RAMAN— THE TEACHER EXTRAORDINARY

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I had the greatest good fortune to be closely associated with Professor C.V. Raman for eleven years (from Nov. 1949 to Oct. 1960), from the very beginnings of the Raman Research Institute, an Institution Raman created for pursuing his scientific interests, after retirement from the Indian Institute of Science. I began my scientific career with him as a research assistant and won his confidence and affection. He was extraordinarily kind to me and shared his scientific and other interests without any reserve.

Raman was a true scientist and lived all his life as an active researcher. In his scientific career he pursued his research interests with great vigour and set for himself highest-standards and goals. His immense curiosity for understanding natural phenomena, power of observation and persistence led him to make one of the greatest discoveries in physics namely "The Raman effect". It is of particular significance that the equipment which Raman employed for the discovery were very simple and amounted to a total cost of Rs. 500 at the time. Raman's discovery and his getting the Nobel prize was not only a personal triumph for him but was very significant for India and India's scientific development. For almost six decades Raman's personality made its deep impression on the Indian scientific scene. He inspired generations of students and was the most loved spokesman for Science. The story of his success has few parallels at least in the Indian context. His achievement can only be attributed to the singular nature of his personality, and the energy and vigour with which he pursued his goals. Raman showed an uncommon ability for independent thinking right from the beginning and gave up a lucrative government job in favour of a scientific career. When he took to scientific research he was supremely confident of outstanding achievement. Apparently he used to remark that he would bring the Nobel prize for physics east of Suez. Rabindranath Tagore had won a Nobel prize for literature in 1913, but Raman was the first Asian to win the Nobel prize in a scientific field. Viewed from the times in which he was born and raised, it was a statement no one lesser than Raman in determination could have made.

Raman was a towering scientific leader and trained a large number of scientists in India to assume leadership in the field. During his lifetime scores of students passed through his laboratory where they learned scientific methods of thinking, and methodology of scientific research. Raman was a source of tremendous inspiration for the young minds and he kindled their creativity and true interest in science. He gave them interesting problems, worked with them in understanding their results, and developed their analytical thinking and skills. He taught them how to write scientific papers and how to give an effective presentation to an audience. Raman's scientific papers were written in such a delectable style, they were like literary expositions. He often used Latin phrases to emphasize a point. His enthusiasm and curiosity about Nature were infectious. One imbibed a great deal of knowledge just observing him. Raman was indeed a teacher extraordinary the like of whom would be very hard to find.

The life and achievements of Raman are told in other articles in this issue and hence I will not dwell on these topics. My purpose will be to show what a great and gifted teacher Raman was and how he inspired his students and coworkers. He did not teach in the conventional way, although during his tenure as Pallt Professor in Calcutta University he taught the M. Sc. classes to which I shall refer to later. One learned an incredible amount of physics by just being associated with him, listening to his lectures, in discussions with him and by observing him when he was working in the laboratory on a scientific problem. From him one learned how to appreciate Nature, for he had an intense curiosity about Nature and natural phenomena. Colours and symmetry in nature fascinated him and he tried to understand them deeply from the point of view of a physicist. It was the colour of the sky and the blue of the ocean that set him on the trail of discovery of the light scattering effect named after him.

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Raman the scientist

Raman went through four distinct phases in his life. Following a brilliant academic career he entered the Financial Civil Service in 1907, at the tender age of 18 ½, as an Assistant Accountant General in Calcutta. Driven by an irresistible urge to do scientific research Raman discovered the Indian Association for Cultivation of Science, soon after he arrived in Calcutta. From 1907 to 1917 he conducted experiments at the Laboratories of the Association during his leisure hours, which meant most mornings, evenings and weekends, and he published a stream of papers in the *Bulletins* of the Association and in foreign journals. His outstanding work on the acoustics of musical instruments and optics earned him name and international fame. Soon, students and disciples started gathering around him for participating in scientific research, and the Raman School of Physics came into being. This may be called the first phase and Raman's entry into physics seriously.

In 1917 Raman was offered the Palit Professorship at the Calcutta University by its distinguished Vice Chancellor Sir Asutosh Mukherjee. Raman gave up the lucrative government job and took up the Palit Professorship for a fraction of the salary that he was getting as an Officer of the Finance Department. Thus from 1917 Raman's career entered the second phase and he now became a full time researcher and a teacher at the Calcutta University. He took full control of the laboratories of the Indian Association for the Cultivation of Science as well as the laboratories at the Calcutta University. From 1917 to 1933 Raman held the Palit Professorship of the Calcutta University and it was during this period he took to light scattering studies which culminated in the discovery of the Raman effect.

