

Book Reviews

Max Born on His Vocation

Physics in My Generation. MAX BORN. Second edition. Springer-Verlag, New York, 1969. viii, 172 pp., illus. Paper, \$3.80. Heidelberg Science Library.

My Life and My Views. MAX BORN. Scribner, New York, 1968. vi, 216 pp. \$4.95.

Briefwechsel, 1916–1955. ALBERT EINSTEIN and HEDWIG and MAX BORN. Commentary by Max Born. Nymphenburger, Munich, 1969. 332 pp. DM 24.80.

Max Born, who died last January in his 88th year, was one of the great names of the "heroic era of quantum physics." This was Niels Bohr's phrase for the period earlier in this century when "a whole generation of theoretical physicists from many countries" created "a new outlook regarding the comprehension of physical experience." Born's statistical interpretation of the wave function is an essential aspect of this "new outlook," whose most striking feature is its abandonment of the classic scientific goal of a complete, deterministic description of natural phenomena. It was for this contribution to our new way of trying to understand nature that Born was finally awarded the Nobel prize in 1954; by this time Born's ideas had been in constant use by physicists for over a quarter of a century. Born was particularly pleased to be recognized for this work of interpretation; despite his complete mastery of mathematical formalisms and his skill at elaborate calculations he liked to think of himself as basically a student of the philosophy of nature. When he was appointed to a professorship at Edinburgh several years after having been dismissed from his position at Göttingen by the Nazis, he was delighted to learn that his new chair was officially named the Tait Professorship of Natural Philosophy: the old term matched his view of his calling.

The three books under review represent only a small portion of Max Born's work. He wrote some 300 sci-

entific papers and more than a dozen other books, several of which were the standard works in their fields for over a generation. But these three give us a picture of the man and the nature of his involvement with his work, and it is a picture well worth contemplating. Born was probably the only one among the principal creators of quantum physics who did not acquire a vivid personal image among his fellow physicists. Einstein was unique, of course, and Bohr became a kind of father figure for theorists everywhere. Dirac's very individual style and evident genius and Pauli's combination of profundity with abrasiveness have been the basis for physicists' stories for 45 years. But Born apparently lacked any of these varieties of personal glamor. His essays and correspondence reveal him as "merely" an outstanding physicist who was also a thoughtful, sensitive, cultured man, one who took his responsibilities as professor and scientist absolutely seriously.

The collection of papers, *Physics in My Generation*, presents a selection of Born's views on a rather wide range of subjects. It includes an early statement of the essentially statistical character of the new physics—the article "Physical Aspects of Quantum Mechanics," based on a paper given in 1926—and Born's restatement and defense of this idea in his 1954 Nobel prize lecture. In another paper Born develops the idea that the apparent determinism of classical mechanics is really spurious because of the long-term effects of the inevitable lack of absolute precision in the experimental specification of initial conditions.

Since Born's scientific career extended over a period of half a century it is not surprising that several of these essays present his reflections on the unprecedented changes in scientific thought during this period. When he started to study physics at Breslau in 1901, x-rays, the electron, and radioactivity were all fresh and new. Planck's

concept of energy quanta had just appeared in print, but its devastating implications were not yet suspected. A student at that time could still describe Maxwell's theory of the electromagnetic field as "revolutionary" and consider it to be "the most fascinating subject" for study (the words are those of Born's contemporary, Albert Einstein). By the time Born retired from his Edinburgh professorship, quantum mechanics and relativity were part of the standard curriculum, a new renormalized quantum electrodynamics had explained such subtle effects as the Lamb shift, and high energy particle physics was attracting the interest of both theorists and experimentalists. For Born, however, as for a number of others, an even more fundamental change had taken place: he had lost his faith in "the superiority of science over other forms of human thought and behavior" and his hope that it could help lead "towards a better understanding between human beings." The community of physicists, he decided, "had contributed nothing to a better understanding of nations, but had helped in inventing and applying the most horrible weapons of destruction."

Born's awareness of the part scientists had played in making possible the large-scale and impersonal destruction of human life during the Second World War—Hiroshima and Nagasaki being only the exemplary extreme cases—darkened his view of his vocation and deeply affected his later writings. In the second edition of *Physics in My Generation* several papers on the conceptual problems of quantum mechanics were dropped to make room for some late essays, including the moving "What Is Left to Hope For?"

This aspect of Born's thought, with its strong and even stern emphases on the need for scientists to take responsibility for the social consequences of their work and on the absolute necessity of world organization for world peace, is central in *My Life and My Views*. The autobiographical promise of the title is kept only very incompletely, in two brief essays by Born on his education and his work as a physicist. His reflections on his own career led him to a somber conclusion:

I am haunted by the idea that this break in human civilization, caused by the discovery of the scientific method, may be irreparable. . . . The political and military horrors and the complete breakdown of ethics which I have witnessed during my lifetime may be not a symptom of an ephemeral social weakness but a nec-

essary consequence of the rise of science—which in itself is among the highest intellectual achievements of man. . . . This is no prophecy, only a nightmare. Though I have not taken part in applying scientific knowledge to destructive purposes . . . I feel my own responsibility.

