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Mister Photosynthesis of the 21st Century, Govindjee

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ABSTRACT

We celebrate the 90th birthday of Govindjee Govindjee in the upcoming year (2022) by sharing our personal thoughts. Detailed information on his work and career are available at his website at the University of Illinois at Urbana-Champaign (UIUC): https://www.life.illinois.edu/govindjee/.

Keywords: Allahabad, Bicarbonate effect, Photosystem II: Robert Emerson, Eugene Rabinowitch

EARLY LIFE AND OUR CONNECTIONS

Of life's energy transformations, photosynthesis is the greatest, and one of the most significant scientists and educators in this field is Govindjee. There is one special connection with Govindjee for one of us, AK: Shri Swami Dayal Tewari, AK's father, studied at Allahabad University (A.U.), the same university Govindjee attended much later. Tewari completed his MSc in Botany, eleven years before Govindjee, in 1943, and later worked with K.C. Mehta at Agra College, Agra, before joining Champa Agarwal College, Mathura, U.P., where he settled finally. At that time, the professors and heads were from Great Britain or trained there, as was Shri Ranjan (MSc (Cantab); DSc from France), who had been Govindjee's teacher in Plant Physiology. The A.U. was, and remains today, one of the top universities of India. The Department of Botany once had been headed by Shri Ranjan; other stalwarts at A.U. included Julian Mitter (PhD from UK) and Ram Kumar Saxena (DSc from France). During the time of AK's father, Divya Darshan Pant was an appointed demonstrator, equivalent to a junior lecturer. Further, Birbal Sahni, the great paleobotanist, taught at A.U., and Pant was his student, thereafter, becoming a respected authority in that field. Both Ranjan and Pant were Govindjee's favourite teachers. It was in 1953 that Govindjee opted to take the "Special Paper in Plant Physiology" under Ranjan; and unlike other classes, it was held as a seminar course where students gave talks. Thus, began Govindjee's interest in photosynthesis. Figure 1 shows a recent photo of Govindjee, who is nicknamed Mr. Photosynthesis of the 21st Century.

One of us (AK) began admiring Govindjee during post graduate teaching and research when studying the book on photosynthesis by Rabinowitch and Govindjee (1969). AK had a chance to meet him and Melvin (Mel) Klein in 1980, at the American Society of Photobiology Annual meeting, Colorado, U.S.A. (Figure 2). Here, AK with his mentor (Karl-Hermann Neumann), and a colleague, L. Bender from the Institute of Plant Nutrition, Justus Liebig University, Germany, made a presentation on the development of photosynthetic apparatus in *Daucus carota* L. callus cultures (Kumar *et al.*, 1980; also see Neumann *et al.*, 2020). We proudly note that Govindjee was elected and served as the 1981-1982 President of the American Society of Photobiology at this meeting. (See the Wikipedia article on Govindjee at https://en.wikipedia.org/wiki/Govindjee.)

Figure 1: An impromptu portrait, taken in June, 2021, of Govindjee relaxing in a park in Urbana, Illinois, USA. *Source:* Archives of Govindjee's family.

We note that Joy Block (JB), coauthor of our paper, is connected with Govindjee through an extensive personal interview on Govindjee's journey from Allahabad (India) to Urbana (IL, USA). See her article on this interview (Block, 2022, *in press*), from which we reference some parts in this article. Further, coauthor Arthur Nonomura (AN) is connected with Govindjee through their common interests in photosynthesis, botany, and remembrance of pioneers in the field. See, for example, Nonomura *et al.* (2017); Govindjee *et al.* (2016) and Govindjee *et al.* (2020) for the life and discoveries of Andrew A. Benson, James A. Bassham, and Melvin Calvin, on the path of carbon in photosynthesis; and, in fact, Nonomura *et al.* (2017) marks the celebration of the last issue in this series. In addition, AN is sponsoring Govindjee's Educational Poster Series (see reference to these and other posters in Stirbet *et al.,* 2020) for public distribution, *gratis*. Further and most recently, the two have been discussing the role of lectins in the carbon reactions for field modulation of glycoregulation by the first plant growth regulator for

Figure 2: A snapshot taken during a break at the 1980 American Society of Photobiology Annual meeting, Colorado, USA. Left to Right: Ashwani Kumar, Govindjee, and Melvin Klein (a topmost authority in photosynthesis from University of California, Berkeley). *Source:* Personal collection of Ashwani Kumar

photosynthesis, that has been proven to substantially enhance the quality and quantity of crops (see e.g., Nonomura *et al.*, 2020).

