

Gordon research conference on photosynthesis: from evolution of fundamental mechanisms to radical re-engineering

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Abstract We provide here a *News Report* on the 2014 Gordon Research Conference on Photosynthesis, with the subtitle “From Evolution of Fundamental Mechanisms to Radical Re-Engineering.” It was held at Mount Snow Resort, West Dover, Vermont, during August 10–15, 2014. After the formal sessions ended, four young scientists (Ute Ambruster of USA; Han Bao of USA; Nicoletta Liguori of the Netherlands; and Anat Shperberg-Avni of Israel) were recognized for their research; they each received a book from one of us (G) in memory of Colin A. Wraight (1945–2014), a brilliant and admired scientist who had been very active in the bioenergetics field in general and in past Gordon Conferences in particular, having chaired the 1988 Gordon Conference on Photosynthesis. (See an article on Wraight by one of us (Govindjee) at <http://www.life.illinois.edu/plantbio/Features/ColinWraight/ColinWraight.html>.)

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Introduction

The 2014 Gordon Research Conference (GRC) on Photosynthesis was held during August 10–15, 2014, at Mount Snow Resort, West Dover, Vermont. For a brief history of this conference, see <http://www.grc.org/conferences.aspx?id=0000207>. The 2014 conference was chaired by David M. Kramer (Michigan State University; Fig. 1, top left; and bottom left); the Vice Chair was one of us (Fabrice Rappaport; Fig. 1, top left; and bottom right). Arthur Grossman (Carnegie Institute of Science, at Stanford; Fig. 1, right) will serve as Vice Chair at the 2015 Gordon Research Conference on Photosynthesis, where Fabrice will be the Chair. All are welcome to watch for the announcement in *Science* and apply in advance.

The 2014 conference had an emphasis on “From Evolution of Fundamental Mechanisms to Radical Re-Engineering” that can contribute to the development and use of solar energy as a renewable energy source.

This conference was quite international. Although about 50 % of ~170 participants were from USA, 10–15 each came from Germany, the Netherlands, and the United Kingdom, and 2–7 each came from Australia, Czech Republic, Finland, France, Italy, Israel, Japan, and Poland. Lastly, one each came from Argentina, Australia, Belgium, Canada, China, Hungary, New Zealand, Norway, and Taiwan. In fact, more than 20 countries were represented at this conference. Fig. 2 shows a group photograph of most of the participants.

Fig. 1 *Top left: (left to right) Fabrice Rappaport (Vice Chair, 2014) and David Kramer (Chair, 2014). Top right: Arthur Grossman (Vice Chair, 2015). Bottom left: David Kramer with Junko Yano. Bottom right: Fabrice Rappaport with Alizée Malnoë (Chair of the 2015 Photosynthesis Gordon Research Seminar, GRS) handing over the GRS diploma to Eliezer M. Schwarz (2014 Chair of GRS)*



Speakers

Reflecting the interdisciplinary nature of photosynthesis research, a diverse group of international speakers presented a variety of scientific approaches to investigate photosynthesis for the benefit of mankind. Speakers and Discussion leaders included (in alphabetical order) James Allen; Ute Armbruster; Eva Mari Aro; Benjamin Bailleul; Leeat Bar-Eyal; Robert Blankenship; Katharina Brinkert; David Britt; Donald Bryant; Kai Cormann; Nicholas Cox; Roberta Croce; Richard Debus; P. Leslie Dutton; Giovanni Finazzi; Marc Fontecave; Petra Fromme; John Golbeck; Arthur Grossman; Leonardo Guidoni; Marilyn Gunner; Guy Hanke; Michael Hippler; C. Neil Hunter; Anne Jones; Martin Jonikas; Radek Kana; Nir Keren; Helmut Kirchhoff; Diana Kirilovsky; Josef Komenda; Haijun Liu; Johannes Messinger; Jun Minagawa; Gary Moore; Eva Nowack; Fabrice Rappaport; Elisabet Romero; William Rutherford; David Swainsbury; Gregory Scholes; Gabriela Schlau-Cohen; Mark Aurel Shoettler; Cornelia Spetea; Hristina Staleva-Musto; Janina Steinbeck; and Junko Yano. Figures 3, 4 and 5 show some of the speakers, with other participants.

