One / Methodological Considerations for a Philosophical Approach to Science

THE PHILOSOPHICAL PROBLEMS raised by the experimental sciences have long been an object of interest to philosophers. Highly competent professional philosophers with a firm grasp of the scientific facts have conducted investigations into the epistemology of scientific research and discussed the information supplied by science. The number of such philosophers is so great and their names so well known that it would be pointless to detail their work here. And yet, despite all of these courageous efforts, a disturbing fact remains. A satisfactory integration of science and philosophy, though widely desired, still appears to be missing. The estrangement between the so-called two cultures provides the obvious, if sad, evidence for this state of affairs. It is my intention to discuss here the reasons for such a situation and suggest a method to overcome the impasse.

1.1 The Difficulties of Intercultural Dialogue

Probably one of the main sources of the intercultural split is the paradoxical situation that seems to prevail among scientists as regards philosophical investigation. They are not really refractory to this type of interest. Philosophical discussions keep coming up among practicing scientists. Creative scientists themselves write frequently on philosophical themes. And yet scientists as a group are wary of a dialogue with professional philosophers. Even those scientists who write about philosophical problems usually keep aloof from established philosophical schools. The principal reason for this behavior appears to be the following. The scientists are under the impression that the philosophers are facing the problems on their own terms rather than on the terms that appear relevant to the scientists themselves. To put the matter somewhat more bluntly, the scientists seem to resent the aprioristic systematism of the philosophers—as though in some way the

legitimate autonomy of science were not given its due recognition. Indeed, the fact is that the philosophers cannot start their investigation of science from a vacuum, but must possess some systematic conceptions to guide this very investigation. Now the scientists are sometimes inclined to think that the philosophers thereby force the scientific issues into some sort of pre-established logical system. A celebrated text of Einstein, answering the criticisms of some friendly epistemologists (Lenzen and Northrop) may serve as an illustration of this state of mind.[1] If one adds to this the embarrassment experienced by the scientists when confronted with the apparent lack of agreement among the philosophers themselves, it becomes clear why the intercultural dialogue appears so difficult.

1.2 Guiding Principles for a Philosophical Investigation of Science

The problem of the intercultural rift is so serious that it is necessary to obtain the willing cooperation of both scientists and philosophers to solve it. Hence an approach must be sought which, while preserving its philosophical character, will also appear meaningful to the scientists. This consideration lies at the root of the somewhat novel approach taken in this book. To clarify the issue, I shall premise some basic definitions, then discuss the requirements of a philosophical method that may meet the expectations of the scientists.

Science is defined here as the study—consisting in description and explanation—of the intelligible aspects of reality which can be discovered by any possible form of observational-deductive scheme. Science is thus characterized both by an object and a method. The object is reality as directly or indirectly observable to man. The method is experimental observation combined with precisely defined rules of mathematical calculation. Philosophy, on the other hand, is the study of the intelligibility of reality that can be attained through a systematic intellectual reflection on any kind of factual information. Philos-

1 "The reciprocal relationship of epistemology and science is of noteworthy kind. They are dependent upon each other. Epistemology without contact with science becomes an empty scheme. Science without epistemology is—insofar as it is thinkable at all—primitive and muddled. However, no sooner has the epistemologist, who is seeking a clear system, fought his way through to such a system, than he is inclined to interpret the thought-content of science in the sense of his system and to reject whatever does not fit into his system. The scientist, however, cannot afford to carry his striving for epistemological systematic that far. He accepts gratefully the epistemological conceptual analysis; but the external conditions, which are set for him by the facts of experience, do not permit him to let himself be too much restricted in the construction of his conceptual world by the adherence to an epistemological system. He therefore must appear to the systematic epistemologist as a type of unscrupulous opportunist . . ." Quoted in P. A. Schilpp, ed., *Albert Einstein, Philosopher-Scientist* (New York: Harper Torchbooks, 1959), 2 vols, p. 683f.

ophy, too, is characterized by both object and method. Philosophical investigation aims at discovering the nature of knowledge and the properties of reality which make it capable of being known by man. We can thus say that the object of philosophy is intelligibility as such, to be investigated both epistemologically and ontologically. Epistemology inquires about the criteria which make man certain of his ability to know. Ontology tries to grasp the essential properties and the mutual relationships of the beings which are accessible to human understanding. As for the method of philosophy, it consists essentially of intellectual reflection. Man meditates on his own personal experience as a knower in order to realize what knowledge actually is and what makes reality knowable.

