

Princess Nora University  
Faculty of Computer & Information Systems



جامعة الأميرة نورة بنت عبد الرحمن  
Princess Nora Bint Abdul Rahman University

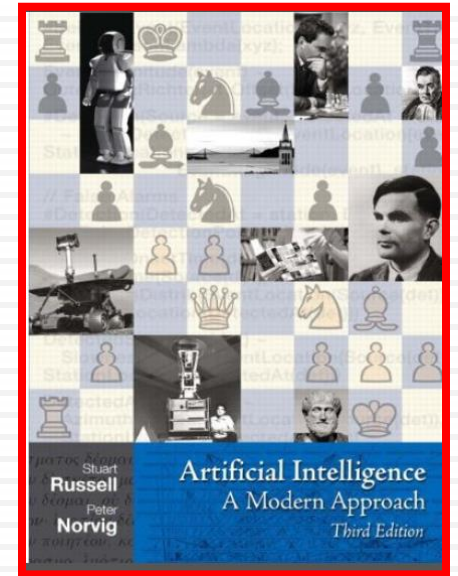


# ARTIFICIAL INTELLIGENCE

## (CS 370D)



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# (CHAPTER-18)

## LEARNING FROM EXAMPLES

### NEURAL NETWORK



# Outlines

1. Biological Inspiration.
2. Artificial Neuron.
3. Artificial Neural Networks.
4. Applications of Artificial Neural Networks.
5. Artificial Neural Network Architectures.
6. Learning Processes.
7. Artificial Neural Networks Capabilities & Limitations





# Biological Inspiration





# Biological Inspiration

## Some numbers...

- The human brain contains about 10 billion nerve cells (neurons).
- Each neuron is connected to the others through 10000 synapses.

## Properties of the brain:

- It can learn, reorganize itself from experience.
- It adapts to the environment.



