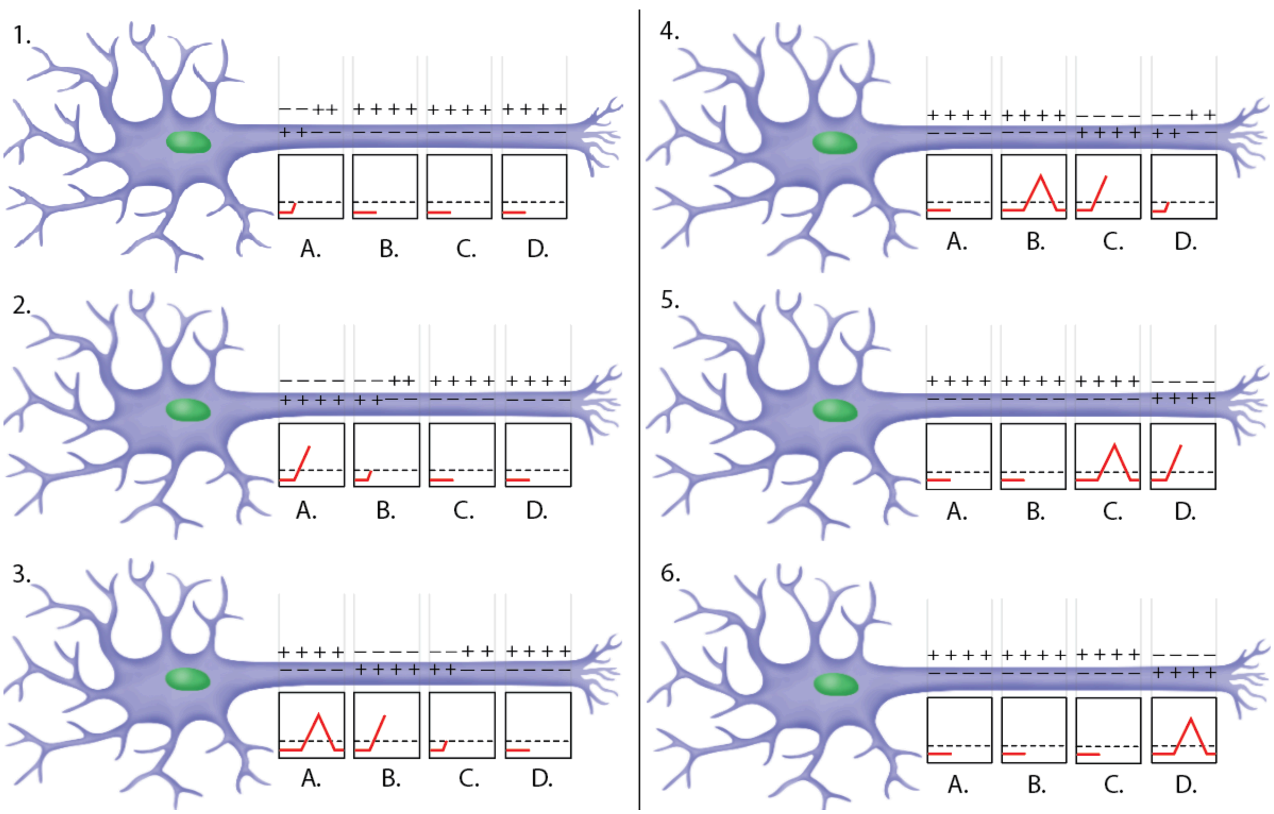
5.3.6

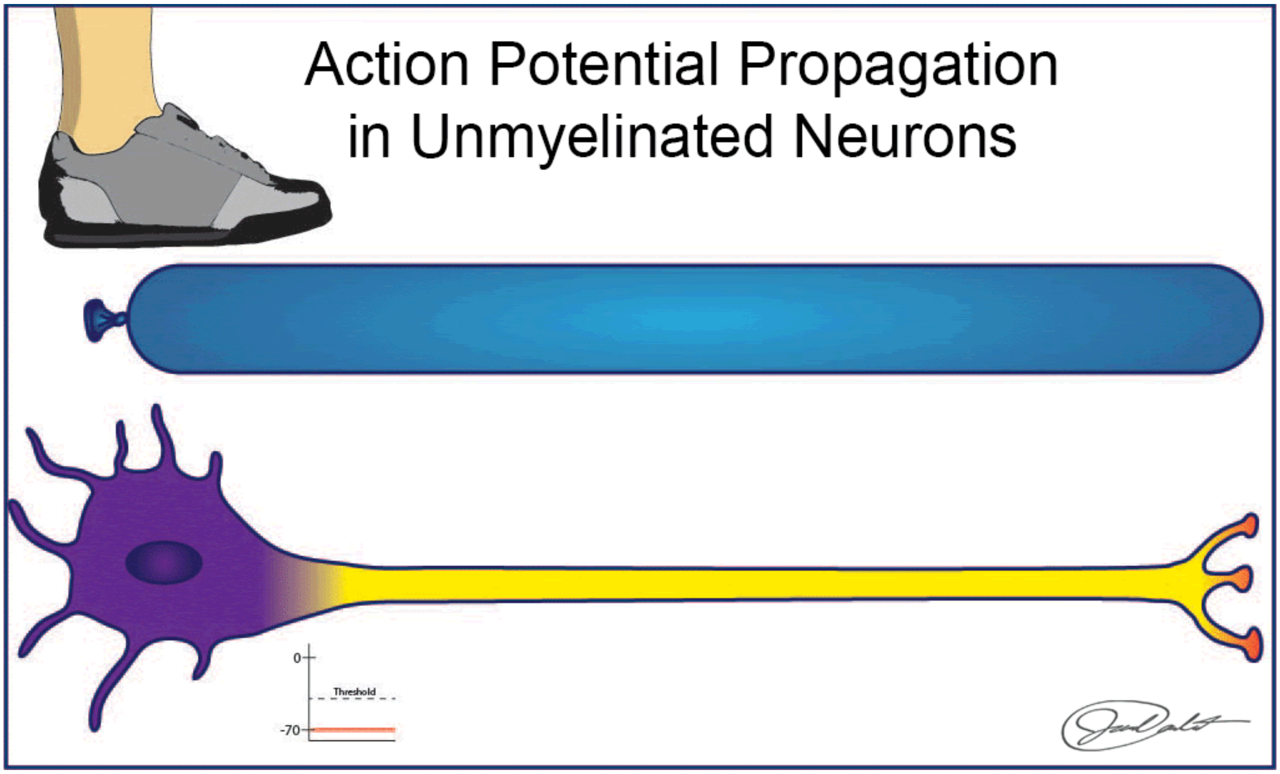
Propagation of an Action Potential

Action potentials are usually generated at one end of a neuron, typically the cell body, or soma, and then "propagated" like a wave along the axon towards the opposite end of the neuron.

The image below shows how an action potential might have started near the cell soma (notice the depolarization in 1A) and as it propagates down the axon towards the opposite end (2-6). The membrane potential behind the moving action potential eventually repolarizes and returns to resting membrane potential (e.g. 4A). The axon ahead of the depolarization current has not yet depolarized, and it is also at resting membrane potential (e.g. 2C&D). Where the action potential is occurring, we find the membrane potential depolarized, and the outside of the membrane at that spot is negatively charged relative to the inside of the membrane at that spot (e.g. 3B). As sodium diffuses into the cell, it will depolarize the next adjacent spot on the axon in the direction that the action potential is propagating (e.g. 3C). Action potentials cannot propagate in reverse because that section of membrane is most likely in refractory periods and does not depolarize.

