Introduction To Artificial Neural Network [ANN]

Course Title: Artificial Intelligence

Course Code: cse-403

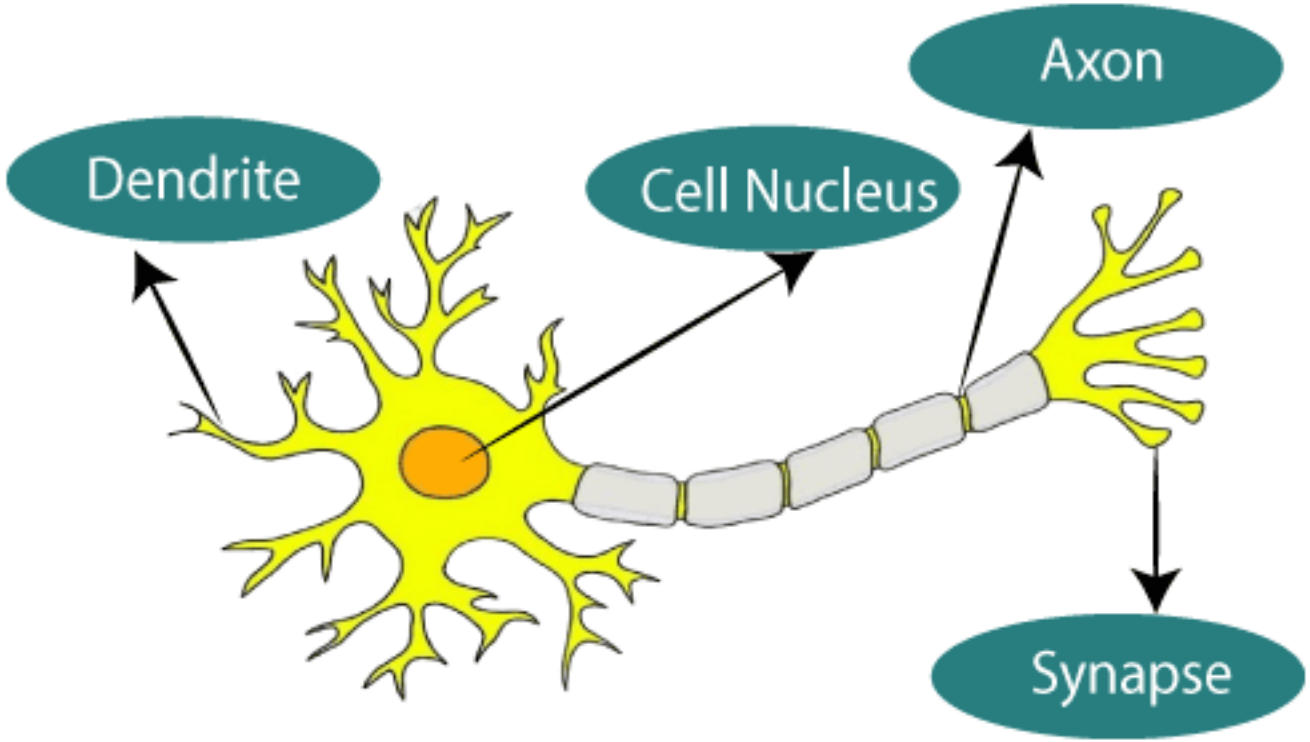
Outlines

1. What is Artificial Neural Network?
2. Relationship between Biological neural network and artificial neural network
3. The architecture of an artificial neural network
4. How do artificial neural networks work?
5. What are the types of Artificial Neural Networks?
   - ✓ Feedforward network
   - ✓ Feedback Neural Networks (RNNs)
6. Adjustments of Weights or Learning
   - ✓ supervised learning,
   - ✓ unsupervised learning,
   - ✓ reinforcement learning
7. Applications of ANN

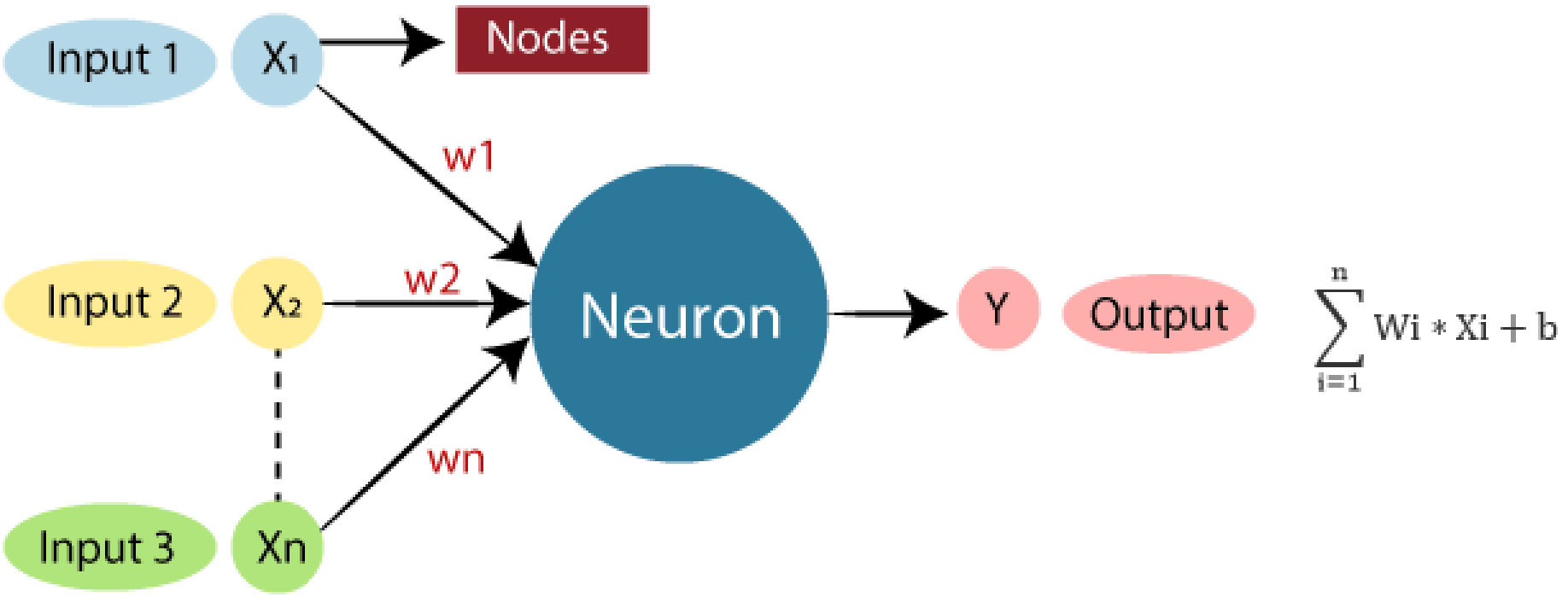
❑ What is Artificial Neural Network?

- ✓ The term "**Artificial Neural Network**" is derived from Biological neural networks that develop the structure of a human brain.
- ✓ Similar to the human brain that has neurons interconnected to one another, artificial neural networks also have neurons that are interconnected to one another in various layers of the networks.
- ✓ These neurons are known as nodes.

