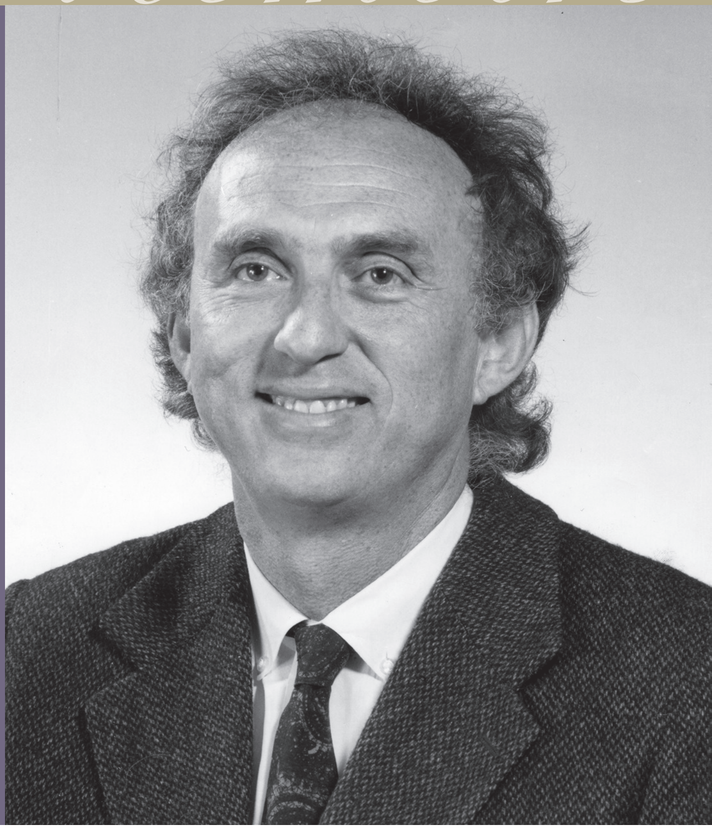
Martin L. Perl

1927–2014

BIOGRAPHICAL *Memoirs*



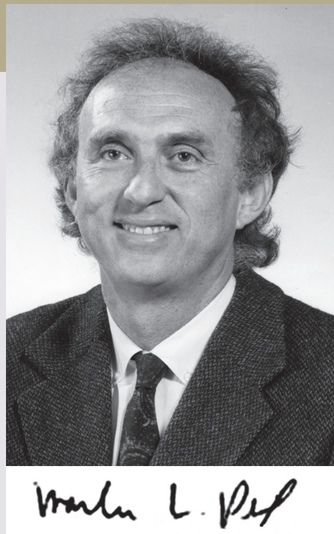
A Biographical Memoir by
Gary Feldman,
John Jaros,
and Rafe H. Schindler

NATIONAL ACADEMY OF SCIENCES

MARTIN LEWIS **PERL**

June 24, 1927–September 30, 2014

Elected to the NAS, 1981



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By Gary Feldman,
John Jaros,
and Rafe H. Schindler

Particle physicist Martin Lewis Perl was recognized worldwide for his discovery of the τ (tau) lepton. For that achievement he received the 1982 Wolf Prize and shared the 1995 Nobel Prize in Physics. He was also a Fellow of the American Physical Society and a member of the National Academy of Sciences (elected 1981).

Martin's distinctive approach to scientific investigation had its origins in his upbringing and in the influence of I. I. Rabi, his graduate advisor at Columbia University.

After coming to Stanford University in 1963, Martin sought to understand why there should be two and only two families of leptons: the electron and its associated neutrino; and the muon and the muon neutrino. His discovery of the τ provided evidence for a third family of fundamental leptons. The bottom quark was discovered shortly afterward at the Fermi National Accelerator Laboratory, providing evidence for a third family of quarks. Direct evidence for the τ neutrino came later, thereby completing the third lepton generation, while the discovery of the top quark in 1995 completed the third generation of quarks. These achievements established leptons and quarks as fundamental constituents of matter and, along with the fundamental forces, provided the experimental basis of the "Standard Model," our picture of how all matter is made up and how its components interact. Why there are three and only three families of leptons and quarks remains an unsolved mystery to this day.

Upbringing

Martin was born in New York City, the son of Russian-Jewish immigrants Oscar Perl and Fay Rosenthal[1] who as children had fled with their families the poverty and anti-Semitism prevalent in what was then the Polish part of Russia. Oscar and Fay were not very religious, and neither of them had been educated beyond high school, but both worked hard to move up into the middle class. Fay was a secretary and then bookkeeper in a firm of textile merchants, and Oscar was a clerk and salesman in a printing and stationery business. By the 1920s, when Martin's sister Lila and then Martin were born, Oscar had established his own company, Allied Printing, and the family was able to move into better and better Brooklyn neighborhoods. These locales were still "not the fanciest," in Martin's words, but "the schools were quite good." Allied Printing got the family through the Depression years.

Martin's parents' values, manifested by a strong and persistent work ethic and a firm belief in the importance of education, were firmly impressed upon him.

Both Martin and Lila were encouraged to get very good grades, and both of them were excellent students. Martin later reflected how painful it was for him to see how remote his parents were from his schools and teachers, in contrast to parent-teacher relations common today. He took this as an early lesson that he must make his own way in an impersonal and sometimes harsh world; that realization, he later found, was "good training for the world of research." In a similar vein, he learned to persevere through sometimes boring classwork, learning skills at which he wasn't particularly adept, simply because his parents demanded high grades. This too he considered effective training for doing research, where some drudgery is often required.

Growing up, Martin had two loves: books, and any and all things mechanical. An avid reader of everything from fiction to science, he was fortunate to live close to two public libraries, where he remembered always taking out the maximum number of books allowed. He also loved to read magazines like *Popular Science* and *Popular Mechanics*. Martin especially liked the popular science books by the British zoologist and statistician Lancelot Hogben: *Mathematics for the Millions* and *Science for the Citizen*. He never thought to buy his own books; this was something his parents would have considered extravagant. In later years, he compensated by surrounding himself with books, both at home and at work.

