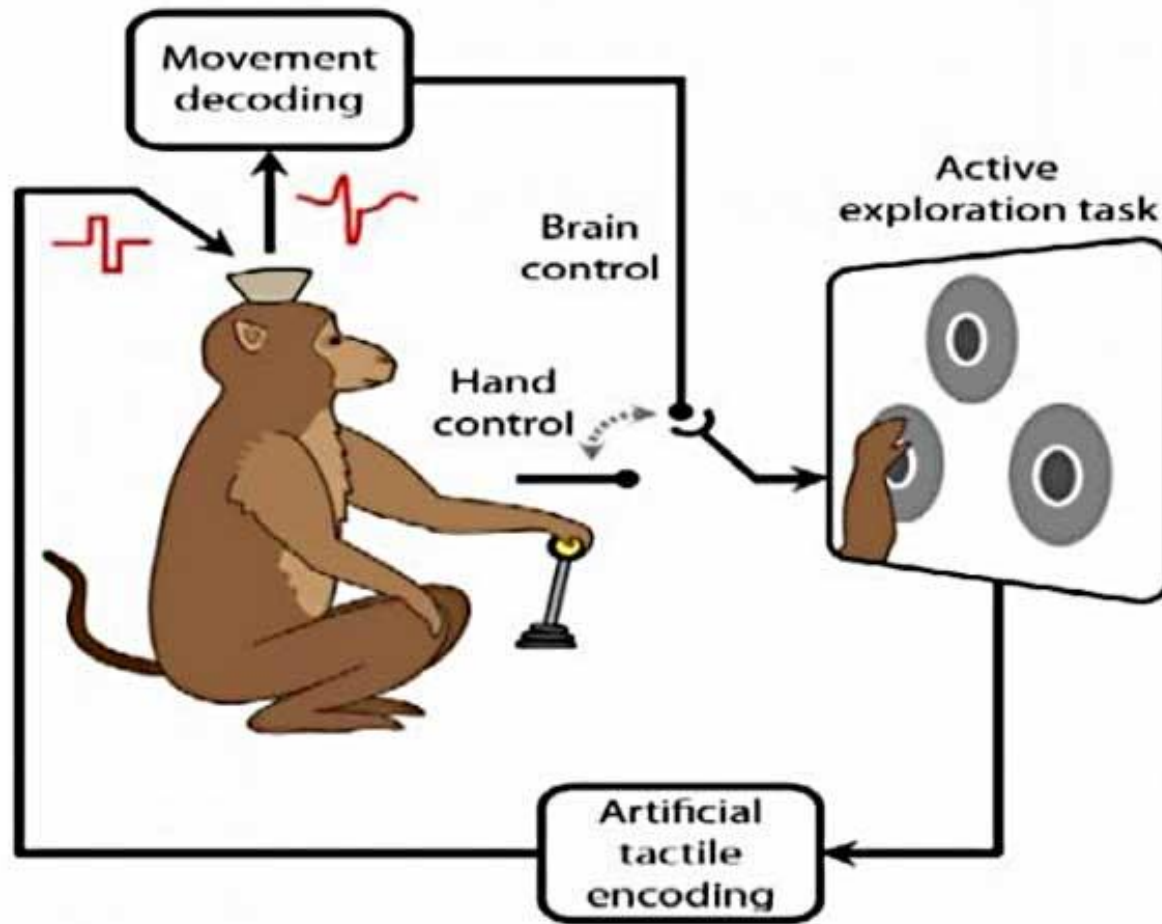


Edward Evarts



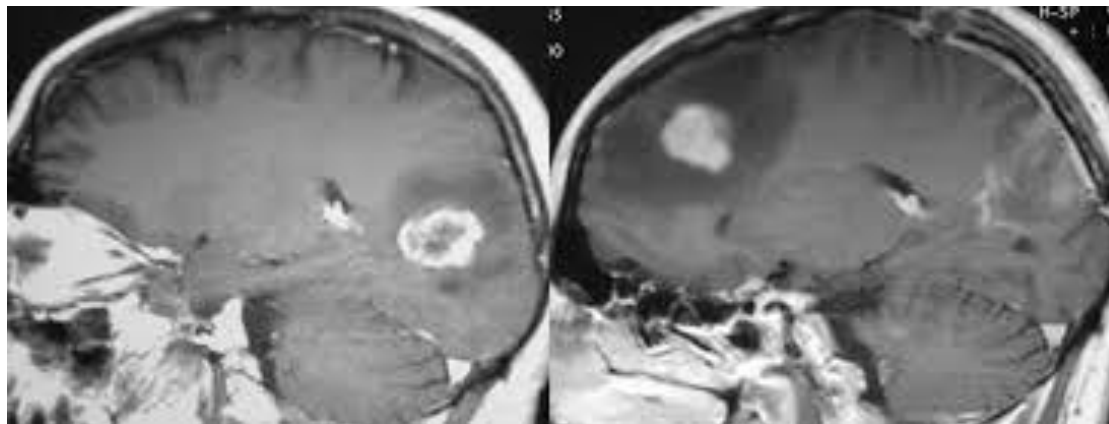
- At the National Institutes of Health
- To **correlate** the activity of **specific populations of neurons** with specific **perceptual and motor processes**
- They found that, **mechanisms of perception** are much the same in humans, monkeys, and even simpler animals
- Different **combination** of brain areas involved in specific cognitive task.
- These approaches changed the **way the biology of behavior**

