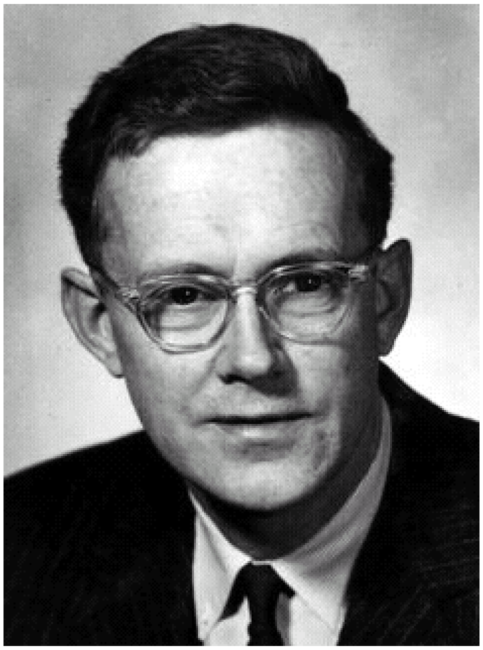

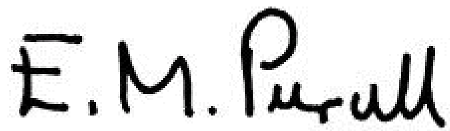

Edward Mills Purcell

August 30, 1912 — March7, 1997

By Robert V. Pound

EDWARD MILLS PURCELL, NOBEL laureate for physics in 1952, died on March 7, 1997, of respiratory failure at his home in Cambridge, Massachusetts. He had tried valiantly to regain his strength after suffering leg fractures in a fall in 1996, but recurring bacterial lung infections requiring extended hospitalizations repeatedly set back his recovery.

Two of the best known of Purcell's many outstanding scientific achievements are his 1945 discovery with colleagues Henry C. Torrey and Robert V. Pound of nuclear magnetic resonant absorption (NMR), and in 1951 his successful detection with Harold I. Ewen of the emission of radiation at 1421 MHz by atomic hydrogen in the interstellar medium. Each of these fundamental discoveries has led to an extraordinary range of developments. NMR, for example, initially conceived as a way to reveal properties of atomic nuclei, has become a major tool for research in material sciences, chemistry, and even medicine, where magnetic resonance imaging (MRI) is now an indispensable tool. Radio spectroscopy of atoms and molecules in space, following from the detection of the hyperfine transition in hydrogen as the first example, has become a major part of the ever-expanding field of radio astronomy.

Purcell made ingenious contributions in biophysics, as exemplified by his famous analysis of life at low Reynolds numbers, which described the locomotion of bacteria in water. In astronomy, he made important contributions to the study of the alignment of interstellar grains. As a teacher he had a great influence on many students whom he advised and who sat in his beautifully crafted courses at Harvard. His introductory textbook on electricity and magnetism set a new standard of scholarship. Finally, Purcell was looked to as a most valued advisor and consultant throughout his professional life, having served on innumerable committees, including two periods of service on the President's Science Advisory Committee in the administrations of Presidents Eisenhower, Kennedy, and Johnson.

EARLY YEARS

Edward M. Purcell was born on August 30, 1912, in Taylorville, Illinois, the older of two boys. His father, Edward A. Purcell, was manager of the local telephone exchange in Taylorville, and moved, when the boy Edward was fourteen years of age, to Matoon, Illinois, some 60 miles southeast to become general manager of the Illinois Southeastern Telephone Company, an independent regional company. Ed's mother, Elizabeth Mills Purcell, was a graduate of Vassar College and taught Latin in the Taylorville high school before her marriage. Both of Ed's parents had strong influences on his lifetime interests, his father's profession leading to his pursuit of technology and science and his mother's to his interest in literature, writing, and the humanities.

His father's connection with the telephone company played an important role in his youthful interests. It made available to him discarded equipment, such as lead-jacketed cable and copper wire and the old hand-cranked bell-ringer magnetos replete with horseshoe magnets. Of even greater influence were the periodic issues of the highly scientific *Bell System Technical Journal*. Although his father's company was not a part of the Bell System, it did maintain the area lines for the system and received the journal. These publications were a source of inspiration to the young Edward and he held onto and referred to them into his college years. In an interview recorded at Harvard by Katherine Sopka in 1977, transcribed at the Center for the History of Physics of the American Institute of Physics, Purcell is quoted as stating, "They were fascinating because for the first time I saw technical articles obviously elegantly edited and prepared and illustrated, full of mathematics that was well beyond my understanding. It was a glimpse into some kind of wonderful world where electricity and mathematics and engineering and nice diagrams all came together."

