Neural Network Theory

Artificial Intelligence and Brain

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Materials are here:

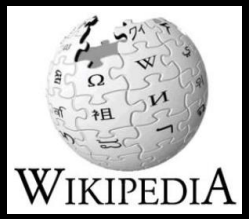
https://github.com/yungbyun/neuralnetworks

git clone *[link]*

Agenda

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

Intelligence



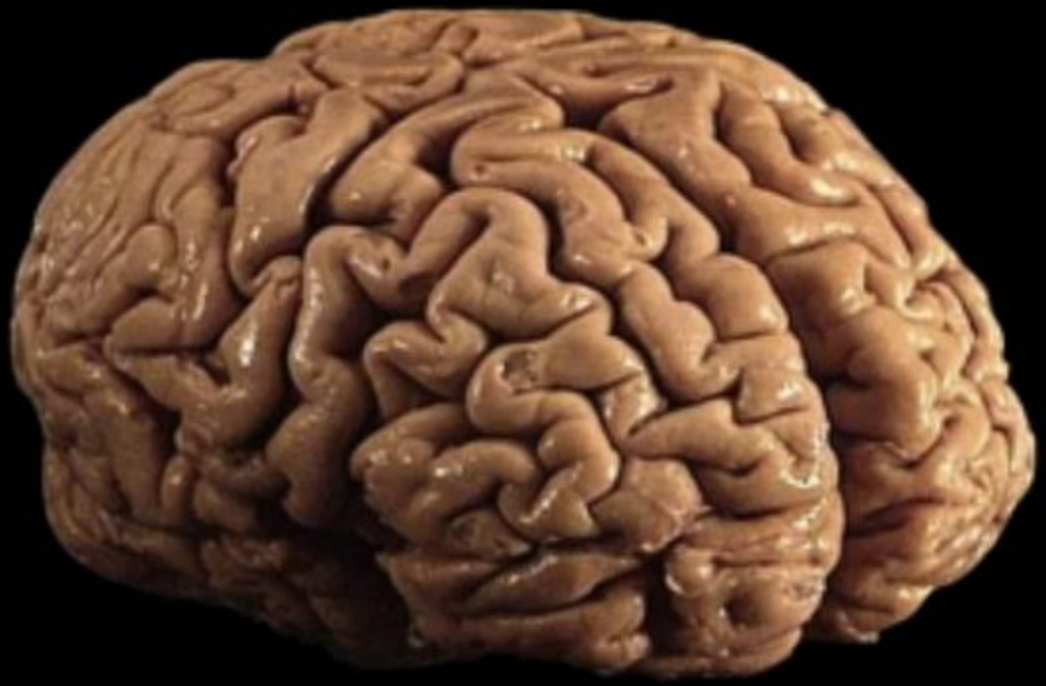
- One's capability for logic, understanding, self-awareness, learning, planning, creativity, and problem solving
- The ability to perceive information, and to retain it as knowledge to be applied towards adaptive behaviors within an environment
- Human Intelligence = Natural Intelligence

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?



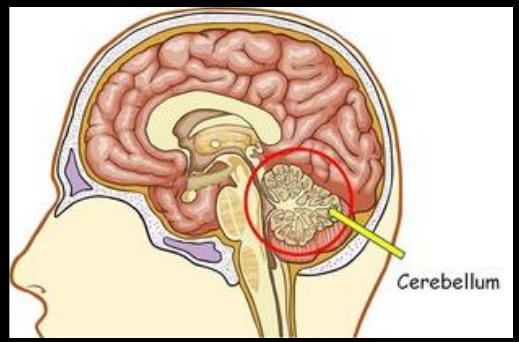
What happens inside the human brain?

Neuroanatomist

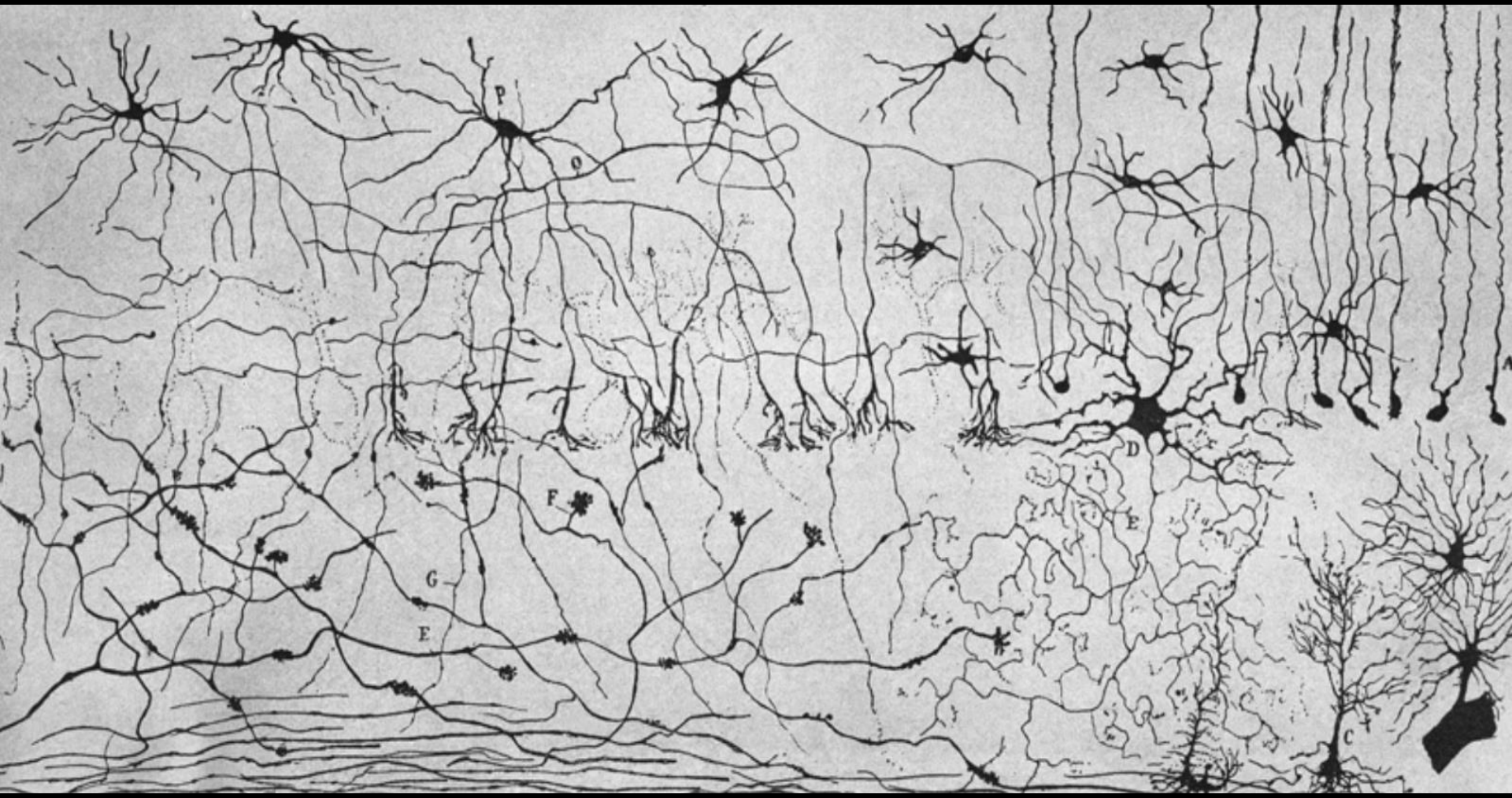
신경해부학자

Santiago Ramón y Cajal, 1852-1934

Cerebellum(소뇌) : controls muscles



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


1
2
3
6
5

1천억개 이상

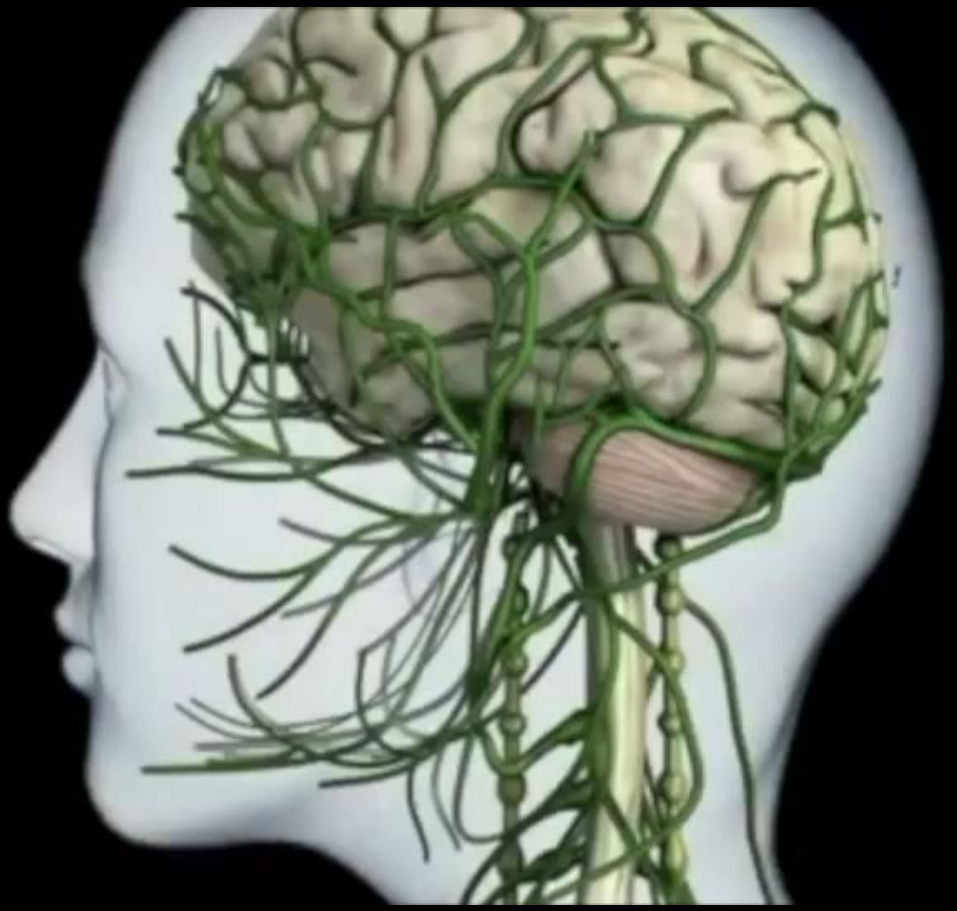
100 billion neurons

more than

the number of stars

in the universe

So, what happens inside?