# Recording setup



# Second; lesion study

- Lesions of different regions of the brain can result in quite specific cognitive deficits
- It belongs to **neuropsychology**
- Behavioral analysis of patient with brain lesion tells us **function** of specific neural pathways
- Lesion studies have shown that **cognition is the product of several specialized systems**, each with many components
- **Causal relation**





# Third; development of imaging technique

Positron emission tomography (PET)

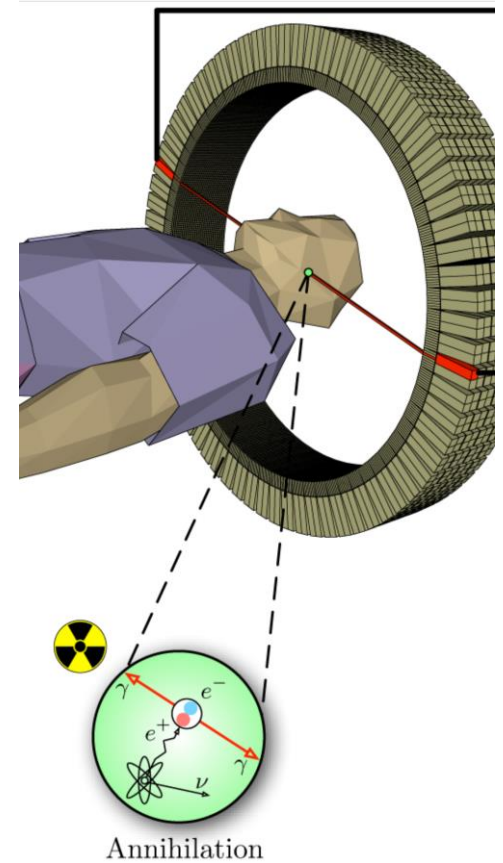
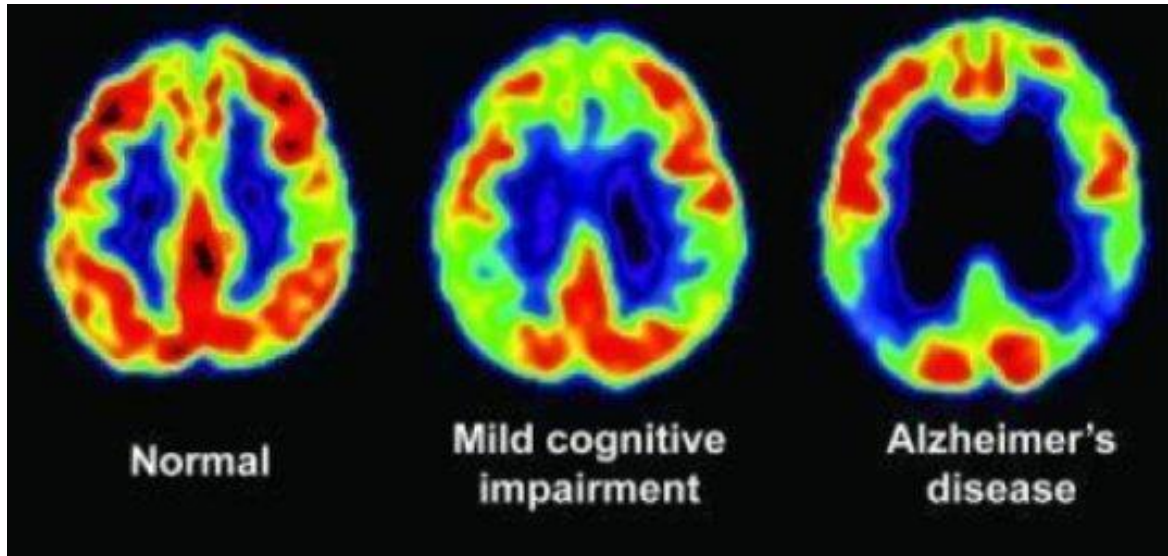
Functional magnetic resonance imaging

