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Information and Intuition: An Autobiographical Essay

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Section I (Schooling)

I was born in Srinagar, but my earliest recollections go back to isolated events in Basohali, Bilawar, and Kathua. I have the memory of a snake slither up the wooden frame of the cot on which I lay asleep at night. When discovered, there was uproar and the snake was chased out. I recall playing in Srinagar at my sick maternal grandfather's home.

Almost every other year, father would be transferred to a different town in Jammu and Kashmir. His assignment was as head of the government's animal husbandry dispensary and as regional veterinarian. It generally came with a reasonably roomy residence next to the dispensary. After Udhampur, we were in Kulgam for two years, followed by Baramulla for one year, Leh for two years, and Anantnag for several more years. I did school-leaving tenth grade examination as well as the pre-university college examination from Anantnag.

I was an exceedingly shy child. My parents tell me that when we moved into rented rooms where we shared the courtyard with the landlord's family in Udhampur (where two other siblings arrived), no one saw or heard me speak. After a couple of months the landlord commiserated with Pitaji for he was sorry that I was mute.

In spite of being quiet, perhaps because of it, I was fascinated by language and meaning. I recall mulling for hours in my second grade over why some words have different meaning in different contexts. For example, I was perplexed by lagana, because it could mean different things such as to "get hurt", "to feel", "to be attached", "to fix", "auspicious time", and a specific "ritual". Just a small change in emphasis could alter the meaning from "reality" to "illusion" in going from *brahma* to *bhrama*.

We were raised on stories from the Mahabharata, the Ramayana, the Puranas, and local folk stories. Often the chowkidars in Pitaji's office would tell us stories in the evening. One particularly gifted story teller in Kulgam made remarkable embellishments to the tales.

I remember writing my first verse in Leh in Hindi when I was about 11 years old. It was written in the *doha* style of medieval Hindi poetry:

Vidya padho, vidya padho, vidya se ati labh

Jo vidya na padhata hai, use na koi abh.

I finished high school in 1961 and joined the local college for the year-long pre-university course. The high school examinations took place in March/April. Didda, my father's adoptive mother, passed away just before the examinations and my parents and siblings left for Srinagar for the various observances. My father arranged for Dwarka Nath, who was an employee in the Department, to be with me for this period and do the cooking for me. Dwarka Nath was from a village near Pahalgam but he and Pitaji had known each other for over 15 years. Although he was a lowly employee in the Department, he was the disciple of a guru in Pahalgam who had been very fond of Pitaji and Mummy, and in that sense he was my father's equal in spiritual aspiration.

A sadhu had left the complete edition of the Hindi translation of the Bhagavata Purana at home. Now that my mother was not there to check me, I spent the entire period of the examinations reading the book. I don't think I understood the deeper spiritual meaning of the text, but at the level of the stories in it, the book was simply astonishing and quite unlike anything I had read before.

Dwarka Nath took excellent care of me. We slept in the same room on different wooden beds. Since I was reading the Bhagavata Purana like a maniac night and day, I saw that he woke up around three in the morning, and did his spiritual practice sitting on the bed with the blanket over him, staying in this posture for several hours.

In a few weeks the results of the statewide examination came in. I had done quite well and obtained a top rank in the entire state.

I joined Anantnag College at Khanabal and I would ride there on bicycle. This college had the best library I had seen and it opened up the world to me. I read what I could get of fiction, philosophy, biography, and history. During the summer, we had several visitors who were spending their vacations in Kashmir. One of the relatives had brought books on Christopher Marlowe and that opened up the fascinating world of Elizabethan drama.

Back in Anantnag, it was assumed that after the pre-university course, I will join a degree college for further studies in science or literature. The other thought was that like my older brother Avinash, who was studying engineering in Madras (Chennai) after completing his college in Kapurthala, I should also do engineering. But somehow months passed and one day my mother woke up to the fact that the deadline for admission to the engineering college in Srinagar, which had opened the previous year, was approaching fast. Since time was short, she arranged for my application to be hand carried to the college.

The college was operating out of barracks under the chinar trees of a magnificent Mughal garden called Naseeem Bagh that faced the Dal Lake, next to the town of Hazratbal, an ancient Hindu pilgrimage centre that is now one of the most important Muslim shrines in the valley. I was reluctant to apply for admission but Mummy said I had to do it because there was no way I was going to be able to feed my family as a writer.

I was called for interview but told that I was below age. A few weeks later, I heard again from the college with the word that I had been admitted. The day to leave for the college arrived and my parents saw me off in the bus that stopped in front of our home. As my father kissed me goodbye and turned away, I saw tears in his eyes for the first time.

I was originally assigned mining and metallurgy but after a few months we were told that this specialization was going to be closed and we were given the choice to pick another area of specialization. I picked electrical engineering in part because that is what Avinash was studying in Madras.

In early December the college shut down and I was back in Anantnag for the winter holidays. It was snowing and bitterly cold. Late evening on 26 December, 1963, people started talking agitatedly around in the market that we could see from our second-story window. Later we heard out that the relic of Prophet Muhammad's hair had disappeared from the Hazratbal shrine (situated not too far away from my engineering college). Resentment and anger began to build up rapidly and next day the town shut down and buses were redirected to Srinagar to take people to the shrine.

The crisis had broken out during Khwaja Shamsuddin's watch as Chief Minister of Jammu & Kashmir, but he was inexperienced. Nehru sent the Home Secretary V. Vishwanathan to Srinagar. On 4th January the government announced that the relic had been recovered, and a caretaker at Hazratbal had been arrested. If the government had assumed that this would be the end of the crisis, it was mistaken. The crowds declared this was a ruse and they wanted proof that it was the hair that was lost.

