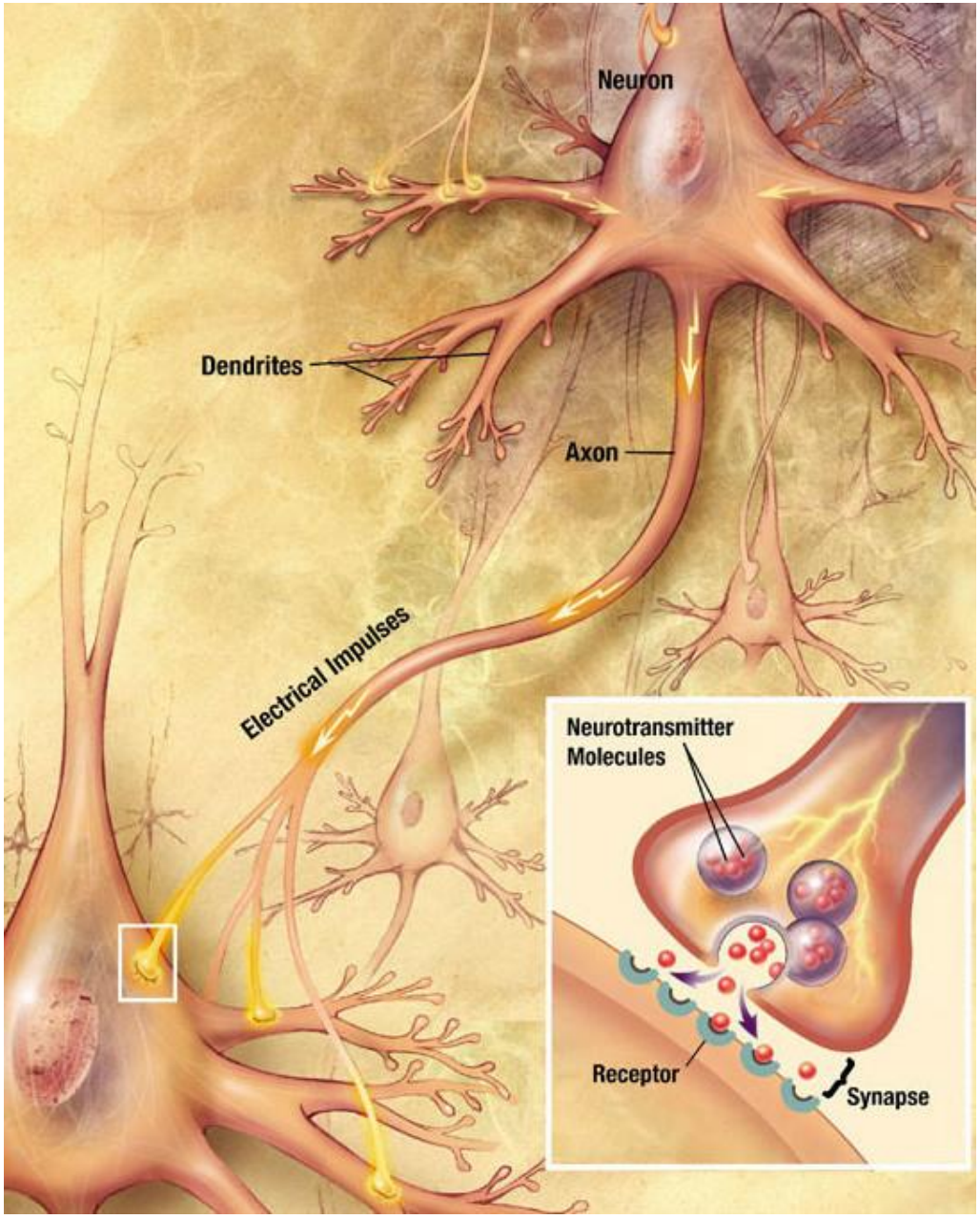


What happens to the spike (action potential) when it reaches the end of an axon?

