of intricacies that allowed for lineages in which the trend was size decrease – which was based on natural selection too. See Bonner, J. T., *Why Size Matters: From Bacteria to Blue Whales* (Princeton University Press, 2006).

25. These ideas were explored in *Cells and Societies* (1956), *The Evolution of Complexity by Means of Natural Selection* (1988) and *First Signals* (2000). Bonner's paper 'The origins of multicellularity' (*Int. Biol.*, 1998, **1**(1), 27–36) made an immediate mark. His favourites, the cellular slime moulds, were ideal, because they were at the same time multicellular organisms and social groups; Bonner, J. T., *The Social Amoebae*: *The Biology of Cellular Slime Molds* (Princeton University Press, 2008). A paper with R. Gadagkar highlighted parallels between social amoebae and social insects (*J. Biosci*., 1994, **19**(2), 219–245).
26. Bonner, J. T., *The Evolution of Culture in Animals*, Princeton University Press, 1980.
27. An Honorary Fellow of IAS, he was in Bengaluru as Raman Professor of the Academy. Bonner, J. T., *Curr. Sci.*, 1993, **64**(7), 459–466.
28. He called it range variation. Bonner, J. T., *Size and Cycle*, Princeton University Press, 1965.
29. To his delight, he found that even here Darwin had anticipated him. Bonner, J. T., *Randomness in Evolution*, Princeton University Press, 2013.
30. Cambridge University Press brought out an abridged edition edited by Bonner in 1969. Unlike the original, it can be read in bed.
31. Today we see D'Arcy Thompson (1860–1948) as an advocate of the importance of mechanics and physical principles for understanding changes of form in evolution, a precursor of S. A. Newman and others. Medawar rates *On Growth and Form* very highly, yet falls short of appreciating its full importance (*Perspect. Biol, Med*., 1962, **5**(2), 220–232).
32. Newman, S. A. and Comper, W. D., *Development*, 1990, **110**, 1–18; Newman, S. A., *J. Biosci*., 1992, **17**(3), 193–215. In Bonner's way of putting it, '...[genes] seem to seep in unavoidably, a bit like my old chemistry teacher at school who used to wear both a belt and a pair of suspenders'. (*Life Cycles*, p. 89).
33. Evo-devo stands for evolutionary developmental biology. Hall, B., *Int. J. Dev. Biol*., 2003, **47**, 491-495. Hall dates the origin of the field to studies on comparative embryology fuelled by the publication of *The Origin of Species*.
34. Bonner was Department Chairman at the time. Cox, E., Nanjundiah, V. and Wurster, B., Foreword to *Researches on Cellular Slime Moulds*, IAS, Bengaluru, 1991.

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Bhaskar Dattatraya Kulkarni (1949–2019)

Dr B. D. Kulkarni, popularly known as BD to his friends, and a well-known chemical engineer passed away suddenly at Pune on 14 January 2019. A true 'scientist–scholar' in every sense of the word, Kulkarni was an undisputed leader in the area of chemical engineering.

Born in Nagpur on 5 May 1949, Kulkarni earned his M Tech degree in chemical engineering from Laxminarayan Institute of Technology, Nagpur in 1972. He joined the National Chemical Laboratory (NCL), Pune in 1973 to pursue his Ph D work with L. K. Doraiswamy, and stayed there till the last day of his life. His doctoral research was on the subject of modelling of gas–liquid and gas–solid reactions, which led to the development of the delayed diffusion concept in chemical reaction engineering. Beginning his professional career as a Scientist C in 1979, he rose to the position of Deputy Director (2002–09), CSIR-Distinguished Scientist (2010–15), INSA Senior Scientist and a JC Bose Fellow in a stellar career spanning over 45 years. He was a complete home-grown product who never went out of India for education or scientific training. He transcended man-made boundaries in science and technology because of his mastery over mathematics, which he used as a 'language' to successfully unite and make high-impact contributions in the physical, chemical, biological and engineering sciences. His ability to translate physical phenomena to mathematical models

which could be analysed to reveal interesting features that the human mind was incapable of comprehending, was widely acknowledged. His extraordinary intellect coupled with his rich R&D experience gave him the uncanny ability to recognize patterns in results and data – those that could be universal and those that were unique to the phenomena – much to the astonishment of others. His work effortlessly traversed between deterministic and stochastic modelling, cutting across time and length scales.

