Why Teaching Evolution and Photosynthesis is Imperative for an Understanding of the Living World

Article · December 2023

CITATIONS
0

READS
78

2 authors:

Ulrich Kutschera
I-Cultiver, Inc., S.F. Bay Area, Tracy, CA USA
316 PUBLICATIONS **6,279** CITATIONS
SEE PROFILE

Rajnish Khanna
i-Cultiver
36 PUBLICATIONS **1,967** CITATIONS
SEE PROFILE

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 10 Issue 12, December 2023
ISSN (Online) 2348 – 7968 | Impact Factor – 6.72
www.ijiset.com

Why Teaching Evolution and Photosynthesis is Imperative for an Understanding of the Living World

Ulrich Kutschera and Rajnish Khanna

I-Cultiver, Inc., Manteca CA 95336 & Department of Plant Biology, Carnegie Institution, Stanford CA 94305 (USA)
E-mail: kutscherau@gmail.com ; rajnishkcal@gmail.com

Abstract

The rejection of some US-science books by the Texas Board of Education because of their presentation of climate change and evolution, as discussed in The Wall Street Journal (Nov. 17, 2023), is very disturbing and reminiscent to the struggle for science education in India, on which we want to comment. We document that "parochial nationalism" may be the major cause of the rejection of Charles Darwin's principle of evolution in India. In addition, we argue that an understanding of light-driven carbon dioxide (CO2)-assimilation (i.e., oxygenic photosynthesis of green leaves) is of equal importance and show that an Indian scientist, Govindjee, contributed much of our current knowledge on photosynthesis, inclusive of net primary production of plants, algae plus cyanobacteria, and the evolution of this key process of the biosphere. Finally, we come back to the situation in Texas-USA, with reference to rising carbon dioxide (CO2)-levels, global greening, and climate change.

Keywords: *Climate Change, Govindjee, Evolution, Intelligent Design, India, Photosynthesis*

Introduction

The On November 17, 2023, The Wall Street Journal published under the headline "U.S. Education News" the following article: "Texas Rejects Science Textbooks Over Climate Change & Evolution Lessons". Other major newspapers, such as the Houston Chronicle, also reported on the fact that the Texas Board of Education is still debating evolution, nearly a century after the "Scopes Monkey Trial", an American legal case-1925, where a high-school teacher was accused of violating State Law by teaching human evolution.

In this article, we want to discuss science education in India, with reference to evolution, a topic of general interest that was a highly controversial, hotly debated issue in many journals and newspapers over the past several months. We refer to human evolution and photosynthesis research, and explain the difference between gross- and net-primary production in the biosphere. Finally, we will return to the situation in the USA, with a focus on evolution and climate change as interrelated natural processes.

Evolution, Intelligent Design, and Green Plants

In their Editorial "Not teaching evolution is an injustice" (Science 380, 1303; 2023), L.S. Shashidhara and A. Joshi complain about the fact that, in India, research and teaching of evolution is currently under pressure. This opposition to the unifying principle of the life sciences [1] is, at least in part, influenced by the quasi-religious concept of "Intelligent Design", a Christian idea popular in the USA that has no empirical basis. In India, where Hinduism is the dominant spiritual worldview, the situation is different from that in the US. As a result, in this Asian country, the evidence in support of Charles Darwin's (1809–1882) principle of "descent with modification", i.e., organismic evolution, is overshadowed by the irrational ideology of "parochial nationalism", i.e., the claim that "all major scientific insights can be traced back to ancient India".

The authors of the Editorial stress the importance of teaching evolution for an understanding of the biomedical sciences with reference to topics of global importance for mankind, such as ageing, cancer development, zoonotic pandemics, ecological problems, human health etc. To all of these problems, Indian scientists with an evolutionary perspective have contributed significantly, i.e., Darwin's basic concepts are "well and alive" among academics in this country. This conclusion is supported by the following fact. On September 3, 2023, the Times of India reported on a recent paper published in Science under the headline: "Bottleneck in human evolution explained using novel genomic analysis techniques". This downturn in

human ancestral populations in the Early Stone Age, about 900.000 years ago (from about 27.000 to only ca. 1.300 African Homo erectus-individuals) may have been caused by natural climate change (global cooling), resulting in droughts, and associated food shortages due to loss of vegetation, i.e., the demise of a large fraction of land plants [2].