Martin's infatuation with things mechanical extended from cars, trains, and trucks to derricks and steamboats. He liked to make drawings of these and other such things and often built them from wood. He coveted his cousin's Erector Set and electric trains, and played with them frequently. He lamented not having his own, as they were items his parents would not consider buying. But after he grew up he filled his home and office with construction sets collected from around the world. At one point, he even started prototyping his own idea for a modern construction set, dubbed BIG-NUT. Like many-children with scientific leanings, he wanted a chemistry set, but that too was denied him for "reasons of safety."

Early education

Skipping grades, Martin graduated in 1942 from Brooklyn's Madison High School at the age of 16. Although he won the school's Physics Medal upon graduation, he never thought to become a physicist, or a scientist of any kind. He and Lila had been taught that to escape Brooklyn you had to use your education to "earn a good living." For him, this meant possibly becoming a doctor or a lawyer. But Martin and his parents took his aptitude for science, mathematics, and mechanics into account in deciding that he would study chemical engineering in college; his father had been convinced by clients in the chemical industry that there would always be a job in that field. So Martin entered the Polytechnic Institute of Brooklyn (now the New York University Tandon School of Engineering) and majored in chemical engineering. Although Martin had been exposed to classical physics in high school, and once again in his first years at college, he developed no fascination for it. Indeed, he deemed it a "dead field" compared to chemistry.

World War II interrupted Martin's education. His parents refused to let their 18-year-old son enlist in the Army, but they agreed to the Merchant Marines, where he became an engineering cadet at the U.S. Merchant Marine Academy in Kings Point, NY (on Long Island's north shore, about 20 miles east of New York City) in 1944. After leaving the Merchant Marines at the end of the war, Martin returned home to help his father at Allied Printing while waiting to reenter college. Ironically, it was then that he was drafted into the Army to serve an uneventful year stationed in Washington, D. C. He finally returned to school in 1947, and with the help of the G. I. Bill completed his B.A. in 1948 at the Polytechnic Institute, graduating summa cum laude. Years later, Martin credited his skills as an experimenter to the knowledge and experience he gained there.

It was also in 1948 that Martin met Teri Hoch, another Brooklynite, on a blind date.[2] Teri taught piano, as she had done while working on her Bachelor's Degree at Brooklyn College. She, like Martin, wanted desperately to escape Brooklyn and she sensed that Martin was someone who was "going somewhere." By the end of that first date they had fallen in love and decided to marry. The next day they met and braved a New York blizzard to walk to Martin's house where they broke the news to his parents. Martin, just shy of 21 years of age, had to get permission from them to marry. They approved, and the wedding took place on June 19th of that year, just a few days shy of his 21st birthday. Teri was to play a major role throughout Martin's life in helping him through all of his critical decisions. They remained close friends even after their separation in 1980 and subsequent divorce in 1988.

Martin's first real job was at the General Electric Company. He spent his first year there in an advanced engineering training program, and then he and Teri moved to Schenectady, NY, where he worked as a chemical engineer in a production facility of the G. E. Electron Tube Division. Because Martin had had little or no interest in radios and electronics while growing up in the 1930s, and had taken no college classes in modern physics, he needed to learn more of the physics of vacuum tubes for his work at G. E. So he enrolled at Schenectady's Union College, where he took challenging courses in advanced calculus and nuclear physics. It was only then, at age 23, that he was exposed to and fell in love with the subject matter of modern physics.

Martin attributed this passionate interest to the influence of a single professor, Vladimir Rojanski, a quantum theorist who taught physics at Union from 1935 until 1955. David Peak, another professor at Union, wrote, "Rojanski's lectures were so compelling that Martin was left with no choice but to resign from G. E. and pursue an advanced degree in physics."[3] Teri, who also was taking classes at Union "for fun," strongly encouraged Martin to make the leap, something he was only too glad to do. "Martin was never the one to take the 'safe job,'" she recalled, but rather to "go where the action was."[4]

Higher education

So in the fall of 1950, Martin entered graduate school at Columbia University, where he would receive his Ph.D. in atomic physics in 1955.

One of Martin's early sculptures in clay, circa 1950.

Martin, as he later acknowledged was "a bit arrogant about my abilities to learn fast," and being less well trained in physics than his fellow students, quickly got in trouble with his coursework. Being married and already a father, and having the tacit approval of his parents to return to school, he resolved to persevere, finish his Ph.D., and earn a living as a scientist.

His advisor, Nobel laureate I. I. Rabi, was instrumental in molding Martin into an experimental physicist. He influenced Martin's taste in physics and taught him how to select research problems and approach them experimentally.

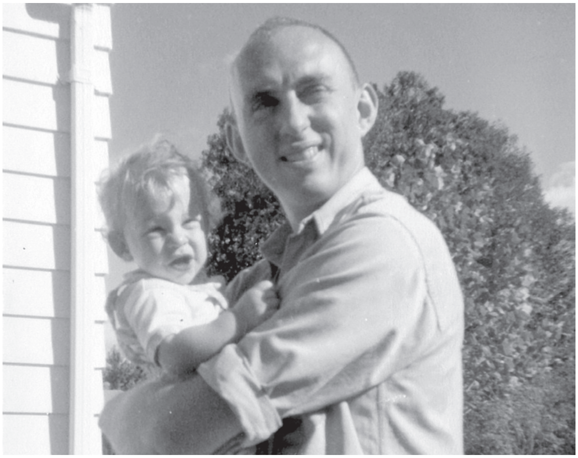
Rabi had strong ideas, which quickly became imprinted on Martin. He once told Martin that he would never pursue an idea already suggested by someone else —even if he himself had been thinking about it as well.

Martin's thesis research was the measurement of the quadrupole moment of the sodium nucleus by means of the atomic beam resonance technique, which Rabi had pioneered. Rabi was not known for spending much time in the lab, and thus left Martin to learn techniques from the more advanced graduate students and Rabi's experimental colleagues. In later years, Martin would echo his own difficult learning process when he told his own students, "there are no answers in the back of the book when the apparatus doesn't work or the measurements look strange." You're on your own.

