building of the Hanford reactor by the Dupont Co. The memoirs take up over a hundred pages and provide a fascinating new window to the involvement of physicists in the atomic bomb project. This aspect of the story has not been addressed before, and it is told here with candor and passion by one of the principal actors.

Volume VI, which deals with Wigner's philosophical reflections and syntheses, is introduced with a very helpful essay by Gerhard G. Emch. A little over a third of the volume is taken up by essays on the philosophical problems of quantum mechanics, including the measurement problem. Wigner had contributed importantly to the formulation and analysis of the measurement problem that John von Neumann expounded in his *Mathematische Grundlagen der Quantenmechanik* of 1932.

Subsequently, and especially after World War II, Wigner grappled with the conceptual difficulties engendered by the von Neumann formulation of quantum mechanics. He made manifest the restrictions that superselection rules and additive conserved quantities impose on the measurability of Hermitian operators, and he exposed the severe difficulties encountered in a relativistic treatment of measurement. But it was the mystery surrounding the reduction of the wavepacket that elicited Wigner's greatest concern, and he was thus led to speculate about the role of consciousness in describing microscopic phenomena and whether the laws of physics could explain consciousness. To see whether solutions to the reduction problem existed that did not invoke the consciousness of the observer, following a suggestion by Heinz-Dieter Zeh, he explored the implications of the fact that the measuring apparatus must be a macroscopic object and, therefore, that its energy levels are so densely distributed that it can never be considered an isolated system. All these matters are clearly expounded in the essays. Except for John Bell, no one addressed these foundational issues as critically as Wigner did.

Another third of volume VI presents Wigner's essays on symmetries, invariance and conservation laws (including his Nobel Prize lecture). The rest of the volume is made up of writings relevant to the history of nuclear physics and essays the editors have characterized as "philosophically broader." Among the latter are his wonderful essays, "The Limitation of Science" and "The Unreasonable Effectiveness of Mathematics in the Physical Sciences." All of the essays in volume VI are at the level of the curious nonexpert who possesses a minimal command of the quantum mechanical formalism. They are rigorous, lucid and challenging. It would be wonderful if the bulk of the essays in this volume could be made available in an inexpensive paperback edition.

Needless to say, the entire set of Wigner's *Collected Works* should be in every science library. They constitute the legacy of one of the greatest scientists of the present century. We are indebted to Arthur Wightman and his collaborators for making them available.

Health Effects of Exposure to Low-Level Ionizing Radiation

Edited by W. R. Hendee and F. M. Edwards
IOP, Philadelphia, 1996. 568 pp. $250.00 hc ISBN 0-7503-0349-2

Assessments of the health effects of ionizing radiation and the use of these assessments in the framing of public policies remain in a frustrating state. There is a clear and quantifiable connection between cancer induction and radiation exposure at doses above 50 rem (500 millisieverts). But despite intensive investigations—including innumerable epidemiological, animal and cellular studies—it is still not known if ionizing radiation is harmful at the much lower doses encountered in most cases of actual or potential exposure of the public, including the average natural radiation dose of 0.3 rem per year.

Faced with scientific uncertainty, most official and semi-official bodies charged with advising on radiation risks or formulating radiation protection standards have adopted the guideline that the cancer risk is linearly proportional to the dose, down to zero dose—albeit sometimes with a small "dose rate reduction factor" at low doses and low dose rates. At the same time, many scientists believe that the health risks at low doses may be negligible (or zero) and that regulatory agencies have gone too far in erring on the side of caution. For example, the Health Physics Society, a leading US professional organization, earlier this year adopted a controversial policy statement concluding that below 10 rem "risks of health effects are either too small to be observed or are nonexistent."