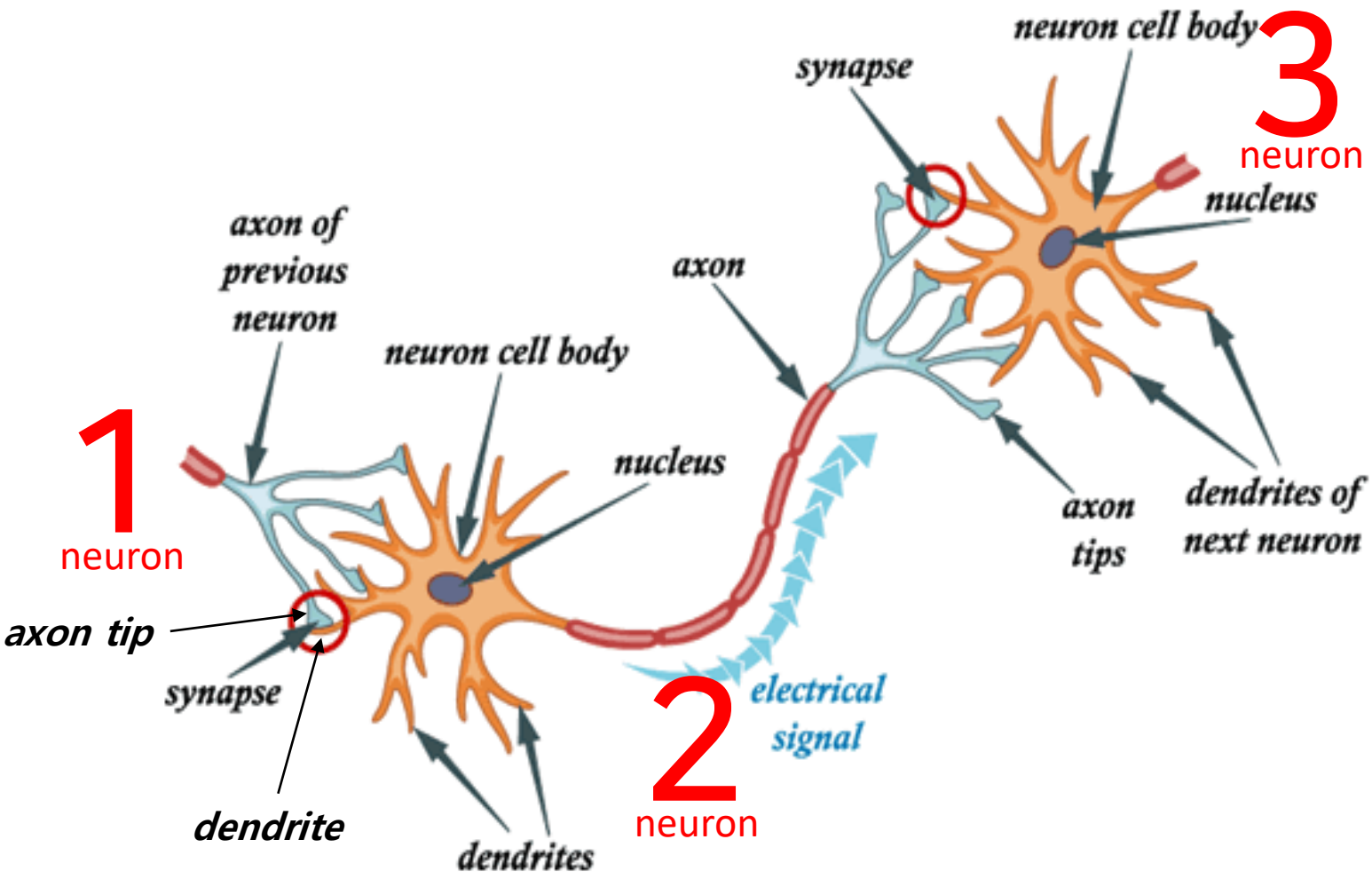
electric signal called
axon potential

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

Simulation(signaling)

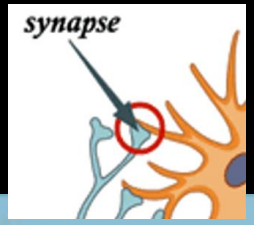
A brain in a supercomputer | Henry Markram

