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A Resonant Life

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Keywords

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Abstract

I embody the quintessential Californian spirit: Raised in Los Angeles, I spent weekends either at the beach or skiing at Big Bear, rode motorcycles, hiked the Sierras, and cherished the sounds of the Beach Boys and Creedence Clearwater Revival. Restless, undisciplined, and irreverent, I applied to only one college—UC Santa Barbara—mainly because that is where my high school friends were going. Although we like to think our intellect transcends culture, my childhood and teenage years were shaped by the rhythms of the 1960s: space flight, NASA, and virtually every episode of *Star Trek* (often watched multiple times). Unmoored, I entered college intending to major in biochemistry but drifted into chemistry while also immersing myself in the physics curriculum. I earned a PhD in chemical physics at Caltech, yet chose to work with a chemical engineer. When my thesis advisor was suddenly killed, I completed my dissertation at Xerox Palo Alto Research Center, working on solar cell materials alongside Cambridge-educated physicists. While my chemistry peers pursued academic postdocs, I went instead to IBM Yorktown Heights, dividing my time between silane reactor engineering and amorphous semiconductor physics. Would I ever become anchored? Here is the rest of the story that led to 43 years on the Berkeley faculty. Including motorcycles.

1. DISCOVERING SCIENCE

Louise Glück (1) famously wrote, "We look at the world once, in childhood. The rest is memory." I ponder that quote often as I imagine the powers, principalities, and culture that shaped a boy born in 1954.

By the time I was six, I had become a keen observer of my parents, aunts, uncles, and their friends debating the suitability of JFK for president, the "communist infiltration into the media," the downing of Gary Powers's U-2 spy plane, and segregation in the South. These overheard conversations, often absorbed while listening through the heater vents in my bedroom, may have been my earliest lessons in the power of dialogue and dissent.

Even as a child, I saw the world as something to be interrogated. A life of paying attention, of wrestling with meaning through argument, began to take shape. Later, my mother would jokingly warn that she might have to tie my hands to the table to keep me from gesticulating wildly in our dinner-table debates about Vietnam.

As a response to the world's relentless intensity, haunted by assassinations (I watched the RFK shooting unfold on TV in June 1968), race riots, and a bloody, relentless war on the evening news, or perhaps as a way to process it, I became absorbed with reading and fiction. I retreated into what is now called YA fiction: first the Tom Swift books; then the works of Asimov, Heinlein, Bradbury, Clarke, and Herbert; followed by a subscription to *Analog Science Fiction and Fact* and eventually *Scientific American*.

I grew up during a fertile period of scientific and speculative thinking—when imagination and intellect offered the perfect antidote to an imperfect world. Fueled by that energy, I moved into nonfiction. Two books in particular lit the way: Asimov's *Understanding Physics* trilogy and *Intelligent Life in the Universe* by Shklovskii and Sagan.

The photograph in **Figure 1** captures these two themes. In sixth grade, I chose to do an oral presentation on aerodynamics for a required project. Science—and oral exposition—was how I looked at the world in childhood. Combining these with youthful passion resulted in high approval from the adults in my life. The rest is memory.

2. UNMOORED

One might assume that witnessing the political and cultural turmoil of the 1960s would lead naturally to reflective teenage years. For many of my colleagues, and for many students I've taught, adolescence felt like a time of awakening, when science and mathematics offered a sense of purpose and wonder. But that wasn't my experience. Younger readers may find it helpful to know that I spent my teen years less immersed in intellectual pursuits and more consumed by intense self-absorption and, as I say in the abstract, a kind of unmooring.

In this way, I mirrored the broader arc of American youth culture. Music turned wild, confrontational, and emotionally raw. I blasted songs like "Break On Through," "Whole Lotta Love," and "My Generation"—not for solace, but to rage against the world and assert a sense of self. Heinlein's *Stranger in a Strange Land*, which I read later, pushed my thinking on taboo, especially around religion and sexuality.

What I remember most vividly from those years isn't classroom learning but motion: skiing with friends, tearing around a motocross track called Indian Dunes (now buried under houses), fishing along the coast, backpacking in the Sierras. AP physics, chemistry, and calculus blur together. But I do recall a gifted biology teacher, Miss Mansfield, who led the Science Club on field trips to the lagoons of San Diego County. Those trips—along with time spent outdoors—planted the seeds of what would become a lifelong concern for the environment.

One memory from that time rises above the rest. Caltech hosted monthly public lectures at Beckman Auditorium, and I drove to Pasadena to attend nearly all of them. I expected to be dazzled

Figure 1

"The world in childhood...."

by physics or astronomy. Instead, one lecture that stayed with me was on African masks, delivered by an anthropologist whose name I've forgotten. It was spellbinding. From it, I took two lasting impressions: first, that public lectures could be a form of storytelling—ideas made vivid through narrative and image—and, second, that the world outside physics and chemistry could be just as intellectually rich. The first insight shaped how I approached public engagement in my career. The second influenced where—and how—I chose to teach.

My college decision reflected the same aimlessness I'd felt in high school. With no college graduates in my immediate family, I had little guidance. I simply followed my friends to UC Santa Barbara (UCSB) and declared biochemistry as my major. Why biochemistry? I don't remember. But that major required first-year students to attend a one-hour seminar series, and that's where I first encountered Garrett Hardin (2), author of "The Tragedy of the Commons." One quote from his paper, and his lecture, never left me: "Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons" (2, p. 1244). That line would come to shape my thinking, though I wouldn't realize it until much later.

