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FREDERICK DOMINIC ROSSINI
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A Biographical Memoir by

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Frederick D. Rossini

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BY ERNEST L. ELIEL

FREDERICK D. ROSSINI was one of the preeminent thermodynamicists of the twentieth century. The thermochemical data he produced and catalogued continue to be invaluable not only in fundamental science (for example in conformational analysis and molecular mechanics) but also in applied science, notably in the petroleum industry, which, through the American Petroleum Institute, funded much of Rossini's research in this area.

Fred Rossini was born in Monongahela, Pennsylvania, in 1899, the oldest of six children of Martino Rossini and Constanza Carrera, both immigrants from Italy. His father died when Fred was eight, and the need to help support his family forced Fred to drop out of high school at sixteen to go to work as a hardware clerk, work he continued when his mother died three years later. Fortunately the principal of the high school (H. W. Crane, whom he had previously got to know as a football coach) provided him with a special program to finish high school with honors. At twenty-one Rossini entered Carnegie Institute of Technology (now Carnegie-Mellon University) in Pittsburgh, and soon was awarded a full-time teaching scholarship. He graduated with a B.S. in chemical engineering in 1925, followed by an M.S. degree in science (physical chemistry) in 1926. As a result

of reading Lewis and Randall's classical text *Thermodynamics and the Free Energy of Chemical Substances* he wrote to Gilbert Lewis; an offer of a teaching fellowship at the University of California at Berkeley resulted. Among his teachers were Gilbert Lewis and William Giauque (both NAS members; Giauque received the Nobel Prize in chemistry in 1932). Rossini's doctoral dissertation on the heat capacities of strong electrolytes in aqueous solution was supervised by Professor Merle Randall. His Ph.D. degree was awarded in 1928, after only 21 months of graduate work, even though he continued to serve as a teaching fellow throughout this entire period.

Through his teaching supervisor W. C. Blasdale, Rossini was recommended to Frederick G. Cottrell (NAS member famed for the Cottrell precipitator and for endowing Research Corporation), who in turn passed on the recommendation to Edward W. Washburn (also an NAS member), who offered a civil service appointment to Rossini in the National Bureau of Standards (now National Institute of Science and Technology). He began work at the National Bureau of Standards in September 1928 in the field of thermochemistry under Washburn (at a salary of $2,600 per year). Rossini stayed at the bureau for 22 years, and a substantial part of his most important research was undertaken there.

AT THE NATIONAL BUREAU OF STANDARDS (1928-50)

In the mid-1920s Washburn, as editor-in-chief of the *International Critical Tables*, had become aware of a lack of reliable enthalpies of formation of many simple chemical compounds. Rossini stepped into the breach; his more than 20 publications between 1928 and 1935, all sole-authored, deal with such fundamental quantities as the heat of formation and of ionization of water, the heat of combustion of methane, carbon monoxide, methanol, ethanol, ethane, propane,

butane, and pentane, as well as the heat of formation of hydrogen chloride and the thermodynamic properties of certain electrolytes in aqueous solution. All of this work was published in the *Journal of Research of the National Bureau of Standards* and was reviewed periodically by Rossini in *Annual Survey of American Chemistry*. That this work has stood the test of time and is still fundamental to present-day thermochemistry is a token of the extreme care Rossini took not only in the calorimetric measurements but most especially in the separation and purification of the compounds in question. (In a lecture delivered in 1975, he gives credit for part of the calorimetric work to both the Heat Division and the Electrical Division of the National Bureau of Standards, which had a number of excellent scientists knowledgeable in the areas of calorimetry, thermometry, and maintenance of standard cells and standard resistances for the accurate measurement of electrical power.) In this period Rossini, in collaboration with M. Frandsen and Washburn, also developed the basis for the "Washburn" correction for bomb-calorimetric results, invaluable in later calorimetry work. In 1936, in coauthorship with F. R. Bichowski, Rossini published an extensive self-consistent table of "best" values for the heats of formation of many of the substances by then studied.

About his early years at the National Bureau of Standards Rossini said, "I shared Washburn's liking for thermodynamics and thermochemistry, for experimental measurements of high precision and accuracy, and for a logical order of arrangement of things." The precision and accuracy of the values he placed in the literature is certainly legendary; some specific examples will be given later. His work reflected his personality; he was thorough, painstaking, hard-working, purposeful, and focused.

