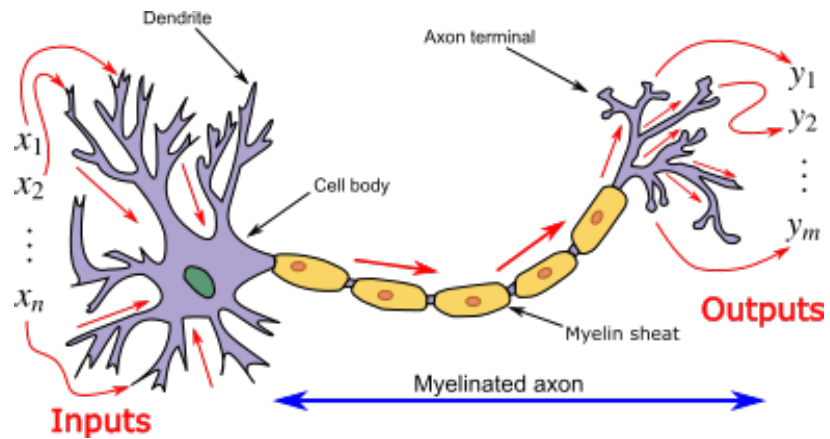


# From Biological Neurons to Artificial Neural Networks

James M. Irving, Ph.D.

Updated 10/30/20

# TOPICS TO COVER

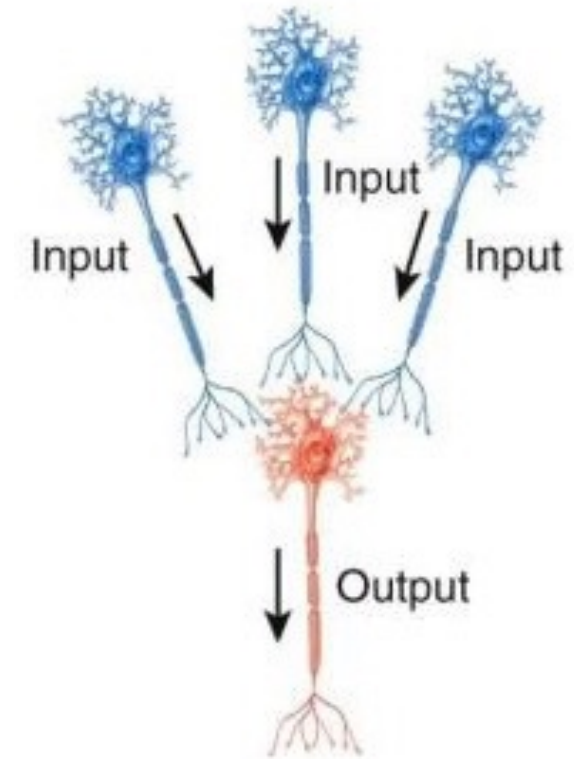
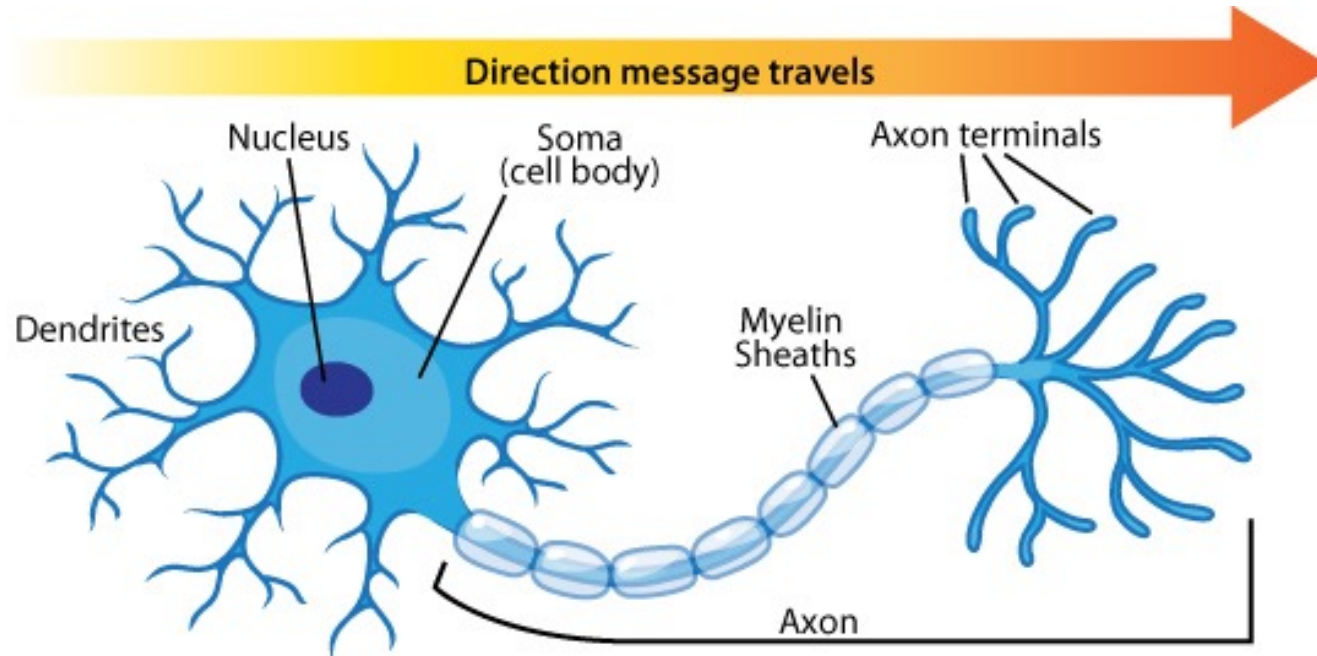


