



Milestones in Chromatography

This column is the first of a two-part "Milestones in Chromatography" series dealing with the life and activities of key chromatographers who were active during the early unparalleled growth and expansion of gas chromatography. In the present installment, Leslie Ettre discusses eight pioneers.

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Milestones in Chromatography
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Fifty Years of Gas Chromatography — The Pioneers I Knew, Part I

The First International Congress on Analytical Chemistry was held in September 1952 in Oxford, United Kingdom. The highlight of this meeting was a lecture on "Gas-Liquid Chromatography: a Technique for the Analysis of Volatile Materials," by A.J.P. Martin (1). Almost simultaneously, the seminal paper of A.T. James and A.J.P. Martin on the theory and practice of this technique (the manuscript of which was submitted on 5 June 1951) was published in *Biochemical Journal* (2), and within a few weeks it was announced that Martin and R.L.M. Syngé would receive the Nobel Prize in Chemistry "for the invention of partition chromatography."

Since these events, the evolution of gas chromatography (GC) has been unparalleled in the history of chemistry. It was the right technique introduced at the right time, when the new petrochemical industries were looking for better methods for the analysis of their complex raw materials and products. These companies were the first to utilize the new technique, but they soon were followed by other chemical laboratories. Within a decade, GC became the most widely used analytical technique and gave rise to the modern era of instrumental analysis.

I started in GC in 1957, five years after its inception, first in charge of an industrial GC laboratory. In a little more than one year I joined Perkin-Elmer, and during the next 30 years I actively participated in the evolution of the technique. I also had the opportunity to participate at frequently held symposia and to visit many laboratories on five continents. I was fortunate to know most of the pioneers of GC, not only professionally, but also socially, and I established fairly close relationships with a number of them. Therefore, I felt that the most fitting way to celebrate the 50-year anniversary of GC is to reminisce about the pioneers I knew. I arbitrarily selected a few key chromatographers, most of whom are no

longer among us. In the first three decades of GC they were most active in the development of the technique and its applications. They participated at the meetings, lecturing on their newest results, and one could not find any publication in which their work would not be quoted. They were the true pioneers of GC.

Rudolf Kaiser, one of the still-active pioneers, once said that chemists usually don't quote any paper that is more than seven years old; this material belongs in the archives and is no longer part of a "living science." In this two-part "Milestones in Chromatography" column, I want to change this opinion. My aim is to resurrect these pioneers and present them as living human beings. I will summarize briefly their scientific achievements but will deal mainly with them as colleagues and friends who worked in close contact, collaboration, and cooperation with their peers.

I added A.J.P. Martin to the list of deceased chromatographers discussed here. Without his activities none of us would be in this field, and this magazine would not exist; thus, it is most fitting that when speaking about the pioneers, we start with him. The others will follow in alphabetical order. I divided the discussion into two parts, dealing with the first eight pioneers in this article. Part II will follow in a later issue of *LCGC*.

My discussion is based on numerous sources, including the individual entries in the book *75 Years of Chromatography — A Historical Dialogue*, which was published in 1979 (3); various anniversary editorials; award announcements and obituaries; and my personal recollections.

A.J.P. Martin (1910–)

In a rare, candid, and very personal interview (4), Archer Martin discussed in detail his early life and his university years at Cambridge, United Kingdom. Originally, he planned to become a chemical engineer but changed to biochemistry on the influ-

ence of J.B.S. Haldane, then a reader in biochemistry. After graduation, Martin remained at the university's Dunn Nutrition Laboratory, where, among other endeavors, he tended to 30 pigs while working on the antipellegra factor. He met R.L.M. Synge in 1938, and their association led to the development of partition chromatography, which was discussed in a recent "Milestones" column (5). Between 1948 and 1956 Martin was associated with the laboratories of the British Medical Research Council: it was there that he developed gas-liquid partition chromatography with A.T. James, a young associate.

