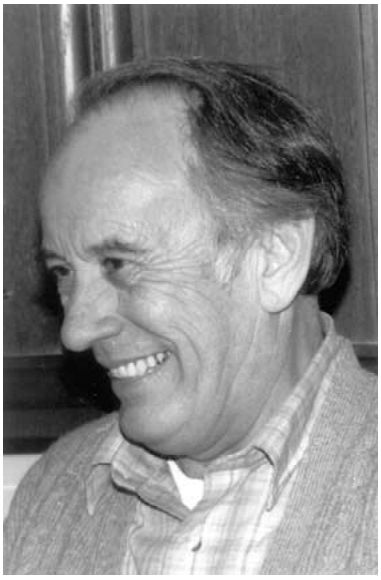
Photosynthesis Research **70:** 245–247, 2001.



*Obituary*

# Remembering George Cheniae, who never compromised his high standards of science



**George M. Cheniae (1928–2001)**

Dr George M. Cheniae, Professor at the University of Kentucky, passed away on August 25, 2001, in Lexington, Kentucky as the result of chronic obstructive pulmonary disease. He received his primary and secondary education in the small farming community of Mounds, Illinois where he was born on August 27, 1928. In high school, George played basketball on a team that is remembered by Illinois basketball fans to this day because their small-town team defeated much larger high schools to win the state tournament.

Following his undergraduate studies at the University of Illinois at Urbana-Champaign, George became a research associate in the Biology Division of the Oak Ridge National Laboratories. He was then assigned to the research division of the US Army Chemical Corps in Fort Dietrich, Maryland, where he did work on biological weapons during the Korean War. George did his graduate work at North Carolina State University where he studied the mechanism of action of nitrate reductase with Harold Evans. The Evans' lab was exploring many aspects of nitrogen metabolism at that time that included investigations concerning the role of molybdenum in the reduction of dinitrogen to ammonia. After completing his PhD in 1959, he spent a year as a postdoctoral scholar in the Biochemistry Department at Cornell with Martin Gibbs.

In 1960, Bessel Kok hired George as a research scientist in the biology section of the Research Institute for Advanced Studies (RIAS) in Baltimore, Maryland. Martin Aircraft, a major defense and aerospace company, had established RIAS as a research Institute comparable to the better-known Bell Labs. Although mostly devoted to basic research projects, the biologists of RIAS developed mass spectroscopy and oxygen electrode assays to test for the existence of life on Mars during the Viking II and III missions. These missions were terminated after the Viking I landing on Mars. However, these techniques would be used by the RIAS biologists to make several important discoveries in photosynthesis.

With technician Iris Martin (now Iris Heichel), George began to study the role of manganese in photosynthetic oxygen evolution. In 1966, they reported that the function of Photosystem II was impaired in manganese-deficient *Scendesmus* cultures (Cheniae and Martin 1966). Using $^{54}Mn$, they found that the algae required light to incorporate the manganese and restore oxygen-evolving capacity. The oxygen-evolving system was referred to as the 'black box of photosynthesis' because it was the least understood process of photosynthesis at that time. However, this changed when Cheniae and Martin (1970) reported that Tris buffer, at high concentrations, selectively inactivates the oxygen-evolution process in spinach thylakoid membranes by depleting thylakoids of 4 Mn/400 Chlorophyll, and thus, 4 Mn per Photosystem II. The linear manner with which the extent of Mn extraction correlated with $O_2$ evolving activity indicated that the 4 Mn were part of a single metal cluster that was responsible for the production of $O_2$. The conclusion that photosynthetic water oxidation uses a single cluster of 4 Mn has been confirmed by numerous independent experiments in subsequent years.

The same year that George found that the 'oxygen evolving complex' (OEC) contained a 4 Mn cluster, the laboratory of Bessel Kok concluded that the OEC cycles through 5 sequential states (called by them as the 'S' states) with each state transition driven by an electron transfer event in photosystem II prior to the release of $O_2$. Kok and coworkers derived the S-state mechanism from experiments on the flash-induced oxygen evolution, based on the 1969 pioneering work of Pierre Joliot and coworkers. George spoke often of the stimulating conversations about this mechanism during Pierre's extended visit at RIAS at this time. Shortly thereafter, Alan Stemler (a student of Govindjee, at the University of Illinois) and Richard Radmer, also at RIAS, confirmed that the origin of the oxygen generated by photosynthesis did not derive from $CO_2$ but from the oxidation of water. George and coworkers also began to investigate the assembly of the manganese cluster by the apo-enzyme (Cheniae and Martin 1971; Radmer and Cheniae 1971). They found that two electron transfer events in Photosystem II spaced about 0.5 seconds apart were required for this process that became known as *photoactivation*.

