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OBITUARY

In Memoriam: Klaus Biemann (1926–2016)

Klaus Biemann passed away on June 2, 2016, at the age of 89 after a short illness. He was born in Innsbruck, Austria, in 1926. Following a family tradition, he began his studies to become a pharmacist. However, he found organic chemistry more interesting and went on to receive a Ph.D. degree in this field from the University of Innsbruck, Austria, in 1951, where he studied under the direction of Professor Hermann Bretschneider. After completing his degree, he continued as a researcher in the same department, but he soon became restless and was able to take advantage of the new Fulbright Fellowships program, which brought him to the United States for his first − albeit short − stay in 1954, when he carried out research with Professor George Büchi in the Department of Chemistry at the Massachusetts Institute of Technology. This visit introduced him to modern, synthetic (natural products) chemistry and fundamentally altered the course of his career. He returned to Austria as an instructor in organic and pharmaceutical chemistry at the University of Innsbruck but found that he was going to have a difficult time becoming an independent investigator there. In 1955, Professor Büchi learned of this situation and offered him a postdoctoral position in his laboratory at MIT. Klaus accepted and moved back to MIT, where he was to remain for his entire career.

Klaus' progression in the Department of Chemistry was rapid. He moved through the ranks with appointments as a Research Associate in 1955–1957, an Instructor (at that time the starting position toward tenure) in 1957–1959, an Assistant Professor in 1959–1962, an Associate Professor in 1962–1963, and he became a Professor in 1963 at age 37. He became a Professor Emeritus in 1996, after 45 productive years as a scientist and as a mentor for over 130 doctoral students and postdoctoral associates.

Klaus Biemann in 1965 at a Friday afternoon research group "meeting." Photograph by John M. Hayes; used with permission.

Early Life

But this is not the whole story. Knowledge of what Klaus faced during his early life and the choices he made as he began his academic and research career reveals what led him to focus his life work on the mass spectrometry of organic molecules and indicates his life-long ambition to forge his own scientific path. Even before he was able to attend even college, Klaus was drafted into the German Army because of the desperate need for troop replacements towards the end of World War II. In 1945, Klaus was close to the eastern front when the war ended. In his own words:

> "The last day of World War II found me in a small village north of Dresden (Germany). A friend and I decided to avoid, at any cost and risk, falling into the hands of the Soviet Army. On that night, we took off on bicycles with a loaf of bread, towards the southwest. During the next night, we abandoned the bicycles and crossed the river Elbe just downstream from Dresden in a small boat and continued on foot towards the mountains and what had just become again Czechoslovakia. That region had been occupied by American forces a few days earlier but was at that time being turned over to the Russians in accord with the agreement the Allies had signed just 3 months earlier at Yalta. … So we quickly turned west to get over the line into the region controlled by the Western Allies. On the fourth day of our hike, we bode each other goodbye, my friend going north while I turned south, hoping to reach a tiny village near Innsbruck (Austria) where my mother, with my two older sisters, had sought refuge before Vienna was occupied by the Soviet Army. This was a 600 km walk, along country roads, sometimes through woods and fields, to by-pass occasional checkpoints. These were set up because in those days

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immediately after the end of the war, people were not allowed to move far beyond their communities. There was nothing to eat, except an occasional raw egg or a boiled, but cold, potato obtained from a kind, understanding farmer or his wife. But that was the least of my concerns.

