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CONFERENCE REPORT

Gordon Research Conference on Photosynthesis 2025: Mechanisms of the Process Driving the Biosphere Through the Lenses of Experiment and Computation

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Abstract

Herein, we report on the 2025 Gordon Research Conference (27 July–1 August) and its preceding Gordon Research Seminar (26–27 July) on Photosynthesis, entitled "Mechanisms of the Process Driving the Biosphere Through the Lenses of Experiment and Computation". Both were held at Sunday River Resort in Newry, Maine, USA. The seminar and conference brought together an international group of photosynthesis researchers to discuss the most cutting-edge work uncovering photosynthetic mechanisms *via* computation, genetic manipulation, systems biology, structural biology, and much more.

Keywords: Gordon Research Conference; photosynthesis; scientific community.

Gordon Research Conference

The 2025 Gordon Research Conference on Photosynthesis, "Mechanisms of the Process Driving the Biosphere Through the Lenses of Experiment and Computation", was held at Sunday River Resort in Newry, Maine, USA, from 27 July to 1 August. The conference was chaired by Kevin Redding of Arizona State University, and co-chaired by Roberta Croce of Vrije Universiteit Amsterdam (Fig. 1). The conference brought together diverse researchers from around the world to exchange insights on the latest advancements in photosynthesis research (Figs. 2–5). Discussions covered a wide array of topics, including whole-cell perspectives, light-harvesting mechanisms, water oxidation, energy conversion, artificial photosynthesis, and the evolution and regulation of photosynthetic systems. The conference comprised 156 participants, featuring 35 oral presentations and 100 poster presentations.

Importantly, the chair introduced a new format to stimulate discussion. Research talks were scheduled for 20 min followed by 10 min of Question and Answer, rather than the traditional 25+5 format. Each scientific session concluded with a 20-minute general discussion period led by the discussion leaders, prompted by questions and ideas suggested by the session's speakers, and carried out by all interested attendees. These exchanges often led to consensus on the most critical questions to be addressed for the field.

There were nine scientific sessions, the first of which was the keynote session on "A Whole-Cell View of Photosynthesis" led by Sabeeha Merchant of the

Highlights

- Summarizes the 2025 Gordon Research Conference on Photosynthesis
- Showcases new experimental and computational insights in photosynthesis
- Highlights global collaboration and mentorship in the photosynthesis community

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University of California, Berkeley, USA. It contained three presentations: “Integrating Biological Complexity: Why Do We Need So Many Models for a Whole-Cell Understanding of Photosynthesis” by Anna Matuszynska of Rheinisch-Westfälische Technische Hochschule Aachen University, Germany, “Towards a Mechanistic

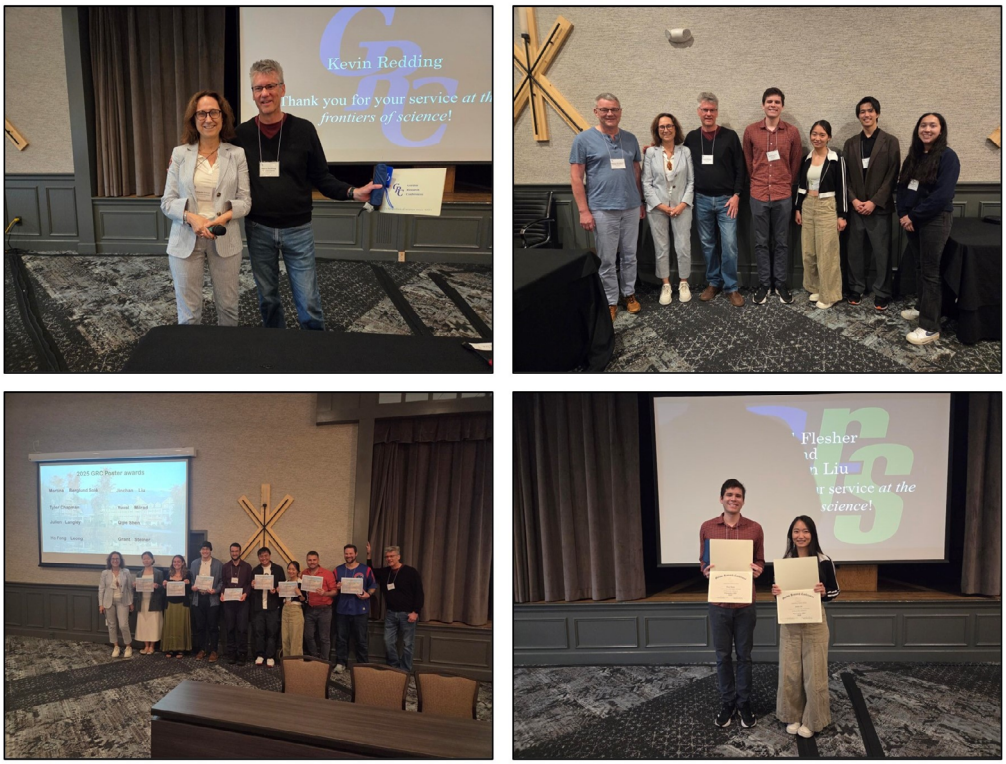

Fig. 1. *Top left*: GRC co-chair Roberta Croce and chair Kevin Redding. *Top right*: Co-chair of the upcoming 2028 GRC on Photosynthesis Helmut Kirchoff, Roberta Croce, Kevin Redding, GRS chair David Flesher, and co-chair Jinchan Liu, and the upcoming 2028 GRS chair Ko Imaizumi and co-chair Raquel Ponce. *Bottom left*: Poster prize winners. *Bottom right*: David Flesher and Jinchan Liu.