People interested in understanding what is known and not known about radiation effects will find a valuable resource in the newly published *Health Effects of Exposure to Low-Level Ionizing Radiation*, edited by William Hendee and Marc Edwards. The book presents an extensive overview of the field and the background needed to understand the ongoing controversies, although the focus is more on pedagogy than on controversy. It is aimed at a broad audience of students and professionals, including physicians and physicists, and it does a fine job of meeting the needs of this diverse group.

The book contains 17 chapters, 5 written by the editors and the remainder by highly qualified contributors. With some overlaps, the material falls into four areas: interactions of radiation with matter, results of epidemiological studies, the sources of radiation and the responses of society.

The basic processes involved in radiation damage are described at successive levels, including atoms, cells and laboratory animals. Physicists are likely to find the sections dealing with the interaction of radiation with cells to be especially valuable, even if it is crammed with unfamiliar terminology. If the holy grail in radiation protection is the functional relationship between cancer risk and radiation dose at low doses, then studies of mechanisms at the cellular level may offer the best chance of finding it.

At present, our quantitative knowledge of cancer risks is heavily based on epidemiological studies, most prominently of Hiroshima and Nagasaki atomic-bomb survivors. These and other data are considered in some detail by several authors. In addition, a comprehensive chapter focuses on genetic effects, probably a lesser concern in the absence of statistically significant effects in the Hiroshima–Nagasaki studies.

Other parts of the book provide a detailed picture of the natural, medical and nuclear sources of radiation exposure. Two closing chapters tackle the relationship between public understanding of radiation and the future of such technologies as food irradiation, medical diagnosis and therapy, and, of course, nuclear power. A particularly interesting chapter combines science and good sense in a somewhat standalone discussion on the counseling of pregnant women facing diagnostic or therapeutic radiation exposures.

A good index and an extensive glossary would have been valuable in this wide-ranging book; the existing index lacks adequate topic listings and reliable page references, and there is no glossary beyond a summary of radiation dosimetry terms. But an index and glossary do not make or break a book. The present volume has a wealth of important material, presented in a lucid and balanced fashion and (discounting some misprints) at a high level of scientific reliability. If its price is not an obstacle, the book should be very useful to scientists in many fields, and certainly to physicists seeking an introduction to radiation health effects.

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Julian Schwinger: The Physicist, the Teacher and the Man

Edited by Y. Jack Ng
World Scientific, River Edge, N.J., 1996. 194 pp. $38.00 pb ISBN 981-02-2532-6

Prodigies don't always pan out. Julian Schwinger did. He had fastened onto physics for his life's work while still in his early teens, when he got to the letter "P" in a systematic odyssey through the *Encyclopaedia Britannica*. Not much later, he was spotted reading (and understanding) Paul Dirac. Tales of the boy wonder began to circulate while he was still in high school. Schwinger's first two papers were published when he was seventeen, and a flood of others began to appear by his nineteenth year. Having transferred from the City College of New York to Columbia University, where he came under the tutelage of I. I. Rabi, Schwinger was off to a spectacular start. By age 20 Schwinger was, in Paul Martin's felicitous words, a recognized "impresario in a field for which the twentieth century has been a golden era."

Schwinger died on 16 July 1994 at the age of 76. Not long after, friends and colleagues organized several commemorative symposia, one held at Drexel University, another at the University of California, Los Angeles, and a third at a joint meeting in Washington, DC, of the American Physical Society and the American Association of Physics Teachers. *Julian Schwinger: The Physicist, the Teacher and the Man* is a collection of the talks given at those sessions, together with a brief preface by Y. Jack Ng. There are two valuable appendices as well: a list of Schwinger's doctoral students and his updated publication list.

