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# The Role of Professor Boris B. Vartapetian in the Foundation of the International Society for Plant Anaerobiosis and a New Avenue in Ecological Biology

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## ABSTRACT

This paper is dedicated to Professor Boris Vartapetian's 85th anniversary. Special attention is paid to the scientific contribution of Prof. Vartapetian in investigating plant hypoxic and anoxic stresses. The authors also emphasize the role of Prof. Vartapetian in the foundation of the International Society for Plant Anaerobiosis and in facilitating its successful activities at the international level over 30 years.

**Keywords:** new scientific discipline, plant anaerobic stress

## PROFESSOR BORIS B. VARTAPETIAN

Professor B.B. Vartapetian, a well-known Russian plant physiologist and biochemist, has been involved for nearly 60 years in investigating molecular mechanisms of oxygen metabolism and plant anaerobic stress phenomena.

The early scientific activities of B. B. Vartapetian date back to the 1950s, when he was a biology student at Moscow State University. These studies were guided by Professor A. L. Kursanov, a Member of the USSR Academy of Sciences, in the A. N. Bakh Institute of Biochemistry, USSR Academy of Sciences, and dealt with an investigation of the physiological role of $CO_2$ of rhizospheres that is transported from the root system into the above-ground plant organs and participates in photosynthesis. The results were published in 1952 in the *Proceedings of the USSR Academy of Sciences*. After graduating from Moscow University (1952) he entered the post-graduate programme of the A. N. Bakh Institute of Biochemistry, and continued his research under the direction of Professor A. L. Kursanov, becoming involved in the study of plant oxygen metabolism. In this post-graduate period Boris Vartapetian was particularly active in efforts to develop methods for working with the stable oxygen isotope $^{18}O$ in biological experiments.

In 1956, after the defense of a thesis entitled "Study of Oxygen Metabolism in Plants", Boris Vartapetian was enlisted in the K. A. Timiryazev Institute of Plant Physiology of the Russian Academy of Sciences as a junior researcher. In subsequent years he continued his studies in the field of oxygen metabolism and in 1966 defended his doctoral thesis "The role of atmospheric oxygen and water in plant metabolism". In 1972 he was awarded the title of Professor. By now he had published 250 scientific publications including three monographs.

Throughout his scientific life, Professor Vartapetian has principally concentrated his research in two main fields: metabolic pathways of atmospheric and water oxygen, and anaerobic stress phenomena in plants.

In his early studies Professor Vartapetian made frequent use of the heavy oxygen isotope $^{18}O_2$ and $H_2{}^{18}O$ in investigations of oxygen metabolism in plant and animal organisms. In particular he succeeded, using stable oxygen, as $^{18}O_2$ and $H_2{}^{18}O$, to demonstrate in experiments with intact plants (wheat), that molecular oxygen absorbed in the course of respiration is used as a terminal electron acceptor while oxygen in $CO_2$ respiration originates from water. Professor Vartapetian advanced a new hypothesis (oxygenase mechanism) on vitamin A biosynthesis from its precursor (β-carotene), as demonstrated in experiments with animals (rats) using a micro- method of $^{18}O_8$ assay in the nuclear reaction $^{18}O_8$ (α, n γ) $^{21}Ne_{10}$ in the cyclotron. This scientific discovery has entered into biochemical reference books and textbooks and is reflected in metabolic maps. The enzyme responsible for this transformation (β-carotene 15-15 dioxygenase) was isolated soon afterwards. The use of $^{18}O_2$ enabled B. B. Vartapetian, in experiments with animals (silkworm *Bombyx mori* and *Eurygaster integriceps* Put.) and plants (wheat *Triticum aestivum*, cacti *Cereus hexagonus*), to demonstrate for the first time the biosynthesis and accumulation of endogenous water resulting from $^{18}O_2$ fixation in the course of respiration and to assess the role of biosynthetic water in water balance of the studied organisms. His original ideas on recycling during respiration and photosynthesis in succulents (cacti) leading to the continuous biosynthesis and utilization of endogenous water under conditions of prolonged water stress have been subsequently confirmed by American and Australian researchers.

