Robert F. Christy

1916–2012

BIOGRAPHICAL *Memoirs*

A Biographical Memoir by
David L. Goodstein
and Judith R. Goodstein

NATIONAL ACADEMY OF SCIENCES

ROBERT FREDERICK **CHRISTY**

May 14, 1916–October 3, 2012

Elected to the NAS, 1965

Robert F. Christy. Photo courtesy the Archives of California Institute of Technology.

By David L. Goodstein and Judith R. Goodstein

An early participant in the Manhattan Project during World War II, Robert F. Christy played a leading role at the project's Los Alamos, New Mexico, laboratory in developing the world's first nuclear bomb. Although he later made contributions to non-weapons-related nuclear-physics theory and cosmic-ray studies and did important research on the astrophysics of pulsating stars, it was his design of the "Christy gadget"—the plutonium implosion device successfully tested at the Trinity site in Alamogordo, New Mexico, on July 16, 1945—that brought him lasting recognition.

The early years

Christy was born in Vancouver, Canada, in 1916, the son of Hattie Alberta Mackay and British immigrant Moise Jacques Cohen, a McGill University-trained electrical engineer who changed the family's surname to Christy shortly before his death. Robert's mother, who taught school before marriage and was left a widow after a power-plant accident killed her husband when Robert was two, died eight years later. He and his older brother, John, were raised by their maternal grandmother, Alberta Mackay, and a great-aunt and -uncle.

An excellent student, Christy skipped two grades to graduate from Magee High School in Vancouver at the age of 16. "I found mathematics very easy," he later related in a Caltech Archives oral-history project.[1] Chemistry and physics offered no difficulties either, "because it was factual material." English and history were another matter. "I understood the material perfectly well," he remembered. "But…somehow or other, I never wrote the kinds of things they wanted me to write. So I got Cs in [these courses] until the end of high school." In 1932, however, he achieved the year's highest score among all the seniors taking the required general examination in British Columbia ("The exams were all one-word answers [and] I could get top marks in…that kind of exam") and he won the Governor General's Gold Medal. That fall, having completed the equivalent of the first-year of college in high school, he entered the University of British Columbia (UBC) as a sophomore on a Royal Institute Scholarship, which enabled him to attend college during the Depression as his brother worked odd jobs to help support the family.

At UBC Christy studied mathematics and physics, later recalling that classical mechanics taught him "how to calculate monkeys climbing string all over the place." Quantum mechanics was not part of the curriculum "because no one knew any," so he and some other students taught themselves the material using Linus Pauling's and E. Bright Wilson's seminal textbook[2] on the subject. Graduating in 1935 at age 19 and at the top of his class, Christy stayed on as a teaching assistant and earned a master's degree in 1937. By then, word reached UBC that J. Robert Oppenheimer had created a school of theoretical physics, second to none in the United States, at the University of California, Berkeley, and Christy decided to apply there for his Ph.D. Oppenheimer was already dividing his time between the physics departments at Berkeley and the California Institute of Technology (Caltech), and in time Christy joined the cavalcade of students who followed their mentor's migrations between the two campuses.

At Berkeley, where he spent the next four years, Christy became part of Oppenheimer's theoretical-physics group, joining Leonard Schiff, Robert Serber, Philip Morrison, and future Nobelist Julian Schwinger as well as experimentalists E. O. Lawrence, Luis Alvarez, Edwin McMillan, Willis Lamb, and Chien-Shiung Wu. Christy took Oppenheimer's course in quantum mechanics ("It was the first difficult course I had ever had") and studied electromagnetism with Lawrence, who he found to be a terrible teacher. In 1939 and 1940 Christy visited Caltech with Oppenheimer, where he was introduced to mathematical physicist Richard Chace Tolman, father-and-son experimentalists Charles[3] and Thomas Lauritsen, and future Nobelist William A. "Willy" Fowler. The trio would be instrumental in bringing Christy to Caltech after World War II.