COLLEGE YEARS

From this background, Ed elected to enter Purdue University in 1929 to pursue a course of study in electrical engineering. Ed described his training in the old style of electrical engineering, which included learning about such practical things as the design and construction of the armatures of electric motors, as continuing to interest him and to influence his later work. While he was a Purdue undergraduate, he discovered that his true interest was physics. It was the arrival of Karl Lark-Horovitz as the new head of the physics department there that led to an increased visibility of that subject. The department that previously did not even offer a major undergraduate program began to include graduate students engaged in research. During his junior undergraduate year, although technically still an engineering student, Ed signed up with the physics department for a newly offered course of independent study. His supervisor initially was Professor Walerstein, who put him to work refurbishing a spectrometer based on a Rowland grating. He then went on to building an electrometer to measure nuclear half-lives. With that experience, Ed became enamored with physics, and in his senior year he worked with H. J. Yearian, then a graduate student finishing a Ph.D. thesis project in electron diffraction. Ed stayed on for the summer after he graduated to participate in writing his first two papers, which grew from this experience, the first dealing with electron diffraction (1934) and the second reporting a method for making the required thin films (1935). In that connection he once told me he believed he, luckily, must not be allergic to beryllium oxide. His evidence was that, in connection with preparing samples for the electron diffraction studies, he had manually swept the BeO from the smoke produced by an arc with a beryllium electrode running in air. This was well before beryllium toxicity was widely recognized.

Ed graduated from Purdue University in the spring of 1933 with the B.S.E.E. degree, and with the support of Lark-Horovitz he was awarded an exchange fellowship that took him to the Technische Hochschule in Karlesruhe, Germany, for the following academic year. It was an awkward time to be in Germany, because the effects of the Nazi Party's coming to power were beginning to be felt. He expressed regret that he did not take more interest while there in the history of Heinrich Hertz, who first produced radio waves at Karlesruhe. In traveling to Germany by ship that autumn Ed had met Beth C. Busser, another exchange student, from Bryn Mawr College, who was to visit Munich. Although she was studying German literature, he persuaded Beth to attend a lecture by the distinguished physicist Arnold Sommerfeld at Munich. She did so and took notes for him, although the subject had little meaning to her. Beth and Ed were married four years later in Cambridge, Massachusetts, where she survives him.

Again with the support of Lark-Horovitz, Ed joined the physics department of Harvard University as a graduate student in the fall of 1934, where he would remain for the rest of his life, except for various leaves of absence for special purposes. Of particular influence on his interests in later years was the course on electric and magnetic susceptibilities of Professor John H. Van Vleck. Ed and Malcolm Hebb, then an advanced student of theory with Van were the only students in the course. Van Vleck had just joined the Harvard faculty after some years at the University of Minnesota and the University of Wisconsin. He persuaded them to publish their joint term paper in the then quite new *Journal of Chemical Physics*. This work (1937) was an analysis of experiments in cooling by adiabatic demagnetization then being carried out mostly in The Netherlands and Great Britain. Ed has emphasized that this experience and his study with John Van Vleck had an important influence on his later interests in physics.

As a thesis project, after a couple of unrewarding tries, Ed undertook an experiment suggested to him by Professor Kenneth T. Bainbridge, who was then especially concerned with the focusing of charged particles by magnetic and electric fields in connection with his work with mass spectrographs and nuclear physics. This project was to study, both theoretically and experimentally, the focusing properties of the electric field in the space between two concentric metal spheres forming a spherical condenser. (It now would be called a capacitor!) The experimental aspect of this project involved a complex glass-blowing effort to construct the device, and Ed was always grateful for the expert help of the department's resident glass blower, Mr. H. W. Leighton. The experiment, which basically confirmed Ed's analysis of the three-dimensional focusing properties for electrons, was published (1938) and provided him with his dissertation. Some thirty years later the concept resurfaced for refocusing low-energy electrons in X-ray-induced electron emission experiments.

