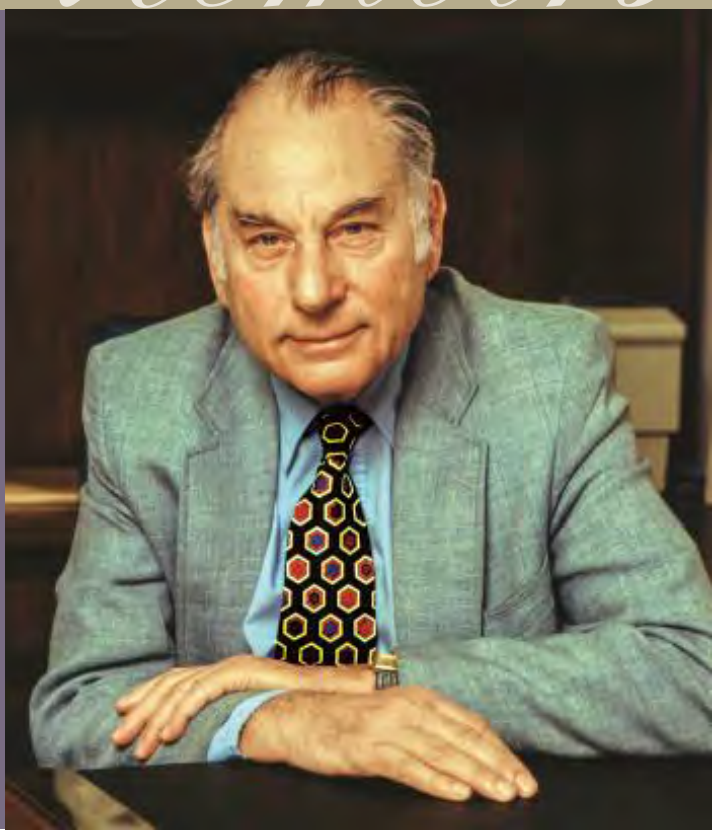
Ernest L. Eliel

1921–2008

BIOGRAPHICAL *Memoirs*



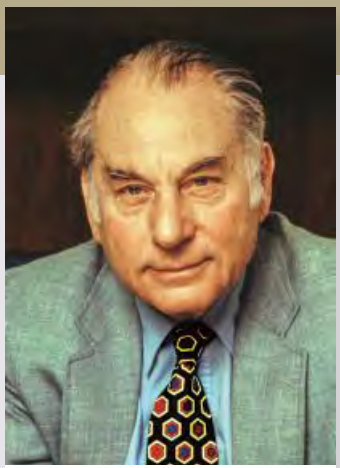
A Biographical Memoir by
Jeffrey I. Seeman

NATIONAL ACADEMY OF SCIENCES

ERNEST LUDWIG **ELIEL**

Dcember 28, 1921–September 18, 2008

Elected to the NAS, 1972



Photograph courtesy Chemical & Engineering News and the American Chemical Society

By Jeffrey I. Seeman[1]

Ernest L. Eliel was a professional's professional, an academic's academic, a chemist's chemist. As a scholar, he made major contributions to organic chemistry. He provided much of the modern fundamental knowledge in organic stereochemistry and conformational analysis and the effect of conformation on chemical properties and reactivity. As an educator, he mentored many graduate students and authored, co-authored, and edited specialized textbooks and reference books in stereochemistry. These books served several generations of chemists—and continue to serve—as the primary educational tool for stereochemistry for generations of chemists. A teenage refugee from Nazi Germany, Eliel understood the need to reach out and help others. He worked tirelessly to improve education at all levels with a special focus on assisting young foreign chemical scientists from underdeveloped countries. As a professional committed to the community of chemists, he served as president and chairperson of the board of directors of the American Chemical Society (ACS) and as president of the Council of Science Societies. As a scientist involved in public service and international activities, he was a founding member and president of the U.S.-Mexico Foundation for Science and participated in many activities to improve chemistry and chemical education in the United States and in underdeveloped countries. As a friend and colleague, he always provided advice and personal assistance to those in need. His files contain instances of his proofreading manuscripts and grant proposals for foreign colleagues. And I can attest that he provided German-to-English translations of chemical texts, for he did just that for me.

In addition to Eliel's autobiography (1990) and several autobiographical statements made concurrent with his running for national office in the ACS (1986, 1990) and other reasons (Eliel, 1982), several biographical articles are available (Seeman, 2002; Seeman,

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2009). Eliel's papers are available in the archives of the Chemical Heritage Foundation in Philadelphia, and a finder's guide is available (Mangravite, 2013).

The Early Years: From Cologne to Havana

Ernest Ludwig Eliel was born the youngest of three sons into a prosperous and highly educated, intellectual family in Cologne, Germany, on December 28, 1921. His paternal grandfather, after whom he was named, had been a member of the Cologne town council. His maternal grandfather, Leonhard Tietz, was a successful merchant, having been the founder of a very popular and sizeable department store. His father, Oskar, was a highly educated man who treasured knowledge, a lawyer who represented the family's mercantile business, and "a strong role model" for Eliel, who said:

> *He had a huge library, read avidly and was most interested in philosophy... he was a contemplative individual; I always had an enormous admiration for the fact that he was such a learned man, and I am sure of the drive in my own life came from the desire to imitate him, and, at least in some areas, to do even better than he did.*

Eliel's mother, Luise,

> *was an activist and an early woman's libber. She belonged to many organizations, spent a lot of her time on 'good works,' such as the presidency of a local orphanage...If the contemplative streak in me comes from my father's side, the activist streak certainly comes from my mother's.*

In the 1920s, elementary schools in Cologne were denominational, and, although he was Jewish, Eliel attended a Catholic elementary school, where he was "diligent, somewhat introverted, and therefore not very popular."

> *When I entered the fourth grade of high school, I had to decide between the Gymnasium (where the languages would be Latin and Greek, with some limited continuation of French and no teaching of English) and the Realgymnasium (where French and English were stressed, Latin downplayed, and Greek...not taught at all). Of course there was no question that I would pursue the modern-language track, and I told my father so. Although he was prepared for my decision, he, nevertheless, remonstrated with me. When I asked him why I should learn Greek, my father*

Eliel, mid-1930's.

told me that it was essential for any educated person to know the Greek alphabet and to know the Greek language roots found in many modern (especially scientific) terms. Thereupon, we agreed that he would teach me the Greek alphabet and Greek word roots on Sundays, and he did so. Later I got back at him by telling him that his education in the Gymnasium had been inadequate in that he had not learned calculus and that an educated person should know calculus! He agreed that I should teach him calculus in a series of Sunday lessons!

