A life like a beaker, full of molecules and surprises

(Conversation with Prof. Richard N. Zare)

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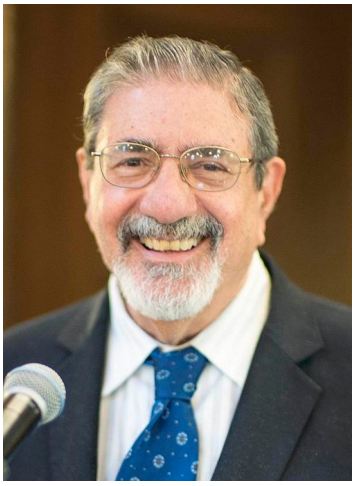

Sometimes we get the chance to meet great people, whom for instance we admire for their professional accomplishments or successes, although quite often we just read or hear about them in books or journals. To me, great scientists have always created this sense of fascination. One of them is for sure Richard N. Zare. In my second year of the undergraduate degree in chemistry in Pisa, I happened to read an interview of him between the chapters of the Skoog and West "Fundamentals of Analytical Chemistry". It was mainly devoted to his contributions to the field of laser spectroscopy, being Zare the discoverer of a technique named "Laser-Induced Fluorescence", or LIF. But Richard Zare has not been just a pioneer of spectroscopic techniques in chemistry, since in his more than half-a-century career he has contributed to many different fields in the chemical sciences, from reaction dynamics to micro-analysis for biomedicine.

All of this to say that the name of "Dick" Zare stacked in my head and I kept reading of his work and also of his articles related to chemical education, being him a chaired professor at Stanford University for more than 30 years. A few days ago I accidentally came across one of his commentaries, which he wrote for the Journal of Chemical Education, entitled "On the Love of Teaching and the Challenge of Online Learning: A Few Reflections". Strange enough, this article was not written as a result of the ongoing distance teaching due to the COVID-19 pandemic, but already in the year 2000. So, moved by this interesting piece from him, I decided to write Prof. Zare and ask him whether we could talk and do a sort of "spontaneous" interview. His reply, quick and kind:

Dear Giacomo

It is an unusual but flattering request. I am available today to chat with you. [..]

Sincerel yours,

Dick

Surely impressed by his reply, I took the chance, thought about a few questions and called him up.

In the next hour and a half, we talked and discussed about various topics, from his early years in science to the importance of teaching, as well as his current reflections on the future of chemical research.
But before going into the details of our unsolicited chat, let me point you out to some biographical references about Prof. Zare's personal and professional life, which would be too hard for me to briefly summarize here [1], [2], [3].

Back to the issue at hand, our video-call started off with him sitting in his office at Stanford, getting on a nice heavy sweater, saying *"You don't mind right, I just like to feel cozy"*. And so I began our conversation asking about the beginning of his career as a scientist, in particular of his PhD in Chemical Physics, which he obtained in 1964, after already graduating from a double major in chemistry and physics from Harvard, under the supervision of Dudley Herschbach (at the time in UC Berkeley and later awarded with the Nobel Prize for Chemistry in 1986).

"We were feeling like a heroic group, working one collision at a time!"

In the early sixties, Herschbach and his group had started studying elementary chemical reactions using molecular beams, basically making atoms and small molecules (or ions) colliding together and then looking at the scattering products. Prof. Zare, who had already had first-hand experience with molecular spectroscopy under the guidance of William Klemperer, moved into this topic as his graduate work.

"I wasn't so good in the lab actually, I've never been particularly talented on the experimental side. I was very clumsy! […] I'm pretty sure I had disappointed Herschbach a few times. Indeed, he wanted me to study a particular photodissociation reaction, but I had done some theoretical predictions about it and, with the small experimental setup I had, I was pretty sure it would have been impossible to do. Therefore, I realized quite early I was capable of spotting what was wrong in mine and other people's experiments. So, very quickly I became pretty good at troubleshooting."

This is indeed interesting, because as graduate students or young researchers we are often told that the best way to build a successful career is to become really good at something and to be very confident on the technical aspects of work, being it an experiment or a simulation. But for Dick this attitude of finding out troubles rapidly lead him to mature as an independent scientist. In his own words, the troubleshooting became *ideas driving*.

"(What's the main point of a PhD?) To learn, for sure, but mostly to become someone who's able to think independently and to solve problems on your own."

Dick Zare followed the advice to become an independent problem solver immediately after finishing his PhD, when he joined MIT as a young assistant professor in 1965.

"(However) I didn't last at MIT for more than nine months, so in 1966 I moved to Colorado to join both the department of chemistry and the one of physics and astrophysics, although working at the JILA (Joint Institute for Laboratory Astrophysics). People in each department, like the one of Chemistry, at the time mostly run by organic chemists, thought I was there to spy on them".

Then, in 1969, at the remarkable age of only 29, Zare was appointed as full professor at Columbia University in New York. His career, although not certainly linear and easy as he reported in his own biographical notes [1], had started a path, which still continues today.
So, looking at a long career in physical and analytical chemistry, ranging from molecular collisions to spectroscopy and chromatography for biological systems, I asked what could be the "red line" connecting all these different research topics.

"I've never actually thought in terms of a particular scientific discipline in which I should work. Maybe because of my initial double degree in chemistry and in physics or because of my upbringing as a child (coming from a Jewish community in Ohio, then forced to move and join a public, Christian school), I developed a sort of cynical and skeptical view about the world. I've never felt I really belonged anywhere! This brought me, though, to get interested in various things, without being afraid whether it was my area of expertise or not, […] I just wanted to do science! Indeed, this is a problem of modern science practice, where people focus more and more in their specializations: I don't believe in sub-disciplines and if anything they are limiting (although they certainly help to get grants and funding). […] When you start a research project, you should approach it without biases or prejudices, so a little dose of ignorance definitely helps! But of course you need to study and work hard if you want to understand the problems you want to solve!"

