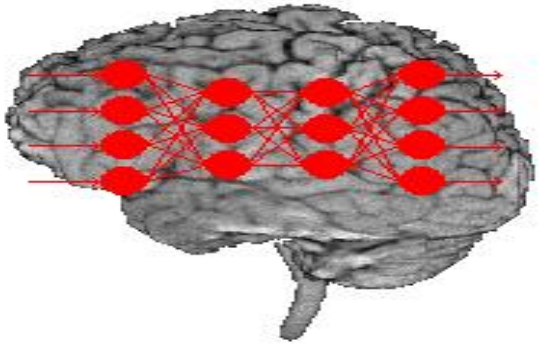
Deep Learning
Lecture-3

Introduction to Artificial Neural Network



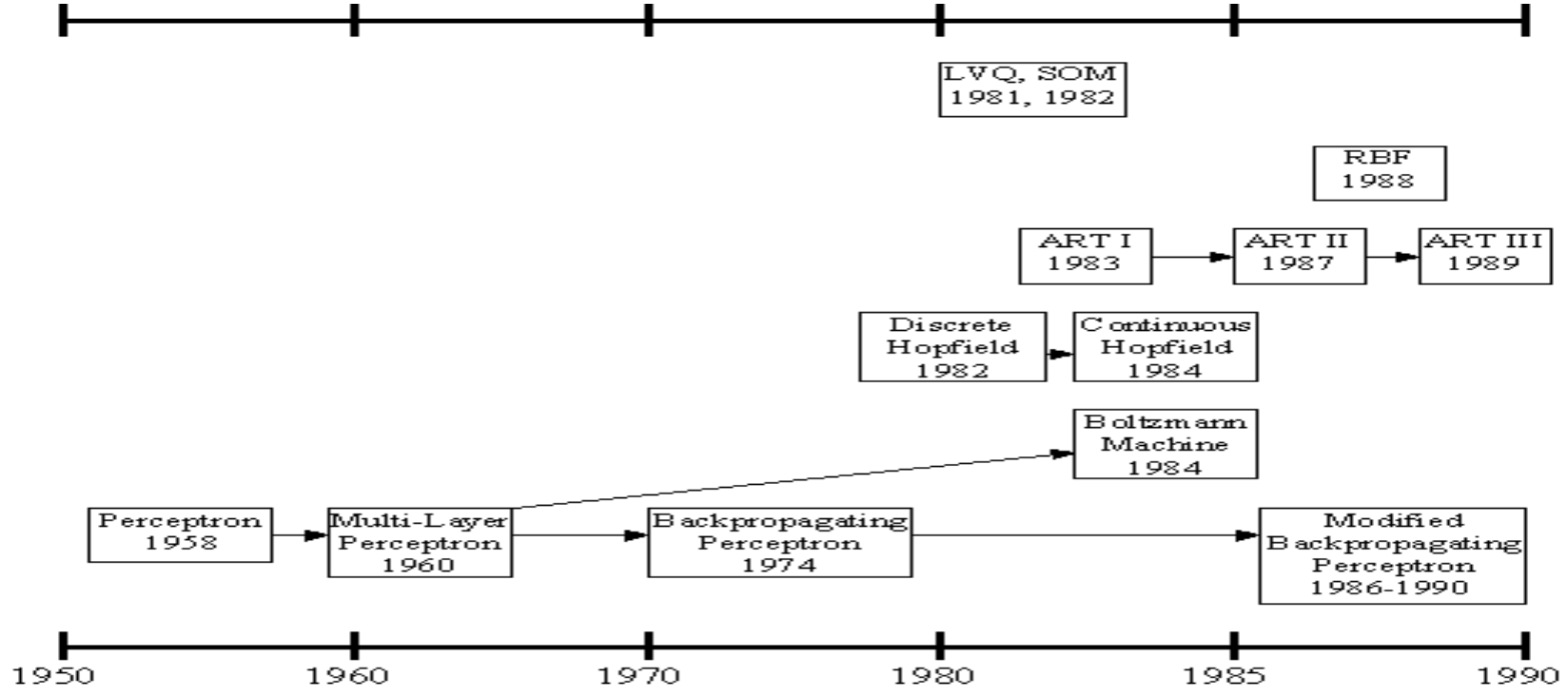
Asst. Lect. Ali Al-khawaja

2025-2026

Class Room

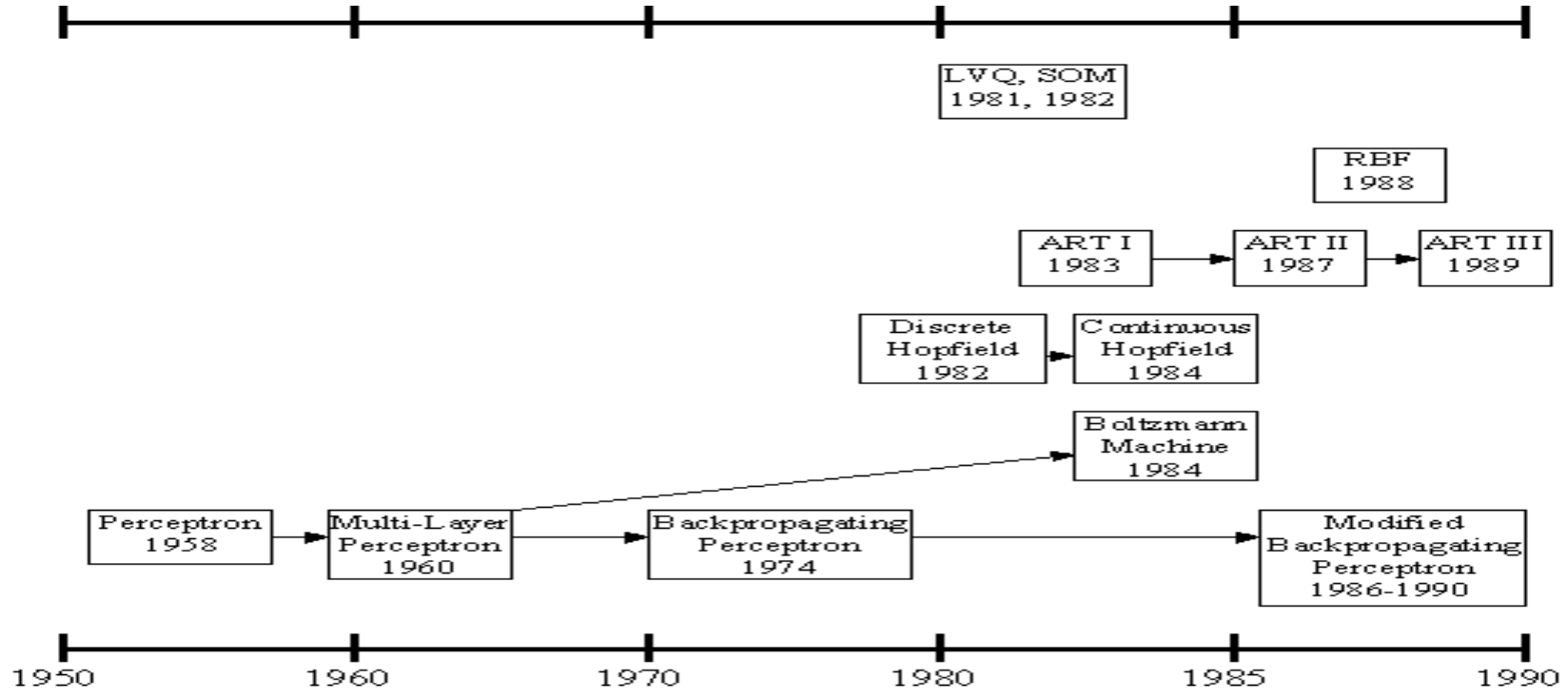
History of the Artificial Neural Networks

- history of the ANNs stems from the 1940s, the decade of the first electronic computer.
- However, the first important step took place in 1957 when Rosenblatt introduced the first concrete neural model, the perceptron. Rosenblatt also took part in constructing the first successful neurocomputer, the Mark I Perceptron. After this, the development of ANNs has proceeded as described in *Figure*.



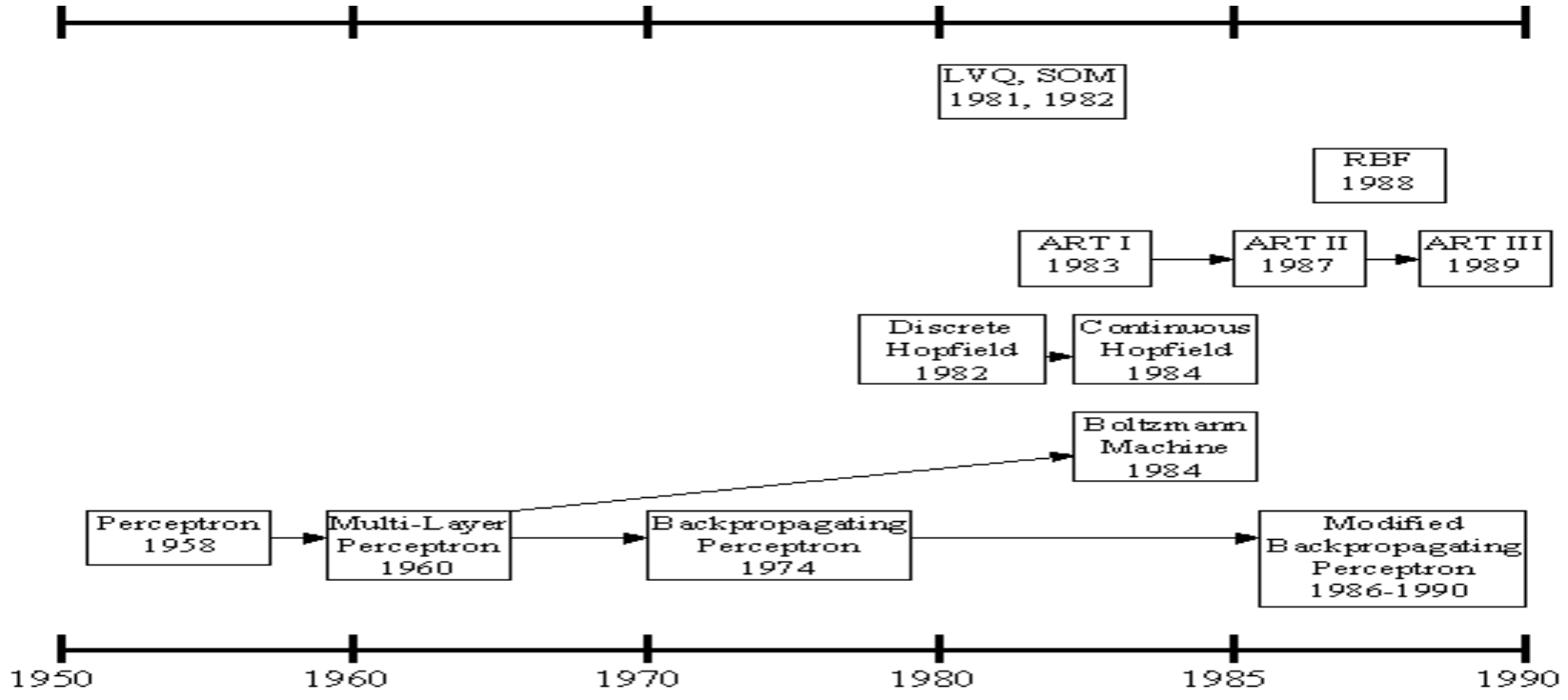
History of the Artificial Neural Networks

