50 years of impact of JFM

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The total number of citations to papers published in 1972, 1980 1990 and 2000 are presented and discussed. Few papers are never cited (less than approximately 3%). The average number of citations per paper per year has almost doubled over this 28 year period from 1.2 to 1.9. The most cited paper attracts more than 30 citations per year on average. Of the 10,702 authors or co-authors of the 13,250 papers in the 50-year-history of JFM, 6,613 (62%) have appeared only once, while the most frequent author has appeared 117 times.

1. Citations

How often is the average JFM paper cited? What percentage of JFM papers are never cited, not even once? How many citations per year does the most cited JFM paper attract? How have these figures changed in fifty years?

All these questions must have occurred to many of the 10,702 authors or co-authors of papers in JFM since its inception. This short article supplies some answers. The Science Citation Index was used to investigate the distribution of the number of citations up to the last week in August 2005 of papers published in JFM during the whole of 1972, 1980, 1990 and 2000. (1970 is the

		1972	1980	1990	2000
1.	Papers	271	255	340	322
2.	Number of citations	10581	9276	9518	3076
3.	Mean number of citations per paper	39.0	36.4	27.9	9.55
4.	Mean number of citations per year	321	371	635	615
5.	Mean number of citations per paper per year	1.18	1.45	1.87	1.91

TABLE 1. Overall statistics for the years 1972, 1980, 1990 and 2000

earliest year to which Science Citations currently documents citations on line. It is a pity that earlier citation numbers are not currently available.)

Table 1 presents the overall statistics for the papers published in the four years: the total number of papers for each year; the total citation numbers since appearance; the mean number of citations per paper; the mean number of citations per year since publication; and the mean number of citations per paper per year. Note that in taking averages the years 1972, 1980, 1990 and 2000 were considered 33, 25, 15 and 5 years ago respectively. The rationale of this decision was that the half-year point and the collation point were roughly separated by an integer number of years. The influence of this counting method on papers published on 10 January rather than 25 December (sic; a date typical of George Batchelor) is greatest for publications in 2000. Table 2 presents more detailed data for the four years: the number (and percent) of papers with either one citation or none; the maximum number of citations (per year on average) received by the least cited 10% and 25% of papers published in that year; the minimum number of citations (per year on average) received by the most cited 50%, 25% and 10% of papers; and the number of citations (per year on average) received by the most cited paper that year.

Figure 1 presents the number and percentage of papers with a total of 0, 1, ...,10 citations for

