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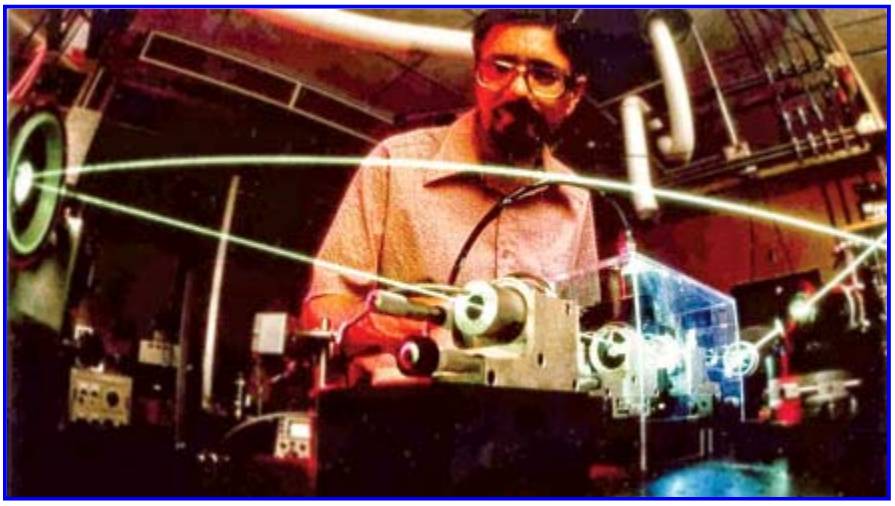
Bubbling With Enthusiasm

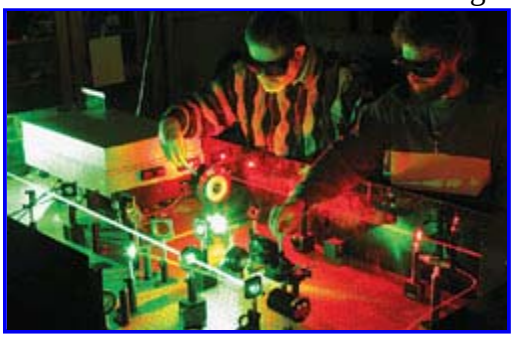
A love of chemistry has taken Richard Zare in many directions throughout his long career

Celia Henry Arnaud



Courtesy of Richard Zare View Enlarged Image

RING OF LIGHT Zare works with a ring laser in the early 1980s.



Courtesy of Richard Zare View Enlarged Image

BRIGHT LIGHTS Zare is best known for his work bringing lasers to the study of chemistry.

Courtesy of Richard Zare View Enlarged Image

NEXT GENERATION Zare shows kids what happens when a ping-pong ball with a tiny hole is dipped in liquid nitrogen.

"Enthusiasm" is the word that people mention most often when describing Richard N. Zare, the recipient of the 2010 Priestley Medal, the highest honor bestowed by the American Chemical Society. And he brings that enthusiasm to everything he does—research, teaching, and public service.

Zare has loved science for as long as he can remember. His father failed out of graduate studies in chemistry at Ohio State University, so chemistry was treated with respect tinged with sadness in the Zare household. Whenever Zare expressed interest in the chemistry texts around the house, his father would tell him that they only lead to unhappiness.

"Being the type of kid I was, that meant that they were much more interesting," Zare remembers. "I actually took them and read them with a flashlight in bed under the covers so my parents would not see what I was reading."

Although his father refused to give him a chemistry set, the young Zare was able to buy laboratory supplies from a local pharmacist—items such as charcoal, sulfur, and potassium permanganate. "The druggist was no fool. He asked me did I know what I was doing. I said I was being very careful," Zare says. "This led to a lot of wonderful pops, bangs, and explosions. It led to me setting the basement of our house on fire when I discovered magnesium."

Zare describes himself as an antisocial kid. "I used my interest in science as a weapon to show how good I was," he says. His rebellion culminated in an ongoing battle with his junior high school science teacher, a newly minted educator who felt that Zare's many questions undermined his authority, Zare recalls. Ultimately, the principal at Zare's school suggested that he should leave the public school system.

