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OBITUARY

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# John Charlton Polkinghorne, 1930–2021

## by David Fairlie

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## 1 | EARLY LIFE AND EDUCATION

John Charlton Polkinghorne was born on 16 October 1930 in Weston-super-Mare to Dorothy Charlton, a groom's daughter, and George Polkinghorne, who left school at 14 to work for the post office. George and Dorothy were regular church attenders. An elder brother, Peter, was killed on active service in the RAF in 1942. Just before John's birth, a sister Ann died in infancy. In the opinion of his children, these tragedies made John particularly feel the responsibilities of being the only surviving child.

As George Polkinghorne's career in the post office prospered, the family moved several times. In 1935, he became postmaster in Street, and John went to school there, first to the local primary school, then as he was slow at reading he had two years of private tuition. In 1938, he went on to the Friends Meeting House School, and later moved on to Elmhurst grammar school. In 1939, George became Head Postmaster at Wells, but the family remained in Street. In 1945, George was promoted again, to be Head Postmaster in Ely, and John attended the Perse School in Cambridge, commuting by train. He was taught 'additional mathematics' by a mathematics master, V. G. Sederman, who was a considerable influence upon John's choice of subject of study. Peter Hall, the theatre director, was a contemporary at school. In 1948, John won a scholarship to Trinity College, Cambridge. At that time, students were required to do a year's national service, during which he taught elementary mathematics as a Sergeant Instructor in the Royal Army Education Corps. While at Edinburgh University, he claimed to have been the youngest Sergeant in the British Army!

He entered Trinity College in 1949 and took the Mathematical Tripos, including Part III, gaining a first in 1952. A number of fellow mathematical students at the time became well known in later life, including Roger Phillips, Ron Shaw (who independently of C. N. Yang discovered non-Abelian gauge theory as a graduate student), Frank Adams, Abel prizewinner Michael Atiyah, and James Mackay, later Lord Chancellor. He was supervised for his PhD, first by Nicholas Kemmer and then, after Kemmer left Cambridge to take up the Tait Chair of Mathematical Physics at the University of Edinburgh, for his final year (1953) by Nobel prizewinner Abdus Salam.

John met Ruth Martin, also a mathematics student, and an able amateur cellist. They were both members of the Christian Union. They married in 1955, and had three children, Peter, born in 1957, Isobel, born in 1959, and Michael, born in 1963.

## 2 | CAREER

John was awarded a research fellowship at Trinity College in 1964. He finished his PhD in 1965. Towards the end of that year, he and Ruth sailed for the United States on a Harkness Fellowship to the California Institute of Technology, where he worked with Murray Gell-Mann, physicist and polymath, who invented the concept of quarks, as permanently confined constituents of what were then regarded as elementary particles such as the proton and neutron, and gave them their name. (The other independent discoverer was Stefan Zweig, also of CalTech, but then on sabbatical leave at CERN.) This resulted in joint work on dispersion relations, although John was somewhat intimidated by Gell-Mann's forceful personality. Returning to the United Kingdom, John took up a lectureship at Edinburgh (1956–1958), where Kemmer was building a noteworthy research group, inspiring many undergraduates who later became well known in the field through his encouragement and the excellence of his lectures which were aimed at the more able students. In 1958, John had the opportunity to return to Cambridge as lecturer, where he quickly built up a research group in elementary particle theory, within the School of Mathematics, hiring Jeffrey Goldstone, Alan Macfarlane, David Olive, Ian Drummond, Hugh Osborn, and Peter Goddard.

In 1965, he was promoted to reader in theoretical physics, and then appointed as professor of mathematical physics in 1968. He was awarded the degree of ScD in 1974, the same year in which he was elected Fellow of the Royal Society. He had several research students, many of whom became university professors. At one point, three of his former students, James Stirling, Wojtek Zakrzewski, and myself were simultaneously professors at Durham University. He attended 17 of the annual or biennial 'Rochester Conferences' on particle physics, and visited several of the world's leading institutions for the study of the subject, including Stanford, Berkeley, Princeton, and CERN. He used this experience to write a book, following the history of the subject as revealed at these conferences, *Rochester Roundabout: The story of high energy physics* [11], with personal characterisations of some of the leading players in the field.

In addition to his service on Cambridge University committees, John was also a member of the Science Research Council from 1975 to 1979, and chairman of the Nuclear Physics Board from 1978 to 1979.

