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NEWS REPORT

Alexander Abramovich Krasnovsky (1913–1993): 100th birth anniversary in Moscow, Russia

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Abstract We provide here a brief News Report on the 100th birth anniversary of Academician Alexander Abramovich Krasnovsky, one of the greatest photobiochemists of our time, who was born on August 26, 1913 and died on May 16, 1993. We provide here a short description of his research, followed by some photographs. He was a pioneering intellectual in the area of chlorophyll photochemistry, and was always ahead of his time; he, indeed, was a remarkable human being.

Keywords Alexander Abramovich Krasnovsky · Chlorophyll · Krasnovsky reaction · Photobiochemistry · Photochemistry

Introduction

During October 10–11, 2013, an International Conference "Photobiochemistry: Problems and Perspectives" was held at the Russian Academy of Sciences in honor of the 100th birth anniversary of Academician Alexander Abramovich Krasnovsky. He was a full member of the Russian Academy of Sciences, and Professor of the Moscow State University. Krasnovsky was a great scientist, who is well known for his scientific achievements,

Fig. 1 Academician Alexander Abramovich Krasnovsky in his office

We thank George C. Papageorgiou (of Greece) for reading and editing this manuscript before its publication. He wrote" This document quite effectively evokes the outstanding personality of Academician Krasnovsky, both as a pioneering intellectual in the field of chlorophyll photochemistry and photosynthesis, and also as a remarkable human being."

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which accelerated the understanding of the mechanism of primary steps of photosynthesis. He was the initiator of photochemical studies of photosynthesis in Russia. He was one of the major pioneers of the idea that only by using physical and chemical methods, one can elucidate the principles of light energy conversion in photosynthesis. Figure 1 shows a photograph of Academician Alexander Abramovich Krasnovsky.

A.A. Krasnovsky, Krasnovsky reaction, and beyond

Alexander Abramovich Krasnovsky was born on August 26, 1913 in Odessa, but in 1921 he moved with his family to Moscow, Russia. There he studied at elementary and secondary schools, and attended special chemistry classes. Already in 1931, he began working at a chemical factory. While still working, he graduated from the Moscow Institute of Chemical Technology, in 1937, and became a postgraduate student at the same Institute. He obtained his Ph.D. (Candidate Dissertation), in Chemistry, in 1940, after doing research on photochemistry of titanium dioxide, titled: *Investigation of photosensitization action of titanium dioxide in dye films*. From 1944 to his last days, he worked at the Aleksey Nikolaevich Bach Institute of Biochemistry of the USSR (Union of Soviet Socialist Republic) Academy of Sciences (now Russian Academy of Sciences). This institute was launched on December 18, 1934, and in addition to Bach, Alexander Ivanovich Oparin (best known for the theory on the origin and early evolution of life) was one of the two founders. For quite a long time, Krasnovsky served as the head of the Laboratory of Photobiochemistry.

Krasnovsky's research and contributions are best described by himself in many reviews (see Krasnovsky 1948, 1960, 1965, 1972, 1977, 1979, 1985a, 1985b, 1992). His lifetime journey in photosynthesis is described wonderfully well in an invited article that was first written in Russian by Acad. A.A. Krasnovsky, and then translated in English, edited, and published later by his son A.A. Krasnovsky, Jr. (1997).

