FUNDAMENTALS OF MACHINE LEARNING IN DATA SCIENCE

CSIS 3290

FUNDAMENTALS OF NEURAL NETWORKS

IN MACHINE LEARNING (1)

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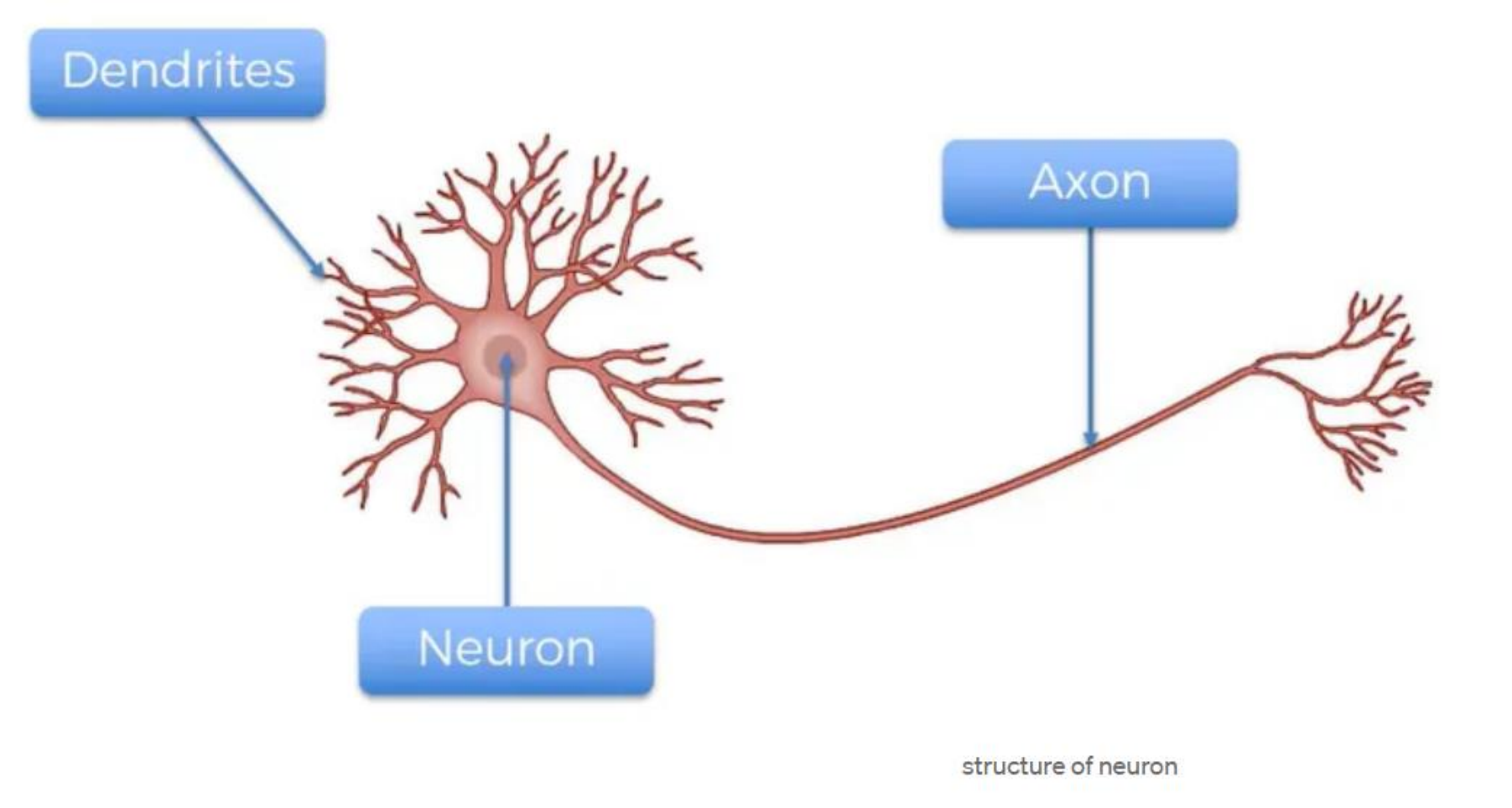
What is a Neuron

- Neuron is a basic building block of artificial neural networks. So just like humans, we are making neurons in machines to work in the same manner. A picture will help you to look at the human neural structure.
- Dendrites and axons help in transmitting and receiving signals.
- Now in a similar fashion, we can relate that how we can create the whole structure of a neuron into a machine learning algorithm.

What is a Neuron



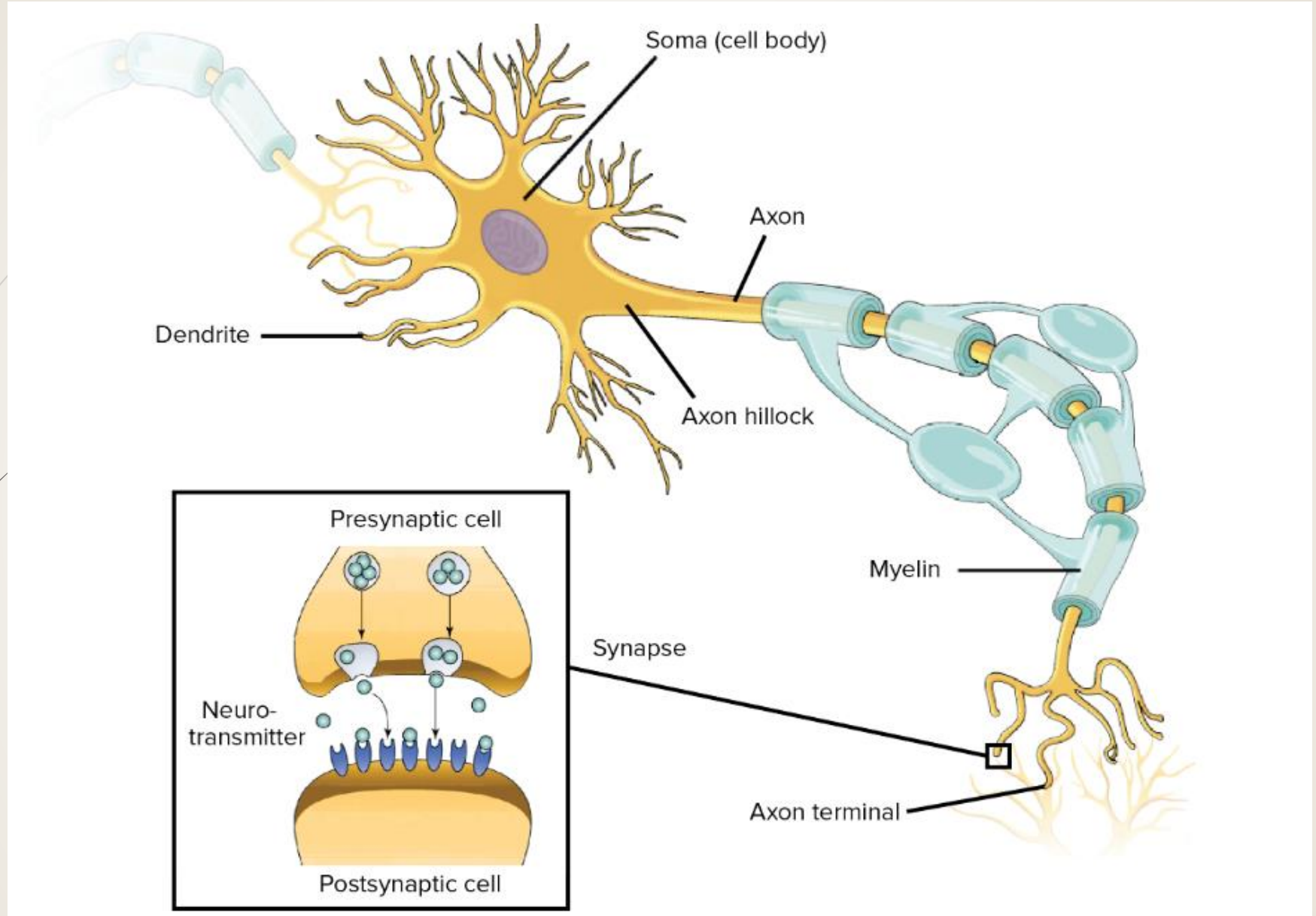
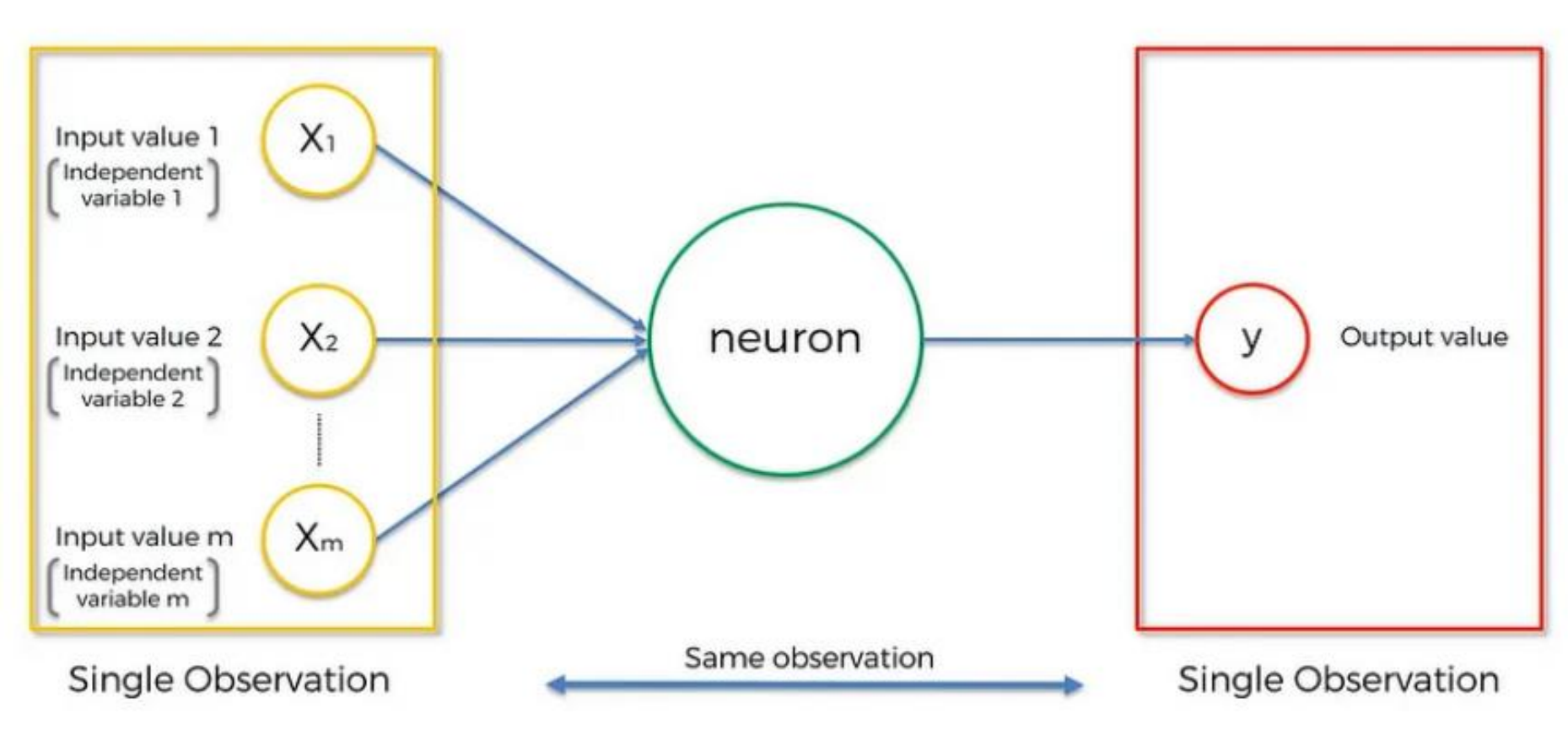


Image modified from "Neurons and glial cells: Figure 2" and "Synapse," by OpenStax College, Biology (CC BY 3.0).

A Neuron in Machine Learning

- So, we can see that if we further categorize individual elements, just like human neuron network structure, we can create a similar structure in the neural network of the machine.
- You can see input values (from 1 to m) are all neurons but dedicated to a particular layer (that is input layer) and transmission happens between a big neuron and input neurons with the help of a medium that is similar in humans which is a synapse.