Magnetoencephalography; Electroencephalography

Voltage and calcium-sensitive dyes (in vitro and in brain)

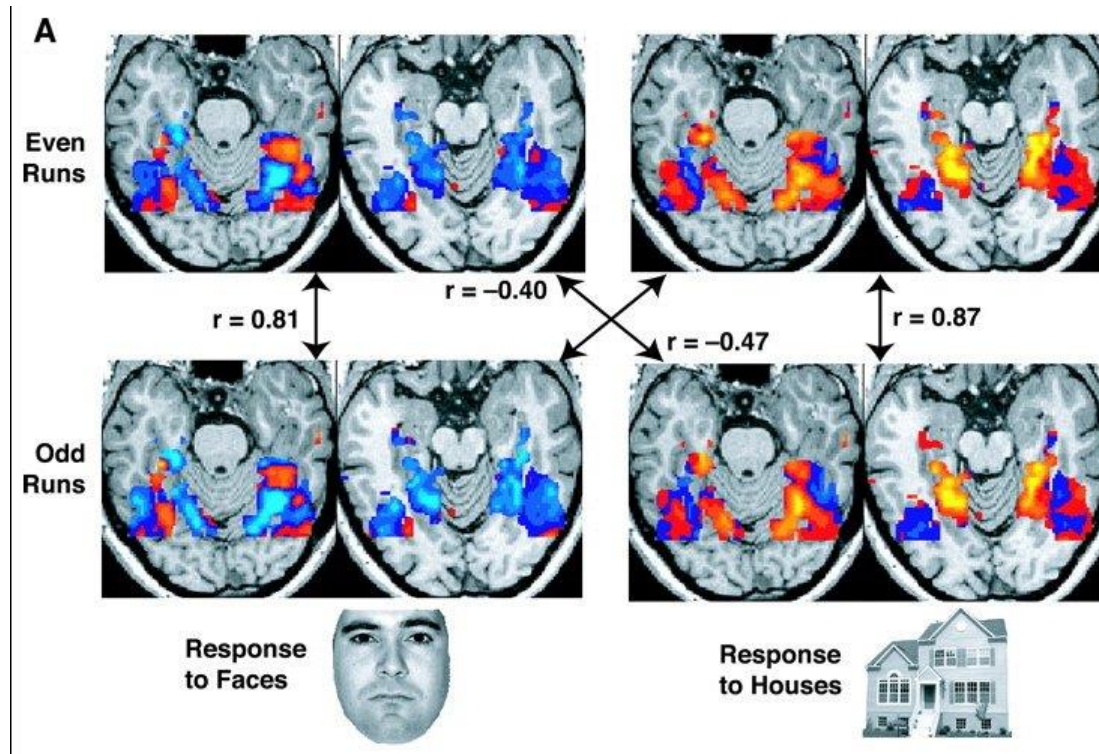
Light sensitive ion channels and optogenetic

