Neural Network Theory

Artificial **Intelligence** and Brain

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Materials are here:

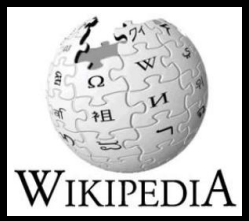
https://github.com/yungbyun/neuralnetworks

git clone *[link]*

Agenda

- Artificial Intelligence
- Brain and neuron
- Synapses, the core of neural networks
- Neuron, equation, and matrix

Intelligence



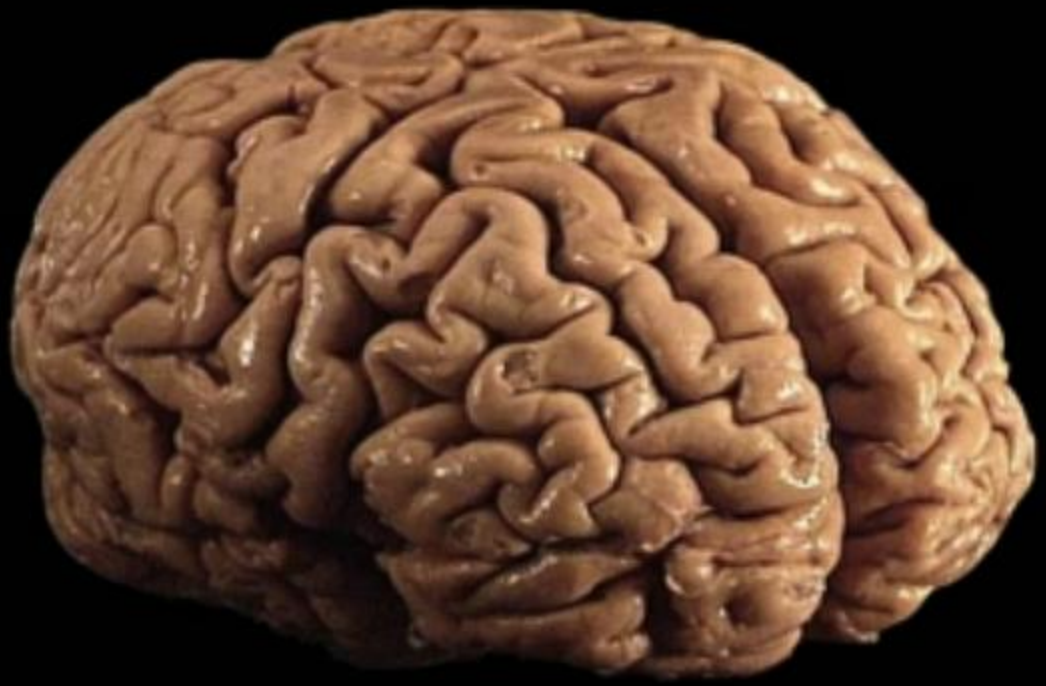
- One's **capability** for logic, understanding, self-awareness, learning, planning, creativity, and problem solving
- The **ability** to perceive information, and to retain it as knowledge to be applied towards adaptive behaviors within an environment
- Human Intelligence = **Natural** Intelligence

Artificial Intelligence

- Intelligence exhibited by machines
- A computerized version of the human (natural) intelligence
- Theory and development of computer systems able to perform tasks such as visual perception, voice recognition, decision-making, and translation between languages

How can machines (computers)get **Artificial** Intelligence?

How can human
get **natural** intelligence?



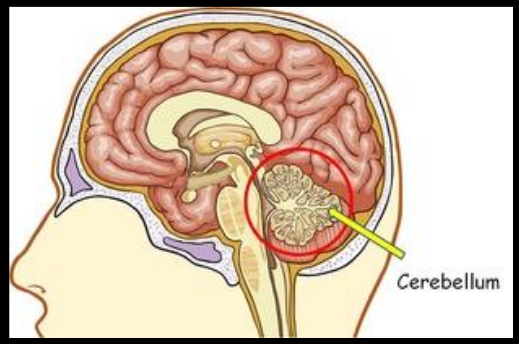
What happens inside the human brain?

Neuroanatomist

신경해부학자

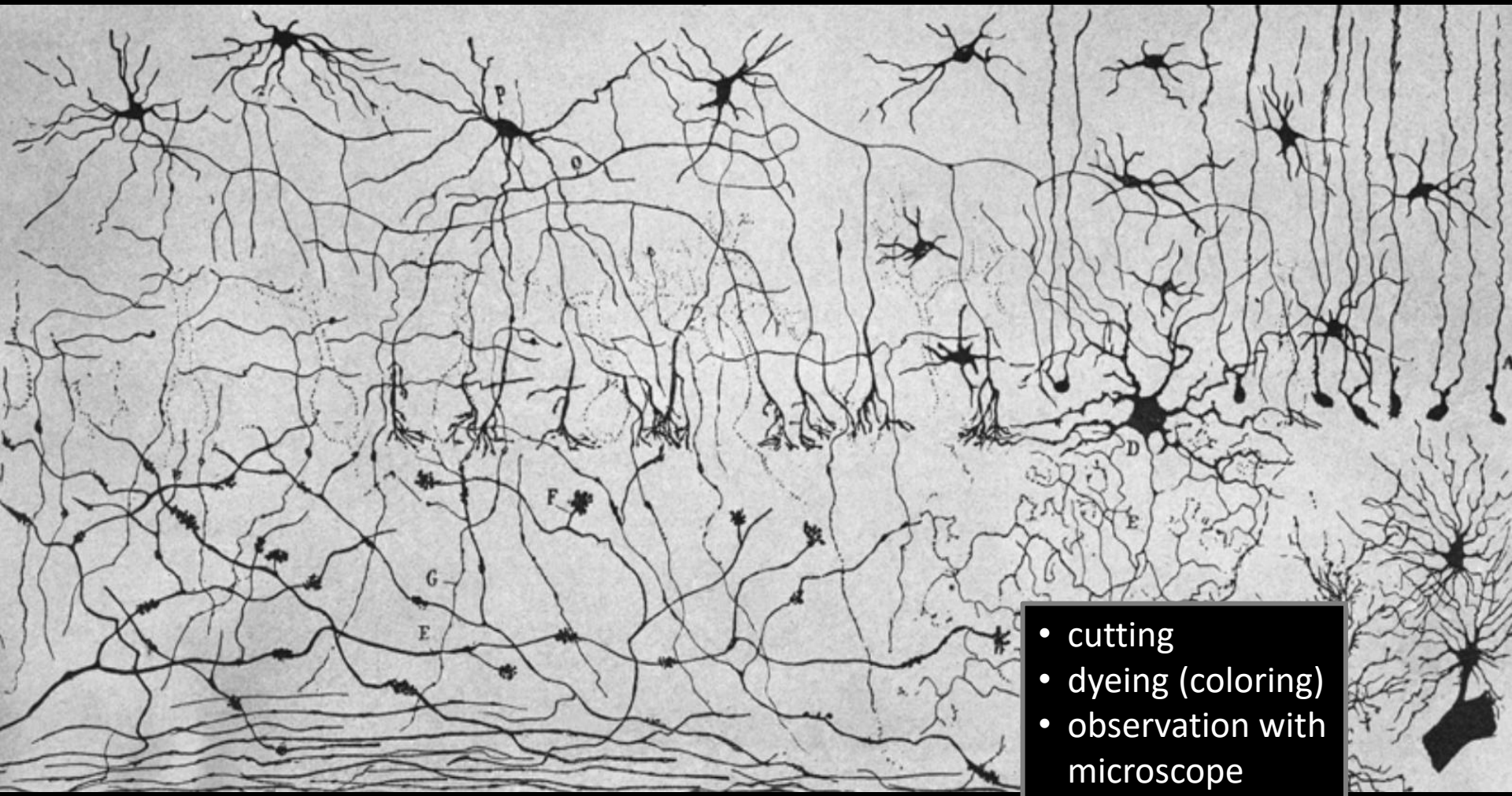

Santiago Ramón y Cajal, 1852-1934

The **cerebellum**(소뇌) that controls muscles



human(spinal animal)

Neurons in a bird's brain



- cutting
- dyeing (coloring)
- observation with microscope

Ramón y Cajal's drawing of the neurons in a bird's cerebellum – a part of the brain.

Brain of Human


1
2
3
6
5

1천억개 이상

100 billion neurons

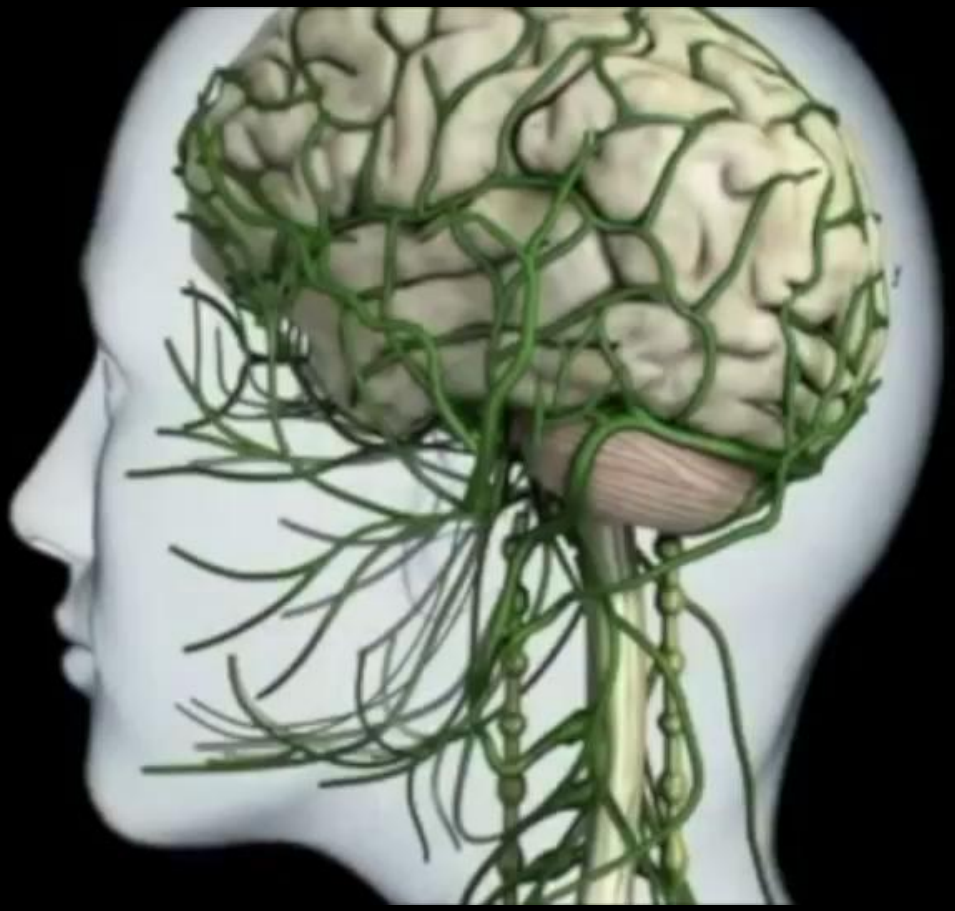
more than

the number of **stars**

in the universe

So, what **happens** inside?

