NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

CC0007 Science and Technology for Humanity

# Artificial Intelligence I (Technology Aspect)

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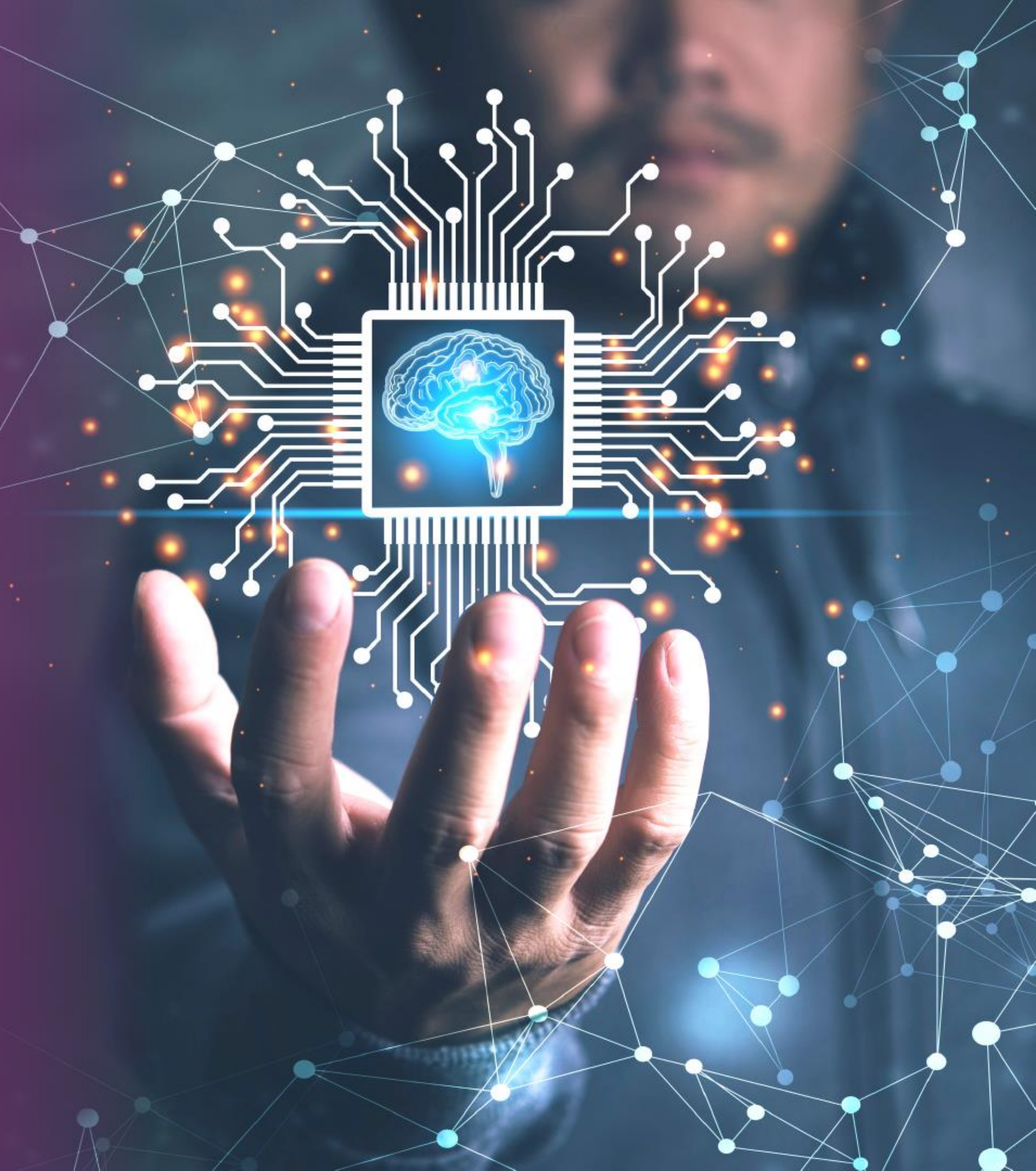
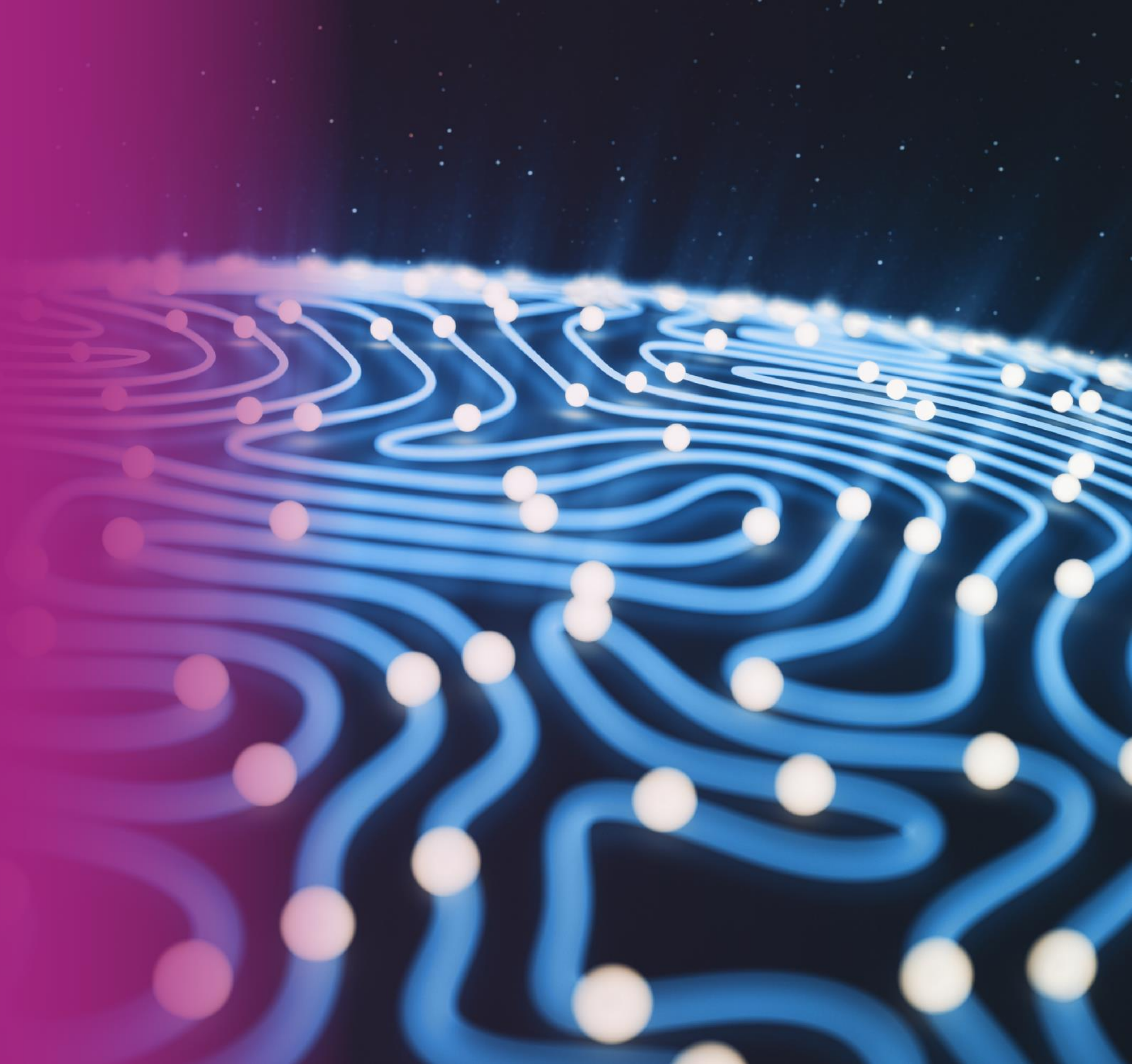
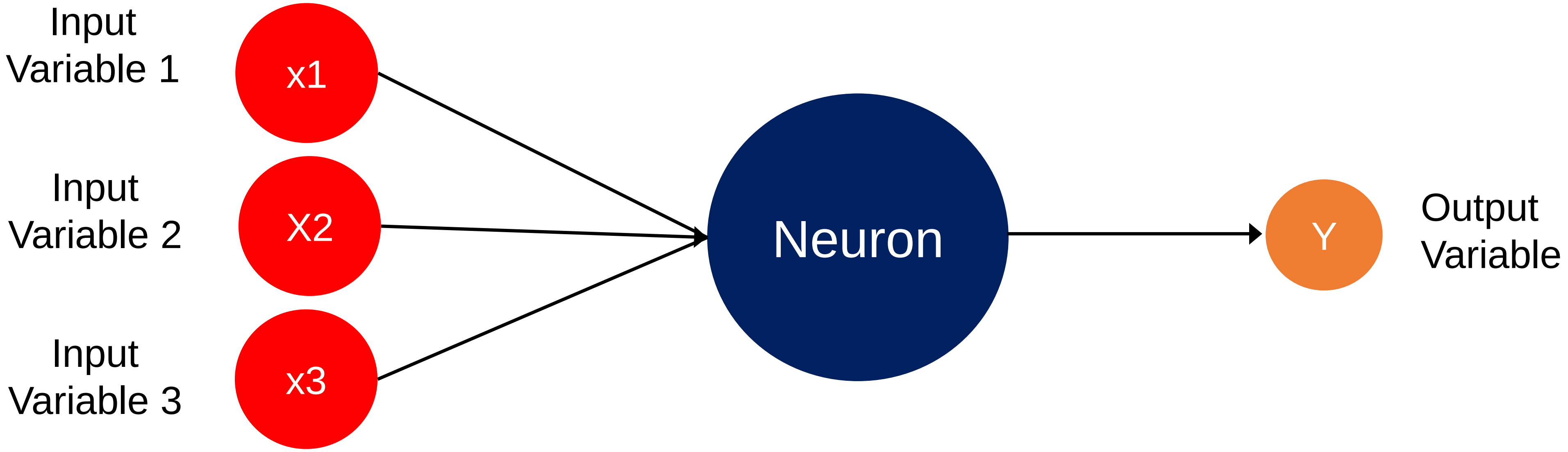


