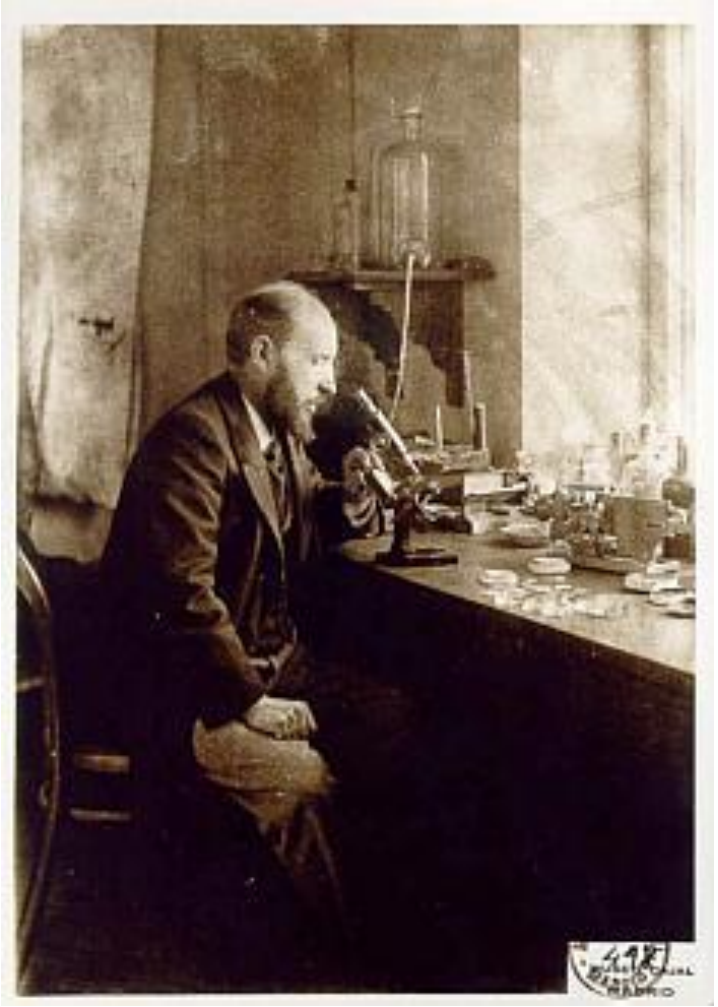
Introduction in Neuroscience

Lecture 1

As the father of Neuroscience
Santiago Ramón Cajal put it:

"As long as our brain is a mystery, the universe - which is a reflection of the structure of the brain - will also be a mystery".



What is neuroscience?

- Neuroscience is a study devoted to understanding the nervous system and its core component, the brain.
- This investigation can occur at multiple levels, from molecular synapses and cellular networks to cognition and behavior.
- Neuroscience combines molecular and cellular biology, physiology, biomedicine, behavioral science, cognitive psychology, electrical engineering, computer science and artificial intelligence to understand the fundamental and emergent properties of neurons and neural circuits.
- Neuroscientists may come from a variety of backgrounds, including psychology, computer science, biology, and medicine.

Why is it interesting and important?

From the point of view of basic research:

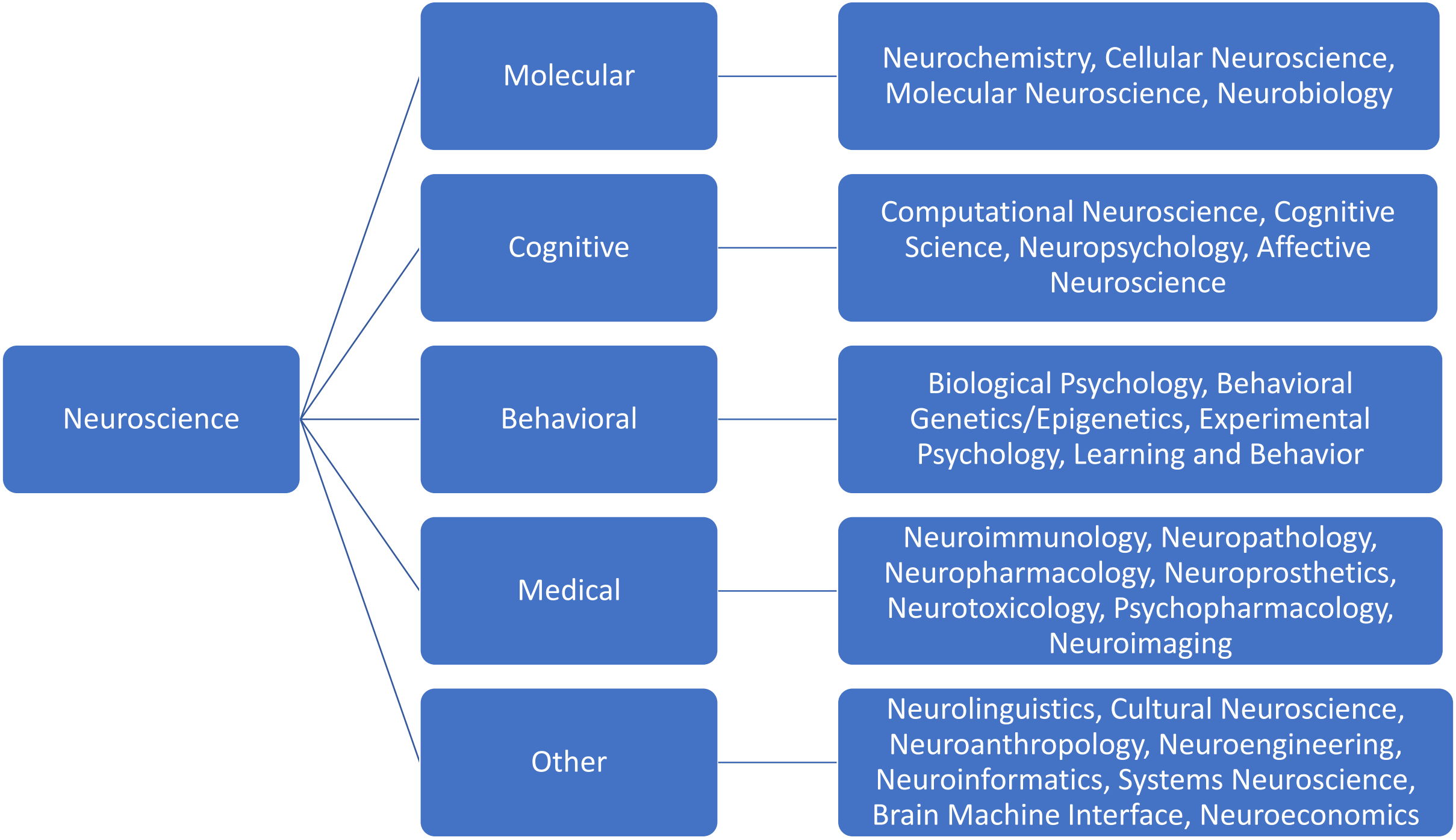
- Neuroscientist hope to understand how cellular circuits enable us to read and speak, how we bond with other humans, how we learn and retain information, how we experience pain, and how we feel motivation.
- Computer science specialists can also hope to increase the performance of artificial intelligence systems by means of understanding the real neural networks operation.
- **The understanding of the biological basis of learning, memory, behavior, perception, and consciousness has been described by Eric Kandel as the "ultimate challenge" of the modern sciences.**

Why is it interesting and important?

From the point of view of medicine:

- Neuroscientists hope to find causes for devastating disorders of the brain and body, as well as ways to prevent or cure them:

  - Understanding the best strategies for recovery from brain injury, including stroke
  - Prediction of the development of various diseases, as well as their treatment or suppression of abnormal brain activity, for example, various types of epilepsy
  - The problem of brain aging and the possibility of treating such terrible diseases as dementia, Parkinson’s and Alzheimer's diseases


Neuroscience
Molecular
Neurochemistry, Cellular Neuroscience, Molecular Neuroscience, Neurobiology
Cognitive
Computational Neuroscience, Cognitive Science, Neuropsychology, Affective Neuroscience
Behavioral
Biological Psychology, Behavioral Genetics/Epigenetics, Experimental Psychology, Learning and Behavior
Medical
Neuroimmunology, Neuropathology, Neuropharmacology, Neuroprosthetics, Neurotoxicology, Psychopharmacology, Neuroimaging
Other
Neurolinguistics, Cultural Neuroscience, Neuroanthropology, Neuroengineering, Neuroinformatics, Systems Neuroscience, Brain Machine Interface, Neuroeconomics

Why is it interesting and important?

