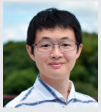
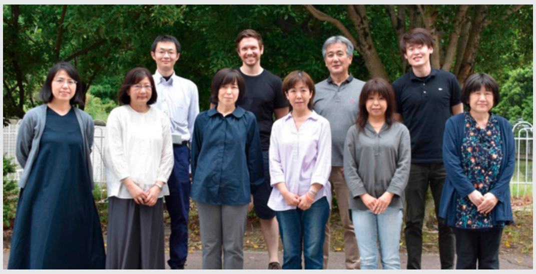
Division of Environmental Photobiology

Professor
MINAGAWA, Jun

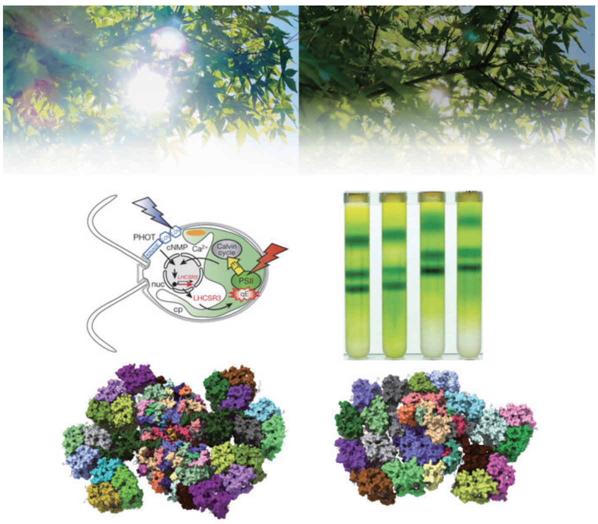


Associate Professor
YOKONO, Makio

Assistant Professor:	*KIM, Eunchul*
Specially Appointed Assistant Professor:	*KOSUGI, Makiko*
Technical Staff:	*NODA, Chiyo*
Postdoctoral Fellow:	*KAMADA, Konomi*
	ISHII, Asako
SOKENDAI Graduate Student:	*YANAKA, Ayako*
Visiting Scientist:	*DANN, Marcel*
Technical Assistant:	*YONEZAWA, Harumi*
	KADOWAKI, Tamaka
Admin Support Staff:	*TOYAMA, Mami*
	SUZUKI, Yuka



Plants and algae have versatile abilities to acclimate themselves to changing environments. We are interested in these acclimation processes, and how they efficiently yet safely harness sunlight for photosynthesis under fluctuating light conditions. Using a model green alga, we are studying the molecular mechanisms underlying photoacclimation of photosynthetic machinery. We are also applying knowledge obtained in the studies of this model green alga to various photosynthetic organisms, including phytoplankton and vascular plants, to explore how environmentally important photosynthetic organisms thrive in their ecological niche.



Visual overview of this lab's work

I. Plant and Algal PSII–LHCII Supercomplexes: Structure, Evolution and Energy Transfer.

Photosynthesis is the process conducted by plants and algae to capture photons and store their energy in chemical forms. The light-harvesting, excitation transfer, charge separation and electron transfer in photosystem II (PSII) are the critical initial reactions of photosynthesis and thereby largely determine its overall efficiency. Knowledge about the architectures and assemblies of plant and green algal PSII–light harvesting complex II (LHCII) supercomplexes are rapidly accumulating (Figure 1). We made pair-wise comparative analyses between the supercomplexes from plants and green algae to gain insights about the evolution of the PSII–LHCII supercomplexes involving the peripheral small PSII subunits that might have been acquired during the evolution (Figure

