Photosynthesis Research **73:** 11–20, 2002.

A list of personal perspectives with selected quotations, along with lists of tributes, historical notes, Nobel and Kettering awards related to photosynthesis

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Received 24 October 2001; accepted in revised form 26 January 2002

Key words: algae, carbon-14, history of photosynthesis research, photosynthesis, plants

Abstract

The history of photosynthesis research can be found in original papers and books. However, a special history is available from the prefatory chapters and the personal perspectives of various researchers who published them in several journals over the last 40 years. We have compiled a list of such perspectives published since 1964. Selection is not easy, especially of authors who were not directly engaged in photosynthesis research; some are included for their special insights related to central issues in the study of photosynthesis. Our journal, *Photosynthesis Research*, contains other valuable historic data in the occasional tributes, obituaries and historical notes, that have been published. Lists of these items are included. This article ends by listing the Nobel prizes related to photosynthesis and the Kettering Awards for Excellence in Photosynthesis Research. Wherever possible, a web page address is provided. The web page addresses have been taken from the article 'Photosynthesis and the Web: 2001' by Larry Orr and Govindjee, available at http://www.life.uiuc.edu/govindjee/photoweb and at http://photoscience.la.asu.edu/photosyn/photoweb/default.html.

'When I find a bit of leisure
I trifle with my papers.
This is one of the lesser
frailities.'
– Horace, Satires I, IV.

List of personal perspectives

1960–1969

[*Notes*: # Nobel-laureates; *those who have papers in this issue]

#**Warburg, Otto** (**1964**) Prefatory chapter. Ann Rev Biochem **33**: 1–14 (Warburg's biography appears at http://www.nobel.se/medicine/laureates/1931/warburg-bio.html) (see also 'Otto Warburg: Cell Physiologist, Biochemist and Eccentric' by Hans A. Krebs, published by Oxford University Press, Oxford, 1981)

Tamiya, Hiroshi (**1966**) Synchronous cultures of algae. Ann Rev Plant Physiol **17**: 1–21

Van Niel, Cornelis B (**1967**) The education of a microbiologist; some reflections. Ann Rev Microbiol **21**: 1–30

Gaffron, Hans (**1969**) Resistance to knowledge. Ann Rev Plant Physiol **20**: 1–40

'Everything reasonable has been thought of before. We just have to try to think it once anew.'
– Goethe

'It is hardly possible to state any truth strongly without apparent injustice to some other.'
– Mach

1970–1979

Hill, Robert (**1975**) Days of visual spectroscopy. Ann Rev Plant Physiol **26**: 1–11

> 'Who said why is grass green and blood red.'
> – Sage

French, C Stacy (**1979**) Fifty years of photosynthesis. Ann Rev Plant Physiol **30**: 1–26

1980–1989

#**Ochoa, Severo** (**1980**) The pursuit of a hobby. Ann Rev Biochem **49**: 1–30 (Ochoa's biography appears at http://www.nobel.se/medicine/laureates/ochoa-bio.html)

Stanier, Roger Y (**1980**) The journey, not the arrival matters. Ann Rev Microbiol **34**: 1–48

Vennesland, Birgit (**1981**) Recollections and small confessions. Ann Rev Plant Physiol **32**: 1–20

Gunsalus, IC (**1984**) Learning. Ann Rev Microbiol **38**: 1–26

> 'E.B. White characterized writing as an act of faith, nothing else. And, he added "it must be the writer, above all others, who keeps it alive – choked with laughter or pain. The laughter is here, and the pain may show." '

Kamen, Martin D (**1986**) A cupful of luck, a pinch of sagacity. Ann Rev Biochem **55**: 1–34 (the reader is encouraged to read Martin Kamen (1985) 'Radiant science, dark politics: a memoir of the nuclear age', University of California Press, Berkeley, California)

Good, Norman E. (**1986**) Confessions of a habitual skeptic. Ann Rev Plant Physiol **37**: 1–22

Sweeney, Beatrice M. (**1987**) Living in the golden age of biology. Ann Rev Plant Physiol **38**: 1–9

***Clayton, Roderick K** (**1988**) Memories of many lives. Photosynth Res **19**: 205–224

#**Calvin, Melvin** (**1989**) Forty years of photosynthesis and related activities. Photosynth Res **21**: 3–16 (Calvin's biography appears at http://www.nobel.se/chemistry/laureates/1961/calvin-bio.html)

Duysens, Louis NM (**1989**) The discovery of the two photosynthetic systems: a personal account. Photosynth Res **21**: 61–80

Kamen, Martin (**1989**) Onward into a fabulous half century. Photosynth Res **21**: 137–144

1990–1999

Menke, W (**1990**) Retrospective of a botanist. Photosynth Res **25**: 77–82

Katz, Joseph J (**1990**) Green thoughts in a green shade. Photosynth Res **26**: 143–160

