Edward B. Lewis 1918 – 2004

Edward Lewis, the Morgan Professor of Biology, Emeritus, died July 21 after a long battle with cancer; he was 86. Lewis worked on the genetics of the *Drosophila* fly for almost 70 years, 61 of them at Caltech, and was engaged in active research until the final months of his illness. He also played a key role in the debate on nuclear testing in the '50s. Caltech president David Baltimore called him "one of the true masters of genetics, the bridge between the pioneers of *Drosophila* work—Morgan, Bridges and Sturtevant—and modern developmental biology."

Lewis was awarded the 1995 Nobel Prize in Physiology or Medicine for discovering a group of master control genes that orchestrate the development of a fly embryo's body parts, and for showing that these genes are strung along the chromosome in the same order, from head to tail, as the body parts that they control. These same genes, containing almost identical stretches of DNA, have since been found in all other animals, including humans: a strategy for development that gave rise to the first primitive marine animal over 550 million years ago had been preserved by all the invertebrates and vertebrates descended from it. Lewis, who worked on a group of genes called the bithorax complex, shared the Nobel Prize with Eric Wieschaus and Christiane Nüsslein-Volhard, who identified genes that work at an even earlier stage of development. Prior to his Nobel Prize, Lewis had received the Wolf Prize in Medicine in 1989 and the National Medal of Science in 1990, among many other honors.

Lewis championed the value of basic research for its own sake, and stressed that he hadn't set out to make the discoveries that led to his awards; he was simply trying to find out how genes worked, what they were made of, and how new genes could arise from old. By being allowed to do his research without having to justify its health benefits to funding bodies, he had ("by many circuitous routes") contributed toward the understanding of human congenital malformations.

He loved the abstraction of genetics, which "allows one to deduce many properties of genes without any knowledge of what they are made of." In fact, for the first 20 years of his research, genes were thought to be proteins—which turned out to be completely wrong. But it didn't affect his results, because "the laws of genetics have never depended upon knowing what the genes are chemically and would hold true even if they were made of green cheese."

The four-winged fly (normal flies have only two wings, the second pair having evolved into gyroscopic knobs called halteres) that became the visual icon of his work was one of the most striking bithorax mutants. But it was "just a stunt," Lewis said, "a byproduct of the theory we were testing." (A modest man who disliked self-aggrandizement, he always used "we," even when he had done all the work himself.) After working on four-winged flies, flies with stunted halteres, flies with legs in the wrong place, and many others for 32 years, he finally published, in 1978, "his miraculous paper," said longtime colleague Howard Lipshitz, "that laid out a paradigm for the genetic control of development." Lewis's work united three separate disciplines of biology—genetics, developmental embryology, and evolution—into one.

Born May 20, 1918, in Wilkes-Barre, Pennsylvania, where his father was a watchmaker, Lewis loved the wildlife that lived near the banks of the Susquehanna river, especially the insects, toads, turtles, and snakes. After reading about the work of Morgan and Bridges on *Drosophila* at Caltech, he spotted an ad in the back of *Science* for cultures of the flies at $1 each. Seventeen-year-old Lewis and schoolfriend Edward Novitski scraped up some money, ordered a few tubes, and spent their spare time in the high school biology lab breeding the tiny flies, sorting through their offspring with magnifying glasses, and analyzing the results. Lewis, a talented flutist, gained a music scholarship to Bucknell College, but transferred to the University of Minnesota

(chosen for its low out-of-state tuition fee of $25) after a year. It was a lucky choice: genetics professor C. P. Oliver encouraged the undergrad to carry on with his *Drosophila* hobby at a desk in his lab. Lewis worked on a new mutant sent by Novitski (who also became a geneticist; PhD '42) from Purdue.

After earning a BA in biostatistics ('39) in just two years (a zoology degree would have taken a third, unaffordable, year), a recommendation from Oliver landed Lewis a teaching fellowship at Caltech as one of Sturtevant's graduate students. He discovered a way to tell if two recessive genes were on the same gene or on two different ones, the *cis-trans* test, an important new technique for genetic analysis that won him his PhD in 1942.