From the point of view of neurotechnology:

- controlling the movement of robots and exoskeletons
- revealing and controlling some brain pathologies
- assessing and controlling the person's psychophysiological state
- monitoring human cognitive activity

Major questions in neuroscience

- How do we learn and remember?
- What are emotions?
- How and why does the nervous system malfunction? What can be done to reverse, halt, and/or treat adverse physiological or psychological symptoms that result from these malfunctions?
- What are the implications of neuroscience on law and morality?
- What is consciousness?
- Can intelligence be improved?
- Where does a sense of self come from?

History of neuroscience: ancient period

- **First neurosurgical operation :** trepanation, the surgical practice of either drilling a hole into the skull for the purpose of curing head injuries or mental disorders, or relieving cranial pressure, was first recorded during the Neolithic period.
- Trepanation was actively used by the ancient Indians in South America (Incas and related tribes)
- Manuscripts dating to 1700 BC indicate that the Egyptians had some knowledge about symptoms of brain damage.

Pandya, Sunil K. "Understanding brain, mind and soul: Contributions from neurology and neurosurgery." ***Mens sana monographs*** **9.1 (2011): 129.**

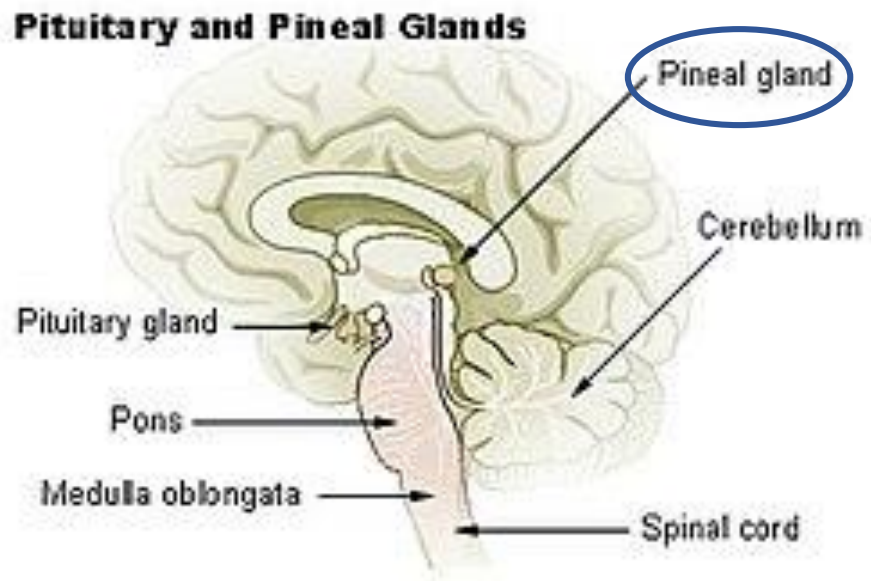
Brain and mind

- **Plato :** rational soul in brain - part of the mind nearest to the heavens
  - **Aristotle :** warm and active heart houses the mind cool and inert brain cools the blood
    - **Galen :** brain - mind in fluid filled ventricles

Pandya, Sunil K. "Understanding brain, mind and soul: Contributions from neurology and neurosurgery." ***Mens sana monographs*** **9.1 (2011): 129.**

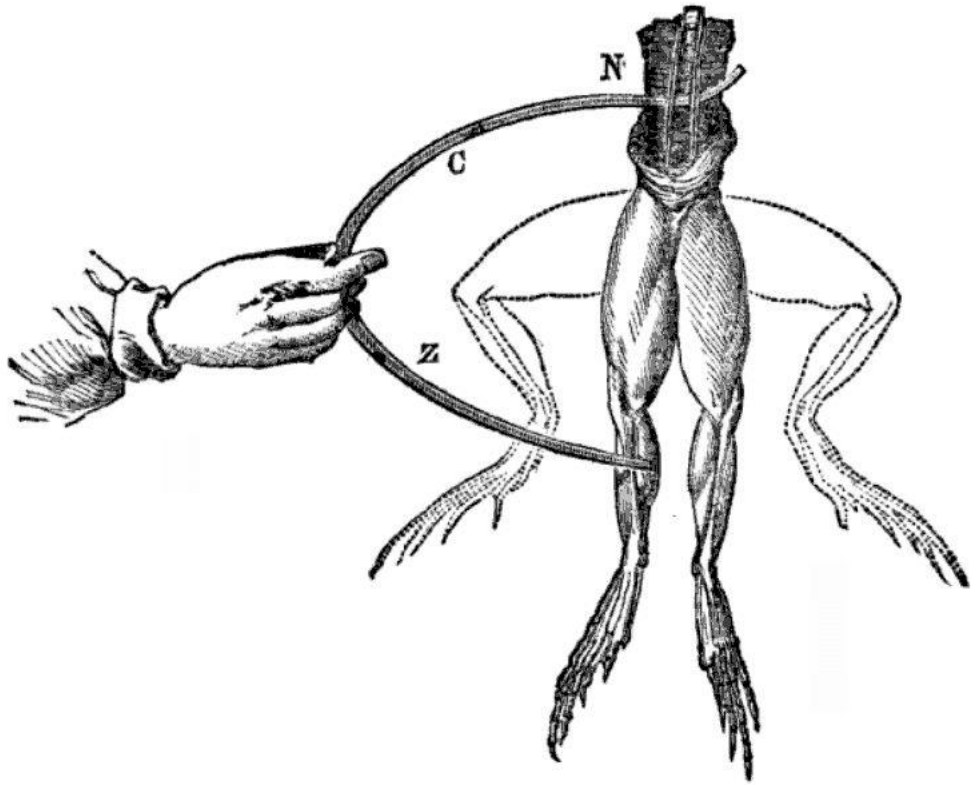
History of neuroscience: middle ages

- In the Medieval Muslim world, Abulcasis, Averroes, Avicenna, Avenzoar, and Maimonides described a number of medical problems related to the brain.
- In Renaissance Europe, Vesalius (1514–1564), René Descartes (1596–1650), Thomas Willis (1621–1675) made several contributions to neuroscience.
- Descartes, in the framework of his dualist teachings on the separation between the soul and the body, hypothesized that some part of the brain served as a connector between the soul and the body and singled out the pineal gland as connector.



History of neuroscience: modern history

- In the late 1700s Luigi Galvani shown the electrical excitability of muscles and neurons.