Christy wrote his dissertation (coauthored with fellow graduate student Shuichi Kusaka) on the spin of the mesotron, now known as the meson. In later years Christy attributed his lifetime interest in bridging theory and experiment to the cosmic-ray research that served as the template for his doctoral thesis. "My greatest strength was not in creating new theories…but rather in seeing how theory and experiment related," he said. "This is probably what I did best." He received his Ph.D. in 1941 and that same year married Dagmar Elizabeth von Lieven, who had placed second in the 1932 British Columbia general examination, just behind Christy. The couple had two sons, Thomas (born at Los Alamos in 1944) and Peter.

Serving the Manhattan Project

After a short stint at the Illinois Institute of Technology, Christy took a research position at the University of Chicago in 1942. That appointment paved the way for him to join the Manhattan Project. Recruited by Eugene Wigner, who headed the project's theoretical group at Chicago, Christy initially did calculations aimed at controlling the rate of fission in a nuclear chain reaction. He went on to assist Enrico Fermi in developing a series of small graphite-based chain-reacting systems, work that extended to machining the graphite once the Chicago physics department had been "commandeered as a graphite machining shop," Christy recalled. He was present at the startup of the "pile" on December 2, 1942, when Fermi's experiments culminated in the first controlled self-sustaining nuclear chain reaction on the squash courts under the university's Stagg Field stands. While Christy and the others expected the chain reaction to happen, "only Fermi knew when." One of Christy's last projects at Chicago involved the basic engineering design for large-scale reactors, starting with one for the proposed new Argonne National Laboratory.

Early in 1943, Oppenheimer,[4] newly named the director of the Los Alamos effort, recruited Christy to come work with him there. The New Mexico facility was not yet complete, so Christy was dispatched to the University of Minnesota and the University of Wisconsin to help interpret the data on their fast-neutron experiments, even while continuing his work on the Argonne reactor. At Los Alamos, where he and his wife temporarily shared digs with Richard Feynman, Christy was assigned to the Theoretical Division, headed by Hans Bethe, who set him to work calculating the critical mass of a solution of Uranium-235 in salt water. Christy became instantly famous at Los Alamos when he came up with a figure that proved to be very close to the actual number of neutrons required.[5] "I've forgotten the number," he admitted years later. "Now I will confess that anytime you hit something within a percent, it's largely luck. But I didn't go around telling people it was luck. So that was a triumph."

As the lab grappled with the challenge of an implosion device with a plutonium core—to trigger the detonation of the nuclear bomb, Christy became the chief liaison between the calculators and experimenters, a role that he later credited with helping him gain a

The explosion itself remained seared in his memory. "It just grew bigger and bigger and it turned purple," he recalled.

crucial insight about the implosion mechanism that became known as the Christy gadget. Unlike previous designs, which involved a hollow and potentially unstable shell of fissile material that might fail to detonate, Christy's design was both simpler and more robust. It featured a solid core of a nearly critical mass of plutonium metal, with a small cavity containing an "initiator" that supplied neutrons to get the fission reaction started as the core imploded. Assembled as soon as enough plutonium became available, the Christy a crucial insight about the implosion mechanism that became known as the Christy gadget was successfully detonated at Alamogordo Air Field on July 16, 1945. "I felt it would work," said Christy, who witnessed the explosion at Alamogordo along with three bus loads of other Los Alamos personnel. "But I had no idea what it would be like."

The explosion itself remained seared in his memory. "It just grew bigger and bigger and it turned purple," he recalled. "The purple was an interesting thing, which I certainly hadn't anticipated. But it was in this ball. The debris was intensely radioactive, and it was sending out beta particles and gamma rays in all directions, and those ionized the air. So the air around this ball emitted a bluish glow, which comes from ionized air. It was most fantastic, to see this thing going up and swirling around and eventually cooling off to the point where it was no longer visible."

A month later, a plutonium implosion bomb based on the Christy gadget was dropped on the city of Nagasaki (the Hiroshima bomb, dropped three days earlier, had used a gun trigger to drive two pieces of U-235 together to form a critical mass). Years afterward, describing his reaction to reports of the devastation in both cities, Christy said, "It was very sobering. I feel that we were accustomed at that time—we were in a war, and there had been many battles in which thousands of soldiers had died. So it was not as though, suddenly out of the blue, you have people killed. There had been bombs dropped on cities. There had been firestorms, and so forth. I believe people nowadays don't realize that in war your objective is to beat the enemy. And unfortunately, mostly that involves killing a lot of the enemy. …But I felt then that although this was a terrible event, it probably saved many, many more Japanese lives. They probably would have lost millions if they had had to defend themselves against an invasion. And we would have lost hundreds of thousands. So in that context, it probably saved lives. But nevertheless, it's a very sobering thing. And we saw pictures of the destruction of Hiroshima. It was practically leveled."

