CHANDRASEKHARA VENKATA RAMAN

1888–1970

Elected F.R.S. 1924

I. Early years

Education

Chandrasekhara Venkata Raman was born at Trichinopoly in South India on the 7 November 1888. Raman's parents, Chandrasekhara Iyer and Parvati Ammal, lived at that time in what was then called the province of Madras, a part of India now known as the Tamil Nadu. The family, for many generations, had been pursuing the profession of agriculture and were of moderate means. Family traditions in those days were such that if anyone attempted to break off from them, it would have been regarded as a bold step. Raman's father did take such a bold step when for the first time in the family, he took to teaching in the local English High School. This bold step was followed by another when Mr Chandrasekhara Iyer decided to accept the post of lecturer in physics and mathematics at the Mrs A. V. N. College, Vizagapatam; Raman was then four years old. Vizagapatam, now known as Visakhapatnam, is a sea-port town on the east coast of India and situated in the State of Andhra Pradesh. Thus, the parents and with them the four-year-old son moved to Vizagapatam. The next ten years of Raman's life were spent at Vizagapatam, where he studied for eight years in the High School and two years in the College. He passed the Intermediate examination in 1902, enabling himself to join for a university degree course. In January 1903, he moved to Madras and joined the Presidency College. He passed his B.A. degree examination in 1904, winning the first place and a Gold Medal in physics. He passed the M.A. degree examination in 1907, again obtaining a first division and record marks.

It is noteworthy that while he was still a student and an undergraduate at the Presidency College, young Raman felt the urge towards scientific research and undertook original investigations in acoustics and in optics. Research in modern science in those days was quite unknown in India and it was unusual for an undergraduate to have not only evinced such interest but also to have published the results of his work in well-known international journals. Raman's first research paper was on 'Unsymmetrical diffraction-bands due to a rectangular aperture', observed when light is reflected very obliquely at the face of a prism. The paper was published in the *Philosophical*


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Magazine in November 1906 and it is interesting to see that it was communicated by the author himself and contains no acknowledgement for any kind of help received from anyone else. Thus, it is clear that Raman was already standing on his own legs and building up confidence in himself. This was followed by another note in *Nature* in 1907. Raman was in his eighteenth year when he contributed these publications, on all counts an early manifestation of special talent.

During his work and in all his contacts with his colleagues and teachers as an undergraduate, he displayed an inquiring and restless mind with a sharp and incisive intellect so that he was regarded as an uncommon student. It was quite clear, even at that time, to many who came into contact with him that he was cut out for a scientific career and was destined to reach great heights. However, circumstances and conditions in India, rather than his own tastes and talents, led young Raman to temporarily choose, after graduation, a career involving administrative duties in the service of the Government of India.

Marriage

While still awaiting a posting in the Government, Raman married Loka Sundari Ammal, who later proved to be a worthy and life-long companion to him. Those who have known her through the decades that have since gone by, had often said that her principal interest in life was to enable Professor Raman to carry on his scientific work with efficiency and in an uninterrupted manner. Lady Loka Sundari Raman is highly talented in her own right and possesses a flair for mastery over several languages. Seldom did she permit projection in the public of her own personality as distinct from that of her husband. This aspect of hers, besides being in line with the best of Indian traditions, was so noticeable on occasions that she drew the admiration of all concerned. On several journeys she had travelled widely with Professor Raman and looked after him with great and loving care. They had two sons, Chandrasekhar and Radhakrishnan, born in the years 1921 and 1929 respectively. Lady Raman has survived Sir Venkata Raman and she continues to live in and look after the Raman Research Institute at Bangalore.

Service in the Finance Department

One of the reasons which made Raman choose in the first instance a career in the Government was that pursuit of science in India at that time offered little inducement to young and talented persons. Most college professors used to advise the bright graduates of each year to appear in one or other of the competitive examinations conducted by the government for recruitment to different types of civil service. Raman appeared for the competitive examination held in February 1907 and secured a first-class therein. Thus he joined the Indian Finance Department as an Assistant Accountant-General at Calcutta in June 1907. The next ten years of his life were spent as an officer of the Finance Department. It was fortunate that a great part of those ten years was spent in Calcutta, although immediately after joining, he was transferred for a while to Rangoon and then to Nagpur.