With the completion of his thesis project, Ed joined the teaching staff of the Harvard physics department, becoming a Faculty Instructor, a rank with a five-year term that was created in Harvard's reconstruction of its faculty structure and tenure policy. (The title reverted to the more widely recognized Assistant Professor in later years.) Ed continued to collaborate with Kenneth Bainbridge in the completion, bringing into operation, and initial research in nuclear physics of the pre-war Harvard cyclotron. In this connection he developed current-carrying shim coils for adjusting the shape and homogeneity of the field of the cyclotron magnet. In the autumn of 1940, when the Radiation Laboratory was established at the nearby Massachusetts Institute of Technology, Ed was asked to follow Bainbridge there to undertake emergency work to develop microwave technology for military radar.

THE MIT RADIATION LABORATORY

Ed went on a leave of absence from Harvard from the beginning of 1941 to join the MIT project and continued it until July 1946. For most of that time he headed the advanced developments group, which was responsible mainly for moving the radar systems to shorter wavelengths, initially from 10 cm to 3 cm and then to 1.25 cm. A major gain from these moves was the improved resolution, especially from aircraft, where space seriously limited the antenna dimensions and therefore the sharpness of the beams. After sufficient progress had been made, serious preparations were made for production of the 1.25-cm systems, the principal one being code named H_2K. However, as the warmer weather of the spring of 1944 arrived, a disappointing decrease in the detection range was found. This was soon recognized to be associated with the increasing atmospheric humidity that brought with it a serious absorption of that particular wavelength by water molecules. This effect had been anticipated because of the complex structure of the energy states of the free water molecule, but its strength and the wavelength had not been established. The choice of 1.25 cm for the so-called K-band radar systems, made in the absence of prior data, turned out to be unfortunate.

With the ending of World War II on V-J Day, August 14, 1945, the MIT Radiation Laboratory prepared to close down, but several of its members, including Purcell, were asked to stay on. Most of the staff members were leaving to resume their pre-war careers or to begin new ones. Some of us stayed to contribute to the writing of a series of books that would preserve the technology developed over five years at the laboratory and its collaborating organizations under conditions of military secrecy. During this period, in the autumn of 1945, Ed proposed to his two friends and colleagues Henry C. Torrey and me that we three should jointly design and undertake in our spare time an effort to detect resonant absorption of radio-frequency energy by atomic nuclei in solid matter held in a strong magnetic field. He was led to think along those lines by his writing for the series about the absorption of microwaves by water vapor (1951). The absorption was attributed to two energy states of the free H_2O molecule that happened to have an energy difference corresponding to the quantum energy of the K-band radio waves. The concept of nuclear magnetic resonance in molecular beams had recently been highlighted with the award of the 1944 Nobel Prize for physics to our colleague I. I. Rabi for his pre-war research. Rabi and several of his associates from his laboratory at Columbia University had played important roles in microwave developments, both at the Radiation Laboratory at MIT and its counterpart of the same name at Columbia University. Henry Torrey was one of the Rabi laboratory veterans, and this influenced Purcell to seek Torrey's view about the possibility of detecting NMR as an absorption of radio-frequency energy. An experiment was improvised largely from inactive Radiation Laboratory equipment and was moved to the Research Laboratory of Physics at Harvard to use a magnet built in the 1930s by J. Curry Street to provide bending of tracks of cosmic rays in his cloud chambers. Our three-member team worked mostly evenings and weekends and, on Saturday afternoon, December 15, 1945, succeeded in detecting the absorption of radio-frequency by protons in paraffin wax by magnetic resonance (1946).

AFTER WORLD WAR II

In July 1946, anticipating his return to Harvard--where he had been promoted to the tenured rank of Associate Professor--Ed undertook to develop this newly opened field of magnetic resonance of nuclei. In February 1946 graduate student Nicolaas Bloembergen, just arrived from Utrecht, The Netherlands, joined in the effort. As a research assistant, Bloembergen helped initially to develop more sensitive instrumentation for the NMR studies. With it the team of Bloembergen, Purcell, and Pound carried out a series of fundamental experiments in 1946 and 1947. The one that has become widely known by the initials BPP was the important study and explanation of thermal relaxation of the nuclear spins and of collision narrowing of NMR resonance lines in liquids and gases and in solids with certain internal motion. The report of this work was the basis of Nicolaas Bloembergen's Ph. D. thesis, which was submitted to Leiden University in 1948. The article in *Physical Review* (1948) established a record for its citations, according to the publishers of the Citation Index.