The flow of sodium (Na^+) and potassium (K^+) ions generates an electrical signal.

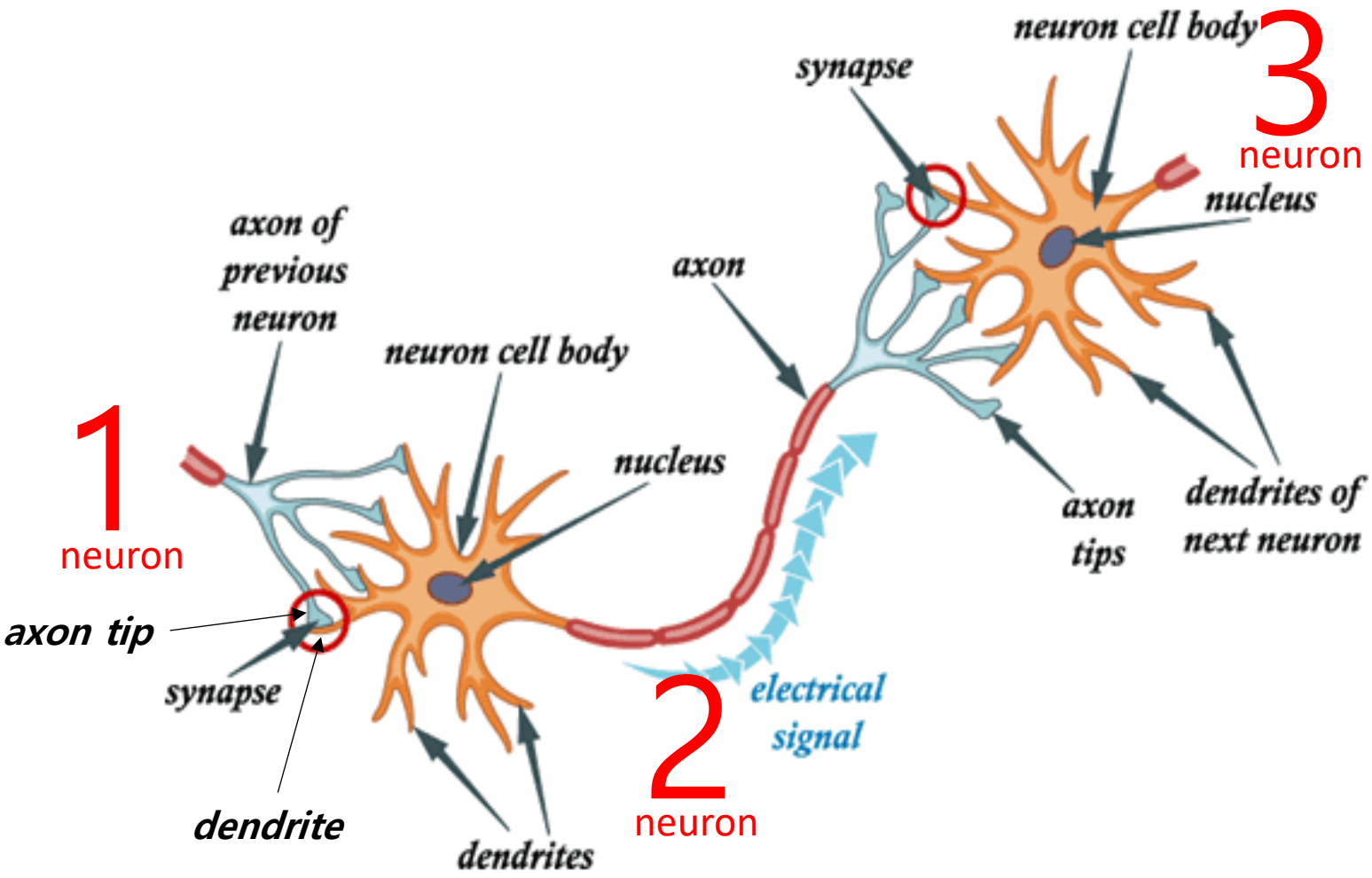


From a DVD that comes with the illustrated medical atlas, The Human Brain, DK Publishing UK.

Simulation(signaling)

A brain in a supercomputer | Henry Markram

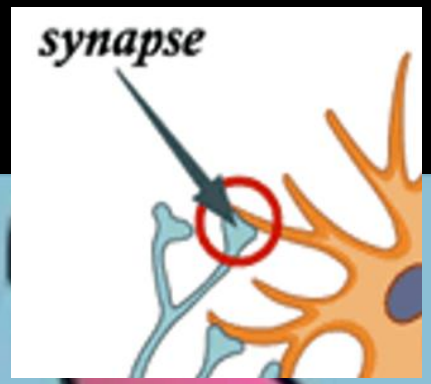
3 neurons and **Connection**

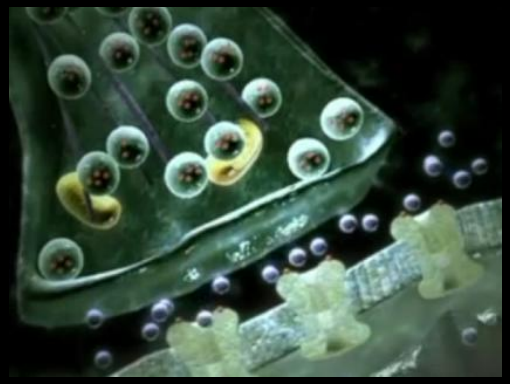


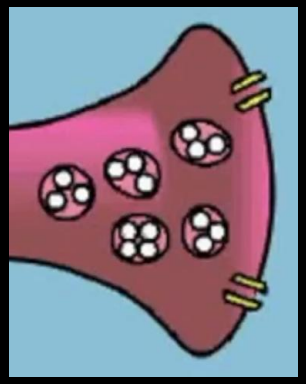
GPT-3.5 Model
175,000,000,000 = 175 Billion = 1,750억 개


GPT-3.5 Model
175,000,000,000 = 175 Billion = 1,750억 개
Synapse
시냅스

Synapse (simplified)



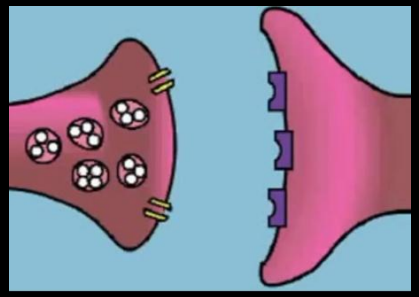




Neurotransmitter in synapse

신경전달물질

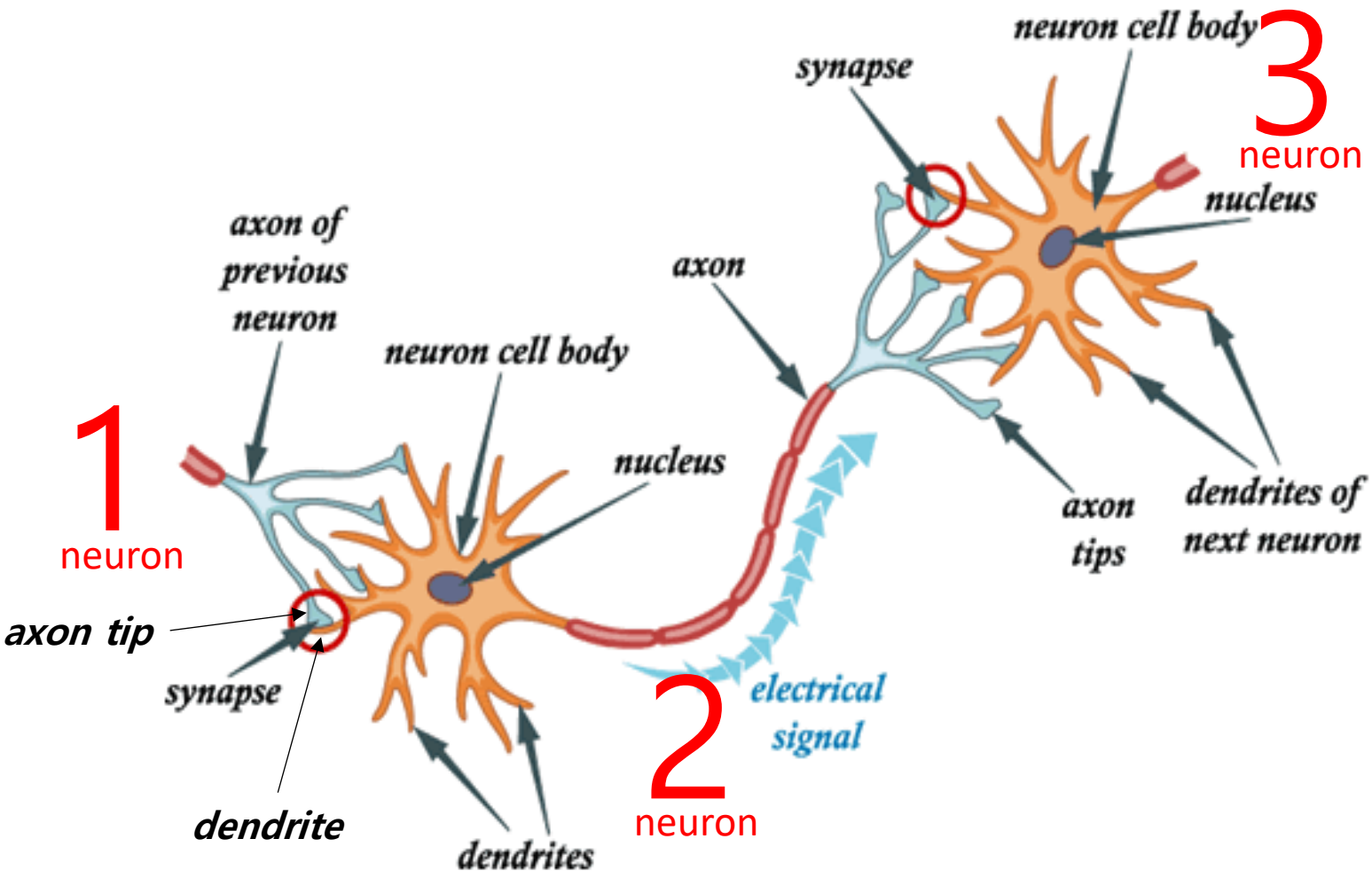
How much neurotransmitters in a synapse?



