Identifying Significant Research

Literature citation counting is evaluated as a means for identification of significant research.

J. H. Westbrook

There has been a tendency in recent years to measure the scientific performance of laboratories, individuals, and journals by simply counting the number of papers published (*1–4*). While it is no doubt true, as Fisher (*4*) has maintained, that such a count is a reasonable measure of scientific *activity,* it gives little indication of the *quality* or *significance* of that work. Not only do both laboratory publication policies and journal acceptance standards vary widely, but work on a trivial problem may be so performed and so described as to meet even the highest standards of publishability and yet have no marked significance, either permanent or transitory.

How, then, does one distinguish, on an objective basis, the brilliant research paper from the marginally acceptable, the trivial from the significant piece of work? This study (*5*) explores the possibility of measuring the quality of published research by examining the references cited in published papers. The concept of a publication citation parameter is not novel. Various investigators have employed it heretofore with this objective (*2, 3, 6*) as well as for other purposes (*7*). The present article is a more extensive examination of the approach than has previously been reported. Furthermore, by employing citations from research papers, it is not, as is Lehman's analysis (*2*), subject to the inherent bias of a single authority.

For a definable subject field, study of literature citations attributable to a certain source rather than study of the published papers emanating from that source offers the advantage of a process of natural selection. That is, provided the sample is large enough for the derived results to be statistically significant, repeated citation of a particular source by independent research workers whose own contributions have met some standard of publishability is very probably indicative of the worth of the scientific output of that source (*8*). In principle, it is believed that with this parameter—the number of literature citations—it should be possible to identify laboratories, individuals, or even specific papers of unusual significance, provided only that the sample size be adequate. In the present study, attempt is made by this means to identify *laboratories* that are doing the most significant work. The subject field was limited to ceramics by reason of my previous experience and current interest, but it is believed that the approach is of more general applicability.

It will be demonstrated that this method yields a useful measure of the significance of research. Two shortcomings must be acknowledged, however, at the outset. First, science, like many other fields, is subject to changing fashions of interest which may lead in this case both to a distorted number of published papers in a given subject and to an inordinately high level of citations for a laboratory which happens to have been one of the first working on the fashionable subject. This difficulty could be overcome in principle by extending the analysis over a period of years. A second problem is that there is no means for appraising work performed but not published, either for proprietary reasons or simply because publication is not encouraged by the laboratory in question. However, as Fisher (*4*) points out, this may not actually be a serious difficulty, at least for basic research, because of the strong motivation for research scientists to gravitate to laboratories with a liberal publication policy.

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The Sample

Two populations were chosen for analysis: the references cited in the 99 papers published in the 1958 *Journal of the American Ceramic Society,* hereafter called population *A*, and a composite group of papers bearing on ceramics, chosen from the respective volumes for 1958 of *Acta Metallurgica,* the *Journal of Applied Physics,* the *Journal of the Physics and Chemistry of Solids,* the *Journal of Physical Chemistry,* and the *Journal of the American Chemical Society*—a group of references hereafter called population *B*. The details of the method for selecting papers for this latter population are given below. In both cases, "Letters to the editor" and "Notes" were considered as well as full research papers.

Table 1. Counts for all population *A* source laboratories having five or more net citations.

Rank	Source	Citations (No.) Gross	Citations (No.) Net
1	National Bureau of Standards	93	45
2	Geophysical Laboratory	37	36
3	Massachusetts Institute of Technology	31	29
4	University of Sheffield	24	24
5	Pennsylvania State University	47	22
6	General Electric Company	25	19
6	University of London	19	19
8	University of Illinois	17	13
9	Ohio State University	15	12
10	N. V. Philips (Eindhoven)	10	10
11	Bell Telephone Laboratories	9	9
12	Alfred University (N.Y. State College for Ceramics)	19	8
12	University of California	11	8
12	Carnegie Institute of Technology	8	8
12	Eastman Kodak	8	8
12	Max Planck Institute (Berlin)	8	8
17	Battelle Memorial Institute	8	7
17	Cambridge University	7	7
17	Corning Glass Works	8	7
17	General Electric Co., England	7	7
17	University of Göttingen	7	7
17	Oak Ridge National Laboratory	10	7
23	University of Chicago	6	6
24	Raytheon Electrical Manufacturing Co.	5	5
24	United States Steel	5	5
24	Westinghouse	5	5

Table 2. Provenance of published papers, population *A*.