Topics of the talks

Topics included new approaches and radical re-engineering of photosynthesis (re-engineering biological enzymes to exploit their catalytic feat; as well as re-wiring photosynthesis; and toward artificial and bio-inspired photosynthesis). In addition, we had sessions on light harvesting; reaction centers (from their basic functions to their redesign); Oxygen evolution; and the electronic and ionic circuits of photosynthesis: protons and ions.

Topics of the posters

There were more than 130 poster presenters. On the first two days, we had about 30 posters each, distributed into two major topics: *Light harvesting: mechanism and regulation*; and *Reaction centers: basic functions and engineered*. On the third and fourth days, we had about 30 posters each, almost equally distributed into the following three topics: *Regulation, biodiversity, and evolution of photosynthesis*; *Metal centers: water oxidizing complex and iron sulfur*; and *Photosynthetic electronic and ionic circuits*.



Fig. 2 A group photograph of participants at the 2014 Gordon Research Conference on “Photosynthesis: From Evolution of Fundamental Mechanisms to Radical Re-Engineering,” August 10–15, 2014, Mount Snow Resort, West Dover, Vermont. Chair: David Kramer; Vice Chair: Fabrice Rappaport. *This photo is a courtesy of Gordon Research Conference, provided to Govindjee by Gerri A. Miceli, Program Manager Gordon Research Conferences.* The participants are (row-wise, left to right) as follows: Row 1 Diana Kirilovsky, Srividya Ganapathy, Nicoletta Liguori, Sophie Clowez, Charusheela Ramanan, Dortha Eisele, Elisabeth Romero, David Kramer, Fabrice Rappaport, Govindjee, Nigar Ahmadova, Misato Teramura, Anat Shperberg-Avni, Orly Levitan, Fedor Kazminov, Tanat Cardona, Su Lin, and Anthony Larkum. Row 2 Atsuko Kanazawa, Han Bao, Robert Niederman, Johannes Messinger, Bart van Oort, Swarnavo Sarkar, Anne Jones, Petra Fromme, Tien Olson, Hiroki Makita, Chris Schroeder, Gabriela Schlauf-Cohen, Junko Yano, Julian Eaton-Rye, and Gary Brudvig. Row 3 Patrick Saboe, P. Leslie Dutton, Donald Bryant, Erika Erickson, Katie Grayson, Eva Nowack, Roberta Croce, Montserrat Perez Navarro, Sarah Soltan, Leeat Bar-Eyal, Anjali Pandit, James Allen, Joann Williams, Sebastian Szweczyk, Gary Moore, and Michael Hippler. Row 4 Harvey Jian-Min Hou, Josef Komenda, Maxim Gorbunov, Mark Schoettler, Jeremy Harbinson, Stenbjorn Styring, Gennady Ananyev, Richard Debus, Terry Bricker, Serget Savikhin, Colin Gates, Imre Vass, Cornelia Spetea Wiklund, Wojciech Giera, Daniel Ducat, and Jiali Li. Row 5 Danilo Pivano, Tomas Morosinotto, Michael Jones, C. Neil Hunter, Joseph Tang, Kai Cormann, Mikko Tikkanen, Nicholas Sauter, Roman Sobotka, Esa Tyysjärvi, Daniel Canniffe, Heta Mattila, Amy Stevens, and Damian Carrieri. Row 6 Radek Kana, Raimund Fromme, Lijin Tian, Guy Hanke, Thea Pick, Nicholas Paul, Marc Nowaczyk, Ronald Pace, Luca Bersanini, Andrei Herdean, Tomas Polivka, Michael Nuccio, Giovanni Finazzi, Kentaro Inoue, and Katharina Brinkert. Row 7 Michal Gwizdala, Wade Johnson, Fikret Mamedov, Holger Dau, Robert Burnap, Nico Betterle, Joel Kamwa, Guannan He, Paul Oyala, David Tiede, Vital Yachandra, Samansa Maneshi, and Felix Ho. Row 8 Robert Blankenship, Gadriel Saper, Peter Jahns, Rienk Van Grondelle, Oliver Caspari, Gregory Scholes, Ricarda Hoehner, Janina Steinbeck, Jianping Yu, Anagha Krishnan, Sahr Khan, David Swainsbury, Lene Hau, and Sujith Puthiya Veetil. Row 9 Krzysztof Gibasiewicz, Helmut Kirchhoff, Hans-Henning Kunz, Bryan Ferlez, Wojciech Nawrocki, Peter Dahlberg, Cristian Sanchez, Brad Abramson, David Vinyard, Herbert Van Amerongen, Volha Chukhutsina, Mikhail Askerka, Hristina Staleva-Musto, and Marius Reitegan. Row 10 Benjamin Baillieul, Rafael Picorel, Elmars Krausz, Leonardo Guidoni, Cheng Zhao, Xin Wang, Ben Lucker, Martin Hohmann-Marriott, William Rutherford, Martin Jonikas, R. David Britt, Alizée Malnoé, and Dagmar Lyska