Enter…
the Synapse

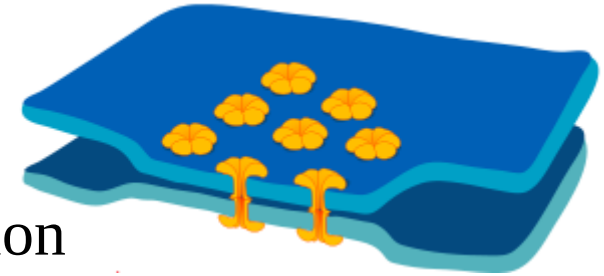
Image Source: Wikimedia Commons

What is a Synapse?

- A Synapse is a "connection" or junction between two neurons
  - Electrical synapses use *gap junctions*
  - Chemical synapses use *neurotransmitters*

Neuron A

Gap junction



for synchronize

Neuron B

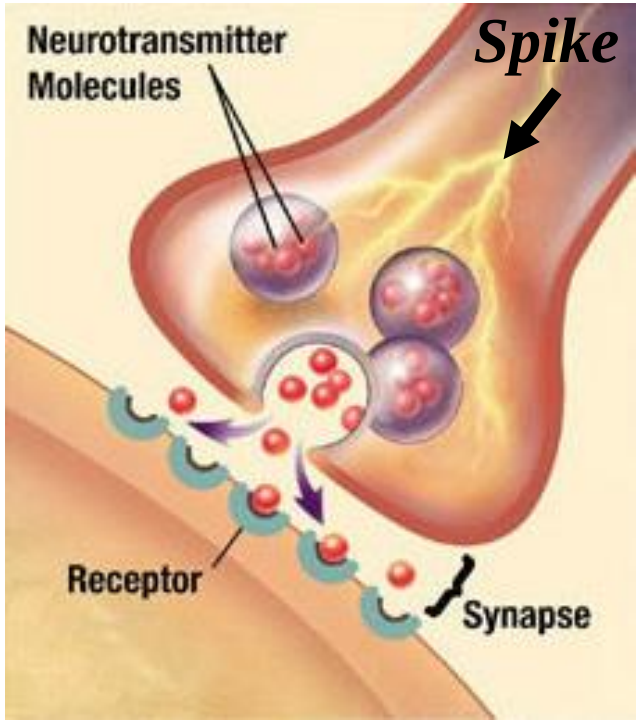


Image Source: Wikimedia Commons

Distribution of synapses on a real neuron…

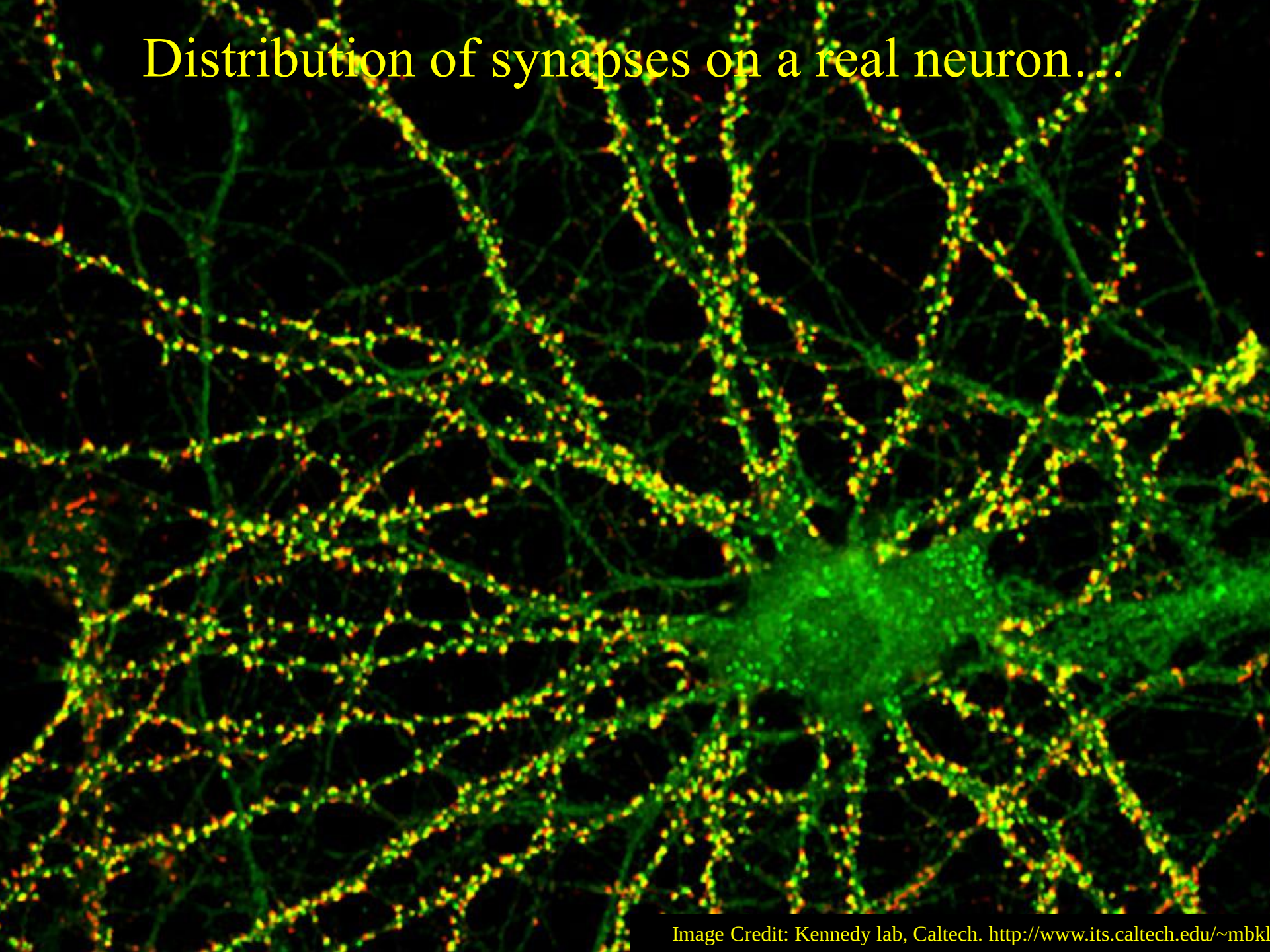
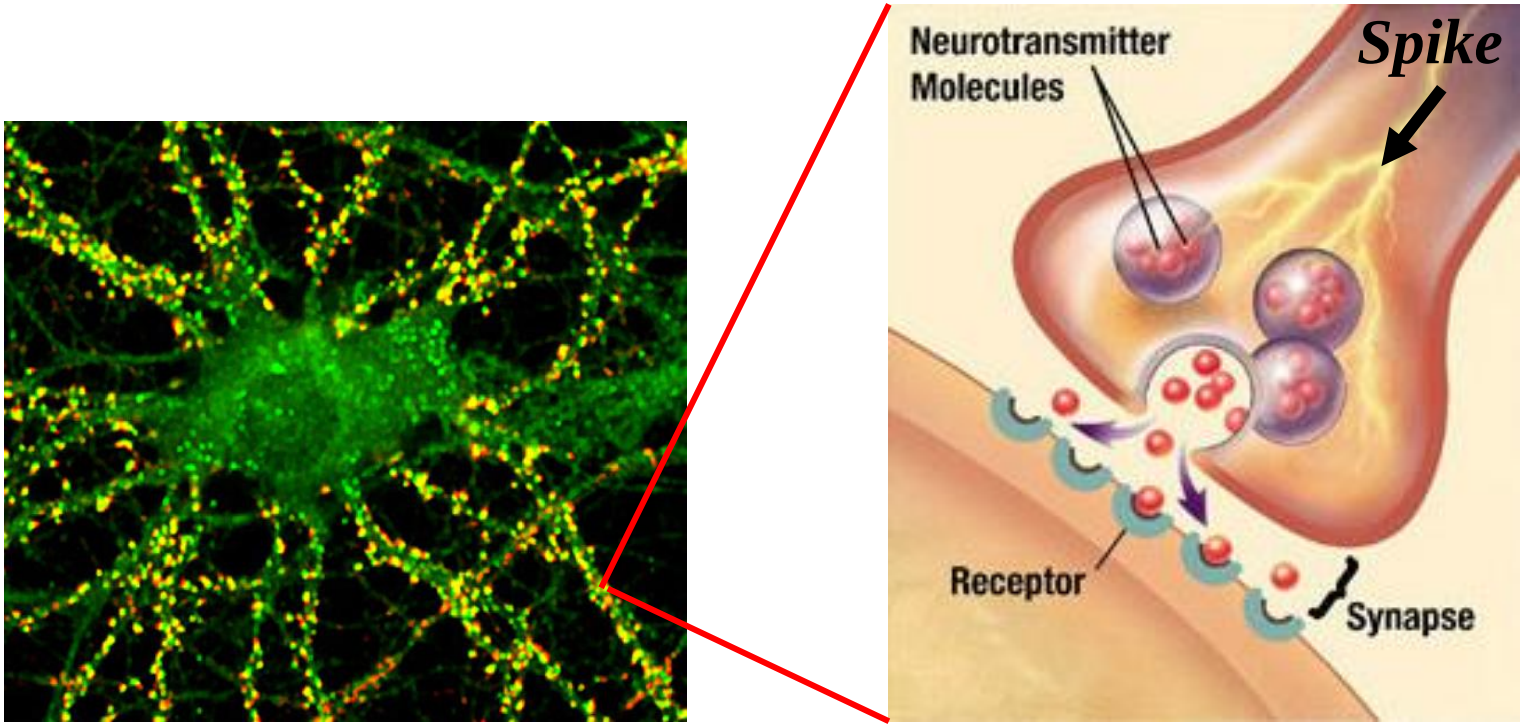