In 1932 Fred Rossini married Anne Kathryn Landgraff.

Their son Frederick Anthony was born in 1939.

Edward Washburn died in 1934 and Rossini was asked to succeed him as director of the American Petroleum Institute Research Project 6 on hydrocarbons in petroleum. He held this position at the National Bureau of Standards for 16 years, while he perfected calorimetric measurement and, with the help of a growing group of dedicated coworkers, determined the heats of combustion of a total of 118 compounds, including all alkane isomers through C_8, as well as some nonanes, a number of alkylbenzenes, alkylcyclohexanes and alkylcyclopentanes, ethene, propene, cyclopropane, cyclooctatetraene, carbon, benzoic acid, and deuterium. (The methods used for the extensive purification of these compounds are described in his 1953 book with Mair and Streiff.) In 1936 Rossini also took on the position as chief of the Section on Thermochemistry and Hydrocarbons at the National Bureau of Standards.

In the late 1930s Kenneth Pitzer (later an NAS member) published seminal work on the statistical calculation of entropies of hydrocarbons (which gave rise to his renowned paper on the rotational barrier in ethane: J. D. Kemp and K. S. Pitzer, *J. Chem. Phys.* 1936, 4, 749). Rossini established contact with Pitzer around 1940 realizing that the combination of his thermochemical with Pitzer's entropy data would allow a determination of the standard Gibbs free energy of hydrocarbons and their isomerization equilibrium constants over a wide temperature range. The first paper on the free energies and isomerization equilibrium constants of the butanes, pentanes, hexanes, and heptanes appeared in 1941, and in 1947 Rossini and Pitzer jointly published a seminal paper on the configuration and thermodynamic properties of the dimethylcyclohexanes based in part on Rossini's amazingly accurate thermochemical data. (The heats of combustion of the 1,3-dimethylcyclohexanes are of the order of

5,200 kJ/mol. The difference between the *cis* and *trans* isomers is 7.2 kJ/mol. The presently accepted conformational enthalpy [i.e., axial-equatorial enthalpy difference] of a methyl group in methylcyclohexane based on numerous studies, which should in principle be equal to the above difference, is 7.1 ± 0.1 kJ/mol. Rossini's experiment has been likened to the accurate determination of the weight of a captain of a boat by first weighing the boat with the captain, then weighing it without the captain and taking the difference!)

The ability to determine complete thermodynamic properties of hydrocarbons (and other compounds) prompted Rossini to launch the American Petroleum Institute Research Project 44 on properties of hydrocarbons and related compounds in 1942. A unit of that project was also established at the University of California at Berkeley under the associate directorship of K. S. Pitzer. The initial results of this project, involving 483 data sheets relating to physical and thermodynamic properties, were summarized in 1947 in National Bureau of Standards Circular 461, S*elected Values of Properties of Hydrocarbons and Related Compounds*. A later, more extensive version was published in 1953.

During World War II the efforts of Rossini's group were directed to the analysis of aviation fuels. Beginning in 1944, the American Petroleum Institute Project 6 began to make available highly pure hydrocarbons (of certified purity) for spectral and physical and thermodynamic measurements outside of the National Bureau of Standards. Rossini served on the U.S. Petroleum War Council, in the U.S. Office of Rubber Reserve, in the U.S. Office of Scientific Research and Development, and on the U.S. Atomic Energy Program.

Rossini had been interested in teaching ever since holding a teaching assistantship at Carnegie Tech and later at Berkeley. Shortly after arriving at the National Bureau of

Standards, he began teaching a graduate course in chemical thermodynamics in the bureau's after-hours graduate school. In addition he taught thermodynamics at Howard University in 1937-38 and lectured on petroleum chemistry at the Catholic University of America in 1942. These endeavors eventually gave rise to his 1950 text *Chemical Thermodynamics*. The course at the bureau also gave Rossini an opportunity to see the younger members of the staff there in action; several of his coworkers were recruited from this group. It is obvious that the thermochemical work required a high degree of discipline. A former collaborator of Rossini's has characterized him as "kind, strict, and meticulous." He expected the work to be done by the high standards he set, but he was generous to his staff and treated them well. He was clearly a very effective organizer.

