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# Professor (Dr) Sukh Dev: an iconic scientist with an innate sixth sense who radicalized natural product synthesis & organic chemistry

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It is a great honor and a pleasure for us to serve as guest editors of this special *Organic & Biomolecular Chemistry* themed collection celebrating the 100th birthday of Professor Sukh Dev. We are delighted that so many of his students and colleagues have joined us in paying tribute to him through the submission and dedication of a diverse set of excellent papers to this themed collection.

During the mid-twentieth century, an imaginative mind emerged that started seeing, analyzing, and designing science concepts differently compared to the scientific frontiers of the Western world. This was the time when scientists from Eastern and underdeveloped blocks had long wrestled with very limited scientific tools and resources. The pioneering genius who emerged with the determination to find a way to meet the unmet needs, while fighting against the odds in these surroundings, was none other than the legendary Dr Sukh Dev.

Born in Chakwal, Lahore to Hari Chand Lala and Maya Vanti in June 1923, he gained his master's degree from D.A.V. College in Lahore in 1945 and then proceeded to the Indian Institute of Sciences, Bangalore to obtain his PhD in 1950, and DSc in 1960. Prior to stepping into his phenomenal career legacy, during his IISc days, he accepted a short-term assignment as a research associate at the University of Illinois (1957), during which time he worked with Professor E. J. Corey, one of the Nobel Laureates of Chemistry. His periods of service at the Indian Institute of Sciences, Bangalore (1945–1959); National Chemical Laboratory, Pune (1960–1974); Malti-Chem Research Center, Nandesari, Baroda (1974–1988); and the Indian Institute of Technology, New Delhi (1989–1993) were times of exceptional productivity and dedicated service to academia, with novel discoveries of natural products that later turned out to have multi-faceted useful applications for mankind, including synthetic methodologies and chemical transformations that continue to be applied in academia and industry even today. The reflections of the value of his inventions are evident through his >395 peer-reviewed journal publications, 50 patents, close to 100 PhD dissertations, and authorship of 10 books. His discoveries were well received by the global scientific communities and have been well recognized both nationally and internationally as being iconic and at the frontier of natural product chemistry. He also served on the editorial board of *Tetrahedron* and *Tetrahedron Letters* (1976–1995), *Tetrahedron Asymmetry* (1990–1995) and *Dictionary of Organic Compounds* (5th edition). He was also conferred DSc (h.c.) by Bundhelkhand University, Jhansi (2000) and by the Indian Institute of Technology, Delhi (2008).

## National & international distinguished awards and honors

- Dr Sukh Dev was conferred the Sudborough Medal by IISc (1949)
- Guha Research Medal by IISc (1958)
- SS Bhatnagar Award (1964)
- Acharya PC Ray Medal by the Indian Chemical Society (1970)
- Dr K. G. Naik Gold Medal by MS University, Baroda (1977)
- Vishwakarma Medal by INSA (1979)
- Ernest Guenther Award by the American Chemical Society (1980)
- Distinguished Alumni Award by IISc (1980), VASVIK Award (1980)
- FICCI Award (1980)
- Professor TR Seshadri 70th Birthday Commemoration Medal by INSA (1981)
- Meghnad Saha Medal by INSA (1987)

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• Satyendra Nath Bose Research Professorship by INSA (1988–93)
• TWAS Award in Chemistry (1988)
• Srinivasan Ramanujan Birth Centenary Award by the Indian Science Congress Association (1992)
• Lifetime Achievement in Chemical Research and Education Award by the Indian Chemical Society (1999)
• Lifetime Achievement in Chemistry Award by the Chemical Research Society of India (2000)
• He was elected as Fellow of the Indian Academy of Sciences, Allahabad (1974)
• The Academy of Sciences for the Developing World (1992)
• President of the Indian Chemical Society (1978–79)
• Padma Bhushan (2008)
• ACS Board of Directors Recognition for 60 Years of Service Excellence (2023)

## Academic & research achievements

When you picture a scientist, do you see a white-coat-clad PhD holder pipetting away at a lab bench? Or maybe the head of an organization of a department engulfed with administrative duties during most of the daytime, attending webinars, virtual conferences and squeezing in time to meet with his favorite research team? Well, Dr Sukh Dev and his days of research were different. Cell phones and computers were not common. There were no emails. There was no Google, Zoom or MS team meetings, no PowerPoint presentations, not to mention the fact that research analytical tools were not readily available, as many reagents had to be imported to India, and the list goes on and on... Therefore, working with natural products was evidently an extremely difficult task. It was not only time-consuming, but elucidating absolute structures and collecting sufficient quality data to publish in world-class peer-reviewed journals was just a dream to many scientists when Dr Sukh Dev accomplished these nearly impossible tasks. He was indeed a man with a sixth sense. His devotion to science spread out not only to natural products but to several other areas of organic chemistry due to his adaptive mindset that enabled him to engage in career-phase and time-appropriate scientific explorations seeking novel inventions.