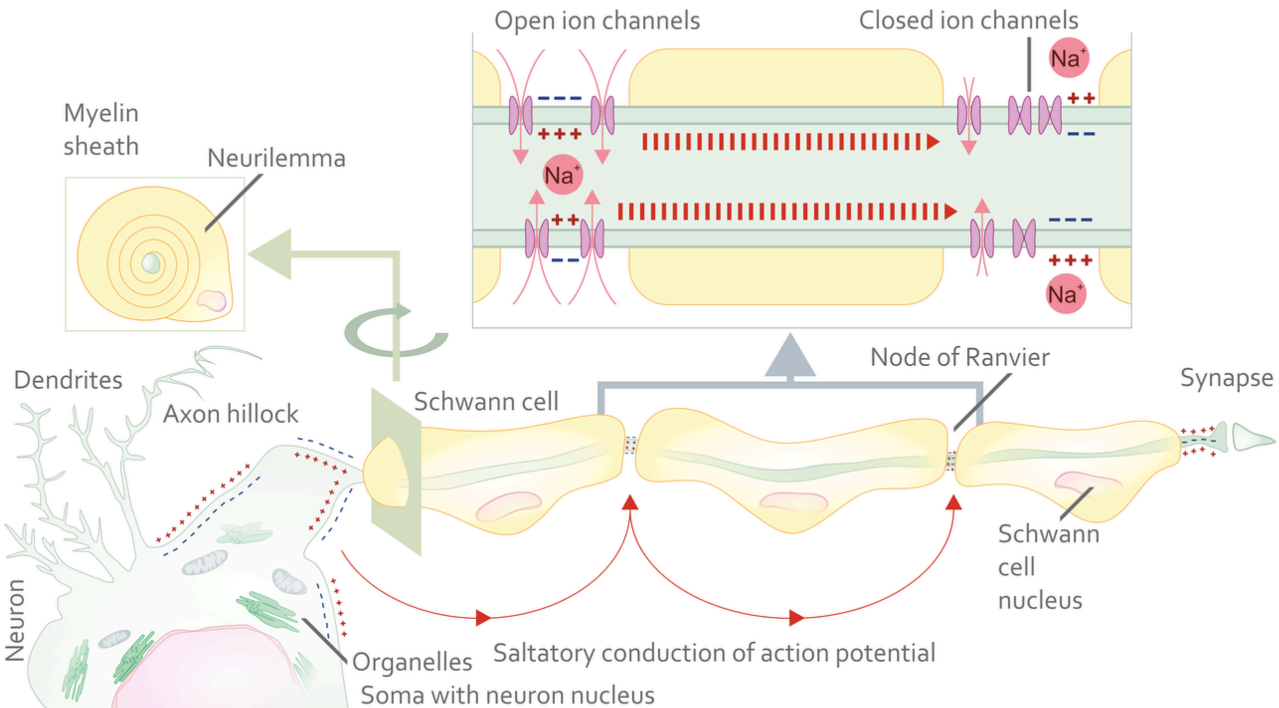


The image above shows how an action potential propagates down the neuron axon. Each number (1-6) represents a different timepoint of action potential propagation. The square insets below each neuron shows the stage of an action potential that exists at each axon segment. *Image by Beck Torgerson S18*



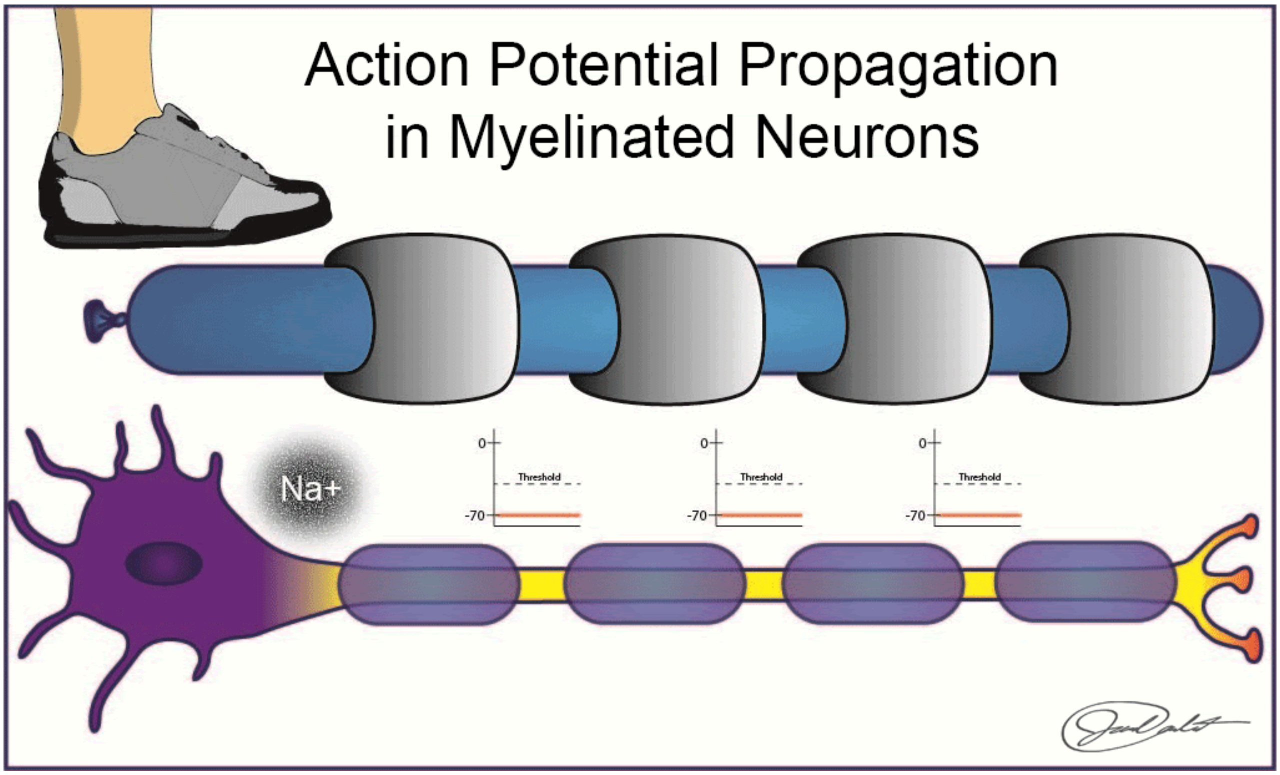
Animation of Action Potential Propagation in Unmyelinated Neurons. *BYU-Idaho image created Winter 2015*

