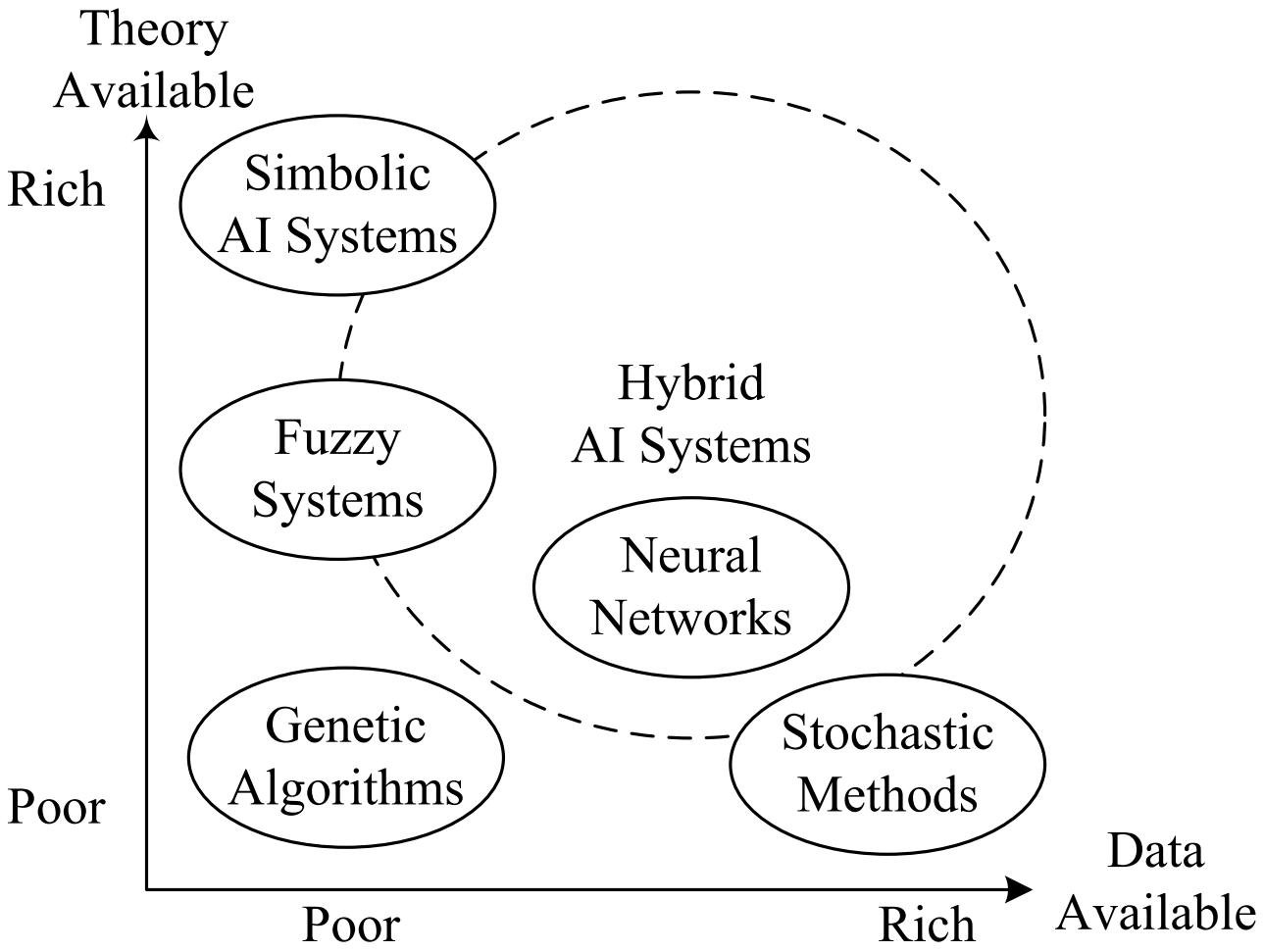
Methods in Knowledge Engineering



Gödel's Conjecture

Kurt Gödel presented in 1931 a conjecture
that shook the dominant mathematics conviction . In simple words Gödel's conjecture is:

"Every axiomatic formulation free of contradictions in number theory contains sentences that can not be verified nor denied"

Otherwise a **computer programs** could always be written **to solve any problem** that could be formalized!

