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PHILIP MORRISON
1915—2005

A Biographical Memoir by

LEO SARTORI AND KOSTA TSIPIS

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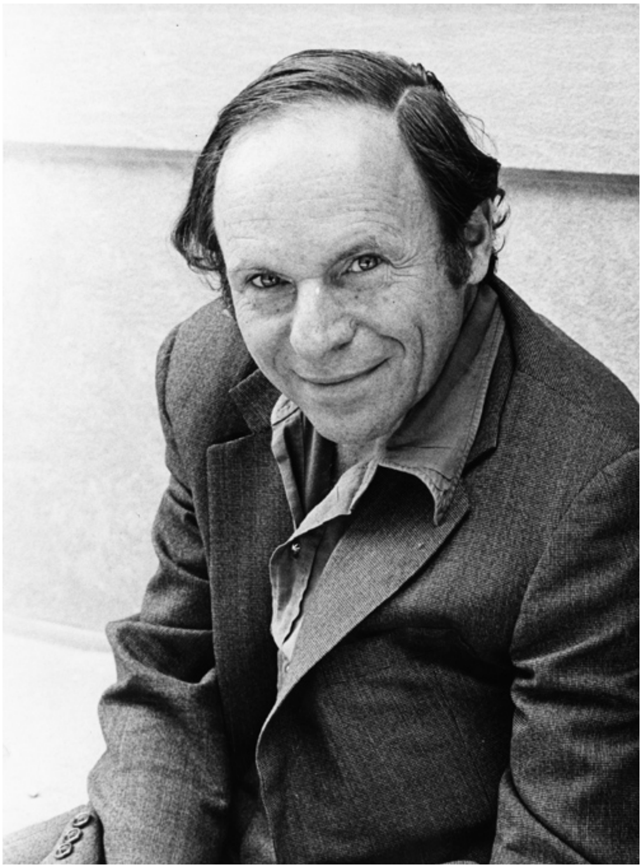
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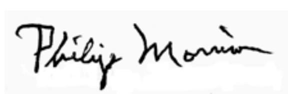

PHILIP MORRISON

November 7, 1915–April 22, 2005

BY LEO SARTORI AND KOSTA TSIPIS

After the explosive lenses were initiated, the nuclear chain reaction proceeded to its fateful maturity." These are the words of Philip Morrison ("Phil" to all who knew him) describing the first engineered release of nuclear energy: the plutonium bomb test explosion in the desert near Alamogordo New Mexico on July 16, 1945. The sentence epitomizes the man: a nuclear physicist, a major contributor to the development and testing of the plutonium bomb, deeply concerned about the fateful implications of nuclear weapons for the survival of humanity, and legendary for his mastery of the English language. Philip Morrison, the only son of Moses Morrison and Tillie Rosenbloom, was born on November 7, 1915, in Somerville, New Jersey. He died on April 22, 2005, at age 89, of respiratory failure.

When Phil was two the family moved to Pittsburgh to live in his grandparents' large house. Although his parents were of modest means (his father was a clothing salesman) the Rosenblooms were affluent, having owned a still that was operated under special license during Prohibition and were involved in a steel manufacturing facility outside Pittsburgh. At the age of four Phil was stricken by polio, which left him permanently affected; in his last years he was confined to a wheelchair. But his condition did little to restrain his activity; in a very real sense he was not handicapped.

Phil attended a private preschool and entered regular school only in the third grade. His aunt Florie recognized his extraordinary intellectual prowess and provided him with an endless stream of books, which he read avidly. His astonishing reading speed, as well as his encyclopedic knowledge, originated at an early age. On Phil's fifth birthday his father presented him with an Aeriole crystal radio, and he became an avid tinkerer, with a cellar laboratory filled with interesting "junk." By the age of 12 he had a ham radio operator's license and was communicating with people around the world. With top high school grades he entered Carnegie Tech (now Carnegie Mellon University) intending to major in electrical engineering. He quickly became bored by the narrow focus and emphasis on detail of engineering, however, and switched to a field that suited his curiosity and imagination better: physics. Yet the tinkerer's proclivity acquired in early childhood remained with him throughout his life. In 1936 he graduated from Carnegie and entered graduate school at Berkeley, fascinated by the fields and quanta that dominated physics in the 1930s. He became a student of J. Robert Oppenheimer.

