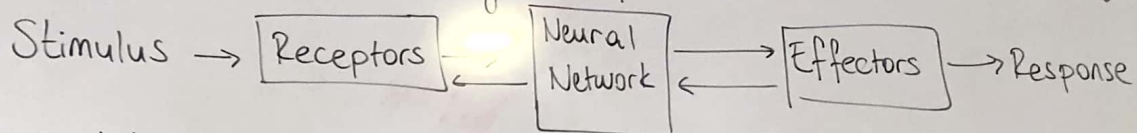


THE NERVOUS SYSTEM

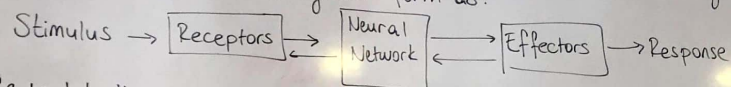
The human nervous system can be broken down into three stages that may be represented in block diagram form as:



- * Central to the system is "the brain", represented by the neural network, which continually receives information, perceives it, and makes appropriate decisions.
- * The receptors collect information from the environment, e.g. photons on the retina. They convert stimuli from the human body or the external environment into electrical impulses that convey information to the brain.

THE NERVOUS SYSTEM

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



- * Central to the system is "the brain", represented by the neural network, which continually receives information, perceives it, and makes appropriate decisions.
- * The receptors collect information from the environment, e.g. photons on the retina. They convert stimuli from the human body or the external environment into electrical impulses that convey information to the brain.
- * The effectors generate interactions with the environment, e.g. activate muscles. They convert electrical impulses generated by the neural net. into discernible responses as system outputs.

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* The flow of information/activation is represented by arrows.

* The arrows pointing from left to right, indicate the forward transmission of information bearing signals through the system.

* The arrows pointing from right to left, signify the presence of feedback in the system.

Stimuli and Response

- * The human brain processes inputs (stimuli) from our sensory organs (eyes, ears, skin, nose and tongue)
- * These inputs indicate what is happening from the outside world.
- * If a response is required, the brain will then decide on the appropriate response to the stimuli and directs movement to the appropriate system.

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NEURONS

- * The association between stimuli and response is a learned process.
- * The learning process takes place inside the brain, where there are billions special cells called neurons.
- * Neurons are electrically excitable cells that transmit information by electrical signaling.
- * In the brain, billions of the neuron cells are interconnected to form a neural network.

Stimuli and Response

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* There are several types of neurons:
Sensory neurons: accept sensory inputs
motor neurons: responsible for directing muscle movements
interneurons: interconnector between different types of neurons.

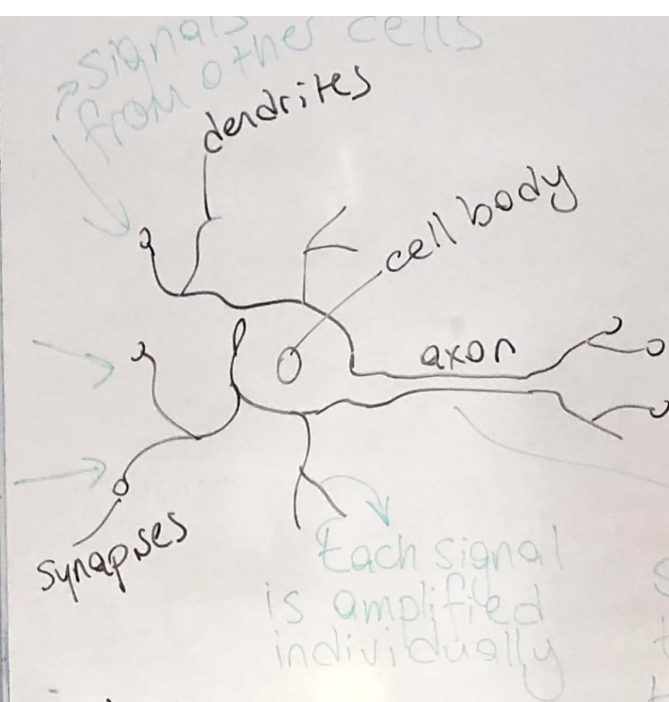
- * The neurons interconnect most actively at a young age. They degenerate when they are not used.
- * Unlike other cells, neuron cells die off as you age, and are not replaced with new ones.

