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BRUNO HASBROUCK ZIMM
1920—2005

A Biographical Memoir by

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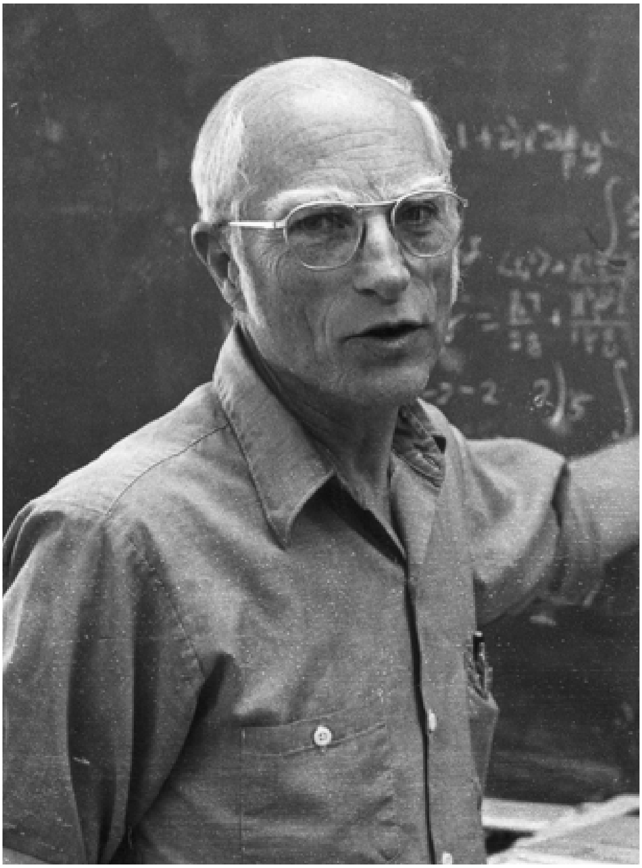
Biographical Memoir



Bruno H. Zimm

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October 31, 1920–November 26, 2005

BY CAROL BETH POST AND RUSSELL F. DOOLITTLE

FAMILY AND CAREER

PROFESSOR BRUNO H. ZIMM, distinguished scientist and premier polymer chemist, died on November 26, 2005, in La Jolla, California, at the age of 85 after a hard-fought battle with Parkinson's disease. Bruno Zimm was born in 1920 in Woodstock, New York, to Bruno Louis Zimm, an acclaimed sculptor, and Louise Zimm, a writer. He married Georgianna Grevatt in 1944, and together they raised two sons, Louis Zimm and Carl Zimm.

Zimm's pioneering contributions to polymer chemistry laid the groundwork for modern research on biological and synthetic macromolecules, and established him as a founding father of the physical chemistry of macromolecules. His lasting impact on not only science but also on researchers is unparalleled. Zimm's scientific preeminence was recognized early, and he was elected to the National Academy of Sciences in 1958 at the young age of 38, with many of his celebrated works yet to be published.

Bruno Zimm received his B.S. in chemistry from Columbia University in 1941, and in 1944 earned his Ph.D. under the tutelage of Joseph E. Mayer, also at Columbia. As this was the time of World War II, Zimm spent a summer working on a war-related project under the direction of Victor

