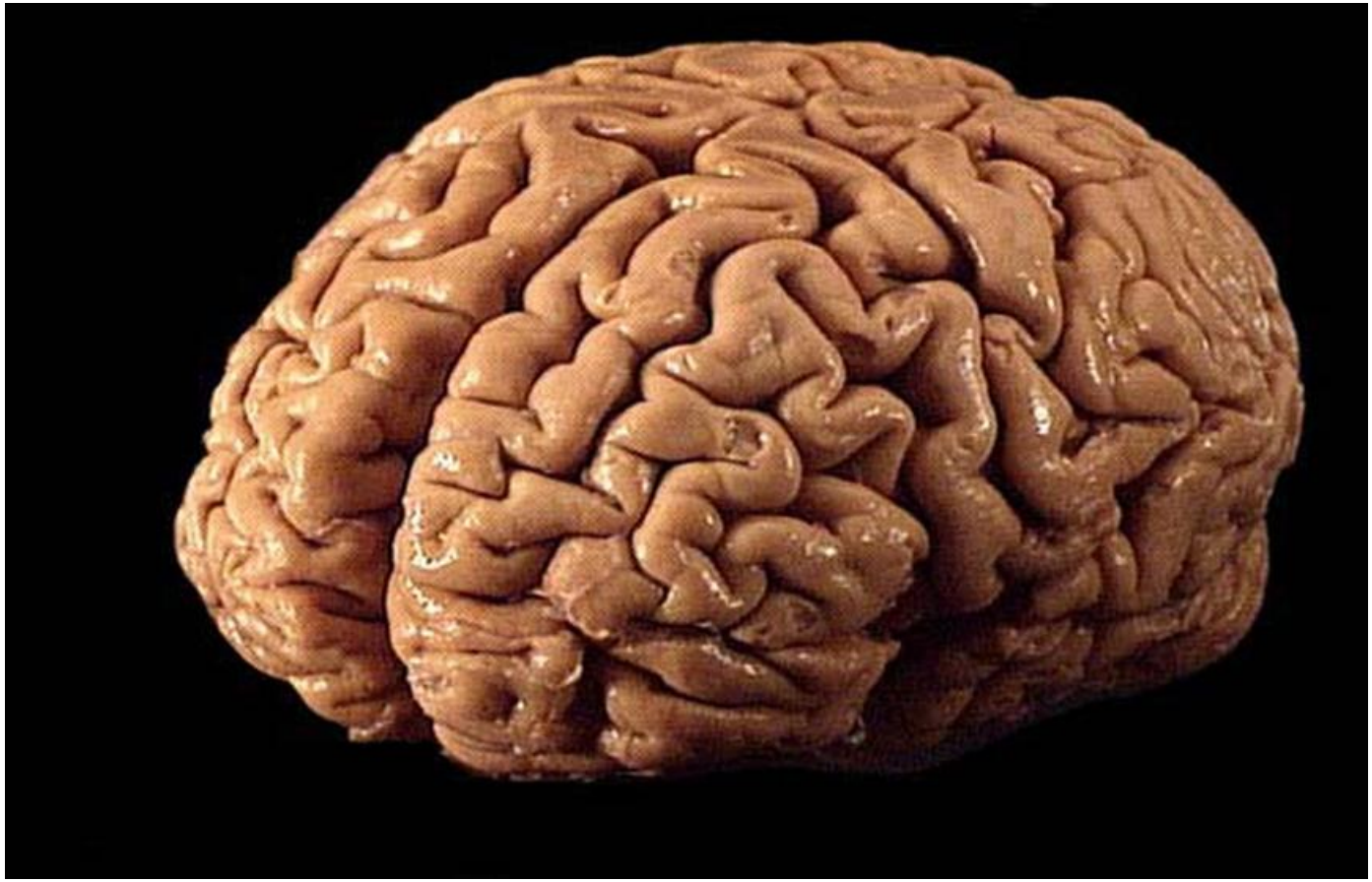
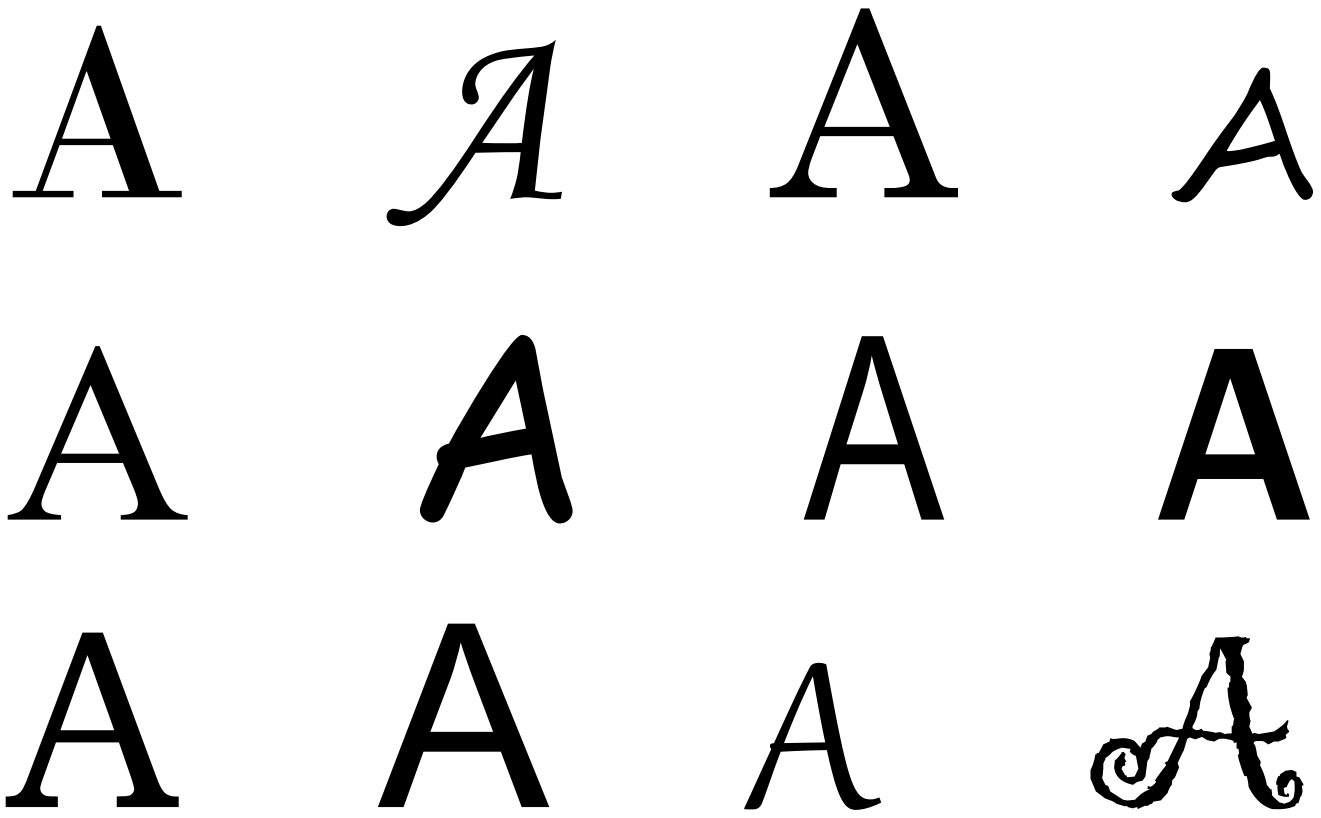
Human Vision: Electrophysiology and Psychophysics

Why study biological systems?