Anatomy of a Neuron

How Neurons Process Info

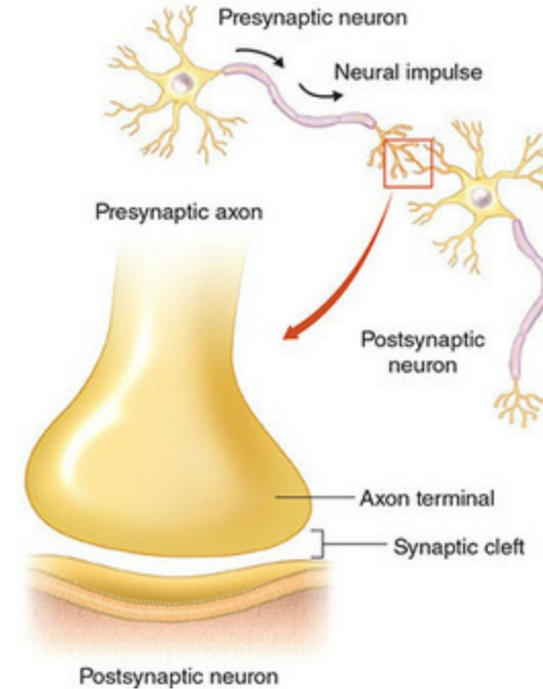
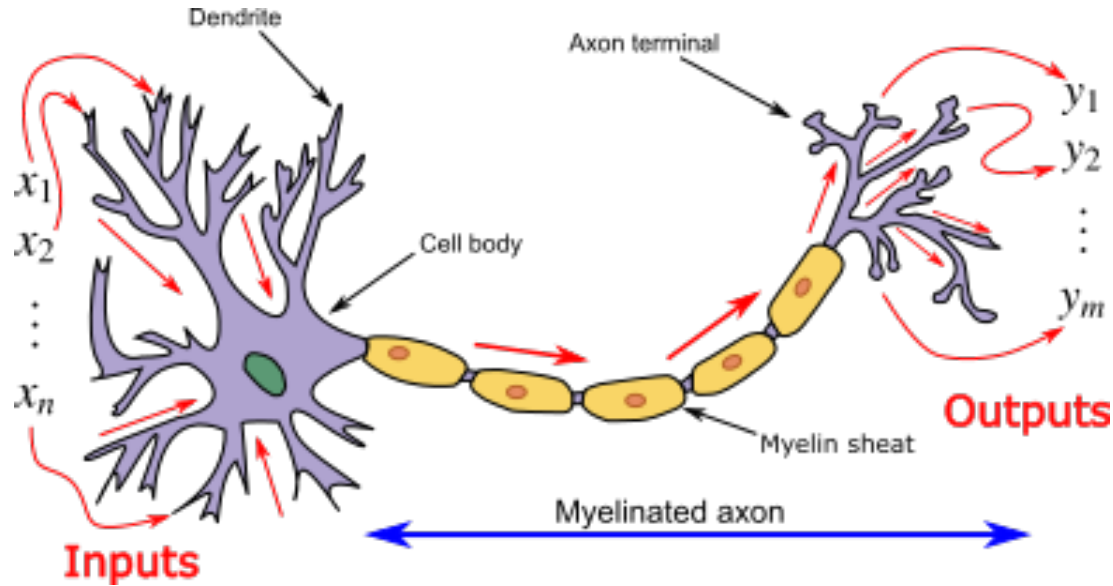
Strengthening / Weakening  
Connections

# Anatomy of a Neuron I



- ▶ **Neurons are shaped kind of like a tree.**
  - ▶ There are branches with leaves at the top (the dendrites/soma)
  - ▶ It has a long trunk (the axon)
  - ▶ The trunk ends with roots that connect to other neurons (the axon terminals)

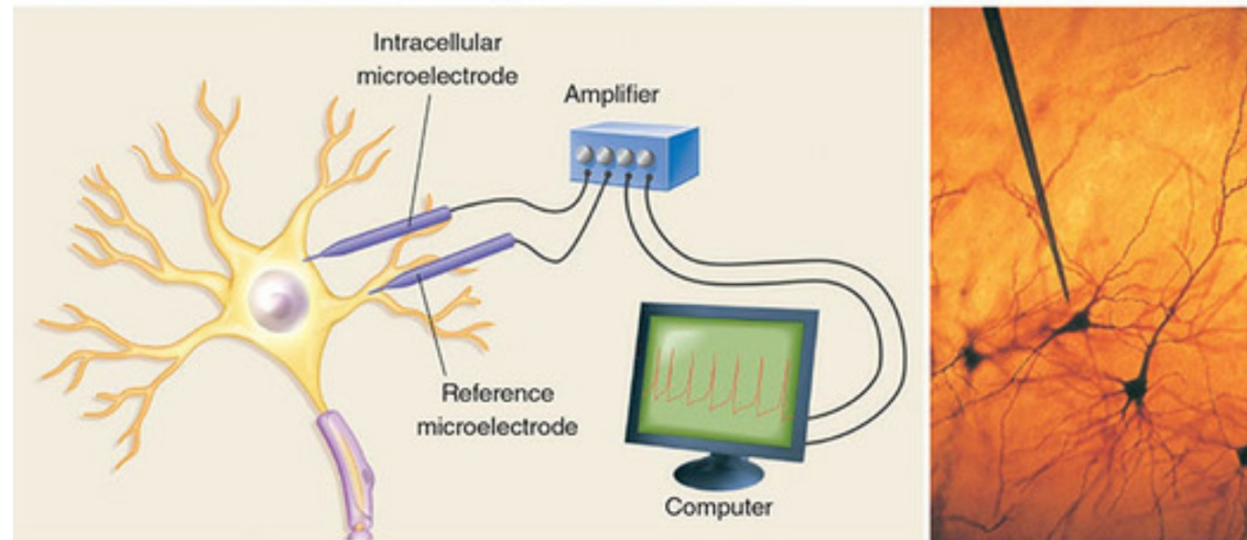
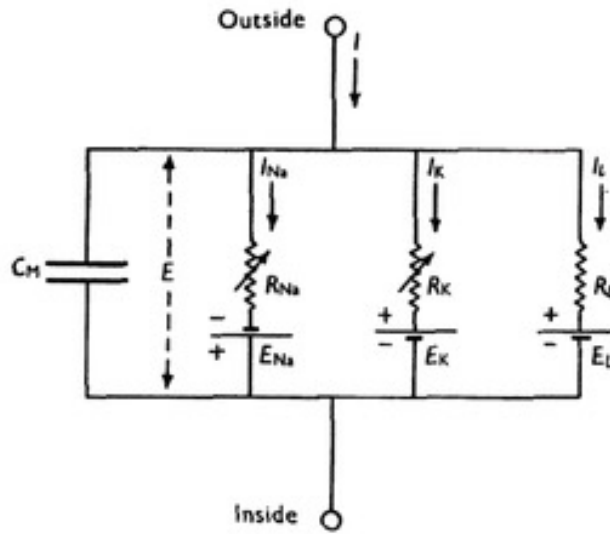
# Anatomy of a Neuron II



