NATIONAL ACADEMY OF SCIENCES

CARSON DUNNING JEFFRIES

1922—1995

A Biographical Memoir by

WALTER KNIGHT, JOHN REYNOLDS, ERWIN HAHN, AND ALAN PORTIS

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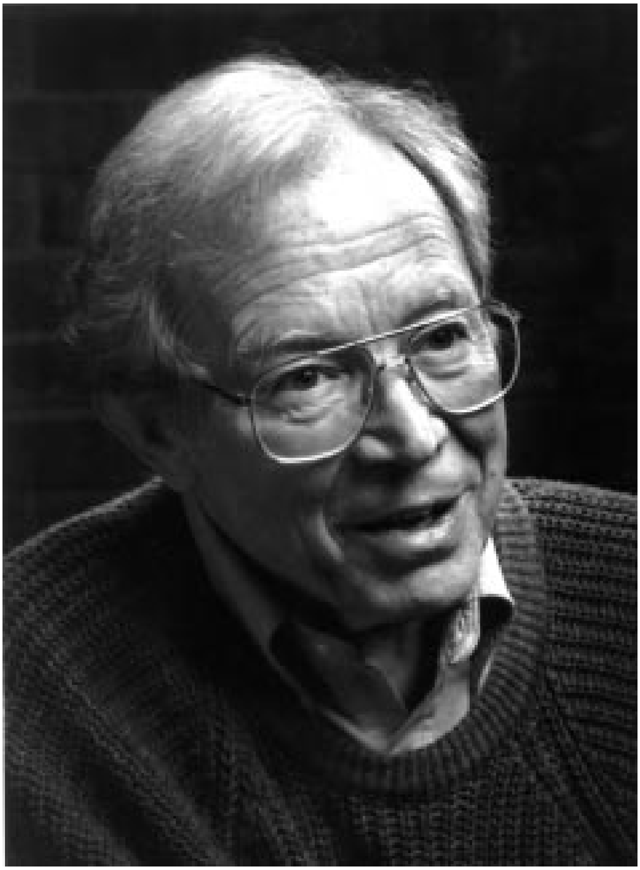
NATIONAL ACADEMIES PRESS
WASHINGTON D.C.



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CARSON DUNNING JEFFRIES

March 22, 1922–October 18, 1995

BY WALTER KNIGHT, JOHN REYNOLDS,
ERWIN HAHN, AND ALAN PORTIS

CARSON JEFFRIES MADE MAJOR fundamental contributions to knowledge of nuclear magnetism, electronic spin relaxation, dynamic nuclear polarization, electron-hole droplets, nonlinear dynamics and chaos, and high-temperature superconductors. These accomplishments involved the Ph.D. programs of thirty-five graduate students, numerous postdoctoral scholars, and resulted in more than a hundred significant publications between 1947 and 1992. As an accomplished artist he exhibited early examples of correlated sound and laser color displays. It is evident that unusual scientific and artistic abilities reinforced each other in a remarkably talented and productive man. He is also remembered for being an uncommonly kind and gentle human being.

PERSONAL HISTORY

Carson was born on March 22, 1922, in Lake Charles, Louisiana, where his father Charles William Jeffries was postmaster and his mother Yancey Dunning a Latin teacher. He had three brothers and a sister, all of whom have survived him. He considered attending a local junior college, but after interviewing the physics instructor (who told him that a rope draped over a frictionless pulley would move so as to equalize the length on the two sides of the pulley!), he decided to go elsewhere and earned his B.S. degree at Louisiana State University in 1943.

Education was important to Carson partly because his mother kept track of all the children in school matters. Beyond this, he possessed a strong fascination with what he imagined went on in the schoolhouse. For example, Carson accompanied his one-year-older brother walking to brother's first day at school. Brother immediately disliked it and wanted to return home. Carson, however, wanted to stay, but he was too young and he had to wait a year for the pleasure of attending school. Asked when he became interested in physics, Carson commonly replied, "by the age of four." When he was somewhat older, he was allowed to build his own shed to contain his tools and whatever apparatus he was working on. At any rate, there is no doubt that he wanted to become a scientist at an early age. Much later, when he was in the hospital being prepared for a surgical procedure on his hip, he was visited by a social worker, who informed him, "Mr. Jeffries, we have chaplains of every faith—Christian, Jewish, Buddhist, Muslim . . . Which would you like to come and talk with you?" Carson half sat up in bed and shouted, "Science is my religion!" The social worker beat a hasty retreat.