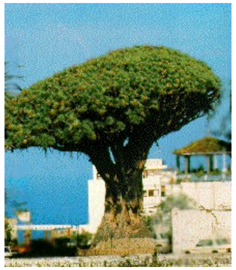
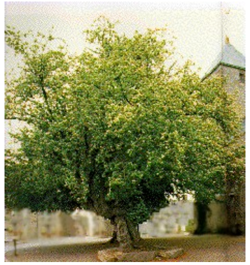
Pattern recognition











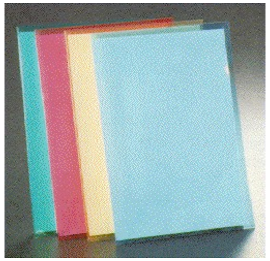


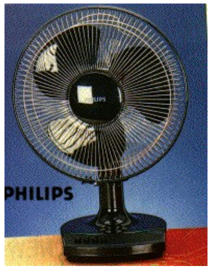











PHILIPS

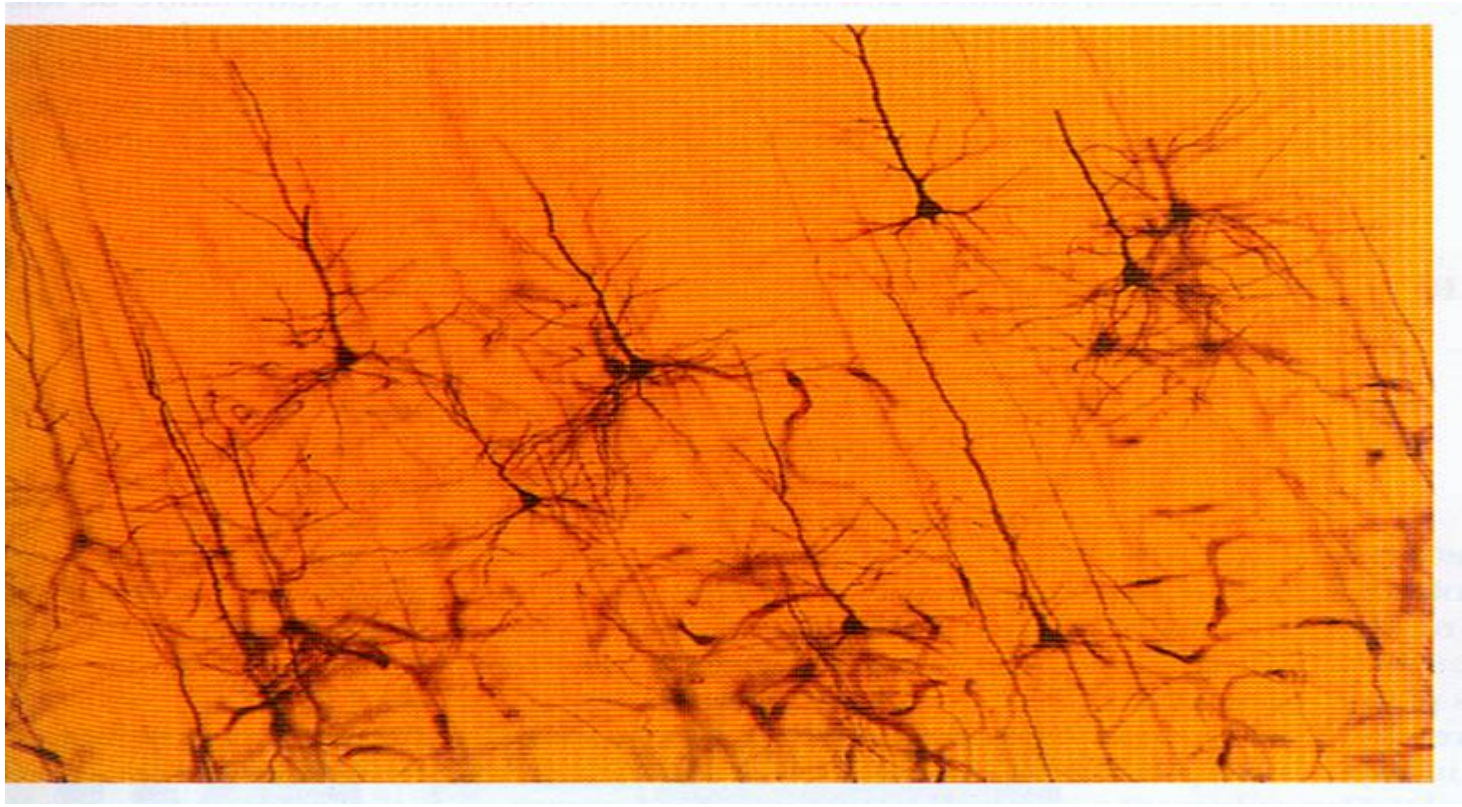
Artificial neural networks are used to solve problems in fields as diverse as

- pattern recognition
- optimisation
- locomotion and spatial recognition
- sequence prediction

