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GEORGE KEITH BATCHELOR
8 March 1920–30 March 2000
Founding Editor, *Journal of Fluid Mechanics*, 1956

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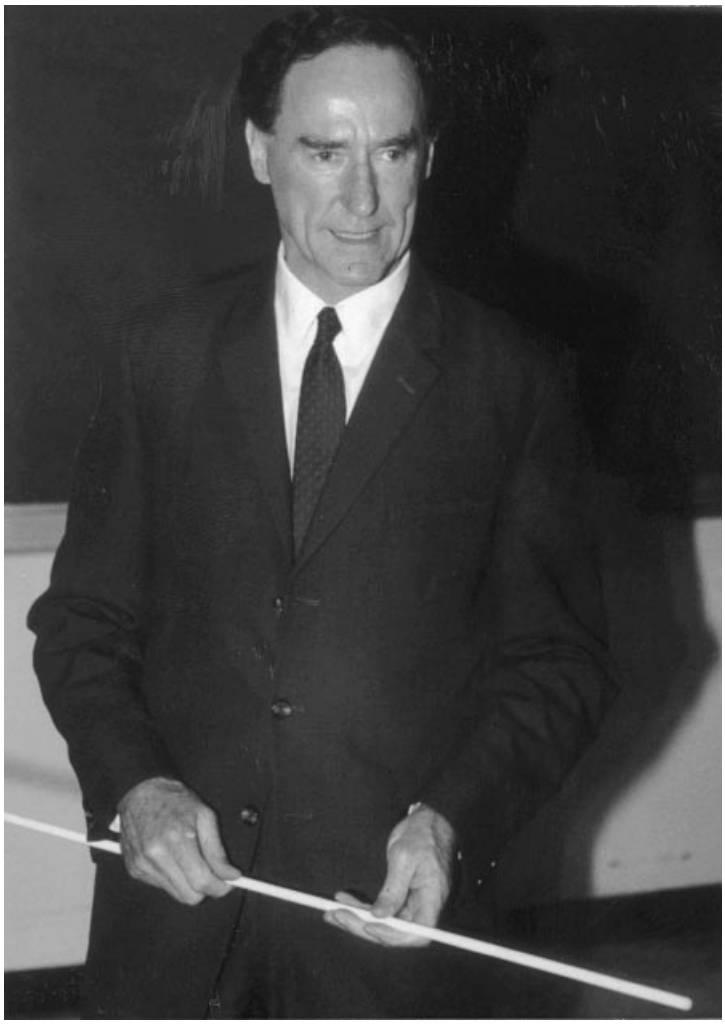

FIGURE 1. A very relaxed George, who has just retired from his Professorship at Cambridge and being head of DAMTP, giving the Prince Lecture at Arizona State University in November 1983.

George Batchelor was one of the giants of fluid mechanics in the second half of the twentieth century. He had a passion for physical and quantitative understanding of fluid flows and a single-minded determination that fluid mechanics should be pursued as a subject in its own right. He once wrote that he 'spent a lifetime happily within its boundaries'. Six feet tall, thin and youthful in appearance, George's unchanging attire and demeanour contrasted with his ever-evolving scientific insights and contributions. His strongly held and carefully articulated opinions, coupled with his forthright objectivity, shone through everything he undertook.

George's pervasive influence sprang from a number of factors. First, he conducted imaginative, ground-breaking research, which was always based on clear physical thinking. Second, he founded a school of fluid mechanics, inspired by his mentor G. I. Taylor, that became part of the world renowned Department of Applied Mathematics and Theoretical Physics (DAMTP) of which he was the Head from its inception in 1959 until he retired from his Professorship in 1983. Third, he established this *Journal* in 1956 and actively oversaw all its activities for more than forty years, until he relinquished his editorship at the end of 1998. Fourth, he wrote the monumental textbook *An Introduction to Fluid Dynamics*, which first appeared in 1967, has been translated into four languages and has been relaunched this year, the year of his death. This book, which describes the fundamentals of the subject and discusses many applications, has been closely studied and frequently cited by generations of students and research workers. It has already sold over 45 000 copies. And fifth, but not finally, he helped initiate a number of international organizations (often European), such as the European Mechanics Committee (now Society) and the biennial Polish Fluid Mechanics Meetings, and contributed extensively to the running of IUTAM, the International Union of Theoretical and Applied Mechanics. The aim of all of these associations is to foster fluid (and to some extent solid) mechanics and to encourage the development of the subject.