# Part 2:
# The Neural Network



# Neural Network: Neurons and Synapses

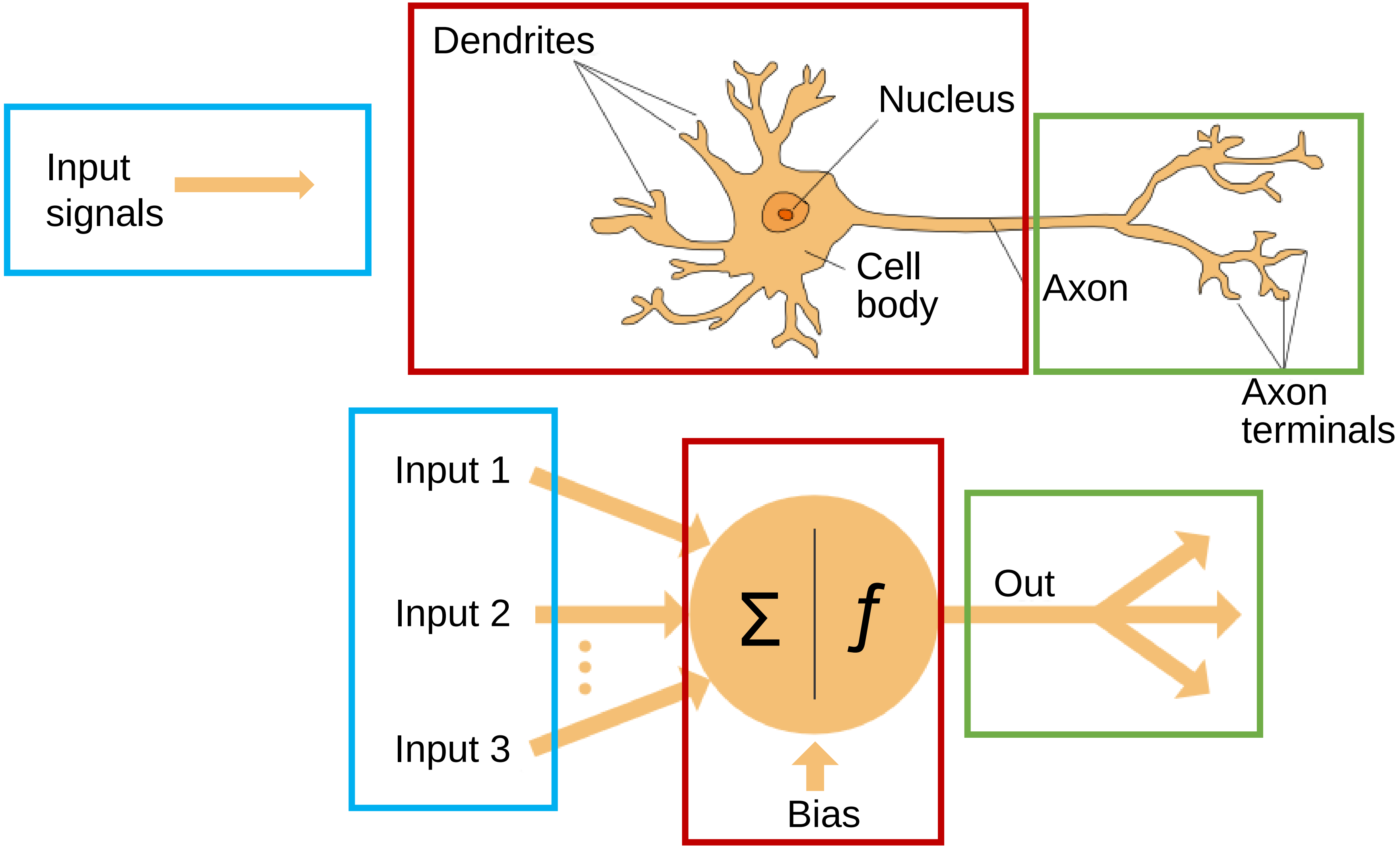
- Neurons are information messengers that transmit information via **electrical impulses** and **chemical signals**.
- In deep learning models, neurons are nodes in which data flow and computations are performed.



# Motivation Behind Neural Network

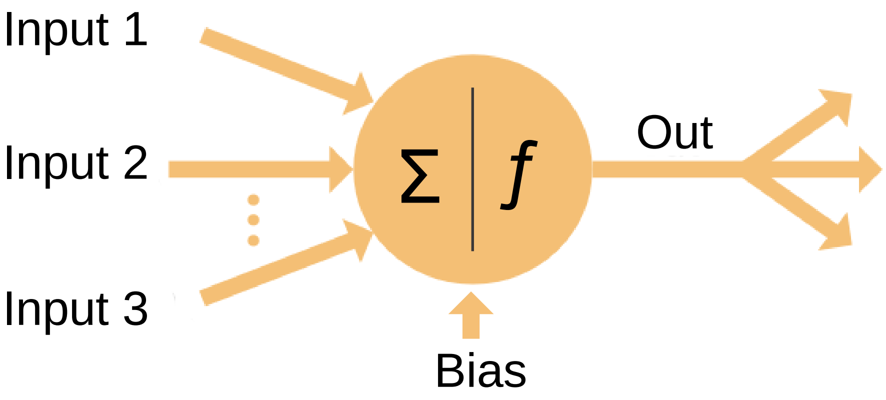
- Human brain is the **best processor** even though it functions slower than computers.
- Human brain consists of about 86 billion neurons and an estimate of 1000 trillion synapses.
- Neurons are interconnected to many other neurons to form a network.