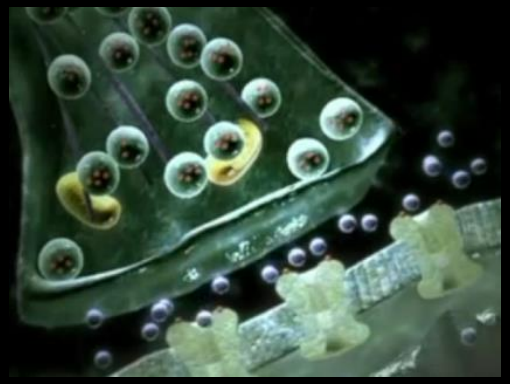
Connection between neurons

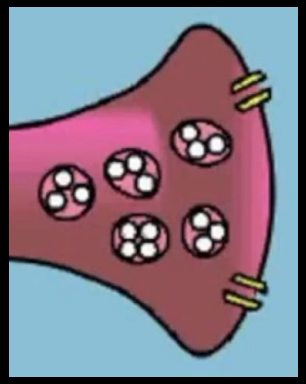



Synapse
시냅스

Synapse



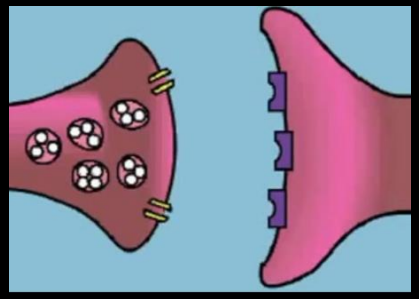




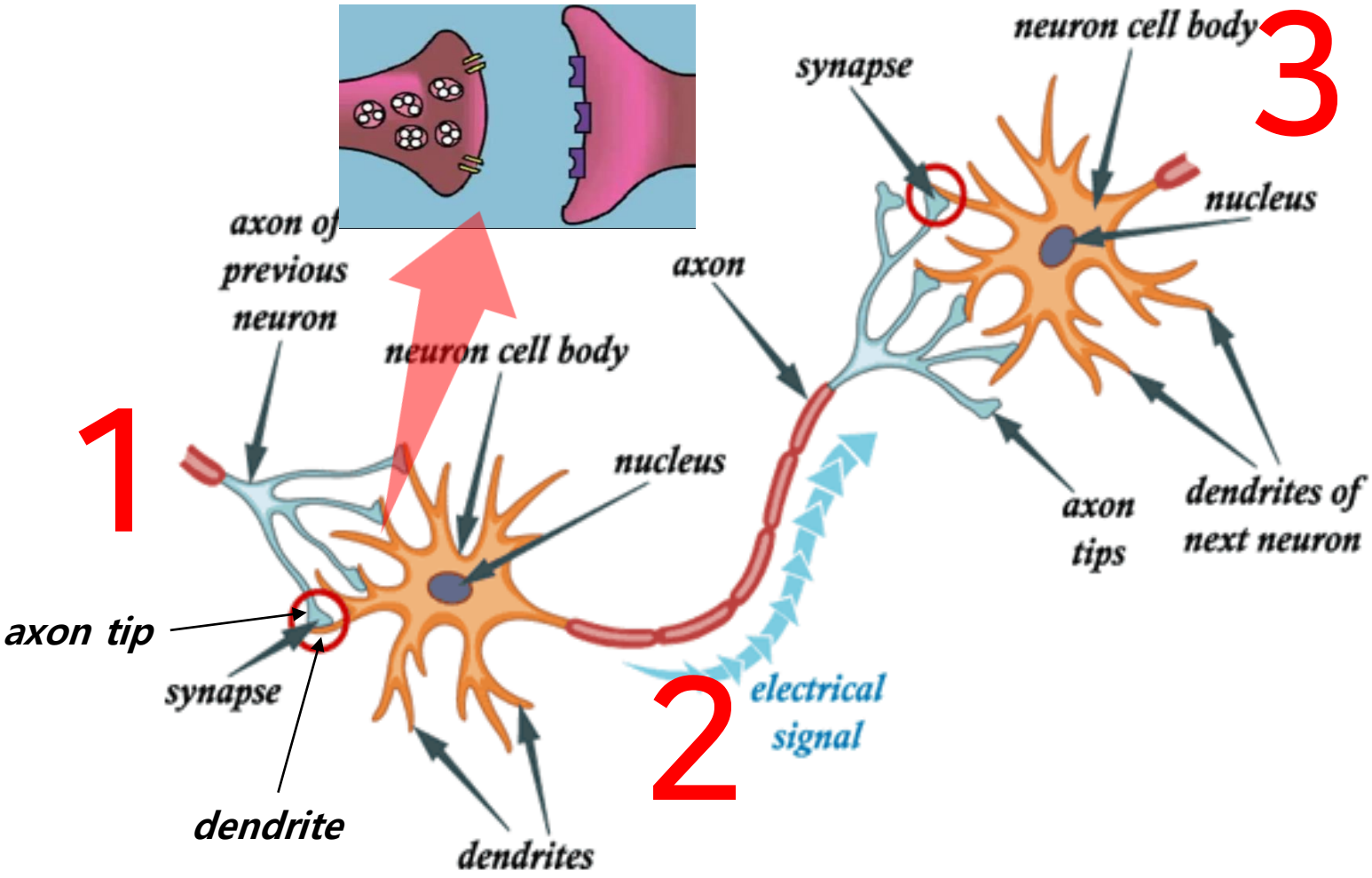
Neurotransmitter in synapse

신경전달물질

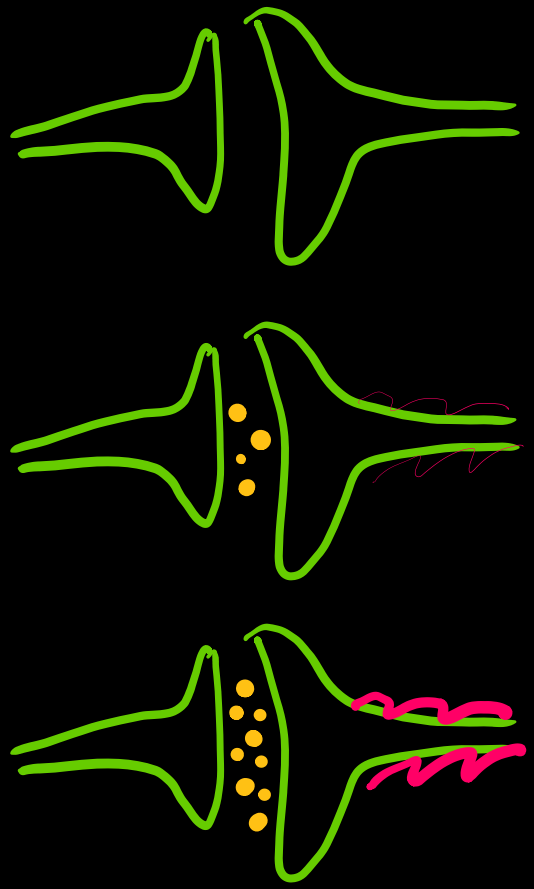
How many neurotransmitters in a synapse?



Connection between neurons



How it works?

