LECTURE 1

From the discovery of neuron to artificial neural networks

Picture in gold by Greg Dunn and Brian Edwards, 2014-2016 (borrowed from [3])

Summary

You can download this lecture from

www.math.tecnico.ulisboa.pt/~plima/ShortCourse

Or sites.google.com/view/pedrolimaneuro

- 1. Structure of Brain
- 2. The Discovery of Neuron
- 3. Structure of Neuron
- 4. Synapses
- 5. From Biological to Artificial Networks
- 6. Algorithms for Neural Network Learning

1. Structure of Brain

According to a lower estimate from 2009, the human nervous system contains

- about 0.89×10^{11} neurons,

which are connected by

- about 10^{14} synapses.

The cerebral Cortex

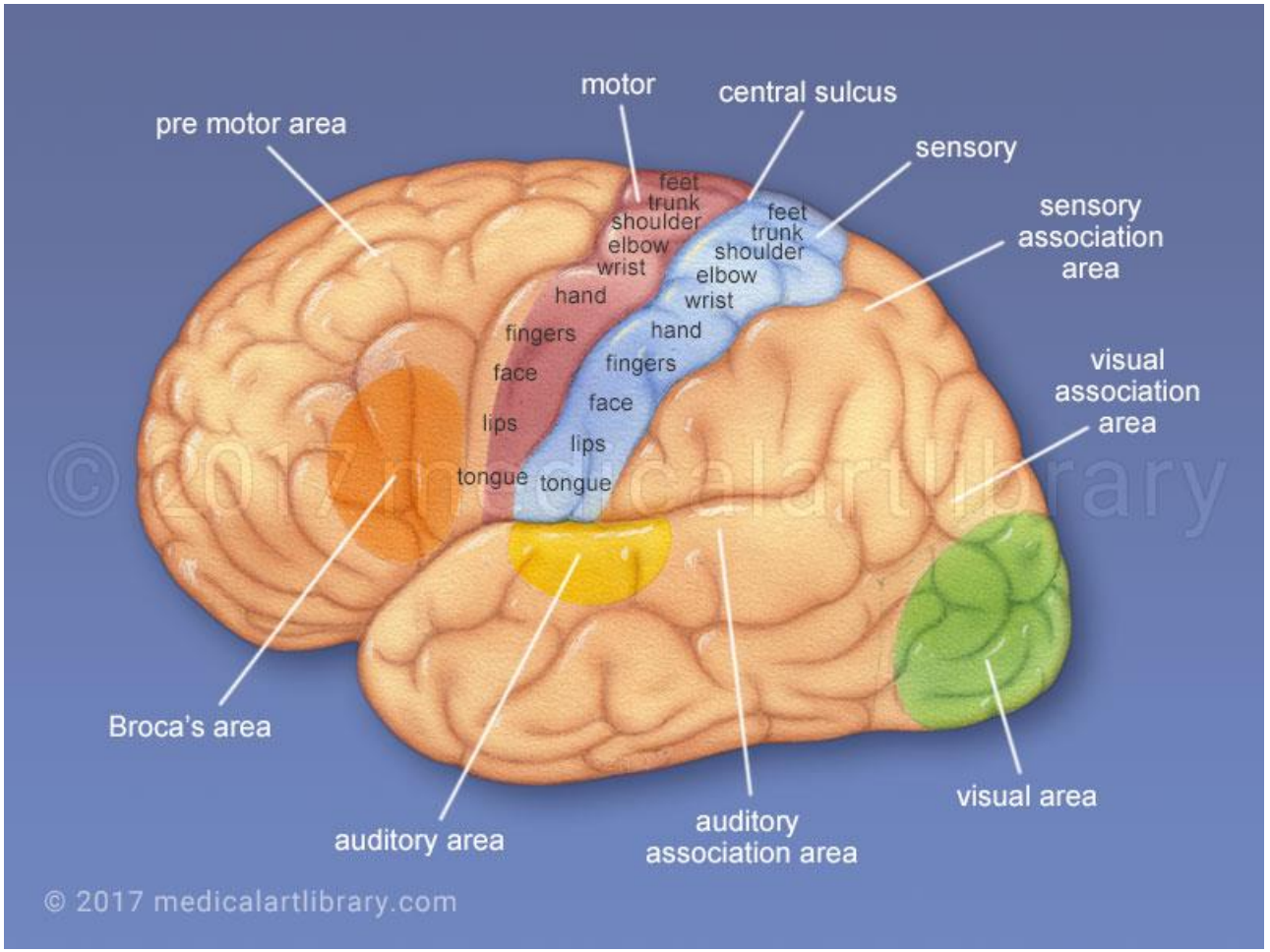
The cerebral cortex is the brain's outer layer of neural tissue in humans and other mammals.