Source laboratories	Published papers in sample (No.)
Pennsylvania State University	10
National Bureau of Standards	9
Alfred University	7.5
University of Illinois	5
General Electric	4
Ohio State University	4
University of Utah	4
Corning Glass	3
Oak Ridge National Laboratory	2
Owens-Illinois Glass Company	2
Portland Cement Association	2
Clemson University	2
A. O. Smith	2
Mellon Institute	2
Raytheon	2
Armour Research Foundation	2
Hanford Atomic Power Laboratory	2

It was necessary to eliminate certain types of references from the total before beginning the detailed identification and analysis of the citations to avoid duplicate publications and to ensure a minimum scientific standard. Such groups as private communications, internal reports, government contract reports, theses, reference works, and monographs were therefore eliminated. Aside from recognized scientific journals, the only accepted references were references to the proceedings of special symposia, which are frequently published separately from the usual journals although sponsored by competent scientific bodies.

Procedure

The 838 references remaining in population *A* after the discards described above had been made were put on punch cards, together with notation of the parent article and journal, and punch-indexed accordingly. (The cards prepared by the *American Society for Metals* for literature-filing purposes proved to be convenient and easily adapted for this use.) The affiliation of each author of each cited reference was then determined and noted on the face of the punch card, and this information was also indexed. Insofar as possible, identification was made by consulting the cited journal directly. Where this proved to be impossible, recourse was made to *Chemical Abstracts* or, in a few cases, to biographical works such as *American Men of Science* and its foreign counterparts. Particular care was taken to identify the laboratory at which the work was done rather than the affiliation at the time of publication or the permanent affiliation of the author. It was not possible to identify the source of 100 percent of the cited references. However, in the case of population *A*, only 27 references (or slightly more than 3 percent) remained unidentified. A similar degree of success was achieved with population *B*; in no case did the percentage of unidentified citations from a single journal exceed 5 percent.

The identified citations were next sorted as to source laboratory. It was found that the 811 identified citations in population *A* represented 213 laboratories. It was considered necessary at this point to reject certain citations from the identified population. First, all citations were rejected whose laboratory attribution was the same as that of the source article. Such elimination of what I will designate "in-house" citations is a conservative and perhaps (as will be seen) unnecessary step, but one which serves to increase the objectivity of the analysis. After this, a few more citations were rejected when it was found that the author referred to his own work performed at an institution with which he had previously been affiliated. The 660 cards remaining after elimination of these "self citations" were designated "net citations."

Table 3. Representative titles of source articles in population *B*.

J. Appl. Phys.
"Nucleation and growth in a photosensitive glass"
"Magnetic susceptibility of neutron irradiated quartz"

J. Phys. and Chem. Solids
"Hall effect and electrical conductivity of transition metal diborides"
"Deviations from stoichiometry in binary ionic crystals"

J. Phys. Chem.
"Reduction of contaminated rutile surfaces by degassing"
"Hydrothermal reactions between calcium hydroxide and amorphous silica"

J. Am. Chem. Soc.
"The preparation, lattice parameters, and some chemical properties of rare earth mono-thio oxides"
"The stoichiometry of the hydration of beta-dicalcium silicate and tri-calcium silicate at room temperatures"

Acta Met.
"Dislocation patterns in potassium chloride"
"Precipitation of magnetite in the sub-structure boundaries of an iron protoxide rich in oxygen"

Table 4. Counts for all population *B* source laboratories having five or more net citations.