After receiving his undergraduate degree, he worked on radar countermeasures at Harvard. There his talents impressed Felix Bloch, who urged him to plan for graduate studies later at Stanford, where Bloch was to resume his professorship in 1946. In the meantime, Carson married Elizabeth Dyer, a native of Maine. Carson and Betty shared many interests—drama, for example. After they came to Berkeley (see below) they regularly attended the annual Christmas dinner and performed in the accompanying theatrical performance at the Ahwanee Hotel in Yosemite Valley.

Carson was a graduate student at Stanford from 1946 to 1950. During this period he witnessed the discovery and development of nuclear induction, now called nuclear magnetic resonance (NMR), which significantly influenced his subsequent research. His thesis project was to measure the ratio of the proton magnetic moment in water to the free proton orbital moment in an inverse cyclotron mode in the same magnetic field. The method of measuring related quantities in the same magnetic field can eliminate the need to achieve high accuracy in measuring the magnetic field itself. Several other important experiments performed in those days used a similar technique. For example, J. H. Gardner and E. M. Purcell at Harvard measured the NMR of the proton and the cyclotron frequency of the electron in the same magnetic field, which is equivalent to measuring the proton magnetic moment in units of the Bohr magneton.

PROFESSIONAL DEVELOPMENT

After he completed his Ph.D. in 1951 under Bloch's guidance, Carson and Betty departed for Zürich, Switzerland, where he became an instructor and assistant to Hans Staub at the University of Zürich Physical Institute. He built and operated the first NMR apparatus in Switzerland and taught the atomic physics lab on the magnificent salary of $125 per month. Carson, Staub, and associates published papers on the measurement of several nuclear magnetic moments, which before the advent of NMR had been known only imprecisely.[1]

When he joined the Physics Department at the University of California, Berkeley, in 1952 as instructor, his salary skyrocketed to $350 per month, and he became a part of the nucleus of the condensed matter physics group, which included Charles Kittel, Arthur Kip, and Walter Knight.[2] In the following we summarize several important phases of his research in more or less chronological order.[1]

NUCLEAR MAGNETIC RESONANCE AND ELECTRON SPIN RESONANCE, 1952-57

Carson measured several nuclear magnetic moments. In the course of this work he observed that resonance linewidths of the two silver isotopes in metallic samples were unusually broad. The effect was later analyzed theoretically by Ruderman and Kittel and is often called the Ruderman-Kittel effect. It is also called the indirect exchange interaction in which an itinerant electron interacts with a nuclear spin, which polarizes the electron spin. The reoriented electron spin subsequently interacts at random with some other nuclear spin, which consequently experiences a significant local hyperfine magnetic field. This sequential double interaction is a long-range effect which results in increased resonance linewidths of both isotopes of silver in silver metal. The effect was soon thereafter observed by Bloembergen and Rowland in thallium metal, which has a stronger hyperfine interaction, resulting in a correspondingly larger line broadening. Similar isotropic spin-spin interactions had also been observed for molecules in liquids.

Carson and his students went on to investigate electron spin relaxation and demonstrated for the first time the phonon bottleneck effect, confirming particularly the work of John Van Vleck, who was much impressed by Carson's work. Setting a pattern for the future, Carson worked out as much as he wanted to know and proceeded to a new investigation.

OPTICAL PUMPING AND DYNAMIC NUCLEAR POLARIZATION IN SOLIDS, 1956-57

Independent of A. Abragam, Carson formulated and implemented the methods of dynamic nuclear polarization. This made possible polarized targets in nuclear scattering experiments, such as were carried out with Chamberlain and Shapiro. In the early experiments he employed microwave techniques, but later experiments on rare-earth solids required optical pumping techniques, which Carson added to his repertoire to make it possible to explore a wider range of materials. He also worked out a method of spin population transfer by crystal rotation in a magnetic level crossing experiment, the "nuclear spin refrigerator."

