Neural networks

Lecture 02

Introduction to Neural Networks (1)

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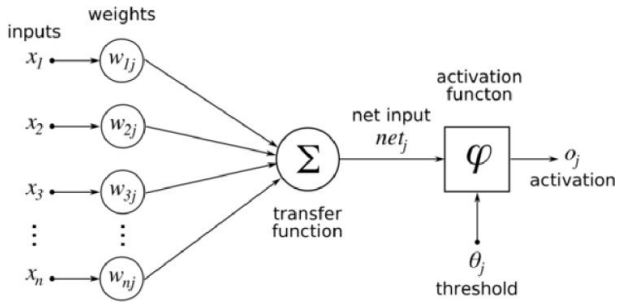
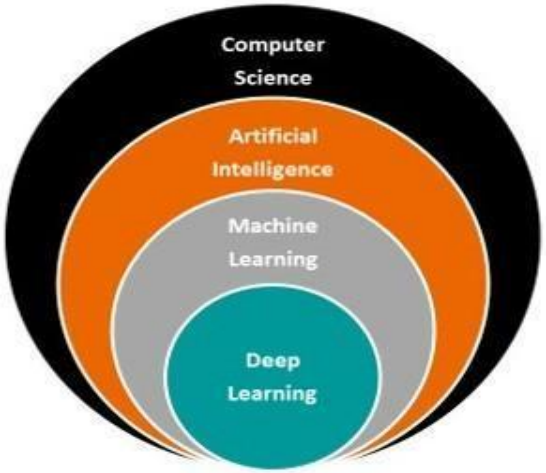
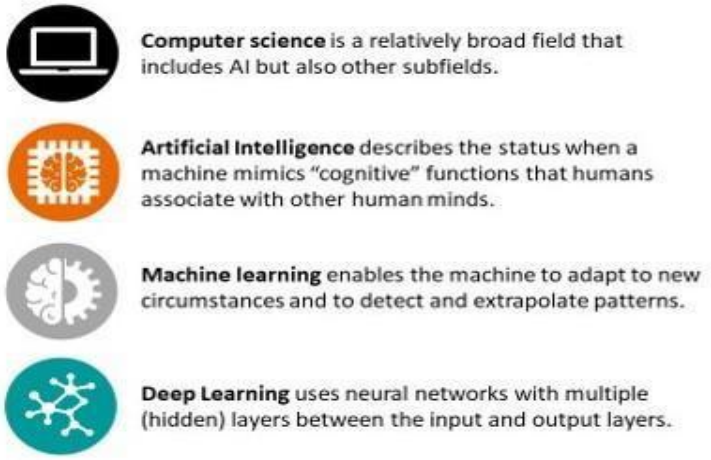


Introduction to ANN

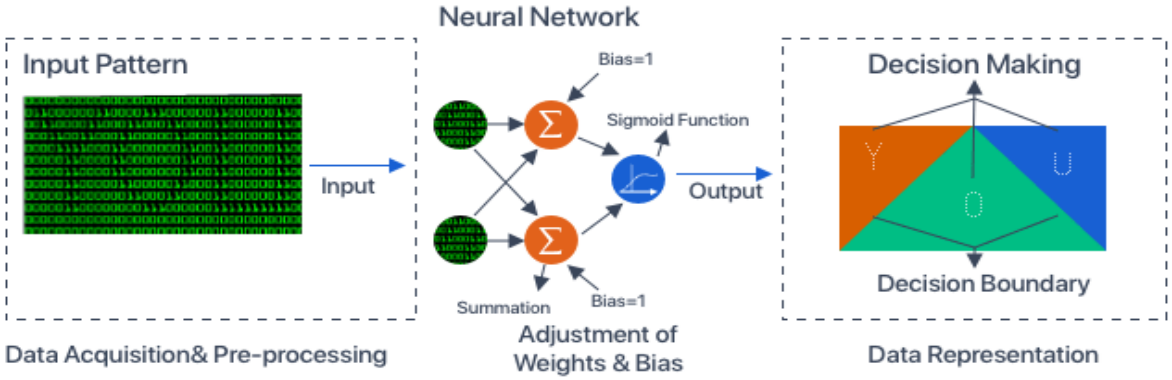
- ANN (Artificial Neural Network) is at the very core of **Deep Learning (DL)** an advanced version of **Machine Learning (ML)** techniques, sub-field of **artificial intelligence (AI)**.
- ANN was first introduced in 1943 by the neurophysiologist Warren McCulloch and the mathematician Walter Pitts.
- The term ANN refers to a biologically inspired **AI** modeled after the brain. Thus, it is usually a computational network based on **biological neural networks** that construct the structure of the human brain.





