Neural networks

Lecture 03

Introduction to Neural Networks (2)

Md. Mijanur Rahman, Prof. Dr.

Dept. of Computer Science and Engineering, Jatiya Kabi Kazi Nazrul Islam University, Bangladesh.

Email: mijanjkkniu@gmail.com; mijan@jkkniu.edu.bd | Web: www.mijanrahman.com

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  - **Processing Elements and Activation**
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  - **Biological Neurons**
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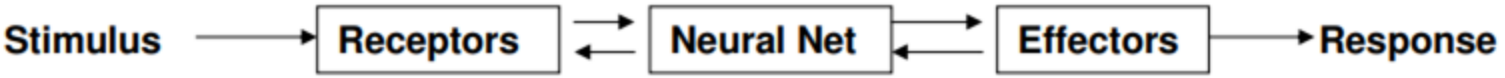
  - Advantages and Disadvantages of ANN
  - Applications of ANNs

The Nervous System

The human nervous system can be broken down into three stages that can be represented in block diagram form as



(adapted from Arbib, 1987)

The **receptors** convert stimuli from the external environment into electrical impulses that convey information to the neural net (brain)

The **effectors** convert electrical impulses generated by the neural net into responses as system outputs

The **neural net (brain)** continually receives information, perceives it and makes appropriate decisions.

The flow of information is represented by arrows – feedforward and feedback

Brains vs. Computers

Processing elements: There are 10^{14} synapses in the brain, compared with 10^{8} transistors in the computer

Processing speed: 100 Hz for the brain compared to 10^{9} Hz for the computer

Style of computation: The brain computes in parallel and distributed mode, whereas the computer mostly serially and centralized.

Fault tolerant: The brain is fault tolerant, whereas the computer is not

Adaptive: The brain learns fast, whereas the computer doesn't even compare with an infant's learning capabilities

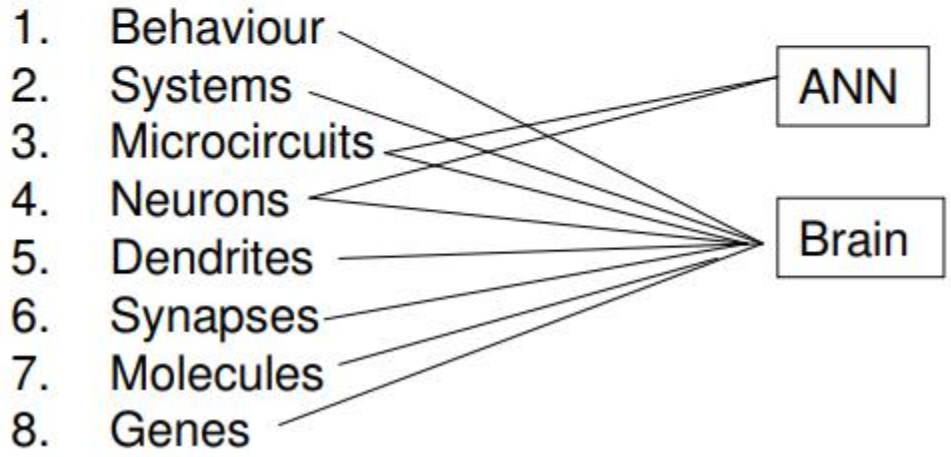
Intelligence and consciousness: The brain is highly intelligent and conscious, whereas the computer shows lack of intelligence

Evolution: The brains have been evolving for tens of millions of years, computers have been evolving for decades.