In early April 1933, soon after Adolf Hitler became Chancellor of Germany, Hitler ordered a boycott of Jewish businesses, including department stores. Shortly thereafter, according to Eliel,

> *the [family] business had to be sold at a severe loss and my father lost his job. At the time, my classmates were one third Nazi, one third opportunists, and of the remainder about a half were devout Rhenish Catholics, who had a much deeper, more basic hatred of Nazism. After [increasing intimidations], my class was five-sixths Nazis (the opportunists and aristocrats had joined up quickly) and they were very careful not to speak to me.*

By 1938 the Eliel family had fled their home in Germany: Ernest to Scotland; one brother, Edgar, who was 13 years older, to England; and another, Erwin, who was 10 years older, eventually to the United States by way of Holland, Portugal, and Brazil. Their parents fled to Palestine. Even though Eliel had applied for a U.S. visa in 1937, he was told

> *that I had to wait three years because the immigration quota was filled. I only learned recently [ca. 1998], on a visit to the Holocaust Museum, that the quota was not filled in 1937, it was filled in 1938 but was not filled in 1939. There was then a great deal of anti-Semitism in the U.S., and there was also a Depression and a lack of jobs, and they just didn't want that many Jewish immigrants. The State Department was especially well known for being anti-Semitic.*

Eliel arrived in August 1938 in Scotland, where he completed his pre-university education. Based on his ranking in the Scottish Universities' entrance examination taken in March 1939, he was awarded a stipend for four years of university education. Just as he was completing his first year in university, Germany invaded France, Belgium, the Netherlands, and Luxembourg on May 10, 1940. Within two days, Eliel was reclassified as "an enemy alien." He spent a month each in two internment camps (one near Liverpool and one on the Isle of Man), then was deported to "a destination that was a military secret. Thus I left Europe for good. The ship went to Canada." In May 1941, after a year in two Canadian internment camps, Eliel was "released" because his family had helped him obtain a Cuban visa. Eliel arrived in Havana via Trinidad and Venezuela in July 1941.

Research in Chemistry: From Havana to Chapel Hill

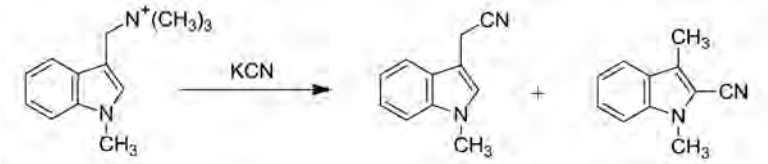
> *A very wise friend told me that 'wherever you are, act as though you were going to spend the rest of your life there.' I have never forgotten that advice, and at that time I knew clearly what I would do—I would go back to studying chemistry.*

A series of roadblocks worked to prevent Eliel from matriculating in the University of Havana. He was told that he needed notarized documents from the University of Edinburgh, which had to be "legalized by the Cuban State Department." He was then told he needed his birth certificate from Germany, notarized by a Cuban consul. After his Cuban attorney manufactured a fake certificate of identity "with ribbons and sealing wax," Eliel was able to present it to the appropriate authorities and matriculate. He graduated in 1946 with the equivalent of an undergraduate degree, even though it was called a Doctor en Ciencias Fisico-Químicas (D. Phys.-Chem. Sci.). His university studies were not as fulfilling as he had experienced in Germany and Scotland, though he did write an undergraduate thesis: "*El Aldehido Homoverátrico, Intermediario Para la Síntesis de Homoveratrilamina y Acido Homoverátrico*" ("Homoveratraldehyde, an Intermediate in the Synthesis of Homoveratrylamine and Homoveratric Acid"). Eliel performed research at the Laboratorios Vieta-Plasencia under the supervision of George Rosenkranz and Stephen Kaufmann—both of whom were Hungarian refugees who had earned their Ph.D.s with 1939 Nobelist (chemistry) Leopold Ružička at the Eidgenössichte Technische Hochschule (Zürich). Rosenkranz was later president of Syntex.

Eliel, third from left, with other students in the Laboratorios Vieta-Plasencia in Havana, Cuba, at an extension course in organic analysis and synthesis, summer 1945.

Eliel applied to three graduate schools: Harvard, which turned him down because they had incorrectly concluded that he already had a Ph.D.; the University of Michigan, which was then admitting only in-state residents; and the University of Illinois, which admitted him, partly because of a strong recommendation by Alfred Lee Sklar. Sklar had been a visiting professor in Havana on a Rockefeller Fellowship for whom Eliel had performed some library work. Upon arrival in Champaign-Urbana, he discovered that before admission he was required to find housing. "The only way to find a room (in a university town flooded with returning World War II veterans making use of the GI Bill) was to knock on doors and ask for one. The result provided me with an immediate demonstration of the American kindness and hospitality to a stranger."

Eliel chose as his Ph.D. advisor the then-young 36-year-old Harold R. Snyder. Snyder had joined the staff of Illinois in 1937 but had spent the war years working for the Committee on Medical Research of the Office of Scientific Research and Development. Together with two other Illinois faculty, Nelson J. Leonard and Charles C. Price, Snyder developed a process for the production of the antimalarial chloroquine, which was used in the South Pacific during the last years of World War II. One of Snyder's first Ph.D. students, Eliel completed his Ph.D. in two years, a feat further enhanced by eight publications that resulted therefrom. He studied the regiochemistry of carbon alkylation of indole Mannich bases (Scheme 1). Eliel loved experimental work and benefited from a close working relationship with James Brewster who, while working on a related project, loved library work and did most of Eliel's literature searches while doing his own.

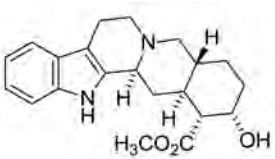


Scheme 1. Two reactions were observed: direct displacement of trimethylamine by cyanide and SN2′ displacement of trimethylamine with double bond isomerization.

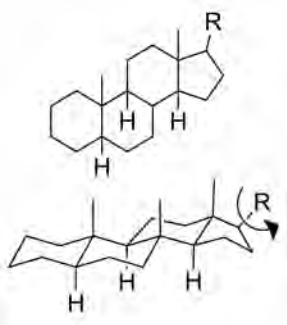
In 1948, while he was applying for a post-doctoral position at MIT and Illinois, Eliel was offered and accepted an instructorship at Notre Dame by one of his former teachers, Charles Price, who had just left Illinois to become head of the Chemistry Department at Notre Dame. Eliel was at Notre Dame until 1972, when he joined the faculty at the University of North Carolina, Chapel Hill, where he remained for the rest of his life.

Eliel (at far right) with fellow graduate students at the University of Illinois, ca. 1947.

Eliel's first independent research projects involved a study of the mechanism of hydride reduction of organic halides; the synthesis of nonracemic but minimally chiral $C_6H_6CHDCH_3$ (where D = ^2H, deuterium), demonstrating that chirality due to deuterium could give rise to measurable optical activity; and for him, the overly ambitious and ultimately unsuccessful attempt at the total synthesis of yohimbine. As Eliel himself reported, his first years at Notre Dame were not outstandingly productive, and "the academic year 1952-1953 may have marked the nadir in my scientific career." Nonetheless, he produced some interesting and publishable results and was promoted to assistant professor in 1950 and associate professor with tenure in 1953. He had not yet found the sweet spot for his research career.