When trying to formulate the guiding principles for a philosophical investigation of science, the first consideration that offers itself is that of taking science concretely. Such a principle is obvious, but not necessarily a truism. Einstein's well-known remark ("don't listen to their words, fix your attention on their deeds") remains an important piece of advice not only when one wants to understand the method of theoretical physics, but also when philosophical questions are the issue.[2] In particular, if science is to be taken concretely, one cannot consider it to be only a logical scheme of abstract axioms and mathematically rigorous deductions. Science must rather be seen as it really is, namely, a continually developing enterprise. It is the continual effort to discover new information and integrate it harmoniously into a growing body of knowledge which makes science so appealing to the philosophically minded observer.

The second methodological principle that recommends itself is to approach science as autonomous in its relation to philosophy. The relationship between science and philosophy forms a complex topic and cannot be discussed here in detail.[3] However, as far as the present study is concerned, we may assume, on the basis of the definitions outlined above, the mutual autonomy of science and philosophy. The two modes of studying reality are characterized by independent methods and objects; it will suffice to draw the conclusion following naturally upon this fundamental admission. If science is an autonomous activity relative to philosophy, the philosopher should begin by accepting the results of science as a fact, as a datum which is to be understood rather than questioned. In other words, the philosopher should not start by critically doubting, as though science were in need of philosophical

2 "If you want to find out anything from the theoretical physicists about the methods they use, I advise you to stick closely to one principle; don't listen to their words, fix your attention on their deeds," A. Einstein, *Ideas and Opinions* (New York: Crown, 1954), p. 270.

3 I have discussed this matter at length elsewhere. See my paper "Science and Philosophy: Some Reflections on Man's Unending Quest for Understanding" in *Dialectica*, **22** (1968), 132–166.

justification, but rather by experiencing wonder at the existence of science, its uninterrupted development, its increasing achievements.

The third methodological principle derives from the two foregoing ones. It concerns the aim of the philosophical investigation of science. Indeed, if science is an autonomous activity which the philosopher has to investigate in its concreteness, it is clear what the aim of the philosopher should be. It should consist in finding out in what sense science possesses an immanent, though inexplicit, philosophical structure of its own. The central point is that science has an immanent philosophical structure. Although the idea is not novel, it may be rewarding to enlarge on it a little. The history of science indicates that the creative scientists are motivated by a basically philosophical insight. That is to say, the first inspiration to scientific creation comes to them as a consequence of their asking fundamental questions about the nature of knowledge. These questions lead them to challenge the sufficiency of the interpretations of available data that other people take for granted, and a new insight is developed as a result. As an example, we may mention here the names of such trailblazers as Galileo and Einstein. Furthermore, even when a new scientific theory begins to take shape, it is still an implicit, but genuine, philosophical attitude that guides the scientists. Indeed, they proceed to develop hypotheses and theories by following precise, if implicit, philosophical principles. It is these principles that provide them with criteria for discussing and criticizing results, admitting or rejecting conclusions. In short, we can say that the creative scientist carries out an authentic and continual, though informal, philosophical activity, quite independent of the intervention of any professional philosopher. Both scientists and philosophers may object to calling the "natural" methodology of scientific investigation philosophical. Scientists may prefer to consider it a necessary attitude of the human mind when studying nature. Philosophers may dismiss it as something pre-philosophical. Yet it cannot be denied that, if we take philosophy as defined above, then the activity of the scientist necessarily falls into the realm of philosophy.

What then should be the role of the philosopher relative to science? His task consists in making the philosophically relevant aspects of science come to the surface, so to speak, and making them assimilable to others by giving them a clear and organic expression. In other words, we can speak of a negative as well as a positive role of the philosopher relative to science. Negatively speaking, he should try scrupulously not to read anything into, or away from, actual science. He should spare no effort in making sure that his assertions are about science as it actually exists rather than about some appealingly abstract scheme of logical relationships which are not the science they purport to stand for. Positively speaking, the task of the philosopher is that of giving an explicit formulation to the inherently philosophical aspects of science. He should give a precise expression to the philosophical principles which

as a matter of fact enable scientists to achieve their successes; he should discuss the philosophical issues which follow immediately from scientific discoveries; finally he should help man become more human as a result of his scientific achievements. The contribution of the philosopher to science is that of helping science become reflectively conscious of itself, and consequently fully integrated into a well-rounded humanism.