Image Credit: Kennedy lab, Caltech. http://www.its.caltech.edu/~mbkl

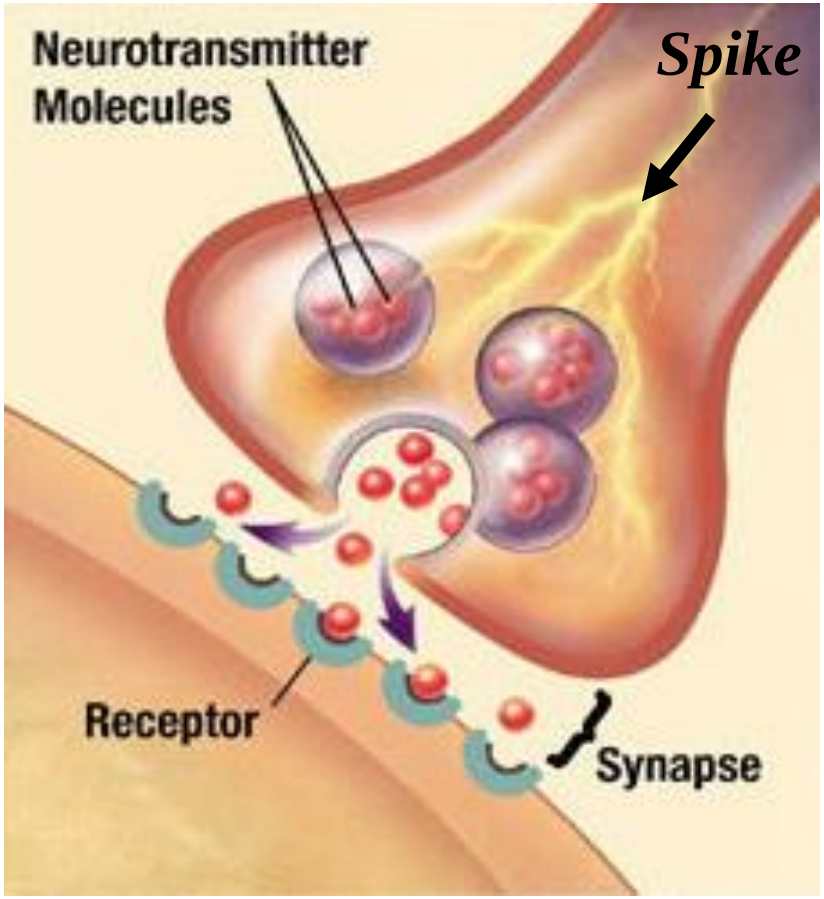
Synapses can be Excitatory or Inhibitory



