

Raman, the man, his contribution, and his message: what they mean to us in this the 21st century

1. Opening remarks

Mr President, Fellows of the Academy, Distinguished Guests, Ladies and Gentlemen! It is a pleasure to be with you this morning and I thank you all for your kind presence.

Mr President, I am especially grateful to you for inviting me to speak today. Honestly, I least expected your invitation considering that I have reached an age when the Academy deals with me only via automated computer messages! However, this year somebody from the Academy actually called me, following which I received a letter asking me to speak. So here I am to offer my tribute and respects to Raman, the first Indian to win the Nobel Prize for scientific work and that too done in this country, who also founded our Academy. And what better setting could there be than this wonderful Institute we are now in, of which Raman was the first Indian to hold the office of Director?

As announced, my talk is titled: ***Raman, the man, his contribution, and his message***, the subtext being: ***What do Raman's life and legacy means to us in this day and age?***

2. Early life

First, the mandatory biographical details. Raman was born on 7 November 1888, in the village of Tiruvanaikaval in Tanjore district, now Tanjavur district, in Tamil Nadu. Raman was the second son of Ramanathan Chandrasekhara Iyer and Parvathi Ammal. Before Raman came Subramanyan, the father of the distinguished astrophysicist Chandrasekhar.

When Raman was about three years old, his father who was a teacher moved to what is now Seemadhra, to work in Mrs A. V. Narasimha Rao College in Visakhapatnam—back then it used to be Vizagapatam. Brilliant as he was, Raman raced through school to join Presidency College in Madras—now Chennai—in the BA class. The year was 1903.

In college, Raman's teachers quickly realized that he was a boy genius and wisely left him alone. Raman did so well in the BA exam that many advised him to proceed to England for further studies. However, this required a medical exam, which Raman failed. Much later Raman said, 'I am eternally grateful to that doctor for failing me.!'!

Unruffled by the inability to go to England for higher studies, Raman enrolled for the MA degree, which he cleared with effortless ease, bagging many awards in the process. More important, while still a student Raman published two papers in *Philosophical Magazine* published from London. I cannot recall anyone other than Professor Chandrasekhar, one of the founder members of our Academy, who has repeated that feat.

Since research careers did not exist back then, Raman decided to join the Financial Civil Service or FCS as it was called. But first he had to write a qualifying exam, which he did, emerging as the topper. For the record, Raman's elder brother Subramanyan was already in the FCS. Following this Raman got married, and in June 1907 Raman arrived with his young wife in Calcutta to serve as an Assistant Accountant General for a fabulous salary of Rs400 per month, which included marriage allowance.

3. Double life

Destiny obviously had other plans for Raman, the FCS job being merely a set-up. The story of how Raman, the Assistant Accountant General, soon discovered the Indian Association for the Cultivation of Science (IACS) and started leading a double-life from 1907 onwards, sharing time between office and scientific research, has been narrated in considerable detail in the book ***Journey into Light***. I shall therefore skip that part. By the way, from now on when I say Association it means IACS. To have ready access to the Association and at all times convenient to him, Raman moved into the house next door and also put in a door directly connecting his house to the premises of the Association. This allowed him to spend long hours in research. His faithful assistant Ashutosh Dey, whom Raman always referred to as Ashish Babu, has recalled that many nights Raman would

just sleep on one of the benches in the lab. Waking up in the morning, Raman would rush to his house, shave with a few dextrous swishes of the razor as one of his students later described, bathe, gulp some breakfast, and rush to office.

Raman's double-life went on till 1917, at which point there was a sharp turn, a turn for the good I might add. But before I come to that I must mention that during the decade 1907 to 1917 Raman was preoccupied largely with studies relating to the vibration of strings and the acoustical properties of a few musical instruments, both Indian and Western. Happily, Raman's work in this area will be the theme of Prof. Dipankar Bhattacharya's talk, which is to follow. For my part, perhaps I could offer two side stories.

As you will soon hear, Raman was the first to make a scientific study of the tabla and the mridangam, drawing attention to how different they are in their notes, compared to the Western drum, which Raman described as a mere noise-maker. From a mathematical point of view, our percussion instruments use non-linear membranes, whose unusual vibrational properties seem to have been empirically discovered by our ancients.

Let me now jump to the early forties when Raman was asked to set a question paper for MSc students of Allahabad University. As a brain teaser, Raman included a question on the normal modes of a non-linear membrane. However, he did not expect anyone to answer that question, skipping it in choice. That precisely is what all students did, except one. This lone student answered that question in full but did not answer any other.