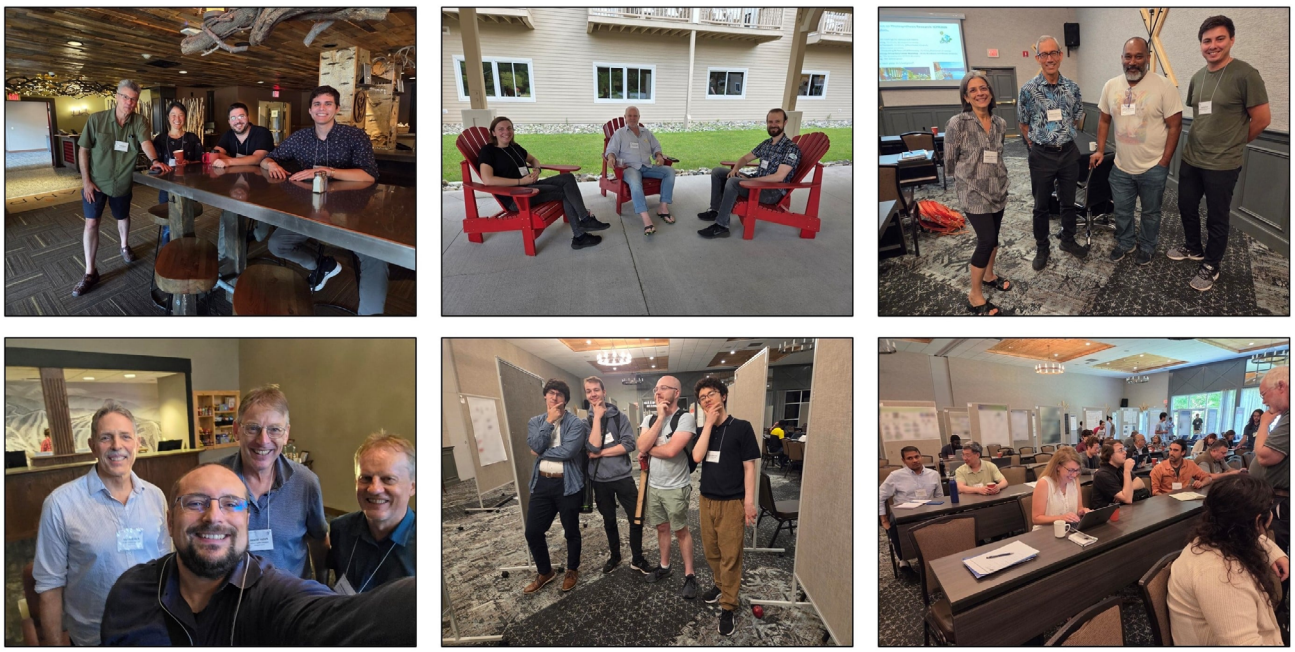

Fig. 2. *Top left*: Kevin Redding, Setsuko Wakao, Dvir Harris, and David Flesher. *Top center*: Sarah Mäusle, Gary Hastings, and Dennis Nürnberg. *Top right*: Sabeeha Merchant, Kris Niyogi, Jeffrey Moseley, and David Rolo. *Bottom left*: Robert Burnap, Christopher Gisriel, Peter Nixon, and Josef Komenda. *Bottom middle*: Tyler Chapman, Felix Lindner, Samuel Nix, and Kenta Renard. *Bottom right*: Candid photo of the conference room between sessions.

Fig. 3. *Top left*: Jesse Granstrom, Michal Koblížek, Josef Komenda, and Hiroki Makita. *Top right*: Divya Matta, William Armstrong, and Gary Brudvig. *Bottom left*: Nicoletta Liguori, Michal Gwizdala, and Qijie Shen. *Bottom right*: Maximino Emerson, Christian Brininger, and Christopher Gisriel.

Understanding on How Cells Balance Reductive Chloroplast Metabolism *via* Ferredoxin Isoforms" by Daniela Strenkert of Michigan State University, USA, and "Exploring the Diatom Pyrenoid: Insights From Icelandic Environmental Samples" by Manon Demulder of Biozentrum Basel, Switzerland.

The second session was on "Light Harvesting and Antenna Systems" led by Doran Raccah of the University of Texas, Austin, USA. This session contained four presentations: "Far-Red Photosynthesis with a Minimal Gene Set" by Dennis Nürnberg of Freie Universität Berlin, Germany, "Probing the Red Chlorophylls of Photosystem I with Multispectral Multidimensional Spectroscopy" by Jessica Anna of the University of Pittsburgh, USA, "Dynamical Multiscale Simulations for the Exciton Dynamics in Plants and Diatoms" by Ulrich Kleinekathöfer of Constructor University, Bremen, Germany, and "Photosynthetic Proteins in Action: Towards a Real-Time Investigation of How Light Harvesting is Regulated in Plants" by Nicoletta Liguori of the Institute of Photonic Sciences, Spain.

The third session was on "Diversity of Photosynthetic Processes", led by Tomas Morosinotto of the University of Padova, Italy. The session contained three presentations: "Unraveling Regulation of Photosynthesis with Emerging Algal Systems" by Melissa Roth of the University of California, Berkeley, USA, "About the Biosynthesis of Carotenoids in Diatoms" by Graham Peers of Colorado State University, USA, and "Photosynthesis in the Dynamic Light and Nutrient Environments of the Oceans" by Alexandra Worden of the Marine Biological Laboratory, USA.

