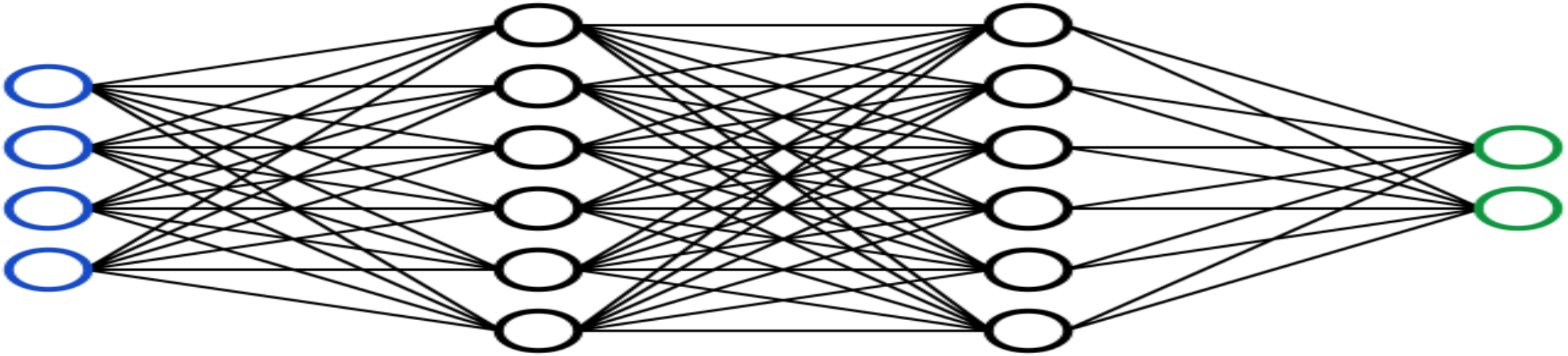

Artificial Neural Network (ANN)

Lecture 2

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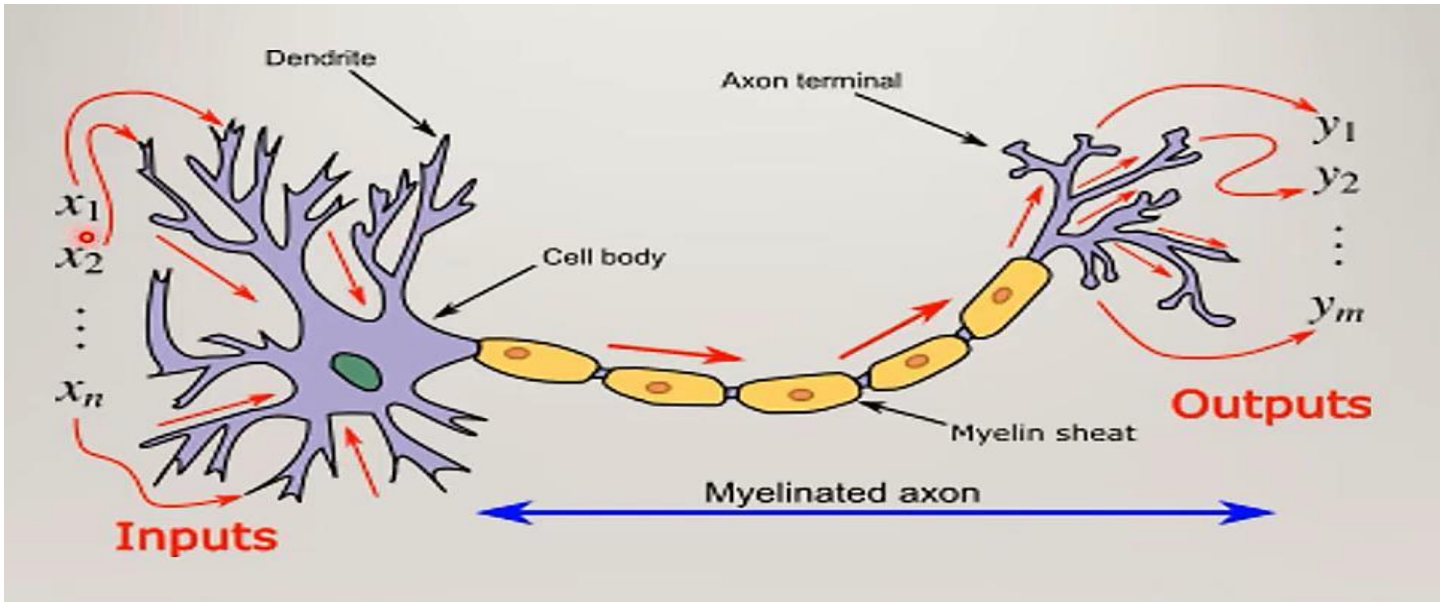
Biological Background

- Neuron consist of:
  - Soma: body of the neuron.
  - Dendrites: receptors or inputs of the neuron.
  - Axon: output of the neuron, connected to dendrites of other neurons via synapses.
  - Synapses: transfer information between neurons.