- ▶ Lots of neurons (hundreds-thousands) act as Inputs to the neuron by connecting to the neuron's branches.
  - ▶ These are called “synapses”
  - ▶ Neurons released Neurotransmitters to send information across a synapse

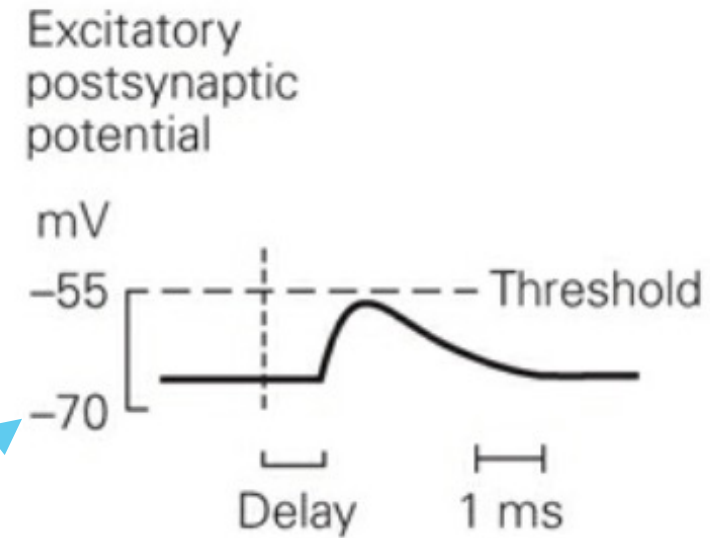
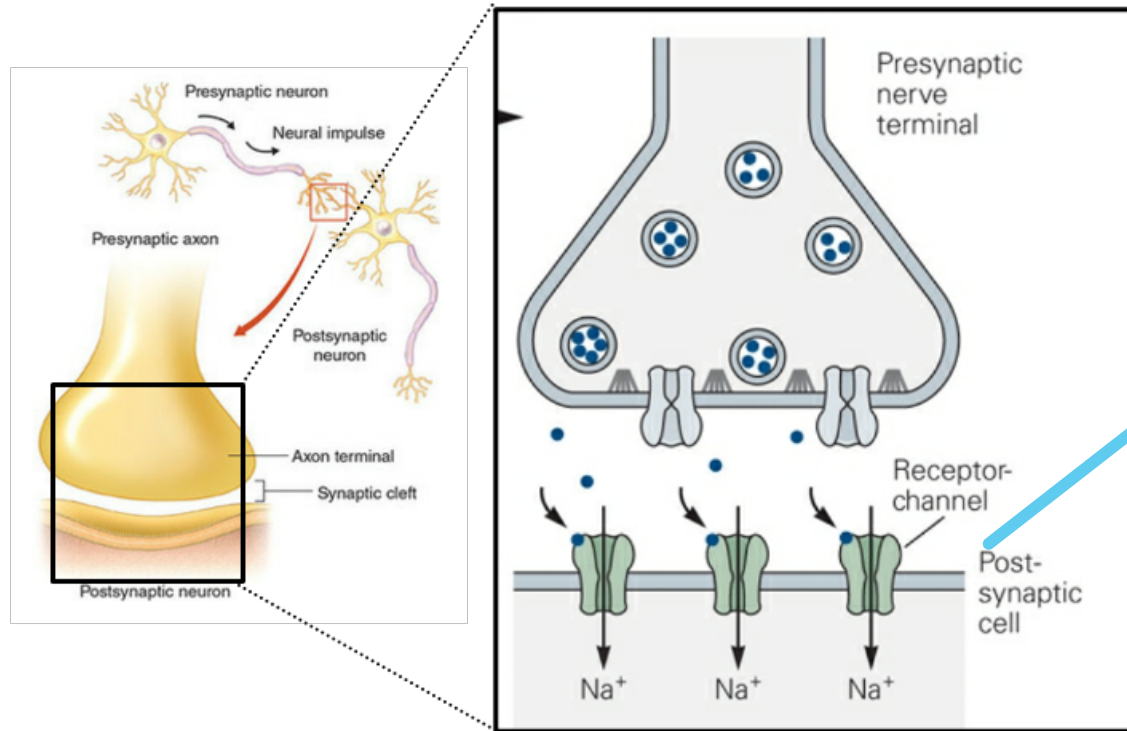
# Neurons are Like Batteries

- Neurons are like electrical circuits with batteries.
- They have a certain resting voltage ( $\sim -70\text{mV}$ ).
- Normally, neurons are NOT firing. They are waiting for input, sitting at a specific voltage.



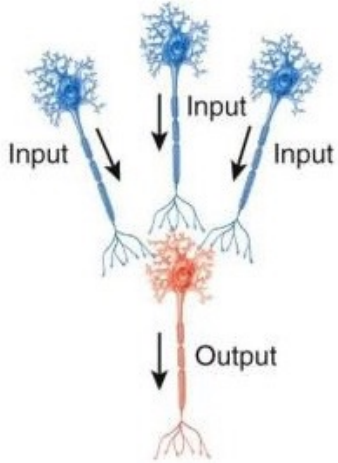
# How Neurons communicate

- Neurotransmitters open special pores in the neuron that let in ions (electricity)
- The change in electrical input will change the Voltage of the neuron.