Yohimbene



Typical steroid skelton.

During 1950-1953, Eliel experienced several intellectual stimuli that would meld together in his mind and pivotally shape his scientific career.

• In 1950 Eliel heard an "electrifying lecture" at Notre Dame by Derek Barton on conformational analysis. Barton was at Harvard as a visiting lecturer from England during the academic year 1949-1950, sitting in for R. B. Woodward, who was on sabbatical leave.

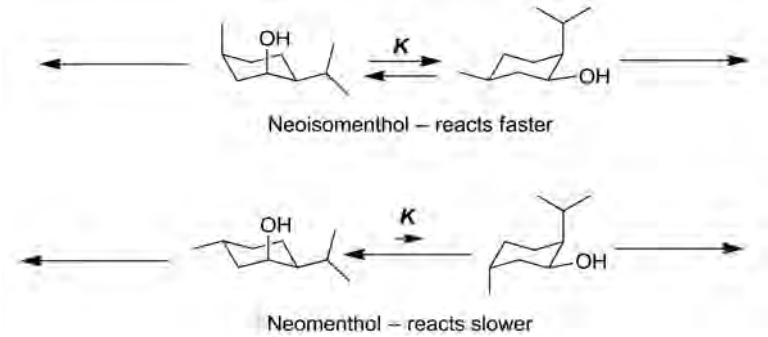
• In the spring of 1950 Barton published his breakthrough Nobel Prize paper "The Conformation of the Steroid Nucleus," in the journal *Experientia*.

• In the 1949-1950 academic year, Albert Burgstahler, who performed undergraduate research with Eliel at Notre Dame and later became a faculty member at Kansas, was a first-year graduate student at Harvard. As recounted by Eliel, "In a series of letters inspired by Barton's lectures, Burgstahler logically interpreted all [his undergraduate research reactions] in conformational terms."

• In the spring of 1950, Vladimir Prelog from Zürich was a Reilly Lecturer at Notre Dame. He and Eliel "developed a close personal relationship" during that time and surely discussed stereochemistry, the topic on which Prelog would receive the Nobel Prize in Chemistry in 1975.

• In the summer of 1952, Eliel's summer sabbatical at Ohio State University provided intense interactions with Melvin S. Newman, Herbert C. Brown, and visiting lecturers David Curtin, Jack Roberts, and others. They were among the leading physical organic chemists of the time, and Curtin had just published what became known as the Curtin-Hammett principle (see below).

Today, it is hard to imagine that for half the 20th century, many chemists thought about molecules and drew them as if they were all planar—that is, two dimensional—especially in terms of reaction mechanisms and stereochemical consequences of reactions. It was only in the early 1950s that chemists began to understand that the three-dimensional character of molecules would affect their physical and chemical properties. Barton's 1950 breakthrough paper focused on the three-dimensional character of steroids. However, except for substituents appended to the steroidal backbone (for example, R in the graphic), most steroids are conformationally fixed—that is, the ring system exists in a single, fixed conformation.

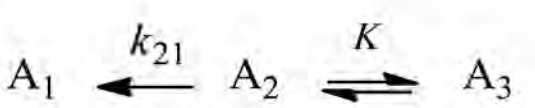


Scheme 2. Neoisomenthol, which exists in two conformations of relatively equal composition, reacts much faster than neomenthol which exists primarily in the conformation in which the two alkyl groups are equitorial and the hydroxy group is axial.

From the confluence of these stimuli, Eliel's work on conformational analysis and stereochemistry would burst into bloom in 1953-1957. As seminal as Barton's Nobel Prize-winning paper was, and it was, it failed to consider conformationally mobile compounds—that is, compounds that exist in multiple conformations, each conformation having unique physical and chemical properties.

Eliel was at the right place at the right time. What he explained was the effect of conformation on physical properties and chemical reactivity in conformationally *mobile* compounds—of which there are far more than conformationally fixed compounds. His 1953 paper, published in *Experientia*, was a Gedankenexperiment, a thought experiment. He was able to explain why neomenthol is esterified more slowly than neoisomenthol using published though then indecipherable reaction rate data (see Scheme 2). Uncertain about the value of his analysis, Eliel shared his ideas with Herb Brown during Eliel's summer sabbatical at Ohio State. Brown encouraged him to publish his first paper in what would be a 50-year research program in stereochemistry and conformational analysis.

Scheme 3 represents the general equation for a molecule that exists in two conformations, A_2 and A_3, each of which reacts to give a different product. Eliel taught that the more reactive conformation is not necessarily its most stable form, a concept directly related to the Curtin-Hammett principle. Today, these concepts are well recognized in chemistry and in biochemistry. By a kinetic method of conformational analysis, Eliel

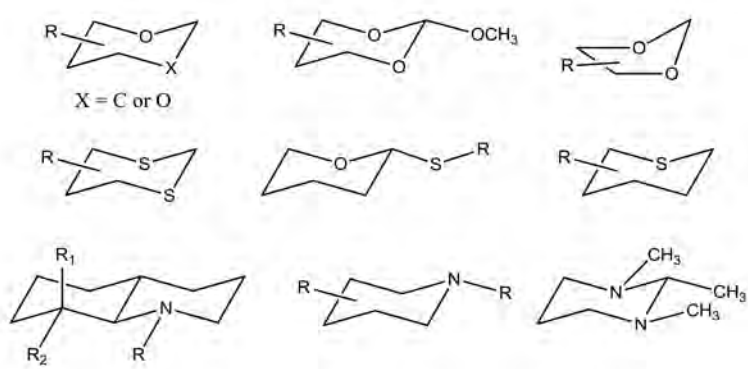


Scheme 3. The simplest kinetic system for a compound which exists in multiple, distinction conformatins, A_2 and A_3, each of which reacts to give unique products, A_1 and A_4, respectively.

determined the overall reaction rate constant for Scheme 3 and estimated the reaction rate constants for the two conformations using model compounds, thereby allowing him to calculate the equilibrium distribution, *K*, for Scheme 3 systems. This method was independently and simultaneously developed by Saul Winstein and N. J. Holness at UCLA. To further illustrate the closely knit nature of chemistry at the time, Holness had been a Ph.D. student of Barton's and brought with him, from England, Barton's early interests in conformational analysis.

Eliel soon devised two methods superior to the kinetic method of conformational analysis. One of these, an equilibrium method of conformational analysis, relied on the equilibration of diastereomers. The second, and ultimately the most powerful, of the three was a nuclear magnetic resonance method, which relied on Eliel's utilization of the fact that any property of an equilibrating system was equal to the mole fraction-weighted sum of that property of the individual conformations. This generalization was then used in a variety of fashions—for example, by determining equilibrium distributions, then called "A-values," using nuclear magnetic resonance (NMR) chemical-shift data.

