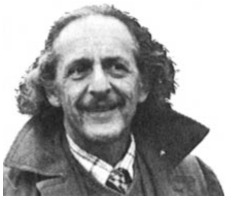
Essays of an Information Scientist, Vol:6, p.363-372, 1983 Current Contents, #45, p.5-14, November 7, 1983

Current Comments®



How to Use Citation Analysis for Faculty Evaluations, and When Is It Relevant? Part 2

Number 45 November 7, 1983

[Part 1 of this essay reviewed the literature on conventional tenure procedures. It described how citation analysis can identify a candidate's "invisible college," and thus reveal which experts are competent to judge the candidate's work. The essay also reviewed many caveats in citation analysis for faculty evaluations. This portion of the essay concludes last week's discussion.]

Once you've determined how often candidates are cited, and by whom, you may also want to know *why* their work has been noted by other scientists. This type of information can only be found by examining papers that cite the candidate's work. Using two related techniques, called citation *context* and *content* analysis, you can read the passages or sentences in the papers which cite the relevant work to find out why it is quoted. Citation context analysis will usually tell you which aspect of the paper was actually mentioned by the other publishing scientists. Citation content analysis will tell you if these scientists were, for example, criticizing or supporting that aspect of the paper. Whereas the mapping and clustering techniques described in Part 1 of this essay will indicate that certain authors or papers are "connected," context and content analysis will often help to reveal how each cited paper fits into the development of the specialty.[36]

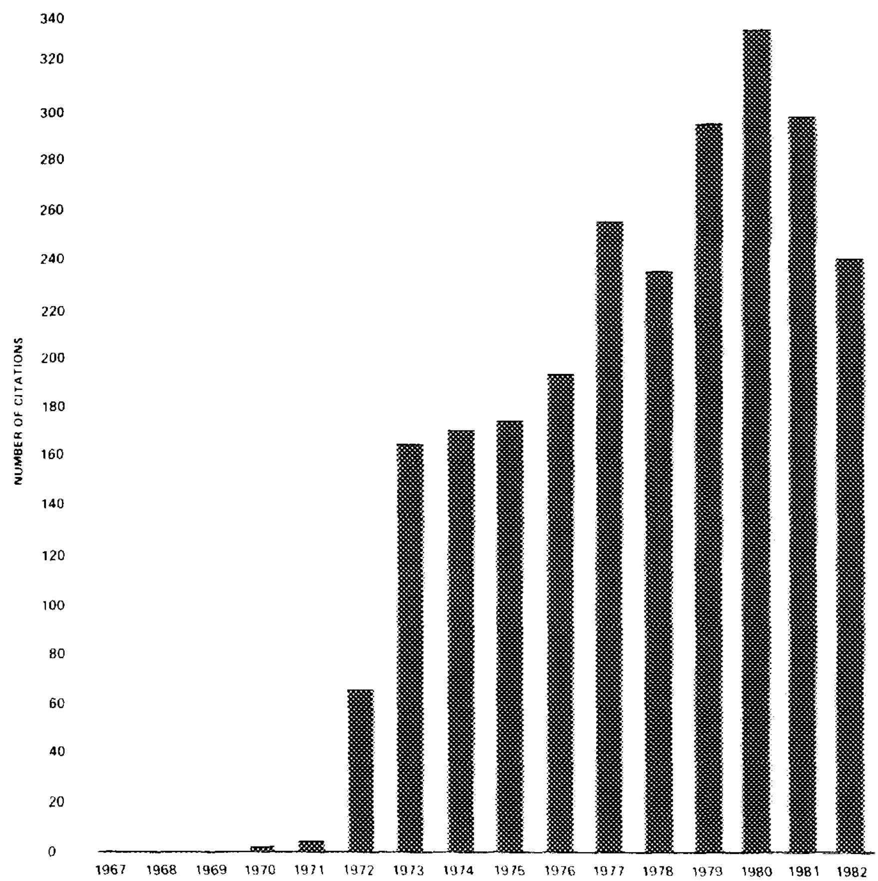
In his 1978 analysis of chemistry literature,[37] ISI®'s Henry Small used context analysis to identify the concepts for which a paper is best recognized. For each core paper, he selected a sample of citing papers. He then recorded the sentences or phrases in which these highly cited papers were referenced. Using these "contexts," he determined the percentage of times the core paper was identified with a specific concept. Small found that the more often a paper is cited, the greater is the degree of consensus on what is most significant.