FASCINATION WITH PHOTOSYNTHESIS

Early on, during 1954-1956, when Govindjee was teaching plant physiology at A.U., he had developed a keen interest in understanding the research of the Nobel laureates Richard Willstätter (https://www.nobelprize.org/prizes/chemistry/1915/willstatter/biographical/) and Hans Fischer (https://en.wikipedia.org/wiki/Hans_Fischer). In addition, he became fascinated with the research of Robert Emerson, of the Department of Botany, UIUC, on the role of chlorophyll *a* in photosynthesis. He applied for admission to UIUC under its Fellowship Program and was accepted into its doctoral program in 1955, in Physico-Chemical Biology (later changing to Biophysics), also receiving the Fulbright Foundation travel grant to go to USA. Both Govindjee and his wife Rajni benefitted from the scholarly heritage of not only Emerson, but another UIUC luminary, Eugene I. Rabinowitch (whose post-doctoral professor, James Franck, was the 1926 Nobel laureate in experimental physics; https://en.wikipedia.org/wiki/James_Franck). For information on Rajni's research, see an article by Ebrey (2015), where he calls her, "*Brighter than the Sun*".

According to Govindjee, "Although Emerson had been right in his concept of the two light reactions and two photosystems, he was wrong in believing that one system was run by chlorophyll *b* and the other by chlorophyll *a"*. Govindjee's 1960 work, published in the prestigious international journal, *Science*, proved that both systems are run by different spectral forms of chlorophyll *a* (Govindjee and Rabinowitch, 1960). He has told many of us that, "It's too bad that Emerson was not there to see this work and to coauthor my paper". Figure 3 shows his photograph with a plaque in honor of Emerson, as well as Rabinowitch (see Govindjee and Govindjee, 2021, for accounts of these mentors).

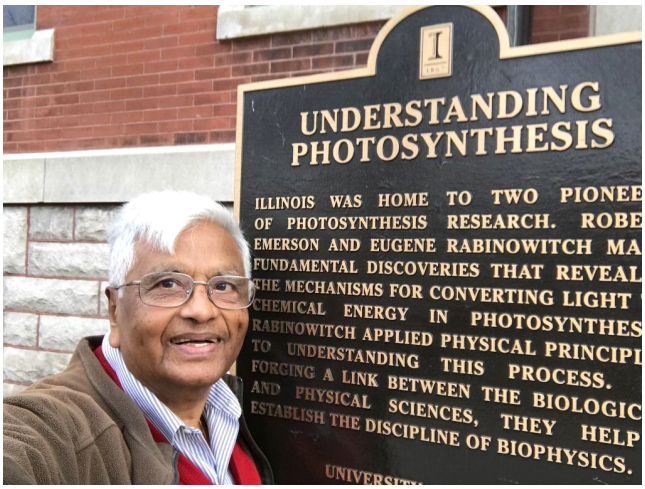

Figure 3: Govindjee with a plaque remembering two of his mentors: Robert Emerson and Eugene Rabinowitch. This photograph was taken in 2018. *Source:* Govindjee archives (for further information, see Govindjee and Govindjee, 2021; Govindjee *et al.*, 2019)

RESEARCH HIGHLIGHTS

Govindjee has been recognized highly by others in photosynthesis research for over six decades in the field (see Appendix A); and here we recognize his 65-year tryst in research, as described in his own words (Govindjee, 2019a, 2019b). He has been a leading expert on the following: (1) the use of chlorophyll (Chl) fluorescence to study photosynthesis (see e.g., his paper on the discovery of the "two-light" effect through Chl fluorescence (Govindjee *et al.*, 1960), and his book with his first PhD student George Papageorgiou (Papageorgiou and Govindjee (eds), 2004); (2) the primary photochemistry of photosynthesis (see e.g., Fenton *et al.*, 1979; Govindjee and Wasielewski, 1990); and, most importantly, (3) for his pioneering studies on the role of *bicarbonate* in electron (and proton) transport in Photosystem II (see e.g., a review by Shevela *et al.*, 2012). We now will expand on some of his specific fields of scientific advancement.

Oxygenic photosynthesis involves the conversion of light into chemical energy, using two photosystems and many enzymes to oxidize water to molecular oxygen and to reduce carbon dioxide to carbohydrate (Rabinowitch and Govindjee, 1969; Shevela *et al.*, 2019; Blankenship, 2021). Indeed, today we identify the singular process of photosynthesis in two metabolic pathways, as the light and carbon reactions. It was the curious phenomenon of the "Red Drop" (Emerson and Lewis, 1943; very low "photosynthesis" when plants receive only far-red light, "i.e., when they excite only chlorophyll *a*), that had inspired Govindjee" to pursue his graduate studies with Emerson at UIUC. Govindjee arrived at the UIUC in September 1956.