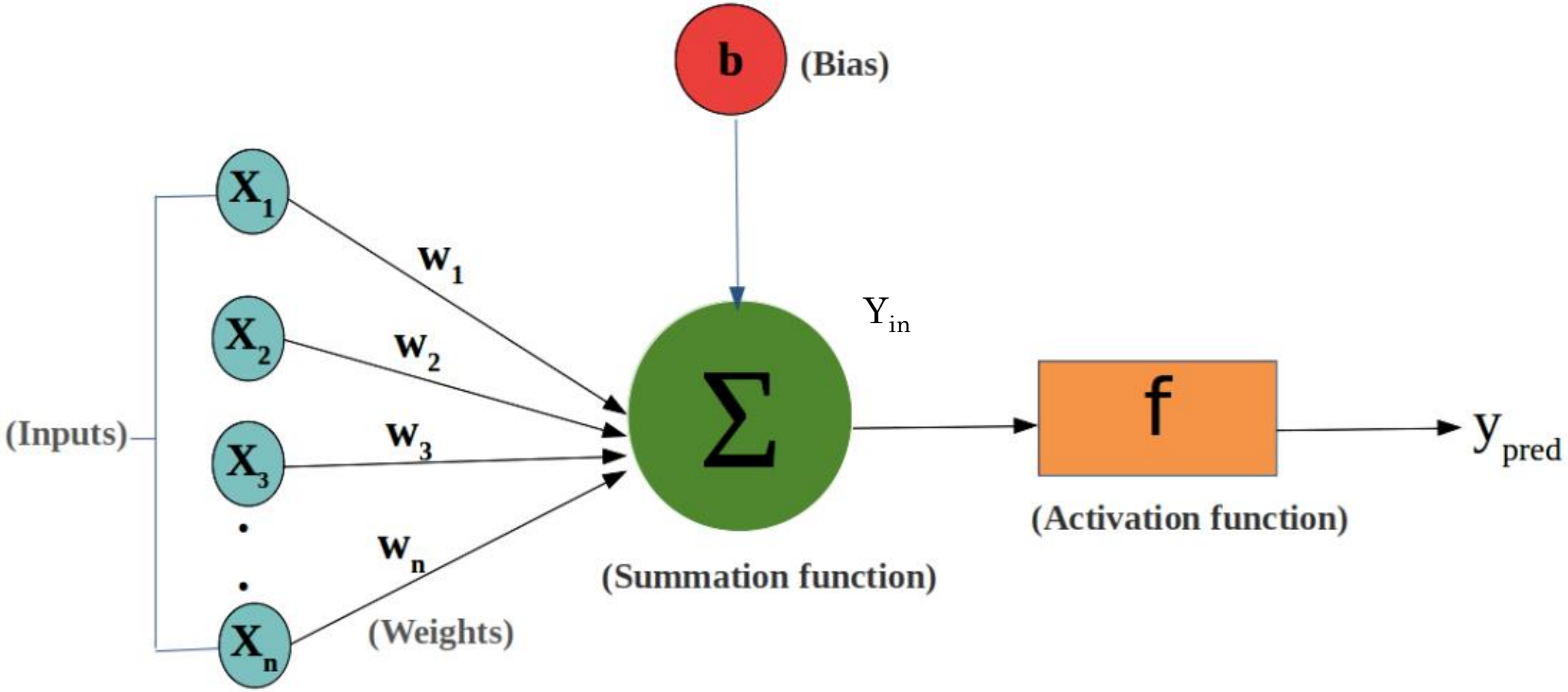
The given figure illustrates the typical diagram of Biological Neural Network.



The typical Artificial Neural Network looks something like the given figure.



- ✓ Dendrites from Biological Neural Network represent inputs in Artificial Neural Networks, cell nucleus represents Nodes, synapse represents Weights, and Axon represents Output.

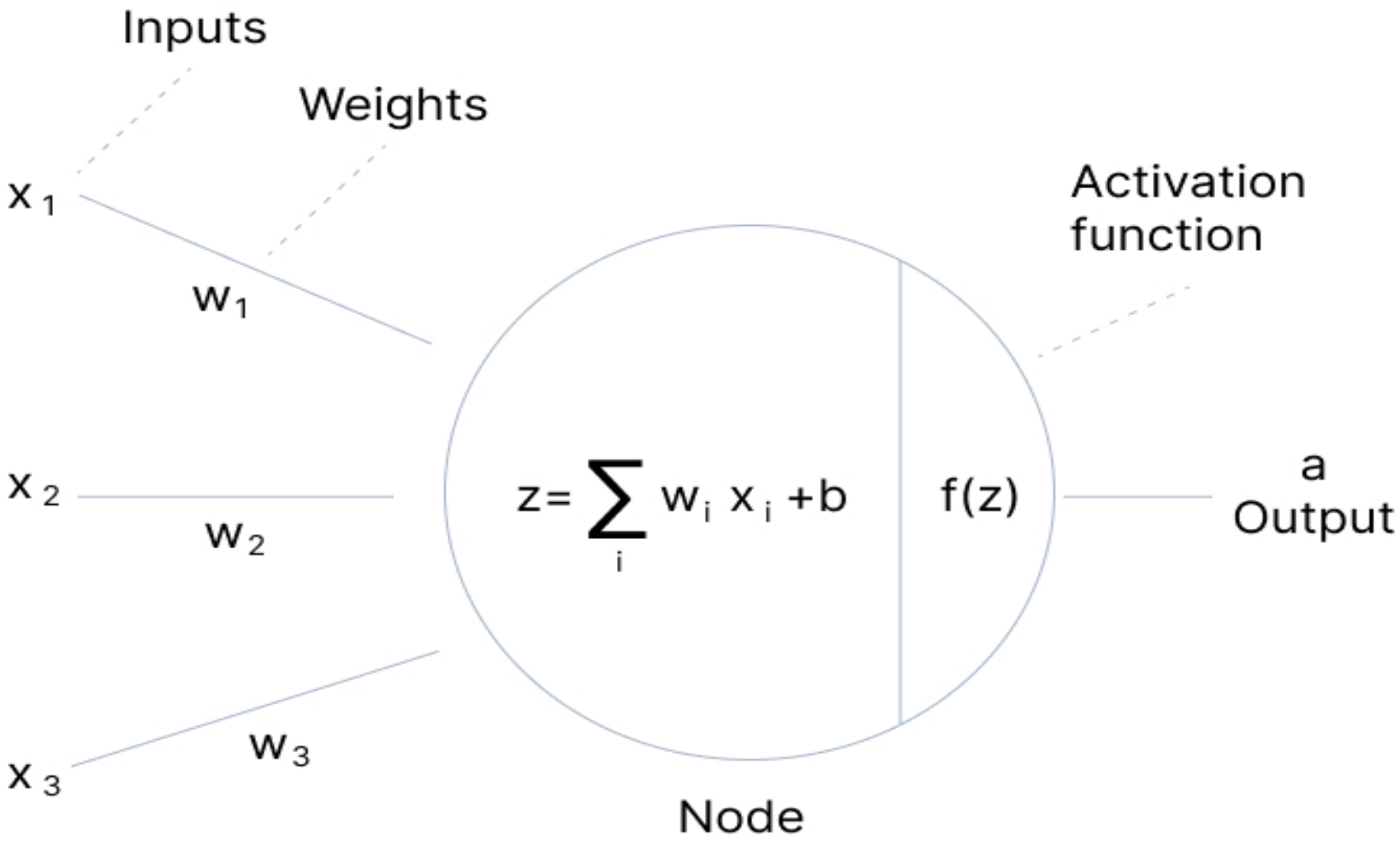


$$Y_{in} = [x_1 * w_1 + x_2 * w_2 + x_3 * w_2 + \ldots\ldots + x_n * w_n] + b$$

$$Y_{in} = \Sigma(x_i * w_i) + b$$

$$Y_{in} = \sum_{i=1}^{n} Wi * Xi + b$$

$$Y_{out} = f(Y_{in})$$



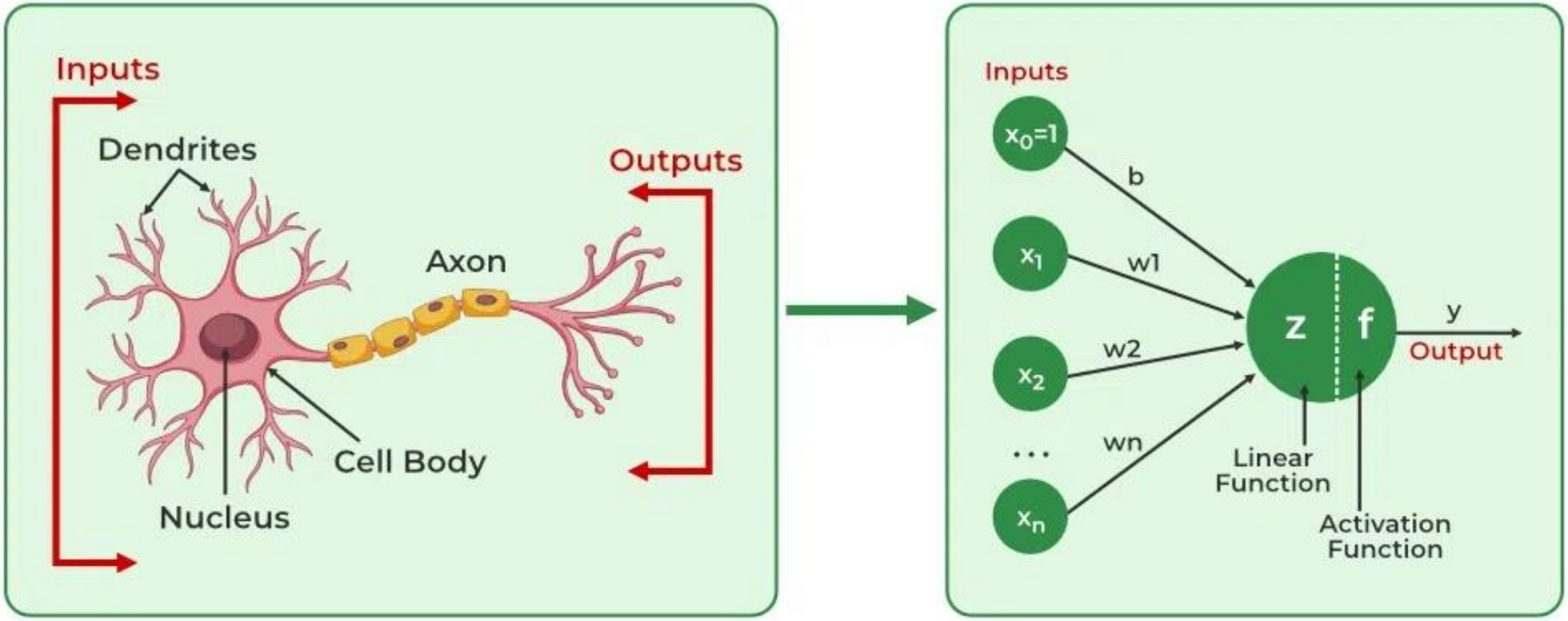
$$Z = [x_1 * w_1 + x_2 * w_2 + x_3 * w_2 + \ldots\ldots + x_n * w_n] + b$$