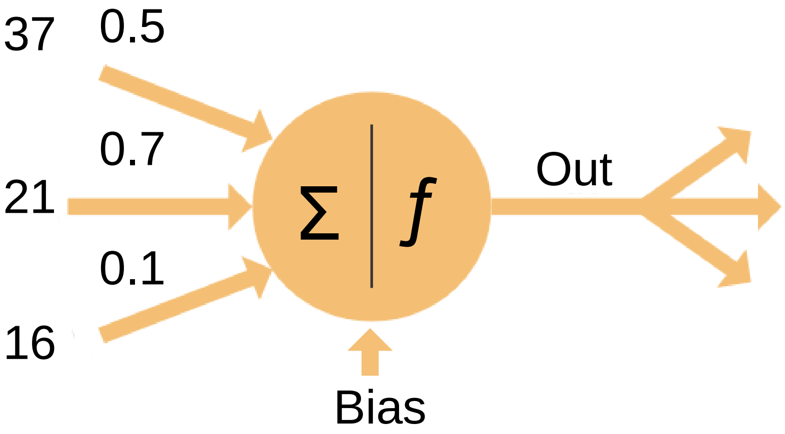
# Motivation Behind Neural Network



# Perceptron

- Perceptron is an **artificial neuron** and is the **simplest model** of a biological neuron in an artificial neural network.
- The perceptron algorithm was built for **classification tasks**.
- It works by **multiplying and summing** the inputs.

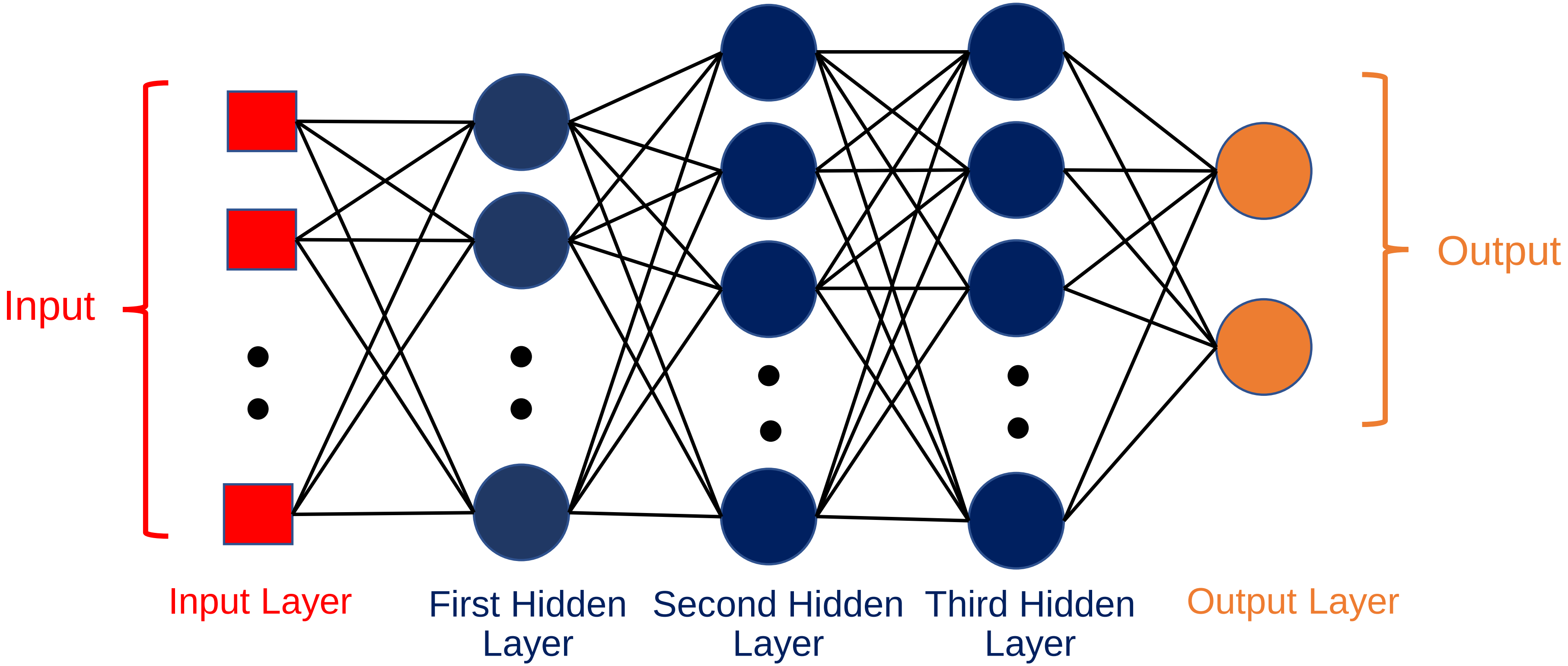



Output = 37(0.5) + 21(0.7) + 16(0.1) = 34.8

# Multi-Layer Perceptron

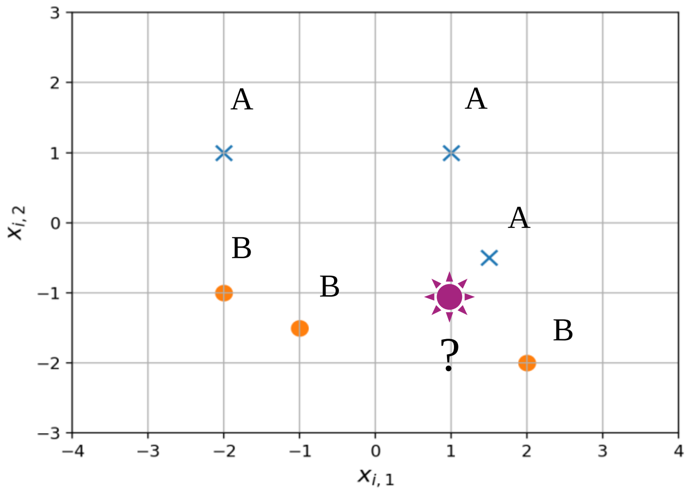
- Multi-layer perceptron consists of **more than** one hidden layer.
- A five-layer network:



# Training a Perceptron for Classification

- Consider six insects (three from each type) that were spotted on a 2-D map with location $x_{i,1}$ and $x_{i,2}$.