George's lifetime motivation was the detailed and accurate understanding of the dynamics of fluids, which he viewed as the most enjoyable of occupations. Once asked, admiringly, by Ted Wu, of Caltech, how one man could accomplish so much, George replied: 'It was easy, really. The recipe is work … work … and more work'. After his death, I found a quotation from Noel Coward in George's drawer which said: Work is much more fun than fun.

Many obituaries of George have appeared in newspapers all over the world and in special articles. As a consequence of his eminence and influence, a number of George Batchelor Lectures have been set up over the last decade and more will no doubt follow. Many of the selected Batchelor Lecturers have commenced (and will continue to commence) their presentations with a description of George and his life. While also presenting a brief description of his life, this article will, as appropriate, focus on his influence on this *Journal*.

Conceived in England, George Keith Batchelor was born in Moonee Ponds, a suburb of Melbourne, Australia on 8 March 1920. He was a precocious schoolboy who earned the top mark in the state of Victoria in the final mathematics exam. He entered Melbourne University aged just 17 to graduate in 1941 with an MSc in both mathematics and physics and a number of scholarships and prizes. Near the end of his life he wrote: 'It was a recurrent theme of my childhood thinking or dreaming that one day I would be a leader of some kind. The dream did not have a definite form but I imagined myself being distinguished as a creative organizer of things and/or people'. That dream was to be richly fulfilled in the future. In the meantime, unable to leave Australia because of World War II, George worked in the

FIGURE 2. George aged about 5 in Melbourne.

Division of Aeronautics of the Council for Commonwealth Scientific and Industrial Research on a series of aeronautical problems connected with the war effort. At first he was not very keen on aerodynamics. He wrote in his private diary that it 'seems too much like an engineering subject for my liking – the reason I do not like that is that I have never been very good at these semi-practical and close-to-reality subjects. The more abstract it is the better I like it'. But the necessity of practical work motivated by the war effort and his success in solving some real physical problems seems to have changed his mind. It particular, he was introduced to the essential nature and problems of turbulent flows and was challenged to come to grips with this difficult subject. George read avidly the inspirational work of the world's greatest expert on turbulence at the time, G. I. Taylor. Taylor was well known to Tom Cherry, the Professor of Mathematics at the University of Melbourne, who (like

FIGURE 3. George with daughters Adrienne, Bryony and Claire and wife Wilma in Poland for the Polish Fluid Mechanics Conference in 1963. (Photograph taken by H. K. Moffatt.)

Taylor) had been a Fellow of Trinity College, Cambridge and who had checked all the complicated algebra of Taylor's long and innovative 1923 paper on the instability of flows between rotating circular cylinders. After some correspondence, Taylor agreed to supervise George for a PhD. In January 1945, before the war was over, George embarked on a marathon ten-week voyage to Britain, along with his new wife, Wilma, whom he had first met and begun courting while still a schoolboy of 16. Wilma was devoted and understanding, and they were each others' almost only companion and confidant for more than fifty years. Their three daughters, Adrienne, Claire and Bryony, brought enormous pleasure to both their parents. The family lived in the appropriately named Cobbers, which George played a large role in designing, even conducting research to determine the best gap between the double-glazed window panes.

In Cambridge, George rapidly produced a series of formidable papers on turbulent flows which culminated in his authoritative book *The Theory of Homogeneous Turbulence* and set new standards in the subject. This essay is not the appropriate place to detail George's scientific research, which will be described by Keith Moffatt in articles to be published in the *Annual Review of Fluid Mechanics* and in the *Biographical Memoirs of the Royal Society*. I hope it suffices to document that for the first fifteen years of George's research life he concentrated on turbulence. While still a graduate student, he wrote a series of papers explaining for the first time the essence of Kolmogorov's theory, initially published in 1941, on the structure of small-scale turbulent motions. He continued to apply statistical and geometrical approaches to derive laws governing the motion of large eddies and the effects of temperature fluctuations on turbulent flows. By the early 1960s the excitement he derived from his research into turbulence had waned considerably and he turned his mind to other pursuits. During the years of gestation of *An Introduction to Fluid*

FIGURE 4. (*a*) George in September 1956. (*b*) George in Auckland, New Zealand, December 1960.

