



Selected topics  
in cognitive science and biomodeling.  
L2. Emergence of brain research.

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# A bit of the brain research history

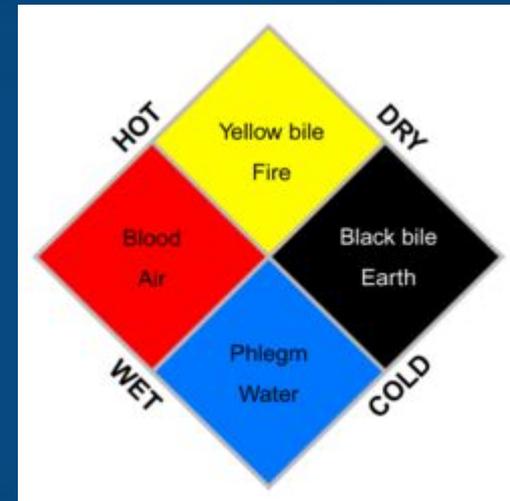
# Ancient History



Trepanation of the skull has been practiced in ancient times all around the world, with some skulls being 7000 years old – it is not clear why they did it.

... from the brain, and from the brain alone, arise our pleasures, joys, laughter and jokes, as well as our sorrows, pains, grief's and tears. Through it, in particular, we think, see, hear, and distinguish the ugly from the beautiful, the bad from the good, the pleasant from the unpleasant...

Attributed to Hippocrates, 5th century BC

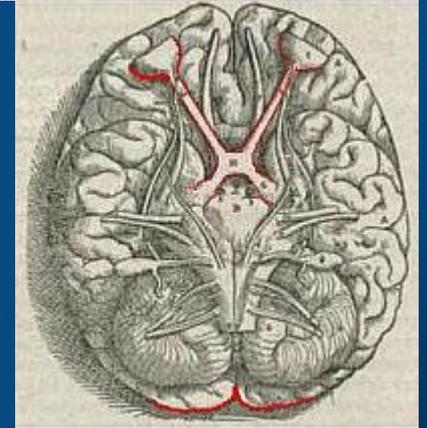
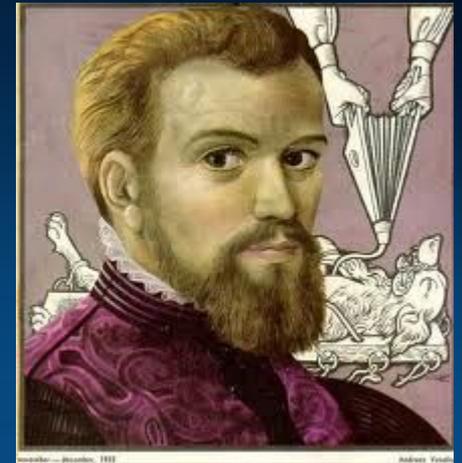


Hippocrates promoted theory of humors, believed by Greek, Roman and Islamic physicians, that survived until the XIX century. The four humors/characters:

- black bile (gr. melan chole), melancholic, despondent, irritable
- yellow bile (gr. chole), choleric, bad tempered
- white phlegm (gr. phlegma), phlegmatic, calm
- red blood (lat. sanguis), sanguine, courageous, hopeful, amorous

# Early History

- **Galen of Pergamon** (129 – 199) was most famous medical researcher, his theories based on dissection of monkeys and pigs dominated for 1500 years, his works were studied even in 19<sup>th</sup> century! He discovered that brain controls movement through cranial and peripheral nerves.
- *The Canon of Medicine* (1025), encyclopedia of Galenic medicine, compiled by **Ibn Sīnā (Avicenna)**, an example of the great Islamic school of brain surgery.
- **Andreas Vesalius** (1514-1564), a Belgian physician, published 7 volumes of detailed anatomy based on dissections of human body *De humani corporis fabrica* (1543), correcting Aristotle & Galen errors.
- **William Harvey**, *On The Motion Of The Heart And Blood In Animals* (1628): mechanism of blood circulation.



# Renaissance

Anatomy lessons (here dr Willem van der Meer by M.J. van Mierevelt) became quite popular in 17th century, students traveled whenever fresh body of an executed criminal was available ...

**René Descartes** (1596 -1650), a mathematician and philosopher is considered as the originator of modern philosophy of mind.