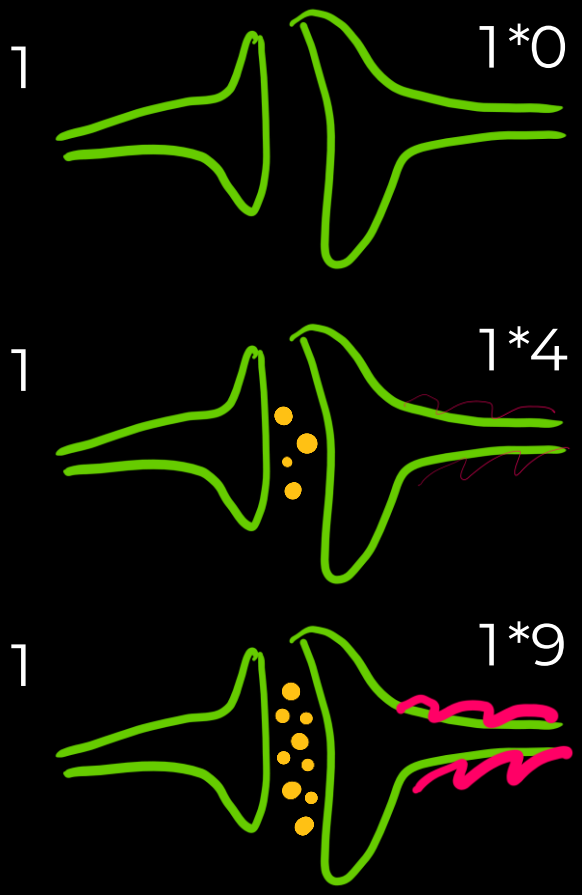
w = 17

In a figurative sense, 비유적으로 표현할 때

3 neurons and **Connection**

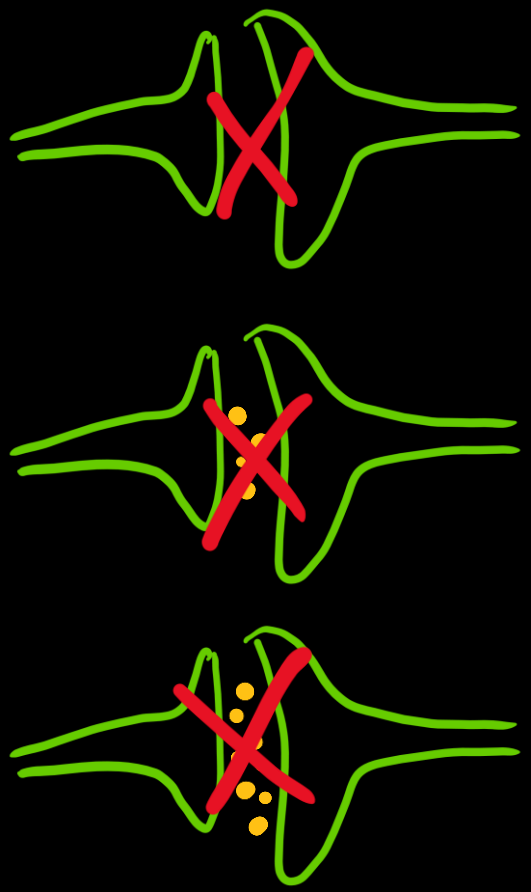


How it works?