Rank	Source	Citations	
		Gross	Net
1	Bell Telephone Laboratories	45	31
2	National Bureau of Standards	21	21
3	University of London	20	20
4	University of California	20	19
4	University of Chicago	20	19
6	General Electric Company	30	18
7	University of Göttingen	17	17
7	Harvard University	17	17
7	Massachusetts Institute of Technology	20	17
10	N. V. Philips (Eindhoven)	15	15
11	University of Cambridge	15	14
11	Oak Ridge National Laboratory	25	14
13	University of Bristol	21	13
13	Max Planck Institute (Stuttgart)	13	13
15	Carnegie Institute of Technology	12	12
15	University of Grenoble	12	12
17	Oxford University	11	11
18	Westinghouse	15	10
19	University of Amsterdam	9	9
19	Naval Research Laboratory	9	9
19	University of Turku, Finland	18	9
22	Cornell University	8	8
22	University of Illinois	11	8
22	Pennsylvania State University	10	8
25	Battelle Memorial Institute	7	7
25	Columbia University	7	7
25	University of Oslo	7	7
28	University of Danzig	6	6
28	General Electric Co., England	8	6
28	National Research Council, Ottawa	6	6
28	University of Pittsburgh	6	6
28	Purdue University	6	6
28	Siemens and Halske	6	6
28	United States Bureau of Mines	25	6
35	University of Birmingham, England	5	5
35	Eastman Kodak	5	5
35	Institute of Inorganic Chemistry, Kiev	5	5
35	University of Jena	5	5
35	University of Manchester	5	5
35	Stanford University	5	5

Results, Population A

Table 1 lists the counts for all source laboratories having five or more net citations. The top ten sources account for almost 30 percent of all identified citations, although they represent less than 5 percent of all sources in the population. Inspection of the data in column 3 (headed "Gross citations") reveals that if the in-house and self citations had not been eliminated, the top ten source laboratories of population *A* would have been almost exactly the same; the order of rank is changed only in a minor way.

It is of interest to examine the

sources of the parent papers which provided the references of population *A*. Sixty-five papers are represented by the sources shown in Table 2; each of the remaining 34 papers came from a different source. Comparison with Table 1 shows that six of the laboratories appearing in Table 2 are also among the top ten sources in Table 1. The worth of the comparison is obviously lessened somewhat by the fact that the references cited in the sample must be of an earlier date than 1958, the year in which the parent papers were published. To obtain specific information on this point, the number of citations per calendar year was obtained for all identified citations; the results are plotted in Fig. 1. One immediate consequence of this result is the finding that the modal year, 1956, might be a more meaningful year than 1958 if a comparison is to be made between the numerical leaders in publications and the leaders with respect to citations (*9*). However, marked changes in the character or standing of a given laboratory are unlikely to occur in as short a time as two years. To identify the point in time to which our measures refer is an elusive problem. The work represented by the modal year of citation (1956) was probably submitted for publication in 1955 and performed in 1954.

Results, Population B

Population *B* was made up, so as to conform in size to population *A*, of 100 papers on ceramics—20 from each of the 1958 volumes of the journals cited above. It will be noted that there are represented two physics, two chemistry, and one metallurgical journal.

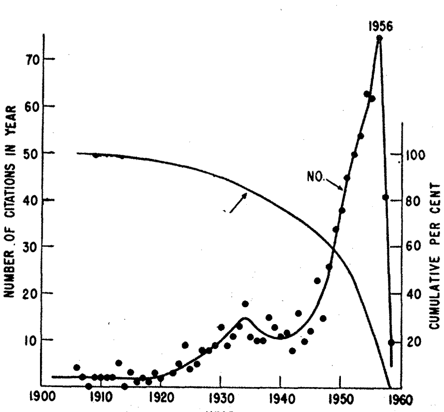

Fig. 1. Year of publication of papers cited in 1958.

Table 5. Breakdown by journals of net citations for population *B*.

Laboratories	Net citations (No.)					Total
	Acta Met.	*J. Phys. and Chem. Solids*	*J. Appl. Phys.*	*J. Am. Ceram. Soc.*	*J. Phys. Chem.*	
Bell Telephone Laboratories	4	15	7	3	2	31
National Bureau of Standards	1	1	2	13	4	21
University of London	4	0	0	7	9	20
University of Chicago	4	3	3	4	5	19
University of California	1	1	1	4	12	19
General Electric	11	3	2	1	1	18
University of Göttingen	1	13	1	0	2	17
Harvard University	4	6	3	1	3	17
Massachusetts Institute of Technology	6	2	4	0	5	17
N. V. Philips (Eindhoven)	0	11	1	0	3	15

