PRATIDHVANI — EPISODE 44

In Conversation with Deepak Dhar

Statistical Physicist par Excellence

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Note on this transcript

This transcript has been edited lightly for readability. Filler words, false starts and repetitions have been removed, punctuation and sentence breaks added, and proper nouns — names of people, institutions, journals and physical models — restored from the garbled forms produced by automatic captioning. The substance and sequence of the conversation are unchanged. Where the source captions were unclear or absent, this is marked in square brackets.

PAVAN KUMAR G V

Welcome to Pratidhvani, where we try to humanize science. I'm your host, G V Pavan Kumar. It is my delight, my pleasure and an honour to welcome a guest on this particular episode: Professor Deepak Dhar. Deepak is a very distinguished theoretical physicist, and he is extremely well known for his work on statistical physics and stochastic processes, including a variety of different questions in statistical mechanics — random lattices, the introduction of spectral dimensions in the study of fractals, and also very interesting questions related to self-organized criticality, among many other things. Welcome to Pratidhvani.

DEEPAK DHAR

Thank you.

PAVAN KUMAR G V

I should also mention to the listeners that Deepak is a very decorated scientist. He was awarded the Boltzmann Medal in 2022 — he happens to be the first Indian to receive it — and subsequently he was awarded the Padma Bhushan in 2023. It is an honour to welcome you.

DEEPAK DHAR

Thank you very much.

PAVAN KUMAR G V

So Deepak, as we do in Pratidhvani, the conversation will be biographical and also mixed with the scientific aspects of your life. Tell us, how did you develop an interest in science in your childhood? Give us a view of where you were born and the kind of things you did.

DEEPAK DHAR

My father was in the State Judicial Service, so we moved around. I was born in Pratapgarh, near Allahabad — that is eastern Uttar Pradesh, somewhere near Prayag.

PAVAN KUMAR G V

Somewhere near Prayag.

DEEPAK DHAR

But I was there only until I was one year old. After that my father was transferred to Agra, and we stayed there for two years. Then he was transferred to Moradabad, and we stayed three years, and so on and so forth. So I have been in many different towns in Uttar Pradesh. I never went back to Pratapgarh afterwards. We have passed through the city by car on the way from Allahabad, but we have never been inside it. I don't know anybody in Pratapgarh, so to say. It is just an accident of birth.

DEEPAK DHAR

How did I develop an interest in science? I think it was my father who encouraged me to look beyond the Indian Administrative Service, which was sort of the hang-up of a lot of people in India at that time, and in Uttar Pradesh especially. This was not, of course, when I was very, very young, but from about my fifth grade onwards he would try to tell me that there are other things, and he gave me all kinds of small books about science.

DEEPAK DHAR

I remember in particular there was a British magazine called Understanding Science, which was sort of the equivalent of Science Today, an Indian publication — but Science Today started much later. This was around 1960, when I was ten years old. He would buy these magazines from the bookstore. I think he was the only one in that city to get a copy, so it was roughly a special order, and being a British magazine it was kind of expensive for Indians. But he used to manage to get me that magazine and ask me to read it. They were written in English and I didn't know enough English at that time, but I struggled and managed to learn a little bit and understand half of it, kept the magazine and learnt it later, and so on and so forth. So that is roughly how the interest in science started.

DEEPAK DHAR

I think I was good in mathematics, or in academics in general, and mathematics has its own charm — you can start appreciating the beauty of the Pythagoras theorem or something like that, which is true for most people. There are many students who can do this. So that was one fascination. I think the distinction between science, physics and mathematics was realized much later; at that time it was all these things put together. So we just used to learn whatever was taught in school, roughly speaking, plus a few books from the outside.

DEEPAK DHAR

At that time, when I was ten or twelve years old, I couldn't read so much English, but I could read all these Hindi novels in translation — Bengali novels translated into Hindi, and stuff like that. So we read a lot of them. In summer we would go to my maternal grandfather's, Nanaji's, house, and he had a lot of old Chandamama issues stored there, so we could read all of them in the summertime.

There was nothing else to do; you cannot go out. So we used to read a lot of them, and I got to learn about a lot of stories from the Puranas and the Arabian Nights and all kinds of stuff, which used to be well presented in Chandamama at that time.

PAVAN KUMAR G V

This anchoring of knowledge in stories is something that we, as scientists, also do in a slightly different context. When you were getting exposed to these kinds of stories during your childhood, was it implicit or explicit in your mind, by any chance, that this is a way of thinking?

DEEPAK DHAR

No, I thought it was just an interesting thing. For example, when you listen to music, I think it is very hard for young children to describe what they are appreciating. Of course it has a nice beat and it has a nice storyline or some such thing, but beyond that one doesn't really think much. You can say, oh, I like to read stories — that was the status at that time. And one could see that these are imaginative stories and they have some sense of humour at times. Not Indian stories so much, but British stories quite often have some sense of humour in them, and that was also very nice.

DEEPAK DHAR

I think this came much later, but for example Alice in Wonderland is really remarkable, and I can read it even now and enjoy it a lot. It is also deeply mathematical — of course, not very deep, but very interesting. It is presented to eight-year-old children, and at least some of the stuff they can appreciate very well even at that age.

PAVAN KUMAR G V

True, true. Which means that you were also getting introduced to the world of literature. And as you mentioned, translation is one of the important things. Growing up in the 1960s, the trend of translations was probably still prevalent, and it is still going on. But my only concern is, why did that not happen in the sciences?

DEEPAK DHAR

Actually — this is a little bit later, around when I was in tenth grade or so — we used to get lots of books in English from Russian publishers, Mir Publishers, because those were the cheap books available. The American books would be very, very expensive; these were very cheap and they were actually translations. Very nice physics books, chemistry books, the story of the elements, things like that. So we learnt a lot of science through these books too.

PAVAN KUMAR G V

Nice, nice. Very interesting. So how was the schooling experience? Did you feel welcome, did you enjoy it?

DEEPAK DHAR

At that time it was not an idea of enjoying school; it was just good. But one thing which I still remember, which was true at that time and perhaps still is: we used to move from city to city, so I would often come into a new class where I am the only newcomer and everybody else knows everybody else. Then all the previous students kind of try to bully you in some way. That is unavoidable. Initially I was very scared to go to school for a few days — four or five days — after

that things renormalized, but the first few days were always fairly stressful. You don't know anybody, then you try to talk to somebody and sometimes they snub you down and things like that. But that's part of life.

PAVAN KUMAR G V

Yes, especially for boys. I of course studied in the same school up to the eighth standard — I also had a transition after the eighth standard — but I have seen that students, especially boys, who make a transition sometimes really have to worry about this bullying aspect. It is a major concern.

DEEPAK DHAR

I was somewhat protected, because my father was a government officer, so it was not so bad. And then I used to get good grades, so soon enough people would stop doing that kind of bullying. But at least in the first few days it used to happen.

PAVAN KUMAR G V

Nice. Did you also pick up your interest in physical activity then? We'll come to that point later on, but I know that you are also very physically active.

DEEPAK DHAR

Actually I was of a very small size, not in very good health — scrawny and introverted. It was around twelfth grade that my father insisted I should get some more physical activity, so he would take me out on morning walks and make me jog and things like that. He was actually, when he studied at the university in Allahabad, the cross-country race champion.

PAVAN KUMAR G V

Wow, okay.

DEEPAK DHAR

It is just a university championship, but still, even then. At least he encouraged me to take swimming lessons and things like that, which didn't work out very well, but from his side he was insisting that you should have physical activity. After some time I started enjoying walking a lot, and I still jog a little bit now and then.

PAVAN KUMAR G V

To the listeners I should mention that Deepak is very regular in the mornings, because that is one place we also meet quite often, and he's been kind of inspirational to a lot of us to be regular.

DEEPAK DHAR

What I realized was that unless you have good physical health you cannot do anything. My capacity to work becomes zero whenever I'm not well.

PAVAN KUMAR G V

Absolutely.

DEEPAK DHAR

So for me it is almost necessary to go for a morning walk; otherwise I find that in two or three days I become somewhat unwell, physically as well as psychologically. So I do it as a maintenance activity. You may enjoy it, you may not enjoy it, but you just have to do it.

PAVAN KUMAR G V

Absolutely.

DEEPAK DHAR

At one time some friends were saying, oh, you jog so well. So one day I decided, okay, I'll time myself. I timed myself for 400 metres, and my speed was one third of the Olympic speed.

PAVAN KUMAR G V

Well, that would also scale to a lot of other things, right?

DEEPAK DHAR

The point is I was never going to become a sports star. It was just to keep happy and maintain your health a little bit.

PAVAN KUMAR G V

This is a very important point you're mentioning. We'll elaborate a little bit more once we also discuss more about science, because the fact that physical health has a reinforcement on mental health, and that reinforces the way you work, is very, very important. This is an important lesson a lot of us can take away.

PAVAN KUMAR G V

So, proceeding further — you were getting a good education, and in the 1960s Allahabad University was very well known, including greats like Meghnad Saha and others.

DEEPAK DHAR

He was by that time actually dead.

PAVAN KUMAR G V

Yes, that is already done, but there was a legacy of that.

DEEPAK DHAR

In Uttar Pradesh it was sort of still considered the best university. I think that would be fair to say.