We learnt from Govindjee that Emerson was already solving the mystery of the 'Red Drop', in 1956. By 1957, Emerson had discovered what is now called "The Emerson Enhancement Effect" in photosynthesis, which goes as follows: the rate of oxygen evolution measured when far-red light is given together with light of a shorter wavelength is greater than the sum total of oxygen evolution measured when these two different light wavelengths are given separately (see Emerson *et al.*, 1957, for the original discovery). This new observation suggested the existence of two light reactions and two pigment systems in photosynthesis (Rabinowitch and Govindjee, 1965; Govindjee *et al.*, 2017).

Now, let us address the role of bicarbonate in the light reactions of photosynthesis, for which we will mention a few important aspects, based on our conversations with Govindjee. Although Otto Warburg (graduate advisor of Emerson, and a 1931 Nobel laureate; see, <https://www.life.illinois.edu/govindjee/nobel.html>) was wrong

in his conclusion that oxygen comes from CO_2 (see e.g., Stemler and Radmer, 1975), his suggestion on the requirement of 'bicarbonate' in the Hill reaction (Warburg and Krippahl, 1958) inspired Govindjee and his graduate students to study this 'bicarbonate effect'. Govindjee *et al.* (1976) established the effect of bicarbonate at the 'two-electron gate' of Photosystem II (PS II). Govindjee and his students examined, with excitement, this unique role for bicarbonate in PS II. They found that without it, $Cytb_6f$ would not receive any electrons from PS II. Together, with his many graduate students and postdoc associates, from USA, Europe, and Asia, he studied the effects of 'bicarbonate' on the electron and proton flow in the Z-scheme of photosynthesis (see reviews by Govindjee and Van Rensen, 1978; Vermaas and Govindjee, 1981; Shevela *et al.*, 2012; cf. Govindjee *et al.*, 2017). There are two effects of bicarbonate: one is on the electron acceptor side of PS II – bicarbonate is bound to the non-heme iron located between "Q_A" and "Q_B" – and the other is on the electron donor side of PS II (see e.g., Stemler *et al.*, 1974; Wydrzynski and Govindjee, 1975; Khanna *et al.*, 1977, 1981; Siggel *et al.*, 1977; El-Shintanawy *et al.*, 1990). Several researchers have provided further detailed information on the role of bicarbonate on both the electron acceptor and the electron donor sides of PS II (see, e.g., Brinkert *et al.*, 2016; Shevela *et al.*, 2020). The 'bicarbonate' effect on the electron acceptor side is essential at a site where several herbicides inhibit photosynthesis, as shown by Govindjee's past students and postdocs, e.g., Rita Khanna (PhD, 1980); Wim Vermaas, Jiancheng Cao (PhD, 1992); and Jin Xiong (PhD, 1996). For details, see also Khanna *et al.* (1981); Vermaas and Govindjee (1981, 1982); Vermaas *et al.* 1982; Cao *et al.* (1992); Xiong *et al.* (1996, 1997); and Shevela *et al.* (2012). Furthermore, key experiments by Julian Eaton-Rye (PhD, 1987) and Chunhe Xu (PhD, 1992) provided a detailed understanding of the bicarbonate effect at the Q_B site (see e.g., Robinson *et al.,* 1984; Eaton-Rye and Govindjee 1988a, 1988b; and Xu *et al.* 1991). Indeed, Govindjee *et al.* (1991) showed that formate, used to achieve a state deficient in bicarbonate, releases CO_2. However, searching for the mechanism of how bicarbonate functions has still a long way to go.

CONCLUDING REMARKS

We emphasize that all of Govindjee's recent publications (since 1994) are available at <http://www.life.illinois.edu/govindjee/recent_papers.html>; and all his earlier papers from 1955-1993 are at <http://www.life.illinois.edu/govindjee/pubschron.html>. For a background on the basics of photosynthesis, see Eaton-Rye *et al.* (2012); Shevela *et al.* (2019); and Blankenship (2021). For a list of Govindjee's graduate students, see <https://www.life.illinois.edu/govindjee/g/GraduateStudents. html> and Govindjee (2019a, 2019b). Also see, https://www.life.illinois.edu/govindjee/world-historical.html for conferences attended in India. Finally, for perspectives on both Govindjee and his scholar wife, Rajni, see (1) "Govindjee and Rajni Govindjee - Confluence of Photosynthesis and Photobiology", by Ravi Sharma: https://www.linkedin.com/pulse/govindjee-rajni-confluence-photosynthesis-dr-ravi-sharma, and (2) "Govindjee: The Living Legend I Met", also by Ravi Sharma.

