GEORGE FREDERICK JAMES TEMPLE, 1901–1992

OBITUARY

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George Temple was born in London on 2 September 1901. He stressed the good fortune of having three outstanding mathematics teachers: Ray Gilbert (briefly) at Northfields Elementary School, P. G. Goodall at Ealing County School and C. V. Coates at Birkbeck College, to which George had gone in 1918 as an evening student, having had to leave school after less than five years at the secondary level because of his father's death. In 1919 Professor Albert Griffiths made George his part-time research assistant in physics. It was in the same year that he was received into the Roman Catholic church. He took the General Honours BSc in 1922, and became Steward in the Physics Department for two years, having already written his first paper [**1**], inspired by Smart's lectures on projective geometry and by Whittaker's Cambridge Tract. At this time he began to study general relativity, and by 1924 he had published a paper on Whitehead's modification of the special theory, which was a gravitational theory. This was a time when the heavy differential geometry of the general theory still made such a modification worthwhile in many people's eyes. In [**2**] Temple extended Whitehead's theory to a space of uniform constant curvature, and in [**3**] he showed that Whitehead's theory gave the same planetary orbits as general relativity. It was Whitehead's interest in these papers that led to Temple's appointment in 1924 as Demonstrator in Mathematics in Imperial College. He continued the work in relativity [**4**, **5**, **6**], and these three papers were accepted for a PhD. In [**4**] he rediscovered the theory with a conformally flat metric and field equations the contraction of Einstein's; this gives a retrograde motion of perihelion. In [**5**] he considered a rather *ad hoc* modification of Newtonian gravitation in which the potential energy causes changes of mass. Finally, [**6**] marked Temple's acceptance of general relativity, and a proof that, for static metrics of the form

$$ds^2 = w^2 dt^2 - \psi^4(dx^2 + dy^2 + dz^2),$$

the principle of covariance alone is enough to give the Schwarzschild solution.

Temple's interests now turned to analysis [**7**], and although the results in that paper and [**12**] are now only of historical interest, they show one source for his later interest in generalised functions. He began by using $(C, 1)$-summability to study series solutions of the eigenvalue problem

$$u''(z) + [\rho^2 - \ell(z)]\, u(z) = 0$$

with two-point boundary conditions. A 'null series with parameter ξ' is a series of eigenfunctions of the equation which is uniformly $(C, 1)$-summable to zero in the closed intervals $[0, \xi - \delta]$, $[\xi + \delta, \pi]$. Temple proved that the only such series are $\sum_{n=1}^{\infty} \phi_n(\xi)\, \phi_n(z)$, so anticipating the Dirac delta function. In [**12**] he started from the

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idea behind Fatou's theorem to introduce a 'doubly orthogonal set of orthogonal functions' $[\phi_n(x)]$ such that

$$\sum_n \int_a^s \phi_n(\xi)\,d\xi \int_a^t \phi_n(\eta)\,d\eta = \min(s-a, t-a).$$

Then he showed that the 'Fourier series' (with respect to ϕ_n) of the Heaviside unit function converges weakly to $H(x)$, and so derived Fatou's theorem and Parseval's theorem for such systems. It was at this time that his teaching led him to look at Rayleigh's Principle [**8**, **10**]. He had been called upon to teach a rule of thumb for estimating the fundamental frequency of a linear vibrating system, which gives an upper bound. In [**8**] he provided a rigorous proof, generalised the principle to higher harmonics, and gave a lower bound for the fundamental frequency. He improved this derivation in [**10**].

Whitehead was leaving the chair at Imperial College when Temple was appointed, but Temple was further encouraged by Whitehead's successor, Sydney Chapman, who recommended him for an 1851 Exhibition in 1928. The first year of the Exhibition was spent at Imperial College, working on the new quantum theory in the form of wave mechanics [**9**, **11**]. The first of these papers is a straightforward investigation of Rutherford scattering. But already certain 'classical' doubts about quantum mechanics had begun to rise in Temple's mind. In [**11**] he tried to understand the theory in terms of an electric fluid supplemented by a force derived from a quantum potential, in rather the way later followed by Bohm. But he put these doubts on one side in 1928 when Dirac published his first-order equation for the electron, relativistically invariant but not of tensor form. Temple went to work with Eddington in Cambridge for the rest of his 1851 time; Eddington's mistaken belief, which Temple in common with many others shared, that the tensor calculus produced all invariant equations, had been badly shaken. An explanation in terms of two-valued representations of the Lorentz group would be ahistorical. Temple's first reaction [**13**] was to try to rewrite the offending equation in tensor form, but he gave up this project [**14**] once he was installed with Eddington as his PhD supervisor, in favour of a thorough-going study of Dirac's algebraic quantities [**15**] as abstract elements not in terms of matrix representations. This led him to the important [**16**], in which he was able to use the same abstract methods for the hydrogen atom. This paper begins by a straightforward translation of Dirac's treatment into more abstract form, but instead of following Dirac in expanding the resultant wave equation into its matrix components in terms of one particular matrix representation of the operators, and successively eliminating components of the wave function, Temple shows his originality and his characteristic ability to see the essence of the problem by transforming the equation as it stands to polar coordinates. He simplifies the result by a canonical transformation and then solves for the new wave function by what is essentially Frobenius's method applied to an equation whose coefficients and dependent variables are all abstract algebraic quantities. He followed this by using the same methods for the Zeemann effect [**17**, **18**].