The government was wary of the idea of verification. What if the people said that it was fake? After lengthy negotiation it was decided that a special *deedar* (showing) of the hair would take place. On the appointed date and time, a huge crowd assembled in Hazratbal. There was a hush as the relic in the glass tube was displayed and everyone was waiting with bated breath about what would happen next.

An old maulavi associated with the *dargah* stepped forward and inspected the relic for several seconds and then declared in a clear voice that this was indeed the holy relic. The crowd burst into wild cheers. The mystery of who had stolen the relic and how it was found was never made public. Poor Khwaja Shamsuddin was fired at the end of February, after being in office for less than five months.

My brother, Avinash, completed his engineering degree in mid-1966, and, awaiting his results, he came to the engineering college and became a junior lecturer for the summer months. Later, Avinash got word that he was selected by the Indian Institute of Technology in Delhi to do his Ph.D.

In December 1966, our class went on an India tour in the College bus. The trip took us through Jammu, Ludhiana, Chandigarh, Delhi, Aligarh, Agra, Shivpuri, Bhopal, Burhanpur, to Bombay (now Mumbai). In Delhi, I spent two of the four nights with my brother at his IIT Delhi hostel room and was impressed with the campus of the Institute. Avinash suggested that he would be most happy if I was also selected to do Ph.D. there like him.

An incident with enormous impact on me occurred during this tour. We were at the Bombay Zoo, and I was observing a pair of bears in their cage when my eyes met theirs and I experienced an overpowering feeling of mutual recognition. As I was reflecting on this feeling, the bears suddenly turned violent and started striking each other in apparent rage. Soon they were bleeding from their many wounds. I felt I was also a bear, although in a human body. It appeared as if the bears had put up the show to amuse me, to teach how it all amounted to nothing.

I was an animal, but I was an animal with special knowledge. The experience was ego shattering, but it was also oceanic: it seemed to expand my consciousness.

The experience hung about me for months. I felt that consciousness was universal, and this appeared to give me a feeling of power. I seemed to be able to get out of my skin and empathize with almost everyone else. There arose a sense of love that I wished to share with everyone. I also had a strong emotion regarding my mortality. I had experienced a penetrating feeling of death.

Section II (My years at IIT Delhi)

I graduated from the engineering college in 1967 and joined IIT Delhi as a Ph.D. student. The plan was that I will work with Professor P.V. Indiresan, the head of electrical engineering department, who was also Avinash's supervisor. He was forty, a short and wiry person with a forceful personality. His interests were mainly in applications of information theory. He had done his own engineering degree from the Indian Institute of Science in Bangalore followed by Ph.D. from Birmingham. From his name I gathered he was Tamilian.

Indiresan went on to become prominent in Indian scientific world. He established a research laboratory in IIT Delhi for advanced research in electronics that did important work for Indian military. Later he was director of Indian Institute of Technology Madras, and still later the president of Indian National Academy of Engineering

When I met him, he asked me to look around the department and to get to know the professors. Remembering that I had spoken of my ideas on physics at the interview, he suggested that I work with Professor M.S. Sodha of the physics department, who was a specialist in electromagnetic wave transmission in plasmas.

I went to see Professor Sodha. He was a genial man, who switched to Hindi once he realized I was from Kashmir. He held research grants from NASA and he presided over a large research group of over twenty students. These students mainly worked on the problem of overcoming the re-entry blackout as a spacecraft entered the earth's atmosphere. The blackout occurred as the spacecraft's motion caused the air around it to ionize into plasma. Sodha's students considered different mathematical models for the plasma and then numerically evaluated the solutions to see if signals could be transmitted through it.

This applied problem did not interest me and I reasoned that plasmas was as much of a new subject as signal processing by arrays which, I suspected, Indiresan would want me to work on. Sodha had graduated a large number of students and one could believe that any hard-working student could hope to get his degree working with him quickly, whereas Avinash was one of the first Ph.D. students to work under Indiresan and no one knew what expectations he had of his students.

After much thought, I decided to work with Indiresan. He had come across as a broad-minded person and I felt that I would have greater freedom to explore my ideas working with him. It would be a greater challenge and it would help me discover how good I was and know about myself. I told him my decision and he was pleased.

Avinash and I were fast-tracked into the Ph.D. program without the need for the two-year long M.Tech degree. We were the only two students who had been

directly admitted into this program. This meant that we did not have to attend courses and we were free to begin with research as soon as it was possible. The minimum amount of time for completion of Ph.D. in this program was three years.

I began reading research books and papers. Since my self-reading at the engineering college had involved topography of space I thought first of the problem of geometrization of circuits. Indiresan asked me to prepare a report on Hilbert transforms, which had applications in communications theory. I thought it would be fine if I did what Indiresan wanted while exploring other ideas. In this I was hoping to emulate Avinash who was working on antennas prompted originally by Indiresan's interest in array processing but he had moved to issues that lay beyond. Both Avinash and I hoped to do fundamental research.

The preparation of the report on Hilbert transforms opened up the formal theory of information to me. I also studied transforms in general since they played a central role in preparing signals in forms that were suited for transmission in noisy channels. They were also important in analyzing data for hidden patterns and for processing of speech and images.

This was the time that technology was taking its first steps in going from transmission and storage of information in its continuous form, the form in which it is created, to a digital format. The mathematical theorem detailing the conditions under which such digital representation causes no error is called the sampling theorem. I began researching this theorem.