### 2.1 | Research students

John supervised many research students during his scientific career, several of whom went on to have successful university careers; all are now retired. At the beginning, some were only partially supervised by him at the end of their studentships: S. M. Kahana, T. W. B. Kibble (Imperial College), D. B. Fairlie (St Andrews and Durham), G. R. Screaton (Edinburgh and Oxford), P. V. Landshoff (Cambridge), R. W. Lardner (Simon Fraser University), M. Fowler (Virginia Tech), I. Drummond (Cambridge), I. G. Halliday (Imperial College and Swansea), C. O. Escobar, M. Bloxham, B. Renner (deceased) (CERN), D. Scott, W. J. Zakrzewski (Durham), and W. J. Stirling (deceased) (CERN, Durham, Cambridge, and Imperial College).

To many people's surprise though not to all who knew him personally, he resigned from his Chair and commenced training for the Anglican Ministry at Westcott House, meanwhile continuing to act as a tutor for Trinity College. As he said at the time, ‘Theoretical Physics is a young man’s game’, and he felt that his best work in this area was behind him. His Christian vocation had remained strong, and he took the direction of exploring the role of religion in scientific understanding. From 1981, he served as priest in St Andrew’s Chesterton, St Michael and All Angels, Windmill Hill, Bristol, and St Cosmas and St Damien in the Blean, near Canterbury. He returned to his beloved Cambridge as Dean of Chapel at Trinity Hall, then became President of Queen’s College until his retirement in 1996. As a consequence of his change in career, he served on many medical ethics committees, and was knighted for this and other services to the community.

## 3 | CONTRIBUTION TO THEORETICAL PHYSICS

It is not generally recognised to what extent theoretical physics is a matter of fashion. In the mid 1950s, the direction of particle physics, describing the behaviour of the so-called elementary particles, the proton, neutron, electron, neutrino, pion, and photons, many of which are no longer considered elementary, switched from a description in terms of quantum field theory, which had been extremely successful in describing the electrodynamic behaviour of these particles at a quantum level, but was seen as inadequate to explain the strong interactions of elementary particles, that is, nuclear forces. Instead, the motivation changed from a detailed description of particle interactions to an investigation of what could be said about a particle scattering process simply from general principles of physics.

The two main principles were those of causality and the unitarity of the scattering matrix (the $S$-matrix) of Heisenberg and Wheeler. Along with this approach, which became encapsulated in the formalism of dispersion relations, there was also an increased interest in the classification of particles according to geometrical principles, leading to the association of particles with low-dimensional representations of Lie groups.

John’s foray into this area occurred with the paper *On the classification of fundamental particles* [13] with his second supervisor, Abdus Salam, after his first research mentor, Nicholas Kemmer, left for the Tait Chair at Edinburgh. As Richard Feynman amusingly put it: ‘When confronted with a problem, theoretical physicists either disperse, or form a group’. However, John’s subsequent work was largely concerned with the analytic approach, studying how far the principle of regarding physical quantities as boundary values of complex variables, constrained by the principles of causality and unitarity, could be used to constrain the form of the scattering amplitudes, which encapsulate the probabilities of the processes when two fundamental particles of physics scatter. The principle of causality, succinctly expressed as no output before input, or more colloquially as ‘No light before the switch is pressed’, was expressed mathematically as follows: If the output of a process $f_{\text{out}}(t)$ at time $t$ is related to the input $f_{\text{in}}(t)$ by the convolution

$$f_{\text{out}}(t) = \int_{-\infty}^{\infty} f_{\text{in}}(\tau) H(t-\tau)\, d\tau, \tag{3.1}$$

then, if the process is causal, that is, if $f_{\text{in}}(t) = 0$ for $t \leqslant t_0$, then also $f_{\text{out}}(t) = 0$ for $t \leqslant t_0$. By Titchmarsh’s theorem, this implies that $\bar{H}(\omega)$, the Fourier transform of $H(t)$ regarded as a function of a complex variable $\omega$, is analytic with no poles in the upper-half $\omega$ plane.

This was used by John Toll [18] to connect the principle of causality with the analyticity of scattering amplitudes, in terms of the square of the total four-momentum, usually denoted by $s$ in the literature, when $s$ is regarded as a complex variable, whose real component is the measured physical quantity. There is a second Lorentz invariant $t$, the square of the momentum transferred, and together they completely characterise the scattering amplitude of four scalar (spinless) particles, $A(s,t)$. Unitarity is an expression of the conservation of probability; that the probabilities of all possible outcomes of a scattering process should sum to unity.

