not been possible to capture the nuances of many situations, decisions, and complex personalities that have made the program the great scientific effort that it is.

One has to marvel at the author's ability to produce such a well-documented (containing over 700 citations of references of various sorts) and generally well-written history of the program while manifesting a modestly good understanding of plasma theory. There are, however, a few slips that to the knowledgeable reader will be worrisome distractions. The printer's errors are somewhat more disturbing. These include a missing figure 4.1, $v_{\perp}$ substituted for $v_{\parallel}$ on p. 57, and some missing material between pp. 253 and 254.

As the fusion program begins to shift from being purely an endeavor of physics to being one where engineering feasibility is a prime concern, the difficulties and frustrations will continue. It will come as a major surprise to this reviewer, however, if the next 30 years of fusion history are as exciting as the past 30. It is unfortunate that the author chose not to present an appraisal of where the program is today and where it must go from here so that future historians can better put her account into perspective. Nevertheless, Bromberg's contribution to the history of this challenge is well worth reading.

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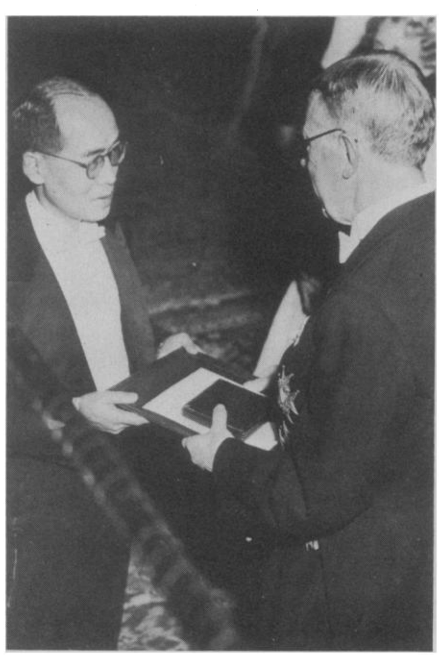
Physics: A View of the Japanese Milieu

"Tabibito" (The Traveler). HIDEKI YUKAWA. Translated from the Japanese edition by L. Brown and R. Yoshida. World Scientific Publishing, Singapore, 1982 (U.S. distributor, Heyden, Philadelphia). vi, 218 pp., illus. Cloth, $33; paper (to individuals and purchasers in developing countries only), $14.

Hideki Yukawa, who died in 1981, was well known in the scientific community for his formulation of the meson particle theory and the 1949 Nobel Prize it brought him, and in this work he presents a detailed and penetrating account of his life up through 1934 when the meson theory first appeared in print. But *Tabibito* is no ordinary description of one scientist's early career. It raises significant questions about and suggests insights into several important aspects of the growth of Japanese science. It is also the first book-length biography of any modern Japanese scientist who did his work at home to appear in English (*1*). For these reasons the work takes on an importance that does not necessarily attach to biographies of scientists in general.

Yukawa's recruitment into physics is a major theme of the book. He had considerable interest in literature as a young student and not much in science, but he did find mathematics exciting and received his best grades in that subject. In elementary school (1912–18) he once figured out his own method for obtaining the sum of an arithmetic progression. He enjoyed problems whose solutions required many hours of thinking, and by high school he was "captivated" by the beauty of Euclidean geometry. Yukawa's interest in mathematics obviously persisted throughout life, but he began to shift toward physics just before entering Kyoto University. The exact sequence of events is unclear, but the combination of an authoritarian mathematics teacher and a stimulating physics course at Kyoto's prestigious Third Higher School appears to have done the trick. Yukawa found that he took pleasure in at least some of his physics experiments. He was stimulated by Hajime Tanabe's popular work in Japanese, *Recent Natural Sciences*, and read in German with particular pleasure works on quantum theory by Fritz Reiche and by the founder of that theory, Max Planck.