He now had to enlist for war service, but president Robert Millikan guaranteed him an instructor's job afterward. Lewis took the Caltech-based U.S. Army Air Corps meteorology course (MS '43) and was sent to Hawaii and Okinawa as a weather forecaster. The year he came back to Caltech, 1946, was also the year he married Pamela Harrah, a Stanford graduate trained as a scientific illustrator. She was working in George Beadle's lab in Stanford that year, but Beadle was moving to Caltech and he wanted her with him to look after his *Drosophila* stock collection. Son Hugh Lewis, speaking at a memorial service last October, takes up the story: "One day [Beadle] looked at Pam and said, 'Pamela, how tall are you?' 'Five foot four,' she replied. And he said, 'Well, there's a nice young man at Caltech, and he's also kind of short (Lewis was about five foot two); his name's Ed Lewis. You could meet him, he'd fall in love, and you could get married.'" It worked.

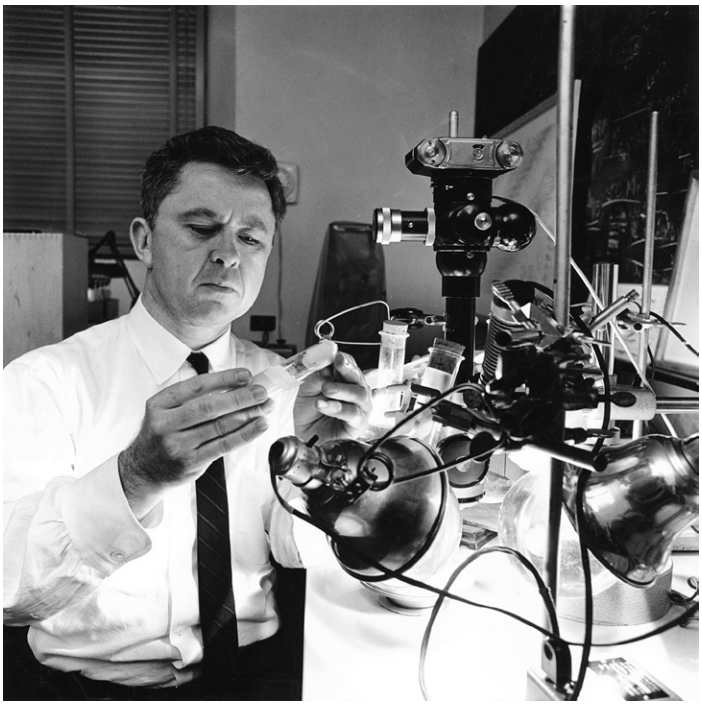
Lewis published infrequently, often in obscure journals, and his papers were difficult to read, according to Lipshitz, whose book *Genes, Development and Cancer: The Life and Work of Edward B. Lewis* was published a few months before Lewis's death. "His publication rate would be considered atrocious by most grant review panels or academic promotions committees." Seymour Benzer, Boswell Professor of Neuroscience, Emeritus, once joked, "Ed is a maverick who could never survive in a normal institution." Lewis was also unusual in that he worked alone. "The number of postdocs he had in 60 years could be counted on one hand, and the number of graduate students was even less," Lipshitz wrote. "Ed continued to do science for himself his whole life."

Yet he wasn't antisocial. Speakers at the Caltech memorial service recalled him as friendly, collegiate, kind, and caring. Provost Paul Jennings remembered more than 40 years of lively lunchtime discussions with him at the Athenaeum faculty table (Lewis came into work very early, and left very late, but was a popular lunchtime regular.) Jennifer Caron (BS '03), whose senior thesis, "Biology and 'The Bomb'" (published in *E&S*, 2004, no. 2), was about his important role in highlighting the health risks of above-ground nuclear-bomb tests, recalled his patience and helpfulness, and how, when she visited his room on the top floor of Kerckhoff, he would "move a stack of papers, rearrange the journals and bottles of fruit flies, and offer a chair."

Lewis loved art, and was renowned for his Halloween costumes; he would come to parties as a painting, often a Magritte. Always a keen flute player, he arranged chamber music sessions with friends, took part in Caltech musicals, and fit in lessons from San Francisco opera flutist Patricia Farrell (who performed a short piece at the end of the memorial service) when in the Bay Area for the opera season.