$$Z = \Sigma(x_i * w_i) + b$$

$$Z = \sum_{i=1}^{n} Wi * Xi + b$$

$$Y_{out} = f(Z)$$

✓ Relationship between Biological neural network and artificial neural network:



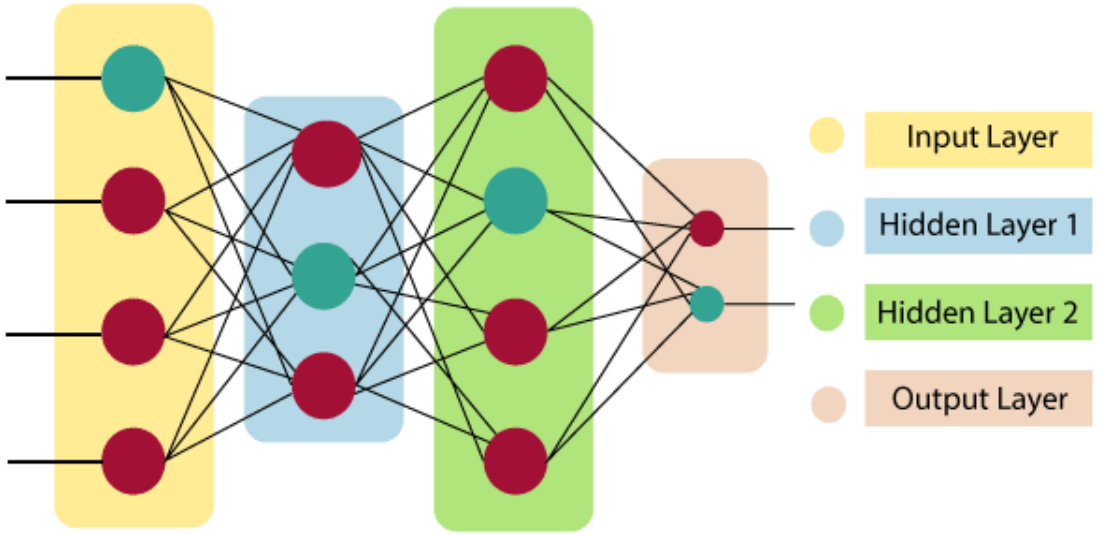
Biological Neural Network	Artificial Neural Network
Dendrites	Inputs
Cell nucleus	Nodes
Synapse	Weights
Axon	Output

- ✓ An **Artificial Neural Network** in the field of **Artificial intelligence** where it attempts to mimic the network of neurons makes up a human brain so that computers will have an option to understand things and make decisions in a human-like manner.
- ✓ The artificial neural network is designed by programming computers to behave simply like interconnected brain cells.
- ✓ There are around 1000 billion neurons in the human brain. Each neuron has an association point somewhere in the range of 1,000 and 100,000.
- ✓ In the human brain, data is stored in such a manner as to be distributed, and we can extract more than one piece of this data when necessary from our memory parallelly. We can say that the human brain is made up of incredibly amazing parallel processors.

The architecture of an artificial neural network:

To understand the concept of the architecture of an artificial neural network, we have to understand what a neural network consists of. In order to define a neural network that consists of a large number of artificial neurons, which are termed units arranged in a sequence of layers. Lets us look at various types of layers available in an artificial neural network.

Artificial Neural Network primarily consists of three layers:



Input Layer:

As the name suggests, it accepts inputs in several different formats provided by the programmer.

Hidden Layer:

The hidden layer presents in-between input and output layers. It performs all the calculations to find hidden features and patterns.

Output Layer:

The input goes through a series of transformations using the hidden layer, which finally results in output that is conveyed using this layer.

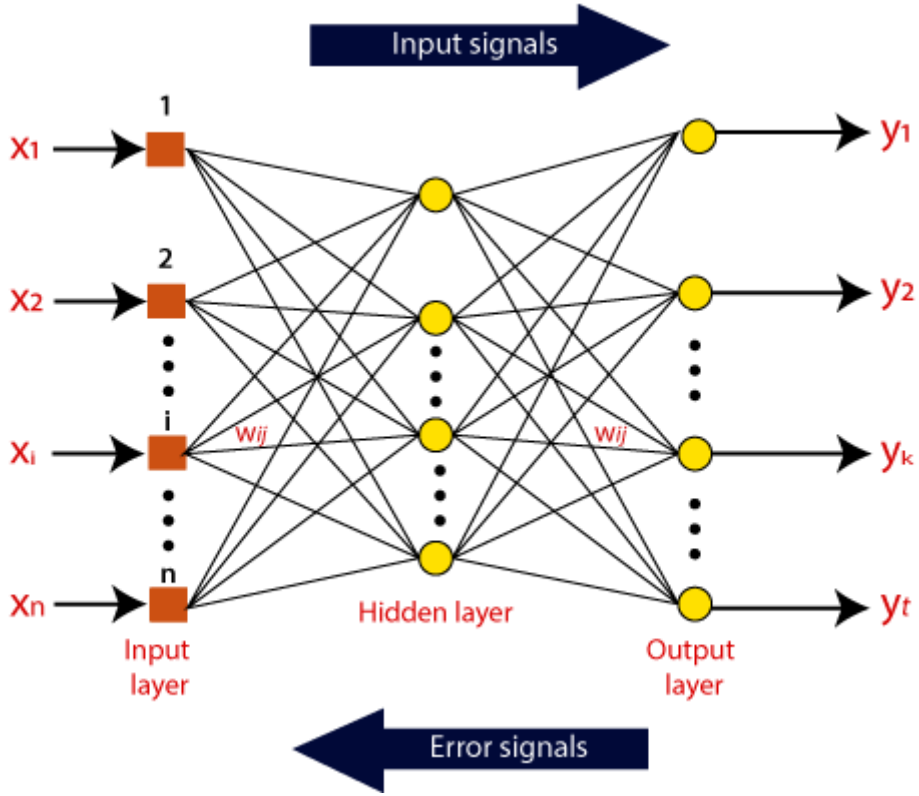
The artificial neural network takes input and computes the weighted sum of the inputs and includes a bias. This computation is represented in the form of a transfer function.

$$\sum_{i=1}^{n} Wi * Xi + b$$

It determines weighted total is passed as an input to an activation function to produce the output. Activation functions choose whether a node should fire or not. Only those who are fired make it to the output layer. There are distinctive activation functions available that can be applied upon the sort of task we are performing.

How do artificial neural networks work?

Artificial Neural Network can be best represented as a weighted directed graph, where the artificial neurons form the nodes. The association between the neurons outputs and neuron inputs can be viewed as the directed edges with weights. The Artificial Neural Network receives the input signal from the external source in the form of a pattern and image in the form of a vector. These inputs are then mathematically assigned by the notations x(n) for every n number of inputs.



❑ Working of Artificial Neural Networks

Instead of directly getting into the working of Artificial Neural Networks, lets breakdown and try to understand Neural Network's basic unit, which is called a **Perceptron**.