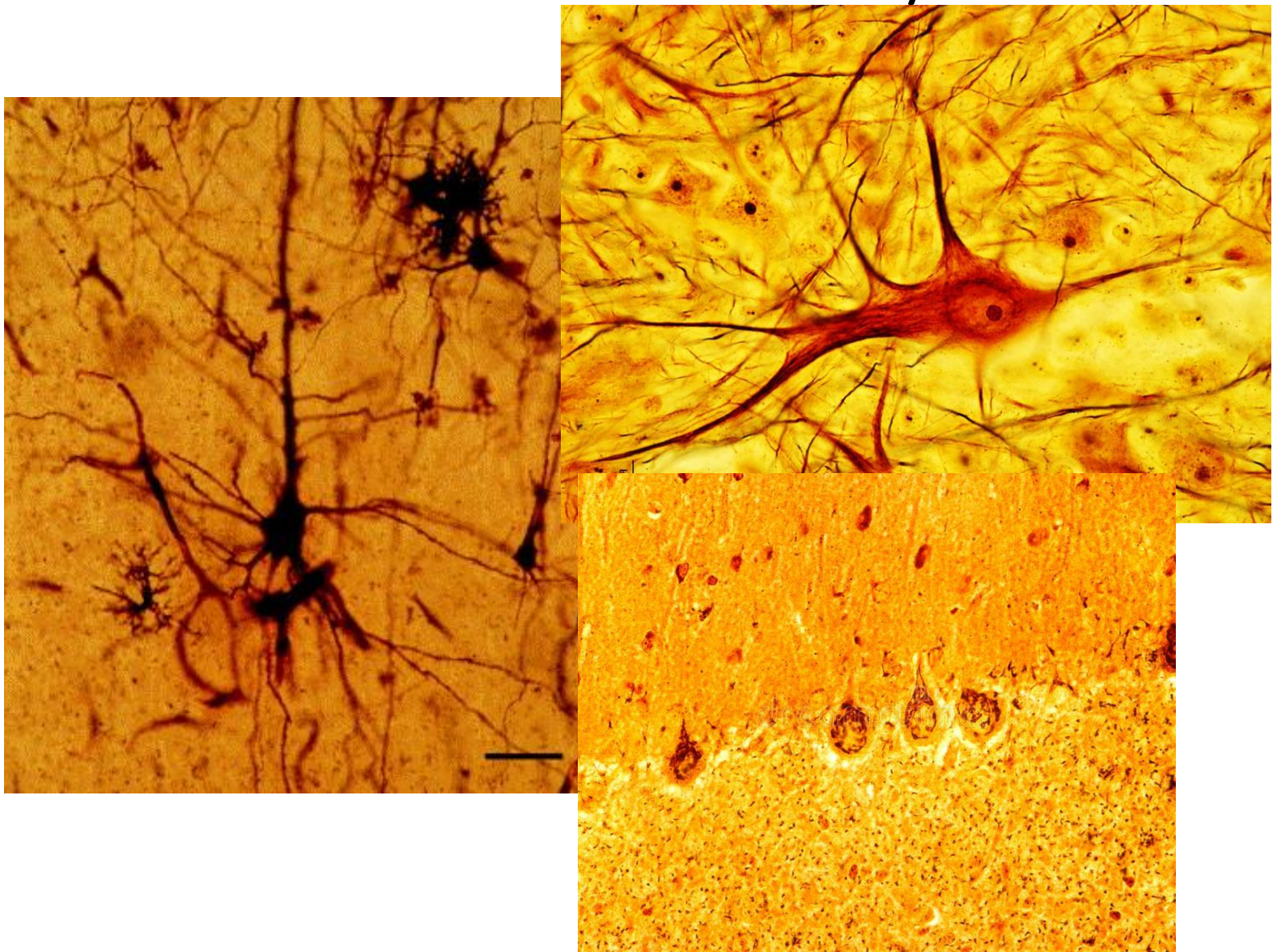
Electrodes touch a frog, and the legs twitch into the upward position

History of neuroscience: modern history

- In 1843 Emil du Bois-Reymond demonstrated the electrical nature of the nerve signal, whose speed **Hermann von Helmholtz** proceeded to measure
- In 1875 Richard Caton found electrical phenomena in the cerebral hemispheres of rabbits and monkeys. Adolf Beck published in 1890 similar observations of spontaneous electrical activity of the brain of rabbits and dogs.
- Studies of the brain became more sophisticated after the invention of the microscope and the development of a staining procedure by Camillo Golgi during the late 1890s. The procedure used a silver chromate salt to reveal the intricate structures of individual neurons.
- Based on this technique Santiago Ramón y Cajal led to the formation of the neuron doctrine, the hypothesis that the functional unit of the brain is the neuron.

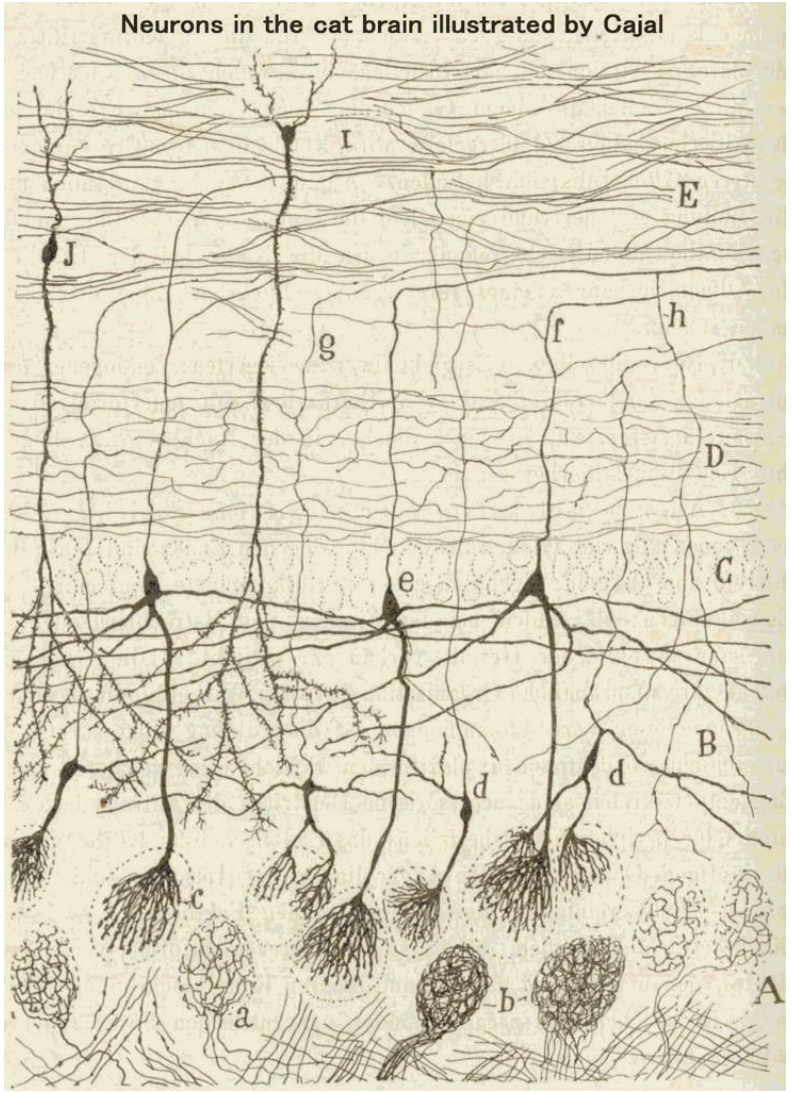
History of neuroscience: modern history

- Two fathers of neuroscience - Camillo Golgi and Santiago Ramón y Cajal, who shared the 1906 Nobel Prize for their extensive observations, descriptions, and categorizations of neurons throughout the brain.



Neurons visualizations

Santiago Ramón y Cajal drawings of neurons



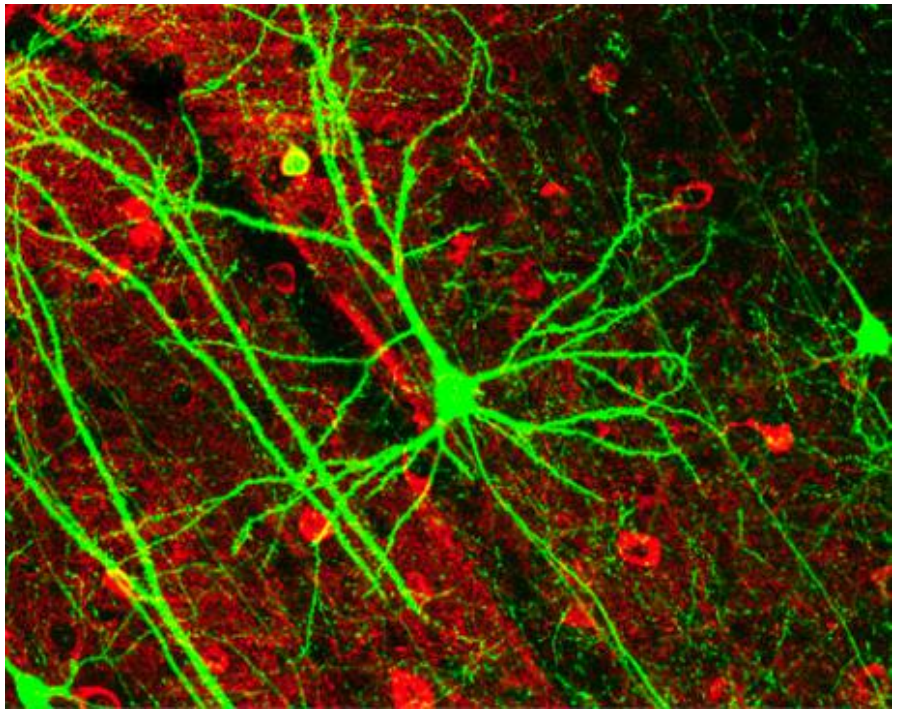


Image of pyramidal neurons in mouse cerebral cortex expressing green fluorescent protein (optogenetic visualization).

