Photosynthesis Research
https://doi.org/10.1007/s11120-019-00641-w

HISTORY AND BIOGRAPHY

Eugene I. Rabinowitch: A prophet of photosynthesis and of peace in the world

Govindjee[1] · George C. Papageorgiou[2] · Rajni Govindjee[1]

Received: 17 March 2019 / Accepted: 23 April 2019

Abstract
More than 45 years have passed since Eugene I. Rabinowitch died, on May 15, 1973, at the age of 75, but many still remember him as a photosynthesis giant, the author of a 2000-page "Bible" on photosynthesis, a great chemist and physicist, a discoverer of several basic photoreactions, one of the founders of modern biophysics, a peacemaker, a poet, an architect, an artist, a wonderful human being, and above all a great mentor. Sir John Rotblatt cited Eugene Rabinowitch, together with Bertrand Russell, for their key contributions that led to the Nobel Peace Prize awarded in 1995 jointly to Rotblatt and the Pugwash Conferences on Science and World Affairs "for their efforts to diminish the part played by nuclear arms in international politics and, in the longer run, to eliminate such arms." Already in 1965, Eugene Rabinowitch had received the prestigious Kalinga Prize from UNESCO "in recognition of his work to encourage international cooperation among scientists and to bring to light the potential dangers of science to the public."

Keywords James Franck · Robert Emerson · Chlorophyll · Photogalvanic effect · Difference absorption spectroscopy · Bulletin of Atomic Scientists · Kalinga Award

Evgenii Isaakovich Rabinovich was born on April 14 (April 26/27 according to today's calendar), 1898 to Zinaida Moiseevna and Isaak Moiseevich Rabinovich in St. Petersburg (renamed Petrograd in 1914), Russia. He graduated from the private Prince Tenishev School there in 1915. Then, a year before the Russian revolution, he enrolled at St. Petersburg University, where he majored in Chemistry in the Faculty of Natural Sciences. In August 1918, he and his parents left Petrograd for Kiev, but 11 months later, the family left for Warsaw, Poland, to escape the new Soviet regime in Russia. After a 2-month stay in Minsk along the way, they arrived in Warsaw in September 1919.

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s11120-019-00641-w) contains supplementary material, which is available to authorized users.

✉ Govindjee
gov@illinois.edu

George C. Papageorgiou
gcpap@bio.demokritos.gr

Rajni Govindjee
Rajni_govindjee@yahoo.com

[1] University of Illinois at Urbana-Champaign, Urbana, IL 61801, USA

[2] National Centre of Scientific Research, Demokritos, Athens, Greece

In Germany

From Poland, the Rabinowitch family soon moved to Berlin, Germany, where Eugene did his PhD in Chemistry, receiving it in February 1925 from the University of Berlin. He worked on volatile hydrides (GeH_4 and SnH_4), under Fritz Paneth, a collaborator of Georg von Hevesy, the 1943 Nobel Prize winner "for his work on the use of isotopes as tracers in the study of chemical processes." While in Berlin, he attended an exciting physics seminar series, where the first benchers included five Nobel Prize winners: Albert Einstein, Max von Laue, Walther Nernst, Erwin Schrödinger, and Max Planck.

Figure 1 shows a photograph of Eugene Rabinowitch with his wife Anna (Anya) and his mother Zinaida.

Eugene wrote reviews for the German Chemical Abstracts, then a fabulous 522-page volume on "Rare Gases" (1928); several shorter contributions for Abegg's *Handbuch der Anorganische Chemie* (IV. 3. Erster Teil; see

Fig. 1 Eugene Rabinowitch (right) with his wife, Anna (Anya; middle), and his mother, Zinaida (left), Göttingen, Germany, 1932 (source: Rabinowitch Family Archives)

Rabinowitch 1928); and then, with Erich Thilo, a book on the "History and Theory of the Periodic System" (Rabinowitch and Thilo 1930). In these publications, he combined chemistry with physics, the latter being his special interest (in fact, he had studied physics more than chemistry).

From 1929 to 1933, Eugene worked as a private research assistant at the University of Göttingen, under James Franck, the 1925 Nobel laureate in physics. Here, he discovered the so-called "cage effect" (also known as the Franck–Rabinowitch effect) which describes how the properties of a molecule are affected by its surroundings (Rabinowitch and Franck 1934; Rabinowitch 1936a, b). At Franck's institute, he had the privilege of meeting and listening to Max Born, Edward Teller, and Friedrich Hund (who had developed the formal theory of atomic spectra), as well as Edward Condon (co-discoverer with Franck of the Franck–Condon Principle).

