

On ‘An inspirational scientist who revealed the secrets of photosynthesis—Govindjee’, by Kapoormal Jain

Translated, with minor modifications, from Hindi to English

by

Arun Kumar¹

¹National Agri-Food Biotechnology Institute (NABI), Mohali, Punjab, 140306, India

(e-mail: arunkumar@nabi.res.in)

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Prologue

A free, not a verbatim, translation, from an article, in Hindi” *Prakash Sanshleyshran Kay Rahashyon Ko Ujagar Waley Preyrak Vaigyanik—Govindjee*” by Kapoormal Jain (see < <https://www.life.illinois.edu/govindjee/> > for the pdf; cf. Jain, 2019). The key points of this paper are captured by its subtitles (we can call them Govindjee’s thoughts of action). However, at places, some text and a limited number of references (provided by Govindjee) have been added. We encourage the readers to read his life by Block (2022; also see: Kumar et al., 2021) and the life of his life-long partner Rajni Govindjee by Balashov et al. (2023; also see Ebrey, 2015). Further, the current article is interspersed with a few photographs from Govindjee’s life (provided by his family); they are different than those published by Jain (2019).

[We note that the postal address of Kapoormal Jain (at the time of the original paper in Hindi) was 72 A, Srikrishna Society, Chuna Bhatti, Kolar Road, Bhopal, India.]

Introduction

The botanist (the plant biologist) Govindjee has done amazing research work in uncovering the secrets of the process of 'Photosynthesis'. This is the reason why the world community considers him synonymous with 'photosynthesis'. Let us now see how we may receive guidance from Govindjee’s life -- which may prove helpful in preparing us for our own new flight of life.

Figure 1 shows Govindjee wearing the glasses his professor Robert Emerson wore when teaching him the tricks of ‘glass-blowing’.



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33 **Figure 1.** Govindjee wearing, for fun and frolic, glasses that belonged to the late Robert
 34 Emerson (1903-1959). Source: Govindjee's family archives

35 **Adopt progressive ideas**

36 Govindjee was born on October 24, 1933 [1932, according to his family] in Allahabad in the
 37 family of an educationist Visheshwar Prasad (1898-1943). Unfortunately, when Govindjee
 38 was only eleven years old, his father passed away (Govindjee, 2007). In those days, his mother
 39 Savitri Devi was also not in good health. Therefore, the responsibility of the upbringing of
 40 Govindjee was performed by his eldest brother Krishnaji (1922-1997). Krishnaji was a
 41 professor of physics at Allahabad University and was a role model for Govindjee (Govindjee
 42 and Srivastava, 2010).

43 The child Govindjee was greatly influenced by the progressive thoughts of his father Shri
 44 Visheshwar Prasad, who was first a teacher in a college and 'General Secretary' of the United
 45 Provinces (Uttar Pradesh) Teachers Association, and then he became the sales representative
 46 of the Oxford University Press (OUP) for all of North India. He was a scholar of Hindi, English
 47 and Urdu. He considered all people equal and was against dividing the society into castes.
 48 These qualities of the father came in him in the form of his '*Sanskar*' (culture). That's why, like
 49 his father, Govindjee also never believed in the caste system in his life and never used his caste-
 50 indicative surname 'Asthana' as a part of his name. *In this way, we get to learn from him*
 51 *to adopt progressive ideas.*

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55 **Study and debate to get to understand the issues**

56 Since his childhood, Govindjee was a child of very inquisitive nature. 'Why?' and 'How?' were
57 the questions on his lips about everything. His eldest brother Krishnaji used to say that
58 Govindjee always enjoyed arguing so much that he used to dislike those who shyed away from
59 arguing. He always tried to pacify his curiosity and did not rest until that curiosity was satisfied.
60 *He was always eager to know and learn new things and loved to study and debate*
61 *on any subject.*

62 **Explore your career while learning from the wonders of nature**

63 Govindjee's schooling was in Colonelganj High School and in Kayastha Pathshala
64 Intermediate College, both in Allahabad. In the school itself, he met a teacher who introduced
65 him to the wonders of Nature. He became so fascinated with the world of flora that he would
66 spend hours gazing at the plants growing in his school garden. The process of making food by
67 plants (photosynthesis) was (and is very important for him. The process of photosynthesis
68 attracted him a lot and later on he took it seriously in his life and adopted this research as his
69 career. Nature is indeed full of surprises. We can learn a lot by carefully observing every
70 incident that happens in it, and being inspired by it, we can choose the direction of our own
71 career. *This is a great learning from him which should be helpful in exploring our*
72 *own careers.*