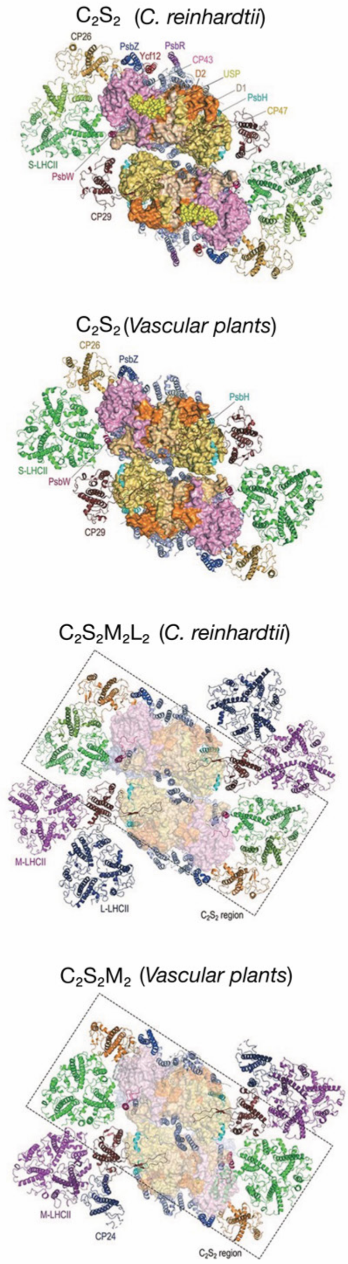


Figure 1. The overall architecture of PSII–LHCII supercomplexes from C. reinhardtii and vascular plants (C_2S_2 from Spinacia oleracea, $C_2S_2M_2$ from pea). Sheng *et al*. (2021) Plant Cell Physiol., *62*:1108-1120.

2) and about the energy transfer pathways that define their light-harvesting and photoprotective properties (Figure 3) (Sheng *et al*., *Plant Cell Physiol.*, *62*:1108-1120).

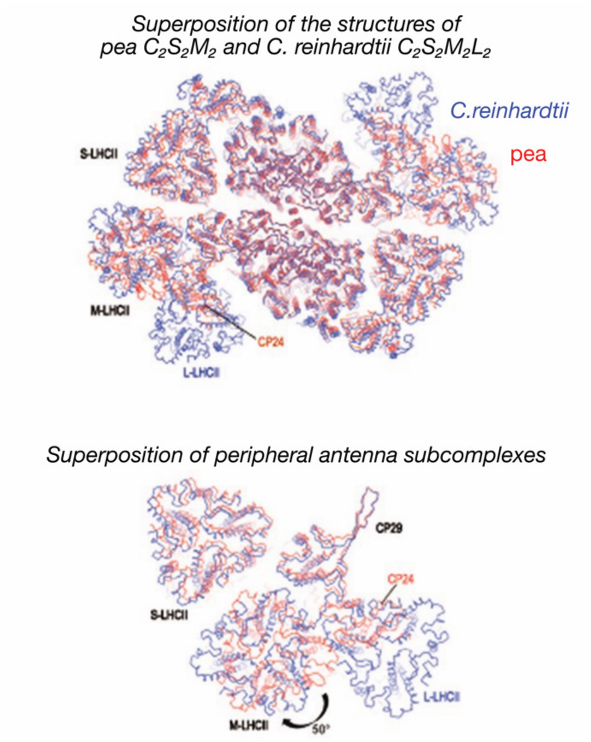


Figure 2. Superposition of green algal and plant PSII–LHCII supercomplexes and evolutionary insights from pea $C_2S_2M_2$ and *C. reinhardtii* $C_2S_2M_2L_2$ supercomplexes. Sheng *et al*. (2021) *Plant Cell Physiol.*, 62:1108-1120.

