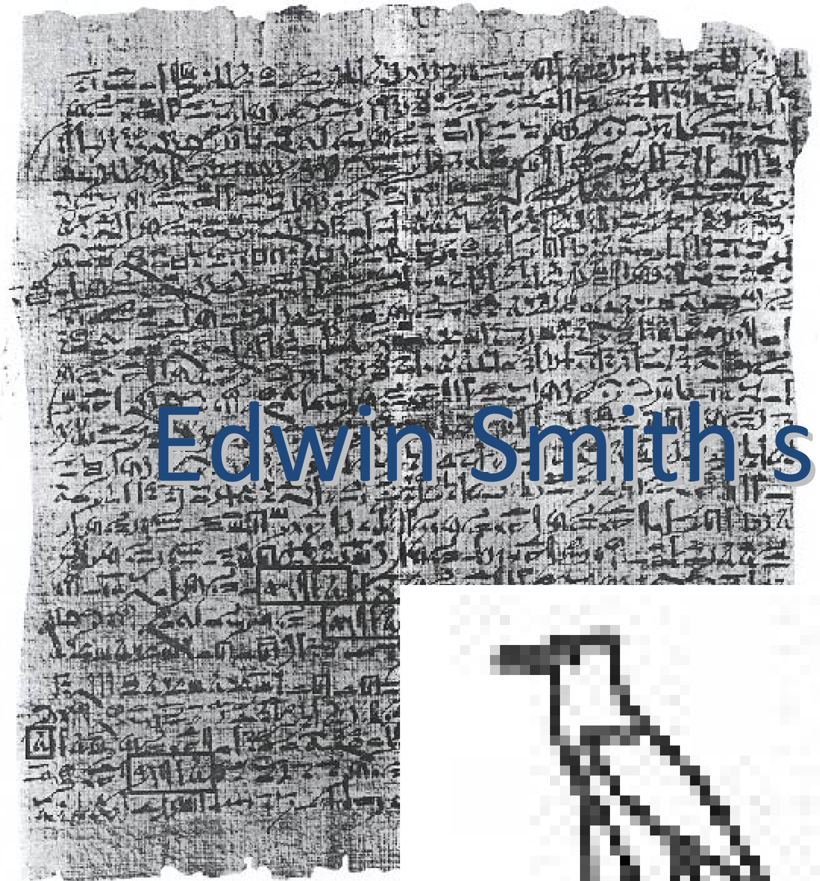
Neurobiology

Introduction to neurosciences for Cognitive MAs.

Edwin Smith surgical papirus



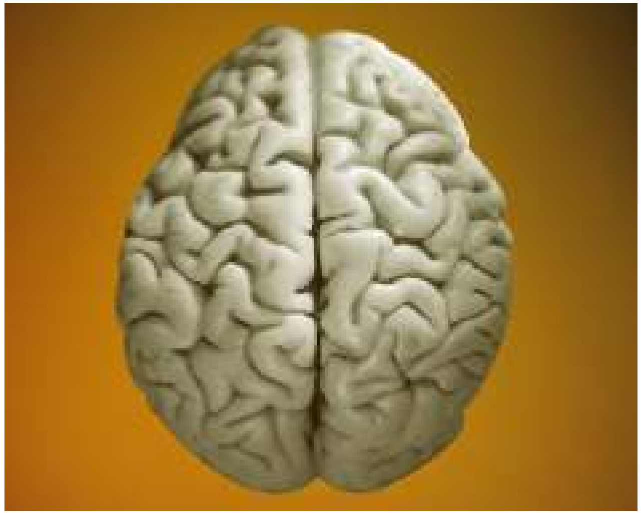
Columns II (left) and IV (righ

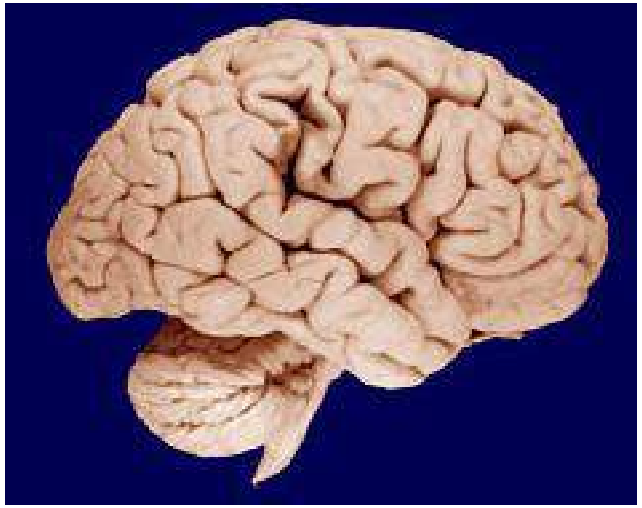
This papyrus, written in the Seventeenth Cent
anywhere in human records. According to Jame
document in 1930, the word brain (ʿyš) o
on these pages of the Smith Papyrus describing
patients, wounded in the head, who had comp
now in the Rare Book Room of the New York Academy of Medicine.

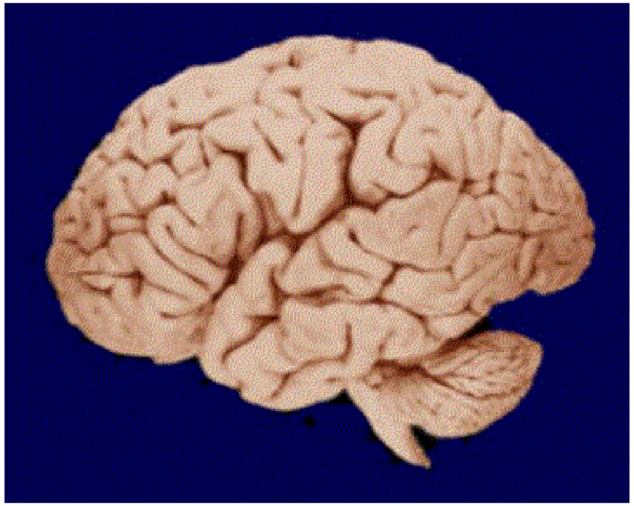
Reference: Breasted, James Henry. The Edwin Smith Surgical Papyrus, 2 volumes. The University of Chicago Press, Chicago. 1930.

