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Obituary

A tribute to Eugene Garfield: Information innovator and idealist

ARTICLE INFO

ABSTRACT

No other individual has had a greater influence on the fields of scientometrics, informetrics, and information science generally than Eugene Garfield. Most of his contributions over the decades are found to have had their origins very early in his career. Chemistry and chemical information launched his career and led to his involvement with medical information, computing technology, and the field of documentation. Content page products provided the foundation to his business, and the singular invention of a citation index for science, his most far reaching achievement, led to many spin offs including journal analyses, historical charting, evaluation, and science mapping. His idea for a science newspaper was derived from his early work in current awareness. The paper concludes with discussion of his management style, approach to business and philanthropy, and how they shed light on his complex personality and motivations.

1. Introduction

With the passing of Gene Garfield at the age of 91 years on February 26, 2017, we have lost one of the great pioneers and innovators of the information age. It was my good fortune to have been associated with Gene for 45 years. It was exciting to be involved in the applications of citation indexing, and it continues to be an intellectually rewarding journey. I think this is because the database he created is an incredible window onto the entire scientific landscape

For me Gene was a larger-than-life figure who was a commanding presence in my working life at the Institute for Scientific Information (ISI), the company he founded. He was in turn an information pioneer, innovator, entrepreneur, a demanding boss, outspoken critic, a fighter for what he believed in, a nudge, a workaholic, a mentor, a father figure, good friend, and generous soul. Clearly, this is a complex picture and most people who have worked with him feel many conflicting emotions. But without his dogged and sometimes annoying persistence, it is unlikely that we would have seen the products, services, and ideas that have been for me and scholars the world over the essential nutrients of our intellectual life. Through his contributions many of us have built our careers

When I went to work at ISI in 1972, I did not realize that I would witness the birth of a new field of scholarship we call scientometrics and informetrics. The development of the new field was made possible in large part by Gene's citation index in combination with the rapidly expanding power of computing

We are fortunate to have many excellent accounts of his life in the form of audio and video interviews and historical accounts written by him or by colleagues (Garfield, 1987; Garfield, 1997, 2007; Thackray & Brock, 2000; Wouters, 1999). What I will do here is highlight some his achievements and how they were an expression of his unique personality, ambition, and idealism

2. Chemical indexing products

We now think of Gene mainly in terms of his most successful and visible products, namely *Current Contents* and the *Science Citation Index*. But his early work was in chemistry and chemical indexing. He studied chemical engineering for one semester at the University of Colorado before joining the army, and after the army continued his schooling at Columbia University. In 1949 he graduated with a degree in chemistry but could not find a job as a chemist. With a recommendation from a cousin who was working on his PhD at Columbia, he got a job in the lab of the prominent chemist, Louis P. Hammett

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1751-1577/

His interest in chemical information stems from his work in Hammett's lab. Gene learned how to do literature searches in Chemical Abstracts and also created an index for the chemicals in Hammett's store room which had been synthesized in the lab. He had learned typing in a high school summer course and thought at one point that he might be a secretary. It turned out that this skill was very useful in his indexing work. However, due to some mishaps and explosions in Hammett's lab, he was fired. "I think it might be a good idea if you modify your career expectations" Hammett told him diplomatically (Garfield, 2007, 17)

Gene often said that one reason for his success was his ability to talk to anyone. Attending a meeting of the American Chemical Society in New York, he introduced himself to James W. Perry, a chemical engineer, who had given a presentation on chemical information sponsored by the ACS Division of Chemical Literature. Gene asked him "How do you get a job in this racket?", and invited Perry to dinner at his mother's home. Perry offered him a job at MIT, but before that could happen, the project lost funding. At Perry's suggestion, he went to Johns Hopkins in Baltimore but discovered that his job would be with Sanford Larkey at the Welch Medical Library working on chemical nomenclature. It turned out that Larkey was a friend of Perry. Later on, gaining access to his personnel file at the Welch Medical Library, Gene found out that Hammett, whom he had given as a reference, had written a letter to Larkey stating that "Garfield is an extremely hard worker but not a particularly original thinker." Looking back with a smile Gene would later say, "Was he surprised!" (Garfield, 2007, 18)

His work in chemical information continued in 1954, after he had completed a library degree at Columbia. At that time he relocated to Philadelphia and took a job as a consultant at the drug company SmithKline & French where one of his projects was indexing steroids. These were identified by scanning journal articles. Realizing that Chemical Abstracts was seriously out of date, he came up with the idea for a chemical information service that would quickly identify newly synthesized chemical compounds. This became his first chemical product in 1960 which he called Index Chemicus. Like his steroid work, this was based on a scanning of journal articles. Needing a way to identify and index new compounds, he developed a method for converting chemical names into molecular formulas which could be easily indexed. This conversion method became the basis of his PhD from the linguistics department of the University of Pennsylvania which at 10 pages became, somewhat notoriously, the shortest PhD dissertation ever granted by the department

3. Contents page services

In some ways, the foundation of Gene's career was the idea of providing the table of contents pages of journals in a timely manner which served the needs of readers to find out the latest publications in their field and of publishers to publicize their

Fig. 1. Gene Garfield in the 1950 with an early version of Current Contents.

upcoming content. In fact, *Current Contents* was the first, best known, and most commercially successful of his products, and for many years provided a critical source of revenue for his other ventures (Fig. 1).

One event in his early life remarkably foreshadows his later interest in title scanning. As a young boy his apartment in the Bronx was across the street from a branch of the New York Public Library. He recalls going into the adult section of the library and reading the titles of books on the shelves until he could see them in his head. Late in life he could still recall some of the titles. Was this a refuge from adversity, simple curiosity, or bragging rights? He could not say.

His first job in the field of information was, as mentioned, working at the Welch Medical Library at Johns Hopkins in Baltimore. The Welch project was sponsored by the Army Medical Library and was the precursor of the National Library of Medicine where, among other things, pioneering work was done on what would later become Index Medicus, and the Medical Subject Heading (Mesh) system. At the project he got to meet many of the leading librarians of the day. Part of his job was to work on the Current List of Medical Literature, a publication of titles of medical articles indexed by the project. On his own and without the approval from the project's director, Larkey, Gene decided to produce a similar service for library and information science journals which he called "Contents in Advance". To compile it, he wrote to journal publishers to obtain the contents pages of their forthcoming issues which he reproduced photographically. He had realized in his work on the Current List and also with Chemical Abstracts that indexing services were very slow due to the amount of indexing work required to produce them. His solution was to create a product that would alert readers to new articles as soon as they were available from publishers. This emphasis on timeliness became one of his mantras and affected every other product he produced.

