A very good year

ALEX PINES ON WINE, CHESS AND CHEMISTRY

Fertile soils and gentle rains do not develop the character of wine. Nor does a carefree youth necessarily develop the character of a scientist. Difficult growing conditions can allow good scientists, like good wines, to deepen their character and continue to develop subtleties for many decades.

For both wine and science, 1945 was a vintage year. In the Bordeaux region of France, frost, drought, heat and the hardships of WWII led to a small harvest, but one that would produce exceptional wines. In the same year, Felix Bloch at Stanford and Edward M. Purcell at Harvard independently developed the basic techniques of nuclear magnetic resonance, a feat for which they would share the Nobel Prize in Physics in 1952.

1945 was notable for another reason. In that year Berkeley chemistry professor Alex Pines, who would become a seminal figure in the development of NMR, was born in Tel Aviv. His parents had met in Egypt during WWII, where they both fought with the British Army against the Germans in North Africa.

Pines's father Michael, born in Warsaw, had fled his home in the Baltic city of Vilnius as the Nazis rose to power in the 1930s. He settled in Southern Rhodesia, a British colony in Africa, and served in WWII as part of the Rhodesian Brigade. Pines's mother Neima lived in Palestine, where she joined the British Women's Auxiliary Air Force.

When Pines was four months old, his family returned to Southern Rhodesia. Pines was raised in the city of Bulawayo, located 20 degrees below the equator. It is the second largest city in Zimbabwe, the name taken by the former colony when it achieved full independence in 1980. Bulawayo sits on a high rolling plain or *veld* at an altitude of 4,500 feet, giving it a moderate sub-tropical climate.

"My father started a produce store with his brother Simon that is still in business today," says Pines. "I remember the huge African avocados at the store, so big you could eat them with a tablespoon. I had devoted parents, three younger brothers and a circle of friends from school." Pines played chess and practiced the piano, excelling at both in national competitions. Although the location was unusual, in some ways he had a typical 1950s suburban childhood.

What made the household unique were the intellectual talents of Pines's parents, many of which were passed on to their four sons. "My father had pursued law and mathematics but was excluded from further study by anti-Semitic restrictions," says Pines. "He was a brilliant mathematician and chess player—for many decades he was the national champion of the Federation of Rhodesia and Nyasaland." His chess mentors included Akiba Rubinstein, one of the world's best players in the early decades of the 20th century. Rubinstein believed that had Pines's father been able to stay in Europe, he could have been a great Grandmaster.

Says Pines, "My father was an intimidating presence at the chessboard—chain-smoking, staring with a piercing gaze. Although I am quite a good chess player myself, and I was the under-21 champion at our local club, I was never able to beat him. Not once."

Pines's mother was a talented musician who sang, played the piano and gave concerts in Bulawayo. She made the Pines home a center of classical music performances. From her, Pines inherited his musical abilities. He was a gifted pianist as a child who auditioned for London's Trinity College at age 15.

Bulawayo was a temporary home for an eclectic group of people who were escaping the devastation of WWII and the dismantling of Great Britain's colonial empire. Among their circle of friends the Pines family counted the author Doris Lessing, who won the Nobel Prize for Literature in 2007. Best-selling Scottish author Alexander McCall Smith, creator of the *The No. 1 Ladies' Detective Agency* novels, was born in Bulawayo in 1948. Chess world champion Max Euwe visited Bulawayo, stayed at the Pines home, and played chess with his host and other local masters.

Southern Rhodesia's geographical isolation did not protect Pines from the epidemic of polio that swept across the globe during the 1950s. The Salk vaccine had just become available, and Pines had received two of the four shots when he contracted polio at age 11. As Pines recollected in a 1999 interview, "I was disabled for quite a while and spent many months in a convent isolation ward, subsequently recovering almost completely. I recall the isolation

Clockwise from above: **Alex Pines sets up a classic chess opening in his Stanley Hall office. A 1945 Bordeaux from Chateau Calon-Ségur, the bottle of wine presented to Pines on his 60th birthday. Pines playing piano in his childhood home of Bulawayo, Southern Rhodesia, and milking a cow as an agricultural high school student in Israel. Pines's father Michael at the chessboard in a painting by artist Udi Peled.**

PINES'S GREATEST HITS

- Time reversal and violation of the spin-temperature hypothesis
- Cross polarization and proton-enhanced NMR of dilute spins in solids
- NMR studies of molecular structure and dynamics of liquid crystals
- Multiple-quantum spectroscopy and selective high n-quantum excitation
- Berry's phase and gauge kinematics in magnetic resonance
- Iterative quantum control of spins
- Zero-field NMR and MRI by magnetic field cycling
- SQUID detection of NMR and MRI at ultralow magnetic fields
- Amplification of magnetic resonance with a laser magnetometer and remote detection
- Laser polarization and development of a xenon-based biosensor
- Imaging of heterogeneous catalysis with enhancement by parahydrogen
- Microfluidics and NMR/MRI on a chip

and uncertainty as quite traumatic. Only the love and support of my family made it at all bearable."