In 1938, while still in graduate school, Phil married Emily Kramer, whom he had known since high school; they were divorced in 1961. In 1965 he married Phylis Hagen Singer, with whom he shared an idyllic relationship until Phylis's death in 2002. Phylis was a match for his intellectual prowess and was his partner in numerous educational enterprises. Together they raised Phylis's son, Bert.

Phil completed his Ph.D. in 1940 under Oppenheimer; his dissertation was entitled "Three Problems in Atomic Electrodynamics." He wrote 13 job applications before obtaining a position as instructor at San Francisco State College. In 1941 he became an instructor at the University of Illinois in Urbana.

Phil joined the Manhattan Project, the U.S. program to develop a nuclear weapon, in January 1943 at the instigation of his graduate school friend Robert Christy. Like many other American physicists he was motivated by the fear that Nazi Germany might develop nuclear weapons and use them against the Allies. That fear was well founded: after all, nuclear fission had been discovered in Germany in 1938, the Germans had a large corps of excellent nuclear physicists, and they had access to ample supplies of uranium in Czechoslovakia. Phil at first worked in the Metallurgical Laboratory in Chicago led by Enrico Fermi, whose team had just achieved the first nuclear chain reaction. In collaboration with Eugene Wigner his initial assignment was to calculate neutron cross-sections and to advise the DuPont Company in the design of the Hanford, Washington, reactors.

Concerned as he was about putative German advances in nuclear explosives, Phil persuaded General Leslie Groves in the spring of 1943 to initiate Project Alsos (*alsos* in Greek means grove), an effort to gather hard, firsthand information about German nuclear activities. After D-Day a team headed by physicist Samuel Goudsmit was assigned to follow the advancing Allied armies, examine captured equipment, and interview German scientists. By December 1944 Goudsmit's team had established that the German nuclear program lagged far behind the American one and there was no chance the Germans would acquire the bomb before the European war ended.

In the summer of 1944 Phil was transferred to Los Alamos, where he became a group leader in the laboratory's effort to achieve criticality for the plutonium bomb by implosion. Phil's task was to determine how much plutonium would be necessary so that "the reaction would grow fast"; he concluded that 6 kg would be enough. With George Kistiakowski, the explosives expert from Harvard, Phil assembled a plutonium bomb mock-up and established that about 2000 kg of high-explosive lenses would be needed for the implosion. Unlike the uranium bomb, which was dropped on Hiroshima without any test, the plutonium device required testing. Phil literally carried the plutonium core from Los Alamos to the test site in the back seat of a Dodge sedan, checking the stability of the plutonium once an hour along the way. He assembled the core of the test bomb and witnessed its successful detonation from an observation point 10 miles away. He was surprised by the heat that he felt on his face and was awestruck by the sight of the ascending cloud, "a sight never seen before." Like most physicists in the project he was elated by the success of the test; they had been curious as to whether their calculations would be verified.

Phil took part in the final assembly at Tinian Island of the uranium bomb that destroyed Hiroshima and carried out the final assembly of the plutonium weapon on the plane on its way to Nagasaki. Shortly after the end of the war, he and Robert Serber were sent to Hiroshima to assess, at first hand, the effects of a nuclear detonation on an urban center. In describing what he had witnessed he wanted his audience to confront and understand the immense scale of the destruction. Phil had not favored the use of the bomb against Japan but believed the existence of the bomb should be made public before the end of the war in order to inform the world and avoid a hidden nuclear arms race. "The public must realize that the bomb opened a door to fear, expense, and danger rather than just end the war."