Larkey, however, did not approve of Contents in Advance, even if Gene was doing it on his own time, and his refusal to stop work on it led to his being fired from the Welch project. However, the publication continued after he left the project and went to Columbia Library School. Later on, after relocating to Philadelphia, he undertook other specialized contents page products for management and pharmaceutical journals which eventually morphed into the various editions of *Current Contents* (CC).

4. Punch cards and computers

The advent of computers and punch card technology for storing and searching data had opened up new horizons for libraries and information centers. Gene got his first exposure to this technology on the Welch project. There he gained his reputation as an IBM punch card "guru" and information "engineer", as he called himself, and an expert at programming the IBM 101 statistical machine which had newly arrived in a building across the street from the library. This involved programming the IBM 101 by the method of rewiring which he learned from reading manuals and talking to IBM representatives. He was able to program the machine to search simultaneously on multiple classification codes of medical articles through the method of superimposed coding which had been developed by Calvin Mooers. One of Gene's earliest published papers in 1954 dealt with the use of punch card technology (Garfield, 1954).

He had a talent for seeing how what we would now consider to be primitive computer technology could be applied to solve large scale information problems. This was particularly true in his proposal for a citation index for science. In effect, he was able to find an engineering solution to an information problem, using punch card technology to store and manipulate the data records.

After leaving the Welch project and completing his library degree, he wanted to pursue a PhD and tried to put together an interdisciplinary committee since Columbia did not have a PhD program in library science. The title of his proposal was "Machine Methods of Scientific Documentation: the Application of Computers". However, he was thwarted in his efforts when it proved impossible to convene the committee. He initially set up his business in Philadelphia first calling it "DocuMation Inc.", later changing it to "Eugene Garfield Associates – Information Engineers". However, he was informed by the State of Pennsylvania that he could not call himself an engineer because he had not been licensed.

5. Citation index for science – conception

The origin of the idea for a citation index for science holds particular fascination because, of all of Gene's innovations, it has had the greatest impact, not only on information retrieval, but also on the field of scientometrics. In the 1950s the idea of creating a unified index for all of science was gaining momentum, including a possible role for the Federal government in building a national documentation center for science (Garfield & Hayne, 1955). Early ideas included combining of information from all the then available disciplinary services into one giant enterprise. Centralization and government support seemed important not only because of the magnitude of the task but also the need for cross-disciplinary research.

The head of the advisory committee at the Welch project, Chauncey Leake, had been pestering Gene to study review articles and find out why they were so important to scientists. He studied reviews and realized that almost every sentence was like an indexing statement associated with a bibliographic reference, like "a continuous string of indexing statements" (Thackray & Brock, 2000). His first thought was that perhaps these statements could be used somehow in his indexing work on the Welch project and he wrote a paper on the idea (Garfield, 1952, 1963). Thus, Leake's suggestion had focused Gene's attention on references in scientific papers.

The next piece of the puzzle came from an unexpected place, via a letter from William Adair, the retired president of Shepard's, a citation index to legal decisions (Wouters, 1999, 23). Adair's letter had been prompted by a conference held at

Fig. 2. Gene Garfield (second from left) at the Symposium on machine methods in scientific documentation in 1953.

the Welch Library which Gene had played a major role in organizing. The opening speaker was Lowell Reed, a vice president of Johns Hopkins, whose statement that "man was going to drown in a flood of papers" was picked up by the newspaper wire services and came to Adair's attention in Colorado (Fig. 2).

The letter from Adair suggested that the legal citator idea used in Shepard's might be applicable to science, and that indeed he had suggested that it be used to index the medical and engineering literature back in the 1930s. Shepard's enabled lawyers to look up an older court decision and see whether more recent cases had affirmed or overturned the original one. Since Gene had never seen Shepard's, he went over to the Enoch Pratt Central Library in Baltimore to have a look. Putting the citator idea together with his insight into how review articles index references, the lightbulb went off.

While at Columbia for his library degree, he wrote a term paper on citation indexing which became the basis of his landmark 1955 paper in Science (Garfield, 1955). In his new role as an associate editor of American Documentation, he also asked Adair to write a paper on how the citator idea could be applied to scientific literature (Adair, 1955).

Gene's 1955 Science paper described how a citation index could be constructed from elemental building blocks of citing and cited records that could be numerically coded to fit into the 80 columns of an IBM punch card. The index also required an inversion of the order of references from how they are presented in the literature to their arrangement by cited item, so that a user could look up a reference and find where it had been cited, turning the usual order of presentation on its head.

The paper stressed the value of a citation index for information retrieval, especially in bringing to light criticisms of earlier papers, to prevent the propagation of "uncritical citation of fraudulent, incomplete or obsolete data". On a more positive note, he went on to say that a citation represents an association of ideas between citing and cited authors, and that this association is at the "molecular" unit of thought, rather than the more general subject category level of traditional indexes. But, he asserted, the citation index could also be used in historical research to assess the "impact" or "significance" of a work for its historical period, including the transmission of ideas, and would enable historians to "measure the influence of the article – that is its 'impact factor'". In short, he saw the value of citation indexing both in terms of retrieval of highly targeted information and for assessing impact, a dual purpose that set the framework for much of the work to follow.

Fig. 3. From left, Hilary Koprowski, Gene Garfield, and Joshua Lederberg at an ISI Board of Directors meeting.

6. Science Citation Index – birth

Initial efforts to obtain government funding to create a citation index, however, were not successful, in part, because Gene was not affiliated with an academic institution. He also attempted to sell the U.S. Patent Office on the idea of a citation index for patents. The National Science Foundation had also turned down his proposal, but he did get support from Gordon Allen, a geneticist at the NIH. Wouters has described all the twists and turns in getting the citation index off the ground (Wouters, 1999).

Then in 1959 Gene received a letter from Joshua Lederberg who had recently received the Nobel Prize (Lederberg, 2000). He had read Gene's 1955 paper in Science and wrote to him asking what had become of the idea. Lederberg said he could have used such a tool himself to see if there had been any follow up work on a previous paper, the very task that a citation index was designed to do. There ensued an exchange of letters between the two that had a decisive effect on the development of the citation index (Fig. 3).