Following the development of these methods of conformational analysis, the next most reasonable step would be to assess the conformational preferences of a wide variety of molecules. And he and his group did just that. Extensive tables of A-values, typically for cyclohexane derivatives, were determined by Eliel and other research groups around the world using Eliel's methodologies. Eliel then turned his attention to saturated heterocyclic systems—five- and six-membered ring systems in which one or more of the ring atoms are heteroatoms—for example, oxygen, nitrogen, and sulfur. Some of the systems examined by Eliel are illustrated in Scheme 4. These studies provided fundamental knowledge of the synthesis, structure, and conformational preferences of many simple heterocyclic systems, systems found in many pharmacologically active drugs and other valuable materials.

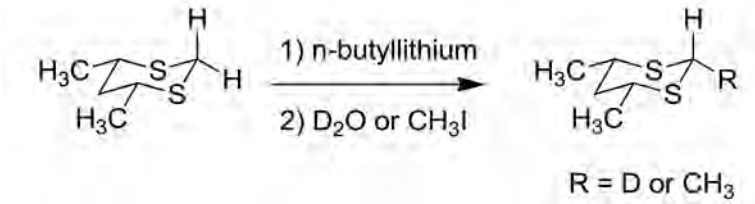


Scheme 4. Examples of heterocyclic systems whose conformational preferences were determined by Eliel and his research group.

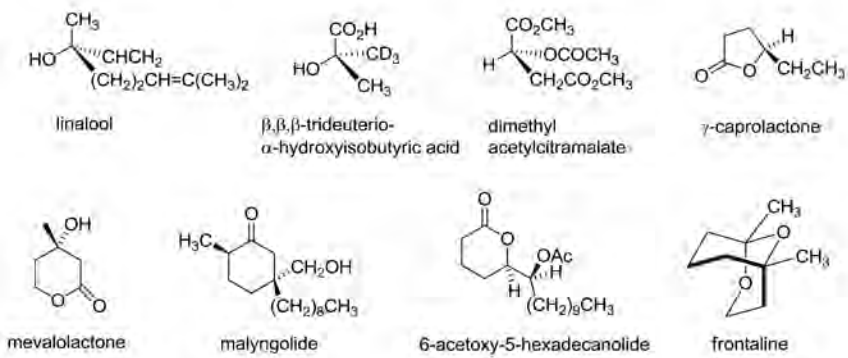
Within just 15 years (1955-1970) organic chemists went from thinking about molecules in two dimensions to understanding their three-dimensional structures and using this insight for structure determination and organic synthesis. It was a paradigm shift in perspective and vision. Combined with advances in equipment that allowed separation and purification of compounds from complex mixtures and then spectroscopic methods for structure elucidation, this understanding of stereochemistry and conformational analysis propelled organic chemistry into a new generation of execution and accomplishment.

As in most experimental studies, unanticipated results always appear that suggest new avenues for research and improved understanding. This, too, accompanied Eliel's research. His work shed light on the size of lone pairs of electrons on oxygen, nitrogen and sulfur; on conformational preferences related to the anomeric effect, of importance in carbohydrate chemistry; on the consequences of bond length and bond angle modifications in heterocyclic compounds compared with their carbocyclic parents; and on his postulate of a novel dipole repulsion effect of two parallel lobes of unshared electrons, a phenomenon he termed "the rabbit ear effect," which was subsequently and more appropriately understood to be and named the "generalized anomeric effect," causing him some degree of amusement tinged with a greater degree of embarrassment.

One unanticipated yet remarkable result—an instance of serendipity—was the observation by Armando Hartmann in 1970 that butyllithium-mediated reactions of conformationally locked 1,3-dithianes led to stereoselective equatorial protonation or



Scheme 5. Stereoselective alkylations leading to enantioselective syntheses.

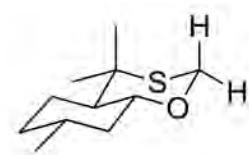


Scheme 6. A series of natural products synthesized by the Eliel group using enantioselective methodologies.

methylation (Scheme 5). In fact, Hartmann proposed this experiment to Eliel, who was not enthusiastic. As Eliel recounted,

> *I have a principle that, in order to encourage originality among my co-workers (and also to keep up their morale!), if they make a suggestion that is neither clearly wrong nor obviously very expensive in terms of time or materials, I allow them to follow up that suggestion.*

In this instance, Hartmann's observations ultimately led Eliel—clearly not a synthetic organic chemist—to harness the stereoselectivity observed in Scheme 5 for the enantioselective syntheses of a number of simple natural products (Scheme 6) using an oxathiane derived from pulegone. These syntheses, accomplished with very high enantiomeric excess, were performed in the mid-1980s and



Oxathiane from pulegone.

hence placed Eliel among the early leaders in the field. Of course, the *catalytic* enantioselective reactions of Barry Sharpless and Ryōji Noyori (recipients of the 2001 Nobel Prize) and others in the same time period had advantages over Eliel's method, which involved a chiral auxiliary reagent, even an inexpensive one, in stoichiometric equivalent amounts.

It is here that we see the evolution of Eliel's research program: first, he studied the relationship between conformations and reactivity; second, he examined a wide range of carbocyclic and heterocyclic compounds and identified their conformational preferences; and last, he combined all this knowledge to perform enantioselective syntheses. In the course of his multi-decade research program, he stretched his interests beyond the areas of stereochemistry, and he has pointed to these in his scientific autobiography, *From Cologne to Chapel Hill*, published in 1990 by the American Chemical Society.

I end this section with Eliel's philosophy of being a scientist.

> *When I was on sabbatical in Zürich in 1967-1968, I learned the German word 'Dünnbrettbohrer.' 'Dünn' means 'thin,' 'Brett' means 'board,' and 'Bohrer' means 'one who drills holes.' Hence, 'Dünnbrettbohrer' means an individual who picks easy problems and solves them successfully and then tries for, and sometimes gets, credit. A great scientist is not of that ilk. On the other hand, you need to be aware of your own limitations. You need to be at the limit of your ability to solve the problem, but not pick a board so thick that you have no chance of getting through it! That is an interesting balance, to challenge yourself to the maximum. But what is maximum is a very personal decision.*

Teaching: Chemistry and the Chemical Profession

From his father's influence, it is not surprising that Eliel's commitment to education was his mantra and the whole world was his gridiron. On a one-on-one basis, Eliel said,

> *I have written about 300 research papers, of which only about 20 will survive for some length of time, which is not a bad ratio. Since these 20 were important and have been summarized in reviews, it is really the reviews and books and not those 20 papers that will survive. On the other hand, I trained about 100 graduate students and postdocs, and about 70 of them are still in the profession, so I probably did more for people than for publication.*

Eliel's commitment went way beyond his own students. His archives contain many letters from colleagues around the world seeking his help or his input. Some of the requests were simple, yet extraordinary given his status. He answered requests from many to help with Spanish-to-English and German-to-English translations. When I had critical text in German that needed exact translation, I often went to Ernest. I have found documents in his archives from Latin American chemists asking him to "correct the grammar and spelling…
I did my best to write the paper, but here in Argentina, I did not know any English native chemist to do the proofreading…" There were many letters of thanks, such as "your concern and thoughtfulness touched me. It is not often that I hear a positive endorsement of the work…Your comments have given me the encouragement to pursue the effort."

