THE CAREERS AND CONTRIBUTIONS OF EUGENE RABINOWITCH

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INTRODUCTION

ALL WHO STUDIED IN the Photosynthesis Research Project at Urbana in the years between 1947 and 1968 will understand the sentiments of gratitude and affection which prompt these words of biography of and tribute to Eugene Rabinowitch. Many others in photosynthesis and related science throughout the world will share my feelings.

I am indebted to Eugene for some autobiographical notes which sketch his several lives in Europe and America, in science, journalism, and public affairs. Like all his writings, these notes combine good prose with penetrating insights. Unlike his scientific writings, they also include reminiscences dealing with war and revolution and encounters with the great scientists of the age when quantum physics and quantum chemistry were born. My sketches of Eugene's career before Urbana and of his activities in science and public affairs are based on his notes. Entirely mine are the portions about Eugene at Urbana and in Vermont. While he may scold me for some of my remarks, he will know that this task is undertaken out of the great admiration and respect I bear him as teacher and scientist, and out of the deep friendship and affection I have for him and his wife, Anya.

BEFORE URBANA

Eugene graduated from the private Prince Tenishev School in St. Petersburg a year before the Russian Revolution. In the fall of 1916, one of the first class of seven, he entered the new Chemistry Division of the Natural Sciences Faculty of the University of St. Petersburg. His education, however, was soon interrupted by the revolution, at first by political activism (first in the form of parading and patrolling the streets with the militia, and later as boss of 70 clerks in the census of voters and vote tabulation in the election of the Constituent Assembly), and, later, in the summer of 1918, by his family's move to the Ukraine to escape food shortage and civil disorders then sweeping Russia.

In Kiev, university study was commenced and cut short again when, upon the fall of the puppet government, the Russian Civil War spread into the Ukraine. At this time, in order to earn money, Eugene worked for a workers' cooperative founded by the still half-alive Mensheviks; he organized a reading room and, incidentally, erected an arch covered with posters across the main street for the May Day parade in Kiev. When the new Communist government began to mobilize former officers for the new Red Army, Eugene's older brother, Victor, an army lieutenant since the February revolution, went into hiding, and the family decided to move to the West. With an assortment of false documents and after hair-raising encounters with military police, the family proceeded to Minsk in Byelorussia, and, then, posing as returning Polish refugees, to Warsaw.

The family dwelt in Warsaw from the fall of 1920 until the following spring. Eugene's brother Victor died there of tuberculosis. For a third time, Eugene tried to study and was distracted, this time to serve as a journalist for a Russian language newspaper, for which he wrote short stories, editorials, and news stories mostly culled from the London *Times*. His analyses of the campaigns of the then raging Russian Civil War were authoritative enough for rumor to attribute them to a high officer of the Polish general staff. Eventually, in the face of dwindling finances and the editor's mysterious disappearance, the newspaper staff vented their true feelings in a final Christmas issue; immediately afterwards Polish censors closed the paper, citing as reason a poem of Eugene's construed to be critical of the Polish government's policies.

In the spring of 1921, the family moved to Berlin. There, at the university, Eugene once more began studying chemistry, and this time continued to completion. Except for Einstein's course on relativity and Schrödinger's on wave mechanics, and except for the Physics Colloquium at which Planck, von Laue, Schrödinger, Nernst, and Einstein occupied the front bench, Eugene attended no lectures but spent all his time in the year-long laboratories in qualitative analysis, quantitative analysis, and organic chemistry. After passing the *Verbandsexamen*, the special examination for the chemistry profession, he started doctoral studies with a major in chemistry and minors in mathematics, physics, and—as then required of all Ph.D.'s—philosophy. His thesis, prepared under Fritz Paneth (who together with the future Nobel laureate Georg von Hevesy had invented the radioisotope tracer method) dealt with the preparation and properties (including extreme toxicity to dogs) of gaseous metal hydrides, in particular, GeH_4 and SnH_4. Four articles in the *Berichte* of the German Chemical Society and a review of the properties of volatile metal hydrides in relation to position of the metal in the periodic table appeared in 1924–25 and were the first of about 150 scientific research papers he has published to date.

