A Conversation with Prof. C. N. R. Rao: The Future of Science in India and the Developing World

Photo Credit: Raju Doone, Raj Photography, Pune, India

Prof. C. N. R. Rao at the National Chemical Laboratory Diamond Jubilee International Workshop on Nanotechnology and Advanced Functional Materials

I had the opportunity to talk to Prof. C. N. R. Rao at the National Chemical Laboratory (NCL) in Pune, India when we both attended the NCL Diamond Jubilee International Workshop on Nanotechnology and Advanced Functional Materials, where he gave the Presidential Lecture and I gave the Prof. J. W. McBride Memorial Lecture. In addition, we celebrated his 75th birthday at the meeting.

PSW: What do you think science in India needs most?

C. N. R. Rao: In one sentence, India suffered from the absence of funds, foreign exchange, and the funds to even manage its own programs, [such as] its own biotechnologies.

Now, India is economically well off, so the strategies India adopts will be very different. For example, if you want technology, now, you can buy it; you can do a number of things. Similarly, innovation never got enough importance in India. So, there will be a change in the entire policy of Indian research and development.

In the last two years, you will see that we have invested a lot more on fundamental research and science. You have just given a lecture at one of the IISERs [Indian Institutes of Science Education and Research, Figure 1]. These five institutes will all have new campuses. [This is a significant] investment, right away $500 million for them, which we could never have done 3−10 years ago. The GDP growth of 7−9% has helped India to restructure its organization, reexamine its priorities, and also reexamine the way it is going to do things. I only hope that now the new government will really sit down and plan its strategies for future science and technology in a different way. We've matured, come of age. We have money, and I hope that we do the right things. We are in a very critical state, where India has to take a big departure from its past. I feel proud for the first time in India, having lived here for so many decades.

PSW: Do you think that is dependent upon the particular government in office?

C. N. R. Rao: Of course! India has voted for development. The vote, this time, was for science.[1] I'll tell you why. Many [politicians] brought in religion, [India's] past, and every kind of division possible and appealed to the voter, but the voter said "no." They listened to [the politicians] and then voted to give a majority vote for progressive development, and there's no question of going back. The Indian voter—some of them may even be illiterate, but they seem to have a mind of their own, and they throw out people they do not like and they vote for what they want. They have given a vote for progressive development, unlike countries that are going backward in time rather than forward.

PSW: In terms of technology, innovation, and economic drivers for jobs, what do you think India needs to succeed?

C. N. R. Rao: There are three types of efforts required of India. One is the immediate problem of getting rid of poverty and disease. We have to do many things for infectious diseases, things that are native to India, and eliminate them as problems of India in the next 5−10 years. In another 10 years, India should no longer talk about poverty and disease; they should be going to the next step. There is some research, some development required in that area too, because many of these things are really Indian in nature (for example, food security).

To hear Prof. Rao's advice to young scientists in English and Kannada, please visit us at the audio page of http://www.acsnano.org/.

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Figure 1. Plans for the new 100-acre Pune campus of the Indian Institutes of Science Education and Research. Image courtesy Dr. K. N. Ganesh.

Then, India has to do something where it is going to succeed. There are three to five areas where we are going to be a big name and compete with the rest of the world.

We have to do something about climate and energy, which are global issues, but the consequences are local as well. We are already seeing the problems of climate and energy in India severely. I think that we will have to do all these three things.

If we do not succeed in India in the next 5−10 years, the same electorate will say something different.

PSW: Compared to the very large number of young people in India, there are relatively few spots at universities to train them. There is also a missing piece of the talent pool that may be the great majority. How can that be resolved?

C. N. R. Rao: As you know, for a long time India complained about the "brain drain". "These few intelligent people we have, [who are] well-trained, go away." I think we should forget about that. I think the world is going to involve more and more human migration in the years to come. Americans will come to India, Indians will go to America; I think things will change.

