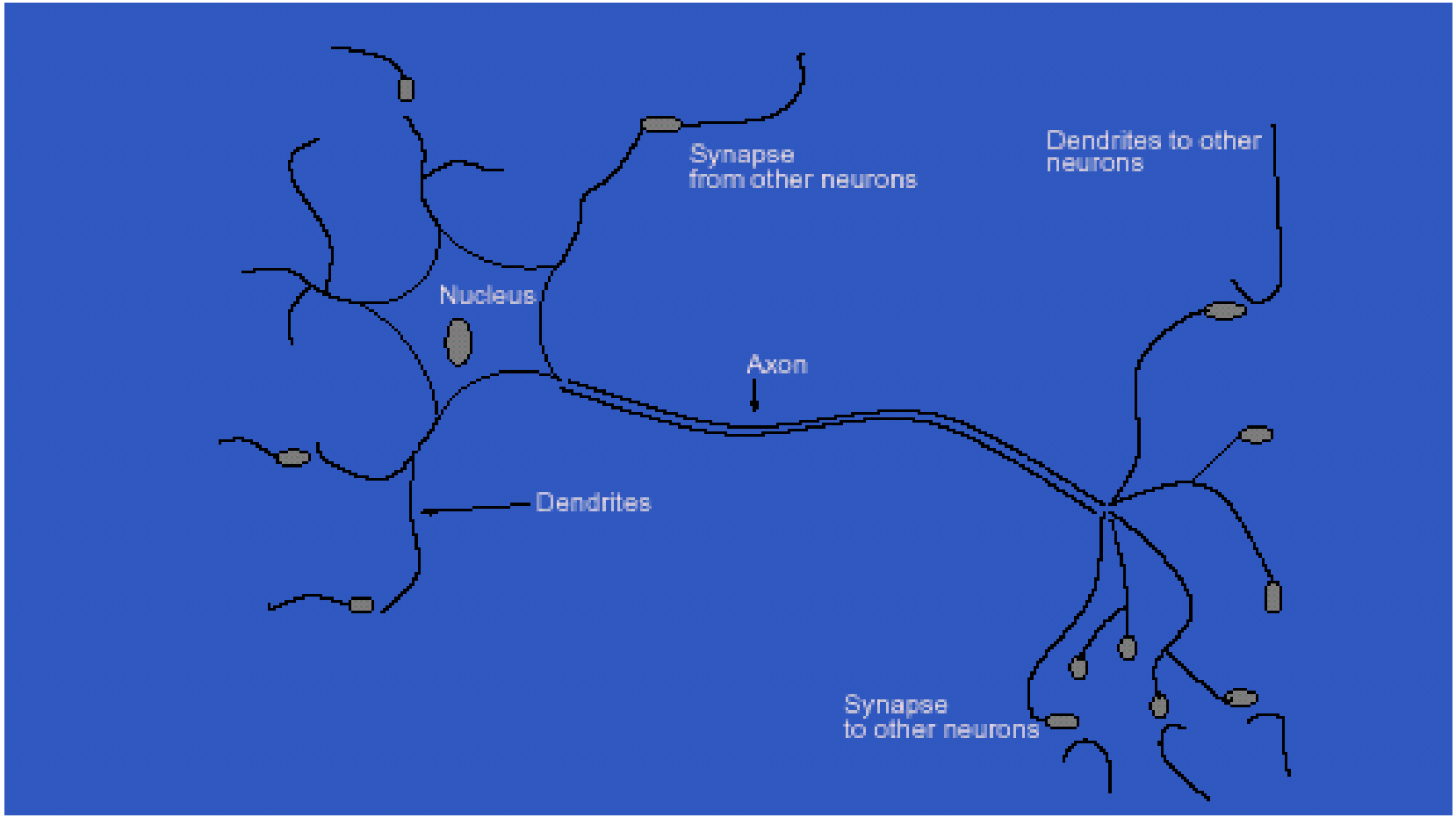
Brain as computer: bio-neural networks

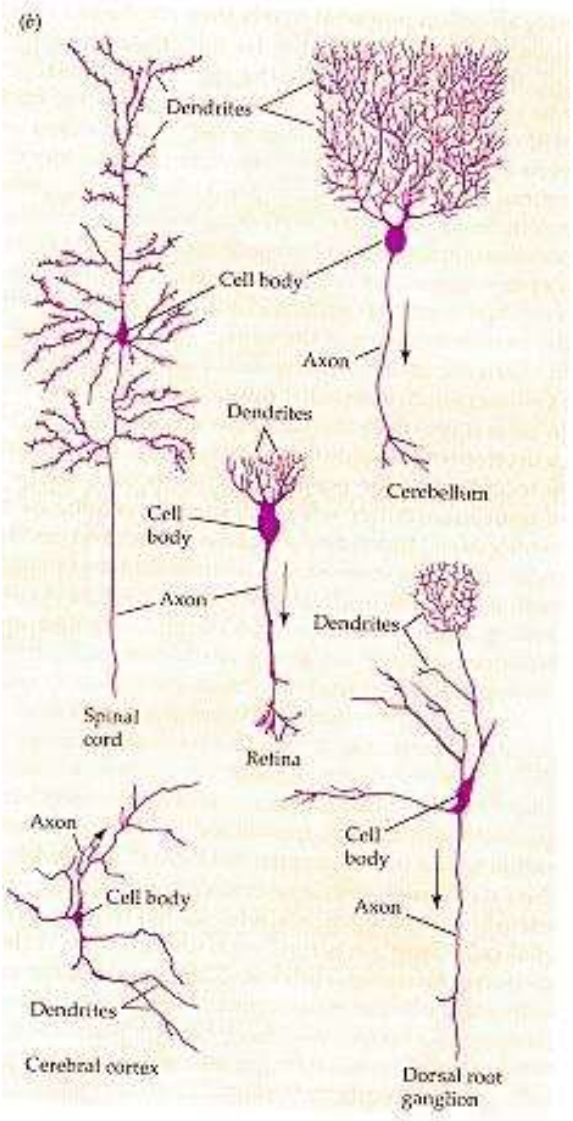
Click to add Text

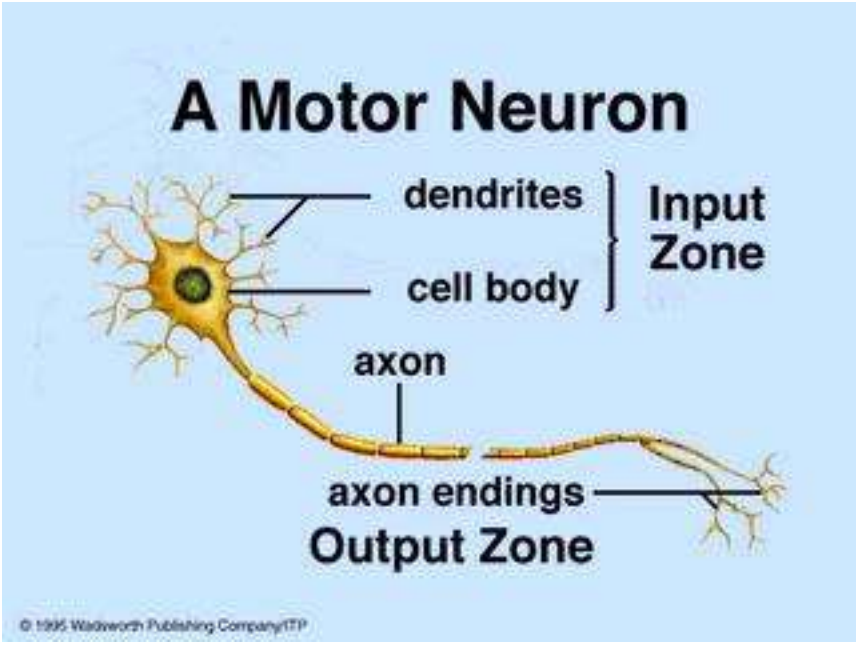
Inspiration from Neurobiology

Human Biological Neuron



Biological Neural Networks

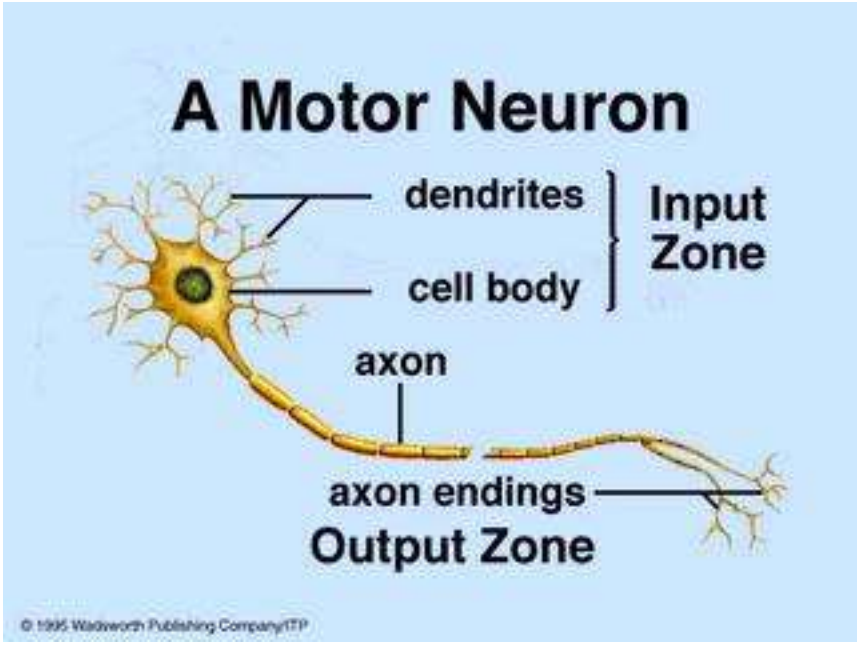




Biological neuron

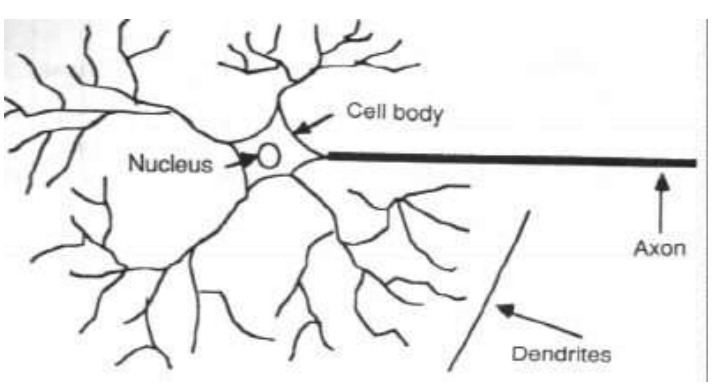
Biological Neural Networks

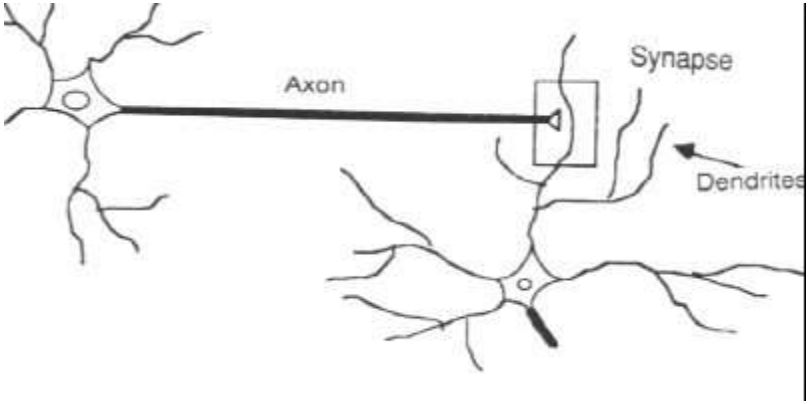
- A biological neuron has three types of main components; dendrites, soma (or cell body) and axon.
