The Introduction To Artificial Intelligence

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2024-2025-1

The Introduction to Artificial Intelligence

- Class Administration
  - What are we going to learn in this term?
    - *Part 1 Brief Introduction to AI*
    - *Part 2 Model selection*
    - *Part 3 Machine Learning*
    - *Part 4 Neural Networks*
    - *Part 5 Applications*

The Introduction to Artificial Intelligence

- Nowadays
  - Foundation Model!

The Introduction to Artificial Intelligence

- 选题: 大模型

大作业	
小组形式	1-5人一组
提交格式	PPT，10页及以上
讲解时长	5-7分钟
截止时间	2024.12.13 12:00

- 逻辑清晰，讲解清楚

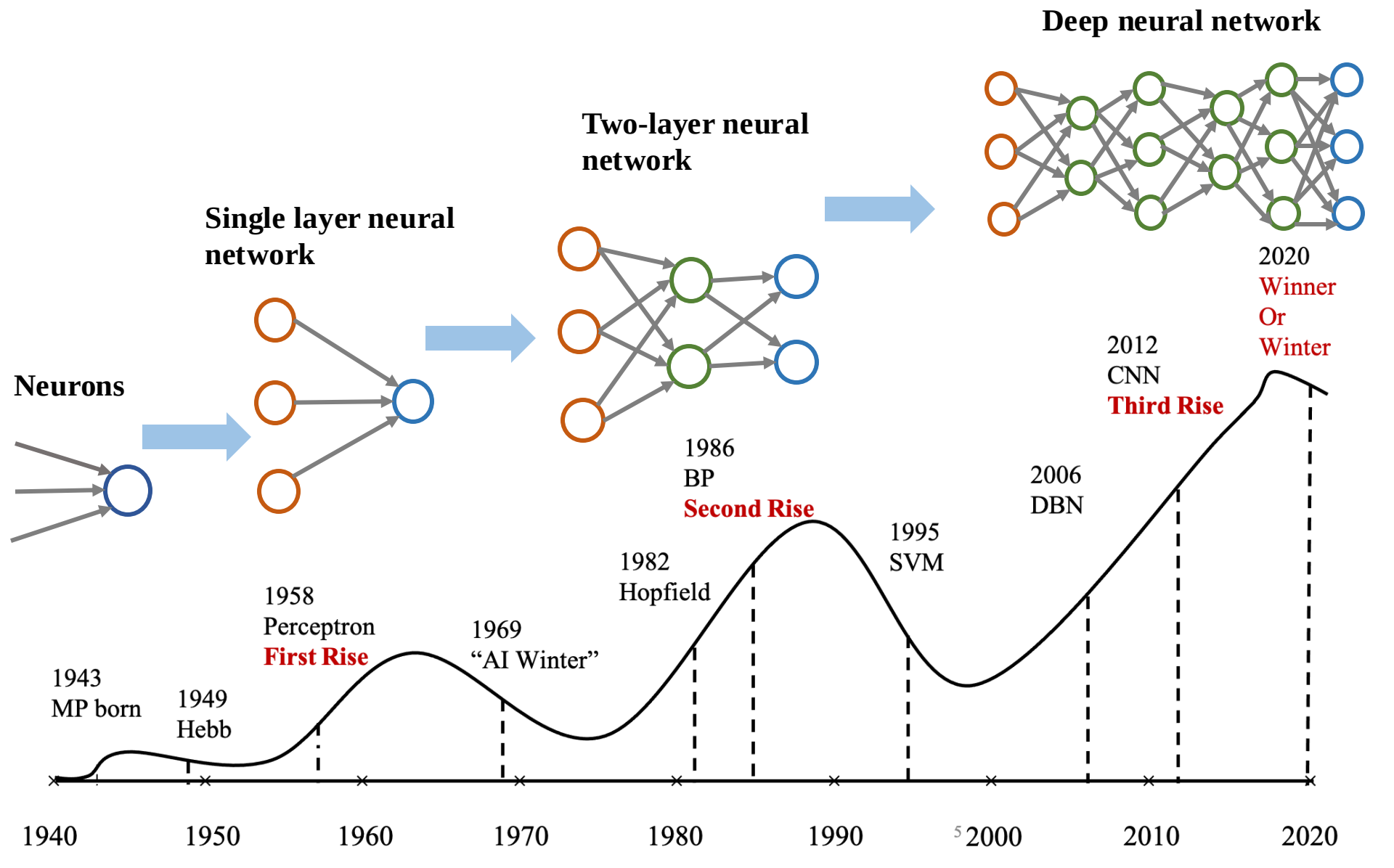
The Introduction to Artificial Intelligence

- 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

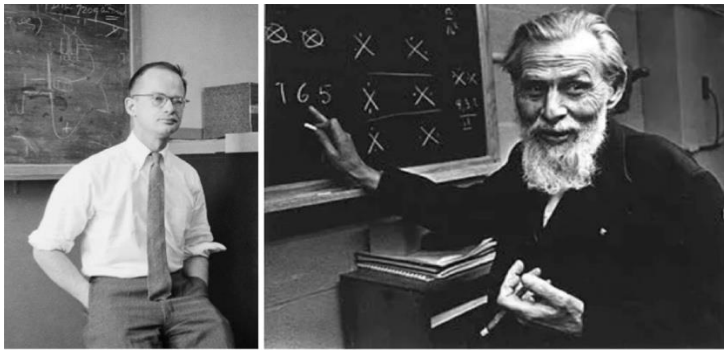
- *The Development History of Neural Networks*
- Where does Intelligence Come From ?
- Biological Neurons and Neural Networks
- Computational Model of Neural Network
- Feedforward Neural Network
- Recurrent Neural Networks

The development history of neural network

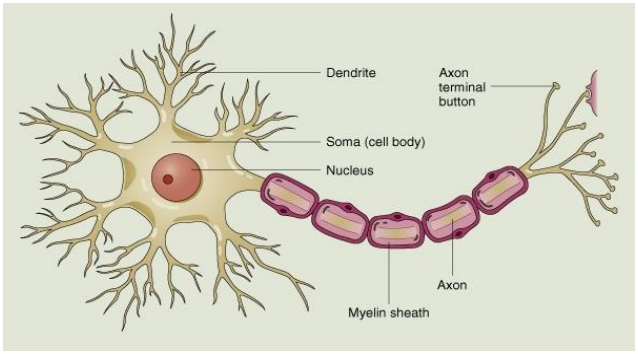


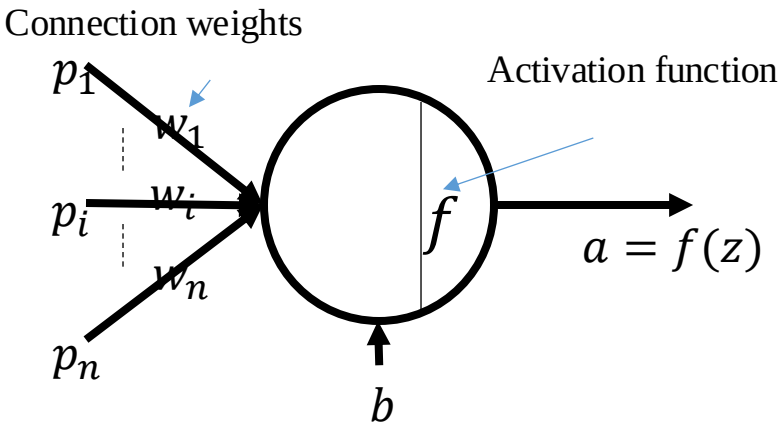
The development history of neural network

- Artificial neuron



Walter Pitts　　Warren McCulloch



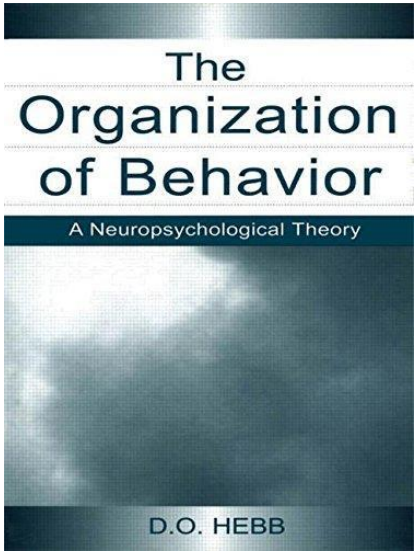


1943年，心理学家沃伦·麦卡洛克(Warren McCulloch)和数学逻辑学家沃尔特·皮茨(Walter Pitts)在合作的《神经活动中固有思想的逻辑演算》中提出并给出了人工神经网络的概念和人工神经元的数学模型。开创了人工神经网络研究的时代。

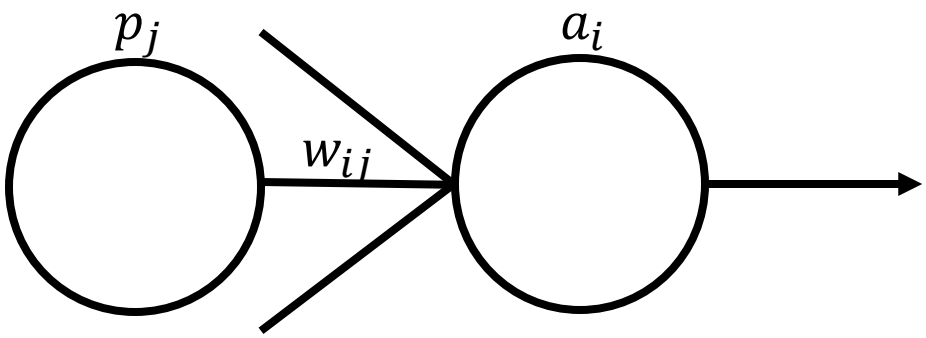
Currently the most widely used neuron model

The development history of neural network

- Hebb Rule



D. Hebb



•**Hebb Rule**：如果突触两侧的两个神经元同时被激活，突触的强度就会增加。如果不是同时，联系就会减弱

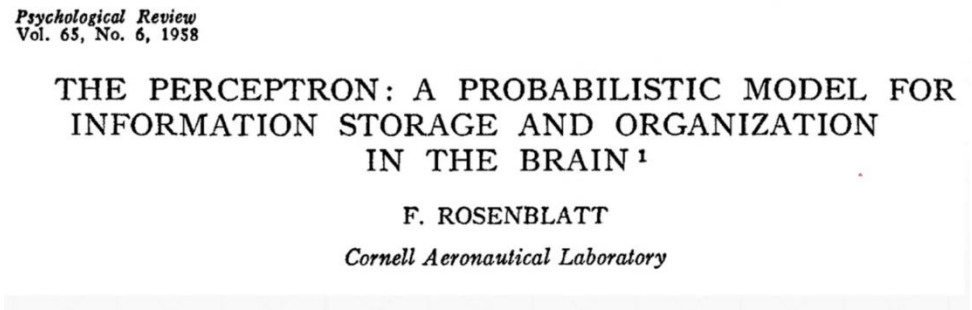
$$w_{ij}^{new} = w_{ij}^{old} + \alpha f_i(a_i) g_j(p_j)$$

The development history of neural network

- Perceptron

Frank Rosenblatt

1957年，Frank Rosenblatt从纯数学的角度重新审视了这个模型，并指出通过学习算法可以从一些输入输出对(X，y)中得到权重W和B。



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=±1,to find a function so that: $f(X)=y$

Sensor:

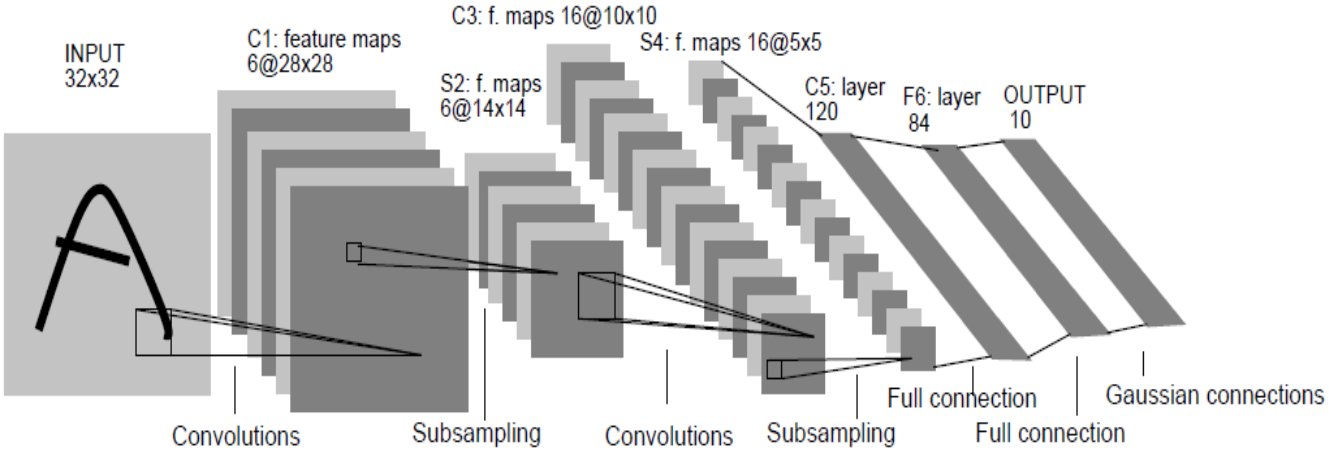
Set $f(X)=sign(W\text{^}T\ X+b)$, automatically learn from the input and output pairs, and get W and b.

