

Electrical Stimulation of the Heart

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Brad Roth studies the electrical activity of the heart, and uses mathematical modeling to simulate how the heart behaves. This research is at the interface between physics, computational science, and medicine. Many of his computer calculations are based on the bidomain model, which is a mathematical model of the anisotropic electrical properties of cardiac tissue, consisting of a system of nonlinear partial differential equations. These numerical simulations indicate where the heart is stimulated, when it is stimulated, and how the resulting waves propagate and interact.

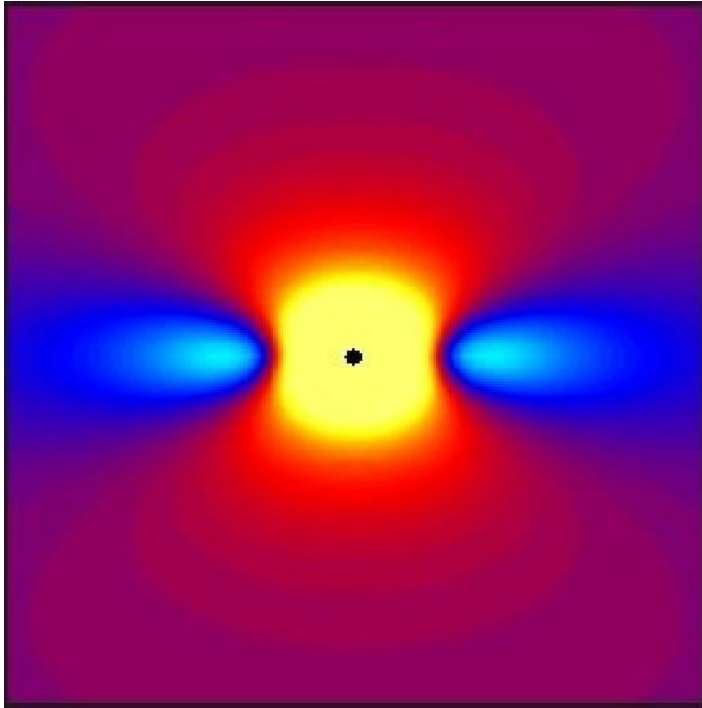
One prediction of the bidomain model is the transmembrane potential distribution around an extracellular electrode injecting current, such as in a pacemaker. The transmembrane potential becomes positive (is depolarized) directly under the electrode. However, there also exist regions of negative transmembrane potential (hyperpolarization) adjacent to the electrode along the fiber direction. During a strong shock, the regions of hyperpolarization affect both the mechanisms of wave excitation and the induction of a cardiac arrhythmia. For instance, if the tissue is depolarized just before the shock, the regions hyperpolarized by the shock may cause the tissue there to recover excitability, thereby creating an excitable path that can support wave propagation in one direction. A strong and well-timed shock can result in a type of arrhythmia called quatrefoil reentry, which is a simple model for ventricular fibrillation. Roth's calculations predicted the existence of quatrefoil reentry, which was subsequently observed in experiments using optical methods to measure the transmembrane potential.

More information about Roth's research can be found on his website at www.oakland.edu/~roth.

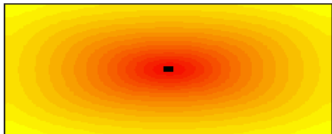
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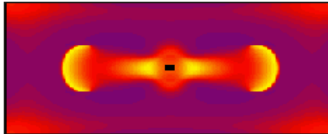
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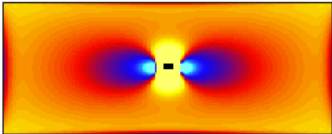
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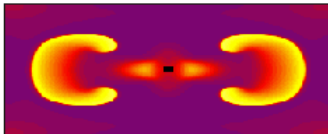
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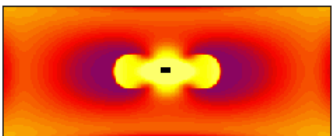
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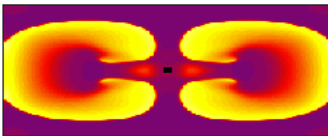
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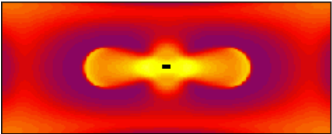
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