Dynamics, George realized that some techniques of statistical turbulence could be profitably applied to the area of flows in fluids containing small particles or bubbles. He named this field microhydrodynamics and wrote a series of very influential papers, first providing a secure foundation for the subject, and then solving some long-standing, difficult and fundamental problems. In particular, he showed for the first time how to incorporate far-field effects into calculations involving randomly ordered suspensions, thereby making advances on results obtained by Einstein more than fifty years previously.

George had already indicated his great independence and organizational skills at an early stage in his career. For example, in May 1947, while still a graduate student in Cambridge, he set up the first of what was to become the famous Friday afternoon 4:30 p.m. seminar series in fluid mechanics, which he attended and presided over for more than fifty years. G. I. Taylor was the first speaker and George on 'Diffusion in Isotropic Turbulence' was the second.

Just as he saw the need for a specialized seminar series in fluid mechanics, George saw the need for a specialized journal, to promote the power and attractiveness of his favourite subject.† He also wanted to raise the standards of scientific communication. Influenced by Nevill Mott, he approached the well-known

† This was not the first time he was involved in setting up a journal. When 13 he attempted to produce a form magazine to be called *C1 Rag* with himself as editor. He collected contributions, but then found that the production would be too costly and had to abandon the idea. 'I had no idea how very involved the production of a form magazine was' he wrote at the time.

London publishing firm Taylor & Francis, who agreed to print and publish the new *Journal of Fluid Mechanics*. The price was to be £1 per part (of slightly more than 100 pages) with six parts per volume. The first issue of the *Journal* had on its front page, as it still has today, the broad rubric that it *exists for the publication of theoretical and experimental investigations of all aspects of the mechanics of fluids*. George did not intend *JFM* to have a mathematical bias, nor did he ever approve of its reputation for doing so. In particular, he positively encouraged the submission of experimental papers. He has written that he 'was careful to ensure that the first few volumes contained papers which appealed to relatively young people, so that the readership would grow into the journal' and further 'that there was little or no support for the idea of a new journal in fluid mechanics in 1956 from people over 40'. He assembled a team with himself as the sole editor, G. F. Carrier, W. C. Griffith and M. J. Lighthill as Associate Editors and T. B. Benjamin and I. Proudman as Assistant Editors. The average age of this international editorial team was 32.

The *Journal* was a success from the outset and attracted high quality papers from great names (and future great names) in fluid mechanics. The first part of volume 1 appeared in May 1956 and contained eight papers received between 15 November 1955 and 3 January 1956 – there seems to have been no difficulty in obtaining referees' reports rapidly for the early volumes. From the outset George knew exactly what he wanted from authors, referees and publishers alike, which can be summarized as: accuracy, clarity, elegance and attention to detail. He gave the Associate Editors complete autonomy – they could accept or reject each paper as they saw fit, having, of course, first obtained careful referees' reports. He always believed that individual decisions were better and more imaginative than those made by any committee. New Associate Editors in later years were often amazed at how little explicit instruction and close supervision they received from George. But, through his large number of contacts, he always had his ear to the ground and knew the style and reputation each editor was developing.† Almost the only call for uniformity were six-monthly circular letters to editors which contained a list of the titles of papers being handled and the acceptance rates for each editor. The letter almost always contained a strong reminder that acceptance rates should usually be around 0.46; and George's own acceptance rate was invariably one of the closest to the desired figure. In the early years the duty of the Assistant Editors was to prepare all the copy for the *Journal*. This allowed George to insist on the highest standards of proof reading and accuracy of presentation. It also saved considerable money over hiring professional, and probably less meticulous, copy editors. This practice continued with each Assistant Editor working approximately 10 hours per week on the Journal, until 1967, when the first professional copy editor, or editorial assistant, was finally hired. The work is now carefully performed by Dr Linda Drath who, as George liked to say, is the only person in the world who has read (twice) every paper over the last 16 years.