The development history of neural network

CNN

Yann Lecun

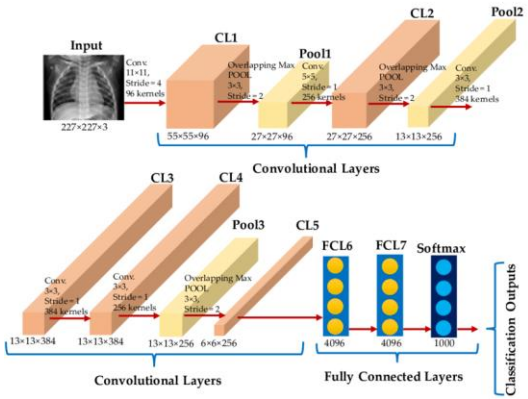
卷积神经网络(CNN)提出于20世纪90年代。Yann Lecun是第一个使用CNN进行手写数字识别的人，并一直保持着在这方面的优势。



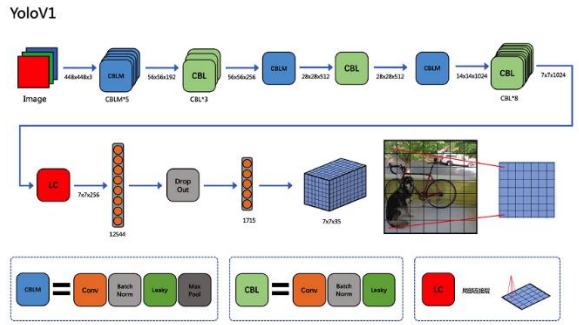
1. LeCun Y., Bottou L., Bengio Y., and Haffner P., Gradient-based learning applied to document recognition, Proceedings of the IEEE, pp. 1-7, 1998.

The development history of neural network

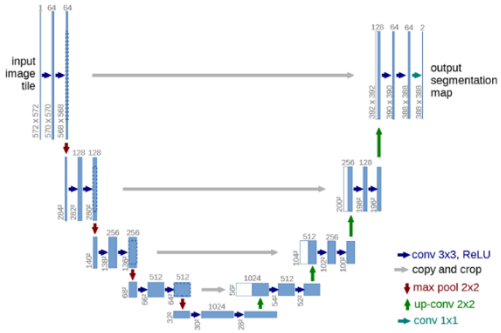
- CNN
  - The current popular neural network structure



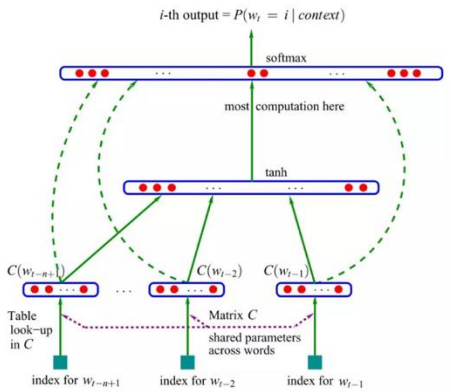
Classification



Target Detection



segmentation



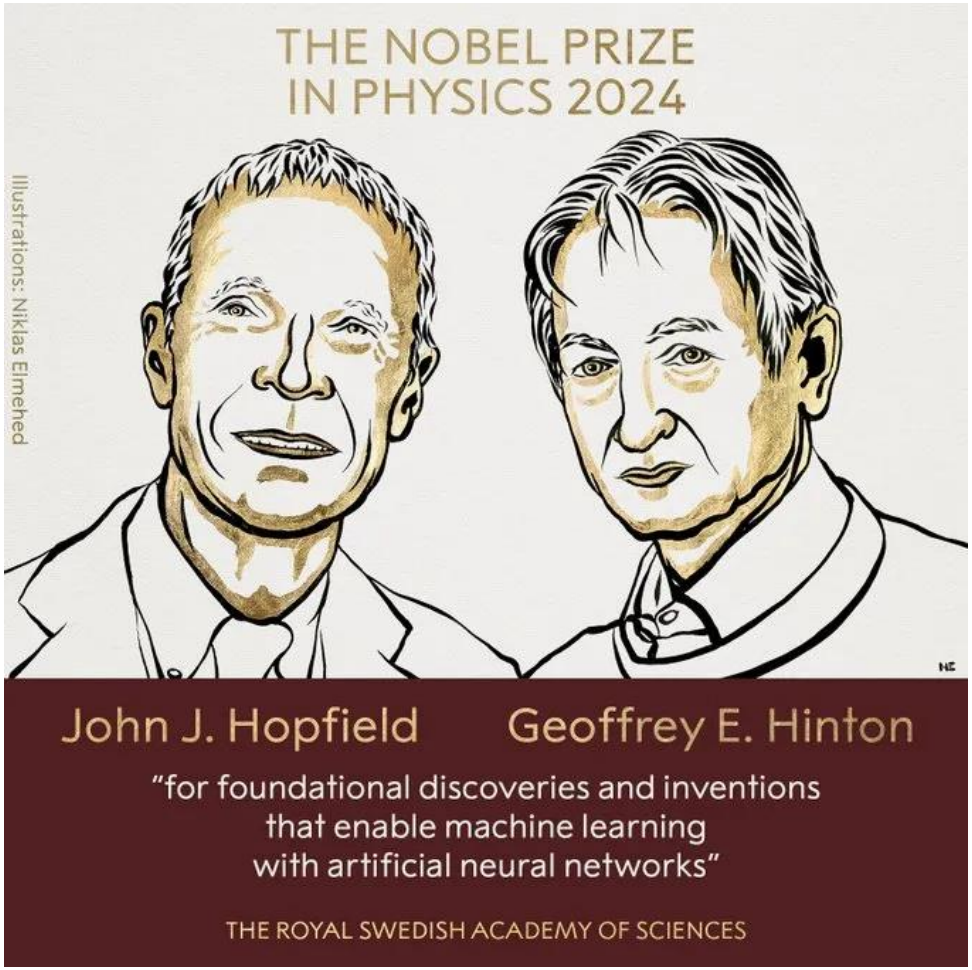
Natural language processing

The Introduction to Artificial Intelligence

Neural Network

The 2024 Nobel Prize in Physics has been announced. American and Canadian scientists John J. Hopfield and Geoffrey E. Hinton were awarded for their “fundamental discoveries and inventions that enable machine learning with artificial neural networks."

2024年诺贝尔物理学奖揭晓。美国和加拿大科学家John J. Hopfield、Geoffrey E. Hinton获奖，以表彰他们“基于人工神经网络实现机器学习的基础性发现和发明”。



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?

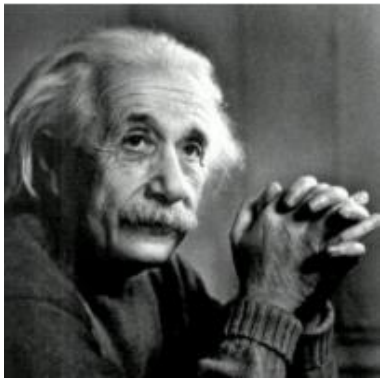
Where does intelligence come from ?

- Thinking: What determines biological intelligence?

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

B. Maybe it depends on athletic ability?

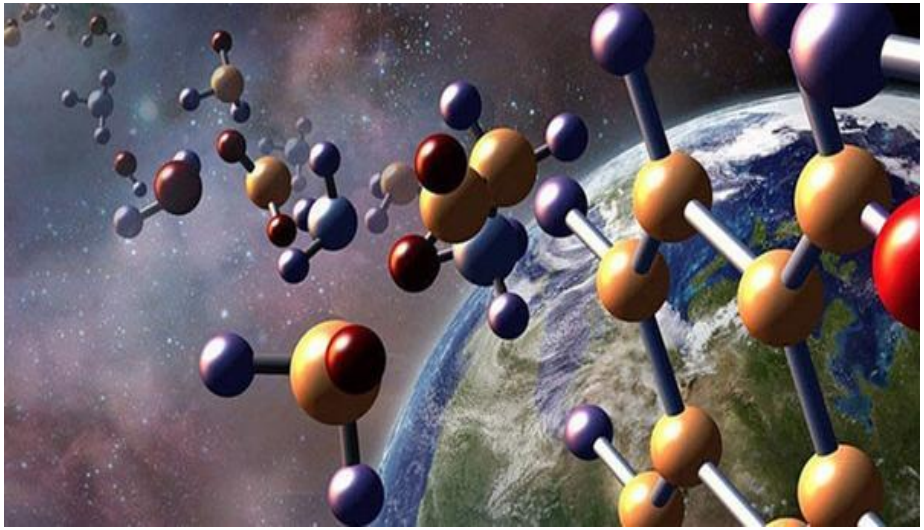
C. Anyway, humans are the smartest!

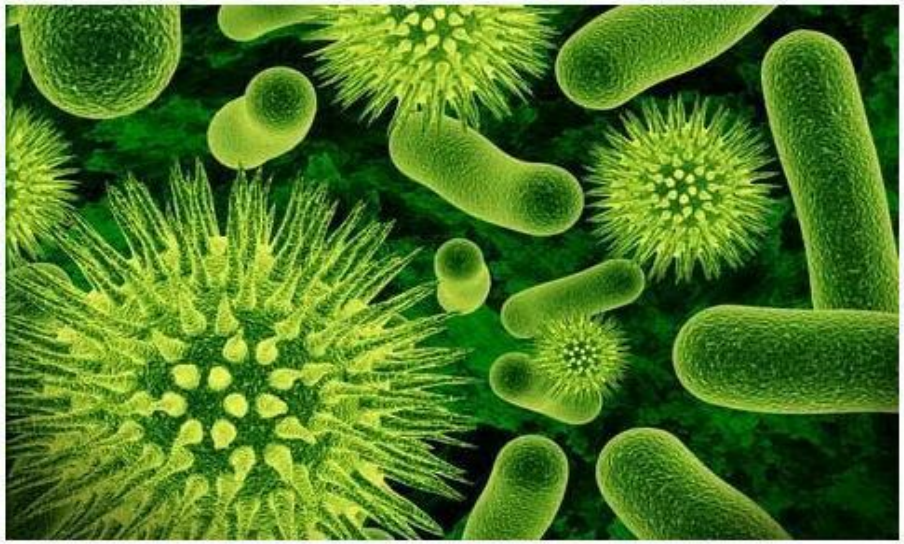


D. May it be the legendary neocortex?

Where does intelligence come from ?

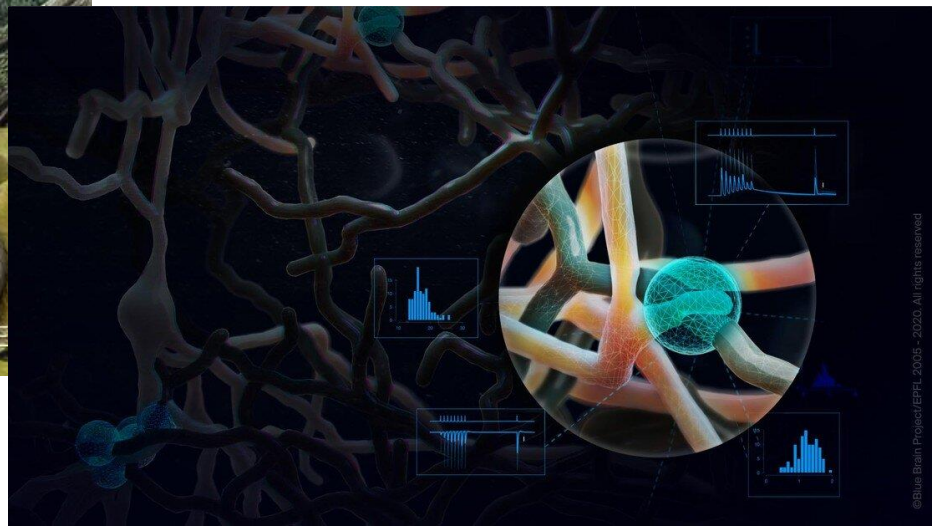
- The first life originated in the ocean
- Life is just a simple cell without a brain





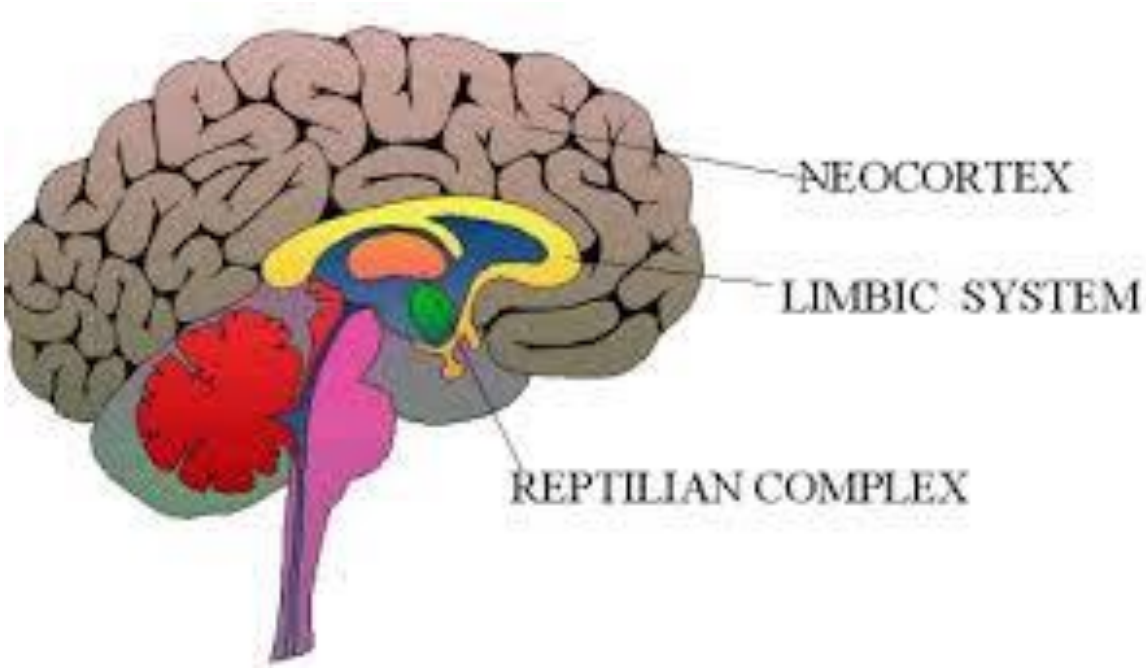
Where does intelligence come from ?

