cast of characters who embark on a six-day exploration.

In the course of these six days, a number of case studies are explored. These include Claude Louis Berthollet's struggle to understand what is today called "mass action"; Louis Pasteur's work on the connection between optical activity and living processes; Alexander Fleming's work on penicillin; and Root-Bernstein's own discovery of protein–protein transcription. Along the way, one encounters snippets ranging from the work of Galileo to the work of Einstein, of Bohr and of Feynman. There are long, discursive investigations of the history and of the philosophy of science, all of it aimed at uncovering the essential features of the conditions under which discovery takes place: Are there really such things as accidental discoveries? Are theories confirmed? Are they falsified? Are data anything more than propaganda for an already established point of view? Does an aesthetic temperament make a difference? What role does the social milieu play in the right question being asked at the right time? This culminates in a summation—a so-called "Manual of Strategies for Discovering"—containing 93 mutually contradictory principles. In the end one is quite worn out. Perhaps that is the point. But the result is an ultimately unsatisfying sense of frustration. For me the frustration is not that there are no clear answers, but that the field of questions has been muddied. For as one of the characters in the dialogue very properly points out, in scientific inquiry it is not the answers but the questions that last.

Galileo used his dialogues as a bully pulpit to focus our attention on a single issue—for example, the choice between two cosmologies, between two views of the strength of materials or between two theories of motion. Ultimately, the intricate, idiosyncratic structure of Bernstein's dialogue distracts our gaze and intrudes on our concentration. (An index that included more than proper names would have heightened my appreciation for the idiosyncratic nature of the format.)

At the finish one is left at the point where we entered: The more we examine our navels in search of the crucial variables in the creative act, the more fugitive it becomes. As a historian of science interested in using the history of science as a heuristic tool for educating nonscientists, I know all too well that any case study can be used in the service of virtually any epistemological or ontological viewpoint. The secret is not in discovering how to discover. The secret may be contained in Percy Bridgman's dictum concerning the scientific method: It is, Bridgman insisted, nothing more than "doing one's damnedest with one's mind, no holds barred." If we take that dictum seriously, I am confident that creativity will take care of itself. I suspect Root-Bernstein thinks so too.

STANLEY GOLDBERG
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Currents of Death: Power Lines, Computer Terminals and the Attempt to Cover Up Their Threat to Your Health

Paul Brodeur
Simon and Schuster, New York, 1989. 333 pp. $19.95 hc ISBN 0-671-67845-0

Cross Currents: The Promise of Electromedicine, The Perils of Electropollution

Robert O. Becker
Jeremy P. Tarcher, Los Angeles, 1990. 336 pp. $19.95 hc ISBN 0-87477-536-1

The possibility of health effects from exposure to nonionizing radiation and extremely-low-frequency electric and magnetic fields—including the power-line frequencies of 60 and 50 hertz—is becoming a serious scientific, political and perhaps economic question. In recent years experimental and epidemiological studies have suggested that unexplained field–cell interaction mechanisms may affect the nervous, circadian and immune systems, and perhaps lead to or exacerbate such health problems as cancer and chronic depression. But the science has not progressed to the point of providing a coherent theory of the observed phenomena. Individuals as well as organizations are faced with making decisions on what, if anything, they should do to minimize the potential health effects. The scientific uncertainty and the economic stakes have caused those with vested interests to take the position that we currently do not know enough to warrant concerted action. Some have chosen to deny the evidence. This certainly compounds the public's confusion and bewilderment.

The conventional argument has been that the 60-Hz and similar low-frequency fields we encounter daily are harmless because the energy quanta are too small to cause ionization, and their intensities are too weak to produce any significant heating of the tissue. However, some cellular-level experiments have shown that these fields may cause changes in the action of the cell membrane. This can lead to alterations of the rates of critical processes such as calcium efflux from brain tissue, which may in turn influence processes of growth and development, of critical periodicities in the nervous system and other biochemical feedback mechanisms, and of immune resistance. Epidemiological studies have shown an association between residential-level fields and childhood and adult leukemia, and between occupational-level fields and leukemia and brain tumors. Studies on rats have shown that the fields affect the rhythm of pineal melatonin, a chemical that in humans has been associated with chronic depression and tumor growth rates. To complicate matters, cellular phenomena show frequency and intensity resonances, as well as nonlinear variations with the period of exposure. The biology and physics of the fields' interaction with the cell membrane have not developed to the point where we can say what measure of field exposure represents "dose." It is not clear if the effects of sinusoidal fields of low frequency, such as those produced by electric power systems are similar to pulsed fields, which are created by devices such as the video display terminal, or to megahertz radio-frequency fields.

