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(b. Vienna, Austria, 12 August 1887; d. Alpbach, Austria, 4 January 1961)

theoretical physics.

Schrödinger's father, Rudolf Schrödinger, inherited an oilcloth factory, which, although run in an old-fashioned manner, was successful enough to free him of financial worries. After studying chemistry he turned to his real interests—painting and, later, botany—and published a series of scientific papers in the *Abhandlungen* and *Verhandlungen der Zoologisch-botanischen Gesellschaft in Wien*. He married the daughter of Alexander Bauer, professor of chemistry at the Technische Hochschule in Vienna; Erwin was their only child.

Schrödinger attended public [elementary school](#) only once, for a few weeks in Innsbruck, while his parents were on vacation. In Vienna an [elementary school](#) teacher came to his home twice a week to tutor him; but, in Schrödinger's opinion, his "friend, teacher, and tireless partner in conversation" was his father. In the fall of 1898 Schrödinger entered the highly regarded academic Gymnasium in Vienna. As was then customary, the curriculum emphasized Latin and Greek, the sciences being somewhat neglected. Schrödinger wrote: "I was a good student, regardless of the subject. I liked mathematics and physics, but also the rigorous of the ancient grammars. I hated only memorizing 'chance' historical and biographical dates and facts. I liked the German poets, especially the dramatists, but hated the scholastic dissection of their works."

As a student Schrödinger regularly attended the theater in Vienna and was a passionate admirer of [Franz Grillparzer](#). He kept an album containing programs of the performances he had seen and made extensive annotations on them. He did not, however, neglect his studies. In 1907, during his third semester at the University of Vienna, he began to attend lectures in theoretical physics, which had just been resumed after a nearly two-year interruption following the death of Boltzmann. Friedrich Hasenöhl's brilliant inaugural lecture on the work of his predecessor made a powerful impression on Schrödinger.

Schrödinger highly esteemed Hasenöhl and attended his lectures on theoretical physics five days a week for eight successive semesters. He also was present at the mathematics lectures of Wilhelm Wirtinger and those on experimental physics of Franz Exner, whose laboratory assistant he later became.

In 1910 Schrödinger received the doctorate under Hasenöhl, and the following year he became assistant to Exner at the university's Second Physics Institute, where he remained until the outbreak of war. During these years Egon von Schweidler was *Privatdozent* at the university; Schrödinger was obliged to supervise the large physics laboratory courses, a duty for which he was very thankful all his life because it taught him "through direct observation what measuring means."

Schrödinger served in [World War I](#) as an officer in the fortress artillery; and in the isolated areas where he was stationed, he often had time to study physics. In 1916, while at Prosecco, he learned the fundamentals of Einstein's [general theory of relativity](#), which he at first found quite difficult to understand. Soon, however, he was able to follow Einstein's train of thought and the relevant calculations; he found much in the initial presentation of the theory that was "unnecessarily complicated."

As early as 1918 Schrödinger had as sure prospect of obtaining a position; he was to succeed Josef Geitler as extraordinary professor of theoretical physics at the University of Czernowitz (now Chernovtsy, Ukraine). "I intended to lecture there honorably on theoretical physics, at first on the model of the splendid lectures of my beloved teacher, fallen in the war, Fritz Hasenöhl, and beyond this to study philosophy, deeply immersed as I then was in the writings of Spinoza, Schopenhauer, Mach, Richard Semon, and Richard Avenarius." The collapse of the Austro-Hungarian monarchy prevented this plan, and after the war he worked again at the Second Physics Institute in Vienna. As a result, Schrödinger's first scientific papers were in the experimental field. In 1913, at the summer home of Egon von Schweidler at Seeham, Schrödinger collaborated with K. W. F. Kohlrusch on a work that was awarded the Haitinger Prize of the Imperial Academy of Sciences and that was published as "Radium-A-Gehalt der Atmosphäre in Seeham 1913." At Seeham, Schrödinger met Annemarie Bertel, whom he married on 6 April 1920.

Shortly after his marriage Schrödinger moved to Jena, where he was an assistant to Max Wien in the experimental physics laboratory. He left Jena after only four months, in order to accept an extraordinary professorship at the Technische Hochschule in Stuttgart. He remained there for only one semester; in the meantime he had received three offers of full professorships—from Kiel, Breslau, and Vienna. He would have preferred to succeed Hasenöhl at Vienna, but the working conditions for university professors in Austria were then so poor that this alternative was unacceptable. Instead he went to Breslau, where a few weeks after his arrival he received and accepted an offer to assume the chair formerly held by Einstein and [Max von Laue](#) at Zurich.