73 **Build your strong background according to your natural instincts**

74 Govindjee took great pleasure in knowing and learning about flora and fauna through reading
75 biology books. However, in these subjects one also has to learn through practical (laboratory)
76 work also. Animals had to be dissected in the experimental study of zoology. While doing this,
77 his confidence started to shake, inspiring a dislike of zoology. However, his confidence in the
78 practical studies of botany was tremendous. This was the reason that he found it suitable in
79 terms of his career to select botany, a subfield of biology. A good understanding of physics
80 and chemistry is also necessary in the study of this subject. Fortunately, in college he had
81 teachers ,such as Prof. Jalpa Prasad and Prof. M.L. Gaur, who recognized his talent and ignited
82 his interest in biology and chemistry by giving him books to read from their personal libraries.
83 His interest in physics existed already due to his brother Krishnaji. In this way, a brilliant and
84 strong background was being prepared for his research in botany (plant biology), which later
85 became very useful for him.

86 When he came to Allahabad University and was elected as the Secretary of the Student
87 Botanical Society of Allahabad University, he had the opportunity to organize a seminar on
88 the topic of '*Reincarnation of Photosynthesis Research*'. Its purpose was to bring before all the
89 fellow students the era of photosynthesis research in which the initial discoveries were made.
90 The discoveries made by the Dutch physiologist Jan Ingenhousz, who wanted to understand
91 the process of making food by plants, were of great importance in the early times. Ingenhousz
92 did many experiments which established that the process of making food by plants is completed
93 only in the presence of *light*. This special seminar was presented by six students who played

the role of scientists that had made important contributions to understanding the process of photosynthesis. Since these discoveries were made in European countries, everyone wore European clothes. Govindjee played the role of Ingenhousz. The seriousness with which Govindjee played his role won everyone's heart. *Like him, we too should take 'role-play' as a mode of study seriously. By doing this we would receive many opportunities to learn and get inspired.*

Take your own words seriously

In the seminar mentioned above, Govindjee played the role of Ingenhousz and argued brilliantly that the process of making food by plants, i.e. photosynthesis, is essential for life on earth. In leaves, the green part of trees and other plants, as well as in other organisms (e.g., algae), this process of photosynthesis takes place within chloroplasts which contain chlorophyll molecules. These molecules absorb the blue and red parts of light falling on it and the process of photosynthesis begins. Plants grow from the ground in the presence of light. Converting water, received from the soil, and carbon dioxide, received from the atmosphere, they make food in the form of carbohydrates (molecules made of carbon and hydrogen), releasing oxygen and putting it in the atmosphere. During the debate at the above seminar, it seemed that Ingenhousz himself had appeared! At the end of the debate, he said on his part that “this process plays its most important role in keeping the earth a living planet; it not only gives us food to eat, but it also gives us oxygen to breathe and keeps us alive.” *We can learn a big lesson from this. Whenever we get a chance, we should make and keep our point very seriously.*

Dreams are born when the strings of the heart meet

Govindjee's heart strings were tugged at the play in the seminar held at Allahabad University while he was immersed in his role as Ingenhousz because, since his early school days, he was interested in knowing and understanding photosynthesis. The program was so effective and heart touching that everyone present participated in it fully.

Govindjee received great comments as he had played his role very brilliantly. He was indeed very happy after getting everyone's appreciation. Inspired by this, he started to consider doing research on photosynthesis. After successfully playing this role, he started dreaming of becoming a scientist like Ingenhousz. *That's the advantage of the 'role-play' mode. If the heart strings are found while performing live, then dreams start to take birth and the path of one's career starts to be formed.*

Always keep the interest of the society in mind

Despite much important information about photosynthesis, scientists had no idea about the specifics of this process. The possibility arose in Govindjee's mind that if this process was understood properly then the problem of hunger could be erased from our Earth. This inspired him to study and work deeply in this direction. *In this way, we see that in the field in*

which Govindjee decided to work, the interest of the society remained at the center.