So, a perceptron can be defined as a neural network with a single layer that classifies the linear data. It further constitutes four major components, which are as follows;

1.Inputs

2.Weights and Bias

3.Summation Functions

4.Activation or transformation function

The main logic behind the concept of Perceptron is as follows:

The inputs (x) are fed into the input layer, which undergoes multiplication with the allotted weights (w) followed by experiencing addition in order to form weighted sums. Then these inputs weighted sums with their corresponding weights are executed on the pertinent activation function.

- **Weights and Bias**

As and when the input variable is fed into the network, a random value is given as a weight of that particular input, such that each individual weight represents the importance of that input in order to make correct predictions of the result.

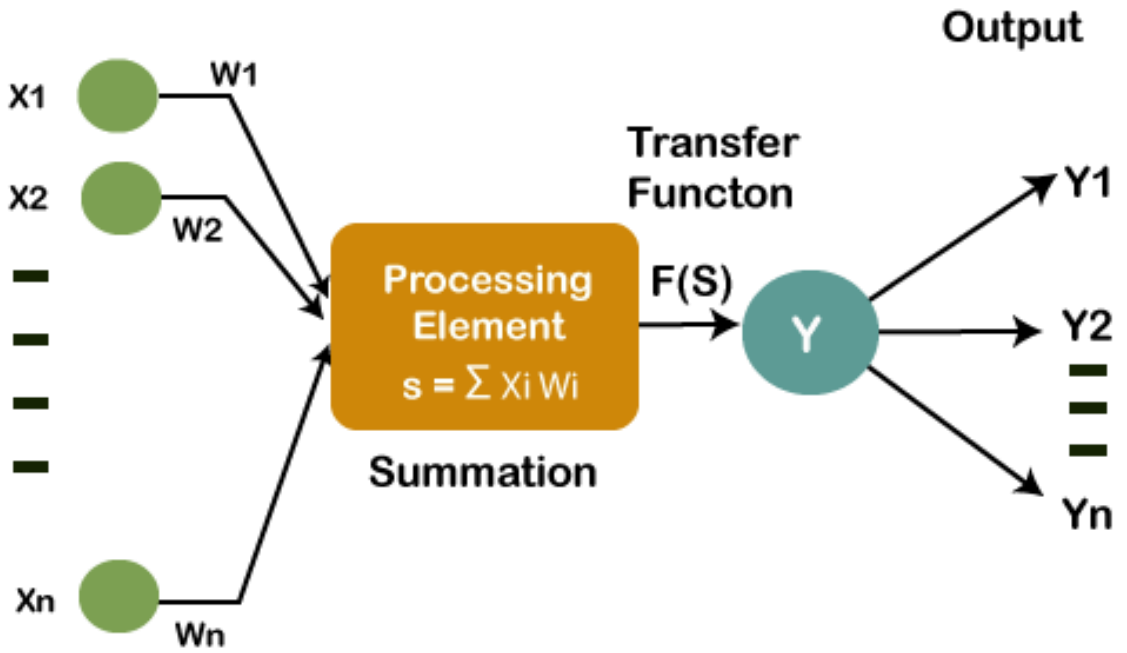
However, bias helps in the adjustment of the curve of activation function so as to accomplish a precise output.

- **Summation Function**

After the weights are assigned to the input, it then computes the product of each input and weights. Then the weighted sum is calculated by the summation function in which all of the products are added.

- **Activation Function**

The main objective of the activation function is to perform a mapping of a weighted sum upon the output. The transformation function comprises of activation functions such as tanh, ReLU, sigmoid, etc.



Afterward, each of the input is multiplied by its corresponding weights (these weights are the details utilized by the artificial neural networks to solve a specific problem). In general terms, these weights normally represent the strength of the interconnection between neurons inside the artificial neural network. All the weighted inputs are summarized inside the computing unit.
If the weighted sum is equal to zero, then bias is added to make the output non-zero or something else to scale up to the system's response. Bias has the same input, and weight equals to 1. Here the total of weighted inputs can be in the range of 0 to positive infinity. Here, to keep the response in the limits of the desired value, a certain maximum value is benchmarked, and the total of weighted inputs is passed through the activation function.

❑ What are the types of Artificial Neural Networks?

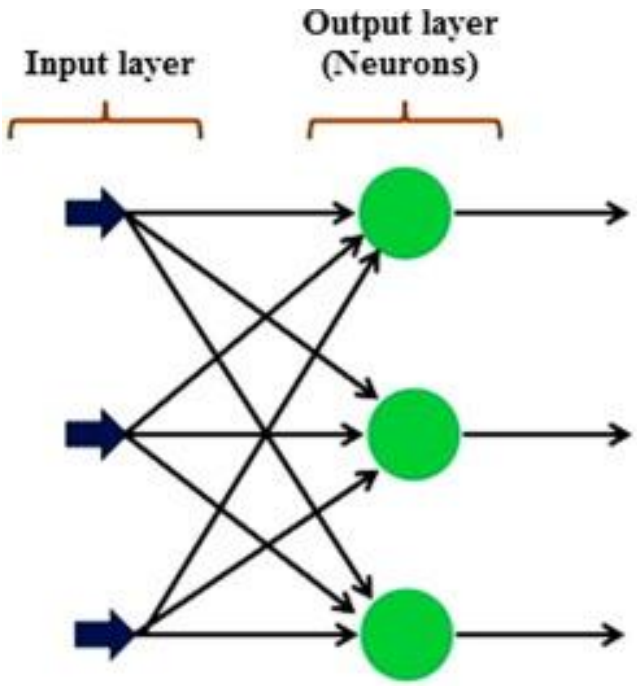
- Feedforward Neural Network
  - Single layer
  - Multi layer
- Convolutional Neural Network
- Modular Neural Network
- Radial basis function Neural Network
- Recurrent Neural Network

❑ Feedforward network:

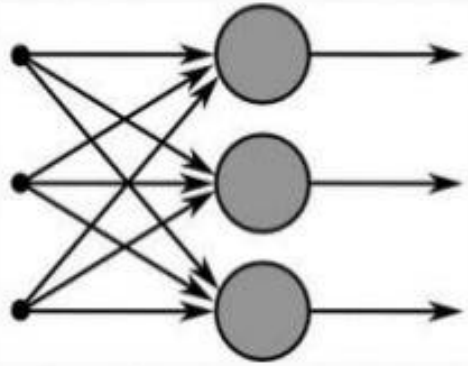
The advancement of layered feed-forward networks initiated in the late **1950s**, given by **Rosenblatt's** perceptron and **Widrow's** Adaptive linear Element (ADLINE).

✓ Single-layer feedforward network[SFFN]

Rosenblatt first constructed the single-layer feedforward network in the late 1950s and early 1990s. The concept of feedforward artificial neural network having just one weighted layer. In other words, we can say that the input layer is completely associated with the outer layer.

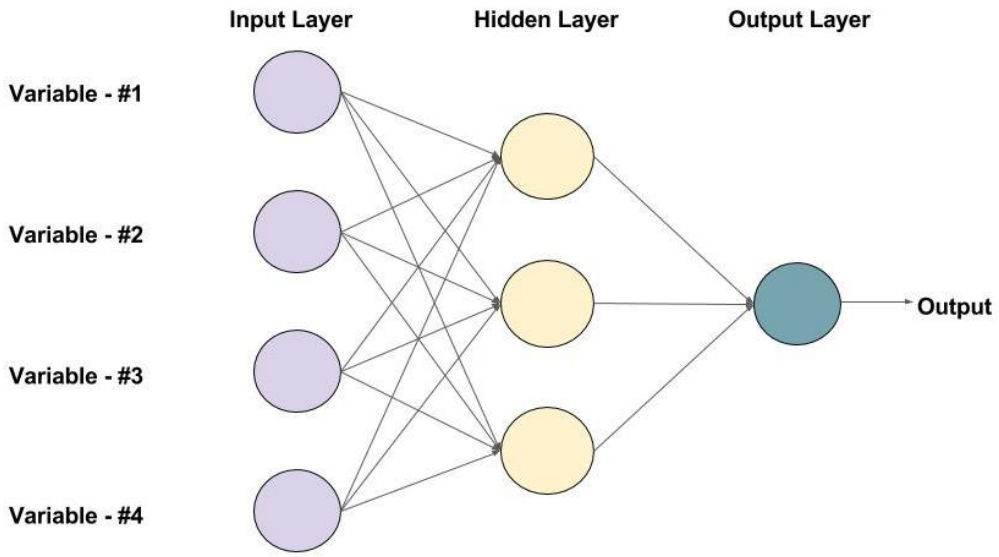


- Layer is formed by taking processing elements and combining it with other processing elements.
- Input and output are linked with each other
- Inputs are connected to the processing nodes with various weights, resulting in series of outputs one per node.