Biological Background (Cont'd)

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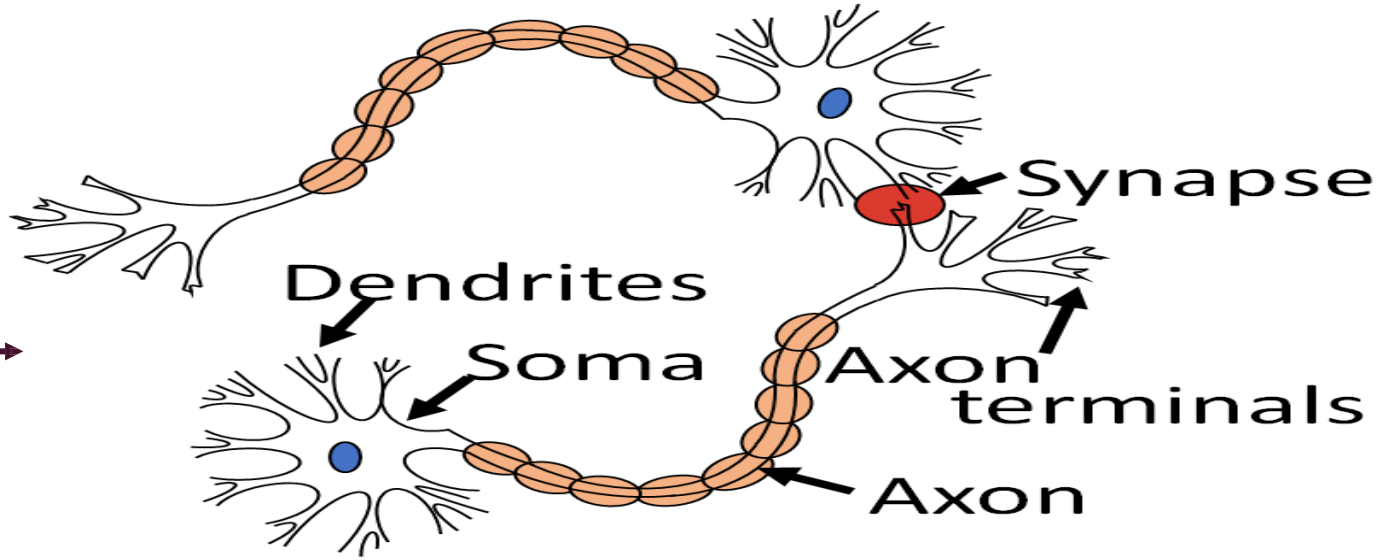


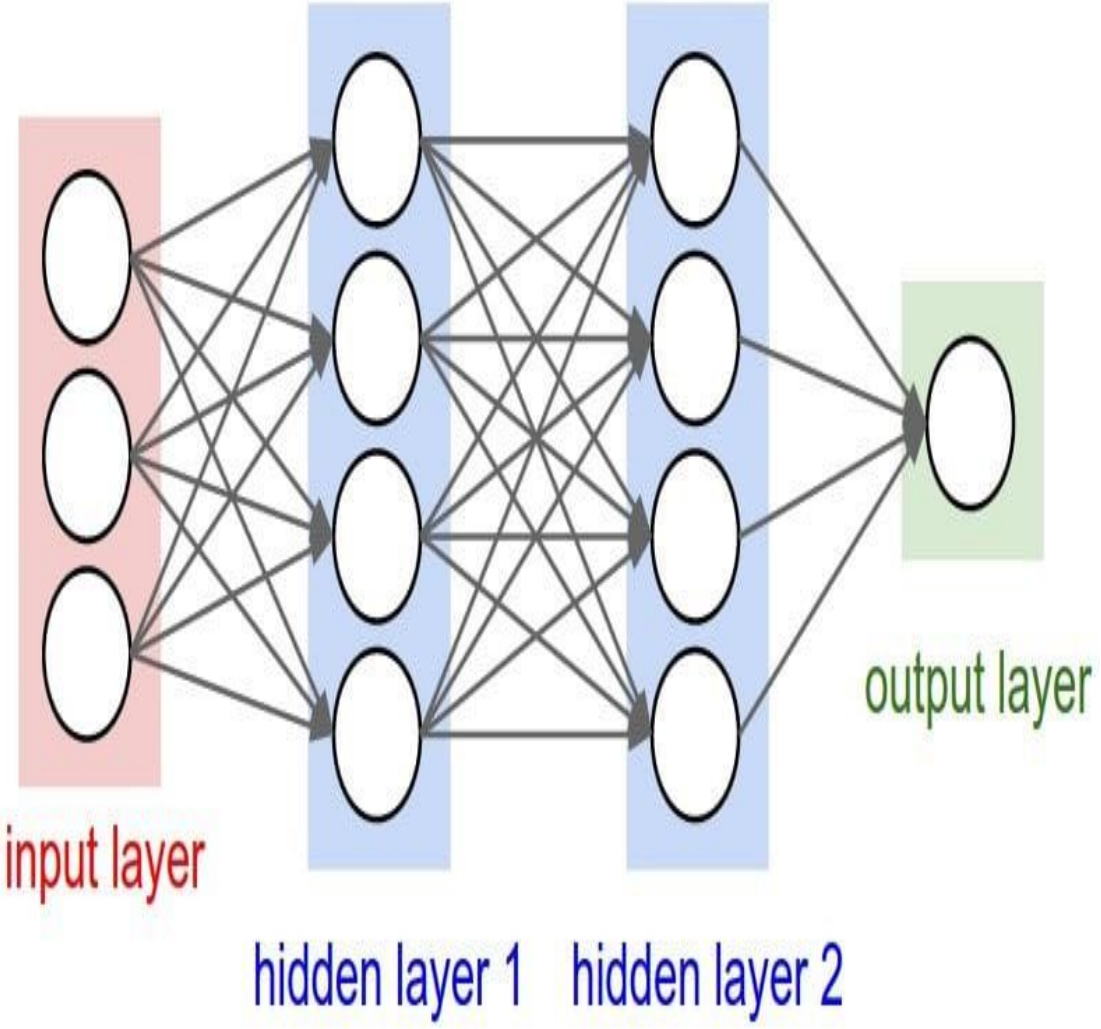
What is a neural network?

