

science is big physics, almost all of the essays deal with big physics spectacles, big physics institutions and big physics personalities—Ernest Lawrence's early cyclotrons, Pief Panofsky's SLAC, CERN, Tsukuba, Los Alamos, the space telescope, the Gravity B Relativity Gyroscope Program and the Plutonium Project. The essays are grouped into three parts: "The Big Physics of Small Particles," "Sponsored Research and External Interests" and "Big Science and National Security." As in many multi-authored collections, the essays vary in quality. My favorite was a spritely account of the Gravity B Relativity Program by a participant, W. Francis Everitt. Indeed, the essays written by historians sometimes seemed to me to lack verisimilitude as compared to those written by actual protagonists such as Everitt.

I found Panofsky's essay on the history and politics of SLAC to be especially insightful, largely because he tries to address what I regarded in 1961 as the central social problems of big physics: its enormous expense, its effect on the ethos and style of science and its relation to and justification in comparison with "little science." Panofsky insists that the concern that big physics would become too journalistic (in other words, that new discoveries would be announced by the press *before* being peer reviewed for a scholarly journal) has not been borne out by events. Standards of scientific quality are at least as high in big physics as in less expensive undertakings. Though conceding that big physics is expensive, Panofsky points out first that support for little physics tends to parallel support for big physics. Secondly, he asks, "if certain answers crucial to man's understanding of nature can be obtained only by large effort, is that sufficient reason for not seeking such answers?"

A recurring theme in several of the essays is the sometimes difficult relationship between physicists and engineers in big physics. This matter is explored in David Hounshell's essay on research and development at DuPont and DuPont's wartime role in the engineering of the Hanford plutonium-producing reactors. Hounshell had access to the yet-to-be-published wartime diaries of Crawford H. Greenewalt of DuPont who at the time was the chief of liaison between the Chicago physicists (mainly Eugene Wigner and Enrico Fermi) and the DuPont company. The essay clarifies the origins of the dispute between Wigner, the inventor of the Hanford reactors, and the DuPont engineers who actually built the

plant.

Historians of technology will have a field day comparing Wigner's memoirs of the Plutonium Project with Greenewalt's when both diaries become generally available. My own estimate is that although Wigner underestimated the required size of the Hanford project and DuPont underestimated the engineering, let alone scientific, genius of Wigner, both DuPont and Wigner were necessary for Hanford's success.

Galison and Hevly seek to make the history of big science a new subfield of the history of science. This book is a good start; it contains much to chew on for historians and for physicists who practice either big or little science.

ALVIN M. WEINBERG

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The Mind of God: The Scientific Basis for a Rational World

Paul Davies

Simon and Schuster, New York, 1992. 254 pp. \$22.00 hc ISBN 0-671-68787-5

The remarkable explanatory power of modern science hardly needs emphasis but is nevertheless a source of wonder. Scientific explanations of reality receive a ready acceptance in the most diverse cultures and are an intellectually unifying phenomenon of the present-day world. What can science tell us about the ultimate questions of human existence? Is a universally satisfying "theory of everything" possible?

Paul Davies confesses to having been dazzled by the explanatory power of science as a student. His earlier book *God and the New Physics* was an attempt to grapple with the clash of ideologies of science and religion in their explanations of the world; his present book is, in his own words, a more considered attempt.

His exploration of what may constitute an ultimate explanation of the world is fascinating reading. He writes in the lucid and delightful style his readers have come to expect and appreciate, reliably steering the non-technical person through the most difficult issues of quantum cosmology, applications of Gödel's theorem and the ontological status of physical laws. He recognizes, however, that the search for a closed logical scheme that provides a complete and self-consistent explanation for everything is doomed to failure. Gödel's theorem warns one that the axiomatic method

of making logical deductions from given assumptions cannot in general provide a system that is both provably complete and consistent. Davies concludes that if one perseveres with the principle of sufficient reason and demands a rational explanation for nature, then one has no choice but to seek that explanation in something beyond or outside the physical world. For convenience, the reason for the universe may be labeled God—whether one has in mind a person, a creative force, an ethical requirement or some concept not yet formulated.