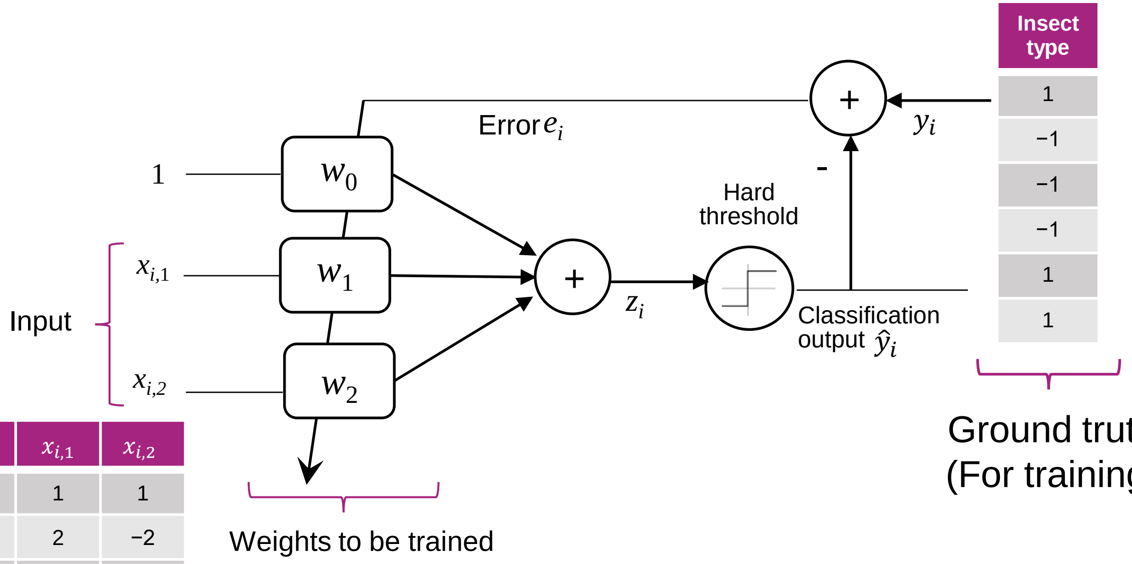
| $i$ | Location $x_{i,1}$ | Location $x_{i,2}$ | Insect type |
|---|---|---|---|
| 0 | 1 | 1 | A |
| 1 | 2 | −2 | B |
| 2 | −1 | −1.5 | B |
| 3 | −2 | −1 | B |
| 4 | −2 | 1 | A |
| 5 | 1.5 | −0.5 | A |




- An unknown insect has appeared at location $x_{i,1} = 1$, $x_{i,2} = -1$. Are we able to determine the type of insect it belongs to?
- To solve the problem above, we would like the machine to determine a boundary that separates the above data points.
- Once this is done, if the unknown insect lies below the boundary, it can be classified as Insect B. Conversely, if the unknown insect lies above the boundary, the insect is classified as Insect A.

# Training a Perceptron for Classification

- To determine the boundary that separates the data points, we employ the ***perceptron.***




| $i$ | $x_{i,1}$ | $x_{i,2}$ |
|---|---|---|
| 0 | 1 | 1 |
| 1 | 2 | −2 |
| 2 | −1 | −1.5 |
| 3 | −2 | −1 |
| 4 | −2 | 1 |
| 5 | 1.5 | −0.5 |

Ground truth
(For training)

Assign
Insect A = 1
Insect B = −1

Initialise the weights

For each data point $i = 0, \ldots, 5$

Compute the predicted output

$$z_i = w_0 + x_{i,1}w_1 + x_{i,2}w_2$$

$$\hat{y}_i = \begin{cases} 1 & \text{if } z_i \geq 0 \\ -1 & \text{if } z_i < 0 \end{cases}$$