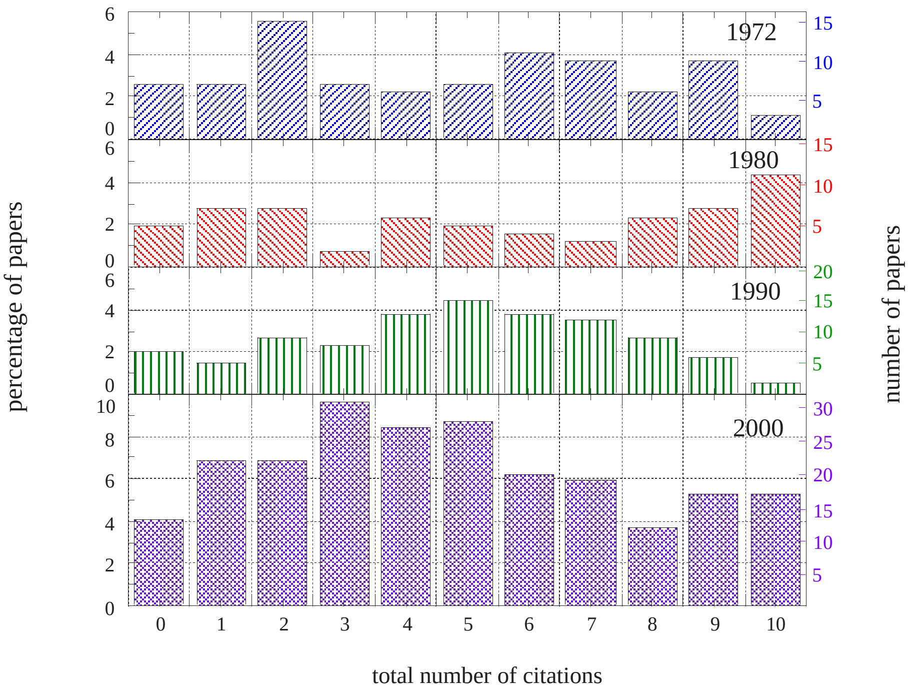

FIGURE 1. The percentage and numbers of papers with a total of 0, 1, 2,...,10 citations to date for papers published in 1972, 1980, 1990 and 2000. Each group uses the same scale for percentages (but not for number because the total number of papers published each year is different).

each year. Figure 2 graphs the same data but up to 50 citations. Figure 3 presents the number and percentage of papers in bins of 0.5 citations per year on average.

The most cited papers are: Batchelor (1972); Gollub & Benson (1980); Rom-Kedar, Leonard & Wiggins (1990) and Grossmann & Lohse (2000). For comparison purposes, it might be noted that the most cited paper in the history of JFM is Brown & Roshko (1974) which has been cited 1035 times, an average of 33.4 times each year.

Four of these five papers are on the challenging and changing subject of turbulent flows and the characteristic ways in which these flows can greatly enhance mixing of scalars; two of the papers are mainly experimental, one almost entirely numerical and one uses experimental data,

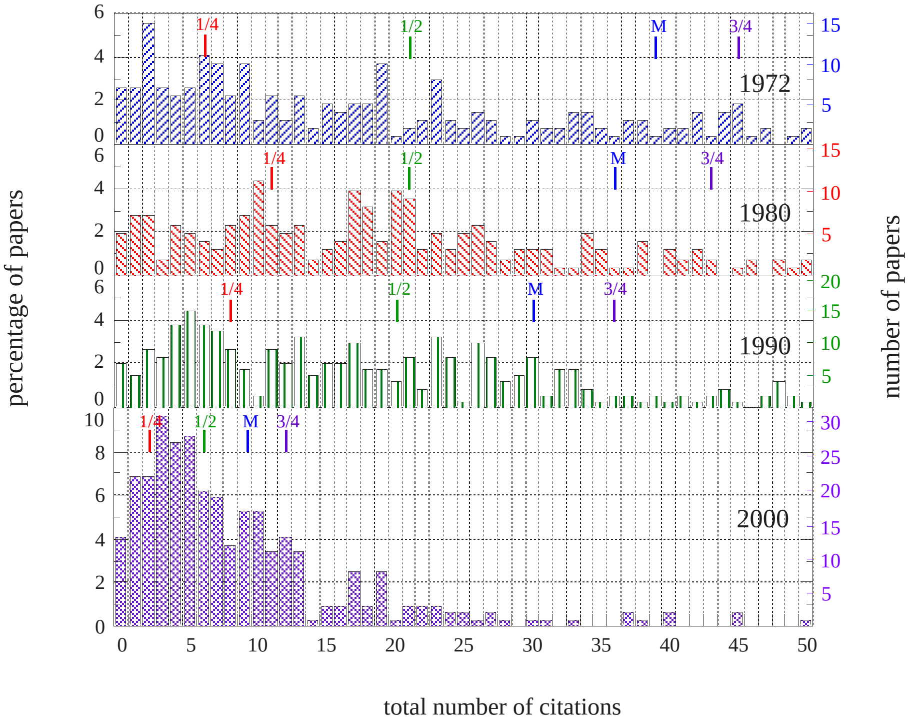

FIGURE 2. The percentage and numbers of papers with a total of 0, 1, 2,..., 50 citations to date for papers published in 1972, 1980, 1990 and 2000. Each group uses the same scale for percentages (but not for number because the total number of papers published each year is different). 1/4, 1/2, 3/4, M represent: the maximum number of citations for the least cited 25% of papers; the minimum number of citations for the most cited 50% and 75% of papers; and the mean number of citations per paper, respectively.