The fourth session was on "Photosynthetic Reaction Centers", led by Dimitrios Pantazis of the Max-Planck-Institut für Kohlenforschung, Germany. The session contained five presentations: "Time Resolved Structural Studies of Photosynthetic Reaction Center Proteins" by Jan Kern of Lawrence Berkeley National Laboratory, USA, "Broadband Fluorescence-Detected Two-Dimensional Electronic Spectroscopy: Challenges and Benefits in Studying Photosynthetic Systems" by Jennifer Ogilvie of the University of Ottawa, Canada, "Unexpected Photochemistry from what Eon" by Philip Laible of Argonne National Laboratory, USA, "Mechanism of Dynamic Assembly of Plant Rubisco Activase" by Po-Lin Chiu of Arizona State University, USA, and "Two Solutions for Efficient Light-Harvesting in Phototrophic *Gemmatimonadota*" by Michal Koblížek of the Czech Academy of Sciences, Czech Republic.

The fifth session was on "Water Oxidation" and was led by Junko Yano of the Lawrence Berkeley National Laboratory, USA, and contained three presentations: "Computational Studies of the OEC in Photosystem II: O6 Myth or Reality" by Victor Batista of Yale University, USA, "Developing the Fastest-Growing Phototrophs with Photosystem II-Cyclic Electron Flow" by Colin Gates of Loyola University Chicago, USA, and "Assignment of the Substrate Waters of Oxygen Production in Photosystem II" by Johannes Messinger of Umeå University, Sweden.

The sixth session was on "Electron, Proton, and Ion Transport" and was led by Marilyn Gunner of City College of New York, USA. It contained five presentations: "Uncovering Ion Transporters Important for Photosynthetic Function" by Cornelia Spetea of the University of Gothenburg, Sweden, "Action at a Distance: The Remarkable Coupling of CO_2 Uptake to Electron Transfer in Cyanobacterial NDH-1 Complexes" by Robert Burnap of Oklahoma State University, USA, "Modeling the Energy Economy of a Photosynthetic Cell in Terms of the Rate Limitation of Transport Processes" by Melih Sener of Arizona State University, USA, "Downregulation of Photosynthetic Electron Transport through the Luminal Acidification" by Toshiharu Shikanai of Kyoto University, Japan, and "Molecular Operation and Regulatory Function of Cytochrome b_6f: Insights from Structural and Spectroscopic Studies" by Patryk Kuleta of Jahiellonian University, Poland.

The seventh session was on "Bioenergy and Artificial Photosynthesis" and was led by Matthew Posewitz of the Colorado School of Mines, USA. It contained three presentations: "Brothers From Another Mother: Probing Chlorophyll Biosynthesis, Electron Transfer and GreenCut Targets with *Chlamydomonas* and *Auxenochlorella*" by

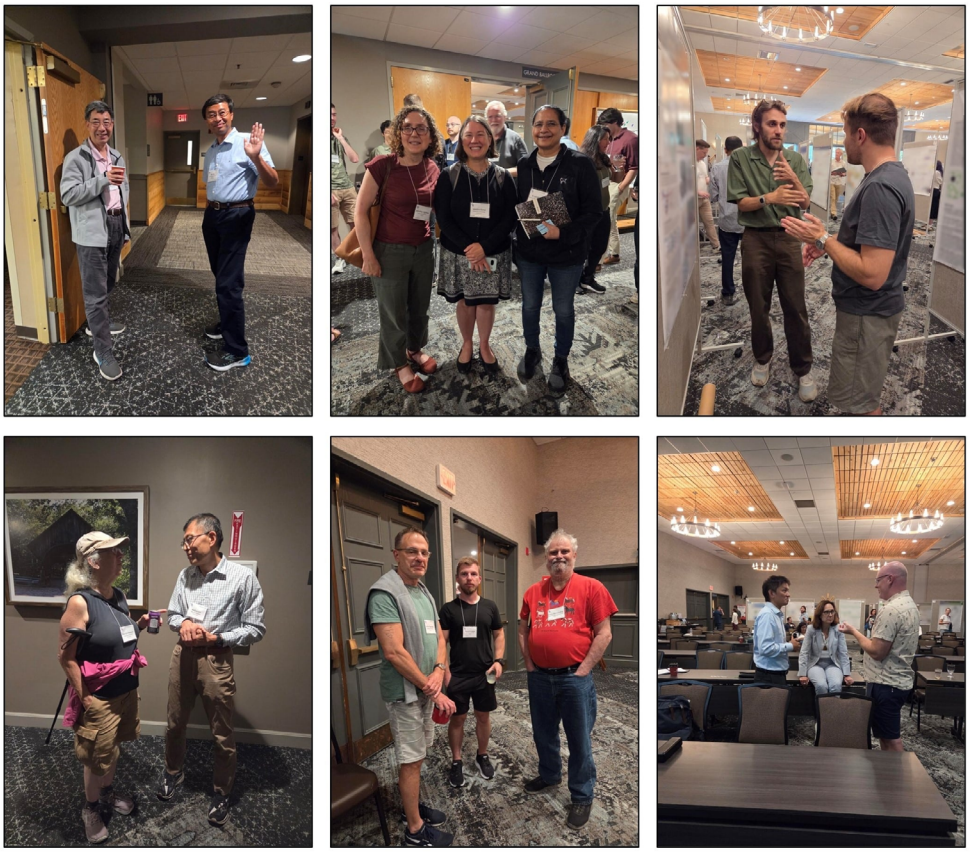

Fig. 4. *Top left*: Harvey Hou and Wu Xu. *Top center*: Jennifer Ogilvie, Jessica Anna, and K.V. Lakshmi. *Top right*: Giovanni Consoli discussing his poster. *Bottom left*: Marilyn Gunner and Haijun Liu. *Bottom center*: Artur Osyczka, Patryk Kuleta, and Robert Blankenship. *Bottom right*: Kentaro Ifuku, Roberta Croce, and Graham Peers.

