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GUEST EDITORIAL

In honor of Vladimir A. Shuvalov: light energy conversion in photosynthesis

Robert Carpentier · Suleyman I. Allakhverdiev

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Sharp decreases in the reserves of traditional energy sources and the negative impact of the consumption of raw materials are leading to resource depletion and degradation of the environment in the World. The burning of fossil fuels is leading to a substantial increase in the carbon dioxide (CO_2) content of our atmosphere. According to the International Panel on Global Warming (International Panel on Climate Change), the annual release of CO_2 has grown by 80 % from 1970 to 2004. With the increasing concentration of CO_2 in the atmosphere, global warming is clearly taking place on Earth. Thus, scientists in many countries are actively searching for alternative sources of energy, which can solve this serious problem facing all of us. Several reserchers are now working on hydrogen production. The advantage of hydrogen over other energy sources is the inexhaustible reserve and the environmental safety of its use (Allakhverdiev 2011, 2012).

R. Carpentier (✉)
Department de Chimie-Biologie, Université du Quebec à Trois Rivières, 3351, Boulevard des Forges, C.P. 500, Trois Rivières, QC G9A 5H7, Canada
e-mail: robert.carpentier@uqtr.ca

S. I. Allakhverdiev
Controlled Photobiosynthesis Laboratory, Institute of Plant Physiology, Russian Academy of Sciences, Botanicheskaya Street 35, Moscow 127276, Russia

S. I. Allakhverdiev (✉)
Institute of Basic Biological Problems, Russian Academy of Sciences, Pushchino, Moscow Region 142290, Russia
e-mail: suleyman.allakhverdiev@gmail.com

S. I. Allakhverdiev
Department of Plant Physiology, Faculty of Biology, M.V. Lomonosov Moscow State University, Leninskie Gory 1-12, Moscow 119991, Russia

The ultimate source of energy is sunlight and that of oxygen is water, two virtually unlimited resources available on Earth. It is the advent of oxygenic photosynthesis some 3.7 billion years ago in the ancestors of cyanobacteria that transformed the whole environment on Earth from anaerobic to oxygenic, leading to an unprecedented explosion in biological activity. Oxygenic photosynthesis allowed 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. Photosynthesis is still and will remain, the most important biological process on Earth in terms of providing energy in form of organic materials and maintaining the proper environment for oxygenic life. In fact, two major issues that we face today or in the near future are problems of energy supply and environmental pollution. The solutions to these issues are closely related with photosynthesis.

The energy stored in petroleum, natural gas, and coal ultimately comes from the sun as a result of consuming carbon dioxide via photosynthesis, as does the energy in firewood and other organic materials, which are major fuels in many parts of the world. If we are to fulfill our energy supply continuously and sufficiently and to reduce the emission of CO_2, we must learn from photosynthesis how to obtain energy from the sun artificially and efficiently. Thus, studies on the mechanism of photosynthesis have remained for several decades and are still one of the central topics in the field of biology in general and in the area of bioenergetics in particular.

In view of considerable complexity of the proteins and reactions involved in photosynthesis, several disciplines, such as biochemistry, biophysics, molecular biology, structural biology, and theoretical chemistry, have been employed in revealing the secrets of photosynthesis. As a result of extensive studies already available, the architecture of most of the protein complexes involved in light energy harvesting, water-splitting, electron transport, and in ATP synthesis is now known. A notable example is the recent atomic level crystal structure of photosystem II at a 1.9 and 1.95 Å resolution (Umena et al. 2011; Suga et al. 2015), which has provided the basis to uncover the mystery of light-induced water oxidation that is important for artificial photosynthesis. Meanwhile, many questions remain beyond the structures. An important point is that there is diversity among photosynthetic organisms, but only a few limited ones have been investigated. Clearly, we need extensive investigations on many more organisms to fully understand the structure and function of diverse photosynthetic apparatus and corresponding reactions.

