

Neural Network Theory

Artificial **Intelligence** and Brain

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Materials are here:

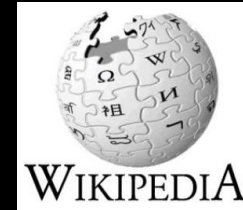
<https://github.com/yungbyun/neuralnetworks>

git clone *[link]*

Agenda

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

Intelligence



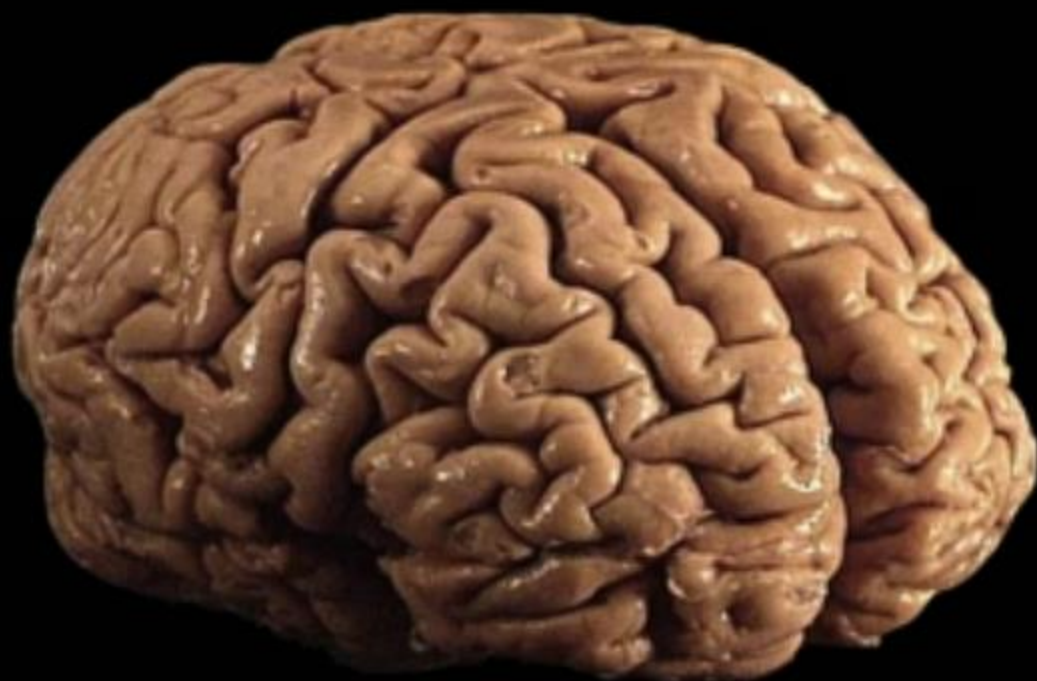
- One's **capability** for logic, understanding, self-awareness, **learning**, planning, creativity, and problem solving
- The **ability** to perceive information, and to retain it as knowledge to be applied towards adaptive behaviors within an environment
- Human Intelligence = **Natural** Intelligence

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?

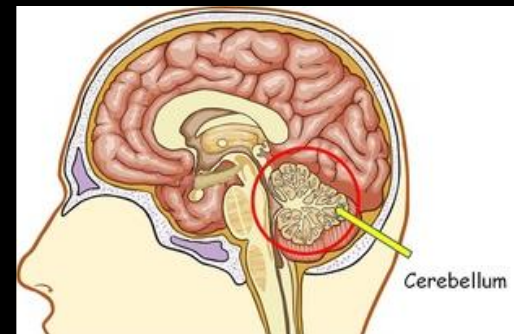
Neuroanatomist

신경해부학자



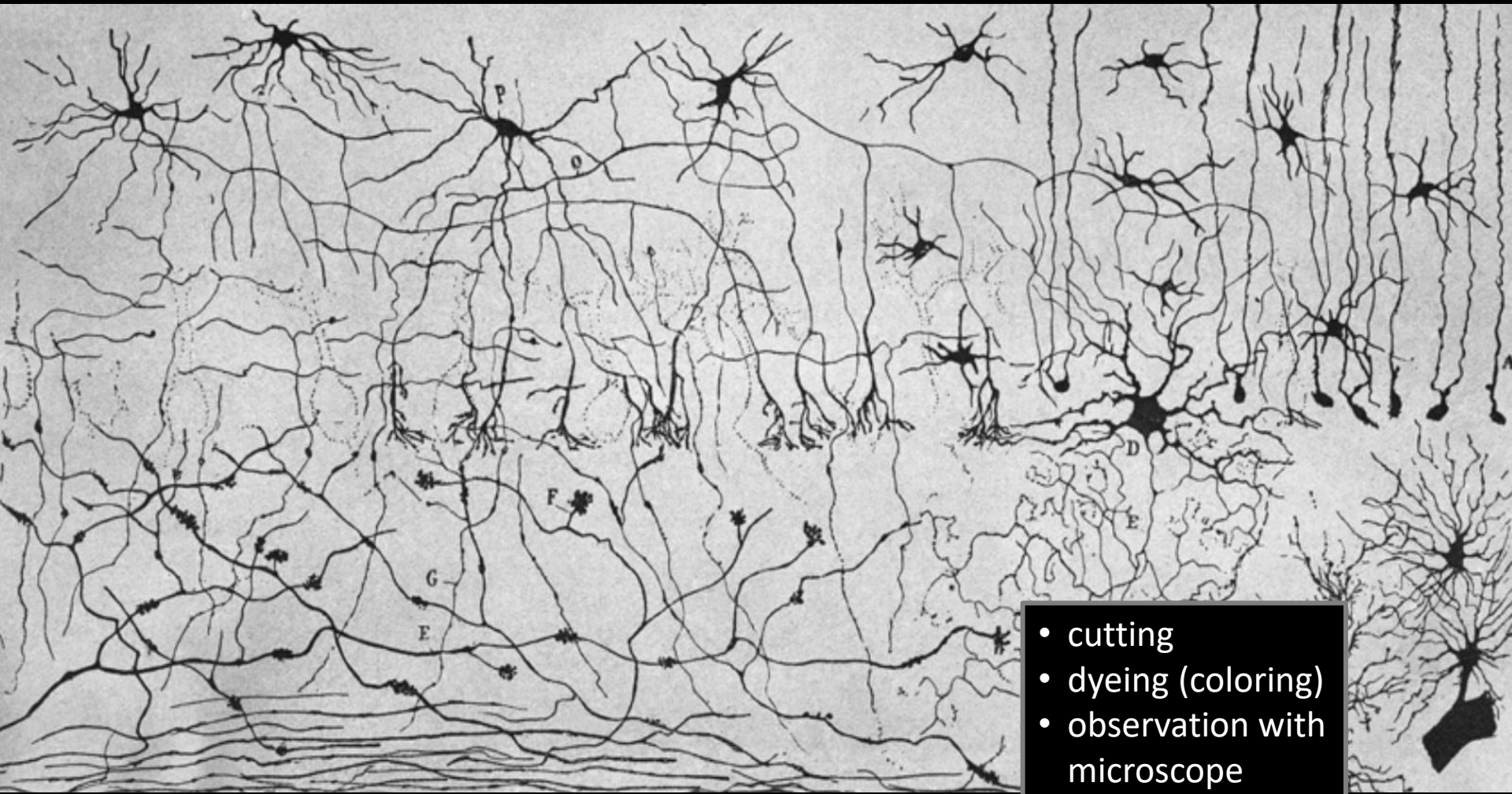
Santiago Ramón y Cajal, 1852-1934

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



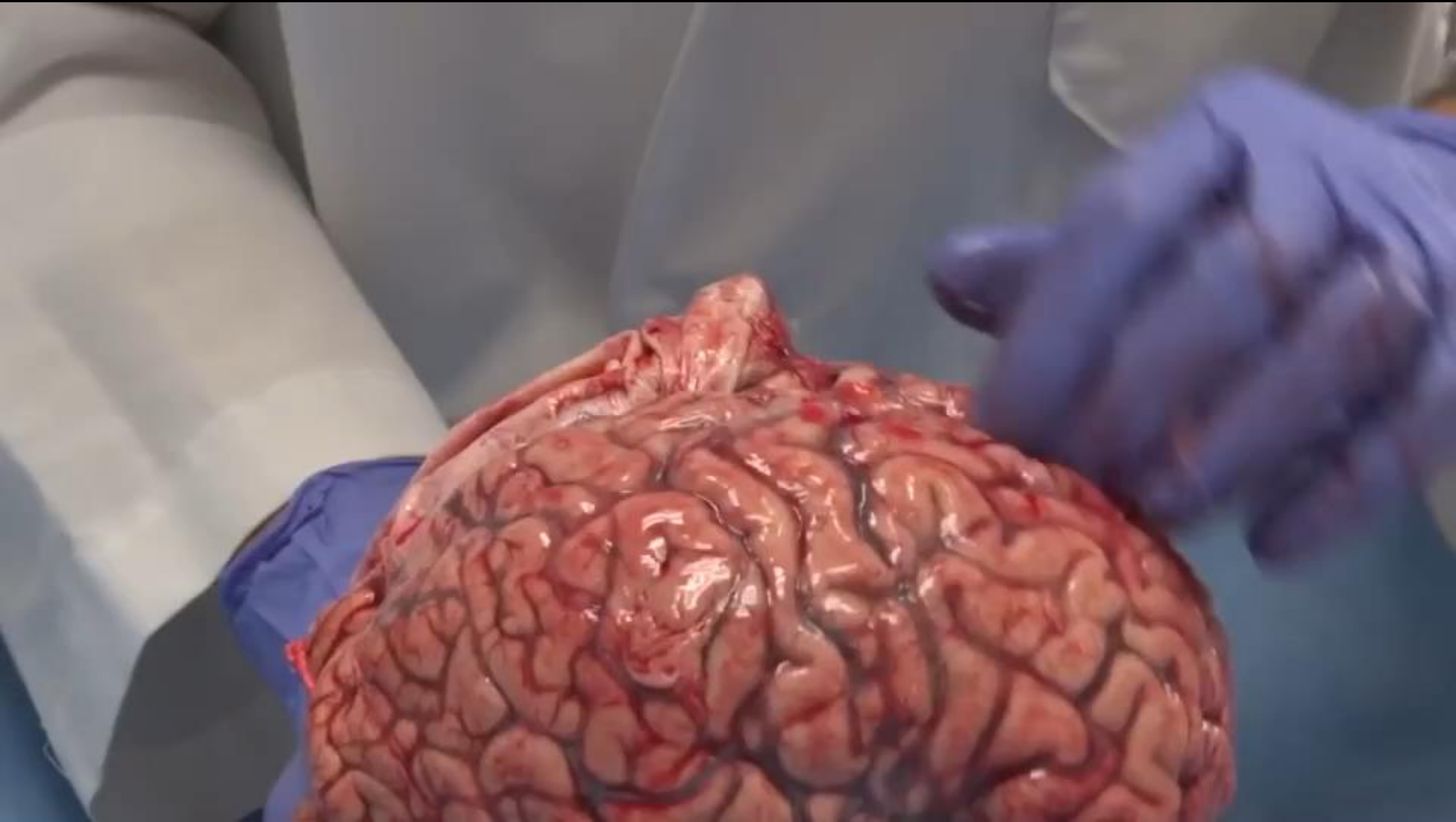
human(spinal animal)