GPT-3.5 Model
175,000,000,000 = 175B Synapses = 1,750억 개 시냅스

What happens if …



치매환자
Alzheimer’s

Paralysis, loss of memory

moving
memory
thinking
emotion
and everything

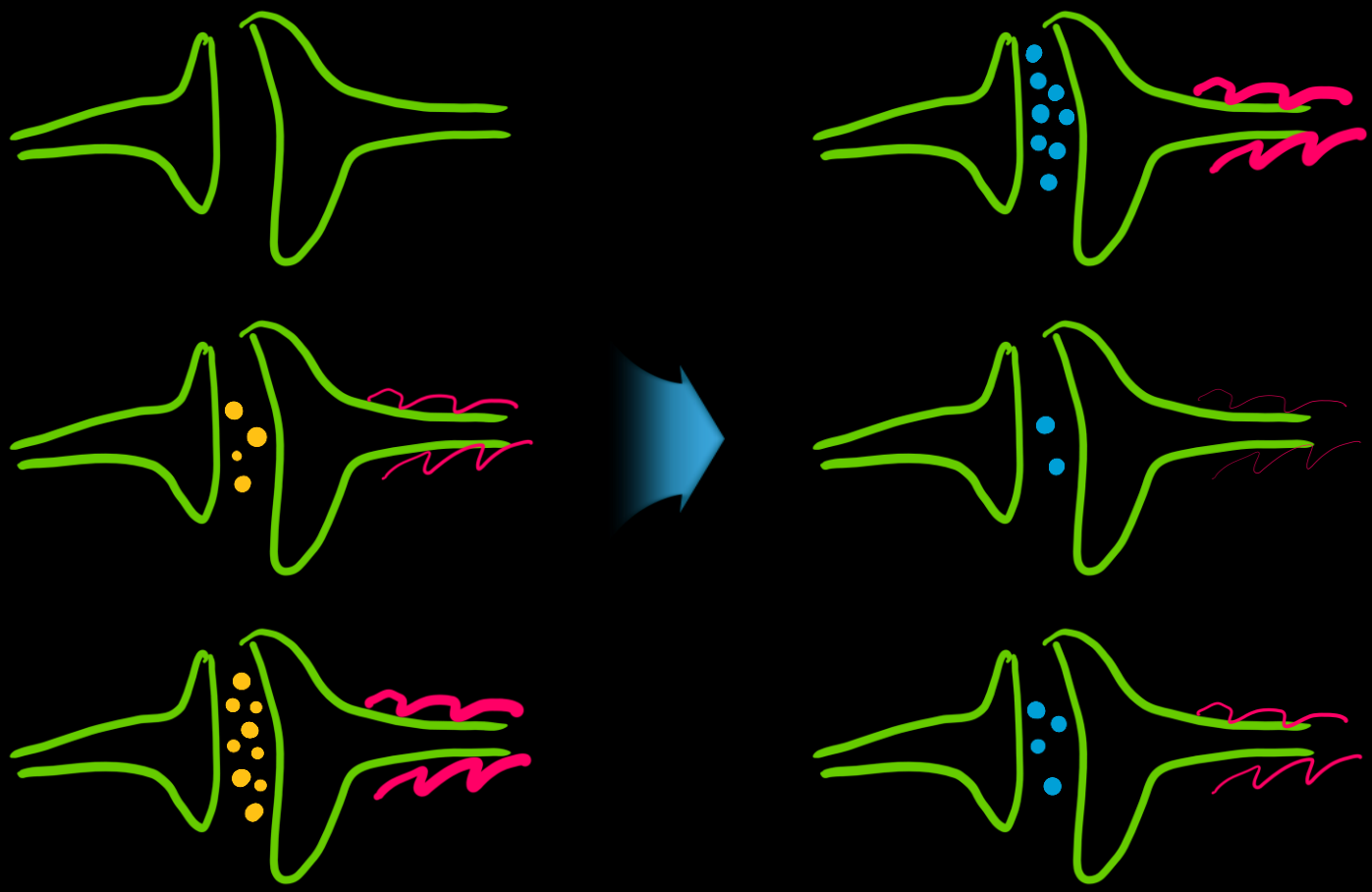
식물인간
Person in a vegetative state

Initialized(?) Synapses

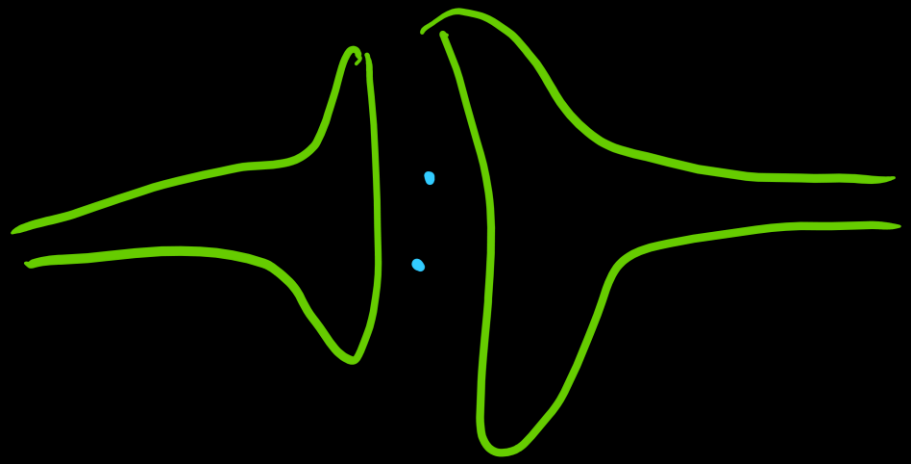
Experience &

Adjusting of the amount of neurotransmitter

Experience → Adjusting



3 variables implementation with Python



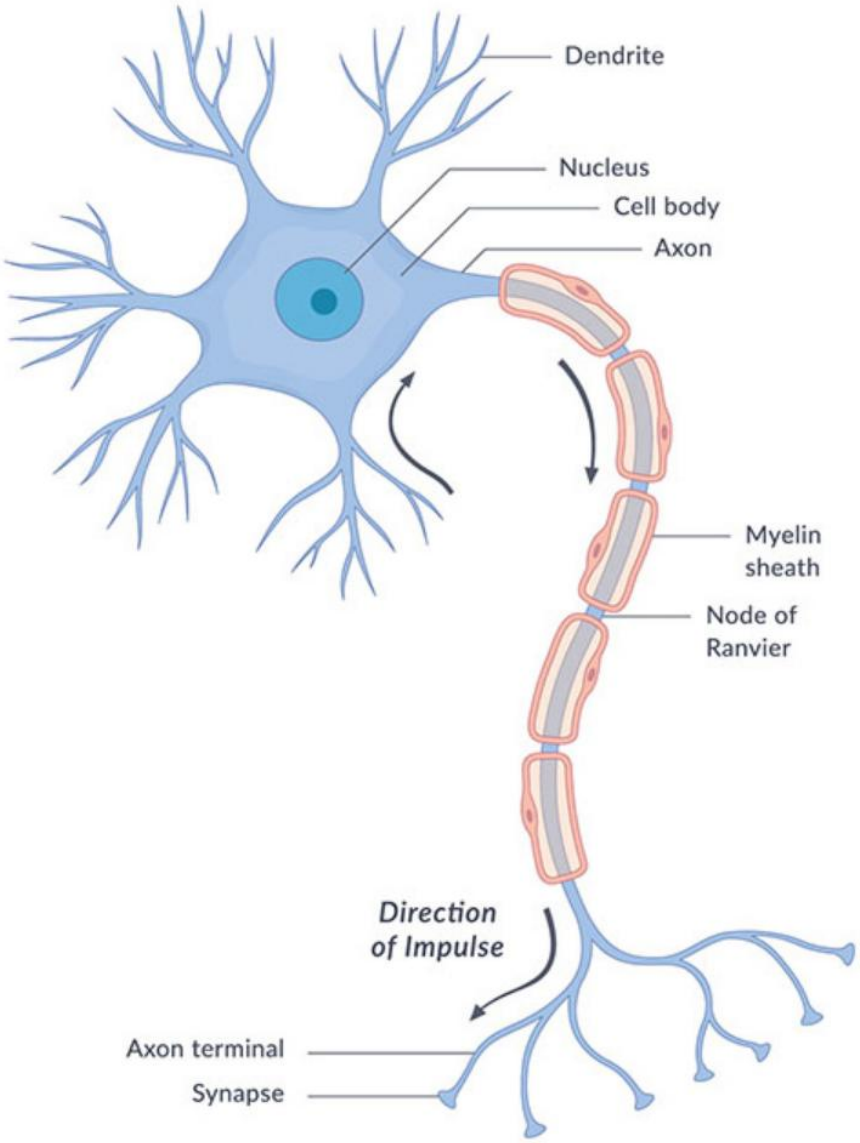
That is **learning**.

to the direction to increase

to the direction to decrease

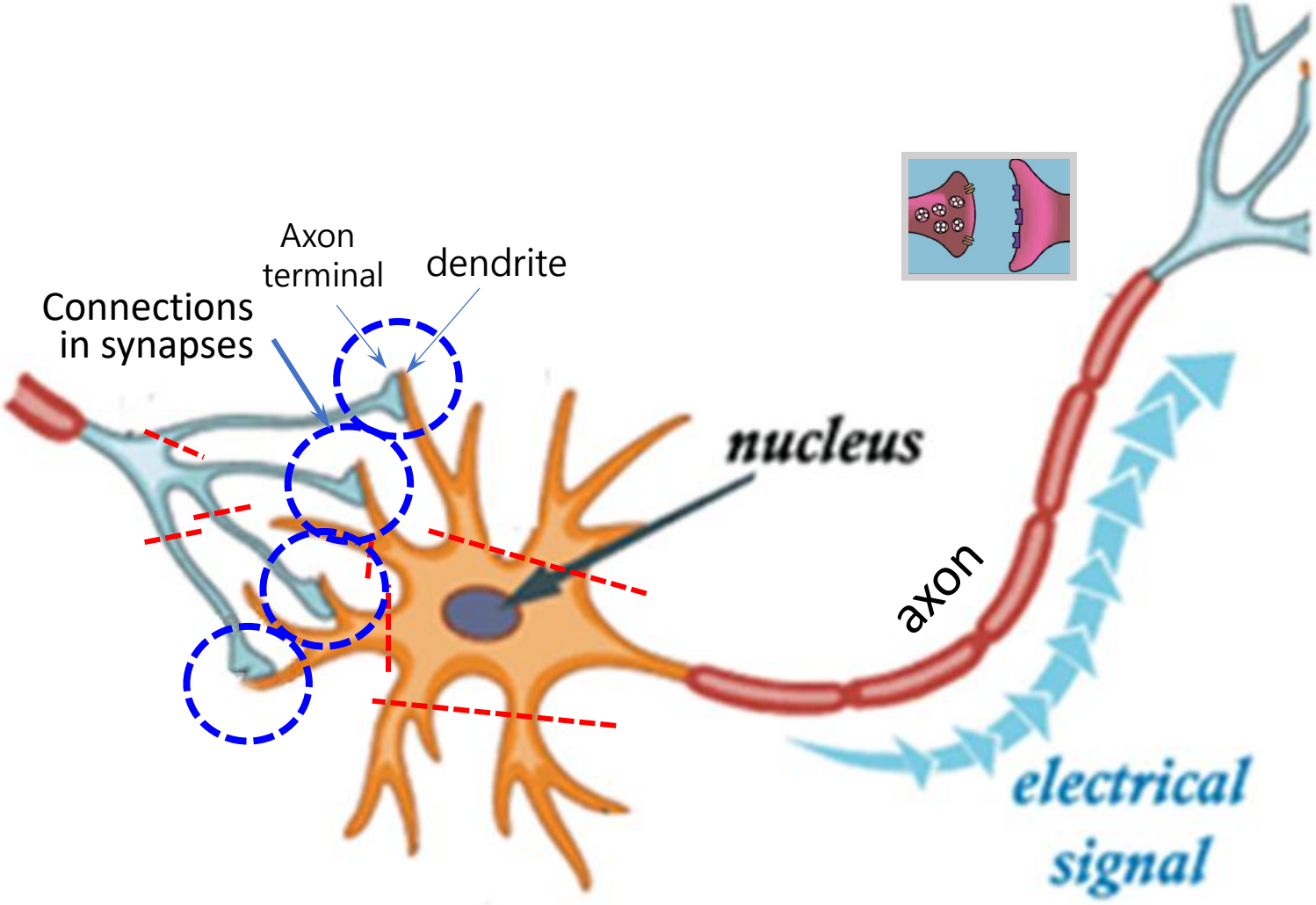
Stress/Error/Cost/**Loss function**

S/W implementation
→ AI

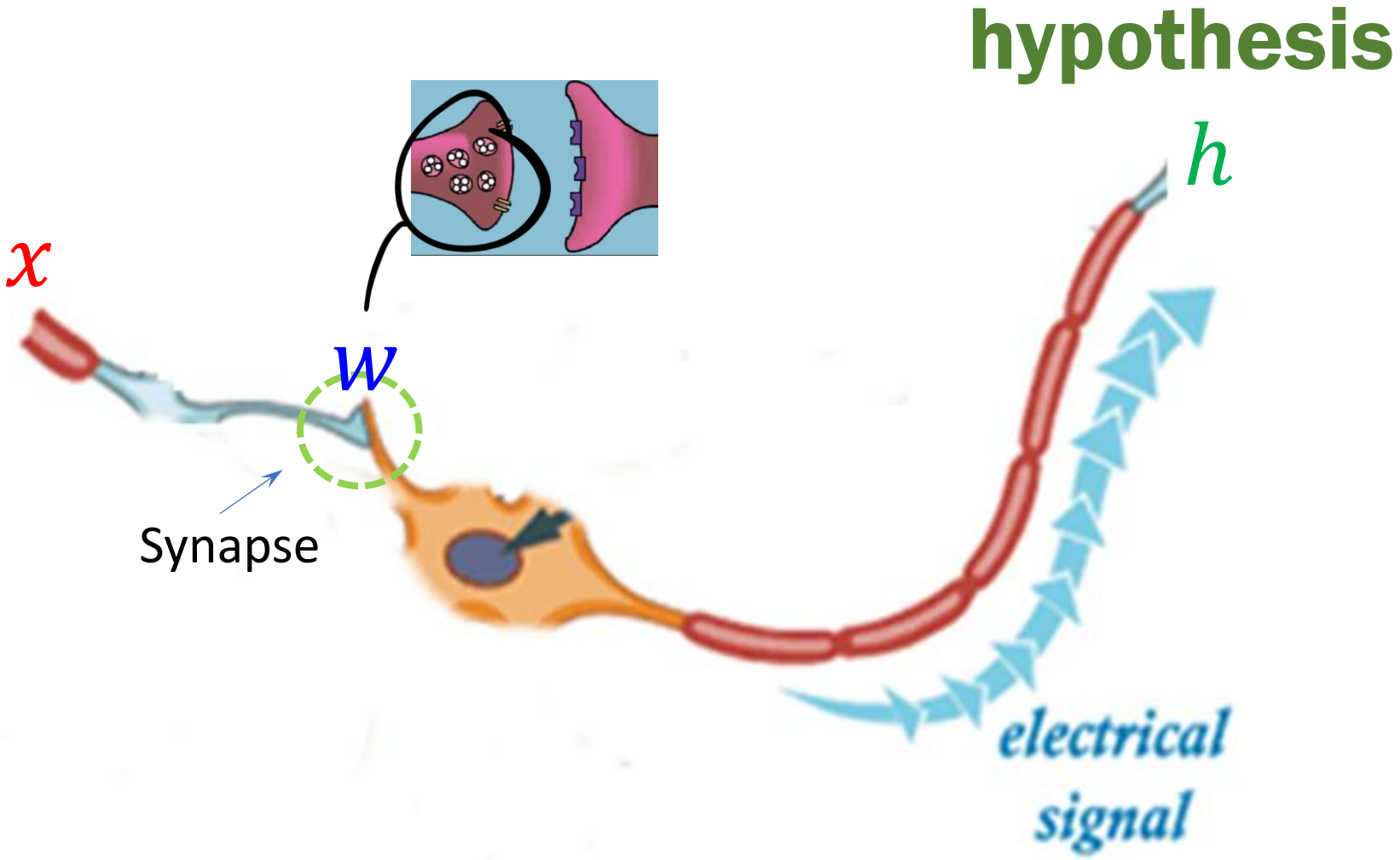


https://www.nichd.nih.gov/health/topics/neuro/conditioninfo/parts

A Neuron with **Multiple** Inputs



A Neuron with **1 Input**



h, Hypothesis

A **hypothesis** is a proposed **explanation (assumption)** for a phenomenon.