I had no overarching ideas for my research. My hope was that working on different models I will be able to make significant improvements while keeping the larger question of reconciliation of mechanistic science and biological freedom in the background to be revisited as I obtained mastery over the necessary mathematical tools. But I was dismayed that the assumptions on which models of reality were based came with their own problems of meaning.

Classical physics did not worry about information and physics was about the complete description about a physical object and its relationship with other objects. That the question of what "physical laws" were needed to be considered carefully became apparent when one visualized the universe.

I was aware that at the deepest level our understanding of what science means is somewhat subjective and looking for truth is equivalent of looking for the moon beyond the mountain. Science simplifies, but is it always correct that simplicity represents the truth? Perhaps, I had stopped believing in reality a bit too soon. My aims now reminded me of a remark regarding a man of the world: *He went to seek virtue, but since she was not to be found, he got power.*

Meanwhile, I was getting into conflict with Indiresan. He wished for me to work on some ideas that I thought were not going to go anywhere. At best, they would mean tedious simulations without any significance. On the other hand, the ideas I was working on seemed too theoretical to him. I bought some time by telling him that I had sent some work for publication.

Things came to a head in September 1968 when I went to his office with a rejection letter from a journal. I told him that the referee's report was not completely negative and there was room for revision and with the experience gained from writing up this work I had a much better understanding of the problem. He now completely rejected my line of thinking. The editor of the journal had given him the stick to beat me with. He said that I had had my chance at freedom and failed it. I was now to follow a program that he would set up for me. He said that he wanted me to do experimental work on electronics, for which I did not possess the right background and which did not appeal to me. When I expressed my reservations, he said that we could discuss this matter again next week.

I was thinking furiously the next few days, and when we met again, I suggested that the problem of information content of continuous signals that were constrained in a variety of ways was original and it might lead to important new insights and applications. He was adamant, however. At best, he would give me a few more days to make up my mind.

I left the room dejectedly and went to check my mail in the office. There was a letter of acceptance from a journal. I rushed back to Indiresan's office and showed him the letter. From his looks I knew that I had gained my freedom.

In the summer of 1969, John Hancock, the head of the electrical engineering department at Purdue

University, visited our department for a few days. During this visit he happened to attend a seminar given by Avinash, who is a naturally gifted teacher. Hancock was so impressed that he offered him a faculty appointment on the spot. Avinash had not yet completed his Ph.D. dissertation. So he doubled down and completed the writing in the next couple of months and the dissertation was dispatched to the three examiners: one foreign, in the US, another in India from another university, with the third being the supervisor, Professor Indiresan.

In the next two months time Avinash got married in Jammu to his Kashmiri girlfriend in IIT Delhi who was doing her Ph.D. in humanities. Now that the family was getting together for this ceremony, the *yajnopavit* ceremony for us brothers was also done before the wedding.

Although he was supposed to begin his teaching in the January semester at Purdue, IIT received the examination reports only in February. Fortunately, Purdue agreed to wait for his arrival. The formal defense was hurriedly arranged and Avinash and his wife were able to fly out to the United States on 17th February.

These were tough days for India. There were horrible heat waves and prolonged drought in 1967, 1968, and 1969. Food shortages were felt even in the dining halls of IIT Delhi. While India was helped by U.S. wheat under the Food for Peace program (PL-480), this program that had gone on for several years had, strangely enough, exacerbated the agriculture productivity problem by allowing the governments to postpone essential agricultural reforms, fail to give agricultural investment sufficient priority, and maintain a pricing system which gave farmers an inadequate incentive to increase production. The PL-480 program was good to sell the surplus production of the American farmers and it alleviated world hunger, but by disrupting market forces it had serious unintended consequences.

I do remember how during the worst days of the drought each chapati served to us at the IIT dining hall had dozens of bugs in them. We would pluck the bugs off the surface before eating the chapati.

I finished my Ph.D. in December 1970. Its title was "Studies in Signal Theory." In it I gathered solutions to the various problems of information theory I had solved. The work was not revolutionary, but it had four significant results. First, was the discovery of the discrete version of the Hilbert transform [1]; second, was a sampling theorem for Walsh-Hadamard analysis which extended the standard sampling theorem that was at the basis of discrete signal theory [2]; third, was a proposal that Walsh-Hadamard transforms be used to measure randomness [3], which was later generalized by others who proposed various other transforms for this purpose; and fourth, I suggested how one could do better than the sampling theorem rate under certain constraints that were quite common [4].

These results had applications to the emerging field of digital communications. The main problem was how best to take a continuous waveform such as speech or an image and sample it at regular intervals and represent these samples in terms of binary bits and do so while degrading the signal as little as possible.

Just a couple of weeks after I submitted my dissertation, IIT Delhi offered me lecturer's position in the Department. I began teaching courses in communications theory.

I was not much older than the undergraduates I taught and younger than many of my students in the postgraduate courses. I had to spend much time preparing for the lectures because I had not formally studied this material in the classroom. I taught a whole variety of courses in the communications area and this cut down on the time I had available for research.

I don't think I was as good an instructor as my brother Avinash, but as I was friendly and approachable, my students quite liked me. Soon after I joined teaching faculty at IIT Delhi, Professor P.S. Satsangi returned after spending a few years in Canada doing his Ph.D. He was one of the most dedicated professors in the department and he did his best to spread systems thinking at IIT Delhi and in the country.