Rabi had strong ideas, which quickly became imprinted on Martin. He once told Martin that he would never pursue an idea already suggested by someone else —even if he himself had been thinking about it as well. Apparently, Rabi would go as far as avoiding conversations with other experimenters for fear of hearing his ideas emerging from their mouths. Martin adopted this unusual, perhaps eccentric, advice on the importance of choosing one's own research path. He later wrote in his Nobel Prize lecture: "I stay away from lines of research where many people are working, and in particular I stay away from lines of research where very smart and competent people are working. I find it more comfortable to work in uncrowded areas of physics."[5]

Martin with son Jed at Jones Beach during summer of 1954 while working at Brookhaven National Lab.

As an experimentalist, Rabi insisted on working carefully and methodically toward the correct result and on checking it thoroughly before making it public. This was reinforced for Martin when he went to publish his thesis research. Rabi delayed him almost two months while he confirmed the consistency of the results with a French group doing a similar experiment.



Martin with daughter Anne (1959).

Subsequently, Martin impressed this meticulous style of research on his graduate students, perhaps most visibly on 1976 Nobel laureate-to-be Samuel C. C. Ting, and Martin acknowledged that Rabi was its source. Encouraging his graduate student Petros Rapidis to attend a lecture by Rabi, Martin told him, "You will see where I got my style." And indeed, Martin followed a strict methodology himself more than 20 years later when he proposed the existence of the τ lepton to his skeptical collaborators.

Finally, Rabi preached to Martin the importance of choosing only "fundamental" problems to work on. He pressed Martin to go into the emerging field of particle physics rather than staying in atomic physics, perhaps sensing that that was where the important discoveries would be made, and Martin took Rabi's advice.

The University of Michigan and strong interactions

In 1955, Martin was presented with job offers from several prestigious physics departments (Yale and the University of Illinois among them). But ignoring conventional wisdom, he chose the University of Michigan in Ann Arbor, the (then) least prestigious offer, on the basis that he'd enjoy more freedom and have the best chance of getting credit for what he'd done.

As a new assistant professor, Martin first worked with Donald Glaser doing bubble chamber physics. But when the opportunity for independent research presented itself, he and his colleague Larry Jones initiated their own program in strong-interaction physics. Along with Jones, Don Meyer, and Michael Longo, Martin learned the experimental techniques of particle physics, and mastered the use of spark chambers,[6] scintillation counters, trigger electronics, and data analysis. He even co-invented the "luminescent chamber," which recorded the tracks of particle interactions in a NaI crystal with primitive-image intensifiers.

The group conducted its early experiments—on pion-proton elastic scattering with spark chambers—at the Bevatron of the Lawrence Berkeley Laboratory, with Martin's graduate-student Ting taking part. Perl loved these experiments and the equipment, but he found strong interactions theory to be "a complex mess." Martin clearly longed for something simpler, more compelling, and not so oversubscribed. He started thinking about leptons, and the puzzling relationship between the electron and the muon.

Still, about 10 years later, as a professor at the Stanford Linear Accelerator Center (SLAC), Martin published the textbook *High-Energy Hadron Physics*, a rather personal summary of the complex field of strong interactions. This book would soon be made obsolete by the discoveries at SPEAR at SLAC.

Move to Stanford University and SLAC

Martin on sabbatical at Imperial College, London, June 1970 with family (spouse, Teri Hoch Perl, and children –left to right- Anne, Matthew, and Joe). Jed was already at college that year and did not accompany the family.

In 1963, following his intuition about where the next fundamental discoveries might be made, and with Teri's support and encouragement, Martin left his faculty position at Michigan to come to the nascent SLAC, whose faculty had been impressed by Martin's visit the previous year to talk about his Bevatron research.

He became leader of SLAC's Experimental Group E, one of the five original research groups established by director Wolfgang K. H. Panofsky to build and guide the new lab's experimental program. In the early days, the group leaders were all known for their strong personalities, short tempers, and great impatience. Martin fit right in.

In a notable finding around 1970, Martin's group measured muon inelastic scattering on protons[7] in order to compare them with the earlier electron inelastic scattering experiments done by the Friedman-Kendall-Taylor group at SLAC.[8] The conclusion was that no significant differences could be found. After that, Martin's group studied the hadronic final states produced in inelastic electron scattering from protons[9] and nuclei.[10]

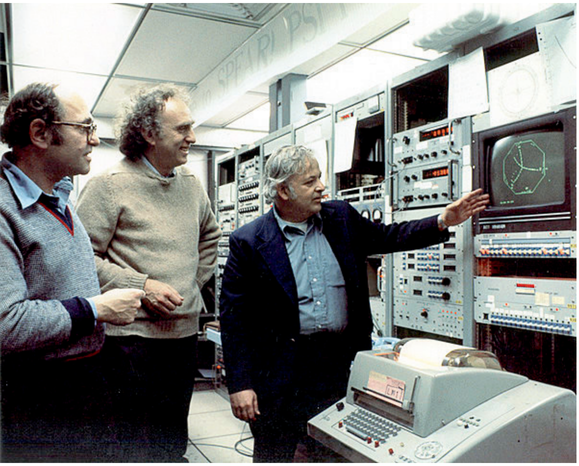
SPEAR and Mark I: The discovery and confirmation of the τ lepton[11]

In 1971, Martin's Group E joined Burton Richter's Group C and the Chinowski-Goldhaber-Trilling group from the Lawrence Berkeley Lab to propose the construction of what was later known as the Mark I detector. Their aim was to study the collisions of high-energy electrons with high-energy positrons at Richter's e^+e^- storage ring—the Stanford Positron Electron Accelerating Ring (SPEAR)—at SLAC.

