The Interaction of Calcium and Metabolic Oscillations in Pancreatic $\beta$-cells

UMBC REU Site: Interdisciplinary Program in High Performance Computing
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Problem

Diabetes is a disease characterized by an excessive level of glucose in the bloodstream, which may be a result of improper insulin secretion. Insulin is secreted in a bursting behavior by pancreatic $\beta$-cells in islets, which is affected by oscillations of cytosolic calcium concentration. We used the Dual Oscillator Model to explore the role of calcium in calcium oscillation independent (CaD) versus calcium oscillation dependent (CaI) modes as well as the synchronization of metabolic oscillations.

Biological Model

Synchronization is measured on a scale from zero to one, with one representing complete synchronization, using a Pearson correlation.

Dual Oscillator Model

Simulations were run for one hour starting with a distribution of initial conditions with a $5 \times 5 \times 5$ cube of cells, equal-50-percent bursting pattern, increasing voltage and calcium coupling, pairwise $J_{GK}$ values in three different modes, CaI, CaD, and mixed CaI and CaD.

CalI Calcium Coupling Trend

In CaI regions increasing calcium coupling increases synchronization.

Increasing voltage coupling increases synchronization in CaD modes.

Voltage & Calcium Coupling

In CaD regions increasing calcium coupling desynchronizes voltage.

Conclusions

Coupling complex cells together has interesting dynamic effects. When in CaI mode, increasing calcium coupling with no voltage coupling increases synchronization. In CaD modes, increased voltage coupling with no calcium coupling increases synchronization. However, in CaD modes, voltage coupling with high calcium coupling causes desynchronization in voltage. Mixed modes tend to behave like CaI modes.

References & Acknowledgments

- Technical report: HPCF-2016-14  hpcf.umbc.edu > Publications
- REU Site: hpcf.umbc.edu
- NSF, NSA, DOD, UMBC, HPCF, CIRC