It was an important observation for a young man who would be torn between his mathematical and musical talents as he sought his path in life. It was not math or music, but scientific research that had produced the vaccine that had saved him. Yet science *per se* had not been enough—the human connection mattered, too. Later in his life, Pines's devotion to both science and the human connection—his regard for both research and teaching—would become a hallmark of his career.

By age 15, Pines was growing restless. The world of Europeans in Southern Rhodesia was a small one. While other former colonies in Africa were granted independence, Southern Rhodesia remained a segregated state dominated by a white minority government. Over time, the country would become more like South Africa, its neighbor to the south. As Pines matured, life in a segregated society weighed more heavily on him.

In 1961, at an age when most young people are settling into high school and dreaming of learning to drive a car, Pines left home, enrolling in an agricultural high school in Israel. "My family didn't have enough money to send me to a conventional boarding school," he says, "so I got up at 4:00 a.m. to milk cows and do other farm labor in exchange for room and board. Fortunately, I have a good ear for languages, because I arrived not knowing any Hebrew—English was my native language."

The school lacked instruction in higher math, physics and chemistry. Pines studied these subjects on his own and passed an external matriculation exam with an outside examiner sent from Tel Aviv. His test results allowed him to enroll in the Hebrew University of Jerusalem. But the multi-talented student still wasn't sure what to study—law, math, science? The answer came in the form of a book, Linus Pauling's classic, *The Nature of the Chemical Bond*, first published in 1939.

"Pauling's book was a profound influence," says Pines, "literally the catalyst that allowed me to see how chemistry brought together the rigor of mathematics, the beauty of music, the prospect of scientific progress. After reading Pauling, I knew I wanted to do chemistry."

Pines left Israel for a new adventure in a new country—a Ph.D. program at MIT in Cambridge, MA. Ironically enough, among all his choices, only UC Berkeley's College of Chemistry had not accepted him.

At MIT, it didn't take long for Pines to find his way to the lab of John Waugh. Pines still recalls their first meeting. "When I told Waugh I was interested in joining his group, Waugh, who was also

associated with the MIT Research Electronics Lab, handed me a circuit board and instructed me to find a postdoc to help build a single sideband amplifier circuit. So that's what I did."

"At that time," says Pines, "Waugh's lab was the center of the world of high-resolution NMR. He was doing spectacular work on solid state NMR, just as the related techniques of magnetic resonance imaging (MRI) were being developed. For a budding scientist, it was an incredibly exciting place to be."

In the words of National Institutes of Health NMR scientist (and Pines lab alumnus) Robert Tycko, "Around that time, Waugh's group included Ulrich Haeberlen, Michael Mehring, Bob Griffin and others who went on to become world leaders in various areas of magnetic resonance. But even in that illustrious group, Alex Pines's brilliance, creativity, and strength of personality stood out."

Waugh's group was extending the use of NMR to solids. This led Pines to attempt to detect carbon-13, an isotope that should, under the right conditions, yield a precise NMR signal. Unlike the abundant isotope carbon-12 which is "spin silent," or magnetically inactive, the relatively rare carbon-13 (only about one percent of naturally occurring carbon) will produce an NMR signal.

Pines learned how to use a series of radio frequency pulses to align or polarize the spin states of the protons in hydrogen and then transfer this polarization to carbon-13, greatly amplifying its signal. Along with Waugh and fellow student Michael Gibby, Pines co-authored a paper on the technique that appeared in 1973 in the *Journal of Chemical Physics*. To date, the article has been cited 1,985 times—one of the most highly cited papers in the scientific literature on NMR.

"I was very fortunate to have worked with John Waugh," says Pines. "He is a great scientist and a great person." Pines completed his Ph.D. at MIT in 1972 and came to UC Berkeley for a prestigious Miller Fellowship with physicist and NMR pioneer Erwin Hahn. However, the College of Chemistry, not wanting to miss a second chance to attract him, persuaded Pines to join its faculty instead, where he has been a professor ever since. "Thankfully, Erwin Hahn took the change of plans in stride, and he has continued to be a mentor and colleague all these years," says Pines.

Having traveled from Africa to the Middle East and then to North America, Pines found a home in Berkeley, and his career quickly blossomed. Even though he lacked the experience of a postdoctoral appointment, he set up a working lab and earned tenure in three years.

Says Pines, "Solid state NMR became a huge success, with many talented practitioners." Today, chemists, chemical engineers and materials scientists routinely use NMR hardware that incorporates concepts first developed in Pines's lab.

"After several years, the point came where I began to feel that the field had matured and was dominated by a new generation, including many of my former students who had become tenured professors. I was waking up in the mornings without new ideas in solid state NMR." Never one to jump on a bandwagon, Pines recognized that even though he had participated in creating the solid state NMR bandwagon, it was time for something new.

With the same restless spirit that had propelled Pines across the globe earlier in his life, he set out to explore new areas in NMR. Success in this new journey would require both a profound understanding of the nature of NMR, and a creative vision of what innovative applications were possible.