Davies declares that it is not obvious that this postulated being who underpins the rationality of the world bears much relation to the personal God of religion, still less to the God of the Bible or the Koran. Many modern theologians would concur with his sentiments, albeit from a different perspective. For example, the biblical scholar José Miranda states that whereas according to ontology God first exists and then commands, the biblical God ceases to be God at the moment at which He is objectified into any representation and thus ceases to command (His command being perceived essentially as a demand for justice). A biblical notion of God, which has moral concern at its very core, cannot arise from the purely gnostic approach of the kind explored by Davies. At least from a Christian perspective, this is surely the main weakness of his study.

Nevertheless this exposition of traditional questions of the meaning of the world from the perspective of the latest developments in physics, so engagingly and clearly written, contains much to interest and inform. It is a book that deserves to be widely read.

CHRISTOPHER MOSS

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Impure Science: Fraud, Compromise and Political Influence in Scientific Research

Robert Bell

Wiley, New York, 1992. 291 pp. \$22.95 hc ISBN 0-471-42913-3

Science has been getting bad reviews. Highly publicized cases, including the cold fusion fiasco, false claims for the "Star Wars" x-ray laser program, fabricated data in the David Baltimore case, improper charges on research grants at Stanford and the growing reliance on pork-barrel funding of scientific research, have created a public perception that science,

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particularly academic science, in the United States is not being conducted in the public interest. Considering the enormity of scientific activity, scientists argue, abuses are rare. The number of scientists involved, they insist, is tiny. Robert Bell, an economics professor at Brooklyn College, disagrees. "Although the overwhelming majority of scientists have not been direct participants," he charges in *Impure Science*, "they have remained silent onlookers or have looked the other way."

To support this sweeping indictment of the scientific community, Bell analyzes a number of examples of misconduct. After studying court records, government investigations, Congressional testimony, Freedom of Information Act requests and personal interviews, he concludes that these examples demonstrate a pattern. Certainly they should make every scientist squirm.

The most notorious examples have to do with outright fraud. The unhappy reality is that with science growing more rapidly than science budgets, the intense competition for funds has tempted some scientists to fabricate research results. Perhaps we should not be too surprised that the institutions involved are often reluctant to pursue charges of misconduct and that faculty review boards, convened to examine such charges, are frequently pushovers. Instances of deliberate fraud, after all, are still rare. Far more frequent are the occasions on which a university must defend the rights of a faculty member to hold unpopular or nonconformist views. Because universities are expected to serve as the defenders of faculty rights, it may be too much to expect them to serve also as watchdogs.

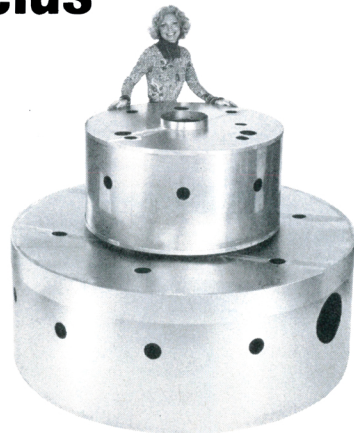
In any case, the sad truth is that it has remained for Federal agencies and sometimes Congressional investigations, to establish that a few scientists commit high crimes against science itself. Faculty review boards too often seem unwilling to believe that colleagues would deliberately deceive them. But this only establishes that scientists are gullible, not culpable.

If criminal fraud is rare, sleaze is much less so. Perhaps the most widespread ethical problem in science today is conflict of interest. Except for the hopelessly naive, members of the public know to be skeptical of lung cancer studies by tobacco company scientists, but the commercial entanglements of universities and faculty are often hidden. The problem has mushroomed since the passage of