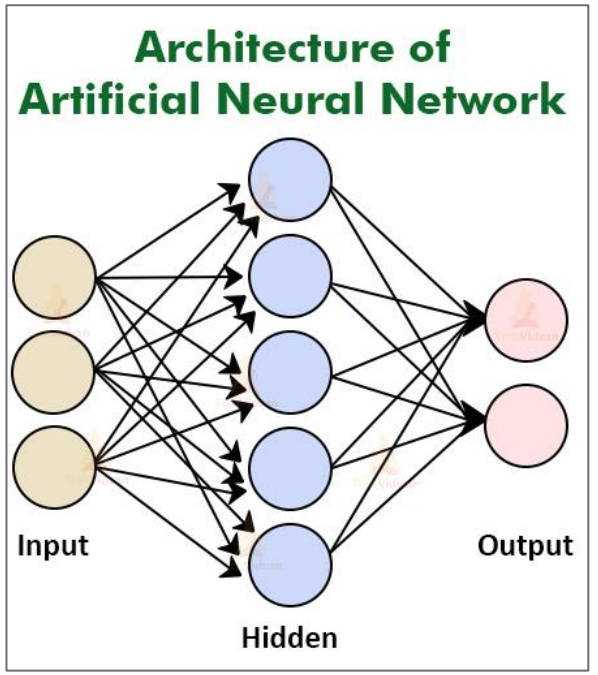


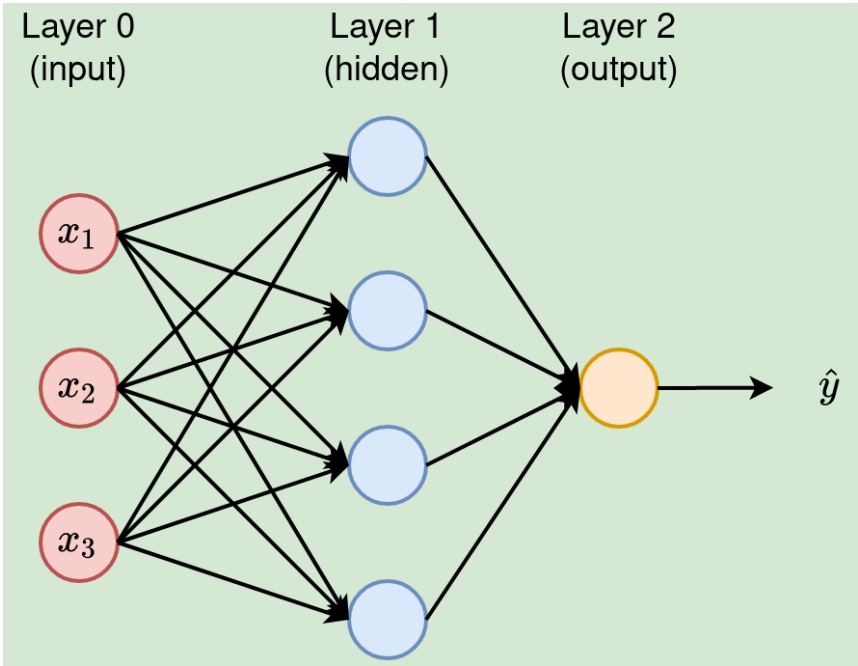
✓ Multilayer feedforward network [MFFN]

- ✓ A multilayer feedforward neural network is a linkage of perceptron in which information and calculations flow are uni-directional, from the input data to the outputs.
- ✓ The total number of layers in a neural network is the same as the total number of layers of perceptron.
- ✓ The easiest neural network is one with a single input layer and an output layer of perceptron.
- ✓ The concept of feedforward artificial neural network having more than one weighted layer. As the system has at least one layer between the input and the output layer, it is called the hidden layer.



An example of a Feed-forward Neural Network with one hidden layer (with 3 neurons)





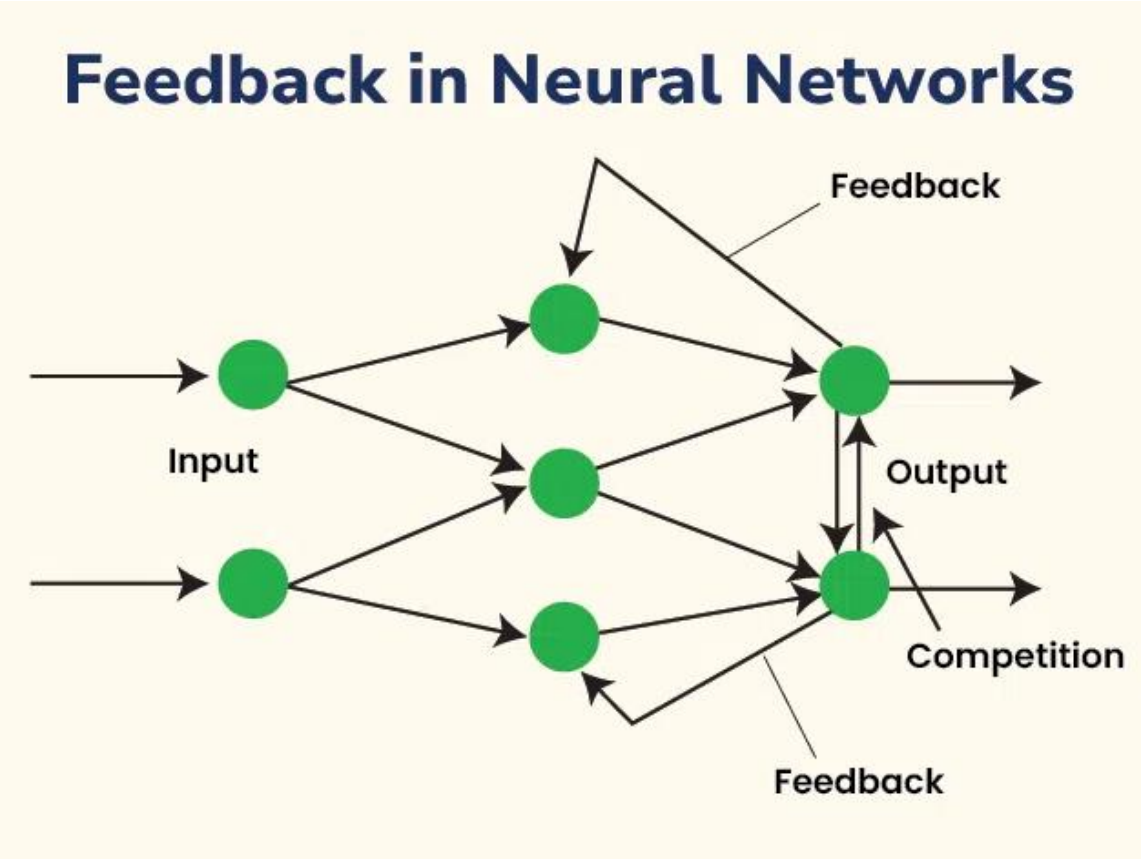
- **Feedback Neural Networks (RNNs)**: These networks have connections that loop back, allowing information to be fed back into the network. This structure enables them to handle sequential data and temporal dependencies, making them suitable for tasks like time series prediction and language modeling.

  Structure of Feedback Neural Networks

  Feedback neural networks, or RNNs, are characterized by their ability to maintain a state that captures information about previous inputs. This is achieved through recurrent connections that loop back from the output to the input of the same layer or previous layers.

The key components of an RNN include:

- **Input Layer**: Receives the input data.
- **Hidden Layers**: Contain neurons with recurrent connections that maintain a state over time.
- **Output Layer**: Produces the final output based on the processed information.



