Mathematically Modeling Dynamics of Physiological Systems

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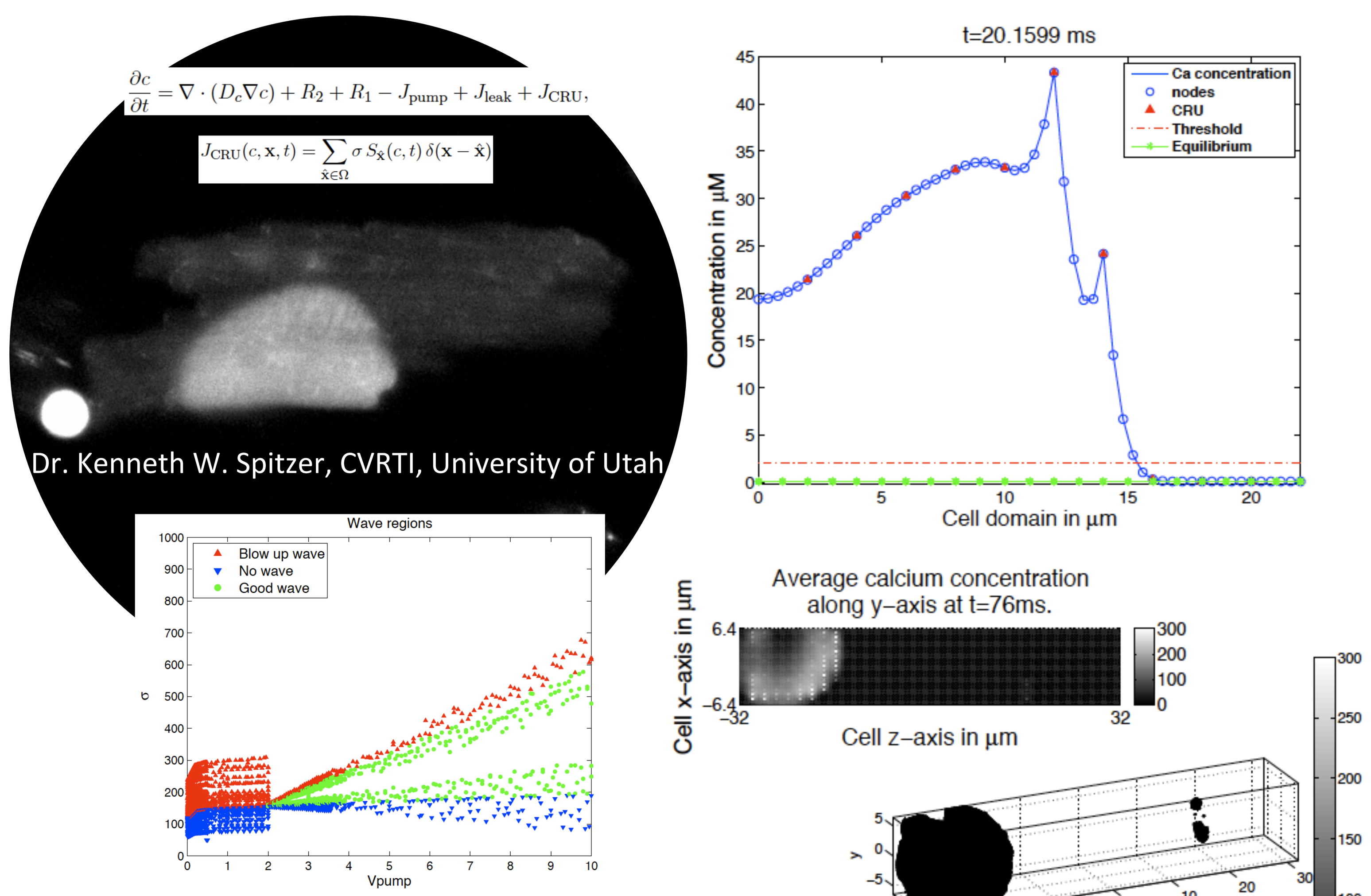
We provide an overview of the modeling performed on the various physiological systems in the Peercy group. Biological application examples are stochastic simulation and reductive analysis of cardiac cell calcium dynamics, intracellular signaling via cAMP in pancreatic beta cells and computational islets, activation pathway parameter estimation of transcription factor nuclear translocation in skeletal muscle to control fiber type and muscle atrophy, extracellular and intracellular signaling for clustered cell migration, and how vitamin D levels vary in across genotype and impact macrophage antimicrobial peptide production. Our goal is predictive experiments through mathematical analysis.

