Introduction to Cognitive Neuroscience

Lecture 01: Introduction;

how can we study mind and brain

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BrainGate Pilot Clinical Trial
Drinking From a Bottle Using a Robotic Arm
Participant S3
Trial Day 1959 / 12 April 2011
Hochberg *et al.*, 2012

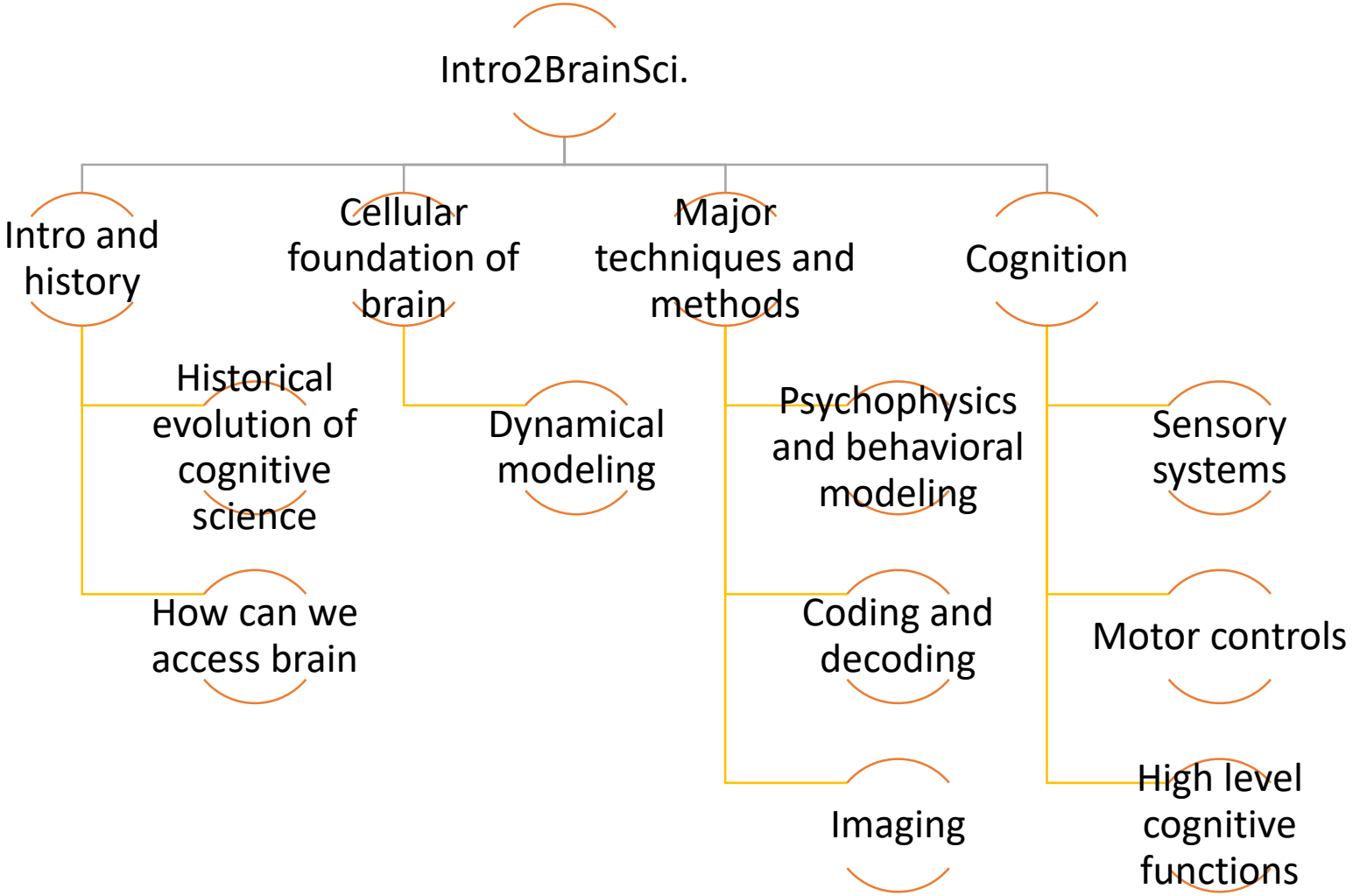
Caution: Investigational Device. Limited by Federal Law to Investigational Use.

Why should we study the Brain

- To know thyself
  - Your mind/brain is who you are
- To understand the origin and limitation of human knowledge
  - How does the structure of our brain shape the structure of our thoughts (empirical epistemology)
- To advance AI
- It seems brain is the greatest intellectual quest of all time.

Course aim and topics

- To prepare students to start brain research with minimum effort
- 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


Intro2BrainSci.
Intro and history
Cellular foundation of brain
Major techniques and methods
Cognition
Historical evolution of cognitive science
How can we access brain
Dynamical modeling
Psychophysics and behavioral modeling
Coding and decoding
Imaging
Sensory systems
Motor controls
High level cognitive functions

Course structure

- Lectures (concepts)
- Assignments (skill and techniques)
  - 4 assignments
  - In each one we cover one type of data (behavioral, single neurons, EEG, and MRI)
  - Students are subject of one behavioral task (mandatory) and EEG/fMRI task (optional with bonus)
  - No delay policy
  - The necessary material will be provide by workshop and recitations
- Paper days (4 sessions)
- Final project
- Exams and quiz

Evaluation

- Midterm : 5 score (Farvardin 26^{th})
- Final: 6 score
- Quiz: 1.5 score
- Assignments: 6 score
- Final project: 2 score

- The final exam cover all topics with main focus on after midterm sessions.

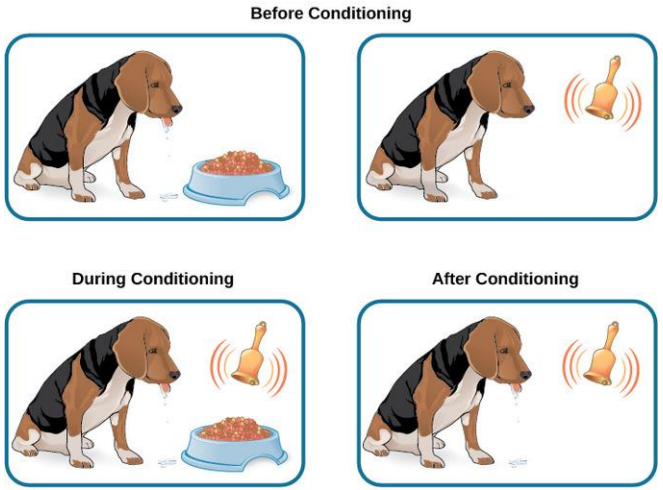
Brief history

The 19th century

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

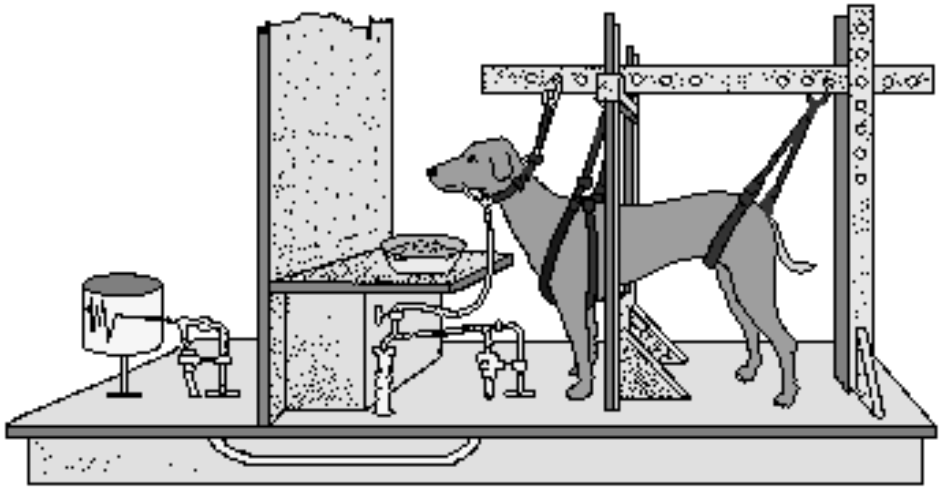
Behaviorism; rigorous empirical school of psychology