Aside from that lecture—and the memory of my first girlfriend—that first year is mostly a blur. My transcript shows that I was an unremarkable but capable student. It would take a spark—what I would eventually recognize as resonance—to moor this wandering undergraduate.

3. DISCOVERING RESONANCE

That spark came in the winter quarter of 1974, during my sophomore year, when I took organic chemistry. I loved the first quarter of the course, but in the second, the instructor introduced NMR

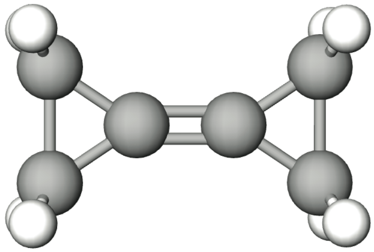


Figure 2

My first design project.

spectroscopy as a method for determining molecular structure. We had to follow rules, recognize patterns, and find the correct answers. But I wondered, Why did those rules exist? What governed the peaks and splittings in the spectra? An office hour question led to two turning points: an invitation to do undergraduate research in synthetic chemistry with my professor, Don Aue, and a suggestion to go down the hall and talk to the department's NMR expert, Professor J.T. "Tom" Gerig.

During the academic year and the following summer, I worked with Professor Aue and discovered that synthetic chemistry offered an immersive dive into astonishing design projects that drew on kinetics, thermodynamics, transport phenomena, and separations (though I didn't know those terms at the time). Among the many projects I undertook in his lab was synthesizing large quantities of bicyclopropylidene (**Figure 2**).

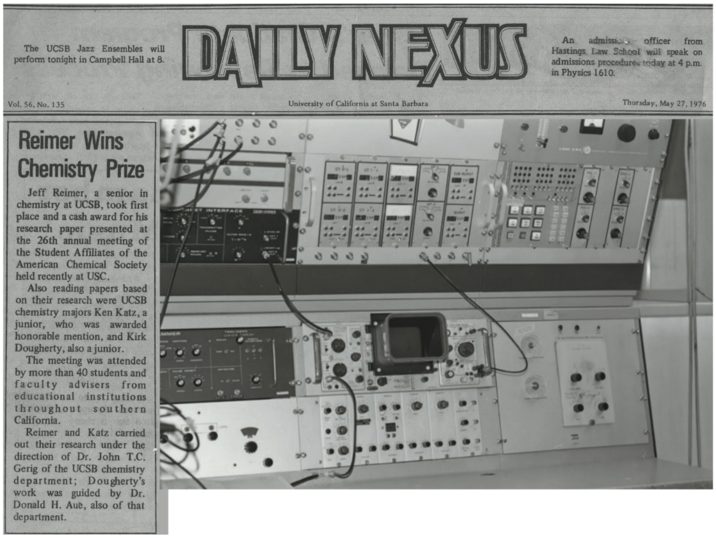
Going down the hall, I asked Tom Gerig to help me understand what was going on with NMR. He challenged me to acquire the best-resolved proton NMR spectrum of neat ethanol using the department's Varian T-60 spectrometer. Eager to impress, I returned with a spectrum—terrible, of course. But Tom, ever patient, guided me through a text on high-resolution NMR and eventually opened his lab to me for two years of hands-on work. Gerry Matson, then a postdoc with Tom, even let me work on his home-built pulsed NMR instrument and introduced me to relaxation dispersion via the Carr–Purcell–Meiboom–Gill technique; I ultimately used these methods to understand the motion of molecules in solution and the binding of inhibitors to proteins. The work resulted in two published papers and an award-winning oral presentation at the local American Chemical Society section (**Figure 3**).

The freedom and privilege I experienced at UCSB between 1974 and 1976 still stand as the most meaningful professional gift of my life. The experience launched my connection between science and intellectual engagement and showed me that the laboratory could be both a creative and a communal space.

4. A LIFETIME OF RESONANCE

Working in Tom Gerig's lab taught me a great deal about instrumentation and independent research. In the fall of 1976, I went off to Caltech to join Bob Vaughan's group. Caltech is uncompromising, and I soon realized that I had taken a less rigorous path than many of my peers. Yet I made up for that with hard-earned experience—building equipment, making molecules, and collecting copious amounts of data.

Bob suggested I begin my PhD by building an NMR spectrometer from scratch. And I did (**Figure 4**)! It wasn't the one shown here, but similar (I gave the original away to another PhD student). The spectrometer in the photo I would use and rebuild multiple times during my graduate years.



The UCSB Jazz Ensembles will perform tonight in Campbell Hall at 8.

DAILY NEXUS

An admissions officer from Hastings Law School will speak on admissions procedures today at 4 p.m. in Physics 1610.

Vol. 56, No. 135 University of California at Santa Barbara Thursday, May 27, 1976

Reimer Wins Chemistry Prize

Jeff Reimer, a senior in chemistry at UCSB, took first place and a cash award for his research paper presented at the 26th annual meeting of the Student Affiliates of the American Chemical Society held recently at USC.

Also reading papers based on their research were UCSB chemistry majors Ken Katz, a junior, who was awarded honorable mention, and Kirk Dougherty, also a junior.

