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BOOK REVIEW

Kärin Nickelsen and Govindjee: The Maximum Quantum Yield Controversy: Otto Warburg and the "Midwest-Gang"

Bern Studies in the History and Philosophy of Science, University of Bern, Switzerland; Institute für Philosophie, ISBN: 978-3-9523421-9-0

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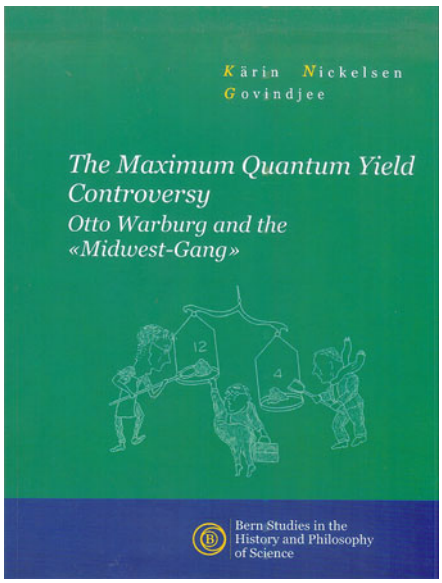
This rather small book, 138 pages to be precise, details the history of an important chapter in photosynthesis research: decades of attempts to determine the minimum quantum requirement of oxygenic photosynthesis (i.e., the minimum number of light quanta (photons) needed to evolve one oxygen molecule; this is simply the inverse of the maximum quantum yield, which is the maximum number of oxygen molecules evolved per photon absorbed). It was truly an incredible story. This book is an important contribution to the history of photosynthesis research and also gives insights into personal and philosophical aspects of research on complex subjects.

Numerous scientists were involved, eventually resulting in two "camps" reporting discordant results. The leading figures of the opposing groups were Robert Emerson at the University of Illinois at Urbana-Champaign (UIUC) and Otto Warburg (1931 Nobel-laureate in Physiology or Medicine) in Berlin, Germany. Nickelsen (a historian of science; Professor of History of Science at University of Munich, Germany) and Govindjee (a former graduate student of Emerson and of Eugene Rabinowitch; now Professor Emeritus of Biochemistry, Biophysics and Plant Biology at the University of Illinois at Urbana-Champaign, USA) are to be complimented for their excellent documentation of the quantum requirement problem: Are 4 (Warburg) or 8–12 (Emerson and others) photons of light needed to obtain one oxygen molecule in oxygenic photosynthesis? The answer was in favor of Emerson's values.



The book includes profiles of the many scientists involved and description of an extraordinary meeting[1] in

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[1] I personally remember the 1948 meeting, and my recollections are included in this book: According to Albert Frenkel the 1948 meeting in Urbana "was civilized, and without the nasty quality that the controversy would later acquire." As stated in a footnote on page 52 in the book, I had attended the meeting and clearly remember Warburg's opening remarks, translated by Victor Schocken as he spoke. Warburg said that the crux of the disagreement was that American scientists simply did not know how to measure light intensity accurately, whereas he (Warburg) knew how because his famous father, Emil Warburg, taught him. Farrington Daniels immediately challenged this insult in gentlemanly fashion. Warburg's arrogance was a key factor in prolonging an extraordinary expenditure of effort and research funds by a large number of dedicated scientists. Eventually there was a general consensus that Emerson was right and Warburg wrong about the maximum efficiency of photosynthesis in the green alga Chlorella.

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Urbana on December 18, 1948 in which the protagonists came face-to-face. Emerson had the right idea of inviting Warburg to Urbana, Illinois, and trying to do the tests in ONE lab. However, Warburg had "converted" a specific biophysical question into an unparalleled "psychodrama." There was no resolution of the controversy at the meeting, and it continued on for many years. As the decades passed and many new discoveries on photosynthetic mechanisms were made, interest in the "exact" minimum quantum requirement faded. It is important to note that practically all of the investigators involved used the unicellular green alga *Chlorella pyrenoidosa* as the experimental system. Equally important is the fact that the major combatants, except for Warburg, had backgrounds mainly in the physical sciences. Unlike microbiologists, they were obviously unaware of the great differences in the metabolic and other properties of cultures of unicellular microbes that depend on many factors: age of the cells, the exact chemical composition of the growth medium, and the physical growth conditions. No wonder their results differed from day-to-day and laboratory-to-laboratory! Nobel Laureate Warburg was a biochemist of great distinction, and had made important discoveries on enzyme catalysis and intermediary electron carriers, but very rarely worked with microbial cells.

It is worth mentioning that in 1968, 9 years after Emerson's death, and 2 years before Warburg's death, Govindjee (one of the authors of this book) and his wife Rajni Govindjee, both trained in plant biology, measured a minimum quantum requirement of 8–10 per molecule of oxygen evolved in young synchronous cultures of *Chlorella* under conditions prescribed by Warburg. The value of 8-10 is, of course, accepted by all since the discovery in 1957 of the Two-Light Effect (Enhancement Effect) by Robert Emerson, presented in 1958 at the Phycological Society of America meeting, held in Bloomington, Indiana, the 1960 two light reaction scheme of Robin Hill and Fay Bendall, published in Nature; and the 1961 antagonistic effect of light 1 and light 2 on the redox level of cytochrome *f* by Lou Duysens and Jan Amesz, also published in Nature.