# Biological Inspiration

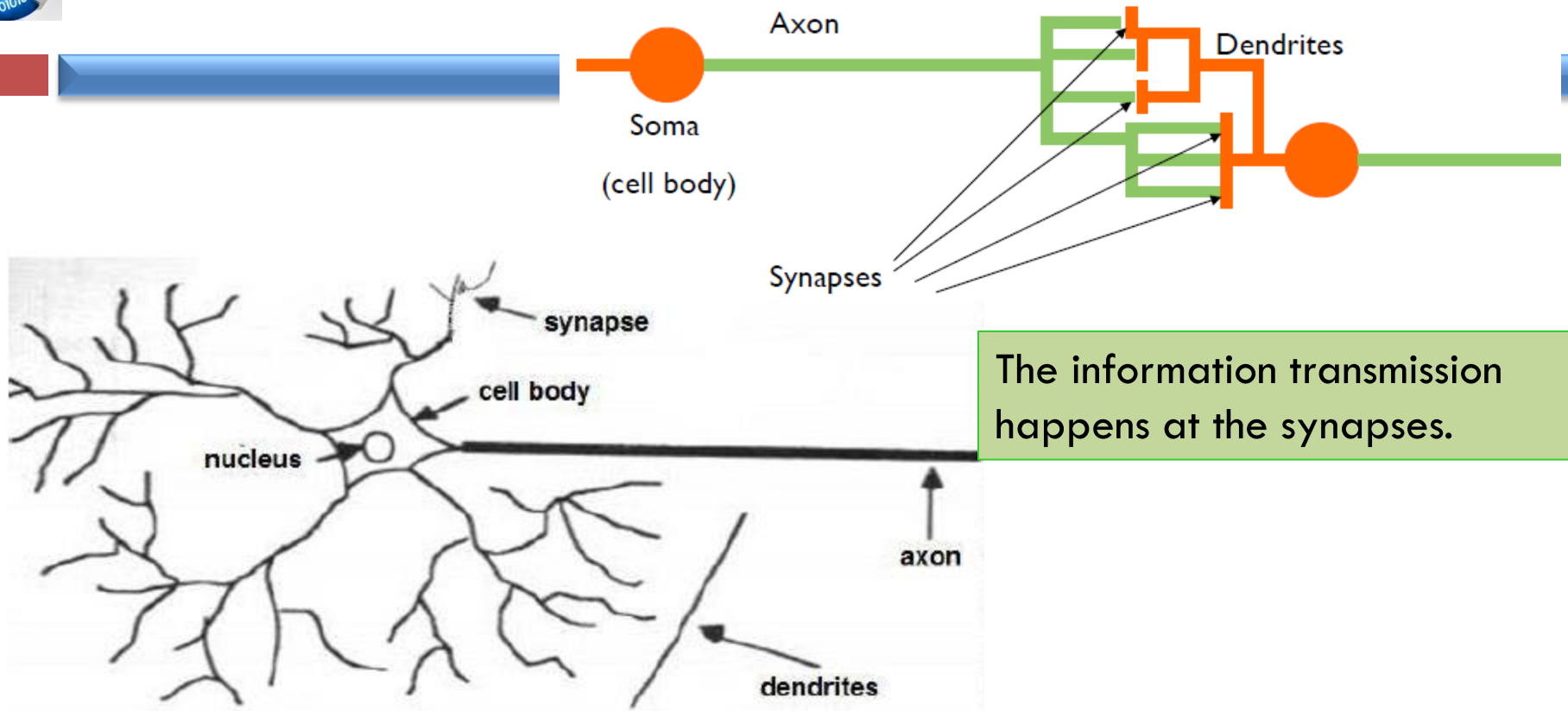


- Animals are able to react adaptively to changes in their external and internal environment, and they use their nervous system to perform these behaviours.
- An appropriate model/simulation of the nervous system should be able to produce similar responses and behaviours in artificial systems.
- The nervous system is build by relatively simple units, the neurons, so copying their behaviour and functionality should be the solution.





# The Neuron in Real Life



The information transmission happens at the synapses.

➤ The neuron receives nerve impulses through its **dendrites**.  
It then sends the nerve impulses through its **axon** to the terminals where neurotransmitters are released to stimulate other neurons.