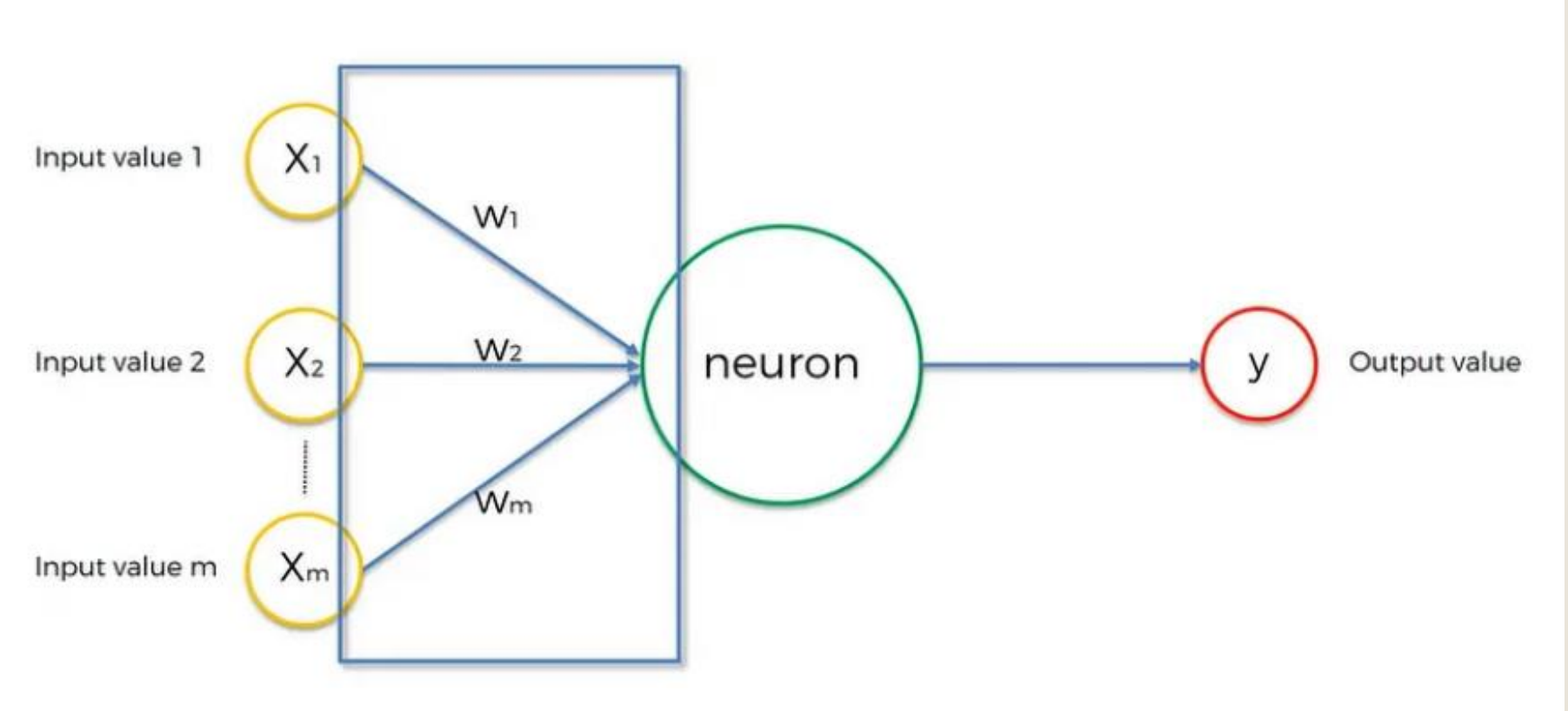
A Neuron in Machine Learning



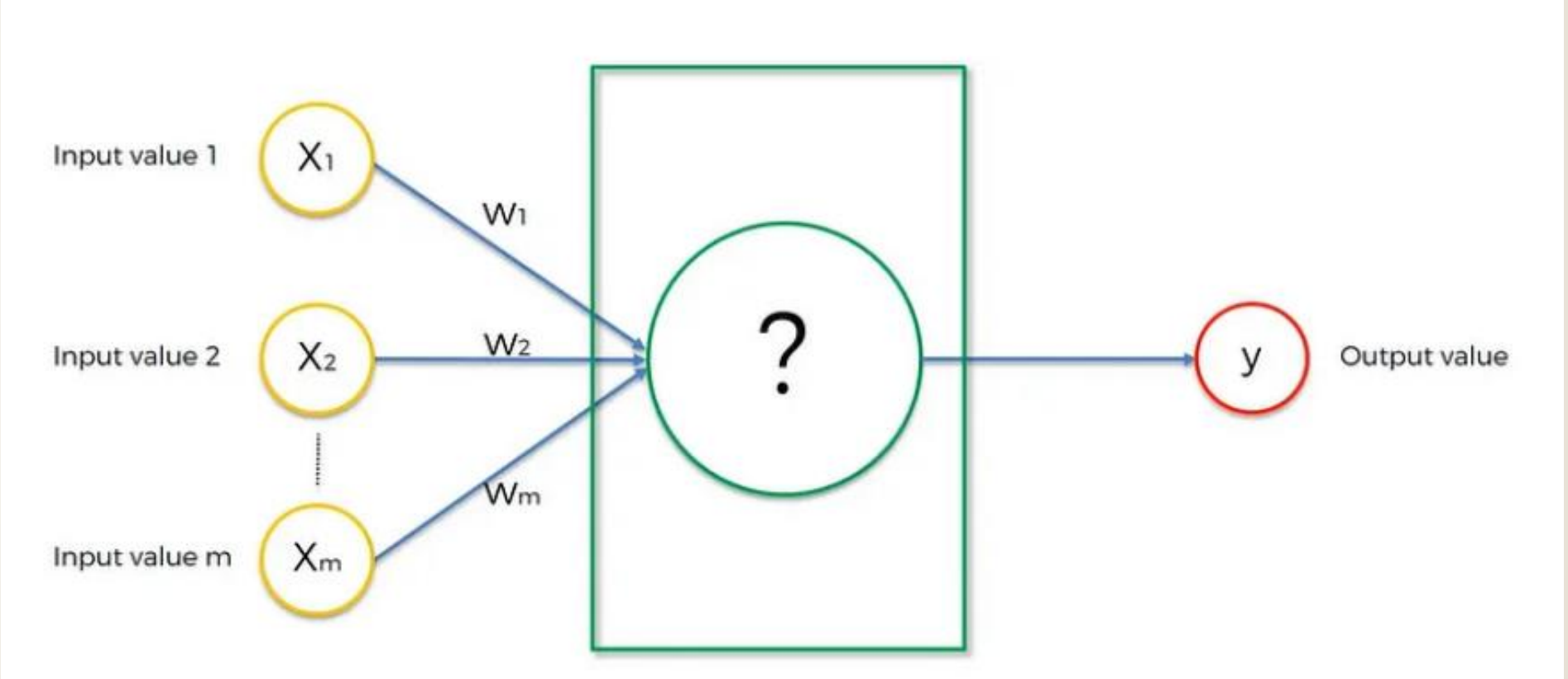
A Neuron in Machine Learning

- Now doing the deep analysis, the input layer is the layer of all the independent variables, the middle layer is the hidden layer and the last layer is the output layer (which will either give a single result or multiple results).
- With this, if we further add weights to the edges then it will help neural networks to learn. Basically, weights assigned to synapse helps to add the significance level of an individual independent variable or input layer neuron.
- So now we have added weights but **what is the significance of middle layer neurons?**

A Neuron in Machine Learning

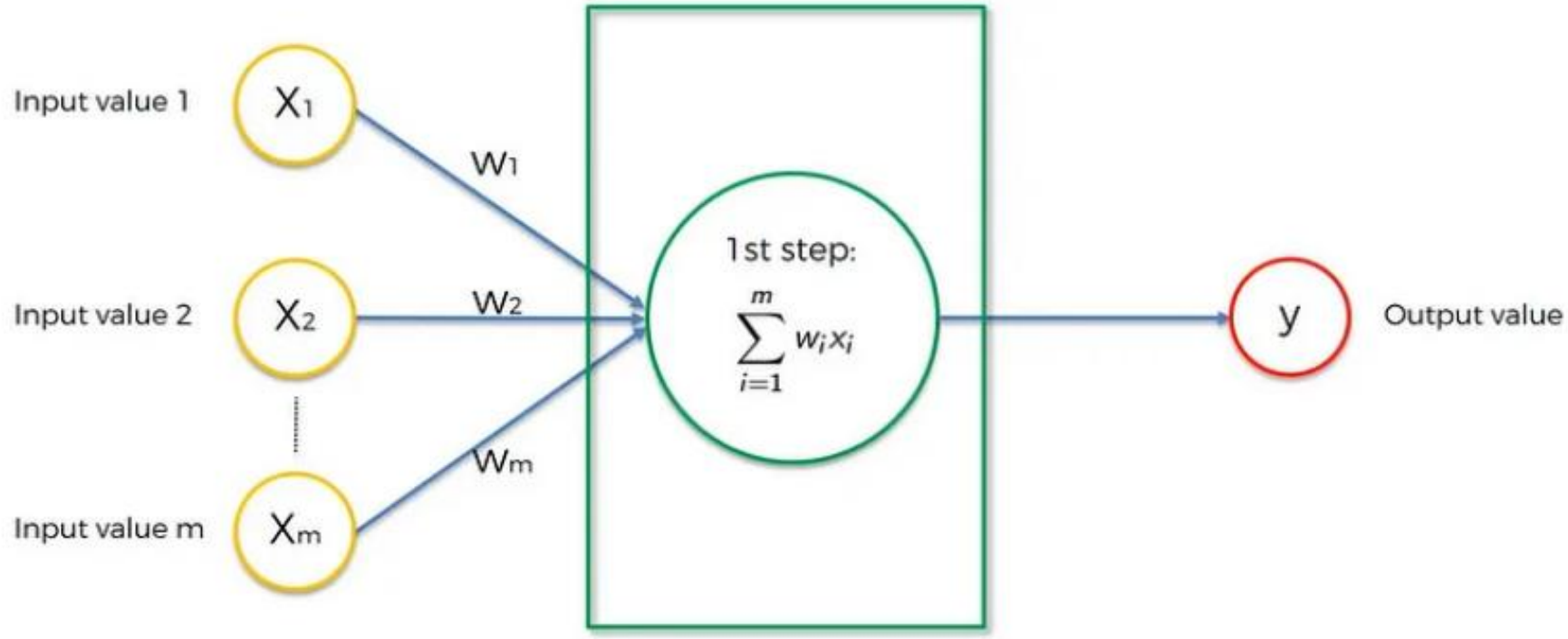


A Neuron in Machine Learning



Neural Networks

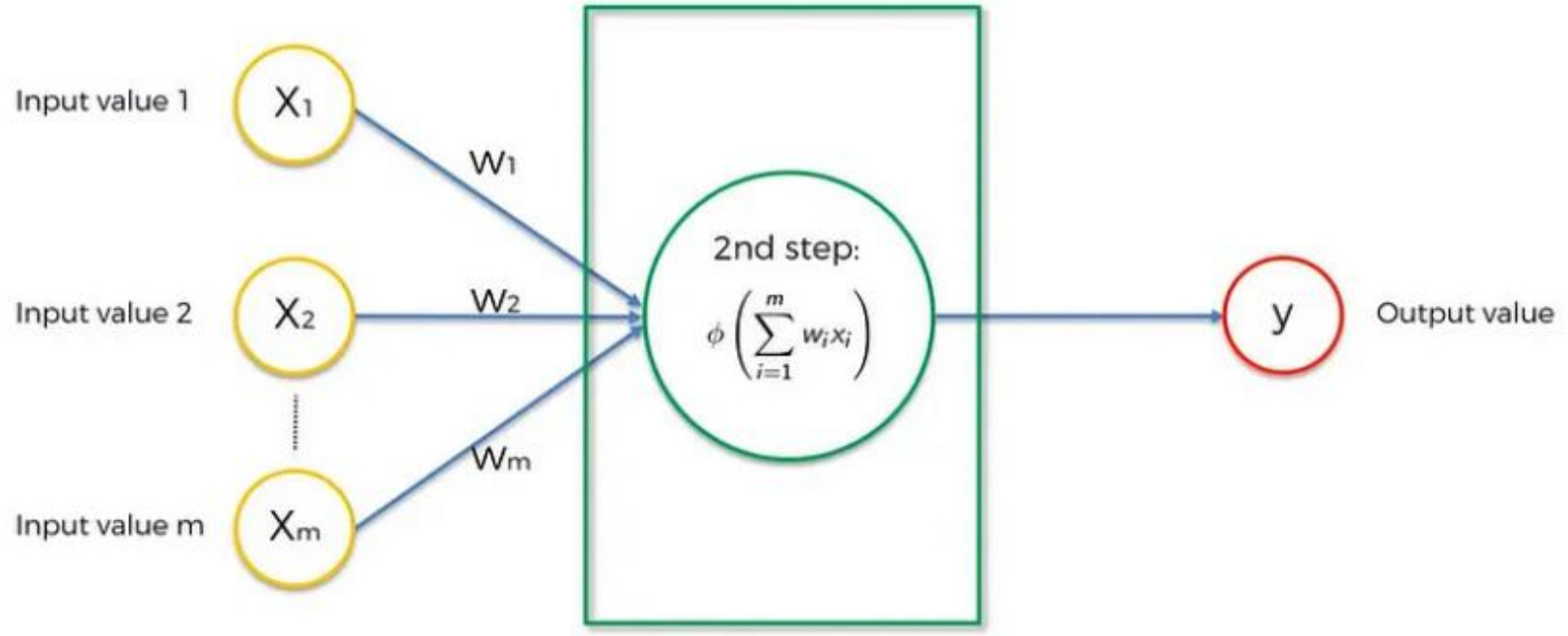
Step 1. Multiply all individual weights with there independent variables and do the summation.