It is interesting to see that, though the duties of his office occupied most of his time, Raman sought and found opportunities to not only keep up his interest in science, but also to conduct experimental investigations, sometimes under difficult and improvised conditions. While in Calcutta, by a chance look at its sign board while on his way to his office, he came to know of the existence in Calcutta of a privately endowed scientific institution by the name of the Indian Association for the Cultivation of Science. This Association was founded in 1876 by Mahendralal Sarkar, and at the time when it attracted the attention of Raman, Amritlal Sarkar, son of the founder, was the Association's Secretary. This Association was later to become the working place for Raman for many years and indeed it was while working in that institution that he conducted many experiments over many years which led to the discovery of the Raman effect. Even during the short spells of his stay in Rangoon and in Nagpur, he never gave up pursuit of science but continued his investigations. During this period of Government service, he contributed about 30 original papers in different branches of physics to *Nature*, to the *Philosophical Magazine* and to the *Physical Review*.

There is a story, still being recalled by a citizen of Nagpur whose collection of a few hundred-rupee notes was nearly burnt by a blazing fire. The perturbed individual went to the Accountant-General's office and presented the half-burnt bundle, but with little hope of retrieving any. Any other officer would probably have shown him the door, but Raman who was then in the office of the Accountant-General, took the trouble to scrutinize the notes under a magnifying glass, one by one, and instructed the treasurer to give him fresh notes. Raman argued that the numbers on the half-burnt notes were visible and thus it was a genuine case.

During his part-time link with the Indian Association for the Cultivation of Science, he came into contact with Sir Asutosh Mookerjee, then judge of the Calcutta High Court and an active member of the Association. Sir Asutosh was also the Vice-Chancellor of the Calcutta University. Raman's successes in scientific research during the period 1907-1917, besides attracting the academic circles in India and abroad, also attracted the attention of Sir Asutosh Mookerjee. That was the time when the University Science College was just being founded in Calcutta and special chairs were being established with the help of generous donations from various philanthropic persons amongst whom, Sir Taraknath Palit was one. When Sir Asutosh wanted a Professor, capable of filling the newly-created Palit Chair of Physics, he thought of Raman and offered him the post. Although Raman knew very well that from a pecuniary point of view, he would be a great loser, with scant regard to the monetary handicap which he would be bringing upon himself by accepting the professorial assignment, Raman joined the Calcutta University as Palit Professor of Physics and bid good-bye to administration and government service in 1917.

In this connexion, while announcing his plans for filling the chair, Sir Asutosh Mookerjee stated that, 'For the chair of Physics created by Sir Taraknath Palit, we have been fortunate enough to secure the services of Mr Chandrasekhara Venkata Raman, who has greatly distinguished himself and acquired a European fame by his brilliant researches in the domain of Physical Science, assiduously carried on under the most adverse circumstances amidst the distraction of pressing official duties . . .

'I shall fail in my duty if I were to restrain myself in my expression of the genuine admiration I feel for the courage and spirit of self-sacrifice with which Mr Raman has decided to exchange a lucrative official appointment for a University Professorship, which I regret to say, does not carry even liberal emoluments. This one instance encourages me to entertain the hope that there will be no lack of seekers after truth in the Temple of Knowledge which it is our ambition to erect.'

II. The Golden Era of Calcutta (1917-1932)

Indian Association for the Cultivation of Science

Professor Raman left government service and joined the University of Calcutta as Palit Professor of Physics in July 1917. In 1919, following the death of Amritlal Sarkar, Raman was elected as Honorary Secretary of the Indian Association for the Cultivation of Science, then situated in a dusty old building at 210 Bow Bazar Street in Calcutta. This was one of the most crowded parts of the city and yet Raman chose to live in a house so close to the Association that he could literally walk into his work by opening a back door, any time of the day or night. Indeed, he used to do so very often, and his whole time was thus available for scientific work. He had at his disposal the facilities and the resources of both places, namely, the Department of Physics in the University College of Science of the Calcutta University and the Indian Association for the Cultivation of Science. His position as Honorary Secretary gave him full control of the resources of the Association and proved to be of great value and help to him for the development of his scientific activities.

