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HIROSHI TAMIYA
1903–1984

A Biographical Memoir by

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BY ANDREW A. BENSON

HIROSHI TAMIYA'S PILGRIMAGE IN BIOLOGY

HIROSHI TAMIYA WAS BORN in 1903 into a family of medical doctors, having been, since the sixteenth century, poets and physicians attending feudal lords in the Koochi (Tosa) Prefecture on the island of Shikoku. His father, Koreharu, a learned man, had received his western medical instruction from a Dutchman, Dr. C. Elmerence, one of the few knowledgeable sources at that time. Hiroshi's brother Takeo, 14 years his senior, was a professor emeritus of the University of Tokyo and president of the National Cancer Center. Their mother's ancestors could be traced back to the twelfth century as feudal lords in Iyo (Ehime Prefecture), who were defeated by Toyotomi, builder of the Osaka castle. They escaped to Tosa to become a samurai family. The young Hiroshi received much stimulus from Takeo as well as impetus toward the life of a scientist. As it was, and still is, the families of medical doctors want their sons to become medical men. Hiroshi Tamiya began his pilgrimage in science to become a medical man. Daunted, however, by the shock of seeing anatomical dissection of human bodies in the Faculty of Medicine, he gave up the study of medicine against the wishes of his late father and selected the course of botany (although he had no interest in the study of higher plants). Plant taxonomy and morphology bored him; he concentrated more on music, playing the cello, and preferred the study of physiological processes and functions. From his childhood he was interested in microorganisms or any cells that he could observe with his father's German-made microscope. This became the inspiration for him to study microbiology and cell physiology

An unexpected fortune awaited Tamiya in his second year at the Department of Botany of Tokyo University. It was the opportunity to attend the lectures of Professor Keita Shibata, then the most outstanding plant physiologist in Japan. There was further timely good fortune. World War I ended in 1918, and there appeared, mainly from England and Germany, a stream of papers and books by leading scientists dealing with cell physiology and biochemistry. After his graduation in 1926, by virtue of his teacher's thoughtful recommendation, he was accepted as a member of the Tokugawa Institute for Biological Research, founded by Marquis Yoshitake Tokugawa. Apart from his ordinary university duties, he was able to spend much of his energy and time working freely in this relatively richly equipped and generously supported laboratory. After some preliminary physiochemical work, he decided to investigate phenomena that are fundamental and common to all living organisms, such as growth and cell proliferation, respiration, and energy metabolism. Thus, before and during the so-called "Chinese Incidents" followed by the Pacific war, he published a series of studies on respiration and energy metabolism during the growth of cells, using the mold *Aspergillus oryzae* as experimental material. His originality became apparent with his unique way of devising methods and apparatus adapted to gain his own experimental objectives. He constructed a special calorimeter combined with a respirometer with which he measured the heat produced and oxygen consumed during the growth of the fungus and demonstrated that the total heat liberated was greater than the heat produced by respiration alone. He concluded that the respiratory process consisted of two parts, one quantitatively related to the growth process and the other related to maintenance of the preexisting cells. It was just at the time when heme-containing respiratory enzymes were discovered by Otto Warburg in Berlin and cytochromes were found in various aerobic cells by D. Keilin in England.

PARIS, 1934

Hiroshi and Nobuko Tamiya lived in Paris during 1934. In the Institut du Biologie Physico-Chemique, of which René Wurmser was the director of the Départément Biophysique, Hiroshi pursued the subject of interrelations of oxidation and reduction pathways in bacteria and microalgae. He translated Wurmser's "Les potentials d'oxido-réduction" into Japanese. Nobuko earned the Diplom de Cordon Bleu. In the difficult years after the war when Hiroshi's salary, as a professor in the Botany Department of the University of Tokyo, was the equivalent of $50 a month, Nobuko became the major breadwinner for their little family by scheduling French cooking classes for 30 to 50 young ladies in their home, where her kitchen facilities could accommodate 6 to 10 students each day of the week.

Hiroshi's enthusiasm for the concepts of Heinrich Wieland in Freiburg and René Wurmser in Paris clearly influenced the direction of his research. From the period of his cytochrome studies (1928-1939) his attention moved from the heat of combustion balance sheet to the mechanisms underlying the oxidations and reductions involved. He applied reaction kinetics, his unique way of approaching a problem. Using a single-hand spectroscope, he measured kinetics of the observed changes in bacterial species and noted their differing patterns. This discovery was later followed by the works of his admired friend Martin Kamen: isolation and structure determination of bacterial cytochromes. His ardent admiration for Professor Otto Warburg remained an unalterable model for his spirit as a scientist. Warburg's development of the study of photosynthesis influenced him, and in 1941 Tamiya began his own investigations of photosynthesis. He applied inhibitors of photosynthesis as a rigorous quantitative tool. Six years earlier Constance Hartt in Hawaii had independently initiated use of such tools in deducing the nature of the compounds involved in photosynthesis of sucrose in the sugar cane leaf (Benson et al., in preparation).