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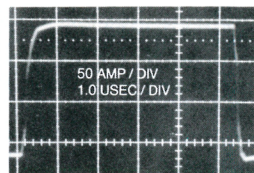
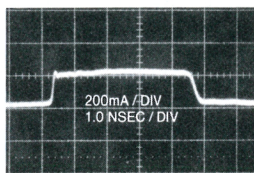
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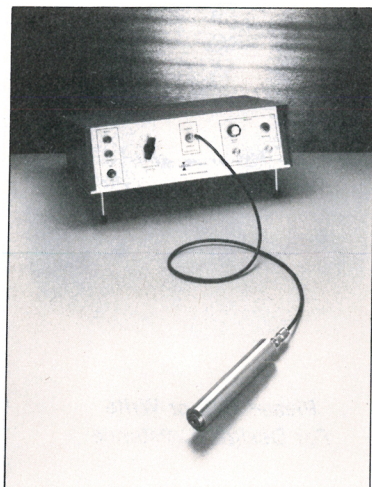
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legislation in 1980 permitting universities to hold the patents to technologies resulting from government-funded research. The intent was to speed the transfer of new technologies to the private sector, but as universities become involved in marketing the products of research, their prime function as creators and transmitters of new knowledge is compromised. The remedy, Bell says, is full disclosure.

The book is weakest when it attempts to deal with political influence. Congressional earmarking of projects that have not been subjected to impartial review by qualified experts—pork-barrel funding—is a serious threat to American science. But technical excellence is not the only factor Congress should consider in appropriating funds; Congress is also responsible for such matters as affirmative action and economic development. Indeed, the popularity of earmarking is a recognition of the importance of a strong university research program within the local economy. The problem comes when relative scientific merit is ignored or misrepresented.

When scientists seek Congressional support for their research, exaggerated claims for the potential benefits of the proposed research and "low-balling" cost estimates do a disservice to science and the nation. But willful misrepresentation in such cases can be hard to distinguish from self-deception. Self-deception in a scientist is a very bad trait—but it's not a crime. There is, I think, far more incompetence and far less conspiracy in some of the cases Bell analyzes than he imagines.

In the end, the examples in *Impure Science* give us plenty to worry about. But Bell's charge that the scientific community has chosen to ignore misconduct does not stand up.

ROBERT L. PARK
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Great Ideas in Physics

Alan Lightman
McGraw-Hill, New York, 1992.
250 pp. \$22.39 pb
ISBN 0-07-037937-8

It's no secret that science education in the US is in deep trouble. You only have to look at the graduate students at your own institution to be convinced that too few Americans are entering science to provide the force to drive our economy into the next century. There is, however, another area in which science education is in trouble, and that is in the education of

people who have no intention of ever becoming scientists. This problem comes under the general rubric of "scientific literacy."

There are many different approaches to the problem of scientific literacy. One approach is to look at the kinds of science that an ordinary person is called upon to use in daily life and to ask whether our high schools and universities are in fact supplying training in these areas. The answer to this question, for reasons too complex and lengthy to go into in a short review, is clearly "no." Courses based on this approach to scientific literacy try to span the sciences, providing the student with a general background, but not trying to get them to "do science" or to think the way scientists think.

The other approach to scientific literacy is to examine in great detail one or two examples of scientific thinking. One hopes that by exposing the students to the scientific method and the scientific view of the world, one might encourage them to learn more on their own and incorporate the scientific mode of thought into their lives and work.

I have always been an advocate of the first approach to scientific literacy, but I am aware that many of my colleagues prefer the second. Alan Lightman, a prominent astrophysicist and author, has taken the second road in *Great Ideas in Physics*. Lightman looks at four general areas of science: conservation of energy, the second law of thermodynamics, relativity (particularly special relativity), and quantum mechanics (particularly the problem of wave-particle duality). Based on a series of lectures he gave to Princeton University undergraduates, this book looks at these four questions in some detail and depth. Lightman's hope is that the student who is exposed to these ideas will be able to understand better the world in which he or she lives.

Experienced teachers will recognize that Lightman has chosen some of the most difficult topics to explain to nonscientists. He does an excellent job dealing with the hard physics: He presents each topic without apology and with the expectation that the student will be able to follow mathematical arguments at the level of elementary algebra. For example, he explains the second law of thermodynamics in the context of the allowed states of a system. This is a fairly sophisticated notion, but Lightman makes it seem reasonable that the abstract counting that goes into his arguments is relevant to deep questions such as the direction of time and