Illuminating Photosynthesis in Single Cyanobacterial Cells

Imaging

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Cyanobacteria use light energy to perform oxygenic photosynthesis, converting CO2 and H2O into biomass. This process is driven by the photosynthetic reaction centers, photosystem I (PSI) and photosystem II (PSII), within the cyanobacterial internal thylakoid membrane system. Previous studies have shown that PSII becomes damaged due to its normal activities and upon acute exposure to excess light. In response to this photodamage, PSII must be constantly repaired by the cells. Thus, the steady-state level of PSII in a cell is the result of the relative rates of synthesis, degradation, dilution, damage, and repair/recycling. When conditions exist in which the rate of damage is greater than the rate of repair, cells experience photoinhibition, resulting in reduced photosynthetic activity and biomass production. Understanding how each of these processes are integrated into the cellular response has been difficult using traditional ensemble approaches due to cell-cell heterogeneity. For example, in bulk culture, cells are exposed to a dynamic light environment that is a function of mixing, cell density, and cell state. To overcome this limitation, we have developed an automated imaging approach to film the growth of cyanobacterial cells using long-term, time-lapse, fluorescence microscopy, as well as software to analyze the resulting images. By growing cells in a two-dimensional layer, we avoid shading effects and can generate highly reproducible, growth conditions. Using this platform, we can simultaneously analyze the growth and physiology of multiple strains under defined photoautotrophic conditions, including those that induce photodamage. Our analysis reveals an asymmetric cellular response to photodamage, with implications for how cells achieve maximum growth in light and CO2, as well as the evolution of the photosynthetic apparatus in phototrophic microbes.