What India has to do is to give greater opportunities to the best of our young minds. Of course, everyone should be given an educational opportunity. That we will do. That is why I've been an author and a supporter of the creation of outstanding institutions for training and educating the very best; five new science institutes, eight new IITs [Indian Institutes of Technology]. They are admitting another couple thousand undergraduates in engineering every year, so at the end of the next 5 years, we will have another 10,000 students. Imagine, every year they will produce another 2000−3000 of the very best world-class engineers and a similar number of scientists. This will create a high level of engineering, science, and technology for the country.

What is more hopeful to me is what we will do at the [primary] school level. We have created literally 1,000,000 scholarships for young people in poor areas, as of this year. So, any young boy and girl who cannot afford to go to school—whose parents are very poor—can go to these schools, which are completely residential. Clothing, food, fees, everything is paid by the government. We are giving scholarships for these students up to the Ph.D. There are another 10,000−15,000 scholarships.[2] My hope is with the rural youth, where 60−70% of India's population resides. Of that group, 55−60% are below 25 years old. We are a very young country!

I will not be alive when this happens, but I would not be surprised if India becomes the *provider* for knowledge and manpower for the world, because the rest of the world is becoming old. Everywhere you see average ages going up: United States, Japan, and Europe are among the worst cases. I hope India will take on serving the world. I consider this service to mankind: educated Indians working as nurses, scientists, teachers, engineers, *whatever* is required. India should prepare itself for that. If I'm asked "why?" by the prime minister, I would say this is simply one of the major roles for India in the future.

PSW: How does a child in a village get access to those schools?

C. N. R. Rao: It is very easy. In fact, just now—you will not believe this—the numbers are pretty good. We have 550 residential schools in the villages working already, which have 250,000 students, as of today. These children are all first-generation learners. These children are able to speak in excellent English. I am involved in children's programs, all over India, about 8−10 a year. Usually, 1000 children come for a program, which is enough for a theater, lecture, or to show multimedia packages. You see these very excitable kids, very enthusiastic. You do not see that in cities like Pune (Pune is not so bad), Bangalore, Bombay. The rural kids are *very* enthusiastic.

There are primary schools everywhere. Those kids are picked at the *panchayat* level (the local self-government of villages). The local governments pick any children who want to go to school, and put them through the residential schools. I'm recommending that we set up another 500 such schools, for an additional 250,000 children. There is hope for India.

PSW: At the other end, there are a tremendous number of Indian students and postdocs abroad who are almost in a holding pattern. We can see them waiting for some opportunity here.

C. N. R. Rao: If good, bright students do a postdoc with the very best [faculty abroad], they get a faculty position, a

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good position. What happens is that many who go to America want a position at IIT or a new institute and there is a mismatch of what they want, what they can get. That is true in America, too—you cannot give everybody a job at Penn State or at Harvard. So, you have to go to a slightly smaller place, a class three or class four institution. The situation was bad also because there were no industries in India.

But now, industries have really taken off. GE has its biggest R&D in Bangalore,[3] and all the R&D from Schenectady [New York, USA] has been shifted to Bangalore. They have 500−600 Ph.D. [scientists] right now, which will grow to 1000. General Motors has a lab in Bangalore. Lots of them, Honeywell, Motorola, IBM, that are international [are here]. There are Indian companies with R&D laboratories, too. The entire situation has improved because of that. I'm hoping that industrial research will see a big upturn in the next 5−10 years. Jobs will not be a problem. But, everybody wanting to be a professor at the best institutes will be difficult.

With the new universities coming up, there are about 2000 faculty positions that are vacant right now. In my own Center, I am looking for four or five people in the physics and chemistry of materials. I just recruited one from Cornell, and one from MIT. We are going to look for the best when it comes to faculty. But, there must be someplace else to go. In America, for example, start-up companies have recruited so many Indians (and Americans). We did not have start-up companies. Now, start-up companies are coming and lots of Ph.D. [scientists] will be recruited by these companies. I hope that is the kind of India that will emerge in the next few years.