Anatomical and Functional Neuroanatomy

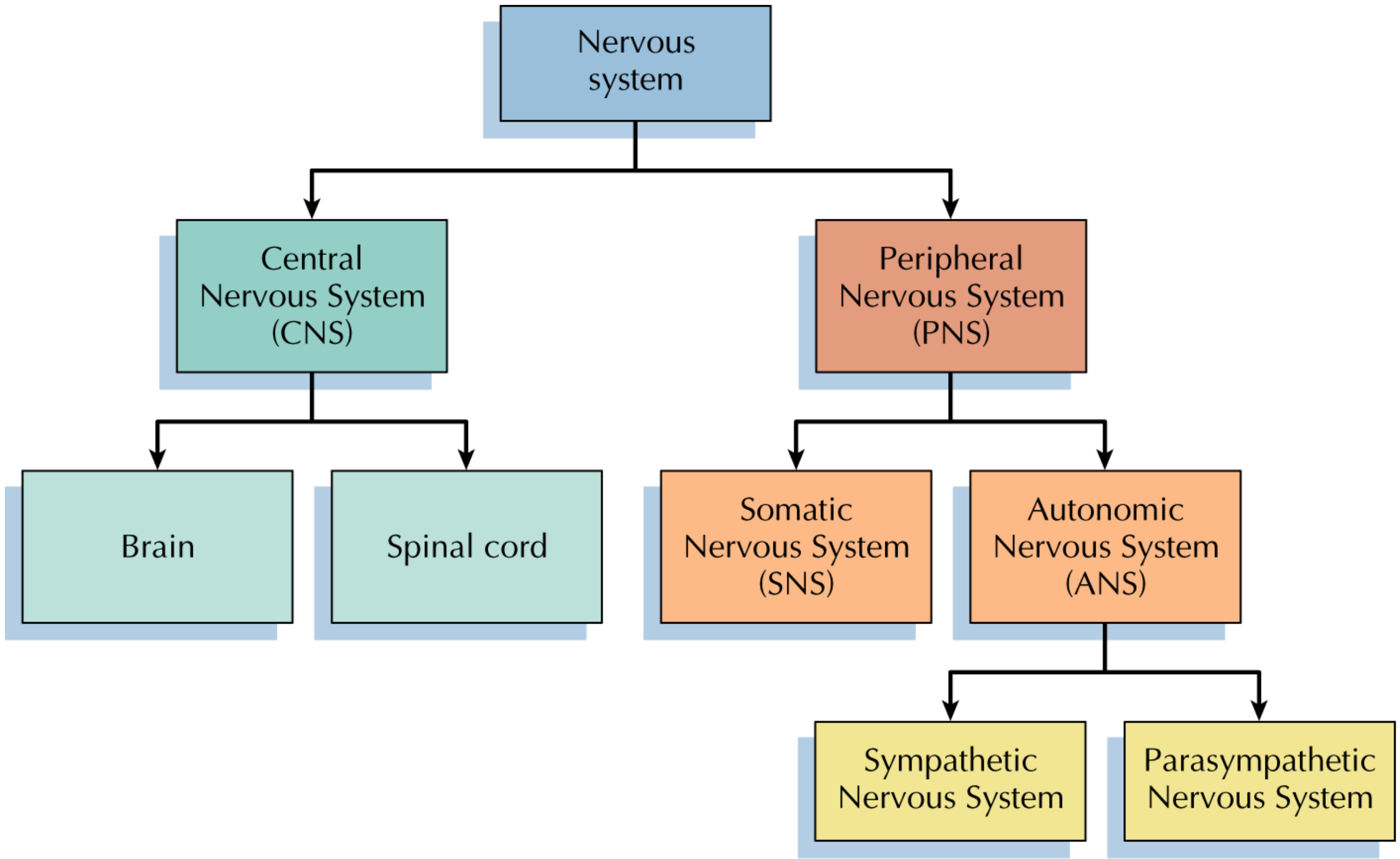
Tutorial: www.neuropat.dote.hu



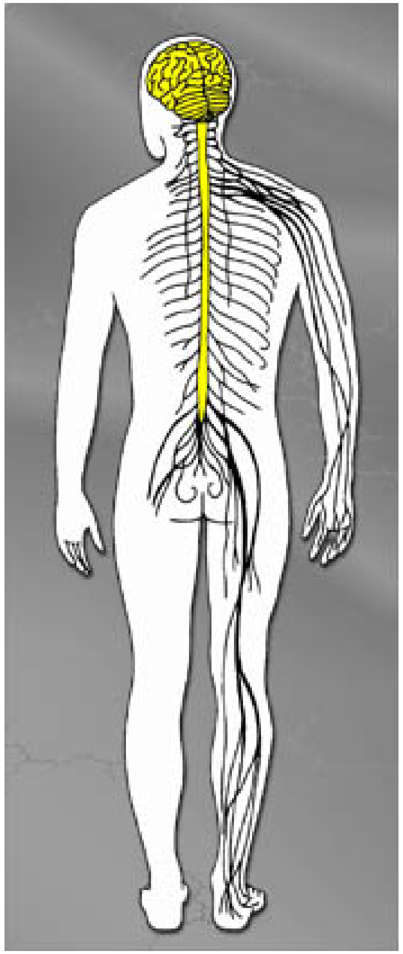




The Nervous System



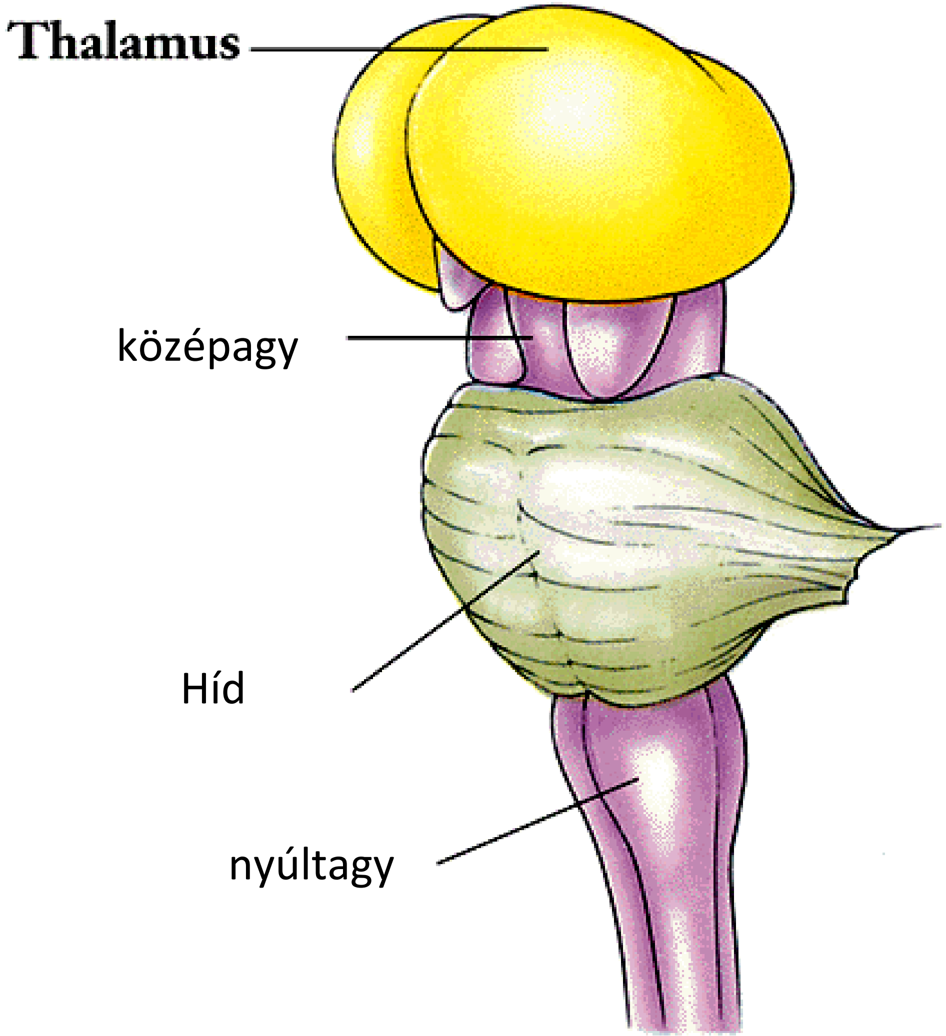
Részei



- Agy: agytörzs. Kisagy és agykéreg
- gerincvelő
- Perifériás idegek

- autonóm
- szomatikus
- enterális

Agytörzs



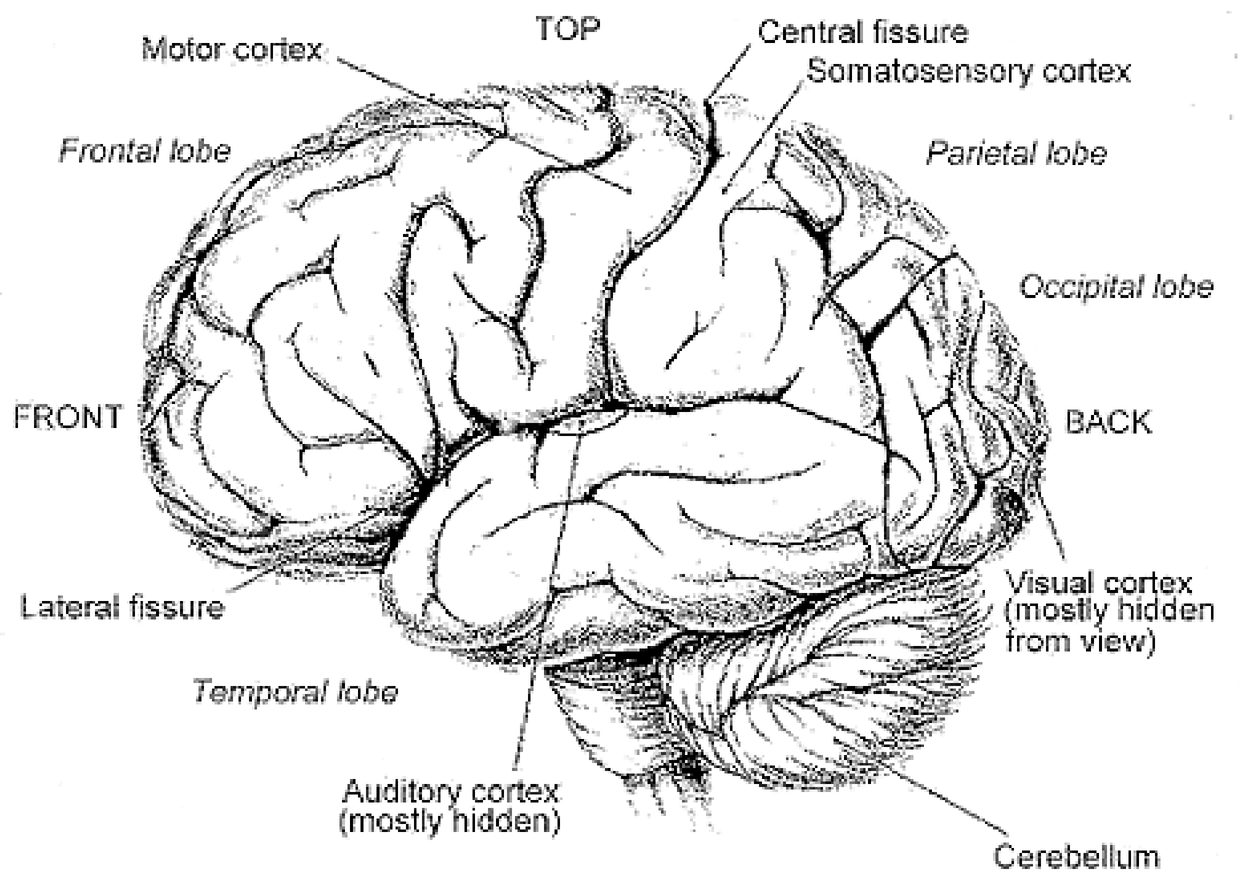
Agykéreg: 4 lebeny

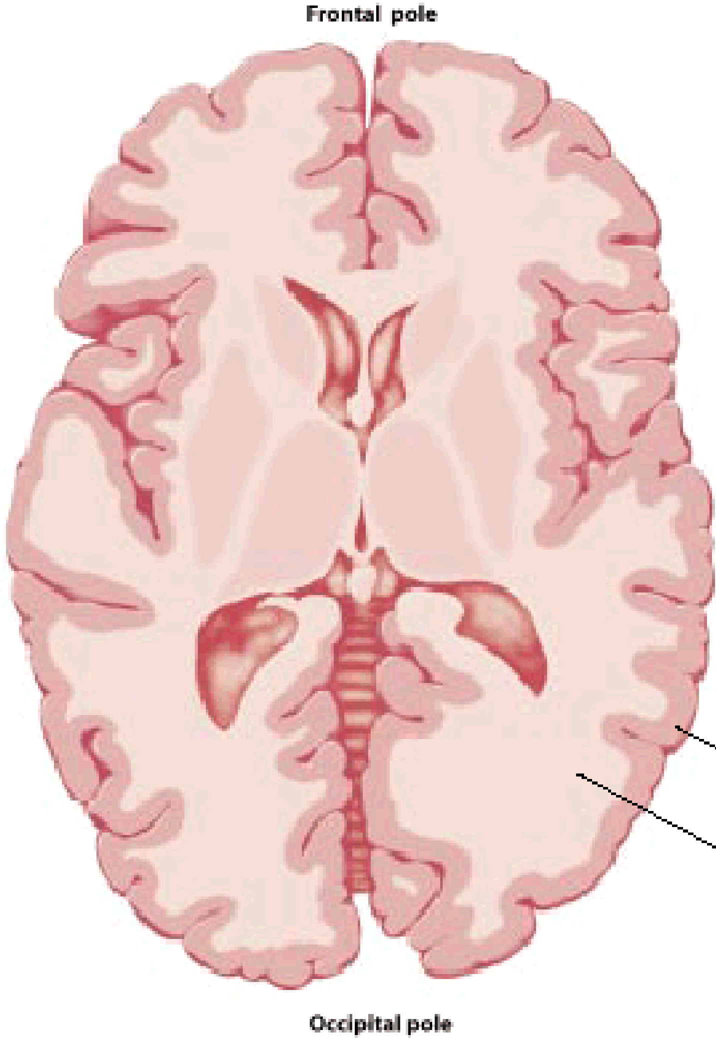
- Frontális (homlok)
- Temporális (halánték)
- Parietális (fali)
- Occipitális (nyakszírti)

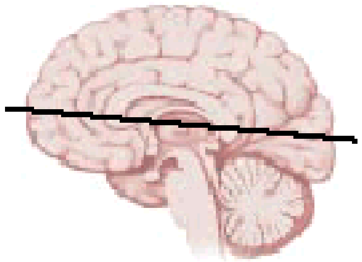
Agy

- frontális lebeny - motor activity, tervezés & mozgás, beszélt nyelv, affektiv tényezők
- temporalis lebeny – hallás, nyelv, (Wernicke' s area)
- parietális l - szomatosensation, tér érzékelés
- occipitalis l - látás