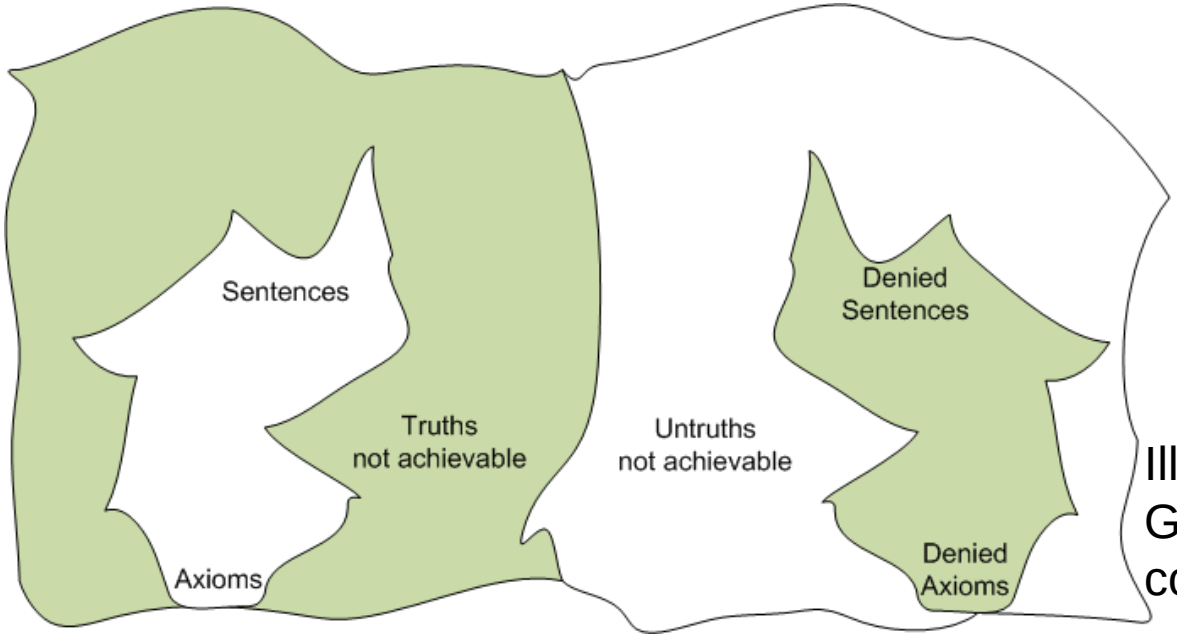


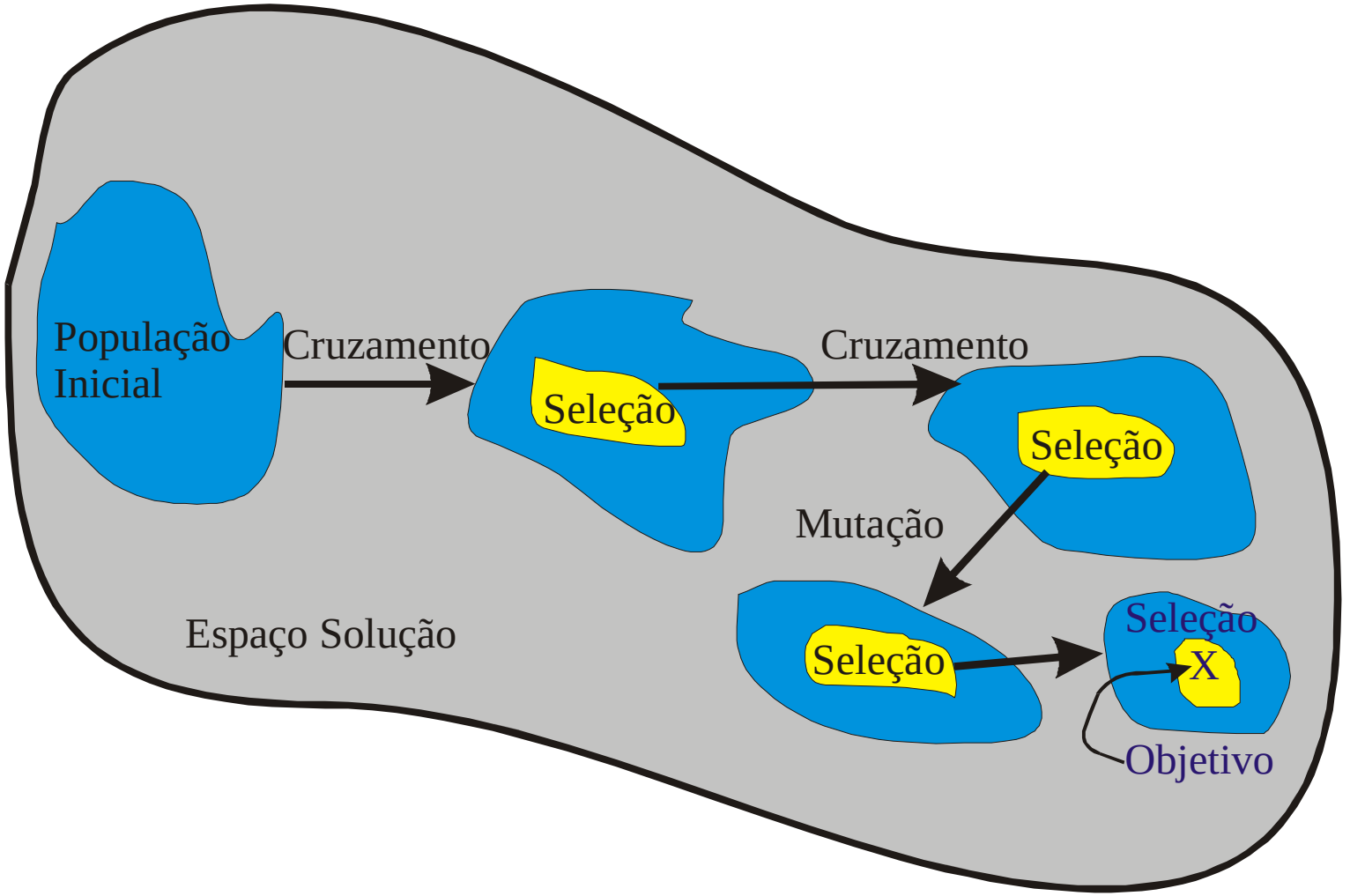
Illustration of Gödel's conjecture

Genetic Algorithms

- Genetic algorithms, as well as the so-called evolutionary computing, are **heuristic methods** for solving problems.
- John Holland, proposed GAs in 1975, inspired by Darwin's evolution theory

- Basic Concepts
  - Gen
  - Chromosome - represents an individual, a possible solution
  - Population
  - Crossing
  - Mutation
  - Evaluation Criteria
  - Selection

Graphical representation of the GA



Example: Mastermind game

guess the number 001 010

The selection criterion is the proximity to the number 001010 (number of correct bits).

Initial Population	Evaluation	Selection
A 010101	1	
B 111101	1	
C 011011	4	*
D 101100	3	*

New population in which the individuals C and D are the parents.

	New Population	Evaluation	Selection
C 01:1011	E 01 11 00	3	
D 10:1100	F 10 10 11	4	*
C 0110:11	G 01 10 00	4	*
D 1011:00	H 10 11 11	3	

Example: Mastermind game (cont.)

guess the number 001 010

New population in which the individuals F and G are the parents.

		New Population	Evaluation	Selection
F	1:0 10 11	I 11 10 00	3	
G	0:1 10 00	J 00 10 11	5	*
F	10 1:0 11	K 10 10 00	4	*
G	01 1:0 00	L 01 10 11	4	

New population in which the individuals J and K are the parents.

		New Population	Evaluation	Selection
J	00 10: 11	M 00 10 00	5	
K	10 10: 00	N 10 10 11	5	*
J	00 10 1:1	O 00 10 10	6	Success – END
K	10 10 0:0	P 10 10 01	3	

Success after 16 questions.

By exhaustive search we would have $2^6 =$ 64 possible questions.

Universal Approximators

A heuristic rule is of the form:

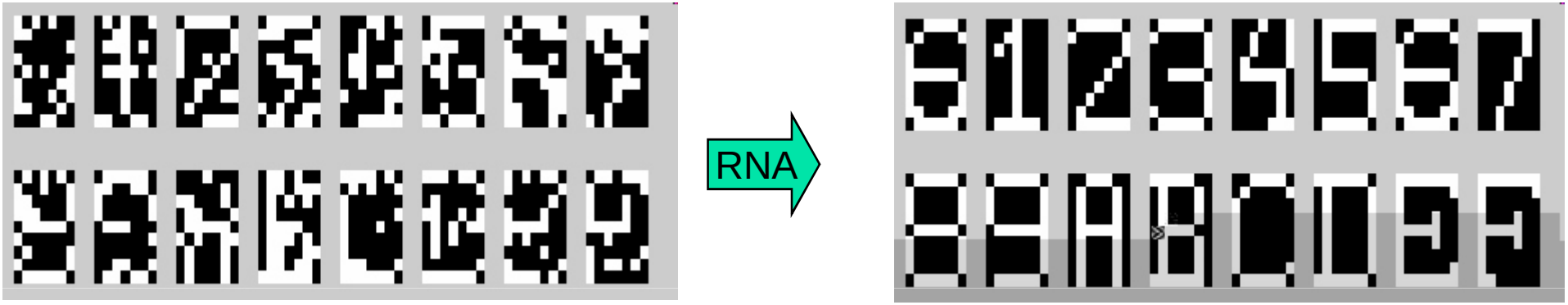
IF <condition> THEN <conclusão>

- fuzzy systems - heuristic knowledge represented by fuzzy rules.
- artificial neural networks - learn heuristics from the data.

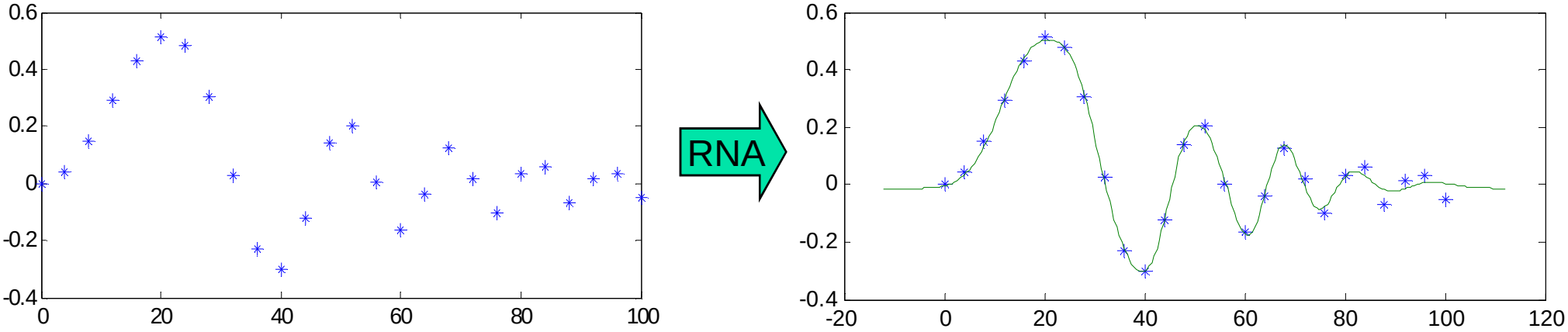
Both are ***universal approximators***,
that is, they can approximate any function with **arbitrary precision**.

