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Supervised Learning
(Introduction to Neural Networks)

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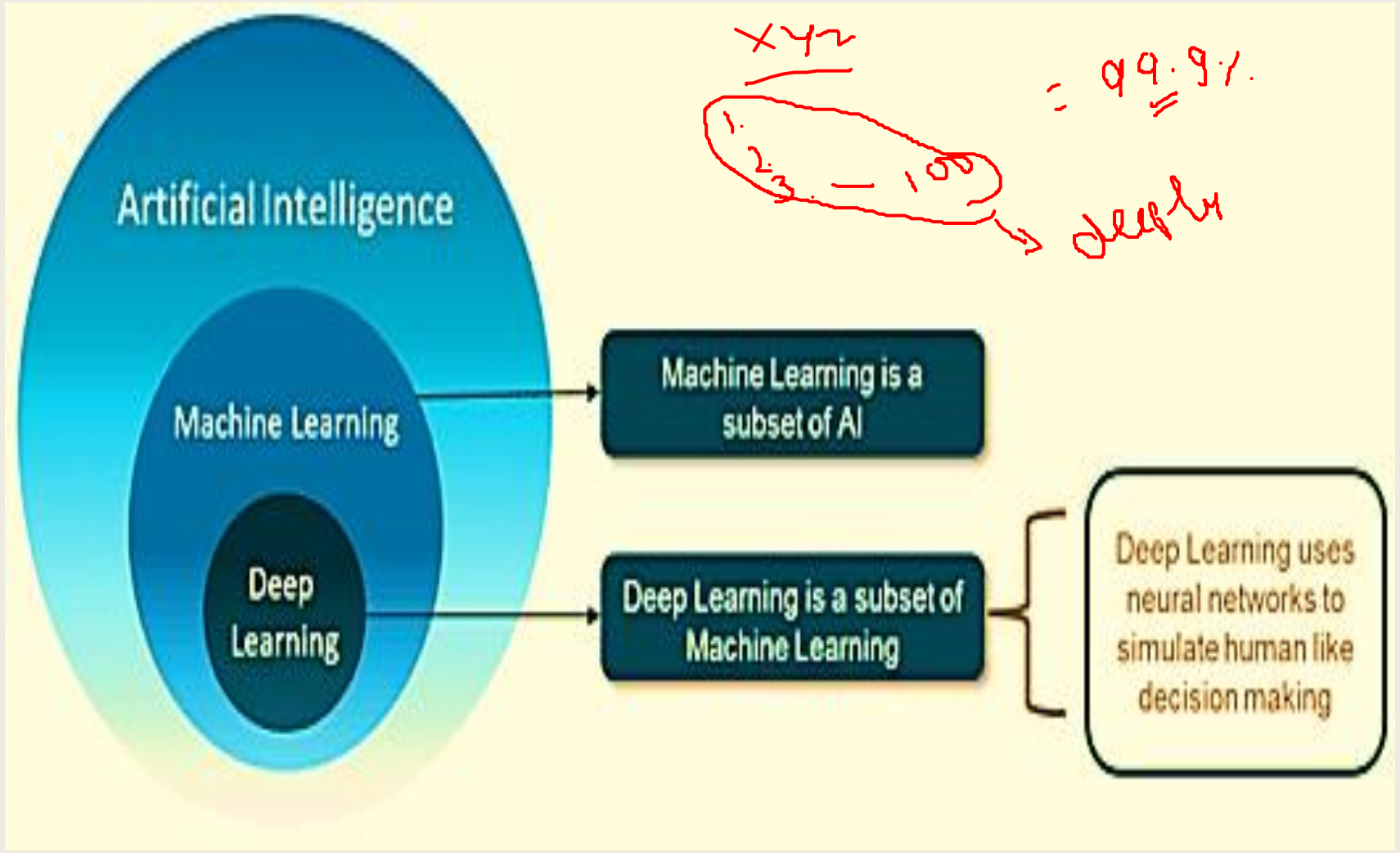
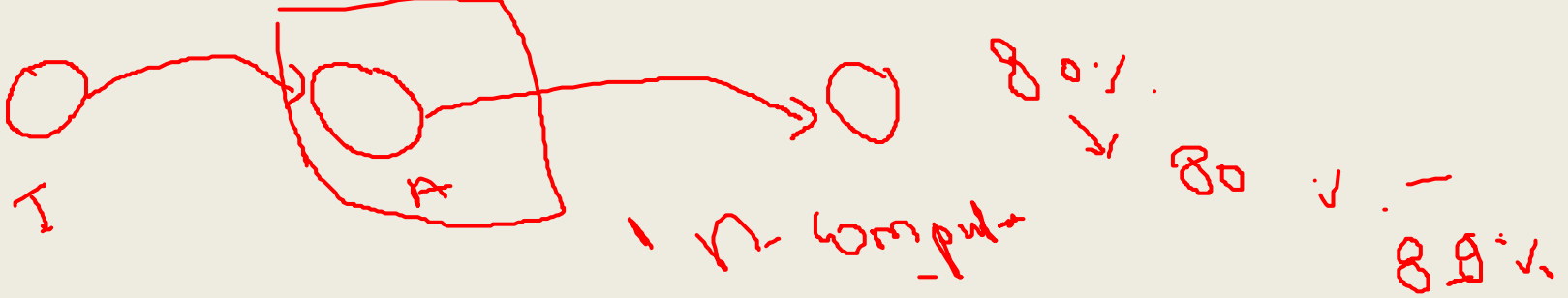
Difference Between AI, ML, and DL (Artificial Intelligence vs Machine Learning vs Deep Learning)

- People often tend to think that Artificial Intelligence, Machine Learning, and Deep Learning are the same since they have common applications. For example, Siri is an application of AI, Machine learning and Deep learning.

