R. Stephen Berry

1931–2020

BIOGRAPHICAL *Memoirs*

A Biographical Memoir by
Stuart A. Rice
and Joshua Jortner

NATIONAL ACADEMY OF SCIENCES

RICHARD STEPHEN **BERRY**

April 9, 1931–July 26, 2020

Elected to the NAS, 1980

By Stuart A. Rice and Joshua Jortner

We have prepared this memoir to bear witness to the life of R. Stephen (Steve) Berry, with emphasis on the view that a memorial is about reminding ourselves and others of more than his many and varied contributions to science; it is also to remind us of his personal warmth and freely offered friendship, of his generous support for all of us in a variety of situations, and of his loyalty to his friends and the institutions he served. The record of an individual's accomplishment is commonly taken to define his/her legacy. Using that protocol, creative scientists are fortunate in that their contributions are visible, and those contributions endure, or not, on their own merits. Steve Berry was one of the most broadly ranging and influential scientists in the world. His seminal experimental and theoretical contributions are distinguished by a keen eye for new concepts and innovative and practical analyses. These contributions, which are remarkable in both scope and significance, have helped to shape our scientific perception.

They have had, and continue to have, great influence on the development of chemistry, biophysics materials science, the science and technology related to the use, production, and conservation of energy, the societal applications of science and technology, and national and international science policy. But that record of accomplishments is an incomplete definition of Steve's legacy. Of equal importance were his personal interactions with others, his humanity beyond his professionalism, and how those interactions with others changed their behaviors. Steve Berry had an open and friendly attitude, was supportive of others, and was an exemplar of the best representation of an intellectual. He had a sense of collegiality that led to fruitful collaborations, and he worked effectively with many different colleagues, both theorists and experimenters, in the United States and worldwide. With the touch of a master teacher, he educated many students and postdoctoral research associates, a significant fraction of whom have become major contributors to science.

The Early Years

Steve Berry was born in Denver, Colorado, on April 9, 1931. He grew up in a middle-class family with two working parents supporting his younger sister and himself. His father traded in real estate and real estate loans, and his mother was a kindergarten and elementary school teacher for lower grades in the Denver slums. Steve went to kindergarten in a school near the airport; he recalled that at that early age, he would go on Sundays with his father to watch the airplanes land and take off. He attended Steck Elementary School, Gove Junior High School, and East High School, graduating in 1948. School became interesting for him with some creative writing activities in elementary school, and more interesting with mathematics and science in junior and senior high school. General science and biology were stimulating for him, but high school physics was not. For years, Steve had a chemistry laboratory and a dark room in the basement of his home. Indeed, photography remained a passionate hobby throughout his life.

An important factor in Steve's early life was becoming a finalist, one of forty, in the Westinghouse Science Talent Search and winning a trip to Washington, D.C., in the spring of 1948. As Steve pointed out: "The whole thing came as a complete surprise; I had entered the competition almost as an afterthought, so when the telephone call came to notify me of my success, I was quite astounded. This trip was my first opportunity to meet real scientists." This formative experience considerably expanded Steve's intellectual horizons. He believed that contact with the other Westinghouse finalists influenced his development by illustrating how much one can learn on one's own.

Steve Berry and his mother, Edith Berry, at radio station KLZ, Denver, April 1948, for the announcement of his selection as a finalist in the Westinghouse Science Talent Search.

Education and Research at Harvard

In 1948, towards the end of high school, Steve's interests changed from focusing on a pure technical education to wanting a broader, liberal education. When Steve learned from other Westinghouse winners that one could get the best of both types of higher education at Harvard University, he applied and was accepted. Steve used to say that going to Harvard as an undergraduate, rather than to MIT or Caltech, was probably one of the more important branch points of his life. He received all of his higher education at Harvard: a bachelor of arts in 1952, a master's degree in 1954 and a Ph.D. in 1956. Steve attributed to William G. McMillan and Leonard K. Nash the guidance that, as an undergraduate, aroused his interest in quantum theory and thermodynamics, and he attributed great influence to his evolution as a scientist and his taste in science to his thesis advisor, William Moffit, whom Steve characterized with the description: "Moffit's sparkling flamboyance, Catholic tastes, physical intuition and analytic insights dazzled and stimulated all his few students."