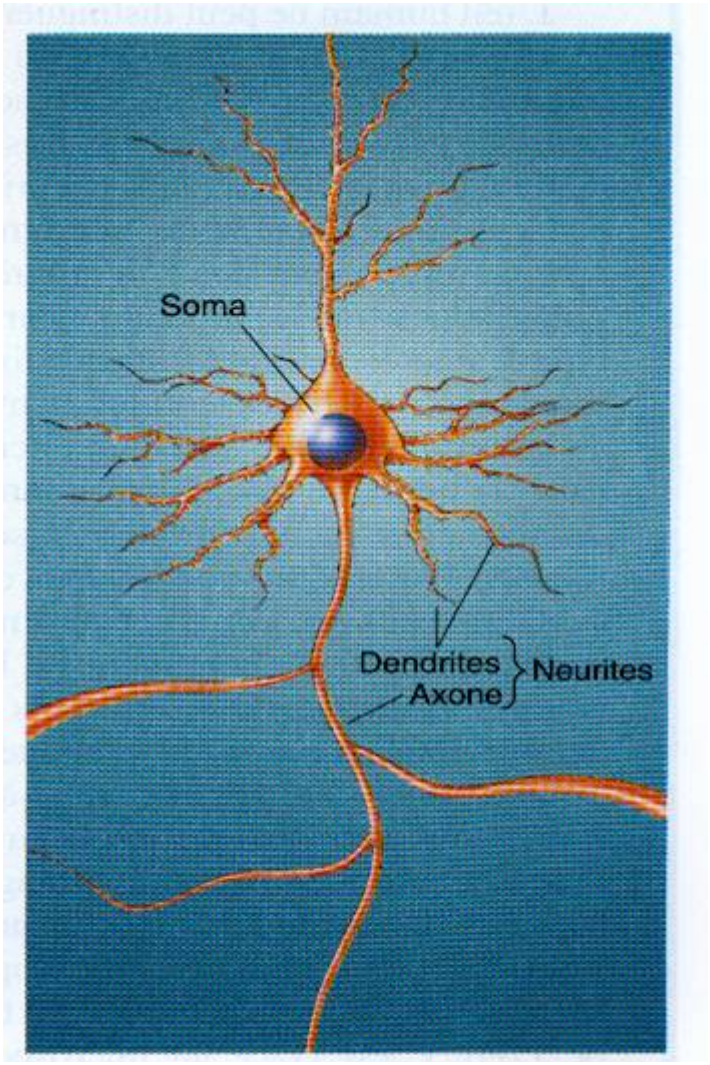
In contrast to previous efforts in artificial intelligence, there is focus not only on the algorithm necessary for solving a problem, but also the underlying brain architecture and physiology that solves this problem.

Short Introduction to Neuroscience

The brain is made up of neurons



At one time there was a debate as to the question of whether the brain was composed of a continuous system of wires or whether it was a discontinuous network made up of individual neurons



Soma – contains the nucleus

Dendrite – receives input

Axone – sends output

The neuron is a superchip

The neuron is the basic building block for all the activities in the brain – these activities are as diverse as

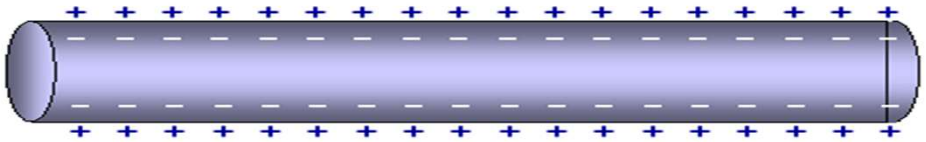
- sensory function – vision, audition, touch, smell
- motor functions – muscle contraction
- perception
- cognition

For these functions, one neuron can receive upto 10000 contacts and send signals to hundreds of other neurons.

The neuron and electricity

Question Why are neurons frequently described even in the experimental field with terms that come from the field of electricity

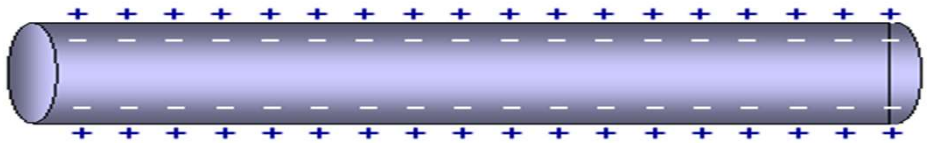
Answer This is because biological membranes exhibit properties similar to electrical circuits.



The neuron and electricity

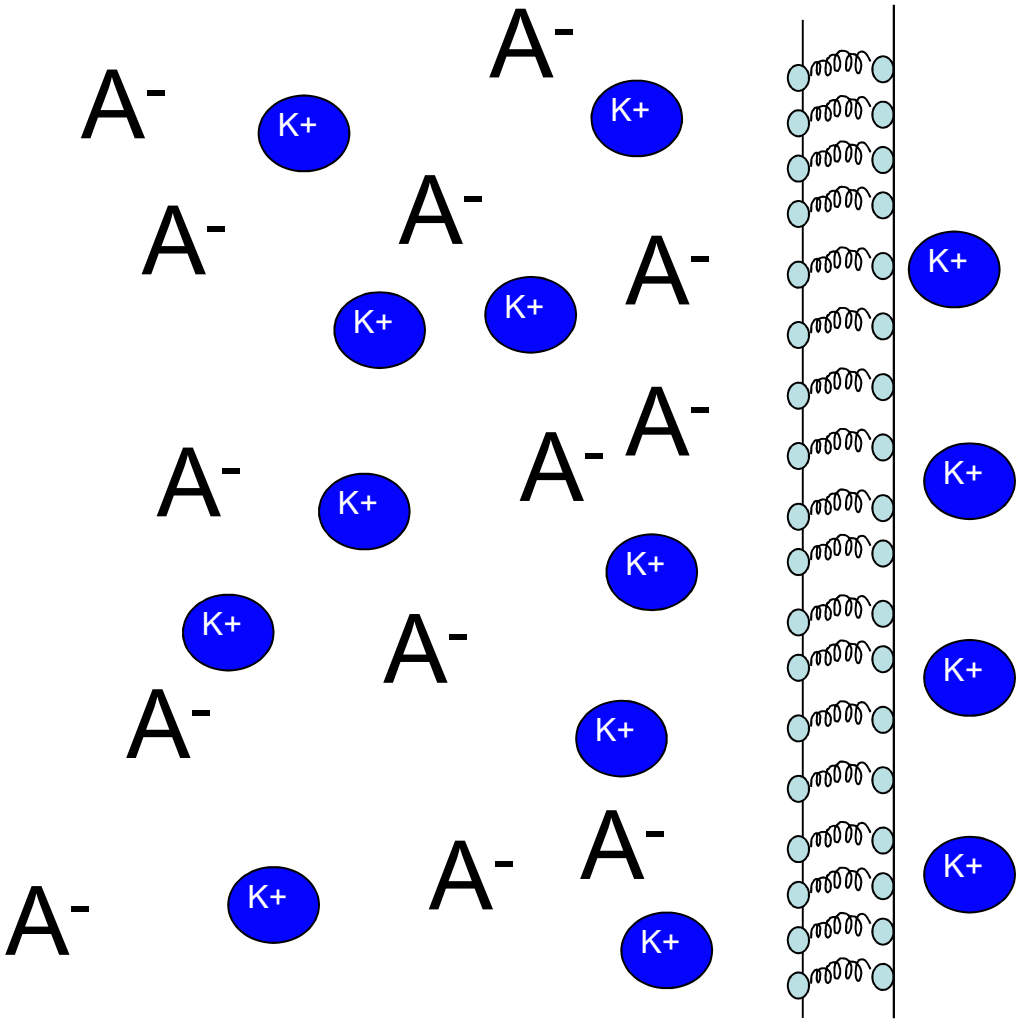
Question What is the source of this electricity?