PAVAN KUMAR G V

Fair to say.

DEEPAK DHAR

And there were also very famous literary figures there — Jaishankar Prasad, Mahadevi Verma, Firaq Gorakhpuri, who used to be in the English department. It's sort of very funny, but for example U. R. Ananthamurthy, who wrote all the time in Kannada and was a Jnanpith Award winner, was actually in my university's English department. I think this was a colonial legacy: the English department used to provide some new ideas, you could get what is meant by criticism, whereas the corresponding stuff in the other language departments was not really available. There would be one or two good critics but not too many, and there were not enough teachers to be able to provide a good level of instruction in those subjects. That is why those departments were not considered very highly.

PAVAN KUMAR G V

So in that sense you had a smooth transition from school to college. You probably proceeded at the same place?

DEEPAK DHAR

My high school was at Meerut Government Inter College; for eleventh and twelfth grade I studied in Muzaffarnagar; for my bachelor's I went to Allahabad University; my master's was at Kanpur, and my PhD at Caltech.

PAVAN KUMAR G V

We'll come to that, we'll come to that one by one. First, give us a little bit of the flavour of your bachelor's days, before we go into the master's — especially at the University of Allahabad physics department. As we mentioned, there were very big names, a very good legacy in that physics department.

DEEPAK DHAR

I was actually a very introverted person, and the university did not encourage too much interaction between students and faculty. We were shy people and the professors were big shots, and we actually never met many of them outside the lecture room.

PAVAN KUMAR G V

Wow, okay.

DEEPAK DHAR

I met two or three professors outside the lecture room, but otherwise our interactions were restricted to: he gives a lecture, I take notes. So I was not very happy as a student in Allahabad, because it was not a very stimulating environment.

DEEPAK DHAR

Anyway, I had managed to get something called the Science Talent Search scholarship.

PAVAN KUMAR G V

Yes, yes.

DEEPAK DHAR

That helped a little bit, because it helped us meet other students from Allahabad, or actually from all over India. So we got in contact with them and we could see what the subject is like, not just the textbook. There was also a provision of providing a local mentor in each university. My mentor was Bipin Kumar Agarwal, who was a very good physicist and also a painter, so he had some interest beyond just physics. I don't think I learnt much physics from him, but he would give me textbooks on physical chemistry, for example, which was beyond the textbook for me. So he provided some general guidance which was very valuable, in addition to whatever minor questions I would have about the subject itself.

PAVAN KUMAR G V

Nice. So during this bachelor's phase were you already developing some interest towards physics? This would probably be an honours programme?

DEEPAK DHAR

No, there was no honours. It was just physics, chemistry, mathematics as a combination for me; for other people some other combination.

PAVAN KUMAR G V

So there was no biology?

DEEPAK DHAR

For me there was no biology.

PAVAN KUMAR G V

Okay. So what was the kind of stuff you were studying then — the conventional topics?

DEEPAK DHAR

It was very conventional. But I still remember that I read Saha's Heat and Thermodynamics, which is actually still very good and sort of gives you some appreciation of the subject. By that time I could get all these other books on relativity and so on from summer schools, so I could learn those as well, which were not part of the textbook. So the fact that I liked physics was quite clear by that time.

DEEPAK DHAR

I enjoyed the chemistry labs very much, because it was very amazing to see — you take a test tube with a red solution and a green solution, join them and it becomes blue or some such thing. And these indicators, where you drop one drop extra and it becomes pink, and before that it was fully white and the drop was also white. These kinds of things were very fascinating.

DEEPAK DHAR

The interesting point about the bachelor's in Allahabad was that the best students were expected to appear for the IAS exam, and the university would pride itself, saying that this year ten students cleared it, or some such thing.

PAVAN KUMAR G V

Okay, okay. So it's been there for a long time.

DEEPAK DHAR

Nowadays it is Delhi — if you want to be in the IAS you have to be in Delhi and be coached there. I think at that time, if you were from Uttar Pradesh or Bihar, you would go to Allahabad and be coached there. It's like going to Kota now. But then, if you say that you don't want to appear for the IAS, you are looked upon with a very surprised eye — what's wrong with this person?

PAVAN KUMAR G V

Like people not going to engineering. Fascinating, fascinating. Which also means that you still harboured a very strong preference towards physics, because that further takes you to IIT Kanpur, your next stop. Was it a deliberate choice, because it is already in Uttar Pradesh, or was it anything beyond that?

DEEPAK DHAR

Actually, after eleventh grade we went to our first summer school, which was in Kanpur, and I liked it very much. For me, a young guy coming from Meerut in the 1970s —

PAVAN KUMAR G V

Right, the seventies.

DEEPAK DHAR

There were these things called punched cards, which many of you have not seen at all, but at least for us they were just lying there on the side. Very high, advanced technology was just around you everywhere. So that was very impressive. All the people who gave lectures in the school were very impressive, and so that made me feel that one would rather study here than in Allahabad. The same feeling was shared by other students from the Science Talent Search, and all of us appeared and all of us were taken in.

PAVAN KUMAR G V

One of the important aspects of IIT Kanpur, especially during that particular time and still, is that the quality of the work — the science and the engineering which is done — is very, very good. The Kanpur of the 1970s was actually considered one of the top-notch cities in India, and it was the place to go and really study and also become a faculty member. Could you paint us a picture of how it was for you to enter that great institution?

DEEPAK DHAR

I was not awfully overawed, because I had seen it before, and I had seen that my other friends were applying there. There was an interview, there was no written exam. I don't remember all the questions which were asked, but I think I didn't do everything well. One question which I still remember was: you have this terylene shirt, and when you take it off sometimes there are sparks — where do they come from? I was fully tongue-tied. I roughly knew there is some electrostatics involved, but the idea that there is a spark and there is such a high voltage was not known to me. Then they asked some other questions about whether you can expand cosine 2x in cosine x and sine x, and those kinds of questions I could do. So I was finally selected.

DEEPAK DHAR

I don't think I had a very impressive academic career at Kanpur. I was okay — I got some 9.6 kind of average.

PAVAN KUMAR G V

Oh, that's pretty good.

DEEPAK DHAR

But not the 10.0 kind of stuff, you know, like a person who does everything well. But I learnt in time that in order to clear an exam you need to know very little; you can get ten out of ten and not know much about the subject. Which happened to me for quantum mechanics, for example — I didn't understand it, but I still got a good grade.

PAVAN KUMAR G V

There lies an important lesson, because the fact that students do get full marks should not create an impression that their knowledge is also complete. This is also true for a lot of people.

DEEPAK DHAR

This is slightly out of chronological order, but let me just mention that I was an assistant of Feynman at one time. One thing which I learnt there, which he taught me, was this. He asked me to grade the exam, which I graded actually the same way as the previous grader had done: each week they would give two or three questions, you submit the answers, and by the end of the semester there are twenty or thirty questions. The previous grader used to give one, a half, or zero to each, and I did the same. So he said, no, no, no, this won't do — you have got to grade out of ten for each question. The point was that if you want to distinguish between ten and 9.5, that cannot be done on a scale of zero, half, one. A good student needs to know that he is not perfect, that he can do better, and that feeling is somehow lost if you get fifteen people who get the first rank in a university exam. Of course, if you use grading only to throw out people then it doesn't make a difference; or to make people happy, then give everybody the first rank. But it does give the idea that this is the best you can do — and that is not true, you can do much better than whatever you did.

PAVAN KUMAR G V

Absolutely correct.

DEEPAK DHAR

And that feeling should be kept. I think grade inflation is a very bad thing which has happened.

PAVAN KUMAR G V

I agree with you.

DEEPAK DHAR

It doesn't happen only here, it happens also in the US and so on, but it should be avoided as much as possible.

PAVAN KUMAR G V

In that sense, if you look at the time you were spending at IIT Kanpur — and Kanpur also has very good departments in the basic sciences — you were entering after having a good foundational education at the University of Allahabad. So now you're also getting exposed to physics because you are specializing in physics. In what sense were you developing your interest in slightly more advanced topics in physics?

DEEPAK DHAR

I was following the textbooks, just learning them a little bit better. No, I didn't learn much specialization at that time.

PAVAN KUMAR G V

And you were exposed to conventional classical mechanics and those kinds of things. How was your overall experience there as a student at IIT? Of course, you are a distinguished alumnus of that particular place now.

DEEPAK DHAR

The first thing which I can say is this. I finished my MSc at IIT Kanpur and then I joined Caltech. In the first year they still have courses there, which I took, but most of the courses were a repeat and I didn't have to work very hard. So I think the courses taught at Kanpur at that time were comparable to, or as good as, the courses in the best places in the US. That was certainly good.

DEEPAK DHAR

After that I started trying to look for problems to work on in research. That took some time. When I had gone to Caltech I thought I would work in high energy physics — that was the place — but soon I realized that no, no, no, that is not my cup of tea. I think it was like this: the kind of questions they ask, the simplest of which was something like the scattering of pions with pions. So what happens if one pion hits another? Somehow I felt that I have never seen a pion in my life, so I don't know what a pion is, and the whole question was very abstract. Of course it was also phrased in this quantum field theory language, and the question of what happens when a pion scatters against a pion is embedded in some deep formalism of quantum field theory which is very subtle. You have to write all those propagators, do all those integrals, and in the end something comes out. That was my feeling. Of course it was not fully right, but that is how it felt. So I felt that I couldn't do this kind of high energy physics, in which there was a lot of abstract machinery and various nus and sigmas and gammas, all kinds of symbols thrown in, and some integrals done, and something happens.

