widely regarded as the "father of the Indian dyestuff industry," Venkataraman was an author of the Baker-Venkataraman rearrangement of flavones. An institution builder, he nurtured first the University Department of Chemical Technology at Mumbai and then the National Chemical Laboratory at Pune into cutting-edge research centers. His own work, on the analytical chemistry of synthetic dyes, is among the definitive texts on the subject in the twentieth century.

Early Years. Born in south India, Krishnasami Venkataraman—KV to his friends—was the third child in a family whose members were noted for their impish, often mordant, sense of humor and their distinctive, husky voices. His father, Pudukottai Krishnasami, was a civil engineer and a Sanskrit scholar. His mother, Dharmambal, was a frugal and resourceful woman. Both parents were strict and the children were brought up in the old-fashioned style of those times, as soon as they graduated from university; at the same time they were taught to choose professions that exercised their minds and served the public good. This early training imbued the three brothers with a drive that led them to excel in their chosen fields. Venkataraman's older brother, Krishnasami Swaminathan, was a celebrated teacher and authorized editor of the Collected Works of Mahatma Gandhi; a project that he began in 1960 and relinquished thirty years later, shortly before the publication of the 100th volume in 1994. His younger brother, Krishnasami Sanjivi, was a legendary doctor and founder of the Voluntary Health Service of Tamil Nadu, the state where Madras was the capital.

Educated at Presidency College Madras and Madras University, where he received his bachelor's and master's degrees. Venkataraman went to Manchester University in England on a Madras government scholarship in 1923. There he was awarded the MSc (Technology), PhD, and DSc degrees. His research guide was a major figure in modern organic chemistry, the Nobel laureate Robert Robinson.

On his return to India in 1927, Venkataraman held a one-year research fellowship at the Indian Institute of Science in Bangalore. He then moved to northern India in 1928, taking the post of lecturer in Forman Christian College in Lahore (now in Pakistan). It was here that he made one of his most significant contributions to the field of organic chemistry in an article titled "A Synthesis of Flavones at Room Temperature," published in Current Science in 1933. By one of those fortunate conjoinatures in science, Wilson Baker published a similar synthesis of flavones and 3-acyclromones ("Molecular Rearrangement of Some O-Acylxyacetophenones and the Mechanism of the Production of 3-Acylromones") in the Journal of the Chemical Society at about the same time. The reaction that they both described came to be known as the Baker-Venkataraman rearrangement (see Figure 1), and it had immediate application to biologically active compounds.

Flavones are naturally occurring oxygen heterocycles. Their propensity to show biological activity has led to the development of many synthetic flavonoid drugs to treat or inhibit medical ailments. The Baker-Venkataraman rearrangement is a simple, two-step reaction through which substituted flavones can be formed. In the first step, 2-hydroxyacetophenone, or a derivative, is treated with an aromatic acid chloride to form an aryl ester. In the second step, the aryl ester is reacted with a base and transformed into a diaryl 1,3-diketone through an intramolecular rearrangement. When the intramolecular rearrangement product is treated with an acid, the reaction leads to the corresponding flavone.

A range of 2-hydroxyaryl alkyl ketones and aromatic acid chlorides can be deployed through a simple synthetic procedure in order to make a large number of substituted flavones and 3-acyclromones for medical use, especially as preventive mechanisms or disease inhibitors. Moreover, as Venkataraman showed, chalcones and flavonanes can further be oxidized by selenium dioxide, and benzyl o-hydroxyphenyl ketones can be cyclized to isoflavones by ethyl formate, thus widening the range of available medicinal applications.

The Baker-Venkataraman rearrangement continues to be one of the most effective and widely used methods of creating substituted flavones for medicinal purposes; it was, for example, applied in the early 1990s to the synthesis of styrylchromones, some of which are cytotoxic to specific leukemia cells, selectively inhibiting RNA synthesis.

