

Computational Neuroscience

Zoltán Somogyvári

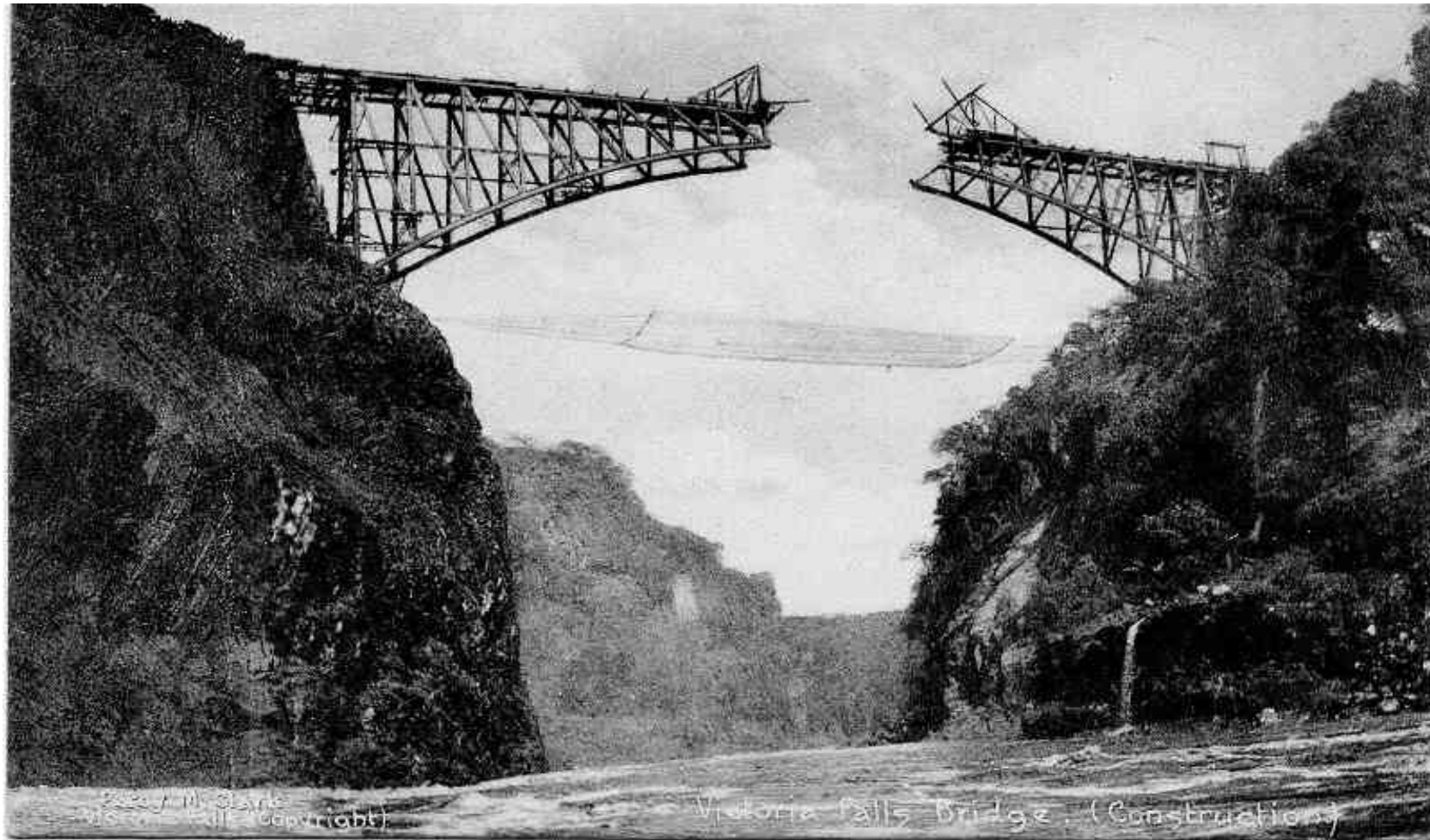
senior research fellow

KFKI Research Institute for Particle and Nuclear Physics

Supporting materials: <http://www.kfki.hu/~soma/BSCS/>

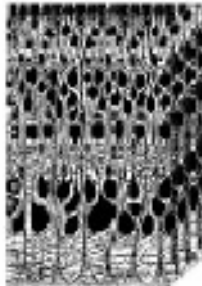
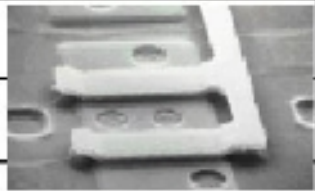
BSCS 2010