- Mammals already have tiny neocortex



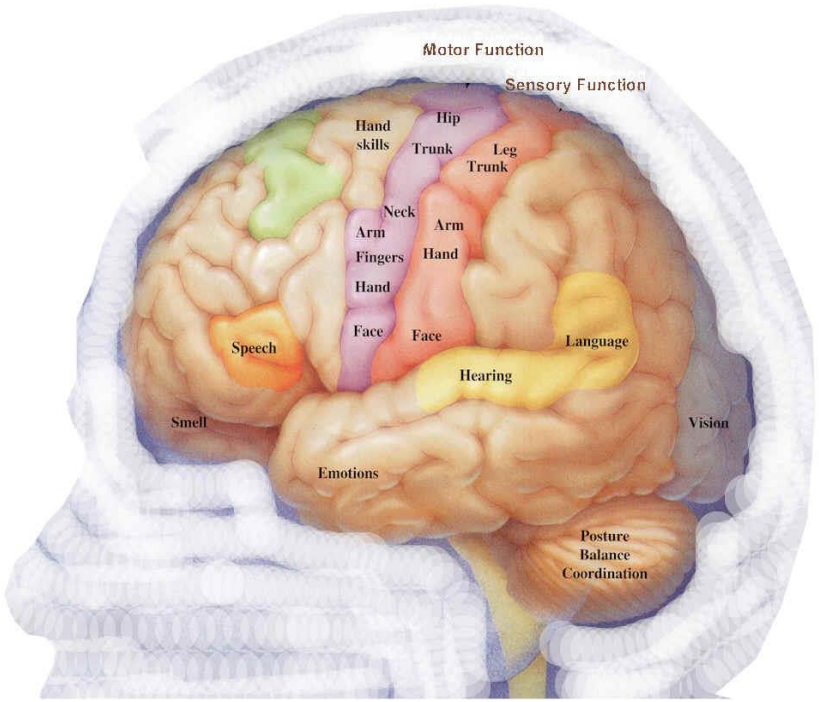
Where does intelligence come from ?

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

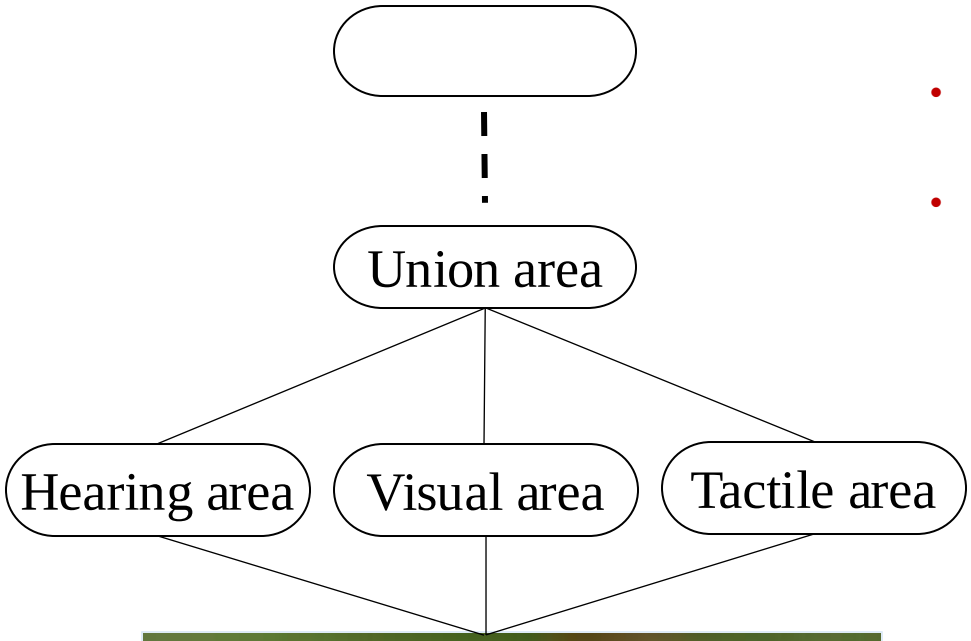


Where does intelligence come from ?

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



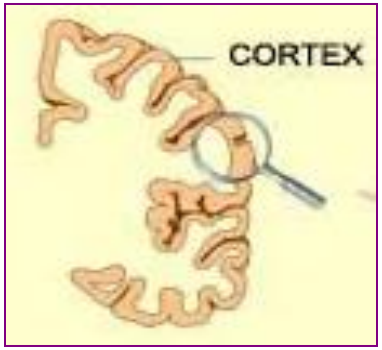
Where does intelligence come from ?

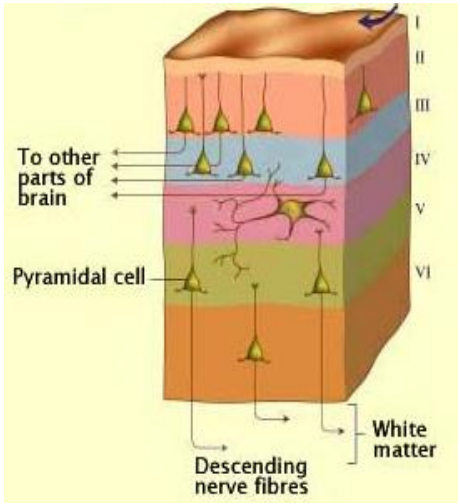


Region

- 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

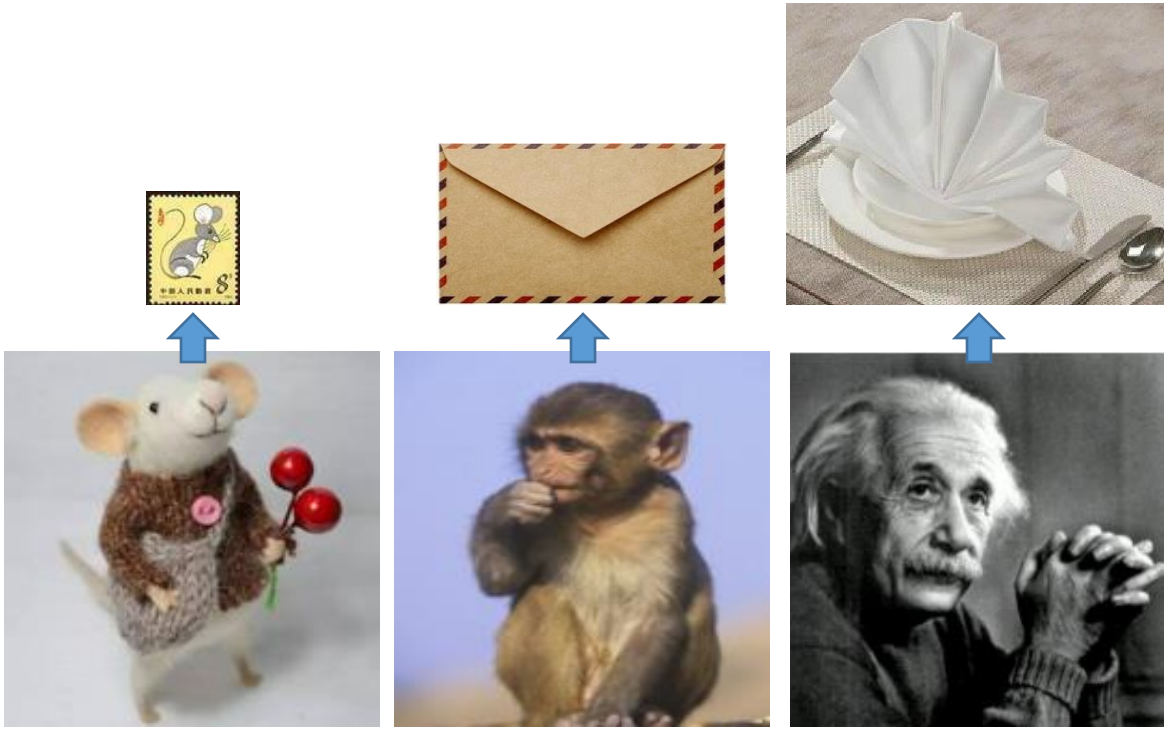
Where does intelligence come from ?





- 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 ?

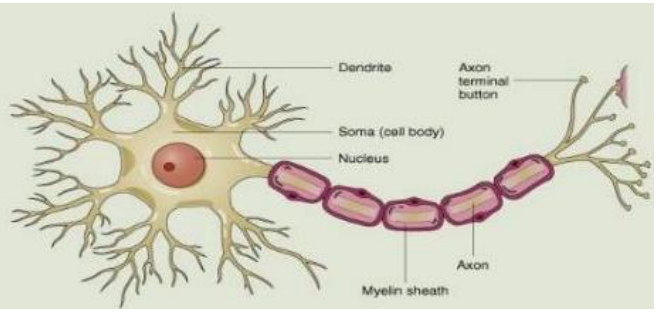


- Neocortex
- The size of a napkin （about 1000cm^2)
- The thickness of six playing cards （about 2mm ）
- Each square millimeter of the area contains about 100,000 neurons
- About 30 billion neurons in total
- About 100 trillion synaptic connections

新皮层是脊椎动物大脑的薄薄(thin: thing)的表层。它是大脑和整个神经系统进化史上最新、功能最先进的部分。它显示了不同哺乳动物(尤其是人类)之间“最大的体型差异”。

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

- The Development History of Neural Networks
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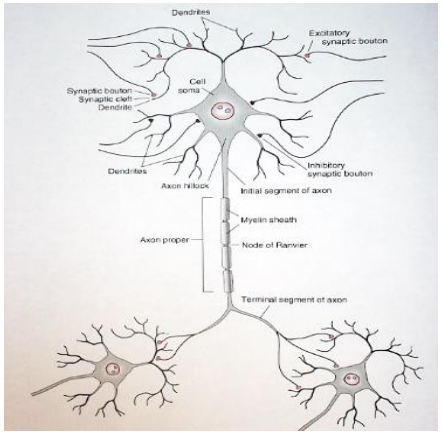
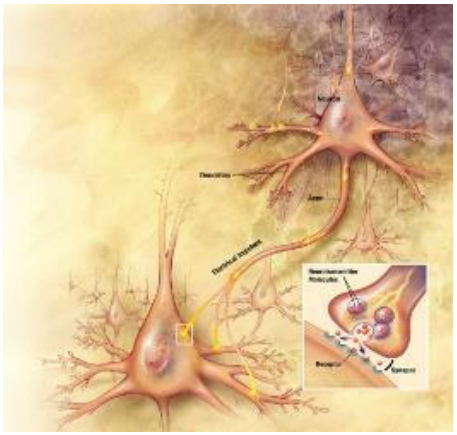
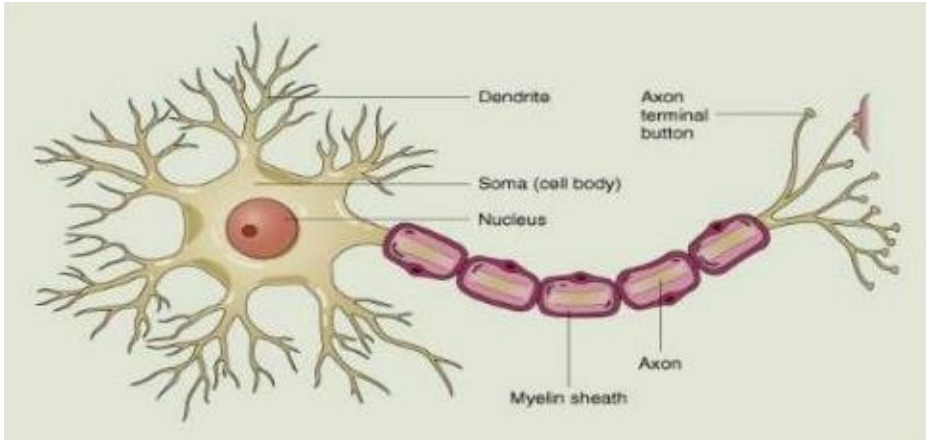
Biological Neurons and Neural Networks



