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FOREWORD

JULIAN J. EATON-RYE

Department of Biochemistry, University of Otago, P.O. Box 56, Dunedin 9054, New Zealand

This Special Issue of *Photosynthetica* has been assembled to celebrate Professor Govindjee's 85th birthday which was on October 24, 2017. Govindjee (Fig. 1) has been a contributor par excellence to the field of photosynthesis since commencing his PhD studies in the laboratory of Robert Emerson (1903–1959) in 1956 at the University of Illinois at Urbana-Champaign. Upon the tragic death of Robert Emerson in a plane crash on February 4, 1959, Govindjee, along with his wife Rajni, was invited to join the laboratory of Eugene Rabinowitch (1901–1973) (Eaton-Rye 2007a,b, 2013). Rajni Govindjee (nee Varma) had also joined the laboratory of Emerson to study for her PhD in September 1957 and Rajni and Govindjee were married that same year on October 24. Robert Emerson, a renowned biologist and biochemist (Rabinowitch 1961) and Eugene Rabinowitch, a distinguished physicist (Atomic Heritage Foundation 2018), had come to the University of Illinois in 1947 to establish a center of research in photosynthesis and it was, perhaps, under the excellent mentorship of these two pioneers in photosynthesis research that Govindjee acquired his breadth of interest in the field that he has expressed both as a researcher and educator up to the present day. In 1994, Govindjee established the *Advances in Photosynthesis and Respiration* book series (http://www.springer.com/series/5599), now in volume 44, that reflects the great sweep of his interest in the subject and this depth and breadth is reflected in the 46 contributions to this volume of *Photosynthetica* from 166 authors representing 21 different countries.

The articles in this volume have been gathered under five headings. The first of these, **Photosynthetic pigments, molecular biology, artificial photosynthesis and history**, illustrates both the extensive interests of Govindjee and the high regard in which Govindjee is held across the discipline by both young and established researchers alike. In the first paper by Larkum *et al.* (2018) the authors provide an in-depth review of the roles of chlorophylls, bacteriochlorophylls, and rhodopsins in capturing solar radiation. This is followed by a perspective by Borisov and Björn (2018) that provides an estimation of how many years are required to generate the current level of molecular oxygen in the atmosphere given the portion of incident solar energy that is used for oxygenic photosynthesis. These articles are followed by a review on RNA editing of plastid-encoded genes (Lu 2018) followed by a closer look at chloroplast ribonuleoprotein-like proteins in the moss *Physcomitrella patens* revealing a lack of involvement in both RNA stability and editing

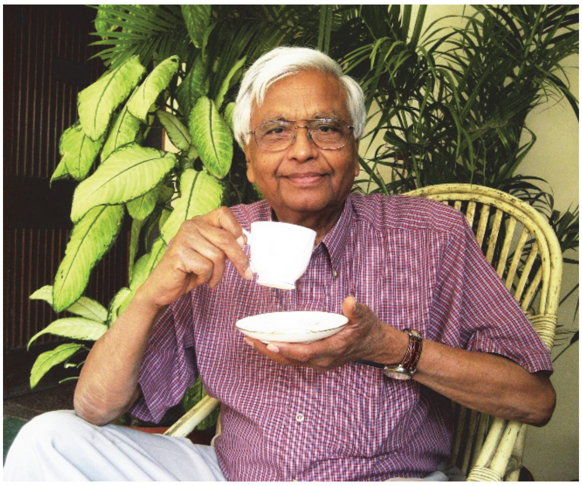

Fig. 1. Govindjee relaxing with a cup of tea in Bhopal, India in 2016.

(Uchiyama *et al*. 2018). Artificial photosynthesis is the topic of the next paper which describes the synthesis of a novel metalloporphyrin, cobalt(II) 5,10,15,20-tetrakis (3-fluorophenyl)porphyrin containing a 4-vinylphenyl surface attachment group (Khusnutdinova *et al.* 2018). This eclectic grouping finishes with a contribution to the history of photosynthesis research focusing on Otto Warburg's scientific career during the Nazi period in Germany (Nickelsen 2018).