Answer A differential distribution of charges (ions) across the neuronal membrane



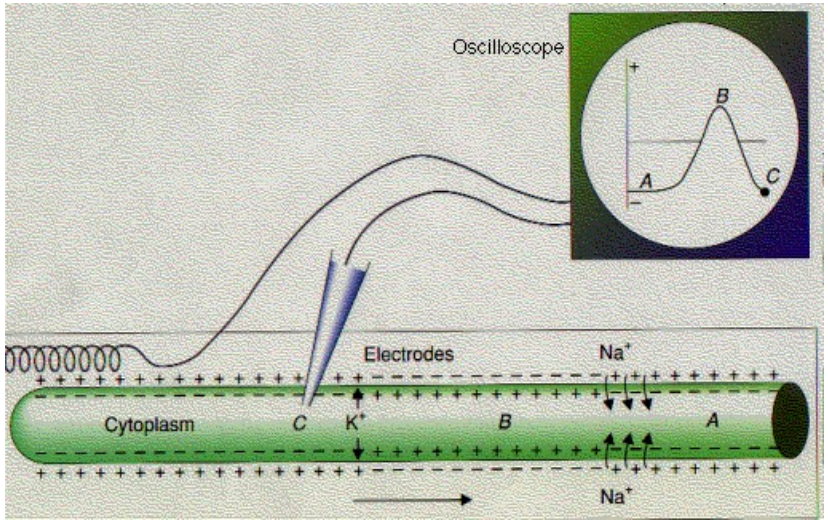
This creates a potential difference called the membrane potential. In a neuron at rest (ie a neuron that is not actively sending out signals), this is called the resting membrane potential. It is about -60mV.

Large negatively charged molecules in the cell. These anions lead to a NET negative charge across the membrane



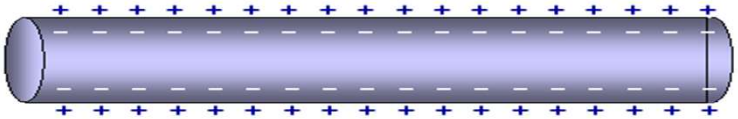
Recording the membrane potential

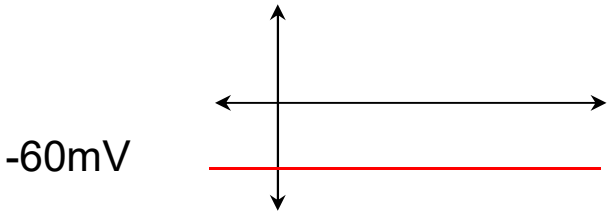
The membrane potential is measured with two extremely fine tipped electrodes glass electrodes – one inside the cell, and the other in the extracellular fluid. The signal that is measured is extremely feeble. The signal has therefore to first go through an amplifier. It is then displayed on an oscilloscope.



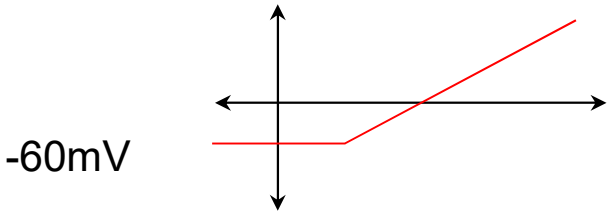

-0.00
10ADC

Changes in membrane potential

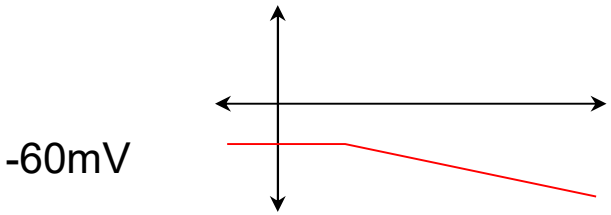




-60 mV (rmp), neuron is polarized



greater than -60 mV, neuron is depolarized



Less than -60 mV, neuron is hyperpolarized

The neuron is in a network and the information processing capacities of the neuron lie in its capacity to communicate with the other neurons. This communication is done via synapses.