During the Manhattan Project, Phil performed so many varied tasks that he was, it is generally agreed, the best-informed witness to the making of the bomb. The indelible visual experience of the apocalyptic results of the Hiroshima explosion and his firsthand assessment of the indiscriminate leveling effect of a single nuclear explosion on human habitat wove Phil's commitment to peace into the fabric of his life. One day after the end of the war he became a founding member of the Association of Los Alamos Scientists, which advocated international control of atomic energy. A short time later he wrote the draft of the aims of the newly established Federation of American Scientists (FAS): "To safeguard the spirit of free inquiry . . . without which science cannot flourish," an implicit plea for sharing nuclear weapons know-how, and served as the first president of FAS until 1949. During these years Phil was an active insider, testifying repeatedly before Congress on legislation to ensure civilian control of atomic energy. In 1945 the Los Alamos scientists had estimated that the Soviet Union would get the bomb within five years (which turned out to be an accurate estimate) and were concerned about the nuclear arms race that could (and did) ensue.

During Phil's presidency, FAS played an active role in a number of science policy debates. It spearheaded the successful effort to ensure civilian control of atomic energy in the United States; it proposed creation of the National Science Foundation; and after the Soviet bomb test in 1949, it proposed to internationalize control of atomic energy and supported the early version of the Lilienthal-Acheson plan (later called the Baruch plan), which was rejected by the Soviets. In addition, Phil spearheaded the (unsuccessful) FAS opposition to the development of the hydrogen bomb.

Phil stayed on at Los Alamos for a year after the war ended. During that period, he initiated and led the design of the first fast-neutron chain reactor. In 1946 he accepted Hans Bethe's invitation to join the Cornell Physics Department, having turned down an earlier offer from E. O. Lawrence to return to Berkeley. "It is too noisy a place for me," he said of Berkeley. (There were other reasons as well for the choice of Cornell.) He remained at Cornell until 1964 when he joined MIT, having spent an earlier term at the institute as a visiting professor in spring 1953. My (L.S.) earliest memories of Phil stem from that semester, when I was a graduate student at MIT. I recall that Phil gave three seminars simultaneously—one on quantum electrodynamics, one on astrophysics, and one on biophysics. It was my first exposure to the vast range of Phil's interests and knowledge.

Phil remained at MIT for the rest of his career; in 1974 he was named Institute Professor, the highest distinction for an MIT faculty member. His awards include the Pregel Prize of the New York Academy of Sciences (1955); the Babson Prize of the Gravity Research Foundation (1957); the AAAS-Westinghouse Science Writing Award (1961); the Oersted Medal of the American Association of Physics Teachers (1965); the Joseph A. Burton Award of the Forum on Physics and Society (1982); the Andrew Gemant Award of the American Institute of Physics (1982); the AAAS-Westinghouse Public Understanding of Science Award (1988); and the Klumpke-Robert Award of the Astronomical Society of the Pacific (1992). He was elected to the National Academy of Sciences in 1971.

In his youth Phil was drawn to left-wing causes, as were many idealistic intellectuals during the turbulent years of the Great Depression. He joined the Young Communist League in 1936 and the Communist Party itself some time later. At Berkeley he was active in party affairs; many of Oppenheimer's students were radicals, as was Oppy himself. (Morrison resigned from the party in 1942.) The security people at Los Alamos were aware of Phil's radical connections, as they were of Oppenheimer's. His FBI file was already over a hundred pages long. But he was evidently considered so valuable to the project that the security concerns were overridden.

In his early years at Cornell, Phil was quite active politically. He was a steadfast supporter of the American Peace Crusade; he participated in the 1949 Civil Rights Congress in New York, in the Committee for Peace Alternatives to the Atlantic Pact (NATO) in November 1949, and after the Soviet nuclear test, he initiated the movement Towards the Atomic Era of Peace. He was a leading participant in the Cultural and Scientific Conference for Peace in March 1949, attended by hundreds of prominent scientists and artists (Paul Robeson was among them). He was an active supporter of the Progressive Party and was one of the featured speakers at the party's 1948 convention, which nominated Henry Wallace for President. He participated in the organizing committee of an international World Congress for the Defense of Peace, in Paris in 1950; in 1949 he was part of the National non-Partisan Committee to defend the rights of 12 U.S. communist leaders. In February 1950 Phil was the keynote speaker, after Linus Pauling, at a Carnegie Hall meeting of the National Council for the Arts, Science, and the Professions. Several of the groups mentioned were accused of being communist-front organizations.