Compute the error

$$e_i = y_i - \hat{y}_i$$

Weight update equations

$$w_0 = w_0 + \eta e_i$$

$$w_j = w_j + \eta x_{i,j} e_i$$

# Training a Perceptron for Classification

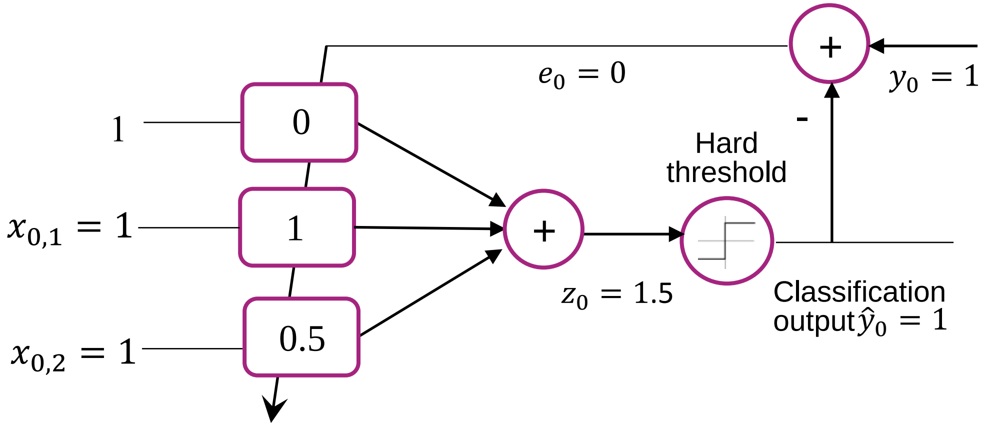
- Let step-size be $\eta = 0.1$ and we initialise the weights

$$w_0 = 0, w_1 = 1, w_2 = 0.5$$

We will use the weights to form the boundary.

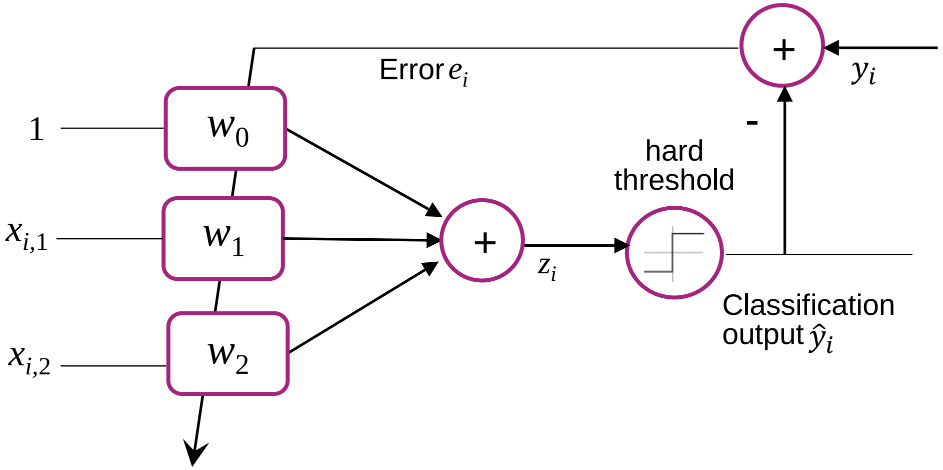
- Since decision will be made between $z_i \geq 0$ and $z_i < 0$, we let $z_i$=0 draw the boundary.

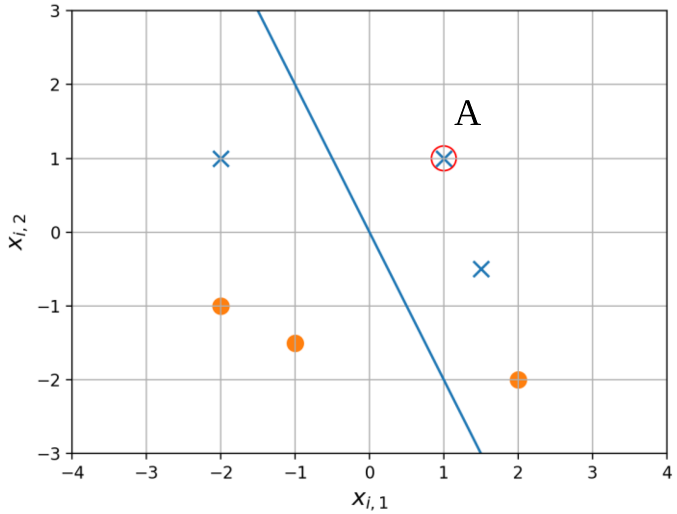
$$z_i = w_0 + x_{i,1}w_1 + x_{i,2}w_2 \quad \Rightarrow \quad 0 = 0 + 1x_{i,1} + 0.5x_{i,2} \quad \Rightarrow \quad x_{i,2} = -2x_{i,1}$$




- Since error is zero, the weights are not updated and boundary is the same.

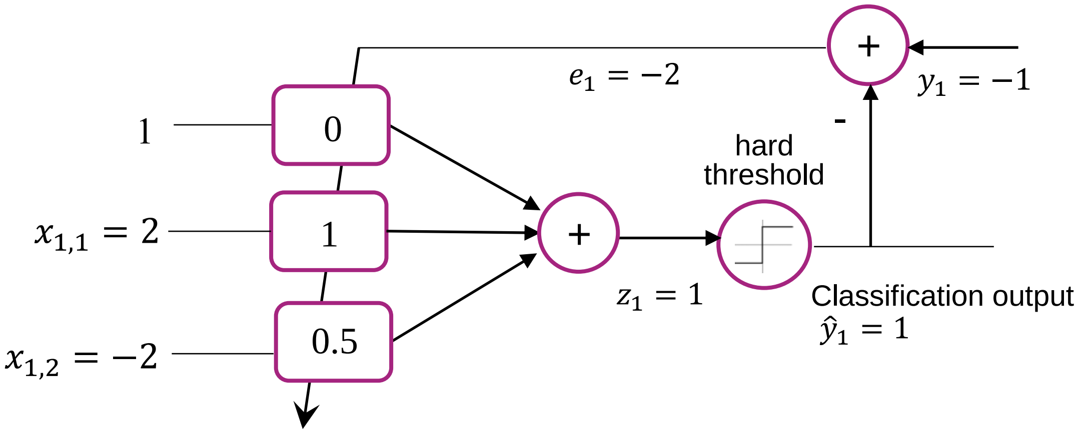
$$w_0 = w_0 + \eta e_i \qquad w_j = w_j + \eta x_{i,j} e_i$$

