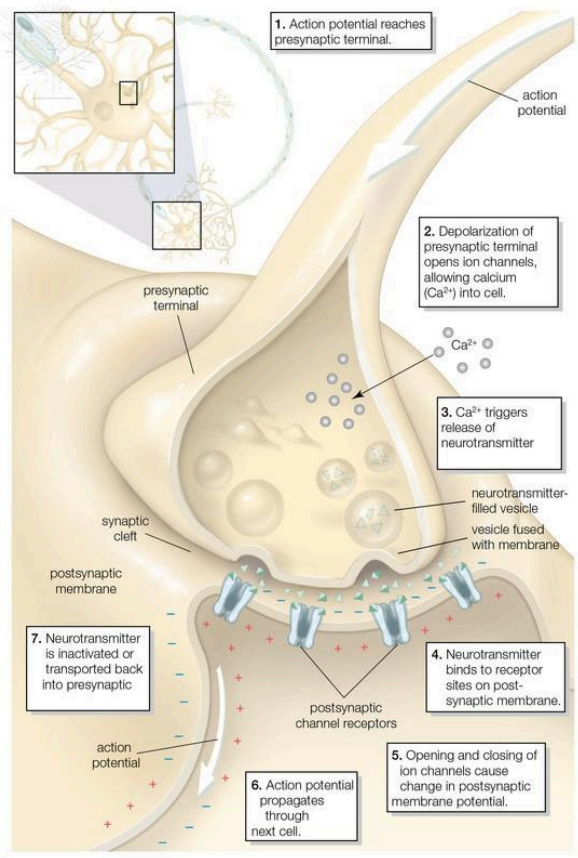
6.2.1

The Synapse

Structurally, two types of synapses are found in neurons: chemical and electrical. **Chemical synapses** occur when neural membranes are very close together but remain distinct, leaving a space called the synaspe. **Electrical synapses** occur when membranes are linked together (gap junctions) via specialized proteins (connexins) that allow the flow of ions quickly from one cell to another. Electrical synapses are found in heart muscle and in various other cells. Because electrical synapses are rare in the nervous system, the remainder of this section will address the chemical synapse.

Chemical synapses use chemicals called *neurotransmitters* to communicate the messages between cells. The part of the synapse that releases the neurotransmitter into the synapse is called the *presynaptic terminal*, and the part of the synapse that receives the neurotransmitter is called the *postsynaptic terminal*. The narrow space between the two regions is called the *synaptic cleft*. Both the presynaptic and postsynaptic terminals contain the molecular machinery needed to carry out the signaling process. The presynaptic terminal contains large numbers of vesicles that are packed with neurotransmitters. When an action potential arrives at the presynaptic terminal, voltage-gated Ca^{++} channels open, which allows for the influx of Ca^{++} which then activates an array of molecules called SNARE proteins in the neuronal membrane and the vesicular membrane. These newly activated SNARE proteins cause the vesicle containing neurotransmitter to fuse with the presynaptic terminal membrane which leads to exocytosis of the vesicles, which results in the release of the neurotransmitter. The neurotransmitter then diffuses across the synaptic cleft and binds to receptors located in the postsynaptic membrane and induces a conformational change. These ligand gated channels undergo a conformation change which causes the receptor to act as a pore in the membrane for ions to move through. Depending on the type of ion, the effect on the postsynaptic cell may be depolarizing (excitatory) or hyperpolarizing (inhibitory). To turn off the signal there are enzymes that reside in the synaptic cleft that breakdown and inactivate the neurotransmitters. The components of the neurotransmitter are then taken back up by the presynaptic terminal to be recycled to make more of the neurotransmitter. An example of one of the enzymes is acetylcholinesterase that breaks down the neurotransmitter acetylcholine.



Synapse *© 2013 Encyclopædia Britannica, Inc. Taken from BYUI Image Quest Dec 2013.*

If the neurotransmitter causes the membrane post synaptic potential to go towards threshold it is called an **EPSP** which is the abbreviation for an *excitatory post synaptic potential*, whereas an inhibitory response takes the membrane potential away from threshold (further towards hyperpolarization) and is called an **IPSP** or *inhibitory post synaptic potential*.