The meeting was attended by more than 40 students and faculty advisers from educational institutions throughout southern California.

Reimer and Katz carried out their research under the direction of Dr. John T.C. Gerig of the UCSB chemistry department; Dougherty's work was guided by Dr. Donald H. Aue, also of that department.

Figure 3

Affirmation by the adults in the room, and the NMR spectrometer that helped achieve that. I spent the entire prize money that night at a local bar!

Bob's group meetings were run by "dice roll": Any of us could be called on to present our own work, or someone else's, at a moment's notice. This open, interdisciplinary culture, spanning chemistry, chemical engineering, applied physics, and energy research, left a deep imprint on how I would later mentor students myself.

In early 1979, Bob and I were using silicon–hydrogen films from Xerox Palo Alto Research Center (PARC) to test a methodology called Average Hamiltonian Theory. I had begun collecting promising proton spectra and shared them with Bob just before he left for a conference. I never heard his thoughts—he was killed in the crash of American Airlines flight 191.

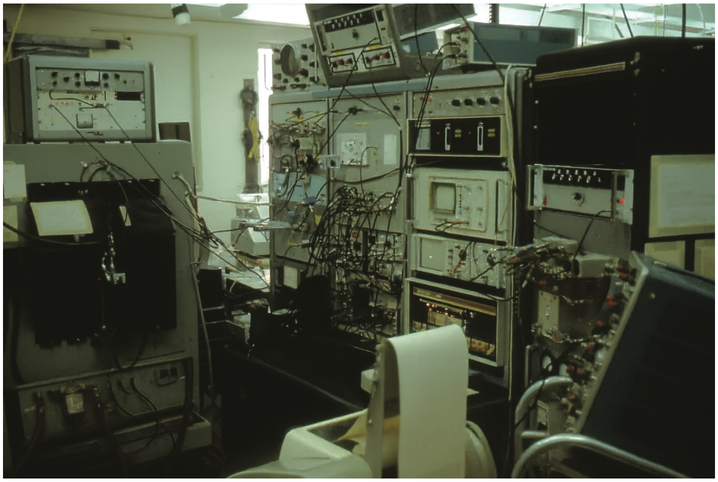


Figure 4

Home-built NMR spectrometer at Caltech, circa 1976.

The team at PARC, led by physicist John Knights, took me in. Our early spectra revealed insights into hydrogen distributions in amorphous silicon and their link to solar cell efficiency, culminating in several papers, one of which remains among my most cited (3). Though far from the NMR mainstream, I found a new home in condensed matter physics, and I thrived. Indeed, John Knights became a formative mentor and later helped me land a postdoc at IBM. But first, I had to finish a thesis.

Professor Sunney Chan generously stepped in as advisor. We met daily at 7 AM to refine the manuscripts—an unflagging commitment for which I remain deeply grateful. From him I learned to write more clearly, to question more deeply, and to respect the rigor that good science demands.

In the fall of 1980, I headed to IBM in New York, determined to leave magnetic resonance behind and enter the world of solid-state physics. For the most part, I succeeded. Few places could match the exhilaration of Caltech and PARC, but the IBM Thomas J. Watson Research Center did. The yin and yang of supervision, my postdoctoral mentors Bruce Scott and Marc Brodsky, offered a unique combination of influences. From Bruce, I absorbed chemistry with a flair for synthesis, while Marc modeled hardcore physics with a stringent commitment to analytical rigor. I loved my time at IBM—extraordinary freedom, abundant resources, and brilliant colleagues. Surprisingly, IBM research staff were rewarded for collaboration rather than siloed expertise. That ethos shaped my career in lasting ways, and I saw early signs of it during my time there. Sometimes the whole research staff would drop everything to tackle a manufacturing problem—experiences that felt more exhilarating than burdensome.

But resonance was never far from my mind. By day, I worked on silane gas-phase chemistry, metal silicide physics, and amorphous hydrogenated silicon solar cells—but the real excitement lay across the Hudson at AT&T Bell Labs (the so-called evil empire), where my former Caltech officemate Mike Duncan could be found using NMR to tackle catalysis. . . in a chemical engineering group! I would occasionally head off to Murray Hill to experiment in Mike's lab, and together we published one of my favorite papers—on the local bonding environment of phosphorus in amorphous silicon, revealed through NMR (4). This would be the only NMR work I published during my postdoctoral years (Mike and I would go on to publish a chemical engineering textbook; see the section titled Discovering Community).

By 1982, I was ready for something new beyond IBM. The most compelling reason was a long-held desire, ignited by the Caltech public lectures, to teach at the university level. So I sent a résumé to every PhD-granting school west of Denver. Culture also played a role in this choice: After two years in New York, I missed the ethos of the American West, California in particular (see *Fast Times at Ridgemont High*). I happened to be searching during a hiring boom and received three offers: one each from chemistry, physics, and chemical engineering departments. The last surprised me, as I had never taken a single chemical engineering course in my life.

I chose chemical engineering at Berkeley. In late 1982, I moved to Northern California and began my academic career.