During his sojourn at the National Bureau of Standards Rossini received the Hillebrand Award from the Chemical Society of Washington in 1934 and the Gold Medal Exceptional Service Award of the U.S. Department of Commerce in 1950. In 1946 he was elected president of the Standing Committee on Thermochemistry of the International Union of Pure and Applied Chemistry, a position he held for 15 years although the name was changed in 1953 to the Commission on Chemical Thermodynamics and in 1961 to the Commission on Thermodynamics and Thermochemistry, of which Rossini continued as a member until 1973. In 1948 Rossini received an honorary D.Sc. degree from his alma mater, the Carnegie Institute of Technology, and in 1951, shortly after his departure from the National Bureau of Standards, he was elected to the National Academy of Sciences.

AT THE CARNEGIE INSTITUTE OF TECHNOLOGY (1950-60)

In 1950 Rossini was offered the position of Silliman professor and head of the Department of Chemistry at Carnegie

Institute of Technology in Pittsburgh by President John E. ("Jake") Warner (later an NAS member), who knew Rossini well both personally and professionally. Simultaneously Rossini became director of the Chemical and Petroleum Research Laboratory at Carnegie Tech and moved American Petroleum Institute Projects 6 and 44 to Pittsburgh. Beveridge J. Mair became associate director of Project 6. At this time Rossini received additional support from the newly formed National Science Foundation (NSF), and both Assistant Professor C. C. Browne and a total of seven graduate students and one postdoctoral associate became involved in Projects 6 and 44, in addition to the professional staff. Project 6 reached its twenty-fifth anniversary in 1952, and in 1953 Rossini, B. J. Mair, and A. J. Streiff published *Hydrocarbons from Petroleum: The Fractionation, Analysis, Isolation, Purification and Properties of Petroleum Hydrocarbons: An Account of the Work of American Petroleum Research Project 6*, which constitutes an extensive account of the preparation of pure samples of petroleum constituents by a wide variety of techniques. In the 10 years at Carnegie, a total of 87 additional compounds were studied, including a number of alkenes, cycloalkanes and -alkenes, naphthalenes and decalins, alkanols, and several perdeuterated hydrocarbons. From these measurements much fundamental information was derived: the enthalpy of *cis-trans* isomerization in non-terminal alkenes, the effect of substituents on the heat content of 1-, 1,1- and 1,2-substituted alkenes, the difference in enthalpy between alkylcycloalkenes and alkylidenecycloalkanes, and the difference in enthalpy between *cis*- and *trans*-decahydronaphthalene (decalin) and between *cis*- and *trans*-hydrindane. These measurements (and the earlier ones on the dimethylcyclohexanes) were of great interest to organic chemists and continue to be cited in standard textbooks of stereochemistry.

During this period Rossini became chairman of the Divi-

sion of Chemistry and Chemical Technology of the National Research Council (1955-58); he was a member of the Committee on Physical Chemistry of that division from 1948 until 1962.

When Rossini left Carnegie Tech in 1960, he entrusted American Petroleum Institute Research Project 44 to Bruno J. Zwolinski, who had been assistant director of the project since 1957. In 1961 Zwolinski moved to Texas A&M University, taking the project with him.

AT THE UNIVERSITY OF NOTRE DAME (1960-71)

Rossini was a devout Catholic all his life, and this was probably an important factor in his move to the University of Notre Dame in 1960 as dean of the College of Science there. The head of the chemistry department G. F. D'Alelio had resigned the previous year and the department was rudderless. Realizing that chemistry was one of the better departments in the college but needed help, Rossini additionally assumed the position of acting head, which he filled for over three years. (I followed him as head in 1964.) The combination of these administrative responsibilities obligated Rossini to suspend his beloved thermochemical research for the 11 years he stayed at Notre Dame.

In his new positions, Rossini proceeded to tackle several lingering problems involving budgets, inadequate salaries, and lack of organization. Having just taken on the deanship, being the only member of the National Academy of Sciences at Notre Dame, and arriving just when Notre Dame's President, the Reverend Theodore Hesburgh, was appointed to his second term on the National Science Board, Rossini clearly had the persuasiveness that comes with a professional honeymoon. The status of the department and its faculty improved markedly. In 1966 the college received a Center of Excellence grant from the National Science

Foundation, which allowed addition of faculty and some facilities. (No funding was found for the much-needed new chemistry building, which was to be the University's contribution to the grant. It was only built in 1980-82 according to the general plans that my colleague Rudolph Bottei and I had developed in the mid-1960s.) On the other hand, the Radiation Laboratory under Professor Milton Burton as director, which had existed since 1946, first with funding from the Office of Naval Research and later with generous support of the Atomic Energy Commission, did move into a major new building in 1966.