- He thought that animals are automata, only humans can think, have rational souls. His famous statement was: *cogito ergo sum* ("I think, therefore I am").
- The problem of Cartesian dualists: how is the immaterial mind interacting with material body? This has been discussed since antiquity till now.
- **Antonio Damasio's** *Descartes' error. Emotion, Reason, and the Human Brain* discussed connections between emotions and cognition, with body as "canvas for emotional expression", leading to embodied intelligence.

# Evolution

**Charles Darwin** (1809 –1882). Books:

*On the origin of species by means of natural selection, or the preservation of favoured races in the struggle for life* (London, 1859).

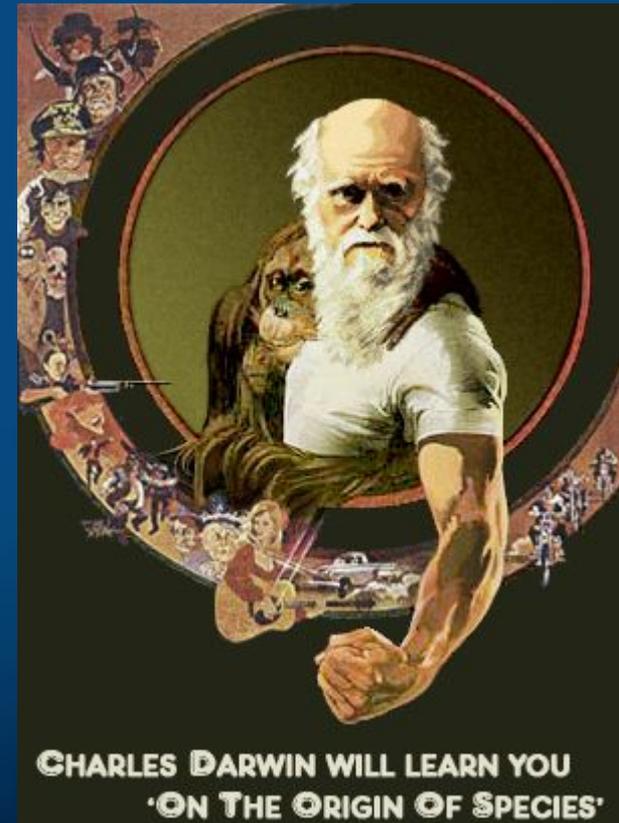
*The descent of man, and selection in relation to sex* (London, 1871)

*Expression of emotions in man and animals* (London, 1872) - emotions are not just a cultural invention, they have biological origins => embodiment ideas.

The mood of his time (1873): "The abdomen, the chest, and the brain will forever be shut from the intrusion of the wise and humane surgeon". Sir John Eric Ericksen, Surgeon-Extraordinary to Queen Victoria.

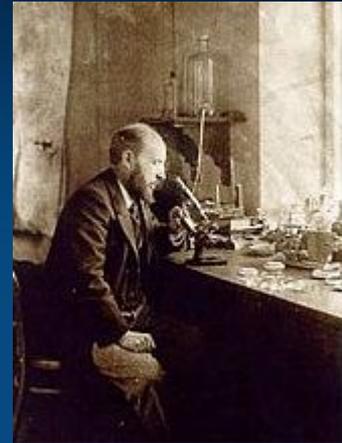
Psychosurgery started ~ 1935 with lobotomy, cutting thalamus-frontal lobes connections in mentally ill.

Antonio Moniz got Nobel prize (1949) for this bad idea.



