Books

THE PHYSICISTS
The History of a Scientific Community in Modern America

by Daniel J. Kevles

Alfred A. Knopf $15.95

Reviewed by Robert F. Bacher

Some years ago when Daniel Kevles met I. I. Rabi, the much respected physicist, Rabi asked him, "Why doesn't someone write about my generation of physicists? . . . After all we changed the world." His special twinkle accompanied this purposely provocative and exaggerated statement, and their further discussion did much to encourage the author to write this book.

Daniel Kevles started out "to study the scientists who came to professional maturity after World War I, mastered the atom, then built the bomb and rushed the world for better or worse into a fundamentally new era." He came to realize that to get a proper perspective he needed to go back to the earlier days of physical science when it was just beginning in America after the Civil War. His digression for perspective comes close to taking over the book from his original purpose.

Most research in physics in the last quarter of the 19th century, with the exception of the work of Willard Gibbs and a very few others, was carried out in Europe, and the education of most physicists was completed there. Kevles has written a most interesting and lively history of this early period including much not known even to the older generation of present-day physicists. He has carefully outlined the heavy dependence of physics in America on the work of the Europeans, especially on their theoretical work. Just before the turn of the century X-rays were discovered by Roentgen and radioactivity by Becquerel, and the latter discovery was greatly extended by the Curies. Soon thereafter J. J. Thomson discovered the electron, and the revolution accelerated with Planck's quantum ideas and Einstein's special theory of relativity. Soon came Rutherford's brilliant experiments leading to the nuclear atom, and then came Bohr's revolutionary theory of the atom.

The account of what physicists were doing meanwhile in the United States and how they related to the physical science revolution in Europe is a thorough and scholarly job, with many references to then current accounts and private papers. Kevles particularly focuses on the people and their interactions with each other, with the federal government, and with society in general.

At about the same time as the physical science revolution in Europe, physics in the United States had reached a stage where there were enough interested physicists to start the American Physical Society. Kevles focuses particularly on one of the Society's founders, Henry Rowland of Johns Hopkins, an extraordinary experimenter who ingeniously made diffraction gratings that were in demand all over the world. Rowland was a strong believer in quality in physics—best science, or scientific elitism as Kevles calls it. This is a theme that Kevles follows throughout the book, pointing out the conflicts which increasingly arose with the use of federal money. Political representatives demanded that federal funds be distributed widely geographically and used for purposes that were deemed socially desirable. The conflict thus generated had been experienced by John Wesley Powell, the colorful conqueror of the Colorado, who had used his considerable popularity to keep the western arid lands reserved.

During the first 20 years of this century there was a rapid growth of physics in the United States, both in research and teaching. The account of the contributions of the better known scientists of the day—Hale, Lyman, Trowbridge, Michelson, Millikan, Langmuir, Nichols, Webster, and numerous others—to the advance of physics, and of their efforts to make contributions to the First World War is set forth well.

After the First World War physics, stimulated by the scientific revolution in Europe and by vigorous entrepreneurial scientific leaders in the United States, grew by leaps and bounds. In the twenties, physics in the United States, especially experimental physics research, began to be more nearly comparable with physics in Europe. This was promoted by numerous visits from famous European physicists, including Bohr, Einstein, Planck, Sommerfeld, Schroedinger, and others, and by the advent of quantum mechanics, which was quickly taken up by many European-trained U.S. physicists. It was also helped by the immigration of many excellent young European physicists, and this influx was greatly accelerated when the Nazis came to power. By the early thirties, physics research in the United States was close to the best in Europe in spite of the serious setback due to the Great Depression. All this is recounted by Kevles with thoughtful perspective and documentation.

