Spatiotemporal Dynamics of Photosynthetic Metabolism in Single Cells at Subcellular Resolution

Colin Gates (colin.gates@colorado.edu)[1,2], Taewoo Lee[2], Ivan Smalyukh[2], and **Jeffrey C. Cameron[1,2,3,4]**

[1]Department of Biochemistry, University of Colorado, Boulder, CO 80309, USA.
[2]Renewable and Sustainable Energy Institute, University of Colorado, Boulder, CO 80309, USA.
[3]Department of Physics, University of Colorado, Boulder, CO 80309, USA.
[4]National Renewable Energy Laboratory, Golden, CO 80401, USA.

Project Goals: The project objective is to design and build a multimodal nanoscopy system to generate adaptive 3D images with high-resolution, and real-time, dynamic label-free chemical imaging of metabolic processes in photosynthetic organisms.

Abstract:

Metabolism is highly organized in space and time. In bacteria, this spatial and temporal organization of metabolism enables multiple, often competing, reactions to occur simultaneously in the same cell. However, the architectural principles of metabolic reaction networks and underlying cellular complexity of bacterial cells is only beginning to be appreciated. To unlock the true potential of synthetic biology and design novel microbial systems, signaling pathways and metabolic networks, the subcellular environment must be considered (in space and time). Our interdisciplinary research team harnesses cutting-edge synthetic biology tools, advanced live-cell imaging modalities, quantitative image analysis, and an integrated theoretical framework to investigate the regulatory and physical design principles underlying the spatiotemporal modulation metabolism in single bacterial cells.

Cyanobacteria are major primary producers and are unique in their ability to perform oxygenic photosynthesis, nitrogen fixation, and CO_2 fixation using light energy; these reactions are naturally optimized through spatial and temporal separation. These attributes make cyanobacteria ideal platforms to investigate and modulate cellular architecture and metabolism. We have developed a new imaging system to enable multidimensional measurements of photosynthetic metabolism in vivo and will describe the new types of measurements that can now be made in single cells. Understanding the design principles that enable robust functionality of the photosynthetic and carbon-fixing machinery is a fundamental challenge to improve native and heterologous metabolic pathways.

References

1. Nicholas C. Hill, Jian W. Tay, Sabina Altus, David M. Bortz, Jeffrey C. Cameron. (2020). Lifecycle of a cyanobacterial carboxysome. *Science Advances* 6 (19): eaba12692.

2. Kelsey K. Dahlgren, Colin Gates, Thomas Lee, Jeffrey C. Cameron**.** Proximity-based proteomics reveals the thylakoid lumen proteome in the cyanobacterium *Synechococcus* sp. PCC 7002. (2020). *Photosynthesis Research*. https://doi.org/10.1007/s11120-020-00806-y

3. Sarah J. Hurley*, Boswell A. Wing, Claire E. Jasper, Nicholas C. Hill, Jeffrey C. Cameron*. Cyanobacterial oxygenic photosynthesis dominated Mid-Proterozoic primary productivity. (2021) *Science Advances* Vol 7. No. 2, eabc8998, DOE: 10.1126/sciadv.abc8998 (*Corresponding Author)

This study was financially supported by the U.S. Department of Energy (DOE) DE-SC0019306 (to J.C.C.).