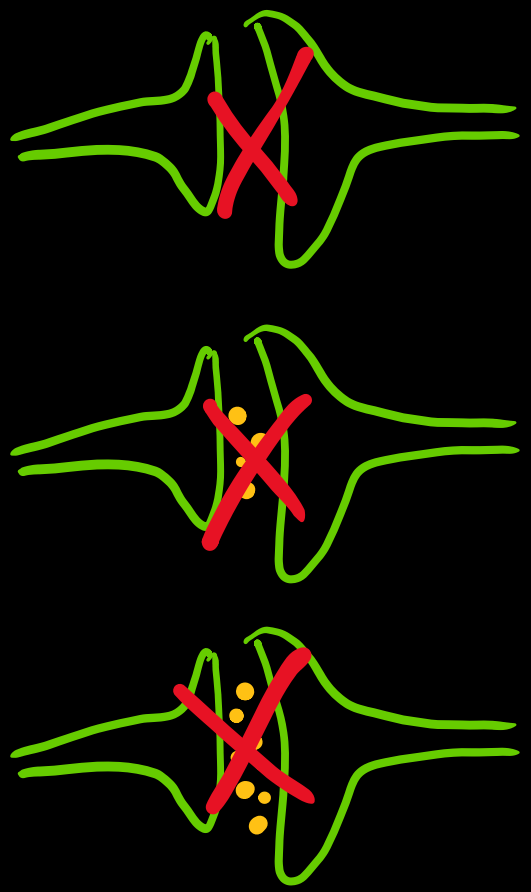


No neurotransmitter
No signal transmission
No connection

small
week

big
strong

What happens if



Alzheimer's

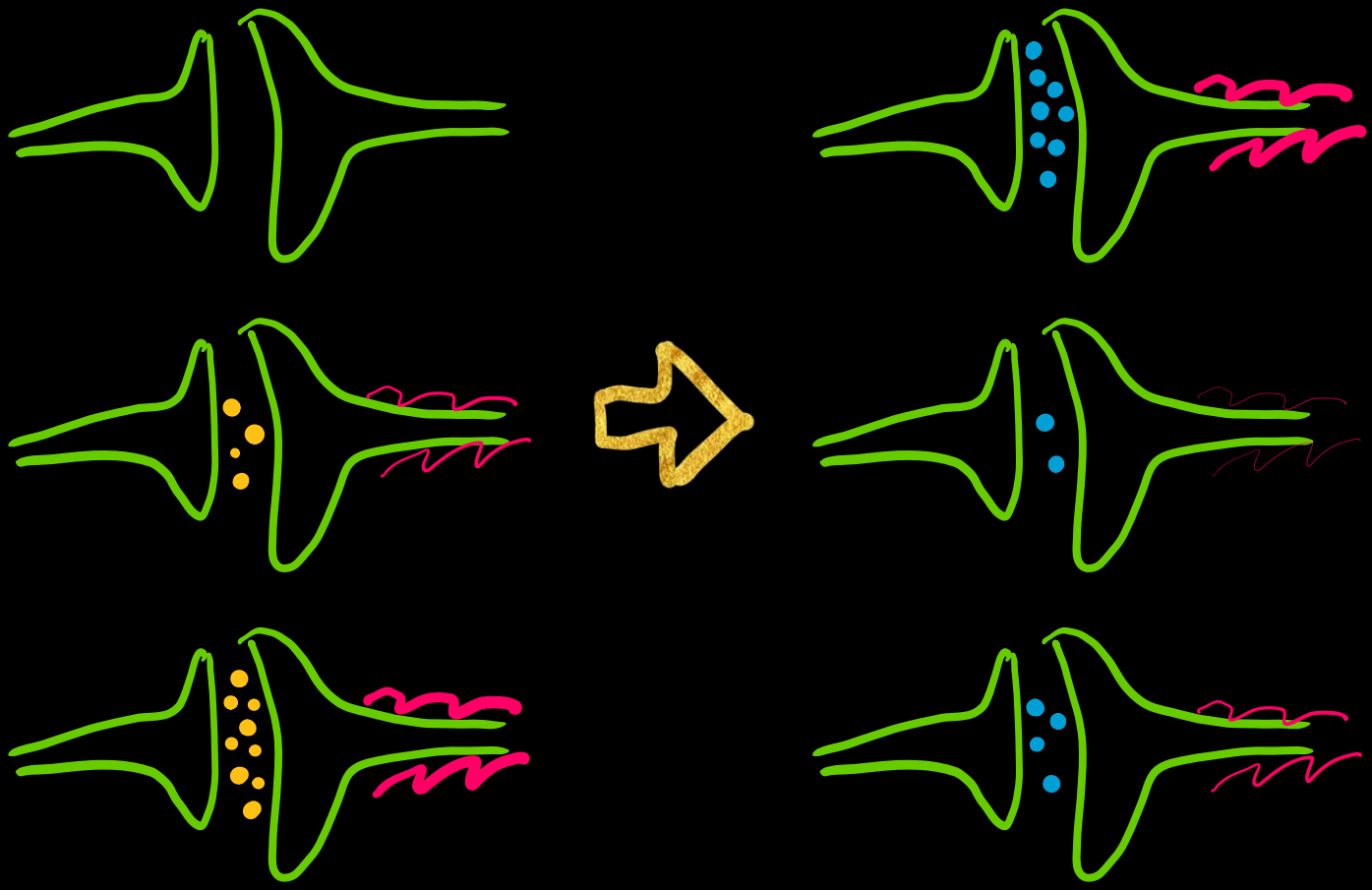
Loss of memory, Paralysis

Our memory
thinking
moving
emotion
and everything

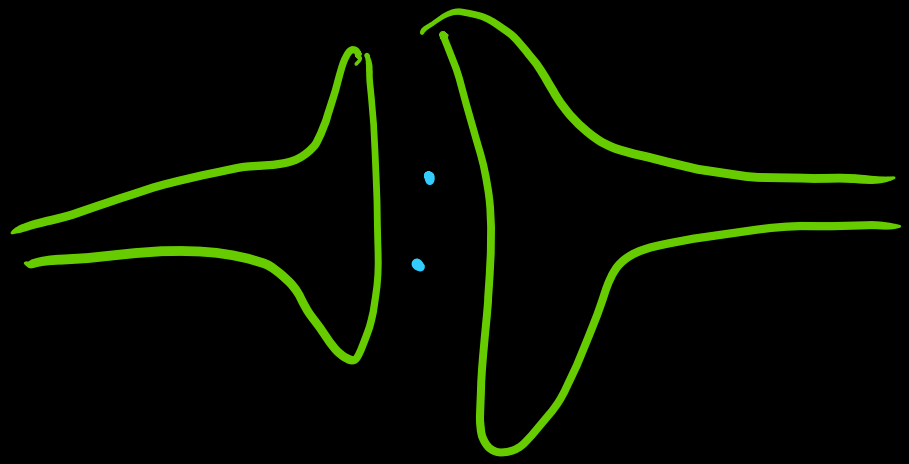
Initialized(?) synapses

Experience and the adjusting of the amount of neurotransmitter

Experience → Adjusting



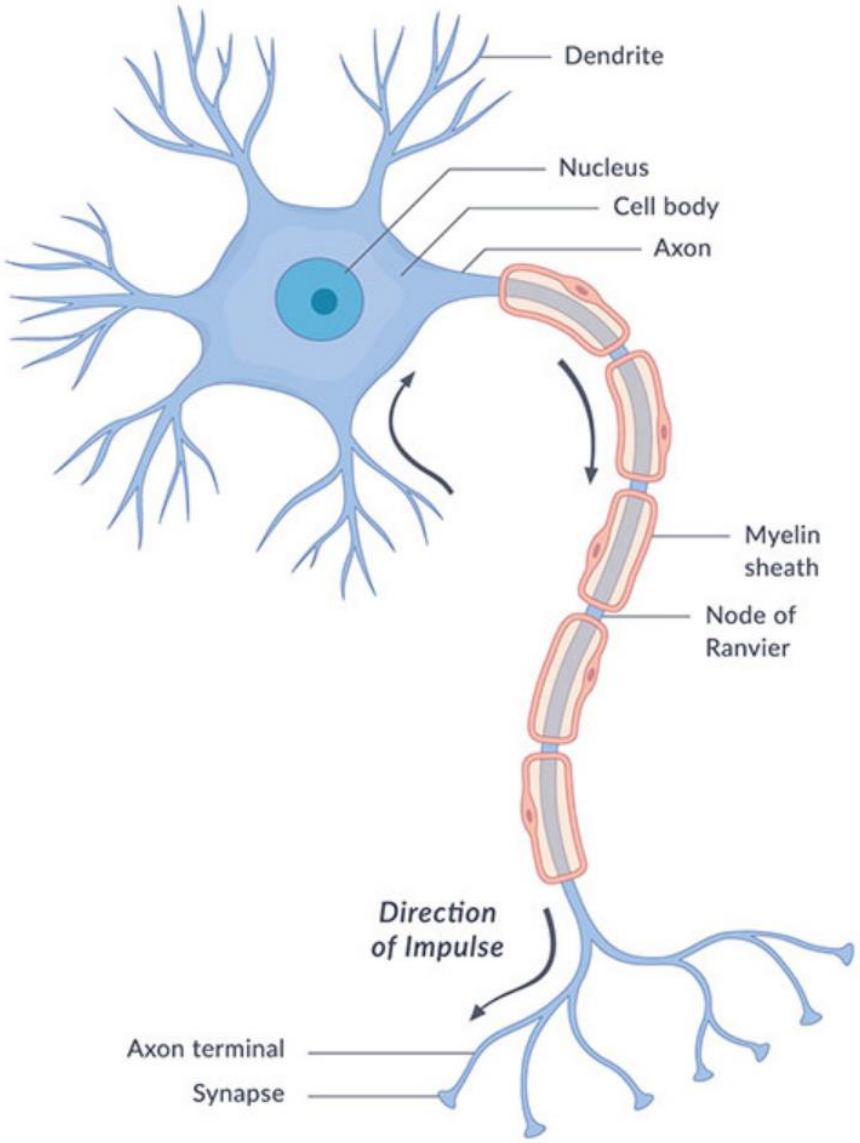
3 variables implementation with Python



So, what is Learning?