Fig. 3 Several speakers (and participants) selected randomly from the photo collection of Gennady Ananyev and Govindjee, #1. **a** Anne Jones; **b** Elisabet Romero wearing Robert Emerson's lab coat, lent to her by Govindjee; **c** Dave Britt and Rick Debus; **d** Helmut Kirchoff **e** Gary Moore and Nick Cox; in the background is Bill Rutherford chatting with Leonardo Guidoni; **f** John Golbeck during the lively discussion that followed his talk



Recognition of young scientists

The following four young scientists were selected for the best posters (Fig. 6):

- **Ute Armbruster** (of Carnegie Institution for Science, Stanford, USA) for her work on “Ion antiport accelerates photosynthetic acclimation in fluctuating light environments.”
- **Han Bao** (of Oklahoma State University, USA) for her work on “Mutations disturbing water cluster alter the kinetics of the final steps of water oxidation.”
- **Nicoletta Liguori** (of Vrije Universiteit (VU), Amsterdam, the Netherlands) for her work on “In silico view of the dynamics of Light Harvesting Complex II (LHCII) embedded in a model native membrane.”

Fig. 4 Several speakers (and participants), selected randomly from the photo collection of Gennady Ananyev and Govindjee, #2. **a** Left to right: Michal Gwizdala, and Les Dutton; Rick Debus is standing; **b** Left to right: Greg Scholes, Dorthe Eisele enjoying a glass of wine after an evening session, Giovanni Finazzi keeping his hands in his back, and Michael Hippler, having a beer; **c** Gary Brudvig, Neil Hunter and Petra Fromme, drinking beer “because they can and they like it” to quote N. Hunter; **d** an Italian gathering; left to right: Roberta Croce (who lives in the Netherlands), Tomas Morosinotto and Dario Piano; **e** Gabriela Schlau-Cohen center, with her magnificent smile, surrounded by Rienk van Grondelle (the tall guy) and Govindjee (who has been around for a while); **f** a touch of Great Britain with Jeremy Harbinson (who lives in the Netherlands) and Bill Rutherford enjoying a tepid beer



- **Anat Shperberg-Avni** (of the Weizmann Institute of Science, Israel) for her work on “Electron microscopy study of state transitions in cyanobacteria.”

We present here a brief write-up on each of our four awardees:

Ute Armbruster received her Ph.D. in Biology from the Ludwig-Maximilians University (Munich, Germany) in 2008. During her research with Dario Leister, she characterized novel proteins, which function in the biogenesis of thylakoid membranes. Her achievements included (i) discovery of a conserved Photosystem II (PSII) assembly

Fig. 5 Several speakers (and participants), selected randomly from the photo collection of Gennady Ananyev and Govindjee, #3. **a** Left to right: Leonardo Guidoni, Nick Cox, and Tony Larkum; **b** Terry Bricker, Vittal Yachandra, Don Bryant, and Bob Blankenship, having run short of crackers. **c** left to right: Govindjee, Oliver Caspari, Srividya Ganapathy, and Johannes Messinger; **d** Leslie Vogt, David Vinyard, Wade Johnson, and Damian Carrieri



factor that upon duplication evolved a novel function in the assembly of the chloroplast NDH complex in plants and (ii) the finding that the structure of the thylakoid network is controlled by four distantly related proteins. For the past years, Ute has been at the Carnegie Institution of Science where she works with Martin Jonikas on understanding the dynamics of photosynthesis in response to fluctuating light. Her poster demonstrated that a potassium/proton antiporter is critical for minimizing energy loss. In high light, conversion of light energy to heat protects the photosynthetic apparatus. However, upon a transition to low light, residual conversion of light energy to heat limits photosynthetic yield. The activity of the thylakoid K^+ -efflux antiporter 3 (KEA3) allows the rapid down-regulation of the heat dissipation mechanism and a fast recovery of high photosynthetic yield.