Since my Ph.D. dissertation was on problems on which not much remained to be done, I was looking to work on something significant on the problem of information, but I realized that going beyond what I had done required grounding either in physics or biology. In IIT, we worked in isolation. This was unlike

the West, where directions and priorities in research are determined either by funding agencies, by informal exchanges amongst researchers at conferences and meetings, and by collaboration with scholars who bring complementing strengths to the partnership. There was no one I knew in IIT, or elsewhere in Delhi, who was interested in deeper questions related to information, either as philosopher, physicist, biologist, or psychologist.

For most people, research done in IIT, or elsewhere in India, was essentially derivative in which one read journals and looked for things where additional work could be done. Often the research in the journals was already two or three years old and what one took up to work on was stale.

New insights are not a product of bureaucratic diktat but rather of debate and challenge. That was non-existent in the top-down system of science that India created after independence. Although publishing papers and doing original research was praised, only a small minority of faculty were actively doing research. But if intellectual laziness was a problem characterizing many faculty members, it was the lack of a point of view about science, their role in society, and the nature of reality that was more troubling.

Apart from my own technical research, I spent much time reading up on different scientific subjects including fundamental physics. I was also looking at how the idea of information could be applied to physics. One idea was that if quantum mechanics is associated with a fundamental uncertainty, which could be called a kind of a veiling, then perhaps this uncertainty is counterbalanced by new quantum attributes [5].

The idea of information in physics is not a straightforward one. Normally, information involves two parties—let's call them A, the sender, and B, the receiver. Both A and B know what the alphabet is, as in the case of transmission of text. Before the receipt of a letter in a sequence, there is an expectation related to the probability of each letter in the language in which the communication is being carried out. The expected probabilities of the letters of the English alphabet may be calculated by counting their frequencies in a large text. Receipt of a letter with a lower probability communicates higher information.

The same idea can, in principle, be used in speaking of conversation between two individuals. It is essential to assume that they are using the same language and that they are not talking past each other. One can assume that information concerns ideas chosen out of a large set. In practice, it is not convenient to compute information here because there is no reliable way to determine what the set of ideas is within the individuals' minds.

But what kind of a game can we suppose when we speak of information associated with an object? Is it a game between Nature and the human observer? If we speak of choice between different alternatives in communication of text as denoting a certain measure of information, is the number of possibilities in which a physical object can be constructed a measure of its information? This is a theme to which I was to return again later.

Within a few months of this period I started having problem focusing my eyes. It was a strange ailment: each of my eyes had perfect vision but looking at anything caused great eye strain. I went to the best eye doctors in the All India Institute of Medical Sciences and they did not know what to do. Thinking that perhaps my eyesight problem was a consequence of muscle fatigue, I was advised eye exercises.

Meanwhile, IIT Delhi had a young post-doc visitor from France named Olivier Pironneau whose interest in coming to India was Sri Aurobindo and fellowship at Auroville. He told me how the way he did his meditation was by just tracking his thoughts until his mind became quiet, a method that is called *vipashyanâ* (looking away) in Sanskrit. This brought back to my mind the conversations I used to have with my father on meditation when I was a boy, and I decided to meditate and see if that would help me with my eye problem.

For a week, I did not sleep. I took the idea of tracking my thoughts and followed that up with that of concentration on the chakras of yoga up the spine. I was able to generate energy from down the spine, build it up, raise it to the top of the head, and then fire it way down back to the body. This was sequential *mûla bandha* followed by *jâlandhara bandha*, or in other words I was exchanging energy between *mûlâdhâra* and *sahasrâra* chakras. The yogic practice

was exciting and I was literally doing it the entire nights for a week without a wink of sleep until I was exhausted. At the end of it, apart from other insights, I discovered that my eyes were fine and, in fact, I did not use glasses for reading until I turned sixty!

I had become a popular advisor to the senior students doing their research projects. One of these students was Rakesh Kaul, who told me about his maternal grandfather, the famed yogi Gopi Krishna. Gopi Krishna was born in 1903 and I had heard of him first in 1967 when the Kashmir Pandits were agitating in Srinagar for political rights. His autobiography, *Kundalini: The Evolutionary Energy in Man*, became widely popular. His ideas were embraced by many Western scientists because he held out the possibility of scientific tests to check transformation in intelligence by means of meditation.

I got to meet him and he very kindly gave me a set of his books. I also visited him in his Srinagar home during summer vacations. I saw him on another occasion in Delhi when a planeload of his disciples had arrived from the West and he had called a meeting to welcome them to India.

Having read Gopi Krishna and armed with my own experience of meditation, I was saddened to determine that there was no systematic study of this phenomenon, so deeply a part of Indian cultural experience, in the academia. Indian professors knew little of the Western tradition of philosophy of science and even less of India's own scientific tradition. I didn't come across one who could read the Indian scientific texts in original Sanskrit or who had an idea of their contents.

Mahesh Yogi had brought meditation into popular imagination and I heard him once when he, together with many of his Western followers, came to IIT Delhi and gave a talk in the jam-packed sports hall. But he was speaking more of how meditation could help people be more effective, which is perhaps why it was picked up so quickly in the West. I thought this emphasis had placed in the background the deeper implications of the cosmology at the basis of meditation.

Gopi Krishna, on the other hand, spoke of his counter-intuitive experiences. This was going much further beyond yoga as therapeutic and it had the promise in it of taking one to the very heart of consciousness with the possibility that it was different from what any scientist had imagined.