Tamiya's 1942 paper revealed little change in approach to consideration of the energetic relation between growth and respiration applied in his 1935 paper in *Actualitiés Scientifiques et Industrielles.* For comparison, the report on generation and metabolic utilization of phosphate bond energy in the previous volume of F. Lipmann (1941) applied superbly the thermodynamic relationship, $\Delta F = \Delta H - T \Delta S$.

René Wurmser published the volume *Oxydations et Réductions* in 1930, wherein he referred to the classic 1923 work of Lewis and Randall, *Thermodynamics.* Wurmser's book utilized its concepts of atomic structure and thermodynamic energy expressed in the three laws of thermodynamics. It appears that Tamiya's 1935 and 1942 publications did not recognize the importance of thermodynamics in the study of biochemical transformations.

FLASHING LIGHT EXPERIMENTS

Tamiya continued his investigation of the mechanism of photosynthesis using *Chlorella,* the alga used by Otto Warburg. The most extensive study involved measuring photosynthesis under intermittent light (1948). Discrimination between the "light" and the "dark" steps of photosynthesis was carried out using "pre-illumination" techniques. These permitted elucidation of the modes of inhibition of photosynthesis by several "poisonous" substances, including oxygen gas. (Discovered by Warburg, 1919; confirmed by Wassink et al., 1938, by Tamiya and Husizige, 1949, and by Calvin and Benson, 1948).

Since Warburg's work, it had been shown repeatedly that the dark reaction of photosynthesis shows a characteristic temperature-rate relationship not in accordance with the well-known Arrhenius theorem. It had been inferred that the reaction involves two consecutive steps. Temperatures, pH, and pO_2 effects were used to identify sites of inhibition by inhibitors in each of the two steps (1948).

OXYGEN INHIBITION OF PHOTOSYNTHESIS

Tamiya's masterful application of the kinetics of photosynthesis had delineated the three processes in "the dark reaction." The 1941 kinetics study of the dark reactions of photosynthesis led to a major publication in 1949 by Tamiya and Huzisige. Here they clarified the inhibition of photosynthetic productivity by oxygen at high light intensity. They postulated that oxygen attacks the primary step in one of two dark reaction components not inhibited by cyanide, the mechanism in which carbon dioxide is combined with a certain component in the cell. They referred to this as the "Ruben enzyme." It led to conclusions regarding the binding of CO_2 by a receptor compound. This was fortunate since Tamiya's initial acceptance of Ruben and Kamen's premise of reversibility of $CO_2 + RH \rightarrow RCOOH$ was actually misleading. The Rubisco-catalyzed reaction is irreversible (Cleland et al., 1998; Benson and Cleaves, unpublished).

Thus, Tamiya and Huzisige presented evidence for a Rubisco-type reaction involving CO_2 and O_2 fixation. Tamiya wrote, "It is our great regret that fate did not allow us to pursue this experiment owing to the unfortunate destruction of cyclotrons in our country." This conclusion led Hiroshi and Nobuko Tamiya to travel to Berkeley in 1952 to test it with an experiment with $C^{14}O_2$ in the old Radiation Laboratory. Thus, a plan conceived in 1940, for experiments with $C^{11}O_2$ to be produced by the Nishina cyclotron in Tokyo, was finally executed in this author's laboratory a few feet from the original 37-inch cyclotron of Ernest O. Lawrence. That was one year after ribulose diphosphate was identified (Benson, 1951) and found to be susceptible to oxidation by oxygen in vitro. The results corroborated the previously observed glycolate production by photosynthesis with $C^{14}O_2$ in the presence of air (oxygen).

TOWARD A RENEWAL OF JAPANESE SCIENCE

The problem of reorganizing science for the postwar world was universal. German science had collapsed under Nazi control and many scientists had fled. Japanese science, dominated by German influence, was in disarray. U.S. science was concerned with the relation between science and government and the questions of civilian control of atomic energy and the future of basic research. Maintaining government support for the scientific enterprise and keeping scientific research insulated from government control and protected from politics were incompatible goals. Vannevar Bush's report, "Science—The Endless Frontier," clearly stated the ideal.