- Rosenblatt's original perceptron model contained only one layer. From this, a multi-layered model was derived in 1960. At first, the use of the multi-layer perceptron (MLP) was complicated by the lack of a appropriate learning algorithm.
- In 1974, Werbos came to introduce a so-called backpropagation algorithm for the three-layered perceptron network.



History of the Artificial Neural Networks

- in 1986, The application area of the MLP networks remained rather limited until the breakthrough when a general back propagation algorithm for a multi-layered perceptron was introduced by Rummelhart and Mclelland.
- in 1982, Hopfield brought out his idea of a neural network. Unlike the neurons in MLP, the Hopfield network consists of only one layer whose neurons are fully connected with each other.



History of Artificial Neural Networks

Since then, research on artificial neural networks has remained active, leading to many new network types, as well as hybrid algorithms and hardware for neural information processing.

Artificial Neural Network

- An artificial neural network consists of a pool of simple processing units which communicate by sending signals to each other over a large number of weighted connections.

Artificial Neural Network

- A set of major aspects of a parallel distributed model include:
- a set of processing units (cells).
- a state of activation for every unit, which equivalent to the output of the unit.
- connections between the units. Generally each connection is defined by a weight.
- a propagation rule, which determines the effective input of a unit from its external inputs.
- an activation function, which determines the new level of activation based on the effective input and the current activation.
- an external input for each unit.
- a method for information gathering (the learning rule).
- an environment within which the system must operate, providing input signals and _ if necessary _ error signals.

Computers vs. Neural Networks

"Standard" Computers	Neural Networks
• one CPU	highly parallel processing
• fast processing units	slow processing units
• reliable units	unreliable units
• static infrastructure	dynamic infrastructure

Why Artificial Neural Networks?

- There are two basic reasons why we are interested in building artificial neural networks (ANNs):

- **Technical viewpoint:** Some problems such as character recognition or the prediction of future states of a system require massively parallel and adaptive processing.

- **Biological viewpoint:** ANNs can be used to replicate and simulate components of the human (or animal) brain, thereby giving us insight into natural information processing.

Artificial Neural Networks

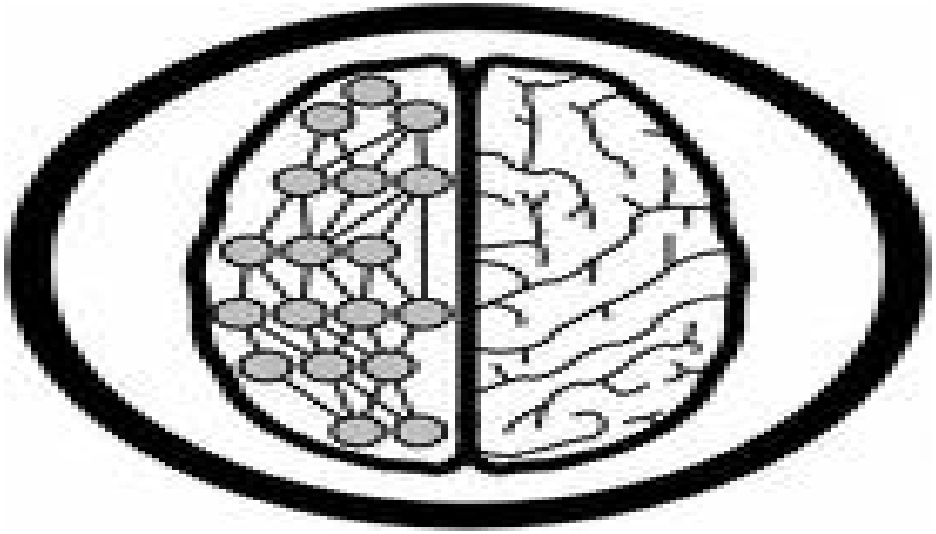
- The "building blocks" of neural networks are the **neurons**.
  - In technical systems, we also refer to them as **units** or **nodes**.
- Basically, each neuron
  - receives **input** from many other neurons.
  - changes its internal state (**activation**) based on the current input.
  - sends **one output signal** to many other neurons, possibly including its input neurons (recurrent network).

Artificial Neural Networks

- Information is transmitted as a series of electric impulses, so-called **spikes**.
- The **frequency** and **phase** of these spikes encodes the information.
- In biological systems, one neuron can be connected to as many as **10,000** other neurons.
- Usually, a neuron receives its information from other neurons in a confined area, its so-called **receptive field**.

How do ANNs work?

- An artificial neural network (ANN) is either a hardware implementation or a computer program which strives to simulate the information processing capabilities of its biological exemplar. ANNs are typically composed of a great number of interconnected artificial neurons. The artificial neurons are simplified models of their biological counterparts.
- ANN is a technique for solving problems by constructing software that works like our brains.

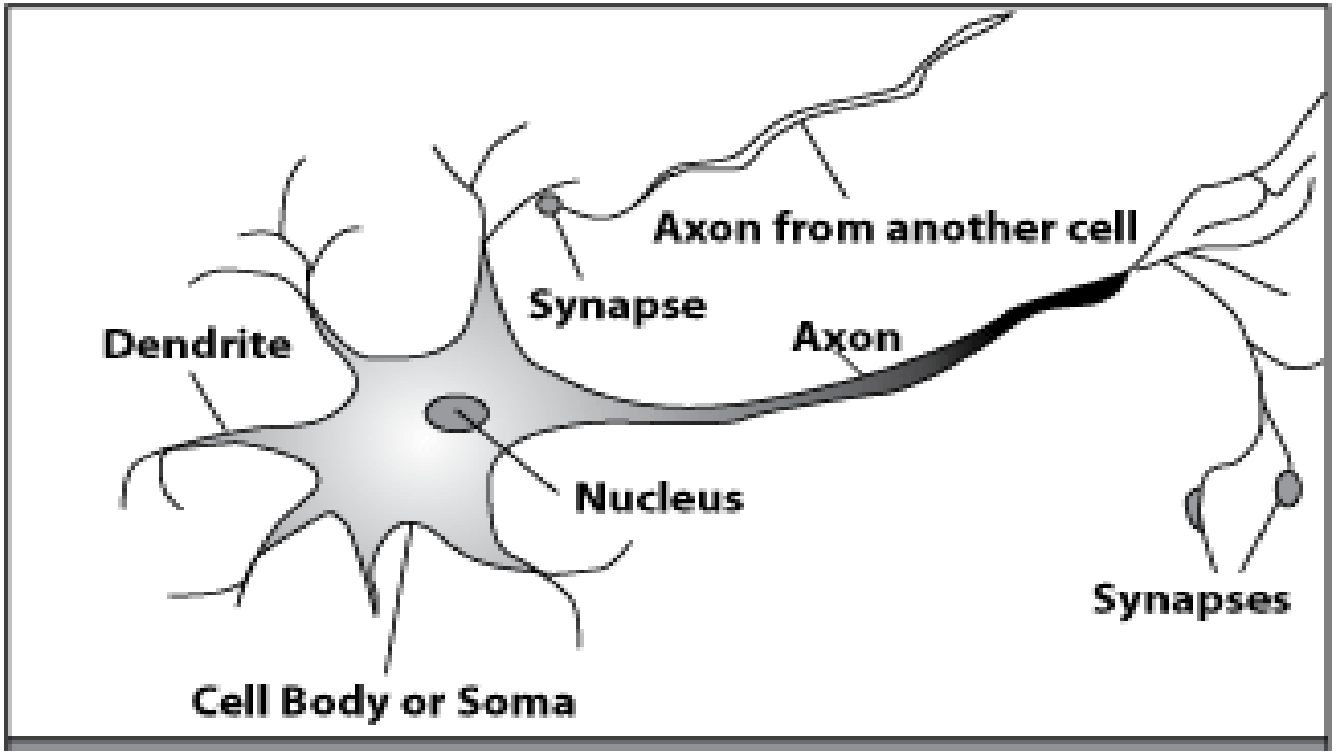


How do our brains work?

- The Brain is A massively parallel information processing system.
- Our brains are a huge network of processing elements. A typical brain contains a network of 10 billion neurons.

How do our brains work?