Another field of research that was greatly influenced by the wartime development of new electronic technology was radio astronomy. Beginning in the late 1940s Purcell encouraged graduate student Harold I. Ewen to look for an astronomical spectral line based on the hyperfine splitting of the ground state of the interstellar atomic hydrogen in the galaxy. As known from laboratory experiments, the quantum energy of that splitting corresponded to a wavelength of 21 cm, or a frequency of 1420 MHz. Purcell applied to the Rumford Fund of the American Academy of Arts and Sciences for support in the amount of $500, with which he was able to construct the horn antenna and carry out the project. The spectral line was first detected, as an emission, on March 25, 1951. In a gentlemanly gesture, Purcell sent information about the technique and the success to two astronomers he knew were interested. One was Professor Jan Oort in Leiden, The Netherlands, and the other was J. L. Pawsey of the Radio Physics Laboratory in Sydney, Australia. He delayed the publication of the news in *Nature* until confirming reports from those two teams could join it (1951). Professor Oort had much earlier, after learning of the discovery of radio signals from space by Carl Jansky and then by Gerth Reber before World War II, hoped to study the details of the galaxy by observing the strength and Doppler shifts of some radio spectral lines. The suggestion of looking for the hydrogen hyperfine line had been made to him by H. G. van de Hulst in 1944. Only after receiving the description of Ewen and Purcell's success was Oort also successful. He reported early data on galactic structure in that first article and went on to do so in impressive detail in later reports. Atomic and molecular spectroscopy has grown to become a major activity in radio astronomy in the years since that seminal experiment of Ewen and Purcell. Prior to that discovery, radio astronomy had mainly dealt with sources emitting broad noise, mostly at lower frequencies.

Throughout his professional career, Edward Purcell was continuously sought out as a consultant and advisor. He spent time on a variety of studies for agencies of the U.S. government. Following almost immediately from the period at the MIT Radiation Laboratory he served for many years on the Air Force Science Advisory Board at the request of Lee Dubridge. In the fall term of 1950 Ed took a leave of absence from his duties at Harvard to join Project Troy, a secret study based at MIT for the U.S. Department of State.[1] This was also a critical period in the development of the search for the astronomical atomic hydrogen line, and I became more closely involved in its progress in Ed's absence. Through this and later studies he developed a close friendship with Edwin H. Land, founder of the Polaroid Corporation and inventor of its instant photography techniques. They both served on the original President's Science Advisory Committee that began under President Eisenhower in response to the Soviet *Sputnik* revelations. There, Purcell chaired the subcommittee on space and he and Land wrote, with the participation of Frank Bello, formerly of *Fortune* magazine, a pamphlet sometimes called the "Space Primer" to educate as many people as possible about the possibilities of space exploration.[2] Ed was proud of the degree to which their projections proved correct as the program developed in the following years, including the moon landings, whose possibility they had described. He and his committee colleagues had important influences on the organization of the National Aeronautics and Space Administration (NASA), the whole developing space exploration program, and the later conduct of the Apollo mission. One such contribution was their persuading NASA to provide the astronauts with specially designed color stereo cameras to make photographs of the undisturbed lunar surface around the landing site on the initial and later missions. Another outgrowth of one of the studies for national defense was the invention of a long-distance communication system (1952) for very short wavelengths, using scattering from turbulence in the troposphere.

In 1952 the award of the Nobel Prize for physics (1953) recognized Purcell's role in the founding of NMR and its even then rapidly increasing range of applications. He shared that honor with Felix Bloch of Stanford University, who had reported a successful detection of nuclear induction with collaborators William W. Hansen and Martin Packard a few weeks after the publication of our group's report.

In the first few post-war years after returning to Harvard, Purcell directed thesis research in aspects of magnetic resonance by a distinguished group of able young men. Following almost in parallel with the well-known work of Nicolaas Bloembergen, George E. Pake joined in. His name has been immortalized in NMR by the term "Pake doublet" (1949), which results from the pairing of protons in water of crystallization. Charles P. Slichter studied a related relaxation question in electronic paramagnetic resonance in crystals. Walter Brown used NMR to calibrate the magnetic field of a specially constructed ß-ray spectrograph to establish a better value for the absolute energy of an internal conversion electron from radium, often used as a calibrational reference. A new way to understand so-called spin echoes, which had been invented by Erwin Hahn at University of Illinois was developed with Herman Carr into a method of measuring molecular self-diffusion, using an applied magnetic field gradient.