I couldn't agree more with Prof. Zare's words, even though I haven't figured out a way yet to apply this advice to my work. But then teaching came into play…

"You know, a way to get inspired and have ideas about projects is definitely teaching. I have always liked teaching and in Stanford, I have taught freshman chemistry courses for more than 30 years. People often consider teaching as a waste of time, taking them away from lab or research work. To me it's quite the opposite! I never understand something deeply, even if relevant to my research, until I teach it! […] Think about classical thermodynamics. I took it first when I was in my Junior Year at Harvard and I thought I had understood it. Then in graduate school, I took statistical mechanics, and this shaped again my current understanding of chemical thermodynamics. But then, I really could say I understood the concepts when I started teaching it every year (and now I don't say I'm a genius of thermodynamics, but at least I got the basic principles!)."

Such a humbleness it's rarely seen in the scientific community and Dick Zare is a true example of that.

"Think about what simple things one can get inspired from. For instance, I always ask my students showing them a one-liter beaker filled with water: «What's inside it?». And so they go on with «55 moles of H2O», or "10^{-7} molar concentration of H+ and OH- ions, which is why the pH of neutral water is 7». Well, if you just take a droplet of that water and you put it into a liquid with different polarity, you'd be impressed with what you find. We indeed looked at the behavior of these microdroplets (down to a micron size) in oil and we found something amazing. For instance, at the water/oil interface an instantaneous electric field is generated, small but strong enough to enhance H_2O' self-ionization, so that at the surface of the droplet we find a greater concentration of OH, called the hydroxide anion. Assisted by the strong electric field at the interface, the OH- loses an electron and becomes the hydroxyl radical OH. The OH radicals swim around and find each other – recombine – to form HOOH, which we call hydrogen peroxide. We are presently looking into the possibility that chloride anion (Cl^-) coming from a trace amount of dissolved salt (NaCl) may go on to form HOCl and OCl^- which we recognize as the main constituents of bleach."

Prof. Zare's look at science is somehow like the one of a kid in front of a dinosaur at the Natural History Museum, simple and continuous wonder. Indeed, when I asked him, after all those years of teaching and mentoring, what's the most important concept or skill for a young chemist to acquire, he replied:

"The sense of wondering. That's what you need!"

Of course, the importance of hard work and serious study is not to be underestimated in the opinion of Dick Zare. Speaking of his mentor and scientific hero Herschbach, he said:

"He was really a very hard worker. He would stay in the lab until late at night and fall asleep on the bench. Of course, this changed a bit when he got married (different priorities!)."

Eventually, knowing he had developed many experimental techniques, especially in the field of lasers application for chemistry, like the LIF-technique, I asked Prof. Zare what could be the next methodology that could revolutionize chemical sciences.

"I sit on the board of the The Camille and Henry Dreyfus Foundation (which is one of the few philantropic organizations really pushing for the advancement of chemistry) and I ask myself this question a lot. I believe a true and big change will come from machine learning and data science. Although the recent hype for this topic might be exaggerated, I strongly believe that the use of algorithms and computational tools to make use and analyze large amount of information will change the game. Imagine how much data you get from a mass spectrum or an NMR experiment? The small human brain is only capable of spotting out the largest values or to compare a few numbers. But the issue is hidden in the big numbers and that's where machines can help, because they can be used to find patterns and clusters of different data related to each other. For instance, there are multiple descriptors associable with a disease and only looking at patterns in the data we will be able to figure out analysis of complex biological systems".

Such enthusiasm for data-driven chemistry is not just a metaphor for Dick, he indeed showed me a few examples of recent work done in his lab, where they have been looking at exudate (sweat) analysis from humans and analyzed it using mass spectrometry.

"It's amazing what you can learn just by looking at the sweat of people. You can figure out where they come from or if they are male or female, or what they have been eating. I can even tell you how old the person is, with an accuracy of ±5 years. It's all in the metabolic fingerprints! Another example is saliva, we can now easily spot evidences of pathological conditions (like cancer) just by in-depth analysis of chemicals in the fluid. But what would be a real paradigm shift will involve the understanding of complex bio-analytical markers and their patterns."

I would have talked with Prof. Zare for hours, but the conversation reached an end. After a few greetings and chat, I thanked him again for allowing me to ask these silly questions and promised him I would have tried to put everything we said in some (nice) form. And this is it!

Speaking with such a giant of science, especially when behind the awards and the phenomenal career there's a humble, cheerful man, is a true privilege. I hope this conversation will inspire other young scientists and show them the importance of being passionate and keeping a sense a wonder for the natural world. Besides the papers and the scientific results there's also an important human side and we should acknowledge it. As Dick said:

"We're just people!"

P.S. Dick Zare is now 81-years old and he keeps working in his lab at Stanford University. He recently got the second vaccine-shot against COVID-19 and he's doing well. Speaking of the pandemic, he goes: *"I don't understand why people got so fixed with washing their hands. I mean it doesn't hurt for sure, but it's clear the virus is not transmissible through surfaces, since it's airborne!"*. Well, Professor, that's for another chat!

For references:

[1] "Molecole e vita". R. N. Zare, Di Renzo Ed. (2008)

[2] "My life with LIF: A Personal Account of Developing Laser-Induced Fluorescence". R. N. Zare, Annu. Rev. Anal. Chem. (2012)

[3] "The Hydrogen Games and Other Adventures in Chemistry". R. N. Zare, Annu. Rev. Phys. Chem. (2013)