Neural Networks

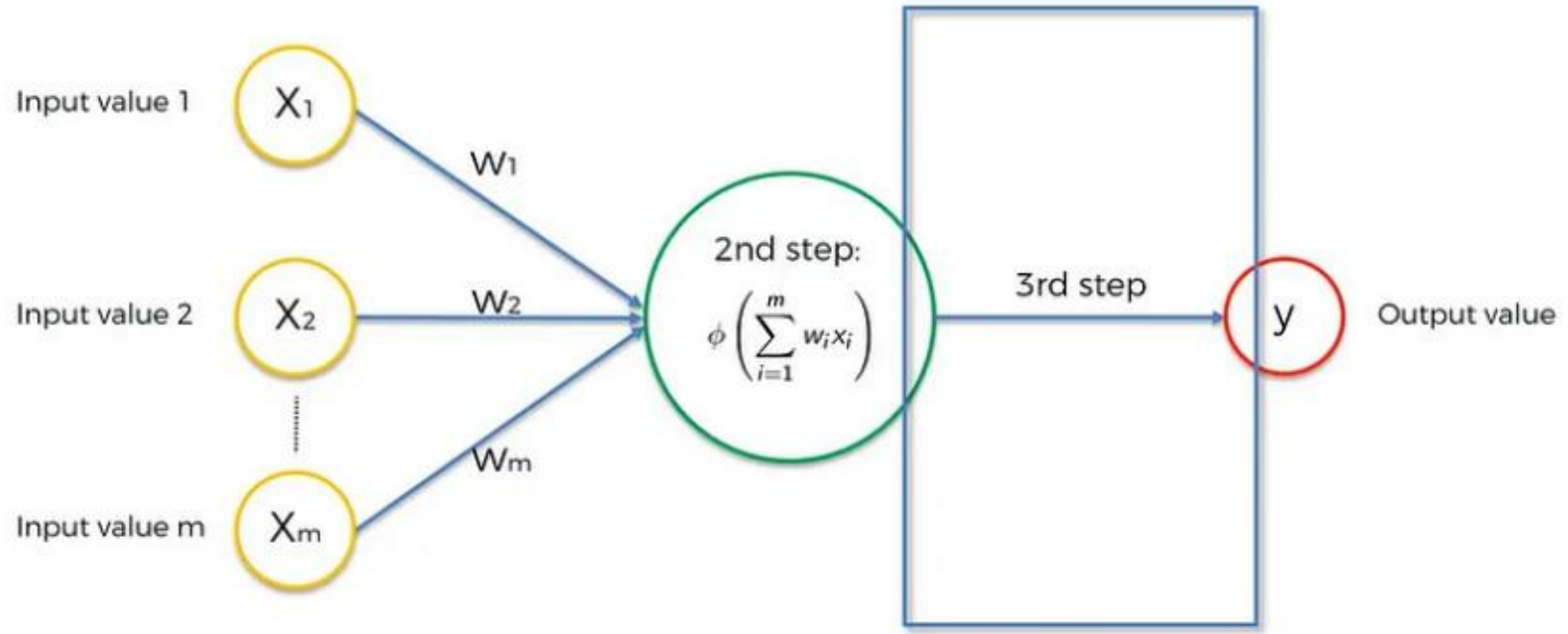
Activation Function plays a very important role in artificial neural networks. It basically helps to decide that a neuron is active or not.

Step 2. Now apply the activation function to this added sum. We will discuss the activation function in detail but now consider it a part of the neural network.



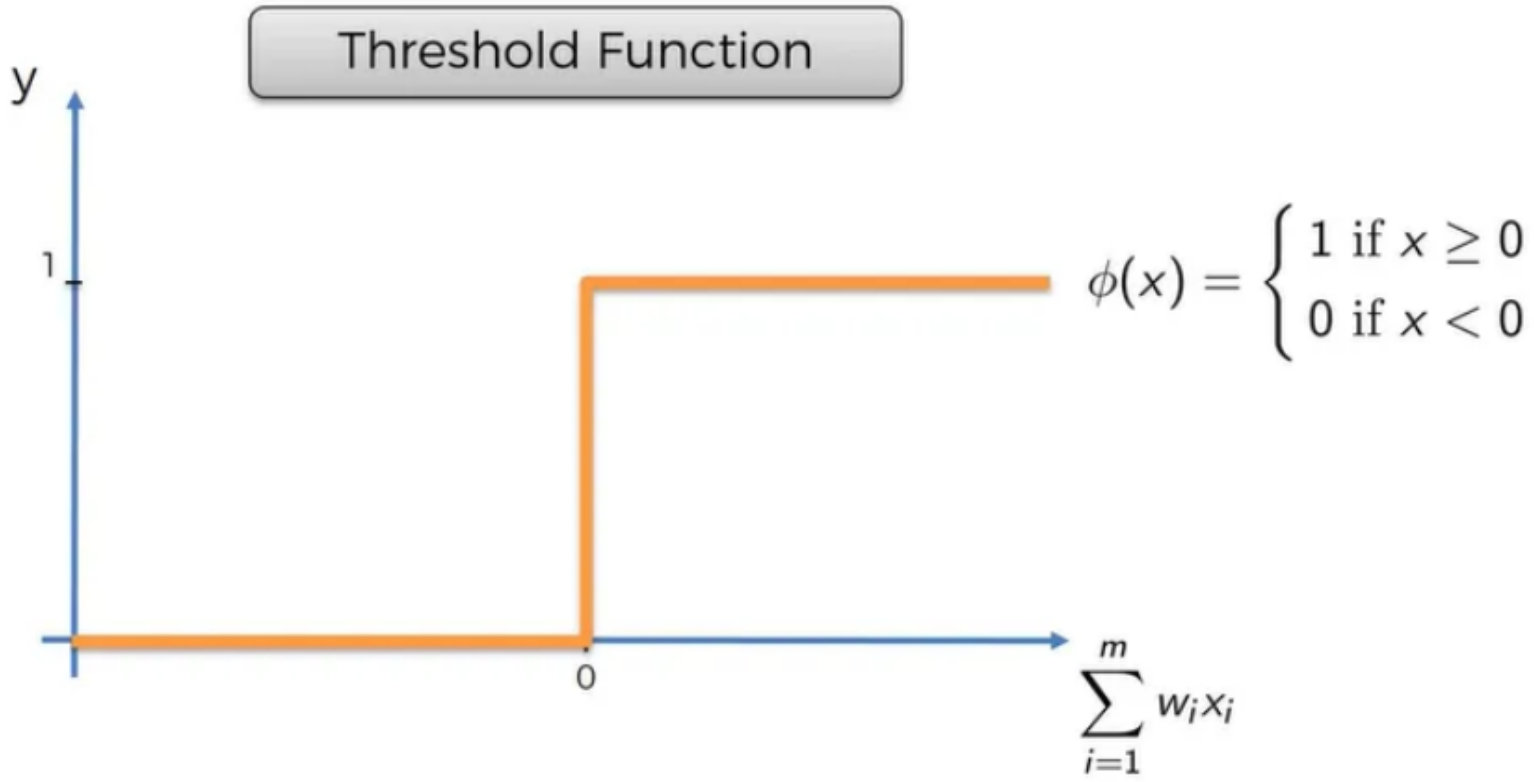
Neural Networks

Step 3. Now pass the result to the output neuron.



Types of the Activation Function

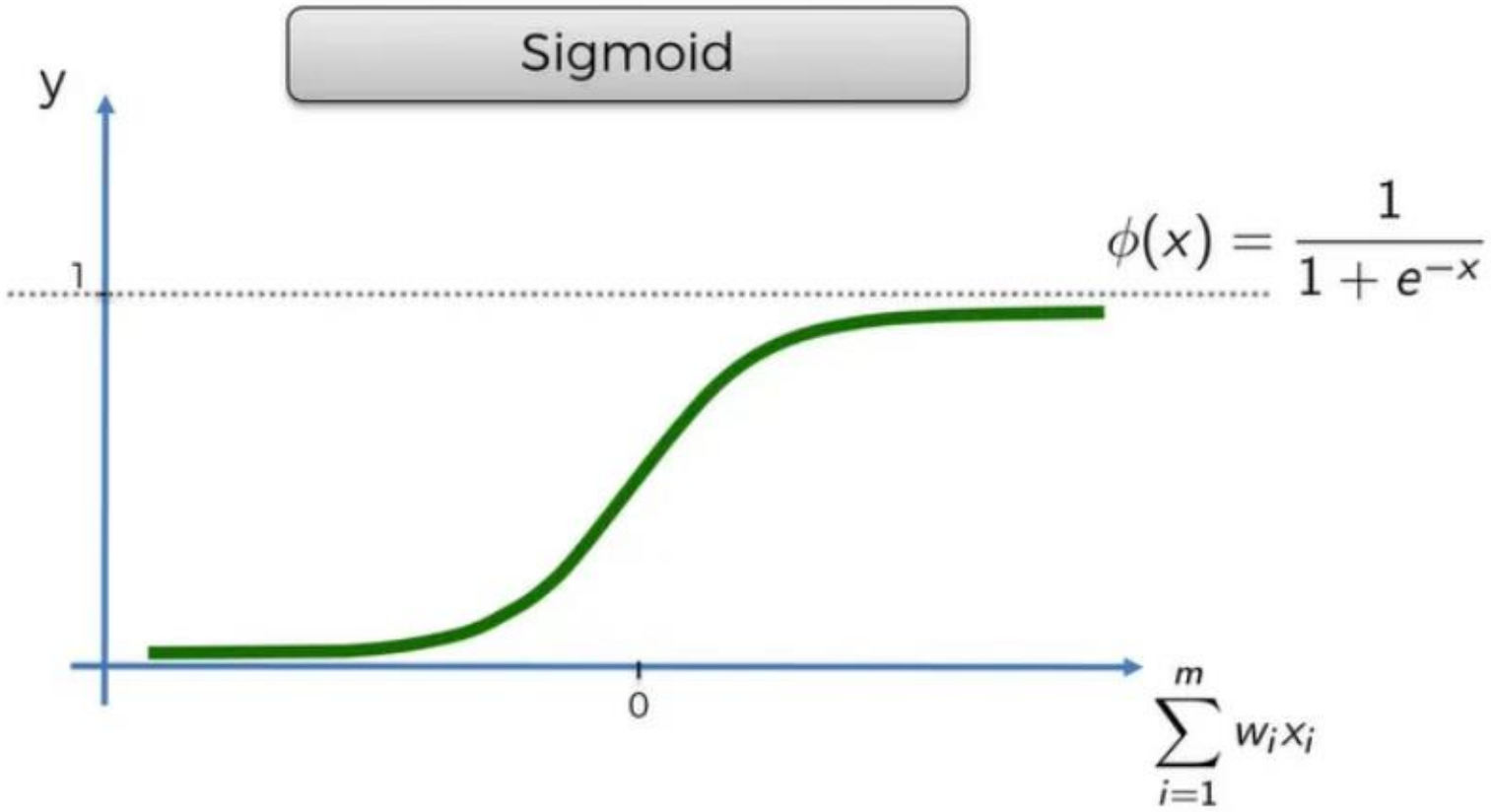
1. **Threshold Function:** This function may be defined as a yes or no function. Where 'x' is a threshold such that if 'x' is greater than equal to zero the value is 1 otherwise if the value of 'x' is negative value is 0.



Threshold Function

Types of the Activation Function

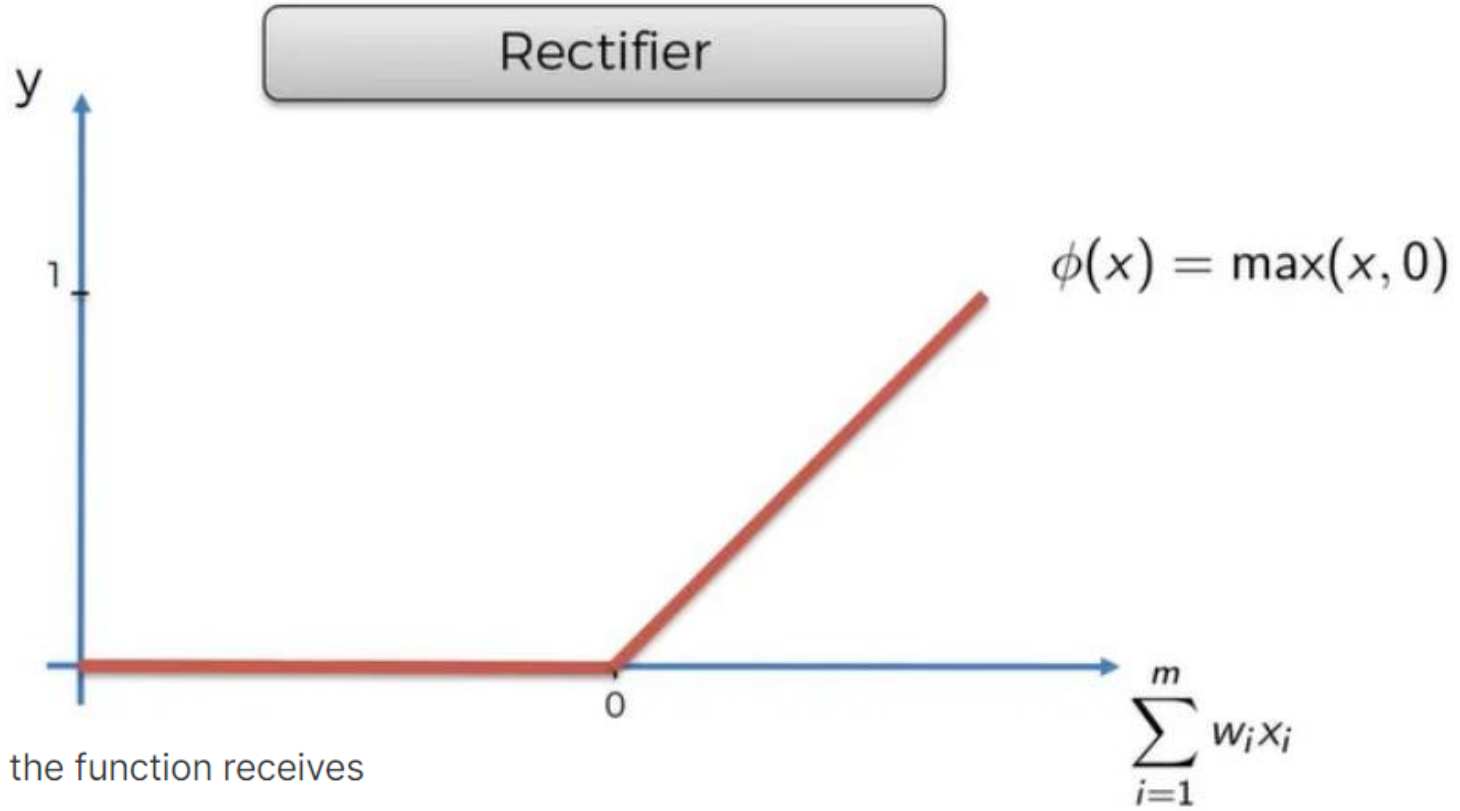
2. **Sigmoid Function:** This function may be defined as a probabilistic function, which helps to predict the probability of a specific value.