# Neurons are coming

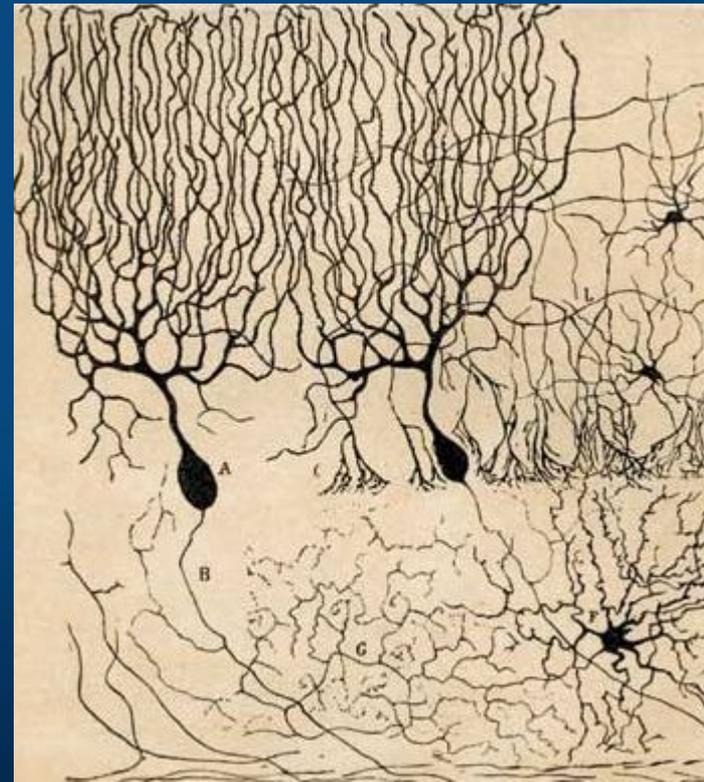
In 1838 **Theodore Schwann** and **Matthias Schleiden** proposed that organisms have cells, but the brain seemed to have fused cells, a network of tissue, as reticularists believed. The neuronists finally won the dispute, thanks to **Santiago Ramon y Cajal** (1852–1934) who created Neuron Doctrine drawing and describing various types of neurons stained by Golgi's method (**Golgi** was reticularist).



The term *neuron* was introduced in 1891, *synapse* between nerve and muscle has been described by **Charles Sherrington** in 1897.

## The Neuron Doctrine:

- neurons are functional units of nervous system
- neurons are discrete cells composed of
- the dendrites, axon and cell body,
- information flows along the neuron from the dendrites to the axon, via the cell body.



# Mind?

In 19<sup>th</sup> century mental life was considered to be a function of conscious mind, controlled by immaterial soul seated in the brain.

In 1860 neurologist **Thomas Laycock** in *Mind and Brain, or, the Correlations of Consciousness and Organisation* had to admit that brains also show reflex action, unconscious reaction to stimuli, like other ganglia in nervous system.

**Ivan Mikhaylovich Sechenov** published in 1863 *Reflexes of the brain* (in Russian) and in 1866 *Physiology of the nervous system* (in Russian), showing link between brain activity and electric currents, introducing electrophysiology, investigating automatic brain reflexes and claiming that mental life comes from sensory stimulation. He was on trial in 1866 for “spreading materialism and debasing of Christian morality”, but not persecuted.

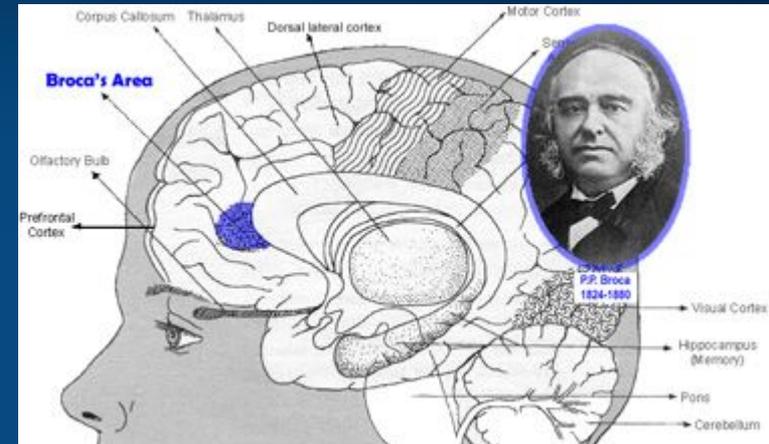
Many British and German scientists came to the same conclusion observing results of brain damage.

**Sigmund Freud** (1899) created psychoanalysis to understand psychology of unconscious mind, but his theory has never been verified in scientific way.