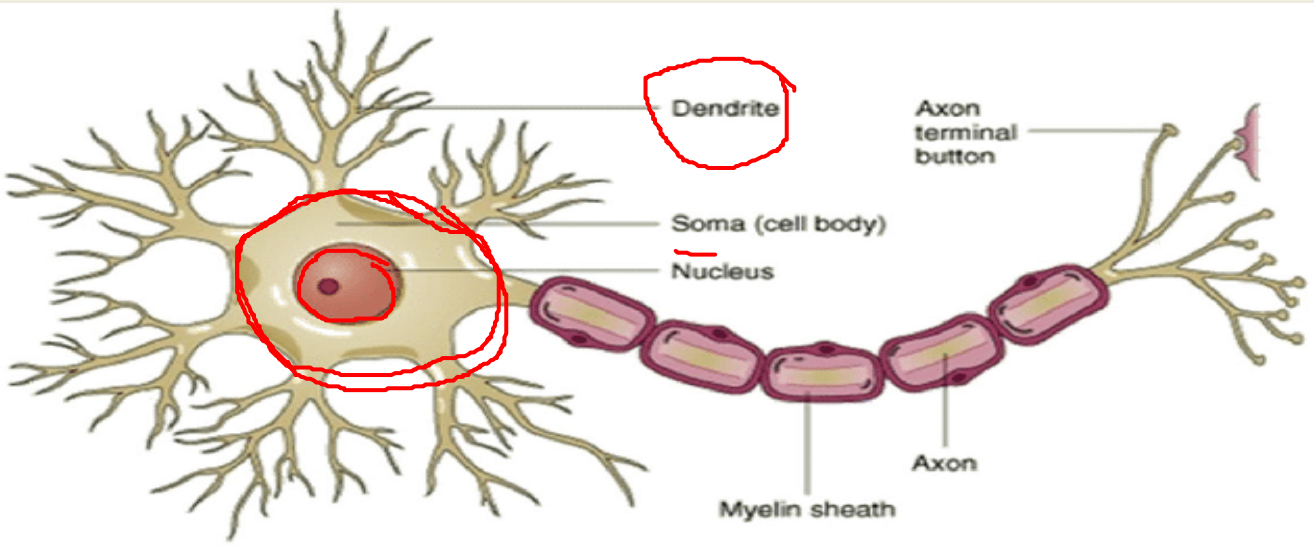




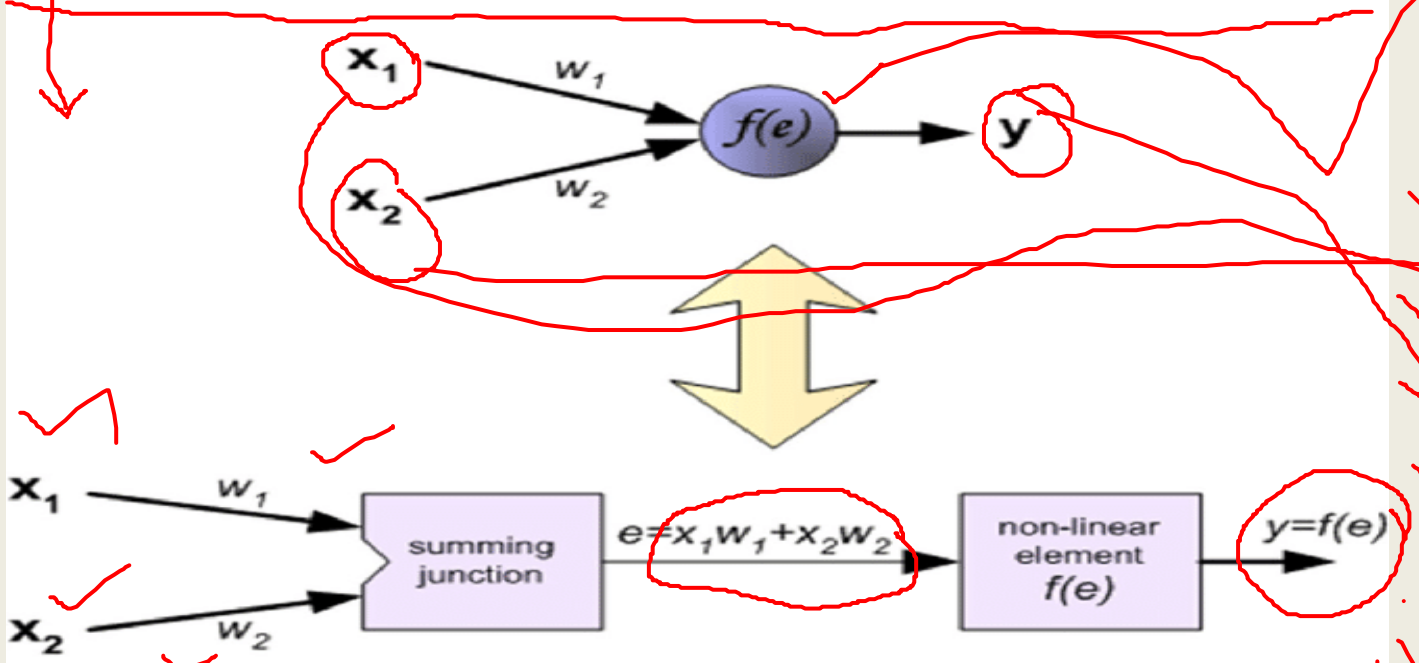
1. Artificial Intelligence is the science of getting machines to mimic the behavior of humans.
2. Machine learning is a subset of Artificial Intelligence (AI) that focuses on getting machines to make decisions by feeding them data.
3. Deep learning is a subset of Machine Learning that uses the concept of neural networks to solve complex problems.

To sum it up AI, Machine Learning and Deep Learning are interconnected fields. Machine Learning and Deep learning aids Artificial Intelligence by providing a set of algorithms and neural networks to solve data-driven problems.

Biological neuron and Artificial neural network

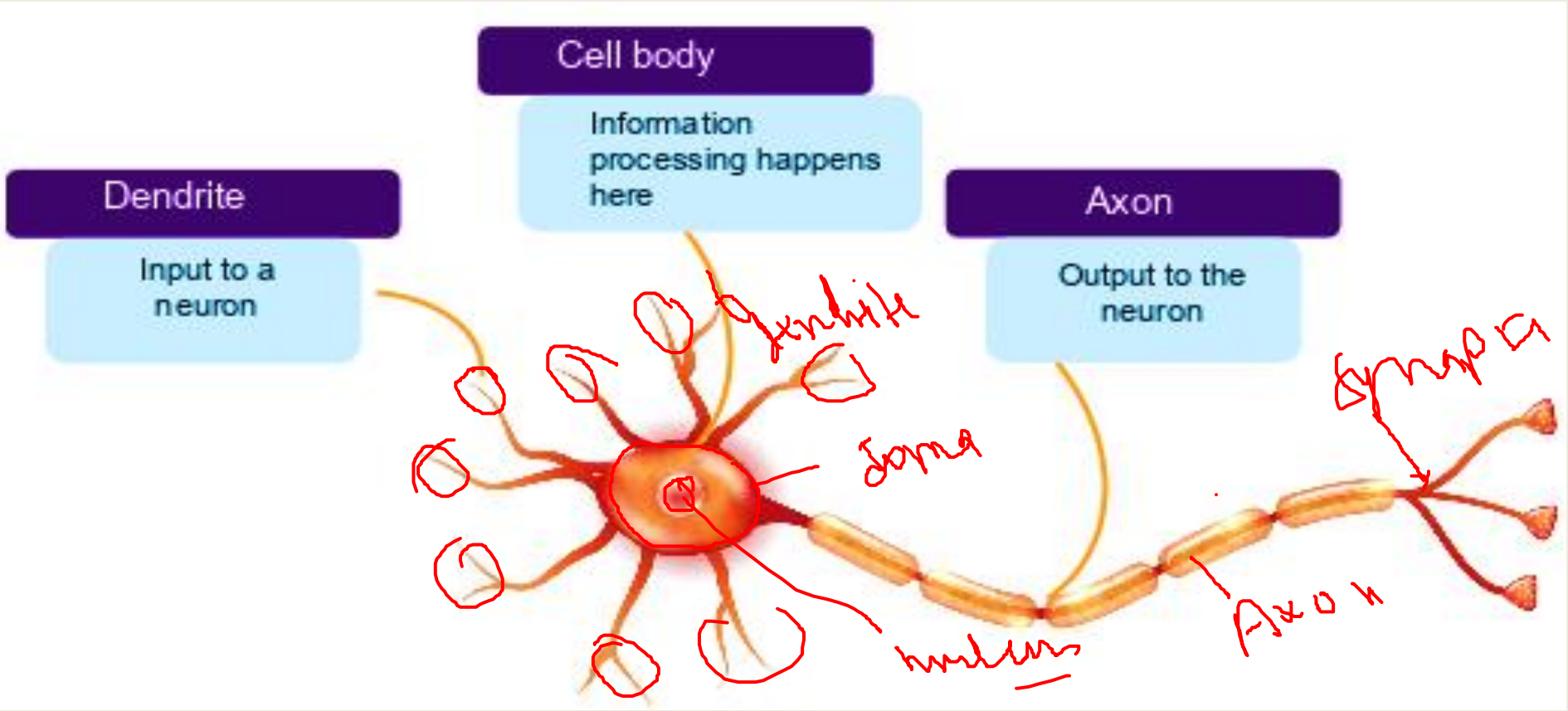


(a) Biological neuron



(b) Artificial neural network

Biological Neuron	Artificial Neuron
Dendrites	Input
Cell Nucleus(Soma)	Node
Axon	Output
Synapse	Interconnections



