

# Schrödinger

LIFE AND THOUGHT



Walter Moore



## Schrödinger

### life and thought

Erwin Schrödinger was a brilliant and charming Austrian, a great scientist, and a man with a passionate interest in people and ideas. In this, the first comprehensive biography of Schrödinger, Walter Moore draws upon recollections of Schrödinger's friends, family and colleagues, and on contemporary records, letters and diaries.

Schrödinger's life is portrayed against the background of Europe at a time of change and unrest. His best known scientific work was the discovery of wave mechanics, for which he was awarded the Nobel prize in 1933. However, Erwin was also an enthusiastic explorer of the ideas of Hindu mysticism, and in the mountains of his beloved Tirol he sought a philosophic unity of Mind and Nature. Although not Jewish, he left his prestigious position at Berlin University as soon as the Nazis seized power. After a short time in Oxford he moved to Graz, but barely escaped from Austria after the Anschluss. He then helped Eamon de Valera establish an Institute for Advanced Studies in Dublin. It was here that he spent the happiest years of his life, and also where he wrote his most famous and influential book *What is Life?*, which attracted some of the brightest minds of his generation into molecular biology. Schrödinger enjoyed a close friendship with Einstein, and the two maintained a prolific correspondence all their lives.

Schrödinger led a very intense life, both in his scientific research and in his personal life. Walter Moore has written a highly readable biography of this fascinating and complex man, which will appeal not only to scientists but to anyone interested in the history of our times, and in the life and thought of one of the great men of twentieth-century science.



*A portrait by Lotte Meitner-Graf, made in London (c. 1935).*

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## Contents

<i>Preface</i>	<i>page</i> vii
<i>Chronology</i>	x
<i>Introduction</i>	1
1 Family, childhood and youth	7
2 University of Vienna	32
3 Schrödinger at war	79
4 From Vienna to Zürich	111
5 Zürich	145
6 Discovery of wave mechanics	191
7 Berlin	230
8 Exile in Oxford	278
9 Graz	320
10 Wartime Dublin	352
11 Postwar Dublin	415
12 Home to Vienna	455
<i>References</i>	483
<i>Name index</i>	502
<i>Subject index</i>	510



## Preface

In this book I have tried to tell something of the life of Erwin Schrödinger in such a way that even those who are not scientists may be able to understand the greatness of his work, the range of his ideas, and the kind of person he was. Montaigne wrote that 'our life is divided betwixt folly and prudence: whoever will write of it only what is reverend and canonical will leave about the one-half behind'. In order to come closer to the whole of Schrödinger, I have included some account of his personal life. It is not thirty years since his death and thus many personal memories and sensitivities have not yet receded into history, a situation that is both a help and a hindrance for a biographer. It is possible to interview former friends and colleagues, but some important collections of letters and memoirs remain closed to research.

My book was made possible by the generosity with which Schrödinger's eldest daughter, Mrs Ruth Braunizer, made available many of the archives concerning her father's life.

Special thanks are due to Professor Ludvik Bass of the University of Queensland, Schrödinger's last postdoctoral student, who reviewed the entire manuscript; his scientific and historical comments have been invaluable.

Dr Linda Wessels of Indiana University provided many helpful suggestions. Professor James McConnell of the Dublin Institute for Advanced Studies never failed to answer my seemingly endless questions about Schrödinger's Dublin years. Dr Anthony Bracken reviewed several theoretical sections; Professor David MacAdam clarified some of the difficulties of color theory. My friend and neighbor, Robert Halporn, assisted in the decipherment of Gothic script and in explaining life in Vienna and the Austrian educational system. Dr John Fletcher helped with the study of Schrödinger's poetry. Professor Sture Nordholm provided translations of the Nobel Archives, and Dr Kirsten Streib translated some of Niels Bohr's letters from the Danish. Professor Karl v. Meyenn of Barcelona made available unpublished material about Schrödinger in Spain, and Professor

Kenji Sugimoto shared his collection of photographs. My family was enlisted in various ways: Professor Joseph Wiecha as consultant on German language and literature, my sister Mary Wiecha for comments on style and content, and my nephew Dr John Wiecha for one of the interviews.

So many others provided help with interviews and research material that I can only mention their names and the relevant section, even omitting their often distinguished titles.

*Dublin.* Charles Acton, Ronald Anderson, Otto Bergmann, Hermann Bruck, Basil Clancy, Ernesto Corinaldesi, Brigid Dolan, Eithne Dunne, Nuala Feric, Stephen Feric, Gerald Gardner, Herbert Green, Jim Hamilton, Vincent Hart, Margaret Holmes, Fred Hoyle, Ray Kavanagh, John Lewis, Alexander Lieven, A.J. McConnell, William McCrea, Lena McManus, Ernán McMullin, Des McNamara, Harry Messel, Lillian Murnane, Maire Cruise O'Brien, Sean O'Coinneide, H.W. Peng, Jim Pounder, John Ryan, Brendan Scaife, Alfred Schulhof, Neville Symonds, John Synge, Louis Werner, Nicole Whitney, Evelyn Wills.

*Austria.* Maria Bertel, Bruno Bertotti, Johanna Bianchi, Arnulf Braunizer, Manfred Breiteneker, Ferdinand Cap, Erika Cremer, Auguste Dick, Dieter Flamm, Wilhelm Frank, Leopold Halpern, Otto Hittmair, Berta Karlik, Wolfgang Kerber, Ernst Kohlrausch, Emmy Krafack, Kurt Mählberber, Hermann Mark, Rena Mayer-Rieckh, Suzanne Nemenz, Heinz Oberhammer, Gerhard Oberkaufler, Heinz Pelzer, Kurt Polzer, Mario Rella, Roman Sexl, Ulrike Smola, Walter Thirring, John Ullmann, Paul Urban.

*Britain.* D.J. Allen, Hansi Bauer-Böhm, Gustav Born, Duncan Davies, Margit Dirac, Patrick Dolan, Margaret Farley-Born, Charles Frank, Fanchon Fröhlich, Herbert Fröhlich, David ter Haar, Barry Hickman, Paul Hoch, Patrick Johnson, Nicholas Kemmer, Heinrich Kuhn, Nicholas Kurti, Catherine Macmillan, Penelope Hughes Minney, Karl Popper, Lucie Rie, N.H. Robinson, Robin Schlapp, Charlotte Simon, Geoffrey Stephenson, Leslie Sutton.

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*Switzerland.* Valentine Bargmann, E. Peter Fischer, Beat Glaus, Hans Herwig, Hedwig Herwig, Itha Jennings, Res Jost, Miguel Jungen, Alexander v. Muralt, Gunter Rasche, Michael Weyl.

The custodians of various scientific archives always responded generously and efficiently to requests for research documents and permissions to quote from them: Dr Wolfgang Kerber of the Zentralbibliothek für Physik in Wien; Professor Bengt Nagel for the Nobel Committee; Dr Volker Wahl of the University of Jena; Dr Christa

Kirsten of the Academy of Sciences of the D.D.R.; Dr I. Stolzenberg of the Prussian State Library; Paul Schuchman of the Princeton Institute for Advanced Study; Dr Earle Coleman of Princeton University; Hofrat Dr Waissenberger of the City Museum of Vienna; the staffs of the Library of the American Philosophical Society in Philadelphia, the Bohr Library in New York, the Fisher Library in Sydney, the Deutsches Museum in Munich, and the Indiana University Library in Bloomington.

Special thanks are due to Mr Ehud Benamy of the Einstein Archives for his assistance, and to the Hebrew University of Jerusalem, Israel, for permission to quote from the letters of Albert Einstein.

Dr Simon Capelin, Senior Physics Editor of Cambridge University Press, provided not only valuable editorial comments and criticisms but also unerring judgment in matters of design and production.

The book could not have been written without the devoted assistance of my wife Patricia, who arranged and recorded the many interviews, managed an extensive correspondence, and suggested the most tactful pathways for research.

## Chronology

- 1887.8.12 Erwin Schrödinger born in Vienna III, Erdberg  
1898–1906 Student at Akademisches Gymnasium  
1906–1910 Student at University of Vienna  
1910.5.20 Award of degree Doctor of Philosophy  
1910–1911 Military service as one-year volunteer in the Fortress Artillery  
1914.1.9 Habilitation – *venia legendi* for Physics at University of Vienna (Privatdozent)  
1914–1918 Military service  
1919.12.24 Death of his father Rudolf in Vienna  
1920.1.17 Faculty recommends associate professorship at Vienna  
1920.3.24 Marriage with Annemarie Bertel  
1920 Assistantship with Max Wien, University of Jena  
1920.9.6 Associate Professor in Jena  
1920–21 Winter semester: Associate Professor Technische Hochschule Stuttgart  
1921 Summer semester: Professor for Theoretical Physics, Breslau  
1921.9.12 Death of mother Georgine in Vienna  
1921.10.12 Professor for Theoretical Physics, University of Zürich  
1922 Seven-month rest cure for tuberculosis, Arosa  
1926 Six major publications on wave mechanics in *Annalen der Physik*  
1926–1927 December to March, travel in U.S.A.  
1927.10.1 Professor of Theoretical Physics in Berlin, successor to Max Planck  
1929 Elected to membership in Prussian Academy of Sciences  
1933 Leaves Berlin at end of May in disgust for Nazi regime  
1933.10.3 Elected Fellow Magdalen College, Oxford  
1933.11.9 Nobel prize in Physics  
1936.10.1 Professor at University of Graz  
1938.9.1 Dismissal from Graz. Escape to Oxford  
1938–1939 Guest professor, University of Gent

- 1939.10.7 Arrival in Dublin
- 1940–1956 Senior Professor, School of Theoretical Physics, Dublin  
Institute for Advanced Studies
- 1956.3.28 Return to Vienna as Professor of Theoretical Physics  
(personal chair)
- 1958.9.30 Emeritus Professor, Vienna
- 1961.1.4 Death in Vienna
- 1961.1.10 Burial at Alpbach, Tirol



## Introduction

When the Great War began in August, 1914, Erwin Schrödinger at the age of twenty-seven was a *Privatdozent* at Vienna University, at the outset of a promising career in physics. He served throughout the war as a commissioned officer in the Austrian fortress artillery, first on the Italian front and later assigned to the imperial meteorology department in Vienna. On October 7, 1915, his revered professor of theoretical physics, Fritz Hasenöhr, was killed by a grenade in an Italian attack on Mount Plaut in the South Tirol.