# Positron emission tomography (PET)

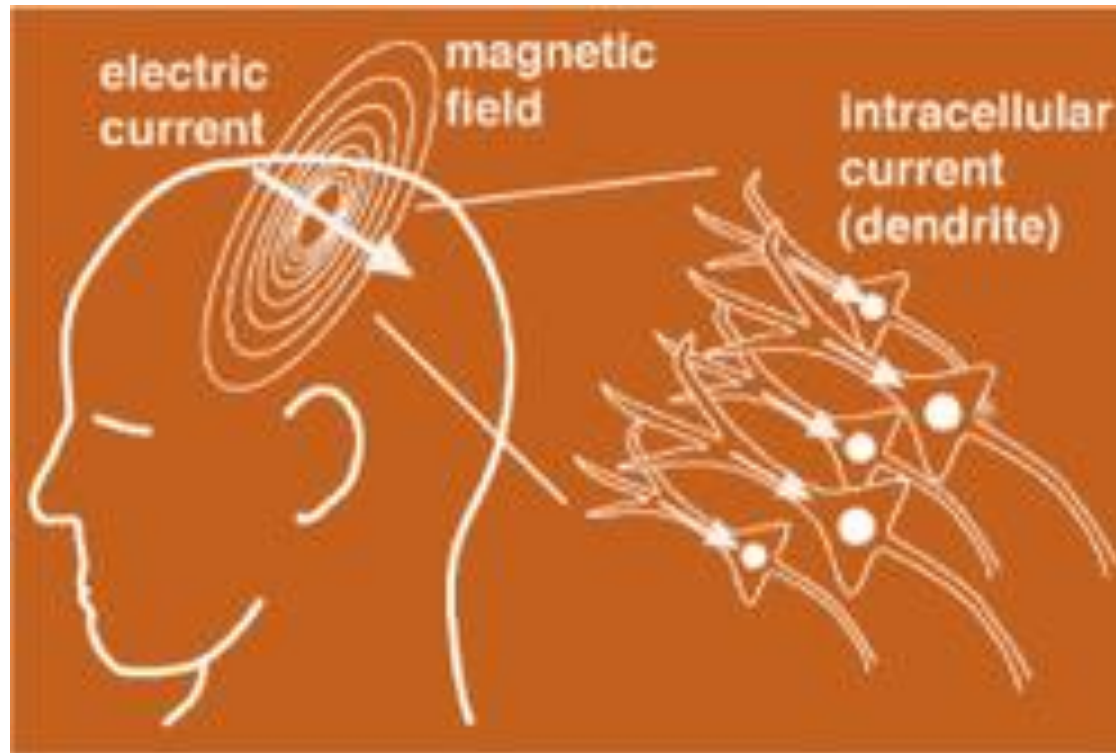




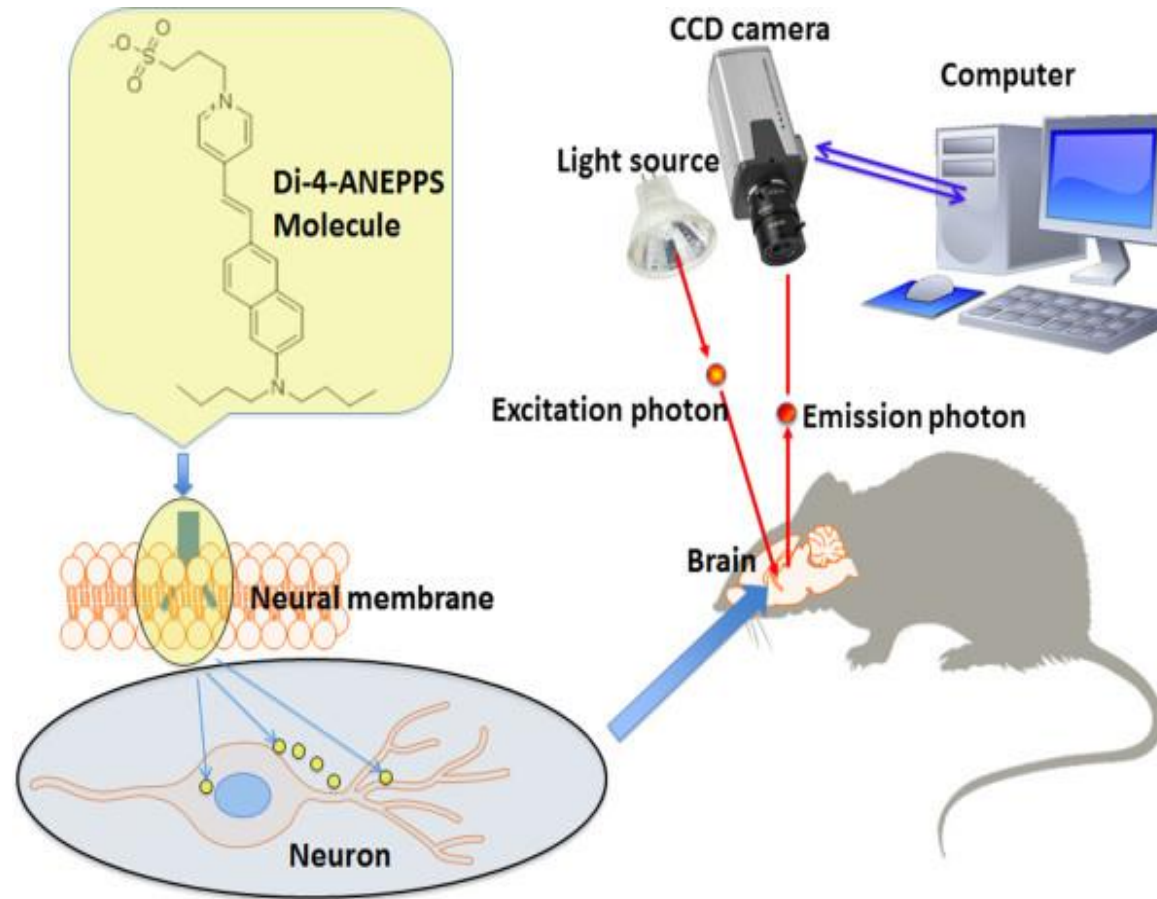
# Functional magnetic resonance imaging



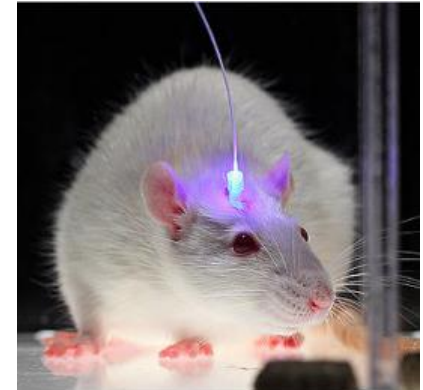