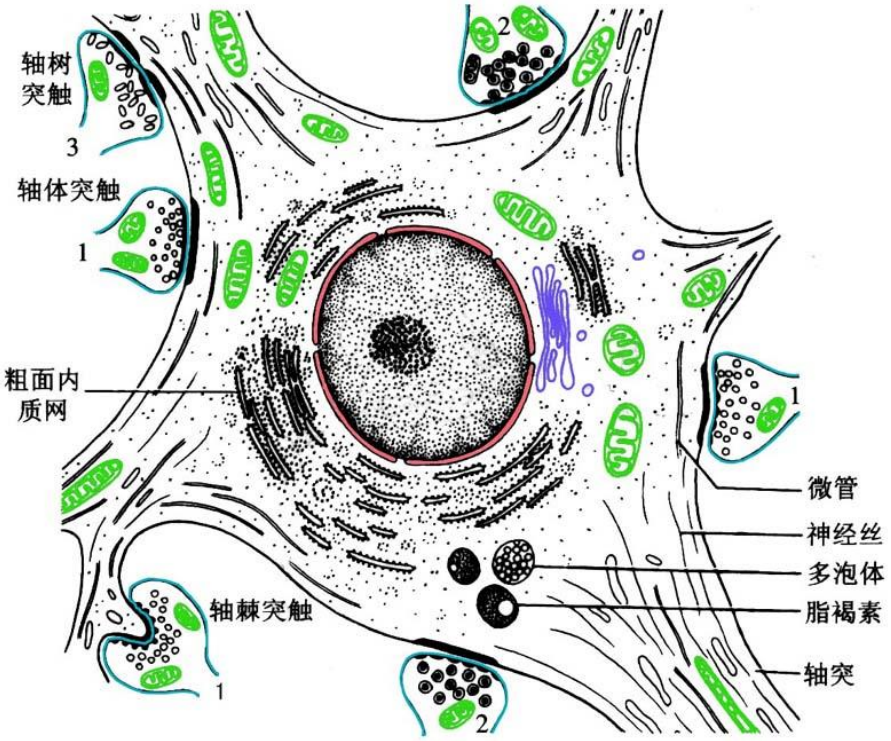




- Three main components
  - Soma （胞体）
  - Dendrite （树突）
  - Axon （轴突）
- Neurons are cells in the brain that can receive electrical stimulation
- Neurons process and transmit information through electrical and chemical signals

Biological Neurons and Neural Networks

- Soma: Soma is the nutrient center of the cell.
- 神经活动所需的大量蛋白质主要在尼氏体中合成，然后流向细胞核、线粒体和高尔基复合体
- 制造蛋白质，这些蛋白质保证神经元有独特的功能来传递、接受和存储信息



Biological Neurons and Neural Networks

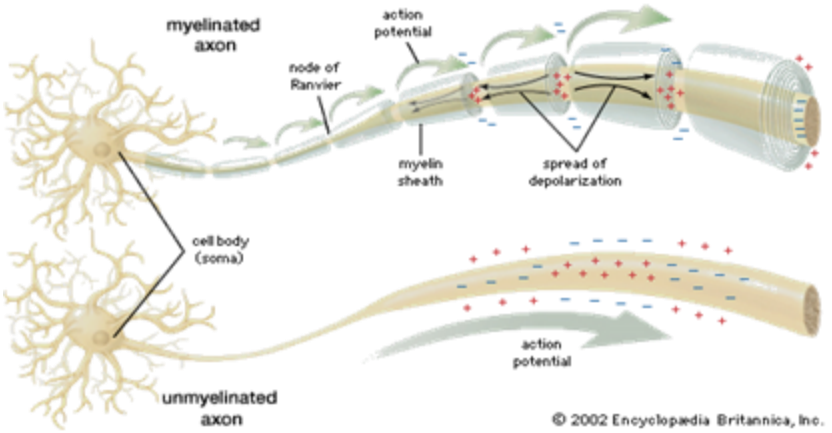
- Dendrites receives inputs from many other neurons and transmits these signals to the soma.
- Dendrites gives neurons a unique branching shape, the size of dendrites far exceeds the size of the soma

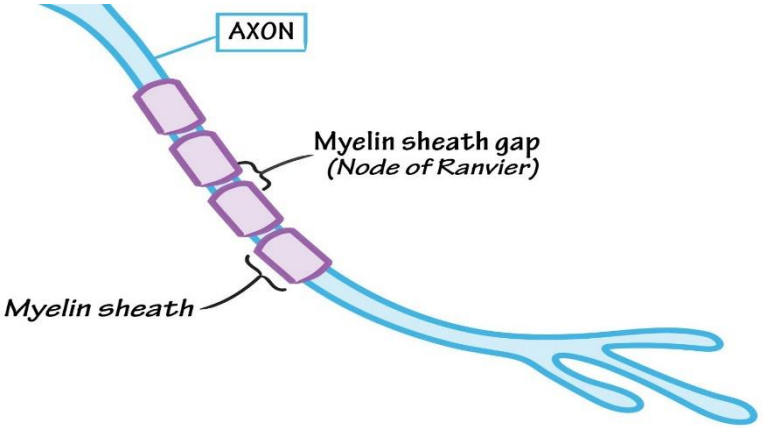
"这是一个巨大的远距离天线，可以‘听到’突触输入的数千个信号，这些信号分布在网络中其他神经元的分支结构上。"

MIT McGovern Brain Science Institute

Biological Neurons and Neural Networks

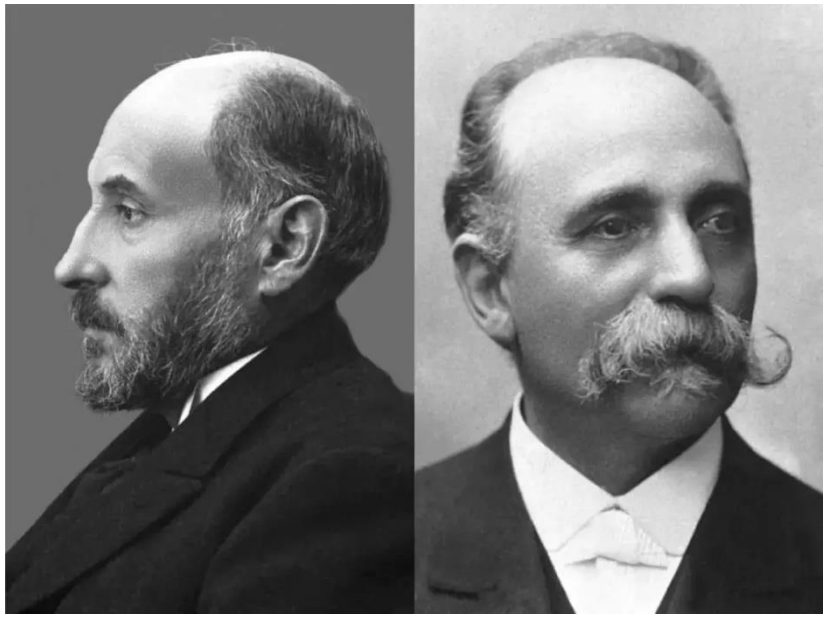
Axons: transmit information to each synapse in the form of electrical impulses



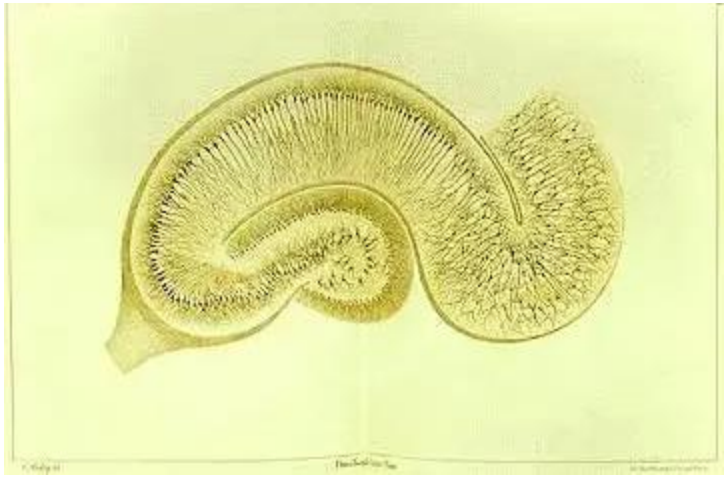


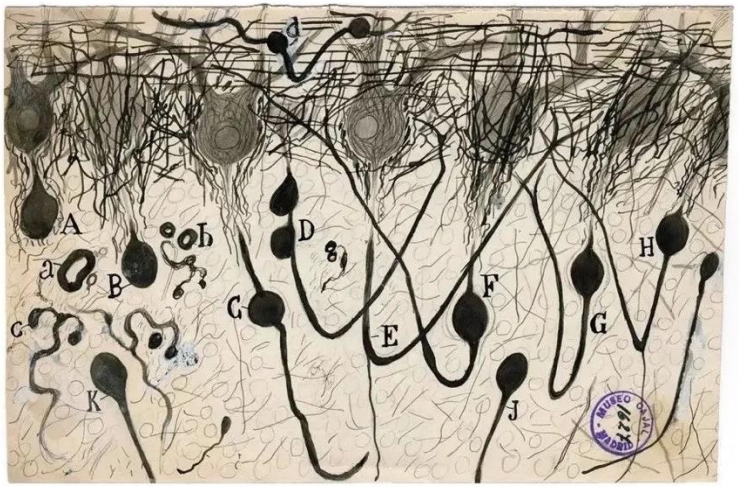
Biological Neurons and Neural Networks

- The connection of Neurons



Santiago Ramon y Cajal Camillo Golgi

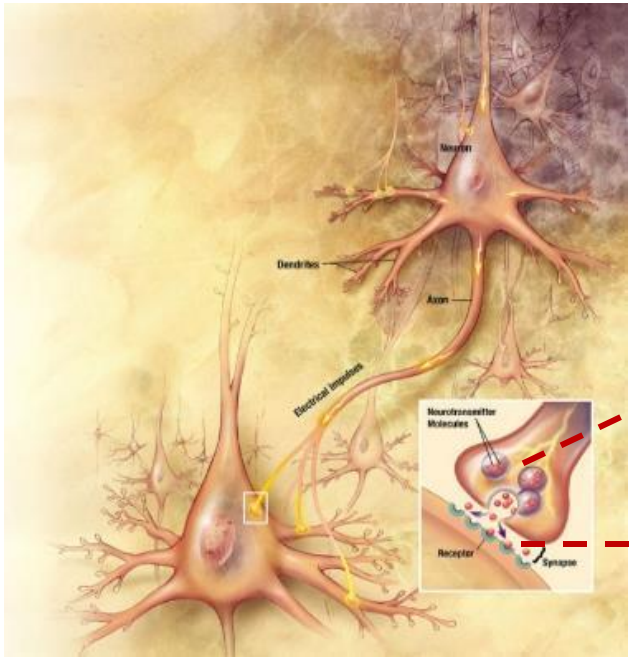


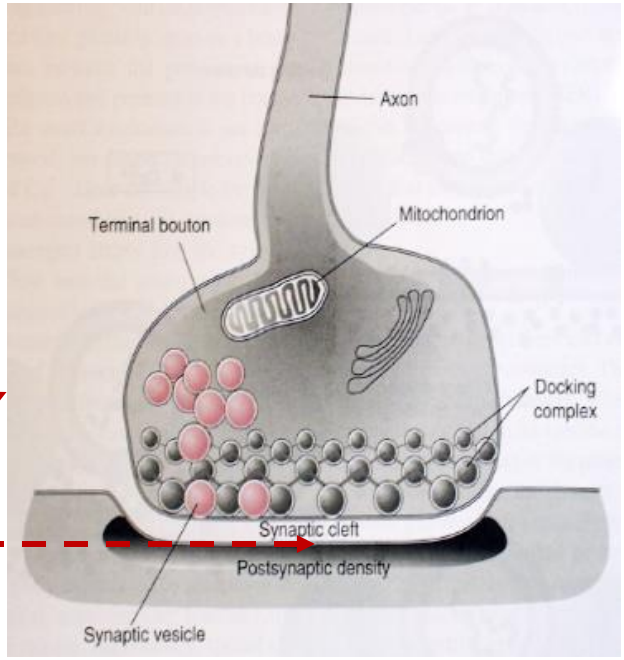


Shared the Nobel Prize in 1906

Biological Neurons and Neural Networks

- Synapse: 一个神经元的脉冲传递到另一个神经元的接触结构。

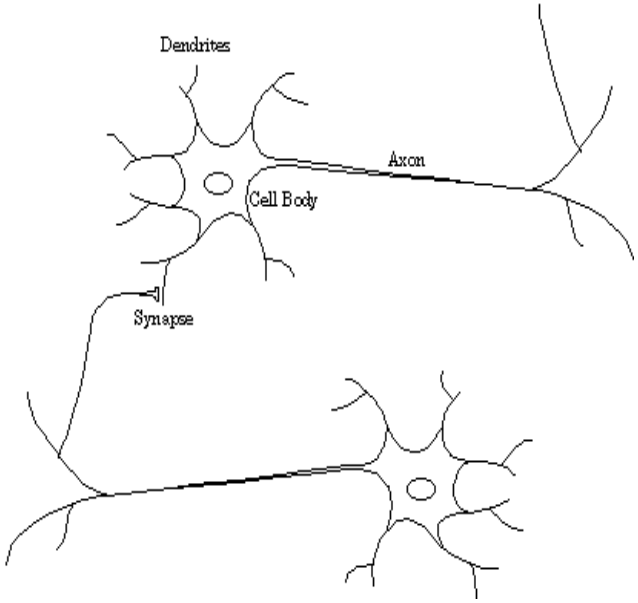




- Nerve impulses from one cell affect the behavior of another cell.
- the strength of the connection between the two neurons will increase when two neurons produce a peak almost at the same time.