Move to Bombay. In 1934, as the Indian movement for independence from British rule gathered momentum and the first rifts appeared between Muslims and Hindus in Lahore, Venkataraman left Forman Christian College to join the University of Bombay (later Mumbai) as reader in dyeing and printing in the new Department of Chemical Technology, which was then headed by the British chemist Robert B. Forster. In 1936 Venkataraman succeeded Forster as professor and director of the Department of Chemical Technology and served as its director until 1957. His commitment to institution building made it the foremost center of chemical technology in India during those years.

Venkataraman's approach was unusual in India at the time. He developed a teaching program that encouraged original research, at the same time placing an emphasis on the practical application of research findings. He believed ardently in the potential as well as the need to develop Indian science and technology through private-sector collaboration, and he believed equally that the private sector had an important role to play in contributing towards health and safety in the country at large. His own research focused on medical applications of his work on flavones was partly stimulated by conversations with his younger brother, a doctor with whom he was extremely close; the same commitment to health and safety led him to collaborate with Indian pharmaceutical industries, and later the Indian textile industry, on related issues. The cutting edge Ranbaxy Laboratories Ltd. and Bombay Dyeing were among the companies that he advised.

During his tenure as director of the Department of Chemical Technology, Venkataraman pursued, in addition to his work on flavonoids, original research on dyes, dyeing and related textile processing, and mechanistic studies. Color had always fascinated him, and he was able to enlist the support of the Indian textile industries concentrated in and around Mumbai to fund research at the department on the chemistry of natural and synthetic coloring matters, especially textile auxiliaries and naturally occurring antraquinones and flavones. The new research programs he introduced earned him the nickname of "the father of dyestuff research in India" and led a group of his students to found the Indian Dyestuffs Industries, Ltd., in Mumbai. The company was the first of its kind in India.

A gifted and inspiring teacher—though his family considered him to be a distant second to his older brother in that profession—Venkataraman was happier among his students than at meetings of administrative or government committees and always favored the former when there was a conflict of schedules. He was a dedicated mentor and a hard task master who demanded undivided attention from his students towards their research. His training placed equal emphasis on research in the laboratory and honing skills in presentations and writing.

Venkataraman's devotion to bringing out the best in his students drew lasting and rufeful affection. They joked that though he expected to see them from 8 a.m. to 12 noon in the laboratories and from 4 p.m. to 8 p.m. in his room, he reserved the afternoon for administrative work, so they could use that time to escape to the movies, where they were often joined by Mrs. Venkataraman.

Research on Dyes. Venkataraman's own research now focused on the synthesis of colorants, the determination of structures by degradative and spectroscopic methods, and procedures for the analysis and estimation of dyes. In the course of this research, he developed several new synthetic procedures and chromatographic separation techniques and invented simple practical methods for the characterization and estimation of dyes.

Amongst Venkataraman's more important contributions in these areas of the chemistry of synthetic dyes were novel applications of Raney nickel reductions for the desulphurization of dyestuffs; exploration of structure-property relationships in insoluble azoic dyes to improve their production directly onto or within the fiber; experiments with temperature to concentrate disperse dyes; and reductions to induce solubility of vat dyes. Among the techniques he used were paper chromatography for separating and identifying mixtures of dyes that are substantive to cotton in their dyeing behavior; and applications of nuclear magnetic resonance (NMR) spectroscopy to solve dye-fiber interaction problems concerning azoic, disperse, reactive, cationic, and vat dyes. His correlation of applications of NMR spectroscopy and mass spectrometry to azophenol-quione hydradzene tautomerism provided insights into the improved bonding of dyes and fibers. And his studies of structure-property...
relationships in the surface-active agents that are used in textile processing were of immediate use to the Indian textile industry.

Venkataraman used Raney nickel catalyzed hydrogenation in the synthesis and determination of the structures of dyes and flavones. The method led to the clean desulphurization of sulphanilic acid dyes and the production of tosylate derivatives of phenolic compounds and other sulphur-containing compounds, making the dyes more evenly spread and longer lasting on a variety of textiles. The products that were formed by the hydrogenation process were more amenable to analysis by NMR and mass spectral techniques than had been possible earlier. Therefore, many anthraquinone dyes that are used as food as well as textile colorants could be and were analyzed using this procedure, as were violanthrones that act as sensitizers. Additionally, his thiosemicarbazide reagent became the basis for reductive amination of amines using alcohols.