George specified precisely all the details of printing and style of the new Journal. He would have arrived at these after careful thought and would have been convinced

† In my own case, George drew up a 'contract' dated 18 June 1971 and typically hand-written on an otherwise discarded piece of cardboard. In it he states that there is to be 'No terminating date; *JFM* editors die in harness', and that the duties included 'Initially to become familiar with printing processes and procedures and .... On a long-term basis (1) to help obtain reviews of books and (2) to take editorial responsibilities for some submitted papers'. He listed amongst the perks the 'Honour and glory of the position and a share in making of policy for *JFM*'. Just above his signature at the end of the 'contract' he wrote: 'Looks like a good proposition to me'.

that they were the *only* sensible decisions. Thus, for example, each paper in the *Journal* starts on a right-hand page so that the offprint commences on the first page (and not on the second page, or worse, as happened to me in another journal, with the references of the previous paper); the references are in alphabetical order of first author's surname, with initials following (and not in the order of citation which makes it difficult for a reader to peruse just the reference list, and used to mean BC (before computers) that the whole paper had to be rewritten if one extra reference was included). George drew up a style sheet of a dozen pages of tightly typewritten instructions for use by the copy editors and noticed even the slightest deviations from the recommended style. One day in the mid-1980s he entered the editorial assistant's office holding the latest issue of *JFM* and commented, kindly: 'I had not remembered that we decided to give the Book Review heading a lower case r.'

Book reviews (or Reviews!) were instigated in the third part of the first volume (with a review of C. C. Lin's *The Theory of Hydrodynamic Stability* by Paul Owen) and were regarded by George as one of the important processes of educating the fluid mechanics community. Many stimulating reviews have been printed, and George, as always leading by example and inspiration, prepared a number of them. His acerbic comments on sloppy writing and lack of careful thought became famous. In his first review (*J. Fluid Mech.*, vol. 2, 1957, p. 204) after a four-page description and critical evaluation of the contents of the book he wrote that it 'is also marred by slipshod writing. Non sequiturs, clumsy constructions, ill-chosen words, and even grammatical errors are numerous'. Near the end of the review he writes 'It is of course always possible to learn something from a new book. [From this book] it is that when one is establishing the equation of continuity, it is nowadays desirable to exclude the possibility that nuclear reactions are going on.' He also showed his disdain for mathematics for its own sake, unconnected to real physical situations, when he wrote that the book contained 'long derivations of formulae of which they (the authors) make no use and about which they make no comment. This is no more than a genuflexion before the altar of "high-brow" analysis.' In the next volume of *JFM* he complains about an author's 'diverting habit of incorporating slices of other people's papers in his book. … I was able to recognize three whole paragraphs and some odd sentences from two of my own papers. … Scissors and paste may be useful accessories at a lower level of writing, but at this level it is impossible.' (*J. Fluid Mech.*, vol. 3, 1958, p. 549). In the next volume, in a review of the Proceedings of a Conference, he writes: 'What puzzles me is that the practice of publishing in book form an almost random collection of papers read at a conference is becoming so common.' He goes on to suggest that such publications are of no serious use to authors, readers, editors or publishers. It is a theme he returned to often. I do not think he realized that such Proceedings only appear when someone in control, often the owner of a private publication house, makes money out of the book.