# Localization of language

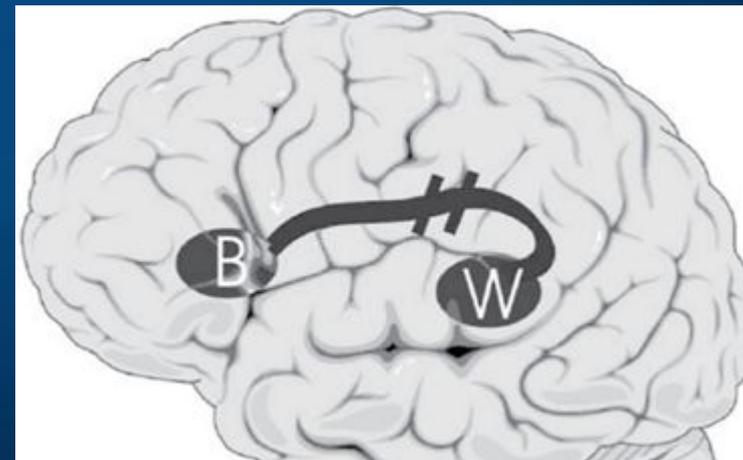
Paul Broca (1824-1880) studying the brains of aphasic patients in 1861 discovered that the damage to left posterior inferior frontal gyrus (called now Broca's area) leads to speech production problems (**expressive aphasia**, Broca's aphasia).



Localization of complex function in the brain was quite surprising, most people had a holistic view of mental functions, although the pseudoscience of **phrenology** claimed localization of all functions since 1810.

Carl Wernicke (1848-1905) in 1873 noticed that lesion to the left posterior superior temporal gyrus (Wernicke's area) leads to problems with understanding and producing meaningful speech, known as Wernicke's or **receptive aphasia**.

B & W disconnection => **conduction aphasia**.



# Mind-brain

Psychology was initially understood as the science of mental life, consciousness, psyche+logic.

Introspection, trying to analyze thoughts and mental states in terms of sensations, feelings and images, brought a lot of confusion.

Many scientists (Wundt, Fechner, Helmholtz) developed psychophysics, linking sensory data with percepts.

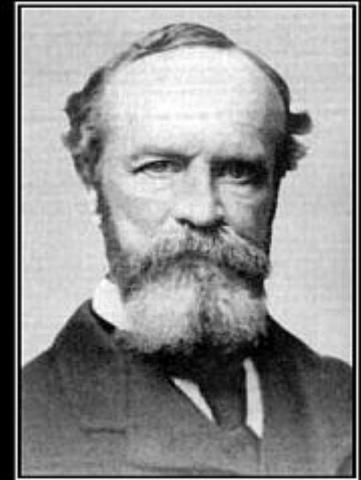
The **Weber–Fechner law** describes logarithmic relationship between the physical characteristics of stimuli and its perceived intensity.

Experimental psychology labs started to investigate memory, animal reflexes.

Pavlov experiments with dogs (1900) on classical conditioning convinced psychologists that all behavior can be derived from simple reflexes.

Behaviorists wanted to change psychology into “objective experimental branch of natural science”, removing introspection, leaving only measurable data.

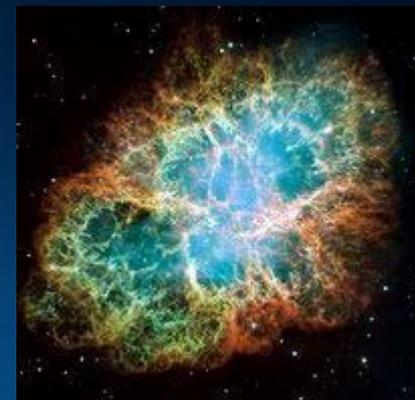
For decades research on consciousness and mind became a taboo.



WILLIAM JAMES

1842-1910

# Elements



First: stars form heavy elements from hydrogen.

Then: supernova!

Different elements => different colors.

Earth 4.5 By, crust contains mostly oxygen and silicon.

Life, 3.7 By: carbon, nitrogen.

Human body:  $\approx 10^{27}$  atoms, most H, O, C.  
Carbon 1/10, but 1/5 mass.

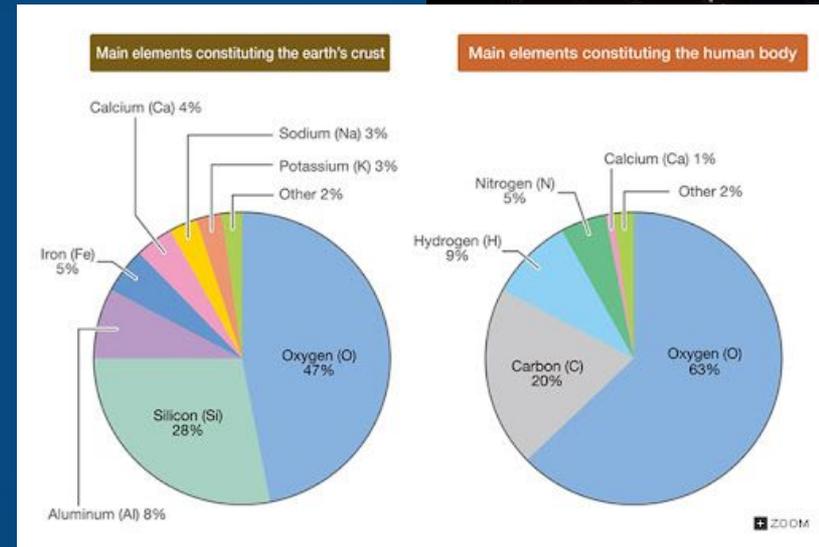
Mass of H<sub>2</sub>O in human body:

overall 60%, brain 73%, lungs 84%, muscles 79%, bones 31%.

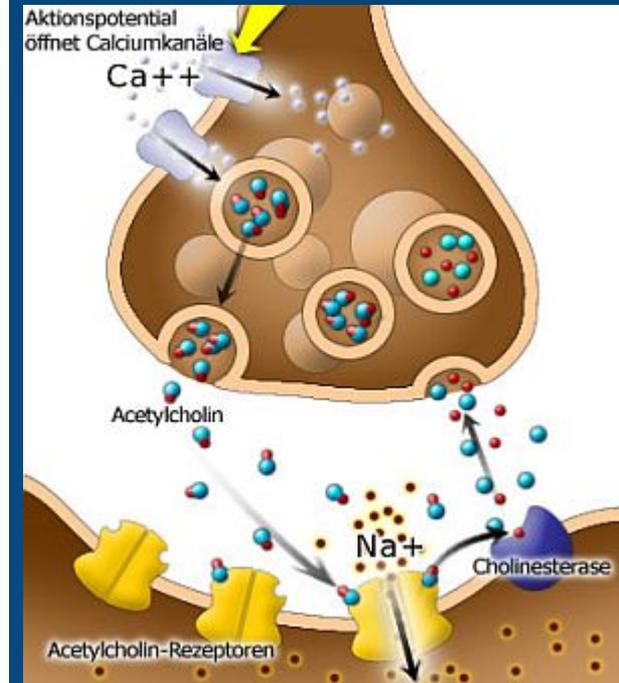
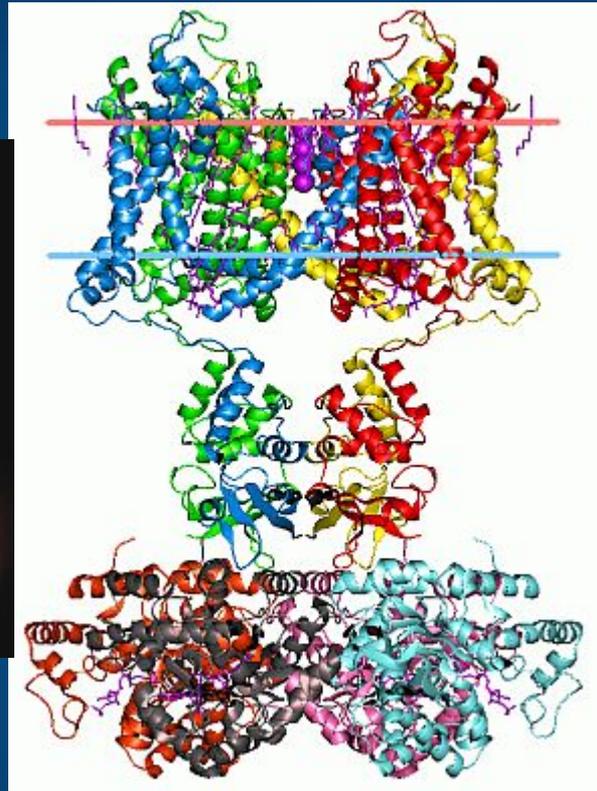
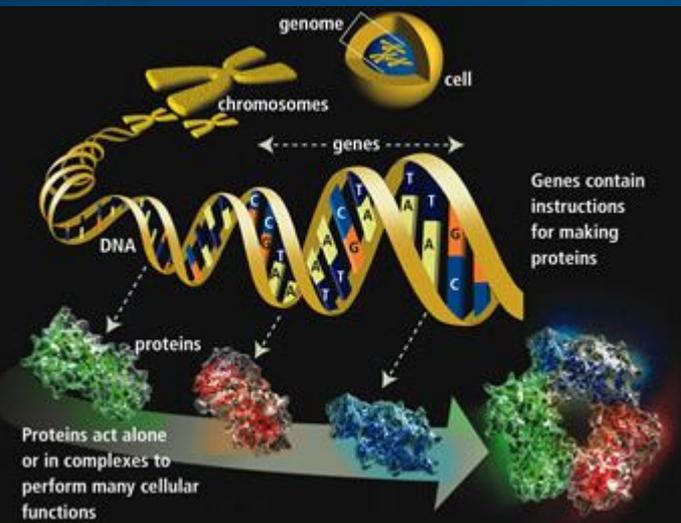
60 elements, half important, some harmful. 1.5% Calcium, 1% Phosphorus, 0.5% Potassium, 0.3% Sulfur, 0.2% Sodium, 0.2% Chlorine, 0.2% Magnesium. Copper only 0.0002% (< 0.1 g), but it is in all proteins.