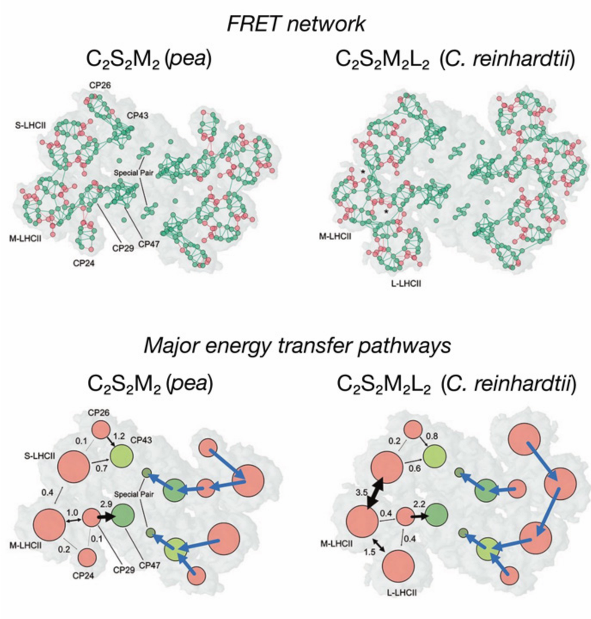


Figure 3. Förster resonance energy transfer (FRET) networks of green algal and plant PSII-LHCII supercomplexes and major energy transfer pathways. Sheng *et al*. (2021) *Plant Cell Physiol.*, *62*:1108-1120.

II. Structural basis of LhcbM5-mediated state transitions in green algae.

In green algae and plants, state transitions serve as a short-term light-acclimation process in the regulation of the light-harvesting capacity of photosystems I and II (PSI and PSII, respectively). During the process, a portion of light-harvesting complex II (LHCII) is phosphorylated, dissociated from PSII and binds with PSI to form the supercomplex PSI–LHCI–LHCII. We reported high-resolution structures of PSI–LHCI–LHCII from *Chlamydomonas reinhardtii*, revealing the mechanism of assembly between the PSI–LHCI complex and two phosphorylated LHCII trimers containing all four types of LhcbM protein (Figure 4). Two specific LhcbM isoforms, namely LhcbM1 and LhcbM5, directly interact with the PSI core through their phosphorylated amino terminal regions. Furthermore, biochemical and functional studies on mutant strains lacking either LhcbM1 or LhcbM5 indicate that only LhcbM5 is indispensable in supercomplex formation. The results unravel the specific interactions and potential excitation energy transfer routes between green algal PSI and two phosphorylated LHCIIs (Pan *et al*., *Nat. Plants*, *7*:1119-1131).