ELECTRON-HOLE DROPLETS IN SEMICONDUCTORS, 1972-83

This was probably the most spectacular of his experiments. The phenomenon had been recognized as a possibility by Russian physicists, but not in the surprising form obtained by Carson, and the Russians were stunned by the results. Photographs of the luminescence of decaying excitons from the droplets taken by Carson and his students appeared on national television and the NBC evening news reported "a new state of matter." As a matter of interest we report here (according to Eugene Commins, department chair at the time) that Carson once took over the weekly colloquium and gave a superb ad lib talk on electron-hole droplets when the scheduled speaker canceled out.

NONLINEAR DYNAMICS AND CHAOS IN SOLID STATE SYSTEMS, 1981-95

Here Carson investigated and displayed period doubling and routes to chaos in semiconductor junctions, helical plasma waves, and spin waves in ferromagnets. His experimental plots are often quoted as exemplary in the field.

NONLINEAR DYNAMICS AND HARMONIC GENERATION IN HIGH TC SUPERCONDUCTORS, 1987-95

There are several papers dealing with these effects, with remarkable oscilloscope displays of response patterns for, e.g., the yttrium barium copper oxide compounds considering granularity and intergranular links. A variety of similar experiments, along with electron-hole droplets, occupied Carson scientifically toward the end of his career.

One of the authors (JR) described Carson's mode of research in recommendations to the department chair regarding Carson's award of the Berkeley Citation:

> Jeffries is one of those happy scientists who enjoys working productively in his lab with his own hands more than just about anything else on earth. Moreover, he is one of the most skillful experimentalists I have ever known. He is particularly good at designing, building, and operating sophisticated electronic equipment. When he starts a new project he systematically clears a lab room for it, organizes his tools and test equipment, and proceeds to put circuitry together with incredible speed. His single-minded concentration on a new project is extraordinary, and one would find him in his laboratory day and night, almost oblivious to whatever else is going on in the world. Within weeks he is getting results, usually in a new field—his knowledge and proficiency in experimentation permit him to enter entirely new fields, competing effectively with scientists in well-equipped industrial or government laboratories who are not obliged to prepare and deliver regular lectures. In each new field he rapidly became a leading and innovative practitioner, winning international recognition of his contributions.

GRADUATE STUDENTS AND TEACHING

Carson excelled in teaching his research students. His ability to work in new fields made him a popular thesis adviser over the years. Starting with very able students, he worked with them side by side in the laboratory, stimulating them to develop their talents to a high level.

The list of his Ph.D. students and their postdegree positions prepared by him in 1990 is impressive:

Total number: 35
Number now professors: 13
At institutions: Harvard, 2; Illinois, 2, University of California, Santa Cruz, 2; Massachusetts, 2; Rochester, 1
Permanent staff members at industrial labs: IBM, Xerox, GTE, Raytheon, Dupont
Government labs: Oak Ridge, Goddard, JPL, LBNL, Naval Research Lab

SCIENTIST AS ARTIST

Carson had an artistic side. He engaged in periods of intense activity, reminding us of his scientific work style. Not the least of his accomplishments was the building of a solar house, which might well be called a sculpture because of its design and setting. The observer inside is aware not only of function but also artistic design. For example, some of the copper hot water heaters are hung flat on the wall to be seen and admired, as well as to keep him warm in winter. Outside one sees the house in an exotic setting amidst a group of power transmission pylons. The house won him a prize from Pacific Gas and Electric Company for its efficiency.

Carson's art progressed from an initial period of abstract painting to kinetic works. After visiting and revisiting an exhibition (Directions in Kinetic Sculpture) assembled by Peter Selz, director of the University Art Museum, Carson informed Peter that he thought he could contribute something in that genre. Art professor Karl Kasten recalls that Carson became intrigued with the aesthetic aspects of materials in motion. "He proceeded to produce a series of works primarily for the delectation of his family and friends.

