IN CONVERSATION

Prof. Govindjee

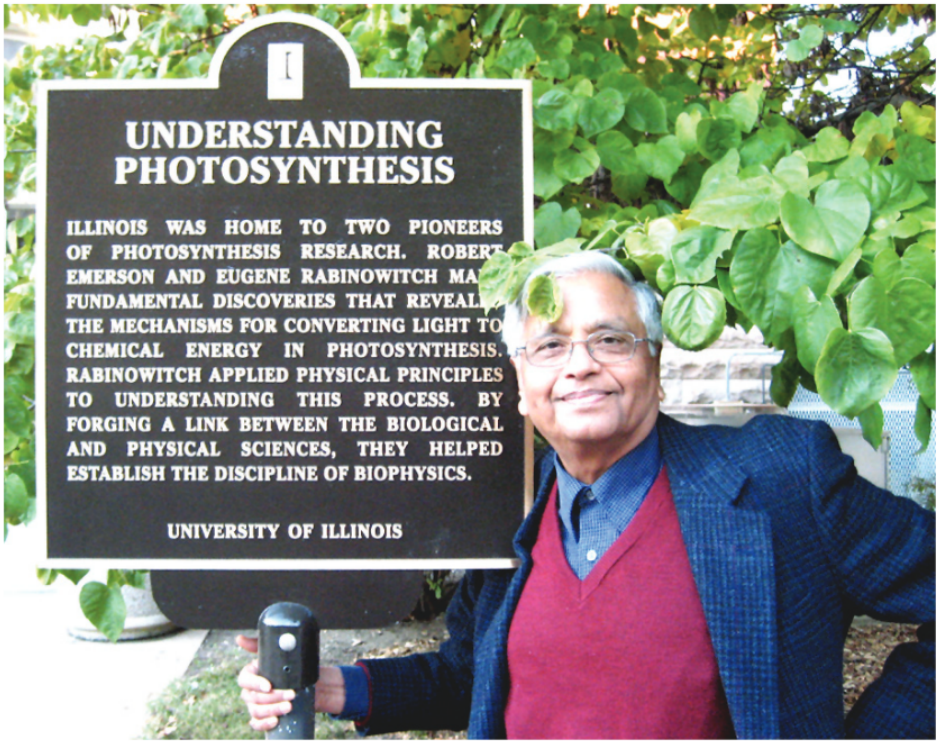
A Pioneer in Photosynthesis Research

Meher Wan: *Prof. Govindjee, you are still involved in your scientific work at the age of 87. How do you feel after such a long journey in science?*
Prof. Govindjee: I feel really very good that I am still able to participate in research and writing on a topic that is very dear to me and it is very important for the benefit of us all.

MW: So, how did this journey begin?
Prof. Govindjee: This journey began when I was an MSc student of Prof. Ranjan in the Department of Botany, University of Allahabad. Prof. Ranjan himself had studied under Professor Blackman of UK. Blackman was known for his pioneering research in photosynthesis. There was a Botanical Society at the University of Allahabad. We students used to organise quite a few activities to learn science together. In the process of organising one of the events, I became interested in photosynthesis.

MW: *You, along with your fellow students, organised a mock symposium during your MSc at the University of Allahabad. What was that?*
Prof. Govindjee: Yes, this was the real beginning in photosynthesis and great fun as we assumed the role of major

PROF. Govindjee is an Indian-American scientist who is known for his seminal scientific contributions in understanding the mechanism behind Photosynthesis. He was born in Allahabad and did his MSc from University of Allahabad, then moved to the USA for his PhD under renowned scientist Robert Emerson. Prof. Govindjee has been recognised as an expert in photosynthesis and bestowed upon several prestigious awards for his pioneering scientific contributions including Fellow of the American Association for the Advancement of Science (AAAS) in 1976 and the prestigious communication award from the International Society of Photosynthesis Research in 2007, to recognise his important service in communication and outreach to the general public on photosynthesis.



discoverers in photosynthesis like Prof. Joseph Priestley, Otto Warburg, Jan Ingenhousz and even Robert Emerson. It brought to life the past discoverers and their discoveries before the students and teachers. We went to libraries and professors to understand the discoveries of those scientists and then presented in that mock symposium. It was a unique process of learning for us. I think I played Robert Emerson in that symposium.

MW: *How did you become interested in photosynthesis?*

Prof. Govindjee: It was during Prof. Ranjan's special topics in Plant Physiology course (probably in 1953-54). Prof. Ranjan had asked us to give a presentation on the topic of our choice. I went to the library and discovered a paper from Emerson and Lewis (1943) that showed that photosynthesis was inefficient where only 'chlorophyll-*a*' absorbed light beyond 680 nm. This was a paradox since 'chlorophyll-*a*' is what does the photosynthesis. This intrigued me as it had Emerson at that time. And it continued to haunt me. Finally, in late 1955 when I was a Lecturer in Botany at Allahabad University, I began to correspond with Emerson.

MW: *The University of Allahabad was a seat of learning at that time. How was the teaching scenario then?*

Prof. Govindjee: I studied at Allahabad University from 1950-1954. My wonderful teachers (in Chemistry, Botany & Zoology) were responsible for my interest in going deeper and deeper in understanding how Biology works. I refrain from naming them for fear that I may miss any. We had all the encouragement from our teachers and we certainly enjoyed learning from them through their lectures and answers whenever we asked them questions in their offices.

MW: *How difficult was it to move to the USA for a PhD at that time for youth from a small town to?*

Prof. Govindjee: I have no idea of any difficulty as when I applied for PhD to work with Prof. Emerson, I received a fellowship at the University of Illinois and then when I applied for Fulbright Travel Award, I received it. So, that is how it was.