Since in contrast to the source journals for population *A*, these journals publish over a wide range of pure and applied science, it was necessary to adopt a definition of the term *ceramic research* to aid in selecting papers to make up the sample. For the purposes of this analysis a broad definition was chosen—namely, all nonmetallic inorganic materials and all metallic compounds. While many will quarrel with this definition, it permits inclusion of work on graphite, on carbides and other interstitial compounds, on alkali halides, and on intermetallic compounds, all of which are subjects of great current activity in ceramics laboratories throughout the world. In general, the first 20 papers from each journal were chosen. Representative titles of papers thus selected are given in Table 3; these should serve to indicate the pertinence to the subject field of these source journals and of the papers selected therefrom.

According to the procedures used for population *A*, 949 gross identified citations were obtained from an original gross of 998 indexed references in population *B*. Table 4 lists gross and net counts for all sources from population *B* having five or more net citations. The top ten sources yield 20 percent of all identified citations, although they comprise less than 5 percent of all sources in the group. On comparing Table 4 with Table 1 it may be noted that five laboratories appear near the top of both lists: National Bureau of Standards, University of London, General Electric, Massachusetts Institute of Technology, and N. V. Philips. This result would seem to imply that the two populations are rather similar but nonetheless possess certain differences. Table 5 presents some figures on net citation breakdown by journals for the leaders in Table 4, figures which show the predilection of some laboratories for certain publication media.

Analysis of the attribution of the source papers of population *B* is made in Table 6; these data may be compared with the analogous data for population *A* in Table 2. The 17 sources shown in Table 6 represent 56 papers; 44 other laboratories contributed one paper each to the sample population. The fact that only three laboratories are common to Tables 2 and 6 is indicative of a difference between the two populations, perhaps one of concern with fundamental versus applied science or of individual preference for particular publication media.

Additional Analyses

The analyses made thus far do not permit us to distinguish between two types of laboratories. One group is

Table 6. Provenance of published papers, population *B*.

Source laboratories	Published papers in sample (No.)
Bell Telephone Laboratories	8
General Electric	5
University of Illinois	5
Bureau of Mines	5
Massachusetts Institute of Technology	4
Oak Ridge National Laboratory	4
Westinghouse	3
University of California	3
International Business Machines	3
Radio Corporation of America	2
Concepción University	2
Brooklyn Polytechnic Institute	2
Naval Ordnance Laboratory	2
Illinois Institute of Technology	2
Du Pont	2
Tufts University	2
University of Chicago	2

typified by laboratory X, which produces only a few papers per year, most of which are significant. The other group is exemplified by laboratory Y, which produces a large number of papers annually of which only a fraction are significant; the significant papers of laboratory Y, however, are perhaps numerically equivalent to those of laboratory X simply because the sample is large enough for a wide spectrum of scientific talents to be represented. Therefore, a different, and perhaps more meaningful, comparison of laboratories engaged in ceramics research can be made by asking what *proportion* of the work done by a laboratory is significant in the sense of this study (that is, results in literature citations). Since it is essentially impossible to obtain data on the actual output of ceramics research publications for individual laboratories, the attribution of the source papers comprising the sample populations will be used as a measure of the publication output. Since the numbers with which we have to deal are small, we will combine populations A and B. We then proceed, using data previously obtained, to plot the number of citations for a given laboratory against the number of source papers attributed to that same laboratory in the 1958 populations A and B (*10*).

Table 7. Comparison of the median year of citation for some leading laboratories.

Laboratory	Net citations (No.) (populations A + B)	Median year of citation
Geophysical Laboratory	37	1924
University of Göttingen	24	1939
Harvard University	19	1940
Bureau of Mines	9	1942
Cambridge University	21	1948
Sheffield University	25	1949
Corning Glass	9	1950
N. V. Philips (Eindhoven)	25	1950
Ohio State University	16	1950
Bristol University	16	1951
Grenoble University	15	1951
University of Chicago	25	1951
Over-all (*A* and *B*)	1785	1951
University of London	39	1952
Carnegie Institute of Technology	20	1952
National Bureau of Standards	66	1952
University of Illinois	21	1952
Pennsylvania State University	30	1953
Massachusetts Institute of Technology	46	1953
University of California	27	1953
General Electric	37	1953
Bell Telephone Laboratories	40	1953
Alfred University	9	1954
Westinghouse	16	1954
Oak Ridge National Laboratory	21	1955

Table 8. Source of papers and citations, by categories, for populations A and B. Percentages in parentheses.