There is a back story relevant to Steve's dissertation research. From his first day in graduate school, Steve displayed an original approach to problems, a nose for what was interesting, and a talent for seeing connections and exploring questions that would later become key areas of inquiry. In a very rare and courageous choice for a new graduate student, he began research with his own independently conceived attempt to determine the lowest triplet-state excitation of benzene by electron impact spectroscopy. Working alone he designed the necessary apparatus, a key component of which was an elaborate glass chamber. This experiment had to be prematurely terminated when the failure of the temperature controller of the glassblower's annealing oven irreparably ruined that chamber. Steve's dissertation research on the π-electronic structure of butadiene was a fallback project. Indeed, in a wave of self-criticism, he considered his Ph.D. thesis as "being more a comparison of theories than a description of the butadiene molecule." During the last stage of completing his thesis, he undertook what he specified as his first "original or seminal" work. He joined Bill Klemperer and one of us (SAR) in studies of the vibrational and electronic spectra of gaseous alkali halide and similar diatomic molecules, undertaking first an experimental study of the ultraviolet spectra of LiCl, LiBr, and LiI, immediately followed by a theoretical study of the interaction of vibrational and electronic motion in the NaI molecule. He developed a seminal interpretation of the origin of the difference between the diffuse banded electronic spectrum of NaI and the continuum electronic spectrum of KI, showing that it arises from breakdown of the non-crossing rule. This interpretation, which resolved a problem that had by then

lingered for more than twenty-five years, has subsequently been influential in deciphering spectra associated with, for example, pre-dissociation.

Early Academic History and Research

Steve's first academic appointment was as a chemistry instructor at Harvard. He held that position for 18 months and then in 1957 moved to the University of Michigan as a chemistry instructor. In 1960, after three years at Michigan, he moved to Yale University as an Assistant Professor of Chemistry. Steve's stay at Yale was short; in 1964 he moved to the University of Chicago as an Associate Professor of Chemistry, where he remained for the rest of his life. He was promoted to Professor of Chemistry in 1967 and then awarded the James Franck Distinguished Service Professorship in 1989.

Steve's interest in the spectroscopy of molecules persisted throughout his career, during which he made important theoretical and experimental contributions to the understanding of fluxional (floppy) molecules, the determination of electron affinities, the spectroscopic signatures of transient species, electron impact spectroscopy, photoelectron spectroscopy, and Penning ionization spectroscopy. During his tenure as an instructor at the University of Michigan, he reported (with G. N. Spokes and Martin Stiles) the first observation of the important reactive intermediate benzyne and the first theoretical description of the properties of nonrigid molecules and their rearrangement via the mechanism now known as the Berry pseudo-rotation. The International Union of Pure and Applied Chemistry defines a pseudo-rotation as a "stereo-isomerization resulting in a structure that appears to have been produced by rotation of the entire initial molecule, the result of which is a structure that is super-posable on the initial one, unless different positions are distinguished by isotopic labelling." The dynamics of the Berry pseudo-rotation in the floppy triagonal bipyramidal PF_5 molecule, interrogated by NMR spectroscopy, was rationalized in terms of nuclear tunneling, with the axial and equatorial ligands undergoing exchange on a time scale much faster than the NMR T_2 relaxation time. This was Steve's first excursion into the world of intramolecular dynamics in large molecules. The several initial examples studied have since been joined by many others, including enzyme-catalyzed reactions such as the hydrolysis of phosphate esters. Subsequent follow-up studies of the pseudo-rotation mechanism, carried out with Michael Kellman and Greg Ezra, dealt with atomic motion in small floppy polyatomic molecules, and the development of the correlation diagrams that connect the rotation-vibration energy levels of idealized limiting models with those of a floppy polyatomic molecule. For example, for a tetratomic molecule they relate the energy levels of the completely nonrigid homonuclear four-atom species to, respectively, those of the nearly rigid regular

tetrahedron and square, the dimer of two identical homonuclear diatomic species, and the ammonia-like inverter. Although by construction the applicability of these correlation diagrams is restricted to the few atom systems explicitly created, the underlying concepts provide useful clues to rearrangement motions in larger clusters of atoms, a subject that Steve also devoted much of his later attention to.