The Spark of Calcium in a Cardiac Cell*

with, Zana Coulibaly[G], Dr. Matthias Gobbert, UMBC, Math&Stat



Coulibaly, Gobbert, Peercy, Intl. J. Comput Math, 2014

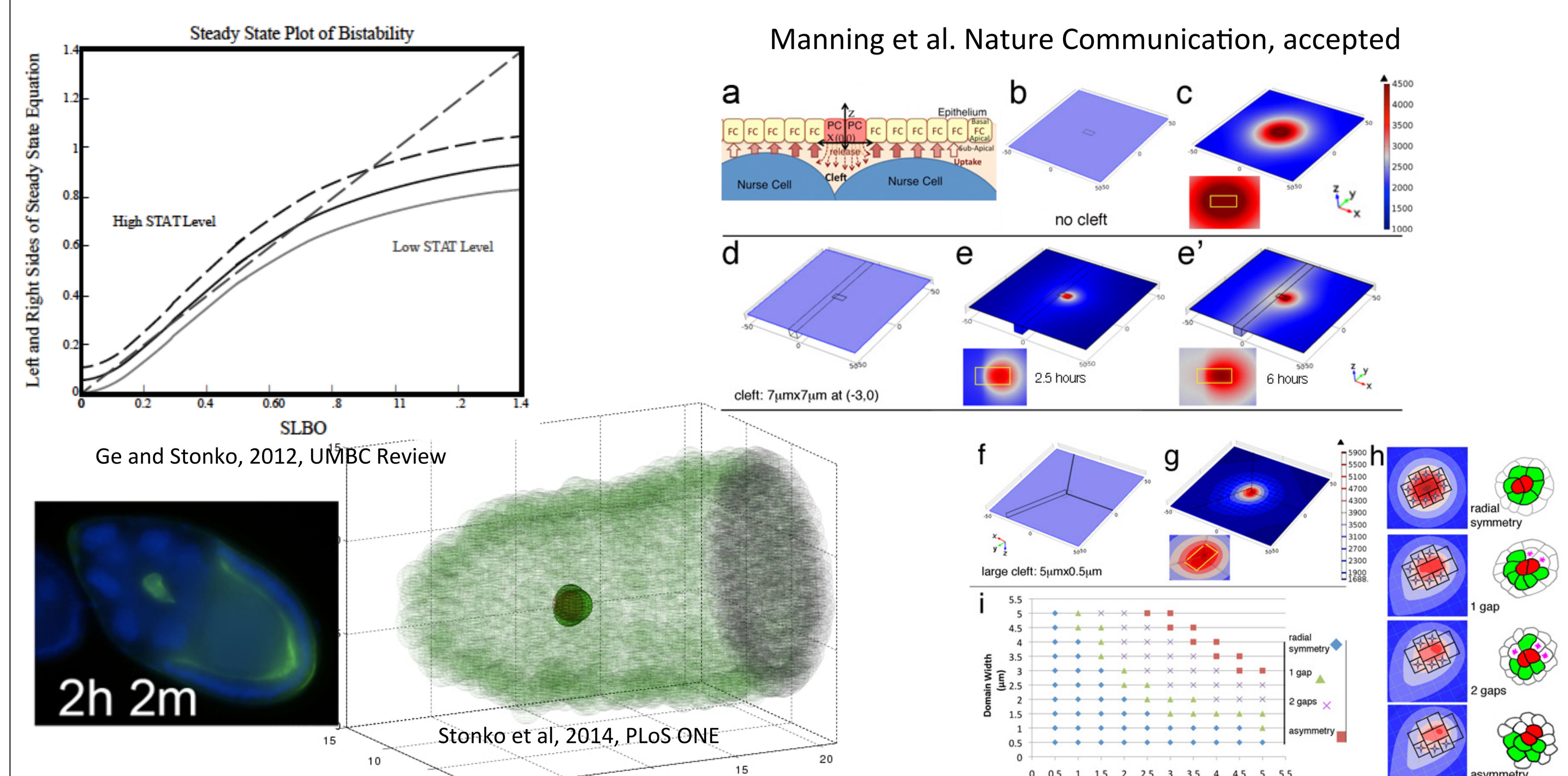
Spontaneous calcium release can organize into sustained release providing substrate for cardiac arrhythmias in pathological conditions. We use a previously developed specialized finite volume code to realize long-time calcium dynamics including intracellular waves.