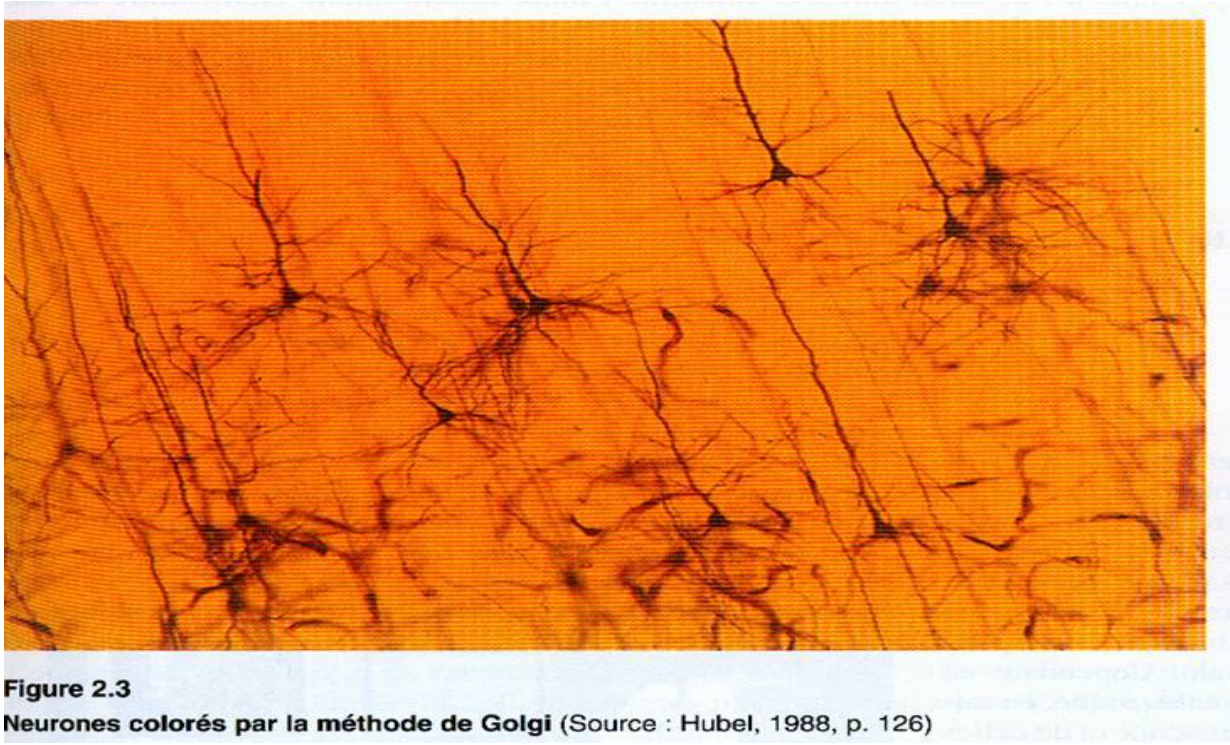
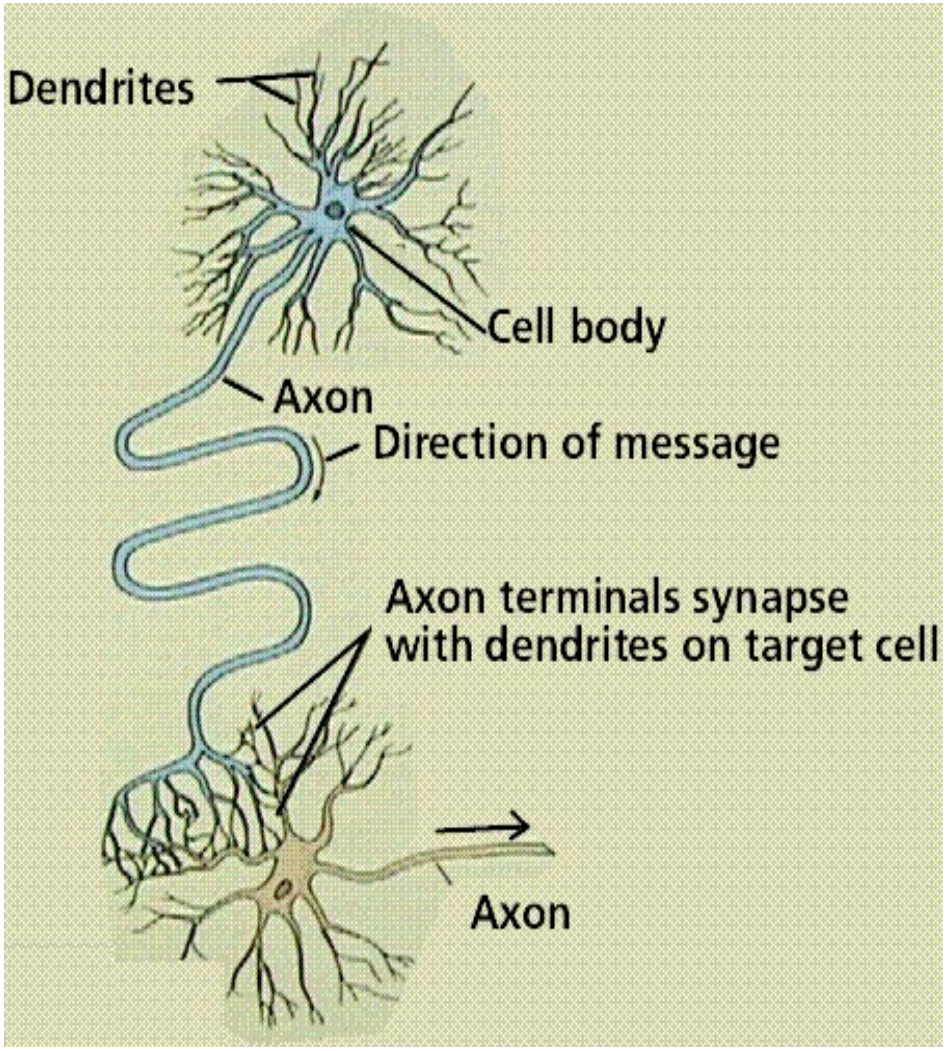
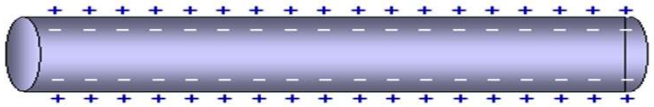
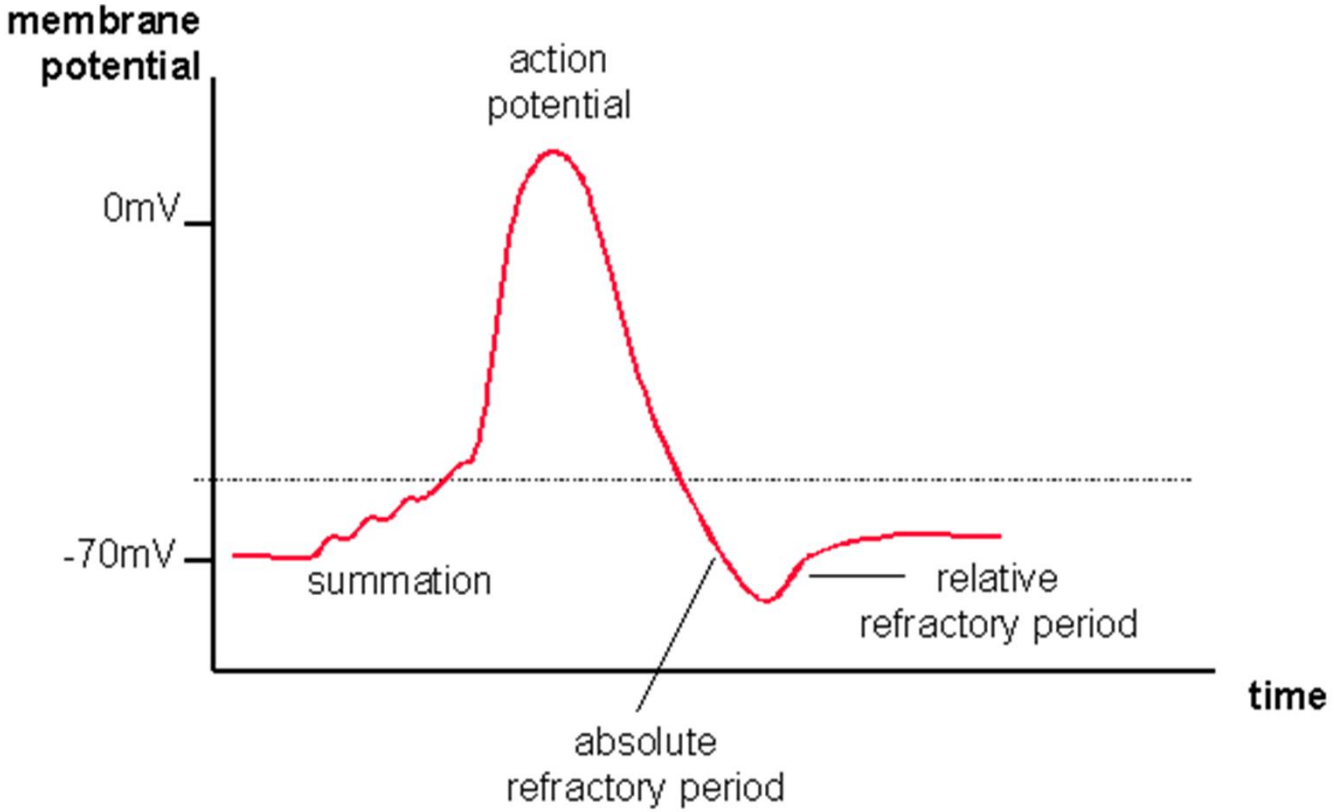


