OBITUARY

JOHN FRANK ADAMS

Frank Adams was born in Woolwich on 5 November 1930. His home was in New Eltham, about ten miles east of the centre of London. Both his parents were graduates of King's College, London, which was where they had met. They had one other child—Frank's younger brother Michael—who rose to the rank of Air Vice-Marshal in the Royal Air Force.

In his creative gifts and practical sense, Frank took after his father, a civil engineer, who worked for the government on road building in peace-time and airfield construction in war-time. In his exceptional capacity for hard work, Frank took after his mother, who was a biologist active in the educational field.

In 1939, at the outbreak of World War II, the Adams family was evacuated first to Devon, for a year, and then to Bedford, where Frank became a day pupil at Bedford School, one of a group of independent schools in that city. Those who recall him at school describe him as socially somewhat *gauche* and quite a daredevil; indeed, there were traces of this even when he was much older. In 1946, at the end of the war, the rest of the family returned to London while Frank stayed on at school to take the usual examinations, including the Cambridge Entrance Scholarship examination in which he won an Open Scholarship to Trinity College. The Head of Mathematics at Bedford, L. H. Clarke, was a schoolmaster whose pupils won countless open awards, especially at Trinity.

Although National Service was still compulsory at this time, it could be deferred by those accepted for university entrance. Frank, however, decided to get it out of the way and served for a year in the Royal Engineers, where he attained the rank of Corporal. He looked back on this experience with amusement if not enthusiasm.

Trinity College

Adams, as we shall call him in relation to his professional life, entered Trinity in 1949, which was a vintage year for mathematicians. His contemporaries included several future Fellows of the Royal Society, including M. F. Atiyah, I. G. MacDonald and J. C. Polkinghorne. He was successful academically, obtaining a first in Part II of the accelerated Mathematical Tripos and a distinction in Part III. Outside academic work, he developed an enthusiasm for rock-climbing and mountaineering generally, which lasted the rest of his life. He was also an active 'night-climber' of college buildings and, with a friend, performed the remarkable feat of climbing into and out of every one of the then men's colleges in the course of a single night. In addition, he built up a remarkable repertoire of strenuous parlour tricks, which he would exhibit on social occasions in later life—given a little encouragement—such as manoeuvring himself all round the walls of a room without touching the ground, or drinking a glass of beer placed on top of his head without using his hands.

After completing Part III, Adams began graduate work in Cambridge under the distinguished Russian emigré mathematician A. S. Besicovitch, whose main interest

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at this period was in what would nowadays be called geometric measure theory. Adams' first published paper, 'On decompositions of the sphere' [**1**], was obviously influenced by Besicovitch, and later he provided an extended appendix to a paper by the latter's former student E. R. Reifenberg [**15**], whose tragic death while rock-climbing, a few years later, cut short a most promising career. However, the Besicovitch phase of Adams' graduate studies did not last long, and by 1953 he had settled down as a research student of Shaun Wylie, whose lectures had introduced him to algebraic topology. Wylie, with characteristic modesty, described Adams as 'essentially self-taught'. Be that as it may, Adams soon began to forge ahead in his new field.

It was in the previous year that Adams met his future wife, Grace, at a Congregational Youth Club in New Eltham. At this time they were both graduate students in Cambridge, where she was preparing to become a minister of the Congregational Church. Their marriage took place in 1953. Grace's early career took her first to Brighton and then Bristol, with Frank joining her at weekends, and it was some while before they were able to establish a regular home together.

Photographs of Adams taken at this time show a strikingly handsome young man. Fairly tall and of excellent physique, he enjoyed good physical health at least until he was in his mid-fifties and, without making a show of it, kept remarkably fit. He was always ready to outwalk almost anyone, and if he happened to find himself near a mountain of any note, he would set off and climb it as soon as he could.

Oxford and Cambridge

The leading school of algebraic topology in the United Kingdom in the post-war period was that led by J. H. C. (Henry) Whitehead at Oxford. The Whitehead influence on Adams' early work is unmistakeable, and must derive considerably from the seminar run by P. J. Hilton, a former research student of Whitehead's who was then a lecturer at Cambridge. In the summer of 1954, Whitehead organized a 'Young Topologists' conference in Oxford, at which Adams had the opportunity to meet not only members of the Whitehead circle, but also several overseas topologists such as J. C. Moore from Princeton, J-P. Serre from Paris and H. Toda from Osaka.