Raman was so impressed that he not only passed that student but also awarded him the highest marks. This naturally raised a firestorm amongst the rule-pundits but Raman had his way. That student happened to be Harish-Chandra, who later came to Bangalore to work with Homi Bhabha, who referred him to Dirac. Harish-Chandra then went to Cambridge to work with Dirac but was apparently not satisfied with Dirac's 'lack of rigour'—so I gather. Harish-Chandra then moved to Princeton, divorced physics, swore eternal loyalty to mathematics and lived happily thereafter!

The next nugget relates to what happened when the famous violinist Yehudi Menuhin called on Raman, after the latter had retired. When Raman presented Menuhin a copy of his paper on the violin, the latter accepted the gift and signed it, declaring himself to be an ignorant violinist!

4. Raman as professor in Calcutta

Let me get back to Raman's career. One person who was keenly watching Raman's work at the Association from the sidelines was Sir Asutosh Mookerji, then Vice Chancellor of Calcutta University. In earlier times Sir Asutosh, himself considerably skilled in mathematics, used to lecture at the Association. Impressed by how Raman single-handedly made the sleepy Association spring to life, Sir Asutosh offered him the Palit Chair for Physics in Calcutta University, which Raman accepted without any hesitation despite a salary cut of about 50%, plus having to give up a wonderful career prospect in government service. Since he could now draw upon university students to assist him, Raman's research gained additional momentum. This also was when Raman switched from acoustics to light scattering, a change which eventually led to the discovery of the Raman Effect.

Back then it was often alleged that this discovery was a kind of fluke, while others claimed that Raman barely understood what the Effect he discovered was all about. The fact is that, ever since he explained why the sea is blue, Raman was constantly thinking about the quantum aspect of light. Again and again he asked himself: 'How would the quantum nature of light show up in a light scattering experiment?' Indeed, after the discovery of the Compton Effect, Raman was absolutely certain that there must be an optical analogue of the Compton Effect, which he ultimately discovered. It is the anniversary of that day, i.e. 28 February 1928, which is now celebrated as the National Science Day. The beauty of Raman's experiment is that it brought together the discovery of Einstein who pointed out the photonic nature of light (about which many were quite sceptical at that time) and Bohr's discovery regarding the quantum nature of the atom.

5. The Prize

In 1930, just two years after his discovery, Raman was in Stockholm receiving the Nobel Prize. It is interesting that Raman received the Prize **before** the founding fathers of quantum mechanics did. Heisenberg got it in 1932, Schrödinger and Dirac received theirs in 1933, while poor Max

Born had to hang around till 1954! In passing we note that Einstein, who drew attention to the quantum nature of light as far back as 1905, had to wait till 1921 for his Nobel, while Niels Bohr who developed his famous model of the atom in 1913 had a nine-year wait. Compared to them, Raman seems to have got his on a *tatkal* basis! More seriously, Raman in faraway India was rewarded quite early because his discovery showed for the **first time** and in **one single experiment** that quantum mechanics was **the** Law of Nature, with respect to light as well as matter. Incidentally, it was also in 1928 that Dirac proposed the now famous Dirac equation, bringing to a close the first chapter in the history of quantum mechanics.

6. To Bangalore

Around 1932, the Indian Institute of Science was looking for a new Director to replace Sir Martin Forster who was due to retire shortly. It was customary then to look for candidates in England. When Lord Rutherford was approached, his reaction was simple: 'Why look in England when India already had a Raman?' When Raman was sounded out, he was not averse to the idea of moving to Bangalore.

The transition from Calcutta to Bangalore proved to be a double whammy. While Raman's exit from Calcutta was turbulent, his entry into Bangalore raised a firestorm. Since many of today's generation may not be aware of those facts, a brief reference to them is not out of place. There are of course many versions regarding what happened in Calcutta but mine has been put together from what I heard from late C. Ramaswamy, the younger brother of Raman, supplemented by some deep background given to me by Prof. Chandrasekhar during an hour-long discussion I had with him in 1987, plus inputs from a few others who knew Raman.

It all started like this. For quite some time, there was simmering tension between Saha and Raman. It was the period when quantum mechanics was taking shape in Europe. Saha was strongly of the opinion that instead of focussing on these new and epoch making developments Raman, the Professor of Physics, was still busy with experiments in classical physics. This, Saha felt, was totally injurious to the interests of the university. This strong difference in attitude apparently manifested in various snide remarks and sharp exchanges during seminars delivered by Raman.

The straw that finally broke the camel's back was a meeting held when Raman was preparing to leave for Bangalore. Remember, while Raman was Professor in the University, he was also holding the position of Secretary of the Association, after the last family member of Mahendralal Sircar, founder of the Association, died. Before leaving for Bangalore, Raman wanted someone to replace him (i.e. Raman) and be in charge of the Association. Since funds were available, Raman decided that a Chair should be established and named after Mahendralal Sircar and filled—that, Raman felt, was the simplest way of ensuring continuity.

