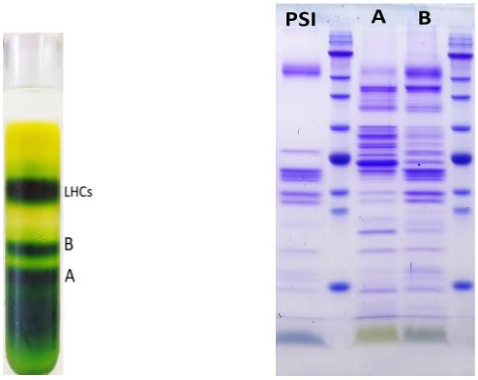


(**a**) (**b**)

Figure S1: Sucrose gradient and SDS-PAGE of *Chlorella ohadii* PSII preparation: (**a**) Sucrose density gradient of the final *Chlorella ohadii* PSII preparation. The three fractions collected are marked A, B, and LHCs. The A fraction was used for cryo-EM data collection; (**b**) SDS-PAGE of the fractions A and B and previous PSI preparation for comparison with new preparation.

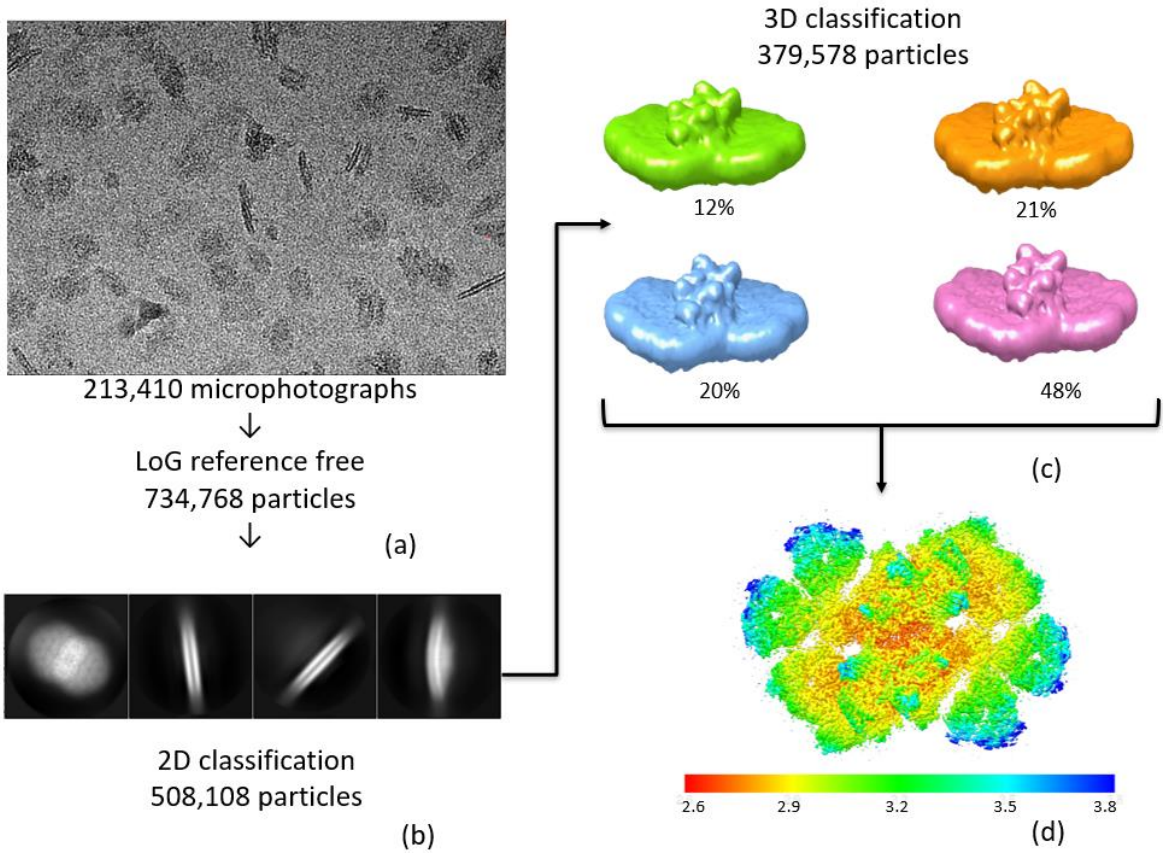