ANN Applications

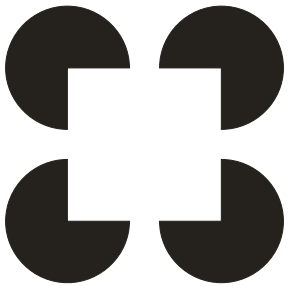
- Pattern Classification

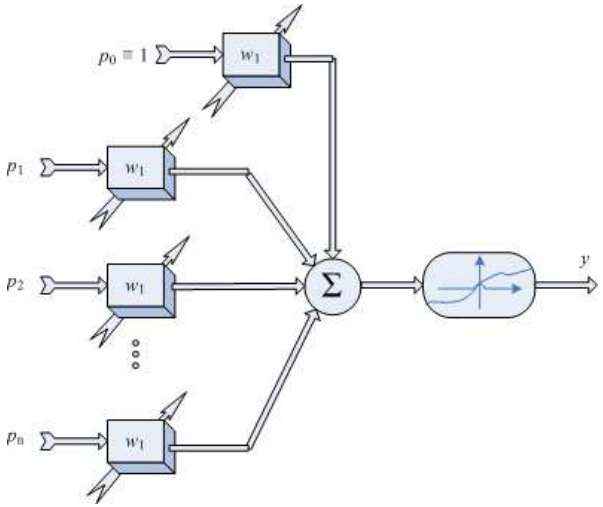


- Function Approximation (non linear)



Part 2 – Artificial Neural Networks

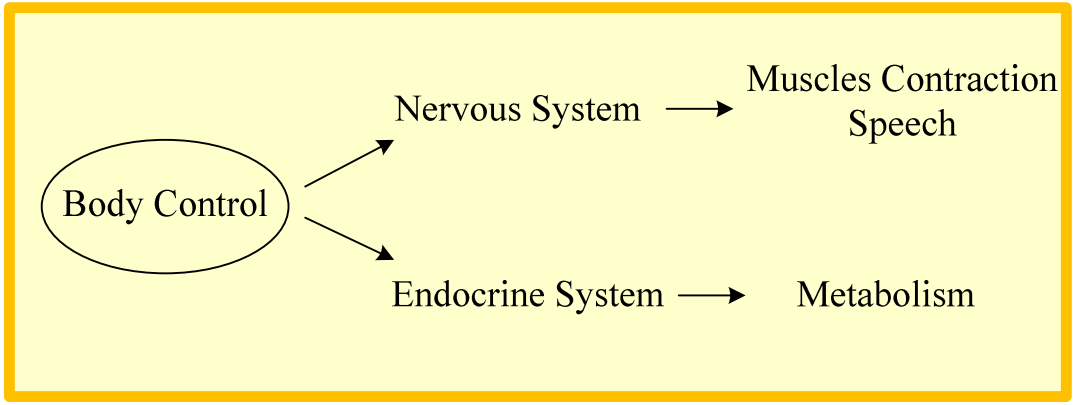




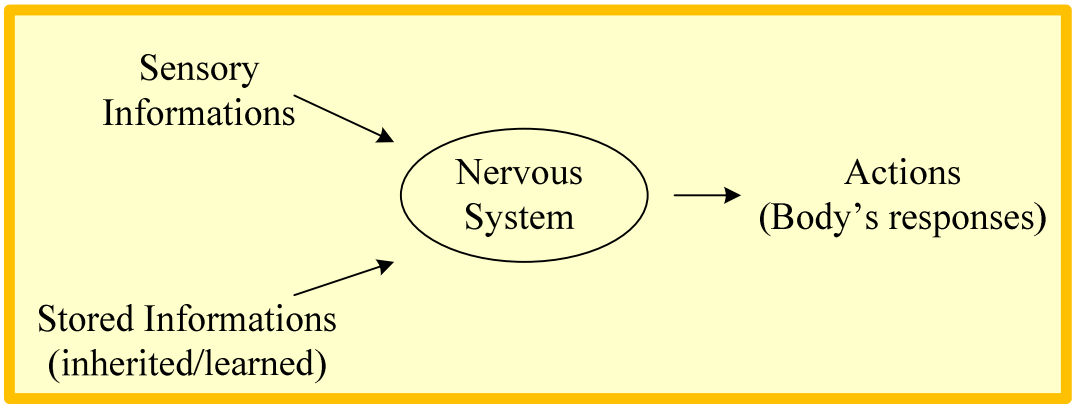
Biological Fundaments

The nervous systems gatters information from the surroundings through sensors wich are combined with stored information to produce the actions of the body.

Only a small part of the captured information is relevant to the well functioning of the body.



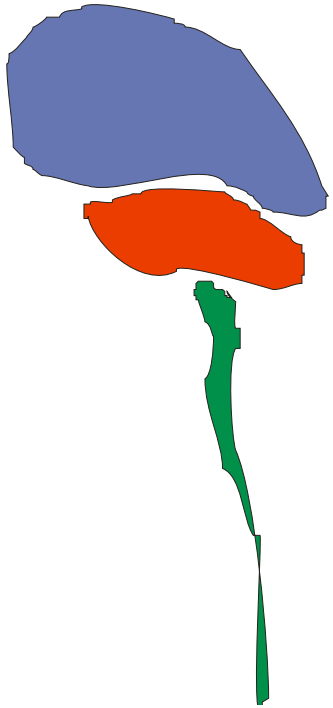
The nervous systems and the endocrine systems control the body.



Sensors + Memory + Inference → Action.

Biological Fundaments

The nervous system comprehends three levels.



Cortex

Low Brain

Spinal Cord

Each one build by
neurons of different anatomies.

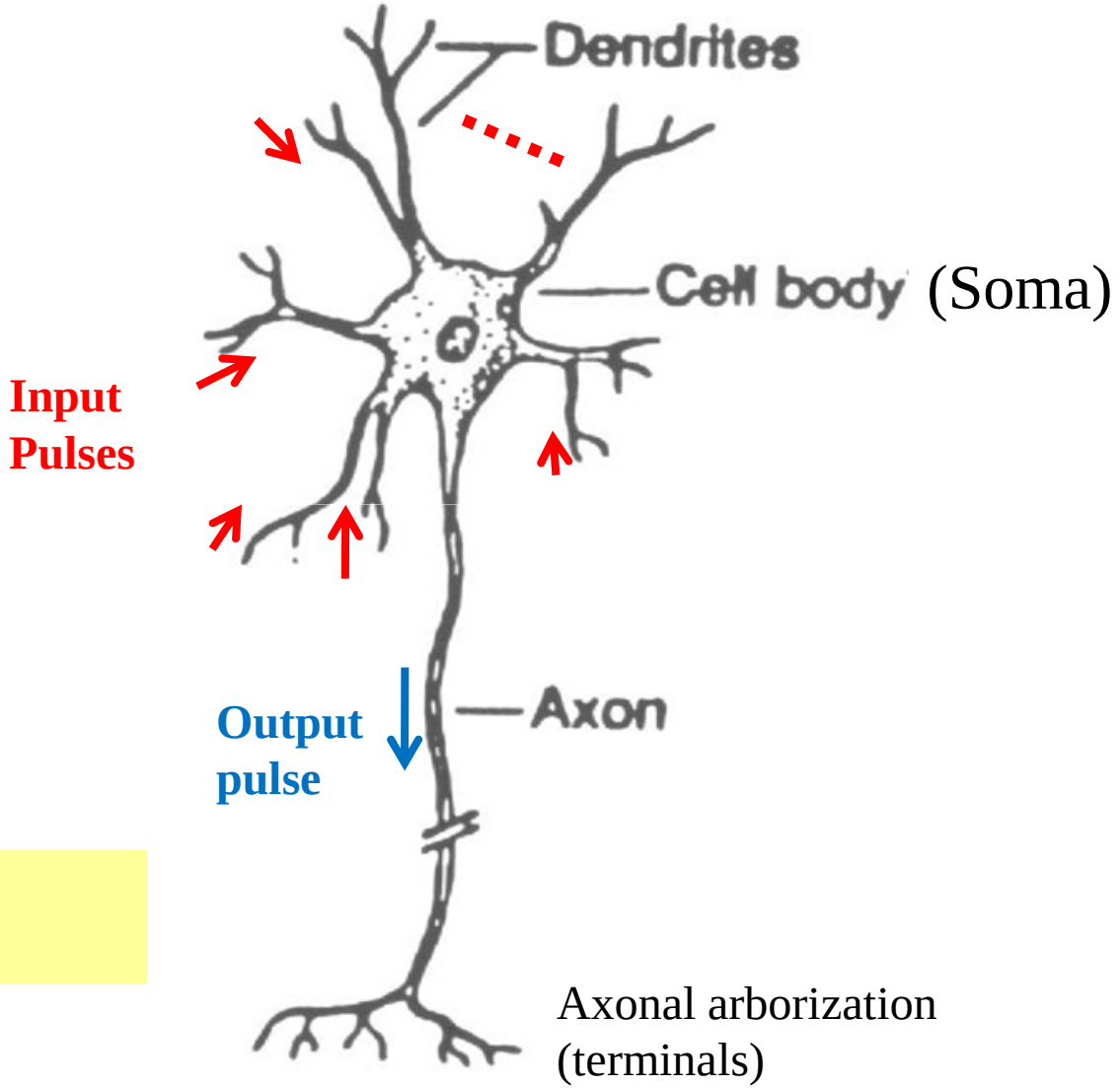
It is estimated that the human brain has about 10^{11} neurons,

Whose summed lenght reaches 10^{14} meters.

