Integrative biosystems derive their complexity and heterogeneity due to multiscale interactions over hierarchical arrangements within spatially organized three-dimensional (3D) assemblies. Tracking and optimizing heterotypic cellular interactions within 3D biomimetic micro-environments is a major challenge due to the absence of tools and biomarkers for real-time monitoring of cell phenotypes. Our research group is focused on the development of device platforms for spatial organization of biosystems towards controlling their interactions for characterizing the emergence of phenotypic heterogeneity by monitoring intracellular electrophysiology and temporal profiling of relevant biomarkers. Applications include early diagnosis of diseases; guidance of cells for morphogenesis and tissue regeneration, and the directed assembly of nanostructured biomimetic materials.
Tissue Regeneration
The patterning of neural circuits and guided assembly of bio-degradable polymeric scaffolds to mimic the extra-cellular matrix can serve as a platform for regeneration of nerves, ligaments, and muscles. Our research group develops device interfaces for spatially localized and temporally resolved electric fields for nanostructure alignment and patterning towards the hierarchical control of biofunctionality as well as for development of electrical stimulation paradigms.

Biomarker Analysis for Disease Diagnosis
Sensitivity gains within lab-on-a-chip device technologies through device scaling are currently limited by the need to enable selective, localized and enhanced coupling of biomarkers with nanostructured sensor elements. Our group focuses on electrokinetic micro/nanofluidic devices for localized trapping, enrichment and separation of biomarkers using label-free dielectric and magnetic methodologies. Applications include biosensing and localized initiation of electroporation, electro-fusion and wound healing.

Optimizing Microbiota to control Infections
The role of the human microbiota in health and disease has become increasingly apparent. However, characterizing microbial to microbial and polymicrobial population to host interactions has been challenging. Our effort is focused on contact-less and real-time analysis of microbial electrophysiology within microfluidic co-cultures to monitor the emerging phenotypic alterations during polymicrobial interactions.

Environmental Implications of Nanotechnology
Our research group examines the risks and benefits to society from the use of silver nanotechnologies for antibacterial and wound healing applications. Specifically, we characterize toxicity using microfluidic assays on model organisms.

RECENT RESEARCH DEVELOPMENTS
• Better Biosensors:
  - Enhancing detection sensitivity through micro/nanofluidic devices:
    Lab Chip (2015), 15, 4563 – 4570
    Biosens. Bioelectron. (2016), 78, pp. 244-252
• Integrative tissue regeneration:
  - Spatial control of cell division through nanoimprinted structures
    Biointerphases (2015); 10 (4), 041008: 1-8
    Acta Biomaterialia (2012), 8, 3982

RECENT GRANTS
• AFOSR – Aptamer-based nano-slit platforms for characterizing human performance biomarkers
• NSF EFRI – Electrically mediated complex tissue regeneration
• Naval Air Warfare Center – FaSTR DNA Profiling Systems for Forensic Analysis
• Coulter Foundation – Microfluidic Selection & 3D-Bioprinting of Islets for Transplantation in Diabetes
• VBHRC – PHENOCHIP: Isolation of Tumor Initiating Cells

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