Freeman Dyson: A Tribute

by Abhigyan Ray - Monday, March 16, 2020

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To claim to write an obituary of Freeman Dyson would be laughable at best and foolish at worst because as the great Edward Witten, Dyson's colleague at IAS, himself stated, "*His contributions were so wide-ranging that it is virtually impossible for any one person to summarize them adequately!*" Their colleague down the road at Princeton University, Elliott Lieb, was equally hard-pressed to find a suitable natural metaphor to describe Dyson, at one point grappling with an elephant with at least six legs and maybe two trunks before settling upon a giant tree in the middle of a statistical mechanics rain forest. And indeed, one would be hard-pressed to find someone with such diverse interests ranging from nuclear engineering to solid-state physics to astrobiology to public policy, all the while making versatile contributions that left an indelible mark in their field. One would wager, Dyson and not Thomas Young, earned the title of "The last man to know everything''!

Born to composer Sir George Dyson and Mildred Atkey in Crowthorne, England, on December 15, 1923, Dyson was a precocious talent as a child and after completing his schooling from Winchester College, he headed to Trinity College, Cambridge where he studied physics with Dirac and Eddington and found an intellectual role model in the renowned mathematician G.H. Hardy, who incidentally mentored Ramanujan too! He worked for the Royal Air Force's Bomber Command during World War II before graduating with a BA in Mathematics in 1945 and was a fellow at Trinity until 1947 before he was awarded a Commonwealth Fellowship which took him across the Atlantic to Cornell University to pursue graduate studies in physics with Hans Bethe but he famously never earned a PhD and forever earned the moniker "A 'Rebel' Without a Ph.D."

The epicentre of his dynamic life was undoubtedly mathematical physics, which he characterised as, "*A discipline of people who try to reach a deep understanding of physical phenomena by following the rigorous style and method of mathematics. It is a discipline that lies at the border between physics and mathematics. The purpose of mathematical physicists is not to calculate phenomena quantitatively but to understand them qualitatively. They work with theorems and proofs, not with numbers and computers. Their aim is to qualify with mathematical precision the concepts upon which physical theories are built.*" An outstanding Dyson hallmark was the ability to recognize a core problem in physics and then single-handedly create the mathematics necessary to crack the problem. The original proof of the quantum-mechanical stability of matter by Dyson and Andrew Lenard in 1966, where they gave the first rigorous proof that the Pauli exclusion principle between electrons is enough to ensure that matter is stable and does not undergo spontaneous collapse, is a tour de force in mathematical physics and contributed extensively to developing quantum statistical mechanics where Dyson made many subtle contributions regarding the "phases" of quantum and sometimes classical matter. Many hot topics today grew into a cluster of activity centred around his original insight.

As a mathematician, Dyson published papers in disparate areas like number theory, analysis, and algebraic topology. He first published on Simultaneous Diophantine Approximation in 1941 and further developed the concept known as "Dyson's transform", as part of his proof of Mann's theorem, which today serves as a fundamental technique in additive number theory. Starting in 1962, Dyson, along with Eugene Wigner and others, was largely responsible for developing what is now known as random matrix theory whose original goal was to give a statistical description of the energy levels of atomic nuclei but has now developed into a major topic with far-flung applications in mathematics, physics and computer science. One of the most surprising applications arose in the 1970s, when Dyson, combining his interests in number theory and random matrices, helped the number theorist Hugh Lowell Montgomery, who had just made his pair correlation conjecture concerning the distribution of the zeros of the Riemann zeta function, recognise the formula as the pair correlation function of the Gaussian unitary ensemble, which in turn suggested that there might be an unexpected connection between the distribution of primes and the energy levels in the nuclei of heavy elements such as uranium. This has been confirmed in many different ways, ranging from theoretical proofs to computer experiments, and is regarded as a key clue about the still unresolved Riemann hypothesis.

Among physicists, Dyson is fondly known as one of the pioneers of quantum electrodynamics (QED) which describes how light and matter interact. By the late 1940s, three very different and potentially incompatible approaches by Richard Feynman, Julian Schwinger, and Shin'ichir? Tomonaga of QED existed. At Cornell, he had befriended the legendary Feynman and in the spring of 1948, Dyson accompanied Feynman on a fabled cross-country road trip that was a classic Feynman experience, and not only etched their lifelong friendship but also culminated in one of the most remarkable breakthroughs of 20th-century physics. A rainstorm in Oklahoma allowed them to discuss quantum electrodynamics in a seedy brothel and a hefty speeding charge marked the end of the rollercoaster ride in a New Mexico courthouse. After spending six weeks listening to Julian Schwinger's ideas in Ann Arbor, which were similar to Tomonaga, on his way back to Princeton to begin his first Membership at the IAS, he was able to prove the equivalency of the three approaches in a "flash of illumination on the Greyhound bus." This resulted in a seminal paper which was published by The Physical Review in 1949 under the title, "The Radiation Theories of Tomonaga, Schwinger, and Feynman" where Dyson's insights provided a more precise understanding of sub-atomic particles consistent with quantum mechanics and special relativity, enabled the first use of Feynman diagrams in calculating scattering amplitudes, and showed how perturbative QED could be logically understood!! The theory of quantum electrodynamics that he helped establish is the prototype that was eventually elaborated into the Standard Model of particle physics and throughout the 1950s, Dyson made multiple important contributions to continue developing the framework of quantum electrodynamics and in 1965, Shin'ichir? Tomonaga, Julian Schwinger, and Richard Feynman were jointly awarded the Nobel Prize in Physics "*for their fundamental work in quantum electrodynamics, with deep-ploughing consequences for the physics of elementary particles.*" Dyson would have been included too, only if the three-person limit on Nobel Prize had not precluded it.