The Lewis family pets weren't the furry kind, recalled Hugh. Desert tortoises roamed the backyard of the family home in San Marino, and octopuses lived in large tanks inside. He was one of the first to get them to breed in captivity.

Lewis became professor of biology in 1956, was named the Morgan Professor of Biology in 1966, and became an emeritus in 1988. With the advent of molecular biology in the '60s, bacteriophages



Lewis's love affair with *Drosophila* (he didn't like it referred to as a fruit fly) began in 1935 and continued through 1964, above, and 1996, right. He numbered his genetic crosses sequentially from the day he started his research, and ended at number 53,446.

and bacteria were in favor. Lewis, still working with flies, became an anachronism. But when David Hogness (BS '49, PhD '53), Welcome Bender (PhD '78), and others decided to clone a higher organism, they chose the bithorax complex of *Drosophila* because of Lewis's detailed knowledge of this area and his outstanding collection of mutants, which he generously lent them. When the positional cloning was complete, "the physical map of the bithorax complex corresponded perfectly with the genetic map," Lipshitz wrote, "validating over 35 years of Lewis's genetic results."

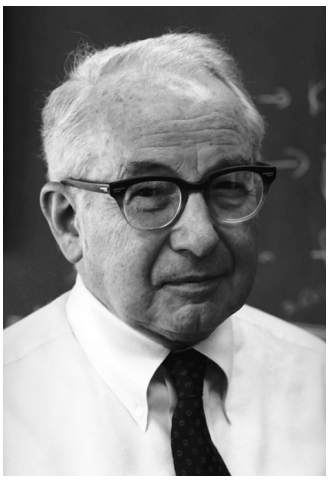
Worried about above-ground nuclear testing in the '50s, Lewis challenged the current dogma that exposure to low amounts of ionizing radiation didn't damage human tissues. As told in "Biology and 'The Bomb,'" he calculated the relationship between radiation doses and leukemia using publicly available data, and published the results in *Science* in 1957. His conclusion that even small amounts of radiation caused leukemia created such a stir that he was summoned to appear before a congressional joint committee on atomic energy. Despite the grilling they gave him, he continued to publish on radiation risks for another 20 years. "Ed has a permanent place in the history of radiation and chemical protection policy in the U.S.," James Crow, of the University of Wisconsin–Madison, said at the memorial service. "This is not the work he won the Nobel Prize for, but maybe as far as public policy is concerned, it might be the most important work he did."

Lewis is survived by his wife, Pamela, and two sons, Hugh, an attorney, and Keith, a biologist. A third son, Glenn, died in his early teens in a mountaineering accident.

"Ed did science because he loved it, rather than for fame and fortune," said Andrew Dowsett (BS '74), "and when it brought him fame anyway, one could only smile and think that sometimes, nice people *do* finish first." □–*BE*

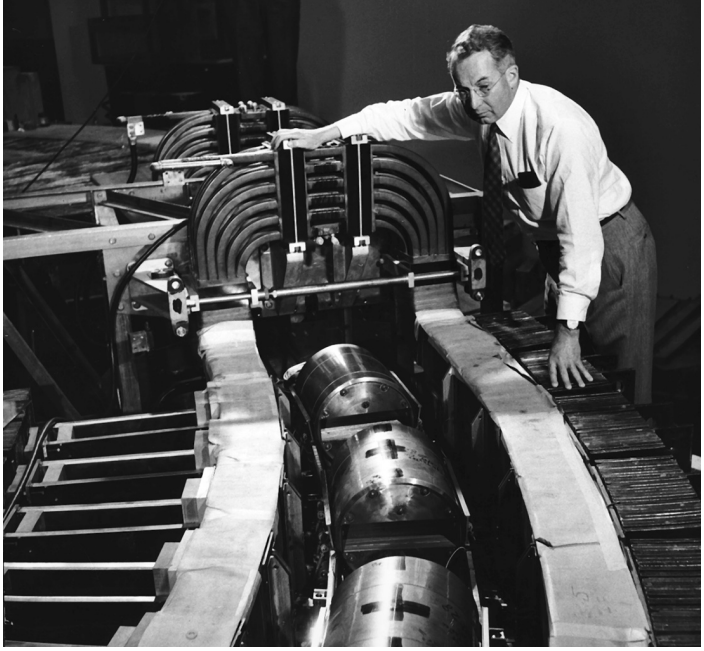
At the 1995 Nobel Prize celebrations in Stockholm, Ed and Pam were guests of King Carl XVI Gustaf of Sweden and Queen Silvia. Crown Princess Victoria is on the left.