During his time at IISc and the early part of his career at NCL, his focus was on isolating new natural products from medicinal plants and their complete structural elucidation. The scientific world started seeing evolutionary changes with modernized tools for scientists and that made the life of chemists easier and the outcome of their quality work quicker. In the two and half decades following 1950, a total metamorphosis was noticed by the scientific world. With the change in the way the wind was blowing, Dr Sukh Dev also transformed his strategies toward science and his research. Structure determination then became vastly simplified. With these developments, emphasis in natural product chemistry shifted to biologically active molecules or compounds with novel structural features. Dr Sukh Dev's efforts in these directions led to the discovery of several new types of terpenoid structures, as well as characterization of the active principles of some Ayurvedic drugs. Dr Sukh Dev was the first to emphasize that while investigating crude Ayurvedic drugs or other medicinal plants, one must specifically look for the biological activity for which the drug is renowned in Ayurveda or folklore. Thus, from *guggulu*, the gum resin of the tree *Commiphora mukul*, well-known in Ayurveda for the treatment of lipid disorders, his group was able to isolate two steroidal ketones with pronounced hypocholesterolemic and hypolipaemic activity. Shatavarin-I isolated from the roots of *Asparagus racemosus* is still in use in Ayurveda for its anti-oxytocin potency and has been used in the treatment of threatened abortions. Dr Sukh Dev's group was the first to demonstrate that himachalenes occurring in essential oils show useful broad-spectrum activity against a variety of ectoparasites (fleas, ticks, mites, lice), and the group also assisted in their commercialization.

In a nutshell, Dr Sukh Dev's wide range of scientific contributions may be summarized as follows.

## Natural product chemistry

The unforgettable key scientific contributions of Dr Sukh Dev to natural product chemistry were mainly made during the early days of his career at IISc and NCL. These contributions included structural elucidation of novel, complex, secondary plant metabolites, such as zerumbone, himachalenes, malabaricol, cheilanthatriol, kodocytochalasins, bakuchiol, guggulsterones, and guggultetrols; development of new techniques and processes including silver nitrate–silica gel (for thin-layer chromatography, organic reactions in a solid matrix, heterolytic cleavage of homoallylic alcohols); and concepts such as the absolute stereochemistry biogenetic rule. He worked on Indian economic raw materials, such as lac, Indian turpentine oil, *devadaaru*, and Indian medicinal plants. Longifolene, a typical component of Indian turpentine, was converted into useful aroma compounds, which are being manufactured not only in India, but also in foreign countries. Carene, another characteristic constituent of this oil, was fashioned into several commercially important molecules. Himachalenes, hydrocarbons from *devadaaru*, were recognized for their effectiveness against ectoparasites and have been commercialized as a veterinary drug. Several Ayurvedic crude drugs were investigated and evaluated for their therapeutic claims. For example, *guggulu* is claimed in Ayurveda as a treatment for lipid disorders. Investigations led to the isolation of compounds (guggulsterones) responsible for this activity, and the products based on this are being manufactured not only in India, but also by several parties abroad. Currently, there is much scientific interest in these molecules globally. Bakuchiol, a compound isolated from baakuchi, has been converted into a highly potent juvenoid, and

has been successfully evaluated for its use in sericulture. In the 1950s and 1960s, there was considerable interest in azulenes, tropones and, in general, in nonbenzenoid aromatic systems.

## Organic reactions, reagents and synthetic methodologies

During his time at NCL, Pune, Dr Sukh Dev expanded his vision and mission considerably from focusing his attention on natural products only. He recognized a considerable gap in the field of functional-group transformations and his novel efforts started bridging that gap. His efforts helped the scientific world to enjoy new reactions, reagents, and synthetic methodologies. Dr Sukh Dev's group did extensive work on the use of polyphosphoric acid for intramolecular acylation of alpha- and beta-lactones to furnish cyclopentenones. Due to its value and application, this chemistry later found a commercial use in the manufacture of dihydrojasmone, a useful aroma chemical. Dr Sukh Dev's group was the first to propose organic reactions in a solid matrix, a concept and technique now widely practiced. Other similar value-driven chemical transformations include composite amine catalysis for Knoevenagel-type condensations, chromic acid for oxidative work-up of ozonides, thiourea for reductive cleavage of olefin ozonolysis products, titanium tetrachloride for thioacetalization and improved Lindlar catalysts for semi-hydrogenation of acetylenes. His group was the first to introduce the use of silver nitrate–silica gel for thin-layer chromatography of olefins (1962), a technique now used worldwide.

## Technology development

Dr Sukh Dev's interactions with industry were kindled during the late stages of his stay at NCL, Pune. However, his decision to move out of NCL, Pune to the Malti-Chem Research Center, Nandesari, Vadodara in 1973 opened an enormous window to a wide spectrum of scientific contributions with immense industrial value and applications. The rest of his career until 1988 was mostly devoted to technology development based on original research in parallel with his continuing guidance on PhD dissertations. It is noteworthy to remember and recognize how many world-renowned eminent scientists, chemists, and academicians have come out of his nearly 100 PhD dissertations! What else does one need to prove his untouchable second-to-none mentorship?