	Universities	Industry	Govt. agencies	Other	Total
Output of papers (*A* and *B*)	90 (45)	68 (34)	27 (14)	14 (7)	199 (100)
Distribution of gross identified citations (*A* and *B*)	1010 (57.5)	437 (25)	266 (15)	47 (2.5)	1760 (100)

It is to be expected that if a relation exists between these two quantities, it could be represented by

$$C_n = KP_n^{1/m}$$

where C_n is the number of citations, P_n is the number of papers published, and K and m are constants. This function meets two basic criteria in that it passes through the origin and increases less than linearly. The first requirement is obvious, since a laboratory that produces no papers can have no citations made to its work according to the rules followed in this analysis. The second requirement is imposed on the functional form, inasmuch as a laboratory which produces an increasingly large proportion of the total published work in a field must suffer a consequent decrease in proportion of *net* citations (by definition, in-house citations are eliminated).

Figure 2 presents such a treatment of our data. Taking arbitrary values for the constants m and K, we find that a major portion of the data points for leading U.S. laboratories falls within a band defined by a small range of values of K and with $m = 3$. Foreign laboratories were not considered since they are not adequately represented in the output parameter used. Furthermore, no points are shown for any laboratory with $\leqq$ 14 net citations or $\leqq$ three source papers.

It appears from this analysis that three U.S. laboratories are responsible for an unusual proportion of significant ceramic research: the National Bureau of Standards, Massachusetts Institute of Technology and the Geophysical Laboratory. This finding, however, requires qualification. The NBS publishes a captive journal (*Journal of Research of the National Bureau of Standards*), which is the exclusive publication outlet for much of its work. Indeed, of the 66 net citations credited to NBS in populations A and B, 51 were to papers published in its own journal. No reflection on the scientific calibre of the work is implied, but these facts indicate that the figure used for publication volume of this laboratory in Fig. 2 (as well as in Tables 2 and 6) is much too low. Were it possible to correct for this difficulty, the point for NBS might well fall within the scatter band, far to the right. A similar difficulty does not arise with respect to Bell Laboratories, for only one citation out of 40 was to the *Bell Laboratories Technical Journal*.

Another sort of ambiguity attaches to deductions made from Fig. 2. Consider the case of a laboratory, prominent as a source of significant research contributions some years ago, whose volume productivity is now low. It may still receive a large number of citations because of its early work, but its current output parameter will be low. Such instances might include the Geophysical Laboratory or Carnegie Institute of Technology. Correspondingly, a very new center of research activity in the subject field might be responsible for a current publication rate which is high in proportion to the impact which these publications have thus far had as evidenced by citation counts.

Table 9. Data for the top 20 journals.

Journal	Citations (No.)	
	Population A	Population B
*J. Am. Ceram. Soc.**	216	12
*J. Am. Chem. Soc.**	29	104
Phys. Rev.	7	112
*J. Phys. Chem.**	19	54
*J. Appl. Phys.**	20	36
J. Research NBS	48	3
Acta Cryst.	17	31
Z. physik. Chem.	9	39
J. Soc. Glass Technol.	33	10
J. Chem. Phys.	10	30
*Acta Met.**	4	29
Trans. AIME	19	13
Phil. Mag.	3	26
Am. J. Sci.	26	0
Z. anorg. Chem.	7	15
Z. Physik	4	18
Trans. Brit. Ceram. Soc.	20	0
Bull. Am. Ceram. Soc.	18	0
J. Chem. Soc.	4	13
J. Inst. Metals	2	13

* Journal included in this study.