In 1960 Steve moved from the University of Michigan to Yale University. At that time, of the many atomic and molecular properties of interest, whether experimentally or theoretically determined, the electron affinity was the least well known, the typical best precision being only a few percent. The electron affinity of an atom or molecule is a key quantity in understanding its electronic structure because electron correlation plays a relatively larger part in determining the properties of a negative ion than it does in other species. Indeed, electron affinities are frequently of about the same magnitude as the differences between correlation energies in atoms and in the corresponding negative ions. Steve realized that precise spectroscopic measurements of the electron affinities of halogen atoms could be obtained from their photo-detachment thresholds if a sufficient concentration of free halide ions could be created. Working with his student C. W. Riemann and postdoctoral fellow G. N. Spokes, the team generated the needed concentrations of the several halide ions using a shock tube that created temperatures in the range of 3000K in the shock front. The electron affinities of the halide ions were then determined from their photo-detachment thresholds with a precision of about 0.1 percent, far better than any prior measurements. The research conducted by Steve in the period between 1956 and 1964 laid the foundations for his future work on the spectroscopy, energetics, and dynamics of photoelectrons that is revelatory of nuclear and electron energetics and dynamics in molecular systems.

Science, Education, and Public Policy at the University of Chicago

In 1964 Steve moved to the University of Chicago, where his research agenda broadened considerably. Steve joined the Chemistry Department and the Institute for the Study of Metals (now the James Franck Institute). The Institute was a post–World War II organization, connected with but outside the traditional academic departments and structured to promote close collaboration between physical chemists and physicists and to generate high-quality interdisciplinary science. Steve became deeply immersed in this endeavor, developing strong personal and scientific ties with members of the Physics Department, among them Robert Mulliken, Clemens Roothaan, and Ugo Fano. The Thursday afternoon Physics Colloquia, also attended by physical chemists, included expositions of the frontiers of chemical physics. Steve's research agenda started with the continuation,

extensions, and generalizations of themes he had explored earlier and that then evolved in several directions. These several research directions are conveniently grouped as: (i) studies of atomic and molecular electronic processes, such as electron scattering from molecules, dynamic coupling phenomena in molecular excited states, visualization of electron correlation in atoms, the angular resolution of multiphoton-generated photo electrons, autoionization and electron attachment and detachment processes, Penning ionization, and more; (ii) intramolecular dynamics and prediction of the phenomenon of molecular quantum beats; (iii) studies of the structure of clusters, the transition from micro- to macro-system behavior, and the dynamics of motion in topologically complex phase spaces and on complicated potential energy surfaces; (iv) the development of Finite Time Thermodynamics; (v) the development of Life Cycle Analysis, based on the comparison of energy and free energy with theoretical ideal thermodynamic limits for each step in a manufacturing process, from raw-material creation to product disposal; (vi) studies of the mitigation of atmospheric and water pollution and the development of generalized methods for the assessment of the roles of science, technology transfer, and economic analyses in formulating science policy.

Steve's theoretical and experimental studies of atomic and molecular electronic processes (research category i), which continued from 1964 into the early 2000s, covered diverse subjects. These included inventive analyses of the radiative capture of electrons by atoms, electron-atom and electron-ion scattering, angular distribution of photoelectrons from multiphoton excitation, theory of photoionization and autoionization, dynamic coupling in molecular excited states, binary collisions of ions, electron correlation in excited atoms and ions, Penning detachment, above-threshold ionization of atoms, and more. The theoretical studies were complemented by elegant experimental studies of the angular distribution of photoelectrons focusing on the understanding of electron correlation effects and by studies of ion-ion and ion-molecule collisions using merged beams.

Experimental and theoretical work on radiationless transitions began in the mid-1960s. Early theoretical models provided the conceptual basis for understanding radiationless transitions in a bound-level structure in excited electronic and vibrational states of isolated, collision-free, large molecules. These models for intramolecular energy acquisition, storage, and disposal rest on near-resonance coupling between states accessible for excitation and a background vibronic quasi-continuum, on the introduction of molecular eigenstates, on the dynamics of wave-packets of such eigenstates, and on finite-time evolution and practical irreversibility in a bound-level structure. Radiationless transition theory elucidates interstate and intrastate coupling and relaxation in sparse, intermediate,