In his autobiography, George A. Olah, who was awarded the Nobel Prize in Chemistry in 1994, mentions the frequently stated opinion that the Nobel Prize often represents the *de facto* end of the recipient's active research career (6). In essence, this was true about Martin. After receiving his Nobel Prize he wanted to be involved in different matters. He first set up his own company to manufacture and sell certain devices for chromatographs (7), but this venture was unsuccessful. He started to serve as consultant to some companies and also had a number of academic appointments in The Netherlands (University of Technology, Eindhoven), United Kingdom (University of Sussex, in Brighton), the United States (University of Houston, Texas) and Switzerland (Federal Technical University, Lausanne). However, he did not

carry out any systematic research with notable finished results. This does not mean that he was idle; he presented a number of very interesting lectures that predicted further developments in chromatography, carried out some basic investigation into electrophoresis, and studied the possibility of scaling down laboratory operations. Particularly, his discussion of such possibilities, originally presented at the 1962 Hamburg Symposium (8), is most intriguing. However, I cannot compare this period to his golden decade during which partition chromatography and its variations — liquid column, paper, and gas chromatography — were developed.

I heard a story about Archer in Houston that probably best characterizes his activities in the later period of his life. At the University of Houston he occupied the Robert A. Welch Foundation Chair, a very prestigious endowment. After the first year, he found that the foundation required a periodic report on the awardee's activities. After some consideration, he wrote a brief report consisting of a single sentence: "I was thinking." Indeed, Archer was full of ideas up until the end of his professional life, when illness finally stopped him. It was a great pleasure to have the opportunity to sit down with him and discuss the widest variety of questions, be they about science, sociology, or philosophy. He always had some interesting ideas, although some might have sounded somewhat unusual. As

expressed by S.R. Lipsky, these conversations "certainly have to be considered some of the most exhilarating, intensive, and exhausting exercises — an 'intellectual encounter of the highest order,' if you will — that one can experience" (9).

Martin's last public appearance was in May 1985, when he received an honorary doctorate from the University of Urbino (Italy), where his 75th birthday was celebrated by a representative symposium that was attended by many of his friends and admirers (10). By then, his tragic illness had already started to overwhelm him. At the writing of these words, he is still alive, suffering from Alzheimer's disease.

Without question, Archer Martin can be considered one of the most original thinkers in science. He belongs to the small group of people who changed the face of chemistry and biochemistry.

Fabrizio Bruner (1935–1996)

Fabrizio Bruner belongs to the second generation of chromatographers who continued the work of the early pioneers and enhanced it with their own contributions. He was born, raised, and educated in Rome. Despite his German-sounding name, he was a real *Romano di Roma*: his ancestors lived in the Eternal City for at least five generations. Fabrizio received his doctorate from the University of Rome in 1960 with a thesis on capillary GC. After graduation, he remained at the university as a member of the Analytical Chemistry Research Group of the Italian Research Council (CNR). In 1966, he had the good fortune to be able to join Prof. Klaus Bie-mann at the Massachusetts Institute of Technology (MIT, Cambridge, Massachusetts). He spent two years at MIT, where he learned the intricacies of modern mass spectrometry (MS). Upon returning to Italy, Fabrizio joined the Air Pollution Research Institute of CNR, where he advanced to the position of research director. He also became an adjunct professor at the University of Rome.

Fabrizio's plan was to become a full professor at Rome University eventually. However, according to the Italian system, young scientists usually start at one of the regional universities and later advance to a major school. Accordingly, in 1975 he was appointed *professor incaricato* (about equivalent to an associate professorship without tenure in the United States) at the University of Urbino and started to teach physico-chemistry and analytical chemistry. Within a few years, his plans changed as he fell in



Archer Martin (center) with Denis Desty (left) and Victor Pretorius (right) (University of Pretoria, South Africa) around 1975.

love with the beautiful city in the Apennine Mountains, 20 miles from the Adriatic Sea, and saw the potential of its university. The present university grew slowly from the *Collegio dei Dottori*, founded in 1502 by the Duke Guidobaldo Montefeltro. Natural sciences represented a most recent addition to the older faculties, but due to the excellent leadership of Carlo Bo, serving as the university's president for more than 25 years, it grew very rapidly. Dr. Bo gave all the assistance Fabrizio needed, providing funds to purchase sophisticated, high-resolution mass spectrometers for GC-MS and LC-MS systems. In 1980, Fabrizio became a full professor and the director of the Institute of Chemical Sciences and soon succeeded in building a very strong, large, and dedicated research group, one of the largest in analytical chemistry in Italy. He was highly respected by his peers, who elected him as the chairman of the Chromatography Group of the Società Chimica Italiana.