Lithium, Molybden are important elements although it is only  $10^{-9}$  of our mass.

Harmful: arsenic, cadmium, mercury, lead.

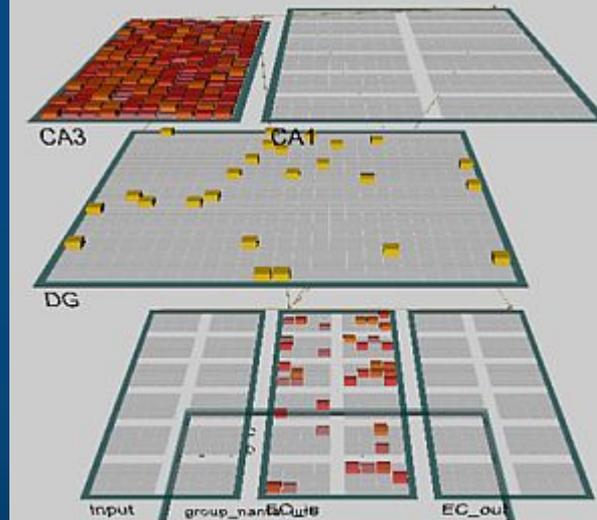
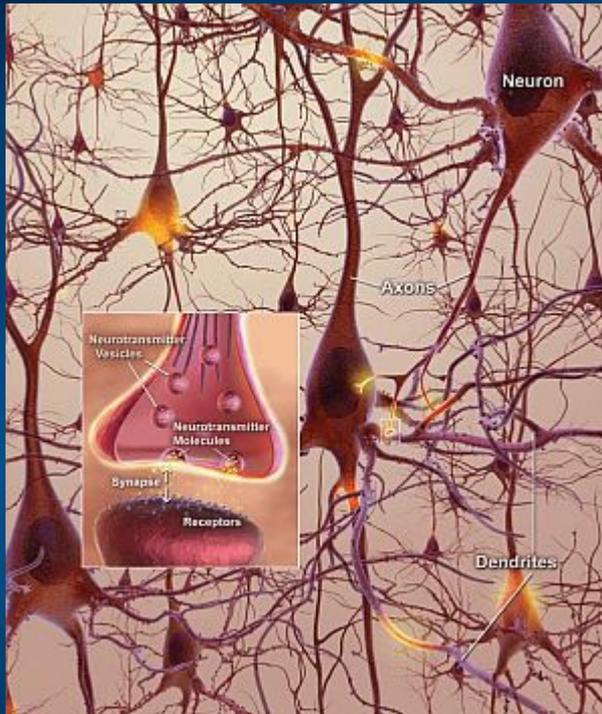


# From Genes to Neurons



DNA (1953), genes (1972) => proteins => receptors, ion channels, synapses, soma  
=> neuron properties

# From neurons to behavior



⇒ network structure ⇒ **neurodynamics** ⇒ neuron properties  
⇒ behavior (abnormal), cognitive phenotypes,

# Space/time scales

Spatiotemporal resolution:

- spatial scale: 10 orders of magnitude, from  $10^{-10}$  m to 1 m.
- temporal scale: 10 or more orders of magnitude, from  $10^{-10}$  s to 1 s.

Architecture:

- hierarchical and modular
- ordered in large scale, chaotic in small;
- specific projections: interacting regions wired to each other;
- diffused: regions interact through hormones and neurotransmitters;
- functional: subnetworks dedicated to specific tasks.