Biological Fundaments

Brain Information Processing Levels

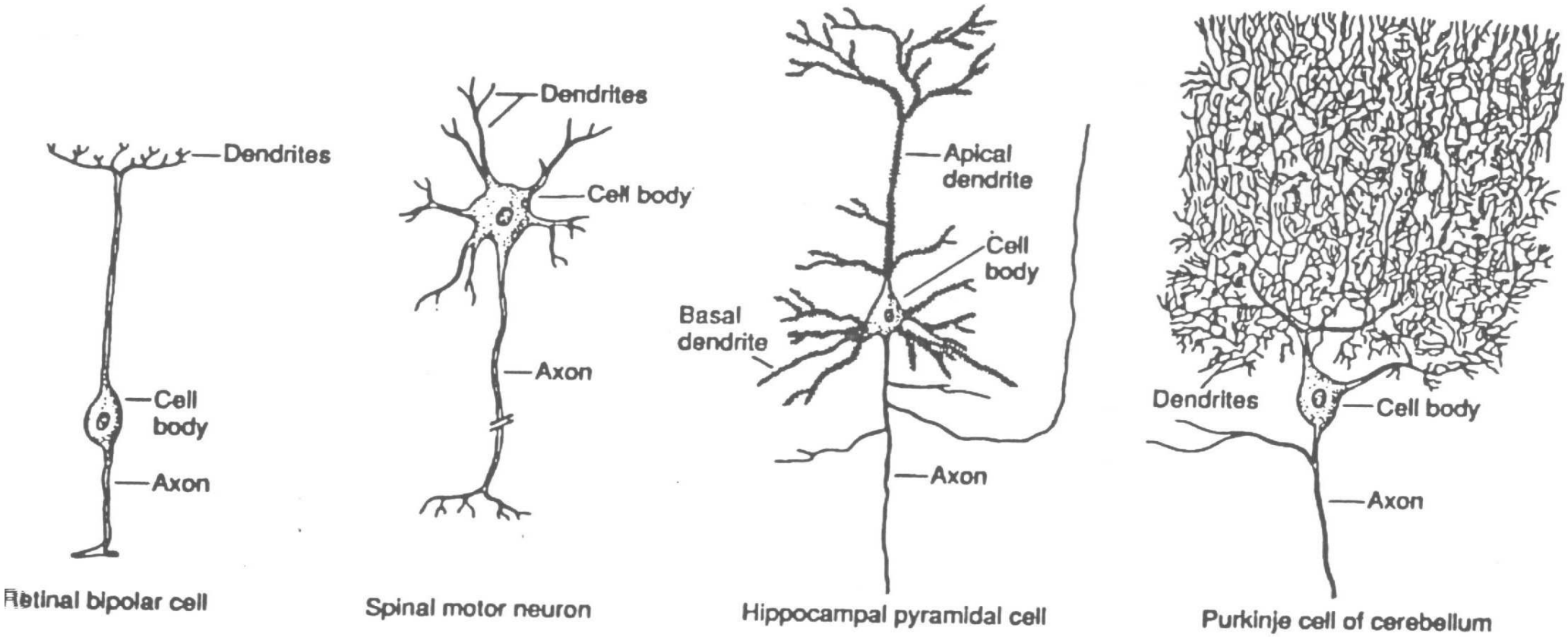
- Structural
- Physiologic
- Cognitive



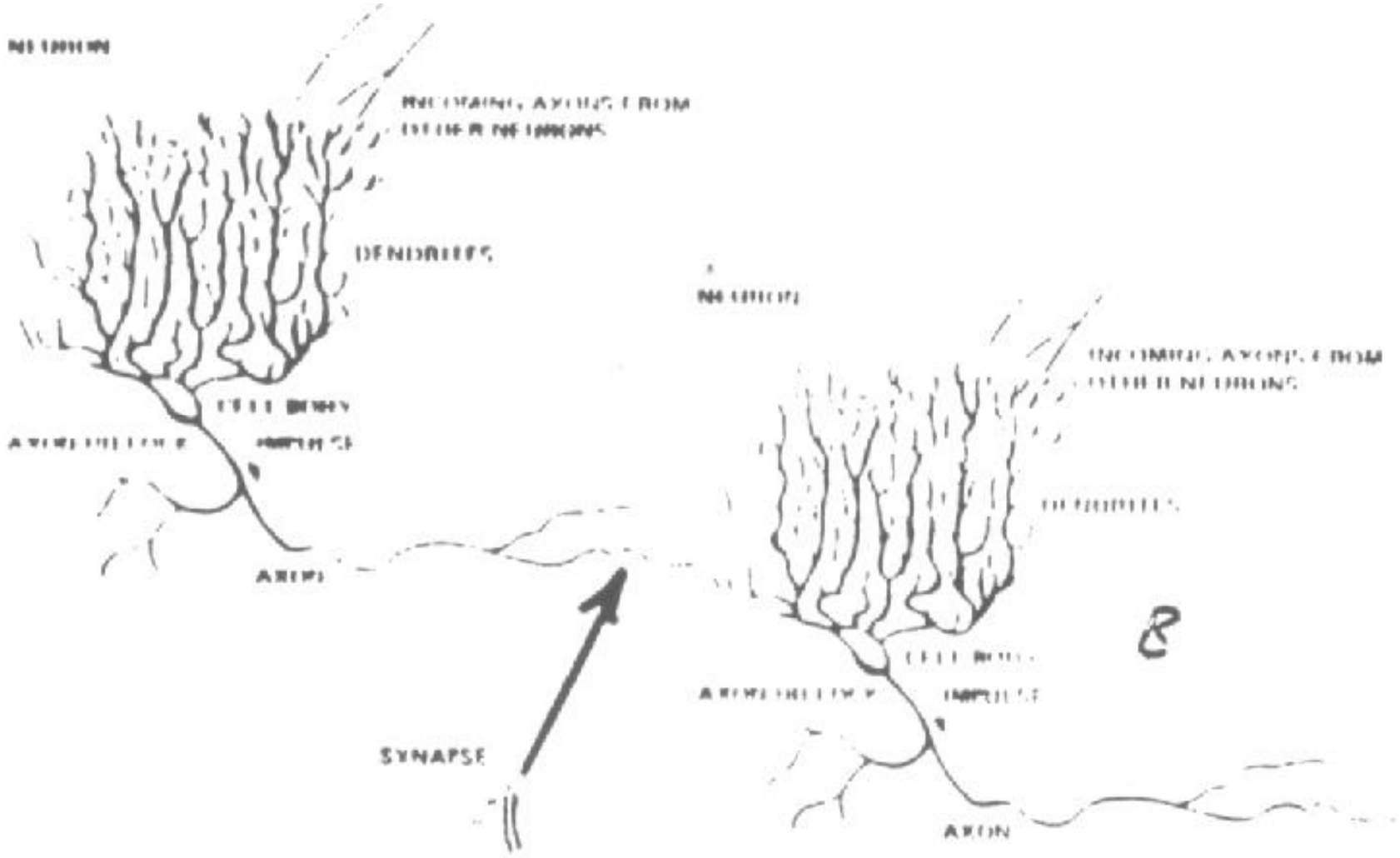
The information flow (electric current) is always from the dendrites to the axon.

