

The Vinod Wadhawan Blog

Celebrating the Spirit of Science and the Scientific Method

Home

Monday, May 30, 2016

DOING SCIENCE IN INDIA. A PERSONAL NARRATIVE (Part 1 of 3)

Thank you, Internet, for enabling me to survive and prosper as a scientist in India, and for enabling me to accomplish the task of science popularization and promotion of scientific temper in society.

As the cynic said, 'science is what the scientists do'. Since our science is entirely what certain humans have been doing, there is clearly a human angle to it. But the great thing about this noblest of all professions is that scientists have agreed to study natural phenomena by strictly following the rigours and the discipline of what I have called elsewhere *the 8-fold way of the scientific method* (Wadhawan 2014a).

I am 100% a product of the Department of Atomic Energy (DAE), Government of India (GOI). I am very grateful for what the DAE has given me. I want to make special mention here of Dr. Srikumar Banerjee and Dr. Anil Kakodkar, who were particularly helpful in the advancement of my scientific career. Dr. Banerjee's role, in particular, has been so steady and substantial that he finds a mention in the acknowledgement section of practically all my books (Wadhawan 2000, 2007, 2010, 2011/2014).

Who has been my mentor? Undoubtedly Mike Glazer (Prof. A. M. Glazer, University of Oxford, UK). Irrespective of the good things done for me at the early stages of my career by some bosses, the most steady well-wisher and mentor I can name is Mike Glazer. Thank you Mike, for being what you are.

If I have to name my role model as a scientist, it *has* to be the late Bob Newnham (Prof. R. E. Newnham of the Pennsylvania State University, USA), but more on that later.

Who is the greatest Indian of recent times? I must name two: Dr. Abdul Kalam and PM Narendra Modi.

Dr. Avul Pakir Jainulabdeen Abdul Kalam, a great nationalist, died recently. My idea of a nationalist Indian has nothing to do with that person's religious beliefs (or their absence). I cannot say 'RIP' for him because I believe that nothing is left of a person after death, except the consequences of his/her thoughts and actions. Dr. Kalam left behind a lot we Indians can be truly proud of.

The name 'Mahatma Gandhi' is familiar all over the world, even among those who do not understand what the word 'Mahatma' means. When Kalam died, this is what I wrote on my Facebook page (on 30th July 2015): 'Abdul Kalam, the real 'Mahatma' '. I hope the epithet 'Mahatma Kalam' catches on.

The other great Indian of recent times is our PM, Narendra Modi, the bad-mouthing by some of the most important idiots of India notwithstanding. I shall remain eternally grateful to the venerable Mr. Mani Shankar Iyer for his famous *chaiwala* (tea-seller) remark about Modiji. In fact, one should be grateful to some other worthies also for similar reasons.

In the Indian conditions one has to make a distinction between a *senior* scientist, an *important* scientist, an *eminent* scientist, a *great* scientist, and a *successful* scientist; of course, sometimes the same person can be two or more of these. It is always a good idea to choose one's words carefully and precisely.

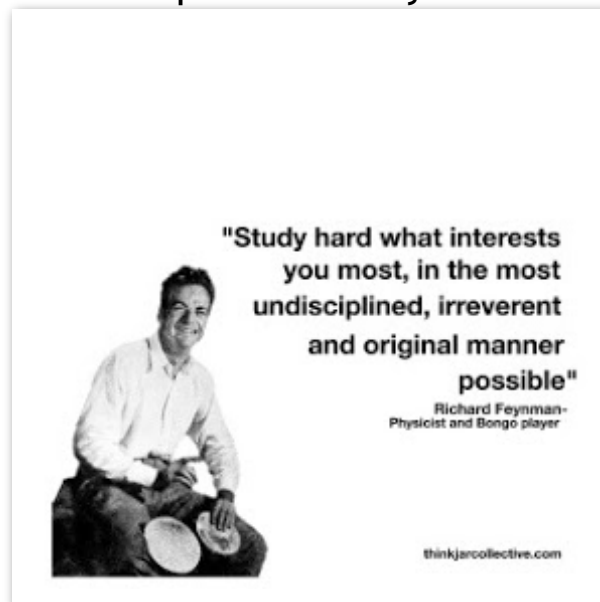
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1. THE EVOLUTION OF MY LANGUAGE SKILLS

A scientist conducts research for understanding natural phenomena, and then he publishes the findings. The drafting of the research paper calls for a high level of discipline and mastery in the use of the language, mostly English. Moreover, one should not only be able to write well, but also speak the language well for explaining the significance of the work at conferences etc. I started my academic life with a serious handicap on these matters.

