White paper
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Research interests:

My research program focuses on developing modular genetic platforms for programming information processing, computation, and control functions in living systems, resulting in transformative technologies for engineering, manipulating, and probing biological systems. My laboratory has pioneered the design and application of a broad class of RNA molecules, called RNA devices, that process and transmit user-specified input signals to targeted protein outputs, thereby linking molecular computation to gene expression. We have developed frameworks that provide general design strategies for assembling RNA components, encoding basic functions of sensing, actuation, and information transmission, into genetic devices that perform tailored information processing, computation, and control functions. This technology has been extended to efficiently construct multi-input devices exhibiting various higher-order information processing functions (including logic gates, signal and bandpass filters, programmed cooperativity), demonstrating combinatorial assembly of many information processing, transduction, and control devices from a smaller number of components. These technologies have important implications for the design of integrated biological systems, leading to transformative advances in how we interact with and program biology, providing access to otherwise inaccessible information on cellular state, and allowing sophisticated exogenous and embedded control over cellular functions. My laboratory is applying these technologies to addressing key challenges in cellular therapeutics, targeted molecular therapies, and green biosynthesis strategies.

Main challenges and state of the art:

Core activities within synthetic biology are focused on new approaches that support the design and construction of genetic systems. However, our ability to construct large genetic systems (e.g., entire microbial genomes) currently surpasses our ability to design such systems (e.g., pathways encoded by several genes), resulting in a growing 'design gap' that must be addressed. The technical challenges that are resulting in this growing design gap are:

i) limited diversity and utility of existing biological parts
ii) lack of scalable, integrated design strategies for building biological systems that exhibit robust and predictable behavior over time
iii) lack of effective and efficient troubleshooting tools

Important directions of research:

Important directions of research include:

- development of foundational tools and technologies that work across diverse organisms of key interest and beyond *E. coli* (including yeast, cyanobacteria, mammalian cells, and plants)
    - these tools should support both fabrication and design of integrated genetic systems
- development of new measurement and troubleshooting tools
- implementation of these tools in key application areas (e.g., agriculture, biomanufacturing, medicine) toward the engineering of biological systems exhibiting desired behaviors

    - focus on demonstration/implementation of tools toward making the engineering of biological systems more scalable, faster, reliable, cheaper
- enhancing knowledge (understanding) of biological systems to advance design
    - discovery or generation of new biological component activities
    - discovery or elucidation of mechanisms by which biological components interact to form integrated systems