History of neuroscience: modern history

- During the 20th century, neuroscience began to be recognized as a distinct academic discipline in its own right, rather than as studies of the nervous system within other disciplines.
- The integration of basic anatomical and physiological research with clinical psychiatry was originated at the Walter Reed Army Institute of Research, starting in the 1950s.
- During the same period, a “Neuroscience research program” was established within the Biology Department at the Massachusetts Institute of Technology, bringing together biology, chemistry, physics, and mathematics. This is the first official use of the word "Neuroscience”
- The first free standing neuroscience department (then called Psychobiology) was founded in 1964 at the University of California.
- The Institute of Higher Nervous Activity was established in 1950 at Moscow.

Our course

- 15 lectures / 5 quizzes

Alexander E Hramov

1 lecture per week

- 15 seminars / 2 projects

Andrey V Andreev

1 class per week

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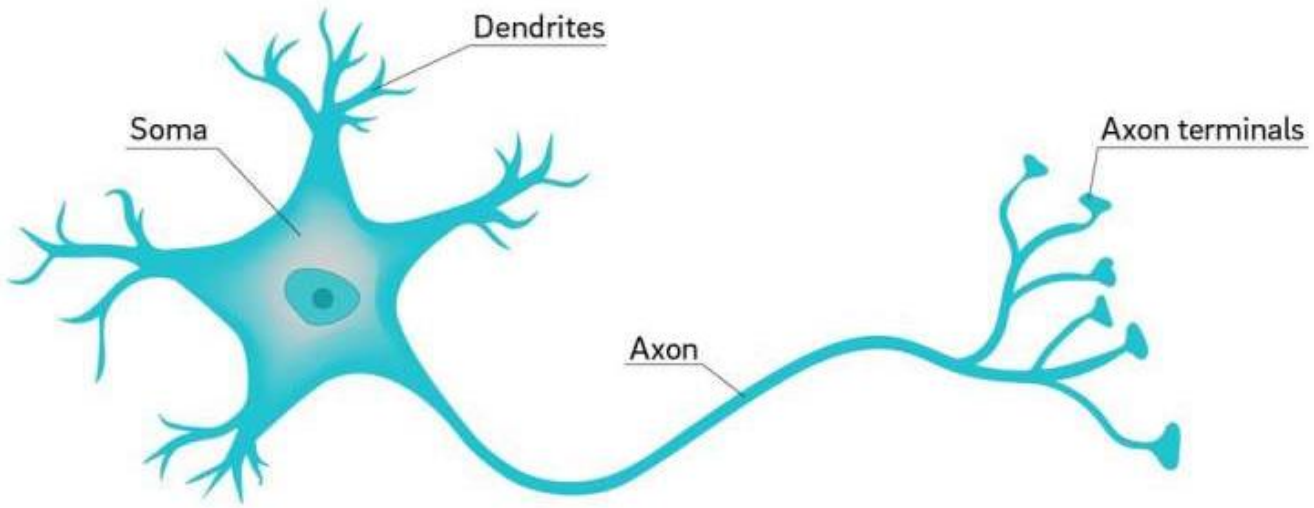
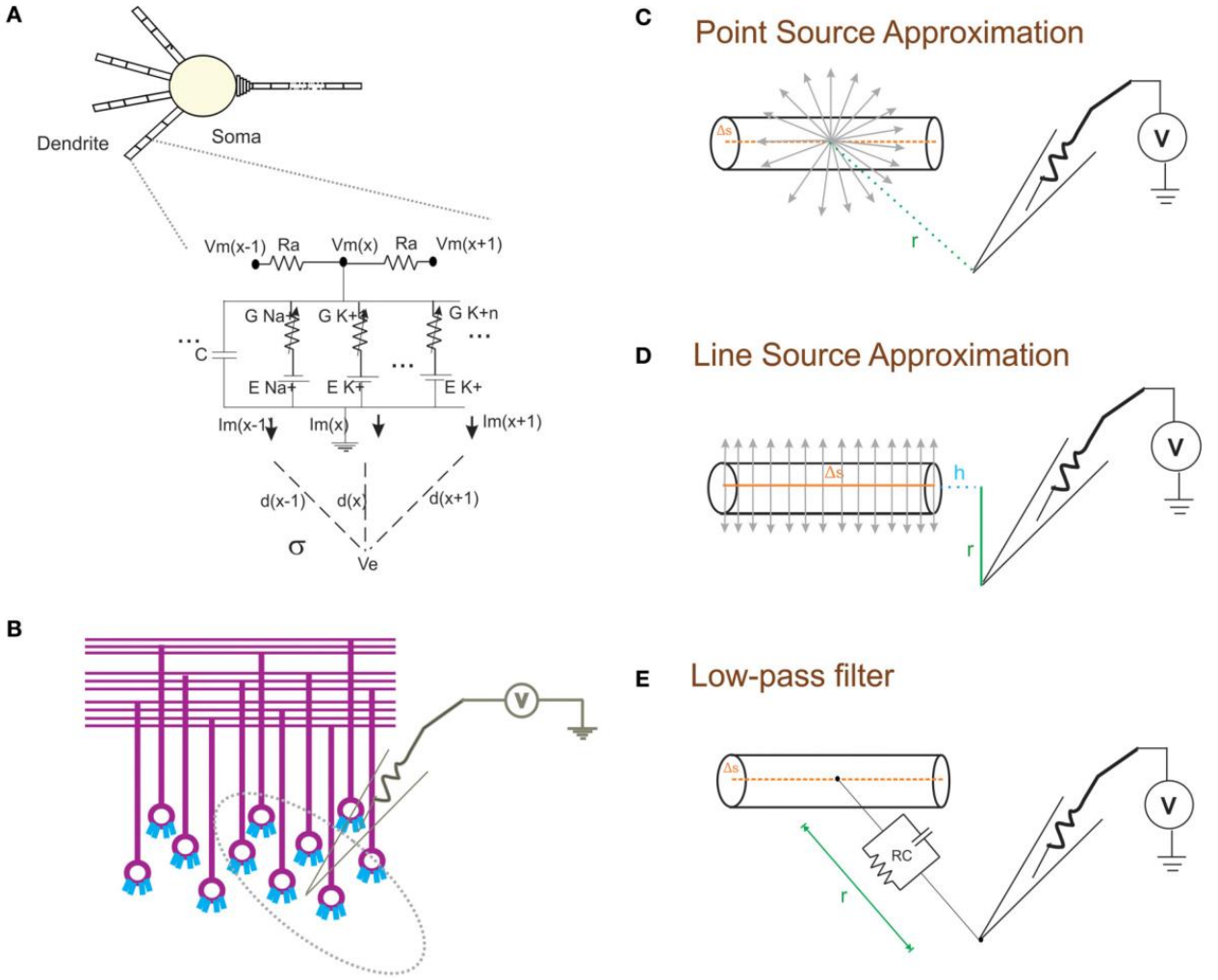
A good test results and the implementation of two projects gives an excellent examination score