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

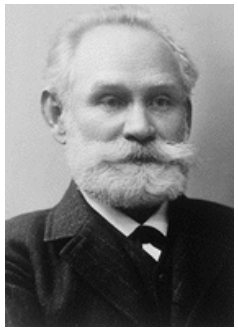


Born: 1849 - 1936, Russia

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)

Behaviorism; 1950s

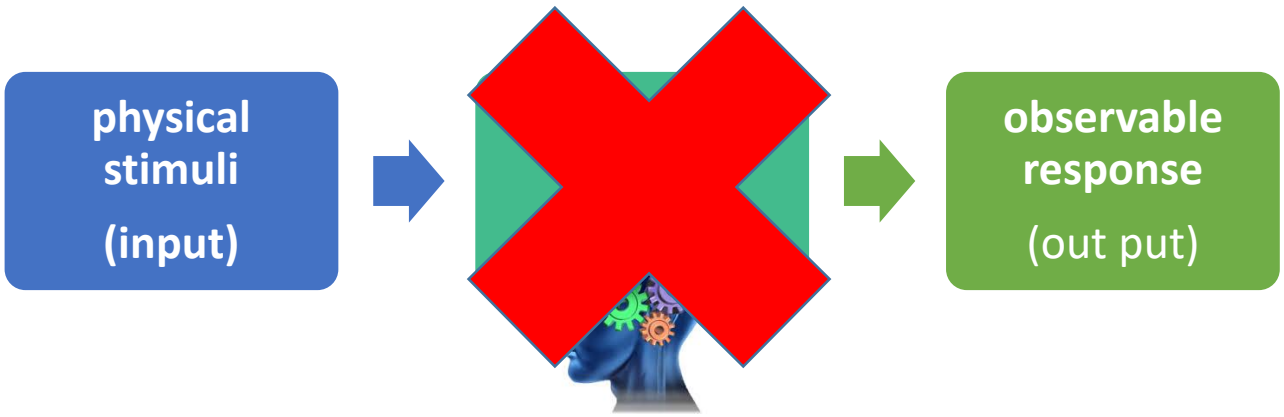
John B. Watson

B. F. Skinner

- They argued that behaviour could be studied with the **precision of physical science**, but only if psychologist abondoned **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**.

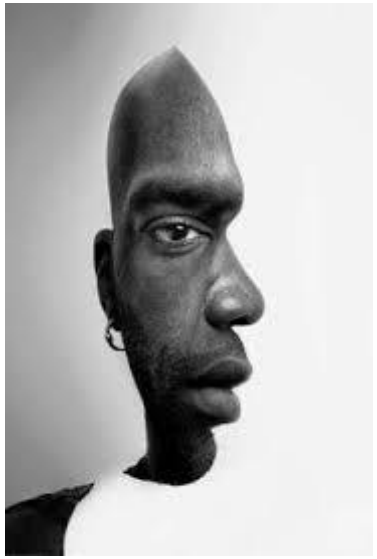
- They focus on relationship between specific **physical stimuli** and **observable response** in intact animal.
- They treat to all cognitive process that intervene between stimulus (input) and behavior (output) as **irrelevant**



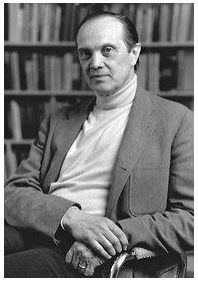
The **observable behavior is all there is to mental life**

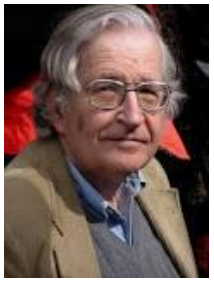
Cognitive psychology 1960s

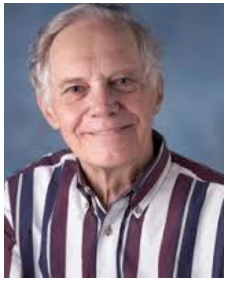
Earlier evidences form **Gestalt** psychology, **psychoanalysis**, and **neurology** make it easy for cognitive psychologist to convince the scientific community that behaviorism **was too limiting**




Frederick Bartlett


George Miller


Noam Chomsky


Ulric Neisser


Edwin Tolman

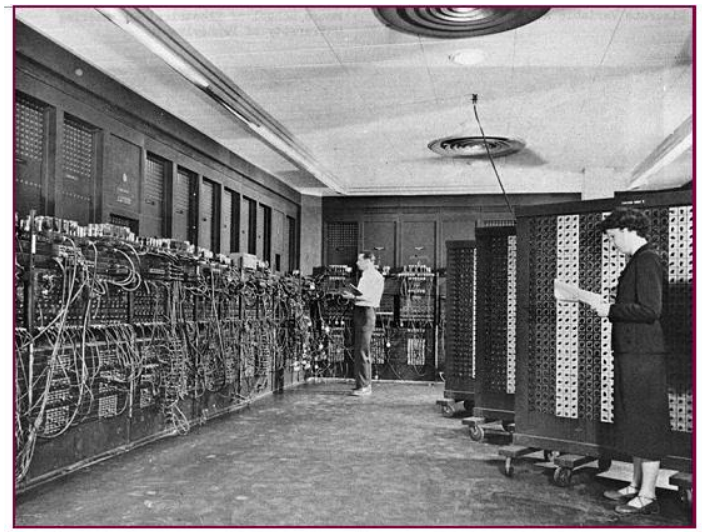
- They demonstrate our **knowledge is based on our biological equipment**
- Perception is a **constructive process** **that depend not only on the stimulus but also mental apparatus** of perceiver (the organization of sensory and motor system).
- We now realize that this process also involves **emotion,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