Figure S2: Cryo-EM data collection and processing scheme for unstacked PSII complex. (**a**) Sample micrograph collected for the *Chlorella ohadii* PSII dataset displaying stacked and unstacked PSII particles from multiple views; (**b**) 2D classes showing unstacked PSII complexes were created in RELION followed by 3D classification; (**c**) Chosen unstacked PSII 3D classes subjected to refinement with numbers and percentage of all chosen particles; (**d**) Final model of *Chlorella ohadii* PSII with a color-coded global resolution of 2.72 Å.

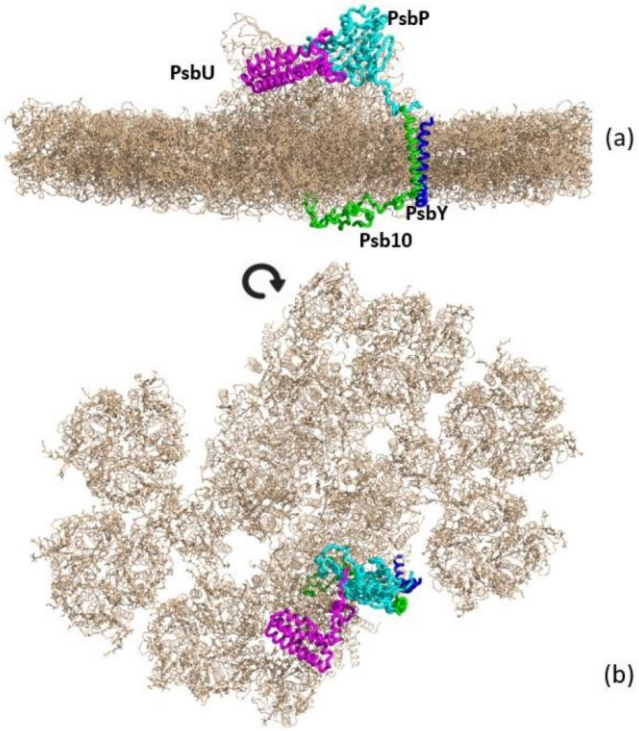
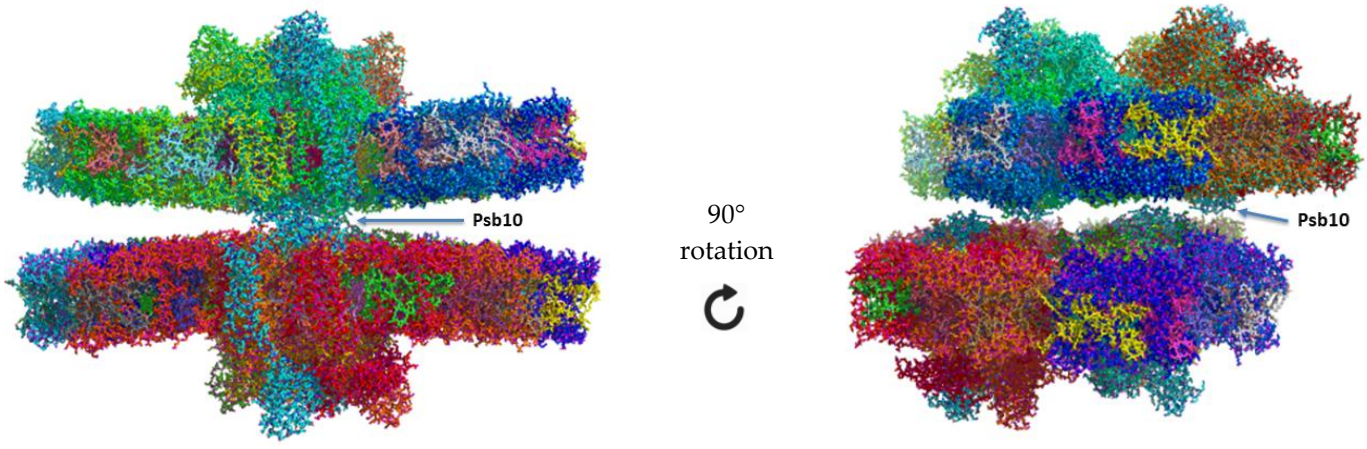