backed up by theoretical models, to determine analytical relationships. Brown & Roshko (1974) developed a new apparatus to analyse turbulent mixing between two plane streams of different densities. Their high speed movies were one of the first visualisations of coherent eddy structure clear enough to quantify their growth and interaction, an approach to the analysis of turbulence which came to stand alongside the statistical description of earlier workers. Gollub & Benson's (1980) experimental study of transition to turbulence in Benard convection was performed at a critical time when emerging ideas of nonlinear dynamics were challenging the traditional picture

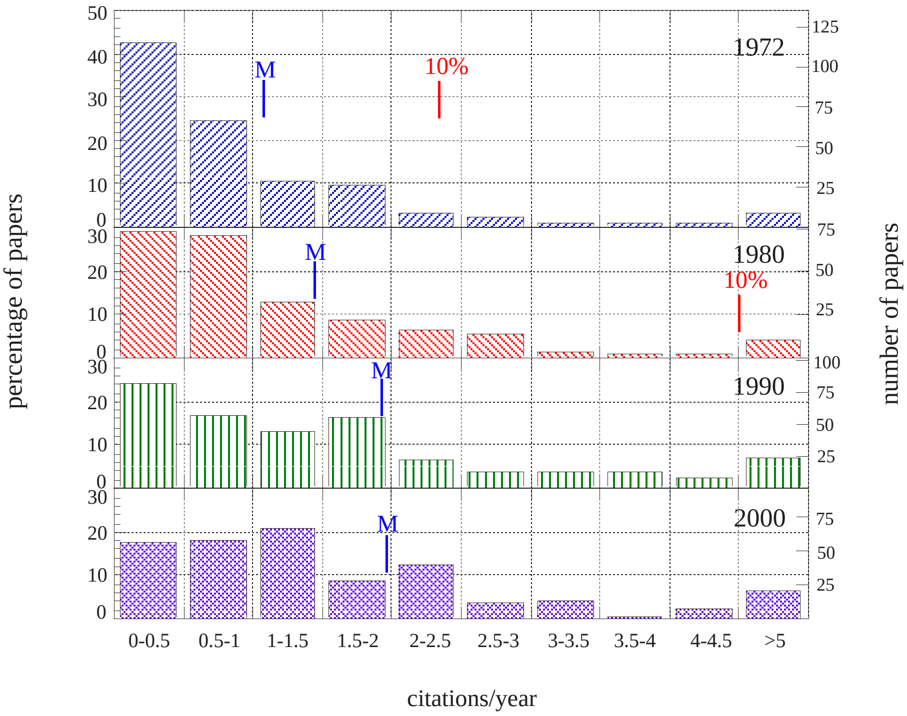

FIGURE 3. The percentage and number of papers with an average of 0 to 0.5, 0.5 to 1.0,..., 4.5 to 5.9, greater than 5 citations per year in 1972, 1980, 1990 and 2000. Each group uses the same scale for percentages (but not for number because the total number of papers published each year is different). M and 10% represent the mean number of citations per paper per year and the minimum for the most cited 10% of papers respectively. The values of the latter figure are in excess of 5 citations per year for papers published in 1990 and 2000.

(due to Landau) that turbulence arises as an infinite series of bifurcations from a steady flow as the Reynolds number increased. They showed how chaotic behaviour occurs with a smooth spectrum at finite Reynolds number, identifying four distinct sequences of instabilities leading to turbulent convection in a low Prandtl number fluid, echoing the new theoretical predictions of Ruelle & Takens (1971) and Feigenbaum (1980). Rom-Kedar, Leonard & Wiggins (1990) also adopted a dynamical systems approach, but in their case to study the kinematics in mixing. In particular they analysed the chaotic mixing induced by a vortex pair interacting with an oscillating strain rate field. Grossman & Lohse (2000) compiled all the available evidence from Benard convection experiments at high Reynolds number to suggest a series of power relationships between the Nusselt number and the Rayleigh and Prandtl numbers in different parts of the Rayleigh, Prandtl number plane. The relationships are backed up by simple models of the flow in the bulk and boundary layers. These results may be of considerable practical use, but the geometry of their flows are quite special and they raise the question of whether power-law relationships are generally the correct description; even though they are the most easily expressed. Finally, Batchelor (1972), in one of his first ventures in low-Reynolds number hydrodynamics of suspensions, developed a systematic approach to evaluate the mean fall velocity of a large number of identical small rigid spheres in random positions in a Newtonian fluid. Previous investigations had all lead to divergent integrals; Batchelor showed how to reformulate the problem and subtract off similarly divergent quantities to lead to finite results. His approach laid the ground for many subsequent studies determining average properties of dilute suspensions of interacting particles.