Types of the Activation Function

Leaky ReLU = f(x) = max(0.01*x, x)

3. **Rectifier Function:** Rectifier Function is the most widely used activation function which is chiefly implemented in the hidden layers. This function is better than the sigmoid function.

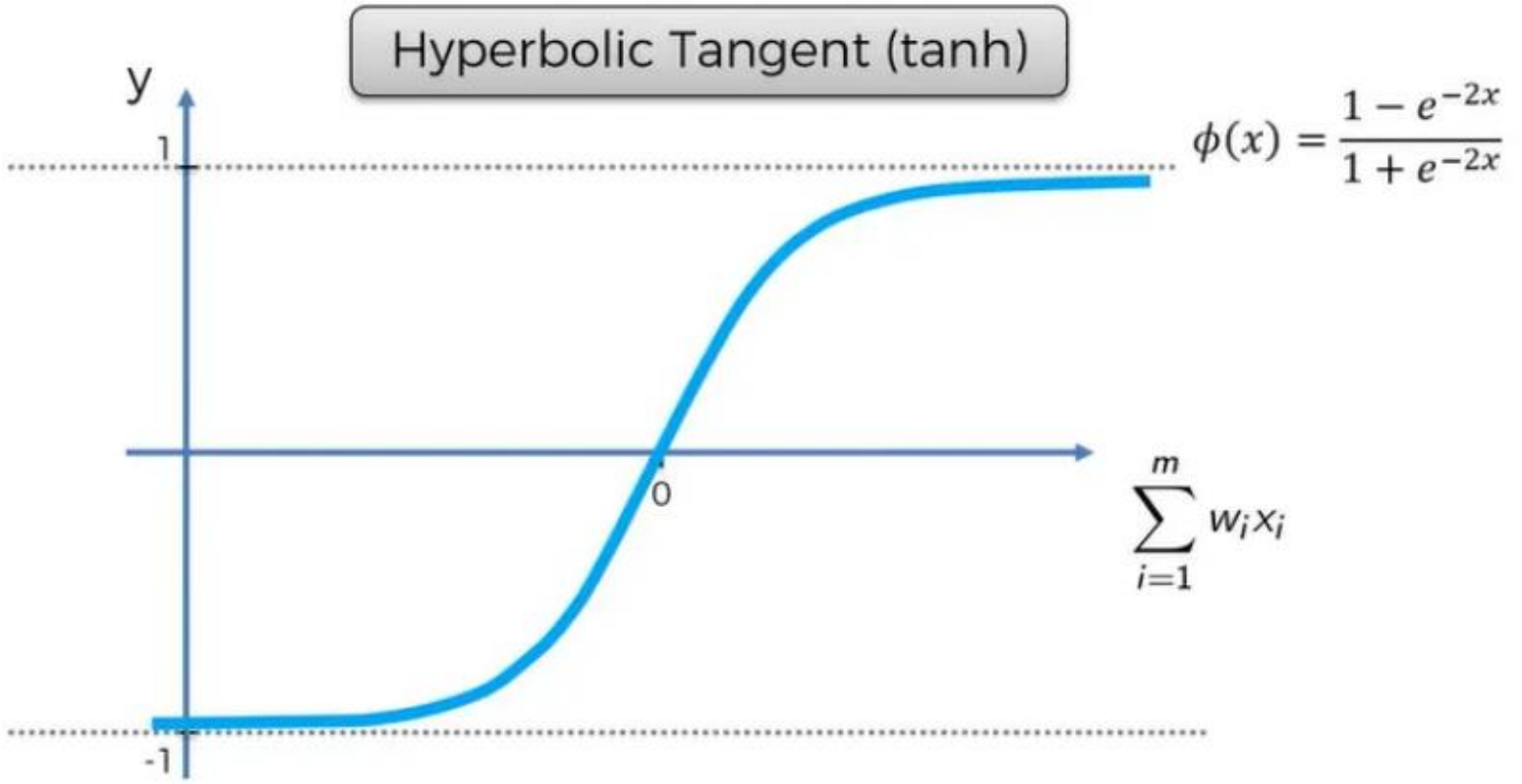


Both the ReLU function and its derivative are monotonic. If the function receives any negative input, it returns 0; however, if the function receives any positive value x, it returns that value. As a result, the output has a range of 0 to infinite.

https://deepchecks.com/glossary/rectified-linear-unit-relu/

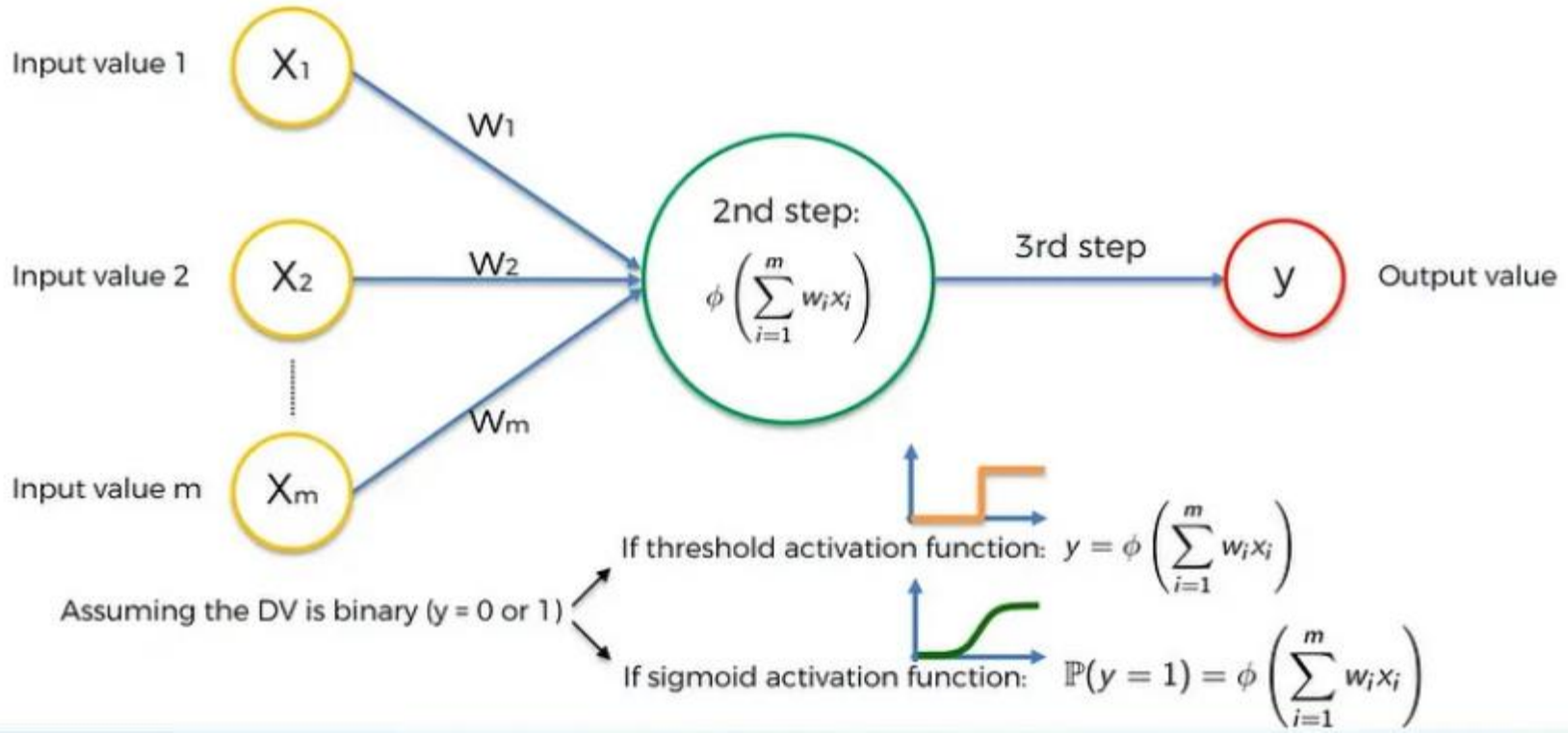
Types of the Activation Function

4. **Hyperbolic Tangent('tanh') Function:** Hyperbolic function is a modified version of the sigmoid function or we can say that better than sigmoid function.



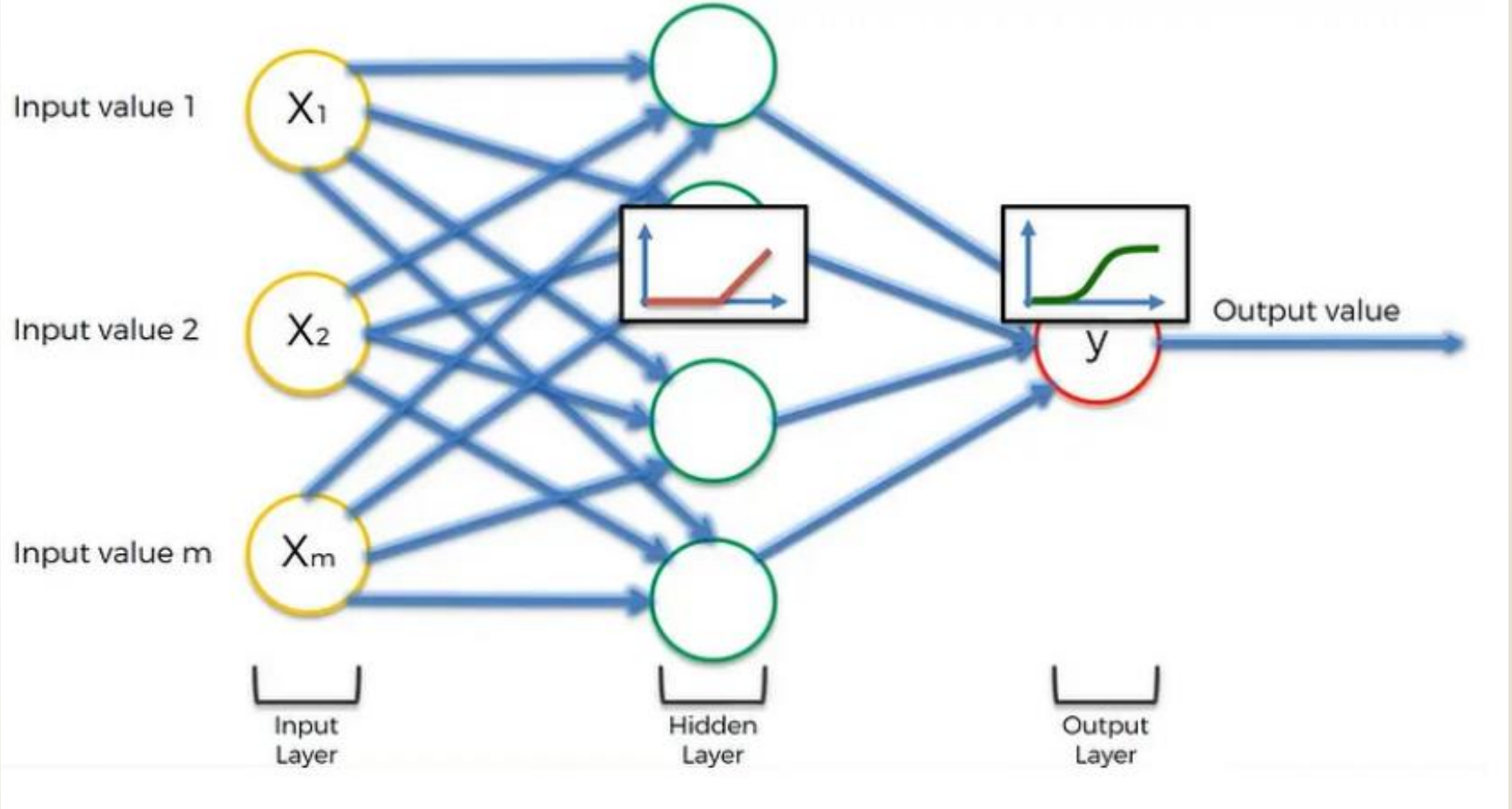
Activation Function

So the answer is we can either use the threshold function or sigmoid function.