Since Eugene was a nationless bearer of a Nansen passport issued by the League of Nations, and since academic jobs were only open to German nationals, Paneth recommended him to the editor of *Abegg's Handbook of Inorganic Chemistry*. Eugene's talent for monographs was revealed when *Rare Gases*, a 500-page volume of the *Handbook*, was published in 1930 and enthusiastically reviewed in scientific journals. In the same year, Eugene, together with his friend, Erich Thilo (also a student of Paneth's and now member of the East German Academy of Sciences and director of its research institute on complex salts), published a treatise *Periodic Systems—History and Theory*, which included systematic calculations of stability of binary ionic compounds of all elements.

In 1929, Eugene accepted a research associateship with Hans Beutler in the Kaiser Wilhelm Institute for Physical Chemistry in Berlin-Dahlem. There, he undertook his first photochemical research: on mercury hydride and hydroxide formed by irradiating mercury vapor in the presence of hydrogen or water vapor. Fritz Haber, director of the Institute, recommended Eugene as assistant to James Franck, then a young physics professor at Göttingen. (Franck's work with Gustav Hertz on "critical potentials" of ionization and excitation of atoms had provided the first striking confirmation of Bohr's theory of atomic structure; its importance was recognized by a Nobel Prize in Physics in 1926.)

Franck's influence has been great on all who knew him. Eugene was particularly struck by Franck's humanity, humility, and his utter obsession with science. Franck had a unique ability to draw conclusions from contemplation of atoms and molecules, in which he envisaged not only their classical but also their quantum characteristics. The well-known "Franck-Condon principle" originated in such contemplation, strengthened by Condon's mathematical elaboration. The so-called Franck-Rabinowitch principle or "cage effect," pointing out that a pair of adjacent molecules in a liquid is enclosed in a "cage" of solvent molecules and must undergo a series of consecutive collisions before they can separate by diffusion, was one fruit of Eugene's association with Franck. Another was Eugene's infection with Franck's fascination for photosynthesis, the mystery of which Franck hoped might yield to investigators armed with knowledge of the physical laws of the interaction of light with atoms and molecules.

In 1932, Eugene married an old friend from Russia, Anya Maiersohn, who, under the stage name of Anna Morosoff, had played on the dramatic stage, first in Kiev, and later in traveling troupes all over Europe. Their twin sons, Alex and Victor, were born in 1934. Alex is now Professor of History at the University of Indiana in Bloomington; he specializes in Russian history and is the author of a monograph *Prelude to Revolution—June–July 1917*. Victor, a Ph.D. in zoology from the University of Wisconsin, with a specialization in animal behavior, is director of the program on science and development in the Office of the Foreign Secretary of the National Academy.

When Hitler's purge of Jews began in 1933, Eugene was an early victim. With his fellowship canceled and his continued income from literary work uncertain, he accepted an invitation from Niels Bohr to take up work in the experimental section of the Institute of Theoretical Physics at Copenhagen. There he began studying the photodissociation of halogen molecules. He developed for this purpose the "crossbeam method" in which a weak measuring beam is used to detect changes produced by a strong actinic beam, a method later widely used in the study of photochemical problems. This work, continued in London in 1934–36, established recombination rates of iodine and bromine atoms in the presence of various molecules acting as recombination catalysts.

From his year in Copenhagen, Eugene recalls not only the exciting colloquia and heady discussions at this leading intellectual center of atomic physics, but also parties held in Bohr's palatial villa behind the walls of—and amply provisioned by—the Karlsberg Brewery. (The Karlsberg Foundation supported much scientific and artistic activity in Denmark.) At one party honoring Heisenberg, Dirac, and Schrödinger on the occasion of their Nobel awards, Eugene remembers regal Margaret Bohr (a second mother to all physicists) stroking the hair of Wolfgang Pauli, whose personal life was troubled, and Dirac lost in contemplation of a ping-pong ball bouncing in a fountain.

In January of 1937, Eugene went to London, one of a number of displaced German scientists recruited by Imperial Chemical Industries to work in chemistry departments of several English universities, with the purpose of strengthening there the modern physical-chemical approach to chemical problems. Eugene joined University College in London, where Frederic G. Donnan was head of the chemical laboratories. There, with the late W. Clifford Wood, a young Canadian who had been his student at Göttingen, Eugene continued to study the kinetics of free atoms. He looks back on this period as his most productive, because of Cliff Wood's unique capacity to convert ideas into experiments. In association with another German expatriate, Joseph Weiss, later professor at the University of Durham, Eugene worked on the reversible photoreduction of the dye thionine by ferrous ions, and began studies of chlorophyll photochemistry. He discovered the reversible photo-oxidation of chlorophyll by ferric ions, a reaction which he felt (and still feels) may be related to chlorophyll's function as photocatalyst in photosynthesis.