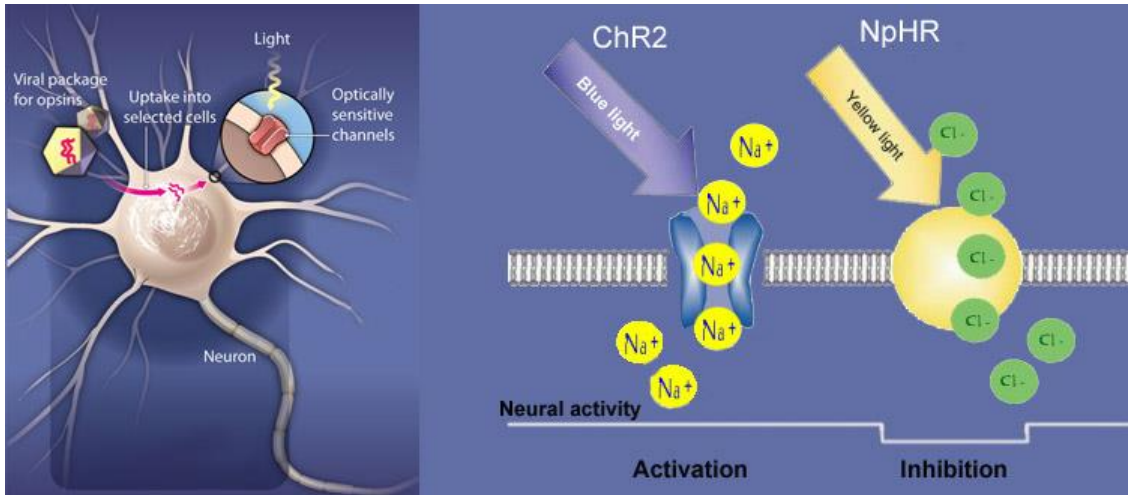
# Magnetoencephalography; Electroencephalography



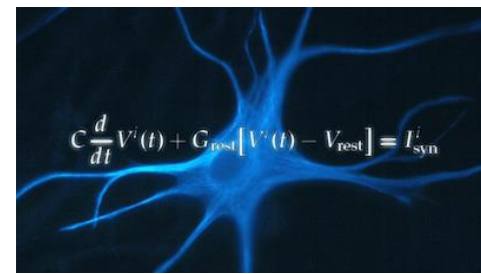
# Voltage and calcium-sensitive dyes (in vitro and in brain)