Computational Neuroscience



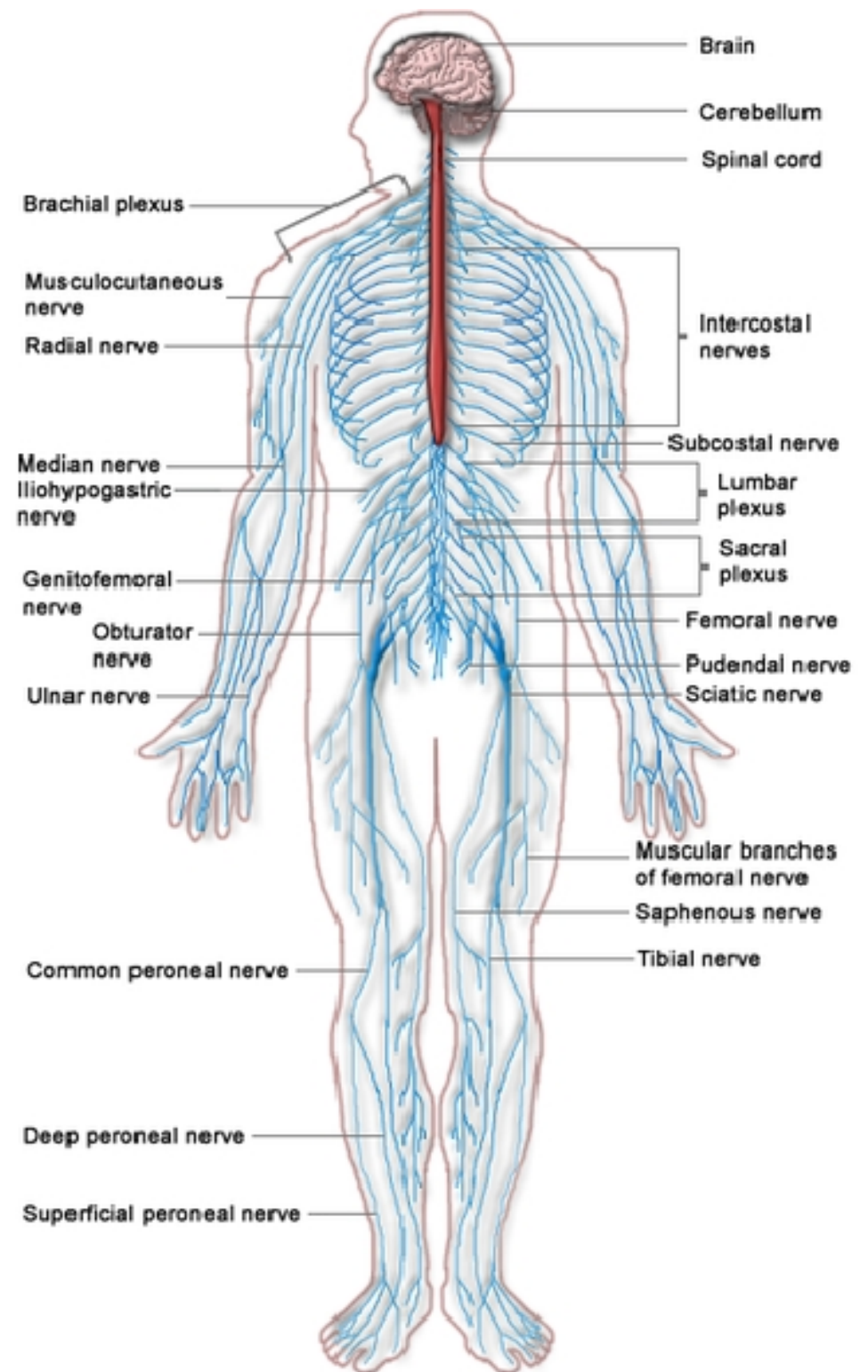
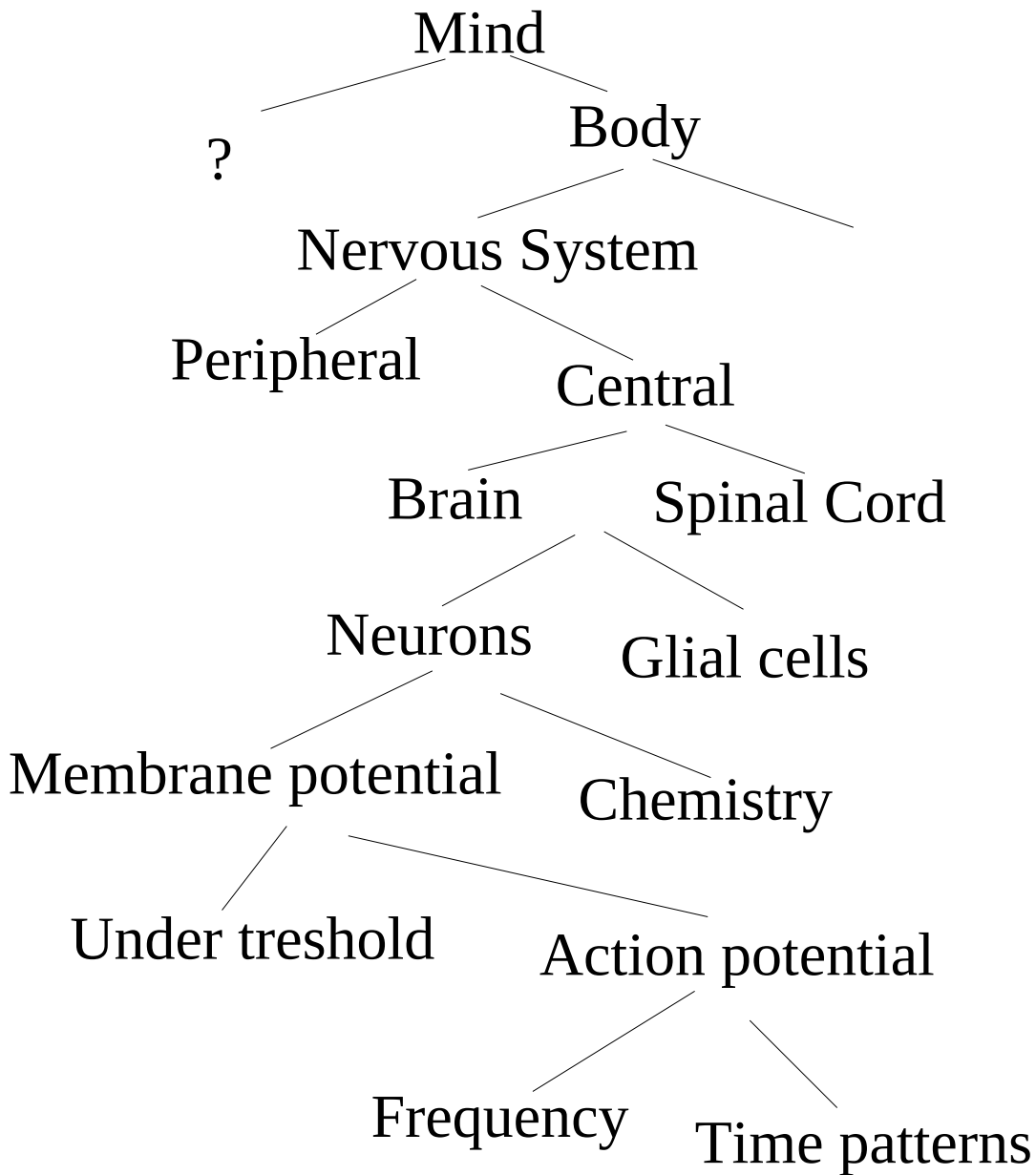
Structure – Dynamics – Implementation – Algorithm – Computation - Function

The brain and the computer

	1 mm ³ of cortex		1 mm ² of a CPU	
Number of units	50,000 neurons		1 million transistors	
Connections/unit	10,000		2	
Total connections	500 million		2 million	
Wiring	4 km of axons		0.002 km of wire	

	Whole brain		Whole CPU	
Weight	1.3 kg		~0.4kg	
Power	20 W		27 W	
Units	10 ¹¹ neurons		10 ⁸ transistors	
connections	1 × 10 ¹⁵		2 × 10 ⁹	
wiring	8 million km of axons		2 km of wire	

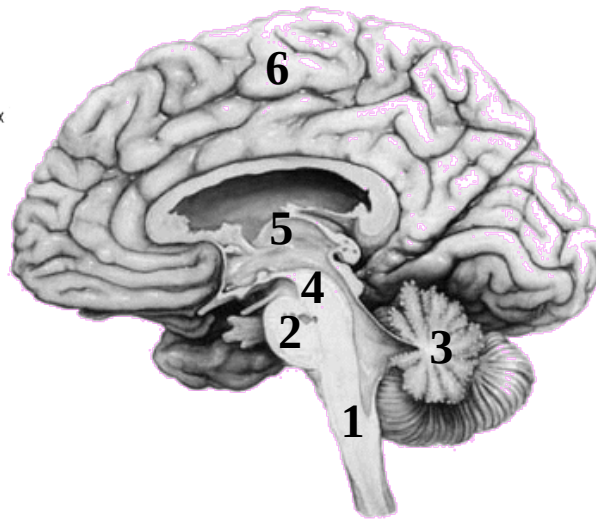
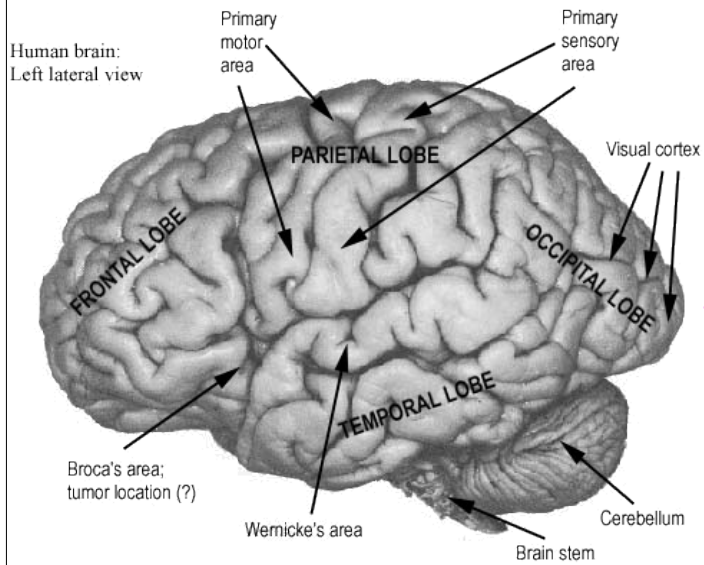
Hierarchy of description