Weber, Gregorio (**1990**) Whither biophysics. Ann Rev Biophysics **19**: 1–6

Arnold, William A (**1991**) Experiments. Photosynth Res **27**: 73–82

Witt, Horst T (**1991**) Functional mechanism of water splitting photosynthesis. Photosynth Res **29**: 55–77

Chance, Britton (**1991**) Optical method. Ann Rev Biophysics Biophys Chem **20**: 1–28

***Hatch, Marshall** (Hal) **D** (**1992**) I can't believe my luck. Photosynth Res **33**: 1–14

Krasnovsky, AA (**1992**) Excited chlorophyll and related problems. Photosynth Res **33**: 177–193

Frankel, Albert W (**1993**) Reflections. Photosynth Res **35**: 103–116

***Joliot, Pierre** (**1993**) Earlier researches on the mechanism of oxygen evolution: a personal account. Photosynth Res **38**: 214–223

Shen, Y (**1994**) Dynamic approaches to the mechanism of photosynthesis. Photosynth Res **39**: 1–13

Akazawa, T (**1994**) Reminiscences, collaborations and reflections. Photosynth Res **39**: 93–113

Pirson, André (**1994**) Sixty years in algal physiology and photosynthesis. Photosynth Res **40**: 207–222

***Gest, Howard** (**1994**) A microbiologist's odyssey: bacterial viruses to photosynthetic bacteria. Photosynth Res **40**: 129–146

Katoh, S (**1995**) The discovery and function of plastocyanin: a personal account. Photosynth Res **43**: 177–189

Thornber, J Philip (**1995**) Thirty years of fun with antenna pigment-proteins and photochemical reaction centers: a tribute to the people who have influenced my career. Photosynth Res **44**: 3–22

***Drews, G** (**1996**) Forty-five years of developmental biology of photosynthetic bacteria. Photosynth Res **48**: 325–352

***Myers, Jack** (**1996**) Country boy to scientist. Photosynth Res **50**: 195–208

***Walker, David A** (**1997**) 'Tell me where all past years are.' Photosynth Res **51**: 1–26 (this perspective begins, 'This is the story of a young man who

wished to go to sea like his father and finished up, instead, in photosynthesis'; it is available as pdf file at http://www.life.uiuc.edu/govindjee/history/WalkerPP.pdf)

Tolbert, NE (**1997**) The C2 oxidative photosynthetic cycle. Ann Rev Plant Physiol Plant Mol Biol **48**: 1–25

Feher, George (**1998**) Three decades of research in bacterial photosynthesis and the road leading to it: a personal account. Photosynth Res **55**: 1–40 (available as pdf file at http://www.life.uiuc.edu/govindjee/history/FeherGeorgePP.pdf)

'... it finally dawned on me: biology is a 'doer's' field; you have got to run centrifuges and gels and not 'waste your time in deep thoughts.'

His Personal Perspective clearly shows he became a 'doer.'

*__Jagendorf, André T__ (**1998**) Chance, luck, and photosynthesis research: an inside story. Photosynth Res **57**: 215–229 (available as pdf file at http://www.life.uiuc.edu/govindjee/history/JagendorfAndrePP.pdf)

Gibbs, Martin (**1999**) Educator and editor. Ann Rev Plant Physiol Plant Mol Biol **50**: 1–25

Forti, G (**1999**) Personal recollections of forty years in photosynthesis research. Photosynth Res **60**: 99–110 (available as pdf file at: http://www.life.uiuc.edu/govindjee/history/FortiGeorgioPP.pdf)

Fuller, RC (**1999**) Forty years of microbial photosynthesis research: where it came from and what it led to. Photosynth Res **62**: 1–29 (available as pdf file at http://www.life.uiuc.edu/govindjee/history/FullerClintPP.pdf)

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Krogmann, David (**2000**) The golden age of biochemical research in photosynthesis. Photosynth Res **63**: 109–121 (available as pdf file at http://www.life.uiuc.edu/govindjee/history/KrogmannDavidPP.pdf)

Zelitch, Israel (2001) Travels in a world of small science. Photosynth Res **67**: 157–176

*__Benson, Andrew A (2002)__ Paving the path. Ann Rev Plant Biol 53: 1–25

Feher, George (2002) My road to biophysics: picking flowers on the way to photosynthesis. Ann Rev Biophys Biomol Struct **31**: 1–44

Selected quotations

The selection is arbitrary with a goal of providing a flavor of different views on diverse topics of historical importance, as judged by the authors. Some of the quotations may be considered controversial, but they are intended to interest the reader in the personalities as well. In Part 2 of the special issues, readers will also be presented with a detailed historical 'Time-Line of photosynthesis research.'

Robin Hill is best known for the discovery of the Hill reaction, various cytochromes and the formulation of the Z-scheme of photosynthesis. He wrote the following words describing his earliest observations (see Hill, 1975, listed in the section 'List of personal perspectives').