When Adams was appointed to a Junior Lecturership at Oxford in 1955, just before he completed his PhD, he came more directly under the influence of Whitehead, and joined the circle surrounding him. He was particularly close to M. G. Barratt, who did much to transmit Whitehead's thinking to younger mathematicians. Adams always referred to his Oxford year with great pleasure. He liked to describe himself as morally a Whitehead student, and would frequently quote Whitehead's aphorisms.

Adams' PhD thesis, dated 1955, is really more a collection of articles with some common elements than a conventional thesis. He expresses his gratitude to Gugenheim, Hilton, Moore and Whitehead, as well as to Wylie. The thesis, which was examined by Hilton and Whitehead, is entitled 'On spectral sequences and self-obstruction invariants'. In the first three chapters Adams makes comparisons between various types of spectral sequence. The fourth chapter, on the self-obstruction invariants (that is, what are now usually called Postnikov invariants), was later published [**3**]. Of the three appendices, the first two, 'On a theorem of Cockcroft' and 'On products in minimal complexes', were published as [**2**] and [**4**], respectively. Of more interest was the last appendix, which gave a method of computing the homology of the loop space of a CW-complex. An improved version appeared in [**5**] as a joint paper with Hilton; in a further improvement [**6**], Adams gave a purely algebraic construction from one chain complex to another, which he called the cobar construction.

Adams submitted his PhD thesis for a Research Fellowship at Trinity, and was elected for the period 1955–58. For the first of these three years he was on leave at Oxford (see above), and so he did not really take up his research fellowship until the second year. He and Grace were then able to establish their first real home together, at Wood Ditton near Newmarket, where Grace was responsible for a group of Congregational churches.

It was during this period that Adams began to develop the ideas that made him famous, most notably the spectral sequence which quickly came to bear his name. The theory of Postnikov systems is dual to the theory of CW-complexes. The idea is to build up spaces through fibrations where the fibre is an Eilenberg–MacLane space, rather than through cofibrations where the cofibre is a Moore space (for example, a bouquet of spheres). This provides a valuable alternative conceptual framework for homotopy theory, as not only is it essentially intrinsic, but it provides a direct approach to the problem of calculating homotopy groups. This problem was one of the principal technical challenges of the time, and most of the known results had been proved by Cartan and Serre, who had developed the theory into a method known as 'killing homotopy groups' for the purpose.

Adams had made a small contribution to the theory in his thesis, but he now undertook a thorough examination of it which led to a substantial reformulation of the entire technique—known ever since as the Adams spectral sequence—which completely changed the direction of work in the field. Instead of considering a whole series of Leray–Serre spectral sequences of fibrations, where the ingredients are cohomology algebras, the essentials were encoded in this new sequence, which starts from the cohomology of the Steenrod algebra (with coefficients the algebra in question). The method was announced in [**8**], with a preliminary application, and the details given in [**9**].

Commonwealth Fellowship

At this point Adams obtained the prestigious award of a Commonwealth Fellowship, and as a result he spent the academic year 1957–58 in the United States. This was unquestionably a most important step in his professional development. Adams arranged to go early, and spend the summer of 1957 as a Research Associate at the University of Chicago. The lectures he gave there on his work made a deep impression on Eilenberg, in particular, who gave an account of Adams' work at the International Congress of Mathematicians in Edinburgh the following year.

Adams took up his Commonwealth Fellowship in the autumn, when he moved to Princeton; his wife joined him for the customary tour of the United States the following summer. In the report he wrote for the Commonwealth Fund at the end of his stay, he describes the leading American algebraic topologists at the time as S. Eilenberg (Columbia), S. Maclane (Chicago), N. E. Steenrod (Princeton) and G. W. Whitehead (MIT). He also gives a long list of other mathematicians with whom he had contact. He summarizes his experiences in the following words.

> … I regard the progress of my researches in America as most successful. Without going into technicalities, I can explain that my programme

> specified a quantity of preliminary work, leading to certain goals; and that by taking thought I was able to attain these goals without ploughing through all the preliminary work. By good luck, moreover, my new methods were sufficiently powerful to answer one of the classical problems of my subject, that proposed by H. Hopf in 1935.