ROLE OF NEURONS IN LEARNING

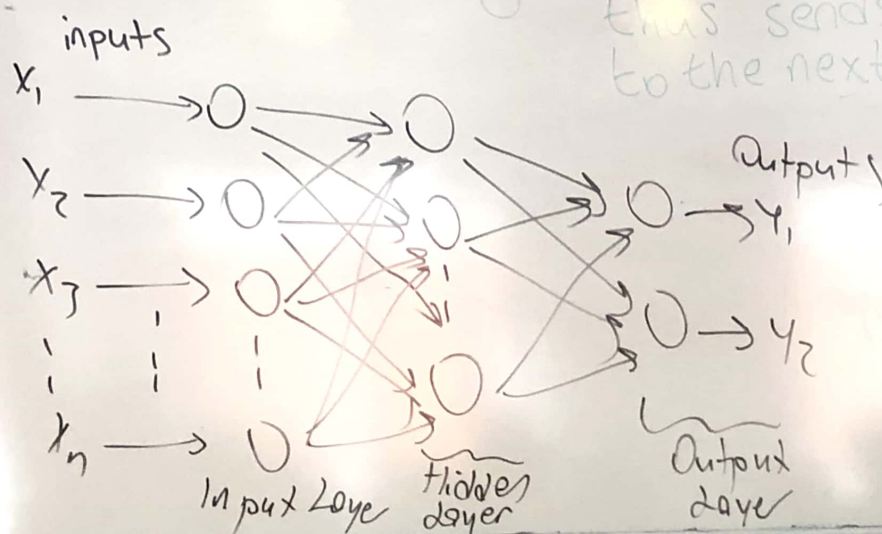
- * Each neuron is responsible to transmit an electrical signal through it.
- * It can amplify or weaken the signal when the signal flows through it.
- * The amplification value is updated constantly as we are learning.
- * The amplification value also weakens slowly if we do not use it in learning.
- * The amplified input signal goes into the cell body, which activates the neuron if sufficiently strong signal is achieved.

NEURONS

- * The association between response is a learning process.
- * The learning process happens inside the brain.
- * Billions of special neurons are present in the brain.
- * Neurons are electrical cells that transmit electrical signals.
- * In the brain, cells are interconnected in a neural network.



△ If the combined signal is strong enough the neuron fires, thus sends a signal to the next neuron.



ROLE OF NEURONS IN LEARNING

- * Each neuron transmits information through synapses.
- * It controls the signal flow.
- * The signal is updated during learning.
- * The signal weakens in learning.
- * The signal is into the neuron is achieved.

ARTIFICIAL NEURAL NETWORK

- * A neural network consists of an interconnected group of artificial neurons.
- * In most cases, an ANN is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase.

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and Response
 A brain processes inputs from our sensory organs (skin, nose and tongue) to indicate what is from the outside world. When a response is required, the brain decides on the appropriate response to the stimulus and directs movement of the appropriate system.

Some Notations

Ordered set of related numbers is called a vector.

$$X = [x_1 \ x_2 \ \dots \ x_n]^T \quad \text{-- column vector}$$

Addition of two vectors of the same length.

$$Z = [x_1 + y_1 \ x_2 + y_2 \ \dots \ x_n + y_n]^T \quad \sum_{i=1}^n x_i y_i$$

$$Z = X + Y$$

$$X = [x_1 \ \dots \ x_n]^T$$

$$Y = [y_1 \ \dots \ y_n]^T$$

Multiplication of two vectors of the same length:

$$X^T Y = \sum_{i=1}^n x_i y_i = x_1 y_1 + x_2 y_2 + \dots + x_n y_n \rightarrow \text{scalar}$$

$$X = [x_1 \ \dots \ x_n]^T$$

$$Y = [y_1 \ \dots \ y_n]^T$$

MATRICES

$$W = \begin{bmatrix} w_{11} & w_{12} & \dots & w_{1n} \\ \vdots & \vdots & & \vdots \\ w_{m1} & w_{m2} & \dots & w_{mn} \end{bmatrix} \quad (m \times n)$$