Levels of Organization in the Brain

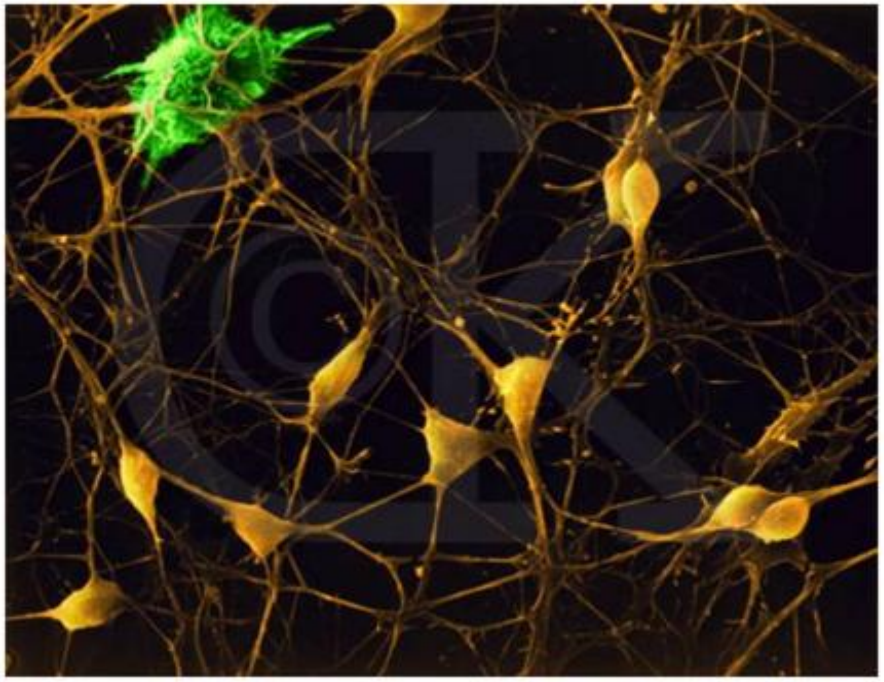
In the brain there are both small-scale and large-scale anatomical organizations, and different functions take place at lower and higher levels.

There is a hierarchy of interwoven levels of organization:



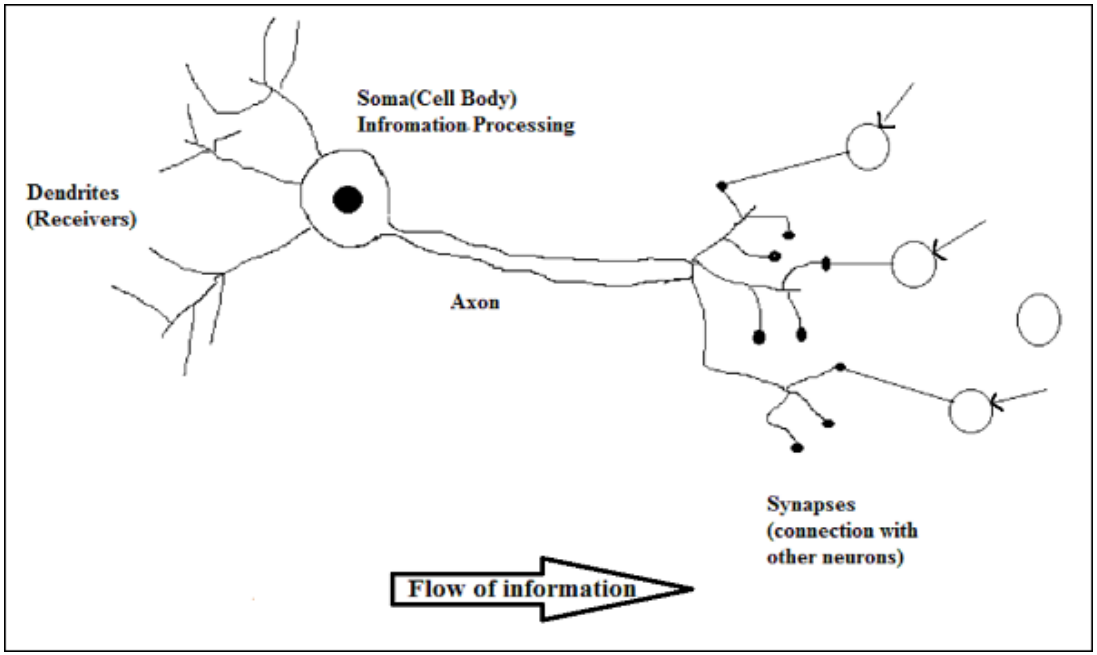
Microscopic View of the Nervous System

- Nervous system is made up of cells
- A cell has a fatty membrane, which is filled with liquid and proteins known as cytoplasm as well as smaller functional parts called organelles
- There are two major types of brain cells: (1) neurons, and (2) glia
- Neurons are the principal elements involved in information processing in the brain
- Glia provide support and homeostasis to neurons.