1.3 The Inductive-Genetic Approach in the Philosophy of Science

The foregoing considerations will provide us with a method of investigating science which, while remaining philosophical, can meet the rightful expectations of the scientists. In fact, if science is to be taken concretely and in its autonomy, we have an immediate indication as to how to approach it. Science manifests two evident characteristics: it is a multifaceted study of reality, differentiated according to the field of inquiry; and it has an essentially developmental character. As a consequence, we are invited to study the philosophical significance of science by means of an inductive-genetic approach.

First, the approach should be *inductive*. Although it is not unreasonable to speak of science in general, it would certainly be hopeless to attempt to understand science by considering it in its whole complexity at once. Indeed, one should rather speak of a variety of sciences, each science consisting of a number of more or less well-developed theories. Consequently the philosophical approach to science, to be successful, should concentrate on the detailed study of individual, fully developed theories. Secondly, the approach has to be *genetic*. Each scientific theory arises out of a slowly growing body of information. Hence the nature of the scientific endeavor and its achievements cannot be properly realized unless one follows the developments of individual theories as they gradually unfold and develop in time.[4]

In practical terms the inductive-genetic approach consists of selecting individual theories truly representative of the mature scientific endeavor and systematically examining them from the philosophical standpoint. A theory can be significant for a philosophical understanding of science when it provides a phenomenologically complete description and explanation of an observable set of events. One

4 The word genetic, as used here, is similar to, but not synonymous with, the term historical. The philosopher resorts to history for documentation about the origin and development of ideas leading to the formulation of an overall theory. But he is not interested, centrally at least, in strictly historical matters such as priorities, mutual influences between discoverers, and controversies. On the other hand, when occasion arises he goes beyond history in his investigation of origins. In particular, he has recourse to psychogenetical studies of the kind, for instance, that have made famous Piaget's school at Geneva.

celebrated example is Newton's gravitational theory of local motion. Once a theory has been chosen, it has to be investigated from the dual standpoint of epistemology and ontology. Epistemology is the philosophical study of knowledge. Thus the approach suggested here will require a careful analysis to bring out the actual meaning of the cognitive terms employed by the scientists working in the field under examination. The other branch of philosophical inquiry is ontology, or the study of the nature, essential properties and mutual relationships of various types of being. The inductive-genetic approach, therefore, aims in the second place at discovering the significance of the ontological terms presupposed or implied by the scientific theory under investigation.

1.4 An Example of Inductive-Genetic Research: Investigation of Atomic Order

In this book I am going to apply the inductive-genetic method to the philosophical problems raised by atomic physics. In particular, I shall concentrate my attention on atomic order.

The selection of the topic needs no special justification. Atomic research has long appealed to the reflective mind of the philosopher, at the present more than ever. In the first place, it presents a clear instance of the nature of science as both an intellectual conquest and a source of power. In the second place, atomic theory offers an almost ideal example of a scientific attainment in which epistemological and ontological aspects played a predominant role. Thirdly, atomic physics finds expression in a theory which is widely regarded as typical of the scientific endeavor, providing not only a description but also an explanation of a phenomenologically complete set of events. In the case of atomic physics we can speak of such a complete set of events because the theory embraces all the regularities which can be observed by probing the structure of matter with energies which are not so high as to split the nuclei involved.

Atomic physics presents various aspects under which it can be studied philosophically, and concentration on one central issue is a requirement for a successful application of the method. Hence there is need of defining more precisely the topic of investigation before passing to the philosophical analysis. The theme of order is particularly suited to an inductive-genetic study. For it constitutes that aspect which makes matter accessible, hence relevant, to both science and philosophy. Actually, the discovery and understanding of order has been the goal of atomic research from the early investigations of macroscopic regularities to the progressive discoveries about the internal structure of atoms right up to the eventual discovery of the intrinsic principles which account for the observed regularities of matter.