The ethos at my home was 100% Punjabi. We spoke in Punjabi. There is something about speaking a language which gets into your system. The twist of phrase, the idioms and phrases, the choice of words, all have a cultural history which affects your thinking and self-image. Even today I am happiest speaking in Punjabi.

I got my education in an ordinary government school, in which the medium of instruction was not English. After school I joined the B. Sc. (Physics Honours) course of the University of Delhi, along with a school friend of mine, Tejbir Singh Jaggi. He and I felt lost and forlorn in this new scenario in which most other students spoke English fluently and confidently. An interesting incident comes to mind here.

In the practicals class for physics, each of us had a partner for conducting experiments. I and Tejbir were one such pair. Our teacher was one Dr. Mela Ram Wadhawan. On the first day we found that he was surrounded by

students, taking instructions from him and asking questions. We felt timid, not knowing how to converse with him in English in front of everybody. So we went to a corner and constructed sentences, correcting each other as we proceeded, and did some rehearsal on what we were going to ask the teacher about the experiment assigned to us!

I took this incident seriously, and decided to do something about my English. I found Bertrand Russell's writing skills very fascinating. His mathematical habits showed up even in sentence construction. His utmost regard for logic in whatever he wrote was very educative for me. I tried to emulate him. I also enjoyed the raw power of Jack London's stories, as also the brisk narrative of Sherlock Holmes stories.

In due course I have also inculcated the habit of avoiding logical fallacies in whatever I speak or write. I try to make sure that no complete sentence of mine can be misquoted out of context.

So much for written English. What about spoken English? I had a terrible start. In mid-1979 I landed in London, on my way to Oxford to work with Mike Glazer as a Nuffield Foundation Travelling Fellow. At the airport I was received by an official from the Nuffield Foundation who, among other things, handed over a cheque to me for the initial expenses. I was telling this gentleman that Mike was based at the Clarendon Laboratory, and that he also taught at the St. Jesus College. He could not help smiling because the way I pronounced the word 'Jesus' did not make any sense to him (or so he pretended)! Those were the days. I decided that I would use my stay at Oxford for improving my spoken English as well. This came easy. I have a rather keen sense of observation, particularly about how people speak. Watching the English people speaking their mother tongue (particularly on BBC Radio) was very instructive, and I was a quick learner.

Encouragement followed soon after, though not for spoken English. Mike and I decided to co-author a book (though the idea was dropped later). I did some sample drafting and showed it to him. He was very impressed, and said: 'Vinod, I wish my countrymen could write English like you do' (cf. Glazer & Roleder 2010). This was indeed a far cry from my school days.

I have also tried to learn Russian, French, and Italian, but not with much success. One good thing that has happened though is that I can recognize words in English which have been borrowed from these languages.

2. THE PUNJABIS

I am an Indian from Punjab, and that has a lot to do with my conduct and worldview.

Punjab has been known by several other names in the distant past: Sapta Sindhva; Hafta Hindva; Pentopotamia; *Madra Desh* (named after Madri, mother of the Pandvas in the epic Mahabharat) (Gupta & Gupta 1999). Going back in time, although Indologists continue to differ on the age of the Indian civilization, there is agreement that it is among the oldest in the world, and that Punjab was its cradle. Excavations at Harappa and Mohenjo-Daro indicated that the Indus Valley Civilization flourished around 3000 BC [recent studies have shown that the Indus era is ~8000 years old]. It seems to have embraced the whole of Sindh and Punjab, as also large parts of Kathiawar, the valleys of the North-West Frontier Province, and some parts of the Gangotri basin.

The Vedic Civilization emerged in this era. It is associated by some with the coming of the tall and fair Aryans, although nobody can say for sure where they came from (if at all they came from outside; the current thinking is that there was simply a migration of the indigenous people eastwards due to a prolonged weakening and failure of monsoon). The Aryans lived in tribes, spoke Sanskrit, and worshipped Nature in all its manifestations. Vedic Hinduism evolved in Punjab. Many of the great works of Sanskrit literature were written here.

The Rigveda is the most important among the four Vedas. It is the oldest literature of mankind, and thus contains the earliest recorded human thought. It is the fountainhead of practically all the basic concepts developed in India, and in a way (because of its antiquity), throughout the world.

Punjab is mostly fertile plains which, along with its invigorating climate and a hardy populace, have been the source of its wealth. The wealth invited a string of foreign invasions, mainly through the Khyber Pass. There came the Persians, the Greeks, the Bactrians, the Scythian tribes, the Mongoloid Huns, and then the Muslims (Arabic, Pushto, Turkish, Afghan). Naturally, Punjab has seen a large amount of racial intermingling and assimilation. And, of course, wars. It is important to remember these facts when one tries to understand the Punjabi mind, particularly the never-say-die spirit and the sense of humour.