Industries built upon chemistry started seeing the positive catalyst effects soon after Sukh Dev started his activities at Malti-Chem. Thus, a molybdenum oxide-promoted RANEY® nickel catalyst was developed for facile hydrogenation of glucose to sorbitol and several metric tons of sorbitol is now made worldwide by this process annually. Likewise, a copper–nickel–manganese catalyst for the dehydrogenation of cyclohexanones to phenols was developed, and thymol has been produced from readily available menthones by this method. The highlight of Dr Sukh Dev's activity in this area is the way his group demonstrated the value of restructuring abundantly available natural products into chiral molecules of economic value. Thus, the optically pure (+)-3-carene, the chief hydrocarbon of Indian turpentine (ex *Pinusroxburghii* Srg. syn. *P. longifolia*) has been restructured to produce an array of low-volume, high-value compounds of commercial interest, in the correct optically active form, using methods that are commercially viable. Processes thus developed include routes to (−)-menthol, (+)-carvone, (+)-mentha-2,8-dienol (a valuable raw material for the synthesis of tetrahydrocannabinol, an anti-nauseant for cancer patients undergoing chemotherapy), and pyrethroid intermediates (+)-chrysanthemic acid, (−)-caronaldehyde acid hemiacetal and (+)-pyrethric acid. To demonstrate the possible value of the resin from *Commiphora mukul* as a new steroidal raw material, his group transformed guggulsterones into the valuable glucocorticoid, dexamethasone. Bakuchiol, which has a weak juvenile hormone activity, has been converted into a potent juvenoid with good promise for use in sericulture.

It would be highly disrespectful if we failed to share and introduce the molecules that have seen the light of day and helped millions of patients by Dr Sukh Dev and his group (see Fig. 1 and 2).

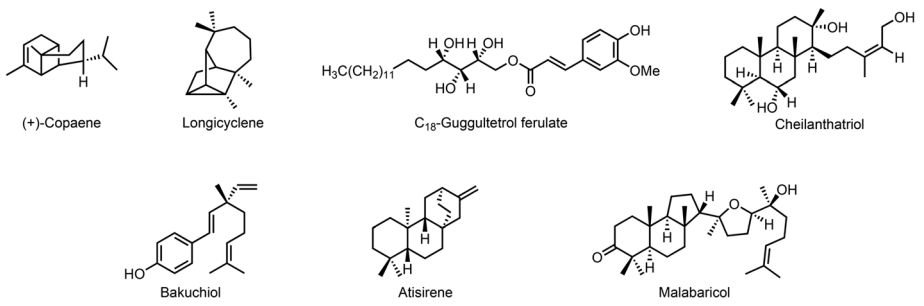


Fig. 1 Novel natural products isolated by Sukh Dev group.

 

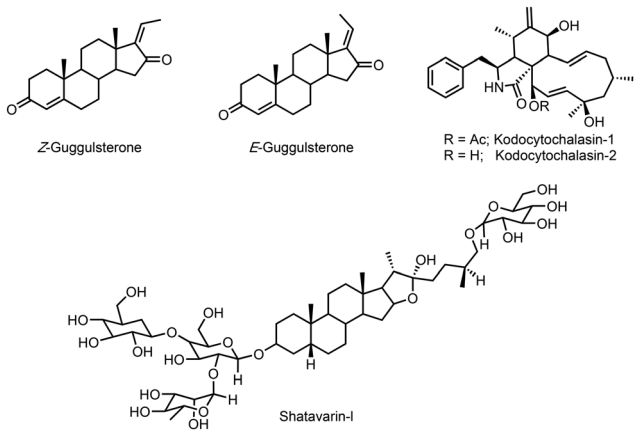


**Fig. 2** New natural product structures assigned by Sukh Dev group.

By every measure we, or anyone else, could come up and admit with us, "Yes, he was a man with a sixth sense". We are so proud and cherished to be remembered as his students and others should be equally happy and proud that by getting an opportunity to work with him, associate with him, or having lived at the same time accepting inspiration from a legend like him, makes our career and lives well decorated and joyful.

One of the authors shared with us one of his conversations with Dr Sukh Dev and his response. He stated that he had always wondered what triggered the great ideas. The way Dr Sukh Dev replied was "An idea is a neat little thing. Ideas can easily show up, uninvited, and disappear without warning. That quantum moment matters. If one can connect, correlate or expand that momentary flashed idea, that could be the triggering point to bring an idea to reality. Breaking a myth with evidence is science. Science doesn't always happen from serendipity. We need to debug the myth. We should debunk historical myths so that when we talk about scientific creativity our claims are based on evidence instead of fiction". That was his answer!

A life devoted to science. A man who was created by God to see the unseen, hear the untold and do the unmet by mankind. That is Professor (Dr) Sukh Dev.