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INFORMATION FLOOD: FICTION AND REALITY

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ABSTRACT

Scientific information is a matter of great importance in research and development. The rapid growth of science and technology has created an extensive database of scientific information, together with the problems of how to retrieve relevant knowledge from the mass of available data. Careful examination proved that only a tiny part of all published material is significant, and established effective tools for the identification of important information. These allow one to perform literature searches, to optimize the management of literature collections and the design of educational plans, to map the structure of science and to follow the dynamics of its specialities.

The main product of science is information, i.e., communicable knowledge (Eugene Garfield [1])

INTRODUCTION

The aim of scientific work is to find the truth about nature and to throw light upon the principles that rule it. Individual partial achievements in this struggle are attained only by the long-term coordinated efforts of many researchers. Hardly any other human activity is as collective, essentially social, as is the labour in the field of science. A magnificent mirror of truth is pasted together from many pieces of knowledge and, in order for the assemblage to be successful, the contributions of all participants must be well harmonized. As is well known, the building of the Tower of Babel failed for lack of cooperation, not because of a lack of material or manpower.

Every researcher should follow carefully what happens and what has been done in his speciality (and also in the neighbouring spheres), linking up his own work with the work of others. And there is much that should be followed: about 250 000 articles on chemistry are published annually [2] and 450 000 new substances are reported each year [3]. However, scientists undertake creative work rather than the study of the scientific literature,

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they prefer writing to reading. This is demonstrated, e.g., by the statistics of repeated discoveries [4]. This is why a review of fundamental data and new facts about the following and searching of the scientific literature, as presented here, may be useful.

CONCENTRATION OF SIGNIFICANCT INFORMATION

"There are four things that make this world go round: love, energy, materials and information. We see about us a critical shortage of the first commodity, a near critical shortage of the second, an increasing shortage of the third but an absolute glut of the fourth" (Robert A. Day [5]). According to the "World List of Scientific Journals", 59 961 journals are published throughout the world (in 65 languages) in which about 1 million articles appear a year; in addition, some 300000 scientific monographs are published each year plus 15 000 conference proceedings. How can one orientate oneself in such an information flood? Is it ever possible to find in the sea of information that which is correct and the most important without spending all one's time on it so that nothing remains to extract some value out of this hard-earned information?

Yes, it is possible. Statistical analyses of large libraries indicate that only a small part of the total of published information is really valuable and that people are able to recognize which part it is. Thus, the Library of Congress in Washington, DC, the largest library in the world, holds about 14 million books, but more than half of them have never been borrowed. The British Lending Library subscribes to 45 000 journals, but 70% of them are seldom, if ever, borrowed; on the other hand, 5000 journals represent 80% of all loans. A mathematician would say that the significance (usefulness) is very unevenly distributed amongst information items—books, journals (individual articles, papers in conference proceedings, etc.). This is the condition that is necessary for us to be able to take reasonable advantage of the huge amount of annually published scientific information. If all information were equally important, if there were something significant, something valuable in every book and article, then it would be necessary to read all that has been published—which is of course absolutely impossible.

The clue to the problem of which scientific information is significant can be found directly in the literature: it is expressed by its citation rate (how often it is cited). Papers, books, journals and conference proceedings can be searched, classified and evaluated according to their citation in other papers, books, journals, etc. If an article is frequently cited, then it must have been used by many people in their work; hence it is a valuable article, as other workers will cite only useful material; nobody needs poor papers, so nobody cites them. There are plenty of such redundant articles: around one-third to one-half of all papers are never cited. On the other hand, only 1% of articles account for 90% of all citations; 25% of workers write only one paper during their career but 10% of workers write 50% of all articles. On average a given article is cited 1.7 times in a given year, whereas on average an article by a Nobel Prize winner is cited 58-times during a year and only 1% of all articles have such a high citation rate. With journals, the situation is similar; there are about 60 000 scientific journals, but only 152 of them are responsible for the material cited in half the references and 2000 journals account for 85% of all references [6]—these are the most significant journals which are to be subscribed to and read. The citation of publications gives an accurate picture of the state of the art as it is done by those who publish (thus forming contemporary science), and it is current (author cites recent works he has actually used), interdisciplinary (papers originating from seemingly unrelated disciplines are cited where the citing author managed to find sources for his own work) and cost effective (it is provided automatically by the author when compiling a list of references).