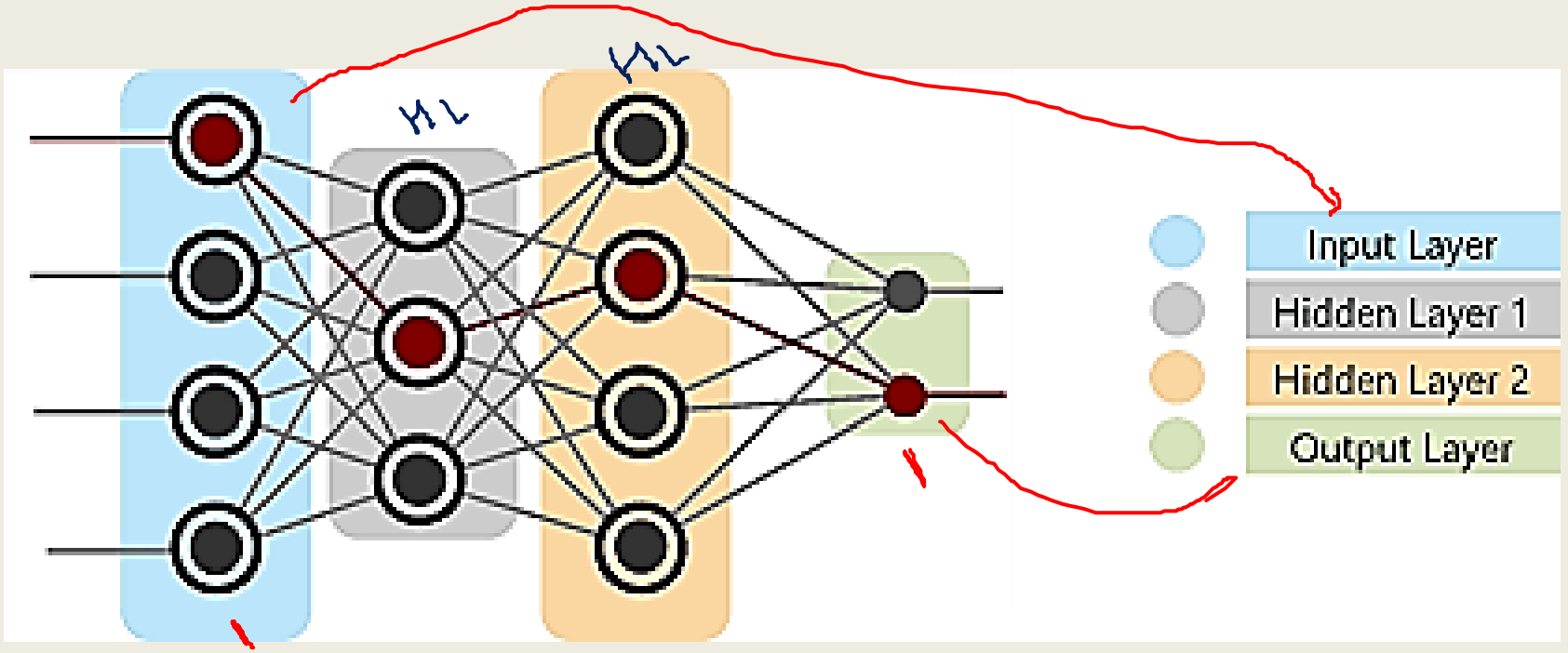
- Dendrites - These receive information or signals from other neurons that get connected to it.
- Cell Body - Information processing happens in a cell body. These take in all the information coming from the different dendrites and process that information.
- Axon - It sends the output signal to another neuron for the flow of information. Here, each of the flanges connects to the dendrite or the hairs on the next one.

Biological neuron and Artificial neural network

	
Biological neurons or nerve cells	Silicon transistors
200 billion neurons, 32 trillion interconnections.	1 billion bytes RAM, trillion of bytes on disk.
Neuron size: 10-6 m.	Single transistor size: 10-9m.
Energy consumption: 6-10 joules per operation per sec.	Energy consumption: 10-16 joules per operation per second.
Learning capability	Programming capability

Simple Definition Of A Neural Network

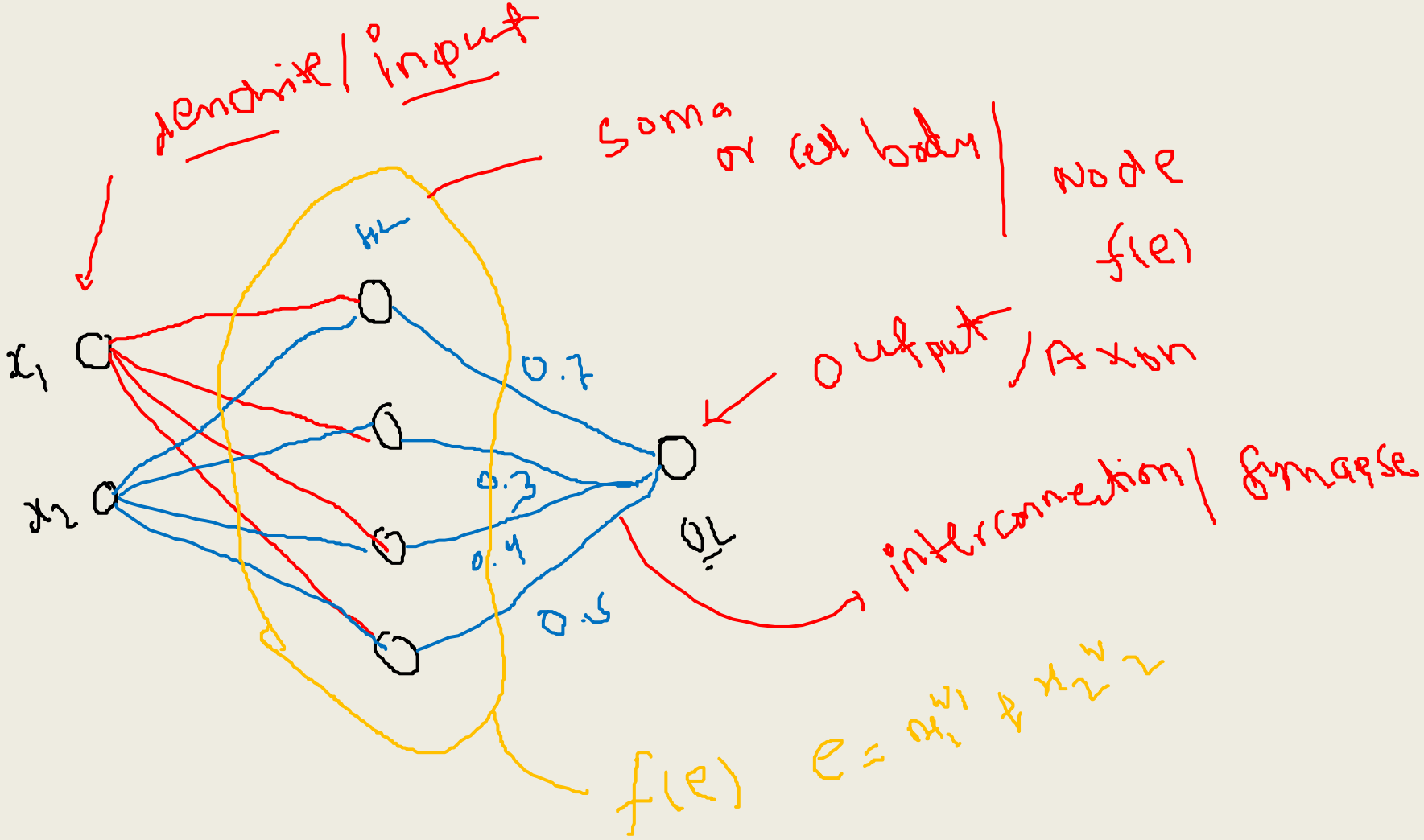
- Modeled in accordance with the human brain, a Neural Network was built to mimic the functionality of a human brain. The human brain is a neural network made up of multiple neurons, similarly, an Artificial Neural Network (ANN) is made up of multiple perceptron (will be discussed into coming lectures).

