The Introduction To Artificial Intelligence

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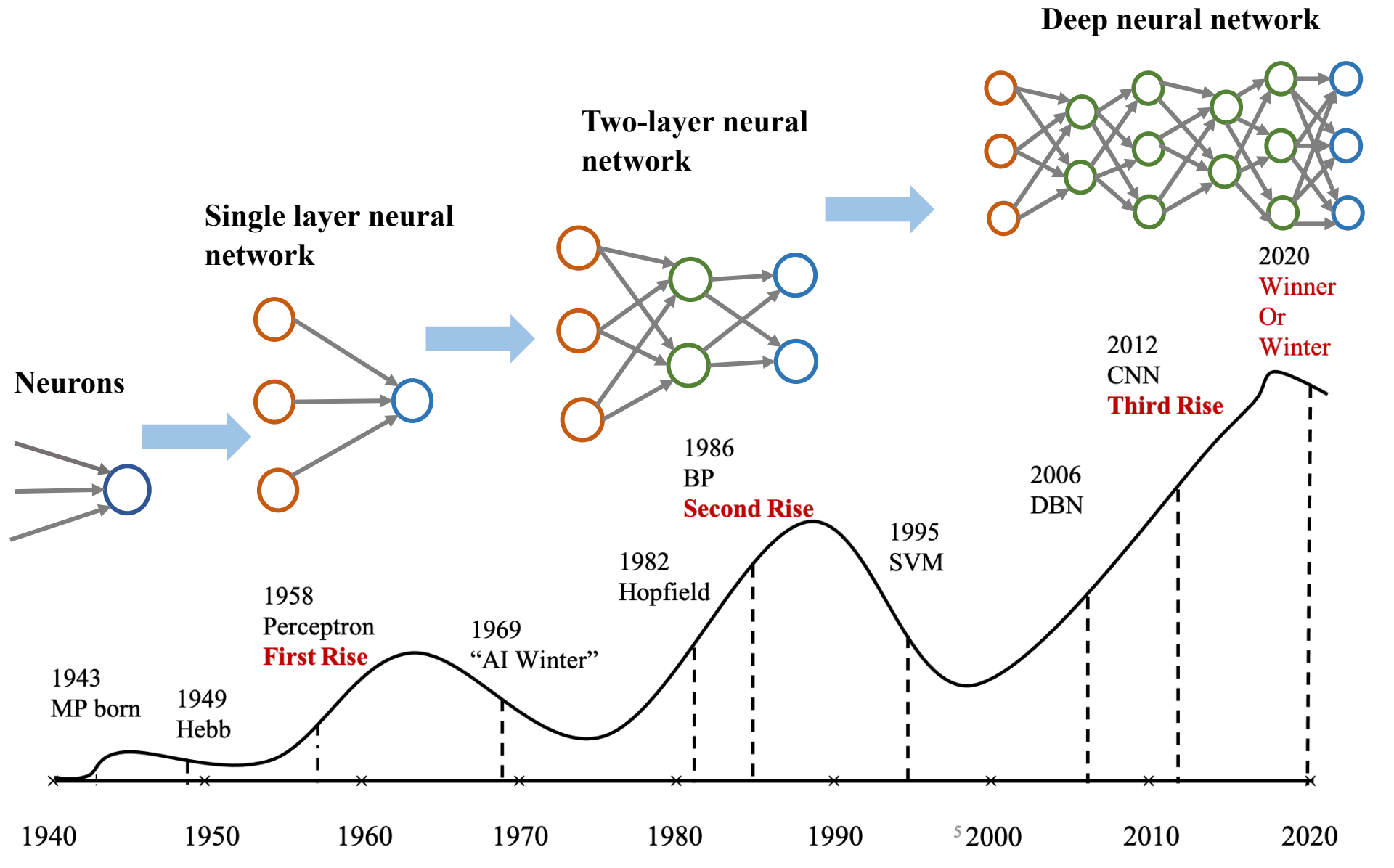
The Introduction to Artificial Intelligence

- Part I Brief Introduction to AI & Different AI tribes
- Part II Knowledge Representation & Reasoning
- Part III AI GAMES and Searching
- Part IV Model Evaluation and Selection
- Part V Machine Learning
- Part VI Neural Networks

Neural Networks

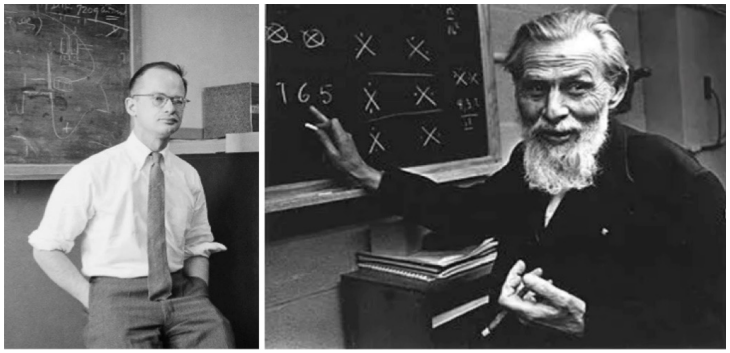
- *The Development History of Neural Networks*
- Where does Intelligence Come From ?
- Biological Neurons and Neural Networks
- Computational Model of Neural Network
- Feedforward Neural Network
- Recurrent Neural Networks

The development history of neural network

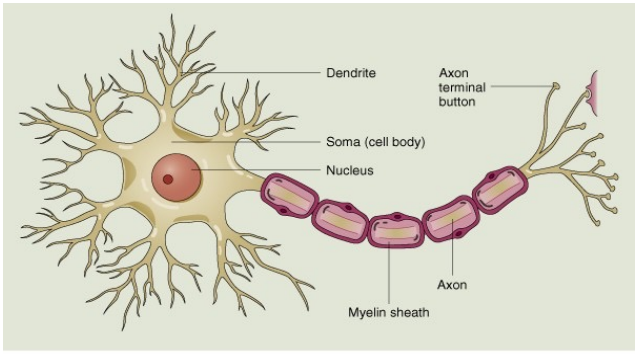


The development history of neural network

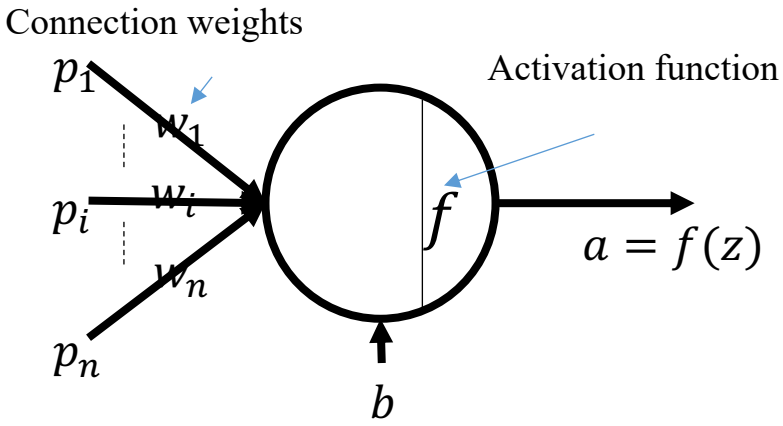
Artificial neuron



Walter Pitts Warren McCulloch



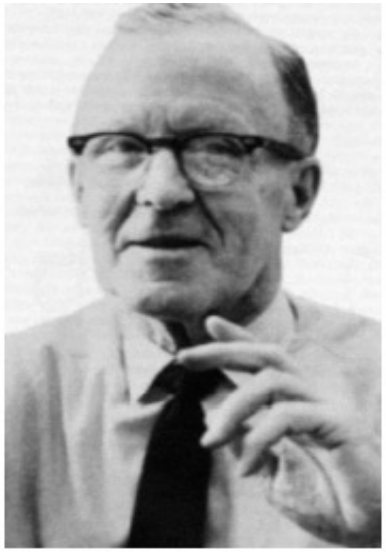
- In 1943, psychologist Warren McCulloch and mathematical logician Walter Pitts put forward and gave the concept of artificial neural network and the mathematical model of artificial neuron in the collaborative "A logical calculus of the ideas immanent in nervous activity". Inaugurated the era of artificial neural network research.



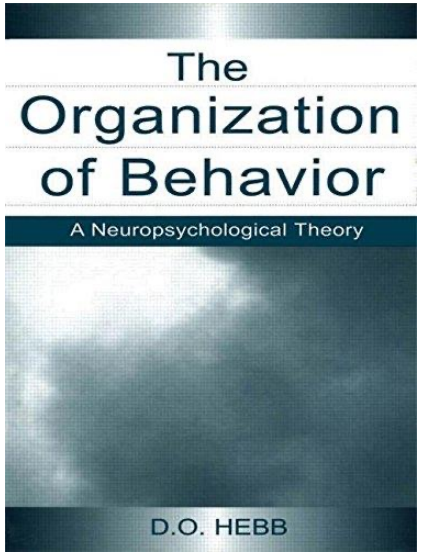
Currently the most widely used neuron model

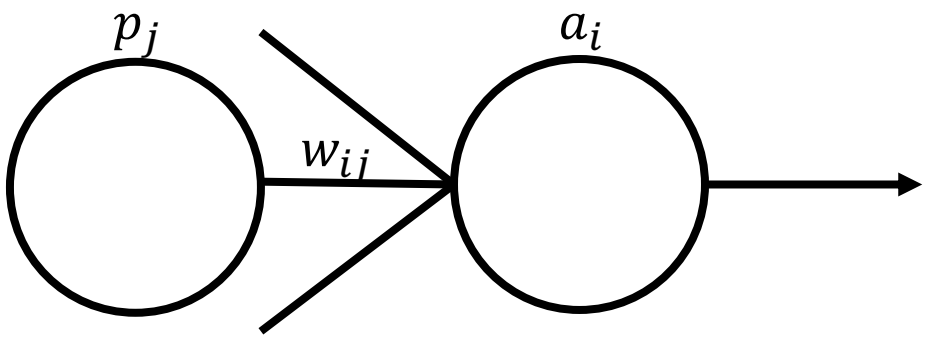
The development history of neural network

- Hebb Rule



D. Hebb





•**Hebb Rule**: If two neurons of either side of a synapse are activated simultaneously, the strength of the synapse will increase. if not at the same time, the connection will be weakened

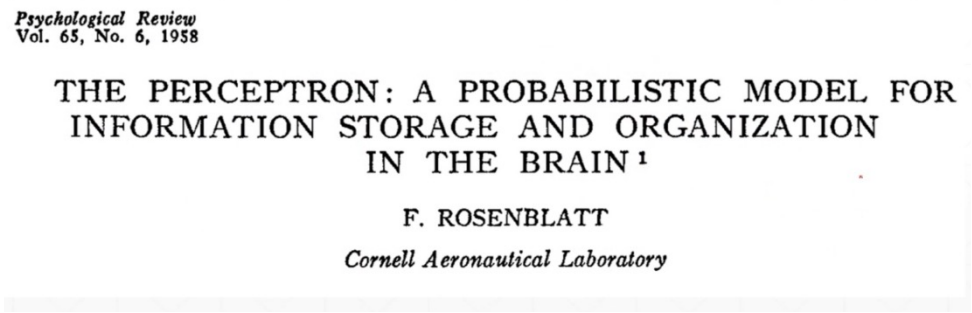
$$w_{ij}^{new} = w_{ij}^{old} + \alpha f_i(a_i) g_j(p_j)$$

The development history of neural network

Perceptron

Frank Rosenblatt

In 1957, Frank Rosenblatt re-examined this model from a purely mathematical point of view, and pointed out that the weights W and b can be obtained from some input and output pairs (X,y) through learning algorithms.



Psychological Review
Vol. 65, No. 6, 1958

THE PERCEPTRON: A PROBABILISTIC MODEL FOR INFORMATION STORAGE AND ORGANIZATION IN THE BRAIN[1]

F. ROSENBLATT

Cornell Aeronautical Laboratory

Question: Given some input and output pairs (X,y), where $y=\pm 1$,to find a function so that: $f(X)=y$

Sensor:

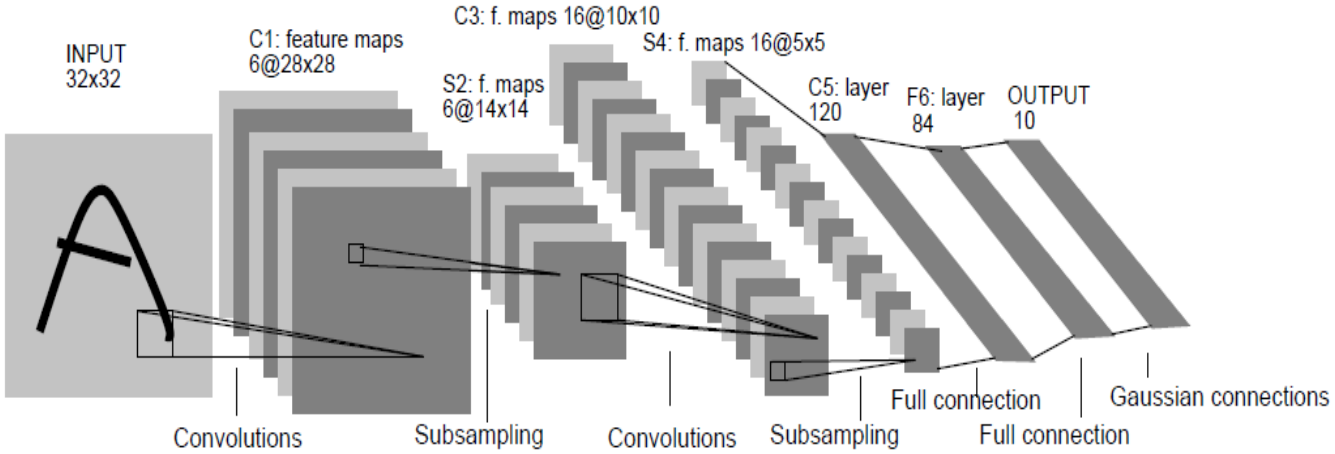
Set $f(X)=sign(W\hat{}T\ X+b)$, automatically learn from the input and output pairs, and get W and b.