The foregoing considerations indicate how a study of atomic physics

may meet the scientists' expectation in a philosophical dialogue. For the inductive-genetic method recognizes the concreteness and legitimate autonomy of science. Yet one objection on the scientists' side has still to be met. The scientists, as was mentioned at the beginning, feel wary of entering a dialogue with the philosophers because of the apparent disagreement of the philosophers among themselves. Can the proposed method help to overcome this stumbling-block? I think that the answer is definitively positive. Truly, the philosophical discussions about atomic physics can be seen as a typical case of disagreement among philosophers. Yet the method advocated here can serve to clarify the situation, without obliging anyone either to give up his conviction or accept on trust any interpretation. For the method takes us back to the things themselves. With Martin Buber, one can speak of a "philosophical discovery."[5] It may be a discovery for the scientists to see why some aspect of their professional activity arouses such burning interest among the philosophers. The scientists might, as a consequence be more understanding of the reasons why the philosophers disagree among themselves. As for the philosophers, they may consider the proposed method to be a sort of phenomenological analysis of the content of atomic physics. For them, too, it may be a discovery to realize that, once the issues are seen in their concreteness, many disagreements of interpretation either vanish or can be easily settled.

A concluding remark will characterize the nature of the present investigation. This study intends to be no more than an introduction, or preliminary investigation, into the philosophical structure inherent in atomic physics. The method to be followed is the inductive-genetic one. The justification for adopting such a method is the results expected. Because of these results the limitations entailed by the method itself—though honestly acknowledged—are also to be accepted in the bargain. The principal limitation consists in refraining from discussing the works of the professional philosophers which bear on atomic physics. The reasons for this restriction are clear. The first is of practical nature. The number of philosophers writing on our theme is so great, and their fundamental viewpoints so different, that one could not do justice to them without such painstaking examinations and comparisons as to make this book insufferably long. The second reason is a psychological one. An introductory work like this one could not go into a detailed analysis of the various interpretations proposed by philosophers without running the risk of giving a false impression to the readers. Readers, in fact, could be easily led to believe that the philosophical problems of atomic physics are not, after all, something that concern the reflective scientists themselves, but are merely matters of dispute among philo-

5 "All philosophical discovery is the uncovering of what is covered by the veil woven from the threads of a thousand theories." *Between Man and Man*, trans. R. G. Smith (London: Collins-Fontana Books, 1961), p. 221.

sophical schools. This impression would be wrong indeed. For, if the method advocated here is successful, it should rather lead to the conclusion that philosophical problems are an integral (though implicit) part of science itself—this, at least, as long as science intends to be creative and have a vital significance for man. The third and chief reason is the internal consistency within the inductive-genetic method itself. The reader should avoid taking side with any philosophical school against another on specific points before having had the opportunity of carefully considering the philosophical problems involved in their concreteness and entirety. This methodological restriction, however, should not be interpreted as detracting from the value of the works of the professional philosophers already available. On the contrary, it should be seen as a confirmation of the importance of such works. For once the reader has been provided with sufficient evidence to understand clearly the problems involved he can then turn with more profit to the philosophical books in question.

1.5 An Outline of the Investigation of Atomic Order

In what follows I shall limit my considerations to atomic physics in the strict meaning of the term as opposed to other areas of microphysics such as nuclear physics, particle theory, or field quantization. The reasons for such a decision are partly practical, partly theoretical. On the practical side, it is obviously necessary to keep the investigation within manageable bounds. Atomic physics in itself constitutes the subject of a good-sized research project. But also, theoretical considerations are important here. These, again, derive from the necessity of a consistent adherence to the inductive-genetic method. In order to test the validity of the inductive-genetic method, one must follow the progressive developments of a theory as they actually took place, from its early origins right up to the final formulation which is considered satisfactory by the scientific community. Now atomic theory was developed, tried, and pronounced satisfactory at its own level by the scientific community as a whole quite independently of the investigations in the other fields mentioned. The philosophical reasons for such a fact will emerge at the end of the research itself.[6]

If we consider how a philosophical investigation of atomic order can be carried out, a natural division of the subject matter suggests itself

6 Concerning the omission of nuclear physics, a few more words may be added. It would seem that man cannot understand atomic order unless he understands the structure of the nucleus. Now this is not so, as history shows. The reason is the fundamental independence of energetic levels arising from the quantization of matter. As a consequence the nucleus—insofar as atomic physics is concerned—is a given unit characterized by such phenomenological features as mass, spin, angular momentum, and quadrupole moment. In a similar way, for much of atomic physics, fields may be treated classically, i.e., taken for granted.

to us from the very beginning. Since science and philosophy each have their own autonomy, it is advisable to split this research into two distinct parts. Accordingly I propose to consider separately the achievements of atomic physics as such and the philosophical implications of these achievements.