After Martin Marietta Company was formed as the result of a merger with American Marietta, it began to demand that the RIAS investigators spend a greater fraction of their time on applied projects, and in 1975, George left RIAS to become a professor at the University of Kentucky. Here, George and Wayne Frasch first identified treatments that affect a specific S-state of the OEC (Frasch and Cheniae 1980). During the early 1980s, a controversial report of the purification of the protein complex responsible for oxygen evolution appeared. Ultimately, George was able to disprove the early work and, with Richard Sayre, achieved the first reconstitution of oxygen evolution in detergent solubilized thylakoids (Sayre and Cheniae 1981, 1982). The protein factors needed to reconstitute oxygen evolution were later shown by Bertil Andersson and colleagues to be the extrinsic polypeptides of the oxygen evolving complex. George's lab subsequently made several contributions to the understanding of the function of these polypeptides in the catalysis of water oxidation (Callahan et al. 1986).

The process of photoactivation became a major focus of George's laboratory at this time. Ultimately, Tamura and Cheniae (1987) established conditions for the *in vitro* assembly of the functional OEC from manganese, calcium, chloride and the apo-enzyme. Light can also cause the destruction of Photosystem II via a process known as photoinhibition. Photosystem II is particularly sensitive to this process when the manganese cluster has been removed. George realized that this process was a limiting factor to the yield of assembly of the oxygen-evolving complex *in vitro*, and in collaboration with Danny Blubaugh, Gerald T. Babcock and John Golbeck, identified the sites of photodamage (Blubaugh et al. 1991). George's work on the biochemistry of photoinhibition is still regarded as one of the most careful work carried out in this area.

George received several honors for his work over the years among which was the Charles F. Kettering Award for excellence in photosynthesis in 1990. Without a doubt, George's most memorable characteristic was the intensity with which he approached his work. He was deeply committed to his work and his skills of critical thinking were extraordinary. His students and professional acquaintances were enriched by his close scrutiny of a problem and the clarity of the questions he posed. George did not suffer fools gladly. He was regarded as one of the sharpest critics in the field. Many young, as well as seasoned investigators, were humbled by George's penetrating questions, whether during a seminar or later over a glass of Kentucky bourbon. When one spoke to George it was best to be prepared, very well prepared. Rob Rabson, former Director of the Energy Biosciences Division of the Department of Energy, referred to George as the 'quality control standard' for the field of bioenergetics. It is fair to state that some may feel that they have suffered from his critical judgement. George also was among the first to acknowledge a job well done. He often worked behind the scenes to help advance the careers of young scientists whose potential he recognized.

George also had many interests (perhaps passions is a better term, for George never approached anything halfway) outside the lab. His gardening skills were renowned. Much of the spinach he used for his photosynthesis experiments was home grown and always gave the best photosynthetic rates. One of the great surprises many a young student experienced was George's prowess (the hustle) on the basketball court. In his mid-fifties, George could still outplay many twenty-year-olds. George also loved jazz and blues and had an extensive collection of old disks. At the 10th International Congress in Photosynthesis in Montpellier, France (1995), a blues concert featuring the Baskervilles Blues Band led by William Rutherford was held as a tribute to George. It would be the last International Congress that he would attend.

George is survived by his wife Rachel, children Margaret, Audrey, and Michael, and five grandchildren. His greatest love was his family and his grandchildren and his retirement was spent enjoying them. Those of us who had the opportunity to know George were greatly touched by his scientific passion and rigor, his work ethic, and his humanity. George will be greatly missed but his memory will live on because of George's unique character.

## Acknowledgements

We are grateful to Iris Martin Heichel and to Richard Radmer for their recollections when writing this article.

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