Michael E. Fisher (1931–2021)

Michael Ellis Fisher was a pre-eminent theoretician who had a vast influence on the field of critical phenomena and allied fields through his work and his influential engagement with other workers in the field, in both theory and experiment.

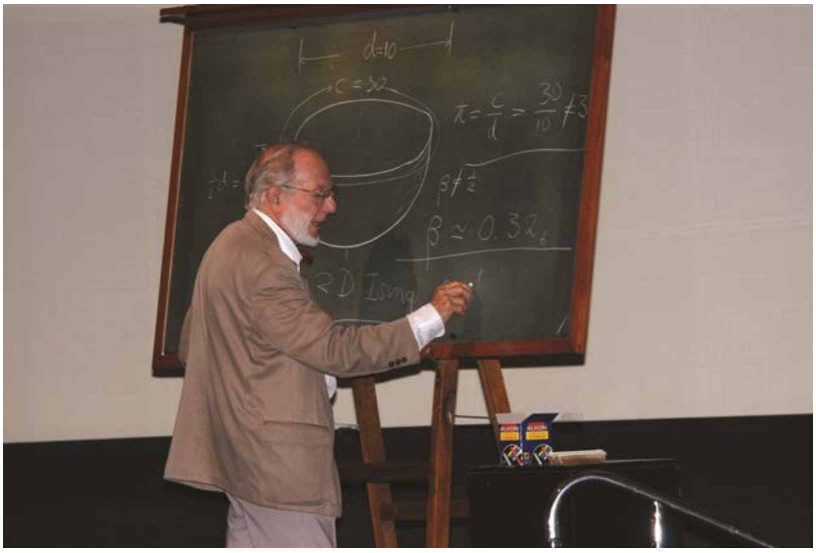
Fisher was born in Trinidad in the West Indies in November 1931. He studied in Britain and graduated with a bachelor's degree from King's College, London, in 1951. After teaching for a couple of years at the Air Force as part of National Service, he came back to King's College and did a Ph.D. in analogue computing with Donald MacKay. He completed his doctoral studies in 1957. The following year, he was appointed lecturer at King's, and full professor in 1964. In 1966, he shifted to Cornell University and was appointed Horace White Professor of Chemistry, Physics and Mathematics in 1971. In 1987 he moved to the University of Maryland as Distinguished University Professor and Regent's Professor, where he stayed till retirement in 2012. He passed away in November 2021.

Looking back at how the field of critical phenomena grew, one may identify three broad stages of development. The first involved recognizing that the state at the critical point, for example, in a fluid or ferromagnet, is in fact a new state of matter, and that the singularities near a critical point are related to anomalous fluctuations around a uniform state. In the second stage, a vast amount of experimental and theoretical data was assembled and analysed, leading to the development of a compact scaling description and the recognition of universality in the critical properties of very different systems. The third and last stage involved building an effective conceptual and calculational framework to address and explain the scaling and universality that had been unearthed. As discussed in more detail below, Fisher was intimately involved with all three stages and played a key role in bringing the critical point problem and its ultimate resolution to centre stage. His contributions to statistical physics earned him many accolades, including the Wolf Prize in Physics, the Boltzmann Medal of the IUPAP Commission on Statistical Physics, the first Lars Onsager Prize of the American Physical Society, the Irving Langmuir Prize of the American Chemical Society, and the Fellowship of the Royal Society. Fisher was an Honorary Fellow of the Indian Academy of Sciences.

Fisher was introduced to problems having to do with critical points by Cyril Domb, who was professor at King's College, while Fisher was a student. Lars Onsager's brilliant analytic solution of the two-dimensional Ising model in 1944 had shown the inadequacy of the classical (mean-field) theories to capture the singular behaviour of thermodynamic quantities near the critical point. Further, extensive work based on the analysis of high and low-temperature series by Domb and coworkers demonstrated that the inadequacy persisted in three dimensions. Important work by Fisher in this period focused on the decay of correlation functions, which measure the influence of fluctuations at one point on other points in a system. The range of influence is quantified by the correlation length ξ, which diverges as the critical point is approached. Fisher highlighted the divergence of ξ and the nature of decay of correlations precisely at criticality. In his words[1], '*Indeed, once ξ is measured in hundreds of Angstroms, one is already moving into what is effectively a new state of matter.*' Later, reviewing the developments during this period, Fisher wrote[2], '*From this challenge* (meaning Onsager's results) *and from experimental evidence pointing in the same direction, grew the ideas of universal but nontrivial critical exponents, special relations between different exponents, and then scaling descriptions of the region of a critical point.*'