There is another issue associated with photosynthesis. It is about hydrogen production by photosynthesizing organisms. In certain types of microalgae and cyanobacteria, the photosynthetic machinery is used for the production of small amounts of hydrogen. The ability of green microalgae to release hydrogen was found by Gaffron and Rubin about 65 years ago. Over time, the ability of microalgae to release hydrogen has been considered as a curious fact with no particular practical relevance: most of the algae release hydrogen in very small amounts. Recently, however, interest in the production of biohydrogen with the help of photosynthetic organisms has increased due to significant research efforts in many laboratories around the World. One of the important directions for the production of hydrogen energy is to find organisms that produce hydrogen in large concentrations in open ponds or closed bioreactors. Further, we need to develop regimes that promote high hydrogen yield. Among these promising "green" facilities are the most promising autotrophic green (*Chlorophyta, Chlamydomonas*) microalgae and cyanobacteria (*Cyanophyta*, such as *Anabaena varaiabilis* and *Synechocystis* PCC 6803) (Allakhverdiev 2011). Work is underway to obtain mutants of green algae with hydrogenase, which would be insensitive to oxygen. Further, mutagenesis is being carried out in order to direct the flow of electrons along the path of light-depended hydrogen production, rather than toward carbohydrate synthesis. The main technological challenge for biohydrogen production is that hydrogen evolution reaction in algae and cyanobacteria is catalyzed by hydrogenase or nitrogenase, both being sensitive to oxygen. The main question for the future is How to make these enzymes less sensitive to the oxygen?

To address some of the issues discussed above, scientists from all over the world were brought together; the goal was to have a discussion on the state of the art studies on *light energy conversion in photosynthesis* in a diverse range of organisms. The conference "Photosynthesis Research for Sustainability-2014 in honor of Vladimir Shuvalov" was held in the town of Pushchino, Moscow Region, during June 2–7, 2014; it had followed earlier conferences held in 2004, 2006, 2011, and 2013.

This special issue of *Photosynthesis Research* "Light Energy Conversion in Photosynthesis" is dedicated to Professor Vladimir A. Shuvalov at his 70th birthday. Vladimir Shuvalov is one of world's leading experts in the field of the *Primary Processes of Photosynthesis* of both plants and bacteria. He was born in 1943 in Omsk city (Russia); he graduated in 1965 from the Department of Biology and Soil Science of the Lomonosov Moscow State University (MSU), Moscow, Russia. He received his Doctorate degree in 1969, from the Institute of Biochemistry of the Russian Academy of Sciences (RAS) (Moscow), working with Academician Alexander A. Krasnovsky and Dr. of science F.F. Litvin. His thesis was on "Delayed light emission from chlorophyll of green leaves," while he was a researcher at the Academy of Science of the Union of Soviet Socialist Republics, USSR (1969–1979), he went first to the Charles F. Kettering Lab in Yellow Springs, Ohio, USA, to work with Bacon Ke (1978–1979), and then with William (Bill) Parson (1980–1981), at the University of Washington, Seattle, USA. Vladimir has been recognized for his research with many awards and honors. In 1991, he was the USSR State Prize winner, and in 1997, he was honored with a full membership in the RAS. Since 1996, he has served as the Director of the Institute of Basic Biological Problems (IBBP) of RAS. In 1999, he received the Order of Friendship, and in 2004, he received the Order of Honor of Russia. Currently, he is the Head of the Laboratory of Primary Processes of Photosynthesis of IBBP RAS, as well as the Head of the Department of A.N. Belozersky Scientific Research Institute of Physical–Chemical Biology (MSU). Shuvalov has made unique contributions to the basic principles and details of charge transfer processes, beginning in the femtosecond time scale, in the reaction centers of both plants and photosynthetic bacteria. His collaborative spirit can be easily judged by his research with many renowned scientists in Russia as well as in other countries: Germany (Ulrich Heber, and Gernot Renger), Japan (Norio Murata), The Netherlands (Jan Amesz, Louis N.M. Duysens, Peter Gast, Arnold J. Hoff, Hans van Gorkom, and Rienk van Grondelle), and in the USA (Bacon Ke and William (Bill) Parson).

Appropriate to Shuvalov's accomplishment and scientific life, we list below some of his discoveries in collaboration with co-workers: (i) 1976: in bacterial reaction center (bRC), bacteriopheophytin (BPheo) is an electron (e) acceptor that precedes the ubiquinone electron acceptor Q_A; (ii) 1978: in bRC, bacteriochlorophyll (BChl, B_A) is the e acceptor before BPheo; (iii) 1977 and 2008: in Photosystem II (PSII) RC, pheophytin (PheoD1) and chlorophyll (ChlD1) are e acceptors before Q_A; (iv) 1986 and 2010: in Photosystem I (PSI) RC, a Chl (Ao) is actually a primary e acceptor reduced within 100 femtosecond; and (v) 2012: in bRC, primary charge separation occurs in femtoseconds (120–180 fs) within the excited P870, P870* (see Allakhverdiev et al. 2014).

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