It plays a key role in controlling memory, attention, perception, awareness, thought, language and other important processes.

The cortex of a human is about 2-4 mm thick and contains about one fifth of all the neurons.

According to recente estimates, the córtex can store up to 100Tb of data.

Map of Cortex



2.The Discovery of Neuron

In the middle of XIX century there were two theories about the structure of nervous cells:

- Reticularism: The nervous system consists of a large network (reticulum);
- Neuronism: The nervous systems consists of distinct cells (neurons)

Ramon y Cajal

The second theory was defended by Ramon y Cajal (1852-1938).

In 1906 he was awarded the Nobel Prize in Physiology (together with Colgi)

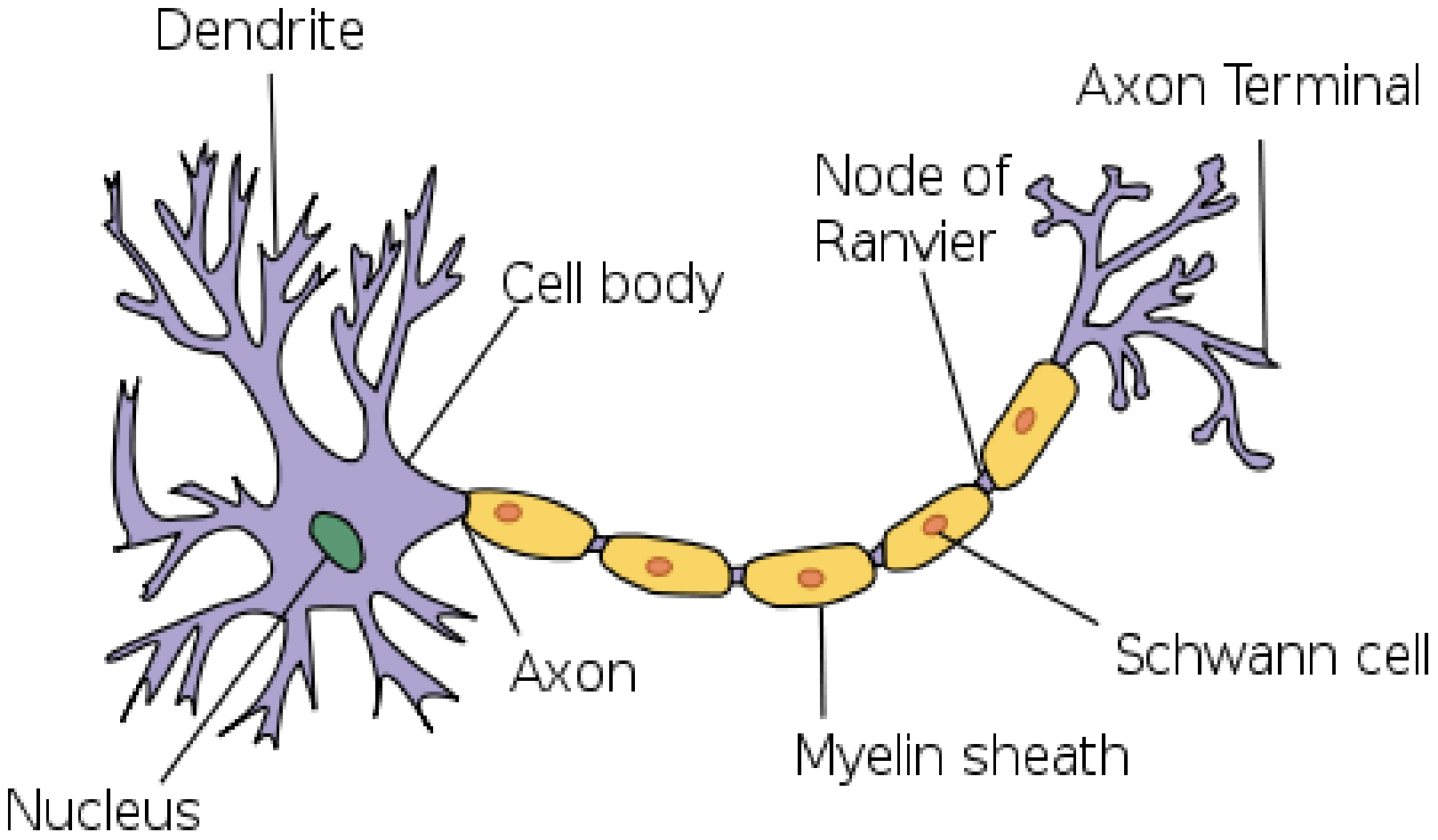
3. Structure of Neuron

The term neuron was introduced in 1891.

Ramon y Cajal developped the so-called Neuron Doctrine:

- The neuron is the structural and functional unit of the nervous system;
- Each neuron is a distinct cell which is not fused with others;
- The neuron is composed by three parts: dendrites, axon and cell body
- Information flow : dendrites → cell body → axon.