DEEPAK DHAR

And I must say that in the first year we were taught something called advanced quantum mechanics by Feynman himself.

PAVAN KUMAR G V

Wow, okay.

DEEPAK DHAR

He explained the diagrams and quantum field theory, and explained in some sense why they are approximate and not fully there — because all these renormalization problems are there and you have to understand them.

DEEPAK DHAR

So I decided I want to do something other than quantum field theory, and it seemed like a reasonable thing to do statistical physics, because it has some nice structure. Then I learnt of some problems of cluster growth in solutions — the Johnson–Mehl model. The name doesn't matter, but you have a solution in which some crystallites grow, and they keep on growing at a constant rate until they collide, then they just join up, and in the end everything is filled with these crystals. What is the distribution of sizes of crystals, and questions like this? So I explained to the person who was supervising me at that time that this is a question which fascinates me, because it's an interplay between physics and geometry. He was trying to tell me to do something about wind.

PAVAN KUMAR G V

Oh, interesting.

DEEPAK DHAR

He was an astrophysicist, and I was saying, no, no, no, I would like to work on this problem. So he listened to me politely but told me, no, no, no, I think we should find some other adviser.

PAVAN KUMAR G V

Oh, okay.

DEEPAK DHAR

So eventually I found Professor John Matthews, who was very generous. His principle was that you should choose your own problem: I will look at it, I will explain to you, I will supervise you, but I'm not going to do that problem. He was very generous about what subjects the student can follow. So I started working with him. I would go to him and say, right now I'm studying this and doing this, and he would listen carefully and make a few suggestions, and it went on like this for a while.

DEEPAK DHAR

Eventually, at some stage, one learnt about the Kasteleyn model and so on, and I explained to him that this is the way it works and I can do this much. And then the next week he told me that in the plane flight from some place back to Pasadena, I was looking at it in the plane, and you can do it like this. Of course it's an old solution to Kasteleyn, but the point is that he didn't have access to Kasteleyn at that time; he was sitting in a plane and he was able to solve it by himself there, and explained to me later how it could be done. That was very encouraging, because otherwise sometimes these fields look like they are great magic and you have to be a magician in order to do this. But then I realized that ordinary mortals can also work in these kinds of fields. And then we just tried various things — some of them work, some of them don't work.

PAVAN KUMAR G V

Wonderful. So we didn't actually go into the specific transition from Kanpur to Caltech in your chronology. Was it a deliberate decision that you chose Caltech, or were you thinking about other places?

DEEPAK DHAR

Actually, I applied to six or seven places in the US and luckily I got admission to all of them. The reason was simple: I got a good score in the GRE. So then it was a difficult choice, which one to take, and I think my final criterion was the famous name, so I went to Caltech. There were some other criteria — Caltech was paying a stipend of 200 dollars per month and some other place was paying 500, but I chose Caltech because it seemed much better.

PAVAN KUMAR G V

Wonderful. Now, going into Caltech — the department itself is very reputed, and you were also a teaching assistant to Richard Feynman. For listeners who may not be aware and should be aware, Richard Feynman is one of the greatest physicists, and Deepak actually also took an advanced quantum mechanics course from Feynman. So give us a little bit of a gist about interacting with him.

DEEPAK DHAR

Feynman was a legendary person. We had heard of him in tenth and twelfth grade.

PAVAN KUMAR G V

He already had a Nobel Prize too, right?

DEEPAK DHAR

Of course he had a Nobel Prize. He also had the book, the Lectures on Physics, which students used to read.

PAVAN KUMAR G V

So it was already there — it was already written around 1960?

DEEPAK DHAR

Yes, and it was already a well-known textbook; people used to study it. So it was like God. When he was giving all these lectures to the students, a lot of faculty people, senior people, forty or sixty years old, from other universities would come and just sit at the back to watch Feynman give a lecture, for one or two lectures. If you are here, why don't you listen to a lecture by Professor Feynman? So even famous professors would come to his lectures just to see.

DEEPAK DHAR

In seminars he would be fairly sharp and ask all kinds of tough questions, and if you don't satisfy him, he will not keep on bugging you, but he will just shake his head and say clearly that no, no, no, that is not a satisfactory enough answer.

PAVAN KUMAR G V

Okay. And you had a very close interaction with him, in the sense that you used to talk to him about the course you were teaching?

DEEPAK DHAR

Not very much. I was a very shy person and he was a big shot, but we used to interact once in a while. I was his teaching assistant for the second year of that quantum mechanics class; the first year I had taken it myself, two semesters, and in the second year, for one semester, I was the TA. When I was a TA I would talk to other students, and they would say that Feynman is great — if you listen to him give the lecture you think you understand everything, and after half an hour you realize you don't understand anything. The reason was very simple: many students listen to the lecture, it sounds great and simple, but they didn't follow it up by repeating that lecture. If you don't go back and read it again then it gets lost. So what you have to do is actually go back and revise, reconstruct — then it becomes part of you. And if you try to do it after a week it won't work quite as well.

DEEPAK DHAR

So, for example, people realized even at Caltech that the Lectures on Physics, his famous volumes, are not good for undergraduates. They are good for more senior people who are actually wiser. Once you have had an exposure to quantum mechanics, then you can appreciate what he's teaching; otherwise somehow it doesn't do enough of a good introduction.

PAVAN KUMAR G V

This is a very important point you're mentioning. Even as a student, when I was studying, the appreciation came only when I went into my master's, because generally that was taught at the

undergraduate level, but once you become a master's student in physics you'll appreciate it far more than if you read it right at the level of an initial textbook. So it also means that you had a kind of ringside view of this person who is very, very reputed. Did it also influence the way you think?

DEEPAK DHAR

I would hope so. I think he was certainly very clear, and one very important thing was: don't get overawed by algebra.

PAVAN KUMAR G V

Yes, yes.

DEEPAK DHAR

He believed in insight, in being able to see through the algebra. One of his standard questions was: can you derive this formula in the shower?

PAVAN KUMAR G V

Nice, typical.

DEEPAK DHAR

Which is to say, you don't have pencil and paper — without pencil and paper, can you do this?

PAVAN KUMAR G V

Wonderful, that's fascinating to know. This is such an important aspect. You also use very, very rigorous mathematics in your own work, but having heard many of your lectures and also having interacted with you, what I've learnt is that you can still present the work, probably post facto, in such a way that people would be able to understand what you're doing in slightly greater detail. In fact this is a concern especially for students who are just starting in physics — those who may not have had a reasonably good foundation in mathematics, or even some people who may have a foundation in mathematics, but using it in physics is not the same as just doing only the mathematics. So what do you have to say for people who would want to understand deeper physics using the machinery of mathematics?

DEEPAK DHAR

Firstly I would say that this simplification necessarily occurs somewhat later. I'm working on some new problem, then I try to find a solution, and I find a solution with great work, but it is very ugly — it involves all kinds of complicated equations and symbols. And then you have to ask, is this the best I can do, or can I find a better solution which is easier than this? Okay, you work for two more weeks and then you can simplify the solution a little bit, and more like that. So it's important to be able to simplify, and not feel very proud of the fact that I can do this very complicated stuff.

PAVAN KUMAR G V

Yes, that's an important point. And the fact that you also have a physical picture in your mind probably will help you do that.

DEEPAK DHAR

Physical, I don't know — a picture in your mind. I'm not sure it's physical, because that might not be the same thing as reality.

PAVAN KUMAR G V

Yes, but you may have a mental model which probably would be used to reconstruct.

DEEPAK DHAR

I think it is useful to tell here one Feynman story for people. He was just talking to some reporter and he was saying, oh, it's very irritating — you are in the airport and people come to you and say, Professor Feynman, can you explain why you got the Nobel Prize? And at the airport it's not the right place to explain. So this fellow just laughed and said, well, you should just tell him that if I can explain it to you here, it is not worth the Nobel Prize. And they both laughed and the reporter went away. But Feynman kept worrying about this question, and after two or three days he rang up the fellow again and told him, no, I was wrong — if I cannot explain what I did to a high school student, then I don't understand it well myself.

PAVAN KUMAR G V

Wonderful, wonderful. Yes.

DEEPAK DHAR

So that is the approach, and it says that complicated formulas which you cannot explain to your younger brother are not really full understanding. They can help you partly, but you have to decode a lot of those symbols — what is this actually, and what is this trace, and all those kinds of words which we use as code words. They have to be deconstructed a little bit to get to the core of the matter.

PAVAN KUMAR G V

Very, very well put. This is also sometimes a concern for a lot of students who want to get started with physics, be it experimental physics or theoretical physics, because you have to really decode. That decoding is a very important thing, because the code is the same for everybody, but the decodes can be different.

DEEPAK DHAR

Exactly. I have been talking to students at IISER, so I realize — I said, how do you go from A to B? Then they say, oh, we start with this, then we say this, then we say this, then we say this — as if the process of saying this is important for the understanding of truth. They cannot do this without going through all those steps and saying all those things, and all those things are like a mantra: once you say this, then everything is okay.

