Structure and evolution of Photosystem I in the early-branching cyanobacterium *Anthocerotibacter panamensis*

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Thylakoid-free cyanobacteria are thought to preserve ancestral traits of early-evolving organisms capable of oxygenic photosynthesis. However, and until recently, photosynthesis studies in thylakoid-free cyanobacteria were only possible in the model strain *Gloeobacter violaceus*. Here, we report the isolation, biochemical characterization, cryo-EM structure, and phylogenetic analysis of photosystem I from a newly discovered thylakoid-free cyanobacterium, *Anthocerotibacter panamensis*, a distant relative of the genus *Gloeobacter*. We find that *A. panamensis* PSI exhibits a distinct carotenoid composition and has one conserved low-energy chlorophyll site, which was lost in *G. violaceus*. These features explain the *A. panamensis* capacity to grow under high light intensity, unlike other Gloeobacteria. Furthermore, we find that while at the sequence level PSI in thylakoid-free cyanobacteria has changed to a degree comparable to that of other strains, its subunit composition and oligomeric form might be identical to that of the most recent common ancestor of cyanobacteria.

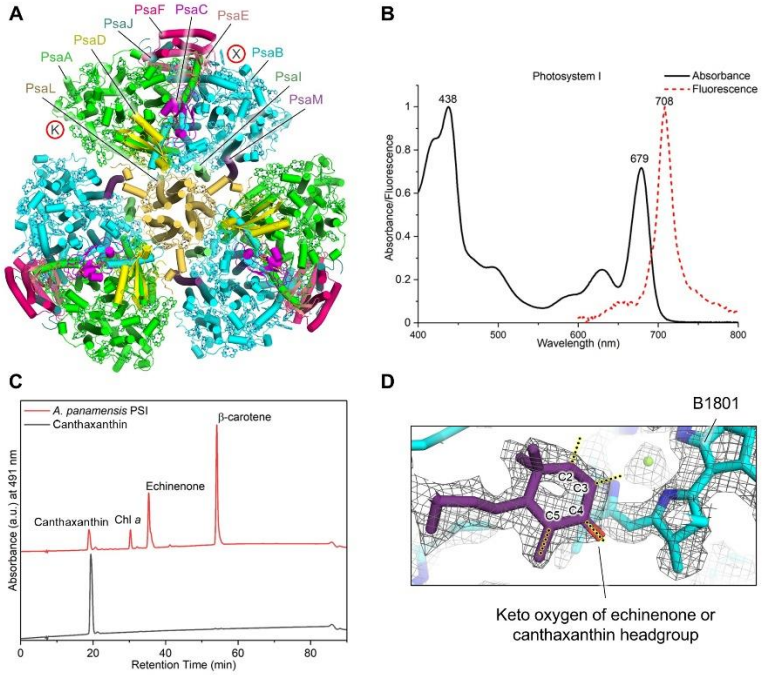

Fig. 1. *A. panamensis* PSI characteristics. (A) Structure of *A. panamensis* PSI. Subunits PsaK and PsaX are not present. (B) Room temperature absorbance and 77 K fluorescence of *A. panamensis* PSI. (C) HPLC chromatogram of pigments present in *A. panamensis* PSI and a canthaxanthin standard. (D) Cryo-EM map near a keto-carotenoid and positions that were quantitatively assessed.