The main goal of his laboratory was the study of the mechanisms of harvesting of solar energy by photosynthesis. It was already known that light energy triggers redox reactions in chlorophyll molecules, but the mechanism of that phenomenon was unclear (see Rabinowitch 1945, 1951, 1956). Rabinowitch and Weiss (1936), as well as Porret and Rabinowitch (1937), had observed reversible oxidation of chlorophyll in solutions. The single-minded goal of Krasnovsky in photosynthesis research was to understand how the molecule of chlorophyll participates in photosynthesis. In 1948, Krasnovsky obtained his *habilitation* (D. Sc., Biology), after his outstanding studies on photoreactions of chlorophyll in vitro; the title of this thesis was *Investigation of photochemical reactions of photosynthesis*, whereas the title of his classic paper was *Reversible photochemical reduction of chlorophyll by ascorbic acid*; it was published in 1948 (Krasnovsky 1948). In this paper, he observed photoreduction of chlorophyll, accompanied by the formation of an intermediate, absorbing in the green region of spectrum (the so-called pink chlorophyll), which was reversible in the dark, regenerating the initial chlorophyll. This photoreaction became known as "*Krasnovsky Reaction*" in the photosynthesis literature. Similar photoactivity was also obtained for bacteriochlorophyll, pheophytin, and protochlorophyll (see Krasnovsky 1965). The reversible photooxidation of various chlorophylls in model systems was also found; these data have been accepted as the first experimental evidence for photoinduced redox activity of chlorophyll and its possible role in the primary reactions of photosynthesis. Krasnovsky and his coworkers showed that chlorophyll is involved in photosynthesis, not only for light-harvesting, but also in electron transport as a donor or an acceptor. However, the details of the partners were not clear at that time.

The 1955–1965 was a period of major discoveries in photosynthesis; we may say that it provided revolution in our thinking about the mechanism of photosynthesis: Emerson Enhancement Effect was discovered in photosynthesis that led to the concept of two-pigment systems and two light reactions, and by 1961, the so-called Z-scheme of photosynthesis was established (for references, see Govindjee and Krogmann 2004). A key event was the elucidation of the mechanism of chlorophyll participation in that process. In 1956 two important papers were published on this subject. Kok (1956), in the Netherlands, discovered that a small number of chlorophyll molecules (less than 1 %), characterized by light-induced absorbance changes at 700 nm, are involved in redox transitions, representing the energy trap (the reaction center). The other paper was from the research group of Eugene Rabinowitch in USA (Coleman et al. 1956). Here, 'light-minus-dark' difference spectrum reflecting changes, in spectral region of chlorophyll absorption with a maximum at 680 nm was observed. In 1963, Krasnovsky and coworkers (Karapetyan et al. 1963) and Rubinstein and Rabinowitch (1963) showed that light-induced changes, observed in Coleman et al. (1956), were due to changes in fluorescence excited by the measuring beam. The idea about redox transitions of small amount of chlorophyll (called later as a primary electron donor in reaction center) in oxygenic photosynthesis was soon established, an idea

that we owe to Duysens (1952) for the reaction center in bacterial photosynthesis. Later the mechanism of the primary charge separation in the photosynthetic reaction centers was established in the studies of Krasnovsky and his colleagues. It was shown that bacteriopheophytin is the primary electron acceptor in photo-induced charge separation in the reaction centers of purple bacteria (Shuvalov et al. 1976; Klimov et al. 1976), pheophytin in the reaction centers of PSII (Klimov et al. 1977), and chlorophyll *a* in the reaction centers of PSI (Fenton et al. 1979; Nuijs et al. 1986; Shuvalov et al. 1986; also see Wasielewski et al. 1987).

Krasnovsky suggested that chlorophyll aggregation may be one of the important factors controlling the formation of different chlorophyll forms in chloroplasts. Low temperature long-wavelength fluorescence found for concentrated solution of chlorophyll *a* was taken to indicate that a chlorophyll aggregate may be responsible for long-wave emission (see a review by Krasnovsky 1992). Long-wavelength chlorophylls were observed in vivo for the first time in green bean leaves as an emission band at 730 nm in the 77 K fluorescence spectra that was related to the aggregated chlorophyll (Litvin and Krasnovsky 1957). The long-wavelength emission, discovered by Brody (1958) in the green alga *Chlorella*, was ascribed by him to be from a 'chlorophyll dimer'. Infra-red spectroscopic investigations of chlorophyll films provided evidence that aggregation indeed can occur in solid pigment films (Krasnovsky and Bystrova 1986). The idea was developed that an aggregation of pigments is involved in both the red shift and the fluorescence quenching of chlorophylls in vivo. Similar ideas were developed in Joseph Katz's laboratory (Katz 1990).