The sequence of letters shows how Gene's thinking evolved on citation indexing, and some of the paths not taken. The basic idea of a comprehensive unified citation index outlined in the 1955 paper appealed to Lederberg. But Gene worried about how such a broad approach could appeal to more specialized communities such as geneticists or journal publishers. Should there be some kind of selection of references to specific journals or papers based on a scanning of reference lists? Should all references from general journals be captured and then select from these an index just for genetics? Or should the index be based on a broader scanning of references, say from all CC journals, but restricted to general science journals as cited targets? Should the index be sliced up by cited journal and provided separately to publishers?

In addition, Gene wondered if the citing sentences should be classified in some manner, or perhaps a page or reference number given to allow users to find where the citation appeared in the article (Lederberg, 2000, 55–57). Should there be coding of references by function, such as confirmation or refutation, or by type of use made by the citing author, or perhaps an indication of the section of the paper the citation came from? He was toying with the idea that knowing the specific citing passage could be very useful, recalling his Welch project study on using review papers as a means of indexing papers they cite.

Lederberg, for his part, was skeptical of many of these qualified or restricted approaches and urged Gene to stick to the original plan of a unified index and full coverage of a set of journals. He urged him not to pursue some of the more intellectually challenging approaches like coding citations by function, but rather to keep it simple and just capture the citing and cited identifiers with minimal additional coding. Lederberg suggested going to NIH with the full concept and felt that they would see the benefits of being able to see how scientific papers had been followed up on. He also brought up the idea that NIH could use such an index in evaluating its "impact on scientific progress". Later on, Gene could explore the

more in-depth research on the nature of citation. "I feel", he wrote, "a good general CI will be of greater value to Genetics than a too specialized run that sticks too closely to the discipline." (Lederberg, 2000, 63). The submission of proposals both to NIH's genetics study section and NSF were ultimately successful. Due to later changes in rules that prohibited NIH giving grants to companies, the money had to be transferred to NSF and converted to a contract.

It is interesting to speculate on what might have happened if Gene had decided to pursue some of the refinements of citation indexing described in his letters to Lederberg, such as coding reference locations within the text or citation function. Clearly adopting any of these refinements would have vastly increased the production effort and probably endangered the whole project. In the first citation index for 1961 and in all subsequent indexes, there is no indication where within the citing paper the citation occurs, and citing items are only identified by initial page. This simplification made it possible to scale up the index through automation without introducing the need for sophisticated indexing.

More recently, of course, issues around how authors cite have become a major research topic under the general rubric of citation context analysis (Small, 1982), and with the advent of more extensive access to full text in electronic form, Gene's original vision of a combined citation and linguistic analysis looks more and more like an attainable goal. In later writings he seemed aware of the possibility. In a 1999 tribute to the late Fred Kochen, he wrote: "It is already possible to use citation links, that is, references, to go back and forth from indexes to full-text journals." (Garfield, 1999)

In 1959 Lederberg also backed up Gene's idea that citation indexing would be valuable for locating interdisciplinary work. The 1955 paper had stated that "cross-fertilization of subject fields is one of our most important problems in science literature." Lederberg had complained: "I have to spend a fair amount of effort in reading the literature of collateral fields and it is infuriating how often I have been stumped in trying to update a topic, where your scheme would have been just the solution!" (Lederberg, 2000, 39) Lederberg's own field of genetics was, he thought, especially suited to citation indexing due to its multidisciplinary nature, involving contributions from disciplines such as biochemistry, statistics, agriculture and medicine. As it turned out, the Genetics Citation Index was created as a subset of the 1961 multidisciplinary index that covered 613 source journals. In addition to a single year genetics subset, an experimental five year genetics index was created covering 38 journals, as was a fifteen year index covering three journals (Garfield & Sher, 1963).

The creation of these subset indexes for genetics, however, proved to be far from straight forward, involving selecting citation records based on both genetics journals and authors (whether citing or cited), matching against specially compiled lists of genetics researchers and journals. Henceforth, the company decided to stick to the original idea of a unified, multidisciplinary citation index covering a selected set of source journals from all fields of science for a single year. As successive annual indexes were compiled, the citations could cross chronological as well as disciplinary boundaries. Lederberg suggested the product be called the *Science Citation Index* (SCI).

An important technical innovation of the first citation index was the introduction of methods to unify cited references. This effort was led by Irv Sher, ISI's first director of research (Garfield, 2001). It turned out, that authors cited papers in different ways using different journal abbreviations and different spellings of author names. Some method was needed to bring together these variants. Otherwise, it would not be possible to gather source papers together that cited a given paper, one of the main objectives of a citation index. By using cleverly constructed keys involving various elements of the bibliographic reference, they succeeded in unifying most of these variant forms. In later years this would also enable the matching of cited references with source article records as required for constructing historical networks.

Following the completion of the first annual SCI for 1961, Gene attempted to get NSF funding for the printing and distribution of the annual index. When this request was turned down, the company had to make the difficult and risky decision whether to fund this effort themselves. As it turned out, initial sales of the SCI were weak, partly due to its high price, and the product lost money for several years. In 1965 he was advised to seek investors from Wall Street which led to his selling 20 percent of the company for half a million dollars. In retrospect, Gene said, this outside money was not needed and the SCI eventually became profitable. The outstanding shares posed problems in later years when a large publisher attempted to take over the company.

By the mid-'60 s the availability of weekly updates of citation data enabled the creation of another current awareness product, the Automatic Subject and Citation Alert, or ASCA report. This was a weekly printout of articles matching a search profile which was submitted by the user. The system was written by Irv Sher and was able to retrieve articles using complex Boolean combinations, what Gene called a "Chinese menu" of key words, authors, and cited references. Despite Gene's enthusiastic support, this product did not take off the way he had hoped, in part due to the difficulty of getting scientists to submit profiles, and was eventually made obsolete by on-line search systems (Fig. 4).

Citation indexing was a radical departure from the traditional methods of indexing and abstracting employed by discipline-based services like the established chemical and biological services which were based on finding the best nomenclature or indexing terms to describe a scientific article, but ignoring the genealogical aspects of the article captured in the cited references. The citation index was the first pan-scientific database knit together by scientists' own handiwork. Scholars still debate what a citation means, whether it represents "influence", "usage", "tradition", or just window dressing. But it seems clear that Gene was aiming for something higher that spoke to the way science was knit together, and the very social nature of that interdependence. Perhaps in simplest terms it represented for him the transmission of knowledge between scientists, somewhat analogous to the passing of genetic information from parent to offspring.

Fig. 4. Irv Sher, ISI's first director of research.