Robert F. Bacher
1905 – 2004



Robert F. Bacher, Caltech's first provost, who had headed the experimental physics division of the Los Alamos Laboratory, died November 18 at the age of 99.

Bacher was born August 31, 1905, in Loudonville, Ohio, but grew up in Ann Arbor, Michigan, where he knew his later-to-be wife, Jean Dow, from childhood. He graduated from the University of Michigan in 1926, to which, after a year of graduate school at Harvard, he returned to earn his PhD in 1930, under Samuel Goudsmit, with a thesis on hyperfine structure in atomic spectra. He and Jean married right after graduation and embarked on a cross-country drive to Pasadena; it was Bacher's first encounter with Caltech—as a National Research Council Fellow. He didn't know much about what went on here, he said in his oral history (recorded by the Caltech Archives in 1981), but it had one of the larger graduate programs in physics at the time. And he admired Ira Bowen as the best spectroscopist in the country. During that year he attended Robert Oppenheimer's lectures, "but I must say, they were extremely difficult to understand." Nevertheless, they later became close friends and colleagues.



Bacher stands beside the magnet of the synchrotron in 1955. At that time the electron accelerator had a peak energy of about 300 MeV; Phase 2, which began operation in 1957 had a peak energy of just over a billion volts.

After another NRC year, at MIT, Bacher returned to the University of Michigan, then went to Columbia as an instructor in 1934, where he worked with I. I. Rabi. A year later he followed Hans Bethe to Cornell, where he started doing experimental work in nuclear physics with Bethe and left theoretical work behind. He was quickly promoted to full professor and director of the Laboratory of Nuclear Studies. Early on, he had felt that the United States needed to start doing war work, and when Lee DuBridge, head of the Radiation Lab working on radar at MIT, summoned him there in 1941, he went.

Then, late in 1942, Oppenheimer approached Bacher about a new lab for nuclear weapons work that was just starting up and the following spring asked him to join the Manhattan Project. Bacher declined initially, telling Oppenheimer that what he needed was engineers. Ultimately, when Oppenheimer made a commitment to hiring more engineers and made him head of the experimental physics division, Bacher signed on. From the beginning, Bacher was firmly opposed to making Los Alamos a military lab and persuaded Oppenheimer, who had agreed to take a commission as lieutenant colonel and had already ordered his uniforms, to keep it under civilian control, at least until they had enough fissionable material for a bomb.

When the project was reorganized in July 1944 to speed work on implosion, Bacher's experimental physics division was split, and he was put in charge of the G (for "gadget," the code name for the bomb) division. Bacher personally escorted the first bomb to the test site in July of 1945. In 1946 he was awarded the President's Medal for Merit for his work on the Manhattan Project.

Bacher returned to Cornell (he had taken a leave of absence during the war), hoping to get back to high-energy physics, but the bomb's aftermath continued to involve him. He felt strongly that there should be some sort of international control of atomic weapons and worked hard on negotiations with the Soviet Union. He admitted in his oral history that this was perhaps idealistic, but thought that getting this technology out in the open might have avoided the subsequent Cold War. When the Atomic Energy Commission was established, Bacher served as the only scientist among its members; he had tried to decline the post but took it on when he learned that there would be no scientist at all if he didn't accept. While a member of the AEC, he pushed for the development of nuclear submarines and breeder reactors for commercial power.

In the meantime, Lee DuBridge, now president of Caltech, offered him a position as chairman of the Division of Physics, Mathematics and Astronomy—or as just a professor, whichever he preferred. "The decision I came to was a fateful one and probably illustrates a major failing in my makeup," Bacher said in the oral history. "I saw what was needed in the division at Caltech and felt some real confidence that I could do a respectable job, so I agreed to take the division chairmanship—at least to get some new fields started and make some additions." What he saw as a "major failing" in his makeup was, in fact, a superb talent for envisioning the future and leading the Institute into it. After getting a commitment that the Institute would support a program in high-energy physics, both theoretical and experimental, Bacher arrived in 1949.