Krasnovsky's scientific interests were very wide, but from the beginning of his research career, he was always interested in the construction of different models of photosynthetic reactions. To develop these models, he used inorganic photocatalysts such as semiconductors, preferentially, titanium dioxide (Krasnovsky et al. 1976; Krasnovsky 1979). The light-induced photo-production of molecular hydrogen was obtained in a system containing solubilized chlorophyll and bacterial hydrogenase (Krasnovsky et al. 1975, 1982).

Krasnovsky served Moscow State University for 40 years as a Professor; he taught modern methods of photochemical investigations. He did much to attract talented young people to scientific work. He has supervised research of about 60 postgraduates and created a scientific school in Russia (what is called "*The Krasnovsky school*"). His former Ph.D. students are now working as leading scientists in various universities and institutes, not only in the former USSR, but in other countries as well; many make up the core of the Institute of Photosynthesis (now Institute of the Basic Problems of Biology, Russian Academy of Sciences, for short RAS) in Pushchino, Moscow Region.

Fig. 2 One of the paintings of A.A. Krasnovsky: "Moscow River near Zvenigorod (Moscow region)". *Source* Archives of the Krasnovsky family; courtesy of A.A. Krasnovsky, Jr

Krasnovsky was well known as a pioneer and was one of the top scientists among international photosynthesis researchers. He delivered his lectures with great poise at many international meetings. When Warren Butler met in 1968 the soviet delegation (more than 10 members) at the First International Photosynthesis Congress (Freudenstadt, Germany), he shouted in Russian: "*Krasnovsky i drugie*" that means "Krasnovsky and others" (or et al., as it usually was mentioned in papers by others when they cited Krasnovsky's papers). Professor Krasnovsky was always open to any new concept or experiment no matter where it came from. One of us (Karapetyan) knows from personal experience that he always gave highly qualified advice in science as well as in life. His remarks during discussion of manuscripts were quick, but were very deep and highly significant. He had a rare talent as a researcher, and lived his life mainly for science and in science. At the same time, he liked to paint and knew much about arts and literature (see Fig. 2 for a photograph of one of his paintings). Those who had the privilege to know him personally enjoyed his humor, kindness, friendship, and patience. He was extremely tactful and attentive, not only with his collaborators, but with others who came in contact with him.

Krasnovsky was a member of many foreign societies, an Emeritus Professor of Szeged University (Hungary), and member of "Leopoldina" Academy (Germany). He was elected as a corresponding member of the USSR Academy of Sciences in 1962 and a full member in 1976. In 1991, the USSR State Prize for Science was awarded to Academician Krasnovsky and his colleagues (in alphabetical order: Yu. E. Erokhin; V.B. Evstigneev (posthumously); N.V. Karapetyan; A.V. Klevanik; V.V. Klimov; V.A.Shuvalov) for studies of the photobiochemistry of chlorophylls.

The Conference 2013

The conference honoring A.A. Krasnovsky was organized by A.N. Bach Institute of Biochemistry RAS (Russian Academy of Sciences): with V.O. Popov as Chairman, N.V. Karapetyan as Co-chairman, and N.P. Yurina as Secretary. It took place at the Headquarters Building of the Russian Academy of Sciences during October 10–11, 2013. Corresponding member of RAS V.O. Popov opened the conference and gave introductory remarks. Then the Academician N.F. Myasoedov offered greetings from the Russian Academy of Sciences. Prof. James Barber (of UK), as the Past President of ISPR (International Society of Photosynthesis Research), greeted the conference participants, before the lectures began. (Also see <http://www.inbi.ras.ru/conference/krasnovsky/krasnovsky-e.html>). The Appendix in our paper gives the complete list of the organizers, organizing committee, as well as Honorary Members and the Members.