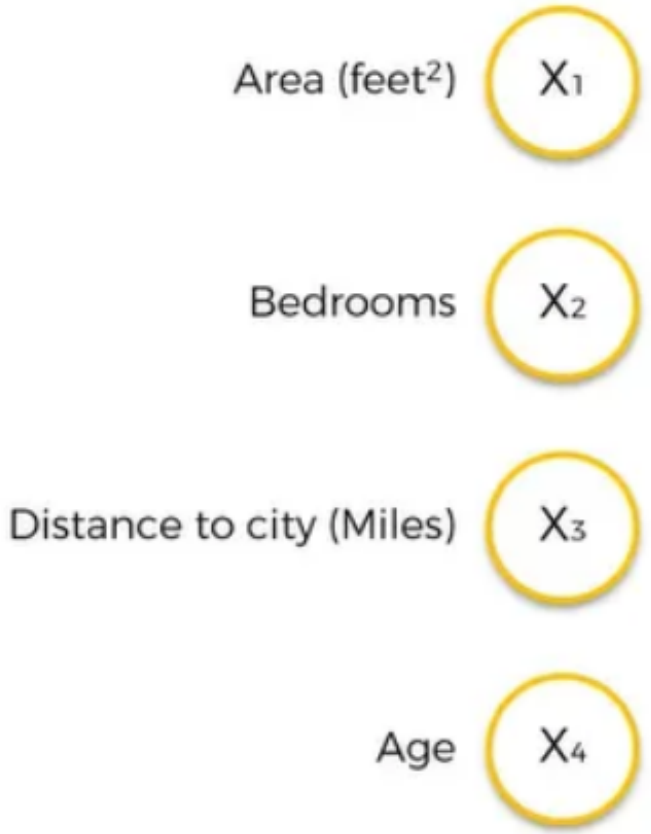
Activation Function

So, you can visualize our problem when we make a neural network where the middle layer contains the **rectifier** function and for the output layer, we can take either of the above-discussed functions for doing the binary prediction.



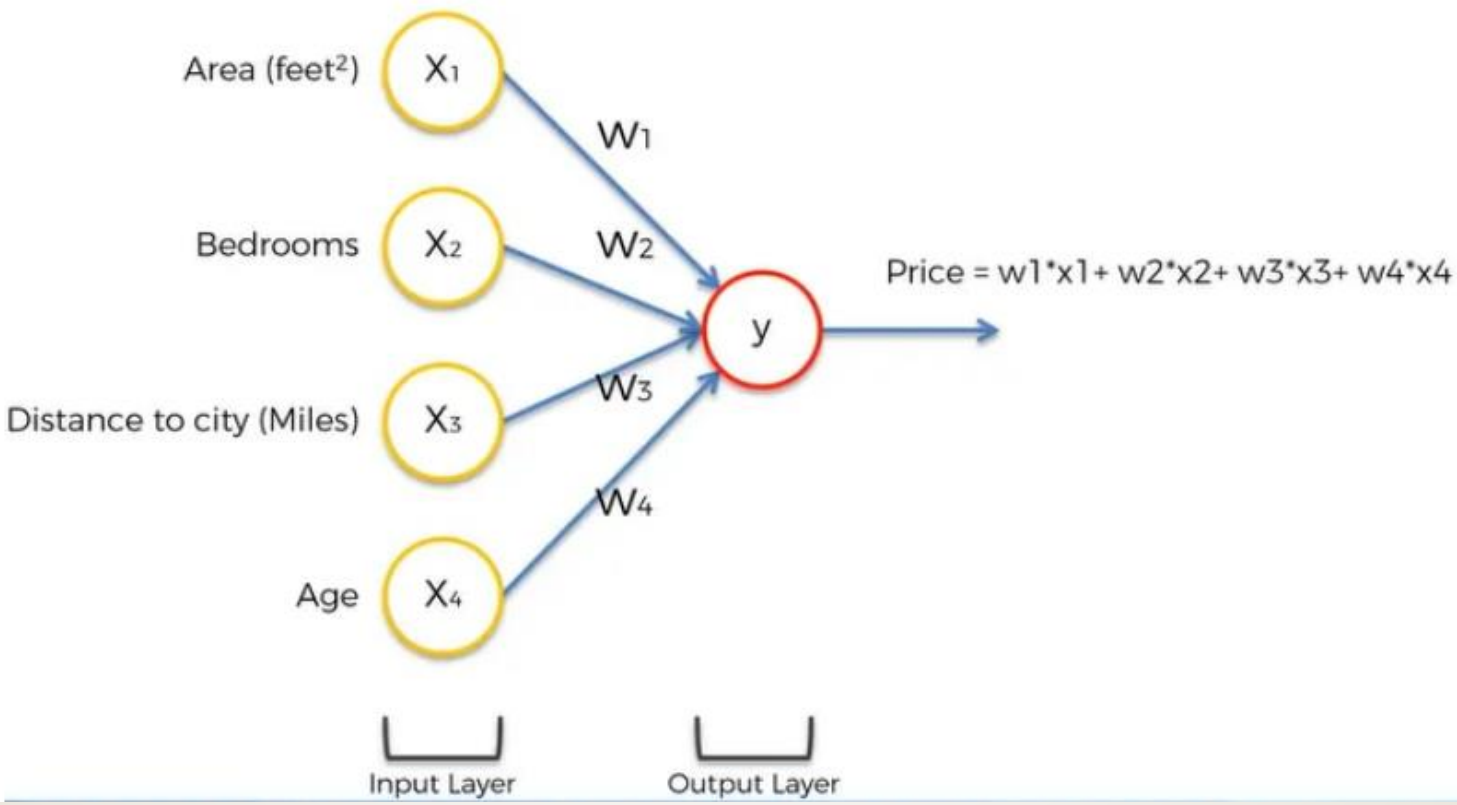
How do Neural Network Works?

So we want to predict the price of a property. So we are having various parameters to predict the property price.



How do Neural Network Works?

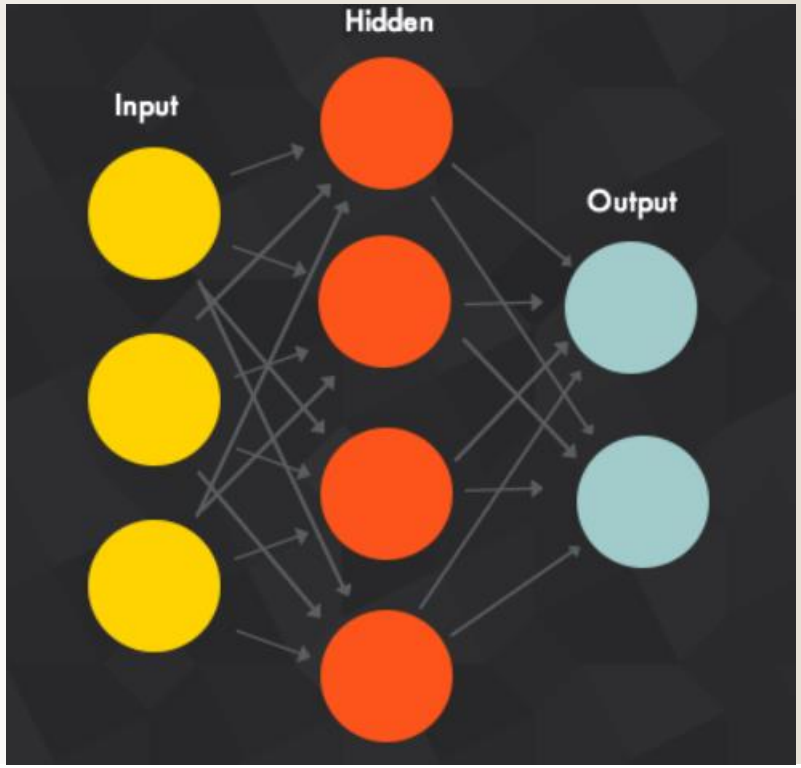
So previously we did the small calculation by calculating the price of with the summation of the multiplied weights and attributes. So, this is a basic approach.



Now in order to increase the accuracy and learning ability, we need to add an extra layer that is a hidden layer which is the backbone of the neural network.

https://datascience.stackexchange.com/questions/14028/what-is-the-purpose-of-multiple-neurons-in-a-hidden-layer

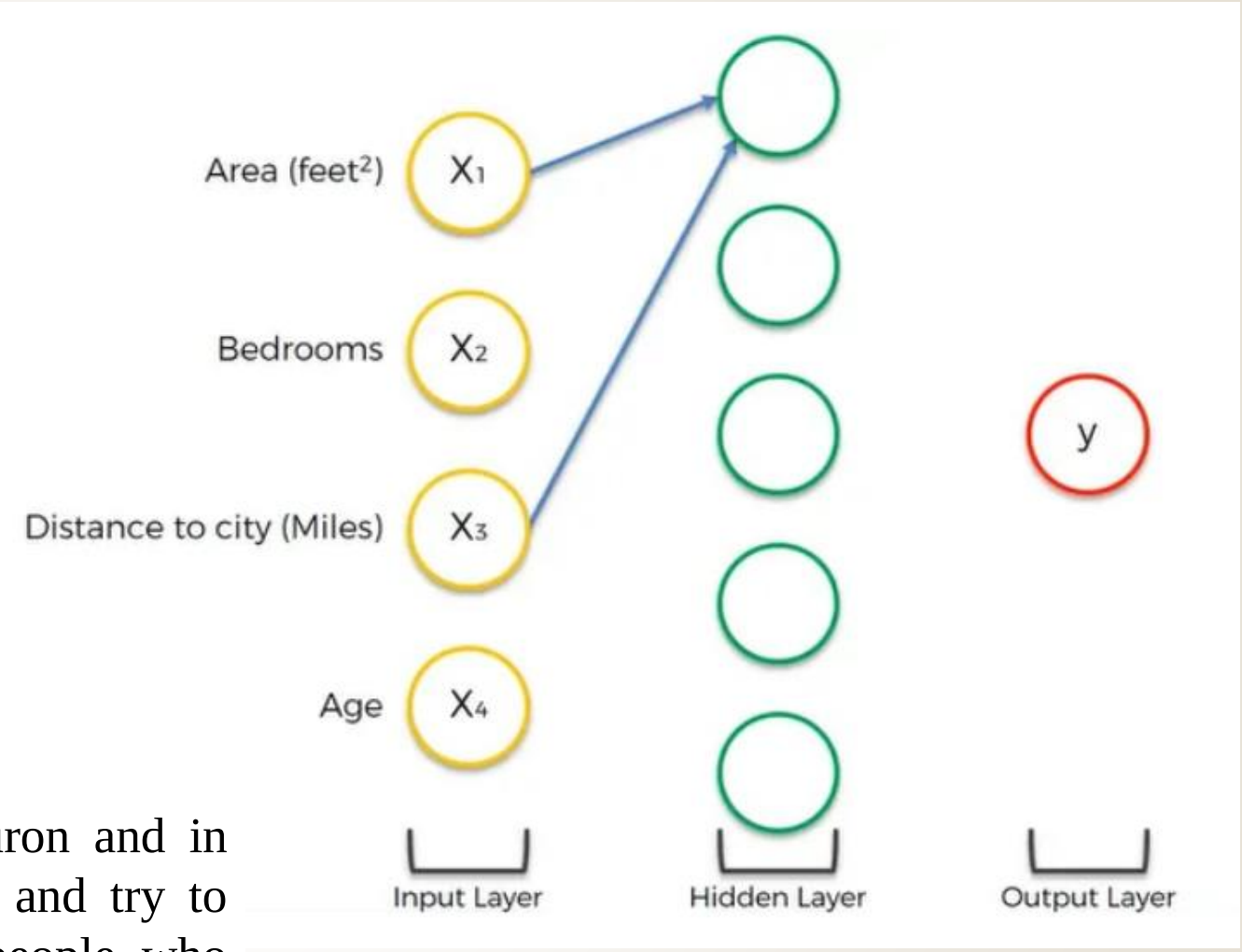
How do Neural Network Works?



The way they will learn different "weights" and hence different functions when fed the same data, is that when backpropagation is used to train the network, the errors represented by the output are different for each neuron. These errors are worked backwards to the hidden layer and then to the input layer to determine the most optimum value of weights that would minimize these errors.