"The real beauty of NMR," says Pines, "is that unlike other spectroscopy techniques, with NMR you can see inside bits of matter, including living organisms, without interfering with their chemistry. And with NMR, the information comes directly from the molecules themselves. The disadvantage of NMR is its low sensitivity. NMR interrogates molecules with relatively low-energy radio waves, and raising the signal intensity requires huge, powerful magnets."

The Pines group set out to harness the strengths of NMR while overcoming its weaknesses. "We are seeking the best of both worlds," says Pines, "the fidelity and penetration of NMR with the sensitivity of optical spectroscopy techniques."

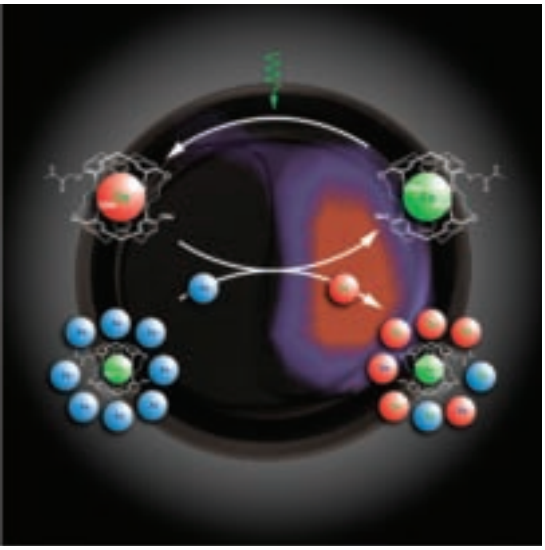
Vikram Bajaj is a postdoc in the Pines lab. Like Pines, he earned his Ph.D. in chemistry at MIT. When asked why he chose to work with the Pines lab, he summarized its accomplishments this way: "Alex has contributed significantly to at least three areas of NMR. First, in the NMR of solids, he has developed some of the basic tools by which structural and chemical information can be teased from the interactions experienced by spins in the solid state. Second, some of his most elegant work has probed the fundamental quantum mechanics and quantum statistics of ensembles of nuclear spins, including methods for their coherent control. Finally, Alex has helped developed many applications of NMR, including zero-field NMR, portable NMR, the use of hyperpolarization in chemistry, biology and medicine, and recently, the combination of MRI with microfluidics."

In 1984, two of Pines's mentors, John Waugh and Erwin Hahn, won the Wolf Prize, an international award that in chemistry and physics is second only to the Nobel Prize in prestige. Seven years later, in 1991, it was Pines's turn. He shared the Wolf Prize in chemistry with Richard Ernst because, according to the award committee, he, "while still a graduate student, helped engineer in 1972 (together with John Waugh) one of the most important revolutions in modern NMR....His later works in Berkeley have continued to profoundly influence modern NMR spectroscopy."

In 2002, Pines was appointed a foreign member of the Royal Society, the United Kingdom's equivalent of the U.S. National Academy of Sciences. He won the Russell Varian Award in 2008, the highest award given by the European NMR research community to one of its own. Pines cherishes most these two awards, along with the Wolf Prize and honorary doctorates from the universities of Paris and Rome.

Right: **College of Chemistry demonstration specialist Lonnie Martin and Pines filming on the set of the eChem educational project.**

Below: **A diagram showing atoms of hyperpolarized xenon as they are depolarized inside a cryptophane cage. The xenon acts as a contrast agent to enhance the NMR signal.**



"The real beauty of NMR is that unlike other spectroscopy techniques, with NMR you can see inside bits of matter, including living organisms, without interfering with their chemistry."

In 2005, Pines's life and career were celebrated at a Symposium of the 4th Alpine Conference on Solid State NMR in Chamonix, France, held in honor of his 60th birthday. But there the award was of a different nature. At the conference, a rare 1945 Bordeaux from the Château Calon-Ségur was uncorked. Like Pines's research, it had aged well over the years, developing complexities and subtleties with time.

One of the many speakers at the conference was Berkeley physicist Erwin Hahn, Pines's long-time mentor and friend. Says Hahn, "Whenever something new comes along, Alex sees the implications before anyone else. He is a great thinker with a good overview of how to integrate new discoveries over a wide range of applications. He is a star attraction for students, especially postdocs. He has been a fountain of inspiration for the NMR community. I find him continually refreshing and always on the ball."

Throughout his career, Pines has never lost sight of the human dimension of his scientific pursuits—mentoring and teaching his students. In 1986, he won Berkeley's highest teaching honor, the Distinguished Teaching Award. He has spearheaded the development of the undergraduate chemistry curriculum, has regularly taught undergraduate chemistry courses and is currently working on the eChem project, a series of videotaped chemistry demonstrations, lectures and quizzes that can be used for online instruction.

Pines credits his research group and collaborators for all of his achievements. In 2000, he was the College of Chemistry's commencement speaker. At the end of his speech, he summarized what he had learned from decades spent pursuing scientific knowledge. He quoted *Ta'anit*, one of the central texts of the rabbinic literature:

Harbe lamad'ti mirabotai,
umichaverai yoter mirabotai,
umitalmidai yoter mikulam

"From my teachers have I been enlightened,
more from my colleagues,
but most have I learned from my pupils."