PSW: Is there some equivalent to the Bayh-Dole Act [U.S. University and Small Business Patent Procedures Act] whereby innovations at universities can be spun out into companies?

C. N. R. Rao: Yes, that has been liberalized. That is one of the major successes. Until last year, it was against the law for a faculty member like you and me doing research and selling or setting up a company. Then, six months ago, we passed a law[4] allowing any faculty member, any scientist anywhere, to use his own discoveries and inventions to set up a company. That is allowed, at last. High time!

> We had no money. We were a poor country. You cannot imagine. The first grant I got when I was a young faculty member (back from Berkeley) was Rs. 1000.

Second, the venture capital and support for innovation are available. Just now, in nanotechnology, we have set up innovation funds. Suppose somebody wants $1 million; we can give them a loan. And, if it is less than $200,000, we can even give a grant if the idea is good. So, we set up funds for nanotechnology. Biotechnology is doing similar things.

We had no money. We were a poor country. You cannot imagine. The first grant I got when I was a young faculty member (back from Berkeley) was Rs. 1000 [*ca.* $1,400 USD when corrected for inflation from 1965]. I used to go with suitcases to America, spend a few months, then bring chemicals and spare parts over to work here. It was hard to work here. Now, I'm in a slightly better position.

PSW: What are the goals of India's Nano Mission?[5]

C. N. R. Rao: When we got the government to support this Nano Mission (I was one of the authors of it), we had very few people working in nano. Today, we have a few hundred students and teachers or more researchers working in nano at various universities. We had to set up minimum facilities in colleges and universities, for example, in Pune. We have a few nanocenters supported by us at the university here. If they want a scanning electron microscope, or they want an AFM [atomic force microscope], or an X-ray diffractometer, the basic bread and butter for nano research, we have provided them in the last three years. Last year, maybe the last two years, we also set up major facilities, for example, a transmission electron microscope for each region. Calcutta had no transmission electron microscope. Can you imagine? It is such a big city! We set up two transmission electron microscopes there. That was only last year. Until then, if anyone wanted to get images, they had to go all over the country. Now we have some facilities in most places.

We are now supporting 8−10 nanocenters. We are setting up two new institutes for nanoscience, one in Bangalore and one in the north, maybe one in Calcutta. In fact, people have just gone to [University of] Alberta, Northwestern, Purdue, Argonne National Laboratory, and a few other places to see the laboratories built there. We will build nano institutes to give greater focus on technology, with an industrial park next to that. We have some 20 acres of land from our state government for the Bangalore center; they have got similar land in the north. In two months, we're going to appoint the directors of both these institutes. These are all the things that we have done with the limited money that we had. The money that we had was not very large; we started with $200−300 million, and we will finish spending that in another year.

We're setting up an entity like the National Science Foundation. The parliament just passed it. This is from our prime minister's advisory council. It is called the National Science and Research Indian Board, the same as NSF, a project of $1 billion. It is not much by American standards, but for India, it is a lot of money, and we're just starting. It will be set up in 2 months or so.

Figure 2. Jawaharlal Nehru, his grandson Rajiv Gandhi, and daughter Indira Gandhi in an undated photo. All three served as prime minister. Image provided and copyrighted by the Aditya Arya Archives, Kulwant Roy Collection.

PSW: In other Conversations I've talked to people about the general public's interest in science. In some countries it is very high (Japan, for instance[6]). How much excitement is there in India?

C. N. R. Rao: There is general interest in science in the Indian public. But science is a subject. What has happened over the past few years is that the economic boom, [and] globalization has given rise to this tremendous force called information technology [IT]. That has sucked away a lot of talent. I'm an anti-IT man. I've known people to say that I lack insight. It is not that I'm against it, but you cannot have IT taking over India. Every intelligent boy is going for IT, to make some money, instead of going for research, engineering, or anything else. That is one reason that we've started these new institutes. In pure science, we've had a shortage of young, bright people.