Increase or decrease postsynaptic membrane potential

Image Source: Wikimedia Commons

An **Excitatory** Synapse

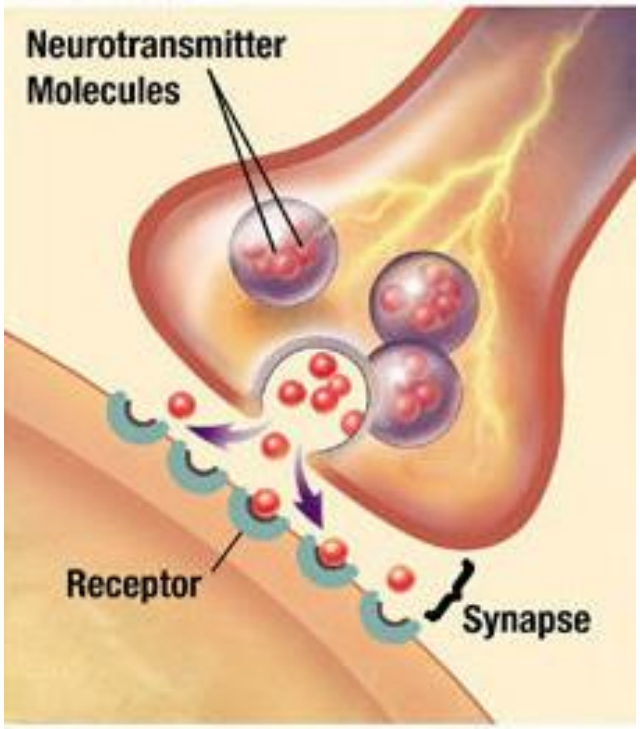


Input spike → Neurotransmitter release (e.g., Glutamate) → Binds to ion channel receptors → Ion channels open → Na+ influx → Depolarization due to EPSP (excitatory postsynaptic potential)

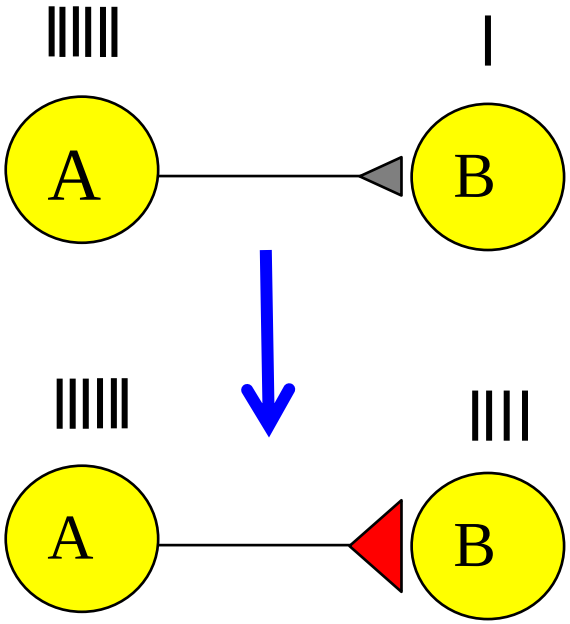
Image Source: Wikimedia Commons

The Synapse Doctrine

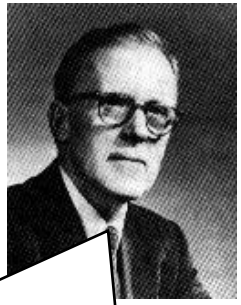
Synapses are the basis for memory and learning