Fabrizio's activity encompassed a wide variety of fields (11). His main forte was the combined use of MS with gas and liquid chromatography (LC) and the utilization of such systems for environmental investigations. In 1993, he published a book on environmental analysis, which is probably the most up-to-date compilation on this subject (12). Another special field in which he had been active for more than 20 years was the development, study, and application of graphitized carbon black. In

fact, the technology for the commercial production of such material in both Europe and the United States was developed by him. Finally, I should mention a very important and practically unknown activity: for more than five years members of Bruner's group were regularly present at an Italian research station on Antarctica for extended periods, collecting air samples which then were analyzed in Urbino.

I visited Fabrizio in Urbino a number of times, both professionally, lecturing to his students, and socially, enjoying the beautiful city, the gem of the Renaissance. Fabrizio was always a wonderful host, and we spent many evenings in his favorite restaurants. For him, deciding the proper courses for dinner and selecting the proper wines was as serious a task as the compilation of a grant proposal for an American professor. His students and associates told me that although he was very demanding and not easy to get along with, any controversy could be resolved quickly over dinner.

In the fall of 1995, at the height of his activities, Fabrizio was diagnosed with liver cancer. In the subsequent months, his health deteriorated rapidly. Meanwhile, it was announced that he would receive the Golay Award at the next International Symposium on Capillary Chromatography. The symposium was held on 20–24 May 1996 in Riva del Garda, Italy, and his associates drove him there to receive the award. Fabrizio gathered all his strength to be able to present his swan song, a summary of his

team's activities in Urbino (13). Two months later, he died.

Erika Cremer (1900–1996)

The year 1952 represents only the beginning of gas-liquid *partition* chromatography. GC in the adsorption mode actually started earlier, well before the work of James and Martin. One of the first scientists who investigated these possibilities was Erika Cremer, then a lecturer at the small University of Innsbruck (Austria).

Erika Cremer was born at the dawn of the twentieth century and remained active almost until the end of the century. She started to study chemistry in 1921 at the University of Berlin and received her doctorate in 1927. At that time it was rare for a woman in Germany to study science and almost impossible to advance as a scientist. Thus, for the next 13 years she occupied fairly low positions in various laboratories but had the opportunity to work with the most important scientists of that period, such as Fritz Haber, Georg von Hevesy, and Otto Hahn — all Nobel laureates in chemistry. Finally, the start of the Second World War, which saw many male scientists called into military duty, provided her the opportunity for a university appointment, albeit one that was considered only temporary. In June 1940, she was appointed a lecturer at the University of Innsbruck, and she remained at this school for the rest of her life. In 1945, at the end of the war, she was appointed as the head of the Institute of Physical Chemistry, and, in 1951, she received the title of a professor. Even after her retirement in 1970, she continued her relationship with the Institute as professor emeritus (14,15).

Professor Cremer's field was physical chemistry and, particularly, the study of adsorption. Her involvement in GC actu-



Fabrizio Bruner (right) with Carel Cramers (center) (University of Technology, Eindhoven, The Netherlands) and Rudolf Kaiser (left) (Institute of Chromatography, Bad Dürkheim, Germany) in 1986.



Erika Cremer (right) with Fritz Prior (her graduate student in 1946–1947). The photograph was taken in 1977.

ally started in 1944. Becoming familiar with liquid (adsorption) chromatography, she was considering the possibility of an analogous process involving gases and concluded that the small differences in adsorption energies of gases would be enough to separate them, utilizing an inert gas in the same role as the solvent used as the mobile phase in LC. She submitted a theoretical discussion of this idea in November 1944 to the journal *Naturwissenschaften*, but it could not be published because the printing plant was destroyed by an air raid while the particular issue of the journal was being printed. (The text of this paper was finally published 32 years later [16].) The

idea continued to occupy her thinking and when, after the war, new graduate students started to flock to the university, she selected this topic as the subject of two graduate theses finished in 1947 and 1950, by F. Prior (17) and R. Miller (18), respectively. Life had not returned to normal in Austria at that time, and the work could not be published until 1951 (19,20). The system used in these investigations corresponded in full to a modern gas chromatograph: it included a (gas) sample inlet, a carrier-gas supply, a thermostated packed column, and a self-built thermal-conductivity detector with galvanometer readout. This system now is exhibited at

the Bonn branch of Deutsches Museum, the world's largest technical museum (21).