Neurons in a bird's brain



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

Brain of Human







1천억개 이상

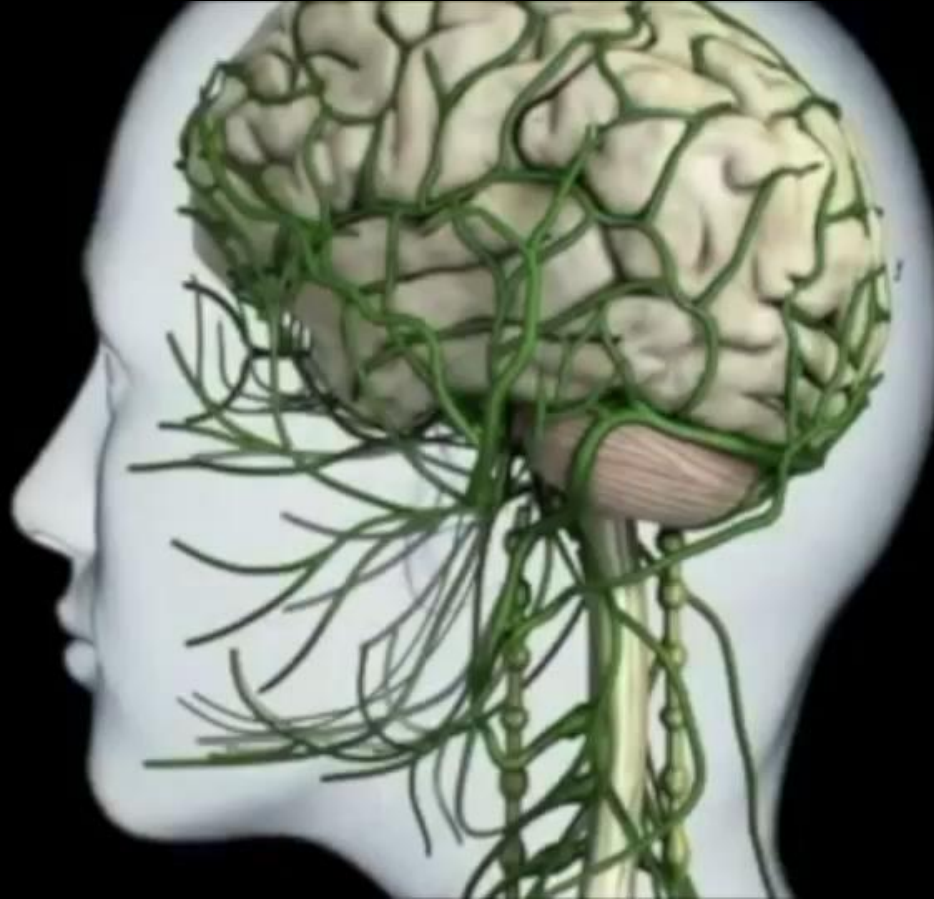
100 billion neurons

more than

the number of **stars**

in the universe

So, what **happens** inside?



Electric impulse
(signal) called axon
potential

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

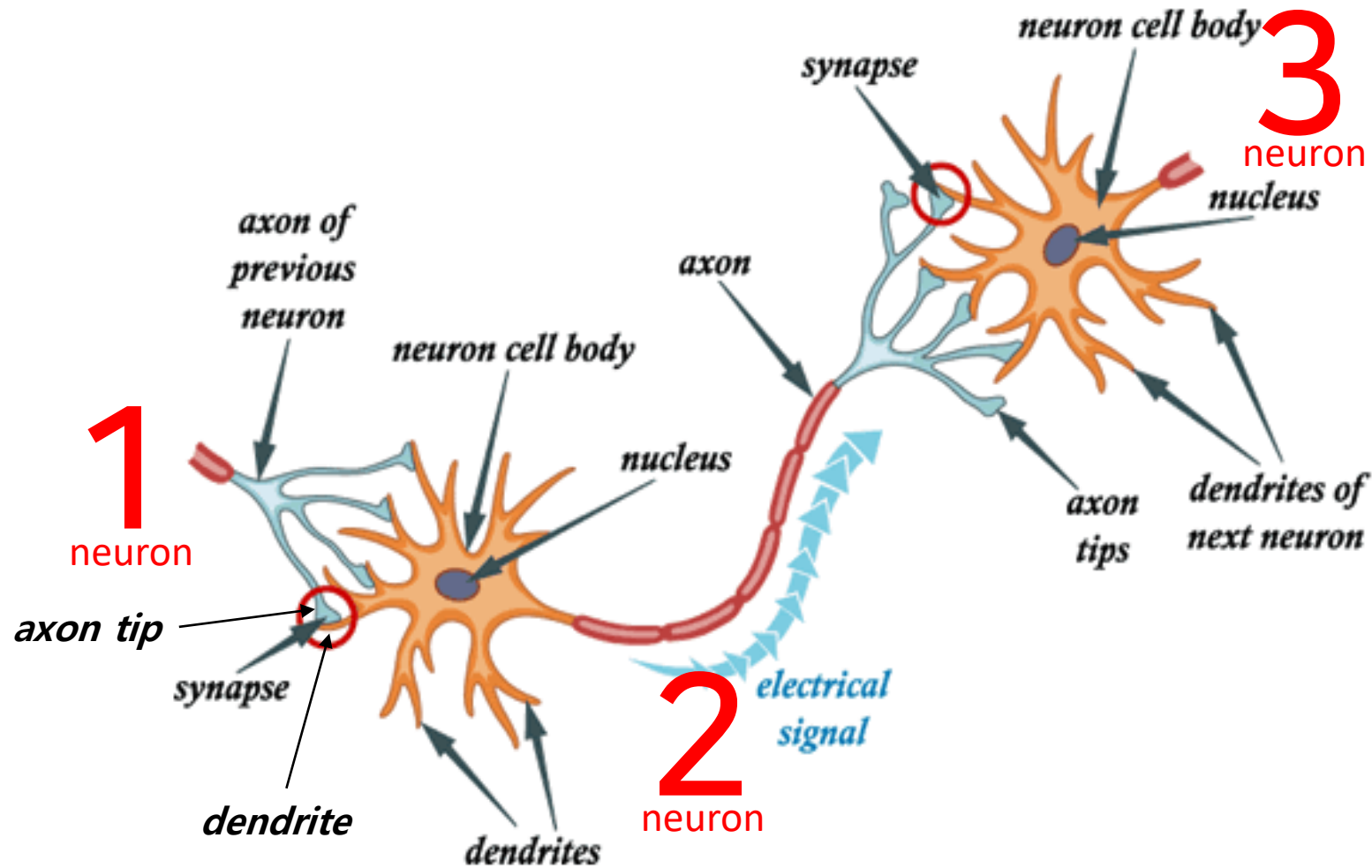


Simulation (signaling)