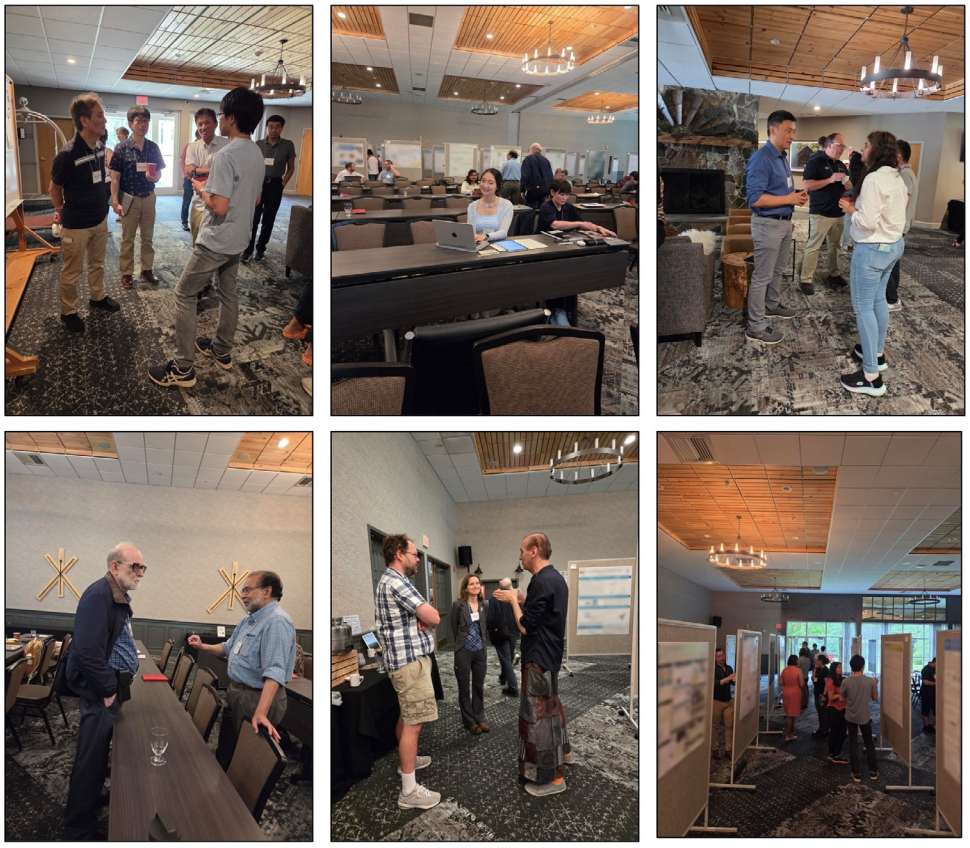

Fig. 5. *Top left*: Jun Minigawa, Ryouichi Tanaka, Kentaro Ifuku, Haruhiko Jimbo, and Wu Xu. *Top center*: Jinchan Liu (center) organizing notes during coffee break. *Top right*: Xin Wang, Michael Vaughn, and Nidhi Kulkarni. *Bottom left*: Richard Debus and Vittal Yachandra. *Bottom center*: Joshua Vermaas, Rebecca Roston, and Melih Sener. *Bottom right*: Candid photo during a poster session.