In the subsequent years, Prof. Cremer continued her studies of GC, clearing up a number of important points, and also became involved in the development of substance-selective detectors. In the 20-year period prior to her retirement, 16 graduate theses in her institute used various aspects of chromatography as their subject.

I first met Prof. Cremer in 1958, during the Amsterdam Symposium. We corresponded in 1959–1960 when I was involved in the development of GC methods for the measurement of the surface area of solids by gas adsorption–desorption, and I first visited her Institute in the summer of 1960. From then on, I had many opportunities to visit her, until the last years of her life. It was always a great pleasure to meet her and discuss the widest possible range of questions of mutual interest, be it chromatography, the history of science (her favorite subject after retirement), or of the Tyrol, the mountainous area she loved so much. For many years Dr. Cremer was an avid mountain climber and wanderer, and, even into her nineties, she maintained a beautiful house in the mountains, just outside Innsbruck.

In 1990, Dr. Cremer's 90th birthday was celebrated at the University of Innsbruck with a two-day symposium attended by many of her former students, friends, and admirers. She actively participated in the discussion of practically every lecture; it was unbelievable to see how alert she still was at that advanced age. In the subsequent years, I had the opportunity to visit her twice, and it was amazing how fresh her mind was.

Professor Cremer's former students remember the openness, objectivity, and humanity learned from their teacher. She was a true pioneer in chromatography and in the study of adsorption.

Stephen Dal Nogare (1922–1968)

In 1958, three major developments changed the way GC analyses were carried out. These were the introduction of ionization detectors, capillary columns, and temperature programming.

The development of temperature programming usually is identified with Stephen Dal Nogare. To be sure, he did not *invent* it: C.S.G. Phillips at Oxford University used the technique as early as 1952, and, around 1958, an instrument developed by the Burrell Corp. permitted



At the 1974 International Symposium on Advances in Chromatography, Houston, Texas. Front row, left to right: Erika Cremer, Mrs. Eva Smolkova-Keulemansova, A.I.M. Keulemans, Mrs. Doreen Desty, Denis Desty, and B.V. Ioffe (University of Leningrad, USSR).



Stephen Dal Nogare (right) with David Grant (center) (Coal Tar Research Association, Leeds, United Kingdom) and Denis Desty (left) at the 1958 Amsterdam Symposium.

the change of column temperature during analysis. It was, however, Steve who demonstrated systematically the advantage of linear temperature programming. His co-workers were the founders of F&M Scientific Corp. (the predecessor of the chromatography part of present-day Agilent Technologies), which was instrumental in making the technique everybody's tool.

After graduation in 1947, Steve joined Du Pont and it was there that all his chromatographic activities were carried out. In the fall of 1967 he joined the faculty of Virginia Polytechnic Institute (Blacksburg, Virginia), but within a few months this association was ended by his tragic death in January 1968.

Steve's activities in GC started with the development of special instruments for high-temperature and high-sensitivity operation. Temperature programming was a logical continuation of this work and he pioneered in exploring all aspects of the technique. He also made other important contributions to GC such as the practical interpretation of theoretical conclusions, explaining the importance of the phase ratio on resolution and efficiency and discussing the optimization of column parameters.

For a decade, Steve probably was the best known American gas chromatographer. He gave a large number of lectures by the invitation of various universities and meetings and served as the chairman of the 1963 Gordon Conference on Analytical Chemistry, which was devoted entirely to GC. In this period, he and R.S. Juvet were the authors of the very important biannual reviews of GC published in *Analytical Chemistry*. However, probably his most important contribution beside temperature

programming is the textbook on GC co-authored with Dick Juvet and published in 1962 (22). In the 1960s, this book could be found on almost everybody's desk, and even today it can serve as a basic reference book.