It is obvious that the physiological-biochemical activity of green plants, which are, like algae and cyanobacteria, the sunlight-driven photoautotrophic producers of the biosphere, is the pre-requisite for the nutrition of humans, as well as all other heterotrophic organisms (Fig. 1). In two recent publications, we have analyzed these interrelationships between heterotrophs (bacteria, fungi, animals) and green plants, with reference to the evolutionary origin of chloroplasts [3, 4]. In addition, we described the fact that both terrestrial and marine photoautotrophs contributed approximately equally to global primary production, as illustrated by the photosynthesis-equation in the Inset of Figure 2. The relationship between gross- and net primary production (GPP vs. NPP) [5] is also illustrated in this Figure. It should be noted that Gross Primary (photosynthetic) Production is measured as the total amount of oxygen produced due to the splitting of water by Photosystem II, excluding autotrophic respiration (AR). Accordingly, NPP is defined as GPP minus AR; it represents the global amount of organic carbon available for heterotrophic processes in plants and other organisms that depend on an uptake of energy-rich biomolecules [5].

Fig. 1 Photosynthetically active maize *(Zea mays*) plants in a Greenhouse, with portrait of the Indian scientist Govindjee (left), and Fava beans (*Vicia faba*), growing in an experimental field (right) at the Carnegie Institution, Dept. of Plant Biology, Stanford, California, USA. During his long career as a biochemist, Govindjee spend two sabbaticals in this Research Center, performing innovative photosynthesis research (original photographs by U. Kutschera, Stanford, CA, 2019).

Biological Evolution and Photosynthesis

Based on these facts we want to stress that L.S. Shashidhara and A. Joshi omit one key topic of major significance for the survival of humanity, to which an Indian plant biologist, – Govindjee (Fig.1, Inset) –, has contributed more insights than most of his competitors: Photosynthesis research, i.e. the study of the mechanisms of light-driven carbon dioxide (CO2)-assimilation in the green leaves of plants, as well as in algae and cyanobacteria, leading to the biosynthesis of energy-rich carbohydrates, and the concomitant release of molecular oxygen (O2) due to the splitting of water (H2O) [3,4,5].

In their Article “Govindjee’s 90th birthday – Congratulations from friends and colleagues”, S. Naithani et al. [6] summarized the scientific achievements of Professor Govindjee, who was born 1932 in Allahabad (India) in an “Asthana” family. Accordingly, his name should have been “Govindjee Asthana”. Since the last name refers to a specific caste, and his father was an Arya Samajist, who rejected the caste system, Govindjee never used his last name “Asthana”. Aa a result,

Govindjee has always used only one name that is recorded in his US Naturalization Certificate of 1972, when he became a citizen of the USA. Unfortunately, since most computer forms require two or more names, he was frequently listed as "F.N.U. Govindjee", with the initials standing for "First Name Unknown". However, in 2018, he changed his name to "Govindjee Govindjee", which is now given in his passport. As a scientist, Prof. Govindjee used, until 2017, only one name – as author, speaker, referee, editor of the journal "Photosynthesis Research" etc.

Govindjee was educated in India, at the University of Allahabad (B.Sc., 1952; M.Sc. 1954; Lecturer in Botany 1954–56). At the age of 24 years, he moved to the United States, earned his Ph.D. (Biophysics, University of Illinois at Urbana-Champaign, UIUC), and remained at this prestigious academic institution until today (Assistant Prof. 1961; Full Prof. of Biophysics & Plant Biology 1969; Prof. Emeritus 1999 – present). In 1963 and 1979, Govindjee was a Visiting Scientist in the Department of Plant Biology/Carnegie Institution at Stanford University in California, where he carried out research in the laboratory of the photosynthesis researcher and former Carnegie-Director C. Stacey French (1907–1995). Figure 1 shows Govindjee's portrait, placed close to a group of green, adult maize plants in a Greenhouse of the Carnegie Institution, where original research on plant growth and photosynthesis under defined conditions has been carried out [3]. Govindjee's pioneering experimental work on the mechanisms of oxygenic (O2-producing) photosynthesis and innovative use of biophysical techniques yielded more than 400 scientific publications, numerous invitations (to India etc.), and prestigious awards [6].