K. LaMer. He and a fellow graduate student, Paul Doty, studied light scattering theory to investigate the optical properties of smokes. This summer's project, therefore, was Zimm's introduction to light-scattering theory. In 1944 he moved across town to the Polytechnic Institute of Brooklyn as an instructor and research associate with Professor Herman Mark. His research there from 1944 to 1946 was the start of a lifelong fascination with biological and synthetic macromolecules. Bruno accepted a faculty position at the University of California, Berkeley, in 1946, and began developing the method of using light scattering for analysis of high-molecular-weight polymer solutions. As a young assistant professor he invented the famous Zimm plot for simultaneous determination of three fundamental macromolecular parameters: radius of gyration, the second virial coefficient, and molecular weight. Three of the publications reporting this pioneering work in 1948-1949 have been cited more than a thousand times, and Zimm is sole author on two of these (1948,1,2; 1949). While associate professor at Berkeley (from 1950 to 1952), he took leave to be a visiting lecturer in chemistry at Harvard University. In 1951 Zimm moved to the General Electric Research Laboratory in Schenectady, New York, where he spent nearly 10 years and made the transition from synthetic polymers to biological ones of polypeptides and DNA. At GE, Zimm published his two most highly cited papers: the report of the Zimm-Bragg theory of the transition between helix and coil in polypeptide chains (1959) and the theoretical description of polymer solution viscoelasticity and flow birefringence (1956). That second paper is regarded as the fundamental description of polymer dynamics with nearly 2000 citations. He returned to academia in 1960 and after a brief stint as a visiting professor at Yale, he moved to the University of California, San Diego, (UCSD), where he remained for the rest of his life. It was at UCSD that Zimm designed the Cartesian-diver viscoelastometer with a freely floating inner cylinder to generate very low shear rate for measuring chromosomal-size DNA, and contributed theories of DNA melting and gel electrophoresis. He became Professor Emeritus of Chemistry and Biochemistry in 1991. He continued his work as long as he was able, and never tired of talking about science and how the world works. After becoming Professor Emeritus and no longer formally mentoring students and postdocs, Zimm published, each year until 2000, one or more papers, several single-authored and some from new collaborations.

Zimm was the recipient of the National Academy of Sciences Award in the Chemical Sciences in 1981, the citation reading:

> For his contributions and influence in theoretical and experimental polymer chemistry, notably his work on polymer interactions, polymer visco-elasticity, the helix coil transition in bio-polymers, the theory of light scattering, and the study of extraordinarily large DNA molecules.

Zimm was also a fellow of the American Academy of Arts and Sciences (since 1969), and a member of several scientific societies. Among the numerous awards and honors he received are the Baekeland Award, North Jersey Section, American Chemical Society in 1957; Bingham Medal of the Society of Rheology in 1960; the American Physical Society High-Polymer Physics Prize in 1963; Kirkwood Medal, New Haven Section, American Chemical Society in 1982. He wrote over 165 scientific publications. Special journal articles and issues highlight many of his substantial accomplishments.[1]

SCIENTIFIC ACHIEVEMENTS

Zimm's lifelong interest in understanding the nature of polymeric solutions was ignited at Columbia University, where he met Walter Stockmayer, his lifelong friend and collaborator. Both Zimm and Stockmayer were inspired by Joseph E. Mayer, Zimm was a doctoral student of Mayer and Stockmayer took a job as an instructor at Columbia with the aim of being near Mayer. Zimm also claimed that Charles O. Beckmann was mostly to blame for his and Stockmayer's conversion into polymer chemistry, but one cannot discount the seminal work of Paul Flory—which drew Zimm's attention as a young physical chemist to the burgeoning field of polymer science—and Paul Doty, a fellow doctoral student with Mayer. Together, Zimm and Doty contemplated how to measure the absolute molecular weight of polymeric molecules and distributions, a curiosity that eventually lead Zimm to measure molecular weights of the enormous chromosomal DNA molecules. In the early 1940s obtaining molecular weights of synthetic polymers was of fundamental interest but all methods known at the time had difficulties. In 1944 Zimm and Doty, both at Brooklyn Polytechnic Institute, heard that P. J. W. Debye had developed an unpublished method to measure polymer molecular weights from light scattering. With insight from their earlier discussions on the Einstein-Smoluchowski theory of light scattering related to density fluctuations of smokes, Zimm and Doty recognized immediately that combining Smoluchowski's equation with Raoult's Law gave an estimate of absolute molecular weight from two measurements: turbidity and the refractive index increment of a solution. In collaboration with Herman Mark, Zimm and Doty conducted experiments that showed the new method worked, and published the results (1944, 1945) soon after P. J. W. Debye's paper appeared in the *Journal of Applied Physics* in 1944.

Zimm's curiosity about polymers endured and as an assistant professor at Berkeley he continued to work on polystyrene, his favorite molecule, for about 15 years. Bruno was exceptional, equally brilliant and proficient with theory and experiment. Even early in his career he combined his deep physical insight with a solid practical sense to develop a now famous experimental method to simultaneously analyze the radius of gyration, second virial coefficient, and molecular weight of a polymer (1948,1). The analytical method, a primary tool utilized by polymer chemists today, is called a Zimm plot. That is, it is called a Zimm plot by everyone except Bruno. While a student of Bruno's, one of us (C.B.P.) used this method to study DNA condensation, and in the first draft of the manuscript called the resultant figure a Zimm plot, as you would expect. In the next draft, and in the 1982 publication of the work, the figure is found described as a "reciprocal-intensity light-scattering plot" as a result of Bruno's editing.