Supported by UMBC SRAIS 2011-2012 and SFF 2010

HPCF at UMBC utilized for computations www.umbc.edu/hpcf

Cell Fate of Epithelial Cells

with Dr. Michelle Starz-Gaiano, David Stonko[U], Xuan Ge[U], Ann Marie Weideman[G], Dominick DiMercurio III[U], Pranjal Singh[U], Lindsey Mercer[U], Lilian Anosike[U]



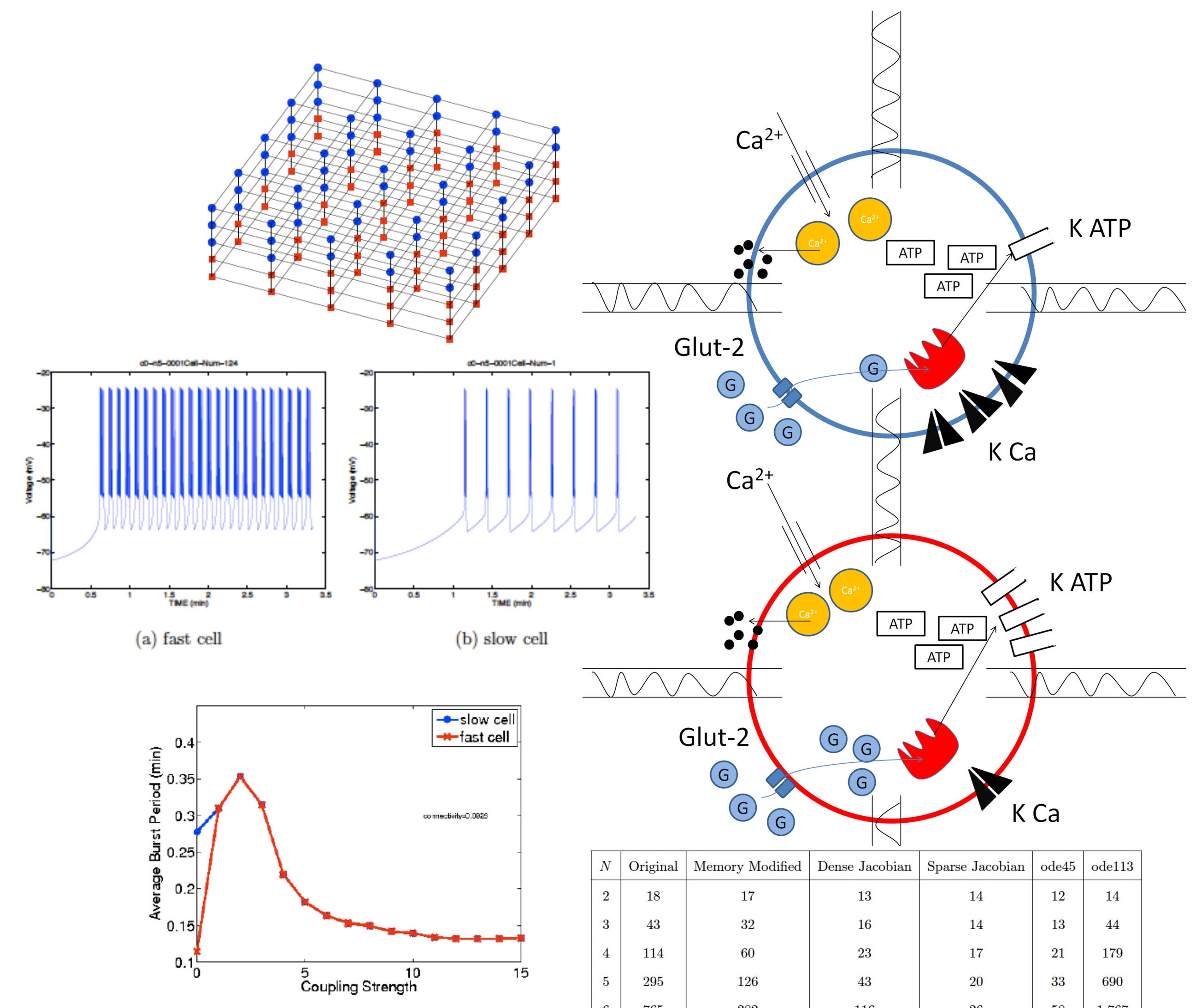
Ge and Stonko, 2012, UMBC Review

Stonko et al, 2014, PLoS ONE

For an epithelial to motile transition we model intracellular signaling yielding a bistable switch, extracellular signaling with geometry biasing morphogen gradients, and migration of cells with minimal force balance dynamics in a model system

Signaling within and between Pancreatic Beta Cells

with Dr. Matthias Gobbert, Samuel Khuvis[G], Kaung San[U], UMBC REU Site on HPC 2010, 2013, 2014, Margaret Watts, Arthur Sherman, NIH