A brain in a supercomputer | Henry Markram

Connection between neurons

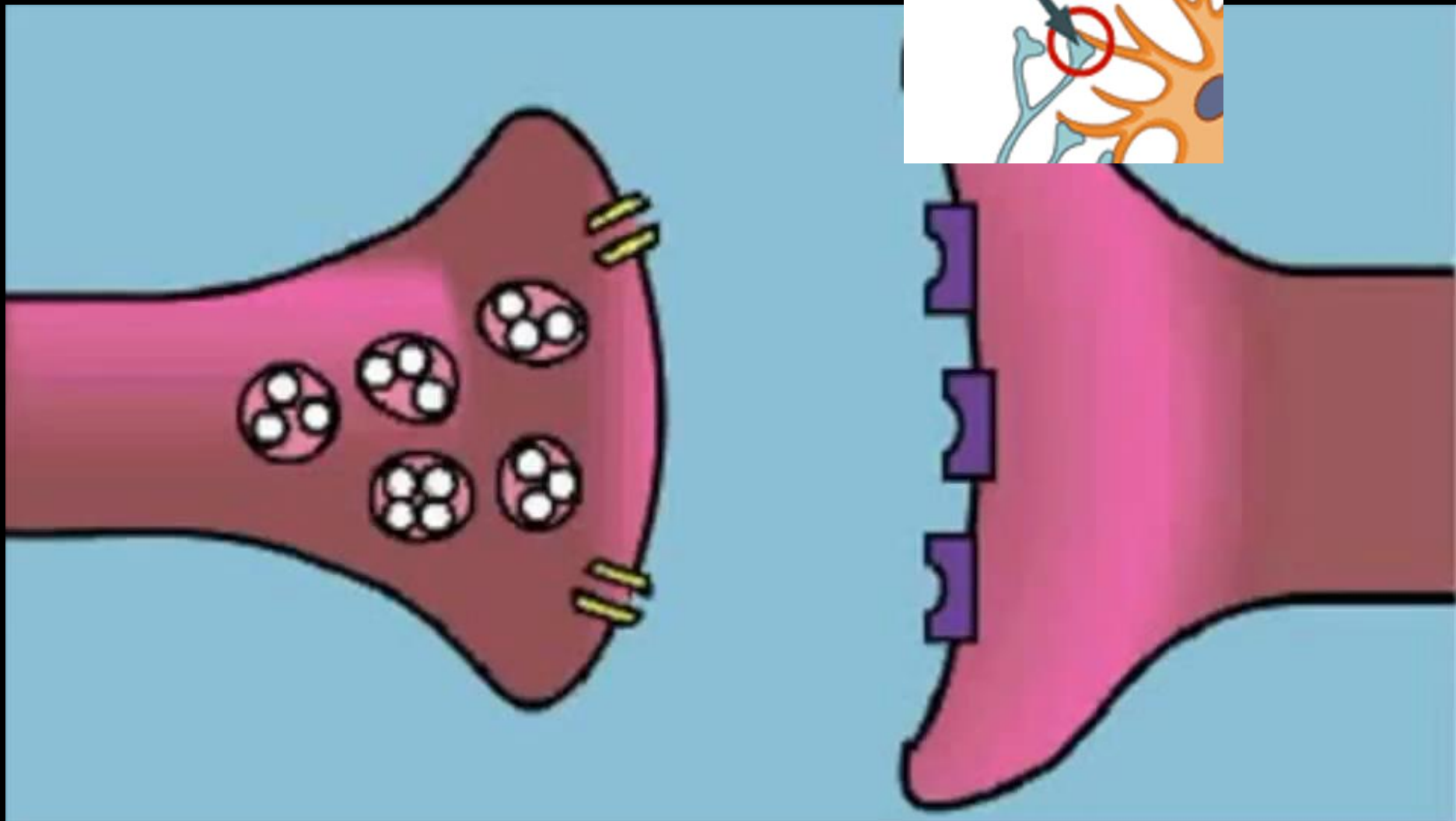
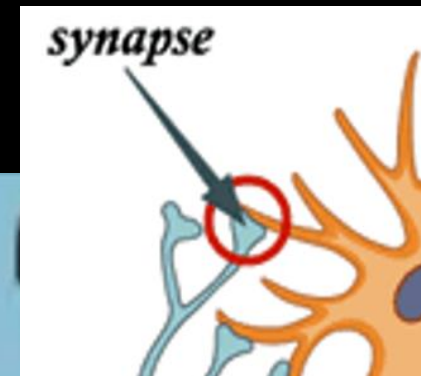


Synapse

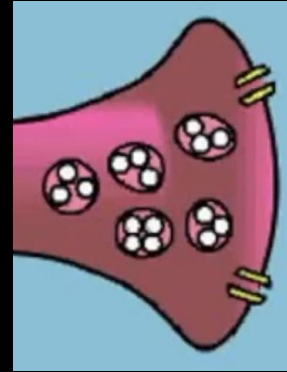
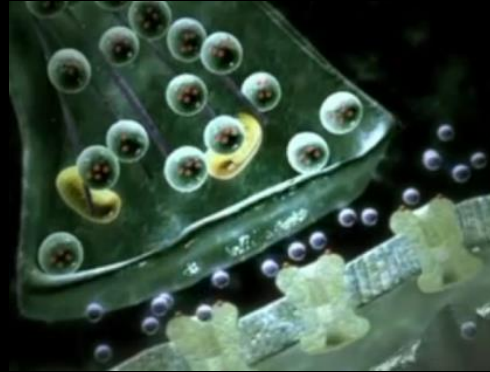
시냅스



Synapse (simplified)



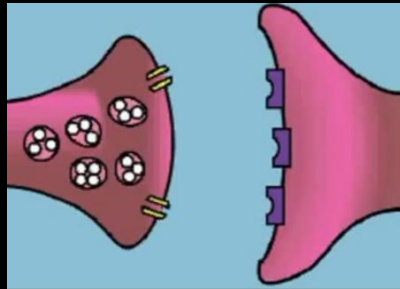
The Brain—Lesson 2—How Neurotransmission Works



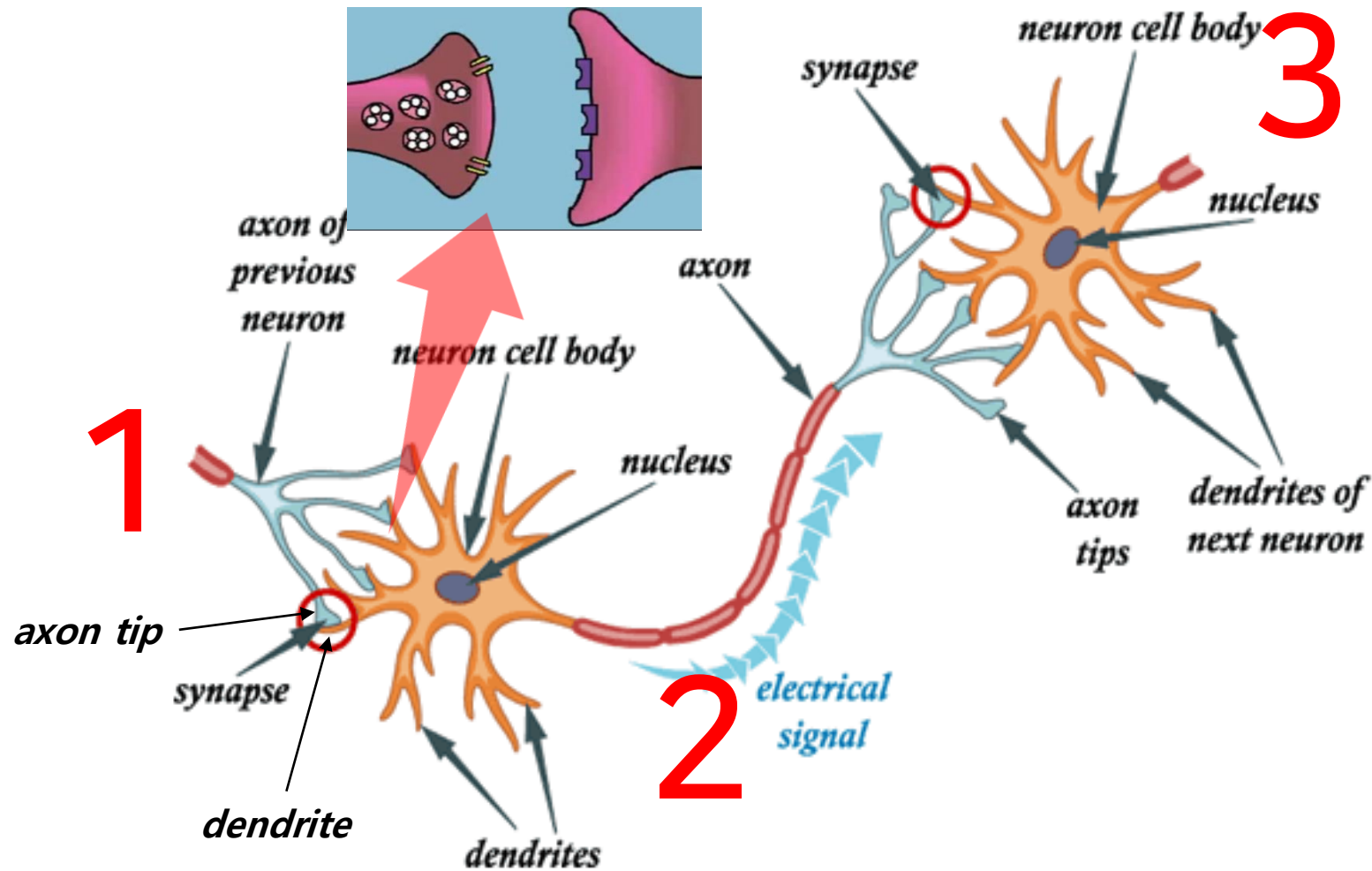
Neurotransmitter in synapse

신경전달물질

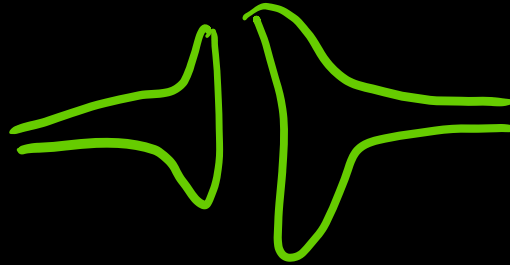
How many
neurotransmitters in a
synapse?



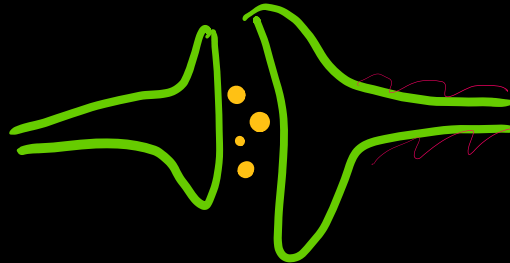
Connection between neurons



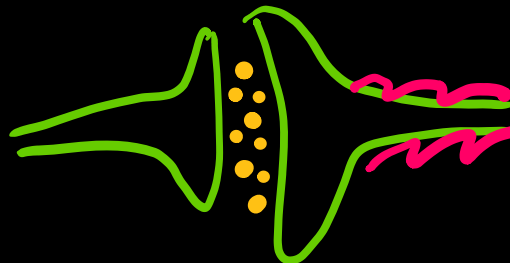
How it works?



No neurotransmitter
No signal transmission
No connection



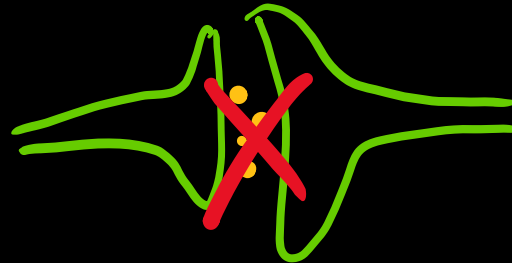
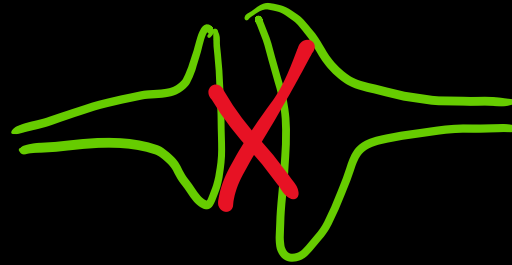
small
weak signal



big
strong signal



What happens if ...