From the beginning George was not happy with the service he received from Taylor & Francis. He worked hard to transfer the *Journal* to Cambridge University Press, which had to pay Taylor & Francis a considerable sum for what would obviously be a tremendous money earner. From a circulation and financial point of view, the *Journal* was to become the most successful, by far, of all the journals published by the CUP. Throughout the 1970s it had a paid-up circulation of almost 2500 with many extra copies being printed for future sale as back issues. To date just over 11 000 papers have been published (and more than twice that number submitted). George felt that *JFM* had been successful in raising and setting standards, but he

FIGURE 5. George with characteristic smile around 1985.

wanted these improved still further. He managed by general encouragement, and a little cajoling, to hold on to his editors for a long time – of the founding editors, George Carrier remained in post for 30 years and James Lighthill for 22 years until he became Provost of University College, London; Keith Moffatt, who joined as an Assistant Editor in 1963, became the second co-editor with George (following Brooke Benjamin) from 1966 until 1983 when he succeeded George as Head of DAMTP; Owen Phillips was an Assistant Editor from 1955 to 1957 and an Associate Editor at Johns Hopkins from 1963 to 1995; and John Miles in Southern California was appointed an Associate Editor in 1966 and is still processing papers at the time of writing, 34 years later.

In 1982, on the twenty-fifth anniversary of the appearance of the first issue, George decided, after due consultation with the other editors, to commemorate the occasion by producing a special issue with 16 present or past editors providing 'editorial reflections on the development of fluid mechanics'. The various papers still make a timely and stimulating collection. Of course, the first was by George himself. Entitled 'Preoccupations of a journal editor', it is well worth reading. He states in the essay that being an editor of *JFM* 'has been an extraordinary experience … a pleasure and a privilege'. He viewed the essay as an opportunity to educate readers about the editorial processes of *JFM* and to ruminate on the communication of scientific ideas. Of course, he also includes a long section on the (lack of) 'clarity, precision and elegance' in scientific writing, and bemoans 'the present dismal standard of composition in scientific journals'. He comments on the fact that over the first '25

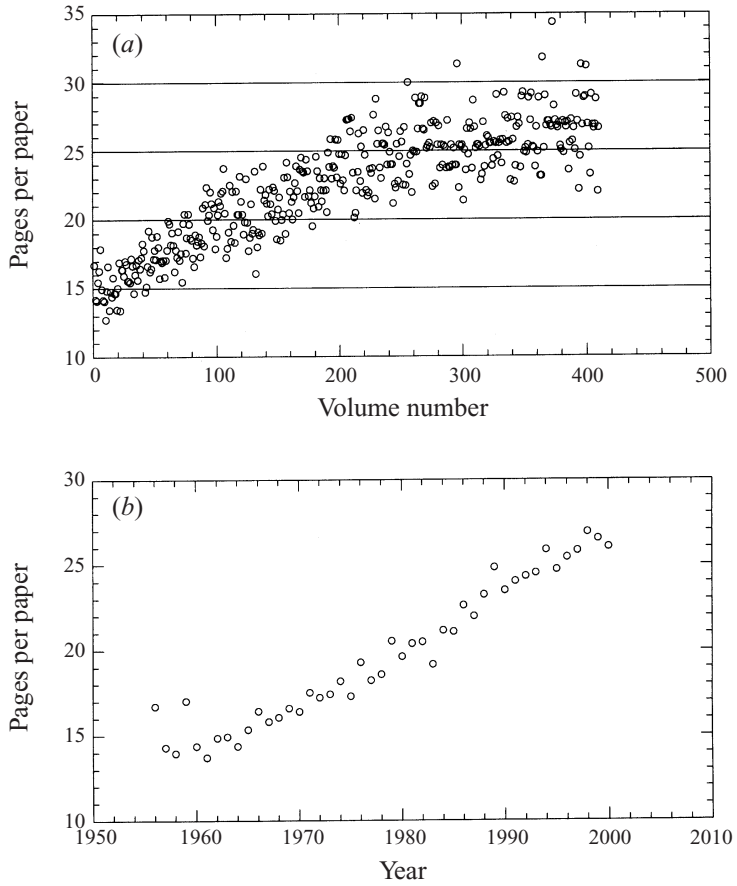

FIGURE 6. (*a*) The average number of pages per paper as a function of the volume in which the paper appeared. This is a continuation of the data presented by Batchelor in his article in *J. Fluid Mech.*, vol. 106. (*b*) The average number of pages per paper as a function of the year since the inception of *JFM*. The presentation differs from that in (*a*) both because the average is taken over more volumes, thus smoothing the data, and because of the gradual change in the annual publication rate – from about a volume each year for the first five volumes, to a volume per fortnight over the last seven years.

years the average length of papers in *JFM* has risen from about 15 to 21 pages' and presents a graph of the number of pages per paper as a function of volume number; a graph which is updated in figure 6. Ever cautious, George says 'I cannot account for this change', but adds in a footnote an explanation suggested by Keith Moffatt that the advent of high-speed computation and the lack of careful consideration by authors of what material to omit is responsible. As can be seen from figure 6, the inevitable rise in length is continuing, at about 0.3 pages per year, despite recent Government pressures for scientists to increase the number of papers published rather than to increase their quality, the ingredient which George considered so essential.