The development history of neural network

- CNN

Yann Lecun

Convolutional Neural Network (CNN) was proposed in the 1990s. Yann Lecun was the first to use CNN for handwritten digit recognition and has maintained its dominance in this issue.

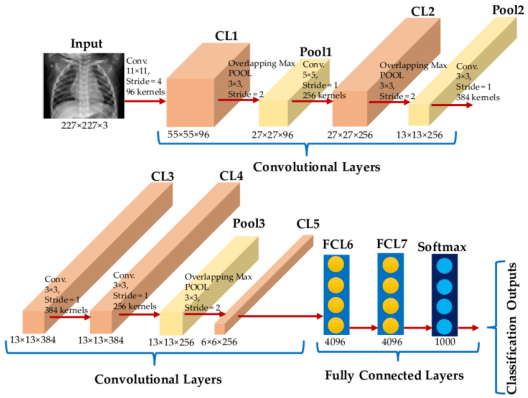


1. LeCun Y., Bottou L., Bengio Y., and Haffner P., Gradient-based learning applied to document recognition, Proceedings of the IEEE, pp. 1-7, 1998.

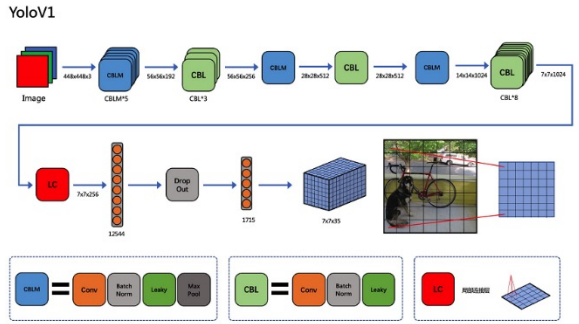
The development history of neural network

CNN

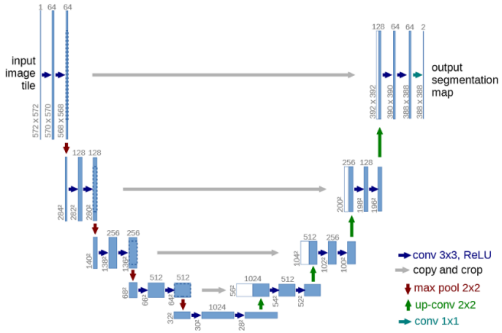
The current popular neural network structure



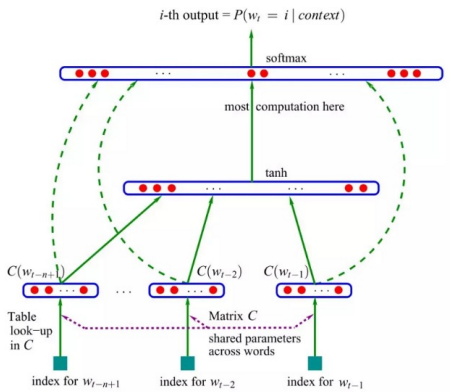
Classification



Target Detection



segmentation



Natural language processing

Neural Networks

- The Development History of Neural Networks
- *Where does Intelligence Come From ?*
- Biological Neurons and Neural Networks
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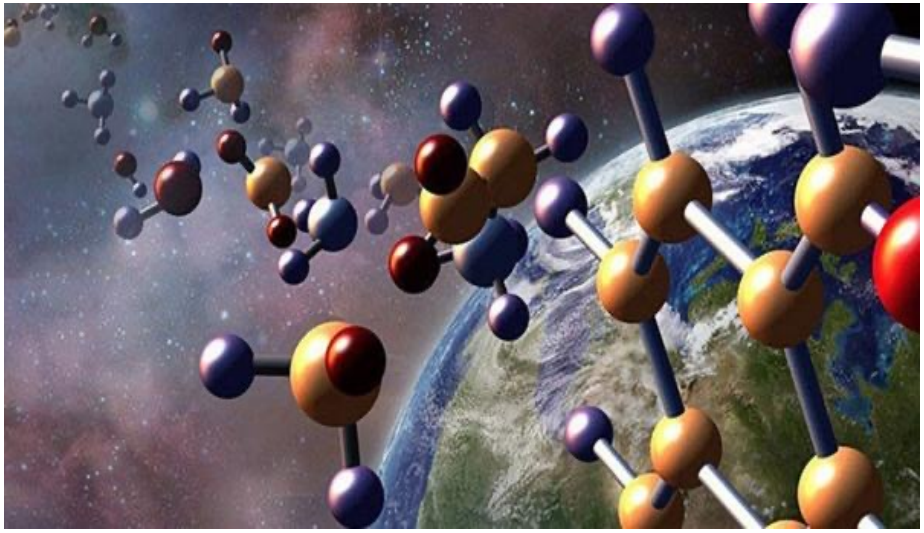
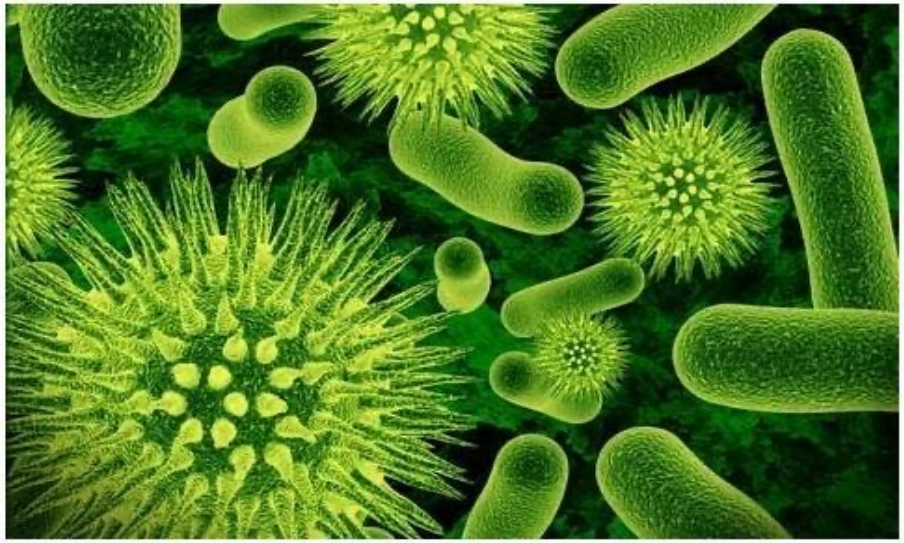
Where does intelligence come from ?

Where does intelligence come from?

Where does intelligence come from ?

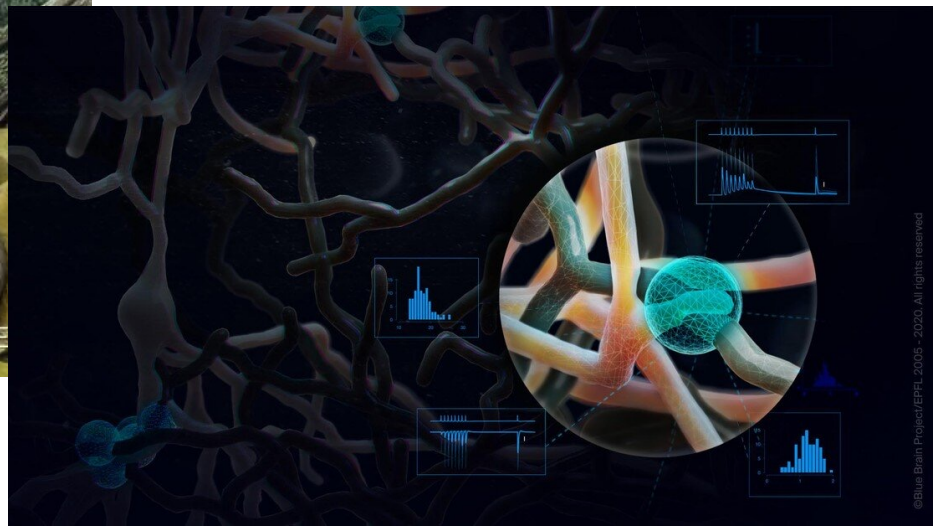
- The first life originated in the ocean
- Life is just a simple cell without a brain





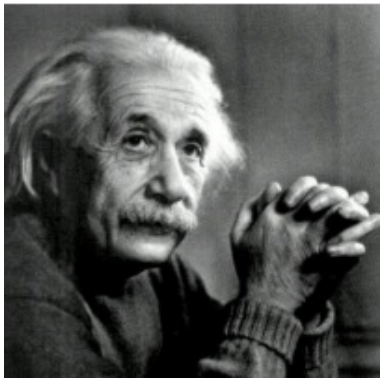
Where does intelligence come from ?

- Mammals already have tiny neocortex



Where does intelligence come from ?

- Thinking: What determines biological intelligence?



A. Could it be determined by the size of the head?

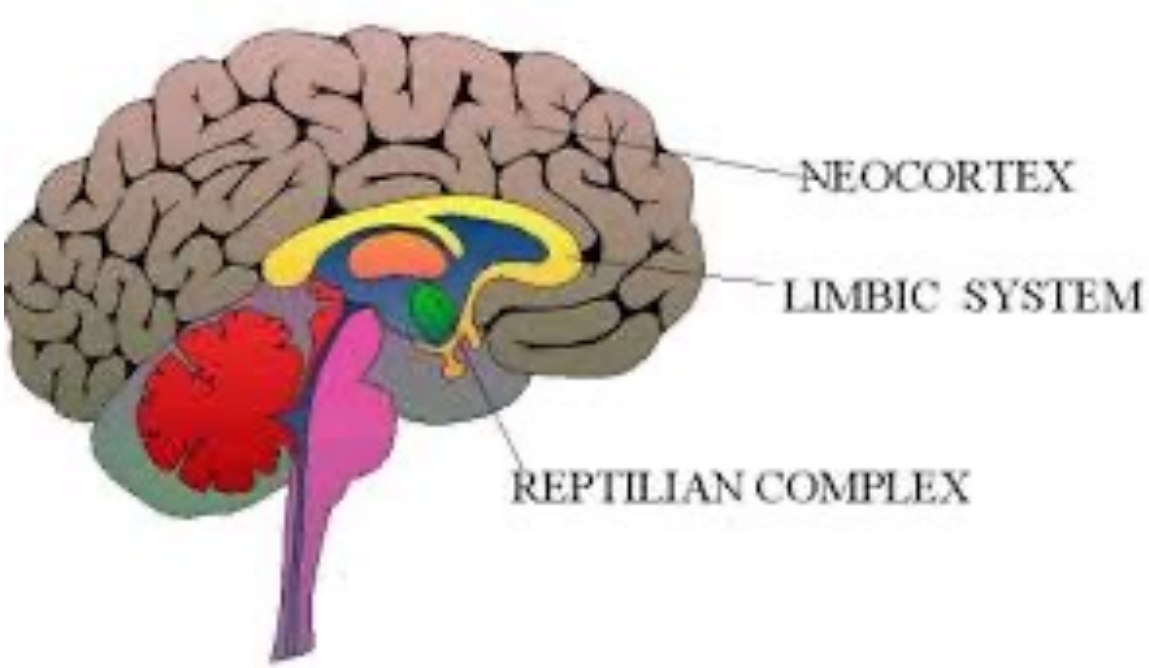
B. Maybe it depends on athletic ability?

C. Anyway, humans are the smartest!

D. May it be the legendary neocortex?

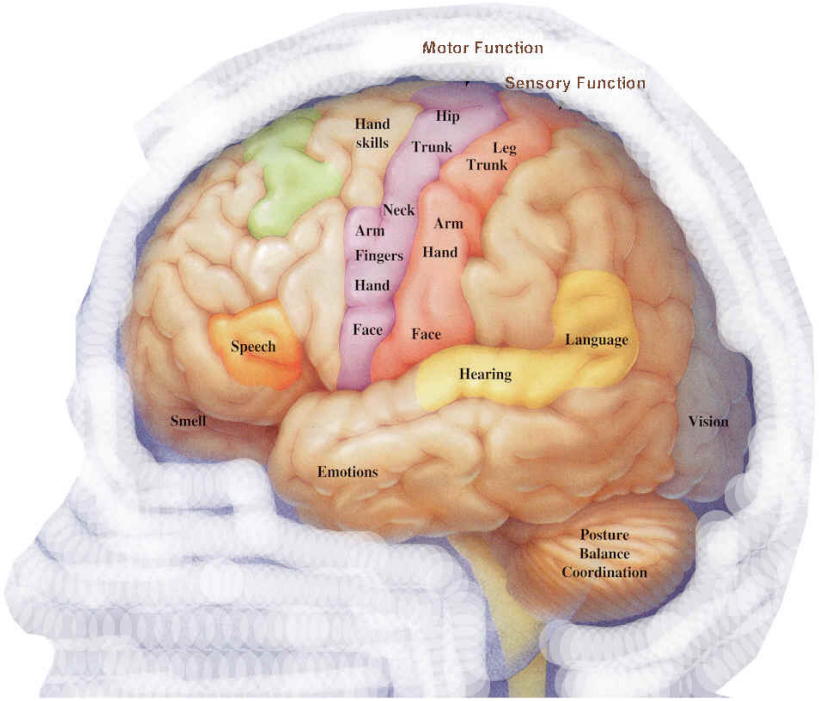
Where does intelligence come from ?