Clearly, Govindjee is a superb role model for all who have studied his life's work; this includes undergraduates, graduates, post-docs, and university faculty. And we know of his virtuous character; he has devoted his life to education of all in the world regardless of race, religion, country, and creed. In his retirement, Govindjee has continued in his pursuit of "The Golden Stag" (see Stirbet *et al.,* 2020, for his favorite quote that will explain the metaphor) at a pace that continues his extraordinary scholarly pursuits at the cutting edge of science. Even when approaching his ninth decade, Govindjee is as energetic as he is humble, lifting his students and colleagues to new heights to the thrill of discovery by application of rigorous science and whilst instilling truth and integrity. Govindjee is, by all means, our superhero-our living planetary treasure-as we are sure he is and will be contributing to the greatest benefit of mankind.

We end this tribute to Govindjee by providing the following: Appendix A, which contains references to some of the articles written on him; Appendix B, which lists some of his selected papers, arranged chronologically from 2021 to 1955; and Appendix C, which lists selected awards and honors given to him, during 1976 to 2020.

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Appendix A

What follows is a partial list of papers, conferences, and interviews of Govindjee, where he was honored.

American Society of Plant Biology, 2011. An interview with Govindjee, by Donald R. Ort https://www.youtube.com/watch?v=cOzuL0vxEi0 See: Annual Reviews Conversations www.annualreviews.org • An Interview with Govindjee, 11 pages.

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Appendix B

Selected Publications of Govindjee

Prologue

We present below a list of "*Selected Publications*" of Govindjee, who changed his name to Govindjee Govindjee in 2019, and who is nicknamed '*Mister Photosynthesis of the 21st Century*' because of his extensive research from a picosecond (10^{-12} second) time scale to even 10^8 seconds in one case!

This list is arranged chronologically from the present (2021) to the past (1955), when his first paper appeared, in *Nature* (London), with his close lifetime friend Manmohan Manohar Laloraya. It catalogs more than 65 years of his research journey – from Allahabad (Uttar Pradesh, India) to Urbana (Illinois, USA). See Govindjee (2019) for his own account of his *Tryst*. Also, see Stirbet *et al.* (2020) for his work during his 20^+ years of retired life (2000-2021), and Eaton-Rye *et al.* (2020) for more than 65 messages at his 88th birthday (*Beiju*, "rice years", in Japanese). In selecting the list below, we have focused on his original research papers and some reviews. Selected Tributes and books are in the addendum to this list. Our apologies to those whose papers could not be included in this list of publications; out of Govindjee's 585 publications; those selected are mainly to give a flavor of Govindjee's interests and outreach to others around the World (references in each year are arranged alphabetically).

Eaton-Rye JJ, Guieysse B, Packer MA, Summerfield TC, and Wood SA, 2020. Introduction: Biology and biotechnological applications of microalgae and photosynthetic prokaryotes: part 2, *New Zealand Journal of Botany,* Vol. 58, No. 4, pp. 275-333; https://doi.org/10.1080/0028825X.2020.1856887.

Govindjee G, 2019. A sixty-year tryst with photosynthesis and related processes: an informal personal perspective. *Photosynthesis Research*, Vol. 139, No. 2, pp. 15-43; doi 10.1007/s11120-018-0590-0.

Stirbet A, Björn LO, Shevela D, Allakhverdiev SI, Nonomura A, Zhu X-G, Lazár D, Pareek A, Garab G, and Eaton-Rye JJ, 2020. Celebrating the contributions of Govindjee after his retirement: 1999–2020. *New Zealand Journal of Botany,* Vol. 58, No. 4, pp. 422-460; https://doi.org/10.1080/0028825X.2020.1852265.

