# Alfred G. Redfield

1929–2019

BIOGRAPHICAL *Memoirs*

*A Biographical Memoir by*
*Thomas C. Pochapsky*



NATIONAL ACADEMY OF SCIENCES

# ALFRED GUILLOU **REDFIELD**

*March 11, 1929–July 24, 2019*

Elected to the NAS, year 1979

Photograph courtesy of Brandeis University

It is true that the importance of someone close to us is often driven home only after they have died. So it was for me upon the passing of my friend, colleague and mentor, Alfred "Al" Redfield on July 24, 2019, in Alameda, California. Al was a fixture in my life for twenty-five years, until he moved from his longtime home in Lexington, Massachusetts, in 2014, as his beloved wife Sarah's health deteriorated, to be close to their eldest daughter, Rebecca and escape the East Coast winters. But it was not until I began preparing his memorial that I came to fully appreciate the breadth of his accomplishments, as well as the impact that he had on my own career.

*By Thomas C. Pochapsky*

Al was one of the giants of nuclear magnetic resonance (NMR), in terms of both his contributions to fundamental science and the practical application of magnetic resonance to real world problems. As a teenager during World War II, he learned circuitry and electronics that he would later apply to building his own NMR spectrometers. However, his genius was not limited to NMR; Redfield relaxation theory has been applied to statistical mechanical and spectroscopic systems throughout the physical sciences. He was elected to the National Academy of Sciences in 1979 and named a Fellow of the American Academy of Arts and Sciences (AAAS) in 1983. Al received the Max Delbrück Prize from the American Physical Society in 2006.

## Education and the IBM years

Al was born in Milton, Massachusetts, and was named after his maternal great uncle, Alfred Guillou (1859– 1921). He grew up in Cambridge and then in Woods Hole, Massachusetts, where his father, Alfred C. Redfield, worked at the Oceanographic Institute. He graduated from Harvard College in 1950 with a bachelor's degree, a master's in 1952, and then obtained his Ph.D. in 1953 from the University of Illinois at Urbana-Champaign. His Ph.D. thesis concerned the Hall Effect in diamonds and alkali metal halogens. Al's thesis acknowledges "Professor C. P. Slichter and his associates for their friendliness and cooperation while I was occupying their magnet and laboratory." Al and Charlie Slichter remained good friends throughout their lives.

After returning to Harvard for a postdoc with Nicolaas Bloembergen, Al published a 1955 *Physical Review* paper titled "Nuclear Magnetic Resonance Saturation and Rotary Saturation in Solids," in which he established the concept of spin temperature in the rotating frame, including spin-locking, $T_{1\rho}$ relaxation, and dipolar order that were essential to many subsequent developments (1). In his *Principles of Magnetic Resonance*, Slichter called this paper "one of the most important papers ever written on magnetic resonance." A more general treatment was published in *Science* in 1969 (2).

Al then took a position at IBM Watson Laboratories at Columbia University, where he remained until 1970, pursuing applications of NMR in solids, as well as examining some fundamental aspects of magnetic resonance. His work at IBM included measurements of spin-lattice relaxation in metals at very low temperatures (3), analysis of spin relaxation in solids driven by translational diffusion (4), investigations of the properties of impurities in copper using field cycling (5, 6), the first demonstration of NMR for characterizing the vortex lattice in a type II superconductor (6), and experiments and theory to show that spin diffusion in a magnetic field gradient generates dipolar order (7). He also developed an indirect detection method for rare spins, observing natural abundance $^{43}Ca$ in $CaF_2$ using $^{19}F$ (8), the intellectual ancestor of contemporary indirect NMR detection methods.

In 1957, Al published his theory of spin relaxation, the eponymous Redfield Theory, in the IBM *Journal of Research and Development*. Years later, John Waugh, the editor of the nascent *Advances in Magnetic Resonance*, convinced Al to publish the theory "for real." His article became the centerpiece of the premier issue of that monograph series (9). Even so, Al would say of his theory when asked, "Well, it was just a better way of writing down what everybody already knew." In 1970, Al received the IBM Outstanding Contribution Award for his development of a high-resolution pulsed NMR spectrometer, which included one of the earliest implementations of quadrature detection in time-domain NMR (10). He also received a faculty appointment at Columbia. In 1969, he began using NMR to investigate biological materials during a sabbatical with Dan Koshland at the University of California, Berkeley.