The image above is another animation that you can watch if you click on the picture. This animation shows how an action potential traveling down the axon is similar to stepping on one end of a water balloon. In reality, a pressure wave in the water balloon would get smaller as it traveled down the length, but a traveling action potential (or depolarization wave) is recreated at every spot on the axon that has voltage-gated sodium channels that open at threshold potential. In this way, the original strength of the depolarization wave is continually recreated.



Propagation of Action Potential Along Myelinated Nerve Fiber. *Author: Helixitta; Site: https://commons.wikimedia.org; /wiki/File:Propagation_of_action_potential_along_myelinated_nerve_fiber_en.png; License: This file is licensed under the Creative Commons Attribution-Share Alike 4.0 International license.*

The image above shows a myelinated peripheral nerve axon. Myelin is a lipid and protein rich tissue that wraps around the axon in a way that "insulates" it from depolarization. In the peripheral nervous system, myelin is made by Schwann cells. Non-myelinated sections in between Schwann cells are called *nodes of Ranvier*. These sections can experience depolarizations and action potentials. What is the effect of myelin? It serves to increase action potential conduction (propagation) time. Since action potentials can only occur at the nodes of Ranvier, action potential propagation can travel much faster (nearly 10 times faster than unmyelinated axons) because depolarizations 'jump' from node to node. This phenomenon is known as **saltatory conduction**. *Saltatory* means, 'jumps or leaps."



Animation of Action Potential Propagation in Myelinated Neurons. *BYU-Idaho image created Winter 2015*

The image above is another animation (click on the picture). It shows how a myelinated axon might compare to a water balloon with segmented cuffs on it. Upon stepping onto the water balloon, a pressure wave is generated that is recreated at each "node;" although notice that, like before, the magnitude of the pressure wave decreases along the length of the water balloon. Similarly, when a myelinated neuron initiates an action potential, the positively charged sodium entering in at the axon hillock (area closest to the soma) causes positive charges to rapidly travel down the axon where they can depolarize each node. Like the water balloon, the strength of these depolarizations decrease along the length of the axon. However, at the most proximal node of Ranvier, this depolarization is sufficient to reach threshold and an action potential is re-created. This re-created action potential then propagates stronger depolarizing currents to the next most proximal node which re-creates another action potential at that node. This process continues along the length of the axon and enables faster action potential conduction time. Consider these three things:

1. The original depolarization event at the axon hillock will open sodium channels at nodes of Ranvier that can facilitate those membrane sections getting closer to threshold.
2. Each node that reaches threshold re-creates an action potential (depolarization wave) that is equal to the first.
3. Depolarization occurs only on bare axon between myelin segments and not along the entire axon surface. This is saltatory conduction and is how myelination increases action potential conduction speed.

SUMMARY

Let's see how well we understand the concepts of this chapter. Consider your fingertips; there are at least five different types of touch receptors that allow you to feel various textures and pressures, but how do they work? Touch receptors are just fancy neurons, but they exhibit the same kinds of phenomena that we just talked about. At rest, these sensory neurons are permeable to K^+ but not Na^+, so the inside of the membrane is negative relative to the outside (-70mV). Consequently, voltage-gated Na^+ channels are in a closed conformation. In order for us to sense touch, we need to convert the touch stimulus into an action potential, but how? The mechanical stimulus of touch causes a conformation change in mechanically-gated Na^+ channels, causing them to open. As Na^+ diffuses into the cell, the positive charges depolarize the membrane (graded potentials) to threshold potential which opens voltage-gated Na^+ channels and initiates an action potential. This action potential is propagated to the brain where it is perceived as touch. Believe it or not, every external stimulus—whether taste molecules, light waves, sound waves, or mechanical touch—is converted to an action potential. Action potentials are a main way the body communicates between tissues and the brain works strictly by discerning and initiating action potentials. These principles will be applied and detailed in later chapters, so please make sure you understand the basics of action potentials, electrophysiology, and membrane transport.