I met Steve first at the 1960 Gordon Conference. Our first contact actually was not professional — we played bridge together every night. From then on, I remained in fairly close contact with him until almost the last weeks of his life. He was one of the nicest people I have ever known. Steve always loved to be with his friends and could warm up even the most somber group in a few minutes. His sudden death in the prime of his life was a great loss to the field of chromatography.

Denis H. Desty (1923–1994)

After serving in the Royal Air Force during the Second World War and studying at Southampton University (United Kingdom), Denis Desty joined the Research Center of British Petroleum (BP) in 1948. He spent the rest of his professional life there in increasingly responsible positions, starting as a technologist and ending as a research associate. In the 1980s, he also was associated with the department of chemical engineering of the University of Surrey as a visiting professor.

The start of Desty's involvement in GC belongs to the legends. In the summer of 1952, before publication of his seminal paper, Martin contacted BP to request some samples of pure hydrocarbons for evaluation of the newly developed technique of gas-liquid partition chromatography. Dr. Birch, the head of the laboratory, sent Desty to see Martin and find out about this new technique. Denis immediately realized its immense potential for the analysis of complex hydrocarbon samples, and within a few weeks he built a gas chromatograph and started to investigate the possibilities of hydrocarbon separation.

In the next decade Denis was the motor of GC evolution in the United Kingdom, as the leader of the newly established GC Discussion Group and the organizer of the first two international symposia on GC held in 1956 in London and in 1958 in Amsterdam. He also contributed significantly to the advancement of methodology. For example, his group carried out the most comprehensive investigations of the capillary columns introduced by M.J.E. Golay at the 1958 Amsterdam Symposium, and he was involved in the design of the machine that enabled the drawing of

glass capillary tubes. His analysis of a Ponca Crude sample on a 900 ft × 0.152 mm glass capillary column coated with squalane, shown in 1961, also belongs to the legends of GC. The first 3-h portion of the chromatogram showed 122 peaks in the C₃–C₉ region, and the total chromatogram contained hundreds of additional peaks. The total analysis took 20 h, and the chromatogram occupied a full roll — 50 ft — of recorder chart paper.

About 1962–1963 Denis moved away from chromatography, becoming involved in other fields such as the design of burner heads for gas flares on oil platforms and the construction of booms for oil spill recovery. However, he still kept himself up-to-date in the newest developments and later became involved again in some GC work, such as the possibility of producing (thick-walled) fused-silica capillary tubes, which he discussed in a 1975 paper, three years before the introduction of the thin-walled fused-silica capillary columns by R.D. Dandeneau and E.H. Zerenner.

I knew Denis since the beginning of the 1960s, and from the mid-1970s on we met regularly at the capillary chromatography symposia. He was always the center of the discussion sessions, and his prominence also was evident in the social part of the symposium's time. We sat for hours in a hotel's restaurant considering various questions, and Denis always was at the head of the table; without specifically asking, he automatically took over guidance of the discussions.

Denis was an extraordinary person, possessing a great understanding of the physicochemical and engineering principles and a full capability of using them. As mentioned by Ted Adlard in his eulogy, Denis' attitude best could be summarized by the common laboratory slogan, "He didn't know it was theoretically impossible, so he went ahead and did it" (23). For his outstanding contributions to science Denis was elected to the Royal Society, a very rare honor for an industrial scientist. Without his contributions, GC would not be where it is today.

Keene P. Dimick (1915–1990)

The development of GC contributed significantly to the evolution of the scientific instrument industry. In turn, the almost immediate introduction of commercial instruments and the activities of the instrument companies had an important impact on the expansion of GC.



Keene Dimick at his vineyard in the Napa Valley.

Although some of the existing instrument companies extended their portfolios with the addition of GC, new companies also were formed to service chemists engaged in GC. Of these, Wilkens Instrument & Research, commonly known as Aerograph, probably was the most well known. This company, founded in 1956 by Keene P. Dimick, became the biggest success story in the field.