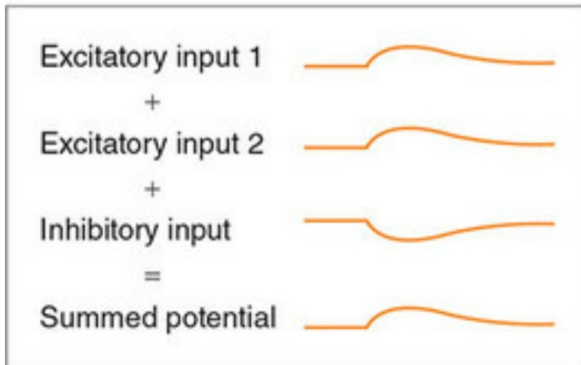




# Neurons are Like Batteries



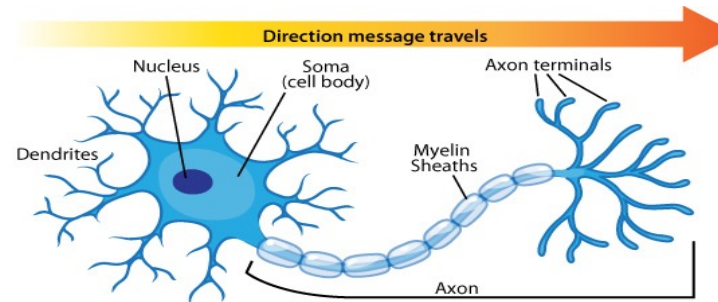
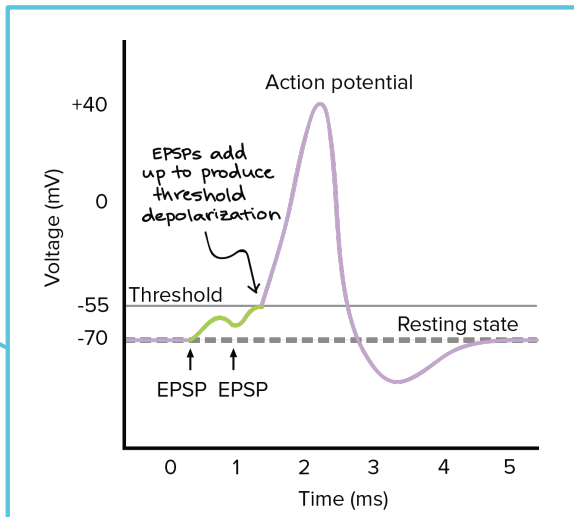
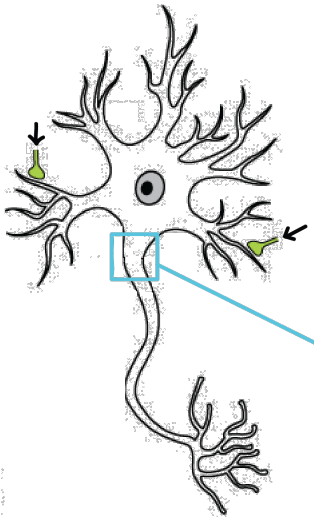
Note that inhibitory potentials cancel out excitatory potentials of equal strength (and vice versa).



Some inputs decrease the neuron's voltage (less likely to fire).

Some inputs increase the neuron's voltage (more likely to fire).

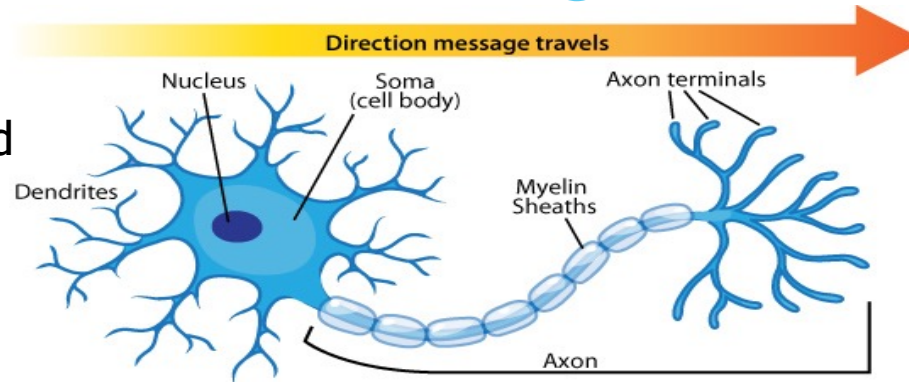
- If the **SUMMED INPUT** of all neurons is greater than the neuron's threshold: the neuron fires.