Early in 1918, Schrödinger received word that he was being seriously considered for the position of *Professor Extraordinarius* [associate professor] in theoretical physics at the University of Czernowitz. 'I made up my mind to lecture there on honest theoretical physics, first of all according to the pattern of the splendid lectures of my beloved teacher Fritz Hasenöhr, fallen in the war, but besides to concern myself with philosophy, deeply immersed as I then was in the writings of Spinoza, Schopenhauer, Mach, Richard Semon, and Richard Avenarius. My good angel intervened, since soon Czernowitz no longer belonged to us. So nothing came of it. I had to stick to theoretical physics, and, to my astonishment, something occasionally emerged from it.'<sup>1</sup> Even on active duty, Schrödinger found time to read deeply in philosophy, and indeed it was the only thing that kept him from despair during the long years of senseless killing and destruction.

A serious interest in philosophy was not unusual among German and Austrian physicists, but with Schrödinger at that time it was so important that he was even tempted to sacrifice scientific research to devote his life to philosophical study. Much later, in 1963, Max Born wrote: 'I am convinced that theoretical physics is actually philosophy. It has revolutionized fundamental concepts, e.g., about space and time (relativity), about causality (quantum theory), and about substance and matter (atomistics). It has taught us new methods of thinking (complementarity), which are applicable far beyond physics.'<sup>2</sup> By his discovery of wave mechanics, Erwin Schrödinger

contributed in a major way to this revolutionary change in our view of the world [*Weltanschauung*]. Now, however, a paradox appears. Schrödinger was more deeply versed in and more sympathetic with philosophic ideas than any other scientist of modern times, yet he rejected the philosophic conclusions that others were so willing to draw from his work, or, to be more precise, he rejected the idea that such far-reaching conclusions could be drawn from any work in theoretical physics.

Arnold Sommerfeld, second to none in his broad understanding of the physics of the first half of our century, said of Schrödinger's discovery of wave mechanics in 1926, 'It was the most astonishing among all the astonishing discoveries of the twentieth century'.<sup>3</sup> This remark might apply also to the discovery of quantum mechanics at almost the same time by Werner Heisenberg. Why were these theories so revolutionary in their philosophical implications? In summary, they had the following results: (1) They devalued the philosophy of materialism that had prevailed in science since the time of Newton. (2) They showed that everything in the world is part of everything else; there are no boundaries and no isolated parts in the world. (3) They contradicted the idea of strict determinism and predictability in nature. (4) They raised deep questions about the role of mind in nature, and restored the human observer to a central position in natural philosophy. As a consequence of all these overturnings of conventional ideas, the influence of the new quantum theory has spread far beyond physics, leaving the philosophy of science, and indeed philosophy in general, in a state of flux whose final resolution can not as yet be discerned.

In his book *The Structure of Scientific Revolutions* (1962), Thomas Kuhn argues that there are two kinds of science, normal science and revolutionary science.<sup>4</sup> In any particular field, normal science is conducted in accord with a set of rules, concepts and procedures, called a *paradigm*, which is accepted by all scientists working in that field. Normal science is similar to puzzle-solving: interesting, even beautiful, solutions are obtained but the rules are never changed. In this normal scientific activity, however, unexpected discoveries sometimes are made that are inconsistent with the prevailing paradigm. Among the scientists, a tense situation then ensues, which increases in intensity until a scientific revolution is achieved. This is marked by a *paradigm shift*, and a new paradigm emerges under which normal scientific activity can be resumed.

This analysis of scientific progress may be less convincing now than when it first appeared; it tries to force the history of science itself into a paradigm with too few variables. Nevertheless, it does fit the work of Erwin Schrödinger. His scientific papers before 1925 were typical

products of 'normal science'; they were competent but certainly not remarkable extensions of subjects that were being pursued by his teachers and coworkers at the University of Vienna. In 1926, his *annus mirabilis*, he published at the 'advanced age' of thirty-eight his four great papers on wave mechanics, than which there is nothing more beautiful in theoretical physics. This was revolutionary science by any standard, but when did the revolution begin? Was it in 1913 with Niels Bohr and the quantum theory of the hydrogen atom? Was it in 1900 with Max Planck and the introduction of the quantum? Or was it as long ago as 1861 with James Clerk Maxwell and electromagnetic waves? Has the history of science become a permanent revolution?

After his great discovery in 1926, Schrödinger was unwilling to retreat to normal science. In his later years, he tried, often desperately, to achieve a second revolutionary discovery, attempting to unify gravitation and electromagnetism in a generalized field theory, but he was under no illusions about the likelihood of success. He told a young Irish scholar at Dublin: this problem is suitable only for old men who have already done something in science.

The Kuhnian analysis of scientific revolutions emphasizes the stress that precedes the breakthrough into a new world view. Schrödinger was a passionate man, a poetic man, and the fire of his genius would be kindled by the intellectual tension arising from the desperate situation of the old quantum theory of Planck, Einstein and Bohr. It seems also that psychological stress, particularly that associated with intense love affairs, helped rather than hindered his scientific creativity. In his short autobiography, he wrote: 'To create a true sketch of my life, for that I am lacking a narrator's turn of mind – and furthermore it is impossible, since leaving out relations with women in my case creates on the one hand a great void, and on the other hand seems to be required, firstly on account of scandal, secondly because they are hardly of sufficient interest, thirdly because in such matters no man is really completely sincere and truthful, nor ought he to be.'<sup>5</sup>

Fortunately Schrödinger published a volume of poetry, and a short poem usually unveils more of the psyche than a long scientific treatise. As Leon Edel remarked, a whole new world of biography has been opened by 'confessional poetry'.<sup>6</sup> Personal letters also provide valuable insights into the psychology of the individual, since they paint a portrait midway between the public and the private persona. 'The public facade is the mask behind which a private mythology is hidden', but in a personal letter the mask often slips appreciably. Schrödinger also kept extensive diaries. Orson Welles once contended that 'addiction to diaries, a secret vice like the eating of hashish, degrades the diarist himself to something like the moral status of a drama critic'.<sup>7</sup> I think, however, that Schrödinger wanted us to know

that a theoretical physicist need not be a man without qualities or passions and left us his diaries to that end.

Erwin Schrödinger had the most complex personality of all the great creators of modern physics. He was a passionate foe of injustice yet he regarded any political activity as contemptible. He despised pomp and circumstance yet he took a childlike pleasure in honors and medals. He was devoted to the vedantic concept that all men are members of one another, yet he eschewed cooperative work of any kind. His mind was dedicated to precise reasoning, yet his temperament was as volatile as a prima donna's. He claimed to be an atheist, but he always used religious symbolism and believed his scientific work was an approach to the godhead. In many respects he was a true son of Austria. 'In this country one acted – sometimes indeed to the extreme limits of passion and its consequences – differently from the way one thought, or one thought differently from the way one acted. Uninformed observers have mistaken this for charm, or even for a weakness in what they thought was the Austrian character. But that was wrong. It is always wrong to explain the phenomena of a country simply by the character of its inhabitants.'<sup>8</sup>

Hans Thirring, one of his closest friends at the University of Vienna, thought that Erwin had a *schizothymic personality*.<sup>9</sup> This is a category invented by Ernst Kretschmer, a German psychiatrist, who believed with Schopenhauer that 'genius is nearer to madness than to the ordinary intellect'.<sup>10</sup> He classified geniuses into two types, the schizothymic adjacent to schizophrenia and the cyclothymic to manic-depressive psychosis. Furthermore, he found evidence that psychological type can be related to bodily structure: schizothymes have long noses, irregular profiles, long oval facial contours, are often small, thin, wiry men. They have hyperesthetic temperaments, subject to 'tense moods, between which the affect jumps . . . The schizothymic soul, worn out by the noisy pathos of the heroic battle, suddenly feels the need for something diametrically opposed, for tearful tenderness, and dreamy bucolic stillness . . . It is just the same with the style of their private lives.'

Kretschmer found that scholars with schizothymic physiques have been devoted to work of an abstract, metaphysical, or theoretical nature, whereas the cyclothymes tend towards experimental and observational research. Among the markedly schizoid types he included Copernicus, Kepler, Leibniz, Newton, and Faraday. He did not discover any cyclothymic theoreticians, but we should have to place Schrödinger's 'scientific grandfather' Boltzmann in that class, both in bodily build and psychopathology, yet Boltzmann, with his devotion to materialism and his contempt for metaphysics, was an unusual theoretician in other respects also.

Psychology teaches that during his life an individual tends to repeat patterns of interpersonal relationships that were learned in childhood; thus the form of living and even the sexual politics of the man are often determined by his life as a child and by the family in which he was brought up. As the only child in an indulgent family, Erwin might easily have come to believe that the world revolved around his center.

The social milieu of Schrödinger's formative years in Vienna must have influenced his philosophy of life, and through this the way in which he conceived his scientific work. It is not difficult to become bedazzled by the brilliance of Vienna at the turn of the century, as one regards the enchanted characters who share the stage: authors, musicians, artists, philosophers, and scientists. At that time the intellectual world of Austria was not fragmented into academic disciplines and artistic circles that rarely communicated with one another. For example, Robert Musil wrote a thesis on Ernst Mach, and Ludwig Wittgenstein was an excellent architect. But the gleaming of Vienna was superficial, like the phosphorescence covering decay. While Schrödinger was attending the university and enjoying the delights of theater parties, new wine, and excursions to the mountains of nearby Semmering, young Adolf Hitler, twice rejected as an art student at the Academy, having pawned his overcoat to buy bread and milk, was prowling about the snowy streets in his shirtsleeves, with uncut hair and a straggly beard, trying to sell a few pictures of Viennese churches. He told a friend, 'I don't want to seem arrogant, but I think the world really lost something worthwhile when I was rejected by the Art School.'<sup>11</sup>

Everything official in the Austro-Hungarian monarchy was referred to as *K & K*, *kaiserlich* and *königlich* [imperial and royal]. Musil, Austria's greatest novelist, called the country '*Kakania*', which might be translated politely as 'Poopooland'. 'By its constitution it was liberal, but its system of government was clerical. The system of government was clerical, but the general attitude to life was liberal. Before the law all citizens were equal, but not everyone, of course, was a citizen. There was a parliament, which made such vigorous use of its liberty that it was usually kept shut.'<sup>8</sup>

Yet, after all, the essence of the life of a creative person is expressed in his work: the music of Mahler, the poetry of Hofmannsthal, the politics of Hitler, the physics of Schrödinger. As Ernst Cassirer wrote in regard to Kant: 'In the last analysis the essential task of every biography of a great thinker is to trace how his individuality blends ever more closely with his work and seemingly vanishes entirely, and how its spiritual outlines yet remain embedded in the work and only thus become clear and apparent.'<sup>12</sup> For a philosopher, such an analysis is obviously reasonable; its possibility is less obvious for a theoretical physicist. We may feel intuitively that the physicist and the philoso-

pher cannot be essentially different kinds of human being, yet a causal chain between a scientific discovery and the structure of a personality is not so easy to discern. So far as any individual is concerned, the great discovery itself may be to some extent accidental, the product of circumstance falling into a fertile field of intellect. Schrödinger touched upon this point in one of his poems:<sup>13</sup>

*Parabel*

Was in unserem leben, freund,  
wichtig und bedeutend scheint,  
ob es tief zu boden drücke  
oder freue und beglücke,  
taten, wünsche und gedanken,  
glaube mir, nicht mehr bedeuten  
als des zeigers zufallschwanken  
im Versuch, den wir bereiten  
zu ergründen die natur:  
sind molekelstösse nur.  
Nicht des lichtflecks irres zittern  
lässt dich das gesetz erwittern.  
Nicht dein jubeln und erbeben  
ist der sinn von diesem leben.  
Erst der weltgeist, wenn er drangeht,  
mag aus tausenden versuchen  
schliesslich ein ergebnis buchen. –  
Ob das freilich uns noch angeht?