Alzheimer's Paralysis, loss of memory

moving

memory

thinking

emotion

and everything

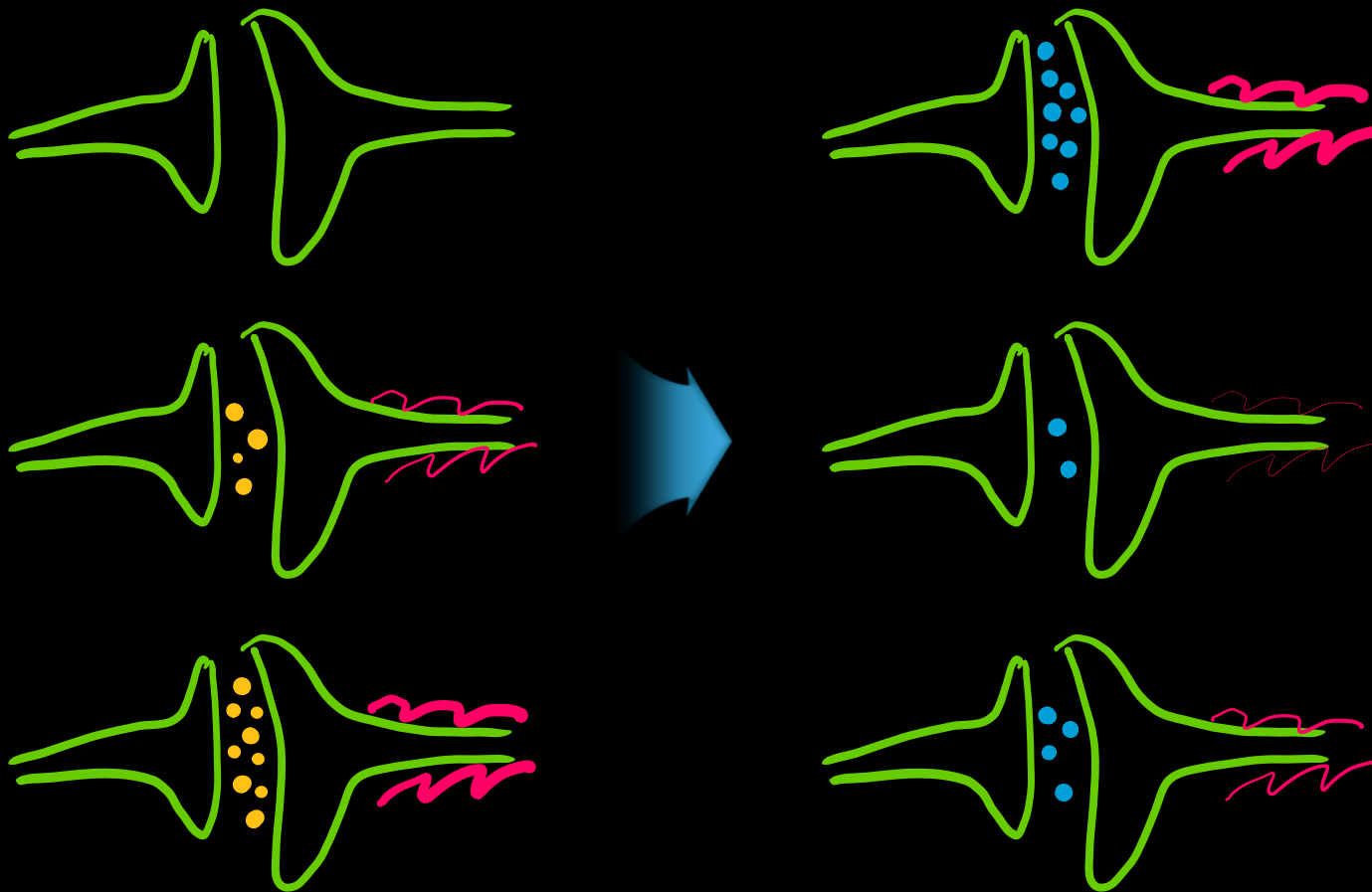
Initialized(?) synapses



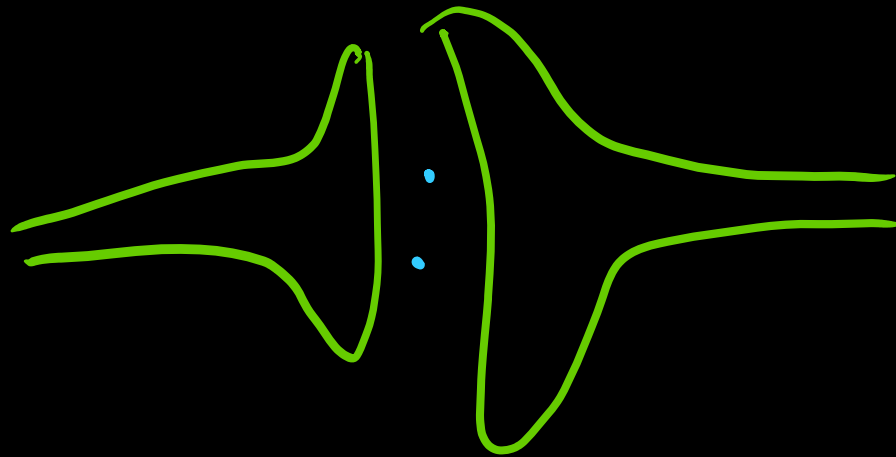
Experience and
the **adjusting** of the
amount of
neurotransmitter



Experience → Adjusting



3 variables implementation with Python



That is **learning**.