The emphasis he lays on experimental evidence is central. Fisher was always abreast of the latest experimental results in the field, and often influenced the course of experimental investigations. He deeply analysed the pertinent results near the critical point, be it in superfluid helium, magnetic systems or liquid mixtures, and carried on a continuing dialogue with the experimentalists, giving suggestions and pointing out subtleties in the analysis of data.

The existence of scaling and its importance, emphasized in the work of Leo Kadanoff, Benjamin Widom and Michael Fisher, laid the foundations for subsequent advances in the field. Widom's early observation that the singular part of the free energy was a generalized homogeneous function of fields (temperature, chemical potential or magnetic field) explained the observed relations between exponents. Kadanoff developed an approximate picture of iterative coarse-graining for a spin model, which gave a theoretical clue to how scaling may arise. Scaling led to a beautifully compact description through the collapse of large amounts of experimental data. It led to the recognition of universality across many fluid, magnetic and other systems, encompassing not only the values of the exponents, but also the collapsed function itself. Clearly, there was a great need for a theory to explain these unexpected and beautiful results. It was not long in coming. The advent of the renormalization group (RG) pioneered by Kenneth G. Wilson at Cornell and the powerful ε-expansion of Wilson and Fisher provided



Michael Fisher at the blackboard, introducing the concept of universality during the 2007 Homi Bhabha lecture at TIFR, Mumbai (Photograph: TIFR Archives).

the path to a detailed theoretical understanding. The latter used a completely original and unconventional idea in which the dimension d, or rather $\varepsilon = 4 - d$, the deviation from four dimensions, becomes an expansion parameter.

Fisher himself has beautifully reviewed the genesis of the full RG concept and the inspired work of Wilson[2]. He strongly stresses the breadth and generality of RG theory and emphasizes that it provides a new framework for discussing many outstanding problems in many-body physics, including, but not confined to, critical phenomena. Examples are Wilson's work on the Kondo problem and the Anderson magnetic impurity problem (the latter done together with H. R. Krishnamurthy, then a graduate student at Cornell). As stated in no uncertain terms by Fisher, the view espoused by some others that RG is simply a way to do perturbative expansions in quantum field theory is myopic and simply incorrect. He explains the place of the ε-expansion within RG in the following words[2]: '*My personal aim as a theorist is to gain insight and understanding: What that may truly mean is, probably a matter for deep philosophical review: After all, 'What constitutes an explanation?' But on the other hand, if you work as a theoretical physicist … you had better calculate something concrete and interesting pretty soon! For that purpose, the epsilon expansion, which used as a small perturbative parameter the deviation of the spatial dimensionality, d, from four dimensions, namely $\varepsilon = 4 - d$, provided a powerful and timely tool. It had the added advantage, if one wanted to move ahead, that the method looked something like a cookbook – so that 'any fool' could do or check the calculations, whether they understood, at a deeper level, what they were doing or not! But in practice that also has a real benefit in that a lot of calculations get done, and some of them turn up new and interesting things or answer old or new questions in instructive ways.*'

Fisher worked on various related problems in statistical physics, some within the framework of RG and others not. These include: Bicritical and tetracritical points, and concomitant crossovers; Nonlinear scaling fields and analytic and nonanalytic corrections to scaling; Multiphase points such as in the axial next-nearest neighbour ising (ANNNI) model, from which spring an infinite number of phases; Wetting transitions; Partial differential approximants, a two-variable generalization of inhomogeneous differential approximants; Interface wandering; Interacting random walks; Coulombic criticality in ionic fluids. Three influential works from his early days remain relevant still – the existence of the thermodynamic limit for the free energy; the renormalization of critical exponents by constraints entailed by specifying a non-ordering thermodynamic density; and the droplet model of condensation, which shows how essential singularities arise at a first-order phase transition. In more recent times, Fisher turned to problems in biophysics related to the movement of molecular motors, including the force a motor protein exerts as it moves along its track.

