BME Systems Biology

Systems biology is the integration of experimental and modeling approaches to dissect complex cellular phenomena. Fundamentally, systems biology aims to better quantify and comprehend the highly multivariate and interactive networks of genes, proteins, and metabolites that regulate cellular function. The faculty in Cornell’s Department of Biomedical Engineering apply new experimental and computational approaches to understand how these gene, signal transduction, and metabolic networks are regulated in healthy tissues and dysregulated, resulting in aberrant cell fates, in pathological settings such as cancer and aging. Furthermore, our researchers use modeling efforts to better engineer both novel biomolecules and new combinatorial therapeutic strategies to treat these pathophysiologys. Increasingly, our efforts aim to marry experiment and modeling at the single-cell level so as to elucidate how cell-to-cell variability arises and underlies disease progression and response to therapy. As such, we are involved in the development of sensitive approaches capable of multiplexed, quantitative measurement with single-cell resolution. These efforts rely on connections with Cornell’s Nanobiotechnology Center, Center on the Microenvironmental and Metastasis (an NIH-funded Physical Sciences Oncology Center), and Stem Cell Program, as well as in collaborations with clinical and research scientists at Weill Cornell Medical College.

BME Research

Within the next five years our department has the goal of being the best BME department in the nation in two research topics: (1) cellular imaging, particularly in vivo optical imaging, and (2) micro-and nano-biotechnology. The department expects to be among the top 10 BME departments in three other areas: (1) biomaterials and drug delivery, (2) molecular, cellular and tissue engineering, and (3) soft tissue biomechanics. For the graduate field of BME, which is much larger than the department, we emphasize six distinct but integrated areas of BME research: Biomedical Imaging and Instruments; Biomedical Mechanics; Micro-and nano-biotechnology; Molecular, Cellular, and Tissue Engineering; Biomaterials and Drug Delivery; and Systems Biology.

Faculty research

Prof. Ben Cosgrove’s lab studies how aging influences a decline in the ability of resident stem cells to regenerate adult tissues. His lab explores how alterations in both the tissue microenvironment and cell signal transduction pathways within the stem cells themselves are altered in aging. His research uses computational and experimental approaches to better understand multivariate interactions in these signaling networks and to target aberrant network functions to rejuvenate stem cells in aged tissues.
Prof. **Iwijn De Vlaminck** leads an experimental physical genomics lab focused on the development and application of sensitive single-cell genome sequencing principles. Single-cell sequencing enables highly multivariate measurements of genomic and transcriptomic cell-to-cell variability. When combined with microscopy techniques, single cell sequencing will enable the study of the systems biology of cells in tissue microenvironments.

Prof. **Jesse Goldberg’s** lab is interested in how systems of interconnected brain regions interact to control behavior. We combine high-channel count neural recording and optogenetics in small, freely behaving animals engaged in trial and error motor learning.

Prof. **Jason Locasale’s** lab focuses on an integrated understanding of metabolism in health and disease. We direct these efforts toward understanding the role of altered metabolism in cancer, emphasizing its targetable liabilities and downstream effects on cellular physiology. At the core of this effort lies the utilization of computational modeling and high throughput technologies such as mass spectrometry-based metabolomics.

Prof. **Julius Lucks’** lab is interested in the bottom-up design and construction of sophisticated genetic systems with predictable function. His group uses computational and experimental biomolecular engineering approaches (i) to design RNA sequences to fold into specific RNA structures that regulate desired gene expression programs and (ii) to infer the general design principles of constructing gene regulatory networks from well-characterized building blocks with predictable function.

Prof. **Xiling Shen’s** lab uses both computational modeling and data-driven integrated network analysis to study non-coding RNA, stem cells and cancer. The focus is on the underlying regulatory network that drives the spatiotemporal evolution of tissue homeostasis and disease progression.

Prof. **Jeffrey Varner’s** lab focuses on the development of physiochemical modeling tools that can be used to rationally “reprogram” signal flow in human signal transduction networks. His group’s central thesis is that physiochemical models, despite their uncertainties, are useful hypothesis-generation engines for suggesting targeted reprogramming strategies. They apply these approaches to model and treat cardiovascular disorders, acute and chronic pain, and cell proliferation and death programs.

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