*Parable*

My friend, what in this life  
Weighty and important seems,  
Whether causing dark depression  
Or gladness and rejoicing,  
Deeds, thoughts and wishes  
Believe me, means no more  
Than a pointer's fluctuations  
In an experiment that we design  
To fathom Nature:  
Merely molecular collisions.  
Nor does the light spot's crazy flutter  
Let you smell out the basic law.  
It's not your joy and trembling  
That makes sense of this life.  
The World Spirit, if it goes about it  
May from a thousand experiments  
Enter finally a result –  
Is it really any of our doing?

A great discovery may be partially a matter of good luck, but it is undeniable that the making of a great discovery has a considerable effect upon the subsequent life of the discoverer. As Franz Grillparzer, Schrödinger's favorite dramatist, wrote:<sup>14</sup>

Let him who once has won it scoff at fame  
It is no empty echo without meaning  
Its fingers are endowed with divine power.

There is no evidence that fame made any marked change in the personality of Erwin Schrödinger, but it probably made it possible for him to express himself more freely. Before his great discovery, he would appear at scientific meetings in a conventional starched collar; after he achieved fame, he would often turn up looking like a Tirolean mountaineer. Max Born, who had many a fierce scientific argument with him, and who was shocked by some of the things he did, nevertheless wrote: 'His private life seemed strange to bourgeois people like ourselves. But all this does not matter. He was a most lovable person, independent, amusing, temperamental, kind and generous, and he had a most perfect and efficient brain.'<sup>15</sup>

# 1 Family, childhood and youth

Heredity or environment, nature or nurture, there is no general solution to the problem of how much each contributes to the structure of a personality or the achievements of a person. It has been said that any medical student can become an adequate surgeon provided he or she is willing to work long hours, follow the hospital rules, and placate the nursing staff. In other words, this particular skill is not significantly determined by genetic factors. No such prescription can be applied to mathematical physics; original work in this field requires a special kind of native aptitude, the genes must be right. This is a necessary but not a sufficient condition. A potential Schrödinger may be lost to physics if he happens to be born in a Bengali village rather than a university town.

Many theoretical physicists have come from academic families, which, at least in Germanic countries, are considered to be upper middle class on the social scale. The fathers of Max Planck, Niels Bohr, Max Born, Wolfgang Pauli and Werner Heisenberg were all university professors, of Law, Biology, Anatomy, Colloid Chemistry and Byzantine Studies, respectively. Paul Dirac's father taught French at a Bristol grammar school, in the English context, a respected but lower-middle-class profession; Paul originally aspired only to be an engineer, but turned to pure theory after his ineptness in practical work became evident. Albert Einstein's lower-middle-class background was exceptional among German scientists. The Einsteins lived in an industrial suburb of Munich, and the early stages of Albert's scientific career were unusually precarious.

Thus the ancestry and family history of Erwin Schrödinger are relevant to the story of his life, even if the relative contributions of genetics and economics cannot be clearly separated. Fortunately his Aunt Rhoda compiled a history of his mother's side of the family; less is known about the Schrödinger side.<sup>1</sup>

## Family history

The story begins with Franziska Zickler, who was a love child of unknown parentage, born about 1780 in a convent in Hungary where her mother had taken refuge. From certain resemblances, it was thought that she may have been related to Josef of Habsburg-Lorraine, a son of Maria Theresia. She grew up to be a temperamental beauty and married a member of the minor nobility, Anton Wittmann-Denglass who was born at St Bernard in Lower Austria in 1771. They had a daughter Josepha, born in 1803 in Joskowicz, Hungary. Although they were a staunchly Catholic family, Josepha fell in love with a Protestant, and was thereupon forced to marry the Catholic family doctor, by whom she had three children. She was widowed and remarried, this time to Alexander Josef Bauer, who had distinguished himself as her father's secretary and later became manager of his estates. Bauer was a native of Bielitz, born in 1802.

Their eldest son was Alexander Bauer, the maternal grandfather of Erwin Schrödinger, born in Unter Altenburg (Magyarovar) in north-west Hungary, February 18, 1836. After graduation from the *Gymnasium*, Alexander studied mathematics and science at the University of Vienna, but transferred to the Polytechnic Institute (later the Technical University) to specialize in chemistry under Anton Schroetter, the discoverer of red phosphorus.

Erwin's maternal grandmother was English. Her ancestry has been traced back to a Norman family, Forestière, whose stronghold was Bamborough Castle near Durham. The name was anglicized to Forster. Thomas, born in 1772, the son of Colonel Forster, the governor of Portsmouth, married Eliza Walker, and they had five children. They lived in Kensington where their eldest daughter Ann was born on June 27, 1816. She was Erwin's great-grandmother, whom he was to meet when he visited England as a child.

Ann married William Russell, a solicitor in Royal Leamington Spa, Warwickshire. She had gone to Leamington to visit a Walker aunt and met him there. He was descended from a moderately well-to-do family who had been concerned with the legal profession in Warwickshire for many years. The Russells had three children, William, Emily (who was called Minnie in the family), and Ann (called Fanny). Emily was born in Leamington on September 14, 1841. She was baptized in All Saints Church, Leamington Priors (the old name of Leamington Spa), which was the first parish of the Church of England in the town. The family lived in a spacious house at 14, Portland Place, with gardens at the back extending to the river Leam.<sup>2</sup>

How did it happen that Emily Russell met and married Alexander Bauer of Vienna? The causal factor was that Emily's brother William

was a chemist. He was not a research scientist like Alexander, but he had set up a laboratory for analytical chemistry, specializing in analysis and control of the waters of the spa. He and Alexander became friends in Paris, where they were both studying chemistry in 1859. Bauer was working at the *École de Médecine* on amylenes and polyamylenes as a pupil of Charles Adolphe Wurtz, known to every beginning student of organic chemistry as the discoverer of the Wurtz synthesis of hydrocarbons, whereby two alkyl halides are linked by the agency of metallic sodium. Emily and her mother visited Paris on their way to a holiday at Montreux, and William took his friend Alex to meet them at their hotel. It was love at first sight between the brilliant and serious young scientist and the lovely nineteen-year-old English girl. We can surmise that her brother William did not hesitate to extol the great abilities of his friend, compared to whom he was a mere dilettante in chemistry.

After this romantic meeting in Paris, Alexander had to return to Austria in the summer of 1860 to work in a sugar factory in Moravia. In 1861, however, his abilities were recognized by appointments as an instructor at the *Handelsakademie* [Trade School] and as Privatdozent at the Institute of Technology. The latter position typically paid little but afforded facilities for research, although the laboratory was poorly equipped even by nineteenth century standards, and water had to be carried in canisters from a nearby brook. The teaching post, however, provided some income and the research gave promise for the future, so that the young chemist was able to ask Emily to be his wife, and he was promptly accepted. He journeyed to Leamington Spa and on December 21, 1862, they were married in the parish church where Emily had been christened. The witnesses were William Russell, Ann Russell, and Fanny Russell.

The newlyweds went to live in a charming small apartment at 20 Kärntnerstrasse, in the heart of old Vienna, not far from the house where Mozart had composed *The Marriage of Figaro*. Alexander registered his marriage at his parish church, the ancient and impressive cathedral of St Stephan. In the summer of 1863, the Bauers visited Leamington, where their first child was conceived. Alex returned to Vienna, while Minnie stayed with her family until the spring of 1864, when she traveled to Vienna, arriving with little time to spare before the birth of the baby on Easter Sunday. This was Rhoda, who became Erwin's most dotting aunt. As a child she heard only English spoken at home, and she spent much time in Leamington including one stay of almost five years. A second daughter was born three years later, on March 27, 1867. This was Georgine (Georgie), the future mother of Erwin.

In 1866, Alexander lost an eye in an explosion of a glass vessel in

which he was carrying out a chemical preparation. This accident considerably lessened his interest in experimental research, and he turned increasingly to teaching, administration, and especially chemical history, for which he became famous as 'the Nestor of Austrian chemistry'. In 1869, he was appointed associate professor of chemical technology at the *Polytechnicum* [later the Technical University] and then to the chair of general chemistry, where he served till his retirement in 1904.<sup>3</sup>

On March 22, 1874, Emily died of pneumonia shortly after the birth of her third daughter, Minnie. Her funeral was conducted in accord with the Anglican rite. Alexander was desolated by the loss of his young wife, but after a year of mourning he revived and married a seventeen-year-old girl, Natalie Lechner. Natalie was not a great beauty, but a young woman of unusual independence and considerable literary ability; she was an excellent musician, playing the viola in a professional string quartet. The position of a young step-mother is always difficult, but it is likely that Natalie, with her strength of character, managed the rather docile Bauer girls without too many problems. She taught Georgie the elements of violin. After ten years, however, Alexander and Natalie agreed to separate, an event which at the time (1885) caused some negative comment. In 1890, Natalie met Gustav Mahler and for twelve years was his constant companion, until he married Alma Schindler in 1902.<sup>4</sup>

After the departure of Natalie, Alexander devoted himself to his daughters and to a steadily increasing variety of professional and civic duties. He became a noted *Salonlöwe* [salon lion] in bourgeois Vienna society. In 1904 he was honored by designation as *Hofrat*, which may be roughly translated as state councilor. In Imperial and Royal (K & K) Austria-Hungary, honorific titles were highly regarded by members of the upper-middle class, as indeed they still are today in modern Austria. Almost all university graduates are addressed as 'Herr Doktor' and with increasing distinction, the titles become increasingly ornate. Alexander once questioned some advice by his old professor Hofrat Schroetter, and was told quite seriously, 'Young man, a Hofrat never makes a mistake.' The interests of Alexander Bauer were not confined to science and technology. He served for twenty years as a curator of the Museum of Art and Industry, and for twenty-one years as a member of the Theater Commission for Lower Austria. Through this work he met the leading directors and actors of the flourishing Viennese theater, and communicated to his grandson Erwin a love for the theater which began in boyhood and continued all his life.