He was an excellent communicator. It was a pleasure to watch his use of the blackboard with coloured chalk, with each chalk stick snug in a metal holder. At the weekly seminar he ran at Cornell along with Benjamin Widom, speakers were allowed to use only the blackboard. His public lectures and talks at meetings, accompanied by meticulously prepared handwritten slides with hand-drawn figures, were crystal clear and carried a punch. Often, as in the photograph in this piece, these would be supplemented by explanations on the blackboard. Likewise, he wrote extremely clearly, and his papers are admired for both content and style. His review articles have had an enormous impact on generations of students, for example his reviews of critical phenomena[3,4] and the renormalization group[5]. The book '*Excursions in the Land of Statistical Physics*'[6] conveys the breadth and depth of Fisher's scientific oeuvre spanning nearly five decades.

The nineteen sixties and seventies were extremely exciting times for statistical mechanics, as the subject of critical phenomena developed and flourished, from the early seeds to full bloom. As a graduate student and then a postdoc in the US in the 1970s, I was exposed to the excitement through conferences and schools. Standards in statistical mechanics were maintained at a high level by the triumvirate of Joel Lebowitz, Robert Griffiths and Michael Fisher, who attended every talk and did not hesitate to offer trenchant criticism where it was called for. Recalling the effect of Fisher's presence in meetings in a recent article[7], Lebowitz said: 'He would always sit in the front row, take notes and ask sharp questions' and was considered 'the terror of the statistical mechanics conference.'

I had a personal experience which was quite the opposite. In a statistical mechanics summer school held in Banff, Canada, in the 1970s, participants were asked to give short talks on their work. I talked about the isostructural phase transition in samarium sulphide through a mapping to Ising variables, within a simplified model. A prominent experimentalist criticized me strongly, saying the model was not realistic enough. But before I could say anything in reply, Fisher, who was in the audience, spoke even more strongly about the importance of simple models in clarifying complex phenomena, and saved me from having to respond!

I had an opportunity to work with Fisher a few years later, when I spent a couple of years at Cornell University, on leave from the Tata Institute of Fundamental Research (TIFR). We worked on the application of partial differential approximants to unravel singular corrections to scaling in Ising-like systems. I found him to be an extremely caring person (especially with younger colleagues), though uncompromising on academic standards. He took science very seriously. He had the ability to get the best out of his collaborators, regardless of their backgrounds or technical skills. I learned a lot from him, physics-wise and otherwise, abstract and practical. He was highly organized himself, and instructed me on the virtues of coloured separators in files (of the hard-bound, not soft, variety). In the course of working with Fisher, I experienced first-hand his meticulous approach to preparing a manuscript. Every word had to be just right, and the figures I prepared would invariably be re-drawn by him before being sent to the drafting section. During summers, he asked me to interact with young students who were yet to start doctoral research (Steven R. White in 1983, and Mohit Randeria in 1984), both of whom were exceedingly bright and are well-known physicists today. Steve White and I wrote a paper which we requested Fisher to read. It came back covered in red, with remarks all over and arrows to mark transpositions, along with the admonition, 'Don't put the cart before the horse!'.

A discussion I remember well had to do with the question of loyalty. Fisher remarked that there are various types of loyalties: to the family, to the country and so on. But equally important is loyalty to one's profession. In this connection, one should try one's best to propagate the subject, never refusing invitations to go to smaller places, including colleges and schools.