While at Zurich, Schrödinger worked chiefly on problems related to the statistical theory of heat. He wrote papers on gas and reaction kinetics, oscillation problems, and the thermodynamics of lattice vibrations and their contribution to internal energy; in other works he elucidated aspects of mathematical statistics. In an article on the theory of specific heats and in a monograph on statistical thermodynamics he gave a comprehensive account of the latter subject.

Although Schrödinger published several contributions to the old [quantum theory](#), he did not pursue that topic systematically. His first papers on relativity pointed to a second major field of interest. In addition to these works, and his early papers on relativity, Schrödinger made a detailed study, through both measurement and computation, of the metric of color space and the theory of color vision. The main results of his efforts were an article in J. H. J. Möller and C. S. M. Pouillet's *Lehrbuch der Physik* and the acceptance by physiologists of his interpretation of the relationship between the frequency of red-green [color blindness](#) and that of the blue-yellow type.

In the meantime, on 25 November 1924, Louis [de Broglie](#) defended his dissertation before the examining committee at the Sorbonne: "Recherche sur la théorie des quanta." The contents of the dissertation first became known through a direct communication from [Paul Langevin](#) to Einstein and then, more generally, through publication in the *Annales de physique*. At first no physicist except Einstein—was willing to believe in the reality of the Broglie waves.

As in his first quantum papers, of 1905, Einstein at the end of 1924 again hypothesized "a far-reaching formal relationship between radiation and gas"; but by the latter year he was concerned primarily with the properties of the gas. Basing his analysis on what is today known as Einstein-Bose statistics, he obtained expression for the fluctuation in number of molecules that hinted at interference effects.

Schrödinger, who in 1925 was also investigating problems of quantum statistics, was "suddenly confronted with the importance of [de Broglie](#)'s ideas" in reading Einstein's "Quantentheorie des einatomigen idealen Gases. 2. Abhandlung," which appeared on 9 February 1925 in *Sitzungsberichte der Preussischen Akademie der Wissenschaften zu Berlin*. He recognized that Einstein had introduced a fundamental new approach, but he sought "to recast it in a more pleasing form, to liberate it from Bose's statistics," which he deeply disliked.

Shortly before the middle of December, Schrödinger completed a paper on this topic, "Zur Einsteinschen Gastheorie," recorded as being received by *Physikalische Zeitschrift* on 15 December 1925. In an important and still unpublished letter to Einstein dated 28 April 1926, Schrödinger gave the following evaluation of his results: "I can ... assert categorically that I have really achieved the liberation I mentioned above... I stress the determination of the frequency spectrum in ~ 3 . This whole conception falls entirely within the framework of 'wave mechanics'; it is simply the mechanics of waves applied to the gas instead of to the atom or the oscillator."

Schrödinger, who generally expressed his judgements in an intensely emotional way, termed the earlier Bohr-Sommerfeld [quantum theory](#) unsatisfactory, sometimes even disagreeable. Seeking to apply the new ideas to the problem of atomic structure, he "took seriously the de Broglie-Einstein wave theory of moving particles, according to which the particles are nothing more than a kind of 'wave crest' on a background of waves." As is evident in a letter of 16 November 1925, from Schrödinger to Alfred Landé, Schrödinger conjectures on this topic date from the beginning of November 1925 and therefore from before the conclusion of his paper on Einstein's gas theory.

The intensity of Schrödinger's work on the problem increased as he saw that he was on the track of a "new atomic theory," and it reached a peak during his winter vacation in Arosa. On 27 December 1925 he wrote to [Wilhelm Wien](#), editor of the *Annalen der Physik* in Munich that he was very optimistic: "I believe that I can give a vibrating system ... that yields the hydrogen frequency levels as its eigenfrequencies." The frequencies of the emitted light rays are then obtained, as Schrödinger observed, by establishing the differences of the two eigenfrequencies respectively.

Consequently the way is opened toward a real understanding of Bohr's frequency calculation—it is really a vibration (or, as the case may be, interference) process, which occurs with the same frequency as the one we observe in the spectroscope.

I hope that I will soon be able to report on this subject in a little more detail and in more comprehensible fashion. In the meantime I must learn more mathematics, in order to fully master the vibration problem—a linear differential equation, similar to Bessel's, but less well known, and with remarkable boundary conditions that the equation 'carries within itself' and that are not externally predetermined.