Martin realized early on that SPEAR presented a practical way to search for a new lepton—a heavy lepton—if it existed, because pairs of the heavy lepton could be produced when the electron and positron annihilated. In the 20-page proposal for the experiment, Martin was given three pages to describe heavy lepton searches. It was the only section proposing to look for new physics, and he convinced his colleagues to allow him to add a longer supplement.[12] In it, he proposed to look for final states with an electron, an opposite charge muon, and missing energy, – given that no conventional process could produce such states. Searches using this signature were already going on at the lower energy *ADONE* ring in Italy.[13] Martin's calculations were aided by Paul Tsai's incredibly accurate pre-QCD calculations.[14]

In 1973, the Mark I and SPEAR started running. The Mark I was a primitive detector by today's standards, and it was difficult to identify electrons and muons above the background from pions, which were produced more copiously in e^+e^- collisions. Martin meticulously combed through the data. In those days, people looked at pictures of the events to confirm the interpretation assigned by the computers. This was a holdover from the earlier bubble-chamber era. Martin joked about collecting printouts of funny events with an electron, a muon, and missing energy, and putting them in his drawer. By the end of the 1974 he had found 24 e-mu events, and through painstaking analysis had calculated that at most 4.7 of these were due to misidentifications.

His collaborators were skeptical, so Martin challenged them to disprove his calculations. By the summer of 1975, everyone agreed that the signal was real, but with so few events it was not possible to distinguish between different hypotheses for the events' origin. Thus in keeping with his strict methodology and his scientific conservatism, Martin referred to the new particle as "U" for unknown. The collaboration went public with the discovery at the 1975 summer conferences and in a first publication in December of that year.[15] The paper, which was titled "Evidence for Anomalous Lepton Production in e^+e^- Annihilation," contained no exuberant claims, and presented just the facts.



Martin in the SPEAR Control Room in November 1974, following discovery of the J/Psi. Left to right, Gerson Goldhaber (LBL), Martin Perl, and Burton Richter.)

By summer 1976 the sample had grown to 139 events with a calculated background of 34—enough for Martin, and for his colleague and critical sounding board Gary Feldman, to show that the events not only were consistent with the production and decay of a new heavy lepton but also were inconsistent with competing hypotheses.[16] At the summer conferences of 1976, it was reported that experiments at the German High Energy Physics Laboratory (DESY) were unable to confirm the heavy lepton discovery. As a result, there was some skepticism concerning Martin's result. Nonetheless, the identification of these events based on SPEAR data was clear; and in March 1977, Martin gave the lepton its permanent name, τ, from the Greek word "triton," which denoted the "third in a series."[17] The confirmation, from two experiments at DESY, would come just a few months later.[18]

The discovery of the τ lepton was the first evidence for a third generation of fundamental particles, and this advance would be followed in just a few years by the discovery of the bottom quark, the first evidence for the third generation of quarks. Direct evidence for the τ neutrino, which came later, completed discovery of the third lepton generation; and the discovery in the early 1990s of the top quark completed the third quark generation.

Uncovering the properties of the τ Lepton

With the growing acceptance that a new heavy lepton had been discovered, Martin and many of his experimental-community colleagues turned to critical tests of the heavy-lepton hypothesis and to more precise measurements of heavy-lepton branching fractions. The new data came from detectors at DESY's PETRA and SLAC's PEP storage rings. Hadronic decays, especially those into $\pi\nu$ and $\rho\nu$, had been rigorously predicted, so seeing them at the expected rates provided a crucial confirmation. Early searches for the pion decay mode, however, had yielded surprisingly null results, but by

1977 hadronic τ decays were observed;[19] and soon thereafter, decays into one or more pions were observed at the expected rates.[20] Detailed evidence for multi-pion modes,[21] including modes with multiple neutral pions, accumulated.[22]

By the end of the PEP and PETRA era, a rather complete portrait of the τ's branching fractions had emerged. Martin participated in these developments, and he became personally involved in solving the "one-prong problem"—the failure to account for the one-prong branching fraction with measured decay modes.[23] (It turned out that under-appreciated systematic errors were to blame.) Martin also continued his search for new physics in the SPEAR and PEP data, and later in the SLAC Linear Collider data. He hunted for "forbidden" τ decays, excluding decays such as eγ and eπ. Having struck gold once, he carefully panned the whole PEP dataset to prospect for additional nuggets—unstable neutral leptons, anomalous events with low multiplicity, and charged lepton-specific forces—but found no further surprises.

The decays of the τ into three charged pions + ν were perfectly suited for determining the τ lifetime. The displacement of the decay vertex from the primary interaction point provided the necessary data, given that τ pairs were produced at the known beam energy. On hearing a proposal to build a collider vertex detector to make these measurements, Martin gave emphatic instructions to "Go do it!" He added his support to the idea, and bolstered it by noting that the device might also measure the *B* meson lifetime. Ever the hands-on experimentalist, Martin built his first drift chamber—a trigger chamber for Mark II—to serve until the Mark II Secondary Vertex Detector (SVD) was built and installed. The SVD initially measured the τ lifetime to better than 20-percent precision and found it just as predicted, confirming e-mu-tau universality.[24]

Other important discoveries at SPEAR

It is notable that Martin and members of his research group participated fully in the SPEAR Mark I and Mark II experiments of the 1970s, which yielded a cornucopia of other fundamental discoveries. In addition to measurements of inclusive muons[25] and electrons,[26] which supported the τ discovery, Martin's group took the lead on a number of other notable quests. One result was the discovery that underlying quarks create jets of hadrons;[27] the measurement of hadron jets has been universally used in all subsequent experiments to study the underlying quarks.

Another result was the discovery of an e^+e^- resonance just above the charm threshold, the ψ(3770), which decays almost 100 percent of the time into a pair of ground-state charmed mesons.[28] Running on this resonance became the standard way to precisely study the decays of these charmed mesons.

And yet another result was the discovery of the first excited state of the charmed *D* meson, the D^* (2010).[29] The significance of this discovery is that the D^* has a distinctive decay mode—into a pion and a *D* meson—which makes it much easier to tag charmed particles in more complex events at higher energies.