The method of analyzing macromolecular properties from light-scattering intensities is not all that appeared in the highly cited 1948 paper first reporting the Zimm-plot (1948,1). Testimony to Zimm's true brilliance, the paper also describes the design of a new photometer, including electronic circuit diagrams and details on performing measurements at different angles. The instrument measured the intensity of scattered light more accurately than other instruments available at the time. It should not be overlooked that Zimm also contributed the theoretical treatment for the angular dependence of scattered light in the preceding article of the same issue of the *Journal of Chemical Physics* (1948,2). Those who emphasize the interdisciplinary nature of modern scientific research should take note of these extraordinary single-authored, back-to-back publications addressing instrumentation, experiment, and fundamental theory, each with more than 1000 citations. Application of Zimm's plotting method yielded plenty of data revealing interesting new behavior of polymer solutions (1950) on which to build future theories.

Equilibrium statistical properties of polymers held Zimm's attention for many years. He applied his incisive understanding of statistical mechanics to numerous problems related to polymer configurations and phase transitions. Early in his career he developed a statistical treatment of solutions of large molecules based on Mayer's theory for nonelectrolyte solutions to obtain a general expression for the second virial coefficient of macromolecules (1946). This work was soon followed by an investigation of the dimensionality of polymer chain molecules. An elegant description of the calculation of the radii of gyration for branched polymers accounting for the effects of excluded volume appeared in a classic paper written with his close friend Stockmayer, or "Stocky" (1949). In the 1950s when the interests of some polymer scientists started to turn toward biomolecules, Zimm published another of his celebrated works: the Zimm-Bragg theory to describe the helix-coil transition of a polypeptide chain (1959,1), accompanied by careful experimental investigations to try out the theory (1959,2). The Zimm-Bragg theory of helix-coil transition remains today an integral component of the theoretical prediction of protein folding and design, as well as experimental measurement of protein structural stability.

Zimm's lasting influence on polymer science also includes his numerous contributions to understanding nonequilibrium properties of polymers. His most highly cited paper (1956) is an insightful and practical treatment of flexible chains to obtain expressions for viscoelasticity, birefringence, and dielectric relaxation. It is a beautiful example of Zimm's ability to recognize how to formulate a problem and apply the right mathematical tools to find a useful outcome (1956; 1959,3). He also investigated dynamic properties of DNA. Some of the problems that captured his attention were how to explain the melting of double-stranded DNA (1960) and the fluorescence depolarization of DNA (1979). In his pursuit of understanding the behavior of polymers, Zimm eagerly adapted new technologies that would help him to investigate these large molecules. He made good use of computational methods, such as Monte Carlo, to test certain assumptions made in deriving analytical theories for sedimentation and other transport properties (1981, 1980), as well as equilibrium counter-ion distributions (1984). More recently Zimm became interested in polyelectrolyte behavior of DNA and developed a rigorous description for the snaking of long DNA chains through a gel under the force of an applied electric field (1985).

Coincident with his arrival at UCSD Bruno embarked on a long-term experimental project to find the true lengths of native DNA molecules. At the time, the true size of DNA molecules was unknown but there was evidence from autoradiography and electron microscopy that these molecules were incredibly long, and therefore fragile. Again, Bruno's creative genius appears on the scene not only conceptually but also in designing and constructing the scientific tools to explore new concepts. Bruno conceived one of his many ingenuous ideas: to operate a rotating viscometer in an inverse design where the inner cylinder rotates while the outer one is fixed (1962). This simple reversal results in the shear stress being fixed and the shear gradient being measured, a condition that removes stress and reduces the chance of breaking a long DNA molecule. Oddly, but true to the nature of this great thinker, the idea occurred to Bruno during the mundane task of washing dishes, when he observed a drinking glass rotating in the dish water and realized from the swirling motion the advantage of rotating the inner cylinder. The culmination of these elegant studies was the measurement, by Bruno and biologist Ruth Kavenoff, of full-length DNA molecules from chromosomes of the fruit fly (*Drosophila*) (1973). The use of chromosomes from different species of fruit fly that had morphologically different-size chromosomes gave them an external gauge that verified their measured values, which ranged from 20 billion to 80 billion Daltons. As a *coup de grace* they used DNA from a mutant strain of fruit fly that had a shortened chromosome, the measured length of which correlated perfectly with what was observed in the microscope. Thus, they had conclusively shown that each chromosome is composed of a single molecule of DNA.