How do Brains Learn? Synaptic Plasticity



Hebbian Plasticity



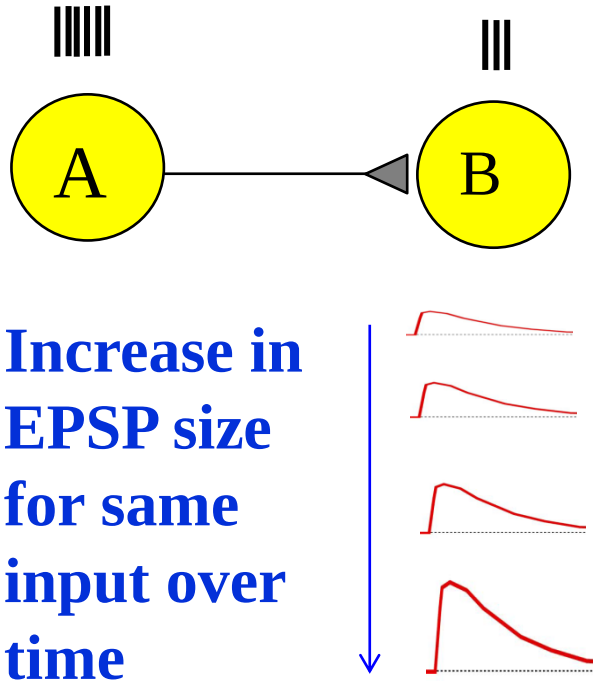
If neuron A repeatedly takes part in firing neuron B, then the synapse from A to B is strengthened

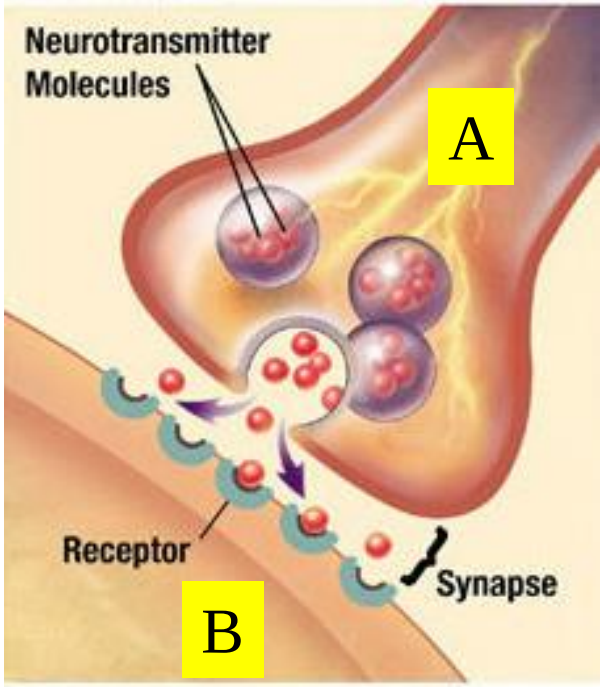
“Neurons that fire together wire together!”