The Tau Charm Factory, CLEO-II, and BaBar

In 1989, with the Mark II program on the SLAC Linear Collider winding down, Martin was re-energized by a visit from a former colleague, Jasper Kirkby (European Organization for Nuclear Research [CERN]), who promoted the idea of a "Tau Charm Factory"—a dedicated high-luminosity e^+e^- storage ring that would generate large samples of tau leptons and charmed particles near threshold. Martin saw this as a way to test for subtle deviations from the Standard Model and to limit the mass of the τ neutrino.[30]

Martin and his SLAC colleague Rafe Schindler expanded the proposal and enlisted members of the Mark III Collaboration at SPEAR to build a new international physics collaboration and initiate detector design and R&D. Meanwhile, John Siemann and the SLAC accelerator group began work on the machine design.

The Tau Charm Factory proposal, competing with a B Factory proposal at SLAC, failed to get approval. So in 1993, Martin and his colleagues explored building the facility on a greenfield site in southern Spain, just outside Seville. The program was being promoted there, by Juan Antonio Rubio (CERN), as Spain's first high-energy physics facility. However, by the end of 1994 this proposal too had failed.

In its place, Martin and his Group E colleagues joined CLEO II at Cornell University and later collaborated with Groups B and C at SLAC to help build the BaBar detector for PEP-II (the B Factory). At Cornell, Martin jumped into the fray, built hardware for the tracking chamber upgrade of the detector, and then pursued the physics.

Martin Perl at a press conference at SLAC following the announcement of the 1995 Nobel Prize (10-13-1995).

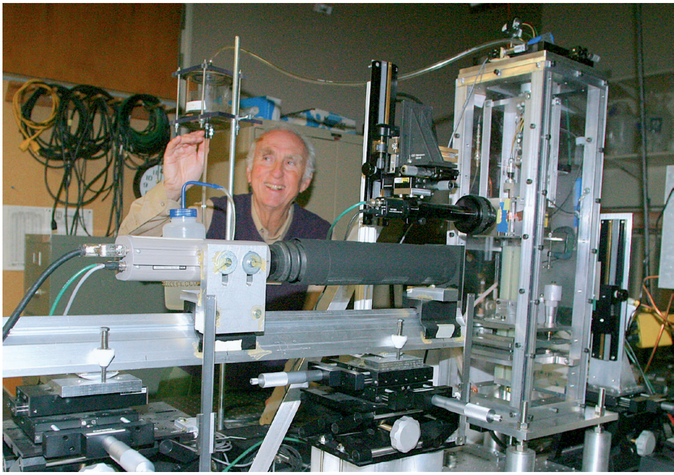
It was in 1995, during this period of some disappointment and profound change of direction, that Martin got the long awaited phone call from Sweden with word of his award of the Nobel Prize in Physics, recognizing him as the sole discoverer of the τ lepton, almost twenty years earlier.

Free quarks, fractional-charge search, and dark energy: The later years at SLAC

Martin was always one to move on when an area of research had come to an end. So it was no surprise that Martin once again turned to a new direction. The search for free quarks and fractional charges in matter had been at the back of his mind since quarks were first proposed by Gell-Mann in the 1960s. In his early days at SLAC, Martin had searched for fractional charges in electro-production[31] (using SLAC's 12 GeV e-beam on Cu targets), and in the mid-'80s developed a "rotor electrometer" to examine bulk samples.[32] The latter work was probably motivated by William Fairbank's (Stanford U.) results in niobium using a levitometer approach. In the e^+e^- collider experiments, Martin had rigorously searched the data for evidence of fractionally charged particles.

In the early 1990s, automating Millikan's famous oil-drop experiment moved front and center in Martin's research. He credited a group at San Francisco State University for initiating this work, but went on to make truly significant advances by incorporating computer control and real-time monitoring.

He worked closely on the problem with a small group of students, postdocs, and technicians. One colleague (Eric Lee) introduced the use of micromachined drop technology, rather like that used in inkjet printers, and revolutionized the search. Tiny drops could be ejected from multiple droppers on demand, monitored with CCD cameras, and analyzed in real time, thus allowing a new level of control of the experiment's systematics and a significantly greater throughput.[33] A postdoc replaced Millikan's technique of switching the applied vertical electric field on and off (which offset gravitational effects) with laminar airflow and a constant horizontal E field. The airflow balanced gravity and permitted much larger drops to be studied, and the constancy of the E field eliminated the aerodynamic crosstalk between neighboring drops that arose when the field was reversed.



Martin Perl with the Fractional Charge Search experiment at SLAC (5-15-2003).
(Photo by Diane Rogers.)

Over several years, throughput increased. An early paper[34] analyzed 40 million drops, a total of 17.4 mg of silicone oil. With a breakthrough by Dinesh Loomba (then a postdoc in Group E) that allowed the suspension of arbitrary materials in the oil, the group was able to analyze 3.9 mg of the Allende meteorite (suspended in 260 mg of oil), but as in previous searches, no fractional charges were found.[35]

After the null result with the meteorite, Martin stopped the search for fractional charge and began thinking about how to observe dark energy. He was intrigued with the sensitivity of atomic interferometry, and began learning the art from experts at Stanford and UC Berkeley. He and his colleagues submitted a proposal to the National Science Foundation to study dark energy in the laboratory with this technique, but the initiative was rejected. Nevertheless Martin was undeterred, and he found informal ways to move into this entirely new arena. Though already in his 80s, and a professor emeritus who might well rest on his laurels, he was still experimentally active and a regular sight at SLAC.

The other side of Martin Perl: Community interactions

While best known for his experimental work in physics, Martin had another side—as an advocate for social programs and change. This can perhaps be traced to 1947, when the G. I. Bill provided him with financial support to complete his engineering degree. Martin became a strong and vocal advocate of the G. I. Bill, having become sensitized to how it had helped so many people move up in life, especially those who otherwise would not have had much of a chance.

In the words of his wife Teri Hoch, Martin became "the pet scientist of the whole art scene at Michigan."