One of his first hires in high-energy physics was Robert Walker, whom he had known at Los Alamos and Cornell. (Walker died January 4; see page 41.) Another of Bacher's early recruits was Richard Feynman, who was reportedly feeling "unsettled" at Cornell; Bacher persuaded him to sign on at Caltech with a sabbatical year in Brazil in between. Feynman then settled in Pasadena in 1951 for the rest of his career. Now, with Feynman and Robert Christy, who had come in 1946, Bacher felt he had the two most outstanding theorists from Los Alamos. Then in 1955 he also hired Murray Gell-Mann.

On the experimental side, he presided over the construction of Caltech's electron synchrotron, one of the first high-energy particle accelerators in the country. Bacher was nominally director of the synchrotron, but Walker supervised much of the research. Although it wasn't shut down (after almost 20 years) until 1969, Bacher had come to the conclusion in the early '60s that if Caltech were going to continue in high-energy physics, "we'd better get started sending people away to work on some of the really big machines." Big Science had arrived, and Bacher was urging Caltech physics into it.

"He was a hands-on provost. He didn't just wait for things to happen; he was a man who got things done."

Next to Robert Millikan, Bacher was the person most important to the early growth of Caltech's reputation in physics and astronomy, says Christy, now the Institute Professor of Theoretical Physics, Emeritus. "He was responsible for building Caltech physics after the war and for making Caltech physics what it is today."

Bacher remained division chair until 1962. During that time he reformed the undergraduate curriculum to make it less rigid, broke up large classes, expanded the teaching staff, and lowered the faculty teaching load. Another field that he helped get started at Caltech was radio astronomy, playing a key role in founding the Owens Valley Radio Observatory in the mid '50s.

He continued to spend quite a bit of time on government work as advisor to the AEC and a member of President Eisenhower's Science Advisory Committee; he served as chairman of a Defense Department committee on nuclear problems and on numerous other committees. In 1958, he was a member of the U.S. delegation to the nuclear test ban negotiations. He was president of the American Physical Society in 1964 and of the International Union of Pure and Applied Physics from 1969 to 1972.

Jesse Greenstein congratulates Bacher on his retirement as provost in 1970. The two were key to starting radio astronomy at Caltech in the mid '50s, when Greenstein was professor of astronomy and Bacher, division chairman.

As Bacher was looking around for new challenges, DuBridge decided he needed someone to be responsible for academic coordination and planning. So, in 1962 Bacher became the Institute's first provost, welcoming the chance to learn about other Caltech divisions. He recruited and hired top social scientists and supported the establishment of graduate programs in the Division of the Humanities and Social Sciences.

"He was a hands-on provost. He didn't just wait for things to happen; he was a man who got things done," said Tom Tombrello, currently chair of Bacher's old division (and Kenan Professor and professor of physics). "He was a man of strong opinions, who knew what he wanted." But he also had a sense of humor and loved bad puns, said Tombrello. "You didn't laugh; you groaned."

Said Christy, who succeeded him as provost: "He was kind of particular about how things were done. He liked to have things done his way." As an example, Christy remembers, before he took over from Bacher as provost, how he insisted that Christy occupy the office next door for six months as a sort of understudy. Bacher wanted to be able to tell him how to do things.

Bacher retired as provost and vice president (incoming president Harold Brown had added the second title in 1969) on his 65th birthday, in 1970, but remained on the faculty exploring new interests in sources of energy. He became professor of physics, emeritus, in 1976. In the late '80s, the Bachers moved into a retirement community in Montecito, where he lived until his death.

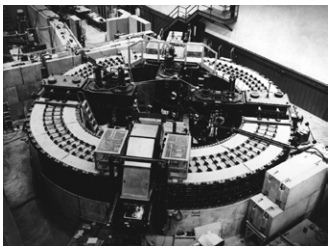
His wife, Jean, died in 1994.

In the synchrotron lab in 1952. From left: Bruce Rule, Robert Bacher, Robert Langmuir, and Robert Walker—the four men who built Caltech's first accelerator.