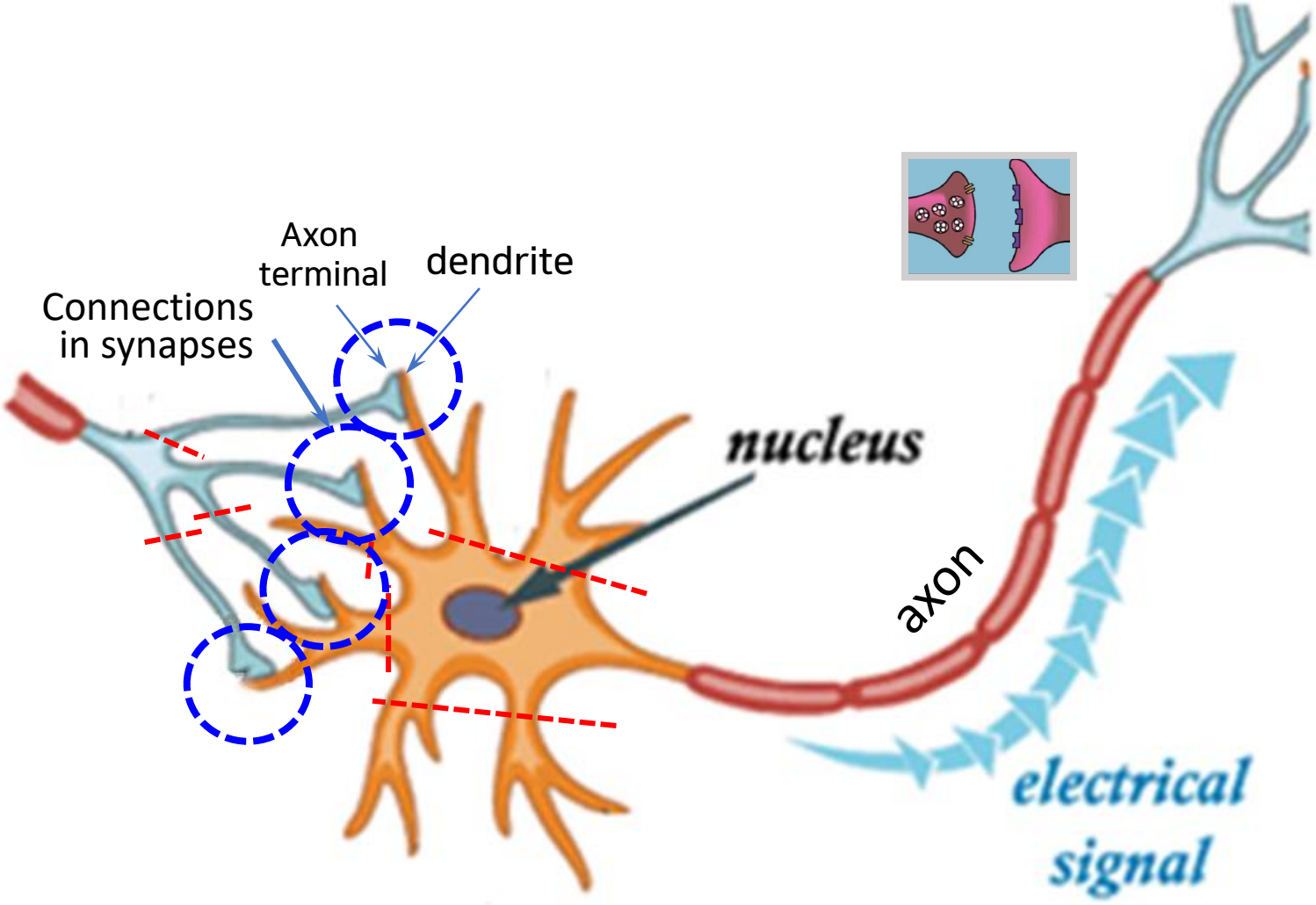
Stress/Error/Cost/Loss function

S/W implementation
→ AI

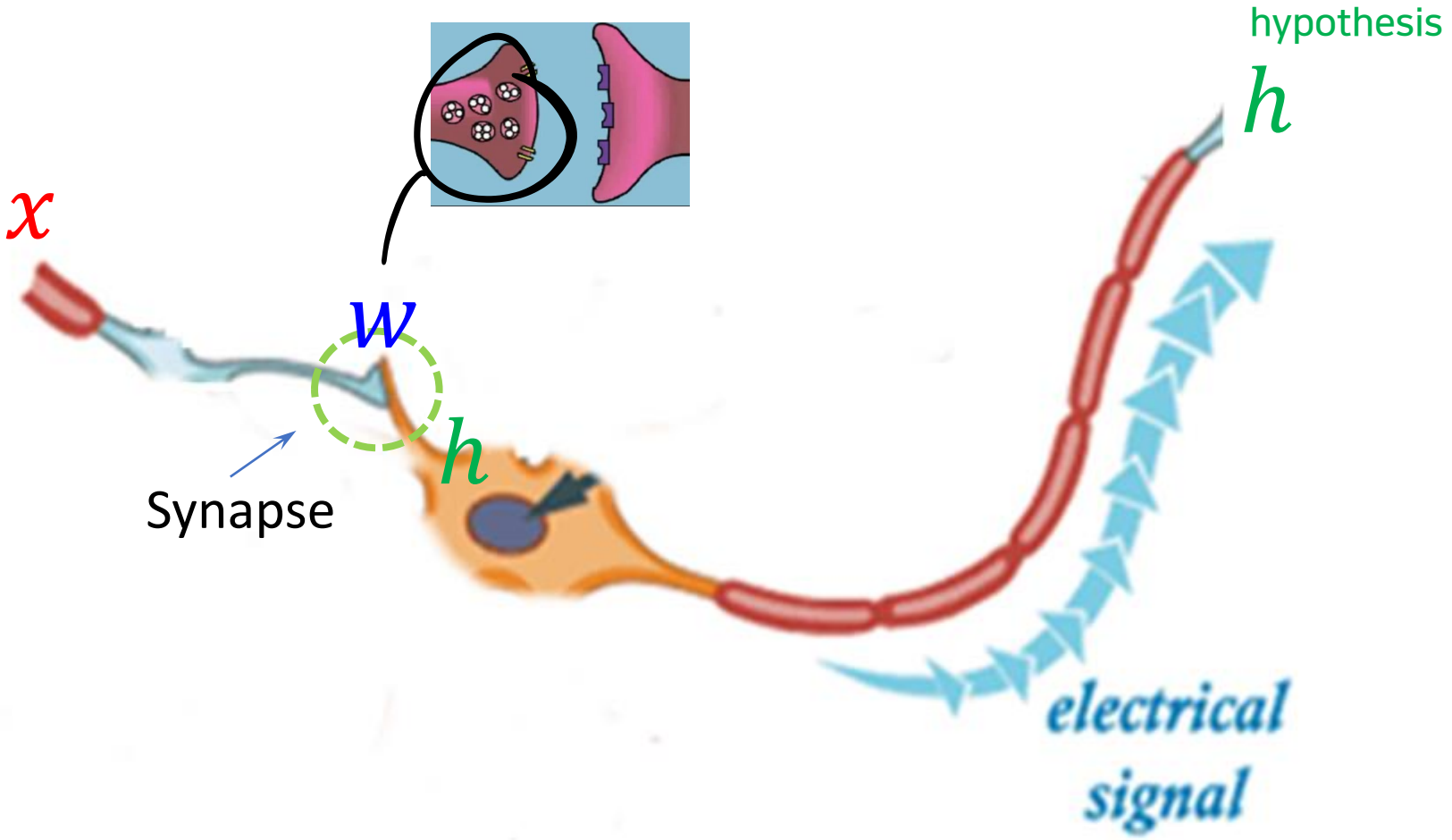


https://www.nichd.nih.gov/health/topics/neuro/conditioninfo/parts

A Neuron with Multiple Inputs



A Neuron with 1 Input



h, Hypothesis

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

가설(hypothesis):
어떤 현상을 설명하는 것.
뉴런의 동작을 설명하는 것

Explanation about the way a neuron works in.

Output of a neuron, prediction

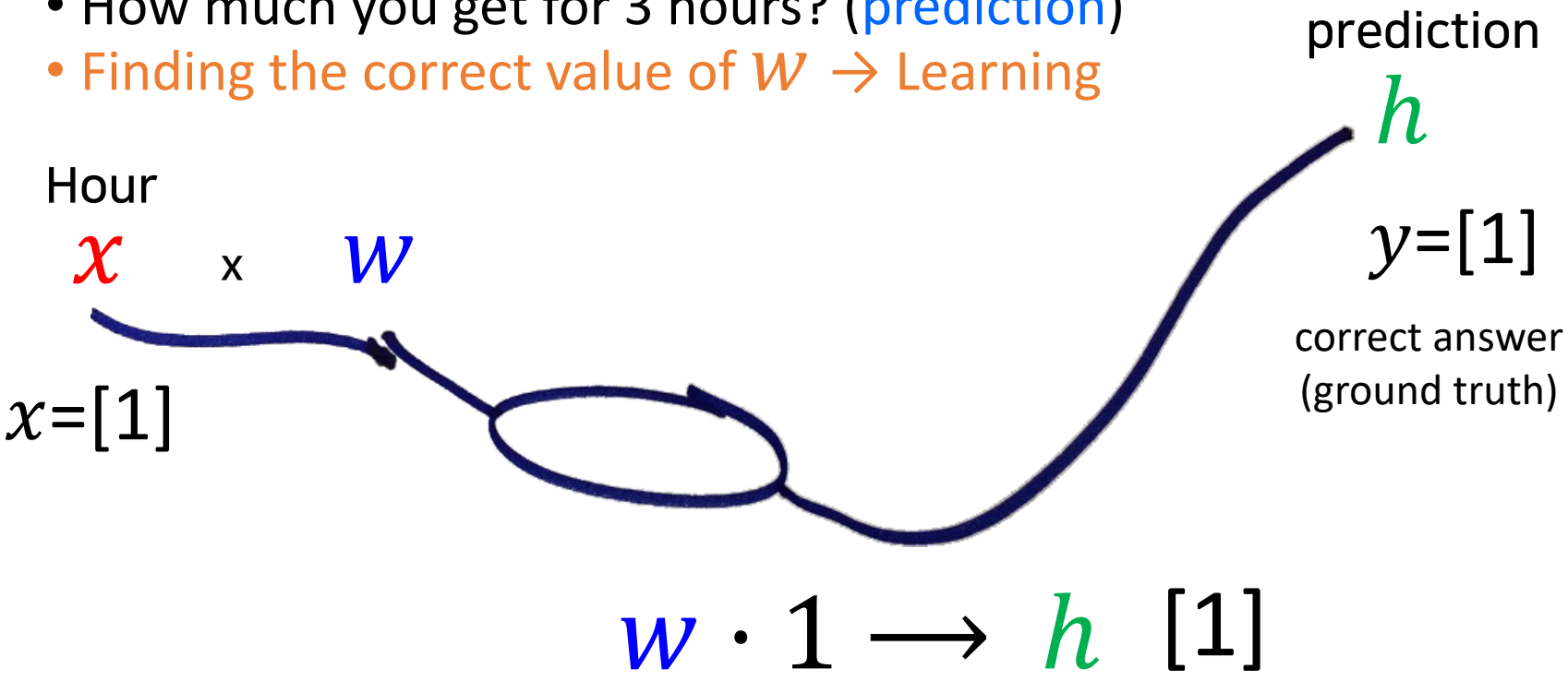
Action of a neuron

$h = wx$ w: $w$eighted

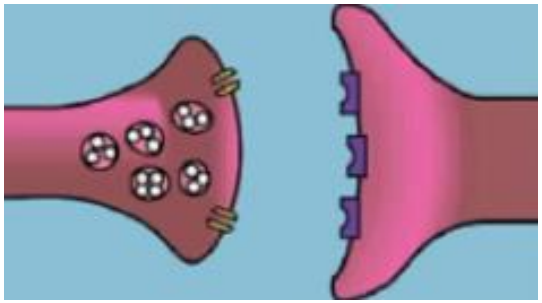
Application: Wage Calculator NN

월급 계산기

- Knowledge: 1 hour working(**input** x) → 1USD(correct answer, **groundtruth** y) payment
- How much you get for 3 hours? (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

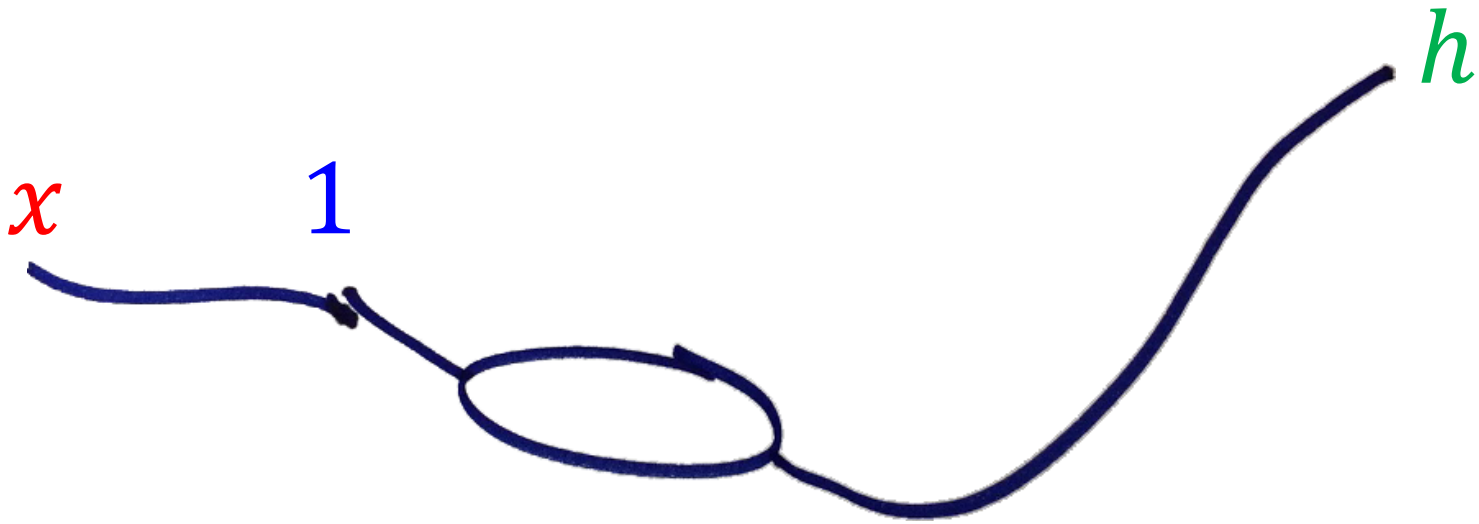
is to find the optimal value of parameter (w) to predict correctly.