To understand the scientific aspects of atomic order, the inquiring philosopher should follow the historical unfolding of the scientific events from the first conceptions of regularity at the atomic level to the gradual discovery of the nature of such an order. Accordingly, after recalling the early evidence for admitting the existence of atoms and molecules, I propose to start out by discussing the origin of the problem of atomic order from the discovery of the periodic law and the structural regularities of atomic aggregates. The second step will consist in the analysis of the evidence that led researchers to recognize an internal complexity and regular structure of atoms. The third stage will be the study of the first attempts to understand atomic regularities by means of the early quantum theory. This proved only partially successful. Hence, in the fourth stage, it will be necessary to examine the new series of experimental results which revealed previously unsuspected interactions of the atomic components. Finally, the investigation of scientific data will be concluded by analyzing the physico-mathematical explanation of atomic phenomena which is generally accepted as satisfactory by present-day physicists.

The primary concern in this first part should be to understand the results of science in an undistorted way, as clearly and exhaustively as possible. Accordingly, the activity of the philosopher should be limited to arranging these results in a clear "genetic" succession with the aim of finding their logical structure and their internal dynamism. Naturally enough, however, this way of proceeding may be open to question by both the scientist and the philosopher, on the grounds that the scientist is already well informed about the physics involved in the discussion, and the philosopher should be also. It may appear that this entire analysis of scientific data recommended as a first step would be merely an unnecessary delay, holding up the direct philosophical discussion. And yet, practical experience seems to indicate that the course proposed here is not without some merit for the interdisciplinary dialogue. In fact, experience shows that philosophical discussions of scientific subjects are rarely endangered by too great an adherence to concrete data, while the opposite risk is incurred only too often. Too many philosophers feel inclined toward sweeping generalizations about science without stopping to examine concrete scientific issues in detail. And their scientific interlocutors, not themselves accustomed to a rigorous philosophical reflection, do not always avoid the danger of accepting appealing philosophical positions which actually lack a precise justification in concrete facts. Hence it is wiser to be perhaps a bit excessive in supplying a background which the informed reader can

easily omit than to run the risk of vagueness and imprecision. After all, the aim of this preliminary investigation is to provide a foundation for the philosophical analysis to follow.[7]

The second part of our investigation will constitute the core of the inductive-genetic approach. It should aim at giving an explicit formulation to the philosophical structure inherent in the atomic theory, both in its tacit presuppositions and in its implicit consequences. Atomic order itself—now with a precise philosophical connotation—will eventually be the main object of interest. But, it will be necessary to begin by discussing at some length the epistemological implications of the atomic theory: that is, an analysis of the main issues touching upon the cognitive reliability of atomic physics will be needed. The principal points to be discussed will be (1) the observational basis and the explanatory significance of the atomic theory; (2) the nature of microphysical reality; (3) the role played by models; and (4) the epistemological perspectives emerging from atomic research and leading to a new idea of critical objectivity. All of this, of course, should be done by following closely Einstein's suggestion of heeding what the physicists do rather than what they say. Here, in fact, is where the lengthy analysis of scientific data described above will begin to pay off. There is one sense, however, in which a philosopher making such an investigation should be allowed to take the liberty of departing from the literal meaning of Einstein's advice. It seems to me that the creative scientists have a right to be considered privileged witnesses to the philosophical implications of the science they have originated. As a consequence, the philosopher has a duty to allow them to be heard, especially when they try to express in words the philosophical structure of their own experience of creativity. At the same time, clearly enough, it is also the philosopher's duty to closely scrutinize the scientists' sayings in order to disentangle their philosophical insights from their sometimes inaccurately worded expressions. Therefore, direct quotations from the writings of atomic physicists form an integral complement to the present investigation. They had to be reproduced mostly in footnotes simply in order to make the text less unwieldy. Such quotations should be carefully read, at least with a view to checking the reliability of the statements contained in the text itself.[8]

7 The scientific information presupposed here does not go beyond that which is usually supplied by introductory university courses. A list of textbooks, of elementary and intermediate levels, can be found in the first part of the bibliography at the end of this book.

8 A certain number of works on history and philosophy of science authored by physicists will be listed in the second part of the bibliography. Two works listed there deserve to be specially mentioned although both of them were unfortunately not yet available when I was conducting my investigation. The first is the anthology edited by Boorse and Motz, collecting in two volumes the original papers pertinent to the historical development of atomic physics. The other is Jammer's book analyzing the conceptual development of quantum mechanics.

