Face to Face

This section features conversations with personalities related to science, highlighting the factors and circumstances that guided them in making the career choice to be a scientist.

Science is Not a Zero-Sum Game

Richard Zare talks to Devendra Mani

Richard N Zare is a Professor and Chair of the chemistry department at Stanford University. He obtained his PhD from Harvard University under the guidance of Nobel Laureate Dudley Herschbach in 1964. He joined MIT as an assistant professor in 1965, but soon moved to University of Colorado in 1966, where he held a joint appointment in chemistry, and physics and astrophysics. In 1969, he left the University of Colorado and became a full professor in the chemistry department at Columbia University. He remained there until 1977 and then finally moved to Stanford University. Zare is very well known for his work in the field of laser chemistry, where he contributed significantly to the understanding of the chemical phenomena at the molecular level. He developed the laser-induced fluorescence technique which is widely used to study reaction dynamics. Zare has authored and co-authored nearly 900 research articles and 5 books. His book on angular momentum is considered as a classic and is widely used in teaching. He is a recipient of many prestigious awards, having won the Wolf Prize in chemistry in 2005, and the Priestley Medal in 2010, to name a few. Zare is an excellent teacher and has been given many teaching awards, the most notable one being the Presidential Award for Excellence in Science, Mathematics, and Engineering Mentoring in 2009.

Prof. Zare with his daughter Prof. Bonnie Zare at IACS, Kolkata.

I had a great opportunity to meet and have several discussions with Prof. R N Zare during his recent visit to Indian Institute of Science, Bangalore. This interview materialized during one of those discussions. Prof. Zare talks here in detail about his love for science and his source of motivation. He discusses what it takes to be successful in research and how important it is to share your discoveries. He also discusses in depth his experiences during his wonderful research journey through different dimensions of science.

DM: What does science mean to you? When did you realize that you want to be a scientist?

RZ: Science, to me, is about asking questions of Nature, to see whether or not systems behave in certain ways. It may be frustrating, but what scientists excel at is disproving, not proving things. It is only when we fail in exhaustive efforts to disprove ideas that we consider them proved. Even then, they may turn out not necessarily to be proved, but instead they need to be modified. For example, the Newtonian laws of motion seem to work very well; they held up for a long time. However, when objects move rapidly, approaching the speed of light, they have to be changed and modified with relativistic corrections. As we study, we will find that further modifications are needed of so-called scientific laws, but that is the nature of science.

I became interested in science very early on. My father was unsuccessful in getting a PhD in chemistry at Ohio State University. Although he did not finish his studies, there were chemistry books lying around the house. But both my parents told me that they only lead to trouble. Being the type of rebellious child I was, that only piqued my interest in them; I was curious that way. Perhaps my first chemistry experiment was carried out at about the age of four. After receiving a spanking, I decided to take revenge on my father by urinating in his aquarium. This killed all his tropical fish which I did not know would be the ultimate result. Although it led to another spanking, it was a great chemistry lesson.

DM: Tell me something about your love for molecules? How did it start?

RZ: As a child growing up in Cleveland, Ohio, I enjoyed playing with fireworks. At that time you could go to the druggist and could get nearly all types of chemicals. I would get such things as charcoal, sulphur and potassium nitrate. The druggist would look at me; he knew perfectly well what I was doing. He would ask if I was being careful and I would say yes. Today that would not happen in United States. I once set my house on fire, but in the end, I had great fun.

To me, there is at most one science. In college, I ended up taking a double major in chemistry and physics. I got a PhD in a field that combines the two, called chemical physics. Now, I find increasingly that I am involved in biological problems. Universities have departments that put

a name on things but real problems do not come with a name of a field they fall into; you generally must use everything you know to solve them.

DM: What are the things you like the most in academia? Are there any dislikes?

RZ: I greatly enjoy teaching. Some people think teaching gets in the way of doing research. I regard it as a secret weapon of a researcher. When you teach something you really question yourself how well you know something. This questioning attitude is very much the basis of how you make breakthroughs in research: not simply accepting what is said to be known, but asking why they said it, why it is thought to be known, and how well it is known. It is that type of scraping away at the foundations that leads to new discoveries and explorations. Every time I have taught a course, I have always come away learning something new and often even influencing my own research. So teaching and research for me go together. I enjoy teaching; I enjoy research. But every job has its drudgery, has aspects that are not interesting. For me, in academia, that drudgery is the paper work. I don't enjoy filling out safety forms. I do want to have a safe laboratory but I don't like all the administrative aspects of that and so forth. You have to decide that you are willing to put up with drudgery to achieve the things you want. Perhaps a more common example can be found in the kitchen. I enjoy cooking, but people who cook by themselves understand at some point that they also need to clean the dishes which is not that much fun – but it is a part of cooking. The same is true in any profession.

