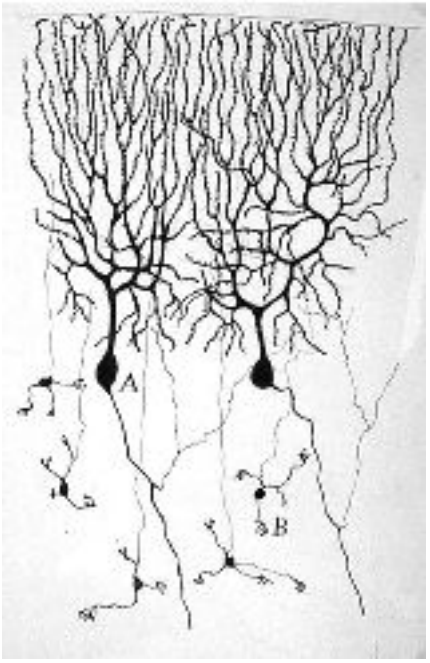
# Neural Networks 1: Introduction	start time:



This activity introduces basic concepts & ideas in **Artificial Neural Networks (ANNs),** a set of computational techniques inspired by natural neural systems. (ANNs are also used to simulate or model natural systems.)

Before you start, complete the form below to assign a role to each member.
If you have 3 people, combine Manager & Reflector.

Team		**Date**	
Team Roles		**Team Member**	
Recorder: records all answers & questions, and provides copies to team & facilitator.			
Speaker: talks to facilitator and other teams.			
Manager: keeps track of time and makes sure everyone contributes appropriately.			
Reflector: considers how the team could work and learn more effectively.			

Reminders:

1. *Note the time whenever your team starts a new section or question.*
2. *Write legibly & neatly so that everyone can read & understand your responses.*

(10 min) A. Nervous System	start time:

Species	**# of Neurons**	**Scale**
ant	10,000	10^4
fruit fly	100,000	10^5
cockroach	1,000,000	10^6
frog	16,000,000	10^7
octopus	300,000,000	10^8
human	100,000,000,000	10^{11}
whale	200,000,000,000	10^{11}

1. In (most) natural systems, information processing is done by the **nervous system,** which consists of the brain, spinal cord, and peripheral nerves.
Each of these parts contains many **nerve cells**, also called **neurons**.
The table above shows the typical number of neurons in various animal species.
Describe the relationship between number of neurons and the animal's:

a.	**size**	
b.	**intelligence**	

2. Neurons can be grouped into 3 broad categories:
   - **afferent neurons** send signals toward the brain
   - **efferent neurons** send signals away from the brain
   - **interneurons** connect other neurons.

(Remember that **afferents approach** the brain,
and **efferents exit** the brain.)

Label each of the following as **A (afferent)** or **E (efferent)**:

a.	photoreceptor (light-sensitive) cells in the retina of the eye	
b.	hair cells that react to sound vibrations in the cochlea of the ear	
c.	cells in muscles that cause the muscles to move	
d.	cells in muscles that sense the relative position of body parts (used for proprioception)	
e.	cells that cause the mouth to produce saliva	

3. **Sensory neurons** sense information, and **motor neurons** control muscles and glands.

f.	Which examples above (a-e) are **sensory** neurons?	
g.	Which examples above (a-e) are **motor** neurons?	
h.	Are **sensory** neurons afferent or efferent?	
i.	Are **motor** neurons afferent or efferent?	

4. Different types of neurons have different shapes and structures, but most contain a similar set of components, shown at right. Match the labels (A-D) to the descriptions below.

a.	The **soma** is the main cell body with the **nucleus**.	
b.	The soma has branching **dendrites** that **receive** signals from other cells.	
c.	The **axon** is the long arm that **sends** signals from the soma.	
d.	**Terminals** connect the axon to the dendrites of other neurons.	

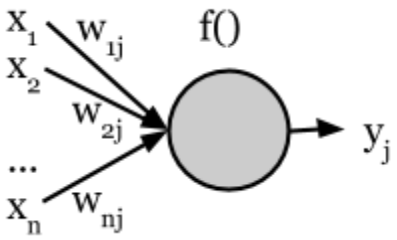
When a neuron **fires**, a electrical signal travels from the soma, through the axon, and to terminals that connect to the dendrites of other neurons, so that some of these other neurons may also fire as a result of this signal. This signal is called an **action potential** and is how the system **reacts**.

The dendritic connections between neurons change over time (more slowly). These changing connections are how the system **learns**.

To create artificial neural systems (either as simulations or to solve other problems), we need to consider both processes - **reacting** and **learning**.

(5 min) B. Perceptrons	start time:

1. In a typical Artificial Neural Network (ANN), each neuron has a set of **inputs** and one **output**. Each input value is multipled by a **weight** (positive or negative) to determine its effect. The weighted inputs are added together, and then an **activation function** (also called a **transfer function**) is applied to the sum to determine the output value.



Thus the neuron's operation can be written as:

$$y_j = f\left(\sum_{i=1..n} x_i w_{ij}\right)$$

Refer to the diagram and equation above and identify:

a.	the letter used for the **input(s)**?	
b.	the letter used for the **output(s)**?	
c.	the letter used for the **transfer function**?	
d.	the letter & subscripts used for the **weight** between input #2 and output #1.	
e.	the letter that best fits a neuron's **dendrites**?	
f.	the letter that best fits a neuron's **terminals**?	
g.	the letter that best fits a neuron's **soma**?	