Fortunately, with these IISERs coming, I'm told that there's a big improvement in bright kids coming to science. Science has suffered badly in the last 3−4 years. All the kids are going for either engineering, *many* to IT, banking, [or] business. Even after [studying] engineering, they do not *do* engineering; they go to business. They all get an MBA or something like that. Even in the world, in international and American companies, Indians are the managers. There are all these MBA's produced from here, which is not a good thing for India or for the world. I think they should do science and engineering.

PSW: You play a leading role in science policy in the government. Do you find politicians here engaged and interested in science?

C. N. R. Rao: Until about 10−15 years ago, the prime minister was the man in charge of science. He always took science as part of his portfolio. Unfortunately, that is no longer the case. It was wonderful working with Ms. Indira Gandhi. Rajiv Gandhi—I was his advisor, too (Figure 2). I have not been a government man, but have only served in an advisory capacity; I always remained in the lab. Rajiv was outstanding. I would meet him in the house, breakfast time, in the parliament. Every week he would call me up, "I want to see you about this!" He was really excited. That is not there any more. However, Mr. Manmohan Singh, the most recent prime minister, has been very supportive; he never said "no" to me. That is good.

"What is so great about science? Why should we support you?" Those questions are not asked now. Our present Prime Minister [Manmohan Singh] is well educated. He was an undergraduate at Cambridge, and did his Ph.D. in economics at Oxford—a professor like you and me. So, he respects science. The science minister [Prithviraj Chavan, appointed June 2009] is a good man. He has an M.S. from Berkeley in engineering. The previous minister [Kapil Sibal] had a law degree from Harvard; that education helps. We've had lots of previous ministers that did not understand a word of science. It was like playing music before a donkey—absolutely no effect.

That, fortunately, is not the case now, they are sympathetic and are fairly supportive. Without this, we cannot do anything. Eventually the ruling politicians control us, [both for] Congress in the U.S. and our Parliament here. The last 5 years have been very successful, mostly with the prime minister.

PSW: The advances are so rapid here now!

C. N. R. Rao: Right! I could not have said any of these things 5 years ago. I have seen the scientific system of India go from absolute poverty—to get $100 was difficult. I remember when I first came back from the U.S., I had to go to a conference in Washington, DC. In those days, India used to give $8 for going out of the country, and so here I was, with $8. I flew to New York. I had written to half a dozen friends, "Please come pick me up!" I did not know what to do with this $8! It was that bad. Nowadays, we do not have to think about dollars; it is a very easy situation. What a change!

It is a good thing for India. The result of all this big growth will be that India will become a powerful country not only economically, but also a coun-

> The future of the world, and peace in the world, will depend on knowledge equality.

try good at science, technology, and innovation. It will take another 10–15 years.

PSW: You also play a leading role in the less-developed world.

C. N. R. Rao: Until recently, I was president of the Third World Academy of Sciences (TWAS), which is now called The Academy of Sciences for the Developing World. Many Americans have taken leading roles in the Academy, like Bruce Alberts. He's a dear friend and past president of the NAS [U.S. National Academy of Sciences]. Mike Klein, at the University of Pennsylvania, Tony Cheetham at UC Santa Barabara, who moved back to Cambridge, are also members. The reason I'm mentioning the names of everyone is that many of them have known what is happening in India. They have been associated with what I am doing, and they come for meetings here.

We have started a major program for the LDCs [Least Developed Countries, a United Nations designation]. One of the things I've been able to do is to get several million dollars from various places to support research grants to good individual scientists in the LDC, so that they can develop right there in their country and not just keep going to the U.S. and Europe and so on. We've been able to give grants of about $30,000 a year for 3 years. Many such programs [exist] with various kinds of cooperation schemes, grants for spare parts, *etc.* There are prizes for the best scientists in the Least Developed Countries. There is one prize named after me [the CNR Rao Prize for Scientific Research]! We do many such things. Then, we elect fellows to the Academy. To be a member of this Academy is as difficult for somebody in Africa as becoming a member of the Academy in this country. We have 90 countries represented in the Academy.