> 'It was simple... use a hemoglobin with a known affinity to determine the amount of oxygen in solution.... So it would seem interesting to put some chloroplasts in with some myoglobin, but nothing happened in the light when I hoped to see some oxyhemoglobin appear. The only working hypothesis was a light reaction and a dark reaction. So I decided to add the dark reaction ... in the form of an aqueous extract of acetone leaves, very strong and soupy. It was a thrilling moment when I saw oxygen.'
>
> [Later] 'Scarisbrick and I found that chloroplasts had a cytochrome component... . So in 1939 Scarisbrick and I had a distant vision of something like a photosynthetic chain.'

Jack Myers is one of the pioneers of photosynthesis research in USA. Below, he describes laboratory equipment during the days of the Depression (see Myers, 1996, listed in the section 'List of personal perspectives' and Myers, this issue).

> 'I will now drag you through some of the gory details of research logistics in 1938. Luckily the glass blower had 2 Warburg manometers, repaired but unclaimed... A water bath came from one of the glass aquaria used in the laboratory study of water plants. In the department bone pile of cast off equipment, I found a thermoregulator and a slow speed motor with an eccentric to provide gentle shaking of flasks and manometers.'

C. Stacy French was one of the pioneers of absorption and action spectroscopy of photosynthetic systems. He wrote about the help he received from Robert Emerson (see French, 1979, listed in the section 'List of personal perspectives').

'In early 1928, a few lectures on photosynthesis by Robert Emerson, who had recently returned with a PhD from Otto Warburg's laboratory in Berlin, got me interested enough to take Emerson's course on photosynthesis the following year, and I have stayed with the subject ever since.'

'Through van Niel's course and his personal interest, I learned to grow and work with bacteria more efficiently. At Caltech I tried to measure their photosynthetic efficiency, but the excellent skiing in the mountains near Pasadena left little time for science, so that year was not productive. Bob Emerson was justifiably disgusted with my performance and we were barely on speaking terms for the academic year. Some years later we became friends again. However, in spite of my performance, he arranged for me to spend the next year in Berlin with Otto Warburg, which was what saved my scientific career.'

Birgit Vennesland was a great biochemist. Her remarks on the Nobel-laureate Otto Warburg are of significance in two areas (see Vennesland, 1981, listed in the section 'List of personal perspectives'). They reveal something of Warburg's method of thought and give the best guess as to why Warburg got low values for the quantum requirement for O_2 evolution. Some context is needed for the quotation. Earlier in this article, the biography 'Otto Warburg' by H.A. Krebs is cited, and it documents Warburg's great contributions to the early stages of the biochemical understanding of bioenergetics. Birgit Vennesland saw and understood these contributions in the 1930s at the beginning of her career. In the 1960s, long past Warburg's prime and Nobel glories, Warburg had become something of a villain in the photosynthesis community, apparently because of his imperious and abrasive ways. Vennesland, who had admired his early brilliance, wondered if this was entirely justified. She wrote the following words.

'A fact that particularly caught my fancy was the catalytic effect of CO_2 on the latter (Hill reaction). (Hans) Gaffron said Warburg's experiments were irreproducible. I decided to try it myself, and found that one could get quite good stimulation of the Hill reaction with CO_2 provided one picked the right conditions. This was the background for my initial visit to Warburg's laboratory in 1961.

A succession of visits ensued and culminated in my accepting a position as a director at Warburg's institute in West Berlin in 1968. There I began to work on nitrate reduction by *Chlorella*. There were complex reasons for the selection of this problem. One was that Warburg regarded nitrate as the "natural" Hill reagent. Later I gradually developed a suspicion that the reason that Warburg got such fantastically low values for the overall quantum requirement of photosynthesis was mainly that he had nitrate in the medium and excess carbohydrate in the cells. Better methods have long superseded those used by Warburg, and the problem of the quantum requirement is no longer cogent.'

'In my opinion, the apparent naivete in Warburg's theories was studied and intentional. The rules seemed to be: keep maximal simplicity and stick to minimal numbers. Make changes only when you must.'

'... He pondered a while and said "Of course, I have made mistakes – many of them. The only way to avoid making any mistakes is never to do anything at all. My biggest mistake was to get much too much involved in controversy. Never get involved in controversy. It's a waste of time. It isn't that controversy itself is wrong. No, it can be even stimulating. But controversy takes too much time and energy. That's what is wrong about it. I have wasted my time and energy in controversy, when I should have been going on doing new experiments..." '

Eventually Vennesland found herself locked out of her laboratory and dismissed from her position. To its great credit, the German government created a new institute for her, and she made several creditable contributions to biochemistry and inspired the careers of some postdoctoral fellows who are now highly regarded scientists. She did not speak harshly of Warburg and seemed to attribute her dismissal to the failing of Warburg in his old age.

