Seminar

"The value of anaerobic structural biology for photosynthetic research"

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Oxygenic photosynthesis is commonly viewed through the lens of light-driven water oxidation and O_2 production. Yet many processes embedded in, or connected to, photosynthetic electron flow remain intrinsically oxygen-sensitive. This apparent paradox reflects the chemistry at the core of photosynthetic bioenergetics: low-potential electron carriers, Fe–S clusters, flavins, transition-metal centers and radical or metallocofactor enzymes are essential for electron transfer, but are often damaged, inactivated or functionally altered by oxygen.

Anaerobic structural biology therefore provides an important and often underappreciated perspective on photosynthetic research. Photosystem I and its downstream electron-transfer pathways are particularly instructive, because they connect oxygenic photosynthesis to low-potential redox chemistry. Photobiological hydrogen production represents an extreme example of this principle. The cyanobacterial bidirectional [NiFe]-hydrogenase HoxEFUYH links photosynthetic electron flow, carbohydrate-derived reductant and molecular H_2 turnover. However, its catalytic [NiFe] center and extended Fe–S relay require strict anaerobic handling for structural and mechanistic analysis. Anaerobic purification and high-resolution cryo-EM of the intact HoxEFUYH complex reveal the complete electron-transfer architecture of the enzyme, including the FMN-containing HoxEFU reductase module, the catalytic HoxYH hydrogenase core and the continuous Fe–S cluster chain that electronically couples both modules. Together with redox biochemistry and spectroscopy, these structures establish cyanobacterial HoxEFUYH as a bidirectional confurcating hydrogenase. H_2 evolution requires the simultaneous input of reduced ferredoxin and NADH, whereas H_2 oxidation couples to NAD^+ and oxidized ferredoxin. These findings revise simple models in which photosynthetic electrons alone are sufficient for cyanobacterial H_2 production and instead show that photo-H_2 metabolism integrates light-generated reduced ferredoxin with NADH derived from carbohydrate oxidation.

Thus, anaerobic structural biology is not only relevant for strictly anaerobic organisms. It is essential for understanding oxygen-sensitive chemistry that remains at the heart of photosynthetic electron flow, and for defining the molecular principles needed to engineer light-driven H_2 production and other photosynthetic redox processes.

Jan Schuller教授はドイツ・ミュンヘン郊外のマックスプランク生化学研究所で博士号を取られた気鋭の電子顕微鏡構造生物学者で、私と近い分野である生体エネルギー変換に関わるタンパク質複合体や嫌気の金属酵素を中心に構造研究を進めておられます。
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Cell **184, 3643** (2021), *Nature* **607, 823** (2022), *Science Adv.* 9, **eadg6689** (2023), *Nature* **628, 894** (2024), *Nature* **642, 814** (2025), *Nature online ahead of print* (2026) 他、*Top Journal* 多数

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Conference Room (L) at the 2nd floor, Main building, IPR
蛋白研2階 大会議室