Shortly thereafter, at the invitation of J. Robert Oppenheimer, the Institute's longest-serving Director and the man who led the Manhattan Project, Dyson accepted a rare lifetime appointment at the Institute for Advanced Study (IAS) in 1953 after Oppenheimer was hugely impressed by Dyson's work on quantum electrodynamics and famously sent him a note of surrender inscribed "Nolo Contendere." At the IAS, Dyson flourished alongside a group of the century's top physicists and mathematicians, including Einstein, Gödel, Tsung-Dao Lee, Deane Montgomery, Siegel, Selberg, von Neumann, and Weyl. And yet, all this happened without him ever earning a doctoral degree!

The Institute provided Dyson with the freedom and flexibility to follow his curiosity to new areas and fields that interested him and the next few years saw Dyson crisscrossing vast swathes of mathematics, physics and engineering with great ease. In La Jolla he engineered an inherently safe nuclear reactor, the TRIGA reactor, that is still in production today and is a staple of medical physics; and took part in General Atomic's ambitious "Project Orion," working with forty scientists to design an atomic spaceship capable of riding a wave of controlled nuclear pulses into deep space describing the fifteen months spent on the short-lived project as "*the most exciting and in many ways the happiest of my scientific life.*" It also marked an important evolution of Dyson's life as he moved from pure physics and mathematics to applied problems, especially problems of war and peace. He was elected to the chairmanship of the Federation of American Scientists that were involved in important issues related to national policy; became a life member of JASON, an elite team of scientists advising the US government on defence problems; and joined the Arms Control and Disarmament Agency. He was engaged in the public debate regarding the nuclear test ban treaty and concluding that further nuclear testing was "*wrong technically, wrong militarily, wrong politically, and wrong morally*", Dyson testified before the U.S. Senate in favour of the treaty on August 28, 1963 and it just so happened that when he came out of the Capitol, he saw a large crowd of people marching to the Washington Mall where Martin Luther King was about to give one of the greatest speeches in history.

Dyson produced a steady stream of books geared for the scientifically curious among the general public. His autobiography Disturbing the Universe (1979), combines prose that flows like silk with a panoramic view of science, history, poetry, politics, and literature, and evidences an intimate understanding of war that is filled with empathy and revelatory human stories, remaining one of the most eloquent, literary and passionate testament by a scientist of his calibre. Weapons and Hope (1984), which won the National Book Critics Circle Award for Nonfiction in 1984, is a study of ethical problems of war and peace. Infinite in All Directions (1988) is a philosophical meditation based on Dyson's Gifford Lectures on Natural Theology given at the University of Aberdeen in Scotland. Origins of Life (1986) is a study of one of the major unsolved problems of science. From Eros to Gaia (1992) is a collection of essays and lectures, starting with a science-fiction story written at the age of nine, and ending with a mugging in Washington at age fifty-four. Imagined Worlds (1997) is an edited version of a set of lectures given in 1995 at the Hebrew University in Jerusalem about human destiny, literature, and science. The Sun, the Genome and the Internet (1999) discusses the question of whether modern technology could be used to narrow the gap between rich and poor rather than widen it. The Scientist as Rebel (2006) is a collection of book reviews and essays, mostly published in the New York Review of Books. A Many-colored Glass: Reflections on the Place of Life in the Universe (2007) is an edited version of a set of lectures given in

2004 at the University of Virginia. Maker of Patterns (2018) is an autobiographical account of Freeman's life through letters written to his parents.

For his contributions to science, mathematics, and public policy, Dyson had been honoured with countless honorary degrees and had been elected to numerous learned societies, including the Fellowship of the Royal Society at the tender age of 30 and the membership of the National Academy of Sciences. Among Dyson's many accolades are the National Space Society's Robert Heinlein Memorial Award (2018), the Henri Poincaré Prize of the International Mathematical Physics Congress (2012), the Templeton Prize for Progress in Religion (2000), the Enrico Fermi Award of the U.S. Department of Energy (1995), the Oersted Medal of the American Association of Physics Teachers (1991), the Wolf Prize in Physics (1981), the Harvey Prize (1977), the Max Planck Medal of the German Physical Society (1969), the Hughes Medal of the London Royal Society (1968), the Lorentz Medal of the Royal Netherlands Academy (1966), and the Dannie Heineman Prize for Mathematical Physics of the American Institute of Physics (1965).

On 28th of February, Freeman Dyson breathed his last at Princeton after suffering complications from a fall. This was a death long time coming but almost everyone I knew eagerly hoped that he'd live to touch 100. Yet at the same time, few can hope to live for so long and have such a chequered career with a frontline view of all the game-changing developments that revolutionised science in the last century! With Freeman Dyson's demise, one of the last standing pillars of the Golden Generation of Theoretical Physics has fallen and an era comes to a close. He was a polymath who was equally at home talking about the S-matrix and diplomacy with the Soviets all the while mulling over T. S. Eliot's "Murder in the Cathedral". The most enduring and endearing quality of this great humanitarian scientist was that of a contrarian and a maverick, someone who always liked playing the devil's advocate, the guy who had his hand raised in a room full of nodding heads, not because he wanted to get a rise out of people but because he believed that science best progresses not through consensus but around the edges, when people ask questions; something that Steven Weinberg, the last standing pillar of that Golden Generation, best described as, "*I have the sense that when consensus is forming like ice hardening on a lake, Dyson will do his best to chip at the ice.*" His favourite motto was the founding motto of the Royal Society - "Nullius in verba", or "Nobody's word is final" something that's the founding motto of science itself and something that we all will do well to remember in a post-truth world!