Types of Feedback Neural Networks (RNNs):

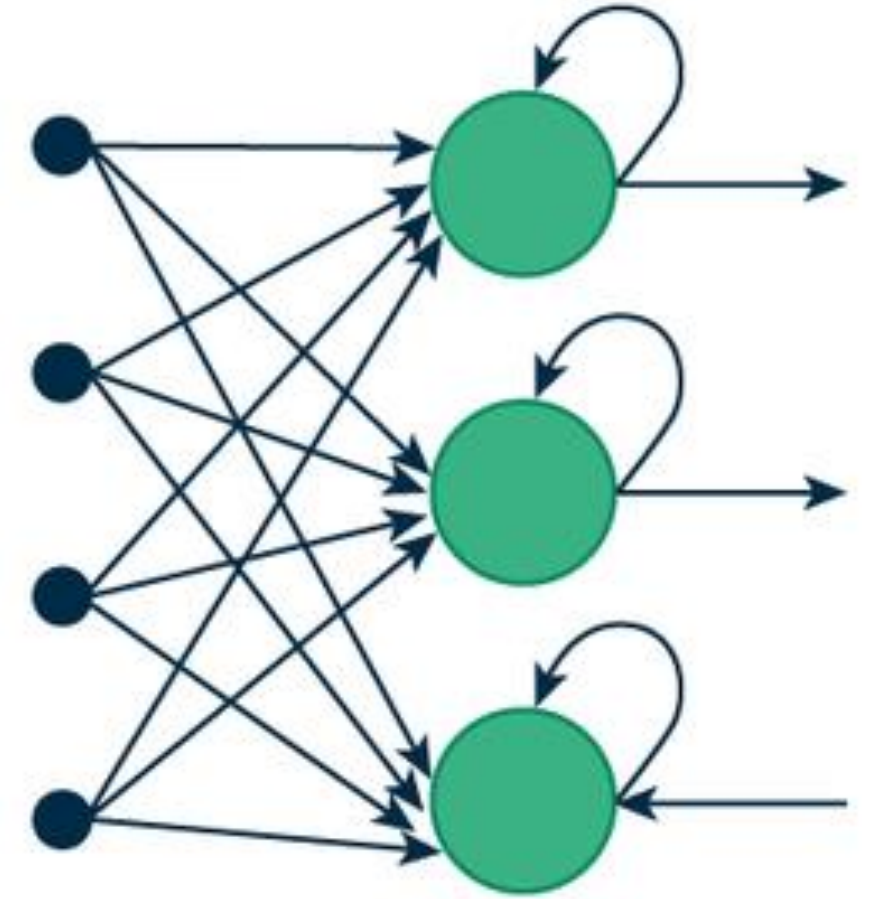
✓ Recurrent network:

The human brain is a recurrent neural network that refers to a network of neurons with feedback connections.

It can learn numerous behaviors, sequence, processing tasks algorithms, and programs that are not learnable by conventional learning techniques.

It explains the rapidly growing interest in artificial recurrent networks for technical applications.

For example, general computers that can learn algorithms to map input arrangements to output arrangements, with or without an instructor. They are computationally more dominant and biologically more conceivable than other adaptive methodologies.

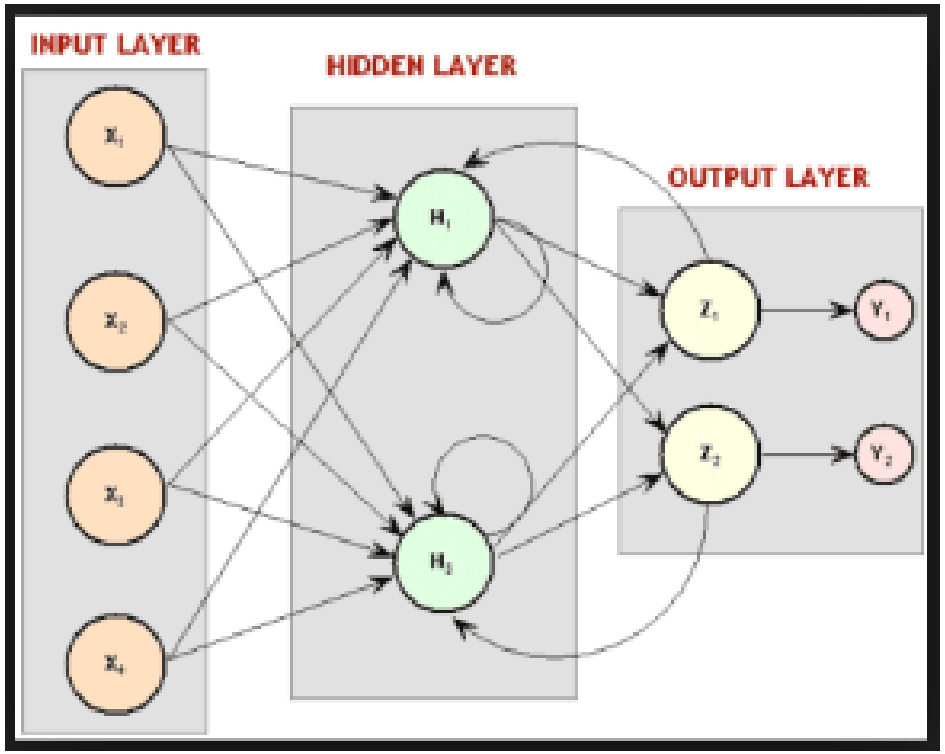


(a) Recurrent Neural Network

✓Fully recurrent network:

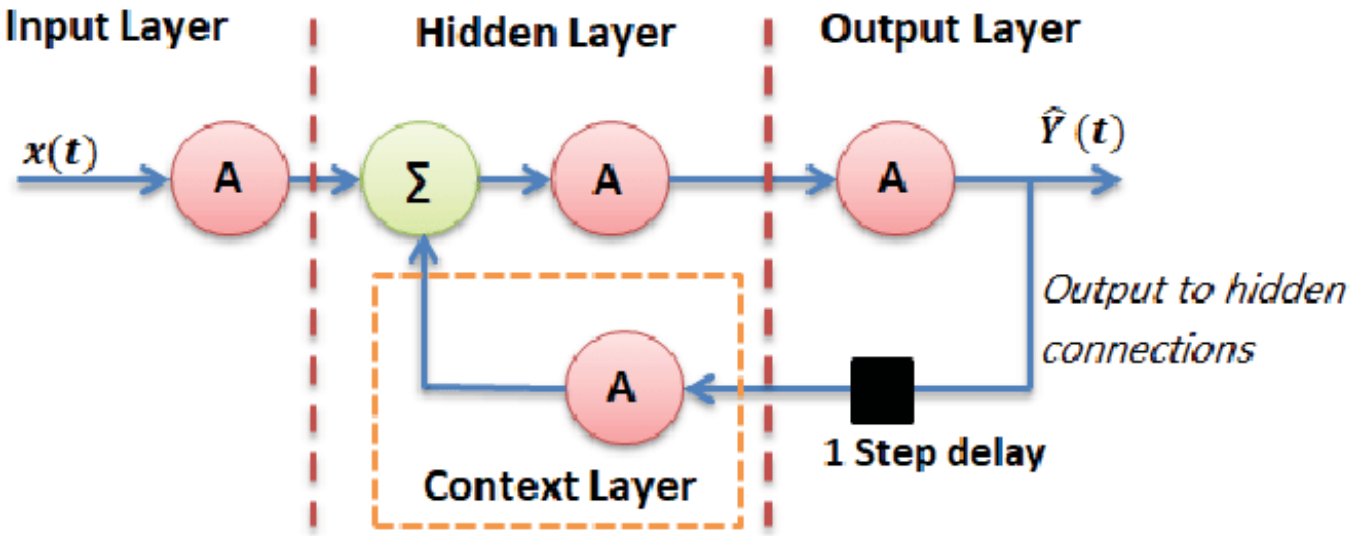
The most straightforward form of a fully recurrent neural network is a Multi-Layer Perceptron (MLP) with the previous set of hidden unit activations, feeding back along with the inputs.

In other words, it is the easiest neural network design because all nodes are associated with all other nodes with every single node work as both input and output.



✓Jordan network:

The Jordan network refers to a simple neural structure in which only one value of the process input signal (from the previous sampling) and only one value of the delayed output signal of the model (from the previous sampling) are utilized as the inputs of the network.