We may assess the extent to which such considerations affect our conclusions by comparing the median year of citation for a given laboratory with the median year for the whole population (1951). In the absence of factors such as those just discussed, and provided our sample size for an individual laboratory is adequate, significant deviations from the over-all median would not be expected. Deviations from the over-all median of more than two or three years are probably indicative of the influence of the suspected factors. The results of such an analysis are shown in Table 7. The apparent prominence of the Geophysical Laboratory is thus due primarily to research of 30 to 40 years ago rather than to its work in the last decade. Göttingen, Harvard, and the Bureau of Mines also appear to have been more prominent in the field some years ago than they are today. The remainder of the laboratories examined in Table 7 show median years falling very close to that for the total population. It is of interest to note that Oak Ridge, a laboratory founded during World War II, has the latest median year.

We may examine our results in yet another way. Thus far, no regard has been paid to replicate citations—that is, to those numerous instances in which the same piece of work is cited by two or more different groups of authors. Obviously such papers are of more than ordinary significance, and a laboratory responsible for a number of repeatedly cited papers is deserving of special attention. The punched cards were readily sorted to yield this information, through use of the author indexing. To obtain a larger total sample, populations *A* and *B* were again combined. The results of this analysis are shown in Fig 3. As may be noted, one paper was cited five times; two, four times; eleven, three times; and 32, two times. The results support the findings of the previous analyses, since five of the top six leaders in this analysis were also leaders in the analyses shown in Tables 1 and 4 and in Fig. 2. The highly selective nature of the replicate-citation parameter may be appreciated from the fact that the 32 papers cited two or more times represent less than 3 percent of all net citations examined.

It may also be of interest to examine the source of both papers and citations by categories. For this purpose laboratories were classified as university, industry, government, and other (*11*). These data are shown in Table 8. Here again, populations *A* and *B* were considered together; examined separately, they did not appear to give significantly different results. It would appear that the universities are responsible for a larger proportion of significant work than is indicated by their volume output of papers, as might be expected. This same conclusion is suggested by the analysis of leading individual laboratories, as shown in Fig. 2.

As a final point we might look at the journals in which the cited articles appear. Data for the top 20 journals are shown in Table 9. The numbers in column 2 indicate a rather extensive amount of "inbreeding" for the *Journal of the American Ceramic Society*. Similar breakdowns for the individual journals in population *B* were not considered feasible because of inadequate numbers. Table 9 may also be examined to assess the propriety of the choice of journals for the sample populations. The selected journals rank 1, 4, 7, 9, and 16 for population *A*, and 2, 3, 5, 8, and 13 for population *B*. The *Journal of Physics and Chemistry of Solids* did not rank among the leaders and is not considered here. It is a comparatively new journal and therefore would not be expected to rank high among the cited journals.

Conclusions

1) Analysis of literature citations is a useful measure of the significance of research. Analyses based on (i) gross number of citations, (ii) net number of citations (in-house and self citations omitted), (iii) replicate citations, and (iv) ratio of citations to papers published give results which are in general agreement.

2) The analyses discussed in this article indicate that the following laboratories are responsible for especially significant work in ceramics (although