Raman showed an uncommon ability for independent thinking right from the beginning and gave up a lucrative government job in favour of a scientific career

In 1933 he left Calcutta to become the Director and Professor of Physics at the Indian Institute of Science, Bangalore. He remained at the Institute of Science until his retirement in 1948. During this period Raman took a large number of students, trained them in research and launched them as physicists. He started the physics department and initiated research in several branches of physics; optics, spectroscopy, light-scattering, ultrasonics, x-ray diffraction. The period from 1933 to 1948 may be called the third phase in Raman's scientific life.

In 1949, after retirement from the Indian Institute of Science, Raman founded the Raman Research Institute for the purpose of pursuing his scientific interests, without the shackles of bureaucratic constraints. He took a few students in the beginning but that was only a trickle compared to the previous phases. He carried out research on the colours of gems and minerals, floral colours, diamonds, physiology of vision and a host of other topics in which he was interested. Whatever interested him became a topic of his study. He gave lectures on such diverse subjects as clouds, weather, atmosphere, vision, earthquakes, sound and hearing, apart from lectures on his scientific research studies. His customary Gandhi Memorial lecture every year in October became an event in Bangalore, when scientists and laymen heard Raman speak with great enthusiasm and fervour. Groups of college students and high school students visited the Raman Research Institute to have a darshan of the great scientist. His museum collection enthralled them. The Raman Research Institute itself with Raman as its central figure became a Mecca of science. A visit to this Institute and seeing Raman and talking to him became the most inspiring experience for anyone, particularly young students of science. Raman was an active scientist until the very end. Only for a month or so towards the end he had to be kept away from his beloved Institute. This may be called the fourth and final phase.

Raman was a staunch nationalist and was proud of his Indian heritage and its past achievements. He admired Mahatma Gandhi and Jawaharlal Nehru although he did not agree with all their policies. In the matter of scientific research he insisted that Indian scientists should not be camp followers and imitate what is being done in the west. He has proclaimed too often that what one does should not only be original but also be relevant to India's needs when it comes to application of research. He was opposed to Indian scientists going abroad for advanced research and believed that it impeded originality of thinking. It is difficult to say whether he was right or wrong but it is a fact that independent India is yet to produce scientists of Raman's caliber, although the money spent on scientific research is enormous compared to the Raman's days. Raman was a man of emotion and could get violently angry. But he had an incredible sense of humour and could keep an audience roaring with laughter just describing what could have been commonplace incidents. Anyone who met him could not but be struck by his zest for life. His exuberance was infectious. Chatting with him for some time was like taking tonic. To him scientific activity was the fulfillment of an inner need. His approach to science was one of passion, curiosity and simplicity. Science was to him a personal endeavor, and aesthetic pursuit, and above all joyous experience.

Raman as a classroom teacher

I quote from L.A. Ramdas' article on Raman as a classroom teacher "Prof. Raman, as a Palit Professor had no teaching responsibilities, but he enthusiastically took part in M.Sc. teaching. He held the view that when a leading research worker takes on some special teaching course, he brings to his teaching the freshness of research and the questioning attitude which makes all the difference between dull pedagogy and inspired teaching. To some of us who had joined the M.Sc. course at Calcutta (both myself and the late Dr. K.S. Krishnan had joined the M.Sc. course

in physics at Calcutta by 1920) Prof. Raman once made the side remark that the best way for him to master or revise any subject in physics was indeed to lecture on it to the M.Sc. classes.

"The M.Sc. teaching used to be naturally shared by the various Professors and Lecturers. Prof. Raman took 'Electricity and Magnetism' in the year 1920-21 and 'Physical Optics' in 1921-22. Both sets of M.Sc. students felt that they were indeed listening to a type of inspired teaching to which was brought all the original flavour and excitement of the great giants of the past who had built up the subject under treatment. In listening spell-bound to Prof. Raman's lectures in 'Electricity and Magnetism', covering a series of nearly 30 lectures, we had shared with him much of the excitement and superb thrill that Benjamin Franklin, Oersted, Arago, Gauss, Faraday, Maxwell, Hertz, Lord Kelvin and many others must have felt while they were making their actual discoveries. This was indeed no routine text-book learning, but reliving the actual past history of the subject. Almost regularly, Prof. Raman with his genius for the subject, his extraordinary eloquence, imagery and fullness of precise expression used to forget himself as well as the time and used to lecture for far more than the prescribed one hour, while the next lecturer had to politely (and perhaps with a sense of relief) retire from the scene after seeing Prof. Raman still at his lecture! Often he used to take the entire forenoon, more than 2 and sometimes even 3 hours—such was his tremendous love of teaching. The mathematics was worked through often with his own improvised simplifications and fully illustrated with physical analogies. Any question or point raised by a student would start off towards uncharted grounds, not touched upon in any text-book. His ready wit and sparkling intellect were a treat to the classes. And after each lecture we used spontaneously to look up original papers and classical treatises like Maxwell's *Electricity and Magnetism,* J.J. Thomson's *Conduction of Electricity,* Faraday's *Experimental Researches,* Lord Rayleigh's and Kelvin's *Collected Papers* and so forth. The lecture in which he worked out Maxwell's field equations and showed that light waves are only electromagnetic waves and the thrill he communicated to the class are still fresh memories.