Caltech, 1946-1986

After the war, Christy returned to the University of Chicago as an assistant professor and, continuing the tradition of interesting roommates, he and his family shared a house for a time with the future father of the hydrogen bomb, Edward Teller. Within six months, Christy received an urgent phone call from Willy Fowler,[6] who told him, "We want you to come to Caltech." He soon learned that the backstory involved Oppenheimer, whose hopes of having a contemplative life of teaching and research at the Pasadena university proved to be at odds with his newfound fame. Asked to suggest a theoretical physicist to take his place, he recommended Christy. "This, of course, was a fantastic compliment," said Christy, "because there's no way that I could replace Oppenheimer."

Physics lecture hall, June 1959. Front row, from left: William A. Fowler, William Houston, Lee A. DuBridge, Robert F. Bacher, Niels Bohr, Robert F. Christy, Richard P. Feynman, and Max Delbrück. Bacher Papers. (Photo courtesy the Archives, California Institute of Technology.)

Christy joined the Caltech faculty as an associate professor of theoretical physics and worked for a number of years with Fowler and Charles Lauritsen's group at the Kellogg Radiation Laboratory while he continued his research into cosmic rays. From Christy's base at Kellogg his influence soon expanded beyond problems connected with nuclear and cosmic-ray physics, and he played a vital role in Caltech's emergence as a world leader in postwar theoretical physics. As Robert Bacher, who arrived at the Institute in 1949 to take up his duties as chairman of the Division of Physics, Mathematics, and Astronomy, later recalled: "I never considered thinking about anything we should initiate in appointments that had anything to do with new fields or theoretical people without first talking to Christy about it."[7] By then, the federal government had begun to invest heavily in peacetime science, and physics had become a thriving enterprise at Caltech.

In 1946, the Office of Naval Research initiated its many years of support for Kellogg's nuclear physics group, thanks in part to associations forged by Lauritsen during the war. Immediately after his arrival, Bacher began to rebuild the physics department, starting with wooing the brilliant high-energy theorist and Christy's Los Alamos colleague Richard Feynman away from Cornell. Feynman was reluctant to take on graduate students, and a bemused Christy soon found that he had become their de facto supervisor, a responsibility that backfired on at least one occasion.

Christy had resumed his research into the meson, whose properties, as they became better known, had increasingly baffled the particle physics community. He realized that this puzzling behavior could be explained if mesons actually came in two varieties—the mu meson (now called the muon) and the pi meson (now known as the pion). He assigned the problem as a thesis topic to one of his graduate students, but they were beaten to publication by the University of Rochester's Robert Marshak, who had arrived at the two-meson hypothesis independently.[8] (The results of the Caltech research were published in 1949.[9]) "This was one of those occasions [when] having extra students to look after kind of slows you down a bit," Christy later said, somewhat ruefully. Today, muons and pions are known to constitute two distinct classes of elementary particles: muons are classified as leptons and associated, like electrons, with the weak nuclear interaction, while pions are classified with protons and neutrons as hadrons and partake of the strong nuclear interaction.

Opposing Nuclear Proliferation

During the 1950s Christy began to question the wisdom of the nuclear arms race. In 1951, at the height of the Korean War, the Army, Navy, and Air Force asked Caltech to investigate the capacity of Western Europe to resist an attack from the Soviet Union. The study, known as Project Vista, dealt largely with the question of whether tactical nuclear weapons could be used effectively on the battlefield, thus avoiding or reducing the need for strategic weapons—whose deployment would inevitably destroy large cities. Christy, Bacher, and Charles Lauritsen, with intermittent participation from Oppenheimer, were primary Caltech investigators on the project, which involved dozens of Institute scientists, as well as military personnel and outside consultants. Many of their conclusions, classified by the Strategic Air Command, remain off-limits to the public to this day (2013).