# Light sensitive ion channels and optogenetic

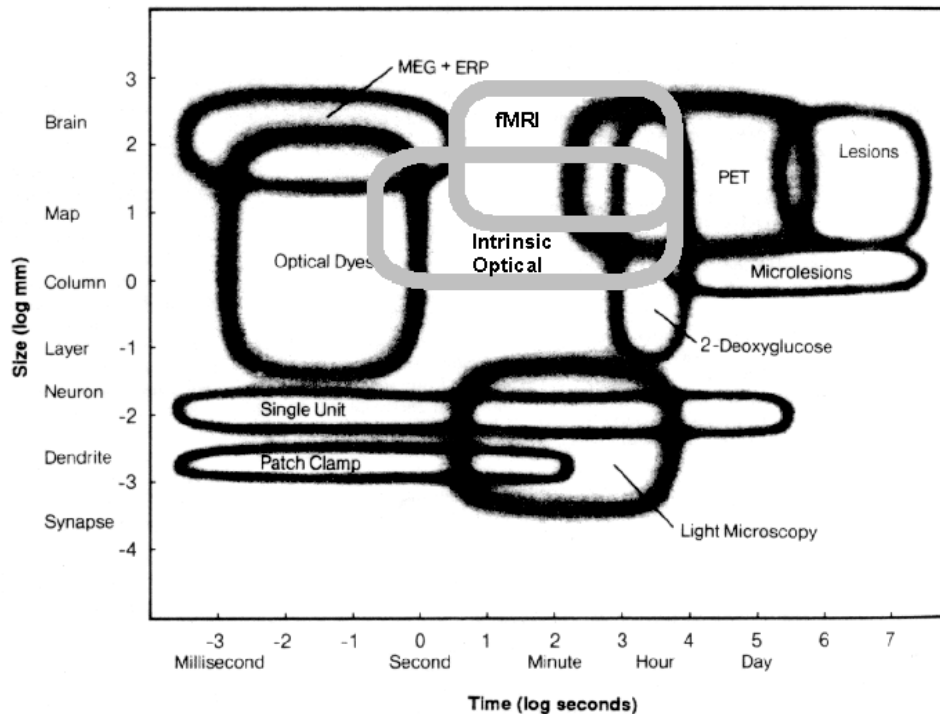
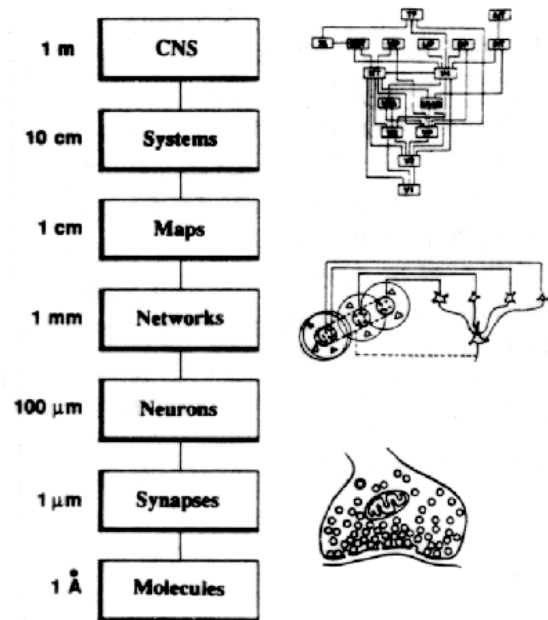


# Finally, computational neuroscience



- Improvement of computer and computational neuroscience have made it possible to
  - **Model** the activity of large population of neurons
  - **Test** ideas about the roles of **specific component** of neural circuits in particular behavior
- We need to understand not only the properties of individual of cells but also the **network properties** of circuits.
- Emergent property:
  - Although network properties depend on the properties of individual neurons in the network, they **are not identical or even similar** to those properties but are an **emergent property** of the way those different cells are interconnected.