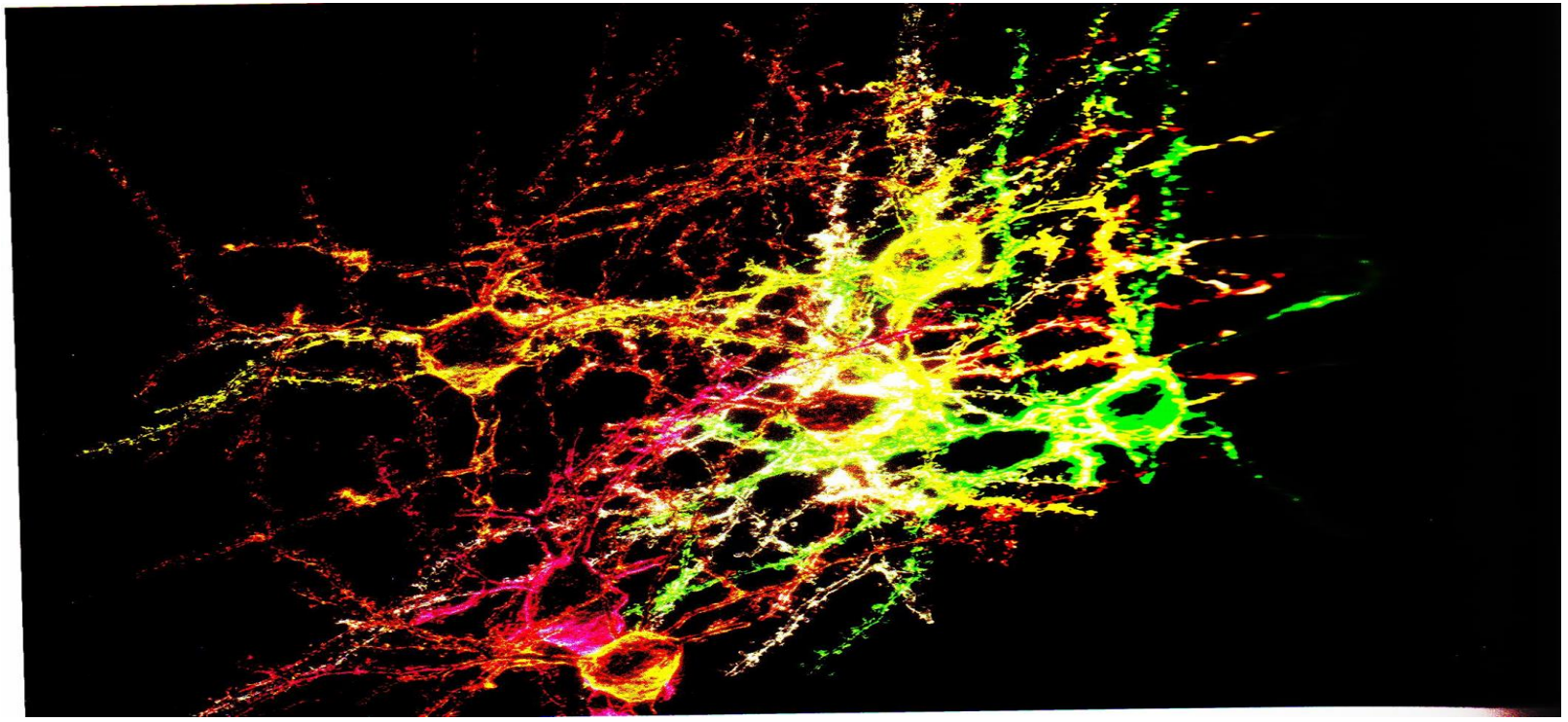
Neuron


Dendrite
Axon Terminal
Node of Ranvier
Cell body
Axon
Schwann cell
Myelin sheath
Nucleus

Drawing by Ramon y Cajal

Scheme of a section of a mammal's cerebral cortex (picture conserved in the Cajal Institute, Madrid, Spain)

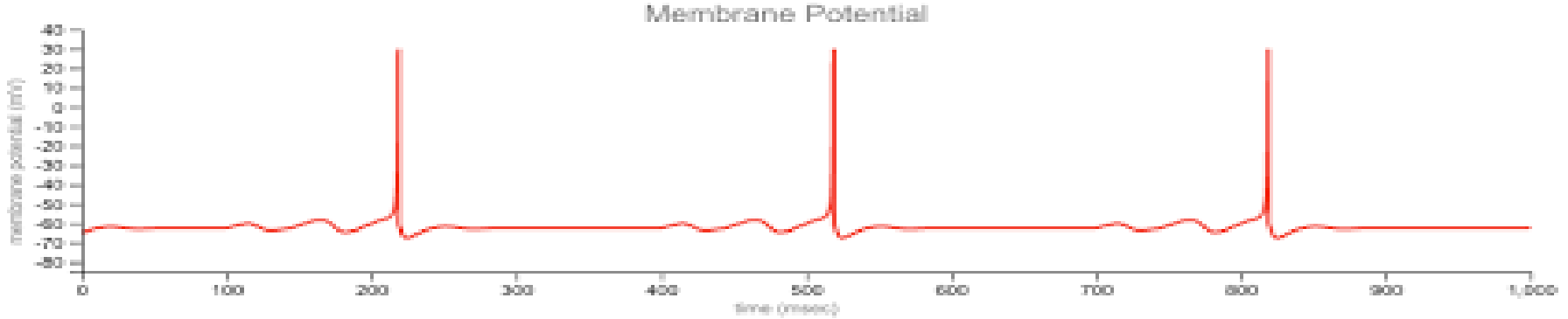
Mouse's Neurons



Neural network in the visual cortex of a mouse (fhoto obtained by means of an electronic microscope)