and dense (statistical) level structures, and it provides a unified description of energetic-spectroscopic-dynamical relations. Steve became fascinated by wave-packet dynamics in the intermediate level structure. In 1968 Steve and one of us (JJ) predicted that in this intermediate level structure a wave-packet of molecular eigenstates can be coherently excited and will exhibit interference effects in the radiative and nonradiative decays, referred to as molecular quantum beats (research category ii). The theoretical predictions were confirmed in 1981–82 when Jan Kommandeur (University of Groningen), Doug McDonald (University of Illinois), and Ahmed Zewail (California Institute of Technology) reported the experimental observation of molecular quantum beats for interstate and intrastate intermediate level structures that were coherently excited by nanosecond laser pulses. During the 1990s, the development of femtosecond laser pulse technology permitted experimental interrogation of vibrational coherence effects, thereby providing significant information on the level structure and nuclear dynamics on the time scale of vibrational nuclear motion in molecules ranging from diatomics to proteins. The influence on subsequent developments of the 1969 theory that laid the foundations for the concept of coherent vibrational wave-packet dynamics in femtosecond chemistry was recognized in the 1997 Nobel Symposium, "Femtochemistry and Femtobiology: Ultrafast Reaction Dynamics at Atomic Scale Resolution," wherein Jörn Manz from the Free University of Berlin referred to the Berry-Jortner theory as the conceptual basis for femtosecond chemistry.

In the early 1980s, Steve became fascinated by the structure, energetics, dynamics and thermodynamics of small atomic and molecular clusters (research category iii), and he made centrally important contributions to the understanding of structural transitions in molecular clusters and how they differ from those in bulk materials. These studies helped define the conceptual framework for the description of clusters and nanoparticles in terms of the properties of their potential energy surfaces, relating topographies and topologies of the energy landscapes to structure-seeking and glass-forming tendencies. In a long series of groundbreaking studies of cluster properties, Steve, Julius Jellinek, David Wales, Thomas Beck, and Heidi Davis determined the coexistence in clusters of solid-like and liquid-like properties at high temperatures over a finite temperature range, and they developed a theoretical description of phases and phase transitions in clusters that provides an interpretive base for such work as the 2019 spectroscopic and computational study by D. R. Moberg et al. of water clusters of 90 molecules at 150K, which reveals oscillations between solid-like ice I and liquid water. In another contribution, Steve extended the theory of phase transitions in atomic clusters to explore the occurrence of negative specific heats of clusters in a microcanonical ensemble.

The relationship of the dynamics of nuclear motion in Ar_3 clusters to conformational changes was first studied in 1988 by Berry, Leitner, and Whitnell. Classical molecular dynamics simulations revealed that away from the saddle point region, when the cluster passes from one structure to another, the dynamics is strongly chaotic, whereas near the saddle point region the dynamics is far more regular. Subsequent studies dealt with the non-linear dynamics of multidimensional Hamiltonian systems and the characterization of regions near a saddle, with a local chaos representation based on local Lyapunov exponents.

Analyses of cluster structures and transitions between them necessarily leads to the examination of the topographies of complicated multidimensional potential energy surfaces that exhibit both simple saddles and multiple saddles that separate the multidimensional basins of local stability. Determination of the rates of transitions between structures, that is, of transitions from basin to basin, requires the analysis of trajectories in the full phase space of the system to understand why and how the condition that a trajectory has a total energy larger than the saddle point energy is only necessary and not sufficient. Conventional transition state theory cannot answer this question, and phase space analyses based on identifying the transition state with a separatrix in the Poincaré surface of section, or tracking trajectories from restricted reactive islands to restricted product islands, become approximations of unknown accuracy if the system has more than two degrees of freedom. In an important series of publications Steve, working with Tamiki Komatsuzaki, discovered from numerical calculations that all of the so-called quasi-regular, semi-chaotic, and fully developed chaotic regimes exist in the region of a saddle of strongly coupled, many-particle Hamiltonian systems. Accordingly, up to energies high enough to make the system manifestly chaotic, approximate invariants of motion associated with a reaction coordinate in a phase space imply a multidimensional dividing hypersurface that is free from re-crossings occurring in that regime, even in a sea of chaos. They then developed an elegant mathematical analysis for the region of potential saddles and a practical algorithm to visualize the dividing hypersurface in the multi-dimensional phase space of a given system, which together provide a greatly improved classical theory of reaction rates in multidimensional systems. They also developed a strong propensity rule and corresponding formula for transitions of chemical reactions, which enables a priori prediction of success of trajectory passage through the saddle to the product or failure and return to the reactant state. In an extended version of this research, the understanding of topologies of the energy landscapes and motions thereon led Steve to an innovative approach to the molecular dynamics in biomolecules, specif-

ically the description of the dynamics of protein folding and the identification of the preferred folded structure of proteins and polypeptides.