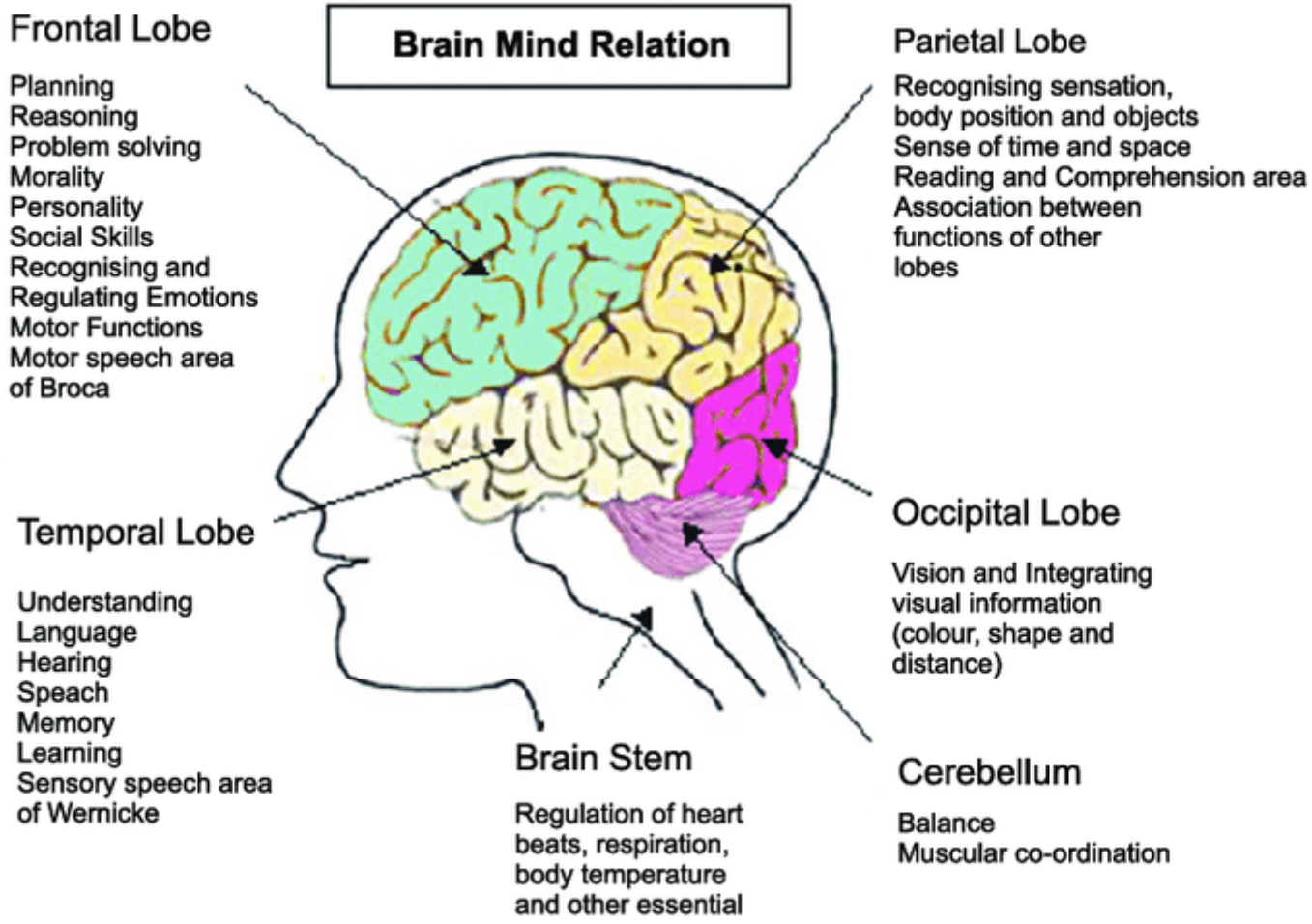
Lecture 2: Neuron structure and function