Govindjee's contributions to photosynthesis research rest on an evolutionary perspective, without which an understanding of this sunlight-driven, life-supporting photo-biological process is not possible. Two examples may suffice to prove this point.

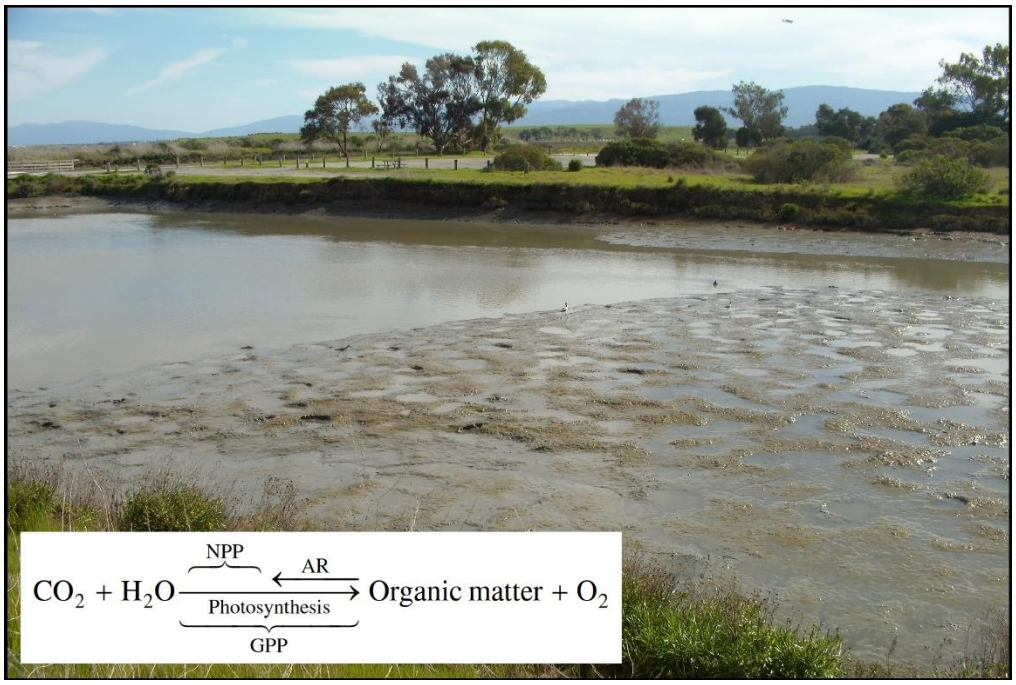

Fig. 2 Terrestrial and marine ecosystems contribute approx. equally to net primary production of the biosphere, as illustrated by this view of the Palo Alto Baylands Nature Preserve close to Stanford, California, USA. The relationships between autotrophic respiration (AR), Gross- und Net Primary Production (GPP, NPP) are illustrated by the equation shown in the Inset (original photograph U. Kutschera, Stanford, CA, 2019; Inset adapted from Ref. 5).

Evolutionary Origin of Oxygenic Photosynthesis

In the "Darwin-year 2009", L.O. Björn and Govindjee published an article entitled "The evolution of photosynthesis and chloroplasts" [7]. In this contribution, they document that ancient aquatic cyanobacteria were the first microbes to carry out oxygenic photosynthesis, which led to the "Great Oyxgenation Event" about 2.3 billion years ago. As a result, the O2-level of the oceans and the atmosphere rose, so that the evolution of more complex forms of life was possible. A few hundred thousand years later, certain cyanobacteria were taken up by aquatic host cells via the process of primary endosymbiosis,

resulting in photosynthetically active chloroplasts, and the evolutionary development of green algae. About 400 million years ago, the rise of the earliest land plants is documented in the fossil record; these ancient, bryophyte-like green organisms were the descendants of certain green algae [1, 3, 4, 7].