By the time of Pearl Harbor, the United States was leading in physics research, and in addition a few engineering schools had added sophisticated applications of science to their training, as had the leading industrial research laboratories. Well before Pearl Harbor, scientists were being mobilized by the NDRC and later by the OSRD, led by Bush, Conant, Karl Compton, and others. The projects that were immediately taken up—microwave radar, the proximity fuze, ordnance and rocket research, loran, and the speculations about a nuclear chain reaction and an atomic explosive—enlisted mainly physicists, since some of these subjects were unknown to most engineers. Furthermore, the engineers were all employed on immediate projects in airplane design, ordnance, electronics, and other fields.

Physicists who had learned to be hardheaded during the Depression quickly took to these new developments, and the rate of technical advance was phenomenal. As a result neither physics nor physicists have ever been quite the same as they were before World War II. The war forced physicists to work on practical problems that needed immediate solutions. The transition from basic science to applied research to development and manufacture, which previously went at a snail's pace, accelerated and this has continued.

The Kevles account of World War II hardly does justice to much of the technical development except radar and the atomic bomb. Even though proximity fuzes, rockets, and many other developments made an enormous impact on the war, they are scarcely mentioned. The whole treatment is comparable in length to that of the First World War, although the technical contribution to the war effort was much greater. Even this treatment is relatively more extensive than the entire period from the end of the war to the present, which is compressed into less than 20 percent of the text proper. Inasmuch as this covers a period in which there have been enormous advances in solid state, low temperature, quantum optics, astrophysics, as well as nuclear and high energy physics and, in addition, applications to other sciences and to technology and industry, the compression puts the treatment out of balance with the earlier history.

Kevles includes a thoughtful chapter on the attacks on science, especially during the late sixties when relatively large federal funds were devoted to research and development in the physical sciences. He notes that critics were advancing arguments that these funds might be better spent to solve social problems than for basic scientific research. He does not, however, make it adequately clear that most of these funds were allocated to specific projects directly determined by the government appropriation, and of these allocated funds most were earmarked for development, test, and evaluation related to these projects. Although it is difficult to be sharp in these categories, most of the funds are not for basic research. The funds for basic research comprise roughly 10 percent of the total and are directed at getting a better understanding of fundamentals on which to build for the future. Often during World War II, projects came against brick walls for lack of basic knowledge.

Daniel Kevles has written a good history of physicists, especially in the United States. It is a scholarly book, with interesting anecdotes that give a feeling for the human qualities. Accuracy is mostly good—although it would have been physically impossible, as stated (p. 368), for McMillan to use the direct current magnet, previously a part of the Berkeley cyclotron and the wartime calutron, for his first electron synchrotron. Also, Los Alamos is not located in the Sangre de Cristo Mountains (p. 329) but on the mesas below the Jemez range west of the Rio Grande.

The last third of the book is unfortunately greatly compressed in dealing with an enormously enlarged and strengthened physics community. Also it is mainly concerned with interactions with Washington and the federal government. Even the last chapter is mostly devoted to happenings of the mid-sixties. This is particularly unfortunate in view of the changing views in Washington, the reinstatement of a science adviser. and the realization expressed more than once recently in Washington that even the most needed applications cannot continue to go forward without understanding scientific fundamentals.

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THE NEXT EIGHTY YEARS

California Institute of Technology $3.50

Reviewed by Bruce E. Cain

The Next Eighty Years is the third study in a series initiated by James Bonner, John Weir, and Harrison Brown in 1957. The intent of the first book, *The Next Hundred Years,* was to identify world trends in population, natural resources, food, industrialization, and technological change. Subsequent studies have tried to revise earlier forecasts and, in the process, to refine the art of prediction by asking where and why previous estimates went wrong.

Apparently, as Harrison Brown tells us in his introductory essay, where they went wrong was not so much in what they said, but in what they did not say. In particular, the two previous studies neglected environmental problems, such as the effects of increasing carbon dioxide in the atmosphere, and underestimated the vulnerability of industrialized societies to disruptions like the Arab oil embargo of 1973.