the amount of neurotransmitter

Drawing a neuron

Representing the below equation:

$$h = 1x$$

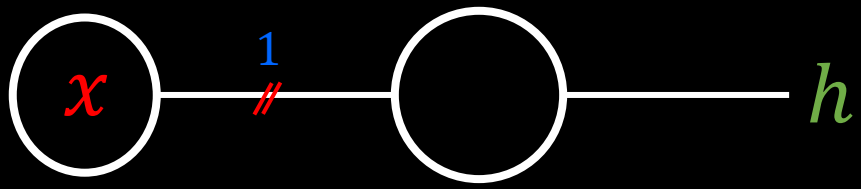


$$h = 1x$$

Matrix notation

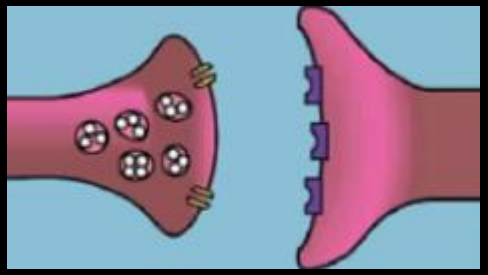
$(x)(1) \longrightarrow (h)$

Simplified version



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

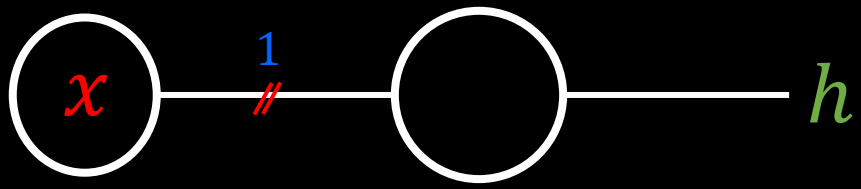
Where is the synapse/connection?



Matrix notation

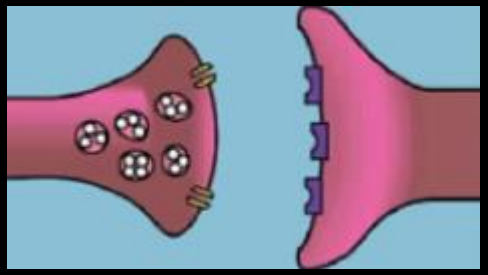
$$(x)(1) \longrightarrow (h)$$

Simplified version



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

Where is the synapse/connection?



Matrix notation

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

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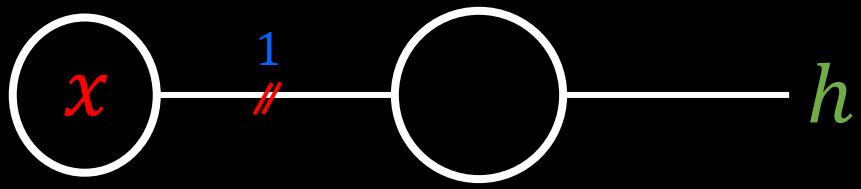
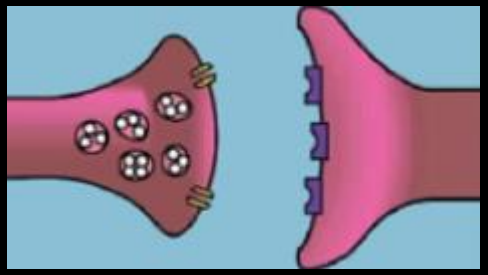


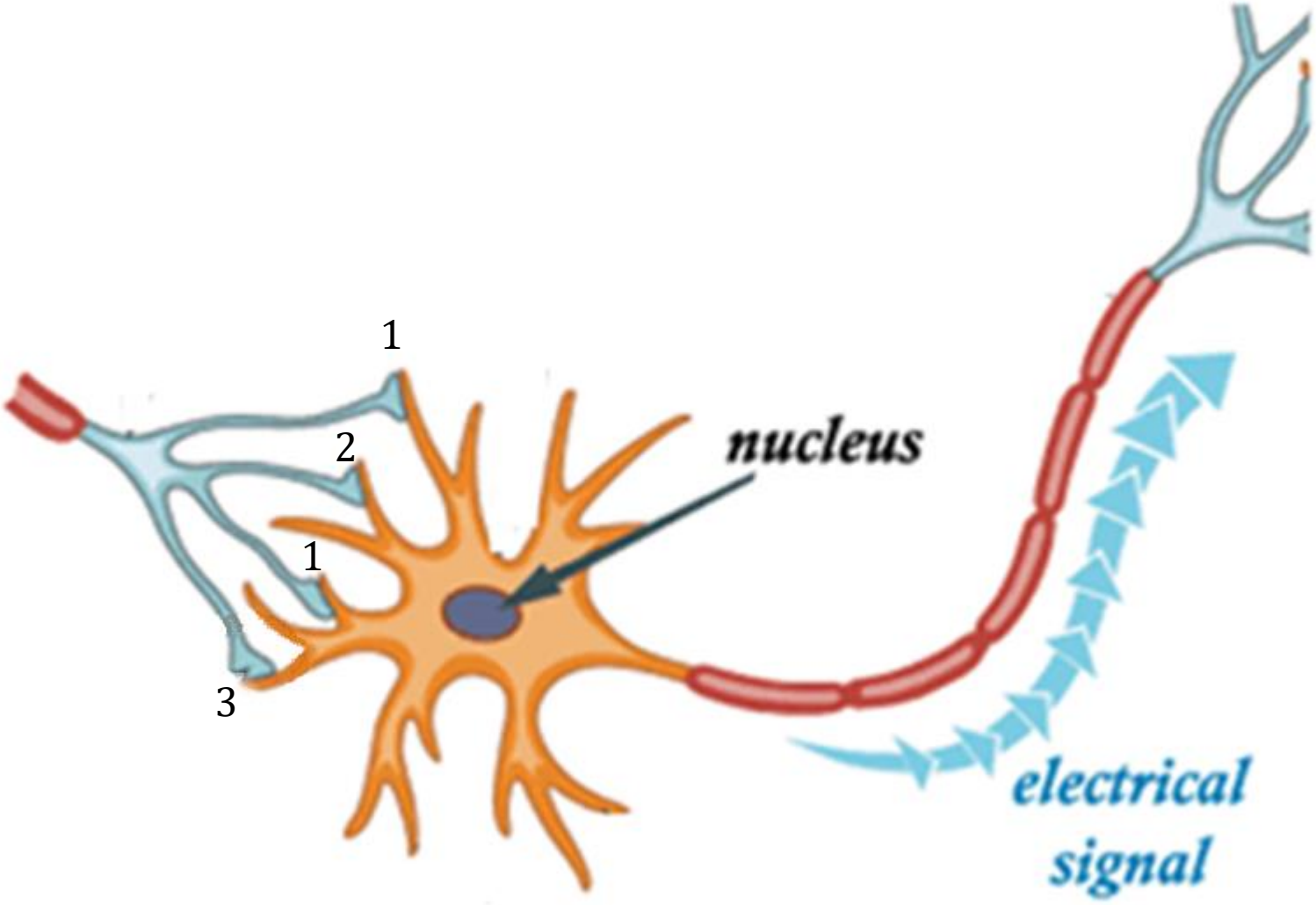
$$\begin{pmatrix} 1 \\ 2 \\ 3 \end{pmatrix}(1) \longrightarrow \begin{pmatrix} h_1 \\ h_2 \\ h_3 \end{pmatrix}$$

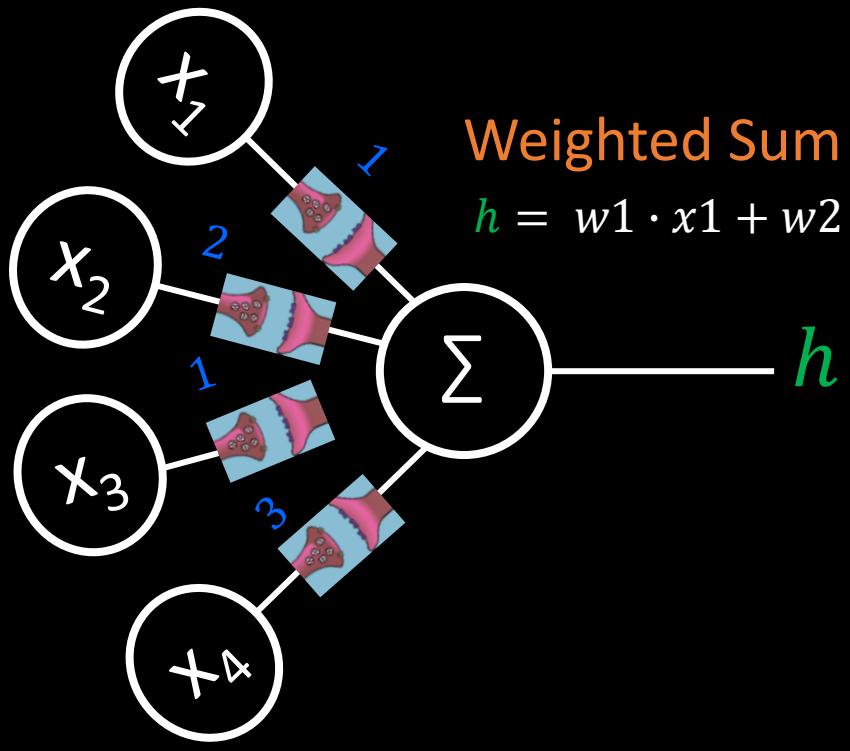
Where is the synapse/connection?