Culture flourishes in times of peace and prosperity. Punjab has had more than its share of prosperity. The rich cultural heritage of Punjab derives from its various social, political and religious movements, not to mention the antiquity

of its existence. Its foundations have been laid by Rishis and Gurus. Thousands of saints, scholars, and martyrs have given nourishment and character to the culture. Punjabis do well, and then they like to show off! Others are not amused by this, and the inferiority complex seeps through in their comments.

In a lighter vein, let us take a look at all the Nobel Laureates of Indian origin in science. All were Punjabis (well, almost!): Prof. Abdus Salam (particle physics); Prof. Hargovind Khorana (molecular genetics); and Prof. S. Chandrasekhar (astrophysics); the last-mentioned spent many of his formative years as a physicist at Lahore in Punjab! Prof. Salam hailed from the Jhang district of Punjab. Prof. Khorana, a Punjabi, migrated to the U.S. after he failed to land a decent job in India.

Punjabis, by and large, have a rather strong sense of humour. They are ever ready to laugh, not only at themselves, but also at others, and this creates problems for them; it surely did for me on several occasions. Here is a more recent example.

There was a gracious and popular lady scientist, several years senior to me. Both of us had 'retired' from service on superannuation, and I was doing a tenure at the BARC as a DAE Raja Ramanna Fellow (2005-2010). I was taking tea with some friends at the canteen when we saw this lady approaching us, a cup and saucer in one hand and a bag in the other. We gave her a welcoming smile, and somebody fetched a chair for her. Suddenly, the tea cup slipped from the saucer and fell on the floor, splashing the tea all around. We all tried to help her, but she was very embarrassed. 'Now that's what I call making a splash!', said I. I realized immediately that this was an inappropriate thing to say, particularly to a lady, the wittiness and the originality of the remark notwithstanding. But it was too late to retract, and I could only feel sorry for my behaviour.

Was this an instance of my Punjabi sense of humour, or was it indicative of a different kind of tendency? We all have the hunger to do or say something original, and being witty in the bargain is something too irresistible, particularly for scientists. Was this indiscretion symptomatic of that? I don't know.

3. MY SCHOOL DAYS

I was about two years old at the time of India's independence and partition of Punjab. We opted to come over to the Indian side of Punjab. So ours was a 'refugee' family. We had lost money, house, belongings, just about everything.

My father had to look for a job and start life all over again.

In due course we settled in West Delhi at Tilak Nagar, a 'refugee colony' started by the government for people like us. My father got a job at an ITI (Industrial Training Institute). The Social Welfare Department of the GOI had opened several such institutes for giving vocational training to people. We also took possession of a house nearby, one among the many the government was constructing for the refugees. The construction work was done in such a hurry that unbaked bricks had to be used, and there were no boundary walls. The roofs were made of wooden planks covered with bricks. No electricity. No water supply. No sewage pipes. No LPG of course.

Tilak Nagar, being a refugee colony, had to start from scratch for everything. There were agricultural fields all around, and facilities were built up one by one. The school I joined was one such.

My mother was a strong, hard-working lady, rather like the lady of the house in Khushwant Singh's novel '*I Shall Not Hear the Nightingale*'. She was also a no-nonsense person, quite aggressive of temperament. My father was of the tactful type, but also very strong-willed. He was very handsome, and in the pink of health.



[With my mother, sister, brother, and father.]

In spite of our poor financial condition, the greatest gift my father gave me was his unshakeable belief in my capabilities. I had no idea about the reasons behind that, but his high expectations, as also his own example of sheer grit and determination, spurred me to do my best to be a worthy son. My mother

also did her best to ensure that I got whatever they could afford, and more.

When I look back I find that, in spite of the fact that mine was an ordinary government school, the teaching was rather good. I have fond memories of our English teacher and the physics teacher, and also the Principal.

There is a bad memory also. Once our class, while waiting for the next teacher to arrive, was noisily discussing this and that. I was of the quiet type and used to sit in the front row. I was reading something, and was not talking to anybody. Our PT teacher, a burly Sikh, walked in and shouted at us about the noise the class was making. He also picked up two boys at random and gave them a big slap each. I was one of them. I was outraged because I was not making any noise at all. I stared at him and said 'what have I done'? I got a further boxing of ears for this act of defiance. Such punishment for standing up for justice, and for asserting my fiercely independent nature, is something I have got again and again in my career.