Martin's time in Ann Arbor reinforced his social consciousness. President Dwight D. Eisenhower's warnings about the growth of the military-industrial complex and the onset of conflicts in Southeast Asia clearly affected Martin. In the words of his wife Teri Hoch, Martin became "the pet scientist of the whole art scene at Michigan."[36] He began to do sculpture and also mingled with the politically left-leaning side of the University. Eventually, the negative effects of the Vietnam War on U.S. society in general and on funding for the basic sciences in particular would move Martin to more concrete action.[37] He and Charles Schwartz (of Lawrence Berkeley Laboratory) established the organization "Scientists and Engineers for Social and Political Action" (SESPA) at the 1969 American Physical Society (APS) meeting in New York City. SESPA later changed its name to "Science for the People," and Martin worked for a time publishing its newsletter. Shortly thereafter, Martin, working with Schwartz, Barry Casper, and Earl Callen, successfully pressed the APS to establish the APS Forums. Martin then served for many years as the first editor of the APS Forum on Physics and Society's newsletter.

His concerns over the education of young people in physics, and their eroding academic career opportunities, coalesced at a conference that Martin co-organized with Roland Good (Pennsylvania State University) in1974. Held under the auspices of the APS Forum on Physics and Society and the American Association of Physics Teachers, the "Tradition and Change in Physics Graduate Education" conference dealt with the crises that students, faculty, and physics departments were experiencing in education, employment, and funding during the late 1960s and early '70s.

In the early 1990s, Martin was very proud to be promoting the Tau Charm Factory project in Spain. He viewed the project not just as an important scientific facility but also as a model training ground for young particle physicists, accelerator physicists, and engineers in Spain. In addition, it gave the Spanish scientific community a modest level of independence from the centralization of European particle physics at CERN.

Martin was also acutely aware of minority underrepresentation and the gender gap in the physical sciences, in particular at Stanford, and he was always a strong advocate for correcting these problems.

Martin's mentoring legacy

Martin served as an advisor to graduate students both at the University of Michigan and at Stanford and as a teacher and mentor to several generations of physicists at SLAC.

They all recognized and appreciated the role he played in shaping their styles as experimentalists. Martin encouraged students and postdocs, as well as his peers, to be thorough and systematic, to demand simplicity and clarity in thought, to question the conventional wisdom, and, most importantly, to pursue new directions when the old ones were exhausted or oversubscribed.

His graduate students included Melissa Franklin, Valerie Halyo, Kenneth Hayes, Frank Heile, Betty Kwan, Nancy Mar, Petros Rapidis, and Samuel C. C. Ting.

Over the years Martin guided, collaborated with, and influenced numerous physicist colleagues. Among them were David Burke, Jonathan Dorfan, Gary Feldman, Melissa Franklin, K. K. Gan, JuanJose Gomez-Cadenas, Valerie Halyo, Gail Hanson, Walter Innes, John Jaros, Peter Kim, Spencer Klein, Dieter Luke, Dinesh Loomba, Clara Mateuzzi, Jim Martin, Rene Ong, John Price, Ting Pun, Daniel L. Scharre, Rafe H. Schindler, and David Stoker.

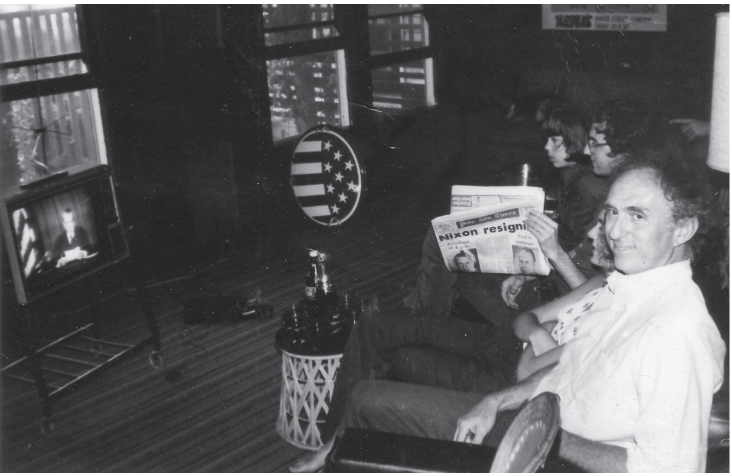
Many of these colleagues benefited from his example, but also more directly from his support of their work. Martin was often a minimalist advisor, indicating the direction someone should take or applauding a proposal, but completely foregoing any micromanagement along the way. He afforded his young people the freedom and independence that he himself had cherished. He recognized and supported new ideas from his colleagues, and worked behind the scenes to guarantee political and financial support for these new directions. He was impeccably honest in acknowledging credit, and magnanimous in recognizing excellence in others.

Martin's family

Teri Hoch Perl, Martin's former spouse and lifelong friend, received her Ph.D. in 1979 from Stanford in Mathematics Education. Teri's research focused on gender differences in 'electing' mathematics when it became a high school elective, rather than a requirement. A gift from Martin helped Teri and Ann Piestrup to found The Learning Company, one of the first educational software firms in Silicon Valley.

Martin and youngest son Joseph in 2011.

Jed Perl, 64, Martin's first son, was the art critic for *The New Republic* for twenty years and a regular contributor to *The New York Review of Books.* He is author of six books on art and culture, and the recipient of a Guggenheim Fellowship. Jed is currently completing the first full-length biography of the sculptor Alexander Calder. He lives in New York City.



Martin in 1974 in his Palo Alto home showing his political/ social side - smiling while sitting with his family watching President Nixon's resignation.

Martin's daughter, Anne Bernard, 58, has an MBA and is an accountant, currently working at Channing House in Palo Alto, CA.

Martin's second son, Matthew Perl, 56, is an MD. He is currently a practicing physician with the Scripps Clinic Medical Group in San Diego, CA, where he specializes in emergency and urgent care.

Martin had a profound and positive impact on his students, but he could be a daunting presence or strict overseer.

Martin's youngest son, Joseph Perl, 55, has a B.A. in medical physics. He has worked at SLAC for many years in its computing division.

Lila Perl, Martin's older sister, died in 2013 at the age of 92. She was a popular author of more than 60 books—largely children's books, but some adult nonfiction as well.