Vennesland's article is full of thoughtful insights about science which are unrelated to Warburg. At the end of the section in her article called 'Photosynthesis and Otto Warburg,' Birgit Vennesland writes: 'The brightest sun casts the darkest shadow... I hope Warburg approves of the present manuscript as he did of an earlier one. After two versions, I finally got the hoped for letter: "Dear Dr Vennesland: Imprimatur! Warburg." '

Martin Kamen is one of the greatest figures in photosynthesis research (see Kamen, 1989, listed in the 'List of personal perspectives'; also see A.A. Benson, this issue). His discovery, with Sam Ruben, of ^{14}C was extremely important for all of biology and medicine. He describes the day ^{14}C was discovered as follows.

'As the account I wrote of the dramatic circumstances attending the birth of ^{14}C is buried in an obscure journal (Environ South West, Vol 448: 11, 1972), I exhume it to quote:

The weather in Berkeley during the winter months can be rugged. February of 1940 was no exception – as I was painfully aware while sitting in the controls of the ailing 37-inch cyclotron in the old Radiation Laboratory on the University campus. I had been there more or less continuously for three days and nights. As the operation drew to an end in the early hours of February 15, there was an extraordinary fanfare of driving rain on the tin roof, punctuated by the blasts of high voltage discharges in the bowels of the machine. Added to the general cacophony were occasional howls, screams and gutteral growls emanating from some recordings of French who-dunnits – a consequence of the activities of language classes which occasionally occupied the lab mezzanine in the upper reaches of the building. Bone-tired and red-eyed, I shut down the machine, rescued the remaining fragments of carbon target, which resembled so many bits of intensely radioactive bird gravel, and shambled over to the ramshackle hut in which Dr Samuel Ruben, my collaborator, worked and would be appearing shortly. These precious bits of discouraged graphite hopefully contained evidence for the existence of a long-lived radiocarbon form of carbon.

Indeed they did! Thus, the most valuable single tool in the nuclear armamentarium, ^{14}C, was revealed. It would contribute immeasurably to the study of life processes, as well as those of death (as elaborated in the ^{14}C dating technique invented by Willard C. Libby). .... In addition to its impact on all natural science, as well as archaeology, it provided proof [reference number deleted by the authors] through its anomously long half-life (5700 years), apparently unique among beta-ray emitters, ... '

Beatrice Sweeney was a pioneer of the biological clock in algae and plants (see Sweeney, 1987, listed in the 'List of personal perspectives'). However, she is one of the few who had talked with Robert Emerson on his discovery of the Enhancement Effect that led to the two light reaction–two photosystem scheme of oxygenic photosynthesis. She gave the following description.

'During the 1950s, I shared a laboratory at Scripps Institution of Oceanography with Francis Haxo. He was interested in the action spectra for photosynthesis in algae, including the red alga *Porphyridium*. The spectrum for this alga was peculiar in that those wavelengths absorbed by phycoerythrin were much more effective in photosynthesis than were the wavelengths absorbed by chlorophyll itself, yet it was known from fluorescence instruments that energy absorbed by the phycobilin pigments was transferred to chlorophyll. What was the matter with light directly absorbed by chlorophyll *a*? Was it for some reason ineffective? Lawrence Blinks had the answer almost in his hand when he showed that when red wavelengths of light were exchanged for green light of the same effectiveness at steady state there was for a short time a peak of higher oxygen evolution. The explanation, however, did not come from a study of red algae but from Robert Emerson's careful measurements of photosynthesis of the green alga *Chlorella* at the red end of the spectrum. He noted that at wavelengths longer than 680 nm the efficiency of photosynthesis decreased a little faster than did the absorption of the chlorophyll. With brilliant intuition, Emerson irradiated *Chlorella* with two wavelengths at once. How he conceived this experiment is beyond understanding. The result, as you know, was his discovery that two photosystems with different pigment composition must be excited at the same time. Emerson immediately understood the explanation for the inefficiency of light absorbed by chlorophyll in red algae, where phycoerythrin is the light harvesting pigment; this was in fact a much clearer case for the "enhancement," as Emerson called it. How do I know he had understood? Because I went to see Emerson at Urbana at this moment. He invited me to lunch with his family and after we had finished eating, he took me by the arm, led me into the living room, sat me down in a corner, drew up a chair, and started asking me questions about what we were doing at Scripps with the red algae – a very exciting experience for me, and a little scary.'

R. Clint Fuller is one of the pioneers of research on the biochemistry of anoxygenic photosynthetic bacteria (see Fuller, 1999, listed in the section 'List of personal perspecties'). It is well known that Melvin Calvin was a dynamic leader in the field of C-fixation by plants and algae, and received the Nobel Prize in 1961 for 'The Cycle.' Fuller presents his personal views and honors also the contributions of Andrew Benson and James A. Bassham to the path of carbon. He writes:

'I would like at this point to express a personal note that represents my own feeling and the recollections of many of the scientists who with me experienced the research years at the ORL (Old Radiation Laboratory) in Berkeley on photosynthesis. Calvin's autobiography, "Following the Trail of Light" (Calvin l992), represents an extremely singular view of the research carried on in the laboratory particularly in the area of the path of carbon for which he received the Nobel Prize. In all the l75 pages of his autobiography there is not one sign of Andy Benson or a mention of him. There is not one picture of Andy in a book that contains 5l photographs ranging from graduate students to the King of Sweden. There is not the citation of single paper with Benson as author or co-author in an extensive bibliography of over 150 references. Benson's name appears nowhere in the text and consequently is absent in the l2-page index. This appears to be an undeserved slight to a great scientist both personally and professionally who had contributed in a major way to all of Calvin's research and technology in the field of photosynthesis. Andy was a real leader in the laboratory both intellectually and experimentally. He should have been a partner in the Nobel Prize. Al Bassham's contributions are also understated, although he is pictured and cited through the text. I know that all of us who were colleagues at Berkeley agree that it was Andy and Al who contributed greatly to our own success in future endeavors. I have no idea what may have caused this unfortunate event, but I think that history should record that the contribution of Andy Benson is not properly recognized in Calvin's autobiography.'

André Jagendorf is one of the pioneers of plant biochemistry and provided the key experiment for Peter Mitchell's chemiosmotic theory (see Jagendorf, 1998, listed in the section 'List of personal perspectives'; and see Jagendorf, this issue). His words describe the discovery of light driven proton accumulation.

'I had heard Peter Mitchell speak about chemiosmosis at a bioenergetics meeting in Sweden. His words went into one of my ears and out the other, leaving me feeling annoyed they allowed such a ridiculous and incompetent speaker in. But Geoffrey (Hind) read Nature. ... During the discussion, it occurred to us that we might be able to see the pH in the medium rise during light driven electron flow. I stayed in the lab late the same evening and watched the needle of the pH meter rise in the light and fall in the dark. It was the first time I remembered an immediately successful test of a working hypothesis – it was fun.'

List of tributes

'He had been eight years on the project of extracting sunbeams out of cucumbers which were to be put into vials hermeticaly sealed, and let out to warm the air in raw, inclement summers. He told me, he did not doubt in eight years more that he should be able to supply the Governor's garden with sunshine at a reasonable rate.'

– Johnathan Swift, Gulliver's Travels, Book III, A Voyage to Laputa, 1726

Brown AH (ed) (1959) **Robert Emerson Memorial Issue**. Plant Physiol **34**: 179–361

Rabinowitch E (1959) **Robert Emerson**, obituary. Plant Physiol **34:** 179–184

Govindjee (ed) (1972) Photosynthesis. A special issue dedicated to **Eugene I Rabinowitch.** Biophys J **12**: 707–929

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

Fock H (1976) Professor Dr **Karl Egle** (1912–1975). Photosynthetica **10**: unnumbered pages [in German]

Vredenberg WJ (1981) Professor Dr **E.C. Wassink** (1904–1981). Photosynthetica **15**: 315–316

Krasnovski AA, Voltovski ID, Chaika MT and Fradkin LI (1985) **Alexander A Shlyk** (1928–1984). Photosynthetica **19**: 485–486

Amesz J, Hoff AJ and van Gorkom HJ (eds) (1986) Current topics in photosynthesis – double special issue dedicated to Professor **Louis NM Duysens** on the occasion of his retirement. Photosynth Res **9**: 1–283

Hungate RE (1986) **Cornelis Van Neil** (1897–1985). Photosynth Res **10**: 139–142

Govindjee, Barber J, Cramer WA, Goedheer JHC, Lavorel J, Marcelle R and Zilinskas B (eds) (1986) Excitation and electron transfer in photosynthesis – special issue dedicated to **Warren L Butler**. Photosynth Res **10**: 147–518

Bishop NI (1986) **Warren L Butler**, A tribute to a friend and fellow scientist (1925–1986). Photosynth Res **10**: 147–149

Šesták Z (1986) **Hiroshi Tamiya** (1903–1986). Photosynthetica **20**: 81

Papageorgiou GC (1987) **George Akoyunoglou** (1927–1986). Photosynth Res **11**: 283–286

Lutz M and Galmiche JM (1987) **Eugene Roux** (1924–1985). Photosynth Res **12**: 91–93

Garab G, Mustardy L and Demeter S (1987) **Agnes Faludi Dániel** (1929–1986). Photosynth Res **13**: 99–100

Blankenship R, Amesz J, Holten D and Jortner J (eds) (1989) Tunneling processes in photosynthesis – dedicated to **Donald DeVault**. Part 1: Photosynth Res **22**: 1–122; part 2: Photosynth Res **22**: 173–301

Parson WW (1989) **Don DeVault**. A tribute on the occasion of his retirement. Photosynth Res **22**: 11–13

Anderson J (1990) **David John Goodchild**. Photosynth Res **24**: 117–125

Siebert M (1991) **Don DeVault** (1915–1990). Photosynth Res **28**: 95–98

Bendall DS and Walker DA (1991) **Robert (Robin) Hill** (1899–1991). Photosynth Res **30**: 1–5 van Ginkel G and Goedheer JHC (1991) **Jan Bartolomeus Thomas** (1907–1991). Photosynth Res **30**: 65–69