School days were fun. A classmate of mine (Sohan Singh) used to boast that he could break a glass pane with the force of his urine stream! He wanted to have a bet on that, but none of us thought much of this claim.

I took my studies seriously. Children from middle-class families like mine usually tend to excel in studies because they know that if they fail to do well, there is no family business, or a rich father, to fall back on for making life livable.

I passed the Higher Secondary examination in 1961. Ours was the first batch from the school to appear in the board examinations. Four boys got first division (more than 60% marks). I was one of them.

4. THE UNIVERSITY DAYS

Since I had scored more than 60% marks, I was able to get admission to the B. Sc. (Honours) course in the physics discipline of the University of Delhi (DU). My friend Tejbir, mentioned above, also got admission to the same course. Tilak Nagar is quite far from the DU campus, so we commuted by bus. At some stage the government started a 'University Special' bus service from Tilak Nagar, and this was of great help. This also meant that we saw the same boys and girls every morning at the bus stop and in the bus.

After doing his B.Sc., Tejbir went to Italy. He brought home an Italian wife, something very unusual those days for people of our background. He was reckless, and crafty too. His two brothers were in the army, and that meant

that they got booze at highly discounted prices. Tejbir used to tell us how he could easily steal whisky at home, and get away with it; the trick was to replace the whisky removed from the bottle by an equal amount of water! And the brothers would complain about the poor quality of whisky sold in the defence canteen!

A craze those days was to be able to impress the girls travelling in our University Special with good spoken English. Something funny happened one day. While we were waiting for our bus, a policeman sauntered in, cane in hand. He picked up an argument with us for no apparent reason, except perhaps that he too wanted to impress the girls with the authority of his position. For good measure, he decided to speak in English. But this turned out to be his undoing. At one stage he said, 'I have told you and I am telling you again . . . '. All of us burst out laughing, much to his embarrassment, although I am not sure whether he indeed understood why we were laughing.

In this incident the boy leading the arguments was, of course, Tejbir, and we had a tough time pulling him away from the law enforcer of the land. But Tejbir was like that, always of short temper, and not afraid of anybody when he knew that he was in the right. In one incident he even got physical with a policeman. I can well imagine how he must have reacted when a mob came baying for his life and that of other members of his Sikh family during the 1984 anti-Sikh pogrom supported and abetted by the Congress Party, following the assassination of Indira Gandhi. He was killed by the mob.

The teaching at the university was good. I learnt, rather early, from our Practicals-class teacher, Dr. Mela Ram, the importance of stating the numerical measure of any physical quantity to the correct number of significant digits, no less no more. One of our assigned experiments was to measure the value of the gravity constant. There were no calculators at our disposal, and we used the log tables which listed the numbers to four digits. Dr. Mela Ram asked me whether my measurement of the gravity constant was indeed that precise or accurate. When I kept quiet, he explained how to estimate errors and use this information for quoting the value of any measurement to the estimated degree of precision and/or accuracy.

One book I liked to read was Worsnop & Flint's *Advanced Practical Physics for Students*. I still remember how I enjoyed reading in it about the atomic mechanism of buoyancy.

Many teachers in our Physics Department taught almost the same course year after year. We also learnt from our seniors that even the jokes these teachers

told in the class were the same every year! One teacher used notes which were prepared, not by him, but by *his* teacher!

Apart from the main subject physics, we also had chemistry and mathematics as subsidiary subjects. We were taught organic chemistry by one Dr. T. R. Seshadry. At that time we had no idea how eminent a chemist this person was. But he did one thing which created a very poor impression on me about his level of intelligence. Some of us students were having a leisurely walk after lunch, gossiping busily about this and that. We did not notice that we had come near an exit door of the corridor and, completely unintentionally, blocked the passage for a couple of girls who wanted to go out of the building. We made way for them as soon as we noticed this. But the venerable Dr. Seshadry happened to have seen this, and took us to task for intentional harassment to girls. This was outrageous, but we poor students could do nothing to convince him that he was wrong.

On one occasion I got badly injured while returning home from the university. The DTC buses used to be very crowded in the evenings, and we often had to hang precariously from the bus entrance door, hoping that there would be some space in the bus later. I was hanging like this when the bus overtook a cart loaded with scrap iron, and I got seriously injured by the sharp and rusted iron stuff. My father decided that he would let me stay in the college hostel, no matter what the financial burden to him. I learnt later that he had to borrow substantial sums of money to see me through college. I decided that I would help him in getting rid of the debt as soon as I could.