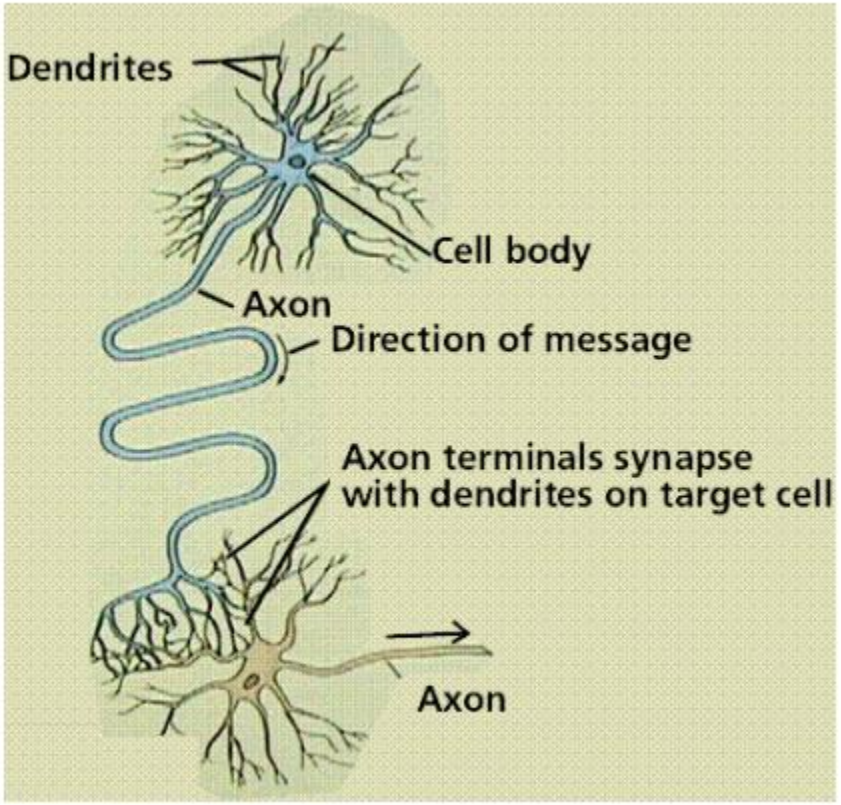
Biological Neurons

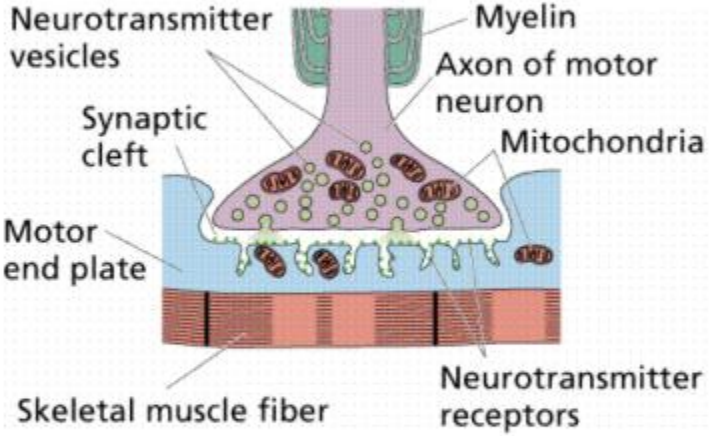
- A nerve cell, known as **Neuron**, is a special biological cell that process information. According to an estimation, there are huge number of neurons, approximately 10^{11} with numerous interconnections, approximately 10^{15}.
- **Schematic Diagram:**