Agy és agykéreg

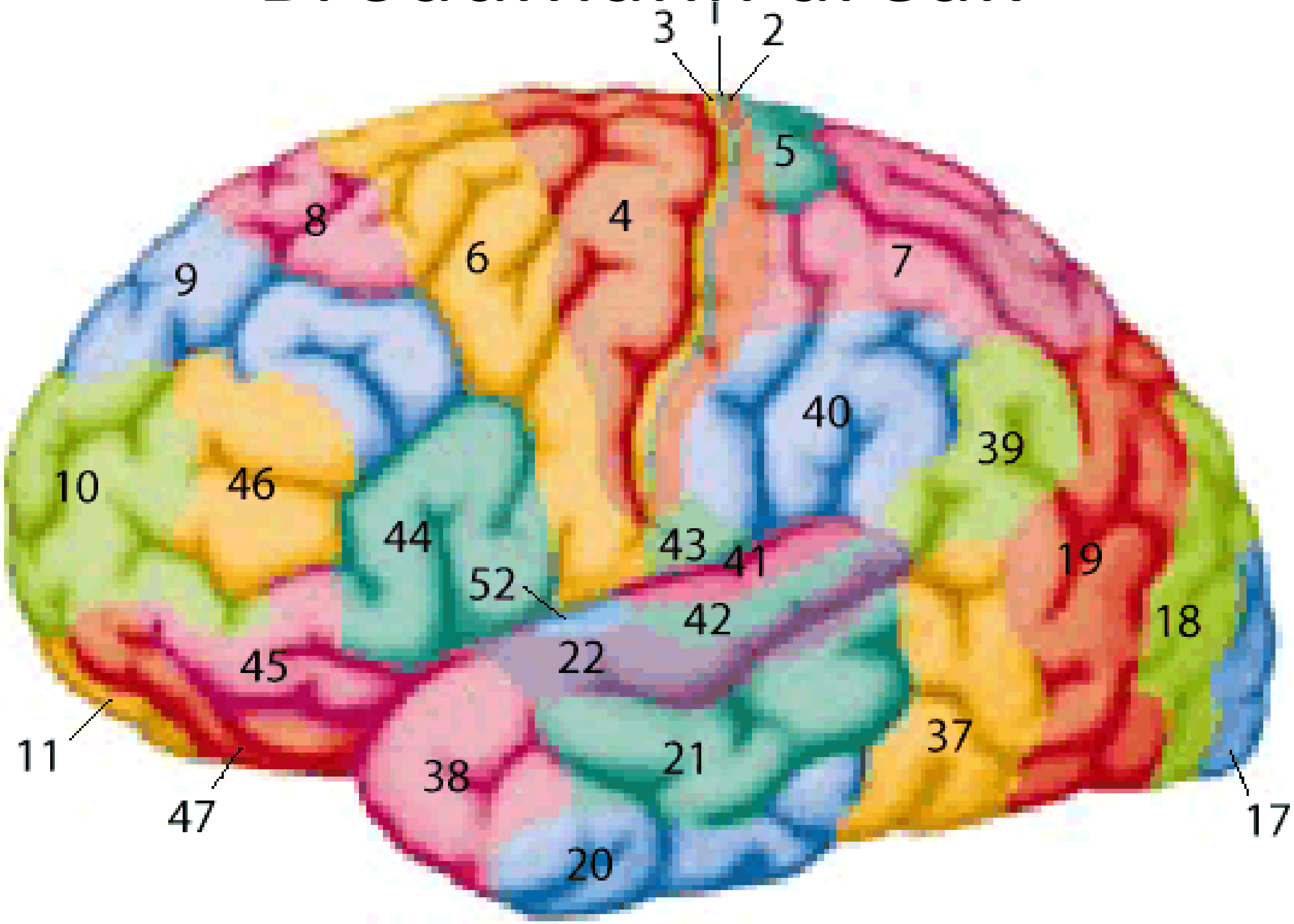






Agykéreg- cortex
szürke
fehér

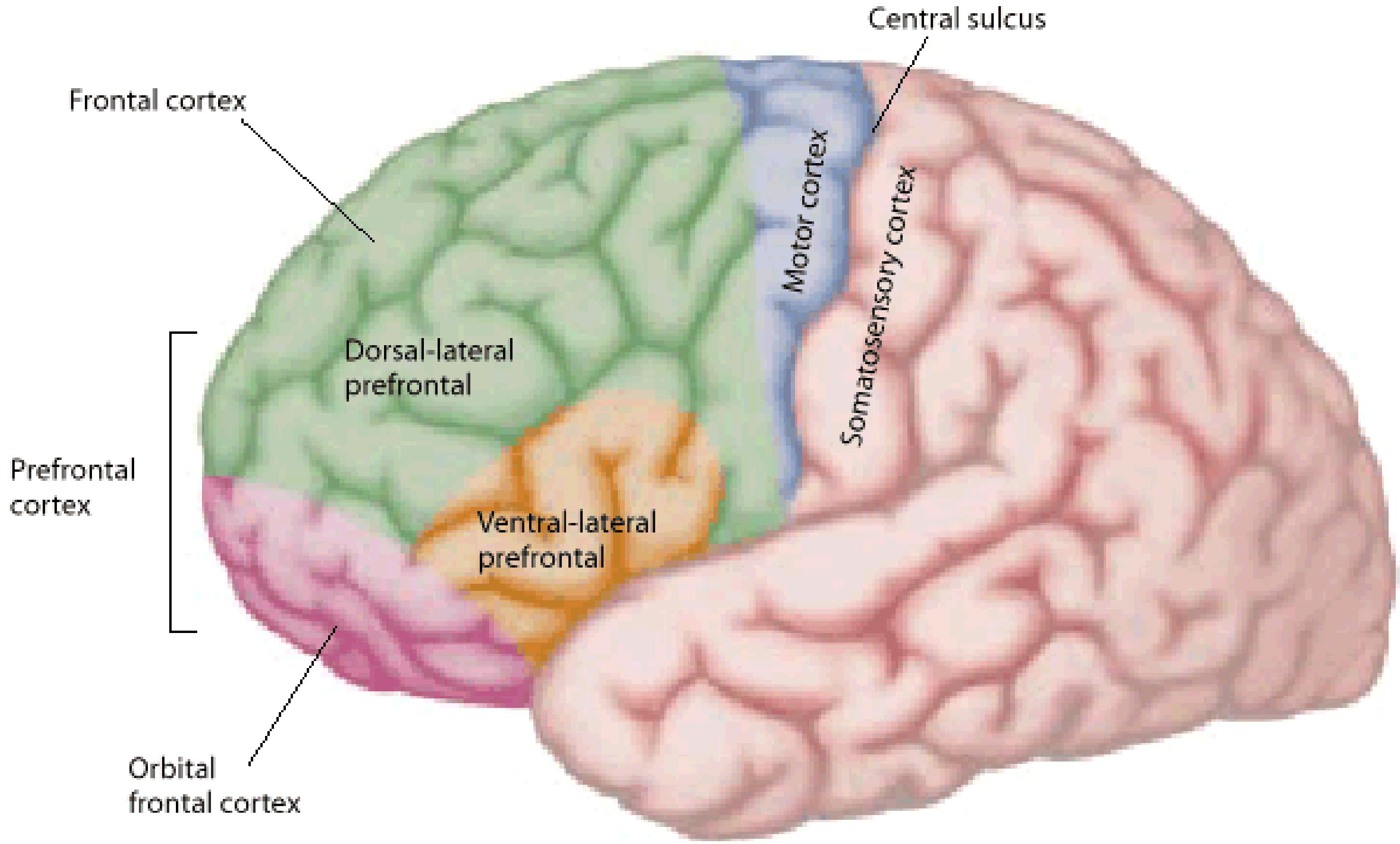
Broadmann áreák



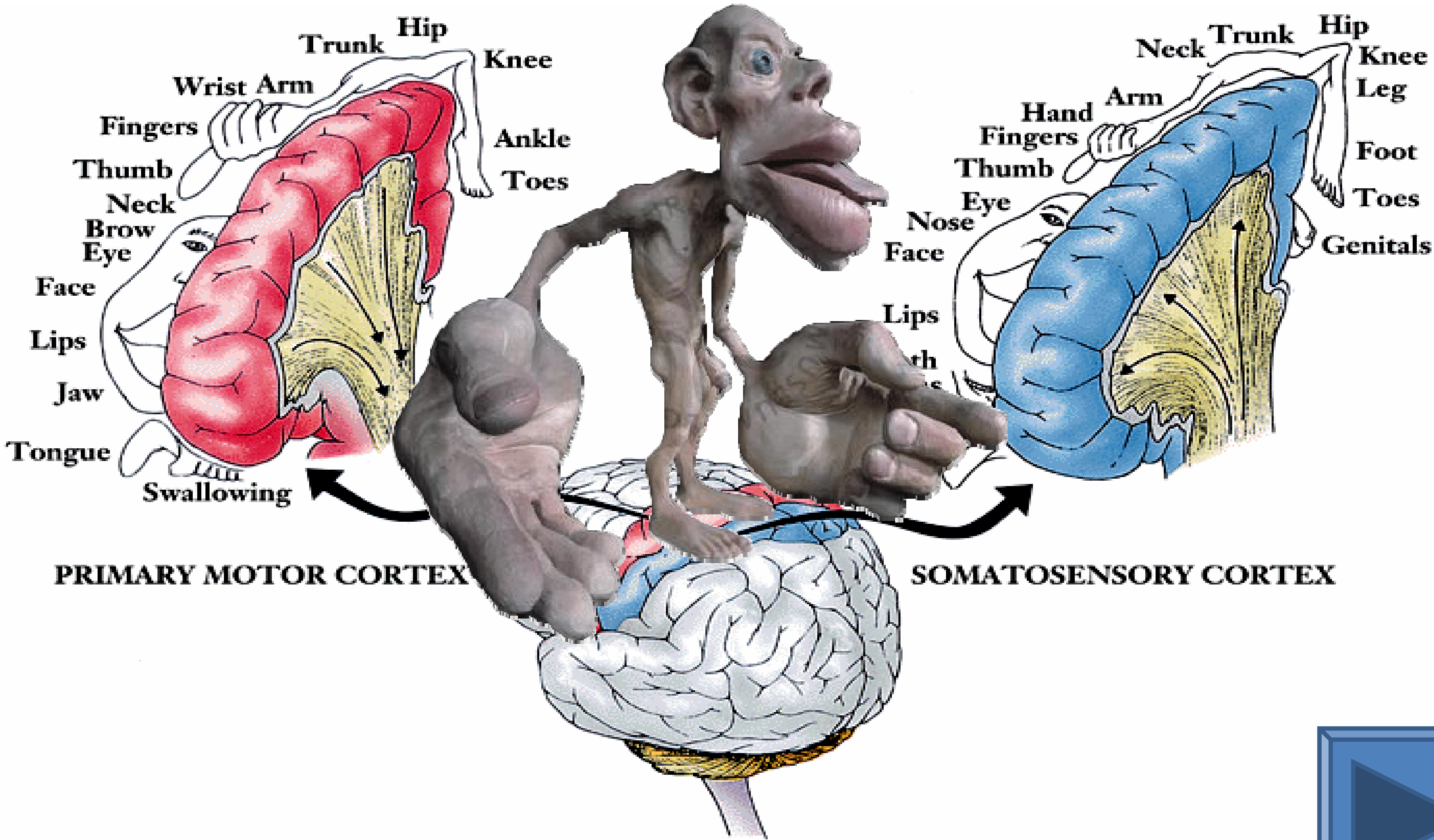
Funkcionális specializáció

- Motoros
- Szenzoros
  - Szomatoszenzoros
  - Halló
  - Látó
- Asszociációs

Motoros kéreg – homlokl.

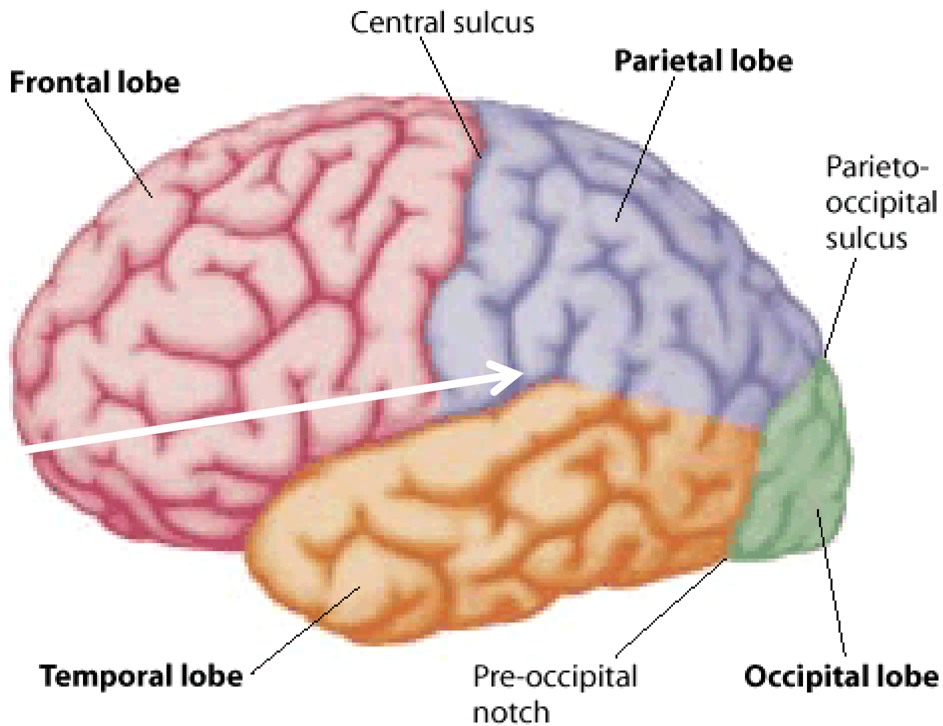


Szomatoszenzoros kéreg- fali l.

