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Book Reviews

Reflections on Big Science. By Alvin M. Weinberg. The MIT Press, Cambridge, Massachusetts (1967). 182 pp. $5.95

Dr. Alvin M. Weinberg has been the dynamic and effective Director of the Oak Ridge National Laboratory for eighteen years. He has served with distinction as a member of the President's Science Advisory Committee and other scientific advisory groups. In these capacities he has had to think through some difficult questions about science and the interrelationship among science, government, and society. This little volume is based on speeches Dr. Weinberg has given on thses topics, revised and expanded to provide a unified account of his philosophy of science and the justification for big science in modern society.

In the first essay, "The Promise of Scientific Technology: The New Revolutions," Dr. Weinberg examines the implications of the energy revolution which would be brought about by low-cost breeder reactors and the information revolution created by high-speed, large-capacity computers. To many, including this reviewer, Dr. Weinberg's expectation that breeder reactors will generate electricity for as little as 1.5 mills per kilowatt hour seems a little overoptimistic. But Dr. Weinberg is on firm ground in pointing out that low-cost nuclear energy would enable the world to support a population much greater than today's, under far better living conditions than today's average. With such low cost energy, it would be economically feasible to produce fresh water from the sea to irrigate potentially fertile but arid lands, to produce fertilizers in abundance, and to extract metals from ores now too low-grade to be utilized. Abundant, low-cost energy is indeed a key to an abundant economy. Dr. Weinberg's eloquent description of how low-cost breeders could revolutionize industry and his clear belief that low-cost breeders can be developed challenge and inspire us all to succeed in their development.

In "The Problems of Big Science: Scientific Communication," Dr. Weinberg writes of the difficulty of today's scientist in assimilating the rapidly growing body of scientific information. He acknowledges that computer-aided indexing and retrieval of documents is helping the scientist to keep abreast of the flood of information, but he suggests several less well-recognized measures in addition, for example, that more able scientists be encouraged to make major commitments of time and energy to streamlining the flow of scientific information, and that a scientist be honored as much for creativity in disseminating information and facilitating its assimilation as in making fundamental scientific discoveries. He makes a strong plea for use of better English in technical writing and suggests that a study of how the structure of a language looks to the human brain might lead to a technical language that is "graceful, easy to write and easy to comprehend." Dr. Weinberg's writing is a splendid example of such a language.

In the four essays grouped under the heading "The Choices of Big Science," Dr. Weinberg asks and answers the difficult question: What are the criteria which government should use in deciding how to allocate support among diverse scientific projects and fields? He concludes that these should be evaluated in terms of scientific, technological, and social merit. A measure of the scientific merit of one field of science is the extent to which it contributes to and clarifies related scientific disciplines, as molecular biology clarifies genetics. Technological merit is judged by the extent to which a branch of science makes possible engineering advances, as low energy nuclear physics now contributes to development of breeder reactors. Social merit is judged by the extent to which a branch of science helps solve the problems of society; research in high energy physics, for example, might have social merit if, conducted with cooperation between the nations of East and West, it contributed to lessening of international tensions. To illustrate his criteria, Dr. Weinberg assesses five fields of science which now are heavily government supported: molecular biology, high-energy physics, nuclear energy, manned space exploration, and the behavioral sciences. Molecular biology is rated highly on all three bases–scientific, technical, and social. High energy physics is rated much less favorably, as it contributes little to other fields of science and has little obvious technical or social value, except as a vehicle for international cooperation. Nuclear energy is rated very highly for technical and social benefits. Manned space exploration is rated poorly on all counts. Behavioral sciences are regarded favorably because of their clear relation to the problems of society.

Dr. Weinberg then asks the question: How much of its resources should society allocate to support of science? For applied science he concludes that the appropriate extent of support can be determined by considering the cost of alternative non-scientific means to achieve the same beneficial result to society. For example, if the social objective were to control population in India, the amount which might justifiably be spent on research on fertility in India or social customs in Indian villages bears some relation to the cost of distributing contraceptives in India. This criterion seems somewhat artificial, but most men would agree that some kind of cost-benefit argument is a proper basis for deciding the degree of support appropriate for a field of applied science. Dr. Weinberg has more trouble with the question of the appropriate degree of support for basic science. He suggests that support for basic science might be regarded as an overhead charge on support for applied science. He expresses the hope that intellectual appreciation of basic science may someday become so general that society can justify support of basic science for the same reason that it today supports the arts.

Dr. Weinberg devotes a chapter to a persuasive plea for massive support of biomedical science, both because of the great social value of the improved general health it is likely to make possible and because of the way in which the biomedical sciences interact with and enrich the physical sciences and the social sciences.