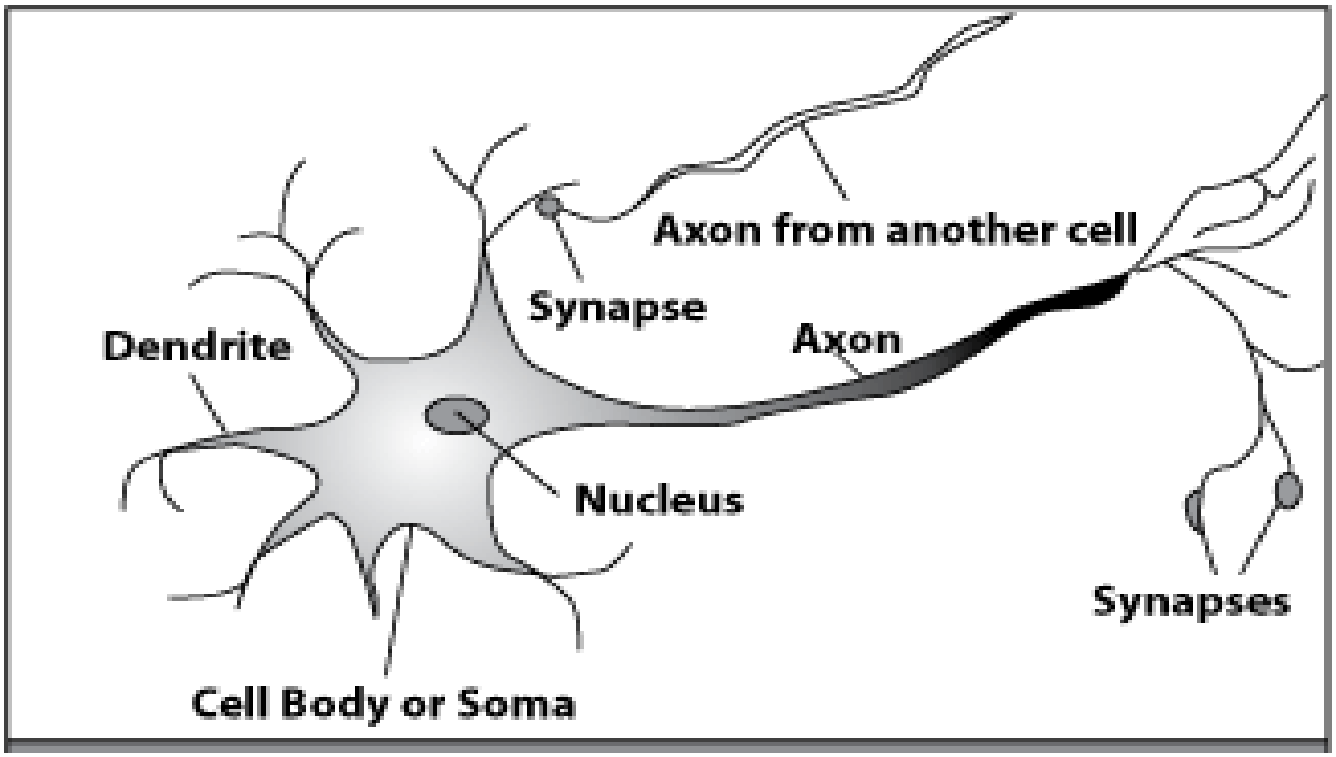
- A processing element



Dendrites: Input
Cell body: Processor
Synaptic: Link
Axon: Output

How do our brains work?

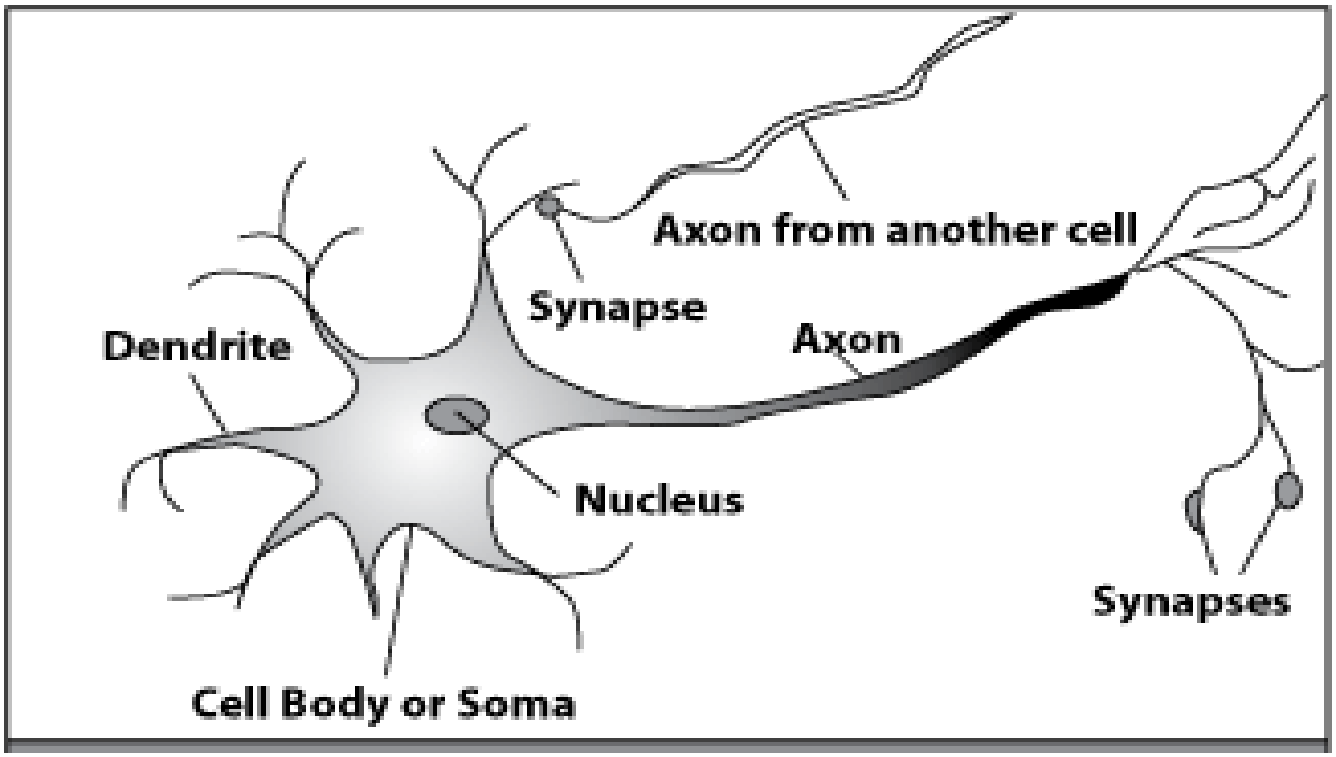
- A processing element



A neuron is connected to other neurons through about *10,000 synapses*

How do our brains work?

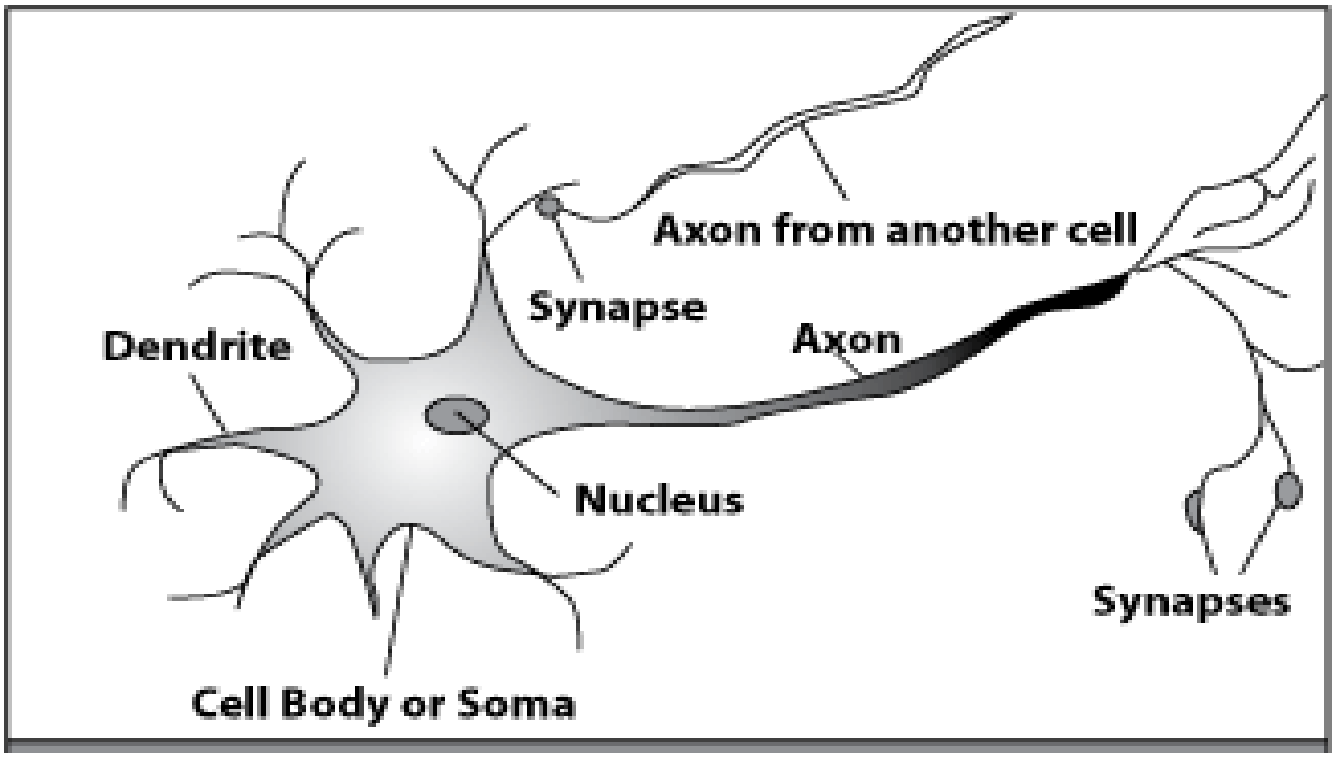
- A processing element



A neuron receives input from other neurons. Inputs are combined.

How do our brains work?