Professor Raman used frequently to refer to this period as the golden era in his career, Many young men gathered round him both at the University College of Science and at the Indian Association for the Cultivation of Science. The latter in particular was the scene of intense scientific activity and several of the research students used to stay inside and around the Association premises so as to be in a position to avail themselves of the meagre facilities as and when they were released by other workers. There were no fixed hours for work nor was it the tradition to observe any closed days. Raman, by his personal effort, steadily improved the resources that were available. He sought and obtained monetary help from many sources. During this period, he attracted some devoted scientists from all over India, who proved to be a succession of gifted collaborators. This enabled Raman to push forward steadily with his investigations. At that time, some of the areas that interested him were vibrations and sound; theory of musical instruments; optical studies such as diffraction, colours and interference; colloids; molecular scattering of light; X-rays; magnetism and magneto-optics, and so on.

The Raman effect, which was discovered in early 1928, stood on a different footing. That naturally became the area of his principal interest in the last four years of that era and literally the place was filled with spectrographs, mercury lamps and several young men working day and night on some aspect or other of the newly-discovered phenomenon.

Travels abroad

Professor Raman made his first brief visit to Europe as a delegate to the Universities Congress held in the summer of the year 1921 at Oxford. It is to be noted that by this time, he had already published numerous papers and his work was fairly well known in scientific circles. It was during this voyage, while travelling on board a steamship, that Raman's attention was first drawn to the problem of the origin of the blue colour of the Mediterranean. He conceived the idea that the colour of the deep sea is partly or even largely to be attributed to the molecular scattering of light by the waters of the sea. Observations made by him during the return voyage again confirmed this hypothesis and as we shall see later, these observations became the starting point for the detailed investigations which he undertook on the scattering of light by liquid, solid, and gaseous media. Such studies were undertaken during the seven years that followed.

His next trip abroad was in 1924, when he was invited to join the British Association for the Advancement of Science in a tour across Canada. He was a guest speaker at a Scientists' Convention in Canada and was requested to open a discussion on the scattering of light at Toronto. During that visit, Raman extensively toured Canada, U.S.A., England and Norway. At the invitation of Professor Millikan, Raman stayed on and served as Visiting Professor for four months at the California Institute of Technology. He attended the Centenary of the Franklin Institute of Pennsylvania as the representative of India and returned to India in 1925. During the same year, he again visited Europe as a guest of the Russian Academy of Sciences to represent India at the bi-centenary celebrations of the Academy in Leningrad and Moscow. In 1929, Raman was invited by the Faraday Society to open a discussion on Molecular Spectra which was held in Bristol. During that visit, he visited and lectured in several other places in Europe. Subsequently, he again visited Europe to receive the Nobel Prize at Stockholm in 1930; to receive the Honorary Doctorate at Paris in 1932; to take part in the International Congress of Physics at Paris and Bologna in 1937;

to participate in the twentieth anniversary celebrations of the discovery of the Raman effect at Bordeaux in 1948; and so on and so on. On each occasion, he lectured at other centres of research and made many personal contacts with friends and scientists of several countries.

Awards and Honours

Raman was a highly successful teacher and investigator. His lectures were very lucid and invariably attracted large numbers of students. These qualities as well as his varied scientific achievements received world-wide recognition. The Royal Society of London elected him to its Fellowship in 1924. The British Government in India conferred a Knighthood on him in 1929. He received the Nobel Prize for Physics in 1930. He was awarded the Matteucci Medal by the 'Societa Italiana della Scienza' of Rome in 1928. The Royal Society of London gave him the Hughes Medal in 1930. In 1941, the Franklin Institute of Philadelphia awarded the Franklin Medal to Raman. The citation on that occasion, amongst other things, said that the award to Sir C. V. Raman was in recognition of his many brilliant contributions to physical science and of his leadership in the renaissance of scientific work and scientific education that has occurred in India. The Soviet Union honoured him with the International Lenin Prize in 1957.

Several Indian Universities among which are the universities of Calcutta, Bombay, Madras, Benares, Dacca (at that time in India), Allahabad, Patna, Lucknow, Osmania, Mysore, Delhi, Kanpur and Sri Venkateswara had conferred Honorary Doctorates on him. Among the Universities outside India, mention may be made of the University of Freiburg which conferred the Hon. Ph.D. degree and the University of Glasgow which conferred the Hon. LL.D. in 1930. He also received the degree of Hon. Sc.D. of the University of Paris in 1932.