Christy's growing concern about nuclear proliferation was reinforced by his distaste for the anti-Communist hysteria that swept across the United States in the early 1950s and

In 1954, soon after an AEC panel stripped Oppenheimer of his security clearance—partly on the strength of Teller's testimony—Christy encountered Teller at Los Alamos. Christy promptly turned away, refusing to acknowledge his former friend and colleague, much less shake his hand. In that instant, as Teller later recounted, he realized that his life as he knew it was over.

eventually entangled his idol Oppenheimer. Christy was appalled by the allegations of disloyalty leveled against Oppenheimer, and he never forgave Edward Teller—who had quarreled with Oppenheimer over the need to develop "the super," or hydrogen bomb—for having told the U.S. Atomic Energy Commission (AEC) that he had reservations both about Oppenheimer's judgment and left-wing politics. In 1954, soon after an AEC panel stripped Oppenheimer of his security clearance—partly on the strength of Teller's testimony—Christy encountered Teller at Los Alamos. Christy promptly turned away, refusing to acknowledge his former friend and colleague, much less shake his hand. In that instant, as Teller later recounted, he realized that his life as he knew it was over. As for Christy, he never expressed any regrets. Forty years later, in his oral history, he said of Teller's testimony: "I felt that it was just the wrong thing to do—for an honorable physicist to testify against Oppenheimer. It just wasn't right. And I was very upset by it. I still am."

In 1956, Christy took his nonproliferation stance public. He, Thomas Lauritsen, and eight other Caltech scientists (including Nobel laureate Carl Anderson and four faculty who, like Christy, had worked on the Manhattan Project) purchased ad space in the Los Angeles Times to publish a letter supporting Democratic candidate Adlai Stevenson's position that the United States should unilaterally halt atmospheric hydrogen-bomb testing as a first step toward more comprehensive arms negotiations. Stevenson's proposal, the Caltech scientists wrote, would be "a useful way to get the negotiations out of the deadlock stage by taking a step which would not endanger our security. …At the very least, the proposal is one that should be widely debated and discussed for the obvious reason that the control of nuclear weapons is vital to our survival."[10] Although the signatories emphasized that they were speaking out as individuals and not as spokespersons for Caltech, the letter was seen in some quarters as a ringing endorsement of Stevenson's candidacy. It drew a sharp rebuke from Caltech Board of Trustees chair Albert Ruddock, who called it "clearly political and must not be taken to represent any official position by the Institute, its officers, trustees, or faculty as a whole."[11]

Robert F. Christy, Robert F. Bacher, Charles C. Lauritsen and others in the control room of Caltech's EN Tandem Van de Graaff accelerator, December 1961. (Courtesy the Archives, California Institute of Technology.)

"We wanted what we said to be noticed and have an impact," said Christy, adding that the episode did not tarnish his relations with Caltech's president Lee A. DuBridge, who "was always one to defend people's right to their own views."

Diverse projects and duties

A scientist of wide-ranging interests, Christy derived great pleasure from identifying new problems to which he could apply his deep understanding of fundamental physics. An example was Project Orion, the brainchild of physicist Freeman Dyson, which involved the design of a very large spacecraft propelled by nuclear explosions. Initiated in 1958, no Orion prototype was ever successfully tested, largely because no one could figure out how, and in 1963 the signing of the Partial [Nuclear] Test Ban Treaty put an end to the prospect of above-ground nuclear detonations.

In 1960, Christy spent a sabbatical year at Princeton University, where he embarked on a study of Cepheid variables (pulsating stars used as "standard candles" for measuring astronomical distances) and RR Lyrae stars (smaller versions of the Cepheids). Decades of observations had established that these stars underwent periodic variations in brightness—often characterized as vibrations—but the physics underlying the phenomenon was poorly understood. Christy had the insight that the implosion calculations developed at Los Alamos could be successfully applied to the problem. "It was known," he said, "that [the Cepheids] were apparently spherical pulsators. That is, they expanded and contracted…in spherical symmetry. I thought: Well, this is very much like the spherical hydrodynamics in implosion.…[T]he theory used to make atomic implosion bombs was the same theory I could apply to certain kinds of variable stars. It's interesting to see how things relate to each other."