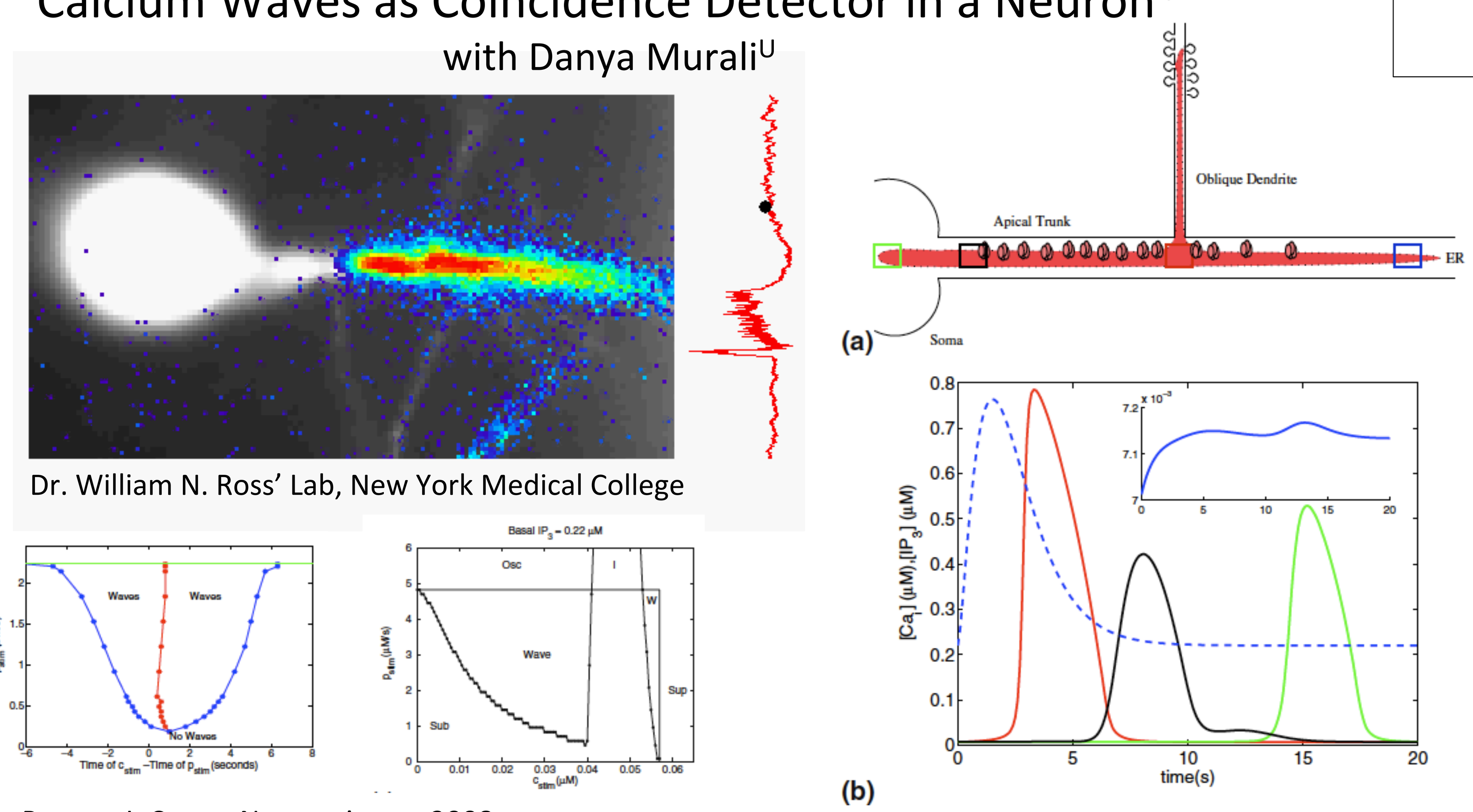
Khuvis, Gobbert, Peercy, Math Biosci, 2014

Heterogeneity between beta cells in the pancreatic islet leads to slower than slow bursting and the need for computational speed up with thousands of cells in an islet.

HPCF at UMBC utilized for computations www.umbc.edu/hpcf

Calcium Waves as Coincidence Detector in a Neuron*

with Danya Murali[U]



Peercy, J. Comp. Neuroscience, 2008

$$\frac{\partial c}{\partial t} = D_c\frac{\partial^2 c}{\partial x^2} + R(x)r_1 x_{110}^3(s_0 - c) + r_2(s_0 - c) - r_3\frac{c^2}{c^2+K^2}$$