- Intelligence comes from the brain
- Intelligence depends on the neocortex of the brain

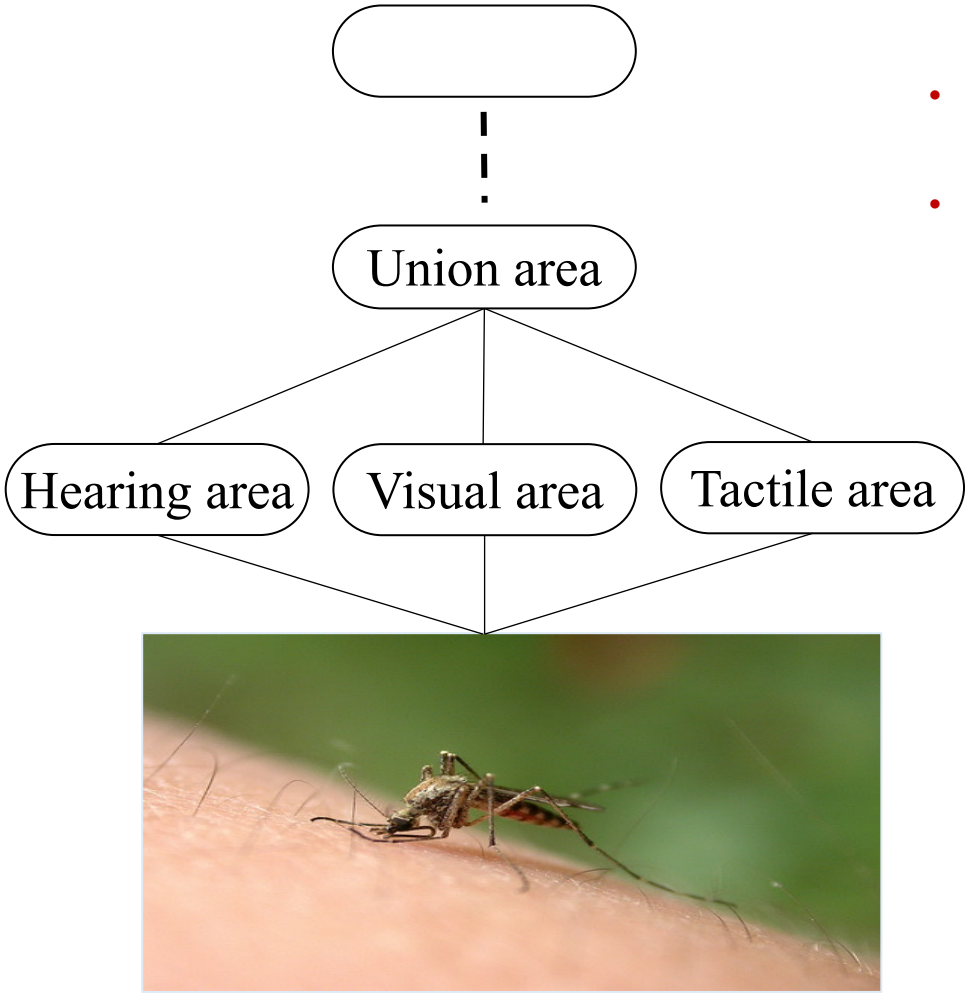


Where does intelligence come from ?

- Neocortex：
  - Functional Region
  - Irregular size and shape of each functional area



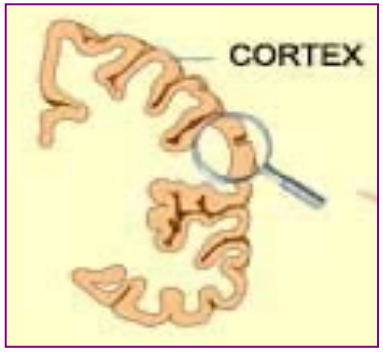
Where does intelligence come from ?

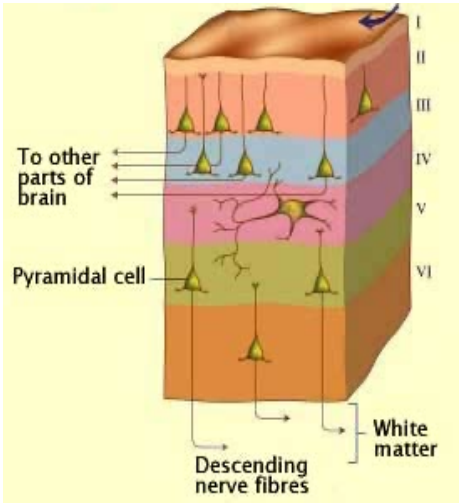


Region

- Seamlessly stitched together physically
- Functionally arranged in a hierarchical structure
  - Visual region : seeing mosquitoes
  - Hearing region : hearing a humming sound
  - Tactile region : feel pain
  - Union region : unite three senses together

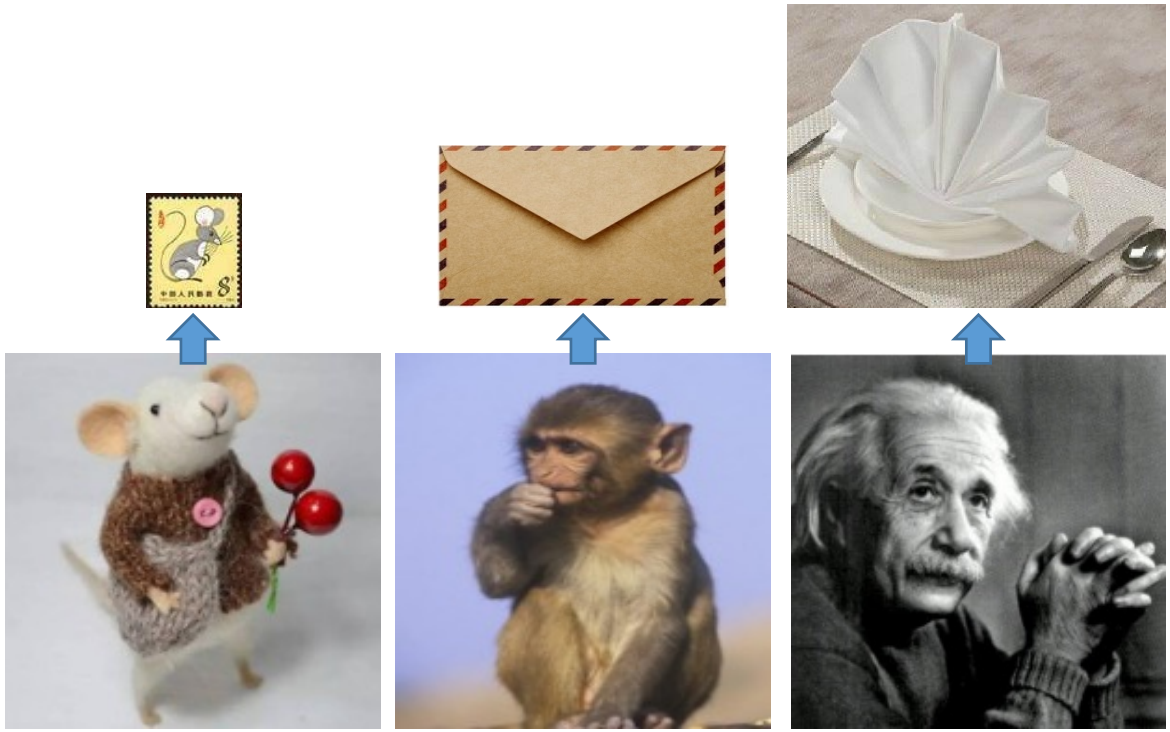
Where does intelligence come from ?





- 6 layers: each layer has different types of nerve cells
- The neocortex plays a key role in most "advanced cognitive functions" such as thinking, memory, planning, perception, language, and attention.

Where does intelligence come from ?

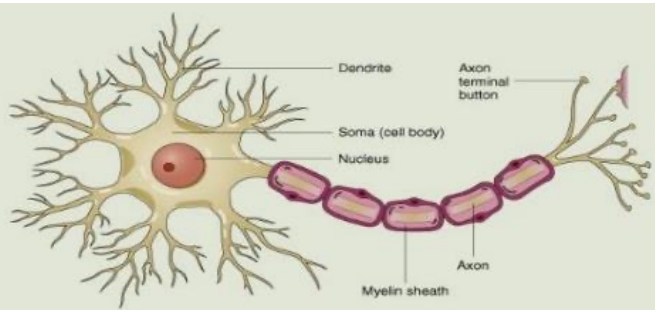


- Neocortex
- The size of a napkin （about 1000cm^2）
- The thickness of six playing cards （about 2mm ）
- Each square millimeter of the area contains about 100,000 neurons
- About 30 billion neurons in total
- About 100 trillion synaptic connections

The Neocortex is the thin surface layer of the vertebrate brain. It is the latest and most functionally advanced part in the evolutionary history of the brain and the entire nervous system. It shows the "largest size difference" among different mammals (especially humans).

Where does intelligence come from ?

The biological neural network in the neocortex plays a vital role in intelligence!



Neurons | Connection between neurons | Neural Networks

- Neuron is the basic unit in neural network
- Connections between neurons are established and changed through learning
- A large number of neurons interconnected to form a neural network

Neural Networks

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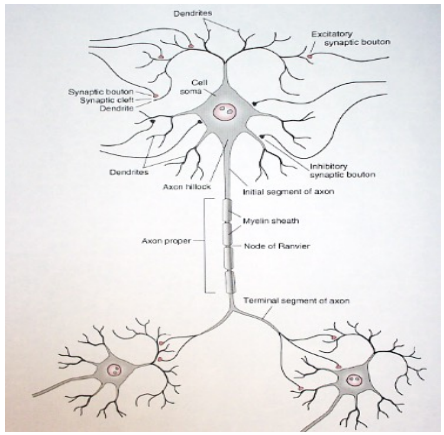
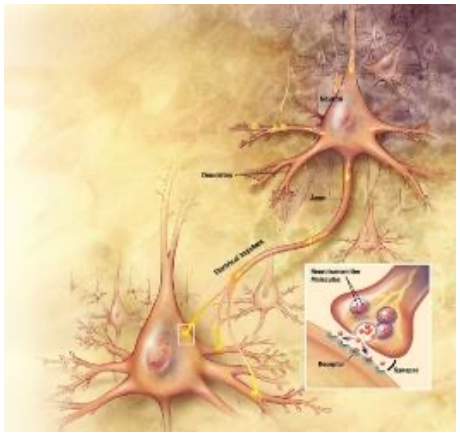
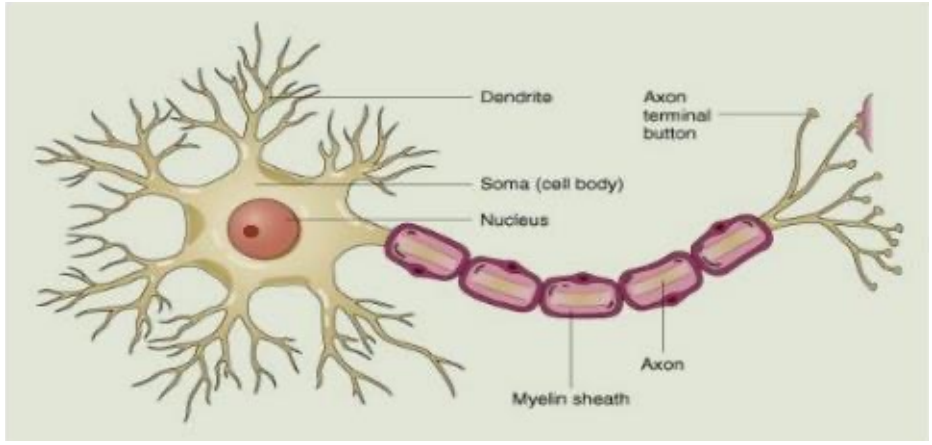
Biological Neurons and Neural Networks



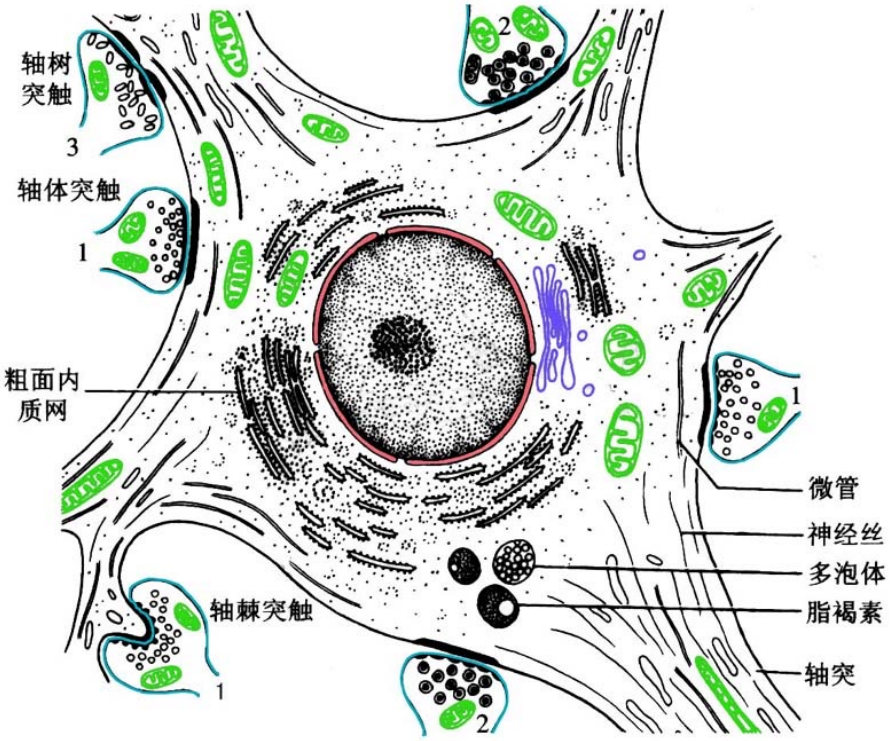




- Three main components
  - Soma （胞体）
  - Dendrite （树突）
  - Axon （轴突）
- Neurons are cells in the brain that can receive electrical stimulation
- Neurons process and transmit information through electrical and chemical signals

Biological Neurons and Neural Networks

- Soma: Soma is the nutrient center of the cell.
- A large amount of protein required for neural activity is mainly synthesized in Nissl body, and then flows to the nucleus, mitochondria and Golgi complex.