7. Historiographs

Gene was able to illustrate this knitting together of ideas over time through the concept of the "historiograph", a graphical representation of citation relationships between scientific papers covering several generations. The idea had come from Gordon Allen at NIH who suggested in a letter to Gene in 1960 that network diagrams could be used to show historical citation relationships and provided an example (Wouters, 1999, 53). Gene responded enthusiastically to this suggestion saying that such an application had not occurred to him. In 1964, Gene and Irv Sher published an extensive report on one such network, for the field of genetics, matching it against the historical account given by Isaac Asimov in his book on the history of genetics (Asimov, 1963; Garfield, Sher, & Sher, 1964). Taken in a collective sense, the historiograph defined a community of researchers, a body of literature, and evolving knowledge on a topic. Finding a clear way to present complex networks, however, proved difficult.

It is significant that Gene's last major research project was to develop software to construct and visualize historiographs called HistCite, thereby automating the process that had been so laboriously carried out in 1964. For this purpose, it was also possible to take advantage of the multi-year cumulation of citation data represented by the Web of Science. The HistCite software that he and a group of programmers from Russia under Alexander Pudovkin created has been used by a number of scholars to analyze the history of research fields (Garfield, Pudovkin, & Istomin, 2002).

8. Journal citation analysis

One of the key questions in creating the citation index was what journals should be covered as "source" journals, that is, journals from which all references should be captured. Estimates of the number of journals in science at the time varied widely from 50,000 and up. But how many of these were important to cover? Financial constraints necessitated that the first citation index cover only about 600 journals. Gene and Lederberg agreed that covering the big multi-disciplinary journals like Science and Nature was a priority, but how to select the others? Critics like John Ziman were quick to point out that some key journals had been left out. As the SCI gained traction in the market, journal publishers and editors clamored to get

their journals covered. Gene had the insight that the most important journals would cite other key journals, but to study that required a new kind of analysis.

Early flow charts were drawn up by Irv Sher for the creation of a journal citation index where the article level citation index was summarized on the cited journal as well as the citing journal. Serious experimentation began in the late 1960s. This summarization transformed the article citation network into a journal network where nodes were either cited or citing journals. Initially, a quarterly sample from the 1969 SCI was used. The biggest obstacle to this work was the variation in the way authors cited journals, necessitating a large scale manual unification of cited journal abbreviations.

It quickly became evident that only a couple of hundred journals of the roughly two thousand journals covered at that time accounted for a majority of the references received. This justified in Gene's mind limiting the coverage of the SCI to a relatively small number of core journals compared to the tens of thousands of journals that were alleged to exist. In his 1972 article in Science on journal citation analysis, he claimed "... a good multidisciplinary journal collection need contain no more than a few hundred titles." (Garfield, 1972) He dubbed this the "law of concentration" (in contrast to Bradford's law of scattering), and maintained that no matter what disciplinary or specialized journals were selected as source journals, the same set of highly cited core journals would emerge (Garfield, 1971).

He also noted that the highly cited journals were also the largest in terms of number of published articles. This led him to explore ways to "discount the effect of size", that is, normalize the journal citation counts for journal size, settling on the ratio of citations received by a journal in a two year period divided by the number of published or citable items in that period which he dubbed the impact factor.

The Journal Citation Reports (JCR) was the culmination of this effort when it became an ISI product in printout form and later a book printed along with the SCI. The JCR also introduced a number of journal metrics besides impact factor, such as the immediacy index, and half-life statistics dealing with the time distribution of citations received or given. These data were used to guide journal selection, and were adopted by journal editors and publishers, as well as by some librarians as measures of a journal's performance. However, they remained controversial within the research assessment community, particularly as a surrogate for assessing the performance of individual papers or scientists. Within ISI, the JCR data were extensively used to carry out custom analyses to study journal coverage in various products or to plan coverage for new products such as the Social Sciences Citation Index. Analysis of specific fields could be performed, such as, starting with the core journals in some field, and summarizing their cited and citing journals. Soon the JCR opened up new opportunities for studying the interaction among journals or journal sets which were taken up by scholars in the new field of scientometrics.

9. Evaluation by citations

In Gene's 1955 paper on citation indexing, the evaluative use of citations was noted but not emphasized. For many years he stressed the primacy of the SCI's use for information retrieval, downplaying its secondary use in evaluation. This may in part have stemmed from a concern that sloppy or inappropriate use of SCI data would reflect badly on the product, and he vigorously defended it against such abuses. He also warned against the use of the impact factor in evaluating individuals. In his view, "Using citations for evaluating people is a very tricky business." (Cawkell & Garfield, 2001). Citation counts depended on, among other things, the field of science, time factors, and nationality, and a proper evaluation of an individual, paper or journal needed to take multiple factors into consideration. In later years he worried that the use of the SCI for evaluation had eclipsed its use for retrieval; in effect, "the tail was wagging the dog". (Garfield, 1998)

He also saw the shortcomings of individual scientists' referencing practice, and sometimes chastised individual scientists for their failure to cite relevant papers, as in the case of Watson and Crick's failure to cite Avery for the identification of DNA as the hereditary substance. At the same time he realized that such omissions were part of the complex competitive social relationships of scientists.

His first systematic use of citation counting was made as part of his study of the history of DNA in 1964 where he used the 1961 citation index to count the number of citations to nodal authors in the DNA historiograph (Garfield et al., 1964). This study also includes comparisons of citation rates of Nobel Prize winners to other genetics authors in the historical network, and presages his later interest in using citation counts to predict future prize winners. The highly skewed nature of the citation count distribution also became apparent. Clearly high citation rate and utility were bound up in an important way (Garfield, 1973). What Gene did achieve was to transform the way people looked at research performance, from simply how many papers were published to how often they were cited.

Despite his reservations toward evaluation, he was not hesitant to use SCI data to celebrate and highlight the achievements of scientists. He regularly published lists of highly cited authors and papers from different fields in his CC editorials. In his project to list the 1000 most cited authors, he opted to list the authors alphabetically rather than rank ordered to avoid the impression that some were more important than others (Garfield, 1981). In 1977 he inaugurated his Citation Classics series which featured commentaries by individual authors of highly cited papers. A few thousand of these commentaries appeared over the years and were reprinted in a series of books.