All these activities attracted attention. *Life* magazine included Morrison's picture in its 1949 gallery of America's 50 most eminent "Dupes and Fellow Travelers." In April 1951 the House Un-American Activities Committee devoted four pages of its *Report on the Communist "Peace" Offensive* to his supposed communist connections. Several right-wing publications published blistering attacks on Phil, as well as on Cornell for harboring such subversives. T. P. Wright, acting president of Cornell, came under intense pressure from right-wing members of the Board of Trustees as well as from alumni to dismiss Phil, even though he had tenure at the time. Although Wright had high regard for Phil and was devoted to academic freedom, he felt compelled to take some action. He urged Phil to (1) disassociate himself from Cornell whenever engaged in a controversial discussion; (2) avoid active sponsorship of any student organization in the field of controversy; and (3) avoid appearing personally on the platform with communists or with persons of great notoriety, such as might lead to widespread newspaper publicity. In his response Phil promised to do his best to act in conformity with Wright's three suggestions, but added the following:

> The problem is this: out of my whole experience in life and especially out of the events in my walking through the rubble of Hiroshima, I have gained the deep conviction that in the true interests of America, my country, it is urgent that some voices speak for peace even in times of crisis and even in the face of bitter opposition. The catastrophe of Hiroshima, matchless in human misery and in the profound moral erosion of a world perverting such powers, can come to the United States. It is not easy to take such a stand, particularly in a world where great power conflict is the way of international life, without angering many who see in the insistence upon peace a surrender of national interest. But I am convinced that the only real security for America is peace, and the best patriots are those who urge a policy of peaceful settlement.

President Wright was satisfied and the turbulence at Cornell subsided temporarily. But Phil's troubles were just beginning. In April 1953, 12 groups were added to the attorney general's list of allegedly subversive organizations; Phil was a member of three of them. In May, Phil was called to testify before Senator Edward Jenner's notorious Senate Internal Security Subcommittee. Against the advice of his conservative lawyer, Arthur Sutherland, he elected to plead the diminished fifth, agreeing to talk freely about himself but not about others. In a closed preliminary hearing Jenner asked him numerous questions about Oppenheimer, which he refused to answer. But in the public session Jenner did not pursue that line of questioning and did not even ask Phil whether he was then a communist. According to Sutherland, Phil testified simply and courteously and altogether made a good impression; nonetheless the committee's report was strongly critical of him.

On September 27 Phil attended a meeting of the National Council of the Arts, Sciences, and Professions and introduced a resolution that called on the United States and the Soviet Union "to adopt a spirit of understanding and conciliation in order to solve the problem of international regulation of atomic weapons." W. E. B. du Bois and Pete Seeger shared the stage with him. The resolution seemed innocuous enough, but a firestorm ensued. The new president of Cornell, Deane Malott, felt that Phil had violated the pledge he had made to Wright and asked him to "show cause in writing why I should not institute proceedings for your dismissal from the University." Malott appointed a special faculty committee to look into the matter. But the physics faculty at Cornell (especially Bethe, Dale Corson, and Robert Wilson) stood by Phil.

Phil replied to Malott, offering to "curtail sharply his associations with those organizations whose public standing has been impaired by the legal action of the Attorney General." He proposed that he and Malott draw up a list of such organizations, and he would then promise not to join them, speak at their meetings, or let his name be used by them. Malott was unwilling to draw up such a list. "You must be the sole judge in the matter of your actions," he told Phil, but "it is my inescapable responsibility to decide whether you are transgressing the limits of tolerance which the University should extend to you. . . I cannot help but hope," he added, "that you will be willing carefully to consider the advisability of withdrawing *all* association from organizations lying outside of your professional field." (Emphasis added.) Phil totally curtailed his public political activities and the furor finally died down. In the words of historian Ellen Schrecker, Phil had survived the inquisition and was one of the few politically active ex-communists to remain academically employed in the 1950s.