Introduction to ANN

- Similar to a human brain has neurons interconnected to each other, artificial neural networks also have neurons that are linked to each other in various layers of the networks. **These neurons are known as nodes.**
- ANNs are versatile, adaptive, and scalable, making them appropriate to tackle large datasets and highly complex Machine Learning tasks such as image classification (e.g., Google Images), speech recognition (e.g., Apple's Siri), video recommendation (e.g., YouTube), or analyzing sentiments among customers (e.g. Twitter Sentiment Analyzer).



Historical Notes

1943 McCulloch and Pitts proposed the McCulloch-Pitts neuron model

1949 Hebb published his book *The Organization of Behaviour*, in which the Hebbian learning rule was introduced

1958 Rosenblatt introduced the simple single layer networks called Perceptrons

1969 Minsky and Papert's book Perceptrons demonstrated the limitation of single layer perceptrons

1980 Grossberg introduced his Adaptive Resonance Theory (ART)

1982 Hopfield published a series of papers on Hopfield networks

1982 Kohonen developed the Self-Organizing Feature Maps

1986 Back-propagation learning algorithm for multi-layer perceptrons was re-discovered, and the whole field took off again

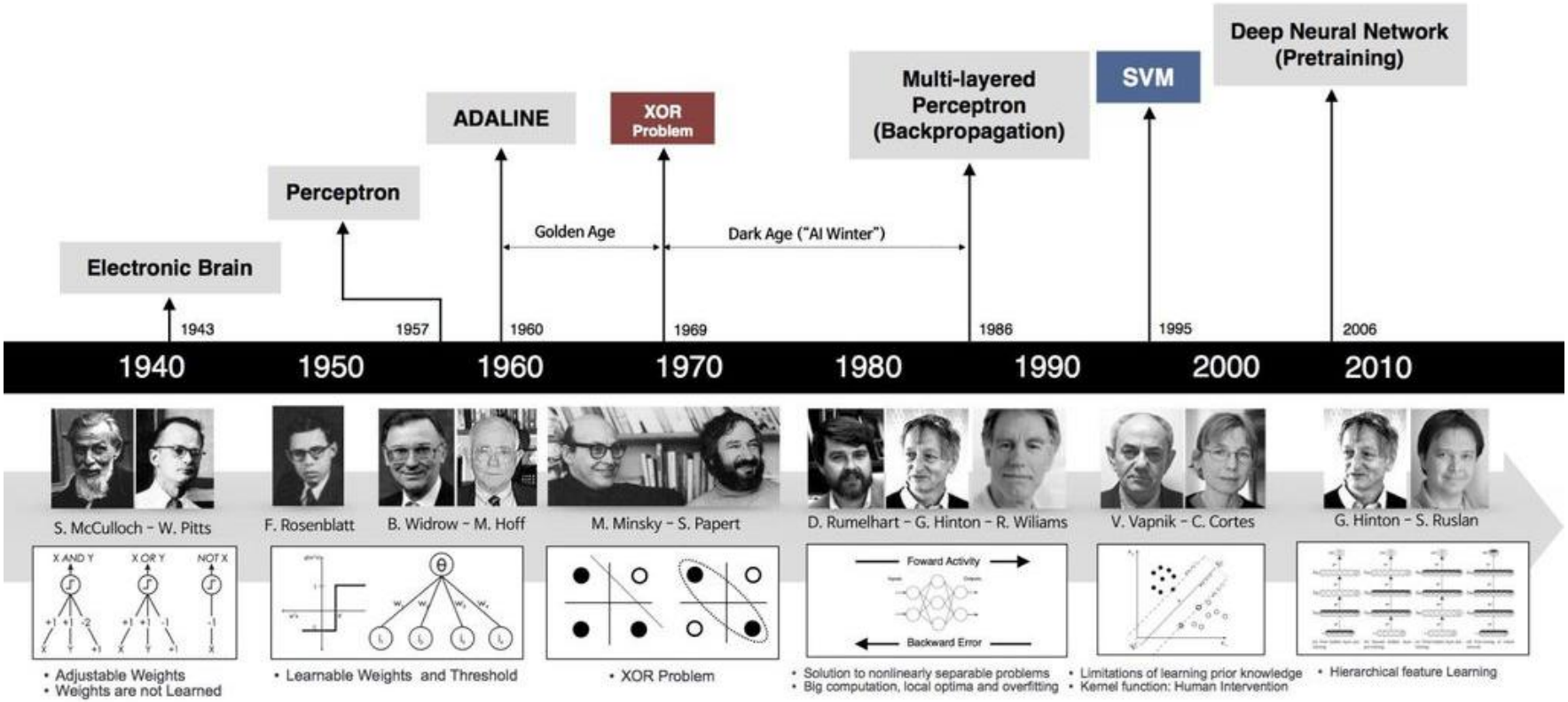
1990s ART-variant networks were developed