Prompted by the publication of this insightful essay, and at other times in the next 18 years or so, I suggested to George that he write an essay on his foundation of *JFM*, to include his initial thoughts, aims and negotiations with editors, authors

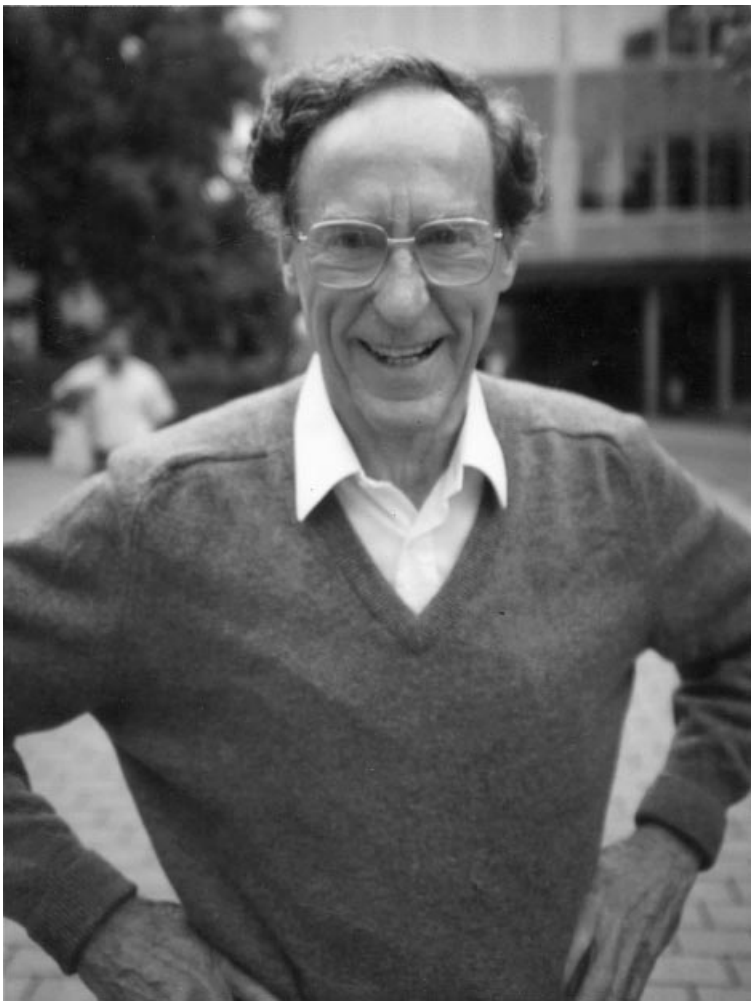

FIGURE 7. George, in a characteristically happy stance, in Hobart, Australia at the end of 1992.

and publishers. He never wrote the piece I had in mind, always saying that no-one would be interested. There is a typical George inconsistency here: fierce ambition and determination to achieve at the highest standard and to influence his colleagues, combined with an apparently modest reluctance to open his private thoughts and methods to the world. We had similar, unsuccessful conversations about an essay on his establishment of DAMTP. I also suggested he write a full autobiography, if only for his family. He was more receptive to this idea and, after he felt he could no longer carry out creative research, he spent a year or so around 1996 reading various autobiographies in order to develop 'a feel for the style'. Sadly, he had already developed Parkinson's disease. The endeavour, though started, with a working title of 'An Academic Life', was not taken very far. A very interesting opportunity was missed.