- A Neural Network is a machine learning program that is based on the biological neural network and makes decisions in a manner similar to the human brain, by using processes that mimic the way biological neurons work together to identify phenomena, evaluate choices and arrive at conclusions.

- Neural networks are not based on any specific computer program written for it, but it can progressively learn and improve its performance over time.

Neural Network Components

- A neural network is made up of a collection of units or nodes called neurons.
- These neurons are connected one to the other by means of a connection called synapse.
- By means of the synapse, a neuron can transmit signal or information to another neuron nearby. The receiving neuron can receive the signal, process it and signal the next one. The process continues, until an output signal is produced.
- Neurons are normally arranged in layers. Different layers may perform different kind of transformation on its input.



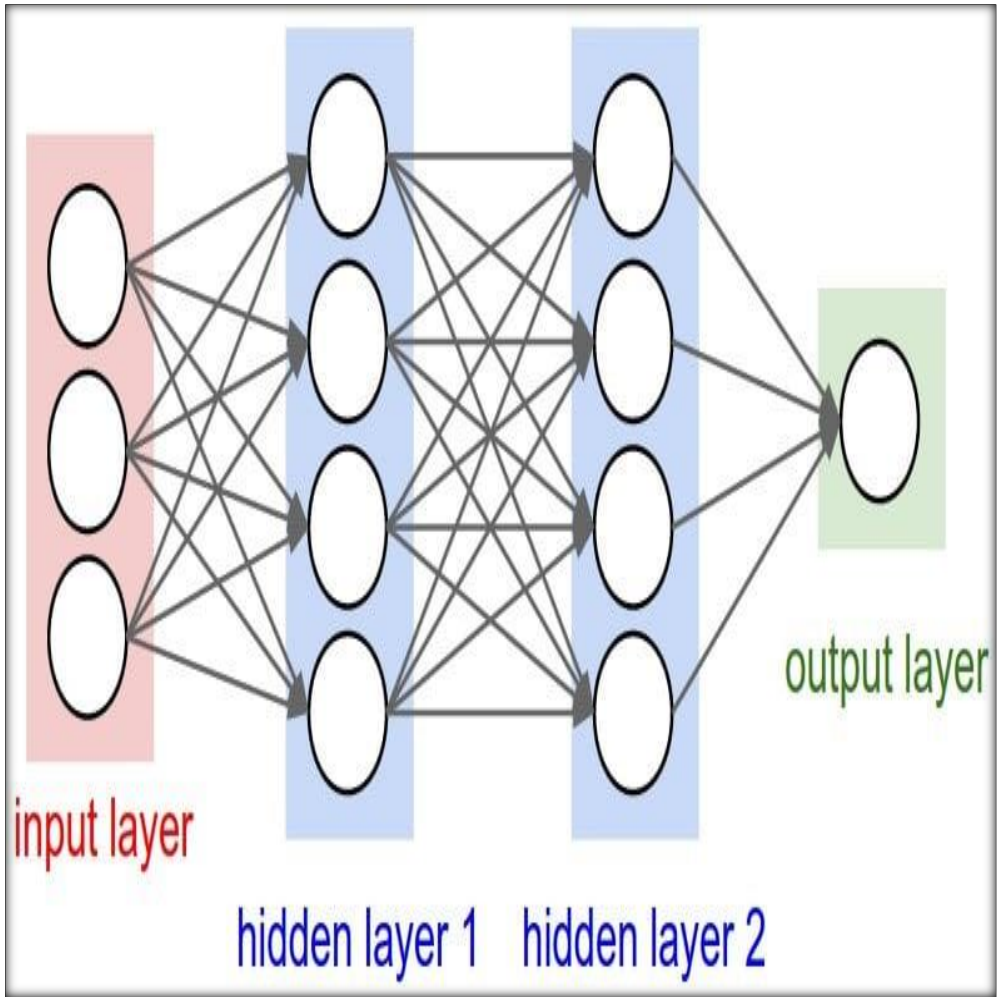
Neural Network Layers:
Exploring their Count and Purpose

- In a neural network, there are typically three main types of layers: input layers, hidden layers, and output layers.

1- <u>Input Layer</u>:

Purpose: The input layer receives the raw input data and passes it to the subsequent layers for processing. Each neuron in the input layer represents a feature or attribute of the input data.