Keene Dimick received his Ph.D. in chemistry from Oregon State University (Corvallis, Oregon). After graduation, he joined the Western Regional Research Laboratory of the U.S. Department of Agriculture (USDA) in Albany, California, where his work included the study of the natural aroma components of strawberries. It took him six years of hard work to finally obtain some 35 mL of oil, representing the essence of the fruit, from 30 tons of strawberries. In 1953, after hearing about the work of James and Martin, he built a gas chromatograph and used it for the investigation of this oil. His results were so encouraging that in 1956 he decided to start to build and sell gas chromatographs. This was done in cooperation with his brother-in-law, Ken Wilkens, an art teacher at the high school in Napa, California. Their company was incorporated on 14 December 1956 as Wilkens Instrument & Research Co. because at that time Keene still was working as a research chemist at the USDA laboratory.

The new company experienced phenomenal growth within a short time; its sales volume increased from \$60,000 in 1957 to \$3 million in 1962, and to \$8.5 million in 1965 (24). Two instruments, in particular, contributed to this success: the Aerograph Hy-Fi, introduced in 1961, and the Auto-prep (an analytical GC with preparative capability), introduced in 1962. Another factor in this success was the company's continuous communication with the user. The *Aerograph Research Notes* (the quarterly publication of the company, which was mailed to tens of thousands of chromatographers) was written almost completely by Keene, and through it he talked directly to the chemists in their own language. Keene was a genius in explaining even complicated questions in a simple way. I still remember the issue introducing the electron-capture detector. There was a simple chromatogram on the front page, showing the determination of traces of chlorinated pesticides, with the title in large, bold-face characters, "Have you ever seen a picogram?"

Keene sold the company in the spring of 1966 to Varian Associates for \$12 million, and it continued as Varian's Aerograph division. However, Keene did not retire — after all, he was only 51 years old — but started new ventures. He developed an exercise machine based on a stationary bicycle, automated to stimulate actual road conditions, and he became the founding trustee of the Institute for Science and Medicine, set up and directed by Linus Pauling, the 1954 winner of the Nobel Prize in Chemistry. In addition, he pur-

chased a 65-acre vineyard in California's Napa Valley; its grapes are used by the Robert Mondavi winery to produce high-quality Chardonnay wine (25). As with everything that Keene touched, this became a successful and rewarding enterprise.

I knew Keene since the early 1960s and always admired his openness and his esteem of good science. He was one of those pioneers who had a key role in building the scientific instrument industry.

J. Calvin Giddings (1930–1996)

In the mid-1950s, GC was just five years old. Although James and Martin presented a theoretical treatment, it did not deal with the details. Thus, optimization of the column and analytical conditions mostly was empirical. Then, suddenly, a young scientist just out of graduate school started to publish brief, concise papers providing an in-depth study of the chromatographic process. This young scientist was Calvin Giddings.

Calvin received his Ph.D. in 1954 from the University of Utah (Salt Lake City). His thesis work was carried out under the tutelage of Henry Eyring, the great physicochemist. His subject was topics in chemical kinetics, in which he already tackled some chromatographic problems; in fact, “. . . and in chromatography” was added to the title of his final thesis indicating that it also dealt with the kinetics of chromatography. These questions fascinated him so much that, as stated in an autobiographical discussion, he “became irreversibly adsorbed to chromatography” (26). His first paper, co-authored with Eyring and published in 1955, already had the ambitious title, “A Molecular Dynamic Theory of Chromatography” (27), and in the next years it was followed by a number of theoretical papers formulating the random walk model of chromatography and applying Giddings’ nonequilibrium theory to the description of various chromatographic processes. Quoting again from his autobiography (26), “for me this work was like laying the bricks of a satisfying edifice, typing diverse chromatographic results to dynamical roots and leading to predictions of efficiency.” The culmination of these investigations over a decade was his fundamental book published in 1965 (28).

In the mid-1960s, Cal turned his attention to the effects of pressure and tempera-

ture on the solubilizing power of the carrier gas. His pioneering work on *dense gas chromatography*, employing pressures as great as 2000 atm, became the precursor of today’s supercritical fluid chromatography. As a continuation of this work, he developed a new elution technique for the separation of colloidal samples. This technique is based on an entirely new separation principle that he termed *field-flow fractionation* (FFF). From the end of the 1960s he devoted most of his attention to FFF and developed it into a separation technique now used widely in fields ranging from medicine to environmental studies. He was the founder and the director of the FFF Research Center at the University of Utah, which spearheaded in this research.