When Saha heard about this, he told Raman that he (i.e. Saha) should be appointed to the proposed Chair. Raman said, 'No, because lately your scientific output has come down sharply; we need a person like Krishnan, who is much more active in research.' For those who may not be aware, back then K. S. Krishnan, who later became the founder-director of our National Physical Laboratory, used to work closely with Raman on light scattering, including on the experiments leading to the great discovery.

Raman's blunt rejection of Saha resulted in a stormy meeting of the General Body of the Association during which Raman was voted out as its Secretary. Incidentally, the proceedings of that meeting were made available only some years later, and I have not seen it. I gather, however, that the report was unfavourable to Raman.

The details may vary, and they are bound to since there were two antagonistic camps involved. I am aware that my version (as given in my book *Journey into Light*) which was based on what I had heard has been strongly criticised. What is not noticed is that I have not painted the other side black. On the contrary, I blamed the situation on the British who did not allow enough space for science to flourish. The country was huge and the number of scientists at that time was barely a handful. If you look at what happened not only to Bose and Krishnan but also to Saha who was forced to move to Allahabad due to refusal of funds to Calcutta University by the British, you would understand what I am talking about. Few of us appreciate how difficult it was way back in the late twenties of the 20th century to get even a pittance of funds to run a department let alone do research. For more details on how difficult it was for Saha in Allahabad, look up my book titled ***Saha and his Formula***.

To get back to my narrative, at the end of it all control of the Association slipped out of Raman's hands; for him, this was a humiliating defeat. It was thus an emotionally shattered and totally devastated Raman who showed up in Bangalore in 1933, to take over the directorship of the

Indian Institute of Science (IISc), the first Indian to do so. Sadly, the entry was no less turbulent but first a bit of history.

7. Raman at IISc

When it was started in 1911, IISc had only three departments, namely General and Applied Chemistry, Organic Chemistry, and Electro Technology. Prior to Raman's arrival, two Committees had reviewed the work of the Institute, one in 1921 and another in 1930; both noted that there was hardly any evidence of research in basic sciences, and that most of the work being done was of a routine and applied nature. In that sense, there was a good welcome mat awaiting Raman's entry into the Institute.

Raman joined the Institute wearing two hats: one as the Director and the other as the Professor of Physics. But there was a problem. While there was an Institute of which he could be the Director, there was no physics department for him to be a Professor in or even a building for physics research! So Raman straightaway allocated some space in the main building for research work; the Director's office was in the ground floor, as it is now. Raman also diverted some funds for the new department, which he thought was reasonable but others did not; and that precisely is how trouble started.

I should mention that back then the Institute often used to be described as a sanatorium to which some laboratories were attached; Raman was determined to change all that, and sure enough there was a firestorm. For all the slackers, Raman's arrival seemed like a bull crashing into a china shop! The unpleasant details of what happened subsequently are chronicled in my book and I shall therefore skip them. In brief there were various committees of enquiry, and although the Viceroy Lord Linlithgow was keen that Raman should remain the Director, the anti-Raman lobby won the day. Result? Raman was given two humiliating choices as follows:

1. Step down from the Directorship and stay content with being the Professor of Physics, along with a big salary cut.
2. Tender resignation with effect from April 1, 1938, on such retiring allowances as he may be entitled to according to the rules.

If Raman declined both options, he would be suspended! Since Raman was keen on continuing his research, he accepted the first option. It was one

more traumatic experience for Raman, coming on the heels of another a few years earlier; even so, few tears were shed. There was, however, a consoling letter from Lord Rutherford who said:

Now that the matter is settled, I trust that you will be able to carry on with your personal work and let bygones be bygones. It seems to me highly important that the staff at Bangalore should pull together for the good of the Institute.

Looking back at that turbulent period from 1933 to 1938, all I can say is, 'Thank God there was no Facebook and Twitter!' If social media and TV were available, Raman would have had to face an even greater hell! Looks to me that where campus politics is concerned, little has changed in most of our universities.

Incidentally, for the benefit of Bangaloreans in the audience I might mention that most of the official meetings took place in the Residency. Back then the state of Karnataka did not exist. Instead there was a princely state called Mysore, ruled by a Maharaja. The British Government was smart. When they took over India from the East India Company in 1857, they retained full control over territories that were called provinces. To keep the size of the army manageable, the British asked the hundreds of princes ruling over bits and pieces of the country not directly under British rule to surrender a part of their sovereignty, in exchange for British protection against attack by other princes. And to make sure that the princes were behaving properly, the British appointed an officer known as the Resident; and the place where the Resident resided was known as the Residency. Thus it is that there is a road in Bangalore known as Residency Road. I do not know whether the name of that road has been changed. However, this I can state with confidence, which is that presently the Governor of Karnataka lives in what was formerly the Residency.