He did not exhibit in public art galleries, which, to my mind, was unfortunate."

His first pieces were ones in which light patterns were modulated by sound. The sculptures had luminous parts, which were controlled microphonically, so that if you spoke to the object it would react to the sounds of your speech with a luminous display. These pieces were the forerunners of important pieces of performance art executed by Carson in collaboration with eminent composers, including John Cage. He had commissions for works exhibited at Expo 70 in Osaka, Japan, and for a 1977 outdoor display in Mexico City.

Late in life Carson created a series of wind-activated pieces on his property high in the Oakland hills. They were related in form and could be seen as individual units or as an orchestrated ensemble moving in the wind, like a ballet company on stage. These pieces varied in height from 5 feet to 8 feet. Each was comprised of colorful sheets of canvas stretched on metal tubing and wire struts, vaguely resembling the frame of an umbrella. The tubes were hinged, pivoted, and delicately balanced, so the slightest breeze would move them in graceful arcs. They also had many modes and degrees of freedom of motion, tending to be aperiodic, and thus related to Carson's interest in chaos. His gentle, sensitive nature was manifest in these creations.[3,4]

Carson was a warm, gentle, modest friend to all who knew him. He bore many difficulties, particularly a disease that led to deterioration of his weight-bearing joints and required numerous surgical operations on his hips and knees. He endured the suffering with remarkable grace and adjusted his life style so that his disabilities had minor impact on his teaching, research, and service. The final tragedy was a malignant brain tumor, which robbed him of his ability to read and resisted all medical attempts to arrest its growth. Fortunately, until the final week of his life he was able to have rewarding conversations with old friends and to display still the gentle humanity we all had known so well. His final decline was swift, and he died peacefully at home on October 18, 1995.

Carson was divorced from his first wife Elizabeth, with whom he had two children, Andrew and Patricia. Andrew and his wife recently had a pair of fraternal twins, Christopher Daniel and Alexander Carson. Patricia and her husband have adopted a boy, making a total of three grandchildren in 1997. Carson's second wife Olivia Eielson gave him support and companionship in his later years. She is a painter, and shared Carson's interests in art and literature.[5]

HONORS

Carson received much recognition for his work. He held prestigious senior fellowships, which allowed him to make extended visits to Oxford (England), Saclay (France), and Harvard. He was elected to the National Academy of Sciences (1983) and the American Academy of Arts and Sciences. He was honored by his former students and postdoctoral associates at a symposium in Berkeley on June 27, 1992. At his retirement party on May 4, 1992, he was awarded the Berkeley Citation. In recommending this award to the chancellor, department chair Professor Steiner commented, "Professor Jeffries is one of our outstanding experimentalists. More than once he has been nominated for the Nobel Prize." His chief memorial is the lasting image in the minds of his family, friends, and colleagues of an inspiring human being.

NOTES

1. Based on notes of Erwin Hahn's after-dinner speech given at Carson's retirement party on May 4, 1992.

2. Recollections of Walter Knight at the time Carson was hired as a member of the Berkeley Physics Department. Professor Emilio Segrè made contact with Carson in Zürich. Subsequently, Carson made an inquiry about job prospects by writing to Professor Raymond Birge, who was department chair. Soon thereafter, when I arrived on the scene in the summer of 1950, Professor Birge asked me to contact Bloch to get his evaluation of Carson, who had completed his degree under Bloch. I reported that Bloch's comments were highly favorable, indicating that he judged Carson to be a genuinely superior candidate, whereupon Birge proceeded with the official appointment.

3. Based on a letter of Professor of Art Karl Kasten to John Reynolds concerning Carson's art work.

4. Video tapes of the wind-activated sculptures were made of them in motion, and it is hoped that they will be available in the Physics Library for the benefit of those who may be interested.

5. We are grateful to Olivia Eielson and Andrew Jeffries for providing personal information about Carson and his family.

SELECTED BIBLIOGRAPHY

1950

With F. Bloch. A direct determination of the magnetic moment of the proton in nuclear magnetons. *Phys. Rev.* 80:305-306.