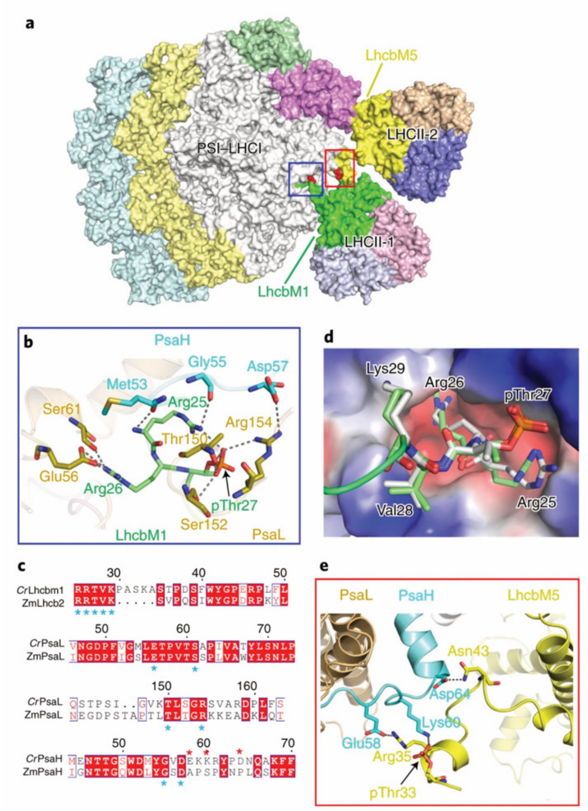


Figure 4. Surface representation of the *Cr*PSI–LHCI–LHCII supercomplex from the *pph1;pbcp* mutant strain, with pThr residues from LhcbM1 and LhcbM5 highlighted in red. **b**, Detailed interaction between the N-terminal region of LhcbM1 and PSI core subunits PsaH and PsaL. **c**, Sequence alignment of the interaction-related regions of LhcbM1, PsaL and PsaH from *C. reinhardtii* (*Cr*) with Lhcb2, PsaL and PsaH from Zm, respectively. Conserved and variant residues involved in intersubunit interactions are indicated by blue and red asterisks, respectively. **d**, Structural comparison of N-terminal five residues (shown as sticks) of *Cr*LhcbM1 (carbon atoms coloured green) and *Zm*Lhcb2 (carbon atoms coloured white). The PSI core is shown in electrostatic surface mode with red and blue representing acidic and basic regions, respectively. **e**, Detailed interactions between the N-terminal region of LhcbM5 and the PSI core subunit PsaH. Hydrogen bond interactions are shown as black dashed lines. Pan *et al*. (2021) *Nat. Plants*, *7*:1119-1131.

Publication List:

〔Original Papers〕

- Maeda, T., Takahashi, S., Yoshida, T., Shimamura, S., Takaki, Y., Nagai, Y., Toyoda, A., Suzuki, Y., Arimoto, A., Ishii, H., Satoh, N., Nishiyama, T., Hasebe, M., Maruyama, T., Minagawa, J., Obokata, J., and Shigenobu, S. (2021). Chloroplast acquisition without the gene transfer in kleptoplastic sea slugs, Plakobranchus ocellatus. eLife *10*, e60176. DOI: 10.7554/eLife.60176
- Morishita, J., Tokutsu, R., Minagawa, J., Hisabori, T., and Wakabayashi, K. (2021). Characterization of Chlamydomonas reinhardtii Mutants That Exhibit Strong Positive Phototaxis. Plants *10*, 1483. DOI: 10.3390/plants10071483
- Pan, X., Tokutsu, R., Li, A., Takizawa, K., Song, C., Murata, K., Yamasaki, T., Liu, Z., Minagawa, J., and Li, M. (2021). Structural basis of LhcbM5-mediated state transitions in green algae. Nat. Plants *7*, 1119+. DOI: 10.1038/s41477-021-00960-8
- Tanno, A., Tokutsu, R., Arakaki, Y., Ueki, N., Minagawa, J., Yoshimura, K., Hisabori, T., Nozaki, H., and Wakabayashi, K.-I. (2021). The four-celled Volvocales green alga Tetrabaena socialis exhibits weak photobehavior and high-photoprotection ability. PLoS One *16*, e0259138. DOI: 10.1371/journal.pone.0259138
- Tokutsu, R., Fujimura-Kamada, K., Yamasaki, T., Okajima, K., and Minagawa, J. (2021). UV-A/B radiation rapidly activates photoprotective mechanisms in Chlamydomonas reinhardtii. Plant Physiol. *185*, 1894–1902. DOI: 10.1093/plphys/kiab004
- Zhang, X.J., Fujita, Y., Tokutsu, R., Minagawa, J., Ye, S., and Shibata, Y. (2021). High-Speed Excitation-Spectral Microscopy Uncovers In Situ Rearrangement of Light-Harvesting Apparatus in Chlamydomonas during State Transitions at Submicron Precision. Plant Cell Physiol. *62*, 872–882. DOI: 10.1093/pcp/pcab047

〔Review Article〕

- Hippler, M., Minagawa, J., and Takahashi, Y. (2021). Photosynthesis and Chloroplast Regulation-Balancing Photosynthesis and Photoprotection under Changing Environments. Plant Cell Physiol. *62*, 1059–1062. DOI: 10.1093/pcp/pcab139
- Sheng, X., Liu, Z., Kim, E., Minagawa, J. (2021). Plant and algal PSII-LHCII supercomplexes: structure, evolution and energy transfer. Plant Cell Physiol *62*: 1108-1120. DOI: 10.1093/pcp/pcab072