During his studies at Allahabad University, Govindjee specialized in Plant Physiology in the field of Botany. Shri Ranjan (1899-1969), Head of the Department, who himself was a student of Frederick Frost Blackman, explained to students about the 'Law of Limiting Factors' and the Dark Reaction (Blackman's reaction) to know what processes affect the rate of photosynthesis. In this way, a suitable background was prepared for Govindjee's research in photosynthesis. Then, he went to the USA to do his PhD in this area. In 1956, he was selected as a Fulbright scholar under the United States Cultural Exchange Program and a Graduate Fellow by the University of Illinois at Urbana-Champaign (UIUC). He received his PhD in Biophysics from UIUC in 1960, working under Eugene Rabinowitch (1898-1973). For further information on Govindjee, see his website: <https://www.life.illinois.edu/govindjee/>.

Understand the subject in its depth

Govindjee's PhD work began under the direction of the eminent scientist Robert Emerson (1903-1959). Emerson's fame was due to many discoveries, but especially due to that of the 'Emerson Enhancement Effect' that he had discovered in 1957. In this effect, he observed that the rate of 'photosynthesis' increased when light of the 'orange-red' part of the spectrum (650 nm) was added to the 'far red' part of the spectrum (700 nm). That is when the two beams of light were added together, the overall rate increased significantly, much more than what would have been achieved by adding the two beams separately. Govindjee understood from the 'Emerson effect' that there are two photosystems (now known as Photosystem-1 and Photosystem-2) working in the chloroplasts of trees, other plants, and algae, where the two photosystems cooperate with each other and generate oxygen. The reaction center of 'Photosystem-1' was then known to be P-700 because of the work of Bessel Kok (1918-1979) while that of 'Photosystem-2' was discovered in the laboratory of Horst Witt (1922–2007), which was later called P-680. We note that Govindjee had made the earliest suggestion for it; see Krey and Govindjee (1964). In this way Govindjee started delving into the depth of the subject, with research in his mind. *We should learn from him the point of getting into the depth of the subject.*

Clarify your focus

Govindjee was enjoying working with Emerson and was going deeper into understanding the process of photosynthesis. Then suddenly Emerson died in an air-plane crash (on Feb 4, 1959). Soon thereafter, Govindjee did his PhD, under the direction of another famous scientist, Eugene Rabinowitch, on the topic of the 'Action Spectra of the Emerson Enhancement Effect in Algae'. See Govindjee et al., 2019; Govindjee et al., 2021; and Govindjee, 2023. During his research work, Govindjee came to understand that a spectral form of chlorophyll a (Chl a 670) has a role in Photosystem-2, which has an important, although an indirect, role in producing oxygen. After that, Govindjee turned his full focus on Photosystem-2. For his recent publications, see : https://www.life.illinois.edu/govindjee/recent_papers.html; for his latest

review on PS2, see Shevela et al. (2023). *In this way, we get the message from him that we should clarify our focus and move forward.*

Move forward with logic by adopting new technologies

The role of chlorophyll a in the process of photosynthesis was known long ago. However, the problem before the scientists was how further action takes place and how oxygen is generated after the absorption of light of 680 nm. Since the whole process takes place very rapidly in different steps, Govindjee started his work by moving away from the traditional techniques and chose 'Absorption and Emission Picosecond Spectroscopy' and 'Kinetics' as tools. He also looked at the delayed light emission (DLE) of chlorophyll a, which provides information on some of the back reactions of Photosystem-2; then, he used it as a signature of even the forward reactions of the whole process of photosynthesis!

From the analysis of the spectrum (and intensity) of DLE, he identified the intermediate co-products formed during the process of photosynthesis and stated that Photosystem-2 acts as a catalyst for the photo-oxidation of water and reduction of plastoquinone and that bicarbonate has an essential role in it. Yes, this effect itself was discovered earlier by Otto Warburg (1883-1970); however, it was Govindjee and his students who clearly showed that it was needed on the electron acceptor side of Photosystem-2. In this way we can say that here that the role of bicarbonate is in another place as well, and that this was discovered by Govindjee and his students. It seems clear from his work that the idea that two water molecules get oxidized to give rise to one molecule of oxygen remains the best hypothesis, but the role of bicarbonate there remains to be discovered.