The three Bauer daughters all espoused men in technical professions whom they met through their father. Rhoda married Regierungsrat Dr Hans Arzberger, Director of the *Medikamenten Eigenregie*

[Pharmaceutical Commission], and Minnie married Dr Max Bamberger, who became Bauer's successor in the chair of general chemistry at the Technical University and later also a Hofrat. Minnie had a daughter Helga, Erwin's first cousin, but Rhoda had no children.

On August 16, 1886, Georgie married Rudolf Schrödinger, who had studied with her father at the Technical University, and who had inherited a small but profitable linoleum and oilcloth factory and wholesale business from his father, and thus was acceptable to Bauer as a son-in-law. The marriage took place in the Lutheran *Stadtkirche*, and the registry indicates that the bridegroom was a Catholic and the bride Georgine Emilie Brenda Bauer was a 'convert' to the Evangelical AB Church.

There are two main divisions of the protestant church in Germany and Austria, Lutheran and Calvinistic. The Lutherans subscribe to the *Augsburgische (AB) Konfession*, a document submitted to the Diet of Augsburg in 1530. They form the major division of the evangelical church in Austria. One may suppose that the Bauer girls were all brought up in the Lutheran religion since it would be difficult to find Anglican churches and instruction in Austria. From a theological standpoint, the differences between the Anglican Church and the Lutheran Church seem negligible, and indeed their differences with the Roman Catholic Church are mostly related to administrative questions such as papal authority and clerical celibacy. The rather tangled religious history of the Bauer family explains how Erwin Schrödinger came to be nominally a Protestant, despite his Catholic background in predominantly Catholic Austria.

Rudolf Schrödinger was born in Vienna January 27, 1857, the son of Josef and Maria Bogner Schrödinger. He was baptized Rudolf Josef Carl in the parish church of Sts Peter and Paul in Erdberg, an outer district of Vienna. Both the father's and mother's families had lived in Vienna for three or four generations, but the Schrödingers originally came from the Oberpfalz area in Bavaria. Rudolf's mother, Maria Anna Josepha Bogner was a nineteen-year-old orphan when she was married in the Catholic church of St Carl on May 14, 1853. Her father had been the proprietor of a coffee house in the suburbs. She had three children, a son Erwin, who died as a child, a daughter Marie, and their last child Rudolf. Rudolf's mother died at the age of twenty-four, six days after the stillbirth of a fourth child. The historian Peter Gay has chronicled the 'devastation that the lethal work of sensuality' so often left in its wake in the lives of nineteenth-century families, when early death in childbirth hung 'like a capricious plague' over the lives of 'flourishing and energetic young women'.<sup>5</sup> Rudolf was less than two years old when his mother died, and his bereaved father did not remarry but undertook the upbringing of his two children.

About three months after their marriage, Rudolf and Georgine effected that fortuitous combination of genes that produces an individual of genius, and on August 12, 1887, the boy was born at home, Apostelgasse 15, in Erdberg, Vienna 3. Georgie, who loved the works of Goethe, wanted to name him Wolfgang after the great poet, but Rudolf, not usually given to sentimental considerations, favored the name Erwin, after his long departed elder brother. The circumstances of the baptism of the child were unusual. It took place at the home of his grandfather Alexander Bauer, Kärntnerstrasse 20. On October 17, the minister of the Evangelical Church came to the house and baptized the baby Erwin Rudolf Josef Alexander. The godfather was Alexander Bauer and there was no godmother. Such a home christening was not unusual but the parental home would have been the expected place. A possible scenario is that Rudolf, who was not a practising Catholic, did not wish to have the baby baptized at all, but that Alexander decided to have it done anyway, and out of deference to his daughter's religion, asked the Evangelical pastor to come to his house and administer the sacrament.

Whether through choice or necessity, Rudolf and Georgie had no more children. Erwin considered his mother to be a woman of delicate constitution all her life. As an only child, he received the full attentions of his mother, and for many years hardly less from Aunts Rhoda and Minnie, as well as the services of a succession of young maids and nurses, all of whom considered him to be a budding genius deserving practically constant adulation. Raised in such an atmosphere of tender, loving, feminine care, it is hardly a wonder that Erwin grew to depend upon it and to expect it as his due, such expectations being fully realized throughout his lifetime.

## **Childhood**

In 1884 a splendid town house, five storeys high, was constructed at 3 Gluckgasse, a fashionable street just off the Neumarkt in the center of the first district of Vienna. The house is of pink limestone faced with marble. Above the second-storey central window is a rococo relief of two cherubs holding a bowl filled to overflowing with grapes. The window above on the next storey is framed by two massive classic male torsos and surmounted with a plaque bearing the date 1884. The house was divided into spacious apartments, only one on each storey. The house was purchased by Alexander Bauer not long after its completion, and in 1890 he rented the top-floor apartment to the Schrödingers and this was to be their Vienna home until the year before the death of Erwin's mother in 1921. The front windows look over tiled roofs to the serrated Gothic spire and flying buttresses of St Stephan's Cathedral.



*Erwin and Grandfather Alexander Bauer (c. 1890).*

Life in the later years of the Habsburgs was pleasant and unhurried for those with ample incomes. Political freedom was not essential to this good life and its absence did not trouble the ordinary citizen, although there were grumblings from subject peoples in distant parts of the Empire. If anything went wrong, there were always Jewish plots to blame, and the endemic antisemitism helped to satisfy both social and religious needs. Until he entered the Gymnasium, however, the interests of a boy like Erwin would be confined almost entirely to the family circle, with a special emphasis on birthdays and holidays.

Erwin's childhood was somewhat different from that in a typical well-to-do Vienna family owing to the absence of siblings and prevalence of aunts. Some recollections of Erwin's childhood have been given by his Aunt Minnie.<sup>6</sup> She was fourteen years older than Erwin but they were great companions. He learned from Minnie to speak English before he ever spoke German properly. She brought him a book of bible stories from England; he was not terribly impressed by the stories but they were his earliest reading in English.

At the age of four, he displayed an early scepticism of hearsay evidence. Sometimes Aunt Minnie would say one thing and his mother would say another. 'This says Mama, and that says Aunt', remarked Erwin. 'They are both only people. They could just as well say the opposite.'

Even before he could read or write, he kept a record of day-to-day happenings, which he dictated to Minnie. This habit of keeping a day book, he maintained all his life. The later books, called *Ephemeridae*, seem to contain everything but scientific material; it is evident that he thought science has a certain permanence, whereas all else is ephemeral. From one of his earliest records, 1891: 'In evening Aunt Emmy cooked a good supper and then we spoke all about the world.' Minnie recalls that 'Despite my small knowledge of the subject, he was especially interested in asking me about astronomy. For example, I would stand and represent the earth and he would be the moon and run around me, and both of us would move slowly about a light that represented the sun.'

A story that gives early evidence of Erwin's appreciation of the powers of money tells of a long walk with Aunt Emmy in the neighborhood of the old castle of Hartenstein, which is about eighty kilometres along the Danube west of Vienna. They went too far and lost their way back. 'Nothing but woods, and the churning stream [the Else not the Danube] and no possibility of finding our way to the village of Hartenstein. For a short time I carried the little fellow on my back, but naturally not for long . . . Just as our predicament



Erwin with Aunt Emily (Minnie) Bauer (c. 1893).

The photograph captures a moment between a woman and a young boy, likely a family member. The woman, Aunt Emily (Minnie) Bauer, is dressed in a formal, dark Victorian-style outfit, including a long coat and a hat adorned with a flower. Her arm is affectionately placed on the boy's shoulder. The boy, Erwin, is also dressed formally in a dark suit and a flat cap. The background shows the exterior of a building with a staircase, suggesting an outdoor or semi-outdoor setting. The overall tone of the image is historical and intimate.

was at its worst, dear Erwin took a copper coin from his pocket, offered it to me, and asked "will this help?" Fortunately a signpost solved the problem and we got back in time for lunch.'

A visit by army officers in uniform awoke his interest, but all attempts to explain to him the nature of their duties and the necessity for wars were useless. 'What would you do if somebody came and took all your clothes, your shoes, and everything away?' 'Nothing', said the child, 'I would keep cool.'

Ever since 1900, when Freud published his first important work, *Die Traumdeutung*, dreams have been anxiously sought by biographers as mirrors of the subconscious mind. The only one of Erwin's boyhood dreams that has been recounted occurred at Semmering, the mountain resort south of Vienna. They were staying at the enormous Südbahn Hotel. One time he awakened in terror, unable at first to speak. He had been in the middle of a bad dream. What was it? 'It was the horrible word *GEFÄNGNIS* [Prison] written in large letters just above my bed.' It is a horrible word, worse in German than in other languages.

Almost every Sunday Erwin would visit his little cousin Dora, the daughter of his father's sister Marie, who was two years older than he, and the children would play together the whole afternoon. One evening, when Minnie brought him home, he was unusually withdrawn, something seemed to be bothering him. He went quietly to bed but did not fall asleep. 'After a while he called me in. "Yes, what is the matter?" He put his arm around my neck and sort of stammered. "Today I gave the little girl, the cousin, a box on the ear." So, now it was out. After this confession, he cheered up and went to sleep, since the young aunt did not take it so tragically.'

Erwin always had a temper, and tantrums were not uncommon. He had some noteworthy rows with his father, and sometimes had to be sent from the table for bad manners or unruly behavior. He also had the usual quota of boyhood fights, although as an only child he never had to contend with sibling rivalries for family affection.

Erwin experienced the gamut of childhood diseases and accidents, somewhat more than average since he was a rather delicate boy. While still very small, he had a severe case of measles. He became apathetic and almost comatose, and the nurse could hardly wake him. The doctor ordered heart stimulants immediately. Grandfather brought cognac and strong wine into play, and perhaps a catastrophe was thereby avoided. It is interesting to note that it was the practical old chemist and not the rather dreamy parents who came to the rescue.

We know, however, from Erwin's own testimony that the influence of his father was always very important:

To my father I am thankful for far more than only this, that he gave us a very comfortable life, and assured for me an excellent upbringing and a carefree university education, while till almost the end of his life he carried on with little zeal or talent the inherited, prosperous oilcloth business. He had an unusually broad culture; after his university studies as a chemist, there followed many years of intense concern for Italian painters, accompanied by his own landscape drawings and etchings, giving way finally to pyxides and microscope, from which arose a series of publications on plant phylogenetics. To his growing son, he was a friend, teacher and inexhaustible conversation partner, the court of appeal for everything that might sincerely interest him. – My mother was very good, cheerful by nature, sickly, helpless in the face of life, but also undemanding. Besides sacrificial care, I have her to thank, I believe, for my regard for women.<sup>7</sup>

When Rudolf and Georgine Schrödinger were married, she was a sheltered girl of nineteen and he was an experienced man of twenty-nine with a comfortable income from a business that he despised. The manufacture of linoleum involves impregnating a burlap backing with gelled linseed oil and pigments and curing the aggregate to produce the finished product. The process provides limited scope for an artistic temperament. If anything, the skills involved in merchandising the products of the factory would be even more demeaning to an amateur artist and botanist, with a love for mountain landscapes, wildflowers and Oriental ceramics. At this time Vienna surpassed all other cities of the world in its relentless *Drang zum Kulturellen* [drive towards the cultural] and Rudolf was carried along strongly by this current.