4. Synapses

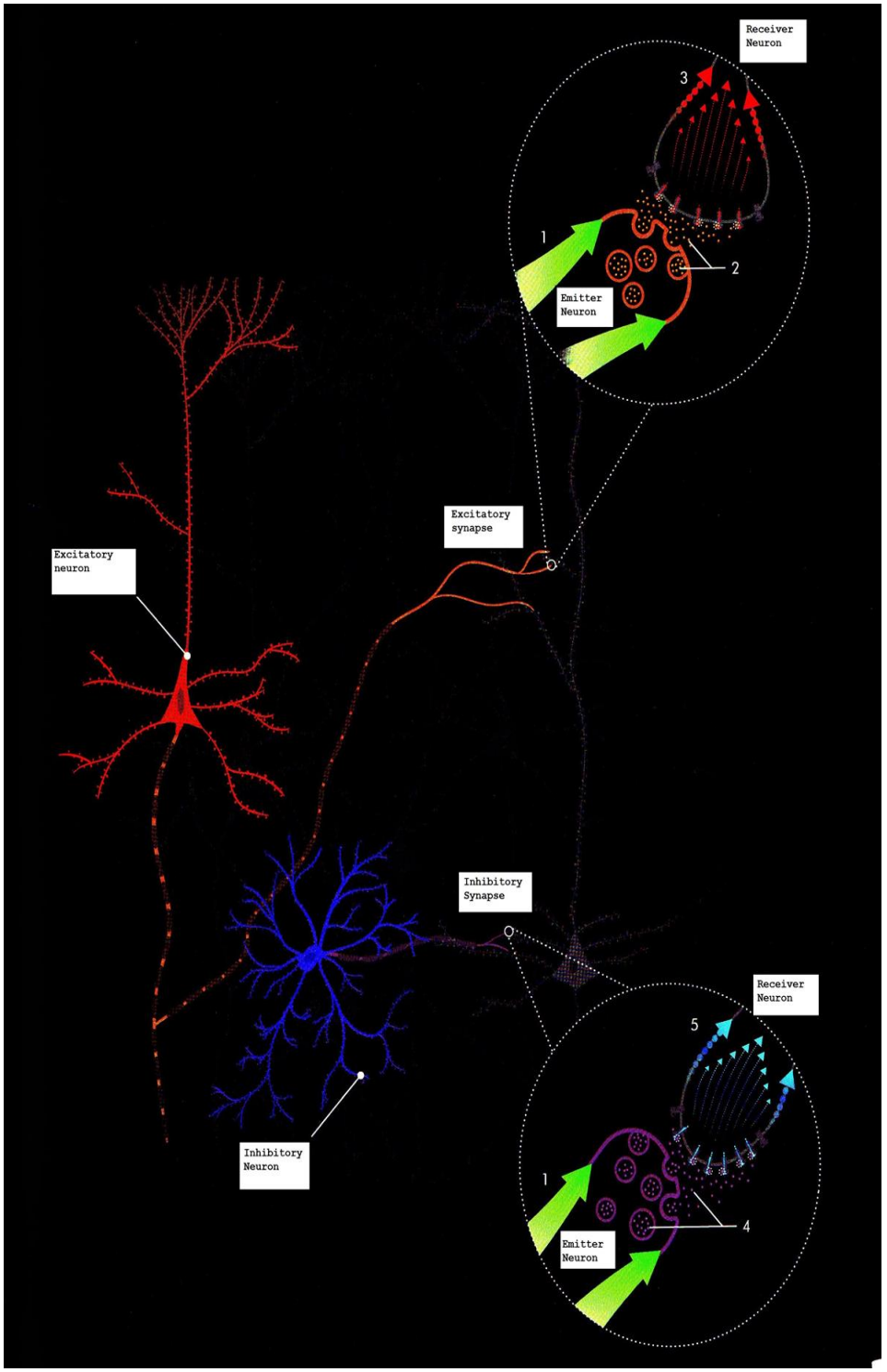
- The change of voltage in the cell membrane of a neuron results in a voltage spike called an action potential, which triggers the release of other neurotransmitters.
- That is, neurons communicate with each other by firing.