On the other hand, while researching the extremely short-lived intermediates of picosecond duration (fluorescence life-time), he did the astonishing work of understanding electron and proton transport processes. He showed through his work how new technologies can be used beautifully to understand the mysteries of nature. For an overview of his own research, in his own words, see Govindjee (2019). *In this way, we get guidance from him to adopt new techniques to solve our problems and move forward thoughtfully with logic.*

Keep Working - Never Give Up

After his PhD, Govindjee worked as a Postdoctoral Fellow of the US Public Health [National Institute of Health, NIH] between 1960 and 1961. From 1961 to 1965, he was Assistant Professor of Botany, from 1965-1969, he was Associate Professor of Botany and Physiology & Biophysics, and from 1969 to 1999, he was Professor of Biophysics and Plant Biology, all at the UIUC. During 1998-1999, he also served as Professor of Biochemistry at the same university.

After retirement in 1999, Govindjee has been Professor Emeritus at the UIUC. He is currently interested in research to improve the efficiency of photosynthesis as well as in understanding the changes in chlorophyll a fluorescence to monitor the regulation mechanisms of plants, algae and cyanobacteria. He is highly active in bringing to light the history related to the research of photosynthesis and the scientists working in this field so that they can be recognized. [See:

209 https://www.life.illinois.edu/govindjee/recent_papers.html for his papers.] *To keep working*
210 *continuously like this is the main ‘mantra’ of his life. And, this is the great thing*
211 *to learn from him.*

212 **Do work in such a way that it becomes your identity**

213 Govindjee's unique research work on photosynthesis has made him synonymous with
214 ‘photosynthesis’. Once on this topic, Los Alamos National Laboratory had organized a seminar
215 in New Mexico. During the seminar the organizers stated that “*We all depend on photosynthesis*
216 *and photosynthesis depends upon Govindjee*”. Thus his work has become his identity. Today,
217 the photosynthetic community cannot be imagined without Govindjee. This was possible
218 because of the high-level work done by him. *Like hi , we should also do our work in*
219 *such a way that it becomes our identity.*

220 **Focus on publishing effectively, persuasively and creatively**

221 Govindjee has also developed the current and correct theory of ‘*Thermoluminescence*’ for the
222 study of algae and plants; furthermore, he has written more than 400 research papers on various
223 areas of photosynthesis, ‘*From a photon to a plant*’. In a career spanning more than 60 years,
224 Govindjee has been working for and influencing many around the World through his various
225 publications (and his prompt e-mails). These include professional scientists, graduate and post-
226 graduate students, and even the general public. His writing is very effective, inspiring and
227 creative. At the heart of his general writings were articles, e.g., on the ‘Role of Chlorophyll in
228 Photosynthesis’ (Rabinowitch and Govindjee, 1965) on ‘Light Absorption and ‘Excitation
229 Energy Transfer’ (Govindjee and R. Govindjee, 1974), and ‘Production of Oxygen by Plants’
230 (Govindjee and Coleman, 1990).

231 Govindjee is the Founding Editor of the ‘Advances in Photosynthesis and Respiration’ Series
232 and of the ‘Historical Corner of Photosynthesis Research’. His writing continues at an
233 uninterrupted pace. Recently, in 2019, his book ‘Photosynthesis: Solar Energy for Life’ was
234 published by the World Scientific. This was written with Dima Shevela and Lars Olof Björn
235 (Shevela et al., 2019). His earlier published (some edited) books include, among others,
236 ‘Photosynthesis’ (Rabinowitch and Govindjee, 1969), ‘*Bioenergetics of Photosynthesis*’
237 (Govindjee 1975, 1982), and ‘*The Maximum Quantum Yield ‘Controversy*’ (Nickelsen and
238 Govindjee 2011). *We should also focus on publishing our work in an effective,*
239 *inspiring and creative way as Govindjee has done.*