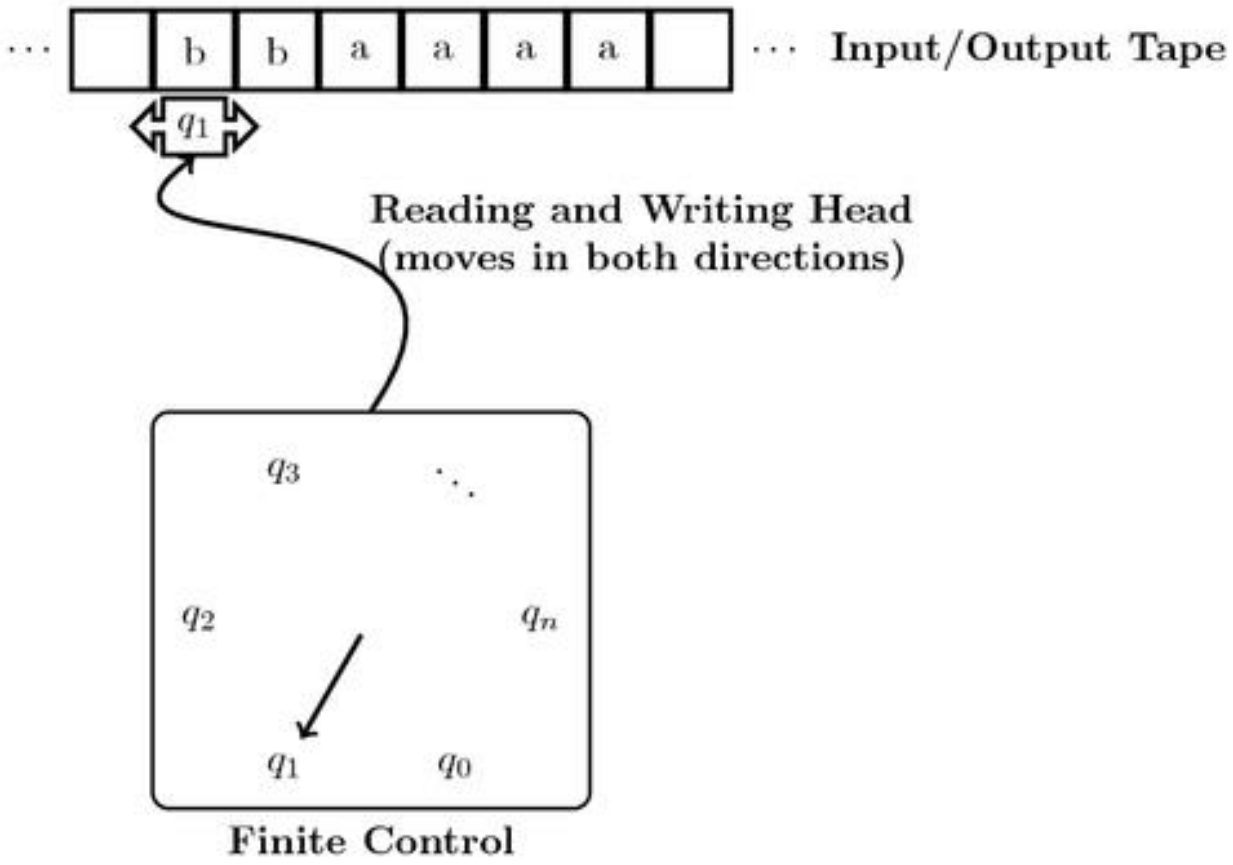
Coincidence with large scale computer

- 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



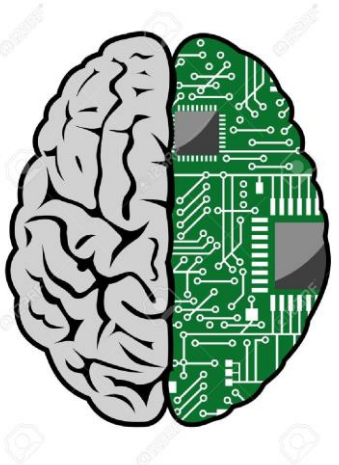
Glen Beck and Betty Snyder program ENIAC, circa 1947 - 1955. Image courtesy of the U.S. Army.

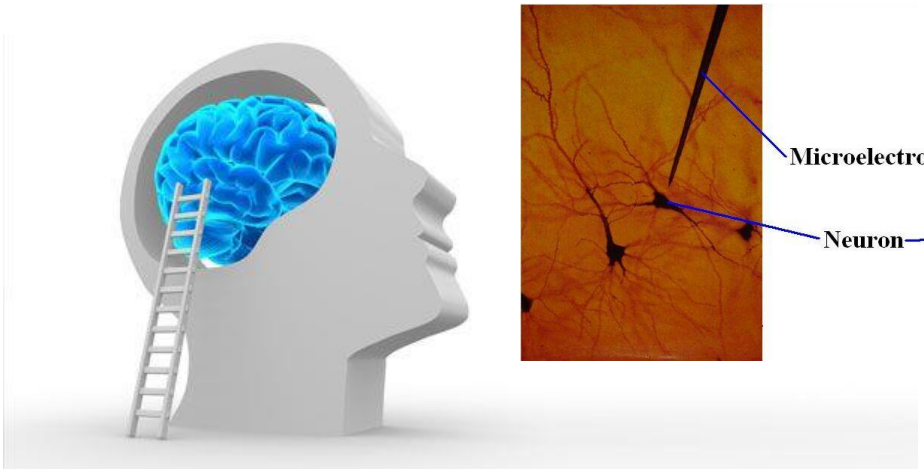
Turing Machine



Mental activity as computational processes in the brain

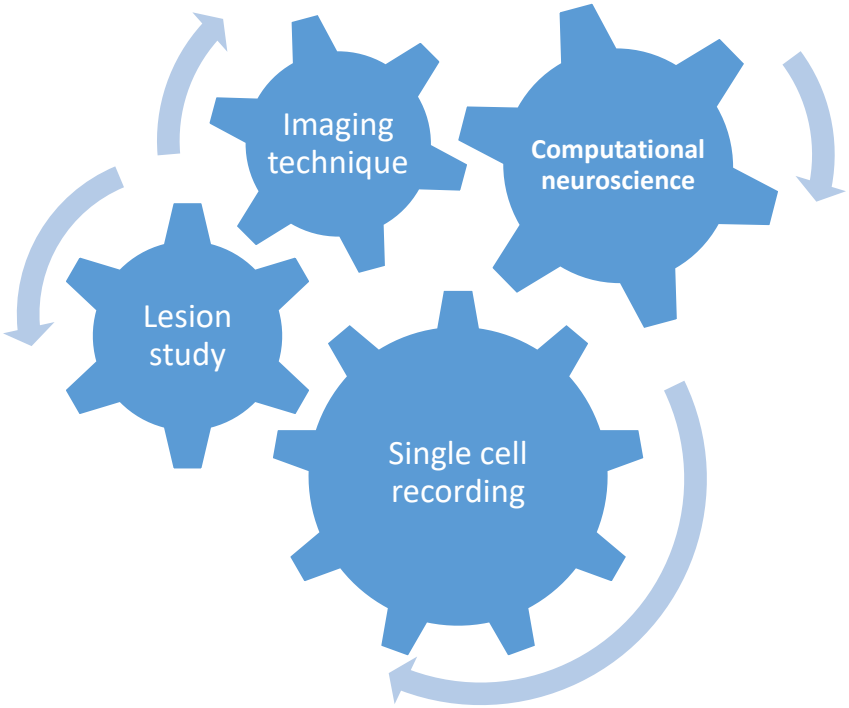
- This view made a lot of **theories for mental process**
- Without direct **access to the brain**, it would be difficult if not impossible to choose between various **rival theories**.



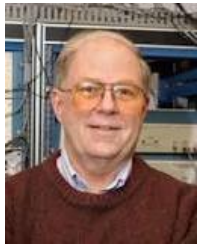


Singleneuron recording and **noninvasive imaging** recording techniques have allowed researchers to access the brain.

Cognitive neural science, four major technical and conceptual developments.