8. Science at IISc

Raman was fifty when he gave up the directorship and had ten more years of service left. Storing away bitter memories of two successive traumatic experiences, Raman continued to gather students and squeeze good work out of them, mostly in optics. World War II was in progress and the financial position was depressing since the war effort sucked most of the money that was available in the country. Nevertheless, Raman's enthusiasm never flagged, and through constant pep talks he kept his students working as hard as ever. One anecdote I heard from an old-timer

of that period offers an example of how Raman cheered his students, and this story goes as follows.

Raman was particular to arrive in the lab very early in the morning, after which he would go round to talk to students, give them advice, and so forth. One day as he was doing his rounds, Raman saw one student slumped in a chair instead of being busy with his experiments. When asked why he was not working, the student replied that he had just heard that a researcher in England was working on the same problem as he had been assigned. What was worse, the competitor in England had a 10 kilowatt light source while he had only a 1 kilowatt source which obviously was a huge handicap. Raman patted the student on the back and said in his characteristic manner, 'Don't worry. Just put a 100 kilowatt brain on the problem and you would get ahead of your competitor.'!

As I said, the handicaps Raman faced were many. Even so, it is worthy of note that in a few cases the work that Raman's students did was, in fact, ahead of its time, like, for example, the discovery of soft modes of lattice vibrations. Equally if not even more worthy of admiration are the pioneering studies on the fluorescence of ruby done by Anna Mani, Thosar and others. Decades later it was their data that acted as input for the design of the ruby laser. The scientists in America who were developing the laser were desperately searching for some fluorescence data on ruby. Where did they finally get it from? The **Proceedings** of **this** Academy! Let us all rejoice in our Academy's great record by giving it a big hand!

Another detail of historical interest is that Raman was able to invite Max Born to the Institute as a visitor. Having managed to get out of Hitler's Germany, Born was looking for a berth, at least a temporary one, and Destiny brought him to Bangalore. Raman was very keen to get Born appointed as a Professor but the administration would not agree.

What a great pity! Born had a PhD in mathematics, and his mentors included David Hilbert, Felix Klein and Hermann Minkowski. Those of you who are familiar with mathematics and great mathematicians would, I am sure, cry 'WOW!'. Add to that the fact that Born it was who saw that what young Heisenberg was doing while introducing his version of quantum mechanics was essentially to represent operators as matrices **without** being aware of it.

I make a special mention of all this because if only Born had stayed, quantum mechanics might have taken excellent roots in the country, for was not Born one of the founding fathers of quantum mechanics? As an additional bonus if Raman had been less stubborn, Born's great classic

The Dynamical Theory of Crystalline Lattices might have been written in Bangalore instead of Edinburgh, as it finally transpired.

9. Raman at RRI and the end

The year was 1948 and it was time for Raman to retire. Clearly he needed a place to go to and continue his work, because he could never keep away from exploring Nature. Luckily for him, much earlier in 1934 when he wanted to establish our Academy, Raman had managed to persuade the then Maharaja of Mysore to gift a ten-acre plot. Two years prior to retirement, that is to say in 1946, Raman began building his new institute (known to us now as the Raman Research Institute) so that he could, as Raman himself put it, take his bag and walk right into his own institute.

At the time of retirement, Raman was offered some money by the government, which he turned down. He never wanted to be obligated to the government in any manner whatsoever. Instead he sought donations and was proud of it. 'Our greatest men were beggars', he declared, 'including Buddha, Sankara and even Gandhi.' Raman not only gifted away most of his property for the benefit of the Institute, but also the money from the various prizes he received.

It was obviously not possible for a 60-plus-year-old Raman, working in isolation and with barely any equipment or money, to sparkle as he did before. Nevertheless, Raman remained busy, doing some cute experiments in optics besides studying the optics of stratified media like shells, for example. In the process, he managed to attract a few students all of whom did exceptionally well later.

Years passed and soon there were no more students, possibly because the funds position was not too good. For a while, Raman withdrew into himself and appeared to be depressed. However, he quickly snapped out of it by inviting children and young people to the Institute and spending long hours with them. He even felt uplifted because he saw a bright future for the country in its young people.

The year was 1970, and Raman's health began to decline. Anticipating the end, Raman prepared detailed instructions about what must happen to the Institute and the Academy after he was gone. The end finally came on 21 November 1970, shortly after his birthday.

10. Looking back

And now to the difficult task of looking back. Although much can be said, I shall restrict myself to only one aspect that seems pertinent for this occasion.