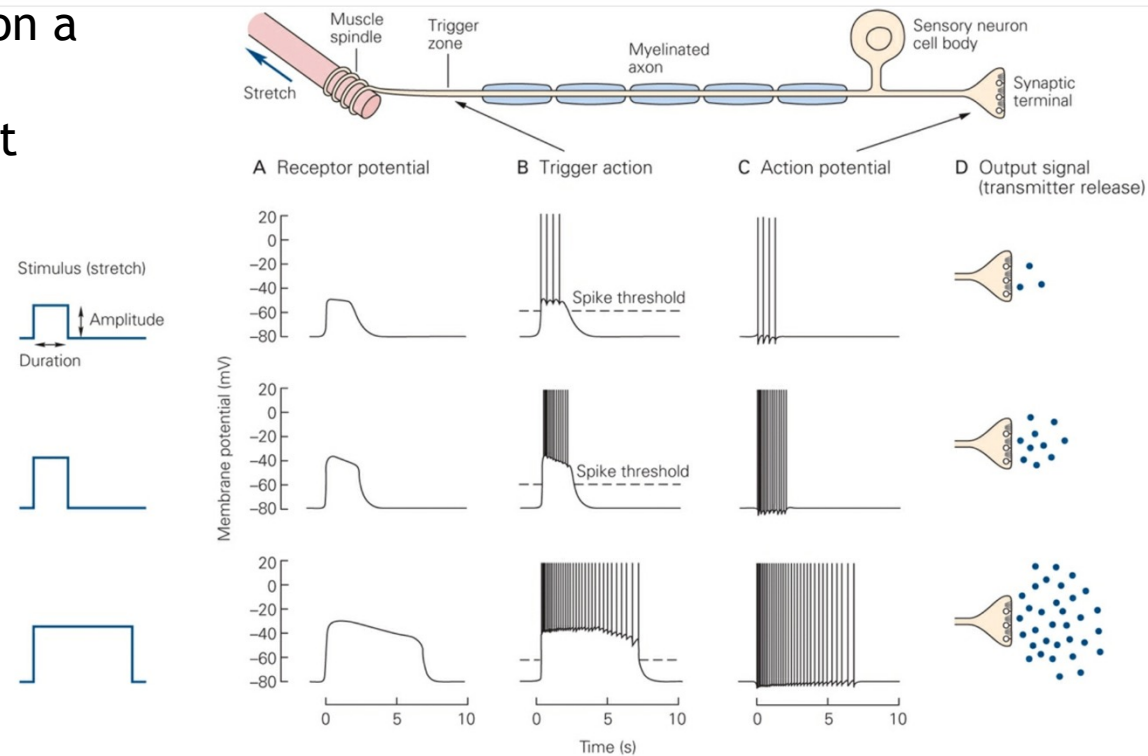
- After the neuron fires, it releases its own NTs onto the **NEXT** neurons.

# Example Information Processing

- Information Traveling Through a Neuron to the next Neuron is called **“forward propagation”**



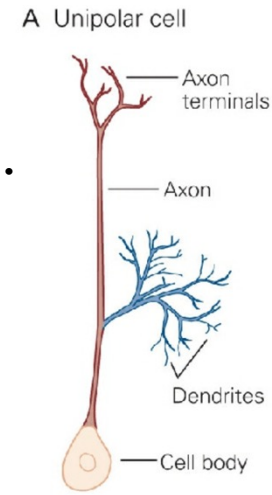
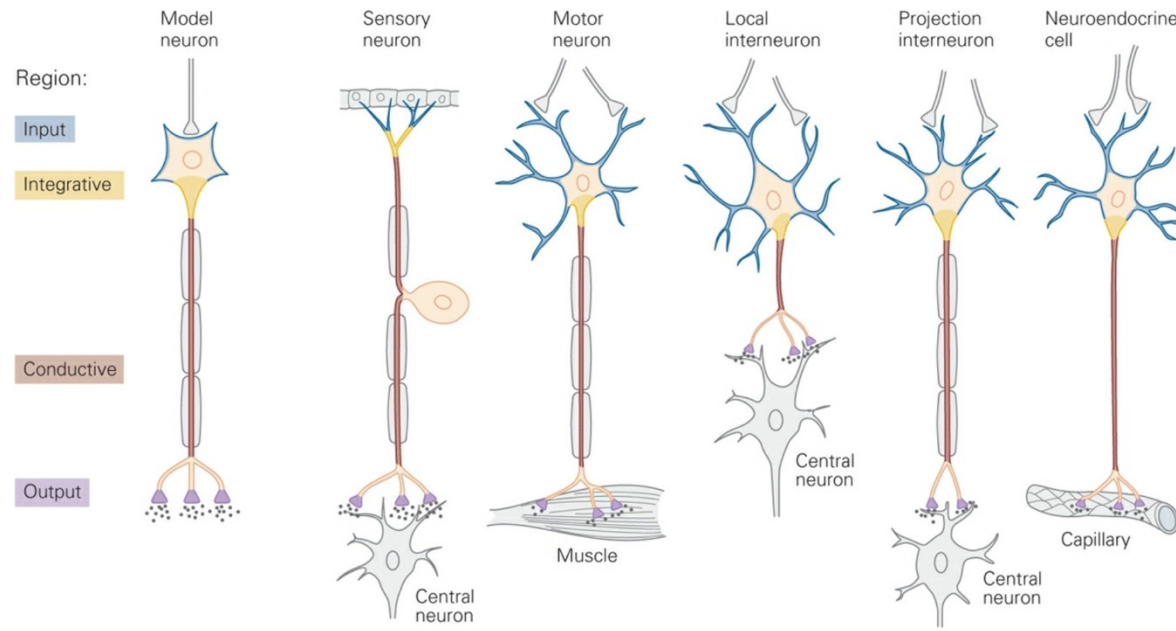
- The more information/excitation a neuron receives, the more information/neurotransmitter it sends to the next neurons.



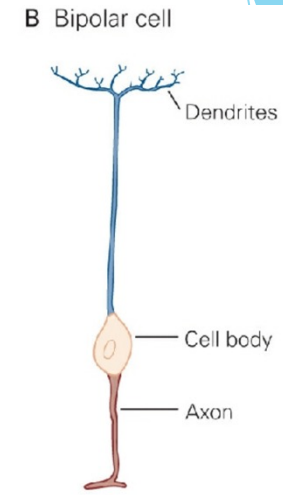


# Many Types of Neurons

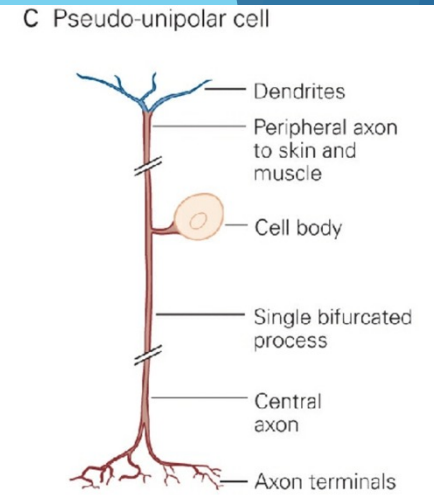
- There are many types of neurons with different properties.
- They have different resting voltages
- They release different neurotransmitters
- They affect other neurons in different ways.