- Dendrites receive signals from other neurons.



- The soma, sums the incoming signals. When sufficient input is received, the cell fires; that is it transmits a signal over its axon to other cells.

How the Human Brain learns





- In the human brain, a typical neuron collects signals from others through a host of fine structures called *dendrites*.
- The neuron sends out spikes of electrical activity through a long, thin stand known as an *axon*, which splits into thousands of branches.
- At the end of each branch, a structure called a *synapse* converts the activity from the axon into electrical effects that inhibit or excite activity in the connected neurons.

Artificial Neurons

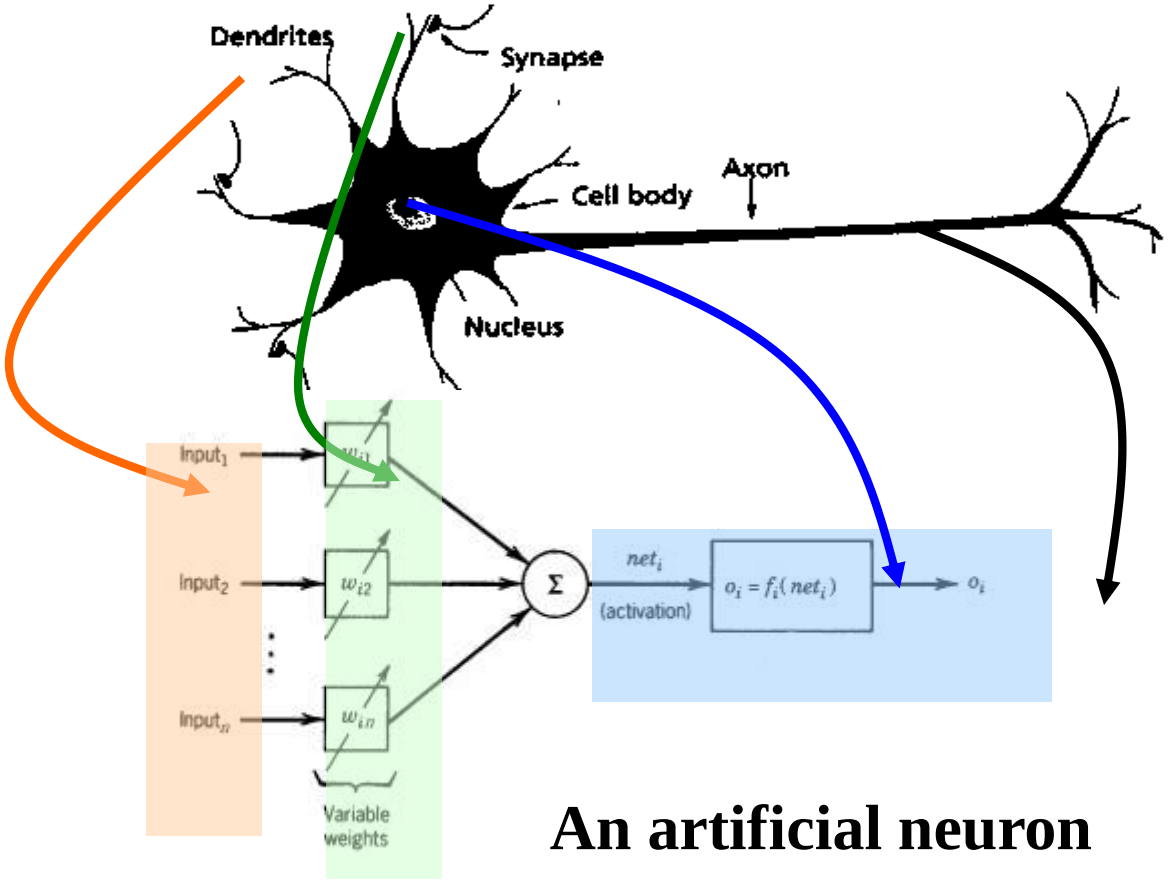
- ANN is an information processing system that has certain performance characteristics in common with biological nets.
- Several key features of the processing elements of ANN are suggested by the properties of biological neurons:

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.**

Artificial Neurons

- From experience: examples / training data
- Strength of connection between the neurons is stored as a weight-value for the specific connection.
- Learning the solution to a problem = changing the connection weights

A physical neuron



An artificial neuron

Artificial Neurons

- **ANNs have been developed as generalizations of mathematical models of 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 typical neural net, multiplies the signal transmitted.**
    4. **Each neuron applies an activation function to its net input to determine its output signal.**

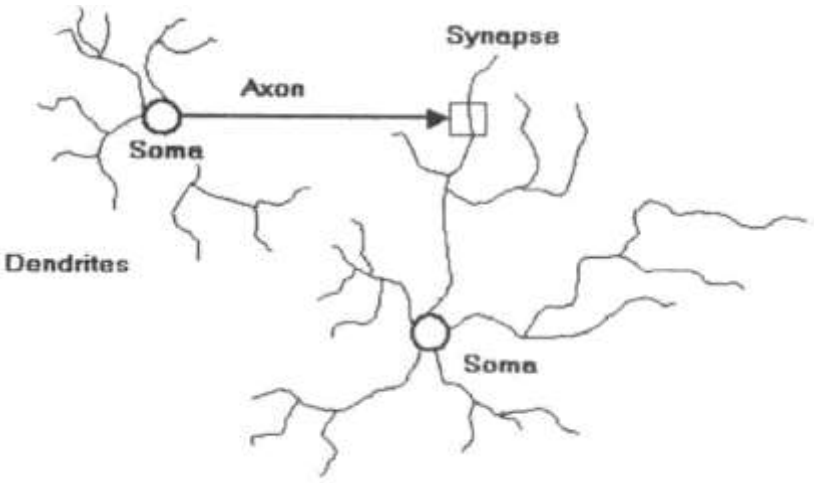
Artificial Neural Network Background

An Artificial Neural Network (ANN) is an information processing paradigm that is inspired by the biological nervous systems, such as the human brain's information processing mechanism.

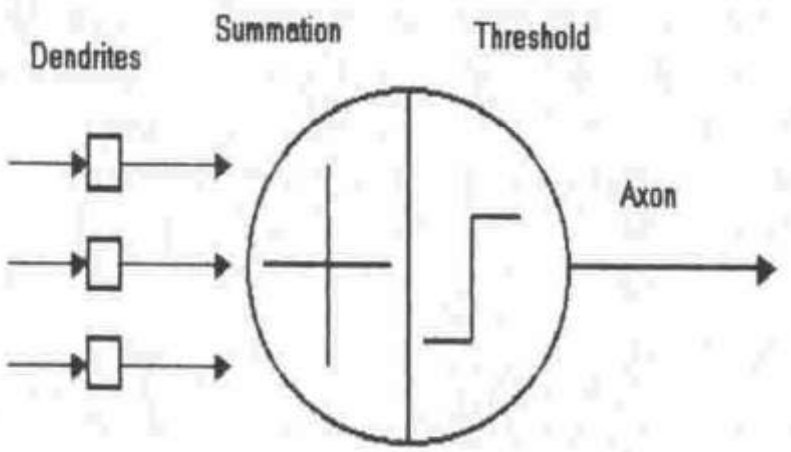
The key element of this paradigm is the novel structure of the information processing system. It is composed of a large number of highly interconnected processing elements (neurons) working in unison to solve specific problems. NNs, like people, learn by example.

An NN is configured for a specific application, such as pattern recognition or data classification, through a learning process. Learning in biological systems involves adjustments to the synaptic connections that exist between the neurons. This is true of NNs as well.