240 **Focus on your actions, they give respect and rewards**

241 Govindjee has been honoured with various awards. He was elected a Fellow of the American
242 Association for the Advancement of Science in 1976, and a Fellow of the National Academy
243 of Sciences (India) in 1979. In 1981, he was elected as the President of the American
244 Association for Photobiology. In 2006, he received the Lifetime Achievement Award of the
245 Rebeiz Foundation for Basic Research. In 2007, the International Society of Photosynthesis
246 Research (ISPR) awarded him its *Communication Award*. In 2022, Govindjee received the

Lifetime Achievement Award of ISPR, one of the most prestigious awards in ‘Photosynthesis Research’ (see: Nonomura and Kumar, 2022). *Thus we see that it is the actions of a person that bring him rewards. That's why we should focus on our actions only.*

Adopt an effective and engaging style

Govindjee has been the best teacher of classes from undergraduate to graduate and post-graduate levels. This included Plant Physiology, Plant Molecular Biology, and Plant Biophysics at UIUC. He has also taught various subjects such as basic biology; Bioenergetics, Biochemistry, Fluorescence Spectroscopy, and Photosynthesis. It doesn't matter to him whether he has 700 students in his class or six! His lectures, and seminars, are often interwoven with stories and are enjoyable. He had and still has a personal connection with everyone he meets. His style of teaching, explaining, and communicating is so effective and interesting that everyone is mesmerized. For fun, see him in **Figure 2** after a seminar at the University of Illinois at Urbana- Champaign.



Figure 2. Govindjee (in the centre) at a Halloween party, after a Plant Biology Colloquium at the UIUC Clockwise (from the left): Sachin Heera (wearing horse mask), Stuti Shrivastava, Ursula Idleman, Clayton Dilks, and Amy Marshall-Colon. October 15, 2015, Source: Archives of Professor Marshall-Colon

Like him, we should also try to make our communication style effective and interesting.

Never forget those who help you

Govindjee believes that in discussion of his research on photosynthesis, he had the best time with Bessel Kok (1918-1979), C. Stacy French (1907-1995; Govindjee and Fork, 2006), William Arnold (1904-2001; Choules and Govindjee, 2014; Govindjee and Srivastava, 2014)

and Louis N. M. Duysens (1921-2015; Govindjee and Pulles , 2016) . The training he received from his mentor Eugene Rabinowitch and from Lou Duysens helped him develop as a biophysicist. He also remembers the teachers from his school and college days, who sparked his initial interest in this field. *Those who help you should never be forgotten.*

Insist on increasing mutual cooperation to achieve the big goal

Govindjee's current scientific interest is in 'Genetic Engineering'. With the help of which, the efficiency of photosynthesis, and, thus, of plant productivity, can be improved and hunger can be eradicated from the world. This is a huge target. To make this a reality, he is working with various scientists and organizations around the world. His students are spread all over the world. See **Figure 3** for a photograph of some of those who had gathered for his retirement party in 1999.



Figure 3. A 1999 photograph of former research collaborators of Govindjee. Left-to-right are: the late Thomas (Tom) J. Wydrzynski; Alan Stemler; Jin Xiong; Teruo Ogawa (from Japan); Paul Jursinic; the late Maarib Bazzaz; Govindjee; Rita Khanna; Barbara Zilinskas; Jack Van Rensen (from The Netherlands); Irene Van Rensen; and Julian Eaton-Rye. Source: Govindjee's family archives.

At present, Govindjee is working with many international scientists, including Prof. Ashwani Pareek [see e.g., Wungrampha et al. (2019)] and Prof. Baishnab Tripathi [see e.g., Kandoi et al. (2022)], both of India, and Dr. Ya [David] Guo of China on projects under which plant production can be increased by various means (see e.g., Pandiyan et al., 2021, and Yuan et al., 2022). They really have a strong sense of teamwork. **Figure 4** shows Govindjee with Ashwani Pareek, and **Figure 5** shows him with Baishnab Tripathy.



Figure 4. Govindjee (on the right) with Ashwani Pareek on a field trip in Rajasthan, India.
Source: Ashwani Pareek's Archives.



Figure 5. Govindjee (on the left) with Deepika Kandoi and Baishnab Tripathy at Jawaharlal University, New Delhi. Source: Baishnab Tripathy's Archives.

We should also try to develop the spirit of working together as a team.

