EMERGENT BEHAVIOR OF INTEGRATED CELLULAR SYSTEMS: AN ENGINEERING APPROACH TO THE DESIGN OF BIOLOGICAL MACHINES

STC Directors’ Meeting
August, 2010
“A New Biology for the 21st Century.” Report from the National Academies

[Despite] recent advances, there is still much to be done to move from identifying parts to defining complex biological systems.

[A] New Biology [is needed] to provide a framework to connect biological research with advances in other branches of science and engineering.
OUR GOALS

- To understand the complexities of integrated cellular systems so that we can ultimately instruct cell populations to develop into unified functional machines
- To educate a diverse generation of students well-versed in the “new biology”
- To inform and educate industry and the general public of the enormous potential for biological machines
PHOTOS FROM OUR MAY RETREAT
WHO WE ARE

Minority-serving partners

Core institutions

International partners

Teaching consortium
Proposed Institute for Cellular and Molecular Nanomechanics (ICMN)

NSF-EFRI: A multi-faceted approach to modeling angiogenesis
EMERGENT BEHAVIOR OF INTEGRATED BIOLOGICAL SYSTEMS

Project 1
Derivation of Specific Cell Types
- Myocytes
- Neurons
- Endothelial Cells

Project 2
Development of Cell Clusters
- Neuron-muscle clusters
- Neuron-clusters

Projects 3-6
Cellular Machines

Education

- Introduction to Emergent Behavior of Integrated Cellular Systems
- Lab Modules
  - Cell Culture
  - Imaging
  - Nanofabrication
- Career Module
  - Communication skills
  - Fundamentals of Cell and Molecular Biology

Diversity

Interdisciplinary Research
Interdisciplinary Education

Knowledge Transfer

Industry
Government
Professional Societies
Public
INTEGRATED CELLULAR SYSTEMS: “BIOLOGICAL MACHINES”

- myocytes
- neurons
- endothelial cells

coordination, integration, new functionalities

actuation
signal processing
transport

transport network & energy supply

sensors
processors
effectors

Cellular System
We need to understand:

- how to control cell differentiation both in isolation and as part of a population of cells
- how cells communicate with their environment and neighboring cells to develop coordinated behavior (the modules of the machine)
- how to assemble the modules to produce functionality of the machine
PUTTING IT ALL TOGETHER.....
SOME EXEMPLARY BIOLOGICAL MACHINES

- Organ mimics for drug testing
- Biological robots
- Implantable systems for drug sensing, synthesis and release
- Self-replicating organisms for toxic waste clean-up

www.biomachinations.com/?cat=17
EDUCATIONAL GOALS AND PLANS

- Educate the next generation of students in the “new biology”
- Develop the fundamental basis for a new discipline
- Some of the innovative components
  - A new approach to graduate education at the engineering/biology interface (a new curriculum for a new discipline)
  - Teaching consortium
  - Summer schools (NSF GEM4)
- Leverage other, existing programs
  - UIUC NIH Cancer Nanotechnology Training Center
  - New UIUC and GT IGERTs
  - MIT NIBIB Training Grant in BioSystems and Biomechanics
- Several educational models to promote wide dissemination
- Evaluation is essential
BRINGING DIVERSITY TO EBICS

Our MSI partners:
• Feeder programs
• Summer exchanges
• Active participation in EBICS research

At MIT:
• CONVERGE
• MSRP
• BE REU program
• MITES

At UIUC:
• MEP
• MERGE
• SURGE
• Inclusive Illinois

At Georgia Tech:
• Women in Engineering
• FASET
• Building on an already successful URM recruiting program
BROAD DISSEMINATION OF EBICS MESSAGE

Teaching consortium

- Industrial ties
- Articles in the popular literature
- Children’s book on Biological Machines
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- Myocyte clusters
- Neuronal clusters
- Endothelial clusters

Projects 3-6
Cellular Machines

Education

Lab Modules
- Cell Biology for Engineers
- Bioengineering
- Non-equilibrium Stat. Mechanics
- Physics of Nanomachines
- Fields, Forces & Flows in Bio Systems

Career Module
- Communication skills
- Entrepreneurship
- Biocompatibility

Advanced Elective Courses
- Basics of Mechanobiology
- Intro to Synthetic Biology
- Coordinated Behavior in Development
- EBICS Seminar Series
- Intra-cellular and Cellular imaging
- Intro to Engineered Biological Systems
- Mechanisms and Models for Cell-Cell Communication

Knowledge Transfer
- Industry
- Government
- Professional Societies
- Public

Interdisciplinary Integration
- Interdisciplinary Research
- Interdisciplinary Education

Interdisciplinary Knowledge Transfer
- EBICS STC
- City College of New York
- UC Merced
- Northrop Grumman