He was an Honorary Member of the Deutsche Akademie of Munich, of the Zurich Physical Society, the Royal Philosophical Society of Glasgow, the Royal Irish Academy and of the Hungarian Academy of Sciences. He was an Honorary Member of the Indian Science Congress Association as also of several other Indian Science organizations. He was General President of the Indian Science Congress in 1929, and has been President of the Indian Academy of Sciences since its foundation in 1934 until his death. He was a Foreign Associate of the Academy of Sciences of Paris and a Foreign Member of the Academy of Sciences of U.S.S.R. He was Honorary Fellow of the Optical Society of America and the Mineralogical Society of America; an Honorary Member of the Academy of the Socialist Republic of Romania and of the Catgut Acoustical Society; a Member of the Czechoslovak Academy of Sciences. In 1961, Pope John appointed him a member of the Pontifical Academy of Sciences.

Amongst the many Indian distinctions he received, special mention may be made of the title and decoration of 'Rajasabhabhushana' conferred by the Maharaja of Mysore in 1935. This is a colourful title for, when literally translated, it would read as The Jewel of King's Court. In 1954, the Government of India awarded the title of 'Bharat Ratna' to him, the only Indian scientist to have been thus honoured.

Scientific work at Calcutta

While at Calcutta, Raman's own work as well as that of other workers in his laboratories, mostly young aspirants for the doctor's degree from different parts of India, covered diverse branches of physics. As a general observation, it appears fairly correct to say that there was a definite bias towards experimentation and that the two areas of acoustics and optics received more attention than any other.

Raman started work in acoustics by interesting himself with the physical theory of musical instruments, particularly of the violin family. This involved a study of the vibrations of stretched strings in great detail. He made fundamental contributions to the motion of the bowed point and the effect of the bridge in coupling the motion of the string to the body of the violin. Later, he worked on the Indian drums—the *mridangam* and the *tabla*. He made the remarkable observation that these drums possess harmonic overtones—a discovery which did not fit easily with the fact that the drums have a circular membrane. It was known that the frequencies of vibration of a circular membrane are not harmonic. He quickly found that the Indian drum heads have a peculiar feature in that they are loaded by sticking at an appropriate place on the membrane, varying amounts of soft material and that this kind of loading results in a harmonic structure for the overtones.

Amongst his early publications dealing with his work in acoustics, mention may be made of Bulletin No. 15 in a series of bulletins which he used to publish on behalf of the Indian Association for the Cultivation of Science. This was an elaborate and richly illustrated memoir embodying the most important scientific contribution of those years, viz., a fully worked out physical theory of musical instruments of the violin family and an experimental verification of the results thereof. Some years later, he was asked to contribute an article on the physics of musical instruments to the *Handbuch der Physik* and he did so for the eighth volume of that serial published in 1927.

Undoubtedly, his best-known scientific work done during that period was in the field of optics generally and about the phenomenon of scattering of light in particular. Commencing with a critical observation of optical effects like the coronas, glories and haloes; studying the diffraction of light by emulsions and by colloidal solutions, passing through similar studies by molecules such as transparent media like liquids and gases and after adopting many original approaches, his work in those years had culminated in the discovery of the Raman effect. In December 1930, when awarding the Hughes Medal of the Royal Society to Sir C. V. Raman, Lord Rutherford said:

'Sir Venkata Raman is one of the leading authorities in optics, in particular on the phenomenon of the scattering of light. In this connexion, about three years ago, he discovered that the light's colour could be changed by scattering. This had been predicted some time before, but in spite of search, the change had not been found. The 'Raman effect' must rank among the best three or four discoveries in experimental physics in the last decade; it has proved and will prove, an instrument of great power in the study of the theory of solids. In addition to important contributions in many fields of knowledge, he has developed an active school of research in physical science in the University of Calcutta.'

When Raman commenced the work around 1921, it was known that light is diffused laterally with varying degrees of intensity by matter in all states of aggregation. When a beam of white light is condensed by means of a lens into the centre of a large glass bulb containing a dust-free liquid like benzene, an observer who shields himself from the direct rays of the source and views the track in the liquid in a transverse direction, will at once see a magnificent blue scattering. This rather easily performed experiment was always explained by attributing the blue colour to a relative enhancement of what is already present in the source. It was not expected that during the process of molecular scattering, it was at all possible that in addition to what is present in the source, light of frequencies not present in the source can be generated and therefore detected in the scattered beam. Professor Raman, by using a simple device of inserting appropriate filters in the paths of incident and scattered beams in the beginning and by using monochromatic sources later, discovered that some new frequencies not present in the incident light appear in the scattered beam as a result of, so to say, interaction between molecules of the illuminated substance and the incident radiation. Thus, in the spectrum of the light scattered by a substance, the Raman effect discloses itself by the presence of new lines adjacent to the original lines of the incident light. The effect may be briefly defined as follows: When a transparent substance is radiated with monochromatic light, a portion of the incident radiation is scattered by the substance in all directions. While a large part of the light thus scattered possesses the same frequency as that of the incident radiation (Rayleigh scattering), a small fraction thereof consists of light which undergoes a change of frequency (Raman scattering), the extent of change being characteristic of the substance.