"It happened to be Mother's Day when I reached the village after a 2-week hike. My family was indeed there, in the home of my mother's friend, who had offered a place to stay in those turbulent times." [1]

Natural Products Training

His postdoctoral research at MIT in the mid-1950s brought Klaus into the world of synthetic organic chemistry and the structural characterization of natural products. His initial project in the Büchi laboratory was to synthesize a natural product called muscopyridine, a terpenoid excreted by musk deer. Büchi had hypothesized a structure based on biogenic grounds (a fairly new concept at the time), and Klaus was to complete the 11-step synthesis, which had been started by a graduate student, and to prove the identity of the synthetic compound by comparison with the natural material. He described this work as follows:

"Any synthesis of a substance that is to prove a proposed molecular structure has to be very rigorous if it is to serve this purpose beyond any reasonable doubt. The product of each of the 11 individual chemical reaction steps had to be characterized. This required careful purification followed by measuring the compound's elemental composition. For that, a small amount (a few milligrams) of it has to be burned to carbon dioxide, water, and nitrogen, and these products carefully measured. Such analyses are performed by specialists to whom one submits a sample and waits (and pays) for the results.

"After a few months of careful work, I reached the last step one day, and it was late at night that I was ready for the crucial test—the 'mixed melting point'—of my synthetic product with a sample of natural muscopyridine. The mixture of the two melted indeed at the same temperature as the individual compounds: that [meant] that the two were identical, and the elaborate synthesis proved that the proposed structure was indeed correct!" [1]

Becoming an Analytical Chemist

The rapidity and quality of Klaus' postdoctoral work was noticed by the Chemistry Departmental Chairman, Professor Arthur C. Cope, who offered Klaus a position as an Instructor in the division of Analytical Chemistry. Klaus was happy to accept this appointment —in part because he had just married Vera Themistocles (an American woman)—but he faced a substantial academic challenge from many points of view. The mid-1950s marked the beginning of remarkable advances in spectroscopy (IR, UV, and even NMR) and their application to organic chemistry. However, Klaus' training and experience was in organic chemical synthesis and the structural characterization of natural products, and he had little experience in these new technologies. In addition, he had to become a full-fledged analytical chemist. In considering his own research direction in this independent academic position and thinking about attracting sources of research funding, Klaus looked back to some experiments he had carried out in Innsbruck on the derivatization of carboxylic acids.

"One idea was quite ambitious and interesting. Towards the end of my years in Innsbruck, I had worked out a chemical reaction that converted an organic acid like acetic acid to a very stable five-membered ring consisting of two carbon and three nitrogen atoms, called a 'triazole.' Although that work had been aimed at making compounds that may become pharmaceuticals, I now thought of an entirely different use: the determination of the amino acid sequence of peptides and, ultimately, of proteins." [1]

Peptide and protein sequencing would occupy his interest for the rest of his career. However, a remarkable event took place at this time that changed the fundamental direction of his work. This was a chance attendance at a conference in Chicago.

"While I was still working in Büchi's group, Firmenich [who supported my work in Büchi's laboratory] wanted to know what was going on at a flavor and fragrances conference held in Chicago in the spring of 1957. Rather than sending someone over from Geneva, they asked me to attend and provide a report. I gladly agreed, not so much because I was interested in the talks … but more because I could take my first ride on an airplane! The only talk I still can remember was by W. H. Stahl, from the Quartermaster Corps Laboratory in Natick, Massachusetts (not far from Cambridge), who spoke about the identification of flavors from various fruits. They were all small molecules, like acetone, methyl butyrate, butyl acetate, etc. [which he had identified] by 'mass spectrometry.' I had never heard of this method, which apparently was widely used in the petroleum industry for the quantitative analysis of crude oils and gasoline. Stahl showed that he could reliably identify these small, very volatile molecules by matching their fragmentation pattern ('mass spectrum') with that of known compounds." [1]