The obverse side of my preoccupation with the nature of reality was the meaning of words and of narrative. I had been writing for over a decade and had published in several literary magazines, so I thought it was a good time to bring out a small collection of verse. I sent a collection of twenty poems to Purushottama Lal, professor and publisher of Writers Workshop in Calcutta. He responded enthusiastically and my book, *The Conductor of the Dead and other poems*, appeared in 1974 [6].

Here're some verses from the principal poem of the book:

I am not what I look:
I am my ghost.

When I was dead
my soul was rejected
in heaven and hell
and finally driven
to the refuge of my bones.

We are beautiful for we die.
Once time had halted its flight
One moment was a thousand years
I was dust, O I was but one idea
how I longed to be again in flesh
for I haven't felt enough
not enough
and when my frozen body thawed
with the stirrings of life
it was ecstasy.

I was happy that the book received excellent reviews. In subsequent years I was to publish several additional volumes of poetry in English and Hindi (e.g. [7]-[11]).

Meanwhile, my sisters and younger brother arrived one by one at Jawaharlal Nehru University, next door to IIT. They joined different departments: economics, German, and linguistics.

JNU, established during Indira Gandhi's administration, was conceived as a new kind of a

research university in India that would focus on social sciences. It was to be small with a structure that encouraged interdisciplinary work. In its conception, it was different from the excessively bureaucratic Delhi University that had failed to keep up with the times. But JNU had to operate within the parameters set up by the University Grants Commission with its arcane rules, so it could not escape the larger culture that ailed Indian higher education.

My sister Shakti was drawn to the Marxists and she became active in student politics. Consequently, in my frequent visits to the campus, I got to know students who were to later become prominent in the CPM (Communist Party Marxist), the main Indian communist party that has dominated politics in West Bengal and Kerala for decades. I also attended many meetings where the speakers spoke in the jargon of the communists where sentences were strewn with words such as oppression, imperialism, revolution, and so on. Many students were Trotskyite. The student politics of Oxford and Cambridge of the 70s had arrived in Delhi.

In 1974, IIT decided to host the first ever National Systems Conference which would be a place where electrical engineers, systems engineers, applied mathematicians and computer scientists would present their research on an annual basis. The Institute selected me to be the convener of the conference which meant that I had to organize it.

We had a successful conference in which delegates from all over India and some from the United States participated. At a special session which was convened by me, it was also decided to create a national systems society.

Organizing this conference gave me firsthand knowledge of how bureaucracy worked. Although I had saved the receipts for minor expenses such as tea and coffee breaks, I was not able to get the accounts officers at IIT to reimburse to me the costs. Each time the file would be sent to the accounts office, trivial objections were noted by the office and the file would be returned. The file had not been processed for nearly three years when I gave up on it.

My housing situation at IIT was not satisfactory. One of the perks of being a professor at IIT was that one was assigned an apartment at a very nominal rent. But the Director of IIT would not approve one for me for he argued I did not need one as I was a bachelor. Instead, I was assigned a room in the Faculty Guest House, where I was obliged to eat at the Guest House dining facility.

The physicist George Sudarshan was visiting IIT Delhi in late summer 1976 and knowing of his interest in Vedanta, I called to see if we could meet. He was gracious and in fact he took me along when he went to Delhi University to give a talk on his work.

Sudarshan was very famous in India for his work on electroweak theory, which was at the basis of the later synthesis of the standard model, and also on tachyons and quantum optics. He was unlucky not to win the Nobel Prize and this may have happened because he was too proud to do academic politics. Unlike most Indian physicists, Sudarshan could quote from Vedantic texts to make his points. This was a refreshing change from what we were used to in meeting Indian scientists.

The early seventies saw agitation by students and employees at IIT. The instigator was a brilliant young Harvard Ph.D. Subramanian Swamy who began as a visiting professor of economics. He was an ambitious man, who openly claimed to aspire to the prime minister's position in India before he turned fifty. He positioned himself as a China expert and he urged for India to build its own nuclear weapons.

Swamy was hobnobbing with politicians and the Governing Body decided not to honour his contract. In retaliation, he organized students, employees, and faculty against the Director. He was dismissed but he went to the courts and eventually many years later, when he was Minister of Law in Government of India, he was to receive back pay and compensation for wrongful dismissal. I kept away from this politics because it wasn't clear what the larger objective of these people was.

In 1975, I received a British Council Fellowship to spend several months in London at Imperial College. As I was finalizing my plans, I was offered a summer appointment of 1976 by N.S. Jayant, a young researcher at Bell Labs in Murray Hill in the United States whom I had met in Delhi when he had come to give a talk.

Arriving in London, I was struck by the difference in material progress and organization between India and Britain. The British Council office impressed me. The staffers were efficient and friendly.

It was cold in London when I arrived. After a couple of nights in a hotel, I was given a room in Linstead Hall, a dorm where students and visiting faculty stayed. Apart from me the other academic visitor in the electrical engineering department was Peter Elias from MIT and he and I had occasion to discuss technical matters during the course of our stay. My host was the electrical engineering professor Colin Cherry, but we did not get to interact with each other as my ideas had gone beyond classical communications theory in which he specialized and on which he had written a very fine book called *On Human Communication.*

Since there was nothing specific in Colin Cherry's group that interested me, I spent most of time in the library. The Imperial College library was better than anything I had seen before. I wasn't just reading physics and information theory in the library, but all kinds of books.

I explored the city and took long walks in Hyde Park. I also visited electrical engineering departments in Manchester, Cardiff, and Edinburgh. In Spring, I went on a bus tour of Netherlands, Belgium, and France. I saw many places at West End including Agatha Christie's *The Mousetrap, Oh! Calcutta!,* and musical performances at the Royal Albert Hall.