My stay in hostel solved one problem, but created another. My rather delicate digestive system could not take for long the kind of unhygienic food and water I had to consume day after day. I was down with typhoid, from which I took rather long to recover. The university exams were approaching, and I was anxious to join classes as soon as possible. One day I ignored the doctor's advice for more rest for complete recovery, and went to the university. The strain was too much for my already weakened system, and there was a relapse of the disease. All in all, my performance in the studies suffered greatly that year.

After doing B. Sc. (Hons), I joined in 1965 the two-year M.Sc. course, specializing in solid-state physics. This time I stayed in the Gwyer Hall Hostel, right inside the DU campus.

Our syllabus included lectures on crystallography, to be given by a very senior scientist from the National Physical Laboratory (NPL), Delhi. But he never

came. The irony is that after getting my Master's degree I started my career in a field none other than X-ray crystallography!

5. LIFE AT THE B.A.R.C. TRAINING SCHOOL (1967-1968)

After doing my M. Sc., I got selected for a job at the Bhabha Atomic Research Centre (BARC), Bombay (now called Mumbai). The entry for scientists and engineers involved (and still does) a one-year orientation course at the BARC Training School. After successful performance at the Training School, one is made a Scientific Officer, a Class 1 gazetted post in the Govt. of India.

I landed in Bombay at the Training School hostel on 15th August 1967. Till my batch (the 11th batch) the hostel was located at Land's End, Bandra. After that it shifted to its new premises inside the BARC campus.

We had to commute to BARC every day for our classes, using a BARC bus. Life at the hostel was fun, its location being at the seashore. The location was a favourite with the people of Bombay, particularly young lovers. They came here, found a secluded spot among the rocks, and had a good time, kissing and exploring.

Some Bengalis of our batch had a bright idea. They pooled together money and bought a pair of binoculars. They took turns having a good close look at what the lovers were up to.

Apart from subsidized accommodation, the trainees got a monthly stipend of Rs. 300. That worked to Rs. 10 per day. The Head of Training School, Dr. Damodaran, is fondly remembered to this day by many of us for his famous statement that 'ten rupees will be cut' from the stipend if any of us stayed away from the classes for a day.

Our teachers were all working scientists and engineers of BARC, and there was a very good teacher-to-student ratio. Teaching by such scientists helped us get a feel for how science and technology are actually applied in real-life situations.

Sometimes even very senior scientists of the DAE came for teaching. One of them for my batch was Dr. Raja Ramanna. He taught us elements of set theory and group theory. He was a remarkable man indeed; one of the 'bosses' of DAE I have genuine respect for. In due course he became Chairman of the Atomic Energy Commission (AEC), and much else. I have had the experience of watching at least five Chairmen of the AEC from close quarters. Dr. Ramanna's

was a towering personality; he was *the* Chairman among Chairmen, the Bhisham Pitamah of *Mahabharat*.

The BARC Training School was where I was introduced to the basics of crystallography, as also of neutron scattering, reactor physics, nuclear physics, health physics, and much else.

6. MY SCIENTIFIC CAREER AT B.A.R.C. (1968 onwards)

On 1st August 1968 I became an employee ('Scientific Officer') of BARC, with a starting take-home salary of Rs. 640. My father happened to be in Bombay when I received my first pay cheque. I handed over the cheque to him, remembering what he and my mother had been through to enable me to see this day. He was very touched, and gave the cheque back to me with his blessings, his eyes moist with happiness and perhaps many other emotions. For the next few years I sent home half of my salary every month.

The Placement Committee had assigned me to the Nuclear Physics Division (NPD), headed at that time by Dr. P. K. Iyengar. In those days solid-state-physics activities were a part of the NPD, and only later was a separate Solid State Physics Division (SSPD) carved out of the NPD.

Dr. Iyengar assigned me to one of the two Sections in NPD which were engaged in crystallographic research (X-ray crystallography and neutron crystallography, respectively). My boss (X-ray crystallography) had a rather strong sense of rivalry with the boss heading the other Section, and this created problems for me (many of them of my own making).

I began by reading up books on X-ray crystallography, including those by M. J. Buerger. My boss had a small, make-shift laboratory housed in the Apsara Reactor Building, and our mandate was to determine the atomic structure of certain crystals by using X-ray diffraction. The simplest technique for growing water-soluble crystals is to make a saturated solution and just leave it somewhere in a clean environment. Since the sizes of crystals required are not very large, this works fine. I am mentioning this here for a reason. The boss had quite an assortment of beakers and Petri dishes, with solutions of various chemicals. I noticed that he seemed to have forgotten certain solutions altogether, and all the water had evaporated from them. I was intrigued by one such solid mass: The crystallization process had resulted in a *huge screw-like growth, with millimetre-sized steps, and growth features extending over several centimetres*. The morphology looked like a giant screw-dislocation, occupying the entire beaker. That was in 1968/69. Much later, when I learnt

about screw dislocations in crystals, particularly from a book by Dr. A. R. Verma, it occurred to me that perhaps I had noticed something never reported anywhere in the scientific literature on crystal growth. I tried hard to have a re-look at that growth feature, but the boss had probably thrown the beaker away.