Additionally, Venkataraman developed a method for the facile hydrolysis of anilides of o-hydroxypyridinecarboxylic acids. Anilides are difficult to hydrolyze; he treated these anilides o-hydroxyphenylcarboxylic acids with 2,4-dinitrochlorobenzene, and the resultant N-2,4-dinitrophenyl derivatives underwent hydrolysis under mild conditions.

For the textile industry, Venkataraman's most important research programs were on the synthesis of azo and alizarin dyes, reactive dyes, and lac dyes. He made modifications in the diazotization procedure of specific anilines and used the modified procedure not only for the synthesis of several new azo dyes, but also to alter the shades of dyes and improve the durability of natural dyes such as those used in Kutch dyeing and calico printing. The other dyes whose chemistry he researched included naphthol derivatives, indanthrones, and benzanthrones.

Reactive dyes contain the b-sulphatoethyl sulphone functional group that is responsible for bonding with fabric in the presence of alkali. Venkataraman provided direct physical evidence, in particular through the use of NMR data, for the formation of an ether bond between the reactive dye and cellulose and proposed a mechanism for how this bond could be formed, which involved the intervention of aliphatic carbon to facilitate $S_{2}$ displacement by the cellulose-–OH group (see Figure 5).

In a separate study he showed that those o xoecocellulars containing b-ketonic acid or aldehyde groups would couple with diazonium salts. He investigated the factors that influence the azo-hydroxy tautomeration in o-hydroxyazo dyes and demonstrated the deshielding effect of the azo group of dyes in their NMR spectra.

Venkataraman also used the diazo coupling of phenolic compounds to introduce a hydroxy group in a specific position and to elucidate structures. In addition, he isolated and characterized a number of natural pigments belonging to the anthraquinone group, such as lac dyes A and B, which are present in lac dye.

Venkataraman's work on textile auxiliary agents proved equally significant to the development of the Indian textile industry. Textile auxiliary agents help in the dispersion of dyes and level dyeing, and they are used for wetting fibers, detergency, emulsifying power, and protective colloidal action during the dyeing process. Venkataraman developed new textile auxiliary agents for use by industry with experiments with soaps, Turkey red oil, Monopole oils, and the products obtained from castor oil on its reaction with sulphuric acid.

**Director of the NCL.** Having moved from the far south of India to the far north, Venkataraman had by the mid-1950s settled in western India. In 1957 he accepted an invitation to become the first Indian director of the National Chemical Laboratory (NCL) in Pune (97 kilometers from Mumbai), taking over from Professor George I. Finch. The National Chemical Laboratory was not new to him. The first and only Indian institution to be devoted purely to chemical research, it was set up and funded by the Indian government. Venkataraman had been associated with the laboratory from its inception in 1950, first as a member of its Planning Committee and then as a member of its Site Acquisition Committee. When the laboratory was established, he was also on its Executive Council and chaired its Chemical Research Committee.

As director of the NCL, Venkataraman reorganized several departments, adding divisions for Organic Intermediates and Dyes and Essential Oils, and expanded its research activities to include a Fine Chemicals Project. To keep the laboratory at the cutting edge of Indian chemical research, he went on an active recruitment drive to attract new talent and continued during the ten years that he directed the laboratory. His staff and students were encouraged to publish internationally, and the laboratory soon became the hub of chemical research in the country, particularly in the areas of natural products and synthetic organic chemistry. Also, the laboratory became an essential stop on the itinerary of international scientists visiting India.

Despite the move from Mumbai to Pune, Venkataraman continued to pursue his research on the separation, purification, and analysis of dyes. He developed the use of column chromatography under hot conditions (100–150°C [212°–302°F]) and used highly polar, unconventional solvents in order to resolve difficulties in the solubility and elution of dyes. He applied paper chromatography to the analysis of aminoanthraquinones and used adsorption on cellulose powder for the separation of vat dyes, using such unusual solvents as aqueous tetraethylpentamine containing hydroxysulphite. He studied the influence of the –OH group in azo dyes on their adsorption properties on alumina.