I have decided to provide here a glimpse of what some others have said about this book; these comments were sent to the authors of this book, and, have been provided to me, when I was writing this short review (reproduced with permission).

Ekkehard Höxtermann (Germany) wrote: "…[the book] is systematic, compact, exciting, quite well balanced between individual/special positions and general conclusions, history of science and contemporary history, etc. I learned a lot, especially on Warburg's stay in the United States."

Colin Wraight (Urbana, Illinois, USA) wrote: "…I started skimming it and was soon quite engrossed. It is a compelling story and very well done. I found myself desperately wanting to be told the answer, i.e., why Warburg got the numbers he did, even though that is not really known. However, I think a degree of satisfaction is provided in the Emerson Strikes Back chapter, and by the Concluding Remarks solidifying the possibility/likelihood of serious issues of integrity."

Lars Olof Björn (Sweden) put it this way: "I have now read through [the book] "The maximum quantum yield controversy". This is great! Important not only for the field of photosynthesis, but for showing how science can go wrong. A bit reminiscent of the religious wars that have been so destructive for humanity!"

Andrew A. Benson (La Jolla, California, USA) recently remembered: "Long ago, when Warburg was in Copenhagen, Denmark, to see his allergist physician when I drove him to Helsingør. I have a photo of him outside a window of the castle where he looked down at the dungeon and exclaimed, 'That's a fine place for The Midwest-Gang'."

I would like to mention some of the interesting historical photographs that are in this book: really great for a book like this. It would have been nice if the book had included a List of Figures in the beginning of the book. I mention some of them here. The book includes a 1948 photograph of Warburg on the cover of the magazine Science, when he arrived at Urbana, Illinois (p. 48); a rather rare photograph of Warburg sitting under a tree (p. 59), surrounded by other scientists including George Wald who later received a Nobel Prize; portraits of Warburg, (p. 12, 51, 53), William Arnold (p. 16, 29; Arnold was the first one to get results different from Warburg, in 1935), James Franck (p. 17, 29; 1926 Nobel laureate in Physics), Emerson (p. 21, 38, 39, 53, 117), C. Stacy French (p. 28), Eugene I. Rabinowitch (p. 31, 113, 117), Victor Schocken (p. 53, see footnote 1). Special mention must be made of two figures: (1) A cartoon that appears in the first chapter (Introduction; see p. 9); this cartoon shows the "fair-minded" Midwest Gang member Eugene Rabinowitch (a Messiah of Photosynthesis Research; Research Professor at the UIUC; later co-inventor of the Doomesday clock on the cover of the "Bulletin of Atomic Scientists") attempting to bring balance between Warburg (who believed that plants and algae needed a minimum of 4 photons to evolve one O_2 molecule) and Emerson (who had measured a minimum value of 8–12 photons to evolve one O_2 molecule). (2) A photograph of the plaque at the University of Illinois at Urbana-Champaign (p. 41) that honors two most prominent members of the Midwest Gang—Robert Emerson and Eugene Rabinowitch—with two of their former students Govindjee and Rajni Govindjee, along with two 2011 graduate students at the UIUC, wearing the Lab apron Emerson wore,

and the glasses Emerson used when at the glass blowing bench.

This wonderful little book is available from Books On Demand (BOD): http://www.bod.de/index.php?id=1132&objk_id=560914 where the web site states: "Whoever turns to the history of photosynthesis research in the twentieth century is soon confronted with the fact that one of its most exciting periods, the years from 1920 to 1960, was in large part overshadowed by a bitter controversy in which many of the leading scientists in the field were involved. It centered on the question, how efficient the process of photosynthesis was. This book attempts a reconstruction of the course of the controversy, based on previously unknown archival sources, and analyzes the arguments brought forward by the two parties."

I end this book review by summarizing my thoughts. In sum: This extraordinary controversy among scientists with different backgrounds and attitudes converging on a difficult problem is perhaps unique in modern scientific history. It could have been avoided if they had all followed an "unwritten" research principle noted by astronomer R. A. Lyttleton who has discussed episodes of mistaken notions in physical sciences: "It is an essential part of scientific investigation to bring every detail of assumption, approximation, method, and all else to the surface, and have every component on the table, as it were, for examination and discussion; nothing should remain buried or left aside that any consideration suggests relevant until its importance or otherwise can be assessed" (Lyttleton 1977).

I recommend this book to all the libraries around the World as well as to all graduate students and teachers of biological, biochemical and biophysical sciences.

Acknowledgments I thank Ekkehard Höxtermann for reading this book review and for approving its submission for publication. I also thank Colin Wraight, Lars Olof Björn, Ekkehard Höxtermann, and Andy Benson for their brief comments on this book. The final version of this book review was also read by Julian Eaton-Rye and George Papageorgiou.

Reference

Lyttleton RA (1977) The encyclopaedia of ignorance. Pergamon Press, Oxford, pp 10–17