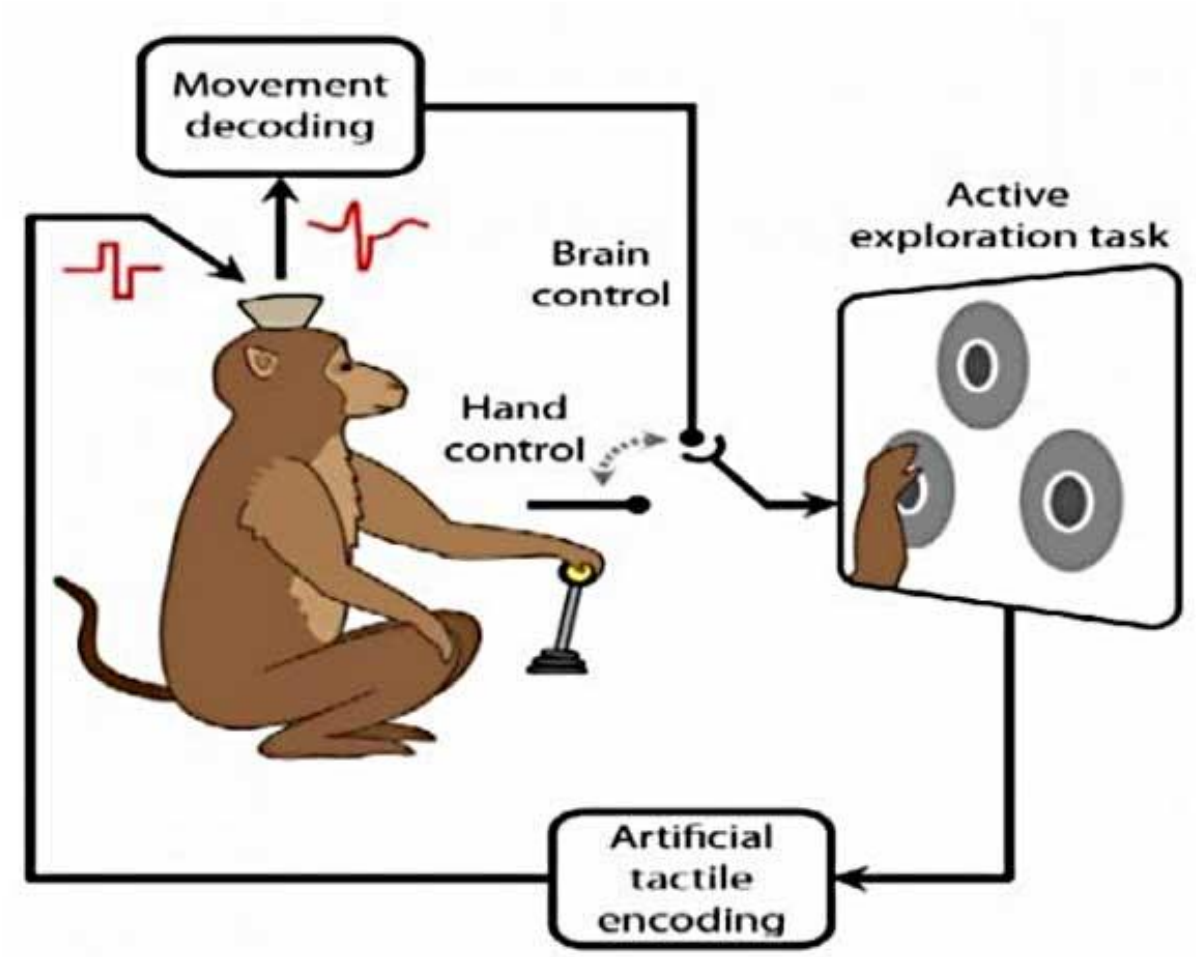
First, Single cell recording in the 1960s and 1970s

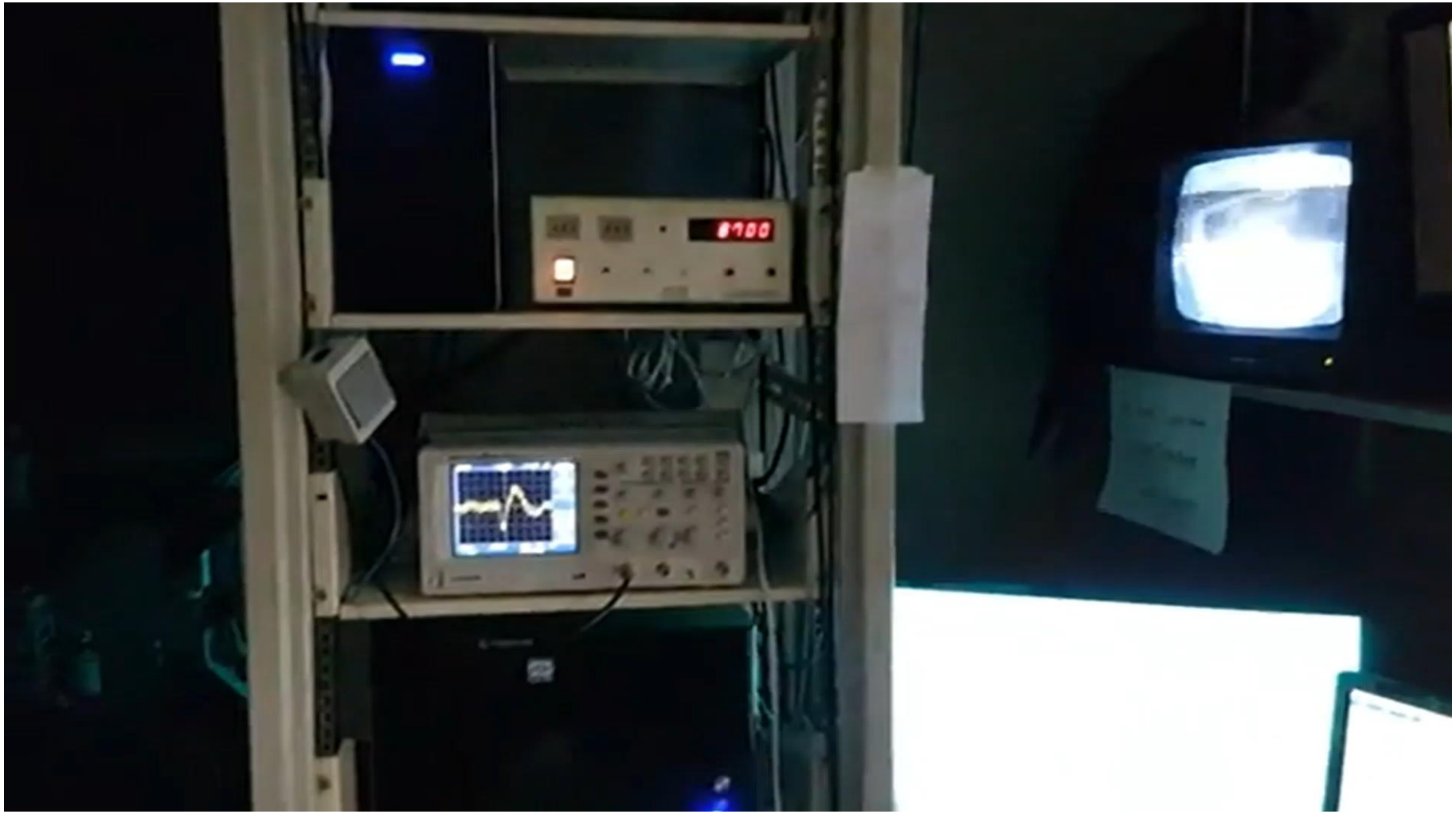

Robert Wurtz


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**

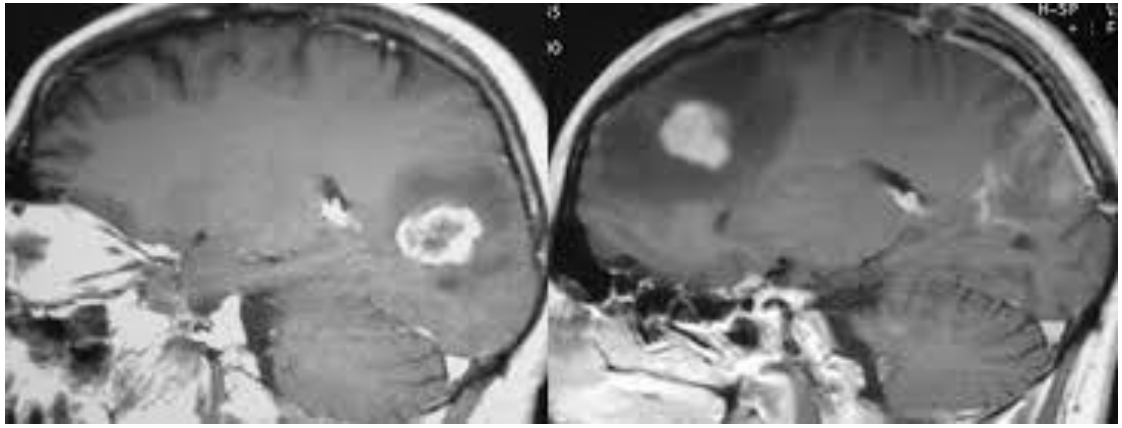
Recording setup





Second; lesion study

- Lesions of different regions of the brain can result in quite specific cognitive deficits
- It is belong to **neuropsychology**
- Behavioral analysis of patient with brain lesion tell 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**