It is best to quote here what Professor Raman himself wrote, nearly 40 years after the discovery, about how he was led to make the discovery.

'Later, I became aware of the remarkably brilliant monochromatic illumination which could be obtained by the aid of the commercially available mercury arcs sealed in quartz tubes. Towards the end of February 1928, I took the decision to make use of such lamps for all further studies in the field of light-scattering. The success which attended this forward step was immediate and highly gratifying. Experience in working with sunlight indicated the technique necessary for the observation of extremely weak phenomena, viz., the rigorous exclusion of stray light and the conditioning of the observer's vision by a prolonged stay in darkness. On setting up the apparatus and making these preparations, I found that the light of the mercury arc diffused by various materials when examined through a direct vision spectroscope showed the presence, besides the lines of mercury, also of other lines the positions of which varied with the substances under study. Amongst the numerous materials thus examined was a large block of clear ice. This showed sharp displaced lines in the spectrum of the scattered light in approximately the same positions as the rather diffuse bands observed with pure water. Within a few days of the discovery, photographic spectra were successfully recorded in which the additional lines showed up very clearly.'

It is of a particular significance that the equipment which Professor Raman employed consisted of three items, a mercury lamp, a flask of benzene and a direct vision pocket spectroscope, all of which would be regarded as crude instruments, even at that time. He always took pride in the fact that his researches never involved costly equipment. On one occasion, he is said to have remarked; 'The essence of science is independent thinking, hard work and not equipment. When I got my Nobel Prize I had spent hardly Rs.200/– on my equipment.'

III. He Moves to Bangalore

Indian Institute of Science

In April 1933 Raman left the Calcutta University and accepted a call from the Indian Institute of Science at Bangalore in South India to become its Director. Bangalore is one of the attractive cities of India and has a salubrious climate. The move came as a welcome change to Raman who, by that time had lived for the previous twenty-five years, not only in the crowded city of Calcutta but also in one of the most crowded parts of that city. It is understandable that ever since then, Raman made Bangalore his permanent home. He continued to stay in Bangalore even after retirement from the Indian Institute of Science. He built an Institute of his own in Bangalore, now known as the Raman Research Institute. He used to make frequent references to the beautiful environment which the city provided and seldom moved out of Bangalore, during his later years.

The Indian Institute of Science, a premier scientific Institution of India and founded in 1909, seemed at first as if it was going to provide afresh a venue for Raman's scientific activities. Physics was not a subject of study at the Institute and the management took the very wise step indeed of creating a Department of Physics, built around Raman soon after he moved to Bangalore. However, serious difficulties between Raman and the management quickly showed up and the former was obliged to give up administrative duties, relinquish the post of Director and accept continuing as Professor of Physics. This he did till 1949. It may be said that his association with the Indian Institute of Science was not a happy one and did not produce the results which the Institute hoped it would, when they invited Raman to become its first Indian Director. The individuals who were connected with the management of the Institute and the course of events during that period left such a nostalgic impression on Raman's mind that in later years, whenever he referred to them in retrospect, he was very bitter. However, looking back over the past, one feels that the enforced isolation did enable Raman to devote all his time to physics. During that period, he started new lines of work and attracted several young scientists to the Institute. His presence there for over 15 years was responsible for the establishment of an excellent school of physics in South India. He trained a band of first-rate physicists, several of whom are today holding important positions all over the country. While writing about Raman and the Indian Institute of Science, one cannot fail to notice that he joined the Institute almost immediately after discovering the Raman effect, after having been awarded the Nobel prize for physics and in fact when he was at the peak of his scientific form. Thus, the conflict between individual greatness and institutional interests became a difficult one to resolve and it happened that he always turned out to be the better known when it became a matter of juxtaposition.