Figure S3. The added subunits are present PSII from *Chlorella ohadii* (PDB 8BD3) are shown on the background of Chlamydomonas PSII (PDB 6KAD) on which the Ohadii PSII was superimposed. PsbU is shown in magenta, PsbP is shown in cyan, PsbY is shown in blue and Psb10 is shown by green. (a) Side view along the membrane plane of PSII. (b) 90° rotation demonstrates the **t**op view of the supercomplex from the stromal side**.** Identical subunits at the same relative position are present in the second half of PSII (not shown).



(**a**) (**b**)

Figure S4: Stacked PSII from *Chlorella ohadii* showing that Psb10 is involved in the stacking formation. (**a**) Side view along the membrane plane of stacked PSII. Psb10 may provide contacts for PSII dimer stacking; (**b**) 90° rotation in the membrane plane of the complex presented on S.Fig.3a

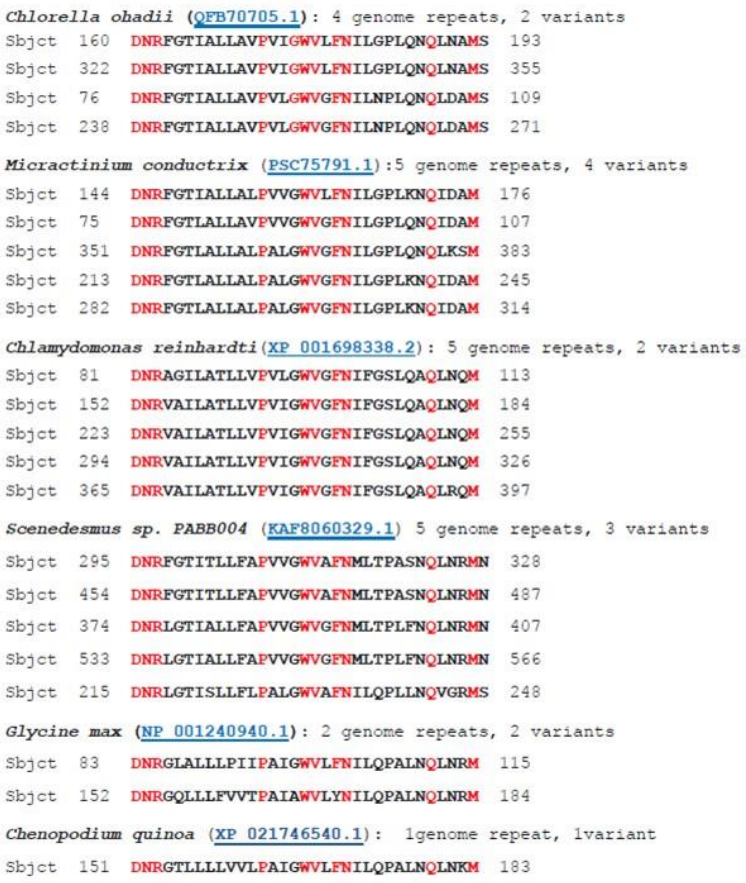


Figure S5. Number of different copies of the PsbY, presented in the single transcripts of 4 algae and 2 high plants.

In algae and other lower plant species represented in the Protein Data Bank (PDB), it is observed that there are typically 3-5 copies of the PsbY subunit present in their Photosystem II (PSII) structures. In contrast, higher plants predominantly exhibit 1 or occasionally 2 copies of the PsbY subunit in their PSII complexes.