Citation data are notoriously puzzling, and each reader will no doubt have his or her own interpretation of the data. However, the most obvious, and non-contentious, conclusions are as follows. The mean citation rate per annum has monotonically increased from 1.2/year to 1.9/year. This could reflect the increasing standard of papers in JFM. Another explanation could be the increasing number of fluid dynamicists publishing an increasing number of papers (in other journals). Few papers (approximately 3%) are never cited. This percentage should be compared with the figure of about 25% for scientific research articles in the general scientific literature, though as to be expected, the figure is much lower for the 200 journals with highest cumulative impact (Pendlebury 1991; Garfield 1998b). Thus, as also is to be expected, JFM is, on this issue, amongst the better cited journals world-wide. This line will be expanded upon below. We note in passing that there was an interesting spat during the last decade when Hamilton (1990, 1991) suggested that 47.4% of scientific articles were uncited within five years of publication. Pendlebury (1991), who was an employee of ISI, immediately replied that Hamilton's 'scientific articles' included "meeting abstracts, editorials, obituaries, letters and marginalia, which one might expect to be largely uncited" (like the biographical memoir in JFM of its Founding Editor, George Batchelor, by Huppert (2000) which at the time of writing was uncited. Garfield (1998b) muses on the large number of uncited publications on average in the sciences (it is approximately twice as large in the social sciences and rises to 93% for articles in arts and humanities journals). He expressed surprise that self citations would not bring this figure close to zero. However, as outlined further in section 2, a large majority of papers are written by authors with only one publication to their name (at least in JFM) and hence these authors never get the opportunity to cite their own work (though they could in other journals, at least in theory).

The figure for just one citation, again approximately 3%, is satisfying low (and the combination of the figures for either 0 or 1 citation is still well below the average figure of about 25% for no citations at all for papers concentrating on new research in the scientific literature). Indeed the percentage of papers with a total citations for each of the numbers from zero to ten is very roughly between 2 and 4%, independent of the number, for 1972, 1980 and 1990. The percentage in each category is about twice as high for 2000, reflecting, I think, the lack of time since then for papers to have had the impact they will eventually generate. As seen on figure 2 there is a gradual decrease of the percentage of papers which receive a larger number of citations, with the distribution being most skewed for 2000, again reflecting, I believe, the short time period.

It would be interesting to compare the figures in table table 2 with prestigious general scientific journals like *Nature* and *Science* or with other high-quality specialised journals. However, discussions with the editorial staff of *Nature*, *Science* and ISI as well as other individuals knowledgeable in this area has not indicated that any statistics for other journals has been collected, or at least published.

		1972	1980	1990	2000
1.	Zero citations (%)	$7(2.6)$	$5(2.0)$	$7(2.1)$	$13(40)$
2.	Only 1 citation (%)	$7(2.6)$	$7(2.7)$	$5(1.5)$	$22(6.8)$
3.	10% least cited (/yr)	$\leq 2(\leq 0.06)$	$\leq 5(\leq 0.2)$	$\leq 3(\leq 0.2)$	$\leq 2(\leq 0.4)$
4.	25% least cited (/yr)	$\leq 7(\leq 0.2)$	$\leq 11(\leq 0.4)$	$\leq 8(\leq 0.5)$	$\leq 3(\leq 0.6)$
5.	50% most cited (/yr)	$\geq 21(\geq 0.6)$	$\geq 21(\geq 0.8)$	$\geq 20(\geq 1.3)$	$\geq 6(\geq 1.2)$
6.	25% most cited (/yr)	$\geq 45(\geq 1.3)$	$\geq 43(\geq 1.7)$	$\geq 36(\geq 2.4)$	$\geq 12(\geq 2.4)$
7.	10% most cited (/yr)	$\geq 81(\geq 2.3)$	$\geq 75(\geq 3.0)$	$\geq 68(\geq 4.5)$	$\geq 21(\geq 4.2)$
8.	most cited (/yr)	$646(19.5)$	$430(17.2)$	$192(12.8)$	$88(17.6)$