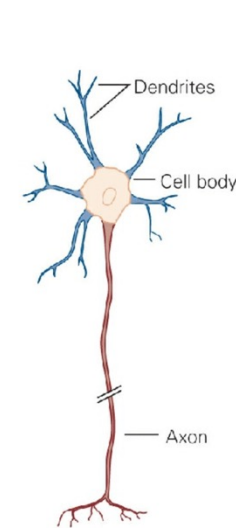
Invertebrate neuron



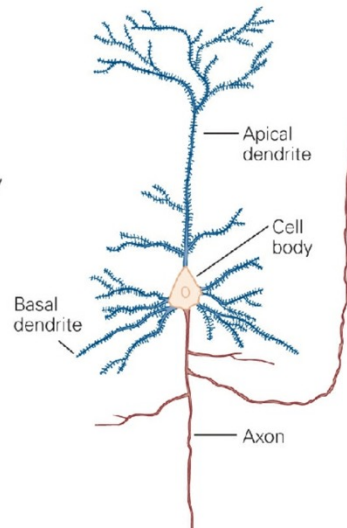
Bipolar cell of retina



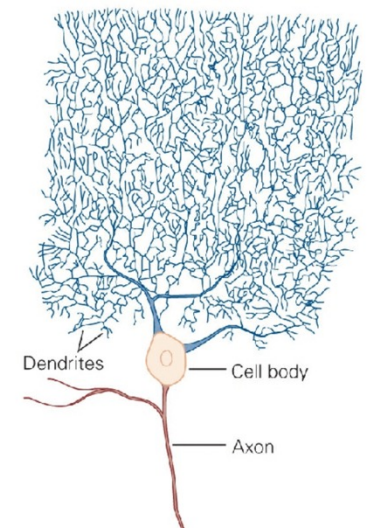
Ganglion cell of dorsal root



Motor neuron of spinal cord



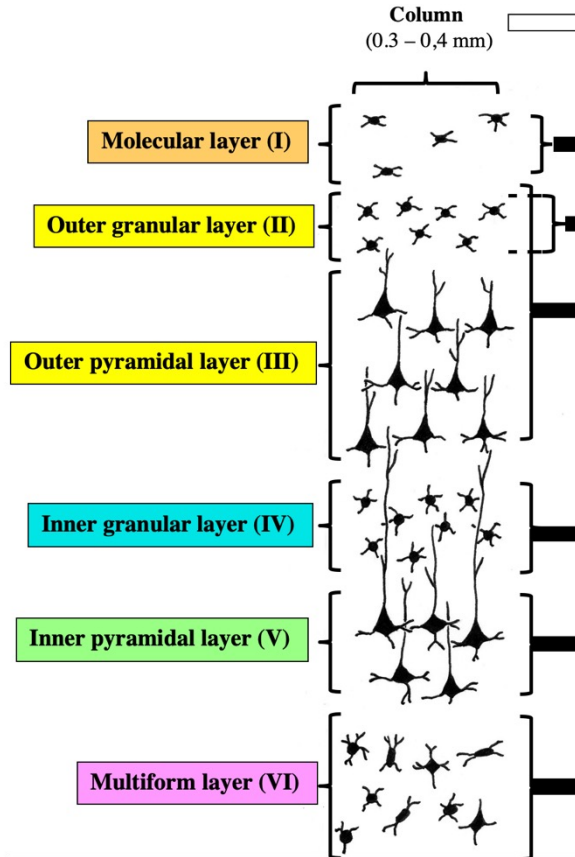
Pyramidal cell of hippocampus



Purkinje cell of cerebellum

# Neurons are Organized into Networks

## Cerebral cortex – Neocortical layers



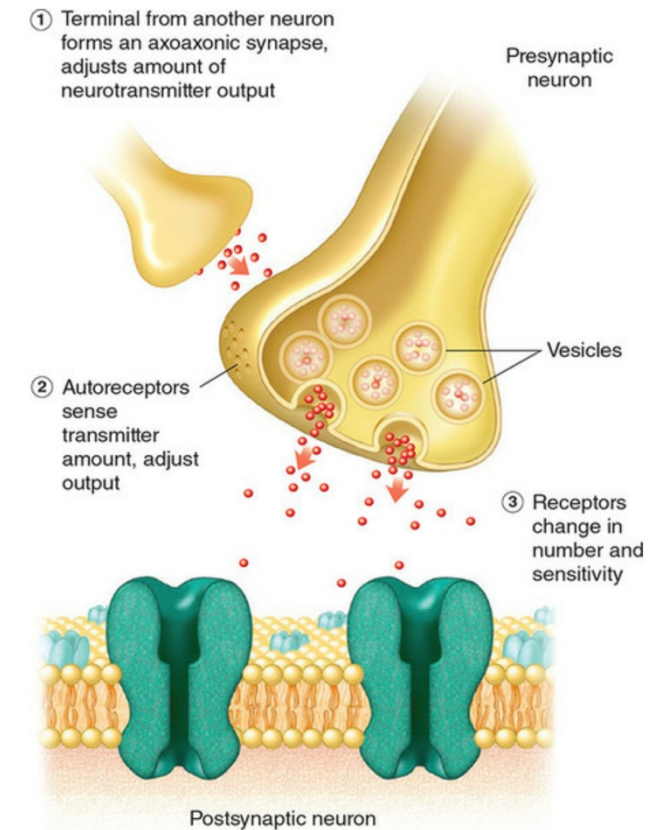
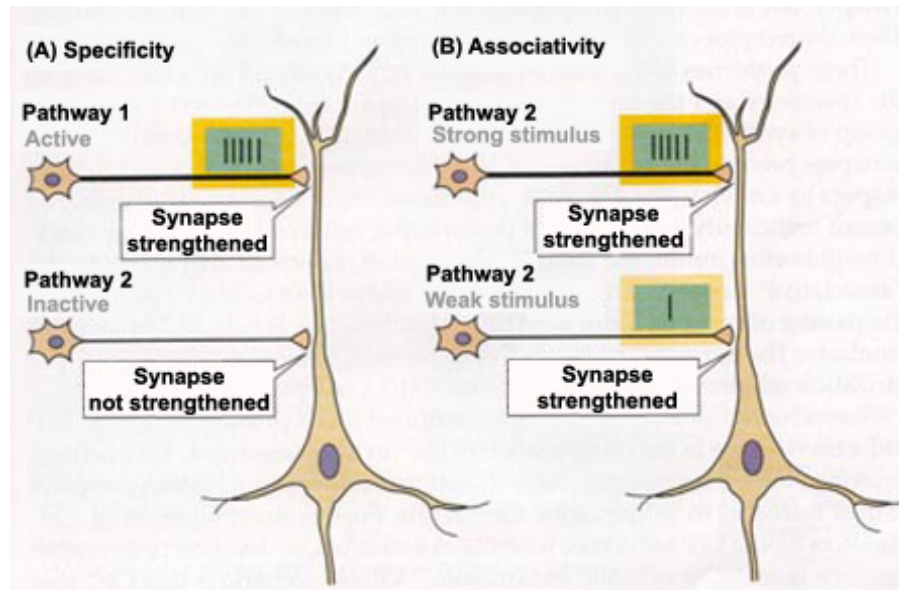
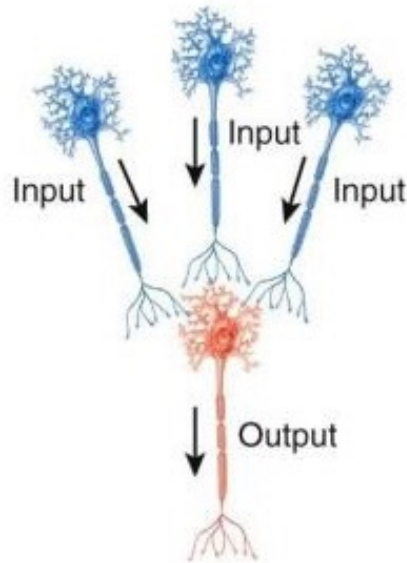