PAVAN KUMAR G V

That's a very, very important point, because that leap sometimes will also give you something slightly different.

DEEPAK DHAR

Also one should not confuse invoking a lemma or something as a substitute for understanding. If you just repeat that, okay, then by somebody's lemma I get this result, it's not the same as having understood what that lemma is. If you understood what that lemma is, then you could say the same thing without using that word.

PAVAN KUMAR G V

Absolutely.

DEEPAK DHAR

That is my feeling.

PAVAN KUMAR G V

In fact this again resonates with what Feynman says — that knowing the bird by its name and knowing the bird are two different things altogether. Beautiful. So I am also aware that you probably had some interaction with Wilson.

DEEPAK DHAR

Yes, yes. Wilson spent one year at Caltech, luckily at the time when I was a student there. I met him once when he came, and then I think I met him four or five times.

PAVAN KUMAR G V

For listeners, I have to mention this is Kenneth Wilson, a reputed physicist — renormalization.

DEEPAK DHAR

He was the founder of the new understanding of renormalization theory. Renormalization was kind of invented by Gell-Mann and Low in 1950, but I think it's fair to say that they didn't understand what they were doing.

PAVAN KUMAR G V

Wow, do you think so?

DEEPAK DHAR

I would say so. Certainly, if they understood it well they would have explained it better. And they didn't understand it, and even people like Feynman didn't understand it at that time, because they only used to say you can cancel infinity and you get a finite answer, and stuff like this. It was only Wilson's understanding of what renormalization actually means which provided a fresh way to look at it and gave it much more power.

PAVAN KUMAR G V

So he had already worked it out by the time he came to Caltech?

DEEPAK DHAR

Yes, yes. He was actually my friend H. R. Krishnamurthy's adviser.

PAVAN KUMAR G V

Wonderful. So this means that you were already getting the taste of renormalization, which is a topic you also have used very, very creatively — we're going to come to that point later on. But were you also getting exposed to those topics?

DEEPAK DHAR

At that time, in 1970 to 72 and so on, everybody in statistical physics was working on renormalization of phase transitions and critical exponents. That was the general direction of work, and it would be very difficult to work on something which was totally different. So I was exposed to

this general idea. I was trying to calculate some critical behaviour or the other myself. Fisher and Wilson had written long articles which we used to read. Shang-keng Ma had written a book.

PAVAN KUMAR G V

So these were already there? But they were new.

DEEPAK DHAR

They were there. The book was there already.

PAVAN KUMAR G V

Oh, Ma was already there.

DEEPAK DHAR

Yes, so all these things were there and we were trying to understand them. I had done some calculation where I did a variational calculation, and as a result of that variational calculation I claimed that the actual singularity in the Ising model is always a first order transition — totally wrong. I showed it to Wilson and he nodded his head and said, yes, yes, it's a variational calculation.

PAVAN KUMAR G V

Wonderful. So was it a very nice experience for you to be there?

DEEPAK DHAR

I think it was very nice to be able to see him. I don't think I directly learnt too much from him in my next research paper.

PAVAN KUMAR G V

Interesting. So tell me also one more story, Deepak, which you have told us regarding you having a party in Feynman's house.

DEEPAK DHAR

This was actually very early. I had just arrived at Caltech, only two weeks old or some such thing, and then some senior students, whose names at that time I didn't know, came and said, let's go to Feynman's house. So what was the occasion? It turned out that Feynman had gone on sabbatical to Japan, and since it was several months he wanted a housekeeper for the house. He got a PhD student in our department to be the housekeeper, and he had a German girlfriend who was also a physics research scholar, so they were taking care of the house. They had instructions: don't go into that room, and don't do all this, but other than that you can use the house. So he just invited the students from our dormitory, because he was living in the dormitory, to go there. So we went there. We didn't do too much, we just stayed an hour or so, we drank some orange cider, apple cider, stuff like that, and just came back.

PAVAN KUMAR G V

Okay, but it was at Feynman's house when he was not there.

DEEPAK DHAR

When he was not there.

PAVAN KUMAR G V

Very interesting story. So now you already have an overview of statistical physics, having started working on a problem which is somehow also getting connected to what you were going to do a little later. Tell us a little bit more about the research problem.

DEEPAK DHAR

During this first year I also took a course called States of Matter by David Goodstein. He was an excellent lecturer, and one of the things they were working on at that time was helium adsorbed on graphite and phase transitions in that. I guess it was known that there is this theory which is somehow useful, but they were trying to do it themselves and do experiments and see how it works, and so on and so forth. Feynman also worked on this. He never published that stuff, but he did obtain some sort of mean-field solution to this problem, a singular mean-field solution. I will not discuss that part in detail here, but he discussed it in class and we were thinking about it.

DEEPAK DHAR

In any case, I was getting to know about the renormalization group, and then there was a paper by Nelson and Fisher which discussed renormalization on fractals.

PAVAN KUMAR G V

Nice, nice, yes.

DEEPAK DHAR

And before that there was of course this famous paper of Wilson and Fisher on phase transitions in 3.99 dimensions.

PAVAN KUMAR G V

An interesting title, right? That's the title of the paper.

DEEPAK DHAR

Yes, and of course the question asked is, what is 3.99 dimensions, which they didn't answer very well. Later this other paper showed how to construct fractals which are actual objects — explicitly constructed fractals. You can define the Ising model on them, and then it has a critical exponent, and you can ask what it is and how it depends on the dimension of the fractal. So that idea interested me very much. So I tried to do this. I took the fractal which they had studied and said, okay, let us study some other model on this fractal. The simplest model one can think of is the spring-mass model. Working that out was somewhat non-trivial, but in the end you can actually get the exact spectrum, and it shows that the low frequency density of states has a power-law behaviour which is different from the dimension obtained by the box-counting method.

PAVAN KUMAR G V

Nice.

DEEPAK DHAR

It was a different dimension, and so that is what I found, and that was my first paper to discuss this stuff.

PAVAN KUMAR G V

Wonderful.

DEEPAK DHAR

Actually it was not really the first paper, it was the second one. The first paper was a small half-page note about line stretching in turbulence.

PAVAN KUMAR G V

Wow, okay, that's interesting. So you have a connection to turbulence right at the beginning.

DEEPAK DHAR

Actually, I was at Caltech and I didn't know what to do, so I was attending all kinds of lectures. There were some lectures by Saffman, who is a very well known person in fluids. He gave a proof of this line stretching in turbulence, that on the average the mean square deviation between two marked particles will grow as a function of time. He gave a proof involving something complicated with eigenvalues of matrices and something. So I went to him and told him that look, this proof can be obtained directly by symmetry — it was four lines, really. And he said, oh, okay, I will look at it, I'll get back to you. After two or three days he came back and said that yes, I agree, your result is correct and it is much simpler than the much more complicated derivation given in the standard treatment, so why don't you write it up? I was somewhat reluctant to write it, saying it's just half a page, four lines, what can you publish? He said it can be published. So I sent it and it was accepted for publication. He was the editor, of course.

PAVAN KUMAR G V

In which journal was this?

DEEPAK DHAR

This was in Physics of Fluids.

PAVAN KUMAR G V

Physics of Fluids, wow, okay. This was not known — this is very interesting. Was your thought process also on that particular thing?

DEEPAK DHAR

At that time I was just looking for some problem to work on, so I looked at all kinds of things.

PAVAN KUMAR G V

Because later on you also came up with the spectral dimension aspect. Was there any connection already, or not?

DEEPAK DHAR

There was a connection in time, but not in space.

PAVAN KUMAR G V

Very interesting. So now you have worked on this particular problem. Did you go on to work on similar problems there at Caltech, or did you change some of the questions?

DEEPAK DHAR

After that I couldn't do anything much in turbulence, so I decided to work on other stuff, easier problems. These fractals seemed interesting, and there was another problem which I wanted to study from the beginning — the theory of melting.

PAVAN KUMAR G V

Melting, yes, that fascinates you even now.

DEEPAK DHAR

Yes. So we made up something, and the model was somewhat interesting, but it was not really a solution to the problem. It got me my PhD.

PAVAN KUMAR G V

Nice. So was there a specific model system you were looking at?

DEEPAK DHAR

Yes. There has been a theory that melting in solids is a layer phenomenon, because people know that you can superheat liquids but you cannot superheat a solid. The idea was that what happens is, when you heat it, layer by layer they just disorder. That was also seen in simulation. So we just took a model in which the lower layer is held rigidly fixed in a periodic lattice, and the top layer is just harmonic springs, and they sit on an external periodic potential which was taken to be sinusoidal. So it is sort of like a discrete sine-Gordon model, it is called. Then by some transformations you can convert it into a Coulomb gas and it undergoes the Kosterlitz–Thouless transition. That renormalization theory was known, but I sort of worked it out for myself in this system, and that was for my PhD.

PAVAN KUMAR G V

Which means that you now have a good exposure both in terms of the techniques and in terms of the questions you are interested in. Were you also thinking about some problems which you were going to work on, or were you just staying in the moment and doing what is necessary?