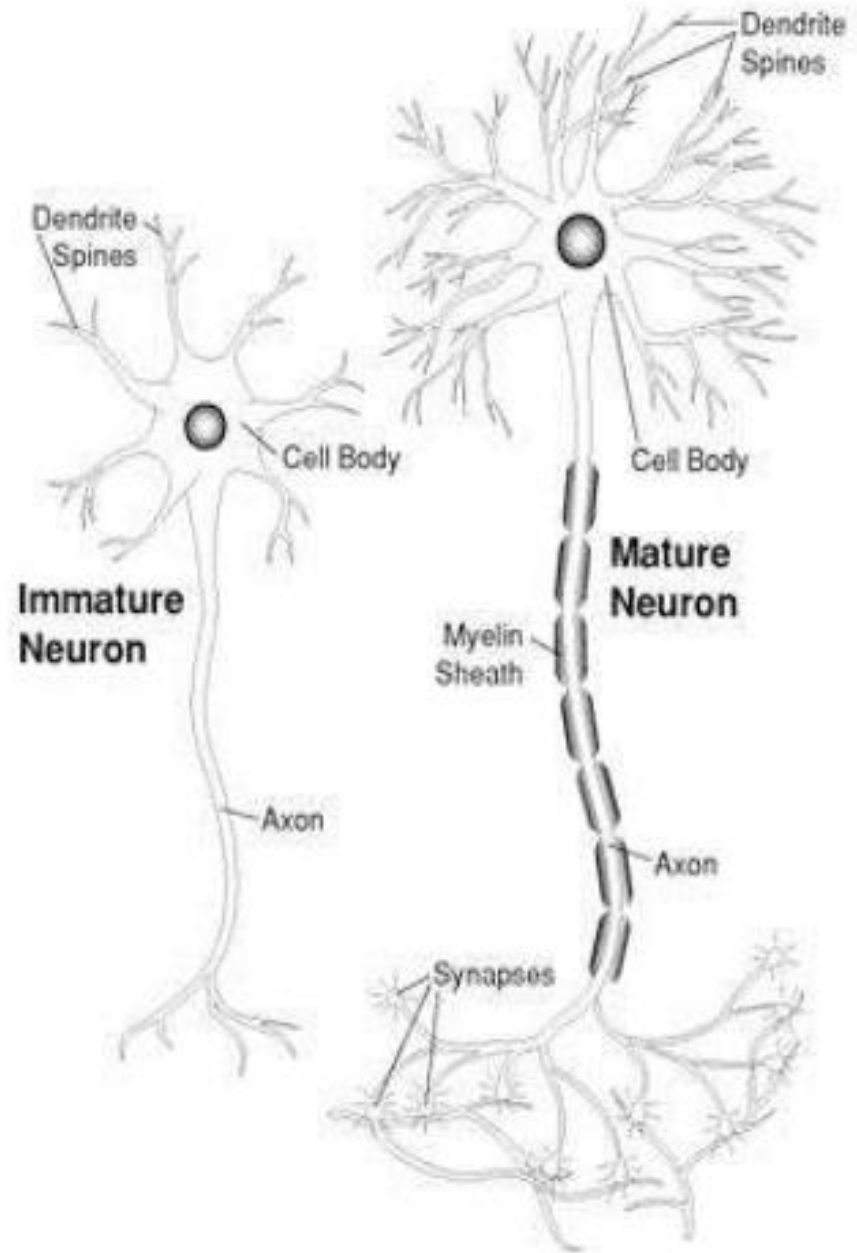
# The Neuron in Real Life

## The unique components are:

- ✓ Cell body or Soma which contains the Nucleus.
- ✓ The Dendrites.
- ✓ The Axon.
- ✓ The Synapses.

## A neuron has:

- ✓ A branching input (dendrites).
- ✓ A branching output (the axon)





# The Neuron in Real Life

- **The Dendrites:** are short fibers (surrounding the cell body) that receive messages and carry signals from the synapses to the soma.
- **The Axon:** is a long extension from the soma that transmits messages, each neuron has only one axon. The axon carries action potentials from the soma to the synapses.
- **The Synapses:** are the connections made by an axon to another neuron. They are tiny gaps between axons and dendrites (with chemical bridges) that transmit messages.





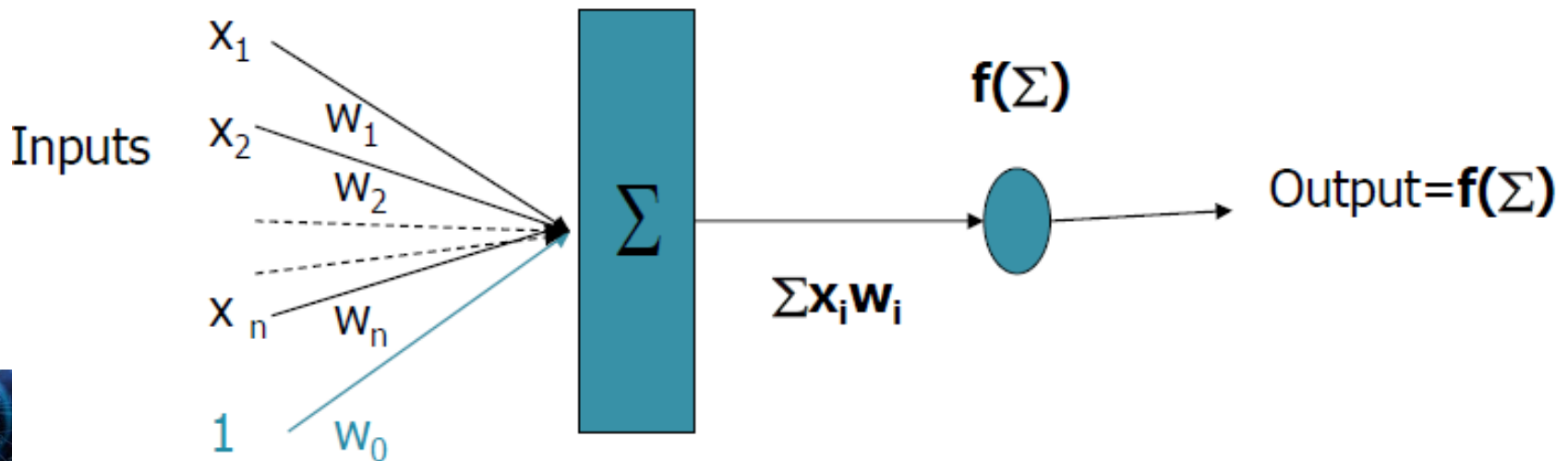
# Artificial Neuron





# Artificial Neuron

- What is an Artificial Neuron?
- **Definition:** Neuron is the basic information processing unit of the Neural Networks (NN). It is a non linear, parameterized function with restricted





# Artificial Neural Networks





# Artificial Neural Networks

- **Artificial Neural Network (ANN):** is a machine learning approach that models human brain and consists of a number of artificial neurons that are linked together according to a specific network architecture.
- **Neuron** in ANNs tend to have fewer connections than biological neurons. each neuron in ANN receives a number of inputs.
- **An activation function** is applied to these inputs which results in activation level of neuron (output value of the neuron).