to the direction to increase



Happiness

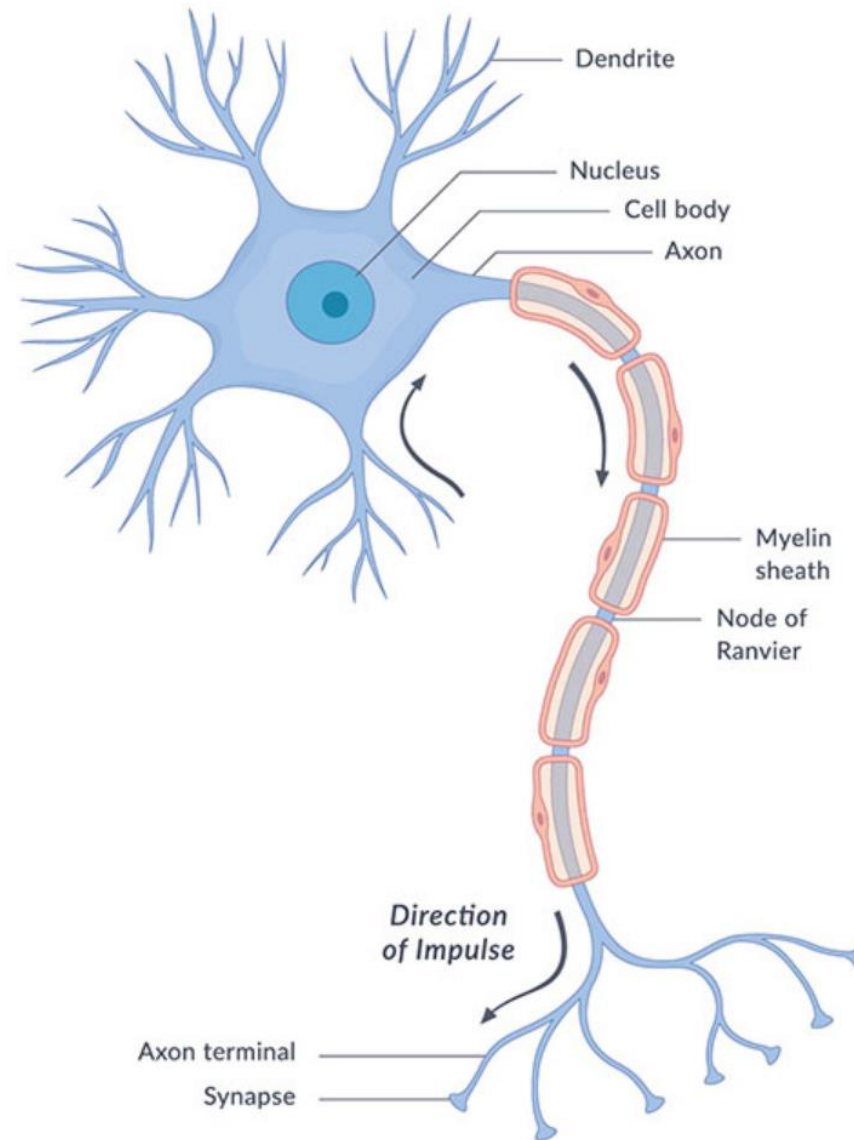
to the direction to decrease



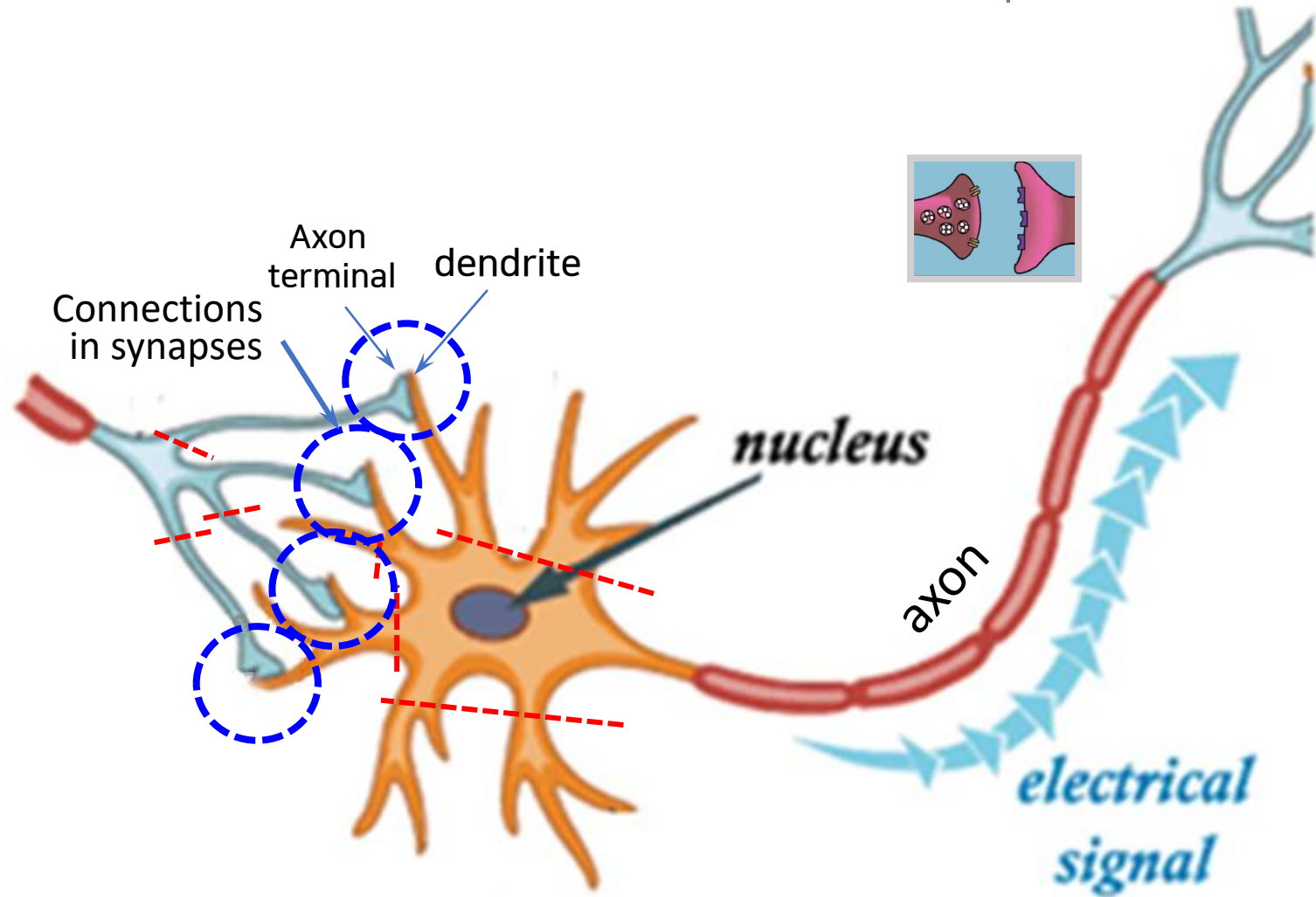
Stress

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

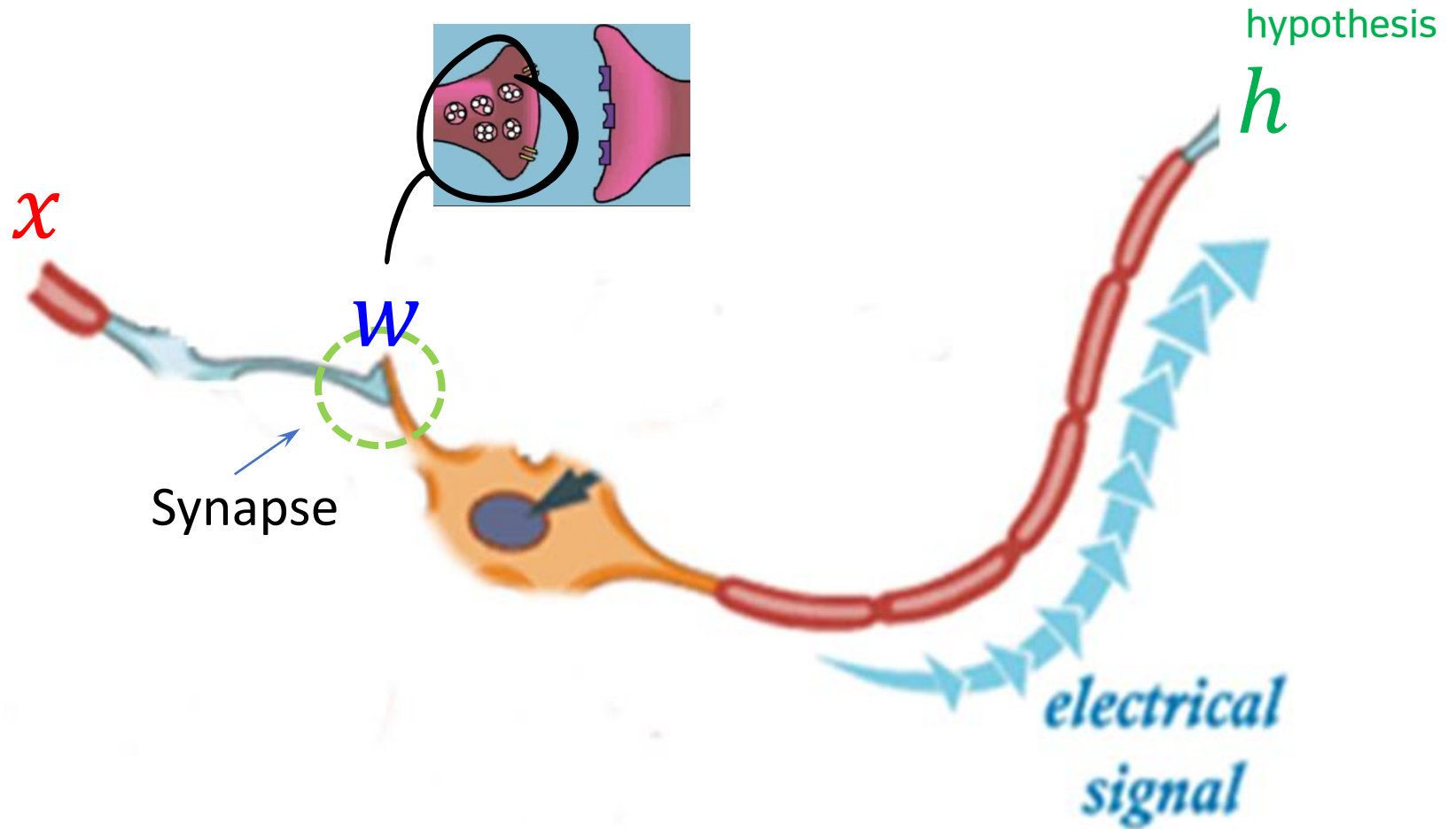
S/W implementation
→ AI



A Neuron with **Multiple** Inputs



A Neuron with **1** Input



h, Hypothesis



A hypothesis (plural hypotheses) 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