In 1938, Imperial Chemical Industries ended its liberal policy of supporting academic scientists, and several English as well as numerous German refugee scientists suddenly lost their support. With aid from a British scientists' organization, the Academic Assistance Council, Eugene came to the United States, with invitations to lecture at Princeton (from Henry S. Taylor), Brown (from W. A. Noyes, Jr.), and Massachusetts Institute of Technology (from Arthur von Hippel). A sequence of lectures all over the country developed, and generated an appointment as Research Associate in Chemistry at MIT, for research under the Solar Energy Project supported by a grant from the Cabot Industries. Eugene remembers with gratitude the helpful and broad-minded attitude he found among American scientists and, in particular, the warm friendship of the pioneer biophysicist Selig Hecht of Columbia, whose deep concern with the happenings in Germany (and later, in all of Europe) contributed to his untimely death.

At MIT, the thionine–ferrous ion reaction was further investigated with the assistance of Leo Epstein (now at Argonne National Laboratory) and Ely Burstein (now professor at the University of Pennsylvania), in the hope that it might be developed into a practical method of solar energy utilization. It was found that when two thionine–ferrous ion half-cells were connected and one illuminated, the electrode in the illuminated solution became negative; evidently the electrode reacts faster with the photoreduced dye-leucodye couple than with the photooxidized ferrous-ferric couple. This Eugene called the "photogalvanic" effect. With Walter Stockmeier (now Professor of Chemistry at Dartmouth), the hydrolysis equilibria of ferric ions in chloride solutions were determined spectrophotometrically.

At this same time (1939–40), during summer vacations at Woods Hole, Mass., the first draft of Eugene's main piece of scientific writing, his 2000-page monograph *Photosynthesis and Related Processes* was composed. It was published by Interscience Publishers in three volumes, in 1945, 1951, and 1956.

In 1943, this work was interrupted when Eugene, at the request of his old advisor and friend, James Franck, then heading the Chemistry Division of the Metallurgical Laboratory of the Manhattan Project at Chicago, joined the Information Division of this laboratory, directed by Robert Mulliken. With the late physicist Hyman Goldsmith, Eugene began the preparation of a *Handbook of Uranium*. He also supervised the organization of information meetings, at which scientists from Chicago, Oak Ridge, and other project laboratories exchanged their experiences. Out of this work came the monograph *Uranium Chemistry—I. Element Uranium and its Binary Compounds*, prepared by Eugene in collaboration with Joseph Katz (now chief chemist at Argonne National Laboratory), and published by McGraw-Hill Book Company in 1951. A second volume covering uranyl compounds and other uranium salts was never completed, but a part of it dealing with the spectroscopic and photochemical properties of uranyl compounds, begun in Chicago, was brought up-to-date, in collaboration with R. Linn Belford of the Chemistry Department of the University of Illinois, and published by Pergamon Press, Inc., in 1964. Other volumes of the series were never completed because of dissolution of the project laboratories after the war.

URBANA

In 1947, Eugene joined Robert Emerson as codirector of the Photosynthesis Research Laboratory in the Botany Department at Urbana. There, for 21 years, until 1968, and in steady friendship and collaboration with Emerson until the latter's death in 1959, Eugene helped to build and sustain one of the most important centers in the world for education and research in photosynthesis.

There could not have been two more different men than Emerson and Rabinowitch. Emerson—tall, muscular, bony, and gaunt—was tense and uncompromising. While there was laughter and friendship in Emerson's lab, the presence of a strong-willed, fussy, demanding man was felt by all. In the early 50s, the Warburg-Emerson quantum yield controversy was at its most bitter, and Emerson's productivity and spirits were often low. While he was by nature kind and thoughtful, and usually in good humor, sometimes his face became pinched and frowning, his eyes stared out unseeing from behind his "granny glasses," and his remarks became perfunctory. A precise and exacting experimentalist, Emerson was a great scientist whose contributions established many of the fundamental facts on which modern photosynthetic theory is founded.