## The Brandeis years

In 1972, Al joined the faculty at Brandeis University in Waltham, Massachusetts, with a joint appointment in physics and biochemistry, where he remained for the rest of his career. Brandeis was less than a quarter-century old at the time, having been established in 1948. But a forward-looking administration was in the process of building a world-class biochemistry department (with people such as Robert Abeles and William Jencks among the faculty), and many of Al's pioneering contributions to biological NMR were done at Brandeis, including early studies of electron transfer in cytochrome c using saturation transfer (11), solvent suppression via composite pulse excitation (12), measurements of hydrogen exchange rates in tRNA and proteins (13, 14), and an early $^{1}H$-detected 2D $^{15}N$-$^{1}H$ multiple-quantum correlation experiment that he referred to as the "forbidden echo" (15, 16).

Al would have been as comfortable in an engineering department as he was in physics. His home-built NMR spectrometer at Brandeis was the first instrument designed to specifically target biological systems. He optimized selective pulses for water suppression years before pulse trains such as WATERGATE and flip-backs came into common usage. Al's first superconducting magnet, a 6.4 T magnet acquired in the late 1970s, was brought to field at Bruker in Billerica, Massachusetts, and shipped cold and charged to Brandeis on a flatbed, a 20-mile trip. FIDs on his earlier instrument were digitized as they were acquired and stored on a 2048-bit ring memory before being passed to an IBM PC for Fourier transformation and analysis. Al wrote all of the processing software used by his group, as well as the pulse sequences implemented on his NMR.

By the time I arrived at Brandeis in 1989, Al's spectrometer had evolved into a surprisingly user-friendly instrument, with a commercial 11.7 T magnet and a probe optimized for multinuclear experiments. At the time, his group was using the spectrometer primarily for studies of $^{15}N$-labeled proteins (17), particularly the *Ras* oncoprotein (18). As I needed access to homonuclear experiments such as NOESY and TOCSY for our ferredoxin research, Al obliged by "burning" firmware EPROMs with those sequences. The appropriate sequence could be selected by a switch, and pulse lengths adjusted with an analog pot to get the best signal-to-noise and "jump-return" selective pulse water suppression. A z-shim gradient ("homospoil") pulse was used to prevent radiation damping of water signals, a critical consideration for biological samples. Al also implemented data transfer protocols for other users that allowed data to be processed with standard software and plotted in contours. (Al consistently used stacked plots for looking at 2D data, something most other users and I could not get used to). Along with his long-time engineering associate Sara Kunz and technician Mary Papastavros, we at Brandeis knew that we could always count on Al's advice, help with grant proposals, and clarification of points of physics.

After his retirement in 1999, Al focused on combining high-resolution NMR with field cycling for characterization of intrinsic relaxation phenomena at low field. He built a portable sample shuttle that could be wheeled up the magnet. His original shuttle was pneumatic, using a vacuum to suck a sample up to an adjustable stop rod for field selection, with a Helmholz coil placed at the top of the magnet for near-zero field measurements. After relaxation at low field, the vacuum was released and a gas cushion used to return the sample to the probe for measurement. He later upgraded to a computer-controlled mechanical shuttle, with transit times less than a second. He used this system for characterizing the relaxation of $^{31}$P, $^{13}$C, $^{15}$N and $^{1}$H over a field range of 0.003 to 11.7 T (19, 20). The shuttle apparatus allowed him to investigate local dynamics of membrane proteins and lipids with a detail not previously possible. Much of this work was done in collaboration with Mary Roberts (Boston College) and Liz Hedstrom (Brandeis) (21).

Al Redfield with his field cycling shuttle in the basement of the Edison-Lecks building at Brandeis University, circa 2008. (Photograph courtesy of Mary Roberts.)

## Historical tidbits and personal recollections

While Al was reticent about his own achievements, he was very proud of his ancestors, the Redfields being of old Yankee stock with a long scientific tradition. Indeed, Al's New England roots could be traced back to the Mayflower, through his mother, Martha (nee Putnam) Redfield. She was descended from John Billington of the original Mayflower Company, making Al a distant relative of President James Garfield and actor Richard Gere. Al also claimed to be related in some fashion to Louisa May Alcott, although he never made clear to me how.