Figure 2.3
Neurones colorés par la méthode de Golgi (Source : Hubel, 1988, p. 126)

Synapse

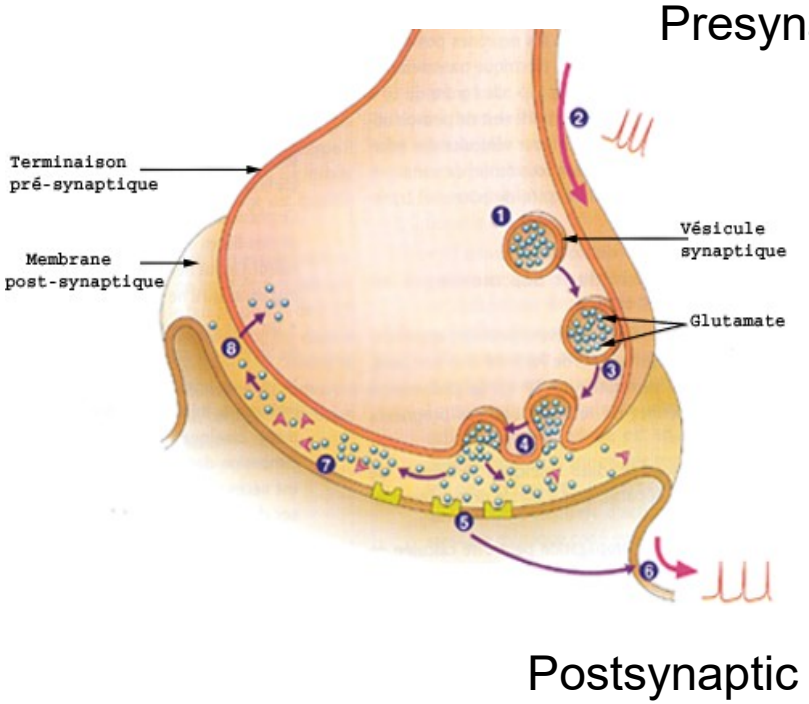

Dendrites
Cell body
Axon
Direction of message
Axon terminals synapse
with dendrites on target cell
Axon

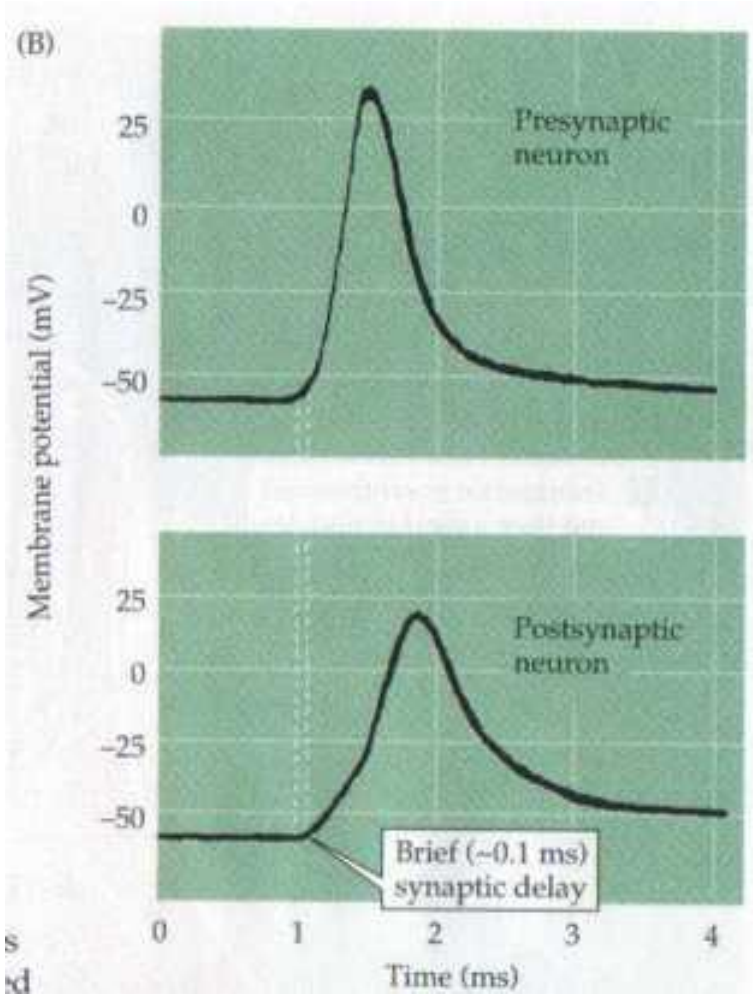



membrane potential
action potential
0mV
-70mV
summation
relative refractory period
absolute refractory period
time

A neuron sends a message via an action potential

The action potential leads to the release of neurotransmitter molecules





The refractory period

- The afterhyperpolarization

- Period during which the neurons capacity to respond is reduced

- Thought to be responsible for many visual illusions

Response to the
presynaptic action potential

2 types of postsynaptic effects

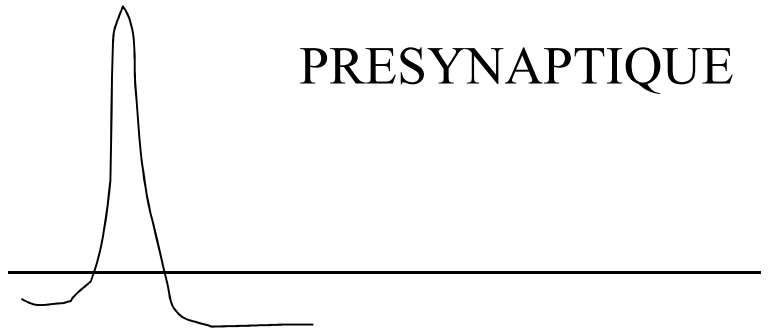
a) Excitatory

b) Inhibitory

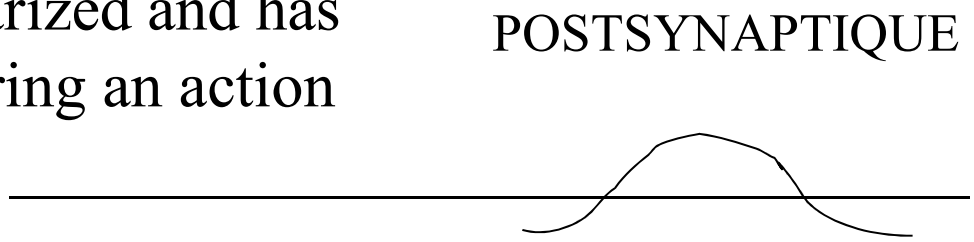
Effects of an excitatory presynaptic signal

