Erwin Schrödinger
Nobel Prize in Physics 1933

Nobel Prize in Physics 1933 "for the discovery of new productive forms of atomic theory"

* 12 August 1887 in Vienna-Erdberg
† 4 January 1961 in Vienna

1921–1927 Professor of Theoretical Physics at the University of Zurich

Alpine Air and the Wave Equation

When Erwin Schrödinger was appointed to the chair for theoretical physics at the University of Zurich in the fall of 1921 – a position that had been vacant since 1914 – no one imagined that six years later he would leave the University and the city hailed as a genius by luminary figures such as Albert Einstein and Max Planck, and celebrated as a star.

Schrödinger arrived in Zurich aged 34. Born in Vienna, he was regarded as a versatile and eclectic scholar, who was at home in all subjects, but who had not yet produced work of any real significance – at what was already considered an advanced age for physicists. When he moved with his wife, Annie, from Breslau to Zurich in 1921, a Nobel Prize must have seemed to him a distant prospect. Schrödinger, whom his biographer Walter J. Moore described as a "brilliant only child, occasionally led astray by intellectual exuberance," suffered from his lack of success and recognition. And his position as chair at the University confronted him with a most daunting legacy: He followed in the formidable footsteps of none less than Albert Einstein, Peter Debye, and Max von Laue – all subsequent Nobel laureates. Nonetheless, Schrödinger would go on to spend six years in Zurich, a time in which he ultimately revolutionized physics.

First, however, he had to recover his strength. When he arrived in Zurich, he was exhausted, both physically and mentally: "I was so worn out that I was incapable of intelligent thought," he later wrote to Wolfgang Pauli. The new professor blamed this on the stress of moving, the "constant decisions about his own future," and the negotiations over his appointment, the latter of which he was not cut out for, as he noted.

With the move to Zurich, Schrödinger left behind him a Germany shattered by war and still haunted by hunger and misery. And he was freed from his financial worries: Unlike his illustrious predecessors, he was granted not merely an associate professorship, but full tenure. The Schrödingers took a spacious apartment, appropriate to their status, at Huttenstrasse 9 in Zürich-Oberstrass.

In addition to exhaustion, Schrödinger had also brought with him from Germany a dangerous and insidious illness. Hardly had he begun lecturing when he was forced by severe bronchitis to take a break. His respiratory troubles lasted the whole winter. Finally, a mild pulmonary tuberculosis was diagnosed and rest prescribed. Thus it came that, in 1922, Erwin Schrödinger withdrew to the holiday and health resort of Arosa, a place that would prove to be steeped in destiny. He stayed there for nine months, cared for devotedly by his wife. The high-altitude cure was successful, the symptoms disappeared, and at the beginning of November Schrödinger was back in Zurich and teaching again. He was able to work, but tired quickly. In Arosa, he had written two articles, one of which, "Über eine bemerkenswerte Eigenschaft der Quantenbahnen eines einzelnen Elektrons" (On a notable property of the quantum orbits of a single electron), in Walter J. Moore's words, could "well be described as an original breakthrough into a new era."

> **"Schrödinger was a brilliant only child, occasionally led astray by intellectual exuberance."**
> Walter J. Moore

Indeed, the alpine air of Arosa seemed to inspire Schrödinger, and he was to return there frequently. Years later, this was where he again devoted himself to electrons and quanta, and thus laid the foundations for his breakthrough in quantum physics.

After his convalescence, Schrödinger taught and researched, and enjoyed the good life in Zurich. He and his wife were part of an academic clique that met regularly for picnics and to go to the newly opened public baths at the Mythenquai; it was a lifestyle that led to friendships and love affairs, such as the one between Hermann Weyl, Professor for Geometry at ETH, and Schrödinger's wife, Annie. For his part, Schrödinger, together with Weyl and his predecessor Peter Debye, then Professor at ETH, enjoyed Zurich's nightlife, not to mention his own share of extramarital affairs. The marriage suffered from the absence of children: Schrödinger longed for a son. From time to time, the couple considered divorce, though in the end they stayed together all their lives.

Schrödinger was popular with his students. He was regarded as a good teacher, and his lectures as "intellectual delights" (Walter J. Moore). When appointed in 1927 as successor to Max Planck in Berlin, his students organized a torchlight procession to Schrödinger's house to persuade him to stay. Schrödinger was touched, but still left for Germany. His open-air lectures, held in good weather by the lake, were legendary. One of his students, Alexander von Muralt, recalled: "In summer, when it was warm enough, we went to the shores of Lake Zurich, sat in the grass with our notebooks, and watched this scrawny figure in his swimming trunks, as he outlined his theories on an improvised blackboard that he had brought along."

And so the time passed, with teaching, marital rows, and affairs, yet no scholarly tour de force. Then, in the summer semester of 1925, Erwin Schrödinger read the doctoral thesis of a young Frenchman, Louis de Broglie, who proposed that matter – such as electrons – also possessed wave properties. This contradicted the prevailing opinion of leading physicists of the time, who assumed that electrons were particles. Albert Einstein was immediately fascinated by de Broglie's bold theory, while other researchers, such as Max Planck, reacted with initial disbelief. De Broglie also gave Erwin Schrödinger cause for thought – in an extremely productive fashion, as it turned out.