Function: The input layer doesn't perform any computation; it simply passes the input data forward to the hidden layers. It acts as the interface between the external world and the neural network.

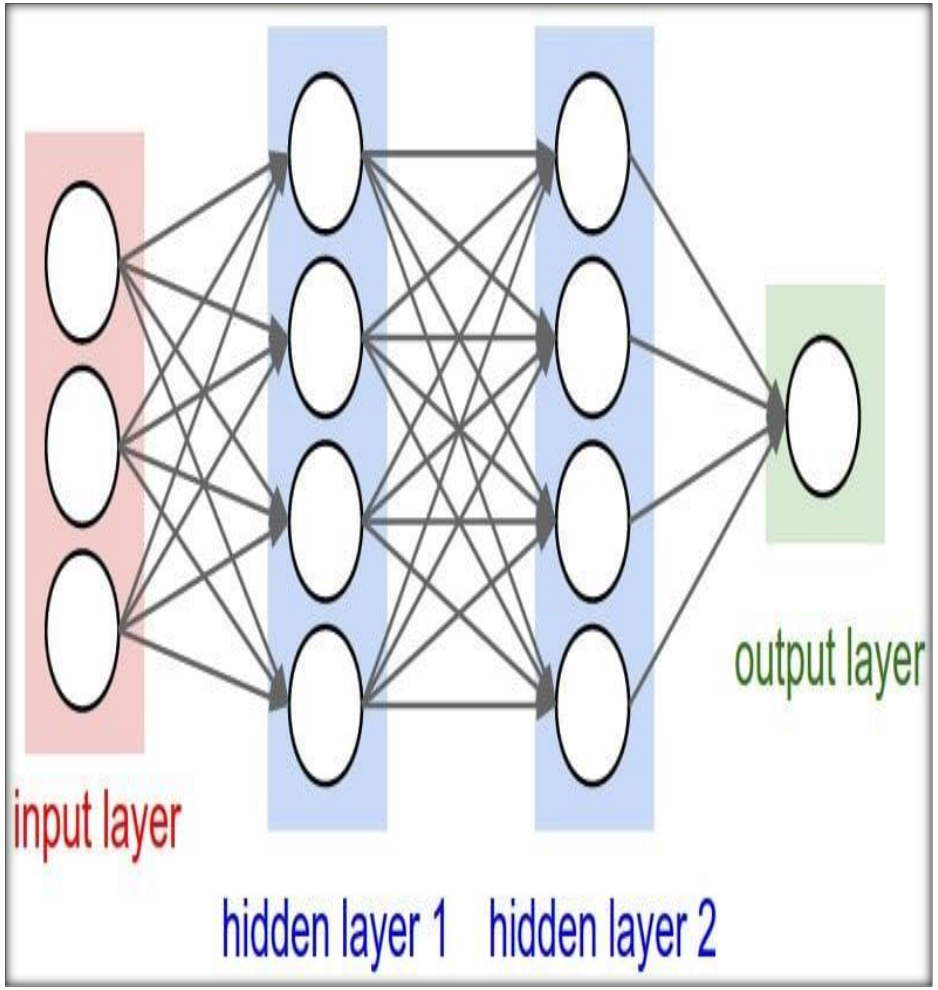


Neural Network Layers:
Exploring their Count and Purpose

2- <u>Hidden Layers</u>:

Purpose: Hidden layers enable the neural network to learn complex patterns and relationships in the data. Hidden layers are responsible for processing the input data and extracting relevant features.

Function: Each neuron in the hidden layers receives input from the previous layer, <u>computes a weighted sum of inputs, applies an activation function to introduce non-linearity</u> (enable the neural network to learn and represent complex, nonlinear relationships within the data it processes), and passes the result to the next layer.

