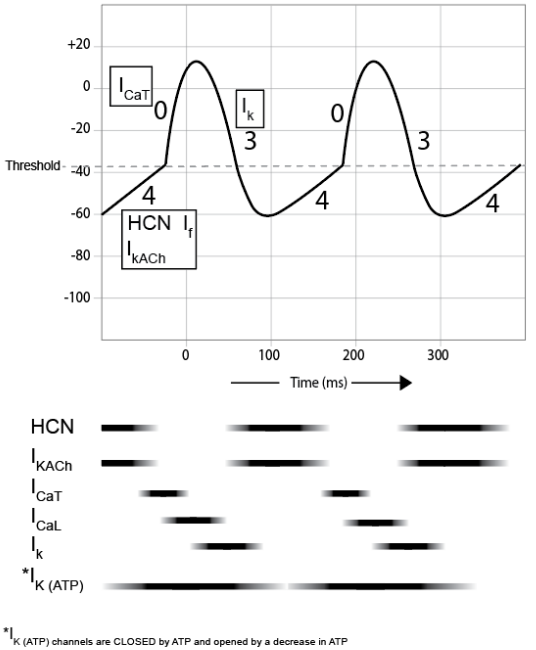
3.2.2

Action Potentials in Cardiac Autorhythmic cells



$^*I_{K\ (ATP)}$ channels are CLOSED by ATP and opened by a decrease in ATP

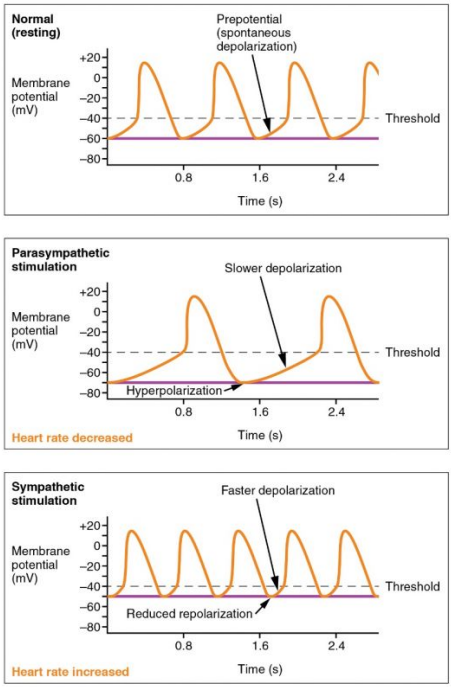
Action potential of Autorhythmic cells.

By BYU-I JS Fall 2013

This figure above shows action potentials in the autorhythmic cells of the heart. Notice that there are only three phases in these action potentials, phase 4, phase 0, and phase 3. Also notice that there is no real resting phase (RMP)in these cells. Once the membrane repolarizes it begins to slowly depolarize again. These action potentials also lack phases 1 and 2 that were seen in the contractile cells. To explain how these action potentials are generated, we need to introduce a new cation channel that we have not encountered previously in our studies. These channels open when the membrane *repolarizes* and close when the membrane *depolarizes*. When these channels were first discovered this behavior (for a cation channel) seemed odd or funny, therefore, the channels were called **"Funny" channels (I_f)**. These channels are also known as **HCN channels**, HCN stands for "hyperpolarized activated – cyclic nucleotide-gated" channels because they open when the membrane hyperpolarizes (voltage regulated) and they can be regulated by the second messenger cAMP, a cyclic nucleotide.

The funny channels allow Na^+ to slowly enter the cell, resulting in the gradual depolarization of the membrane (phase 4). This gradual depolarization is referred to as the **pacemaker potential**. The pacemaker potential causes the membrane potential to eventually reach threshold. Additionally, the RMP is much less negative in nodal cells because these cells lack I_{k1} channels, depending only on K^+ leak channels and I_k currents. In neurons, skeletal muscle and cardiac muscle, reaching threshold triggers the activation of voltage-gated sodium channels. The autorhythmic cells are different, however. Reaching threshold triggers the activation of **voltage-gated *calcium channels*** and the subsequent influx of calcium (I_{ca})results in the depolarization phase of the action potential (phase 0). This influx of Ca2+ occurs through both T-type and L-type Ca2+ channels. Ca2+ channels close more slowly than Na+ channels and so we see a wider tip at the action potential peak. The calcium channels do eventually close and voltage-gated potassium channels open (probably the same type of voltage gated K^+ channels seen in muscles and nerves). The

efflux of potassium results in the repolarization of the membrane (phase 3). Once the potential drops below threshold the potassium channels close, the funny channels begin to re-open and the process begins again. If the heart rate changes, the time between each depolarization wave can decrease or increase depending on how many HCN channels are open and how far below threshold the electrical signal drops before depolarizing again.



Depolarization and change in heart rate

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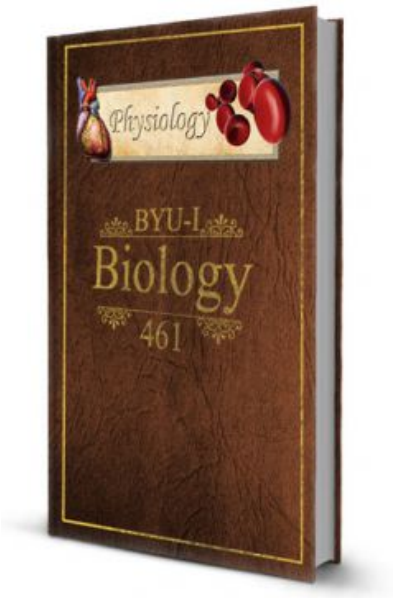

Shaw, J. & Hunt, J. (n.d.). *BIO 461 Principles of Physiology*. EdTech Books. https://edtechbooks.org/bio_461_principles_o