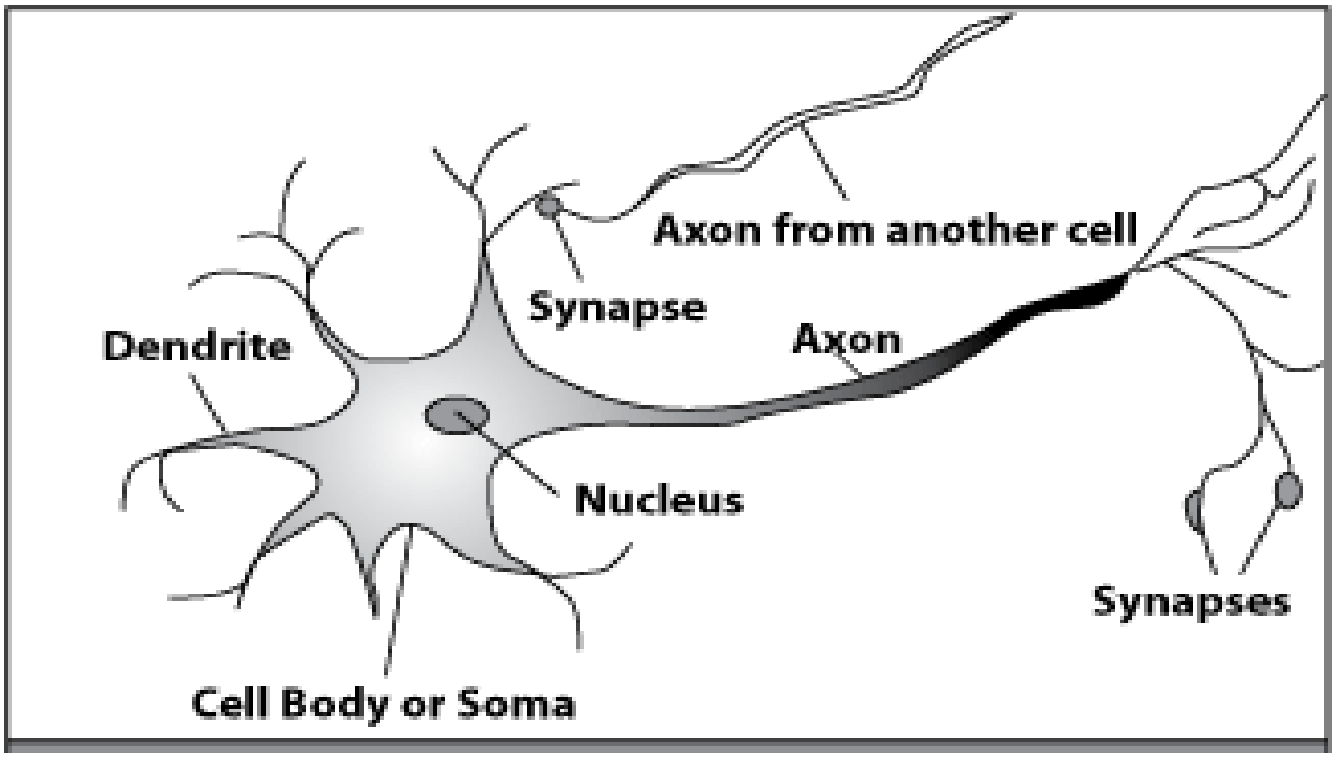
- A processing element



Once input exceeds a critical level, the neuron discharges a spike - an electrical pulse that travels from the body, down the axon, to the next neuron(s)

How do our brains work?

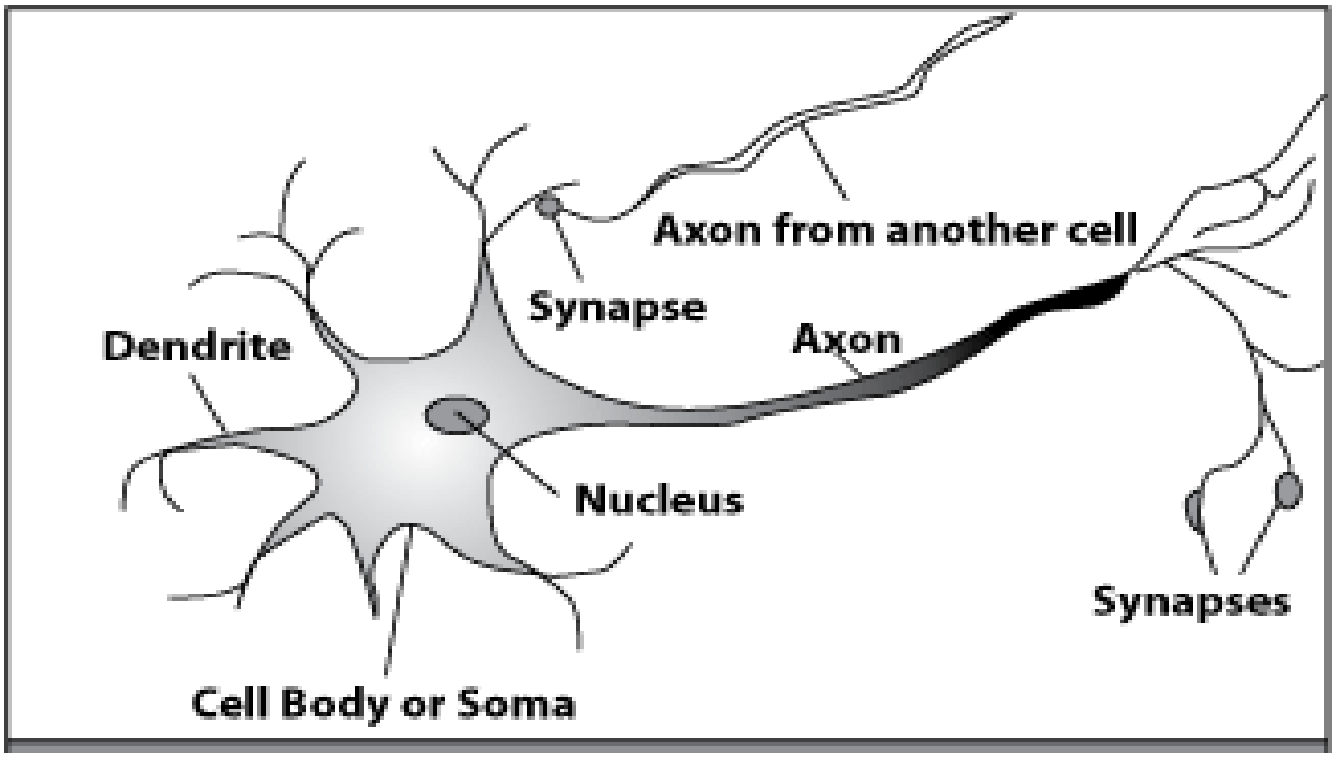
- A processing element



The axon endings almost touch the dendrites or cell body of the next neuron.

How do our brains work?

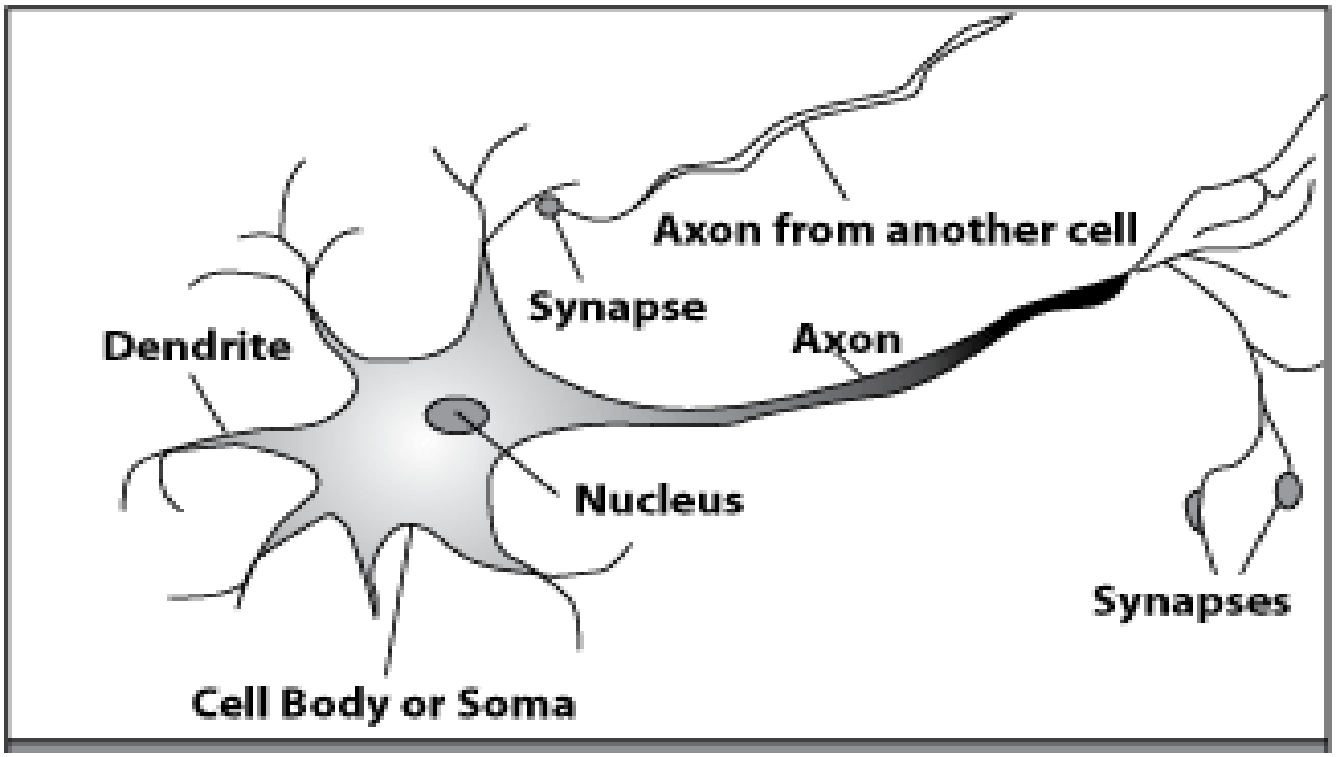
- A processing element



Transmission of an electrical signal from one neuron to the next is effected by neurotransmitters.

How do our brains work?