Han Bao received her Ph.D. in Chemistry at the Chinese Academy of Sciences in Beijing in 2009. There she studied the properties of redox active tyrosine, Y_Z^{ox} , in PSII using EPR (electron paramagnetic resonance) spectroscopy, and other biophysical approaches. Her current project involves studying proposed proton and substrate water pathways of

the Mn_4CaO_5 cluster of PSII. The focus of her current research is on the hydrophobic amino acid Val185 in the D1 subunit, which is located in close vicinity of the oxo bridge atom, O5, of the metal cluster and faces the broad channel, which allows the exchange of the substrates and products as they pass the Mn cluster. She has made mutations of this residue that appear to interfere with water molecules, which are between Y_Z and the putative proton gate residue, D1-Asp61. Using careful polarographic analysis of samples at different temperatures, pH, and with deuterium isotope manipulations, she has revealed a new rate determining step, interpreted to be a molecular rearrangement that poises the reactants immediately prior to dioxygen formation.

Nicoletta Liguori graduated in 2011, with a MS degree, in Solid State Physics at the Roma Tre University, Rome, Italy, conducting research in Teresa Head-Gordon's group at the University of California, Berkeley, USA. At Berkeley, she developed in silico models of the A β 42-peptide (involved in Alzheimer's disease development) and synaptic plasma membranes. In 2012, she joined Roberta Croce's group, as a Ph.D. student at the VU University

Fig. 6 Photographs of the four young investigators. *Top*: Nicoletta Liguori (3rd from left), Han Bao (4th from left), Ute Armbruster (6th from left), and Anat Shperberg-Avni (8th from left); with Govindjee (1st from left), Les Dutton (2nd from left), Fabrice Rappaport (5th from left), and David Kramer (7th from left). *Bottom*: Govindjee handing, as Colin Wraight Award, a book of the Series Advances in Photosynthesis and Respiration to Nicoletta Liguori (*bottom left*), and Ute Armbruster (*bottom right*)



Amsterdam, the Netherlands, to study the molecular mechanisms regulating the switches from light harvesting to quenched states in the light-harvesting complexes (LHCs) of higher plants and green algae. Her research involves using different techniques ranging from ultrafast spectroscopy to molecular dynamics simulations (MDs). She has recently demonstrated that LhcSR, the complex responsible for non-photochemical quenching in *Chlamydomonas reinhardtii*, is the only LHC capable of sensing pH changes. Currently, Nicoletta is exploring pigment-protein interactions in an LHCII-membrane system via MDs.

Anat Shperberg-Avni received her B.Sc. in Biology, in 2003, from Tel Aviv University, Tel Aviv, Israel, and her M.Sc., in 2005, in Biology from the Weizmann Institute of Science, Rehovot, Israel. Currently, Anat is completing her Ph.D. studies under the supervision of Ziv Reich and Dror Noy at the Weizmann Institute of Science. Her research focuses on characterizing the mechanism of state transitions in *Synechocystis* sp. PCC 6803. In her poster, she presented studies on the spatial organization of Photosystem I (PSI) and Photosystem II (PSII) complexes within the thylakoid membrane of state I- and state II-adapted cells. These studies were performed using freeze-fracture methodology



Fig. 7 Participants gathered in groups discussing and enjoying themselves. **a** Holger Dau (center of the stage, 3rd from left), Johannes Messinger (4th from left), Rick Debus (lounging), Leonardo Guidoni (extreme right), along with Marius Retegan, Nick Cox, and Montserrat Perez Navarro, presumably discussing the mechanism by which Mn cluster oxidizes water; **b** Atsuko Kanazawa, Helmut Kirchoff, Rob Burnap, Sujith Puthiya Veetil; **c** Anjali Pandit, Ricarda Hoehner, Bart van Oort, Wojciech Nawrocki, Janina

Steinbeck; **d** left to right: Elisabet Romero, Nicholas Paul (at the computer), Elmars Krausz (standing), and Bill Rutherford, in a nice clair-obscur (chiaroscuro, in Italian); **e** a working meeting gathering (clockwise): Martin Jonikas, Ute Armbruster, Alizée Malnoë, Jeremy Harbinson, Mark Aurel Schoettler, Peter Jahns, Giovanni Finazzi, and David Kramer; **f** left to right: Eliezer Schwarz, Erika Erickson, Dagmar Lyska, and Chris Baker

combined with cryo-scanning electron microscopy. Analysis of the data revealed small-scale spatial rearrangements of PSI and PSII, as well as changes in PSI oligomeric state

between state I and state II. Based on these findings, she has proposed a new model for the organizational changes that occur during state transitions in cyanobacteria.