Biological Neurons and Neural Networks

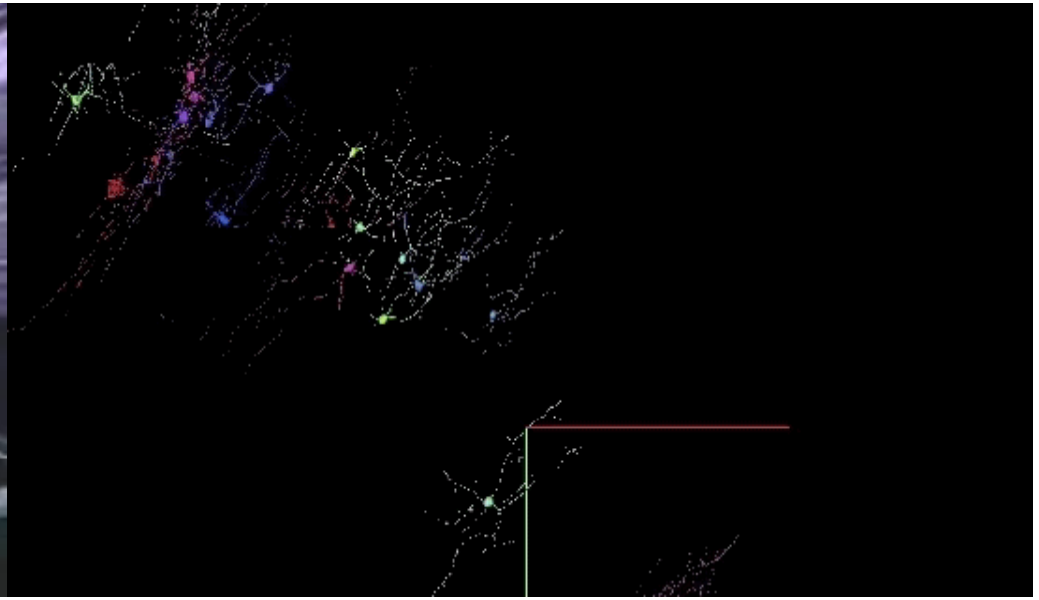
- There are about 30 billion neurons in the neocortex
- About 100 trillion synaptic connections between neurons



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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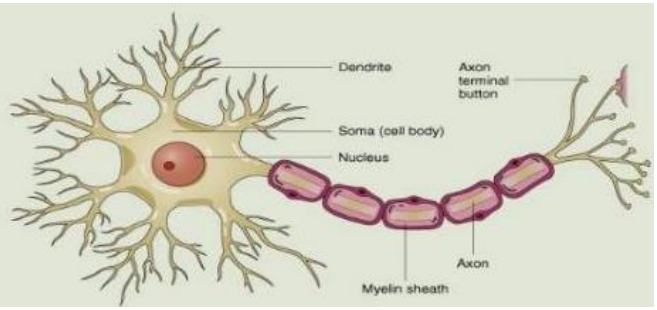
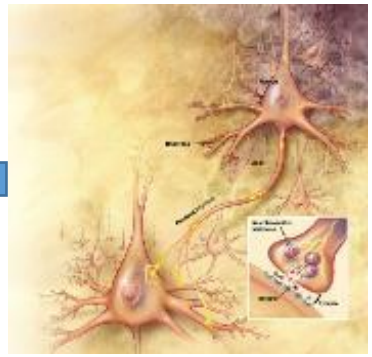
- Feedforward Neural Network

Computational Model of Neural Network

- Artificial Neuron





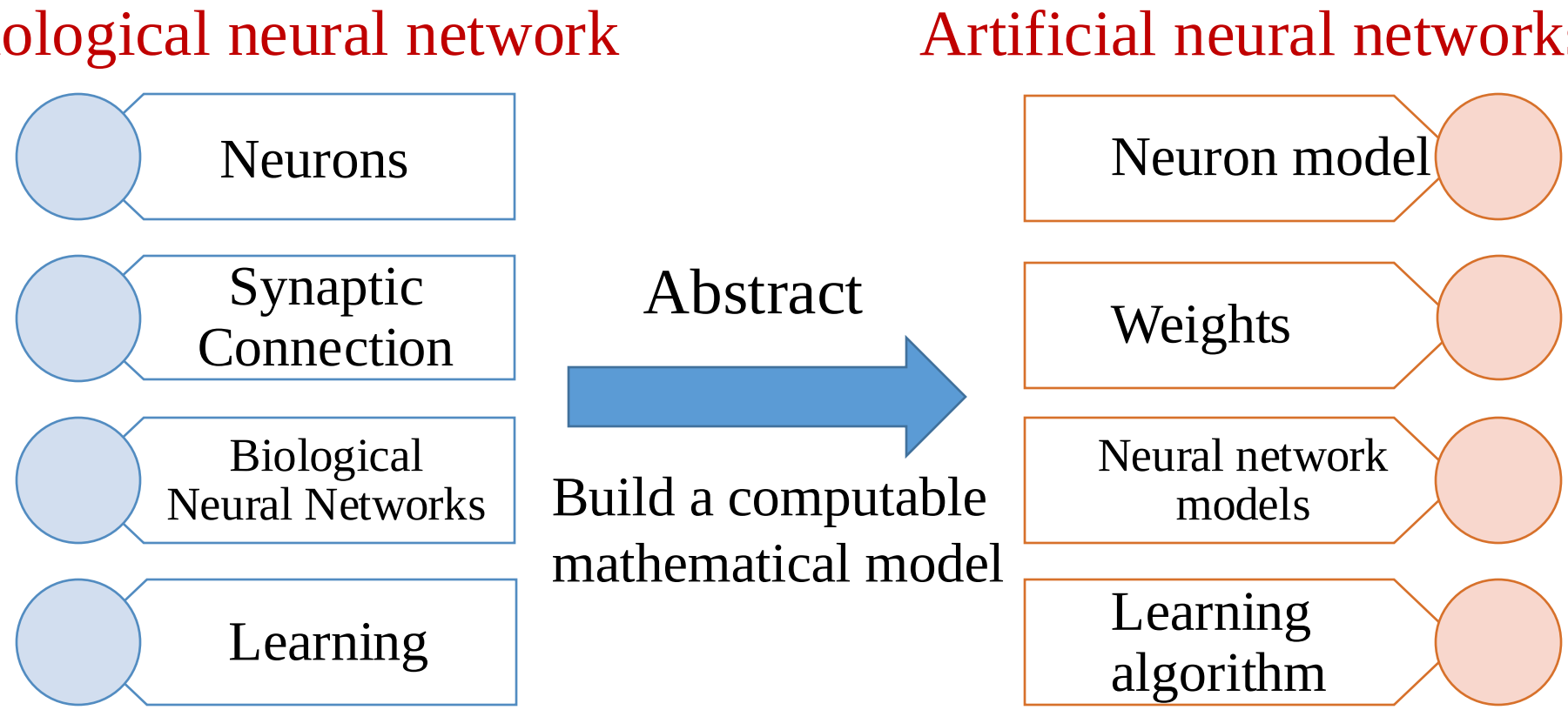
Neurons | Connection between neurons | Neural Networks

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

Artificial neural networks

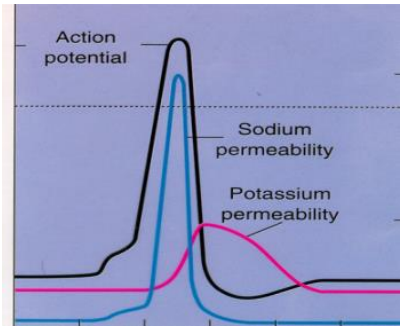
Computational Model of Neural Network

- Artificial Neuron

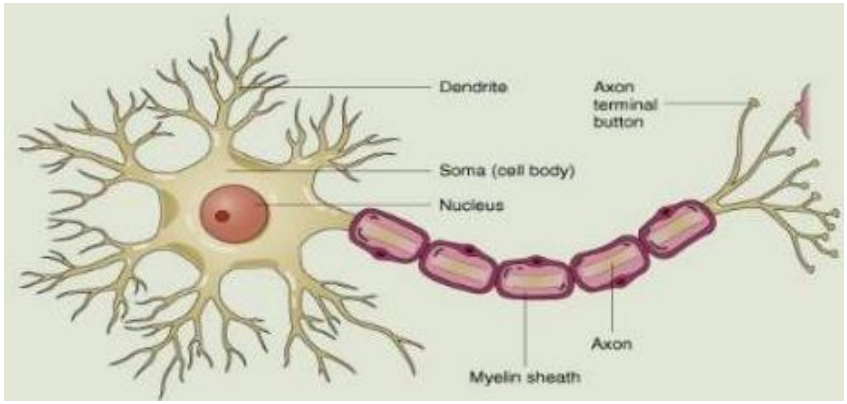


Computational Model of Neural Network

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

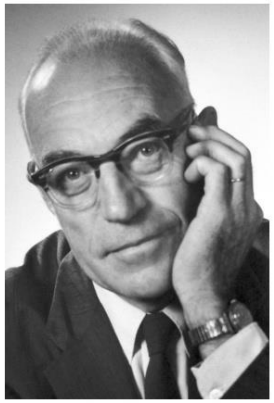


Photo from the Nobel Foundation archive.
Sir John Carew Eccles
Prize share: 1/3

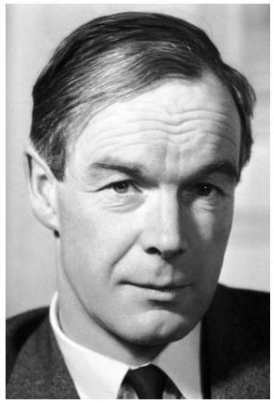


Photo from the Nobel Foundation archive.
Alan Lloyd Hodgkin
Prize share: 1/3

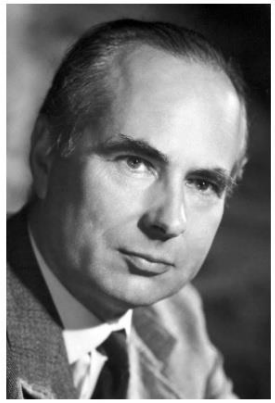


Photo from the Nobel Foundation archive.
Andrew Fielding Huxley
Prize share: 1/3

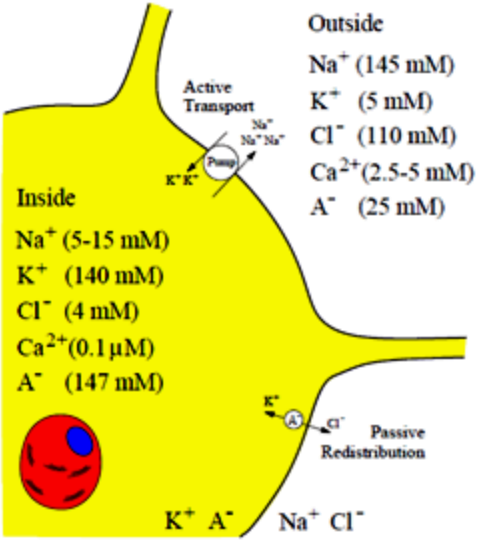
1963年诺贝尔生理学或医学奖授予约翰·卡鲁·埃克勒斯爵士、艾伦·劳埃德·霍奇金和安德鲁·菲尔丁·赫胥黎，“因为他们发现了神经细胞膜周围和中央部分兴奋和抑制的离子机制."

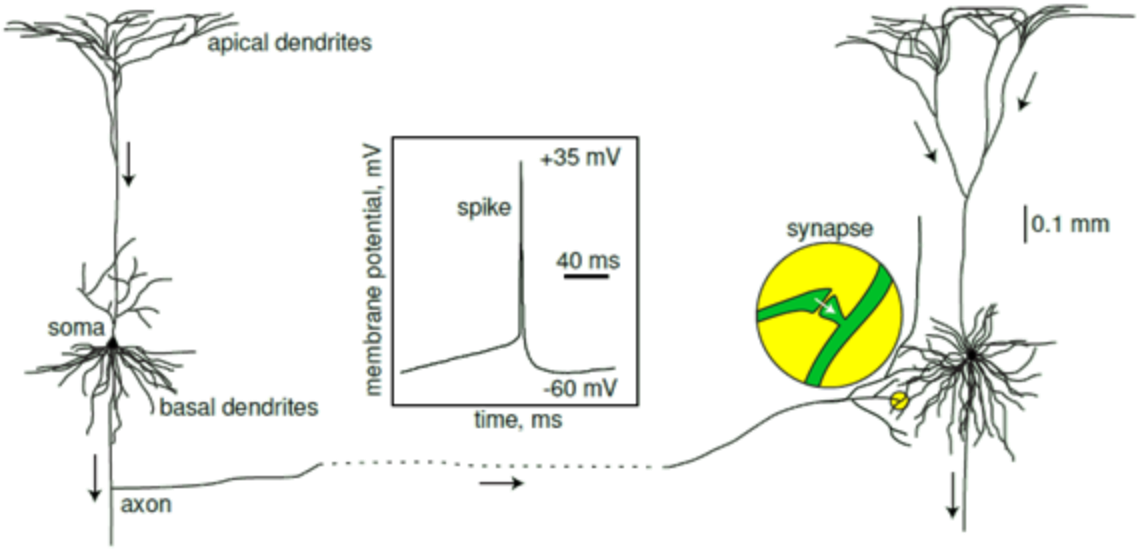
"Because they discovered the ion mechanism of excitement and inhibition in the surrounding and central part of the nerve cell membrane.”