DEEPAK DHAR

I was thinking of different questions, many of which I was not able to do. I didn't think of them as: I have to write my next paper on this topic. Just, it looks like an interesting question, and in some you make some progress, in others you don't make any progress. But when I went to TIFR after my PhD, then Professor Barma was there — he was also newly arrived — and he was working on relaxation in Ising models, so I also started working on that problem. And then the next few papers we wrote on this Ising model, driven Ising model, and stuff like that.

PAVAN KUMAR G V

We'll come to that particular point. But now tell us about the transition, because you headed back to India after you finished your PhD. Why?

DEEPAK DHAR

I finished my PhD and I was looking for postdoc positions. I applied to two or three places in the US and also to TIFR and one more place in India, and only at TIFR did I get an offer. I didn't get it from

any other place, so I just came back. Anyway, I was not planning to settle down in the US at that time.

PAVAN KUMAR G V

Is it? Okay.

DEEPAK DHAR

I was planning to come back maybe after two more years or some such thing, but the offer seemed good, and so I just returned.

PAVAN KUMAR G V

You just returned without any hesitation?

DEEPAK DHAR

No hesitation.

PAVAN KUMAR G V

That's quite fascinating. And this is roughly around the 1970s, right — '78?

DEEPAK DHAR

'78, yes.

PAVAN KUMAR G V

So once you came back, you were also bringing new kinds of problems, probably, and now getting into TIFR and collaborating with Professor Barma and others. So was this transition easy for you?

DEEPAK DHAR

I didn't feel it as a transition. The main point about TIFR was that the postdocs were not supposed to work with a professor. They just sit in the department and do their own work. Of course we reported to senior professors, but we were not working under them, we were not working on the problems they told us to work on. So actually we just discussed with Barma — he likes this and I like this, so we write a paper together on that. It was not a question of bringing problems with us or anything; it was just whatever problem seems interesting at the time, and see if we can make some progress.

PAVAN KUMAR G V

So what were the questions you were thinking about at that time, or what were the specific areas?

DEEPAK DHAR

I think one problem which I started working on with Barma was relaxation in Ising models, and problems with disorder like percolation also started with Barma, and then we just went on from there.

PAVAN KUMAR G V

So tell us about that particular phase, where you also told us some time ago that you heard a particular talk, and that triggered a specific question in your mind, and that led to all the very interesting questions which followed.

DEEPAK DHAR

That particular talk is a little bit later chronologically, so let's not get there.

PAVAN KUMAR G V

Okay, okay.

DEEPAK DHAR

But even before that, in percolation-like questions, we just realized that if you put in a direction then it becomes directed percolation, which of course was studied ten years earlier but not enough. People ten years earlier, in 1970, didn't have very good computers; by 1980 they had become somewhat more powerful, so we could do the kinds of things those people did, much better. And there was some interest in other places also in this new problem, directed percolation. So we didn't do very much — we just did a Monte Carlo simulation.

PAVAN KUMAR G V

Nice, which is a starting point for anything.

DEEPAK DHAR

It was a Monte Carlo simulation of a sort of new angle on the old problem, or a new problem, you can say, which later on became much more interesting — a lot of people picked it up. So it was an impactful paper for me, because my first and second papers were not appreciated very much in the beginning. I think this fractal dimension paper started becoming well known only after it was rediscovered by Rammal and Toulouse five years later.

PAVAN KUMAR G V

Oh, wow.

DEEPAK DHAR

But they were kind enough to refer to our earlier work.

PAVAN KUMAR G V

Wonderful. So which means that you were already looking at percolation and related questions. This is also the time when you were transitioning from postdoc to faculty member?

DEEPAK DHAR

The transition to faculty member actually occurred in 1980. I joined in '78, and in 1980 I was made a regular faculty member. All these papers on directed percolation came around 1982.

PAVAN KUMAR G V

1982, yes. So during that time, were you already thinking about the specific model systems you are working on, or were you also thinking about the Abelian sandpile?

DEEPAK DHAR

The sandpile came much later. I don't have a great research plan for the future. I only look at lots of interesting problems at a given time and see if I can make any progress in any of them. If I can make some progress, then I decide, is this publishable or not? One should appreciate this point, because of course you can make some tiny progress on some problem, but it's not good enough to be

reported. So then you make a threshold: if it is better than this, then I will publish it. And we go ahead with that, and not have any grand plans. So it is just sort of random walking in idea space.

PAVAN KUMAR G V

Nice, that's a nice way of putting it — a random walk in idea space. So tell me about that idea space now, in around the 1980s, probably 1985 or something like that. You are also then having your own group.

DEEPAK DHAR

No group.

PAVAN KUMAR G V

Oh, okay, interesting.

DEEPAK DHAR

It was very interesting at TIFR at that time. There were very few students — roughly three or four students in the whole department in one year.

PAVAN KUMAR G V

Is it?

DEEPAK DHAR

And most of them used to do high energy. So in condensed matter there would be one or zero per year. And those students typically would be registered with a senior professor. So we didn't get to guide a student until pretty late. My first student was in 1990.

PAVAN KUMAR G V

Wow. So till that time you didn't have students to work with you. This is something which is very interesting, and I would like to get your thoughts on it. When you become an independent faculty member, the convention nowadays is that you immediately start a group. And here is a case where you were almost working on your own problems alone.

DEEPAK DHAR

I almost had a group with Professor Barma — I mean, these were two faculty members, if you like. There was one postdoc at that time, funnily enough, but he left after two years to make his own company or something. But that was the level of the group. There were not too many students at that time.

PAVAN KUMAR G V

Which also means that you were thinking mainly by yourself, and you had to do everything. Having experienced academia for the last fifteen years now, I have also found that of course building a group is important, but the other element, of being in your own problem space, is sometimes very enjoyable, because you can ask questions which only you are trying to address, and if you make progress and you think about it, you also feel that you are doing something. That's much easier to do in theoretical physics than experimental, but even then, as an experimentalist I also feel that sometimes, and that's the reason I also do some small things on my own. But tell us a little bit about that independence of thinking, because that is a lesson for all of us to learn a lot from.

DEEPAK DHAR

I would say that one of the things which TIFR gave us was freedom of work, in the sense that we were not asked too many questions about what you are doing, so long as at the end of two years or some such thing you have some substantial work to show. So I'm certainly grateful to them.

DEEPAK DHAR

Just one tiny story I can tell about that phase. I was a young faculty member, and Professor Rohini Godbole was a postdoc. We used to work together at night on the computer there. So one day one of her younger sisters came, and she was showing them the place around — this is where this is, and this is this. And then she said, oh, this is all very great, so how much do you have to pay to work here?

PAVAN KUMAR G V

[laughs]

DEEPAK DHAR

Of course all of us laughed, but that was the point. The point was that we felt it was a privilege for us to be able to work there and do whatever we want. And I think by today's standards the pay was not so great, but it didn't seem to matter much. Life was also slightly simpler then.

PAVAN KUMAR G V

Of necessity.

DEEPAK DHAR

Of necessity, yes. Because that is something which is sort of a boundary condition in a society — the pay scales cannot be very different from the pay scales in some other place in India, so they were all comparable. But the freedom to work was special, which was not there in other places.

PAVAN KUMAR G V

Beautiful. So TIFR is also a place which has many other interesting research areas, and your contemporaries are also very well known in various different fields. How was your interaction?

DEEPAK DHAR

We used to discuss things with people in computer science and people in nuclear physics, astrophysics, like that. So we discussed, but I didn't get to a stage where it could be a publication. Certainly for richness of exchange it was there, and I guess it is possible that those people benefited a little bit from my comment here and there, but it did not reach a level where I would become a co-author.

PAVAN KUMAR G V

It also is a great place, a physically beautiful place, and it probably would have also positively influenced your lifestyle.

DEEPAK DHAR

We took it for granted at some level, and only lately have I appreciated how much of the things we get we take for granted. Recently we went to the hospital for my wife's doctor — she's a very renowned cancer doctor — and we were telling her that the IISER campus is very nice. And she said,

yeah, yeah, all these government jobs have good facilities. If you talk of IISER to an outsider, you will complain about this funding or that funding, but the fact that you have such a huge campus is actually not available to very, very rich people in other areas.

PAVAN KUMAR G V

Absolutely correct.

DEEPAK DHAR

And that somehow we are used to. Even if I go to a state university it will still have a pretty good campus, actually. The university is still able to provide that, even if they don't give you a lot of intellectual stimulus or academic freedom or all kinds of stuff. But those things we often take for granted, and at that time certainly I took all of this for granted.

PAVAN KUMAR G V

True, true. What you mentioned is so correct, because there is also a very famous poem in Kannada where life is all about going from have to have-not — the moment you get something, your focus becomes something which you don't have, so you do not appreciate what you already have.

DEEPAK DHAR

In a sense I would say it's certainly good to not be fully satisfied. You should always try for something more; there's nothing wrong with that, it is actually very desirable. On the other hand, being always sort of complaining about things you don't have is also not right. So something in between is necessary; a good balance is what is needed.

PAVAN KUMAR G V

So correct. This is important especially for the generations who are building stuff in their own careers, because sometimes they might get bogged down.