His new scientific interests

One of the areas, in which he made significant contributions, during the early years of his work at the Indian Institute, is on the diffraction of light by high-frequency sound-waves. When a beam of light traverses a liquid cell in which sound-waves of high frequency are maintained with the help of a piezo-electric oscillator, interesting diffraction effects are noticed and several papers relating to these effects were being published at that time. It was at a chance discussion of such effects that Raman asked several questions and suggested a way by which the phenomenon should be explained. Then followed a series of papers by himself and Nagendra Nath, wherein what is now called the Raman–Nath theory of diffraction of light by ultrasonic waves was developed. This treatment not only explained fully the observed effects but led to several interesting new ideas. Those of his colleagues who saw him tackle this problem, clearly noticed in it a case in which physical intuition got the upper hand in pointing the way for mathematical logic to follow and build an exact theory. Professor Raman frequently adopted this method and quite often with resounding success.

During that period, he started work on a special type of X-ray reflexions. He found that when a beam of X-rays traverses a diamond plate, the octahedral planes of the crystal exhibit well-defined reflexions of the monochromatic X-radiation. These reflexions appear in positions well removed from the ordinary Laue reflexions of white radiation by the same planes. He concluded that in this phenomenon, we are concerned with X-ray reflexions of a second kind having a dynamic origin. Diamond exhibits such reflexions very conspicuously, while other crystals too have since then been found to show the phenomenon, but less conspicuously.

Many other areas, notably in optics, such as the luminescence of fluorspar, colours of stratified media as are found in iridescent crystals of potassium chlorate, optical effects caused by the twinning in felspars, etc., continued to engage his attention. Besides, problems in light scattering and Raman effect which were being studied on a continuing basis, constituted a part of the regular programme in his laboratory.

When on retirement, he left the Physics Department of the Indian Institute of Science in 1948, such good facilities for experimental work in several of the areas that interested him had been built up that he left behind him a very well-equipped laboratory.

The Indian Academy of Sciences

One of the significant developments, on a national scientific level, which resulted from the move of Raman to Bangalore is the establishment of the Indian Academy of Sciences. Professor Raman took steps in the year 1934 to establish an Academy, having distinguished men of science drawn from various parts of India and who were active participants in research work as its foundation fellows. He was elected founder President and continued to be elected President of the Academy until his death. In the year of its foundation, he arranged for the issue of the first numbers of the *Proceedings of the Indian Academy of Sciences* in two sections, one for physical sciences and another for biological sciences. Thereafter, they were issued as regular monthly periodicals devoted to the publication of the results of research workers in India. Bangalore was chosen as the headquarters of the Academy and there has been no parallel in the history of scientific periodicals in India to the unfailing regularity with which the *Proceedings* of the Academy were issued month after month during the 35 years of Raman's association with the Academy as its President. This naturally involved his having to devote much of his time and energy for this purpose. Nevertheless, he often referred to this effort with great satisfaction and a feeling of achievement. The Indian Academy of Sciences and the *Proceedings* issued on behalf of that Academy have been two noteworthy aspects of Indian science during the past three decades.

IV. Raman in the Raman Research Institute

Raman Research Institute

Professor Raman, anticipating his retirement from the Indian Institute of Science and having decided to settle down in Bangalore, took steps to bring into being an independent research institute in Bangalore where he could continue his scientific work. At his instance, the Government of Mysore made a gift to the Indian Academy of Sciences of a magnificently located piece of land. He collected some private benefactions during his tours in different parts of India, sufficient for the cost of a modest building. The construction of the building was commenced in the year 1943 and was completed in the year 1948. The building was occupied in 1949. A research institute, with Raman as Director and a small number of research assistants began functioning in the same year. Thereafter a great number of additional amenities were added and other structures raised. Sir C. V. Raman himself made substantial gifts of money and securities and also gifts of valuable immovable properties for the use and benefit of the Institute to enable it to function as an independent organization. The Institute, known today as the Raman Research Institute, by the name of its Founder-Director Sir C. V. Raman stands on an elevated site and amidst beautiful surroundings from which a panoramic view of the city of Bangalore can be obtained. The first floor of the main building in the Institute is occupied by museums, the library and a lecture theatre. The ground floor contains some research laboratories, the study room and an office for the Director. The museums consist of a very impressive collection, exclusively made by Sir C. V. Raman, of minerals, crystals, birds, butterflies, fossils and a great many other items of scientific interest. Anyone going through this museum will not fail to be impressed by the extraordinary interest which natural objects always evoked in Sir C. V. Raman. He was, indeed, a great naturalist and to him, the primary object of science was the understanding of nature. He was often called a child of nature, for he laboured unceasingly to probe into her inner workings and her hidden secrets. Those of us who were used to meeting him and talking to him in the Raman Research Institute recall vividly that wide-eyed and penetrating look of his and the infectious enthusiasm with which he used to expound the subject of his contemporary interests, to the nearly complete exclusion of all other topics during any conversation. This went on till the last day of his life. The Raman Research Institute is at present being managed by a small Board, constituted by him for that specific purpose, a little before he died.