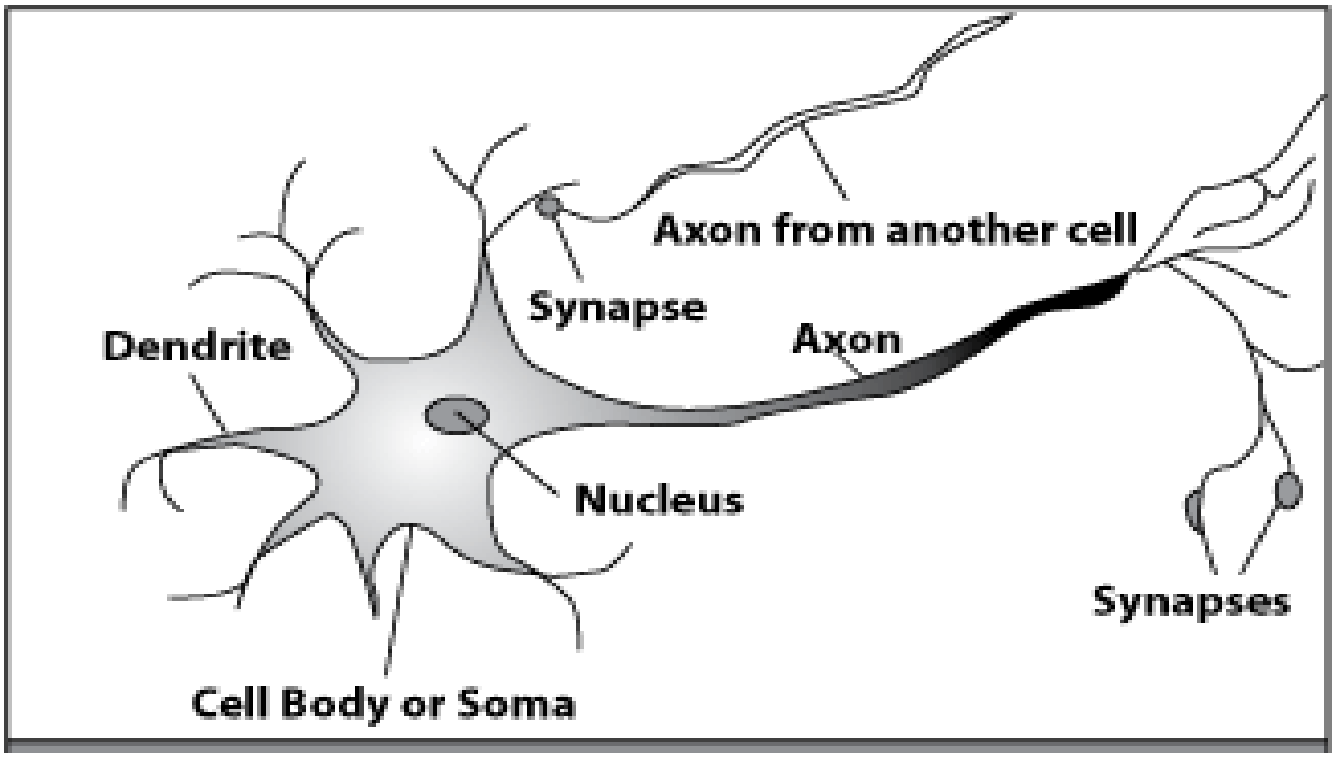
- A processing element



Neurotransmitters are chemicals which are released from the first neuron and which bind to the Second.

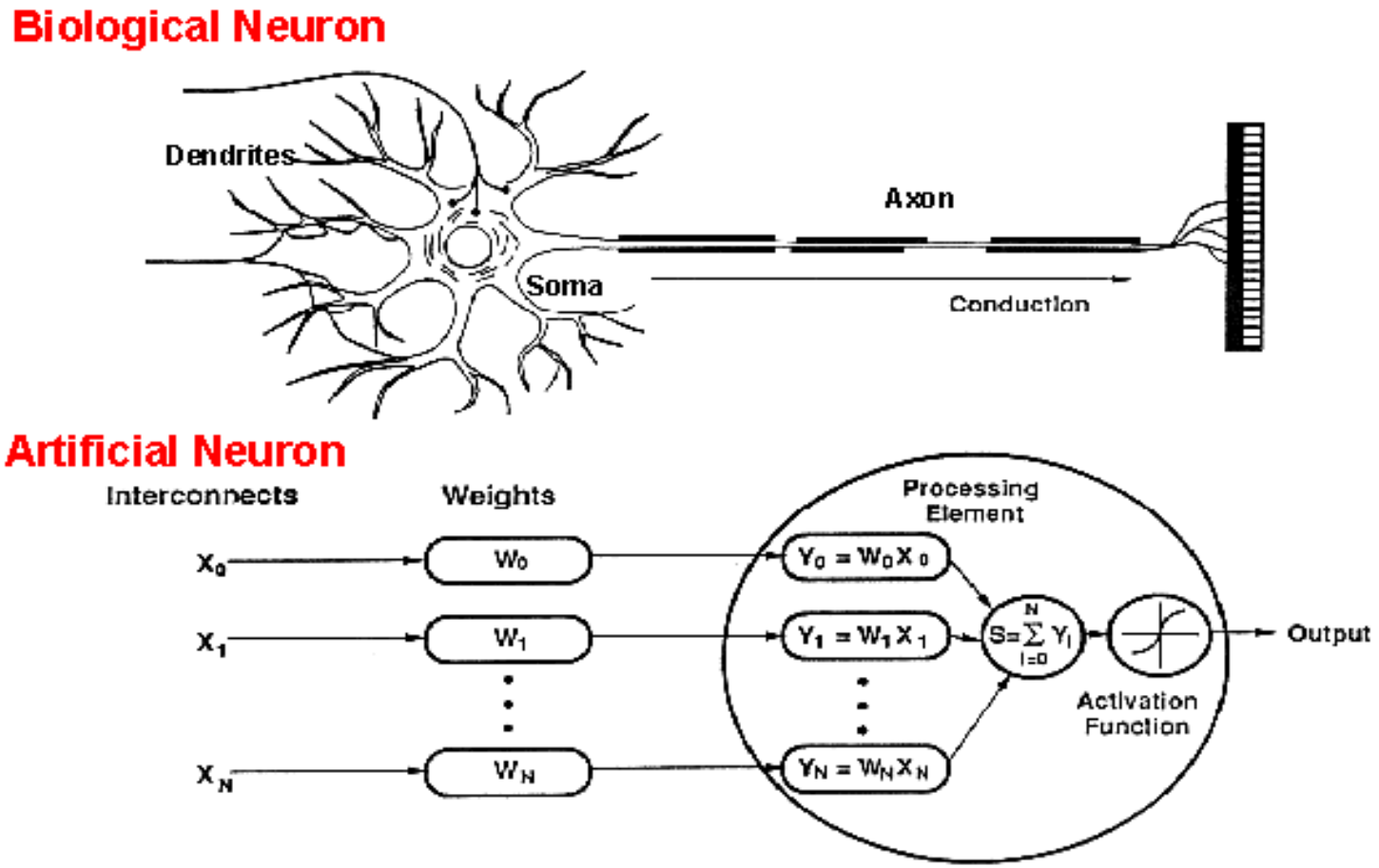
How do our brains work?

- A processing element



This link is called a synapse. The strength of the signal that reaches the next neuron depends on factors such as the amount of neurotransmitter available.

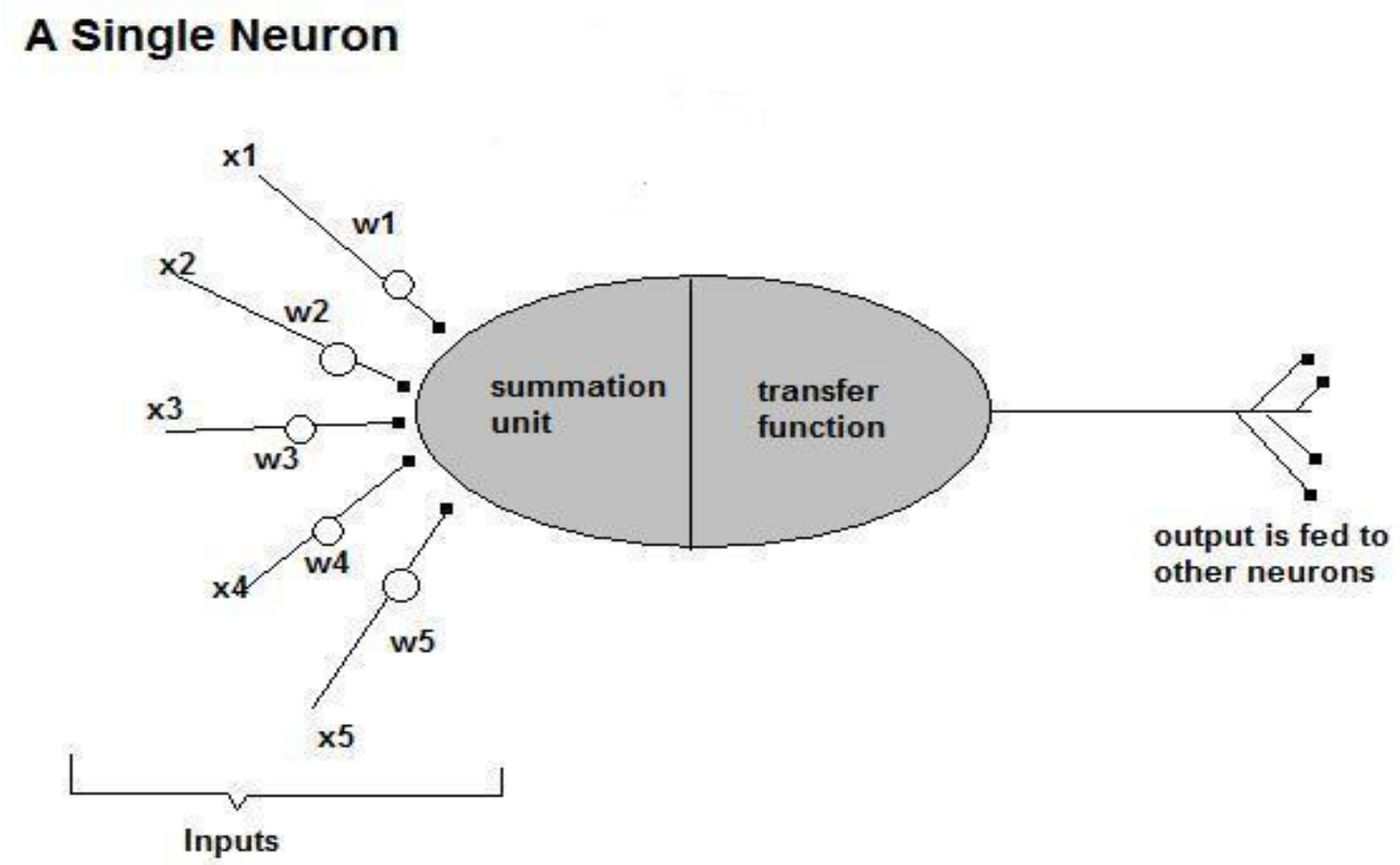
How do ANNs work?



