The book is dedicated to Anatoly Marchenko, who will long be remembered for his courage and persistence, a martyr to human dignity who was killed in Christopol Prison. It might have been Yuri Orlov who was killed, as he struggled to change that "tragic human experiment of scientific socialism." As he battled against a regime that had destroyed sixty-five million souls, the fact that he remained alive is a miracle. He knows what it means to say, "Our dreams may be the loveliest on Earth, but if we wade through blood and terror to achieve them, we will arrive to find ourselves destroyed. Don't kill."

ANDREW M. SESSLER
Lawrence Berkeley Laboratory

Redirecting Science: Niels Bohr, Philanthropy and the Rise of Nuclear Physics

Finn Aaserud
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Redirecting Science is a very close examination of the transition at the Institute for Theoretical Physics in Copenhagen in the mid-1930s from a preoccupation with issues of principle raised by relativistic quantum mechanics and with epistemologic problems in physics and biology, to an experiment-oriented research program in nuclear physics. "The main thesis of this book," Finn Aaserud reminds us in the conclusion to *Redirecting Science*, "can be summed up in one sentence: the transition depended on Bohr's response to and action on changes in funding opportunities for international basic natural science, particularly as represented by the Rockefeller philanthropies." For this thesis the preceding 250 pages provide a clear, carefully developed and substantially convincing argument. Thus Aaserud has provided an important counterexample to the contention that factors external to physics may affect the rate but not the direction of its development, and indeed a challenge to the more concessive contention that external factors may affect the direction but not the content of that science.

Aaserud, now director of the Niels Bohr Archive in Copenhagen, created this book as an elaboration of his Johns Hopkins doctoral dissertation, while serving as an associate historian at the American Institue of Physics's Center for History of Physics. Thus it is with knowledge and sympathy that he draws upon the reminiscences of Bohr's junior collaborators regarding the "Copenhagen spirit," a continuing, self-directing discussion of general conceptual problems, to set the scene and raise the issue.

A chapter on science policy and fund-raising up to 1934 introduces the Rockefeller Foundation and its International Education Board, headed by Wycliffe Rose, whose motto it was "to make the peaks higher" in the belief that doing so "affects the entire system of education and carries with it the remaking of civilization." This conception, together with an all-too-common philanthropic delight in shaking hands with stars, made the foundation's officers extremely receptive to the approaches of the indistinct Dane, who had by 1924 received from three foreign countries more generous offers of professorial research posts than had any other scientist in modern history—Einstein *not* excepted. With the support provided by Rockefeller philanthropy, especially that in the form of postdoctoral fellowships, the number of visitors and publications at Bohr's institute reached a peak in 1927, coinciding with the launching of the "Copenhagen interpretation" of quantum mechanics.

In the following six years, however—the real heyday, one might say, of the "Copenhagen spirit" and the period in which Bohr with a coterie of junior theorists sought the limits of quantum theory and of knowledge generally, but neglected the experimental work of his institute and the tasks of fund-raising—"the scientific activity there, as measured by the number of scientific personnel and publications, fell dramatically." Aaserud gives a detailed and impressively documented account of the direction of Bohr's scientific interests in this period, stressing his efforts to impose upon biology on the one hand and nuclear physics on the other the renunciatory epistemology that he had drawn out of nonrelativistic quantum mechanics. In so doing Aaserud takes particular pains to identify the moment at which, and the connection in which, Bohr turned away from such issues of principle to involve his institute and himself in concrete experimental and theoretical problems of the rapidly advancing field of nuclear physics—and, coincidentally but not accidentally, in the practical problems of coordinating experimental biophysical research at a number of Copenhagen institutes.

This transition, Aaserud shows, began in the spring of 1934, was firmly decided by the autumn and was completed the following year. With it came a major change in Bohr's scientific–epistemic stance, from a reactionary radicalism to a progressive conservativism. Reinstating "the unity between theory and experiment that a decade and a half before had provided his motivation for establishing the institute in the first place," Bohr gave up pontificating about the ineffability of life, gave up his campaign to force nonconservation of energy upon nuclear theory, gave up his resistance to the too facile solution offered by Fermi's theory of beta decay, and gave up his insistence that nuclear systems must be described by essentially different dynamics than atomic systems. He contented himself instead with merely a very different degree of interaction among these systems' constituent particles—thus leading him to the liquid-drop model and the theory of the compound nucleus.

The opportunity whose seizure effected this renovation, revitalization and redirection of Bohr's institute, and of Bohr's own thought, was provided by the availability, indeed the enticement, of large funds, above all those of the Rockefeller Foundation. In 1933, after a hiatus of a few years in which the unfocused International Education Board had been phased out, Rockefeller Institute the launched a program pushing the application of the armamentarium of the physical sciences to biology. Simultaneously, the Rockefeller Foundation instituted an emergency program to relocate senior scientists forced from their positions by the Nazi regime. Bohr seized this twofold opportunity for a range of reasons, of which Aaserud stresses his wish to provide research facilities for his friends James Franck and George Hevesy, who had been dislodged from the universities of Göttingen and Freiburg, respectively. Although Aaserud steers clear of psychoanalyzing Bohr, the possibility of psychodynamic grounds for this reorientation is perhaps to be inferred from a brief paragraph referring to the drowning of Bohr's eldest son in the summer of 1934, while sailing with his father. With this grievous loss could Bohr perhaps finally have been free to renounce renunciation?

Bohr's genius as a policymaker, Aaserud concludes, "lay in completely separating his extrascientific efforts from his collaboration with the young physicists visiting the institute." This technique of compartmentalization, which was to become so characteristic of the pursuit of physics in the decades following World War II, succeeded all too well. The senior physicists practicing this technique, quite as much as those they intended to shield thereby from "misleading" knowledge of the scientific life—we all have been misled by it in our view of physics and its history. Aaserud is therefore to be congratulated for his original, clear—indeed, didactic—work of scholarship and enlightenment, vivified by some 40 photographs, of which the great majority are refreshingly new to the history of physics literature.

PAUL FORMAN
Smithsonian Institution and New York University

Chaos in Classical and Quantum Mechanics

Martin C. Gutzwiller
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Quantum mechanics is clearly a very successful theory. The use of Schrödinger's and Heisenberg's equations to solve microscopic problems has led to innumerable explanations and predictions of physical phenomena. However, in a sense quantum mechanics is not an independent theory, because to formulate its problems one needs to "quantize" the classical version of the problem.

One of the important heuristic pillars of the early formulation of quantum mechanics was Bohr's correspondence principle, which states that a quantum mechanical system should approach the behavior of its classical counterpart in the limit of vanishing Planck's constant $\hbar$ divided by an appropriate action. It is now well known that this simple prescription has problems because in many cases the quantum mechanical quantities show nonanalytic behavior in this limit. The prescription is fulfilled, however, in most of the problems considered by the forefathers of quantum mechanics because they mostly considered classically integrable systems.

In recent years a large amount of literature has been devoted to the study of classical systems for which complete integration of the equations of motion is not possible, even in principle. It is now believed that the set of Hamiltonians that are integrable is actually of measure zero; that is, most Hamiltonian systems are not integrable. For the class of Hamiltonians that are nonintegrable it is found that although Newton's equations of motion are deterministic,