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# HENRY WAY KENDALL
1926—1999

*A Biographical Memoir by*

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*Any opinions expressed in this memoir are those of the authors and do not necessarily reflect the views of the National Academy of Sciences.*

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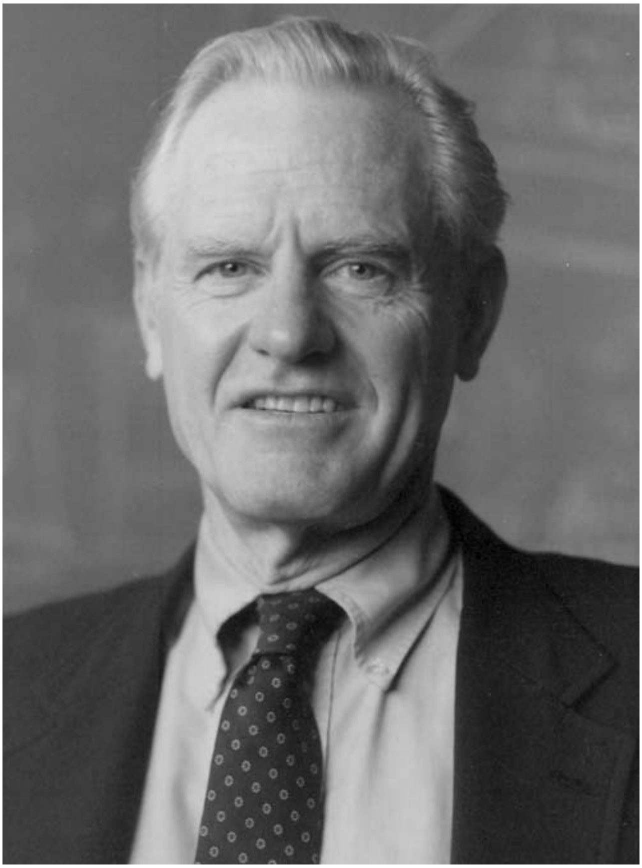

Henry W. Kendall

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*December 9, 1926–February 15, 1999*

BY KURT GOTTFRIED, JAMES D. BJORKEN,
JEROME I. FRIEDMAN, AND RICHARD E. TAYLOR

The world lost a remarkable scientist, innovative environmental activist, and adventurer with the death of Henry Kendall while scuba diving in Florida on February 15, 1999. He shared the 1990 Nobel Prize in Physics with Jerome Friedman and Richard Taylor for experimental discoveries crucial in establishing the existence of pointlike quark building blocks within protons and neutrons. He participated in the founding of the Union of Concerned Scientists in 1969, and subsequently guided its programs until his death. In addition, Henry's accomplishments as mountaineer, diver, and outdoor photographer were legion and widely recognized.

Henry was born in Boston, Massachusetts, on December 9, 1926, and grew up in nearby Sharon. As he put it in his Nobel autobiography, "I developed—or had been born with—an active curiosity and an intense interest in things mechanical, chemical and electrical and do not remember when I was not fascinated with them and devoted to their exploration."

He attended Deerfield Academy, a college preparatory school. On graduating in 1945 he entered the U.S. Merchant Marine Academy and served on a troop transport in the winter of 1945-1946. Henry then entered Amherst College, graduating with a major in mathematics in 1950, and enrolled at the Massachusetts Institute of Technology as a graduate student in physics. His Ph.D. thesis research, carried out under the supervision of Martin Deutsch, was a courageous albeit unsuccessful attempt to measure the Lamb shift in positronium, a feat that was not to be accomplished for more than two decades. Upon receiving his degree in 1955 Henry began his postdoctoral career at MIT and Brookhaven National Laboratory, and made his first foray into innovative instrumentation, which would be a recurring interest throughout his career in experimental physics. In 1956 he took a research position at Stanford University, attracted by the program of Robert Hofstadter that was measuring the size of atomic nuclei by means of elastic electron scattering. This choice soon led him into what would be the central theme of his scientific career. He remained at Stanford until returning to MIT as a faculty member in 1961, becoming a full professor in 1967 and the Julius A. Stratton Professor of Physics in 1991.