Knowledge about the learning task is given in the form of examples called training examples.





# Applications of ANN





# Applications of Artificial Neural Networks

Some tasks to be solved by Artificial Neural Networks:

- ❖ **Classification:** Linear, non-linear.
- ❖ **Recognition:** Spoken words, Handwriting. Also recognizing a visual object: Face recognition.
- ❖ **Controlling:** Movements of a robot based on self perception and other information.
- ❖ **Predicting:** Where a moving object goes, when a robot wants to catch it.
- ❖ **Optimization:** Find the shortest path for the TSP.





# Artificial Neural Networks





# Artificial Neural Networks

□ Before using ANN, we have to define:

1. Artificial Neuron Model.
2. ANN Architecture.
3. Learning Mode.





# Computing with Neural Units

- Incoming signals to a unit are presented as inputs.
- How do we generate outputs?

- One idea: Summed Weighted Inputs.

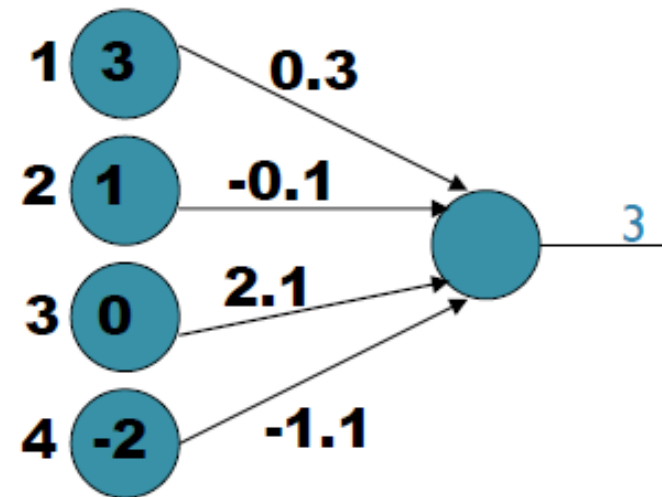
- **Input:** (3, 1, 0, -2)

- **Processing**

$$3(0.3) + 1(-0.1) + 0(2.1) + -2(-1.1)$$

$$= 0.9 + (-0.1) + 0 + 2.2$$

- **Output:** 3





# Activation Functions

- Usually, do not just use weighted sum directly.
- Apply some function to the weighted sum before it is used (e.g., as output).
- → Call this the **activation function**.

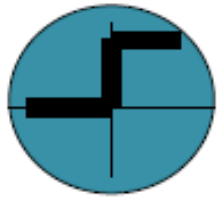
$$f(x) = \begin{cases} 1 & \text{if } x \geq \theta \\ 0 & \text{if } x < \theta \end{cases} \quad \theta \text{ is called the threshold}$$

**Step function**





# Activation Functions



Step  
Function

$$\text{step}(x) = \begin{cases} 1, & \text{if } x \geq \text{threshold} \\ 0, & \text{if } x < \text{threshold} \end{cases}$$

(in picture above,  
threshold = 0)



Sign  
Function

$$\text{sign}(x) = \begin{cases} +1, & \text{if } x \geq 0 \\ -1, & \text{if } x < 0 \end{cases}$$



Sigmoid (Logistic)  
Function

$$\text{sigmoid}(x) = \frac{1}{1+e^{-x}}$$



Linear  
Function

$$\text{pl}(x) = x$$



The choice of activation function determines the **Neuron Model**.