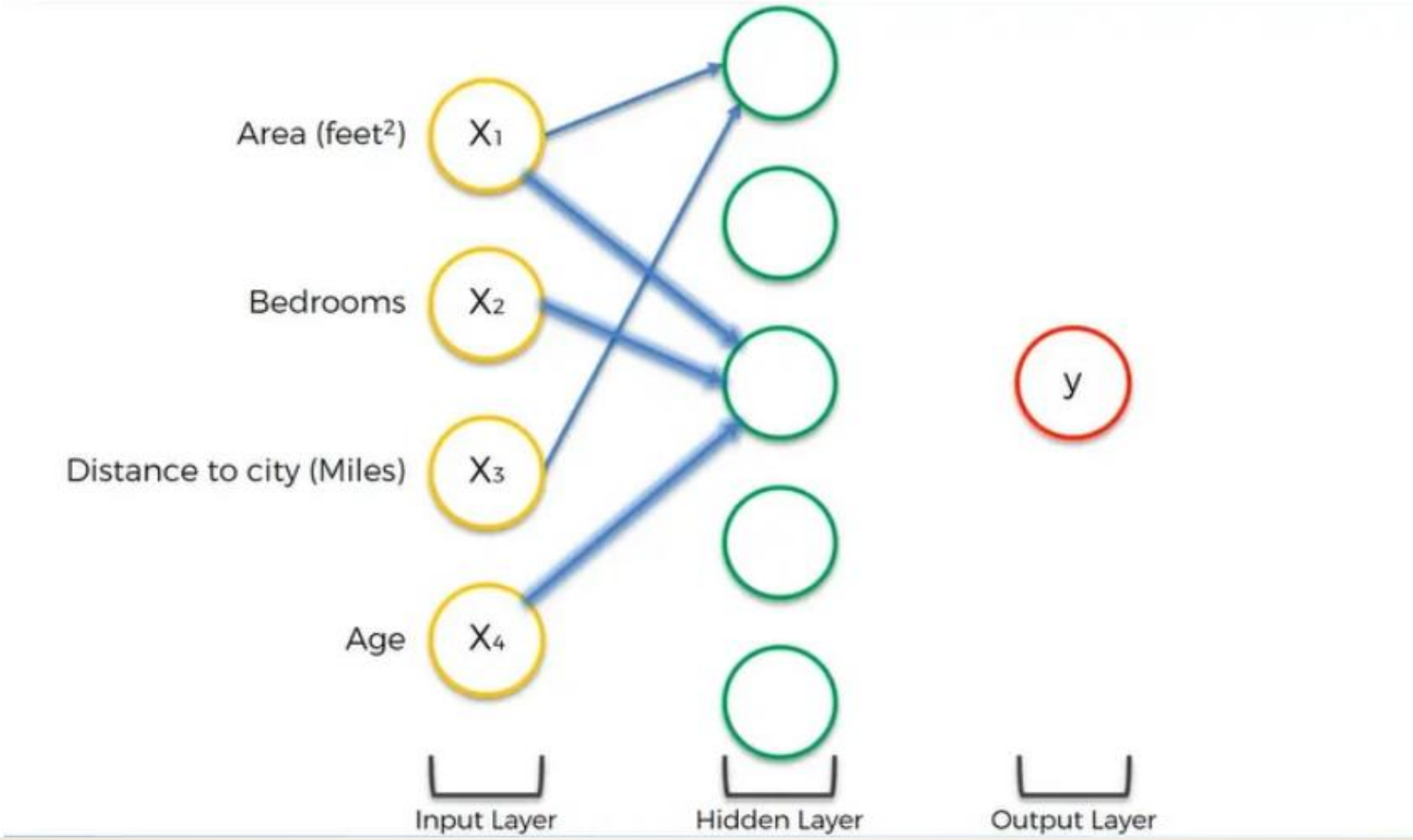
This is why when implementing backpropagation algorithm, one of the most important steps is to randomly initialize the weights before starting the learning. If this is not done, then you would observe a large no. of neurons learning the exact same weights and give sub-optimal results.

How do Neural Network Works?



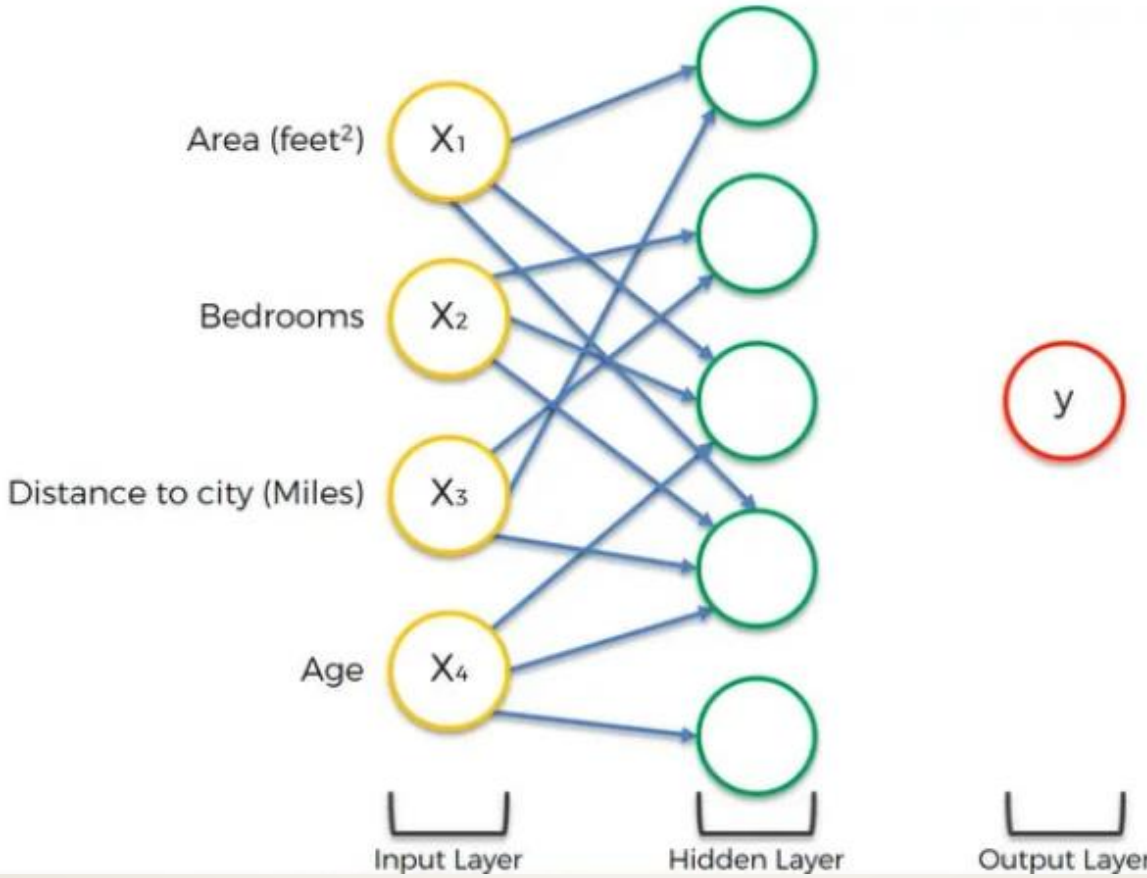
So for that let's consider the first neuron and in which we are considering 2 attributes and try to grab an insight that there are some people who want to buy a property with the following 2 conditions like **Area** should be big and **Distance to the city** should be small.

Now let's take another neuron that is considering the area, bedrooms, and distance to the city. Due to some reason, for example, a person having a big family more bedrooms becomes a necessity.



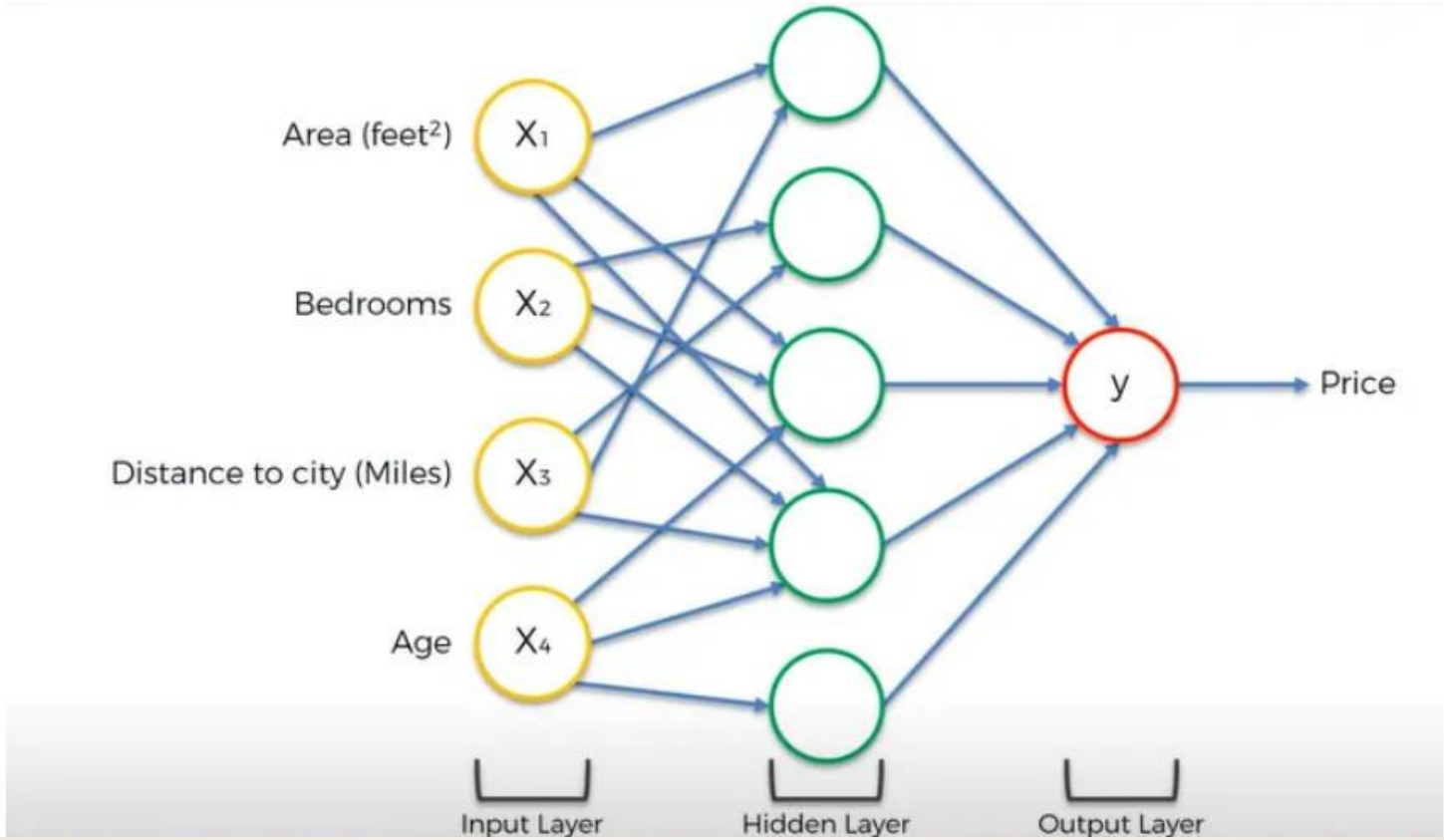
How do Neural Network Works?

So in a similar way, hidden layer neurons will make an analysis based on previous data. and taking several sets of attributes for doing the prediction.



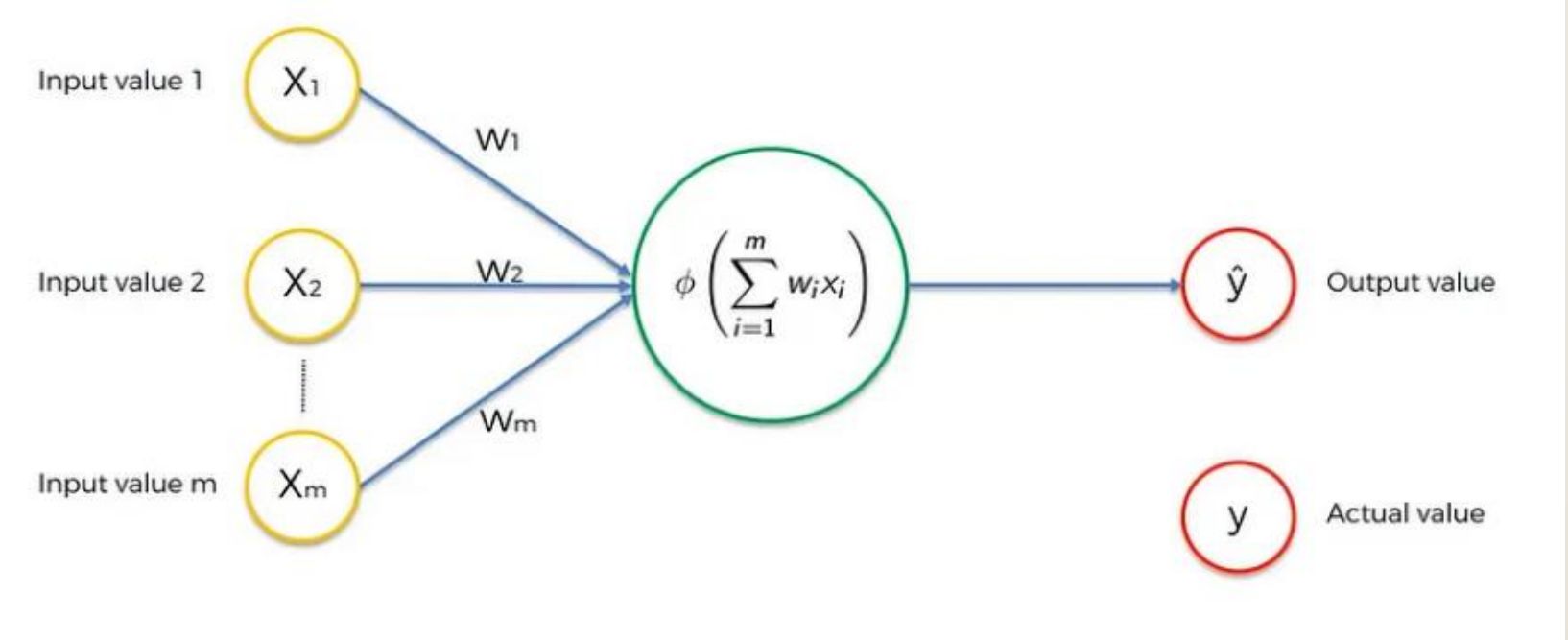
How do Neural Network Works?