Artificial Neuron

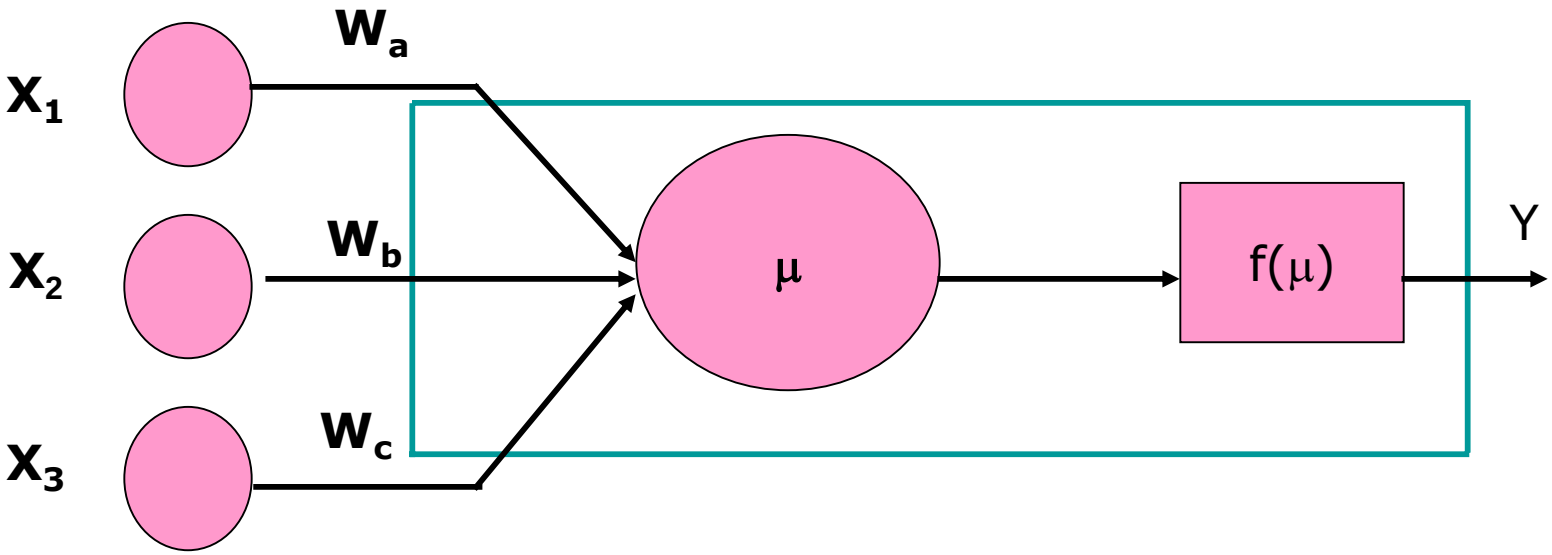


Four basic components of a human biological neuron



The components of a basic artificial neuron

Model Of A Neuron



Input units

Connection weights

Summing function

computation

(dendrite)

(synapse)

(soma)

(axon)

- A neural net consists of a large number of simple processing elements called neurons, units, cells or nodes.

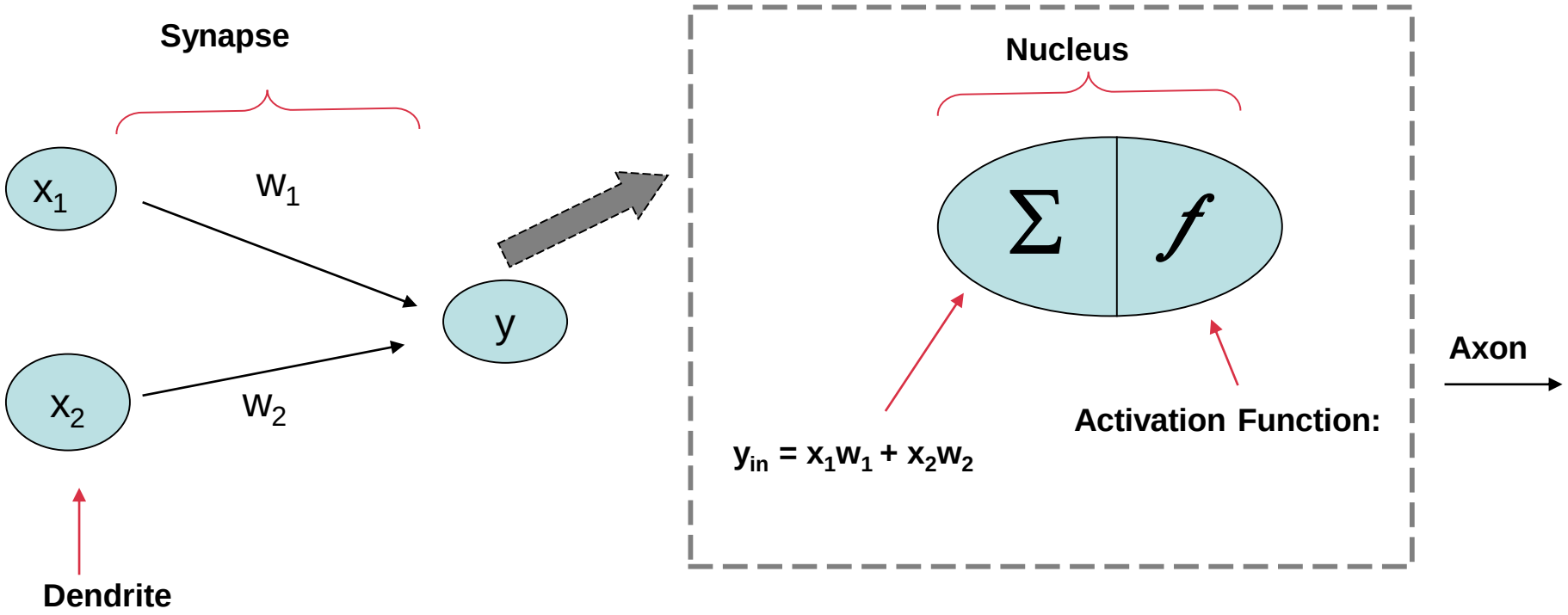
- Each neuron is connected to other neurons by means of directed communication links, each with associated weight.

- The weight represent information being used by the net to solve a problem.

- 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.