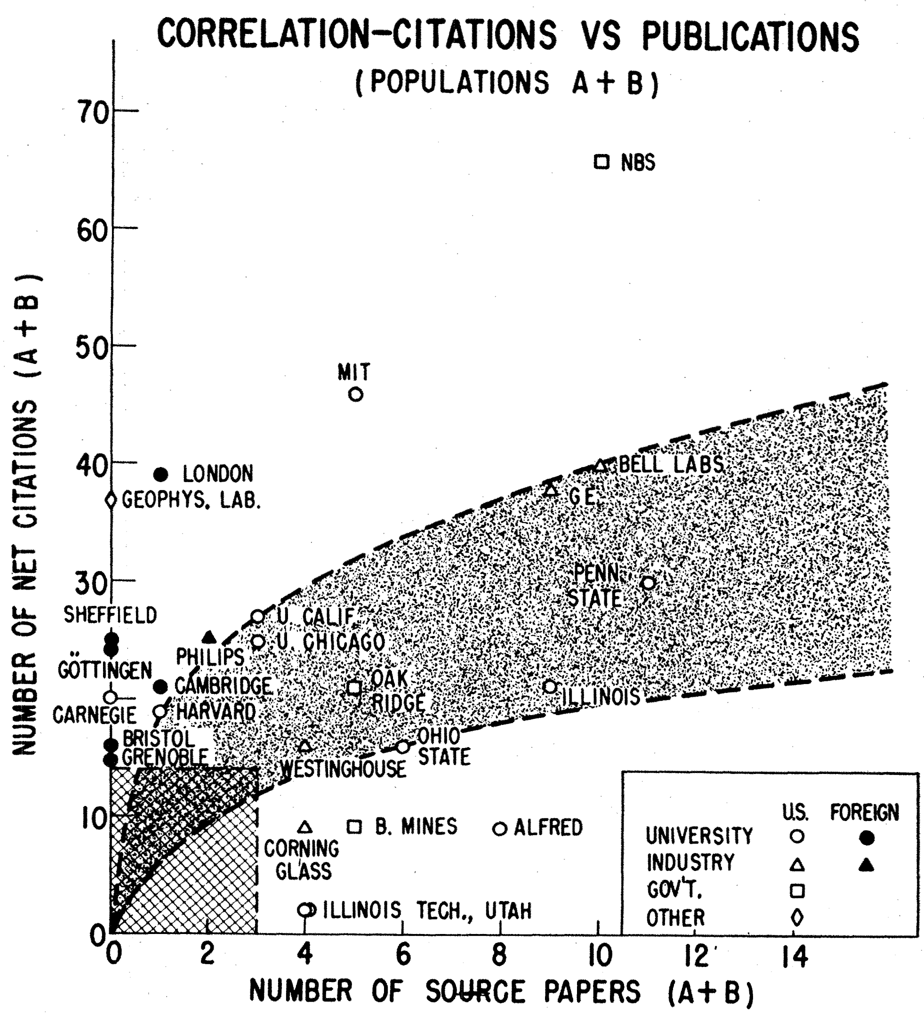

Fig. 2 Correlation of number of citations with number of publications (populations *A* plus *B*).

not necessarily in the order given): the National Bureau of Standards, the University of London, Massachusetts Institute of Technology, General Electric, Philips (Eindhoven), Geophysical Laboratory, and Bell Laboratories.

3) A sample size of 100 papers, yielding about 1000 usable, identifiable citations, is adequate for identification of laboratories doing significant research. Much larger samples would probably be required to extend this analysis—for example, to measure the performance of individual scientists or to identify unusually significant specific papers.

4) The modal year of citation for a given year of publication precedes the latter by about two years, and this difference has been approximately constant over the past 20 years.

5) An equation of the form $C_n = KP_n^{1/m}$ roughly represents the relation between the number of net citations attributed to a given laboratory and the number of its publications.

6) Universities are responsible for a somewhat larger volume of research papers in ceramic science than is industry and for a still larger proportion of significant work. Government agencies play a minor role, as compared to the other two sources, although certain individual laboratories are outstanding, as noted above.

7) Comparison of the median year of citation for individual laboratories with the median year for the whole population can give useful information on the time dependence of the relative prominence of those laboratories.