By contrast, Eugene is short, heavy, hands and face amply and loosely fleshed, careless in movements, his belt buckle buoyed up by a magnificent paunch. Always gentle and even-tempered, his leadership was unobtrusive and loose-reined and never intimidating. In his lab, intellectual life was accompanied by frequent hilarity, to which Earl Jacobs' banjo playing and Stanley Holt's progress reports on brewing experiments beneath his children's cribs contributed, and the hilarity was often infectiously sustained by Eugene's chuckling laugh which geysers up in a body designed for mirth.

While Emerson was busy at the lathe winding springs for his manometers or perched endlessly in darkness peering through cathetometers at reflections of dancing menisci, Eugene occupied a small, worn oak desk cramped in a corner of a small laboratory. His tools were paper and pencil, files of notes for Volume II, Part 2, shelves of reprints in blue loose-leaf binders, a battered brief case, and a nearby telephone. Emerson thought slowly; he would bite off a single important question and would chew it long and thoroughly. He was not especially good at communicating the importance of the questions which most intrigued him until his experimental work was well along and his thoughts almost fully formed. In contrast, Eugene's mind is very quick, free-associating, imaginative, and wide-ranging, and it brings to bear on every question a vast knowledge of physical science. Above all, as his monographs manifest, he is tremendously communicative, and with his agile mind and broad knowledge, he created windows for his students in all directions.

For a graduate student, the "Photosynthetic Unit at Urbana" (as Warburg once described the Emerson-Rabinowitch team) in the 50s was tremendously stimulating. During this period, Emerson worked on transient O_2 and CO_2 exchanges at the beginning of illumination of algae, and, later, on enhancement. Among Emerson's students, Tom Punnett studied soluble factors in the Hill reaction, Ted Cayle demonstrated wavelength-dependent patterns of $^{14}CO_2$ incorporated into amino acids, Marcia Brody extended Emerson's earlier quantum yield spectra of photosynthesis to the red alga *Porphyridium*, and Tanada, to a diatom; Govindjee, his wife Rajni, and Carl Cederstrand undertook studies of the enhancement effect and of algal absorption spectra, which were completed under Eugene after Emerson's death. Across the hall, among Eugene's students, H. Ehrmantraut did flashing-light experiments establishing the identity of the primary photochemical processes in photosynthesis and in the Hill reaction; Earl Jacobs and Stanley Holt first crystallized chlorophyll and discovered the attendant red shift of the absorption band; Paul

Latimer discovered selective scattering of light by plant cells near the chlorophyll absorption band and also measured in vivo fluorescence yields; Steve Brody made the first direct oscilloscopic measurements of the fluorescence lifetime of chlorophyll in vitro and in vivo; Jack Coleman and, later, Danny Rubinstein investigated light-dark difference spectra of plant cells; I studied energy transfer from protein to chromophore in phycocyanin and later the kinetics of the Krasnovsky reaction. Associated with us was Al Vatter who obtained the first high quality electron micrographs of chloroplasts; he also collaborated with Jacobs and Holt in micrography and X-ray scattering studies of crystalline chlorophyll.

Eugene brought a steady stream of postdoctoral associates to Urbana. The late Clendenning, one of the first, worked with Ehrmantraut on the flashing light experiments. Lou Duysens introduced difference spectrophotometry at Urbana. Jean Lavorel made elegant studies of fluorescence quenching in concentrated chlorophyll and fluoroescein solution. Stanley Ainsworth investigated the kinetics of the thionine-iron reaction. There were many visitors; among them were James Franck, Hans Gaffron, Hiroshi Tamiya, Martin Gibbs, and Bessel Kok. Robin Hill showed us how to demonstrate the presence of cytochrome *f* in algae with a microscope and a hand spectroscope. Allan Brown described his mass spectrometer work on respiration of algae in light and in darkness. Stacy French brought early results on fluorescence and fluorescence excitation spectra of plants. Martin Kamen, Barry Commoner, and George Wald also visited; I remember the latter hotly defending Warburg's views on the quantum yield of photosynthesis, to the considerable consternation of Emerson and Eugene.