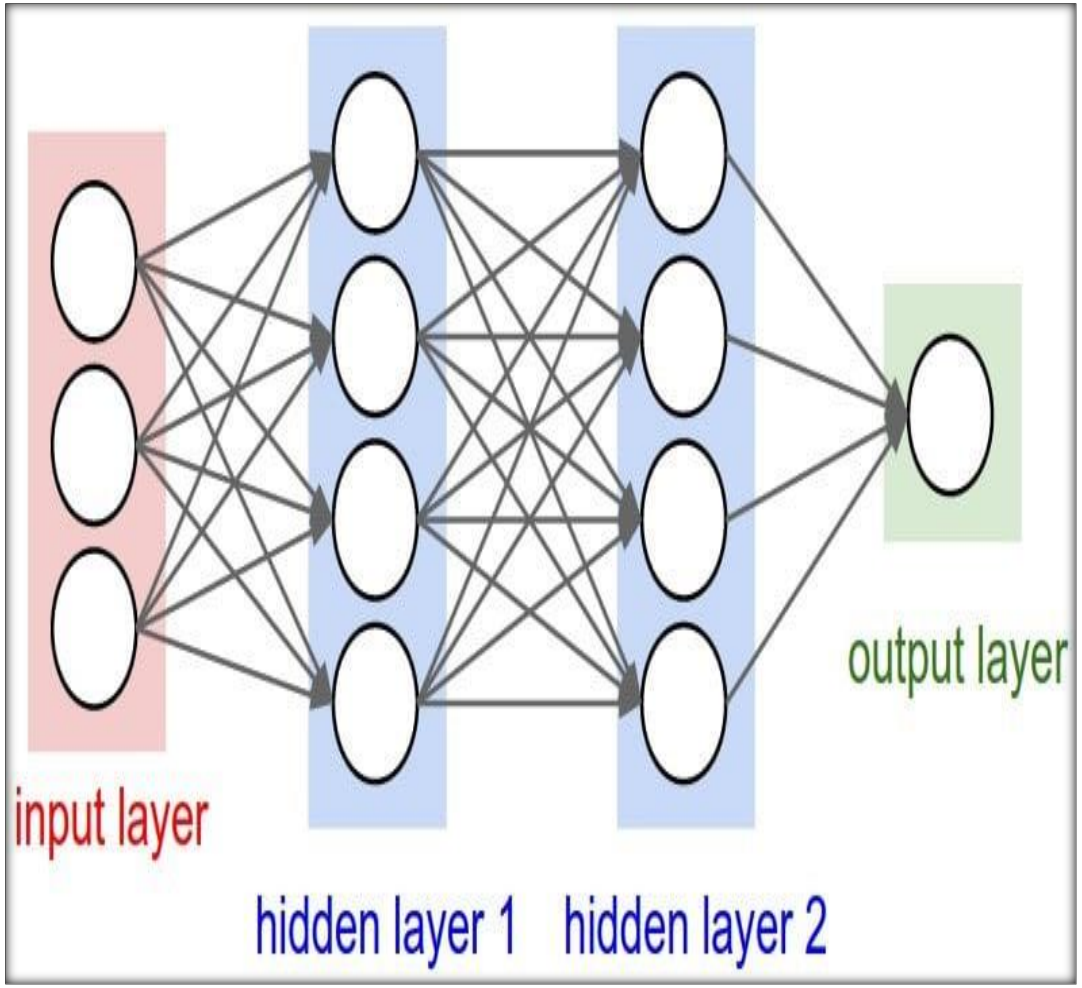


Neural Network Layers:
Exploring their Count and Purpose

3- <u>Output Layer</u>:

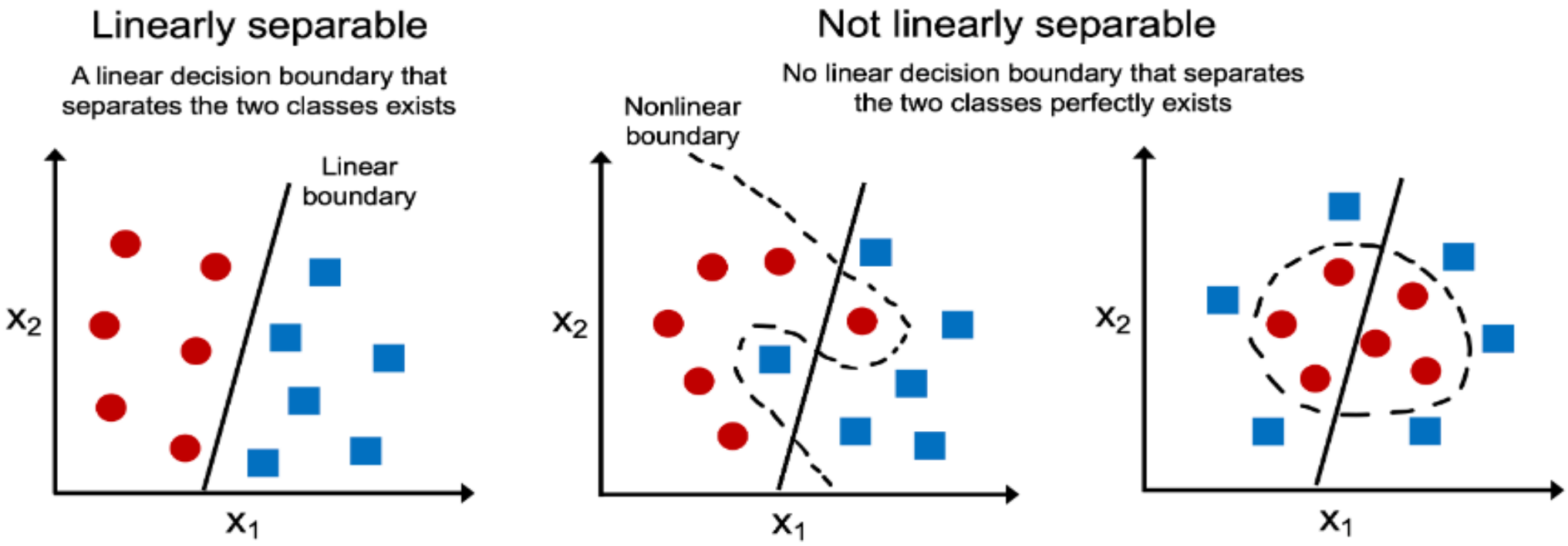
Purpose: The output layer receives the processed data from the hidden layers and produces the final output or prediction of the neural network.