# Bias of a Neuron

- The bias  $b$  has the effect of applying a transformation to the weighted sum  $u$

$$v = u + b$$

- The bias is an external parameter of the neuron. It can be modeled by adding an extra input.
- $v$  is called **induced field** of the neuron:

$$v = \sum_{j=0}^m w_j X_j$$

$$w_0 = b$$

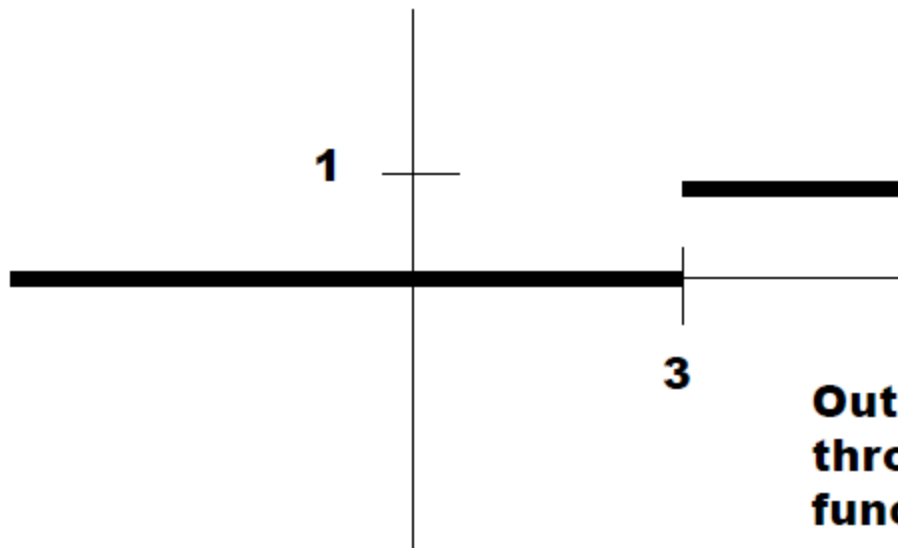
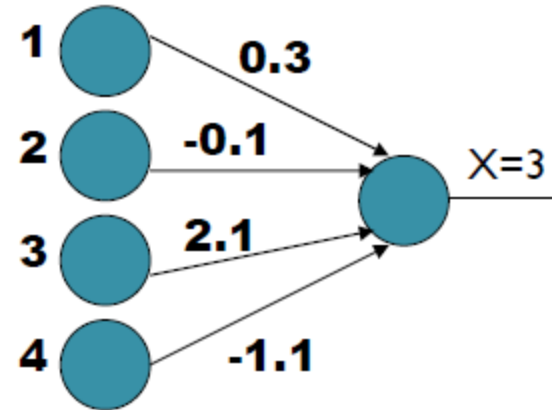




# Example (1): Step Function

- Let  $\Theta = 3$

Input: (3, 1, 0, -2)



Output after passing through step activation function:

$$f(3) = 1$$

.....ahmoud  
(course coordinator)

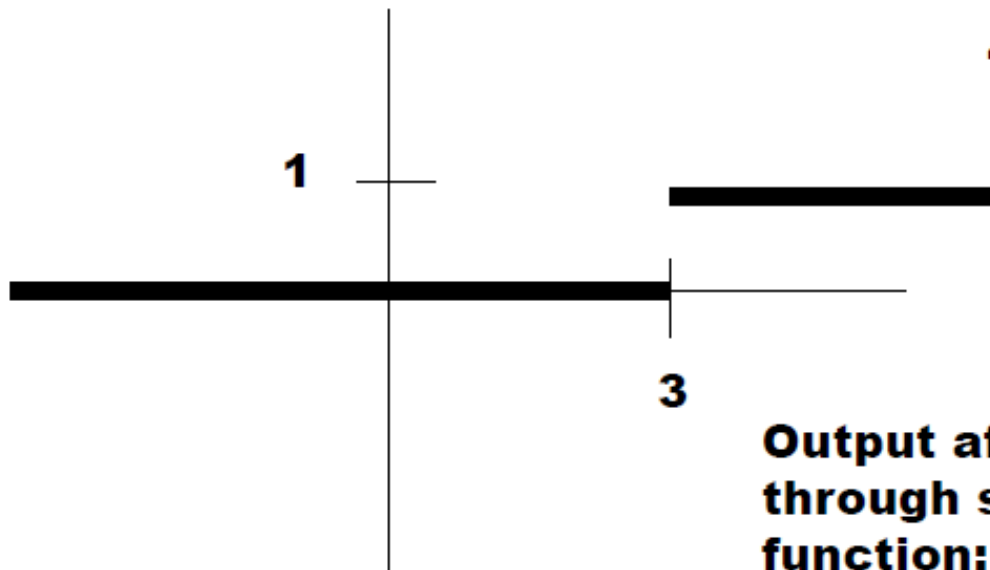
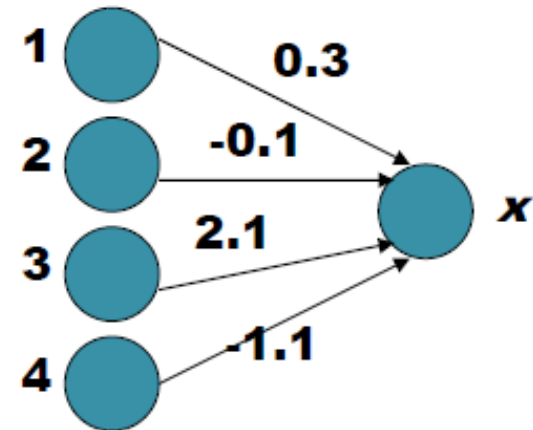