Lecture 3/4: Computational neuroscience

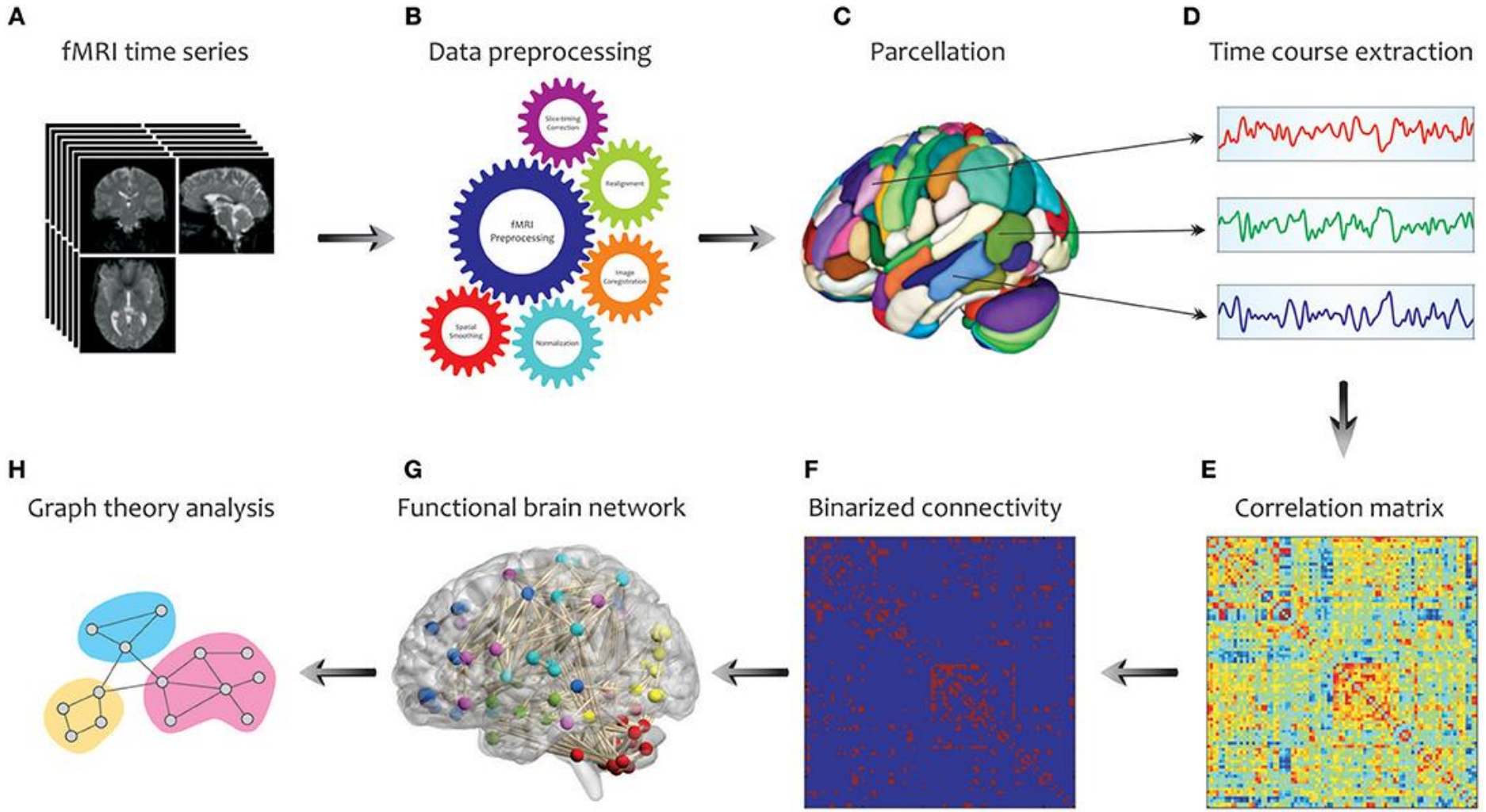


Lecture 5: Structure and functions of brain

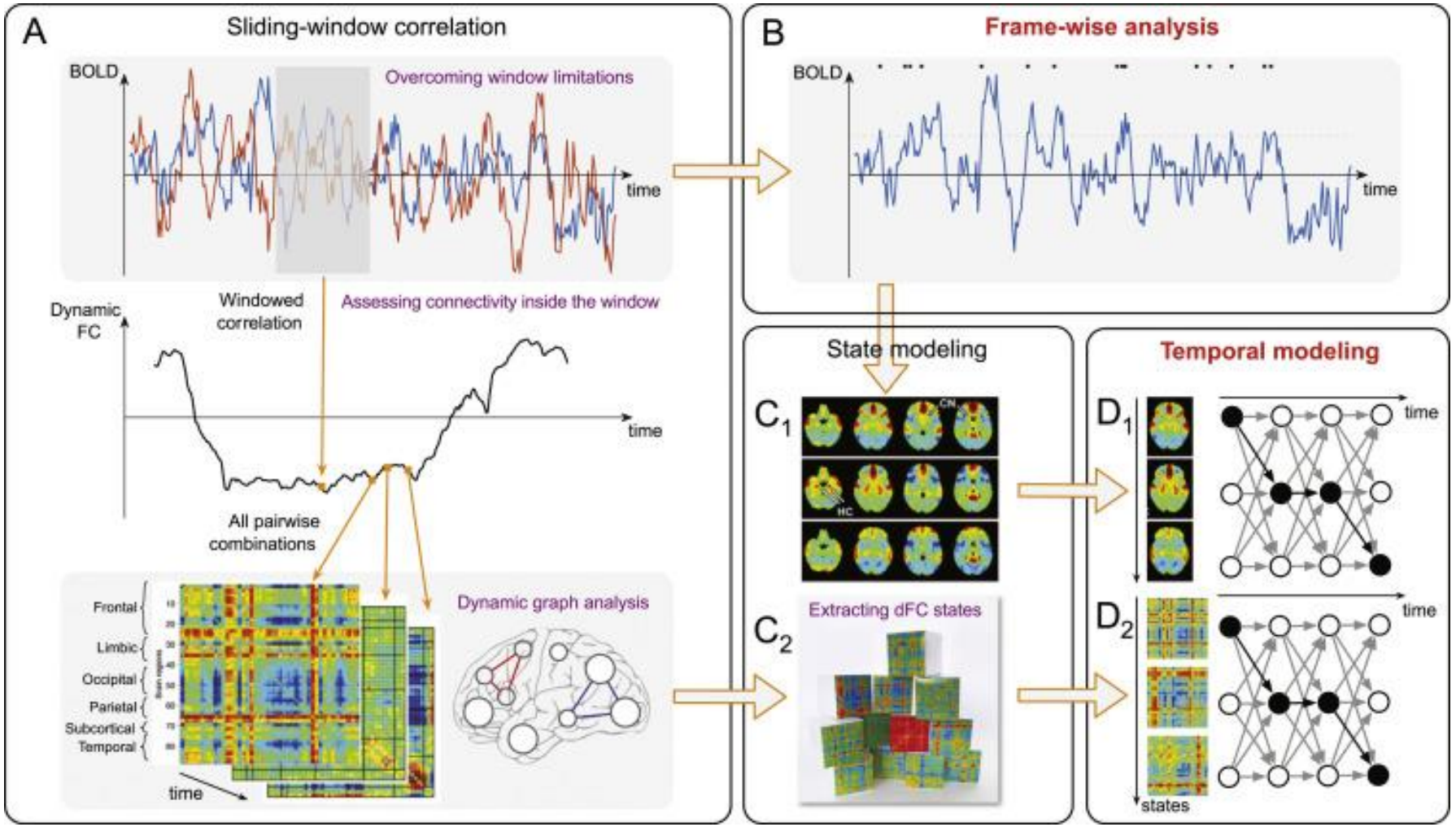


Lecture 6: Methods of neurovisualization

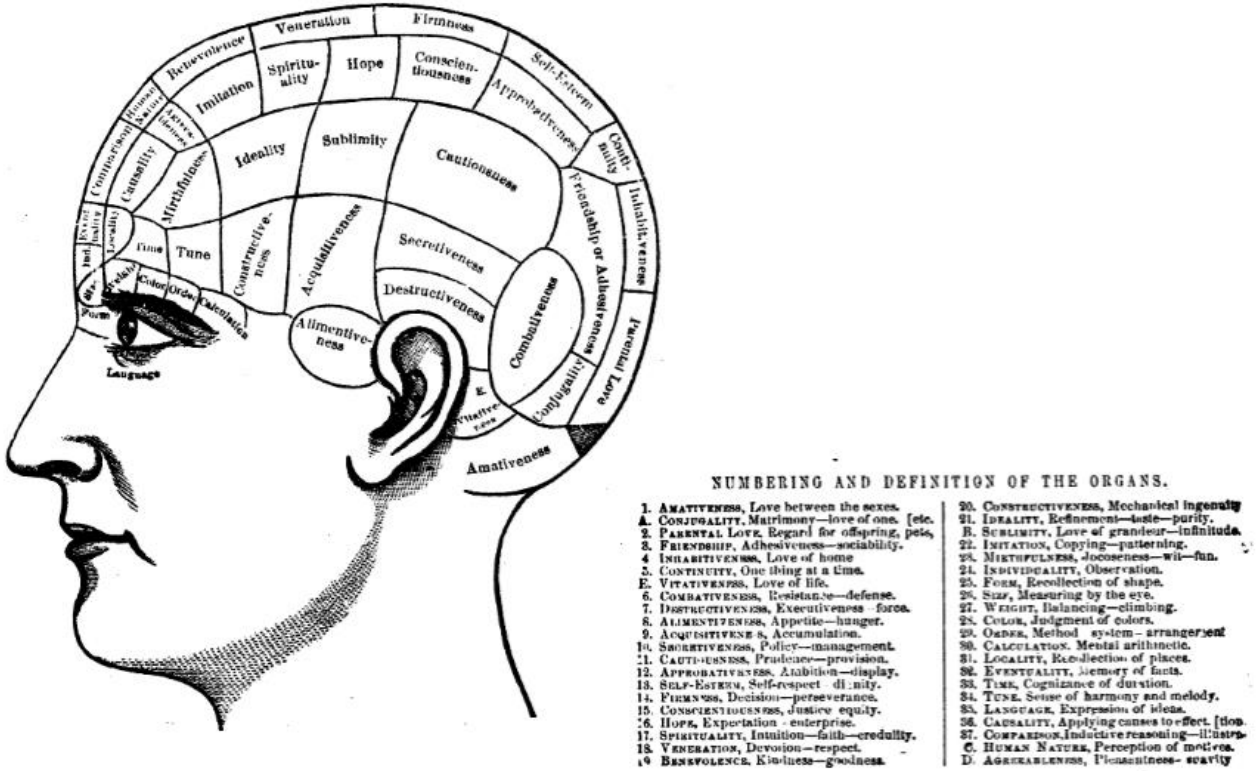
Lecture 7: Brain functional networks



Lecture 8: Methods for functional brain connectivity detection



Lecture 9: Cognitive abilities
Lecture 10: Intelligence and personality

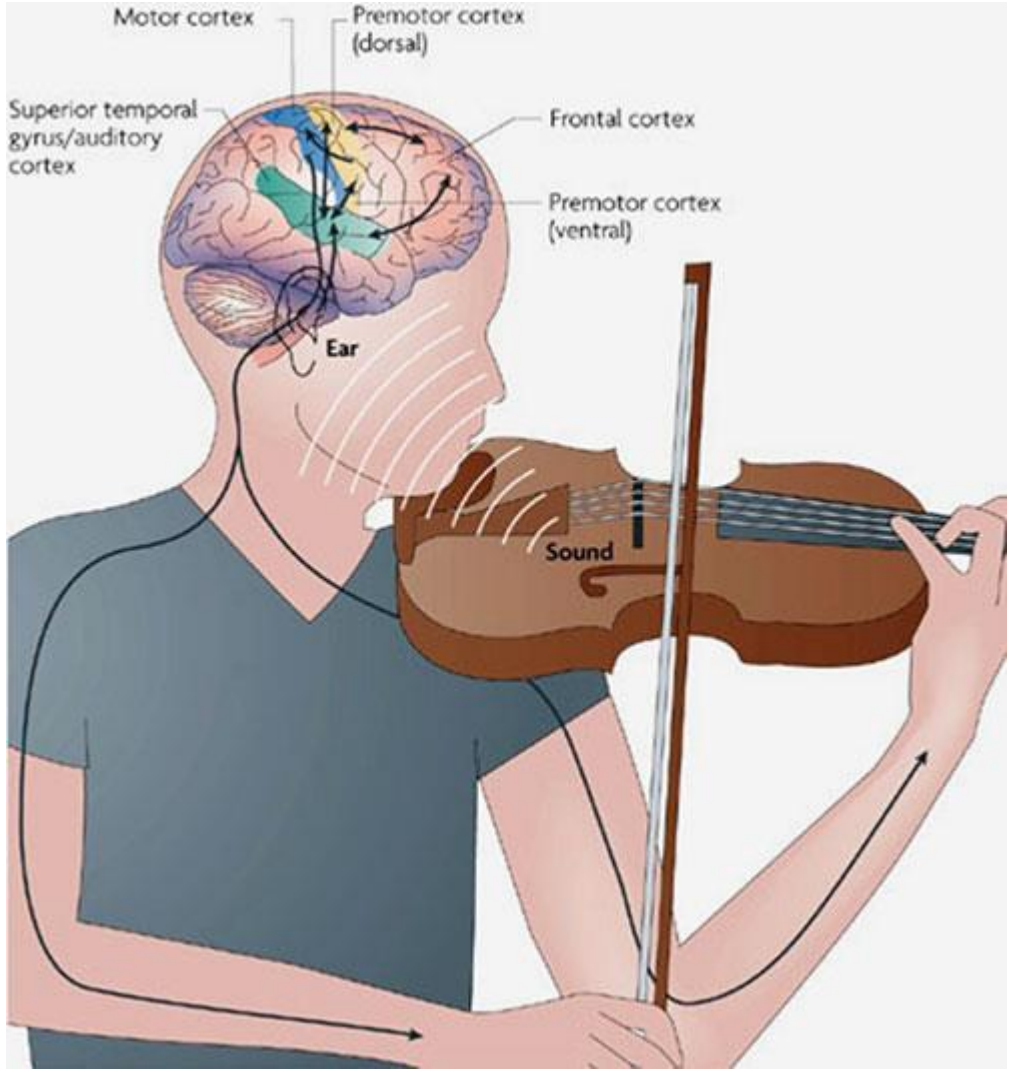


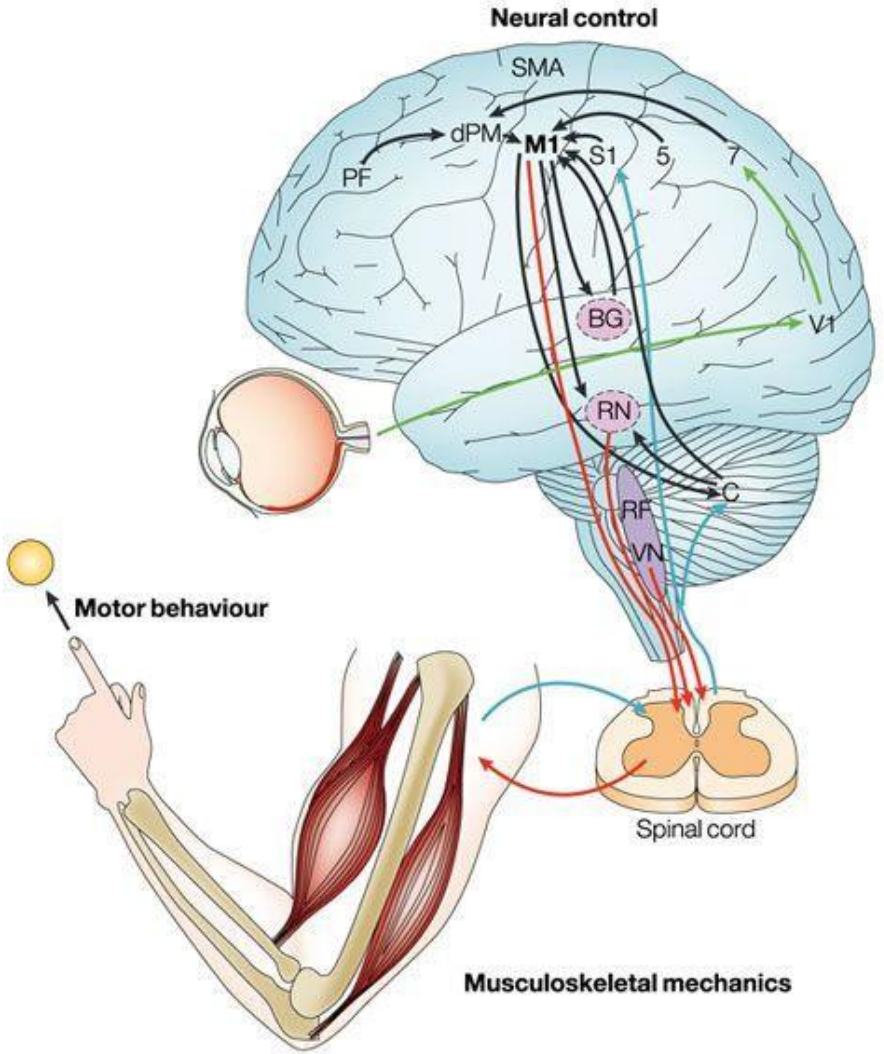
NUMBERING AND DEFINITION OF THE ORGANS.

1. Amativeness, Love between the sexes.
A. Conjugality, Matrimony—love of one. [etc.
2. Parental Love, Regard for offspring, pets,
3. Friendship, Adhesiveness—sociability.
4 Inhabitiveness, Love of home
5. Continuity, One thing at a time.
F. Vitativeness, Love of life.
6. Combativeness, Resistance—defense.
7. Destructiveness, Executiveness—force.
8. Alimentiveness, Appetite—hunger.
9. Acquisitiveness, Accumulation.
10. Secretiveness, Policy—management.
11. Cautiousness, Prudence—provision.
12. Approbativeness, Ambition—display.
13. Self-Esteem, Self-respect dignity.