Christy's mathematical models helped explain why the vibrations occurred and why they were confined to certain types of stars; and in 1967, a year after he had published his findings, he was awarded the Eddington Medal of the Royal Astronomical Society for his contributions to theoretical astrophysics.

Elected to the National Academy of Sciences in 1965, Christy spent part of 1967 at the University of Cambridge as a Churchill Fellow, a position he greatly enjoyed. Returning to Caltech in 1968, he served for two years as executive officer for physics, the Caltech equivalent of a department chairman, and also as chairman of the faculty, a largely honorary position, in 1969. His administrative duties expanded greatly in 1970 when Caltech's president, Harold Brown, asked him to chair a committee to conduct a nationwide search for a new Caltech provost. The group proposed a number of candidates, but as sometimes happens in such cases, when all of the candidates declined, the job was offered to the chair of the search committee. Christy served as provost until 1980, and among many other accomplishments in that capacity he oversaw the establishment of Caltech's doctoral program in economics—the Institute's first Ph.D. program outside the sciences. During this decade, Christy divorced his first wife (in early 1971) and married fellow physicist Juliana Sackmann (in 1973). The couple had two daughters, Ilia and Alexandra.

When Harold Brown left Caltech in 1977 to become secretary of defense in the Carter administration, Christy stepped into the role of acting president while continuing as provost. He held both positions until Marvin L. "Murph" Goldberger succeeded Brown in 1978. After his decade as provost, Christy returned to full-time teaching and research, and he was named Institute Professor of Theoretical Physics in 1983.

At about this time Christy became chair of a U.S. Department of Energy (DOE) working group commissioned to conduct dosimetry studies of the survivors of Hiroshima and Nagasaki; the aim was to determine how much gamma-ray and neutron radiation they had been exposed to in the wake of the atomic bombs. Since 1947, the Atomic Bomb Casualty Commission, established by the National Academy of Sciences, had conducted annual reviews of the health of these Japanese survivors, but little was known about the precise nature of their radiation exposure. The DOE working group, predominantly made up of scientists affiliated with the national laboratories at Los Alamos, Livermore, and Oak Ridge, found good correlation between previous calculations of gamma-ray exposure and the actual doses found in the cities' populations, as well as for neutron exposure in Nagasaki; but it found higher neutron levels than predicted among survivors of Hiroshima. This discrepancy has still not been satisfactorily explained. Speaking a decade later of the health implications of the study, Christy called the working group's work "one of the principal sources of information for medical experts around the world on the effects of radiation on people. So it's been very important to try to get these numbers right."

In addition to his investigations in Japan, Christy served on a number of DOE committees set up to evaluate progress on inertial-confinement nuclear fusion research. Conceivably this technology could be applied to the design and construction of fusion reactors, a source of relatively clean and potentially inexhaustible energy, but the needed breakthroughs have yet to materialize. Summing up the state of fusion research in 1994, Christy expressed a view that still prevails among many today: "Every time we meet and discuss the possibilities of success, it's always at least 20 years down the road. And it's been going on that way for the last 40 years—fusion has always been 20 years down the road."

Christy retired as Institute Professor Emeritus in 1986. Tall (6' 4"), lanky, and a fiercely competitive tennis player, Christy was also a fearless horseback rider. He had learned to ride horses at Los Alamos, and in 1984, when he and Juliana purchased a 240-acre tract of lush wilderness in a mountain valley in Ventura County, about 90 miles outside Los Angeles, he acquired his own horse, which he rode frequently.

Christy died in Pasadena in 2012, after 96 productive years. He was survived by his wife, their two daughters, two sons from his first marriage, and five grandchildren.

ACKNOWLEDGEMENTS

We would like to thank Caltech Archivist Charlotte Erwin for permission to publish selected excerpts from the Robert F. Christy oral history, Loma Karklins for her valuable help with the photographs, and Heidi Aspaturian for a critical reading of the manuscript.

NOTES

1. Lippincott, S. 1994. Interview of Robert F. Christy. Pasadena, California, June 15, 17, 21, and 22. Oral History Project, California Institute of Technology Archives (Hereafter cited as CIT OH). For a slightly different version of this interview, see Lippincott, S. 2006. A conversation with Robert F. Christy. *Phys. Perspect.* 8:282-317, 408-450.