The problem to which Adams is referring here can be formulated in several ways, of which the following is the simplest. An H-space is a topological space that, like a topological group, admits a continuous multiplication with two-sided identity. Hopf showed that the $(n-1)$-sphere S^{n-1} can carry such a structure for $n = 2$, 4 or 8, whereas spheres of even dimension cannot. J. Adem, using the relations between Steenrod operations that he had discovered, further excluded all spheres of odd dimension except those for which n is a power of two. Next, the case $n = 16$ was settled by Toda in the negative; he announced this result at the Young Topologists conference in Oxford.

Adams now showed that (as many had conjectured) only $n = 2$, 4 and 8 are possible. This is his best known result.

An equivalent version of the problem refers to maps $S^{2n-1} \to S^n$: indeed, the given map $S^{n-1} \times S^{n-1} \to S^{n-1}$ may be extended to take $S^{n-1} \times D^n$ to the upper hemisphere of S^n, and $D^n \times S^{n-1}$ to the lower. Using this map to attach a cell gives a CW-complex $S^n \cup_f e^{2n}$ on which the Steenrod square Sq^n is non-zero. Now if n is not a power of 2, Sq^n can be expressed as a sum of products of operations of lower degrees, which vanish in this case since the intermediate cohomology groups are zero.

Adams' idea was to decompose Sq^n in the remaining cases with the factors being secondary cohomology operations. This involved a careful preliminary treatment of the theory of such operations, which occupies much of the paper [**14**] where the results are presented. The identification of the operations required essentially comes from a partial calculation of the Adams spectral sequence.

Cambridge again

On his return from the United States in 1958, Adams succeeded Wylie, his former research supervisor (who had left Cambridge a year earlier), as Fellow, College Lecturer and Director of Studies at Trinity Hall, Cambridge. A contemporary described him as 'an agreeable and interesting colleague, exceptionally courteous and considerate, honest and scrupulous, and helpful in College business'.

Adams' research productivity was high during this period. In [**17**] (to be followed a few years later by [**36**]) he obtained extensive calculations of the E_2 term of the Adams spectral sequence for calculating stable homotopy groups of spheres. Recognizing that the calculations which decided the question about H-spaces involved only the prime 2, he showed in [**16**] that if the sphere is localized at an odd prime, it becomes an H-space. The technique of localizing spaces was to become an important part of the subject a few years later; its use here was highly innovative.

Adams was also beginning to become interested in K-theory, the generalized cohomology theory based on vector bundles, which was then being developed by Atiyah and F. Hirzebruch. At this time, Atiyah held a similar position to Adams at Pembroke College, Cambridge, and although he was originally an algebraic geometer, their professional interests converged for the next few years.

The next major problem to seize Adams' attention was also a classical problem on the interface of algebra and topology. Hopf had shown that a compact manifold admits a continuous field of non-singular tangent vectors if, and only if, the Euler characteristic of the manifold vanishes. In the case of the sphere S^{n-1}, this occurs if, and only if, n is even. B. Eckmann and others had gone on to consider the more general problem of determining the greatest integer k such that S^{n-1} admits a continuous field of $k-1$ linearly independent tangent vectors at each point. Eckmann had observed that by using algebraic results of A. Hurwitz and J. Radon, it was possible to achieve $k = 2^c + 8d$ (known as the Hurwitz–Radon number) when $n = (2a+1)\,2^b$ with $b = c+4d$ and $0 \leqslant c \leqslant 3$. In the other direction, Steenrod and J. H. C. Whitehead had shown, using Steenrod squares, that 2^r was impossible when n is an odd multiple of 2^r.

As is detailed in the introduction to [**23**], Adams originally sought to approach this problem by a development of his existing methods. These led him to construct secondary operations by considering spaces related to the orthogonal group and BO. His much cited paper [**18**] dates from this period.

However, he then realized the advantages of working directly in K-theory, and in the event only primary operations were required. Although cohomology operations in K-theory, such as the exterior powers, had been investigated by Atiyah, among others, Adams used these to construct new operations which enabled him to prove (using earlier work of I. M. James) that the Hurwitz–Radon number is the best possible.