가설(hypothesis):
어떤 현상을 설명(가정)하는 것.
뉴런의 동작을 설명(가정)하는 것

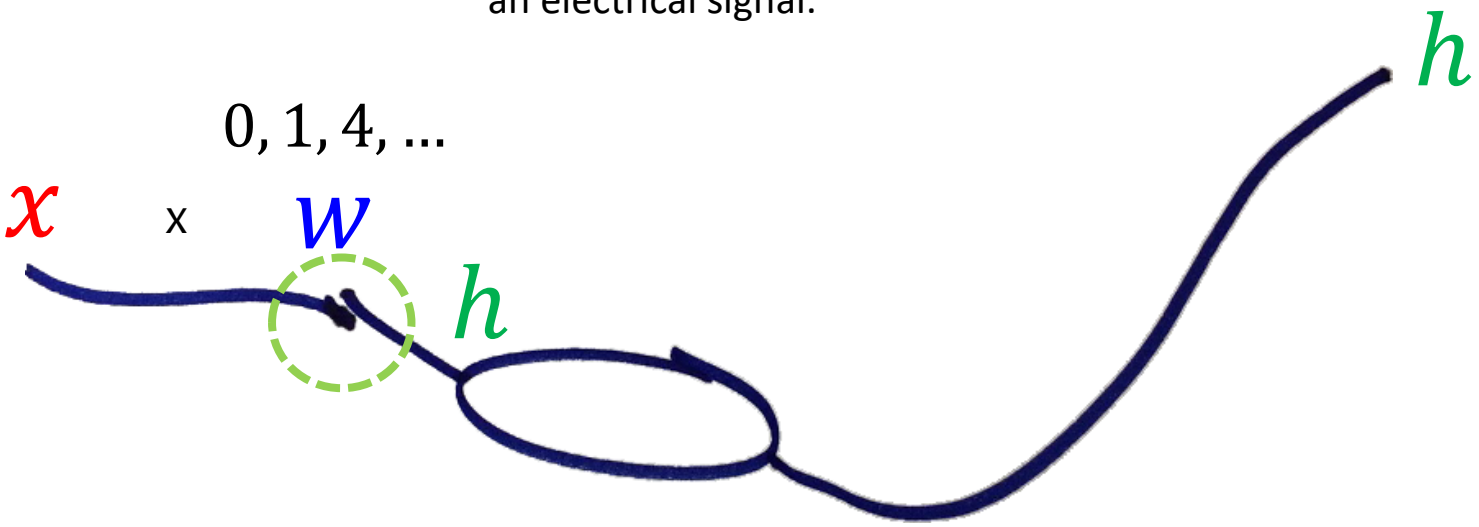
Explanation(assumption) about **the way a neuron works in**.

Output of a neuron, prediction

Action of a neuron

DR. Alan Hodgkin, Andrew Huxley

- Discovered how the action potential works
- The flow of sodium (Na^+) and potassium (K^+) ions generates an electrical signal.



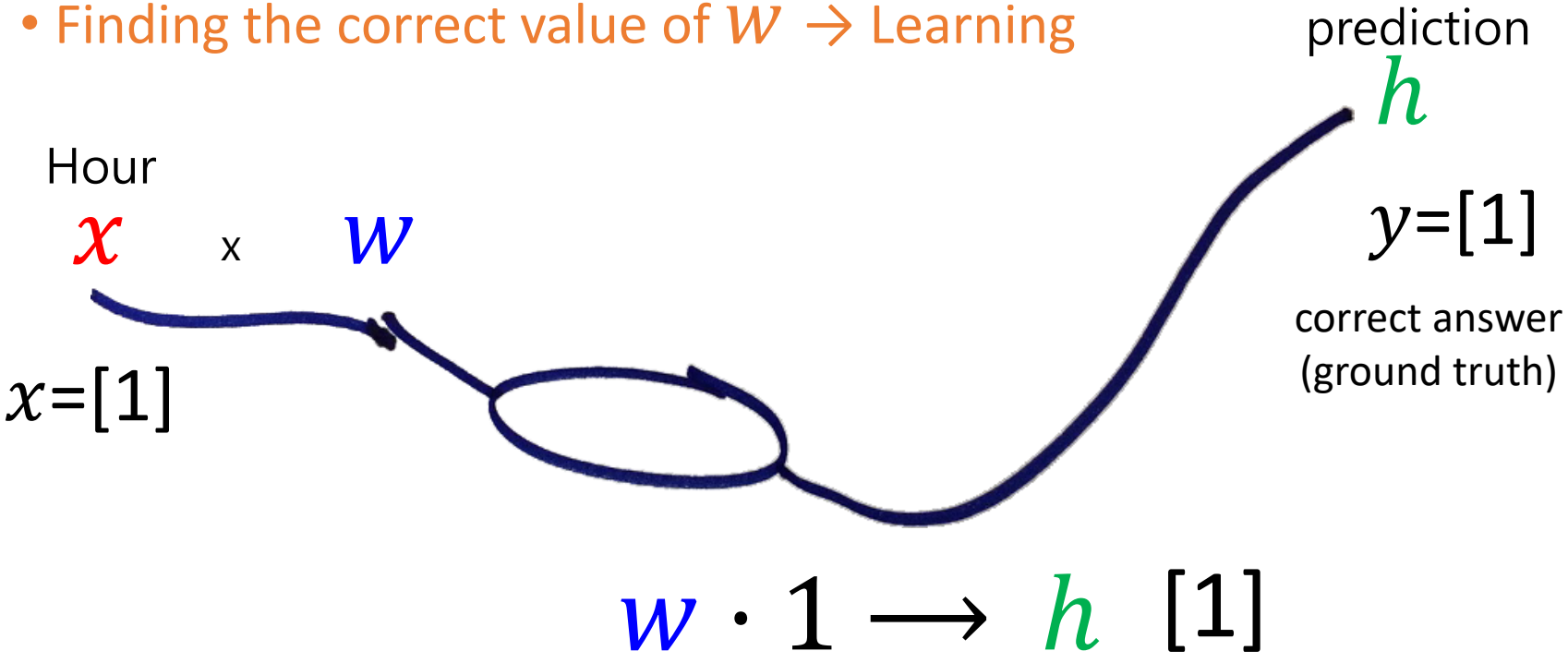
$$h = wx$$

w: $w$eighted

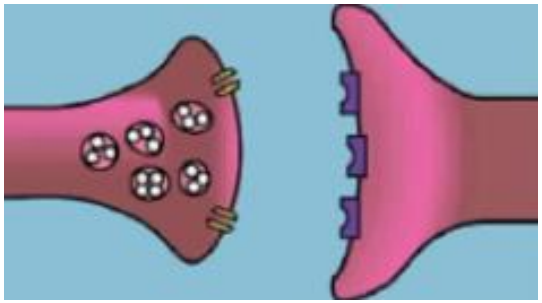
Application: Wage Calculator NN

임금 계산기

- **Experience**: 1 hour working(**input** x) → 1USD(correct answer, **groundtruth** y) payment
- How much you get for 3-hour working? (prediction)
- Finding the correct value of W → Learning



x (hour)	w	Output of a neuron	y (correct answer, wage)	Error/Stress Function	Reaction
1	4(random)	4	1	4-1	scolding seriously
1	2	2	1	2-1	ordinarily
1	1.5	1.5	1	1.5-1	not bed
1	1.3	1.3	1	1.3-1	good but not enough
1	1.1	1.1	1	1.1-1	acceptable



Scolding a dog/dolphin/child automatically updates the connection strength(w)

to make the error smaller in the next step.

Learning

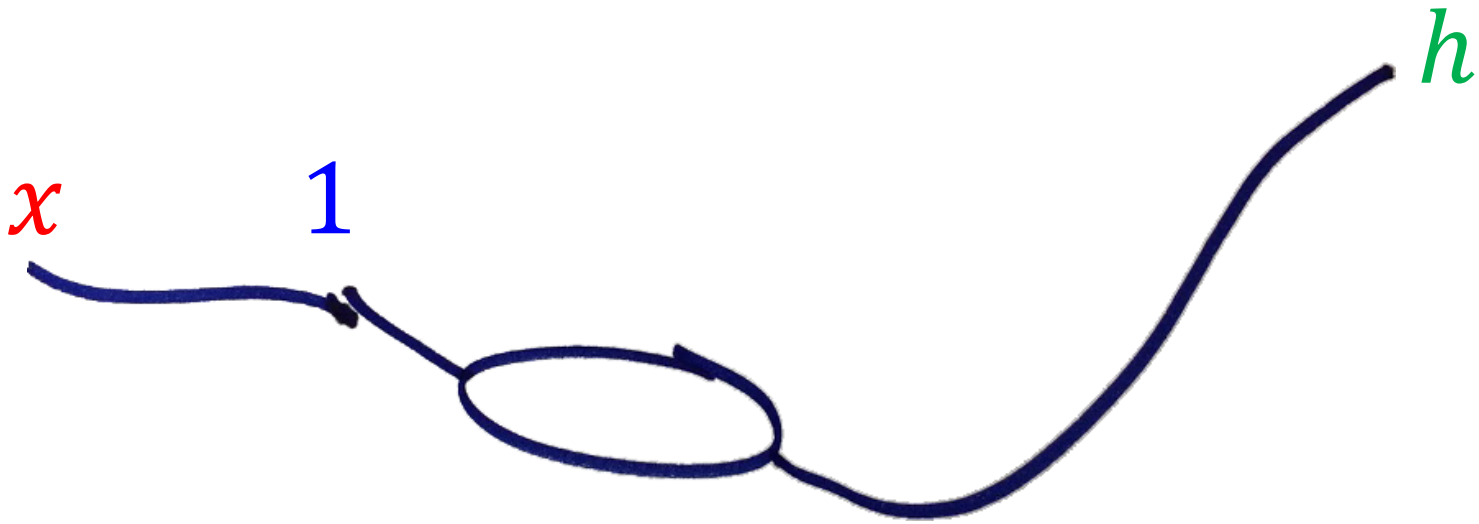
is to find the optimal value of parameter (w) to predict correctly.