Brain of vertebrates (mammals)

as visible with naked eye

human



1. *medulla oblongata*

2. *pons*

3. *cerebellum*

4. *mesencephalon*

5. *metencephalon*

♦ *thalamus*

♦ *hypothalamus*

♦ *epithalamus*

6. *telencephalon*

♦ *ganglia basalis*

♦ *cortex*

■ *paleocortex*

■ *archicortex*

➤ *hippocampus, ...*

■ *neocortex*

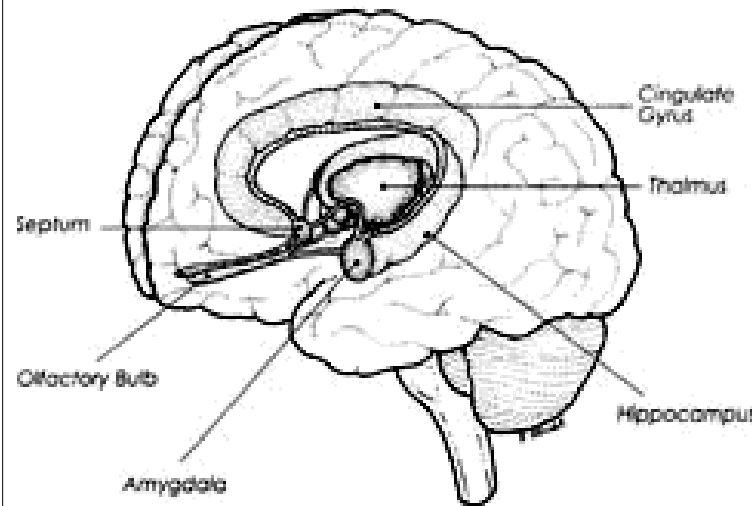
➤ *lobus frontalis*

➤ *lobus parietalis*

➤ *lobus occipitalis*

➤ *lobus temporalis*

rat



Elementary unit of the nervous system: The neuron

Parts of the neuron:

dendrite
soma
nucleus
axon
initial segment
terminal

synapse

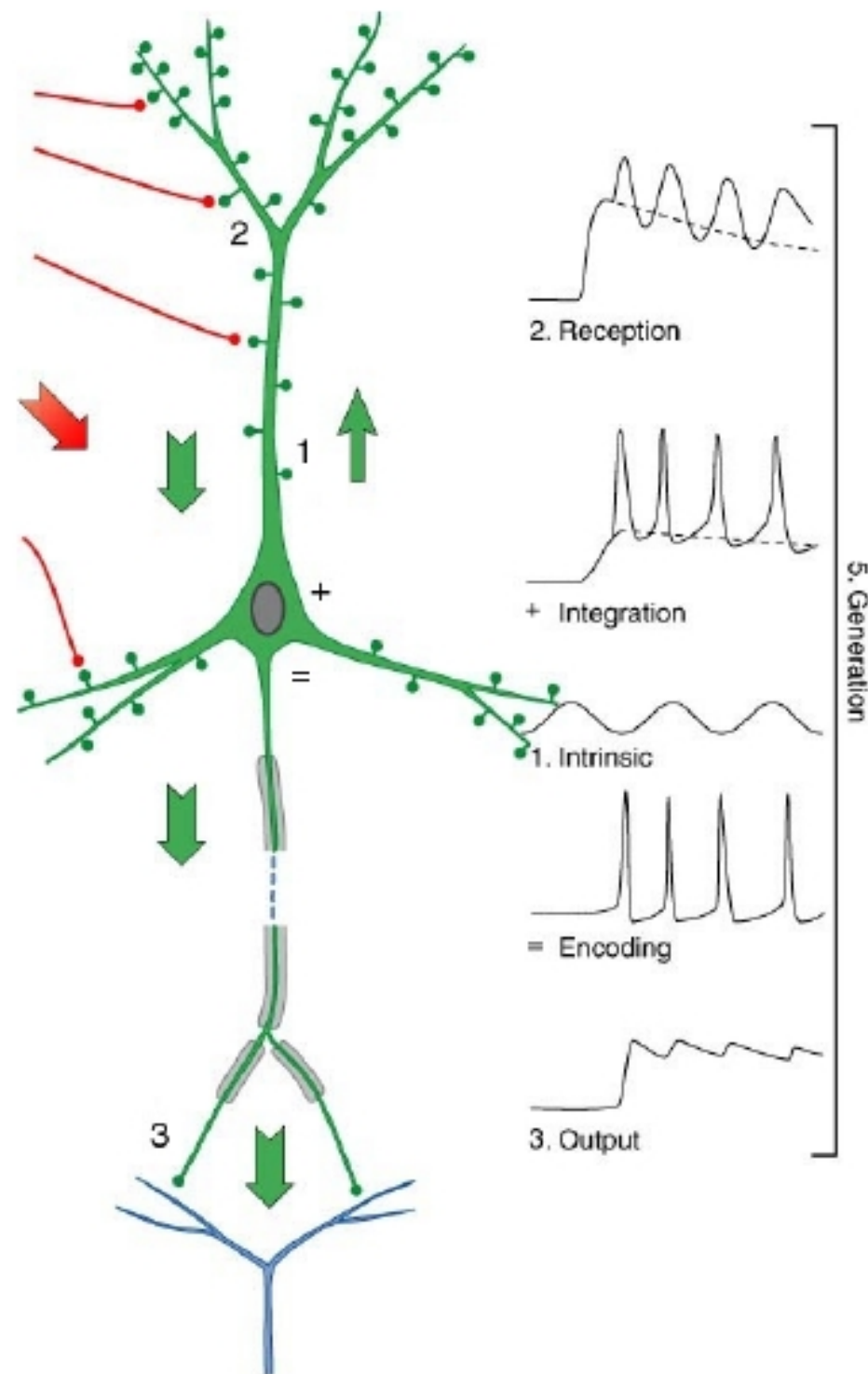
glia
myelin sheath
Ranvier-nodes

Function:

reception
integration
reproduction
transmission
encoding
output

communication

background
speed up
amplification

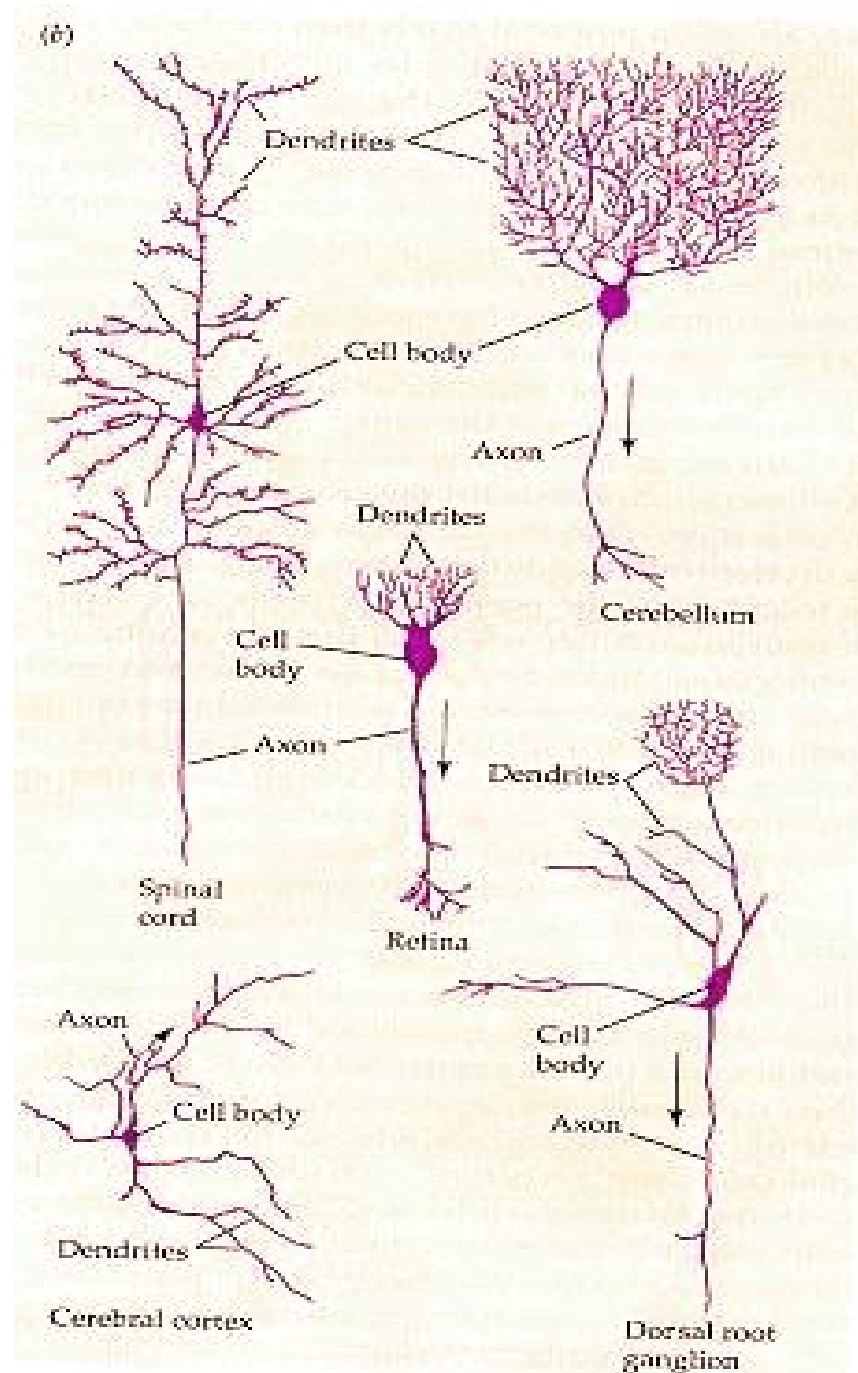


Types of neurons

Pyramidal cell
in the cerebral
cortex

Bipolar cell
in the retinal

Reticular cell
in the
thalamus

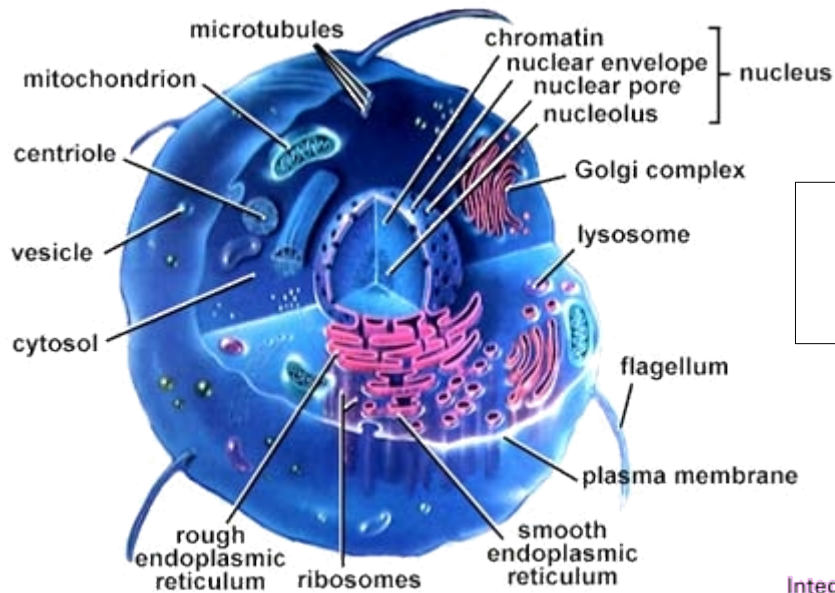


Purkinje cell
in the
cerebellum

Mitral cell
in the
olfactory bulb

The cell

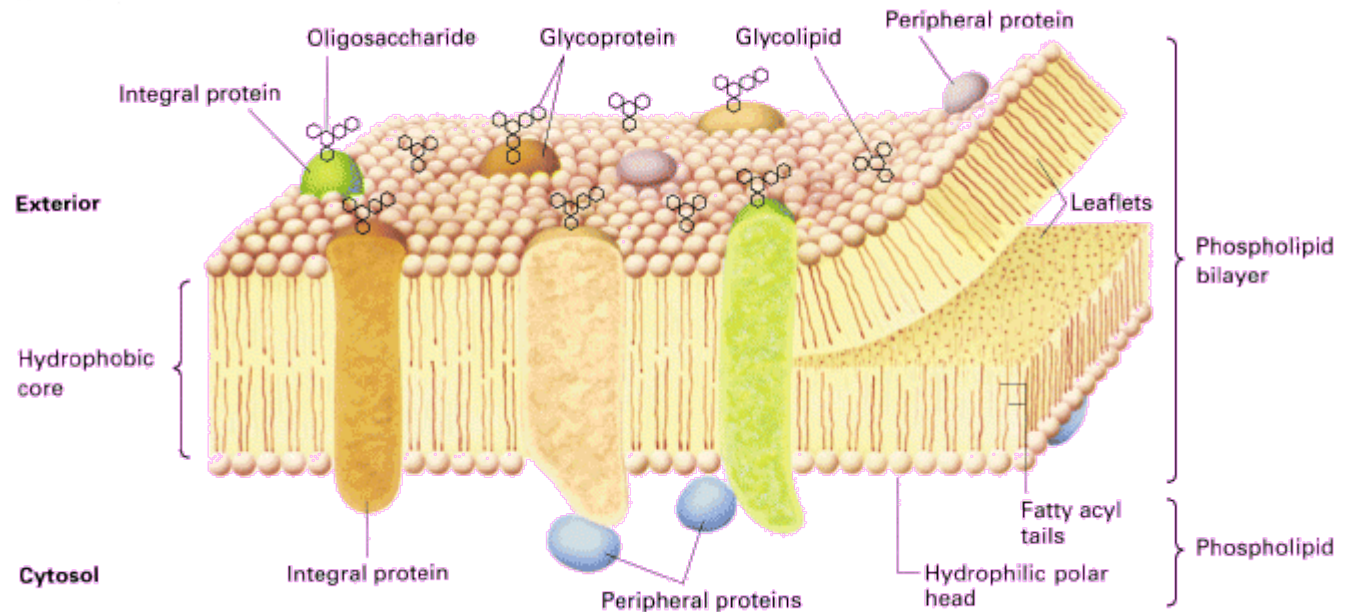
with electronmicroscope



nucleus
cytoplasm
membrane

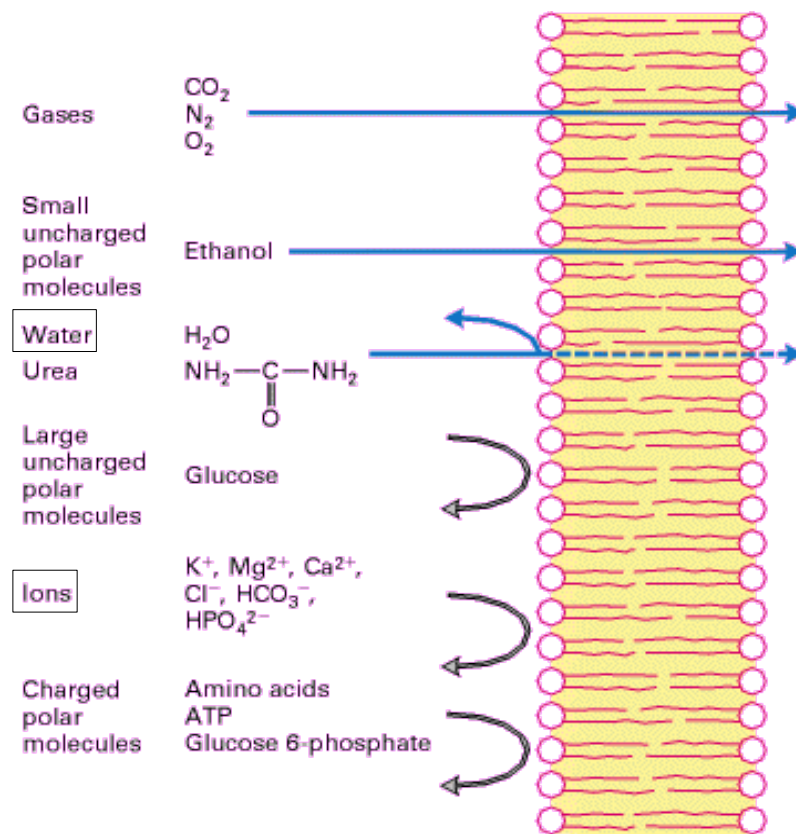
lipid bilayer
proteins
integral
peripheral

extracellular space (EC)
intracellular space (IC)



Trough the cell membrane

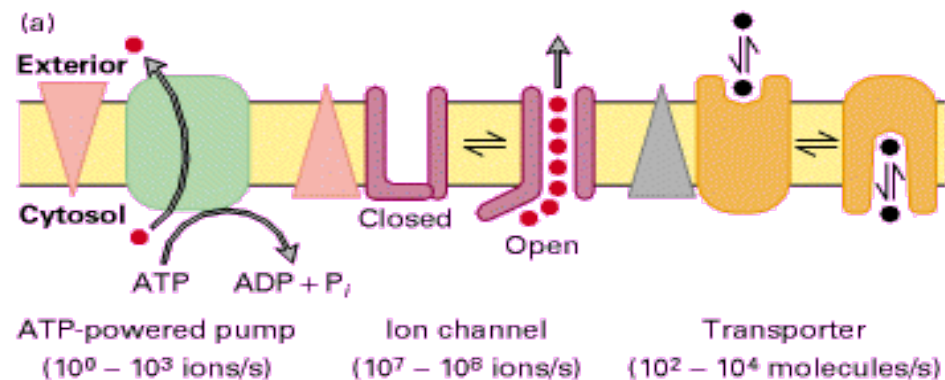
Different permeability, for different ions and molecules