Hideki Yukawa receiving the Nobel Prize, 1949. [Courtesy of Michiji Konuma; from *"Tabibito" (The Traveler)*]

These scholarly inclinations of Yukawa's were encouraged by a favorable home environment. Both parents had intellectual interests. The father was a university professor and the children were encouraged to study. It is also notable that intellectual interests in the family happened to straddle the "old" and the "new." Yukawa's paternal grandfather had been official Confucian lecturer to a *daimyo* (feudal lord) before the Meiji Restoration (1868). His father, whose specialty was geology, actively pursued side interests in Chinese archeology and culture. Yukawa's oldest brother became professor of Chinese history. A second brother became professor of metallurgical engineering, and a third served as professor of Chinese literature. The constellation of Yukawa's interests is scarcely surprising in view of this family environment. As readers of his book *Creativity and Intuition*, published in English in 1973 (*2*), are aware, Yukawa retained a lifelong interest in Taoism and other classical philosophies of China, as well as in physics, mathematics, literature, and various schools of Western philosophy.

This investigator of particle physics, by his own telling, had a personality that was more than a little introverted. As a youth he was easily upset, never had many close friends, and tried to minimize contact with other people. In high school he found he lacked the "brashness" required to sell tickets to the school festival and says his thoughts centered almost exclusively on his reading in literature, philosophy, and science. Relations with his family were also standoffish at times. He was close to his mother and youngest brother—the future Chinese literature scholar—but he fought constantly with his other brothers and tried to avoid most dealings with his father. Yukawa married happily at the age of 25, but he did so by the common Japanese pattern of family arrangement. We are not surprised when he tells us he found scholarly activities an escape from reality. He believed he chose theoretical physics in part to transcend the "problems and contradictions" of human society and as a university student would spend whole days reading scientific journals without ever talking with anyone.

Yukawa's account, in fact, underscores his marked intellectual self-sufficiency. He corroborated his father's claim that he "always made his own decisions" by rejecting paternal efforts to arouse his interest in geology. And he consciously reacted against the family's Confucian heritage on the grounds that Confucianism was "unnatural" and had been "imposed" on him before he was mature enough to think critically. However, it was clearly in physics that this quality was chiefly displayed. He chose Kijuro Tamaki as his first professional mentor, despite their lack of shared interests, because the older man "always respected the freedom of the people in his research room." As a third-year undergraduate Yukawa also decided to put himself in the forefront of theoretical physics and not to go abroad before doing significant work.

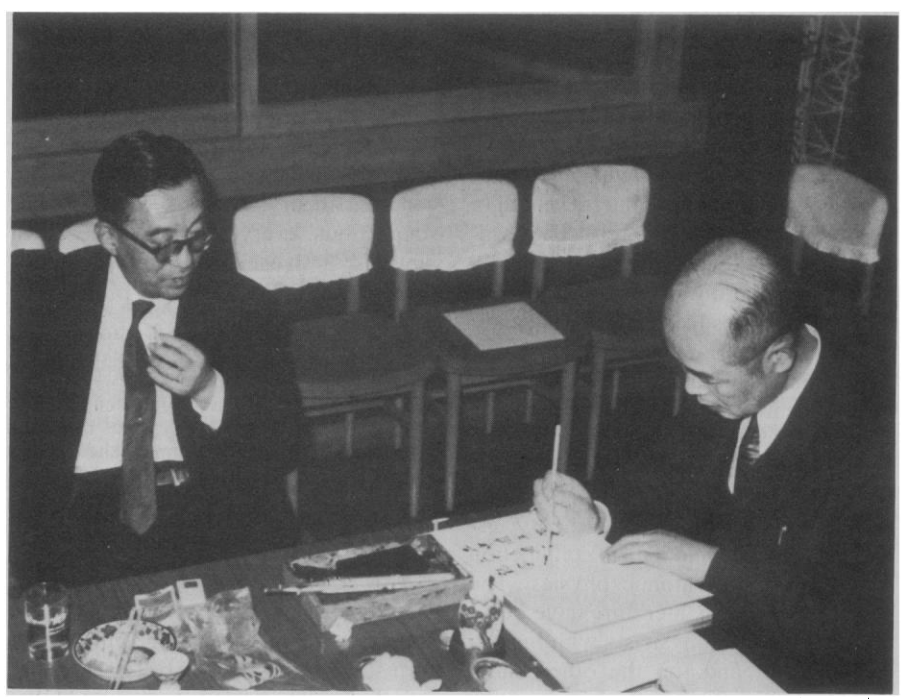
But none of this serves to gainsay the importance of professional colleagues. Yukawa acknowledges in an unspecific way that he derived much stimulation during his school days and thereafter from Shin'ichiro Tomonaga, subsequent winner of the 1965 Nobel Prize in Physics with Richard Feynman and Julian Schwinger. And other help was forthcoming when he worked on the theory of the meson. In April 1933 he substituted an electron with Bose-Einstein statistics for one defined by the Dirac wave equation in his model on the recommendation of Yoshio Nishina, founder of Japanese nuclear physics. And in early 1934 he moved away from a search for known particles toward a concentration on the characteristics of the nuclear force field as a result of information reported in journals by Fermi.