We wish Govindjee the very best at his upcoming 90th birthday that falls on October 24, 2022. May he continue to help students around the World, spreading the importance of photosynthesis through his reviews and educational posters. See his web page: https://www.life.illinois.edu/govindjee/

For his complete publications, see : https://www.life.illinois.edu/govindjee/recent_papers.html and https://www.life.illinois.edu/govindjee/pubschron.html

a. Post retirement period: 2021-2000

2021

Pandiyan S, Govindjee G, Meenatchi S, Prasanna S, Gunasekaran G, and Guo Y, 2021. Evaluating the impact of summer drought on vegetation growth using space-based solar-induced chlorophyll fluorescence across extensive spatial measures. *Big Data* (16 Pages); https://www.liebertpub.com/doi/10.1089/big.2020.0350

2020

Khan N, Essemine J, Hamdani S, Qu M, Lyu M-J A, Perveen S, Stirbet A, Govindjee G, and Zhu X-G, 2020. Natural variation in the fast phase of chlorophyll *a* fluorescence induction curve (OJIP) in a global rice minicore panel. *Photosynthesis Research* (22 pages); https://doi.org/10.1007/s11120-020-00794-z

Negi S, Perrine Z, Friedland N, Kumar A, Tokutsu R, Minagawa J, Berg R, Barry A, Govindjee G, and Sayre R, 2020. Light-regulation of light harvesting antenna size substantially enhances photosynthetic efficiency and biomass yield in green algae. *The Plant Journal*, Vol. 103, No. 2, pp. 584-603; doi: 10.1111/tpj.14751

Nonomura AM, Shevela D, Komath SS, Biel KY, and Govindjee G, 2020. The carbon reactions of photosynthesis: role of lectins and glycoregulation. *Photosynthetica,* Vol. 58, No. 5, pp. 1090-1097; doi: 10.32615/ps.2020.064.

Stirbet A, Lazar D, Guo Y, and Govindjee G, 2020. Photosynthesis: Basics, history and modelling. *Annals of Botany*, Vol. 126, No. 2, pp. 511-537; doi: 10.1093/aob/

2019

Hamdani S, Wang H, Zheng G, Perveen S, Qu M, Khan N, Khan W, Jiang J, Li M, Liu X, Zhu X, Govindjee G, Chu C, and Zhu X-G, 2019. Genome-wide association study identifies variation of glucosidase being linked to natural variation of the maximal quantum yield of photosystem II. *Physiologia Plantarum*, Vol. 166, No. 1, pp. 105-119; doi: 10.1111/ppl 12957.

Mishra KB, Mishra A, Kubásek J, Urban O, Heyer AG, and Govindjee G, 2019. Low temperature induced modulation of photosynthetic induction in non-acclimated and cold-acclimated *Arabidopsis thaliana*: chlorophyll a fluorescence and gas-exchange measurements. *Photosynthesis Research*, Vol. 139, No. 1-3, pp. 123-143; doi: 10.1007/s11120-018-0588-7.

Wungrampha S, Joshi R, Rathore RS, Singla-Pareek SL, Govindjee G, and Pareek A, 2019. CO_2 and chlorophyll *a* fluorescence of *Suaeda fruticosa* grown under diurnal rhythm and after transfer to continuous dark. *Photosynthesis Research*, Vol. 142, No. 2, pp. 211-227; doi: 10.1007/s11120-019-00659-0.

2018

Soda N, Gupta BK, Anwar K, Sharan A, Govindjee G, Singla-Pareek SL, and Pareek A, 2018. Rice intermediate filament, OsIF, stabilizes photosynthetic machinery and yield under salinity and heat stress. *Scientific Report,* Vol. 8, article #4072; doi 10.1038/s41598-018-22131-0 (13 pages).

Stirbet A, Lazár D, Kromdijk J, and Govindjee G, 2018. Chlorophyll *a* fluorescence induction: Can just a one-second measurement be used to quantify abiotic stress responses? *Photosynthetica*, Vol. 56, No. 1, pp. 86-104.

2017

Govindjee G, Shevela D, and Björn LO, 2017. Evolution of the Z-scheme of photosynthesis. *Photosynthesis Research*, Vol. 133, No. 1-3, pp. 5-15; doi 10.1007/s11120-016-0333-z.

Mircovic T, Ostrumov EE, Anna JM, van Grondelle R, Govindjee G, and Scholes GD, 2017. Light absorption and energy transfer in the antenna complexes of photosynthetic organisms. *Chemical Reviews,* Vol. 117, No, 2, pp. 249-293; doi 10.1007/10.1021/acs.chemrev.6b00002

Shabnam N, Sharmila P, Govindjee G, Kim H, and Pardha-Saradhi P, 2017. Differential response of floating and submerged leaves of longleaf pondweed to silver ions. *Frontiers in Plant Science,* Vol. 8, No. 1052, 13 pages; doi 10.3389/fpls.2017.01052.