Biological Fundaments

Some kinds of neurons

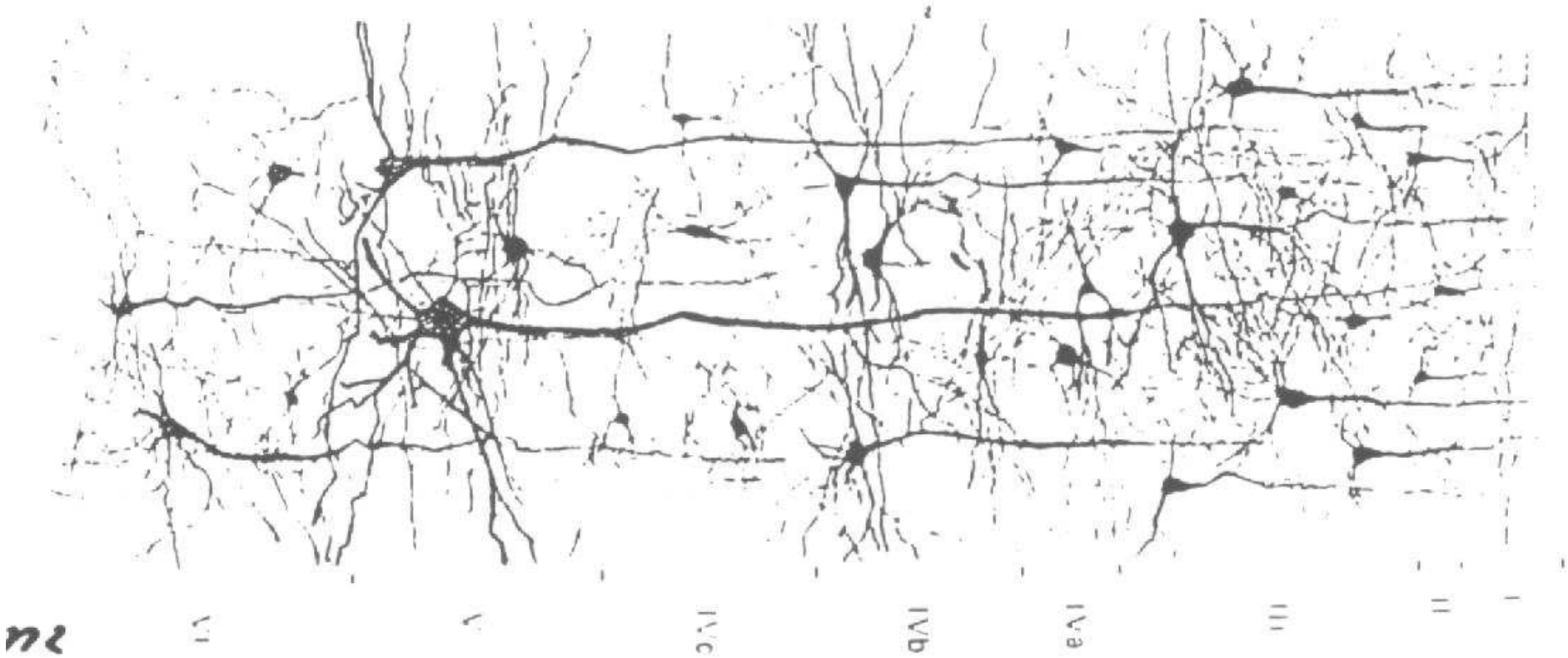


Synaptic Connection

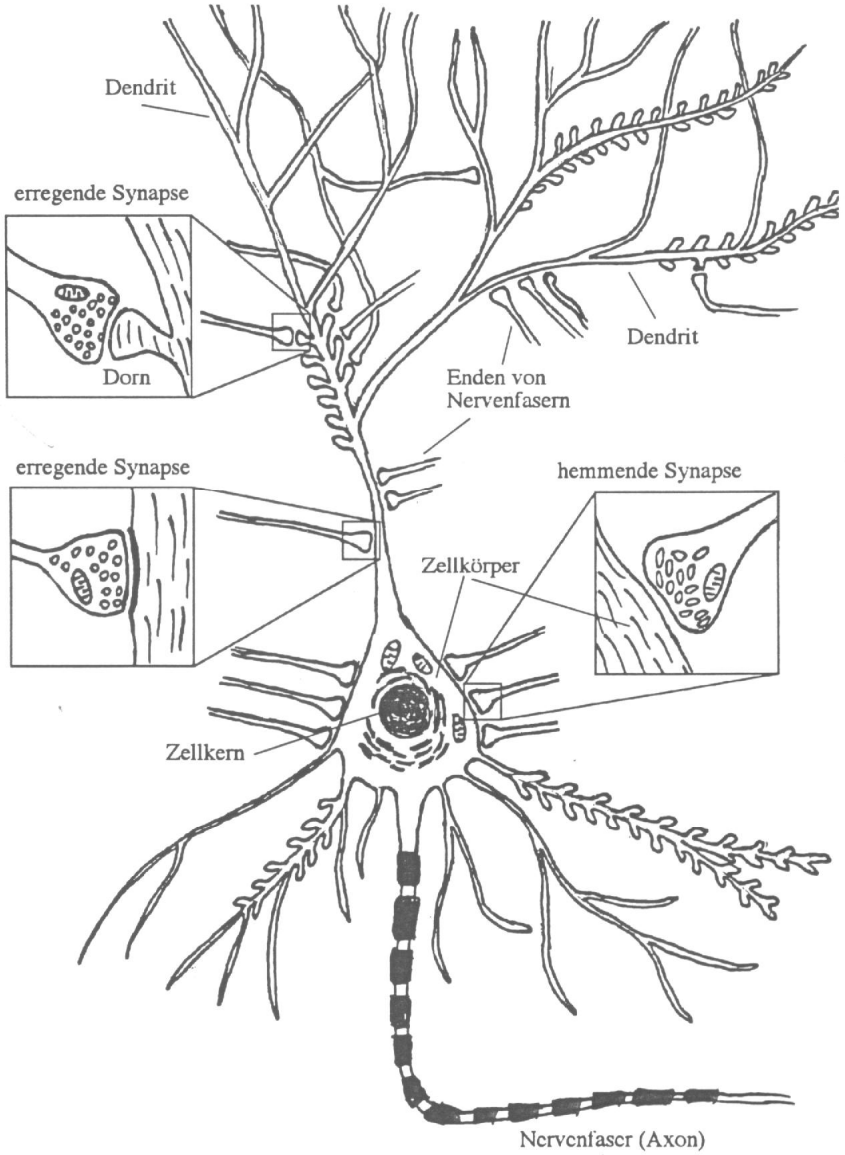


Biological Fundaments

Connection pattern: mostly in layers



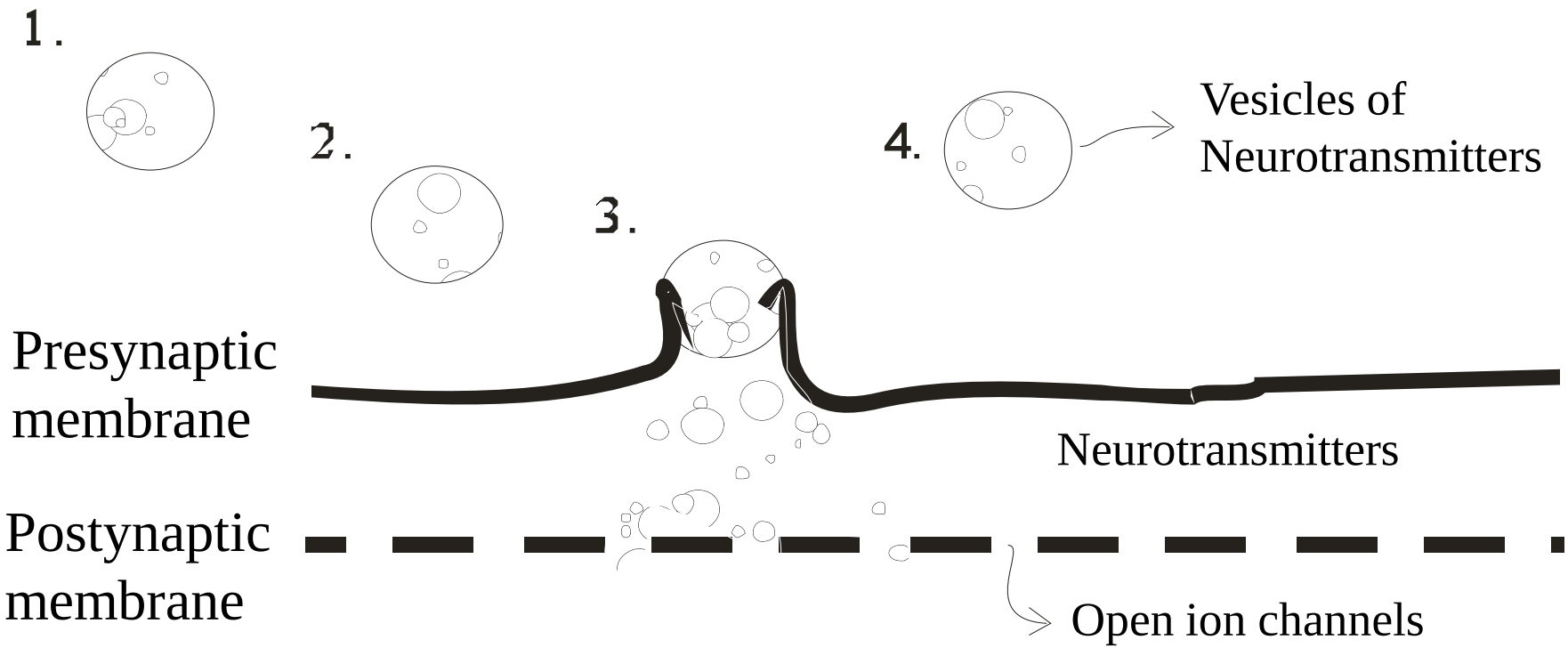
Excitatory and Inhibitory Synapses



Synapses
- Excitatory: $A \uparrow \Rightarrow B \uparrow$
- Inhibitory: $A \uparrow \Rightarrow B \downarrow$