When speaking about chromatography, scientists often imply that it is a unique technique and forget that it is only one of many interrelated separation techniques. This was recognized early by Cal, and in 1966 he founded the journal *Separation Science* to provide a forum for the various separation techniques to be handled under one roof. His persistent efforts to emphasize the need for a unified treatment culminated in 1991 in his book *Unified Separation Science* (29). Today, increasing numbers of universities are establishing courses on separations science, and this trend is mainly a result of Cal’s activities.

Until now I only spoke about Cal the scientist; however, he was also an outdoorsman, an excellent skier, and a passionate kayaker. For years, he served as the president of the American Whitewater Association and his expeditions in kayaks in 1974 and 1975 to explore the Apurimac River in Peru, the headwaters of the Amazon River, are legendary. His book describing these expeditions finally was published just a few months before his death; it is a most fascinating story (30).

I first met Cal at the 1960 Gordon Conference, and in the subsequent years we met at the many meetings that took place almost every six months. In 1978, we received the M.S. Tswett Award together at the International Symposium on Advances in Chromatography, in St. Louis, Missouri. We both were early birds and usually had breakfast together at these meetings while the others were still asleep. Besides discussing science, Cal told me about his outdoor activities, the Utah wilderness, and his exploration of the Apurimac River. I am not an outdoorsman, and some of his stories were like the stories I read in my



Calvin Giddings (left) receiving the Tswett Chromatography Award in 1978.

youth about the Wild West and the early American pioneers.

Cal was at the height of his professional career when he suddenly was stricken by cancer. He always had been a fighter, and he was brave in this final battle.

Through his friends he received some still-experimental drugs — some even from overseas — and for a time, his illness was slowed. However, finally, he succumbed to the deadly disease. With his death, one of the great pioneers of chromatography has passed away.

M.J.E. Golay (1902–1989)

“Few major contributions that can be traced to a single man have had such a profound influence on so many people” (31). This is how the obituary published in *Analytical Chemistry* characterized Marcel Golay, the inventor of open-tubular (capillary) columns. Indeed, this is true: today, more than 90% of GC analyses are carried out using such columns and without them, the analysis of complex samples would be impossible.

Marcel J.E. Golay was born in the French-speaking part of Switzerland and studied at the *Eidgenössische Technische Hochschule*, the Federal Technical University (Zurich), at that time recognized as the best technical school in Europe. He graduated in 1924 as an electrical engineer and was recruited by Bell Telephone Laboratories, with whom he spent four years in New Jersey. Then, he enrolled in the department of physics of the University of Chicago to pursue graduate studies. He received his Ph.D. in nuclear physics in 1931 and then joined the U.S. Army Sig-

nal Corps Laboratories (Fort Monmouth, New Jersey), one of the largest American research centers in electronics and communications. Golay spent almost one-quarter century there, advancing to the position of chief scientist of the components division. In 1955, he retired from the Signal Corps and became a consultant in instrumentation to the Perkin-Elmer Corp. and in electronics to the Philco Co. In 1962–1963, he was a guest professor at the University of Technology (Eindhoven, The Netherlands). From 1963 until the day of his

death, he was a senior scientist at Perkin-Elmer.

Golay's main contribution to GC is the invention of capillary columns and the development of the theory describing the interaction between column characteristics, operational parameters, and column performance. These columns, together with ionization detectors, can be considered the most important milestones in the evolution of GC since the contribution of James and Martin. However, his achievements in chromatography were not restricted to



Marcel Golay in 1988.

these columns, and he was involved in studying the theory and practice of preparative chromatography, various theoretical questions related to the movement of the solute band in the column, and also high-speed liquid chromatography. In addition, he made major contributions to infrared (IR) and nuclear magnetic resonance (NMR) spectroscopy and to radio communications. He created the concept of complementary codes that still are used worldwide in the precision navigation systems, and in information theory his results are widely used in pattern recognition (32).

In spite of his advanced age he was in full command of his mental capabilities and carrying out research until the last moment of his life. He was conducting very difficult experiments on the design of an improved open-tubular column type and preparing a major lecture on chromatography under turbulent flow conditions, based on a detailed theoretical treatment augmented by some experimental work carried out on his request at the University of Technology, when death took him away.