The following speakers presented their talks on October 10, 2013. First, one of the authors of this paper, **Govindjee** (University of Illinois at Urbana-Champaign, USA) presented his lecture[1] "The Great Masters of the Past: Photochemists, Biochemists, and Biophysicists" discussing the story of the discovery of reaction centers and its function in photosynthesis. He emphasized time and again that "Krasnovsky was always ahead of his time." Then **A.A. Krasnovsky Jr.** (A.N. Bach Institute of Biochemistry RAS) in his lecture "A Lifetime Journey with Photobiochemistry" shared wonderful memories about his father and the family.

The next three lecturers (session chaired by J. Barber) discussed the phenomenon of energy migration and primary photochemistry in photosynthesis. **R.E. Blankenship** (Washington University in St. Louis, USA) discussed "Photosynthetic Antennas: The First Step in Biological Solar Energy Conversion"; **V.A. Shuvalov** (Institute of Basic Problems of Biology RAS) presented "Charge Separation in the Reaction Centers of Photosynthetic Organisms", and **J.H. Golbeck** (The Pennsylvania State University) delivered his lecture on "The First Steps in Charge Stabilization in PSI".

The problems of Regulation of Photosynthesis were discussed in the third session (chaired by J.W. Schopf). **J. Barber** (Imperial College London, UK) talked about "From Natural to Artificial Photosynthesis"; **M. Rögner** (Ruhr University Bochum, Germany) discussed "Engineering Photosynthetic Hydrogen Production in Cyanobacterial Cells", and **N.V. Karapetyan** (A.N. Bach Institute of Biochemistry RAS) discussed in his presentation the "Photoprotective Energy Dissipation by Photosynthetic Apparatus of Cyanobacteria".

The problems of Photosynthetic Electron Transfer were discussed the next day, i.e., on October 11, 2013 (session chaired by Govindjee). **A.B. Rubin** (M.V. Lomonosov Moscow State University) presented a lecture on "Regulation of the Photobiochemical Processes in Photosynthesis"; **V.V. Klimov** (Institute of Basic Problems of Biology RAS, Pushchino) discussed "Photosystem II and Photosynthetic Oxidation of Water"; **A.Yu. Semenov** (A.N. Belozersky Institute of Physico-Chemical Biology of M.V. Lomonosov Moscow State University) discussed "The Asymmetrical Primary Electron Transfer in PSI from Cyanobacteria"; and finally **J.W. Schopf** (UCLA, USA) delivered a lecture on the origin of Photosynthesis "Geological Evidence of the Origin of Oxygen-producing Photosynthesis and the Biotic Response to the 2.4–2.2 Ga «Great Oxidation Event»".

The problems of General Photobiochemistry were discussed in the last session (Chairman V.A. Shuvalov). **M.A. Ostrovsky** (N.M. Emanuel Institute of Biochemical Physics RAS) gave a lecture on "Rhodopsin: Photobiochemistry, Physiology, and Pathology of Vision"; **M.S. Kritsky** (A.N. Bach Institute of Biochemistry RAS) on "Model of Flavin-Based Prebiotic Photophosphorylation", and **Yu.A. Vladimirov** (M.V. Lomonosov Moscow State University) on "Excited States and Free Radicals".

Concluding remarks

Here, we include some photographs from the conference, mention two of the messages received after the conference, an announcement of the publication of a special issue of *Biokhimiya* honoring A.A. Krasnovsky; and an expression of gratitude to the Russian hosts by Govindjee.

Photographs. Figures 3, 4, 5 and 6 show some of the randomly selected photographs taken at the conference.

[1] A pdf file of this lecture "Honoring Alexander A. Krasnovsky by Govindjee (2013)" is available at a web site; it is the 16th entry under Announcements at < http://www.life.illinois.edu/govindjee>. Further, right below it is a pdf file showing many group photographs of Krasnovsky, provided by Armin Meister to Govindjee; these photographs were taken, during 1967—1981, at conferences of Council of Mutual Economic Assistance (COMECON or CMEA).