# Example (2): Another Step Function

- Let  $\Theta = 3$

**Input:** (0, 10, 0, 0)



**Output after passing through step activation function:**

$$f(x) = ?$$

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# Example (3): Sigmoid Function

- The math of some neural nets requires that the activation function be continuously differentiable.
  - A sigmoidal function often used to approximate the step function.

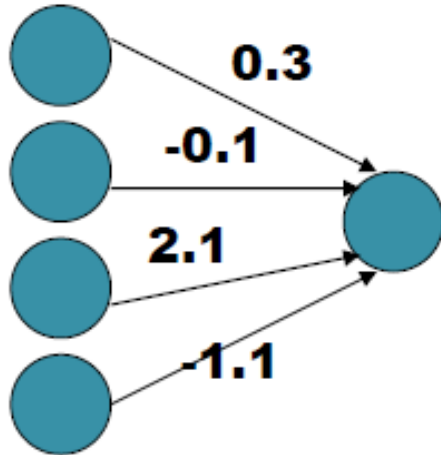
$$f(x) = \frac{1}{1 + e^{-\sigma x}}$$

$\sigma$  Is the steepness parameter





# Example (3): Sigmoid Function



**Input: (3, 1, 0, -2)**

$$\sigma = 2$$

$$f(x) = \frac{1}{1 + e^{-2x}}$$

$$f(3) = \frac{1}{1 + e^{-2 \cdot 3}} = .998$$

**Input: (0, 10, 0, 0)**

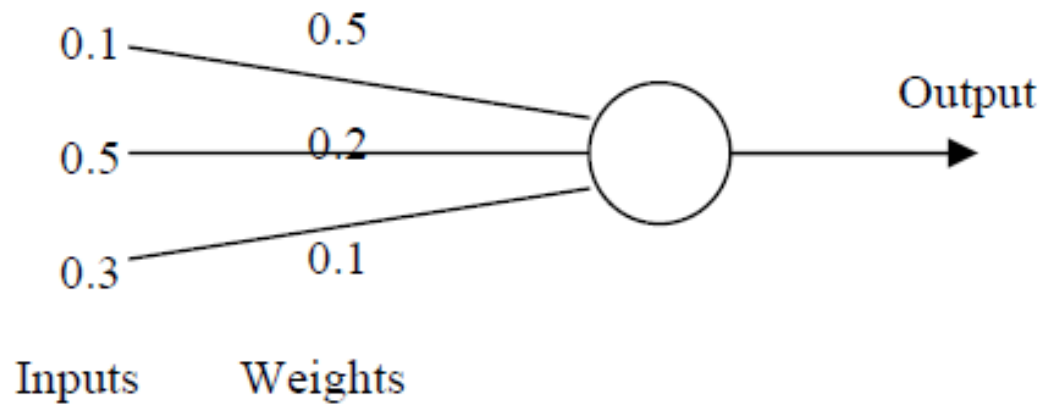
**network output?**





# Example

- Calculate the output from the neuron below assuming a threshold of 0.5:



$$\text{Sum} = (0.1 \times 0.5) + (0.5 \times 0.2) + (0.3 \times 0.1) = 0.05 + 0.1 + 0.03 = 0.18$$

Since 0.18 is less than the threshold, the Output = 0

Repeat the above calculation assuming that the neuron has a sigmoid output function:

$$\text{Sum is still } 0.18, \text{ but now Output} = \frac{1}{1 + e^{-0.18}} = 0.545$$

