4. BEYOND PIONEER QUANTUM MECHANICS

"It must be emphasized that it is not a question of accepting the correct theory and rejecting the false one. It is a matter of accepting that theory which shows greater formal adaptability for a correct extension. This is a formalistic, esthetic criterion, with a highly opportunistic flavor."

John A. von Neumann (1955b)

4.1 INTRODUCTION

The new era of quantum theory began around 1932, and witnessed a maturation, many extensive developments, and a striking turn to an abstract structural approach. Important results of modern quantum theory, although easily accessible, are as yet not very well known. In spite of its urgency, the conceptual recasting of pioneer quantum mechanics has been slow. Even slower is the transference of successful reformulations into our textbooks which are still full of archaisms and inconsistencies; they hardly reflect the important progress made in the last two decades. In this chapter we shall attempt to give a brief outline of the main trends in the development of quantum theory since 1932. In this period, the new results have been so voluminous that it is necessary to limit our discussion and to select a few topics which are of special importance for the theory of molecular matter. Naturally the selection is in part guided by my prejudices, so my apologies are due to all those whose work has been ignored or insufficiently discussed.

The logical and philosophical foundation of quantum mechanics has interested many writers and has been the subject of hundreds of articles. These discussions were mainly critical and had but a small influence on the evolution of quantum theory. What scientists prefer is a creative approach, not just a critical one. The works that changed radically our basic point of view came not from philosophy but from mathematical physics.

One of the most notable features of the new era is the trend to higher levels of abstractions. There is a distinct tendency to move away from specific problems and to prefer comparative studies of the structure of physical theories. Nowadays, physical theories are characterized by
their abstract structural components. Quantum theory has become more abstract, hence simpler (for the initiate). The abstract of yesterday is the concrete of today. The classical pictorial models have been replaced by algebraic mathematical concepts, so that abstract algebra and functional analysis have become highly influential in modern quantum theory. Mathematics is no longer a mere tool for solving specific problems but the basic weapon to generate deep structurally based insight. Clearly, the increasingly mathematical character of science draws our attention again to the philosophical and practical aspects of the connection between science and mathematics. Moreover, there are important educational and sociological problems. According to Wightman (1969), "the older generation almost always regards the younger as 'too mathematical'".

Certainly, there are no a priori reasons to assume a fundamental parallelism between mathematical and scientific concepts. Nevertheless, the concubinage between physics and mathematics has never been an unhappy one. Probably the most important result of this joint undertaking is the gradual emergence of the idea that science is a symbolic construction of man: "... anstatt eines realen räumlich-zeitlich-materiellen Seins behalten wir nur eine Konstruktion in reinen Symbolen übrig" (Weyl, 1949a). If there is any unifying concept, it is very likely to be connected with symmetries. According to the modern point of view, we always should look for the underlying symmetry of a theory and amplify on the role played by the relevant group. More and more, theoretical scientists connect the ultimate reality to the underlying group itself.

The modern versions of quantum theory have been developed not out of a mere desire for greater generality but they have become imperative for a better understanding of thermodynamics and of the classical aspects of molecular matter. Recall that

(i) pioneer quantum mechanics cannot describe classical systems, hence it cannot deal in a proper way with experiments,

(ii) pioneer quantum mechanics is not appropriate to deal with systems having infinitely many degrees of freedom.

Several attempts have been made to analyze quantum mechanics by axiomatization. The basic aim of any axiomatization is to elucidate the logical foundation of the theory and to find the basic structures of physical theories like classical mechanics, pioneer quantum mechanics and thermodynamics. Not all of the currently popular approaches to an axiom-