# *Multi-physics Simulation of the Biomedical Process- Heart Electrophysiology*

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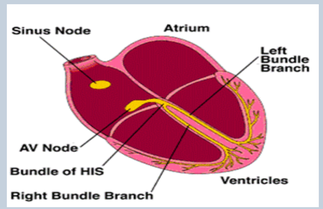
## Introduction

- Heart beats are caused by the interaction of electrical, psychological, mechanical, and fluid processes.
- Diseased cells can cause the heart to beat irregularly. A condition known as Arrhythmia.




http://heartpoint.com

## Purpose

Utilize a set of computer programs to study and simulate the multi-physics phenomena of the heart.

## Steps

- Identify the governing equations for simulating the heart: Monodomain Model and Beeler-Reuter Model.
- Develop the geometry and mesh of the heart.
- Program the electrical models: Beeler-Reuter and Monodomain model.
- Examine the interaction between the electrical and physiological effects of the heart.

## Formulations and results

- **Monodomain Equations (Tissue)**

$$\frac{\Lambda}{1+\Lambda}\nabla\cdot(M_i\nabla v)=\frac{\partial v}{\partial t}+I_{ion}(v,s)$$

$$\frac{\partial v}{\partial t}=-I_{ion}(v,s),\qquad v(t_n)=v^n$$
$$\frac{\partial s}{\partial t}=f(v,s),\qquad s(t_n)=s^n$$

- **Beeler Reuter Model (Cellular)**

**Potential and Current Equations**

$$V^{n+1}=V^n+\frac{dV}{dt}\Delta t+O(\Delta t)^2$$

$$\frac{dV}{dt}=-\frac{(i_{k1}+i_{x1}+iNa+iCa-i_{external})}{Cm}$$

$$i_{k1}=\left\{\frac{4\{\exp[0.04(V+85)]-1\}}{\exp[0.08(V+53)]+\exp[0.04(V+53)]}+\frac{0.2(V+23)}{1-\exp[-0.04(V+23)]}\right\}$$

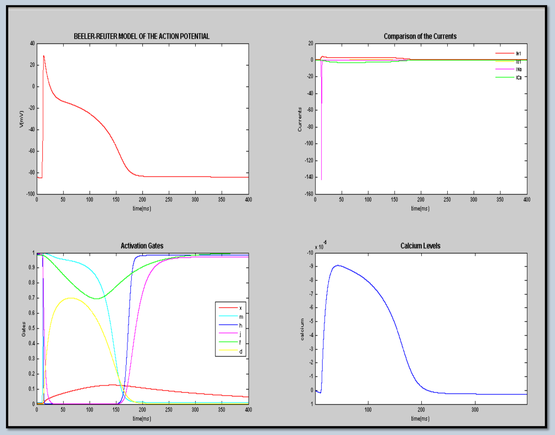
$$i_{x1}=x_1\cdot 0.8\cdot\frac{\{\exp[0.04(V+77)]-1\}}{\exp[0.04(V+35)]}$$

$$iNa=(gNa\cdot m^3\cdot h\cdot j+gNaCa)(V-ENa)$$

**Gates Equations (ODE)**

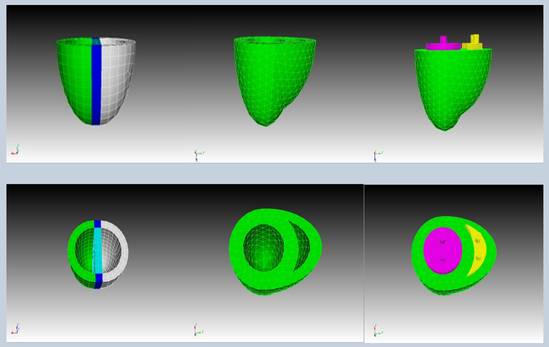
$$\frac{dx_1}{dt}=\alpha_{x1}(1-x_1)-\beta_{x1}x_1$$
$$\frac{dm_1}{dt}=\alpha_{m1}(1-m_1)-\beta_{m1}m_1$$
$$\frac{dh_1}{dt}=\alpha_{h1}(1-h_1)-\beta_{h1}h_1$$
$$\frac{dh_1}{dt}=\alpha_{h1}(1-h_1)-\beta_{h1}h_1$$

$$\frac{dd_1}{dt}=\alpha_{d1}(1-d_1)-\beta_{d1}d_1$$
$$\frac{df_1}{dt}=\alpha_{f1}(1-f_1)-\beta_{f1}f_1$$

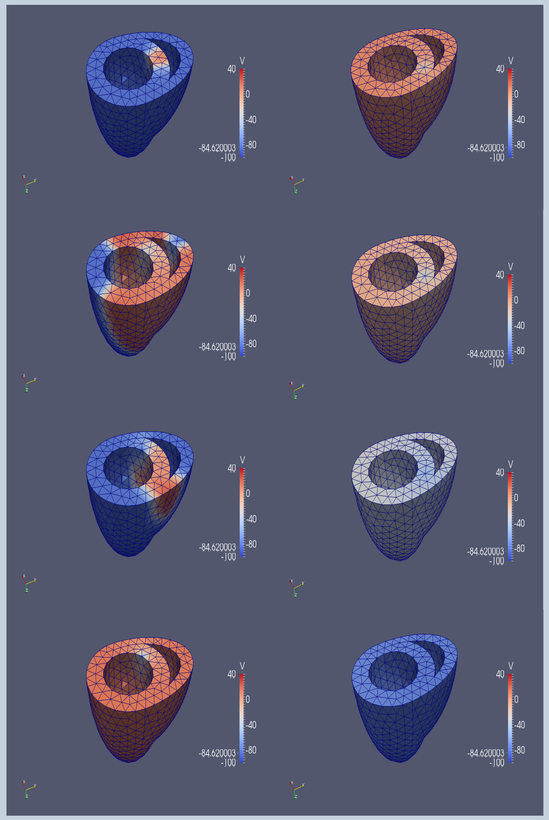



*Graph of Beeler-Reuter Model Programmed in Matlab*

## ❖ Meshing



*Mesh of Heart using CUBIT*



*Simulation in Paraview*

## Discussions

- Computer programs that simulate the heart can be used to understand the effects of drugs on diseases such as Arrhythmia.
- Simulations broaden the scope of experiments conducted on the heart

## Future Work

- Adapt the program to simulate multiple heart beats.
- Adapt the program to simulate cases of Arrhythmia.

## References

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*Fenton, Flavio H., Elizabeth M. Cherry, Harold M. Hastings, and Steven J. Evans. "Multiple Mechanisms of Spiral Wave Breakup in a Model of Cardiac Electrical Activity." Chaos: An Interdisciplinary Journal of Nonlinear Science 12.3 (2002): 852. Print.*

## Acknowledgements

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