I knew Marcel for more than 30 years and, particularly during the last decade of his life, I had the privilege to be fairly close to him. He was 20 years older than me, but he never aged: in many aspects, he behaved like a young person. His broad interests were amazing, and this was true not only in science but in every aspect of life. A discussion with him always was an exciting experience, and one could always learn something new from him. He can be considered as one of the last true polyhistorians of science and as one of the greatest representatives of the theory of chromatography.

References

- (1) A.T. James and A.J.P. Martin, *Analyst* **77**, 915–932 (1952).
- (2) A.T. James and A.J.P. Martin, *Biochem. J.* **50**, 679–690 (1952).
- (3) L.S. Ettre and A. Zlatkis, Eds., *75 Years of Chromatography — a Historical Dialogue* (Elsevier, Amsterdam, 1979).
- (4) G.A. Stahl, *J. Chem. Ed.* **54**, 80–83 (1977).
- (5) L.S. Ettre, *LCGC* **19**(5), 506–512 (2001).
- (6) G.A. Olah, *A Life of Magic Chemistry* (John Wiley & Sons, New York, 2001), p. 170.
- (7) A.T. James, *Chromatographia* **40**, 235–236 (1995).
- (8) A.J.P. Martin, in *Gas Chromatography 1962*, M. Van Swaay, Ed. (Butterworths, London, 1962), pp. xxvii–xxxiii. (Reprinted in *Chromatographia* **51**, 255–259 [2000].)
- (9) S.R. Lipsky, *Chromatographia* **13**, 201 (1980).
- (10) F. Bruner, Ed., *The Science of Chromatography* (Elsevier, Amsterdam, 1985).

- (11) L.S. Ettre, *Chromatographia* **40**, 117–118 (1995).
- (12) F. Bruner, *Gas Chromatographic Environmental Analysis: Principles, Techniques, Instrumentation* (VCH Publishers, Weinheim, Germany, 1993).
- (13) F. Bruner, "Recent Developments in Capillary GC and HPLC," paper presented at the 18th International Symposium on Capillary Chromatography, Riva del Garda, Italy, 20–24 May 1996.
- (14) O. Bobleter, *Chromatographia* **30**, 471–476 (1990).
- (15) G. Oberkofler, *Erika Cremer — Ein Leben für die Chemie* (Studien Verlag, Innsbruck, Austria, 1998).
- (16) E. Cremer, *Chromatographia* **9**, 363–366 (1976).
- (17) F. Prior, Ph.D. thesis, University of Innsbruck, Austria, June 1947.
- (18) R. Miller, Ph.D. thesis, University of Innsbruck, Austria, June 1950.
- (19) E. Cremer and F. Prior, *Z. Elektrochem.* **55**, 66–70 (1951).
- (20) E. Cremer and R. Müller, *Z. Elektrochem.* **55**, 217–220 (1951).
- (21) O. Bobleter, *Chromatographia* **43**, 444–446 (1996).
- (22) S. Dal Nogare and R.S. Juvet, *Gas-Liquid Chromatography: Theory and Practice* (Interscience, New York, 1962).
- (23) E.R. Adlard, *Chromatographia* **38**, 415 (1994).
- (24) L.S. Ettre, *J. Chromatogr. Sci.* **15**, 90–110 (1977).
- (25) K.P. Dimick, *LCGC* **8**(10), 782–786 (1990).
- (26) J.C. Giddings, in *75 Years of Chromatography — A Historical Dialogue*, L.S. Ettre and A. Zlatkis, Eds., (Elsevier, Amsterdam, 1979), pp. 89–98.
- (27) J.C. Giddings and H. Eyring, *J. Phys. Chem.* **59**, 416–421 (1955).
- (28) J.C. Giddings, *Dynamics of Chromatography* (Marcel Dekker, Inc., New York, 1965).
- (29) J.C. Giddings, *Unified Separation Science* (John Wiley & Sons, New York, 1991).
- (30) J.C. Giddings, *Demon River Apurimac* (University of Utah Press, Salt Lake City, Utah, 1996).
- (31) G. Guiochon and L.S. Ettre, *Anal. Chem.* **61**, 922A–923A (1989).
- (32) L.S. Ettre, *J. High Resolut. Chromatogr.* **10**, 221–230 (1987).

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