Biological Neurons and Neural Networks

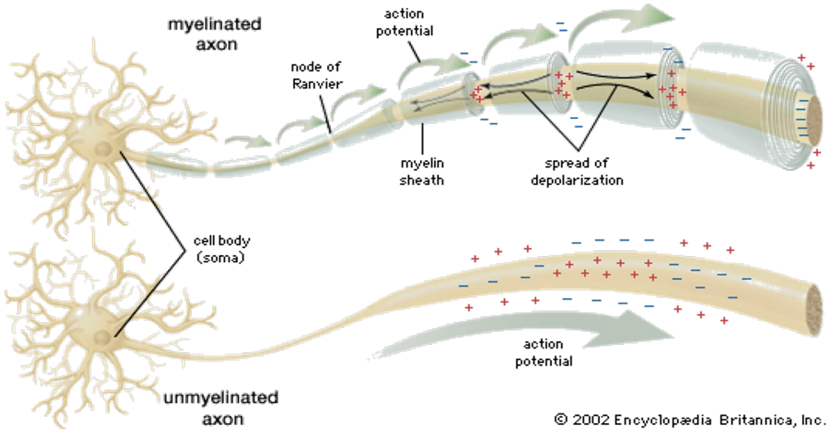
- Dendrites receives inputs from many other neurons and transmits these signals to the soma.
- Dendrites gives neurons a unique branching shape, the size of dendrites far exceeds the size of the soma

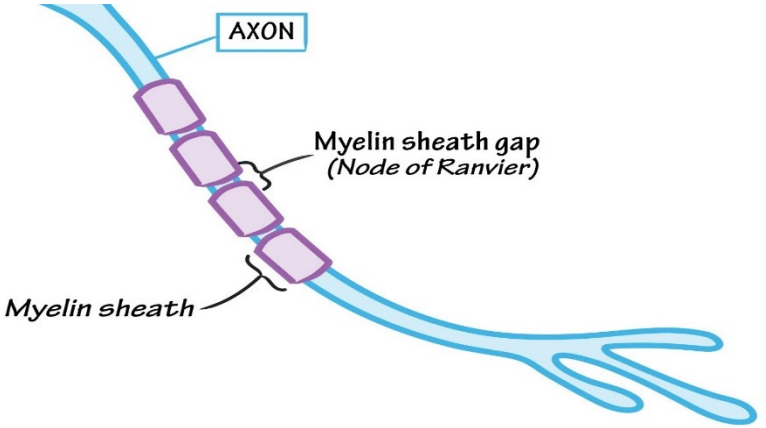
"This is a huge, distant antenna that can 'hear' thousands of signals inputted by synaptic, which are distributed on the branch structures of other neurons in the network."

MIT McGovern Brain Science Institute

Biological Neurons and Neural Networks

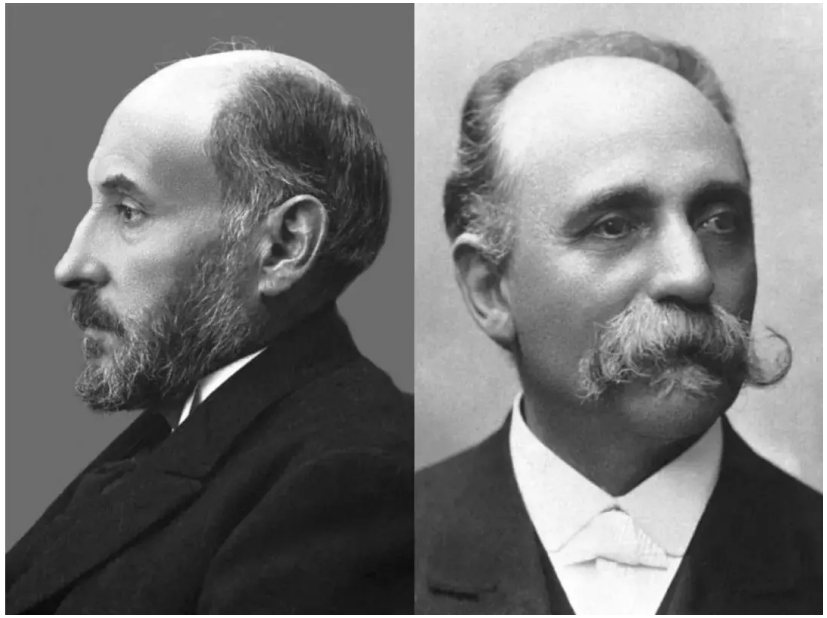
Axons: transmit information to each synapse in the form of electrical impulses





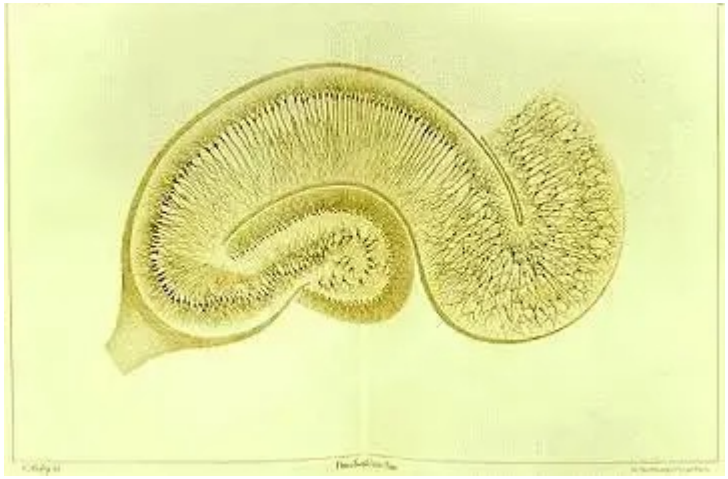
Biological Neurons and Neural Networks

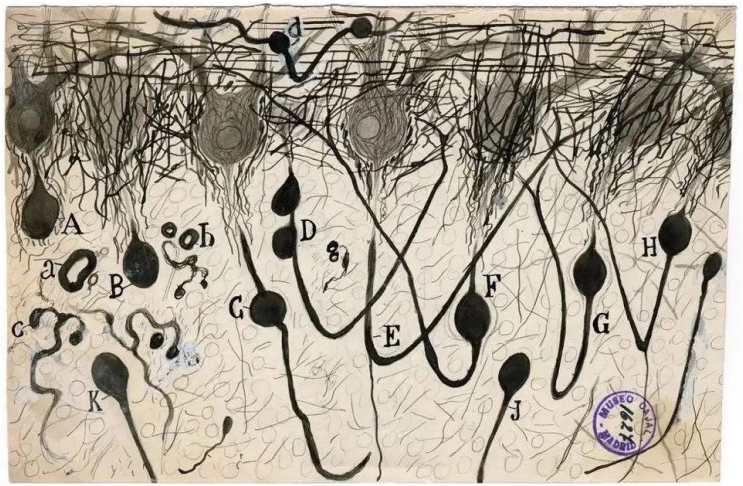
- The connection of Neurons



Santiago Ramon y Cajal **Camillo Golgi**

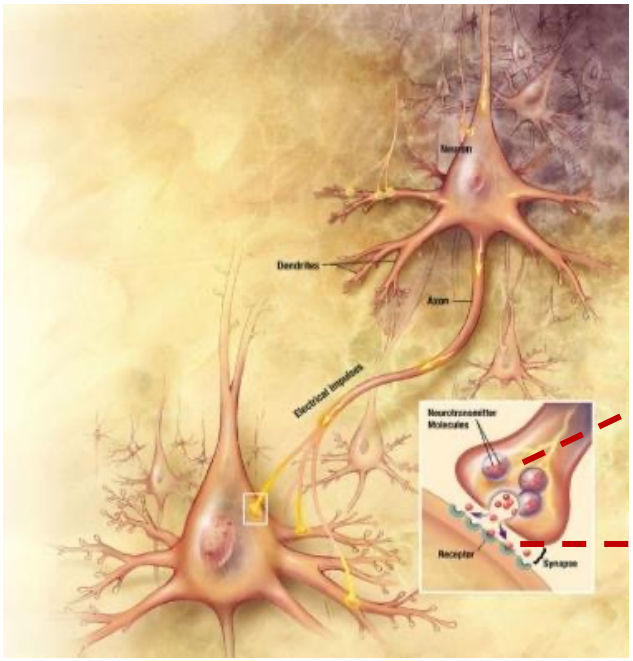
Shared the Nobel Prize in 1906

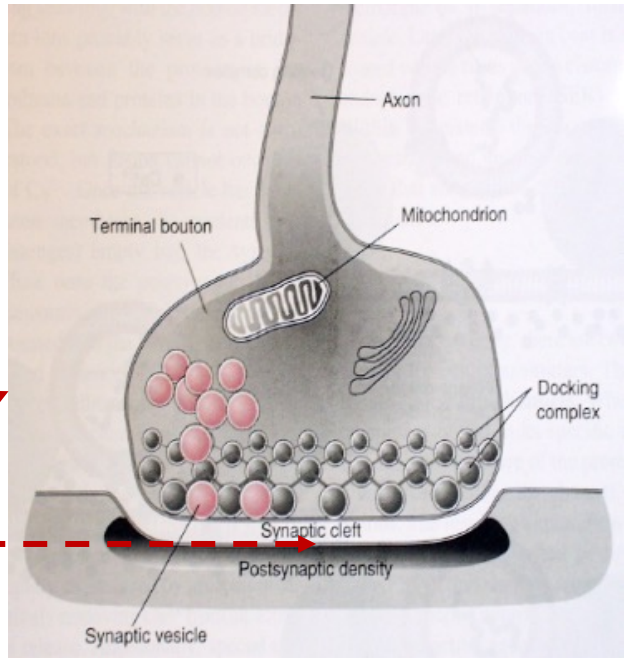




Biological Neurons and Neural Networks

- Synapse: a contact structure in which pulses from one neuron are transmitted to another neuron.

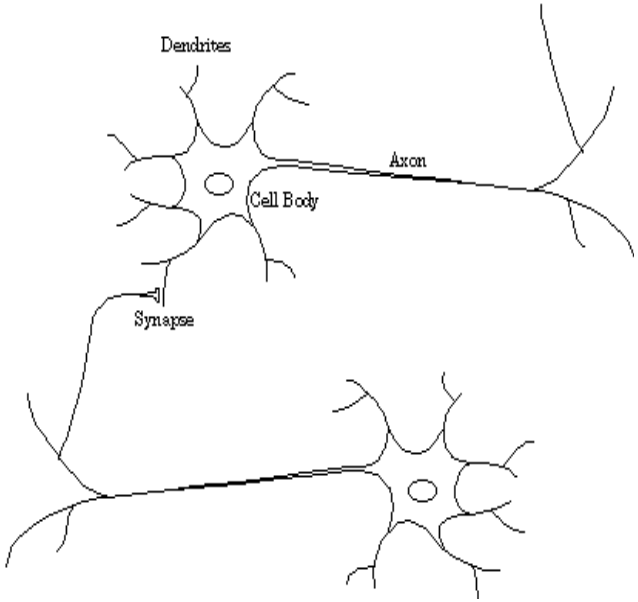




- Nerve impulses from one cell affect the behavior of another cell.
- the strength of the connection between the two neurons will increase when two neurons produce a peak almost at the same time.

Biological Neurons and Neural Networks

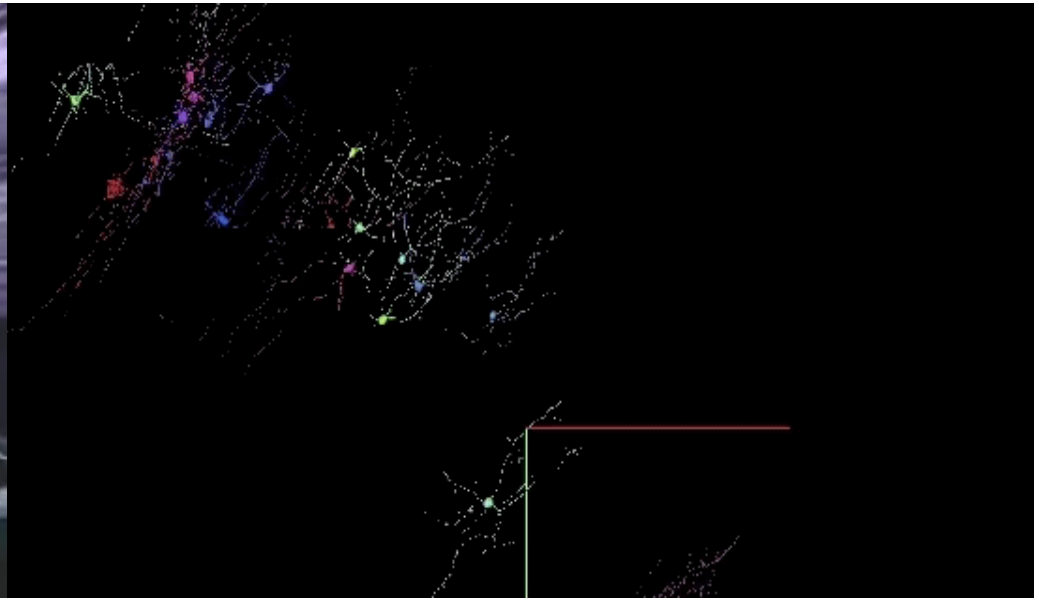
- There are about 30 billion neurons in the neocortex
- About 100 trillion synaptic connections between neurons



Knowledge is reflected in the strength of connections between neurons

Biological Neurons and Neural Networks

Although some progress has been made in understanding the macrostructure of this very complex tissue, its structure at the level of individual nerve cells and the interconnected synapses are largely unknown.