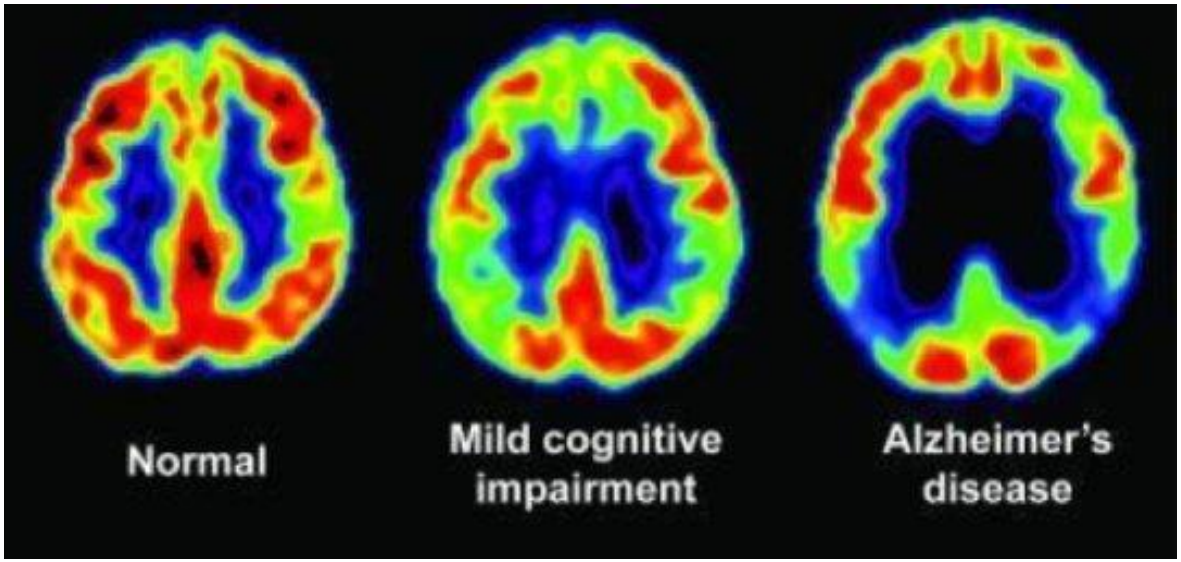


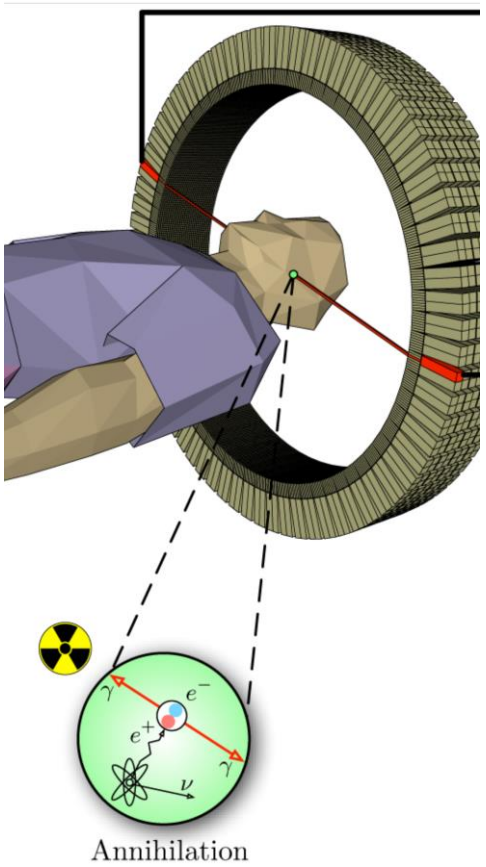
Human brain stimulation

Third; development of imaging technique

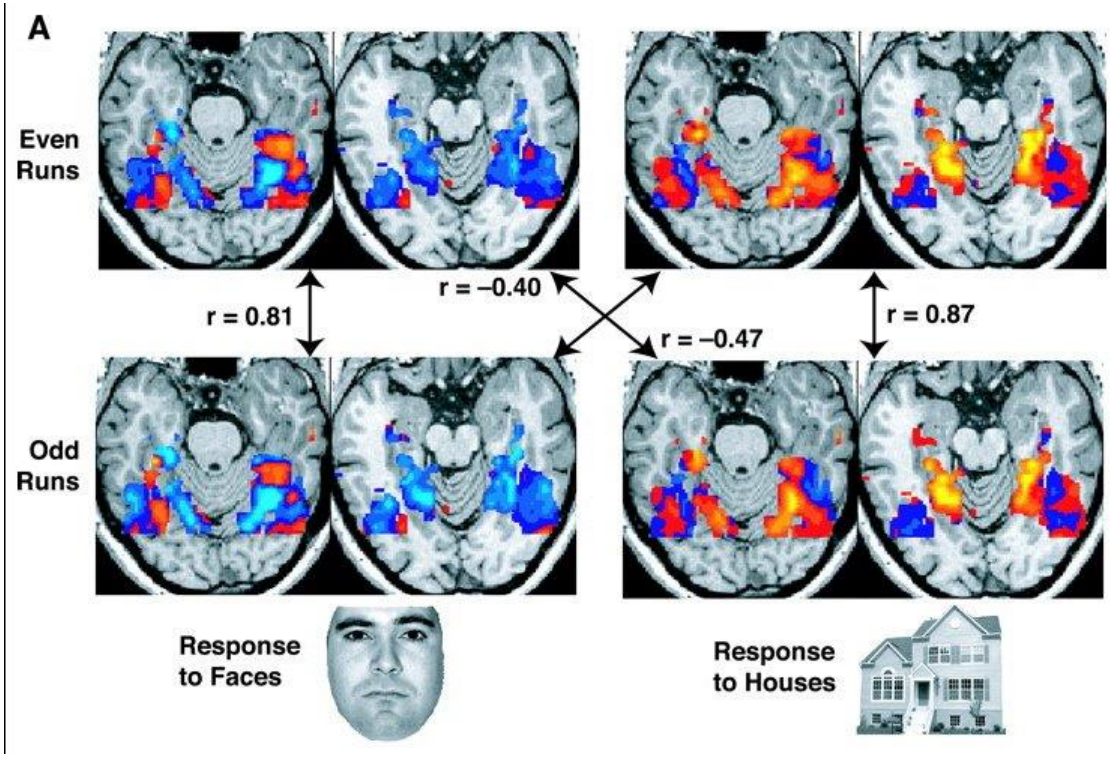
Positron emission tomography (PET)
Functional magnetic resonance imaging
Magnetoencephalography; Electroencephalography
Voltage and calcium-sensitive dyes (in vitro and in brain)
Light sensitive ion channels and optogenetic

Positron emission tomography (PET)