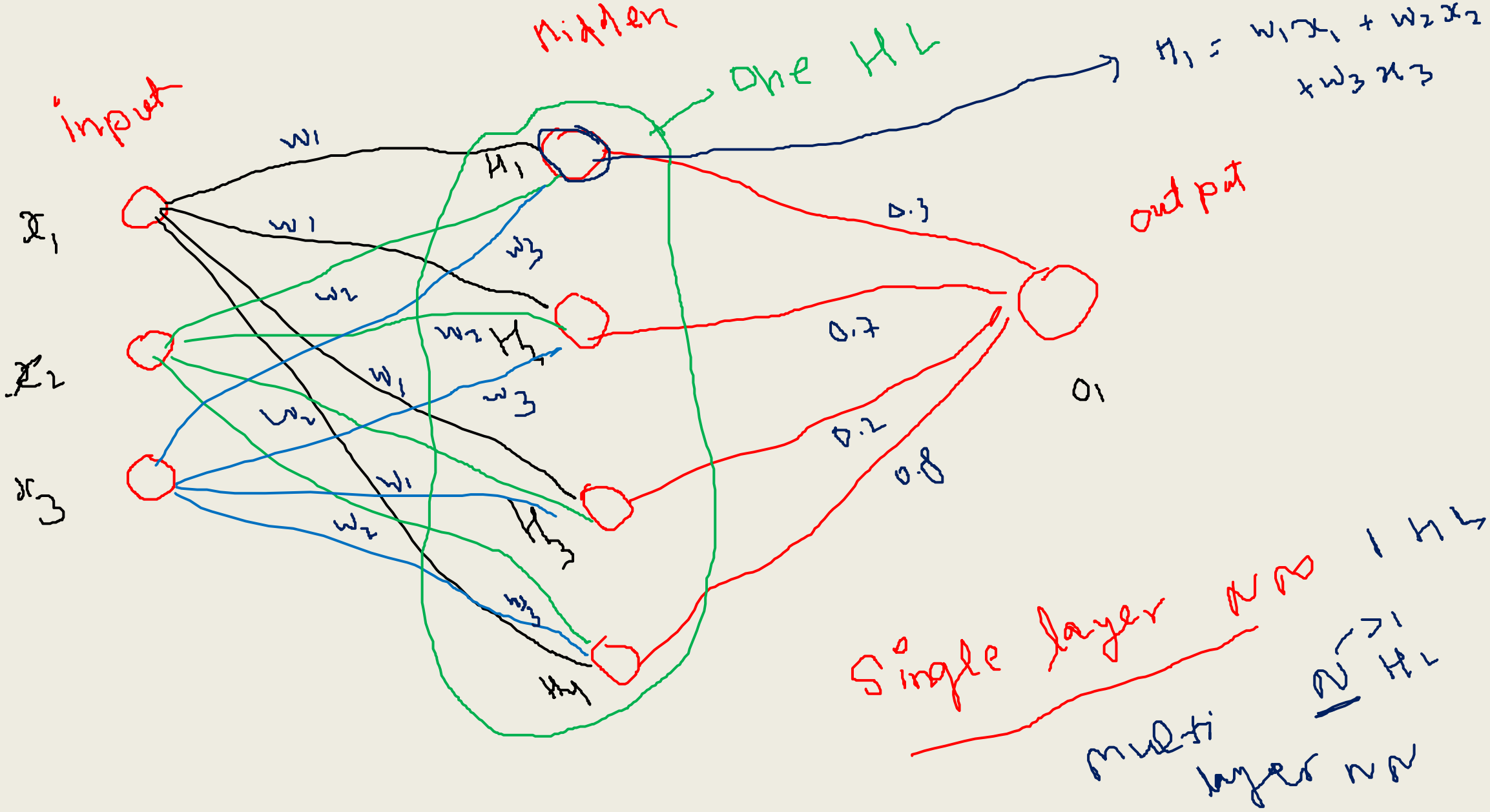


IL = 2

HL = 4

OL = 1


dendrite / input
Soma
or cell body / node
f(e)
output / Axon
interconnection / Synapse
x_1
x_2
HL
OL
0.7
0.3
0.4
0.5
$f(e)$ $e = x_1^{w_1} \& x_2^{w_2}$


hidden
one HL
input
output
$h_1 = w_1x_1 + w_2x_2 + w_3x_3$
x_1
x_2
x_3
w_1
w_2
w_3
h_1
h_2
h_3
h_4
0.3
0.7
0.2
0.8
o_1
Single layer NN 1 HL
multi layer NN
N HL

I = 3

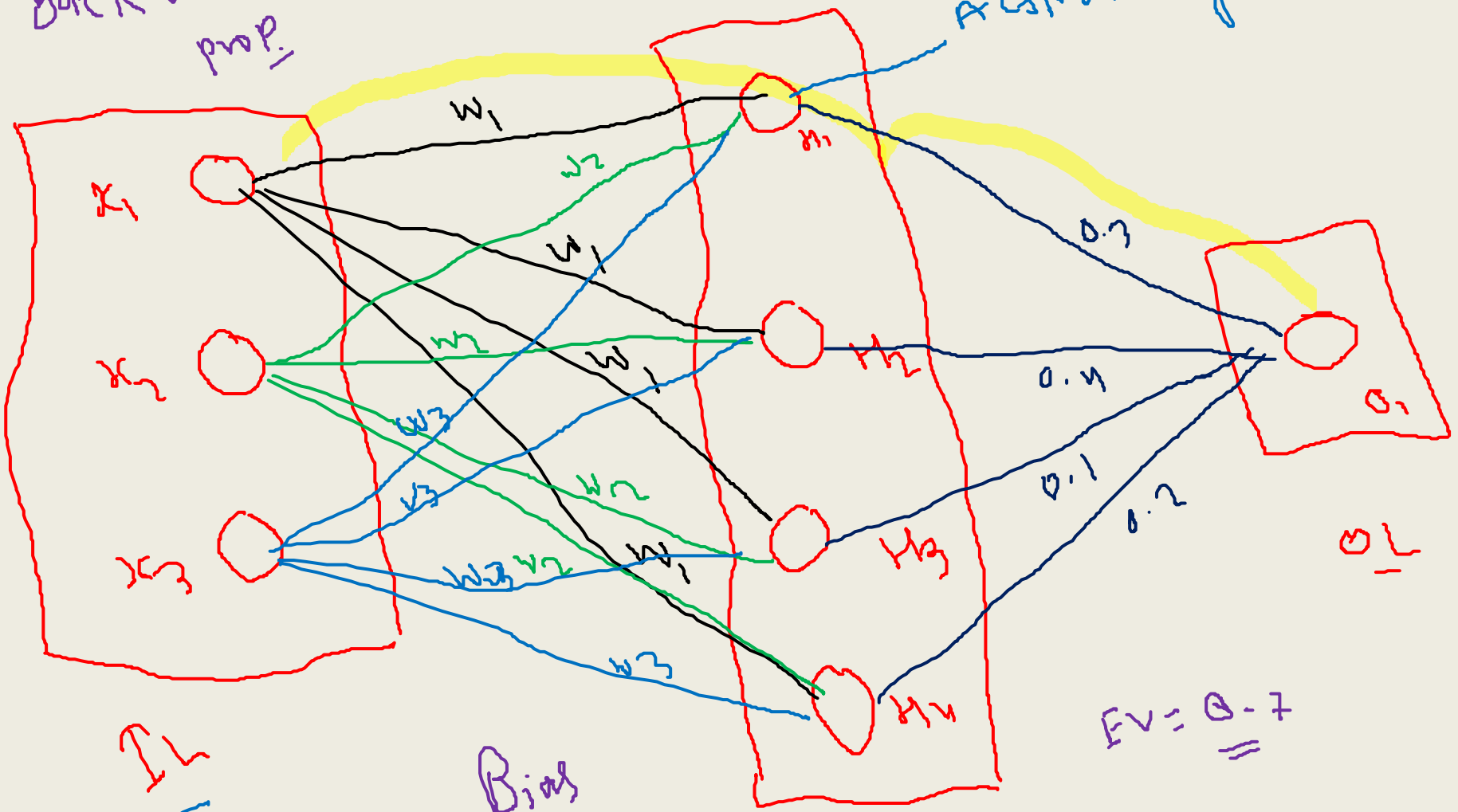
WP = 4

O = 1

Backward prop.