14. Firmness, Decision—perseverance.
15. Conscientiousness, Justice equity.
16. Hope, Expectation enterprise.
17. Spirituality, Intuition—faith—credulity.
18. Veneration, Devotion—respect.
19 Benevolence, Kindness—goodness.
20. Constructiveness, Mechanical ingenuity
21. Ideality, Refinement—taste—purity.
B. Sublimity, Love of grandeur—infinitude.
22. Imitation, Copying—patterning.
23. Mirthfulness, Jocoseness—wit—fun.
24. Individuality, Observation.
25. Form, Recollection of shape.
26. Size, Measuring by the eye.
27. Weight, Balancing—climbing.
28. Color, Judgment of colors.
29. Order, Method system—arrangement
30. Calculation, Mental arithmetic.
31. Locality, Recollection of places.
32. Eventuality, Memory of facts.
33. Time, Cognizance of duration.
34. Tune, Sense of harmony and melody.
35. Language, Expression of ideas.
36. Causality, Applying causes to effect. [tion
37. Comparison, Inductive reasoning—illustra-
C. Human Nature, Perception of motives.
D. Agreeableness, Pleasantness—suavity

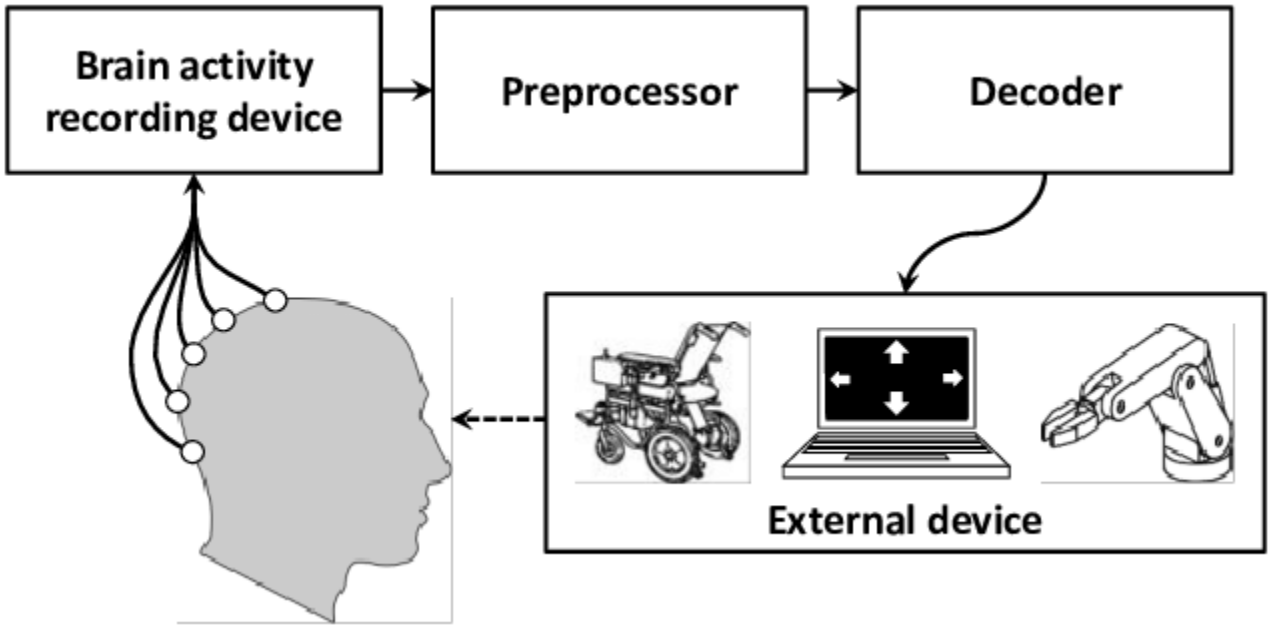
From O. S., and L. N. Fowler. The Self-Instructor in Phrenology and Physiology (1889)