The present volume, based on a conference held in April 1977, attempts to remedy these shortcomings with essays on the effects of climatic change by Stephen Schneider, solutions to the energy crisis by John Teem, and the future of Japan and the United Kingdom by Michio Nagai and Lord Ritchie-Calder respectively. In addition, *The Next Eighty Years* further develops some topics introduced 10 and 20 years ago with discussions of population and poverty by James Bonner and James D. Grant; health care by David Hamburg and Sarah Spaght Brown; and problems of the third world by Marin Maydon, Marcus Franda, and Thayer Scudder.

Given the diversity of topics, authors, approaches, and disciplines

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Accelerator Center was about $114 million; in current dollars, the cost would be much greater. What will happen if it becomes clear that there are specific cancers which can be cured only by treatment with such enormous machines? Will they appear in every doctor's office, costing a quarter billion dollars? Clearly not. There will have to be some kind of system (a) to insure that the therapy is both efficacious and of an acceptable cost/benefit, risk/benefit ratio; (b) to spread that cost in some equitable fashion; and (c) to ration access to the machine in some appropriate way. Such requirements will probably mean that as new, expensive treatments are developed, reimbursement or even use of the treatment will be contingent on the provider and/or patient being enrolled in a national, carefully controlled clinical trial. Such trials are the only mechanism currently available to generate the risk/benefit data required for the rational use of health care resources. They can also assist in controlling the dissemination and proliferation of technologies that have not been adequately assessed.

One further aspect of the organization of health care that is likely to be increasingly important in the future is the multi-specialty group practice concept; one branch of this tree has come to be called "health maintenance organizations," or HMO's. The pooling of physicians and other health professionals is clearly a concept that will gain increasing utility in the years ahead. It is easier for health professionals to keep up with new developments if a collective approach is taken. It is easier to provide 24-hour, 7-day coverage and emergency services through a group practice rather than through a solo practitioner. At the same time, it is possible to preserve to a large extent the individual doctor-patient relationship. Group practices seem to produce a kind of mutual-aid ethic, which will probably continue to grow, in the form of more health maintenance organizations, and other forms of organized health care settings will increasingly be linked to the workplace. In any event, both the workplace and the school are likely to be used more for preventive medicine and health education.

While the developments sketched here seem reasonable to project over the next several decades, it is possible that transforming influences beyond our present vision may have impacts far beyond those noted. The world we have made through science and technology since the Industrial Revolution has little precedent. As we move into a complex future at rates of change unknown to our early ancestors, we must develop a broader science base and a more compassionate society, not only to cope with disease and disability, but to improve the quality of life altogether—and perhaps even to survive as a species. □

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represented in this volume, it is impossible to identify any single unifying viewpoint. Nonetheless, all of the essays do seem to address certain basic questions. One of them concerns identifying the problems future generations will have to face. Can we predict with accuracy the nature and extent of future world problems? Brown and his colleagues are pleased with their past performance. On the whole, Brown tells us, their "batting average" has been pretty good. Twenty years ago, for example, they predicted that there would be close to five billion people inhabiting the earth by the year 2000. As things stand in the seventies, the world population is currently over four billion and still rising. They also predicted that petroleum production in the contiguous United States would peak in 1970, and this too proved to be correct.

At the same time, there were notable failures. In addition to neglecting environmental problems and not foreseeing the vulnerability of industrial societies to boycotts of essential materials and services, Brown and his associates, like others in the fifties, overestimated the demand for PhD's in engineering and science. Moreover, while they predicted the depletion of petrofuel resources in the United States, they were overly optimistic about the future of nuclear energy as a replacement. They did not anticipate the rising concern for public safety in the seventies.

What this seems to suggest is that both changes in conditions per se and in social goals and values can complicate the task of prediction. Viewed retrospectively, the supply and demand of nuclear energy depended upon changing perceptions about the value of a safe environment, as well as upon the costs of development and the availability of resources. Apparently our success in predicting future problems hinges in part upon our ability to say what the goals and values of future generations will be, and that is a very difficult task.