That proved to be a turning point for Zare. He attended the University School, a private school for boys in the Cleveland suburbs, and then Harvard University on full scholarships.

"I was a good student, but I was never the top of the class," Zare says. "There were people who could take tests and always do the right thing. I never was that way." He would put effort into only those topics that interested him.

Because of experiences with computers in high school, Zare entered Harvard thinking he might be a math major. He managed to talk his way into an honors mathematics seminar, even though he had not had calculus in high school. He didn't do well. "By going to the professor and promising not to major in mathematics, he gave me a C or C+, and I was allowed to go away," Zare says. Instead, he majored in chemistry and physics.

As an undergraduate, Zare worked with William Klemperer, who taught him to appreciate the fundamentals. "He really tried to get across this idea of chemical physics. The really exciting things in physics were chemistry, but you couldn't understand chemistry without understanding physics."

When it came time for graduate school, Klemperer (and three other Harvard professors, independently) steered Zare toward working with Dudley R. Herschbach, then a young professor at the University of California, Berkeley.

Zare was skeptical of what UC Berkeley might have to offer, so he wrote Herschbach a letter, which Herschbach has saved all these years.

"It was clear that Dick was, as a lot of Harvard undergraduates are, inclined to think that there was no place but Harvard where you'd want to be," Herschbach says. "He said what he really wanted to do was learn profound things about small molecules rather than shallow things about big molecules," and he wanted to know whether there was "any work like that going on at Berkeley in spectroscopy." Herschbach wrote back, explaining the many ways in which

spectroscopy was being used at UC Berkeley.

Zare did join Herschbach's group. "Dudley wanted me to carry out studies on photodissociation of molecules in molecular beams," Zare says. "I remember him putting a 100-W mercury lamp on my desk and saying this is what we could use. I calculated that it wasn't going to work. There wasn't going to be enough light to do much with our ability to do signal to noise." So Zare ended up doing a purely theory-based dissertation on molecular fluorescence and photodissociation instead.

Two years into Zare's graduate career, Herschbach moved to Harvard, and Zare went with him. He received his Ph.D. from Harvard in 1964.

"Science is not a zero-sum game. Everyone benefits from advances in science."

During a brief postdoc at the Joint Institute for Laboratory Astrophysics (JILA) at the University of Colorado, Boulder, Zare caught the fever for experimental research. In 1965, he started his first academic job at Massachusetts Institute of Technology fired up to do research, but the department was in upheaval and didn't provide the resources he needed.

"I found myself absolutely stymied in what I wanted to do," Zare recalls. The chemistry machine shop wouldn't work with stainless steel, which Zare needed to build his molecular beam apparatus, and another chemistry professor—Zare won't name names—blocked his access to the physics machine shop, which would work with the material. Being naïve about the academic hierarchy, Zare went directly to the provost, who counseled patience.

At that meeting, Zare revealed that he had an offer to return to Colorado, an invitation that he himself had not taken seriously. The provost dismissed Zare's threat as "not credible" because "no one leaves MIT to go to the University of Colorado," Zare remembers. Two weeks later, with a formal offer in hand from Colorado, Zare put a letter of resignation on the provost's desk. "I immediately got access to a machine shop that would do stainless steel," Zare says. "I decided that if this is what it took to cut stainless steel, it would be hopeless for me." He served out his teaching contract and headed west.

At Colorado, Zare started out in the physics department. After less than two years, the chair of the physics department "sold" half of Zare to the chemistry department. "I was in the unenviable position of being in two departments, having tenure in neither," Zare says. Each department treated him like a spy from the other department, he says. As a result of the experience, "I don't recommend joint appointments without having tenure," he adds. Although he loved Colorado, he found the situation intolerable. In 1969, he packed his bags yet again and moved to Columbia University.

Zare loved both Columbia and New York City, but he and his wife, Susan, became increasingly dissatisfied with New Jersey, where they resided, as a place to raise their three daughters. Plus, Susan wanted to be close to home, which meant heading to Northern California. When an offer came from Stanford University, they jumped at it, moving one last time.