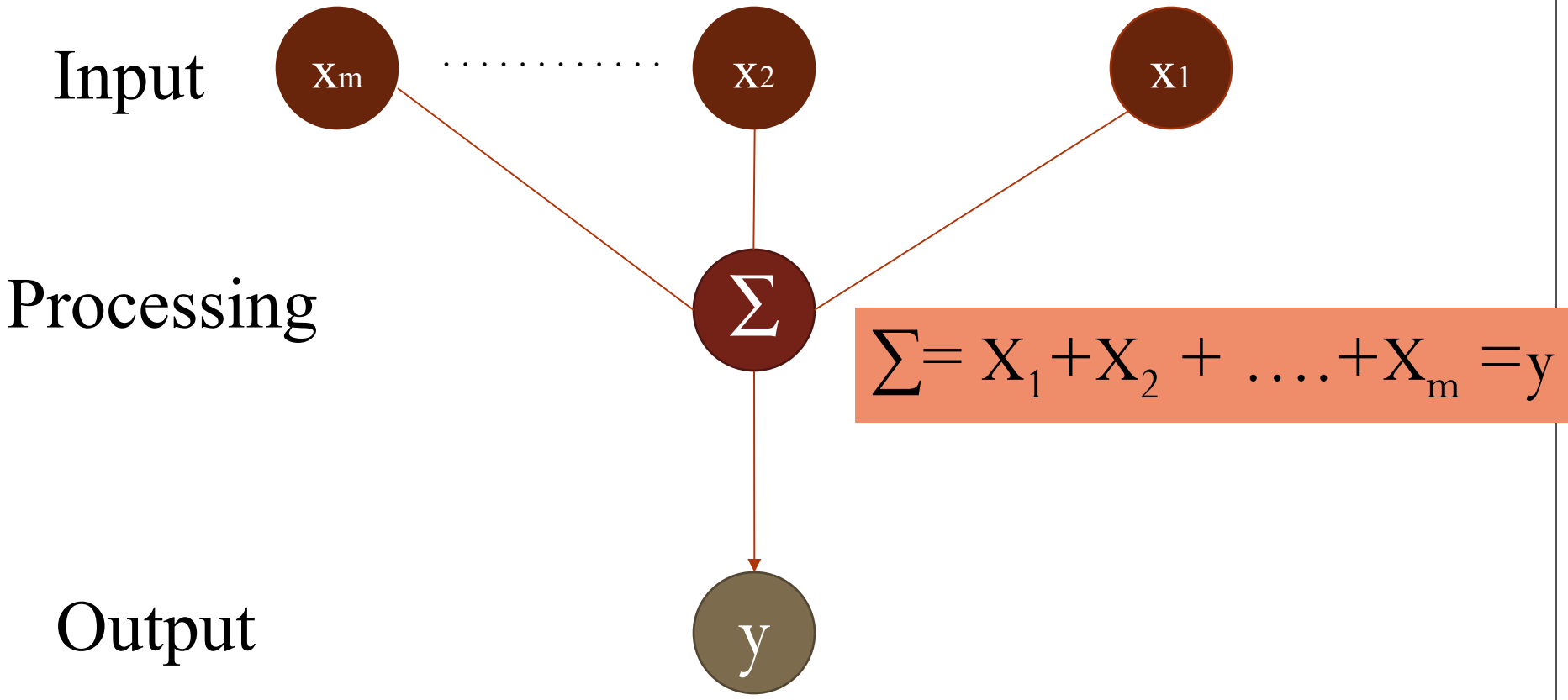
An artificial neuron is an imitation of a human neuron

How do ANNs work?

- Now, let us have a look at the model of an artificial neuron.



How do ANNs work?



How do ANNs work?