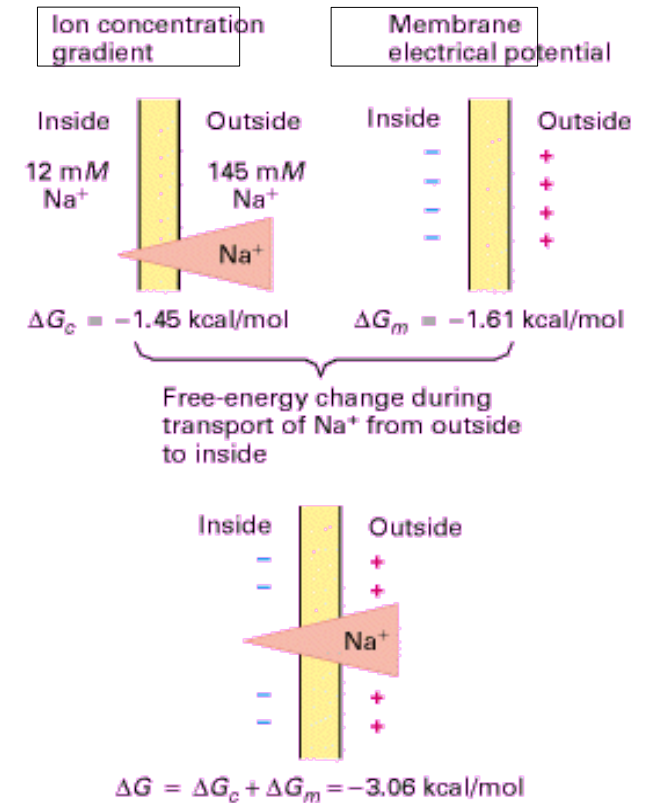
Membrane

transport, trough proteins

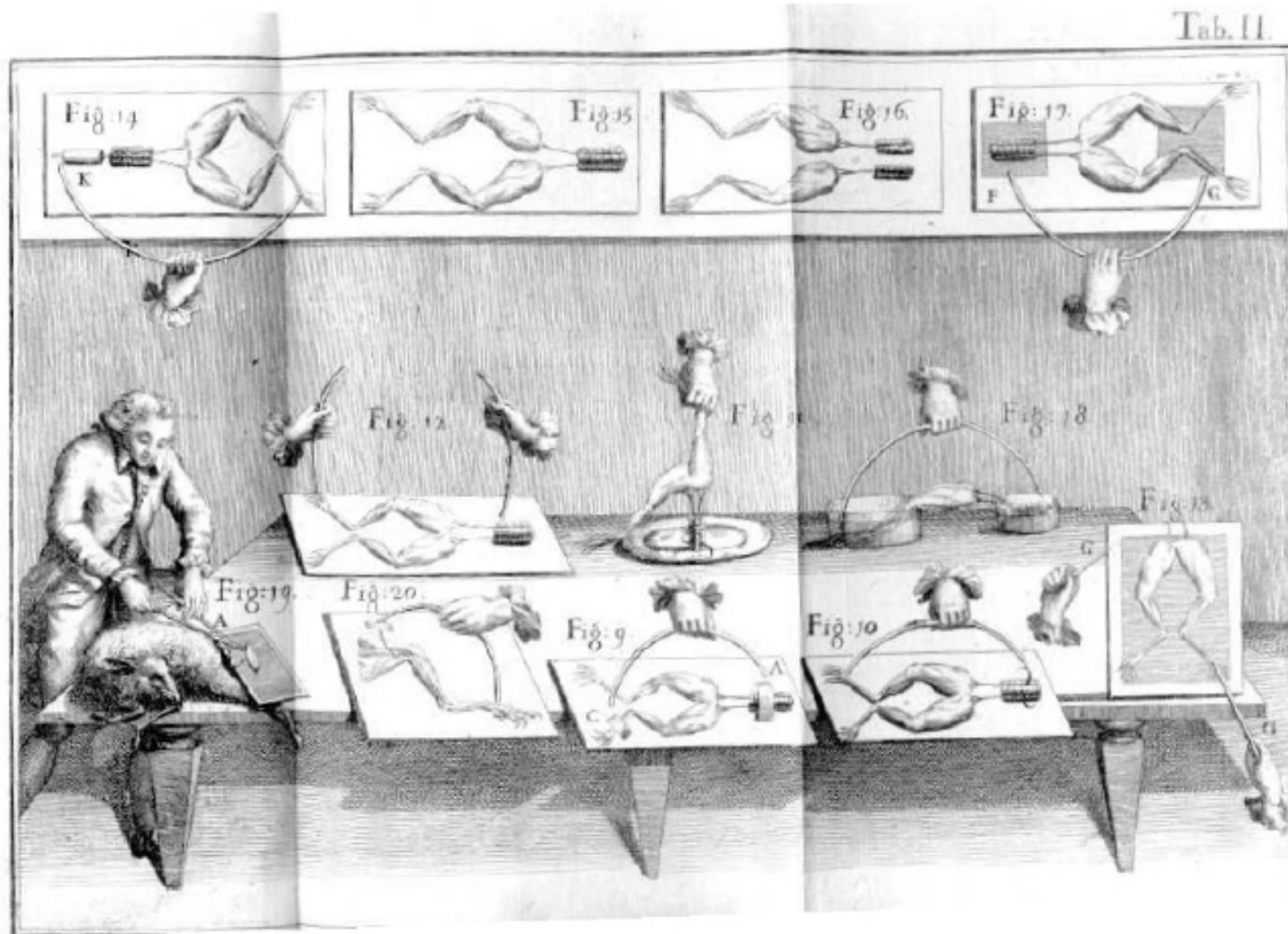
- pumps (+energy!)
- channels
- transporters



