involves it, was much bothered by the apparent need to assume that a particle of matter can act "where it is not". Presumably much of the opposition to the atomic hypothesis in the sixteenth and seventeenth centuries was due to the unwillingness of many scientists to swallow this concept.

Miss Hesse traces the story of the vicissitudes of the concept of action at a distance with clarity, though naturally with necessary skilful compression. She then discusses the development in the eighteenth century of the attempts to study the motion and other behavior of continuous media, as illustrated by the hydrodynamical and elementary elastic wave propagation theories of Euler, the Bernoullis and D'Alembert. This leads up to the general concept of field in electricity and magnetism as exemplified by George Green, Faraday, and Maxwell. The book closes with a brief excursion into relativity and modern quantum physics, which though clear somehow to a certain extent seems to get off the track of the main theme. This does include an interesting and sympathetic critique of Bohm's recent attempt to restore determinism to quantum physics.

Those interested in the general methodology of physics will find the first chapter of Miss Hesse's book ("The Logical Status of Theories") worthy of careful study. She comes down rather hard on the traditional "realist" and "positivist" views of scientific theories, and advocates a return to a "model" theory, expressing the strong feeling that uninterpreted formal systems are not satisfactory for the provision of theoretical explanations. Here of course the author treads on highly controversial ground and the matter needs much more careful consideration than she has been able to give it in her book.

The volume can be highly recommended to all who are interested in the history and philosophy of physics.

Direct Methods in Crystallography. By M. M. Woolfson. 144 pp. Oxford U. Press, London & New York, 1961. $4.80. *Reviewed by J. Gillis, Weizmann Institute of Science.*

DIRECT methods have been a central topic in crystallography for the past fifteen years, and it was certainly time for a book on the subject to enable us to assess the present status of this approach to structure determination. Dr. Woolfson has performed that service and is entitled to our gratitude.

The problem is insoluble in the sense that without the use of chemical information there are always a nondenumerable infinity of possibilities. How much chemical information is needed to make the solution unique is still unknown and certainly depends on the particular structure. The now classical inequality relations take into account the non-negativeness of the electron density, and the literature includes several structures where this has sufficed. It is where it fails that direct methods become complicated. Presumably the logical answer would be to seek the stronger inequalities implied by the additional chemical information at our disposal; e.g., the numbers of atoms of the various types per unit cell, approximate atomic radii, possible limits to the distortion of a benzene ring, etc.

This has not yet been done. Instead refuge has been sought in probabilistic arguments of highly dubious validity. Evidence is piled up to make a result seem probable, but no criterion is suggested for deciding whether the separate items of evidence are in fact independent. And analysis of this question leads to the more disturbing fact that the sample space and random process are themselves undefined. If we associate numerical probabilities with events which are not random we must be prepared to come up against paradox or worse. There may still be significance in the probability concept; but it is not the usual one and we have to specify (and justify) the rules of operation. It is worse than naive to expect the rules of true probability to apply without qualification. What is the probability that the millionth digit in the decimal expansion of π is 6? The digit is not a random variable and the question is correspondingly suspect. There are senses in which the question has meaning, but these senses and the meaning need to be carefully defined. In the crystallographic problem, nobody appears to have even attempted the corresponding definition.

Nevertheless, the fact remains that direct methods do sometimes produce results. Since even the most complicated of them take much less time and labor than an old-style analysis by trial and error, they are usually worth trying hopefully. And the reader will find in the book under review a fairly realistic description of all the known approaches: inequalities, the Sayre-Zachariasen idea, the Karle-Hauptman method, and those associated with Douglas, Cochran, and the author.

Why statistical methods do sometimes work is a matter for speculation. X-ray crystallography is one of those subjects where the correct solution, once obtained, is usually recognized beyond doubt (although "errors of both kinds" have been known to occur). And if a start fails to lead to a solution, one rarely knows whether it was the start itself that was false. Thus, methods which gave the phases of a few leading terms enjoy the inestimable advantage that their successes are nearly always known, but their failures only rarely. However, even discounting for this effect, it would appear that the statistical approach can genuinely claim more than random success. One is tempted to think that all of these methods may be, in a sense, projections on to some simpler thought plane of those elusive exact methods, if indeed they exist, which would be based on complete use of the chemical facts of the structure. If this be so then the more successful cases are presumably those in which the projection happens to give the more faithful representation. But the truth itself is still beyond us.