A gifted veteran writer of *The New Yorker* magazine, Paul Brodeur could have used his book to render the public a service by writing a clear exposition of the difficult scientific concepts, the status of scientific knowledge at this time, the ongoing scientific process, the conflicts between the believers and the nonbelievers, and the varying reasons why some parties do not accept the evidence of health effects. To some extent, he does address these issues, and in so doing tells a dramatic story. He speaks about how the understanding of the effects has unfolded, how some skeptical agencies have delayed the checking of preliminary data and how other parties have used political means to refute the evidence rather than attempt to replicate it.

Currents of Death indeed tells these stories in a captivating style. Brodeur has carefully researched most of the details and anecdotes. The original

three-part series appeared in *The New Yorker*, and the details have been checked by *The New Yorker* editorial staff. Concepts like fields, currents and cyclotron resonance are explained in simple, correct and elegant terms.

It is in his attempt to build a "coverup" theory that Brodeur has done a disservice to the public's understanding of the scientific process in general and of 60-Hz field effects in particular. Scientific uncertainty is exploited by different parties to suit their own ends. Brodeur concentrates on this latter phenomenon and, in so doing, fails to recount the research efforts and international and national meetings that elevated what was a fragmented set of findings as late as 15 years ago to the respected field of bioelectromagnetics research of today. Brodeur has correctly related the experiences of Ross Adey, Robert Becker and Nancy Wertheimer, pioneers in this field. But he has failed to relate how the concerted work by Adey and collaborators, for example, is bringing about what Thomas Kuhn called a "paradigm shift." Many scientists who a decade ago were skeptical about the biological effects of nonionizing fields now believe that extremely-low-frequency fields significantly perturb biological phenomena. The extrapolation of this belief to a potential public health problem is not simple, and the current debate centers primarily around this point. Brodeur has concentrated primarily on the controversies and hearings surrounding the siting of extremely-low-frequency facilities. But by doing this, he has lost a chance to capture the full scientific drama for the public.

There is a need for concerted research to understand what could turn out to be a public health problem. Brodeur could have helped the public understand and the skeptics acknowledge this need. But by concentrating on and sensationalizing the coverup theory, he has made the credibility of the whole book vulnerable to attack by those seeking to ignore the scientific evidence and carry on business as usual.

Robert Becker, a physician and pioneer in experiments that study the health effects of low-frequency electric and magnetic fields, concentrates on a very different aspect of these fields in his book. *Cross Currents: The Perils of Electropollution, The Promise of Electromedicine* advances a model of "energy medicine" to replace or supplement the current school, which he terms the "chemical–mechanistic" school of medicine. Be-

cause of his background, Becker is able to explain many phenomena, such as differentiation and embryonic development, in lucid terms suited to a lay reader. He describes a wide range of phenomena and practices, such as acupuncture and the effective use of pulsed electromagnetic fields, to show the importance of understanding the role of electromagnetic energy in biological systems. Becker then goes on to ascribe various "new plagues," including such diverse illnesses as AIDS, autism and Alzheimer's disease, as perhaps having connections to the modern environment which is permeated with high ambient electromagnetic fields.

This is where Becker makes himself vulnerable to the charge that he indiscriminately attributes all present-day health problems to electromagnetic fields. While Becker's book makes for interesting reading, too many apparently disparate ideas are clustered under the "electromagnetic" explanation.

These two books are important reading for those interested in the recent paradigm shift regarding the biological effects of fields and the accompanying sociological and economic conflicts. However, for the reasons explained above, those books do not stand as complete sources of scientific information for the reader unfamiliar with the subject.

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The Space Telescope: A Study of NASA Science, Technology and Politics

Robert W. Smith
Cambridge U. P., New York, 1989. 478 pp. $39.50 hc
ISBN 0-521-26634-3

The publication of this study of the history of the Hubble Space Telescope about six months before the launch of the telescope reflects both an innovative approach to writing recent history and the delays that resulted from the space shuttle Challenger accident. Robert W. Smith and his colleagues at the Johns Hopkins University and the National Air and Space Museum studied the history of the Space Telescope as it happened. They sat in on meetings, interviewed scientists about their current work (rather than asking them to recall past intentions) and read documents that might later be lost or destroyed.