Our purview was extended further by trips of the whole lab (sometimes in Emerson's 1930-vintage Lincoln touring car) to Chicago for a day's discussion with Franck, Gaffron, and their associates. I remember an early talk of Fager's on $^{14}CO_2$ incorporation into phosphoglyceric acid, another by Mehler on what became known as the "Mehler effect," and an intriguing talk by Brackett on light-induced changes in respiration. We first met Jerome Rosenberg, F. L. Allen, and Norman Bishop at these Chicago meetings. In the spring of 1953, the Chicago group paid a reciprocal visit to Urbana. In the evening, Eugene and Anya held a party of truly Russian munificence. There was beer in the keg, glittering mountains of hors d'oeuvres, and vodka made by Anya from grain alcohol, with glycerine as lubricant, and flavored with *zubrovka*, a special Polish herb. On this occasion, Eugene's vodka and Hans Gaffron's liberal doses of peppermint schnapps had the happy effect of sealing the betrothal of my wife and me.

In the early 50s Emerson and Eugene both worked hard, and not without opposition from the established departments, to introduce a biophysics doctoral program at the University of Illinois. The program was first called "Physical Chemical Biology" and included, among others, a course in photobiology taught jointly by them. Emerson also taught a laboratory course on algal photosynthesis and manometric measurements. Later, under the sponsorship of the Department of Physiology, a revised curriculum "Biophysics" was introduced; in this, Eugene's and Professor William H. Johnson's course "Foundations of Biophysics" was a general requirement. In 1969, growing out of their experiences in teaching photosynthesis, Eugene and Govindjee published a text, *Photosynthesis*, suitable for beginning students.

Despite Emerson's death in 1959, and growing competition from new photosynthesis research centers in the United States and abroad, the Urbana lab remained one of the most productive centers of research in this field. In 1959, to help fill the gap left by Emerson, Jan B. Thomas (Director of the Biophysical Laboratory at Utrecht) came as visiting professor for one year. Soon after, Govindjee finished his Ph.D. thesis and was appointed to the Botany Faculty. At the same time, Rajni Govindjee completed her Ph.D. and she has since been a steady member of the group. In 1964, Christiaan Sybesma came from Leyden and joined the Biophysics Faculty. Together Govindjee and Sybesma and their graduate students formed a "second generation" in photosynthesis education and research at Urbana.

Up to 1968 at Urbana, and thereafter at Albany, Eugene continued to attract an uninterrupted stream of postdoctoral associates. Several worked to extend knowledge of the thionine-iron reaction. K. G. Mathai showed that separation of the photoproducts (and conservation of energy) could be achieved by performing the reaction in an ether-water emulsion; some of the stored energy could be recovered electrically by using separated phases in half-cells joined with a salt bridge. D. Frąckowiak and G. Singhal studied the homologous reaction with other thiazine dyes, and V. Srinavasan showed that complex cobaltous ions can be substituted for ferrous ion, permitting the reaction to proceed in neutral rather than acid solutions.

Other postdoctoral associates extended the oscilloscopic measurements of fluorescence decay and of energy transfer which Steve Brody had begun. Giti Tomita refined the methodology and obtained improved measurements of transfer time, between phycobilins and chlorophyll in red algae. N. R. Murty studied energy transfer in photosynthetic pigments. G. Singhal remeasured the decay of chlorophyll fluorescence and corrected an earlier systematic error which had been taken to indicate two components with different lifetimes. Ashok Ghosh began, and Singhal, J. Hevesi, and Srinavasan continued, a study of energy transfer from thionine to methylene blue when both pigments are absorbed on colloidal micelles. Richard Bauer measured the efficiency of transfer from chlorophyll *b* to chlorophyll *a*.

Still others were concerned with the analysis of absorption spectra. Laszlo and Elizabeth Szalay, and J. Hevesi and Patrick Williams worked on the theoretical relation between the absorption and fluorescence spectra of chlorophyll. Mrinmoye Das studied the "sieve effect," i.e., the "flattening" of absorption spectra caused by concentration of pigments in chloroplasts. Vitaly Sineshchokov investigated the spectra of chlorophyll monolayers.

In all these investigations, as well as in the posthumous publication and interpretation of Emerson's enhancement experiments, and in his participation in the education of the "second-generation" students of Govindjee and Sybesma, Eugene's leadership bore continuing fruit. His physical approaches, learned from Franck, were transmitted to his students and can now be traced to his students' students. The descent of the physical approach is seen, for example, in the physical studies of Govindjee's students Ted Mar, John Munday, George Papageorgiou, and Fred Cho, and the physical and kinetic studies of my students Bruce Love, Richard Wang, and Steven Lien. Eugene's influence must have also affected research outside the Urbana laboratories, particularly through the intermediary of *Photosynthesis*, which became an indispensable source of information and guidance for workers in the field throughout the world.