In 2017, Govindjee et al. [8] published a review on the "Evolution of the Z-scheme of photosynthesis". In this historical perspective, the authors re-construct the origin and experimental discovery/verification of a model of the light reactions of oxygenic photosynthesis, over the time period 1941 to 2016. It becomes clear that only an evolutionary view makes sense in attempts to understand of the gradual emergence of major scientific concepts. Hence, the Darwinian principle of "Descent with modification" (i.e., organismic evolution) was applied by Govindjee in this, and his numerous other, articles on the history of photosynthesis research. In other words: Photosynthesis itself, as well as the discoveries leading to an understanding of this life-supporting process, are only understandable within the framework of evolution – the core principle of all natural sciences, notably biology, geology and medicine [1].

Finally, it should be noted that Govindjee published articles and books under the general topic "Photosynthesis: Solar Energy for Life on Earth", wherein he pointed out the need to develop "artificial photosynthesis systems". In this context, he stressed that "Photosynthesis is the basis of future advances in producing more food, more biomass, more fuel, and new chemicals for our expanding global human population" [6]. In 2018, when Govindjee wrote down this sentence, the world population was ca.7683 million people; it steadily increased by 0.83 % to 1.06 % per year, reaching, five years later, about 8045 million inhabitants (2023; see www.worldometers.info).

Conclusions

This clear "Photosynthesis-statement" of "Govindjee Govindjee" (his name since 2018) quoted above [6] documents that the teaching of evolution & photosynthesis is more important than ever, not only in India, but in all countries of the world. We go one step further and conclude that solid knowledge about evolution and photosynthesis is imperative for an understanding of the living world, i.e. biodiversity of both terrestrial and marine ecosystems (Figures 1 and 2). The Texas Board of Education should take our arguments into account and re-evaluate their opposition to the following two interrelated facts: 1. Rising CO2-levels and climate change over the past decades, which boosted CO2-dependent photosynthesis, leading to global greening [see refs. 9, 10], and 2. Chemical as well as organismic evolution, – as detailed in textbooks for schoolchildren, students and the general public alike.

Acknowledgement

This article is dedicated to our former mentor and friend Prof. Winslow R. Briggs (1928 –2019), former Director of the Carnegie Institution-Dept. of Plant Biology at Stanford University, CA 94305-USA, an active researcher in this Institution until his death.

References

[1] Kutschera U. Evolution. Ref Mod Life Sci, Elsevier 2017 Art. 06399: 1–5.
[2] Ashton N, Stringer C. Did our ancestors nearly die out? Science 381; 2023: 947–948.
[3] Kutschera U, Khanna R. Experimental plant research and the discovery of carbon dioxide-mediated global greening: a tribute to Wilhelm Pfeffert (1845–1920) J Plant Biochem Biotechnol. 30; 2021: 407–420.
[4] Kutschera U, Khanna, R. The origin of chloroplasts: Constantin S. Merezhkowsky (1855–1921) and symbiogenesis. J Plant Biochem Biotechnol 31; 2022: 178–184.
[5] Huang Y, Nicholson D, Huang B, Cassar N. Global estimates of marine Gross Primary Production based on machine learning upscaling of field observations. Global Biogeochemical Cycles 35; 2021: e2020GB006718, 1–18.
[6] Naithani S, Stirbet A, Shevela D et al. Govindjee's 90th birthday-Congratulations from friends and colleagues. Curr Plant Biol 32; 2022: 100263, 1–18.
[7] Björn LO, Govindjee, The evolution of photosynthesis and chloroplasts Curr Sci 96; 2009: 1466–1478.
[8] Govindjee, Shevela D, Björn LO. Evolution of the Z-scheme of photosynthesis: a perspective. Photosynth Res 133; 2017: 5–15.
[9] Kutschera U, Pieruschka R, Farmer S, Berry J., The Warburg-effects: basic metabolic processes with reference to cancer development and global photosynthesis. Plant Signal Behav. 15; 2020: 1776477, 1–10
[10] Kutschera U, Ehnes I. World Climate Declaration: Exhaled carbon dioxide promotes plant development. European Journal of Environment and Earth Sciences. 4/5; 2023: 1–4.