After Hitler's rise to power in 1933, Rabinowitch left Germany for Copenhagen, Denmark, to work with another Nobel laureate, Niels Bohr. There, Eugene worked on the dissociation of iodine and bromine molecules by light, in which the equilibrium states between the atoms and molecules were studied by means of difference absorption spectroscopy, the cross-beam method that Eugene had developed (for references, see below "In England, United Kingdom"). Rabinowitch used spectroscopy to monitor the concentration of bromine molecules, and in this way, he measured the rate of the combination of free atoms under different conditions. He then used this method in the UK, and later at the University of Illinois Urbana-Champaign (UIUC) in Urbana, Illinois, to unravel photochemical steps in photosynthesis.

In England, United Kingdom

After Eugene had been in Denmark for just 6 months, Imperial Chemical Industry helped him to move to the Department of Chemistry, University College London, and to the laboratory headed by Frederick G. Donnan, who discovered the Donnan Equilibrium in ion transport across cell membranes. Eugene spent 4 years (1934–1938) as a research associate in London. He published a series of papers, together with Clifford Wood (a Canadian student), on the recombination kinetics of free atoms. Their papers included experimental studies of the "cage effect" and of the efficiency of "three body collisions." It was a very productive time for Eugene. He published about 15 papers in a couple of years on the photochemistry of pigments (see e.g., Rabinowitch and Lehman 1935; Rabinowitch 1936a, b; Rabinowitch and Wood 1936a, b, c, d, e, g, h, i). After having made important contributions in the area of photochemistry, Eugene developed an interest in chlorophyll (Chl) and photosynthesis, which was to last for years to come. His earliest work had to do with using difference spectroscopy as a tool to study reversible reduction of thionine, an azo-dye, which is reduced by ferrous ions (Fe^{2+}) in light and re-oxidized in darkness. It was this study that led him to do the same with Chl and to discover reversible oxidation–reduction of ethylchlorophyllide by ferric (Fe^{3+}) and ferrous (Fe^{2+}) ions (Rabinowitch and Weiss 1936; Porret and Rabinowitch 1937), an important clue as to how Chl *a*, at the reaction center, might work in photosynthesis.

In the United States of America

In 1938, Eugene emigrated to the United States, joining the Solar Energy Research Project at the Massachusetts Institute of Technology (MIT) in Boston, Massachusetts. It was at MIT that he discovered the details of the photogalvanic effect, which involves the conversion of light energy into chemical energy, a harbinger of artificial photosynthesis (Rabinowitch 1940a, b). As mentioned above, Eugene had observed earlier the reversible shift in the redox state of the thionine in thionine-ferrous or ferric ion systems, and had the idea that this shift would produce redox potential difference; this actually proved to be the case. He spent most of his time at MIT studying the kinetics and the yield of this reaction, with the hope of using it to "store solar energy through chemistry" for the benefit of all.

Figure 2 shows a 1941 portrait of Eugene, when he was at MIT in Boston.

It was at MIT that Eugene began writing his highly recognized treatise on "all there is to know about

Fig. 2 Eugene Rabinowitch at MIT, Boston, 1941 (source: Rabinowitch Family Archives)

photosynthesis"; the first volume of his book *Photosynthesis and Related Processes* was published in 1945 (Rabinowitch 1945); the other two volumes were completed and published later (Rabinowitch 1951, 1956). These three tomes, ~ 2000 pages, were considered for years the "Bible of Photosynthesis" (and Rabinowitch himself was called the "Prophet of Photosynthesis"). All three volumes are available free at Govindjee's web site: (http://www.life.illinois.edu/govindjee/g/Books.html)

In Chicago, as a part of the Manhattan Project

During World War II, Eugene worked on the Manhattan Project in the Metallurgical Laboratory (the "Met Lab") at the University of Chicago, Chicago, Illinois. At that time, he was a member of the Committee on Political and Social Problems, chaired by James Franck. In 1945, with help from Leó Szilárd, Eugene wrote what became known as the Franck Report. The report recommended that nuclear energy should be controlled by civilians, rather than by the military, and argued that the USA should demonstrate the power of the atomic bomb to world leaders in an uninhabited desert or barren island before using it in combat.