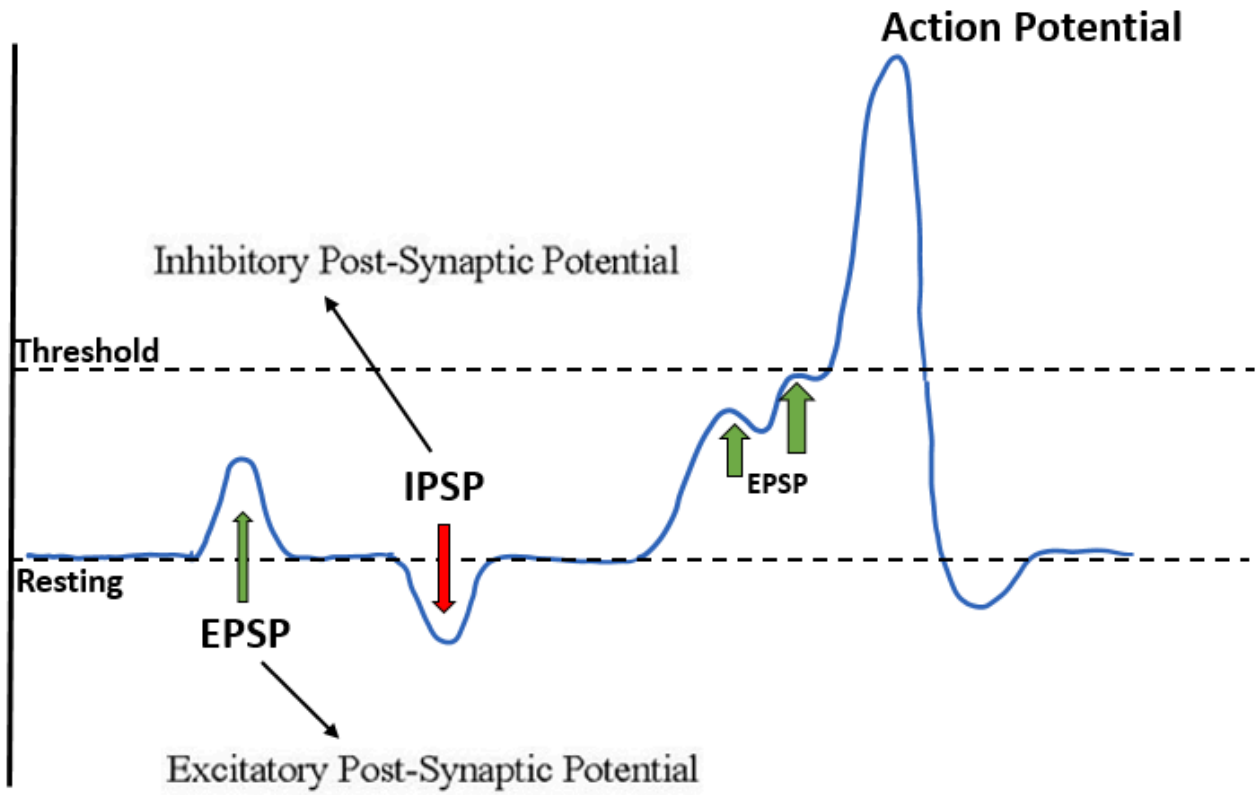


Image by BYU-I student 2017

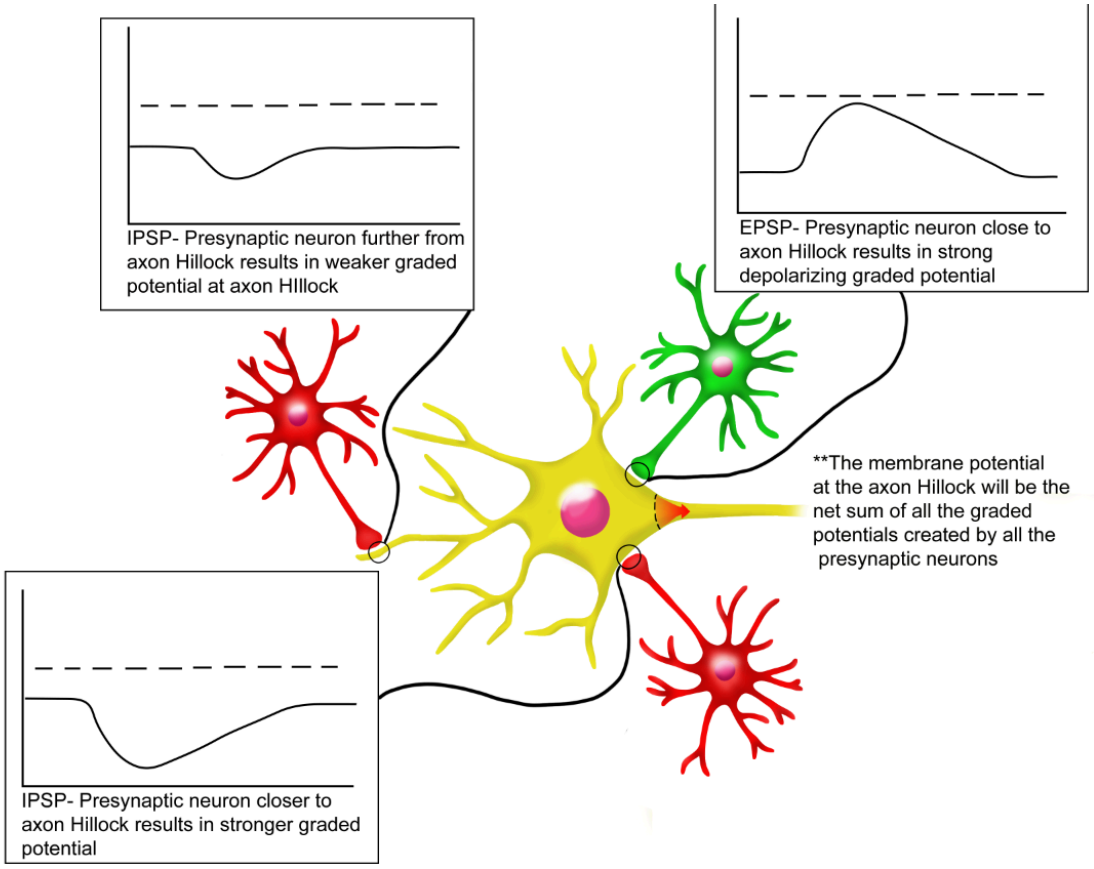


Image by Becky T. BYU-Idaho, 2018.

A cell body will have many synapses on it and on its surrounding dendrites. Some of the synapses will result in the cell body membrane potential moving closer to threshold. Other synapses result in the cell body membrane potential moving farther from threshold (hyperpolarization). As mentioned, any synapse that moves the potential closer to threshold is called an *excitatory post synaptic potential*, and any synapse that moves the potential farther from threshold is called an *inhibitory post synaptic potential*. The net effect of all the EPSPs and IPSPs is experienced at the axon hillock. If threshold is reached at the axon hillock, then an action potential will continue down the axon.

The ultimate goal of an EPSP is to cause enough change in the membrane to initiate an action potential. The goal of the IPSP is to cause a change in the membrane to prevent an action potential. Each EPSP or IPSP lasts a few milliseconds, and then, the membrane returns to the original resting membrane potential. In many cases, a single EPSP is not sufficient to cause an action potential. Therefore, many EPSPs from multiple synapses can combine at the axon hillock, which results in a much larger voltage change that can exceed threshold and cause an action potential. This phenomenon is called **spatial summation**. EPSPs from the same synapse can also combine if they arrive in rapid succession; this phenomenon is called **temporal summation**. Requiring multiple EPSPs to fire an action potential is a way that neurons increase sensitivity and accuracy.