Malkin S (1992) **Mordhay Avron** Obituary. Photosynth Res **31**:71–73

Nelson N (1992) **Efraim Racker** Obituary. Photosynth Res **31**: 165–166

Hangarter RP and Ort DR (1992) **Norman E Good** (1917–1992). Obituary. Photosynth Res **34**: 245–247

Rich PE (ed) (1992) **Robert Hill**. A special issue of perspectives and appreciations. Photosynth Res **34**: 319–387

Nickell G (1992) **Hugo P Kortschak**, the man, the scientist, the discoverer of C_4 photosynthesis. Photosynth Res **35**: 201–204

Champigny ML (1992) **Alexis Moyse** (1912–1991). Photosynthetica **26**: 161–162

Šesták Z (1992) **Mordhay Avron** (1931–1991). Photosynthetica **26**: 163–164

Crofts AR (1993) **Peter Mitchell** (1920–1992). Photosynth Res **35**: 1–4

Anderson MC (1993) **Robin Hill**, FRS: a Cambridge neighbor's appreciation of a great man and his hemispherical camera. Photosynthetica **28**: 321–332

Virgin H and Volotovskii ID (1993) **Tikhon N. Godnev** (1893-1982). Photosynthetica **29**: 163–165

Karapetyan N (1993) **A A Krasnovskii** (1913–1993). Photosynthetica **29**: 481–485

Karapetyan N (1993) **A A Krasnovsky** (1913–1993). Photosynth Res **38**: 1–3

Govindjee and Renger G (eds) (1993) **Bessel Kok**. An appreciation. Photosynth Res **38**: 211–302

Castenholz RW (1994) **William R. Sistrom** (1927–1993). Photosynth Res **42**: 167–168

Brody SS (1995) **Eugene Rabinowitch**. We remember Eugene. Photosynth Res **43**: 67–74

Malkin R (1995) **Daniel Arnon** (1910–1994). Photosynth Res **43**: 77–80

Melis A and Buchanan BB (eds) (1995) **Daniel Arnon**. A tribute. Photosynth Res **46**: 1–71

Olson JM, Ivanovsky RR and Fuller RC (1996) **Elena Kondratieva**. Obituary. Photosynth Res **47**: 203–205

Govindjee, Knox RS and Amesz J (eds) (1996) **William Arnold**. A tribute. Photosynth Res **48**: 1–46

Joliot P (1996) **René Wurmser**. Obituary. Photosynth Res **48**: 321–326

Fork DC (1996) **Charles Stacy French** (1907–1995). A tribute. Photosynth Res **49**: 91–101

Cogdell R (1996) **Philip Thornber** (1934–1996). Photosynth Res **50**: 1–3

Fork DC (1997) **Charles Stacy French** (1907–1995). Photosynthetica **33**: 1–6

Loach P (1997) **Melvin Calvin** (1911–1997). A remembrance of Melvin Calvin. Photosynth Res **54**: 1–3

Aflalo C, Baum H, Chipman DM, McCarty RE and Strotmann H (1997) **Noun Shavit** (1930–1997). Photosynth Res **54**: 165–167

Berg S (1998) **Seikichi Izawa** (1926–1997). Photosynth Res **58**: 1–4

Seibert M and Thurnhauer M (1999) **Therese Marie Cotton-Uphaus** (1939–1998). Photosynth Res **61**: 193–196

Rao KK (1999) **David Hall** (1935–1999). Photosynth Res **62**: 117–119

Fischer-Zeh K (2000) **Helmut Metzner** (1925–1999). Photosynth Res **63**: 191–194

Goyal A (2000) **Nathan Edward Tolbert** (1919–1998). Ed Tolbert and his love for science: a journey from sheep ranch continues. Photosynth Res **65**: 1–6

Garab G (2000) **Gabor Horvath** (1944–2000). Photosynth Res **65**: 103–105

Britt D, Sauer K and Yachandra VK (2000) **Melvin P Klein** (1921–2000). Remembering Melvin P Klein. Photosynth Res **65**: 201–206

Yocum C, Ferguson-Miller S and Blankenship R (2001) **Gerald T Babcock** (1946–2000). Obituary. Photosynth Res 68: 89–94

Frasch WD and Sayre RT (2002) Remembering **George Cheniae**, who never compromised his high standards of science. Photosynth Res 70: 245–247

List of historical papers

'Wherever dappled sun persists
Shy leaves work photosynthesis'

– John Updike, Maples in a Spruce Forest

Jack Myers (1974) Conceptual developments in photosynthesis, 1924–1974. Plant Physiol 54: 420–426

Govindjee (1986) EL Smith: the discovery of chlorophyll-protein complex during 1937–1941. Photosynth Res **16**: 291–292

Howard Gest (1991) The legacy of Hans Molisch (1856–1937). Photosynth Res **30**: 49–60