The information flood appears to be only a peripheral phenomenon, a "paper tiger" that can be mastered by a competent evaluation of scientific information: 90% of all useful (cited) human knowledge is concentrated in 50 000 articles, which can be bound into 2000 volumes of 25 articles each; to this library, 200 volumes of new information must be added each year and 200 volumes of information that became obsolete must be set aside annually. The citation analyses, which serve for the continuous identification of significant information, can be automated to a great extent and performed effectively by computers.

WHICH BOOKS DESERVE TO BE READ

There are a number of monographs on each particular subject. The books are of different quality and it may happen that just the one we choose to read is bad. Of course, we can recognize that the book is bad only after having read it together with several other books on the subject in question, which is necessary for us to be able to make a comparison. However this is a luxury that nobody can afford to repeat many times, so we enquire of professors, senior colleagues and friends, as other people know more and different people may have different opinions. Only extensive investigations can result in an unbiased view. Such a study was conducted by the Institute for Scientific Information in 1974 [7], this analysis was based on approximately 40 million citations from the references of over 3.5 million articles published during the twelve-year period 1961–1972 in about 2400 journals, which covered just about all the disciplines in the natural sciences. The study showed that books are very variable in popularity, which supposedly reflects their diverse qualities. A statistical analysis demonstrated that most citations are concentrated on only a handful of books—these are the best books of greatest importance, at least according to the verdict of the authors of those 3.5 million papers. This ranking is graduated very steeply, as can be seen from the fact that the most frequently cited book was cited 3254 times during the period under review whereas the fifth most heavily cited book was cited only 1514 times and the book ranked 100th only 219 times.

An important result of this study was a list of the 100 most cited books; those which relate to chemistry and physics (42) are listed as references 8–49 here.

The procedure described warrants a high degree of objectivity so that it can be applied to the selection of books, the management of libraries and the design of educational plans.

SELECTION AND CLASSIFICATION OF SCIENTIFIC JOURNALS

The most important sources of scientific information are journals of science. They are so numerous and ubiquitous that we sometimes manage them inefficiently. Decisions about which journals to subscribe to are often made on the basis of tradition, local custom or the loudness with which individual users call for their favourite journal; it is common for a greater number of cheap journals to be preferred to one or two expensive journals when a fixed amount of money is available. Journals are often scored simply according to their subscription rates, without appreciating the benefits that can be obtained from them. However, we do have an objective measure for assessing the relative importance of scientific and technical journals, viz., their citation rate. Statistical analyses show that only 5–6% of the total of almost 60 000 scientific jsournals are ever cited. Only material that is published in these journals is really used in building up contemporary science; therefore, these journals are objectively the most significant journals. The citation rate is distributed very unevenly: only 25 journals are cited in 24% of all references; only 152 journals are cited in 50% of all references; only 767 journals are cited in 75% of all references; and only about 2000 journals are cited in 85% of all references. This provides an opportunity for small libraries, which must operate within a limited budget, to obtain access to almost all significant information cheaply. Conversely, with improper selection, much money may be spent on journals the scientific significance of which is only marginal .

When speaking about science here, I do not mean solely basic research. Pasteur's statement that there is no applied science but only application of science is particularly apt here. People who want to save intellectual effort hunt for detailed descriptions of industrial processes and recipes and make requests for obscure journals where they hope to find such information. It is, of course, much easier than keeping up with the development of scientific knowledge from which technological innovations are deduced with a delay that amounts to several years even in the most advanced countries. It also leads to an inappropriate allocation of acquisition funds, which is detrimental to the economy and retards the advancement of science and technology.