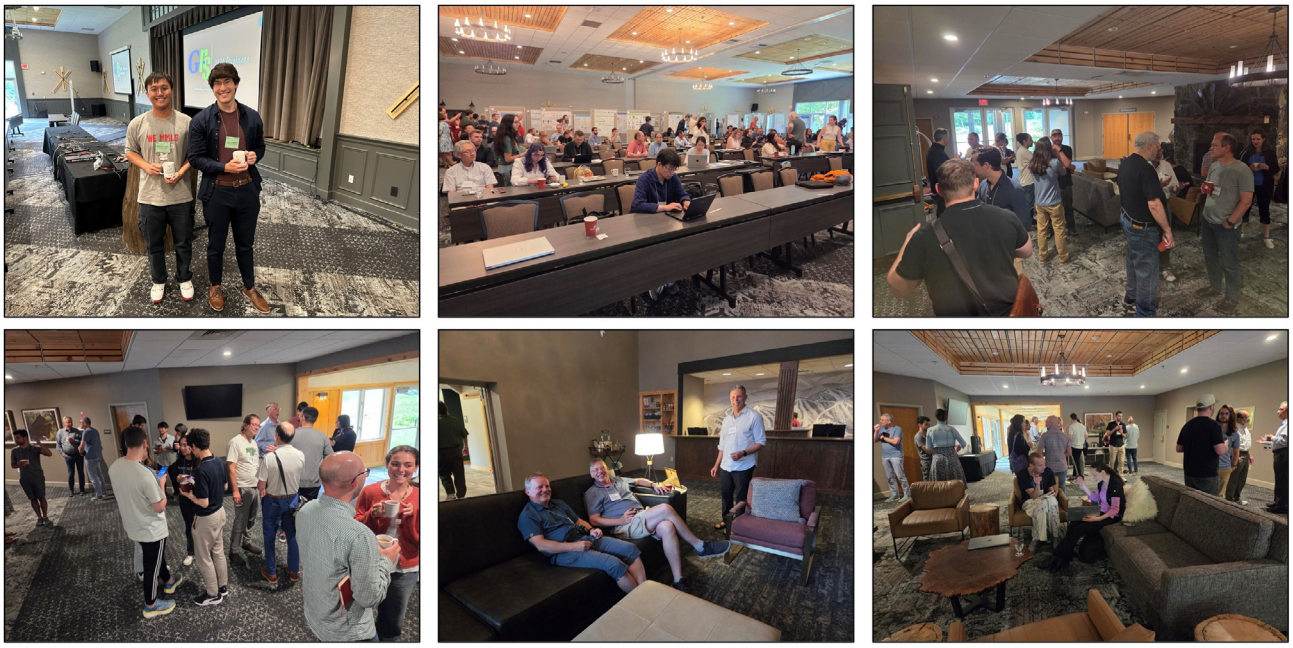

Fig. 6. *Top left*: Ho Fong Leong and Tyler Chapman receiving their GRS celebratory mugs for being voted "the most interesting science" and "the most digestible talk" for their research presentations. *Top center*: A group preparing for the next talk with Michi Suga in the center. *Top right*: Candid photo of a break session. *Bottom left*: Candid photo of a break session. *Bottom center*: Josef Komenda, Peter Nixon, and Robert Burnap. *Bottom right*: Candid photo of a break session with Melih Sener and Daniela Strenkert talking in the center.

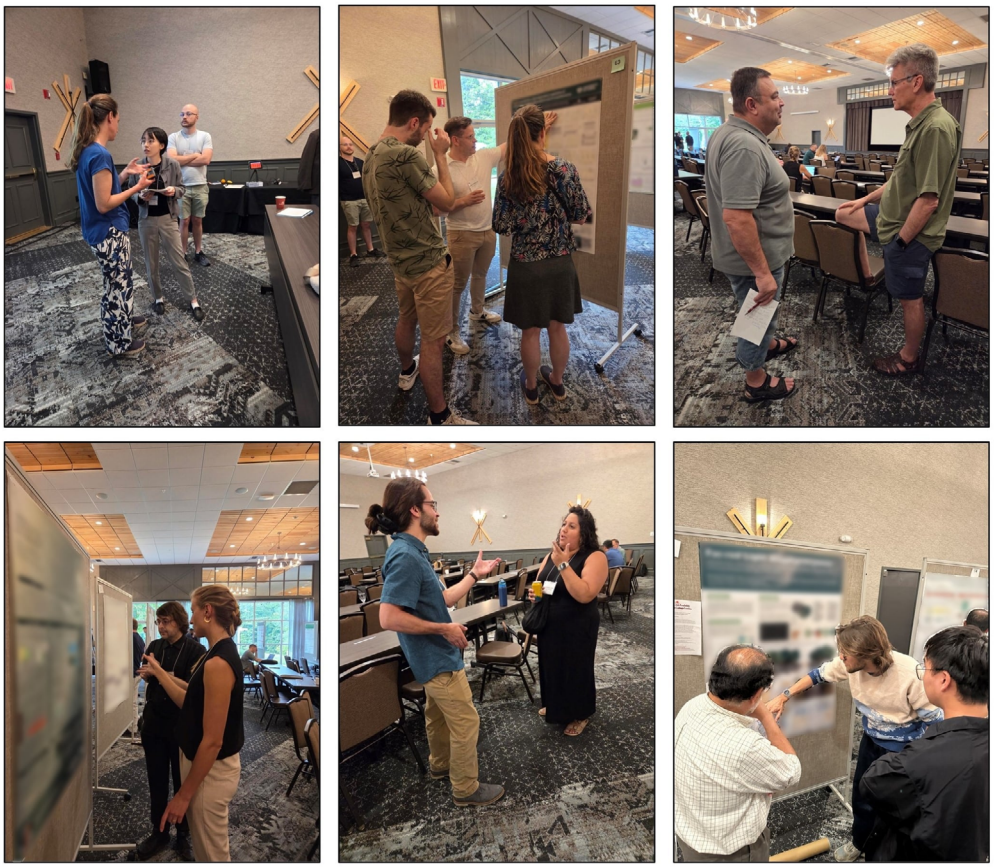

Fig. 7. *Top left*: Emilie Wientjes, Asuka Nakamura, and Samuel Nix. *Top center*: Lauri Nikkanen discussing his poster. *Top right*: Fikret Mamedov and Kevin Redding. *Bottom left*: Colin Gates and Sara Jaehnert. *Bottom center*: Maximino Emerson and Maayan Suissa Szlejf. *Bottom right*: Giovanni Consoli presenting his poster to Vittal Yachandra and Ho Fong Leong.

Jeffrey Moseley of the University of California, Berkeley, USA, "Engineering Photosynthesis through Computational Protein Design" by Nathan Ennist of the University of Washington, USA, and "Photosynthetic Microbes for Bioproduction: Challenges and Opportunities" by Himadri Pakrasi of Washington University in Saint Louis, USA.