During the 1950s Hofstadter established a research program involving electron scattering experiments at the 1 GeV linear electron accelerator in the High Energy Physics Laboratory (HEPL) on the Stanford campus. At the time Henry arrived at Stanford the Hofstadter group's measurements of the charge distributions of nuclei was moving on to similar experiments on the proton and neutron. Henry built and tested a new set of scintillation counters for the experiments that greatly increased the rate of data acquisition, along with an innovative readout system using a modified commercial pulse height analyzer for data accumulation and readout in those precomputer days. In due course Henry befriended the other two young physicists who were to be his collaborators in their historic experiments a decade later: Jerome Friedman and Richard Taylor. With Friedman and others he carried out a variety of electron scattering experiments, often using the deuteron as the target.

The HEPL machine was a precursor to the much larger 20 GeV linear electron accelerator, which was already in the early planning stages, led by Wolfgang K. H. Panofsky and Edward Ginzton. In 1963 after Kendall and Friedman had moved to MIT, they started a collaboration with Stanford Group A, headed by Panofsky and Taylor, to design and build spectrometers that were to have the capability of making the same kind of measurements at the new machine as those Hofstadter had pioneered at HEPL. Because of the much higher energy, this entailed quite radical design changes and a much larger physical scale, as well as a need for sophisticated detectors and for its day a very demanding data acquisition system. Building on his innovative work on hodoscopes at HEPL, Henry designed and supervised the construction of new, complex counter assemblies and electronics for this program. This required a command of fast electronics and complex logic circuitry, all state-of-the-art and in some cases beyond that.

This planning activity dominated Henry's interests in the mid-1960s, and he described those years as "surely the most enjoyable physics I have ever done." Not only was this experience enjoyable, it was also highly rewarding and productive. While the design specifications of the new detectors were controlled by the ability to repeat the elastic-scattering measurements a la Hofstadter, the much higher energy also allowed the exploration of what became known as the deep-inelastic scattering regime. (We believe that this now routine phraseology was coined by Henry.)

Elastic electron scattering experiments can only reveal a time-averaged picture of the charge distribution in the target and for that reason cannot distinguish between a charge distribution due to mobile point-like constituents and one that is fundamentally continuous. In contrast, deep-inelastic scattering provides a near instantaneous picture of the charge distribution and is thereby able to produce such a distinction.

By early 1967 the new Stanford Linear Accelerator Center (SLAC) was ready for operation and the spectrometers were ready for the first round of experimental work. The elastic scattering program got underway immediately, with impressive results, greatly extending the range of the HEPL measurements of Hofstadter et al. and of those carried out at the Cambridge Electron Accelerator and Deutsches Elektronen Synchrotron in Hamburg.