Beginning in 1954 Phil became "a political outsider, more academic and more dissident" in his own words. His commitment to peace and nuclear arms control, and his opposition to the military hypertrophy nurtured by the Cold War, found expression in several books he authored with colleagues: *Winding Down: The Price of Defense* (Times Books, 1979), *The Nuclear Almanac* (Addison Wesley, 1984), *Reason Enough to Hope* (MIT Press, 1998), and a small document *Beyond the Looking Glass* in 1993 in the hope of pointing the Clinton Administration in the right direction. One of us (K.T.) was a collaborator on the last three of these works. Phil remained to the end an articulate opponent of resolving conflict by war and an emphatic voice of reason advocating peace.

Phil Morrison's forte as a theoretical physicist was not complex calculations but rather imaginative ideas. He was a pioneer in numerous fields. It was not by chance that the titles of several of his papers took the form of a question. Phil's first professional publications were in atomic and nuclear physics. In one of his earliest papers (1940), in collaboration with Leonard Schiff, he calculated the spectrum that results when a K-electron flips its spin and is subsequently captured by the nucleus. At Cornell he at first continued to work in nuclear physics. He coauthored (with Bethe) one of the first textbooks on the subject: *Elementary Nuclear Physics,* published in 1952.

Phil's interests soon shifted to problems in astrophysics and cosmic phenomena. A groundbreaking paper coauthored with Giuseppe Cocconi in 1959 stimulated humanity's search for extraterrestrial intelligence (SETI). They reasoned that an advanced civilization sending a message out to the cosmos would choose to broadcast it at a frequency with some unique feature that would attract the attention of anyone who was trying to listen. The 21 cm hyperfine-structure line of hydrogen seemed the most logical carrier for that purpose. Cocconi and Morrison suggested that the search be carried out at that wavelength, which had the further advantage of being at a convenient radio frequency; their paper generated much excitement on the part of the public. Considerable radio telescope time has been devoted to SETI over the intervening years. In an imaginative article written in 1976, on the occasion of Morrison's 60th birthday, the radio astronomer Frank Drake, who had begun the search, speculated that the first message from outer space would be detected in 1996. That date is long past and no message has yet been detected, but the search continues. As Phil himself put it, "The probability of success is difficult to estimate, but if we never search, the chance of success is zero."

Another field of research in which Phil pioneered was the origin of cosmic rays. A 1954 paper with Bruno Rossi and Stan Olbert described the motion of cosmic rays through the galaxy as a random motion between scattering centers represented by moving magnetized clouds, expanding on a hypothesis first put forward by Fermi. Three years later he published an important review article on the subject in *Reviews of Modern Physics* (1957). Most astronomers associate the birth of gamma-ray astronomy with a short paper published by Phil in *Il Nuovo Cimento* in 1958. In this paper he identified potential mechanisms for the emission of both continuous and line-spectrum cosmic gamma rays (for example, the 2.23 MeV line emitted in deuterium formation by neutron capture) and made crude estimates of the gamma-ray fluxes that might be expected. Gamma-ray astronomy is now a flourishing area of research.

In a 1963 paper coauthored with his student James Felten, Morrison called attention to the role of the so-called "inverse Compton" effect in cosmic phenomena. In a collision with a relativistic electron a radio frequency or optical photon can be raised to a much higher energy. (In the center-of-mass system the process is simply Compton scattering.) The synchrotron radiation emitted by many cosmic sources is evidence for the presence of relativistic electrons. The inverse Compton process can be an important source of cosmic X rays or even gamma rays.