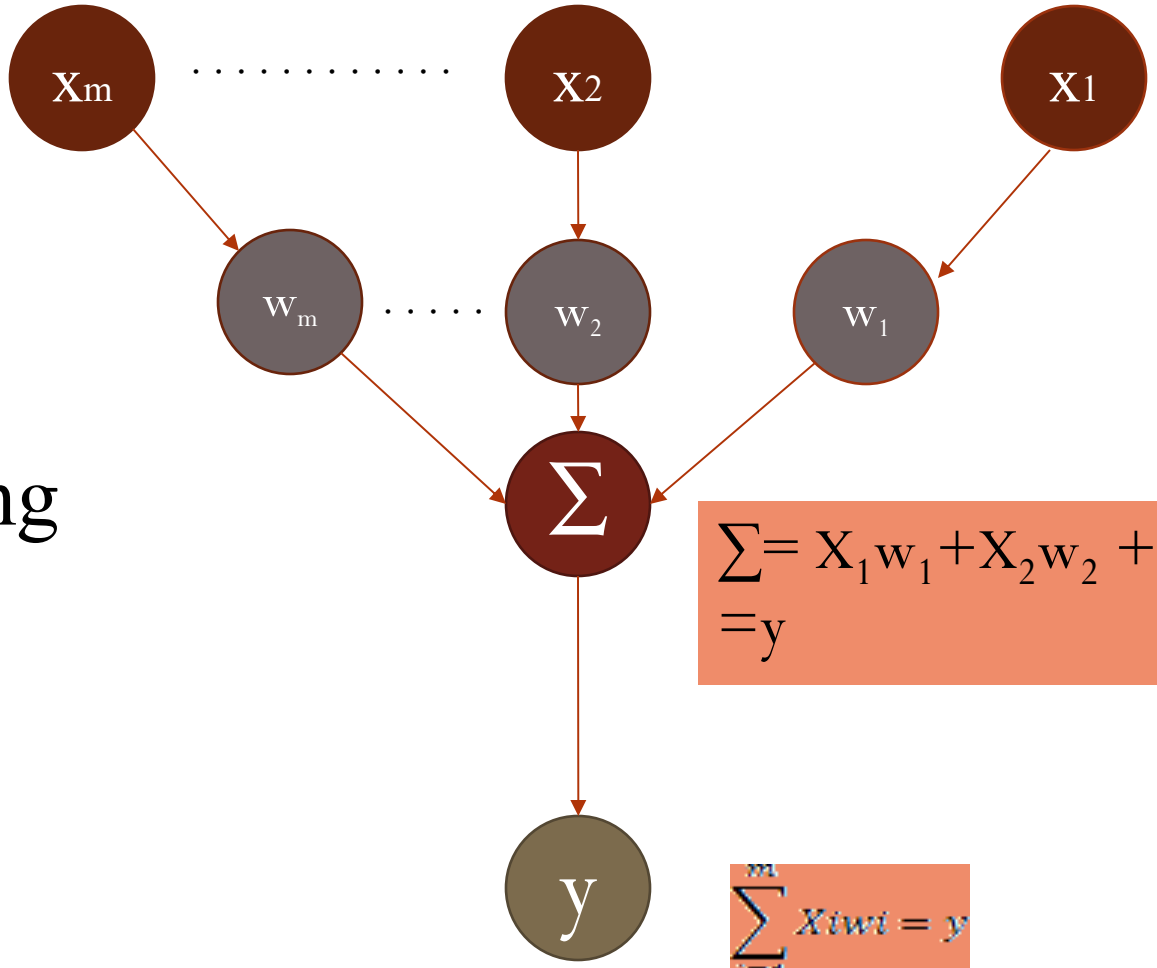
Not all inputs are equal

Input

weights

Processing

Output

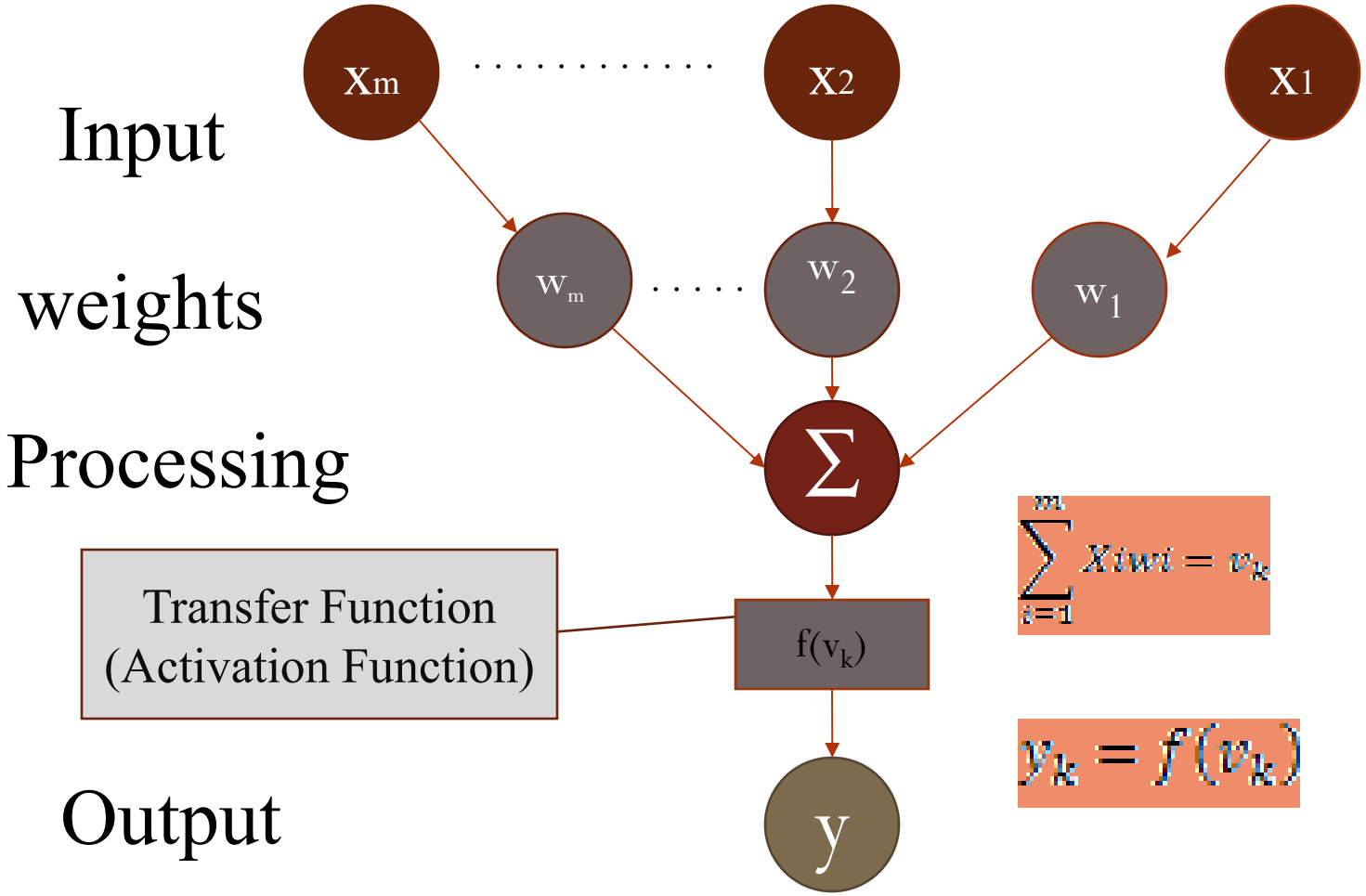


$$\sum = X_1w_1 + X_2w_2 + \ldots + X_mw_m = y$$

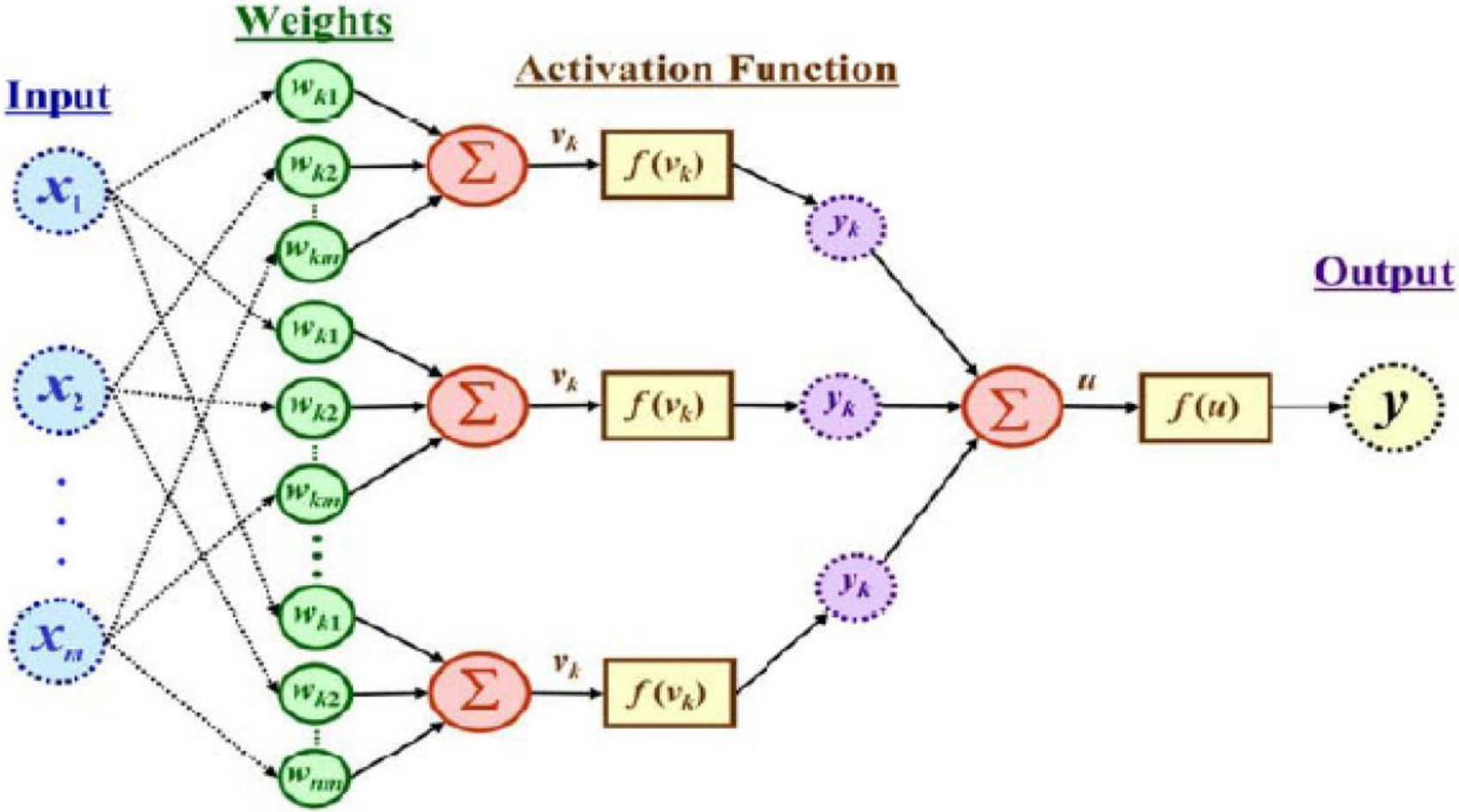
$$\sum_{i=1}^{m} Xiwi = y$$

How do ANNs work?

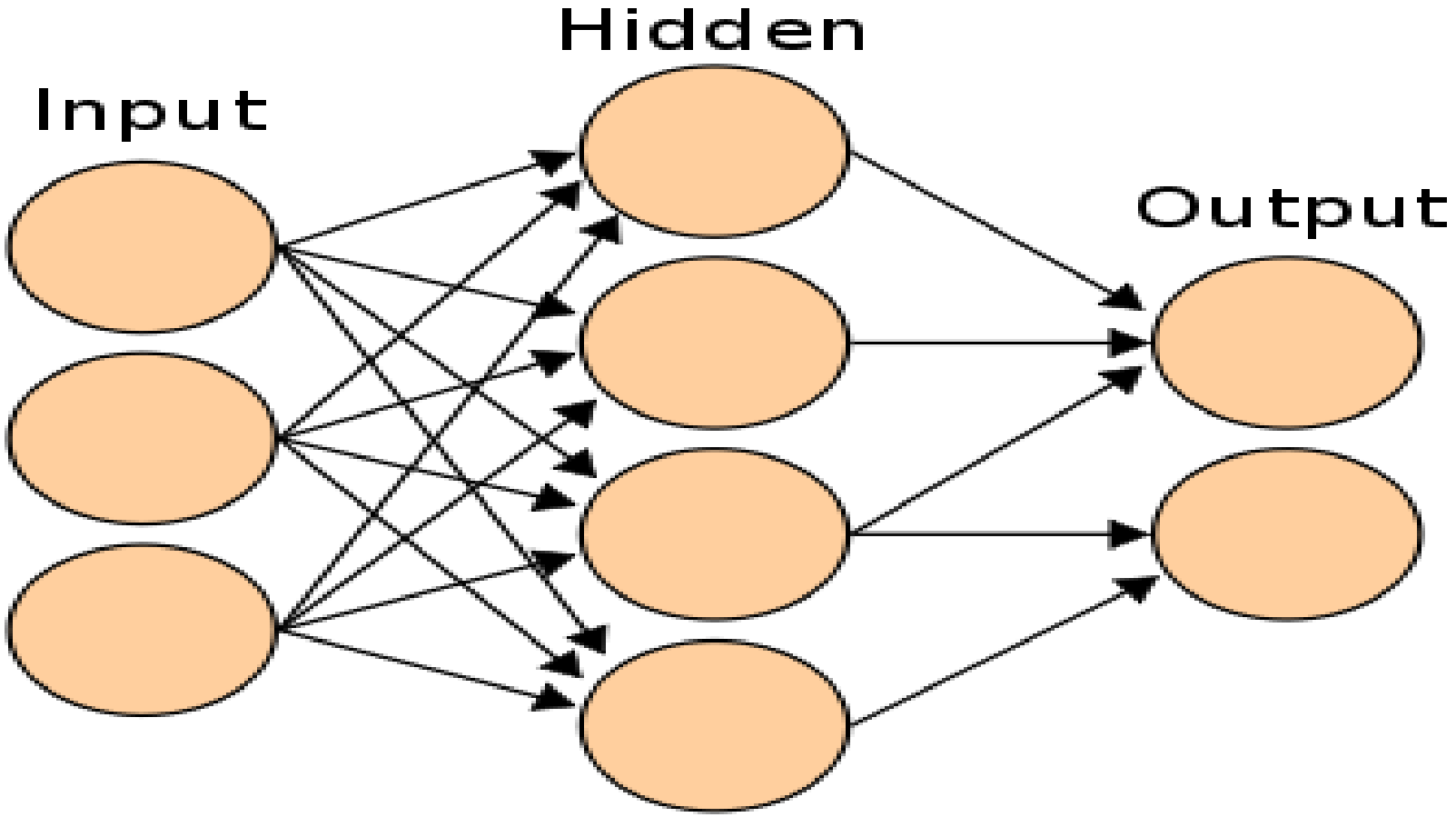
The signal is not passed down to the next neuron verbatim



The output is a function of the input, that is affected by the weights, and the transfer functions



Three types of layers: Input, Hidden, and Output

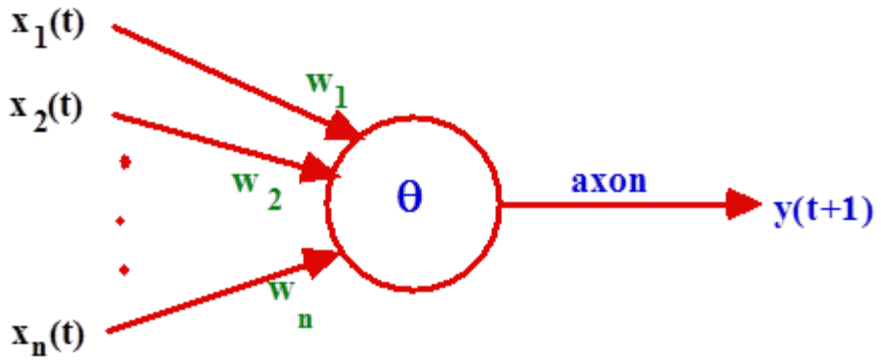


Artificial Neural Networks

- An ANN can:
  1. compute *any computable* function, by the appropriate selection of the network topology and weights values.
  2. learn from experience!
     - Specifically, by trial-and-error

McCulloch-Pitts neuron

A McCulloch-Pitts neuron operates on a discrete time-scale, t = 0,1,2,3, ... with time tick equal to one refractory period



At each time step, an input or output is

on or *off* — 1 or 0, respectively.