I had the idealism typical of my youth, and a certain degree of recklessness. Add to that the Punjabi genes and what you have is a lethal combination (lethal for me). Once I read a book in the library about the bad effect of an inadequate boss on one's career. There was a checklist of questions about one's boss, and the advice was to change the boss or the job if the present boss scored 5 or less, out of 10. My boss got a poor score, so I decided to change the boss!

That was easier said than done in the prevailing situation in my government job. I damaged my career considerably by persisting with my request for a transfer to the other crystallography Section in the same Division. Little did I realize that I was upsetting the prevailing office politics seriously, and that certain things were just not done. Dr. Iyengar accepted my request eventually, but long after considerable damage had occurred to my career (bad and irresponsible Annual Confidential Reports (ACRs) by the boss I wanted to leave, and the consequent slow promotions for some years; the ACRs are secret documents and the person reported upon gets no chance to defend himself except in some extreme situations).

Dr. Iyengar was a man with a tremendous strength of character. He was rough at times, but it was easier to deal with him than certain other bosses who had perfected the art of carrying a frozen smile on their face, irrespective of what was really going on in their minds.

An interesting situation arose when cold fusion was grabbing the headlines. We looked up to our seniors at BARC for what to make of it. There was a wide spectrum of responses among them. In the beginning quite a few jumped onto the bandwagon, theorizing and even writing quick papers. Then the smart ones became ambivalent. And in due course, some of them rejected the whole thing as nonsense. What I found most unsatisfactory was that the only reason they gave for rejecting the cold-fusion data outright was that there was no explanation available for how cold fusion occurs. This was no way of doing science. One person who stood his ground was Dr. Iyengar. He provided full support to his protégé, Dr. M. Srinivasan (cf. Srinivasan & Meulenberg 2015), for carrying out his investigations on this phenomenon.

The BARC main auditorium at the Central Complex became functional at some stage, and one of the earliest symposia for which it was used was the one organized by a senior colleague, Dr. N. S. Satyamurthy. He once called me to review the arrangements in the hall. At that time the embedded microphones among the seats had not become operational. I pointed out that we should place some microphones in the aisles also, so that the participants do not have to walk too much to reach the nearest mike for asking a question or making a comment on a presentation. He said 'Good idea', and issued the necessary instructions. But sometimes funny situations can arise even when you least expect them. In one such symposium, people had a good lunch and came to the hall for the next session. There was a chap sitting in an aisle seat, and he fell asleep. Not only that, he started snoring. It so happened that there was a mike right next to him in the aisle, and his snoring sound got amplified, much to the amusement of everybody!

Talking about symposia, I am reminded of the superb sense of humour and very keen sense of observation of Dr. Ramanna. In the beginning the DAE annual symposium on solid-state physics used to be held jointly with the one on nuclear physics. In one such symposium the respective Secretaries for the two disciplines were Dr. Satyamurthy and Dr. M. K. Mehta, both of stocky build, and a rather jolly air about them. Dr. Ramanna watched them go to the dais every now and then for making announcements etc. When he rose to make his concluding remarks, he said, addressing the remark to the foreigners in the audience, 'Looking at our two Secretaries here, anybody would conclude that India is a well fed country'!

I obtained my Ph. D. degree in X-ray crystallography in early 1977. The title of the thesis was 'Crystal Structure Studies on Compounds of Pharmacological Interest'. The new compounds I investigated had been isolated from plants by people in the Bio-Organic Division of BARC, so knowing their molecular structure was of great interest.

One of the compounds investigated was tylophorinidine. Its heavy-atom derivative, diacetyl tylophorinidine methiodide, was used for determining the crystal structure (Wadhawan & Sikka 1976). The crystals have space-group symmetry C2, with *two* molecules in the asymmetric unit. This meant that I had to determine the locations of as many as 70 non-hydrogen atoms. In those days this was the largest crystal structure determination to date (1974), in India. This research problem required considerable effort by me because I had to work with *visually estimated* (and therefore of poor quality) X-ray diffraction intensity data.