Citation content analysis can be used to find out how frequently authors cite the candidate to refute, support, apply, compare, or simply make note of a concept. For example, in analyzing a sample of high-energy physics papers,[38] D.E. Chubin and S.D. Moitra, Cornell University, Ithaca, New York, found that about 20 percent of the citations were used to provide historical background for citing authors' discussions. Only five percent were negative. We found that 50 percent of a large sample of the many references to Arthur Jensen's controversial work were negative.[39] Others have used content analysis to determine how frequently different categories of citations are used in physics,[40] physical sciences,[41] sociology,[42] and German literary research.[43]

Douglas J. Leadenham, Electric Power Research Institute, Palo Alto, California, and many others use simple graphical procedures for studying an author's influence.[44] You simply create a bar graph showing the number of citations per year. (See Figure 1.) You can also plot the chronological growth of a paper's citations. By looking at how quickly the curve for an individual paper peaks, you'll be able to tell how rapidly the paper became influential. The height of the peak—the year in which the paper was most cited—may indicate its future potential. Leadenham suggests that when using such graphs to study the impact of a candidate's work, you consider the best five-year interval. This overcomes a bias against older papers, whose citation rates may be on the decline. On the other hand, keep in mind that "recent publications...may not yet have had their best interval defined by the data."[44]

In considering these curves, also remember that the life span of a paper differs from field to field, and over time within fields. For example, key papers in a field like physical chemistry may not begin to accumulate citations until several years later than papers in biochemistry.[45] A number of factors may account for this lag time. These may include the rapidity with which research in that field progresses, as well as how long it takes for scientists to learn about the publication, incorporate it into their thinking and research, and publish papers citing the previous work.

Figure 1: Bar graph of **Weinberg S.** A model of leptons. *Phys. Rev. Lett.* 19:1264-6, 1967.



Occasionally, there may be an unusually long period before a paper is cited to any significant extent. This can happen to papers that are premature, or ahead of their time.[46] Gunther S. Stent, University of California, Berkeley, suggests that recognition of a paper may be delayed if its "implications cannot conceptually be connected by a series of simple logical steps to canonical, or generally accepted, knowledge."[47] The unusual citation histories of a few key papers are illustrated in Figure 2. In these cases, there was a considerable delay in the initial citation of these important papers. When evaluating any creative scholar's work, one must consider whether it too may be ahead of its time.

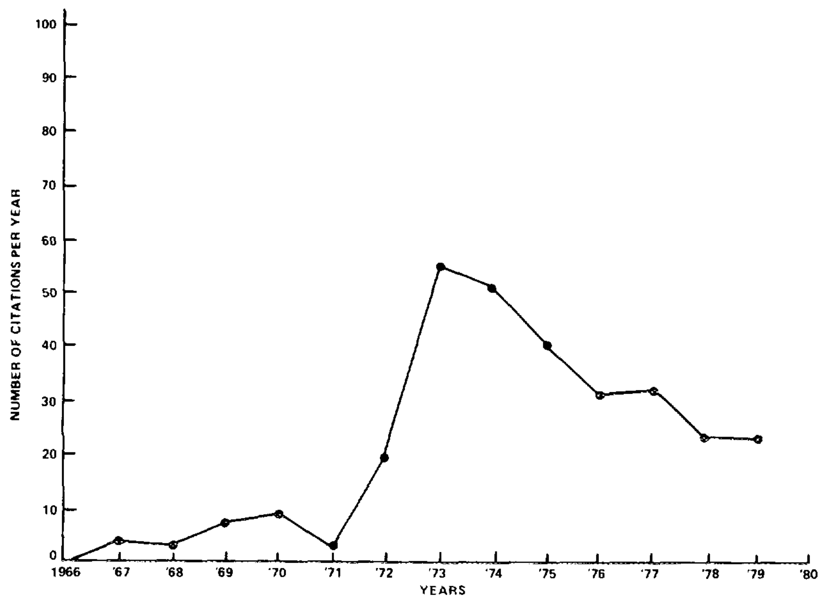
Administrators evaluating young scientists, or comparing them with colleagues who've been publishing for many years, may be more interested in a model for predicting lifetime citation rates. Such a model was developed by a group at the University of Pennsylvania,[48] and was discussed in some detail in an earlier essay.[49] Briefly, it uses several assumptions about the citing conventions of a field, and the growth of scientific literature, to estimate the number of citations a paper is likely to receive 40 years after publication. The authors recommend that people using their method check each paper for irregular citation curves. For example, the technique may be inappropriate for papers that don't fit the normal pattern of quick growth and slower decay in the number of citations received. One such "normal" curve, for astronomy papers, is shown in Figure 3. Helmut A. Abt, Kitt Peak National Observatory, Tucson, Arizona, derived the curve from 326 papers published in 1961 in two leading astronomy journals.[50]