Can one identify future world problems with a high degree of accuracy? Most social scientists think not. The future is characterized by too much uncertainty to project accurately 100, 90, or even 80 years ahead. On the other hand, thinking about future world problems might still be a valuable exercise per se if it forces us to consider the long-range implications of the choices we make now, or if it brings us to think about the obligations we owe to future generations.

A second concern uniting these studies is whether we have the technology to solve anticipated problems. I detect an important progression in attitude on this question from the first to the third book. In *The Next Hundred Years* the authors were extremely optimistic about the prospects of discovering new technology and applying it to solve the world's problems. Commenting, for example, on the issue of food shortages, they said in 1957, "If we can produce sufficient quantities of energy and expend it properly in the production of food and materials, we can meet the demands we foresee for the future. All we need do is add sufficient energy to the system, and we can obtain whatever materials we desire."

Twenty years later, that optimism had dimmed somewhat. As James Bonner points out, despite the Green Revolution in agriculture, the food situation in the third world has deteriorated: 65 percent of the third world receives 250 calories less than is required for optimum nutrition. Moreover, during the last eight years, the food *deficit* has grown at a rate of about 1 percent per year in the developing countries despite a 10 percent increase in the tilled acreage of the world and a higher production per acre due to more irrigation, more fertilizer, high-yielding strains of crops, disease-resistant plants, and the saturating use of pesticides.

Why haven't technological advances solved the food crisis? Bonner cites several factors. One is that while food production in the underdeveloped countries increased by 1.5 percent per year, population increased by 2.4 percent. World problems tend to be interrelated; you can't solve one without addressing the others. Another constraining variable is that the technology of higher food production has inherent limits; as Bonner explains: "The Green Revolution can only work in places that are good for agriculture, with good climates, good water supplies, good soils. It is not yet suitable or applicable to tropical soils, which, when denuded of their hardwood canopy, quickly become eroded and sterile." Thirdly, and perhaps more importantly, there are social and political constraints: the obsession of developing-nation politicians with impressive projects to the neglect of agriculture, corruption, extreme maldistribution of income, and cultural prejudices that favor inefficient meat over vegetarian diets.

One cannot help but notice the progressively political orientation of these studies. In 1967, the contributors to *The Next Ninety Years* still had faith in technology, but they were more conscious than they had been 10 years earlier of the political and social dimensions of world problems. "Science and technology," they told us then, "have given us the power to create a world in which virtually all people can lead free and abundant lives . . . yet, somehow, we can't seem to organize ourselves to use that power effectively to solve mankind's basic problems." Political factors figure even more prominently in *The Next Eighty Years*. With a few exceptions, the contributors to the third volume touch upon political and behavioral as well as technological problems.

This leads us to the third question; namely, can we effectively implement the technology we have, in order to solve world problems? There are two reasons to be guarded in our optimism about these matters. First, decisions about which goals to attack inevitably involve disagreements over priorities, and these priority conflicts can stand in the way of solving problems like poverty and starvation. The contributors to *The Next Eighty Years* offer several examples.

Thayer Scudder writes of the biases in African states in favor of the urban-industrial sector. Agricultural prices are often kept artificially low for the benefit of urban consumers, and showcase projects like dam construction are designed primarily to provide hydroelectric power for the city and industries with little regard for the impact on local rural communities. An obsession with military power is another common competing priority.

Marcus Franda explains how the Indian government's obsession with maintaining a large army—the third largest in the world—diverts valuable resources from health care, agricultural development, and antipoverty programs. Given that none of the Indian political parties dares to advocate diminishing India's military capabilities, Franda despairs of reallocating much "of India's resources out of military-strategic and heavy industry kinds of things and into rural-oriented development matters."