Computational Model of Neural Network

Artificial Neuron: Spiking Model

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

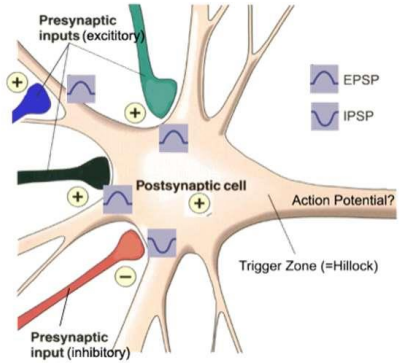


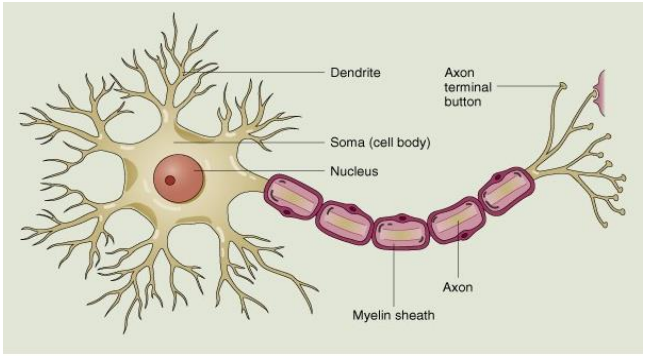


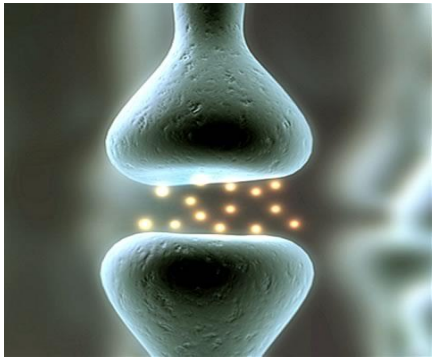
- 1939年，人们研究了鱿鱼神经细胞巨大轴突上的电活动。
- Won the 1963 Nobel Prize in Physiology or Medicine

Computational Model of Neural Network

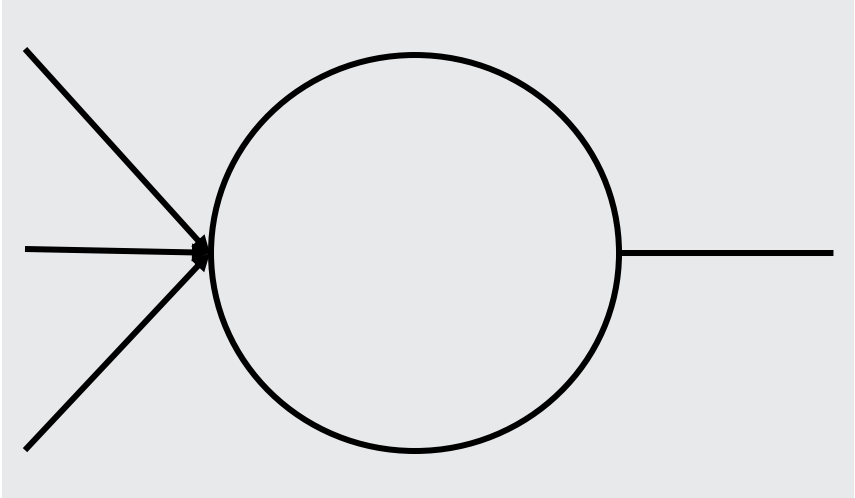
- Artificial Neuron: Firing-Rate Model







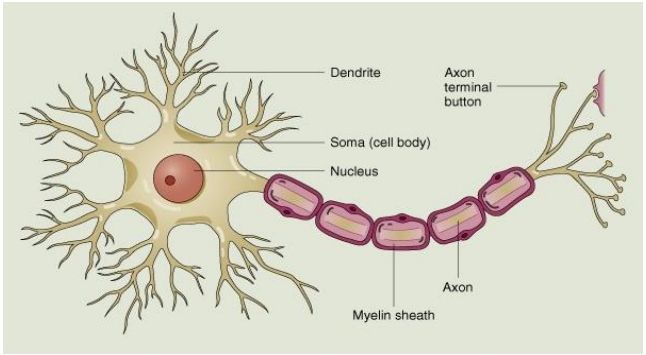
Signals from other neurons



output signal

Computational Model of Neural Network

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



Inputs from other neuron

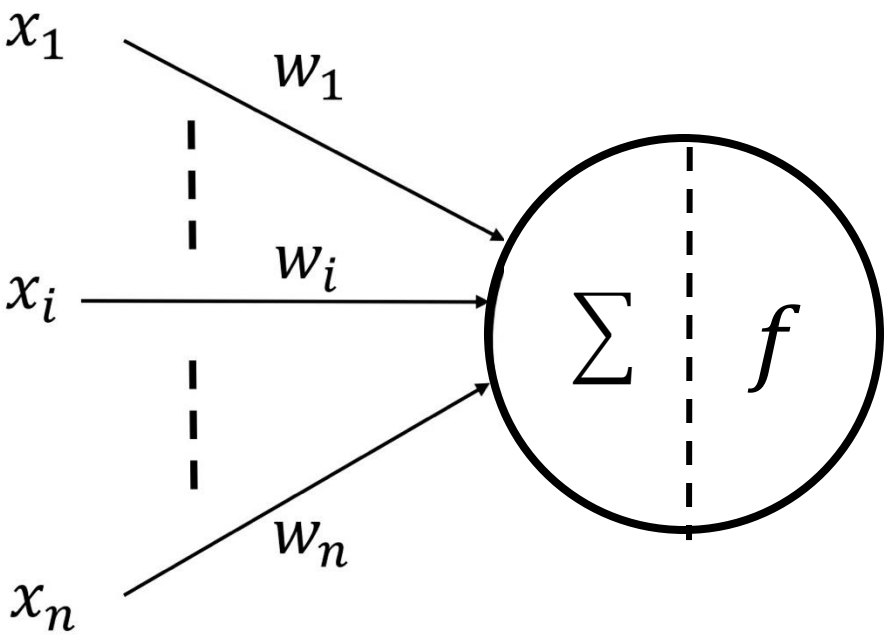
x_1 w_1

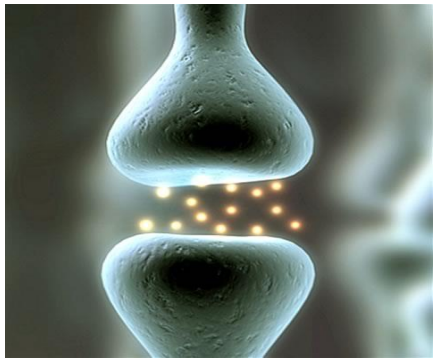
x_i w_i

x_n w_n

Computational Model of Neural Network

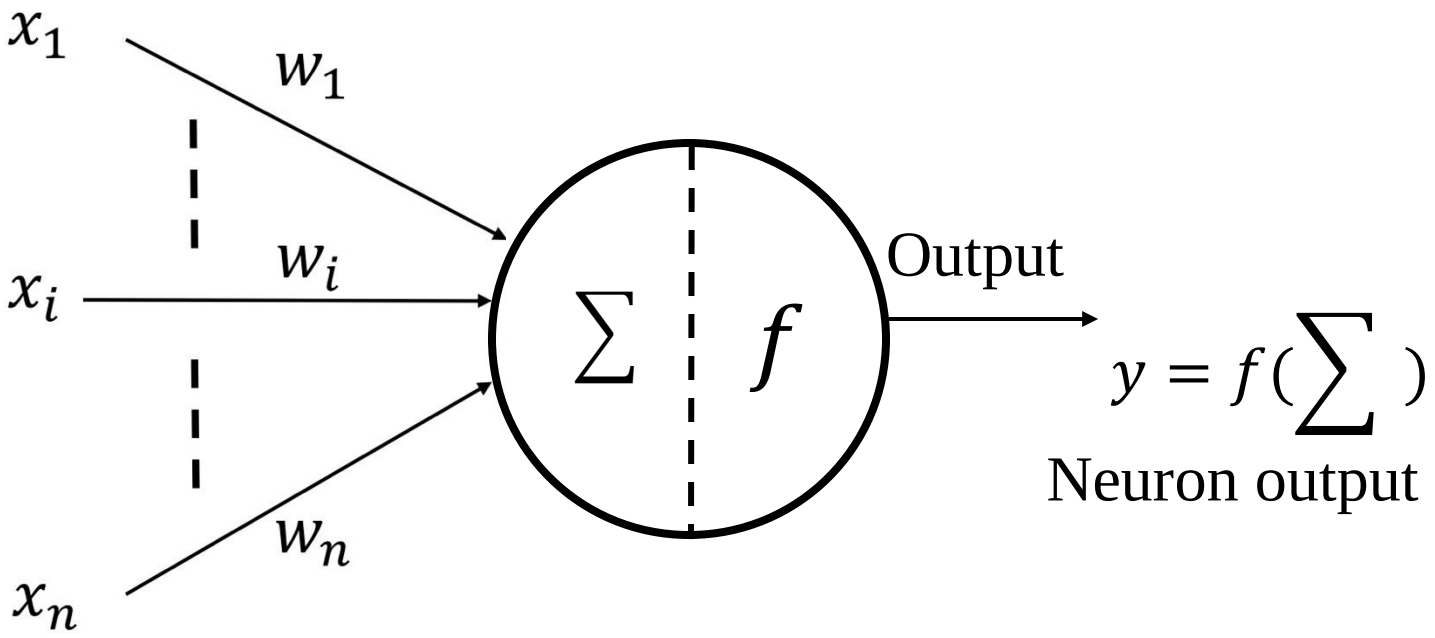
- Artificial Neuron: Firing-Rate Model -- Information Processing Abstract





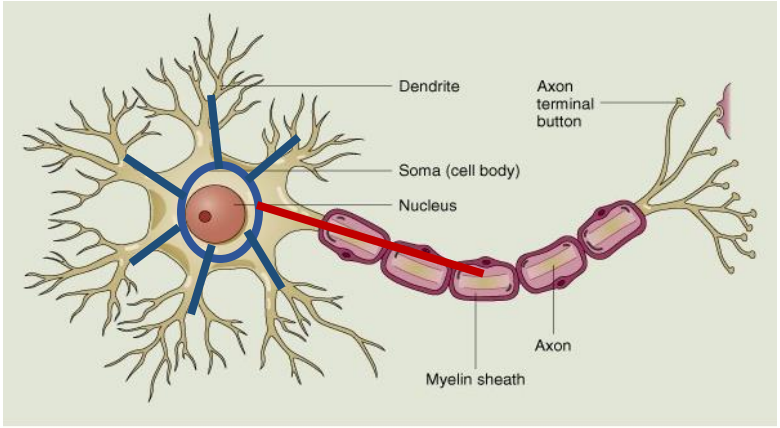
Computational Model of Neural Network

- Firing-Rate Model -- Output abstract



Computational Model of Neural Network

Artificial Neuron: Firing-Rate Model



x_1 **Another neuron axon**

Synapse

Connection strength

w_1

Dendrites

x_i w_i

x_n w_n

Soma

$z = \sum_{i=1}^{n} w_i x$ f

Activation function

Axonal output

$y = f(z)$

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

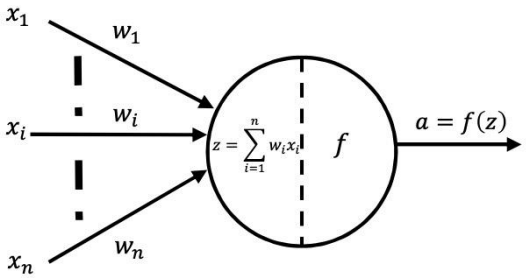
internal input

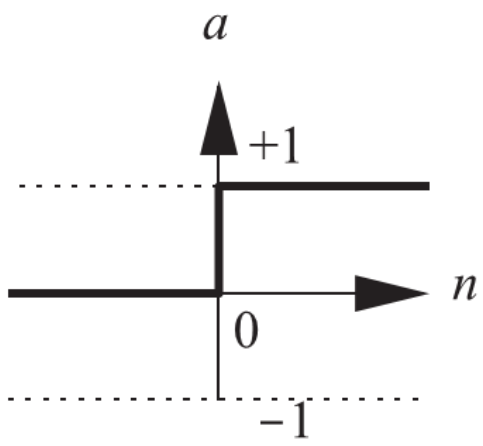
Neuron output

input signal

Computational Model of Neural Network

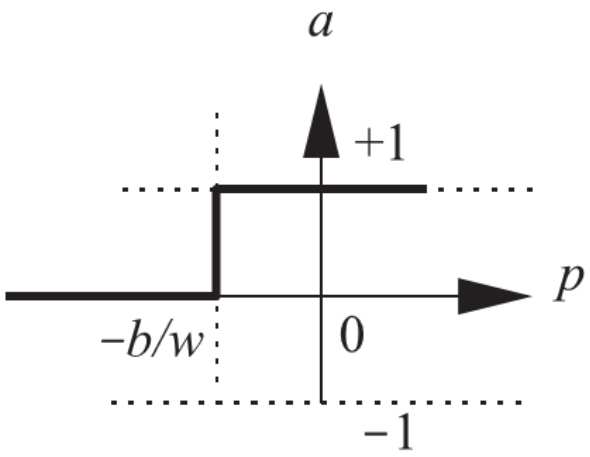
- Firing-Rate Model: Activation function