Temple left Cambridge, without his second PhD, in 1930 when he was offered a Readership at Imperial College, a position which made it possible for him to marry Dorothy Carson. This happy marriage lasted 49 years, until her death. Once back in London, Temple returned to Rayleigh's Principle [**21**, **B**] and also continued in quantum theory [**22**], but with a better understanding the disenchantment returned. He tried to expound the correct physical principles by an analysis of measurement as a form of spectral analysis, basing this on the idempotent character of the measurement operator [**20**, **C**]. The technical details of this book are now part of a standard treatment of quantum mechanics, but Temple's emphasis is unusual. The whole argument rests heavily on the notion of measurement, and it is twenty-four pages before Planck's constant makes its appearance. In 1932, with the support of Eddington and Forsyth, Temple was elected to a chair at King's College London: he was now 31. The head of department, Joliffe, and Principal Halliday, had another man in mind, and so the youthful Temple had to proceed with tact in his aim of raising the very low standards to which the department had then sunk. When Joliffe retired in 1936 and was replaced by Professor J. G. Semple, many changes became possible.

Meanwhile, Temple's views on quantum theory had crystallised, and [**24**] exhibits his view of the 'fundamental paradox' of the quantum theory. In it he shows that the accepted principles for correlating classical variables with quantum operators led to the conclusion that all operators must commute so that Planck's constant is zero. The many criticisms of this paper did not change his opinions, and he gave up quantum mechanics completely. He turned to his other interests, and published over a dozen papers and two books in his time at King's, until the war intervened in 1939. Two of these papers developed out of his Cambridge work [**23**, **28**]. The first merely points out that Maschke's 1900 representation of a quadratic form as the square of an 'ideal vector', where the algebra is taken to be commutative but a convention restricts which products can be admitted, can be replaced by a Dirac-like representation by anti-commuting quantities without the restrictive conventions. The second paper is much deeper and proves the justification for Maschke's work in an extended form. This work, directed towards simplifying the heavy algebra in general relativity, might have been carried much further if the war had not come. From considering the use of differentials in these papers, Temple was led [**26**] to advocate their use in teaching the calculus, but without success. In general relativity he tried unsuccessfully to formulate Gauss's theorem for gravitation in covariant form; as we now know, the problem is insoluble. He also found suitable coordinates for discussing geometrical optics in general relativity [**29**].

Southwell's relaxation method also occupied him at this time [**31**]. Let $W(u_r)$ be the potential energy function for a linear elastic system, so that the stable equilibrium is at a minimum of W. Relaxation methods systematically reduce W by changing the u_r. Thom's Gauss–Seidel method changes the u_r in some order, Southwell's by changing at each stage that u_r giving the greatest proportional change in W. Temple proposed a steepest descent method, changing all the u_r to make $|\text{grad } W|$ greatest, and he then proved that all these methods converged to the equilibrium. This interest proved important, because when the war came Temple was sent to the Royal Aircraft Establishment at Farnborough, where he remained until 1945. He enjoyed his time at RAE because of the novel experience of working as part of a team. His two more mathematical investigations there were in supersonic flow and in dealing with 'shimmy', that is, wheel wobble on landing. In 1939 the received opinion was that when fluid flow velocities reached that of sound, there would be a catastrophic breakdown of some kind. News came of a 1940 German paper (not available) in which von Ringlab gave an exact solution for compressible flow over a range partly subsonic and partly supersonic. Temple reconstructed this [**33**] and also obtained a second solution of similar kind. He returned to supersonic flow in 1944, and during his time at RAE he also worked in incompressible flow and in aerofoil design [**35**]. Shimmy was one of a number of problems of instability which he studied, but it was a favourite. His investigation relied on his modelling the complex dynamical behaviour of a pneumatic tyre by considering the form of the 'tread-line', that is, the line round the tyre which is central when the tyre is undisturbed [**50**]. He was able to give a simple theory of side forces, cornering, the 'crab walk' and the relaxation walk.