Al's great-great-grandfather, William Redfield (1789-1857), a naturalist and the founding president of the American Association for the Advancement of Science (AAAS), was the first person to recognize the cyclonic circulation of hurricanes. On a trip from New York to Boston, not long after the eye of such a storm passed over New York City in September of 1821, Redfield noticed that trees in Connecticut had fallen towards the southwest, while south of the City, they fell to the northeast. Al's father, Alfred C. Redfield, was a physical oceanographer and National Academy member, and a founder of the Woods Hole Oceanographic Institute (WHOI) on Cape Cod in Massachusetts, and his likeness (remarkably like Al's) can be seen in bas-relief on the Redfield Building at WHOI. I remember that not long after Superstorm Sandy in 2012, Al showed me a photocopy of a 1957 article from a popular news magazine which quoted Redfield senior's predictions of the effects of a storm surge on the coastal regions of New York and New Jersey that was eerily prescient of the actual destruction that Sandy had wrought.

Al was also proud of his wife and children: His wife Sarah worked for a while as a Waltham taxicab driver, not for the money but because she liked to meet new people. His son Samuel, an actor and stage designer who was involved in the Seattle grunge rock scene in the early 1990s, was hired as an extra for the filming of Titanic (he pointed his son out to me in one of the crowd scenes). The crowd scenes were filmed in Mexico to avoid union obligations for the extras, including such things as decent food and housing. Samuel organized the extras to protest, and was "escorted" off the shoot by armed guards. (As an aside, Al also pointed out to me that Charlie Slichter's son Jacob was the drummer for the '90s rock band Semisonic).

Nobody is perfect, and Al, despite his genius (or maybe because of it) was no exception. Tact was not his strong point and he was not particularly patient with those who were not as smart as he was, which was about 99.99 percent of humanity. He would often say when asked a technical question: "Oh, you wouldn't understand." (He once told one of my very smart colleagues, who will remain nameless: "You're too stupid to understand.") However, I learned over the years to be persistent with him, and I could generally get an explanation out of him that I could grasp. We often team-taught an NMR course; he would sit politely in the back of the room during my lectures and only afterwards tell me what I got wrong. Indeed, many of the homework problems my wife Susan and I used in our textbook for that course were written by Al and used with his permission. For those students and post-docs that could deal with him on an (almost) equal footing, he was an inspiring research advisor, a source of ideas and critiques that would serve them in good stead in their independent careers.

Al did not often crack jokes or banter. But once he got to know you, his subtle sense of humor would show up. When our first commercial 500 MHz NMR arrived at Brandeis, Al knew he could get me nervous just by waving a soldering iron at the machine and threatening to "make it work better."

I remember with perfect clarity the first time I met Al. When I interviewed at Brandeis in 1987, I knew almost nothing about the place except that Professor Redfield was there. Even I, an organic chemist who could barely tell one end of an NMR tube from the other, knew the reputation of this scientific giant. So when my host, Barry Snider, told me that Al would be coming to my interview seminar, I was, to put it mildly, terrified. But nobody was introduced to me, so I began my talk. About five minutes in, this kind of street-person-looking dude shuffles in, and goes over to get some coffee and pastry. He was wearing cut-off shorts made from a leisure suit (I think he used pinking shears to make them), and a very ragged-looking plaid flannel shirt. He had a vanDyke beard that could have stood some trimming and an odd glint in his eye. I thought, “What kind of an operation are they running here? They just let anybody walk in to seminars!” Well, I had just met Al Redfield for the first time.

In the end, though, Al’s presence was probably the single most important reason that I chose to come to Brandeis, and he was my mentor and friend for many years. His unassuming nature (and admittedly odd wardrobe choices) belied his formidable intelligence. Ideas that he tossed off almost as an aside became the bases of complete careers for others. He would often complain, when seeing what he considered to be a trivial publication, “I thought of that years ago!” I would ask, “Well, Al, did you publish it?” he would invariably answer: “No, I didn’t think it was important.”

## ACKNOWLEDGEMENTS

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