$a = hardlim(n)$

Hard Limit Transfer Function

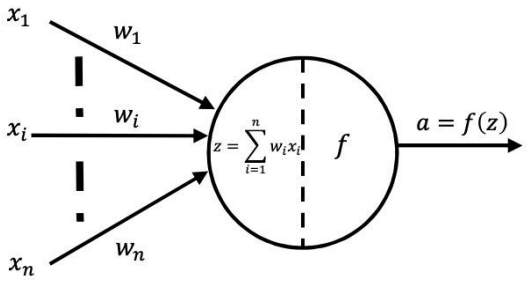


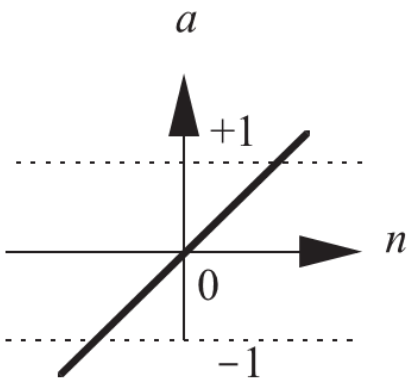
$a = hardlim(wp + b)$

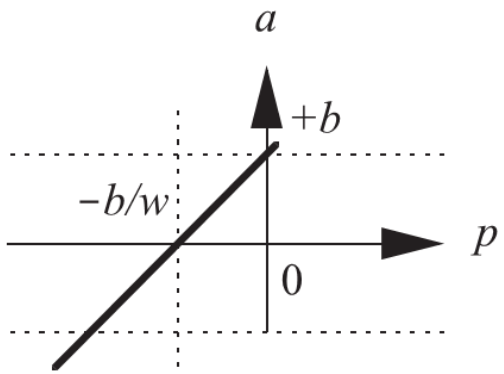
Single-Input *hardlim* Neuron

Computational Model of Neural Network

- Firing-Rate Model: Activation function







$a = purelin(n)$

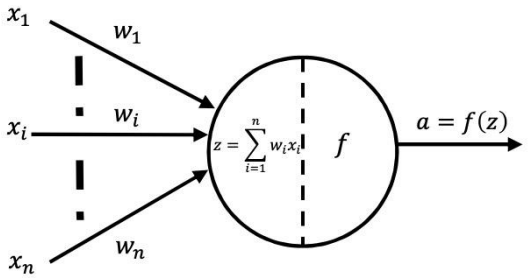
Linear Transfer Function

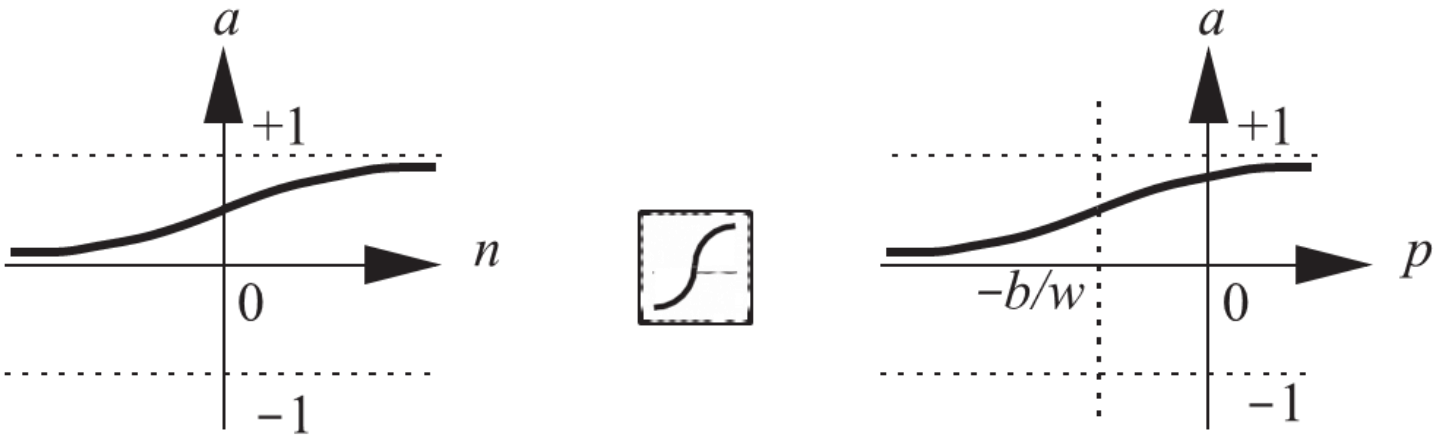
$a = purelin(wp + b)$

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

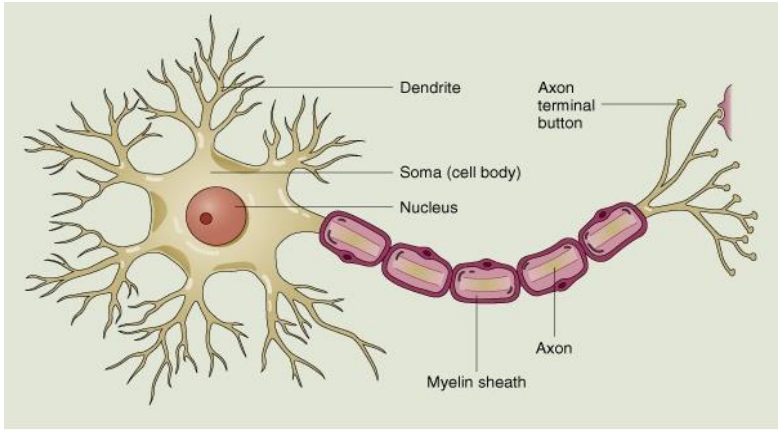
Computational Model of Neural Network

- 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

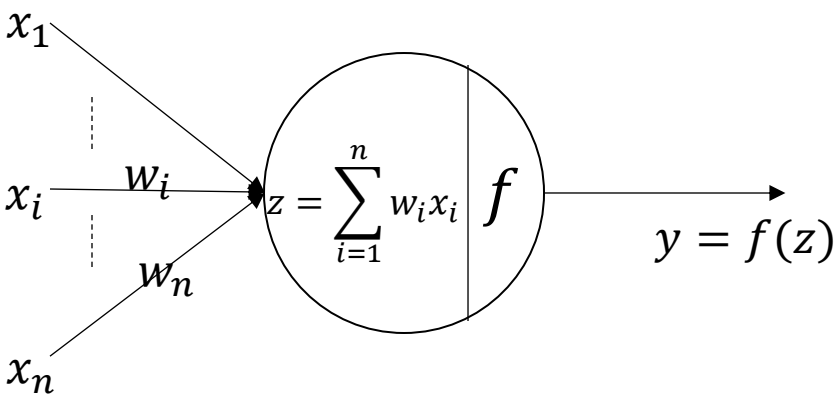
- Artificial Neuron: Firing-Rate Model



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

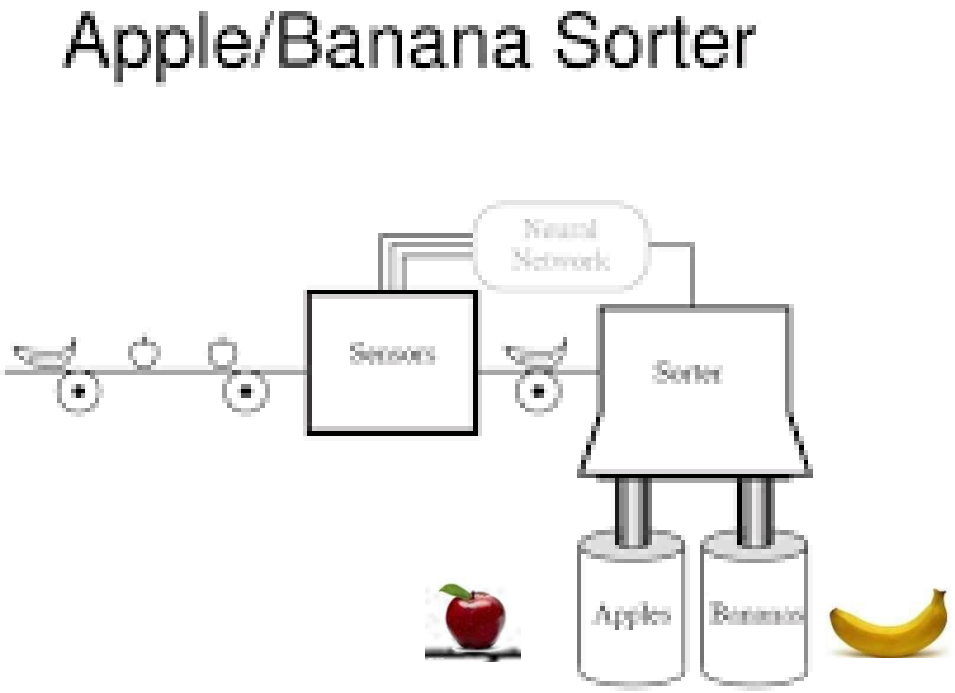
Vector form

$$y = f(Wx)$$



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

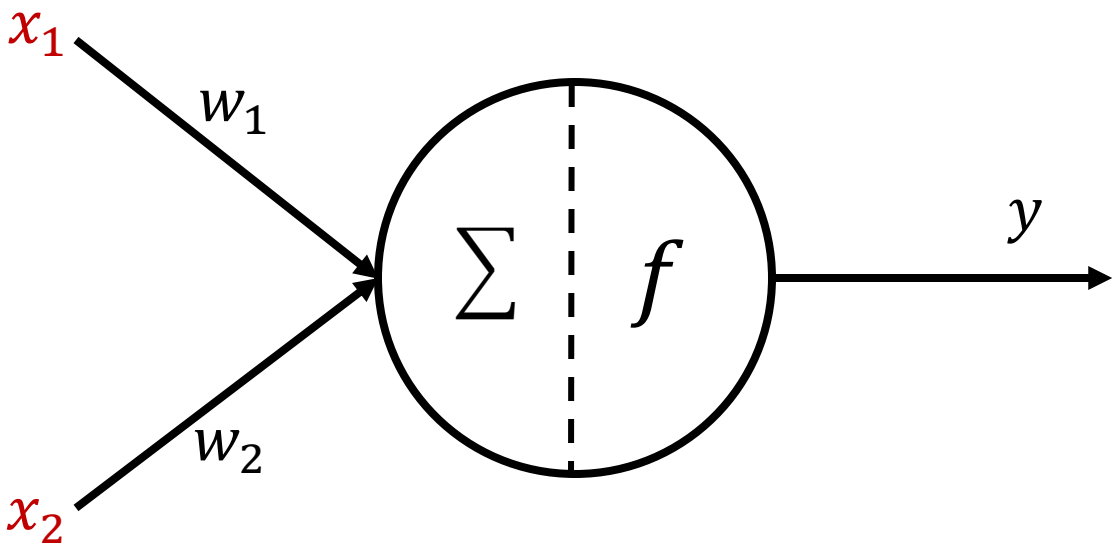
Computational Model of Neural Network

- 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

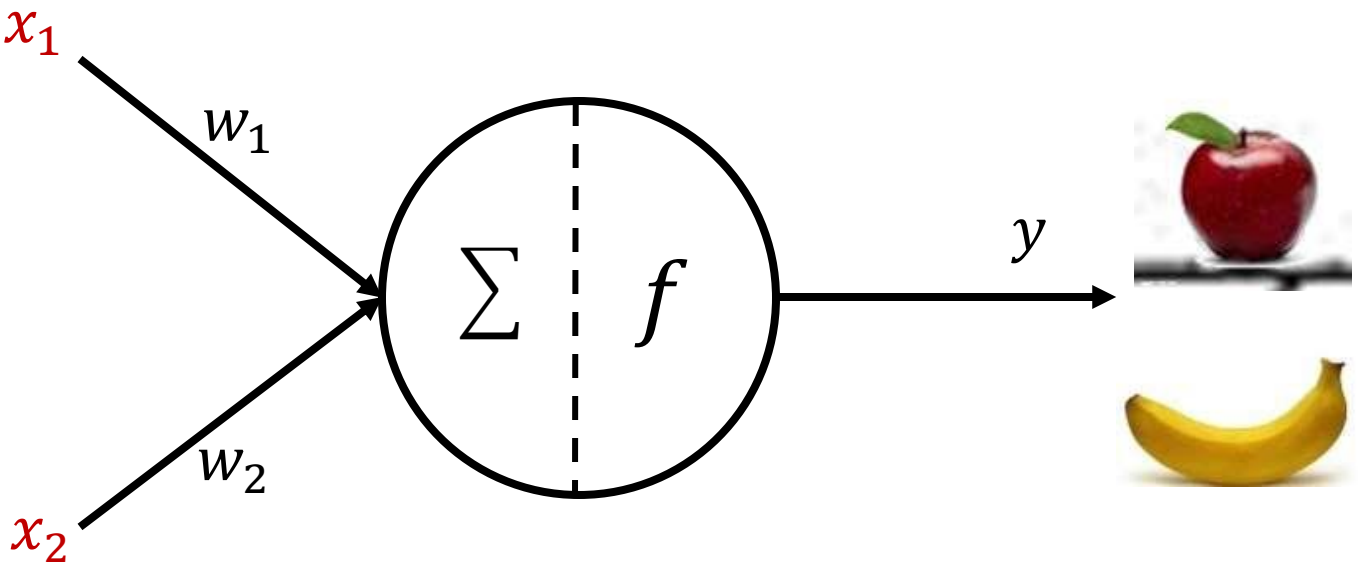


Computational Model of Neural Network

- 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

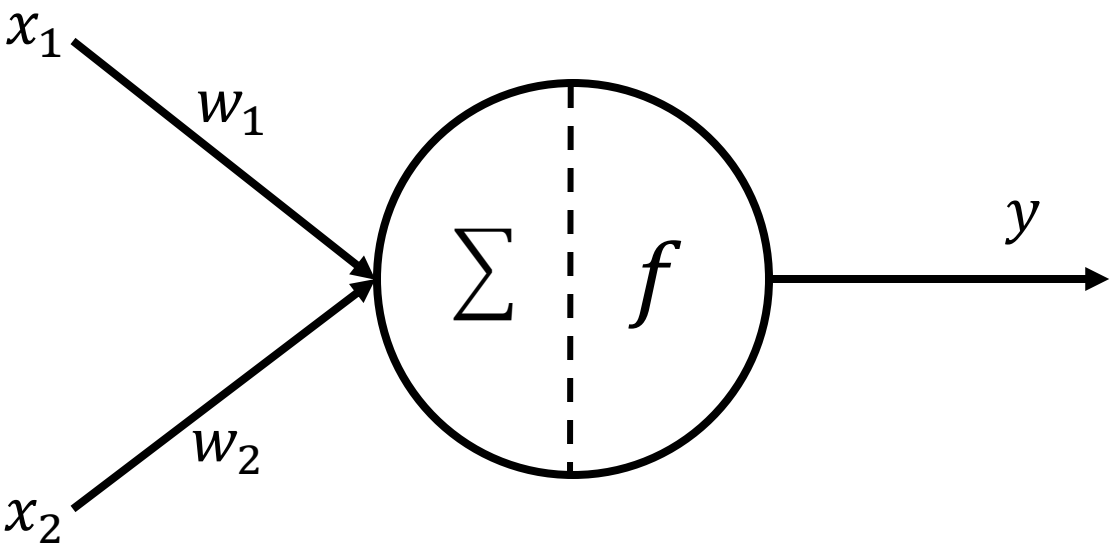
Computational Model of Neural Network

- Example: Auto classifier of apple/banana

Feature: red, round