The main focus of the work of John and his group in the late 1950s and early 1960s was in developing an understanding of the analytic properties of scattering amplitudes, particularly in terms of the contributions to these amplitudes described in perturbation theory in terms of Feynman diagrams. Lev Landau had given a heuristic prescription to determine these singularities, which was put on a more rigorous footing by Polkinghorne and Screaton [14, 15]. Consider a contour integral for a function $f(z)$, where $z$ may stand for several complex variables, given by

$$f(z) = \int_C F(u,z)\,du. \tag{3.2}$$

If $F(u,z)$ is a regular function for all $u$ lying on the contour $C$ for all $z$ within a domain $Z$, then $f(z)$ will also be regular within the same domain. If a singularity of $F(u,z)$ touches the contour in the $u$ plane, then provided the contour can be deformed away from the singularity, then $f(z)$ will remain non-singular, except for the cases when the singularity is at a terminal point of $C$ (end point singularity), or two singularities approaching the contour from opposite sides coincide (pinch singularity). A third possibility is that for some values of $z$, one or more of the singularities may recede to infinity (exceptional points). These may be dealt with by employing a complex transformation to bring the point at infinity into the complex plane. This analysis is the basis for much subsequent work of the Cambridge group.

A major aim at the time was to prove the Mandelstam representation for scattering amplitudes, which was a conjectured double dispersion relation for the scattering amplitude in terms of both variables $s$ and $t$ [6]. It had been proved in potential scattering (scattering by a fixed target) [1, 2] and the quest of the Cambridge group was to try to prove it in perturbation theory. To this end, an exhaustive study of the singularities of contributions arising from distinct Feynman diagrams was undertaken, and the results of this group together with the analytic properties determined by the principles of crossing, unitarity and causality, were summarised in the textbook *The analytic S-matrix* [4]. This has become something of a classic in the field, and is enjoying a considerable revival of interest in the present day, and continues to be referenced.

One of the significant results of this study was the proof, from an examination of three particle scattering, that the general principles of $S$-matrix theory imply the existence of complex pole singularities which provides a connection with field theory as such poles are a signal of the particle propagators $1/(p^2 - m^2)$ which are used to build up Feynman diagrams in field theory. For a short period, a vast number of particle physicists worked on the Mandelstam representation, the theorists trying to prove it, and the phenomenologists to use it to fit experimental data, but as a general proof remained elusive, and a specific diagram contradicting the hypothesis was discovered [5], gradually interest waned and the new fashion became the study of high energy behaviour of scattering amplitudes.

The best fit to scattering at high energies and large momentum transfers was found to be given in terms of the so-called Regge poles, after their proposer Tullio Regge [16]. This was the idea that the large energy behaviour of scattering amplitudes should be dominated by contributions from poles in the complex angular momentum plane. John and his former student Peter Landshoff turned their attention to validating this scheme in perturbative field theory, and showed that a series of diagrams (the so-called ladder diagrams because they were constructed from iterated box diagrams in the manner of a ladder and its rungs) showed Regge behaviour [7, 8]. As the experimental results increased, the description shifted again from field theory to the description of high energy processes in terms of the parton model of Feynman and Field, which envisaged protons and neutrons being composed of strongly interacting hypothetical constituents, or partons as they called them without describing them as Gell-Mann's quarks. (There was some amicable rivalry between Feynman and Gell-Mann, though both were professors at the same institution, the California Institute of Technology.)

John took up this model and, making the interpretation as quarks, produced a series of papers, many with Landshoff on their covariant version of the parton model [9]. They showed that in the available data for large angle proton–proton scattering the differential cross-section for scattering varied as the same power of the energy at each fixed angle. This work is summarised in his book *Models of high energy processes* [10] and contributed to the identification of partons with quarks, and established that the quark concept went beyond a book-keeping device to classify the strongly interacting particles, but also led to an explanation of the dynamics of particle interactions.

## 4 | CONTRIBUTIONS TO PHILOSOPHY AND THEOLOGY

Although John underwent the regular process of training for ordination and served for five years as priest in Anglican churches in Bristol, Kent, and Cambridge, and later was appointed as a Canon Theologian of Liverpool Cathedral, his theological writings were largely not about a personal God, but rather a creator God, of whom he was fond of saying 'God holds the Universe in being'. He considered that the greatest problem for anyone adopting a religious view of the world was that of the existence of suffering. However, while admitting that he had no answer to this question, he turned to debating the relevance of a religious point of view in physics. He was fascinated by the so-called 'fine-tuning problem', the fact that the constants of nature, the parameters which appear in the equations which govern physical processes, are adjusted so minutely that the universe we experience exists in the form we know it.