Lecture 11: Motor control

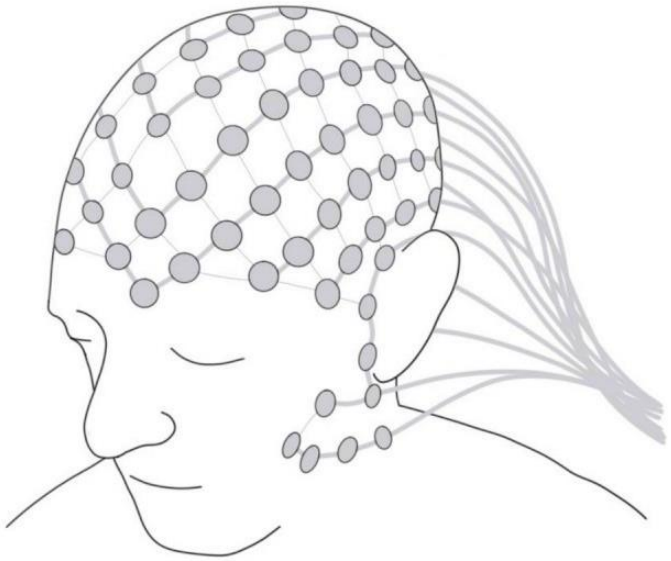


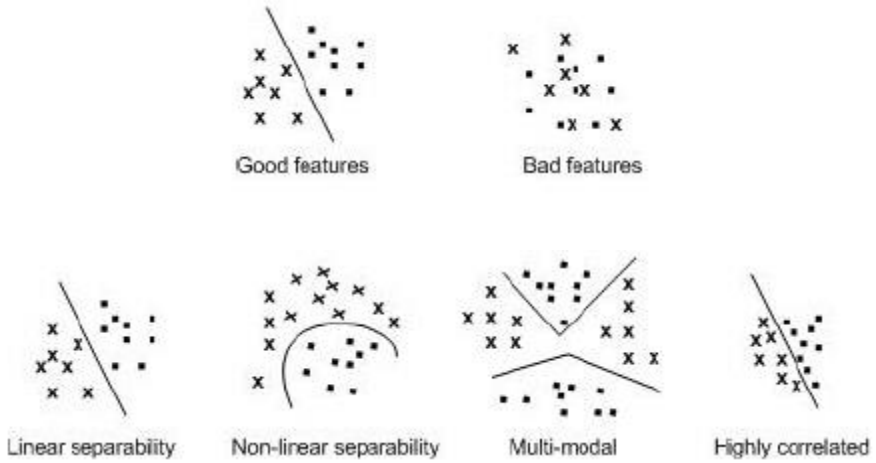


Lecture 12/13: Brain-computer interfaces

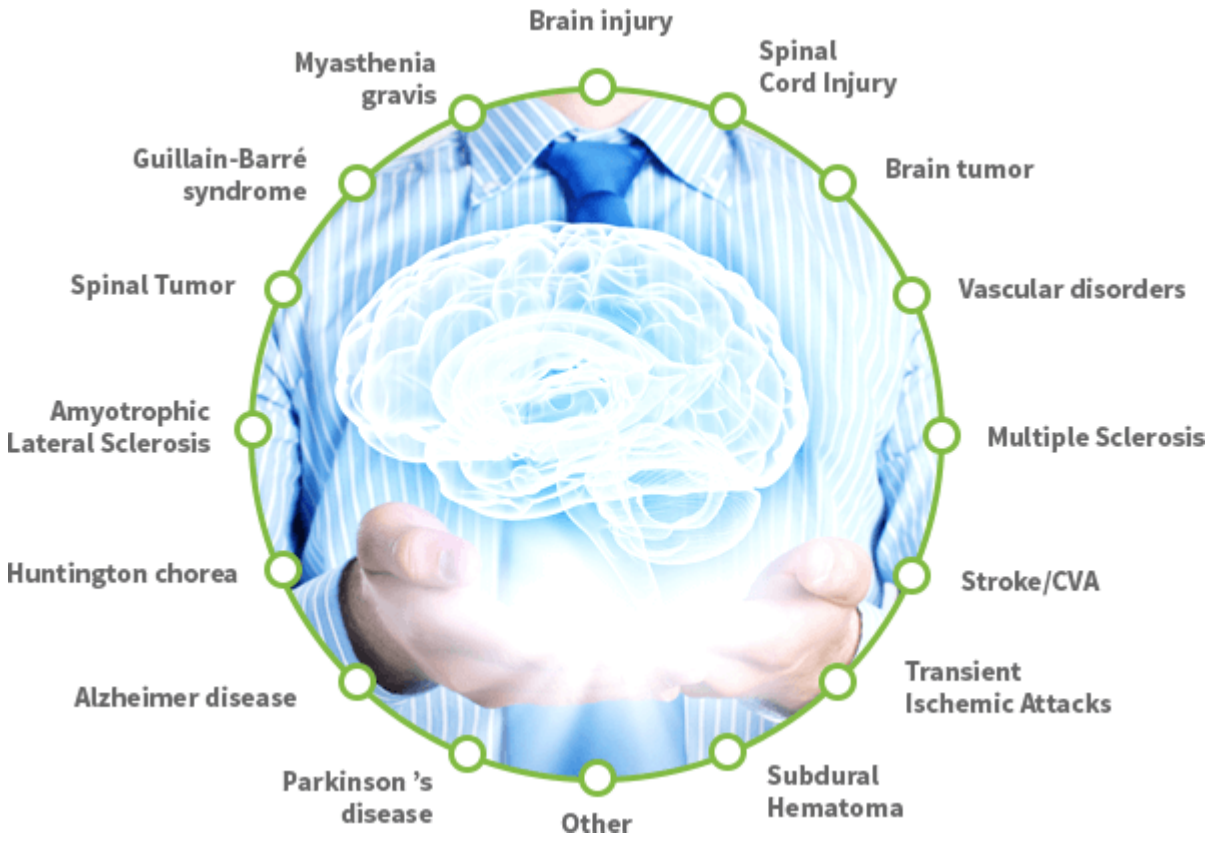


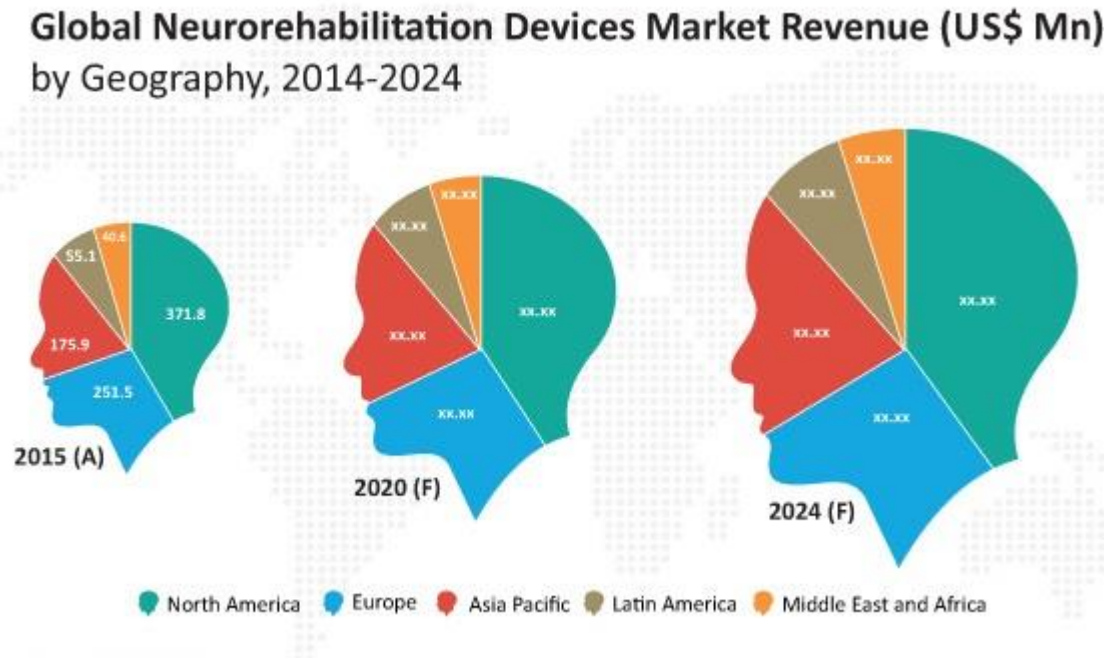
Lecture 14: Brain activity features selection and classification





Lecture 15: Brain diseases and neurorehabilitation





Frontiers in Neuroscience

- Neuroscience will transform the 21st century the way that quantum physics did for the 20th century.
- Even breaking the genetic code was just the beginning in the launch of higher understanding about the human body, and specifically the brain.
- Understanding the miraculous workings of the brain and the nervous system is the vast mission of the relatively young field of neuroscience.

Frontiers in Neuroscience

- Better knowledge about brain function is still needed to treat neurological and psychiatric disorders, lessening their impact on individuals, families, and society.
- With better neuroscience knowledge, we will better understand who we are: our thoughts, emotion, creativity and morality.
- We will design who we will be, modifying our abilities, knowledge and ways of being.
- We will apply this knowledge to create new methods of human-machine and human-human interaction.