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GUEST EDITORIAL

Special issues on Photosynthesis Education honoring Govindjee

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The special issues in volumes 116 and 117 of Photosynthesis Research are all dedicated to Photosynthesis Education. They honor Professor Govindjee, at his 80th birthday on October 24, 2013, for his contributions, dedication, and enthusiasm about photosynthesis, for which he has been called "Mr. Photosynthesis". He is a master educator of our time. The depth of his knowledge and understanding of all aspects of photosynthesis, "From Photons to a Leaf" is enormous. He is also the de facto Ambassador of Photosynthesis to the rest of the World. Govindjee, as he prefers to be called, is a renowned scientist who has made outstanding and significant contributions to photosynthesis research and education.

Govindjee has authored or co-authored more than 400 publications which have brought understanding to many aspects of photosynthesis (for a list since 1994, see his webpage at: http://www.life.illinois.edu/govindjee/recent_papers.html). This includes, most dramatically, his work on exploitation of light emission (chlorophyll fluorescence, delayed fluorescence and thermoluminescence) of plants and algae for understanding photosynthesis. In cooperation with his co-workers, he showed a unique role of bicarbonate in the electron and proton flow on the electron acceptor side of Photosystem II (PSII), and, in his early work on the minimum quantum requirement of oxygen evolution, he proved that Nobel-Laureate Otto Warburg was wrong and that his own professor Robert Emerson was right: i.e. a minimum of 8–12 photons, not 3–4, is required for the evolution of one oxygen molecule. His research, with many collaborators, included the discovery of a short-wavelength form of chlorophyll (Chl) *a* functioning in the Chl *b*-containing system, now called PS II, and of the two-light effects in Chl *a* fluorescence and NADP reduction in chloroplasts. Further, again, with his coworkers, he discovered the existence of different spectral fluorescing forms of Chl *a*, was the first to measure the temperature dependence of excitation energy transfer down to liquid helium temperature (4 K), the first to provide the current theory for thermoluminescence in plants, and the first to make picosecond measurements of the primary photochemistry of PSII.

Equally important, Govindjee has played a key role in global dissemination of research through collaboration with scientists all over the world, and through his lucid lectures on the basics of photosynthesis, as well as on the history of "Photosynthesis Research". A major characteristic of Govindjee is his availability to help anyone and everyone who writes to him; always ready to respond to emails that he receives. In addition, we marvel at his tremendous accomplishments in terms of communication of ideas, and the unsurpassed marathon job he has done editing, which includes numerous books on Photosynthesis,

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especially books in "Advances in Photosynthesis and Respiration Series Including Bioenergy and Related Processes" (see Fig. 1). He pioneered this series in 1994 (volume 1: *The Molecular Biology of Cyanobacteria*) and now in 2013, we have volume 36 that deals with *Senescence of Plants*. To get a glimpse of his research life, we also bring to your attention the interview of Govindjee by Don Ort, for Annual Reviews, Inc (http://www.youtube.com/watch?v=cOzuL0vxEi0&feature=youtu.be).

For further details on Govindjee, see the Tribute by Julian Eaton-Rye (in volume 116). Julian, a former PhD student of Govindjee, honored him at his 75th birthday for his 50 years in research (see Part A and Part B, published in *Photosynth Res* vol. 93 (1–3) 1–244, 2007; vol. 94 (2–3) 153–466, 2007). In addition, he was honored, in 2012, with three chapters on his entire research career in volume 34 of the Advances in Photosynthesis and Respiration Series: *Photosynthesis—Plastid Biology, Energy Conversion and Carbon Assimilation* (Julian Eaton-Rye, Baishnab Tripathy and Tom Sharkey, editors).

For these special issues on *Photosynthesis Education* appearing in volumes 116 and 117, reviews and regular research papers across a broad range of topics, ranging from photochemistry to carbon assimilation, carbon partitioning, and production of bioenergy, were submitted for consideration. The contributors of reviews were asked to prepare these at a level, which will help in educating beginners in the field, and will be useful for teachers of photosynthesis, as well as provide updates for researchers. There was flexibility in approach and length, e.g. review the state of the subject, address open questions, or present educational experiments.

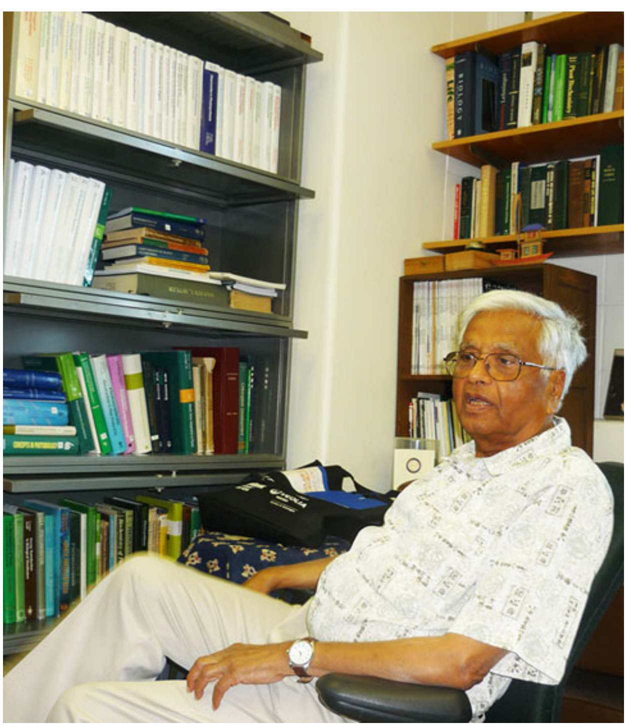

Fig. 1 A recent photograph of Govindjee in his office contemplating future volumes; the latest issues are on the top shelf