With the move to Stanford in 1977, Zare finally found his scientific home. "What Stanford has that I find quite special is a work hard/play hard attitude," he says. It makes the university's environment very healthy, he contends. Zare considers such an attitude to be more about daily living than any particular activity, but his wife remembers a planned trip to Greece that they canceled because Zare tore a tendon while playing touch football with his research group.

Throughout his career, Zare has been strongly associated with the application of lasers in chemistry, especially laser-induced fluorescence. He started out using lasers as a tool for studying reaction dynamics and later moved toward their use in analytical detection methods.

A key turning point for Zare occurred as the result of a chance meeting with a U.S. Department of Agriculture chemist. "Larry Seitz walked into the wrong room at an ACS meeting," Zare says. Zare was talking about the sensitivity of his gas-phase laser-induced fluorescence (LIF) technique. During the question-and-answer session, Seitz asked whether Zare could detect aflatoxins. "I didn't know what an aflatoxin was," Zare says, "but ignorance has never stopped me from making up answers. I told him if aflatoxins fluoresce and you can get them in the gas phase, I could detect them." Aflatoxins, which are produced by species of *Aspergillus* fungi, can contaminate grain during storage.

"Dick works best with people who have a lot of drive and who are resourceful and who would benefit greatly from receiving his love of science."

During subsequent correspondence with Seitz, Zare learned that he wouldn't be able to get aflatoxins into the gas phase. "I began to think about the possibility of doing laser-induced fluorescence on things in liquid," Zare says. He

and postdoc Gerald Diebold, now a chemistry professor at Brown University, did the first chemical analysis using LIF as a detection method (*Science* **1977,** *196,* 1439). That was one of Zare's first analytical chemistry projects, Diebold says.

Until that point, it simply hadn't occurred to Zare that he might want to use LIF in the liquid phase. But once he moved in that direction, a whole new world of applications opened. Zare's then-postdoc Shuming Nie was able to use LIF to detect single molecules in room-temperature liquids, something that previously had been done only in cryogenic matrices (*Science* **1994,** *266,* 1018).

Zare started developing LIF as a detection method for capillary electrophoresis following a visit to James Jorgenson's lab at the University of North Carolina, Chapel Hill. Jorgenson had been using absorption spectroscopy as a capillary electrophoresis detector, but the short path length of the capillary limited sensitivity. "The ability to focus light into tiny volumes and the extraordinary single-molecule sensitivity make laser-induced fluorescence an ideal detection method for capillary electrophoresis," Jorgenson says. "The introduction of capillary electrophoresis on microfluidic devices has made the importance of laser-induced fluorescence even greater."

Zare's enthusiasm for science has repeatedly drawn him into new areas of research. His wide-ranging interests mean that his research group is involved in many diverse projects. Such projects currently under way include methods of drug delivery using nanoparticles, asteroid analysis, and the development of new techniques for isotope analysis. "These are not related in a simple way, and yet they all happen in this group," Zare says. "It means that the people who join this group are willing to embrace adventure."

One person who embraced adventure with Zare is Jonathan V. Sweedler, now a chemistry professor at the University of Illinois, Urbana-Champaign. As a postdoc in Zare's group, he was involved when Zare embarked on one of his many new research directions. While Zare was visiting the University of Arizona for a multiday lectureship, Sweedler, a grad student at the time, approached him with an idea about combining chemistry and neuroscience. "I proposed this crazy idea of looking at how the brain works with capillary electrophoresis and small-volume sampling. He thought it was great. His enthusiasm for any new project was fun to see," Sweedler says. In the interim before Sweedler's arrival in California, Zare had already secured funding for this new area of research. "Not only is Dick really good at enthusiasm, he's also really good at planning these things out so everything falls into place," Sweedler adds.

Sometimes Zare's research has landed him in the news. In the mid-1990s, he collaborated with a National Aeronautics & Space Administration research team to analyze a martian meteorite found in Antarctica. His group had developed a technique called two-step laser mass spectrometry (L^2MS). In this technique, one laser evaporates neutral molecules from a surface, and a second laser selectively ionizes molecules in the plume that have low ionization potential. The technique is especially selective for organic molecules such as polycyclic aromatic hydrocarbons.