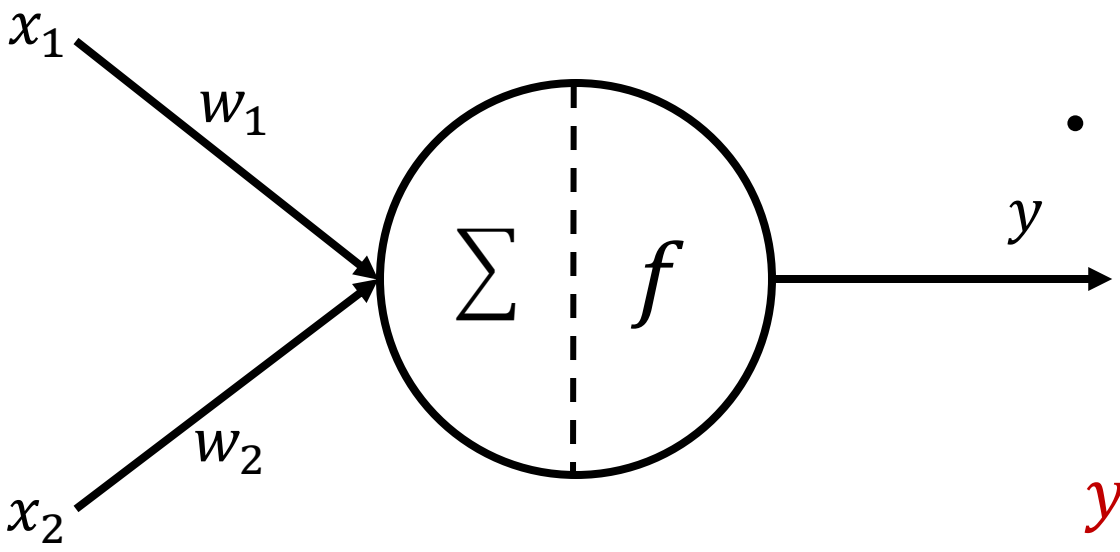
Feature: yellow, strip

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



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) = $\frac{\mathbf{1}}{\mathbf{2}}\boldsymbol{x}$

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

Computational Model of Neural Network

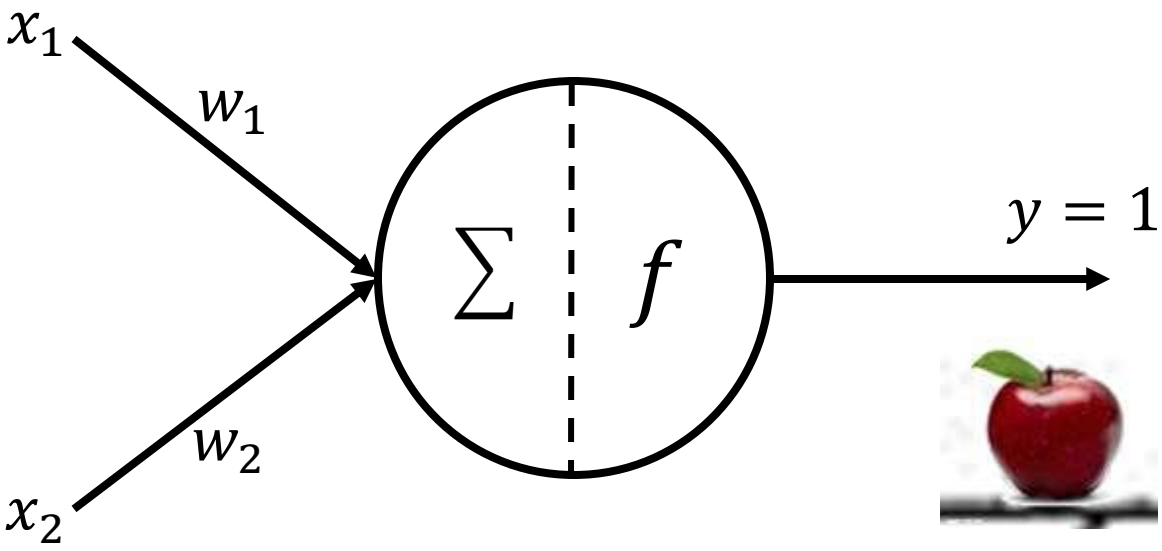
- Example: Auto classifier of apple/banana
  - The mathematics model of neuron

Input:

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

Red: 1

round : 1



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

Computational Model of Neural Network

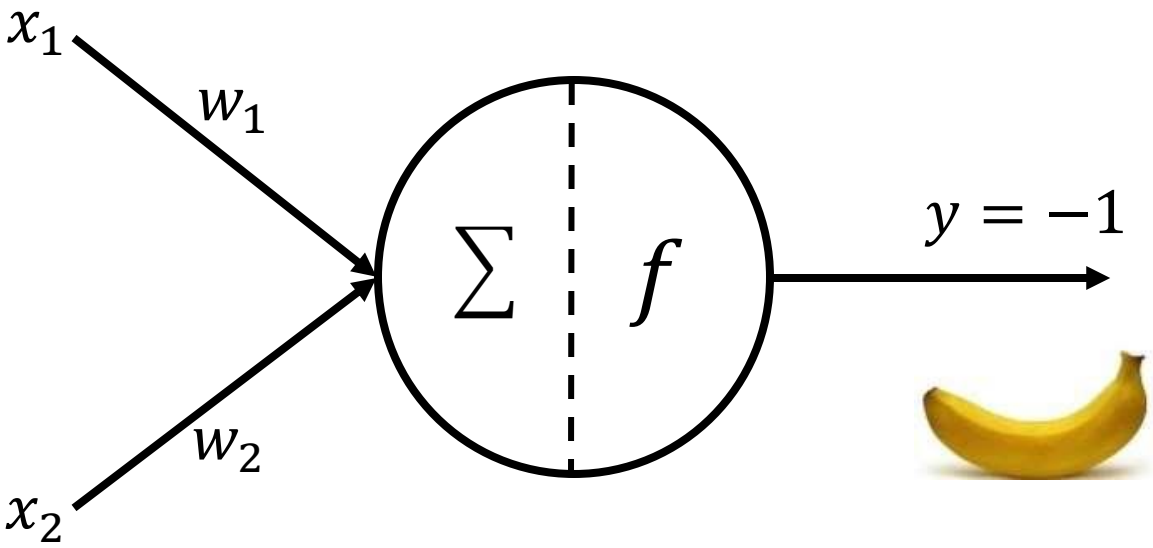
- Example: Auto classifier of apple/banana
  - The mathematics model of neuron

Input:

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

yellow: -1

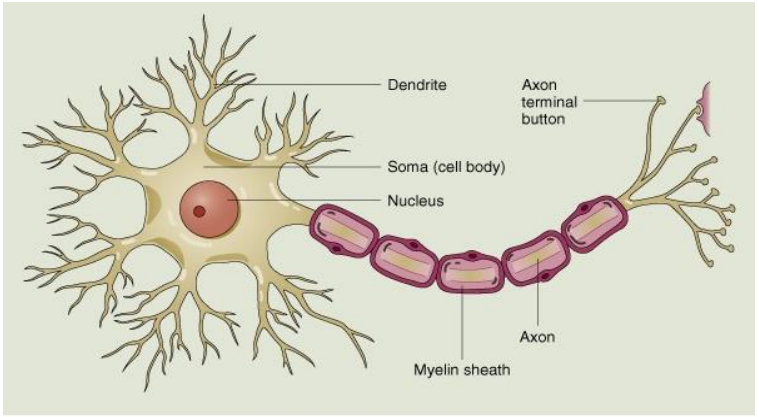
strip : -1



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

Computational Model of Neural Network

- Neural Networks

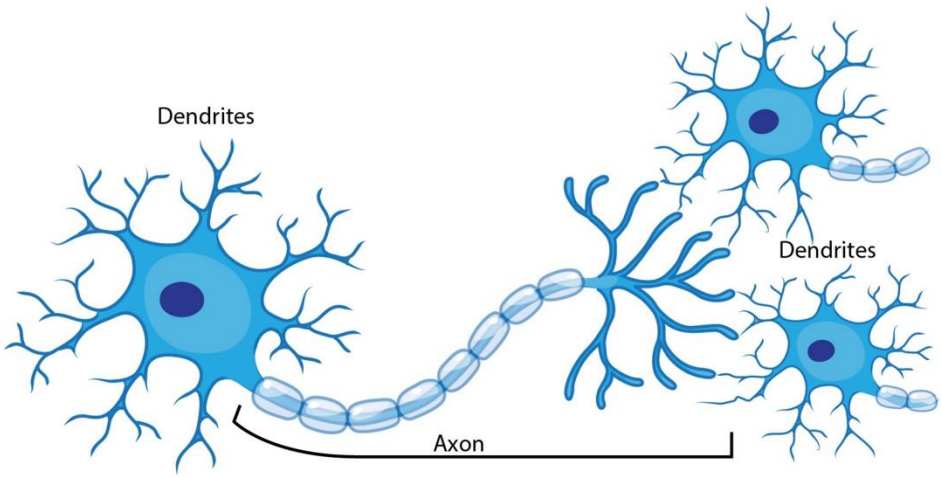


Neurons

Neural Networks

Computational Model of Neural Network

- Neural Networks



Neural Network = Neurons + Connections

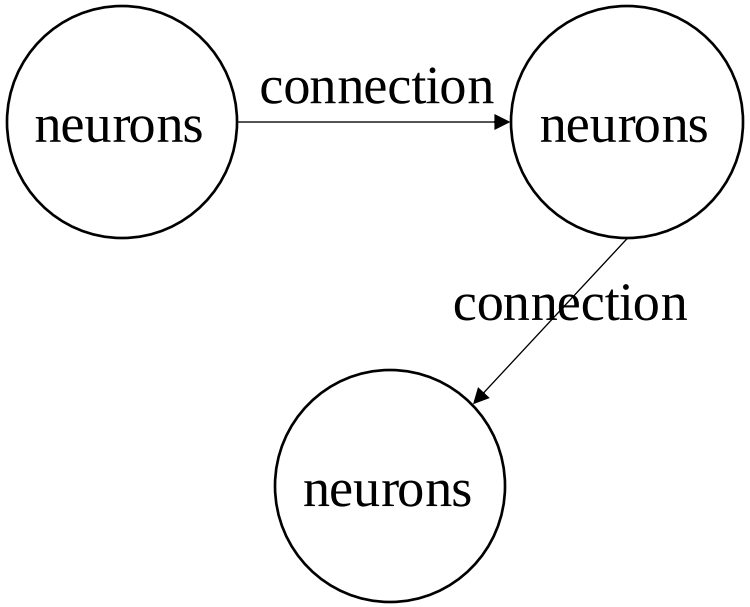
Computational Model of Neural Network

Neural Networks

Feedforward neural network

=

neurons + feedforward connections



Recurrent neural network

=

neurons + recurrent connections