Schrödinger's Contributions to Molecular Biology
by Kristin Hussey ’02

In 1933 Erwin Schrödinger received the Nobel Prize for physics, along with Paul Dirac, for the “discovery of new productive forms of atomic theory.” Specifically, Schrödinger was able to produce a mathematical formulation of wave mechanics that laid the foundation for advances in quantum mechanical theory. While he is perhaps best known for these accomplishments, his work neither began nor ended there. Schrödinger’s incessant quest to understand the world around him caused him to leave his study of physics for a short time while working in Dublin to contemplate the biological sciences. In 1943 Schrödinger gave a series of lectures that detailed his thoughts about the nature of the gene. He later published these lectures as a short book entitled What is Life? Although many of the ideas in this book are neither original nor correct, the book had a profound impact on several key founders of molecular biology. According to his biographer, Walter Moore (1989), molecular biology would have developed without What is Life?, but at a slower pace, and without some of its brightest stars. What is Life? catalyzed the future development of a great field of research unlike any other short semipopular book in the history of science. In this way, Schrödinger contributed significantly to the arrival of molecular biology.

Schrödinger was one of the few physicists of his time to reflect on the puzzles that biology presented concerning the nature and structure of the gene. There were two key influences in Schrödinger's life that may have sparked his interest in this field. The first was his father, Rudolf Schrödinger, who published papers on plant phylogenetics. It is probable that many of the conversations Erwin had with his father as a child involved Rudolf’s love for biology. The second important figure in Schrödinger's life was Franz Frimmel, otherwise known as Fränzel, who was a student of botany at the University of Vienna in 1906. Schrödinger was there at the same time studying physics. They became good friends and together read and discussed the book by Richard Semon, The Mneme as Conservation Principle, which was first published in 1904 and was based on Lamarck's idea of inheritance of acquired characteristics (Moore, 1994). Clearly, Fränzel reinforced Schrödinger's interest in biology and inspired him to do extensive reading and thinking in areas that were foreign to most physicists.

In 1943, Schrödinger formalized his thoughts and theories about biology when he agreed to give a public lecture at the Dublin Institute for Advanced Studies at Trinity College, where he then worked. He decided to make his topic a biological, one based on the effect of X-rays on the mutation rate of the fruit fly, Drosophila melanogaster. It was during this time that P.P. Ewald, a German theoretician, sent him a paper written in 1935 by N.W. Timofeeff-Ressovsky, K.G. Zimmer and Max Delbrück entitled “The Nature of Genetic Mutations and the Structure of the Gene.” According to Moore (1989), this famous three-man paper “suggested for the first time that a mutation is caused by a change at one place in the molecule.” Schrödinger focused on the implications of this result for the chemical and physical mechanism of inheritance. The paper showed that the facts of genetics could be related to fundamental physical theory and this was a great inspiration to Schrödinger. He became curious about how inheritance was constrained by the laws of thermodynamics, chemical kinetics, and quantum mechanics and this became the basis for his lectures (Moore, 1989). These lectures were published the following year under the title What is Life? The physical basis of...
the living cell.

Schrödinger presents many ideas in his book. He calls the first chapter “The Classical Physicist’s Approach to the Subject” and in it he states the central purpose of the book and what he hopes to discover. He writes, “The large and important and very much discussed question is: How can the events in space and time which take place within the spatial boundary of a living organism be accounted for by physics and chemistry” (1994). In the quest to find the answer to this question, Schrödinger examines the apparent contradictions between life and the statistical laws of physics. One way he does so is by referring to a chromosome as an aperiodic crystal. In other words, Schrödinger develops the idea that the gene is a linear one-dimensional crystal that lacks a periodic, repeating structure. He explains that this structure is important because it shows that incredibly small groups of atoms, which are too small to follow exact statistical laws, play a dominant role in the very orderly and lawful events within a living organism (Moore, 1989). Schrödinger also becomes the first to state in clear physical terms that the chromosome is a message written in code (Moore, 1989). He was interested in whether the nucleus could accommodate a sufficient system of ‘determinations’ that could account for the varied developmental patterns in living organisms. Schrödinger supposed that these ‘determinations’ resulted in differences within the genetic molecule based on isomerism. He used the Morse system to make this idea seem more plausible and thus introduced the term ‘code’ to cover the system of ‘determinations’ in the cell nucleus (Teich, 1975). However, it is evident that he was more concerned with the problem of lawfulness in biological systems than with the structure of the gene (Yoxen, 1979). He was particularly interested in how the gene could continue to exist practically unchanged on the molecular level because he was so accustomed to thinking of molecules being governed by an overall tendency to disorder. To explain this he develops his order-from-order laws, which state that an organism continually increases in positive entropy and can only remain alive by continually drawing negative entropy from its environment (1944). These theories and ideas illustrate the ways in which Schrödinger was able to approach biology from a physicist’s viewpoint.

However, despite Schrödinger’s effort to explore biology in terms of physics, What is Life? became vitally important not because of the ideas it presents, but rather because it served to inspire other physicists to begin studying biology. Perutz, winner of the Nobel Prize for chemistry in 1962, states that what was true in the

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book was not original, and most of what was original was known not to be true even when the book was written (1987). Several other scientists share this view. However, most geneticists recognized Schrödinger’s intention to break boundaries between physics and biology and they welcomed this idea (Teich, 1975). A key incentive for other physicists was Schrödinger’s assertion that new laws of physics needed to be discovered to explain the nature of the gene, and more specifically, his order-from-order laws. Schrödinger was able to make the facts of genetics meaningful to a physicist by defining a problem generated by biochemistry and classical genetics in a language they were more disposed to consider (Yoxen, 1979).

Many important scientists have commented that What is Life? had a profound impact on them and was often an important factor that caused them to begin studying molecular biology. In 1962 Francis Crick, James Watson, and Maurice Wilkins received the Nobel Prize in Physiology or Medicine for determining the structure of DNA. Wilkins mentioned in his Nobel Prize address that it was because of Schrödinger’s book that he switched his study from physics to biology after World War II (Yoxen, 1979). In 1965, Francis Crick, who was also trained as a physicist, wrote that the book was particularly influential because it demonstrated that biology needed molecular explanations which only quantum mechanics could provide, thus inspiring physicists to study the biological sciences. (Yoxen, 1979). In the
autumn of 1946, the National Academy of Sciences sponsored a conference in Washington to discuss the borderline problems in physics and biology. Max Delbrück, who was one of the authors of the famous three-man paper that inspired Schrödinger initially and who went on to win the Nobel Prize for Physiology or Medicine in 1969, began the discussion by remarking that it was Schrödinger’s book that had caused them to come together. He went on to say that it would doubtless be the first of many such meetings. (Moore, 1989, p.285)

It thus seems that Schrödinger’s contributions to molecular biology were two-fold. First, biology was revolutionized by the arrival of molecular biology and biochemistry. In turn, the development of molecular biology depended crucially on the introduction of new ideas into chemistry that were stimulated by quantum mechanics. Thus, by discovering the wave equation, Schrödinger directly contributed to the direction of modern biology. Secondly, Schrödinger’s book *What is Life?* encouraged many scientists to think in new ways and approach biological problems from a physical standpoint. In this way he also had an indirect, yet unquestionably important influence on the field of biology. The modern trends of genetics and molecular biology owe their existence, at least in part, to the renowned physicist Erwin Schrödinger.

**REFERENCES**


**ABOUT THE AUTHOR**

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