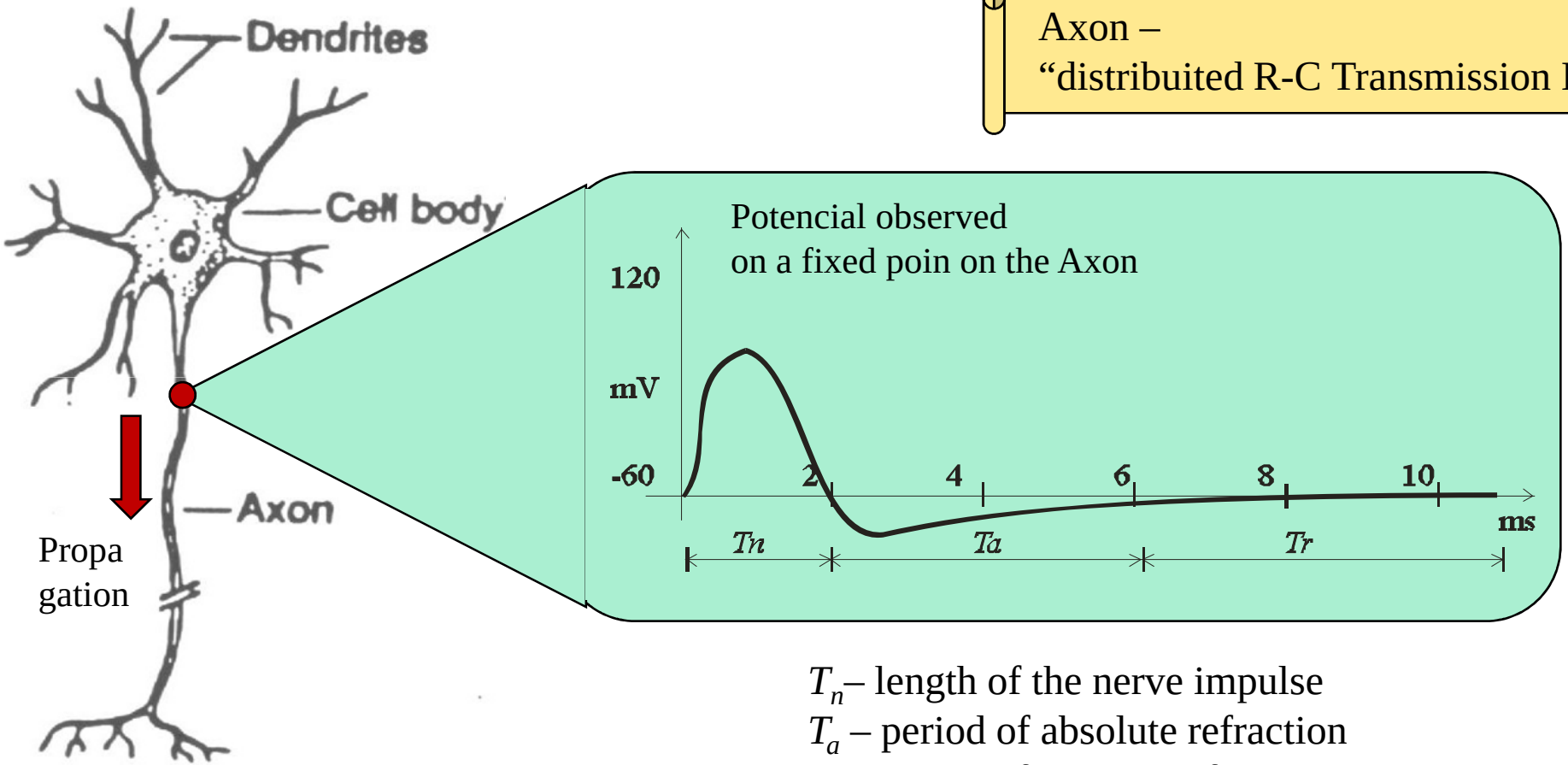
Biological Fundaments

Neurotransmiters in the synaptic gap



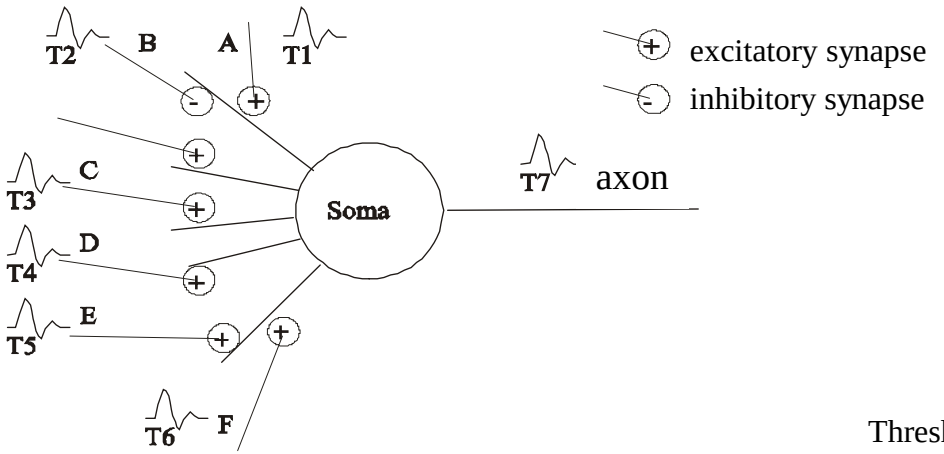
The Action Potential

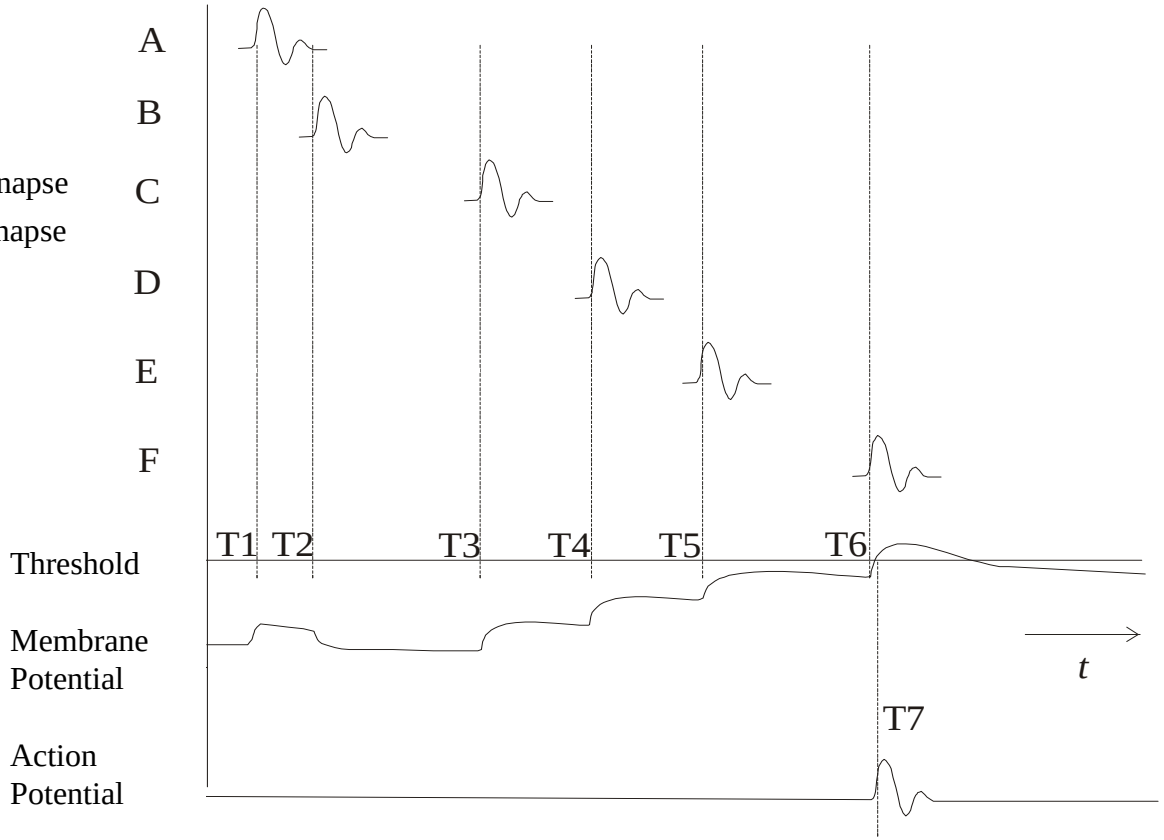
Axon –
"distribuited R-C Transmission Line"



T_n– length of the nerve impulse
T_a – period of absolute refraction
T_r – period of relative refraction

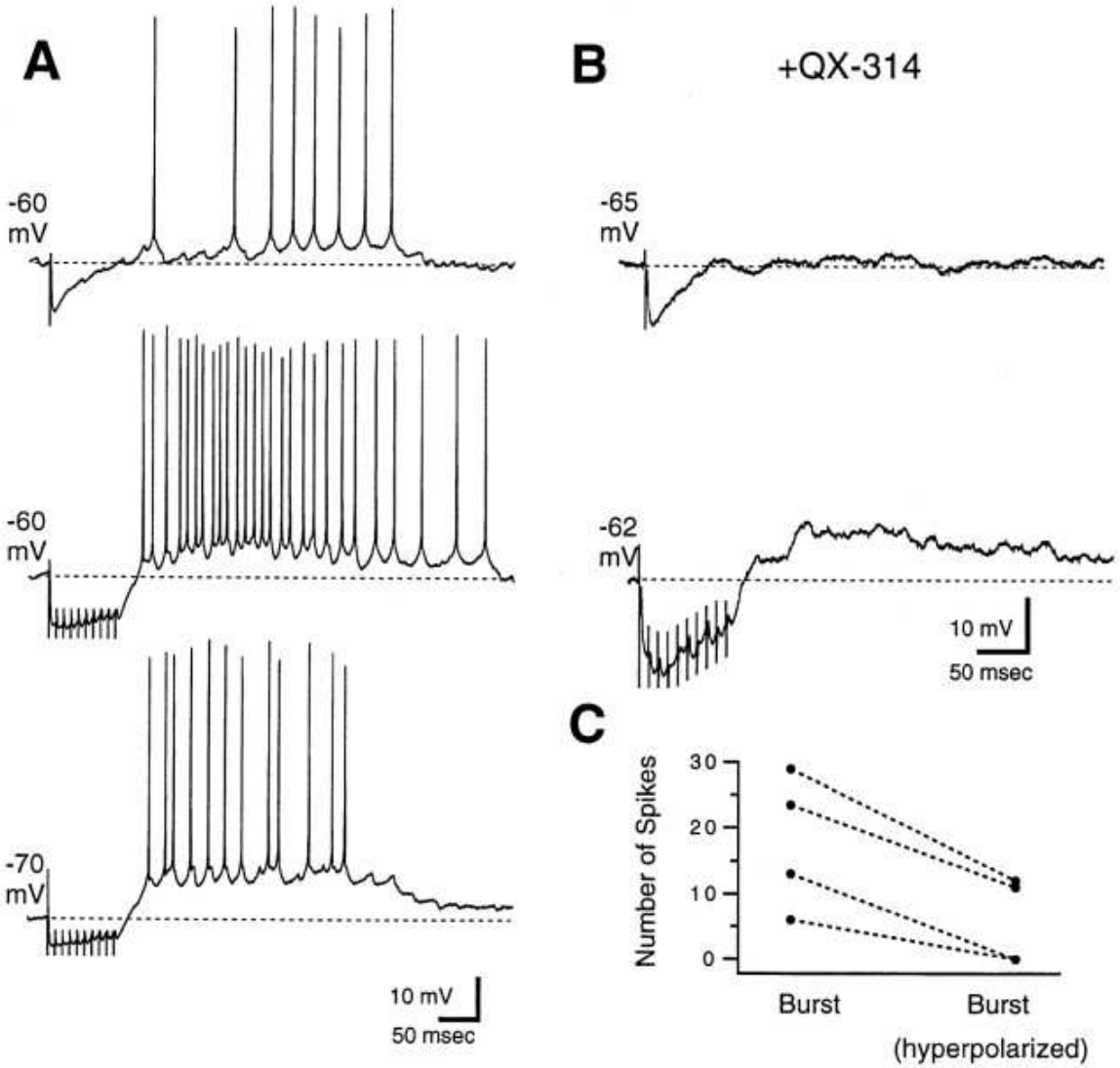