1. Effects of an excitatory neurotransmitter

Presynaptic excitatory neuron

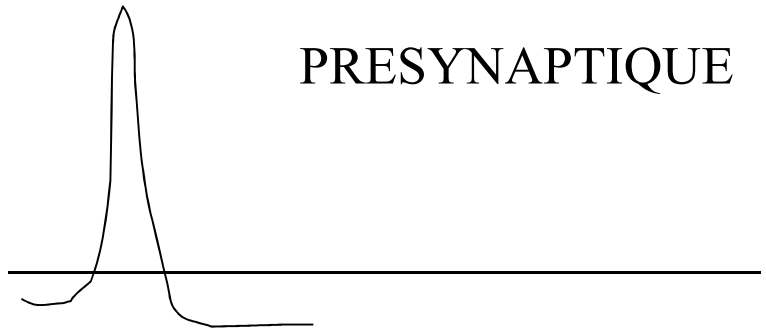


Postsynaptic response is positive. The postsynaptic neuron is depolarized and has an increased probability of firing an action potential



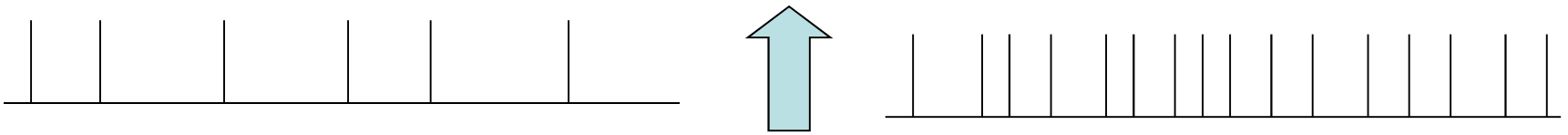
2. Effects of an excitatory neurotransmitter

Presynaptic excitatory neuron



Postsynaptic response is positive. The postsynaptic neuron is MORE depolarized and has an increased firing rate

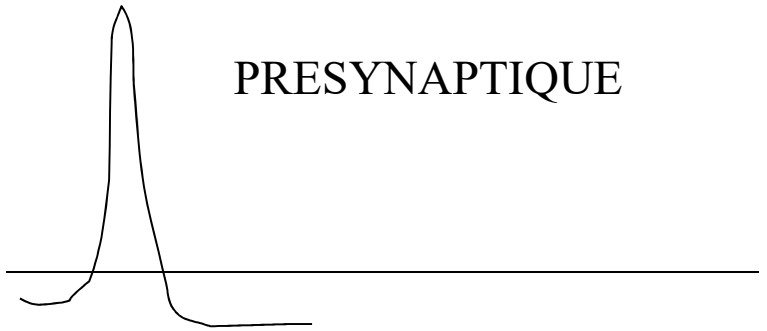
POSTSYNAPTIQUE



Effects of an inhibitory presynaptic signal

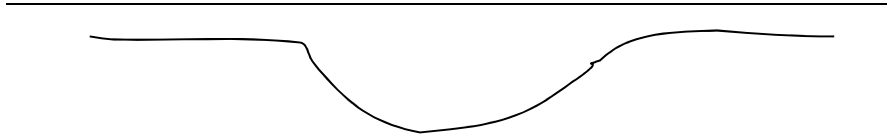
1. Effects of an inhibitory neurotransmitter

Inhibitory presynaptic neuron



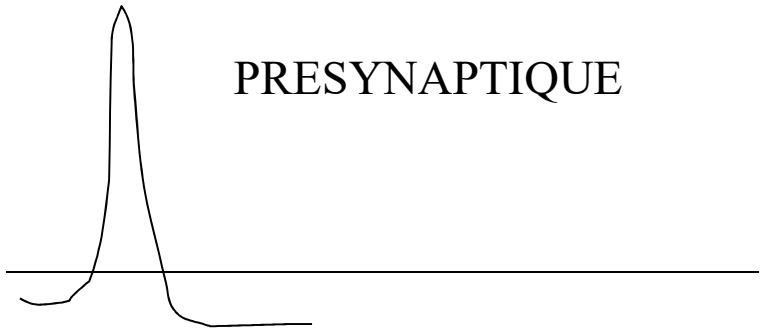
POSTSYNAPTIQUE

Postsynaptic response is negative. The neuron becomes more polarized. There is a decreased probability for the postsynaptic neuron to fire.