$$X = [x_1 \ \dots \ x_n]^T$$

$$W \cdot X = Z$$

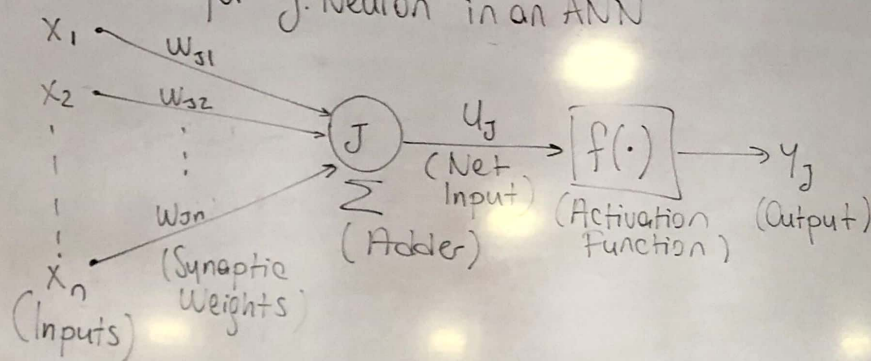
$$Z = (m \times 1)$$

$$Z = \begin{bmatrix} z_1 \\ z_2 \\ \vdots \\ z_m \end{bmatrix}$$

ARTIFICIAL NEURAL NETWORK

* A neural network is a system of interconnected nodes.
 * In most cases, an artificial neural network is a system that changes or adapts its internal structure or weights that flows through it during the learning process.