Michael Fisher worked with several students and postdocs from India. He has publications along with Rahul Pandit (on wetting transitions), S. M. Bhattacharjee (on dimer models), Mohit Randeria (on locations of RG fixed points), Rajiv R. P. Singh (on series expansions for quantum magnets) and

Subir K. Das (on electrolytes near criticality). Further, he maintained a scientific connection with E. S. Raja Gopal, whose laboratory at the Indian Institute of Science studied the critical properties of fluid mixtures. When Fisher visited Bangalore in 1974, H. R. Krishnamurthy accompanied him to the residence of a well-known sitar guru Rama Rao, under whom he took some lessons. The latter helped him to buy a sitar which he carried back and continued to play for years after. Incidentally, Fisher was also a very good player of Spanish guitar, and wrote a column in the *Banjo, Mandolin and Guitar* (*BMG*) magazine.

In 2007 he visited India again, and delivered the Homi Bhabha lecture at TIFR, on the subject of phase transitions. An amusing point: During his visit to Mumbai, he was accompanied by his wife Sorrel and her sister Jacinta, and the three of them stayed at Fariyas Hotel in Colaba. Finding the arrangement in the hotel room not quite optimal, Michael moved the furniture around until he was satisfied. This sort of rearrangement was not unexpected, as it was an unusual but endearing habit he was well known for. See the informative and amusing article by Mermin[8] for an account of similar incidents and other stories about Fisher.

Those who knew Michael Fisher will miss him greatly, and will recall especially the energy and exactitude he brought to bear on every scientific issue that came to his attention. In his passing, the scientific world has lost one of the luminaries of statistical mechanics, one whose influence on the subject will stay for decades to come.

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Nagaswami Venkatasubramanian (1932–2022)

Professor Nagaswami Venkatasubramanian, known to many of us as Dr NVS (and Babu to his family), one of the senior most and distinguished physical organic chemists of India, passed away on 28 July 2022, at the age of 90 in Issaquah, Washington, USA. It was just two weeks earlier (on 16 July) that he requested his son to call me. During the call from his hospital bed, he sounded vibrant and spoke with lucidity as we discussed everything under the Sun. With great affection, he recalled my years spent under his tutelage. In hindsight, I realize now that he knew the end was near and his conversation with me was his way of saying 'goodbye' with dignity and grace.

Venkatasubramanian was born on 25 April 1932, in Villivakkam, a suburb of Madras (now Chennai), Tamil Nadu, India. His father worked as a clerk in Southern Railways, and his mother taught music to complement the family income. NVS attended the Dharmamurthy Rao Bahadur Calavala Cunnan Chetty Higher Secondary School, Perambur and topped the class in SSLC. He then joined as a student of Intermediate in Presidency College, Madras, where he had the opportunity to interact with the legendary T. R. Govindachari, and that propelled him to take up chemistry as the subject of choice. After graduating with M.A. in Chemistry from Presidency College in 1952 with flying colours, he was appointed as Lecturer at the Madras Christian College (MCC), Tambaram. This was a turning point in his career since he came under the influence of the doyen of physical organic chemistry, S. V. Ananthakrishnan, at MCC. He completed his Ph.D. programme under the tutelage of Ananthakrishnan, working on some facets of chromic acid oxidation of secondary alcohols.

NVS joined the Ramakrishna Mission Vivekananda College as the Head of the Department of Chemistry at the age of 29 and was responsible for starting the postgraduate programme in Chemistry there. With him at the helm of affairs, the M.Sc. programme in the college produced 100% results year after year. He was instrumental in developing revolutionary pedagogy and initiating a full-fledged research programme in chemistry. This was a challenging task, considering the meagre resources and infrastructure available at his disposal. Nobody, including the Principal of the College, expected him to succeed in his research endeavours, and NVS proved everyone wrong. His determination, tenacity of purpose, perseverance and the will to succeed paid rich dividends in the following years.

With the skilled support of his research staff, NVS was able to set up a vibrant research group and elevate Vivekananda College to a world-renowned institution in Physical Organic Chemistry research during his tenure. He mentored 27 Ph.D. students, who in turn produced 35 more Ph.D. students. He encouraged his MSc students to take up research and persuaded his faculty colleagues to register for Ph.D. Within a few years, all the Faculty members in Chemistry of the postgraduate college became proud Ph.D. degree holders. To accomplish this feat in a small, private college under trying conditions is no mean achievement but the stuff of folklore! He became the Principal