The eighth session was on "Regulation and Assembly of Photosynthetic Systems" and was led by Krishna Niyogi of the Howard Nughes Medical Institute and University of California, Berkeley, USA. It contained six presentations: "Molecular Mechanisms of Thylakoid Membrane Assembly: The Role of Contact Site Proteins" by Rebecca Roston of the University of Nebraska Lincoln, USA, "Comprehensive Analyses of LHC Proteins Reveal New Components Regulating NPQ in the Diatom" by Kentaro Ifuku of Kyoto University, Japan, "The Dynamic Thylakoid Structure and Organization" by Emilie Wientjes of Wageningen University and Research, The Netherlands, "Engineering Chlorophyll *f* into the Photosynthetic Apparatus" by Peter Nixon of Imperial College, UK, "Chloroplastic Ascorbate Modulates Metabolism Independent of Oxidative Stress" by Szilvia Toth of HUN-REN Biological Research Centre, Szeged, Hungary, and "Robust Light-Harvesting Properties Upon Low Light Acclimation in Purple Bacteria" by Dvir Harris of Israel Institute of Technology, Israel.

The ninth and final session was on "Evolutionary Aspects of Photosynthesis" and was led by Debashish Bhattacharya of Rutgers University, USA. It contained three presentations: "The Evolutionary Origin of a Unique Purple-Green Photo-Symbiosis" by Sergio Munoz-Gomez of Purdue University, USA, "The Endosymbiotic Ratchet: A *Paulinella* Story" by Julia Van Etten of Woods Hole Oceanographic Institution, USA, and "Evolutionary Diversification of Far-Red Light-Harvesting Complexes in Cyanobacteria" by Scott Miller of the University of Montana. The full program is available at https://www.grc.org/photosynthesis-conference/2025/.

After each session, an additional extended discussion session was held in which all the speakers from the session were brought together and discussed audience questions about the broader themes in the research field on the session topic. These discussions highlighted broader trends and big picture ideas in the photosynthesis field and often carried over into the coffee and free time.

Near the end of the conference, eight prizes were given to outstanding poster presenters including six graduate students and two postdocs, each being provided with a certificate of recognition (Fig. 1). These were graduate student Martina Berglund Solé from the Institute of Photonic Sciences, Spain, graduate student Tyler Chapman from Washington State University, USA, postdoc Julien Langley from Australian National University, Australia, graduate student Ho Fong Leong from Imperial College London, UK, graduate student Jinchan Liu from Yale University, USA, postdoc Yuval Milrad from the University of Münster, Germany, graduate student Qijie Shen from the University of Chicago, USA, and graduate student Grant Steiner from Loyola University Chicago, USA.

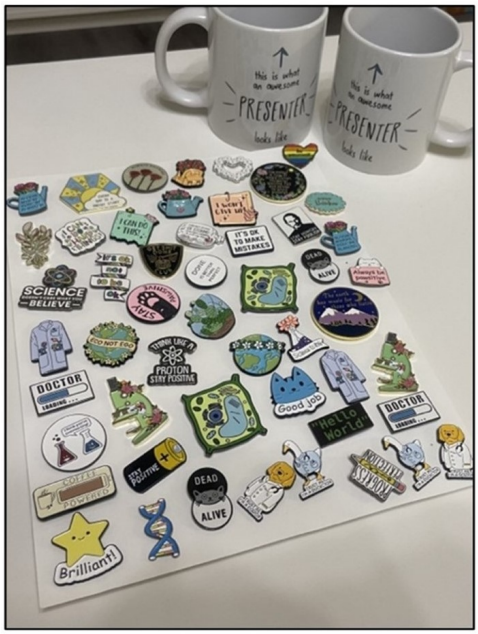

Fig. 8. Scientific pins and mugs used at the 2025 Gordon Research Seminar. Pins were awarded to students who asked questions during talks, while mugs were presented to the winners of the "most interesting science" and "most digestible talk" awards. These items fostered engagement, encouraged discussion, and added a sense of fun to the seminar.

Gordon Research Seminar

Before the main conference was the Gordon Research Seminar, which spanned 26–27 July and was entitled "Photosynthesis Across Molecular, Cellular and Ecological Scales". This event offered a valuable opportunity for graduate students and postdoctoral researchers to share their work through oral and poster presentations, priming these trainees for participation at the Gordon Research Conference. Their research explored both the underlying mechanisms of photosynthesis and the cutting-edge methodologies used to investigate them. The seminar was co-chaired by David Flesher and Jinchan Liu (Fig. 1), both graduate students at Yale University, USA. It comprised 46 participants featuring 16 student research presentations and 44 poster presentations.

Throughout the Gordon Research Seminar, the co-chairs, David Flesher and Jinchan Liu, sought to encourage young scientists to network and engage in scientific discussion. Towards this goal, the first session began with an ice breaker where all attendees were given time to introduce themselves to two people they had never met before on the other side of the seminar room. Furthermore, Jinchan Liu prepared a special system in which students who asked questions during the Question and Answer portion of research presentations were given a scientific pin (Fig. 8). These pins were the envy of faculty during the subsequent Gordon Research Conference. Finally, attendees could vote *via* an online system for the "most interesting science" and "most digestible talk" from the research

presentations. The winners received scientific mugs, with Ho Fong Leong of Imperial College London, UK, receiving the "most interesting science" mug and Tyler Chapman of Washington State University, USA, receiving the "most digestible talk" mug.

The Gordon Research Seminar comprised four sessions, beginning with a mentorship session chaired by Raquel Ponce of the University of California, Berkeley, USA. It contained one presentation entitled "Graduate Student to PI: How to Achieve a Successful Academic Career as a Photosynthesis Researcher" by Christopher Gisriel (Fig. 2) of the University of Wisconsin-Madison, USA.