"In physical optics, a topic on which he himself was conducting several investigations at the time, the students were introduced to all the topics coming, as it were, hot from the 'Lab' and the lecturer's flair for dipping straight into the works of great masters like Huygens, Fresnel, Mascart, Schuster, Wood, Rayleigh, and others of the late 19th and the early twentieth centuries imbued the students with a real love and enthusiasm for what they learned at Prof. Raman's feet, as it were. Whether the subject was Thermodynamics, or the Kinetic theory of gases, or Modern physics, Prof. Raman's treatment of the topic at hand was original and inspiring and left a permanent impression in the student's mind.

"Now let me record a few reminiscences. As an M.Sc. student having direct and free access to Prof. Raman's own personal library, I was astounded to discover that in each and every text book from which he had learned in his own student days, there were marginal criticisms or appreciations of the author. There was no book in which every example and question had not been worked out by Raman. Some questions had the side remark "excellent", while not a few were apostrophized as "elementary" or "silly"! I had no doubt that Prof. Raman had been a most painstaking student and that the definition of 'genius' as the 'capacity to take infinite pains' is indeed true."

Professor Raman thus fully participated in teaching and inspired his students with his enthusiastic lectures. M.N. Saha who later became famous for the "Ionization equation" named after him and S.N. Bose, discoverer of "Bose statistics" were some of the other lecturers at the university college in 1917.

He was opposed to Indian scientists going abroad for advanced research and believed that it impeded originality of thinking

Professor extraordinary

The period between 1920 to 1928 may be said to be the golden period in the scientific life of Raman. With the combined control of the Association and the University Laboratories he had a hectic schedule. L. A. Ramdas has summarized this activity as follows:

"The daily activities at the laboratories of the 'Association' usually started by 7 a.m. Having started an experiment, one would go on working until 1 p.m. After a quick lunch the scholars would be back by 2 p.m. and work on far into the evening and often until 9 or 10 p.m., until the job on hand had reached a satisfactory stage. Working at this furious rate it is no wonder that many of the pupils could work through 5 or 6 major investigations each year. Those who could not cope with such a fast tempo of work would automatically drop off.

"By 1920, Prof. Raman had gathered round himself an increasing number of extremely bright and capable pupils so that, more and more, he could get his research programme executed rapidly by them. He inspired his scholars to use their own initiative and ingenuity to the fullest extent. He would see what was going on and discuss results at intervals. At any given time, however, he would concentrate his attention on the particular scholar who was then entering the most critical phase of his research. Interpretation of results, fruitful suggestions to carry the investigation several stages further and quick discussion of results already obtained resulted in an immediate publication from this effective type of collaboration between the Professor and the pupil. Each of his pupils had his opportunity for such exhilarating collaboration at the developing phase of his investigation. All the time, the

pupils enjoyed the fullest freedom to think, work and improvise for themselves. Spoon-feeding of any kind was absolutely taboo. A spirit of perfect understanding and goodwill pervaded the entire 'Association', with Ashu Babu, the Assistant Secretary, ever ready to help us with any material or facility that we needed, the scholars themselves helping each other spontaneously."

Raman very much maintained the above mode of working and dealing with students throughout his career. Anyone who wished to work under Professor Raman as a regular student had to undergo a searching oral examination in which the candidate's knowledge of fundamentals and capacity for original thinking would be severely tested. Although Raman attached importance to academic records, he always made his own assessment. Once selected, the students felt at ease and he was kind and large-hearted. He had his own way of developing self-confidence and self-reliance in them. He would treat them as his equals, while discussing scientific matters. It was his habit to go round the laboratory every morning, meeting each student, discussing the progress of his work and often suggesting new ideas. He would give free expression to his joy when a new result was brought to his notice. Nagendra Nath, an illustrious pupil of Raman says "One day when I told him that I had found the explanation of the Raman line in diamond which had been mentioned by him as an outstanding problem in his Nobel address, he asked me what it was. I said that the Raman line was to be attributed to the mutual vibration of the two face-centered lattices composing the diamond lattice; he simply yelled out, "You are right, you are right," and insisted that the research paper should be immediately written up. He was in ecstasy over this work. I found myself elected to the Fellowship of the Indian Academy of Sciences, at the age of 23, of which Professor had given no inkling to me."