The Perl character

Throughout his more than 50-year-long career as a particle physicist, Martin was a master at addressing the big questions with simple, direct, and, if possible, hands-on methods. He deeply understood, and lived by, the scientific method for discovery. Over the course of his career he gave distinctive talks and presentations, which were always deceptively simple, strongly conceptual, clear, and logical. His lecture style was built around the needs of the audience; often, he would stop abruptly every few minutes to ask if everyone understood or if anyone had a question, and only after he had responded to any feedback would he move on.

At the SLAC 40 year Service Awards Dinner (3-14-2002). Martin Perl showing off one of his many Erector set projects.

Martin had a profound and positive impact on his students, but he could be a daunting presence or strict overseer. One student recalls Martin's complete mastery of a graduate-level course in hadron physics at Stanford, and his ability to field any and all questions. He also remembers being warned that Martin was sometimes an "arbitrary and mercurial advisor," but signed up anyway and benefited immensely from the interactions. A third recalls Martin's personal warmth and social inclusiveness, somewhat offset by strictly enforced standards for tidiness in the laboratory. For virtually all of his students, and his senior colleagues as well, Martin exemplified the essential experimental particle physicist—a model for how to do experimental science.

Martin prided himself on being a realist—knowing when to persist in a difficult quest, when to quit, and when to start in a new direction. In reflecting on his unsuccessful attempts, in his early scattering experiments, to find differences between the electron and the muon, he said in his 1995 Nobel Prize Lecture:[38]

> *Experimental science is a craft and an art, and part of the art is knowing when to end a fruitless experiment. There is a danger of becoming obsessed with an experiment even if it goes nowhere. I avoided obsession.*

At SLAC, Martin was a strong advocate for new, small, innovative, and independent experiments. Especially in his later years, he worried publicly about the impact of huge collaborations on the field of particle physics, the suppression of personal creativity and invention, and the intolerance of difficult personalities (wherein he counted himself). Martin practiced what he preached. His physics was novel, independent, and of manageable scale, at least in the sense that he was intimately associated with a project's every detail. But in other ways, his physics was anything but small. Martin engaged the largest and most fundamental questions in particle physics, and he helped to shape our present world view.

ENDNOTES

1. Perl, M. L. 1996. Nobel biographical. In *Les Prix Nobel [The Nobel Prizes] 1995*, edited by T. Frängsmyr. Stockholm: Nobel Foundation.

2. Hoch, T. Personal communication.

3. Pilcher, V. E. 1994. *Early science and the first century of physics at union college*.

4. Hoch, T. Personal communication.

5. Perl, M. L. 1995. Nobel lecture: Reflections on the discovery of the tau lepton, December 8. Online at www.nobelprize.org/nobel_prizes/physics/laureates/1995/perl-lecture.pdf.

6. Perl, M .L., L. W. Jones, and S. C. C. Ting. 1963. Pion-proton elastic scattering from 3 GeV/*c* to 5 GeV/*c*. *Phys. Rev.* 132:1252–1272.

7. Toner, W. T., et al. 1971. *Phys. Lett. B* 36:251; Braunstein, T., et al. 1972. *Phys. Rev. D* 6:106.

8. Bloom, E. D., et al. 1969. *Phys. Rev. Lett*. 23:930.

9. Dakin, J. T., et al. 1974. *Phys. Rev. D* 10:1401.

10. Osborne, L. S., et al. 1978. *Phys. Rev. Lett.* 40:1624.

11. A more detailed description of the tau discovery and its confirmation is given in: Feldman, G. J. 1992. The Discovery of the τ, 1975–1977: A tale of three papers. In *Proceedings of the twentieth SLAC summer institute on particle physics. SLAC Report 412.* Online at www.slac.stanford.edu/pubs/slacreports/reports01/ssi92-034.pdf.

12. Larsen, R. R., et al. 1971. SLAC Proposal SP-2. Online at https://www.slac.stanford.edu/grp/rd/epac/Proposal/SP-2.pdf.

13. Alles-Borelli, V., et al. 1970. *Lett. Nuovo Ciimento* 4:1156.

14. Tsai, Y. S. 1971. *Phys. Rev. D* 4:2821.

15.Perl, M. L., et al. 1975. *Phys. Rev. Lett.* 35:1489.

16. Perl, M. L., et al. 1976. *Phys. Lett. B* 63:466.

17. Perl, M. L. 1977. *Proceedings of the Twelfth Recontre de Moriond*, Flaine, France, March 6–18, 75.

18. Burnmester, J., et al. 1977. *Phys. Lett. B* 68:297 & 301; Brandelik, R., et al. 1977. *Phys. Lett. B* 70:125.

19. Brandelik, R., et al. 1978. *Phys. Lett. B* 73:109.

20. Barbaro-Galtieri, A., et al. 1977. *Phys. Rev. Lett.* 39:1058.

21. Alexander, G., et al. 1978. *Phys. Lett. B* 73:99; Jaros, J., et al. 1978. *Phys. Rev. Lett.* 40:1120.

22. Behrend, H. J., et al. 1984. *Z. Phys. C* 23:103; Aihara, H., et al. 1986. *Phys Rev. Lett.* 57:1836.

23. Hayes, K. G., M. L. Perl, and B. Efron. 1989. *Phys. Rev. D* 39:274.

24. Jaros, J., et al. 1983. *Phys. Rev. Lett*. 51:955.

25. Feldman, G. J., et al. 1977. *Phys. Rev. Lett*. 38:117.

26. Barbaro-Galtieri, A., et al. 1977. *Phys. Rev. Lett.* 39:1058. The data reported in this letter came from a lead-glass calorimeter wall that was constructed on one side of the Mark I detector by a collaboration of Martin's group with an LBL group headed by Lina Galtieri.