the amount of neurotransmitter

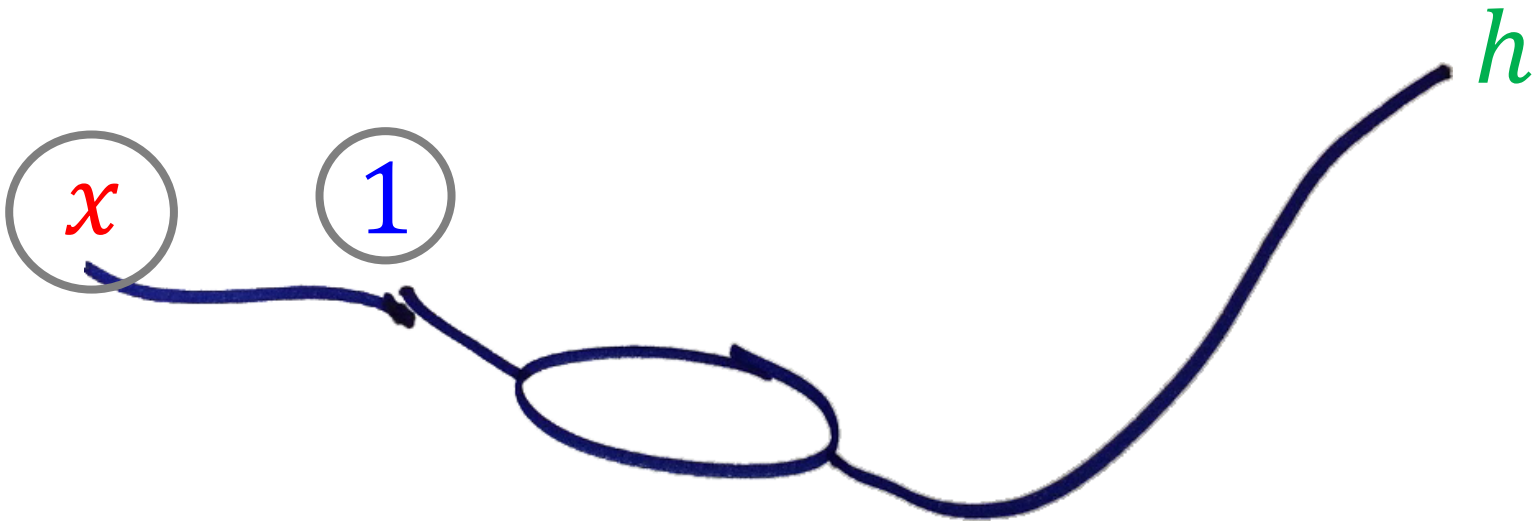
Drawing a neuron

Representing the below equation:

$$h = 1x$$



$$h = 1x$$

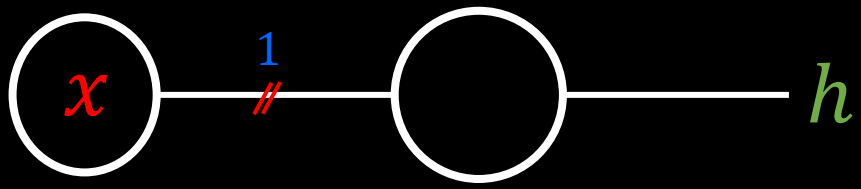


$$h = 1x$$

Matrix notation

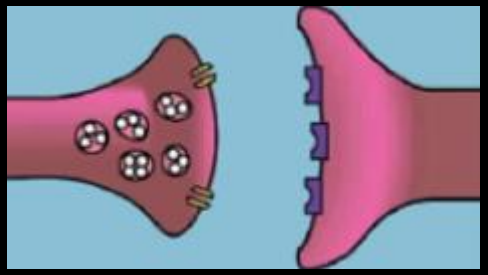
$(x)(1) \longrightarrow (h)$

Simplified version



$(1)\,(1) \longrightarrow (h)$

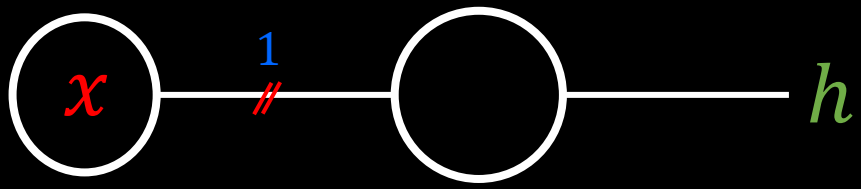
Where is the synapse/connection?



Matrix notation

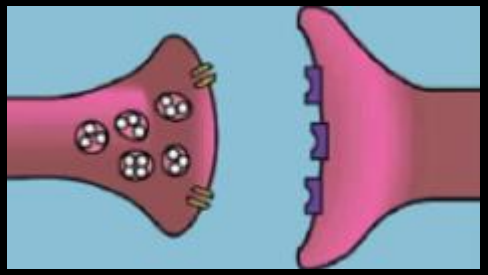
$$(x)(1) \longrightarrow (h)$$

Simplified version



$$\binom{1}{2}(1) \longrightarrow \binom{h_1}{h_2}$$

Where is the synapse/connection?

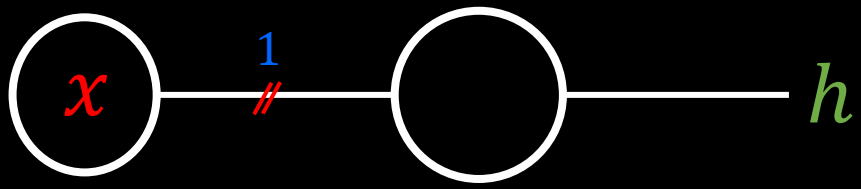


my.csv

Matrix notation

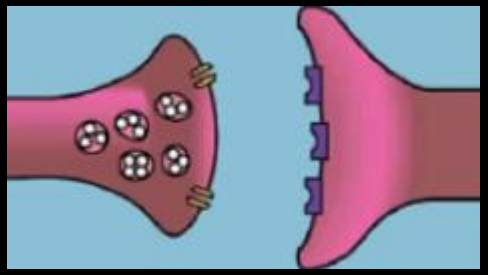
$$(x)(1) \longrightarrow (h)$$

Simplified version



$$\begin{pmatrix} 1 \\ 2 \\ 3 \end{pmatrix}(1) \longrightarrow \begin{pmatrix} h_1 \\ h_2 \\ h_3 \end{pmatrix}$$

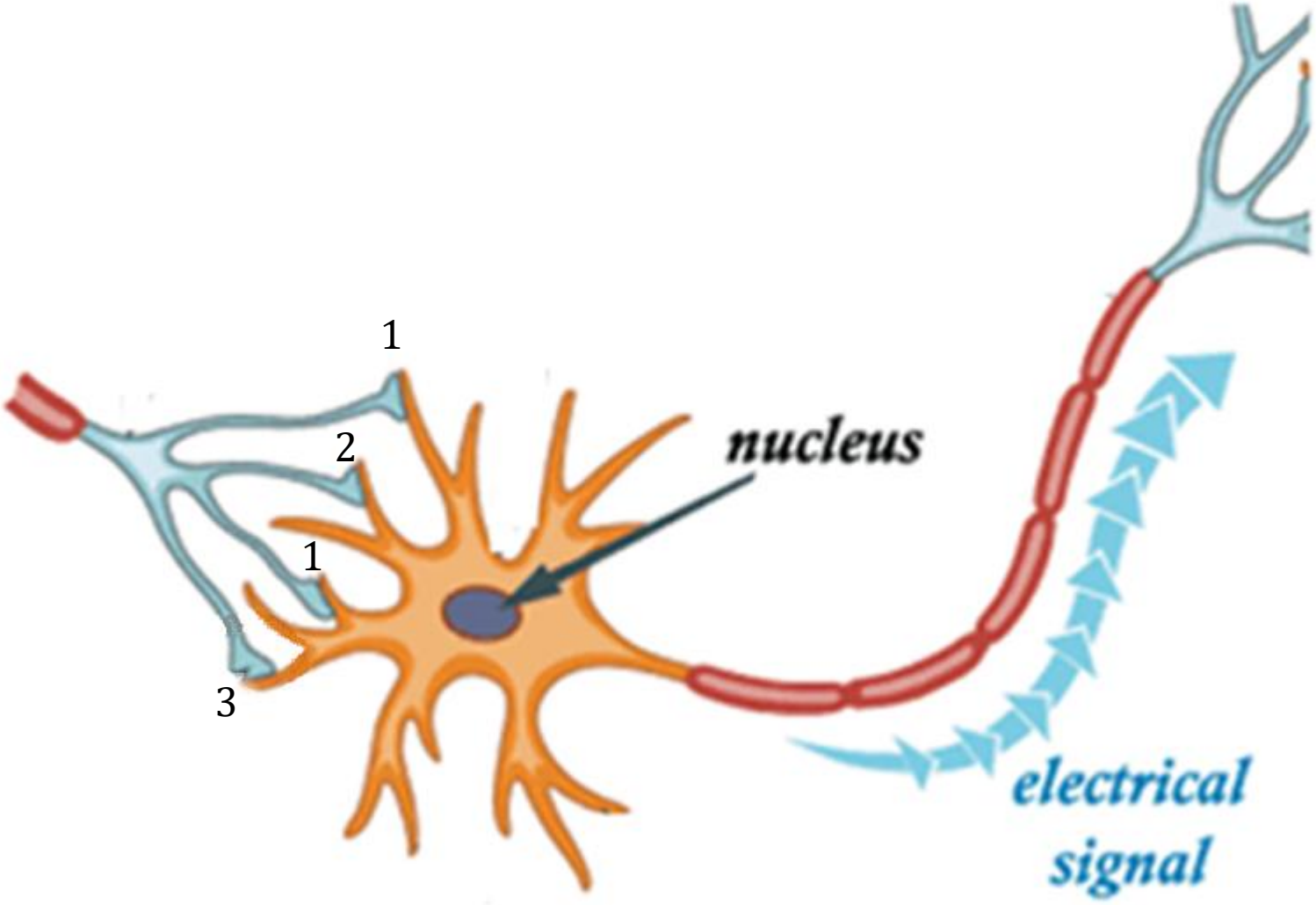
Where is the synapse/connection?