Function: The number of neurons in the output layer depends on the type of task the neural network is performing. For classification tasks, each neuron typically represents a class label, and the output is the probability distribution over all possible classes. For regression tasks, there is usually one neuron that produces the continuous output value.



Linearly separable and linearly inseparable problem

- If you can draw a line or hyper plane that can separate those points into two classes, then the data is separable. If not, then the data is termed as non linearly separable data.

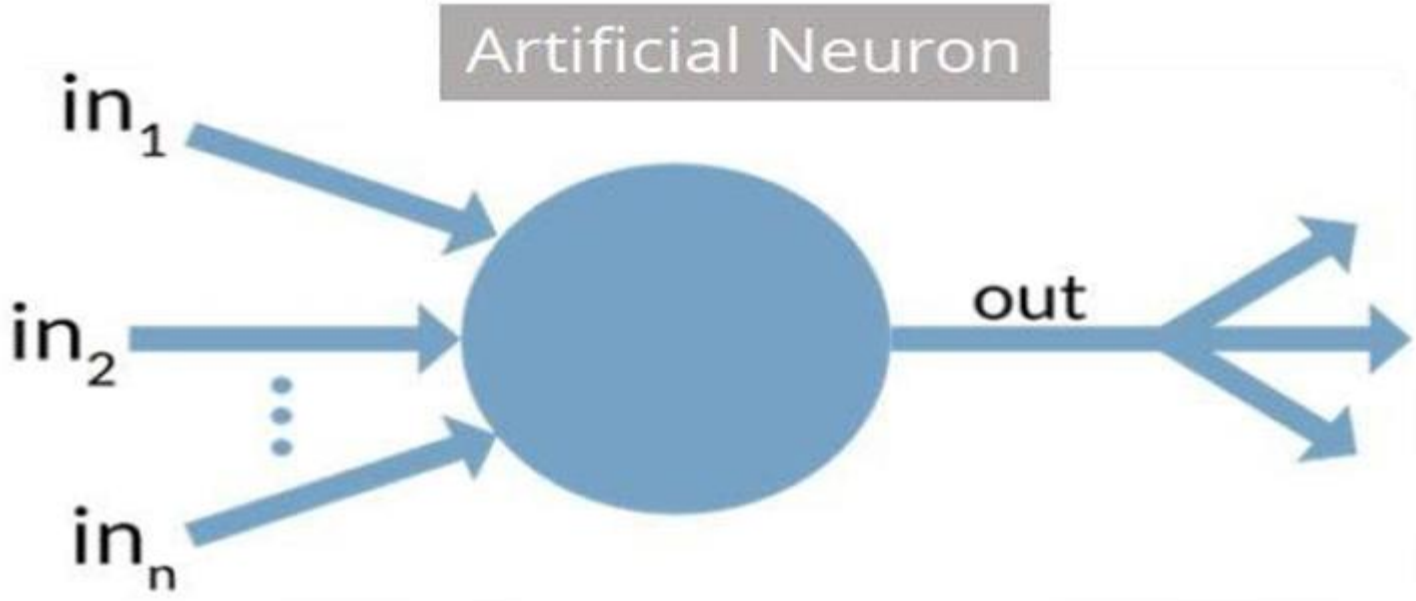


Biological neuron vs. Artificial neuron

Biological Neuron	Artificial Neuron
Cell Nucleus (Soma)	Node
Dendrites	Input
Synapse	Weights or interconnections
Axon	Output

What is an Artificial Neuron?

- An artificial neuron is a mathematical function based on a model of biological neurons, where each neuron takes inputs, weighs them separately, sums them up and passes this sum through a nonlinear function to produce an output.