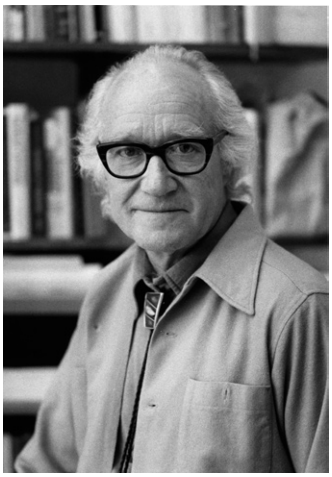
He is survived by their son, Andrew Dow Bacher, PhD '67; daughter, Martha Bacher Eaton; and two grandchildren.

A memorial service is being planned, but not the usual sort of memorial service. When Tombrello broached the idea to Bacher's family, Andrew Bacher (who happens to have been Tombrello's first graduate student) said his father wouldn't like the idea of a bunch of old guys talking about him, and wouldn't want to be there. According to Tombrello, he said his father liked *new* things, what was going to happen *next*. So, early next fall, the "memorial service" will be a celebration of Bacher's 100th birthday; topics for discussion will be "new things" that have their roots in what Bacher started. □—*JD*

Below: The synchrotron lived in the Optical Shop, where the 200-inch mirror for the Hale Telescope was ground. See page 39 for scale.



Robert L. Walker
1919 – 2005



Robert L. Walker, professor of physics, emeritus, died January 4 at his home in Tesuque near Santa Fe, New Mexico, where he had lived since his retirement in 1981. He was 85.

Born June 29, 1919, in St. Louis, Walker earned his BS from the University of Chicago in 1941. While a graduate student at Cornell, he was recruited for the Manhattan Project and spent the rest of the war years at the Metallurgical Laboratory of the University of Chicago and at Los Alamos, where he built pressure gauges to measure the size of explosions. After the war, he returned to Cornell as a student of Boyce McDaniel; they invented a pair spectrometer for measuring gamma-ray energies from light nuclei. He finished his PhD in 1948 and stayed on for postdoctoral research for a year before Robert Bacher (whom he knew from Los Alamos and Cornell) lured him to Caltech, as one of Bacher's first hires in an expanded program in high-energy physics (see page 39).

Walker's immediate task, along with Bruce Rule and Robert Langmuir, was to build a billion-volt electron synchrotron, the design of which had been funded by the Office of Naval Research and the Atomic Energy Commission. It was housed in what was then called the Optical Shop, where the 200-inch mirror for the Hale Telescope had been ground and polished before vacating the premises for Palomar Mountain two years earlier.

Walker supervised most of the work with magnetic spectrometers at the synchrotron until the machine was shut down in 1969, as more energetic accelerators became available elsewhere. For a number of years thereafter, he continued his research at Fermilab (Fermi National Accelerator Laboratory), outside Chicago.

According to Charles Peck, professor of physics, emeritus, who earned his doctorate under Walker, his collaborative research on the synchrotron helped lay the foundation work that led to what is now known as the Standard Model of elementary particle physics. His particular work involved pion photoproduction (in which a proton or neutron is bombarded with a high-energy photon, which produces a pi meson). His research was also useful to his longtime colleague Richard Feynman in his theoretical studies of the underlying mechanisms of particles, according to Peck.

"Bob was also a superb teacher," said Peck. For many years he taught Ph 129, "Mathematical Methods of Physics," and Ph 125, "Quantum Mechanics." He was reportedly the only experimentalist whom the theorists trusted to teach these courses. With Jon Mathews, he coauthored a textbook, *Mathematical Methods of Physics*, described in a review in the January 1965 issue of *E&S* as "a book that not only meets the didactic needs of the first-year graduate student, but also satisfies the practicing physicist who for some time has been hungry for a readable book on mathematical methods written for physicists by physicists."

He was made associate professor in 1953 and professor of physics in 1959. He was executive officer for physics from 1976 to 1981.

Walker retired quite suddenly in 1981. He loaded all his belongings in a U-Haul one day, said Peck, and he and his wife, Dorothy, took off for New Mexico. Peck wrote to Walker on the occasion: "There was no question among the naïve and eager young physics graduate students of 25 years ago about who our favorite prof was. We richly enjoyed your 'Walkerisms,' your occasionally wildly misspelled printing on the blackboard, and especially your subsequently oft-quoted line about something being 'well known—to those who know it well.' I am sure that we all have carried into our careers important lessons from your classroom. I know I have."