The letter confirms what is already known from Schrödinger's publications and from other statements: that, as must have seemed logically consistent from the physics of the problem, he originally developed a relativistic theory. It must be emphasized, therefore, that Schrödinger worked out the relativistic version only at the end of 1925 and not, as historians of science had believed, in the middle of that year. The equation now known as the "Klein-Gordon equation" does yield the correct nonrelativistic Balmer term, but it gives an incorrect description of the fine structure. Schrödinger was deeply disappointed by this failure and must have thought at first that his whole method was basically wrong. Today it is known that the reason for the failure lay not in this bold initial approach but in application of the theory of relativity, which, however, has itself been abundantly confirmed. The relativistic Schrödinger equation is obviously correct, but it describes particles without

spin, whereas a description of electrons requires the Dirac equation. At the time, however, only the first steps had been taken toward an understanding of electron spin.

After a brief interruption Schrödinger took up his method again, but this time he treated the electron nonrelativistically. It soon became apparent that he had arrived at a theory that correctly represented the behavior of the electron to a very good approximation. The result was the emergence of wave mechanics in January 1926.

Schrödinger published the results of his research in a series of four papers in the *Annalen der Physik* bearing the overall title “Quantisierung als Eigenwertproblem.” The first installment, sent on 26 January and received by Wien the next day, contains the first appearance in the literature of his famous wave equation, written out for the hydrogen atom. The solution of this equation follows, as Schrödinger put it, from the “well-known” method of the separation of variables. The radial dependency gives rise to the differential equation

In fulfilling the boundary conditions one obtains solutions only for certain values of the energy parameters, the stationary values. This seemed to Schrödinger to be the “salient point,” but in Bohr’s original theory—as its creator stressed from the beginning—it was one of the two fundamental postulates that had remained unexplained. Schrödinger emphasized that, in his theory,

the ordinary quantization rule can be replaced by another condition in which the term “integral number” no longer appears. Rather, the integrality occurs in the same natural way as, say, the integrality in the modal numbers of a vibrating string. The new conception can be generalized and, I believe, penetrates very deeply into the true nature of the quantum rules.

In solving the differential equation for the radial function, Schrödinger received expert assistance from Hermann Weyl. A crucial element in their rapid success was the fact that the mathematical theory had already been completely worked out by Richard Courant and [David Hilbert](#) in their *Methoden der mathematischen Physik* (1924).

In his second paper (23 February 1926) Schrödinger gave a sort of “derivation” of his *undulatorischer Mechanik* in which he drew on the almost century-old work of [William Rowan Hamilton](#). Hamilton was aware that geometrical optics was only a special case of wavelengths, and he showed how to make the transition from the characteristic (iconal) equation of geometrical optics to the differential equation of wave optics. Hamilton introduced the methods of geometrical optics into mechanics and obtained an equation similar to the iconal equation and now known as the Hamilton-Jacobi differential equation. In it the index of refraction is replaced, essentially, by the potential energy and mass of the mechanical particle.

In Hamilton’s work Schrödinger thus found an analogy between mechanics and geometrical optics. And, since geometrical optics “is only a gross approximation for light,” he conjectured that the same cause was responsible for the failure of classical mechanics “in the case of very small orbital dimensions and very strong orbital curvature.” Both would be only approximations for small wavelengths. Therefore, he said:

Perhaps this failure is a complete analogy to the failure of geometrical optics, that is, the optics with infinitely small wavelengths; [a failure] that occurs, as is known, as soon as the “obstacles” or “openings” are no longer large relative to the real, finite wavelength. Perhaps our classical mechanics is the *complete* analogue of geometrical optics and, as such, false... . Therefore, we have to seek an “undulatory mechanics”—and the way to it that lies closest at hand is the wave-theoretical elaboration of Hamilton’s model.

Consequently, Schrödinger introduced into his development of wave mechanics conceptions that differed completely from those underlying the quantum mechanics formulated by the Göttingen school. He himself stated; “It is hardly necessary to emphasize how much more agreeable it would be to represent a quantum transition as the passage of energy from one vibrational form into another, rather than to represent it as the jumping of electrons.” In many passages Schrödinger (like Heisenberg) expressed his views in an almost polemical tone: “I ... feel intimidated, not to say repelled, by what seem to me the very difficult methods [of matrix mechanics] and by the lack of clarity.”