After getting my Ph. D. degree I felt that I do not want to go on doing crystallography all my life, and looked around for something new to do. A conference abstract by S. C. Abraham introduced me to the new field of ferroelasticity (new from the physicist's point of view). I was hooked to it in no time. This kind of *obsession* for a field of research I develop has occurred again and again in my career, often creating problems for me. The problem created in this case was that my boss emphasized technique-oriented research, which in this case was neutron diffraction and X-ray diffraction. I revolted against this. My idea was that one should identify a good research problem first, and then apply whatever techniques it takes to attack the problem. Why should one get tied down to a technique, and then do whatever research is possible with that?

But disagreement with the boss can be costly, particularly in a government job in India. In my case it meant then that I had to make do with whatever instruments somebody at BARC will let me use for doing my research. With ferroelasticity, since it was a new field, one thing one could do was to try to discover the 'ferroelastic effect' in previously unexplored materials. One simple thing I could do was to use an optical polarizing microscope and see if my crystal specimen exhibited the ferroelastic effect on application of uniaxial stress with simply a toothpick. But I did not have an optical microscope of my own. So I went to people in BARC who had the microscopes and requested them to let me use them. I found that I cannot go to the same person's laboratory again and again, so I had to change my benefactor frequently!

I discovered ferroelasticity in a few materials, beginning with orthoboric acid (H_3BO_3), then $\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$, then some others. Once I gave a 'Physics Colloquium' lecture at BARC, describing the work I had done. At the end I thanked 'Dr. U. R. K. Rao, Dr. S. V. K. Rao, Dr. T. R. Rao, and Dr. K. N. Rao' for letting me use their microscopes. Yes, there were as many as four Raos to thank! My boss, responsible for my plight, was in the audience.

My resolve to pursue problem-based research, rather than technique-based research on which the big boss laid stress, made me a kind of persona non grata. I did not have access to the main journal in my field of interest, namely *Ferroelectrics* because the Library Committee of BARC decided against subscribing to it (the Internet was something unheard of those days, at least by me). No funds for research, no encouragement by the boss. He just let me be. Therefore, call it a good thing or bad, over the years I have developed the tendency to work in those areas of science in which there is no crowding in Indian science. I think this is what they call 'making a virtue out of necessity'.

The more the system ignored and suppressed me, the stronger my resolve became to prove the big boss wrong and show that there is plenty of science in my system. Strange are the ways some people inspire their juniors.

In 1977 I was the only physicist in India working on ferroelasticity. This field in physics was started by Keitsiro Aizu of Japan. I read up a large number of his papers. You can imagine my plight. I was chasing a field of research in which there was nobody in India I could talk to. What is more, my obsession with ferroelasticity made me the object of ridicule by the boss and his cronies. I remember the day when I was in a meeting called by the boss. Every time I uttered the word ‘ferroelasticity’, there was a guffaw of laughter from just about everybody present there. But chasing ferroelasticity obsessively, I ended up writing the first comprehensive book on the subject of ferroic materials (Wadhawan 2000) (ferroelastic materials are a subset of ferroic materials).

Later I wrote a book on smart structures (2007). On both ferroic materials and smart structures I was ahead of my times in Indian science. Nature has a way of compensating the have-nots.

Optical ferrogyrotropy

There are three categories of ‘primary’ ferroics: ferroelectrics, ferromagnetics, and ferroelastics. In ferroelectrics there is spontaneous polarization (a first-rank polar tensor property) which can be switched to a different direction (‘orientation state’) by applying an electric field. For ferromagnetics the spontaneous property is magnetization (a first-rank axial tensor property), which can be switched by applying a magnetic field. For ferroelastics the spontaneous switchable tensor property (mechanical strain) is a second-rank polar tensor, and it takes an appropriately oriented uniaxial stress to switch or reorient it. I asked the question: Can there be a fourth type of primary ferroics in which the reorientable property is a second-rank axial tensor? The answer turned out to be a qualified ‘yes’. Optical gyrotropy, which arises from the first-order spatial dispersion of the dielectric-permittivity tensor, is such a property, and I gave the name ‘optical ferrogyrotropy’ to the phenomenon in which the spontaneous optical gyrotropy tensor of a crystal has two or more equivalent orientation states accessible to it, and one can switch it from one such state to another by applying a suitable force field (Wadhawan 1979, 1982, 2000).

I also showed that optical ferrogyrotropy is only an ‘implicit’ form of

ferroicity. What this means is that ferrogyrotropic state shifts, though very much a reality, cannot be mediated by the gyrotropic tensor. They can only be effected through an accompanying, explicitly ferroic, property tensor. For example, a ferrogyrotropic state shift may occur as a phenomenon concomitant to a ferroelastic state shift or a ferroelectric state shift, etc. (if symmetry considerations permit that).