The manual that enables one to optimize the selection of scientific journals is published annually by the Institute for Scientific Information under the name "Journal Citation Reports" (the first issue appeared in 1975). The "Journal Citation Reports" contains the results of extensive statistical analyses. Thus the 1979 edition [50] (almost 2000 pages) is based on approximately 8 million citations from the references of over 700 000 articles published in the 1979 issues of about 6000 journals, and provides the following data on about 3500 journals: how often each journal is cited; how many items it publishes; how often (on average) each item is cited; how often (on average) each item is cited during the year of its publication; the source journals responsible for the references to each journal; the number of references obtained from each and how they were distributed by the publication years of cited issues; and the number of references each journal published, to what journals and how the references were distributed by the publication years of cited issues.

In this way, i.e., by giving the list of the journals that it cites and the journals that cite it most often, the orientation of the journal under consideration is well defined. This is very important not only in searching for information but also in deciding where to publish in order to reach the correct and widest audience. An inappropriate location of a paper in a journal that is not read by people for whom the paper is relevant may cause it to remain unnoticed and lost in the sea of published material. All authors, especially those who are not renowned, should submit the results of their work to the correct place in the arranged system of scientific information. A mislaid (and therefore lost) piece of knowledge cannot be communicated—and only communicable knowledge becomes part of the system that is called science.

When searching the journals that provide reasonably complete coverage of the literature relevant to a particular discipline, the following iterative procedure can be applied. The starting point is a list (A) of leading journals in the field. In the second step, the journals cited most frequently by A are identified using the "Journal Citation Reports". These journals are then arranged in decreasing order according to the value of the ratio of citations received from the journals of group A to citations from all sources and the first k journals of this list make up group B. In the third step, we again use the "Journal Citation Reports" and identify the major sources of references to the journals of group A. These journals are now ranked in order of the ratio of references to the journals of group A to references to all journals and the first l journals of the list form group C. Combining the journals from groups A, B and C, we obtain a list X $(= A\ B\ C)$ of journals representing an extended core of the literature in the field under consideration. We can go on and take X as the starting point of the next iteration step, proceeding in successive cycles as long as necessary. The list of journals developed in this way is arranged in decreasing order according to how close their relationship to the subject area is.

Thus, using citation data provided by the "Journal Citation Reports", the core literature on thermal analysis can be identified in the following way:

(1) start with "Thermochimica Acta" and "Journal of Thermal Analysis";

(2) find the 10 other journals most frequently cited by "Thermochimica Acta" and "Journal of Thermal Analysis" (1979):

"Analytical Chemistry",
"Journal of the American Chemical Society",
"Journal of Inorganic and Nuclear Chemistry"
"Journal of Physical Chemistry" (U.S.),
"Nature" (London)
"Zeitschrift für anorganische und allgemeine Chemie",
"Bulletin de la Société Chimique de France",
"Journal of Chemical Physics",
"Journal of the Chemical Society",
"Transactions of the Faraday Society";

(3) find the 10 journals that most frequently cite "Thermochimica Acta" and "Journal of Thermal Analysis" and which are not present in the above list:

"Zhurnal Neorganicheskoi Khimii",
"Zeitschrift für Naturforschung, Teil A",
"Journal of Chemical and Engineering Data",
"Zeitschrift für Chemie" (Leipzig),
"Canadian Journal of Chemistry",
"Journal of Chemical Thermodynamics",
"Journal of Less-Common Metals",
"Journal of Materials Science",
"Journal of Polymer Science—Polymer Chemistry Edition",
"Indian Journal of Chemistry A";

(4) find the journals most frequently cited by and most frequently citing the 22 journals identified so far and continue in this way through as many cycles as necessary.