Professor Vartapetian and his co-workers gained international recognition in the field of basic science especially in the study of anoxia and hypoxia in plants. He also had a significant role in the foundation of a new scientific discipline in the field of ecological biology – namely, plant anaerobic stress. The principal scientific achievements of Professor Vartapetian and his co-workers in this area are as follows: discovery of a paradoxical phenomenon – **hypersensitivity** rather than hyper-resistance to anaerobic stress of root cells of plants inhabiting waterlogged and flooded soils (for instance, rice *Oryza sativa*), leading him to conclude that tolerance of these plants and their capability to grow readily on flooded, anaerobic soils could be explained by their ability for long-distance oxygen transport, that is, they avoided anaerobiosis; demonstration that stimulation of glycolysis and fermentation upon feeding plant cells exogenous sugars had a protective effect even under conditions of strict anoxia. From this, he formulated a provision of the key role of energy metabolism in plant metabolic adaptation

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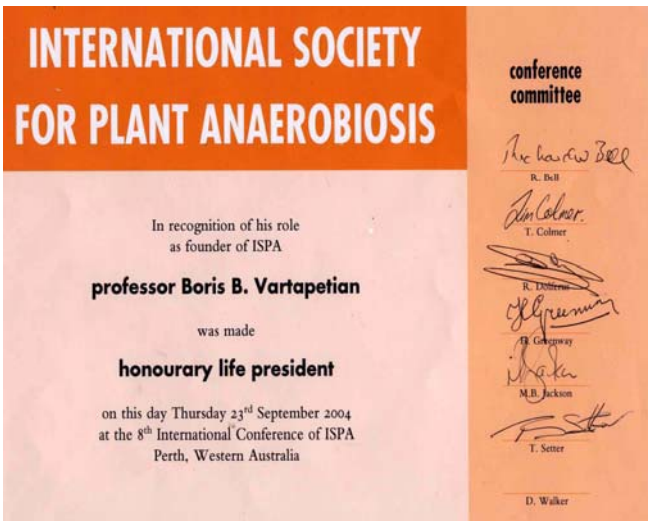
to hypoxia and anoxia. Based on these fundamental provisions Professor Vartapetian introduced the concept of two principal strategies of higher plant adaptation to conditions of anaerobic stress namely, **true** tolerance which is achieved at the molecular level due to rearrangement of metabolism during an absence or deficiency of oxygen (metabolic adaptation), and **apparent** tolerance, resulting from changes at the organ level, such as aerenchyma formation, that allow for long distance oxygen transport and an avoidance of anaerobiosis. Based on the provision of the key role of energy metabolism (glycolysis and fermentation) in plant metabolic adaptation to anaerobic stress, several laboratories developed biotechnological methods (gene and cell engineering) for the creation of plants more tolerant to anoxia and hypoxia. In particular, Professor Vartapetian participated in the development of biotechnological methods of *in vitro* selection (in nutrient medium free of exogenous carbohydrates) of plant cells tolerant to anoxia. The subsequent regeneration of whole plants from such selected cells of *Saccharum officinarum* and *Triticum aestivum* resulted in plants more tolerant to soil flooding. Furthermore, the above-mentioned studies demonstrated that enhanced tolerance of plants regenerated from selected plant cells had a genetic basis that was inherited by subsequent generations. Professor Vartapetian and his co-workers demonstrated, and then first reported at the XII International Botanical Congress (1975) the *de-novo* formation of seven stress proteins in rice coleoptile under anoxia. It is well-known, that induction of the synthesis of a number of stress proteins in plants was demonstrated and fundamentally studied in detail in subsequent investigations of other researchers in relation to both anaerobic and to other ecological stresses. In addition, the major impact of anaerobic proteins on plant adaptation to hypoxia and anoxia was also demonstrated. Notable results in recent years from Professor Vartapetian's group are as follows: the physiological role of exogenous nitrate as a protective factor under conditions of plant anaerobic stress, which was demonstrated with the use of functional electron microscopy; elucidation of the role of anaerobically synthesized lipids and unsaturated fatty acids as terminal electron acceptors under conditions of strict plant anoxia. Professor Vartapetian and his coworkers also demonstrated the phenomenon of the **adaptation syndrome** at the level of mitochondrial membrane ultrastructure under condition of plant anaerobic stress and substantiated molecular mechanisms associated with this phenomenon.

