trait would prevent him from succeeding in physics. Kramers also had a horror of interpersonal conflicts, and would go to extraordinary lengths to avoid them. He regarded this as a family characteristic, telling a young relative "A Kramers has to fight to fight". He was well aware that his inability to fight for his convictions hindered him scientifically.

Perhaps the most remarkable example is Kramers's unpublished anticipation of the Compton effect. The idea occurred to him in 1921, but he allowed Bohr, who at the time was a vigorous opponent of the photon concept, to talk him out of publishing his work. Indeed, Bohr was so effective in converting Kramers to his point of view that Kramers became an even more intemperate opponent of the photon than Bohr himself. Compton later received a Nobel prize for his work, a prize which it is reasonable to suppose Kramers would have shared had he predicted the effect two years before the experiment. It is sad to learn that Kramers's life, like that of many other outstanding scientists, was embittered by his failure ever to receive a coveted Nobel. One is left with the impression of a brilliant, upright and conscientious man, torn by incessant internal conflicts, constantly tormented by feelings of personal and professional lack of fulfilment, who maintained external control over his feelings at a great cost to himself.

How accurate is this picture? It is hard for an outsider to know. Dresden freely admits that the book gives "*my* understanding of Kramers' life". The wealth of intimate detail about Kramers that Dresden provides relies so heavily on personal interviews (Dresden himself notes the " 'soft' character" of this information) that it is difficult for others to assess the evidence until the interviews (which I hope were taped), as well as Kramers's personal papers, are made available to others. Information that would seem important to an assessment of Kramers's psychological development is not always provided. (His father turns up remarried when Kramers is in his mid-twenties, for example, without any indication of what happened to his mother.)

We must be immensely grateful to Dresden for having broken with the genteel tradition of scientific biography by writing a fascinating book that leads us into the forbidden territory of Kramers's personal and psychic life. However, one sometimes feels the need for a more expert guide through this territory, the sort of superlative guide that Dresden proves to be through the world of Kramers's physics. ☐

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Jump in quantum history

Nicholas Kemmer

The Historical Development of Quantum Theory. Vol. 5 Erwin Schrödinger and the Rise of Wave Mechanics. Part 1 Schrödinger in Vienna and Zürich 1887–1925; Part 2 The Creation of Wave Mechanics: Early Response and Applications 1925–1926. By Jagdish Mehra and Helmut Rechenberg. *Springer-Verlag: 1987. Pp.980. Part 1 DM98, £36, $54. Part 2 DM148, £55, $79.95.*

QUANTUM theory was born with this century and needed a quarter of it to reach maturity as quantum mechanics. That theory soon gained almost universal acceptance as the key to a much-deepened understanding of inanimate nature.

As Jagdish Mehra told us at the start of this multi-volume work, he began preparing it just about another quarter-century later. For him, the time was then most auspicious; nearly all those who, from 1925 onwards had taken part in creating and developing quantum mechanics, were still active, not to mention some of *their* teachers. Mehra established happy contacts with, it would seem, nearly all these people. A large part of the work that Mehra then began is now in print. Since 1970 he has had Helmut Rechenberg as partner.

Mehra displays a special ability to convert copious records of formal interviews and informal exchanges into lively accounts that ring very true. These are not just incidental but rather quite central to the structure of the first four volumes of the work, which are not strictly chronological in order. They split into parts presenting the ideas that relate roughly to the work of Planck, Bohr, Pauli, Heisenberg and Dirac. Embedded into the very readable technical sections there are biographies and pen pictures of these men and descriptions of their backgrounds. Naturally the work of many other people is described, some of whom receive similar, though shorter treatment. Also, as an introduction, figures from the prehistory of quantum theory appear in the setting of their achievements, with very detailed documentation for each one.

The reader-interest of different sections of these volumes inevitably varies. For me, the later technical chapters deal with topics and publications I remember from long ago, while earlier parts invite study for the twists and turns of how it was before my time. As for the vast amount of background information and biographical detail, one must be grateful that it exists.

Now, after a five-year gap, a further two-part volume of this work has been published. It is dedicated to Erwin Schrödinger, and appears at a time when the centenary of his birth has just been celebrated. Schrödinger was undoubtedly a great physicist and a remarkable person. Why, however, was he not covered together with the 'greats' of the previous volumes? That would have been appropriate chronologically — and indeed his name is not absent from those earlier pages. Schrödinger receives special treatment because, within the history of quantum theory, he holds a quite unusual position. He was a most distinguished scientist who worked on many aspects of theoretical physics, but until 1926 his contributions to quantum theory were quite modest. In that year he published a series of papers that immediately transformed ideas and methods in quantum theory quite profoundly. In due course this work gained him a Nobel prize. However, because the interpretation of his 'wave mechanics' by the great majority of his colleagues differed drastically from his own, he soon parted company with them. Only his wave equation flourished within quantum mechanics.