Encourage top performers

Post-retirement, Govindjee, has been Professor Emeritus of Biophysics, Biochemistry and Plant Biology at the University of Illinois at Urbana-Champaign. Here he did research and taught from 1961 to 1999. He is proud of all his graduate students (see: <https://www.life.illinois.edu/govindjee/g/GraduateStudents.html> whether they worked with him and/or with others. He maintains in his office the hard copies of their PhD theses; see **Figure 6.**



Figure 6. Hard copies of some of the PhD theses of Govindjee's past PhD students - all related to the mechanism of photosynthesis. Source: Archives of Rita Khanna.

Since 2007, the University of Illinois at Urbana-Champaign has been giving a 'Student Award' (Govindjee and Rajni Govindjee Excellence Award) to encourage students, who have excelled in the 'Biological Sciences'. *Likewise, we should also work to encourage those who excel when given the opportunity.*

Concluding remarks

In this way, the life of the plant biologist and the biophysicist Govindjee [now Govindjee Govindjee] inspires us to adopt progressive ideas: always be eager to learn new things from the Nature, which is full of surprises and gives us a chance to prepare our strong academic background and explore our career. Many guiding and inspirational tips from the life of Govindjee can help us achieve our goals. These include: keep your point of view with full seriousness; keep the interest of the society in mind; always focus on developing your talent; go deeply into any subject to understand it while keeping your 'focus' clear; adopt new techniques and move forward with logic; consider continuous work as the basic *mantra* of life; make your work your identity as best as possible; communicate in an effective, persuasive and creative way; focus on your work; adopt effective and interesting style during expression [communication]; never forget those who help you. In this way, we see that Govindjee is a passionate scientist who dedicated himself completely to research on 'photosynthesis', the process of making food by plants; he has made unique contributions in educating both the beginners and the authorities in this area. . Even at the age of 86 [now 90 in 2023], he is active and is a source of inspiration for young scientists. We end this perspective on Govindjee's life with a photograph (see **Figure 7**) that gives a different message than that in Figure 1. We leave the readers to decide what this photograph means to them.



Figure 7. A photograph of Govindjee taken at his home in Urbana, Illinois. Source: Archives of Govindjee's family.

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REFERENCES

- Balashov S, Imasheva E, Misra S, Kono M, Liu S, Liang J, Govindjee G, Ebrey TG (2023) Contributions of Rajni Govindjee in the Life Sciences: Celebrating her 88th birthday. *International Journal of Life Sciences* 12(1):1-14.
- Björn LO, Shevela D, Govindjee G (2023) What is photosynthesis? - A broader and inclusive view. In: Dalal VK and Misra AN (eds.) *A Closer Look at Photosynthesis*, Chapter 1, Nova Science Publishers. ISBN: 979-8-88697-815-5
- Block JE (2022) Life of Govindjee, known as Mister Photosynthesis. *Journal of Plant Science Research* 3 8(1): 1-22.
- Choules L, Govindjee G (2014) Stories and photographs of William A. Arnold (1904-2001): A pioneer of photosynthesis. *Photosynthesis Research* 122:87-95; DOI 10.1007/s11120-014-0013-9.
- Ebrey T (2015) Brighter than the sun: Rajni Govindjee at 80 and her fifty years in photobiology. *Photosynthesis Research* 124:1-5.
- Govindjee G (ed) (1975) *Bioenergetics of Photosynthesis*. Academic Press, New York, 700 pages.

Govindjee G (ed) (1982) Photosynthesis. I: Energy Conversion by Plants and Bacteria (799pp); Volume II: Development, Carbon Metabolism and Plant Productivity (580pp). Academic Press, NY

Govindjee G (ed.) (2007) Amma and Babuji: Our Life at Allahabad. PDQ Printing, Urbana, Illinois; 122 pages.

Govindjee G (2019) A sixty-year tryst with photosynthesis and related processes: an informal personal perspective. *Photosynthesis Research* 139: 15-43. DOI 10.1007/s11120-018-0590-0.

Govindjee G (2023) On the evolution of the concept of two light reactions and two photosystems for oxygenic photosynthesis: A personal perspective. *Photosynthetica* 61(1): 37-47; DOI 10.32615/ps.2023.006.