SCIENCE AND SOCIETY

Besides being a scientist, Eugene has displayed, from as early as his days as a journalist in Warsaw and in Berlin, an alter ego, as analyst and commentator on political developments and international relations. This talent found renewed motivation and direction in the "atomic scientist movement" that began at the end of World War II. Many Manhattan Project scientists, believing that they had contributed to a technological revolution which could destroy mankind if another major war were permitted to occur, felt an obligation to convince the public and political leadership that nuclear weapons must never be used and should be eliminated from national arsenals by international agreements. The first manifestation of this movement, in June 1945, was the "Franck Report" addressed to the Secretary of War (at that time, Henry Stimson). The report, which Eugene wrote from Franck's notes, scribbled in meetings with Leo Szilard, Glenn Seaborg, and other members of the "Franck Committee," recommended that nuclear strikes against Japan be avoided, or at least delayed, until other means to force Japan's capitulation were exhausted, such as demonstration of an atomic bomb before international observers, including Japanese. This course was recommended not only for reasons of humanity, but also out of concern for the effect which introduction of atomic bombs as legitimate weapons of war would have on future American security.

Subsequently, the concern of the atomic scientists led to the establishment of the *Bulletin of Atomic Scientists—A Magazine for Science and World Affairs* (started December 15, 1945, by Eugene and the late Hyman Goldsmith, a physicist also then working in the Information Division of the Metallurgical Laboratory), of the Federation of American Scientists in 1945, of the International Pugwash Movement in 1957 (a series of conferences on science and world affairs which Eugene helped found and has participated in since), and of the Council for the Livable World originated more recently by Leo Szilard.

Since 1945, Eugene has served steadily as the editor of the *Bulletin*, in which over a hundred of his articles have appeared, and as American member of the Continuing Committee of the Pugwash Conferences, of which the 22nd is to meet in Oxford, England, in 1972. Eugene was President of the movement in 1970, when the annual conference met in Lake Geneva, Wisc. His recent contributions to the Pugwash Conferences have stressed his conviction that even outlawing or destroying atomic weaponry by international agreement will not protect mankind from self-destruction, because if major war is ever permitted to break out, these weapons will be rebuilt and used. Rather, what is needed is an end to the institution of war as an acceptable means of settling international disputes. Eugene argues that the scientific revolution has given all nations the capacity to multiply their wealth by the use of science and technology, without increasing their territory or their command over raw material supplies. Therefore, the closed societies which evolved as means to acquire and hold territory and resources for the benefit of their members, and warfare which these societies have employed throughout history to settle their differences, have become not only prohibitively destructive, but also rationally unjustifiable.

Two collections of Eugene's articles have appeared: *Dawn of a New Age* (University of Chicago Press, 1964) and *The Atomic Age* (Basic Books, Inc., Publishers, 1963); the latter is a general anthology of *Bulletin* articles by different authors, edited by Eugene and his late friend Professor Morton Grodzins of Chicago. *Dawn of a New Age* opens with a remarkably accurate forecast of the course and outcome of the Second World War (written at its outbreak in 1939), and ends with a prediction of developments in the next quarter of a century.

Eugene's leadership in this new field of "science and society" has been recognized by appointment as Visiting Professor of Political Science at the University of Chicago in 1963, the invitation, in 1968, to the State University of New York at Albany to help establish a Center for the Study of Science and Society, and the award of the Kalinga prize by UNESCO in 1964. A new book is promised on the scientific revolution and its implications. It will stress the need of mankind to begin guiding rationally its own evolution if it is to survive in a scientific age, and it will develop the thesis that competition, whether between individuals or between societies, is becoming an ineffective means of guaranteeing human survival in a world where individuals and societies are increasingly interdependent.

