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Kinetics and dynamics for light state transition in cyanobacterium *Spirulina platensis* cells

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ABSTRACT

Light state transition in oxygenic organisms was defined as the ability to equalize the excitation of the two photosystems for maximal photosynthetic efficiency. In cyanobacteria, extensive researches on state transition have continuously provided new knowledge in the past decades but the molecular mechanism and physiological significance are still ambiguous. In this work, kinetics and dynamics of the transition from state 1 to state 2 in cyanobacterium *Spirulina platensis* cells were studied at different intensity of orange light from 10 to 120 μmol m^{-2} s^{-1}. It was revealed that the state transition worked constantly independent of light intensity while the rates varied. The synchronous fluorescence kinetics for phycobilisome (PBS) and photosystem components indicated that the state transition was entirely regulated by "mobile PBS", and continuously changed fluorescence amplitudes suggested a series of intermediate states were involved between state 1 and state 2. The dynamic property of PBS movement during the state transition was revealed by (1,0) distribution of photo-linkable PBSs, indicating a collective movement of all PBSs. The results suggest that state transition in cyanobacteria possesses not only physiological but also photochemical significance.

1. Introduction

Oxygen evolution and carbon fixation in photosynthetic organisms are the fundamental reactions depending on equal excitation of photosystem II (PSII) and photosystem I (PSI) which have distinct light absorptions. Under a light conditions favoring PSII (state 2) or PSI (state 1), the excitation energy would be redistributed by the mechanism named as light state transition [1,2]. In green plants, state transition is achieved by a directional movement of light-harvesting complex II (LHCII) to PSI or PSII due to a reversible phosphorylation activated by certain protein kinases [3,4]. In comparison, the state transition in cyanobacteria is less understood. For several decades, two different models, "mobile PBS" [5,6] or "energy spillover" from PSII to PSI [7–10], were mainly used to explain the state transitions. It was found that "mobile PBS" was common while the "spillover" only took a part in the state transition when dark condition was involved [11,12]. The two mechanisms were cooperative but not competitive [13]. While PBS mobility is necessary for "mobile PBS", it has never been directly detected in a state transition in cyanobacteria. Fluorescence recovery after photobleaching (FRAP) detected the PBS mobility in a cyanobacterial cell [14] but not the PBS movement in a light state transition. The "damped oscillation" fluorescence fluctuation with selective excitation of PBSs in cyanobacterial cells suggested a dynamic behavior of PBSs searching for the "balanced position" [15]. However, whether the fluorescence fluctuation is resulted by a collective movement of all PBSs or relative change in PBS populations on PSII or PSI could not be answered. State transitions are commonly studied in two fixed states – state 1 and state 2, but the observations on the effect of light dosage or temperature in state transition [16] suggested that light state seems to be a continuous but not discrete variable. The continuous light state is important for understanding the physiological significance of state transition in cyanobacteria. Several years ago, it was indicated that state transitions were physiologically important only at very low light intensities ($\leqslant 2$ μE m^{-2} s^{-1}) and would play no role in protection from photoinhibition for growths of the *Synechocystis rpa*C (Regulator of Phycobilisome Association C) deletion mutant [17]. To investigate the kinetics in various light intensity and dynamics may provide some new insight into state transition.

Abbreviations: PBS, phycobilisome; PSI, photosystem I; PSII, photosystem II; C-PC, C-phycocyanin; APC, allophycocyanin.