Eliel at the Notre Dame Post Office, possibly carrying part of the *Stereochemistry of Carbon Compounds*, ca. 1960.

Eliel also extended his personal concern for the well-being of his fellow man to the well-being of chemists in developing countries. He was fully engaged for many years in developing educational programs for chemists in Latin America and elsewhere to study in the United States and to collaborate with American scientists.

All these activities notwithstanding, many senior chemists have concluded that Eliel's books are his greatest contribution to chemistry and chemical education. Over 40,000 copies of S*tereochemistry of Carbon Compounds* (1962) were sold, establishing this book as one of the most important advanced organic chemistry texts of the 20th century. As Eliel recounted, "I hardly fail to meet chemists of the generation who learned their discipline in the '60s and early '70s [and later!] who do not tell me that they learned stereochemistry out of my book." When paired with his book *Conformational Analysis* (1965; written with Norman Allinger, Stephen Angyal, and George Morrison) and the yearly series *Topics in Stereochemistry,* which Eliel edited for two decades, chemists at all levels—from advanced undergraduates to Nobelists—could lean on him for their basic education and state-of- the-art knowledge of stereochemistry. He covered both ends of the educational spectrum in another way: His *Elements of Stereochemistry* (1969, with Fred Basolo) and Basic Organic Stereochemistry (2001, with Samuel H. Wilen and Michael P. Doyle)

provided simplified texts to the broadest audiences. His 1267-page *Stereochemistry of Organic Compounds* (1994; with Wilen and Lewis N. Mander) is almost encyclopedic, likely the last text in this field, and is a treasure trove of hard- earned information, knowledge, and wisdom written by the master of the field. Eliel was so recognized as the master of stereochemistry that the definition of various stereochemical terms adopted by IUPAC generally deferred to those from him, for example, Eliel is credited for influencing the definitions of degenerate rearrangement, stereoselectivity, and stereospecificity.

From 1944 to 1996, Eliel published 10 articles in the *Journal of Chemical Education*, including his very first publication. Seven of these papers deal with some aspect of stereochemistry and conformational analysis. It is interesting to contemplate quotations from the first and last of these 10 papers. The first, issued from the University of Havana by this young Germany-to-Cuba immigrant, begins, "The increasing importance of chromatographic adsorption recommends its presentation to the undergraduate, for which purpose this résumé was prepared." The tenth paper, by this now-seasoned scholar, includes the following statement in its introductory paragraph: "a piece of research is never complete until it has been published in the open literature."

Eliel believed strongly in the value of clear communication. He wrote,

> *Only aficionados read one's original papers but reviews have a much broader audience and thus contribute to one's reputation and professional standing. And reputation and professional standing are what really count in the academic profession. Since it is important that many people read your papers, it is also important that they be written clearly and understandably.*

He also felt strongly that oral presentations, lecture tours, and attendance at meetings were critical to professional advancement and commitment to one's profession. Of course, his love of travel was likely inspired by his experiences as a youth. Eliel held visiting lectureships in Germany, Japan, Canada, Spain, India, and Peru as well as in the United States. To connect well with his audiences, he often lectured in their language: Spanish and German (fluently) and in French (less fluently) on many international lecture tours, in over 25 countries on five continents. I remember his weary joy after a lecture tour in China in the late 1980s or early 1990s. He had, as I recall, paid for his own travel expenses, and yet his Chinese guests had him giving one or even two lectures a day, almost every day, for three weeks —with travel almost every day, as these lectures

were at universities all around the country. Eliel also participated in lecture series, summer conference workshops, and conferences supported by both NSF and the ACS. He was an ACS tour speaker and, of course, attended almost every Gordon Conference on Stereochemistry. I met him and Eva, his wife (more on Eva below), for a meal at nearly every ACS National Meeting for years. I believe his last lecture was at an ACS National Meeting symposium in 2005 honoring important authors and textbooks in organic chemistry, where he talked about his stereochemistry textbooks. Little did we realize that this vigorous man, whose walking had become a bit like shuffling, would decline rapidly and be gone in three years.

Eliel presenting what is likely his last lecture, "Textbooks of Stereochemistry – An Author's Perspective," Monday, August 25, 2005, at the 230th ACS National Meeting, Washington, D.C. Photograph courtesy Jeffrey I. Seeman.

In the mid-to-late 1980s Eliel's focus began to shift from a blend of research and professional activities to mostly the latter. The topics of his lectures shifted as well. Fortunately for historians, he wrote out many of his lectures, and these are retained in his archives, held at the Chemical Heritage Foundation in Philadelphia. The following partial listing provides an understanding of his interests and of what he considered important to communicate to others:

The American Chemical Society and Chemistry Teaching in High School and College in the USA

Challenges to U.S. Research Universities at the End of the Twentieth Century

Chemistry—the Next 25 Years

Contribuciones de la Sociedad Química Americana a la Educatión Química en la America Latina

Current Challenges to Chemistry Departments in US Universities

Education in Chemistry—Problems and Prognosis

The Information Explosion—What Can Be Done About It?

Joys and Woes of an Academic Career

Quel future pour la chimie?

Scientific Manpower

What is the U.S.-Mexico Foundation for Science and What Does It Do?

Whither Chemistry?

Service to Chemists, Chemistry, and the Chemical Community

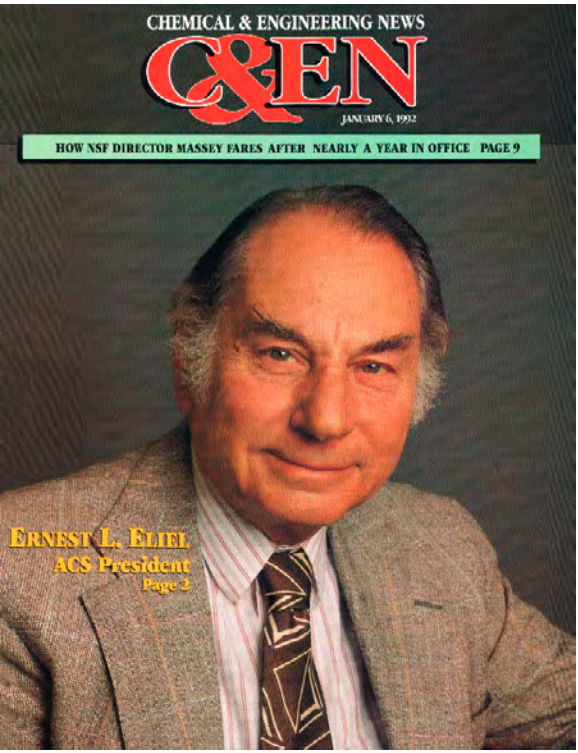
Eliel could have boasted—and yet, he never boasted—of over 50 years of active service in the ACS. His volunteer work in ACS national offices began in the late 1950s. He served as alternate councilor of the St. Joseph Valley Section, headquarters in South Bend, Indiana (Notre Dame!), from 1957 to 1959 and as chair of that section in 1960. He was ACS councilor from 1966 to 1973 and from 1973 to at least 1989. In 1967 he began his nearly 30 years on ACS's committees on publications. To exemplify his service to ACS, consider that in 1972, Eliel was chair-elect of the Division of Organic Chemistry and a member of the Committee on Nominations and Elections, the Council Policy Committee, the Canvassing Committee for the Arthur C. Cope Award, the ad hoc Committee To Study Revenues from Members, the Advisory Board of the Petroleum Research Fund, and Chair of the Council Committee on Publications.