1990s Radial Basis Functions were developed

2000s Support Vector Machines were developed

Historical Notes

- **Major innovations:**

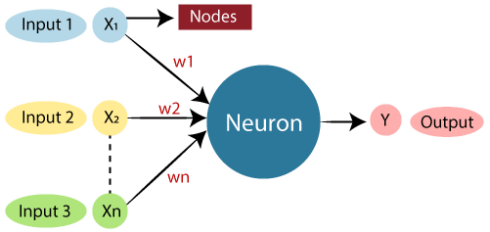


What are ANNs?

- Neural Networks are networks of neurons, for example, as found in real (i.e. biological) brains
- Artificial neurons are crude approximations of the neurons found in real brains. They may be physical devices, or purely mathematical constructs.
- Artificial Neural Networks (ANNs) are networks of Artificial Neurons and hence constitute crude approximations to parts of real brains. They maybe physical devices, or simulated on conventional computers.
- From a practical point of view, an ANN is just a parallel computational system consisting of many simple processing elements connected together in a specific way in order to perform a particular task

What are ANNs?

- **An artificial neural network is an information-processing system that has certain performance characteristics in common with biological neural networks.**
- Artificial neural networks have been developed as generalizations of mathematical models of human cognition or neural biology, based on the assumptions that:
  1. Information processing occurs at many simple elements called **neurons**.
  2. Signals are passed between neurons over **connection links**.
  3. Each connection link has an associated **weight**, which. in a typical neural net. multiplies the signal transmitted.
  4. Each neuron applies an **activation function** (usually nonlinear) to its net input (**sum of weighted input signals**) to determine its output signal.

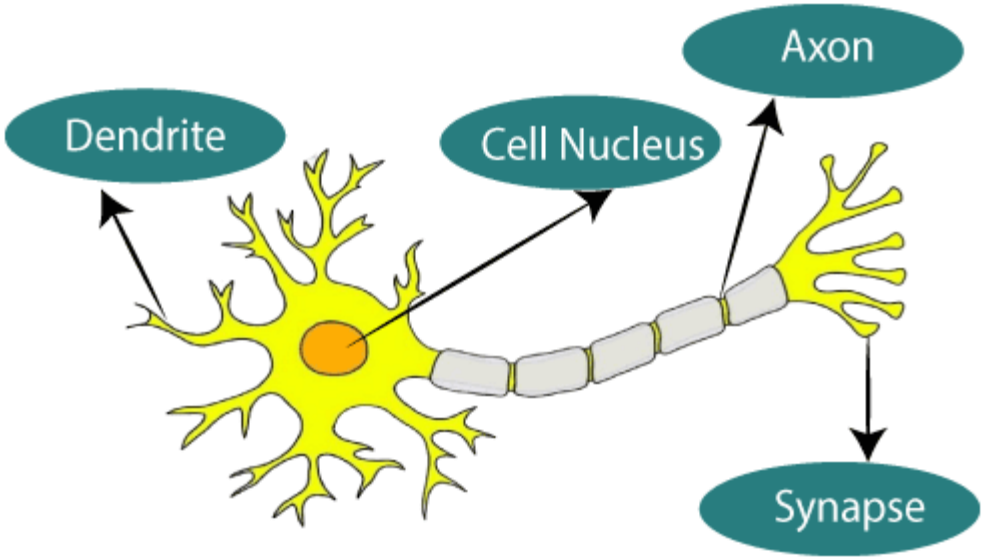


What are ANNs?

- A neural network is characterized by:
  1) Its pattern of connections between the neurons (called its **architecture**),
  2) Its method of determining the weights on the connections (called its **training, or learning algorithm**), and
  3) Its **activation function**.