Minnie provides only glimpses of the married life of the Schrödingers. 'Doubtless both were a loving couple.' Here the adverb immediately engenders doubt; she will not testify from her own close observations of the family. Minnie continues her portrait of her sister: 'Without being a special beauty the little woman [*kleines Fräuchen*, a double diminutive, which Freud might have underlined] was full of charm, with a lovely expression and an attractive coiffure.' On the honeymoon, as he was downstairs smoking his cigarette, Rudolf once overheard a group of guests wondering 'Is this child really his wife?' Did he ever wonder this himself in the course of his marriage? According to Minnie, her sister concentrated all her thoughts on the welfare of her son, but Erwin was never a mother's boy, an aunt's boy possibly as a child, but soon his father became his principal guide and mentor.

Georgie had an interest in playing the violin. 'As a young bride, she did not find so much need for technique as would be the case today but stressed the winning expressiveness of her playing. After she



*Erwin with his parents Rudolf and Georgine on holiday in Kitzbühel.*

unfortunately found no response from her husband, her art wasted away.' Almost uniquely among theoretical physicists, Erwin not only did not play any instrument himself, but even displayed an active dislike for most kinds of music, except the occasional love song. He once ascribed this antipathy to the fact that his mother died from a cancer of the breast, which he thought was caused by mechanical trauma from her violin. More likely he learned this distaste for music as a child, echoing his father's lack of response to his mother's art.

A contemporary of Schrödinger, the novelist Robert Musil, also expressed an intense dislike for music, which he called 'the churned-up somatic sediment of the psyche'. Ulrich, 'the man without qualities', the alter ego of the author in *Der Mann Ohne Eigenschaften*, 'had never been able to stand the sight of this always open piano with its bared teeth, this big-mouthed short-legged idol that was a cross between a dachshund and a bulldog, which had subjugated his friends' lives to itself'.<sup>8</sup>

Eithne Wilkins and Ernst Kaiser, who made the superb English translation of *Der Mann Ohne Eigenschaften*, suggest that music symbolized for Musil the mystical aspect of his personality, which he had to repress and deny as a good positivist and intellectual disciple of Ernst Mach. In the last years of his life, Musil was going through

a spiritual crisis in an effort to escape from the cold prison walls of the solipsistic philosophy of Mach and Avenarius. Erwin Schrödinger struggled with this same problem all his life: 'One recalls in memory the feeling of anxious, heart-constricting solitude and emptiness that I daresay has crept over everyone on first comprehending the description given by Kirchhoff and Mach of the task of physics (or science in general): a description of facts that is as far as possible complete and as far as possible economical of thought.' This was written in his first philosophical statement, in 1925, before his discovery of wave mechanics.<sup>9</sup> He was not able to lighten his solitude with music, which was the solace of the great Jewish physicists especially, and was compelled to turn to other stratagems.

While Erwin was just beginning to talk, a clever maid began to teach him to read the street signs. His father was somewhat anxious lest he be pushed too quickly. He was not sent to the elementary school, but received lessons at home two mornings a week from a private tutor. This arrangement was not unusual in upper-middle-class families. Their principal goal was to ensure that their boys passed the entrance examination for the Gymnasium, usually taken when they were nine or ten years old.

Instead of taking the examination [*Aufnahmsprüfung*] at the usual time, Erwin had a long holiday and was taken to England by his mother and Minnie to visit the Russells at Leamington Spa. This was in the spring of 1898 when he was ten years old. He saw his great-grandmother in her home Modena Villa, on Russell Terrace named after his great-great-grandfather. He visited his mother's aunt, who had married Alfred Kirk, and who had six Angora cats which soon increased to twenty. One was called Thomas Becket. They visited Kenilworth and Warwick castles. He rode the donkeys on the wide beach at Ramsgate and thought it a great sport. He also learned in England to ride a bicycle, a skill he was to practise all his life, for both pleasure and utility.

Minnie reports that they went by horse and carriage for a 'so called picnic, where one takes a spirit stove to make tea and has all sorts of piquant and sweet baked goodies'. Erwin was laughing happily in the middle of the picnic, but, 'Oh Weh!', he wandered away to a little pond and fell in, which seems a bit clumsy for a ten-year-old boy. He was dragged out, but once he was dry, he did not seem at all sorry about it. Considering what a good swimmer he later became, he probably could swim well enough at ten.

On the trip back to Austria, they crossed the channel from Dover to Ostende, and then visited the beautiful medieval city of Bruges. Proceeding to Cologne, they boarded the Rhine steamer and traveled through the lovely country of wine and castles via Koblenz and

Rudesheim to Frankfurt-am-Main. Here they took the train to Munich and thence to Innsbruck.

Here Erwin had his first experience of school. The parents were worried about the entrance examination and 'afraid that I might have forgotten my ABC's'. Therefore he went to the St Niklaus School for a few weeks. His mother tried to preserve an English atmosphere. When they walked in the park, 'Now we are going to speak only English to each other.' She also tried to observe the English custom of half-holidays, but amid all his other holidays these may have been difficult to distinguish. During all his life Erwin allowed nothing to interfere with his vacations and holidays.

### **Akademisches Gymnasium**

As was to be expected, he passed the examination easily, and entered the Akademisches Gymnasium in the fall of 1898, having just turned eleven. He was about a year older than most of the other students in his class. He had never experienced the rough and tumble socialization of the schoolroom and playground, nor the competition with siblings at home. He had been raised almost exclusively in the company of adults, and it was perhaps only to be expected that he would retain something of the *enfant terrible* when he reached manhood.

His Gymnasium was the most secular, the least religiously oriented, of all those in Vienna. Ludwig Boltzmann, Arthur Schnitzler and Stefan Zweig had formerly been pupils there. It was, and still is, situated on Beethoven Platz, just off the Schubert Ring, about ten minutes walk from Erwin's house on Gluckgasse. Djuna Barnes once pictured the schoolboys of Vienna as 'flocks of quail, taking their recess in different spots in the sun, rosy-cheeked, bright eyed, with damp rosy mouths, smelling of herd childhood, facts of history shimmering in their minds like sunlight, soon to be lost, soon to be forgotten, degraded into proof.'<sup>10</sup>

As summarized by Friedrich Paulsen, a contemporary authority, the ideal of education in the Gymnasium was to graduate 'a human being whose faculties enable him to form a clear and definite conception of the actual world, and who, by virtue of his will, is able to follow his original bent, whose imagination and fine emotions are trained to the perception of the beautiful and the heroic. This is a man in the full sense of the word; this is true humanistic culture.'<sup>11</sup>

The education designed to achieve this admirable result was based on an intensive study of the Greek and Roman classics. 'The classical literature is, and will continue to be, the source of all our culture. It must remain therefore . . . the most important study in our high

schools.' This principle, laid down in 1805 by the first superintendent of the Prussian high schools, had remained in force for at least a hundred years. Actually, the emphasis on Latin and Greek was historical in origin, since all the higher schools had originally been founded by the Church for the education of priests, who required these languages in addition to Hebrew, which was formerly also part of the curriculum, but had become an elective by the late nineteenth century.

Since virtually the only way to enter the university was through the Gymnasium, all university students began with a shared background in humanistic studies and mathematics. Such a preparation for science was welcomed by many who later became eminent in this field. Max Laue, for example, wrote 'I doubt that I should ever have devoted myself entirely to pure science if I had not at that time come into that inner harmony with Greek language and culture, which the humanistic Gymnasium and no other kind of school provided . . . If you wish to bring out scientific development later, I have a recipe: send the youth to a Gymnasium and let him learn the ancient languages.'<sup>12</sup> Of course, there is no single recipe for the making of scientists: compared to Schrödinger, Laue, Born, or Heisenberg, most American physicists have been illiterate in ancient tongues, yet the best of them have also done great physics.

For the first three years at Gymnasium, Latin was the most important subject, eight hours a week of it. When they began Greek, the Latin was reduced to only five hours. First came the grammar and then the classic authors. They started with Nepos, *De Viris Illustribus*, short lives designed to bring out the characters of illustrious men, not only of Rome but also of other nations. Next came Caesar, *Commentarii de Bello Gallico*, then selected parts of Livy's *History of Rome*, and to complete the historical works, something from Tacitus, though perhaps not his penetrating criticisms of the imperial system. From Cicero, they read about the Cataline conspiracy and its ruthless suppression. With eight years available for Latin studies, there was ample time left for the poets: Ovid, selections from *Metamorphoses* and *Tristia*; Horace, the *Odes*; Virgil, some of the *Aeneid*. Among the Greek authors studied were Plato (*The Apology of Socrates*), Sophocles (*Oedipus Rex*), and Homer (*The Iliad* and a little of the *Odyssey*). All these classics had been carefully expurgated to be sure that no intimations of erotic life remained. Some classes on elementary biology were given in the first two years.<sup>13</sup>

Besides the Latin and Greek classics, there were classes each year in German language and literature. The sixth-year pupils studied the literature of Middle High German from its inception to Luther, with emphasis on the poetry of the *Nibelungenlied*; the next year was



*Dressed for a special occasion at the Akademisches Gymnasium (1900).*

devoted to New High German, with an in-depth study of Goethe and Schiller; in the final year they read literature from the romantic period to the present, with of course considerable attention to the great Austrian dramatist Grillparzer. Only three hours a week were spared for mathematics and science. Mathematics consisted of algebra and geometry; they did not get so far as calculus.

Erwin was reasonably happy with the Gymnasium. 'I was a good student, in all subjects, loved Mathematics and Physics, but also the strict logic of the ancient grammars, hated only the memorization of incidental dates and facts. Of the German poets, I loved especially the dramatists, but hated the pedantic dissection of their works.'<sup>14</sup> Boltzmann once said 'Without Schiller, there might have been a man with my nose and beard, but it would not have been me.'<sup>15</sup>

About five years ahead of Erwin on the academic ladder, Stefan Zweig found the same school a boring treadmill, monotonous, heartless and spiritless. The classrooms were uncomfortable and poorly lighted. 'We sat pairwise like slaves in a galley, on low wooden benches that bent the spine.'<sup>16</sup> Stefan did not like school, but he did not exaggerate. A government inquiry was undertaken to find the reason for the increasing incidence of poor eyesight among the students; there was fear that their eventual use in the army might be adversely affected. Some attempts were then made to improve lighting in the classrooms, notably the introduction of the Welsbach gas mantles. Like many an earnest student, Erwin had to wear increasingly strong glasses from about the age of twelve to correct his nearsightedness. But he was inspired by the joy of intellectual progress, and neither prosaic teaching nor dismal surroundings affected his spirits.