In 1965 Rossini received the Laetare Medal, Notre Dame's highest honor, awarded annually to an outstanding American Catholic lay person; Rossini was the first Notre Dame faculty member to receive the award in the 83 years of the medal's existence. The award of the medal reflected not just Rossini's scientific and organizational ability but also his deep moral and religious values.

I must mention here that the qualities that had been so essential in Rossini's scientific work—attention to detail and firm control of all operations—were not always appreciated by some of the heads of the science departments, who were used to a substantial degree of independence in their operations. (One of the indications of Rossini's desire to keep control of details were the very frequent memoranda he sent to all the department heads and sometimes to the entire college faculty, usually signed "FDR.") My own relations with Rossini, though rather formal, were generally cordial, and he left me to run the chemistry department without interference, except that the budgets of the science departments, including salaries, were almost entirely set by the dean in those days. He was, however, a strong-willed individual and once he had made up his mind on something, he was not to be contradicted—as I found out to my detri-

ment on one occasion when I tried to bring the problem of the lagging new chemistry building directly to the attention of the vice-president for academic affairs.

Despite his responsibilities as dean and his many other professional involvements, Rossini was anxious for me to give him a teaching assignment. I would have been happy to have him teach a graduate course, but he insisted on taking on undergraduate physical chemistry. (As mentioned earlier, he had written an extensive thermodynamics text and this presumably was to be the basis of his course.) I knew he was frequently away from the campus, giving lectures or participating in national committee meetings, and I was concerned about the course being taught on schedule. We finally solved the problem by my assigning another faculty member as a backup.

During his stay at Notre Dame, Rossini was asked by the National Academy of Sciences to chair a scientific mission to Romania, at that time probably the most dictatorial Iron Curtain country save the Soviet Union itself. Nonetheless, Rossini managed to negotiate a bilateral agreement of the type the Academy has with many foreign academies; he subsequently became a member (1966-71) and chairman (1970-71) of the Academy's Advisory Committee, U.S.S.R. and Eastern Europe. One of the advantages the Notre Dame chemistry department derived from this activity was that we were able to invite Romania's most renowned chemist Costin D. Nenitzescu and his wife to spend several days at Notre Dame.

At about yearly intervals Rossini held receptions at his home for the faculty of the college, which gave us an opportunity to meet his wife. Anne Rossini was a very gentle and amiable person, but even then, especially toward the end of the Rossinis' stay at Notre Dame, she struck us as rather frail. Fred was always very solicitous of her; despite

his formal demeanor he was fundamentally a kind and considerate individual. Perhaps one example is in order here: While I was head of the chemistry department, one of the full professors in the department suffered a suicidal depression, had to be hospitalized, and was clearly unable to fulfill his course assignment. I proposed to the dean that we put him on paid sick leave for the statutory maximum of six months. Rossini pointed out that, if our sick colleague were not ready to return to teaching at the end of that period, I would have to put him on an indefinite unpaid leave, which he clearly could not afford. Instead, Rossini made it possible to keep our colleague on the regular payroll but not to give him a teaching assignment. He did this by providing funds from the dean's budget to compensate the Radiation Laboratory for releasing one of their senior research associates to teach the course.

In connection with his service in the Division of Chemistry and Chemical Technology of the National Research Council, Rossini became a member of the Executive Committee of the Office of Critical Tables in 1957. He continued on the committee until 1969 (when the office ceased functioning) and from 1965 to 1969 was its chairman. It may have been the intent at that time to revise (or redo) the *International Critical Tables,* but this job would have been beyond the available resources. Instead, in 1966, the activity led to the organization of a Committee on Data for Science and Technology (CODATA), of the International Council of Scientific Unions. Rossini was the first president of CODATA (1966-70); the original organizing groups came from France, Germany, Japan, the United Kingdom, the U.S.S.R., and the United States. Rossini's international contacts, his vast knowledge of the data problem and his organizational ability must have helped in the establishment of CODATA, as did the interest and assistance of the foreign secretary of

the Academy, Harrison Brown. The CODATA office moved from Washington to Frankfurt, Germany, in 1968 and later to Paris, where the organization is headquartered today.