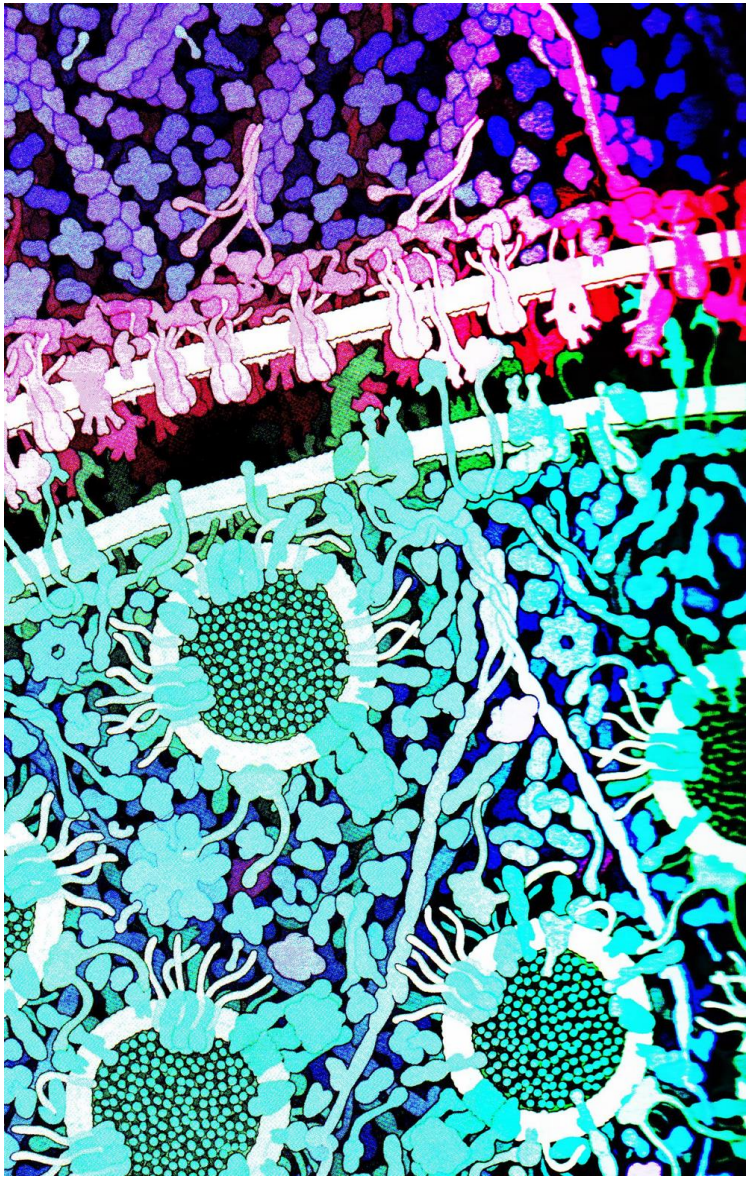
Synapses

The place where two neurons interact is called a synapse. The neuron which emits an electrical signal is called the emitter while the other one is the receiver. There are two kinds of synapses:

- Excitatory – positive charge is transmitted ant the firing probability of the receiver is increased ;
- Inhibitory – negative charge is transmitted and the firing probability of the the receiver is reduced.



- 1-Action Potential
- 2- Excitatory neurotransmitter
- 3-Receiving positive charge
- 4-Inhibitory neurotransmitter
- 5-Receiving negative charge



Excitatory synapse
(the picture is amplified 2000000 times)