These Adams operations have since proved of importance not only in topological K-theory but also in other apparently remote fields such as group representation theory and algebraic number theory. Some years later, they were used by Adams and Atiyah [**34**] to give a much simpler proof of Adams' earlier theorem about H-structures on spheres.

Manchester University

Adams moved to Manchester University in 1962, first as Reader and then, on the retirement of M. H. A. Newman, as Fielden Professor. Those who remember the mathematics department at Manchester in the 1960s describe it as having a particularly stimulating atmosphere. 'Spores through the pores' was Adams' motto, meaning that much could be learned from the informal discussions that took place in the common room. A colleague wrote: 'You could test out any proposed line of investigation on him, and he would usually be able to tell you immediately that it was trivial, or do-able, or inaccessible at the time. Also you could ask him anything in topology and he either knew the answer or knew where to find it'.

In his own sphere, Adams presided over a remarkable team of homotopy theorists, including M. G. Barratt, J. R. Hubbuck, W. A. Sutherland and R. M. Wood, who were from Oxford. Another member of the team was his former Cambridge research student G. Walker, with whom he wrote an important paper [**29**] on the complex version of the vector field problem, showing that a certain necessary condition obtained earlier by Atiyah and J. A. Todd was also sufficient.

At Manchester, Adams continued to develop the theoretical investigations that he had begun at Cambridge. This work was published in a famous series of papers [**25**, **28**, **31**, **35**] which appeared in the new journal *Topology* under the title 'On the groups $J(X)$'. These papers may be said to have revolutionized homotopy theory. Deriving at least in part from his work on the vector field problem, they show how K-theory can be used in other ways, for example to obtain deep information about the homotopy groups of spheres. It was in the first of these papers that Adams made a bold conjecture which excited the interest of homotopy theorists everywhere. The Adams conjecture, as it became known, relates the classification of vector bundles by stable isomorphism to their classification by stable homotopy equivalence of the associated sphere-bundles. Reformulated in various ways, the conjecture, now a theorem, is one of the key results of homotopy theory today. Adams himself proved a special case in [**25**]; later, D. G. Quillen and D. P. Sullivan, independently, showed that the general case could be reduced to the special case.

In 1964 Adams was elected a Fellow of the Royal Society, at the early age of 34. He could look back on the achievements of the previous decade with well-justified satisfaction. Some idea of Adams' general outlook on algebraic topology in the mid-1960s, when he was at the height of his powers, can be obtained from the survey [**37**] which he gave at the International Congress of 1966 in Moscow.

It was in 1965, however, that he suffered the first attack of a psychiatric illness, as a result of which he was on sick leave for some months. (We are most grateful to professionally qualified colleagues for guidance here.) It was apparently brought on by the worry caused by his responsibilities as head of department, which he took extremely seriously; after this experience he tried as far as possible to avoid stressful positions of this type. To what extent his professional work was adversely affected by the nature of the treatment he received to help control the condition is not clear. Certainly, his contributions to research in later years were less innovative than those of his youth, although just as impressive technically; of course, this could also be attributed to increasing age.

Hypomania is not uncommon among those with exceptional creative gifts. Those who suffer from it, as Adams did, have a deep psychological need to defend themselves against the underlying depression, in one way or another. Adams' response to this need was not unusual, but it was at times disconcerting to those who were not fully aware of the situation. For example, the competitive instinct in Adams was particularly highly developed: J. P. May, in his memorial address (Trinity College Chapel, 29 April 1989), described him as 'excruciatingly competitive'. This was seen in his attitude to research. Priority of discovery mattered a great deal to him, and he was known to argue such questions not just as to the day, but even as to the time of day. Again, in a subject where 'show and tell' is customary, he was extraordinarily secretive about research in progress. Certainly his urge to compete was extraordinary, and many stories are told about it. He very much enjoyed punting on the river, for example, but he liked to turn it into a race if he possibly could. He drove cars with remarkable skill but in a style that left a lasting impression on his passengers.