TWAS now has 850 or 900 members, with an office in Trieste [Italy] at the International Center for Theoretical Physics there. I was president for seven years; I am now the Immediate Past President. Jacob Palis from Brazil is now the president; he's a mathematician. The National Academy of Sciences office has given support for us to run meetings for senior scientists in various small countries like Sudan, Senegal, Botswana, and so on, to see that they all establish academies or groups where scientists can get together and do something.[7] We've been able to do this through NAS funding. We now have a budget of a few million dollars a year, which is not bad. I'm very proud to be working for this academy, and it has been a great pleasure to serve the poor countries of the world.

> In my own life, I found that if any young people want to do anything in science or anything else, they'll be able to do it. It is a question of determination, how committed you are to your cause.

You know I meet guys from Togo [in West Africa]; it is a completely different thing. I can imagine myself here 50 years ago. I really believe that the future of the world, and peace in the world, will depend on knowledge equality. There has been no economic equality in the world. There will be no military equality in the world. There will be something more powerful than that! If knowledge equality is there, at least the feeling of inferiority will go away among human beings. The reason I am able to talk to you, the reason I have always been able to talk about this, is because I face no problem of knowledge equality as an individual. I can talk the same science as a scientist at Berkeley. If scientists in LDCs can talk the same language, they can feel equal to everybody else.

Everything is related to this, even this religious thing we're seeing. I wrote an editorial about this some time ago.[8] You should not view what happened, for example, on 9/11 as a purely religious thing. What has happened is this fanaticism/obscurantism that has come because of a lack of equality. If they were educated people, they would not have done what they did. We *must* educate all of these guys; otherwise, we will have a very bad world. For our own sake, for the sake of the enlightened communities of the world, we have to see that education and knowledge improve in the backward parts of the world.

PSW: Is there something that you might suggest that American scientists do?

C. N. R. Rao: Right now, we are trying to implement the equivalent of a Peace Corps, the Global Science Corps;[9] do you know about that? Harold Varmus, who cochairs the U.S. Presidential Council of Advisers on Science and Technology, is the author of this idea. I'm also a member of the group. Harold has been proposing the Science Corps, but it has not yet worked. It has not had enough support. I hope people in America will be working in, say, Nigeria or Tanzania; I think that we should have more of that. People in India working there do not have the same effect. We should make science the basis for relationships.

I think we should take interest in such activities. This religious fanaticism and fundamentalism is very frightening. The more people get educated, the more they will see the way the real world looks outside. Then, things may change. I think there's hope for that.

[It is] the same with Iran. All the professors are educated and have been against the present election. It is interesting that the votes of all these people have not been counted. The results were declared without bothering to count the ballots. The very reason they can fight and shout against this government is because they are educated. If they were not educated they would go along with all the mullahs and that would be the end of it.

PSW: What advice do you have for young scientists?

C. N. R. Rao: In my own life, I found that if any young people want to do

For Indian students, my advice would be not to give up. Anybody in the world who's determined will succeed. I'm sure of it.

anything in science or anything else, they'll be able to do it. It is a question of determination, how committed you are to your cause. For example, when I came to India from the U.S., there were no facilities, no electricity, no equipment in India, but somehow I wanted to succeed here in science instead of succeeding in America. I've been very lucky. I've been able to do this, and train a lot of students.

I think for Indian students, my advice would be not to give up. Anybody in the world who's determined will succeed. I'm sure of it.

[Literature citations and figures were added after our conversation to assist and to direct the reader to relevant publications.]

— Paul S. Weiss

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