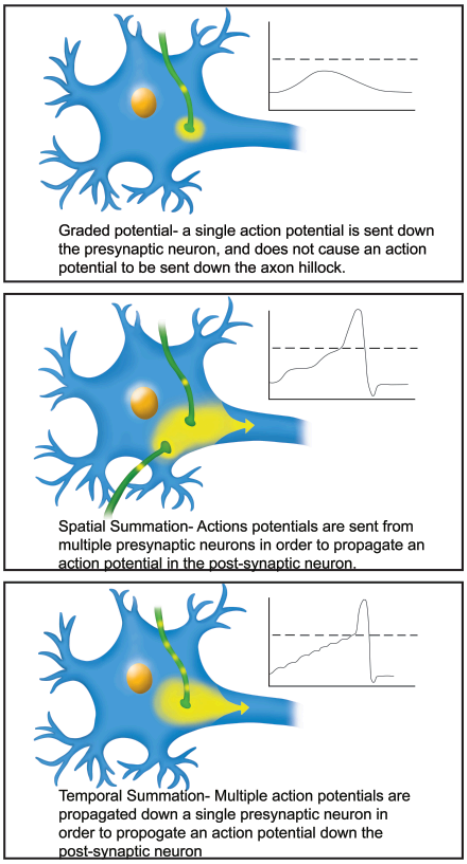
6.2.2

Summation



This Image shows temporal and spatial summation using EPSP synapses as an example. IPSP synapses can also occur in both temporal and spatial summation. The difference would be that IPSP synapses try to drive the membrane potential further down and away from threshold. Whether the membrane potential measured at the axon hillock reaches threshold or not depends on the net effect of all the EPSP and IPSP summations. *Image by BYU-I student - Becky T. 2018*

A response as an EPSP or an IPSP will depend on the type of neurotransmitter/receptor combination present in the synapse. There are over a hundred known neurotransmitters, and many of them have unique receptors. Receptors can be divided into two broad groups: chemically-gated ion channels (ionotropic) and second messenger systems (metabotropic). When chemically (ligand) gated ion channels are activated, certain ions are allowed to flow across the membrane. The ion type will determine whether the result is an EPSP or an IPSP. When a second messenger system is activated, it results in a cascade of molecular interactions within the target or postsynaptic cell. The type of cascade that is elicited will result in the response being either excitatory or inhibitory.

Excitatory Synapses

Most excitatory synapses in the brain use glutamate or aspartate as the neurotransmitter. These neurotransmitters bind to non-selective cationic channels that allow for Na^+ and K^+ to pass. As mentioned earlier, it takes many EPSPs from these kinds of synapses to depolarize a postsynaptic neuron enough to reach threshold of the axon hillock and trigger an action potential.

A very important subset of synapses in the brain includes a group capable of forming memories by increasing the activity and the strength of the synapse. This process is called **long-term potentiation**. Long-term potentiation operates at the synapse, using the neurotransmitter glutamate and the receptor known as the NMDA receptor. The NMDA receptor is unique in that it is both ligand and voltage regulated. When activated by ligands, it becomes permeable to Na^+, but if the charge difference is sufficient, the channel becomes permeable to Ca^{++} as well. Ca^{++} can initiate a second messenger cascade that results in an increase in the number of glutamate receptors, thereby increasing the strength of the synapse, making it easier to reach threshold in the post-synaptic cell. The change in strength can last for weeks, months, or even years depending on whether or not the synapse is continually used. Long-term potenitiaion is a major mechanism underlying memory and learning.

Inhibitory Synapses

It may seem somewhat of a paradox to have inhibitory synapses, but the excitability of neurons is essentially governed by a balance between excitation and inhibition. The main inhibitory neurotransmitters are GABA and glycine. Both neurotransmitters bind to receptors that result in an increase conductance of Cl^-. Because of the negative charge of Cl^- and the fact that it usually moves into the cell, the effect is to oppose depolarization and cause the membrane to move away from threshold (IPSP).