Except for the basal nuclei, the newly formed neurons migrate from the mantle layer, close to the lumen of the neural tube, to form the cerebral cortex. The cortex forms inside out, the first neurons to migrate form the layer VI. The rest of the neurons pass through the formed layer to form layer V and so on. So the last is the molecular layer.

- Neurons are often arranged in a highly-organized multi-layered network
- Information enters the network at specific layers
- The information is processed and passed onto the next layer, and so on.

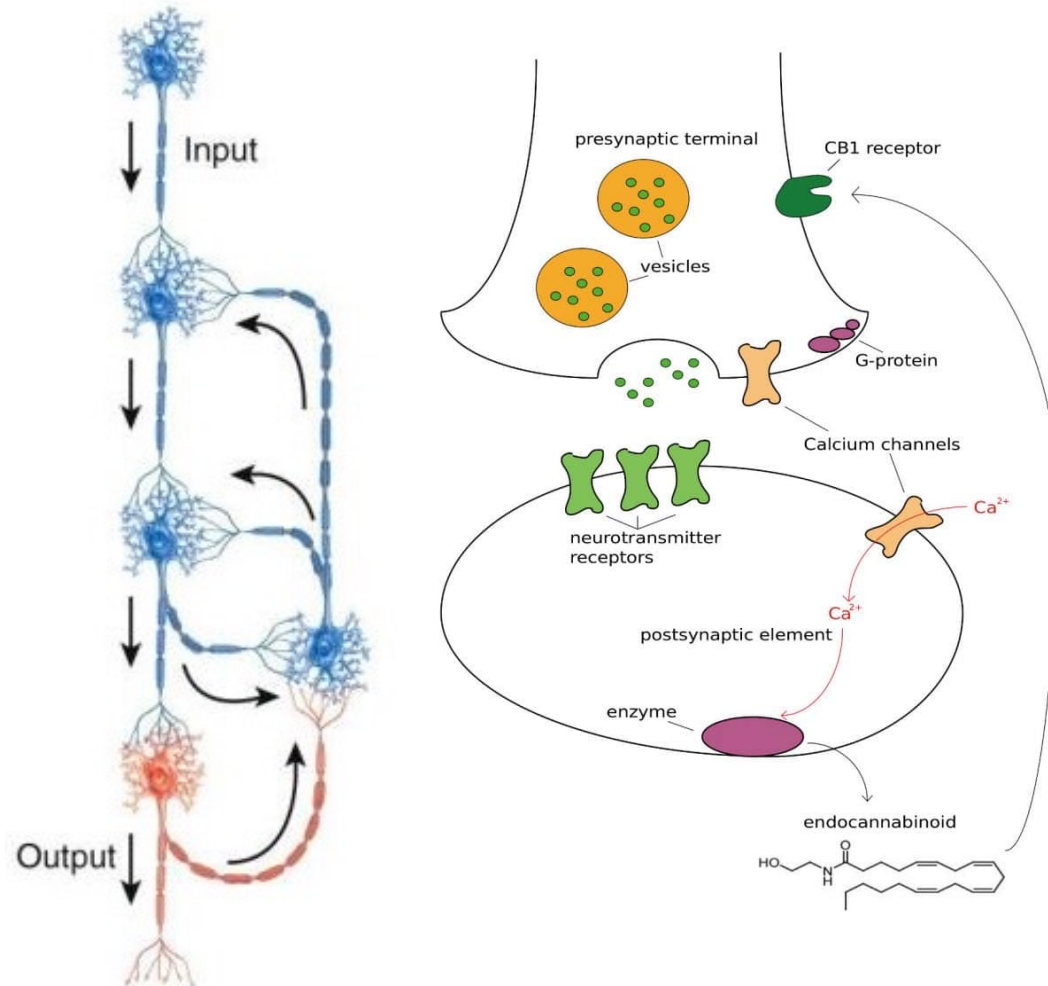
# Strengthening of Connections

Neuroplasticity: “Cells that fire together wire together.”