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

A Neuron with Multiple Inputs





Weighted Sum

$$h = w1 \cdot x1 + w2 \cdot x2 + w3 \cdot x3 + w4 \cdot x4$$

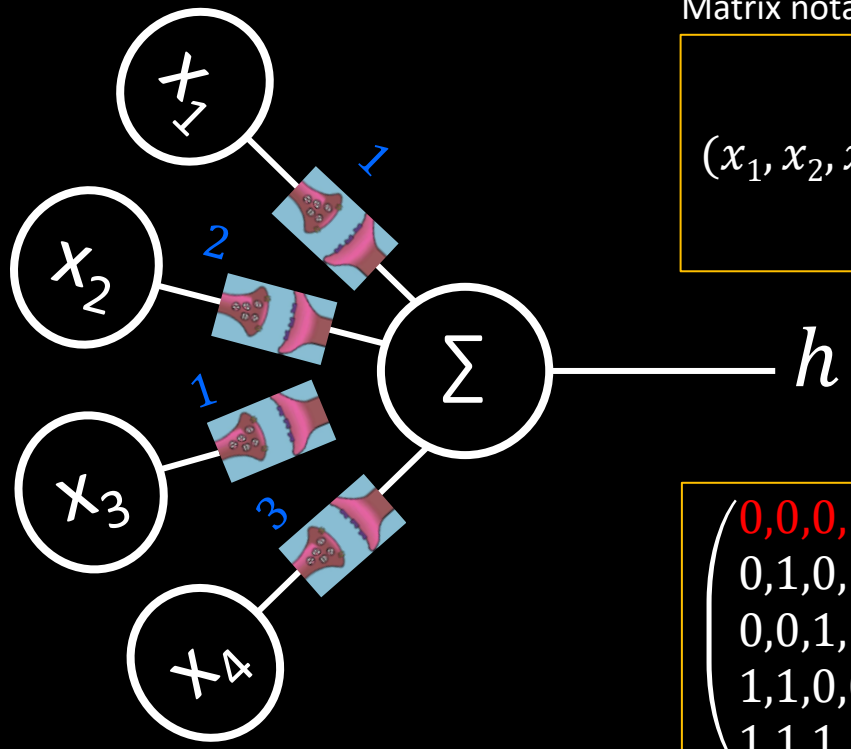
if the input values are $(0,0,0,1)$, then h is ..

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

Matrix notation

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

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



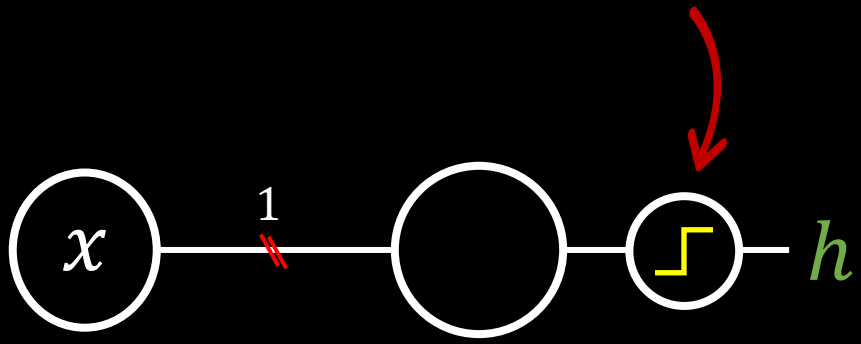
Matrix notation

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

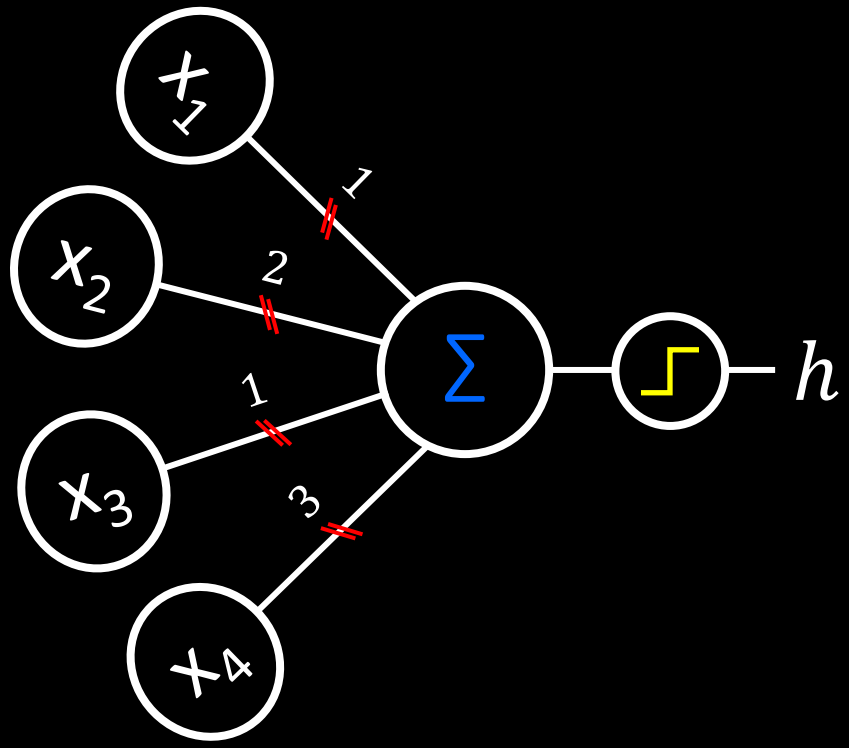
$$\begin{pmatrix}0,0,0,1\\0,1,0,1\\0,0,1,1\\1,1,0,0\\1,1,1,1\end{pmatrix}\begin{pmatrix}1\\2\\1\\3\end{pmatrix} \rightarrow \begin{pmatrix}h_1\\h_2\\h_3\\h_4\\h_5\end{pmatrix}$$

Real operation of a neuron

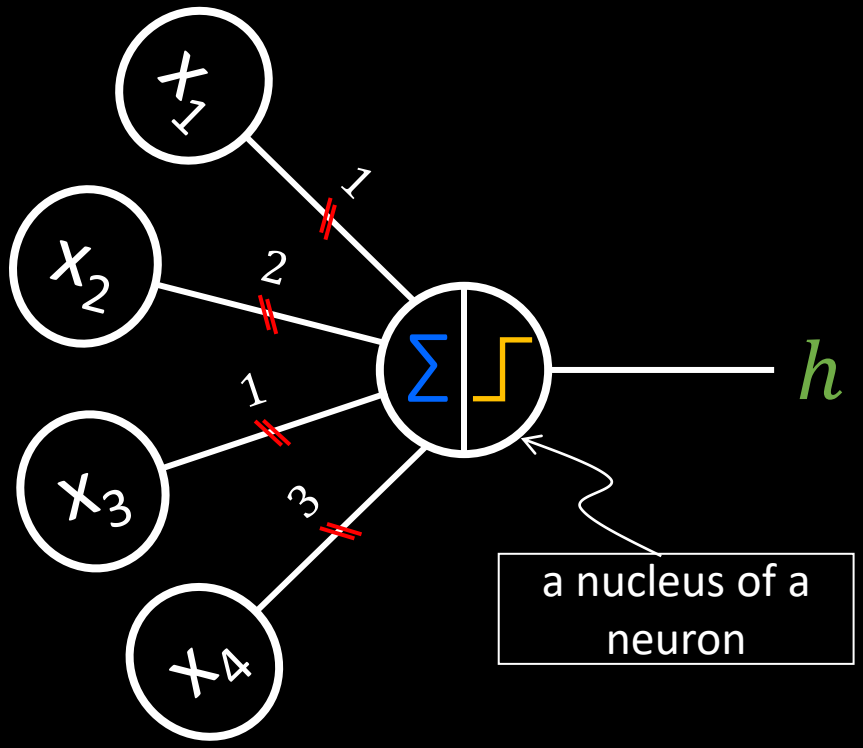
- More than weighted sum
- Thresholding
- signal ON if the weighted sum is greater than T
- otherwise signal OFF