When Phil arrived at MIT, the field of X-ray astronomy was just in its infancy, as potent sources of extrasolar X rays were being discovered and studied. Two experimental groups were active in the Cambridge area: one at MIT led by Rossi and the other at American Science and Engineering under Riccardo Giacconi. Phil quickly became the principal theoretical expert for both groups. He published one of the first review articles on X-ray astronomy in the *Annual Review of Astronomy and Astrophysics* in 1967, as well as several significant papers on various aspects of X-ray astronomy.

In a short 1969 paper Phil pointed out the strong analogy between pulsars and quasi-stellar radio sources (QSS.) A pulsar is a magnetized (as shown by the intensely polarized emission), spinning (as shown by the periodic emission), highly condensed relic of a stellar explosion. Pointing to 3C345 as a prototype, Phil suggested that a QSS is the same sort of object on a larger scale (i.e., the highly condensed relic of a collapsed galaxy or protogalaxy). He coined the term "spinar" to describe an object of this type, and developed the concept in a number of subsequent papers. A 1976 paper with his student F. M. Flasar applied the spinar model to Cygnus A.

One of us (L.S.) had the privilege of a close collaboration with Phil between 1965 and 1972. The work that perhaps gave us the greatest satisfaction was a theory of the light from type I supernovas (SNI), first published in 1965. According to our theory, the quasi-exponential decline characteristic of the SNI light curve after its rapid initial rise represents what we called "optical reverberation" (Phil suggested the name, of course)—fluorescence radiation excited by ultraviolet photons from the exploded star interacting with the surrounding medium, rich in ionized helium, that had been ejected by the pre-supernova. (The 4686 A line of He II is the principal feature of the optical spectrum of an SNI.) The theory predicts that huge Stromgren spheres should surround supernova remnants; the Gum nebula seemed a likely candidate for such a phenomenon. Alas, our supernova theory turned out not to be right. The source of the supernova light is apparently the radioactive decay of Ni^{56}. As Tommy Gold once observed about the steady-state cosmology, the Lord made a big mistake on this one. It was a pretty theory and it deserved a better fate.

Our work on the supernova problem had one interesting by-product. Radio observations of quasars and active galaxies had identified several instances in which the product of an explosive event appears to travel faster than the speed of light. A material object actually moving at such a speed would violate special relativity and would be an event of immense interest. But we showed that the phenomenon can be explained without violating relativity. We constructed a class of models in which a fragment is emitted nearly in the direction of the observer at relativistic (but not super-relativistic) speed and emits radiation. For purely kinematic reasons such a fragment can appear to travel many times faster than c. (Only the transverse velocity is observed, of course.)

We published this work in a paper in *Science* (1971) coauthored with Antonio Cavaliere. (A similar theory was published at about the same time by Martin Rees.)

Yet another result of astrophysical interest that stemmed from the supernova work was that the diameter of a source whose energy output varies appreciably over a time period T is not necessarily less than cT, as is normally assumed. Once again the explanation is essentially kinematic. Over the succeeding years Phil and I published a number of other papers on X-ray and radio astronomy, quasars, and related subjects.

Phil published several significant papers with his student Kenneth Brecher. In 1973 they suggested that pulsing binary X-ray sources such as Her X-1 and Cen X-3 may be rapidly rotating degenerate dwarfs. Their model accounted for most of the features of those systems. In another paper they analyzed the recently observed cosmic gamma-ray bursts, suggesting that the gamma rays are inverse-Compton scattered photons.

Many colleagues have wondered why Phil abandoned nuclear physics in favor of astrophysics. He himself cited several contributing factors, among them the resonance between the Universe as we humans experience it and his own esthetic proclivity. A more practical consideration was the realization that research in nuclear physics and its successor, high-energy particle physics, would depend on government largesse to fund accelerators and ever more colossal equipment, a largesse likely to include bureaucratic strings—political, ideological, even intellectual. Outer space suited his political temperament and esthetic taste much better.