Neural Networks

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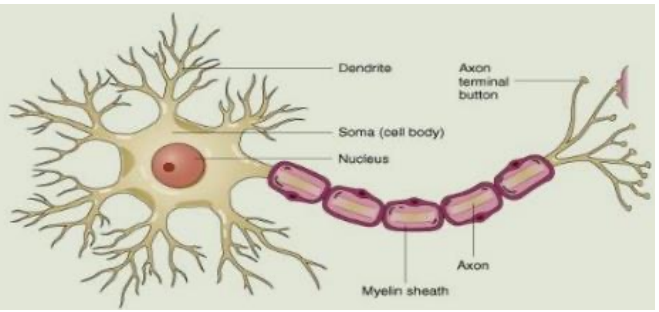
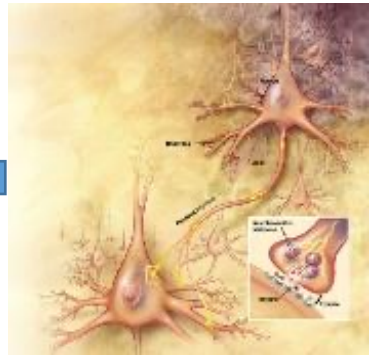
Computational Model of Neural Network

- Artificial Neuron





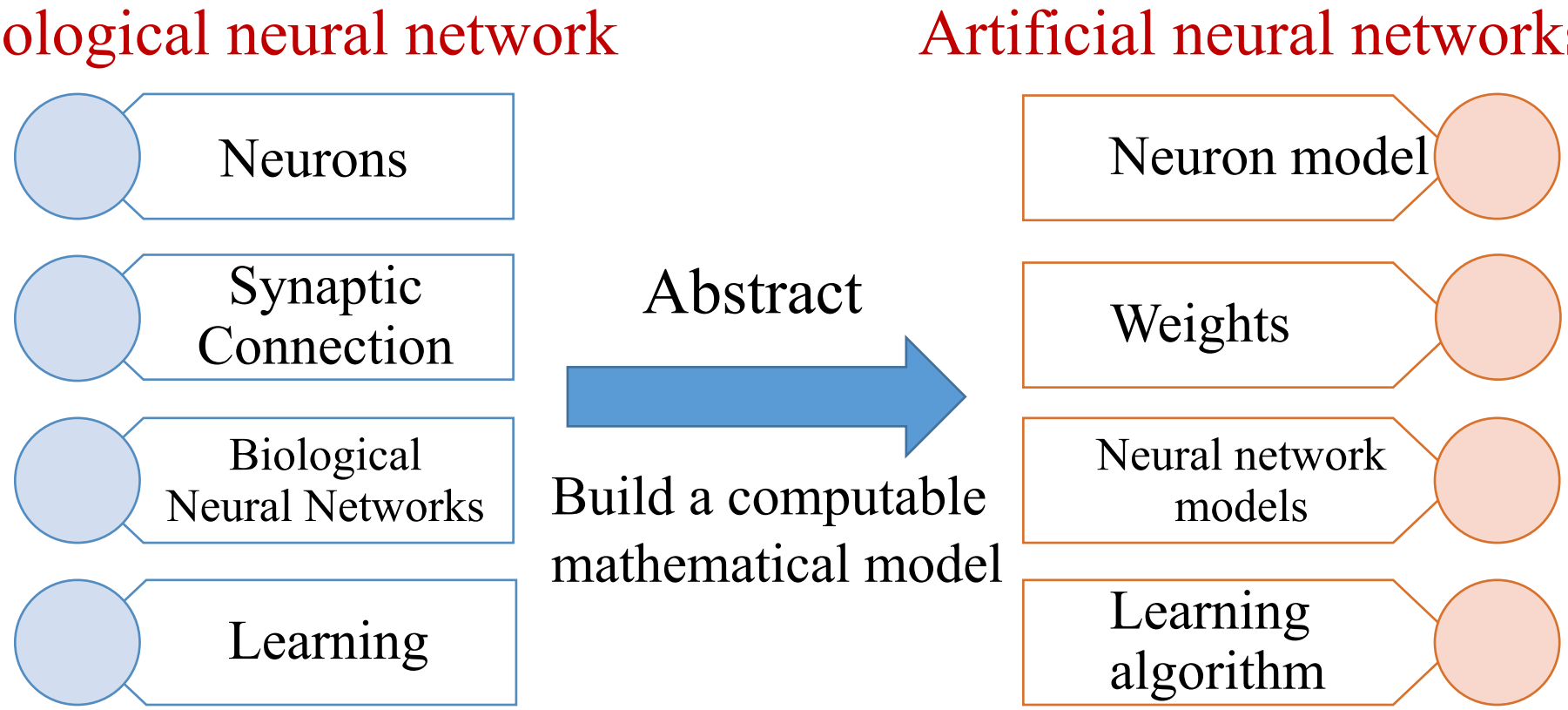
Neurons | Connection between neurons | Neural Networks

Idea: Using computers to simulate the activities of biological neural networks is expected to make machines intelligent

Artificial neural networks

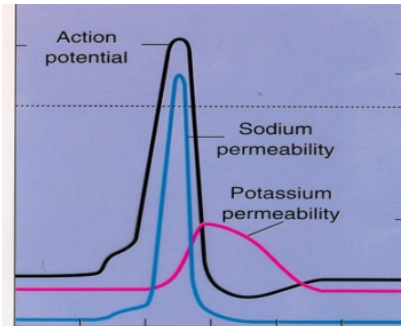
Computational Model of Neural Network

- Artificial Neuron

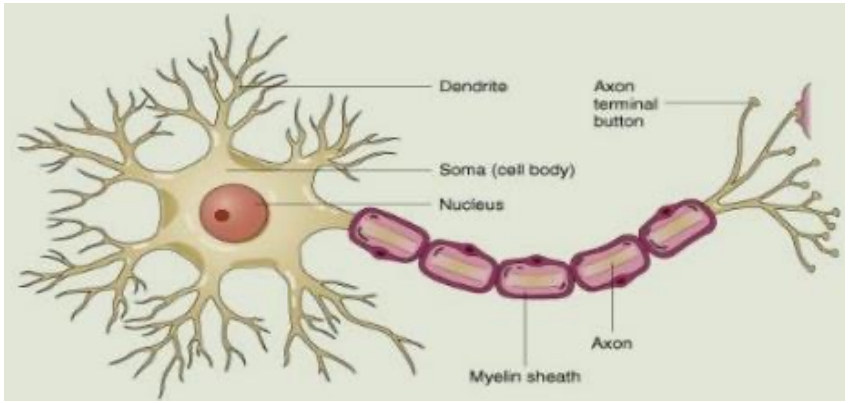


Computational Model of Neural Network

Artificial Neuron



Single neuron structure



How to abstract?

- Soma, Dendrites, Axons
- Function: Collect and transmit signals
- Dendrites receive multiple inputs
- Soma superimposes input information
- Pulses are generated when information is superimposed to a certain extent
- Single output

Computational Model of Neural Network

- Artificial Neuron
  - Spiking Model (放电模型)
    - Membrane potential (膜电位)
  - Firing-Rate Model (点火率模型)
    - Firing rate (点火率)

Computational Model of Neural Network

Artificial Neuron: Spiking Model

The Nobel Prize in Physiology or Medicine 1963

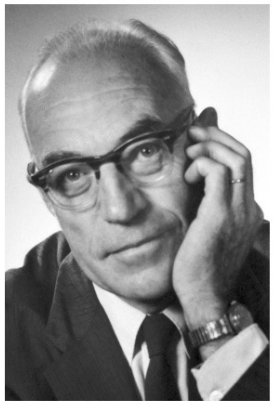


Photo from the Nobel Foundation archive.
Sir John Carew Eccles
Prize share: 1/3

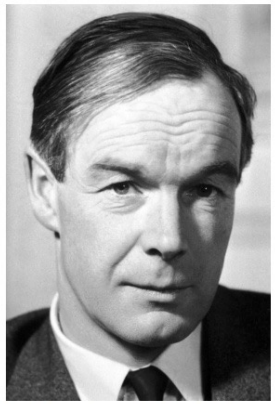


Photo from the Nobel Foundation archive.
Alan Lloyd Hodgkin
Prize share: 1/3

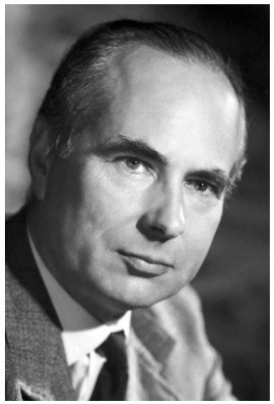


Photo from the Nobel Foundation archive.
Andrew Fielding Huxley
Prize share: 1/3

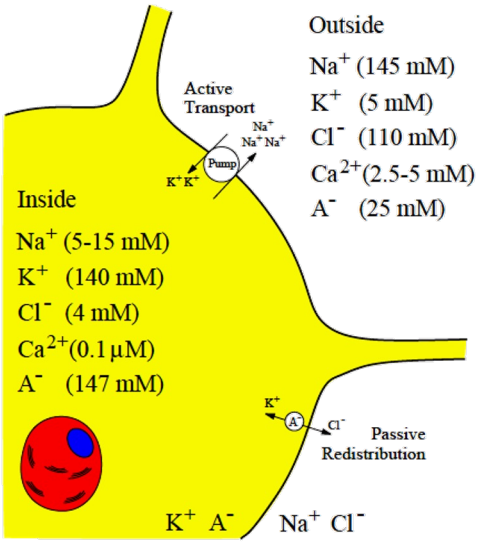
The Nobel Prize in Physiology or Medicine 1963 was awarded jointly to Sir John Carew Eccles, Alan Lloyd Hodgkin and Andrew Fielding Huxley "for their discoveries concerning the ionic mechanisms involved in excitation and inhibition in the peripheral and central portions of the nerve cell membrane."

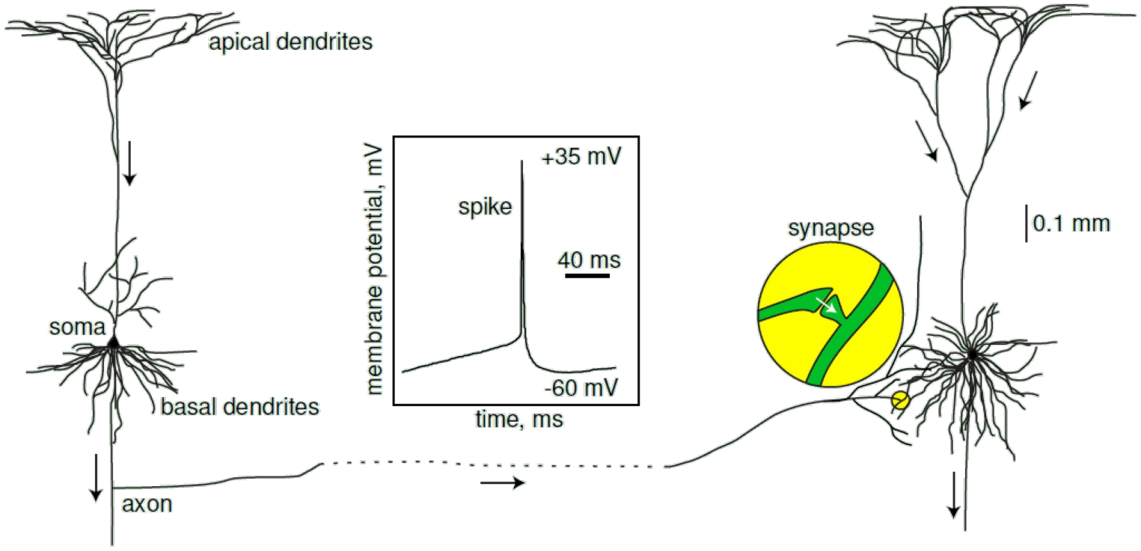
"Because they discovered the ion mechanism of excitement and inhibition in the surrounding and central part of the nerve cell membrane."

Computational Model of Neural Network

Artificial Neuron: Spiking Model

$$
\begin{aligned}
C\dot{V} &= I - \overbrace{\bar{g}_{\mathrm{K}} n^4 (V - E_{\mathrm{K}})}^{I_{\mathrm{K}}} - \overbrace{\bar{g}_{\mathrm{Na}} m^3 h (V - E_{\mathrm{Na}})}^{I_{\mathrm{Na}}} - \overbrace{g_{\mathrm{L}} (V - E_{\mathrm{L}})}^{I_{\mathrm{L}}} \\
\dot{n} &= \alpha_n(V)(1-n) - \beta_n(V) n \\
\dot{m} &= \alpha_m(V)(1-m) - \beta_m(V) m \\
\dot{h} &= \alpha_h(V)(1-h) - \beta_h(V) h \,,
\end{aligned}
$$

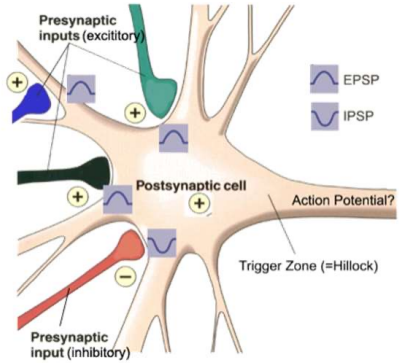


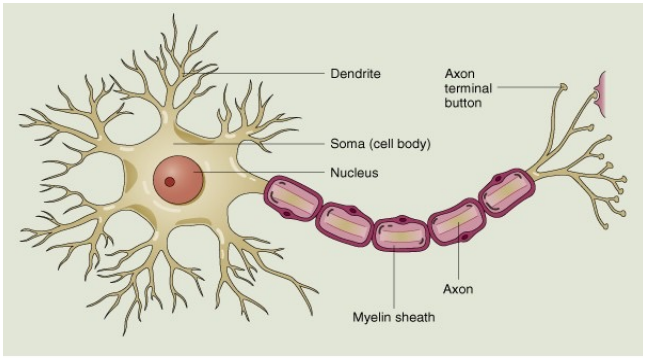


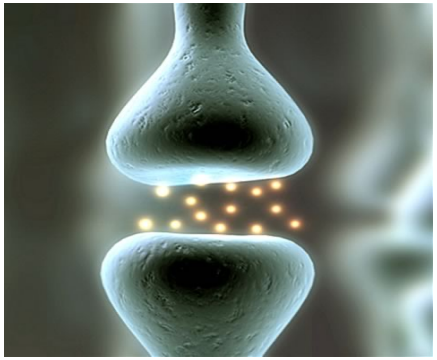
- In 1939, the electrical activity on the giant axons of the nerve cells of the squid was investigated
- Won the 1963 Nobel Prize in Physiology or Medicine