As already mentioned, B.B. Vartapetian had an important impact on creation of a new scientific discipline in ecological biology – the doctrine of plant anaerobic stress, which was internationally recognized and now has been rapidly developed in numerous world-wide universities and scientific centers. Professor Vartapetian was the organizer of the First international symposium on plant anaerobic stress that took place within the framework of the XII International Botanical Congress (St. Petersburg 1975). The proceedings of this symposium edited by Professors D. Hook and R. Crawford (1978) were published as a monograph in the USA. Professor Vartapetian was invited and presented the comprehensive Introduction and first chapter of this monograph. In particular, the above mentioned concept of two principal strategies of plant adaptation to anaerobic stress (**true** and **apparent** tolerances), that was widely accepted and is now actively investigated in a number of world leading laboratories, was first advanced by Professor B. Vartapetian in the Introduction of this monograph. The monograph was reprinted again in 1980. This first symposium and the first book edited by D. Hook and R. Crawford on plant anaerobic stress helped to unite the small group of researchers already active in this field to promote the development of new research groups and centres involved in the study of plant hypoxic and anoxic stresses. Close international contacts were now established between researchers that resulted in joint studies and publications. In this way, the first symposium and the first book on plant anaerobic stress became the basis for establishment of the International Society for Plant Anaerobiosis (ISPA), a society that was founded and headed over three decades by B. B. Vartapetian as its first president. ISPA provided a platform for a new scientific discipline embracing plant life under hypoxic and anoxic stresses. Thus, the labours and efforts of ISPA members laid a solid foundation for a new scientific discipline. The activity of ISPA members has been instrumental in attracting the attention of the international scientific community to the problems of plant life under poorly aerated conditions. It is mainly thanks to ISPA members' activities that new laboratories and scientific centers around the world became engaged in studies of ecological, physiological, biochemical, molecular biological and molecular genetic aspects of the phenomenon of plant anaerobic stress. We feel justified in maintaining that, in addition to traditional branches of ecological physiology and biochemistry, embracing drought, cold, heat, saline and biotic stress factors, a new independent avenue for study of plants under low-oxygen stress has appeared and gained international recognition. The role of Professor B. Vartapetian in the foundation of this novel scientific discipline was emphasized in a preface to a special monograph on plant anaerobic stress, "Plant Life under Oxygen Deprivation" edited by M. Jackson, D. Davies and H. Lambers (Academic Publishing, 1991). B. B. Vartapetian, being the ISPA President, actively cooperated with leading international specialists in this field, Professors R. Crawford (UK), D. Hook (USA), W. Armstrong (UK), M. Jackson (UK), in the course of the development of ISPA and as the new scientific discipline expanded.

During the latter decades, under the aegis of ISPA and with active participation of ISPA members, 17 international conferences and symposia on plant anaerobic stress have been held in the UK, Switzerland, USA, Iceland, Finland, Netherlands, Australia, Japan and Italy, in addition to the founding symposia in Russia. Thirteen international monographs and special issues of international journals or collections of papers devoted to plant anaerobic stress were published by members of ISPA.