The second session was "Tuning Electron Flow: Mechanisms and Engineering of Photosynthetic Charge Transfer", which was chaired by Qijie Shen of the University of Chicago, USA. It contained eight presentations: "Manipulating Photosynthetic Electron Transfer Post Photosystem I Under Anoxia" by Sara Jaehnert of Tel Aviv University, Israel, "The Influence of Chloride on Electron Transfer and Stability in Photosystem II of *Limnospira maxima*" by Leslie Castillo of Loyola University Chicago, USA, "Engineering of an Extrinsic Subunit of Photosystem II to Enhance the Water Oxidation Activity" by Ko Imaizumi of Kyoto University, Japan, "Time-Resolved Single-Frequency IR Spectroscopy Provides Insight into the Functioning of Photosystem II" by Sarah Mäusle of Freie Universität Berlin, Germany, "Investigation of the Secondary Acceptor in the Heliobacterial Reaction Center Using Site-Directed Mutagenesis" by Jesse Granstrom of Arizona State University, USA, "Designing Model Photosystems for Tracking Protein Dynamics in Chromophore's Light-Harvesting Properties" by Gonzalo Pérez Serrano of IMDEA Nanoscience, Spain, "Probing the Timescales of the Orange Carotenoid Protein Photoactivation" by Michal Gwizdala of the Institute of Photonic Sciences, Spain, and "Charge Transfer and Chlorophyll *f* Photochemistry in Far-Red-Light Adapted Photosystem I" by Julien Langley of Australian National University, Australia.

The third session was "Light, Stress, and Adaptation: Structural and Regulatory Tuning of the Photosynthetic Apparatus", which was chaired by Geoffry Davis of the Ludwig-Maximilians Universität München, Germany. It also contained eight presentations: "In the Canopy's Shadows: Functional Assessment of Red Chlorophyll Absorption Forms in Higher Plants" by Antonello Amelii of the University of Verona, Italy, "Far-Red Chlorophylls and Where to Find Them: Structure of Far-Red Photosystem II" by Ho Fong Leong of Imperial College London, UK, "The Effect of Light Intensity on Phycobilisome Complexes' Architecture and Composition" by Maayan Suissa Szlejf of the Israel Institute of Technology, Israel, "Uncovering a Hidden Role of PsbS in Zeaxanthin-Dependent qE in *Arabidopsis thaliana*" by Raquel Ponce of the University of California, Berkeley, USA, "Molecular Determinants of the Mechanism of Action of PSBS under the Computational Microscope" by Gregor Hill of the Institute of Photonic Sciences, Spain, "Understanding the Protective Mechanism of Glycine Betaine for Photosystem II Functionality" by Tyler Chapman of Washington State University, USA, "The Relation Between Interspecific Variations in Photosynthetic Assimilation and the Rate Constants of Photodamage and

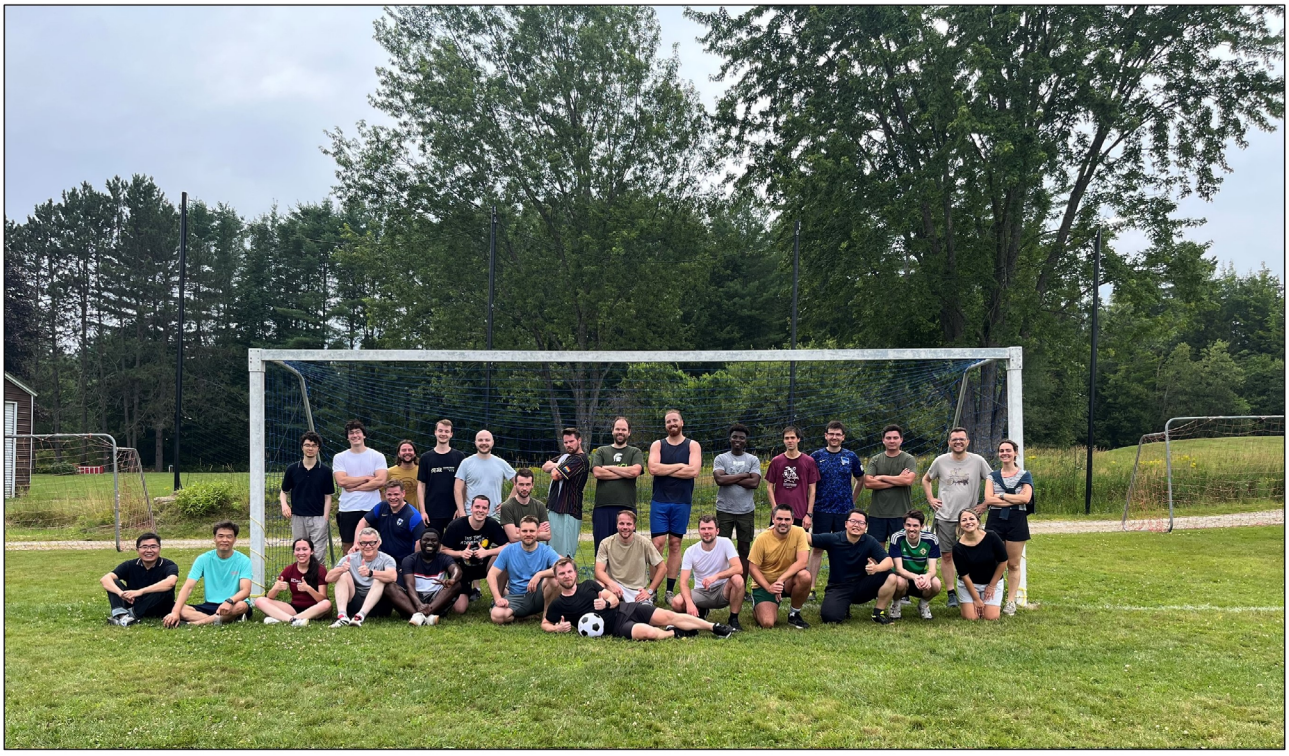

Fig. 9. Photo after the traditional US *vs* rest-of-the-world soccer (football) game. This year, the rest-of-the-world team won.

