Chlorophyll *f* synthase is a unique PSII complex containing divergent copy of the D1 protein

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One route to improve crop productivity is to harvest more sunlight. This could potentially be achieved by incorporating non-native far-red absorbing chlorophylls, such as chlorophyll (Chl) f, into the photosynthetic apparatus. Chl f, produced by certain cyanobacteria, requires the expression of the ChlF subunit, a distant relative of the D1 subunit of oxygen-evolving photosystem II (PSII). Current ideas suggest that ChlF forms a homodimer. Here we show that ChlF expressed heterologously in the cyanobacterium *Synechocystis* PCC 6803 replaces D1 within PSII complexes. Remarkably, mutation of two residues in the second transmembrane helix of D1 enables oxygen-evolving PSII to produce Chl f. Our work reveals that PSII complexes have evolved to play physiological roles outside water-splitting.