Forces of ion transport



Discovery of the electricity in animals

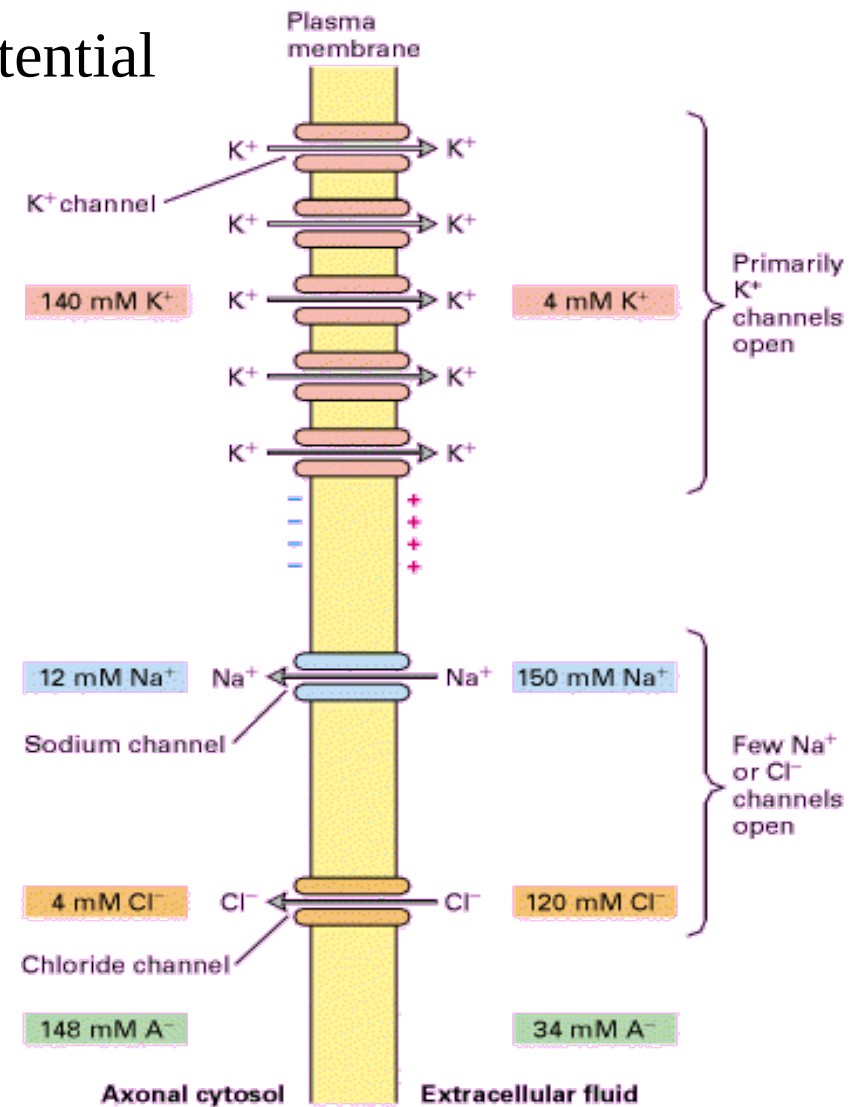
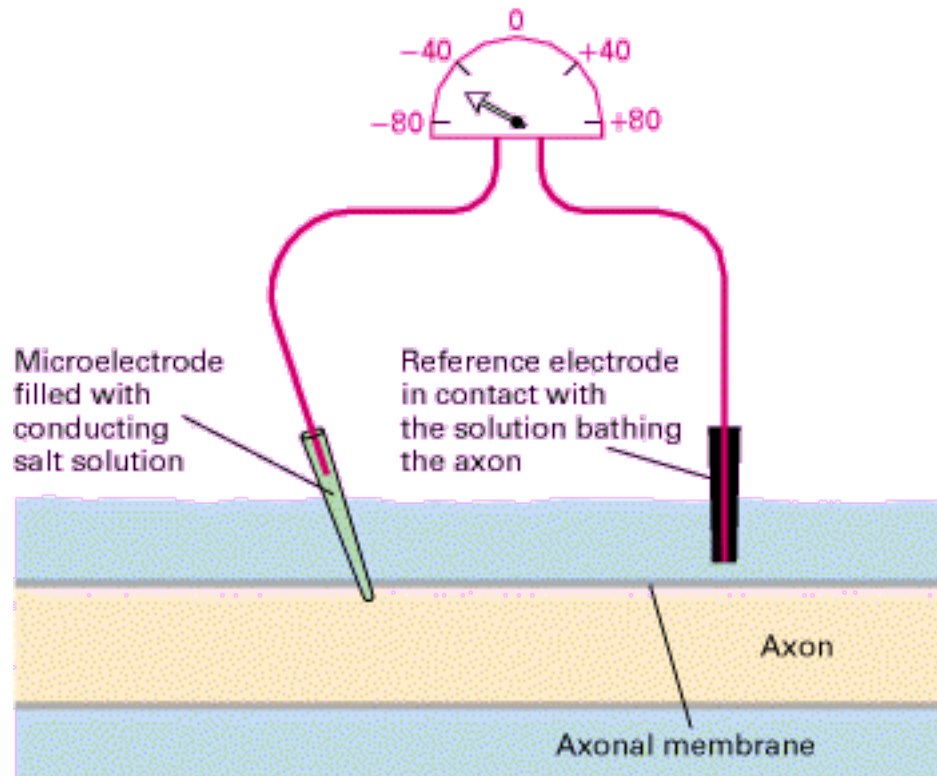


Galvani, De Viribus - Electricitatis in Motu Musculari. 1792.

The electric neuron: resting potential with electrode

The phenomenon:

Potential difference between the two side
EC and IC of the membrane

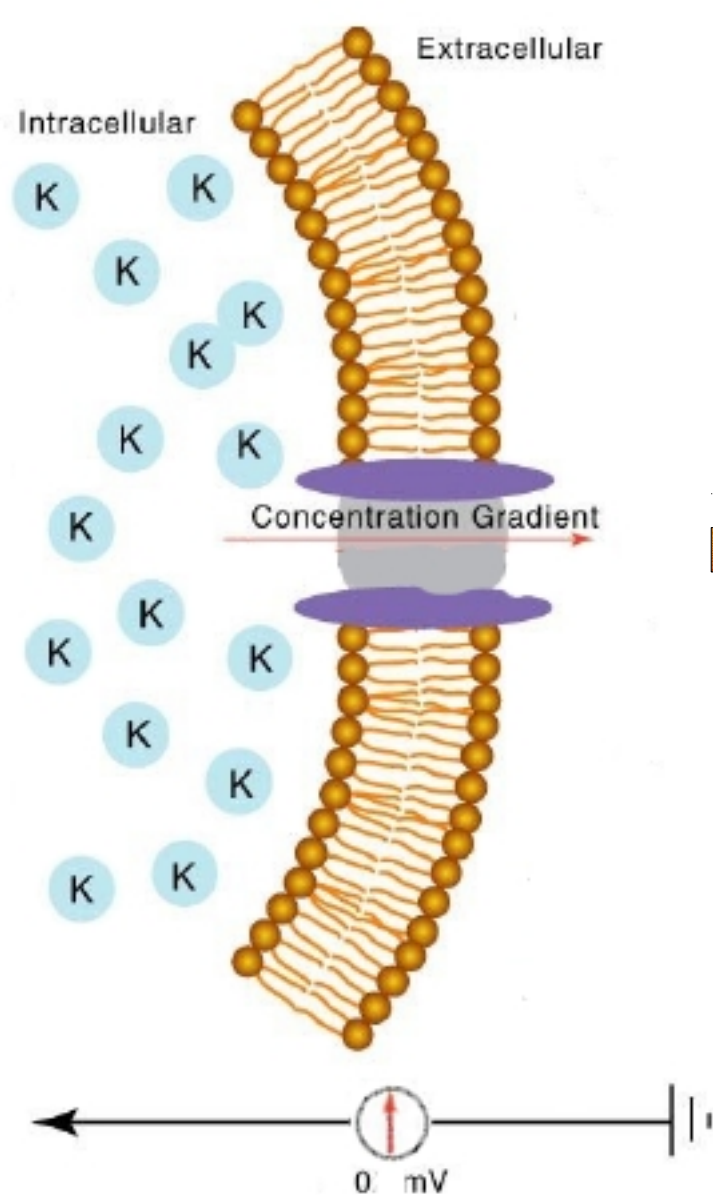


Reason:

on the two different sides of the membrane:

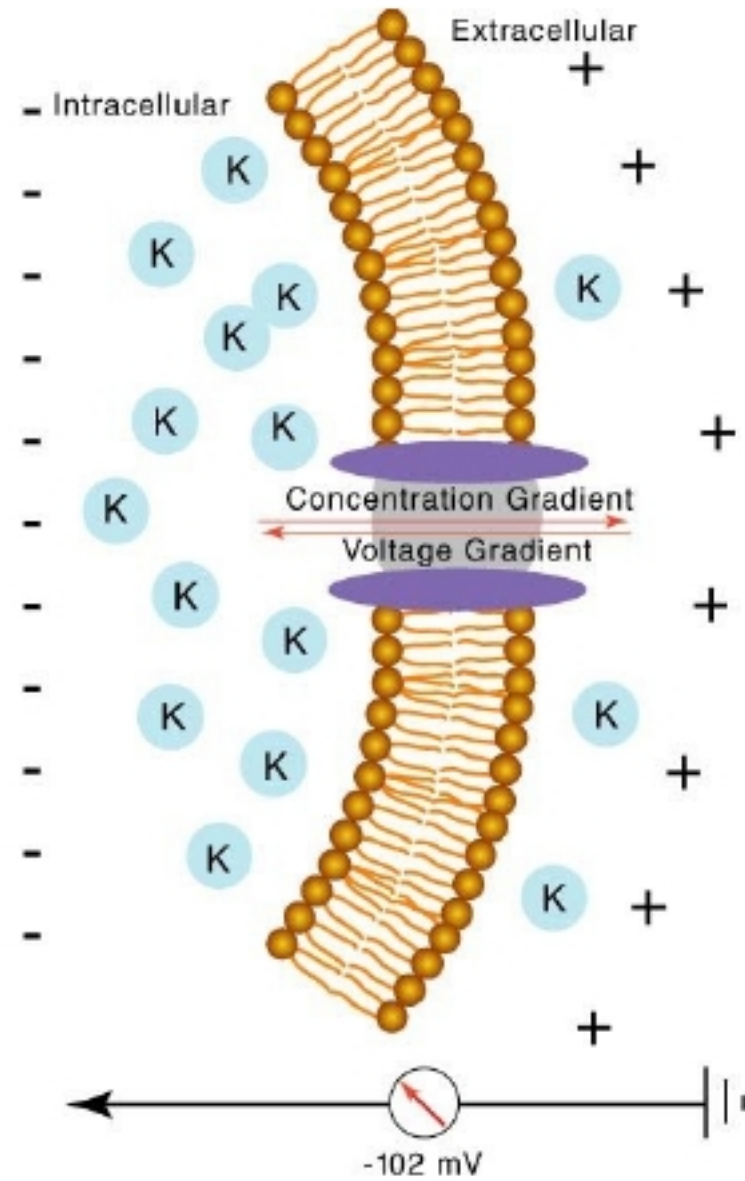
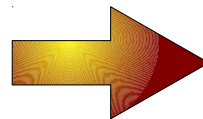
- different concentrations of ions on
- the two side of the membrane
- different permeability for different
- ions

