

Chemical Engineering Colloquium

October 7, 2026

Goddard Hall, Room 227

12:00 PM – 1:00 PM

Building Smarter Microbial Factories With Spatial and Temporal Controls Using Organelle Engineering and Optogenetics

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Microorganisms with engineered metabolisms are effective biocatalysts for the production of fuels, chemicals, bioplastics, drugs, and countless other valuable products. Because of these capabilities, these organisms are often called microbial cell factories. However, achieving commercially viable titers, yields, and productivities with these systems remains a major challenge. Spatial and temporal control over engineered metabolic pathways has emerged as a promising strategy to significantly enhance the efficiency of microbial cell factories.

In the first part of my talk, I will discuss our recent advances in the compartmentalization of biosynthetic pathways in natural and synthetic organelles; specifically yeast mitochondria and engineered liquid-like protein condensates. I will present recent advances on how targeting metabolic pathways to mitochondria and engineering their morphology can boost chemical production. In addition, I will describe our recent progress in the rational design and functionalization of intracellular protein condensates to recruit not only enzymes, but also small molecules and biological membranes to produce synthetic organelles that can channel metabolic flux and exploit membrane functions to enhance compartmentalized pathways.

In the second part of my talk, I will present our pioneering work on the use of optogenetics – the application of light-responsive proteins to control biological processes – to achieve unprecedented dynamic regulation of engineered metabolisms. Light offers several unique advantages over chemical induction: it is orthogonal to native cellular processes, tunable, reversible, and readily programmable via computer interfaces. These properties make it ideal for real-time metabolic control, enabling new strategies for automation and optimization of fermentations. I will describe several optogenetic systems we have developed to regulate microbial growth and metabolism to improve chemical production. This includes innovations to overcome limited light penetration in bioreactors operating at high cell densities, as well as optogenetic systems to control the population dynamics of microbial consortia for enhanced chemical production.

Finally, I will discuss how the integration of dynamic and spatial control strategies is establishing a new paradigm in metabolic engineering—one that promises to significantly expand the capabilities of microbial cell factories.



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