From this brief but provocative account of Yukawa's early years one can glean valuable insights into the growth of the Japanese scientific enterprise. For example, whence did the modern Japanese scientists come? Social scientists have long debated whether modern technical-scientific elites in non-Western societies arise from a wholesale displacement of traditional intellectual elites or from their general acculturation (*3*). Yukawa's case, in which a modern intellectual family descended from a hereditary line of Confucian scholars, clearly points to the latter. But it was hardly unique in Japan. Most Japanese active in or recruited into science by World War I came from precisely this kind of family (*4*). And how strong was the local base of science in Japan at this time? It is a commonplace observation about science in many former colonies or present-day developing countries that scientific communication with the centers of international science may be intimate and efficient while that within the country is sporadic to nonexistent. This was clearly not true of Japan during even the early part of this century. Yukawa's account makes clear that the Japanese nuclear physicists did not suffer from major institutional weaknesses of this kind. On the contrary, they constituted a lively and supportive community from at least the time of Yoshio Nishina's 1929 return from Niels Bohr's Institute in Copenhagen.

Nonetheless, the Bohr connection raises for many Japanese scientists the issue of the "Copenhagen spirit." Could Japanese researchers in Japan create and maintain the Bohr laboratory's spirit of "generosity"—the sense of personal freedom and cooperation among investigators they consider so essential to creativity? Among those who addressed this theme most directly was Yukawa's eminent pupil Shoichi Sakata. In a highly influential essay (*5*) published in 1947 when the oppressive climate of wartime was still a vivid memory, Sakata argued that Japanese society was inherently undemocratic and insisted that major structural reforms would be needed to overcome the negative impact on science of its collectivistic social system and sensitivity to matters of status.

As the years have gone by, this negative creativity theme has proven remarkably tenacious. The biochemists Shoichiro Otsuki and Tokukichi Nojima, adopting Sakata's assumptions, declared in 1963 that the Japanese social system was simply beyond reform (*6*). The anthropologist Chie Nakane claimed in 1970 that strong group affiliations often prevent Japanese researchers in different groups from working comfortably together (*7*). Computer specialist Yasuo Kato stated in 1981 that Japanese are not very creative because the "creative mind is peculiar and . . . Japanese don't like anything peculiar" (*8*). And in 1983 the American physicist Robert Jastrow quoted a well-known Japanese proverb about the hammering down of nails that stick up as indicating limited Japanese possibilities for innovation (*9*).

Those who believe as these critics do might carefully examine this book. Yukawa presents a detailed portrait of a creative Japanese scientist at work and places his account in the broadest possible context. He describes his personality, his schooling, his associations, and the thought processes that led to an epoch-making advance in physics. We do not find here the impediments to creativity so frequently postulated by critics. There are, in fact, various aspects of Yukawa's career that American scientists will perceive as familiar—the intellectualism, the personal detachment, the supportive interaction with peers, and the search for answers to questions. Yukawa's early life suggests that creative people everywhere somehow shape institutions and events to advantage. It raises the definite possibility that many criticisms of science in the Japanese setting are ultimately wide of



Shoichi Sakata and Hideki Yukawa writing a poem in the auditorium at Nagoya University at the celebration of the 25th anniversary of the two-meson theory. [Courtesy of Laurie Brown and Satio Hayakawa] the mark. And it stimulates a conviction that American science and business will continue to ignore this subject at their peril.