The next grouping of papers, **Chlorophyll fluorescence**, is on a topic that is dear to Govindjee (Papageorgiou and Govindjee 2004). In fact, Govindjee is a co-author on the first paper in this section that reviews the use and suitability of chlorophyll *a* fluorescence induction measurements to assess plant responses to abiotic stress (Stirbet *et al*. 2018). A second review follows in this section that examines the information that can be obtained regarding the photosynthetic apparatus by measuring fluorescence emission spectra at 77 K (196ºC) — a tool that has been used in photosynthesis research for many years (Lamb *et al.* 2018) and pioneered in the photosynthesis lab in Urbana (Brody 1958, Govindjee and Yang 1966). Fluorescence induction in anoxygenic photosynthetic bacteria is the subject of the next contribution (Sipka *et al*. 2018) and this is followed by a brief communication detailing how spectrally resolved fluorescence induction can be used to study light-induced nonphotochemical quenching (NPQ) of the excited state of chlorophyll in algae (Kaňa 2018). The topic of NPQ is

Fig. 2. Govindjee in Urbana with Eugene Rabinowitch in 1963. Govindjee gave up his cigars around 1980.

explored further in the next paper detailing how changes in the proton conductance of the $CF_0.CF_1$ ATPase can impact this quenching process in leaves (Vredenberg 2018). This section ends with as assessment of how occupancy of the Q_B-binding site [Q_B is the secondary plastoquinone acceptor of photosystem II (PSII)] by the native quinone or herbicides can modulate the maximum level of chlorophyll fluorescence (F_m) (Prášil *et al.* 2018).

Undoubtedly Govindjee is an authority on PSII. His involvement with PSII research goes back to his early discovery that both of the photosystems unveiled by the pioneering experiments of Robert Emerson and colleagues (Emerson and Lewis 1943, Emerson *et al*. 1957) utilized chlorophyll *a* in what was later recognized to be their reaction centers (Govindjee and Rabinowitch 1960) (Fig. 2). Since this beginning Govindjee has co-authored over 400 research papers and major reviews on many aspects of PSII including delayed light emission (Jursinic and Govindjee 1972) and thermoluminescence (deVault *et al.* 1983) as well as primary charge separation (Wasielewski *et al.* 1989) and the role of bicarbonate (Stemler and Govindjee 1973, Shevela *et al*. 2012). The next section in this Special Issue is entitled **Photosystem II** and contains 14 contributions.

The first contribution in the Photosystem II section examines the origin of the FtsH proteases involved in the repair of PSII following its photodamage and finds the phylogeny of the FtsH proteases to be consistent with an early origin of water-oxidation chemistry (Shao *et al.* 2018). In the following paper, Fourier transform infrared spectroscopy is used to investigate chloride binding to PSII in the presence or the absence of the lumenal PsbP subunit of PSII supporting a role for PsbP in inducing conformational changes that regulate chloride binding in the water-oxidizing complex (Kondo and Noguchi 2018). The contribution of the lumenal subunits of PSII is investigated further in Yamada *et al*. (2018). These authors consider the role of the PsbQ′ subunit found in red algae and show that this lumenal subunit affects the redox potential of Q_A (the primary plastoquinone acceptor of PSII). In addition to the Q_A- and Q_B-binding sites of PSII a third quinone binding site, know has Q_C, has been reported (Guskov *et al*. 2009). The authors of the next contribution show that mutations introduced into the cyanobacterium *Synechocystis* sp. PCC 6803 that target the Q_C site result in improved photosynthetic growth rates and biomass production, in cells grown in a photobioreactor, as a result of altered regulation of photoprotection (Huang *et al*. 2018). Also employing *Synechocystis* sp. PCC 6803, Biswas and Eaton-Rye (2018) show that the low-molecular-weight PsbY subunit of PSII plays a role in protection from photodamage when the PsbM subunit of PSII is not present. Interestingly, the sensitivity of the ΔPsbM:ΔPsbY strain to high light was not observed when bicarbonate was added. The use of membrane-inlet mass spectrometry and ^{18}O-labeling to quantify bound bicarbonate in PSII is the subject of the next paper. These measurements support the presence of one bicarbonate per PSII that is bound to the non-heme iron in the iron-quinone electron accepting complex, while being consistent with a role of unbound bicarbonate optimizing the water-splitting reactions by acting as a mobile proton shuttle (Tikhonov *et al*. 2018), an idea that Govindjee loves so dearly. The action of bicarbonate in PSII is further explored in the cyanobacterium *Arthrospira maxima* in the following paper identifying sites of action for bicarbonate at the water-oxidizing complex and solvent-accessible arginine residues in addition to the non-heme iron binding site (Ananyev *et al.* 2018).