In the fourth and last collection of essays grouped under the heading "The Institutions of Big Sciences," Dr. Weinberg considers the relations between the large federal laboratories and the universities, and the roles appropriate to each type of institution. Dr. Weinberg is at his best in discussing the missions of the federal laboratories, how they choose their goals, obtain their support, and organize their effort. Their task is to organize a multi-disciplinary attack on the complex technical or social problems of society. Examples of today's goals are nuclear energy, fusion, manned space flight, control of disease. Appropriate goals for the future suggested by Dr. Weinberg are production of fresh water from the ocean, control of atmospheric pollution, civil defense, urban renewal, mass transportation. In the federal laboratories, the mission is dominant, and individual sciences and scientists cooperate in accomplishing the mission.

In the universities, Dr. Weinberg contends that the individual disciplines are dominant, that science is pursued primarily for science's sake, and that there is little interaction or cooperation among disciplines. This reviewer agrees that this judgment is occasionally valid, but wishes to cite one example of university activity which is not undesirably fragmented. Mission-oriented departments of engineering schools, such as departments of aeronautical or nuclear engineering, are as good examples of cooperation among diverse disciplines pursuing common goals as can be found in any of the federal laboratories. Dr. Weinberg makes the sound judgment that the primary aim of the university is education, and that the justification for research at a university must be its contribution to education. He points out how federal laboratories and universities can assist and strengthen each other by engaging in joint endeavors and sharing staff, and concludes by expressing the hope that the "Universities and federal laboratories, instead of competing, will continue mutually to reinforce each other to the great advantage of the society that supports them."

In his Preface, Dr. Weinberg writes: "I hope that my essays contribute to clarifying the issues and . . . that they help catalyze the debate both among those that agree and among those who disagree with me on the relation between modern society and modern science." This reviewer concludes that Dr. Weinberg's hope has been admirably achieved in this well-written and thought-provoking volume of essays.

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About the Reviewer: Manson Benedict is Professor of Nuclear Engineering at the Massachusetts Institute of Technology and Head of the Department. His association with nuclear energy has been long and varied, beginning with the technology of gaseous diffusion in 1942, to which he made very significant contributions. He has been chairman of the Atomic Energy Commission's General Advisory Committee and President of the American Nuclear Society. Dr. Benedict's graduate studies were at MIT.

Erwin Schrödinger: An Introduction to His Writings. By William T. Scott. University of Massachusetts Press, Amherst (1967). 175 pp. $6.50.

Most physicists today have come into physics after the full development of quantum mechanics and take this development for granted along with the rest of physics. This book gives them the opportunity to experience something of the spirit of the decade of the twenties (when matrix and wave mechanics were being discovered), through a searching analysis, both critical and sympathetic, of the scientific papers and books of one of the key figures of this startling decade.

The first part is an excellent biographical sketch of the man, Erwin Schrödinger, a delightful human being, as well as a scientist and a philosopher. The reader is then introduced to his thought and achievements through an introduction to his writings. The great Boltzmann had the most profound influence on the young Schrödinger, and his early work was devoted to a variety of papers on the statistical mechanics of gases, solid state applications, specific heats, and the like. Next, there is a review of the development of wave mechanics from Bohr and Sommerfeld through Heisenberg, Dirac, and DeBroglie, followed by a description of Schrödinger's by-now famous series of 1926 papers on wave mechanics. These papers cover the Schrödinger equation; the hydrogen atom, oscillator, and rigid rotator solutions of it; steady-state and time-dependent perturbation theory; and the important *Zitterbewegung* of the Dirac electron.

The remaining sections of the book are devoted to an illuminating survey of the interpretation of quantum mechanics in which Schrödinger was an active participant, and to his philosophical writings on nature, the self, life, and the relations of science and the humanities. For both of these topics, the author shares with his subject a breadth of understanding and interest unusual in the majority of physicists. This circumstance, combined with the historical approach, makes unusually valuable and perceptive the chapter on the interpretation of quantum mechanics in terms of the relation between waves and particles, the fate of the wave function when a measurement is made, configuration space, indeterminacy, etc. The last chapter, which deals with much broader philosophical questions, was for this reviewer the most interesting and provocative of all. It makes valuable reading for those in any field of science, and brings out the great breadth of interest and the capacity of both mind and spirit which marked Schrödinger.

This book is an important contribution to the history of twentieth century science. The author was unusually well fitted for writing it, and has certainly done a great service in undertaking the task. It makes rewarding reading and is highly recommended.

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About the Reviewer: Bill Pollard is a physicist, an administrator, and a theologian. His active academic career, as professor of theoretical physics at the University of Tennessee, was interrupted when the war took him into research on uranium isotope separation by gaseous diffusion; he stimulated the formation of Oak Ridge Asso-