It is often assumed that Raman lacked a mathematical background which substantially crimped his research. The fact is that Raman was not lacking in mathematical skills—after all, it was Lord Rayleigh in faraway England who first inspired him; and Rayleigh's work was always maths-heavy. Furthermore, Raman even published papers in mathematics.

Consider what Prof. Ganesh Prasad said while delivering the Presidential Address of the Physico-Mathematics Section of the IACS in 1913. Referring to the many papers published by Raman in the *Journal of the Indian Mathematical Club*, Prof. Prasad observes:

Professor Raman is well known to you as an experimentalist of worldwide reputation. But some of you will feel surprised to learn that by his recent mathematical researches, he has firmly established his claim to be considered a sound mathematician. The two papers he read before the Calcutta Mathematical Society during the current year are very valuable, and I trust he will continue his mathematical researches.

Again, consider the following remark by Prof. B. S. Madhavarao, made in an article published in **Current Science** in 1971 following Raman's death. Commenting on Raman's work on the vibrational modes of bowed strings, Madhavarao is struck by Raman's analysis of the propagation of velocity discontinuities set up by the act of bowing and says:

Another remarkable result of mathematical interest is his analysis of the nature of motion [of the velocity discontinuities] when n , the number of discontinuities, is a prime > 1 , or is composite. A careful examination of the manner in which this analysis is accomplished shows that he has not used any sophisticated results of prime number theory, but just the definition of a prime number!

The question now arises: 'Why did not Raman inject mathematics while analysing the results of his research, especially while in Bangalore and studying lattice dynamics?' My guess is that Raman always became so excited while studying natural phenomena that he was too impatient to be held back by mathematics. To me, Raman was somewhat like a reader of

a 'who-done-it' mystery who is dying with anxiety to know who the murderer is, and turns the pages rapidly! Born put it more elegantly by saying 'Raman's mind constantly leapt over mathematics'.

More seriously, I believe there might have been a deeper reason. To appreciate my point, consider first what Abraham Pais says about Einstein in his book titled ***Subtle is the Lord***. Commenting on the impact of the violent attacks on Einstein during the anti-Jewish wave in Germany when Hitler came to power, Pais observes:

After that, the creative period ceases abruptly, though scientific efforts continue unremittingly for another thirty years.

Who can gauge the extent to which the restlessness of Einstein's life in the 1920s was the cause or the effect of a lessening of creative powers?

Where science is concerned, Einstein and Raman clearly belonged to two different classes. Trauma, however, is a totally human experience. Thus, based on what Pais said of Einstein, the question can legitimately be asked:

To what extent was Raman's productivity in later years affected by what we would now call PTSD?

Obviously, we would never know but I personally feel trauma must have taken a deep toll on Raman, especially as he had to face two of them in quick succession. There is, however, a positive aspect to Raman's move to Bangalore. Way back in 1933, L. L. Fermor of the Geological Survey of India said that Calcutta's loss would be Bangalore's gain. That indeed has proved to be the case, far beyond any expectations that Fermor might have had.

11. The Academy

One of Raman's gifts to the country is this Academy, which I have the privilege of addressing right now. Writing in *Current Science* a year before the Academy held its first meeting in 1934, Raman said:

The conviction that research is civilisation, and determines the economic, social and political development of a nation has not yet been unreservedly accepted as a part of the administrative policy of India

Sadly, decades later there is still little appreciation in administrative and political quarters about the role scientific research plays in stimulating technology. Thus it is that as late as 1971, S. N. Bose, famous for his monumental discovery of Bose statistics, said, during his Krishnan Memorial Lecture delivered at the National Physical Laboratory:

It is a perpetual challenge to the Indian genius as to how, even though the country is endowed with such natural resources, even though the country has had such a brilliant history, why it continues to remain third-rate in spite of so many resources and so much manpower. Well gentlemen, I stop here with these questions asked to our young men.

That was the great Bose speaking his mind in 1971.

We need to seriously examine the reason for the 'Bose Paradox', if I may call it that, and also why this paradox has become aggravated in recent years. As far as Raman was concerned, he was quite clear that the future of this country lay in its young people. Delivering the convocation address at Patna University in 1941, Raman said:

I would like to tell the young men and women before me not to lose hope and courage. Success can only come to you by courageous devotion to the task ahead of you, and there is nothing worth in this world that can come without the sweat of our brow. I can assert without fear of contradiction that the quality of the Indian mind is equal to the quality of any Teutonic, Nordic or Anglo-Saxon mind.