The schoolwork was easy for him and he had ample time for other things. From entry till graduation in 1906, he was always first in his class. Later a schoolmate wrote:

I can't recall a single instance in which our Primus ever could not answer a question. Thus we all knew that he took in everything during the instruction, understood everything, he was not a grind or a swot. Especially in physics and mathematics, Schrödinger had a gift for understanding that allowed him, without any homework, immediately and directly to comprehend all the material during the class hours and to apply it. After the lecture of our professor Neumann – who taught both subjects during the last three Gymnasium years – it was possible for him to call Schrödinger immediately to the blackboard and to set him problems, which he solved with playful facility. For us average students, mathematics and physics were frightful subjects, but they were his preferred fields of knowledge.<sup>17</sup>

Actually on one occasion he did fail to answer a question in class: 'What is the capital of Montenegro?' He became terribly embarrassed,

his face turned brick red, and the whole class suffered with him. (The answer was 'Podgorica', now called Titograd.) Also he did not really dispense with homework. If anyone in the house asked where he was, the answer was always 'He is upstairs in his room and is studying.' He had two small rooms of his own overlooking the courtyard at the back of the house.

The classes were held from eight in the morning till one in the afternoon six days a week, allowing twenty-eight hours a week of instruction. When Erwin attended the Akademisches Gymnasium the enrolment was about four hundred students, of whom more than a third professed the Jewish religion, although Jews comprised only about eight percent of the city population. The city government was under the Christian Socialist mayor, Karl Lueger, who had been elected on an antisemitic platform, but there was little evidence of antisemitism in the school. Even though Lueger appealed to the voters with antisemitic speeches, his administration was in fact almost free of overt discrimination and he enjoyed friendly relations with many influential Jews. In general, however, the Christian students in the Gymnasien came from wealthier families than the Jewish ones, and there was little social intercourse between the two groups.<sup>18</sup>

On two afternoons a week, Erwin returned to school for instruction in the Lutheran religion. 'From this I learned many things, but not religion.' He had also received the required religious instruction from his tutor as a preparation for the Gymnasium. His favorite question at the end of a bible story was 'Herr Teacher, do you really believe that?' Thus it was not for lack of formal catechism and bible studies that Erwin became indifferent, sometimes even inimical, to organized religious beliefs and practices. His mother was mildly religious, but he learned his negative attitude from his father, and then reinforced it through his own reading, observation and experience. Among the many anecdotes about Erwin's boyhood, Aunt Minnie recalled not one dealing with a religious observance, not even at Christmas. The Schrödingers never entered a church except to be married or to be buried, or to attend similar rites for their friends.

Nevertheless, Erwin had a great respect for saints and mystics. He became anticlerical rather than basically antireligious, yet he seems never to have made a serious study of Christian theology. It was the history of the Church rather than its beliefs that most distressed him. 'For centuries oppressed in the most shameful ways by the Churches, Science has held up its head, and believing in its sacred right, its divine mission, it has struck powerful, hate-filled blows against its old torturers, not caring that they – even if inadequate, indeed derelict in their duties – for all that were the only appointed guardians of the most holy legacy of the fathers.' The adjectives 'sacred', 'divine', and

'holy' in this example from one of his mature statements evidence a subconscious religious spirit beneath the overt anticlericalism.

During his free time in the afternoons, Erwin continued his study of English and began to learn French, subjects not taught at school. He found the philosophical propaedeutic to be badly taught, and during these classes he used to conceal his French translation in his notebook, and work on it while the teacher thought he was assiduously taking notes.

Another subject not included in the curriculum, except for its cursory denunciation as a heresy in the religious class, was the Darwinian theory of evolution. He was able to go into this subject at considerable depth during walks and botanical excursions with his father. 'On the basis of his botany, my father advised caution. The melding of natural selection and the survival of the fittest with the De Vries mutation theory had not yet been made. I don't know why zoologists were more ardent Darwinians than botanists. My father's friend, Hofrat Anton Handlirsch, a zoologist at the Natural History Museum, taught that development is causal not "final", there is no entelechy.' Erwin was soon converted to this view. 'Naturally I was an enthusiastic Darwinian, which I still am today' [1960].<sup>14</sup>

His best friend in high school was Tonio Rella, who later became professor of mathematics at the Technical University in Vienna. Tonio was always second and Erwin first in class during all their eight years at the Gymnasium. In the last days of the war, in April, 1945, Rella was killed by a stray Russian shell, so that the reunion that Schrödinger had anticipated when he returned to Austria never took place.<sup>19</sup>

The Rella family owned a country inn, Kastell Küb, in Semmering, and Erwin used often to spend holidays with them there. The inn, surrounded by extensive wooded grounds with fine views of the Schneeberg, could accommodate 120 persons, and was called a 'rest and recreation home' [*Erholungsheim*]. Both boys were ardent hikers and mountain climbers. Grandfather Bauer had been one of the discoverers of the beauties of Semmering and one of his most loved pursuits was the ascent of 'Sonnenwendstein', the mountain that sheltered the town. Erwin and Tonio often followed the trails that he had blazed forty years earlier.

In the course of time, there came to be another attraction at Semmering, more powerful than the lure of the mountains. This was Tonio's sister Lotte, called 'Weibi', with whom, Erwin later said 'I was fairly permanently in love' [ziemlich dauerhaft verliebt].<sup>20</sup> Weibi was an Italianate beauty with dark brown eyes and a generous figure; in an earlier time, she might have been a model for a Caravaggio portrait.

Erwin used almost always spend his Christmas holiday from about December 22 till the new year at Semmering with the Rella family, but

for Christmas eve he would have to return to Vienna to be with his own family, including grandfather and aunts. He was always unhappy to leave his sweetheart, and anyone who can recall an adolescent first love will understand exactly how he felt, a reluctant member of the family circle whose thoughts were wandering elsewhere. In those days, such a teenage romance would be limited to worship from afar, holding the beloved for a Viennese waltz, perhaps a gentle kiss if rare opportunity occurred, but the sister of a school-friend would be inviolable and a more intimate relationship only a subject such as dreams are made of. Lotte's parents would have been happy to encourage a match with Erwin. His devotion to her was more than a mere *Kinderliebe*, and it would leave an indelible impression on his soul, but he was not prepared at this time to consider any enduring emotional ties.



*Tonio Rella, Erwin, Mother Rella, and Friend – at Semmering.*

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... ..

## A world of Theater

For the students, the years at the Gymnasium spanned the onset of puberty and the pangs of adolescence. They entered as ten-year-old children and left as sexually mature young men of eighteen. Sexuality was an anarchic factor and bourgeois society protected itself by establishing a dual system of behavior. School, family, popular literature and newspapers formed a world in which sex hardly existed outside the privacy of the conjugal bedroom. Parallel with this conventional world of bourgeois morality, there was a flourishing underworld of pornography and prostitution. Sex for pay was not, however, confined to casual pickups and brothels. For the wealthy, there was a demimonde of music halls and artists' studios where attractive mistresses awaited those able to support them, but such pleasures were outside the financial range of most students.

Karl Marx accused bourgeois men of preying on the daughters of the proletariat, but it was often an unresisting prey. In many autobiographies, the sexual initiation of the hero is provided by the family maid, usually portrayed as a fresh country girl whose upbringing on the farm had left her innocent of bourgeois morality and susceptible to the sophisticated urban student. There was also said to exist a charming institution known as *Das süsse Wiener Mädel*, perhaps a shopgirl whose greatest ambition was a sacrificial affair with a university student, to whom she could devote her generous love with never a thought of complications like pregnancy or marriage. Arthur Schnitzler was particularly expert on the subject of the 'sweet Vienna lass'.<sup>21</sup>

The marvelous Vienna theater, then at one of the high points in its history, provided Erwin with at least vicarious experience in the world of romance, in the works of the great dramatic poets at the Hof-Burg Theater on the Ringstrasse.<sup>22</sup> Josef Kainz, believed by many critics to be the greatest actor of all times, was creating some of his most famous roles, Hamlet, Cyrano, Tasso, Orestes, Mephisto, Don Carlos. The emperor's favorite, Katherina Schratt, was one of the leading ladies. Vienna audiences and critics were the most knowledgeable in the world; no *Schlamperei* [sloppy work] was tolerated. Special matinees were held on Sunday afternoons for students and workers' alliances. As Stefan Zweig remarked, this theater was more than a mere stage for plays, it was a microcosm in which Austrian society could see itself. Arthur Schnitzler's *Liebelei*, the story of Christine, the most famous süsse Wiener Mädel of literature, was first produced in 1895. Sigmund Freud wrote to the author: 'Your fascination with the subconscious, with the instinctual nature of human beings, your destruction of the conventional certainties of civilization, the attachment of your ideas to the polarities of love and death – all this affects me with an uncanny familiarity.'<sup>23</sup>

Erwin was a lover of the theater, going as often as he could, sometimes more than once a week, and keeping an annotated record of the performances. As a student, his favorite playwright was Franz Serafikus Grillparzer, who was born in Vienna in 1791, the year Mozart died. A shy man, torn all his life between the demands of his work and romantic loves for beautiful but inaccessible women, he was a master of erotic drama.<sup>24</sup> An example from his *Sappho*:

He who knows what love, what life is, man and woman,  
Does not weigh man's love 'gainst woman's passion.  
Most fickle is man's fitful disposition,  
Subservient to life, most fickle life.

From the later *The Waves of Sea and Love*, the story of Hero and Leander,

And he, my prince of swimmers and of love,  
Found in the cosmos neither love nor pity.  
He raised his eyes, beseeching to the gods,  
In vain! They did not hear – or were they sleeping?

Sometimes Grillparzer provided simply a great adventure story, as in *The Argonauts*:

Who sets his heart on snatching the golden fleece  
That death envelops and most potent perils? . . .  
In the cave it lies concealed, defended by all the horrors  
Of cunning and violence . . . daggers beneath each footstep,  
Death by inhalation! Murder in a thousand shapes.  
And the fleece hangs on a tree, besmeared with poison,  
Guarded by the serpent who never sleeps,  
Unrelenting, Unapproachable.

These were stirring dramas for an adolescent student. They must have helped to convince him that there is more to life than books and theory. And should he wish a change from the splendors of the Hof-Burg Theater, there were many lesser companies always playing in Vienna, the Volkstheater, which could seat 1900 spectators in its red, white and gold auditorium, the Carl Theater which might offer a Strauss operetta or an Ibsen play, or the Josefstadt Theater which might be showing a Parisian farce, an avant-garde piece of Strindberg, Hungarian vaudeville, or even a visiting production by Max Reinhardt.