Despite his distaste for matrix mechanics, Schrödinger was “convinced of [its] inner connection” with wave mechanics. Hermann Weyl, to whom he had presented his purely mathematical problem, was unable to “provide the connecting link.” Thereupon Schrödinger temporarily put aside his conjectures on the matter; but by the beginning of March 1926, much earlier than he had thought possible, he was able to show the formal, mathematical identity of the two theories.

The starting point for this analysis was the following observation:

Given the extraordinary, it is ... odd that these two new quantum theories agree with each other even where they deviate from the old quantum theory. I note above all the peculiar “half-integrality” in the case of the oscillator and the rotator. This is truly remarkable, for the starting point, conception, method, and ... entire mathematical apparatus appear to be fundamentally different for each theory.

Schrödinger remarked that Heisenberg’s peculiar computational rules for functions of the $2n$ variables— $q_1, q_2, \dots, q_n, p_1, p_2, \dots, p_n$ space and impulse coordinates—agree exactly with the computational rules that are valid in ordinary analysis for linear

differential operators of n variables q_1, \dots, q_n . The correspondence is of such a nature that each p_1 in the function is replaced by the operator α/α_{q_1} . As a result Schrödinger rewrote the equation $pq - qp = h/2\pi i$ (first formulated by Bron) simply as because the operator on the left side, applied to an arbitrary function of q , reproduces this function. On this basis Schrödinger proceeded to show the complete mathematical equivalence of the two theories. The matrices can be constructed from Schrödinger's eigenfunctions and vice versa.

With the demonstration of the mathematical identity of wave mechanics and matrix mechanics, physicists at last came into possession of the "new quantum theory" that had been sought for so long. In working with it they could use either of two mathematical tools: matrix computation or the method of setting up and solving a partial differential equation. Schrödinger's wave equation proved to be easier to handle. Moreover, physicists were more familiar with partial differential equations than with the new matrices. Therefore, Schrödinger's methods were more widely adopted for the mathematical treatment of the new theory. He contributed substantially to the elaboration of that treatment in his next two papers, especially through the development of his perturbation theory.

In his first publications Schrödinger had spoken of the wave function ψ as something that could be directly visualized—a vibration amplitude in three-dimensional space. He sought to interpret $\psi\psi^*$ as electric charge density and hoped to establish physics on a thoroughgoing wave conception. Since, however, experiments clearly indicated the existence of strongly localized particles, he attempted to introduce the concept of the wave group: "One can try to construct a wave group of relatively small dimensions in all directions. Such a wave group presumably will obey the same laws of motion as an individual image point of the mechanical system."

Schrödinger attempted to develop this conception in "Der stetige Übergang von der Mikro- Zur Makromechanik." It soon became apparent, however, that in almost all cases such a wave group disappears in infinitely short time and therefore cannot possibly represent a real particle. Schrödinger also observed that in the many-electron problem, the interpretation he originally had in mind is necessarily invalid in ordinary space: " $\psi\psi^*$ is a sort of weight function in the configuration space of the system."

Shortly afterward [Max Born](#) interpreted $\psi\psi^*$ as a probability, a view that Schrödinger considered a complete misinterpretation of his theory. From this time on, quantum theory developed in a way wholly different from the one Schrödinger had foreseen. In 1927 Heisenberg and Bohr succeeded in establishing, on a statistical foundation, an independent and consistent interpretation, "Copenhagen interpretation." Schrödinger was "concerned and disappointed" that this "transcendental, almost psychological interpretation of the wave phenomena" had become "the almost universally accepted dogma." Schrödinger never changed his attitude on this subject, repeatedly defending the notion of "the electron as wave" and seeking to elaborate it without having recourse to the idea of "the electron as particle."

In 1927 Schrödinger accepted the prestigious offer, which had been declined by Arnold Sommerfeld, to succeed Max Planck in the chair of theoretical physics at the University of Berlin. At the same time he became a member of the Prussian Academy of Sciences. The University of Zurich vainly sought to persuade him to stay, offering him, among other inducements, a double professorship jointly with the Eidgenössische Technische Hochschule. Schrödinger was content in Zurich, despite occasional complaints; and his stay there had been very fruitful for the development of his scientific thought. Clearly, however, the city could not compete with Berlin, where, in the truest sense of the phrase, "physics was done." Berlin, with its two universities, the Kaiser Wilhelm Institute, the Physikalisch-Technische Reichsanstalt, and numerous industrial laboratories, offered the possibility of contact with a large number of first-rate physicists and chemists. Still, Schrödinger did not find it easy to make the decision. It was Max Planck who finally brought the vacillating Schrödinger to Berlin with the words: "It would make me happy" —as Schrödinger himself recorded in the Planck family guest book.