$n_1 = x_1 w_1 + x_2 w_2 + x_3 w_3$

Activation function



feed forward NN

Single layer NN

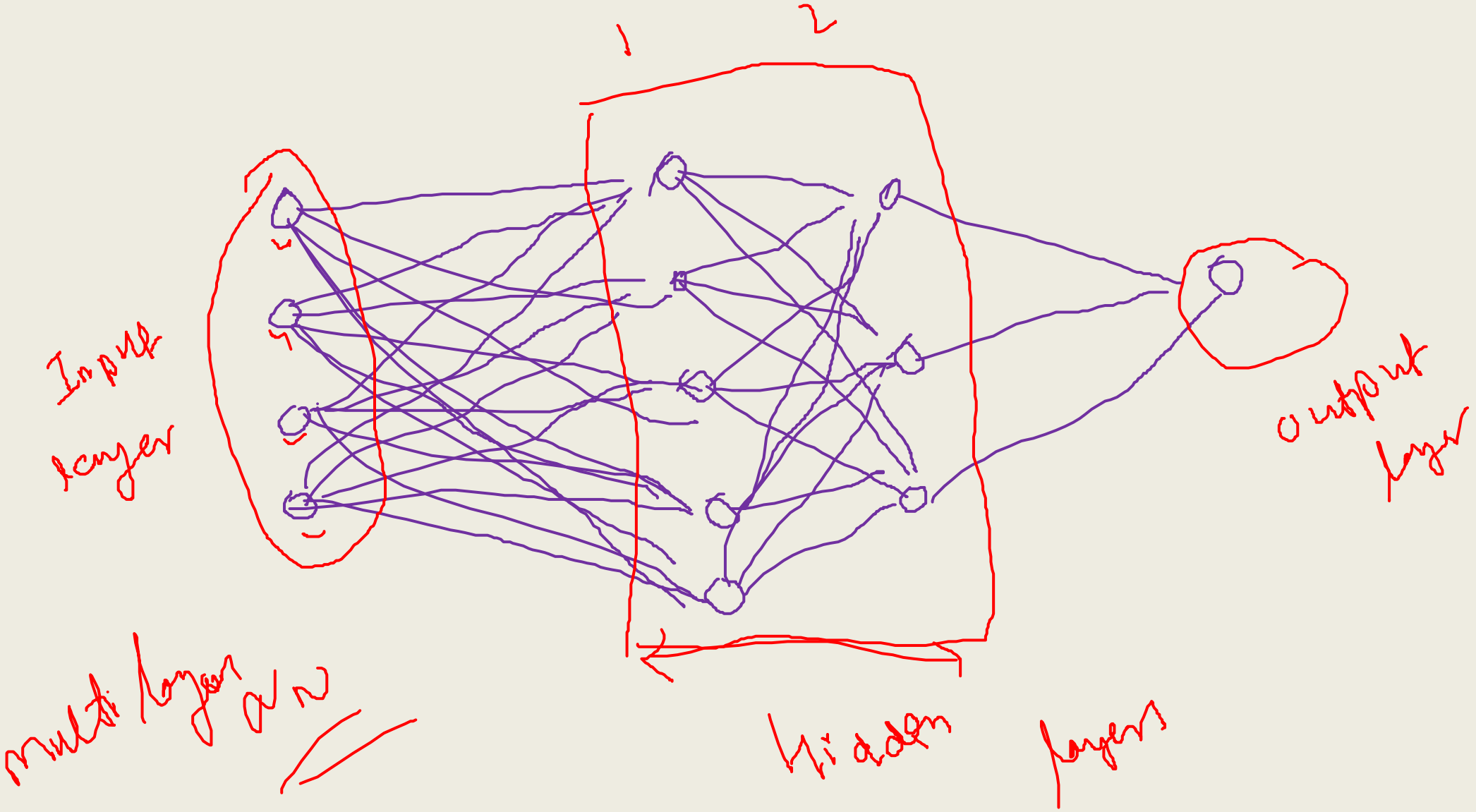
IL

Bias

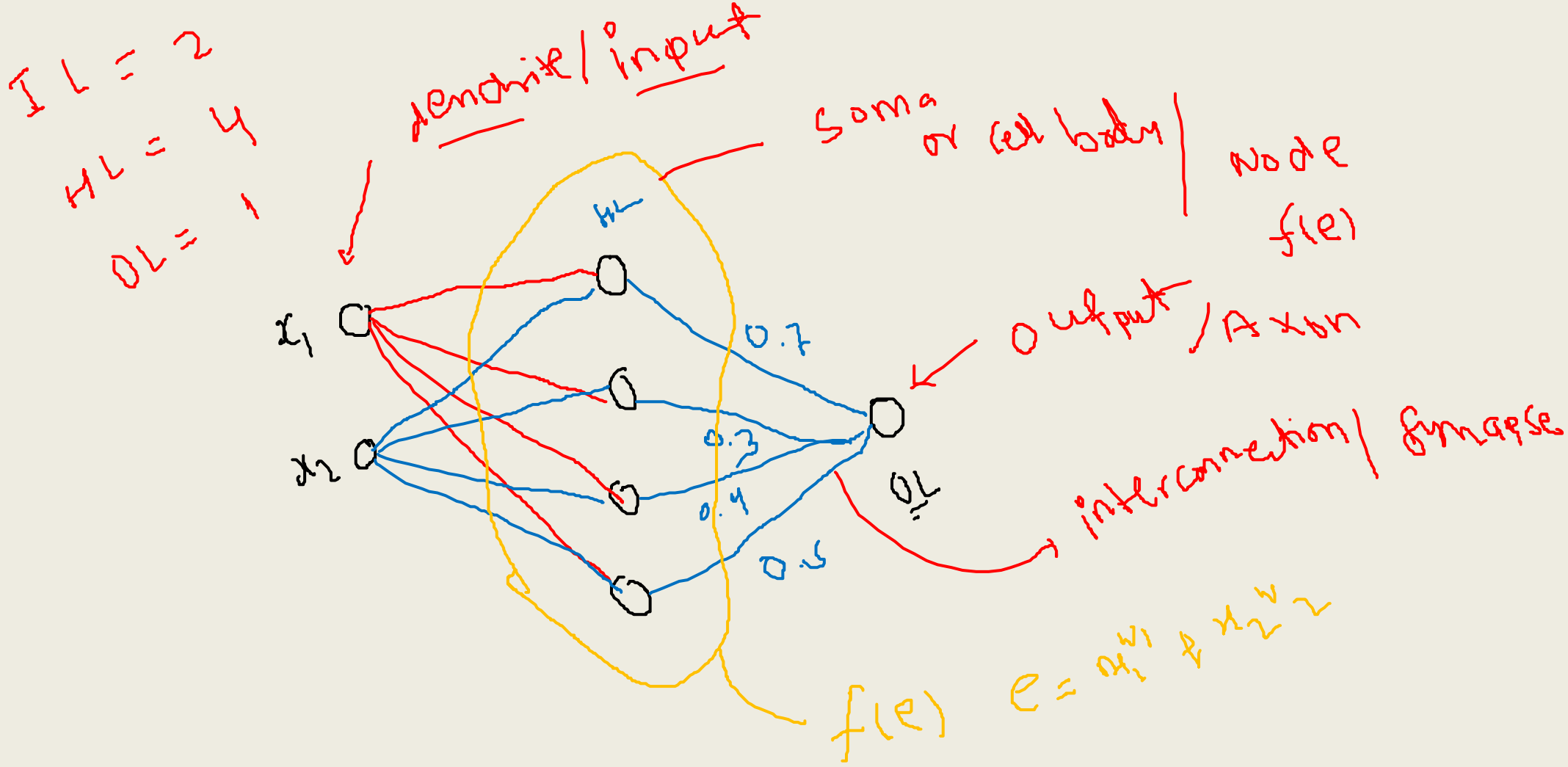
HL

EV = 0.7

OL


1
2
Input layer
output layer
multi layer NN
Hidden layers

OL & IL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x_1
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0.7
0.3
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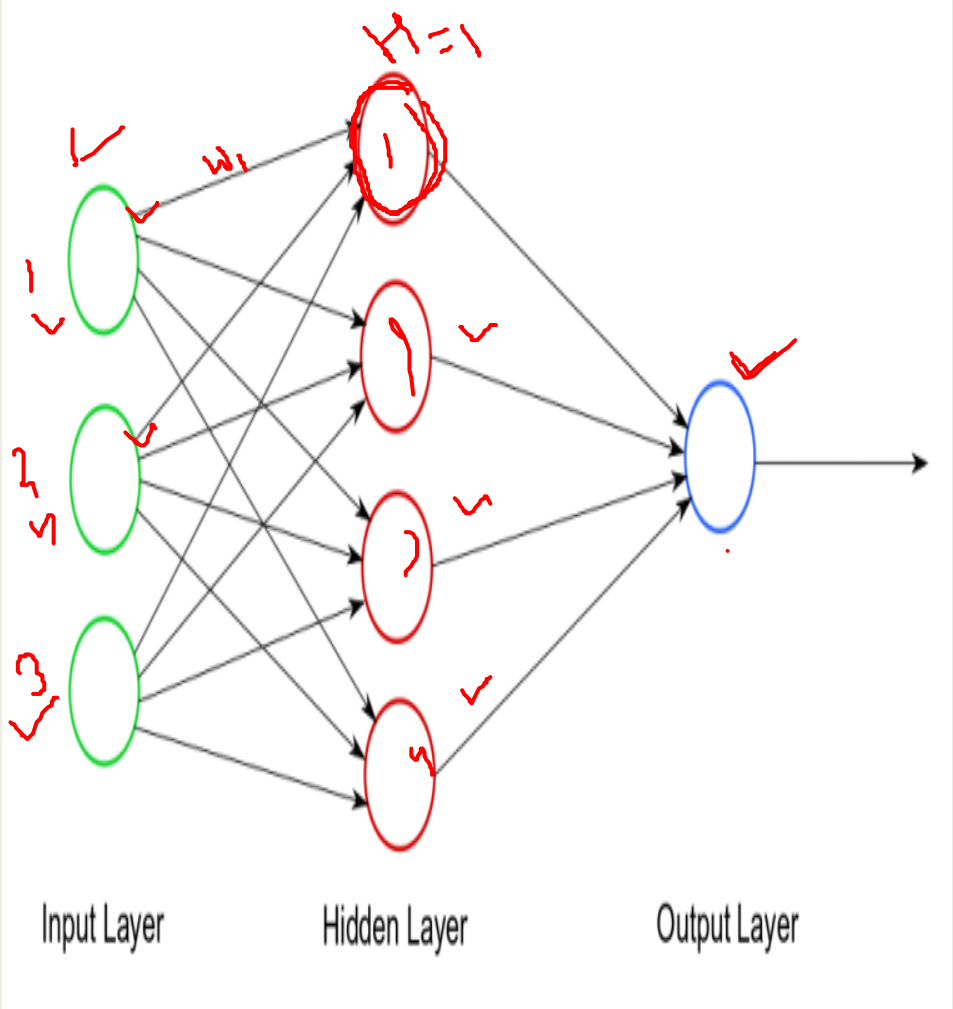
0.5
f(e)
$e = x_1^{w_1} \& x_2^{w_2}$

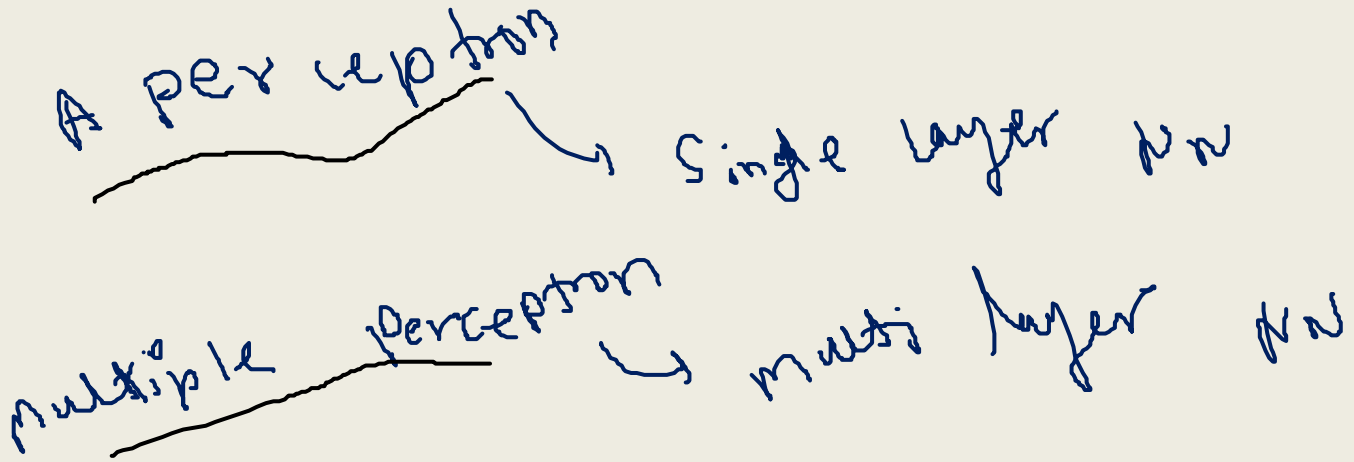
A neural network consists of three important layers