In the preface of a special issue of the Annals of Botany (**96**, 4, 2005) that contained papers from the ISPA conference in Australia, the present President of ISPA Professor M. Jackson and the Chair of this Conference Doctor T. Colmer specially noted the role of Professor B. Vartapetian both in the foundation of the ISPA and in the activity of the Society: **"Professor Boris Vartapetian founded ISPA in 1975 and served as Inaugural President for three decades. We thank Boris for the vision and leadership that initiated this Society and ensured its successful function on the international stage for so many years".** The ISPA Council recognized Boris Vartapetian's special contribution by bestowing on him the accolade of Honorary President for Life:



The active participation of ISPA members, both in research activities and in the organization of international conferences and symposiums within the ISPA framework, and in publication of specialized monographs and journal issues on anaerobic stresses have promoted global recognition of this scientific discipline. In this context important contributions of research teams of A. Alpi (Italy), C. Andrews (Canada), W. Armstrong (U.K.), A. Bertani (Italy), R. Crawford (UK), M. Drew (USA), M. Greenway (Australia), R. Hill (Canada), D. Hook (USA), M. Jackson (U.K.), R. Kennedy (USA), W. Peacock (Australia), A. Pradet (France), J. Roberts (USA), M. Sachs (USA), T. Setter (Australia), H. Tsuji (Japan), B. Vergara (International Rice Research Institute), B. Vartapetian (Russia) during that first period of establishing of this discipline should be mentioned. The support and participation of these colleagues in all the above-mentioned activities within the ISPA framework also played an important role in the establishment of this new trend in ecological biology. As can be judged from further successful development of this scientific discipline, the senior generation passed this baton into the good hands of the following: J. Bailey-Serres (USA), T. Colmer (Australia), R. Dolferus (Australia), K. Fagerstedt (Finland), T. Fan (USA), K. Ishizawa (Japan), A. Ismail (Philippines), B. Mohanty (Singapore), P. Perata (Italy), R. Ratcliffe (UK), T. Van Toai (USA), D. Van der Straeten (Belgium), E. Visser (The Netherlands), L.A.C.J. Voesenek (The Netherlands), and some other ISPA members.

In addition to active participation, as ISPA President, in the above mentioned events, Professor Vartapetian took part in numerous other international botanical, biochemical, and agricultural congresses, symposia, and conferences as invited lecturer, member of organizing Committee or Chairman.

Professor Vartapetian participated in a number of joint research activities with foreign colleagues and ISPA members. He worked in France in Professor C. Costes (Institute National Agronomique) and Professors C. Lance and P. Mazliak (Paris University) laboratories, in United Kingdom with Professor R. Crawford laboratory (St. Andrews University, Scotland). He delivered lectures in universities and research centers of France, United Kingdom, Italy, Czechoslovakia, Australia, USA, and Sri Lanka.

Boris was born on May 1, 1925, in Nagorny Karabakh (Trans-Caucasus). His father Bagrat Vartapetian and mother Siranush Vartapetian were biologists and worked as researchers in Polar Botanical Garden USSR Academy of Sciences. The wife Valentina Vartapetian is also a biologist: Dr. Sc., Head of horticulture laboratory of Biological Department of Moscow State University. His son, Andrey Vartapetian, is Professor of the Moscow State University; he is a molecular biologist and Head of the section of Physico-Chemical Biology Institute. His daughter, Karine Norkina, is an English-Russian translator.

Boris Vartapetian took part in the Second World War. On the 3rd July 1944, during the assault of the Belorussian town of Polotsk he was severely wounded. He is considered by the Belorussian government as **The Liberator of the town Polotsk**. As an active participant in the War he was decorated with 21 governmental orders and medals.

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(**A**) B.B. Vartapetian as a participent of the Second World War. (**B**) The opening of ISPA international symposium on plant anaerobic stress under the aegis of UNESCO (Moscow, 1985). Academician A. L. Kursanov (left) and Professor B. B. Vartapetian (right). (**C**) Founder members of ISPA from left to right, Professors Robert Crawford, Boris Vartapetian, and William Armstrong.