Nonlinear for j . Neuron in an ANN



n = number of inputs

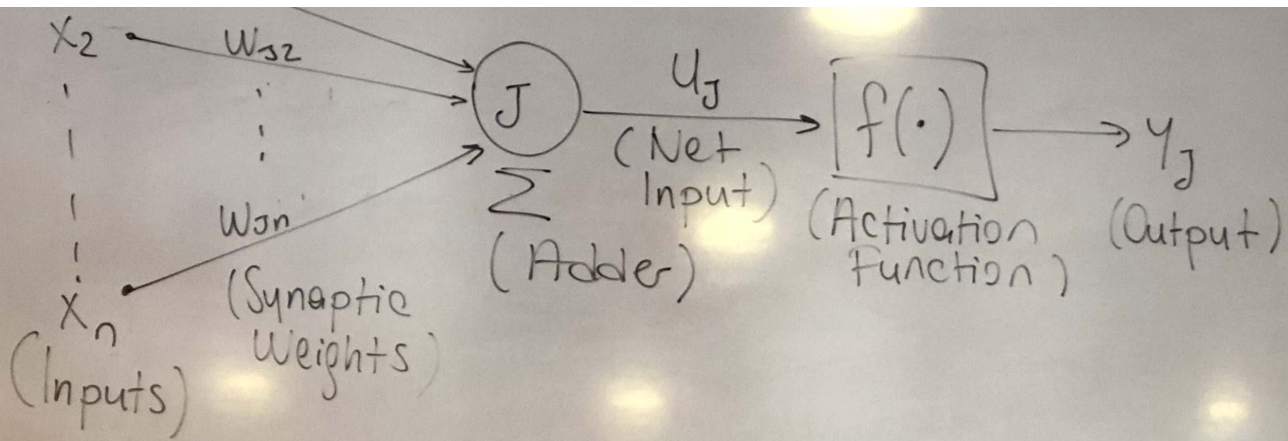
$X = [x_1 \dots x_n]^T$: Input Vector

w_{ji} = weight coefficients from i . neuron to j . neuron

$$u_j = \sum_{i=1}^n w_{ji} x_i \quad \text{Net input for } j \text{ neuron.}$$

$$y_j = f(u_j) \quad \text{Output of the } j \text{ neuron.}$$

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

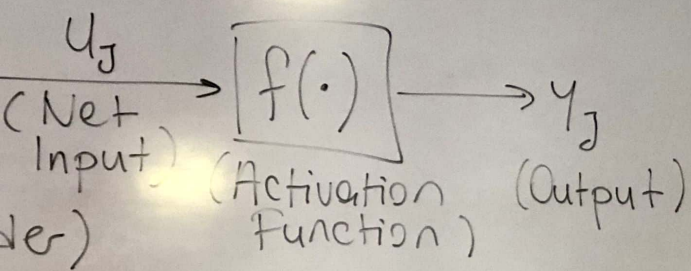


n = number of inputs

$X = [x_1 \dots x_n]^T$: Input Vector

w_{ji} = Weight coefficients from i . neuron to j . neuron

in an ANN



$$u_j = \sum_{i=1}^n w_{ji} \cdot x_i$$

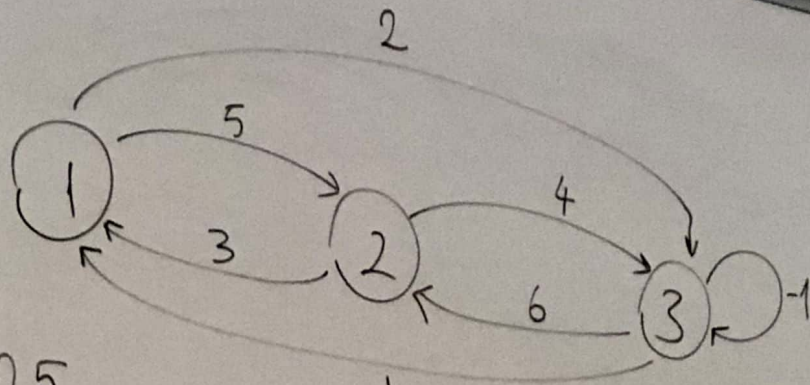
Net input for j neuron.

$$y_j = f(u_j)$$

Output of the j neuron.

$$= f\left(\sum_{i=1}^n w_{ji} \cdot x_i\right)$$

Ex.



$$x_1 = 0,5$$

$$x_2 = 1$$

$$x_3 = 0,7$$

$$f(\cdot) = \text{sgn}(\cdot)$$

$$n = 3$$

$$\textcircled{1} \quad u_1 = \sum_{i=1}^3 w_{1i} \cdot x_i = w_{11} \cdot x_1 + w_{12} x_2 + w_{13} x_3$$

$$= 0 \cdot x_1 + 3 \cdot x_2 + x_3$$

$$u_2 = \sum_{i=1}^3 w_{2i} \cdot x_i = w_{21} \cdot x_1 + w_{22} x_2 + w_{23} \cdot x_3$$

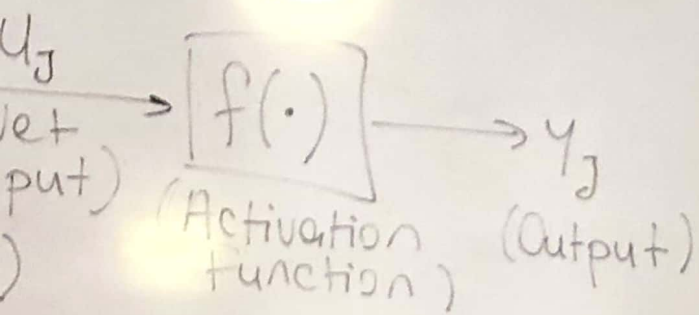
$$= 5x_1 + 0 \cdot x_2 + 6x_3$$

$$W = \begin{bmatrix} w_{11} & w_{12} & w_{13} \\ w_{21} & w_{22} & w_{23} \\ w_{31} & w_{32} & w_{33} \end{bmatrix} = \begin{bmatrix} 0 & 3 & 1 \\ 5 & 0 & 6 \\ 2 & 4 & -1 \end{bmatrix}$$

$$u_3 = \sum_{i=1}^3 w_{3i} \cdot x_i = w_{31} x_1 + w_{32} x_2 + w_{33} x_3$$

$$= 2x_1 + 4x_2 + (-1)x_3$$

in an ANN



$$y_1 = f(u_1) = \text{sgn}(u_1) = 1$$

$$y_2 = f(u_2) = \text{sgn}(u_2)$$

$$y_3 = f(u_3) = \text{sgn}(u_3)$$

$$u = W \cdot x$$

$$u = (3 \times 3) \cdot (3 \times 1) = (3 \times 1)$$

$$\begin{bmatrix} u_1 \\ u_2 \\ u_3 \end{bmatrix} = \begin{bmatrix} 0 & 3 & 1 \\ 5 & 0 & 6 \\ 2 & 4 & -1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 3x_2 + x_3 \\ 5x_1 + 6x_3 \\ 2x_1 + 4x_2 - x_3 \end{bmatrix}$$

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \text{sgn}(u)$$

Vector

row i. neuron j. on

Ex.

$x_1 = 0$
 $x_2 =$
 $x_3 =$
 $f(\cdot)$

$n =$

$W =$