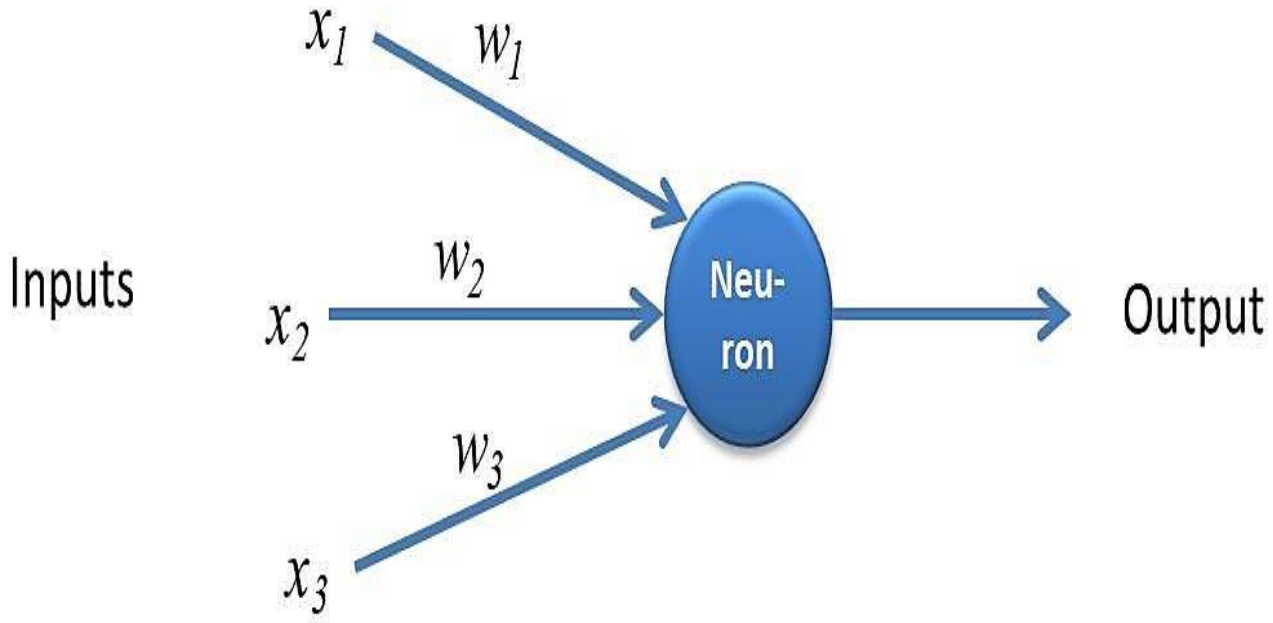


Artificial Neuron at a Glance

- The artificial neuron has the following characteristics:
  - A neuron is a mathematical function modeled on the working of biological neurons.
  - It is an elementary unit in an artificial neural network.
  - One or more inputs are separately weighted.
  - Inputs are summed and passed through a nonlinear function to produce output.
  - Every neuron is connected to another neuron via connection link.
  - Each connection link carries information about the input signal.

Simple Model of Neural Networks: Perceptron

- The perceptron(or single-layer perceptron) is the simplest model of a neuron that illustrates how a neural network works.
- The perceptron is a machine learning algorithm developed in 1957 by Frank Rosenblatt and first implemented in IBM.
- The perceptron is a network that takes a number of inputs, carries out some processing on those inputs and produces an output.



Example:

- ✓ Perceptron has three inputs x_1, x_2 and x_3 and one output.
- ✓ The importance of this inputs is determined by the corresponding weights w_1, w_2 and w_3 assigned to this inputs.

How does Perceptron Work?

Main parameters:

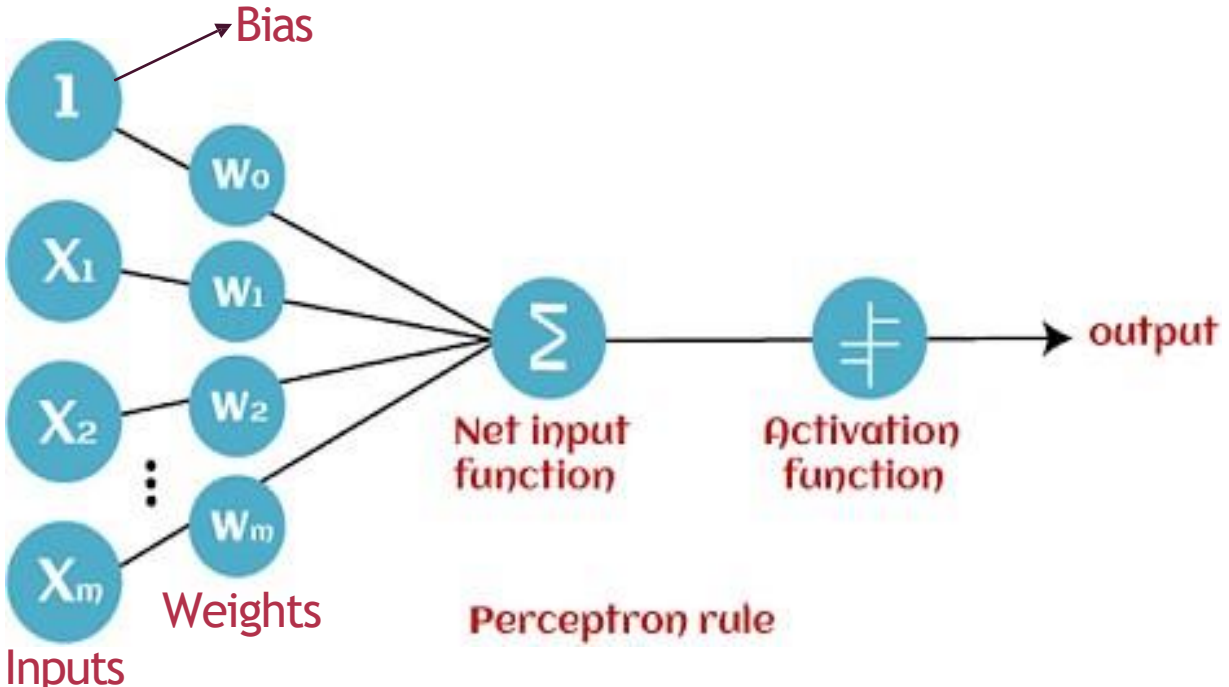
1) Input values: They're usually represented as features of a dataset which are passed on to a neural network to make predictions.

2) Weights: These are the real values associated with the features. They are significant as they tell the importance of each feature which is passed as an input to the artificial neural network.

3) Bias (1 or -1): plays a crucial role in improving the flexibility and learning capabilities of the model.

4) Summation function: It is defined as the function which sums up the product of the weight and the features with bias.