Fig. 8 Participants gathered in small groups, discussing stuff on the topic of the conference, or just having fun. **a** *Left to right*: Marius Retegan, Nick Cox (with both hands up), and Leonardo Guidoni discussing DFT and QM/MM applied to WOC, all those fun things; **b** *left to right*: Dorthe Eisele, Elisabet Romero and Gabriela Schlau-Cohen, in a contest for the best smile; **c** *left to right*: Cheng Zhao, Guannan He, Joseph Tang; **d** *left to right*: Anat Shperberg-Avni, Nir Keren and Orly Levitan, **e** Janina Steinbeck, Guy Hanke, and Daniel Ducat; **f** “who can smile the best” contest continued between (*left to right*) Gabriela Schlau-Cohen, Erika Erickson, and Alizée Malnoë while happily discussing single-molecule spectroscopy



Les Dutton recognized each of the above four, after he had presented a Tribute to Colin Allen Wraight (1945–2014). Govindjee presented, in memory of Colin, each of the four different recent books from his series “Advances in Photosynthesis and Respiration Including Bioenergy and other Related Processes.”

(<http://www.springer.com/series/5599?>).

See a Tribute to Colin A. Wraight by Govindjee: <http://www.life.illinois.edu/plantbio/Features/ColinWraight/ColinWraight.html>.

We would like to add that friends of Colin Wraight are presently in the process of establishing the “Colin A. Wraight Photosynthesis Graduate Research Prize” to be given to graduate students making outstanding research presentations at future Gordon Research Conferences on Photosynthesis.

To give the readers, the wonderful ambiance that was present at the conference, we show here a collection of photographs of the participants, gathered around each other, as well as relaxing at the conference (Figs. 7, 8 and 9).

Concluding remarks

The 2014 Gordon Research Conference on Photosynthesis provided established, as well as beginning researchers, an opportunity to present the latest developments in our field. Likewise, it was a wonderful environment for socializing with colleagues both old and new. Perspectives on previous Photosynthesis GRC’s can be found in Govindjee et al. (2007), Govindjee (2009), Govindjee et al. (2011), and Moore et al. (2012).



Fig. 9 Participants relaxing at the conference. **a** Paul Oyala, Leslie Vogt, David Vinyard, and Lijin Tian, **b left to right** (at lunch): Sarah Soltau, Leslie Vogt, Govindjee, and Guannan He; **c left to right**: Vittal Yachandra, Julian Eaton-Rye, and Govindjee, drinking beer except Govindjee; **d left to right**: Elmars Krausz, Ron Pace, and Felix Ho,

drinking wine during a lively poster session; **e** Nico Betterle, Nicoletta Liguori (with thumbs up), and Luca Bersanini; **f** participants playing checkers or carrom; **g** baby sitting (wearing a white hat; it should have been a green hat?), being looked after by Leeat Bar-Eyal and Orly Levitan (the cute baby's mom)!

Acknowledgments We end this *News Report* by expressing our appreciation to all the attendees of the 2014 Conference for contributing to discussions on various aspects of photosynthesis and advancing the frontiers of science. We thank David Kramer for chairing the 2014 Conference. For the description of the Awardees, we are grateful to Ute Armbruster, Han Bao, Nicoletta Liguori and Anat Shperberg-Avni, who provided us information on their academic activities. We thank Gennady Ananyev for providing us several photographs, as well as the GRC for allowing us the use of the of the 2014 group photograph. Govindjee thanks Ineke Ravesloot (Springer, Dordrecht, the Netherlands) for mailing the books to USA, and David Kramer for bringing the books to the Conference site. We give special thanks to Atsuko Kanazawa for the

exquisite way she took the microphone to different participants who were asking questions of the speakers. Govindjee is thankful to his grandson Rajiv Govindjee for his help in preparing the collage of some of the photographs shown here.

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