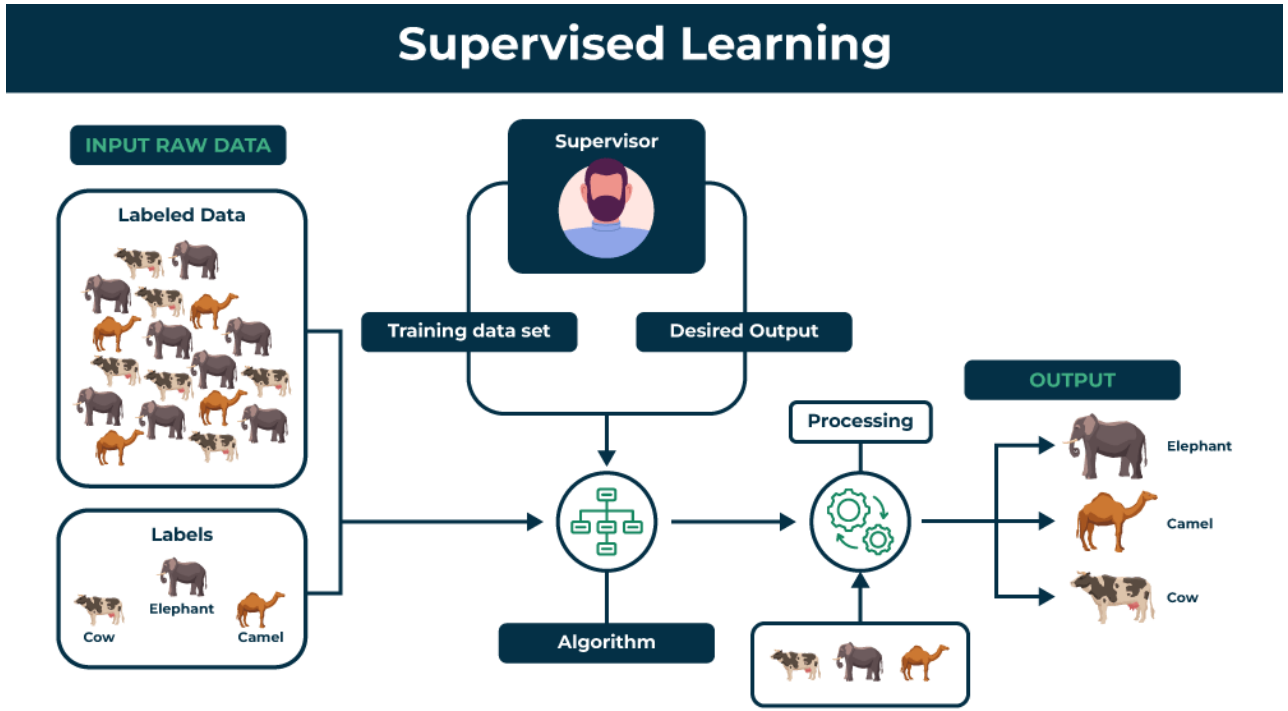


❑ Adjustments of Weights or Learning/ANN Learning Techniques

Learning in ANN is the technique for changing the weights of associations between the neurons of a specified network. Learning in artificial neural networks can be characterized into three different categories, namely **supervised learning, unsupervised learning, and reinforcement learning**.

✓Supervised learning:

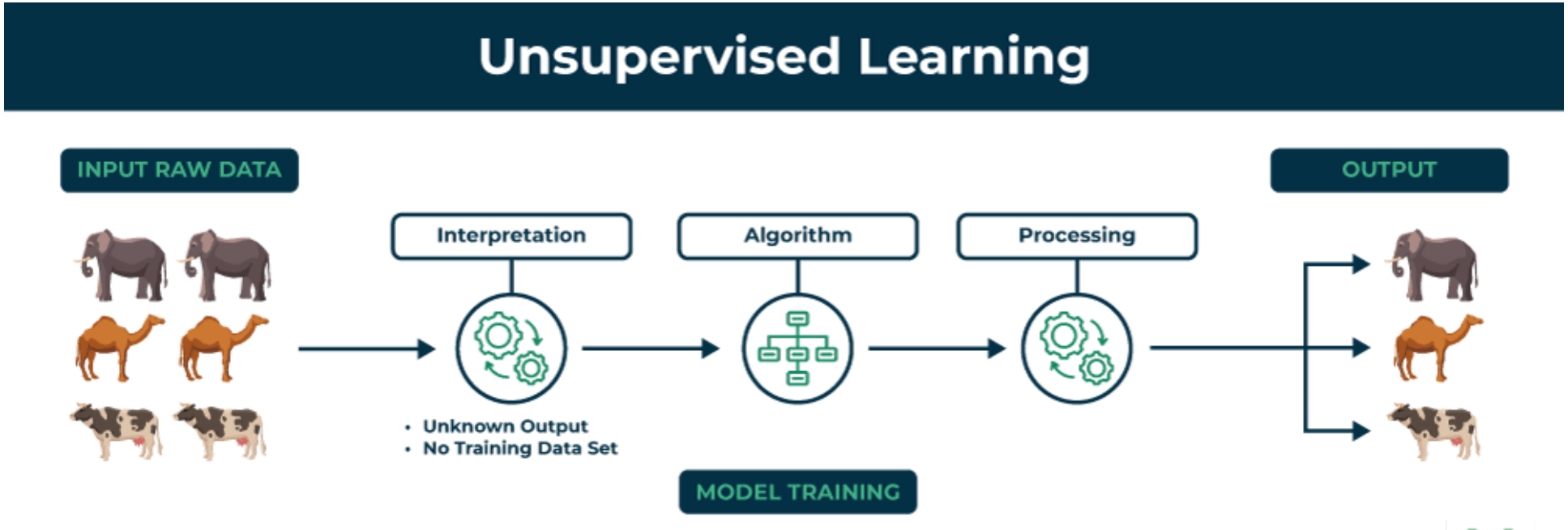
Supervised learning consists of two words supervised and learning. Supervise intends to guide. We have supervisors whose duty is to guide and show the way. We can see a similar case in the case of learning. Here the machine or program is learning with the help of the existing data set. We have a data set, and we assume the results of new data relying upon the behavior of the existing data sets.



It implies the existing data sets acts as a supervisor or boss to find the new data.

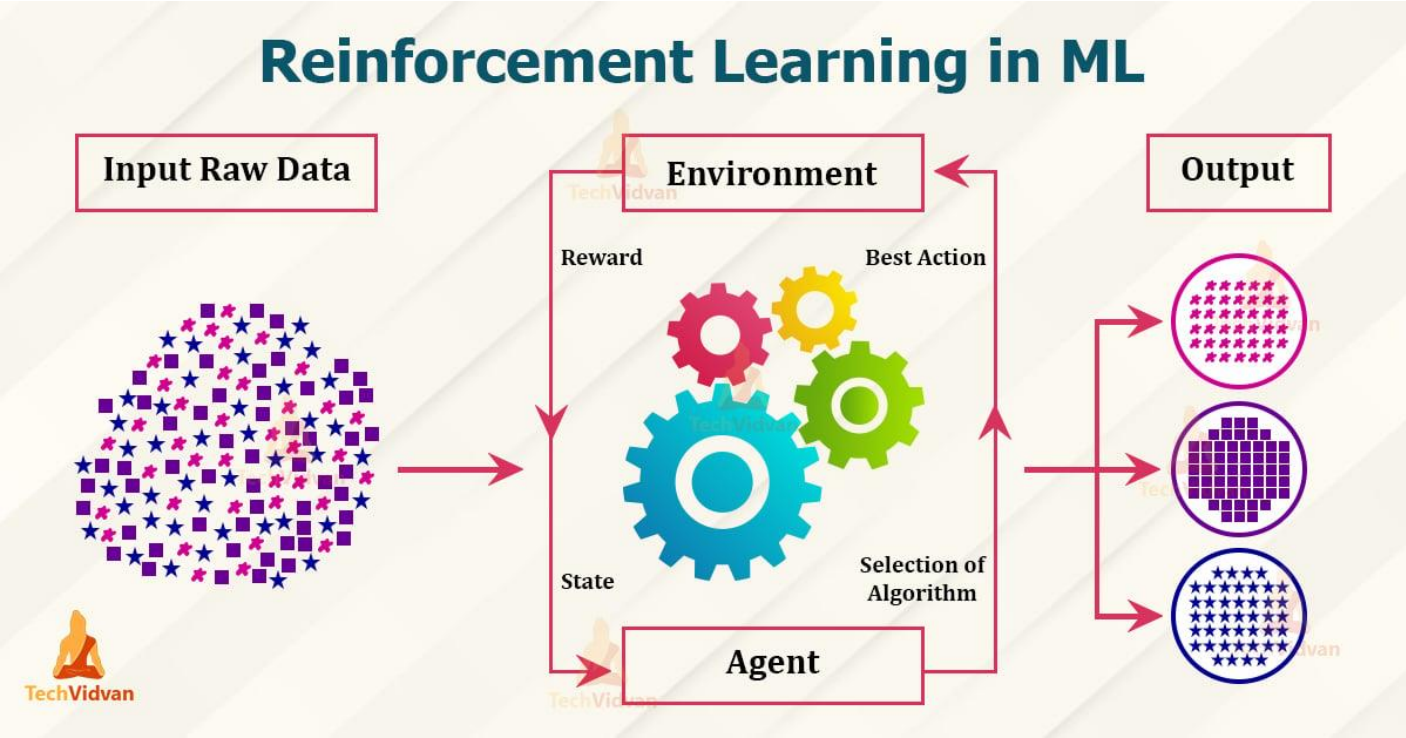
✓Unsupervised learning:

As the name suggests, unsupervised learning refers to predict something without any supervision or help from existing data. In this learning, the program learns by dividing the data with similar characteristics into similar groups. In supervised learning, the data are grouped, relying upon similar characteristics. In this situation, there are no existing data to look for direction. In other words, there is no supervisor. During the training of the artificial neural network under unsupervised learning, the input vectors of a comparative type are joined to form clusters. At the point when a new input pattern is implemented, then the neural network gives an output response showing the class to which the input pattern belongs. There is no feedback from the environment about what should be the ideal output and if it is either correct or incorrect. Consequently, in this type of learning, the network itself must find the patterns and features from the input data and the connection for the input data over the output.