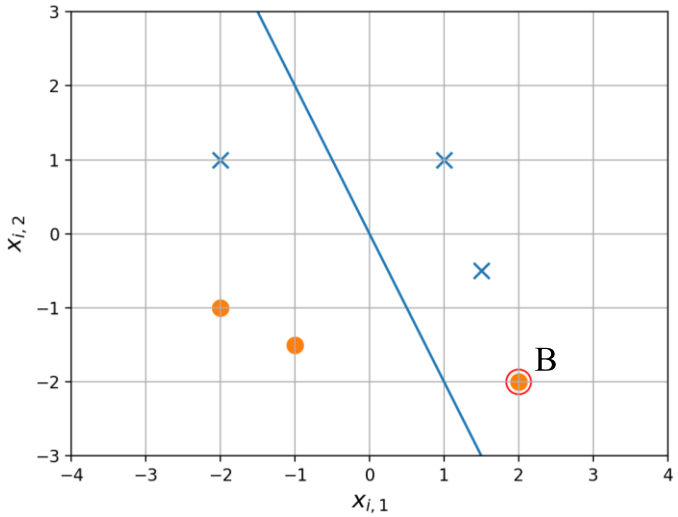


# Training a Perceptron for Classification

- With the boundary, the algorithm analyses data point $i = \mathbf{1}$.




- With $\eta = 0.1$, $e_1 = -2$, the weights are updated as

$$w_0 = w_0 + \eta e_i \qquad w_0 = 0 + (0.1)(-2) = -0.2$$

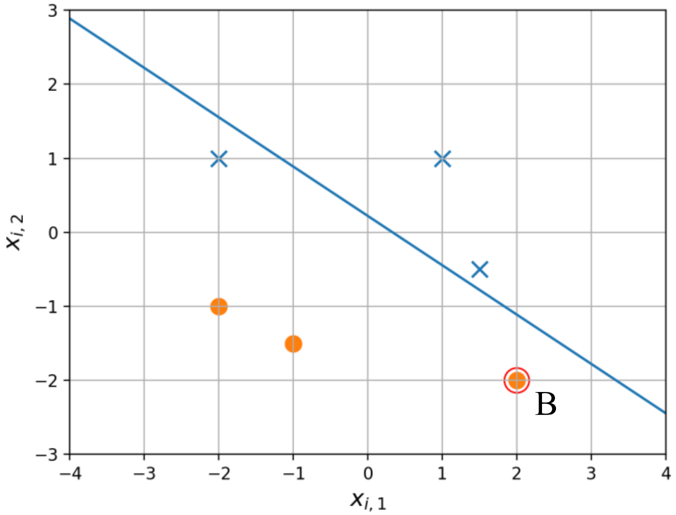
$$w_j = w_j + \eta x_{i,j} e_i \qquad w_1 = 1 + (0.1)2(-2) = 0.6$$

$$w_2 = 0.5 + (0.1)(-2)(-2) = 0.9$$

- With the new weights, boundary is updated as

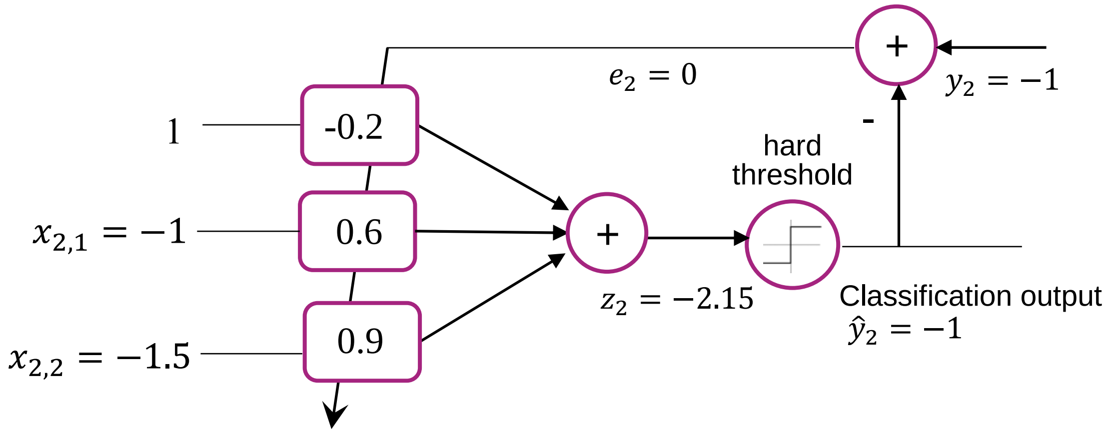
$$z_i = w_0 + x_{i,1}w_1 + x_{i,2}w_2 \quad \Rightarrow \quad 0 = -0.2 + 0.6x_{i,1} + 0.9x_{i,2}$$