This volume is clearly meant both to continue the series and to tell Schrödinger's story. Given the authors' general intent to provide maximum background material, it could hardly be the former without the latter. There was thus a great amount of further background material to collect beyond Mehra's earlier work (which had included interviews with Schrödinger), explaining the time gap between the appearance of the previous volumes and this one. Schrödinger left a huge amount of archival material behind which the authors not only use but also list in detail, and in addition much has been assembled on his Viennese background and some on Zürich, where his irruption into quantum theory took place.

Description of Vienna in the late nineteenth century begins the work. We are told some history of the multinational Habsburg Empire and are introduced to its many-sided culture, including a number of its great figures. Schrödinger enters as an inheritor of great traditions — a polymath growing up in a highly cultured family. Every event, place or person mentioned is the subject of detailed documentation.

The reader learns of many men who influenced Schrödinger in his youth. Perhaps the most relevant of them is Ludwig Boltzmann, because statistical mechanics became one of Schrödinger's main interests. (Boltzmann is first introduced alongside Ernst Mach, and we hear incidentally of their great debate on the acceptability of atoms as real.) In 1912 Schrödinger began to be known to theoretical physicists through his prolific publications on many topics. Space forbids discussing them here, as Mehra and Rechenberg do

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Back in Vienna — Schrödinger in 1956.

in interesting detail. Most of these papers were concerned with properties of matter in bulk, but with digressions, for example into problems of colour vision.

In the present context, Schrödinger's interest in general relativity is noteworthy. It led to his study of the ideas of Weyl, which linked the theory with electromagnetism. There, a line integral (of the four-potential) featured centrally. In 1922 Schrödinger remarks in a note that this integral, taken round a hydrogen Bohr orbit, is proportional to its quantum number! Apart from this prophetic shot, single atoms had been hardly mentioned up to then. Even as his great year of 1926 was approaching, it was not the atom but problems in statistical mechanics that occupied Schrödinger. We read of an interesting discussion between Planck and Einstein on the statistics of the ideal gas, in which they sought to agree on how to count states in an assembly. Schrödinger joined in and was encouraged by Einstein to write a paper. Einstein also told him of Bose's ideas, and then of de Broglie's recent startling suggestion that, for counting purposes, the gas molecules should be represented by waves (de Broglie's work was described in an earlier volume). Evidently it was this replacement of particles by waves in gas statistics — a counterpart to Planck's introduction of the quantum into the statistics of radiation 25 years earlier — that stimulated Schrödinger to study de Broglie's idea. It seems that the part of the latter's paper on the hydrogen spectrum, which relates closely to Schrödinger's 1922 paper, was not where wave mechanics started! In fact Schrödinger seems to have forgotten that three-year-old work of his own. At this point the great idea was not yet fully formed. Debye is reported to have asked Schrödinger whether he had considered the *wave equation* for the new 'matter waves'. When he did so, he first had to examine and discard the relativistic form of the equation. Then came success. The paper, giving the right result for the hydrogen spectrum, appeared on 27 January 1926.

When, shortly afterwards, Schrödinger beat Pauli with his proof that the new 'Göttingen' quantum mechanics and his 'wave mechanics' were *mathematically* the same thing, the great leap forward was complete. Here the first part of the authors' story ends. It is also roughly the end of the first half-volume. It might have been entitled *The Early History of Erwin Schrödinger*.

The second half could be called *The Early History of the Wave Equation*. At this point, abruptly, Schrödinger's equation transformed the character and the rate of progress of research in quantum theory. It divides roughly into two streams. On the one hand, much needed doing before the full scope of the wave equation could be understood. The quantum mechanics initiated by Heisenberg had relied for its general formulation on the use of the classical theory of Hamilton. For the understanding of Schrödinger's equation a similar bridge to a 'classical limit' was found in the Hamilton–Jacobi equation. On the other hand, many concrete problems could be solved by wave mechanical methods and are reported in detail by Mehra and Rechenberg. Thus we read of Heisenberg's explanation of the helium spectrum and then of the concept and applications of Fermi statistics. Schrödinger contributed to both kinds of studies. There are careful and detailed accounts of all this work. However, no single piece of work here reported pinpoints the paradox in the Schrödinger story more than Born's treatment of scattering, in which he made the decisive pronouncement that the wave function does not directly describe any observable physical entity, but is a means of defining *probabilities* of the outcome of observations. This interpretation was forever unacceptable to Schrödinger, an opinion which was shared by Einstein but only a few others.

There are, apparently, more volumes of *The Historical Development of Quantum Theory* to follow. Whether they will record the prolonged debates for and against the accepted probabilistic interpretation of quantum mechanics, we do not know. In any case, we are told by the pioneers of today to look beyond the four-dimensional world of particles for some 'reality' in many dimensions, with objects such as strings inhabiting it. Was Schrödinger so wrong not to believe in the survival of Born's picture? ☐

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