George was a man happy in his work, with an enthusiasm and a life-long love for his subject. He despised sloppy thinking and obfuscation and particularly disliked pomposity. He always knew exactly what he wanted to do and how it should be

achieved, generally without consulting others. He had a social conscience and cared about the welfare of the staff around him, but he also believed that the demands of an institution outweighed those of the individual. He was better than anyone I have ever met at not allowing personal matters or friendships to cloud his intellectual processes. He would reach the same judgement on a paper whether written by a close colleague and friend, a scientist he had not previously encountered or a world-famous fluid dynamicist. He enjoyed administration and the paperwork connected with it, and maintained an immaculate and detailed filing system. Because of his academic standing and the need to be precise when talking with him, most junior scientists were somewhat in awe and afraid of George and occasionally thought him aloof. For my part, I always found him easily approachable, with a broad sense of humour. Maybe because of the stresses connected with his Cambridge life, he was most relaxed away from Cambridge. He particularly enjoyed going to Poland and, somewhat uncharacteristically, drinking a considerable amount of vodka while there. Once retired, he and Wilma enjoyed frequent travel to Australia and the United States, where of course he was a much sought-after lecturer. The Batchelors especially loved dry desert regions such as in Arizona and Central Australia.

A proper evaluation of George's influence must strive to understand his interactions with G. I. Taylor, complicated though they might be. George, who was 34 years younger than G. I., viewed him as the perfect scientist whose approach could be beneficially followed by all. To this end, George (*a*) painstakingly collected, and persuaded CUP to publish in a uniform format, all of G. I.'s papers; (*b*) co-edited *Surveys in Mechanics* in honour of G. I.'s 70th birthday; (*c*) wrote 'An unfinished dialogue with G. I. Taylor' (*J. Fluid Mech.*, vol. 70, 1975, pp. 624–638), an evaluation of G. I.'s life for the *Biographical Memoirs of Fellows of the Royal Society*, (vol. 22, pp. 565–633) and a full-length biography *The Life and Legacy of G. I. Taylor* (CUP 1996); and (*d*) organized a large international conference on Fluid Mechanics in the Spirit of G. I. Taylor to commemorate the 100th anniversary of his birth (*J. Fluid Mech.*, vol. 173).

In order to publicize the meeting, I wrote in a short review (*Nature*, vol. 332, 1986, p. 500) that 'Taylor was one of the giants of physical science in this century'. George, on reading a draft, told me that I had not pressed G. I.'s claims sufficiently. When, some time later, I asked George to comment on an obituary I was preparing of T. Brooke Benjamin (*King's College Annual Report* 1996) he said that it showed only one side of Brooke, without mentioning his shortcomings. Somewhat taken aback, I said that I felt it was difficult to be negative in these situations and added that George had not pointed to any negative features in his much longer Biographical Memoir of G. I. 'Ah', he said immediately, 'that is different; G. I. had no negative aspects to his character'!

G. I. was clearly George's father figure, who could do no wrong. Despite his obvious adoration of G. I. and his scientific contributions, George did not model himself directly on G. I. A significant part of G. I.'s reputation was based on his experimental studies; George never carried out an experiment by himself, though he valued their important influence on the subject. He had to overcome considerable opposition to have a laboratory built at DAMTP when it moved to new accomodation in 1964. This was then an unusual accessory for a mathematics department. Although he strongly supported the laboratory and was proud of its achievements, he hardly ever went there. While G. I. wrote clearly and attractively, his oral presentations were notoriously dense and obscure. George put enormous care into his own writing, though it could be a little long-winded and slightly contorted at times. (My colleague

FIGURE 8. (*a*) The distinguished invitees at George's 70th birthday celebrations on 8 March 1990. From left to right: T. B. Benjamin; A. Yaglom; O. M. Phillips; A. Acrivos; G. I. Barenblatt; George; H. K. Moffatt; M. van Dyke; P. G. Saffman. (*b*) Further birthday celebrations in the Batchelor house, Cobbers. George, Acrivos, Barenblatt and Yaglom with Wilma Batchelor and June Yaglom.