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# Network Architecture





# Network Architecture

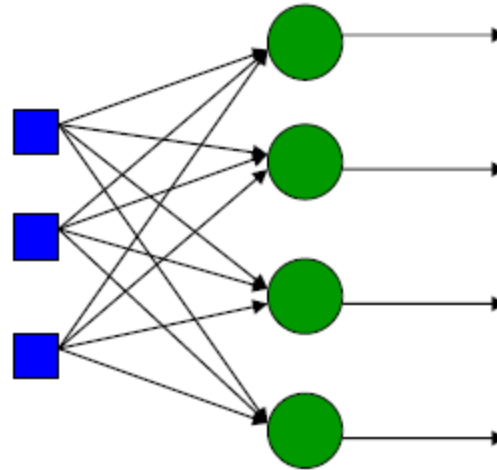
- The Architecture of a neural network is linked with the learning algorithm used to train.
  
- **There are different classes of network architecture:**
  - Single-Layer Neural Networks.
  - Multi-Layer Neural Networks.
  
  - → **The number of layers and neurons depend on the specific task.**





# Single Layer Neural Network

*Input layer  
of  
source nodes*



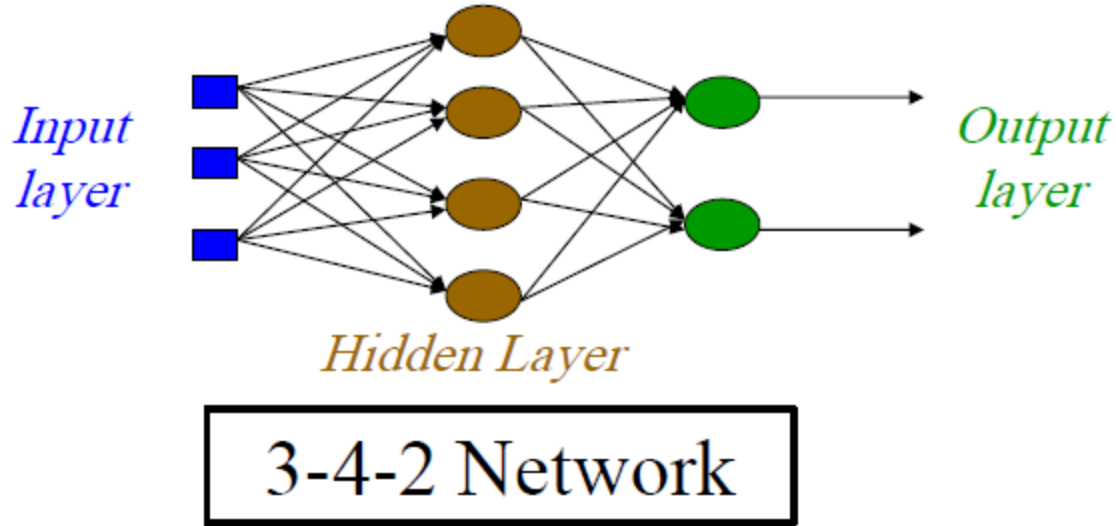
*Output layer  
of  
neurons*

3-4 Network





# Multi Layer Neural Network



- More general network architecture, where there are hidden layers between input and output layers.
- Hidden nodes do not directly receive inputs nor send outputs to the external environment.

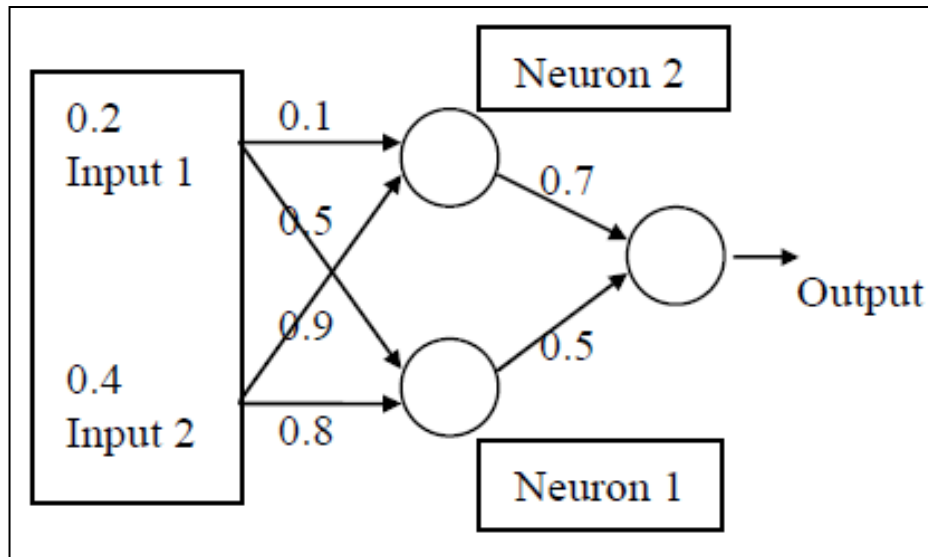
Multi Layer NN overcome the limitation of Single-Layer NN, they can handle non-linearly separable learning tasks.