1. Input Layer: As the name suggests, this layer accepts all the inputs provided by the programmer.
2. Hidden Layer: Between the input and the output layer is a set of layers known as Hidden layers. In this layer, computations are performed which result in the output.
3. Output Layer: The inputs go through a series of transformations via the hidden layer which finally results in the output that is delivered via this layer.



How Does A Neural Network Work?

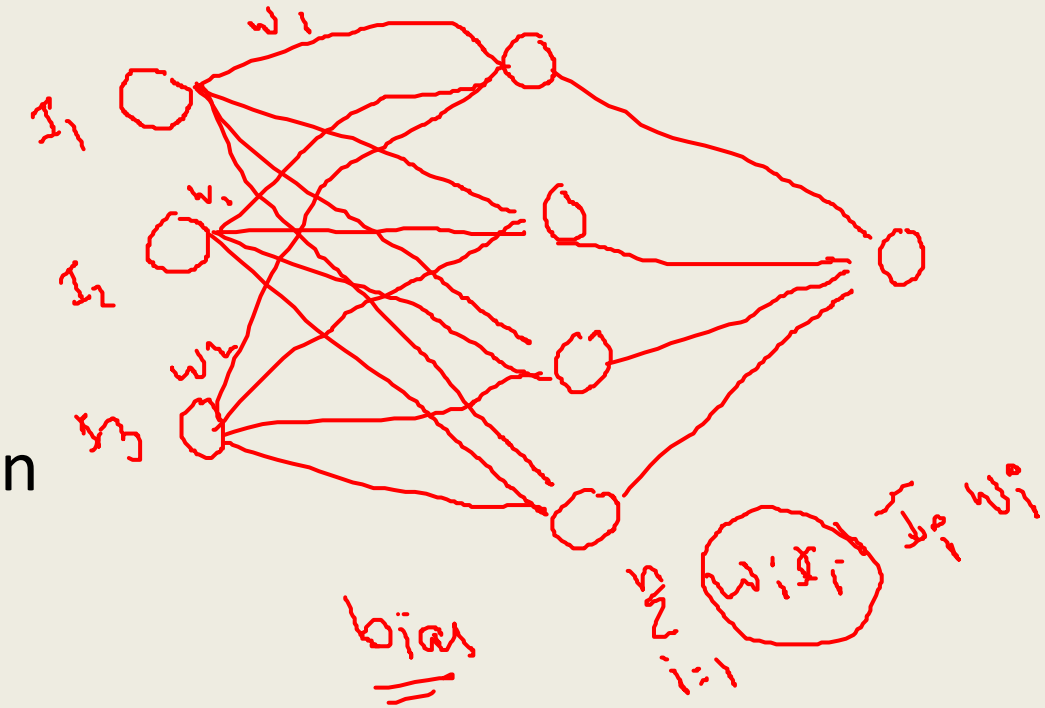
- To understand neural networks, we need to break it down and understand the most basic unit of a Neural Network, i.e. a Perceptron.

