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.

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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,

their solutions show a sensitive dependence on initial conditions that leads to an ensemble of trajectories behaving essentially as though they were random or chaotic. A fundamental question immediately arises: To what extent can quantum mechanics reproduce the informational content of the classically chaotic solutions in the quasiclassical limit? Or, what are the quantum manifestations of classical chaos? Finding an answer to these questions is a nontrivial task because the mathematical and conceptual structure of the two theories is quite different.

The last 10 years have seen a real explosion of papers dealing with this general paradigm. The philosophy in many of these works has been to study in detail specific quantum mechanical problems that are known to be classically chaotic, in most instances with only two degrees of freedom. As a result, explicit quantum manifestations of classical chaos have been found, but many important questions remain unsolved. It has been shown that the quantum solutions mimic the classical trajectories for some time that depends in a nonanalytic way on $\hbar$. After this time the quantum problem reverts to a quasiperiodic evolution in time. The hallmarks of a quantum problem—for example, wave functions, eigenvalues, quasienergy spectrum and scattering phase shifts—show different properties when the classical problem is or is not integrable.

Martin Gutzwiller has played a pivotal role in formulating the general paradigm and in obtaining truly *tour de force* solutions to specific problems. Thus it was with eagerness that I awaited the printing of his book. *Chaos in Classical and Quantum Mechanics* contains a large number of important ideas and explanations, from the fundamental to the technical, with a sprinkling throughout of interesting historical notes. The general philosophy of the book is to construct quantum mechanics from classical mechanics using the path-integral formulation of quantum mechanics as a bridge. To carry out this program one needs to know a good deal about classical mechanics beyond what one can find in any of the standard textbooks.

The book is almost equally divided into classical and quantum mechanical parts. In the first part the author discusses basic concepts, including invariant tori, integrability conditions, Poincaré's surfaces of section, Lagrangian manifolds, the importance of periodic oribits, differential forms, Darboux's theorem, ergodicity, mixing and Kolmogorov's entropy. Although many of these topics can be found in more mathematically oriented monographs, Gutzwiller's intention is to discuss the main ideas behind these concepts from a geometrical viewpoint rather than to engage in long definitions, theorems and lemmas with proofs, which are often repellent to a practicing physicist. He does give ample references, often to original sources, where a more interested reader can find all the details needed to make the statements tight.

The second part of the book deals with quantum mechanics from the quasiclassical point of view. Here the prevailing idea is the Feynman path-integral approach to calculating quasiclassical propagators. The author's clear intention is to make the book useful to those who want to pursue what may be called quasiclassical physics, and it includes his strongly held views on the subject. It is here that the trace formula takes central stage. This formula, which entails summing over classical periodic orbits to obtain the quantum mechanical spectrum, was originally emphasized by Gutzwiller and is based on early work by John Van Vleck. The evaluation of the trace formula for specific problems is, however, a highly nontrivial exercise in asymptotic analysis. The author also discusses the statistical properties of classically chaotic systems, which have provided a successful, though not fully understood, scheme for classifying the quantum manifestations of classical chaos in terms of ideas originally introduced in random matrix theory.

This is an excellent book that allows an interested neophyte to penetrate the intricacies of what has been misnamed quantum chaos. It is also a good source of ideas and of citations of original works; it is a must for people working or planning to work in this field and even for a reader who just wants to know about some of the progress made. This is not a textbook. It has no problems at the ends of chapters, and by and large explicit derivations of results are not provided. Crucial concepts are elaborated in the context of solutions to explicit problems, many of which are problems to which the author has made important contributions: The author's long experience in this field led him to make a sure judgment on the selection of problems that mirror the areas in which he himself has worked in the last 20 years. Of course, in view of the explosion in the number of works related to the search for quantum manifestations of classi-

cal chaos, a book of this size cannot cover many other important developments on the subject. Nevertheless, I am convinced that this book will become a classic in the coming years, and I recommend it highly.

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