Computational Model of Neural Network

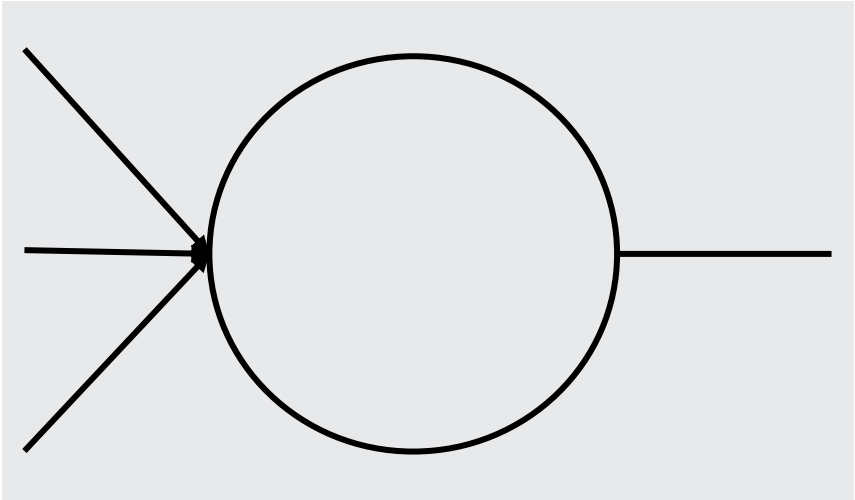
- Artificial Neuron: Firing-Rate Model







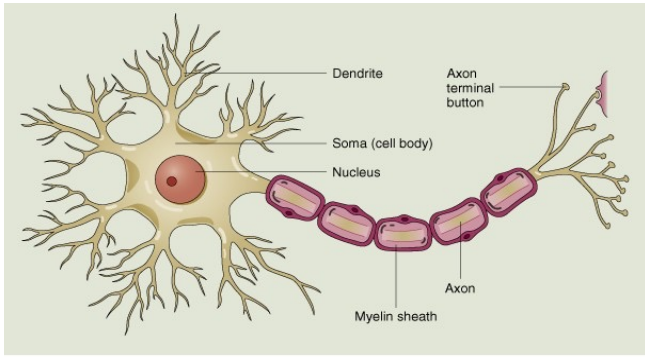
Signals from other neurons

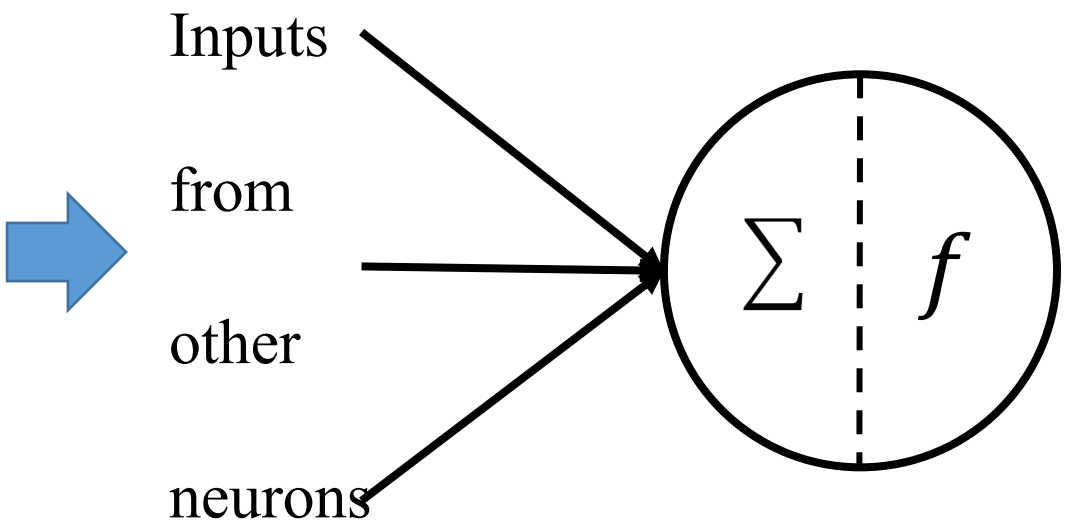


output signal

Computational Model of Neural Network

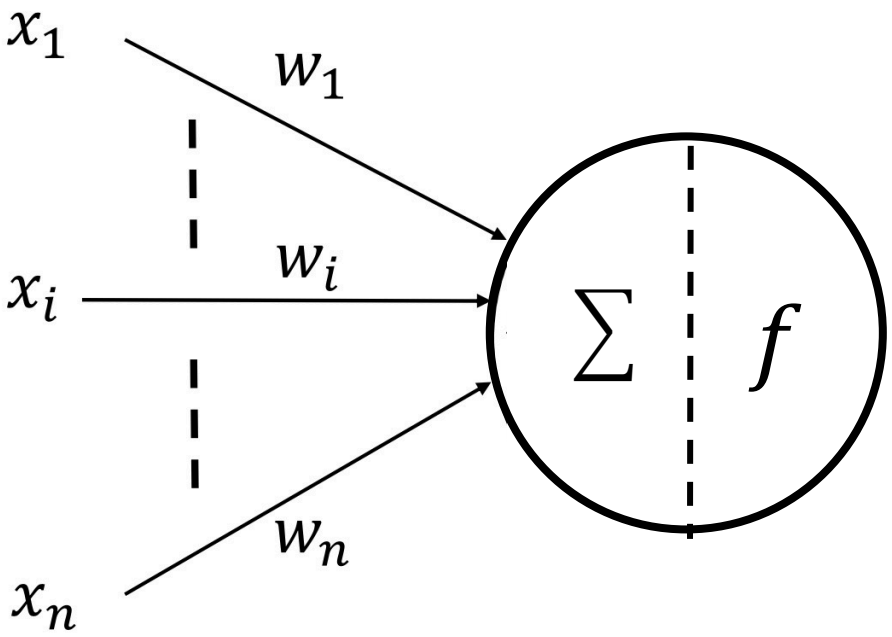
- Artificial Neuron: Firing-Rate Model -- Input abstract

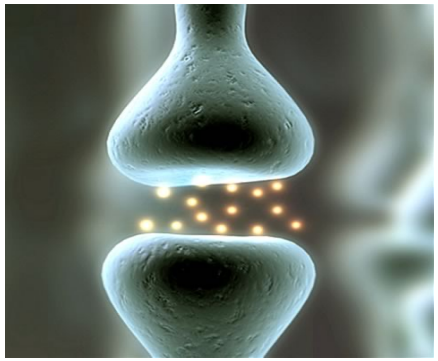




Computational Model of Neural Network

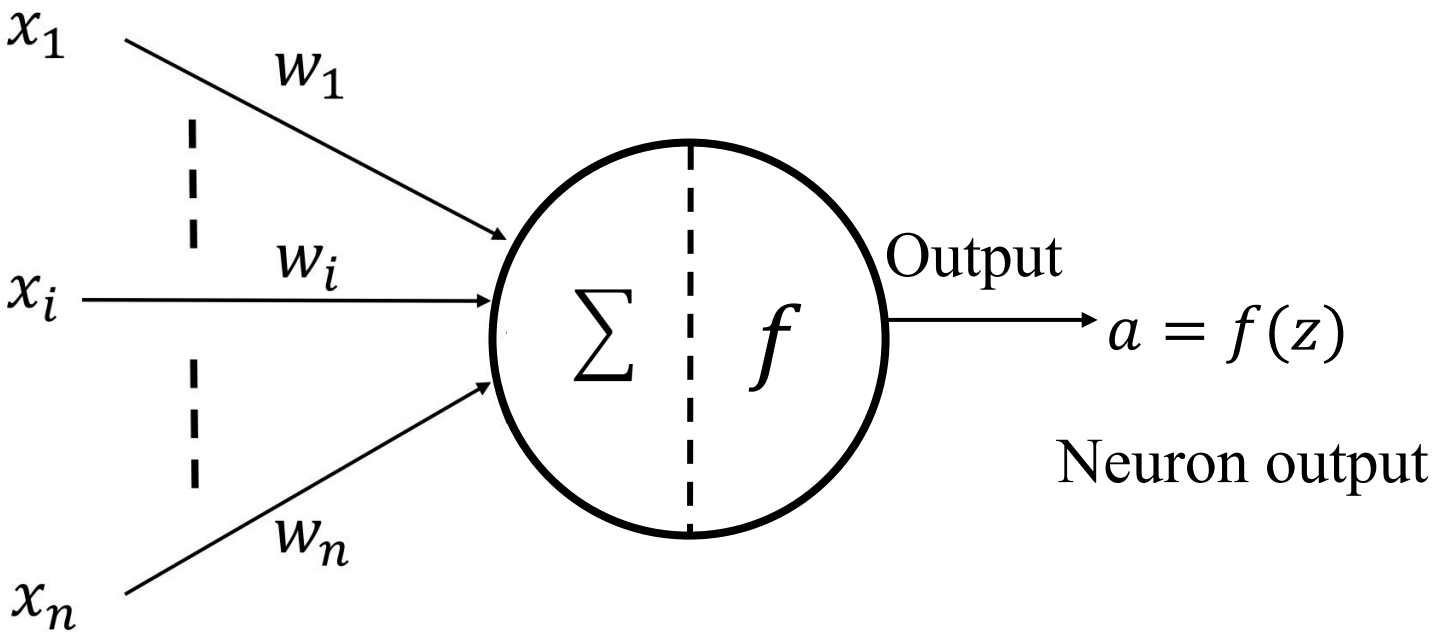
- Artificial Neuron: Firing-Rate Model -- Input abstract





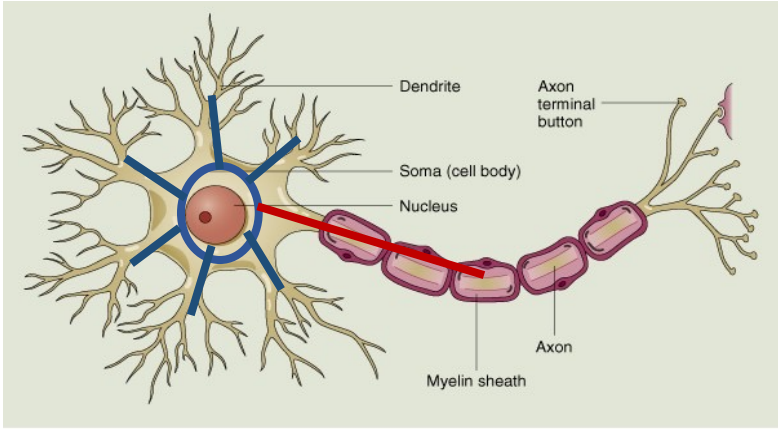
Computational Model of Neural Network

- Firing-Rate Model -- Output abstract



Computational Model of Neural Network

Artificial Neuron: Firing-Rate Model



p_1 Another neuron axon

Synapse

Connection strength

w_1

Dendrites

w_i

p_i

w_n

p_n

Soma

$n = \sum_{i=1}^{n} w_i p_i$

f

Activation function

Axonal output

$a = f(z)$

$a = f\left(\sum_{i=1}^{R} w_i p_i\right)$

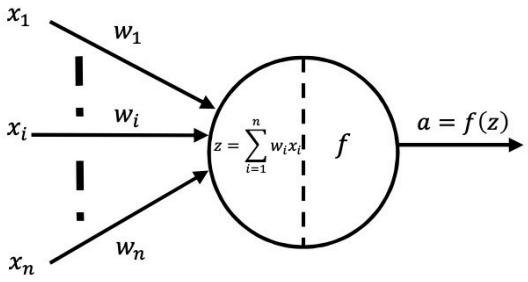
internal input

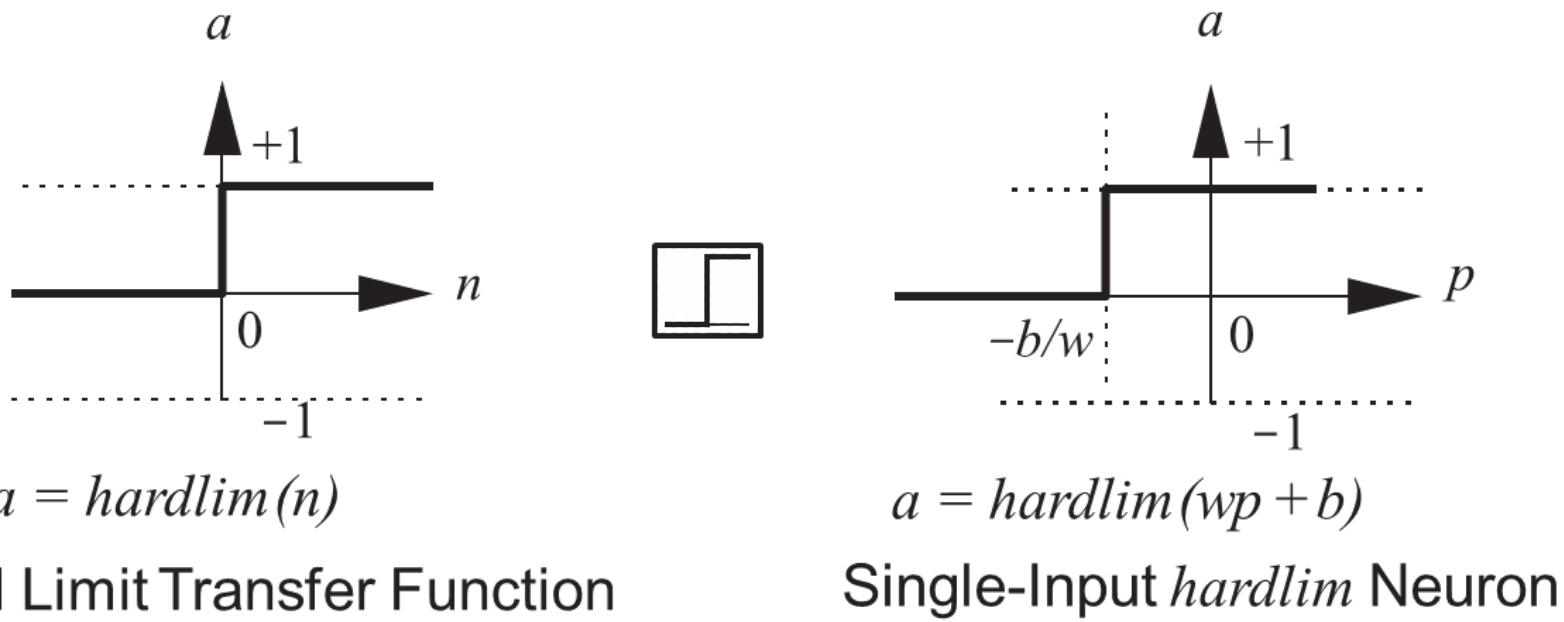
Neuron output

input signal

Computational Model of Neural Network

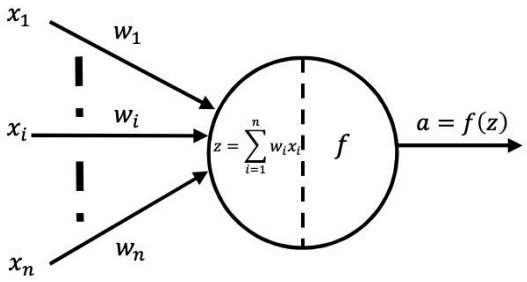
- Firing-Rate Model: Activation function