I was keen to explore ideas on the use of symmetries to characterize information in an elementary particle. I made a simple calculation to measure the equivalent information in the fundamental uncertainty of quantum mechanics and I sent the paper to Abdus Salam for his comments. He was encouraging and I published the paper. Later I discussed my idea with the physicist David Bohm, who was famous for his hidden variable approach to quantum mechanics. Bohm had been sympathetic to the communists during his younger days and when the McCarthy witch hunt against the communists began in the US in the fifties, he lost his job. Eventually, he became professor at Birbeck College in London. Bohm was not sure whether my ideas were useful.

This was not the only subject that interested me then, and I was making progress in arriving at a philosophical basis for my larger work.

I had written to Salam and now I came to know him a bit more during this visit. He was much in the news, as the popular scientific media in Britain built up his case for the Nobel Prize. He commuted between London and Trieste in Italy where he had founded the institute for theoretical physics.

Those were exciting days for physicists. They thought a unified theory was round the corner. The talk of a Theory of Everything was in the air, and Salam was one of the high priests of this revolution. He had made quick progress in his field. Born in 1926 in Jhang in the Punjab, he got his Ph.D. from Cambridge when he was twenty-six, becoming a full professor at Imperial College in 1957.

His wish as a college student had been to join the Indian Civil Service, but the war made that impossible. So he went to England for higher studies. After Partition he returned to teach in Lahore but he found that experience stifling. He was torn between his love for physics and his country. He did his best to serve both as well as he could, and for several years he was a science advisor to the Pakistani government.

It was to repay his love for his country that he persuaded UNESCO and IAEA to establish in 1964 the theoretical physics research institute in Trieste, where researchers from poor countries like Pakistan could interact with other scientists. He was its founding director and continued in that capacity until 1993 when a severe neurological disease forced him to resign. He died three years later.

Salam's work was based on an imaginative synthesis of mathematical structures. In this style he followed his mentor Paul Dirac. But he was also interested in mysticism and he took his religion very seriously.

He was intrigued by ancient Indian ideas. In one conversation with me, he brought up the question of the age of the universe given in the Puranas. He wanted to understand, if at all that was possible, how the present cycle in Puranic cosmology is about the same number as the current estimate of the time of the Big Bang.

As a relatively recent graduate of the Indian Macaulayite education system, I knew next to nothing about Indian science, so I couldn't help him. But after all these years I wonder sometimes if my later work on Indian astronomy was a response to Salam's questioning.

The remarkable part of Salam's personality was that he was able to bring opposites together in his mind. But he must have done this at high cost. He lived in two worlds and he wished to be faithful to both. He had simultaneous loyalties to Pakistan and his physics; to the traditions of his Rajput ancestry and his religion; and to his two wives, one Punjabi and the other English.

The proof of his dual loyalties is clear from his insistence that both his wives attend his Nobel award ceremony. This caused a diplomatic crisis for the hosts; the wives were ultimately seated in different places.

In his philosophy he tried to be loyal to physics where laws don't change with time and the faith his Rajput forbears had adopted several centuries ago, where the prophet represents a unique break in time.

He may have felt his Ahmadi Muslim sect, which believes that prophets are sent by God time after time and their own Ghulam Ahmad (1839-1908) was such a person, was less in conflict with the ethos of physics than the orthodox interpretation of Islam, in which Muhammad's prophethood being the last is a pillar of the faith.

The Ahmadis (or the Ahmadiyya) believe that their founder, Mirza Ghulam Ahmad was a prophet as well as the promised messiah and *mahdi* of Islam.

As Salam's star in the world of physics rose, his sect came under increasing attack by the orthodoxy in Pakistan. The Ahmadis were declared non-Muslim by the Pakistani government in 1974.

He went around and used his prestige and power for the sake of science in the Islamic world. But his enemies were nipping at his heels, and when he went to Pakistan after he had been awarded the Nobel Prize, he was disallowed from entering the premises of any university.

In 1976, I spent the summer working at Bell Laboratories in Murray Hill. The trip did not have auspicious beginning as one engine on our British Airways flight caught fire soon after we took off from London. The stricken plane was able to fly back to Heathrow and as we landed and were met with screaming fire engines, the emergency doors opened and we slid down the escape chutes.

Bell Labs at Murray Hill was then the world's premier place for research in communications and information. I was in the group that worked on creating new digital technologies for speech and pictures. The world's most famous names in this area were part of the group and the work on signal processing that they did is the basis of technology that has changed the world.

The group was headed by Jim Flanagan. Other prominent members included Bishnu Atal, Man Mohan Sondhi, Larry Rabiner, Ron Schafer, and my host N.S. Jayant, a brilliant engineer from Bangalore who was on the permanent staff of Bell Labs. My task was to develop a technique for scrambling of speech that could be used on telephones. This work was eventually granted a patent [12].

The work done by the Bell Lab researchers was to contribute in fundamental way in facilitating the digital revolution that was to come later. Their contributions included techniques of efficient digital representation of speech and pictures so that they can be sent quickly over wirelines or wireless that has made many of the key applications of the Web possible.

I returned to India via London where I stayed for several days at the YMCA to complete the formalities associated with my fellowship. Compared to New York with its skyscrapers and giant bridges, London with its traditional buildings and corner pubs felt like a village. My flight back to India was via Geneva and Cairo.

When I returned to India, the difference in the scientific cultures at Bell Laboratories and IIT Delhi hit me hard. Although IIT had outstanding students, one couldn't say the same about its faculty. I found little passion for truth with most professors spending their days in idle conversation in long tea and lunch breaks. As I became more frustrated with the academic

culture of the place, I decided to explore opportunities elsewhere.