The resulting book is not the type of instant history that journalists sometimes produce, but rather an important contribution to space history. Smith tackles a broad and significant issue: the politics of "big science." He examines the complexity of political, economic and scientific influences that shape large new scientific projects such as the Space Telescope. The result is a book valuable not only to those interested in the history of the Space Telescope and the space program in general, but also for scientists and historians who want to better understand how government funding affects the scientific process.

Smith's book deals with a number of important themes. He shows how work on large, long-term experiments fit (or failed to fit) into scientists' careers. He examines the strategies that supporters of the Space Telescope used to lobby for funds and to build support within the scientific community. Because of the problems that the Space Telescope developed after launch, the theme that stands out most is Smith's analysis of the impact of inadequate funding on the telescope. He shows clearly that NASA managers took significant risks in deciding how much to test the telescope and how closely to supervise the contractors. Funding was so short that the choice seemed to be between taking risks or building a less ambitious telescope that would not represent a significant improvement over ground-based telescopes.

The Space Telescope is well worth reading by anyone affected by big, government-funded science. It reveals the inner workings of funding and development as few other studies have, and it points clearly to a number of important issues. Smith provides no prescription for solving the problems of big science, but he significantly improves our understanding of those problems.

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BOOK NOTE

Discovering Alvarez: Selected Works of Luis Alvarez with Commentary by his Students and Colleagues

Edited by W. Peter Trower
U. Chicago P., Chicago, 1987. 272 pp. $37.50 hc
ISBN 0-226-81304-5

A year before Luis Alvarez's death in 1988, Peter Trower compiled this sampling of the great experimenter's papers, each accompanied by an explanatory reminiscence by a former colleague. The range is incredible: from the discovery of nuclear K capture in 1938; through the heyday of big bubble chambers; to his analyses of the pyramid of Chephren at Giza, the assassination of John Kennedy and the extinction of the dinosaurs.

In addition to the facsimiles of Alvarez's research publications, the volume contains writing of a different sort: his Nobel Prize lecture; his letter to the Japanese physicist Ryokichi Sagane, dropped over Hiroshima with a telemetry package on the fateful day; and Luie's letter to his son, written on that same day aboard a B-29 accompanying the Enola Gay.

The commentaries are informative and entertaining, evincing the deep admiration of these men who knew Luie as friend and colleague. Wolfgang Panofsky recalls their work on accelerator design; Hans Bethe describes the discovery of helium-3; Phillipe Eberhard chronicles the search for monopoles; Stanley Wojcicki tells what it was like to be a student in Luie's group at the Berkeley Rad Lab; and Richard Garwin writes about Luie's analysis of the Kennedy assassination.

Luie had always discouraged the creation of a *Festschrift*, Trower tells us. "There's nothing interesting in getting a year older," he would say. *Festschriften* often stray rather far from the spirit of the honoree. This excellent compilation, giving us so much of Luis Alvarez, is a more than adequate substitute.

—BERTRAM SCHWARZSCHILD

NEW BOOKS

Acoustics

Fundamentals of Noise and Vibration Analysis for Engineers. M. P. Norton. Cambridge U. P., New York, 1990. 619 pp. $95.00 *hc* ISBN 0-521-34148-5; $37.50 *pb* ISBN 0-521-34941-9

Acoustics of Layered Media I: Plane and Quasi-Plane Waves. *Wave Phenomena 7.* L. M. Brekhovskikh, O. A. Godin. Springer-Verlag, New York, 1990. 240 pp. $75.50 *hc* ISBN 0-387-51038-9. *Monograph*

Astronomy and Astrophysics

Accuracy of Element Abundances from Stellar Atmospheres. *Lecture Notes in Physics 356.* Proc. Wksp., Baltimore, Maryland, August 1988. R. Wehrse, ed. Springer-Verlag, New York, 1990. 109 pp. *hc* $32.40 ISBN 3-387-52365-0

Handbook of Space Astronomy and Astrophysics. Second Edition. M. V. Zom-