The papers on PSII continue with a comparison of PSII electron transfer in isolated PSII containing different PsbA-variants from the cyanobacterium *Thermosynechococcus elongatus*. In this report the authors take a novel approach using redox polymer/protein biophotoelectrochemistry to study forward electron transfer in the isolated PSII complexes (Hartmann *et al.* 2018). In the next contribution, we learn about the influence of the disaccharide trehalose on the water-oxidizing complex of spinach PSII core complexes (Mamedov *et al.* 2018) and this is followed by a report on the photooxidation and photoreduction of exogenous cytochrome *c* by PSII preparations following a range of treatments that modify the water-oxidizing complex (Khorobrykh *et al.* 2018). Approximately half of the lipids found in plant thylakoids are non-bilayer lipids. In Kotakis *et al.* (2018) the authors show that modification of the macro-organization of thylakoids membranes through the application of co-solutes results in changes in lipid phase behavior that confers increased thermal stability to PSII. In the remaining two papers belonging to this section we learn first that the phycobilisome terminal emitter in *Synechocystis* sp. PC 6803 transfers its excitation energy at a rate of $(20\ ps)^{-1}$ to PSII (Acuña *et al.* 2018) and then finally a "deep red" state of PSII, which lies at a lower energy than the reaction center P680, is characterized in the red alga *Cyanidioschyzon merolae* (Langley *et al*. 2018).

In addition to their use in PSII research, cyanobacteria feature widely in other aspects of photosynthesis research and Govindjee has worked with cyanobacteria on a range of biophysical topics (Govindjee and Shevela 2011). It is also worthy of note that, as well as the work mentioned above on the primary photochemistry of PSII (Wasielewski *et al.* 1989), Govindjee and colleagues made pioneering experiments on the primary photochemistry of photosystem I (PSI) (Fenton *et al*. 1979, Wasielewski *et al*. 1987). It is therefore fitting that the next section gathers together eight contributions on **Photosystem I and cyanobacterial photosynthesis**.

This next portion of the Special Issue begins with a review of the central role of ferredoxin in shuttling electrons from PSI to a wide range of electron acceptors in addition to its key role in NADPH production and cyclic electron transport (Mondal and Bruce 2018). This is followed by a paper investigating the oligomeric state of PSI in cyanobacteria (Zakar *et al*. 2018) and a subsequent contribution describing the use of a yellow-fluorescence-protein tag on the PsaF subunit of PSI that allows purification of cyanobacterial monomeric and trimeric PSI complexes (Strašková *et al*. 2018). The theme of PSI purification from cyanobacteria is then continued in the next contribution which describes the isolation of PSI from the chlorophyll *f*-containing cyanobacteriun *Halomicronema hongdechloris* (Li *et al*. 2018). In the next paper, the effect of green light on the amount and activity of the NADH dehydrogenase (NDH)-1–PSI supercomplex has been investigated in *Synechocystis* sp. PCC 6803. This study shows that the up-regulation of the CpcG2 phycobilisome linker protein by low-intensity green light increases the abundance of the NDH-1–PSI supercomplex (Gao *et al*. 2018).

Cyanobacteria possess a unique chlorophyll *a*-containing antenna protein known as IsiA that is up-regulated under iron stress: both the underlying function and the distribution of this antenna protein are reviewed in the contribution by Chen *et al*. (2018). The next paper investigates factors affecting photobiological hydrogen production by filamentous cyanobacteria from Thailand (Yodsang *et al*. 2018) and this section closes with a report of the isolation of a new *Leptolynbya* strain possessing chlorophyll *a*, *d*, and *f* and exhibiting far-red acclimation from a desert region in Pozas Rojas, Cuatro Ciénegas, México (Gómez-Lojero *et al*. 2018).

The final section of this Special Issue gathers together 12 papers focused on the whole plant level under the heading **Plant Physiology and Physiological Ecology**. This last section opens with two reviews, the first considering a comparison of the efficiency of photosynthesis in sun and shade plants (Mathur *et al*. 2018) and the second examining the impact of salinity on photosynthesis (Wungrampha *et al*. 2018). The impact of tocopherol on the vascular composition of *Arabidopsis thaliana* leaves is then presented in the next contribution: a tocopherol-deficient mutant exhibited apparently compensatory changes revealing an increased number of minor veins but with fewer phloem cells and smaller tracheary elements such that photosynthetic capacity remained similar between mutant and wild-type plants (Stewart *et al*. 2018). The link between photosynthetic capacity and leaf vascular organization is further explored in the next contribution (Polutchko *et al*. 2018). This is followed by a review that examines the sources of sugars for energy homeostasis in leaves undergoing senescence and emphasizes the role of cell wall hydrolases in providing sugars as a source of energy for the completion of the senescence program (Biswal and Pandey 2018).

