Phycobilisome core architecture influences photoprotective quenching by the Orange Carotenoid Protein

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Photosynthetic organisms rely on sophisticated photoprotective mechanisms to prevent oxidative damage under high or fluctuating solar illumination. Cyanobacteria, which have evolved a unique, water-soluble light harvesting complex—the phycobilisome—achieve photoprotection through a photoactivatable quencher called the Orange Carotenoid Protein (OCP). Phycobilisomes are highly symmetric and modular, formed by hierarchical assembly of conserved subunits into diverse geometries ranging from simple bundles to elaborate fan- or bouquet-like macromolecular architectures. Although OCP is known to provide photoprotection across species of cyanobacteria with different phycobilisome structures, it is not known whether or how these structural variations relate to changes in the photoprotective function of OCP. For example, OCP was recently discovered to bind as a dimer at two specific instances of an abundant structural motif on the tricylindrical phycobilisome of *Synechocystis* sp. PCC 6803, yet these sites are sterically inaccessible on a more common pentacylindrical phycobilisome (*Anabaena* sp. PCC 7120). To understand how structural modularity and binding specificity contribute to conservation of OCP binding sites and function across different phycobilisome architectures, here we compare experimentally measured photophysical states accessible to these prototypical tricylindrical and pentacylindrical phycobilisomes, with and without OCP, at the single-molecule level. Together with Monte Carlo simulations of exciton transfer in OCP-quenched phycobilisomes, our results suggest that OCP binds at distinct and specific sites in each type of phycobilisome, yet provides nearly identical quenching strength to both phycobilisomes. Our findings (Ejaz et al. 2025) highlight the utility of modular phycobilisome structures in balancing robust conservation of photoprotective function with adaptability of site-specific binding across species.

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