What we lack is perhaps courage, what we lack is perhaps the driving force which takes one anywhere. We have, I think, developed an inferiority complex. I think what is needed in India today is the destruction of that defeatist spirit. We need a spirit of victory, a spirit that would carry us to our rightful place under the sun, a spirit which will recognise that we, as inheritors of a proud civilisation, are entitled to a rightful place on this planet. If that indomitable spirit were to arise, nothing can hold us from achieving our rightful Destiny.

Mr President and Fellows of this Academy! These days I often hear that growth and development can come only through FDI, retail stores, and what not. I find this most painful, particularly because these recipes amount to nothing more than superficial and quack remedies for the complex and massive economic problems the country is now facing. In this context, I appeal to the Academy to become appropriately proactive

in forcefully arguing the connection between research and economic development and, through them, the advancement of society and civilization.

Just look at what happened in post-War Europe. Almost every country in Europe was devastated, the victors as well as the losers, and each in its own way. None of these countries was huge as America was, and furthermore none of them could support science the way America was able to. And yet, recently Europe grabbed the honour of discovering the Higgs boson, leaving America bitterly disappointed. We need to pause and learn some lessons from that. Shortly, I shall return to that theme, but first, let me take a short walk down memory lane.

When I joined BARC in 1955, we were still very much a bullock-cart type of country. However, thanks to the dynamic leadership of, first, Homi Bhabha, and subsequently the brief but visionary leadership of Vikram Sarabhai, India began to leapfrog at least in select pockets. In fact, when in 1973 I voluntarily opted to move out of the scientific sanctuary that BARC was, to go to Kalpakkam and participate in founding a new national lab, then named the Reactor Research Centre (RRC) and now renamed the Indira Gandhi Centre for Atomic Research (IGCAR), many felt I was committing scientific hara-kiri; indeed, during my early days at RRC, I often wondered whether I had made a Himalayan blunder.

The housing colony where the staff of all projects being implemented in Kalpakkam lived was sandwiched between two fishing villages. One called Sadras was located right on the coast; this was where the Dutch landed several centuries ago. Around the same time, the British established a foothold about 70 km north of Sadras, and built a fort there. Today, that fort is the seat of the Government of Tamil Nadu. The other village neighbouring our colony was Pudupattinam, skirting the once-famous Buckingham Canal. What I am trying to say is that there in Kalpakkam, still surrounded by rural India, a 500-megawatt power station is nearing completion. This power station is based on a fast reactor, designed to produce 1500 megawatts thermal of heat derived from the fission of plutonium, induced by fast neutrons. The design and technology development for the power reactor was done almost entirely by the scientists and engineers of IGCAR. I vividly recall the meeting that Sarabhai chaired there in 1971 when he outlined the vision for RRC. Today, RRC/IGCAR has delivered the goods. Soon, this prototype fast breeder reactor (PFBR) is due to go critical after which it would start feeding energy to the grid. Many members of the Academy might be aware of all this, at least to some extent. But what is pertinent is that not only have the 500 and odd engineers and scientists of IGCAR developed

the technology for PFBR but, alongside, they have also done a lot of good science of international quality.

In saying all this, I am not forgetting the pioneering contributions made by our other technology-based labs. Where space is concerned, Vikram Sarabhai and Satish Dhawan gave a rocket-like start to our space programme. Likewise, during the brief period my former boss Dr Raja Ramanna spent in DRDO, he brought Dr Abdul Kalam to DRDO to make a sea change to our defence science effort in the field of missiles. Last year when I was in the US, I was amazed to find how many of Kalam's former associates were now working in that country, and in top labs like JPL. In fact, the scientist who took me around JPL was not only a Kalam associate but was the one who had designed and built the power source that drives Curiosity Rover on Mars right now. If I have ventured to draw explicit attention to some of the infrequently mentioned aspects of our progress, it is for several reasons, which I now proceed to mention briefly.

Firstly, much scientific as well as technological progress has been made by our national labs. Even so, somehow the fruits of that progress have not flowed out coherently into our society to be manifested as technological and economic progress. Back in the sixties we had a great example in America, when the work done at MIT benefitted society via the establishment of dozens and dozens of 'basement companies' set up by MIT graduates, which not only supplied high-tech products to the programmes of NASA and the Defence Department, but also gave employment to many scientists. This 'Route 128 phenomenon', as it was then called, later triggered the birth of the famous Silicon Valley miracle, which is still growing strong.

There is a reason for my mentioning all this. I know from my own personal knowledge that over decades BARC scientists had acquired sophisticated technological skills in diverse areas. Unfortunately, till today there has been no well-formulated master plan for these skills to flow into our manufacturing sector in a systematic manner, creating in the process employment opportunities for our young scientists and engineers. That said, it is gratifying that despite this lack of automatic flow of knowledge and skills from source to downstream, thanks to a few intensely self-motivated scientists India has actually supplied many components to both CERN and Fermilab. What it means is that, given support and encouragement, we do have the competence to move forward; what we lack is vision and trust at higher decision-making levels, as also confidence in our youth.