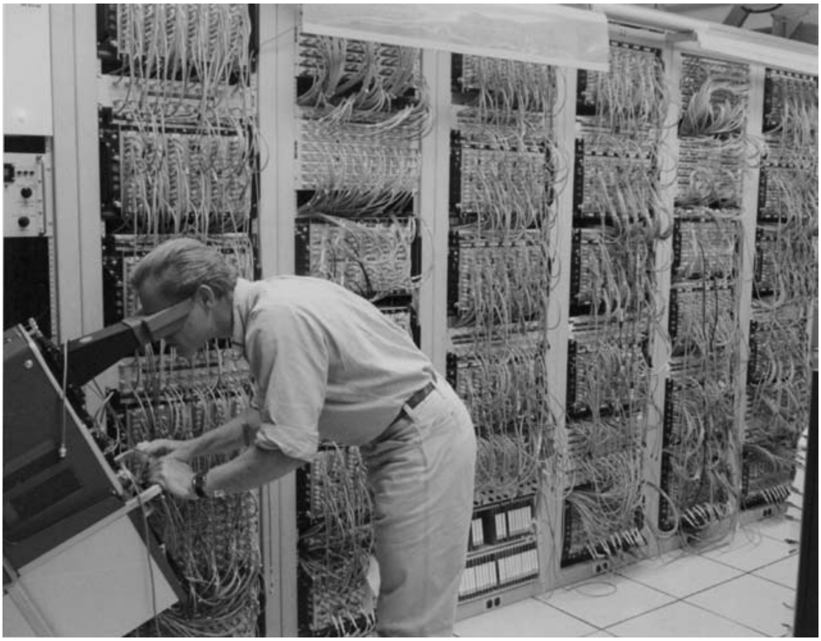

Photo courtesy of SLAC.

The deep-inelastic program followed soon thereafter, using the sophisticated instrumentation developed for this purpose by Henry. It was serendipitous that theorist James Bjorken was close at hand, providing a useful theoretical framework. At that time deep-inelastic scattering was largely uncharted territory, whose importance was generally underestimated by most (but not all) theorists as well as by most experimentalists.

When an electron scatters inelastically from a target, it loses energy both because it radiates photons and excites the target. It is only the latter component that reveals the target's instantaneous charge distribution. The extraction of this component of interest therefore involves a laborious and meticulous unfolding of the raw data, an expertise that Friedman and Kendall had already started to develop in earlier work on electron scattering from complex nuclei.

Kendall and Friedman were in the thick of the Group A analysis effort. When Henry showed Bjorken the radiatively corrected data in early 1968, Bjorken suggested replotting the results in terms of the inverse of the now standard scaling variable in order to test for regularities associated with the possible presence of pointlike charged constituents in the proton. Upon replotting the data Henry experienced what was surely one of the most satisfying moments in his scientific career. He described it as follows: "I recall wondering how Balmer may have felt when he saw, for the first time, the striking agreement of the formula that bears his name with the measured wavelengths of the atomic spectra of hydrogen."

Despite that euphoric moment it would take years of patient and comprehensive measurements of quite exquisite precision and completeness to establish the primary result: that inside the proton and neutron lay pointlike spin ½ constituents with the fractional charges attributed to quarks, as invented in 1964 by Murray Gell-Mann and George Zweig. This fundamental discovery largely came from the electron scattering program of the SLAC and MIT groups, although measurements from experiments using neutrino beams were also vital.

By the mid-1970s the SLAC electron scattering program had become quite mature, and Henry's interests turned to the physics program at the new Fermilab 200 GeV proton accelerator in Batavia, Illinois. He and Friedman collaborated with a group, headed by David Ritson, that measured a variety of particles and processes produced in those high-energy collisions with a spectrometer of a design recognizably similar to the SLAC spectrometers. While this program yielded ample amounts of high-quality, useful data, there were no euphoric moments to be had. In 1982 he and Friedman joined Frank Taylor in a Fermilab neutrino experiment that brought them back much closer to their deep-inelastic roots. This continued until 1988, when they joined the SLAC program of electron-positron annihilation experiments. However, Henry's zeal for such "big physics" research projects waned because "the ever-growing size, scale and duration of particle experiments…made such programs less and less congenial to [him]." Over the same time period his involvement in broader societal issues became more intense.

Throughout his service on the MIT faculty Henry was deeply committed to teaching. He brought his talents as an experimenter and his communication skills to both the freshman laboratory course and the very demanding junior lab for physics majors. In the latter he developed ingenious and simple experiments that demonstrated basic laws of physics. Until his death Henry continued to teach the laboratory courses for the "pure love of it."

Henry exhibited a deep commitment to a variety of societal causes throughout his life, most (but not all) of which were science and technology related. He believed that the scientific community should participate in public debates on issues created by scientific developments that have the potential to imperil the human community and its habitat. He was especially concerned by the dangers inherent in the exploitation of nuclear physics for both military and civilian ends, and more generally by his recognition that science is a double-edged sword, which makes it imperative for societies to both foster the beneficial and constrict the dangerous potentials released by scientific knowledge.