Bryce DeWitt's article on curved spacetime propagators and Walter Kohn's article on density functionals are detailed, technical expositions. There are also two 1993 talks by Schwinger himself (read by Freeman Dyson at one of the symposia). One is Schwinger's response on receiving an honorary degree at The University of Nottingham in England. The other, "The Greening of Quantum Field Theory, George and I," was a talk, also given at Nottingham, that centered on—what else?—Green's functions. The remaining pieces in this volume are reminiscences and tributes contributed by former students and other colleagues: Abe Klein, Bryce DeWitt, Walter Kohn, David Saxon, Paul C. Martin, Kenneth Johnson, Stanley Deser, Robert Finkelstein, Ng, Herman Feshbach, Lowell Brown, Sheldon Glashow, Kimball A. Milton, C. N. Yang. They all describe the same man: shy, gentle, cultured, generous, elegant in his writings and lectures, scientifically conservative, stubbornly resistant to scientific domination by others, something of a loner and, also, somewhat unaccountably, a lover of big, expensive automobiles.

Schwinger supervised about 70 doctoral students, most of them during his years at Harvard, some few from his later period at UCLA. The total is awesome, yet the sum of one-on-one contact hours with the master was considerably more modest. Schwinger was much sought after as a doctoral adviser and apparently accepted all who persisted. Moreover, by all reports, time with him, when it could be had, was well spent. But that time was hard to come by, especially during the earlier years. Klein speaks of a total of three substantive sessions with Schwinger during his Harvard years, DeWitt of perhaps 20 minutes in the course of his thesis work! Much of Schwinger's influence was expressed through his lectures, which were masterpieces of exposition, clarity and originality and were widely attended by faculty and students alike. One did not interrupt with questions, just as one would not interrupt the performance of a Mozart sonata. Although private time with teacher was a scarce commodity, it was not uncommon for Schwinger's students to pick up his verbal and literary style. Even years later, one recognizes the marks of a Schwinger student.

The articles are varied in slant, but all are delightful. Inevitably, some focus more on the writer (and Schwinger), others more on Schwinger and his contributions, but almost all describe his singular work habits. His range was astonishing: nuclear, atomic, particle and condensed matter physics, statistical mechanics, classical electromagnetism, synchrotron radiation, waveguide theory (in the war years), general relativity, quantum field theory and, of course, quantum electrodynamics in particular, and the development of theoretical tools more generally. His work also contained important foreshadowings of the standard model and beyond. One picks up interesting and varying insights from the different contributions here, although the book is not at all a systematic scientific or personal biography of Schwinger. Such a biography is bound to come. It will be especially interesting to understand Schwinger's later years, as his methods came to be overtaken by Richard Feynman's and as the quark picture and then the standard model took hold, without Schwinger's direct participation and, to some extent, against his tastes. His source theory was not widely accepted and was, in any case, overtaken by events. Toward the end of his life, there was his seemingly inexplicable association with cold fusion, about which there is scarcely a word in these talks.

Concerning Feynman, Schwinger's famous comment is reproduced here in Yang's article: "Like the silicon chip of more recent years, the Feynman diagram was bringing computation to the masses." Yang offers a perceptive contrast between these two giants of theoretical physics: "Twenty percent impulsive clown, twenty percent professional nonconformist, sixty percent brilliant physicist, Feynman strived to be a great performer, almost as much as to be a great physicist. . . . Shy, erudite, speaking and writing in crafted and polished sentences, Schwinger epitomized the cultured perfectionist and the quiet inward-looking gentleman."

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Supernovae and Nucleosynthesis: An Investigation of the History of Matter, from the Big Bang to the Present

David Arnett
Princeton U. P., Princeton, N.J., 1996. 598 pp.; $85.00 hc ISBN 0-691-01148-6; $39.50 pb ISBN 0-691-01147-8

A classic 1957 paper by Geoffrey Burbidge, Margaret Burbidge, William Fowler and Fred Hoyle convincingly showed that most of the heavy elements in the universe could be produced by nucleosynthesis in stars. In the past few decades, there has been a steady development in our understanding of the origin of nuclei and their ejection into interstellar gas. David Arnett has been a leading figure in that development, and his book covers many of the topics that he has investigated during his research career.

The main focus of his *Supernovae and Nucleosynthesis* is nucleosynthesis