In a revealing interview with his VP for research, Tony Cawkell, Gene explained his interest in recognizing highly cited scientists: "I came from a socio-cultural-economic family background that cultivated a deep sense of justice. . A lot of people are passed over in the formal reward system of science. . SCI and the citation analysis became for me a vehicle to transform an informal system of recognition into an explicit reward system for science." (Cawkell & Garfield, 2001)

10. An encyclopedia for science

In the lobby of the old ISI building at 3501 Market Street was a holographic etching entitled the "World Brain". This work was commissioned from the artist Gabriel Liebermann. The world brain was an idea proposed by H.G. Wells in a 1938 essay that held particular fascination for Gene, and he wrote often about Wells in earlier papers. Wells's world brain was an idea for an encyclopedia that would synthesize the world's scientific knowledge by combining the existing scientific writings by authorities from all fields, in Wells's words "... knitting all the intellectual workers of the world through a common interest and a common medium of expression into a more and more conscious co-operating unity." (Wells, 1938, 33). It seems clear that, in some sense, Gene regarded SCI as a representation of collective scientific knowledge and a step toward the realization of the world brain encyclopedia. Earlier at library school, he had written a term paper about Paul Otlet's ideas on encyclopedism, and he considered Otlet one of the founding fathers of documentation. In 1981 he would be able to put some of these ideas into operation in a product he called the *Atlas of Science*.

While the historiograph captured the chronological evolution of knowledge, the introduction of co-citation in 1973 opened up the possibility of mapping science in temporal slices or cross sections, and by connecting the major specialties and fields of science, also revealed its interdisciplinary nature (Small & Garfield, 1985). He encouraged the development of co-citation clustering and mapping, and advocated for its introduction into ISI products. Initially this took the form of providing indexing headings for on-line products or specialized indexes such as the Index to Scientific Reviews. Later on, he proposed the idea for an *Atlas of Science* which, initially at least, was to be a compendium of maps and what he called mini-reviews – short summary statements about the nature of a specialty written by scientists or science writers. After a couple of editions appeared in printed form, this product morphed into a series of review journals where the co-citation maps served as a guide to what fields should be reviewed.

11. A science newspaper

Gene had a longstanding interest in creating a newspaper of science and his early ideas date back to the 1960s. His ideas were perhaps stimulated by the success of CC in providing up to date information on what was going on in science. Weekly issues of CC already had the feel of a newspaper. Why not expand the idea? (Garfield, 1975) However, just what such a newspaper would provide underwent many transformations. One early idea was to have a Daily Scientist tabloid that, analogous to stock market listings, would update citations to scientists' papers. Since the company was located on Chestnut Street in Philadelphia in 1961, the name Chestnut Street Journal of Science was floated. Other ideas were to publish articles written for a non-specialist audience, to publish abstracts or even rapid publication of original articles. All of these options, however, would involve a substantial outlay of capital for paper, printing and mailing, and therefore the need for outside investments. In the 1970s, the possibilities of electronic distribution were investigated, modeled after television based systems such as Viewdata or Prestel in Britain (Garfield, 1977). Meanwhile, more and more editorial features were added to the CC front matter in addition to his weekly essays that began in 1962 under the heading "The Informatorium". Features such as Press Digest gave CC more the feel of a news magazine.

Eventually, in the mid-'80 s his ideas gelled around doing a magazine that focused on the business and profession of science, with discussions of science funding, politics, and the job market, and in 1986 *The Scientist* was launched (Garfield, 1986). Together with other new products at the time such as the *Atlas of Science*, *The Scientist* put considerable strain on the company's finances and led in 1988 to Gene's divesting a controlling interest in ISI to an outside investment firm, JPT Holdings, an acronym for the first names of the owners, Joe, Paul and Ted. He later claimed that the new management had misled him into thinking that support for *The Scientist* would continue, but like other newly launched products, this proved not to be the case and the magazine project was terminated. The only option was to continue to support the effort on his own, and spin it off to a separate company which he did in partnership with Vitek Tracz.

12. Gene as boss

We had a memorable first meeting. I had written Mort Malin, ISI's vice president for Corporate Development, and asked if they had a job opening and sent some of my bibliometric work. Gene was coming to New York City on business so I met him in Penn Station. He was wearing orange socks. We went for coffee but he had forgotten to bring money and had to go to a Western Union to have some wired from Philadelphia. We hailed a taxi but then he realized he did not know whether his appointment was north or south on Park Avenue, so we had to find a pay phone. Dropping me off, he asked what kind of a guy I was. I said in my mid-western manner that I was just an ordinary guy. He said "at ISI we only hire extraordinary people." I thought, well, I really blew that one. I nevertheless got the job.

Our relationship got off to a rocky start a few months after I joined the company in 1972. I went to his office with a paper I had written on a new type of analysis you could do with his citation index involving jointly cited papers, what I called co-citation (Small, 1973). His initial reaction was that it was presumptuous of me, an unknown and unpublished scholar, to present him with such a fait accompli. At first I thought I would be fired but when this did not happen, I gained more confidence. I realized he respected you more if you stood up for what you believed in. After this initiation by fire, he accepted me as an independent researcher, and I received his enthusiastic support.

Fig. 5. Portion of the Cathedral of Man mural by Guillermo Granizo showing portraits of Merton, Garfield, de Solla Price, and Lederberg.

He saw that I was interested in using the SCI to study the structure of science and gave me a book he considered pertinent, *Numerical Taxonomy*, a treatise on cluster analysis (Sneath & Sokal, 1973). He encouraged me in my work on clustering the SCI using co-citations, and its application to map science. He generally created an atmosphere in the company conducive to experimentation and innovation. Together with Mort Malin, my boss, we worked on a joint paper on science indicators and participated in a meeting in 1974 at the Institute for Advanced Study in the Behavioral Sciences attended by many luminaries in the sociology of science (Garfield, Malin, & Small, 1977). In 1975 I organized a conference on citation analysis inviting many leading sociologists and bibliometricians which was held in a small conference center in Maryland. Gene brought his saxophone and was heard practicing in his room. I think this was a form of relaxation for him. Years later we worked together on other papers, culminating in a joint paper in 1985 on what we called the "geography of science" which was reprinted in the front matter of the SCI for many years (Small & Garfield, 1985). It also led to our experiments in creating an *Atlas of Science*.

The rank and file employees were an interesting group of creative people including quite a few artists, musicians, writers and non-conformists. One reason for this was that many of the jobs in the company, particularly those in data capture, were relatively routine and repetitive but still required a high degree of literacy. But you could forget your job at the end of the day and pursue your real interests. The other reason was that Gene was drawn to such people and enjoyed being with them, and to some extent identified with them. He had an open door policy and anyone could go to see him. He enjoyed these encounters with employees, and his response to their complaints was usually generous and supportive. This intense engagement with staff fostered a sense of loyalty and dedication. Many of his employees stayed many years at the company because of the collegial atmosphere he created. I am very fond of the inscription he wrote in my copy of the first volume of his multivolume *Essays of an Information Scientist*: "It's a fantastic pleasure to be associated with you in our daily work and in particular as a co-author of these volumes. . Henry, I hope we can get to know each other better in the years to come."