2016

Kana R, and Govindjee G, 2016. Role of ions in the regulation of light harvesting. *Frontiers in Plant Science*, Vol. 7, No. 1849, 17 pages; doi: 10.3389/fpls.2016.01849.

Kandoi D, Mohanty S, Govindjee G, and Tripathy BC, 2016. Towards efficient photosynthesis: Overexpression of *Zea mays* phosphoenolpyruvate carboxylase in *Arabidopsis thaliana*. *Photosynthesis Research*, Vol. 130, No. 1-3, pp. 47-72; doi: 10.1007/s 11120-016-0207-9.

Stirbet A, and Govindjee G, 2016. The slow phase of chlorophyll *a* fluorescence induction in silico: Origin of the S-M fluorescence rise. *Photosynthesis Research*, Vol. 130, No. 1-3, pp. 193-213; doi: 10.1007/s 11120-016-0243-0.

2015

Hamdani S, Qu M, Xin C-P, Li M, Chu C, Govindjee G, and Zhu X-G, 2015. Variations between the photosynthetic properties of elite and landrace Chinese rice cultivars revealed by simultaneous measurements of 820 nm transmission signal and chlorophyll *a* fluorescence induction. *Journal of Plant Physiology,* Vol. 177, pp. 128-138.

Kodru S, Malavath T, Devadasu E, Nellaepalli S, Stirbet A, Subramanyam R, and Govindjee G, 2015. The slow S to M rise of chlorophyll *a* fluorescence induction reflects transition from state 2 to state 1 in the green alga *Chlamydomonas reinhardtii*. *Photosynthesis Research*, Vol. 125, No. 2, pp. 219-231; doi: 10.1007/s11120-015-0084-2

Mamedov M, Govindjee G, Nadtochenko V, and Semenov A, 2015. Primary electron transfer processes in photosynthetic reaction centers from oxygenic organisms. *Photosynthesis Research*, Vol. 125, No. 1-2, pp. 51-63; doi: 10.1007/s11120-015-0088-y

Zhou Y, Schideman LC, Park DS, Stirbet A, Rupassara SI, Govindjee G, and Seufferelеld MJ, 2015. Characterization of a *Chlamydomonas reinhardtii* mutant strain with improved biomass production under low light and mixotrophic conditions. *Algal Research*, Vol. 11, No. 2, pp. 134-147.

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Ostroumov EE, Khan YR, Scholes GD, and Govindjee G, 2014. Photophysics of photosynthetic pigment-protein complexes. In: Demmig-Adams B, Garab G, Adams III, W. and Govindjee (Eds.) *Non-Photochemical Quenching and Energy Dissipation in Plants, Algae and Cyanobacteria*. pp. 97-128; Springer, Dordrecht.

Papageorgiou GC, and Govindjee G, 2014. The non-photochemical quenching of the electronically excited state of chlorophyll *a* in plants: Definitions, timelines, viewpoints, open questions. In: Demmig-Adams, B, Garab, G, Adams III, W and Govindjee (Eds.) *Non-Photochemical Quenching and Energy Dissipation in Plants, Algae and Cyanobacteria.* pp. 1-44; Springer, Dordrecht.

2013

Najafpour MM, Tabrizi MA, Haghighi B, and Govindjee G, 2013. A 2-(2-hydroxyphenyl)-1H-benzimidazole-manganese oxide hybrid as a promising structural model for tyrosine 161/ histidine 190-manganese cluster in Photosystem II. *Dalton Transactions,* Vol. 42, No. 4, pp. 879-884; doi: 10.1039/ c2dt32236f.

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Biswal AK, Pattanayak GK, Pandey SS, Leelavathi S, Reddy VS, Govindjee G, and Tripathy BC, 2012. Light intensity-dependent modulation of chlorophyll *b* biosynthesis and photosynthesis by overexpression of chlorophyllide *a* oxygenase (CAO) in tobacco. *Plant Physiology*, Vol. 159, No. 1, pp. 433-459.

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Shevela D, Eaton-Rye JJ, Shen J-R, and Govindjee G, 2012. Photosystem II and unique role of bicarbonate: A historical perspective. *Biochimica et Biophysica Acta*, Vol. 1817, No. 8, pp. 1134-1151.

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Wang QJ, Singh A, Li H, Nedbal L, Sherman LA, Govindjee G, and Whitmarsh JC, 2012. Net light-induced oxygen evolution in photosystem I deletion mutants of the cyanobacterium *Synechocystis* sp. PCC 6803. *Biochimica et Biophysica Acta,* Vol. 1817, No. 5, pp. 792-801.