His interest in diamonds

Raman had a great fascination for gemstones and the museum he built up at the Raman Research Institute contains some priceless specimens for study and research. In particular, his interest in the study of the diamond, of its remarkable physical properties and of its structure has been more or less a lifelong involvement with him. As long back as 1930, it was found that diamond exhibits a strong and sharp line corresponding to the frequency shift of 1332 cm^{-1} in its Raman spectrum, besides a complex luminescence spectrum, the leading feature of which is a band at 415.5 nm (4155 Å), its intensity varying enormously from specimen to specimen. With this as the starting point, Professor Raman built up his interest in diamonds to such an extent that at one time, every student working in his department was engaged in studying one aspect or other of the properties of diamond. Fluorescence, absorption, luminescence, birefringence, X-ray studies, specific heat, magnetic susceptibility, photo-conductivity, ultraviolet transparency, the Faraday effect and a host of other properties are amongst the several that were the subject matter of intensive studies by him and his collaborators.

He used to purchase, after a personal examination of each specimen, from auctions, shops and individual dealers, many diamonds and add them to his collection. In the museum at the Raman Research Institute today, are several hundreds of diamonds—some in their natural condition, some cut and polished, some cleavage plates, all of which altogether make up a unique collection probably unparalleled anywhere in the world as a laboratory acquisition.

His interest in the physics of the diamond was deep seated. It was both scientific and aesthetic. On many occasions, he gave expression to his views on the subject and as a specimen thereof, we may quote here from one of his writings. 'Diamond is a crystal of the cubic class and it is chemically an element. It exhibits the characteristic properties of the solid state in a superlative degree. Hence, by a study of its physical behaviour, one could hope to discover the principles which are the fundamental basis of crystal physics. It was these considerations which led me to build up a collection of some five hundred diamonds and utilize this material for investigations extending over a period of many years. Memoirs reporting the results have appeared from time to time in the *Proceedings of the Indian Academy of Sciences*.'

Amongst the many interesting conclusions he reached about diamonds are the following. Some diamonds belong to the tetrahedral class and others to the octahedral class of the cubic system. Those belonging to the tetrahedral class exhibit a visible luminescence of a blue colour when illuminated with ultra-violet light. In his collection is present a diamond of this kind which emits enough light in a dark room under ultra-violet irradiation to enable a newspaper held close to it to be read. Those belonging to the octahedral class, under the same circumstances, do not emit any visible light. He concluded that the luminescence is a property of the diamond itself and is not due to any extraneous impurity present within the crystal. His work relating to the special type of reflexion of X-rays from the octahedral planes of diamond has already been mentioned.

Sir C. V. Raman was aware that India was the original home of some of the well-known diamonds which found their way to other parts of the world and helped to spread the fame of this gemstone. A couple of years before his death, he spent a great deal of time studying the geography and the geology of the Krishna valley and of the rivers that flow in and around it, because it has been known that at one time 60 000 people were engaged in diamond mining operations in that area. He concluded that the story of diamonds in the Krishna valley need not be treated as a closed chapter having only historical interest. On the other hand, he felt that it may well prove to be a subject of practical importance at the present time if pursued vigorously with the necessary circumspection.