VERMONT

Summers in Urbana leave something to be desired; heat, humidity, and pollen afflict the body, and some souls—even some who appreciate photosynthesis most—fail to be restored by vistas of maize, oats, and soybeans. For many years, Eugene and Anya have summered high on a hill in southern Vermont. There, on the steeply sloping, rocky soil of an old farm, they relax in bucolic pastoralism. Cucumber, dill, pumpkins, and tomatoes grow in the old chicken yard; what they call "*prostokwasha*" (but is really clabber) is cultured in the kitchen, and spring water gurgles into a great cistern in the cellar. The barn, a little improved after earlier uses, is inhabited by wasps and Russian expatriates who come to write, reminisce, and speak the mother tongue. With Anya in her kerchief and apron at the cast-iron wood range or in the garden, and Eugene in hip boots wading through wet bracken to inspect his springs or orchard, and with Russian echoing in the hills, an American envisions himself transported to the Russian countryside.

Summer residents in Vermont have two preoccupations. One is to improve the property. With Eugene, this took the form of designing and building a high and roomy "chalet" (his first architectural effort since the triumphal arch across Kiev's main street) for use by the Rabinowitch sons, Victor and Alex, and their families, at a spot with an especially sweeping view of the Green Mountains. Adequate water being always a problem on Vermont hills, the student of James Franck and exponent of a rational society tolerated his carpenter inviting a local water-witcher, who, after surveying with forked branch, recommended drilling at a low wet spot on the hillside. There, an abundant spring was found, which with other, lesser sources higher up, gave the property the long-sought name "Five Springs."

The other summer occupation is attending auctions, and from these Eugene and Anya returned with many treasures. At one in Putney, Eugene was a determined bidder and went home jubilantly with a slightly used bathroom scale. Those who have had the good fortune to visit the Rabinowitches in Vermont—and many photosynthesists and others have—have been treated to the wit and hilarity of charming people at their most relaxed and playful.

CONCLUSIONS

Eugene's career as researcher, teacher, and leader of a major laboratory is marked by top intellectual quality and high productivity; his long and steady success in these capacities surpasses that of many of us and earns our acclaim. It is in three other ways, however, that his contributions have been greatest and most nearly unique. The first is the influence he had in promoting physical and physical-chemical approaches in photosynthesis research. The rapid progress in the subject since World War II, both in regard to experimental establishment of fact and to elaboration of theory, is the result of simultaneous biochemical, physiological, and physical approaches. While others, especially James Franck, Robert Livingston, and William Arnold, and later Lou Duysens and Rod Clayton, have championed the same cause, it has been Eugene more than any other who has steadily brought physical scientists and students to the subject, and who, by his publications and discussions at meetings, has most effectively insisted that the physical processes of photosynthesis be studied and that new theory to account for biochemical and physiological advances be consistent with physical knowledge and principles.

The second of Eugene's contributions is as monographer and encyclopedist. His treatises, the *Rare Gases*, the *Periodic System*, the two volumes on *Uranium Chemistry*, the three volumes of *Photosynthesis and Related Processes*, and the recent

(1969), smaller *Photosynthesis* prepared in collaboration with Govindjee, constitute, in their grand comprehensiveness and keen analysis, unique records of the state of knowledge and understanding of several fields. These works establish Eugene among a small number of scientists, such as Samuel Glasstone in physical chemistry and George Evelyn Hutchinson in limnology, whose remarkable talents for organization of knowledge, in combination with wide interests, understanding, and sharp critical powers, have fitted them for monumental summations.

Lastly, one must acknowledge and pay special tribute to that unique combination of wide-spanning talent, energy, and communicativeness, that have, in effect, given Eugene several different, productive careers. As a researcher, teacher, leader of an important laboratory, and major influence in the development of photosynthetic knowledge, he deserves admiration in one career. As a monographer of unusual scope, quality, and productivity, he has met the requirements of a second. To these must be added a third successful career as journalist, editor, student, teacher, and major spokesman on the subject of science, society, and public affairs.

EPILOGUE

To end, I must mention Eugene's authorship of a slender volume of poems (in Russian). The last stanza of the most recent of them runs (in his own translation):

> "The game is up, for much too long I tarried;
> My thoughts were scattered and my deeds were tame.
> No earthly trace behind, I bring the loads I've carried
> Back into night and nothing whence I came."

"Scattered thought" and "tame deeds" without "earthly trace" are poor words to sum up Eugene's life. We trust that sunlight will dispel the photochemist's nights of gloom and verse for many years to come, and that he will "tarry" long and productively in his "retirement."

Received for publication 17 December 1971.