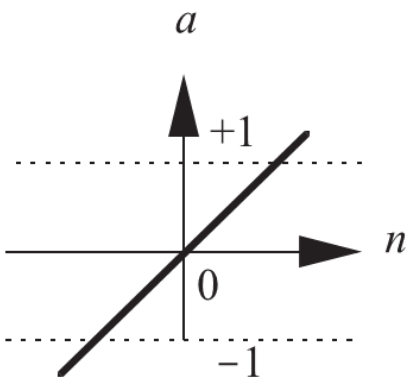




Computational Model of Neural Network

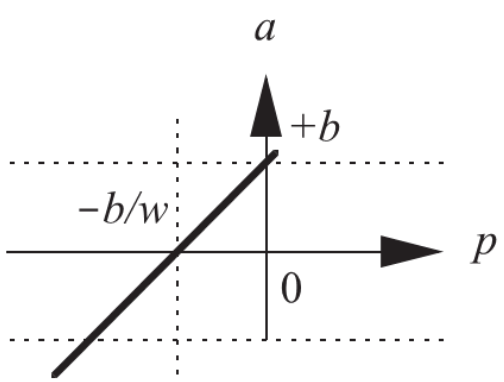
- Firing-Rate Model: Activation function





$a = purelin(n)$

Linear Transfer Function

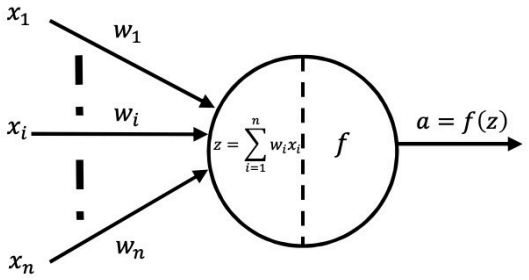


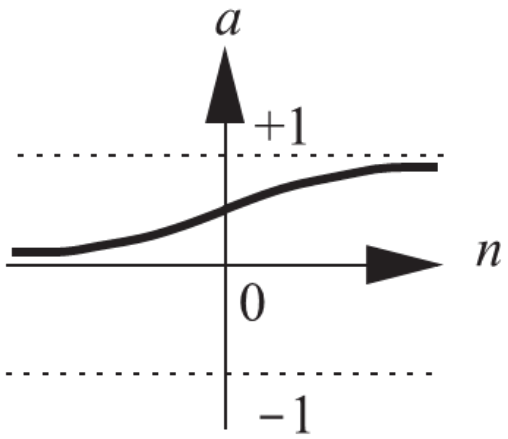
$a = purelin(wp + b)$

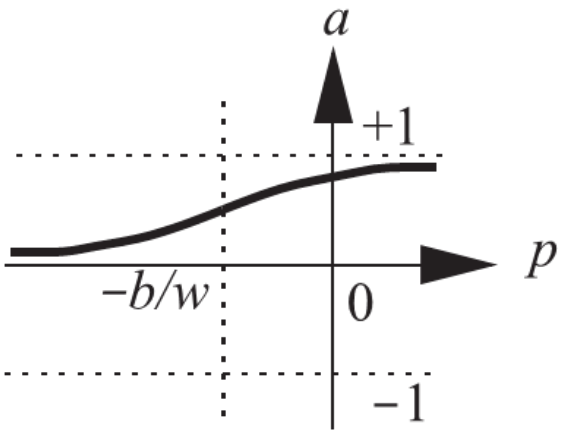
Single-Input *purelin* Neuron

Computational Model of Neural Network

- Firing-Rate Model: Activation function







$a = logsig(n)$

Log-Sigmoid Transfer Function

$a = logsig(wp + b)$

Single-Input *logsig* Neuron

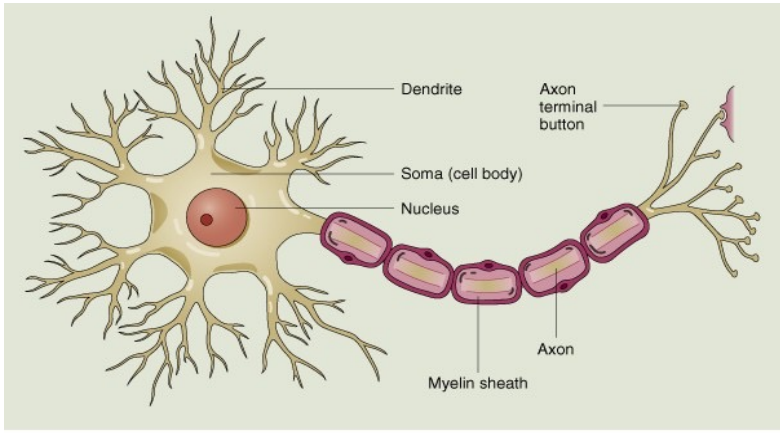
Computational Model of Neural Network

- Firing-Rate Model: Activation function

Name	Input/Output Relation	Icon	MATLAB Function
Hard Limit	$a = 0 \quad n < 0$ $a = 1 \quad n \geq 0$		hardlim
Symmetrical Hard Limit	$a = -1 \quad n < 0$ $a = +1 \quad n \geq 0$		hardlims
Linear	$a = n$		purelin
Saturating Linear	$a = 0 \quad n < 0$ $a = n \quad 0 \leq n \leq 1$ $a = 1 \quad n > 1$		satlin
Symmetric Saturating Linear	$a = -1 \quad n < -1$ $a = n \quad -1 \leq n \leq 1$ $a = 1 \quad n > 1$		satlins
Log-Sigmoid	$a = \frac{1}{1+e^{-n}}$		logsig
Hyperbolic Tangent Sigmoid	$a = \frac{e^{n}-e^{-n}}{e^{n}+e^{-n}}$		tansig
Positive Linear	$a = 0 \quad n < 0$ $a = n \quad 0 \leq n$		poslin
Competitive	$a = 1$ neuron with max n $a = 0$ all other neurons		compet