Klaus spent hours in the library reading about this new technology. He read about the work of Fred McLafferty (at that time with Dow Chemical's Eastern Research Laboratory in Framingham, MA), who was publishing a series of papers on

the use of mass spectrometry to reveal the chemical structures of small organic molecules. Klaus also became aware of the work of Einar Stenhagen and Ragnar Ryhage in Sweden, who were using mass spectrometry to elucidate the structures of fatty acids. He became convinced that mass spectrometry would be perfect for the structural analysis of natural products such as peptides (and later indole alkaloids). He recognized almost immediately the remarkable structural information content that was inherent in electron-ionization mass spectra. With this information, he was able to convince Professor Cope to purchase a mass spectrometer ($50,000 at the time) for his studies, and a CEC 21-103 was installed in late 1958. By the early 1960s, Klaus had discovered how to succeed in obtaining funding from the United States government, and he began a life-time of liberal external funding for his research laboratory. In fact, he was able to purchase a CEC 21-110 high resolution mass spectrometer after obtaining NIH grant support and demonstrating how important mass spectrometry was for organic structural studies. To deal with the flood of data coming from this high resolution instrument, Klaus had to learn about high-speed computing, which at that time was well supported by the MIT administration. Once he discovered the power of computerizing mass spectrometry, his entire approach to mass spectrometry (and analytical chemistry) changed.

Klaus' early work with mass spectrometry had two goals: (1) sequencing proteins and (2) determining structures of indole alkaloids. He pursued these two mega-projects more or less in parallel, thinking that if one or the other failed he would still have something to publish. The sequencing of proteins evolved into a 40-year project aimed at enzymatically and chemically modifying proteins such that he could obtain the mass spectra of the derived peptides, read out their sequence information, and reassemble the peptide sequences in the proper order to yield the full protein sequences. The project on the structural elucidation of indole alkaloids gave more immediate results and made Klaus famous. Here is the story.

> "While working on the synthesis of muscopyridine, I had learned much about other nitrogen containing natural products: alkaloids. The elucidation of the structure of these rather complex … substances, which are produced mainly by plants, had been an intellectual challenge to chemists for many decades. … In their quest to find new drugs, pharmaceutical companies were always looking for new alkaloids by extracting them from plants. The ones showing interesting biological activities were then studied in detail. … Many academic and industrial laboratories were feverishly working on the structures of the many newly isolated alkaloids. But this work was tedious and slow. … It occurred to me that this task could be greatly simplified by the use of mass spectrometry, and I set out to try it on a relatively simple case. I knew from the literature that three research groups had independently suggested a structure for the alkaloid sarpagine based on biogenetic considerations. … However, more than 3 years had passed without a further word that this had been accomplished.
>
> "It so happened that the structure of ajmaline had been determined by Professor Robert B. Woodward at Harvard University, just up the river from MIT. In the course of that work, he had made the degradation product [I needed to prove the structure of sarpagine]. I knew him very well, and he was happy to provide me with a sample. Woodward, the preeminent natural products chemist of that time … was, of course, very curious to learn how my novel approach to structure determination would work out.
>
> "The mass spectra of the two compounds indeed exhibited the exact same fragmentation pattern, with all peaks shifted by the predicted mass difference. … However, for a novel methodology without previous precedent, rigorous demonstration of its validity was necessary. So I obtained a pair of indole alkaloids with a different polycyclic system. Their mass spectra also showed an identical fragmentation pattern, but it was very different from that of the sarpagine/ajmaline pair. This method of structure correlation of alkaloids (and then also other compound classes) became known as the 'mass spectrometric shift technique'.
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> "Before this work appeared in print, I presented it at the biannual conference on natural products organized by the International Union of Pure and Applied Chemistry (IUPAC) held in Australia in August of 1960. My talk, generically entitled 'Application of Mass Spectrometry to Natural Products' … was scheduled for a relatively small lecture room. But word about my work had gotten around through Woodward and others, and the room was packed so that people had to sit on the stairs. … For the next two IUPAC conferences, held in Brussels, Belgium (1962) and Kyoto, Japan (1964), I would already be invited as a plenary speaker. This international recognition speeded my promotion to tenured full professor by 1963.
>
> "This work on alkaloids and related topics made mass spectrometry, almost overnight, well known to organic chemists. A book I published in 1962, entitled *Mass Spectrometry, Organic Chemical Applications*, was written for that readership and described many of the practical tricks we had developed but could not be included in journal publications. The book became a classic text. Soon every respectable chemistry department in the United States wanted to own, or at least have access to, such an instrument." [1]