Although Schrödinger was extremely fond of nature, especially the Alps, and dreaded the prospect of living in a big city, he very much enjoyed his years in Berlin. He developed a close friendship with Planck, whose scientific and philosophical views were similar to his own. After the "wandering years from 1920 to 1927," this time of his life was "the very beautiful teaching and learning period."

In 1933 Schrödinger was deeply outraged at the new regime and its dismissal of outstandingly qualified scientists. Frederick A. Lindemann (later Viscount Cherwell) offered him the support of Imperial Chemical Industries; and after a summer vacation in Wolkenstein in the Grödenertal (Val Gardena), where he had a depressing meeting with Born and Weyl, Schrödinger moved to Oxford at the beginning of November. The fifth day after his arrival, he was accepted as a fellow of Magdalen College. At the same time the *Times* of London called his hotel to tell him that he had been awarded the [Nobel Prize](#) in physics for 1933, jointly with P. A. M. Dirac.

At Oxford, Schrödinger gradually became so homesick for Austria that he allowed himself to be persuaded to accept a post at Graz in the winter semester of 1936–1937. After the *Anschluss* he was subjected to strong pressure from the National Socialists, who had not forgotten his emigration from Germany in 1933. His friends at Oxford observed his difficulties with great concern.

As early as May 1938 Eamon de Valera, who had once been professor of mathematics at the University of Dublin, attempted to find a way of bringing Schrödinger to Ireland. By the time Schrödinger was dismissed, without notice, from his position at Graz on 1 September 1938, the first steps had already been taken. Fortunately, Schrödinger had been left his passport and was able to depart unhindered, although with only a small amount of baggage and no money. Passing through Rome and Geneva,

he first returned to Oxford. De Valera had a law passed in the Irish Parliament establishing the Dublin Institute for Advanced Studies; but in order to keep busy until it opened, Schrödinger accepted a guest professorship at the Francqui Foundation in Ghent.

At the beginning of September 1939, Schrödinger, as a German émigré, suddenly found himself an enemy alien: but once more de Valera came to his assistance, Through the Irish high commissioner in [Great Britain](#), he arranged for a letter of safe conduct to be issued for Schrödinger, who on 5 October 1939 passed through England on his way to Dublin with a transit visa valid for twenty-four hours. Schrödinger spent the next seventeen years in the Irish capital, where he was able to work in his new position undisturbed by external events. He later called these years of exile “a very, very beautiful time. Otherwise I would have never gotten to know and learned to love this beautiful island of Ireland. It is impossible to imagine what would have happened if, instead, I had been in Graz for these seventeen years.”

The new Institute for Advanced Studies consisted of two sections, theoretical physics and [Celtic languages](#), both located in a former townhouse on Merrion Square in Dublin. Young physicists from all over the world were given stipends enabling them to spend one or two years there. On the average there were ten to fifteen scholars in residence. Among them were Walter Thirring, Friedrich Mautner, Bruno Berdotti, and H. E. Peng. Like many of the others, Peng had previously worked with [Max Born](#) at Edinburgh. The yearly “summer school” in Dublin became famous as an informal gathering for the discussion of current problems of physics. Born and Dirac were frequent participants, and de Valera often came too.

In the years after his departure from Germany, Schrödinger published many works on the application and statistical interpretation of wave mechanics, on the mathematical character of the new statistics, and on its relationship to the statistical theory of heat. He also dealt with questions concerning general relativity, notably the relativistic treatment of wave fields, in contradistinction to the initial, nonrelativistic formulation of wave mechanics. In addition he wrote on a number of cosmological problems. Schrödinger, however, devoted an especially fervent effort, as did Einstein in his later years, to expanding the latter’s theory of gravitation into a “unified field theory,” the metric determination of which was to be established from a consideration of all the known forces between particles.