DM: You have been highly active in research for more than five decades now. According to you what is the secret of success in science?

RZ: If there is a secret of success, it is staggering happily from one failure to the next without losing enthusiasm. You do not understand, unless you really get involved in research, how frustrating research can be and how it is often a comedy of errors; one crazy thing after another keeps happening. The important thing is to regard these failures as guides for how to succeed, examples of what does not work which highlight what does. People who are easily frustrated won't be able to do research. It is practiced problem-solving. Just like the more you work crossword puzzles the better you are at working crossword puzzles, the more you solve research problems the better you get at solving problems in research.

For me, research is very much a social activity. Some people say scientists should be guided just by curiosity but, from my point of view, curiosity is not enough. I have to be able to share that result with someone else. For example, how many people do you think would paint pictures if they were told their painting would not ever be put on display for others to see? How many people would compose music when they were told that no one else can hear their musical compositions? Similarly, I think just finding out answers for myself is not sufficient. It is nice

but I really want to share them. I take great pleasure at sharing things and saying, "Look at this crazy world we live in and how exasperating it is." That I find thrilling to me.

DM: You have been a source of motivation for many young researchers worldwide.What motivates you the most?

RZ: I am sure that in the beginning a part of the motivation was to try to prove my worth to my father because I didn't feel that he fully loved me. While that might be the genesis of my motivation, it has since evolved. Now, my interest is in not only finding out new things and how awesome the world is but being able to share that knowledge with the world – not only the knowledge but how to enjoy the quest.

DM: Which scientist inspired you the most? Do you have any ideal?

RZ: One of the heroes of mine is my PhD mentor, Prof. Dudley Herschbach, who is a Nobel Laureate in chemistry. He inspired me greatly. I also was greatly influenced by my undergraduate advisor Prof. William Klemperer at Harvard. There have been many others who have been instrumental in my life such as my teachers when I was in high school and junior high school.

DM: What is the most significant scientific advancement of the 20th century?

RZ: There is not just one! There are many. They range all over the place. Our understanding of how the sun works through nuclear power, our understanding of genetics and the genetic mechanisms of DNA and RNA and the rest, the idea that today we have started making machines whose ability to compute far exceeds those of human beings. All these are revolutions that have taken place and there are many more.

DM: Everyone talks about indexes like h-index. You yourself have a very high h-index! How important are these numbers for judging a scientist?

RZ: I have written about this [*Angew. Chem.,* Int. Ed. Vol.51, pp.7338–7339, 2012]. This h-index is much better for judging the nature of different journals than the nature of different people. I can point out amazing examples of papers which had very little initial impact later on turned out to be revolutionary and other papers which appeared to be so exciting turned out to be mundane. There is such reliance on h-index-type metrics because they are relatively easy for administrators to parse, as opposed to fully understanding the critical comments of other researchers in the field. We still may not appreciate all the details, but it will be better to talk about more than just citation numbers. The question that should be asked is, "Has this research, this paper, really altered the way I think about the topic?" That is what matters.

DM: What is your routine for the day? What kind of lifestyle do you believe in?

RZ: I probably am a 'workaholic' generally. I also do not sleep much. I am a person who often gets only around 5 hours of sleep a night. This is not a matter of my conscious decision to do this; it is just how I am built. I find what I am doing in terms of science and scientific research to be very engrossing. For me it is play, not work, and it is wonderful.

Also later in life, I have developed a hobby which you might call 'political science.' I have become quite interested in science policy matters: whether or not I can have some influence on making the things work better not only for my country but for the world. I want to emphasize that science is not a zero-sum game where one person winning implies that another must lose. Science is a win-win situation. Research and discoveries advance and everyone can win. It must be acknowledged that they win to different amounts, and it helps to have the human network and the infrastructure that can take advantage of the work done where you live, but we still all win.

DM: What do you do in your free time?

RZ: I greatly enjoy playing chess. I'm not a good player but I really enjoy playing it a lot. I also enjoy the arts in general. I go to the theatre and to concerts, and I read.

DM: Would you like to share any specific incident which had a big impact on your career?

RZ: I think one of my wildest stories is about my first faculty appointment at MIT. My PhD adviser Dudley Herschbach asked me if I would like to stick around. Initially, I thought he perhaps meant Harvard. However, he picked up the phone in my presence and he called up a man by the name of A C Cope. Prof. Cope (famous for the Cope rearrangement in organic chemistry) was, at that time, the head of the chemistry department of MIT. When he finished the call, Dudley told me that I would be invited to give a seminar and unless I did something really bad, I would get a faculty offer from MIT. Well, this happened as predicted, and I was excited about my promised future MIT chemistry faculty position.