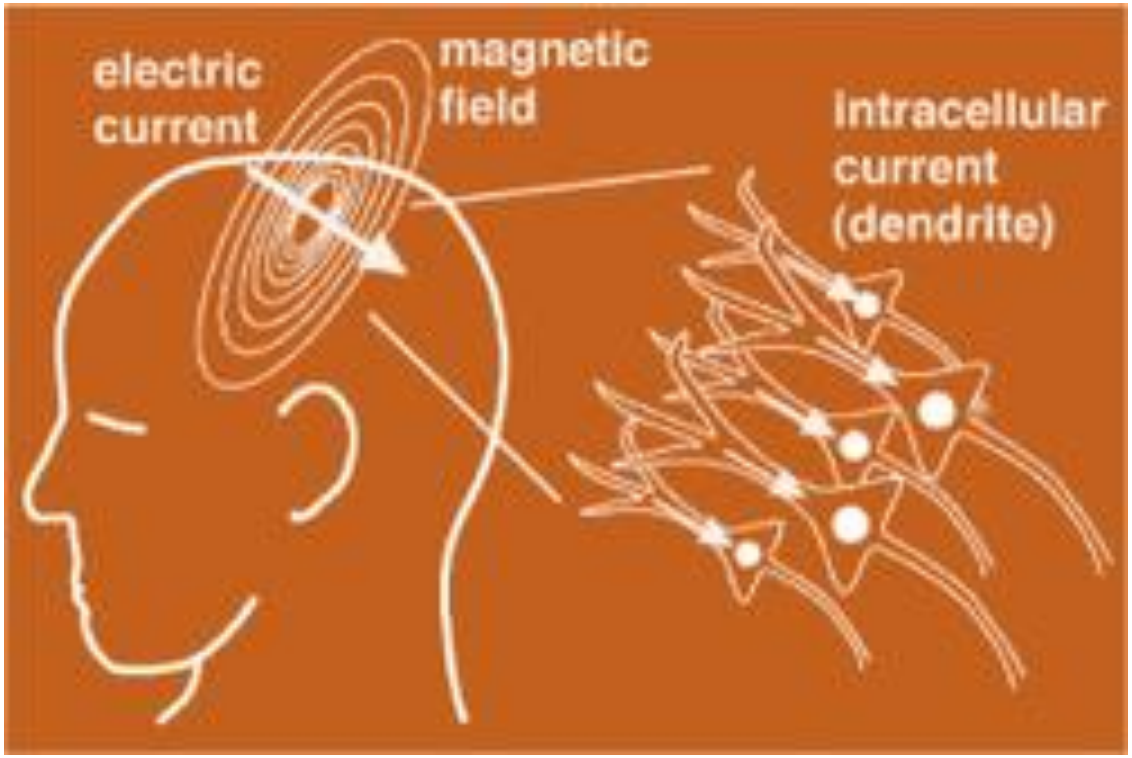




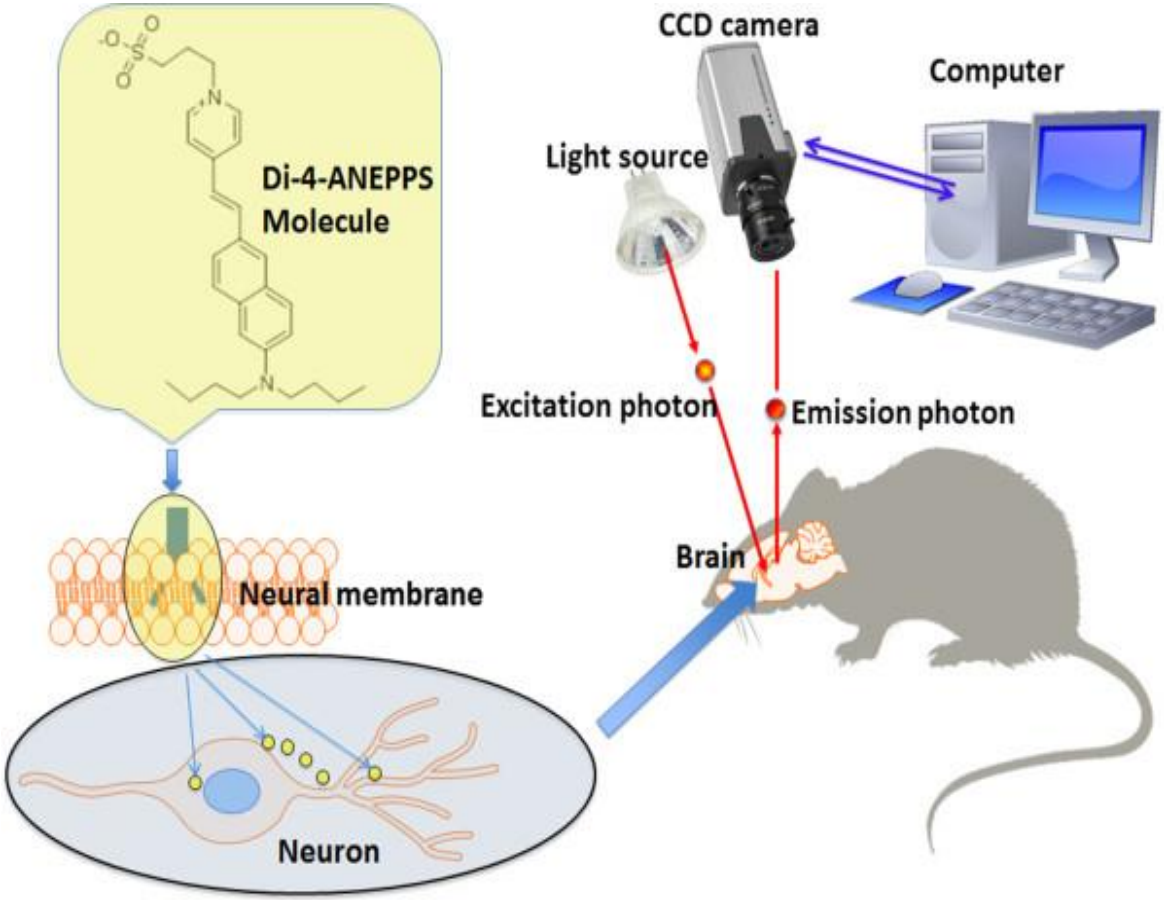
Functional magnetic resonance imaging



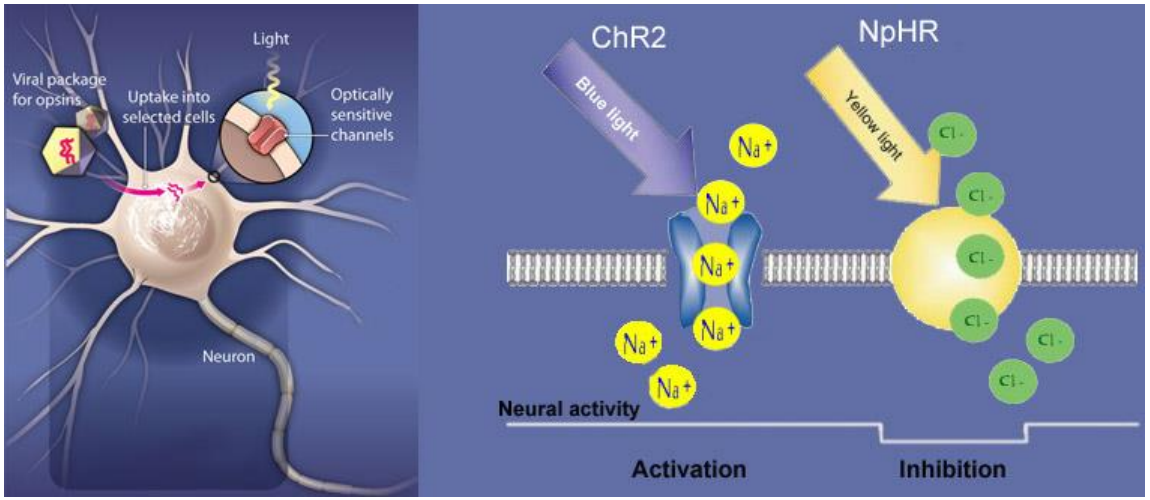
Magnetoencephalography; Electroencephalography

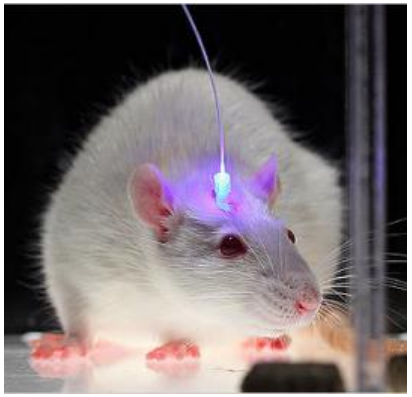


Voltage and calcium-sensitive dyes (in vitro and in brain)