Temple's return to King's was less than enthusiastic, for he correctly anticipated pressure to take many administrative tasks in both college and university. But he avoided the worst dangers, so that he was able to continue with his mathematics and to make the department a most happy one with a strong research tradition. I recall with pleasure the very happy atmosphere in the fifties. Aerodynamics, powered by the primitive mechanical calculators of the time, still dominated the applied research, but it was surprising to what extent the research students understood the exact significance of their problems in a more general context. The breadth of Temple's mathematical interests and knowledge was a constant surprise and a benefit to almost every member of staff. Courtesy, kindness and wit were predominant aspects of his character, and he was much loved by all. He began by tidying up his RAE work in supersonic flow [**40**] and on Rayleigh's Principle [**41**, **46**], and then he developed a simple iterative method for the boundary layer for a semi-infinite plate. His early interests in analysis and his work on quantum theory had earlier directed his attention to the 'scandal' of the Dirac delta function, and his interest in infinitesimals was sharpened by his study of the boundary layer (as was Abraham Robinson's at about the same time). In a series of papers [**42**, **43**, **44**] and especially [**47**], after he had left King's he took the new 'theory of distributions' of Laurent Schwarz and rewrote it. Schwarz's version had got rid of the delta function at the expense of a formulation in terms of linear functionals on a function space which, at the time, was obscure to anyone but a specialist in analysis. The applied mathematician felt that Schwarz had achieved something but only at the expense of writing everything back to front. Temple's rewriting retained the correctness but was quite easy to apply over a wide range of applied mathematics. This work attracted the award of the Sylvester medal of the Royal Society in 1970.

Temple's life at King's was diversified by his appointment as Principal Scientific Adviser to the Minister of Civil Aviation 1948–50, when he advised on new methods of air traffic control. He was Librarian of the Society 1948–51 at a time when the need was to build up connexions with foreign mathematical societies which had been severed by the war. He was instrumental in arranging many exchanges of periodicals. He was President of the Society 1951–53. It was at this time that he began his association with the International Union of Theoretical and Applied Mechanics (IUTAM). He was elected Treasurer in 1952, re-elected in 1956, and then became President in 1960 and Vice-President in 1964, for four years. He enjoyed this work for the insight that it gave him into what was being done and what mathematics would be needed.

In 1953 Temple succeeded Sydney Chapman in the Sedleian chair at Oxford and settled to a happy life at The Queen's College. His papers there were at first looking back to collecting together his own work and setting it in context [**48**, **49**, **50**, **51**, **52**, **53**, **D**, **55**, **56**, **E**], but in 1960 he made a further departure in his application of characteristic forms in geometric integration theory [**57**], using generalised functions to understand the theory of de Rham, Whitney and Hodge. Here the characteristic form of a submanifold M is, as usual, a function of position which is 1 on M and zero outside. Temple covers all possible cases by developing in terms of differential forms the integral of a completely skew-symmetric contravariant tensor of rank p over a q-dimensional differentiable manifold M in a Riemannian space of $p+q$ dimensions. The characteristic function for M is then found to be a skew-symmetric covariant tensor of rank p, and in terms of differential forms the relation for characteristic functions a, $a(\partial C) = d(a(C))$, exhibits the parallel between the boundary operator ∂ and the differential operator d. Temple's later years at Oxford led him to elaborate the idea of a weak function [**59**, **60**, **61**] and to devise a new proof (by means of characteristic functions) of the Heine–Borel theorem [**62**]. He was also engaged with his book on Lebesgue integration [**F**].

On a visit to the United States after his retirement in 1968, it was suggested to him that he might write a book to be called *100 years of mathematics*. It took him ten years, and even then dealt only with 'those branches of mathematics in which I had been personally involved'. So it is not a history, although the arrangement is chronological, but more like one man's contribution in an encyclopedia; the range covered, from logic through analysis to differential equations, is wide indeed. Temple's wife died in 1979, and in 1980 he continued his life-long association with the Benedictines by being admitted to Quarr Abbey in the Isle of Wight. His Solemn Profession as a monk was in 1982 and he was ordained in 1983. He died at Quarr on 30 January 1992.

He had intended to lay down mathematics at Quarr once he had seen *100 years of mathematics* through the press. But he found an irresistible need to work on a field new to him, the foundations of mathematics. He based his investigations on the notion of taxonomy in biology, which he had come upon by a lucky accident in a library. Following the line taken in biology, he begins with undefined terms, called *taxa*, some of which can be connected by an undefined relation called *association*. From this sparse beginning he undertook (in the next ten years) to construct set theory and so all the rest. A preliminary paper [**63**] was written hurriedly, but a definitive exposition was in manuscript form when he died. In it he claims 'the purpose of this investigation is to carry out the primary part of Hilbert's programme, i.e. to establish the consistency of set theory, abstract arithmetic and propositional logic and the method used is to construct a new and fundamental theory from which these theories can be deduced'.

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