Laurie Brown and R. Yoshida deserve generous praise for presenting this book to English-speaking readers.

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References and Notes

1. A microbiologist Hideyo Noguchi has been the subject of two biographies in English, but he did his work primarily in the United States as a member of the research staff at the Rockefeller Institute. See G. Eckstein, *Noguchi* (Harper, New York, 1931), and I. Plesset, *Noguchi and His Patrons* (Fairleigh Dickinson Univ. Press, Rutherford, N.J., 1980).
2. Hideki Yukawa, *Creativity and Intuition: A Physicist Looks at East and West*, J. Bester, Transl. (Kodansha, Tokyo, 1973).
3. The following works are representative of this debate: M. Berger, *The Arab World Today* (Doubleday, New York, 1962); S. M. Lipset and R. Bendix, *Social Mobility in Industrial Society* (Univ. of California Press, Berkeley, 1959); C. E. Dawn, *From Ottomanism to Arabism: Essays on the Origins of Arab Nationalism* (Univ. of Illinois Press, Urbana, 1973); and J. Gusfield, "Educational institutions in the process of economic and national development," *J. Asian Afr. Stud.* **1**, No. 2, 129–146 (April 1966).
4. J. R. Bartholomew, "The Japanese scientific community in formation, 1870–1920" in *Science in Modern East Asia*, vol. 1, L. A. Schneider, Ed. (*J. Asian Affairs* **5** (No. 1), 62–84 [spring 1980]; State Univ. of New York, Buffalo, 1980).
5. Sakata Shoichi, "Kenkyu to soshiki" ("Research and organization"), *Shizen* (Sept. 1947), pp. 10–13, and J. R. Bartholomew, "Japanese culture and the problem of modern science," in *Science and Values*, A. Thackray and E. Mendelsohn, Eds. (Humanities Press, New York, 1974), pp. 109–155.
6. Otsuki Shoichiro and Nojima Tokukichi, "Nihon ni okeru kagaku, gijutsu to kagakusha" ("Science, technology, and scientists in Japan"), in *Kagaku, Gijutsu to Gendai* (Science, Technology, and the Present Age), Sakata Shoichi, Ed. (Iwanami Shoten, Tokyo, 1963), p. 283.
7. Chie Nakane, *Japanese Society* (Univ. of California Press, Berkeley, 1970), p. 74.
8. Y. Kato, quoted in *Business Week* (14 December 1981), p. 29.
9. R. Jastrow, "Science and the American dream," *Sci. Dig.* **91** (No. 3), 48 (March 1983).

A Venture in Writing History

The Historical Development of Quantum Theory. JAGDISH MEHRA and HELMUT RECHENBERG. Vols. 1–4. Vol. 1, *The Quantum Theory of Planck, Einstein, Bohr and Sommerfeld: Its Foundation and the Rise of Its Difficulties, 1900–1925*. Part 1, xlviii pp. + pp. 1–372. $33.80. Part 2, vi pp. + pp. 373–878. $36. Vol. 2, *The Discovery of Quantum Mechanics, 1925*. vi, 356 pp. $32. Vol. 3, *The Formulation of Matrix Mechanics and Its Modifications, 1925–1926*. viii, 334 pp. $32. Vol. 4, Parts 1 and 2, *The Fundamental Equations of Quantum Mechanics, 1925–1926* and *The Reception of the New Quantum Mechanics, 1925–1926*. viii, 322 pp. $38. Springer-Verlag, New York, 1982.

Scientists will be disposed to regard this work—which promises to reach nine volumes—as one of great importance, nay, "one of the most significant scientific works ever published" (J. Gribbin in *The New Scientist*, 24 March). They will be badly mistaken.