"We found organic molecules around carbonates in an igneous rock. These were inside the rock, not on the surface," Zare says. "We wrote a paper that was a speculation that maybe this was evidence for some type of primitive single-celled life from Mars" (*Science* **1996,** *273,* 924). Despite those speculations, Zare has never been convinced that they had actually found life on Mars. The 1996 publication became the focus of a media frenzy that Zare calls "Mars Madness," during which Zare made appearances on such television news programs as the "Today Show" and the "McNeil/Lehrer Report."

Even today, Zare continues to use L^2MS to analyze objects from space. His group is currently looking for organic compounds in fragments of an asteroid that broke up over Sudan.

Some of Zare's projects are just plain fun. For instance, he has been quite interested in what he calls the "fizzics" of beer. "That was motivated by a sense of outreach, of telling people that science is all around us, not just in a laboratory," Zare says. That project started after David Huestis, a scientist at SRI International, asked Zare a question about why bubbles seem to grow and accelerate in a glass of beer. "It took me quite a while to figure it out," Zare says.

Zare's enthusiasm for science means that many of his students and postdocs consider him an "incredible" mentor. "Dick works best with people who have a lot of drive and who are resourceful and who would benefit greatly from receiving his love of science, just being exposed to the childlike enthusiasm and thought process he goes through when he really gets into a problem," says Jason B. Shear, a professor of chemistry and biochemistry at the University of Texas, Austin. Zare taught Shear, who was one of his graduate students, that science should be fun. "So many great scientists do it with no apparent joy. That's so much not Dick," Shear adds.

Zare has encouraged independence in his students and postdocs from his earliest days as a mentor. "When you came to him with good ideas and proved them to him, he was ready to let you run with them," says C. Denise Caldwell, who

worked with Zare as a physics graduate student at Columbia.

Stacey Bent, a graduate student at Stanford in the late 1980s and early '90s, agrees. "We had the independence to propose entirely new research projects," she says.

"It's really a unique facet of this lab that he doesn't put any boundaries on you, especially if you can communicate your enthusiasm for something new," says Aaron Wheeler, a Zare grad student from the late 1990s and early 2000s. "He is eager to believe in you and to believe that this new frontier can be crossed."

Although Zare gives his group members independence, he doesn't cast them adrift. When he's in town, he walks through the lab at least once a day, taking the time to ask each person how things are going. "If you mentioned something about the weather, he would simply make some comment and walk on," Sweedler says. "If you said, 'I'm having problems, this is what's not working' and talked to him about science, Dick was there and enthusiastic as long as you needed him."

Zare's group members leave with the impression that he's interested in them as people as well as scientists. Janet Waldeck left research to become a high school chemistry teacher, but she senses no disappointment from Zare about her career choice.

"He doesn't want us all to be like him," she says. "He wants us to find the area that fits. He used to send me ideas for books or experiments or things that I could do with my students in the classroom."

Waldeck got her first taste of being an educator while she was a grad student in Zare's group. "He involved us in going out into the community and doing enrichment experiences for school-age kids," she says. "He tried to get the students to help in the classroom at Stanford in lots of different ways." Waldeck says it was then that she realized research is not the only important aspect of chemistry. She is now a teacher in the Pittsburgh public school system.

Renato Zenobi, a chemistry professor at the Swiss Federal Institute of Technology (ETH), Zurich, and a former Zare grad student, tells a story about Zare's care for his group members as individuals. After finishing his undergraduate work in chemistry at ETH, Zenobi invested about six months in finishing a violin degree as well.

"I had mixed feelings about this because I was afraid Dick wouldn't approve," Zenobi says. Far from being disapproving, Zare invited Zenobi to perform at his house. Zenobi continued to study the violin, as well as chemistry, and won a competition that gave him the opportunity to perform with the Stanford Symphony Orchestra. "What Dick did that I will never forget is he invited me over to his house after the concert to bask in the glory," Zenobi says. "The way he approached this, making sure that people are emotionally happy, is very typical of him. He encouraged rather than discouraged."