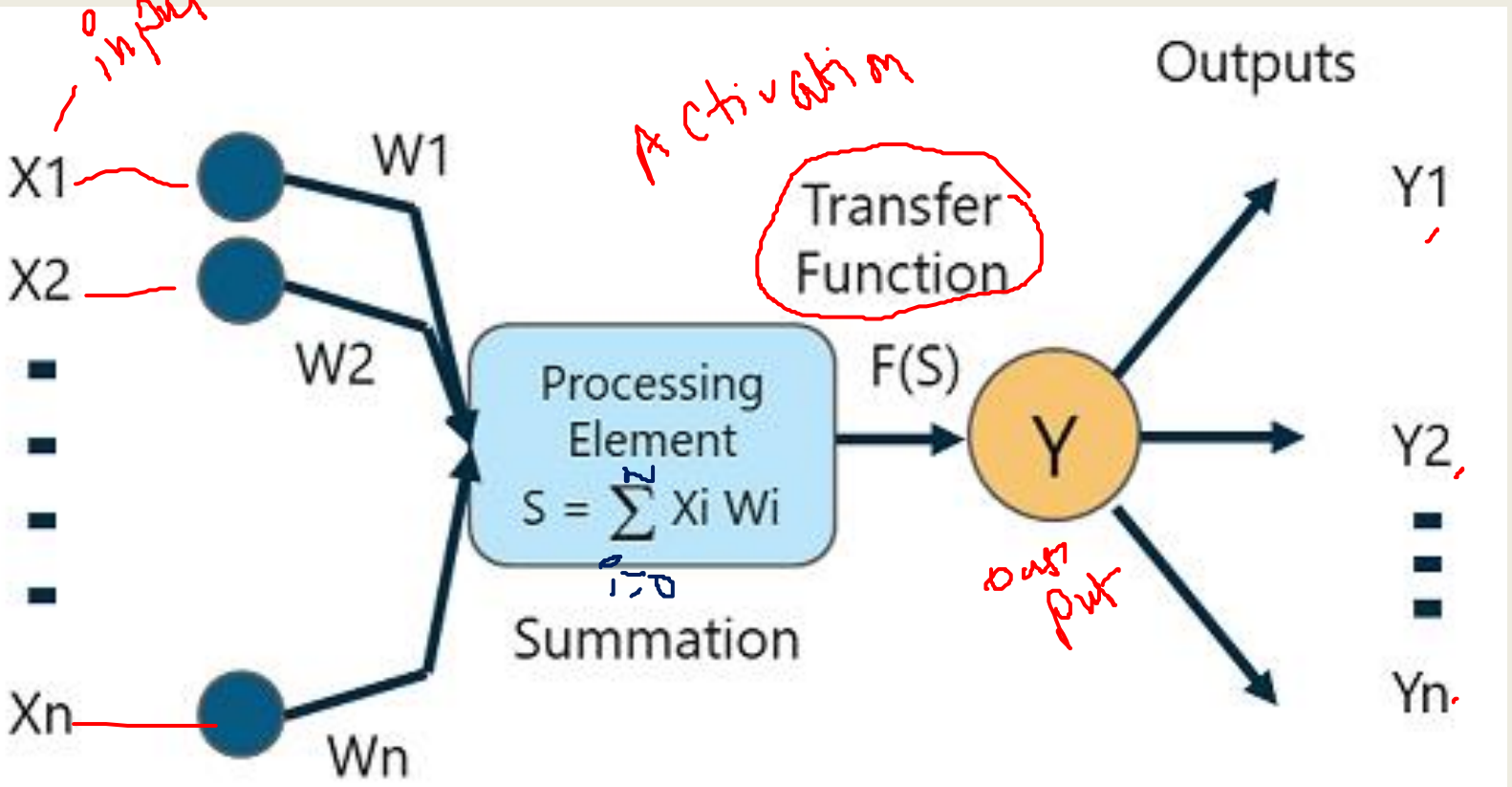


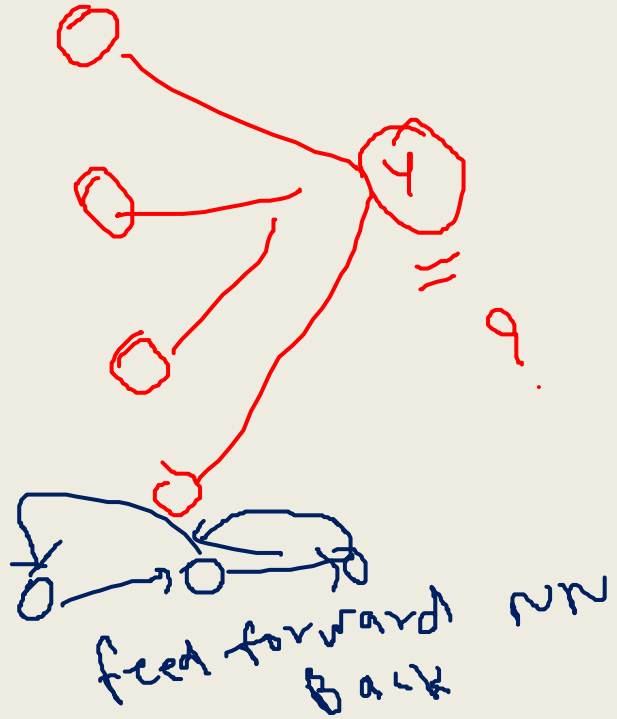
What Is A Perceptron?

- A Perceptron is a single layer neural network that is used to classify linear data. It has 4 important components:

- Inputs
- Weights and Bias
- Summation Function
- Activation or transformation Function







The inputs (x) received from the input layer are multiplied with their assigned weights w. The multiplied values are then added to form the Weighted Sum. The weighted sum of the inputs and their respective weights are then applied to a relevant Activation Function. The activation function maps the input to the respective output.

Weights and Bias

- **Why do we have to assign weights to each input?**

- Once an input variable is fed to the network, a randomly chosen value is assigned as the weight of that input. The weight of each input data point indicates how important that input is in predicting the outcome.

- The **bias** parameter, on the other hand, allows you to adjust the activation function curve in such a way that a precise output is achieved.

$$\sum_{i=0}^{n} x_i * w_i$$

- **Summation Function**
- Once the inputs are assigned some weight, the product of the respective input and weight is taken. Adding all these products gives us the Weighted Sum. This is done by the summation function.

- **Activation Function**
- The main aim of the activation functions is to map the weighted sum to the output. Activation functions such as tanh, ReLU, sigmoid and so on are examples of transformation functions.