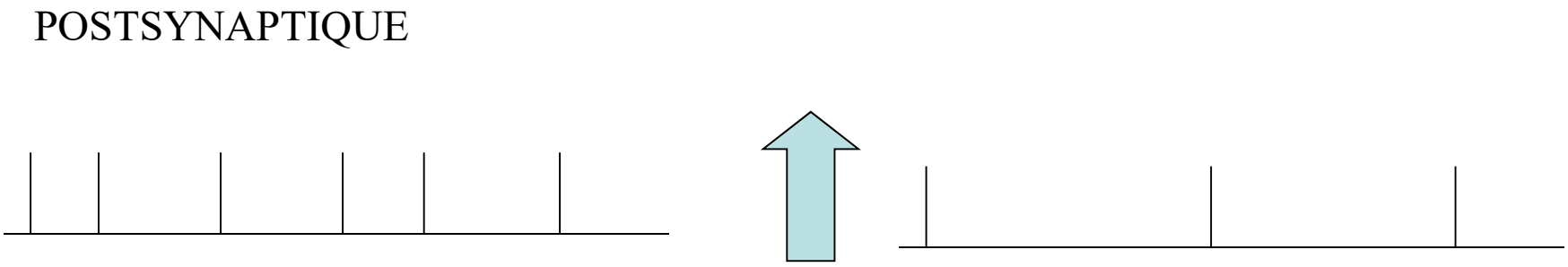


2. Effects of an inhibitory neurotransmitter

Inhibitory presynaptic neuron

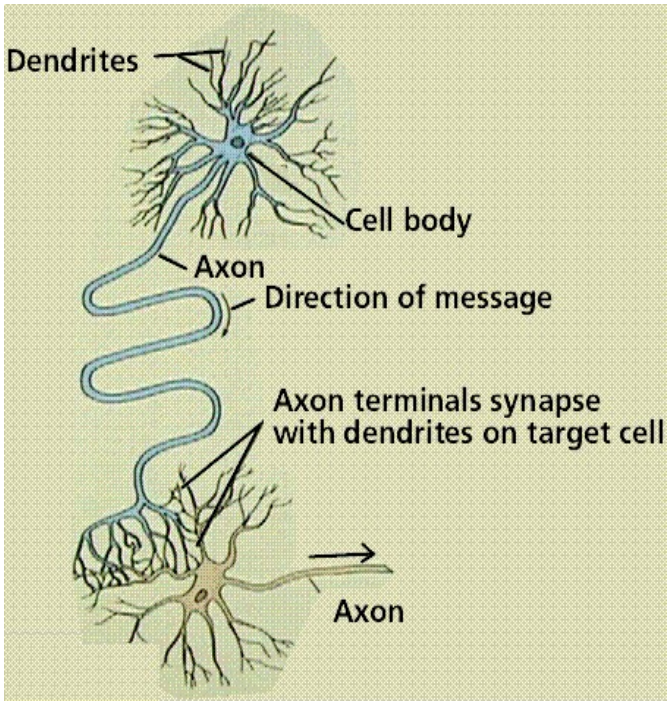


Postsynaptic response is negative. The neuron firing rate decreases

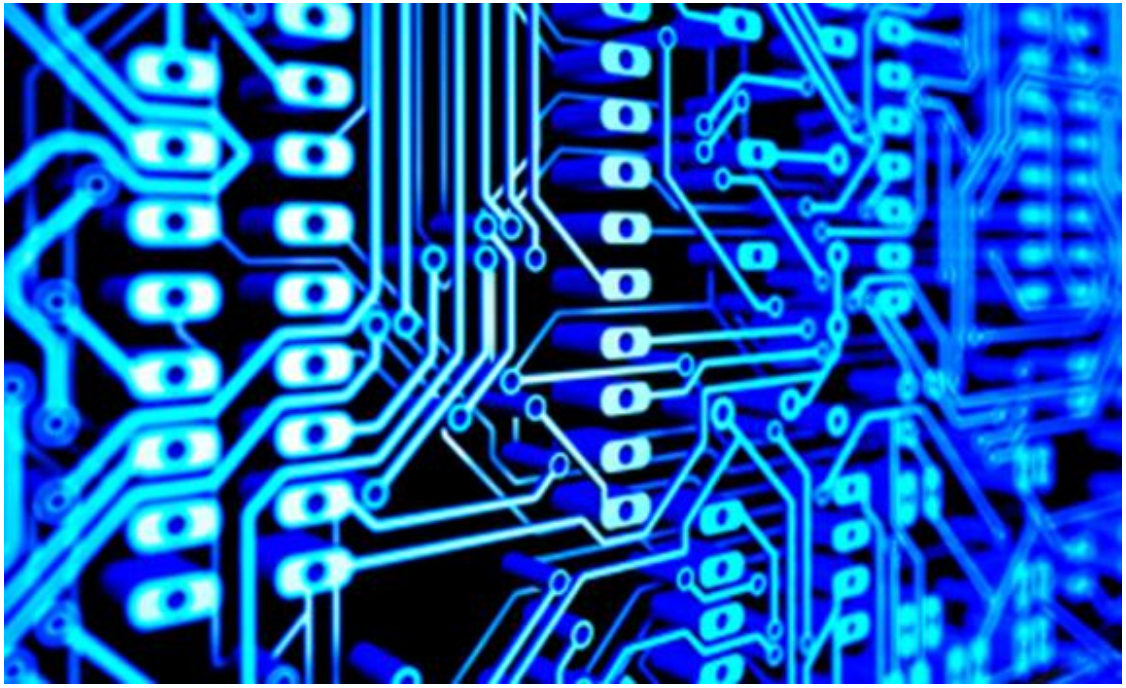


Spatial and temporal summation Σ

Each neuron has thousands of synapses. The signals come in at different times and at different locations over the surface of the neuron

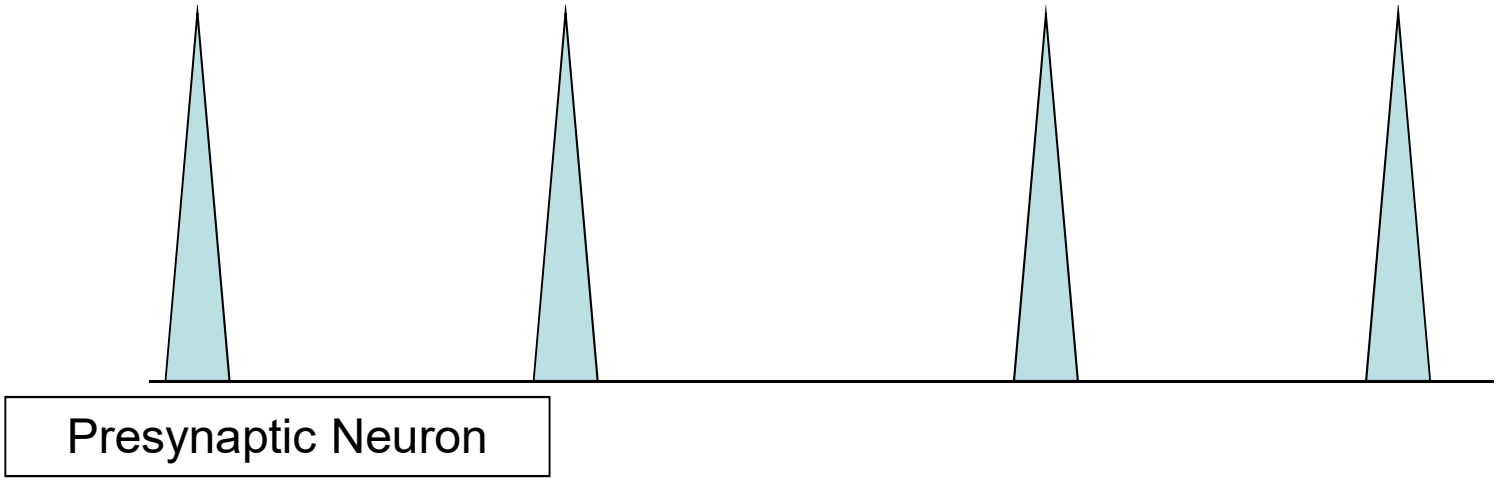


The integration of signals at different locations is called spatial summation. The integration at different times is called temporal summation



Temporal summation

Temporal summation does not take place at low frequencies



Temporal summation

Temporal summation takes place at high frequencies