Since publication counting is characteristic of the "publish or perish" syndrome, there has always been a desire to estimate the worth of papers by relying on the known prestige of the journal in which an author publishes. Clearly, anyone who publishes regularly in *Journal of the American Chemical Society* or *New England Journal of Medicine* must have something going. Barbara A. Rice, New York State Library, Albany, and Tony Stankus, College of the Holy Cross, Worcester, Massachusetts,[51] suggest that evaluators consider the prestige of a journal's editors, referees, and contributors when ranking publications. They also remind us that a common method for ranking recent publications, whether cited or not, is to use the *impact factor* provided for each journal in *Journal Citation Reports*® (*JCR*™). In these annual volumes of *Science Citation Index*® (*SCI*®) and *Social Sciences Citation Index*® (*SSCI*®), journals are ranked in various ways, including immediacy and total citations. But the impact factor is the most widely used. It reflects the average citation frequency of articles recently published in that journal. As D.R. Forsdyke, Queen's University, Kingston, Ontario, explains, "Acceptance of a paper by a journal with a high impact factor is usually an indication that the work has been subjected to a rigorous review."[52]

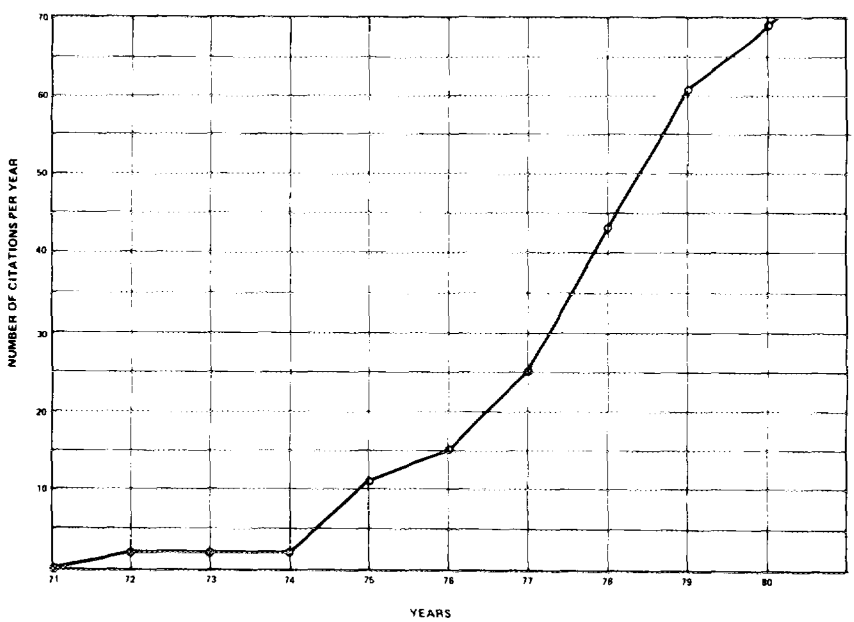
As averages, impact factors are useful. But they must be used cautiously. An analysis ISI recently completed to determine how often 1978 papers were cited from 1978 to 1982 revealed that even high prestige journals publish numerous articles that never get cited. Table 1, which was derived from that article-by-article analysis, shows that many research and review articles in the 25 prestigious journals listed were not cited during the first four years after publication. But presumably just getting published in such a journal indicates that some outside group of peers thought the author had something useful or important to say. Some may even have been invited contributions.