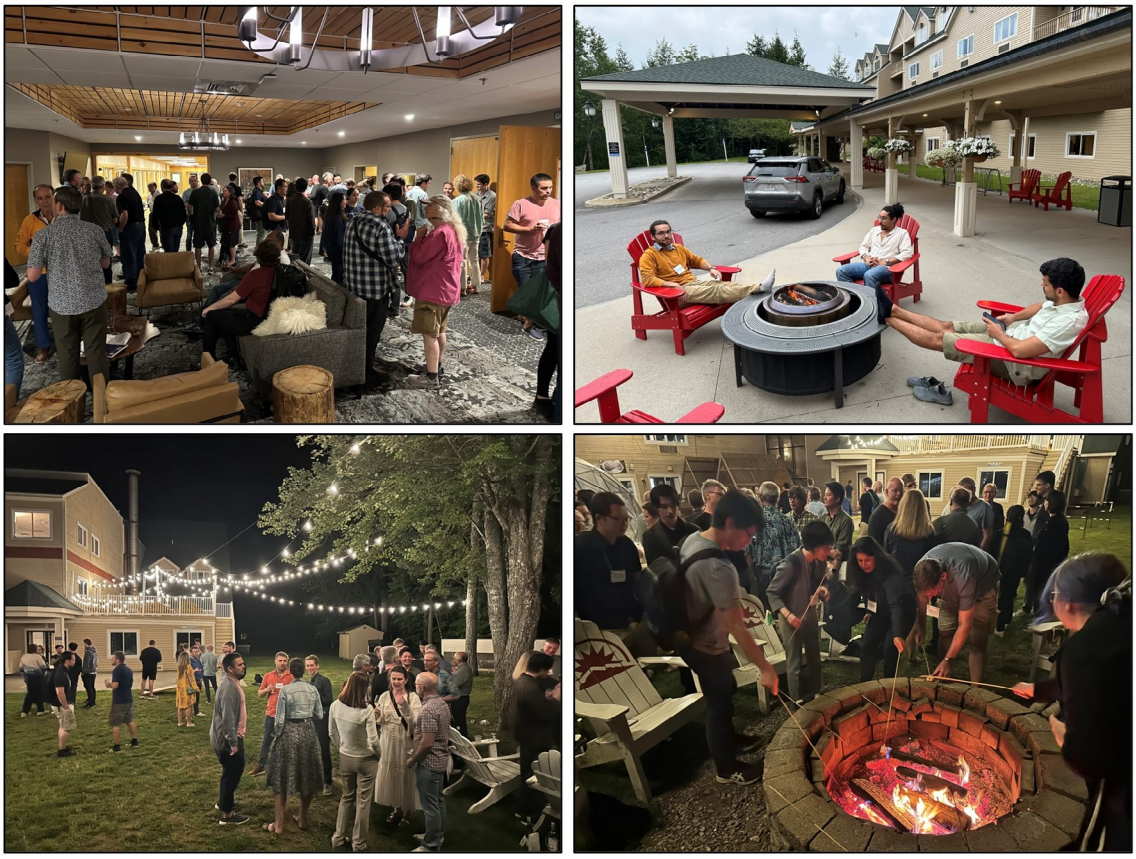

Fig. 10. Candid photos of free time.

Repair of Photosystem II Among Various Woody Species" by Shoko Tsuji of Kyoto University, Japan, and "Confocal Microscopy of Tagged Proteins in *Chlamydomonas* Under Varying Metabolic Processes Shows Dynamic Protein Localizations" by Nidhi Kulkarni of Louisiana State University, USA.

The seminar closed with a keynote session called "Molecular Mechanisms of Photosynthesis" and was chaired by Yuval Milrad of the University of Muenster, Germany. It contained a single presentation: "Fifty Years of Photosynthesis: My Scientific Journey" by Robert Blankenship (Fig. 4) of Washington University in Saint Louis, USA. The complete program can be found at https://www.grc.org/photosynthesis-grs-conference/2025/.

Concluding remarks

The 2025 Gordon Research Conference and Seminar on Photosynthesis provided an exceptional venue for photosynthesis researchers to engage in meaningful scientific exchange, mentorship, and community building. From early-career researchers presenting their first poster to senior investigators delivering keynote presentations, the event cultivated growth in the field and fostered dynamic interactions. The breadth of topics, from atomic-level mechanisms to whole-cell systems, artificial photosynthesis, and ecological descriptions, revealed a community deeply engaged with both fundamental science and broader applications of photosynthesis.

A recurring theme throughout both the seminar and the main conference was the integration of experimental and computational approaches to unravel the complexities of photosynthetic systems. Talks consistently emphasized the importance of cross-disciplinary methods, such as structural biology, biophysics, genetics, and modeling, reflecting the field's shift toward a more holistic understanding of energy conversion in nature.

Beyond the formal sessions, informal discussions, poster sessions, and structured forums such as the Power Hour and Science and Politics discussion encouraged thoughtful conversations about equity, career development, and the societal role of scientific research. These moments were as important as the scientific talks in fostering a sense of shared purpose and scientific curiosity. Furthermore, the conference was simply great fun (Fig. 9 and Fig. 10). Overall, the conference reaffirmed photosynthesis research as a vibrant, inclusive, and forward-looking field, committed to fundamental discovery and its translation into solutions for global energy and sustainability.