1951

A direct determination of the magnetic moment of the proton in units of the nuclear magneton. *Phys. Rev.* 81:1040-55.

1957

Polarization of nuclei by resonance saturation in paramagnetic crystals. *Phys. Rev.* 106:164-65.

With M. Abraham and R. W. Kedzie. Gamma-ray anisotropy of Co^{60} nuclei polarized by paramagnetic resonance saturation. *Phys. Rev.* 106:165-66.

1960

Dynamic nuclear orientation by forbidden transitions in paramagnetic resonance. *Phys. Rev.* 117:1056-69.

With M. Abraham and R. W. Kedzie. Dynamic nuclear orientation of Co^{60}. *Phys. Rev.* 117:1070-74.

1961

With O. S. Leifson. Dynamic polarization of nuclei by electron-nuclear dipolar coupling in crystals. *Phys. Rev.* 122:1781-95.

1962

With P. L. Scott. Spin-lattice relaxation of some rare earth salts at helium temperatures; observation of the phonon bottleneck. *Phys. Rev.* 127:32-51.

With R. H. Ruby and H. Benoit. Paramagnetic resonance below 1°K; the spin-lattice relaxation time of Ce^{3+} and Nd^{3+} in lanthanum magnesium nitrate. *Phys. Rev.* 127:51-56.

1964

With K. H. Langley. Operation of a proton spin refrigerator. *Phys. Rev. Lett.* 13:808-809.

1966

With G. H. Larson. Spin-lattice relaxation in some rare earth salts. I. Temperature dependence. *Phys. Rev.* 141:461-78.

With G. H. Larson. Spin-lattice relaxation in some rare-earth salts. II. Angular dependence, hyperfine effects, and cross relaxation. *Phys. Rev.* 145:311-24.

With K. H. Langley. Theory and operation of a proton spin refrigerator. *Phys. Rev.* 152:358-76.

1968

With W. B. Grant and L. F. Mollenauer. Achievement of significant nuclear polarizations in solids by optical pumping. *Phys. Rev. Lett.* 20:488-90.

1973

With T. K. Lo and B. J. Feldman. New phenomena in exciton condensation in germanium. *Phys. Rev. Lett.* 31:224-26.

1974

With R. M. Westervelt, T. K. Lo, and J. L. Staehli. Decay kinetics of electron-hole and free-exciton luminescence in Ge: Evidence for large drops. *Phys. Rev. Lett.* 32:1051-54.

With R. S. Markiewicz and J. P. Wolfe. Microwave dimensional resonances in large electron hole drops in germanium. *Phys. Rev. Lett.* 32:1357-60.

1975

With J. P. Wolfe, R. S. Markiewicz, and C. Kittel. Observation of large long-lived electron hole drops in germanium. *Phys. Rev. Lett.* 34:275-77.

With J. P. Wolfe, W. L. Hansen, E. E. Haller, R. S. Markiewicz, and C. Kittel. Photograph of an electron-hole drop in germanium. *Phys. Rev. Lett.* 34:1292-93.

1978

With J. P. Wolfe, R. S. Markiewicz, S. M. Kelso, and J. E. Furneaux. Properties of the strain-confined electron-hole liquid. *Phys. Rev. B* 18:1479-1503.

1982

With J. Perez. Direct observation of a tangent bifurcation in a nonlinear oscillator. *Phys. Lett. A* 92:82.

1984

With G. Gibson. Observation of period doubling and chaos in spin-wave instabilities in yttrium iron garnet. *Phys. Rev. A* 29:811-18.

1985

With R. Van Buskirk. Observations of chaotic dynamics of coupled nonlinear oscillators. *Phys. Rev. A* 31:3332-57.

1988

With Q. H. Lam, Y. Kim, L. C. Bourne, and A. Zettl. Symmetry breaking and nonlinear electrodynamics in the ceramic superconductor $YBa_2Cu_3O_7$. *Phys. Rev B.* 37:9840-43.

With P. H. Bryant and K. Nakamura. Spinwave dynamics in a ferrimagnetic sphere. *Phys. Rev. A* 38:4223-40.