This model of a neuron is called a **perceptron**.

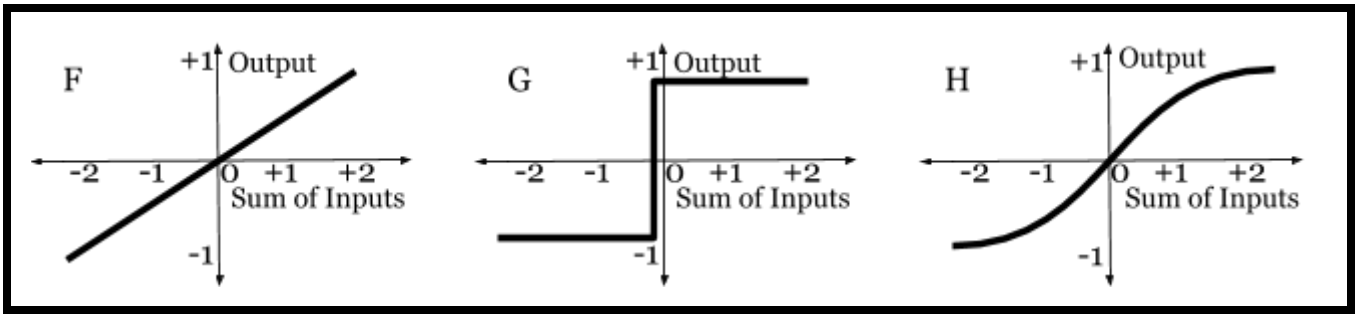
2. Calculate the **outputs** for two perceptrons with the same **inputs** but different **weights**, and where the **activation function** divides the weighted sum by two. Show your work.

x1 = 1.0 x2 = 0.0 x3 = 0.5

w11 = 1.0 w12 = 0.0 w21 = 0.5 w22 = 0.5 w31 = 0.0 w32 = 1.0

a.	y1=	
b.	y2=	

(5 min) C. Activation Functions	start time:

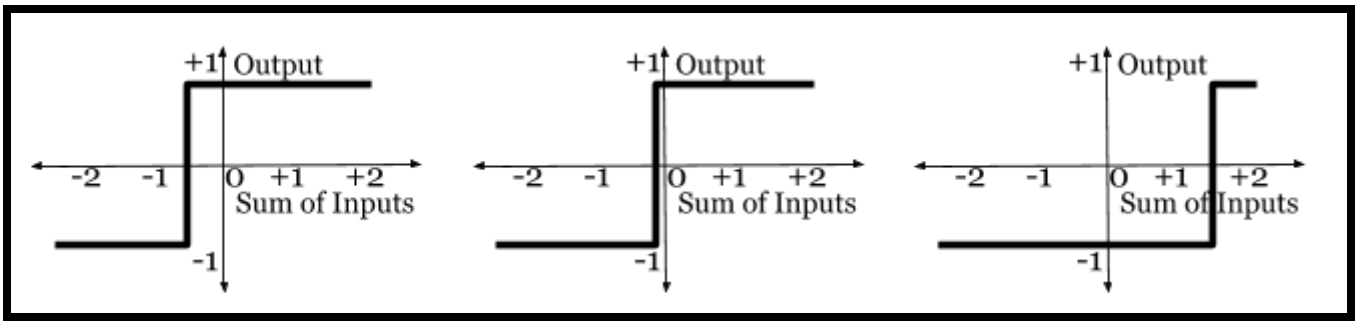


1. An **activation** (or **transfer**) **function** converts the weighted sum of input values into an output value. Use the 3 functions shown above to answer the questions below:

	For Function F (left):	
a.	If the sum of inputs is 2, what is the output?	
b.	If the sum if inputs is 1, what is the output?	
c.	What is the minimum output value for any input?	
d.	Could a small change in one input cause a large change in the output?	
	For Function G (middle):	
e.	If the sum of inputs is 2, what is the output?	
f.	If the sum if inputs is 1, what is the output?	
g.	What is the minimum output value for any input?	
h.	Could a small change in one input cause a large change in the output?	
	For Function H (right):	
i.	If the sum of inputs is 2, what is the output?	
j.	If the sum if inputs is 1, what is the output?	
k.	What is the minimum output value for any input?	
l.	Could a small change in one input cause a large change in the output?	

2. Which of the activation functions (F,G,H) is:

a.	a **step function**?	
b.	a **linear function**?	
c.	a **sigmoid function**?	



3. To describe the shape of a **step function**, we must specify three parameters:
the **minimum** and **maximum** outputs, and the **transition** value where the output changes.
(The figure above shows 3 step functions with different transition values.)
Explain which of these parameters could be replaced or modified with an extra input value.

4, Explain why it might be useful for every input and output in an ANN
to use the same range of values, e.g. {-1.0 … +1.0} or {-0.5 … +0.5 }.
Hint: in ANNs, the output of one perceptron can be an input to other perceptrons.

5. Describe how a **sigmoid** function combines the strengths of **linear** and **step** functions
and avoids their weaknesses.

We have seen how inputs, weights, and an activation function affect a perceptron.
Next, we will explore some simple examples where we can choose the weights.
Later, we will explore ways for ANNs to learn weights automatically.