Taking a broader look at the significance, or rarity, of highly cited *papers* (Table 2), less than one out of 200 papers cited in the 1975-1979 cumulated *SCI* received 51 or more citations. From the perspective of cited *scholars* (Table 3), only about ten percent of authors listed

Figure 2: Two examples of "premature" papers.

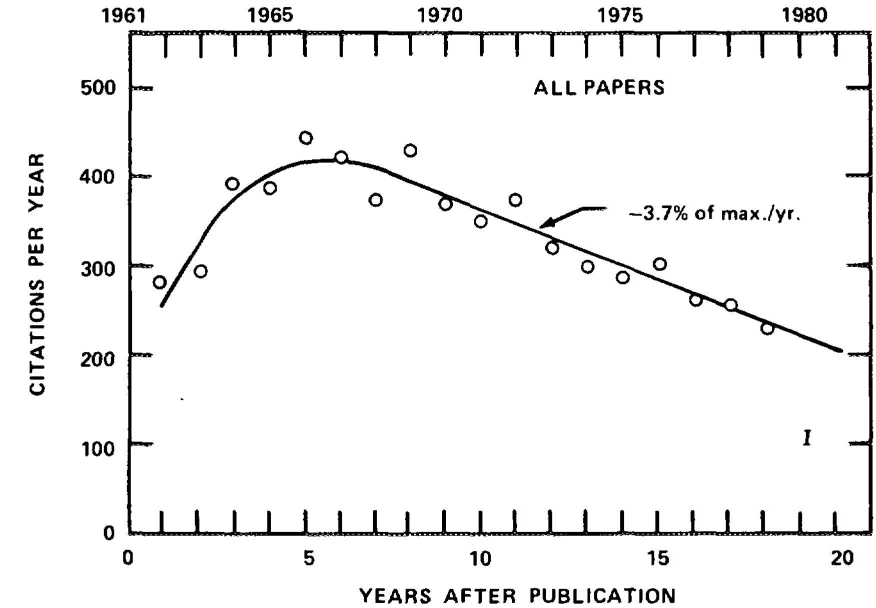


Higgs P W. Spontaneous symmetry breakdown without massless bosons. *Phys. Rev.* 145:1156-63, 1966.



Trivelli L A, Ranney H M & Lai H-T. Hemoglobin components in patients with diabetes mellitus. *N. Engl. J. Med.* 284:353-7, 1971.

Figure 3: The annual number of citations to 326 papers published in 1961 in the *Astrophysical Journal* and *Supplements* and the *Astronomical Journal* is shown as a function of years after publication (lower abscissa) or calendar years (top). The standard error of ± 19 citations per year is shown as a 1 σ bar in the lower right. The decline after maximum is a linear least-squares solution giving a decline rate of -15.4 citations per year or -3.7% per year of the maximum rate.



Source: Abt H A. Long-term citation histories of astronomical papers. *Publ. Astron. Soc. Pac.* 93:207-10, 1981.

in *SCI* from 1961 to 1980 received 50 citations or more.

As the tables show, the vast majority of papers, and authors, are rarely cited. Many papers remain uncited. Most are, at best, cited once or twice. This is far less likely to occur in high impact journals. Candidates should be asked to discuss why certain papers are rarely cited. Quite often, citation to preliminary work is supplanted by surrogate citation of reviews. Rather than citing the original article on a concept or method, authors may cite the review article discussing that concept or method. On occasion, papers reporting significant research remain virtually uncited for years due to premature discovery,[46] mentioned earlier, or because they can't yet be related to other current research. Or they may be awaiting methodological breakthroughs that enable them to be exploited.