Artificial Neural Network



-A neuron receives input, determines the strength or the weight of the input, calculates the total weighted input, and compares the total weighted with a value (threshold)

-The value is in the range of 0 and 1

- If the total weighted input greater than or equal the threshold value, the neuron will produce the output, and if the total weighted input less than the threshold value, no output will be produced

History

- 1943 McCulloch-Pitts neurons
- 1949 Hebb's law
- 1958 Perceptron (Rosenblatt)
- 1960 Adaline, better learning rule (Widrow, Huff)
- 1969 Limitations (Minsky, Papert)
- 1972 Kohonen nets, associative memory

- 1977 Brain State in a Box (Anderson)
- 1982 Hopfield net, constraint satisfaction
- 1985 ART (Carpenter, Grossfield)
- 1986 Backpropagation (Rumelhart, Hinton, McClelland)
- 1988 Neocognitron, character recognition (Fukushima)

Characterization

- Architecture
  - a pattern of connections between neurons
    - Single Layer Feedforward
    - Multilayer Feedforward
    - Recurrent
- Strategy / Learning Algorithm
  - a method of determining the connection weights
    - Supervised
    - Unsupervised
    - Reinforcement
- Activation Function
  - Function to compute output signal from input signal

Diagram of an NN

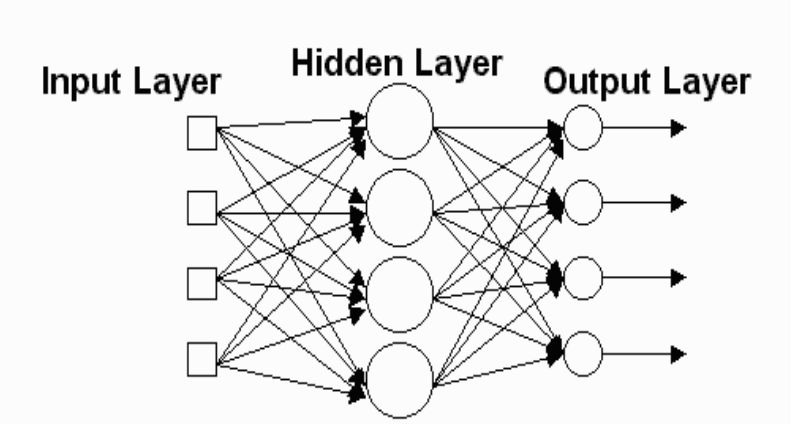


Figure 2 The anatomy of a neural network.

A simple Neural Network

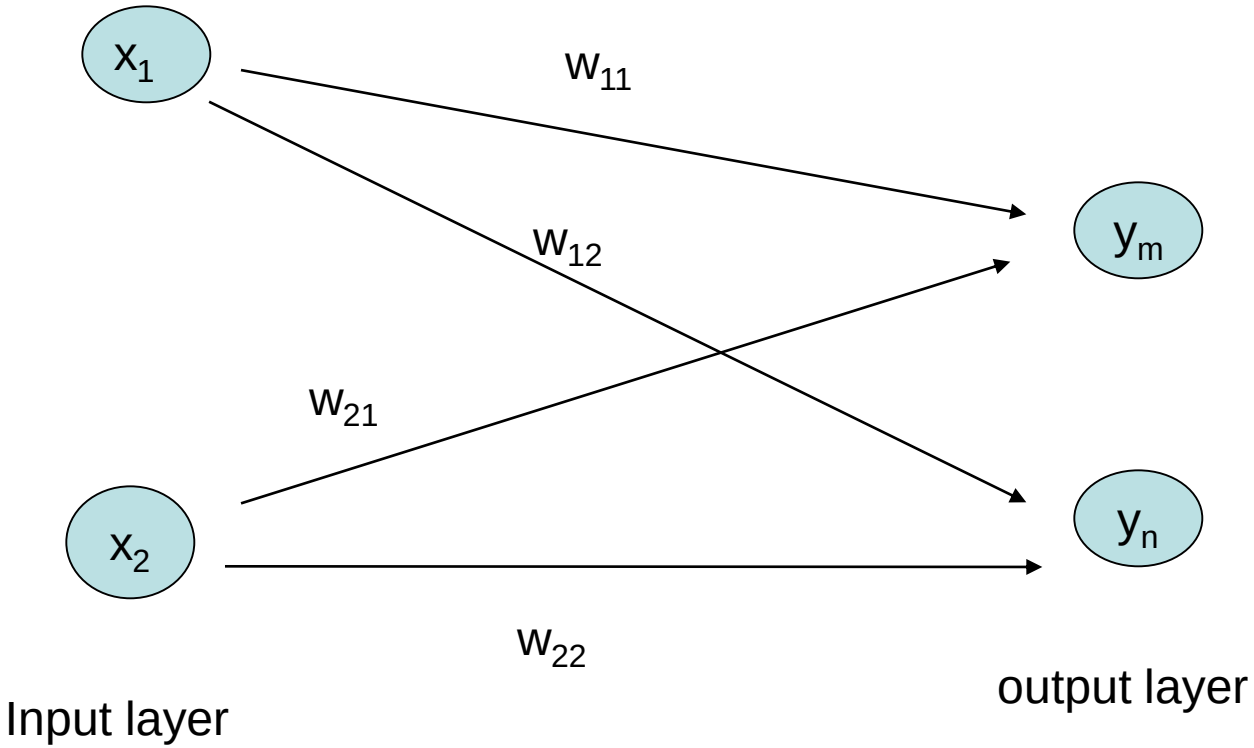
Network Layers

- Input Layer - The activity of the input units represents the raw information that is fed into the network.
- Hidden Layer - The activity of each hidden unit is determined by the activities of the input units and the weights on the connections between the input and the hidden units.
- Output Layer - The behavior of the output units depends on the activity of the hidden units and the weights between the hidden and output units.