Meanwhile, I was offered a one-year visiting appointment (called the Kranzberg Chair) by Technion in Israel. Technion was also paying for my return ticket from Delhi to Tel Aviv. I requested leave from my department but I was turned down because I had not been back for three years from my previous leave.

Later that year I heard that I had been selected to receive the Indian National Science Academy Medal for Young Scientists for my work in electrical engineering and information theory. The medal came together with another cash prize called the Kothari Award. I was to be given this medal and the cash prize by the Prime Minister of India, Morarji Desai, during the course of the Indian Science Congress that was to be held in Ahmedabad, Gujarat, in January 1978.

I had a winter appointment at Tata Institute of Fundamental Research (TIFR) in Mumbai in December 1977. It was decided I would leave for Ahmedabad at the conclusion of the Mumbai appointment.

At TIFR, I worked in the computer science department that was headed by Rangaswamy Narasimhan. His best work was on pattern recognition on which he had worked with Azriel Rosenfeld of University of Maryland. It was interesting that Avinash also worked on pattern recognition and he was to coauthor with Rosenfeld a famous book on it called Digital Picture Processing.

The next day, I was at the festivities of the Indian Science Congress. I was awarded my medal by the Prime Minister and the Rs 5,000 check. Meanwhile, I had run out of money and there was no place there to cash my check. Fortunately, that night a Kashmiri girl student of Gujarat University invited me to her home for dinner. The next morning I caught the train to Delhi. But I had no money to eat anything that day. I reached Delhi in the evening famished and exhausted.

In late 1977 I was introduced to Naumi (Navnidhi) Saklani, who was teaching psychology in Kamala Nehru College of Delhi University. She had finished her clinical work in psychology in Bangalore and was doing her Ph.D. under the supervision of the noted psychoanalyst Sudhir Kakar. It was ironic that Naumi should marry me because I thought Kakar's understanding of India only scratched the surface even though his book The Inner World, in which he explored Indian childhood and society, had received favorable reviews.

Naumi was a Garhwali from Dehra Dun in the Uttar Pradesh. Her sisters lived in Delhi and her parents were then in Jakarta, Indonesia. Our marriage was held in Delhi on 21st January 1979. It was a bitterly cold night. We went for our honeymoon to Udaipur where we stayed at the marvelous Lake Palace Hotel. We also went sightseeing to Ranakpur and Rang ji temple complexes. During the summer we went to Kashmir.

Naumi was keen that we live for some time in America and as I had become disillusioned with academic and intellectual life at IIT Delhi, I made inquiries and received several offers. Of these I chose visiting associate professorship at Louisiana State University in Baton Rouge which was changed to a regular professorial position the following year.

I was impressed with many aspects of the organization of American universities. The administration has considerable autonomy as have professors in their work.

Section III
(Academic career in the United States)

I arrived in Baton Rouge, Louisiana via New York. The City of Baton Rouge was less than 200,000 people with more than half its population of African ancestry. It looked like a sleepy town and when I reached in early August it was extremely humid and hot.

Louisiana State University at Baton Rouge is the main university of the State of Louisiana. Its campus is on the edge of the old, depressed part of the city, and not quite far from the great bridge over the Mississippi. It is an attractive campus with mostly two or three story buildings with tiled roofs and gardens with old oak trees.

The head of my department was Lon (William Alonzo) Porter who had moved here two years earlier from the University of Michigan. He was short, bald and reserved. But he seemed to take a liking to me

and he made things as comfortable for me as could have been expected.

After a couple of nights in a hotel within walking distance of the campus, I rented a furnished apartment on the university bus route so that I could walk to work if I missed the bus. I came to find that buying a car was easy and the money for it could be obtained on loan from the university credit union. In a week, I bought an old dark blue Volkswagen Beatle for $750 and soon I was comfortable driving it around town.

Naumi joined me in October. Our plan was that we would return to IIT Delhi in one year. But since there was a good chance that IIT would extend my leave, I decided to write to a couple of other places for next year's appointment. By February 1980, LSU gave me a regular tenure track appointment with a review in two more years for the position of full professor and IIT decided that my leave will not be extended. In the meanwhile I was invited by North Carolina State University in Raleigh for interview. As soon as I was back, they made me an offer as well. But since I was on a temporary exchange visitor visa, they called my position visiting associate professor.

I was impressed with the Research Triangle Park next to Raleigh and the fact that it was close to Durham and Chapel Hill which had great universities. North Carolina was much more prosperous than Louisiana and North Carolina State electrical engineering department was superior to LSU's. I wrote to NC State and accepted the offer. But later I had second thoughts particularly because of the "visiting" in the title. In a couple of weeks I asked to be released from my acceptance and LSU was very happy that I was staying. Shortly thereafter University of Colorado at Boulder also sent in an offer but it was too late.

Lon Porter was helpful in the paperwork for me obtain the "green card" to stay indefinitely in the United States. I decided not to use a lawyer which I think was responsible for the delay in the arrival of the green card. LSU granted me tenure in 1982, even before my green card had been approved. The following year I was named full professor.

The culture of the American university is different from its Indian counterpart. The administration has considerable autonomy as have professors in their work. The American idea of checks and balances works to a degree even at the academic department.

Although American universities are the best in the world, they suffer from their own malaise. In the sciences, professors spend most of their time chasing grants, and running from one fashionable area to another. In the arts, the faculty is divided into bitter ideological camps.

