

posed to the reasoned certitudes of the scientific intelligence, likewise bears immediate witness to this factor in things, it is not surprising to find philosophy arising and developing in history centuries before the appearance of the nonphilosophical sciences. Though they fish in the same waters of reality, philosophy and science appear to do so at irreducibly different levels. The point of these rather sweeping generalities is simply that for students of science, there exists, within their science itself, an entry to the philosophical realm, an entry which not only respects the specific diversities of these knowledges but suggests their complementarity.

Thus, at the end of our epistemological analysis of physical science as such, we found, underlying and presupposed by the first datum of science, the experimental fact, an unmeasurable and unconstructed existential value to which natural intelligence or common sense also bears spontaneous witness; a value, in short, which imposes itself at every level of human knowledge but unfolds itself only at the philosophical level. Turning from the original datum of science to the scientific intelligence which separates or selects this datum, we found its curiosities, in a sense, over-reaching themselves and disclosing their own unchangeable limits. In its total curiosity, we found the human intelligence aspiring to nothing less than a possession, according to its own mode, of the whole of reality while confined, in its properly physical moment, to the measurable real which does not include itself.

What this real world which invades our consciousness through the external senses *might be* behind the rigorous facade of physical measurements, the physicist can and does propose in his theories. Such theoretical constructs are, we saw, by no means arbitrary fictions indifferent to the demands of the experimental evidences. Indeed such evidences, given rather than constructed, are, in the language of Eddington, the final court of appeal in determining the cogency of any physical utterance. But what this real world first grasped by the unaided senses *is* and cannot be in its ultimate determinants, the physicist as such cannot say. Thus, though we began in epistemology, and, in particular, in the epistemology of physical science as the prototype of all experimental science, our analysis ended in horizons beyond the limits of those disciplines in the elementary possession of which these particular students entered the course. Physical science appears to lead inevitably to these horizons when it becomes fully aware of its own invariable epistemological structure but it cannot enter into them with its essential procedures and operations. To the extent that the students' minds are opened, however dimly, to the irreducible heterogeneity of these two levels of understanding the real world in which he finds himself, to that extent, we think, he may be expected to escape that distorted total view which follows upon exclusive concentration in a single area of thought and, at the same time, lower the barrier to effective communication between scientist and philosopher which has arisen, it would seem, more as a consequence of undergeneralization than overspecialization.

Books

Readings in the Philosophy of Science. Edited by Herbert Feigl and May Brodbeck. 811 pp. Appleton-Century-Crofts, Inc., New York, 1953. \$6.00. *Reviewed by P. Morrison, Cornell University.*

This is a careful compendium of essays within a more or less narrow interpretation of the scope of the philosophy of science. As Professor Brodbeck explains, the readings are restricted to analytic philosophy, to a study of meanings; the social study of science, its moral evaluation, no less than the speculative cosmologies and the natural ethical systems (like those of the *Naturphilosophen*), are all excluded. The logical analysis of science here collected leans perhaps a little too heavily on the works of logical positivists and their kin, from Mach and Poincaré to Carnap and Reichenbach.

An inventory of such a thick tome is unimaginative writing, but serviceable to the reader of a review: Here are about fifty papers, the shortest a few pages long, and the longest monographs of forty pages, arranged into a number of sections. The topics covered comprise the nature of scientific method, the logic of explanation in science and the nature of theory, the philosophy of mathematics, physical concepts, like the nature of space and time and of statistical and causal law, and finally, the philosophy of biological, psychological, and social sciences. There is an epilogue, touching on the sociology of science in a little piece by Professor Wigner looking forward from the Golden Age of today's naive individual effort to the necessity of group research in a future era. And a final page of Professor Einstein's seeks to found ethics upon the empirical values of the emotional experiences of men. (Were more men like Professor Einstein, his argument would be overwhelming.)

It is hard to let this large collection of deep and often bitterly-fought issues go past the reviewer without comment; it is no less hard to do any sort of justice to these fundamental questions in a few off-hand paragraphs. A few impressions may aid the prospective reader, or the busy physicist who wants only to notice the book. Two points were clear to the reviewer. First, much of the touchy and delicate argument of the book, though in the hands of many a wise professional philosopher, takes on a kind of triviality. Such an impression of emptiness comes across to a physicist reader, even to one predisposed to be sympathetic to the theory of theory. The ill-tempered Johnson was petty and naive enough to kick that stone, or the Latin writer to confound Achilles' tortoise by walking, but yet there is much sympathy for their simple-mindedness after an