2011

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Matsubara S, Chen Y-C, Caliandro R, Govindjee G, and Clegg RM, 2011. Photosystem II fluorescence lifetime imaging in avocado leaves: Contributions of the lutein-epoxide and violaxanthin cycles to fluorescence quenching. *Journal of Photochemistry and Photobiology B: Biology,* Vol. 104, No. 1-2, pp. 271-284.

Nickelsen K, and Govindjee G, 2011. 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.

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Orr L, and Govindjee G, 2010. Photosynthesis online. *Photosynthesis Research*, Vol, 105, No. 2, pp. 167-200; doi: 10.1007/s11120-010-9570-8.

Yusuf MA, Kumar D, Rajwanshi R, Strasser RJ, Tsimilli-Michael M, Govindjee G, and Sarin NM, 2010. Overexpression of y-tocopherol methyl transferase gene in transgenic *Brassica juncea* plants alleviates abiotic stress: Physiological and chlorophyll fluorescence measurements. *Biochimica et Biophysica Acta* (Bioenergetics), Vol. 1797, No. 8, pp. 1428-1438.

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Rose S, Minagawa J, Seufferheld M, Padden S, Svensson B, Kolling DRJ, Crofts AR, and Govindjee G, 2008. D1-arginine mutants (R257E, K and Q) of *Chlamydomonas reinhardtii* have a lowered Q_B redox potential: analysis of thermoluminescence and fluorescence measurements. *Photosynthesis Research,* Vol. 98, No. 1-3, pp. 449-468.

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Holub O, Seufferheld MJ, Gohlke C, Govindjee G, Heiss GJ, and Clegg RM, 2007. Flourescence lifetime imaging microscopy of *Chlamydomonas reinhardtii:* Non-photochemical quenching mutants and the effect of photosynthetic inhibitors on the slow chlorophyll fluorescence transient. *Journal of Microscopy,* Vol. 226, No. 2, pp. 90-120.

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the chlorophyll *a* fluorescence rise (OJIP) in pea leaves. *Functional Plant Biology,* Vol. 30, No. 7, pp. 1-10.

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Govindjee G, 2000. Milestones in Photosynthesis Research. In: *Probing Photosynthesis* (eds. M. Younis, U. Pathre and P. Mohanty), Taylor & Francis, UK, pp. 9-39.

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b. Full Professor period: 1999-1969

1999

Gilmore A, and Govindjee G, 1999. How higher plants respond to excess light: Energy dissipation in Photosystem II. In*: Concepts in Photobiology: Photosynthesis and Photomorphogenesis* (eds. G.S. Singhal, G. Renger, K-D. Irrgang, S. Sopory and G. Govindjee) Narosa Publishers/Kluwer Academic Publishers, pp. 513-548.

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1996

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intensity are independent of the antenna size differences between barley wild-type and chlorina mutants: Photochemical quenching and xanthophyll cycle dependent non-photochemical quenching of fluorescence. *Photosynthesis Research,* Vol. 48, No. 1-2, pp. 171-187.

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Vass I, and Govindjee G, 1996. Thermoluminescence from the photosynthetic apparatus. *Photosynthesis Research,* Vol. 48, No. 1-2, pp. 117-126.

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Vernotte C, Briantais J-M, Astier C, and Govindjee G, 1995. Differential effects of formate in single and double mutants of D1 in *Synechocystis* species PCC 6714. *Biochimica et Biophysica Acta*, Vol. 1229, No. 2, pp. 296-301.

1994

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1993

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1992

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1991

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1961

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d. PhD period: 1960-1956

1960

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d. Pre-PhD period: 1955-1954

1955

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Ranjan S, Govindjee G, and Laloraya MM, 1955. Chromatographic studies on the amino acid metabolism of healthy and diseased leaves of *Croton sparsiflorus* Morong. *Proceedings of the National Institute of Science* (India), Vol. 21B, pp. 42-47.

Addendum to Appendix B: Selected Tributes and Books

2021

Govindjee G, and Blankenship RE, 2021. **Martin David Kamen** (1913-2002): Discoverer of carbon 14, and of new cytochromes in photosynthetic bacteria. *Photosynthesis Research* (9 Pages); https://doi.org/10.1007/s11120-021-00854-y

2020

Govindjee G, Nonomura A, and Lichtenthaler HK, 2020. Remembering **Melvin Calvin** (1911-1997), a highly versatile scientist of the 20th century. *Photosynthesis Research*, Vol. 143, No. 3, pp. 1-11; doi 10.1007/s11120-019-00693-y

2019

Govindjee G, Papageorgiou GC, and Govindjee R, 2019. **Eugene I. Rabinowitch:** A prophet of photosynthesis and of peace in the world. *Photosynthesis Research*, Vol.141, No. 2, pp. 143-150; DOI 10.1007/s11120-019-00641-w.