Biological Neurons

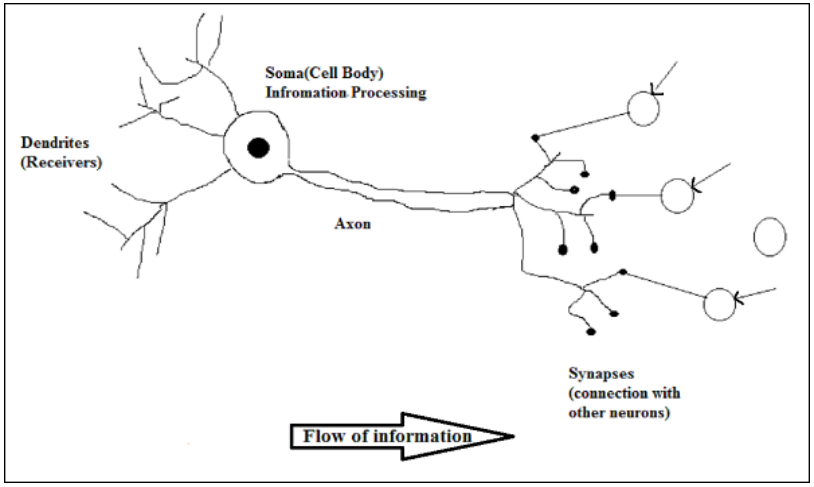
- **Schematic Diagram:**





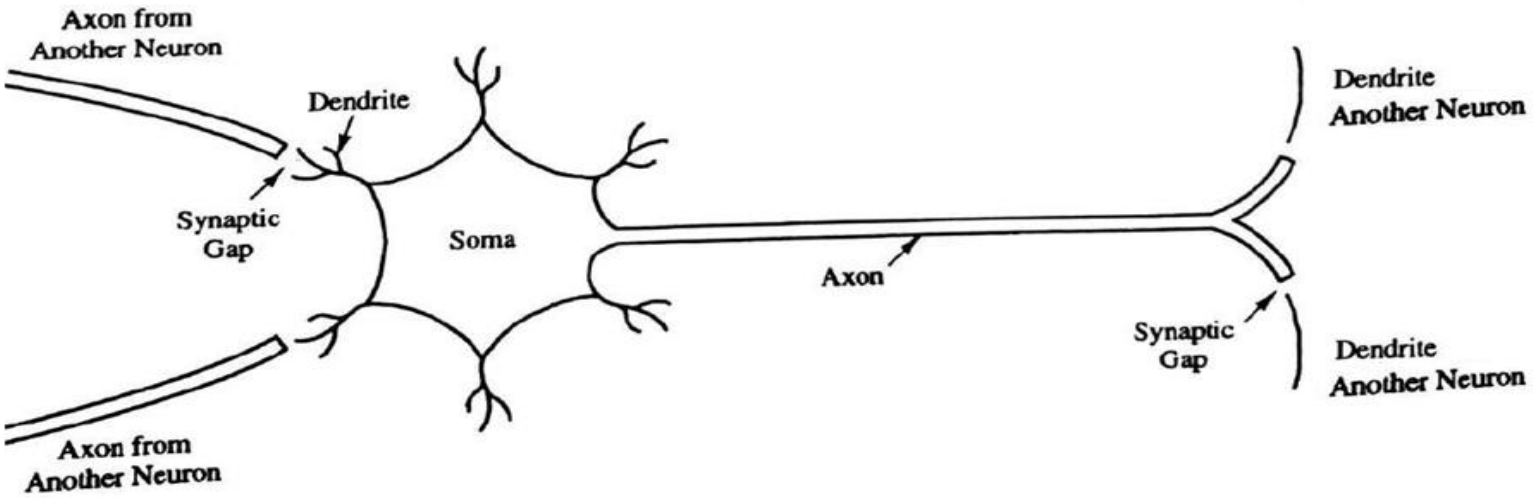
Biological Neurons

- **Components of Biological Neurons:**
  - There is a close analogy between the structure of a biological neuron (i.e.. a brain or nerve cell) and the processing element (or artificial neuron).
  - A biological neuron has three types of components that are of particular interest in understanding an artificial neuron: its **dendrites**, **soma**, and **axon**.



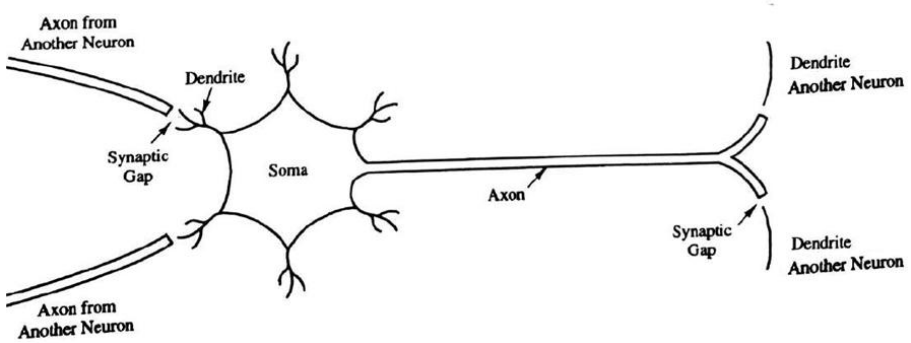
Biological Neurons

- **Working of a Biological Neuron:**
  - As shown in the following diagram, a typical neuron consists four parts (Dendrites, Soma, Axon, and Synapses) with the help of which we can explain its working.
  - The diagram shows a generic biological neuron together with axons from two other neurons and dendrites for two other neurons (to which the original neuron would send signals).



