Biochimica et Biophysica Acta 1817 (2012) 1107–1109

Contents lists available at SciVerse ScienceDirect

Biochimica et Biophysica Acta

journal homepage: www.elsevier.com/locate/bbabio

Preface

Photosynthesis research for sustainability: From natural to artificial

"*I believe that water will one day be used as a fuel, because the hydrogen and oxygen which constitute it, used separately or together, will furnish an inexhaustible source of heat and light.*
I, therefore, believe that, when coal deposits are oxidized, we will heat ourselves by means of water. Water is the coal of the future."

Jules Verne, 1875

More than 3 billion years ago, living organisms, developed the capacity to efficiently capture solar energy and use it to power the synthesis of organic molecules using photosynthesis. The photosynthetic process set into motion an unprecedented explosion in biological activity, allowing life to prosper and diversify on an enormous scale, as witnessed by the fossil records and by the extent and diversity of living organisms on our planet today. Indeed, it was the process of photosynthesis over eons of time which has provided us with the oil, gas and coal needed to power our technologies, heat our homes and produce the wide range of chemicals and materials that support everyday life. Today, it is estimated that photosynthesis produces more than 100 billion tons of dry biomass annually, which would be equivalent to a hundred times the weight of the total human population on our planet at the present time and equal to a global energy storage rate of about 100 TW. The success of this energy generating and storage system stems from the fact that the raw materials and energy needed to drive the synthesis of biomass are available in almost unlimited amounts; i.e., sunlight, water and carbon dioxide. In other words, the solar power is the most abundant source of renewable energy and photosynthetic machinery uses this energy to power the thermodynamically and chemically demanding reaction of water splitting. At the heart of the reaction is the splitting of water by sunlight into oxygen and hydrogen. The oxygen is released into the atmosphere where it is available for us to breathe and to use for burning our fuels. The 'hydrogen' is not normally released into the atmosphere but instead is combined with carbon dioxide to make high energy containing organic molecules of various types. When we burn fuels we combine the 'stored hydrogen' of these organic molecules with oxygen. In this respect, the goal of making artificial photosynthesis is to utilize solar energy and convert it into chemical energy through a series of electron-transfer events. The design of such systems must adhere to the same principle as that of the natural photosystems. It is true that around the world, there have been many attempts to artificially produce oxygen and H_2 with use of chemicals and methods that may not have much to do with how photosynthesis does it. However, much ongoing work now seeks to understand basic processes of natural photosynthesis and chemical conversion, such as light harvesting, electron transfer, and ion transport; application of this knowledge to the development of fully synthetic and/or hybrid devices is still in its infancy. To develop systems that produce energy in an efficient manner, it is important both to understand the biological mechanisms of energy flow for optimization of primary structure and to appreciate the roles of architecture and assembly. Whether devices will be completely synthetic and mimic biological process, or they will use natural biomolecules, as photosynthesis does, or both, is for the future to decide. All avenues must be encouraged, but we believe that learning from the natural systems (cyanobacteria, algae and plants) makes much sense since these have been doing it successfully for millions of years. Today we have considerable knowledge of the workings of photosynthesis and its photosystems, including the water oxidation reaction. However, many questions and details remain unanswered. To fully understand photosynthetic reactions is not only a satisfying intellectual pursuit, but is also an important goal as we strive to improve agricultural yields and develop new solar technologies for splitting of water into pure O_2 and H_2 for use as a potential fuel source, as Jules Verne indicated 137 years ago.

The human life has existed, and exists today, due to photosynthesis and thanks to all the plants, algae and cyanobacteria for doing photosynthesis for us and giving us oxygen, food, biomass, and bioenergy.

This special issue of BBA-Bioenergetics highlights recent advances of our understanding on photosynthesis and is intended to provide to our readers recent information on the photosynthesis research and summarized the characteristics of the natural system from the standpoint of what we could learn from it to produce an efficient artificial system i.e. from natural to artificial. This issue contains 50 invited and selected papers on Photosynthesis Research, presented at the International Conference "*Photosynthesis Research for Sustainability-2011*", that was held in Baku, Azerbaijan, during July 24–30, 2011, with the sponsorship of the International Society of Photosynthesis Research (ISPR) and of the International Association for Hydrogen Energy (IAHE). There were 280 participants from 41 countries. In addition, we had 23 invited plenary lectures, 38 lectures, and about 100 posters. This international conference covered almost all the important aspects of photosynthesis, and their relationship to global issues, as well as hydrogen production and artificial photosynthesis. In this meeting, work performed around the world was presented that focused not only on the understanding of the various facets of natural photosynthesis, but on how it has been impacting on research and development of new technologies for food and fuel production. All the selected and invited lectures provided in-depth analyses of recent progress in the studies of photosynthesis for sustainability. At this conference, awards were given to nine young investigators. We sincerely hope this meeting was enjoyable, fruitful, and memorable for all participants (see Photos). We wish to express our cordial salutations to all of you. The web site of this international conference is at: http://www.photosynthesis2011.cellreg.org. We invite the readers to the next conference on "Photosynthesis Research for Sustainability-2013" to be held in May or June 2013,