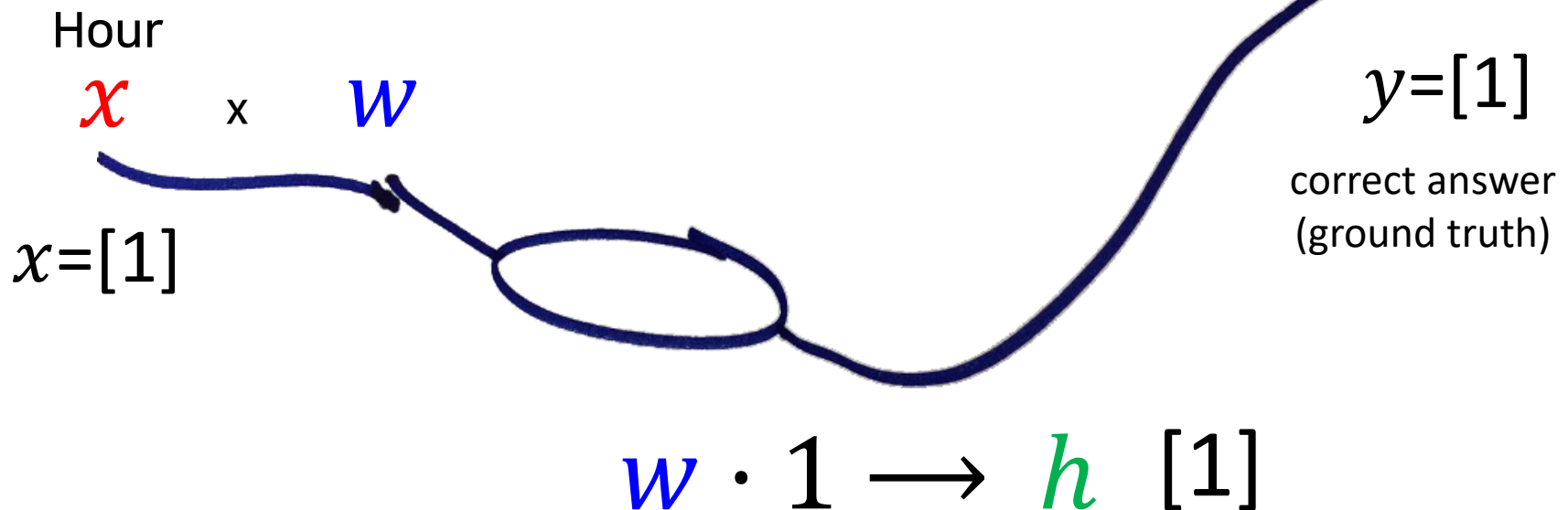


$$h = wx \quad w: \text{weighted}$$

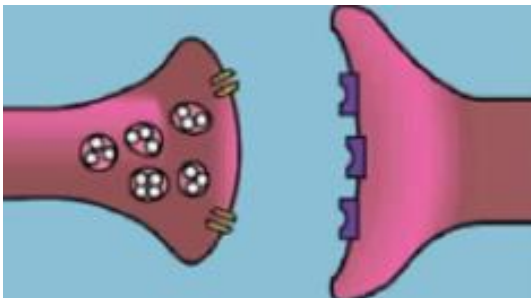
Application: Wage Calculator NN

임금 계산기

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

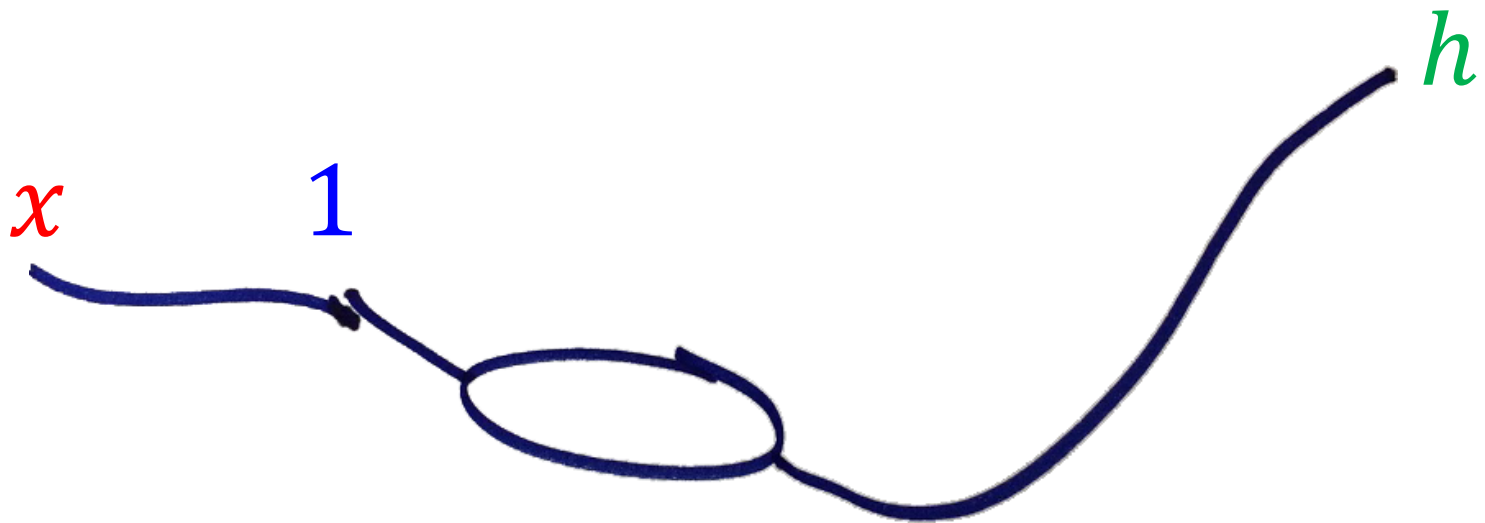
is to find the optimal value of parameter (w) to predict correctly.

the amount of
neurotransmitter

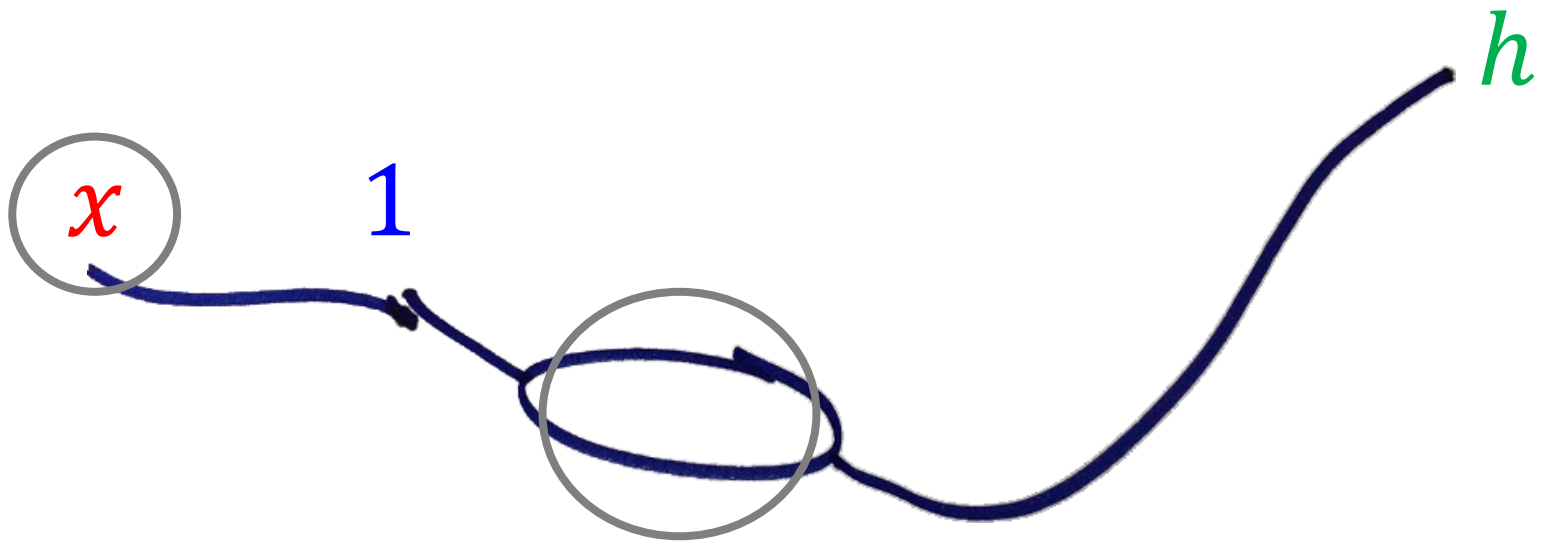
Drawing a neuron

Representing the below equation:

$$h = 1x$$



$$h = 1x$$

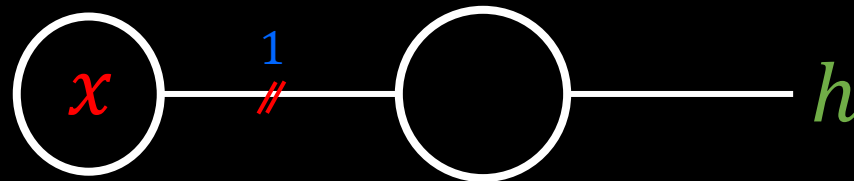


$$h = 1x$$

Matrix notation

$$(x)(1) \rightarrow (h)$$

Simplified version



$$(1)(1) \rightarrow (h)$$

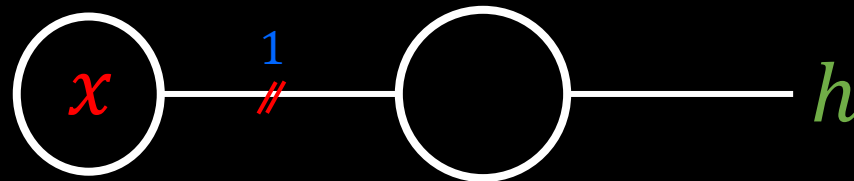
Where is the synapse/connection?



Matrix notation

$$(\textcolor{red}{x})(\textcolor{blue}{1}) \rightarrow (h)$$

Simplified version



$$\begin{pmatrix} 1 \\ \textcolor{red}{2} \end{pmatrix} (\textcolor{blue}{1}) \rightarrow \begin{pmatrix} h_1 \\ h_2 \end{pmatrix}$$

Where is the synapse/connection?

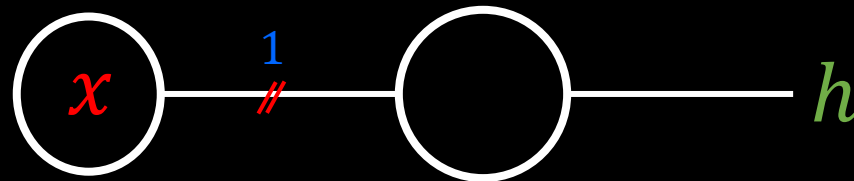


my.csv

Matrix notation

$$(x)(1) \rightarrow (h)$$

Simplified version



Where is the synapse/connection?