In the 1950s, when Steve and the authors of this memorial were students, equilibrium thermodynamics and linear irreversible thermodynamics appeared to be complete theories with separate, well described domains of applicability to macroscopic matter. That apparent completeness was shattered in the succeeding decades by the conceptual developments embodied in seminal analyses of the character of fluctuations, such as the Onsager-Machlup treatment of the dynamics of continuous stochastic processes, the Jarzynski and Crookes relations connecting the free energy differences between two states and the irreversible work along an ensemble of trajectories joining the same states, and the development of stochastic thermodynamics for mesoscopic systems. Yet another addition to the body of thermodynamic theory that is quite different from those mentioned is the development, pioneered by Steve, of so-called finite time thermodynamics (research category iv). He was stimulated by the banal, but also profound, observation that reversible processes, although in principle the most efficient, are unrealistically slow. The formalism of finite-time thermodynamics that he developed covers all thermodynamic processes with the one added constraint that they go to completion in a finite time; it provides limits to, say, the extra expenditure in energy or entropy production required for that to happen, as well as methods to calculate the optimal path or mode of operation to achieve it by placing the system of interest in contact with a time-varying environment that coaxes the system along the desired path. Steve, with Peter Salamon, Abraham Nitzan, Bjarne Andresen, Mary Ondrechen, Boris Smirnov, and other students and postdoctoral coworkers, showed how to define, construct, and evaluate the analogues of thermodynamics potentials for processes constrained to operate in finite time, how to determine extremal values for finite-time processes, including chemical processes, and then a general method for optimization. By virtue of the way they are constructed, the concepts used in finite-time thermodynamics have broad validity and applicability outside conventional thermodynamics; with proper mapping of variables they have found considerable use in economic theory (research category v).

The origins of research category vi is directly traceable to the fact that in 1964, when Steve moved to Chicago, the primary fuels used for home heating were oil and soft coal, resulting in a polluted atmosphere, new fallen snow being quickly covered with grit and soot, and wall washing a periodic necessity. Steve was so disturbed by the air pollution that he wrote directly to then-Mayor Richard Daley with the forthright opening "Dear Mayor Daley, You live like a pig!" and with the further admonition that he could see

no sign of activity to alleviate air pollution. A visit to the then-existing Chicago Air Pollution Laboratory convinced him that nothing substantive was happening to address the problem. That visit led to Steve's involvement in the public anti-air pollution movement, which resulted in the 1967 Federal Air Quality Act, then the Clean Air Act, and then the creation of the Environmental Protection Agency. Along the way Steve, with Margaret Fels, Thomas Long, Margaret Lounsbury, Hiro Makino, and Sandra Hebenstreit, produced a series of provocative articles and studies of the mediation of air pollution, life-cycle energy consumption in automobile and cement manufacture, packaging, transporting and marketing consumer goods, production and destruction of polymers, and water resource management. In 1977 he co-authored, with Linda Gaines and Thomas Long, the important study *TOSCA: The Total Social Cost of Coal and Nuclear Power*. All of these studies, which are related to generalized methods for the assessment, control, and assimilation of technology, are representative of Steve's responses to what he regarded to be the social obligations of the scientific community. With the same spirit of social responsibility, he strongly promoted electronic exchange of scientific information and scientific intellectual property and policies that provide openness and broad availability of scientific data.

Steve Berry in his office at the University of Chicago, 2018.

Recognition and Public Service

The quality of Steve's scientific contributions was recognized widely. He was elected to the National Academy of Sciences (1980), the American Philosophical Society (2011), the American Academy of Arts and Sciences (1978), the Royal Danish Academy of Sciences (1980), and the Japan Society for the Promotion of Science (1984). In 1997 he was awarded the Heyrovsky Medal for Merit in the Chemical Sciences by the Academy of Sciences of the Czech Republic. During his career, he was an Alfred P. Sloan Fellow (1962-66), a Guggenheim Fellow (1971-73), a MacArthur Prize Fellow (1983-88), the Newton-Abraham Professor at Oxford University (1986-87), and a Humboldt Senior Scientist (1993). Steve's 70th birthday was honored by the publication of a special issue of the *Journal of Physical Chemistry*.[1] In addition, he was awarded numerous honorific distinguished named lectureships at universities in the United States and abroad and was much sought after for his active participation in managing the structure of scientific organizations. Steve served as the Home Secretary of the National Academy of Sciences (1999-2003), Vice-President of the American Academy of Arts and Sciences (1987-90), chair of the National Research Council Report Review Committee (2000-04), and over many years on many dozens of federal agency boards and committees.