Höxtermann E (1992) Fundamental discoveries in the history of photosynthesis research. Photosynthetica **26**: 485–502

Hiroshi Huzisige and Bacon Ke (1993) Dynamics of the history of photosynthesis research. Photosynth Res **38**: 185–209

Jack Myers (1994) The 1932 experiments. Photosynth Res **40**: 303–310

Ball R, Richter M and Wild A (1994) What are quantasomes? The background of a nearly forgotten term. Photosynthetica **30**: 161–173

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

Howard Gest (1995) Erwin Esmarch's isolation of the first photosynthetic bacterium. Photosynth Res **46**: 473–478

Howard Gest (1997) A misplaced chapter in the history of photosynthesis research. The second publication (1796) on plant processes by Dr Jan Ingen-Housz, MD, discoverer of photosynthesis. Photosynth Res **53**: 65–72

Govindjee (1999) On the requirement of minimum number of quanta of light for the evolution of one mole of oxygen in photosynthesis. A historical note. Photosynth Res **59**: 249–254

Howard Gest (1999) Memoir of a 1949 railroad journey with photosynthetic bacteria. Photosynth Res **61**: 95–96

Govindjee (2000) Milestones in photosynthesis research. In Younis M, Pathre U and Mohanty P (eds) Probing Photosynthesis, pp 9–39. Taylor and Francis, London

Howard Gest (2000) Bicentenary homage to Jan Ingen-Housz, MD (1730–1799), pioneer of photosynthesis research. Photosynth Res **63**: 183–190

'You do not believe in what you can not see?
Oxygen? Electricity?
Magnetism? Weight?
Photosynthesis?'

– Dorothy Long, Seen and Unseen

List of Nobel Prizes

1915 – Willstätter, Richard Martin, Chemistry, for research on chlorophyll and other plant pigments. (See http://www.nobel.se/chemistry/laureates/1915/press.html and http://www.nobel.se/chemistry/laureates/1915)

1925 – Franck, James, Physics, for work (with Gustav Hertz) on electron-atom collisions; later he developed the principle known as the Franck-Condon principle which is often used in physical description of early events in photosynthesis. Unfortunately, many of Franck's theories on photosynthesis could not be experimentally supported. (See http://www.nobel.se/physics/laureates/1925/press.html) and his biography (http://www.nobel.se/physics/laureates/1925/franck-bio.html.)

1930 – Raman, Chandrasekhara Venkata, Physics, for work on spectroscopy and the effect that now bears his name, Raman spectroscopy, which is used by many photosynthesis researchers. (See http://www.nobel.se/physics/laureates/1930/press.html and http://www.nobel.se/physics/laureates/1930/raman-bio.html.)

1930 – Fischer, Hans, Chemistry, for work on porphyrins and blood and leaf pigments, particularly chlorophyll. (See http://www.nobel.se/chemistry/laureates/1930/press.html and http://www.nobel.se/chemistry/laureates/1930/fischer-bio.html.)

1931 – Warburg, Otto Heinrich, Physiology or Medicine, for work on respiration and the identification of the respiratory enzyme. (See http://www.nobel.se/medicine/laureates/1931/press.html and http://www.nobel.se/medicine/laureates/1931/warburg-bio.html.) Note that Warburg's insistence that the measured minimum quantum requirement for the evolution of one oxygen molecule in photosynthesis is 2.8–4 was proven to be wrong; it was shown to be 8–12, mainly by Robert Emerson and his associates.

1937 – Karrer, Paul, Chemistry, for work on carotenoids, flavins and vitamins (see http://www.nobel.se/chemistry/laureates/1937/press.html and http://www.nobel.se/chemistry/laureates/1937/karrer-bio.html). (For a historical perspective on 'Carotenoids in photosynthesis,' see http://www.life.uiuc.edu/govindjee/papers/CarFin1.html.)

1938 – Kuhn, Richard, Chemistry, for chemistry of carotenoids and vitamins. (See http://www.nobel.se/chemistry/laureates/1937/press.html and http://www.nobel.se/chemistry/laureates/1938/kuhn-bio.html.)

1959 – Ochoa, Severo, Physiology or Medicine, for work on enzymatic processes in biological oxidation and synthesis and the transfer of energy. (See http://www.nobel.se/medicine/laureates/1959/ochoa-bio.html.)

1961 – Calvin, Melvin, Chemistry, for work on carbon dioxide assimilation in photosynthesis, the carbon cycle, also named 'The Calvin Cycle' after him: (See http://www.nobel.se/chemistry/laureates//press.html and http://www.nobel.se/chemistry/laureates/1961/calvin-bio.html.) Andrew Benson and James Al Bassham contributed heavily to this work, and the cycle should be called 'Calvin–Benson–Bassham' cycle, in our opinion.

1965 – Woodward, Robert Burns, Chemistry, for the total synthesis of chlorophyll, vitamin B12 and other natural products. (See http://www.nobel.se/chemistry/laureates/1965/press.html and http://www.nobel.se/chemistry/laureates/1965/woodward-bio.html.)