Neural Network Structure

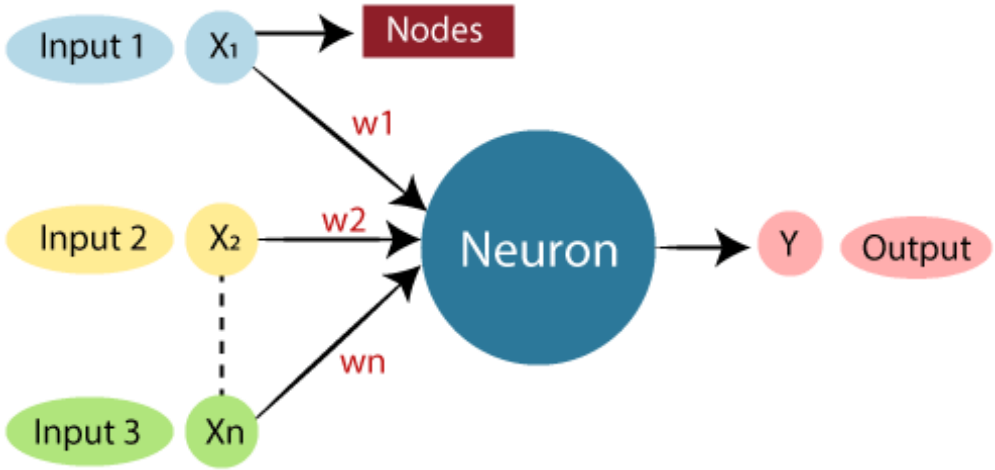
- As the ANN is derived from Biological neural networks that develop the structure of a human brain, it has neurons that are interconnected to one another in various layers of the networks, similar to the human brain.



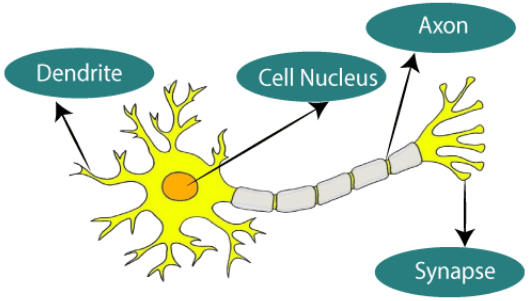
- The given figure illustrates the typical diagram of Biological Neural Network.

Neural Network Structure

- The ANN is designed by programming computers to behave simply like interconnected brain cells. The typical ANN looks something like the given figure.



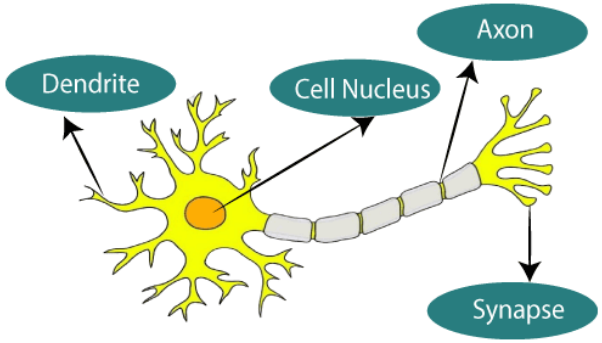
- Dendrites from Biological Neural Network represent inputs in Artificial Neural Networks, cell nucleus represents Nodes, synapse represents Weights, and Axon represents Output.

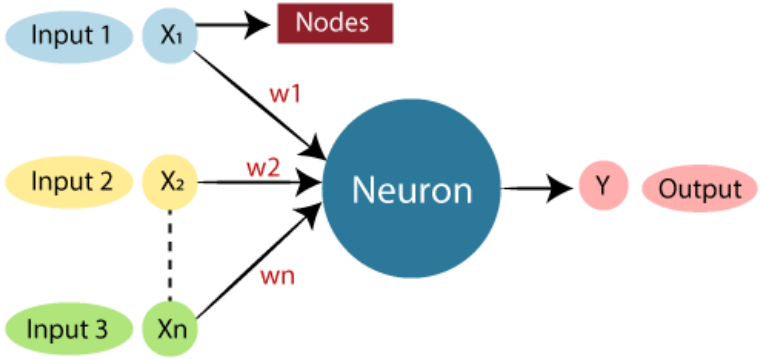


Neural Network Structure

- **Relationship between Biological neural network and artificial neural network:**