Photosynthesis education begins with an understanding of the fundamental process, followed by an understanding of the diversity, which exists during the course of its evolution as it adapts to different environments. Scientists are studying how the components of the process are synthesized, how photosynthesis is regulated, how it is damaged, mechanisms of repair, and mechanisms, which have evolved to tolerate environmental stress. Nearly three billion years ago, living organisms developed the capacity to capture solar energy and use it to power the synthesis of organic molecules using photosynthesis. The photosynthetic process set into motion an unprecedented explosion in biological activity, allowing 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. By liberating oxygen and consuming carbon dioxide, it has transformed the world into the hospitable environment we experience today. This is a fundamental feature of the process; but, an array of differences evolved among photosynthetic organisms in terms of the structure of the photosynthetic apparatus, the processes associated with light absorption and photochemistry, the means of acquiring inorganic carbon for carbon assimilation, and the protection mechanisms against absorption of excess energy.

Directly or indirectly, photosynthesis provides our entire food requirement, and many of our needs for fiber and building materials. The energy stored in petroleum, natural gas and coal all ultimately come from the sun via photosynthesis, as does the energy in firewood and other organic materials, which are major fuels in many parts of the world even in the present day. Thus, humans and other forms of life have existed, and exist today, due to performance of photosynthesis by plants, algae and cyanobacteria, which give us oxygen, food, biomass, and bioenergy. This being the case, scientific research into photosynthesis is vitally important if we are to maintain the demands of the ever-increasing population of our planet.

Currently, it is estimated that photosynthesis produces more than 100 billion tons of dry biomass annually, which is equal to about 100,000 GW of stored energy. Furthermore, half of this activity occurs in the oceans. On a global scale, the raw materials and energy (e.g. water, carbon dioxide, sunlight) needed to drive the synthesis of biomass is available in massive quantities. However, in different ecosystems one or more of these factors can be limiting for photosynthesis. At the heart of the reactions in photosynthesis is the splitting of water into oxygen and hydrogen, through a series of steps that start with absorption of sunlight by photosynthetic pigments. The oxygen produced from water oxidation is released into the atmosphere where it is available for combustion of fuels and for us to breathe. The 'hydrogen' is not normally released into the atmosphere, but instead is combined with carbon dioxide to make various types of organic molecules. When we burn fuels we combine the 'stored hydrogen' in these organic molecules with atmospheric oxygen; in other words, we use the products of photosynthesis to obtain energy required for sustaining our life. Understanding the reactions in photochemistry is crucial to the goal of making artificial photosynthesis, namely to utilize solar energy and convert it into chemical energy through a series of photoelectrochemical events. The design of such systems may benefit greatly from elucidation of the principles of the natural photosystems. Currently, we know a great deal about the workings of the two photosystems, including the water oxidation reaction and reactions of carbon assimilation. However, there are still many gaps in our understanding of photosynthesis, and thus in our ability to use knowledge of the process to benefit mankind. If we can understand and control the intricacies of the photosynthetic process, we have the possibility to increase production of food, fiber, wood and fuel in different environments, as well as to better use our arable land. Also, an important goal is to apply knowledge of photosynthesis to develop new solar energy technologies to produce renewable fuels, such as hydrogen from water.

These special issues on *Photosynthesis education* consist of **Part A**: **Reviews** and **Part B**: **Research papers** (appearing in Volumes 116 and 117).

In **Part A**, we have Reviews on topics covering photochemistry, carbon acquisition, assimilation, partitioning, and bioenergy. First there is a series of reviews on Photosystem I (PSI), PSII, and the Light Harvesting system of photosynthesis. This is followed with exercises for teaching some principles of chlorophyll fluorescence by PSII, and reviews on chloroplast biogenesis, singlet-oxygen-mediated signaling, excitation energy transfer, spectral methods for the analysis of photochemistry, dissipation of excess energy, architectural switches in thylakoid membranes, membrane fluidity, and regulation of electron transport and ATP synthesis. The next set of articles, which covers carbon acquisition and assimilation, contains reviews on the regulation of gene expression in synthesis of components needed for photochemistry and carbon assimilation, the state of knowledge of processes associated with carbon assimilation (conductance of CO_2 to the chloroplast, C_3 cycle, Rubisco, photorespiration, and CO_2 concentrating mechanisms in cyanobacteria, algae and terrestrial plants), photoinhibition, carbon partitioning in plants, biomass and bioenergy.

In **Part B**, we have research papers on a range of topics which were covered in reviews on photochemistry and carbon assimilation. This includes research on excitation energy transfer, energy flux theory, light harvesting complexes, chlorophyll fluorescence kinetics, thermal phase and excitonic connectivity in fluorescence induction, models for the water oxidation complex of PSII, photoinactivation and repair of PSII, technology for simultaneous analysis of proton charge flux and CO_2 assimilation, photoprotection responses under drought, and models for Rubisco–Rubisco activase interactions.

We note that the following paper, scheduled for our Special Issues, appeared, by mistake, in an earlier issue: Ducruet J-M. (2013) Pitfalls, artifacts and open questions in chlorophyll thermoluminescence of leaves or algal cells Photosynth Res 115: 89–99.

We end this Guest Editorial on *Special issues on Photosynthesis Education* with informal portraits of ourselves so that others will recognize us when we are at Conferences we may attend.


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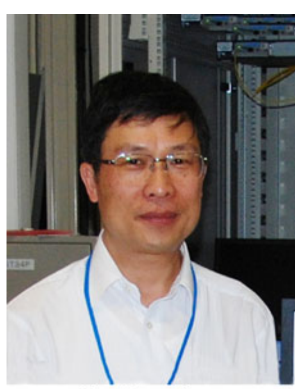
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