MIT physicist Harry Kelly was assigned by the General Headquarters, Supreme Command of Allied Powers, under General MacArthur to its Economic and Scientific Section (Yoshikawa and Kauffman, 1994; Dees, 1997), which a few weeks before had been embroiled in the embarrassment of the destruction of the cyclotrons of Professor Nishina (laboratory of Niels Bohr) and Ryokichi Sagane (who had worked with Ernest Lawrence in Berkeley), deeply embittering

Japanese scientists and public. Kelly deftly overcame local resentment to earn the respect of chemistry professor Juro Horiuchi, who recommended he meet his close friend Hiroshi Tamiya. They met with Kelly in the spring of 1946, and Tamiya advocated a carefully planned process, one that began with an open forum of scientists from all fields to discuss aspects of the Japanese scientific research system and specific problems affecting each discipline. The necessary first step, according to Tamiya, would be the organization of a conference to launch the initiative. “You’re right,” exclaimed Kelly. “So you must organize the conference. I leave everything to you.” Intimidated at first, Tamiya later recalled that Kelly induced him to participate by offering him one rare U.S. cigarette after another. Finally, Kelly’s “Three Musketeers” provided the basis for effective interactions with Japanese scientists and their government. At first there were problems. Kelly requested that Tamiya provide the names of 20 Japanese scholars who were active in the natural sciences to him within two weeks. Tamiya was offended at Kelly’s impatience. “Please wait a minute,” he told the American. “Suppose that Japan had won the war and I was assigned to Washington to sit as you are sitting here today. What would you do?” Kelly was upset by what he considered a brash response. Years later he told Tamiya, “I was truly vexed by your ‘suppose Japan had won the war’ comment. But later, you gave me food for thought. It made me like you and trust you.”

Intent upon building lasting support, Tamiya proceeded cautiously. He organized a forum for Japanese scholars, primarily scientists to discuss representation in exchanges with the occupation forces. His creation of a liaison group provided an opportunity to effect permanent change in the organization of Japanese science. Kelly worked behind the scenes with Tamiya. He suggested that Tamiya write a letter from the Japan Association of Science Liaison to the U.S. National Research Council. The purpose of the letter would be to explain the situation in Japan and ask for NRC's help. "I think American scientists know nothing of the problems except what is in the papers. I will go back to the NRC and ask them if they will help." Tamiya agreed, but only after intense discussion about which group represented Japanese science and its reorganization. They agreed that reorganization was necessary and could be carried out, even though the task was more difficult from the Japanese perspective than from Kelly's.

The next day Tamiya delivered to Kelly the draft of a letter addressed to the National Research Council. Signed by Kaya, Sagane, Tamiya, and 17 other members of the Japan Association for Science Liaison, the letter was sent on July 11. Tamiya spelled out the functions and mission of the association, including its desire to contribute to the rehabilitation of Japan and to improve its traditional systems for the organization of science. He pointed to the scientists' dissatisfaction with "the past impotency and clumsiness of our government authorities in utilizing and respecting scientific talents" as well as to the shortcomings of academic scientists' penchant for what he called "academic fogydom." He spelled out the deplorable material conditions under which the Japanese scientific community was struggling to resuscitate its research efforts and then to focus those efforts on improving the civilian standard of living. The letter sharply criticized Japan's traditional power structure, condemned its "thoughtless and erroneous war" into which these powers had led the nation, and expressed aspirations for a "new Japan which will contribute to the World's Peace and Humanity." Tamiya's letter reflected the views of many progressive intellectuals who believed that in the new democratic postwar order, Japan would demonstrate that a modern industrial nation could exist without arming itself. This view had been given expression in the country's newly adopted constitution, which renounced all war-making activity. By the middle of 1946 Kelly's mission had clearly changed from surveillance to mediation and friendly guidance.

Kelly succeeded in interesting Frank Jewett, president of the U.S. National Academy of Sciences, in organizing a committee of prestigious scientists and engineers to review the Japanese situation. Jewett obtained funding from the Rockefeller Foundation for a six-week mission and recruited six academy members who were experienced in dealing with "people and problems at top level": Roger Adams, head of the chemistry department at the University of Illinois, leader of the group; W. V. Houston, president of Rice Institute; W. D. Coolidge, director emeritus of research at General Electric; W. J. Robbins, director of the New York Botanical Garden; Royal Wasson Sorenson, head of the department of electrical engineering at the California Institute of Technology and past president of the American Institute of Electrical Engineers (honored by the Japanese Institute of Electrical Engineers who designated Professor Sorensen an honorary member); and Merrill Bennett, executive director of the Food Research Institute at Stanford University. Bennett, an economist representing the social sciences, wrote the group's final report. They arrived in Tokyo on July 19, 1947, and stayed until August 28, adding their goodwill and prestige to the reorganization effort. In their report to General MacArthur they advocated a program of reorganizing science in its broadest sense, including the social as well as the natural sciences. Kelly later made arrangements for a second science advisory group to be appointed by the National Academy of Sciences. The three-week mission was headed by Detlev W. Bronk, National Research Council chair and president-elect of Johns Hopkins University. He was accompanied by Nobel Prize-winning physicist I. I. Rabi; organic chemist Roger Adams; metallurgist Zay Jeffries, a vice-president of General Electric and manager of that company's chemical division; and Elvin C. Stakman, chief of the division of plant pathology and botany at the University of Minnesota and president-elect of the American Association for the Advancement of Science. The mission left for Tokyo on November 2, 1948, and departed Japan on December 20.