In 1945, while at the Manhattan Project, Eugene cofounded, with physicist Hyman Goldsmith, the *Bulletin of the Atomic Scientists*, a highly influential periodical that addressed topics related to the cold war, the proliferation of nuclear armaments, and the imminence of a global nuclear catastrophe. Eugene served as its editor from 1945 until his death in 1973; he contributed more than 100 articles, mostly editorials. A popular feature of the *Bulletin* is the famous Doomsday Clock on its cover, which displays how close (in minutes humanity is to midnight), the time of the imminent global nuclear catastrophe. The *Bulletin* continues to play a crucial role in voicing messages of compromise and peace in the World for the problems of climate change as well as conflicts between the nations (see: https://thebulletin.org/; also see Kaiser and Wilson (2015)).

While at the Manhattan Project, in collaboration with Joseph J. Katz, Eugene wrote *The Chemistry of Uranium*, published by McGraw Hill in 1951 (Katz and Rabinowitch 1951). His official role at the Manhattan Project was to prepare a handbook on uranium chemistry for the project. At that time, there was a large amount of new data on the chemistry and physics of uranium that had accumulated during the project; Eugene compiled and correlated this material, compared it with the available open literature, and prepared a treatise that could be used for further research.

At the University of Illinois at Urbana-Champaign

In 1947, Eugene began his professorship in the Photosynthesis Project at the University of Illinois at Urbana-Champaign; his colleague there was Robert Emerson (1903–1959; see Rabinowitch 1959, 1961; Govindjee 2004). At UIUC, Eugene trained many students and postdocs in the area of biophysics of photosynthesis (earlier called physico-chemical biology).

Figure 3 shows a portrait of Eugene taken in the 1950s in his office in the Natural History Building of the UIUC. Each of the authors remembers visiting him in this office.

In Eugene's laboratory, research was more varied than on Emerson's side. Emerson focused consistently and persistently on specific fields, with a high degree of perfectionism. In Eugene's laboratory, there was more switching from subject to subject. Especially during the period when Emerson's work appeared to stagnate, there were interesting new findings in Eugene's laboratory. There, Chl was crystallized for the first time, and a shift of the absorption spectrum of Chl with the size of the crystal was discovered; furthermore, X-ray, infrared, and electron micrograph data were obtained by Stanley Holt, Earl Jacobs, and Al Vater. The interpretation of these data and comparison with the "non-crystalline" Chl and with Chl in vivo led to a partial

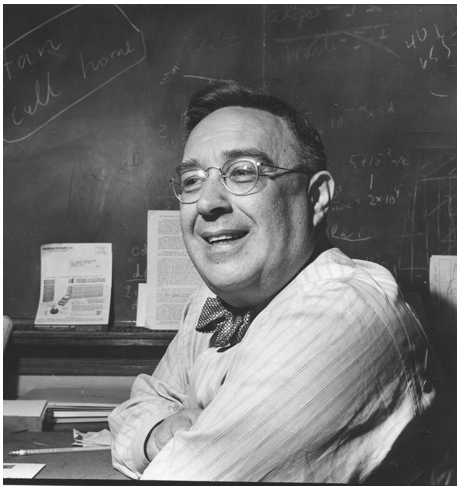

Fig. 3 Eugene Rabinowitch in his University of Illinois office, in the basement of the Natural History Building, Matthews Avenue, Urbana, Illinois, 1950s (source: Rabinowitch Family Archives)

understanding of the state of Chl in vivo. However, there are still open questions. We know that Eugene thought until his death that something interesting and important will come out of work with Chl in vitro.

Then, there was the discovery by Paul Latimer of abnormal (selective, i.e., dependent on wavelengths of light) scattering of light by chloroplasts (Latimer and Rabinowitch 1955, a, b). It was a new property of Chl, and, a new phenomenon at that time. It could have been foreseen from the theory of scattering and theory of abnormal dispersion, but it was never observed earlier, and it was demonstrated in Eugene's laboratory for the first time. Since selective scattering is dependent on packing and arrangement of pigments in the system, this phenomenon has many implications, none of which has yet been fully investigated.

Other interesting observations made in Eugene's laboratory were the first measurements of the life-time of excited Chl in solution and in living cells by Steve Brody and of quantum yield of fluorescence by Paul Latimer. The Rabinowitch group (Giti Tomita, Neti R. Murty, Gauri S. Singhal; see Bannister, 1972) kept improving on the techniques. The first measurement on the transfer time of excitation energy transfer was made by Steve Brody (see Brody 1995, 2002 for Eugene's contributions).