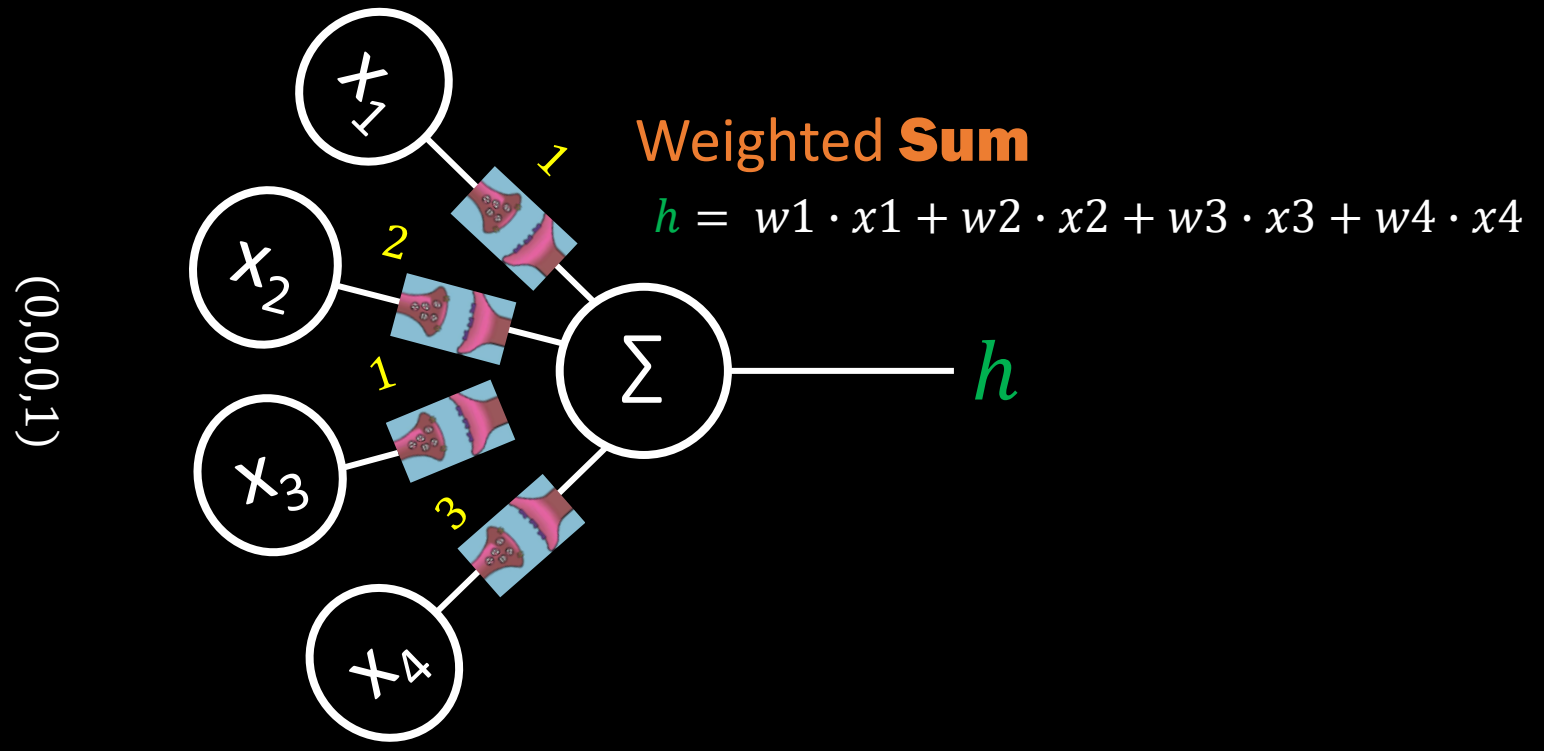


my.csv

A neuron and the **matrix** to describe the action of it.

A Neuron with **Multiple** Inputs





if the input values are (0,0,0,1), then h is ..

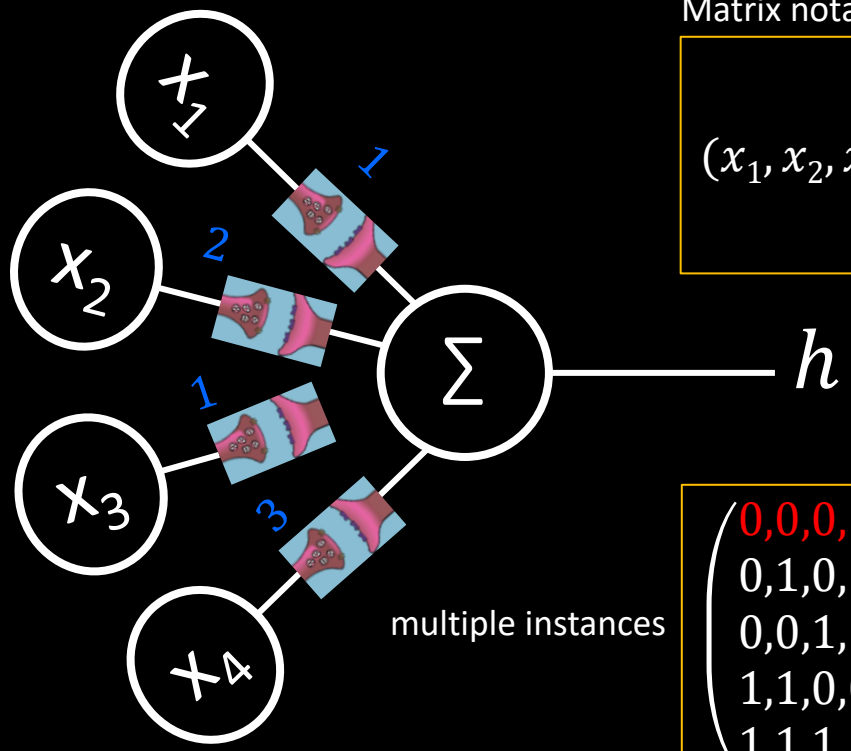
$$h = 1 \cdot x_1 + 2 \cdot x_2 + 1 \cdot x_3 + 3 \cdot x_4$$

Matrix notation

$$(x_1, x_2, x_3, x_4) \begin{pmatrix} 1 \\ 2 \\ 1 \\ 3 \end{pmatrix} \longrightarrow (h)$$

One instance

$$(0, 0, 0, 1) \begin{pmatrix} 1 \\ 2 \\ 1 \\ 3 \end{pmatrix} \longrightarrow (h)$$



Matrix notation

$$(x_1, x_2, x_3, x_4)\begin{pmatrix}1\\2\\1\\3\end{pmatrix} \rightarrow (h)$$

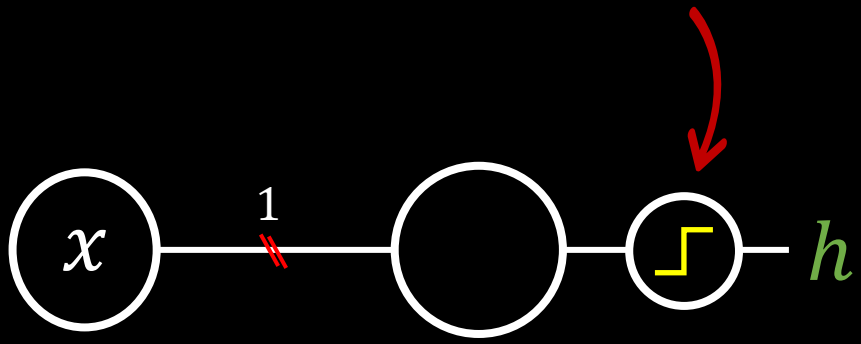
multiple instances

$$\begin{pmatrix}0,0,0,1\\0,1,0,1\\0,0,1,1\\1,1,0,0\\1,1,1,1\end{pmatrix}\begin{pmatrix}1\\2\\1\\3\end{pmatrix} \rightarrow \begin{pmatrix}h_1\\h_2\\h_3\\h_4\\h_5\end{pmatrix}$$

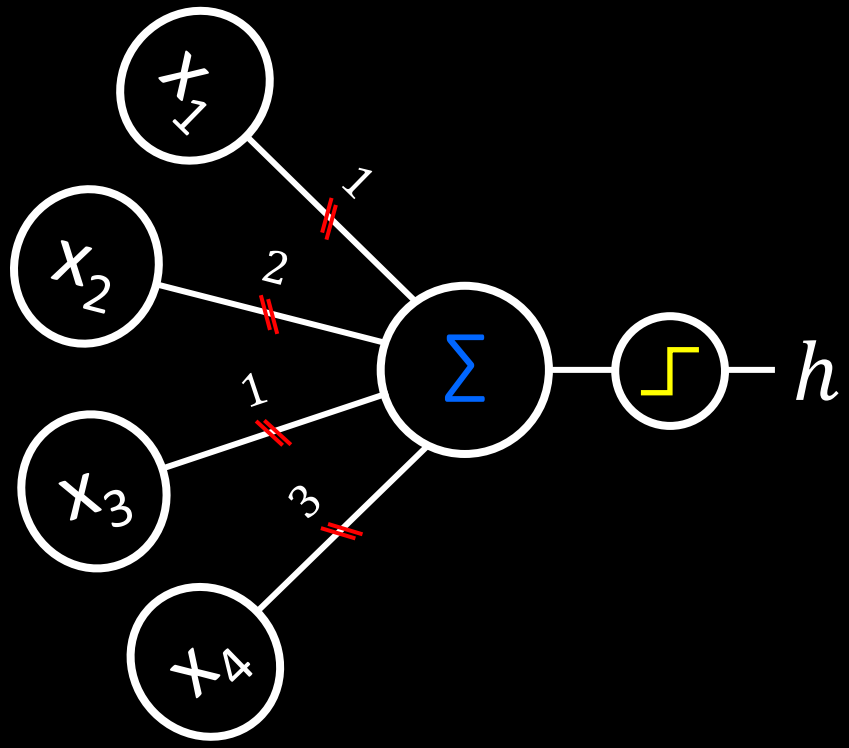
my.csv

Real operation of a neuron

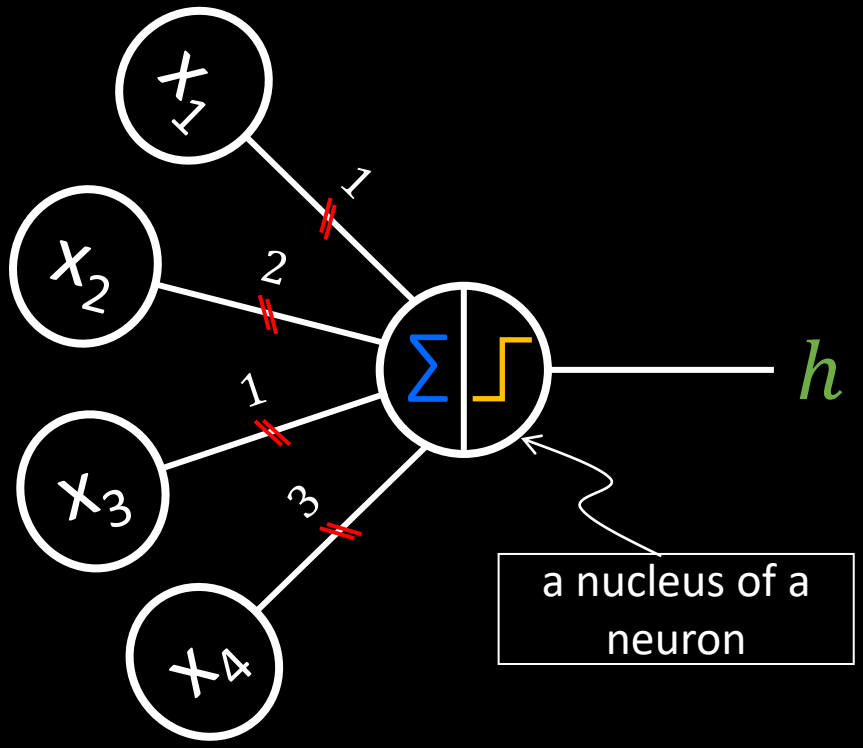
- **Thresholding**
- Signal ON if the weighted sum is greater than T
- otherwise signal OFF