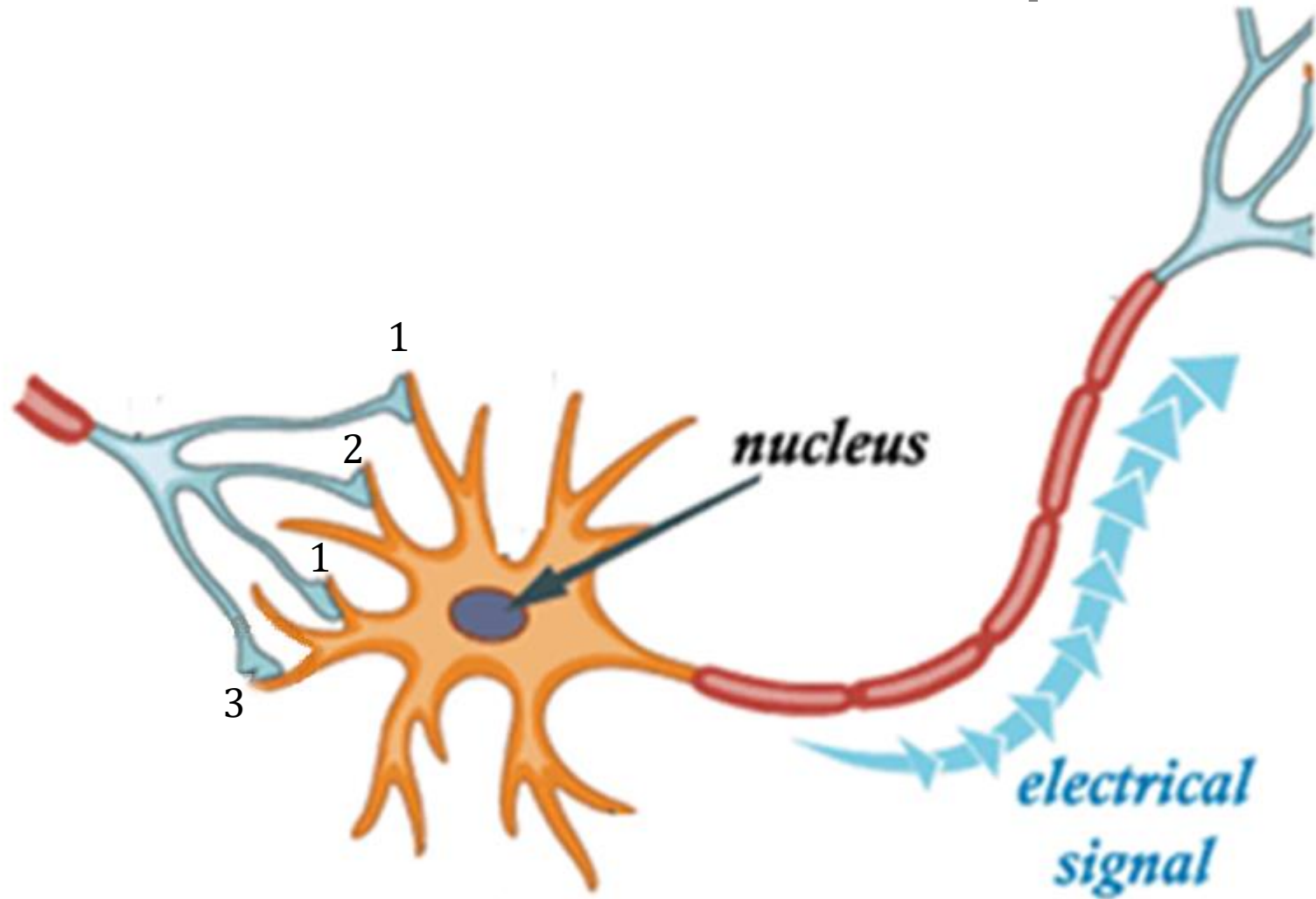


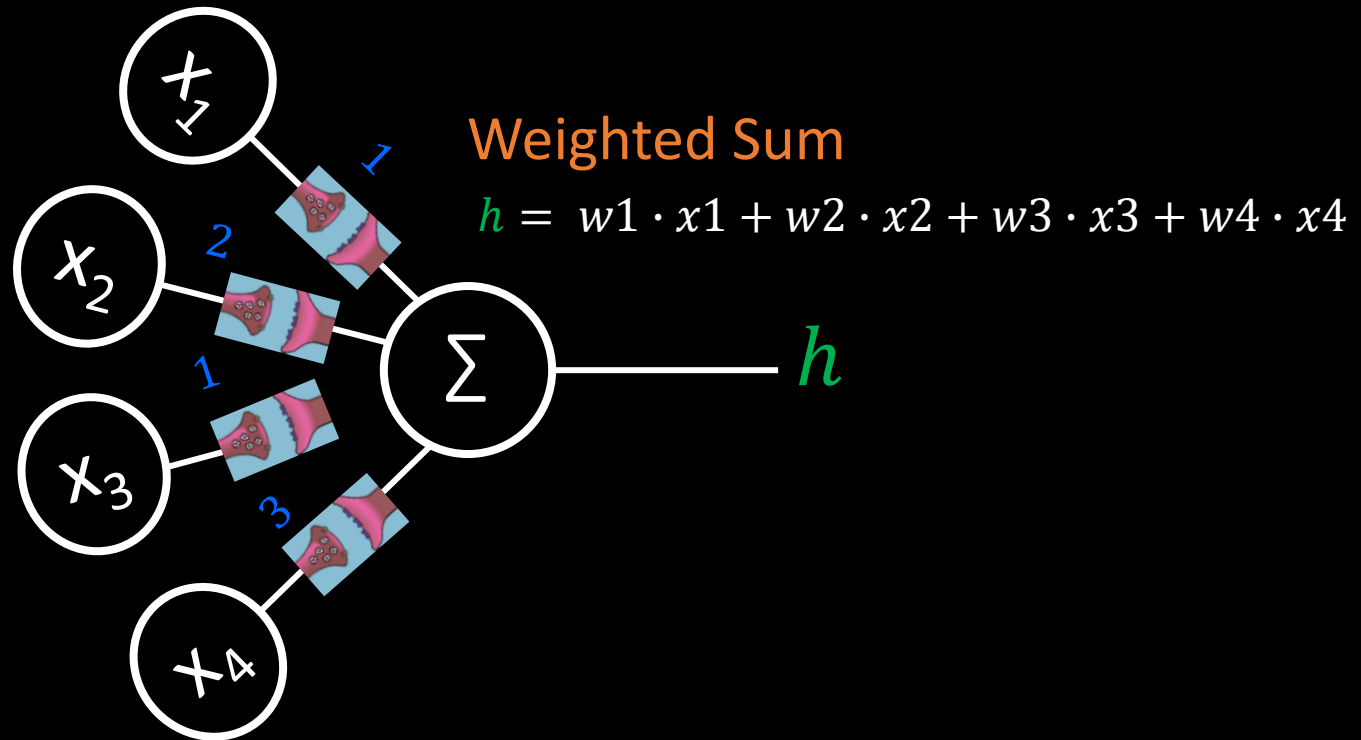
$$\begin{pmatrix} 1 \\ 2 \\ 3 \end{pmatrix} (1) \rightarrow \begin{pmatrix} h_1 \\ h_2 \\ h_3 \end{pmatrix}$$

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 ..

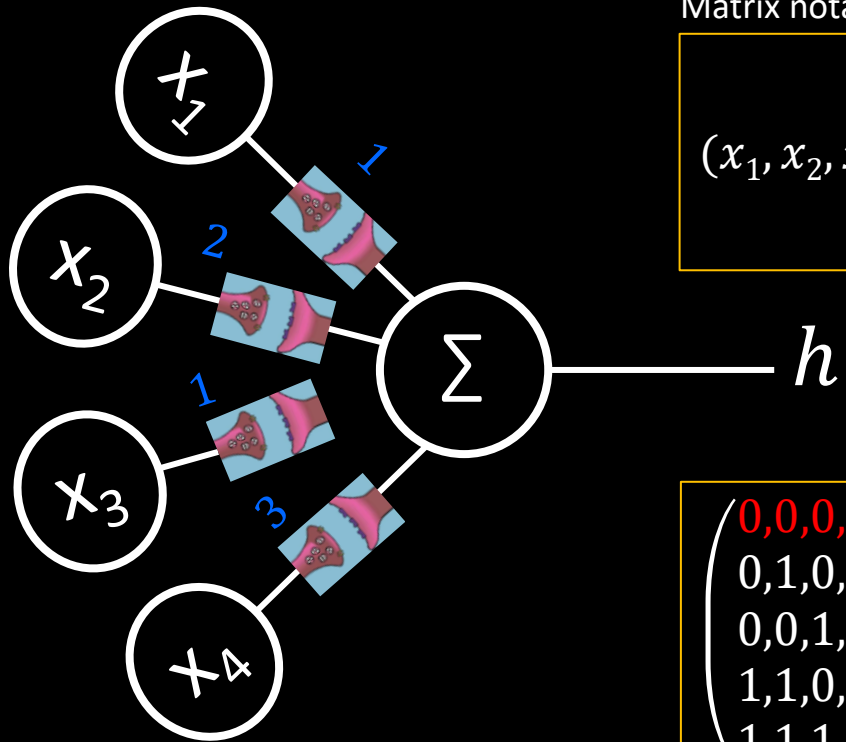
$$h = 1 \cdot x_1 + 2 \cdot x_2 + 1 \cdot x_3 + 3 \cdot x_4$$



Matrix notation

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

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



Matrix notation

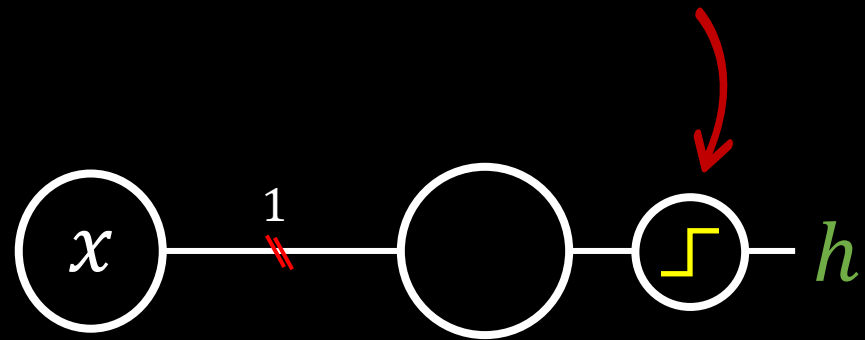
$$(x_1, x_2, x_3, x_4) \begin{pmatrix} 1 \\ 2 \\ 1 \\ 3 \end{pmatrix} \rightarrow (h)$$