TABLE 2. Specific statistics for the years 1972, 1980, 1990 and 2000.

The statistics presented in the paper differ from those used to compile the "impact factor" introduced by Garfield & Sher (1963) and hotly debated since. Garfield and Sher defined the impact factor as: the total number of citations in one year to papers published in the preceding two years, divided by the total number of papers, i.e. in our notation, citations/paper/year but counting only the citations in the preceding two years. This is the 50th anniversary of JFM and so I felt that a full record of citations was of interest, rather than the recent record of the impact factor – and the shortness of two years has been one of the main complaints slung at Garfield's impact factor. (We all know of super papers which were ahead of their time and lay dormant and uncited for years until their true value was appreciated.)

In response, Garfield (1998a) presented the revised impact factor calculations for papers published in 1981-1982 (1989-1990) and cited over the fifteen (seven) years from 1981 to 1995 (1989 to 1995). He called these the 15- (and 7-) year impact factors respectively. In both lists the top twenty or so entries were journals specialising in biology or medicine. Table 3 presents an excerpt from Garfield's list, including the top entry, *Cell, Nature* and *Science* (for comparison) and those journals which I judge include papers which reference or are referenced by papers

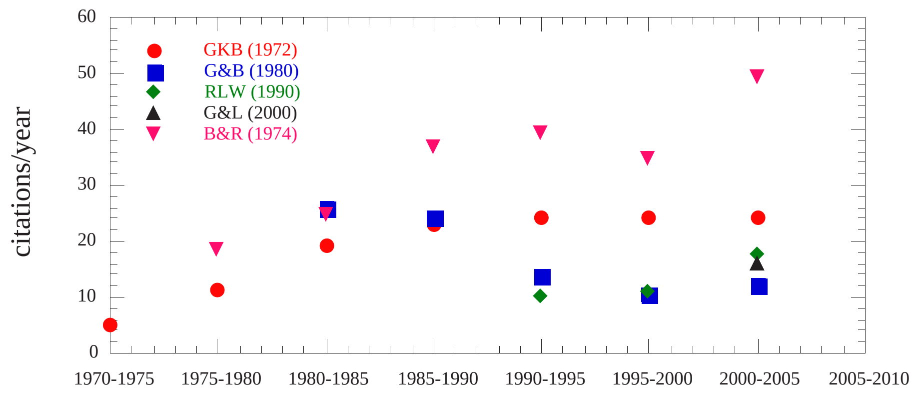

FIGURE 4. The number of citations per year averaged over five-year periods for the three most cited papers published in 1972, 1980, 1990 and 2000 and the most cited paper ever, published in 1974.

in JFM. The 15- and 7- averages yearly for JFM of 1.50 and 1.61 are broadly consistent with the values of 1.45 and 1.87 for the yearly averages in 1980 and 1990 presented in table 1. This suggests that the citation rates are roughly constant with time, at least for JFM. Citation numbers reflect the size of the field, which is the main reason why the values for journals in biology or medicine outstrip those for JFM, by approximately an order of magnitude. Size of field may also explain the larger citation numbers for other journals in the physical sciences. (Comparisons of citation rates across fields are fraught with difficulties).