Shevela D, Björn L, and Govindjee G, 2019. Photosynthesis: Solar Energy for Life. World Scientific, Singapore. [**Book**]

2017

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2016

Buchanan BB, Douce R, Govindjee G, Lichtenthaler HK, and Summons RE, 2016. **Andrew A. Benson,** 1917-2015. *Biographical Memoir of the National Academy of Science*, USA. (16 pages); see http://www.nasonline.org/publications/biographical-memoirs/

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Govindjee G, Bassham H, and Bassham S, 2016a. Remembering **James Alan Bassham (**1922-2012). *Photosynthesis Research*, Vol. 128, No. 1, pp. 3-13; doi: 10.1007/s11120-015-0201-2.

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2015

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2014

Govindjee G, and Srivastava N, 2014. **William A. Arnold** (1904-2001) – *A Biographical Memoir.* National Academy of Sciences, Washington, DC. 18 pages; available free at: www.nasonline.org/memoirs

Karapetyan NV, and Govindjee G, 2014. **Alexander Abramovich Krasnovsky** (1913-1993): 100th birth anniversary in Moscow, Russia. *Photosynthesis Research*, Vol. 120, No. 3, pp. 347-353; doi: 10.1007/s1112001499711

2008

Black CC, and Govindjee G, 2008. **Martin Gibbs** and the peaceful uses of nuclear radiation, ^{14}C. *Photosynthesis Research,* Vol. 99, No.1, pp. 63-80.

Govindjee G, 2008. Recollections of **Thomas John Wydrzynski.** *Photosynthesis Research,* Vol. 98, No.1, pp. 13-31.

2006

Govindjee G, and Fork DC, 2006. **Charles Stacy French** (1907-1995). Biographical Memoirs (National Academy of Sciences), Washington, DC available free at: www.nasonline. org/memoirs

2004

Govindjee G, 2004**. Robert Emerson and Eugene Rabinowitch:** Understanding Photosynthesis. In: "*No Boundaries: University of Illinois Vignettes*" (ed. Lillian Hoddeson), Chapter 12, pp. 181-194. University of Illinois Press, Urbana and Chicago.

1969

Rabinowitch E, and Govindjee G, 1969. *Photosynthesis*. John Wiley and Sons Inc. NY. 273 pp. **[Book]**

Appendix C

Selected awards and honors to Govindjee

*In **1976**, Govindjee was elected a Fellow of the **American Association for the Advancement of Science** (AAAS).

*In **1979**, he was elected a Fellow and Life Member of the **National Academy of Sciences, India**.

*In **1981**, he was elected President of the **American Society for Photobiology**

*In **2007**, he received the prestigious Communication Award of the **International Society of Photosynthesis Research**.

*In **2008**, he received the Alumni Achievement Award from the **University of Illinois at Urbana-Champaign**

*In **2013**, in honor of his 80th birthday, a tribute to Govindjee's life's work in photosynthesis appeared in **Photosynthesis Research**: See: *Photosynthesis Research,* Vol. 116, No. 2, pp. 111–144. doi: 10.1007/s11120-013-9921-3. PMID 24113923. S2CID 13487684.

*In **2016**, he received the Dr. B.M. Johri Memorial award of the **Society for Plant Research, India**

*In **2017**, he was the first recipient of the **Lifetime Achievement award from the Rebeiz Foundation for Basic Research.**

*In **2018**, Govindjee was elected as the Pravasi (Foreign) Fellow of the **National Academy of Agricultural Sciences, India**

*In **2018**, in honor of his 85th birthday, a special issue of *Photosynthetica* was released. See: Garab, G (December 2018). *Photosynthetica*, 56(4): 1235–1236; doi: 10.1007/s11099-018-0826-4. ISSN 0300-3604. S2CID 46974738

*In **2019**, the **University of Illinois at Urbana-Champaign** published an article on his research in photosynthesis and his museum. Yates, Diana (9 July 2019). "Govindjee's Photosynthesis Museum". Illinois News Bureau. Retrieved 28 September 2019.

*In **2020**, Govindjee's innovative research and historical contributions, during 1999–2020, were highlighted, with messages from around the world (see papers by Eaton-Rye *et al.* (2020) and Stirbet *et al.* (2020).

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