## Levels in Neuroscience: Questions to Ask, Techniques to Answer

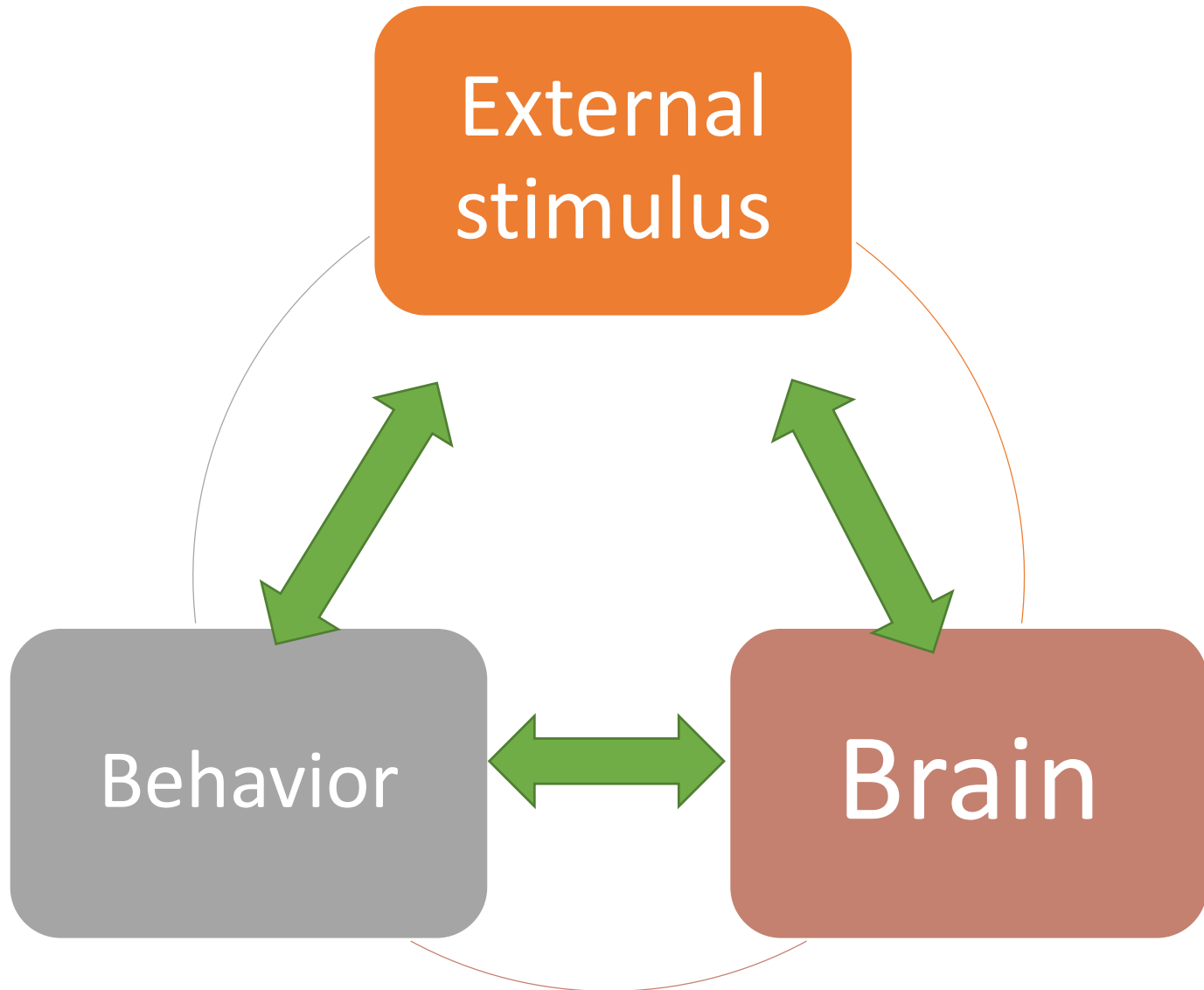


Behavior  
Development  
Pathology/Disease

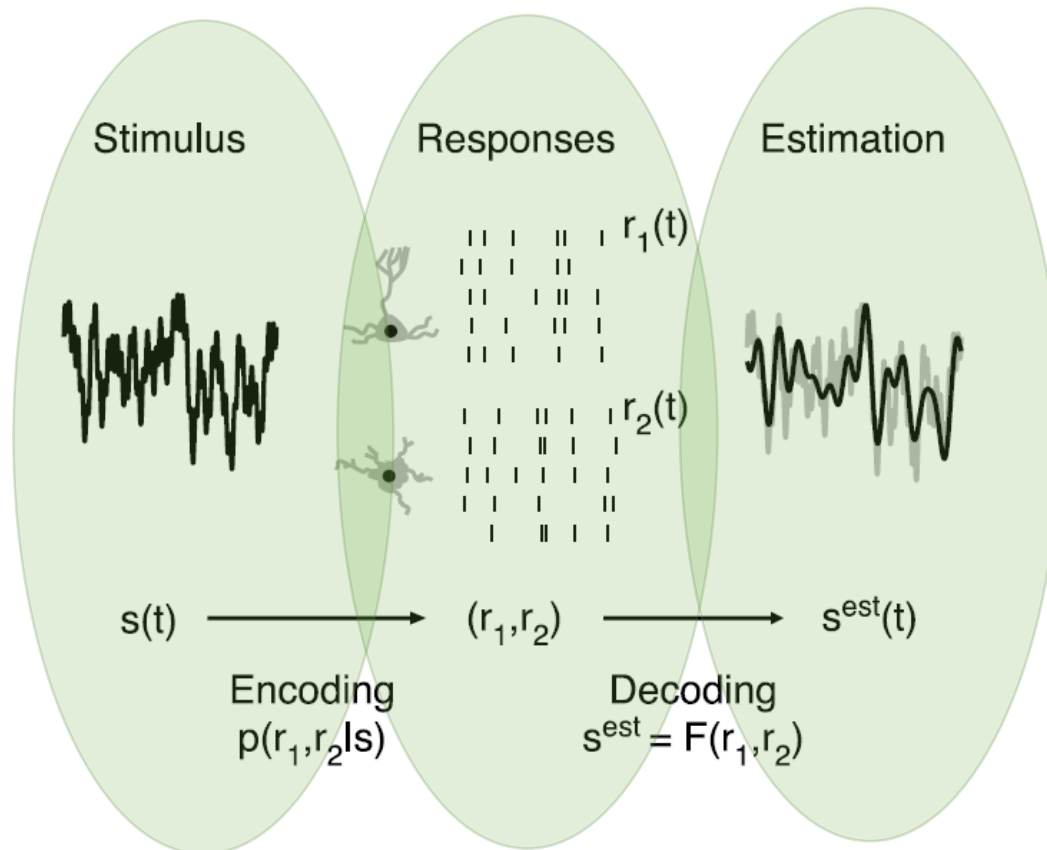
*Churchland and Sejnowski, 1998*



# System neuroscience



# Coding decoding framework

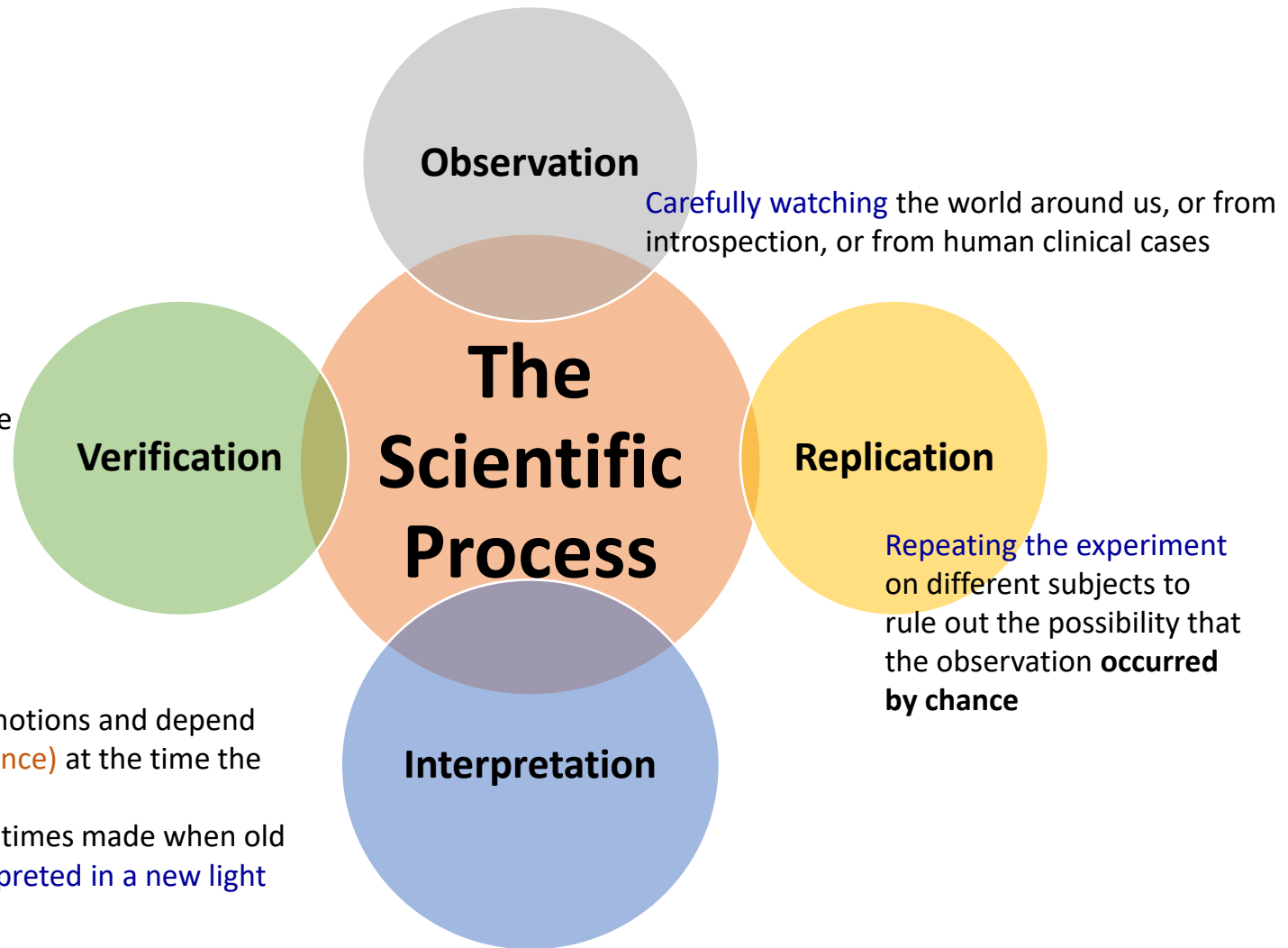




# Behavior in terms of the electrical activity of both individual neurons and systems of nerve

- The ultimate goal of neural science is to understand how the **flow of electrical signals through neural circuits gives rise to mind**—to how we perceive, act, think, learn, and remember.
- **Five basic questions:**
  - How does the brain **develop**?
  - How do nerve cells in the **brain communicate** with one another?
  - How do different **patterns of interconnections** give rise to **different perceptions and motor acts**?
  - How is the communication between neurons **modified by experience**?
  - How is that communication **altered by disease**?

# The elements of scientific process



- Based on preconceived notions and depend on knowledge (or ignorance) at the time the observation
- Breakthroughs are sometimes made when old observations are reinterpreted in a new light