DEEPAK DHAR

But there is also an intellectual life which can still go on. In particular, for PhD students in India, I feel that they are not striving hard enough. They should be much more ambitious. They say, oh, we are doing okay, I have written two papers in the last year or whatever — but is that good enough? Shouldn't you try for more, better quality papers, not necessarily just in numbers but better quality? I would say that the same person, if he worked a little bit harder, could do much better. It is important to realize that it is not just satisfaction in physical terms — intellectually also you should not be satisfied all the time.

PAVAN KUMAR G V

True.

DEEPAK DHAR

At my age, when should I start?

PAVAN KUMAR G V

You are probably the most productive person I have seen.

DEEPAK DHAR

So one has to worry about this. Okay, now I'm seventy plus, so should I be satisfied? I cannot hope to do much more. But no, you can try. It may not work out, but you can try. That's the way.

PAVAN KUMAR G V

Wonderful. These are golden lessons, and listeners, anybody irrespective of their age — this is something which we will have to register in our minds.

DEEPAK DHAR

Actually, on this I can tell a small story, not related to me but a friend's story. My friend Sastry went to Bell Labs, and he was telling me a story that he was a postdoc and one day P. W. Anderson came to his office and told him, oh, you know, these things are very bad, I haven't written a PRL in the last three weeks. I wasn't there, so I don't know the actual story — something Anderson was telling. At that time, when he told me the story, I thought, how stupid is this. How can he say something like this? Why should he bother with one more PRL? But the point was that Anderson was not saying this for himself; he was saying this for the postdoc.

PAVAN KUMAR G V

And he was saying, you should be writing one more PRL in the next three weeks or some such thing. That's what he was trying to convey.

DEEPAK DHAR

The way he said it was that I haven't done any interesting work in the last few weeks, and that one should worry about.

PAVAN KUMAR G V

Absolutely correct. Even Anderson had to worry.

PAVAN KUMAR G V

So we'll proceed in the timeline. Now, coming to what is very strongly associated with you — coming to roughly around the 1990s. Please tell us what are the kinds of questions you are asking.

DEEPAK DHAR

Actually it all started with the talk by Per Bak. He came to Bombay and he gave a talk about his theory of self-organized criticality and how it explains everything in the universe, from water flow in the River Nile to solar flares and earthquakes. And then he described this model of sandpiles, which is the so-called Bak–Tang–Wiesenfeld model. Basically we were not very happy with this talk, because very strong claims were made there. So we decided, let us try to see what happens. We were working on directed percolation and stuff like that, and we said, in a sandpile there is a preferred direction, so things should only fall down and not up. So we modified the Bak–Tang–Wiesenfeld model to say things only fall down, and what will happen? Ramaswamy was there also as a postdoc at that time, and so we decided, let us study this problem, and set up a numerical simulation code, which is not very tough to write — one or two days. And we saw that it looks like the critical density is a half, which is very suggestive. Then we said, can we prove this result? And it turned out you can prove this result. And then we tried to find some other things, like what is the size distribution of exponents, and all those could be done.

DEEPAK DHAR

The point is that this variation of the sandpile model to a preferred direction makes it much easier, much more tractable, and you can solve the model exactly in all dimensions immediately, without too much work, without heavy mathematics. So that was very useful for us. And then we got interested in the problem — you can see some structure, then you can try to extend it to non-directed problems or partially directed problems, and so on. And so that is how that went, in the field of self-organized criticality.

PAVAN KUMAR G V

So were you aware that what you were doing could actually turn out to be something very important? Did you have a hint, because the motivation for the problem is already there?

DEEPAK DHAR

We had some general idea that it's an interesting solution, and there were many other people who were writing papers on this subject. It was considered a hard subject at that time. Then there was some school in Kathmandu where Kadanoff had come to give some lectures, and I also gave some lectures on this model, and he was appreciative, and he said this is nice work, something like that. And that was the end of that. But the fact that people appreciated the work soon after it appeared was very nice.

PAVAN KUMAR G V

Fabulous. So now you take this particular problem and further proceed with it, and you also look at some specific issues related to how it evolves. Could you tell us?

DEEPAK DHAR

We were just sort of trying to see this particular problem and extend it if possible in other directions. And of course there was some general interest which has been there for a long time in modelling of life. So we found that some patterns in sandpiles can be made analogous to proportionate growth in biology. So we tried to develop that idea, and I think it is an interesting idea which is somehow not sufficiently appreciated by biologists — but maybe after five years they will start appreciating it.

PAVAN KUMAR G V

I'll come to that particular point, because I want to pick your brain on the way of looking at biology from a physics perspective. In this particular chronological timeline that we are talking about, it also is a time when you are really working with some very accomplished people, who later on become very accomplished — Ramaswamy and Satya Majumdar, people you actually also have interacted with. How was that?

DEEPAK DHAR

I think it was always very stimulating. These people are very smart and it is a pleasure to work with them, and I'm sure whatever we managed to do would not have been possible but for the common interaction and common interest.

PAVAN KUMAR G V

And you also mentored so many people, including Abhishek, people who are by themselves now leaders in their own respective fields. So what has been your model for grooming young people?

DEEPAK DHAR

I would say that the fact that these people were very good was not in doubt. And I think it was an advantage to be at TIFR that we got very good graduate students at the entry level. So Abhishek would have been very good in any case. But then if you can work with them a little bit, then you can learn with them and they can learn from you at the same time. So I think that was the mode. We just get them interested in some problem and see how it works. It doesn't work equally well with each student — some are better than others, that's the way it is.

PAVAN KUMAR G V

Wonderful. I have also done an episode with another of your students, and she also mentions the influence you had on many of them. It's a very strong view which I get from a lot of people, including from having interacted with you, and even among students who have interacted with you at IISER: that you show, you don't tell. Meaning, you actually show that you can do good things by doing them yourself, and people just have to watch it and then learn from that. That's a very effective model of showing people how to actually work effectively.

PAVAN KUMAR G V

Which brings us to a point where a person who is deeply motivated in science, like you are, is also constantly thinking about research. Tell us a little bit about your thought process of picking a problem and thinking about that problem. What is the kind of process you generally follow?

DEEPAK DHAR

I would say that I try to think of several different things, typically six or seven things at a time.

PAVAN KUMAR G V

Wow, that's a lot.

DEEPAK DHAR

And most of them don't work out. But then you don't sort of feel unhappy about that; you just shelve them, and after five years you can look at them again. It may still not work, but it keeps your overall unsuccess rate lower, because actually it is ten per cent, but then those ninety per cent don't show up, and then you can still say, okay, I got two interesting results this year. So if you don't try five different problems, it won't happen.

PAVAN KUMAR G V

Very interesting, even with the best people.

DEEPAK DHAR

Absolutely right.

PAVAN KUMAR G V

Very important point. But how do you structure this in your day-to-day work? Because if you are really thinking about so many problems, time is limited per day, and you also have other responsibilities.

DEEPAK DHAR

Nowadays, in my ripe old age, what I do is that if I get papers to referee, I actually try to understand them before I write a referee report, which is pretty useful and keeps me up to date with that kind of subject. Because this fellow refers to five or six previous papers — I don't read all of them, but I read two of them, and that way I sort of keep roughly abreast with the subject without reading everything, which would be very hard. So that is how I try to keep up with the subject. Of course one has some hang-ups, and some new subjects I don't like, so I don't look at them at all, but I try not to be too rigid.

PAVAN KUMAR G V

One characteristic feature which I, at least having looked at it a little closely as a colleague in the last few years, notice is that you also still work at an individual level, which is deeply motivating. Especially for me personally, one of the important lessons I have derived from you is that you can still work with students but still work on your own problem. Tell us about that.

DEEPAK DHAR

I don't think there is any sharp divide. Say you try to work with some student and you show him this interesting problem, then they don't make any progress for two months, then it is a little bit frustrating. Then you take it up, then you try to sweat it out yourself a little bit, and then you explain, this can be done like this, but it may work out, it may not work out. So it is a constant give and take. I don't think I work fully by myself, but if I am not able to involve somebody else in it, then I try to do a little bit by myself still.

PAVAN KUMAR G V

So this is a distinct advantage of being a theoretician, because as an experimentalist sometimes you don't have that privilege — even if you want to do it, it would be difficult without some kind of involvement of other people. But going to that particular division in physics, generally speaking — I'm slightly broadening the scope of the discussion — there is the division which is there historically in physics between experiment and theory, and there's also another fault line, which I'll come to later on, between applied and fundamental. To begin with this division, I want to get your views, because you also have interacted with experimentalists and you have contributed towards research problems which have direct implications for experiments.

DEEPAK DHAR

I would say that experiments are tough and they take a good deal of time. If I actually did experiments myself I would not be very successful; I would actually be a major failure. Some people have different talents; I don't have a talent for doing real experiments, so I don't want to try. I can try to persuade some experimentalist to do them, or I can work with them, and that is what I do at times.

DEEPAK DHAR

Long ago, in 1980, we did an experiment. It was making up some arrangement of diodes and doing a percolation experiment to determine the conductivity of the bulk. It turned out that we did spend a fair amount of time and energy, not so much money — the total cost at that time was ten thousand rupees, which still was a low budget in those times. But then we realized that whatever we managed to do with an enormous amount of work, in one scientific assistant, one could do on the computer in fifteen days.

PAVAN KUMAR G V

Yes, yes.