Fortune smiled on me early at Berkeley. I began working with four exceptional students: Mike McCarthy, Karen Gleason, Phil Morrison, and Mark Petrich. Together we launched a surprising set of publications on topics ranging from multiple-quantum-spin counting of hydrogen in silicon to light-induced bonding changes in photovoltaics, to the relationship of NMR linewidths, to electro-optical properties of thin films, to something we cheekily called "diesel CVD." I cannot imagine a more engaging or talented group of students, and they enriched my early years at Berkeley immeasurably. We started with—you guessed it—a home-built instrument (**Figure 5**).

Anchored in NMR, my group steadily grew, with our research increasingly oriented toward environmental applications. This shift was fueled not only by scientific developments but also by cultural and literary forces. I was especially moved by Octavia Butler's *Parable of the*

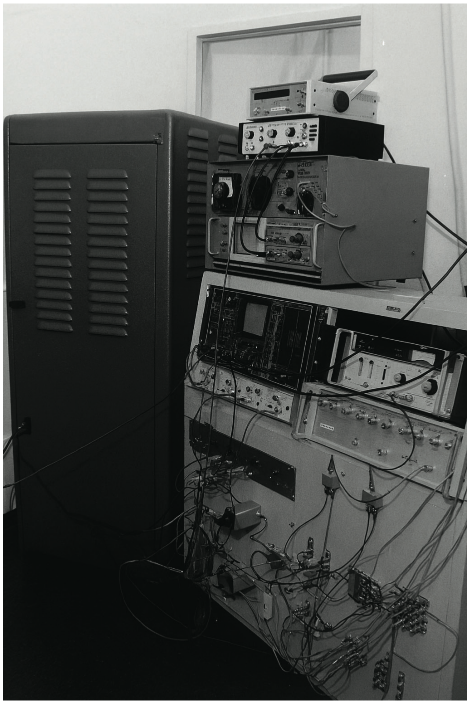


Figure 5

This instrument was built by my first generation of students.

Sower and Kim Stanley Robinson's *Mars* trilogy, novels that cast environmental collapse and ecological stewardship as central human challenges. Although this isn't the place to summarize four decades of scholarly work (you can go to **https://scholar.google.com/citations?user=kx1O-t8AAAAJ&hl=en$** to see my scholarly record) or to acknowledge the more than 50 doctoral students I've mentored, I'll highlight a few projects at the intersection of science and environmentalism. (The collaborative dimensions follow in the next section.)

The 1970s energy crisis sparked our work on amorphous semiconductors, though my deeper motivation stemmed from environmental concerns—especially the Santa Barbara oil spill I witnessed while at UCSB. When federal support for photovoltaics vanished under the Reagan administration, I turned my attention to environmental catalysis: using NMR to study NOx removal (5), fuel denitrification (6), and lightweight polymers designed to replace steel and improve vehicle efficiency (7–9).

These studies interested us not only for their environmental goals but also because they led to the development of some of the first in operando NMR probes (11). These included tools for studying catalysts under flowing gases, polymers under extensional flow (10), and even portable single-sided NMR devices (12). One amusing episode from that era: I was invited to give a plenary lecture at a South American conference, only to learn that they had meant to invite my far more famous coauthor and collaborator, Alex Bell!

As federal attention shifted to fuel cells, we followed. We studied oxygen transport (13) in solid oxides via ^{17}O NMR at 1,300 K—just centimeters from a 4 K superconducting magnet (14)—and monitored methanol decomposition in multilayered membranes for direct methanol fuel cells (15). These experiments demanded both technical creativity and patient sponsors—the latter requiring years of waiting before a paper would be published with instruments and data requiring perspicacity.

By the early 2000s, we had turned to lithium ion batteries, then a promising technology for electric vehicles and renewable energy storage. We used NMR to explore electron–nucleus interactions in cathodes (16, 17), mechanisms of capacity fade (18, 19), and ion transport in electrolytes under electrochemical control (20). As I write this review, a couple of students are still examining transport in electrolytes.

In 2012, motivated in part by teaching, I helped launch, together with Berend Smit, Jeff Long, and Omar Yaghi, a US Department of Energy–funded Energy Frontier Research Center focused on carbon capture (21) using metal-organic frameworks (MOFs)—now a central theme in my lab. Our early efforts targeted CO_2 capture from flue gas; more recently, we've shifted to direct air capture. These studies have yielded both fundamental insights—such as how linkers and metals are apportioned during MOF synthesis (22, 23)—and practical guidance on choosing materials for different CO_2 sources and capture methods (24).

One thread has persisted throughout: nuclear spins, especially optical control of spin (25). We began with xenon gas (26, 27), then GaAs semiconductors (28) and nitrogen vacancy centers in diamond (29, 30), and now chromophoric linkers in MOFs (31). Despite my occasional detours into other methods, I always return to magnetic resonance—for its blend of time-dependent quantum mechanics, ever-evolving instrumentation, and tight link between experiment and the physics of symmetry. What began with a dusty lab and a hand-built spectrometer continues today—with home-built NMR still at the center (**Figure 6**).

5. DISCOVERING COMMUNITY

If resonance set me on the path toward mooring, the community of scholars that gathered around me in the years ahead helped anchor it.