Raman's students came from all over India. He chose them on the basis of merit and shaped them into scientists who went out to carry on the tradition of research wherever they went and worked in their subsequent career. Throughout his life he had a very warm corner in his heart for his many pupils and they knew they could always look up to him for any help that they may need.

In his public lectures, he would refer to his students by name and talk about their work. All this was thrilling experience to young students and powerful incentive for hard work. A unique rapport was established between him and his students.

Raman as a lecturer

Raman excelled in public speaking and could give a lecture, for instance, on Egyptian History off his cuff. His scientific lectures were a treat and he was a superb entertainer. His lectures were replete with spontaneous jokes and were delivered in his high-pitched resonant voice which reached the entire audience (no loud-speakers necessary). Rich in imagery and eloquence, the lectures were rendered in so popular a style that every listener felt that he understood all the science that the learned lecturer was discussing. Once he told me that "the hallmark of a good speaker is that the audience must be under the delusion that they have understood everything that was said by the speaker." In the minds of thousands of his listeners, whenever he gave a public lecture, he used to create the illusion that they understood everything of what he spoke about.

Raman's typical way of giving a lecture is beautifully summarized by Kashyap. "A tall, turbaned figure, casting those searching and curious eyes almost with child-like fitfulness, would walk directly to the dais, with an occasional turn to the right or left, acknowledging a remark or answering a query by the sponsors of the lecture who were leading him to the dais. Confidence incarnate was the figure and even before he started speaking, one got the impression that here was a lecturer who would deliver the goods.

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"His very presence perhaps cut short the longwinded preambles and welcomes that often mar the beautiful effect of a nice lecture. Prof. Raman meant business and a disapproving look would stop a vagrant introduction. His first words uttered in a characteristically punching manner would set the pace for the lecture.

"He spoke of soap bubbles. And, mind you, for some half an hour the evanescent soap bubble that hardly lasts for a couple of seconds blissfully lived!

Raman asked 'Have you ever thought of keeping the soap bubble alive for a long time?' An intriguing question — a question that had never occurred to many. The problem you know, Raman went on to say, is to see that the droplet of water does not collect at the bottom. Then he went on to say how he and other scientists, some in France, managed to keep a soap bubble alive for a few days by subjecting the bubble to an oppositely directed force.

"One would never have a dull moment and would not even realize that the lecture is over. To listen to Raman was something more than learning physics. He had the knack of using the most appropriate expressions, which no textbooks could give. He had the habit of tugging the lapels of his coat which was a Raman characteristic. He would invite questions and answer them all with astounding clarity."

He was forthright when he criticized. During the annual meeting of the Indian Academy of Science in Baroda in 1958, he interrupted the talk of a high-energy physicist who was filling the blackboard with mathematical equations and

said "my dear fellow please try to explain what you have done in a few sentences. If you cannot do this, it is not worth knowing."

Concluding remarks

No single person has done so much for Indian science as Raman. Through personal example of his highest dedication to science, through his success as a teacher-cum-leader in training generations of physicists who in turn have created independent schools of research, through creating scientific Institutions and facilities for research and founding scientific Academies and Journals for dissemination and propagation of science and through his gift of eloquence which served to inspire and stimulate a widespread interest in science, Raman as a single individual has tremendously influenced the progress of science in India.

He was one of the rare breed of men who are no more, who ranged freely in all fields of science from physics to chemistry to biology. Raman stands alone as the greatest scientist that India gave to the world. Just as our poet Valmiki in describing the battle between Rama and Ravana has said in the great epic *Ramayana* "The sky is comparable only to the sky, the ocean only to the ocean and the battle between Rama and Ravana only to the Rama-Ravana yuddham (battle)," in modern India, Raman is comparable only to Raman.

C.V. Raman—Honours and Awards

1. Gold Medal for standing first in M.A. Exam. of Presidency College, Madras—1901
2. Elected Fellow of the Royal Society of London—1924
3. Mateuchi Medal (Rome)—1928
4. Knighted by the British Government—1929
5. Hughes Medal of the Royal Society—1929
6. Nobel Prize in Physics—1929
7. Appointed First Indian Director of the Indian Institute of Science—1933
8. Appointed First National Research Professor of Physics—1949
9. Franklin Medal of the Philadelphia Institute—1951
10. Bharat Ratna—1954
11. International Lenin Prize—1957
12. Appointed Member of the Pontifical Academy of Sciences by Pope John XXIII—1961