DEEPAK DHAR

So for some things it's not necessary to set up a very complicated experiment to be able to verify some idea, which was our motivation for that. So I would say that one should be careful in choosing the experiment, and the luxury of doing the experiment without having an idea of what it will be — serendipity is much harder in experiment than in theory.

PAVAN KUMAR G V

Absolutely.

DEEPAK DHAR

So you can have a lower level of this stuff — that this combination somehow has a higher critical temperature than that combination of elements, or something. But that's the level at which you can work; you cannot sort of invent superconductivity from basic theory. That is too far. So I think this kind of division between theory and experiment is reasonable enough at a functional level. It is necessary; nothing can be done. It cannot be avoided.

PAVAN KUMAR G V

Absolutely.

DEEPAK DHAR

Most of the theorists you see today will not be able to do a good experiment. Okay, you can always find some people who write papers in theory and experiment together, but are they equally good at both? That will be very tough. It is just because things have now diversified a lot, and the things needed to do a good experiment are slightly different from the things needed to do good theory. It's just inevitable at some level.

PAVAN KUMAR G V

True, that's true. And the other division which I wanted to just get your input on is this applied and fundamental.

DEEPAK DHAR

I would certainly say it's a very important, burning issue of the time. We are theoretical people, and now the attitude of society in general seems to be that fundamental research is not needed, that you only need to do some applications. So some work on various applications of some idea or the other is all that they look for. Can this produce patentable stuff in three years' time? If you cannot do this, then it is not worthwhile. I would say that that very mercenary attitude to research is not

desirable. You can put a total amount of money you give to pure theory versus experiment — ten per cent versus ninety per cent, or whatever your favourite number — but don't make it zero.

PAVAN KUMAR G V

Absolutely.

DEEPAK DHAR

That is going to be counterproductive to the purpose you are trying to serve. Unfortunately it is not generally accepted, because nowadays what happens is that people — no names here — like mega projects as opposed to thirty small projects of one lakh each. I would prefer thirty small projects, because a mega project shows more visibility, perhaps it has even a bigger impact on the whole, but at some other level those small projects in small universities would have been good for the overall intellectual climate of the country. The individual research may not be so profound, but at least that keeps that person going.

PAVAN KUMAR G V

Absolutely.

DEEPAK DHAR

And unfortunately, if you stop that funding, you lose a research base which will be hard to replenish after ten more years, because a whole generation of people would be gone.

PAVAN KUMAR G V

Absolutely right. You have made a very strong case for small science — and I'm not in any way demeaning anything small in terms of the investment, but it is something at an individual level. This is music to my ears, because that is something which I also strongly believe, because the nature of the work which at least some of our colleagues do has to do with that individual level. You train a group of students, and that impact unfortunately sometimes doesn't get more attention — the impact you can have on one student getting trained on one thing, they might get a job, they might also become good teachers. Sometimes you cannot fit this into the metrics, but this is actually a real impact which you are really having.

DEEPAK DHAR

Unfortunately the metrics are very faulty, but they have been designed by professors like me — not me, but that kind. It's very funny, actually, that you can ask, how can these people be so foolish that they will make up this metric? But they did. And people think differently than me, that's all I can say. But if you look at the implementation of the education policy — I'm not discussing the basic structure of the idea — the implementation has not been very good in the last thirty, fifty, seventy years. I think that is why we are where we are, while smaller countries like South Korea can do much better than us.

PAVAN KUMAR G V

Overall literacy levels and whatever. And even recently, Vietnam, for example — they have also been scaling up even up to the level of manufacturing. There has been a lot of change.

PAVAN KUMAR G V

So, moving further, one of the questions I would want to ask you, slightly related to the things we are now discussing, is about the scientific way of looking at things in general — not only within the framework of academia, but for the general public. You also interact with students. Recently we had a very nice science day and festival where you were to give a talk on scientific temper and other things. Can you please tell us a little bit about how the general public can and should start looking at things in a slightly more broadly scientific perspective?

DEEPAK DHAR

Actually I managed not to give the talk on scientific temper, because I had Covid.

PAVAN KUMAR G V

Oh, okay, okay, sorry.

DEEPAK DHAR

No, no, it was announced but it was not given. But I prepared something for that purpose, and in that context I realized that somehow there is a perception that scientific temper is for scientists. But it's not true; it is supposed to be true for everybody. And scientific temper just means not having superstitious belief in various things without any cause. If I believe in something, I should actually have some reason for the belief, not just that somebody else said so. Of course there is a different set of people who believe in real faith, where they say that it is given in this book or that book and that's all, I don't need to know anything more. At one time that mode was quite useful, but I think in the current world it is not very helpful to think that way.

PAVAN KUMAR G V

Fantastic.

DEEPAK DHAR

It is helpful for a tiny minority of people who want to rule over others, for whom it will be easy to rule if people are ill educated. But for the good of society it doesn't work. There are things which we call superstition which we don't want to believe in. Like, if I eat some food while there is an eclipse, is it bad or good? There is a story about Chandra, that Rahu ate up this fellow. Can I believe everything which is written in the shastras? The answer is, one should not believe everything which is given there. There are lots of good things given — I take them — but there are other things where I should explicitly say, no, no, this is a nice story but it's only a story. And this distinction between what is a story and what is the truth should be kept in mind.

DEEPAK DHAR

There are speculative stories also. People say that at one time they didn't know what the universe outside is, so they guessed. This guessing is okay, it is allowed, it should be done — even now people are doing this. But it should be understood what that means, and one should not confuse our idea of what it could be with what it is.

PAVAN KUMAR G V

Very, very true.

DEEPAK DHAR

And somehow that distinction is less present in current society than it was present in the intellectual world of 1947. I'm actually mentioning Nehru's name, because he's the one who introduced the word scientific temper, and he thought that it's a good idea for society to have this temper, as opposed to blind faith. That's all. And I think the age when society could work with pure religion based on faith would be difficult now. The religion we can have now is of course — some religion is necessary — but it's very different from the religion which insists on various ceremonies, like unless you wear this thread your life is not good enough. Those kinds of things we don't want to believe in, and we should say so explicitly, and we should not encourage people to do more of these superstitious traditional beliefs just because they have been done long ago. That's what I would say.

PAVAN KUMAR G V

Wonderful. It is something very heartening to hear this, because as you exactly mentioned, it is to distil good ideas, to take what is really forward-looking and then take it forward. Because nobody's asking to abandon the culture; it is just to move forward the way of looking at the world. Very intuitive and very interesting.

PAVAN KUMAR G V

So the other question I wanted to ask, Deepak, was about the talks you have given on the very interesting relationship between physics and mathematics. In fact, I vividly remember, because I was in the audience, where you gave very interesting thoughts on, and also commentary on, Eugene Wigner's viewpoint of how mathematics is very useful in interpreting the physical world. Give us a gist of that.

DEEPAK DHAR

Wigner had written this article called The Unreasonable Effectiveness of Mathematics in the Natural Sciences, and he pointed out that it turns out that some ideas from mathematics are very useful in describing the real world. He gave an example, which I will take two minutes to describe. He said, take a population, plot the number of people with a given height versus height, and it has some bell-shaped curve, and it can be described by the Gaussian, and there is some root pi which appears in the normalization. So where does the pi come from in the distribution of heights of people? Of course, there's some complicated mathematics which goes in, and it's the integration constant and the normalization or some such thing, but in the end the idea of pi, which was the ratio of circumference to diameter, shows up in a totally unrelated problem. And that is what he called the unreasonable effectiveness of mathematics.

DEEPAK DHAR

He gave some other examples which are all known to people. Some of the things we can describe quite well using mathematics, but it still remains true that many other activities of equal interest to us in the real world are not so well described by mathematics. So for example, I gave the example of Tendulkar. He's playing cricket, and I doubt if having a very detailed knowledge of the trajectory will be helpful.

PAVAN KUMAR G V

It will not help you hit better.

DEEPAK DHAR

Exactly. It is much more intuitive, or whatever it is called, but it is non-mathematical. Whatever the skill you develop, it is non-mathematical, and there is not much hope that you will be able to do much better with a mathematical description of cricket in this way. It will not help you play cricket. So one should appreciate that mathematics is very nice and useful, but it has limitations. If I want to worry about how society is going to be twenty years from now — social engineering, it is called — again, mathematics has very little to say. But it doesn't mean that that question is not very interesting or important, or shouldn't be tried.

DEEPAK DHAR

So we should just not be very myopic and think mathematics is everything. Unfortunately this point is not explicitly said very often, and students, when they are impressionable, are given the idea that mathematics is God, or next to God, and I think that feeling should not be conveyed. Because obviously people have said it before — mathematics is the queen of the sciences, Gauss said. But Gauss was a mathematician. So one should just not be very sectarian in this and say that I'm somewhat good in mathematics, so mathematics is everything in the world.

PAVAN KUMAR G V

Very interesting and very important point, because these are all questions which are again revisiting us in the current times. If you look at it, one of the elements which is sometimes lacking among students who are trained in the sciences and engineering is exposure to the humanities. And one can see that there are negatives of not having got that exposure, where mathematics actually is not the central thing. Of course it will surely have some role there, but it is in no way as much as, let's say, in physics or even chemistry. That viewpoint was also mentioned by E. O. Wilson a long time ago — of course it was criticized by many people — where he was saying that in order to do some kinds of biology, not all kinds of biology, you don't really require full-fledged mathematical knowledge. I am aware that a lot of physicists especially were a little upset by that particular argument, but there seems to be a real point there, and it closely relates to something you were mentioning.