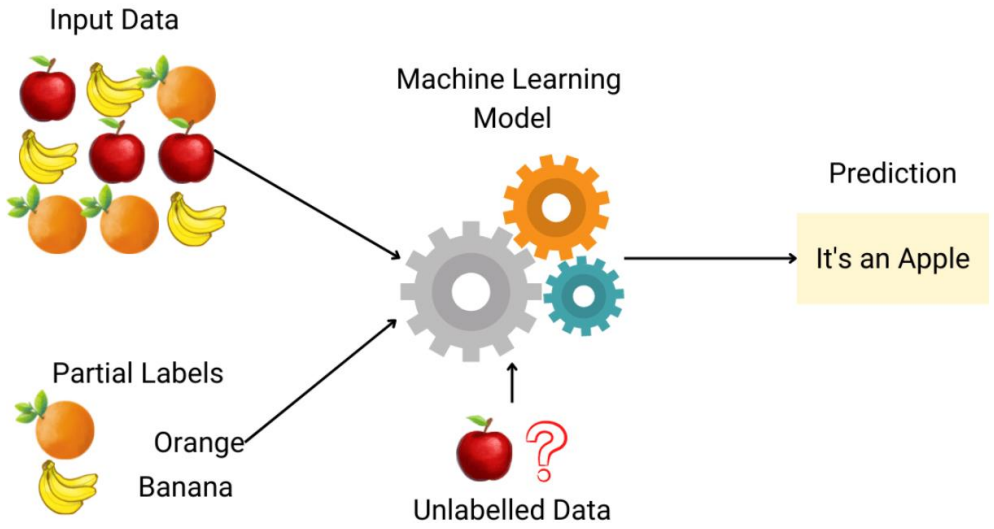


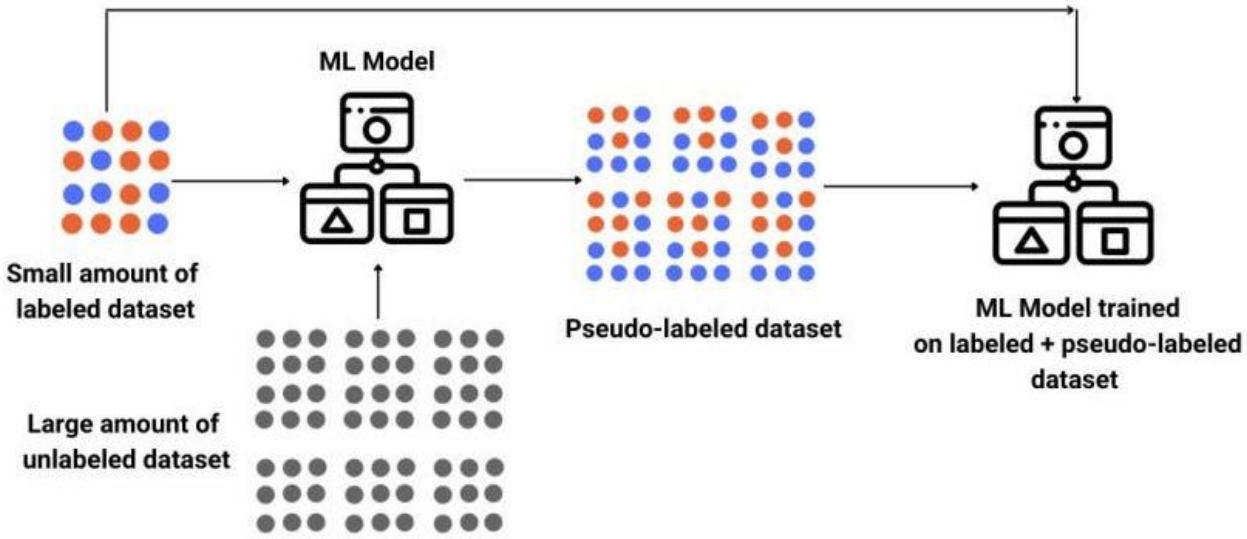
✓ Reinforcement learning:

Reinforcement Learning (RL) is a technique that helps to solve control optimization issues. By using control optimization, we can recognize the best action in each state visited by the system in order to optimize some objective function. Typically, reinforcement learning comes into existence when the system has a huge number of states and has a complex stochastic structure, which is not responsible to closed-form analysis. If issues have a relatively small number of states, then the random structure is relatively simple, so that one can utilize dynamic programming.



✓ Semi-Supervised Learning in ML





Semi-supervised learning is a type of machine learning that falls in between supervised and unsupervised learning. It is a method that uses a small amount of labeled data and a large amount of unlabeled data to train a model. The goal of semi-supervised learning is to learn a function that can accurately predict the output variable based on the input variables, similar to supervised learning. However, unlike supervised learning, the algorithm is trained on a dataset that contains both labeled and unlabeled data.

Semi-supervised learning is particularly useful when there is a large amount of unlabeled data available, but it's too expensive or difficult to label all of it.

Criteria	Supervised Learning	Unsupervised Learning	Reinforcement Learning
Input Data	Input data is labelled.	Input data is not labelled.	Input data is not predefined.
Problem	Learn pattern of inputs and their labels.	Divide data into classes.	Find the best reward between a start and an end state.
Solution	Finds a mapping equation on input data and its labels.	Finds similar features in input data to classify it into classes.	Maximizes reward by assessing the results of state-action pairs
Model Building	Model is built and trained prior to testing.	Model is built and trained prior to testing.	The model is trained and tested simultaneously.
Applications	Deal with regression and classification problems.	Deals with clustering and associative rule mining problems.	Deals with exploration and exploitation problems.
Algorithms Used	Decision trees, linear regression, K-nearest neighbors	K-means clustering, k-medoids clustering, agglomerative clustering	Q-learning, SARSA, Deep Q Network
Examples	Image detection, Population growth prediction	Customer segmentation, feature elicitation, targeted marketing, etc	Drive-less cars, self-navigating vacuum cleaners, etc

❑ Applications of Artificial Neural Networks

1.Social Media: Artificial Neural Networks are used heavily in Social Media. For example, let's take the **'People you may know'** feature on Facebook that suggests people that you might know in real life so that you can send them friend requests.
2.Marketing and Sales: When you log onto E-commerce sites like Amazon and Flipkart, they will recommend your products to buy based on your previous browsing history. This is true across all new-age marketing segments like Book sites, Movie services, Hospitality sites, etc. and it is done by implementing **personalized marketing**.
3.Healthcare: Artificial Neural Networks are used in Oncology to train algorithms that can identify cancerous tissue at the microscopic level at the same accuracy as trained physicians. Various rare diseases may manifest in physical characteristics and can be identified in their premature stages by using **Facial Analysis** on the patient photos.
4.Personal Assistants: I am sure you all have heard of Siri, Alexa, Cortana, etc., and also heard them based on the phones you have!!! These are personal assistants and an example of speech recognition that uses **Natural Language Processing** to interact with the users and formulate a response accordingly.
5.Speech Recognition: Speech recognition relies heavily on artificial neural networks (ANNs). Earlier speech recognition models used statistical models such as Hidden Markov Models. With the introduction of deep learning, several forms of neural networks have become the only way to acquire a precise classification.
6.Handwritten Character Recognition: ANNs are used to recognize handwritten characters. Handwritten characters can be in the form of letters or digits, and neural networks have been trained to recognize them.
7.Signature Classification: We employ artificial neural networks to recognize signatures and categorize them according to the person's class when developing these authentication systems. Furthermore, neural networks can determine whether or not a signature is genuine.