The previous statement of roughly constant average citation rates with time, raises the general question: how do citations to a particular paper vary with time. A complete answer to this question would take us beyond the aims of this article. A partial answer, however, is given in figure 4 which tracks the citations in 5 year periods of the most cited papers in each of the chosen years and the most cited paper throughout the history of JFM. Not much can be said from the graph: for some papers citation rates increase with age; for some they decrease. To say more would need a much more detailed study; and one that would involve investigating the shelf-life, or time

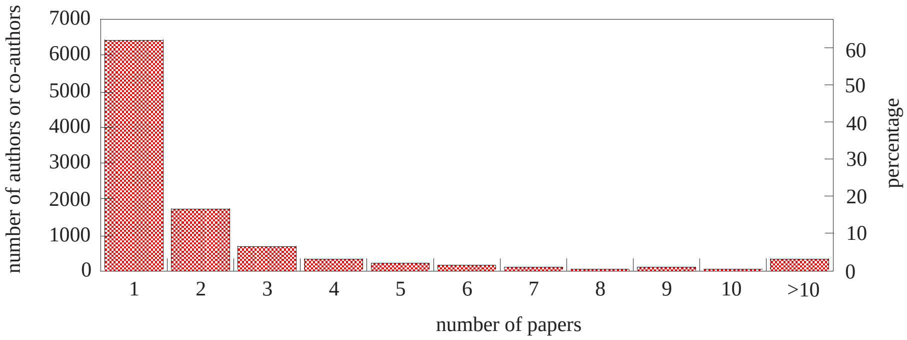

FIGURE 5. The number and percentage of authors with 1, 2,..., 10 and > 10 papers in JFM since its inception in 1956.

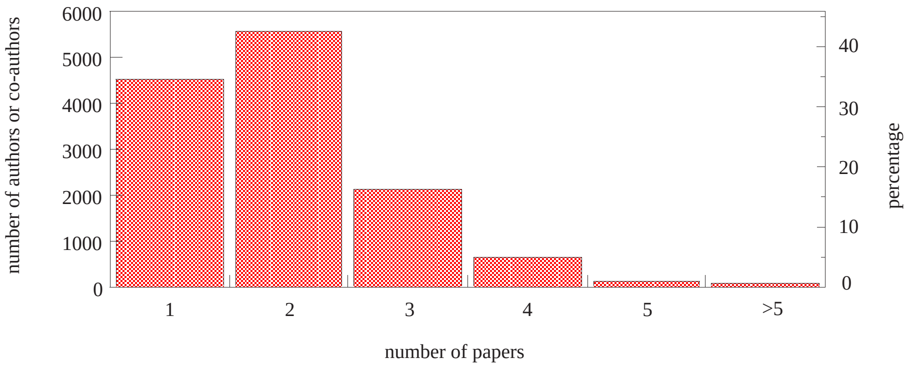

FIGURE 6. The percentage and number of papers solely authored or with 2, 3,4, 5 or more than 5 co-authors.

of citation activity, for various papers, and various journals. Lord May of Oxford is currently undertaking such a study for papers appearing in *Nature, Science* and other journals.

2. Authorship

Finally, I helped the then Editor, George Batchelor, make up the first Index of Past Volumes of JFM, after 100 volumes, from May 1956 until October 1980. I was struck then by the large number of authors whose name appeared only once in the index. I interpreted this as an indication that many young fluid dynamicists published their Ph.D. work in the prestige journal of the field and then no longer worked in academia or a research-oriented position (or at least in fluid dynamics). Mirroring the description in the previous section, we ask of the 10,702 authors or co-authors: what percentage have only one paper in JFM to their name; who are the most frequent authors or co-authors during the 50-year span of JFM; what is the frequency distribution between these groups?

The answers to these questions are: 6,613, or 62% are authors or co-authors of just a single paper in JFM ; the top three most frequent authors or co-authors are J. W. Miles (117; with 95 sole author entries), D. D. Joseph (83; 6) and J. C. R. Hunt (79; 7). Figure 5 presents the number and percentage of authors or co-authors with between 1 and 10 or more than 10 papers. The large majority of names appear but once. 8,828 or 86% of the names appear three times or less.