Happy and clueless, I stepped into my academic career (**Figure 7**). I had no real idea what the chemical engineering curriculum even entailed, yet I chose Berkeley's chemical engineering

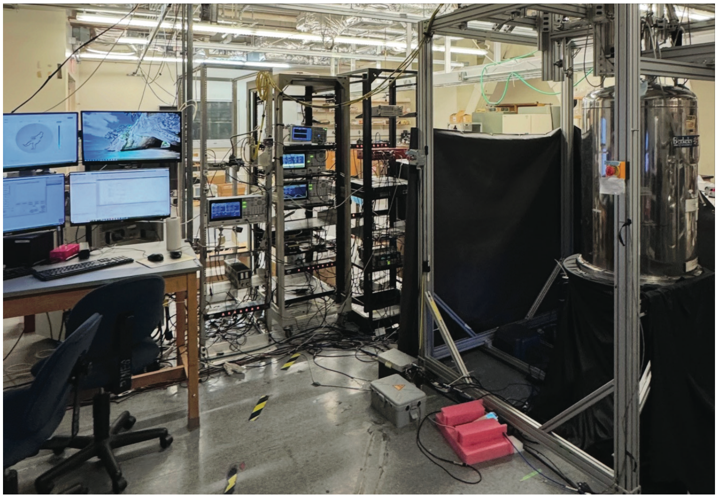


Figure 6

Today's NMR instrument was built together with my chemistry colleague Ashok Ajoy and his group. Although we often use commercial instruments, sometimes we have to build them ourselves to do things no one else can do.

Figure 7

Only a few weeks after starting at Berkeley in 1982. Happy and clueless.

department. Why? On my visits to the three schools that had offered me positions, I asked (unusually, at the time) to meet with students. The Berkeley chemical engineering students sparkled with energy, collegiality, and an awareness of how their discipline mattered in the wider world. They stood in stark contrast to the more self-interested tenor I sensed in other departments. I had glimpsed something similar at Caltech—after all, Bob Vaughan had a foot in both chemistry and chemical engineering—but I didn't fully appreciate what I was seeing then. Moreover, UC Berkeley stood out for its wider world presence—at that time, around 35 disciplines were ranked in the top 10 by the National Research Council. Including anthropology, harking back to African masks. In the end—and this may be shocking to readers of this article—I chose chemical engineering not for its content but for its context and community. That was a choice I would never regret.

My new Berkeley faculty colleagues carried forward this sense of embracing the greatness of our discipline through mentoring and engagement. In those early months, Dennis Hess and Mort Denn showed me what it meant to think like a chemical engineer—and how someone like me might belong in that storied tradition. Berend Smit came to Berkeley as a European midcareer, also an outsider. Berend and I shared rich times creating ideas, courses, and ultimately a textbook (see the section titled Discovering Teaching). Each of these colleagues talked to me about foundational texts, the contexts that shaped their work, and their experiences teaching Berkeley students.

I recall one time when, on the way to coffee, Mort asked, "As a scientist, what do you think the limiting velocity is for a bubble rising in a fluid?" "The speed of light," I answered confidently. I'm not sure I have ever seen him laugh harder. His guffaw sent me back to my office to look up "Reynolds number" in his fluid mechanics text.

My first chemical engineering friends included the incomparable Jim Michaels, Doug Clark, David Graves, and Doros Theodorou—all interdisciplinary, "molecular," and far smarter than me. I'm especially grateful to David for introducing me to the Patrick O'Brian novels, which became a gateway back to Jane Austen. Susan Muller and Arup Chakraborty soon joined us, and we spent countless hours (and more than a few strolls to Caffè Strada) dissecting our research, our teaching, and our relationship to the broader chemical engineering discipline. What a great way to begin a professional life: a community defined not merely by proximity or necessity but by constant reflection on what the field meant and how it ought to evolve.

The notion of community, and the collaborative spirit I first encountered at IBM, would go on to define my career. Tackling research problems shaped by environmental urgency requires not only diverse tools but also diverse perspectives. That conviction led me to seek out collaborators—shamelessly. I've published joint papers with many of my chemical engineering colleagues, a good fraction of the Berkeley chemistry faculty, and researchers and students on three other continents. Moreover, the NMR community has given me both collaborators and close friends. I would be remiss not to extol the blessings of being "next door" to Alex Pines. Cecil Dybowski, at the University of Delaware, and I have been working on a textbook for over 20 years—still unfinished! But here, the process of working together—arguing, deciding, and writing—has been more important than producing the final product. I've mentored graduate students from applied physics, biophysics, bioengineering, chemistry, materials science, and chemical engineering, and my 2015 Humboldt Research Award was spent at a macromolecular science institute. Along the way, I coauthored a book with a team of geologists and a molecular simulator and served for a decade on the board of trustees of a liberal arts college in Switzerland.

Some might see this as a lack of focus—and that criticism is not without merit. But I would offer this in response: The richness of community has been as fulfilling, and as mind-expanding, as any deep specialization. I'm especially grateful that chemical engineering at Berkeley allowed me to pursue scholarship through community.

6. DISCOVERING TEACHING

How do you teach chemical engineering? In 1982, I had never taken a single chemical engineering course in my life. Two colleagues helped me join the community of academic chemical engineers. Mort Denn taught me to channel my enthusiastic exuberance into a mindset grounded in critical thinking, especially the interplay between engineering design and mathematical analysis. Alex Bell showed me that any student can succeed, if we make time for them. I'm also grateful to my early-morning coffee companions, Arup Chakraborty, Susan Muller, and David Graves, who discussed everything from politics to science while I trailed along, bounding with enthusiasm. Most importantly, these three scholars pressed me toward rigor in the classroom. And I owe a great debt to all my colleagues at Berkeley, who (sometimes with a sigh) allowed me to experiment with their courses, their department, and their collective identity.