2. Pauling, L., and E. B. Wilson. 1935. *Introduction to quantum mechanics, with application to chemistry.* New York and London: McGraw-Hill.

3. For more on Charles Lauritsen, see Holbrow, C. H. 2003. Charles C. Laurisen: a reasonable man in an unreasonable world. *Phys. Perspect.* 5:419-472.

4. For more on Oppenheimer's life and work at Los Alamos, see Bird, K., and M. Sherwin. 2005. *American Prometheus: the triumph and tragedy of J. Robert Oppenheimer.* New York: A. A. Knopf.

5. For a full account, see Hoddeson, L., P. W. Henriksen, R. A. Meade, and C. Westfall. 1993. *Critical assembly: A technical history of Los Alamos during the Oppenheimer years, 1943–1945*. Cambridge, England: Cambridge University Press.

6. For Fowler's recollections, see Greenberg, J. 2005. A conversation with William A. Fowler—Part I. *Phys. Perspect.* 7:66–106. Part II. *Phys. Perspect.* 7:165–203.

7. Terrall, M. 1983. Interview with Robert F. Bacher. CIT OH.

8. Marshak, R. E., and H. A. Bethe. 1947. On the two-meson hypothesis. *Phys. Rev.* 72:506–509; Marshak, R. E. 1949. On mesons π and μ. *Ibid.* 75:700–701.

9. Latter, R. 1949. A study of the two-meson hypothesis. Ph.D. dissertation. California Institute of Technology.

10. *Los Angeles Times,* October 14, 1956.

11. A. B. Ruddock to L. A. DuBridge. Oct. 15, 1956. DuBridge Papers, Box 190.5, Institute Archives, Caltech.

SELECTED BIBLIOGRAPHY

1939 With S. Kusaka. Electric quadrupole moment of the deuteron. *Phys. Rev.* 55(7):665.

With J. M. Keller. X-ray spin doublet splittings. *Phys. Rev.* 56:856.

1940 With J. M. Keller. A precise determination of the fine structure constant. *Phys. Rev.* 58(7):658.

1941 With S. Kusaka. The interaction of gamma–rays with mesotrons. *Phys. Rev.* 59:405–414.

With S. Kusaka. Burst production by mesotrons. *Phys. Rev.* 59:414–421.

With J. R. Oppenheimer. The high-energy soft component of cosmic rays. *Phys. Rev.* 60:159–159.

1942 With J. M. Keller. Precise determination of the fine structure constant from X-ray spin doublet splitting. *Phys. Rev.* 61(3–4):147–152.

1947 With S. Rubin. Angular distribution of alpha-particles from Li^7 + p. *Phys. Rev.* 71:275.

With E. R. Cohen, W. A. Fowler, C. C. Lauritsen, and T. Lauritsen. The conservation of momentum in the disintegration of Li^8. *Phys. Rev.* 72(8):698–711.

1948 With R. Latter. Proton widths of light nuclei. *Rev. Mod. Phys.* 20(1):185–190.

1949 Angular distribution of gamma-rays from lithium. *Phys. Rev.* 75:1464.

1953 The coupling of angular momenta in nuclear reactions. *Phys. Rev.* 89(4):839–842.

1954 Low excited states of F^{19}. IV. Angular distributions. *Phys. Rev.* 94(4):1077–1078.

1955 Alpha particle decay of heavy nuclei. *Science* 122(3175):873–882.

1956 With G. R. Burbidge, F. Hoyle, E. M. Burbidge, and W. A. Fowler. Californium-254 and supernovae. *Phys. Rev.* 103(5):1145–1149.

1962 Energy transport in the hydrogen ionization zone of giant stars. *Astrophysical J.* 136:887–902.

1963 Dynamics of RR Lyrae envelopes. *Astronom. J.* 68:275.

1964 The calculation of stellar pulsation. *Rev. Mod. Phys.* 36(2):555–571.

1966 A study of pulsation in RR Lyrae models. *Astrophysical J.* 144:108–179.

Pulsation theory. *Annual Reviews of Astronomy and Astrophysics* 4:353–392.

1967 Computational methods in stellar pulsation. *Methods in Computational Physics* 7:191–218.

1968 The dynamics of variable stars. *SIAM Review* 10(3):291–302.