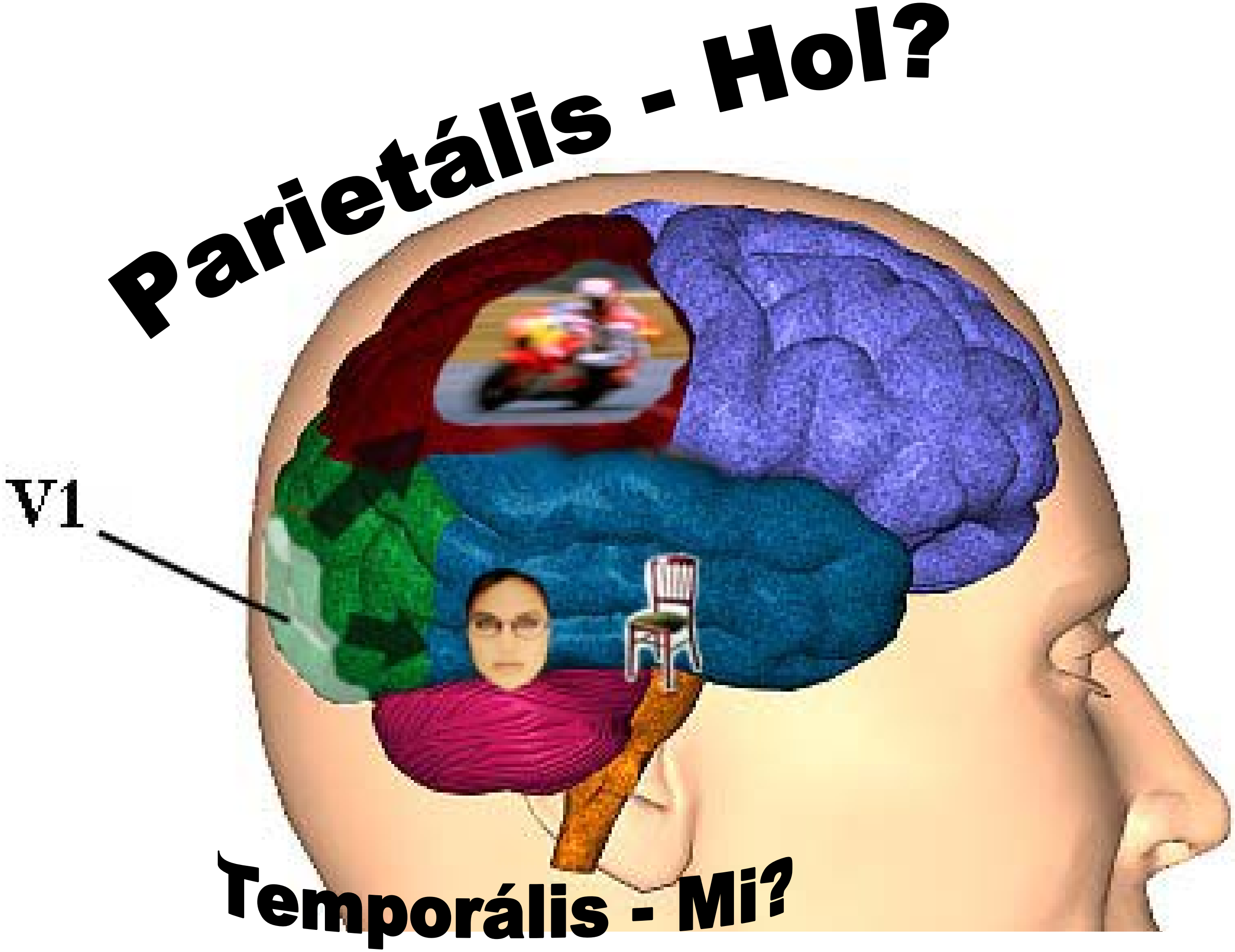


Hallókéreg- halánték l.

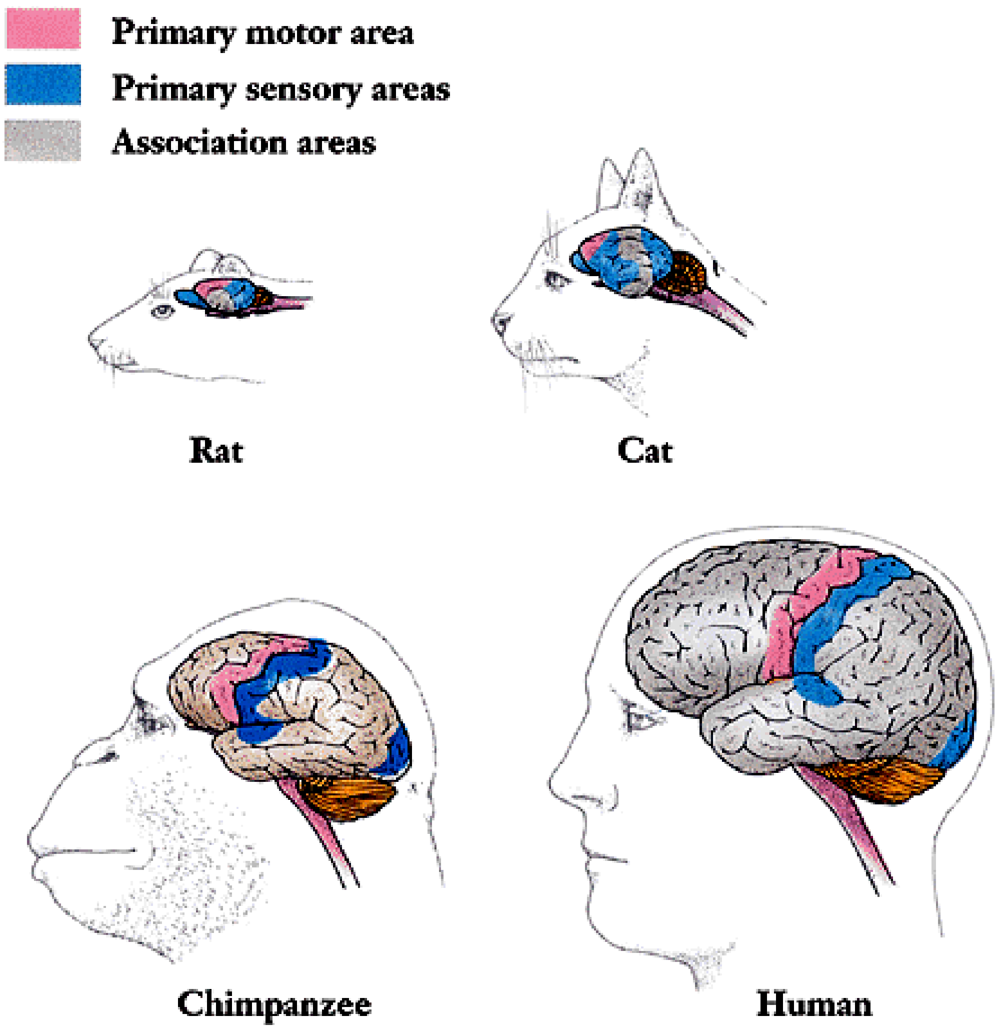
Auditory Cortex



Látókéreg- nyakszírti l .



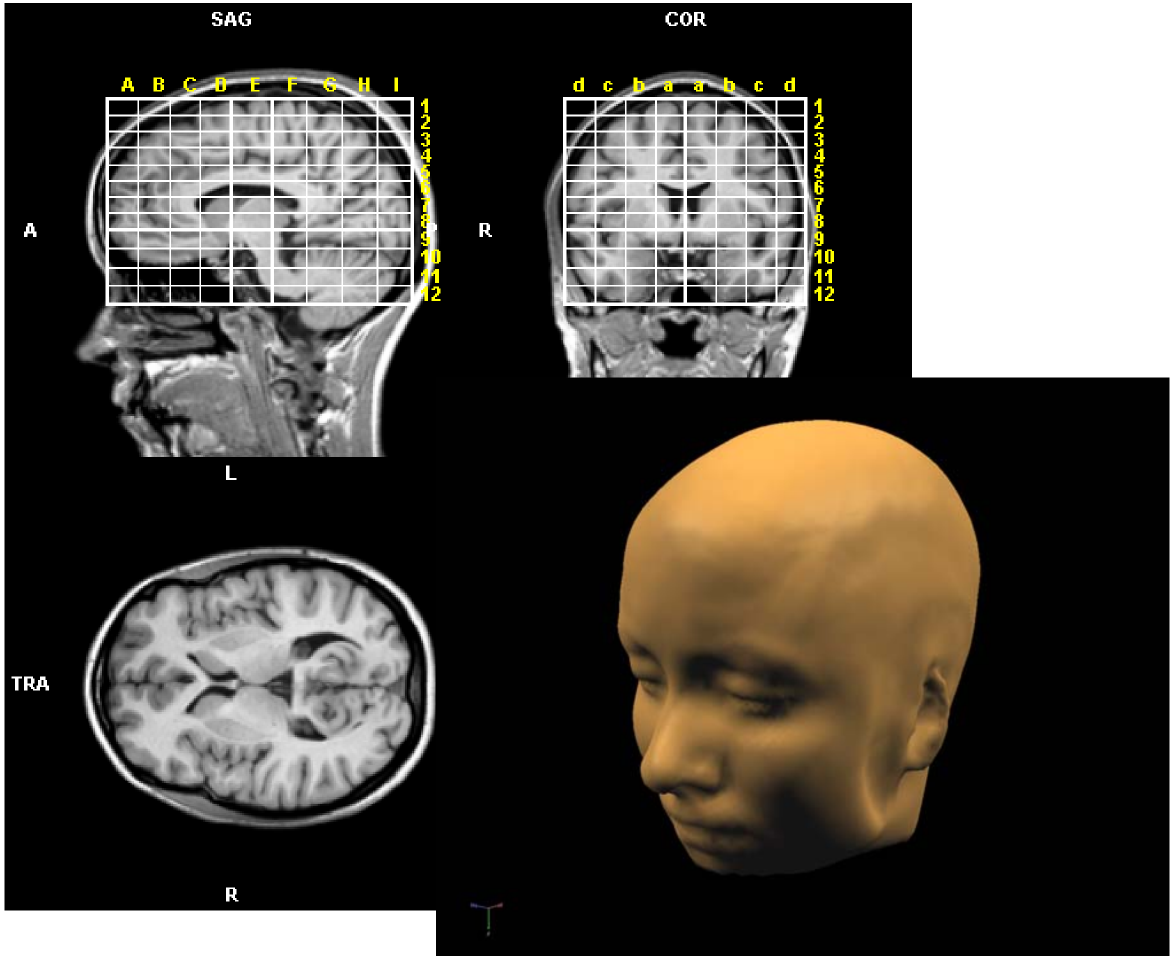
Asszociációs kéreg



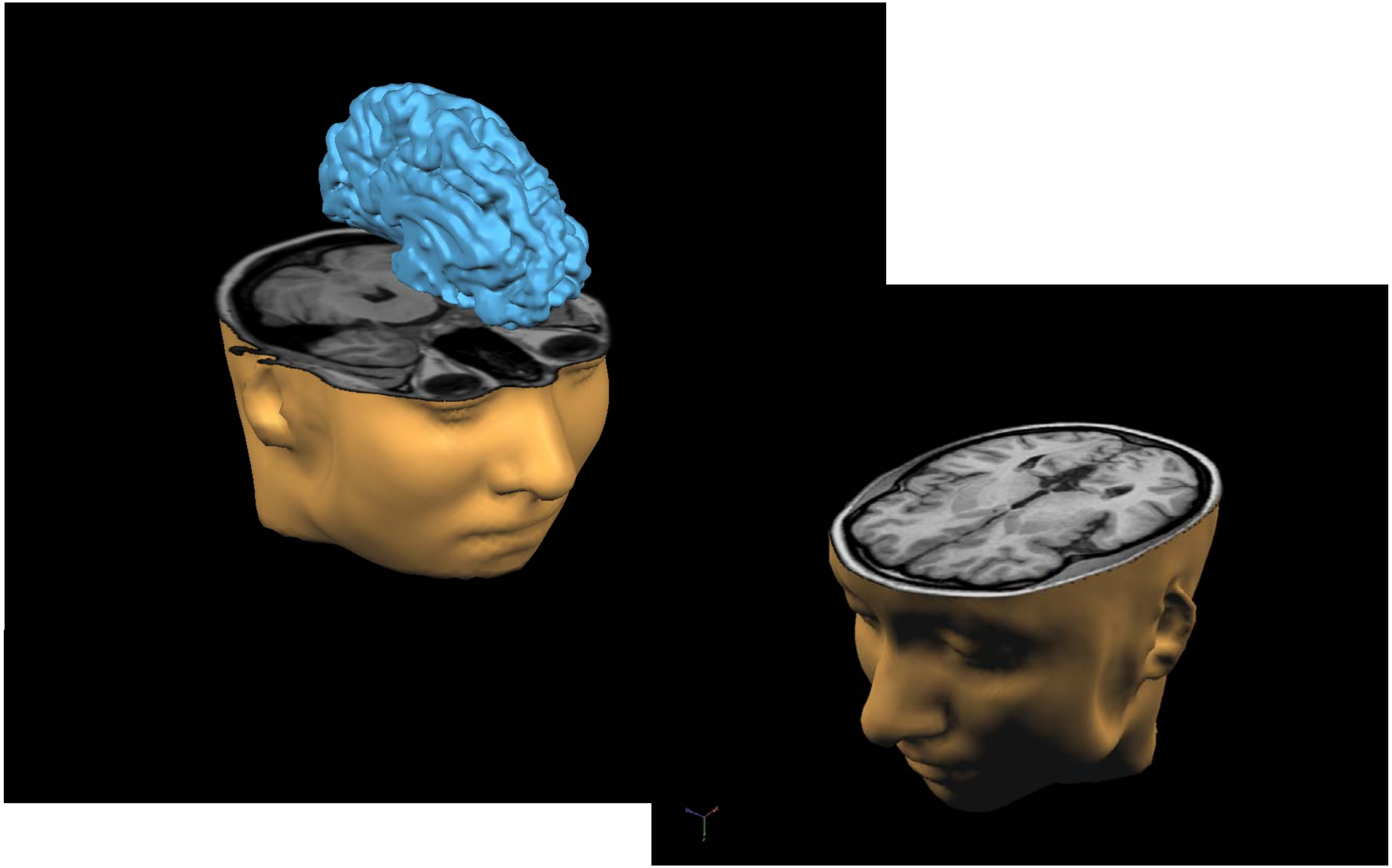
- Nem szenzoros,
- Nem motoros

- Magasabb funkciók, pld beszéd.