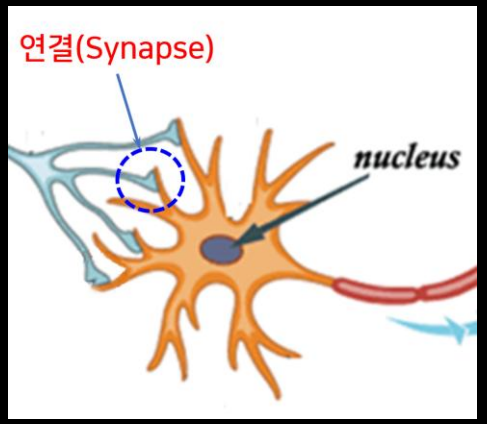


Thresholding

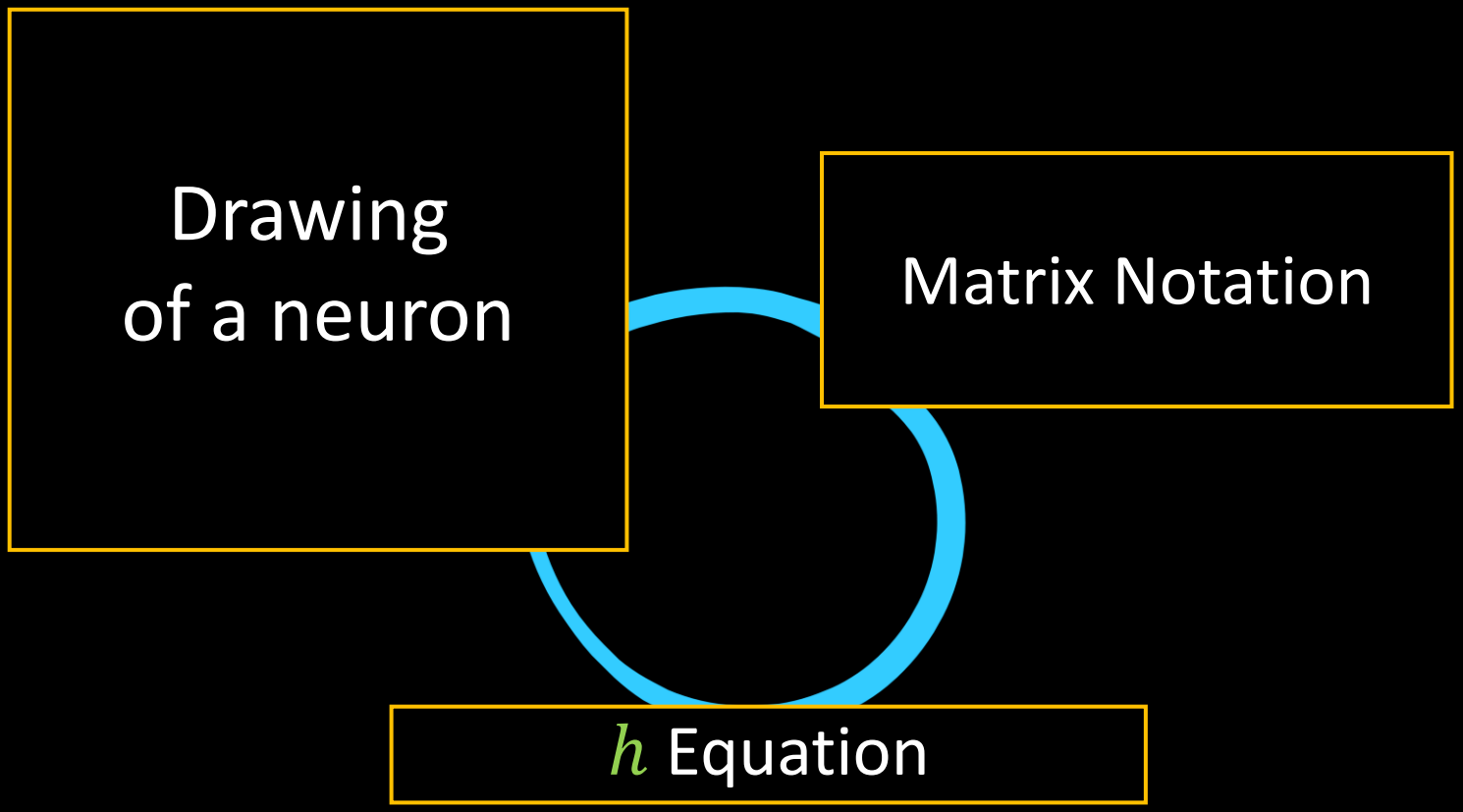


Weighted sum and Thresholding

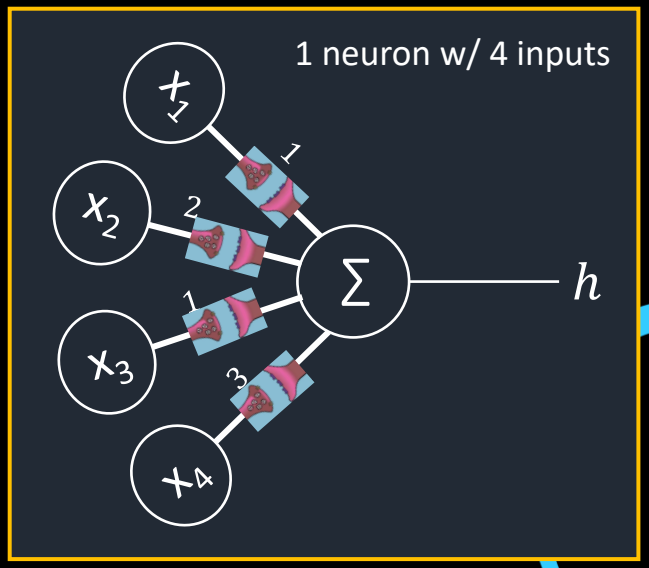




$$h = \begin{cases} 1 & if\ x_1 + 2x_2 + x_3 + 3x_4 > T \\ 0 & otherwise \end{cases}$$


Drawing
of a neuron
Matrix Notation
h Equation

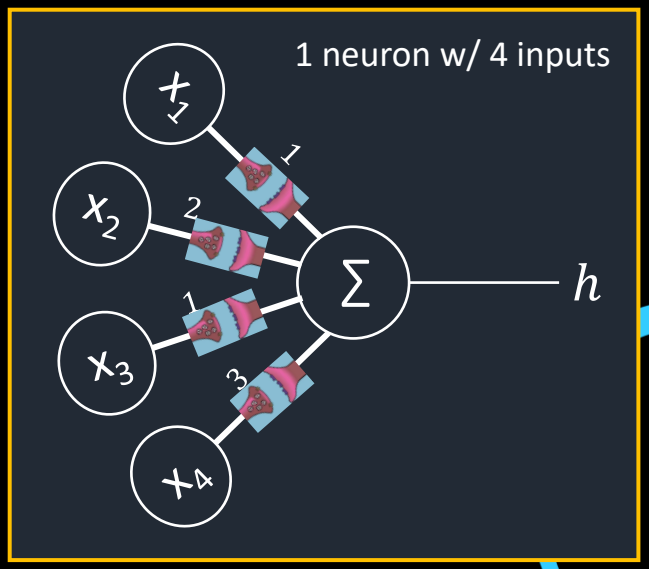
Drawing



Matrix notation

Equation

Drawing

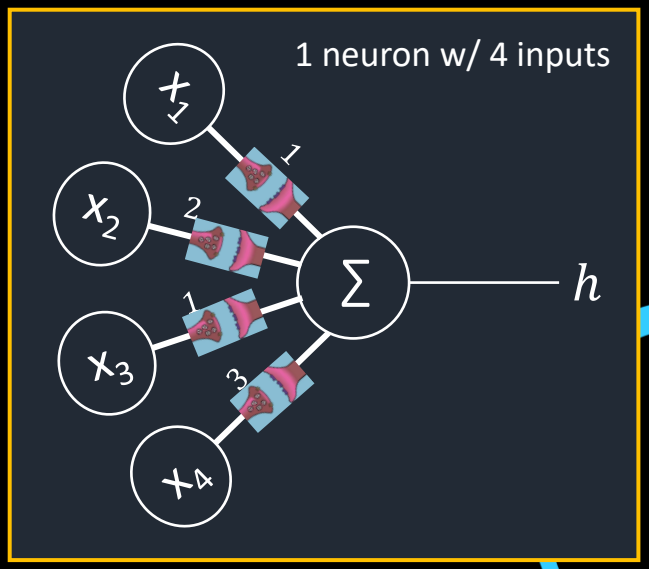


Matrix notation

Equation

$$h = 1 \cdot x1 + 2 \cdot 1 + 1 \cdot x3 + 3 \cdot x4$$

Drawing



Matrix notation

$$(x_1, x_2, x_3, x_4)\begin{pmatrix}1\\2\\1\\3\end{pmatrix} \rightarrow (h)$$

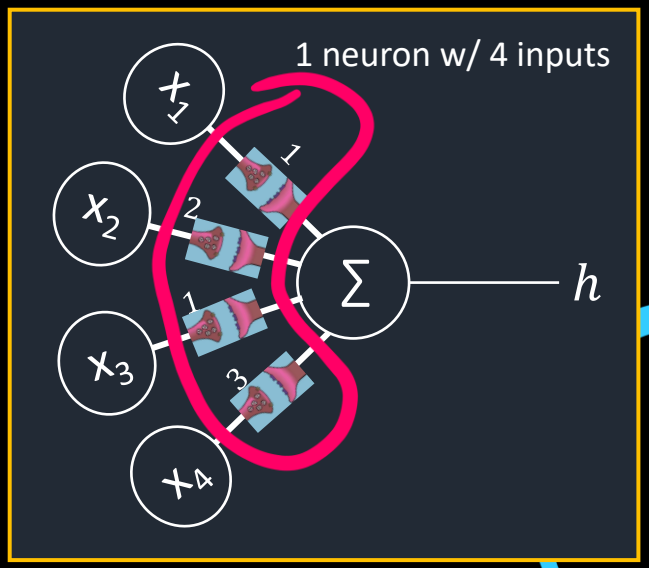
Equation

$$h = 1 \cdot x1 + 2 \cdot 1 + 1 \cdot x3 + 3 \cdot x4$$

What is learning again?

Updating the parameters
(synapses)

Drawing



Matrix notation

$$(x_1, x_2, x_3, x_4) \begin{pmatrix} 1 \\ 2 \\ 1 \\ 3 \end{pmatrix} \rightarrow (h)$$

Equation

$$h = 1 \cdot x1 + 2 \cdot 1 + 1 \cdot x3 + 3 \cdot x4$$

How do we update it?