MW: *What was the understanding of photosynthesis at the time when you joined your PhD? What problem did you decide to move ahead with?*

Prof. Govindjee: Emerson had discovered (but not yet published) a solution to his 1943 problem: two light reactions are needed to do photosynthesis – not one (as believed before). So, when I reached the University of Illinois, I was to first build my background before I could do the experiments. I took courses in basic Maths, Physics, Biochemistry, Physical Chemistry, and Genetics. Since the duration of BS was 4 years in the USA, my MSc was equivalent to BS and to do Photosynthesis Research, I needed basic courses in Math, Chemistry and Physics. This took almost two years before I began doing experiments on the problem of 'Two Light Reactions' in Photosynthesis. As soon as I began research, I discovered something new. I came to UIUC in September 1956, and Prof. Emerson died in a plane crash on 4 February 1959.

MW: *It must have been very difficult to lose your mentor at such an early*

stage of your research. How do you remember him, the way he shaped you as a researcher!

Prof. Govindjee: Emerson had guided me to learn the basics needed to move forward as a researcher. He had also trained me to do experiments very carefully and meticulously. Absolute measurements on the quantum yield of photosynthesis as a function of wavelength of light and how to do the 'Two-Light Effect' experiments. He also taught me how to measure absolute absorption spectra of photosynthetic samples — all needed for thorough research.

MW: *You continued your PhD work with a well-known chemist Eugene Rabinowitch with the same research goal for PhD. How difficult was it to move ahead?*

Prof. Govindjee: Moving ahead was very easy indeed because I had already discovered that photosynthesis was run by two different spectral forms of *Chlorophyll-a*: not by *Chlorophyll-a* and by *Chlorophyll-b*, as Emerson had said and published in 1957 and presented at a conference in 1958. My research needed to be confirmed and reconfirmed since it was, in a way, challenging what was there.

MW: *You solved a very important problem related to photosynthesis in your PhD. Can you tell us something about it?*

Prof. Govindjee: Emerson's idea that *Chlorophyll-b* does one reaction, could not be true as Lou Duysens (in 1952), in the Netherlands, had shown that all quanta of light absorbed by *Chlorophyll-b* are transferred 100% to *Chlorophyll-a*. And my results showed the solution to this dilemma. It was a short wavelength absorbing *Chlorophyll-a* that was doing this reaction, whereas the other reaction was being run by the long-wavelength absorbing *Chlorophyll-a* beyond 680 nm.

MW: *After a path-breaking PhD, what was next?*

Prof. Govindjee: I finished my PhD in 1960 and had a Postdoctoral Fellowship from NIH. During this period, I learned to exploit *Chlorophyll-a* Fluorescence as a tool to understand Photosynthesis. It was during 1960 that I discovered the "Two light Effect through *Chlorophyll-a* fluorescence". I learned a lot from Professor Gregorio Weber during this period.

MW: *Why is understanding photosynthesis so important?*

Prof. Govindjee: It is important because it is the source of all oxygen we need to breathe and all the food we need to live and survive. It converts light energy into chemical energy on a massive scale. It is crucial to find ways sooner rather than later to increase photosynthesis and thus plant productivity so that we can feed our growing population. Then, there is a scientific quest also to better understand the process that drives this world, and to be able to mimic it, and to do it better through "artificial photosynthesis".

MW: *In your research career, you proved a few strong misconceptions wrong about photosynthesis, which were even supported by Nobel Laureates! Please, let us know.*

Prof. Govindjee: One was already in my PhD thesis: Photosynthesis is run by 'Two Light Reactions' both sensitised by *Chlorophyll-a*, but of different spectral forms (1960). Then, many of my PhD students proved that the Nobel Prize Winner Otto Warburg was not right in concluding that CO_2 is the source of Oxygen during the photosynthesis process. Further, my wife Rajni and I proved that Prof. Warburg was wrong in stating that young cells of algae evolve oxygen with four photons of light; they need 8-10 photons as Emerson had found.

MW: *The general conception used to be that plants convert carbon-dioxide into oxygen through photosynthesis. How difficult it was to correct this misconception?*

Prof. Govindjee: It was not difficult as only Warburg had believed it – Martin Kamen, the discoverer of Carbon-14, had already challenged Warburg by using water with heavy isotope of oxygen. The scientific community accepted the fact easily but I don't know about the general public.

MW: *The light absorbed by chlorophylls is used in three processes – photosynthesis, heat loss, and chlorophyll fluorescence. How do these processes affect each other? What was your contribution in understanding plant fluorescence?*

Prof. Govindjee: Fluorescence competes with photosynthesis: as noted above, we used it to prove two light effects but the answer to this question is a long one and will need to be given separately. We have exploited *Chlorophyll-a* fluorescence in many ways to understand the mechanism of energy transfer and to monitor regulation of photosynthesis and to predict productivity of plants and more. This by itself will take much space and time to explain. However, we are using it as a non-invasive and a quick way to predict overall photosynthesis, and even to monitor abiotic stress such as drought ahead of time.

MW: *There's a saying in the scientific community that "Plants depend on photosynthesis and photosynthesis depends on Govindjee." You are also called "Mr Photosynthesis". How do you feel by the appreciation?*

Prof. Govindjee: I feel humbled, honoured and good. I am interested in Education for All – not just the educated.

MW: *Doing good science is a tiring and tough task, it needs to cope with lots of initial criticism, rage, and humiliation. What are the factors that can keep one motivated towards our goal?*

Prof. Govindjee: Positive thinking and belief in yourself. The motto should be: Never give up; keep after it until you find the answer; perseverance is essential for success.

MW: *Any suggestions to the youth who wish to contribute to science?*

Prof. Govindjee: Believe in yourself but work hard and be respectful of all views. Examine and re-examine yourself constantly. We all make mistakes. I do many.

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