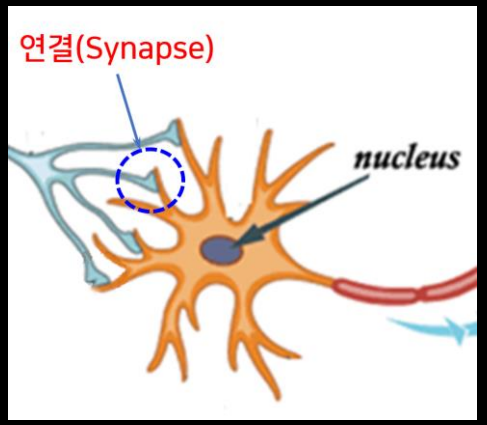


Thresholding

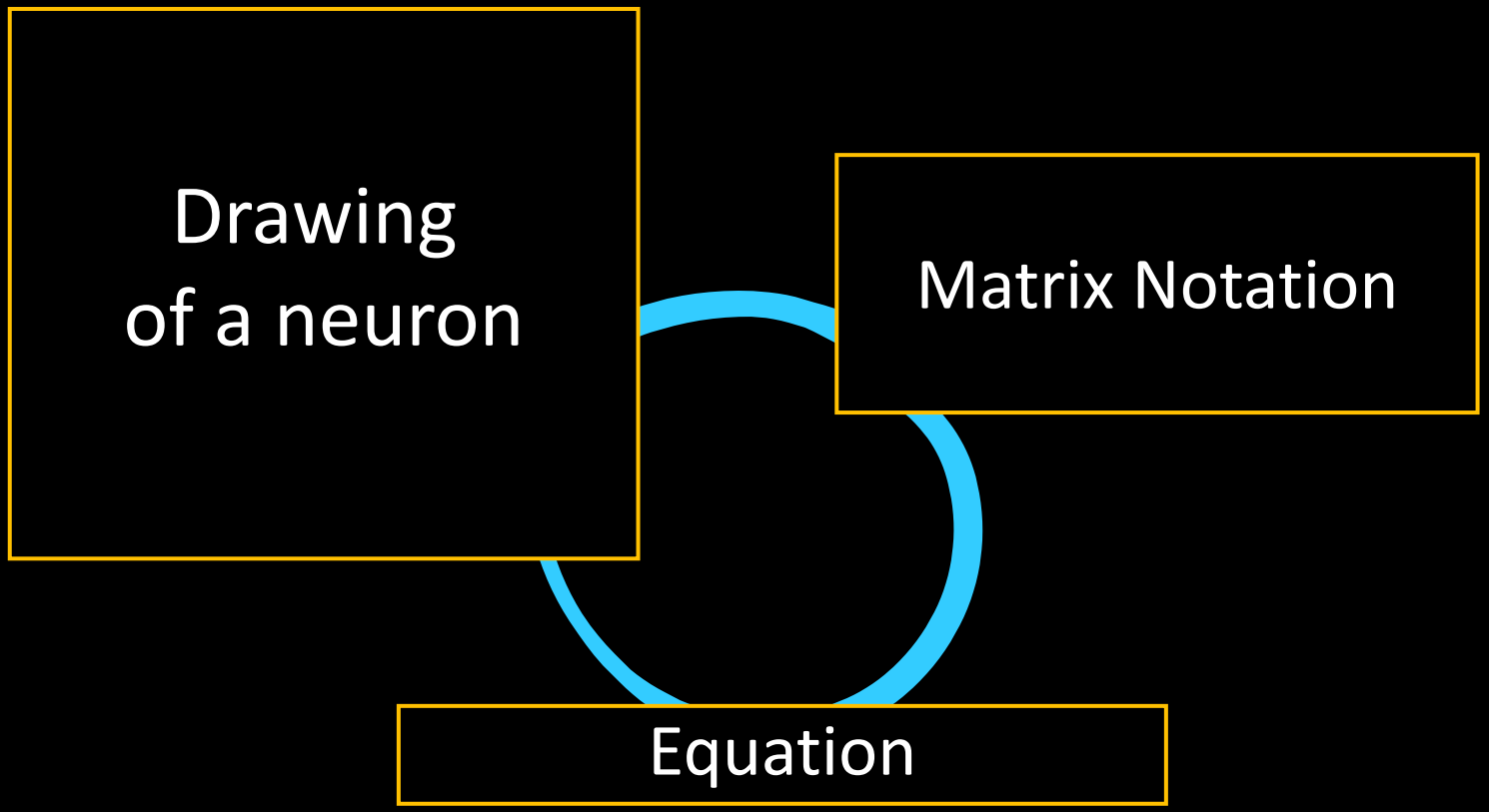


Weighted sum and Thresholding

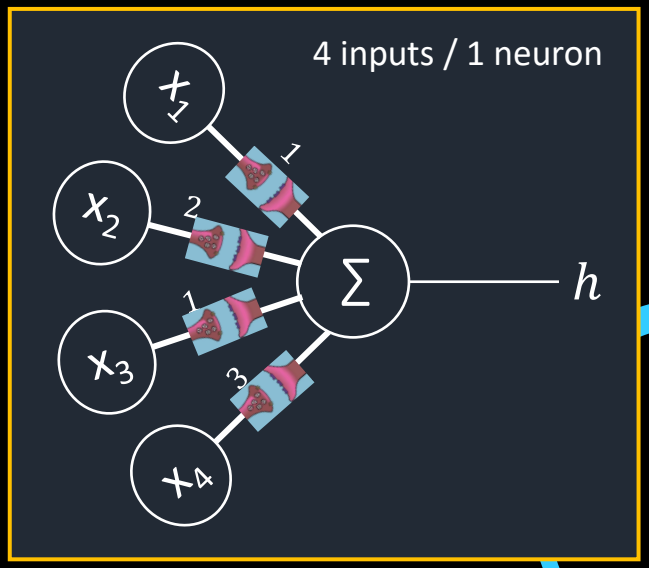




$$h = \begin{cases} 1 & if\ x_1 + 2x_2 + x_3 + 3x_4 > T \\ 0 & otherwise \end{cases}$$


Drawing
of a neuron
Matrix Notation
Equation

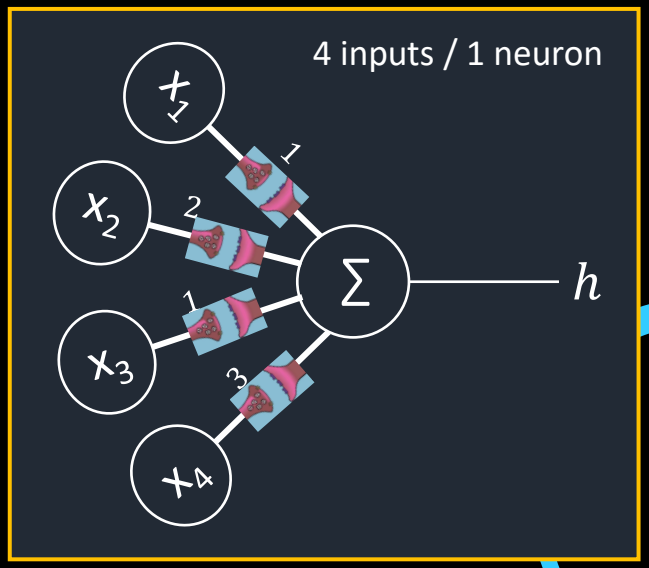
Drawing



Matrix notation

Equation

Drawing

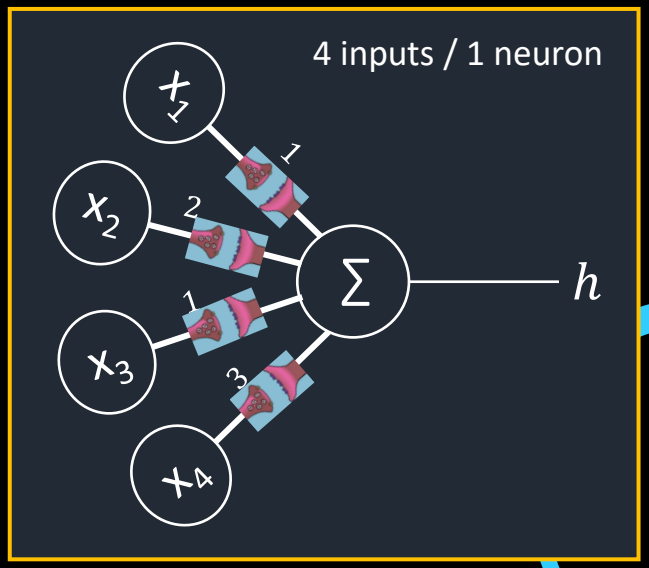


Matrix notation

Equation

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

Drawing



Matrix notation

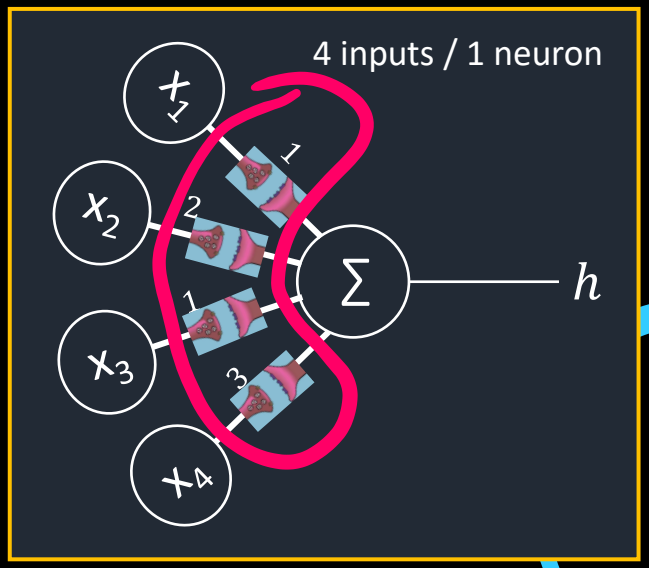
$$(x_1, x_2, x_3, x_4)\begin{pmatrix}1\\2\\1\\3\end{pmatrix} \rightarrow (h)$$

Equation

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

What is learning again?

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?