DEEPAK DHAR

I would say that our mind is a very complex and complicated thing and it has many spheres of activity. If you take a poem and try to understand what it means, and what is a good poem versus a trivial and bad poem, it is hard to tell. That notion of aesthetics is not a purely scientific notion. Even in science we say this is a great theory, this is not so great a theory. There is an equation two plus two equals four, and there is another equation — which one is a more profound equation? At some level they sound equally trivial and equally good. But what you read into them depends on your background and how you interpret them — not just the equation, but what it is trying to convey.

PAVAN KUMAR G V

Very correct.

DEEPAK DHAR

And that depends on our prior exposure and training and that kind of stuff. So I think it would be bad if scientists do not have any appreciation of music. Fortunately, scientists can quite often appreciate music. I cannot do it very well, but at least fifty to seventy per cent of scientists can appreciate music. I cannot say the same for musicians — that fifty per cent of them can appreciate science.

PAVAN KUMAR G V

Precisely.

DEEPAK DHAR

And I think this point is equally harmful and it should be remedied.

PAVAN KUMAR G V

Absolutely.

DEEPAK DHAR

So for the common public, that is the scientific temper part. It is not important to know any particular scientific theory, but the overall structure of scientific thought should be understood — that there are things which are well established, there are things which are less well established, there are things which are well explained, things which are less well explained but can be understood, and there are things which cannot be understood even by God. So the behaviour of hydrogen atoms I can understand; the behaviour of single cells is also kind of understandable at some level; but the behaviour of individual members of a species is unpredictable, even by God, something like that. So I think that point should be appreciated.

DEEPAK DHAR

There is a very famous saying by Walt Whitman, where he said that he contradicts himself. I don't know what that means. I don't know why he should be proud of this fact, so I'm not able to appreciate this point. Maybe that is just my limited understanding, but I'm seeing that he wanted to say something, I'm sure, and he was not bothered about logical rigour — but wouldn't he say it in a slightly different way?

PAVAN KUMAR G V

Very interesting and very important. So this also brings us to another small connecting point, which is your thoughts on biology, because you have worked in a field which has some kind of indirect connection to biology. Given the fact that the system is complex and statistical physics does play a very critical role in such kinds of areas, how should one look at biology, especially from a physicist's viewpoint — because now it's one of the greatest challenges?

DEEPAK DHAR

I would say biology is a difficult subject, a complex subject, and people have tried to understand it for a long time. Of course there are some partially understood and some less well understood areas. What I would say is that physicists sometimes provide a different way of looking at the problem, which is useful even if it is not perfect, even if it doesn't explain everything. It poses a different set of questions, which is enriching. Maybe it doesn't lead to money tomorrow. So if I'm a

very money-counting person then I may not benefit — I will ask, what is the use of this, even if you understand? What is the point? But I would say it provides a different approach to a difficult problem which has not been solved yet, and to that degree it is certainly very useful. And since I have a physics training, I will try to use my physics training to explain biology. Somebody else will do it differently.

PAVAN KUMAR G V

Very interesting point, because biology has become central in various different kinds of questions which are of interest to biophysicists, from a conceptual viewpoint and also from a technical viewpoint. Physics has also been extensively used — specifically statistical physics has been extensively used — to go and try to interpret larger arenas of knowledge: economics and financial markets and other things. What is your thought on that? Is it kind of successful, and to what extent?

DEEPAK DHAR

These stock markets and stuff like that — of course it is partly successful. The point is, the stock market is there and people are there trying to advise you to buy or sell stock A or stock B, and sometimes these theories are useful, sometimes they are not. By definition they cannot always be useful, because some people have to lose, otherwise you cannot win. So it's roughly a zero-sum game, not fully, but roughly. The theories which are successful depend on being able to use past patterns to predict the short-term future, and those things usually do not show up in published journals; they are very privately held properties of the individuals who provide you this not-free advice, paid advice.

PAVAN KUMAR G V

Yes.

DEEPAK DHAR

So I think they are certainly useful at that level, but at the level of economics they are not providing anything extra just now. If I have an AI program which tells me which stock to buy tomorrow, there's an AI program which helps some of the people win, but it will not increase the happiness of mankind by itself. So in those kinds of applications, physics is not playing a very important role. Statistical techniques are used sometimes, but those techniques are like using a Gaussian distribution, and they can be used wherever you want.

PAVAN KUMAR G V

So, last three questions. The first question is on one of the points which has now come into focus in Indian science: the question of inclusivity, in terms of gender and also in terms of economic background. These are very important points. Could you tell us a little bit about how, as a research community and as a scientific community, we should approach this problem? Any specific thoughts you have?

DEEPAK DHAR

Firstly, I think it is important that some section of society not be disallowed access to some kinds of knowledge. So, that girls should not do science — that kind of attitude we should not propagate. And I'm saying this because in some countries right now, luckily outside Afghanistan, they don't want women to study at all, or beyond fifth grade. We don't want to be in that society, we don't

want to be like that. But do we want Shudra people to study science? Questions like this. I think they should be encouraged, or allowed, to study science.

DEEPAK DHAR

Now, historically we have had reservations for seventy-five years, and somehow it hasn't worked in practice. So sometimes you need to put in some slight advantage to offset the long history of disadvantage.

PAVAN KUMAR G V

Absolutely.

DEEPAK DHAR

We have the same idea and we have actually copied it from the West, so I think those programmes are certainly desirable at some level and they should be pursued sincerely.

PAVAN KUMAR G V

Sincerely — that is the hardest part.

DEEPAK DHAR

Because in the past people said reservations were supposed to end in some years and they would not be needed afterwards. It hasn't happened. It doesn't happen. So let it happen, and then we can see. The only thing people nowadays worry about is, is this too unfair, too much advantage given to the poorer sections, and are people much below the required competence being taken, or some such thing? I would say that it is not written anywhere in the Constitution that this should be done, and people should be allowed to say in selection committees that no, we didn't find any suitable candidate. But if you cannot find a suitable candidate in ten years, then there is some problem with your measure.

DEEPAK DHAR

So I'm saying that selection committees should not be given a totally free hand — it doesn't seem to work — but constraining them too much by saying that this year you have to take five thousand people from this category — you take the top five thousand, it will still work out in the end, not too badly. But when the number becomes two and three, then there is a bigger problem, and then I think we should be more careful, and not first set the gender and caste and fifteen other parameters which are needed and then look at which person satisfies all these conditions, and okay, maybe he's also a statistical physicist. That should not be the approach.

PAVAN KUMAR G V

So my penultimate question is a request for you to speak in a few sentences in your mother tongue to our audience about what you are interested in and what motivates you to do science.

[Professor Dhar speaks for a short while in Hindi. This segment was not captured in the source captions and is not transcribed here.]

PAVAN KUMAR G V

Very, very nice. So the final question we generally ask the guest is: tell us a little bit about your influences in terms of things outside the sciences — art, music, reading and other things.

DEEPAK DHAR

My hobbies, or whatever, have evolved in time. When I was very young I used to do a lot of reading, so Chandamama to start with, and then other things in Hindi, translated into Hindi, then English novels also, and fairy tales in general. Some music also I used to listen to. But in time my reading outside has become narrower, because nowadays I don't read so many story books, but I read more biographies. Biography is one of my favourites, because I find that I'm able to get more benefit — psychologically, intellectually — from reading real-life stories, as opposed to totally fabled kinds of stuff. So with time things evolve. Right now I'm not doing too much of literature study.

PAVAN KUMAR G V

What's your general relaxation process, apart from running, which you do?

DEEPAK DHAR

Yoga, which is hateful — it's just a distressing activity.

PAVAN KUMAR G V

Absolutely.

DEEPAK DHAR

And some television. I watch preferably not the news.

PAVAN KUMAR G V

Nobody now prefers that.

DEEPAK DHAR

There is only one TV in our house, so there is some kind of complicated negotiation. But I would like to go outdoors, and just picnic, hiking.

PAVAN KUMAR G V

Hiking, wonderful. This has been extremely illuminating. Almost two hours has gone without my actually realizing the time. I am hoping that whatever has been discussed, a lot of the things can also be taken and thought through further, because a lot of things have their own strands, and these strands are very beneficial for many of us to get more information from. Any last words you want to mention? And do you have any specific plans right now for the future, what you want to work on?

DEEPAK DHAR

I have many plans, but they don't work out. For example, we have been thinking of writing a textbook.

PAVAN KUMAR G V

Oh, wonderful.

DEEPAK DHAR

Somehow the project is more than five years old and it has not happened. But maybe it will.

PAVAN KUMAR G V

Yes, all the best for that particular venture. And I'm again very thankful to you for spending this time and sharing all these thoughts. Thank you very much.

DEEPAK DHAR

Thank you.

PAVAN KUMAR G V

This is Pratidhvani, where we try to humanize science, with the one and only Professor Deepak Dhar. Thank you.

END OF CONVERSATION