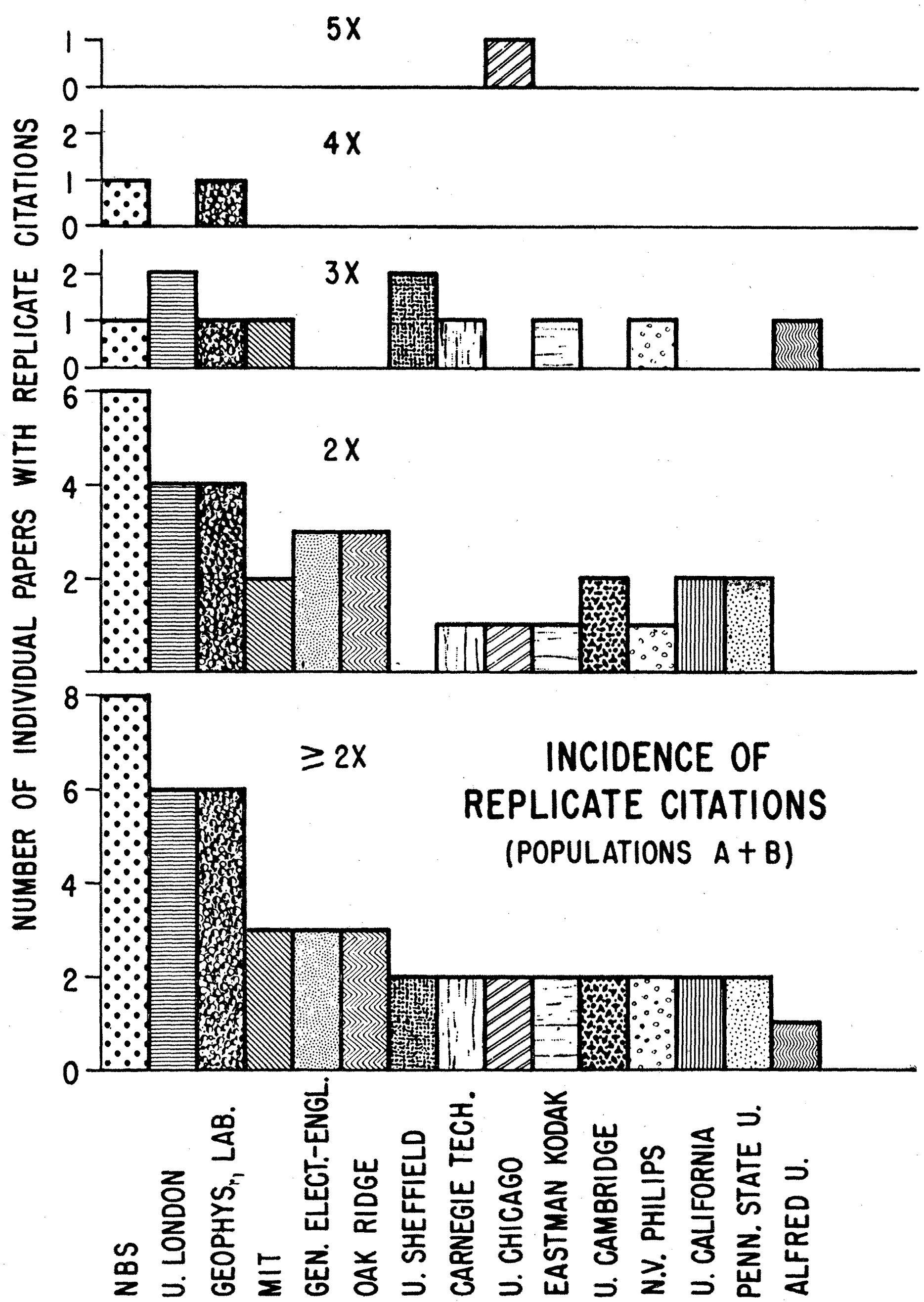

Fig. 3. Incidence of replicate citations (populations *A* plus *B*).

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3. L. Meltzer, *J. Social Issues* **12**, 32 (1956).
4. J. C. Fisher, *Science* **129**, 1653 (1959).
5. I am greatly indebted to Miss M. L. Horrocks and to A. J. Peat for assistance in gathering and analyzing the data used in this study. I also want to thank R. C. DeVries and R. J. Charles for beneficial discussions and critical reading of the manuscript.
6. Studies by Spence, Pelz, and others are obscurely alluded to in *Proceedings* of the 1st and 2nd University of Utah Research Conferences, but no formal publication of these results has been found.
7. P. L. K. Gross and E. M. Gross, *Science* **66**, 385 (192 → L. M. Raisig, *ibid.* **131**, 1417 (196 → P. Weiss, *ibid.* **131**, 1716 (1960).
8. Rare instances may be encountered of repeated citations to an unusually poor paper which gives results so erroneous or conclusions so fallacious that many subsequent workers feel compelled to point these out and directly refute them. It is believed that these instances are so rare that they do not affect the present study.
9. Similar results were obtained for analysis of somewhat smaller samples of referenced citations taken from the *Journal of the American Ceramic Society* for the years 1953, 1950, 1948, and 1939. It had been suspected that the lag between modal year of citation and year of referencing publication might be diminishing with time, but it remains constant at about two years.
10. A separate analysis showed that a three-year average for the output parameter did not yield significantly different results.
11. The category "other" includes foundations, consulting laboratories, research institutes, and so on.