Each connection or synapse from the output of one neuron to the input of another, has an attached weight.

Excitatory and Inhibitory Synapses

We call a synapse

excitatory if $w_i > 0$, and

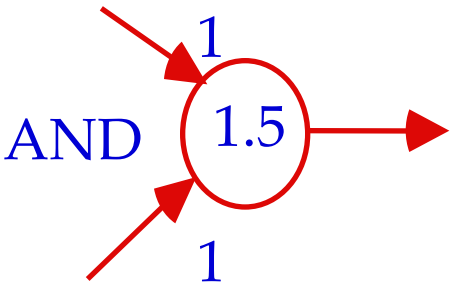
inhibitory if $w_i < 0$.

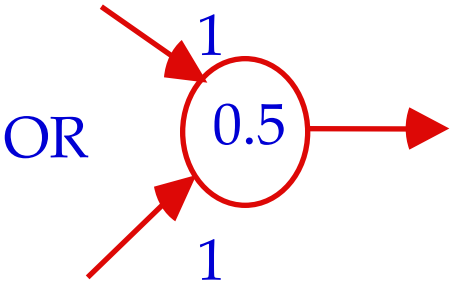
We also associate a threshold θ with each neuron

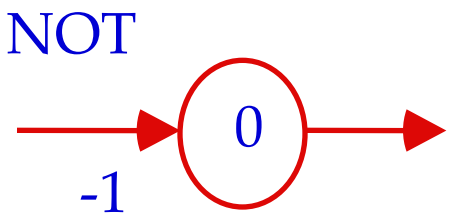
A neuron fires (i.e., has value 1 on its output line) at time t+1 if the weighted sum of inputs at t reaches or passes θ:

$$y(t+1) = 1 \quad \text{if and only if} \quad \sum w_i x_i(t) \geq \theta.$$

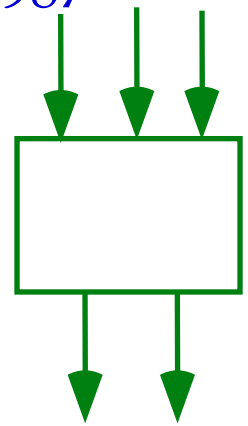
From Logical Neurons to Finite Automata





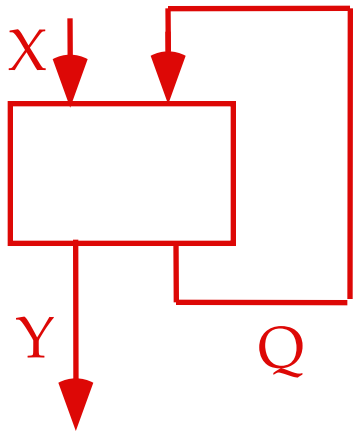


Brains, Machines, and Mathematics, 2nd Edition, 1987



Boolean Net

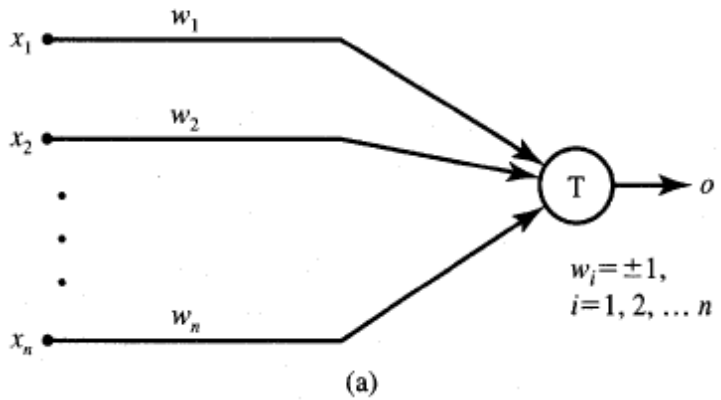
$X \rightarrow Y$



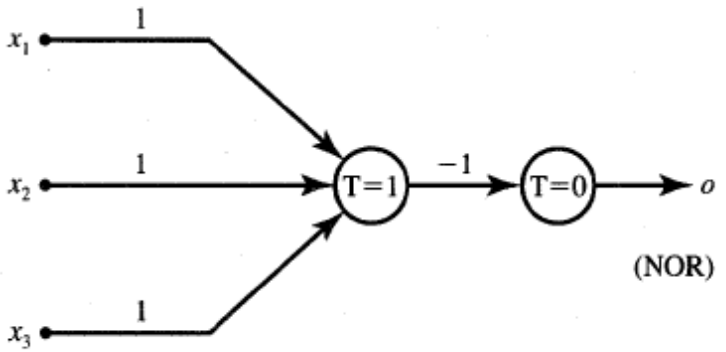
Finite Automaton

McCulloch-Pitts Neuron Model

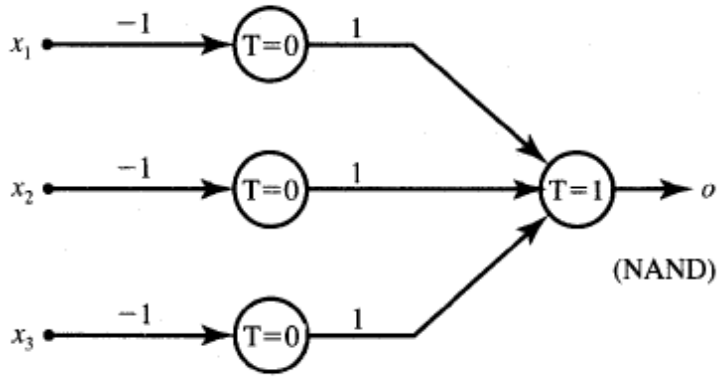
$$o^{k+1} = \begin{cases} 1 & \text{if } \sum_{i=1}^{n} w_i x_i^k \geq T \\ 0 & \text{if } \sum_{i=1}^{n} w_i x_i^k < T \end{cases}$$



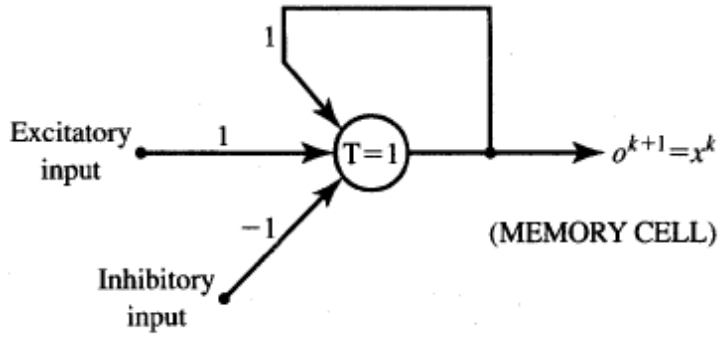
(a)



(b)

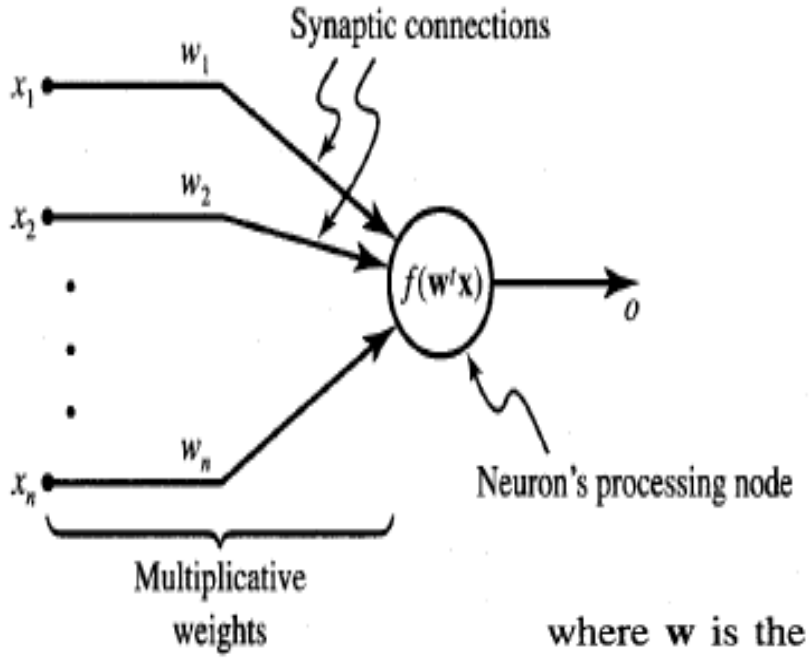


(c)



(d)

General symbol of neuron consisting of processing node and synaptic connections



$$o = f(\mathbf{w}^t\mathbf{x}), \text{ or}$$

$$o = f\left(\sum_{i=1}^{n} w_i x_i\right)$$

where $\mathbf{w}$ is the *weight vector* defined as

$$\mathbf{w} \triangleq [w_1 \quad w_2 \quad \cdots \quad w_n]^t$$

and $\mathbf{x}$ is the input vector:

$$\mathbf{x} \triangleq [x_1 \quad x_2 \quad \cdots \quad x_n]^t$$

Neuron Modeling for ANN

$$o = f(\mathbf{w}^t\mathbf{x}), \text{ or}$$

$$o = f\left(\sum_{i=1}^{n} w_i x_i\right)$$

Is referred to activation function. Domain is set of activation values *net.*

$$net \triangleq \mathbf{w}^t\mathbf{x}$$

Scalar product of weight and input vector

Neuron as a processing node performs the operation of summation of its weighted input.

Increasing the Realism of Neuron Models

The McCulloch-Pitts neuron of 1943 is important

as a basis for:

- logical analysis of the neurally computable, and
- current design of some neural devices (especially when augmented by **learning rules** to adjust synaptic weights).

However, it is no longer considered a useful model for making contact with neurophysiological data concerning real neurons.

Thank you…

Any questions??

يرجى مسح رمز الاستجابة السريعة QR Code لتعبئة نموذج التغذية الراجعة حول المحاضرة. ملاحظاتكم مهمة لتحسين المحاضرات القادمة.

My google site