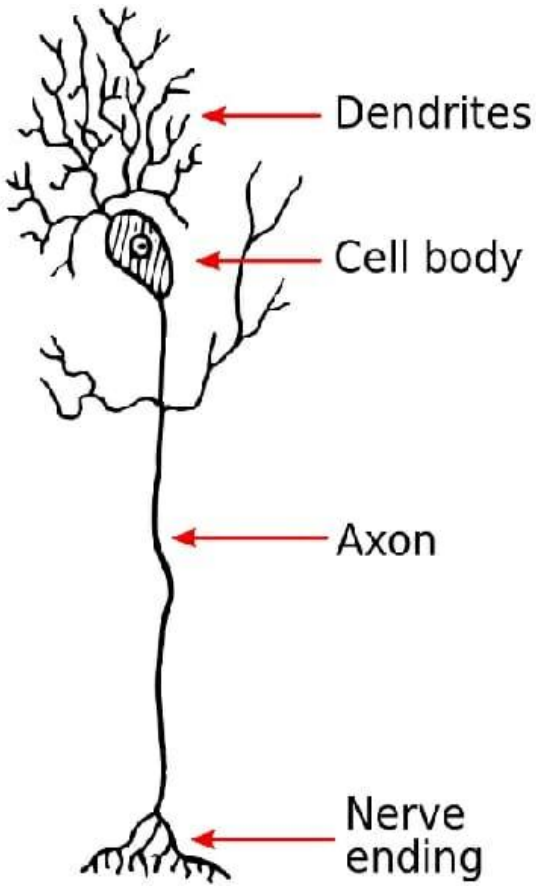
Biological Neurons

- **Working of a Biological Neuron:**
  - **Dendrites** − They are tree-like branches, responsible for receiving the information from other neurons it is connected to. In other sense, we can say that they are like the ears of neuron.
  - **Soma** − It is the cell body of the neuron and is responsible for processing of information, they have received from dendrites.
  - **Axon** − It is just like a cable through which neurons send the information.
  - **Synapses** − It is the connection between the axon and other neuron dendrites.



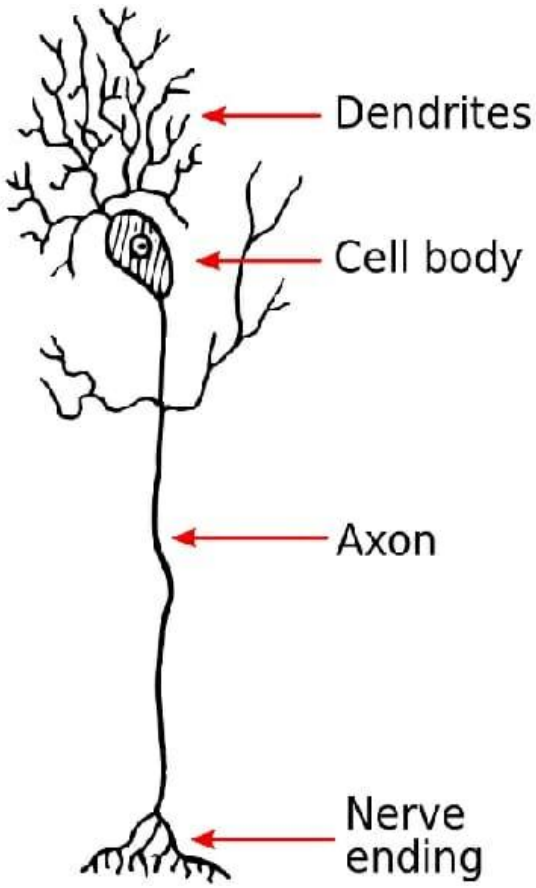
Biological Neurons

- **Dendrites**
  - The many dendrites receive signals from other neurons.
  - The signals are electric impulses that are transmitted across a synaptic gap by means of a chemical process.
  - The action of the chemical transmitter modifies the incoming signal (typically, by scaling the frequency of the signals that are received) in a manner similar to the action of the weights in an artificial neural network.