In 1949 I described to Ed some experiments I had just carried out with a pure LiF single crystal. I had found the nuclear spin systems to require several minutes to build up their magnetization to thermal equilibrium at room temperature when placed in a strong magnetic field. They retained that polarization even if they were removed for a few seconds from the strong magnet and then replaced. I also found that reorienting manipulations on the demagnetized crystal had little effect on its remagnetized state. Ed and I then saw an opportunity to try to invert that magnetization by applying a specially designed magnetic transient to the demagnetized crystal, followed by a return to the strong polarizing field. Ed constructed a simple device to provide such a transient pulse, which indeed resulted in an inverted state relative to the normal thermal polarization when the crystal was subjected to this transient and then returned to the polarizing field. That inverted magnetization decayed back to the normal equilibrium state with the several-minute time constant of its spin-lattice relaxation. When probed by the NMR detector in the inverted condition, stimulated emission rather than absorption was observed. Charles Townes has indicated that his reading about that initiated his thoughts that led to his invention of masers and lasers. Our experiment involved complete demagnetizations at several steps in the process, with the evidence that the inversion persisted without serious loss; so Purcell and I described the resulting situation (1951) as a spin system at negative temperatures. Initially, that concept met with resistance and even antagonism from some well-established thermodynamicists, but with time it became a significant textbook item illuminating aspects of thermodynamics and statistical mechanics special to systems with a bounded set of energy states. Negative temperatures are even hotter than infinite temperatures, not colder than absolute zero, as might naively be supposed.

In 1950 Purcell and N. F. Ramsey questioned whether the argument was valid that nuclei could not possess electric dipole moments. They pointed out (1950) that the basis of the argument was the belief that nuclei obeyed the laws of parity symmetry conservation, for which they could find no direct experimental evidence. As a follow-up of this query they undertook an experiment at the Oak Ridge National Laboratory with graduate student James H. Smith, seeking--but only setting an upper limit to--an electric dipole moment in the neutron (1957). Norman Ramsey has continued this search with other collaborators, setting ever-lower limits, mainly at the ultra-cold neutron facility at the Institut Laue Langevin in Grenoble, France.

Ed's name is applied to the phenomenon known as the Smith-Purcell effect (1953). Recently that concept has been viewed by some as a precursor of the free-electron laser (FEL). In their experiment, Steve Smith, as a graduate student guided by Purcell, sent an energetic beam of electrons very closely parallel to the surface of a ruled optical diffraction grating, and thereby generated visible light. Ed was not happy with the connection recently made to the FEL. He held that the electrons, as they sped past the grating, individually induced moving image charges, and the light produced by those image charges would be completely incoherent. He showed there was negligible effect on the trajectory of the inducing electrons. Later experimenters have, however, tried to produce coherent radiation by using much higher electron energies and optical feedback, thus attempting to develop the scheme into an FEL.

The new strong-focusing accelerator at the Brookhaven National Laboratory, the alternating gradient synchrotron, was to begin in the early 1960s to run a beam of protons having the unprecedented laboratory energy of 3×10^{10} electron volts (30 GeV). Ed became excited by the possibility that a so-far unobserved magnetic monopole might be created by collisions at such energies. He and four Brookhaven-based collaborators designed a simple but elegant detector and carried out over the course of a year and a half in 1960-62 an unsuccessful search for evidence of the Dirac monopole at the alternating gradient synchrotron (1963).