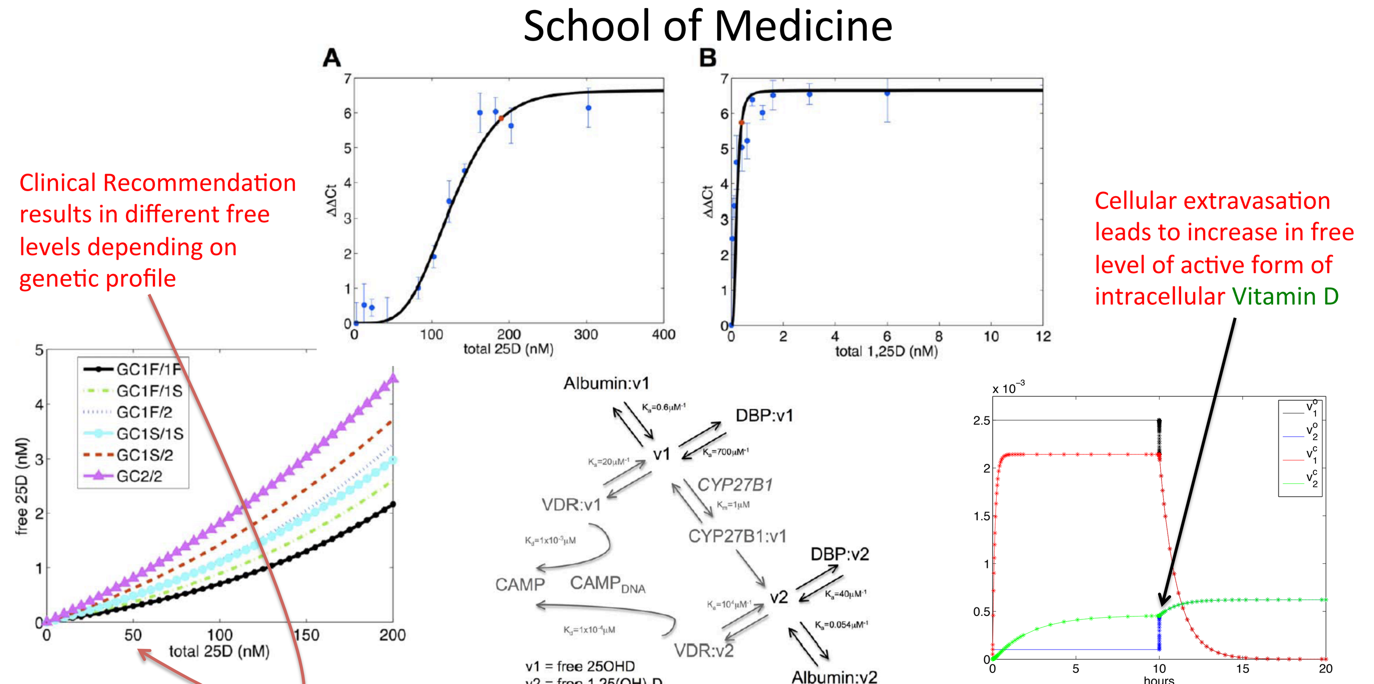
$$\frac{\partial p}{\partial t} = D_p\frac{\partial^2 p}{\partial x^2} + \sum_j p_j(t)\delta(x - x_j) - \beta(p - p_b)$$

Back propagating action potentials coincident with synaptic input can generate a calcium wave in the apical dendrite of a neuron. Nuclear penetration of this wave may enact long term changes in synaptic connections impacting learning and memory.

*Supported by UMBC SFF 2009

Vitamin D Activating Immune Cells

with Josh Austin[G] (UMBC)
Drs. Rene Chun, Martin Hewison, John S. Adams, UCLA, School of Medicine