Some pages from Erwin's *Theater Notizbuch* have been preserved, dating from the autumn and winter of 1904/05, his next-to-final year in high school.<sup>25</sup> The first notice is of one of the greatest dramas in German literature, Schiller's *Wallenstein*, which he found most impressive with Sonnenthal in the principal role at the Burgtheater.

On September 3, 1904, the play was at the Raimund Theater, *Herodes*

and *Mariamne*, a tragedy in five acts of blank verse by Friedrich Hebbel (1813–1863). King Herod was played by Wiecke, and Erwin thought that he surpassed even Kainz, having more temperament and more warmth, ‘a thin figure of unbelievable elasticity’. The grim story is derived from Josephus, and details the hopeless efforts of the faithful queen Mariamne to convince the vicious and brutal king of her loyalty. Finally he orders her execution, and driven by demonic fear and suspicion proceeds to the slaughter of the holy innocents.

On October 8, Erwin got a seat in the uppermost gallery, ‘with the perspective of a bird’, to see Hebbel’s *Gyges and His Ring*, with Kainz as Kandaules, Reimers as Gyges, and Rompler-Bleibtreu as Rhodope. The story is based on Herodotus and set in prehistoric times. A handsome young Greek, Gyges, presents Kandaules, king of Lydia, with a ring that makes its wearer invisible. The king then allows him, while wearing the ring, to enter the royal bedchamber and gaze upon the beauty of the queen, Rhodope. His sigh of admiration reveals his presence to Rhodope, and since only one living man is allowed to see her unveiled, Gyges and Kandaules fight a duel to the death in which the king is killed. Gyges must then marry the queen, but as soon as the ceremony is performed, Rhodope kills herself to purify her soul. Erwin commented that ‘I do not think that a young person of my age can understand this play, not so much the external plot, but just as one can imagine the emotional processes of others when one has experienced them even once in any form, so also with the stage one can enter into an emotional feeling, if one has even once felt something similar, and that obviously does not hold true for the emotional feelings of Rhodope.’ Who is the hero of the play, he wonders; from the title, it seems to be Gyges, but actually Rhodope is central. ‘The ring, like the golden fleece, is a symbol of superhuman power.’ These are perceptive comments: Hebbel originally planned to call the play *Rhodope*. Even mature minds have been perplexed by its psychology and its symbolism; it was rejected by producers all over Europe, and finally performed at the Burgtheater long after the death of the author.

Erwin attended Schiller’s *Wilhelm Tell*, a new production, and found Reimers in the title role to be ‘much better than I had expected, not so much by what he does as by what he has left undone’.

On January 26, 1905, he saw Schiller’s *Don Carlos*, a marathon production, which began at 6:30 p.m. and ended at 12:30 a.m. The title role was played by Kainz, not entirely to Erwin’s satisfaction. ‘I have read Schiller’s *Letters about Don Carlos* with great interest and believe that I shall gradually come to a complete understanding of the play.’ Three nights later, he was at the Deutsches Volkstheater to see *The Brothers of Saint Bernard* by Anton Oborn. ‘It is a drama with a purpose – not a realistic picture of life.’ ‘Realistic’, however, is not an

appropriate adjective for any of the plays described by Erwin in this brief cross-section of his youthful theater-going in Vienna. The classical German drama takes a serious, heroic view of human existence, with powerful men and sacrificial women engaged in matters of momentous portent, usually trapped and destroyed by failures of communication, but going to their destruction with sound and fury. Schrödinger did see a production of *Hamlet* about this time, but one imagines that the subtle and ambiguous psychology of this play was hopelessly weighed down by the German translation and overpowered by the ornate style of the Burgtheater company.

The art world of Vienna at the turn of the century was even more flagrantly erotic than the avant-garde theater, since it had less need to appeal to a large bourgeois audience. In 1897, Gustav Klimt led the revolt of the young artists in founding the movement known as the Secession. Their magazine was called *Ver Sacrum* [Sacred Spring], to recall a pagan Roman ritual in which youths were consecrated to the nation at times of danger. As Carl Schorske aptly said, 'Where in Rome the elders pledged their children to a divine mission to save society, in Vienna the young pledged themselves to save culture from their elders.'<sup>26</sup> In 1894, Klimt, then a brilliant but fairly conventional artist, received a commission to paint three heroic ceiling paintings for the great hall of the new university, to represent philosophy, medicine, and jurisprudence. By the time the first two paintings were completed, in 1900 and 1901, he had fervently embraced the ideas of Wagner, Nietzsche, and Schopenhauer, and translated them into powerful symbolic pictures, filled with disturbingly erotic female figures who seemed to drown the masculine arts of philosophy and medicine in a sea of hopeless sexuality. This was not what either the university professors or the liberal government had anticipated, and a storm of public protest and vicious personal abuse broke over the unrepentant artist. He was accused by the gutter press of being a mere pornographer, by the clericals of being in league with seditious Jewish philosophers, by the academics of being anti-intellectual, and even the social democrats bemoaned his lack of optimism for the future of society. The controversy raged for some years; the government tried to stand firm but the paintings had to be removed to the Modern Art Museum and never graced the university. In 1906 Klimt's friend Egon Schiele was thrown into jail for twenty-four days for painting a lewd picture of a young model, and one of his pictures was publicly burned. It would be interesting to know what Rudolf Schrödinger thought of all this. His own pictures were pleasantly academic and untouched by any of the influences sweeping through contemporary European art.

How was Erwin affected as an adolescent by the erotic art of avant-garde Vienna? Among the papers that he kept all his life were

copies of the journal of the university Science Club. The issue for 1909 has an erotic drawing more or less copied from Klimt's 'Fish Blood', which appeared in the first issue of *Ver Sacrum*.<sup>27</sup> Like so many of Klimt's drawings and paintings, it is a desperate effort 'to capture the feeling of femaleness'. Much of Erwin's erotic life would be devoted to a similar effort, not to master or dominate women, but to capture the essence of their sensuality by experiencing it with them and through them.

All this was for the future. The avant garde was certainly not the world of Erwin Schrödinger and Tonio Rella when they entered the university together in the fall of 1906. Erwin's romance with Lotte Rella continued, but it remained within the bounds set by conventional morality. We know this from his *Ephemeridae*, where he carefully recorded the names of all his loves with a code to indicate the denouement.

## 2 University of Vienna

Vienna is the second-oldest German-speaking university, founded in 1365 by Pope Urban V, seventeen years after the University of Prague. Albert of Saxony, formerly rector of the University of Paris, brought the hitherto secret statutes of that establishment to Vienna as a basis for the new university, and he became its first rector. Students came from all over Europe, but especially from the four nations, Austria, Bohemia, Saxony, and Hungary.<sup>1</sup>

In the sixteenth century, the university joined the battle against Lutheranism, but not without misgivings, since most of the Viennese had become convinced Protestants. In 1550, the Jesuits were called into Vienna, where they established a number of excellent lower schools. The counter-reformation now began in earnest, with many expulsions and a few burnings at the stake, until Catholicism was firmly re-established in the Habsburg lands after a struggle of one hundred years. The professors for the most part resisted the clerics until 1617, when the university was formally united with the Society of Jesus. The Society was a militant order, and no sooner had it achieved its aims, than it began to lose interest in the university and to look for other enemies, which it found in the Dominicans who had refused to swear an oath to the Immaculate Conception of Mary.

In 1683 the Turks appeared in force at the gates of the city. The court fled but the burghers and soldiers defeated the Turkish army, and this siege marked the high point of the Moslem invasions, as the power of the crescent gradually receded from Europe. One thing Vienna learned from the Turk was a love for coffee, and coffee houses soon rivaled university class rooms as centers of intellectual activity.

Charles VI made extensive reforms in the university studies, which he directed more toward the service of the state and less to that of the church. His daughter, the Empress Maria Theresia, who gave Francis I five sons and eleven daughters, embraced the spirit of the Enlightenment with increasing fervor and encouraged the university to develop in new directions. She also provided funds for a magnificent new building, which was opened in 1756 with great celebrations. In 1780,

Josef II issued a patent of tolerance, which abrogated the Catholic oath; Protestants and even Jews were admitted to degrees, but not women of any persuasion.

The first professorship of physics [natural philosophy] was established at the University of Vienna in 1554, but no equipment for experimental work was available till 1715 when a collection of apparatus was made by the Jesuits. Andreas Baumgartner, who became professor in 1823, was the first to give physics lectures in German instead of Latin. He helped to found the Vienna Academy of Sciences and served as its president for fourteen years. Through his efforts, the teaching of physics in Austria was modernized, and brought up to the standards of Germany, France, and Italy.

In the spring of 1848, revolutions swept through Europe. In Vienna, workers led by students of the 'Academic Legion' marched through the streets with red banners, hammers and scythes. A unit of the Viennese Grenadiers joined the rebels and the entire city was soon in their hands. Metternich, after forty years of power, announced his retirement and the Habsburgs fled to Innsbruck. By autumn, the forces of reaction were again in control, and Vienna was recaptured by a large Austrian army brought from northern Italy. The imperial army did not forget its ignominious defeat by the 'intellegentsia in arms' and it seized the university and dispersed the staff into makeshift buildings in outer districts. Some concession to the prevailing discontent seemed to be required, however, and it was decided that the half-witted Emperor Ferdinand must abdicate in favor of his eighteen-year-old nephew Franz Joseph.

## University physics<sup>2</sup>

In 1850, Christian Doppler, a native of Salzburg, was appointed to the chair of physics. He was famous for his discovery that if a source of light is in motion relative to an observer, the wavelength as received by the observer is different from that emitted by the source. The effect on sound waves is familiar to everyone who has listened to the mournful notes of a passing locomotive, but Doppler analogically applied the same principle to light waves moving through 'the aether'. Schrödinger, who was always interested in anything related to the Vienna school of physics, published a paper on the Doppler effect many years later.

When Doppler retired in 1853, Andreas Ettinghausen, who had served from 1835 to 1848, was reappointed. He supervised the move of the Institute to new quarters, an inadequate building at Erdbergstrasse 15, in the Third District of Vienna, actually not far from where Erwin Schrödinger was born.

The problem of a suitable home for the university could not be solved until a liberal government came to power in 1868. Even then the army clung to 200 hectares of prime building site on the Ringstrasse, which it was using as a parade ground. In 1870, Mayor Felder finally won the approval of the emperor for a grandiose building plan, which accommodated the University, the Parliament, and the City Hall [*Rathaus*] on the old Champ de Mars. The university building, large and ornate in the style of the Italian Renaissance, was completed in 1884, but it did not help the physicists, who were still exiled in Erdberg, although the experimental laboratories had been moved in 1875 to another temporary building on *Türkenstrasse*, not far from the new university site.