The concept of premature discovery can be taken too far. There's always the possibility that an individual may claim that his work is ahead of its time. Quite often such claims are transparent. Premature discovery of the classical variety rarely happens. Shortly before his untimely death, Derek J. de Solla Price reminded us that in certain instances in physics there was a citation delay while other scientists read and tested data in the paper. They then published their own reports.[53] This "latency period" will vary from discipline to discipline.[54] Depending upon the quality of the work,

Table 1: 1978 research and review papers. Impact and citation, 1978-1982. A = journal. B = number of papers published. C = number cited, 1978-1982. D = number not cited. E = citations. F = impact.

A	B	C	D	E	F
Angew. Chem.	48	47	1	2,327	48.4
Ann. Intern. Med.	189	182	7	5,215	27.6
Arch. Dermatol.	221	208	13	1,380	6.2
Brit. Med. J.	471	421	50	6,332	13.4
Bell Syst. Tech. J.	156	134	22	756	4.8
Biometrics	51	46	5	297	5.8
Brit. J. Dermatol.	191	174	17	1,428	7.5
Cell	302	302	0	19,854	65.7
Circulation	299	295	4	8,199	27.4
Ecology	131	129	2	1,451	11.1
J. Cell Biol.	245	221	24	7,225	28.4
J. Chron. Dis.	62	51	11	410	6.6
J. Clin. Invest.	257	256	1	8,092	32.0
J. Exp. Med.	277	277	0	13,937	50.3
J. Fish Res.	124	121	3	948	7.6
J. Immunol.	643	639	4	16,716	26.0
J. Mol. Biol.	291	291	0	7,392	25.4
Lancet	487	468	19	13,684	28.1
Mayo Clinic Proc.	93	88	5	1,392	15.0
Medicine	30	30	0	897	30.0
Nature	1,701	1,637	64	44,131	25.9
N. Engl. J. Med.	318	303	15	15,559	48.9
Proc. Nat. Acad. Sci. US	1,341	1,326	15	52,353	39.0
Proc. Soc. Exp. Biol. Med.	382	349	33	2,400	6.3
Science	979	929	50	22,156	22.6

Table 2: Citations received by articles cited one or more times in the 1975-1979 cumulated *SCI®*. The table includes an unspecified number of duplicates cited in variant forms. A = total citations, 1975-1979. B = cumulative number of items. C = cumulative percent of articles.

A	B	C
≥ 1	10,641,323	100.00%
≥ 2	3,873,853	36.00
≥ 5	1,530,937	14.00
≥ 10	670,344	6.30
≥ 17	313,019	3.00
≥ 25	155,486	1.50
≥ 51	44,072	.40
≥ 101	10,481	.10

the paper may or may not warrant even negative citation. Most inferior work is treated with silence.

Some important papers may no longer be cited because they've been "obliterated."[55] Such papers are so well integrated into a field's body of knowledge that scholars neglect to cite them explicitly any longer. We don't know how often this may happen to good papers that never achieve significant citation levels. In some fields, technical or informal reports are quite important. But, as a rule, they receive few citations because they generally reach a smaller audience than the typical journal article. For a similar reason, it is presumed that some papers aren't cited much because they were published in journals that aren't widely distributed. The advent of *Current Contents®* (*CC®*) and other information tools makes this less likely.

Finally, some papers may not receive many recent citations because the research they report has been overtaken by other work. The journal half-life package of *JCR* can help you determine the median age of articles cited in a given year. For example, in 1982, *American Ethnologist* had a half-life of 4.5.[56] This means that half the citations this journal received in 1982 were to articles published during the previous four and a half years. The remaining 1982 citations to this journal were dispersed among all the papers it published since the journal was founded in 1974. However, *Man*, another anthropology journal, founded in 1966, had a half-life of 9.4. The half-lives

Table 3: Citations received by primary authors cited one or more times in *SCI®* from 1961 to 1980. Homographs are not differentiated. A = total citations, 1961-1980. B = cumulative number of authors. C = cumulative percent of authors.