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



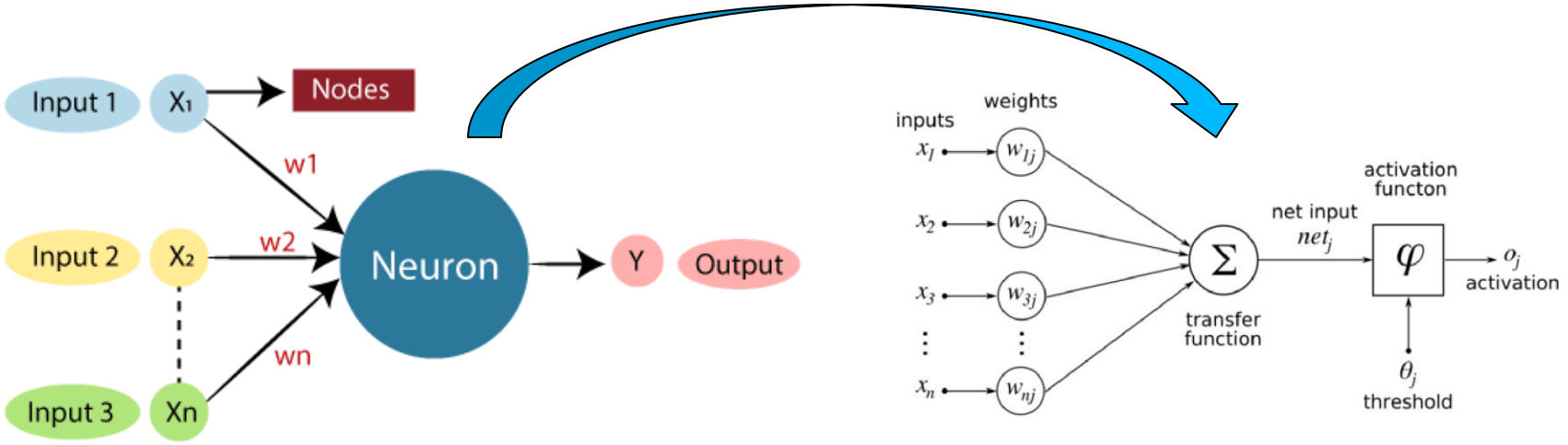


Neural Network Structure

- There are around 100 billion neurons in the human brain. 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. Thus, the human brain is made up of incredibly amazing parallel processors.
- We can understand the artificial neural network with an example, consider an example of a digital logic gate that takes an input and gives an output. "OR" gate, which takes two inputs. If one or both the inputs are "On," then we get "On" in output. If both the inputs are "Off," then we get "Off" in output. Here the output depends upon input. Our brain does not perform the same task. The outputs to inputs relationship keep changing because of the neurons in our brain, which are "learning."

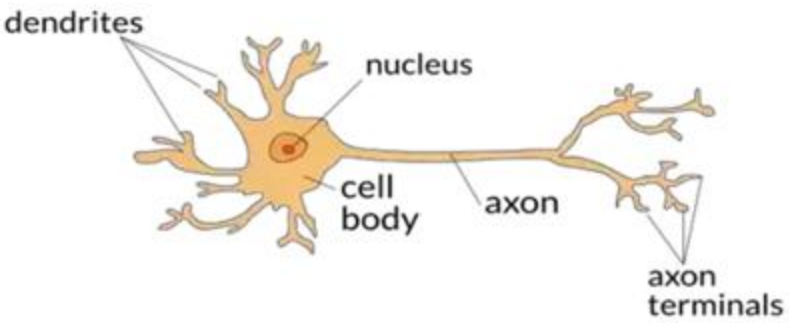
Processing Elements and Activation

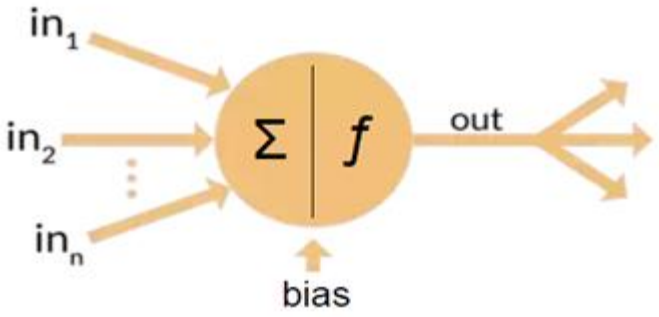
- A neural net consists of a large number of simple processing elements called ***neurons***, ***units***, ***cells***, or ***nodes***.
- Each neuron is connected to other neurons by means of directed communication links, each with an associated weight.
- The weights represent information being used by the net to solve a problem.