The distribution of writings on the history of physics has been emphatically bimodal, concentrated upon the 17th and 18th centuries and upon the first third of the 20th century. Works dealing with this latter period, insofar as they are not biographical, again show a decided doublet structure, being concentrated upon relativity and upon quantum theory, especially as it developed in conjunction with problems of atomic physics. The contributors to this literature have been, on the one hand, physicists with historical interests, and, on the other hand, professed historians of physics, with some few individuals seeking to maintain full standing in both camps. By and large the physicists write book-length histories of the whole field, based largely upon the published scientific literature, whereas the historians write narrower and closer studies of particular problems, usually at but article length. Though many aspects of the history of atomic physics and quantum theory before and after 1925 still await close inspection, the number of such special studies is already considerable. Indeed, a recent listing of the *Literature on the History of Physics in the 20th Century* (Office for History of Science and Technology, University of California, Berkeley, 1981) runs 500 pages.

Now comes a physicist who, as he tells us, has since his postdoctoral studies in the early 1950's pointed his steps toward the full and true history of the quantum theory. Over 25 years Mehra sought out every notable theoretical physicist active before his own time—some 100 are paraded in the preface.

> During this long period my collection of notes and transcripts of tape recordings of conversations, discussions and interviews had become quite large. It was supplemented [note what supplements what] by copies of all the relevant original papers, unpublished manuscripts and notebooks, and letters exchanged between the principal quantum physicists. . . . Thus, there resulted vast materials related to the historical development of quantum theory.

Having gotten in his possession "all" the sources, Mehra's only problem was to turn them into history. Here, 30 pages into the 50-page preface signed by Mehra alone, his collaborator, Rechenberg, is introduced—to meet the task of ordering Mehra's "vast materials," filing them in 39 folders "according to specific problem areas" and preparing notes and outlines for Mehra's use in the writing. The 2000 pages under review, distributed over four volumes bound as five, apparently contain the contents of the first 23 of these folders; the remaining 16 are to fill another four or five volumes.

The two tomes constituting volume 1 encompass nearly half these 2000 pages. They are devoted to the quantum theory prior to the creation of quantum mechanics and are arranged topically, with many names and papers cited. However, quantum mechanics itself, in the authors' view, was the work of just six "heroes": Werner Heisenberg, Max Born, Pascual Jordan, Wolfgang Pauli, P. A. M. Dirac, and Erwin Schrödinger. They did it all, "while the others stayed aside and watched their endeavours." Accordingly, volume 2 is Heisenberg's, from his entrance into Arnold Sommerfeld's seminar in 1920 to his revolutionary invention in the summer of 1925. Volume 3 describes the elaboration of Heisenberg's ideas into a matrix mechanics by Born, Jordan, and Pauli, with three-quarters of the volume being devoted to just three papers written in the latter half of 1925. Volume 4 is in two parts bound as one. It is chiefly Dirac's, part 1 being his intellectual biography through the spring of 1926. Part 2, the last 60 pages of the volume, is a hodgepodge headed "The Reception of the New Quantum Mechanics, 1925–1926." This subject, intrinsically far larger, and historically not less important, than the process of discovery here treated so fulsomely, is, impossibly, addressed before Schrödinger's wave mechanics, which is to receive "epic" treatment in volumes yet unpublished.

The coverage being briefly indicated,

> One may ask how our work relates to or compares with the other accounts of the history of quantum theory. The depth and scope of our work are different from any attempted thus far in the field: we bring in all the physical, mathematical and human details to provide the reader a complete account of the old quantum theory and the discovery and development of quantum mechanics. . . . We are aware of the fact that several accounts dealing with certain parts of the story we cover already exist in print. . . . Our aim, however, goes much beyond such works; we want to give the full story of all significant problems and their interplay.

The quotation is in every respect characteristic for Mehra's work: intellectual poverty, pompous pretension, depreciation of the quantity and significance of the extant historical writing in the field. Obviously, as the work is five times longer than any other on the subject, it