GC/MS and GC/MS Computer System

Klaus' work with indole alkaloids often required their separation by gas chromatography, at that time a relatively new instrumental

technique. The compounds were then cold-trapped in a melting point capillary inserted into the end of the GC column. It did not take long for this approach to become tedious, and Klaus looked for a better approach. He soon developed a carrier-gas separator, which was a fritted-glass tube surrounded by a vacuum. When the chromatographic effluent entered the tube, the carrier gas (helium) effused through the fritted glass, but most of the compound of interest was transmitted to the mass spectrometer. This was one of the first approaches to the now common tool of gas chromatographic mass spectrometry (GC/MS). Klaus' applications of GC/MS were largely qualitative, so he implemented this system on his high resolution mass spectrometer that did not require scanning over the mass range but could quickly record complete mass spectra as individual images on a photographic plate. Using high resolution mass spectrometry for his first GC/MS experiments allowed him to obtain the biggest bang for the buck. Having experience with computing as a tool for "reading" and interpreting these high resolution mass spectra, it did not take long before he computerized low resolution GC/MS too.

> "Once we had begun to use our GC/MS system, we realized that it would be [easy] to keep the mass spectrometer scanning continuously [producing a spectrum] every few seconds during the entire gas chromatographic separation (15–60 minutes). … To avoid the piling up of reams of recording paper, we decided to accumulate the spectra directly in a computer. Thanks to the National Institutes of Health, I had acquired an IBM 1800 computer in 1966, which was ideally suited for this purpose. With its accessories (tape drives, disk drives, line printers, etc.) it occupied an entire room, although its capacity and speed [were] much less than today's simple laptop. However, for its time it was on the cutting edge and what we needed to develop all the data acquisition, processing, and interpretation software required. It served as the basis of the commercial systems used for years to come." [1]

Meteorites, Moon Rocks, and Mars

Klaus extended his research beyond the Earth itself. In the early 1970s, Klaus was heavily involved in the mass spectral analysis of lunar material returned by the Apollo missions. In 1976, Klaus led a scientific team that sent a miniaturized mass spectrometer to Mars as part of the Viking Mission to look for organic compounds in the surface of the Red Planet. Klaus described his decades of participation in what is commonly called space research, beginning in 1963, as quite unrelated to his work in organic chemistry and biochemistry. "However, it required expertise in organic mass spectrometry, and I felt I should get involved." [2] He described it as "scientific charity," but also remarked that it was an unforgettable experience. This he largely attributed to Viking's unique team environment and to the mutual appreciation that developed over the years of planning, and then being together at the Jet Propulsion Laboratory during the landed mission. He enjoyed the camaraderie that developed among the scientists of various disciplines, all working toward a common goal: the understanding of our neighboring planet.

Klaus' interest in extraterrestrial organic compounds originated when he was helping Professor Carl Djerassi install a mass spectrometer at Stanford. In his own words:

> "One day in February 1961, while I was in Carl Djerassi's lab, Joshua Lederberg, Professor of Biology at Stanford University, stopped by. In the course of conversation about mass spectrometry, he asked me whether I thought that this method could be used to detect and identify organic compounds in the surface material of Mars. I thought about it briefly and then replied confidently in the affirmative; thus began my involvement in space research. I began to think about how one could obtain mass spectra of traces of organic compounds embedded in very dry soil, remotely on another planet. Heating the sample directly into the ion source was the simplest method. The ruggedness of a TOF [time-of-flight] MS lent itself best to such experiments. I quickly wrote an application for a research grant from the National Aeronautics and Space Administration (NASA) asking for a Bendix TOF-MS; it was approved and the instrument was installed in early 1962." [2]

To prepare for analyzing the lunar and Mars samples, Klaus studied the organic compounds in meteorites using high resolution mass spectrometry. The idea was to heat the samples directly into the ion source of a mass spectrometer using the direct insertion probe. A relatively large sample of ground meteorite was inserted into the instrument's ion source through the direct probe and heated in stages. This device also greatly extended the ability of mass spectrometry to analyze poorly volatile organic and biological compounds and resulted in some of the first papers on oligonucleotides, free amino acids, and carbohydrates.