The last section continues with a report regarding a plant growth regulator that modulates glycoconjugation through the plant lectin cycle. Treatment of plants with this compound led to increased soluble sugar content in cherry, grape, and melon (Nonomura *et al*. 2018). These authors also include a foreword to their paper that echoes the sentiments of all the contributors to this Special Issue regarding the high esteem in which Govindjee's tireless long-standing contributions to photosynthesis research and photosynthesis education are held. In the next contribution the impact of UV-B on the photosynthetic apparatus is examined in an *Arabidopsis thaliana* mutant deficient in both phytochrome A and B (Kreslavski *et al*. 2018). The susceptibility of an ascorbate-deficient *Arabidopsis thaliana* mutant to high-light stress is the subject of the next study (Zeng *et al*. 2018) and the capacity for *A. thaliana* roots to increase photosynthetic capacity after shoot removal is investigated in the following report. The approach taken by these researchers involves the overexpression of GATA transcription factors along with various hormone treatments to dissect the different roles of cytokinin, auxin, and different transcription factors in regulation of the photosynthetic machinery in root tissue (Ohnishi *et al*. 2018).

The remaining three papers in this Special Issue move away from model plants. In the first of these reports the importance of anthocyanins in photoprotection in the evergreen tree *Acmena acuminatissima* was investigated and indicated an important role for anthocyanins in photoprotection of young leaves in winter (Zhu *et al*. 2018). Photoprotective strategies were also investigated in the next report which examined adaptive physiology in prairie plants at the Cedar Creek Ecosystem Science reserve in East Bethel, Minnesota – the study suggested a combination of photoprotective pigments and altered canopy structure worked together to mitigate oxidative damage resulting from excess radiation in their experimental plants (Kothari *et al*. 2018). The last report, from the National Botanical Research Institute in Lucknow, India, looked at the adaptive strategies of the invasive leguminous tree species *Prosopis juliflora* by comparing the photosynthetic physiology of leaves produced in spring (February–March) with those produced during the monsoon (June–July). The findings of this report suggest the ability of the plant to adapt its photosynthetic physiology to differing environmental conditions contributes to the competitive success of this tree since it has the capacity to form two productive cohorts of leaves throughout the year compared to deciduous tropical tress that have no leaves in winter (Shirke *et al*. 2018).

The large number of contributions and contributing authors to this Special Issue to celebrate Govindjee's 85th birthday mirror the amazing output and service Govindjee has given the photosynthetic community over 60 years of active research and teaching. Govindjee 'retired' in 1999 but has published over 170 articles since 2000 including original research, reviews, tributes to fellow scientists, historical papers and news articles, the latter typically emphasizing contributions from young scientists whose careers are just getting underway. He is the founder of the History & Biography section of *Photosynthesis Research*, from which he has just retired (Fig. 3). In all, Govindjee has published over 540 articles in his professional career. In volume 34 of the *Advances in Photosynthesis and Respiration* Book series (Eaton-Rye *et al*. 2012) the publications of Govindjee were collected in three chapters (Clegg 2012, Eaton-Rye 2012, Papageorgiou 2012). To bring the list up-to-date Govindjee's publications since 2011 are included in an Appendix to this Foreword.

Fig. 3. Rajni Govindjee and Govindjee in 2017.

In conclusion, it only remains for me to thank Helena Synková (Editor-in-Chief) and Ivana Štětinová (Executive Editor) at *Photosynthetica* for their hard work and enthusiasm for bringing this Special Issue to fruition.

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Appendix

Govindjee's publications (2011–2018)

From his 85[th] birthday to his 80[th] (or 79[th]) chronologically arranged: from the present to the past, under 4 categories: (1) Books; (2) Reviews including chapters in books; (3) Original research papers; (4) History & Biography: mainly Tributes & News Reports

(1) Books

Shevela D., Björn L.O., Govindjee: Photosynthesis: Solar Energy for Life. Pp. 300. World Scientific, Singapore 2018.
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