A vacation in clandestine female company signaled the beginning of Schrödinger's *annus mirabilis*, the year he revolutionized physics.

Schrödinger focused intensively on Broglie's proposition that all matter has wave properties. What were the properties of such waves of matter? He attempted to formulate laws and equations that would define them. His breakthrough came extraordinarily quickly, and under unexpected circumstances. Schrödinger spent Christmas and New Year 1925/26 on holiday in Arosa. Not, however, with his wife, but with an unknown companion, often referred to as the "dark lady." This vacation in clandestine female company was the beginning of his *annus mirabilis*, a phase, lasting some twelve months, of concentrated, creative work that revolutionized physics. Schrödinger felt that he was on the track to something big. On 27 December he wrote to his physicist colleague, Wilhelm Wien, "At the moment I am bothered by a new atomic theory. If only I were better at mathematics! I'm very optimistic about this, and hope that it will turn out beautifully as long as I can manage the calculations."

On his return from Arosa, a colleague asked Schrödinger whether he had enjoyed the skiing. He answered that he had been distracted "by some calculations." These calculations resulted in his first article, "Quantisierung als Eigenwertproblem. Erste Mitteilung" (Quantization as a problem of proper values, part one), which he sent to the *Annalen der Physik* on 26 January 1926. In this paper, he first formulated his famous wave equation, which has gone down in physics' history as the "Schrödinger equation." The wave equation makes it possible to calculate the energy levels of electrons in an atom, thus solving one of the great problems in quantum physics. This first paper was followed by three more over the next six months. Ultimately, Schrödinger's revolutionary calculations proved the wave nature of matter proposed by de Broglie.

After Schrödinger's wave equation, nothing in the world of physics was the same again. The dispute as to whether quantum objects such as electrons, atoms, or molecules were waves or particles was settled – but in a most surprising fashion: Schrödinger demonstrated that electrons could have the properties of *either* waves or particles, but are neither the one nor the other; their state can be calculated only with a degree of probability.

In a burst of creativity, spurred on by a high-altitude erotic interlude with his mysterious companion, Erwin Schrödinger shifted the foundations of his subject. What followed was fame and honor. While still employed in Zurich, Schrödinger was invited to the USA where he held 50 lectures in three months at the major universities and was offered several professorships. Schrödinger turned down all the offers, for he had something better in view – the succession to Max Planck in Berlin. He had already moved in time to celebrate his fortieth birthday, on 12 August 1927. Schrödinger's years in Zurich thus came to an end as did his most productive phase as a scholar – one that set him among the greats of his subject. *Thomas Gull*

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Created in Zurich:

A New Atomic Theory

"Schrödinger's equation" is one of the great breakthroughs in the history of physics. Erwin Schrödinger worked it out within a few months at the end of 1925 and the beginning of 1926, and published his findings and calculations in the *Annalen der Physik* between January and June 1926. At this time, the best physicists in the world, including Niels Bohr, Max Planck, Werner Heisenberg, and Albert Einstein, were struggling to understand the atom. Among the unsolved puzzles was the behavior of electrons in an atom. It was unclear whether electrons were particles or waves. The revolutionary aspect of Schrödinger's equation was that it was based on the assumption that electrons were waves that filled space.

The equation gave Schrödinger an elegant means of calculating the energy level of the electron in the hydrogen atom. Interestingly, German physicist Werner Heisenberg had come to the same conclusion at the same time, albeit with another method of calculation that was based on the concept of electrons as particles.

This showed that electrons could have the properties of both particles and waves, a discovery with far-reaching consequences for quantum physics: It means that the nature of the particle in and of itself cannot be determined because the act of observation influences the phenomenon observed.

Schrödinger explained this paradox in 1935 with a thought experiment that has gone down in the annals of physics as "Schrödingers Cat." A cat is placed for one hour in a closed box with an unstable atomic nucleus that can disintegrate at any time (but we don't know when), a Geiger counter, a hammer, and a glass bottle containing cyanide. When the nucleus disintegrates, the radiation is detected by the Geiger counter. The hammer then breaks the glass bottle, the poison is released, and the cat dies. If we can observe the box only from outside, we cannot say whether the cat is alive or dead, as we do not know whether or when the nucleus disintegrates. We can only be certain when we open the box. Until that happens, the cat can be simultaneously dead or alive.

It is the same with particles in quantum physics as with the cat: Their condition can be definitively determined only when they are measured. Until then, it is only possible to discuss the state of the particle in terms of probability.

This uncertainty irritated Schrödinger's contemporaries, who were unwilling to believe that physics is governed by chance. Albert Einstein reacted with the remark that God doesn't play dice. The physical and philosophical consequence of this insight is the question of whether nothing is real – the cat is neither dead nor alive – or everything is real – the cat is simultaneously dead and alive. It is a fundamental question that remains unanswered to this day – a question that indeed may be unanswerable. *(TG)*

Erwin Schrödinger (middle) was part of an academic clique that met regularly in the public baths at Zurich's Mythenquai, which opened in 1923. Photo: Ruth Braunizer/Austrian Central Library for Physics.

Developed a new atomic theory in Zurich: physicist Erwin Schrödinger. Photo: Nobel Foundation