I was taken aback by how bad students were at mathematics even in the engineering program. When our own children, Abhinav and Arushi, went through the school system, we realized that part of the problem was the American school. The science curricula are bad for they emphasize breadth of material over depth of understanding. The teacher salaries are relatively low and teacher union rules bar potentially excellent science and engineering graduates from teaching if they don't possess an additional education degree. The general cultural climate in the United States values sensory gratification much higher than ideals related to knowledge.

At this point I was working in cryptology in the creation of new cryptosystems that would make it possible to do secure business transactions and electronic signing of documents [13]. I also did some number theoretic work on random sequences [14]. I was trying to find some common themes that underlie physics and mathematics. My introduction to cryptography had taken place in Bell Labs in 1976, where I invented a new way of scrambling speech so that telephones could be used in a secure manner. This was the time that revolutionary new ideas of cryptography were being introduced so as to make it possible to authenticate computer communications and do digital signatures. I made contributions to the field, in particular the idea of secure hardware public key cryptography.

My broad interests pushed me into different directions. One of the areas I was looking at was machine translation in which there is need for efficient representations of grammars. I remembered that when I was a boy my father used to talk about the 2,500 year old marvelous Sanskrit grammar by Panini that was like a computer program [15]. This got me interested in examining this grammar and also investigating other scientific contributions of ancient Indians.

I was impressed by what the ancient Indians had done, but surprised at the poor quality of histories of Indian science. I examined various layers of ancient Indian literature, going backward from the Sutras to the Upanishads, Aranyakas, Brahmanas and the Vedic texts, and found that most writers were merely repeating erroneous claims of previous generation of colonial scholars and had not examined the texts themselves. I began writing a series of articles on history of early Indian science for scholarly journals. This included new findings in ancient astronomy and analysis of Vedic ritual and art.

Meanwhile I was studying random sequences that play an important role in communications and computing. I had realized that not much attention had been given to decimal sequences, which are obtained when one number is divided by another in long division. For example, when 1 is divided by 7, we get the decimal sequence 0.142857, where the six digits after the decimal point repeat.

Mathematicians knew the basic properties of these sequences, such as across half the length of the pattern of digits, the individual numbers add up to 9, as in 1+8, 4+5, and 2+7. If 1 is divided by a prime number, the period of the decimal sequence can be as large as the prime minus 1. Similar property holds if the division is carried out to the base 2, so that the expansion is entirely as a sequence of 0s and 1s. I derived more advanced properties of decimal sequences and showed how these sequences, when generalized, could be used for error-correction coding and cryptography.

In 1992, I made three important scientific contributions. First, was the invention of a new neural network architecture that could be trained instantaneously [16]; second, was the demonstration that in a feedback neural network one could obtain specific stored memories starting with the activation of a single neuron [17]; and third, I discovered a long-lost astronomy of the Rigveda [18]. The first two of these contributions had implications for models of learning and recall for brain and in computing machines that mimic the way the brain does, and they could explain short-term learning and recall of a song from just a few notes as well as how neurosurgeons find that specific memories are recalled when single neurons are stimulated. The Rigvedic astronomy discovery has great implications for our understanding of earliest India. It has been called "revolutionary" and "epoch-making" by scholars and it has had considerable influence on archaeoastronomy and the understanding of the rise of science in the ancient world. This work also confirmed my early finding that on probabilistic grounds the Indus script is the originator of the later Brahmi script.

Very soon I was being invited from universities and other organizations from around the world to give lectures on science, Vedanta, and history and so I was traveling quite a bit. I did a book on Rigvedic astronomy [19] and also another one on the rise of early civilizations [20]. I was asked to write on science for the general public and my work was shown in the popular media including Discovery and History channels, PBS, Dutch Public TV and other radio and TV stations. I wrote on the philosophy of mind and showed how recursion plays a fundamental role in art, music and aesthetics.

I was the first to look for information metric for a quantum state in the seventies. I now considered the application of quantum theory to neuroscience. Given new evidence from neuroscience as well as system theory, I argued that brain function is associated with three kinds of language: associative, reorganizational, and quantum [21]. This pointed to limitations in reductionist approaches to brain function.

Of my work in quantum theory, the most useful one from an engineering point of view is my all-quantum protocol for public-key cryptography [22] which I published in 2006. It could become the standard for key distribution for sensitive computer network applications of banking and defense.

A few years ago I argued that the measure of entropy for quantum systems on which most of modern physics is based has serious shortcoming when viewed from the perspective of information. To overcome these shortcomings, I proposed a new measure for it [23]. This work as well as my proposed resolution of the twin paradox of relativity theory [24] received considerable attention in the popular press in 2007. Soon afterwards, I moved to a professorship of computer science at Oklahoma State University in Stillwater.

Looking back at the science of the past forty years, it is clear that there remain fundamental limitations in our understanding of the universe. According to cosmology, only four percent of the universe is visible and the remainder is dark energy and dark matter. The promise of a unified theory of physics has not been fulfilled and quantum theory and gravitation remain unreconciled. And quantum theory itself, with its collapse of the wave function when observation is made, presents enduring paradoxes [25].

Science is unable to explain why life comes with freedom and intentionality when the inanimate world is governed by physical law. We don't know why the computer has no awareness while the brain-machine does, and we don't understand how the mind works. For the scientist there are exciting questions to find answers: Is there a hidden order in physical reality that transcends the capacity of rational understanding? And does this hidden order have the answer to the mystery of consciousness? My current work hopes to address these questions.

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