The successor of Ettinghausen to the chair of physics was Josef Stefan, in 1863. His background was unusual, in that his parents were country folk who could neither read nor write, yet his academic brilliance had surmounted all handicaps. Stefan's most famous discovery was concerned with the properties of what was then called 'black radiation'. All bodies are continuously absorbing and emitting radiation. When a body is in equilibrium with its environment, the radiation it is emitting must be equivalent in wavelength and energy to the radiation it is absorbing. It is possible to imagine a body that is a perfect absorber of all the radiation incident upon it, an 'ideal black body'. Stefan, in 1879, discovered experimentally that the energy of this radiation per unit volume (density of radiation) depends upon the fourth power of the absolute temperature. A few years later, a former student of Stefan's, Ludwig Boltzmann, then at Graz, derived the law theoretically, and it became one of the corner stones of radiation physics, usually called the Stefan-Boltzmann equation,  $\sigma = aT^4$ . The interpretation of the wavelength distribution of the black radiation by Max Planck led directly to the quantum theory.

Another important scientist at the university at this time was Josef Loschmidt. While an assistant to Stefan, he made a major contribution to science, one that required neither experimental nor mathematical skill, but simply the ability to see an important relation that others had missed. As a result of the work of James Clerk Maxwell and Rudolf Clausius, the kinetic molecular theory of gases was becoming generally accepted: a gas consists mostly of empty space in which tiny molecules are flying about at a great rate, colliding with one another and with the walls of their container. The average effect of the collisions with the walls causes the pressure exerted by the gas. A difficulty that prevented universal confidence in this model was that nobody knew either how many molecules are in a given container of gas or what is the size of the molecules of any particular gas. Loschmidt made the necessary calculations of these quantities and

reported the results at a meeting of the Vienna Academy. This was the most exciting thing that had ever happened to molecules – for most physicists, they ceased being hypotheses and became realities. Loschmidt, in rapid succession, was awarded an honorary doctor's degree, appointed to an associate professorship in physics, and then to a professorship of physical chemistry.

Like anyone else, a scientist can have only one biological father, but he can have several scientific fathers, whose influence on his life may be even more important. Thus the history of physics in Vienna traces the scientific ancestors of Schrödinger. He had two scientific fathers, Franz S. Exner in experimental physics and Friedrich (Fritz) Hasenöhrle in theoretical physics. Loschmidt and Stefan were scientific grandfathers of Schrödinger on the Exner side.

The most important influence on the development of Exner as a physicist was, however, Viktor Lang. Lang was another distinguished graduate of the Akademisches Gymnasium. He studied at the Vienna University but took his doctorate at Giessen in Germany, and then worked in Paris with the great experimental physical chemist Henri Regnault, and in Heidelberg with Robert Bunsen and Gustav Kirchhoff on spectroscopy. At the early age of twenty-eight, he was called to a professorship in Vienna, which he held for forty-four years. His principal work was in the field of crystal physics. In 1874, he obtained an assistantship for the Institute, to which he appointed Franz S. Exner.

Exner was appointed associate professor in 1879, and in 1891, when Loschmidt retired, he became professor and also director of the Physical Chemistry Institute. At that time he had a choice among Graz, Innsbruck and Vienna, but he chose to stay in Vienna because he was looking forward soon to the building of a new Institute of Physics to replace the inadequate facilities at Erdberg, a hope that was not to be realized for twenty years. Exner worked on many different physical problems, and he inspired his students with an enthusiasm for these problems, so that the Exner Circle, as they came to be called, shared not only a common university background but also common interests in their research fields. These included electrochemistry, atmospheric electricity, radioactivity, crystal physics, spectroscopy, and the science of color [*Farbenlehre*]. It would not be possible today for one person to do experimental physics in so many different fields, for one thing the cost of equipment would be prohibitive, but Exner had practically no equipment except what he made himself, and consequently his scope of activity was less restricted. Erwin Schrödinger was to work in all the Exner fields except electrochemistry, but usually on theoretical problems, where the only equipment needed was pencil and paper.<sup>3</sup>



*Professor Franz Exner.*

In 1898 the Vienna Academy, on the recommendation of Exner, arranged for the gift to Marie and Pierre Curie of 100 kg of pitchblende residues from the St Joachim uranium mines. From this material, the Curies achieved the first isolation of radium, and they sent Exner a small sample of highly enriched material. With this the Austrian scientists accomplished some noteworthy researches, so that in 1901 the Academy established a Committee for Radioactive Substances, with Exner as chairman, and Suess, Boltzmann, Lang, and Welsbach as members. Welsbach was a brilliant inorganic chemist who had worked with rare earths and made a number of very profitable inventions, including the Welsbach mantle based on thorium oxide which provided the beautiful illumination of the gaslight era. The Academy bought 10 000 kg of residues from St Joachim, and the Welsbach factory processed them to yield 4 g of pure radium chloride, the analytical controls being done at Exner's Institute on the Türkenstrasse by Stefan Meyer and Egon Schweidler. In 1907 the Academy sent Rutherford and Ramsay in Manchester 400 mg of radium bromide, and their great discoveries were all made with Viennese radium. In 1908, Karl Kupelwieser, son of a famous painter, gave the Academy 500 000 crowns to construct a building for an Institute for Radium Research to be located next to the new Institute of Physics.<sup>4</sup>

### Ludwig Boltzmann<sup>5</sup>

We have described the scientific ancestry of Erwin Schrödinger on the experimental side, and now must go back to consider his even more important scientific forebears on the theoretical side. Here the father was Friedrich (Fritz) Hasenöhl and the grandfather was one of the greatest theoretical physicists of all times, Ludwig Boltzmann. A scientific family tree is not subject to biological constraints, so that Hasenöhl was not only Schrödinger's father but also his elder brother, having also taken his first degree under the supervision of Exner, in 1896.

Boltzmann was born in Vienna on February 20, 1844, the son of a 'K & K Cameral Concipist', in other words, a taxation official. The date was Shrove Tuesday, and half seriously he used to ascribe the sudden changes in his spirit between happiness and affliction to the fact that he was born during the dying hours of a gay Mardi Gras ball. He was a typical cyclothyme, short and stout with curly hair; his fiancée used to call him her 'sweet fat darling'. He received his doctorate from the University of Vienna in 1866 for work under Stefan on the kinetic theory of gases. His genius was soon recognized and at the early age of twenty-five he became professor of mathematical physics at the University of Graz.

Boltzmann's temperament was such that he never stayed very long in one place, but wherever he was, he continued to make major advances in the kinetic theory of gases. Quite independently of each other, Boltzmann and Willard Gibbs of Yale created statistical mechanics. This is the science that forms the connecting link between the small-scale world of atoms and molecules and the large-scale world of gases, liquids, and solids. The laws of the large-scale world, for example, the dependence of the pressure of a gas on its volume and temperature, can be derived as the statistical consequence of the mechanical behavior of the enormous number of molecules in any macroscopic volume. So far as the large-scale world is concerned, the positions and velocities of individual gas molecules are *hidden variables* which underlie the ordinary laws of gas behavior but do not explicitly appear in the gas laws. A considerable part of Schrödinger's research was devoted to statistical mechanics, his publications in this field filling the 514 pages of Volume I of his *Collected Works*.

In Boltzmann's time, chemists and physicists were much concerned with the question of the 'reality' of atoms and molecules. This concern was not the old philosophic conflict between 'realism' and 'idealism', although this too was mixed up in the scientific question. Many scientists, however, then believed that diamonds and carbon atoms are entities of a qualitatively different kind. Diamonds 'really do exist' and can be bought and sold, but carbon atoms are only theoretical concepts that are useful to derive mathematical equations. Most would admit that a tiny diamond, invisible to the naked eye but observed with a microscope, is just as real as a five-carat gem, but beyond that the fundamental building stuff of nature was energy, which could not really be broken up into little particles called 'atoms' or 'molecules'. For Boltzmann, however, atoms were every bit as real as diamonds.

In 1895, at a conference in Lübeck, an attempt was made to resolve these conflicting views of the fundamental structure of the world. The report in favor of energetics was given by Georg Helm of Dresden; behind him stood Wilhelm Ostwald of Leipzig, the leader of physical chemistry, and behind both was ranged the powerful positivist philosophy of the absent Ernst Mach. The leading opponent of energetics was Boltzmann, seconded by the mathematician Felix Klein. Arnold Sommerfeld reported that the struggle between Boltzmann and Ostwald equaled outwardly and inwardly 'the struggle of the bull with the supple matador. But this time the bull conquered the matador despite all his finesse. The arguments of Boltzmann drove through. All the young mathematicians stood on his side.'

When Stefan died in 1894, Boltzmann was appointed to his chair at Vienna University. The next year Ernst Mach was appointed to the

chair of history and philosophy of science. Boltzmann was a good friend of Ostwald, despite Ostwald's opposition to atomism, but he could not stand Mach. Thus in 1900, he accepted a chair of theoretical physics at Leipzig. In 1901, however, Mach retired because of ill health and Boltzmann returned to Vienna, since his former chair there had not been filled. Rather ironically, considering his dim view of most philosophers, he was also assigned the course in philosophy that had been given by Mach. He was a realist and a materialist in philosophy, but in personal relationships he was very soft-hearted, he never failed a student. An ardent supporter of Darwinism, he saw in evolution the mechanism by which inanimate atoms had evolved into mechanical structures called human brains, capable of love, pity, and artistic creativity. Modern molecular biologists like Francis Crick and Jacques Monod would have felt perfectly at home with Ludwig Boltzmann. His philosophical lectures were greeted with great public enthusiasm, the audience overflowing the largest lecture hall available. Even Franz Josef heard about them and he invited Boltzmann for an interview at his palace.

The attacks on atomism continued, however, and Boltzmann was called 'the last pillar of that bold edifice of thought'. As his health declined, he became more depressed, feeling each tremor of what he began to believe was a tottering edifice that would collapse with all his life's work under the rubble. In the summer of 1906 he went for a holiday to the beautiful Bay of Duino near Trieste and committed suicide by hanging while his wife and daughter were enjoying a swim. As Rilke wrote in one of his Duino Elegies: 'Aber die Liebenden nimmt die erschöpfte Natur in sich zurück, als wären nicht zweimal die Kräfte, dieses zu leisten.' [But exhausted Nature takes lovers back into herself, as though there were never the powers to create such a thing twice.]

Although it was sometimes said that suicide was a way of life in Vienna, the loss of Boltzmann was a terrible shock to all the members of the physics department. Erwin Schrödinger was personally broken hearted, for he had expected to begin his studies in theoretical physics within a few months under the great master. He recalled his feelings of that autumn, when he entered the physics building: 'The old Vienna Institute, from which shortly before Ludwig Boltzmann had been torn away in a tragic fashion, the building where Fritz Hasenöhrle and Franz Exner worked and many another of Boltzmann's pupils went in and out, engendered in me a direct empathy for the ideas of that powerful spirit. For me his range of ideas played the role of a scientific young love, and no other has ever again held me so spellbound.'<sup>6</sup>