Image Source: Wikimedia Commons

Long Term Potentiation (LTP)

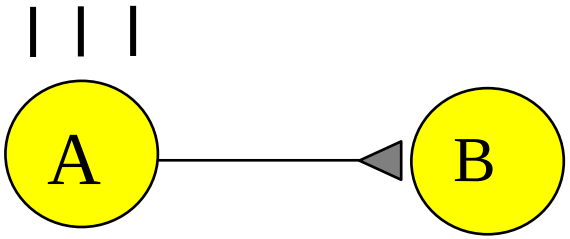
LTP = Experimentally observed *increase* in synaptic strength that lasts for hours or days



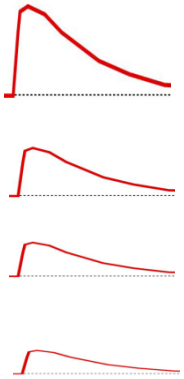


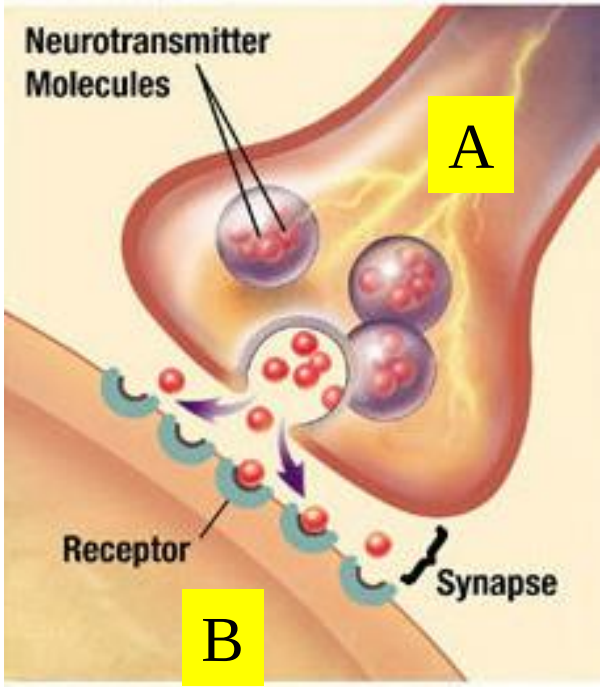
Long Term Depression (LTD)

LTD = Experimentally observed *decrease* in synaptic strength that lasts for hours or days