Fig. 3 Some of the audience in the conference Hall at the Headquarters Building of the Russian Academy of Sciences. *First row* (*left to right*) R.E. Blankenship, Govindjee, B.P. Gottikh. *Second row* N.V. Karapetyan, V.V. Klimov, M. Rögner, J.H. Golbeck. *Third row* J.W. Schopf (sitting just behind Rögner); and V.N. Sergeev

Fig. 4 *Left to right* A.A. Krasnovsky, Jr. and J.W. Schopf

Fig. 5 *Left to right* Matthias Rögner; Navasard Karapetyan; Govindjee: James Barber; Robert Blankenship; Vladimir Shuvalov; and three students of Moscow Lomonosov State University: Anastasia Sharapkova, Maria Dubkova & Anastasiia Sokolova. Photograph is a courtesy of Konstantin V. Neverov

Messages. Many messages were received by one of us (Karapetyan). We mention two of them. **Robert E. Blankenship** (USA) wrote: "It was a very high level meeting and I learned a lot and had a good time meeting with the Russian scientists. I enjoyed the conference very much. It was a great opportunity for me to visit the Russian Academy of Sciences and hear outstanding lectures by both the Russian and foreign scientists." **Matthias Rögner** (Germany) wrote: "The meeting was excellent. It was marvelous to meet up with Russian colleagues who I have known for a very long time."

Announcement. We are delighted to announce that Biochemistry-Moscow (**Biokimiya**) is publishing in 2014 a special issue dedicated to Academician A.A. Krasnovsky (Guest-editor: A.A. Krasnovsky Jr.). This issue will be volume 79 (# 3 and #4) of the journal and will contain about 18 papers from around the World. See their web site <http://www.protein.bio.msu.ru/biokhimiya>.

Thanks on behalf of guests. On behalf of many participants, one of us (Govindjee) expresses his thanks for the wonderful ambiance at the conference, great welcome and exquisite parties, with wonderful food, provided by the

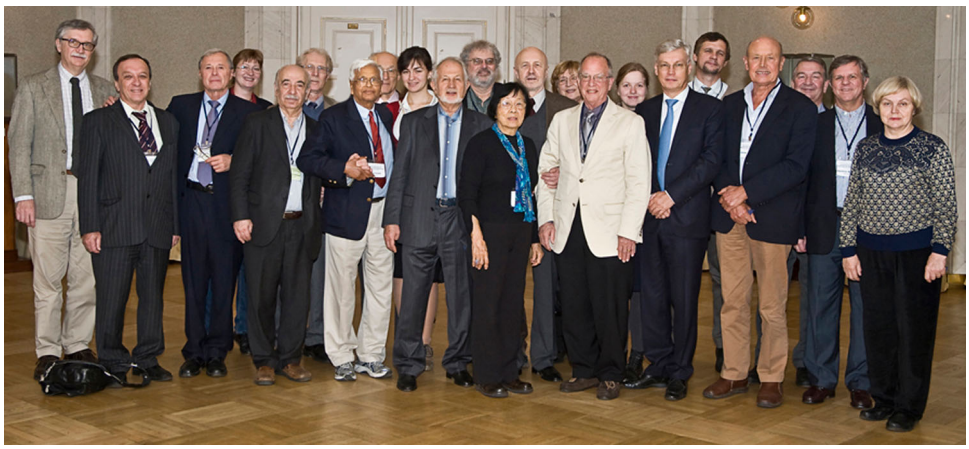

Fig. 6 A photograph of some of the conference participants at the Headquarters Building of the Russian Academy of Sciences. *Left to right* J.H. Golbeck, A.Yu. Semenov, M.A. Ostrovsky, I. G. Strizh, N.V. Karapetyan, B.B. Dzantiev, Govindjee, Yu.A. Vladimirov, A. Sokolova, A.B. Rubin, R.E. Blankenship, J.S. Schopf, M.S. Kritsky, N.P. Yurina, J.W. Schopf, M. Dubkova, V.O. Popov, K.V. Neverov, J. Barber, V.V. Klimov, M. Rögner, and T.A. Telegina

Fig. 7 A photograph of the two authors: Navasard Karapetyan (*Left*) and Govindjee (*Right*)

Russian hosts. Special thanks are due to several students, and their leader Konstantin V. Neverov who took care of showing the visiting scientists their wonderful city (Moscow) and its gardens.