Therefore, if train our model in a similar way the prediction becomes more accurate. and this is how a neural network works?



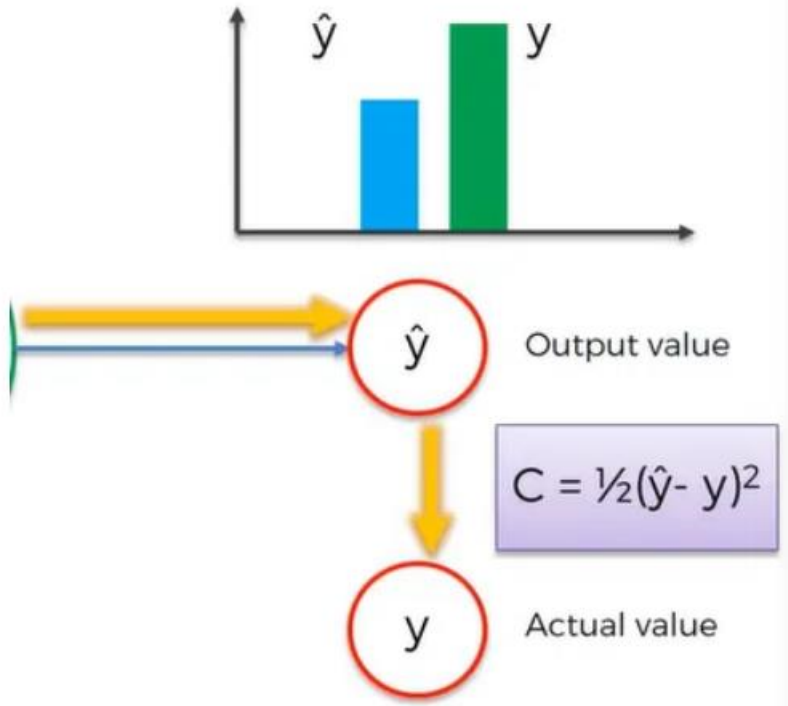
How do Neural Networks Learn?

So we have talked about how neural networks work but most important question is that **how do neural networks learn on its own?** so that there is minimal difference between the actual and the predicted value.

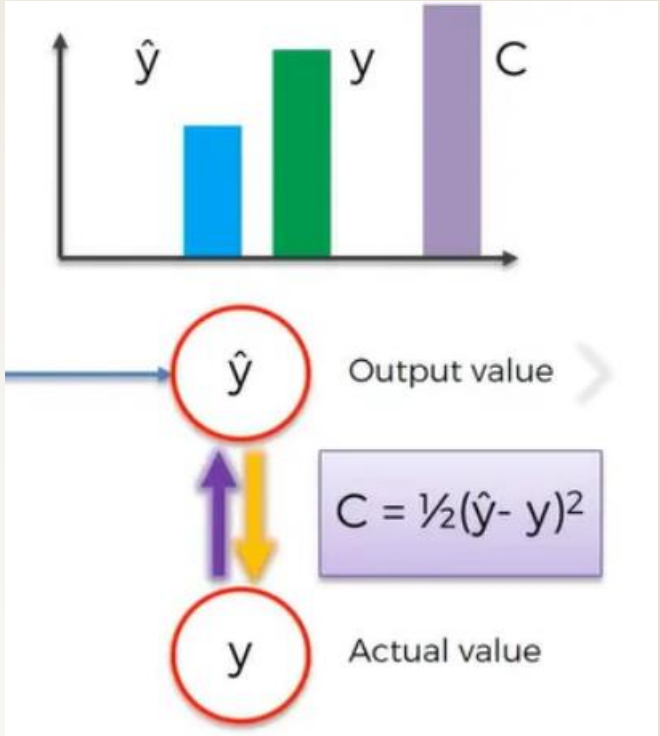


Cost Function

Now we need to calculate the **Cost Function** the difference between the actual and predicted result.

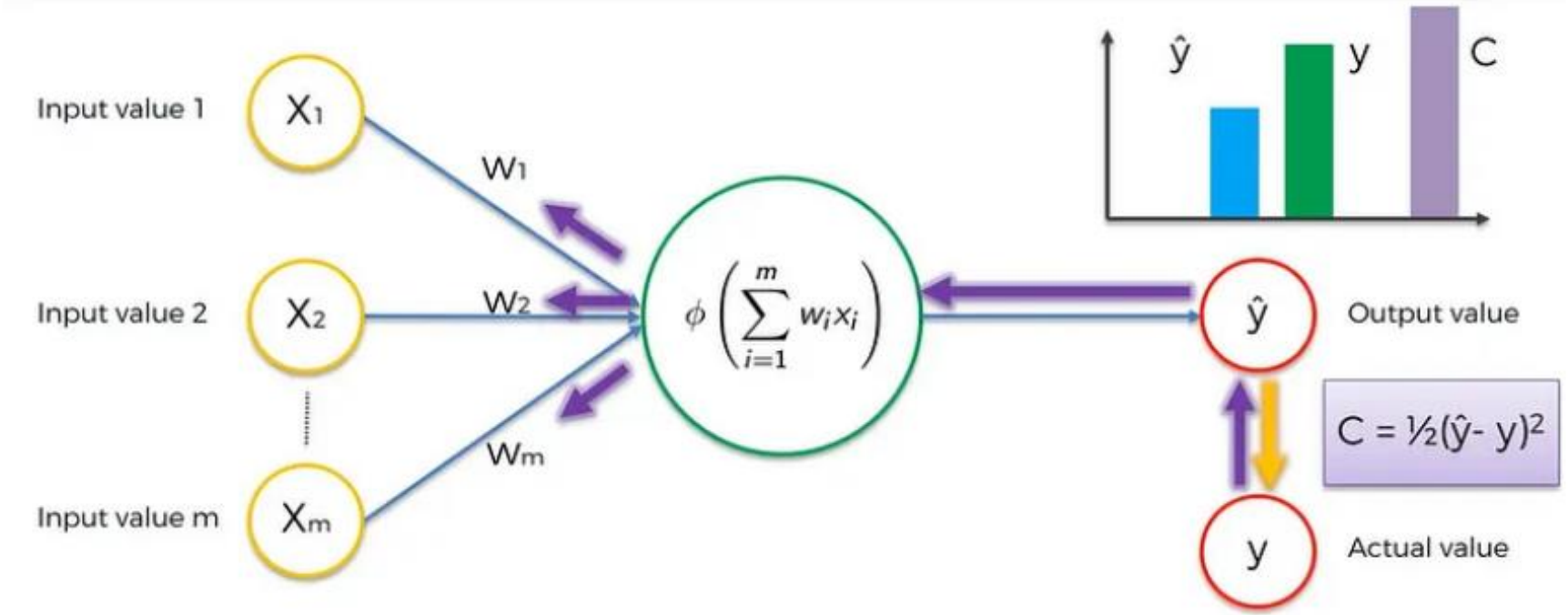


Cost Function



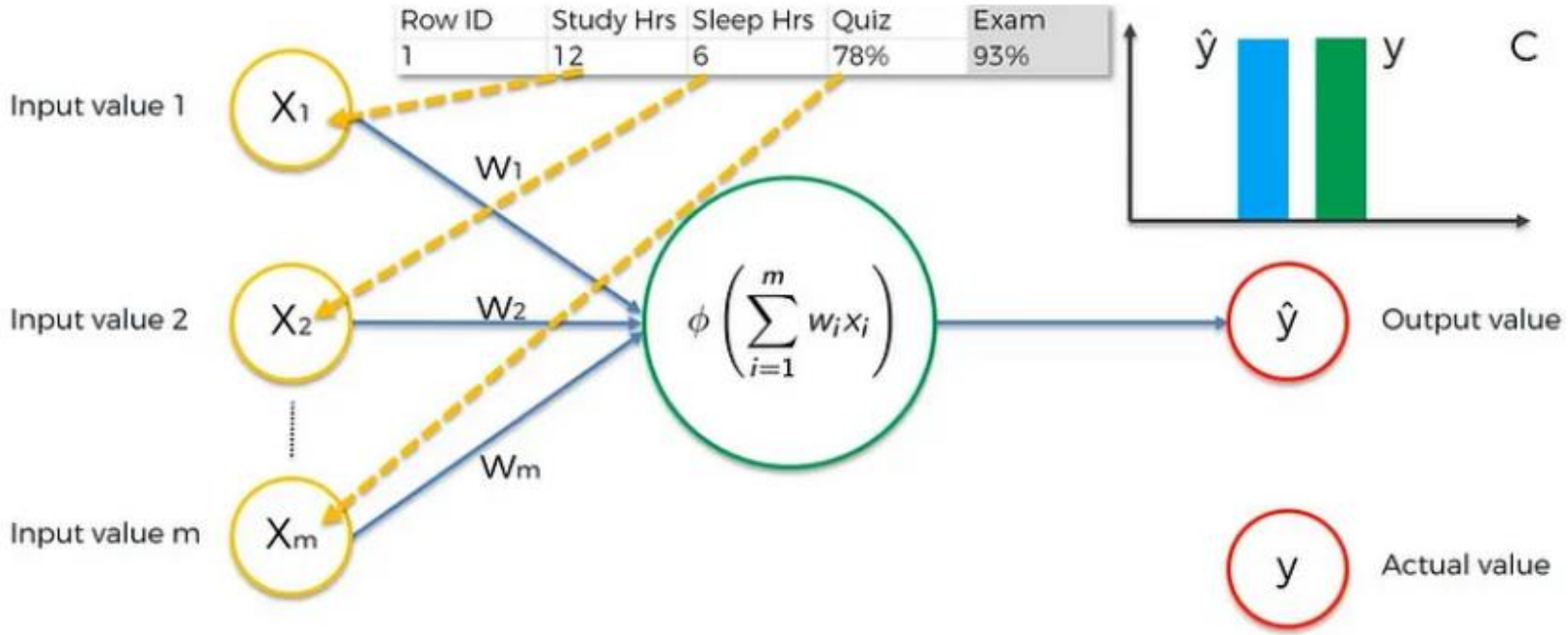
Cost Function

Now we send this information back to the neural network in order to update the weights because we need to minimize the **Cost Function.**



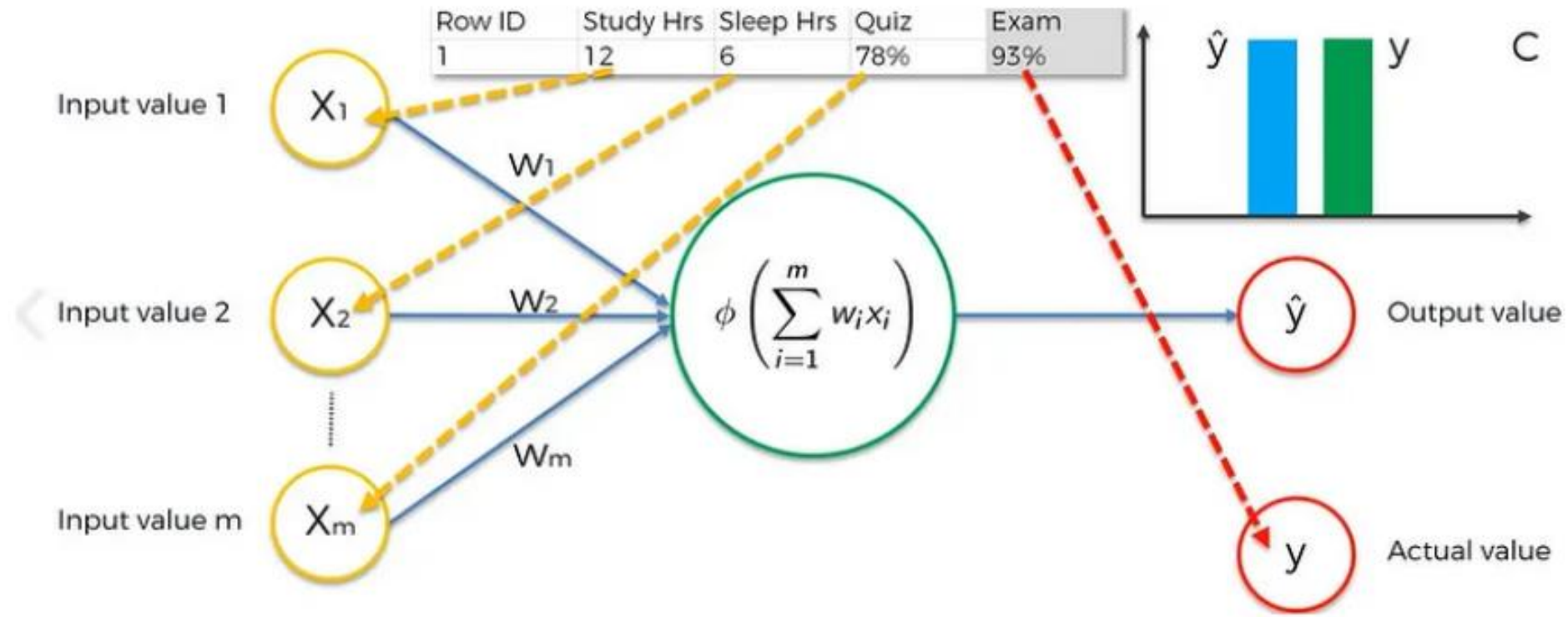
Example

Example: We are taking an example that helps to predict our result in exams based on the independent variables.