A	B	C
≥ 1	2,747,630	100.00%
≥ 2	1,678,757	61.10
≥ 5	1,033,840	37.63
≥ 10	729,966	26.57
≥ 50	280,197	10.20
≥ 100	165,726	6.03
≥ 250	69,852	2.54
≥ 500	30,810	1.12
≥ 750	17,408	0.63
≥ 1,000	11,018	0.40
≥ 1,500	5,427	0.20
≥ 2,000	3,043	0.11
≥ 2,500	1,864	0.07
≥ 5,000	332	0.01
≥ 7,500	102	0.01
≥ 10,000	46	0.01

for the better known journals, *Science*, which was started in 1880, and *Nature*, which was started in 1869, are 5.6 and 6.5, respectively. The half-lives for the *Journal of the American Chemical Society*, begun in 1879, and *Journal of Biological Chemistry*, begun in 1905, extend further back, at 9.2 and 8.1, respectively.

Half-life can be interpreted as an indicator of the rate at which a journal's papers become obsolete. This, in turn, may reflect the rate of obsolescence of information in the subject area covered by that journal. When confronted by a paper that hasn't received many recent citations, evaluators might determine if the paper's age exceeds the half-life for the journal in which it was published. If it has, the research reported in the paper may simply be obsolete, or less popular, rather than of poor quality. Only a small percentage of publications and authors are distinguished by enduring citations.

Although the procedures described so far are aimed at promotion decisions, they can be used just as well for hiring. Of course, if you are hiring someone to fill an endowed "named" professorship, you may be fortunate enough to be evaluating candidates who have already received the Nobel prize or other prestigious awards. But if you want to determine the impact that a scientist is currently having on the scientific community, you should consider limiting your analysis to more recent works. Incidentally, there is good evidence that age is not a significant factor in productivity, unless the scholar involved has been diverted to administrative or other duties.[57-59]

Most universities, of course, can't afford to hire the leading scientists in a field. They might instead be looking for someone who is a "rising star." In such cases, the type of citation investigation described should be especially relevant. Daniel S. Hamermesh, Michigan State University, East Lansing, and colleagues recently found a strong correlation between citations and the salaries of economics professors.[60] If this correlation holds true for other disciplines, universities seeking potential "rising stars" should identify them before their citation counts, and salaries, get too high.

Administrators might also take heed of what happened after Philip H. Gray, Montana State University, Bozeman, published a study in which citation data were used to evaluate administrative accountability. In this study, Gray reported that most faculty salaries at his university did not correlate with faculty members' citations, awards, and years of teaching experience. Presumably, adjustments were made after this detailed information became available to the university's governing bodies.[61]

Administrators responsible for making hiring, promotion, and tenure decisions aren't the only ones who can benefit from the techniques described in this essay. J. Davidson Frame, George Washington University, Washington, DC, for example, explains how citation data can be used to assess groups of scholars to evaluate the effectiveness of research projects and programs.[62] Citation data are equally effective for self-evaluations. Researchers can find out what sort of impact their work is having on the scientific community by examining research fronts in which their papers appear, or doing a content and context analysis of the papers that cite them. If your university or company does not employ citation analysis in its evaluations, you might include an analysis of your own work in the documentation that you provide your review committee. Furthermore, finding out who your work is influencing might help you decide which journals are most appropriate for publishing your papers as well as which agencies are most likely to fund your research.

Review articles can also be very useful for assessing the influence a candidate is having on a field of research, or for finding out how his or her research projects fit into work under way in that field. You can find these articles in *SCI* and *Index to Scientific Reviews*™ (*ISR*™). Another source of review-type information is the encyclopedic *ISI Atlas of Science*®, which we've described on numerous occasions.[63] The second prototype volume of the *Atlas* will appear soon and covers about 125 research fronts in biotechnology. The minireviews that accompany each research front (see Figure 4) provide valuable information about some of the papers and people who've contributed to the individual specialties. Ideally, evaluators should have a similar minireview prepared for the research field relevant to the candidate under evaluation.