We end this News Report by showing a photograph of the two authors (see Fig. 7).

Acknowledgments We thank the Russian Foundation of Basic Research (Grant: 13-04-06034), Biology Division of the Russian Academy of Sciences, A.N. Bach Institute of Biochemistry RAS, Institute of Basic Problems of Biology RAS (Pushchino), and Biology Faculty of Moscow State University. Thanks to all the members of the organizing committee (see Appendix) and all the participants and guests who contributed to this important meeting.

Appendix

Organizers were: Division of Biology Sciences of the Russian Academy of Sciences (RAS); A.N. Bach Institute of Biochemistry RAS; Institute of Basic Problems of Biology RAS, Pushchino; Biology Faculty of M.V. Lomonosov Moscow State University; Scientific Council RAS on Biophysics; Scientific Council RAS on Plant Physiology and Photosynthesis; Scientific Council RAS on Biochemistry; Russian Photobiology Society; and Russian Foundation for Basic Research.

Members of the organizing committee were (as also mentioned in the text): Chairman V.O. Popov, Corresponding Member of RAS, Director of the A.N. Bach Institute of Biochemistry RAS, Moscow; Co-chairman N.V. Karapetyan, Professor at A.N. Bach Institute of Biochemistry RAS; and Secretary N.P. Yurina, Professor at A.N. Bach Institute of Biochemistry RAS.

Honorary Members of the congress were: James Barber, Fellow of the Royal Society of UK, and Professor at Imperial College, London, UK; Robert E. Blankenship, Professor at Washington University in St. Louis, Missouri, USA; Govindjee, Professor Emeritus at the University of Illinois at Urbana-Champaign, USA; Matthias Rögner, Professor at Ruhr University Bochum, Germany; J. William Schopf, Member of the National Academy of Sciences of USA, and Professor at the University of California Los Angeles, USA; Gilbert Seely (USA); Mikhail V. Alfimov, Academician RAS, Center of Photochemistry RAS; Ralph A. Gasanov, Professor at Baku State University, Azerbaijan; Mikhail P. Kirpichnikov, Academician RAS, Biology Faculty of M.V. Lomonosov Moscow State University; Felix F. Litvin, Professor of Biology Faculty, M.V. Lomonosov Moscow State University; Vladimir P. Skulachev, Academician RAS, Institute of Physico-Chemical Biology of M.V. Lomonosov Moscow State University; Alexander S. Spirin, Academician RAS, Protein Institute

RAS, Pushchino; Igor A. Tarchevsky, Academician RAS, Institute of Biochemistry and Biophysics RAS, Kazan; and Yuri A. Vladimirov, Academician RAMS, Faculty of Basic Medicine of M.V.Lomonosov Moscow State University.

Members were: V.A. Shuvalov, Academician RAS, Institute of Basic Problems of Biology RAS, Pushchino; M.A. Ostrovsky, Academician RAS, N.M. Emanuel Institute of Biochemical Physics RAS; A.B. Rubin, Corresponding Member of RAS, Biology Faculty of M.V. Lomonosov Moscow State University; Yu.E. Erokhin, Professor at Institute of Basic Problems of Biology RAS, Pushchino; V.V. Klimov, Professor at Institute of Basic Problems of Biology RAS, Pushchino; A.A. Krasnovsky Jr., Professor at A.N. Bach Institute of Biochemistry RAS; M.S. Kritsky, Professor at A.N. Bach Institute of Biochemistry RAS; A.F. Orlovsky of A.N. Bach Institute of Biochemistry RAS; and I.V. Sharova, also of A.N. Bach Institute of Biochemistry RAS.

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