The last few years of his life

Isolation from other scientists in India, arising partly from his disappointment with the trends that the growth of science in India was showing and partly from his desire to devote himself wholly to his chosen lines of work, was a noticeable feature of the last few years of Raman's life. He was generally critical of the post-Independence scientific efforts in India but became strongly so as time went on and bitterly complained against the growing dependence of Indian scientists on foreign institutions for their equipment and support and even for their ideas. He disapproved of young men going out of India for building up scientific careers but, during the last two decades of his life, the times were such that the so-called brain drain was gaining momentum in India as in other similar developing countries. He disapproved of organizations spending large sums of money on equipment and often said that where there is creativity of mind, the magnitude of external tools did not matter. But the expansion in Independent India was such that large sums of money came to be invested on national laboratories and other Government-controlled scientific institutions. Thus, the widening gap between Raman's intuitive ideas and India's facts of life was a phase of his association with the Raman Research Institute. It is on record that when the late Jawaharlal Nehru, then Prime Minister of India, admonished India's scientists and asked them to come out of the ivory towers in which they had confined themselves, Raman reacted in a typically sharp manner and said 'The men who matter are those who sit in ivory towers. They are the salt of the earth and it is to them that humanity owes its existence and progress.'

A few years before his death, he ventured into a new field of scientific activity, although distantly related to his original interests like colour and optics. He asked of himself two questions, namely, How do we perceive light? and What is colour and how is colour related to the physical characters of light? These questions had been asked by many a man of science in the past and answers furnished, but Raman always preferred to look at a basic problem like that in his own way. He was, as a consequence, led to make several systematic observations. More than ever before in his life, he surrounded himself with nature. The colours of flowers from the extensively grown garden in the Raman Research Institute fascinated him at all times and were the subject matter of intensive studies by him. The culmination of that work was the publication of a treatise entitled *Physiology of vision*, just a couple of years before his death.

While he grew into being regarded and respected as the Father of Indian Science, the Government instituted National Professorships and conferred on him the first such Professorship to enable him to do the work that he liked while functioning as the Director of the Raman Research Institute. Towards the end, he became an 'Institution' in himself and as loneliness surrounded him, work became all that mattered to him in his life. When he fell ill, and was confined to bed, the end coming nearer and nearer, he told his doctors 'I do not want to survive my illness if it means anything less than a hundred per cent active and productive life'. Less than a couple of months before his death, he went up the first floor of the Raman Research Institute like a young schoolboy, delivered the Gandhi Memorial lecture on

2 October 1970—the last lecture he gave in his life wherein he expounded his ideas about the theory of hearing. This incident is more than proof that he not only believed in work, but also practised what he believed in, and was active till the very end. After a short illness, he died in the early hours of the morning of Saturday, 21 November 1970. His mortal remains were cremated in the grounds of the Raman Research Institute. Thus passed away Sir Chandrasekhara Venkata Raman, the legendary figure of science in modern India, into the pages of history. How much of the tradition and how many of the institutions he handed over to the present generation of Indian scientists will survive is a matter for the future and for those who have inherited the same.

Some general observations

There are some features in Raman's make-up that have been noticed and admired by those who came close to him as well as by those that knew him only from a distance. He was richly endowed with a child-like sense of wonder at the unknown and not understood facets of nature so that, throughout his life, he was pushed into exploring these aspects. Such being the motivation, he was often and appropriately referred to as the child of nature and nothing fascinated him more than nature herself. Subjects like colours, origin of minerals, birds and butterflies, the blue of the ocean, the sky and other natural phenomena were his primary concern. On the contrary, he could not reconcile himself with the fact that large human resources and material wealth are being put into programmes such as those that deal with space and so on, and do not concern themselves with things on earth and of immediate interest to mankind. He was a self-made man and had always set an example to his associates and students, of hard work, indomitable will and total dedication to science.

His intuitive abilities enabled him to jump several steps in mathematics. His capacity to expound complicated concepts in physics in a simple and appealing manner always made him a very popular speaker. Thus he attracted thousands of listeners whenever he gave public lectures. He was forthright when he criticized what he considered wrong or unscientific and by such action, he had hurt many a public man on occasions.

He was always more than generous in acknowledging the share of his co-workers, encouraged every deserving student that came to him and could never tolerate foolishness. He had a delicate sense of humour and was a great attraction when he chose to make an after-dinner speech. He loved art. He loved music. He lived, worked and died for science and in science.

Mr V. S. Ramaswami has helped in compiling the Bibliography. Lady Loka Sundari Raman very kindly read the script with a view to verifying the correctness of early biographical details. The photograph is from E.G.K. and Son of Bangalore.

S. Bhagavantam

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