As was common, I then took a year to be a postdoc, finding myself at the Joint Institute for Laboratory Astrophysics (JILA) at Boulder, Colorado. I enjoyed my time, and the people I worked with invited me to join them in Colorado on the faculty. I thanked them but I told them I had a job at MIT. Unfortunately, during that year, Cope was removed as head of the MIT chemistry department because he was an alcoholic. (Cope died the next year in a very sad situation.)

Professor Cope had forgotten to tell others that I had been hired as a junior faculty member. When I finally arrived at MIT I found out that I had to show them that I had an offer letter which

proved I had a faculty position. I had been given no office, I had no lab, and the department had broken out into war among the various sub-disciplines in the wake of Cope's dismissal. It was a tough time.

I decided to get started on my research, but I required some custom machining of stainless steel for making a molecular beam machine. I sent my request to the chemistry machine shop but at that time, in the 1960s, they did not have the tools to cut stainless steel. They said if you want to cut stainless steel you must put your order the physics department's machine shop. So, I sent the order to the physics department. I waited for a long time but heard nothing of the progress, and finally I tried to find out what was happening. My investigations led me to discover that one of my chemistry colleagues had told them not to do any work for me because he had been told that there are too many chemists using the physics department machine shop and this colleague did not want to have his own work stopped there. I did not know what to do.

I was in deep despair and, not being too wise in the ways of the world, I picked up the telephone book and thumbed through and decided the person I should call was the provost. The person who had been the provost had just let go of that position and been replaced by a much younger, electrical engineer by the name of Jerry Wiesner. Wiesner would later become president of MIT and President Kennedy's science advisor. I arranged to see Jerry in his office. He had been provost at this point for only a couple of weeks. I told him how unhappy I was and how things were going so poorly and how I couldn't even get my research started because I couldn't get basic parts machined. He asked me how long I had been at MIT and I told him about 3 months. He told me to be patient. But I had not come here to MIT to be patient; I came here to get some research done and that looked impossible. He just looked at me, not knowing what to say. Then it welled up in me and I said, "You know I have an offer to leave." He said, "Oh! That is very important, that isn't anywhere in my notes." Well I never told anyone at MIT, so of course it was not in his notes. Honestly, I had never considered even mentioning the JILA offer, but at this point I was getting very desperate. He asked me where JILA was located and I told him. He dismissed it as "not a credible offer." I said, "What do you mean not a credible offer" and he said, "Well, no one leaves MIT to go to University of Colorado." And that was true in 1965.

I was their first exception to that rule because I called up the people in Colorado and Edward U Condon – a man whose name is familiar to a number of people – flew to Boston and delivered an offer to me a couple of weeks later. I accepted that offer and put a letter of resignation on Wiesner's desk. Well, then Wiesner gave me access to the physics department machine shop, but I decided if that is what it takes to cut stainless steel then MIT is not a place for me. So I followed through on my threat and I went to Colorado. I had a great time. I would later leave to

go to Columbia University and then on to Stanford. I didn't care about institutional names all that much; I really cared about getting my research done and when I saw I couldn't get anything done at MIT I decided to go and find some better ways to do it.

DM: Did you ever think if you were not a scientist what career path you would have considered?

RZ: No, there has never been another path for me.

DM: Do you think there is some power which controls the universe?

RZ: I do not consider myself to be a religious person. I respect people who are and I understand that there are influences which seem to control what happens. I don't refer to them as God, but they exist and, believe me, I don't understand them. But I don't understand them in the same way that I don't understand gravity: it is there, and I am used to it, but I don't understand how or why it functions. This is not what drives me though, but I try not to stop others who feel that way.

DM: You have visited India many times. Is there something which specially stands out in your opinion?

RZ: India is colourful, it's chaotic, in some sense it is unclean, and yet the people here are happy! I can contrast that with countries which are drab, which are totally organised, which are neat and clean, but there people are grim. I like India very much. I love India, actually. I have been watching it and it has a huge future ahead of it. I am very excited about how India will develop.

DM: Your message for young researchers especially in developing countries like India.

RZ: My message for young researchers anywhere, whether they are in a developing country or not, is to play. Find something that you love, find something that you can throw yourself into, and work at it. Work harder at it than you have worked at anything else and you will find a life worth living.

Devendra Mani received his PhD under the supervision of Prof. E Arunan at the Indian Institute of Science, Bangalore in March, 2014. Currently, he is working as a research associate in the same group. His area of research is microwave spectroscopy of weakly bound complexes.
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