The "Journal Citation Reports" is a source of information that is highly useful in evaluating, comparing and assessing scientific journals. Thus, the value of the so-called "impact factor" is given for each of 3500 journals: this is a measure of the frequency with which the "average cited article" in the journal has been cited in a particular year. The impact factor is basically the ratio of citations to citable items published: all journals' 1979 citations of 1977 and 1978 items published by journal X, divided by the total number of source items published in 1977 and 1978 by journal X. Another parameter introduced by the "Journal Citation Reports" is the "immediacy index", This is a measure of how quickly the "average cited article" in a particular journal is cited (the result of dividing the citations of 1979 articles by source items published in 1979). "Half-life" is defined as the number of journal publication years from the current year backwards whose articles have accounted for 50% of the total citations obtained in a given year (it tells us something about the rate of obsolescence of information published in the journal in question, which is important in making decisions about journal collection maintenance and deacquisition of individual journals).

RETROSPECTIVE SEARCHES

Searching the literature in a given field is a two-step procedure, which is made up of two processes that link with each other but differ widely in their mechanisms, possibilities and difficulties. The first (more difficult) step in the literature search consists in looking for relevant papers (books, patents, theses or other information items) making use of title words, subject terms or names of authors and their institutions. From each of the papers identified in this way, a number of further relevant articles are then obtained routinely in the second stage of the search procedure as references to this paper, references to all of the references in this paper, etc.

The further we proceed in this manner, the denser the network of references becomes, so that the list of "old-timers" will be complete. However, we are usually more interested in recent work, and it is much more difficult to achieve completeness on a current basis. If a relevant paper cannot be identified by the terms used by its author in the title of the paper (or by the name of the author or his affiliation), there still remains the possibility that it may be found using the so-called subject terms. These are terms that describe the contents of the paper and are attached to it by an indexer, a person, usually with specialized knowledge of the subject covered, who must read the paper. Indexers, who monitor the scientific literature, may compile from time to time a new edition of a subject index, i.e., a list of standardized terms ("subject terms") which are then used to identify the subject of papers. The basic problem is the timeliness of the subject indexes, which are usually years behind the literature. Science develops quickly and many new concepts and even disciplines may exist for years without being incorporated into subject indexes. This is why the effectiveness and reliability of a search with regard to recent information on the latest problems is the weakest point of retrospective searches.

A discovery of immense importance for the methodology of literature searching was the finding that a paper (or any published document) can be identified or indexed not only by its title, author, keywords and the fact that it may have been cited in some later articles, but also by the fact that it cites certain earlier papers (books, research reports, etc.). It cites documents that support, provide precedents for, illustrate or elaborate on what the author of the present article has to say. Thus, citations are the formal, explicit linkages between papers that have particular points in common. We can make use of these linkages to acquire relevant literature on any given subject: the simple citation of one important paper pertinent to the subject will lead us directly to a list of papers that have cited it, and experience has shown that a significant percentage of the citing papers are likely to be relevant. The search of articles citing any former paper can be conducted by using the "Science Citation Index", a large index to the international scientific and technical literature produced by the Institute for Scientific Information (first edition in 1963). The annual coverage of the "Science Citation Index" (about 20 000 pages) consists of approximately 600 000 source articles and 7 million references from 3000–4000 journals and multi-authored books in all scientific disciplines. The "Science Citation Index" connects papers published during the current year with past papers (books, letters, theses, etc.) that they have cited in references. It is organized alphabetically by cited author; under each cited author are chronologically listed the papers that have been cited in references and under each cited item are listed the sources of the references.

In our pursuit of scientific information, we should not neglect direct contact with the scientists who created this information. The authors of papers published less than 20 years ago (which are exactly the papers in which we are usually interested) are mostly still active and will usually gladly provide further details of their work. The location of authors' addresses for correspondence can be obtained from the "Current Bibliographic Directory of the Arts and Sciences", an international directory, issued annually by the Institute for Scientific Information and listing over 365 000 authors publishing in the sciences, social sciences, arts and humanities, and featuring abbreviated citations of papers published by an author during the current year. The "Current Bibliographic Directory of the Arts and Sciences" is made up of three sections arranged alphabetically by the names of authors, organizations and addresses.