We come closest to Max Born in the last of these three books, in which, just before his death, he collected and commented on his correspondence with Albert Einstein. The two men became acquainted in 1909 at a scientific meeting in Salzburg. Both were in Berlin during the First World War, and their friendship grew during those difficult years. Born was only a few years younger than Einstein, but he looked up to him throughout his life as one might look up to a wiser, more experienced, ideal older brother. The correspondence actually involved three people, with Born's wife, Hedwig, joining in. Her lively and witty letters, often accompanied by her poetry or other writings, drew replies from Einstein written in a lighter vein than his answers to her husband's uniformly serious letters. Born's comments on the correspondence, explaining many of the allusions to people and events, help to fill out the picture of the two men and their changing settings.

An extended correspondence between two thoughtful and articulate men is bound to interest us in a variety of ways. In the present case, the particular fascination is in following the direct exchange of ideas between two great physicists both concerned with fundamental issues during a crucial period in the history of their science. In the early 1920's both men were struggling to find a way out of the seemingly hopeless confusions and contradictions that beset the quantum theory, Einstein proposing one "crucial experiment" after another and Born adapting the complicated methods of Poincaré's perturbation theory to quantum problems. When Werner Heisenberg proposed a new way of attacking the problems in 1925, and Born and Jordan helped give this idea mathematical form as matrix mechanics, Einstein was at first very impressed. "Dull resignation has given way to a unique kind of suspense," he wrote to Mrs. Born early the next year. But within a few months he had grown more skeptical: "An inner voice tells me that it is still not the true Jacob. The theory produces a lot, but it brings us hardly any closer to the secret of the Old One. In any case I am convinced that He doesn't play dice." Einstein never accepted the enormously success-

ful quantum mechanics as a really satisfactory theory. His long exchanges with Born on this issue in the 1950's, sometimes sharp in tone despite their long friendship, bring out his commitment to the goal of a theory that will describe the world as it is, rather than one that relates only our observations.

Physicists of a later generation could dismiss Einstein's objections as misguided or simply wrong, but to his contemporaries such an attitude was impossible. Niels Bohr felt the need to go on defending his ideas against Einstein's criticism even after his old antagonist was dead, and Born's reaction was basically similar. He deeply regretted Einstein's refusal to accept and to help develop the new quantum mechanics, and once wrote: "Many of us regard this as a tragedy—for him, as he gropes his way in loneliness, and for us who miss our leader and standard-bearer. . . . But in spite of this he remains my beloved master."

I know no better way to summarize the impression produced by the Born-Einstein correspondence than to quote from Bertrand Russell's brief preface to the book:

These letters, which clearly were not written for publication, record their hopes and anxieties in war and peace, their private thoughts about the progress of their work and that of colleagues, and much that will prove invaluable source material in the history of science.

Something of the nobility of their lives is also revealed. I have deeply valued their friendship over many years. Both men were brilliant, humble and completely without fear in their public utterances. In an age of mediocrity and moral pygmies, their lives shine with an intense beauty. Something of this is reflected in their correspondence, and the world is the richer for its publication.

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Perceiving and Thinking

Visual Thinking. RUDOLF ARNHEIM. University of California Press, Berkeley, 1969. xii, 348 pp., illus. \$11.50.

It is unique to find an inquiry about thinking that takes visual perception as paradigm. This way of looking at thinking—and perceiving—comes naturally, however, to Rudolf Arnheim, a psychologist widely known for his studies of the visual arts, who brings to this

work the fruits of his reflections upon a persistent issue in psychology.

The issue, as the author poses it, is the relation of perceiving to thinking. A long tradition has separated these functions. Perceiving, it is said, has to do with the concrete, the individual, while to think is to abstract and generalize. Arnheim rejects this starting point. To describe perceiving as unthinking and thinking as nonperceptual is to distort the character of both functions. The title of the work, *Visual Thinking*, states in compressed form the author's thesis of the unity of perceiving and thinking. He proposes that the essentials of thinking are present in perception itself, that there is no difference in principle between them.

In support of this position Arnheim argues that perceiving is an intelligent activity; the book is a wide-ranging examination of this proposition. He chooses to talk about visual perception, in many ways the richest modality. Foremost is the point that to perceive is to apprehend patterns or structures. This is a constructive activity that goes far beyond the recording of what is given. We perceive not only—or mainly—data, but the constructions we form out of them; structures are not given as things that the mind or brain copies. Thus visual perception is from the start visual interpretation. Most important for the main argument, to perceive is to see the general in the concrete, the universal in the particular. The percept of a single triangle, even if it is the only triangle one has experienced, contains the generic features of triangles. Only because this is the case does it become possible to compare one triangle with another. In this sense a visual form is a visual concept.

Arnheim is most effective in his account of perceiving. He draws skillfully upon familiar phenomena and puts them to novel use. Consider the perception of a body as a solid. At no time do we see it in its entirety; at any one moment we have only a partial view of it. To bring the successive views into a single representation, to see each as part of a whole, is an instance of productive activity, of problem solving. Other perceptual effects, such as transparency and the constancies, are treated similarly, as well as the connection between perceiving and artistic representation. A few strokes on a page evoke an object in restlessness or repose; despite omissions and simplifications, often because of them, an immobile pattern makes forces and their inter-