Phil's fundamental credo, one that undergirded his public activities over his entire life, was that power and responsibility belong to the people and a scientist's role is to inform and educate the public so that it can influence the political leadership in formulating rational national policy. Between 1949 and 1976 he wrote 68 science and science education articles for the general reader, 10 of them in *Scientific American.* Immediately after the end of World War II, he lectured on the radio on many occasions, explaining the workings of nuclear weapons and their catastrophic effects. He undertook extended visits for lectures and teaching around the world. The institutions he visited included the University of California, Los Angeles; University of Arizona; George Mason University; Imperial College, London; Tata Institute, Bombay; University of Kyoto; Pontifical Academy, Rio de Janeiro; the Weizmann Institute; Universities of Lagos and Ife; Fort Haire College in South Africa; and Space Applications Centre, Ahmedabad, India.

Phil also appeared on numerous television programs and in two films: *Powers of Ten,* which covered 41 orders of magnitude, from the proton to the galaxies, produced by Charles and Ray Eames in 1979, and the six-part television series *The Ring of Truth,* which aired in 1987 on PBS. In addition, he took part in television shows and films: *Fabric of the Atom,* BBC, 1961; *Christmas Lectures* at Royal Institution, BBC, 1966; *A Whisper from Space,* BBC/NOVA, 1977; *Termites and Telescopes,* BBC/NOVA, 1979; and miscellaneous appearances on BBC, CBC, CBS, NBC, ABC, and PBS local channels.

The more technical books authored by Phil include *Elementary Nuclear Physics,* with Hans Bethe (Wiley, 1952); *Charles Babbage,* an anthology with Emily Morrison (Dover, 1956); and *Origins of Cosmic Rays* in *Encyclopedia of Physics* (Springer, 1960), as well as several books written for the general public: *My Father's Watch* with Donald Holcomb (Prentice Hall, 1974); *Powers of Ten,* with Phylis Morrison and Ray Eames (Scientific American Library, 1982); *The Ring of Truth* with Phylis Morrison (Random House, 1987); and *Nothing Is Too Wonderful to Be True* (a Faraday dictum) (American Institute of Physics, 1994).

In 1956 a group called the Physical Science Study Committee (PSSC) was formed under the leadership of Jerrold Zacharias and Francis Friedman of MIT, with the objective of improving the teaching of secondary-school physics, which was then judged to be in a deplorable state. The group produced a textbook, *Physics*, published in 1962 by D. C. Heath, which was generally praised and achieved widespread use for several years. Phil was an active member of PSSC and wrote several sections of the textbook.

The PSSC spawned several successor projects, among them the Science Teaching Center and the Education Research Center; Phil was active in both those efforts. In his last decades he was increasingly involved in educational projects of various kinds, at both the elementary- and secondary-school levels, often in collaboration with Phylis. Both he and Phylis were intimately associated with the Exploratorium, a hands-on scientific museum in San Francisco founded by Frank Oppenheimer.

Among the most widely appreciated of Phil Morrison's literary contributions were his legendary book reviews for *Scientific American,* almost 1500 in all. In 1965 Gerard Piel, the publisher of *Scientific American,* asked Phil to become its book reviewer. Phil requested some sample volumes before deciding whether to accept the offer. Promptly about two dozen books arrived at the Morrisons' cramped row house in Cambridge. Early one Sunday morning Phil placed the books on a table on the sidewalk outside his house and discreetly observed the developing scene from an upstairs window. Within two hours passersby had helped themselves to all the books. "Yes, I will do the reviews," he told Piel, as the threat of a book tsunami had predictably receded. Thereafter each issue contained a major review and half a dozen or more shorter ones, all written by Phil, some jointly with Phylis.

Each December issue featured children's science books. The books reviewed spanned a broad range of topics, but Phil seemed to be an expert in all of them. It was a true tour de force. After the reviews ended, Phil and Phylis continued to write a monthly column for the next eight years.

Phil Morrison, a polymath with a prodigious memory, had a multifaceted personality, each side complementing the others. Intellectually protean, he possessed a wealth of knowledge, and encyclopedic and inspiring enthusiasm animated those who worked with him. His interests spanned not only many areas of physics but also elementary and secondary education, nuclear arms control, public policy, and showing the general public how the world works. The Morrisons' home was filled with simple, beautiful artifacts from all over the world and his crammed book cases reflected his spherical taste and interests: books ranging from metaphysics and archeology to quantum field theory and molecular genetics.