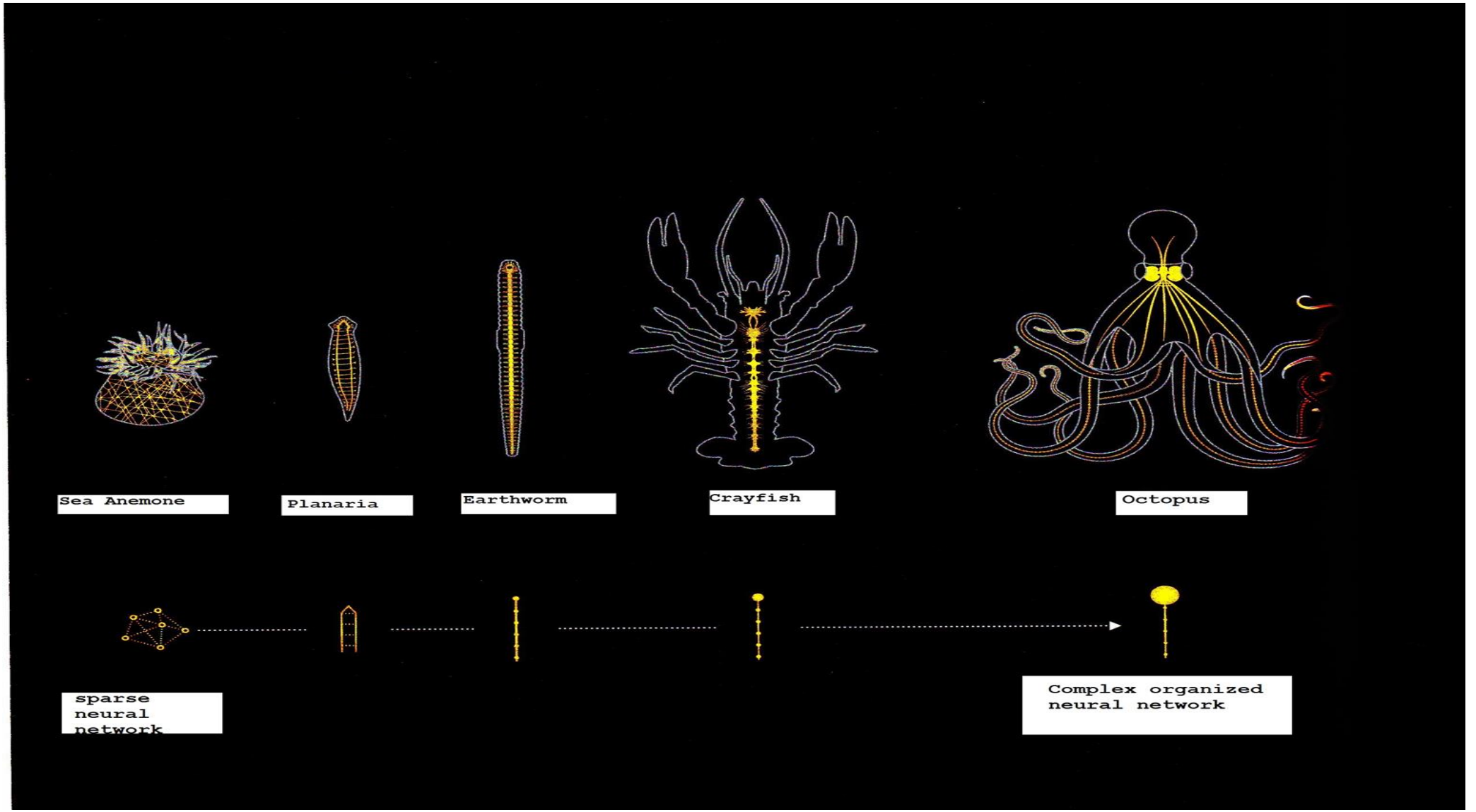
Inhibitory Synapse
(the picture is amplified 2000000 times)

5. Biological Neural Networks

- In different animals neural networks are organized in various ways:
- scattered neurons with simple forms (like in the anemone)
- to complex forms, with neurons grouped in clusters (like in the octopus).

Neural Networks in Invertebrates

(picture borrowed from [3])



Artificial Neural Networks

The investigation of biological neuron networks in animal brains has inspired the mathematicians to create artifical neural networks (ANN).

In 1943 Warren McCulloch and Walter Pitts created a computational model for neural networks based on mathematics and algorithms.

The original goal of the neural network approach was to solve problems in the same way that a human brain would.

Artificial Neural Networks

The ANN learns to do tasks by considering examples, generally without task-specific programming.

An ANN is based on a set of connected units called artificial neurons.

Each connection(synapse) between neurons can transmit a signal to another neuron. The receiving neuron can process the signal and then send a new signal to neurons connected to it.