Beyond his mentorship of more than 200 grad students and postdocs, Zare has had an impact on education in many other ways—from teaching to research to writing textbooks.

Zare loves teaching, even general chemistry. "I find teaching is a secret weapon of doing research," he says. "Every time I teach a course, I come out with new research ideas of some sort or another."

Zare stresses that teaching is less about information transfer than it is about inspiring students. "A search engine will beat me every time if I want information," Zare says. "What the search engine won't tell you is why you want to know about that."

His 1988 graduate-level textbook "Angular Momentum" is considered a classic and takes Zare back to his roots in the fundamentals of molecular spectroscopy. "Angular momentum algebra is something that wasn't really taught, even at the graduate level, before Dick Zare's book made it feasible and accessible to people in what we call chemical physics," Harvard's Herschbach says. "Even in the area of more classical physics, it was considered too fancy, too demanding, for an ordinary course in quantum mechanics. It used to be a dividing line, a cultural gulf." Paul J. Dagdigian, a Columbia-era Zare postdoc and now a chemistry professor at Johns Hopkins University, teaches a specialty course using Zare's book.

In addition to his work in teaching and research, Zare has been lauded for his support of women. In 2008, he was named a fellow of the Association for Women in Science (AWIS). "When Dick became department chair in chemistry at Stanford, he set out to address issues that are very important to women," says Robert L. Lichter, who nominated Zare as an AWIS fellow. For example, "Dick convinced his colleagues that it was to the benefit of the department and to the whole enterprise to provide paid maternity leave to women graduate students."

After Zare established maternity leave in the chemistry department, Stanford adopted a similar, although less generous, university-wide policy. The chemistry department offers 12 weeks for maternity, whereas the university offers six.

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"To my great surprise, I've been thanked for this by a lot of male graduate students who are going to be fathers," Zare says. "I broke open a taboo topic. It is now possible for them to talk to their adviser and say, 'Things have to change for me about what you expect in terms of time in the lab or what I'm able to do because I have other responsibilities, too.' "

He has also added his voice to the chorus of people who suggest that Title IX, a federal law prohibiting discrimination against women and girls in federally funded education, should be used to encourage gender equity. "I don't think of this as a blunt instrument but rather as a way to help people do what many people, particularly young people, want to have happen anyway," Zare says.

"For somebody with his stature in the research community to take this on is the kind of leadership that's really needed," Lichter says. "It's got to be people who have the respect of the community. Dick is one of the first people to do that."

Zare has also brought his enthusiasm into the realm of public service. He served on the National Science Board (NSB), the governing body for the National Science Foundation, from 1990 to 1996, and spent the last two years as the board's chair.

Marye Anne Fox, chancellor of UC San Diego, overlapped with Zare on NSB for the first four years of his term. "What Dick did so brilliantly was he said let's stop talking about what NSB might or might not have as a role and focus down on things that are important for the country and for science," she says.

Zare was appointed to NSB during George H. W. Bush's Administration and continued in Bill Clinton's Administration, so he experienced science policy under both major political parties. "For a science policy to be successful, it needs to not be partisan," Zare says. Partisanship in science policy is a "roller coaster. That's not the way you support fundamental science," Zare adds. "You really have to get people to believe that it's for the good of the country."

Zare's zeal for service extends beyond the borders of the U.S. For example, he has twice participated in science camps intended to encourage high school and college students in India to pursue scientific studies.

He urges people to move beyond the idea of science as an international competition. "Science is not a zero-sum game," he says. "Everyone benefits from advances in science. You don't have to discover something in your country to benefit from it. It really is an international community."

He has offered advice to science officials in countries such as China and India. "I told them they should send their young people to the U.S. and elsewhere. Some of the young people would not come back, but some of them would," Zare says. "The U.S. did the same thing in the 1920s when it sent people to Germany. At that time, if you wanted to be a chemist or a physicist, you went to Germany and came back. We've all gained by it."

Now 70, Zare has no plans for retirement. "I don't think of myself stopping," he says. "I'm a little bit frightened when people say this is an award for lifetime achievement. Sorry, I was planning to continue."

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