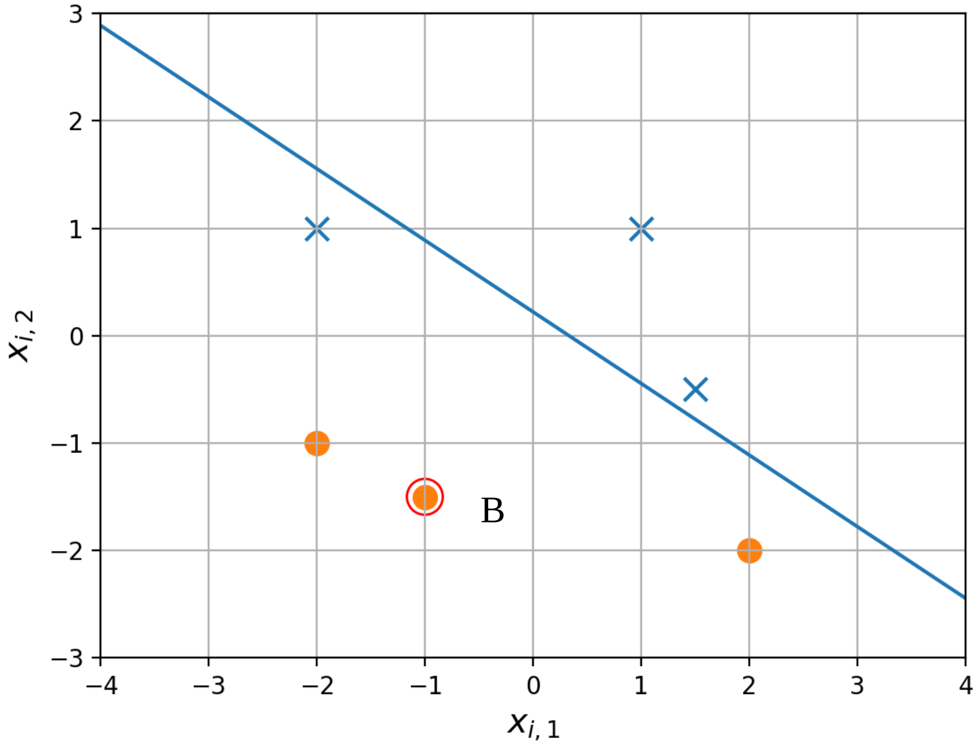
$$\Rightarrow \quad x_{i,2} = -0.67x_{i,1} + 0.22$$



# Training a Perceptron for Classification

- With the boundary, the algorithm analyses data point $i = \mathbf{2}$.




- With $e_0 = 0$, the weights are not updated.

$$w_0 = w_0 + \eta e_i$$

$$w_j = w_j + \eta x_{i,j} e_i$$

$$w_0 = -0.2 + (0.1)(0) = -0.2$$

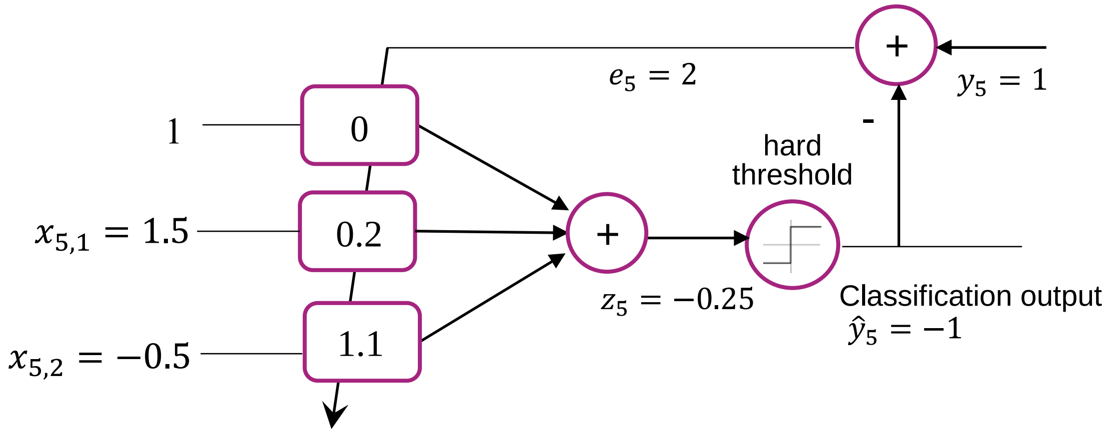
$$w_1 = 0.6 + (0.1)(-1)(0) = 0.6$$

$$w_2 = 0.9 + (0.1)(-1.5)(0) = 0.9$$

- Boundary is unchanged (which is expected since class label is correct).

# Training a Perceptron for Classification

- With the boundary, the algorithm analyses data point $i = \mathbf{5}$.




- With $\eta = 0.1$, $e_0 = 2$, the weights are updated as

$$w_0 = w_0 + \eta e_i \qquad w_0 = 0 + (0.1)(2) = 0.2$$

$$w_j = w_j + \eta x_{i,j} e_i \qquad w_1 = 0.2 + (0.1)(1.5)(2) = 0.5$$

$$w_2 = 1.1 + (0.1)(-0.5)(2) = 1$$

- With the new weights, boundary is updated as

$$z_i = w_0 + x_{i,1}w_1 + x_{i,2}w_2 \quad \Rightarrow \quad 0 = 0.2 + 0.5x_{i,1} + 1x_{i,2}$$

$$\Rightarrow \quad x_{i,2} = -0.5x_{i,1} - 0.2$$