Return to Cambridge

By 1970 Adams was the undisputed leader in his field, and his reputation was such that he was seen as the obvious person to succeed Sir William Hodge on the latter's retirement as Lowndean Professor of Astronomy and Geometry at Cambridge. Unfortunately, returning to Cambridge was not without drawbacks. His family was unable to move to the Cambridge area immediately and so he had to concentrate his teaching duties there into one exhausting day each week. Some of the Cambridge mathematicians Adams knew best were no longer there; Atiyah had moved to Oxford the year before Adams went to Manchester and, not long afterwards, Wall, Zeeman and others had left. As a result, Adams found himself in some ways more isolated than before, and this remained the situation until C. B. Thomas joined him some ten years later. However, he was delighted to return to Trinity, his old college. Although he was seldom very active in college affairs, he took great pride in being a Fellow of Trinity and loved showing mathematical visitors around.

From 1972 onwards, the family lived at Hemingford Grey, a semi-rural community on the Cambridge side of Huntingdon; Frank took pride in their comfortable modern home and its attractive garden. It was here that their children grew up. Family life was extremely important to Frank although, on the whole, he preferred to keep his private life separate from his professional life. The four children—a son and three daughters (one adopted)—describe him as a 'full-time father'; they were hardly aware of his stature as a mathematician. When he was away from home he kept in close touch with them with frequent postcards and daily telephone calls.

Members of the family used to do many things together, especially fell-walking in the Lake District: they ascended all the 'Wainwrights', that is, peaks over 2500 ft. Grace had by this time migrated from the Congregational Church to the Society of Friends (Quakers), and although without strong religious convictions himself, Frank regularly accompanied Grace to the meetings on Sunday mornings. In the afternoon, they would often go to Alconbury, the local cruise-missile base, to support the peace-vigil. On one occasion Frank went to court to stand bail for another supporter who had been arrested. Frank acted as treasurer for the local branch of the Labour Party, and might be described as an intellectual Fabian in outlook.

Adams wrote numerous papers during this period. A feature of many of them is a strenuous effort to state results in their most natural framework: this is conspicuous in all the papers which he selected to submit in 1980 for his DSc, which include [**40**], [**42**], [**52**], [**58**] and [**59**]. In [**42**], which originates from his Manchester period, it is shown that a complete analysis of operations in K-theory can be obtained if one studies the K-homology of BU; the systematic use of generalized homology (instead of the more usual cohomology) was a theme further pursued in his book [**49**]. In [**58**] a uniqueness theorem for the infinite loop space structure on BSO is obtained using the special features of this example: this yields a stronger result than do more general techniques. The key step involves extensive calculations with the Adams spectral sequence.

One theme that held particular interest for Adams was the homotopy theory of the classifying spaces of topological groups. In the striking paper [**55**], extending special cases proved by Mahmud, it is shown in general that a map $BG \to BH$ with G, H compact connected Lie groups induces (using cohomology) a homomorphism of maximal tori and of the Weyl groups; and that the converse may be obtained modulo finite localization. The methods involve primary cohomology operations and number theory. In [**62**], following correspondence with C. B. Thomas, Adams extends these results to arbitrary compact Lie groups.

In the joint paper [**63**] with C. W. Wilkerson, Adams returns to connected finite H-spaces G, but now seeks to characterize the algebras $H^*(BG)$ that can occur. To quote from the introduction to that paper:

> What polynomial algebras can arise as cohomology rings of spaces? More precisely, let p be a fixed prime, and let $F_p[x_1, x_2, \ldots, x_l]$ be a polynomial algebra on generators $x_1, x_2, \ldots, x_l$ of degrees $2d_1, 2d_2, \ldots, 2d_l$; then is there or is there not a space X such that $H^*(X; F_p) \approx F_p[x_1, x_2, \ldots, x_l]$? This problem is related to the study of 'finite H-spaces'. More precisely, let X be

a 1-connected space such that ΩX is homotopy-equivalent to a finite complex; then $H^*(X; F_p)$ has the form considered above for all but a finite number of primes p and one would like to infer restrictions on the 'type' $(2d_1, 2d_2, \ldots, 2d_l)$. We will complete the solution of this problem when the prime p is sufficiently large, in the sense that p does not divide $d_1 d_2 \ldots d_l$.