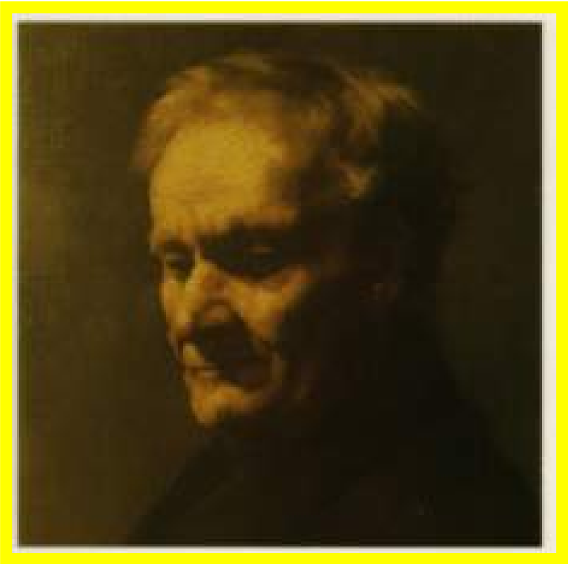
Brain normalization to Standard Tailarach Coordinates



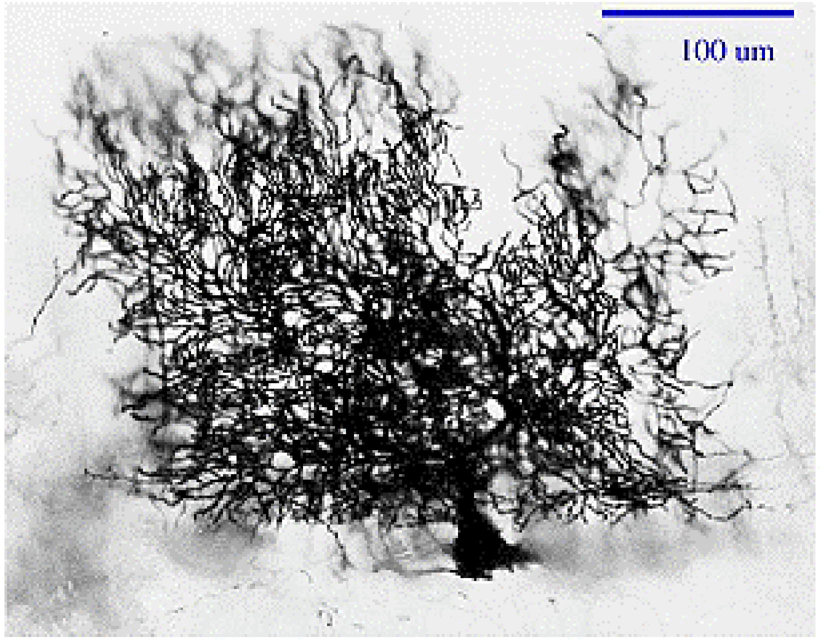
Brain Segmentation and 3D reconstruction



Neuron-idegsejt
Neuronális hálózatok

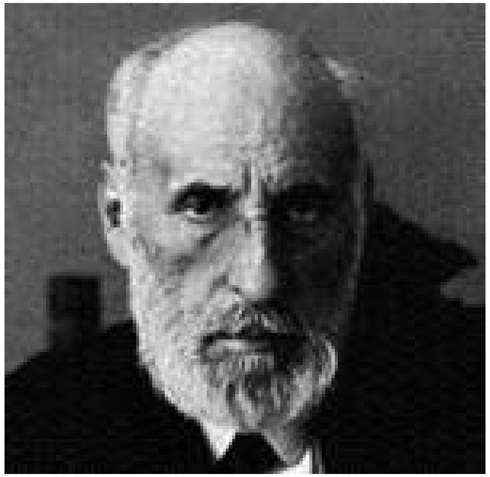


Jan Purkinje

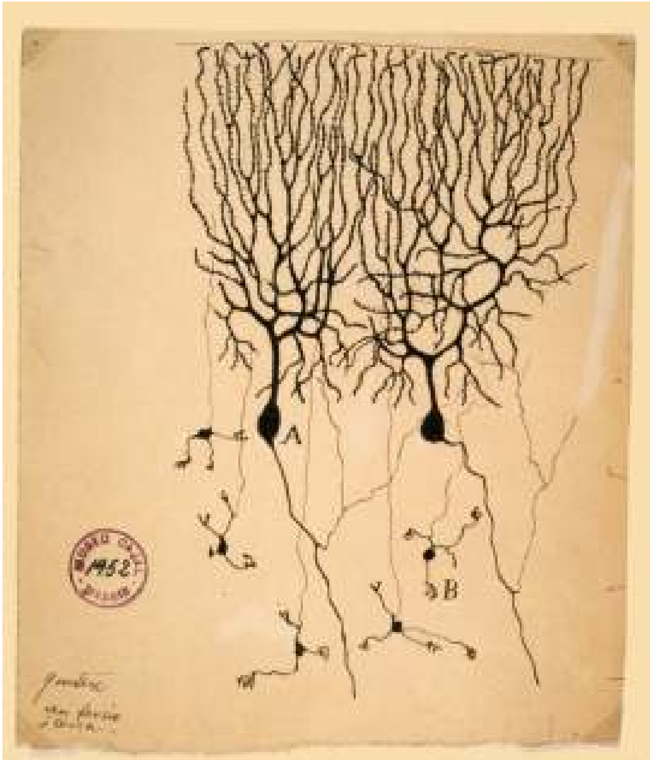


Purkinje cell – first viewed in 1837

Cajal és Golgi – 1906 Nobel Díj



Santiago Ramon y Cajal

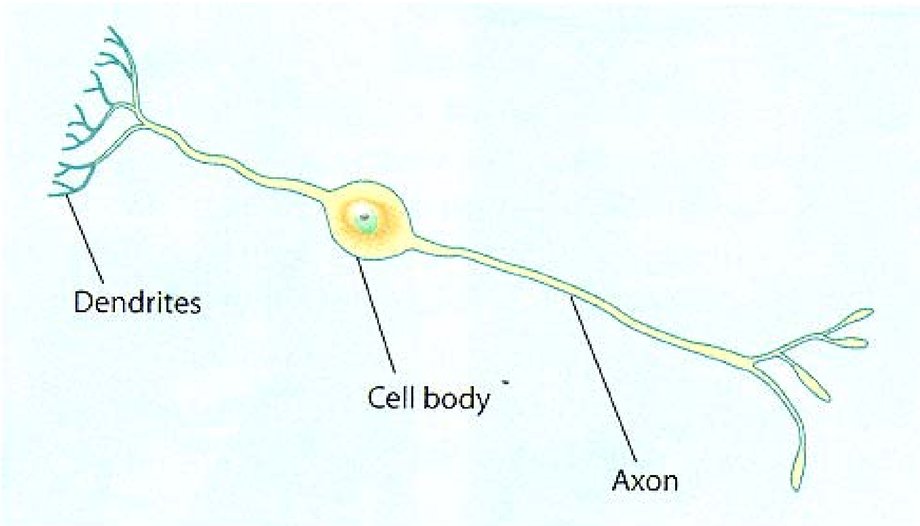


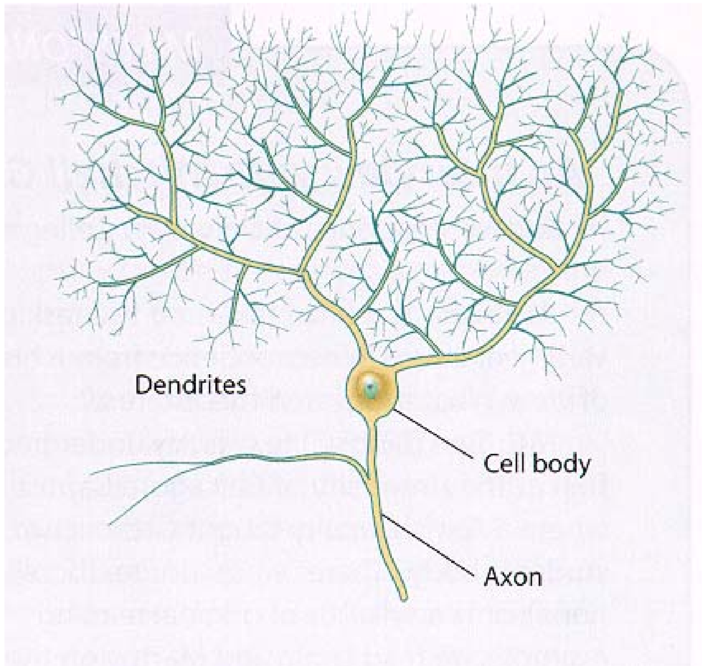
"Pigeon cerebellum. A, Purkinje cell, B, granule cell
Modified from a photograph taken from the original
(14X15.5 cm). Drawn on sheet/paper. P.Y. 1899. S.R.
y Cajal Institute - CSIC - Madrid, Spain.