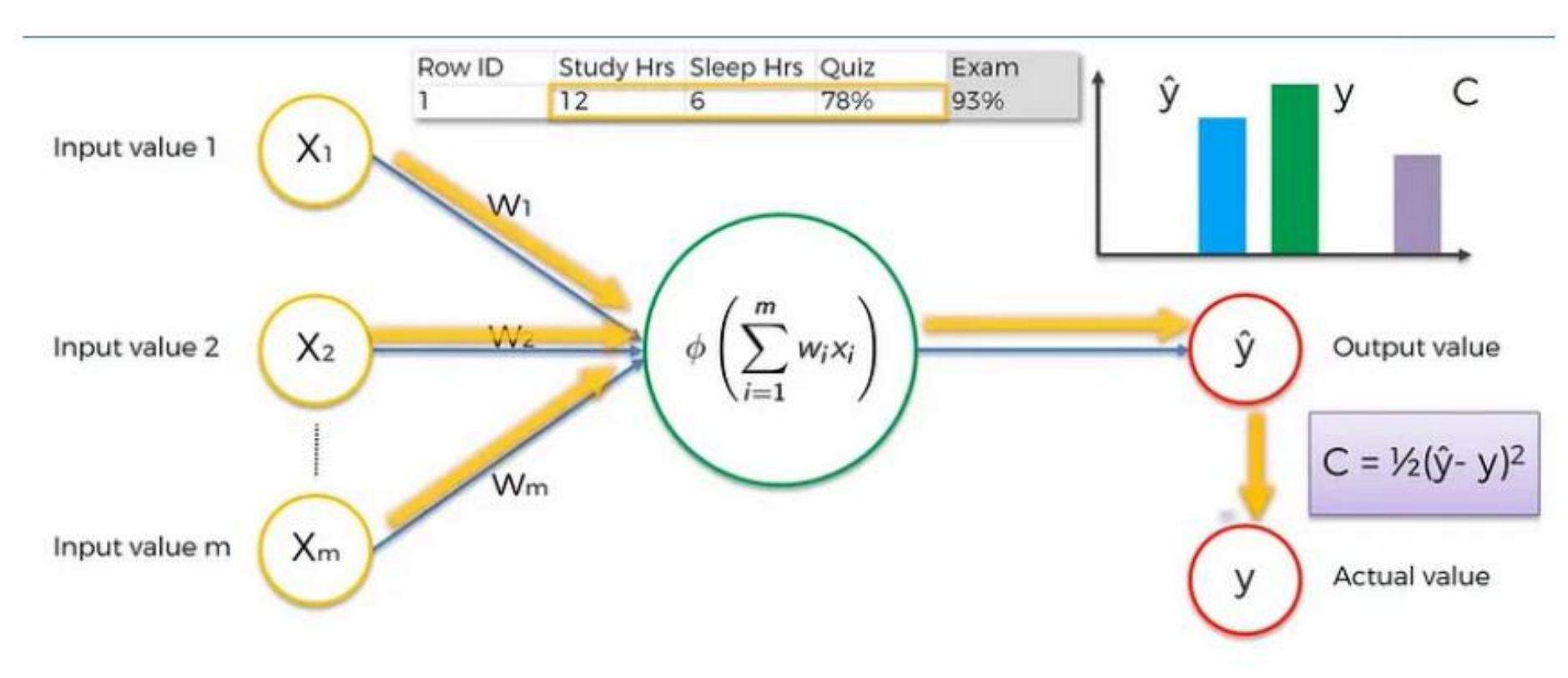


Example

And now comparing the result with the predicted one.

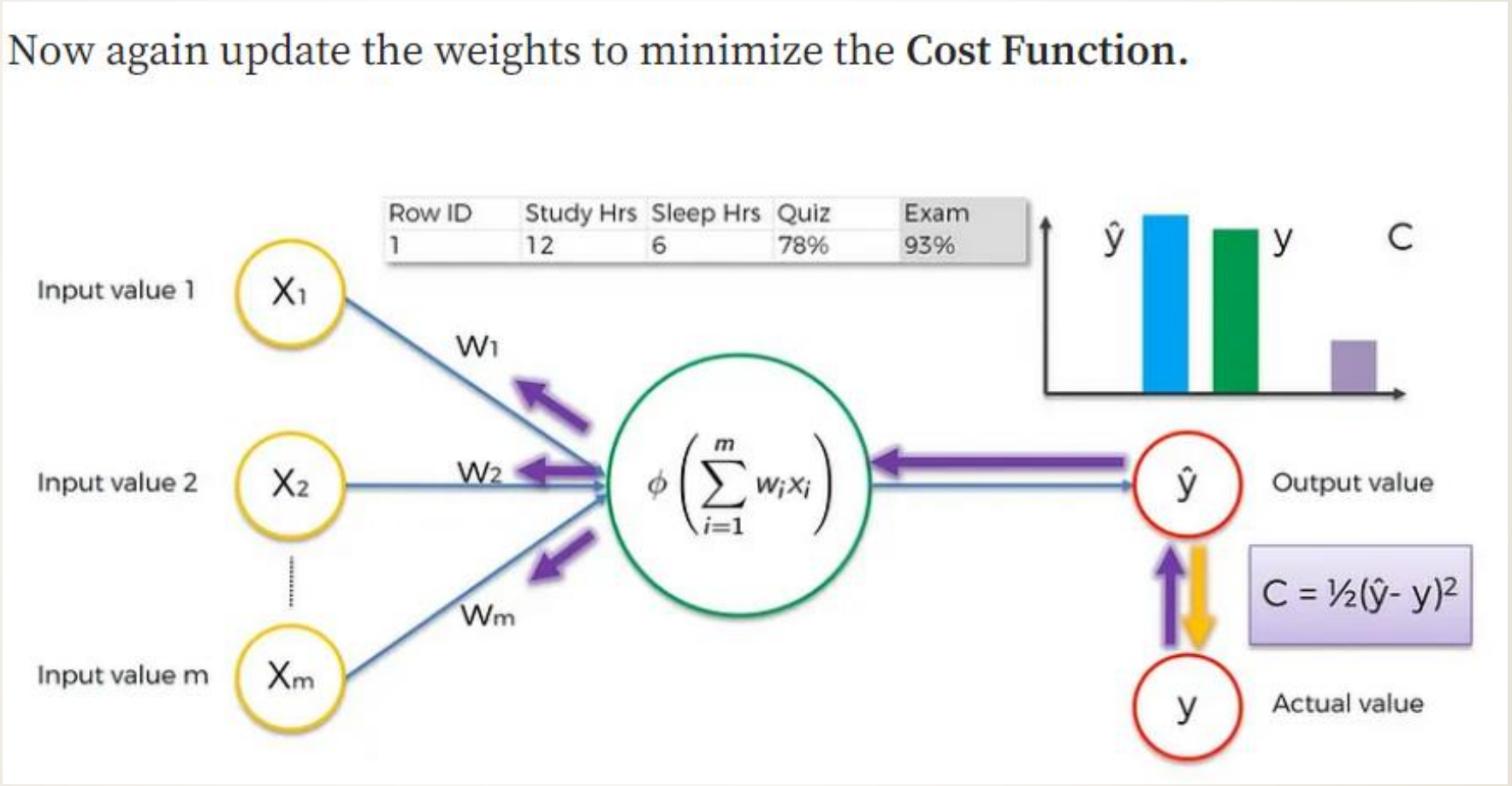


Example


Row ID | Study Hrs | Sleep Hrs | Quiz | Exam
1 | 12 | 6 | 78% | 93%
Input value 1
Input value 2
Input value m
X1
X2
Xm
W1
W2
Wm
$\phi\left(\sum_{i=1}^{m} w_i x_i\right)$
ŷ
y
C
ŷ
Output value
y
Actual value
C = ½(ŷ- y)²

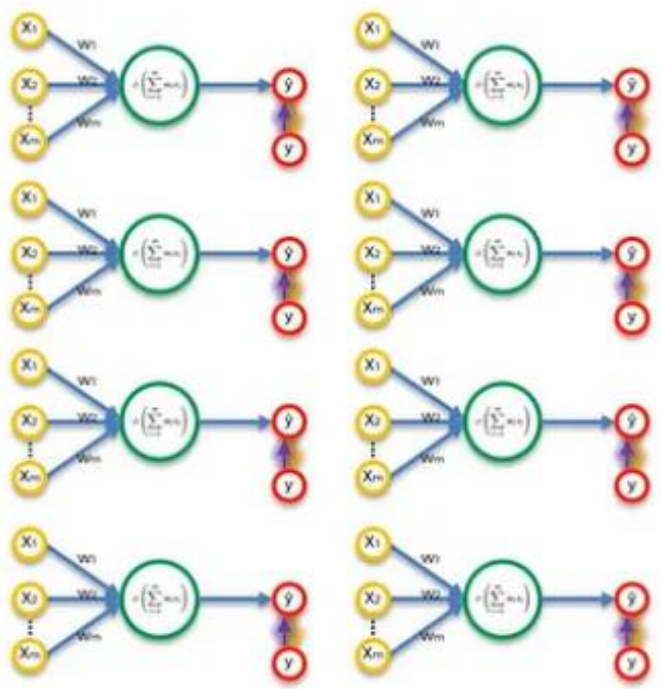
Example

Now again update the weights to minimize the **Cost Function.**



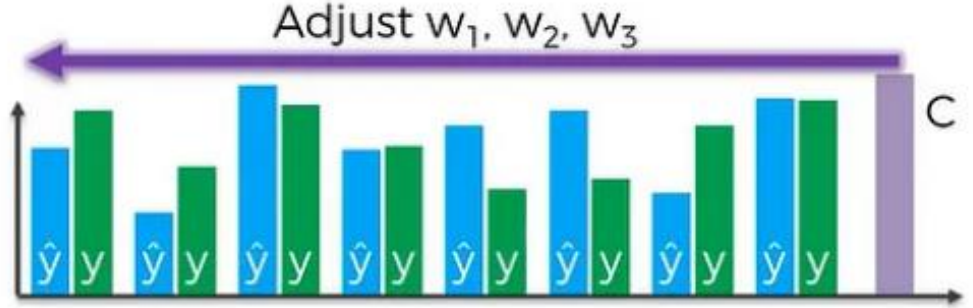
Example

The above example is just for one row if we have many rows then the visualization looks like this.



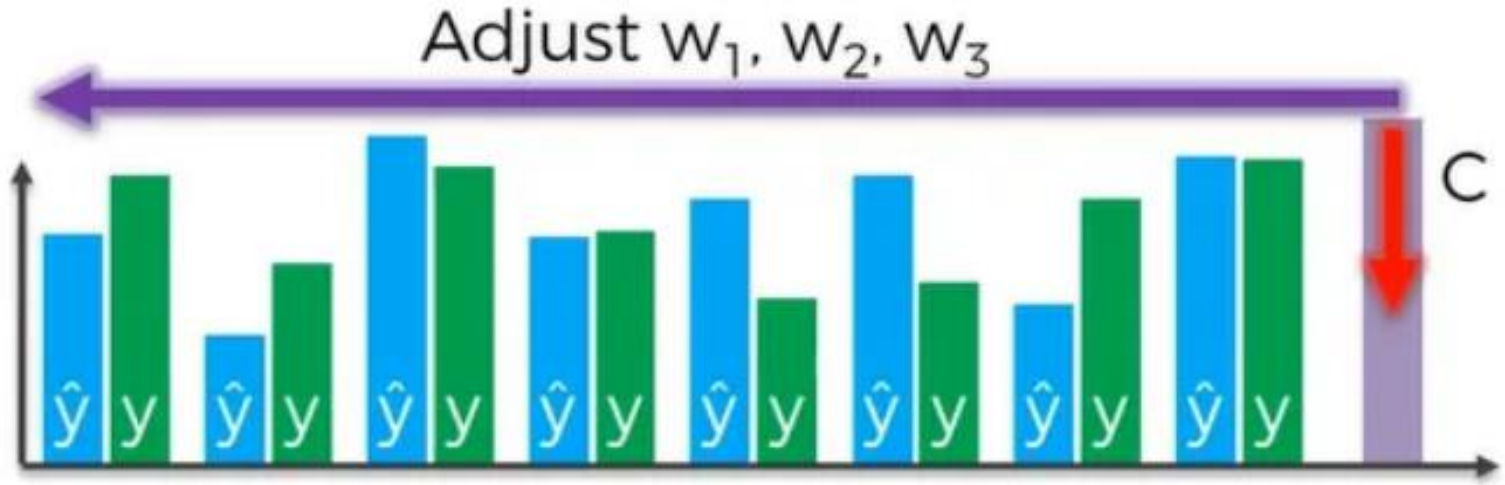
Row ID	Study Hrs	Sleep Hrs	Quiz	Exam
1	12	6	78%	93%
2	22	6.5	24%	68%
3	115	4	100%	95%
4	31	9	67%	75%
5	0	10	58%	51%
6	5	8	78%	60%
7	92	6	82%	89%
8	57	8	91%	97%

$$C = \sum \tfrac{1}{2}(\hat{y} - y)^2$$



Example

Here, we need to do the same process in order to minimize the cost function.



Reference

https://medium.com/swlh/fundamentals-of-neural-network-in-machine-learning-44fd9b04b825

https://www.khanacademy.org/science/biology/human-biology/neuron-nervous-system/a/overview-of-neuron-structure-and-function