The generation of the resting potential



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Modellek az idegrendszer-kutatásban - ELTE TTK, 2002 tavaszi félév
<http://www.rmki.kfki.hu/~lmate/kurz/>



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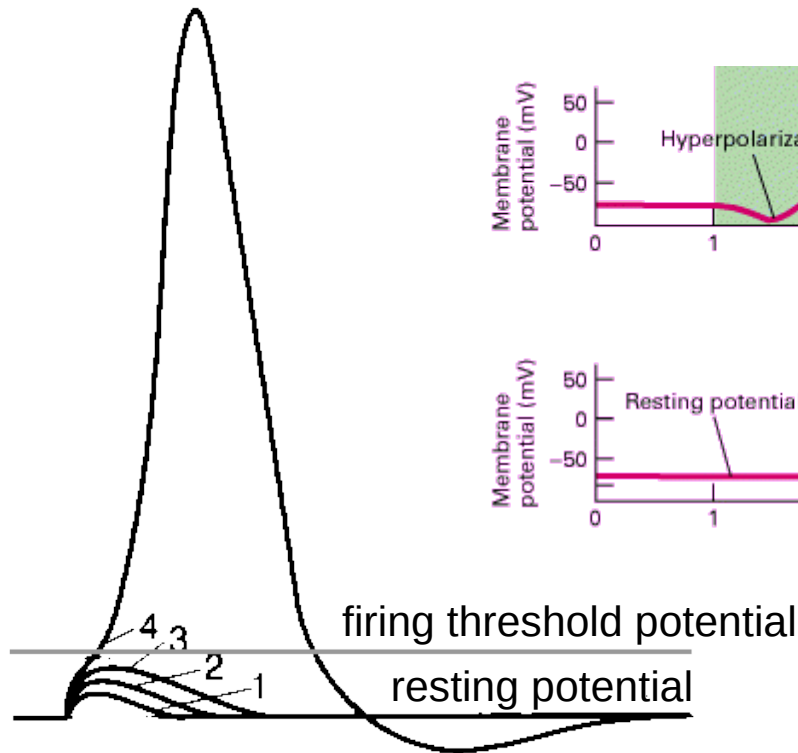
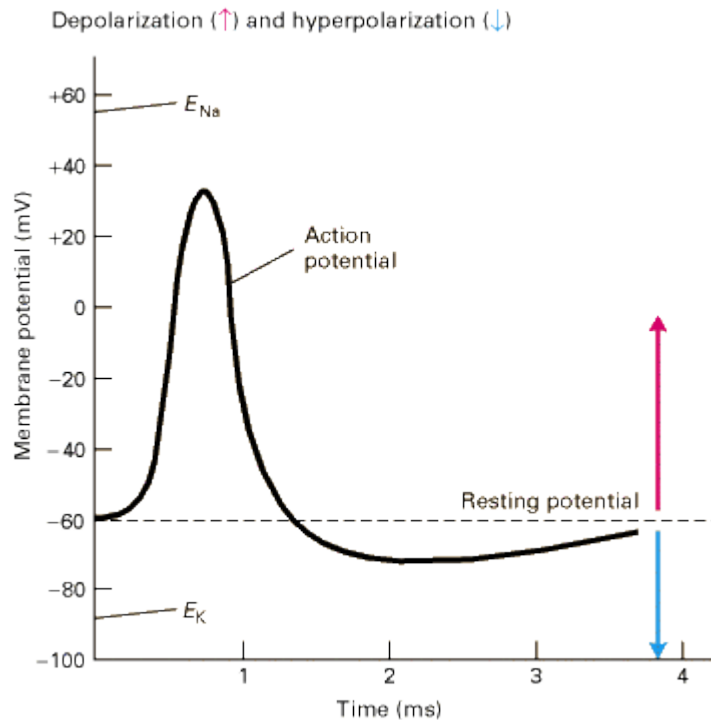
Larry R Squire and others: *Fundamental Neuroscience 2nd Edition.*, Academic Press, 2002

The electric neuron: action potential

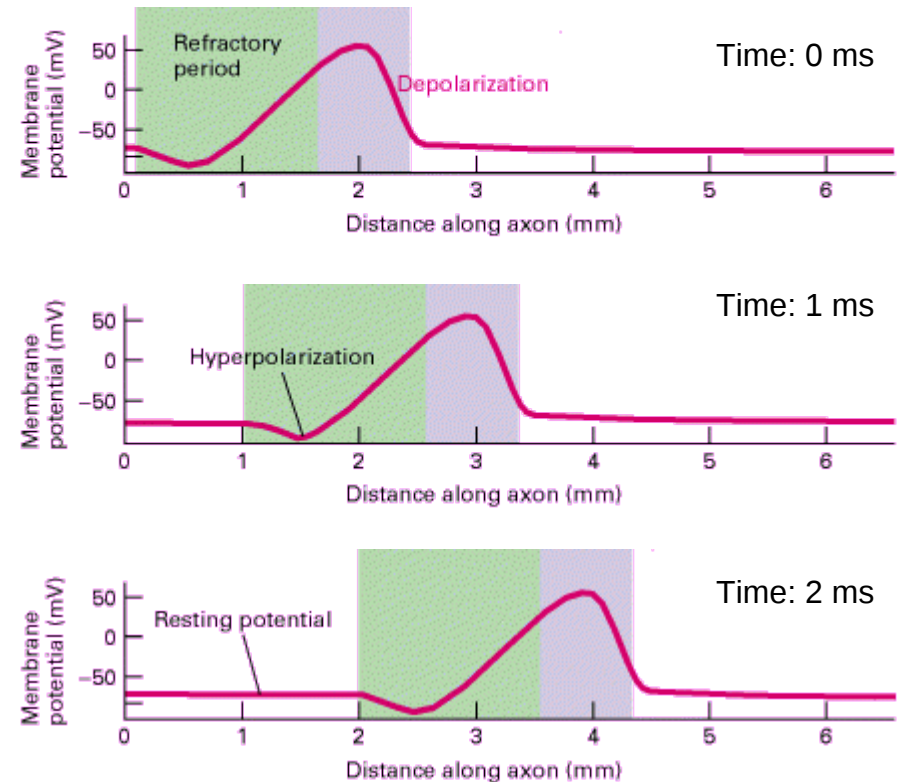
with electrode

What is the action potential?