Camillo Golgi

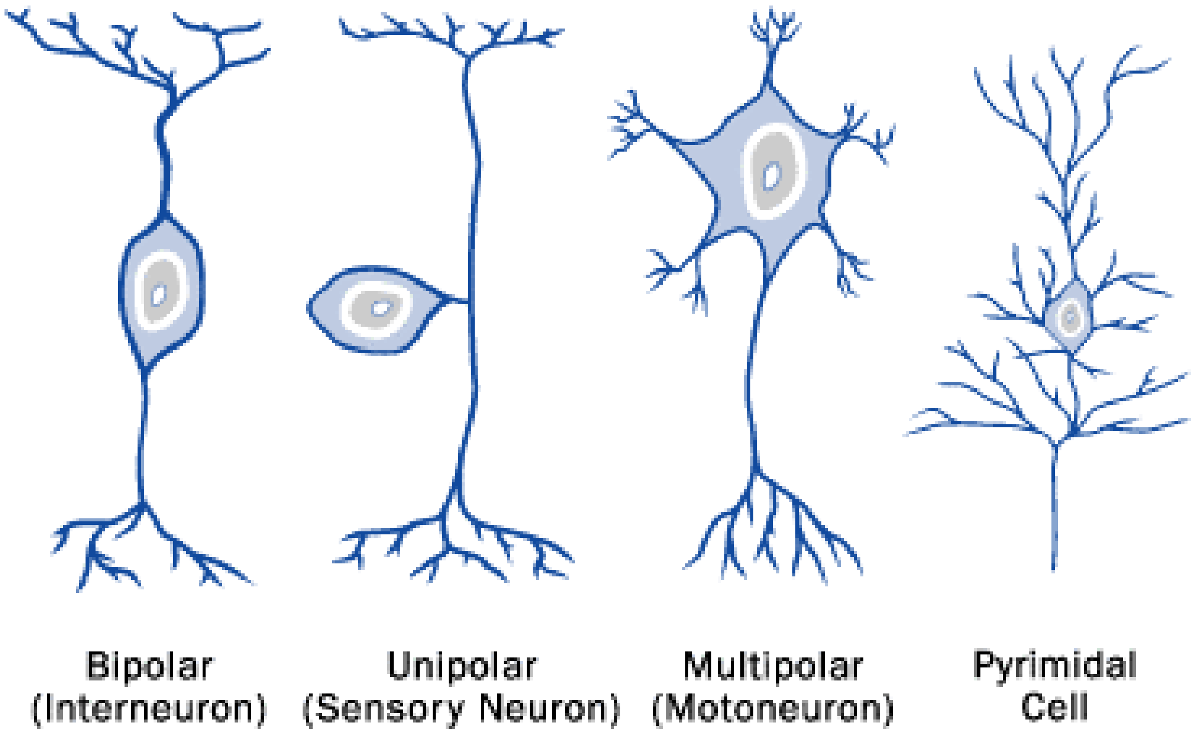
A neuron

ca 10^{12} neuron/agy

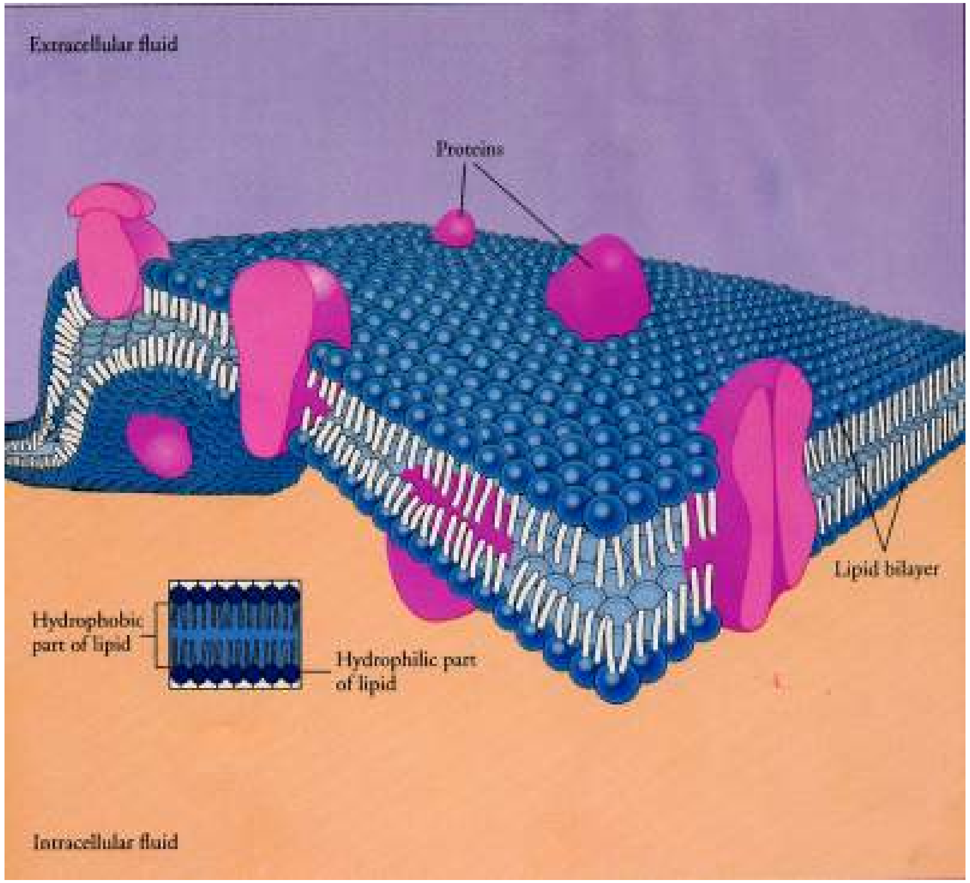




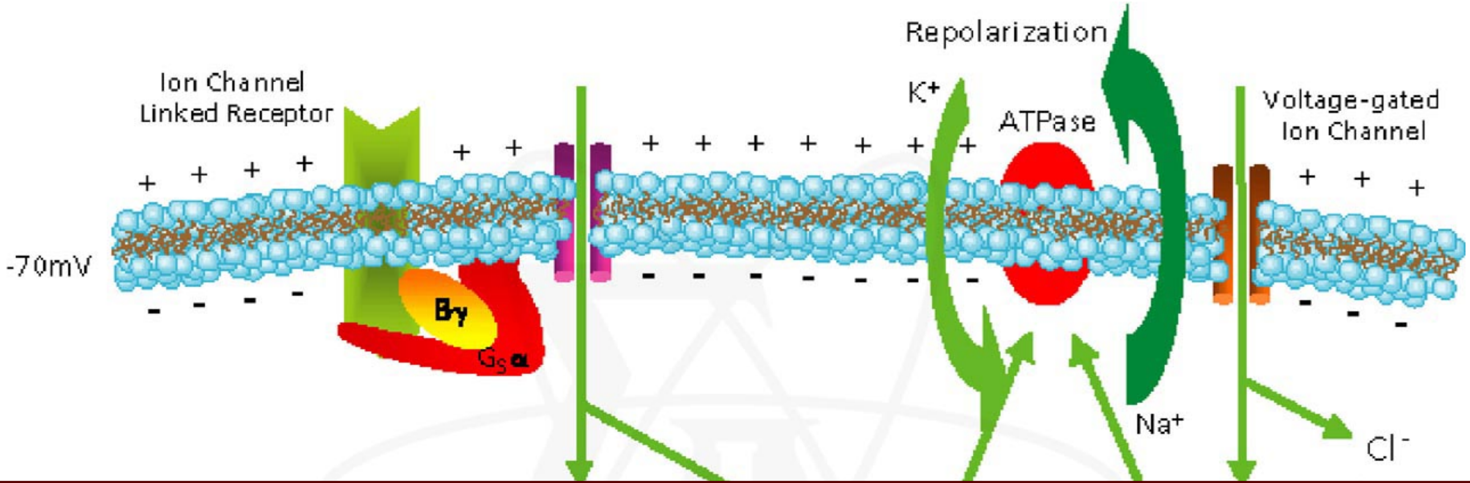
Neurons, Membranes, and Electrical Potentials



Neuronal Membrane



Transmembrane Transport



a) communication among neurons

- **neural systems:**

  * action potential

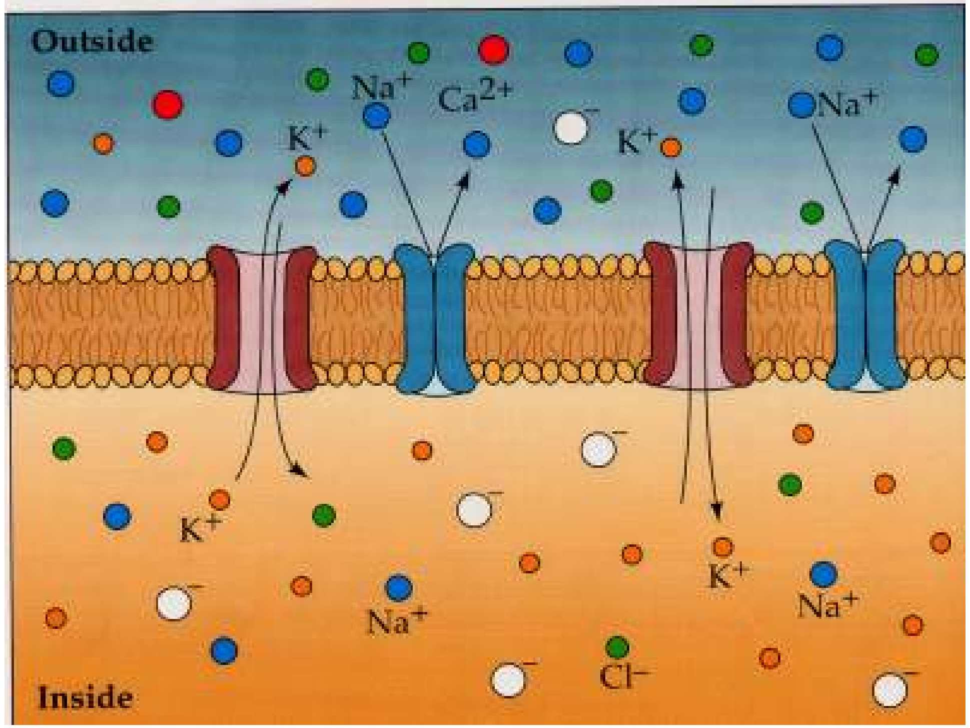
  * synaptic signaling

b) receptor – brain communication

- **heart muscle**
- **signaling and regulatory processes**

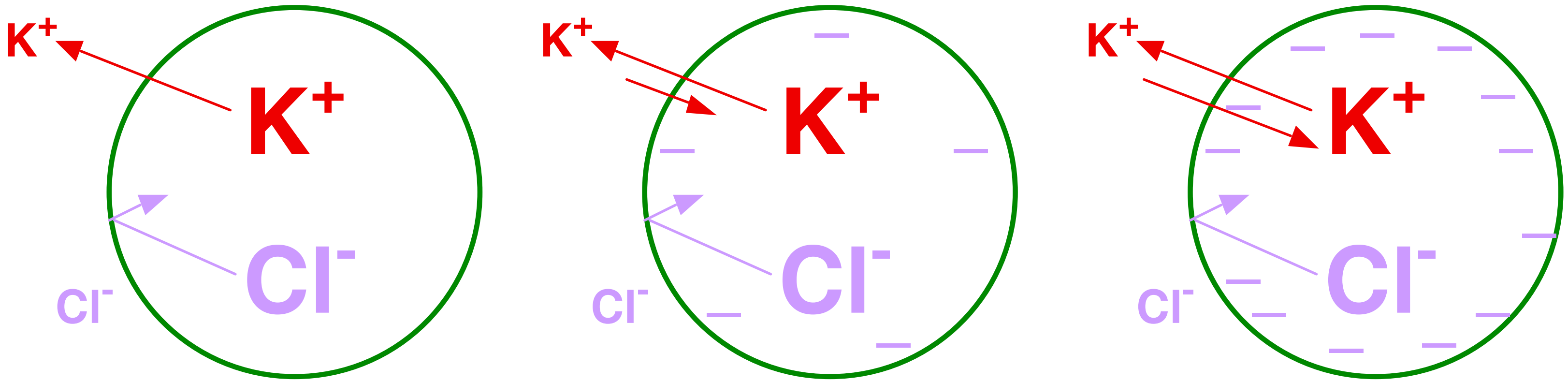
Ion Concentration Gradients

	= Na^+	= K^+	= Cl^-	= Ca^{2+}	= Anion
Outside cell	440	20	560	10	few
Inside cell	50	400	40–150	0.0001	many



Channel Permeation - Nernst

Consider a cell containing a high concentration of KCl
External [KCl] is low
Consider the cell membrane to be permeable to K^+ only.



initial condition   after some diffusion   equilibrium

V_r is known as the: Nernst potential
reversal potential
zero current potential
equilibrium potential

Channel Permeation: Ohm's Law

Current (flow) is equal to voltage (driving force) times conductance (1/resistance)

$$I = (V - V_r)\ G$$

Current (I) is measured in amps (pA, nA, µA)

Voltage (V) is measured in volts (mV)

Conductance (G) is measured in Siemens (pS, nS)