Although he retired in 1986, Venkataraman continued to take PhD students at the National Chemical Laboratory and remained associated with its research activities until 1990. More than eighty students received their doctorates under him, several of them going on to become famous in their own right. His students treated him like an affectionate uncle, and he for his part nagged and fussed over their work while his wife tried to cheer them up with slapdashes and loving meals. One of his happiest days was when a former student, Bal Dattatreya Tilak, took over from him as director of the National Chemical Laboratory.

**Publications, Honors, and Awards.** Retirement allowed him time for his own writing, and between 1970 and 1978 he edited the third through sixth volumes of the monumental six-volume *The Chemistry of Synthetic Dyes* for which he was to become famous. The volumes were an expansion on his two-volume treatise on *The Chemistry of Synthetic Dyes*, which was published in 1952 and was the first definitive twentieth-century work on synthetic dyes; it was subsequently translated into Russian and Chinese.

While Venkataraman was working on *The Chemistry of Synthetic Dyes*, the range of detail that he was forced to absorb convinced him of the need for a new, single volume, analytical text. This he later edited as a collection of pieces by international chemists, titled *The Analytical Chemistry of Synthetic Dyes* (1977); repetition was clearly not a concern of his when it came to scientific titles.

In his almost sixty years of scholarly work, Venkataraman wrote 271 published papers. His first, “Notes on Bixin,” was published in the *Indian Journal of Science* in 1924, and his last, “Cyanoic Chloride, a Useful Reagent for Macrocyclic Lactonization,” was published in *Tetrahedron Letters* in 1980.

Venkataraman was on the editorial advisory board of *Tetrahedron, Tetrahedron Letters, Organic Preparations and Procedures International*, and the *Indian Journal of Chemistry*: a member of the USSR Board of Editors; and a fellow of the Deutsche Akademie der Naturforscher Leopoldina, the Polish Chemical Society, the Indian Academy of Sciences, and the Indian National Science Academy and an honorary fellow of the Society of Dyers and Colourists (UK). The Mendeleev Institute of Chemical Technology in Moscow conferred an honorary doctorate of science upon him, and in 1961 the government of India awarded him one of its highest honors, the Padma Bhushan. He was president of the Indian Chemical Society in 1959–1960 and received the K. D. Naik and T. R. Seshadri Seventieth Birthday Commemoration Medals.

**Personal Life.** No scientist is without eccentricities, and Venkataraman’s was an excessive, almost faddish, attention to health and hygiene. An asthmatic from birth, he battled his debilitating ailment through a rigorous routine of exercise and diet as well as, in his own words, “segregating potential sources of germs.” He carried four handkerchiefs—one for his spectacles, one for his nose, one for his forehead, and one for his hands. It was this discipline, he always said, that kept his asthma in check and permitted him to work so productively. Tall for an Indian and spindly, he looked frail beside his energetic wife, whom he chided gently for her untidiness; however, he cherished until his dying day the tomboy quality in her that he had fallen in love with when she was fourteen.

Though his home was austere and the food of nursery-like blandness, it was a beacon for family friends and students. Twenty-five years after his death, and almost fifty years after he had left the Department of Chemical Technology, its governing board honored him by naming the lecture theater in which he had taught after him. In 2006, at IITC’s Sesquicentennial Celebration, the department—now an institute in its own right—formally inaugurated the Venkataraman Lecture Hall; the ceremony was attended by a large number of his former students, some in their seventies, who had traveled from all over India to attend.

Venkataraman died at the age of seventy-five years.

His wife survived him only briefly. His daughter, Dharma Kumar, was a well-known economic historian and founder-editor of the later prestigious Indian Economic and Social History Review; she died in 2001, leaving behind her only daughter, Radha Kumar.
WORKS BY VENKATARAMAN


P. K. Ingle

S. Sivaram

Radha Kumar

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