On the same occasion, Bacher, who noted that their paths had "run close together for nearly 40 years," wrote: "Without you, I doubt if we

Walker's project in the year 2000 was to build a fortepiano (an 18th-century forerunner of the modern piano). He took its design from a full-scale drawing in the Smithsonian Institution, believed to be of an instrument built about 1795 by Johan Ludewijk Dulcken. Walker's wife, Dottie, sits at the keyboard.

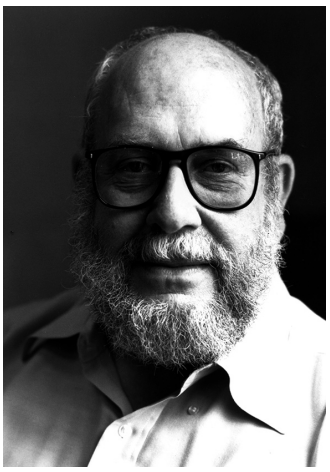
would have been successful in setting up a high energy physics program at Caltech. You made major contributions at every stage from the earliest ideas of what we would do to the present. These contributions were of wide variety from the initial plans of our synchrotron, to its construction and successful use for elucidating the first nucleon resonance, and to many subsequent photonucleon experiments." In listing Walker's "major contributions," Bacher wrote: "As I put them down I realize even more how impressive they are and how much we are in your debt."

In New Mexico, Walker turned to something completely different: he built harpsichords, which have been in great demand by professional musicians throughout the Southwest. Several years ago Walker tackled a fortepiano. It took him, he wrote, about 650 hours to build and another 200 hours "to cure its deficiencies." The "principal challenges were forming the bentside, taming the idiosyncrasies of the action, and figuring out how to convince the upper notes to make more musical sound and less clunk.

"Why would anyone want to make a fortepiano? Well, it's something different and it was fun."

Dorothy Walker died in 2003. They are survived by their two children, Robert Craig Walker and Jan Walker Roenisch. □—*JD*

Thomas K. Caughey
1927 – 2004



Thomas Kirk Caughey, the Hayman Professor of Mechanical Engineering, Emeritus, died Tuesday, December 7, in Pasadena. He was 77.

A native of Rutherglen, Scotland, Caughey earned bachelor of science degrees in mechanical and electrical engineering from Glasgow University, a master's degree from Cornell University, and a doctorate in engineering science from Caltech. He joined the faculty in 1953 as an instructor, and spent his entire career here. He was named the Hayman Professor in 1994, and in 1996 became the Hayman Professor Emeritus.

Caughey's research involved nonlinear differential equations, stability theory, stochastic processes, vibrations and acoustics dynamics, and classical physics. He was involved in a Sloan Foundation project on campus in the early 1970s to use the campus interactive computer facilities in teaching applied mathematics and engineering systems analysis.

He is survived by his wife, Jane; four children, Penelope, William, Catherine, and Christine; four grandchildren; and six great-grandchildren.

A memorial service is planned and will be covered in a subsequent issue of *E&S*. □

Iwan to Coordinate Tsunami, Quake Investigations

Wilfred Iwan, professor of applied mechanics, emeritus, and director of the Earthquake Engineering Laboratory, has been appointed by the Earthquake Engineering Research Institute to coordinate the tsunami and earthquake investigations that the EERI is conducting as part of its Learning from Earthquakes program. This effort includes more than three dozen investigators from universities, government agencies, and private firms carrying out field studies in the countries devastated by the December earthquake and tsunami in South Asia.

"There are many lessons to be learned from this extraordinary event," said Iwan. "These range from science and engineering to societal impact and public policy. We must improve our understanding of such events so that we can prevent such catastrophes from happening in the future."

Iwan will be working with leading seismologists, tsunami experts, civil and structural engineers, lifeline engineers, and social scientists to compile a comprehensive picture of the events and to extract lessons for research and practice in other countries at risk.

EERI is a multidisciplinary, national, nonprofit, technical society. Its Learning from Earthquakes program is more than 30 years old and is funded by the National Science Foundation. □