Fluent in English and broadly educated in European science as well as in Japanese science and politics, Tamiya served in a crucial position as "native guide" for both committees. His sense of humor and ebullient enthusiasm instilled respect and appreciation in both groups. As a host he was also a delightful and knowledgeable entertainer. He was a skilled magician and a gifted caricaturist, delighting each member with his drawings.[1] Fortunately most of these have been preserved, though many were given to his guests. All members expressed their appreciation of Tamiya's culture, science, and hospitality.

VANNEVAR BUSH

Hiroshi Tamiya did not meet Vannevar Bush in Japan, but he was familiar with his status in the U.S. war effort. "However, I had the honor of meeting him in 1952 in his office in Washington when I was invited from the Carnegie Institution (Division of Plant Biology at Stanford) as a guest investigator. I was deeply impressed by his erudition and personality which was reminiscent of our Samurai. . . . When I told about my admiration to my friend, Harry Kelly—a physicist with whom I had become acquainted in Japan during the Occupation—he said, 'Vannevar Bush is really the *bravest* scientist we have in this country.'. . . The words 'brave scientist' moved me greatly," wrote Tamiya. "At that time, and even at present, Japanese people are using the adjective 'brave' only for such people as warriors, with such words as 'brilliant,' 'prudent,' 'scrupulous' or 'diligent.' Soon after coming back to Japan, I wrote in a popular scientific journal that Japan must have 'brave scientists' like V. Bush in the future." Bush later proposed a National Foundation for Scientific Research, writing, "In the last analysis the future of science in this country will be determined by our basic educational policy." Tamiya followed Bush's model by sending the best young Japanese scientists to the United States, an invaluable contribution to the scientific successes of the author of this memoir and the young scientists' own future in Japan.

CHLORELLA CULTURE

After termination of the war, Tamiya was asked by his old friend H. A. Spoehr of the Carnegie Institution of Washington to study the feasibility of mass culture of *Chlorella* with the purpose of using the alga as food or animal feed. After many trials and errors he developed a unique open circulation method with a device for intermittent sweeping. Nobuko Tamiya collaborated in developing culinary applications of the nutritious algae. Finally, Tamiya concluded that the idea was hardly feasible because of the high cost of the culturing techniques.

An important by-product unexpectedly emerged from the unsuccessful efforts of mass algal culturing. In laboratory experiments *Chlorella* was grown under diurnal alternation of light and darkness: 12 hours light and 12 hours darkness simulating natural outdoor conditions. It was found that the algal cells grew and divided almost synchronously in the light period, while cellular division took place during the dark period, so that almost all the cells were large at the end of the light period and small at the end of the dark period. By improvements of the culture techniques, it became possible to obtain complete and very uniform synchronous cultures of the alga. This technique, first reported in 1953, opened a new avenue of approach in microbiology to the elucidation of various cellular events occurring during the life cycles of microorganisms that could not be studied by conventional techniques (1966).

INTERNATIONAL BIOLOGICAL PROGRAM

In the beginning of the 1960s, Hiroshi Tamiya was invited to join an international cooperative research project, the International Biological Program. He assumed the chairmanship of the Japanese National Committee for the International Biological Program in 1964 and prepared its summary report in 1974. The studies recalled the lofty slogan of the program, "Biological Basis of Productivity and Human Welfare." His colleagues had warned him that as a laboratory biologist, working with the multitude of field biologists would be fraught with difficulty, for his colleagues rather scurrilously called the field biologists solipsistic wolves (formidable individualists). Tamiya commented on Chairman Roger Revelle of the U.S. National Committee's opening address, when Revelle remarked that one of the most gratifying and unexpected outcomes observed after their participation in the International Biological Program was that it made the otherwise strongly individualistic biologists willingly cooperate with each other in recognition of the international and human significance of the project. Tamiya felt that the same was the case in Japan.