Not only were artists employed at ISI, Gene decorated his new 3501 Market Street building, a building designed specifically for ISI by a prominent post-modern architectural team, Venturi Scott Brown Associates, with murals and art works, including some that were controversial. The mural called the "Cathedral of Man" by Guillermo Granizo featured cameos of people who were influential in his life like Robert Merton, Derek Price, Joshua Lederberg and information greats, including Gene himself, drawn on orange tiles, his favorite color (Fig. 5).

He was also a lover of the complex and colorful yarn art by the Mexican Huichol artist Emeteria Rios Martinez whose work decorated the walls of the building. In 2009 the company under the control of Thomson Reuters decided to vacate the Market street headquarters that bore the unmistakable stamp of his career and personality, to take up occupancy in a non-descript office building on Spring Garden Street. A part of him and us stayed in the old building (Fig. 6).

When he travelled, which was often, he took issues of CC, ASCA reports and a small red notepad on which he would scribble semi-legible notes to employees on things they should work on. When he returned to the office these notes were sent out. Much time was spent deciphering these missives, and trying to figure out how or if to respond. We all had collections of these notes on our desks, always dreading the follow-up or reminder: "did you reply to Dr. so and so? . . .", "was this error corrected? . . ."; "did you write a paper refuting this statement? . . .", "read this and discuss with me". . . Often he would forget what he had asked you to do, but sometimes these follow-ups would mysteriously reappear to our horror. Even years later, he could suddenly ask you out of the blue "did you ever do that research front animation we talked about?"

The extent of his social network became apparent to me when I occasionally accompanied him on road trips. He seemed to know personally every library director, head of department, and researcher along the way. He was almost a celebrity

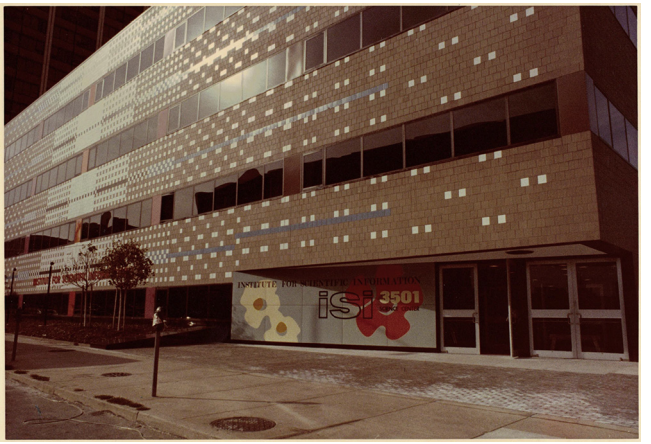

Fig. 6. ISI headquarters in the late 1970 at 3501 Market Street, Philadelphia, PA designed by Venturi Scott Brown Associates.

in Europe, more so than in the States. This was brought home to me while on a lecture tour of Europe in 1985. We were walking down a dark street in Zurich when out of the shadows came a figure who said, "Good evening, Dr. Garfield". He was evidently a scientist who had recognized Gene from his picture in CC. The stranger started talking about incidents in Gene's life, including when he drove a cab in New York, which he had read about in CC essays. Many people we encountered on that trip felt as if they knew him personally through these editorials.

13. Gene as business man

In the late 1950s the company he formed went through several name changes until finally settling on the Institute for Scientific Information (ISI) in 1960. This name was chosen to project more of an academic and non-profit image, making it easier to sell to libraries and individual scientists. The name was suggested to him by the name of a soviet information organization called VINITI, which translates to Soviet All-Union Institute of Scientific and Technical Information (Garfield, 1987). Perhaps by coincidence, Bernal's book, *The Social Function of Science*, contained a discussion of a proposed organization called Science Information Institute (SII) which could also have subconsciously influenced his choice (Bernal, 1939, Appendix 8). As a young man he had been given a copy of Bernal's book by one of his socialist uncles, and Gene considered Bernal one of his intellectual forbearers, endowing an award in his honor at the Society for Social Study of Science (Garfield, 1982) (Fig. 7).

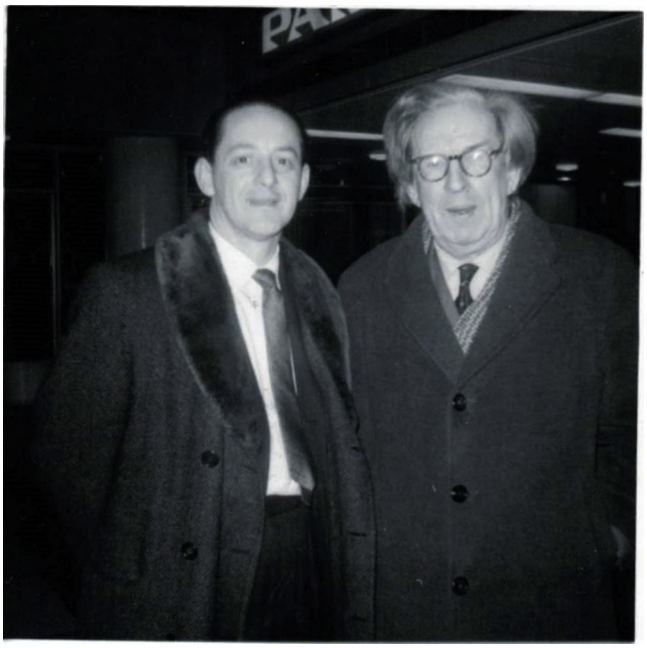

Fig. 7. Gene Garfield and J.D. Bernal in 1958 at the International Conference on Scientific Information, Washington, DC.

Gene considered himself a "super-salesman" and promoter, and the early success of products like CC and the SCI were largely due to his sales efforts. Sometimes his marketing efforts went too far, for example, when he had fortune cookies made up containing the message "the SCI makes you a successful scientist". The FASEB society would not allow him to distribute the cookies at their meeting.

His approach to products was not that of a conventional business man, but rather as a visionary and innovator. New products often teetered on the edge of profitability. He retained controlling interest in the company and fended off a number of attempts to wrest control from him. If he believed in a product idea and thought it would be useful to customers, there was no dissuading him from pursuing it even if it lost money. Eventually, he thought, customers would see its merits. If someone told him it could not be done, he was even more determined. Some of his early products like the *Index Chemicus* did not turn a profit for many years. In the beginning, he would use the profits from a successful product like CC to fund new products like the SCI which took several years to be profitable.