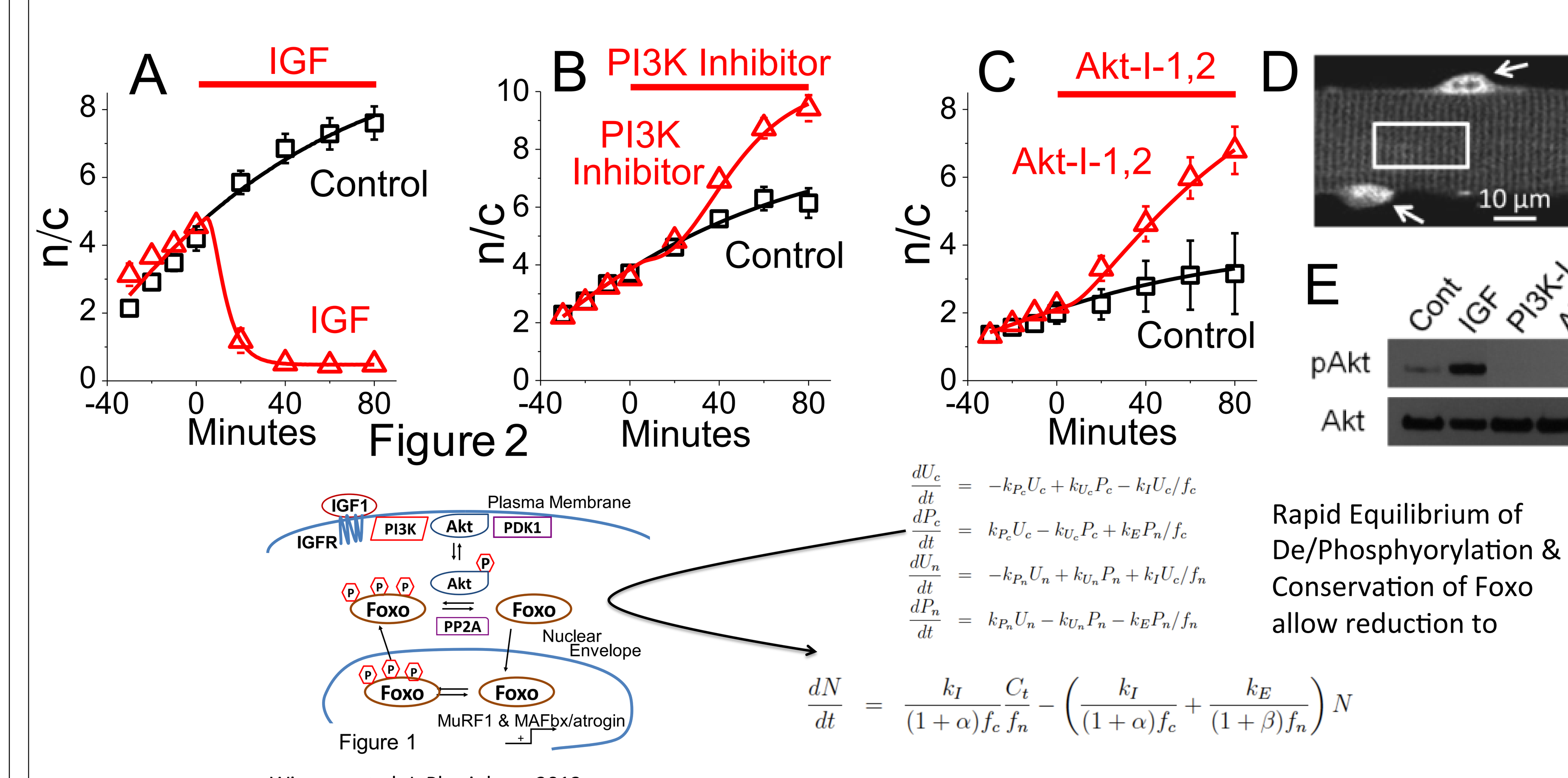
Chun, Peercy, Hewison, Adams, 2012, PLoS ONE

Austin, Peercy, Chun, Hewison, in preparation

Free, active vitamin D controls antimicrobial peptides (AMP) in monocytes. We show genetic variation in vitamin D binding proteins impacts free levels of vitamin D and show the impact of micro-domains on increasing AMP production in monocytes leaving the blood.

Muscle Atrophy Signaling by Foxo1 Nuclear Translocation

with Dr. Martin Schneider, Robert Wimmer[G], UMB, Biochemistry and Molecular Biology, Samtha Furman[U], Graham Antoszewski[U], UMBC



Rapid Equilibrium of De/Phosphorylation & Conservation of Foxo allow reduction to

$$\frac{dN}{dt} = \frac{k_I}{(1+\alpha)f_c}\frac{C_t}{f_n} - \left(\frac{k_I}{(1+\alpha)f_c} + \frac{k_E}{(1+\beta)f_n}\right)N$$

The model of de/phosphorylation reactions in both the cytoplasm and nucleus relates to nuclear influx and efflux and yields quantitative values from kinetic data.

[U]=undergraduate student
[G]=graduate student