# Example of multilayer ANN

- Calculate the output from this network assuming a Sigmoid Squashing Function.

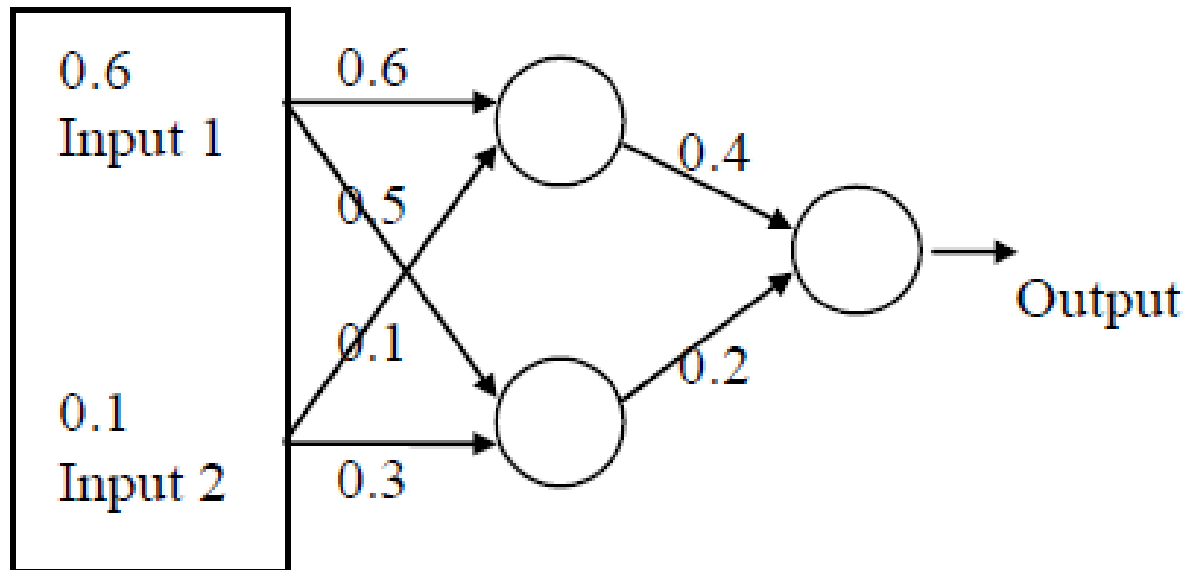


$$\text{Input to neuron 1} = (0.2 \times 0.5) + (0.4 \times 0.8) = 0.42. \text{ Output} = \frac{1}{1 + e^{-0.42}} = 0.603$$

$$\text{Input to neuron 2} = (0.2 \times 0.1) + (0.4 \times 0.9) = 0.38. \text{ Output} = \frac{1}{1 + e^{-0.38}} = 0.594$$

$$\text{Input to final neuron} = (0.594 \times 0.7) + (0.603 \times 0.5) = 0.717.$$

$$\text{Final Output} = \frac{1}{1 + e^{-0.717}} = 0.672$$



- Try calculating the output of this network yourself.





# ANN Capabilities & Limitations

## Main capabilities of ANN includes:

- ✓ Learning.
- ✓ Noise filtering.
- ✓ Parallel processing.
- ✓ Distributed knowledge base.

## Main problems includes:

- ❖ Learning sometimes difficult/slow.
- ❖ Limited storage capability.





# Thank you



## End of Chapter 18