Space/Time Integration of the stimuli





Anatomy - structure
Physiology – function, operating modus

Pulse frequency as the information



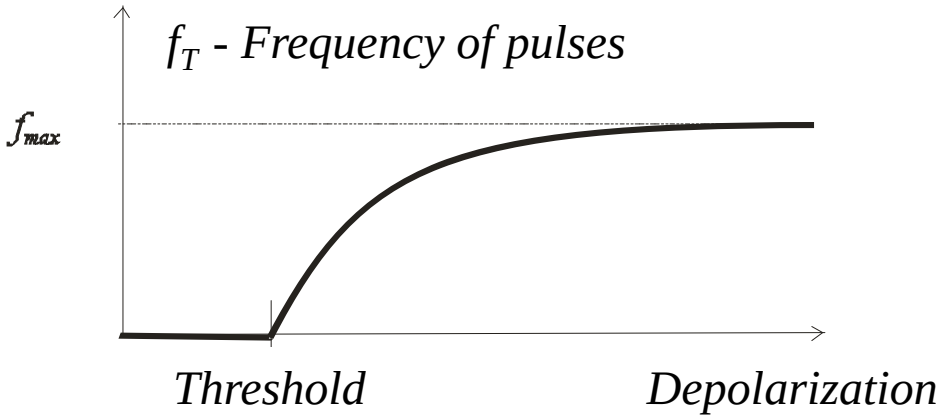
Biological System:
Information is coded using
Pulse Frequency Modulation

Aizenman et al.,
Polarity of Long-Term Synaptic Gain Change is Related to Postsynaptic Spike Firing at a Cerebellar Inhibitory Synapse,
Neuron, Vol. 21, 4, 1998.