Still another field in which Eugene's group had worked was the field of difference absorption spectroscopy. In a certain sense, Eugene had been the first to use difference absorption spectroscopy for reaction kinetics in chemical reactions when he was in London. He had first started this technique in Copenhagen in Niels Bohr's laboratory. There, he had used the "cross-beam" method to study the kinetics of dissociation of molecules and association of free atoms. It was logical that Eugene should apply difference absorption spectroscopy to the study of photosynthesis. He once told Govindjee, "However, I was very slow in developing ideas, and so the first measurements in this field came from Lou Duysens (1952) who made very important research using difference spectroscopy, even naming the pigment, which is bleached in light, as P 870 in a photosynthetic bacterial system."

Duysens' work included a very large amount of interesting and novel research. He indeed was the first to publish results showing interesting changes in absorption spectra of plants and photosynthetic bacteria during photosynthesis. Eugene invited Duysens to work in Urbana, and he stayed in Eugene's laboratory for almost a year. Then, Jack Coleman worked in this field as Eugene's student but left before finishing his Ph.D. However, they thought that they had made an important discovery: evidence for the reversible change of Chl a absorption in vivo, with a peak around 685 nm (Coleman et al. 1956). Later, however, it turned out that this band was really due to changes in Chl fluorescence (Rubinstein and Rabinowitch 1963). What is interesting is to point out that they had also discovered small absorption changes around 700 nm, but they did not say much about it. However, Bessel Kok (1957) who saw a band around 705 nm in many photosynthetic systems stated "On the basis of our available experimental material we prefer to ascribe the discussed absorption change to the photochemical transformation of a pigment that is different from chlorophyll a in its normal status and that occurs universally in the plant kingdom." It is not clear to us as yet as to who was the first to call the reaction center Chl a as P700 (for PSI). See Govindjee and Renger (1993) for an appreciation of Bessel Kok. In the 680–685 nm region, P680 was suggested to be reaction center (trap) of PSII by Krey and Govindjee (1964) and shown to exist by Döring et al. (1969) in Horst Witt's research group. Soon thereafter, Govindjee et al. (1970) confirmed that it was without the artifact of Chl *a* fluorescence changes.

Eugene (personal conversations with Govindjee, during 1960–1965) was never 100% certain that all of the changes discovered by Jack Coleman were due to fluorescence changes. He thought, in 1964, that difference spectroscopy was still the most promising approach for the intimate study of the mechanism of photochemical processes in photosynthesis, and he still hoped that the instrumentation developed over a period of years in his laboratory might yet produce important contributions in this field. However, Eugene retired from UIUC in 1968 and accepted a position as Professor of Chemistry and Director of the Center for Science and Human Affairs at the State University of New York (SUNY) in Albany, New York. Eugene died on May 15, 1973. For further information about Eugene, see articles by Bannister (1972), Brody (1995), Govindjee (2004), and Rabinowitch (2005), as well as the web sites listed in

Fig. 4 Left to right: Eugene Rabinowitch (reading a Swedish newspaper); Rajni Govindjee, and Govindjee at the 1st International Biophysics Conference in 1961, Stockholm, Sweden (source: Govindjee Family Archives; Fig. 1 (top) in Govindjee 2019)

Appendix 1. We end this *Memoriam* with our personal recollections, which give a glimpse of some of the research we published with him.

Reminiscences by the authors

Govindjee and Rajni wrote

After obtaining our MSc. degrees in Botany (with specialization in Plant Physiology, in 1954 and 1955, respectively) from the University of Allahabad, India, and after a two-year research stint under Shri Ranjan, we received University of Illinois Fellowships, in 1956 and 1957, respectively, to work under Robert Emerson.

While Govindjee was working for a PhD in Physico-Chemical Biology (Biophysics) and Rajni in Botany (Plant Biology), Emerson died in a plane crash on February 4, 1959. Both of us were very fortunate that Eugene Rabinowitch accepted us as graduate students in his laboratory. Each of us learned everything that was known then in the area of “Photobiology and Photochemistry” directly from Eugene and from his course. Govindjee finished his PhD in 1960, and Rajni in 1961. Govindjee discovered that both photosystems are run by two different spectral forms of chlorophyll *a* (Govindjee and Rabinowitch 1960; cf. Govindjee 2019), and Rajni discovered that the Emerson Enhancement Effect was in photosynthesis, not in respiration (Govindjee et al. 1960).

Figure 4 (reproduced from Govindjee 2019) shows Eugene with both of us (G & RG) in 1961 at a conference in Sweden after we finished our PhDs.