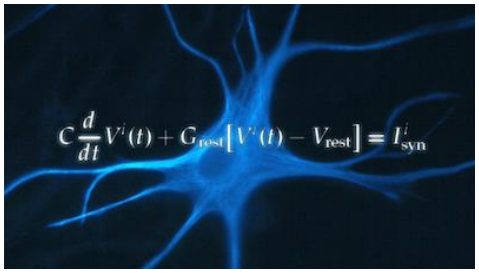


Light sensitive ion channels and optogenetic



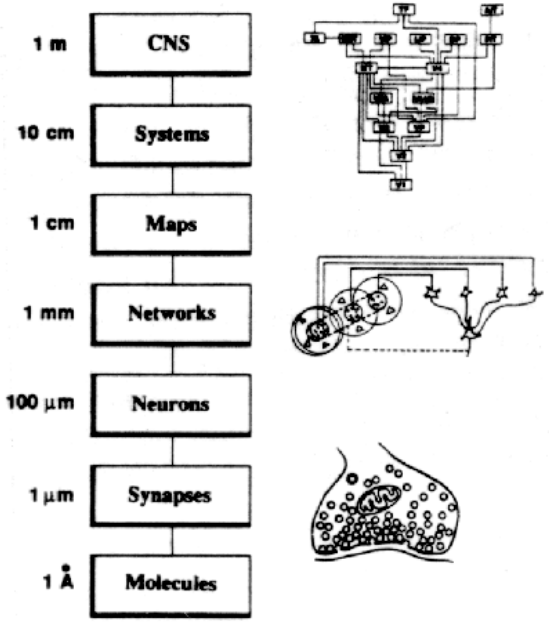


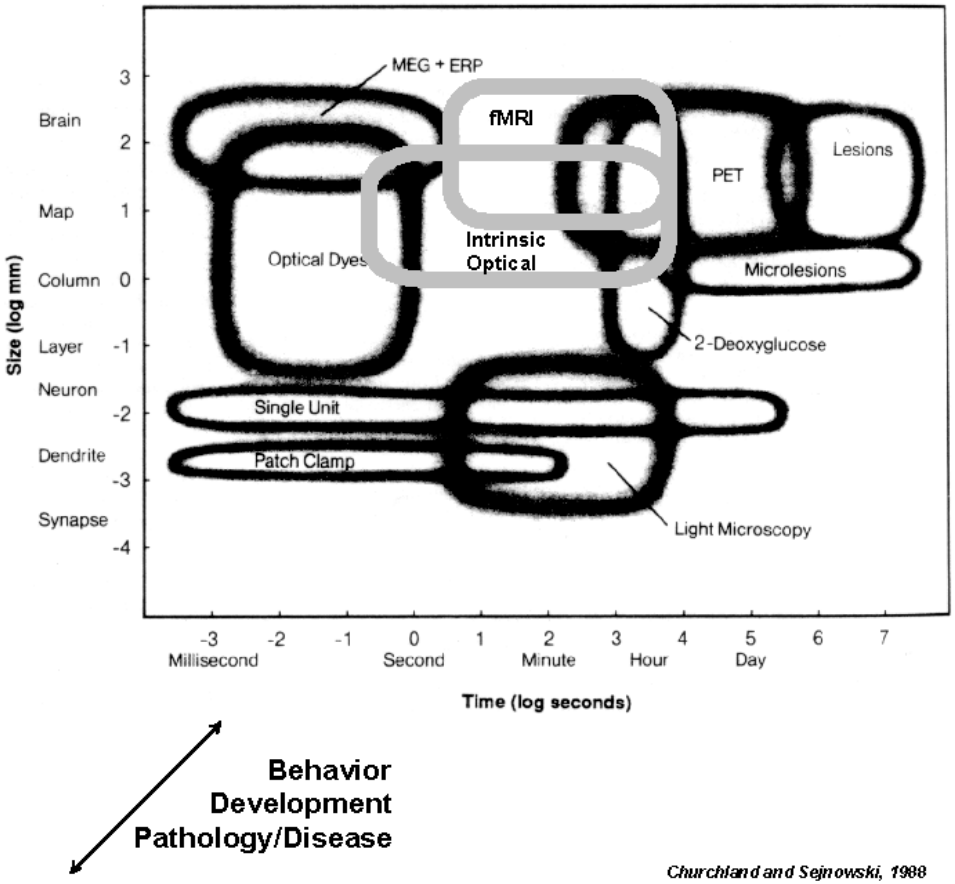
Finally, computational neuroscience



- 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.

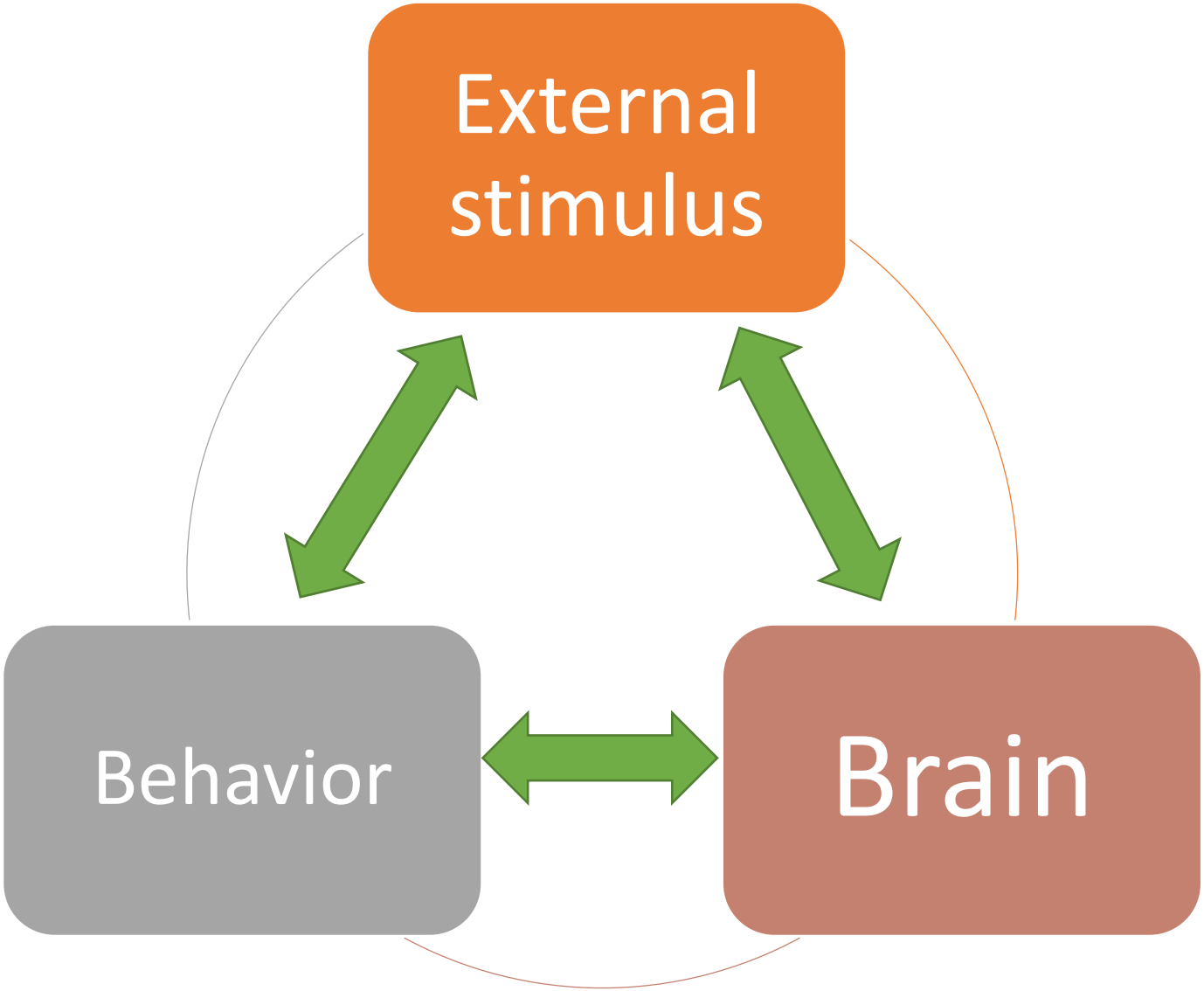
Levels in Neuroscience: Questions to Ask, Techniques to Answer