The distribution of the number of co-authors is given in figure 6, which presents the percentage and number of papers written by the 1, 2, 3, 4, 5 or more than 5 co-authors. The mode number of authors is 2 with 5,557 papers representing 43% of the total. Sole authorship is the second highest entry with 4,503 papers (35% of the total), while third come three authors with 2,148 papers (16% of total). Clearly, having a co-author is thought favourable, as might having none, or possibly even two, but more than that becomes unwieldy.

3. Conclusion

Many fluid dynamicists have contributed to the impact and success of JFM, each in their own way. It is difficult to guess what the Founding Editor, George Batchelor, would make of this success, or this article. As to the success of JFM, I think he would feel a genuine satisfaction for the outcome of his imaginative creation 50 years ago. Undoubtedly, however, he would also look forward to much more hard work during the next 50 years. As to this article, as for all of my previous articles that I showed him, he would undoubtedly have made many creative, sensible

Title	15-year rank	Impact factor	15-year average	2-year rank	7-year impact factor	7-year average
Cell	1	137.4	9.16	1	161.2	23.0
Nature	8	79.0	5.27	4	99.1	14.2
Science	10	70.8	4.72	3	106.1	15.2
Phys. Rev. Lett.	34	47.3	3.15	20	35.8	5.11
E.P.S.L.	64	35.9	2.39	68	18.3	2.61
Ap. J.	76	34.6	2.31	72	17.9	2.56
J. Atmos. Sci.	134	26.8	1.79	199	13.3	1.90
D.S.R.	149	25.7	1.71	153	15.1	2.16
Geology	186	24.6	1.64	220	12.6	1.80
JFM	197	22.5	1.50	265	11.3	1.61

TABLE 3. 15-year and 7-year rankings, modified impact factors and averages for the top ranked journal, Cell, Nature, Science and journals devoted to the physical sciences.

and penetrating suggestions for its improvement and then taken considerable pride in noting its impact. He was a thoughtful considerate mentor, whose influence and ability to make correct decisions I still miss.

Dr Linda Drath, the highly efficient editorial assistant of JFM for more than 22 years, is gratefully thanked for supplying some of the data on which this article is based. Some of the other data was prepared for me by the DAMTP computer officer, Elie Bassouls. Helpful comments were gratefully received from Rex Britter, Peter Davidson, Gene Garfield, Brooks Hansen, Julian Hunt, Sian Lewis, Bob May, John Rallison, Dan Rubenstein, Grae Worster and Carl Wunsch.

REFERENCES

BATCHELOR, G. K. 1972 Sedimentation in a dilute suspension of spheres. *J. Fluid Mech.* **52**, 245-268.

BROWN, G. L. & ROSHKO, A. 1974 Density effects and large structure in turbulent mixing layers. *J. Fluid Mech.* **64**, 775-816.

GARFIELD, E.& SHER, I. H. 1963 New factors in the evaluation of scientific literature through citation indexing. *American Documentation* **143**, 195-201.

GARFIELD E. 1998a Long-term vs short-term journal impact: does it matter. *Scientist* **12**, (3), 11-12.

GARFIELD E. 1998b I had a dream... about uncitedness. *Scientist* **12**, (14), 10-10.

GOLLUB, J. P.& BENSON, S. V. 1980 Many routes to turbulent convection. *J. Fluid Mech.* **100**, 449-470.

GROSSMAN, S. & LOHSE, D. 2000 Scaling in thermal convection: a unifying theory. *J. Fluid Mech.* **407**, 27-56.

HAMILTON, D. P. 1990 Publishing by – and for? – the numbers *Science* **250**, 1331-1332.

HAMILTON, D. P. 1991 Research papers: who's uncited now? *Science* **251**, 25-25.

HUPPERT, H. E. 2000 George Keith Batchelor. *J. Fluid Mech.* **421**, 1-14.

PENDLEBURY, D. A. 1991 Science, Citation, and Funding. *Science* **251**, 1410-1411.

ROM-KEDAR, V., LEONARD, A. & WIGGINS, S. 1990 An analytical study of transport, mixing and chaos in an unsteady vortical flow. *J. Fluid Mech.* **214**, 347-394.