A pivotal moment came during a 1992 sabbatical at Cornell, where I reconnected with my former graduate school officemate, Mike Duncan. This friendship spurred our shared mission to transform introductory chemical engineering. We set out to develop a textbook that reimagined the curriculum from the start, presenting a "just-in-time" blend of mathematical, graphical, and dimensional analysis. Most importantly, it reintroduced engineering design to the introductory course, which had long been sacrificed for symbolic and mathematical rigor. This text marked the beginning of a broader pedagogical approach—one that spoke to varied learning styles.

I had the good fortune to work with UC Berkeley's Graduate Student Instructor Teaching and Resource Center. Its director, Dr. Linda von Hoene, brought imaginative and well-resourced ideas for preparing teaching assistants, and she had a lasting impact on my own teaching philosophy. She encouraged me to approach teaching as a scholarly discipline (32), held to the same standards I expect in research. For the practice of scholarship in teaching, I'm indebted to every TA and doctoral student I've worked with—they allowed me to experiment on them in the name of better pedagogy. Marjorie Went, a former Berkeley PhD who became a lecturer in our department, led me (along with Berend Smit) on an exploration of the flipped classroom, especially breaking my assumptions about what students do outside the classroom. I am compelled to thank my former PhD student and TA Milo Koretsky for imprinting on me a fundamental truth: The students in our classrooms are, first and foremost, fellow human beings.

Please allow me a visual metaphor that frames how I think about teaching. In Turkey, I once saw a dervish dance, a Sufi tradition. One arm was lifted to receive divine grace; the other was turned downward, connecting with the earth. While I'm not Muslim, this image moved me. I see my roles—administrator, mentor, teacher—as governed by my highest ideals (the raised arm) and enacted through daily, grounded work (the lowered arm). I offer here a glimpse of my own "trance," not as a prescription but as an example of how I navigate the "slings and arrows" of higher education.

My most deeply held belief is this: I am called to an unconditional commitment to imperfect people. That is my right arm lifted. Now let us see where my left arm leads.

For 14 years as department chair, I wrote promotion and merit cases for the Berkeley chemical engineering faculty. I hired 11 of our colleagues. It's fair to say that most of the faculty you know have been assessed, supported, and recommended by me for merit and promotion. I also wrote many of their award nominations. That's where my left arm reaches—into the practical work of the university.

We are all tempted to judge, rank, and sort others. The department chair has countless opportunities to do so. But such acts violate my right-arm principle. The reconciliation became clear when I realized our campus had published merit criteria: what constitutes a routine merit increase and what defines "exceptional." So I chose not to judge or rank but rather to reveal and affirm their contributions through the lens of those criteria. Are they perfect? Of course not. But if you examine the exceptional things they do, and compare that with what the campus defines as meritorious, the case nearly writes itself.

This approach irritated some administrators, as the dean once told me. The provost had chided him in front of all the deans: "Why does chemical engineering submit the most exceptional merit requests on campus?" The irony? Nearly all were approved. My commitment focused not on sorting or gatekeeping but on supporting. Admittedly, writing a case in a field far from my own—say, genetic engineering—required time, a furrowed brow, and Wikipedia.

This quiet, often invisible work became one of the most fulfilling parts of my academic life. In supporting my colleagues, I saw a mirror of my commitment to students: individuals with strengths worth recognizing and celebrating. In the end, both arms—the one lifted in aspiration and the one grounded in daily labor—moved together.

Mentoring students—undergrads, grads, postdocs—offers perhaps the clearest opportunity to demonstrate an unconditional commitment to imperfect people. Consider the classroom. Here, that commitment runs headlong into inherited ideas, especially about "merit." We celebrate the student with a 3.95 GPA, six coauthored papers, outreach leadership, and varsity sports. But what about the student who came to my office last spring in tears over a B+ in organic chemistry—convinced it meant a life of working as a barista and living with their parents—perceived as failure. That conversation stopped me. I began to wonder: Has our definition of merit contributed to the mental health crisis on our campuses? Have I, in ranking and sorting, been part of the problem?

My response has evolved. I now hold myself to one promise: Every student in my class will leave confident in their grasp of the most straightforward fundamentals and apply them to real-world settings.

A colleague once pushed back: "That's just the baseline—you should expect more!" I do—but perhaps not in the way they meant. Drawing on my work with Mike Duncan, I began assessing learning through design as well as analysis. In 2012, I taught the introductory mass and energy balances course with 208 students. Their final project:

> Design, build, and execute James Joule's experiment on the equivalence of heat and work. You may spend no more than $20 (not including thermometers). No external power sources. Present your work via a YouTube video where we will watch, and evaluate them as a group, during Reading week. Peer evaluation counts for 20% of the grade.

Few days in my teaching life thrilled me more than December 7, 2012. Students with average exam scores often produced imaginative, well-reasoned designs. A few projects might have made Joule jealous. Even flawed experiments demonstrated teamwork, creativity, and insight. What if every course invited students to "create, measure, and assess" what has never been? What employer wouldn't want graduates trained that way?