The idea here is spectacular: it is shown that the algebraic closure of $H^*(BG; F_p)$, considered as an unstable algebra over the Steenrod algebra, is polynomial in 2-dimensional generators, so can be regarded as $H^*(BT)$ for a 'torus' T; even, under a favourable hypothesis, that $H^*(BG)$ is the ring of invariants of a finite reflection group acting on $H^*(BT)$.

Finally, Adams developed a deep interest in equivariant homotopy theory, especially in the Segal conjecture. At the 1970 International Congress, G. B. Segal made a far-sighted conjecture about the stable cohomotopy of classifying spaces of finite groups. Although Segal gave a heuristic argument in support of his conjecture, it was not until almost ten years later that it was proved in the simplest non-trivial case by W. H. Lin. After this breakthrough, Adams and others [**76**, **78**] set out to extend the proof to other groups, leading to the proof for finite groups in general by G. E. Carlsson in 1984. Adams also published several expository papers on equivariant homotopy theory, such as [**72**].

However, these contributions to research in homotopy theory form only part of Adams' published work. He also wrote several expository books of lasting importance, beginning with the *Lectures on Lie groups* of 1969, which is an invaluable introduction to the subject for non-specialist topologists [**38**]; it is said that he prepared this while in hospital. In 1972 he collected together some of the articles on homotopy theory, by various authors, which he regularly recommended his research students to read, and published them, with connected passages, as *Algebraic topology: a student's guide* [**44**]. He contributed greatly to the development of stable homotopy theory and his *Stable homotopy theory and generalised homology* of 1974 is the definitive work in that area to this day [**49**]. This was based on courses he gave at the University of Chicago, which he revisited from time to time. His last book, *Infinite loop spaces*, was based on the 1975 Hermann Weyl lectures he gave at the Institute for Advanced Study [**61**].

After the last episode of psychiatric illness, in 1986, Adams became markedly less intense. He continued to write research papers in collaboration with other workers in the field, but he started to reduce his activities in other directions, for various reasons. He let it be known that he would not be taking on any new research students. He stopped writing up the lecture notes on his course on the exceptional Lie groups, of which [**73**] may be regarded as a sample.

The last mathematical event Adams attended was the conference held at Kinosaki in August 1988, in honour of the 60th birthday of Toda, the distinguished Japanese homotopy theorist who he first met as a graduate student. Adams gave the opening address—a review of Toda's work [**82**]. A similar meeting to celebrate Adams' own 60th birthday was being organized by his former research students but, sadly, took the form of a memorial conference.

As a person

Adams was undoubtedly an awe-inspiring supervisor who expected a great deal of his research students and whose criticism of work that did not impress him could on occasion be withering. He gained the reputation of being rather dismissive of the less gifted students who came his way, especially if they seemed to be lacking in initiative, and he was concerned about this. For those who were stimulated rather than intimidated by this treatment, however, he was generous with his help. These included S. Cormack, J. P. C. Greenlees, J. H. Gunawardena, P. Hoffman, P. T. Johnstone, C. R. F. Maunder, R. M. F. Moss, A. A. Ranicki, N. Ray, R. J. Steiner, G. Walker and many others, some of whom became close friends, and all of whom were deeply influenced by his teaching.

Adams' lectures were always well prepared, and his delivery was clear and direct; he usually wrote detailed notes. Questions were answered in a forthright manner. These lectures, which made a deep impression on all who heard them, were enlivened with admonitions such as: 'Be careful to get your signs right here because if you don't they will turn round and BITE you'. (It would be interesting to know the present whereabouts of a tape-recording of a seminar by Adams, with 15 slides, which was made in 1967.) On one occasion, the undergraduate recipients of a particularly ambitious short course on multilinear algebra delivered a sort of petition: 'The class wishes to inform Professor Adams that it has been left behind'. He was highly amused by this, and kept it pinned up in his office, saying 'At any rate I have done exterior algebra, even if the second year haven't'.

As an examiner he had a reputation for severity, and when his critical instincts were aroused he did not hesitate to speak plainly. Those who collaborated with Adams on research, as many did, did not always find him the easiest of partners. 'After initially finding him abrasive and challenging, I later found him encouraging and stimulating' is a typical comment.