I have been mentioning 'orientation states' above. A ferroic material always has two or more equivalent orientation states, which are a relic of a 'ferroic phase transition' in it, a transition which necessarily breaks the point-group symmetry of the crystal (Wadhawan 2000). The phase transition is taken as occurring from a certain 'prototype' symmetry. There is a group-subgroup relationship between the prototype (point-group) symmetry and the ferroic-phase symmetry. Each such distinct pair of point-group symmetries defines a 'ferroic species'.

Work on gyrotropy, or rather ferrogyrotropy, brought me in contact with the great group-theory expert Kopsky, whom I was to meet again much later during my one-month stay in Czechoslovakia, and he has been a good friend since then. He was probably one of the two referees of my paper 'Gyrotropy: An Implicit Form of Ferroicity' (Wadhawan 1979). In fact, unknown to me, his group had also published at about the same time an extensive analysis of gyrotropy in the context of ferroic phase transitions (Konak, Kopsky & Smutny 1978). They had derived and listed the possible ferroic species of 'pure' gyrotropics resulting from nongyrotropic prototype phases. Independently of them, I had also identified a similar list by inspection from an exhaustive table of ferroic species published by Aizu (1970). I pointed out in my paper that my list of 18 such species included some which were missing in the work of Konak et al. (1978). Kopsky wrote to me, explaining why his list was smaller. So I agreed to include a 'note added in proof' in my paper which read as follows: 'In a personal communication Dr. Kopsky points out that Table 1 of Konak, Kopsky & Smutny (1978) gives only those pure gyrotropic species which involve equitranslational phase transitions associated with a single transition parameter. Thus the scope of their Table 1 is more limited than ours. The 18 species listed in the present paper exhaust all possible pure gyrotropic non-magnetic species'.

As a digression, I should explain here the organizational structure at BARC. The largest subunits of BARC are the Groups, with each of them headed by a Group Director, who reports to Director BARC. An example is the Physics

Group, headed at that time (1977) by Dr. Iyengar. Under each Group are the various Divisions (e.g. the NPD), and a Division may have one or more Sections.

Crystallographers around the world are a well-organized community. There is an over-arching International Union of Crystallography (IUCr), and then there are National Committees on Crystallography in many countries. The IUCr holds a huge Congress every four years. In 1978 it was held at Warsaw in what was then Czechoslovakia.

I had published a significant paper on the ferroelastic effect in orthoboric acid crystals (Wadhawan 1978), and I sent an abstract of this work to the IUCr Congress. My application for financial support was duly forwarded by my office to the funding agency (DST) at Delhi. At some stage I was told by my senior that my paper has been shortlisted for financial support, and that it was at the top of the list, purely on merit. The next thing I learnt was that I shall *not* be getting any financial assistance for travel, clearly because of the manipulations quite common in government circles. Dr. Iyengar was not pleased by these developments, and immediately sanctioned my travel expenses. He also wrote to a scientist friend of his at Warsaw to arrange for meeting all my local expenses.

I made a poster presentation at the Warsaw Meeting. This was my first visit abroad.



[With Prof. Gopinath Kartha and one other scientist, at the IUCr Congress,

Warsaw (1978).]

At the Warsaw Congress I met Mike Glazer for the first time. I told him that I was looking for a post-doctoral position at his Clarendon Laboratory. He agreed, so long as some funding agency supported my tenure. I applied for and won the Nuffield Foundation Travelling Fellowship for a period of one year. I landed at Oxford in mid-1979, and my family joined me a few months later.

[Continued in Part 2. The references cited are listed at the end of Part 3.]

Vinod Wadhawan at 8:25 PM

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About me



 **Vinod Wadhawan**

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I am a condensed-matter physicist. For the last few years I have been active spreading **the message of science and the scientific method**. In this context I have written over 30 articles at **Nirmukta.com**. I am listed as an '**Enthusiastic Bright**' at the Brights Net.

[Books written](#)

1. [Introduction to Ferroic Materials](#) (2000)

2. [Smart Structures](#) (2007)

3. [Complexity Science](#) (2010)

3a. [Nauka złożoności. Trudne pytania, które zadajemy o sobie i o naszym Wszechświecie](#) (2010)
(Polish version of Book No. 3. Translation by Malgorzata Koraszewska.)

4. [Latent, Manifest, and Broken Symmetry](#) (2011)

I did editing work for the journal *Phase Transitions* (Taylor & Francis, U.K.) for 25 years, and took voluntary retirement from the task of [Associate Editor](#) in 2010.

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