REFLECTIONS

Bruno Zimm was universally liked and respected as an exemplary scientist, teacher, and person. For the National Academy of Sciences Award in the Chemical Sciences, he was cited for research "that in the broadest sense contributes to better understanding of the natural sciences and to the benefit of humanity." He was not a man enslaved by professional ambitions. His wife, Georgianna, once said, "He didn't think about those things [awards and recognition]. He did it [research] because he enjoyed it." He pondered the world and delighted in the joy of discovery and the understanding of how the world works. As Stocky noted in celebrating Bruno's 65th birthday,

> [His modesty] turned into perhaps the most admirable and certainly the most lovable of all of Bruno Zimm's gifts: he simply is unaware of his stature, and treats all creatures, anthropoid or not, always patiently and affectionately as no less than complete equals.[1]

The photograph at the beginning of this memoir captures Bruno at one of his most loved activities: working on an analytical theory (and probably teaching a student) at the chalk board. He preferred working with a small group and rarely took on more than two or three graduate students and a few postdocs at a time. Nonetheless, he left a remarkable legacy of students and postdocs, with the overwhelming majority having careers in academia. Two members of his first group of students and postdocs at UCSD, Don Crothers and Vic Bloomfield, wrote a seminal text on DNA physical chemistry. He kept his group small because he was always thoroughly involved with his students and needed time to be available to listen to their ideas and to hear out their problems. Not only was Zimm one of the world's great thinkers and most gifted scientists, he was also a wonderful listener. He listened to the thoughts, ideas, and questions of colleagues and students, as well as to their problems. But he also wanted time to think for himself. Many of his papers throughout his career are single authored.

Consistent with his proficiency in both experiment and theory, Bruno enjoyed working with his hands as much as he did thinking. Research and the lab were more like a hobby than a job to Bruno. His lab at UCSD included a shop filled with tools he collected over the years: equipment for glass blowing (a diamond saw, torches, gas cylinders), electronics (soldering guns, 'scopes, circuit boards), and a lathe, one of Bruno's favorite toys. Naturally, Bruno was glad to have any student who shared his fondness for tinkering make use of the shop. One, however, was seldom left alone in the shop, as the entrance was across from Bruno's office, and it was difficult to enter unnoticed. Once the lathe, for example, started to turn, Bruno would appear—with a smile—to ask, "Wouldn't you like some help with that?"

From his father, a sculptor, and his mother, a writer, Bruno inherited a deep appreciation of art and music. He loved to play the clarinet. For a number of years Friday lunch-time was spent playing duets in his office, and in the lab one could hear the sounds of Bach emanating from across the hall. He also read extensively in German and English. He learned the theory of light scattering as a student at Columbia by reading the original German edition of *Optik* by Max

Born (published in 1933). Bruno once noted that after the exercise of reading Born's elegant German, he found other German readings easy. He later translated the memoirs of Ludwig Boltzmann (of whom Bruno was a fan) for the simple satisfaction of doing it. He was also an avid sailor and doted on his beautiful wooden Norwegian sail boat, *Altair*. He took pride in maintaining it, and occasionally enlisted the help of a student or two for the required painting and refinishing, always followed by an invitation for a sail.

Beyond these tangible contributions to science, the many lives Bruno has influenced cannot be determined. Being mentored by Bruno was a priceless gift, a joy, and a lifelong honor. Many felt privileged to have been taught by someone with such extraordinary insight and depth of thinking, but one who could reduce complex systems to simple ones. Yet, this unassuming master of science was exemplary in his humanity, teaching, patience, and support. He was a role model in a manner that, sadly, in modern scientific times is difficult to follow.

NOTE

1. W. H. Stockmayer. Bruno H. Zimm on his 65th birthday. *Macromolecules* 18(1985):2095-2096. Special Issue: Honor of B. Zimm. *Biopolymers* 31(1991):1459-1667.

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