In his last creative period Schrödinger turned to a thorough study of the foundations of physics and their implications for philosophy and for the development of a world view. He wrote a number of studies on this subject in book form, most of them appearing first in English and then in German translation. It becomes particularly evident from the posthumously published *Meine Weltansicht* that Schrödinger was greatly concerned with the ancient Indian Philosophy of life (Vedanta), which had led him to concepts that closely approximate [Albert Schweitzer](#)’s “reverence for life.” In “What Is Life?” Schrödinger points out why physics had amassed so little empirical evidence that might be applicable to the study of cell development: a periodic crystals, in terms of which a gene should be considered, had not been investigated. But according to Delbrück’s model, quantum physics made it possible to understand general persistence as well as the case of spontaneous mutation. Schrödinger was convinced that the biological process of growth could also be conceived on the basis of quantum theory according to the schema “order out of order.” His analysis is outdated today: but during his lifetime it exerted enormous appeal among physicists (as Francis Crick corroborated) and induced many young people to study biology. Thus the great advances of [molecular biology](#) are indirectly linked to Schrödinger. He was a master of exposition, and Arnold Sommerfeld even spoke of a special “Schrödinger style.” Schrödinger wrote and spoke four modern languages (as well as Greek and Latin), translated various items, and published a volume of poetry—while continuing to bestow great care on the preparation of his lectures, as is evident from their exceptional accuracy. To keep up this pace he required a marked alternation of intensely productive periods with creative pauses.

Soon after the end of the war, Austria tried to convince Schrödinger to return home. Even the president, [Karl Renner](#), personally intervened in 1946; but Schrödinger was not willing to return while Vienna was under Soviet occupation. In the succeeding years he often visited the Tirol with his wife, but he did not return definitively until 1956, when he was given his own chair at the University of Vienna. A year later he turned seventy, the customary retirement age in Austria but lectured for a further year (*Ehrenjahr*).

In his last years Austria honored Schrödinger with a lavish display of gratitude and recognition. Immediately after his return he received the prize of the city of Vienna. The national government endowed a prize bearing Schrödinger’s name, to be awarded by the Austrian Academy of Sciences, and Schrödinger was its first recipient. In 1957 he was awarded the Austrian Medal for Arts and Science. He wrote that “Austria had treated me generously in every respect, and thus my academic career ended happily at the same Physics Institute where it had begun.”

On 27 May 1957 Schrödinger was accepted into the German order *Pour le mérite*. He was also granted honorary doctorates from a number of universities and was a member of many scientific associations, including the Pontifical Academy of Sciences, the [Royal Society](#) of London, the Prussian (later German) Academy of Sciences. In 1957 Schrödinger survived an illness that threatened his life, and he never fully recovered his health. he died on 4 January 1961 and is buried in the small village of Alpbach, in his beloved Tirolean mountains.

BIBLIOGRAPHY

I. Original Works. Schrödinger's important papers on wave mechanics are reprinted in *Abhandlungen zur Wellenmechanik* (Leipzig, 1927; 2nd ed., 1928); and *Die Wellenmechanik*, vol. 3 of *Dokumente der Naturwissenschaft* (Stuttgart, 1963), which contains an extensive bibliography compiled by E. E. Koch of Schrödinger's writings (pp. 193–199).

Some important correspondence is in Karl Przibram, ed., *Schrödinger. Einstein. Lorentz. Briefe zur Wellenmechanik* (Vienna, 1963), also translated into English by Martin J. Klein as *Letters on Wave Mechanics* ([New York](#), 1967), which does not, however, contain Schrödinger's letter to Einstein (28 Apr. 1926). Unpublished letters to Arnold Sommerfeld are at the Sommerfeld estate in the library at the Deutsches Museum, Munich. Two letters to Hermann Weyl were published by Johannes Gerber in *Archive for History of Exact Sciences*, **5** (1969), 412–416. The sources of other letters to and from Schrödinger are in T. S. Kuhn *et al.*, *Sources for History of [Quantum Physics](#). An Inventory and Report* (Philadelphia, 1967), 83–86.

II. Secondary Literature. See Johannes Gerber, "Geschichte der Wellenmechanik," in *Archive for History of Exact Sciences*, **5** (1969), 349–416; Armin Hermann, "Erwin Schrödinger—eine Biographie," in *Die Wellenmechanik* (see above), 173–192; Max Jammer, *The Conceptual Development of Quantum Mechanics* ([New York](#), 1966), 236–280; Martin J. Klein, "Einstein and the Wave-Particle Duality," in *Natural Philosopher*, **3** (1964), 1–49; V. V. Raman and Paul Forman, "Why Was It Schrödinger Who Developed de Broglie's Ideas?" in *Historical Studies in the Physical Sciences*, **1** (1969), 291–314; William T. Scott, *Erwin Schrödinger, an Introduction to His Writings* (Amherst, Mass., 1967); Robert Olby, "Schrödinger's problems: what Is Life?" in *Journal of the History of Biology*, **4** (1971), 119–148).

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