Processing Elements and Activation

- Each neuron has an internal state, called its *activation* or *activity level*, which is a function of the inputs it has received.
- **Typically, a neuron sends its activation as a signal to several other neurons.**
- It is important to note that a neuron can send only one signal at a time, although that signal is broadcast to several other neurons.





Processing Elements and Activation

- For example, consider a neuron Y that receives inputs from neurons X_1, X_2 and X_3 , as shown in the following figure.
- The activations (output signals) of these neurons are x_1, x_2 and x_3, respectively.
- The weights on the connections from X_1, X_2 and X_3 to neuron Y are w_1, w_2 and w_3, respectively.
- The net input, y_{in}, to neuron Y is the sum of the weighted signals from neurons X_1, X_2 and X_3, i.e.,

$$y_{in} = w_1x_1 + w_2x_2 + w_3x_3$$

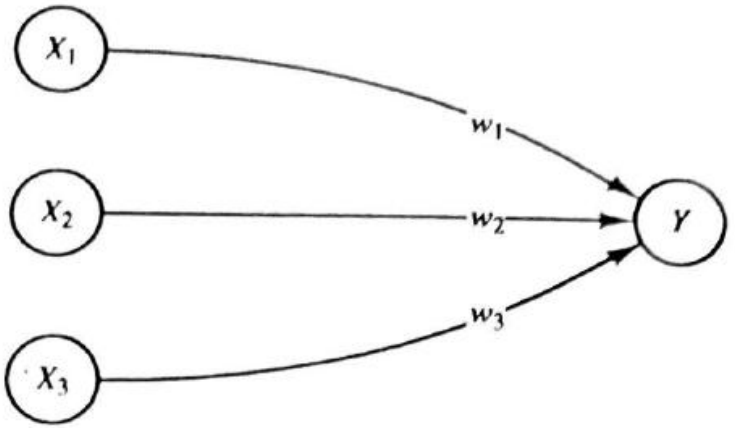


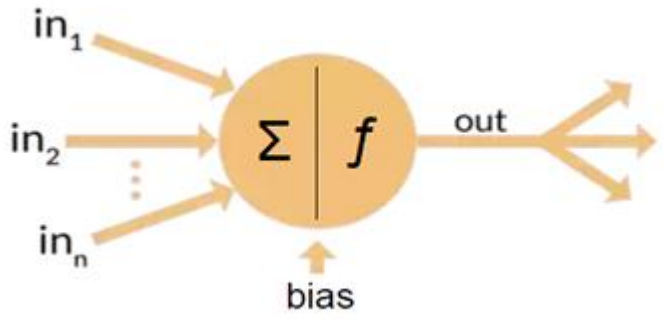
Figure: A simple (artificial) neuron.

Processing Elements and Activation

- The activation y of neuron Y is given by some function of its net input (y_in), y = f(y_in).
- Here f is the logistic sigmoid function (an S-shaped curve), given by-

$$f(x) = \frac{1}{1 + \exp(-x)},$$

- Or any of a number of other activation functions. Several common activation functions used in the ANN computation. We will discuss later.



Processing Elements and Activation

Key features of the processing elements:

- Several key features of the processing elements of artificial neural networks are suggested by the properties of biological neurons, that is:
  1. The processing element receives many signals.
  2. Signals may be modified by a weight at the receiving synapse.
  3. The processing element sums the weighted inputs.
  4. Under appropriate circumstances (sufficient input), the neuron transmits a single output.
  5. The output from a particular neuron may go to many other neurons (the axon branches).

Processing Elements and Activation

- **Other features of artificial neural networks that are suggested by biological neurons are:**

  6. Information processing is local (although other means of transmission, such as the action of hormones, may suggest means of overall process control).

  7. Memory is distributed:

     a. Long-term memory resides in the neurons' synapses or weights.

     b. Short-term memory corresponds to the signals sent by the neurons.

  8. A synapse's strength may be modified by experience.

  9. Neurotransmitters for synapses may be excitatory or inhibitory.

INTRODUCTION TO NEURAL NETWORKS

To be continued.