He was elected to the ACS Board of Directors from 1985-1993, serving as chair for the three-year maximum term 1987-1989. He ran unsuccessfully for ACS president-elect in 1986, losing to Gordon L. Nelson, but Eliel—indefatigable, described often as a bulldog—defeated Eli M. Pearce for that position in 1990. (Pierce also ran again and served as ACS president in 2002.)

Presidents of organizations and chairs of boards of directors come and go, and typically one cannot identify anything of substance connected with their particular reign. But not so with Eliel. He was a person to take a governance position seriously, by formulating and leading with that responsibility and, even more, with that opportunity. He also had a great advantage, having had so many years of experience participating in many different ACS local and national committees. But he recognized the challenges when he wrote,

> *What are the impediments an ACS president faces (other than his or her own limitations)? I can see two major ones: First, many of the problems we face as chemists are closely intertwined with broader problems facing our country as a whole. And second, chemical scientists—who constitute ACS—are a conservative group reluctant to make changes.*

As chair of the board, Eliel spearheaded the "Campaign for Chemistry" which raised more than $26 million (though the goal was in the $30-50 million range). Those monies provided for major, forward-thinking projects: a new building and equipment for the



Cover of the January 6, 1992 issue of *Chemical & Engineering News*, marking the beginning of Eliel's year as President of the American Chemical Society. Photograph Courtesy C&EN and the American Chemical Society.

Chemical Abstracts Service, which serves as the center of information and knowledge in chemistry as well as a major source of continuing income for ACS; an endowment for Project SEED, the Chemistry Olympiad, the expansion of ACS's high school chemistry text, "Chemistry in the Community," and adapting the text for use by college non-majors; an endowment for the Arnold and Mabel Beckman Center for the History of Chemistry, which has led to the now $150 million endowed Chemical Heritage Foundation, chemistry and chemical engineering's library, archives, and center for scholars; and to establish a chemistry/science exhibit in the Smithsonian Institution's National Museum of American History. All of these objectives were met. In addition, through essays published in *Chemical & Engineering News*, Eliel spoke to ACS's members, explaining "why ACS cannot raise the money necessary for all these activities through its regular budget…[which] ACS operates for the benefit of the science and profession of chemistry."

As ACS president, Eliel focused on strengthening the international relations of the society and improving the lot of chemists in developing countries in the Americas and Eastern Europe (see below). He was deeply concerned about decreasing federal support for basic research. Eliel felt it was critical to communicate to Congress and others that make budgetary decisions that commercial applications often relied on serendipitous discoveries that occur only during basic research. To that end, he co-authored a booklet on "Serendipity in Chemistry." He was interested in enhancing chemical education in K-12 and for introducing a biochemistry-oriented ACS-approved curriculum. He favored programs that provided outreach to members: the newsletter "ACSESS" was sent

to every ACS member, partly due to his influence. He supported National Chemistry Week activities and enhanced local section activities. He was committed to improving ACS's relationships with industrial chemists—many of ACS's leadership were academics, focused on their own peer group—and enhancing services to them. He advocated for improved services for unemployed chemists.

I know that Ernest was active in the National Academy of Sciences, as he and Eva often spent a day and night with me in Richmond on their way to or from that Academy's annual meeting in Washington, D.C. We enjoyed the Virginia Museum of Fine Arts together several times and a number of Virginia plantations. Relevant to this memoir, I found evidence in Ernest's archives that in 2004 he was coordinator of memoirs for deceased members of the chemistry section of the Academy.

As a tribute to his devotion to the scientific community as a whole and in recognition of his governance strengths, Eliel was appointed and served for seven years on the Council of Scientific Society Presidents (CCSP). He was CCSP's secretary in 1993 and its president (or chair) in 1996. At the time, and indeed continuing today, CCSP's goals included influencing "science and education issues of national or international scope… public understanding and appreciation of science…and improving communication among the various scientific disciplines…"

International Relations

Eliel had been a refugee, not by choice. He was also the recipient of kindnesses and chemical education in four countries not of his birth. He also saw the importance of connectivity and the global reach of science, having grown up in Germany, which had the heritage of being the predominant power in chemistry. For these reasons, combined with his generous spirit to those of lesser means and the role model of his activist mother, he was a leader and a worker, helping others, especially chemists around the world. He was committed to service.

Eliel began his international science activities early: he helped establish graduate chemistry programs in Peru under a Notre Dame project funded by the Ford Foundation in the early 1970s. As ACS president and a member of its board of directors in the 1980s and 1990s, he promoted the broadening of international connections in chemistry. He was committed to improving—and forming new—relationships between ACS and other scientific and engineering societies, especially with chemical societies abroad. He was largely responsible for various programs that brought chemical scientists from Latin American and Central Europe to U.S. laboratories for short sabbaticals with the goal of

forming long-term collaborations. Less frequently, the exchanges went from the United States to those countries. Several of these programs were co-funded by the NSF. He was a founding member of the U.S.-Mexico Foundation for Science and also served as the president of its board in 1995-1996. This organization's main objective was to support joint research projects between Mexican and American chemists. Eliel was one of the co-organizers of three U.S.-Taiwan symposia, two in Taiwan and one in San Diego entitled "Innovations in Undergraduate Education in Chemistry" in April 1994. He initiated "Global Instrument Partners" in the early 2000s to help Latin American chemists gain access to advanced analytical instrumentation.

From left to right Vladimir Prelog, Eliel and Jeffrey I. Seeman at the Bürgenstock Conference, Switzerland in 1989.

In his 1992 lecture to chemists who had recently immigrated to the United States entitled "A Western European Experience from Years Past" Eliel spoke of the

enormous friendliness and helpfulness of almost everyone I met...one does not complain about trivia...don't spend too much time emulating the exact pronunciation of your hosts, especially since that varies quite a bit in different part of the country...the honesty of the people... business was often done with a handshake rather than with a contract...be careful not to overdress...our humor tends to be uncomplicated...most American are generous with time and money, but it is well not to take this for granted... Americans spend [a lot] on volunteer activities on behalf of a variety of causes ranging from charitable to political...unless you are a determined agnostic, you may wish to affiliate with a church or synagogue of your choosing; friendships and useful contacts may result...it is customary to call each other by first name here after having seen each other only once or twice...work hard, be flexible and enterprising, be inventive, and above all, get along...I have lived in this country since 1946; it has provided great opportunities for me, I love it deeply. I hope those of you have come to our shores recently will have the same good experience.