Both of us remember Eugene as the most wonderful mentor and friend. We enjoyed memorable parties at the home of Anya and Eugene on 1021 West Church St., Champaign, IL, where Vodka was a standard drink. we were family to them. Anya even taught Rajni how to make vodka using bison grass, Zubrowka. In addition, Anya and Eugene Rabinowitch were wonderful hosts to us at their summer home in Vermont; it was there that a *Scientific American* article (Rabinowitch and Govindjee 1965) and our highly successful book on photosynthesis were written (Rabinowitch and Govindjee 1969). We remember Eugene vividly and have fond memories; he was the most wonderful human being that we have known in our lives (Govindjee 2004). We were family to Anya and Eugene.

Figure 5 shows a mid 1960 photograph of the camaraderie Govindjee had with Eugene while both were serving on the faculty of UIUC.

We end this personal tribute by mentioning a paper in which Rajni and Govindjee proved, with Eugene, that the minimum quantum requirement for oxygen evolution in the green alga *Chlorella* (even under Otto Warburg’s conditions) was 10–12 (as Emerson had found), not 3–4 as Warburg had claimed (Govindjee et al. 1968).

George Papageorgiou wrote

After obtaining a BS degree in Chemistry from the University of Thessaloniki, Greece, and after a mandatory service in the Greek Army, I was very fortunate to be accepted as a graduate student in the PhD Program in Biophysics at the University of Illinois at Urbana-Champaign (UIUC), USA. One of the first courses I opted to take was Biophysics of Photosynthesis. As a chemist, with a physico-chemical tilt,

Fig. 5 Eugene Rabinowitch with Govindjee in Rabinowitch’s office in Morrill Hall, University of Illinois, at Urbana-Champaign (UIUC), Goodwin Avenue, Urbana, Illinois, 1963 (source: Govindjee Family Archives; Fig. 2 in Eaton-Rye 2018)

Fig. 6 Eugene Rabinowitch with part of Govindjee's research group, 1969, in Morrill Hall, UIUC, Goodwin Avenue, Urbana, Illinois; left to right: George C. Papageorgiou (one of the authors), Alan Stemler, Eugene Rabinowitch, Pat Breen, and Govindjee (source: Govindjee Family Archives; for another picture with Ted Mar, see Fig. 2, 3rd row, left in Eaton-Rye 2007)

I knew something about photosynthesis and chlorophylls *a* and *b*, but I was totally unaware of Robert Emerson's great discoveries of the two light reactions and the two photosystems (and their accessory pigments) in photosynthesis. The course, taught by Professor Eugene Rabinowitch and Assistant Professor Govindjee in a large amphitheater, was very interesting and quite a large number of students attended it. In his first lecture, Govindjee declared that all that is important in photosynthesis we owe to discoveries by the late Professor Emerson and to Professor Rabinowitch, both of the UIUC. The exaggeration was obvious but it, nevertheless, impressed me, so I decided to visit the Photosynthesis Lab in order to explore the possibility of doing my PhD thesis research there. I met Govindjee, and I was once more very fortunate to be accepted by him as his graduate student.

At that time, the Laboratory of Photosynthesis at the UIUC had many post-doctoral scientists and graduate students, from all around the world. For that time, the lab was very well equipped with absorption and fluorescence spectrophotometers (suitable for measuring turbid suspensions of cells and chloroplasts), instruments to measure oxygen (manometric and electrochemical), and culture facilities; moreover, there were expert technicians that managed this complex operation. In short, it was an ideal lab for research on various aspects of biophysics of photosynthesis.

Eugene was surrounded by an aura of intellectuality in all situations. In addition to being associated with the topmost authorities in physics and chemistry in Europe (see above), he had a deep appreciation of the cultural heritage from Ancient Greece; so, having a Greek student in the lab was an opportunity for occasional discussions. Eugene was a humble person; he preferred not to be addressed as "Professor Rabinowitch." He was readily approachable and happy to offer his advice. I do recall that during my time in Urbana-Champaign I was invited, with Sophie, my wife, several times to his home. Every week there was a laboratory seminar, where we had the opportunity to interact with Eugene. He was a perfectionist, endlessly editing and improving the drafts that Marion Carter, his secretary, typed for him.

I was the first PhD student of Govindjee, and I published many key papers on biophysical aspects of photosynthesis with him (see e.g., Papageorgiou and Govindjee 1968a, b). However, I also published a paper on the "Sieve Effect" in algae with Eugene's research team which included Mrinmoye Das, from India, and the late Laszlo Szalay from Hungary (see Das et al. 1967).

Figure 6 shows a 1969 group photograph of Eugene with several of us from Govindjee's research group.[1]

Concluding remarks

To remember Eugene is like remembering many persons in one. No tribute can describe this human being who walked on this Earth. He was first, and foremost, a great human being, a friend to all, a top leader in science, and a person who constantly thought and strived for peace in this world. He was always fair to all who came to know him. He was a great teacher and mentor. He received the most prestigious Kalinga Prize (established by the donation of Biju Patnaik of India) for the Popularization of Science, given by UNESCO; he indeed had exceptional skills in presenting scientific ideas to lay people (see Smith 1966; also see: Long 1972).