hour or two of pondering model languages, law-like sentences, and the distinction between *explanans* and *explanandum*. It is perhaps easy to attack any technical work by such citations of its jargon, but the feeling is inescapable that the machinery here mounted far outweighs the results that the philosophers can place before the thinking reader. All theory, we are told by the poet, is gray, and the theory of theory becomes just the shadow of gray. The green bough of growing physical theory itself seems a better guide to its own meaning, by example, than are most of the earnest commentators with their somewhat forced precepts. Analysis is drawn here a bit too fine. It is good that discussions of operationalism and of logical positivism are found both in their classic formulations (Bridgman, Frank, Schlick, Carnap, Nagel) and in sharp criticisms at the hands of such writers as Carl Hempel. It is a pity that the magnificent piece of Professor Hempel on *Fundamentals of Concept Formation* is omitted in favor of some shorter pieces in the same vein, that of showing the inescapable and complex nexus relating theory and experiment, before which the effort to make sensory convenience into science seems at last to have fallen. Perhaps a touch more of the speculative, metaphysical philosophers would have done some good as a counterweight to the refined hard-boiledness of the works here emphasized.

Second, the pieces on the sciences of more complexity, like the social sciences, seem by contrast rather more meaty. There is always the fear that this reflects a physicist's ignorance, but it seems at least to be true that common sense and logical analysis are more patently fruitful in subjects where precision of measurements is perhaps not yet even to be desired, let alone obtained. A really impressive and down-to-earth essay by Edgar Zilsel is convincing (at least to a physicist) on the hope and the probability of finding laws of human history.

This anthology is perhaps a bit restricted for the average reflective physicist; he might prefer to read only the more familiar works, in fuller versions. But serious students will without doubt find it valuable. And it will be a long time before the usefulness of the really excellent annotated bibliography, with its more than five hundred citations arranged by subject matter, is approached elsewhere or outdated. For this last labor of skill and love the editors deserve special gratitude. Libraries of physics will find this volume well worthwhile; it would be justified by this bibliography alone.

Physical Properties of Solid Materials. By C. Zwikker. 300 pp. Interscience Publishers, Inc., New York, 1954. \$8.75. Reviewed by R. Smoluchowski, Carnegie Institute of Technology.

Books dealing with physical properties of solids are mostly either theoretical treatises placing stress on a systematic analysis of fundamentals or engineering textbooks, which discuss and tabulate various data of practical significance. Zwikker's book strikes the aim somewhere in-between and it does it in an unorthodox and

often interesting manner. A short introduction to the basic notions about particles and forces is followed by thirteen chapters on various selected subjects. These vary from such obvious and "conventional" matters as constitution (i.e., structure), elasticity, plasticity, thermal properties, transformations, ferromagnetism and ferroelectricity, electronic properties etc. to rather new treatments of such topics as heterogeneity, anisotropy, systematic relations (extensive and intensive parameters, reciprocal relations, etc.), porosity and permeability, surfaces, etc. Although the writing is very compact and sometimes difficult to follow, this is partly offset by the numerous illustrations and diagrams, many of them quite original. There are many references to papers in recent literature and also many examples of how various basic physical phenomena appear in engineering problems or even in daily life. This inclusion of treatments of several somewhat out of the ordinary matters in a book which tries to cover the huge field of physical properties of solids in about 300 pages necessitates various rather significant omissions or radically short mentions. For instance, there is no appropriate description of diamagnetic and paramagnetic properties or of the numerous kinds of lattice imperfections (with the exception of dislocations) nor of microwave resonance. The author makes a point of using the mks system except where it becomes too awkward.

The book should be of particular value to nonphysicists who need to have a rather good general background in physics and also to those physicists who want a quick survey of the field without going into the more detailed consideration of its problems.

Dislocations in Crystals. By W. T. Read, Jr. 228 pp. McGraw-Hill Book Company, Inc., New York, 1953. \$5.00. Reviewed by Harvey Brooks, Harvard University.

Although the theory of dislocations in crystals is relatively old, it is only within the last ten years that it has become a fashionable branch of solid-state physics and acquired a measure of respectability even among practical metallurgists. One of the primary aims of this admirable monograph is to increase the respectability of the subject by drawing attention to those features of the theory which are well-established and noncontroversial. About two thirds of the book is devoted to a logical deductive presentation of dislocation theory from a few relatively obvious geometrical postulates and crystallographic concepts, and the other third is concerned with two applications of dislocation theory to metallurgical problems in which the predictions of the theory can be tested critically and quantitatively—namely, Frank's theory of crystal growth, and the dislocation theory of grain boundaries as set forth first by Burgers and later by Shockley and Read.

The greatest practical interest of dislocation theory lies in the possibility of explaining the plastic properties of crystals. Mr. Read for the most part avoids these subjects because there exists at present no quantitative theory of mechanical strength, and no generally ac-