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

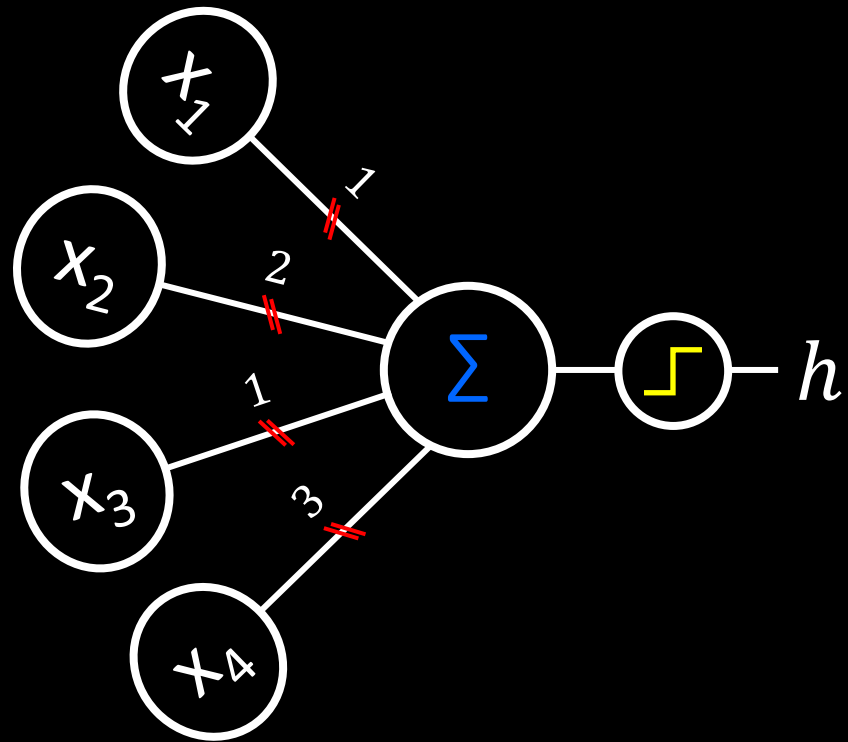
my.csv

Real operation of a neuron

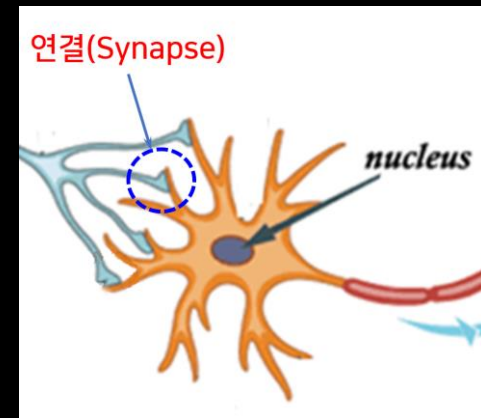
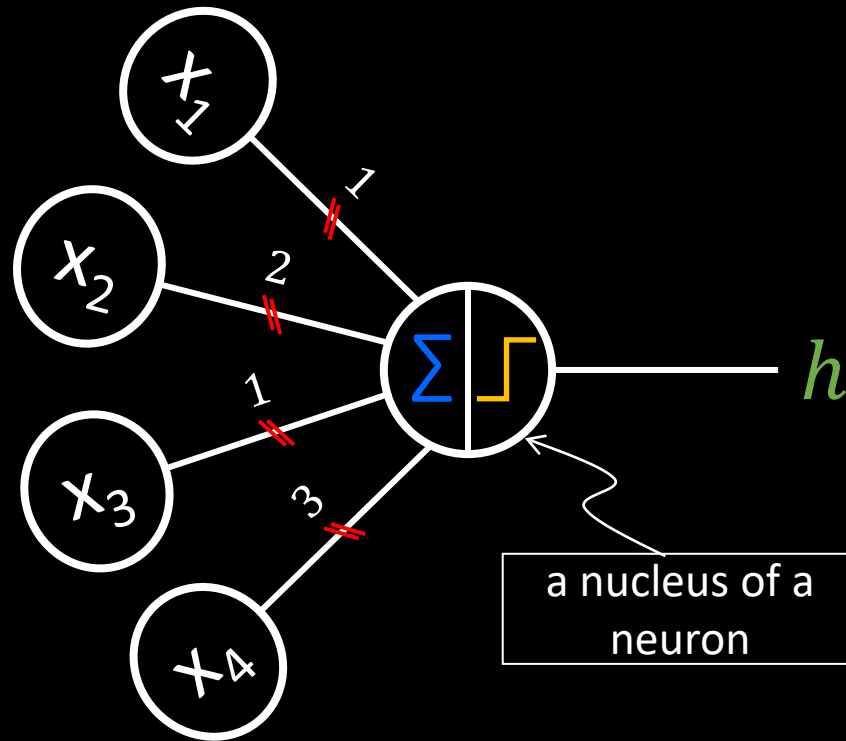
- More than weighted sum
- Thresholding
- signal ON if the weighted sum is greater than T
- otherwise signal OFF



Thresholding



Weighted sum and **Thresholding**



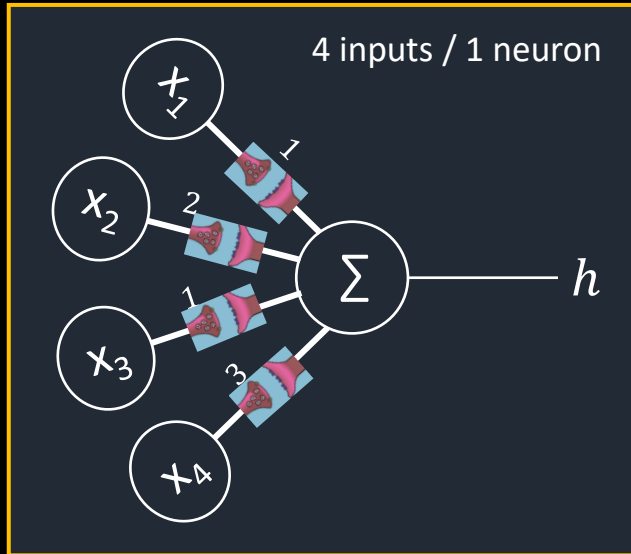
$$h = \begin{cases} 1 & \text{if } x_1 + 2x_2 + x_3 + 3x_4 > T \\ 0 & \text{otherwise} \end{cases}$$

Drawing
of a neuron

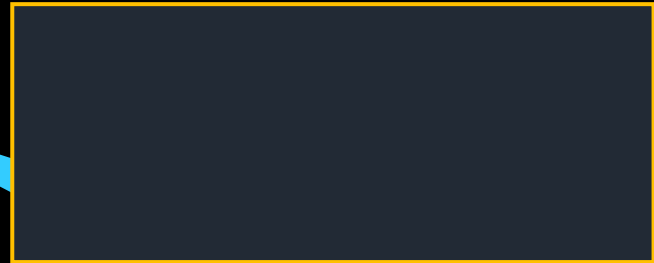
Matrix Notation

Equation

Drawing



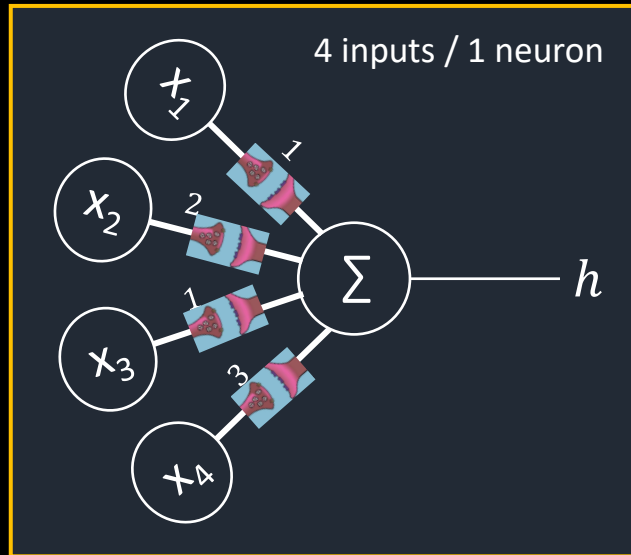
Matrix notation



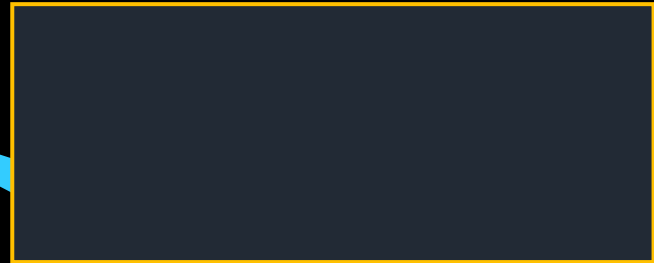
Equation



Drawing



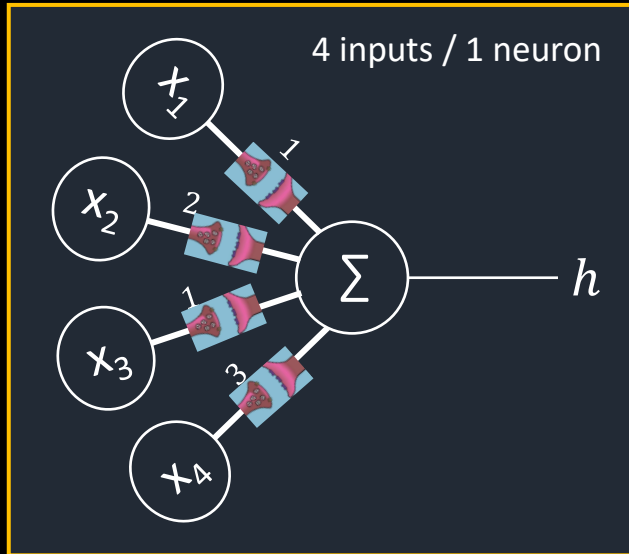
Matrix notation



Equation

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

Drawing



Matrix notation

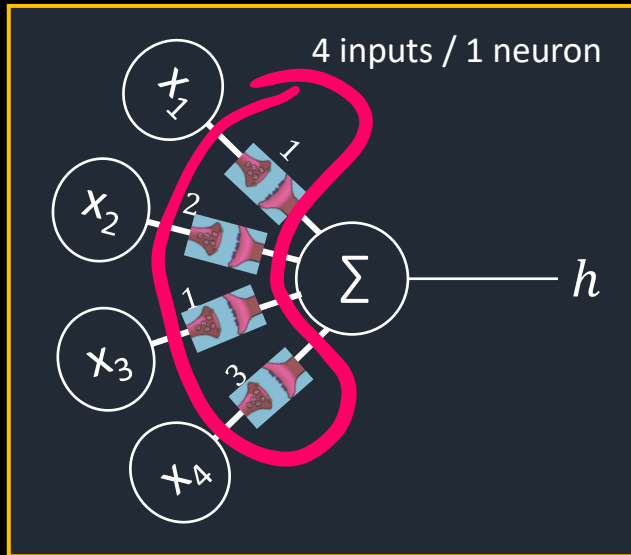
$$(x_1, x_2, x_3, x_4) \begin{pmatrix} 1 \\ 2 \\ 1 \\ 3 \end{pmatrix} \rightarrow (h)$$

Equation

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

What is learning again?

Drawing



Matrix notation

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

Equation

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

How do we update it?