Peptide Sequencing Revolution

While all of this was going on, Klaus had continued his work on sequencing peptides and eventually proteins. It was in this area that Klaus is perhaps best remembered for his groundbreaking research advances in biochemistry. By 1960, he had worked out the conversion of peptides to their polyamino alcohols using $LiAlD_4$, found that these derivatives were volatile enough to be separated by GC/MS, and determined that they preserved the amino acid sequence information of the original peptide. The first protein to be sequenced was monellin, which originates from a South African plant and had potential for use as a sweetening agent; its subunit B had been sequenced by the Edman method (see below) but the 44-residue subunit A had not yielded to this strategy. The success of Klaus' approach culminated in 1979 with the announcement of the complete amino acid sequence of bacteriorhodopsin, an

extremely hydrophobic, 248-residue membrane-associated protein, in one of Klaus' most cited papers that resulted from a collaboration with Har Gobind Khorana, an MIT colleague whose group had isolated the protein.

> "Demonstrating a principle and applying it to practical cases are, however, two different things. So we spent the next few years on the improvement and refinement of the methodology. It had to work with the very complex mixtures produced by the degradation of a protein using acid or enzymes at the level of a few milligrams of starting material yielding only micrograms of each peptide. Here the high sensitivity of the mass spectrometer was of importance, combined with the ability of gas chromatography to separate very complex mixtures in a matter of 30–60 minutes. The development of our GC/MS system described above greatly facilitated this task. Improvements in the chemistry extended our methodology to hexapeptides, which facilitated protein sequencing.
>
> "Other protein sequencing research did, of course, not stand still either. Pehr Edman in Sweden … developed a chemical method for the stepwise removal and identification of one amino acid after the other from the 'amino end' of a protein. Once that approach had been automated and was commercially available, most protein sequencing was done that way. However, there were a number of situations in which it did not work. For example, if the amino end is acylated (chemically blocked), which is the case for many mammalian proteins, the first amino acid cannot be removed and the process cannot start. For our mass spectrometric approach, this was no problem but, rather, a simplification because the first step in our conversion to the more volatile amino alcohols was the acetylation of the amino group anyway.
>
> "We were often asked not only to sequence these blocked peptides but also to determine the structure of the blocking group, which practically 'fell out' of the mass spectrum. For certain proteins, particularly those that span cell membranes, a combination of the Edman method and ours was most effective. The determination of the structure and function of rhodopsin, the protein occurring in the retina and involved in vision, is one example.
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> "Soon thereafter it became possible to determine the sequence of nucleotides in DNA and, thus, of the genes that code for the sequence of amino acids in proteins. At the outset, DNA sequencing was subject to many errors. For example, missing only one single nucleotide in the many hundreds that make up the gene completely changes the derived amino acid sequence to an erroneous one. However, using our 'GC/MS' methodology to quickly determine a few short amino acid sequences from the corresponding protein, we could readily detect and correct such errors with relatively little effort. Thus, in the late 1970s and early 1980s, we determined, in collaboration with a number of DNA sequencing laboratories, the structure of quite a few so-called 'aminoacyl-tRNAsynthetases' proteins 500 to almost 1000 amino acids long." [1]

Another step forward came in the 1980s, with the development of fast atom bombardment (FAB) mass spectrometry developed in the laboratory of Michael Barber in Manchester, UK. This ionization method produced a beam sufficiently stable that the molecular weights of much larger peptides could be measured, and their molecular ions could be selected and fragmented to ions that provided information on the amino acid sequence of the peptide. Klaus immediately implemented FAB on one of his existing instruments and shortly thereafter had a JEOL, four-sector, high-performance tandem mass spectrometer constructed to fully exploit this advance. With this methodology, he made rapid progress in the development of software for the interpretation of the resulting spectra and in the sequencing of a very broad range of biologically important proteins.