- Cells that interact strongly will make their connection stronger.

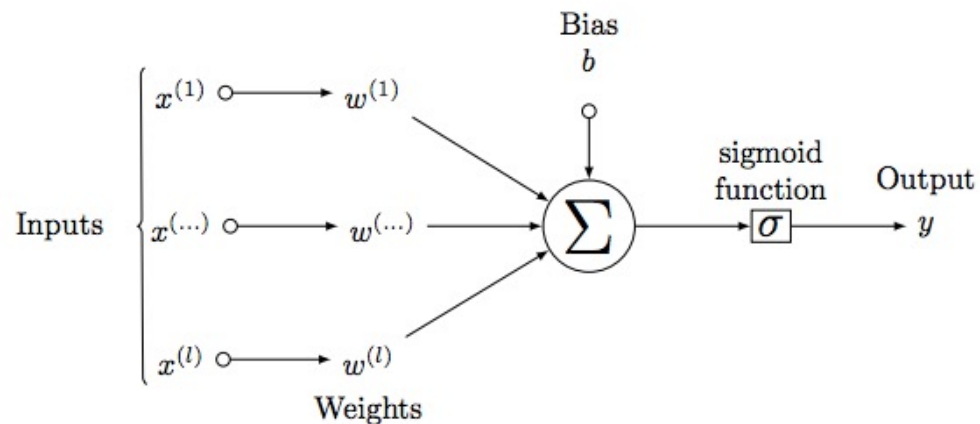
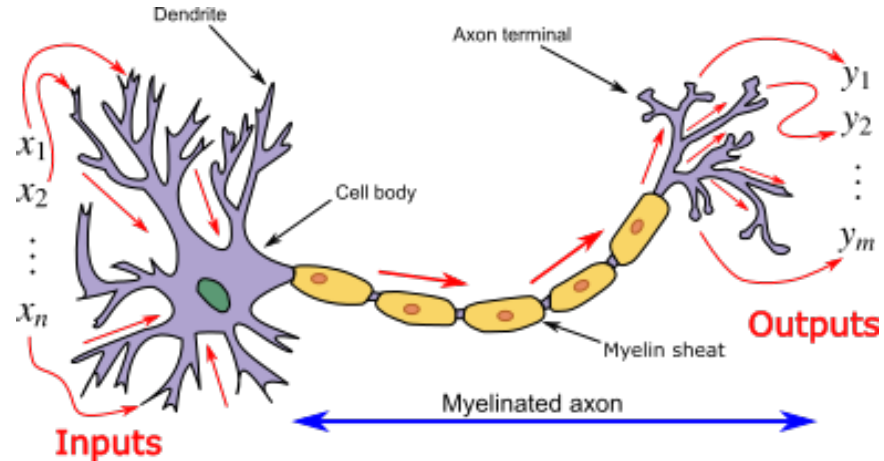


## Weakening of Connections / Negative Feedback



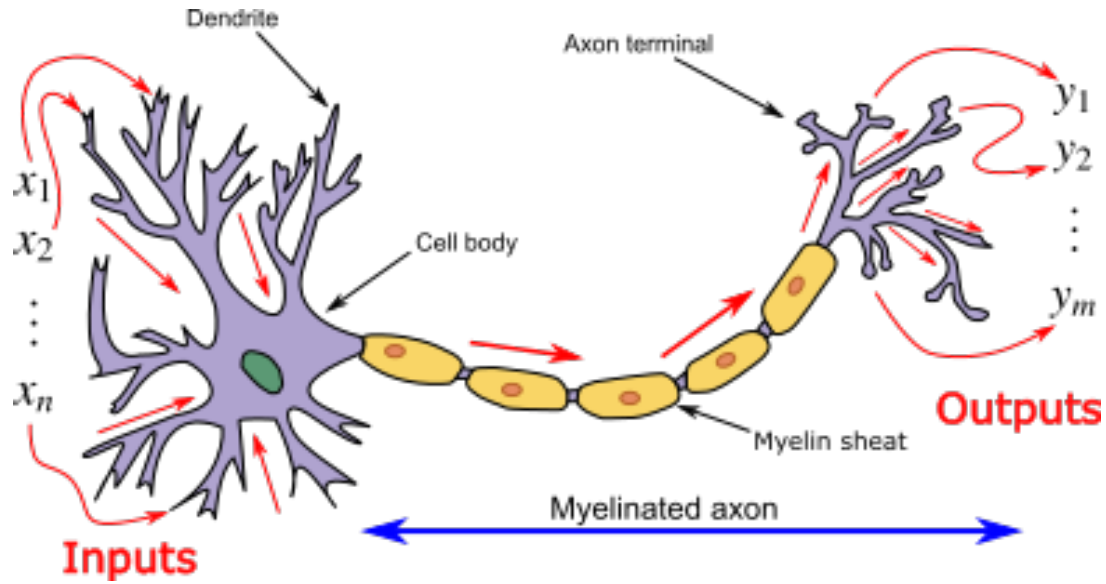
- ▶ Weakly/poorly activated neurons will weaken their connections

# From Bio to Artificial



- ▶ Artificial Neural Networks mimic the activity of bio neurons:
- ▶ They take in lots of inputs from other neurons.
- ▶ They sum up the input signal inside their cell bodies and then depending on the signal and then pass that message onto the next neurons.
- ▶ The different properties of the cells (like activation functions) result in different information being shared.





Now Back to the Notebook...