The point I am making is that there is so much more that could have been done in recent decades, if only we had an **organized system on a national scale** for actively enabling technology and specialized skills to flow downstream into our manufacturing sector from our four major lab-chains, i.e. the labs managed by DAE, ISRO, CSIR and DRDO. Sadly, we have left many decades slip by. The question is: 'How long would it be before we wake up?'

When I was in service, our industrialists used to look down with contempt at our engineers and our scientists as if we were all substandard. Unlike our engineering colleges, the IITs were set up mainly to train engineers to do design. However, the country did not bother to create an environment where designers had a role to play. Is it any wonder that IIT graduates migrated in droves to greener pastures? But you know what? Starting about the year 2000 or so, MNCs have begun to set up labs here. Just look at Bangalore; we have labs set up by GE, Honeywell, Microsoft, Intel, and so on. Do you think they would set up research labs here if there were no people to hire? This abundantly proves Raman's observation made as far as back as 1942 that *'the quality of the Indian mind is equal to the quality of any Teutonic, Nordic or Anglo-Saxon mind'*.

Simply put, it is as if we presently have many of the 'bits and pieces' but not a proper assembly line to deliver many of the systems we need. Instead, we just import them, when a good percentage of it could well have been made here, creating jobs in the process.

Take simple things like lab equipment for schools and colleges. We have so many schools and colleges. If we had a serious national plan to provide good and high-class science equipment, that in itself would be a decent business, at least at the medium-scale industry level, providing employment to many. Equally important, consider how helpful it would be in training science students to become good scientists. By the way, this is what China started doing way back in 1975 or so, some time before its technological leapfrog. I remember having a long chat regarding this with late Dr P. K. Iyengar who was my colleague then and later rose to become the Chairman of our Atomic Energy Commission.

Where the medical equipment industry is concerned, GE has openly announced that it is shifting focus to portable and smart diagnostic equipment because these can be sold in **hundreds of thousands in China and India**, as opposed to big machines like CT and MRI scanners that are complicated to build and hard to sell since the market for them is relatively small. If GE is planning to develop, build and market small

medical diagnostic machines that have the potential to be sold in huge quantity, do you mean to say we cannot do the same, when we can send a space probe to Mars?

This brings me back to Raman's remarks made in *Current Science*, which I quoted earlier. Those comments were made eight decades ago, several years before Independence. Given the considerations I set forth earlier, I strongly feel that the time has come for the Academy to move to a larger orbit. Far too long, we in the academic community have remained mute witnesses, maintaining an almost ascetic profile to the point that people at large in this country have now come to believe that pure science is irrelevant as far as this nation is concerned. 'Why should we bother?', they seem to say, adding, 'It is simpler to let America and China handle the design and manufacture; all we have to do is import.'

While this might be an easy way for the corporate sector to make money, we in the academic community have to search our souls and ask if this is acceptable for a country that would soon have the highest population in the world. Here in this very Institute where we are presently gathered, one man, i.e. Raman, worked so hard at a time when there was neither money nor encouragement for science. Thanks to the push Raman gave, others who came later were able to build on it to a point where IISc now proudly stands as the MIT of India. It is as a result of this and similar steps by the early pioneers that India could, when it became free, leapfrog at least in select sectors.

Turning now to the Academy, there is absolutely no question whatsoever that it has made monumental strides in the post-Raman era. Even so, I believe that our real work begins **now**, when the country is at a crossroads, with more and more people, including those in high positions, starting to believe in the magic of the marketplace instead of in education, research and the talent locked up in our young people. We must remind ourselves that if today we enjoy much better support for scientific research than our predecessors did, it is because of the many sacrifices they made. And let us not forget that one of the duties of a living system is to propagate its species. This cannot be done merely by doing good science and a few allied things.

In my view, the time has come for the Academy to become some kind of a Conscience Keeper of the Nation. More explicitly, the Academy must command the respect of the nation to such an extent that those in authority and people in various sectors like education, manufacture and the public in general turn to it for counsel in matters relating to education and scholarship, creating public awareness about the delicate linkages

between science and technology, and making the people at large understand that in a huge country like India, technology must have **strong native roots** based on an equally strong native scientific tradition.