> "Over the past two decades, instrumentation for mass spectrometry has greatly advanced. In combination with the now much more reliable DNA sequencing, which led to the delineation of the entire human genome and fast computational methods, the identification of proteins in biological systems has become fast and routine. Because the proteins originally produced in the cell along the genes must be 'activated' by shortening and/or chemical modification of certain amino acids, their final number is much greater than that of the corresponding genes. These structurally modified proteins are nowadays identified and characterized almost exclusively by mass spectrometric techniques. The studies of the detailed structure of the proteins in a cell and their biological significance now have even their own name: 'proteomics'." [1]

The importance of mass spectrometry to the field of proteomics cannot be overemphasized. Klaus' pioneering work, starting in the 1950s and extending over the next 40 years, enabled the revolutionary impact of proteomics seen in recent years.

The "MIT School of Mass Spectrometry"

Klaus was always proud of training several generations of mass spectrometrists, and in 1994, he put together a

list of all of the students and post-doctoral associates who had passed through his laboratory at MIT [3]. That list has been updated and is appended here. These people, in turn, have trained more generations of mass spectrometrists, and Klaus' influence lives on.

"With Klaus Biemann's passing, science has lost a true hero," says Harry Hertz, former graduate student in the Biemann laboratory and Director Emeritus of the Baldrige Performance Excellence Program at the National Institute of Standards and Technology. "When each of us joined Klaus' research group, we quickly learned that we had joined something extraordinary. Klaus was a great mentor; he challenged us to imagine and 'strongly encouraged' us to deliver. It was a special time for each of us. We discovered the excitement of scientific research and the power of collaboration. We were truly a research group. But what made it even more special was Klaus, the person. He was a man who taught us about scientific integrity and brought the highest regard for each of us as a person to our interactions with him and each other. We achieved because we were in an environment of greatness, with Klaus as our guide."

"With his students and postdocs, Klaus was simultaneously formal, demanding, infallibly supportive, and an unfailing source of good humor," says John Hayes, a former graduate student and scientist emeritus of the Woods Hole Oceanographic Institution. "He inspired do-or-die effort and respect that came from the heart as well as the mind. Among his many honors, this may be the greatest."

Another graduate student from the Biemann laboratory, Ronald Hites, Distinguished Professor at Indiana University, says, "Klaus taught all of us who passed through his research group how to do research and, more importantly, how to communicate our work—keep to a simple story and focus on the big picture. He was always supportive throughout our careers."

Catherine Costello, William F. Warren Distinguished Professor and Director of the Center for Biomedical Mass Spectrometry at Boston University, who was Klaus' colleague for more than 20 years at MIT, points out, "His impact on engaging scientists in adjacent fields to utilize mass spectrometry resulted from his constant outreach to other chemists, to biologists, and to those in the medical professions, to identify areas of research where mass spectrometry could make a novel and unique contribution and to drive the development of mass spectrometry systems to accommodate those needs. He set up the first NIH Research Resource in 1966 to make these techniques available to the community, and this center continued to lead technological developments and applications for 30 years."