In 1967 Rossini left the deanship of the college to become vice-president of research at Notre Dame, a newly created position that he held until 1971, when he reached the mandatory retirement age of seventy-two. That same year (1971) he received the Priestley Medal, the highest distinction conferred by the American Chemical Society. In his Priestley address "Chemical Thermodynamics in the Real Word" he made a clever comparison of the counterplay of enthalpy and entropy in thermodynamics with that of security vis-à-vis freedom in the world at large.

AT RICE UNIVERSITY (1971-78)

After 11 years as an administrator, Rossini was anxious to resume the research he had to stop in 1960. Fortunately, Norman Hackerman (NAS), president of Rice University, offered Rossini a part-time appointment, which he held until 1975; he stayed on at Rice as professor emeritus until 1978. He taught a course in physical chemistry for biology majors and, in laboratory space provided by Professor John L. Margrave and with a grant from the Robert A. Welch Foundation, Rossini resumed his thermochemical work in collaboration with undergraduate scholars and postdoctoral associates. In this period he determined the heats of combustion of several C_{12} and C_{14} hydrocarbons as well as several azo compounds. He was also a supportive elder statesman and consultant to the younger faculty. In addition, in 1973 he was Strosacker visiting professor of science at Baldwin-Wallace College in Berea, Ohio. In the same year the Commission on Thermodynamics and Thermochemistry—in recognition of Rossini's service on the commission and its precursors for nearly 40 years—established a Rossini lec-

ture, and Rossini gave the first lecture at the International Conference on Chemical Thermodynamics in Montpellier, France, in 1975. In 1977, while still at Rice, he received the National Medal of Science for his "contributions to basic reference knowledge in chemical thermodynamics."

THE LATE YEARS (1978-90)

Anne Rossini's infirmity worsened in the late 1970s, and in 1978 the Rossinis moved to Fort Lauderdale, Florida, to be close to Anne's brother and sister-in-law. They had planned to proceed to a retirement community in Juno Beach, but before this move was realized, Fred damaged his spine trying to help Anne, and he realized she had to be cared for in a nursing home, where she died on December 18, 1981. Fred did move to Juno Beach in late 1982. There he met Dorothy Thompson Purcell, a retired AT&T executive, who became his second wife in 1983. Rossini kept up his scientific interests and introduced his new wife to his colleagues at the National Academy of Sciences meeting in 1985. In 1986 he had a bad fall that seriously impaired his health, as did a developing case of glaucoma. He became legally blind in 1988. In 1990 he contracted pneumonia and died peacefully on October 12. He will long be remembered for the enormous volume of broadly useful thermochemical data that he assembled, put on permanent record, and, in important part, generated.

HONORS AND AWARDS

A few of Rossini's honors and awards, including the Laetare and Priestley medals and National Medal of Science, have already been mentioned. In 1965 he received the John Price Wetherill Medal of the Franklin Institute and a year later the William H. Nichols Medal of the New York Section of the American Chemical Society. The United Kingdom's In-

stitute of Petroleum honored him with the Redwood Medal in 1972, and the Deutsche Gesellschaft für Mineralölwissenschaft und Kohlechemie conferred the Carl Engler Medal on him in 1976. In addition to the honorary D.Sc. from Carnegie Tech he was awarded honorary degrees by Duquesne University (1955), University of Notre Dame (1959), Loyola University of Chicago (1960), St. Francis College, Loretto, Pa. (1962), University of Portland (1965), and the University of Lund (Sweden) in 1974.

Besides being a member of the National Academy of Sciences Rossini was a member of the American Academy of Arts and Sciences and of the Philosophical Society of Washington and a fellow of the American Association for the Advancement of Science, American Institute of Chemists, American Physical Society, Franklin Institute, and the Washington Academy of Sciences—in addition to holding membership in a number of other organizations, including honorary membership in Phi Lambda Upsilon.