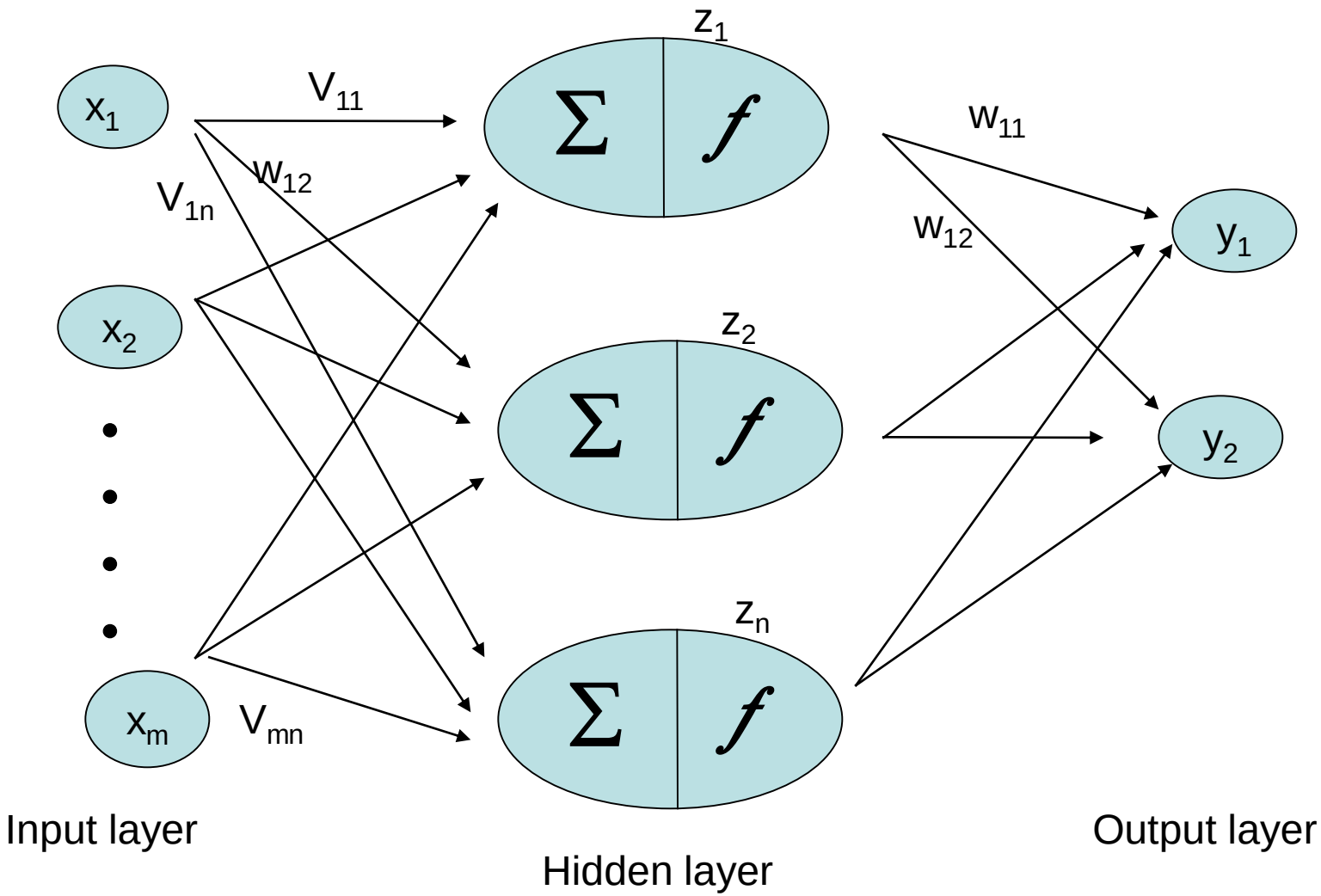
Continued

- This simple type of network is interesting because the hidden units are free to construct their own representations of the input.
- The weights between the input and hidden units determine when each hidden unit is active, and so by modifying these weights, a hidden unit can choose what it represents.