Robert Murphy, Distinguished Professor of Pharmacology at the University of Colorado Medical School, recalled, "Klaus taught us how to look at data, how to generate hypotheses, how to think clearly but

Table 1. List of doctoral students and post-doctoral associates, who have "graduated" from the "MIT School of Mass Spectrometry" sequenced by the year when they left MIT. Some of these scientists were both doctoral students and post-docs in Klaus Biemann's group, and some post-doctoral associates stayed on as, eventually, senior scientific staff. An asterisk (*) indicates that the person is known to be deceased

Fritz Gapp, post-doc 1959
Josef Seibl, post-doc 1960
Margot Friedmann-Spiteller, post-doc 1961
Gerhard Spiteller, post-doc 1961
Alma L. Burlingame, Ph.D. 1962
Gottfried G. J. Deffner, post-doc 1962
Helga Diechti-Vetter, post-doc 1962
Walter Vetter, post-doc 1962
Wolfgang Benz, post-doc 1963
Don C. DeJongh,* post-doc 1963
David B. MacLean, post-doc 1963
James A. McCloskey, Ph.D. 1963
Bhupesh Das, post-doc 1964
Chris Falshaw, post-doc 1964
William Hargrove, post-doc 1964
Walter J. McMurray, post-doc 1964
John L. Occolowitz, post-doc 1964
Ute S. Richter, post-doc 1964
Wilhelm J. Richter,* post-doc 1964
Hans Achenbach, post-doc 1965
Georg E. Albers-Schönberg, post-doc 1965
Peter Bommer, post-doc 1965
Shigenobu Okuda, post-doc 1965
Heinrich K. Schnoes, Ph.D. 1965
Paul Vouros, Ph.D. 1965
J. Throck Watson, Ph.D. 1965
Brian R. Webster, post-doc 1965
Pierre Witz, post-doc 1965
Dominic M. Desiderio, Ph.D. 1966
John M. Hayes, Ph.D. 1966
Sukenari Tsunakawa, post-doc 1966
John Edgar, post-doc 1967
Agnes Jacquesy, post-doc 1967
Istvan Lengyel, post-doc 1967
Helmut Seidl, post-doc 1967
David W. Thomas, Ph.D. 1967
Lubomir Baczynsky, post-doc 1968
Fabrizio Bruner,* post-doc 1968
Conrad Cone, post-doc, 1968
August Curley, post-doc, 1968
Paul V. Fennessey, Ph.D., 1968
Ronald A. Hites, Ph.D., 1968
Donald F. Hunt, post-doc, 1968
Asher Mandelbaum, post-doc, 1968
Sanford P. Markey, Ph.D., 1968
David A. Evans, post-doc, 1969
Steven Hecht, post-doc, 1969
Robert Lovins, post-doc, 1969
Ray Salamone, post-doc, 1969
Shang-Wai Tam, post-doc, 1969
James R. Althaus,* Ph.D., 1970
Paul Donaghue, post-doc, 1970
Robert C. Murphy, Ph.D., 1970
M.-Mehdi Nafissi-Varchei, post-doc, 1970
Harry S. Hertz, Ph.D., 1971
George Preti, Ph.D., 1971
Milica Djuricic, post-doc, 1972
Hans-Joachim Förster, post-doc, 1972
James A. Kelley, Ph.D., 1972
Toshio Sakai, post-doc, 1972
Ferdinand Wirtz-Peitz, post-doc, 1972
John J. Dolhun, Ph.D., 1973
Arthur L. Lafleur, Ph.D., 1973
Vernon N. Reinhold, post-doc, 1973
Brian D. Andresen, Ph.D., 1974
Charles E. Hignite, Ph.D., 1974
Heinz Nau,* post-doc, 1974
Leonard C. C. Wan, post-doc, 1974
Tyrone R. Smith, Ph.D., 1975
Abdul M. Choudhury, post-doc, 1976
Guy P. Arsenault, post-doc, 1977