Computational Model of Neural Network

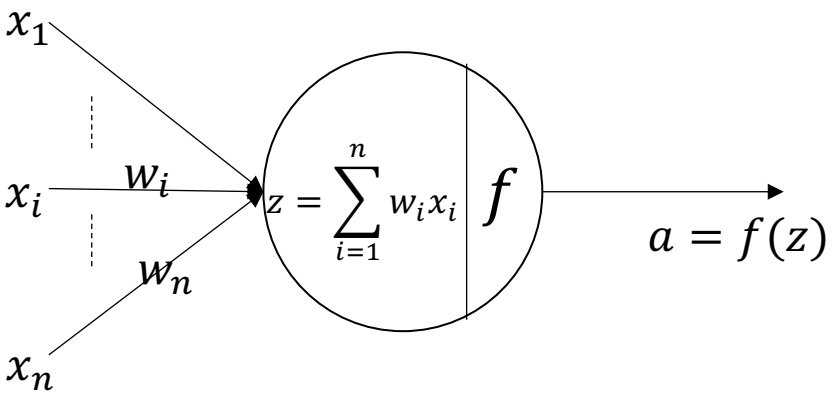
- Artificial Neuron: Firing-Rate Model



$$y = f\left(\sum_{i=1}^{n} w_i x_i\right)$$

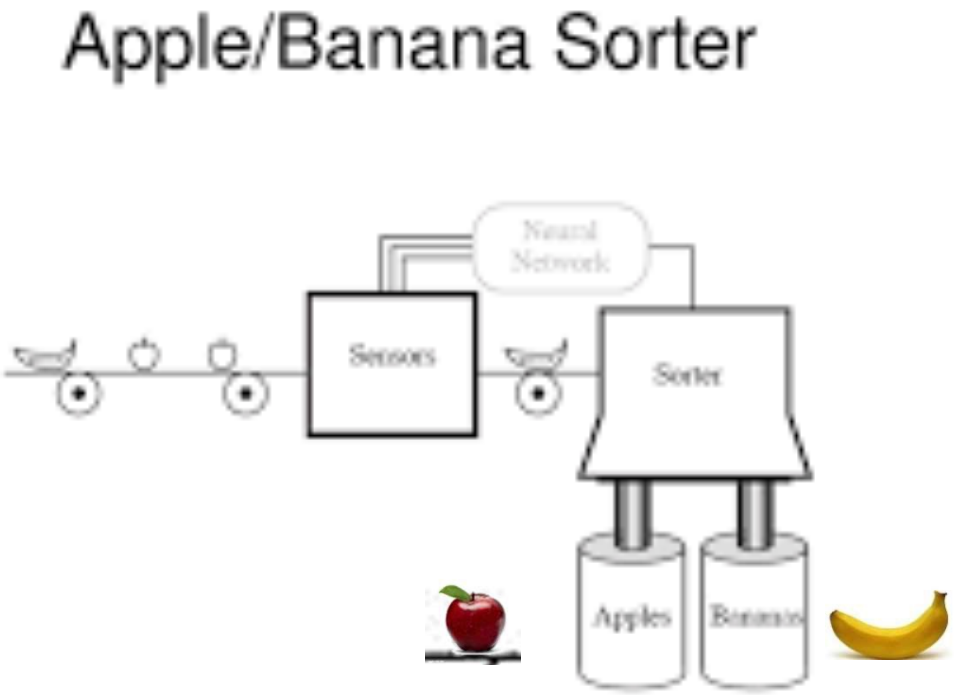
Vector form

$$y = f(Wx)$$



Computational Model of Neural Network

- Example: Classification on one neuron



Computational Model of Neural Network

- Example: Auto classifier of apple/banana

Feature:
red,
round

Feature:
yellow,
strip

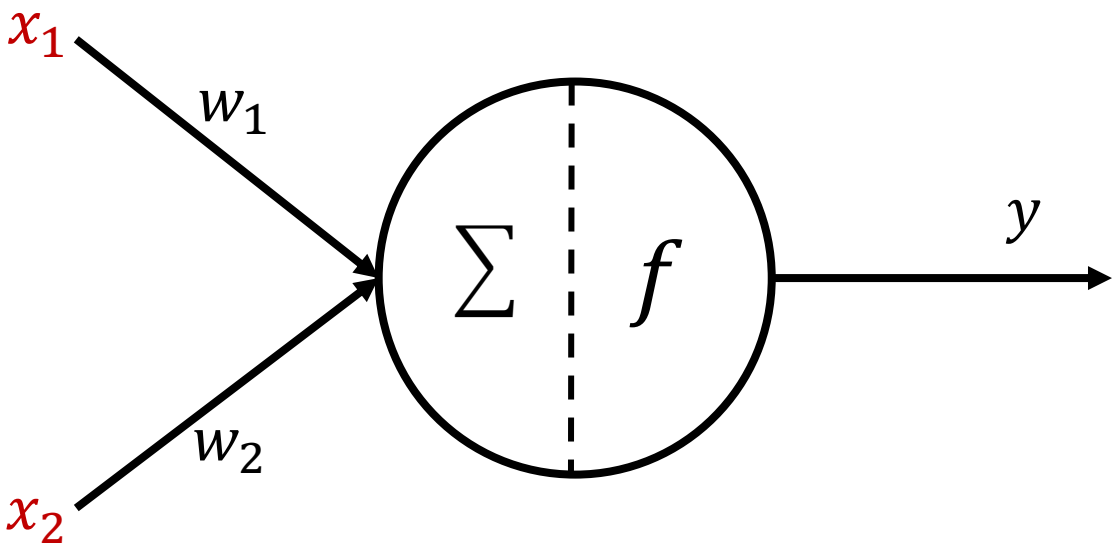
Computational Model of Neural Network

- Example: Auto classifier of apple/banana

Feature:	Feature:	
red,	yellow,	x_1
round	strip	x_2

Computational Model of Neural Network

- Example: Auto classifier of apple/banana
  - The mathematics model of neuron

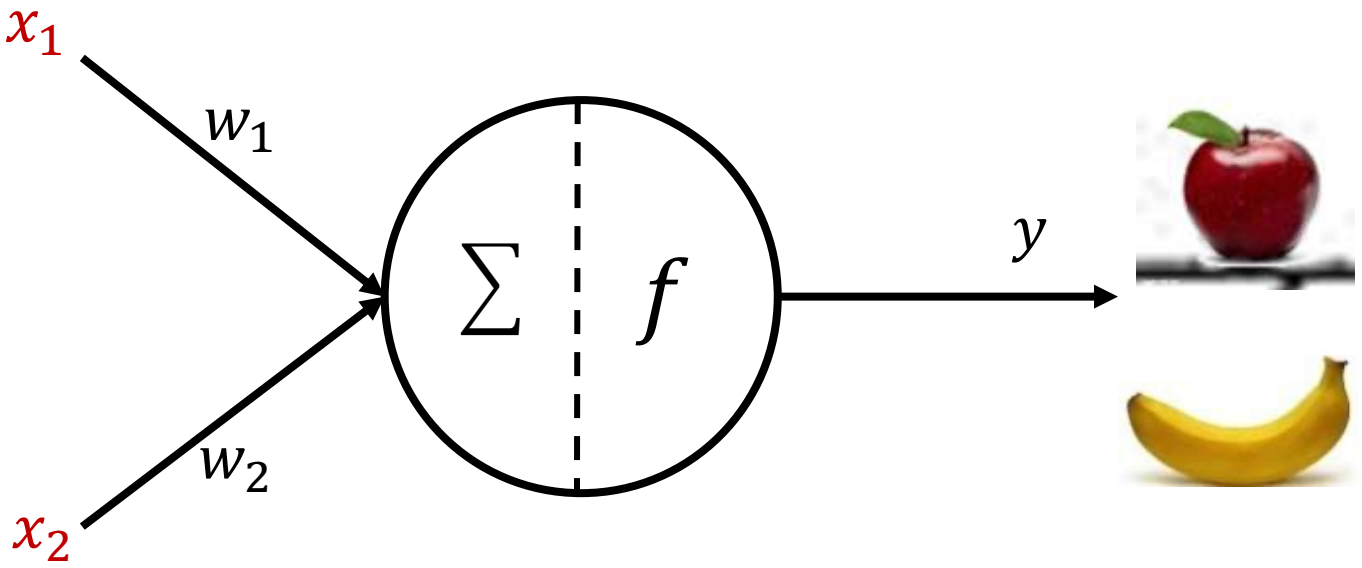


Computational Model of Neural Network

- Example: Auto classifier of apple/banana

Feature: red, round

Feature: yellow, strip



Computational Model of Neural Network

- Example: Auto classifier of apple/banana

Feature: red, round

Feature: yellow, strip

Color { Red: 1 ; yellow: -1

shape { round : 1 ; strip : -1

: 1

: -1

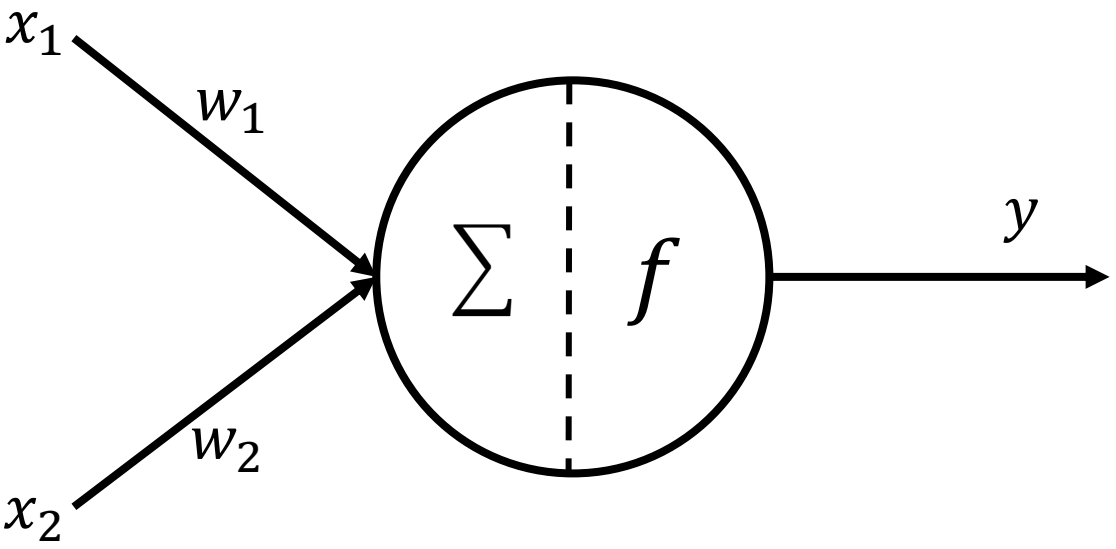
Computational Model of Neural Network

- Example: Auto classifier of apple/banana

Feature: red, round

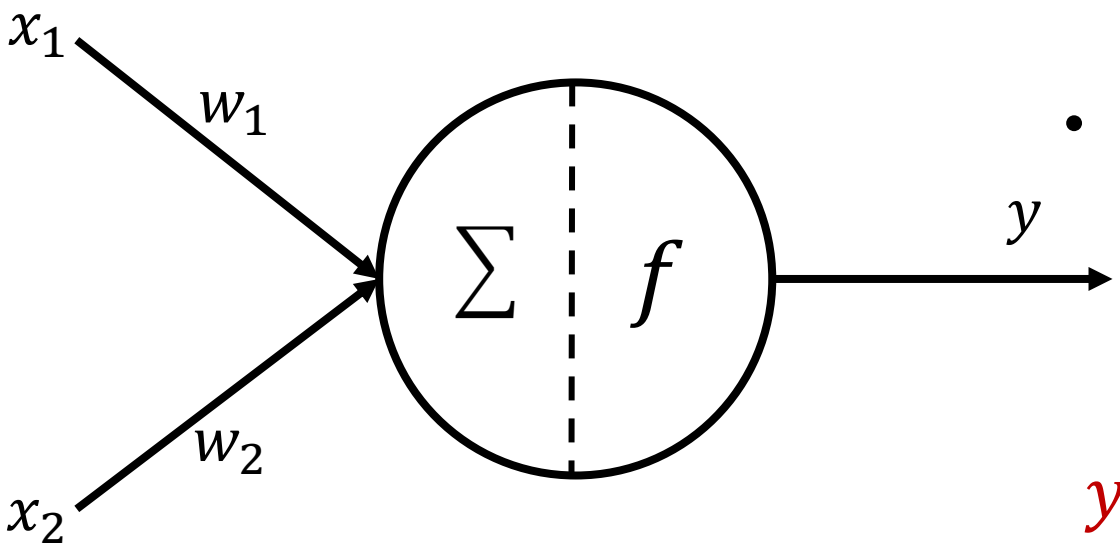
Feature: yellow, strip

$$\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$



Computational Model of Neural Network

- Example: Auto classifier of apple/banana
  - The mathematics model of neuron



Set:

- Weight $\boldsymbol{W} = \begin{bmatrix} w_1 \\ w_2 \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$
- Active function $f(x) = \frac{1}{2}\boldsymbol{x}$

$$y = \frac{1}{2}(x_1 + x_2)$$

Computational Model of Neural Network

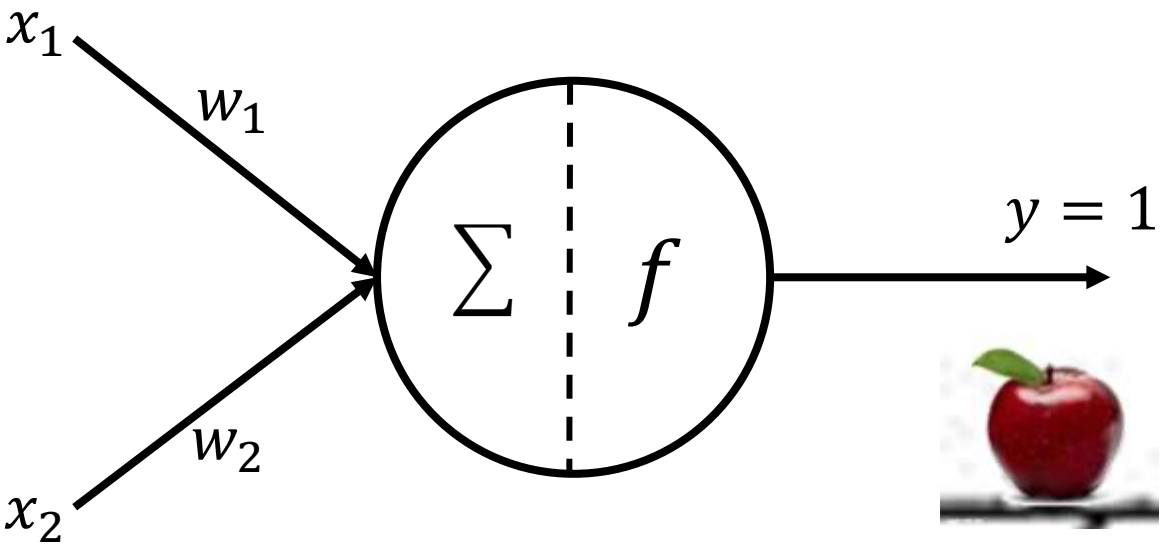
- Example: Auto classifier of apple/banana
  - The mathematics model of neuron

Input:

Apple $\boldsymbol{X} = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$

Red: 1

round : 1



$$Output\text{: } y = \frac{1}{2}(x_1 + x_2) = 1$$

Computational Model of Neural Network

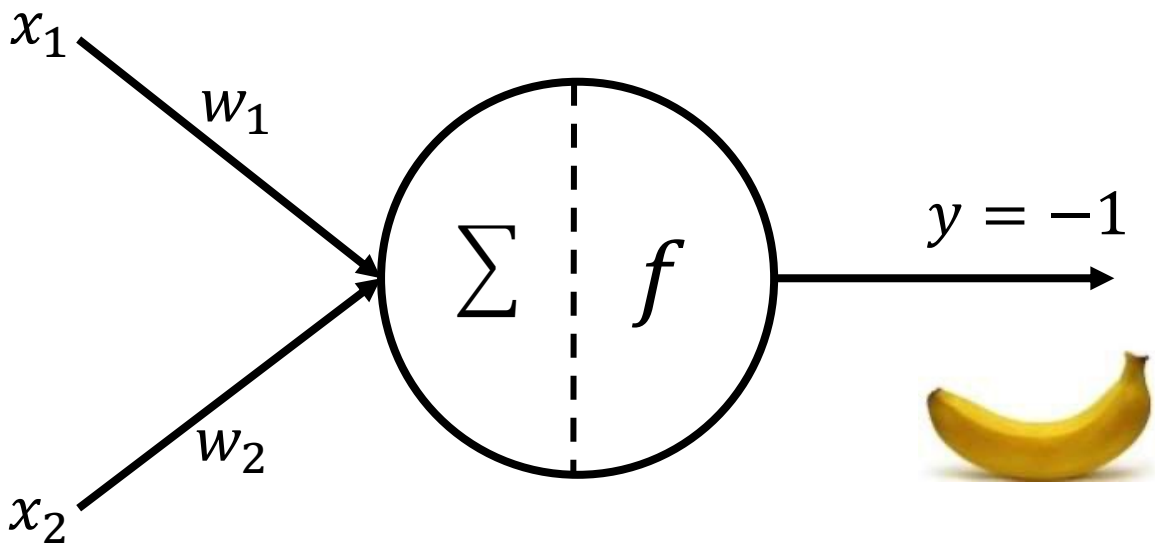
- Example: Auto classifier of apple/banana
  - The mathematics model of neuron

Input:

Banana $\boldsymbol{X} = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} \begin{bmatrix} -1 \\ -1 \end{bmatrix}$

yellow: -1

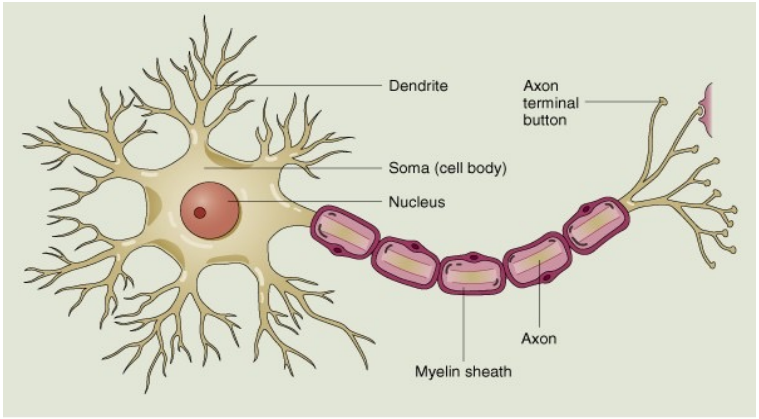
strip : -1



$$Output\colon\ y = \frac{1}{2}(x_1 + x_2) = -1$$

Computational Model of Neural Network

- Neural Networks

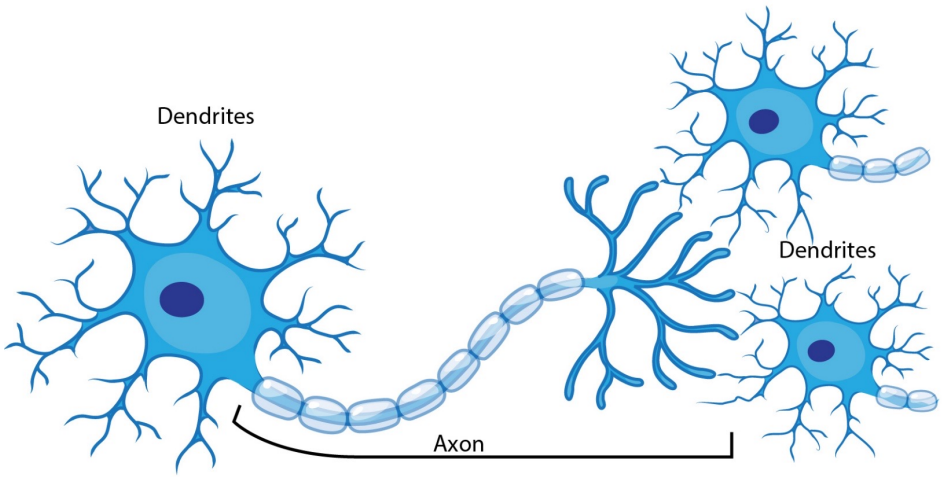


Neurons

Neural Networks

Computational Model of Neural Network

- Neural Networks



Neural Network = Neurons + Connections

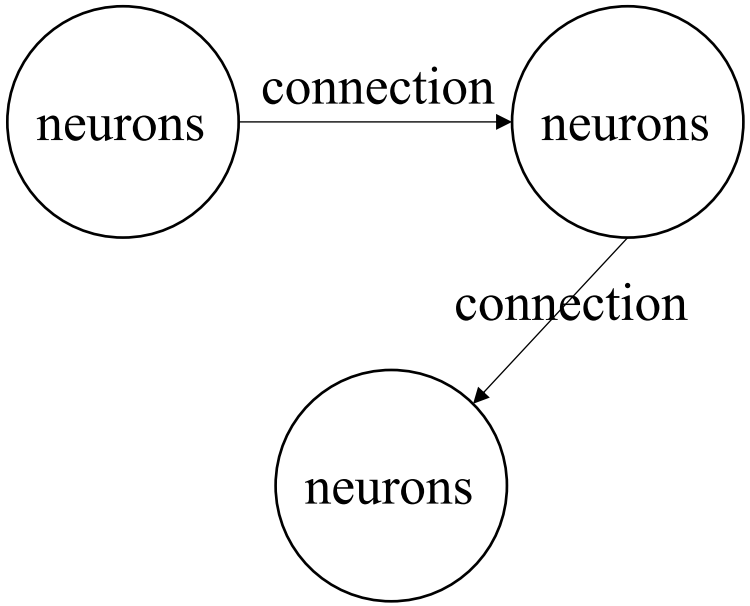
Computational Model of Neural Network

Neural Networks

Feedforward neural network

=

neurons + feedforward connections



Recurrent neural network

=

neurons + recurrent connections