For an expenditure of $500 to $1,000, one can prepare quite a decent and detailed report. The investment is worth making. Not only will it prevent a great deal of wasted effort, it will save money in the long run. ISI is prepared to do "custom" minireviews on demand, but clearly it is within the capability of your own staff to do such reviews for you. The library staff can help you identify the core papers and people, and the candidate can aid in the process by preparing a draft document that can be reviewed by peers inside or outside the department. Once such a document is prepared for each member of the faculty, this collection of minireviews can become a vehicle for updating the progress made within each department. For in the final analysis, tenure or promotion evaluations can only be as good as the documentation behind them.

Evaluation of individuals and departments goes on all the time. It is a very sensitive issue and few people admit to the need for more systematic procedures. The very aesthetic nature of

Figure 4: Sample minireview from the new *ISI Atlas of Science*®*: Biotechnology and Molecular Genetics 1982*. These minireviews provide information about papers and people who have contributed to the development of specialty areas.

Specialty (58)

Primary-Structure, Secondary-Structure and Function of r-RNA

In the first stage of protein synthesis, transcription of the genetic code within deoxyribonucleic acid (DNA) into messenger RNA (mRNA) takes place. In the second stage the message carried by mRNA is translated into protein by the linking together of amino acids which have previously been activated by complexing with transfer RNA (tRNA). This translation takes place on the ribosomes, which contain a third type of RNA, ribosomal RNA (rRNA). The ribosomes present in both prokaryotic and eukaryotic organisms play an essential role in protein synthesis, and it is

by this earlier work may not be so clear cut.

Because of its smaller size, the prokaryotic 5S RNA secondary and tertiary structure and interaction with ribosomal proteins can be more readily investigated than is feasible for the much larger 16S and 23S RNAs (17). A considerable number of physico-chemical techniques ranging from enzymatic cleavage ([illegible]) to laser Raman spectroscopy ([illegible]) have been employed and a number of models for the secondary structure of 5S RNA proposed. Several of these are modifications (e.g. [illegible]) of that proposed earlier by Fox and Woese much research seems the antithesis of what, at first, appears to be a purely quantitative, uncritical technique. But the procedures I reviewed here require a dedicated commitment to identifying and understanding the true nature of creativity and excellence. Citation analysis is not a shortcut to be used as a replacement for thinking. It is the point of departure for those who are willing to explore every avenue to thorough evaluation.

Recognizing the controversial nature of this topic, I have taken unusual precautions in seeking outside comment on this review. While it would be tempting to include the names of the more than 30 individuals involved, I do not wish to imply their endorsement. I take full responsibility for whatever opinions are implied or expressed and hope that I have succeeded in dispelling much of the mythology that has developed on this touchy subject. Undoubtedly, the literature on citation analysis, both for tenure and more so for other evaluative purposes, will continue to grow. Perhaps an annual review of this literature in *CC* would be relevant considering the number of citation-based studies we publish.

The references provided here include one of the most readable reviews of the literature published to date, by Linda C. Smith, University of Illinois at Urbana-Champaign.[64] Julie A. Virgo's paper was based on her doctoral dissertation.[65] It is a pioneer study comparing peer review with citation analysis. Lawani and Bayer recently updated her results.[66] The papers by White[67] and McCain[68] were selected as excellent examples of how to use online co-citation techniques to identify invisible colleges. Also discussing co-citation are Price and Small. Price discusses the significance this technique will have on information retrieval, as well as the philosophy, sociology, and history of science.[69] Small uses clusters to compare the way knowledge develops in the social and natural sciences.[70] Since citation analysis is, in some cases, displacing publication counting as a measure of productivity, we have included the Helmreich[71] and Folly[72] papers which compare these two measures of research output. Folly also examines the effect of various types of self-citation on individual citation records. Psychologists have been involved in citation analysis for many years, and their findings on departmental productivity are represented in the papers by Endler,[73] Morris,[74] and Rushton.[75] Roche also discusses departmental productivity and describes the use of citation data for ranking journals.[76]

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My thanks to Joan Lipinsky Cochran and Amy Stone for their help in the preparation of this essay.

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