PROFESSIONAL SERVICE

The amount of professional service provided by Rossini was so prodigious that it must be enumerated here, at least in part. His diligence, thoroughness, and strength of personality made him a leader; he was not only a member of many organizations but frequently was called on to chair them. In some instances he did this to further the cause of thermochemistry and thermodynamics—subjects not generally fashionable during much of his lifetime—but in other instances he seems to have been motivated by a pure sense of duty.

He was a member of Council of the American Association for the Advancement of Science (1963-66); and chairman of the Washington Section (1950), of the Petroleum Chemistry Division (1954) and member of the Council

(1941-42, 1947-50, and 1957-60) of the American Chemical Society; in the latter capacity he also served as chairman of the Committee on Constitution and Bylaws (1949-50). He was also a member of the American Chemical Society's Petroleum Research Fund Advisory Board (1966-68); *Chemical & Engineering News* Advisory Board (1966-68); Editorial Board of the *Journal of the American Chemical Society* (1946-56), and of the Gibbs Medal Award Jury, Chicago Section (1965-73). He was president of Sigma Xi (1963-64), Washington Academy of Sciences (1948), Catholic Commission on Intellectual and Cultural Affairs (1958-59), and the Albertus Magnus Guild (1961-65).

While at Carnegie Tech Rossini also served as director (1955-60) of the Manufacturing Chemists Association's (now Chemical Manufacturers Association) Research Project "Data on Chemical Compounds." He chaired the Gordon Conference on Petroleum Chemistry in 1944 and co-chaired the "Conference on Geochemistry, Origin of Petroleum" in 1963. He was chairman of the Division of Chemistry and Chemical Technology of the National Research Council (1955-58) and chairman of its Advisory Board for Numerical Data (1969-70). He chaired the U.S. National Committee for the International Council of Scientific Union's Committee on Data for Science and Technology (1966-70) and the NRC's Committee on Climatic Impact (1974-75), in addition to being a member of other NRC committees. His service with the International Union of Pure and Applied Chemistry has already been mentioned. He was president of Associated Midwest Universities (1967-68), vice-president of the Argonne Universities Association and chairman of its Committee on Environmental Studies(1968-71), president of the World Petroleum Congress (1967-75), and chairman of the Advisory Board of the *Journal of Thermodynamics*, which he helped found (1968-75).

Other organizations on whose councils, committees, panels, or missions he served were the U.S. Army Ordnance Corps, the United States-Japan Cooperative Science Program, the U.S. Department of State, the Inter-University Committee on Travel Grants, the National Science Foundation, Argonne National Laboratory, St. Bonaventure University (trustee, 1968-71), State of Indiana Educational Services Foundation, State of Illinois Board of Higher Education, International Research and Exchanges Board, the Houston (Texas) Chamber of Commerce, and the Environmental Protection Agency.

MUCH OF THE INFORMATION in this memoir comes from Rossini's own writings: His Rossini lecture in *J. Chem. Thermodynamics,* 1976, 8, 803-34 and the preface thereto by S. Sunner, L. McGlashan, and E. F. Westrum, Jr.; his description of the CODATA history in *CODATA Newsletter* No. 38, 1986, 2-3 and his autobiography dated June 1978 in the files of the National Academy of Sciences. Obituaries in *J. Chem. Thermodynamics*, 1991, 23, 521-22 and the *CODATA Newsletter* were also helpful, as were entries in standard reference compendia.

Professor John L. Margrave (NAS) kindly made available press releases from Rice University; Dean Francis J. Castellino arranged for press releases to be forwarded from the University of Notre Dame; and Dr. Johanna Levelt-Sengers (NAS) provided information from the archives of the National Bureau of Standards.

I am greatly indebted to the late Professor Kenneth S. Pitzer (NAS) for providing much helpful detail, including correspondence with Rossini from 1940 and the late 1980s, and I regret only that Pitzer's death precluded his coauthoring this memoir.

Very useful telephonic and written information was obtained from Dr. David Lide (National Bureau of Standards, retired), Dr. Frederick Anthony Rossini, and Dean Francis J. Castellino (University of Notre Dame). Personal or telephonic conversations with Professor Robert Parr, Dorothy Rossini, Dr. John Jost, Professor Arnold Ross, Professor Robert B. Carlin, Dr. Alphonse Forziati, and the late Anton Streiff also helped to enliven this report.

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