5) Activation function: It is required to add non-linearity to the neural network model.



Steps of Perceptron (Mathematical Notation)

- Step 1:
  - ✓ Multiply all input values with corresponding weight values and then add to calculate the weighted sum. The following is the mathematical expression of it:

$$\sum w_i * x_i = x_1 * w_1 + x_2 * w_2 + x_3 * w_3 + x_4 * w_4$$

  - ✓ Add a term called bias 'b' to this weighted sum to improve the model's performance

$$(\sum w_i * x_i + b)$$

- Step 2:
  - ✓ An activation function is applied with the above-mentioned weighted sum giving us an output as follows:

$$y = f(\sum w_i * x_i + b)$$

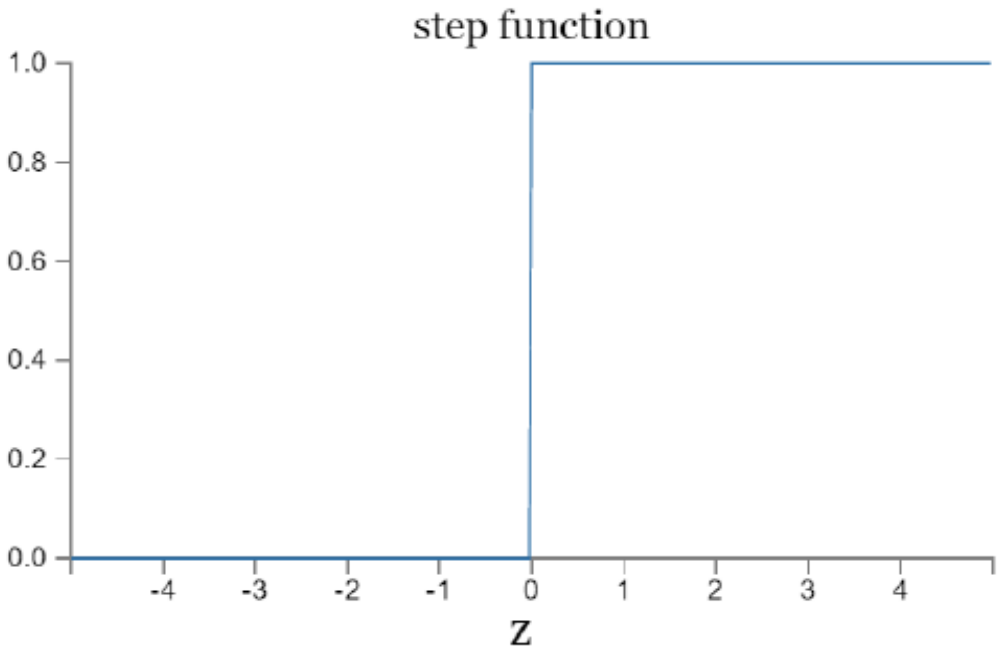
Activation Function

- Each neuron has an activation function that determines when the neuron is fired
- So far we used a step function that outputs 0 (don't go) or 1 (go) based on the inputs, weights, and threshold

$$z = w \cdot x + b$$

$$\text{output} = \begin{cases} 0 & \text{if } w \cdot x + b \leq 0 \\ 1 & \text{if } w \cdot x + b > 0 \end{cases}$$

Threshold



Perceptron Example

The perceptron tries to decide if you should go to a concert.

Is the artist good? Is the weather good?

What weights should these facts have?

Criteria	Input	Weight
Artists is Good	**x1** = 0 or 1	**w1** = 0.7
Weather is Good	**x2** = 0 or 1	**w2** = 0.6
Friend will Come	**x3** = 0 or 1	**w3** = 0.5
Food is Served	**x4** = 0 or 1	**w4** = 0.3
Alcohol is Served	**x5** = 0 or 1	**w5** = 0.4

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The Perceptron Algorithm

1. Set a threshold value
2. Multiply all inputs with its weights
3. Sum all the results
4. Activation function

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Threshold = 1.5

Perceptron Example

1. Set a threshold value:

- Threshold = 1.5

2. Multiply all inputs with its weights:

- x1 * w1 = 1 * 0.7 = 0.7
- x2 * w2 = 0 * 0.6 = 0
- x3 * w3 = 1 * 0.5 = 0.5
- x4 * w4 = 0 * 0.3 = 0
- x5 * w5 = 1 * 0.4 = 0.4

3. Sum all the results:

- 0.7 + 0 + 0.5 + 0 + 0.4 = 1.6 (The Weighted Sum)

4. Activate the Output:

- Return true if the sum > 1.5 ("Yes I will go to the Concert")

Perceptron Example

- Note
  - If the weather weight is 0.6 for you, it might different for someone else. A higher weight means that the weather is more important to them.
  - If the threshold value is 1.5 for you, it might be different for someone else. A lower threshold means they are more wanting to go to the concert.

Perceptron Example (Python)

```
threshold=1.5
inputs=[1,0,1,0,1]
weights=[0.7,0.6,0.5,0.3,0.4]
sum=0
for i in range(len(inputs)):
 sum+=inputs[i]*weights[i]

activate=(sum>1.5)
print(activate)
```