This approach led to many conflicts within the company. For example, in 1969 a group of four executives – Gene called them the four horsemen of the apocalypse – walked out over his unwillingness to focus on profitability, and formed their own company to compete with ISI. The new company, however, failed and one executive, Irv Sher, rejoined ISI. Gene would later comment how difficult it was to run a for-profit company like a non-profit. He was aware that he had a reputation as a risk taker, or "crapshooter" as he called himself (Garfield, 1987), and admitted that there was an element of ego in his decisions (Cawkell & Garfield, 2001). Eventually, stretched financially, having too many products for which a market had yet to be developed and tired of day to day management, he decided to sell the company (Garfield, 1997).

He travelled often to the Soviet Union to sell products and give talks and he got to know a number of prominent scientists and dissidents like V.V. Nalimov, who had written a book entitled *Naukometria* which translates to scientometrics. Eventually Tibor Braun at the Hungarian Academy of Sciences founded the first journal in the new field using that name. However, some communist countries would only buy one copy of an ISI product, and then photocopy it for distribution. The CC editorials he wrote on topics in American society were interesting to foreigners, but the Soviets were paranoid and heavily censored them.

14. Gene as humanitarian and philanthropist

Gene believed strongly in the positive impact of science on society and the social returns of investing in scientific research, later sponsoring an award for the best paper on the topic at Research! America. He also strongly believed that information products like CC and SCI accelerated the progress of science and ultimately led to economic growth and human welfare. Despite resistance from publishers, he thought open access to the scientific literature would ultimately be realized. He also believed that citations were a form of symbolic reward or currency for scientists which would help them in their careers. As a champion of both private enterprise and social welfare, he was not opposed to government sponsorship of information systems as long as they did not unfairly compete with his own products. He benefited from some government support but was critical of policies that made it more difficult for private companies to obtain that support. His social consciousness is evident in his support of the ACLU.

The child care center he built behind his new headquarters building on Market Street enabled employees to keep their children nearby during working hours, and was perhaps inspired by his experience of being raised by a single mother and also having been a single parent himself. He supported children in other ways, through Project Home in Philadelphia dedicated to alleviating poverty and homelessness, and his sponsorship of Opera Company of Philadelphia rehearsals for school children. He also supported young scholars with doctoral dissertation awards in various library and information schools and societies, as well as a medical scholarship for minority students. When the ISSI society was formed at the 1993 meeting in East Berlin, he agreed to sponsor a doctoral dissertation award.

15. Summation

The reasons for Gene's enormous influence are many. He began his professional career when computing was in its infancy and information services were almost exclusively provided in printed form. His career spanned the great revolution in computing power culminating in the invention of the internet. The information products he developed were ideally suited to electronic delivery, and their adaptation to the new medium gave ISI tremendous impetus. Equally important was the rapid expansion of science in the post-war era, including a growing government funding for science after Sputnik and the Watson and Crick revolution in biology. His early products were aimed at improving scientists' access to information. But the most important factor for his success, I believe, was his ability to envision how relatively simple yet powerful ideas on the organization and delivery of bibliographic data could transform the information seeking behavior of users.

He concluded his first letter to Lederberg in 1959 with words that tell us something about Gene's motivation and idealism: "I have great faith that the citation index will one day be a spur to many new scientific discoveries in the service of mankind." (Lederberg, 2000, 42)

In 2007 Gene participated in Vitek Tracz's "Web of Stories" project in which he spoke informally about his life and career on videotape (Garfield, 2007). I was fortunate to be his interlocutor. This turned out to be a marathon session over the course of three days and in these videos you can see his true personality, his joy of life, his incredible memory for names and events, his intellect, and sense of humor.

In talking about how research scientists regard literature searches, he said: "We used to talk about, do scientists really want to do literature searches?. . I said to a librarian, do you think that the average scientist who comes to you is happy when you come up with papers that anticipate his ideas? He's looking to you to prove that it's a novel idea, not that it's unoriginal. . That's one of the dilemmas that we face in using information for discovery purposes. . But people like Josh Lederberg always pointed out that if you're a mature scientist eventually you get over that and his talent, and people like him, is framing questions for which you give them partial answers. . If you're working in the field of genetics if somebody answers some fundamental question, that's what you give people prizes for. But you don't get upset by the fact that somebody like Jim Watson, you know, identified the double helix. You go on from there and you go to the next step, right? So it's your attitude, being mature about it, how you use and await discoveries. There's plenty more to be discovered after your great idea proves to be not so original any more. . That's what make science goes around." (Garfield, 2007, 81)

Gene goes on to discuss his contributions, and that people give him credit for things he did not do. He admitted he was not much of a theoretician and wished he had made more discoveries. He joked that even the so-called Garfield constant is always changing. "You'd like to think that you spent your life doing things that help improve the condition of man. . So I think that the challenges will remain and I hope there will always be interesting and useful questions that people will keep on answering. That there will never be an end to the number of new questions that could be asked. The unanswered questions of science: that was another one of the projects we never finished." (Garfield, 2007, 82)

Ironically, even in his philosophical musing he was reminded of an unfinished project. There is no doubt that the information products he has given us will, as long as they survive, supply us and future generations of scientists with an unending stream of questions and partial answers that lead to more questions, and this is the real legacy of Gene Garfield.