It is such an eco-chain alone that can breed self-confidence, so essential for true growth, and not a superficial one where not only is money borrowed but also almost everything is purchased through imports. It is easy to borrow money, fill our shops with brand-name items, build luxury flats, and get people to buy all these on so-called EMI. But what happens when people do not have jobs, even though they have degrees? How much worse it becomes for people who once used to survive via local auto shops and the like but are now not able to because hitech cars have robbed them of jobs, left right and centre? I do not see anybody worrying seriously about such matters. Eugene Wigner, one of the towering giants of 20th century physics, once famously said, 'Mathematics is too important to be left to mathematicians alone.'! In the same vein, I would like to submit that education, research, technology, growth, scholarship, culture and civilization are too important to be left solely to bureaucrats, no matter how well-meaning they might be.

As of now, the market has not completely taken over this country, but the moment that happens, the public at large would be lulled into the belief that growth would do everything for the country. People often criticise our villagers for being superstitious. Maybe, but at least they slog and feed the country. But when market-savvy, globe-trotting economists tell us to have faith in a mysterious thing called market, nobody considers that as spreading superstition!

I personally find it amazing that long before the world entered the era of the market, Raman correctly saw the future of our country in our youth, in research and the fruits of research manifesting as the development of the nation. I beg to submit that what the Founder of our Academy would like us to do at this critical juncture would be to come out of a self-imposed limited set of duties and become the Conscience Keeper of the Nation as regards research, which is the fountainhead of civilization. We as the inheritors of Raman's legacy have—so I believe—a duty to make our Founder's vision come true.

Sadly, even in America the tail is now wagging the dog, with conservative politicians there applying great pressure on the government to cut down spending on research, and lobbying hard to make education a feeder sector to the market, just as auto-ancillary industries serve auto manufacturers. You do not have to take my word for it; just glance

through the book titled ***What Money Can't Buy***, by Michael Sandel of Harvard. If we want to copy America, let us stick to what is good and beneficial there—and actually, there is a lot we would do well to copy—instead of rushing to follow what is clearly detrimental to our young people and to the country as a whole.

12. Concluding remarks

And now, it is time to wind up. On 15 August 1954, the Padma and Bharat Ratna awards were announced for the first time. Three were to be honoured with the Bharat Ratna, those three being: C. Rajagopalachari or Rajaji as he was better known, Dr S. Radhakrishnan, and Raman. I am sure that it has not escaped your attention that their names begin with the letter R, and that all three had close association with Madras. For the sake of completeness I should mention that Rajaji was the only Indian to occupy the post of Governor General of India (this was shortly before we became a republic), while Dr Radhakrishnan was, for many years, a professor of philosophy sharing time between Benares and Oxford. After we became a republic, he served as Vice President of India; later he became President.

One of the first to congratulate Raman after the announcement was made was Indira Gandhi—at that time, she had not yet entered politics, and was staying with her father in Teen Murti House. Writing on the very day of the announcement and in long hand, Indira Gandhi said:

As you know, I have been an ardent admirer of yours since that journey to England in 1937 [when they met on the boat], and have regarded you as the “Rathna” of India. I am happy to learn that now you are officially a Bharat Ratna. It is a title that you richly deserve.

Raman promptly responded, conveying his profuse thanks to Indira Gandhi for her message.

On 19 January 1955, Raman received a telegram from Dr Rajendra Prasad, President of India. The President said:

I shall be glad if you stay in Rashtrapathi Bhavan as my guest, when you come to receive your Bharat Ratna Award (stop) Kindly let us know your mode and date of arrival for reception arrangements.

Raman sent a reply to the President on 20 January 1955 in which he said, and I quote:

My dear Dr. Rajendra Prasad,

I was greatly touched by your very kind telegram received last night, inviting me to be your guest at 'Rashtrapathi Bhavan' for the Investiture Ceremony on the 27th January 1955.

Immediately on receiving the official invitation to the Investiture, I wrote to the Military Secretary and to the A.D.C in waiting explaining that I find myself unable to come up to Delhi for the function. Even ordinarily, my work here is all-engrossing and prevents me from accepting assignments which call me away from Bangalore. At the present time I am firmly tied down here to enable one of my students to complete his Doctorate thesis which the Regulations require him to submit to his University before the end of January. Thus my duty as a teacher has to take precedence over my own personal affairs. I feel fully confident that you will appreciate the compelling nature of the circumstances which prevent me from accepting your kind and gracious invitation to come to Delhi.

Yours sincerely,

C. V. Raman

Raman stayed back in Bangalore to fulfil his obligations to his student, skipping the glamour, the glitter and the limelight of Delhi. Later, the Bharat Ratna medal and the Citation were routinely hand-delivered at his residence by an ordinary messenger of the Mysore Government. That was the way Raman received the nation's highest award—no one to cheer, stand up and applaud, or even to congratulate.

I believe the incident I just narrated reflects Raman's commitment to duty and to the future, via his students. Need I say anything more?

THANK YOU!