This approach also made him recognize areas and problems that would be decades ahead of their time. For example, he realized that studying nonlinear systems, which are usually the real life and common place situation, required new and innovative algorithms for analysis. This set the course for his scientific contributions in the seventies. The synthesis of the pen-and-paper approach to arrive at nonlinear system models and subsequent use of computational methods of analysis, whereby the accuracy and speed of obtaining solutions could be improved led to studying of complex systems for their multiplicity, bifurcation, oscillatory and chaotic behaviour. It included studying the phenomenon of high-dimensional space–time pattern-forming systems by statistical quantifiers at a time when studies of nonlinear dynamics and stability itself were in their infancy. It is interesting to note that Kulkarni used phenomena in chemical engineering systems as examples and threaded the vision gained by studying them to envelope research at the highest levels of even physics and biology. In fact, his development of stochastic models and their analysis has been published as a highly acclaimed monograph. The analysis of how coupled nonlinear subunits can lead to the observance of their complete synchronization even in the event of disturbances (noise) and the control of high-dimensional space–time chaos in reaction–diffusion systems have led to a number of seminal research contributions in the recognition and understanding of pattern formation. The point made is that systems need not be complex to exhibit complex behaviour and that even simple systems can exhibit complex dynamics when they are open/continuous, have nonlinearity with feedback mechanisms operating was unequivocally demonstrated.

Interestingly, a body of his work addressed situations when the first principles of the nonlinear phenomena are not known, but experimental data are available. In this situation recourse to black-box modelling strategies using evolutionary algorithms (e.g. AI-ANNs, genetic algorithms, adaptive control algorithms, SVR, directed evolution, surrogate analysis, ant colony optimization, etc.) were recognized and published by him even before they became the buzzwords that they are today. To be sure, a detailed look at his recent biodata brings out contributions in multiple shooting algorithms, support vector regression, pattern recognition, classification of large data, etc. that are more than likely to be forerunners to making accurate predictions in time and space from high-throughput complex data. The importance is seen when one considers this as a precursor to optimizing and controlling system behaviour.

Being an engineer, his work focused on creating applications and putting them into practice. In doing so, he recognized that for increased sophistication in experimental data monitoring techniques and their digital storage, development of rigorous mathematical algorithms for big-data analysis is essential. Also, what is not recognized fully is that experimental noise in the data needs to be filtered before working towards applications. Modern mathematical formalisms involving multiresolution studies such as wavelet transforms were shown to be effective even from a generic interdisciplinary viewpoint. In fact, his work in this area led to US patents, which were licensed to companies overseas.

This apart, as Head of the Division of Chemical Engineering and later Process Development at NCL, Kulkarni led many process development projects from the front that resulted in technology transfer, commercial-scale implementations and licensing to industries. Based on his deep insights in nonlinear dynamics of flows, he suggested new and innovative process designs. For example, he was involved in the design of fractal impellers that show remarkable improvement in mixing properties of fluids when compared to conventional impellers. His in-depth studies of complex hydrodynamics of conventional reactors and reacting systems like bubble columns, fluidized beds and microemulsions have found wide application in industry. The data-driven reactor control algorithms developed by Kulkarni have been successfully deployed in an operating polyethylene plant at Hazira, Gujarat.

Another facet of Kulkarni's life was his unique horizontal vision which enabled him to relate and communicate with scientific and industrial practitioners with ease. In fact, he was well known for getting to the heart of a matter in no time and then summarizing the discussion in a way that put everybody in sync. And, because of this ability, scientific and process development activities involving him always had the advantage of proceeding in the right direction for success. Many will recall with amazement his ability to lecture extempore in seminars without a paper or slide, non-stop on complex subjects with such clarity and lucidity that even those non-initiated into the subject would be enriched and enlightened.

During his illustrious career, Kulkarni nurtured and mentored 66 Ph D students, 10 postdocs, and interestingly, over 150 summer students from universities and colleges. A qualitative and quantitative measure of success in his career lies in over 350 peer-reviewed publications in journals, 26 US and Indian patents, 3 authored and 4 edited books. It is worth noting that his publications span a wide spectrum of scientific journals covering diverse scientific disciplines, a feat not easy to accomplish or replicate. Awards and accolades are too numerous to list. He received the Bhatnagar Prize at a young age of 39 and was an elected Fellow of all the learned academies of science and engineering, including The World Academy of Sciences, Trieste. He served on the editorial boards of the prestigious *Chemical Engineering Science* (Elsevier), *Chemical Engineering Journal* (Elsevier) and *Industrial and Engineering Chemistry Research* (ACS) for many years.

Kulkarni had a deep insight into the working of an organization such as NCL. He was the 'go-to-man' for trouble-shooting for several Directors, whom he served with absolute and unwavering dedication and commitment. His advice was often sought on sticky matters, as he had an uncanny perspective that was closer to the ground and reflected realities than what a Director may perceive sitting in the confines of his sequestered office. As long as he was in the service of CSIR, no NCL Director would take a difficult decision before bouncing it off with Kulkarni. Such was his practical wisdom.

As an individual, Kulkarni was the personification of humility, ever smiling and soft-spoken. No one ever saw him lose his temper. His patience was legendary. He was a great listener that endeared him to his colleagues. His presence in the NCL campus will be deeply missed, especially by many who sought his advice on matters pertaining to science or otherwise, and, were always assured that he would give correct, comforting and most dispassionate suggestions. He leaves behind his wife, two daughters and a grandson.

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