We end this "Memoriam" by mentioning that Eugene always had great respect for many photosynthetikers in the USA (including C. Stacy French (Govindjee and Fork 2006)) and abroad, including Lou Duysens (Govindjee and Pulles 2016).

Acknowledgment We thank Barbara Zilinskas to have suggested changes in an earlier version of our manuscript that led to improvement

[1] Supplementary Material shows three additional photographs of Eugene Rabinowitch: Figure S1 (a 1925 photograph when he was a student in Germany); Figure S2 (a 1957 photograph showing him sizing up his height with that of Rajni (Govindjee's wife), at her wedding reception; and Figure S3 (a 1964 photo of Eugene receiving a Honorary Degree at Dartmouth).

of our presentation. We are equally grateful to Robert Blankenship and to Julian Eaton-Rye for important suggestions.

Appendix 1

Web sites related to Eugene Rabinowitch

- Atomic Heritage Foundation
  https://www.atomicheritage.org/profile/eugene-rabinowitch
- Bulletin of Atomic Scientists
  https://thebulletin.org/biography/eugene-rabinowitch/
- Franck Report, written by Eugene Rabinowitch [Restricted Data]
  http://blog.nuclearsecrecy.com/2012/01/11/weekly-document-9-the-uncensored-franck-report-1945–1946/
- New York Times (by Linda Greenhouse)
  https://www.nytimes.com/1973/05/16/archives/dr-eugene-rabinowitch-dies-manhattan-project-chemist-71-a-sense-of.html
- Pugwash Conference
  https://physicstoday.scitation.org/doi/full/10.1063/1.1387592
- State University of New York (SUNY) at Albany
  https://meg.library.albany.edu:8443/archive/view?docId=ger075.xml#
- University of Chicago: Guide to Rabinowitch's papers
  https://www.lib.uchicago.edu/e/scrc/findingaids/view.php?eadid=ICU.SPCL.RABINOWITCH&q=India
- University of Illinois Archives
  https://archives.library.illinois.edu/archon/?p=collections/controlcard&id=3724
- Wikipedia:
  https://en.wikipedia.org/wiki/Eugene_Rabinowitch
- The Voice of Eugene Rabinowitch [Sometimes, it does not work]
  https://books.google.com/books?id=jgoAAAAMBAJ&pg=PA14#v=onepage&q&f=false

References

Bannister TT (1972) The careers and contributions of Eugene Rabinowitch. Biophys J 12:707–718

Brody SS (1995) We remember Eugene (Rabinowitch and his laboratory, during the fifties). Photosynth Res 43:67–74

Brody SS (2002) Fluorescence lifetime, yield, energy transfer and spectrum in photosynthesis, 1950–1960. Photosynth Res 73:127–132

Coleman JW, Holt SA, Rabinowitch E (1956) Reversible bleaching of chlorophyll in vivo. Science 123:795–796

Das M, Rabinowitch E, Szalay L, Papageorgiou G (1967) The "Sieve Effect" in *Chlorella* suspensions. J Phys Chem 71:3543–3549

Döring G, Renger G, Vater J, Witt HT (1969) Properties of the photoactive chlorophyll a-II in photosynthesis. Z Naturfosch B 24:1139–1143

Duysens LNM (1952) Transfer of excitation energy in photosynthesis. Doctoral Thesis, State University Utrecht, Utrecht, The Netherlands

Eaton-Rye JJ (2007) Snapshots of the Govindjee lab from the late 1960s to the late 1990s, and beyond…. Photosynth 94:153–178

Eaton- Rye JJ (2018) Foreword to a special issue celebrating Govindjee's 85th birthday. Photosynthetica 56(1):1–10

Govindjee (2004) Robert Emerson, and Eugene Rabinowitch: understanding photosynthesis. In: Hoddeson L (ed) No Boundaries: University of IllinoisVignettes, Chapter 12. University of Illinois Press, Urbana, pp 181–194

Govindjee (2019) A sixty-year tryst with photosynthesis and related processes: an informal personal perspective. Photosynth Res 139(1–3):15–43

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

Govindjee, Pulles MPJ (2016) Louis Nico Marie Duysens (March 15, 1921–September 8, 2015): a leading biophysicist of the 20th century. Photosynth Res 128:223–234