Humorous touches, always with a serious underlying purpose, can frequently be found in his writings. For example, there is the letter in 'Finite H-spaces and Lie groups' [**66**] pretending to be from the exceptional Lie group E_8 'given at our palace, etc.', which makes a good point about the relationships between torsion in K-theory and torsion in ordinary cohomology. Or again, when describing the behaviour of his spectral sequence [**57**], he wrote that

> In this region [it] is a bit like an Elizabethan drama, full of action in which the business of each character is to kill at least one other character, so that at the end of the play one has a stage strewn with corpses and only one actor left alive, namely the one who has to speak the last few lines.

From among the many anecdotes told about Adams, we shall mention just one more. A certain firm started producing three-dimensional jigsaws. The hardest of them became known as really hard, defeating several very bright people, and so some of the Cambridge students of J. H. Conway bought one, dismantled it and gave it to Conway to reassemble. It took him nearly two hours; when he had finished, he took it apart and put the pieces on one side. Shortly afterwards, Adams came into the room and asked some simple non-mathematical question. While Conway was answering, Adams listened attentively, then thanked him, picked up the pieces, put them together and walked away.

Advisedly, after his experience at Manchester, Adams did not seek out the positions of authority and responsibility for which his professional standing would have recommended him. Nevertheless he served a turn as Chairman of the Faculty Board of Mathematics at Cambridge, although this is not a particularly stressful position in a departmentally organized faculty. He also acted in an editorial capacity for several journals, notably the *Mathematical Proceedings of the Cambridge Philosophical Society*.

Editors of research journals knew Adams as an exceptionally conscientious referee who would go to a lot of trouble to explain what he thought was wrong with a submitted paper and how it might be improved. Such reports, and other critiques that he circulated privately, show in a most vivid manner how he would set to work on a piece of mathematics. He maintained an extensive international correspondence, dispensing much useful advice and good sense. To quote one characteristic example, from the end of a long letter to a young American who wrote to Adams about the problem he had been working on:

> In my opinion this is an ill-chosen problem. (a) If you solve it, it won't do the rest of algebraic topology much good. (b) It's hard so you stand to lose time and self-esteem. (c) Finally, it's addictive … kick the habit now.

6 January 1989 was a particularly happy day for the Adams family. Katy, the youngest member, had come home to attend the Twelfth Night feast at Trinity. To mark the occasion, Frank gave her a beautifully made piece of *cloisonné* work, a technique which was a hobby of his: he was extremely clever with his hands.

The following day Frank and Grace had been invited to attend the retirement party of an old friend in London. Neither of them was feeling very well, but at the last moment Frank decided to go on his own. On the way back that evening, within a few miles of home, his car skidded on a slippery bend of the Great North Road, overturned after striking the edge of a culvert, and smashed into a tree. He sustained very severe injuries and died almost immediately, at the age of 58.

In all that Adams did, he set himself a high standard of excellence, and this was recognized by national and international honours of various kinds. He was awarded the Junior Berwick and Senior Whitehead Prizes of the London Mathematical Society, and the Sylvester Medal of the Royal Society. The National Academy of Sciences of Washington elected him a Foreign Associate, the Royal Danish Academy elected him an honorary member, and the University of Heidelberg conferred on him an honorary doctorate.

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Students of J. F. Adams

List of students, dates, thesis titles and further comments, including subsequent employment where known.

1. *Cambridge*

60–63 Richard Maunder [Southampton, Cambridge].
61–64 Michael Moss, 'Products in Adams spectral sequences' [Hull, Stirling (retired 1990)].

2. *Manchester* (1963–1971)

61–68 Grant Walker, 'On the odd primary components of the stable homotopy groups of complex Stiefel manifolds' [Manchester].
63–66 Peter Hoffman, 'Moore spaces and the complex e-invariant' [University of Waterloo].
65–68 Andreas Zachariou, 'Cohomology operations in the cobar construction: applications'.
65–68 Anthony Brearley, 'On relations between operations in extraordinary cohomology theories'.
66–69 Nigel Ray, 'SU and Sp bordism' [Manchester].
67–70 Albert Harris, '$K_*(K)$'. (Did not finish, but work in [**42**].)
68–71 Sheila Cormack, 'Hopf algebras for general homology and an analogue of homological dimension' [Edinburgh (retired 1993)].
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