Decrease in EPSP size for same input over time



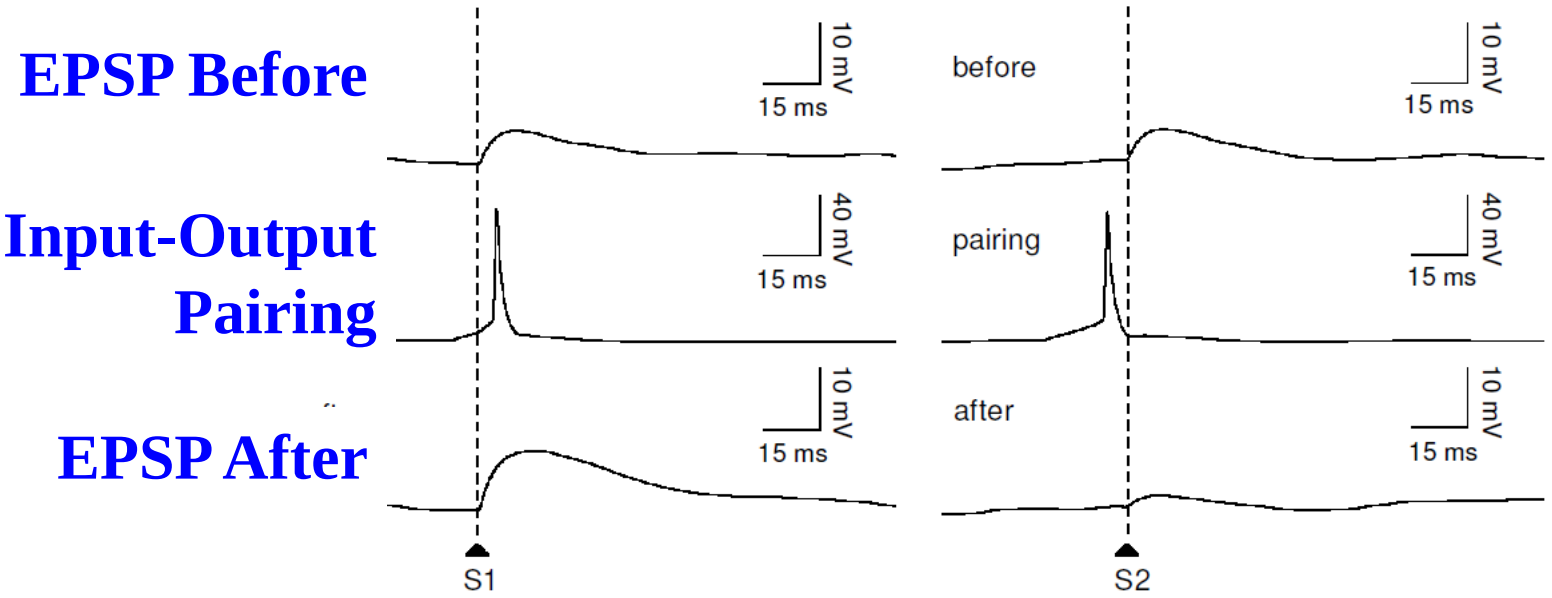


Synaptic Plasticity depends on Spike Timing!

LTP/LTD depends on relative timing of input and output spikes

Input Spike before Output Spike

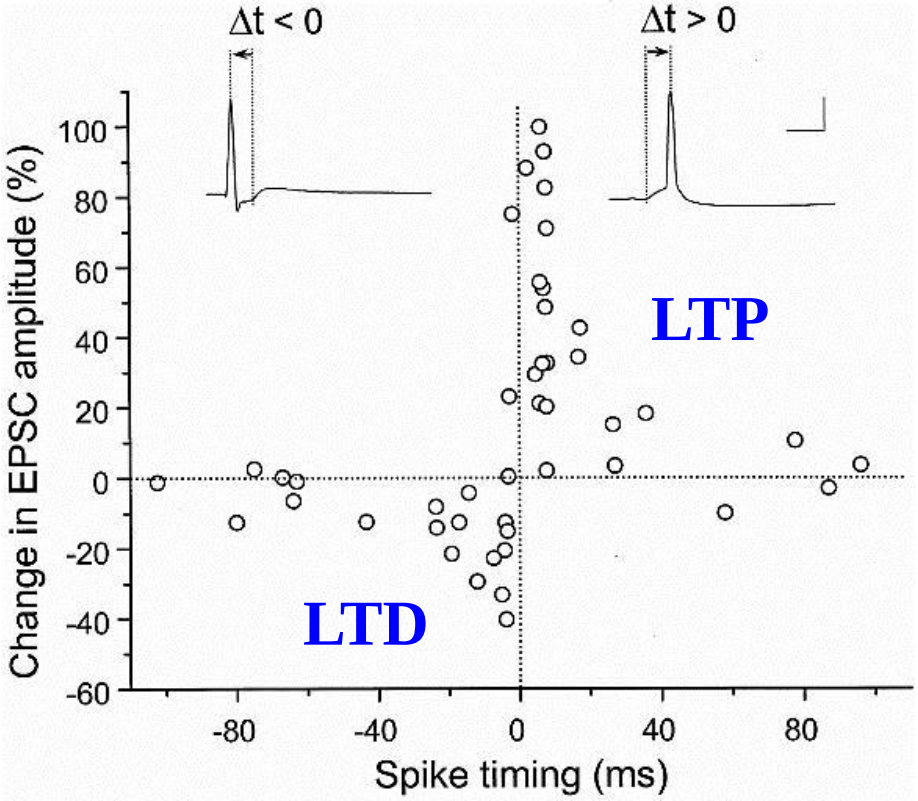
Input Spike after Output Spike



LTP **LTD**

Spike-Timing Dependent Plasticity (STDP)

Input after Output Input before Output



(Bi & Poo, 1998)

We seem to know a lot about channels, neurons, and synapses…

What do we know about how networks of neurons give rise to perception, behavior, and consciousness?

Not as much

Next: Brain organization and information processing in networks of neurons