Eliel, The Man

I believe that Eliel was proud to have been characterized as a bulldog, as he did not hide that characterization at all. He was efficient and effectual but not dramatic. He was hard working, focused, conservative, and realistic. He had a sense of moving projects forward with a responsibility to both the present and the future. He was self-confident, unafraid of conflict yet he did not search for it; he was not an intellectual swordsman, as one interviewer described him several years ago. After his three years as chair of the Chemistry Department at Notre Dame, Eliel was described by a colleague as "a despot—but a benevolent despot." He had strong, deep convictions and acted decisively, persistently, and with persuasiveness to achieve his goals. He was introspective, and his self-characterizations were right on the mark. He wrote, when campaigning for the ACS Board of Directors, "If elected to the board, I promise to argue as persuasively as I can (and to cast my vote) for those things that I consider best for ACS and its members—and I mean all its members. But I also promise that when I am outvoted, as inevitably will happen, I shall go on to the next item of business without annoyance or bitterness."

I asked his two daughters to provide adjectives that best characterized their father. Carol Eliel responded, "Brilliant, indefatigable, generous, curious, adventuresome, true intellectual, a gourmet and a gourmand, steady, hard-working." Ruth Eliel independently listed "brilliant, kind, intense, absent-minded, moral, loving."

He typically hid his emotional side. I share two examples where his emotions and sentimentality revealed themselves. In March 1987 I attended a joint 65th birthday celebration at the University of North Carolina, Chapel Hill, for him and his UNC colleague Bob Parr. The after-dinner speaker, a distinguished physical chemist colleague of Parr's, kept referring to Eliel as "Ernie" instead of "Ernest." As the evening ended, I sought Eliel to shake his hand, wish him happy birthday, and obtain his autograph in my program booklet. When I inquired how he felt about being called "Ernie," he shuddered and grimaced, forming a sour expression just as a child does when swallowing a very bitter-tasting medicine. Yet the warmth of the man perhaps can best be understood by Eliel's seeking out each of his friends, one by one, and thanking them for their presence and asking that they autograph his banquet program.

For many years I would visit the Eliels late in the basketball season. Ernest had season tickets to UNC basketball games, purchased for his nephew, a physician who lived in the area. However, he kept two tickets for the two of us, much to the regret of his nephew: usually for the Duke-UNC game, the season's premier event. I can recall on several

occasions, UNC, after being down by an ungodly number of points, made a spectacular rally to draw ahead of Duke. On all of those occasions, the usually sedate Eliel was transformed, like the Incredible Hulk, from a normal mortal to a screaming fanatic: up from his seat, arms waving, and cheering his team's success! I can feel it still.

Eliel also had a fine sense of humor. I laugh as I recall his dry but incisive manner. In a letter to Helen Free, then ACS president, praising Eliel's autobiography, I had referred to his "interment" as described in his autobiography, From Cologne to Chapel Hill. Eliel immediately responded, "I hope I did not suffer 'interment' in Scotland and Canada – if I did, I successfully dug myself out twice!" Yes, "internment" was the word.

Awards

Eliel received many awards, including the Manufacturing Chemists' Association College Chemistry Teachers' Award (1965); Guggenheim Fellowships (1975-1976, 1983-1984); the Amoco Teaching Award at UNC (1975); the Laurent Lavoisier Medal of the Chemical Society of France (1968); the Harry and Carol Mosher Award, Santa Clara Section, ACS (1982); the Distinguished Chemist Award, North Carolina Institutes of Chemists (1985); membership in the National Academy of Sciences (1972); the North Carolina Award in Science (1990); Corresponding Membership of the Academia de Investigación Científica (subsequently becoming the Academia Mexicana de Ciencias) (1991); UNC's Thomas Jefferson Award as most distinguished faculty, the highest faculty recognition at UNC (1992); the George C. Pimentel Award in Chemical Education of the ACS (1995); the Priestley Medal of the ACS (1996); and the National Academy of Sciences Award for Chemistry in Service to Society (1997). He was also named one of Chemical & Engineering News's Top 75 Contributors to the Chemical Enterprise.

Family

Eliel married Eva Schwarz in December 1949. Eva also came from Germany but had lived in the United States for 12 years by the time of their marriage. She was an incisive, energetic woman who gave a great deal of time to community activities. For example, Eva was co-editor of *The Distaff* (which she named), the newsletter of the Ladies of Notre Dame. In the fall of 1966 she penned the motto for *The Distaff*, "Published more or less monthly by the Ladies of Notre Dame." From 1967 till 1995 she ran a classical music program for WUNC, the public radio station in Chapel Hill. Eva passed in Chapel Hill on March 23, 2013, at the age of 89. It was only a few years prior that she ceased playing tennis! In fact, Ernest—not particularly noted for his athletic abilities—was swimming 10 laps a day just a few years prior to his passing.

At their engagement, Fire Island, Summer 1949.

Eliel with his two daughters Ruth (left) and Carol on the *S. S. Constitution* on their way to Zürich for Eliel's sabbatical, summer 1967.

Ernest and Eva after lunch with the author at a National Meeting of the American Chemical Society, ca. 2000. Photograph courtesy Jeffrey I. Seeman.

Eva and Ernest were well suited for each other. Eva was petite in size but massive in learned opinion, ideas, and positions. Ernest had to be more on his toes around her than he had to be in any of his professional positions. Not dissimilar to many of his academic colleagues, Ernest said of his wife, "A good bit of my subsequent success as a scientist, I am sure, is due to her unfailing support and to her willingness to take care of our household, and, later, of our two children while I spent my time in the laboratory or at the writing desk."

The Eliels had two daughters. Ruth Louise was born in 1953 and is married to Bill Cooney; she is a professional in the field of performing arts management, having been associated with the Lewitzky Dance Company, the Los Angeles Chamber Orchestra, and the Colburn Foundation. Carol Susan, who was born in 1955 and is married to F. Thomas Muller, Jr., is Curator of Modern Art at the Los Angeles County Museum of Art and also served (2011 – 2013) as president of the Association of Art Museum Curators and continues as a lifetime trustee emerita.

Memories, By Friends

Although it has been a long time since those World War II years when I worked with Ernest Eliel, I remember him well. I recall that Ernest was serious but also had a dry sense of humor. He indulged in some mischief by signing his Christmas cards to me as 'Your faithful dishwasher.' At the time, he was already president of the American Chemical Society. It was a pleasure to educate him in the true Ružička tradition. I remember Ernest as having respect for hard work and discipline.

—George Rosenkranz, supervisor in a pharmaceutical laboratory, Havana, early 1940s.