Of course, there are objections. "They're playing with propellers instead of learning Maxwell relations!" But surely one can imagine a design project that draws on Maxwell relations. More often than not, the objection comes down to time: "I can barely keep up with mandatory trainings!" "The curriculum is already packed!" I get it. My unconditional commitment to students is easier said than done. Ideals don't always align with institutional reality. But I believe our institutions must change if our students are to heal. Let's work together. Let's hold our institutions accountable.

Around this time in my life, my daughter Jennifer—then a PhD student in Berkeley's Department of Ethnic Studies—introduced me to two powerful works of fiction: Edwidge Danticat's *The Farming of Bones* and Chimamanda Ngozi Adichie's *Half of a Yellow Sun*. Set in the Dominican Republic and Nigeria, respectively, both novels offer stark portrayals of political violence and the silencing of marginalized peoples. You might say they were my gateway to "being woke," but they also gave me pause: Was higher education itself complicit in a kind of passive violence toward the marginalized? What would that look like?

Consider accommodations. Of all modern practices, none provokes more discomfort. Some colleagues say: "These students think they run the place." Or worse: "Accommodating a learning disability in chemical engineering is like encouraging a paraplegic to be a carpenter." Many see Gen Z as fragile. But what if the forces shaping their lives have broken them—and broken us too?

Few actions enact my right-arm principle more clearly than affirming accommodations. I used to think fairness meant treating everyone the same. Now I think it means giving each person the support they need to thrive. I embrace accommodations, and push back—hard—when institutions fail to do so.

My left arm also had to grapple with the discontent I felt with our present "meritocratic" rules:

- Behave: Take tests, earn AP credits, build the résumé.
- Believe: Trust that those in power deserve to be there.
- Belong: Be proud to join the ranks.

But I've learned to reverse that order:

- First: Our students belong. They were admitted. That's enough.
- Second: I believe in them. I tell them so.
- Third: They behave—with professionalism, integrity, and imagination.

Belong. Believe. Behave. They reflect the left-arm consequences of my right-arm convictions. I don't expect everyone to adopt my approach. You may see gaps or flaws—I welcome that. But I do believe each of us must live out our highest values across the campus. Create your own dervishes. Let your ideals shape your steps. It brings joy. It sustains.

I am called to an unconditional commitment to imperfect people. I am, of course, imperfect. At my best, I live up to my dervish—saying and doing things that uplift. Sometimes I fail. Sometimes I echo the very cultural biases I seek to undo.

But each student, each colleague, deserves our unconditional commitment to their success, imperfections and all. This, I believe, captures the essence of a just and ethical society. And in these times especially, nothing feels more urgently needed.

7. DISCOVERING ENGAGEMENT

Those African masks. . . . They still remain on my mind, so many decades later. How might I use the visual to engage the public in science?

I've long been drawn to an aesthetic and philosophical principle—one often attributed to poets (including Louise Glück), psychologists, feminists, and artists: "The personal is the universal." How would the personal become the universal in explaining science?

Against my parents' express prohibition, my older brother bought me a motorcycle on my sixteenth birthday, a Honda SL100—mechanically simple, with minimalist styling, advertised for entry-level riders as a versatile bike suitable for both street riding and off-road adventures. I still have a California motorcycle license but, alas, no bike to call my own. For now. Yet the motorcycle would play a key role in engaging the public, as I began to use my motorcycles to illustrate materials chemistry in public lectures (**Figure 8**). I used the catalytic converter, plastic panels, and chain as visuals to illustrate topics like NOx chemistry, polymer chain entropy, and lubrication. I became famous (infamous?) for riding the bike into Tan Hall for a public lecture during the building inauguration in the late 1990s.

Climate change began to motivate my research, and toward that end I first taught a course on carbon and energy and then, with Berend Smit, cowrote a book on carbon capture (33). The first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Sparking Some Chemistry Between UC and Berkeley High Students

By Dana Kiyomura
Contributing Writer

STAFF PHOTO BY KRISTEN LOKEN

Chemical engineering Professor Jeffrey Reimer wheeled his motorcycle into Lewis Hall to help illustrate the practical uses of science.

Figure 8

My beloved Yamaha YZF750: 125 horsepower, 0 to 60 in 3 seconds, top speed ~165 mph.

four chapters of the book, and my teaching experience, prompted me to seek out, shamelessly, any venue that would listen to a lecture on climate. Following the African masks, I began to learn how to create compelling graphics in slides that contained no words. Secondary schools, churches, local TV, colleges, YouTube, and courses here at the Berkeley campus, as well as institutions from Israel to Switzerland to Germany—all became subject to talks on climate: how the atmosphere is changing, why it is changing, the consequences of these changes, and what can be done about it. Harking back to Garrett Hardin, I seek to persuade the public that the commons is a place for community to work together. I hold a stubborn optimism that within those audiences, some have felt a spark—minds stirred, passions lit—ready to make the world better.

8. DISCOVERING LEADERSHIP

William Howard Taft High School did not have a science club. This astonished me, given the prevalence of science, NASA's space program, and science fiction in US popular culture. Biology teacher Marilyn Mansfield ("Miss Mansfield") agreed to be the sponsor, so I launched my first leadership role: club president. Although I remember little from high school, Science Club stands out—especially the challenge of organizing people and creating activities alongside the ever-energetic Miss Mansfield. I adopted a servant leadership role: not telling people what to do, but rather listening to what they hoped to do, then working hard to make it so. That would define me in my leadership roles throughout my career.