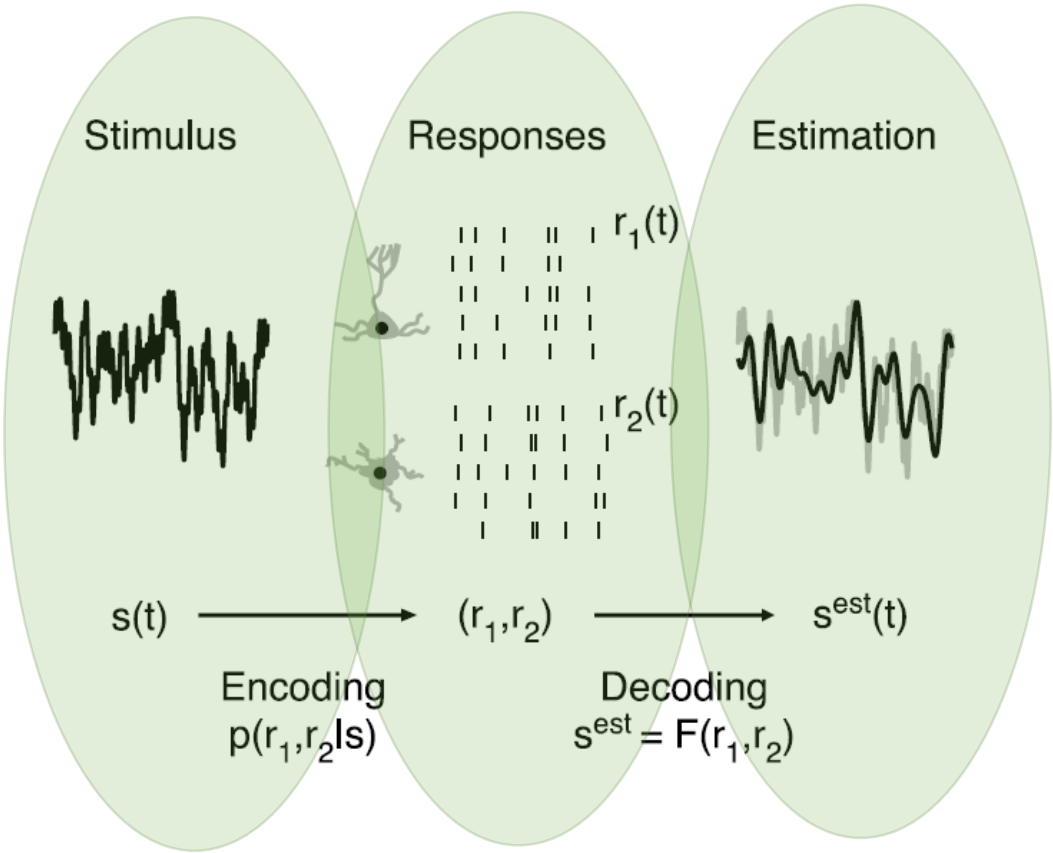


Churchland and Sejnowski, 1988

System neuroscience



Coding decoding framework

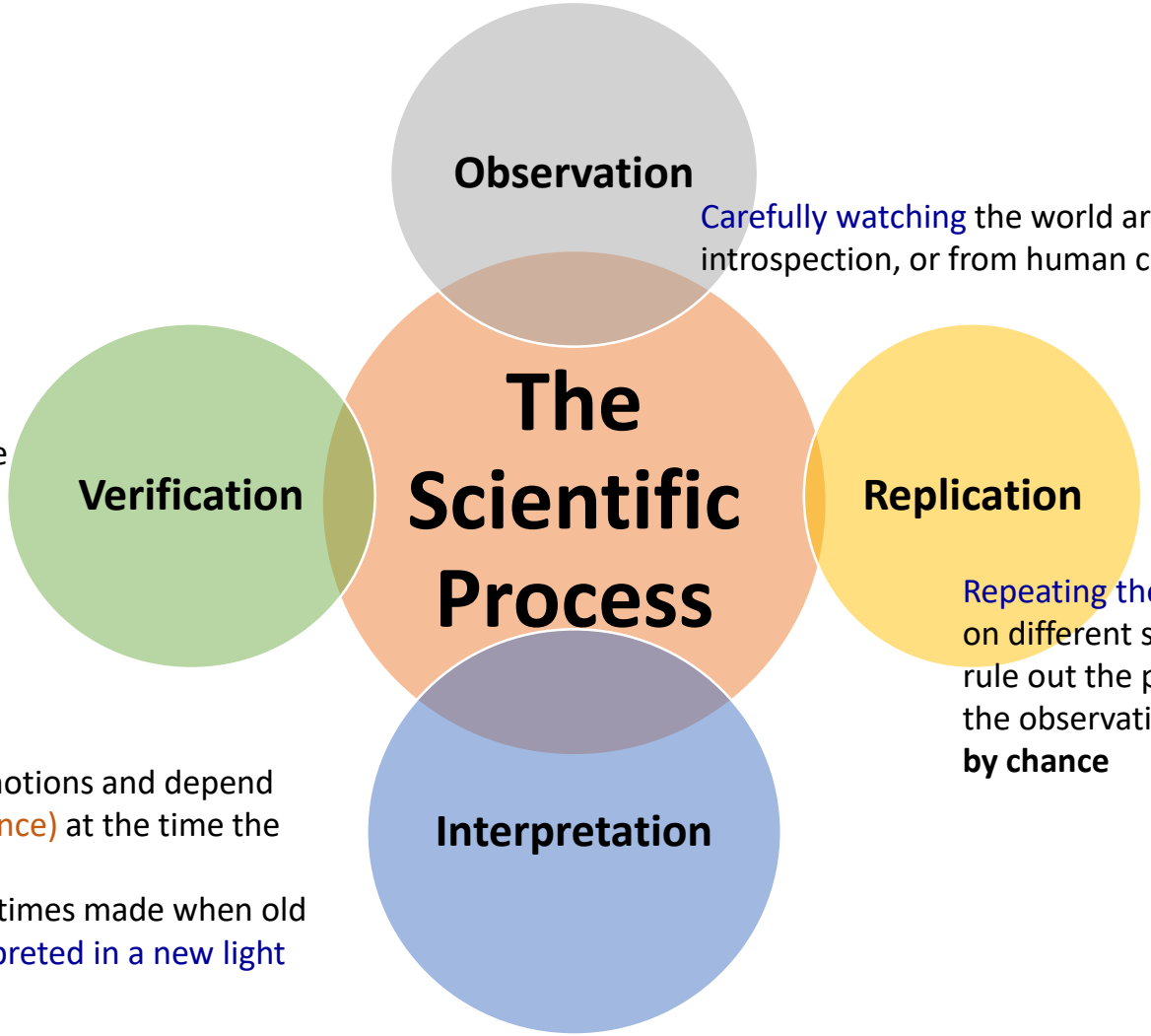


(Elad Schneidma 2003)

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



Carefully watching the world around us, or from introspection, or from human clinical cases

It will be reproduced by any competent scientist who precisely follows the protocols

Repeating the experiment on different subjects to rule out the possibility that the observation **occurred by chance**

- 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

Bear, Mark F., Barry W. Connors, and Michael A. Paradiso, eds. *Neuroscience*. Vol. 2. Lippincott Williams & Wilkins, 2007.