When we turn to the ontological implications of atomic physics, we will be at the center of the philosophical study of atomic order. These are the main steps of the research I consider relevant in this area. First, the ontological signification of the quantum will have to be sought. This arises from the fact that the quantum is the characteristic of autonomous totalities. Then an ontological analysis of the observable properties of the atomic aggregates must be undertaken. But matter at the atomic level presents some properties that appear incompatible with the classical, i.e. mechanistic, idea of matter itself. Hence a brief analysis of the mechanistic conception of matter will follow in order that we may see clearly what is new in the quantum conception. Finally an attempt will be made to state explicitly what the new idea of matter amounts to. It will be seen to be the notion that order and specificity themselves constitute the fundamental characteristics of matter.

At this point the objective of our whole research could be considered to have been attained. However, it does not seem that it will be advisable to break off the inner dynamism of the philosophical investigation without some additional considerations. Ultimately, order itself is of interest to both science and philosophy only as a source of intelligibility. Consequently, a short discussion of the intelligibility of matter will follow. This discussion will aim at discovering in what sense atomic physics is an intellectual achievement and at summarizing what are the long-range philosophical perspectives opened up by its success. It is clear that such an investigation will contribute to a better understanding of the relationships between science and philosophy. Hence it will be appropriate to terminate the overall discussion by drawing some inferences that will be of use in fostering cooperation between scientists and philosophers.

1.6 Conclusion: The Philosophical Nature of the Inductive-Genetic Approach

I have tried to present the main features of a method for understanding the philosophical structure of science from within. I have outlined the investigation of atomic order as a concrete example of the method. Needless to say, many objections can be, and actually are, raised from the philosophical side against this attempt. I shall try to meet them by discussing, in conclusion, the philosophical nature of the inductive-genetic approach.

Does a research of the type described above deserve to be called philosophical? Obviously the answer depends on the way in which one conceives of philosophy. Following the definition adopted here, however, there should be no doubt about an affirmative reply. As long as the professional task of the philosopher consists in consciously reflecting both on the ways man acquires knowledge and on the ways reality

manifests itself as intelligible to the human mind, it is clear that the inductive-genetic investigation deserves to be called philosophical. For it is such in aim and method. The aim is philosophical, because by studying in detail the actual development of a scientific theory the investigator tries to understand the effective—though implicit—influence exerted by philosophical principle and conceptions upon scientific research and, conversely, the impact of scientific results on philosophy proper. The method is philosophical because the scientific data and theories are never considered from any other angle except that pertinent to philosophical interests.

Doubtlessly, the philosophical character of the investigation we have described should not be overrated. Knowledge of the genesis and development of concepts cannot be identified with the whole of philosophy. Philosophy is an autonomous discipline which, besides information, requires critical discussion and systematic organization. Hence the genetic analysis cannot claim to be anything more than a preliminary stage in a philosophical study. And yet its contribution may be crucial for the philosophical understanding of science. The success or failure of the philosophical interpretation of science may be the direct consequence of the success or failure of this first step. Moreover, the contribution of the inductive-genetic investigation can be important for the progress of philosophy as a whole. Philosophy has much to learn from a concrete analysis of knowledge in action. The study of scientific discovery offers unique opportunities for gaining an insight into the concrete ways ideas are born and tested.

On the other hand, can the scientist, too, gain some benefit from the analysis described above? In this case, once again, the answer appears to be definitely positive. It is no secret that science is frequently learned as a practical tool for solving problems. As a consequence the important philosophical insights of scientific progress—actually the profoundly human significance of science—tend to be overlooked and neglected. Thus, it is the right and the duty of the philosopher to show concretely how philosophy can comment significantly on the importance of science. The inductive-genetic method offers the philosopher an invaluable opportunity to this end. It allows him to gain the respect of the scientist through his complete trust in and consideration for the achievements of science. By directing the philosopher to understand science from within, the method proposed here enables him to give precision and clarity to the scientist's philosophical insights. In brief, a properly prepared philosopher can do much for science. Scientific principles and results are frequently blandly assumed as intuitively obvious. The philosopher should help make them come to life for what they truly are—awe-inspiring discoveries which have a relevant message for modern man.

To sum up, the aim and scope of the inductive-genetic method, as concretely applied here to atomic physics, are clear. This book is intended to be no more than an introduction to the philosophical

problems of atomic order. Precisely because of its introductory character, it should leave the reader rather with a desire for more than with a sense of completeness. It will be successful if it can contribute in some way to stimulate the reader to a personal rethinking of the great issues involved.