In the early years after World War II, Ed, much involved in teaching the introductory physics course, joined with his Harvard colleagues J. Curry Street and Wendell Furry to write a serious introductory textbook for students intending to concentrate in the physical sciences. This book, which began as an updated edition of a well-known text, became much more changed than anticipated and was published under its own title.[3] Many years after this initiation into textbook writing, Ed, through his membership in the newly established Commission on College Physics, undertook while on a leave of absence at Berkeley to write a new textbook on electricity and magnetism; this became volume II of the Berkeley Physics Series organized by Charles Kittel and supported by the National Science Foundation (1965). In that elegantly structured text he made particular use of the interdependence of electric and magnetic phenomena in moving frames of reference as established by the special theory of relativity. He took special pains with the clarity and simplicity of the illustrative figures, as well as the problems. He supplemented the textbook with a separate book of problem solutions, reproduced directly from his carefully prepared manuscripts and lettered out in his own recognizable hand. When he discovered that the publisher and some users of the text were keeping its existence secret from the students, he was angry. He felt that the problems and their solutions made a major contribution to the pedagogical content of his course. He brought out a revised second edition in 1985 in which he gave in, to some extent, to the mounting pressure to use SI (Systeme International) units by including alternative versions of the equations in those units, but still retaining his preferred Gaussian units.

ASTROPHYSICS AND BIOPHYSICS

Although Edward Purcell's contribution to radio astronomy brought him into contact with astrophysics, it was in the early 1960s that he moved most of his creative research energies into astrophysics. He had always been strongly attracted to theoretical modeling and analysis, and the problem of understanding the mechanisms of the interactions of interstellar dust and light propagating through the galaxy consumed a large part of his efforts in his later years. In 1969 he published his initial article in this field under the title "On the Alignment of Interstellar Dust," and followed up with an article authored jointly with the astrophysicist Lyman Spitzer, Jr., of Princeton University entitled "Orientation of Rotating Grains" (1971). He went on to develop the image of interstellar grains brought into states of high-speed rotation--which he entitled "Suprathermal Rotation"--by their interactions in space. In 1982 Purcell was invited to give the Halley Lectures at Oxford University, England, on this subject. He told me that our mutual friend there, Brebis Bleaney, suggested that his title referring to interstellar dust would be better received in England if he avoided the word dust in his title, because the English use it for less pretty materials. Witness Mr. Doolittle, Eliza's father, the dustman in G. B. Shaw's *Pygmalion*. Such is a problem of our shared language.

One of Ed's academic roles had been to serve for several years as a senior fellow of Harvard Society of Fellows, where he became closely acquainted with some of the fascinating projects of the junior fellows. One particular junior fellow was a physicist converting to biophysics--Howard Berg. Ed and Howard devised an elegant machine based on concentric rotating cylinders for separating molecules in liquid states according to their masses. Ed expressed astonishment at the heavy response of the biological community to this publication in the *Proceedings of the National Academy of Sciences.*

A little later, when Howard was studying the locomotion of *E. coli* bacteria, he was able to prove that they moved by continuous rotation of their corkscrew-like flagella, rather than by flapping them. With this model, Ed developed the description of their hydrodynamic situation. This led to the publication of a transcript of his talk at a symposium, held in honor of Victor Weisskopf, under Ed's title "Life at Low Reynolds Numbers" (1977). He compared the bacteria's problem of generating thrust to that of a man trying to swim in a tank of thick molasses. He demonstrated the inefficiency of their mechanism by scaling up to small spiral wire coils that he dropped through a viscous fluid, observing the small rotation induced in the coils by their falling velocity. He thus showed the reciprocal effect of the rotation-to-thrust model and developed a matrix to describe the situation quantitatively. Initially he used corn syrup as the viscous medium, but was very happy when I suggested to him that silicone fluids of great optical transparency were available in a wide range of viscosity. He once mentioned to me that his tank of silicone fluid cost him about the same as that amount of Jack Daniels. Ed was able to project this demonstration onto a lecture screen, giving graphic evidence of his analysis. It demonstrated the little thrust the bacteria could produce in water, because their rotation mainly carried the viscous fluid round with it out to a quite large distance. The *E. coli* had no other way to pursue needed nourishment, and so had to put up with it. Ed and Howard Berg were jointly awarded the Biological Physics Prize of the American Physical Society in 1984 for their work.

In the years between 1983 and 1988 Purcell conducted a pedagogical column in the *American Journal of Physics* under the heading "Back of the Envelope." In this he posed problems for thought, which he could solve quantitatively by a few lines on the back of an envelope. In the next issue he gave his consistently educational and insightful solution. This was yet another way Ed enjoyed playing what he felt to be his primary role, that of educator. Of course, he received many honors over the years, including membership in the National Academy of Sciences in 1951, foreign member of the Royal Society, the National Medal of Science in 1979, and membership in the many other scholarly academies. He was particularly happy with the recognition of his teaching conveyed by his award of the Oersted Medal of the American Association of Physics Teachers in 1968.