1967 – Porter, George, Chemistry, for development of flash photolysis (along with Ronald Norrish). Lord George Porter later did work on aromatic molecules and chlorophyll, energy transfer in photosynthesis and primary photochemistry of photosynthesis in femtosecond-picosecond time scale. (See http://www.nobel.se/chemistry/laureates/1967/press.html and http://www.nobel.se/chemistry/laureates/1967/porter-bio.html.)

1978 – Mitchell, Peter D, Chemistry, won for work on biological energy transfer through the formulation of the chemiosmotic theory. (See http://www.nobel.se/chemistry/laureates/1978/press.html and http://www.nobel.se/chemistry/laureates/1978/mitchell-bio.html.)

1982 – Klug, Aaron, Chemistry, for development of crystallographic electron microscopy and structural elucidation of biologically important nucleic acid-protein complexes. (See http://www.nobel.se/chemistry/laureates/1982/press.html and http://www.nobel.se/chemistry/laureates/1982/klug-autobio.html.)

1987 – Lehn, Jean-Marie, Chemistry, for work on mimicking natural processes such as photosynthesis and for doing the groundwork for small synthetic structures called 'molecular devices.' (See http://www.nobel.se/chemistry/laureates/1987/press.html and http://www.nobel.se/chemistry/laureates/1987/lehn-autobio.html.)

1988 – Deisenhofer, Johann, **Huber, Robert**, and **Michel, Hartmut**, Chemistry, for determining the three-dimensional structure of bacterial reaction center using X-ray crystallography. (See http://www.nobel.se/chemistry/laureates/1988/press.html; http://www.nobel.se/chemistry/laureates/1988/deisenhofer-autobio.html; http://www.nobel.se/chemistry/laureates/1988/huber-autobio.html; and http://www.nobel.se/chemistry/laureates/1988/michel-autobio.html.)

1992 – Marcus, Rudolph, Chemistry, for his contributions to the theory of electron transfer reactions in chemical systems, including photosynthesis. (See http://www.nobel.se/chemistry/laureates/1992/press.html and http://www.nobel.se/chemistry/laureates/1992/marcus-autobio.html.)

1993 – Smith, Michael, Chemistry, for fundamental contributions to the establishment of oligonucleotide-based, site-directed mutagenesis and its development for protein studies is a common technique for studying photosynthetic organisms. (See http://www.nobel.se/chemistry/laureates/1993/press.html and http://www.nobel.se/chemistry/laureates/1993/smith-autobio.html.)

1997 – Boyer, Paul D and **Walker, John E**, Chemistry, for the elucidation of the enzymatic mechanism underlying the synthesis of adenosine triphosphate (ATP). (See http://www.nobel.se/chemistry/laureates/1997/press.html; http://www.nobel.se/chemistry/laureates/1997/boyer-autobio.html, and http://www.nobel.se/chemistry/laureates/1997/walker-autobio.html.) We also recommend Boyer PD (1998) ATP-synthase–past and future. Biochim Biophys Acta **1365**: 3–9. Here Boyer reflects on the accomplishments of individuals involved in research on ATP synthase during a prior 50-year period.

1999 – Zewail, H. Ahmed, Chemistry, for studies of the transition states of chemical reactions using femtosecond spectroscopy. (See http://www.nobel.se/chemistry/laureates/1999/press.html and http://www.nobel.se/chemistry/laureates/1999/zewail-autobio.html.)

List of Charles F. Kettering awardees

American Society of Plant Biology (formerly American Society of Plant Physiology) is responsible for selecting candidates for Charles F. Kettering Research Awards for Excellence in Photosynthesis Research. It is currently been awarded every two years. A list of all past awardees is given below. †Deceased.

1962: Robin **Hill**†; 1963: William **Arnold**; 1964: Lou NM **Duysens**; 1965: Hans **Gaffron**†; 1966: Cornelis **van Niel**†; 1967: Eugene **Rabinowitch**†; 1968: Martin **Kamen**†.

1970: Pierre **Joliot**; 1972: Jack Edgar **Myers**; 1976: Horst Tobias **Witt**; 1978: André T. **Jagendorf**.
1980: Hugo **Kortschak**†; M.D. **Hatch**; and C.R. **Slack**; 1984: Daniel I. **Arnon**†; 1986 William L. **Ogren**; 1988: Norman E. **Good**†.
1990: George M. **Cheniae**†; 1992: Antony **Crofts**; 1994: Richard E. **McCarty**; 1996: William A. **Cramer**; 1998: Bob B. **Buchanan**.
2000: Gerald T. **Babcock**†.

Acknowledgments

Thanks are due to Larry Orr for the web addresses. We thank David Walker, Howard Gest, Sabeeha Merchant and David Knaff for suggestions and comments. Authors are solely responsible for errors and incompleteness of this paper.