Govindjee, Rabinowitch E (1960) Two forms of chlorophyll a in vivo with distinct photochemical function. Science 132:355–356

Govindjee, Renger G (1993) In appreciation of Bessel Kok. Photosynth Res 38:211–213

Govindjee R, Thomas JB, Rabinowitch E (1960) "Second Emerson effect" in the Hill reaction of Chlorella cells with quinone as oxidant. Science 132:421

Govindjee R, Govindjee, Rabinowitch E (1968) Maximum quantum yield and action spectra of photosynthesis and fluorescence in *Chlorella*. Biochim Biophys Acta 162:530–544

Govindjee, Döring G, Govindjee R (1970) The active cchlorophyll a-II in suspensions of lyophilized and tris-washed chloroplasts. Biochim Biophys Acta 205:303–306

Kaiser D, Wilson B (2015) American scientists as public citizens: 70 years of the *Bulletin of the Atomic Scientists*. Bull At Sci 71(1):13–25

Katz JJ, Rabinowitch E (1951) The chemistry of uranium: the element, its binary and related compounds. Dover, New York

Kok B (1957) On the reversible absorption change at 705 mμ in photosynthetic organisms. Biochim Biophys Acta 22:399–401

Latimer P, Rabinowitch E (1955) Selective scattering of light by pigment containing plants. In: Brown AH, French S, Livingston R, Rabinowitch E, Strehler BL, Tolbert NE (eds) Research in photosynthesis. Interscience Publishers Inc, New York, pp 100–106

Latimer P, Rabinowitch E (1956a) Selective scattering of light by pigment-containing plant cells. J Chem Phys 24:480–483

Latimer P, Rabinowitch E (1956b) Selective scattering of light by pigments in vivo. Arch Biochem Biophys 84:428–441

Long FA (1972) Eugene Rabinowitch: an appreciation. Bull Am Acad Arts Sci 26(1):12

Papageorgiou GC, Govindjee (1968a) Light-induced changes in the fluorescence yield of chlorophyll *a* in vivo. I. *Anacystis nidulans*. Biophys J 8:1299–1315

Papageorgiou GC, Govindjee (1968b) Light-induced changes in the fluorescence yield of chlorophyll *a* in vivo. II. *Chlorella pyrenoidosa*. Biophys J 8:1316–1328

Porret D, Rabinowitch E (1937) Reversible bleaching of chlorophyll. Nature 140:1098–1099

Rabinowitch E (1928) (a) Edelgase (Rare gases). (Pt. 3.1). 514 pp. (b) Iron atom. (Pt. 3.2). 50 pp. (c) Cobalt atom. (Pt. 3.3). 54 pp. (d) Nickel atom. (Pt. 3.4). 79 pp. *In* Abbegg's Handbuch der Anorganishen Chemie. Hirzel Verlag S., Leipzig, Germany