MONITORING THE CURRENT LITERATURE

The annual output of science amounts to 1 million papers. Although most significant information is concentrated in only several thousand (or, at most, in a few tens of thousand) articles, it is impossible for any person to read all of them each year. It is estimated that an average researcher reads no more than about 200 papers annually. This is why workers trying to keep up with the literature tend to read only abstracts (20 times more frequently) or even titles of articles (500 times). Abstracts seem to be the best compromise. There are plenty of powerful abstracting services such as as "Chemical

Abstracts Service", "Metals Abstracts", "International Nuclear Information System Atom Index" and "Current Abstracts of Chemistry and Index Chemicus" that help scientists to locate the specific portion of the literature that is related to their work. However, abstracts are more effective in retrospective searches than in current awareness services. They are still too long. If a researcher wanted to read 50 000 abstracts per year it would take him 2000 hours (2.5 min each) and no time would be left for his own research. Thus anyone who wants to be acquainted even roughly with all significant new research findings and advances in science throughout the world has to confine himself to reading only titles of articles. In an hour or two a week it is possible to examine the titles of 3000 articles, thus obtaining information on about 150 000 papers annually.

This can be done using "Current Contents", a publication of the Institute for Scientific Information that displays tables of contents from thousands of the world's leading journals and hundreds of important new multi-authored books annually. Started in 1960 and issued weekly, Current Contents is published in seven editions: Life Sciences; Clinical Practice; Agriculture, Biology and Environmental Sciences; Physical, Chemical and Earth Sciences; Engineering, Technology and Applied Sciences; Social and Behavioral Sciences; and Arts and Humanities. The user of Current Contents can examine hundreds of tables of contents each week and decide whether or not he wants to read any of the articles listed. Each issue of Current Contents contains an author-address directory that provides a full mailing address for the senior author of every article, so it is easy to write for reprints of articles that cannot be obtained from the individual's library. Each issue of Current Contents also contains a subject index listing every significant word and word phrase that appear in the titles of the articles covered. Current Contents is used by over 250 000 researchers worldwide [51,52].

Prior to being published in journals, new ideas and reports on the latest researches are presented and discussed at scientific meetings. Three-quarters of about 15 000 conferences, seminars, symposia, colloquia, conventions and workshops that take place each year, result in a published record of the papers presented. These "proceedings" make up the "conference literature". Current awareness and retrospective searches of the published conference literature can be conducted using the "Index to Scientific and Technical Proceedings". This is published by the Institute for Scientific Information and covers over 3000 proceedings annually—indexing both proceedings and the individual papers in the proceedings—with complete entries for over 95 000 items. First authors' addresses are given of each individual paper to facilitate reprint requests.

Citation patterns between published papers reflect the intellectual structure of science, past and present. Straight citation counts identify frequently cited items in a given year. Co-citation counts, i.e., the number of times a pair of papers has been cited by individual source papers in that year, classify the papers into clusters and show the relationships between clusters. A cluster consists of all the papers linked by cocitations at a frequency level greater than a given threshold. These papers represent the core literature of a speciality. Their titles have certain words in common that suggest names descriptive of the speciality. Following the picture of cluster behaviour with time allows one to show diagrammatically the evolution of research fronts. The Institute for Scientific Information has developed a computer procedure capable of mapping the structure of science in terms of its most active specialities. The maps [53] plotted by this method over a period of time show significant changes in the relative importance of different disciplines, shifts in the relationships between individual areas of research and the emergence of important new specialities.

CONCLUSIONS

For their work in the laboratory, chemists need instruments, chemicals and information. Of these three requisites, information is the least expensive and a good assortment is available. Nevertheless, neglect or misuse of information may cause more harm than the lack of an important catalyst or damage to an expensive piece of apparatus. This is why each chemist should pay due attention to scientific information and to its sensible use.

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