His first major involvement was in the 1960s, through membership in the JASON Group of the Institute for Defense Analyses. In those days the JASON Group, comprising a large number of particle physicists and a lesser number of scientists in other fields, advised the Department of Defense on a variety of military issues, concentrating on the nuclear arms race as well as the electronic barrier concept aimed to suppress guerrilla activity during the Vietnam War.

By 1969 he became convinced that he might be more effective working "on the outside" rather than "from the inside" as a JASON Group member, and joined colleagues in the MIT physics department who had founded the Union of Concerned Scientists (UCS). In the early 1970s he ran a seminar at MIT devoted to issues raised by the exploitation of science by society. Stimulated by inquiries from a Massachusetts citizens group he initiated a study of the safety of nuclear power plants. This led to his being a key witness in widely reported 1971 hearings held by the Atomic Energy Commission on the reliability of the emergency core cooling systems in nuclear power plants, in which his testimony anticipated some of the problems that arose in the Three Mile Island accident.

In 1974 UCS became a formally organized nonprofit, with Henry as its chair from then until his death. Under his leadership UCS grew steadily in reach and effectiveness. He was personally involved in its programs on nuclear arms control, missile defense, and renewable energy. In 1989 he convinced UCS to become one of the very first public interest groups to confront the challenge posed by climate change.

In 1992 he broadened this perspective by composing the "World Scientists' Warning to Humanity," which summarized the evidence that "human beings and the natural world are on a collision course." This statement was signed by 1,700 senior scientists across the globe and the majority of Nobel laureates in the sciences. During the last years of his life, Henry chaired panels that advised the U.S. Department of Energy on the management of radioactive wastes at nuclear weapons facilities and the World Bank on transgenic crops and environmentally sustainable development.

Henry's commitment to environmental issues was complemented by his own active involvement with the natural world. In his youth he had already become an expert diver and underwater photographer and had written books on these subjects and developed some of the technology. Throughout his life he dove in the waters off Massachusetts and as far afield as the Falklands and South Georgia. In New England he became a proficient skier, serving on the ski patrol at Stowe, Vermont. Upon arrival at Stanford he joined the Stanford Alpine Club and quickly became an expert mountaineer and rock climber, participating in expeditions to the Canadian Rockies and the Andes, and in an early (unsuccessful) attempt on El Capitan in Yosemite Valley. In addition, he became a skilled mountain and outdoor photographer. It was typical of Henry that upon embarking on any new endeavor, he set towering personal standards and was unsatisfied until that endeavor was fully mastered.

In addition to his membership in the National Academy of Sciences (elected in 1992), Henry Kendall was a fellow of the American Academy of Arts and Sciences, the American Physical Society, and the American Association of Arts and Sciences. He was awarded a number of prizes in addition to the 1990 Nobel Prize. These included the Bertram Russell Society Award in 1982, the Environmental Leadership Award

Photo credit: K. Gottfried

from the Tufts University's Lincoln Filene Center in 1991, the Ettore Majorana-Erice Science for Peace Prize in 1994, the Award for Leadership in Scientific Stewardship from the Johns Hopkins Center for a Livable Future in 1997, and the Nicholson Medal for Humanitarian Service from the American Physical Society in 1998. In 1981 he shared the Szilard Award of the American Physical Society with Hans Bethe.

Henry Kendall was a prolific writer. He authored or coauthored more than 70 published scientific papers and some 60 technical reports, wrote numerous popular articles, and coauthored six books, including *Energy Strategies—Toward* *a Solar Future* (1980), *Beyond the Freeze* (1982), *The Fallacy of Star Wars* (1984), *Crisis Stability and Nuclear War* (1987), and *A Distant Light: Scientists and Public Policy* (1999).

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