Govindjee G, Coleman W (1990) How plants make oxygen. *Scientific American* 262: 50-58.

Govindjee G, Fork DC (2006) Charles Stacy French (1907-1995). *Biographical Memoir, National Academy of Sciences, Washington, DC*. 88:2-29.

Govindjee G, Govindjee R (1974) Primary events in photosynthesis. *Scientific American* 231: 68-82.

Govindjee G, Govindjee R (2021) Personal reminiscences of Robert Emerson and Eugene Rabinowitch. *Journal of Plant Science Research* 37(1): 101-106.

Govindjee G , Pulles MPJ (2016) Louis Nico Marie Duysens (March 15, 1921-September 8, 2015): A leading biophysicist of the 20th century. *Photosynthesis Research* 128:223-234; DOI 10.1007/s11120-016-0256-8.

Govindjee G , Srivastava SL (eds.) (2010) A Tribute: Krishnaji (January 13, 1922 - August 14, 1997). (xii + 266 pages + graphics + new appx), Apex Graphics, Allahabad.

Govindjee G, Srivastava N (2014) William A. Arnold (1904-2001)-A *Biographical Memoir*. *National Academy of Sciences, Washington, DC*. 18 pages; nasonline.org/publications/biographical-memoirs/.

Govindjee G, Papageorgiou GC, Govindjee R (2019) Eugene I. Rabinowitch: A prophet of photosynthesis and of peace in the world. *Photosynthesis Research* 141(2): 143-150. DOI 10.1007/s11120-019-00641-w.

Jain KM (2019) Prakash Sanshleyshran Kay Rahashyon Ko Ujagar Waley Preyrak Vaigyanik—Govindjee. *Science India* 13 (8): 14-24.

Kandoi D, Ruhil K, Govindjee G, Tripathy BC (2022) Overexpression of cytoplasmic C4 Flaveria bidentis carbonic anhydrase in C3 *Arabidopsis thaliana* increases amino acids, photosynthetic potential, and biomass. *Plant Biotechnology Journal*, pp. 1-15, PMID: 35467074. DOI 10.1111/pbi.13830.

Krey A, Govindjee G (1964) Fluorescence changes in *Porphyridium* exposed to green light of different intensity: A new emission band at 693 nm: Its significance to photosynthesis. *Proceedings of the National Academy of Science USA* 52: 1568-1572.

Kumar A, Block JE, Nonomura AM (2021) Mister Photosynthesis of the 21st Century, Govindjee. *LS - An International Journal of Life Sciences* 10 (2): 61-80.

Nickelsen K, 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.

Nonomura A, Kumar A (2022) Celebrating the 2022 lifetime achievement award of the International Society of Photosynthesis Research to Govindjee, who hails from Allahabad. *International Journal of Life Sciences* 11(3): 153-155. DOI 10.5958/2319-1198.2022.00014.8.

Pandiyan S, Govindjee G, Meenatchi S, Prasanna S, Gunasekaran G , 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) DOI 10.1089/big.2020.0350.

Rabinowitch E, Govindjee G (1965) The role of chlorophyll in photosynthesis. *Scientific American* 213: 74-83.

Rabinowitch E, Govindjee G (1969) Photosynthesis. John Wiley & Sons, NY.

Shevela D, Bjorn L, Govindjee G (2019) Photosynthesis: Solar Energy for Life. World Scientific, Singapore.

Shevela D, Kern JF, Govindjee G, Messinger J (2023) Solar energy conversion by photosystem II: principles and structures. *Photosynthesis Research* 156: 279-307; DOI 10.1007/s11120-022-00991-y.

Wungrampha S, Joshi R, Rathore RS, Singla-Pareek SL, Govindjee G, Pareek A (2019) CO₂ and chlorophyll a fluorescence of *Suaeda fruticosa* grown under diurnal rhythm and after transfer to continuous dark. *Photosynthesis Research* 142: 211-227. DOI 10.1007/s11120-019-00659-0

Yuan S, Tang H, Fu L J, Tan J L, Govindjee G , Guo Y (2022) An open Internet of Things (IoT)-based framework for feedback control of photosynthetic activities. *Photosynthetica* 60 (SI): 77-85. DOI 10.32615/ps.2021.066.

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