The resting potential

Origin: diffusion potential
Na-K pump

Nernst and Goldman equations

The membrane as capacitor:

$$V = I \cdot R$$

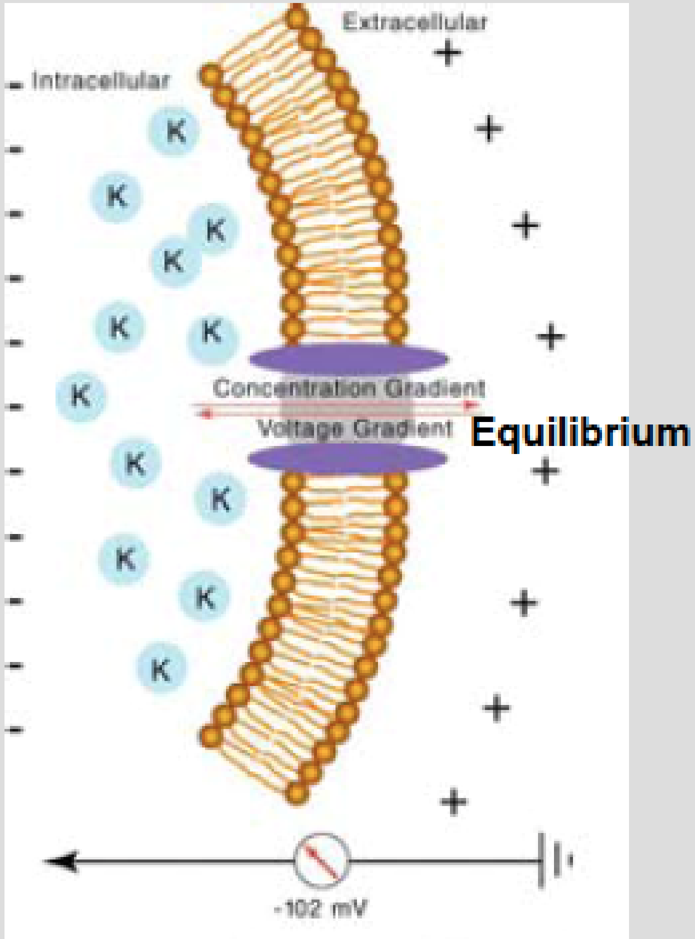
$$\tau = R \cdot C$$

Ion	Concentration (mmol/l H_2O)		Equilibrium potential (mV)
	intracellular	extracellular	
Na^+	15,0	150,0	+60
K^+	150,0	5,5	-90
Cl^-	9,0	125,0	-70

Resting membranepotential = -70 mV

$$E_K = \frac{RT}{FZ_K} \ln \frac{[K_k^+]}{[K_b^+]} = 61{,}5 \log \frac{[K_k^+]}{[K_b^+]}, \; 37\,°\text{C-on}$$

$$V = \frac{RT}{F} \ln \left(\frac{P_{K^+}[K_k^+] + P_{Na^+}[Na_k^+] + P_{Cl^-}[Cl_b^-]}{P_{K^+}[K_b^+] + P_{Na^+}[Na_b^+] + P_{Cl^-}[Cl_k^-]} \right)$$



typical concentrations for K^+
inside: 400 mM
outside: 20 mM

Nernst equation

$$E_{ion} = RT/zF * \ln([ion]_o/[ion]_i)$$

R: gas constant=8.315 J/(K*mol)
T: temperature [K]
F: faraday constant=96.485 C/mol
z: valence of ion

at 20° C

$$E_{ion} = 58.2 * \log([ion]_o/[ion]_i)$$

E_K= -76 mV (inside negativ)

at body temperature (37° C)

$$E_{ion} = 61.5 * \log([ion]_o/[ion]_i)$$

E_K= -80.01 mV

Properties of electrotonic potentials

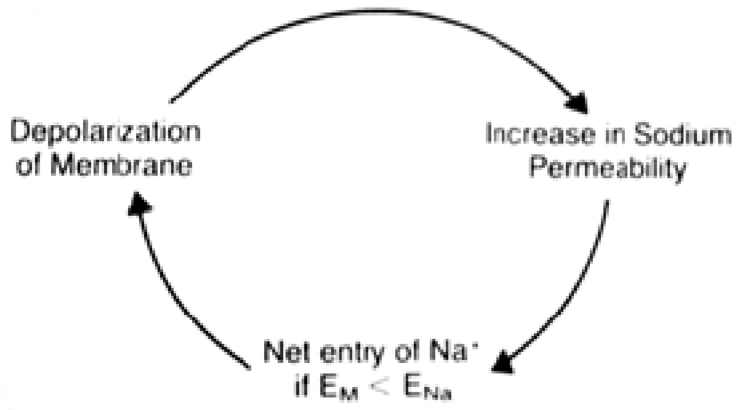
- Graded response determined by the strength of the stimulus
- Depolarizing or hyperpolarizing direction
- Time course determined by the membrane time constant
  $\tau = R \bullet C$
- Response in elongated cells determined by the membrane length constant
  $\lambda = rm / ri$
- No refractory periods
- Passive, linear membrane behaviour, voltage dependent Na channels do not open

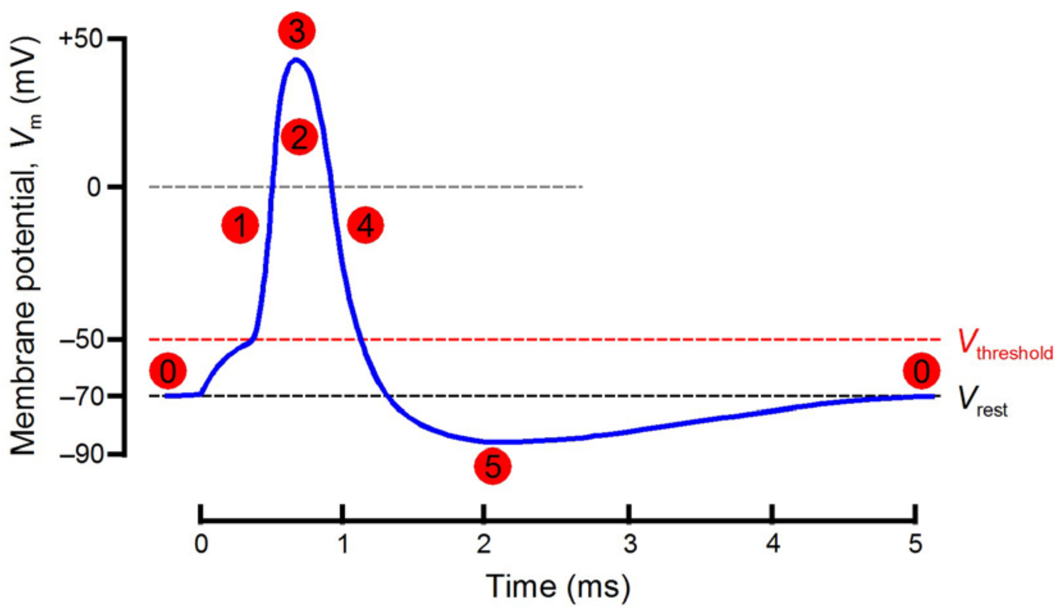
The action potential

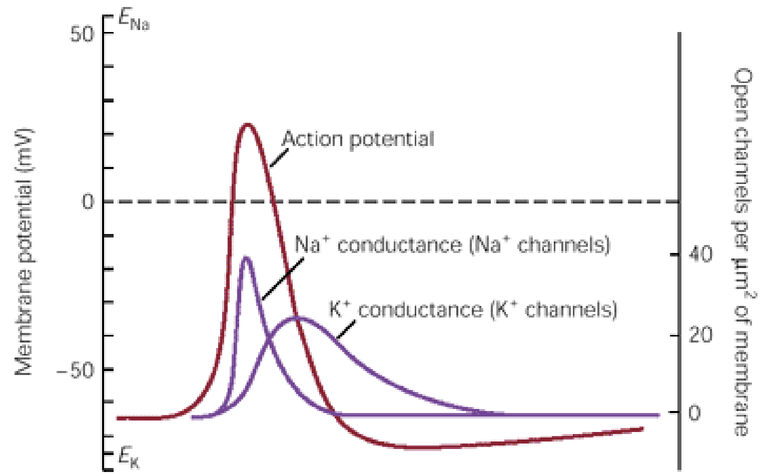
<u>The time course of action potential and the associated g_{Na} and g_K:</u>

1. electrotonic foot region (propagation)
2. fast changes of g_{Na} (Hodgkin-cycle)
3. slow changes of g_K (afterhyperpolarization)

Hodgkin-cycle:

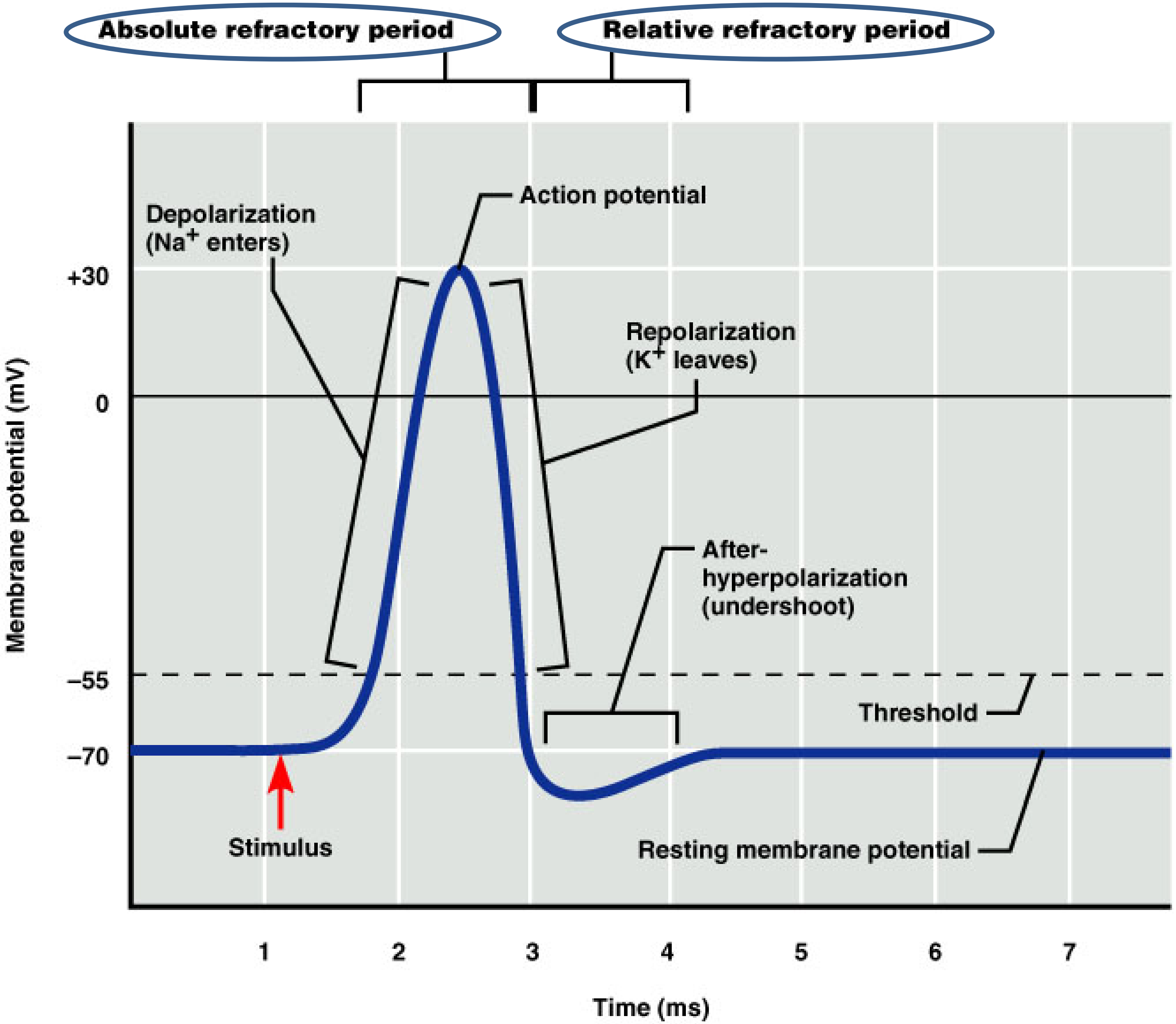






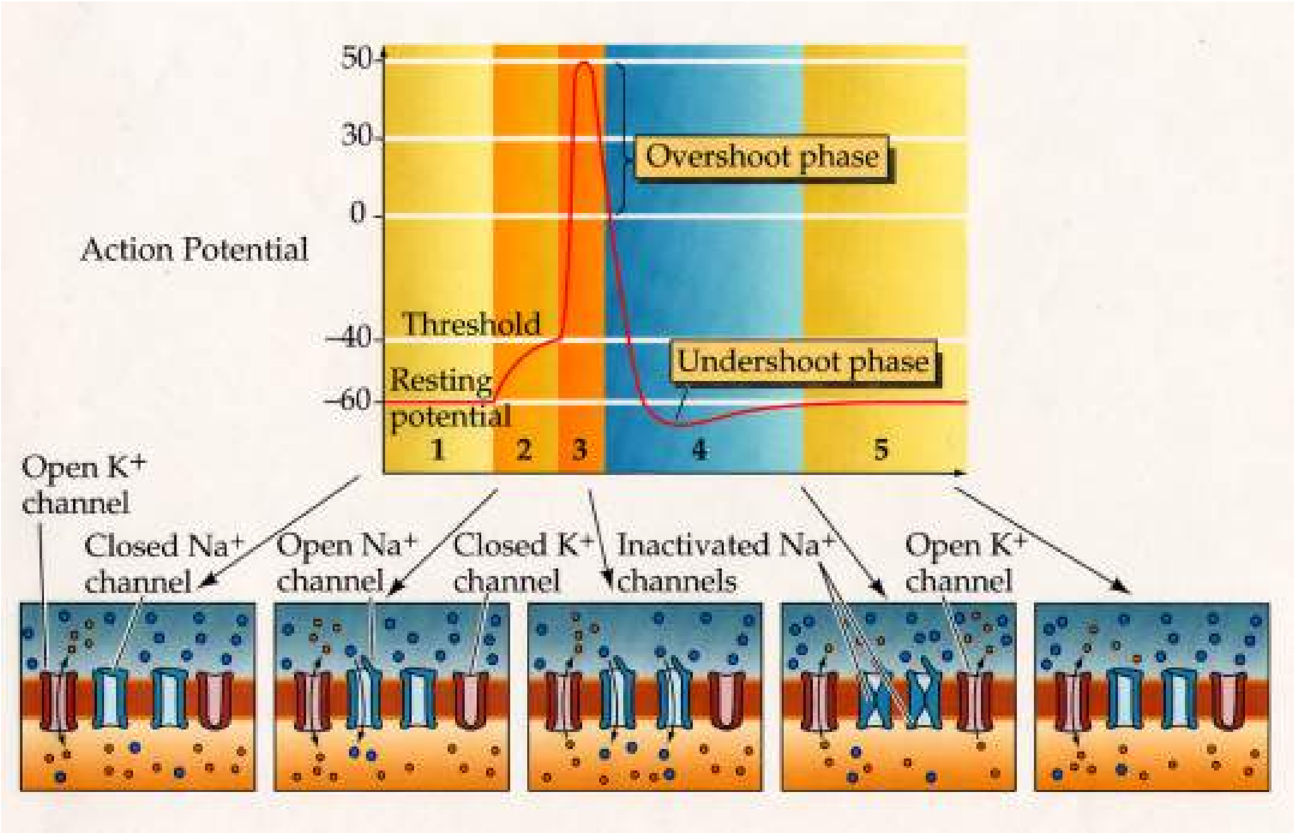
Repolarization

- Ensured by the *activation of K^+ channels* and the consequent K^+ efflux
  - Voltage-gated K^+ channels are NOT ESSENTIAL for the repolarization to occur – but they are rather handy, as they ensure much faster repolarisation, without which high frequency firing would not be possible
- *Not the Na^+/K^+ pump is responsible for repolarization*
  - *pump is responsible for **long-term maintenance** of the electrochemical gradients*


Absolute refractory period
Relative refractory period
Action potential
Depolarization
(Na^+ enters)
+30
Repolarization
(K^+ leaves)
0
Membrane potential (mV)
After-
hyperpolarization
(undershoot)
–55
Threshold
–70
Stimulus
Resting membrane potential
1
2
3
4
5
6
7
Time (ms)

- the **peak of the action potential** is determined by
- – the **sodium equilibrium potential**
- – the **time course of sodium channel inactivation**
    - The peak of AP approaches the sodium
- Nernst-potential (~ +60 mV)

Ion Flow in 5 Phases of the Action Potential



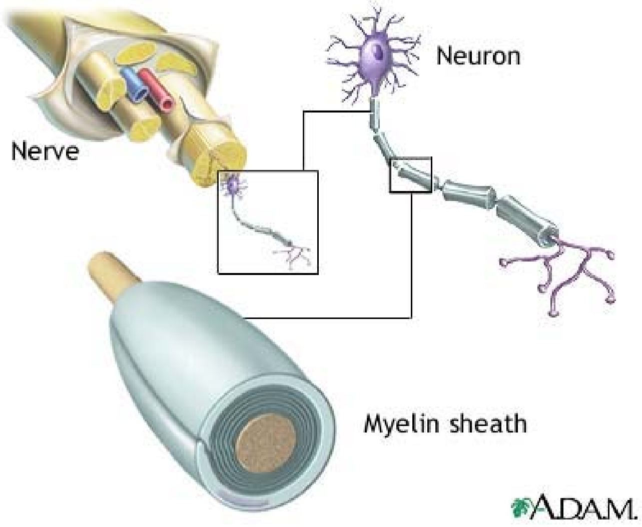
AP propagates without decrement

- Because the AP in one region causes depolarization that triggers an AP in an adjacent region or node

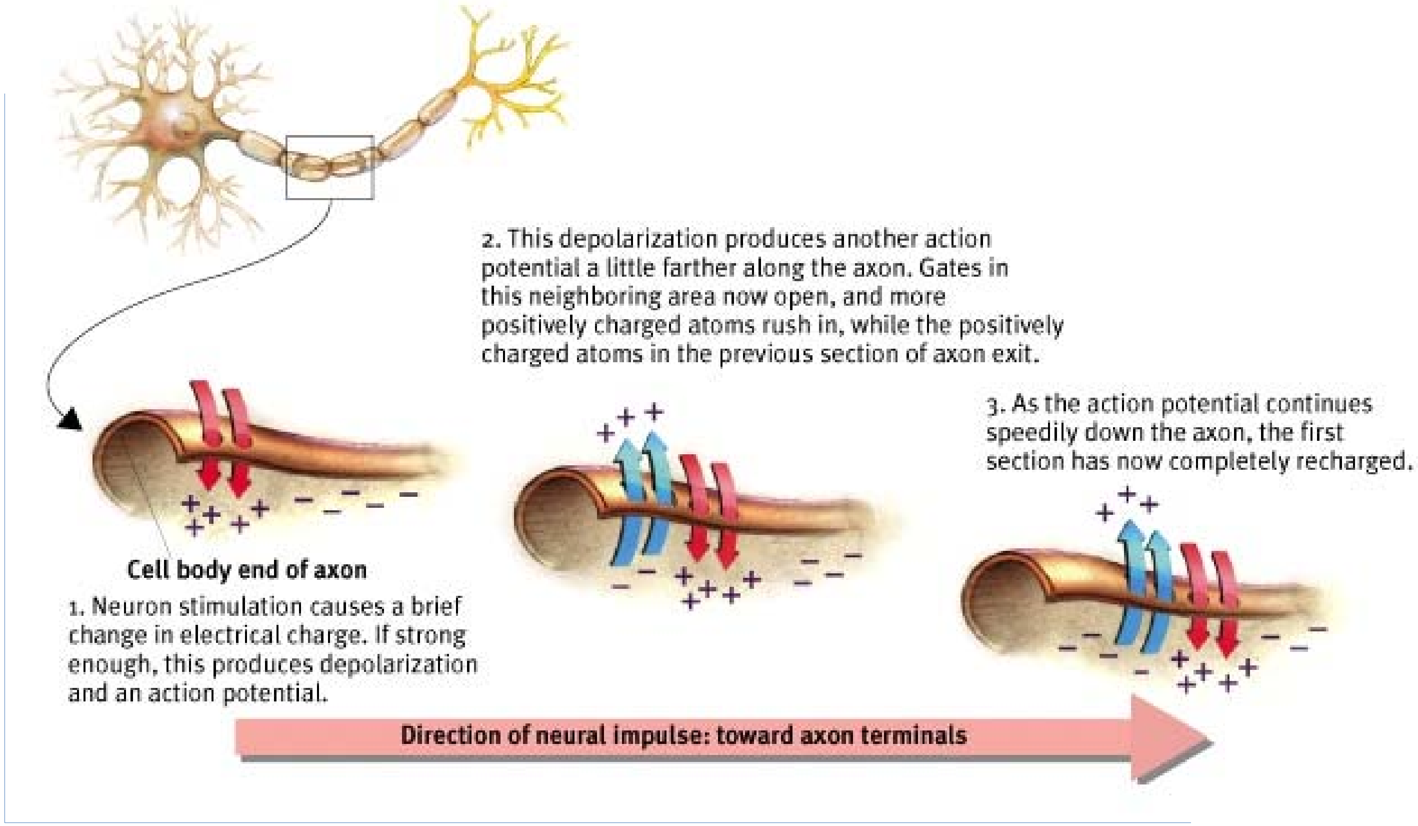
- **Factors affecting conduction velocity**
- • *Size*
- • *Myelination*

Myelin

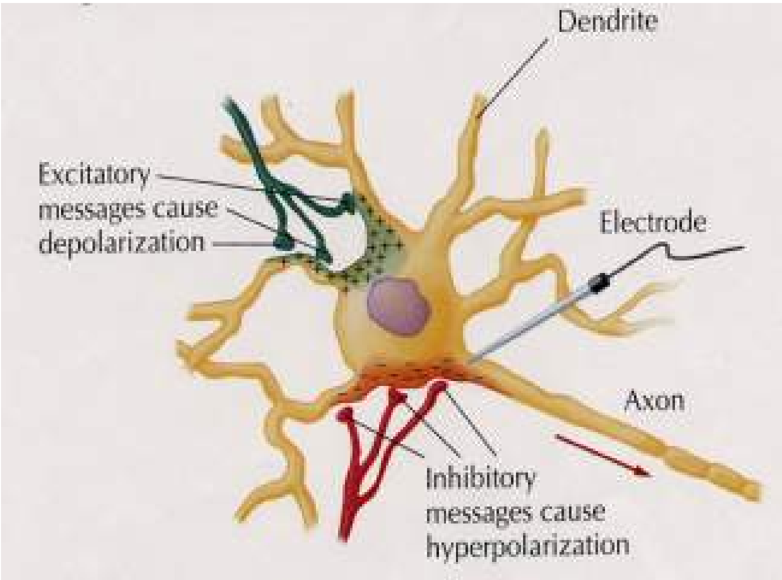
- Myelin is a fatty, waxy substance coating the axon of some neurons.
- Functions:
  - Speeds neurotransmission
  - Insulates neurons from each other
  - Makes neurotransmission more efficient

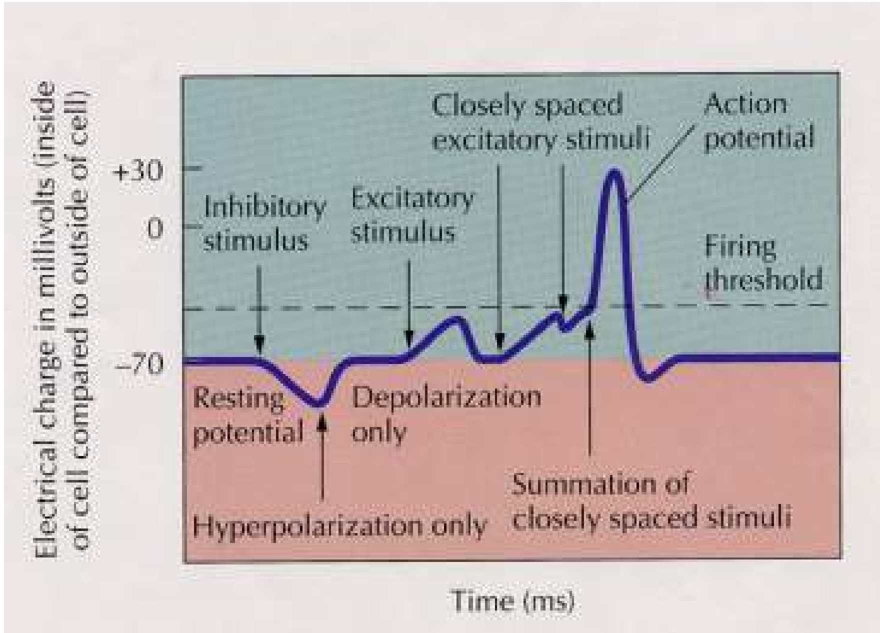


How Impulses Travel Down the Neuron



Summation of EPSPs and IPSPs





Synaptic Transmission and Brain Neurochemistry