Many individuals provide support for the scientific enterprise by serving on committees and boards of organizations, but very few create a new organization. Steve's belief in the importance of face-to-face dialogue among individuals with new ideas and disparate backgrounds led him, with his student Peter Salomon, to create the Telluride Science Research Center in 1984 with the purpose of hosting workshops aimed at the exploration of new, exciting, open questions across the entire spectrum of science.[2] Since its founding, the workshop program has blossomed to become a prominent venue for many interdisciplinary meetings, and the Center has become an important player in the promulgation of leading science.

Intertwined Other Worlds

All of the preceding has been descriptive of Steve Berry as a scientist and his role in the scientific world. That world intersected with the worlds of his family and friends. Steve had an intense and supportive family life intertwined with his many professional activities. While an undergraduate, he met Carla Friedman, a contemporaneous undergraduate at Radcliffe. They married in 1955 and had three children—Andrea (1957), Denise (1959), and Eric (1964)—and were devoted grandparents to eight grandchildren. Carla earned an Ed.D. in Education from Harvard, and for many years she worked in the

field of early childhood education via association with the Erikson Institute of Chicago and other organizations. As a respite from the frenetic pace of life in Chicago, the family valued their time in Aspen, with seasonal skiing, hiking, and other activities. Steve was an avid traveler. Amongst his many professional trips all over the world, he, with the family, spent lengthy periods as a distinguished visiting professor in Copenhagen, Oxford, Paris, Tokyo, and Tel Aviv.

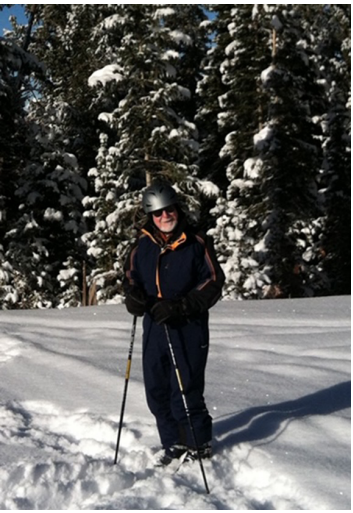
The intensity of interaction between Steve and his friends' worlds is illustrated by the stories of the authors of this memoir. For SAR, that interaction began in in mid-September 1952, in a line of new graduate students waiting to register for courses. Steve Berry and I stood together, introduced ourselves, and by some mystery associated with personal chemistry, instantly bonded. For the next 68 years, our lives were intertwined professionally and personally. Although we published only a few papers together, we had a continuous scientific dialogue that covered a very broad spectrum of scientific, political, social, and administrative subjects; we jointly wrote, with John Ross, a textbook that embodied our approach to teaching physical chemistry; we had numerous family dinners and outings and often attended the same concerts and theater productions. Our children grew up together. I remember fondly Steve's impersonation of R. B. Woodward in the 1952 Harvard Chemistry Department Christmas party skit; the night that Carla Berry left a dinner at our house to give birth to Eric Berry; Steve teaching me to ski on an icy slope when we were at a meeting in Spatind, Norway; serving as surrogate parents and cheerleaders for a live stage performance by Denise Berry while Steve and Carla were in Europe; being driven around Telluride in an ancient jeep; a wonderful week-long archeological trip to Jordan with Steve and Carla and Joshua and Ruthi Jortner; both Steve and Carla's wedding ceremony and their fiftieth wedding anniversary, and much more. Steve was a passionate lover of music, covering the range from early to contemporary music. He and Carla regularly attended opera, orchestral, and chamber music concerts, often several weekly, and he hosted Sunday morning sessions at which he and his friends played. The Steve Berry I knew and loved was a straightforward

Steve Berry in Aspen, with his vintage Jeep, ca 2000.

individual who would speak his mind directly and sometimes brusquely, often incisively, sometimes with terrible puns, but who would never intentionally wound another.