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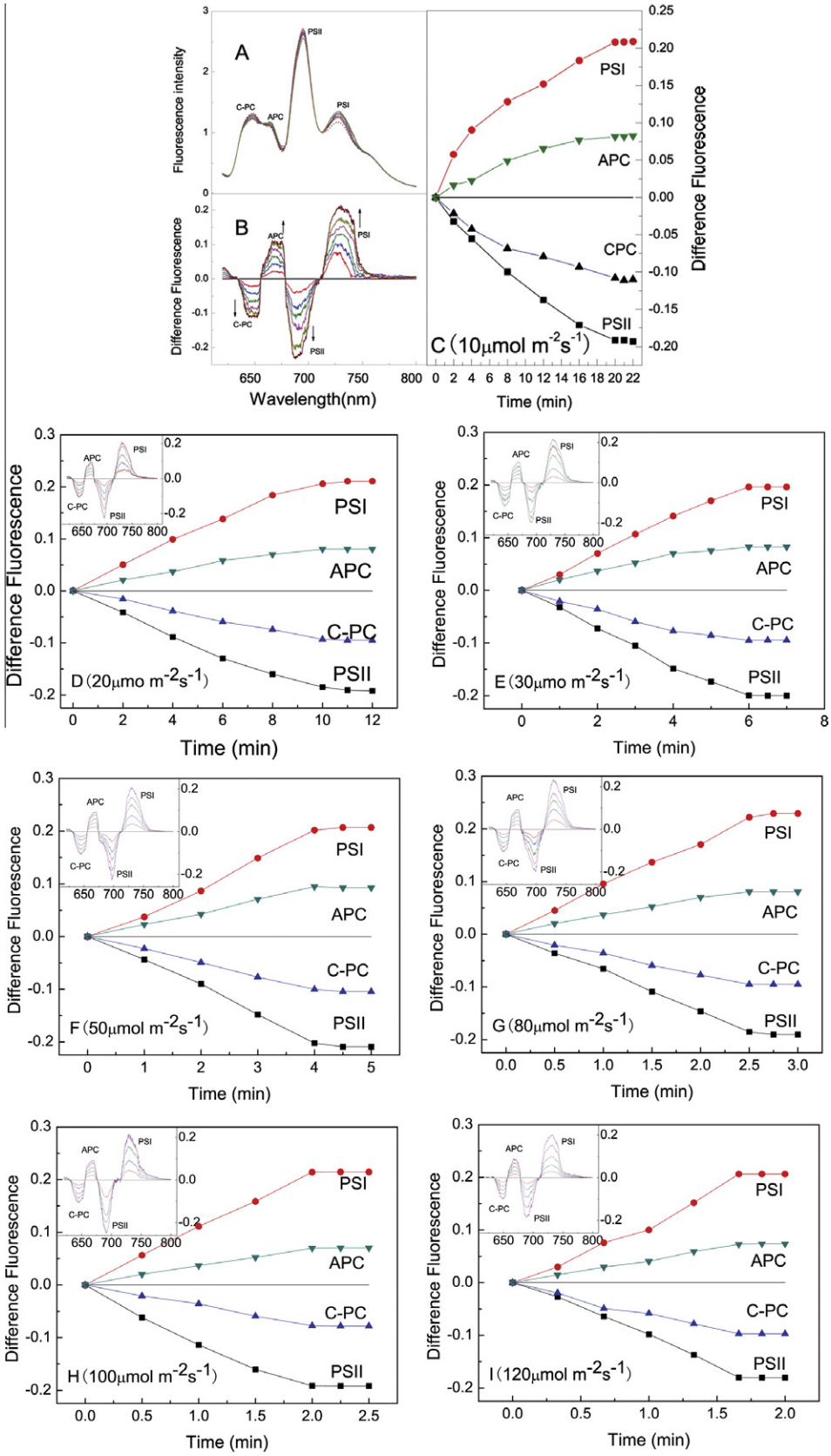

Fig. 1. 77 K fluorescence emission spectra (A), the difference spectra (B) and plots of amplitudes for the four components as denoted to time (C) for state-1 cells under orange light at 10 μmol m^{-2} s^{-1}. Arrows in (B) indicate direction of the changes. (D–F) Are the same to (C) but the light intensity is 20 (D), 30 (E), 50 (F), 80 (G), 100 (H) or 120 (I) μmol m^{-2} s^{-1}, respectively. The difference spectra (insets) derived from 77 K fluorescence spectra (omitted). Excited at 580 nm and normalized to 712 nm.

In this work, 77 K fluorescence spectra were monitored at a series of time for *Spirulina platensis* cells initially at state 1 illuminated by orange light of different intensity, from which kinetics of the state transition at various light intensity was determined. In