Space/Time Integration

Maximum frequency of pulses in the axon

$$f_{\max} = \frac{1}{T_a + T_n}$$

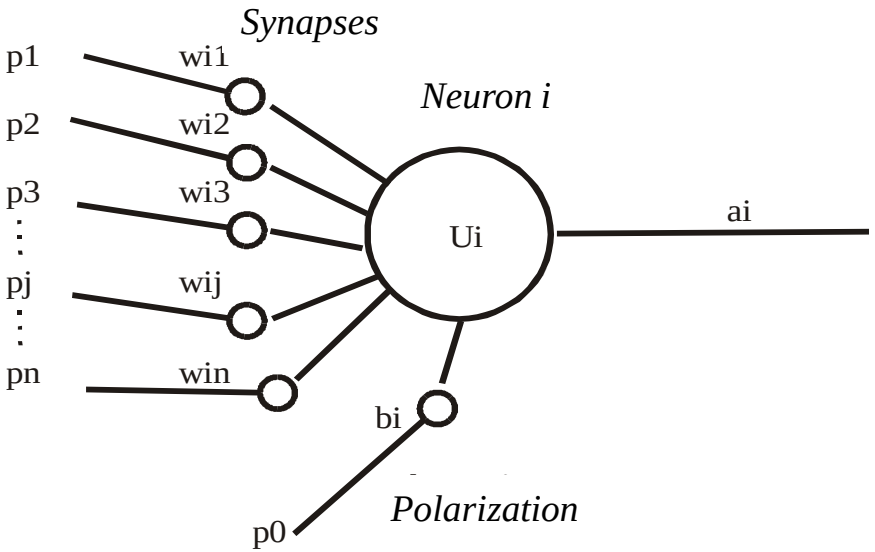


$$f_T = g\left(\int_0^T \sum_i \alpha_i(t)\, x_i(t)\, dt\right)$$

f_T – average frequency of nerve impulses in the time interval T,
$\alpha_i(t)$ – synaptic gains,
$x_i(t)$ – inputs of neurons.

Difficult to implement as an Electrical circuit!!

Basic model of an artificial neuron

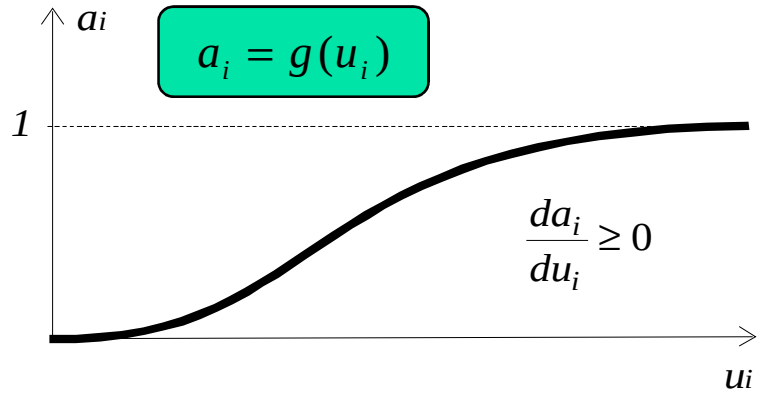


$$u_i = \sum_{j=1}^{n} w_{ij} p_j + b_i = \mathbf{w}_i^t \mathbf{p} + b_i$$

$$\mathbf{p} = \begin{bmatrix} p_1 \\ p_2 \\ \vdots \\ p_n \end{bmatrix}, \qquad \mathbf{w} = \begin{bmatrix} w_{i1} \\ w_{i2} \\ \vdots \\ w_{in} \end{bmatrix}.$$

Excitatory synapse $w_{ij} > 0$,

inhibitory synapse $w_{ij} < 0$.



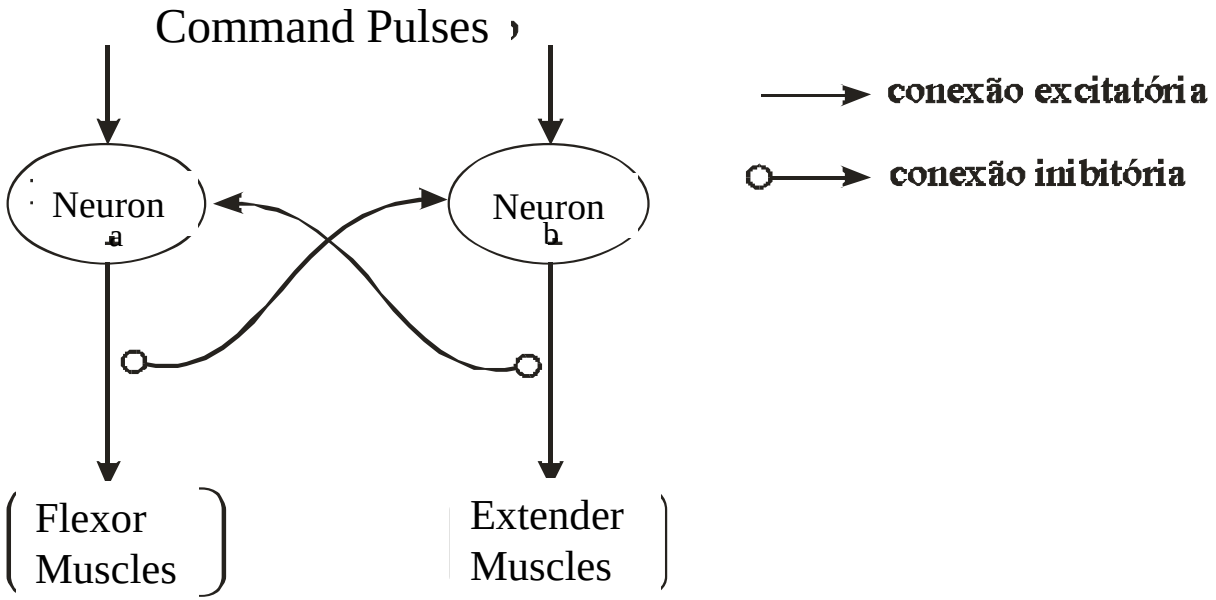
$$a_i = g(u_i)$$

$$\frac{da_i}{du_i} \geq 0$$

g(.) - Usually, a non-Linear activation function, e.g.: Sigmoid (“S” shaped)

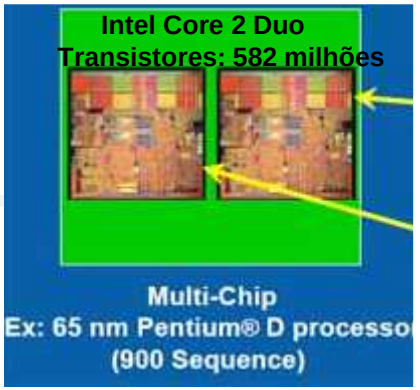
ANN – same funcionality
easy DSP implementation !!

Neurons with lateral connection



Neural circuit with antagonism inhibition

Comparison Brain x Computer



	Brain	*Computer*
# processing elements	~ 10^{11} neurons	~ 10^{9} transistors
Processing Form	Massively parallel	In general serial
Memory	Associative	Addressed
Switching time	~ 1 ms	~ 1 ns
Switchings /s	~ 10^{3} /s	~ 10^{9} /s
Total Switchings (theory)	~ 10^{14} /s	~ 10^{18} /s
Total Switchings (real)	~ 10^{12} /s	~ 10^{10} /s

100 steps rule

People recognize a familiar face in ~0.1 s.

Considering 1ms per neuron: 100 sequential steps to recognize the pattern.

⇒ parallel processing architectures!

Historical Perspective of ANNs

1943 McCulloch	Boolean neuron	
1949 Hebb	Learning rule	
1957 Rosenblatt	Perceptron	
1960 Widrow-Hoff	ADALINE/MADALINE	LMS
Rosenblatt	Multilayer Perceptron, without training	
1969 Minsky-Papert	*Perceptrons*	
1974 Werbos	*Error Backpropagation Algorithm – without repercussion*	
1982 Hopfield	Network with feedback	
1986 Rumelhart, Hinton & Williams		
PDP – MIT	*Backpropagation for Multilayer Perceptron*as Activation Funciont still continuous sigmoid	
1987 Kosko	BAM	

Starting Enthusiasm

Disenchantment

Resurgence