The problem of conflicting priorities does not belong exclusively to developing nations. Other priorities may prevent industrialized nations from tackling the energy crisis or dealing with world poverty. A greater appreciation for the environmental costs of unrestrained development may restrain us from fully exploiting our energy resources. Moreover, as John Teem points out, "trade-offs that are politically desirable in developed countries may be viewed from quite a different perspective in the less-developed countries." Developing countries may not "want to pay the necessary costs for a clean environment, to the same extent that the developed countries do." Such post-industrial second thoughts may create real obstacles for developing countries in the future.

Even when a nation decides that it really ought to do more about poverty, circumstances can conspire to prevent it from carrying through on its resolve. As Maydon tells us, Mexico wanted very much to redirect its efforts into the industrial sector during the seventies but found that the need to slow down growth in order to correct a growing deficit in the balance of payments and the difficulty of redirecting funds from old to new priorities thwarted its intentions.

Thus, divisions in goals and priorities can make it hard for society to organize itself effectively in order to apply technology to the solution of pressing problems. Sometimes, however, institutions that mediate conflicts over goals can become obstacles themselves. The function of a polity is to provide a mechanism for making and enforcing public choices where there are conflicts over goals and values. One of the real dangers in developed countries is that their political and economic systems may ossify and become institutionally resistant to beneficial change and innovation. Michio Nagai hints at this prospect in Japan and suggests that, like Britain before it, Japan may lose its industrial preeminence to upstart competitors like South Korea.

Even when technological innovation offers the prospects of material improvement, there are strong incentives in developed economies to continue with the old technology. Studies have shown how it is often in the interest of both managers and workers to inhibit competition in the market, and to slow down the rate of technological innovation even when it is not in the long-range interests of the society as a whole. In addition, the role of vested interests in political parties and the desire of politicians not to rock the boat can bring the force of the government on the side against innovation and change. This has been the bitter experience in Great Britain during the last 25 years.

Thus, the key issue for the future in America may not be a particular set of problems per se but whether our political and economic institutions will be prepared to deal with new problems, whatever they turn out to be. Can we design our institutions so that people cooperate efficiently but without excessive coercion? Can we undermine the incentives that are resistant to change and innovation and prevent the ossification of political and economic institutions in countries like Britain, the United States, and Japan? These are the questions that emerge finally from these studies, and that require the urgent attention of scientists and social scientists alike.

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DYNAMIC ECONOMICS

by Burton H. Klein

Harvard University Press $15.00

Reviewed by Edward A. Schroeder IV

Those of us who took Professor Burton Klein's course on the economics of technology at Caltech several years ago used to wonder if he would succeed in getting his many ideas collected together in written form. The book finally made it into print in 1977, as *Dynamic Economics.* The delay in publishing was probably just as well, since many of the references in the book are to work published in the last few years.

Several of this wide-ranging scholar's favorite subjects show up in this book: Thomas Kuhn on scientific revolutions (briefly), Thomas Jefferson's ideas on dynamic processes (frequently), and the history of the automobile and aircraft manufacturing industries (in detail). It is a pleasure to read an economist who can make use not only of various material from economics but also such diverse subjects as thermodynamics, Maslow's theories of personality, Feynman and Heisenberg on science, and various issues in engineering.

I believe that most economists have a far better grasp of the "static" than they do of the "dynamic." In fact, when many so-called dynamic models are really only embellished static models, it seems fair to say that economists have not yet agreed on how to approach dynamic questions, although we can agree on their importance. To his credit, Professor Klein has taken on difficult questions in his book; the answers to these questions will not come easily.

Professor Klein argues that the traditional economic concept of efficiency is a static one, and that a new dynamic concept of efficiency, which may well be in conflict with static efficiency, is needed in order to answer the real questions about an economic society. His dynamic definition of competition is quite different from the standard approach. His policy prescriptions for promoting private inventive behavior through public promotion of proper risk is certain to be controversial.

The book, of necessity, covers only a small part of what is required in order to develop a useful, workable theory of dynamic economics. However, I believe that Professor Klein's insights and wide range of interests have produced a book that will be of help to future investigators in this area.

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