One such example was that discovered by Fred Hoyle [3]. He was interested in the nucleosynthesis of the elements in stars, and calculated that for a stable form of carbon 12 to be created by the fusion of three helium atoms, it should have a state with an energy level around 7.7 MeV, otherwise there would be insufficient carbon to continue the process of nucleosynthesis, and the resulting universe would not contain the heavy elements. At the time, no such state was known to exist, until Hoyle persuaded some experimentalists at the California Institute of Technology to look for it; it was found at an energy of 7.656 MeV, vindicating his expectation. This example and other coincidences led John to the conviction of the existence of an intelligent Creator. He subscribed to the view that human beings are qualitatively different from other animals in caring for each other in time of misfortune and experiencing grief. In recent years, more evidence of altruistic and grieving behaviour in chimpanzees and elephants has arisen, but some writers, such as Raymond Tallis [17] have robustly defended the position of human uniqueness.

He became increasingly interested in the limitations of our knowledge resulting from the probabilistic nature of quantum mechanics and also the indeterminacy inherent in chaotic behaviour. He also saw parallels between physicists' struggles in developing quantum mechanics and theologians wrestling with their concerns, such as the problem of evil [12]. John was awarded the Templeton Prize in 2002, and donated much of his prize to Queens' College, Cambridge, to fund a fellowship for research into the relationship between science and religion.

## 5 LATER LIFE

John was remarkably successful in his two distinct careers, first as a theoretical physicist, then as a leading member of the increasingly large group of scientists and theologians discussing the interface between science and religion. Here he became known to a much wider audience, especially in the United States, lecturing to large crowds. John excelled as a lecturer, with an innate sense of how to pace his presentation, and how much detail to include. He used a heavily Latinised vocabulary and had some characteristic expressions; unconventional persons were described as 'rum', the man in the street was 'the man on the Clapham omnibus' and a favourite word was 'nugatory'. He was very firm in his opinions, and was impervious to persuasion to bend the rules for his colleagues and associates, when pressed to do so. He was also an efficient administrator; a noteworthy characteristic being his habit of replying by return of post to any letter sent to him, and that is in the days before the importunate missives of e-mail! While I was on sabbatical leave at CERN in 1970, John Polkinghorne came out for a short research visit. At CERN, it was customary to greet our friends every morning when we first met for the day with a handshake. Accordingly, when John arrived, I extended my hand; he looked at it a little suspiciously, then shook it saying, 'I suppose it's some time since we last saw each other!' He was very much the reserved Englishman.

It seems to have been a surprise to many that he relinquished his Chair in Mathematical Physics to start a new career in religion, characterising theoretical physics as a 'young man's game'. It was no surprise to me: as one of his earliest students, I have long known of his ambitions in the Church. He had been encouraged by his mentors in Cambridge to become a distinguished physicist, and this he achieved first, before having a remarkably successful second career in the field of science and religion. During this second phase of life, John served on various Medical Ethics committees.

John's wife Ruth died from leukaemia in 2006. In his latter years, he suffered from reduced mobility and also hearing loss. He spent some of his time re-reading nineteenth-century classical literature, and also history, another of his interests. He remained at home, helped by a devoted carer. With the help of friends, he often attended church, and sometimes lunched at Queens' College.

## 6 HONOURS AND AWARDS

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| 1984 | Honorary Professor of Physics, University of Kent |
| 1993 | Gifford Lecturer, University of Edinburgh |
| 1994 | Canon Theologian, Liverpool Cathedral |
| 1994 | Honorary DD degree, University of Kent |
| 1994 | Honorary DSc degree, University of Exeter |
| 1995 | Honorary DSc degree, University of Leicester |
| 1996 | Six Preacher, Canterbury Cathedral |
| 1997 | KBE |
| 1999 | Honorary DD degree, University of Durham |
| 1999 | von Humboldt Foundation Award |
| 2002 | Templeton Prize |
| 2003 | Honorary DSc degree, Marquette University |

## Honorary fellowships

1989 Trinity Hall, Cambridge
1996 Queens' College, Cambridge
1999 St Chad's College, Durham
2002 St Edmund's College, Cambridge

David Fairlie

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