27. Hanson, G., et al. 1975. *Phys. Rev. Lett.* 35:1609.

28. Rapidis, P. A., et al. 1977. *Phys. Rev. Lett.* 39:526; Erratum. 1977. *Phys. Rev. Lett.* 39:974.

29. Feldman, G. J., et al.1977. *Phys. Rev. Lett.* 38:1313.

30. Perl, M. L., and R. H. Schindler. 1991. *The Tau Charm Factory: Experimental perspective*. SLAC-PUB-5666.

31. Bellamy, E. H., et al. 1968. *Phys. Rev.* 166:1391.

32. Price, J. C., et al. 1986. *Rev. Sci. Instrum.* 57:2691.

33. Mar, N. M., et al. 1996. *Phys. Rev. D* 53:6017.

34. Lee, I. T., et al. 2002. *Phys. Rev. D* 66:012002.

35. Kim, P. C., et al. 2007. *Phys. Rev. Lett.* 99:161804.

36. Hoch, T. Personal communication.

37. Schwartz, B. 2014. Obituary for Martin Perl at the APS Forum on Physics and Society. A personal memoir focused on Martin as an activist in the early days of the formation of the Forum on Physics and Society.

38. Ekspong, G. (ed.). 1997. *Nobel lectures, physics, 1991–1995*. Singapore: World Scientific Publishing Co.

SELECTED BIBLIOGRAPHY

1957 With D. I. Meyer and D. A. Glasser. Scattering of K+ mesons by protons. *Phys. Rev.* 107:279–282.

1959 With L. W. Jones. The luminescent chamber and other new detectors. In *Proceedings of the 2nd International Conference on High-Energy Accelerators (HEACC 59)*. Edited by L. Kowarski. pp. 561–570 CERN Conference C59-09-14.

1963 With L. W. Jones and S. C. C. Ting. Pion-proton elastic scattering from 3 GeV/*c* to 5 GeV/*c*. *Phys. Rev.* 132:1252–1272.

1968 With E. H. Bellamy, R. Hofstadter, W. L. Lakin, and W. T. Toner. A search for fractionally charged particles. *Phys. Rev.* 166:1391–1394.

With A. Barna, J. Cox, F. Martin, T. H. Tan, W. T. Toner, T. F. Zipf, and E. H. Bellamy. A search for new particles produced by high-energy photons. *Phys. Rev.* 173:1391–1402.

1971 With W. T. Toner, T. J. Braunstein, W. L. Lakin, F. Martin, T. F. Zipf , H. C. Bryant, and B. D. Dieterle. Comparison of muon-proton and electron-proton deep inelastic scattering. *Phys. Lett. B* 36:251–256.

1972 With J. T. Dakin, G. J. Feldman, W. L. Lakin, F. Martin, E. W. Petraske, and W. T. Toner. Measurement of the inclusive electroproduction of hadrons. *Phys. Rev. Lett.* 29:746–749.

1974 With J. E. Augustin et al. Discovery of a narrow resonance in e^+e^- annihilation. *Phys. Rev. Lett.* 33:1406–1408.

1975 With G. S. Abrams et al. Evidence for anomalous lepton production in e^+e^- annihilation. *Phys. Rev. Lett.* 35:1489–1492.

With G. Hanson et al. Evidence for jet structure in hadron production by e^+e^- annihilation. *Phys. Rev. Lett*. 35:1609–1612.

1976 With G. Goldhaber et al. Observation in e^+e^- annihilation of a narrow state at 1865 MeV/c^2 Decaying to $K\pi$ and $K\pi\pi\pi$. *Phys. Rev. Lett.* 37:255–259.

With G. J. Feldman et al. Properties of anomalous $e\mu$ events produced in e^+e^- annihilation. *Phys. Lett. B* 63:466–470.

1977 With G. J. Feldman et al. Properties of the proposed tau charged lepton. *Phys. Lett. B* 70:487–490.

1979 With G. S. Abrams et al. Observation of Cabibbo-suppressed decays $D^0 \rightarrow \pi^- \pi^+$ and $D^0 \rightarrow K^- K^+$. *Phys. Rev. Lett.* 43:481–492.

1980 The tau lepton. *Ann. Rev. Nucl. Part. Sci.* 30:299–335.

1983 With J. Jaros et al. Precise measurement of the τ lifetime. *Phys. Rev. Lett.* 51:955–966.

With N. Lockyer et al. Measurement of the lifetime of bottom hadrons. *Phys. Rev. Lett.* 51:1316–1326.

1985 With T. Barklow et al. Searches for unstable neutral leptons in low-multiplicity events from electron-positron annihilation. *Phys. Rev. D* 32:2859–2868.

1986 With J. C. Price, W. R. Innes, and S. Klein. The rotor electrometer: A new instrument for bulk-matter quark search experiments. *Rev. Sci. Instrum.* 57:2691–2718.

1988 The tau missing decay modes problem and limits on a second tau neutrino. *Phys. Rev. D* 38:845–849.

1989 With K. G. Hayes and B. Efron. Application of the bootstrap statistical method to the tau decay mode problem. *Phys. Rev. D* 39:274–832.

With C. A. Hawkins. An exploration of the limits on charged lepton-specific forces. *Phys. Rev. D* 40:823–832.

With G. S. Abrams et al. Measurements of Z-boson resonance parameters in e^+e^- annihilation. *Phys. Rev. Lett*. 63:2173–2176.

1991 With R. H. Schindler. The tau-charm factory: Experimental perspective. SLAC-Pub-5666. Online at *http://www-public.slac.stanford.edu/sciDoc/docMeta.aspx?slacPubNumber=SLAC-PUB-5666*.

1996 With N. M. Mar, E. R. Lee, G. T. Fleming, B. C. K. Casey, E. L. Garwin, C. D. Hendricks, K. S. Lackner, and G. L. Shaw. An improved search for elementary particles with fractional electric charge. *Phys. Rev. D* 53:6017–6032.

2002 With I. T. Lee, S. Fan, V. Halyo, E. R. Lee, P. C. Kim, H. Rogers, D. Loomba, K. S. Lackner, and G. L. Shaw. Large bulk matter search for fractional charge particles. *Phys. Rev. D* 66:012002.

2007 With P. C. Kim, E. R. Lee, I. T. Lee, V. Halyo, and D. Loomba. Search for fractional-charge particles in meteoritic material. *Phys. Rev. Lett.* 99:161804.

2009 Can the existence of dark energy be directly detected? *Int. J. Mod. Phys. A* 24:3426–3436.