For JJ, that other world was a 58-year-long friendship with Steve that started in April 1962 via mail, stimulated by overlapping interests in negative ion spectroscopy. I first met Steve face-to-face in November 1962 in SAR's office; our rapport, both scientifically and personally, was immediate. I remember Steve introducing me, during a visit to Yale in February 1963, to Lars Onsager, who was very interested in the then-ongoing theoretical and experimental work in Chicago on excess electron localization in bubbles in normal and superfluid liquid helium. Our shared scientific interests led to a 1965 paper on charge transfer states in molecular crystals and the 1968 paper "Radiationless Transitions and Molecular Quantum Beats." Although we saw each other regularly for the next three decades, we did not again directly collaborate until 2002-03, in studies of the dynamics of complex systems and the dynamics of peptides. For 58 years, close personal relations between the Berry and the Jortner families flourished. Steve and Carla were very close to my children, and I remember with delight Iris Jortner, age four, playing the flute with Steve, in Copenhagen, and Roni Jortner lecturing at one of Steve's Telluride workshops. I recall joint adventures in Europe and in Colorado, with Steve's concern for my erratic driving in Paris, and with Steve taking me to a concert of bluegrass music in Telluride, and I remember fondly the visits of Steve, Carla, and their three children to Israel, the wonderful archeological trip by the Berry, Rice, and Jortner families to Jordan, and an instructive tour with Steve and Carla to southern Lebanon. Steve and Carla were gracious hosts in Chicago, Aspen, and Telluride, and it was a moving experience to attend Eric Berry's wedding ceremony in New Mexico. The Steve Berry I knew, respected, and loved, taught me that human dignity is best realized by embracing knowledge.

The other world of Steve Berry also includes his life in Aspen and Telluride. Some people love water and dislike mountains, and vice versa. Steve was a mountain man. In the 1960s, he built a house in Aspen and spent summers and university breaks there. Life in Aspen was a remarkable combination of science and culture, as it housed both the Aspen Center of Physics and the Aspen Music Festival and School. There, Steve avidly pursued science, music, and outdoor activities, including skiing in the winter and mountain hikes and mushroom picking in the summer. He regularly spent time at the Aspen Center for Physics, and he and Carla attended frequent concerts. Having co-founded (with Peter Salamon) the Telluride Science Research Center, he both organized and went to many workshops there and took advantage of the local opportunities for high-altitude



Steve Berry, skiing in Aspen, 2017.

mountain climbing. Steve did notice as the years passed that mountain climbing around Telluride became more difficult for him, leading him to quip that "the mountains had become higher." From early adulthood, Steve was interested in gourmet food and high-quality wines (he was a Chevalier de Confrerie des Vins de Cahors, and he built a very large collection of wines), and he enjoyed drinking vintage wine in the wine cellar of the Aspen house of Prince Bender, the Ambassador of Saudi Arabia to the United States. For a lengthy period in the late 1960s and 1970s, the Bakery restaurant in Chicago was a favored venue at which to entertain visiting speakers. Steve convinced the owner (who had a Ph.D. in psychology) to place a blackboard near the table so as to promote scientific discussions. It worked! Arguably the high point of Steve's gastronomic expertise was in the handling of the poisonous fugu fish, gained during visits to Japan. Simply put, Steve enjoyed life in all its aspects and lived it fully.

Legacy

We believe that Steve's legacy has three important components. First, and arguably most obvious, is the body of research he produced and the co-workers he educated. In the course of his career, Steve authored and co-authored about 600 papers and six books, and mentored sixty-nine graduate students, thirty-nine postdoctoral students and thirty undergraduates. He was a master in the training of graduate students and postdoctoral colleagues, many of whom have become major contributors to science in the United States, Europe, Japan, and Israel. Second is the lasting influence of his emphasis on the social responsibility of science and scientists and on the incorporation of science in public policy, which provides a standard for how to optimize the integration of what science contributes with what society requires. Third is the creation of a lasting venue for the exploration of new, exciting, open questions across the entire spectrum of science. Steve's role in the founding of the Telluride Science Research Center is a permanent gift to the scientific community writ large.

On July 29, 2020, after Steve's death, the *University of Chicago News* carried an article under the title "R. Stephen Berry – one of the most influential chemists of his generation,"[3] in which Steve Sibner, a long-time colleague at the University of Chicago, was quoted as saying: "Steve was one of a kind. We will not see his like again for a long time." Scientists are fortunate to be able to combine their avocation and their vocation. Steve Berry's life shows how fruitful that combination can be.

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