He was generous and wise, effervescent and kind, and at the same time stubborn, adversarial, and argumentative when seeking to get to the bottom of a problem. His immense self-confidence, acquired at a very early age, made him an enthusiastic, intrepid explorer of the cosmos. He did not like mysteries or uncertainty; he was impatient, curious, and adventurous, both intellectually and physically. Once while at Berkeley, he took the ferry to Sausalito and walked the catwalk of the Golden Gate Bridge to its very end while the bridge was still under construction. People who knew him well remember him as an iconoclast with a quiet, exhilarating sense of humor and an impish smile.

Phil's command of language was legendary. His physics colloquia were masterpieces of clarity and incisiveness. In his writings for the general public he managed to resolve the tension between truth and clarity, a permanent dilemma for those who attempt to explain natural phenomena to lay audiences. An MIT student once declared that "listening to Professor Morrison teach classical mechanics is like listening to poetry." His teaching style was eloquent, elegant, and intellectually demanding. He showed how the universe works by pointing out that nature is not threatening but understandable and exciting. Constantly thinking of ways to amaze his audience, he frequently explained physical phenomena and facts, or fundamental and profound physical principles, by using simple but unexpected analogies from everyday life that delighted his students and his lay audiences. On one occasion he showed a class how one can weigh neutrons by freezing heavy water into ice cubes, wrapping them in plastic bags and dropping them into a beaker of ordinary water: the cubes sank. On another occasion, in order to illustrate the immensity of Avogadro's number, Phil asked his class to estimate the number of grains of sand on the eastern seaboard of the United States. The students came up with an approximate number of 10 to the 20th power and Phil pointed out to them that Avogadro's number is yet a thousand times greater, giving them a tangible sense of its immensity. In describing the heat emitted by the plutonium core of the test bomb that he had carried in his lap from Los Alamos to Alamogordo, he said that the "core felt slightly warm, like a small cat." In *The Ring of Truth* Phil estimated that the average contestant in the Tour de France expends the energy content of 32 jelly doughnuts daily. To illustrate his point he built a bonfire of 32 jelly doughnuts, to the delight of the television audience.

Morrison was kind and generous and loyal to his students. His office door was always open, and he was always ready to help, to produce enthusiasm for the task at hand. "He was an enthusiastic polymath," according to one of his colleagues.

Phil's social and political views crystallized early. The Great Depression that amplified the chasm between the affluent and the working class, the emergence of fascism in Europe with the Spanish Civil War and the ascent of Hitler in Germany, radicalized him. He had a strong social conscience; he wanted a basic well-being for all, to encourage people to be optimistic, generous, and concerned not only about themselves but also about their moral obligation to the common good. He insisted that policy responses to problems of the "Commons," both national and global, should be approached not only with logic but also with empathy. A symbolic sartorial expression of his belief in the equality among people was his refusal to wear a tie: he did not want to perpetuate the distinction between white- and blue-collar workers. A more tangible proof of his insistence on equality and justice is the effort he spearheaded while a graduate student at Berkeley to raise the stipend of research and teaching assistants at the university to the level prevalent in other universities; he succeeded. President Sproul agreed to equalize pay.

Phil lost confidence in the Truman Administration immediately after the end of the war because of the Japanese cyclotron incident. Washington had promised the Los Alamos scientists that it would not order the destruction of the Japanese research cyclotron laboratory; Phil was infuriated by the order to destroy it. He took part in the demolition partly in order to save as much as possible of the laboratory equipment from the mindless military, and finally succeeded. Only the cyclotron itself was destroyed, but his distrust of the government took hold then.

Phil was a peace-oriented socialist, an idealist, the unfailing social conscience of the physics community, a passionate opponent of resolving conflict by combat, who mistrusted fanaticism as an acceptable motive for action. He was, in the words of professor Paul Horowitz, "a sensible visionary."

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