Neural Networks Explained With An Example

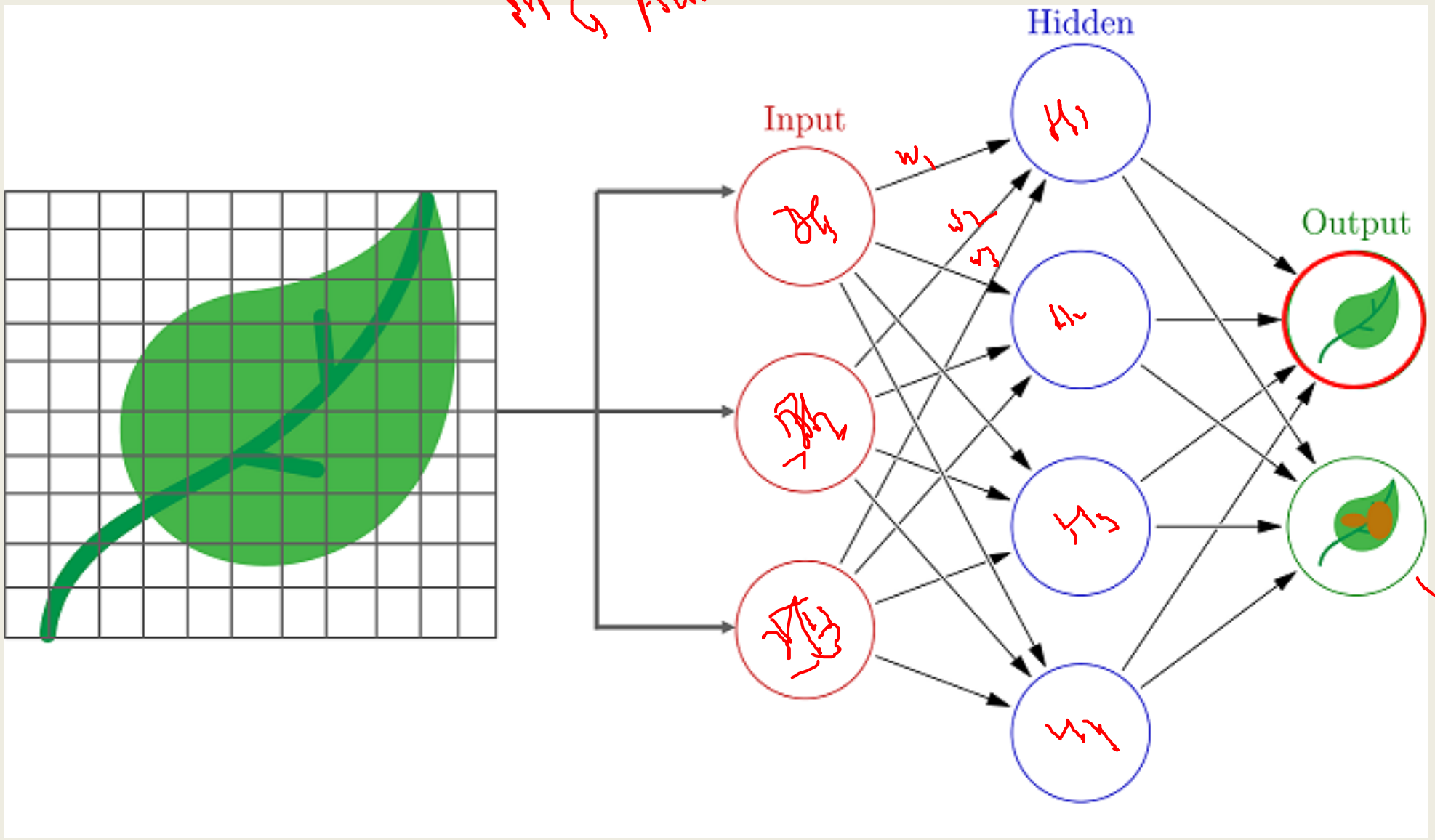
- Consider a scenario where you are to build an Artificial Neural Network (ANN) that classifies images into two classes:

- Class A: Containing images of non-diseased leaves
- Class B: Containing images of diseased leaves

- So how do you create a Neural network that classifies the leaves into diseased and non-diseased crops?

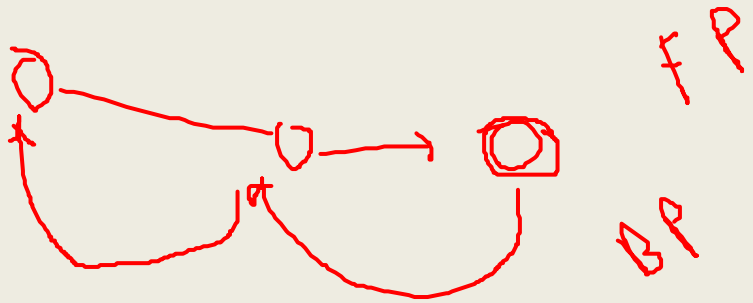
- The process always begins with processing and transforming the input in such a way that it can be easily processed. In our case, each leaf image will be broken down into pixels depending on the dimension of the image.

- For example, if the image is composed of 30 by 30 pixels, then the total number of pixels will be 900. These pixels are represented as matrices, which are then fed into the input layer of the Neural Network.


Hidden
Input
Output

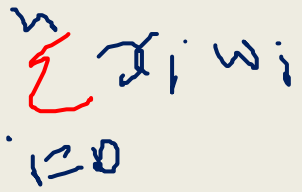
- Just like how our brains have neurons that help in building and connecting thoughts, an ANN has perceptron that accept inputs and process them by passing them on from the input layer to the hidden and finally the output layer.

- As the input is passed from the input layer to the hidden layer, an initial random weight is assigned to each input. The inputs are then multiplied with their corresponding weights and their sum is sent as input to the next hidden layer.



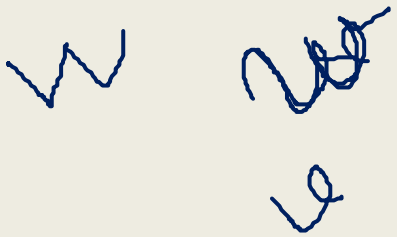
- Here, a numerical value called bias is assigned to each perceptron, which is associated with the weightage of each input. Further, each perceptron is passed through activation or a transformation function that determines whether a particular perceptron gets activated or not.
- An activated perceptron is used to transmit data to the next layer. In this manner, the data is propagated (Forward propagation) through the neural network until the perceptrons reach the output layer.
- At the output layer, a probability is derived which decides whether the data belongs to class A or class B.

- Sounds simple, doesn't it? Well, the concept behind Neural Networks is purely based on the functioning of the human brain. You require in-depth knowledge of various mathematical concepts and algorithms.



Areas of Application

- Speech Recognition
- Character Recognition
- Signature Verification Application
- Human Face Recognition



Speech Recognition

- Speech occupies a prominent role in human-human interaction. Therefore, it is natural for people to expect speech interfaces with computers. In the present era, for communication with machines, humans still need sophisticated languages which are difficult to learn and use. To ease this communication barrier, a simple solution could be, communication in a spoken language that is possible for the machine to understand.

- Great progress has been made in this field, however, still such kinds of systems are facing the problem of limited vocabulary or grammar along with the issue of retraining of the system for different speakers in different conditions. ANN is playing a major role in this area. Following ANNs have been used for speech recognition −

- Multilayer networks
- Multilayer networks with recurrent connections
- Kohonen self-organizing feature map

Character Recognition

- It is an interesting problem which falls under the general area of Pattern Recognition. Many neural networks have been developed for automatic recognition of handwritten characters, either letters or digits. Following are some ANNs which have been used for character recognition −

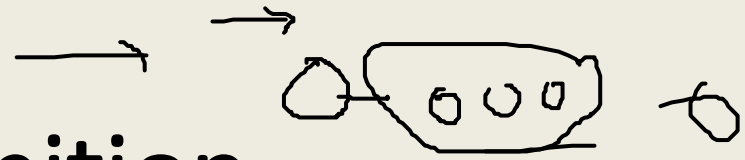
- Multilayer neural networks such as Backpropagation neural networks.
- Neocognitron

- Though back-propagation neural networks have several hidden layers, the pattern of connection from one layer to the next is localized. Similarly, neocognitron also has several hidden layers and its training is done layer by layer for such kind of applications.

Signature Verification Application

- Signatures are one of the most useful ways to authorize and authenticate a person in legal transactions. Signature verification technique is a non-vision based technique.

- For this application, the first approach is to extract the feature or rather the geometrical feature set representing the signature. With these feature sets, we have to train the neural networks using an efficient neural network algorithm. This trained neural network will classify the signature as being genuine or forged under the verification stage.



Human Face Recognition

- It is one of the biometric methods to identify the given face. It is a typical task because of the characterization of “non-face” images. However, if a neural network is well trained, then it can be divided into two classes namely images having faces and images that do not have faces.
- First, all the input images must be preprocessed. Then, the dimensionality of that image must be reduced. And, at last it must be classified using neural network training algorithm. Following neural networks are used for training purposes with preprocessed image −
  - Fully-connected multilayer feed-forward neural network trained with the help of back-propagation algorithm.
  - For dimensionality reduction, Principal Component Analysis PCA is used.

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