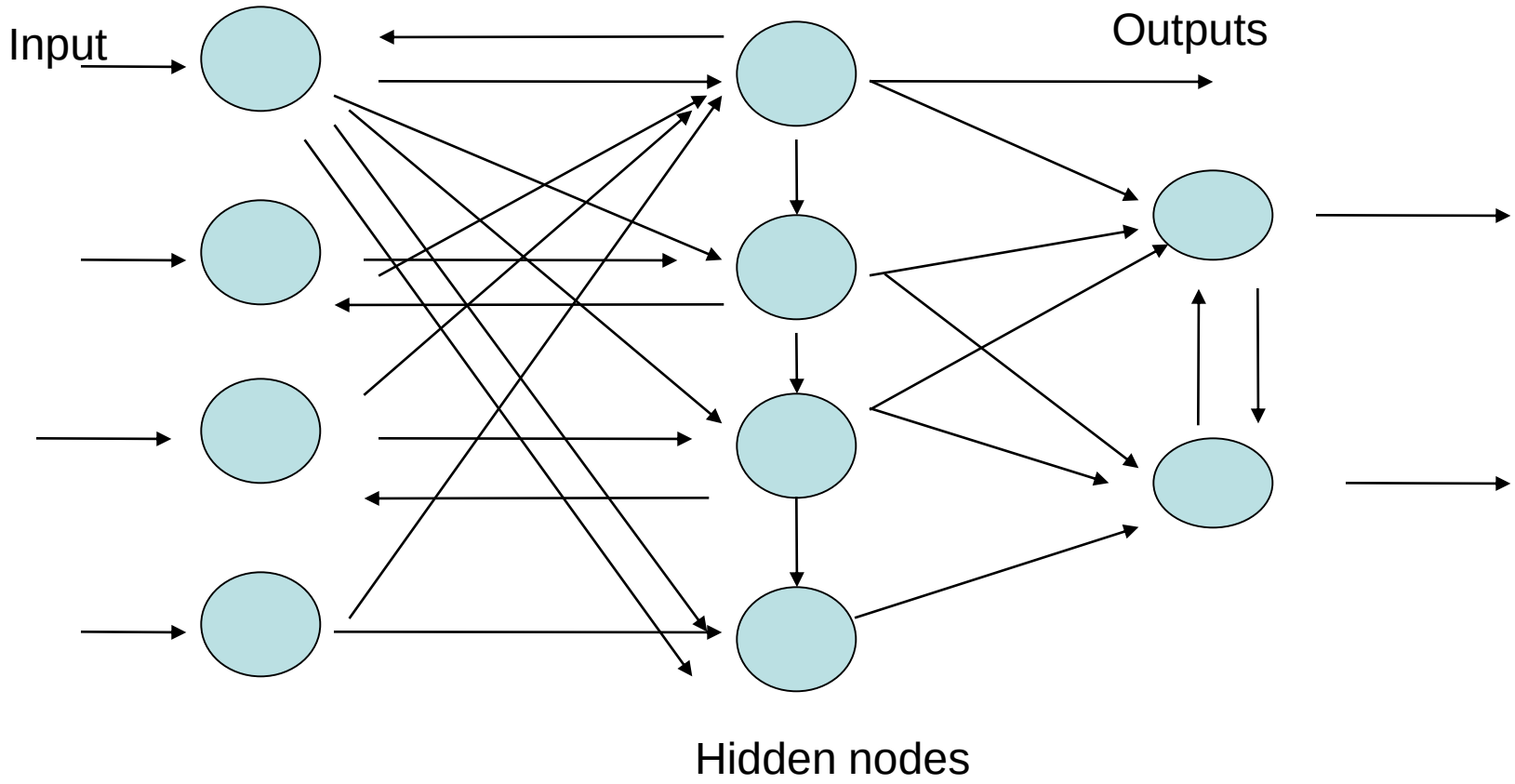
Single Layer Feedforward NN



Multilayer Neural Network



Recurrent NN



Neural networks in Medicine

- Artificial Neural Networks (ANN) are currently a hot research area in medicine and it is believed that they will receive extensive application to biomedical systems in the next few years.
- At the moment, the research is mostly on modelling parts of the human body and recognizing diseases from various scans (e.g. cardiograms, CAT scans, ultrasonic scans, etc.).

- Neural networks are ideal in recognizing diseases using scans since there is no need to provide a specific algorithm on how to identify the disease.
- Neural networks learn by example so the details of how to recognize the disease are not needed.
- What is needed is a set of examples that are representative of all the variations of the disease.
- The quantity of examples is not as important as the 'quality'. The examples need to be selected very carefully if the system is to perform reliably and efficiently.

Modeling and Diagnosing the Cardiovascular System

- Neural Networks are used experimentally to model the human cardiovascular system.
- Diagnosis can be achieved by building a model of the cardiovascular system of an individual and comparing it with the real time physiological measurements taken from the patient.
- If this routine is carried out regularly, potential harmful medical conditions can be detected at an early stage and thus make the process of combating the disease much easier.

- A model of an individual's cardiovascular system must mimic the relationship among physiological variables (i.e., heart rate, systolic and diastolic blood pressures, and breathing rate) at different physical activity levels.
- If a model is adapted to an individual, then it becomes a model of the physical condition of that individual. The simulator will have to be able to adapt to the features of any individual without the supervision of an expert. This calls for a neural network.

- Another reason that justifies the use of NN technology, is the ability of NNs to provide sensor fusion which is the combining of values from several different sensors.
- Sensor fusion enables the NNs to learn complex relationships among the individual sensor values, which would otherwise be lost if the values were individually analyzed.
- In medical modeling and diagnosis, this implies that even though each sensor in a set may be sensitive only to a specific physiological variable, NNs are capable of detecting complex medical conditions by fusing the data from the individual biomedical sensors.

Characteristics of Biological Neural Networks

1) Massive connectivity
2) Nonlinear, Parallel, Robust and Fault Tolerant
3) Capability to adapt to surroundings
4) Ability to learn and generalize from known examples
5) Collective behavior is different from individual behavior

Artificial Neural Networks mimics some of the properties of the biological neural networks

Some Properties of Artificial Neural Networks

Assembly of simple processors

Information stored in connections – No Memory

Massively Parallel

Massive connectivity

Fault Tolerant

Learning and Generalization Ability

Robust

Individual dynamics different from group dynamics

*All these properties may **not** be present in a particular network*