A short change in the membrane potential

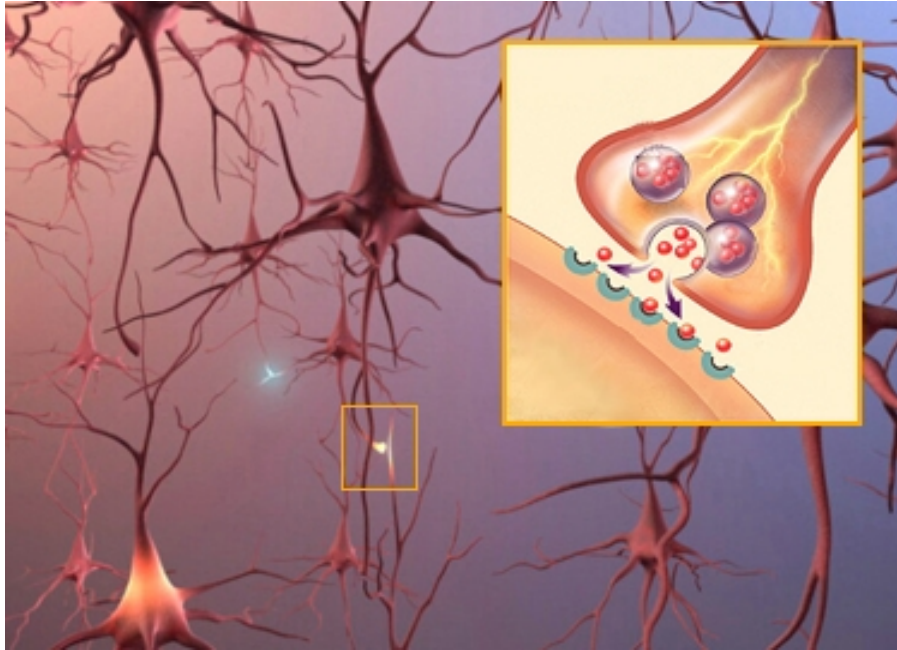


Traveling action potential

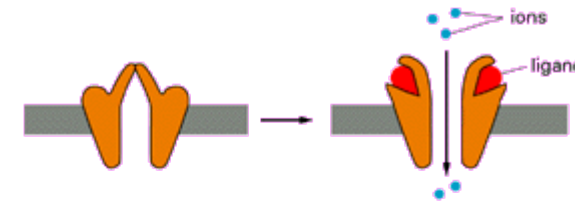


The action potential is an 'all or none' phenomenon

Between two neuron: The synapse

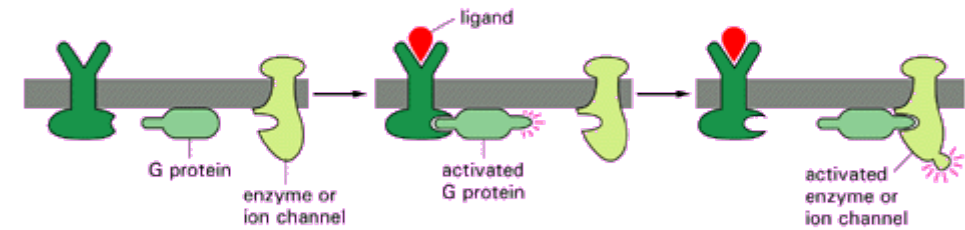


(A) ION-CHANNEL-LINKED RECEPTOR

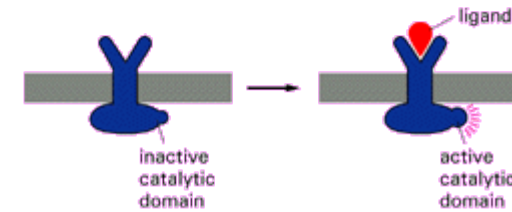


Ionotropic (A) and metabotropic (B,C) receptors

(B) G-PROTEIN-LINKED RECEPTOR

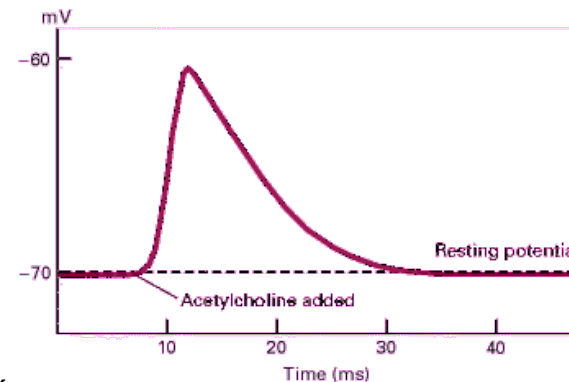


(C) ENZYME-LINKED RECEPTOR

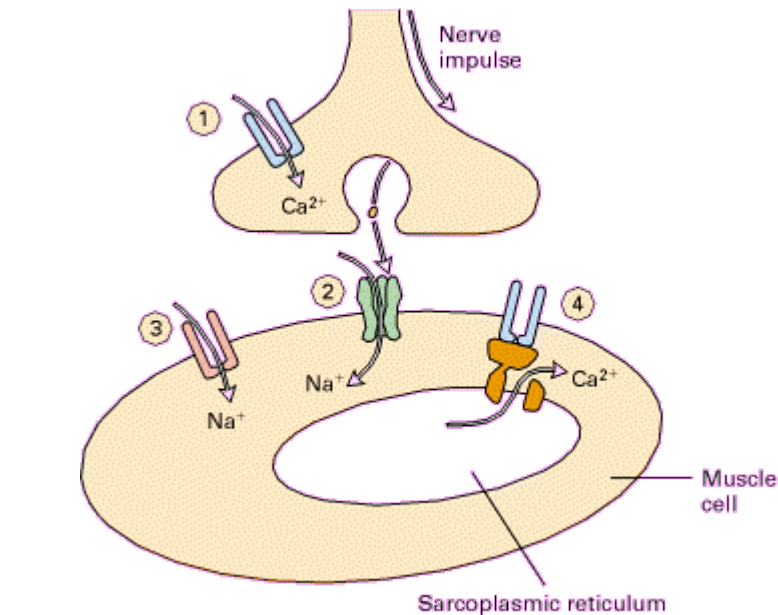
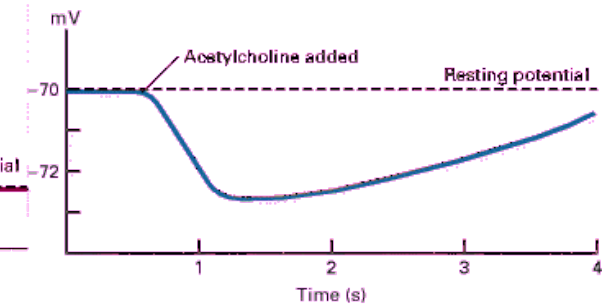


Excitatory and inhibitory postsynaptic potentials

(a) Excitatory synapse



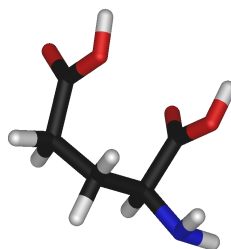
(b) Inhibitory synapse



Excitatory and inhibitory neurotransmitters

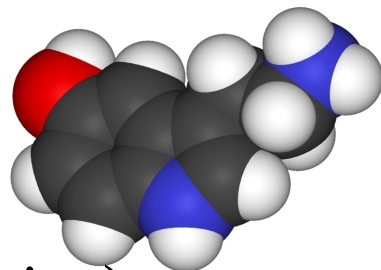
Glutamat

(information transmission)



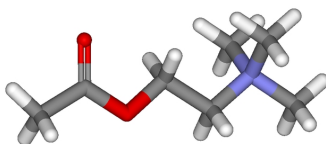
Serotonin

(mood, wake/sleep)



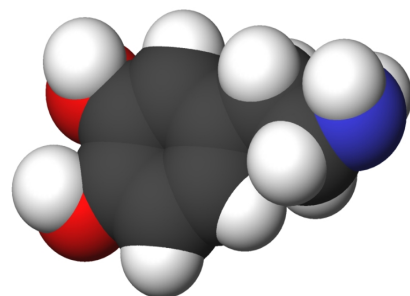
Acetlicholin

(neuromuscular junction)



Noradneraline

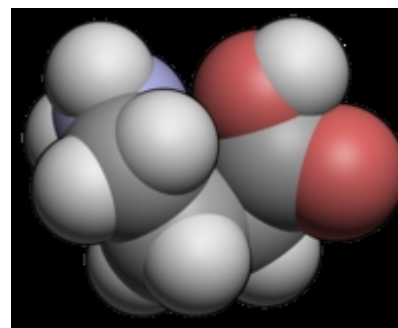
(arousal)



Dopamine

(reward system,
Parkinson disease,
schizophrenia)

GABA-gamma aminobutyric acid
(in the central neural system)



Glycine

(in the periphery)