One anecdote from Science Club: The members decided that we should visit the Salk Institute in San Diego, and I wrote to them on behalf of the club, seeking an invitation to visit. The Institute wrote back affirming a date, so the club piled into a couple of cars and headed to La Jolla for what turned out to be an amazing visit. Alas, this club president never thought to get permission from the high school for the absence, and when we returned the next day, the school disciplined all of us for an "unexcused absence." Parental apologies followed, along with club president apologies—and we were forgiven. This experience left an important impression on me: the age-old adage "better to seek forgiveness than ask permission."

The address 6619 Del Playa, an apartment I co-rented with five other students, would become famous during my college years for hosting the most outrageous parties. The servant role played out in this venue as well. Devote as much time and resources as possible to create *a party*: strobe lights, playlists of music that reached crescendos followed by slow dances, amazing tubs of refreshments that included dry ice, and most of all acting as hosts who made sure everyone was safe—and happy. A different kind of leadership role to be sure, but one in which the servant role persisted. During my senior year, at one of the final parties before I graduated, midway through the evening my cousin appeared; she and her friend had driven for an hour from LA because they "had heard about this place that throws great parties"—not realizing that her cousin was the host.

At UC Berkeley I would not host such parties, but I would still seek to use the servant model to pursue leadership roles. After tenure, I volunteered to serve as a member of Berkeley's Academic Senate Graduate Council; here I made a point of volunteering to do what no one else wanted to do. This reputation, along with a STEM professor's comfort with "going to the blackboard" to answer questions, earned me an invitation to be an associate dean of the graduate school, a campus-wide position in an office that oversaw Berkeley's approximately 10,000 graduate students. It was a perfect match for me; the dean, Mary Ann Mason—a brilliant lawyer and scholar—led with a visionary approach to graduate education, leaving her associate deans to do operations and "run the ship." I would take on staff management, admissions, and IT. My first major assignment? To move the campus's paper graduate applications online, then restructure departmental reviews that had earned a reputation for being dysfunctional. In restructuring our departmental reviews I had the privilege of embedding myself in reviews of programs ranging from dance and performing arts to history to physics. Here, my interdisciplinary mindset proved tremendously valuable in relating to departments whose metrics for success differed greatly from those in STEM fields (e.g., What are the metrics for success in music?). What an exciting five years spent serving Berkeley's educational mission.

Around 2005 or so, I had to make a decision: Did I want to pursue campus administration? If yes, then I had to assume the dreaded role of department chair. So I became chair in 2006 for the canonical five-year term. Doug Clark would take on the chair position in 2011, but his rapid ascent to the college dean position prompted my second term as chair, from 2013 to 2018. I would start a third term, and ultimately step down in 2022, with a total of 14 years as chair. I would wind up overseeing the appointment of 11 of the (in 2022) 17 faculty members. I would receive the Berkeley Citation, awarded for "contributions to UC Berkeley that go beyond the call of duty" and "achievements [that] exceed the standards of excellence in their fields."

I could write a great deal about those 14 years, including many amusing stories. I will relate only one, which turns out to be an excellent metaphor for leadership. When first appointed as department chair, I thought it a good idea to host a holiday party at my home in December, inviting the greater faculty and their partners. Seeking to make a mark and host a good time, I arranged for the local middle school jazz band to come and play for the party. The middle school hosts a famous music program, and the students, about five of them, played excellent music. I was very impressed. My home is small, so it was a bit of a shoehorn to get it all to work out. Yet I noticed that very few of my colleagues stayed in the living room to hear the band; they compressed themselves into a smaller space toward the back of the house. The key lesson: What I wanted as chair was not important; seek first what others want. A poignant reminder of servant leadership.

9. CONCLUSIONS

I still love science fiction (see *The Expanse*), especially environmental sci-fi (like Robinson's *The Ministry for the Future*) and the visionary worlds of N.K. Jemisin. After reading Isabel Wilkerson's *Caste*, I sometimes find myself listening to raging music (Green Day) really loud and feeling haunted by the persistence of violence, in both the United States and around the world.

But resonance remains my theme—across research, in experiencing a life fulfilled through community, in crafting a classroom and department that seek to undo social injustices, and in creating visual, technical meaning accessible to the public. These are the moorings I return to. So I also read Jane Austen and Barbara Kingsolver, and I listen to Taylor Swift and Sabrina Carpenter. I attend home concerts. I love classical music. Maybe, just maybe, I am grounded.

Many students think they know what it takes to be a faculty member: a singular focus, "genius" in a narrow domain. They imagine professors featured on NPR or in the *New York Times*, their presence in academe seemingly affirmed by such platforms. I hope the reader sees my story as something different: that success in academia can also emerge through collaboration, service, and a pedagogical ethic that connects one's deepest values to professional practice. I'll never be on NPR or in the *New York Times*—and I'm perfectly happy with that.

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I have intentionally omitted discussion of family, faith, and my community outside academe. This does not seem the place to fully acknowledge Karen—or our children, Jennifer, Jonathan, Charlotte, and Martin—or to reflect on a lifetime of service in Christian education, especially at a time when the public practice of that faith often appears bound to political power and policies at odds with its most basic tenets. I'll leave that for another essay.

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