Ernest and I were graduate students working on related projects with Harold Snyder at the University of Illinois immediately after the war. Ernest encountered lingering remnants of prewar anti-Semitic attitudes, even on campus, but responded, not with rancor, but with patience, sly humor, a deep determination to excel in scholarship and research and with the formation of a few firm friendships. Ernest frequently employed thermodynamic concepts to current events.

—James H. Brewster, Purdue University

Eliel with Kurt Mislow at the Ciba Foundation's worskhop on nomenclature, London, 1968.

It was easy to underestimate Ernest Eliel. His physical appearance was unprepossessing. He was a quiet, gentle person who seldom raised his voice. I never heard him shout. Nevertheless, his vision, determination, and capabilities made him quite effective. I think back to when he was appointed mid-1964 to chair the chemistry department at Notre Dame. Ernest insisted to the Dean that he be 'Head of Department,' not Chairman. Ernest had things he wanted to get done, and he wanted the authority to do them. He was most successful in starting a graduate program in biochemistry and enhancing inorganic chemistry in the department. However, his push to build a new chemistry building was not forthcoming until 1981, nine years after his departure to UNC. Ernest was relentless in his campaign to replace our 1917 building, but in doing so, he wore out his welcome. In 1972, he moved to a university that he was convinced was more progressive than Notre Dame. I still marvel that most of the current strengths of today's department can be traced back to Ernest's years as 'Head.'

—Jeremiah P. Freeman, colleague at Notre Dame

For most of our professional lives, Ernest and I had a common interest in stereochemistry. While his development of kinetic and equilibrium methods in the study of conformationally mobile molecules constituted a significant advance in conformational analysis, his textbooks on the stereochemistry of organic compounds were by far his most important scientific contribution. For novices, these widely admired volumes provided an excellent introduction to the field; his all but encyclopedic treatment of the subject was a tribute to the unflagging energy that Ernest brought to his work.

—Kurt Mislow, Princeton University

I never heard Ernest argue something that seemed for him alone—it was for the department good."

—Royce Murray, University of North Carolina.

As a mentor and graduate student thesis advisor, Ernest provided me with the starting ideas, but then gave me freedom to work out the projects according to my own understanding and intuition. Indeed, he acknowledged that part of my thesis work was carried out in a rather independent way by me (at that particular time Ernest had spent a sabbatical year in Princeton and at the ETH in Switzerland). Thus, Ernest decided that my name should appear first in the publication. (In the 1970s and 1980s, it was customary that the name of the research director would appear first on all publications.) Ernest also covered the expenses so that I could present the results at the National Meeting of the American Chemical Society that took place in San Francisco in August of 1976. This was a very important event in my life—my first participation as speaker in a major scientific conference! Of course, Ernest was in the lecture hall, just in case there was a question that I could not answer (and to give me support).

—Eusebio Juaristi, former graduate student of Eliel's, Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional

Ernest Eliel served as ACS President-Elect during my term in 1991 as American Chemical Society President, having previously been Chairman of the ACS Board. His history as an émigré from Germany via Canada and Cuba provided not only linguistic capabilities but an intense interest in promoting international collaboration in the basic sciences and especially in science education. As ACS President, he spearheaded many Society initiatives to support fellowships in the U.S. for Latin American and other foreign investigators. Especially noteworthy was his leadership in creating and chairing the U.S./Mexico Foundation for Science in the mid-1990's to further scientific interaction between our neighboring countries at both governmental and educational levels. Ernest was a tireless, inspirational and effective leader to whom chemistry and the American Chemical Society are deeply grateful.

—S. Allen Heininger, ACS President, 1991

I've been following in the ACS footsteps—quite literally—of Ernest Eliel for most of my professional life! It began when Ernest and I (fresh out of college) became fellow members of the St. Joseph Valley Section of the ACS—he as Professor of Chemistry at the prestigious University of Notre Dame and I as a lowly control chemist at Miles Laboratories. It continued with my election as the section Councilor after his election to the ACS Board of Directors, and it culminated in 1992 with my election as President-elect during Ernest's term as ACS President. As to his unique quality, I would say that he could be described as 'a bulldog'—but a 'gentle bulldog.' Ernest was like a bulldog because once he made up his mind, he hung on and on to his position—BUT he was always polite and always a 'gentle man.'

—Helen Free, ACS President, 1993

Ernest Eliel was one of the few scientists in modern history who defined stereochemistry of organic compounds. In preparing their recommendations on stereochemical terms from multiple sources, IUPAC Commissions generally accepted the definitions that he devised from his exhaustive understanding of the literature and his own instinctive insights.

When he was a candidate for President-Elect, I wrote the following to 450 faculty at 250 undergraduate institutions: 'Ernest understands the special role that colleges and universities such as ours have in the education of students, and he understands our unique problems. He has been a guiding force for new curricular designs that will allow undergraduate students to view chemistry as the basic core for their professional development. At the same time, he is an active proponent of research with undergraduate students, and he recognizes the critical role of this experience in attracting students into chemistry.'

—Mike Doyle, University of Maryland and co-author with Eliel of one of his textbooks

Final Words

Eliel was one of the rare scientists of the past century who made significant and lasting contributions to all of the areas relevant to science: research, teaching and authoring of textbooks, service to professional societies, national science policy, and international rela-

tions among universities, foundations, and scientists. This assemblage of involvements and engagements began in his earliest days as a professional and continued as long as he could walk and talk. "What does it take to be a successful chemical scientist?" he was once asked. He responded, "Commitment and dedication, a real interest in science and enthusiasm …intellectual [capability], hard work and persistence, scrupulous honesty… originality, inventiveness or imagination…"

Eliel with Jeffrey I. Seeman at a dovecote at a plantation along the James River, Virginia, ca. 1995.

He also said:

•An academic career can be very enjoyable. I have thoroughly enjoyed mine; I have always looked forward to the next day's work.

•I have almost always felt right at home everywhere, as a member of the international; confraternity of chemists!

•Finally—as in many but not all endeavors—if one does a good job, one earns the respect of one's colleagues.

For me, Eliel was a model of the best a professional can be, a professional's professional. He was a role model in many ways. His last several years were marred by a slow debilitating disease that was never fully diagnosed. The best the doctors could say was "atypical Parkinson's." I visited him often those last years. We would talk seriously, we would laugh, we would disagree with Eva on this or that subject, usually under our breaths with much levity. I remember one summer afternoon, sitting outside in the sunshine. It was a sweet occasion. Several months later, it was to be the last time. There was no light in his eyes. Just tiredness. As I was taking my leave, ever so uncomfortably, he reached out and said, with peace and acceptance, "It is a parting." He provided that one more model for me, of a respectful separation.

Ernest Ludwig Eliel earned the respect and friendship of many, likely of all whose path he touched. We miss Ernest Eliel—I miss my friend. But the memories of all of us—and our bookshelves—remain full of this special human being.

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