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References

Adair, W. C. (1955). Citation indexes for scientific literature? *American Documentation*, *6*, 31–32. http://garfield.library.upenn.edu/papers/adaircitationindexesforscientificliterature1955.html
Asimov, I. (1963). *The genetic code*. New York, NY: New American Library.
Bernal, J. D. (1939). *The Social function of science*. London: G. Routledge & Sons.
Cawkell, T., & Garfield, E. (2001). Institute for scientific information. In E. H. Fredriksson (Ed.), *A century of science publishing: A collection of essays* (pp. 149–160). Amsterdam: IOS Press. http://www.garfield.library.upenn.edu/papers/isichapter15centuryofscipub149-160y2001.pdf
Garfield, E., & Hayne, R. (1955). Needed – A national science intelligence and documentation center. In *Symposium on storage and retrieval of scientific information, annual meeting of the AAAS* http://www.garfield.library.upenn.edu/papers/natlsciinteldoccenter.html
Garfield, E., & Sher, I. H. (1963). *Genetics citation index: Experimental citation indexes to genetics with special emphasis on human genetics*. Philadelphia, PA: Institute for Scientific Information. http://garfield.library.upenn.edu/essays/v7p515y1984.pdf
Garfield, E., Sher, I. H., & Sher, R. T. (1964). *The use of citation data in writing the history of science*. Philadelphia, PA: Institute for Scientific Information. http://www.garfield.library.upenn.edu/papers/useofcitdatawritinghistofsci.pdf
Garfield, E., Malin, M. V., Small, H., et al. (1977). Citation data as science indicators. In Y. Elkana, & J. Lederberg (Eds.), *Toward a metric of science* (pp. 179–207). New York, NY: John Wiley.
Garfield, E., Pudovkin, A. I., & Istomin, V. S. (2002). Algorithmic citation-linked historiography: Mapping the literature of science. In *65th annual meeting of ASIS&T* http://garfield.library.upenn.edu/papers/asis2002/asis2002presentation.html
Garfield, E. (1952). Review literature as a source of critical entries for scientific indexes. Unpublished manuscript.
Garfield, E. (1954). Preparation of subject-heading lists by automatic punched-card techniques. *The Journal of Documentation*, *10*(1), 1–10. http://garfield.library.upenn.edu/essays/v6p444y1983.pdf
Garfield, E. (1955). Citation indexes for science: A new dimension in documentation through association of ideas. *Science*, *122*(3159), 108–111. http://www.garfield.library.upenn.edu/papers/science.v122v3159p108y1955.html
Garfield, E. (1963). *Science citation index. Science citation index 1961, 1*. pp. v–xvi. Philadelphia, PA: Institute for Scientific Information. http://garfield.library.upenn.edu/papers/80.pdf
Garfield, E. (1971). The mystery of the transposed journal lists – Wherein Bradford's law of scattering is generalized according to Garfield's law of concentration. In *Essays of an information scientist. 1962–73, 1*. pp. 222–223. Philadelphia, PA: ISI Press. http://www.garfield.library.upenn.edu/essays/V1p222y1962-73.pdf
Garfield, E. (1972). Citation analysis as a tool in journal evaluation. *Science*, *178*, 471–479. http://www.garfield.library.upenn.edu/essays/V1p527y1962-73.pdf
Garfield, E. (1971). Citation frequency as a measure of research activity and performance. In *Essays of an information scientist. 1962-73, 1*. pp. 406–408. Philadelphia, PA: ISI Press. http://www.garfield.library.upenn.edu/essays/V1p406y1962-73.pdf
Garfield, E. (1975). Ever think of Current Contents as a newspaper? In *Essays of an information scientist. 1974-76, 2*. pp. 349–350. Philadelphia, PA: ISI Press. http://www.garfield.library.upenn.edu/essays/V1p406y1962-73.pdf
Garfield, E. (1977). Viewdata and SCITEL brings interactive information into the home. In *Essays of an information scientist. 1977-78, 3*. pp. 253–258. Philadelphia, PA: ISI Press. http://garfield.library.upenn.edu/essays/v3p253y1977-78. pdf
Garfield, E. (1981). The 1000 contemporary scientists most cited 1965–1978: The basic list and introduction. In *Essays of an information scientist. 1981-82, 5*. pp. 269–278. Philadelphia, PA: ISI Press. http://www.garfield.library.upenn.edu/essays/v5p269y1981-82.pdf
Garfield, E. (1982). J.D. Bernal-the sage of Cambridge: 4S award memorializes his contributions to the social studies of science. In *Essays of an information scientist. 1981–1982, 5*. pp. 511–523. Philadelphia, PA: ISI Press. http://garfield.library.upenn.edu/essays/v5p511y1981-82.pdf
Garfield, E. (1986). The Scientist: How it all began. In *Essays of an information scientist. 9*. Philadelphia, PA: ISI Press [p.249]. http://www.garfield.library.upenn.edu/essays/v9p249y1986.pdf
Garfield, E. (1987). Oral History Interview with Arnold Thackray and Jeffrey L. Sturchio, 16 November.
Garfield, E. (1997). Oral history interview with Robert V. Williams, 29 July 1997. In *Oral history program*. Chemical Heritage Foundation. http://www.garfield.library.upenn.edu/papers/oralhistorybywilliams.pdf

Garfield, E. (1998). From citation indexes to informetrics: Is the tail now wagging the dog? *Libri*, *48*, 67–80. http://www.garfield.library.upenn.edu/papers/libriv48(2)p67-80y1998.pdf
Garfield, E. (1999). From the world brain to the informatorium-with a little help from Manfred Kochen. In *University of michigan symposium in honor of manfred kochen* http://garfield.library.upenn.edu/papers/kochen_worldbrain.html
Garfield, E. (2001). Recollections of Irving H. Sher 1924–1996 polymath/information scientist extraordinaire. *Journal of the American Society of Information Science and Technology*, *52*(14), 1197–1202. http://garfield.library.upenn.edu/papers/sherjasis&t52%2814%29p1197y2001.pdf
Garfield, E., 2007. Eugene Garfield: Life Story (video). Web of Stories. https://webofstories.com/play/eugene.garfield/1.
Lederberg, J. (2000). How the Science citation index got started. In B. Cronin, & H. Atkins (Eds.), *Web of knowledge: A festschrift in honor of Eugene Garfield* (pp. 25–64). Medford, N.J: Information Today, Inc.
Small, H., & Garfield, E. (1985). The geography of science: Disciplinary and national mapping. *Journal of Information Science*, *11*(4), 147–159.
Small, H. (1973). Co-citation in the scientific literature: A new measure of the relationship between two documents. *Journal of the American Society for Information Science*, *24*(4), 265–269.
Small, H. (1982). Citation context analysis. *Progress in Communication Sciences*, *3*, 287–310.
Sneath, P. H. A., & Sokal, R. R. (1973). *Numerical taxonomy*. San Francisco. CA: W.H Freeman & Co.
Thackray, A., & Brock, D. C. (2000). Eugene Garfield: History, scientific information, and chemical endeavor. In B. Cronin, & H. Atkins (Eds.), *Web of knowledge: A festschrift in honor of Eugene Garfield* (pp. 11–23). Medford, N.J: Information Today, Inc.
Wells, H. G. (1938). *World brain garden city*. New York: Doubleday Doran [p. 33]
Wouters, P. (1999). *The citation culture*. Amsterdam: University of Amsterdam [Ph.D. dissertation].

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