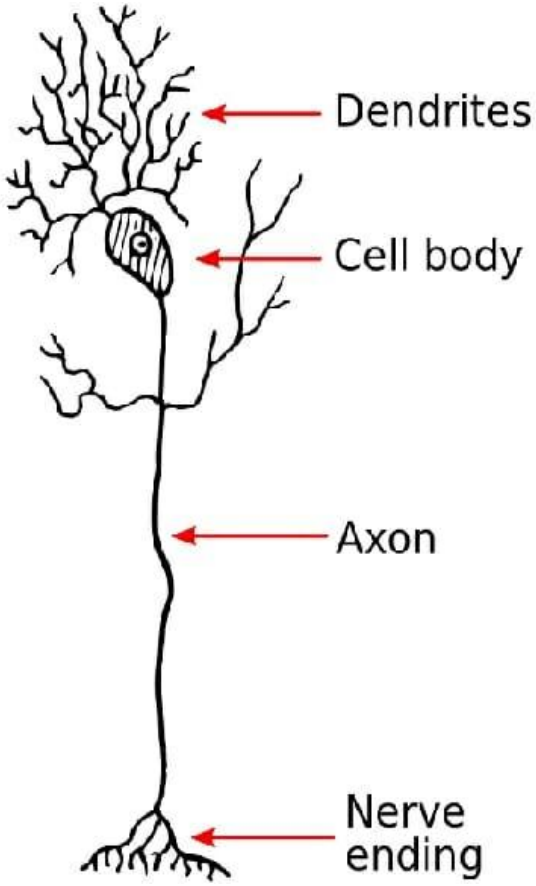
Biological Neurons

- **Soma**
  - The soma, or cell body, sums the incoming signals. When sufficient input is received, the cell fires; that is, it transmits a signal over its axon to other cells.
  - It is often supposed that a cell either fires or doesn't at any instant of time, so that transmitted signals can be treated as binary.
  - However, the frequency of firing varies and can be viewed as a signal of either greater or lesser magnitude. This corresponds to looking at discrete time steps and summing all activity (signals received or signals sent) at a particular point in time.



Biological Neurons

- **Axon**
  - The transmission of the signal from a particular neuron is accomplished by an action potential resulting from differential concentrations of ions on either side of the neuron's axon sheath (the brain's "white matter").
  - The ions most directly involved are potassium, sodium, and chloride.



Biological Neurons

Key Characteristics:

- **Ability to learn** from its environment, and to improve its performance through learning.
- **Fault tolerance**, in two respects:
  - **First, we are able to recognize many input signals that are somewhat different from any signal we have seen before.** An example of this is our ability to recognize a person in a picture we have not seen before or to recognize a person after a long period of time.
  - **Second, we are able to tolerate damage to the neural system itself.** Humans are born with as many as 100 billion neurons. Most of these are in the brain, and most are not replaced when they die. In spite of our continuous loss of neurons, we continue to learn.

In similar manner, the artificial neural networks can be designed to be insensitive to small damage to the network, and to learn from environment.

ANN vs. BNN

- Similarities based on the terminology between these two:

Biological Neural Network (BNN)	Artificial Neural Network (ANN)
Dendrites	Input
Cell nucleus (Soma)	Node
Synapse	Weights or Interconnections
Axon	Output

ANN vs. BNN

- The comparison between ANN and BNN based on some criteria mentioned below:

Criteria	BNN	ANN
Processing	Massively parallel, slow but superior than ANN	Massively parallel, fast but inferior than BNN
Size	10^{11} neurons and 10^{15} interconnections	10^2 to 10^4 nodes mainly depends on the type of application and network designer
Learning	They can tolerate ambiguity	Very precise, structured and formatted data is required to tolerate ambiguity
Fault Tolerance	Performance degrades with even partial damage	It is capable of robust performance, hence has the potential to be fault tolerant
Storage Capacity	Stores the information in the synapse	Stores the information in continuous memory locations

INTRODUCTION TO NEURAL NETWORKS

To be continued…