Penn Engineering
University of Pennsylvania
Chemical and Biomolecular Engineering

Spring 2023 Seminar Series

YIFAN DAI

"A New Phase of Biological Controls: A Design Framework for Programmable Synthetic Biomolecular Condensates and the Mechanisms of a Functional Liquid-Liquid Interface"

Wednesday
February 15, 2023
3:30 PM
Wu and Chen Auditorium
Levine Hall

Department of Biomedical Engineering
Duke University

ABSTRACT

A fundamental question in nature is how the cellular processes are organized with sequential and spatial precision in a dynamic and densely packed environment. Evidence is now mounting that biomolecular condensation, a demixing process mediated by phase separation coupled with percolation, dictates the organization principles of cellular biochemistry. From the perspective of synthetic biology, programmable condensation in living cells represents a new fundamental capability for biological design, going beyond the current engineering capability of lock-and-key interactions. In the first part of the talk, I will introduce a rational design strategy of synthetic intrinsically disordered proteins toward functional synthetic biomolecular condensates for cellular controls in bacteria and human cells. I will demonstrate the applications of synthetic condensates on four distinct cellular processes: cell division, transcription, translation, and modulation of protein circuits, providing a toolbox for orthogonal central dogma.

In the second part of the talk, I will dig into the physical chemistry principles of condensate microenvironments, by which condensates can encode unique electrochemical features at its liquid-liquid interface. I will introduce a theoretical framework we developed for condensate interface, which allows us to understand the density transition process of condensate formation from the perspective of electrochemistry. I will then discuss our experimental discoveries on the fundamental electrochemical properties of liquid-liquid interface and how these features can regulate cellular processes. These discoveries open new directions of condensate research and provide answers for many previously unexplained biological activities of biomolecular condensates.

Overall, the first work has established a design principle for programmable condensation as a new capability of synthetic biology. The second work combining insights from physical chemistry, electrochemistry and cell biology has delivered a new paradigm for understanding how condensates can engender cellular functions through its chemical environments and liquid-liquid interface.

BIO

Yifan Dai is a postdoc associate at the Department of Biomedical Engineering at Duke University, co-advised by Professor Ashutosh Chilkoti and Professor Lingchong You. He obtained his B.S. and Ph.D. in 2017 and 2020 both in Chemical and Biomolecular Engineering from Case Western Reserve University. Since his undergraduate, he had worked on engineering strategies to integrate synthetic biology with electrochemistry to enable translation of biological signals into electricity for biosensing applications, which have led to multiple licensed technologies. In his postdoc, he has worked on 1) uncovering the principles of biomolecular phase transitions for engineering biology and 2) establishing the theoretical framework of condensate microenvironments and liquid-liquid interface.