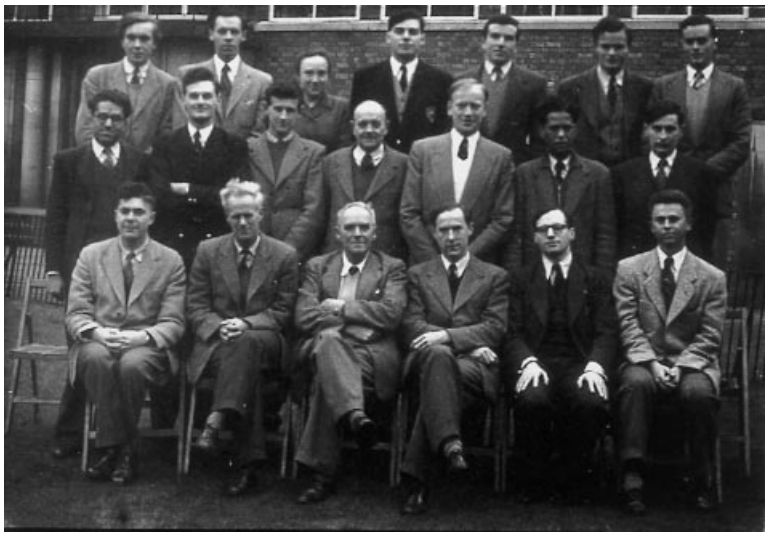

FIGURE 9. The Fluid Dynamics group in the Cavendish Laboratory, April 1955. Front row: Ellison, Townsend, Taylor, George, Ursell, van Dyke. Middle row: Barua, Thomas, Morton, Thompson Phillips, Bartholomeusz, Thorne. Back row: Nisbet, Grant, Hawk, Saffman, Wood, Hutson, Turner.

Julian Hunt compares it to the writing of Henry James, one of George's favourite authors.) George's verbal presentations, as might be imagined, were precisely detailed and exacting. The science was almost always of the highest quality, but George was not a showman (like Lighthill or Feynman) and there was little straight entertainment value. But most important, George was a leader of men, and had been since his early youth, and was an unashamed builder of empires. G. I. worked almost entirely on his own and, except possibly during the two World Wars, was never part of a team, let alone a leader of one.

In my opinion George, who generally could evaluate and understand well the thoughts and attitudes of his fellow scientists, had a partial blind spot when he thought, talked or wrote about G. I. My conjecture is that G. I., who was 60 when George first met him in 1945, represented what the young, assertive, ambitious graduate student hoped to achieve. As George matured, he found his own path, but he never let go of those original feelings of golden admiration.

As befits a scientist of George's international eminence, he received many awards world-wide. He always expressed considerable pleasure and some surprise when first informed of the latest recognition of his achievements. He was elected to the Royal Society in 1957 and received its Royal Medal in 1988. He was elected a Corresponding Member of the Australian Academy of Sciences, an Emeritus Member of the Academia Europaea, and to foreign membership of the Scientific Academies of France, Poland, Sweden and the United States. He was invited to deliver a dozen or more prestigious, named lectures and was awarded several scientific medals, including the G. I. Taylor medal of the US Society of Engineering Science. The Universities of Grenoble, Melbourne, McGill and Michigan, along with the Technical University of Denmark and KTH, Stockholm bestowed honorary doctorates on him. Strangely, not one honorary degree came from Britain, the country in which he had worked for over fifty years and whose Universities were awash with Professors who had been the

FIGURE 10. A rather formal picture of George at his desk in DAMTP in May 1993.

recipients of George's efforts, encouragement and kindness when they were graduate students in Cambridge.

Except for the last few years of his life George was a man happy in his work. He was almost totally ruled by his formidable intellect. He would never have allowed himself to say it openly to others, but I think he derived a quiet inner satisfaction in his accomplishments. He helped mould the careers of many fluid dynamicists during his lifetime and has influenced the way fluid dynamics will be researched, taught and communicated for many future generations.

I am grateful to my many friends and colleagues who helped me in the preparation of this obituary, to Adrienne and Bryony who gave me free access to the collection of family photographs, and to Mark Hallworth who carefully collated all the data presented in figure 6.