To conclude, Edward Purcell contributed strongly to the advance of many sciences and taught a large number of students and colleagues his special insight for explaining complex phenomena in simple ways. It was a universal reaction of those who encountered his way of analyzing a new problem to marvel at his quick understanding. In addition to his deep interest in so many aspects of science and his interest in teaching others, he had a deep wish to avoid wars and especially to control weapons of mass destruction. It was his distaste for our involvement in Vietnam that brought him to resign from the President's Science Advisory Committee in 1965 and sever his ties with all military advisory panels from then onward. In September of 1967 he was persuaded as our member who was acquainted with Johnson from his role in the advisory committee to serve as spokesman for a group of Harvard faculty members. We had been invited to meet with President Johnson at the White House to present our views in opposition to the continuing war in Vietnam that had been presented to him in a letter earlier. Ed accepted the role with reluctance. From my seat on Johnson's left side at the big table in the Cabinet Room, I watched as he wrote on his pad "improvement relations Harvard University. " Otherwise he only talked for over an hour of rambling defense and was quite unmoved by the arguments Ed presented.

Testimony to Ed's evident wisdom and clarity of thought and expression is presented in the autobiographical work of James R. Killian, Jr., the first chairman of the President's Science Advisory Committee.[4] Killian writes, "When Eisenhower was later to speak in memorable tribute of 'my scientists' he was surely recalling among others this quiet, modest, lucid man. Robert Kreidler, in an interview I had with him in preparing for this memoir, spoke almost with awe of his impact on PSAC. 'Ed Purcell did not speak often,' he said, 'but when he did there would be enormous silence in the room, because everybody knew that whatever he said was going to be worth listening to with careful attention.' "

Through many of these years Ed and Beth dedicated much of their energies to their role as parents of their two boys, Dennis W. and Frank B., born in the early 1940s. In more recent times they have enjoyed watching their three grandchildren grow to adulthood. Ed was happy to know a great-grandchild in his last years. For most of my own professional life I have benefited greatly from Ed's unstinting and wise advice and support. It is difficult to accept that it is no longer there for my colleagues or me.

ALTHOUGH I HAVE HAD a close personal and professional relationship with Edward Purcell for almost sixty years, I found two recent biographical sources helpful with some details. In 1991 the IEEE held a special session of its meeting in Boston commemorating the fiftieth anniversary of the Radiation Laboratory. In connection with that meeting about forty interviews were held with Radiation Laboratory alumni. John Bryant interviewed Ed, and these, entitled *Rad Lab: Oral Histories Documenting World War II Activities at the MIT Radiation Laboratory*, were published by the IEEE in 1993 (ISBN number 0-7803-9968-4, Center for the History of Electrical Engineering, Piscataway, N.J.). Another source of biographical information appeared in a chapter that amounts to an authorized biography, written with considerable consultation with Ed and many other sources, by James Matson in the volume *The Pioneers of NMR and Magnetic Resonance in Medicine: The Story of MRI* (Bar-Ilan University Press, Ramat Gen, Israel; published in the U.S.A. by the Dean Book Co., Jericho, N.Y., 1996). That book is sometimes seen as seeking particularly to promote the role of one contributor to the development of MRI. Nevertheless, Matson has captured much interesting detail in his biography of Edward Purcell.

NOTES

[1] The origin and purposes of Project Troy and Harvard Provost Paul Buck's promise to have strong Harvard participation are described by James G. Hershberg in his *James B. Conant*, p. 511, New York: Alfred A. Knopf, 1993.

[2] Reprinted in James R. Killian, Jr.'s autobiographical memoir *Sputnik, Scientists, and Eisenhower,* as Appendix 4, pp. 288-99, under the title *Introduction to Outer Space,* with a foreword by President Eisenhower. Cambridge, Mass.: MIT Press, 1977.

[3] W. H. Furry, E. M. Purcell, and J. C. Street. *Physics for Science and Engineering Students.* New York: Blakiston, 1952; New York: McGraw Hill, 1960.

[4] *Sputnik, Scientists, and Eisenhower*, op. cit., p. 123.

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