Tamiya criticized the Japanese National Committee for the International Biological Program for having been negligent of fostering young scientists who would pursue and further develop the studies of a similar nature. He deplored the failure to include surveys in cooperation with countries in Southeast Asia and Korea, especially "with our colossal neighbor, the Republic of China."

ACCOMPLISHMENTS AND HONORS

On Tamiya's initiative the Japanese Society of Plant Physiologists was founded in 1958. The publication *Plant and Cell Physiology* owed much to his efforts. Tamiya cooperated with the occupation to establish the Science Council of Japan and the reestablishment of RIKEN, a Japanese research organization. Tamiya's research was supported by the Rockefeller Foundation and then by the Charles F. Kettering Foundation. The Tokugawa Institute for Biological Research was terminated on March 31, 1970, after 53 years of activity since its inception in 1917.

Tamiya was the recipient of the Ehrenmitglied der Deutschen Botanischen Gesellshaft and Mitglied der Kaiserische Deutschen Akademie der Naturforscher and was a corresponding member of the American Society of Plant Physiologists and the Botanical Society of America. He was elected in 1966 to foreign associate membership in the U.S. National Academy of Sciences. Tamiya was the recipient of the Order of Culture from the emperor of Japan in December 1977.

Tamiya was a man of superior intelligence and deep insight into every angle of human culture, especially in music and art, and his talent and vitality would have placed him in the first rank of any occupation he might have chosen. He stated that most literary scholars in Japan could recognize 20,000 kanji characters, while he could recognize 40,000. He did not hesitate to coin new words when he needed them in conversation. His use of the word "Kamenism" described phrases typically used by his friend Martin Kamen.

Tamiya's warm hospitality, which was shared by his wife, Nobuko, in their home, entertained a multitude of visitors from throughout the world. Behind the man's mild face, however, there dwelled a spirit of stern criticism and resistance against meanness and injustice, which he never hesitated to show before those who sold and bought in the sacred temple of his science. Nevertheless, he grew much in generosity and understanding while his inborn sense for keenly distinguishing between what is worthy in science and what is not became more and more sharpened with age. "Science is the god he serves and the ultimate source of his pleasure," wrote Atusi Takamiya in Hase et al. (1990).

Nothing will bear better evidence of his personality than the unaltered friendship he enjoyed over decades with his countless friends. His family, his students, and loyal friends meet each January 5th to celebrate his birthday and the memory of his life.

ACKNOWLEDGMENTS

The author acknowledges the importance of Hiroshi Tamiya to successes in his own academic and cultural life. Michio Seki, auditor of RIKEN, provided impetus for appreciating Tamiya's contributions for renewal of Japanese science after the war. Parts of this memoir were adapted from Atusi Takamiya's "Life and Work" in Hase et al. (1990) and from Tamiya's "Pilgrimage of a Man in Biology" lecture presented at the meeting of the Korean Association of Biological Sciences, in Seoul, on October 30, 1971. The Tamiyas' talented daughter, Takako Tamiya Horie, has helpfully contributed copies of her father's caricatures. Bowen C. Dees generously offered his collection of Tamiya's caricatures and personal recollections of his extensive work with Hiroshi Tamiya and the restructuring of Japan's national science organizations.

Material for this memoir was derived from published information in English from Takako Tamiya Horie, daughter of Hiroshi and Nobuko Tamiya; from Bowen C. Dees (1997), successor to Harry Kelly as deputy chief of the General

Headquarters, Supreme Command of Allied Powers, postwar administration in Japan and longtime friend of Hiroshi Tamiya; and from the author's letters exchanged with Hiroshi Tamiya from 1951 to 1984. The text of this memoir was enhanced by the valuable contributions of Bowen C. Dees, R. Clinton Fuller, Carole Mayo, Tatsuichi Iwamura, and Bunji Maruo.

The author's privilege of performing an important laboratory experiment with Hiroshi Tamiya in Berkeley was an important step toward understanding plant photorespiration. Traveling in Japan with the Tamiyas and appreciating often the hospitality of their home provided ample impetus for contributing this memoir of a great international ambassador of science.

NOTE

1. Hiroshi Tamiya's caricatures of the two committees' members are preserved as national treasures and copies have been provided by his daughter, Takako Tamiya Horie, and by Bowen C. Dees, successor to Harry Kelly at the Scientific and Technical Division, Economic and Scientific Section, General Headquarters, Supreme Command of Allied Powers, and close friend of Hiroshi Tamiya and his family. The caricatures are preserved in the membership files of the National Academy of Sciences and are accessible by members and historians.

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