Rabinowitch E (1936a) The collision mechanism and the primary photochemical process in solutions. Trans Faraday Soc 32:1381–1387
Rabinowitch E (1936b) Zur Kinetik der halogen atom rekombination, insbesondere ueber die Bedeutung der konvektion. Zeit Phys Chem 33:275–282
Rabinowitch E (1940a) The photogalvanic effect. I. The photochemical properties of the thionine- iron system. J Chem Phys 8:551–559
Rabinowitch E (1940b) The photogalvanic effect. II. The photogalvanic properties of the thionine- iron system. J Chem Phys 8:560–566
Rabinowitch E (1945) Photosynthesis and related processes, vol I. Interscience Publishers, New York
Rabinowitch E (1951) Photosynthesis and Related Processes. Part 1, vol II. Interscience Publishers, New York
Rabinowitch E (1956) Photosynthesis and related processes. Part 2, vol II. Interscience Publishers, New York
Rabinowitch E (1959) Robert Emerson 1903-1959. Plant Physiol 34:179–184
Rabinowitch E (1961) Robert Emerson 1903-1959. Biogr Mem Natl Acad Sci USA 35:112–131
Rabinowitch A (2005) Founder and father. Bull At Sci 61:30–37
Rabinowitch, Franck J (1934) Some remarks about free radicals and the photochemistry of solution. Trans Faraday Soc 30:120–130
Rabinowitch E, Govindjee (1965) The role of chlorophyll in photosynthesis. Sci Am 213:74–83
Rabinowitch E, Govindjee (1969) Photosynthesis. Wiley, New York
Rabinowitch E, Lehman HL (1935) Kinetics of recombination of bromine atoms. Trans Faraday Soc 31:689–705
Rabinowitch EI, Thilo E (1930) Periodisches System, Geschichte und Theorie. (Periodic System, History and Theory). F. Enke, Verlag, Stuttgart, W. Germany. 302 pp. Russian translation (Moscow)
Rabinowitch E, Weiss J (1936) Reversible oxidation and reduction of chlorophyll. Nature 138:1098–1099
Rabinowitch E, Wood EC (1936a) The extinction coefficients of iodine and other halogens. Trans Faraday Soc 32:540–546
Rabinowitch E, Wood EC (1936b) Properties of illuminated iodine solutions I. q Photochemical dissociation of iodine molecules in solution. Trans Faraday Soc 32:547–556
Rabinowitch E, Wood EC (1936c) Properties of illuminated iodine solutions II. The negative absorption effect in benzene and other solvents. Trans Faraday Soc 32(5):816–823
Rabinowitch E, Wood EC (1936d) Kinetics of recombination of bromine atoms. Part II. Trans Faraday Soc 32:907–917
Rabinowitch E, Wood EC (1936e) The heterogeneous recombination and the diffusion coefficients of halogen atoms. Trans Faraday Soc 32(6):917–922
Rabinowitch E, Wood EC (1936f) Ionic exchange and sorption of gases by chabazite. Trans Faraday Soc 32(6):947–956
Rabinowitch E, Wood EC (1936g) The collision mechanism and the primary Photo chemical process in solutions. Trans Faraday Soc 32:1381–1387
Rabinowitch E, Wood EC (1936h) Dissociation of excited iodine molecules. J Chem Phys 4:358–362
Rabinowitch E, Wood EC (1936i) Kinetics of recombination of iodine. J Chem Phys 4:497–504
Rubinstein D, Rabinowitch E (1963) Fluorescence and absorption changes in *Chorella* exposed to strong light: the red band. Science 142:681–682
Smith AC (1966) Rabinowitch Awarded Kalinga Prize. Science 153(3744):1627

Supplementary Material

for

Eugene I. Rabinowitch: A prophet of photosynthesis and of peace in the world

by Govindjee; George C. Papageorgiou; and Rajni Govindjee

We show here three photographs from different periods of Eugene Rabinowitch's life. Figure S1 is from 1925 when he was a graduate student in Germany, Fig. S2 is a fun photograph from 1957 with one of us (Rajni Govindjee), and Fig. S3 is from 1964 when he was honored with a doctorate by Dartmouth University.

Figure S 1. Eugene Rabinowitch, Physical Institute, Friedrich-Wilhelm University (now Humboldt University), Berlin, Germany, c. 1925. Source: Rabinowitch Family Archiv

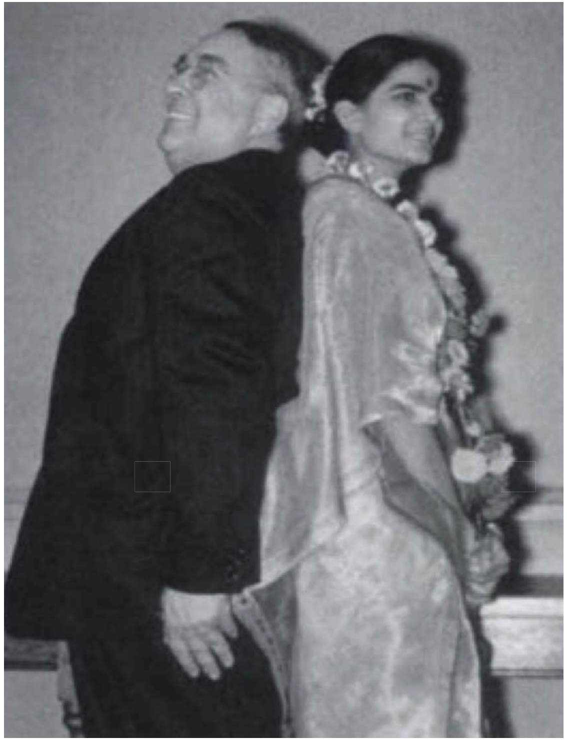

Figure S2. Eugene Rabinowitch sizing up his height with Govindjee's bride Rajni, at their wedding reception, University YMCA, Champaign, Illinois, 1957. Source: Govindjee Family Archives; photo from Govindjee (2004)

Figure S3. Eugene Rabinowitch receiving honorary degree at Dartmouth University, 1964. Source: Rabinowitch Family Archives

For additional information on Eugene Rabinowitch (1898—1973), write to Govindjee Govindjee (e-mail: gov@illinois.edu)