Pierre Borgeat, post-doc, 1977
Gail A. Hudson,* Ph.D., 1977
Olga Nakamine de Wong, Ph.D., 1977
Lan Kan Wong, Ph.D., 1977
Bary W. Wilson, post-doc, 1978
Robert J. Anderegg, Ph.D., 1979
John M. Lavoie, Ph.D., 1979
Michel A. Lhermitte, post-doc, 1979
Norman Mancuso, post-doc, 1979
Linda J. Anthony, Ph.D., 1980
Koka Jayasimhulu, post-doc, 1980
Linda Ng (Li), post-doc, 1980
Andrew Schkuta, post-doc, 1980
Walter C. Herlihy, Ph.D., 1981
Agnes M. Van Langenhove, Ph.D., 1981
Robert A. Bethem, post-doc, 1982
David A. Kidwell, Ph.D., 1982
Nancy J. LeGendre, Ph.D., 1982
Asao Murai, post-doc, 1982
Kin Sing Chiu, Ph.D., 1983
Steven A. Carr, Ph.D., 1984
Bradford W. Gibson, Ph.D., 1984
Julie A. Leary, Ph.D., 1984
Henrianna Y. Pang, post-doc, 1984
Thomas F. Dorsey, post-doc, 1985
W. Rodney Mathews, post-doc, 1985
Markus Zollinger, post-doc, 1985
Gunter Allmaier, post-doc, 1986
Mamoru Fujioka, post-doc, 1986
Hubert A. Scoble, post-doc, 1986
John J. Gagel, Ph.D., 1988
Richard S. Johnson, Ph.D., 1988
Achille Cappiello, post-doc, 1989
Bruno Domon, post-doc, 1989
Daniel B. Kassel, post-doc, 1989
Stephen A. Martin, Ph.D., 1989
Pierangela Palma, post-doc, 1989
Wade J. Adams, post-doc, 1990
Adam S. Plaziak,* post-doc, 1990
James E. Vath, Ph.D., 1990
Amit Ghosh, post-doc, 1991
Alain Jaquier, post-doc, 1991
Roland S. Annan, post-doc, 1992
Stephan Apfalter, post-doc, 1993
James E. Biller,* Ph.D., 1993
Yoon-Seok Chang, post-doc, 1993
Simin D. Maleknia, post-doc, 1993
Ioannis A. Papayannopoulos, Ph.D., 1993
Binghuang Wang, post-doc, 1993
Catherine E. Costello, post-doc, 1994
Kevin M. Downard, post-doc, 1994
Peter M. Gehrig, post-doc, 1994
Peter Juhasz, post-doc, 1994
Helene Perreault, post-doc, 1994
Joseph Zaia, Ph.D., 1994
Vladimir V. Papov, Ph.D., 1996
Chenhui Zeng, Ph.D., 1996
James A. Hill, Ph.D., 1997
Heinrich J. Köchling, Ph.D., 1998
Andrew Rhomberg, Ph.D., 1998

critically, but most importantly how to be a gentleman in all things. I was able to work side by side with him for many hours while we were setting up the mass spectrometer at the Lunar Receiving Laboratory, which was a remarkable experience."

Klaus' many awards and honors include the Benjamin Franklin Medal in Chemistry (2007), the Thomson Medal from the International Mass Spectrometry Foundation (1991), the Field and Franklin Award in Mass Spectrometry from the American Chemical Society (1986), the Fritz Pregl Medal of the Austrian Microchemical Society (1977), the Exceptional Scientific Achievement Medal from NASA (1977), and the Stas Medal of the Belgian Chemical Society (1962). He was elected to the National Academy of Science in 1993 and a fellow of the American Academy of Arts and Sciences in 1966. The American Society of Mass Spectrometry annually recognizes an early-career scientist's mass spectrometry achievements with the bestowal of the Biemann Medal, which was initially endowed by contributions from his former students and associates.

Klaus' wife, Vera, predeceased him in 2008. Klaus, Vera, and their two children, Hans-Peter and Betsy, were faculty residents at MIT's McCormick Hall (at that time the only women's dormitory at MIT) from 1967 to 1971. Klaus and Vera had four grandchildren.

James A. McCloskey
San Antonio, Texas
President ASMS 1978–1980

Ronald A. Hites
Indiana University
President ASMS 1988–1990

Robert C. Murphy
University of Colorado
President ASMS 1990–1992

Catherine E. Costello
Boston University
President ASMS 2002–2004

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