0005-2728/$ – see front matter © 2012 Published by Elsevier B.V.
doi:10.1016/j.bbabio.2012.03.002

Photo 1. *Top Left* The main building of the Azerbaijan National Academy of Sciences. *Top Right* Registration of the participants. *Bottom* Some of the participants at the conference "Photosynthesis Research for Sustainability-2011", Baku, Azerbaijan, July 24–30, 2011. *Left* Kamala Gulmammadova, Konul Bayramova, Nargiz Sultanova, Elmira Maharramova, Irada Huseynova, Gulnara Balakishiyeva, Gultakin Mammadzade and Samira Rustamova.

Photo 2. *Top* Opening ceremony of the conference "Photosynthesis Research for Sustainability-2011", Baku, Azerbaijan, July, 2011, held at the main building of the Azerbaijan National Academy of Sciences. *Left to right* Jalal Aliyev (Honorary Chairman), James (Jim) Barber (Chairman, Past President of the International Society of Photosynthesis Research (ISPR)), Ali Abbasov (Chairman of the Local Organizing Committee, Minister of Communication and Information Technology of the Republic of Azerbaijan). *Bottom* Prof Hiroshi Nishihara's plenary lecture on "Photosensing systems composed of photosystem I and molecular wire" at Conference.

Photo 3. Audience at the opening ceremony. Place: The main building of Azerbaijan National Academy of Sciences, Baku.

in Baku, Azerbaijan. Information will be posted at: http://www.photosynthesis2013.cellreg.org.

Acknowledgements

I am highly thankful to the Editorial Team of the BBA—Bioenergetics, especially the Executive Editors Uli Brandt, Fabrice Rappaport, Content Development Manager Andy Deelen, and Journal Manager (BBABIO Special Issues) Sandra Tokashiki, and to all the authors, referees from many countries for their outstanding contributions to this special issue. I am especially grateful to Govindjee, Jim Barber and Robert Carpentier for their advice to develop this exciting issue, for their constant support and for their comments on this Editorial. I acknowledge the Russian Foundation for Basic Research (grant nos.: 11-04-01389a, 11-04-92690a, and 12-04-92101a), the Molecular and Cell Biology Programs of the Russian Academy of Sciences, and the Russian Ministry of Science and Education (grant no. 16.740.11.0176) for support.

Photo 4. A group photograph of some of the participants at the conference on the grounds of the Crescent Beach Hotel.

Photo 5. Some of the participants visiting Baku. *Top Left* Seeram Ramakrishna, Gyözö Garab and Barry Bruce. *Top Middle* Ernst-Walter Knapp and immediately behind Fabrice Rappaport; *Top Right* Jim Barber`s plenary lecture. *Middle Left* Nathan Nelson and Robert (Bob) Blankenship. *Middle Middle* Suleyman Allakhverdiev (Coordinator of the meeting) and Gyözö Garab. *Middle Right* Esa Tyystjarvi. *Bottom Left* Jim Barber, Rika Heshiki, HideoYamasaki and Norio Murata. *Bottom Right* Elvin Suleymanoglu Allakhverdiev (13 years old participant) and Jean-David Rochaix.

Photo 6. *Top Left* John Golbeck with his wife. *Top Right* (3nd from left) Aleksandra Orzechowska, Joanna Grzyb, Andrei Rubin and Katarzyana Gieczewska. *Middle Left* Junji Uchiyama, Kamala Gulmammadova, Esa Tyystjarvi, Mai Watanabe; *Middle Right* Olaf Kruse and Jean-David Rochaix. *Bottom Left* Norio Murata; Kentaro Ifuku; Mercedes Roncel. *Bottom Middle* Hazem Kalaji, Katarzyana Gieczewska. *Bottom Right* Carina Glockner, Julia Hellmich and Athina Zouni.

Photo 7. Expression of thanks to Jalal Aliyev. *Top Left* Jim Barber and Jalal Aliyev. *Top Right* Jalal Aliyev; Asaf Hajiyev; Ali Abbasov and Jim Barber. *Middle Left* Bill Rutherford (President of the ISPR) and Jalal Aliyev. *Middle Right* Jalal Aliyev and Ali Abbasov. *Bottom Left* Jalal Aliyev, Gernot Renger, Norio Murata and Gyözö Garab. *Bottom Right* Leslie Dutton and Jalal Aliyev.

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